rf design

ideas for engineers

May 1986

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Special Recruitment Issue

Education Feature — The Making of an RF Engineer

These Numbers Mean Business

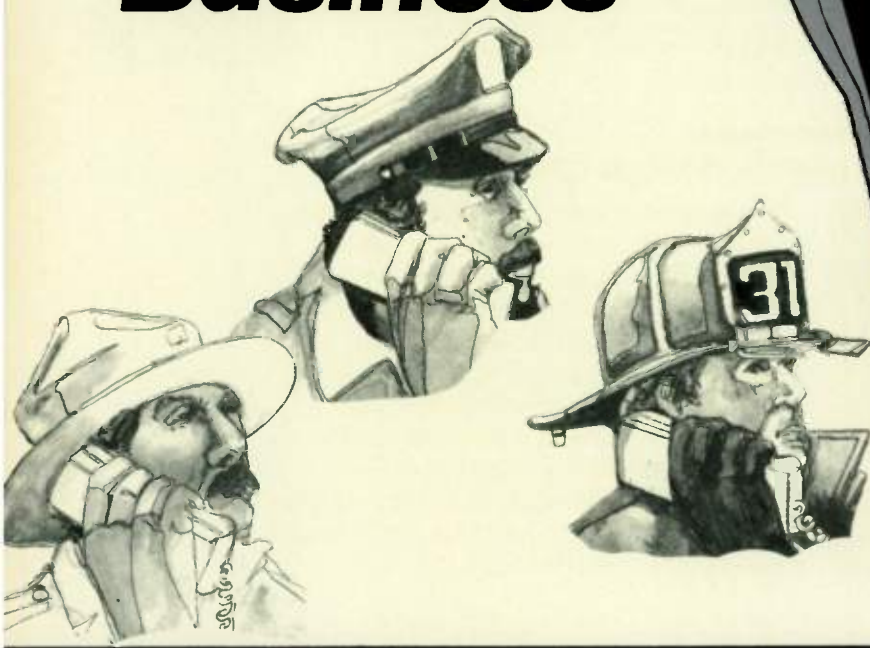
900 MHz	MOBILE APPLICATIONS				
Type	Power (W)	Freq. (MHz)	Gain (db) min.	VCC (V)	Package
BLU98	0.5	900	9.0	12.5	SOT-103/E1
BLV90	1	900	7.5	12.5	SOT-172
BLV91	2	900	6.5	12.5	SOT-172
BLU99	4	900	7.3	12.5	SOT-122
BLV92	4	900	8.0	12.5	SOT-171
BLV93	8	900	6.0	12.5	SOT-171
BLV94	15	900	6.0	12.5	SOT-171

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

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

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

66 to 870 MHz	AMPLIFIER MODULES FOR LAND MOBILE				
Type	Freq (MHz)	P In (MW)	P Out (W)	VCC	Package
BGY32	68-88	100	20	12.5	SOT-132
BGY33	80-108	100	20	12.5	SOT-132
BGY35	132-156	150	20	12.5	SOT-132
BGY36	148-174	150	20	12.5	SOT-132
BGY43	148-174	150	13	12.5	SOT-132B
BGY40A	400-440	100	7.5	12.5	SOT-132C
BGY41A	400-440	150	13	12.5	SOT-132C
BGY40B	440-470	100	7.5	12.5	SOT-132C
BGY41B	440-470	150	13	12.5	SOT-132C
BGY40A	470-512	100	7.5	12.5	SOT-132C
BGY41C	470-512	150	13	12.5	SOT-132C
BGY45A	68-88	150	30	12.5	SOT-301-A-03
BGY45B	144-175	150	30	12.5	SOT-301-A-03
BGY46A	400-440	30	1.5	9.6	SOT-26NC
BGY47A	400-440	45	2.2	9.6	SOT-26NC
BGY47B	430-470	45	2.2	9.6	SOT-26NC
BGY47C	460-512	45	2.2	9.6	SOT-26NC
BGY22	380-512	50	2.9	12.5	SOT-75A
BGY23	380-480	2.5 WATTS	7	12.5	SOT-75A



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INFO/CARD 1

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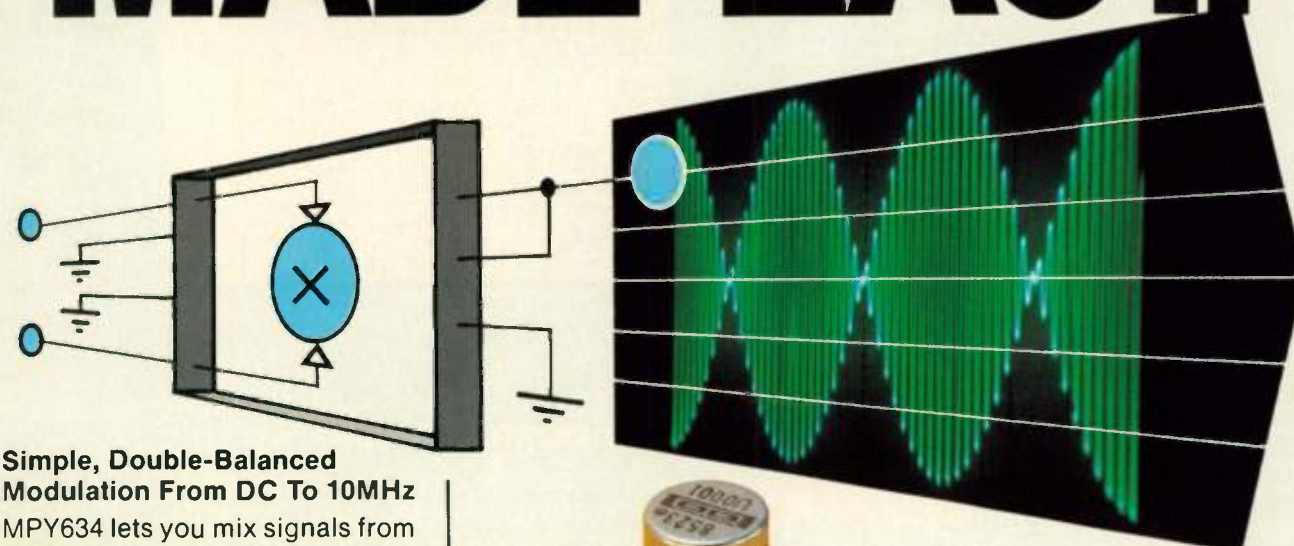

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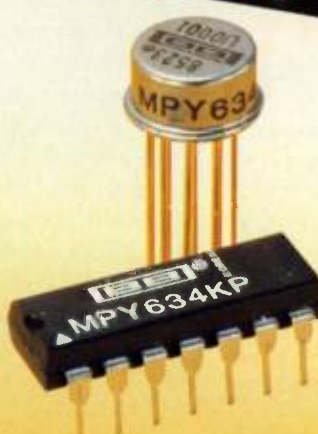

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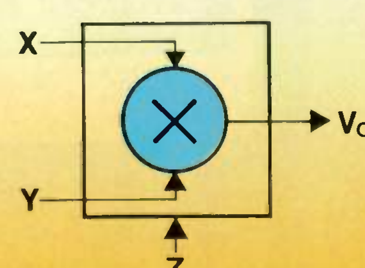

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Feedthrough (500kHz)*	50dB	55dB	60dB	55dB
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*No trimming required. ‡Domestic U.S. prices only.

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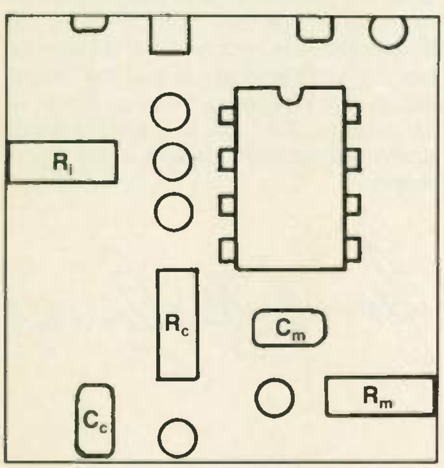
INFO/CARD 3

rf design

May 1986

Page 33 — Laptop CAD Workstation

Page 43 — Spiral Inductors



Page 70 — Wideband Opamps

Cover

This month's cover shows the Toshiba T1100 laptop computer, just introduced in the United States, custom modified by Communications Consulting Corp. for use as an RF design engineer's personal CAD workstation. The computer is fully IBM compatible and has a built-in modem, serial and parallel ports.

Features

Departments

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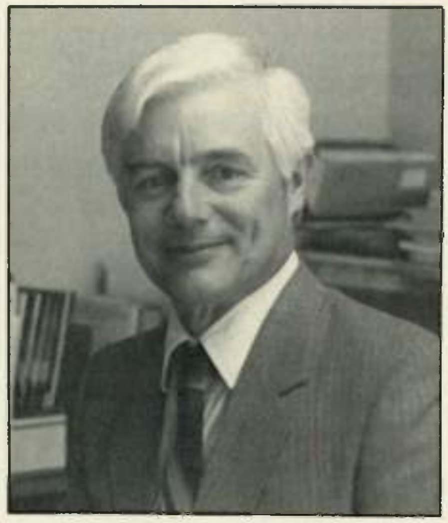
rf editorial

The Koreans Are Coming



By James N. MacDonald
Editor

Last month we carried a news story about a study of the Korean electronics industry by Benn Electronic Publications, Ltd., Luton, England. One conclusion of the study was that Korea is on its way to challenging Japan as a supplier of low cost semiconductor devices.

Benn said South Korea is rapidly emerging as the world's third largest producer of semiconductor devices. A series of five-year plans has been aimed at transforming the country from an agrarian to a high tech economy. In the 1980s, the emphasis has been on electronics, with the U.S. and Japan the major export markets. Despite a smaller market than Korea expected because of the slump in the semiconductor industry, the government is optimistic about the future.

What interests us most about this report is the irony of it. After years of protests by U.S. industries about Japanese trade practices, when it finally seems that the U.S. government is ready to pressure Japan for more equitable pricing, a new threat to both countries may be rising. Benn sees Korea changing from an offshore extension of the U.S. and Japanese semiconductor industries to an independent manufacturing base. From a manufacturer of parts and components, Korea has become a manufacturer of color TVs, VCRs, microwave ovens and other such consumer products. Many Korean products are now on American store shelves. Korea has openly said it is after the Japanese share of the U.S. market, Benn reports.

As with Japan, it has been government support of research and development that has helped Korea advance so rapidly. It may give satisfaction to some American industries to see Japan facing the kind of economic competition it has given the U.S., but it is a fleeting satisfaction. The situation offers no help to American industry. In this case, the American companies may have created their own competition. The largest segment of Korean semiconductor production is made up of assembly facilities operated by American/multinational companies. We have taught the Koreans how to compete with us.

All this is of limited concern to RF companies. The competition is in semiconductor products. The longer time frame is worth watching, however. The automotive industry was the first to feel the effect of Japanese competition after first refusing to take it seriously. Have you noticed all the recent television commercials for Korea's Hyundai? According to newspaper reports it has become one of the fastest selling cars in America. Hyundai Electronics Industries Co., Ltd., is one of the major Korean companies studied in the Benn report.

James N. MacDonald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INFO/CARD 5

rf viewpoint

The Magic is Back(?)

By Gary A. Breed
Technical Editor

"Our students know where the action is, and they're asking for more RF-related courses."

This isn't really a quotation, but a composite of comments made by educators in engineering schools across the country, both large and small. These same professors and administrators back up their students' insight, observing that top graduates are no longer going to computer or component companies, but are being sought by military, aerospace and communications companies with strong programs involving RF technologies. We in the industry have known of the growth in RF, now the word is getting down to the grass roots!

In a moment of nostalgia, I recalled my own introduction to the magic of RF at age 9, when I discovered plans for a crystal set in a library book. With a coil wound on a paper tube and a detector made from a "blue blade," safety pin and pencil lead, this device of my own creation actually could receive the local radio station! This wasn't exactly the Dark Ages, either (it was 1958).

Magic was all around us then, with the infancy of the space program, the wholesale changeover from tubes to transistors, the rise of the computer, and the fall of the slide rule. There was magic in the Kennedy mystique, and a certain excitement in the activism that was beginning to arise on college campuses.

That kind of emotional magic is gone now; the "new" magic is *opportunity*, represented both in terms of technical challenge and financial reward. The current generation is not out to change the world, but they certainly want to make their mark. Right now, RF technology offers the challenges and the jobs for ambitious engineers to do just that.

Where are these challenges? *Military systems:* C^3I, TEMPEST, ECM, ECCM and SDI is a good place to start (despite Gramm-Rudman). *Consumer electronics* has not seen any letup in demand for mobile phones, wireless control systems, and advanced audio and video products. These products are not all made offshore, either.

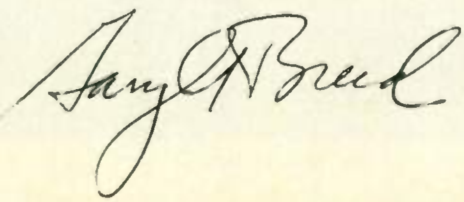
Business needs RF, too. Local Area Networks need RF modems; high speed signal processing is needed for data communications and encryption. RF communications, electromagnetic compatibility (EMC) requirements and inter-system communications have major roles in manufacturing and service industries.

In the area of R&D, *RF design techniques* need development engineers for better CAD/CAM component and system models, high speed digital and analog circuit construction techniques and surface-mount design (SMD). *Basic scientific research* is rich in opportunities, too. Fusion research, fundamental particle physics, and medical systems need RF drivers and detectors. Chemical and biological research and radio astronomy need sophisticated signal processing techniques.

RF *integration* with other electronic technologies is perhaps the greatest challenge, requiring broad knowledge and teamwork within a diverse project group having talents in RF, digital, optical, materials and other techniques.

The challenges and opportunities are there, but it will take a combination of innate ability and proper education to meet them. Are today's new engineers prepared for these challenges? Do they get the right technical training? Do they understand the roles expected of them in the workplace? Some answers to these questions can be found on page 74 in "The Making of an RF Engineer," where the views of educators, students and industry provide an interesting look at the education of an engineer.

The magic is returning to the world of RF. It's a bit different than the old magic, but it's definitely *not* an illusion.



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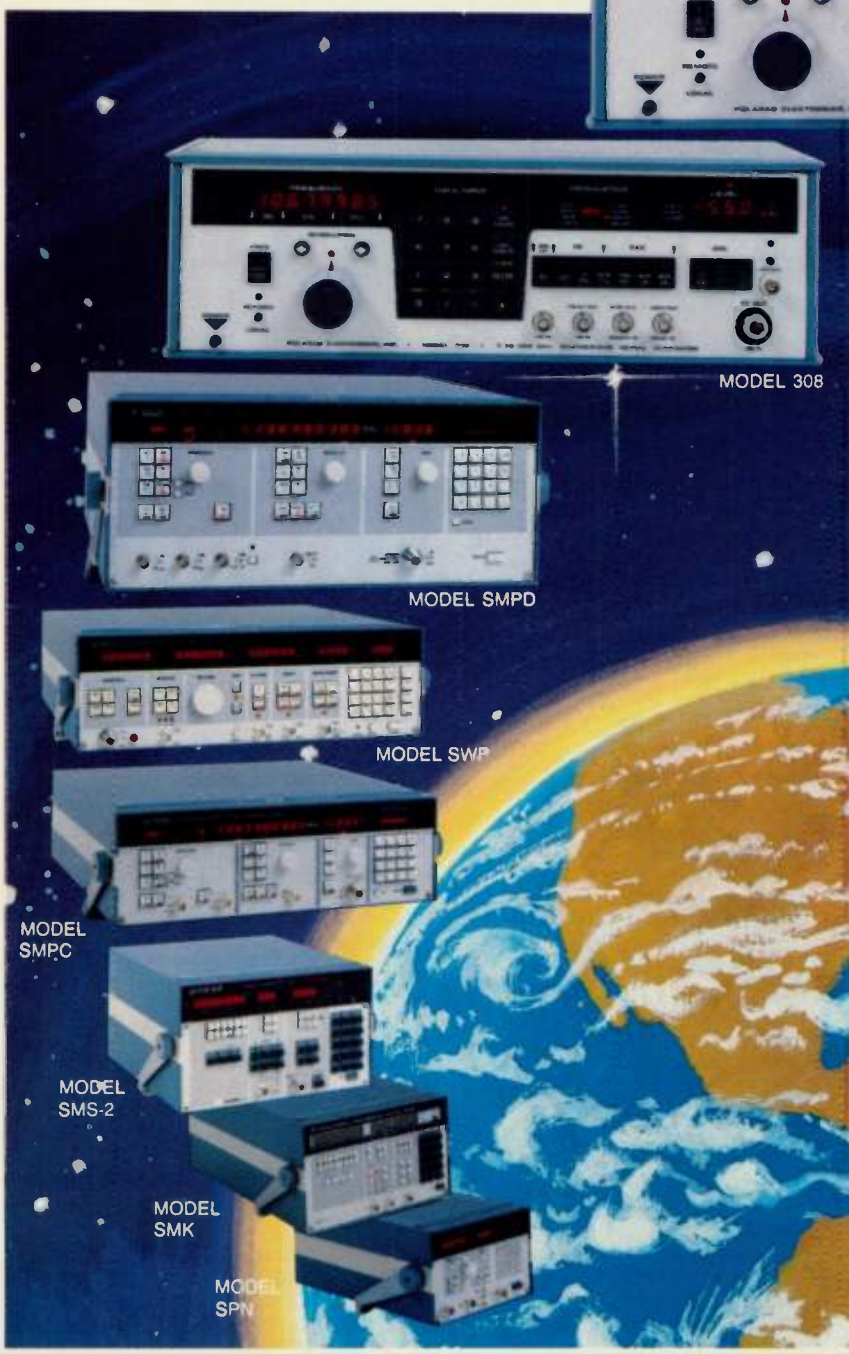

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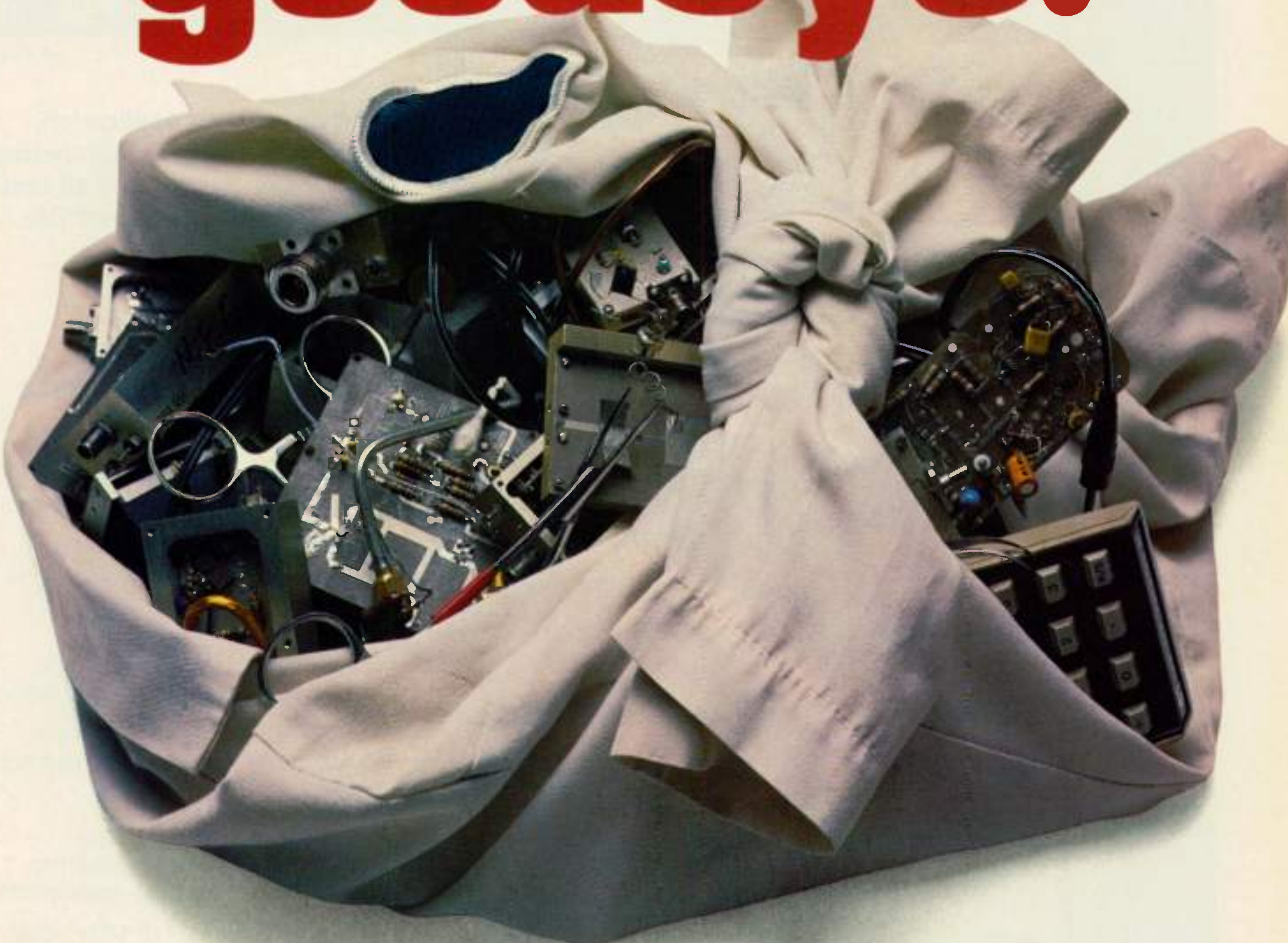

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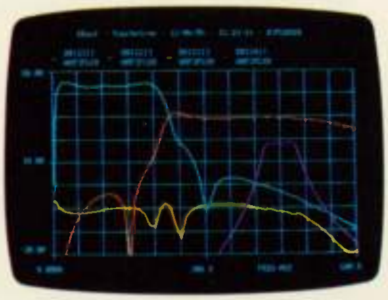
A Touchstone analysis of an active triplexer circuit with sampled output

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

C Schematic diagram of the active triplexer analyzed above

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



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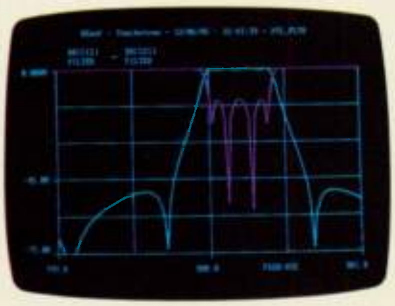

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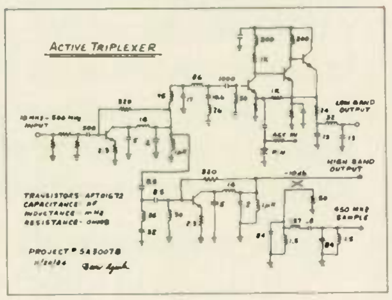

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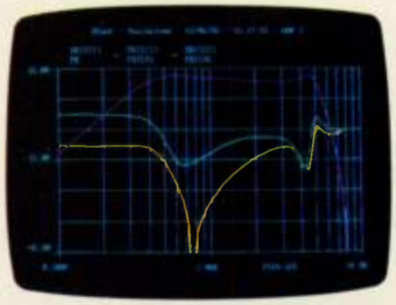

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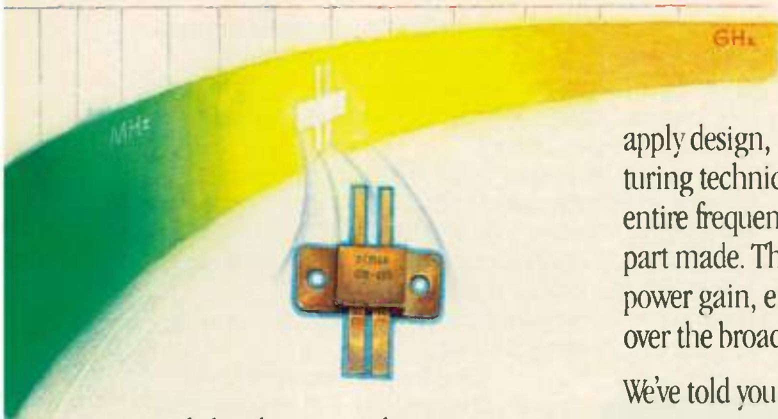
“There is no such thing as part of the Frequency Spectrum.”



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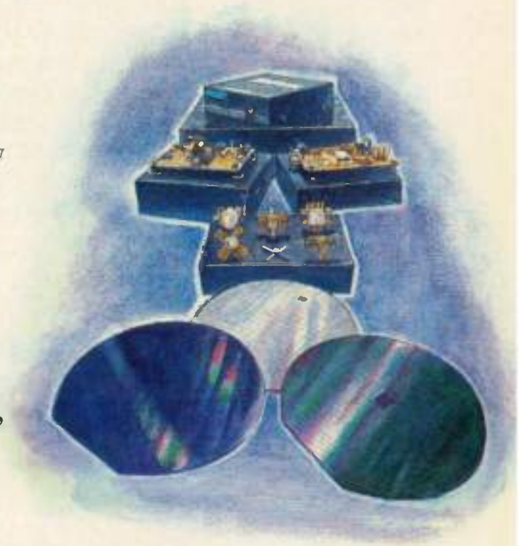

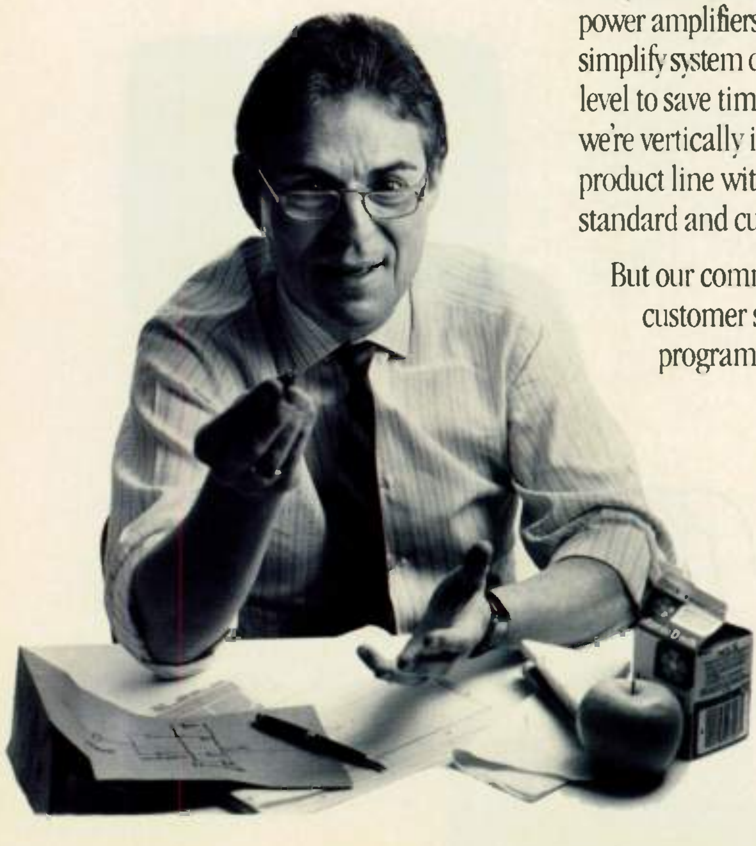

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INFO/CARD 10

rf letters

Editor:

Although Ed Oxner is a long-time colleague of mine, I must take exception to a portion of his letter on page 14 of March 1986 *RF Design*. Most of Ed's points are well taken, but his comment about *professionalism* when attempting to compare *RF Design* with *QST* and *Ham Radio* is a bit unfair to my way of thinking. Good electronics circuit design and application is germane not only to consumer and non-hobby commercial products, but it applies also to Amateur Radio equipment. It is inequitable to consider an amateur journal nonprofessional, when in fact many amateur developments have led the way to state-of-the-art commercial products. Professionalism in the publishing field is more related to the *quality* and accuracy of the papers that are presented — not to the type of circuit treated.

Having been the Senior Technical Editor of *QST*, and the Technical Department Manager for many years (now retired), I take exception to any implication that *QST* is not a professional journal. It is read by countless scientists, engineers and technicians, and many of them are professionals rather than hams.

Furthermore, the ARRL does not use C64 computers as implied. The major inhouse computer is a Honeywell, and Compugraphic computers are used in the production department. Countless IBM and Apple-IIe systems are in use throughout the building as personal computers. I am not aware of any C64s being used for day-to-day business or circuit analysis.

Doug DeMaw, W1FB
President, Oak Hills Research
Luther, Michigan

Editor:

The analysis of low impedance shunt stubs presents an interesting dilemma. Mr. D'Agostino's treatment (March issue) of such a stub as a length of low impedance transmission line must be true for very short stubs. Stub treatment must be true for longer, high impedance shunt lines. The in-between cases would be worth a master's degree thesis.

The series high impedance line suggested by Mr. D'Agostino is an excellent way to identify the location of the line. To avoid capacitance effects between the main line and the wide shunt line, the high impedance line should not be too short.

Another solution to this problem is the use of radial lines. The shunt line is very narrow where it joins the main line and spreads out as a fan. This line is treated in Hewlett-Packard Application Note 976, Broadband Microstrip Mixer Design: The Butterfly Mixer. References to earlier uses of the radial line are included in the application note.

Jack H. Lepoff, Applications Engineer
Hewlett-Packard,
San Jose, California

Editor:

H.P. Shuch, writing in your March 1986 issue, should be congratulated for using the correct term "angular velocity" instead of one of the misnomers, such as angular frequency. Hopefully, the future will bring additional beautification of our technical language by changing his cycles and radians to cycle and radian. The number tells how many, but must never tell what kind. The unit tells what kind, but must never tell how many, as it does when we add the plural s. Actually, on top of page 58 Shuch makes the very correct technical statement with reference to the past that "the unit of frequency was the cycle per second." If that is so, why not keep it that way instead of violating logic.

Harry E. Stockman
Sercolab
E. Dennis, Massachusetts

Editor:

I have been looking at the latest article by Burwasser in the March magazine, and I am forced to conclude that there may be significant errors in it as it stands.

Some of the filters are low pass, some high pass, and others are band pass, with some being band rejection. The titles on the Figures 3 through 10 are very deceptive because of this. It would be very helpful to have their natures more carefully defined.

With Figure 5, I suspect the X1 and X2 under the radical sign should be multiplied, as otherwise it is possible for one to get an imaginary value for X1. I don't believe that is very likely!

It is not generally known, but circuits consisting of a single tuned circuit with a magnetic coupling loop can be overcoupled. I have seen an example of this where the two frequencies had a 3:2 relation to one-another, and the circuit in question was preceded by a tripler. Needless to say, the resulting oscillation was easily cured by reducing the coupling to critical. This is a common cause of interference in the front end of commercial radio equipments like televisions.

Numbering equations would be helpful both to the author and to readers. The "round-number" value for Q*(bw/fo) is almost two, as it must be.

The diskette would be useless to me, as I would have to change the nomenclature to that suitable for the TI-99/4A, a task that makes the price unreal, particularly with the errors that seem to be in the text. Perhaps the diskette is better. I favor putting this kind of material into BASIC, but my floppy disk unit won't read IBM format.

There may be an error in the conversion of Figure 13 to the modified form. The input capacitors don't seem to jibe with the 70.03 value on the unmodified filter. The input circuit should resonate at about the same frequency as the original one, shouldn't it?

Design information like this is hard enough to convert to a non-IBM PC without having to try to resolve possible errors in the text. It would seem that the author should be given a chance to check at least the equations.

Keats A. Pullen, Jr.
Kingsville, Maryland

You are correct about the equation in Figure 5, Keats. In checking all equations again, we also discovered three other errors. The equation $XB = -X2 - X'$ *was omitted from Figure 3; in Figure 6* $X' = -\sqrt{X1 \cdot X2/K}$*; and in Figure 10* $X1 = RS \cdot Q$*. It would be helpful to let the author check equations, but our tight production schedule usually makes that impossible. We appreciate your calling our attention to these errors. — editor*

Editor:

Here's a great big pi in the face to the typesetter and proofreader who managed to mangle H. Paul Shuch's article, "Radian Review," in the March 1986 issue.

The value of pi, as printed, has a 3 instead of 4 in the second decimal place, making it less accurate than the grade school approximation to pi of 22/7. (A much better approximation is 355/113 which has an error of only 8.5×10^{-6} percent.)

Later in the article, the number of degrees in a radian is calculated by $350/2\pi$. The Department of Weights and Measures should be alerted to these 350 degree circles!

Jacob Z. Schanker
Chief Engineer,
Scientific Radio Systems, Inc.
Rochester, New York

We apologize to Paul Shuch and all our readers for these glaring errors. It looks like we succumbed to the human tendency to skim over familiar material. — editor

rf calendar

May 5-7, 1986
36th Electronics Components Conference
Westin Hotel, Seattle, Washington
Information: Tom Pilcher, Electronics Industries Association; Tel: (317) 261-1592

May 13-15, 1986
Electro/86 High Technology Electronics Exhibition and Convention
Exposition Center, World Trade Center, Boston, Massachusetts
Information: J. Fossler, Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, CA 90045; Tel: (312) 299-9311

June 2-4, 1986
IEEE MTT-S International Microwave Symposium
Baltimore Convention Center, Baltimore, Maryland
Information: LRW Associates, 1218 Balfour Drive, Arnold, MD 21012.

June 24-26, 1986
Military Microwaves '86
Metropole Convention Centre, Brighton, England
Information: Roger Marriott, Microwave Exhibitions and Publishers Ltd., Convex House, 43 Dudley Road, Tunbridge Wells, Kent TN1 1LE, United Kingdom; Tel: 0892-44027

June 16-19, 1986
EMC Expo 86
Sheraton Washington, Washington, DC
Information: EMC Expo 86 Registration Manager, 117 King St., Suite 200, Alexandria, VA 22314; Tel: (703) 548-2802

June 23-27, 1986
Conference on Precision Electromagnetic Measurements
National Bureau of Standards, Gaithersburg, Maryland
Information: Judy Wilson, Conference Assistant, National Bureau of Standards, Gaithersburg, MD 20899; Tel: (301) 921-2721

September 8-11, 1986
16th European Microwave Conference
National Concert Hall, Dublin, Ireland
Information: Roger Marriott, Microwave Exhibitions and Publishers Ltd., (see address above)

September 9-11, 1986
Midcon/86 High Technology Electronics Exhibition and Convention
Dallas Convention Center, Dallas, Texas
Information: J. Fossler, Electronic Conventions Management (see address above)

September 30-October 2, 1986
Northcon/86 High Technology Electronics Exhibition and Convention
Seattle Center Coliseum, Seattle, Washington
Information: J. Fossler, Electronic Conventions Management (see address above)

November 10-12, 1986
RF Expo East
Boston Marriott Copley Square, Boston, Massachusetts
Information: Kathy Kriner, Convention Manager, Cardiff Publishing Co., 6530 So. Yosemite St., Englewood, CO 80111; Tel: (303) 694-1522

November 18-21, 1986
Wescon/86 High Technology Electronics Exhibition and Convention
Anaheim Convention Center, Anaheim, California
Information: J. Fossler, Electronic Conventions Management (see address above)

rf courses

The George Washington University

Electronic Warfare Systems: Technical and Operational Aspects

June 9-13, 1986, Ottawa, Canada
July 14-18, 1986, Washington, DC

SAW Devices and Their Signal Processing Applications

June 16-19, 1986, Washington, DC

Information: Merril Ann Ferber, Assistant Director, Continuing Education Engineering Program, The George Washington University, Washington, DC 20052; Tel: (800) 424-9773

Interference Control Technologies

Grounding and Shielding

May 6-9, 1986, San Jose, California
May 20-23, 1986, Minneapolis, Minnesota

Tempest Design, Control, Testing

May 20-23, 1986, Sunnyvale, California

Mil-Std 461/462 and System Level Testing & Procedures

May 20-23, 1986, Philadelphia, Pennsylvania

Practical EMI Fixes

May 20-23, 1986, Seattle, Washington

Information: Penny Caran, Registrar, Interference Control Technologies, State Route 625, PO Box D, Gainesville, VA 22065; Tel: (703) 347-0300

R & B Enterprises

Electromagnetic Pulse Design and Test

May 14-15, 1986, Washington, DC
June 16-18, 1986, Boston, Massachusetts

Two-Week EMI Training Institute — Commercial (FCC)

May 1-2, 1986, Philadelphia, Pennsylvania

EMI in the Automotive System

May 7-9, 1986, Dearborn, Michigan

Grounding, Bonding, Shielding

June 10-11, 1986, Boston, Massachusetts

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

National Bureau of Standards

Conference on Precision Electromagnetic Measurements

June 23-27, 1986, Gaithersburg, Maryland

Information: Sara R. Torrence, Public Information Division, National Bureau of Standards, Gaithersburg, MD 20899; Tel: (301) 921-2721

University of Colorado

Computer Aided Design of Microstrip Circuits and Antennas

May 27-30, 1986, Boulder, Colorado

Information: Office of Conference Services, University of Colorado, Campus Box 454, Boulder, CO 80310; Tel: (303) 492-5151

Motorola to Supply First 800 MHz Cellular System in China

Motorola, Inc., based in Schaumberg, Ill., was selected from an international field of competitors to supply the People's Republic of China (PRC) with its first 800 MHz cellular radiotelephone system. The system, to be installed and implemented in Beijing, the capital city of China, will be a TACS (Total Access Communications System) similar to the type adopted in the United Kingdom. The contract value is in excess of $3.7 million. Bernard Smedley, vice president and general manager of the Cellular Infrastructure Division, said the equipment for the system will be supplied by Motorola facilities in the United Kingdom and the United States.

The installation of cellular telephone systems represents another significant step in the rapid modernization of communications facilities throughout the Peoples Republic of China, said an official of the Beijing Telecommunications Administration (BTA). The BTA anticipates that other cities in the PRC will be installing cellular systems soon. These systems will form an important part of the PRC's developing infrastructure and will ensure more efficient telecommunications services to new industrial and commercial enterprises.

"Motorola is committed to a long term relationship with the PRC in several areas of high technology," said Smedley. "We feel privileged to have this opportunity to demonstrate our skills and experience and are actively working to strengthen our ties with the PRC."

EPSCO R.F. Division to Produce Subsystems

The R.F. Division of EPSCO, Inc., Westlake Village, Calif., has received a $1.2 million follow-on order from Hughes Aircraft Company, Ground Systems Group, Fullerton, Calif., for major RF subassemblies for the NATO AEGIS/Hit Split Link Terminal Program. The RF subassemblies were designed by EPSCO's R.F. Division (formerly 3 dBm Systems, Inc.) as part of the Cable Interconnection Link and Microwave Link Interface Segment (AEGIS) which is used with the Joint Tactical Information Distribution System (JTIDS). The AEGIS system integrates E-3A AWACS track data into the established NATO Air Defense Ground Environment (NADGE) network to provide early warning detection capability against low altitude airspace intruders. The EPSCO equipment is part of the communication link between the ground transmit and receive terminals.

EEsof Forms International Users' Group

An international users' group for currently registered customers of EEsof's product line has been formed by EEsof, Inc. The first scheduled meeting will be held June 1, 2:00-6:00 p.m., in conjunction with the 1986 IEEE MTT-S International Microwave Symposium, Baltimore Convention Center, Baltimore, Md., June 2-4.

According to Jim Lindauer, vice president of sales and marketing, "the users' group offers a forum for the discussion and exchange of applications and ideas relating to the engineering and design of circuits using Touchstone, MiCAD, Microwave SPICE, and other EEsof products. The group," Mr. Lindauer continues, "is intended to address questions and topics of interest to all registered users of EEsof products and will provide the opportunity for customers to express their ideas about program enhancements and future development."

Officers will be elected at the June 1st meeting, the group's charter will be developed, and plans for the first year of operation will be made. Technical papers will be presented.

A users' group questionnaire was mailed out in March to all registered customers of EEsof's programs. Invitations were mailed to all registered users.

EEsof, founded in 1983, is a leading software developer and manufacturer in the field of computer-aided microwave and RF engineering, design, and test. EEsof's engineering and software products are fundamental productivity tools intended to enhance and support the microwave/RF/analog design engineer.

For further product and sales information, contact Jim Lindauer, vice president of marketing and sales, EEsof, Inc., 31194 La Baya Drive, Westlake Village, CA 91362. Phone: (818) 991-7530, or circle INFO/CARD #134.

Motorola Announces New Returns Policy

Motorola has announced a major change regarding the conditions under which semiconductor products will be accepted back from OEM customers.

"If a customer finds a defect in any lot of Semiconductor Product Sector components within 45 days of our ship date, the product may be returned for replacement, *with no questions asked,*" says Gary Tooker, general manager of Motorola Semiconductor Products Sector.

This new "no questions asked" policy for OEM product returns reflects a heightened level of confidence in the quality of Motorola products based on the continual improvements in the measured defect rate of Motorola components during the past few years. Because of these quality improvements, the company no longer sees a need to attach AQL (Acceptance Quality Level) stipulations on quality-related defects.

"This policy change is intended to express to our customers the confidence we have in our products," Tooker stated. "We consider this policy a major, positive step in serving our customers. We want to underscore the fact that Motorola is *the* supplier with whom it is easy to do business."

The policy change will affect OEM quality-related returns only. Motorola's policy for customer convenience returns will remain — as before — at the discretion of the appropriate Motorola product marketer. The policy on administrative returns will also remain unchanged, with these returns being corrected as expediently as possible.

Scientific-Atlanta Receives Antenna Test Contract from Navy

Scientific-Atlanta, Inc., has received a $1.9 million contract from the Norfolk Naval Air Rework Facility for an indoor radome antenna test system. In conjunction with on-going expansion of existing antenna test range facilities, Scientific-Atlanta will build and install an anechoic chamber, a model 5752 compact antenna range, a model 2022A automatic antenna analyzer, a mobile antenna test positioner and related sub-systems. The system will be used to test F-14 and EA-6B aircraft antenna systems.

Cold Neutron Research Facility a Bargain, NBS Official Tells Congress

The administration's request for $10 million in fiscal year 1987 for a "cold neutron" facility for advanced materials research is a bargain compared with what Western Europe and Japan are paying for similar facilities, an official of the Commerce Department's National Bureau of Standards (NBS) said.

IEEE-488

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The new 6060B.

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We've added three popular options to the standard 6060B model for much less than you'd pay for each separately. Now standard are: Non-Volatile Memory that can store 50 instrument settings up to two years without power, Reverse Power Protection, and Sub-Harmonic External Reference input.

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Frequency range	10KHz – 1050MHz
Amplitude range	+13dBm to −127dBm
Accuracy	±1.0dB
Harmonics	< −30dBc
Spurious	< −60dBc
Modulation	AM/FM
IEEE-488 Interface, opt. 488 switch speed	< 100 ms, typ

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INFO/CARD 13

MICROWAVE CAD

RIGHT ON TARGET

Testifying before the House Subcommittee on Science, Research and Technology, Lyle Schwartz, director of the NBS Institute for Materials Science and Engineering, urged approval of the funding "in a competitive world in which standing still guarantees falling behind." Without such a facility, Schwartz said, "our nation will be left far behind our main industrial competitors in access to essential cold neutron measurement technology."

Over the past 15 years, $150 million has been spent in Western Europe to build cold (low-energy) neutron facilities, and the Japanese recently committed $50 million to build their own, Schwartz said. The United States can develop a major cold neutron facility at such modest cost, Schwartz said, in part because a 20-megawatt research reactor located at NBS in Gaithersburg, Md., already has provisions for a cold neutron source.

Electrospace Receives IFF Grant

Electrospace Systems, Inc., Richardson, Texas, has been awarded a $2,289,371 contract from Aeronautical Systems Division, Wright Patterson Air Force Base, Ohio, for the design, analysis, fabrication and installation of MARK XV IFF (Identify Friend or Foe) equipment in one C-135 and two C-141 aircraft. The three aircraft are test beds that will support airborne tests leading to future systems procurement. The electrical load analyses will be conducted in Electrospace's Fairborn, Ohio, offices. Structural stress analyses will be conducted at the company's Richardson facility. Fabrication and installation work will be accomplished at the company's new Aircraft Modification Center in Waco, Texas, which became operational in March 1985. Completion of the contract is scheduled for December 1986.

TIW Systems, Inc. to Install Telemetry Antenna

TIW Systems, Inc., Sunnyvale, California, has been awarded a contract for a telemetry antenna by the Eastern Space and Missile Center/AFSC, Patrick Air Force Base. The Large Aperture Telemetry Antenna (LATA) will be installed at the Jonathan Dickinson Instrumentation Facility (JDIF), Florida. The LATA is part of a significant upgrade program being undertaken by ESMC at the JDIF.

Under a $2,475,000.00 contract, TIW Systems will design, manufacture and install a full motion elevation over azimuth pedestal supporting a 50 foot diameter Cassegrain antenna. The LATA is designed to automatically track at rates up to 10°/sec with accelerations up to 5°/sec^2. The tracking system features a five horn tracking feed, a redundant LNA/receiver system and an antenna control unit based on three thirty-two bit microprocessors.

For additional information, contact Rob Wellins at TIW Systems, Inc., 1284 Geneva Drive, Sunnyvale, California 94089-1196; (408) 734-3900, or circle INFO/CARD #133.

TRW Consolidates Resistor Products in Boone

On March 1, 1986 all sales, marketing and customer service functions of TRW's Resistive Products Division were consolidated at Boone, N.C. Manufacturing will continue at two other locations, Philadelphia, Penn., and Corpus Christi, Texas, as well as at Boone.

"This consolidation reflects our empha-

sis on customer orientation," explains Dick Paden, director of sales and marketing for resistive products. "With all functions under the same roof, we can cut response time on all fronts — faster turnaround on quotations, prompter order entry and earlier shipment."

"We've always been good generalists," adds John Carwile, vice president and general manager of the division. "Now we aim to be equally good on specifics. We have developed a tremendous technological base, which we have used in fulfilling quantity orders for large customers. We can now apply that knowledge to help customers solve specific problems.

"We have also tripled our production capacity. Late in the last quarter of 1985, we saw orders turn around and really take off. And we expect the trend to continue as other industry segments begin to share in the upswing."

"TRW already has the broadest line of surface-mounted resistors, and we are continuing to add products," says Paden. "We're working on new flat chip, cylindrical chip and film chip resistors. And we're putting our technical background to work in developing hybrid circuits — using both thick-film and thin-film technology. And we're working in other areas, too. The new SSP semi-precision, for instance, is a highly cost-effective conformally-coated and flame-retardant wire-wound resistor." For information, circle INFO/CARD #132.

Besser Associates Offers On-Site CAD Seminars

Les Besser, president of Besser Associates, has developed two on-site seminars for using EEsof computer aided design tools. The courses cover the Touchstone/E-Syn/Line Calc/Monte Carlo family of programs. One is a two-day course that outlines the basic capabilities of the programs. The other is a three-day advanced course for those already familiar with the programs, who want to maximize their effectiveness in using CAD. Other courses on MiCAD and M-SPICE will follow soon, said company spokesman Ron Rose.

All courses include extensive hands-on laboratory sessions where participants apply the principles learned. The course material may also be tailored to the specific needs of the attendees. The instructors have extensive CAD and educational experience in the RF/microwave field.

The fee for the two-day course is $4,500 for up to 10 participants and $450 for each additional person. The three-day course is $6,000 for up to 10 participants and $500 for each additional person. For further information contact Ron Rose, Besser Associates, Inc., 3975 East Bayshore Road, Palo Alto, CA 94303, telephone (415) 969-3400, or circle INFO/CARD #131.

New Directory Locates 900 Federal Labs

Hundreds of federal laboratories and engineering and information centers now make their expert advice, specialized services, and facilities available to assist U.S. businesses and researchers, according to the National Technical Information Service, Springfield, Va. The participating laboratories listed in NTIS's Directory of Federal Laboratory and Technology Resources offer unique capabilities and expertise not generally available from other sources.

This second edition of the directory contains information about special labs, research centers, testing facilities, and special technology information centers. The publication fully describes the individual capabilities of each organization. The name and phone number of a specific contact for each facility is provided. The directory is organized for easy lookups by technical areas of interest and for instant identification of the unique capabilities and the contact person. Detailed indexes cover subject, location by state, organization name, and federal agency.

This directory is published by the Center for the Utilization of Federal Technology (CUFT); a special program located at NTIS for the purpose of increasing technology transfer from the federal government to private industry. Order PB86-100013/KCS, Directory of Federal Laboratory and Technology Resources — A Guide to Services, Facilities and Expertise, 1986-1987, (288 pp., softcover) $29, plus $3 shipping and handling, from NTIS, Springfield, VA 22161, (703) 487-4650.

Proceedings of Japanese Access Seminar Available

How the United States can gain better access to Japanese technical literature in electronics and electrical engineering is the topic of a 155-page report now available. The report summarizes a June 1985 seminar held at NBS and offers transcripts of presentations by representatives from Congress, industry, universities and federal agencies.

The common thread in the presentations was interest in maintaining current knowledge of technical progress in Japan despite frustration over language barriers. Few Americans can read Japanese, and only about 20 percent of Japanese technical literature is routinely published in English. This raises questions such as: How important is the 20 percent available in English? How can one gain access to the other 80 percent?

The seminar offered possible answers, including a more active translation role for professional societies as well as support from American industry. The report, "U.S. Access to Japanese Technical Literature: Electronics and Electrical Engineering" (SP 710), is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 for $6 prepaid. Order by stock number 003-003-02709-0.

Eaton EID Wins Major Ford Aerospace Contract

The Electronic Instrumentation Division of Eaton Corporation (EID) has been awarded a $957,000 contract by Ford Aerospace's Satellite Control Facility (SCF) in Sunnyvale, Calif., for its 384M Direct Synthesized Signal Generators. These instruments will be incorporated in the first phase of a multi-phase program for the Automated Remote Tracking Station (ARTS). ARTS is a key element in modernizing the Air Force's worldwide satellite control assets into a more effective interoperable network, the Air Force Satellite Control Network (AFSCN).

This contract represents the first four of a potential 14 systems to be used on the ARTS program. The initial design effort will be supplemented by production awards over the next five years. There is a potential for over $3 million in add-on instrumentation business for Eaton.

The first installation of Eaton 384M Signal Generators is scheduled for shipment in the first half of 1986. According to Paul Gianfortune, vice president of marketing for EID, Ford Aerospace chose the Eaton synthesizers for their field proven capability and the ability to meet all of Ford specifications. The Eaton 384 is designed to operate to 4 GHz with 20 microsecond switching.

The new automated systems will replace older communications bays which have grown obsolete with respect to today's technology and expensive to operate. ARTS will reduce costs, create additional capability, and provide facilities for efficient growth. The new ARTS program will increase the Satellite Control Facility Station capability through faster turnaround by automatically acquiring and tracking the various satellites. Each station will employ Eaton 2075-2A Noise-Gain Analyzers, 7650 System Noise Sources and 384M Frequency Synthesizers.

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The A-7550 Spectrum Analyzer by IFR is the most advanced, low cost, portable spectrum analyzer on the market today.

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To further enhance the operational simplicity of the A-7550, the microprocessor system automatically selects and optimizes the analyzers bandwidth, sweep rate, center frequency display resolution and the rate of the frequency slewing keys. An operator override is also provided when non-standard settings are required.

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Optional Features Include:

▪ Internal rechargeable 5 APH battery for portable operation ▪ Tracking generator with 10 dB step attenuator ▪ Tracking generator with 1 dB step attenuator ▪ FM/AM/SSB receiver ▪ IEEE-488 interface bus ▪ RS-232 interface bus ▪ 75Ω adaptor ▪ Quasi-peak detector

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INFO/CARD 19

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These miniaturized extremely wide-band matrices are perfect for Automatic Test Equipment (ATE) where fast rise time, wide bandwidth data from the unit under test must be connected to any array of test equipment, or in telecommunications where wideband data rates must be connected between modems, transceivers or satellite uplink/downlink terminals.

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INFO/CARD 21

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So order one to go, with everything, or one of our other tantalizing specials.

MODEL #	FREQ. RESP.	DESCRIPTION
SAS-200/510	300 - 1800 MHz	Log Periodic
SAS-200/511	1000 - 12000 MHz	Log Periodic
SAS-200/512	200 - 1800 MHz	Log Periodic
SAS-200/518	1800 - 18000 MHz	Log Periodic
SAS-200/530	150 - 550 MHz	Broadband Dipole
SAS-200/540	20 - 300 MHz	Biconical
SAS-200/541	20 - 300 MHz	Bicon'l, Collapsible

MODEL #	FREQ. RESP.	DESCRIPTION
SAS-200/542	20 - 300 MHz	Biconical, Folding
SAS-200/550	.001 - 60 MHz	Active Monopole
SAS-200/560	per MIL-STD-461	Loop - Emission
SAS-200/561	per MIL-STD-461	Loop - Radiating
BCP-200/510	20 Hz - 1 MHz	LF Current Probe
BCP-200/511	100 KHz-100 MHz	HF-VHF Crnt. Probe

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A.H. SYSTEMS

INFO/CARD 22

A Drop Test of Magnetic Shielding

Mishandling or Abuse of Magnetic Materials Causes Deterioration of Shielding Effectiveness.

S.M. Kamens
Amuneal Manufacturing Corporation, and
R.L. Coren
Drexel University

It is well known that any shock, such as vibration, dropping or striking lowers the effectiveness of a magnetic shield, but just how much, in what way, and to what extent can it be restored? At what point will the attenuation factor deteriorate beyond acceptability?

While physicists studying magnetic material have an understanding of the changes which occur when high μ materials are stressed to various degrees, their results are obtained under controlled laboratory conditions and are difficult to apply in the complex conditions of a "real world" shield accident. As a result, in practical cases there have been intelligent hunches and guesses guided by understanding, but no conclusive results have been available from appropriately planned experiments. This article examines the effect of such accidents by shocking magnetic shields in a manner simulating events in the field. While generalization from any set of experiments is limited, the results presented here do seem to offer answers to the above questions.

For simplicity, the parameters of the experiment were limited to a sampling involving one material, one thickness, and one geometry. The material was an 80 percent nickel-iron alloy which its manufacturer specified to have the following percentage alloying constituents:

Ni:	80.1	C:	.018
Mo:	4.33	P:	.002
Mn:	.52	S:	.001
Si:	.32		

The manufacturer's testing of ring samples of this material, according to induced current — ASTM test #A-753 — provided the potential permeability value of μ =95,010 at B=40 Gauss.

For statistical reliability in evaluating the results, five identical samples were constructed. These were shielding cylinders, 2.4" I.D., 10" long, and 0.020" thick, fabricated from sheet material by rolling and spot-welding a 1/2" overlap at 3/8" intervals along the axis.

Attenuation tests were performed immediately after fabrication of the cylinders, according to ASTM specification 698-74, the Helmholtz method, in a 60 Hz field of 2 Oersted. The following values were found for the attenuation factor.

Shield No.	Attenuation	
1	14	
2	13	
3	14	
4	14	
5	13	Average 13.6±0.55

The mean value of the attentuation factors is 13.6 ± 0.55, where 0.55 is the statistical standard deviation of the measurements. (If the test were repeated with equivalent samples, 68 percent of the measured valued should fall in the range 13.6-0.55 to 13.6+0.55). The size of the standard deviation is an indication of the reliability of the result; in this case the standard deviation of only 4 percent of the mean value indicates excellent uniformity.

Following these tests the cylinders were subjected to a full hydrogen anneal in one of Amuneal's furnaces. Anyhydrous ammonia is cracked at 1750°F to make pure dry hydrogen at a dew point of −60°F. They were soaked for three hours at 2150°F and cooled at an average rate of 370°F per hour.

The attenuation tests were repeated, now giving:

Shield No.	Attenuation	
1	526	
2	500	
3	500	
4	487	
5	500	Average 502.6±14

Note that the high temperature anneal increases magnetic attenuation by a factor of 37.

Drop Tests

To provide realistic shock conditions each cylinder was oriented with its axis horizontal and dropped from fixed heights to a linoleum covered wooden floor. No attempt was made to control the angle of impact or bounce or distortion of the cylinder as a result of the drop.

A specific test schedule was used:

Phase 1

- Three drops from a height of 1 foot — the attenuation was measured after each drop.
- The shields were rolled and sized to return the cylinders to their original shape.

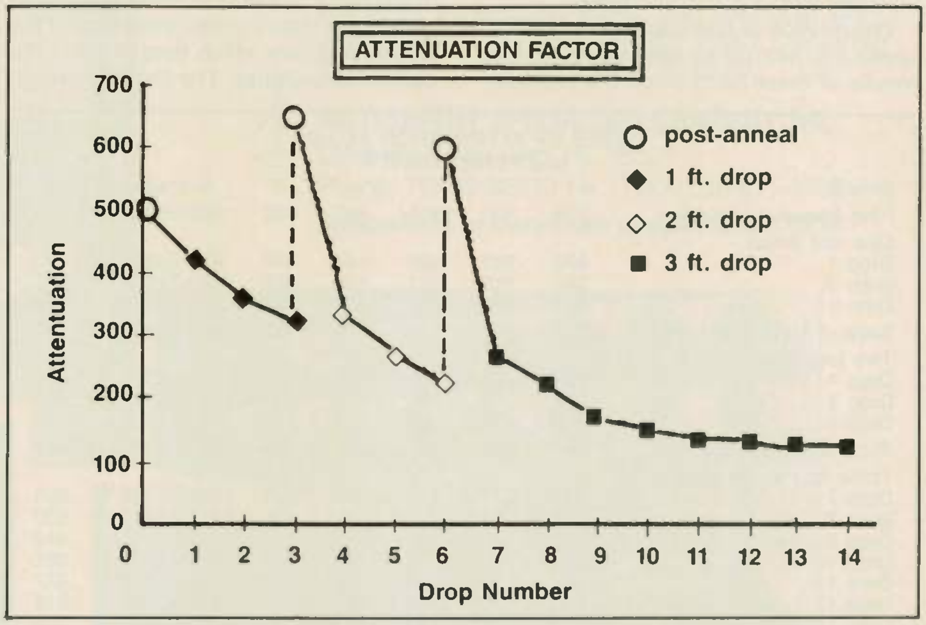

Figure 1. Average measured attenuation of shielding cylinders during testing sequence of annealing and drops.

7. The fact that a single line then spans the entire range means that after an intermediate anneal, a single drop-shock almost reduces the sample to the condition it had before that anneal. An intermediate conclusion indicates that the effect of reannealing these abused shields is practically eliminated by a single new shock incident. It seems that the initial anneal after fabrication sets the response rate. It also appears that shield abuse might set a "pattern" for strains in the material and, though annealed out, they more easily reappear in response to subsequent shocks.

Figure 2 also shows that after a number of impacts (11 drops in this case) there is saturation of the strain mechanism and further changes are much smaller. Here we see that the total change of μ (and of the shielding effectiveness) is by a factor of 4 or 5.

The fact that a single line passes through all the points on Figure 2 also implies that the difference between a one-foot, two-foot, or three-foot drop is not a major factor. It is true that the immediate change of permeability is greater for the greater distance drops after each anneal, but this merely serves to return the datum point to the straight line. It is important to realize that this conclusion is based on the scantiest of evidence and more testing, perhaps over a larger range or different types of strain-inducing shocks, would be necessary to confirm this point.

For no data point is the standard deviation greater than 8.5 percent, and it is generally much lower. Such small values impart great confidence that the test results represent behavior which would be found with other, similar types of tests, and that the conclusions are reliable.

We should note that for the alloy composition used here the material constants which determine sensitivity to structure are known to be very small, so the magnetic behavior is relatively insensitive to strains. It follows that if these tests were performed on other commonly used shielding alloys, one would expect to observe greater changes.

The results of these experiments may be summarized as follows:

- Dropping a magnetic shield degrades the permeability and lowers the shielding effectiveness. It is expected that the same is true for any vibration or shock, such as dropping a tool on a shield surface, walking on it, etc.
- A degraded shield can be re-annealed to restore optimal magnetic properties. If this is done the subsequent sensitivity to abuse is greater than that of the "virgin" shield but, in any event, the shield performance is never worse than without the reanneal.
- Full hydrogen anneal is mandatory for maximum shielding attenuation. rf

Reference

(1) R.S. Tebble and D.J Craik, *Magnetic Materials,* Wiley-Interscience, New York, 1969, Ch. 13.

About the Authors

S.M. Kamens is president of Amuneal Manufacturing Corp., 4737 Darrah Street, Philadelphia, PA 19124, telephone (215) 535-3000.

Dr. R.L. Coren is Professor of Electrical and Computer Engineering at Drexel University, Philadelphia, PA 19104.

Part I: A Laptop CAD Workstation

By Ulrich L. Rohde
Communications Consulting Group

The IBM personal computer has stirred up a large interest in high power full CAD workstations for the RF and microwave areas. Now, Communications Consulting Corp. has developed a software package optimized for the IBM PC and based on normal techniques like adaptive optimization and adaptive matrix manipulations. While the statement "CAD" is typically misleading because the initial process is to move from a set of electrical specifications to a schematic which then gets analyzed and optimized, it is appropriate here because we have also introduced synthesis capabilities to help the user.

Taking advantage of the very latest laptop computers, such as the new Toshiba T1100 (with some custom hardware modifications) or the Grid, the 8087 numerical coprocessor, and such new software tools as high performance Pascal and Fortran, significant reductions in code size and vast improvements in speed are possible.

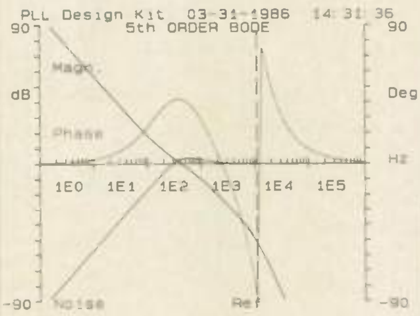

Figure 1. BODE diagram from the type 2, fifth order loop.

Until recently, software tools in the area of CAD predicted the analysis of existing circuits and synthesized functions like physical transmission line parameters from electrical specifications or matching networks. These capabilities are insufficient for a complete workstation approach. We have, therefore, developed a broad spectrum of tools which go beyond the traditional limited synthesis capabilities and, for the first time in the industry, cover more than the limited microwave area. They are:

1) Frequency selection for minimum IMD products in mixers;
2) Determination and optimization of noise figure or intercept point of cascaded amplifiers, mixers, and filter systems;
3) Design of compensated wideband transformers;
4) Design of gain equalizers;

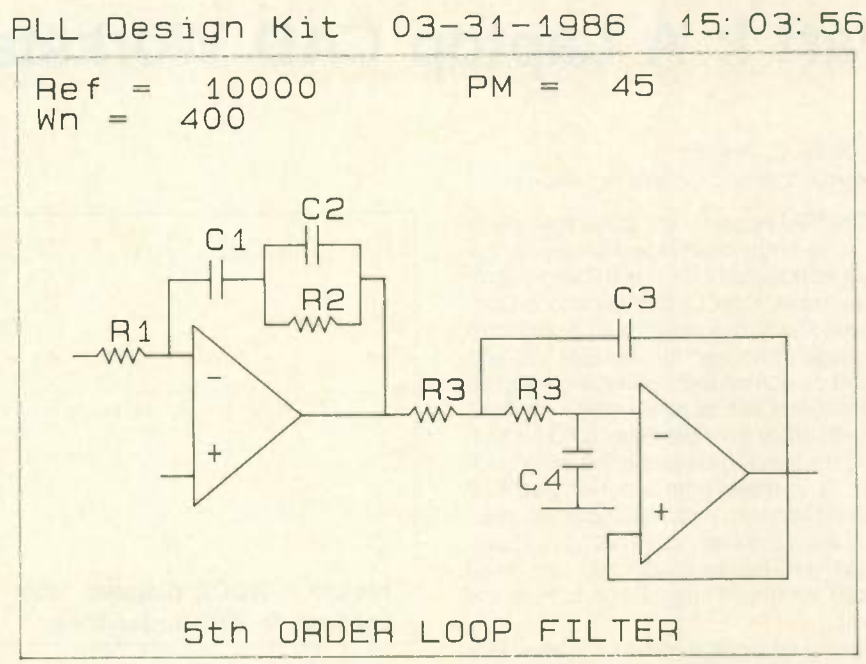

Figure 2. Filter arrangement for the type 2, fifth order loop.

5) Design of dual loop AGC systems with group delay correction;
6) Design and analysis of digital filter systems;
7) Synthesis of Chebyshev, Butterworth, and elliptical highpass/lowpass/bandpass filters;
8) Synthesis of crystal filters up to the order of 6;
9) Synthesis of helix filters;
10) Synthesis of interdigital filters;
11) Matching of complex load and sources based on the Carlin and Yarman technique for a minimum insertion loss;
12) Determination of complex impedances of electrical antennas;
13) Determination of antenna array patterns with all driven elements;
14) Synthesis and optimization of type 2,

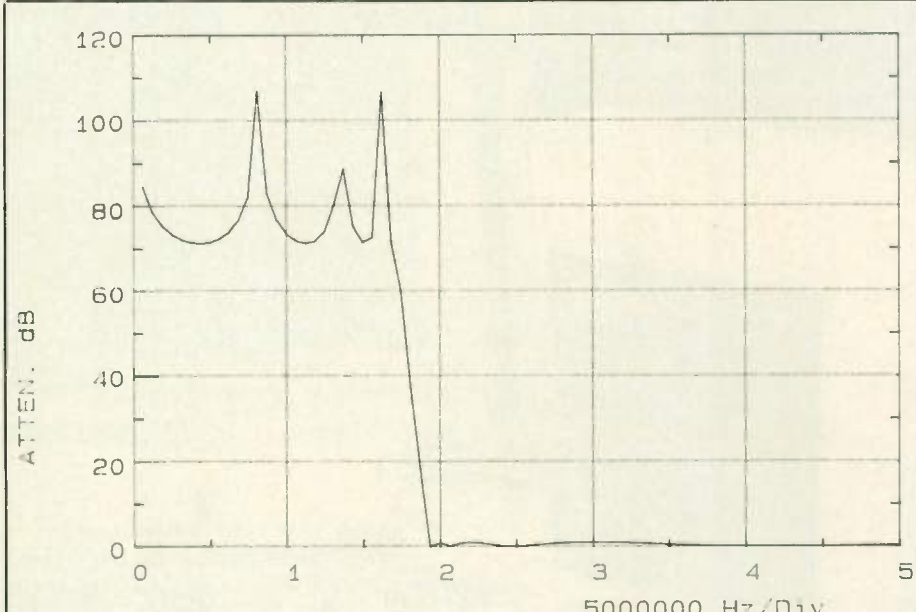

Figure 3. Frequency response for the elliptical filter from the filter synthesis program.

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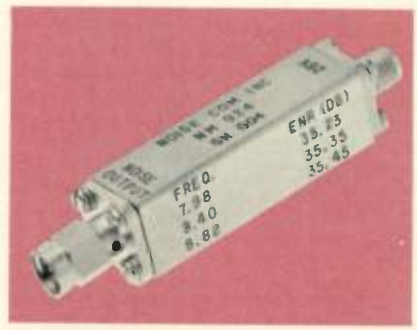

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second order, third order, and fifth order digital phase locked loops;
15) General analysis of quasi-arbitrary digital PLL circuitry;
16) SSB phase noise analysis of free-running VCOs and closed loop VCOs; and
17) Transient switching response of higher order loops.

Figures 1 through 3 show some typical screen outputs for these programs.

Taking these capabilities one step further, we have developed a new, very inexpensive, general purpose CAD package called CADEC 4, optimized for the small computer environment, which is ideal for RF and microwave frequencies up to 4 GHz. The list of elements includes all commonly used lumped elements, such as crystals, non-ideal wideband transformers, MMIC spiral inductors and interdigital capacitors, gyrators, isolators, coaxial cables, and advanced semiconductor models for bipolar transistors and MESFETs. In the microwave area, all of the necessary distributed microstrip non-ideal and ideal components, such as shorted and open-circuited stubs, microstrip couplers, bends, gaps, steps, T-junctions, and crossing junctions, are provided.

```
CADEC DISK # 1 CCC DEMO                          31 MAR 86 15:01 FILE # 20
     PRI 6_18ghz WB AMPLIFIER
  1: SRC              2V  50ohm
  3: TER              50ohm
  4: REF              50ohm
     REM INPUT/OUTPUT DOES NOT HAVE TO BE EQUAL
     OPT   S21/DB=7.6/.15
  5: LFR              4GHz  20GHz  1GHz
  8: NAB              300K
  9: UOS              100ohm  64deg(0deg/360deg)  18GHz  10E3
 13: .USS             70ohm  141deg  18GHz  10E3
     ..CAS
 17: .UTL             100ohm  23deg  18GHz  10E3
     ..CAS
     .OLD D1
     ..REM    20 Ghz TRANSISTOR WITH NOISE DATA COMPUTED FROM PHYSICS.
     ..CAS
 21: .UTL             100ohm  16deg  18GHz  10E3
     ..CAS
 25: .USS             51ohm(40ohm/100ohm)  70deg  18GHz  10E3
     ..CAS
     .NAE
     .DUP
     ..CON  2  0  5
     .CON  4  0  7
     REM Z=SQR(Ze*Zo) , a=LGT (( Ze-Zo)/(Ze+Zo)) [dB]
     REM WIC           50 ohm 12Ghz -2.093dB ' WILKINSON COUPLER ELEMENT
 29: CPL              144.3ohm  17.3ohm  245.9mil  1  1
     REM COUPLED LINE FILTER
     INS  1  4  3  2
     INS  5  8  7  6
 34: RS               50ohm
     .DUP
     ..CON  6  0  0
     .CON  3  0  0
     TWO  1  8
     .OUT IRC/DB ORC/DB  NF/DB   S21/DB
```

Figure 4. Circuit description including CADEC 4 optimization commands.

Noise Analysis Capability

As a rare novelty, the program can handle complete noise analysis for nodal circuit arrangements using any arbitrary combination of active and passive components. Noise data can be entered as measured data or calculated from data on semiconductor physics in papers published in the Proceedings of the IEEE on Microwave Theory and Techniques over the last few years. In particular, noise analysis is based on a dissertation by Christos Tsironis at the University of Aachen, a dissertation by K. Hartmann, "Computer Simulation of Linear Noisy Twoports with Special Considerations for Bipolar Transistors up to 12 GHz," at the Federal Swiss Institute of Technology in Zurich, and in-house work done by the staff of Communications Consulting Corporation (CCC).

The mathematics used to calculate the noise performance of correlated and non-correlated noise sources with unrestricted topology is based on two papers: "An Official Method for Computer Aided Noise Analysis of Linear Amplifier Networks," from the IEEE Transaction on Circuits and Systems, Vol. CS-23, No. 4, April 1976, and "Computationally Efficient Electronic Circuit Noise Calculations," by Rohrer, from the IEEE Journal of Solid State Circuits, Vol. SSC-6, No. 4, August 1971. The

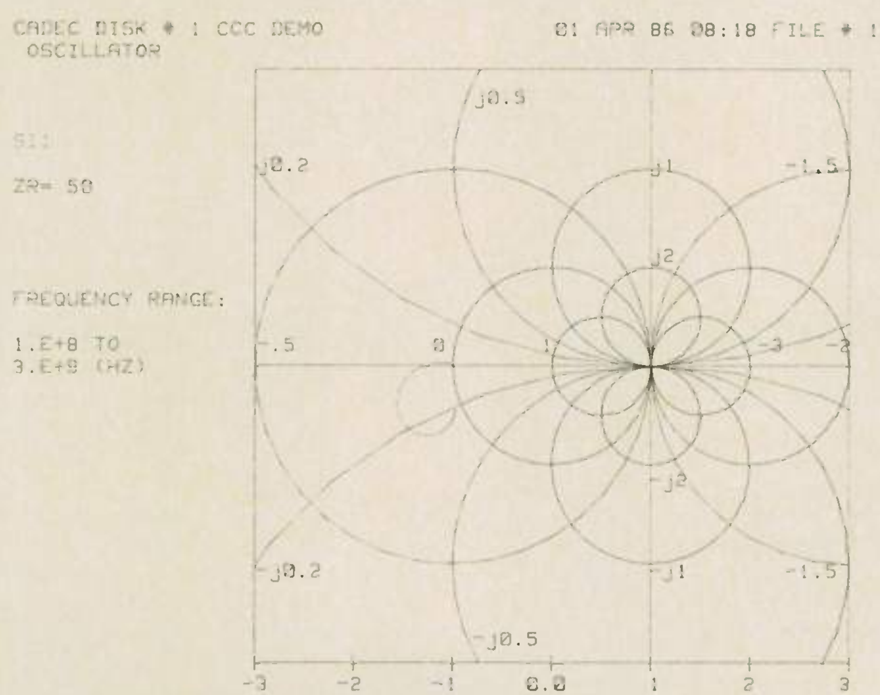

Figure 5. A Smith diagram for oscillator design.

CCC staff combined these techniques into an efficient adaptive matrix algorithm to prepare the analysis portion for nonlinear circuit capabilities based on Voltera Series Expansions or Harmonic Balance Method.

While circuit descriptions are entered in user dimensions like pF or nH, the online editor also accepts absolute values and can handle even the most complex optimization cases, including setting of variable boundaries.

This adaptive optimization, described in the May 1985 issue of Microwave Systems News, performs the most user-friendly optimization, combining the best of pseudo-random search and gradient optimizers. It evaluates the sccess rate of trial optimizations and avoids unsuccessful directions. The built-in intelligence of the software automatically switches after initial optimization through the gradient method and, therefore, can handle the optimization in much faster time.

An adaptive method is also used to handle the matrix computation inside the program. Here the program determines whether or not full noise analysis is called for and uses matrix reduction and inversion techniques which do not have the traditional difficulties associated with real underflow and overflow based on matrix handling. Figures 4 through 6 show some of these screen outputs.

The last but equally significant capability is the ability to handle time domain analysis. It allows the user to generate any arbitrary waveform and use it to probe the circuit response. This is particularly important in a multi-tone environment. Programs like SPICE only provide table and graphics waveform outputs, have no optimization feedback control and, typically, do not have any microwave components. CADEC 4 can generate and store waveforms at the input and output of the circuit and, with a software demodulation process, show reflections at the point of occurrence and other forms of signal distortion. Figure 7 shows the VIT signal distortion.

Taking advantage of the latest in microprocessors and hardware and new mathematical algorithms, it was possible to port a CAD workstation on a small computer like the laptop Toshiba T1100 or the Grid, showing significant performance enhancements. These computers can be tied together with larger workstations and are compatible in exchanging work files.

For information about this CAD workstation circle INFO/CARD #130.

About the Author

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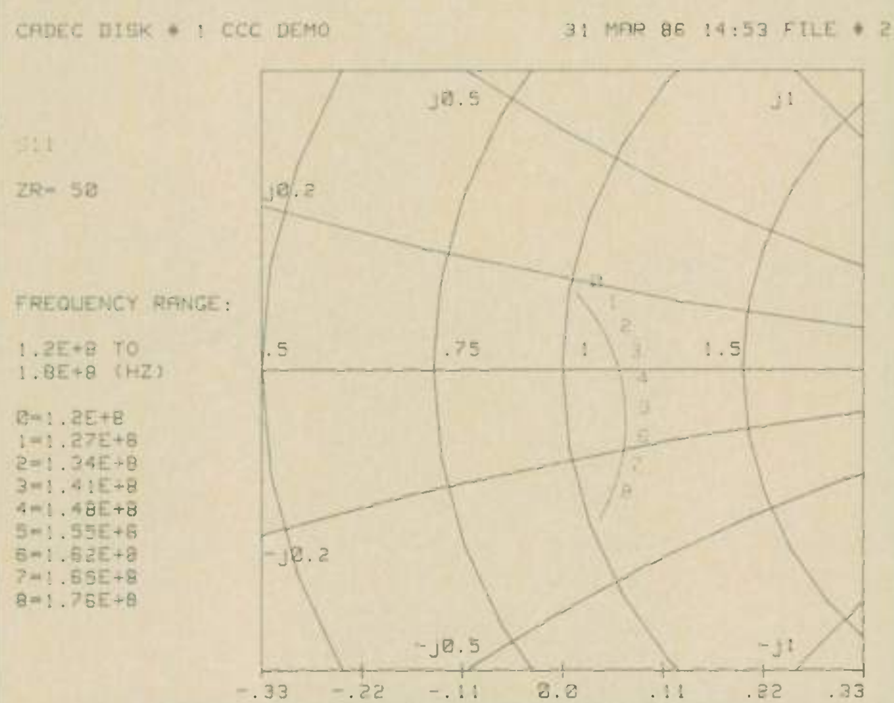

Figure 6. An expanded Smith diagram for high resolution.

Part II: Microcomputer for the

By James N. MacDonald

The most rapid change in the current RF engineering scene is the development of computer aided design software. By handling complex calculations, computers give designers time to try new ways of solving problems. This increased efficiency can make the engineer's work more valuable to the company and more interesting to do.

Trade magazine articles with programs written by engineers to solve design problems have long been popular. A few years ago most articles were written for programmable calculators; now most are written for microcomputers. Hardware prices have dropped significantly during the past year, allowing more engineers to buy personal computers. New software companies, usually started by engineers, are announced almost monthly, and new programs come out so often that *RF Design* magazine will carry a separate section for design software in the RF Products pages.

The first CAD programs for circuit designers were written for mainframes and available only to engineers with access to company computers or time-sharing networks. Now versions have been developed to make many of the capabilities of mainframe programs available on microcomputers. Two major companies leading this trend are Compact Software, now owned by Communications Consulting Corp., Paterson, N.J., and EEsof, Inc., Westlake Village, Calif.

The latest development in this direction is the subject of this month's cover and is described in an article by Ulrich Rohde in Part One of this Special Report. Communications Consulting Corp. has developed software that allows a new laptop computer to be used as an RF design engineer's workstation. The Toshiba T1100 computer shown on the cover is fully IBM compatible, has 525K of memory and will communicate with a color graphics monitor, as shown in the cover photograph. It has the RS-232 serial interface and a parallel printer port.

This section of the Special Report is a roundup of some of the microcomputer software available to RF design engineers. Descriptions of these programs and their capabilities were provided by the companies and *RF Design* has not at-

Software RF Designer

tempted to verify the claims. Interested readers may circle INFO/CARD numbers for additional information from the companies.

Touchstone/RF: Touchstone is a well-known program by EEsof, Inc., Westlake Village, Calif., to design, analyze and optimize linear RF/microwave circuits, from simple ladder networks to complex distributed amplifiers. Touchstone/RF is a lower cost version of the program for RF design engineers, with added enhancements and without microwave models not needed by the RF designer. With this program the designer can build and optimize a circuit on a microcomputer, saving time in the lab.

A new program, to be demonstrated at the MTT-S, June 2-4, in Baltimore, is E-Syn I. E-Syn I maximizes circuit efficiency by providing an array of circuit topologies based on the required electrical specifications. It synthesizes thousands of networks, including impedance-matching and filter networks. E-Syn I is capable of matching a resistive source impedance into a resistive load impedance for developing a transformer structure.

Once a user supplies the required electrical parameters, E-Syn I synthesizes all possible networks, so a designer can select the most efficient topology; one which employs element values consistent with specifications. E-Syn I is designed to run on an IBM PC-AT or compatible personal computer. It requires a minimum of 640K of memory, and must utilize a 10 MB hard disk and a 360K flexible disk drive. The file output of E-Syn I is also compatible with EEsof's linear circuit analysis and optimization program Touchstone, which allows users to combine synthesis networks with other circuit elements and obtain a complete component or subsystem design.

E-Syn I, Touchstone and other EEsof programs are the subject of on-site seminars offered by Besser Associates, Palo Alto, Calif. The seminars on using computer-aided design are described on page 22 of the News section.

EEsof has just introduced two microwave filter design programs for the IBM-PC and compatibles, the first in a series being developed by the company. Filter I: Edge-Coupled Stripline, and Filter II: Edge-Coupled Microstrip, are designed for expert and non-expert use. They can be used as stand-alone programs or in conjunction with Touchstone, which can create graphic plots of the filter's performance characteristics. Data stored in the filter's scattering parameter files can be used with Touchstone to integrate filter response with other components for system analysis. For information about these and other EEsof products please circle INFO/CARD #128.

S/Filsyn: DGS Associates has released a microcomputer version of S/Filsyn, a program to design and synthesize LC filters, including crystals, microwave, active RC filters, and digital filters (both finite and infinite impulse response form). The complete program comes in five modules that can be bought separately, including utilities to automate the design of some filter types. INFO/CARD #127.

OPTI-MIC: Summit Technology, Los Gatos, Calif., has just released OPTI-MIC software for design and optimization of RF and microwave circuits. The program has nodal analysis for easy circuit topology entry, full interactive graphic capabilities, and an interactive gradient optimizer for efficient circuit design. Its format allows use of input or manufacturer's transistor S parameters for amplifier and oscillator design. It is available for both IBM-PC and Apple II microcomputers, with site licensing as well as single user option. Please circle INFO/CARD #126.

SYSCAD: This software by Webb Laboratories, North Lake, Wis., is designed to allow transmit/receive free space link behavior to be predicted in as versatile a manner as possible, to allow receiver and transmitter frequency conversions to be analyzed at a useful level, and to permit receiver and transmitter architectures to evolve quickly and efficiently. The company has just released Version 2.1, which includes a program to calculate phase and frequency jitter for arbitrary phase noise spectral density functions and system noise band limits and adds the ability to create and store on disk customized mixer spur tables for use in the spurious analysis program. SYSCAD will run on the IBM-PC and compatible machines. INFO/CARD #125.

8th Dimension: 8th Dimension Enterprises, Sunnyvale, Calif., has produced RF lumped element filter design programs for the Apple II and IIe and will soon release them for the IBM-PC and compatibles. Totally menu-driven programs design low pass filters from DC to 1200 MHz, high pass filters from 1 kHz to 1100 MHz, band pass filters from 10 kHz to 1000 MHz, and band reject filters from 10 kHz to 1200 MHz. Another program, Microstrip Low Pass Filter CAD, designs a low pass filter between 1 and 26 GHz. INFO/CARD #124.

COMTRON: A program for HP desktop computers, COMTRAN, by Jensen Transformers, Inc., N. Hollywood. Calif., is a general purpose linear circuit analysis and optimization program featuring both time domain and frequency domain analysis of circuits having R, L, C, and voltage-controlled current source components. Closed-loop gain and stability can be studied for circuits using either ideal op amps or real op amps with user specified open-loop characteristics. The frequency domain module is the AC-Circuit Analysis Program (AC-CAP), expanded and improved by the authors of the original HP program of that name. Operating much faster, it interfaces with an improved time domain module, S-WAVE. These are combined with PLOTFT, a new waveform analysis program to analyze magnitude and phase response, complex impedance, group delay and phase delay, waveform response, component tolerance effects, and sensitivity analysis, for active and passive filter design and op amp design. INFO/CARD #123.

RF Notes: Etron Radio Frequency Enterprises, Diamond Bar, Calif., recently announced RF Notes No. 1 for the IBM-PC and compatibles. The eight programs are written in BASICA, and some use color graphics. They convert voltage, current or power ratios to dB, convert voltage or power levels to dBm; calculate circuit constants for five resonant circuit configurations; calculate required microstrip and stripline width for straight runs; and compute cross products when input and output frequencies and output guard band are known. INFO/CARD #122.

ECA-2: Electronic Circuit Analysis, Version 2.2, is a high performance analog circuit simulator just released by Tatum Labs, Newton, Conn. With ECA-2 all components, even inductors and capacitors, can have non-linearities. Even resistors can be assigned bandwidth, phase shifts, and time delays, and capacitors can have inductance and resistance. The performance of a circuit can be seen as it varies with temperature, and component values can be varied with time and frequency. The program includes a proper diode model, including temperature effects,

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breakdown, leakage, and the correct exponential characteristic. With ECA-2 the designer can look at voltages and currents anywhere in the circuit. The program will show power dissipations, port impedance, the small signal values of devices, incremental resistance in a nonlinear analysis, and the complex impedance of parts in an AC analysis. The program has a built-in editor and accepts standard ASCII files. It also has full worst case and sensitivity analysis and Monte Carlo analysis. INFO/CARD #121.

Nodal: A program for the IBM-PC with 128K of memory, Nodal will analyze circuits with up to 50 elements and unlimited nodes. Twenty-five element types are available and print options have up to 100 frequency points. IR&D Electronics, Mountain View, Calif., now also offers Nodalizer, an RF and microwave circuit optimization program that interfaces with Nodal. The company also has MacNode, for the Macintosh. INFO/CARD #120.

STAR: This general purpose RF analysis and optimization program is produced by Circuit Busters, Stone Mountain, Ga., for IBM-PCs, Apples, Commodore 64 and Kaypro. Optimization with selectable weights of any 10 values is allowed, with up to 100 frequencies in one run. Circle INFO/CARD #119.

CIAO/DESIGN: SPEFCO Software, Stony Brook, N.Y., introduced these two circuit optimization and synthesis programs for microcomputers last year. CIAO can analyze and optimize broad classes of active and passive networks. Magnitude and phases of scattering parameters of networks can be optimized over a frequency band. DESIGN performs truly automated synthesis of broadband, gain-sloped, lumped element, or distributed-parameter matching networks. Please circle INFO/CARD #118.

This has been an attempt to summarize the most recent arrivals on the RF design software scene known to us. Since the field is developing so rapidly it is likely that some programs have been overlooked in this report. We will attempt to keep up with developments in this area, and new programs will be described in the RF Software section as we learn of them. rf

BASIC Program Plots Spiral Inductors

By Dennis D. King

The model listings for Touchstone™ or Super Compact™ contain some handy models for spiral inductors. These microstrip structures can provide a reasonable Q inductance at low cost, using relatively little space. Since the models include distributed capacitance to ground, the inductors can even be designed to be self-resonant for decoupling circuits, using less board area than a printed ¼ wave transmission line. There are circular spiral and rectangular spiral models, although the rectangular spirals take up slightly more space.

Recent work presented a good application for a circular spiral. An inductor was optimized in a circuit model and preparations made to build a breadboard. The spiral layout was tougher than expected!

When presented with the task of laying out a circular spiral and fabricating a photo tool, a printed circuit draftsman immediately said something uncomplimentary. It seems that unusual circular objects are not popular among rubylith-cutters or CAD operators. Plotting a spiral by hand was found to be very difficult.

It was then decided that a simple BASIC program could plot out a scaled rough outline of a circular spiral on a printer. Rubylith can be cut out to this rough outline, then photo-reduced to the appropriate size with adequate resolution.

Defining the spiral

The center of a spiral inductor trace can be described by the equation:

$R = A\Theta + R_o$, where:

R = radius of spiral for a given angle
A = constant defining expansion rate of spiral
Θ = instantaneous angle of spiral
R_o = inner starting radius of spiral
Θ_f = final value of angle

Some models (like the one used in Touchstone) describe the spiral in terms of center to center inside and outside diameters (DI and DO), line width (W) and line spacing (S). Other models (like the one used in Super-Compact) describe the spiral in terms of starting inside radius (IR), number of turns (N), line width (W) and line spacing (S).

To accommodate both types of descriptions the following equations were derived to determine the basic constants A, R_o, and Θ_f:

$$A = \frac{W + S}{2\pi}$$

$$R_o = \frac{DI - A\pi}{2}$$

$$\Theta_f = \left[\frac{\left(\frac{DO + A\pi}{2}\right) - R_o}{A}\right] \text{Radians}$$

or:

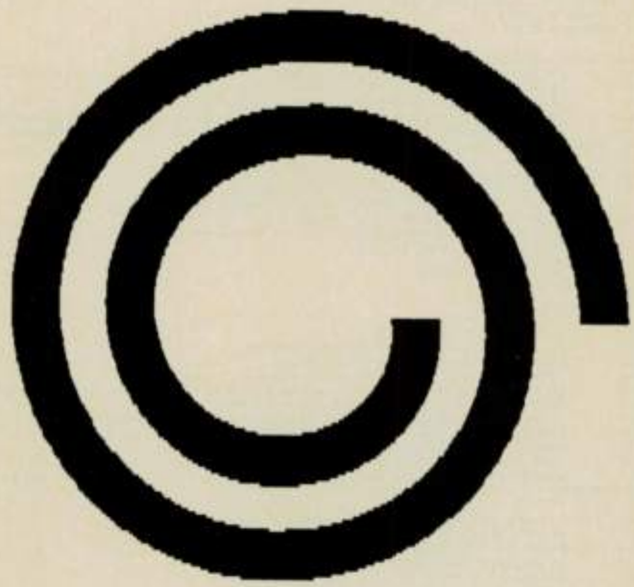


Figure 1. Typical spiral output plot.

$$A = \frac{W + S}{2\pi}$$

$$R_o = IR + \frac{W}{2}$$

$$\Theta_f = N \times 2\pi \text{ Radians}$$

The Computer Program

The program is written to plot the spirals on a PC screen for previewing. When the proper spiral is displayed, a "PRINT-SCREEN" type screen dump then plots out the spiral on a PC graphics compatible printer (Figure 1). The printed output is to scale. The program uses only one graphics type BASIC command (LINE) to be compatible with as many versions of BASIC as possible.

Two variables may need modification to ensure proper scaling. The .0295 in line 700 may need adjustment to produce the proper size spiral on the printed output. In line 710, the 2.4078 aspect variable can be adjusted to produce the proper aspect ratio on the printed output. The factors are checked by actual measurement of the printed output. Once these are adjusted for a particular printer, the program is ready for use.

A spiral can be plotted out to any degree of angular resolution. It's faster to use 10 degrees per point resolution for spiral previewing on the screen, and when a final design is chosen, one degree per point provides the best resolution on the printed output.

If W and S are equal, the angular resolution can be set to 90 degrees and the program prints out rectangular spirals. Everyone has different preferences and requirements, so the program is structured for easy modification.

Spiral inductor computer program (written in BASIC for IBM-PC or compatible units).

```
5 COLOR 15,4,1 'optional, makes for nicer color display of '
10 CLS
20 GOSUB 200 'Printing program description
30 GOSUB 400 'Determine spiral type
40 GOSUB 600 'Getting input parameters
50 GOSUB 800 'Calculating equation parameters and printing them
60 GOSUB 1000 'Plotting spiral
70 INPUT"Plot again?(Y/N)";A$
80 IF A$="Y" THEN 60
90 SCREEN 0:GOTO 5
100 '
200 'Printing program description
210      PRINT"This program calculates and plots the dimensions of a spiral"
220      PRINT"inductor."
230      PRINT"The spiral physical parameters are typed in,"
240      PRINT"as well as a scale factor for the output size.The program then"
250      PRINT"plots the spiral to scale on the printer using PRINTSCREEN."
260 RETURN
270 '
400 'Determine spiral type
410      PRINT:PRINT"Do you want to describe a spiral with:"
420      PRINT:PRINT"1-Line width, width of space between turns,"
430      PRINT"C-C ID and OD  or;":PRINT
440      PRINT:PRINT"2-Line width, width of space between turns, #turns,"
450      PRINT"inside edge radius?"
460      PRINT:PRINT"3-Quit."
470      PRINT:INPUT WHICH
480 RETURN
490 '
600 'Getting input parameters
610      IF WHICH=3 THEN SYSTEM
620      PRINT"INPUT ALL VALUES IN MILS":PRINT
630      INPUT"What is the line width W";W
640      INPUT"How wide is the space in-between lines";S
650      IF WHICH=1 THEN INPUT"What is the c-c inside diameter DI";DI:GOTO 670
660      INPUT"What is the number of turns";TURNS
670      IF WHICH=1 THEN INPUT"What's the c-c outside diameter DO";DO:GOTO 690
680      INPUT"What is the radius to the inside edge of spiral";IR
690      INPUT"What scale factor";SCALE
700      FACT=SCALE*.0295 'This sets the correct scale for your printer
710      ASPECT=2.4078 ' This sets the correct aspect ratio for your printer
720 RETURN
730 '
800 'Calculating spiral equation parameters A,R, THETA
810      A=(W+S)/(2*3.141593)
820      PRINT "A=";A 'Spiral "gain" term
830      IF WHICH=2 THEN R=IR+W/2:GOTO 850
840      R=(DI-A*3.141593)/2
850      PRINT"R=";R ' Radius term at 0 angle
860      IF WHICH=2 THEN THETA=TURNS*360/57.2958:GOTO 880
870      THETA=(((DO+A*3.141593)/2)-R)/A
880      PRINT"THETA=";THETA  'Radians of turn in the spiral
890      THETADEG=THETA*57.2958 'Degrees of turn in the spiral
900      PRINT"This is ";THETADEG;" Degrees"
910      PRINT"or ";THETADEG/360; "Turns"
920 RETURN
930 '
1000 'Plotting spiral
1010      INPUT"Do you want to plot this spiral?(Y/N)";PLOT$
1020      IF PLOT$="N" THEN RETURN
1030      INPUT"How many degrees/point resolution do you want plotted";INCR
1040      SCREEN 2:CLS
1050   'Plotting inside of spiral
1060    FOR I=0 TO THETADEG STEP INCR
1070      ANG=I/57.2958
1080      RAD=A*ANG+R-W/2 'Determines inside radius
1090      X=RAD*COS(ANG)
1100      Y=RAD*SIN(ANG)
1110      X=CINT(X*ASPECT*FACT+320)'Scaling X
1120      Y=CINT(Y*FACT+100)'Scaling Y
1130      IF I=0 THEN XO=X:YO=Y:LINE -(XO,YO),0'Storing init.coordinates XO,YO
1140      LINE -(X,Y),1
1150    NEXT I
1160   'Plotting outside of spiral
1170    FOR I=THETADEG TO 0 STEP -INCR
1180      ANG=I/57.2958
1190      RAD=A*ANG+R+W/2 'Determines outside radius
1200      X=RAD*COS(ANG)
1210      Y=RAD*SIN(ANG)
1220      X=CINT(X*ASPECT*FACT+320) 'Scaling X
1230      Y=CINT(Y*FACT+100) 'Scaling Y
1240      LINE -(X,Y)
1250    NEXT I
1260      LINE -(XO,YO)
1270      PAINT (XO+5,YO+5)   'Optional-Fills in spiral
1280 RETURN
```

Here is one last piece of advice about designing with spiral inductors for the first time: Make certain to build several spirals and test them at the frequency of interest before committing to a design.

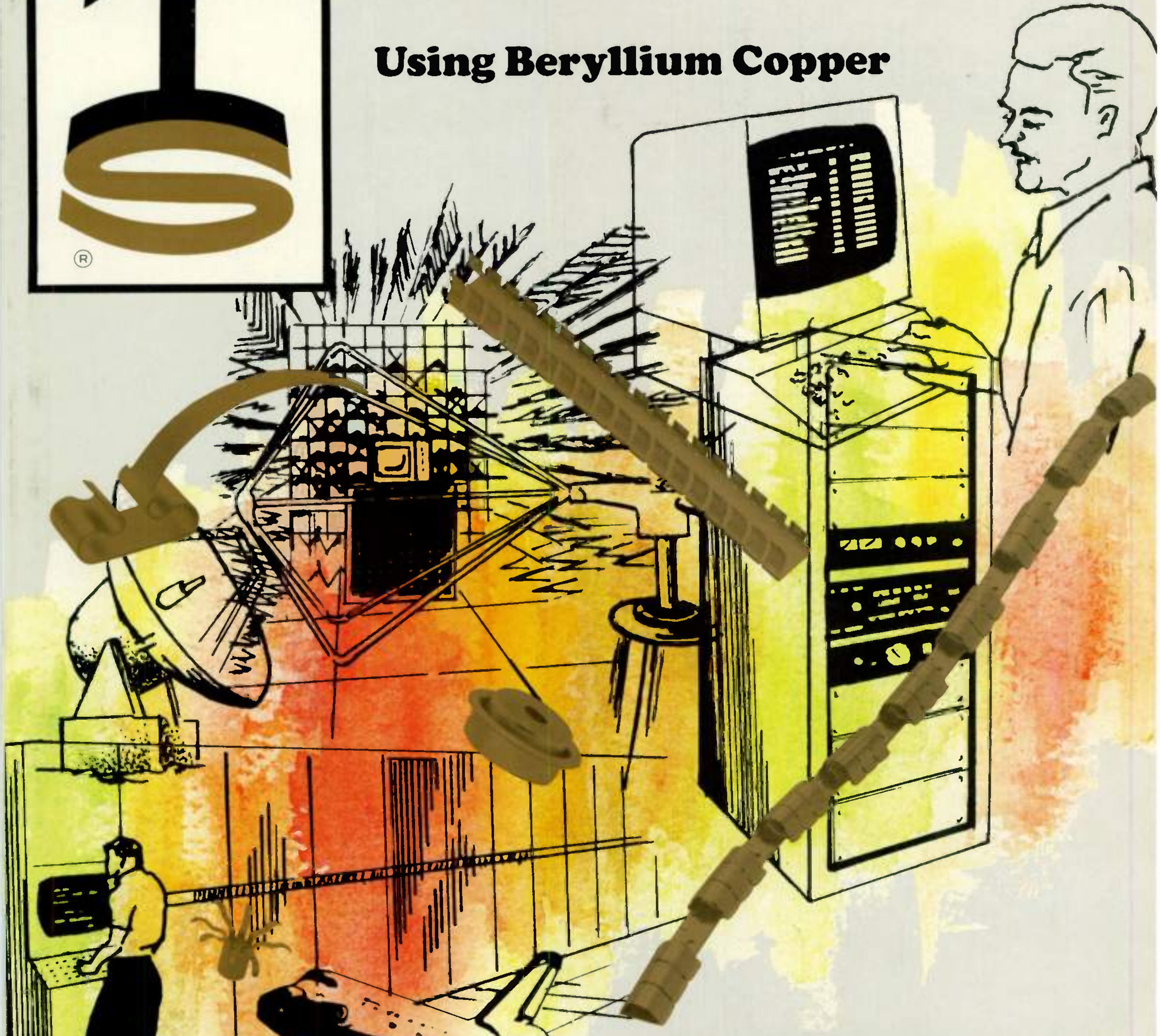
Touchstone is a registered trademark of EEsof, Westlake Village, Calif. **Super-Compact** is a registered trademark of Compact Software Inc., Palo Alto, Calif. rf

About the Author

Dennis King is an RF engineer currently working under contract with E-Systems Montek Div., Salt Lake City, Utah. He can be contacted at Dennis P. King Engineering, 1350 East 8020 South, Sandy, Utah 84092.

Guide to Interference Control

Using Beryllium Copper

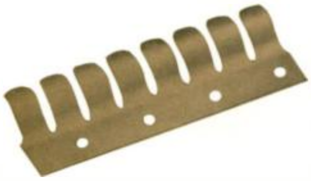


INSTRUMENT SPECIALTIES CO., INC.

Specialists in beryllium copper since 1938

CATALOG E^3-68-RF

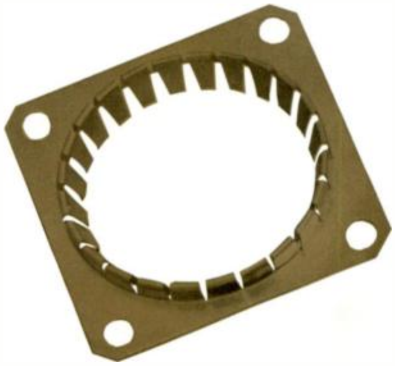
Why Specify Beryllium C



Simply because Beryllium Copper's inherent characteristics produce superior RFI/EMI shielding devices. Here are some of the advantages exhibited by Beryllium Copper:

- Excellent penetration of oxidation due to designed wiping action; generally self-cleaning.
- Does not absorb moisture or support fungus growth.
- No weathering problems; usable at higher temperatures than elastomeric materials (except for "sticky fingers" tape).
- Does not burn or support combustion; nothing to outgas.
- For "RF-only" gasket applications the Be Cu gasket is 1/6th to 1/10th the weight of equivalent elastomeric gaskets.
- Excellent thermal and electrical conductivity, with better shielding effectiveness over a much broader frequency range.
- Will not compression-set; has high mechanical dynamic range; exhibits indefinite shelf life.
- Not affected by air, ozone, ultra violet, nuclear radiation, EMP, or solvents.
- Usable at lower contact forces: 1/10 to 1/5 the force required for elastomers and meshes respectively.
- Cannot flake or break into small conductive pieces to short out electronics; cannot stretch or tear in use.

opper Shielding Material?



Why specify Instrument Specialties Beryllium Copper Shielding Strips?

Because Instrument Specialties' precision manufacturing techniques bring out all of the inherent advantages of beryllium copper.

Beryllium copper by its very nature offers characteristics that can result in electronic gaskets and shielding strips far superior to those made from conventional materials. But the ultimate performance of a beryllium copper strip is a function of every step in the manufacturing process.

Instrument Specialties begins by insisting on extra-quality beryllium copper. It's made to our specifications. We test *every* incoming lot. We then select the exact lot of beryllium copper appropriate for the design and application of the particular strip needed.

Unique equipment, precision tools and more than 45 years of specialized experience are then brought into play. Much of our equipment and all of our quality control procedures have been developed internally.

The result? Precision strips of superb quality, unusually close tolerances, and long, dependable service life.

For many years, Instrument Specialties has been recognized as the leader in the industry. Our engineers and designers are continually working to produce shielding of the highest precision for today's market—as well as the ideas and manufacturing methods that will meet the even more demanding needs of tomorrow. Let us be of service to you. Write or call for further information.

Table of Contents

Shielding for Electrom

DESIGN CONSIDERATIONS

Electromagnetic compatibility (EMC) is the technology of minimizing the electromagnetic interference (RFI/EMI) and susceptibility (EMS-ESD) effects on electrical or electronic devices or systems.

These effects include computer glitches, radio and television interference, weapon systems malfunctions and many other undesirable events.

Both the interference and susceptibility effects are created by time-variant electromagnetic fields which may be propagated along a conducting medium or by radiation through space. Because the source of the conducted and radiated interference energy levels may be related, a coordinated systems design effort is required to reduce these effects. The design program consists of:

- Reducing the interference at its source.
- Isolating the offending circuits by filtering, grounding and shielding.
- Increasing the immunity of any susceptible circuits.

These three steps (suppression, isolation, desensitization) should be carried on throughout the entire equipment design and implemented as early as possible within the design program.

After the implementation of good circuit design controls, the most significant EMC design element for reducing the interference and susceptibility effects is an effective shield.

The shield not only reduces the radiated electromagnetic fields, it also provides an isolated ground reference which effectively reduces internal and circuit path coupling and overall common mode coupling. In many cases, the shield alone will eliminate the need for EMI filters. In the event that filters *are* required for conducted emissions, the shield can provide a better ground sink for the filter, and will isolate the filter input and output, preventing the RF energy from bypassing the filter.

SHIELDING TECHNOLOGY

Shields are designed to either contain or exclude radiated electromagnetic interference. A shield functions by reflecting and absorbing incident electromagnetic radiation. Depending upon whether the EMI source is internal or external to the shield, the reflected component may or may not add to the overall shielding.

As illustrated in Figure 1, the shielding effectiveness (SE) in terms of the field strength (FS) is given by:

$$SE_{dB} = 20 \log_{10}\left(\frac{FS_1}{FS_2}\right)$$

This may be further expanded (for the source external to the shield) and generalized as:

$$SE_{dB} = A_{dB} + R_{dB} + B_{dB}$$

Where: A = Absorption loss in dB

$$= 3.338\, t_{mils}\, (f_{MHz}\, \mu_r\, \sigma_r)^{1/2}$$

REPRESENTATION OF SHIELDING PHENOMENA FOR PLANE WAVES

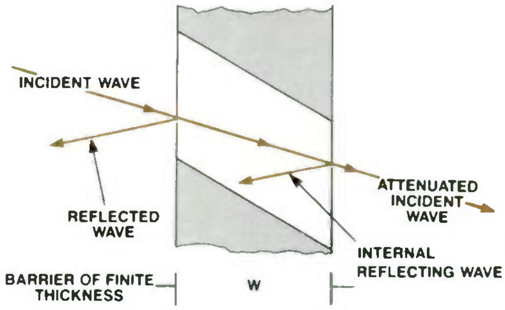


Figure 1

B = Correction factor for internal reflections. This factor is ordinarily insignificant, particularly if the absorption loss is greater than 10 dB.

t = thickness in mils

f = frequency

μ_r = relative permeability

σ_r = relative conductivity

The absorption loss is easy to calculate and very important, because when the interference source is to be contained within a shielded enclosure, only the absorption loss provides attenuation. The internal field reflections simply bounce back and forth.

When the source is external to the enclosure, the reflected component disappears into space and is lost. The degree of reflection loss depends upon the mismatch between the incident wave impedance and the shield material impedance.

The field impedance (Z) is equal to the ratio of the electric (E) and magnetic (H) field intensity at the location of measurement.

$$Z = \frac{E}{H}$$

For nearby sources, the wave impedance varies with both the source impedance and the separation distance ($d < \frac{\lambda}{2\pi}$) between the source and the shield. Within this region it is possible to have either a dominant electric field or a dominant magnetic field component. Beyond the $\frac{\lambda}{2\pi}$ distance, the wave impedance becomes constant at 377 ohms regardless of the source impedance or separation distance.

The reflection losses for the various combinations may be calculated from the following equations.

ELECTRIC (HIGH IMPEDANCE) FIELDS $d < \frac{\lambda}{2\pi}$

$$R_{dB} = 152.4 - 10 \log_{10} (\mu_r\, f^3_{MHz}\, d^2_{ft}/\sigma_r)\ \text{dB}$$

(Note: d is the separation distance in feet)

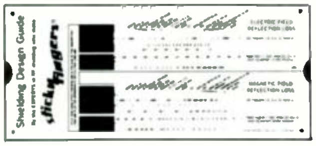
MAGNETIC (LOW IMPEDANCE) FIELDS $d < \frac{\lambda}{2\pi}$

$$R_{dB} = 64.5 - 10 \log_{10} (\mu_r/f_{MHz}\, \sigma_r\, d^2_{ft})\ \text{dB}$$

FAR FIELD (PLANE WAVE) CONDITIONS $d \geq \frac{\lambda}{2\pi}$

$$R_{dB} = 108 - 10 \log_{10} (\mu_r\, f_{MHz}/\sigma_r)\ \text{dB}$$

Instrument Specialties has available a special slide rule which has been designed to solve the shielding equations. This slide rule makes it easy to compare different materials as a function of frequency. For more information, contact Instrument Specialties and ask for our "Shielding Design Slide Rule."



TOTAL SHIELDING EFFECTIVENESS vs FREQUENCY
FOR ELECTRIC AND MAGNETIC FIELDS AND PLANE WAVES

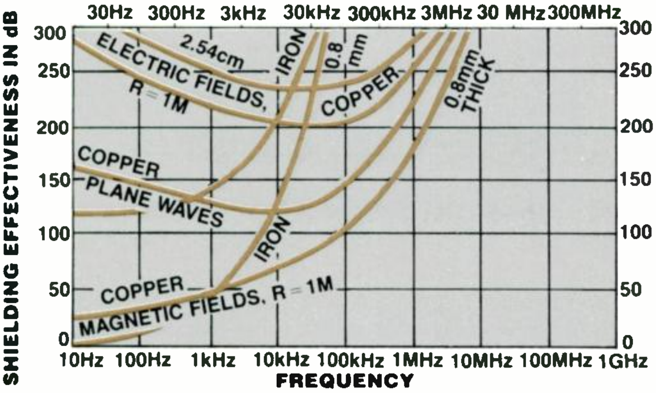


Figure 2

Figure 2 shows the total shielding effectiveness for an all welded homogeneous enclosure made from either 1/32 inch copper or iron. Note that the shielding effectiveness is greater than 100 dB for all frequencies above 100 kHz. (5kHz for iron).

MINIMIZING THE EFFECTS OF OPENINGS

Unfortunately, it is not practical to build an all welded enclosure. Most enclosures require various openings for controls, access panels, ventilation, viewing apertures, etc.

SHIELDING EFFECTIVENESS -vs- FREQUENCY
FOR VARIOUS LENGTH OPENINGS

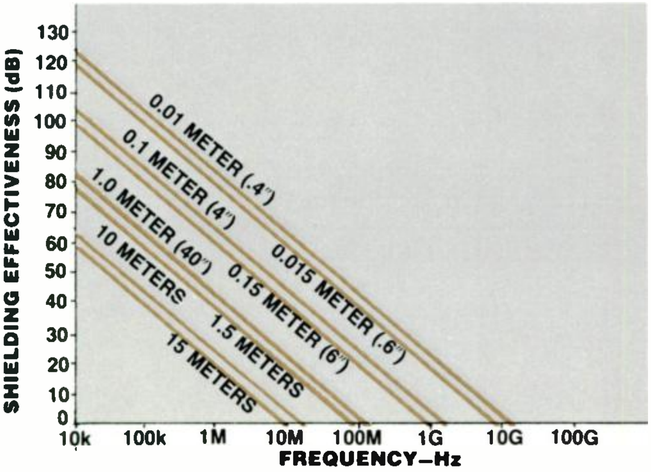


Figure 3

Figure 3 shows the maximum shielding effectiveness possible when an opening or slot is introduced into the enclosure. The worst case shielding effectiveness of the slot (ℓ) is given by:

$$\text{Slot Atten (dB)} = 20 \log \frac{\lambda}{2\ell}$$

where (ℓ) $< \frac{\lambda}{2}$

It is obvious from these figures that the shielding effectiveness is determined more from openings or discontinuations than from the shield materials. The openings around the perimeter of the larger components such as doors, ventilation or access panels, and viewing apertures have the greatest effect on the shielding. These are also the most difficult to seal. There are two approaches to connect the mating surfaces electrically. The first is to use conductive fasteners at close intervals to reduce the slot length. The second is to use RF gaskets to seal the opening.

RELATIONSHIP BETWEEN ELECTRIC, MAGNETIC, AND PLANE WAVE FIELDS

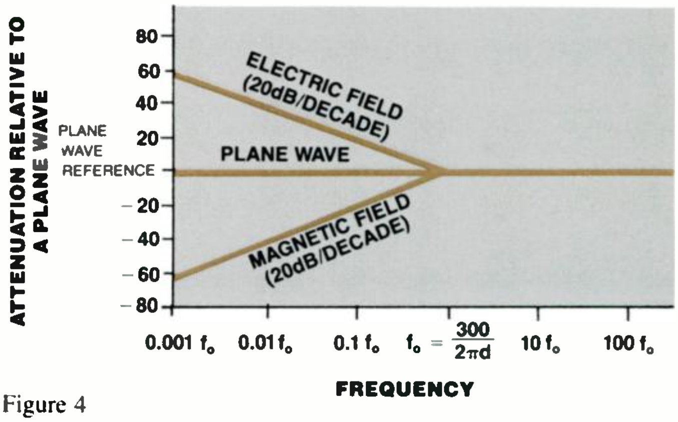


Figure 4

$$f_o = \frac{300}{2\pi d}$$

WHERE $d = \frac{\lambda}{2\pi}$ (SOURCE-TO-SHIELD DISTANCE, NEAR FIELD FAR FIELD CROSSOVER)

$f\lambda = 300$ (f in MHz, λ in METERS)

Typical values of shielding using a beryllium copper gasket in a single row configuration to seal the opening are shown on page 8. Values are higher for multiple row configurations.

Figure 4 shows the relationship between electric, magnetic, and plane wave fields. This enables calculation of electric or magnetic shielding effectiveness from plane wave data for any source-to-source distance.

Beryllium copper gaskets have a number of good features which result from the excellent anti-corrosion, mechanical wear, spring qualities and RF properties of the material. These features are listed on page 2.

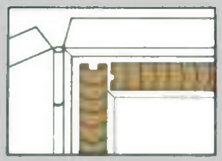
Shield gaskets should be installed to provide the highest surface conductivity, metal-to-metal condition. If the mating materials must be environmentally protected, the protective coating should be electrically conductive. Installation requirements are given on page 20.

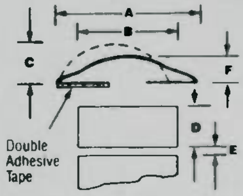
In all cases the gasket material should be selected or plated to galvanic compatibility. The tables on pages 20 and 23 provide a list of compatible materials along with the various platings that are available from Instrument Specialities.

Sticky Fingers

NEW!

SYMMETRICAL SLOTTED SHIELDING (S³)





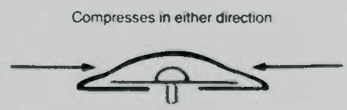
Series 97-951/954/957 are low-compression, adhesive-mounted beryllium copper shielding strips. Designed as a continuous band, the strip is slotted to permit spring contact throughout its length. A generous radius profile provides for the greatest incident engagement angle with the lowest force. As with all Sticky Fingers® shielding strips, a self-adhesive tape makes mounting easy and secure.

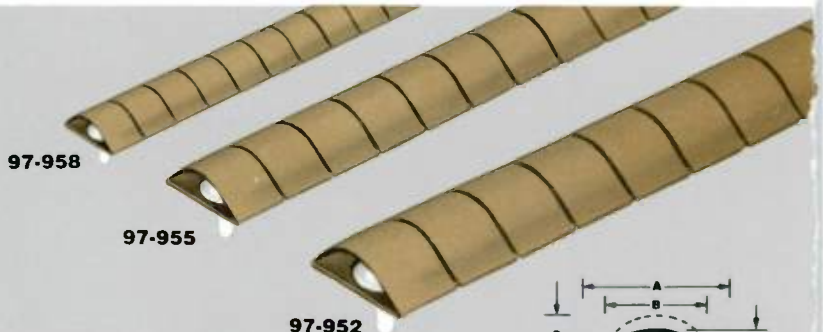
Available in 15″ lengths, and in galvanically compatible platings.

SERIES	A	B	C	D	E	F
97-951	.760	.616	.220	.345	.030	.062
97-954	.512	.446	.140	.228	.022	.062
97-957	.380	.350	.110	.170	.018	.040

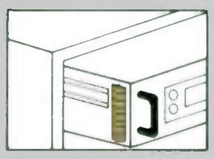
ALL STRIPS EXHIBIT TYPICAL MINIMUM VALUES OF 100 dB at 100 MHz.

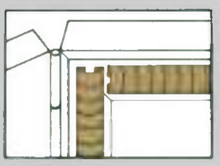
NEW!

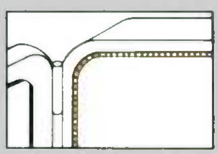


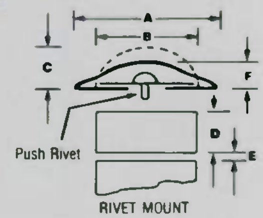


SYMMETRICAL SLOTTED SHIELDING (S³) with bi-directional rivet mount*


Sliding drawer application


Typical electronic enclosure application


Typical military-style enclosure application



*patent pending

Series 97-952/955/958 are as described above, but with the addition of an integral pierced track to provide for mounting with nylon push rivets in a .125″ dia. hole. Rivets are spaced every 4.50″ beginning .75″ from either end. Designed especially for slide applications, this configuration allows total symmetrical compression action with bi-directional engagement. This series is recommended for high temperature and/or extremely high side load situations, such as PC board connections, electronic drawers, etc.

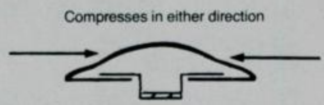
Available in 15″ lengths, and in galvanically compatible platings.

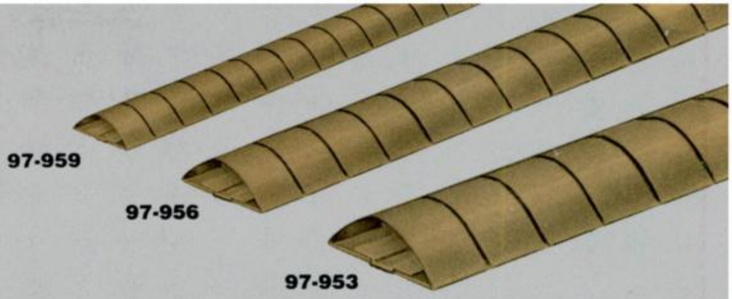
SERIES	A	B	C	D	E	F
97-952	.760	.616	.220	.345	.030	.062
97-955	.512	.446	.140	.228	.022	.062
97-958	.380	.350	.110	.170	.018	.040

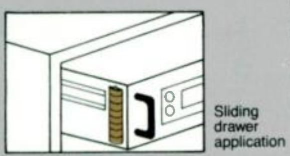
ALL STRIPS EXHIBIT TYPICAL MINIMUM VALUES OF 100 dB at 100 MHz.

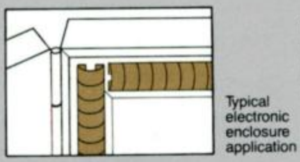
Sticky Fingers NEW!

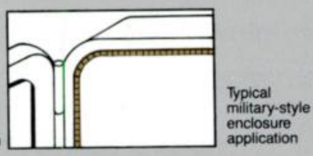
SYMMETRICAL SLOTTED SHIELDING (S^3) with bi-directional adhesive mount*

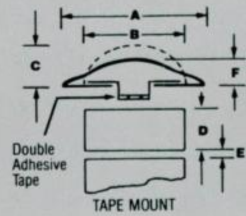












*patent pending

Series 97-953/956/959 also incorporate an integral track-mount design, but employ a double-faced adhesive tape instead of push rivets. This provides for fast, easy field replacement in military applications, especially where high frequencies do not permit the use of mounting holes.

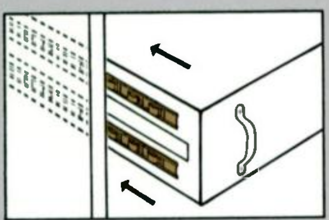
Available in 15" lengths, and in galvanically compatible platings.

SERIES	A	B	C	D	E	F
97-953	.760	.616	.220	.345	.030	.062
97-956	.512	.446	.140	.228	.022	.062
97-959	.380	.350	.110	.170	.018	.040

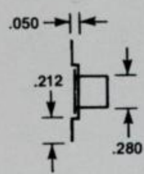
ALL STRIPS EXHIBIT TYPICAL MINIMUM VALUES OF 100 dB at 100 MHz.

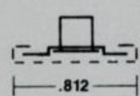
Sticky Fingers NEW!

LONGITUDINAL GROUNDING SERIES

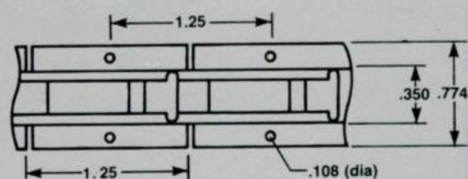


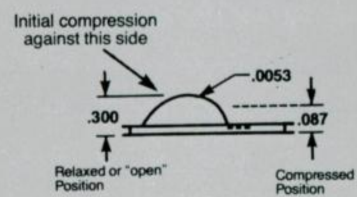
97-975





Suggested channel mounting configuration





This series of beryllium copper strips combines finger compression with the direction of motion in the longitudinal axis.

Ideal for use with rack-mounted, sliding door, and slide-drawer assemblies. Eliminates awkward grounding straps for moving assemblies, yet, provides a reliable and complete ground.

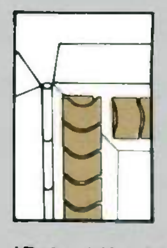
Typical installation methods include hardware mounting, channel mounting or use of the Sticky Fingers® self-adhesive strip.

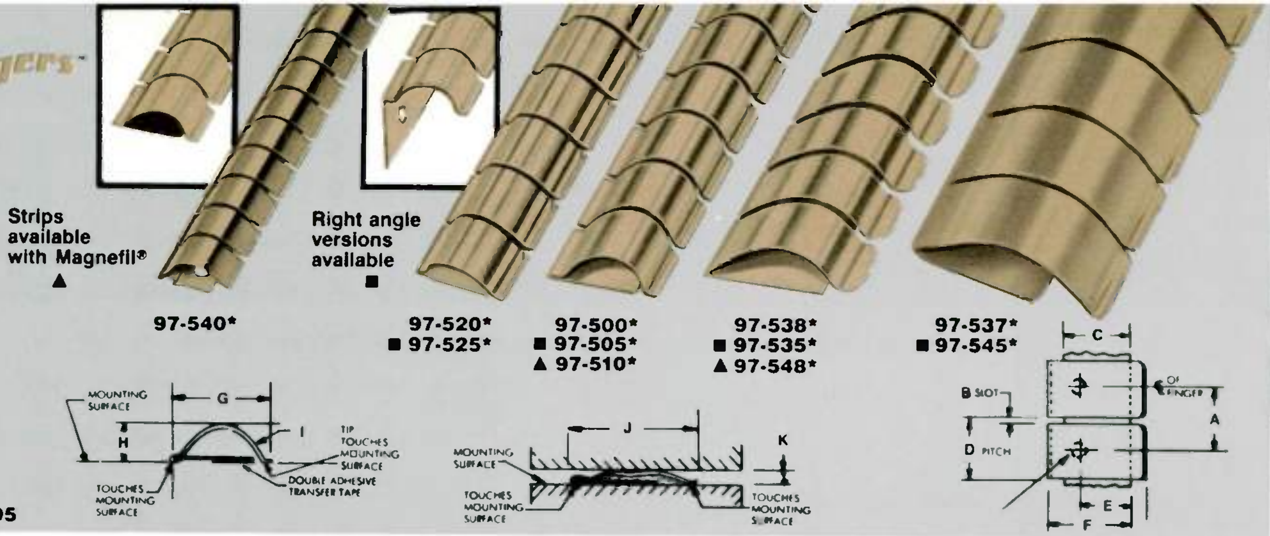
Available in standard 18.75" lengths and in standard finishes (see pages 20 and 23).

As with all Instrument Specialties Sticky Fingers® strips, they attach quickly and securely with a really sticky self-adhesive strip. You simply peel off the backing, press the strip to the surface selected, and the job is complete!

Sticky Fingers

for INSTANT RFI/EMI Shielding





*Patent No. 3504095

These versatile shields are high-performance beryllium copper finger contact strips with a self-adhesive backing—sold under the name "Sticky Fingers." They provide an extremely tight, instant bond, and are ideal as an all-purpose contact strip for metal cabinets and electronic enclosures, particularly where space is critical.

The adhesive strengthens as it cures with age and is unaffected by temperatures from −40F to 250F. Moreover, the geometry of the strip design when fully compressed further assists in strengthening the bond. Soldering and mechanical fastenings are thus completely eliminated.

To install, simply peel off the protective paper backing . . . place strip into position . . . and press down firmly. This produces an instant seal against RFI/EMI interference in all types of metal cabinets and electronic enclosures.

Shielding effectiveness of these strips has been proved to be greater than 46 dB at 14 kHz magnetic, and 108 dB at 10 GHz plane wave. When tested per MIL-STD-285 for electromagnetic shielding, these strips showed superior performance under minimum compression. They proved to be especially effective where variations exist in the space to be shielded, and in applications that require high shielding performance despite frequent opening and closing of the cabinet.

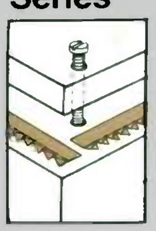
SERIES	A	B	C	D	E	F	G (ref)	H (min)	I	J (max)	K (min)	L (dia)
97-540	.188	.018	.150	.188	.075	.234	.280	.107	.0027	.370	.040	.062
97-520	.250	.022	.187	.250	.094	.308	.375	.130	.0030	.520	.062	.062
97-500	.375	.032	.400	.375	.310	.500	.580	.219	.0035	.770	.062	.078
97-538	.375	.040	.469	.375	.375	.531	.781	.250	.0043	.938	.062	.142
97-537	.500	.040	.688	.500	.562	.781	1.125	.406	.0070	1.937	.062	.142

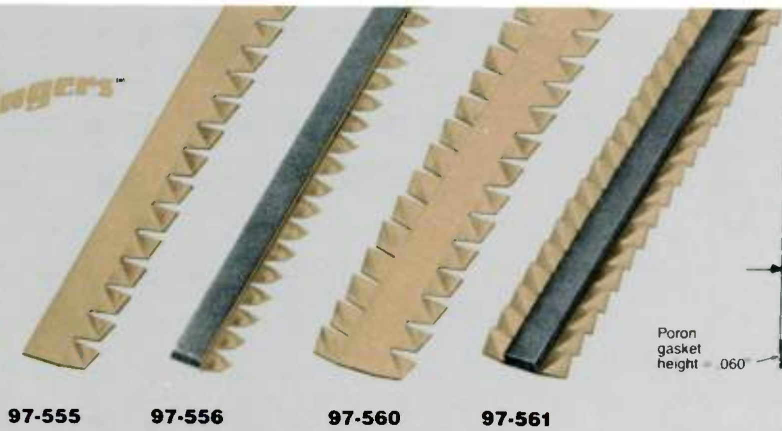
Note that designated strips are available with Magnefil®, a rubber strip filled with magnetic particles, and inserted within the curve of the fingers. Magnefil® provides increased magnetic field shielding.

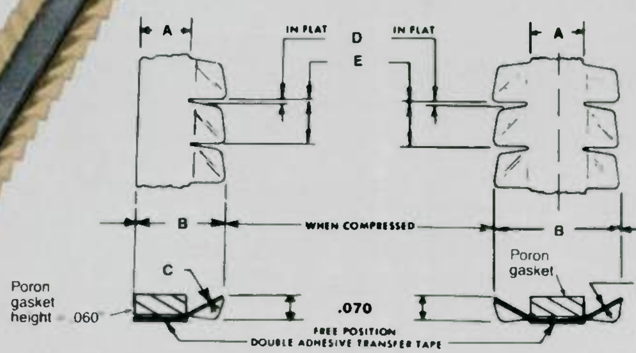
Strips 97-500 and 97-538 are furnished in standard lengths of 24 inches and in continuous 25 foot coils. Series 97-520 and 97-540 are supplied in standard 16 inch lengths and in continous 25 foot coils. 97-537 strips are 12 inch lengths. All are available in your choice of finishes (see pages 20 and 23).

Sticky Fingers

Twist Series







Self-adhesive beryllium copper contact strips with scientific twist design offer narrower-than-ever electronic gaskets for general shielding applications where space is at a premium.

Series 97-555 single edge contact strip measures only .375" wide, yet shielding effectiveness is greater than 85 dB at 100 MHz plane wave. Ideal for all types of panels or electric enclosures.

Series 97-560 strips are especially suitable for cabinets with panel-divider bars. Unique double edge design, .50" wide permits panels to be easily removed and replaced without damage to the installed strip. This design also provides increased shielding effectiveness: greater than 110 dB at 100 MHz plane wave.

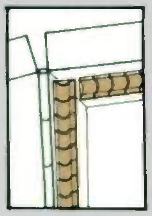
Series	A	B	C	D	E
97-555, -556	.187	.34	.003	.015	.165
97-560, -561	.187	.50	.003	.015	.165

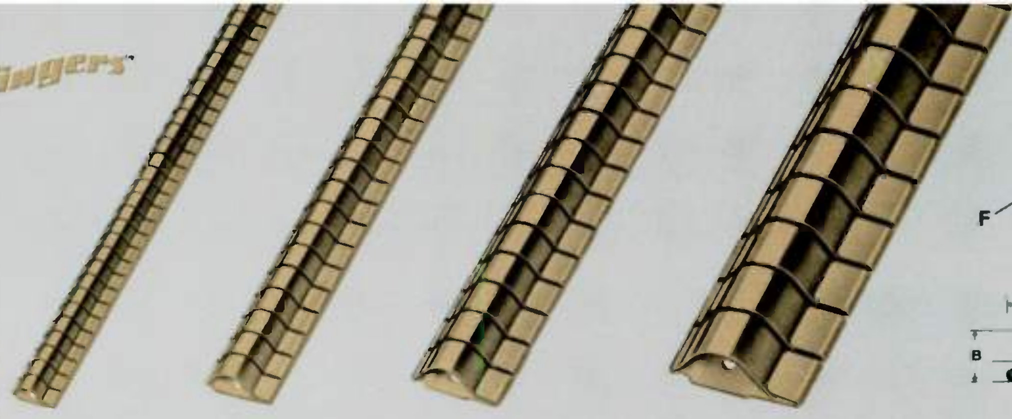
Series 97-556 and 97-561 are versions of 97-555 and 97-560, respectively, incorporating a rubber gasket to act as an environmental shield, offering a high degree of protection against dust and moisture.

All twist series are furnished in 24" lengths or in standard 25 foot coils. Available in standard finishes (see pages 20 and 23).

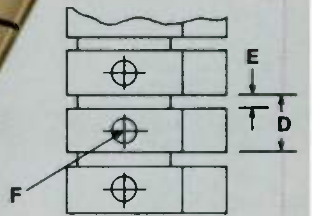
Sticky Fingers

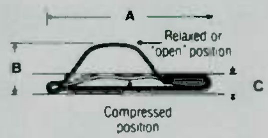
Foldover Series





97-542* 97-541* 97-521* 97-515*





*Patent No. 3504095

This version of Sticky-Fingers beryllium copper shielding gaskets features a special, U-shaped end that permits the upper part of the strip to slide when enclosure doors are closed and retains the strip's fingers when enclosure doors are open, thus protecting against accidental damage to the strip's fingers.

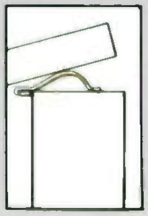
Four models provide you a choice of widths to suit your application. As with all Instrument Specialties Sticky-Fingers shielding strips, they attach quickly and securely with a *really* sticky self-adhesive strip. You simply peel off the backing, press the strip to the surface selected, and the job is done!

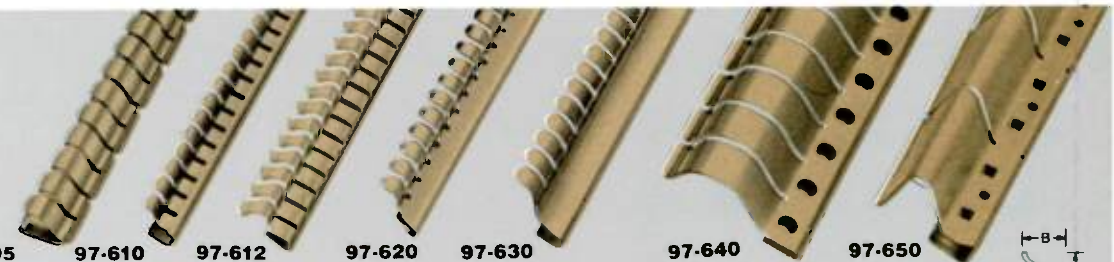
At the same time, you get the same high shielding effectiveness offered by all Sticky-Fingers.

Series	A	B (min)	C (mingap)	D	E	F
97-542	.250	.079	.035	.188	.018	.062
97-541	.380	.100	.040	.188	.018	.062
97-521	.512	.130	.062	.250	.022	.062
97-515	.760	.220	.062	.375	.032	.078

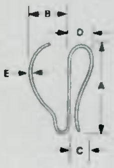
Available in standard 16" lengths, except 97-515 which is furnished in 24" lengths. Also, all styles are available in continuous 25 foot coils, and in your choice of finishes (see pages 20 and 23).

CLIP-ON Shielding Strips

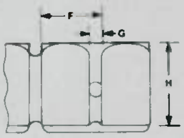




97-605 97-610 97-612 97-620 97-630 97-640 97-650



97-605



97-610

through

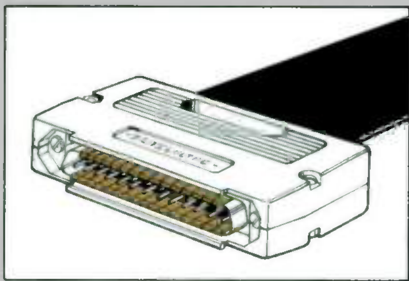
97-650

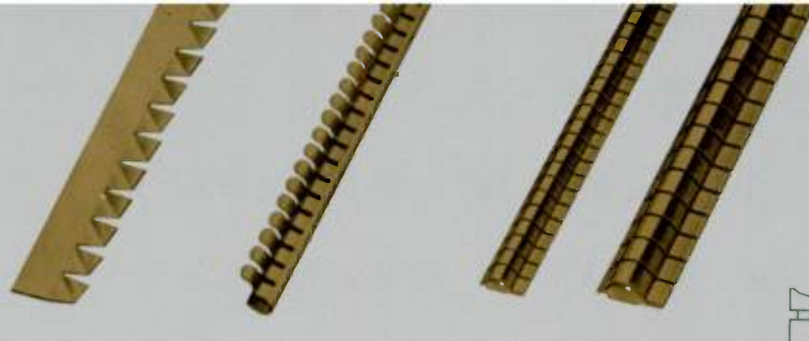
For use where high temperatures or other considerations preclude the use of adhesive-backed Sticky Fingers.

Available in 16" lengths and in all standard finishes (see pages 20 and 23). They exhibit the same shielding characteristics and effectiveness as Instrument Specialties' Sticky Fingers.

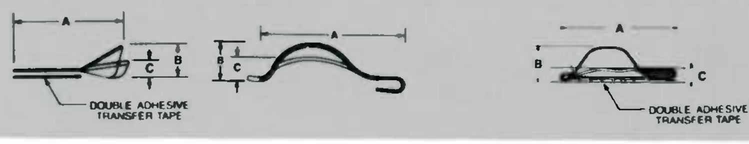
Series	A	B	C	D	E	F	G	H
97-605	.375	.200	.070	.080	.0052	.250	.040	.375
97-610	.297	.100	.070	.187	.0048	.187	.047	.195
97-612	.436	.100	.070	.187	.0030	.187	.047	.436
97-620	.438	.078	.070	.187	.0048	.187	.047	.248
97-630	.600	.205	.070	.187	.0048	.187	.047	.290
97-640	1.093	.255	.070	.281	.0048	3.75	.040	.843
97-650	.940	.400	.200	.300	.0039	1.000	.030	.660

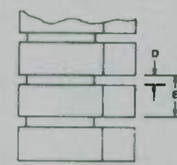
GROUNDING CONTACTS FOR CONNECTORS:



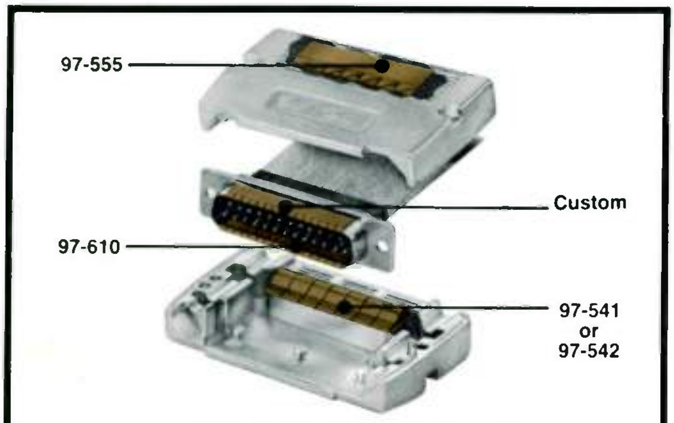


97-555 97-610 97-542 97-541





Typical pitch layout



Strips shown above are suggestions only. Various combinations may be chosen to suit your needs.

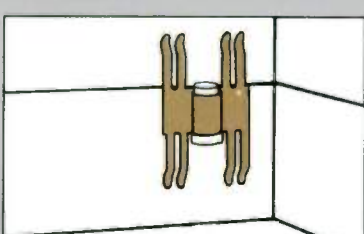
Series	A Relaxed Width	B Relaxed Height	C Compressed Height	D Slot	E Pitch
97-610	.297	.100	.040	.047	.187
97-555	.340	.070	.008	.015	.165
97-542	.250	.079	.035	.018	.188
97-541	.380	.100	.040	.018	.188

"off the shelf" Grounding Strips are easily installed in most common connectors by means of the self-adhesive strip or the self-contained spring clip. This style contact provides consistent interconnection grounding in mated pairs, as a result of the superior spring characteristics of the Beryllium Copper material.

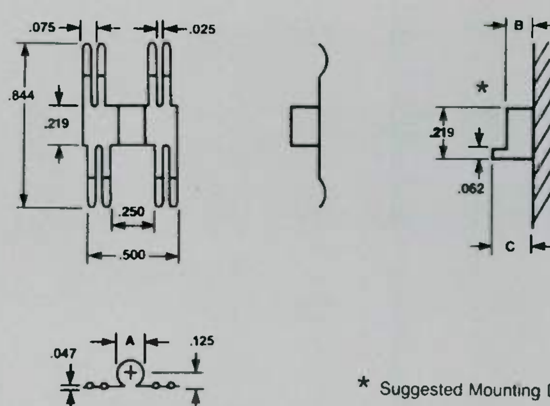
Many custom variations are also possible. Where necessary, Instrument Specialties can create the precise strip to meet your specific requirements.

NEW!

GROUNDING CONTACTS FOR CONDUCTIVE-COATED PANELS



97-961/962



* Suggested Mounting Dowel

This series offers a high performance, multiple-contact beryllium copper conductor, designed to assure a reliable, complete circuit path at butting edges of conductive-coated, plastic panels and enclosure assemblies.

Provides superior contact pressure without relaxation. Available in bright finish and with all conductive paint compatible platings.

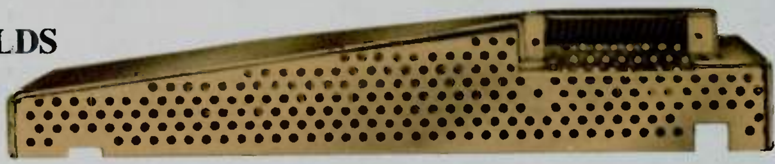
Available in quantities of 100, 200, 500 or 1000.

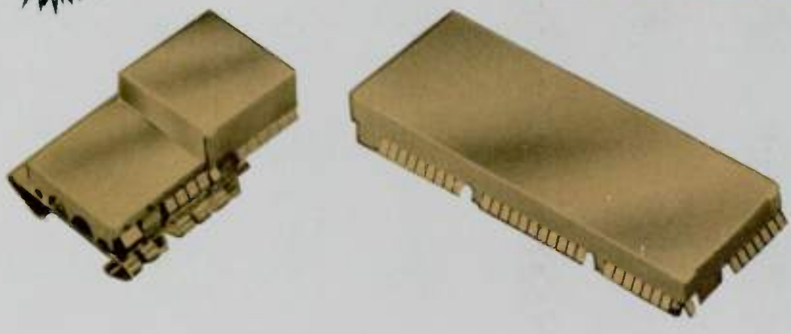
SERIES	A	B	C
97-961	.170	.187	.250
97-962	.109	.125	.187

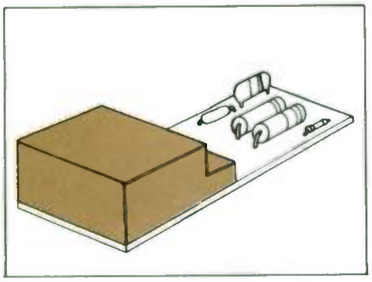
Simple snap-on installation is provided for .187" dowels (97-961) and .125" dowels (97-962).

PRINTED CIRCUIT BOARD SHIELDS

NEW!





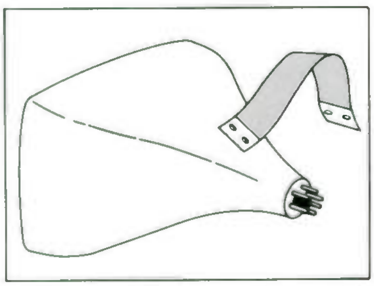


For shielding high-frequency emitting components or printed circuit boards, where RFI/EMI emissions must be contained. Made from copper alloys in thicknesses commensurate with the attenuation required, the box-like structures may be fitted with spring contact terminations for surface mounting or through-hole assembly. A necessity for TEMPEST hardening. Many custom variations are possible.

Refer to pages 4 and 5 of this manual for design considerations or contact us directly for engineering consultation.

LAMINATED GROUNDING STRAPS

NEW!



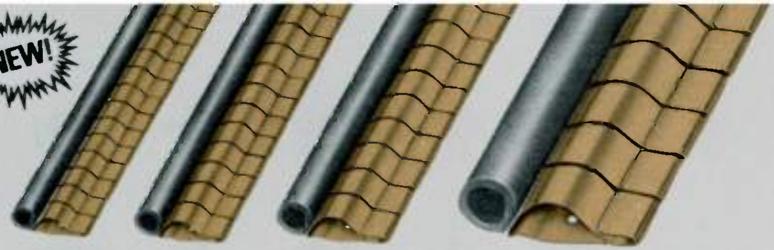
Copper ground straps may be used for ESD and chassis interfacing to maintain continuous ground planes. Made from #102 Copper to provide maximum conductivity, the straps are tin-plated to meet galvanic compatibility and corrosion resistance requirements. An insulating layer of .004" thick Mylar is laminated to both sides. The ductile nature of the base metal allows easy shaping of the part to fit odd configurations. Ask about custom configurations also.

SERIES	A	B	C	D	E	F	G
97-790	3.00	2.62	2.24	1.50	1.00	.187	.013
97-795	10.00	9.50	9.00	3.00	2.00	.201	.013

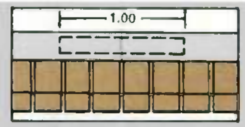
Sticky Fingers

NEW!

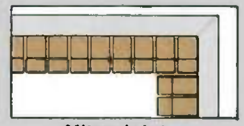
ENVIRONMENTAL LOW COMPRESSION SERIES

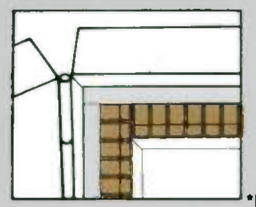


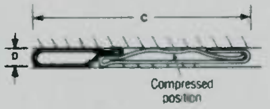
97-842* 97-841* 97-821* 97-815*

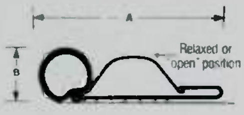

Straight Coupler

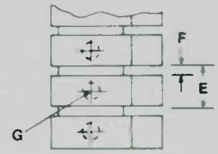

Butt Joint


Miter Joint









*Patent No. 3504095

These new Sticky Fingers® combine a neoprene rubber seal with beryllium copper strips for applications where control of noise, dust, moisture and chemical contaminants is required.

The unique design of these sealing strips permits the use of extremely low compression forces, compared to conventional elastomers, to make contact with the surface of both the environmental and electromagnetic shield.

Complete continuity is ensured by use of designated straight joint couplers and mitering or butting corners as shown above (no special tools or soldering required).

As with all Instrument Specialties Sticky Fingers® strips, installation is fast and secure.

Available in continuous lengths (25 ft. standard) and in 16" lengths (except 97-815, which is available in 24" lengths) with standard finishes (see pages 20 and 23).

SERIES	A	B	C	D	E	F	G	Use coupler
97-842	.312	.109	.350	.062	.188	.018	.062	97-837
97-841	.450	.156	.500	.062	.188	.018	.062	97-835
97-821	.650	.203	.700	.094	.250	.022	.062	97-833
97-815	.900	.281	1.030	.094	.375	.032	.078	97-831

Shielding effectiveness is greater than 80 dB @ 100 MHz, plane wave. Temperature range: −30F to 212F.

NEOPRENE RUBBER COUPLERS

Packaged in lots of: 100, 200, 500 and 1000. Advise quantity required.

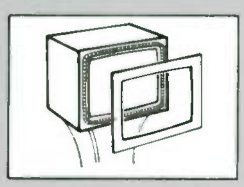
SERIES	97-837	97-835	97-833	97-831
Dia.	.051	.098	.145	.223

NEW!

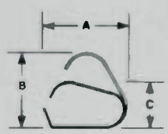
FLEXIBLE LOW COMPRESSION SERIES

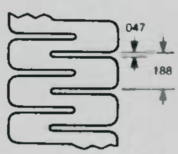

97-941*

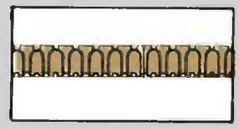

97-921*

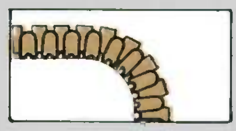


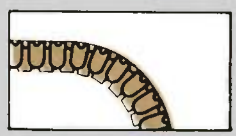
*Patent Pending










Typical Installations

Series 97-941/942 are low compression, flexible beryllium copper contact strips for applications where a continuous shield must conform to irregular shapes and turn tight-radius corners in either direction.

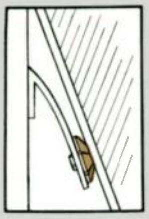
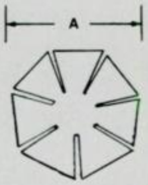
Simple snap-in installation is possible for Series 97-921 (.250" slots) and 97-941 (.187" slots), however soft-solder or conductive adhesive can be used for mounting to flat surfaces.

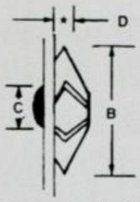
Available in continuous lengths (25 ft. standard) or in 24" lengths and in all standard finishes (see pages 20 and 23).

SERIES	A	B	C
97-941	.195	.170	.110
97-921	.258	.225	.141

Shielding effectiveness is greater than 80 dB @ 100 MHz, plane wave.

MUSHROOM
WITH PLASTIC PUSH RIVET

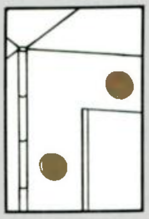
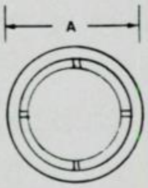


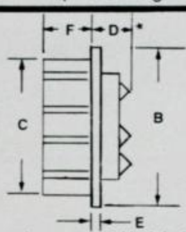
97-700

Patent No. 4,543,447

*compressed height is .055

POP-UP

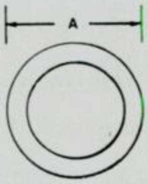


97-710
97-715

*compressed height is .015

CONTACT PLATE



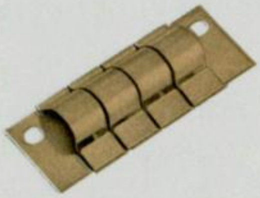
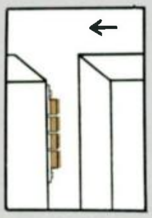


97-720
97-721

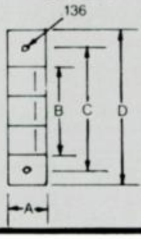
Provides mating surface for
97-700, 97-710, 97-715

Series	A	B	C	D	E	F
97-700	.580	.580	.250	.055	N/A	N/A
97-710	.938	.938	.750	.156	.015	.375
97-715	.562	.562	.375	.125	.015	.250
97-720	.922	.922	.750	.297	.078	N/A
97-721	.500	.500	.375	.235	.062	N/A

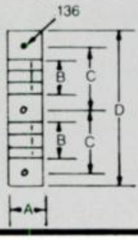
GROUNDING BARS

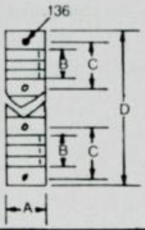
STYLE A



STYLE B



STYLE C



Series	Style	A Width	B Dimension—# of Fingers		C Hole-to-Hole	D Length
97-731	A	.512	.228	1	.500	.728
97-732	A	.512	.478	2	.750	.978
97-733	A	.512	.728	3	1.000	1.228
97-734	A	.512	.978	4	1.250	1.478
97-735	A	.512	1.228	5	1.500	1.728
97-741	A	.760	.343	1	.750	1.093
97-742	A	.760	.718	2	1.125	1.468
97-743	A	.760	1.093	3	1.500	1.843
97-744	A	.760	1.468	4	1.875	2.218
97-745	A	.760	1.843	5	2.250	2.593
97-751	B	.512	.228	1	.500	1.228
97-752	B	.512	.478	2	.750	1.728
97-753	B	.512	.728	3	1.000	2.228
97-754	B	.512	.978	4	1.250	2.728
97-755	B	.512	1.228	5	1.500	3.228
97-761	B	.760	.343	1	.750	1.843
97-762	B	.760	.718	2	1.125	2.593
97-763	B	.760	1.093	3	1.500	3.343
97-764	B	.760	1.468	4	1.875	4.093
97-765	B	.760	1.843	5	2.250	4.843
97-775	C	.512	1.228	5	1.500	15.228
97-785	C	.760	1.843	5	2.250	22.843

For grounding of high voltage static discharge with discrete points of contact

These electrostatic discharge assemblies provide omnidirectional loading and deflection offering optimum contact force with a minimum of stress on the contact. Mounting is compatible with all surface textures and materials, and galvanic relationships are assured by our complete spectrum of platings if necessary (see Metals Compatibility on pages 20 and 23).

The 97-700 "Mushroom" is a two-piece assembly consisting of a beryllium-copper top plate and a plastic push rivet which mounts through a .250 inch diameter hole.

The 97-710 and 97-715 brass "Pop-ups" are spring assemblies in a serrated cup for easy snap-in mounting. One pound of compression force yields over 1000 pounds contact force/sq. in. The 97-708 and 97-709 installation tools make assembly even easier.

The 97-720 and 97-721 brass "Contact Plates" are used with the 97-700, 97-710 and 97-715 as a mating surface of consistent quality which mounts in the opposing plane.

The "Grounding Bars" are identical in style and deflection characteristics to parts 97-515 and 97-521 shown on page 7. They are mounted on chassis and cabinet frame components by riveting, heat staking, or by using common hardware such as screws and fasteners. Redundancy of contact points is varied by selecting the number of fingers necessary. Many custom variations are also possible.

For standard finishes, see page 23.

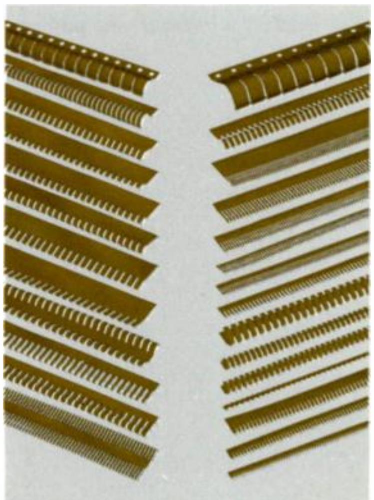
contact strips

for grounding and shielding in high-frequency equipment... for forming large-diameter contact rings

A wide variety of beryllium copper contact strips provides engineers and designers with flexibility in the solution of grounding and shielding problems. Various lengths, widths, thicknesses, contours and hole locations are possible for many of the standard catalog items shown here.

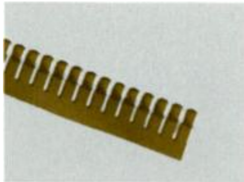
Engineering Design Kit Available

An Engineering Design Kit is available to permit the engineer the utmost latitude in his search for the exact strip configuration to effectively meet his needs. Each assortment contains short lengths of at least 50 items listed on Pages 6 through 18. Includes data sheet on elastic performance of finger strips.



Order assortment by Number 97-272.

figure A



CONTIPS available

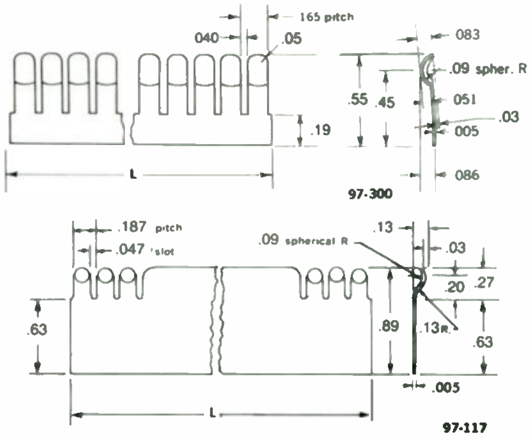
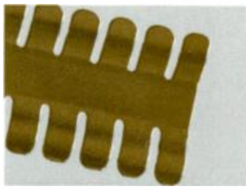


figure B



CONTIPS available

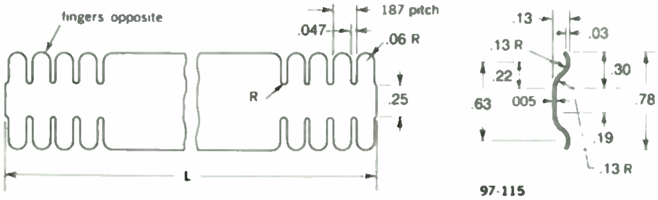
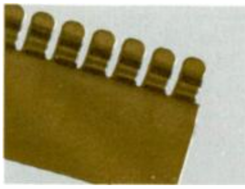


figure C



CONTIPS available on 97-111, 97-112, 97-114 and 97-116 only

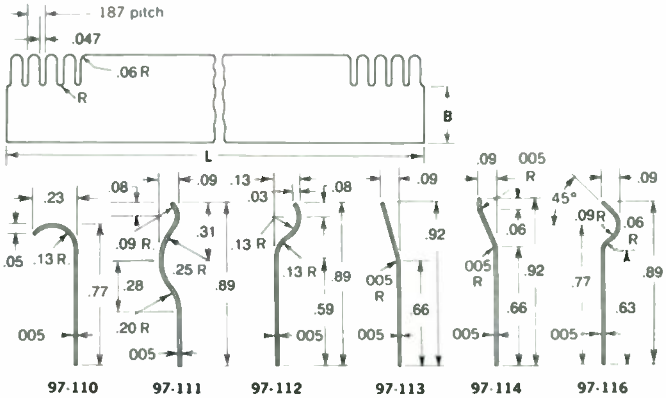
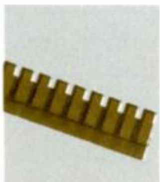


figure D



not available with CONTIPS

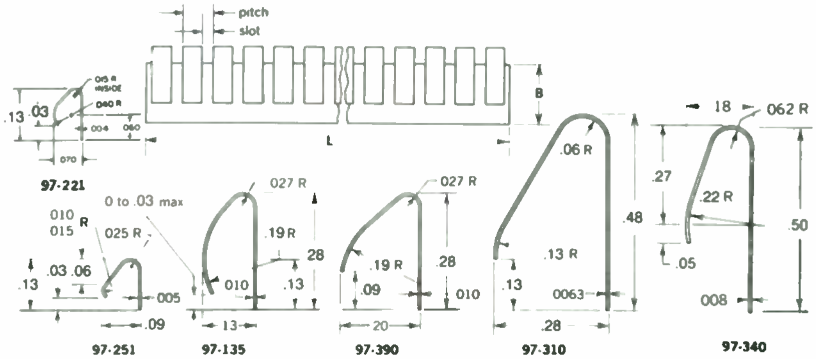
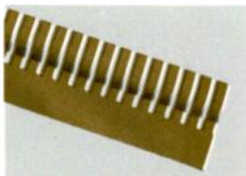


figure E



CONTIPS available

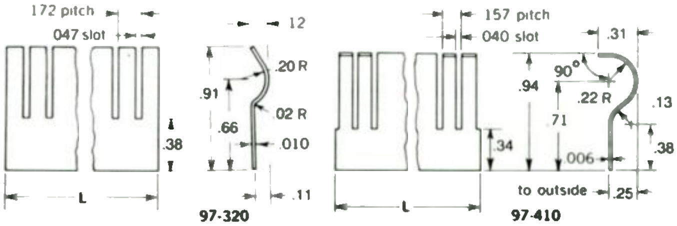
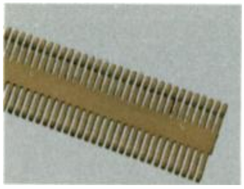
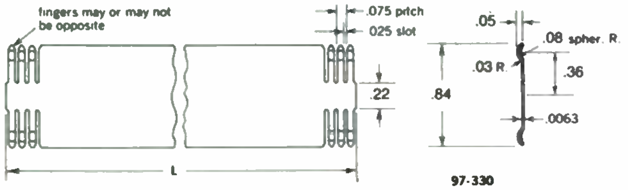


figure F



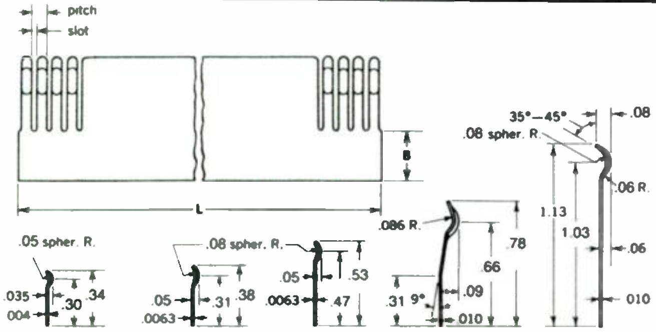
CONTIPS available



97-330

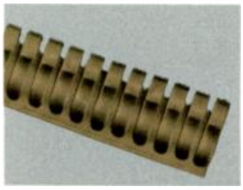
figure G

CONTIPS available

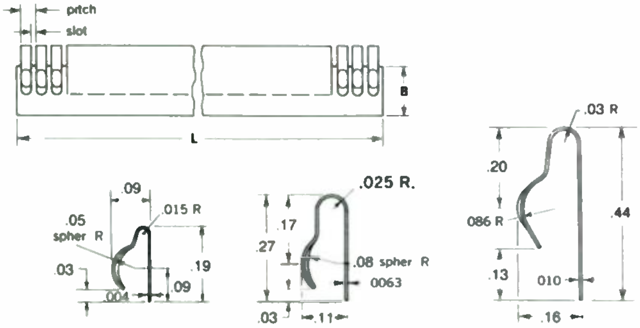


97-223 97-136 97-134 97-137 97-290

figure H

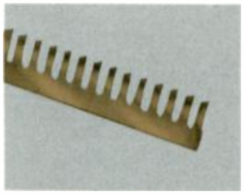


CONTIPS available

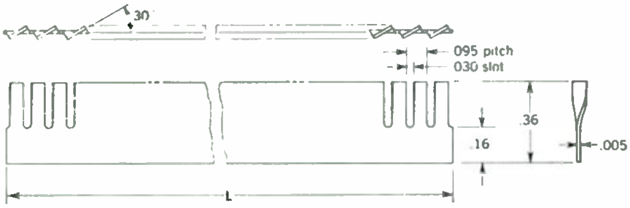


97-380 97-360 97-139

figure I

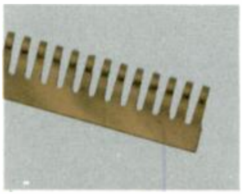


not available with CONTIPS

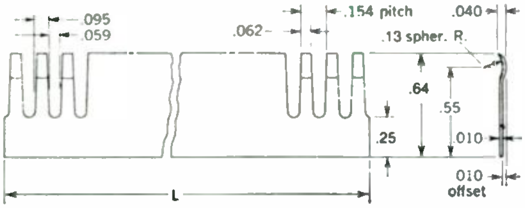


97-370

figure J

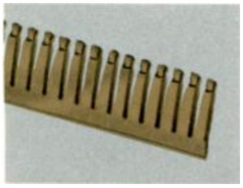


CONTIPS available

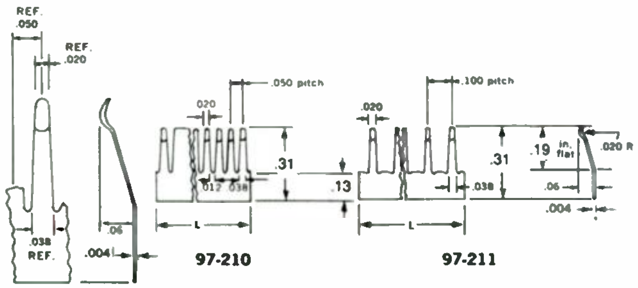


97-430

figure JJ



CONTIPS available



97-210 97-211

dimensions in inches

catalog number	fig-ure	pitch	slot	B	stock length L■	wt. per 1000 in., lb
97-110	C	.187	.047	.63	16	1.3
97-111	C	.187	.047	.63	16	1.3
97-112	C	.187	.047	.63	16	1.3
97-113	C	.187	.047	.63	16	1.3
97-114	C	.187	.047	.63	16	1.3
97-115	B	.187	.047	—	16	1.1
97-116	C	.187	.047	.64	16	1.3
97-117	A	.187	.047	.63	16	1.3
97-134	G	.075	.025	.22	16	.9
97-135	D	.134	.040	.23	16	1.4
97-136	G	.075	.025	.06	16	.6
97-137	G	.094	.031	.31	16	2.0
97-139	H	.094	.031	.31	16	2.0
97-210	JJ	.050	.012	.13	12	.5
97-211	JJ	.100	.062	.13	12	.5
97-221	D	.060	.020	.09	12	.3
97-223	G	.060	.020	.13	16	.35
97-251	D	.127	.050	.09	12	.3
97-290	G	.075	.025	.69	16	3.0
97-300	A	.165	.040	.19	16	.8
97-310	D	.187	.062	.38	16	1.4
97-320	E	.172	.047	.38	16	2.4
97-330	F	.075	.025	—	16	1.3
97-340	D	.163	.015	.25	16	1.6
97-360	H	.075	.025	.22	16	.9
97-370	I	.095	.030	—	16	.43
97-380	H	.060	.020	.13	16	.35
97-390	D	.134	.040	.23	16	1.4
97-410	E	.157	.040	.34	16	1.8
97-430	J	.154	.059	.25	16	1.4

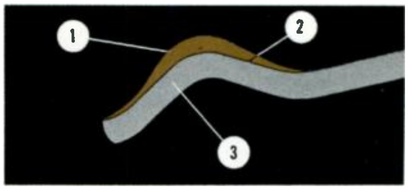
■ **lengths:** Stock lengths supplied unless shorter lengths are specified . . . cut to nearest slot. Specified lengths may have partial fingers removed.

widths: Other widths and special contours available to order.

For standard finishes, see page 23.

CONTIPS®

localized deposits of silver or gold



1. CONTIP; 2. 100% bond; 3. convex portion of spring

	add suffix to catalog number
SILVER CONTIPS only (K)	11
SILVER CONTIPS plus silver plating (KS)	12
GOLD CONTIPS only (GK)	13
GOLD CONTIPS plus gold plating (GKG)	14

contact rings

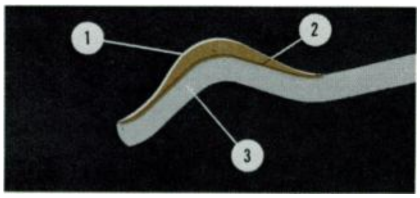
for tube cavities, tuning and shielding applications

The large variety of sizes and shapes of contact rings available offers engineers a wide choice in meeting design requirements for microwave cavities, tuning and shielding applications. These rings are furnished in any diameter above minimum (shown in chart on Page 17) which contains an integral number of fingers. Rings are made from strip stock formed into an unclosed circle which, when assembled, becomes a complete ring.

For standard finishes, see page 23.

CONTIPS®

localized deposits of silver or gold



1. CONTIP; 2. 100% bond; 3. convex portion of spring

	add suffix to catalog number
SILVER CONTIPS only (K)	11
SILVER CONTIPS plus silver plating (KS)	12
GOLD CONTIPS only (GK)	13
GOLD CONTIPS plus gold plating (GKG)	14

Engineering Design Kit

Thirty-six contact rings . . . all different . . . all identified. One or more from each family of rings shown in tables on opposite page. Catalog number 97-273.

figure K

CONTIPS available

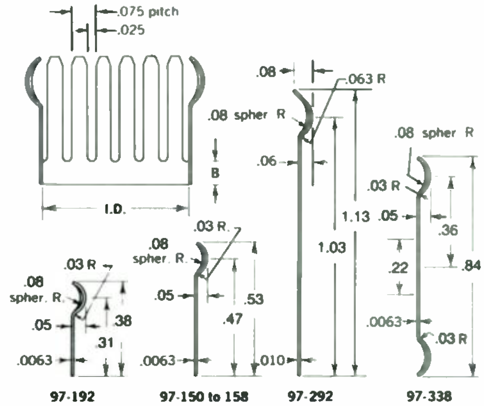


figure L

CONTIPS available

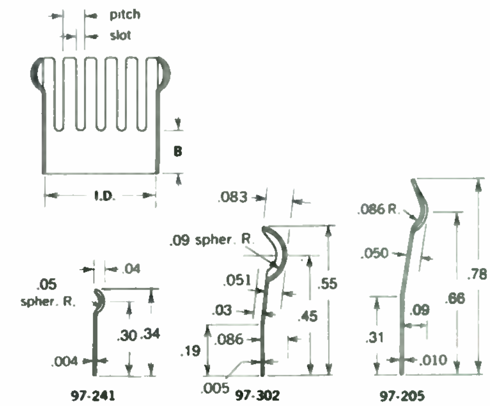


figure M

CONTIPS available on 97-215 only

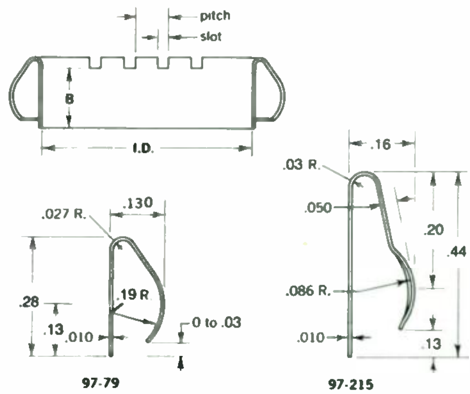


figure N

CONTIPS available

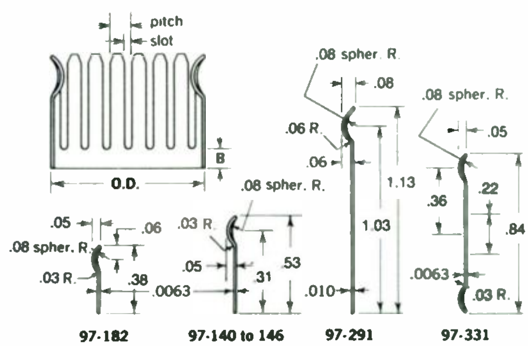
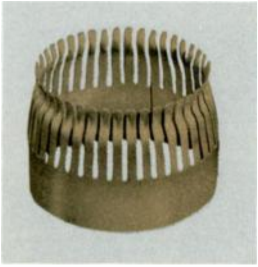


figure O



CONTIPS available

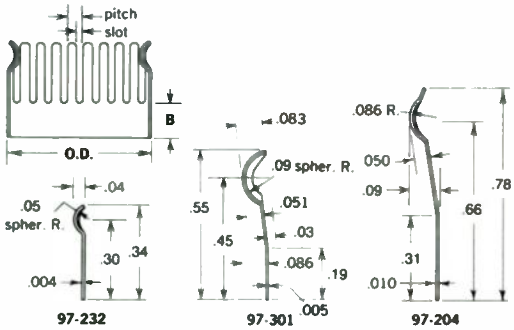


figure P

CONTIPS available

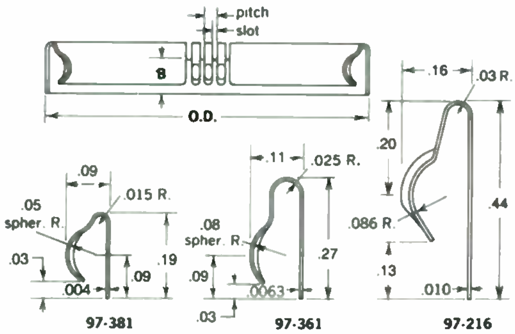


figure Q

not available with CONTIPS

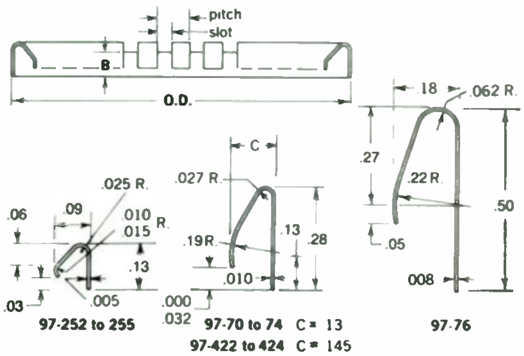
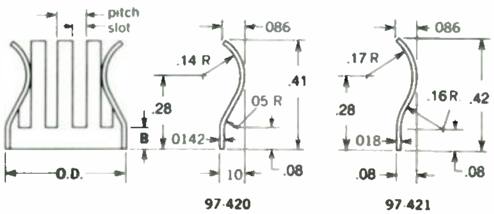


figure R

not available with CONTIPS



standard products

other diameters and designs available to order.

dimensions, in inches

dimensions shown apply after assembly

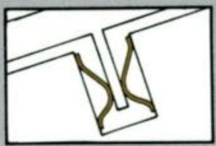
male

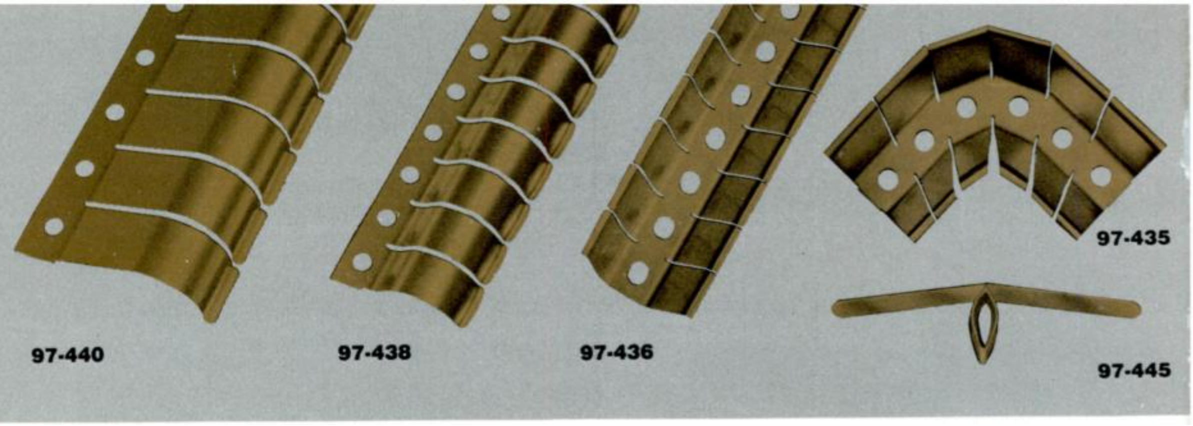
catalog number	fig-ure	pitch	slot	I.D.	number of fingers	nominal ring dia.	B	weight in. lbs. per m	made from strip
97-79	M	.135	.040	.851	20	1.05	.23	3.7	97-135
97-150	K	.075	.025	.208	9	.25	.22	.6	97-134
97-151	K	.075	.025	.327	14	.38	.22	1.0	97-134
97-152	K	.075	.025	.447	19	.50	.22	1.3	97-134
97-153	K	.075	.025	.685	29	.75	.22	2.0	97-134
97-154	K	.075	.025	.949	40	1.00	.22	2.8	97-134
97-155	K	.075	.025	1.449	61	1.50	.22	4.3	97-134
97-156	K	.075	.025	1.952	82	2.00	.22	5.7	97-134
97-157	K	.075	.025	.855	36	.91	.22	2.5	97-134
97-158	K	.075	.025	1.880	79	1.94	.22	5.5	97-134
97-192	K	.075	.025	.447	19	.50	.06	.9	97-136
97-205	L	.094	.031	.886	30	1.00	.31	5.3	97-137
97-215	M	.094	.031	1.240	42	1.50	.31	8.6	97-139
97-241	L	.060	.020	.339	18	.38	.13	.4	97-223
97-292	K	.075	.025	1.192	50	1.25	.69	11.0	97-290
97-302	L	.165	.040	1.842	35	1.97	.19	4.6	97-300
97-338	K	.075	.025	.447	19	.50	—	1.8	97-330

female

catalog number	fig-ure	pitch	slot	O.D.	number of fingers	nominal pin dia.	B	weight in. lbs. per in.	made from strip	min. O.D. O.B.
97-70	Q	.135	.040	1.219	28	1.02	.23	5.5	97-135	.744
97-72	Q	.135	.040	1.000	28	.80	.23	4.5	97-135	.744
97-74	Q	.135	.040	.875	20	.67	.23	3.9	97-135	.744
97-76	Q	.163	.015	.637	12	.34	.25	3.2	97-340	.637
97-140	N	.075	.025	.292	12	.25	.22	.8	97-134	.200
97-141	N	.075	.025	.436	18	.38	.22	1.3	97-134	.200
97-142	N	.075	.025	.555	23	.50	.22	1.6	97-134	.200
97-143	N	.075	.025	.795	33	.75	.22	2.3	97-134	.200
97-144	N	.075	.025	1.057	44	1.00	.22	3.1	97-134	.200
97-145	N	.075	.025	1.558	65	1.5	.22	4.3	97-134	.200
97-146	N	.075	.025	2.059	86	2.00	.22	6.0	97-134	.200
97-182	N	.075	.025	.555	23	.50	.06	1.1	97-136	.200
97-204	O	.094	.031	1.040	34	1.00	.31	6.6	97-137	.461
97-216	P	.094	.031	1.244	41	1.00	.31	7.0	97-139	.937
97-232	O	.060	.020	.536	28	.50	.13	.6	97-223	.160
97-252	Q	.127	.050	1.250	31	1.085	.09	1.1	97-251	.448
97-253	Q	.127	.050	1.155	28	.985	.09	1.0	97-251	.448
97-254	Q	.127	.050	.905	22	.735	.09	.8	97-251	.448
97-255	Q	.127	.050	.650	16	.480	.09	.6	97-251	.448
97-291	N	.075	.025	1.065	44	1.00	.69	10.0	97-290	.200
97-301	O	.165	.040	1.737	33	1.63	.19	4.3	97-300	.428
97-331	N	.075	.025	.795	33	.75	—	3.0	97-330	.200
97-361	P	.075	.025	1.008	42	.84	.22	2.3	97-360	.605
97-381	P	.060	.020	1.207	63	1.06	.13	1.3	97-380	.463
97-420	R	.193	.075	.500	8	.323	.06	1.9	—	.500
97-421	R	.100	.050	.500	15	.368	.06	2.2	—	.435
97-422	Q	.154	.050	.600	12	.368	.25	2.2	—	.550
97-423	Q	.159	.050	.775	15	.540	.23	3.	—	.550
97-424	Q	.135	.040	1.050	24	.810	.23	4.7	—	.873

Shielding for large enclosures





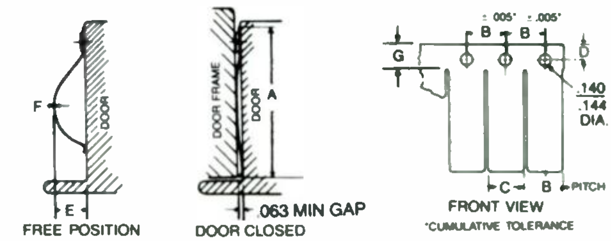
These standard beryllium copper contact strips offer ideal RFI/EMI shielding of doors and movable components in electronic screen rooms, trailers, computers and communication equipment.

They have been scientifically designed for wiping closures, but are also usable in compression. Moreover, these contact strips feature extremely good endurance life as well as a high dynamic range. In tests, attenuation up to 112 dB has been measured at 100 MHz plane wave. Fastening of strip is usually accomplished using screws or rivets. Soldering is optional.

For pricing, please advise catalog number, total footage and surface finish required.

Available in continuous lengths (25 ft. maximum) and in all standard finishes (see pages 20 and 23).

Series	A	B	C	D	E	F	G
97-438	1.281	.375	.335	.156	.250	.005	.250
97-440	1.90	.50	.460	.187	.406	.007	.312



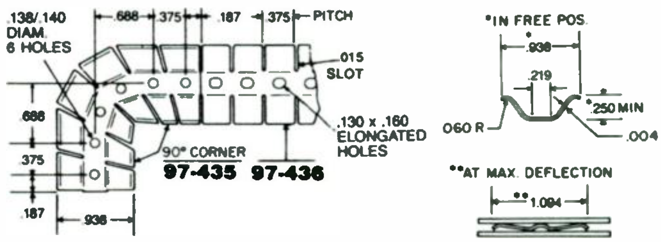
BALANCED FINGER STRIPS OFFER 90° CORNERS

When contact strips are required for rectangular openings or structural joints, they can be quickly and easily installed in field or factory.

Matching 90° corners provide a perfect fit and spring clips hold the strips firmly in place. (No special tools or soldering required.) Result: More simplified design and construction of cabinets and enclosures.

These strips feature a mechanically balanced design to provide high dynamic range, long endurance life and multiple lines of contact under relatively light pressure. Attenuation of more than 102 dB at 100 MHz plane wave has been measured using Series 97-436 gaskets. For standard finishes (see pages 20 and 23).

prefabricated 90° corners



Available in all standard finishes (see pages 20 and 23).

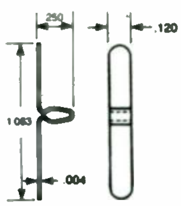
QUICK SPRING CLIP FASTENER

Designed for use with Series 97-436 and Series 97-435 finger strips. Permits full strip compression, yet is easily installed without special tools. Fastener also permits temporary lifting of gaskets for cleaning of contact surfaces.

spring clip fastener

packaged in lots of 1000
(advise total quantity needed.).

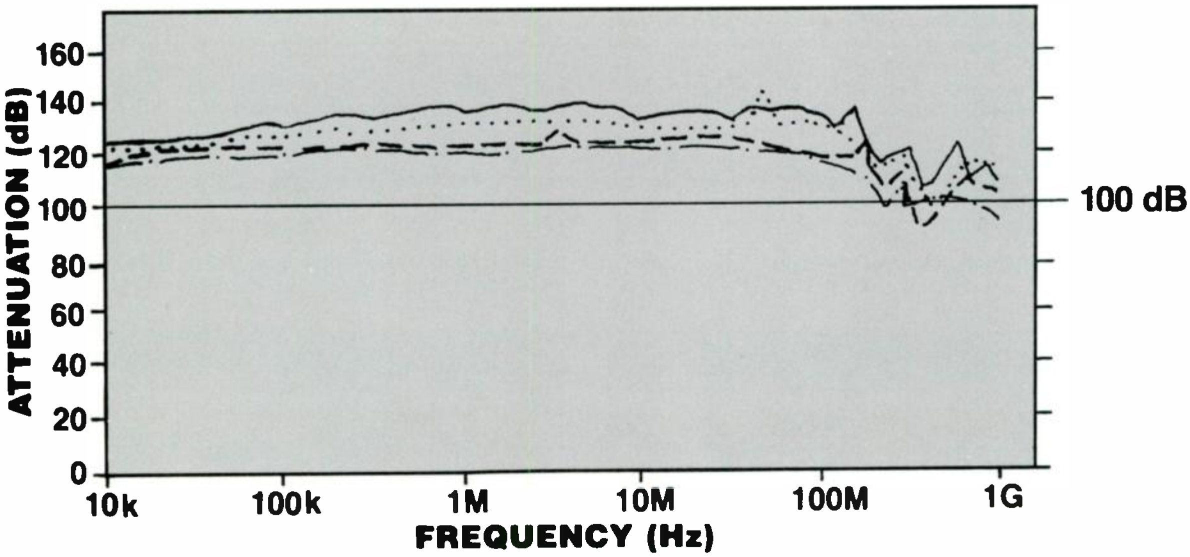
Available in all standard finishes
(see pages 20 and 23).



97-445

TYPICAL SHIELDING PERFORMANCE VALUES

The performance data shown is the result of testing typical beryllium copper shielding configurations. Each reading was developed with the specimen compressed only 25% of its potential dynamic range—a confirmation of the fact that only a slight amount of compression is necessary to attain this type of high performance.



APPROXIMATE FORCE REQUIRED FOR 25% DEFLECTION

97-500	97-520	97-538	97-540
12 lbs./ft.	18 lbs./ft.	17 lbs./ft.	21 lbs./ft.

Note: Attenuation per one meter length measured I.A.W. SAE ARP-1705, at deflection of 25% of dynamic range.

97-520: . . . .
97-540: — — — — —
97-500: —·—·—·–
97-538: ————————

FINISH: Bright clean
SURFACE: Copper

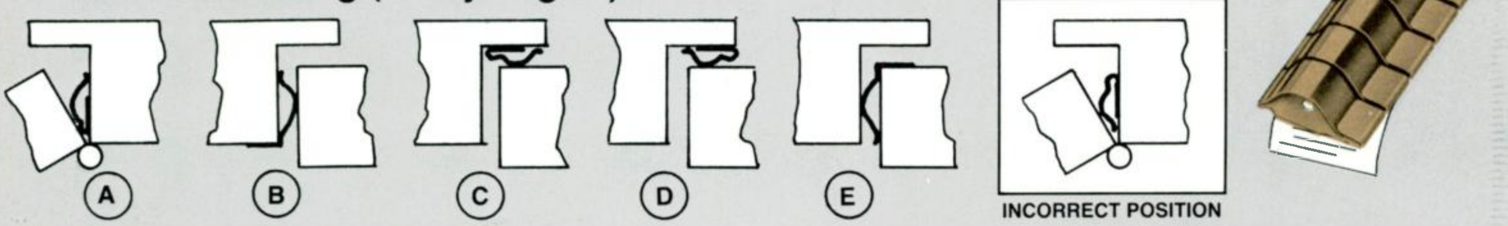
Metals Compatibility

To avoid galvanic action between metals that contact each other, refer to the chart below. Each group overlaps, making it possible to use materials from adjacent groups safely. Platings shown in boldface are available from Instrument Specialties.

Group	Metal Groupings
1	**Gold**—Platinum—Gold/Platinum Alloys—**Rhodium**—Graphite—Paladium—**Silver**—Silver Alloys—Titanium
2	**Rhodium**—Graphite—Palladium—**Silver**—Silver Alloys—Titanium—**Nickel**—Monel—Cobalt—Nickel and Cobalt alloys—Nickel Copper Alloys—AISI 300 Series Steels—A286 Steel
3	Titanium—**Nickel**—Monel—Cobalt—Nickel and Cobalt Alloys—Nickel Copper Alloys—**Copper**—Bronze—Brass—Copper Alloys—BERYLLIUM COPPER—Silver Solder—Commercial Yellow Brass and Bronze—Leaded Brass and Bronze—Naval Brass—Steels AISI 300 Series, 451, 440, AM 355 and PH hardened—Chromium Plate—Tungsten—Molybdenum
4	Leaded Brass and Bronze—Naval Brass—Steels AISI 431, 440, 410, 416, 421, AM 355, PH hardened—Chromium Plate—Tungsten—Molybdenum—Tin-Indium—**Tin Lead Solder**—Lead—Aluminum 2000 and 7000 Series—Alloy and Carbon Steel
5	Chromium Plate—Tungsten—Molybdenum—Steel AISI 410, 416, 420, Alloy and Carbon—**Tin**—Indium—**Tin Lead Solder**—Lead—Aluminum—All Aluminum Alloys—**Cadmium**—**Zinc**—Galvanized Steel—Beryllium—Zinc Base Castings
6	Magnesium—**Tin**

Instrument Specialties Shielding Devices may be mounted quickly and easily, using any of several different methods. Each installation method is described below. However, if you run into a unique problem, not solvable by any of these procedures, a call to Instrument Specialties will produce the help you need.

Adhesive Mounting (Sticky Fingers)



1. Smooth the mounting surface with emory cloth if necessary, and **solvent-clean to remove all grease and film.** Avoid contact with fingers after cleaning.

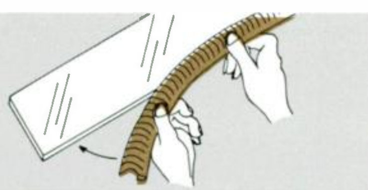
2. Peel off the protective paper backing. Avoid finger contact with adhesive.

3. Be sure strip is in correct position (see diagrams A thru E). **Press firmly** to ensure a good mechanical bond. Avoid repositioning, which might impair the effectiveness of the adhesive or may bend or kink the strip.

NOTE: On items where fingers cover the solid portion of strip, pressure may be applied by inserting a mandrel in the strip and pressing down. Alternatively, run a small screwdriver or similar object under the fingers several times with downward pressure. Contact Strips with Magnefil® insert, in effect, have built-in mandrels. Simply press down on the fingers.

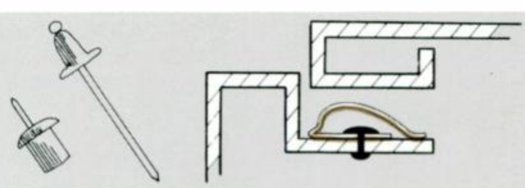
4. Allow 24 hours minimum "curing" time.

Clip-on strips



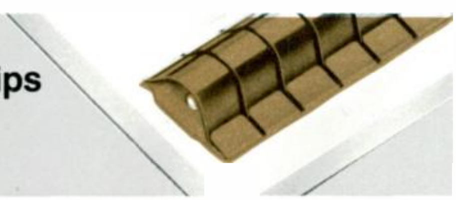
Clip-on strips hold firmly due to their own spring characteristics. Simply push the strips onto the edge or flange of your door or enclosure.

Riveting strips



Riveting produces a tight, long-lasting installation. Use either plastic or copper rivets.

Soldering rings and strips



Follow normal low temperature soldering techniques, cleaning and fluxing parts with a non-acid material.

Welding parts

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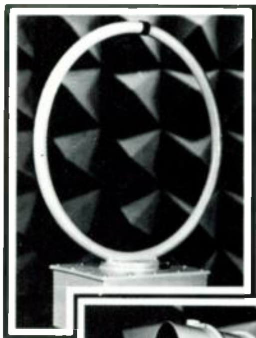

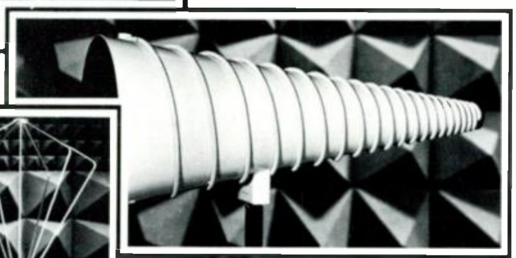

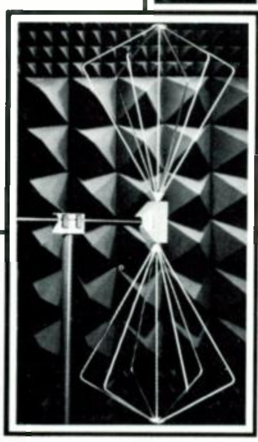

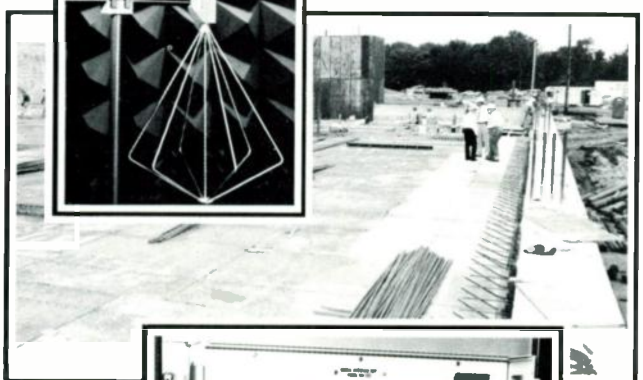

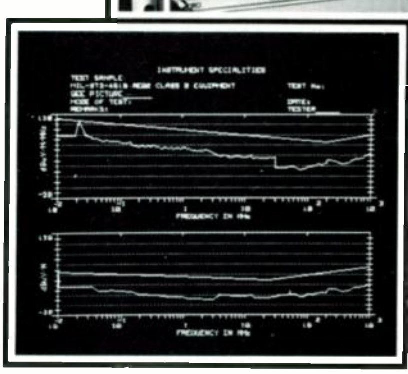

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The FCC has defined acceptable emission levels for all computer devices by class of product.

Class A devices are used in commercial, industrial or business applications. Two examples are computers (any electronic device generating and using timing signals at a greater rate than 10,000 pulses per second and using digital technique) and peripherals. Class A devices must comply by being tested to FCC criteria and by being documented by test data on file which is subject to FCC agency audit.

Class B devices are those used in residential applications. Some examples are personal computers, electronic games and calculators. These devices must be *certified* (*not* simply be in compliance) by submitting actual test data or hardware for agency review.

A total of three requirements must be met:

1. Radiated emissions—unintentional signal transmissions
2. Conducted emissions—amount of signal fed to AC line
3. Labeling and Instructions Manual requirements

EMI REQUIREMENTS

Class	Frequency (MHz)	Distance (m)	Field Strength (μV/m)	Max. Voltage (μV)
A-Radiated	30-88	30(3)	30(300)	
	88-216	30(3)	50(300)	
	216-1000	30(3)	70(700)	
A-Conducted	0.45-1.6			1000
	1.6-30.0			3000
B-Radiated	30-88	3(30)	100(10)	
	88-216	3(30)	150(15)	
	216-1000	3(30)	200(20)	
B-Conducted	0.45-30.0			250

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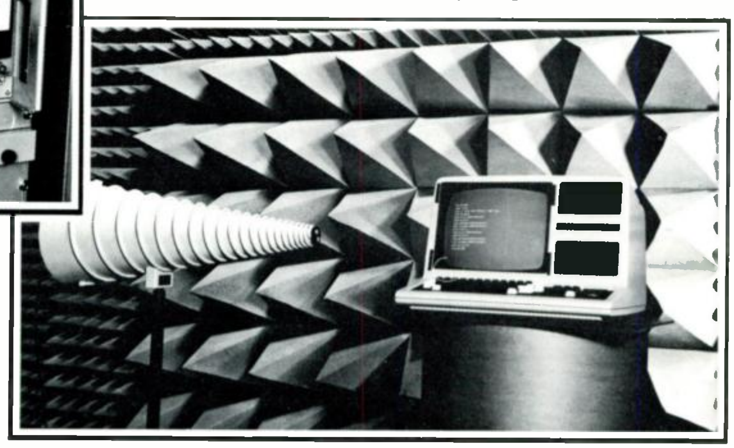

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STOCK ITEM		UNIQUE PART I.D.		FINISH I.D.
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- Instrument Specialties Part Number 0097-0821-02 is a 97-821 Environmental Strip with a bright clean finish.
- Standard plating finish is .0002 ± .0001″ (gold .000050″ min.) and footnoted with your custom instructions.
- Special orders are specified by an "X" (following finish I.D.) unless otherwise specified.
- Utilize the catalog number for Unique Part I.D. and the following chart for Finish I.D.

Required Finish	I.D.
Heat Treated (H)	01
Bright Clean (A)	02
Gold (.00005″ min) (G)	03
Silver (S)	04
Cadmium Chromate (CdC)	05

Required Finish	I.D.
Cadmium (Cd)	06
Tin Lead (Sn Pb)	07
Satin Tin (Sn-S)	08
Dull Nickel (NiD)	09
Nickel/Gold (NiG)	10

Required Finish	I.D.
Silver Contip (K)	11
Silver Contip/Plating (KS)	12
Gold Contip (GK)	13
Gold Contip/Plating (SKG)	14
Zinc (Zn)	15

Required Finish	I.D.
Zinc/Chromate (ZnC)	16
Bright Tin (SnB)	17
Electroless Nickel (ELNi)	18
Bright Nickel (NiB)	19
Silver Plate/Gold Contip (SGK)	20

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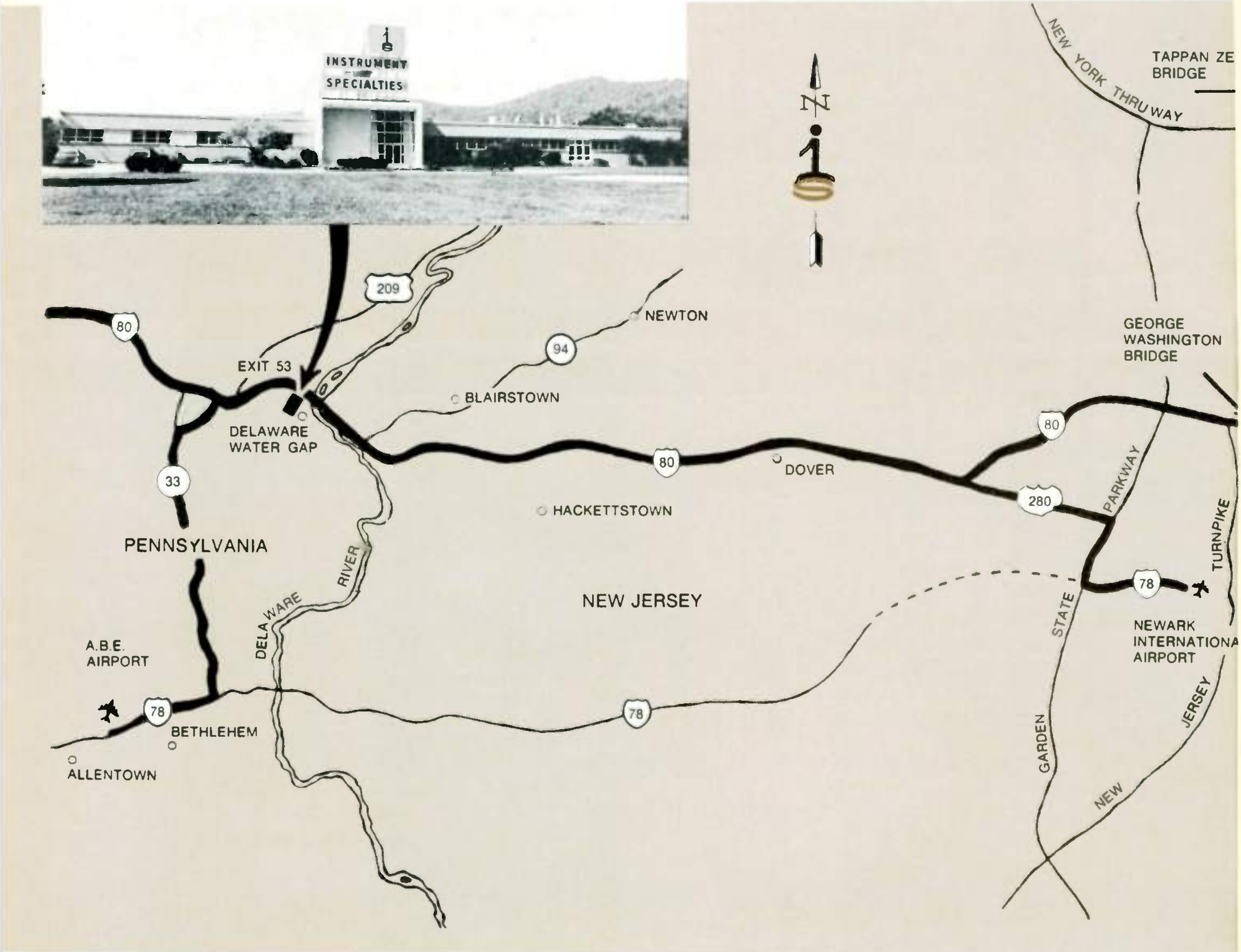

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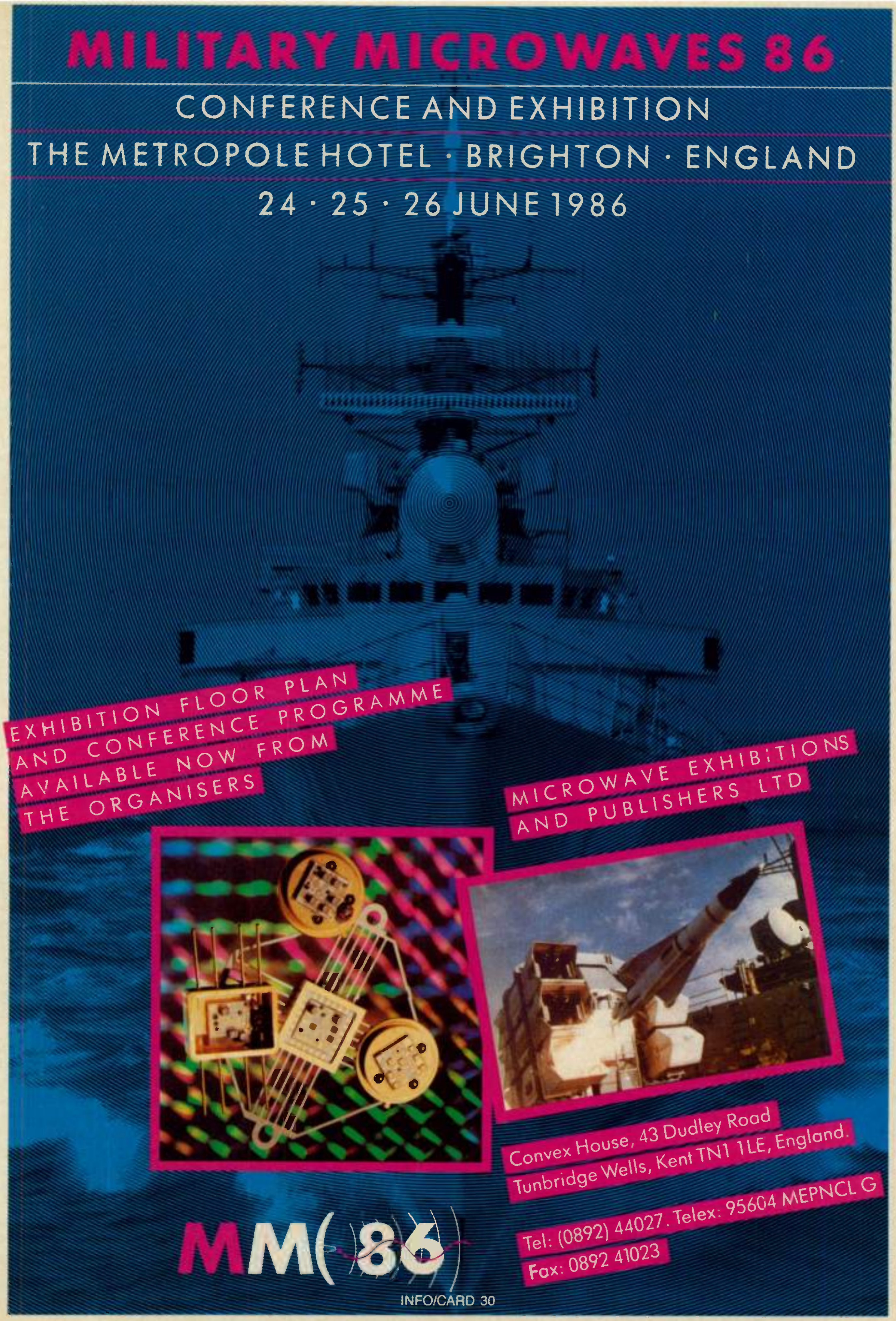
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WRH

Using Wideband Operational Amplifiers

By Steve Rickman
General Electric Medical Systems

Given the option, most analog designers would much prefer to use operational amplifiers (op-amps) in a circuit rather than discrete transistors. For simplicity of design and predictability of performance, op-amps can't be beat, and it is hard to match the DC precision of op-amp circuits with assemblies of transistors.

One of the greatest stumbling blocks to using op-amps has been the limited bandwidth of monolithic devices. High-speed operation required hybrid op-amps, which tend to be expensive and power-hungry, but the past few years have seen the bandwidth limit of monolithic op-amps pushed back. There are now several monolithic op-amps available with small-signal bandwidths of more than 100 MHz, and there are dozens of parts with bandwidths greater than 10 MHz going for a few dollars each in volume.

The present leader in wideband monolithic op-amps is Harris Semiconductor, which offers several different series of high-performance devices. Wideband op-amps are also available from Signetics, National Semiconductor, RCA, and Motorola, plus several smaller companies, such as Third Domain, and Elantec.

Now it is possible to design low-cost op-amp circuits with closed-loop bandwidths of greater than 10 MHz, but the new wideband op-amps are not as easy to use as the venerable 741. Before committing resources to a design based on one of the new wideband op-amps, the designer should take a close look at some key specifications and application practices.

Defining "Wideband"

There is no exact definition of "wideband" as the term applies to op-amps, and any such definition would quickly become outdated as manufacturers introduced higher performance parts. At present, however, we might reasonably call wideband any op-amp with a small-signal bandwidth of 10 MHz or more.

Small signal bandwidth is simply the frequency at which the open-loop gain of the op-amp is unity. Notice that small-signal bandwidth is not the same thing as "gain-bandwidth product," a time-honored specification whose day is all but past. A gain-bandwidth product specification is useful only for an op-amp in which the open-loop gain rolls off under the influence of a single dominant pole. If that is the case, then the open-loop gain will decrease at a constant 20 dB per frequency decade, and the open-loop phase shift will be −90 degrees over most of the bandwidth. That is decidedly *not* the case for most wideband op-amps. To be sure, they do roll off to unity gain, but not necessarily at a constant 20 dB per decade, or with the constant −90 degree shift. Since most wideband op-amps are uncompensated or undercompensated internally, the response may cross several critical frequencies before unity gain is reached. In order to determine open-loop gain and phase at a particular frequency you must study carefully the published plot of open-loop frequency response, remembering that such plots are always "typical."

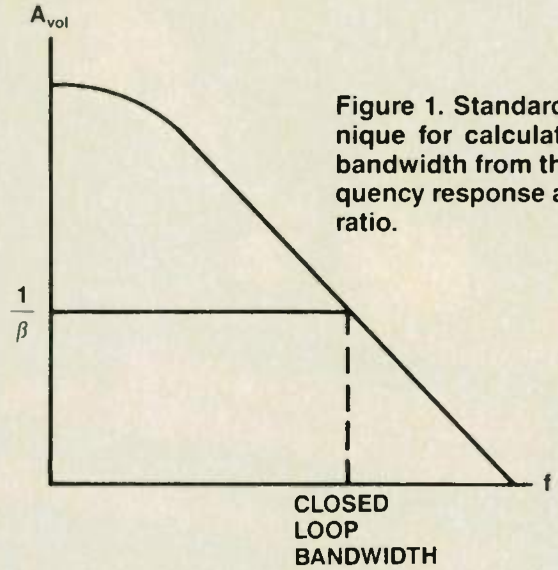


Figure 1. Standard graphical technique for calculating closed-loop bandwidth from the open-loop frequency response and the feedback ratio.

Bandwidth and Accuracy

For most amplifier applications, select an op-amp having just enough small-signal bandwidth, and no more. In general, a wider bandwidth op-amp will cost more and be more difficult to stabilize. A very high bandwidth device may also have unusual performance characteristics such as low input impedance, low DC open-loop gain, limited output swing or high DC output offset.

How much bandwidth is enough? The usual exercise for closed-loop frequency response calculation is to draw a line across the open-loop frequency response plot at the level of the closed-loop gain (i.e., the inverse of the feedback ratio). The frequency at which that line intersects the open-loop gain is said to be the closed-loop corner frequency, or the closed-loop bandwidth (Fig. 1).

Although this method may be useful as a first approximation to closed-loop frequency response, it can be misleading.

Remember that an essential characteristic of an op-amp is high open-loop gain. The so-called loop gain, which is the excess of open-loop gain over closed-loop gain, is then traded for all sorts of closed-loop advantages such as gain accuracy, high input impedance, low output impedance, phase-linear response, and low harmonic distortion. If the loop gain is not large, these "ideal" op-amp characteristics will deteriorate.

The effect of low loop gain on the amplifier may be calculated by means of a generalized error multiplier:

$$E = \frac{A_{vol}\beta\angle\Theta}{1 + A_{vol}\beta\angle\Theta}$$

where,

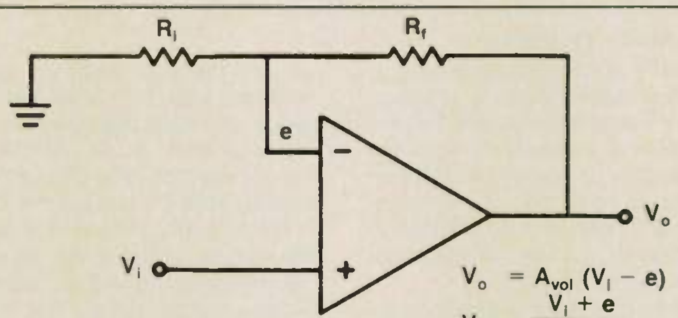
E = error multiplier
A_{vol} = open-loop gain magnitude at the frequency of interest
β = feedback ratio
Θ = open-loop phase shift

For example, if the ideal amplifier gain in either the inverting or non-inverting configuration is A_v, the actual gain is:

$$A'_v = A_v \times E$$

Consider an op-amp amplifier in which the open-loop phase shift is −90 degrees at the closed-loop corner frequency. As might be expected, at that frequency the error multiplier magnitude is .707 and the phase is −45 degrees. Back up enough in frequency for a loop gain of 6 dB and the error multiplier magnitude and phase become .89 and −26 degrees, respectively. That is a significant improvement, but the errors still can cause problems in an application where precise gain or phase linearity is important.

On top of this, how much faith can be had in the manufacturer's "typical" plot of open-loop frequency response? Only rarely do the makers supply guaranteed minimum specifications for bandwidth. What percentage of op-amps fall on the low side of the typical frequency response characteristic? What is the worst case deviation? Any engineer will have difficulty finding these answers. A good rule of thumb, if gain accuracy and phase linearity are important, is to allow a minimum of 20 dB loop gain, referenced to the plot of typical response at the highest frequency of interest.



$$V_o = A_{vol}(V_i - e)$$

$$V_{cm} = \frac{V_i + e}{2} = V_i - \frac{V_o}{2A_{vol}}$$

Figure 2. In the non-inverting configuration, if the input is large, the common-mode voltage presented to the op-amp is approximately the input voltage. At higher frequencies CMRR deteriorates and there may be distortion.

Slew Rate and Power Bandwidth

Just as important as the small-signal bandwidth is the slew rate of the op-amp. It does little good to have deep loop gain at an operating frequency if the op-amp cannot generate sufficient output swing at that frequency. Note carefully that wide bandwidth and high slew rate do not always go hand in hand.

The slew rate of an op-amp is the maximum frequency at which the output can generate a full-swing sine wave without distortion. "Full swing" usually means the maximum output voltage swing available at low frequencies for given power supply voltages. A full swing of ±10 V for ±15 V is a typical value.

The power bandwidth is easily calculated from the slew rate and full swing specifications. if the full swing is $\pm V_p$, then:

$$f_p = \frac{SR}{2\pi V_p}$$

where,

f_p = power bandwidth in MHz
SR = specified slew rate in volts-per-microsecond
V_p = peak amplitude of an output sine wave

At frequencies higher than f_p, the maximum rate of change of a sinusoid of V_p volts amplitude is greater than the op-amp slew rate. The op-amp can't keep up and begins to turn the sinusoid into a triangle wave of lesser amplitude. Of course the op-amp does not become suddenly useless at the limit of the power bandwidth. The issue is the maximum rate of change of the output sine wave. The maximum rate of change at a given frequency can be reduced by lowering the amplitude V_p. For sine waves of some amplitude less than the full swing, the application-specific power bandwidth can be calculated from the equation above. Just remember to use the *minimum* slew rate specification. (If only a typical value is supplied by your manufacturer, be prepared to screen your op-amps.)

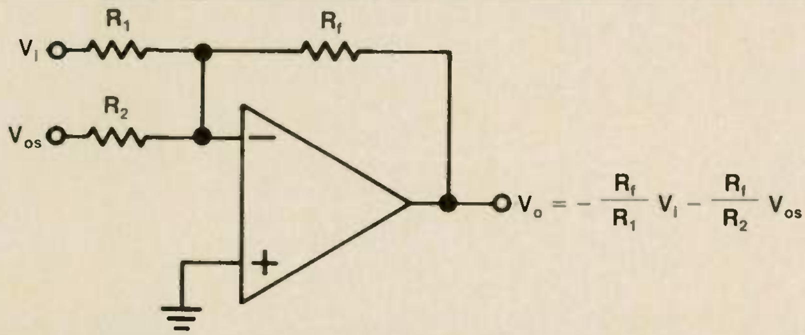


Figure 3. Simple method of applying a DC offset (V_{os}) to the amplifier while maintaining zero common-mode voltage.

Common-Mode Rejection

With virtually all op-amps, wideband or low frequency, common-mode rejection ratio (CMRR) will deteriorate at higher frequencies. With low-frequency op-amps the deterioration is rarely a problem because the op-amp runs out of bandwidth before common-mode rejection drops significantly, but with wideband op-amps there can be trouble.

It is not only differencing amplifier circuits that require good common-mode rejection, but every non-inverting amplifier as well. Consider Figure 2. If the differential open-loop gain of the op-amp is high, then the potential difference between the inverting and non-inverting terminals must be small. If the input is large, both terminals are presented with the input voltage as a common-mode signal. An ideal op-amp will ignore this signal. A practical wideband op-amp may not.

As a typical example, consider op-amp "X." With a typical small-signal bandwidth of 150 MHz and a slew rate of at least 160 V/μs, op-amp "X" is a very respectable performer. Yet at 1 MHz its common-mode rejection ratio is only 30 dB. According to the way the manufacturer measures CMRR, this means that at a frequency of 1 MHz, an instantaneous common-mode signal of 1 V can generate a 33 mV change in the input offset voltage. Furthermore, the manufacturer cannot say whether this offset is positive, negative, or depends on the signal polarity. At best, the reduction in CMRR with frequency causes gain inaccuracy; at worst it causes distortion.

Fortunately, there is a simple solution for this problem: eliminate common-mode signals. Don't use the non-inverting configuration. If you must offset the signal by any significant amount, do it at the inverting terminal (Figure 3).

Power Supply Rejection

Like common-mode rejection, power supply rejection degrades with frequency in virtually all op-amps, becoming a problem with the extended frequency range of wideband op-amps. Consider again op-amp "X." At 1 MHz the positive supply rejection is 60 dB but the negative supply rejection is a dismal 0 dB.

Power supply rejection is specified as the inverse ratio of a change in input offset voltage to the change in power suppy voltage producing it. The input offset voltage is amplified by the noise gain (i.e., non-inverting gain) of the amplifier (Figure 4). To see what this means, suppose that a 20 dB inverting amplifier is constructed around op-amp "X." Suppose further that there is a 1 MHz noise signal of 10 mV on the negative supply. With 0 dB of negative supply rejection at 1 MHz, the same 10 mV appears as an AC input offset voltage. Since the noise gain of the amplifier is 11, the noise signal finally appears at the output with a whopping amplitude of 110 mV.

Obviously, this can be a serious problem if small signals must be handled, and the solution is simply to maintain a clean power supply. Unless a single op-amp is running on a battery, the supply terminals should be decoupled with 0.1 μF or .01 μF capacitors. Whether this will be enough depends on ripple and regulation supply and other circuit variables, including the characteristics of the op-amp.

The next level of effort is the addition of low Q-series inductors in the supply leads. Small-value resistors could be used, but are not as effective as inductors. Remember that the objective is preventing high-frequency noise on the supply from reaching the op-amp. The combination of a 10 ohm resistor and a 0.1 μF capacitor provides approximately 17 dB attenuation at 1 MHz. The combination of a 100 μH inductor and a 0.1 μF capacitor provides approximately 52 dB attenuation at 1 MHz, a tremendous improvement.

How large an inductor should be used? Use the largest value having a self-resonant frequency at least as great as the closed-loop bandwidth of the op-amp. There is one major caution: Don't attempt to "share" the decoupling inductor between the op-amp and other active devices, the sharing devices will be coupled with a resonant LC circuit.

Stability and Compensation

Some designers may hesitate to use wideband op-amps because of stability concerns. (What if it oscillates?) Wideband op-amps *do* have more of a tendency to "fly" than their low-frequency cousins, but if the rules of compensation and layout are followed conscientiously, any wideband op-amp can be as stable as a 741.

Most wideband op-amps are undercompensated internally, meaning that for gains less than some low value (typically 3 to 5) the op-amp is inherently unstable. If the chosen gain is greater than this

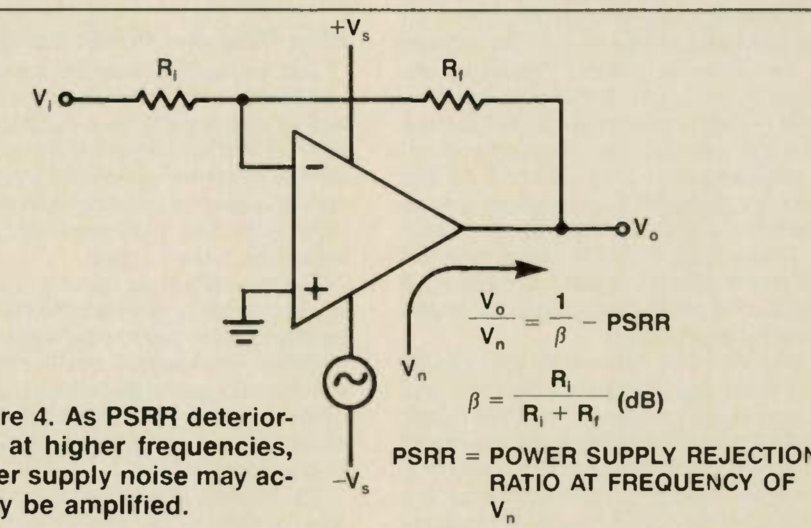


Figure 4. As PSRR deteriorates at higher frequencies, power supply noise may actually be amplified.

critical value, there is no worry about compensation. If the gain is less than or equal to this value, compensation is required.

The favored method of compensation for wideband op-amps is a series RC network from the inverting terminal to the non-inverting terminal (Figure 5A). The manufacturer will usually supply values or calculation data for optimum performance. Technically, this is lag-lead compensation, but it is very easy to understand intuitively. The corner frequency of the RC network is somewhat lower than the frequency at which the open-loop phase shift veers dangerously toward −180 degrees. For frequencies less than the corner frequency of the RC network, the network impedance is high and it has minimal effect on amplifier characteristics. At the corner frequency the network impedance drops and the amplifier feedback ratio is lowered, analogous to increasing the non-inverting gain to a safe level.

However, the circuit gain does *not* increase. The effect on circuit gain is only a slight degradation of gain accuracy, as would occur if the R of the RC network were tied directly between the inverting and non-inverting terminals. The great virtue of this method of compensation is that it does not affect closed circuit bandwidth. It simply introduces a relatively minor error term at the upper band edge.

In addition to the primary compensation, it is usually necessary to add a small capacitor (3 to 5 pF) in parallel with the feedback resistor. The purpose of this capacitor is to compensate for capacitance at the inverting input terminal which could create a troublesome pole in the feedack loop.

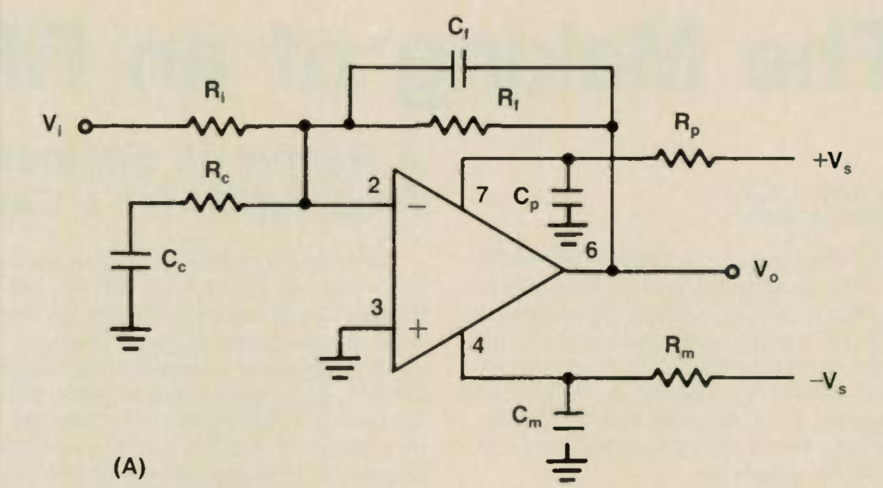
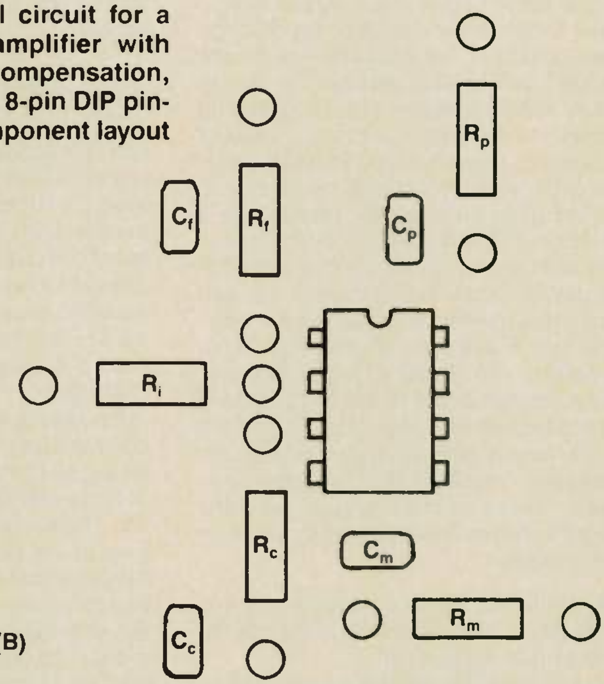


Figure 5. (A) Typical circuit for a wideband op-amp amplifier with feedback and input compensation, assuming a standard 8-pin DIP pinout. (B) Practical component layout for best stability.



Layout Practices

The most common cause of instability in wideband op-amp circuits is not poor compensation, but poor layout practices. Never leave the layout of a wideband op-amp circuit to any printed circuit board designer. It takes RF engineering practices to do it, right down to the point-to-point runs between pins. Circuit board designers are trained to arrange components in a manner that is neat, simple and orderly. A good wideband op-amp layout is neither of these (Figure 5B). The basic rules of layout are:

1. Protect the inputs. Strive for an absolute minimum trace length between the input terminals and connected components.
2. Orient critical components for minimum coupling. For example, don't place the input and feedback resistors of an inverting amplifier side-by-side. Set them at right angles to one another.
3. Let the layout follow the signal flow. In strings of amplifiers or processing stages, don't double back the processed signal near prior stages.
4. Beware of feedback through the power supply or ground system, particularly in processing chains with power outputs. Always decouple power supply terminals. Use dedicated ground and supply traces for power stages.
5. Build on an etched circuit board and use a good ground plane. Wirewrap and the various embedded-wire technologies are basically incompatible with wideband analog circuits, where the placement of every component and conductor must be optimized.

In selecting a device for a specific application, pay close attention to dynamic specifications. Wideband op-amps are not created equal. rf

About the Author

Steve Rickman is an analog design engineer with General Electric Medical Systems, Ultrasound Product Section, 3920 Security Park Dr., Rancho Cordova, CA 95670, and holds an MSEE degree from California State University, Sacramento. He can be reached at the above address or at (916) 361-4331.

The Making of an RF Engineer

A Report on Engineering Education and the Preparation for a Career in RF Technology.

By Gary A. Breed
Technical Editor

RF Engineers are a valuable commodity, if the law of supply and demand means anything! Demand is high for engineers with RF design skills, but supply is far short of that demand. Some schools report increasing interest in RF-related courses, but it will take time for this increased awareness to be translated into more RF engineers.

This report began as a simple questionnaire to determine if an aspiring RF engineer could get the education he or she needed, but larger questions were soon raised about the nature of the engineering profession and about the proper roles of education, industry and the individual in the engineer's professional development.

How does an engineer prepare for a career in RF? Are colleges and universities able to provide the proper technical education? How much more is needed beyond purely technical aspects of engineering? These are definitely not *simple questions with simple answers. However, there are significant points of agreement and disagreement that have filtered out of discussions with managers, educators, recruiters, students and working engineers. These comments and concerns begin to tell us what it takes to make an RF engineer.*

Among the views contributed to this report, four points received almost unanimous agreement:

1. A good RF education can be obtained at many universities, but it requires exceptional awareness and effort *by the student* to identify a school with proper curriculum and faculty support.

2. Understanding of the *non-technical* roles of an engineer is essential for success in the workplace.

3. Employers have some specific expectations of engineers, to complement their business goals. Employers need to communicate these expectations to their engineers, and engineers need to pay attention to the goals of the company as a whole.

4. Engineers tend to have a number of definite personality traits and attitudes. It is important for engineers and their employers to understand these characteristics to avoid serious conflict in the workplace.

The first two points are the most specific to engineering careers, with RF having specific and unique requirements. The latter two points are universal in any job, but are magnified in engineering where salaries, expectations and technical performance are higher than in an "average" occupation. It is clear that engineering has unique requirements for those working in the field, with RF being even more specific.

Putting RF into a BSEE

Not every engineering school has the rich RF tradition of an Ohio State, University of Illinois or Stanford. Not every prospective RF engineer is going to be able to attend one of the few schools with unquestioned quality in RF education. It is possible, however, to get a solid RF education at many engineering schools, but it takes a combination of student awareness and faculty interest to make a program work.

Educators are unanimous in their recommendation that a BSEE be as broad-based as possible, exposing the student to fundamental principles in all areas of EE. The majority of engineers and managers in the RF industry agree that solid fundamentals are essential, and that elective courses should be used to add some RF emphasis. For RF preparation, the most important difference between schools is *attitude* and *interest* in RF by students and faculty. RF still has an aspect of "black art" which requires experience and an intuitive understanding that can only be achieved over time. One faculty member who can keep a few interested students focused on RF concepts may be all that is needed to make a good engineering program into a good RF education!

What does a beginning student look for in a school when he or she is looking toward a career in RF? Faculty interest is at the top of the list. If there is a digital emphasis or a control theory emphasis among engineering professors, even the basic courses in field theory and communications theory can be skewed away from necessary RF understanding.

Selection of textbooks is another way to judge an engineering program. A trip through the college bookstore can identify the orientation of an engineering department. For example, a communications theory text that analyzes noise in terms of Bit Error Rate and emphasizes FSK and QPSK modulation over AM, FM and ΦM is a dead giveaway that this is a "digital" course!

An engineering curriculum is a difficult road for a student with a heavier course load than a liberal arts major and complex concepts to master. Elective courses can be used to shape a BSEE into an RF emphasis, but much more important is a continuing awareness of RF applications in all of the courses and laboratory work. It requires students to have an exceptional awareness of their career goals, and the encouragement of faculty.

Specialization in a specific area of RF can be accomplished in post-graduate study, in combination with on-the-job training. Although some industries desire more specific training at the BSEE level, their number is few, with most companies insisting that their RF engineers get a broad-based EE education as a foundation for more specialized training.

What engineering schools don't (and can't) teach

"There aren't enough Renaissance Men to go around," says Ron Jetton, Associate Dean of Bradley University's College of Engineering and Technology. Technical excellence is the primary role of engineering education, but there are so many *non-technical* aspects of an engineering career that it is impossible to include them in a curriculum that is already 20% longer than Arts and Sciences. A successful career may begin with a technical education, but it can only continue successfully if the engineer has sufficient abilities and understanding beyond circuit design!

In discussions about the necessary traits an engineer must have, the talk quickly turns from technical skills to writing, speaking and organizational skills. George O'Clock, Professor at Mankato State University, put it a bit more bluntly, "If you write and speak like a moron, you'll be treated like a moron." Judgment of an engineer's performance in the workplace will be based on total performance, including the quality of written reports, participation in seminars and discussions, and coherent and organized lab notes.

The engineer's personality is, unfortunately, basically in conflict with the non-technical functions that are expected. Engineers tend to be technical "artists" who want to design the perfect circuit. Rather than being a judgment, this is a statement of fact made by the most experienced engineers interviewed. Engineers and their employers need to understand the conflict that an engineer faces every day between the motivation for an ideal creation and the need to achieve specified performance, on a definite timetable, in a cost-conscious manner.

Where are these things to be learned? Engineering schools have a minimum of general education requirements in English, Speech, Economics or the Humanities. An engineering student with a vision of the future will take these classes seriously, as they may be the only formal opportunity to round out an education. But we are all aware that this part of the college curriculum is "tuned out" by students who find such classes unrelated to their interests. Most engineers discover the need for writing, verbal and economic skills after they are on the job. Sometimes a senior engineer acting as a mentor to the rookie can help overcome these problems, but it is much more difficult to achieve at this late date. The few engineering professors who emphasize these aspects of a career do a great service to their students and should be commended for their efforts.

The last chance an engineering student has to gain a perspective on the workplace is the Senior Seminar offered at many schools. Often regarded as a wasted couple hours every week, this is the only exposure some students will get to the "professional" aspects of engineering before they enter the workplace. It is the responsibility of the students to learn from the presentations of engineers, managers, and other industry representatives. Jim Freeman, EE Department Chairman at San Jose State, reports that his students actively participate in these seminars. Dr. Freeman's explanation of this above-average interest is his university's location in a concentrated high-tech area, where students have some awareness of the requirements of an engineering career.

Where's the Controversy?

This education report has a conspicuous absence of references to R&D funding for universities, quotations from company presidents and engineering society leaders, or descriptions of programs at the top few engineering schools. These areas and the controversy surrounding them have been well covered by both technical and general publications, but they represent only one viewpoint — from the top.

The report presented here is based on input from the "grass roots" of engineering. Staff engineers and engineering managers contributed their viewpoints, as well as executives of large and small companies. Recruiters from large firms were interviewed along with officers of small companies who do their own hiring. Both students and professors offered their comments, not just college presidents and deans. Attention was given to the many smaller engineering schools who produce by far the greatest number of engineers compared to the few major universities.

Among this group, there is far less controversy and politicking about engineering education. The roles of engineers in the workplace are better understood by staff level personnel who are far removed from the "ivory towers" of upper management and administration. Working managers know exactly what they want in an engineer, what they can expect, and what they don't get enough of. Students, professors, and staff engineers demonstrated remarkable insight into the best ways to meet the requirements placed upon them.

Industry has high expectations

There are a number of specific expectations that industry has for new RF engineers. First is a good, solid fundamental BSEE with as much RF orientation as possible. Most senior engineers and managers noted that a Masters Degree is really not necessary, nor highly advantageous for a new engineer. Recruiters and personnel staff preferred an advanced degree if specialization was in the area they needed.

Computer literacy, using current design and analysis programs, is absolutely essential. This may be the single area where a new graduate has an edge on an experienced colleague. A high school senior looking for an engineering school should put available CAE/CAD facilities high on the list of requirements for a college.

Recruiters and managers alike put experience right after grades and the content of a new engineer's education. Experience can be part-time work, a Co-op program or summer jobs in an engineering environment. In RF this is more important than most areas, with the need for an intuitive "feel" for the subject. It is also interesting, as a recruiter from GTE Government Systems noted, that firms involved in telecommunications and data communications are currently seeking digital engineers with experience in RF!

Beyond technical background, there are a lot of *desirable* traits that are not absolutely required of all engineers. Realistic companies understand the tendencies of engineers to be purely technical, with less than average regard for writing, speaking, interpersonal relationships, and dress habits.

Top-notch technical ability and productivity will often allow a company to ignore certain eccentricities in an engineer, but not all engineers are at the top in ability, and need to be productive in other ways. Getting along well with co-workers seems a small matter, but its absence is real trouble. Writing good reports, presenting ideas in group discussions, and good organization of people and ideas are as much a part of productive engineering as outstanding circuit design. Ed Oxner of Siliconix identified communications as the number one trouble spot in an engineering career. An engineer who can get ideas across and listen to the ideas of others has an edge on all the rest. The company that has effective communications between management and engineering will achieve the highest productivity from each.

Trouble areas

Employers need more from their employees than just technical competence. The nature of engineers is to be less than well-rounded in education and interpersonal skills, a factor complicated by the complex and demanding technical understanding that is required of them. Complaints that engineers can't read, spell or write are compounded by further complaints that they are standoffish and antisocial. These are not unfounded complaints, but they are neither universal nor as serious as some employers claim. There is a definite conflict between technical and non-technical capabilities that has to be understood by both engineers and employers.

". . .some of the colleges are turning out visionaries rather than engineers who can come to grips with practical matters," says Doug DeMaw of Oak Hills Research.

This comment was echoed by a number of engineering managers who expressed difficulty in finding engineers with RF abilities, especially among new graduates. Educators tend to agree with the statement, but place the blame on a changing society, where kids no longer get "hands on" exposure to electronics, mechanics or the use of tools. The ready availability of electronic appliances and the decline of the do-it-yourself parent has taken some of the learning out of growing up. The intrigue of listening to a distant radio station has been replaced by a Walkman that takes radio everywhere.

Colleges are quick to note that they are getting better engineering students than ever, in scholastic terms. Most will also note that nearly all new students are starting completely from scratch in their understanding of electronics. They may know BASIC, but they don't understand how the computer works. They may watch TV and listen to the radio, but they don't have any idea what goes on inside. These intelligent students are very capable of understanding theory, but practical matters are becoming harder and harder to get across. A serious problem for education and industry is the changing attitudes in society that must somehow be compensated for.

Engineering careers — In the long run

Some wise philosopher once said that education doesn't end with graduation, it just moves to a different classroom. Receiving a BSEE and taking the first job is really the *beginning* of an RF education! Additional formal study will probably be needed, and will likely be supported by the employer. Seminars and technical symposia will play a large part in the development of specific engineering expertise. Self-study through periodicals and books will never stop throughout an engineer's career. Most engineers will make a contribution to the education of others through technical achievements, or as group leaders or managers.

A lot of discussion among engineers is about management. A good engineering manager is first a good engineer, who happens to have the organizational and interpersonal skills to oversee others. Unfortunately, many managers have used their position to remove themselves from the need for technical excellence. Often there is a difficulty in finding the right place in an organization for a senior engineer, and management is a common way to be "kicked upstairs." Several engineers lamented the fact that relatively few companies take best advantage of technically-oriented "elder statesmen." The point noted earlier about understanding the nature of an engineer's personality and attitude certainly needs close attention in this area.

With so many opinions and observations, it is hard to derive a simple summary of the state of RF engineering education. The main points have been made, and there are many other fascinating notes and suggestions which were made in interviews and discussions leading to this report, which will be carefully noted as we continue to seek the views of industry, education, students and engineers on the subject. The future of RF is very bright, but to reach its full potential good engineers are needed to do the work, and wise management is needed to obtain their best performance.

rf opportunities

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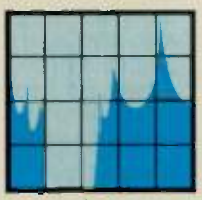

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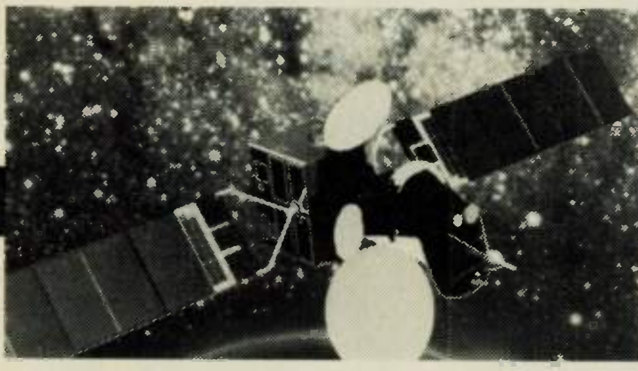

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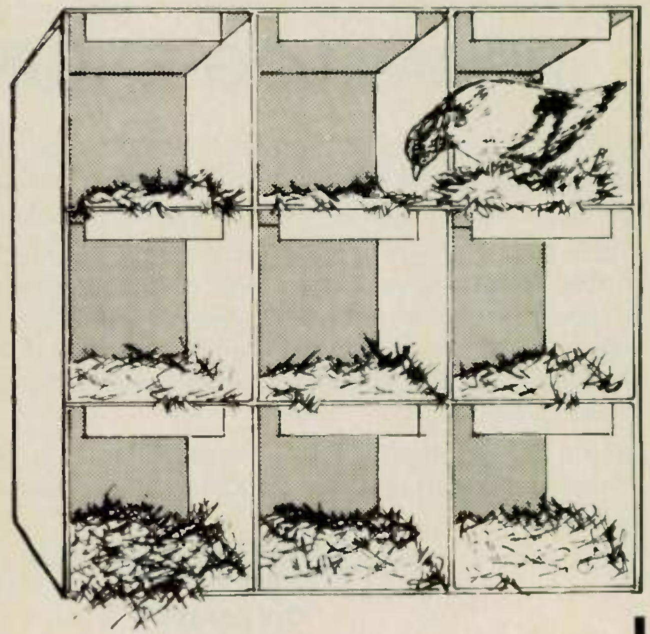

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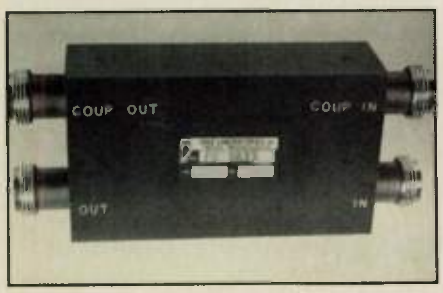
UHF Bi-Directional Coupler Handles 1500 Watts

Sage Laboratories has developed a modifiable custom UHF medium power bi-directional coupler. The unit, Model FC3833, was designed to operate at 445 MHz with an input power of 1500 watts CW only limited by the type N connectors.



It features forward and reverse coupling values of 36 dB (nominal) and typical directivity of 25 dB. Other specifications include an insertion loss of less than 0.1 dB and a VSWR of less than 1.10:1 typical. The unit can be modified for other specialized applications and measures 2" × 1" × 3.42" plus connectors. **Sage Laboratories, Inc., Natick, Mass. Please circle INFO/CARD #175.**

Amplifiers Introduced for Lab, Communications and NMR Uses

American Microwave Technology has introduced three new amplifiers. Model 3010 provides 1 kW pulse power at 185-205 MHz for NMR, using power FET design. Model 2010 is a 500 watt continuous power amplifier for 800-900 MHz communications or laboratory applications, and has VSWR and thermal protection, plus full remote operation capability. In the 200-450 MHz range, the model 2040 provides 200 watts CW for laboratory or systems uses. It has VSWR and thermal protection, LCD power metering, and can be ALC leveled to ±0.5 dB. **American Microwave Technology, Inc., Fullerton, Calif. INFO/CARD #174.**

System Measures RF Exposure

Certain users of RF are required to meet RF exposure requirements: The FCC requires all broadcasters to assess

the RF exposure levels at their facilities; and CDRH issued a voluntary guideline for stray radiation from RF heaters and sealers. These requirements are generally based on the ANSI C95.1-1982 Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields (300 kHz to 100 GHz). Holaday Industries has developed the HI-5000-SX system utilizing the HI-3002 Broadband Field Strength meter and the HI-3320 datalogger to display the current six minute average while taking readings. This system allows one to conveniently monitor both the instantaneous exposure level and the time-averaged level. In addition, the datalogger stores test data for subsequent printout or for display on the LCD readout. The price of the HI-5000-SX system is $4,990. An optional 80-column thermal printer is available for $295. The system may also be rented for a fee of $650 per month which includes the printer. **Holaday Industries, Inc., Eden Prairie, Minn. INFO/CARD #173.**

Evaluation Kit Demonstrates K Connector™

With the Wiltron K Connector evaluation kit, circuit designers can see for themselves how to use the DC to 46 GHz coaxial K Connector. The kit contains all the parts and specialized tools necessary: a 10-inch straight 0.118 inch semi-rigid cable assembly, step drill and tap set, microstrip test fixture, two each of the female flange and the female sparkplug

launcher assemblies, five glass beads, five each of the stripline and the microstrip stress relief contacts, and one each of the K soldering fixtures for flange and for sparkplug launcher glass beads. Price is $295 for the model 01-101A. **Wiltron Company, Morgan, Hill, Calif. Please circle INFO/CARD #172.**

FSK Radio Receiver Combines Performance, Low Cost

The SM450 is a low power radio receiver for direct FSK data transmission systems, using a "zero IF" system in which VHF frequencies are converted directly to the audio frequency range. The direct conversion approach, has performance advantages including no image response and very high IF rejection. Low power is achieved with the low frequency IF. Supply voltage range is 1.8 to 6 volts. Power consumption is 3 mA at 5 volts. Input sensitivity is 0.5 microvolts. Output data rate is 4000 b/s maximum for 4.5 kHz FSK frequency deviation. The unit is a PCB 2" × 3", trimmable to 2" × 1.4". Price is $35.00 U.S. in 1,000 unit quantities. **Siltronics, Ltd., Kanuta, Ontario, Canada. INFO/CARD #171.**

Image Reject Mixer/ Single Sideband Modulator

Electrowave Products, Inc. has introduced an Image Reject Mixer/Single Sideband Modulator for the 225-400 MHz range, with IF frequencies of 50-100 MHz. Sideband/image rejection is 25 dBc minimum, with port-to-port isolation of 25 dB minimum. Conversion loss is 7.5 dB maximum. The mixer/modulator is packaged in a 2 × 2 × 0.5 inch case with SMA or F connectors, or a 1 × 1 × 0.15 inch flatpack. Octave bandwidth versions are available from 10 to 500 MHz. **Electrowave Products, Inc., Jersey City, N.J. Please circle INFO/CARD #170.**

GaAs MMIC Frequency Converters for 0.8-8.0 GHz

Pacific Monolithics, Inc., has announced three new additions to its MMIC converter series. These subsystem-level ICs are 10 to 20 times smaller than subsystems based on discrete technology, with improved phase and gain matching, higher reliability and lower cost. The new products, which convert an RF signal to an IF signal at a 20- to 40-dB conversion gain, include 0.8-3.0 GHz, 3.0-6.0 GHz and 5.0 to 8.0 GHz versions. The single-chip PM-CV0301-A, 0.8-3.0 converter, includes an RF amplifier, a mixer, an LO buffer and IF amplifier. The RF port operates from 1.0 to 3.0 GHz; both high-side and low-side operation are possible. The IF frequency range is 100 to 800 MHz and the noise figure is 4.5 dB. Other models in the series are the PM-CO0601A for 3-6 GHz, and the

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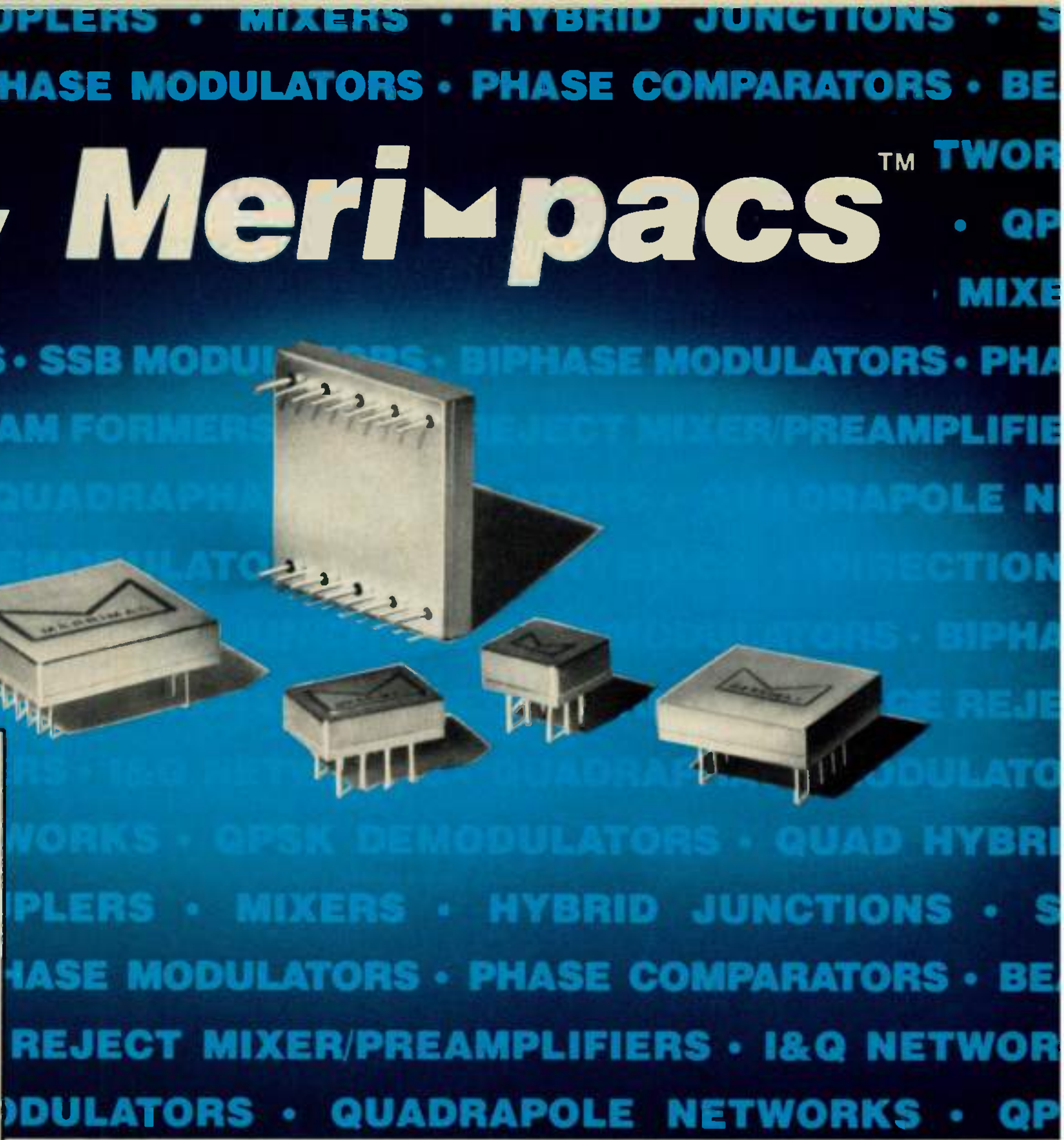
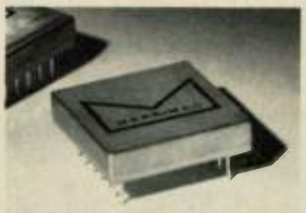


1″ sq. Mixer with Pre-Amp



8/10″ sq. Phase Comparator

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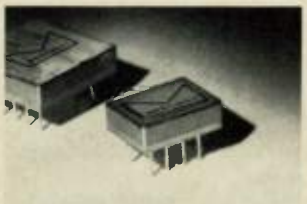

1/2″ sq. Phase Shifter

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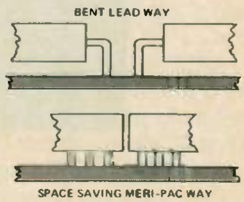

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Merrimac's extensive Hi-Rel product experience in RF and IF signal processing is available in every configuration; flat pack, low profile TO cans, relay packages, discrete connectorized SMA or OSP low profile packages, and NOW in new Meri-pac.

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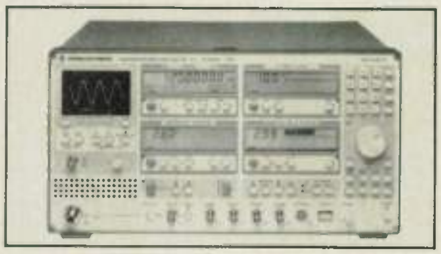
INFO/CARD 40


THE DAWN OF A NEW GENERATION
MSC POWER GaAs FETS
MSC announces a "New Generation" of upright, passivated GaAs Power FETs. Key features include higher linearity, higher operating voltages and improved efficiency.
Packaged for commercial as well as high rel applications, these new source-via FETs may be purchased as chips, as well as in discrete or internally matched packages.
A new dimension for MSC, our GaAs product line will soon be expanded to include MMICs, as well as Digital and Linear IC's.
MICROWAVE SEMICONDUCTOR CORP.
A Siemens Company
100 School House Road, Somerset, New Jersey 08873-1276
MSC
For more information on the "New Generation" MSC GaAs FETs contact your local MSC representative or call us direct at (201) 563-6447.
INFO/CARD 34

PM-CV0801-A for 5-8 GHz. The converters are priced at $500 each in small quantities and at $50 each in production quantities (10,000 pieces per year). **Pacific Monolithics, Inc., Sunnyvale, Calif. Please circle INFO/CARD #169.**

Radiocommunication Tester Analyzes AM, FM, PM from 0.1-1000 MHz

Rohde & Schwarz-Polarad's new Radiocommunication Tester CMT is designed for testing AM, FM and PM equipment to the most stringent national and international requirements. The CMT covers carrier frequencies of 0.1 to 1000 MHz and handles continuous powers of up to 50 W. Features such as a built-in oscilloscope, adjacent-channel power measurement,



full-duplex testing, an RF-millivoltmeter probe, DTMF decoding and a unique second audio synthesizer (for CTCSS, DTMF, etc.) may be included as required. A sensitive second RF input permits off-air measurements. In addition to the non-volatile storage of front-panel settings the CMT features a novel learn mode, in which up to 100 complete test routines may be stored in the internal semiconductor memory. **Rohde & Schwarz-Polarad, Inc., Lake Success, N.Y. Please circle INFO/CARD #168.**

Acousto-Optic Modulator Includes RF Driver

Andersen's OEM-40-V-7 light modulator driver combines the features of an acousto-optic modulator cell and its associated RF drive electronics into a single package. The overall unit measures 2.7" × 2" × 1", and is designed for compact laser systems where space is limited. It offers a modulation bandwidth of 7 MHz and can be used to modulate lasers of wavelength 440 nm to 700 nm with light power densities of up to 5000 watts/cm^2 CW. Units optimized for specific wavelengths or requiring wider modulation bandwidths are available upon request. **Andersen Laboratories, Inc., Bloomfield, Conn. INFO/CARD #167.**

Low Noise Signal Generator Features Interactive Control

A new AM/FM low noise signal generator has been introduced by Solartron Instruments. The Model 4002 is intended for high quality RF measurements in development, design and production of radio and stereo receivers as well as VOR systems. It is particularly well suited for intermodulation and blocking measurements in AM/FM receivers. Frequency deviations up to 800 kHz can be set in frequency ranges with wideband modulated radiotelephony services. In addition, the high frequency modulation quality of the 4002

enables it to be used for stereo receiver measurements. The low phase response of its amplitude modulation is ideal for VOR system measurements. Operating from 100 kHz to 1000/2160 MHz, the 4002 processes the frequency using the PLL technique. The range up to 1000 MHz is generated directly, while the frequency of 2160 MHz is achieved by installing a doubler stage. The frequency range of 0.1 to 1000 MHz has a resolution of 10 Hz with a switching time of 20 ms. The Model 4002 exhibits phase noise of 136 dBc per Hz at 25 kHz offset. **Solartron Instruments, Elmsford, N.Y. INFO/CARD#166.**

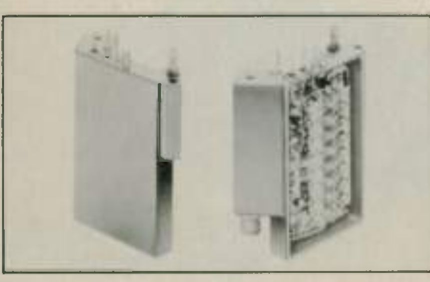
Surface Mount Chip Resistors Feature High Power

International Manufacturing Services Inc. has introduced a new line of chip resistors rated from 1 watt to 10 watts in sizes from .240" × .120" to .620" × .270", available in any value between 10 ohms and 25 megohms with tolerances of 1%, 2%, 5%, 10% and 20% (consult factory for values under 10 ohms). Standard terminations include solder coated palla-

dium silver, palladium silver, or gold. Metalized back plane is also available as a standard option for mounting or better heat dissipation. **International Manufacturing Services Inc., Portsmouth, R.I. INFO/CARD #165.**

Log Amps Designed for Amplitude Monopulse System

RHG Electronics Laboratory has announced the repackaging of its ultraminiature log amps into a custom hermetically-sealed housing designed to fit inside the circumference of a three-inch missile. The log amps form a critical part of the mis-



sile's 3-channel monopulse radar homing system. The log amps have a wide bandwidth centered at 160 MHz, high sensitivity, and a wide dynamic range. The three individual units track each other to within ±2 dB over the entire frequency and temperature ranges. **RHG Electronics Laboratory, Inc., Deer Park, N.Y. Please circle INFO/CARD #164.**

Scalar Analyzer Microscope Shares Sweeper

The SAM-II Scalar Analyzer Microscope is a 1-26.5 GHz scalar network

MICROWAVE MODULES & DEVICES, INC.

SOLID STATE

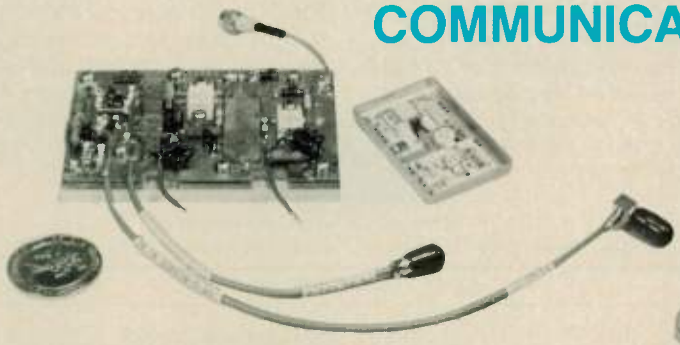
POWER

- CUSTOM MODULES
- RF FUNCTIONS

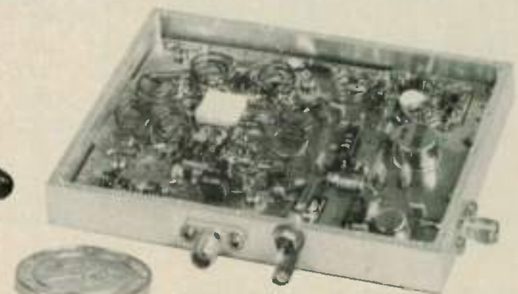
MMD's unique integration of device and circuit technology has resulted in a major breakthrough of current technological barriers leading to a new high order of performance in the areas of VHF, UHF and microwaves.

The twelve groups shown herein are typical of the wide range of products currently being designed and produced by MMD. However, neither products, categories nor frequency ranges are restricted to those listed.

COMMUNICATIONS

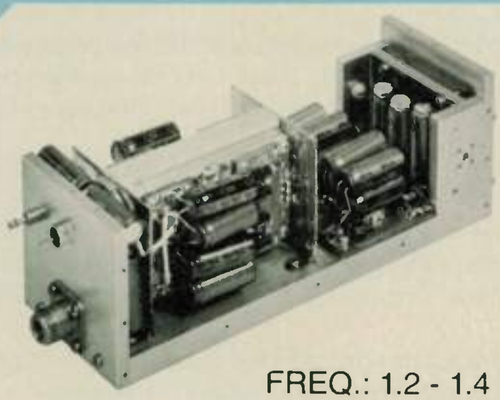


FREQ.: 420 - 450 MHz
PWR: 10W & 160W pulsed.

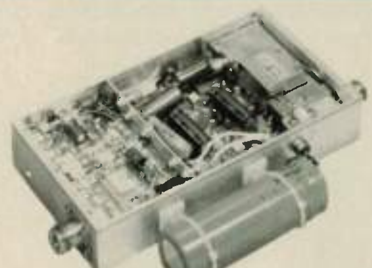


FREQ.: 250 - 350 MHz.
PWR: 13W.

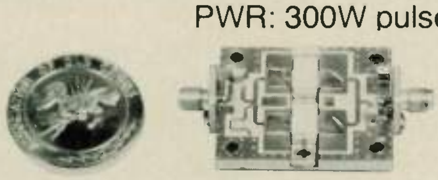
RADAR



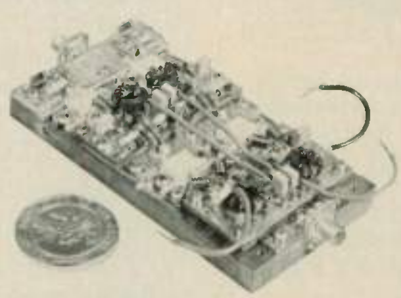
FREQ.:
420 - 450 MHz
PWR: 1200W
pulsed.



FREQ.: "L" band.
PWR: 1000W
pulsed.



FREQ.: 1.2 - 1.4 GHz
PWR: 300W pulsed.



FREQ.:
420 - 450 MHz.
PWR: 700W.

MICROWAVE MODULES & DEVICES, Inc.
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½ Watt to Multi KWs

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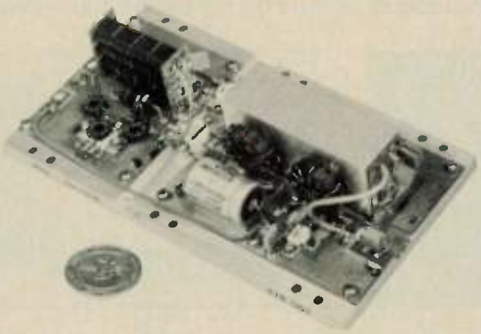
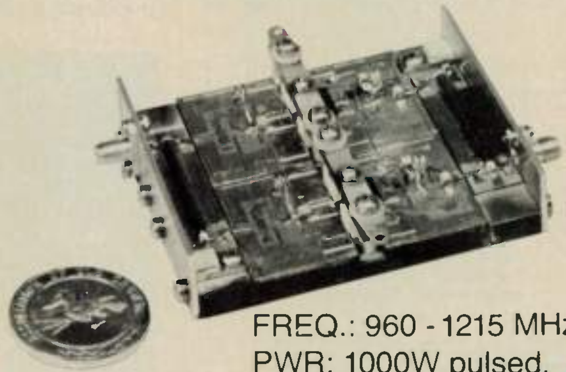
ECM • EW



FREQ.: 1 - 150 MHz.   PWR: 150W.

AVIONICS

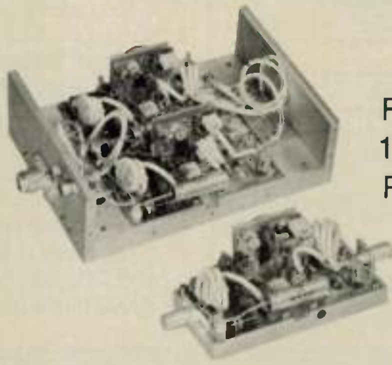


FREQ.: 960 - 1215 MHz.
PWR: 1000W pulsed.

BROADCAST

FREQ.:
88 - 108 MHz.
PWR:
150W & 600W

TELEVISION

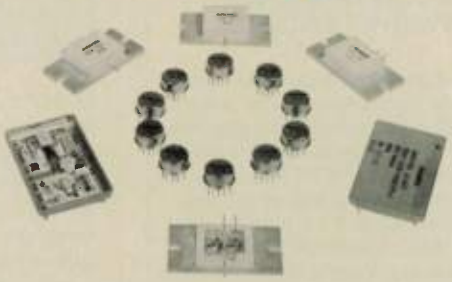


FREQ.:
170 - 230 MHz.
PWR:
100 - 200W.

ATTENUATORS, GAIN SLOPERS

FREQ.: VHF/UHF. PWR: Up to 300W.

WIDEBAND HYBRID AMPLIFIERS



FREQ.: 20-2000 MHz. PWR: Up to 10W.

MMD™
MICROWAVE MODULES & DEVICES, Inc

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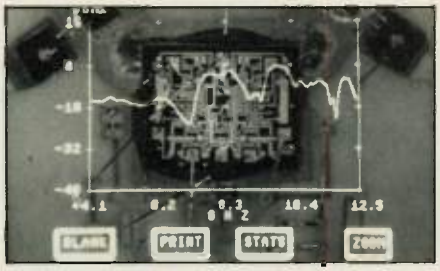
Demonstration, INFO/CARD #56.   Literature, INFO/CARD #57.

analyzer integrated into a stereo microscope. Within the microscope's field of view, the user can simultaneously see the device under test and the CRT display. Also included are through-the-optics voltmeter display, floppy disk system parameter and trace storage, a menu driven microscope-viewed display with trackball



user interface, and hardcopy output via HPIB interface. The instrument also has an expandable frequency base for use in shared sweeper setups. The optional video camera can be used to monitor alignment procedures and output for technician training programs. Price less optional graphics printer and video camera: $13,450. **Micro Video, Inc., Los Gatos, Calif. INFO/CARD #163.**

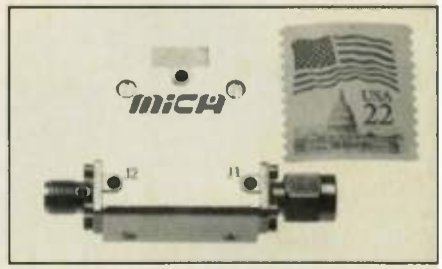
TCXO is DIP-Package Compatible

Designed for high volume users, Kyocera models KTXO and KTVXO temperature-compensated crystal oscillators are compatible with 14-pin DIP IC packages and TTL and CMOS circuits. The model KTXO has a frequency range of 4 MHz to

50 MHz and is used to generate signals for applications such as facsimile machines, mobile telephones and test equipment. The voltage-trimmable model KTVXO crystal oscillator has a frequency range of 10 MHz to 20 MHz. A fine frequency adjustment can be obtained with 1 to 5 volts on Pin 1. The KTVXO's modulation sensitivity is a minimum of 10 PPM per volt. This oscillator is designed for alarms, synthesizers and LAN modules. The prices start at $15 each in quantities of 1,000 depending on stability specs. **Kyocera International, Inc., San Diego, Calif. INFO/CARD #161.**

L-Band Isolator for 1150 MHz to 1700 MHz

Mica Microwave introduces the Model T-201S01 L-Band Isolator, designed to cover any 20% band from 1150 MHz to 1700 MHz with 20 dB isolation and 0.5 dB insertion loss, tunable to 25 dB isolation and 0.3 dB insertion loss over any 10%

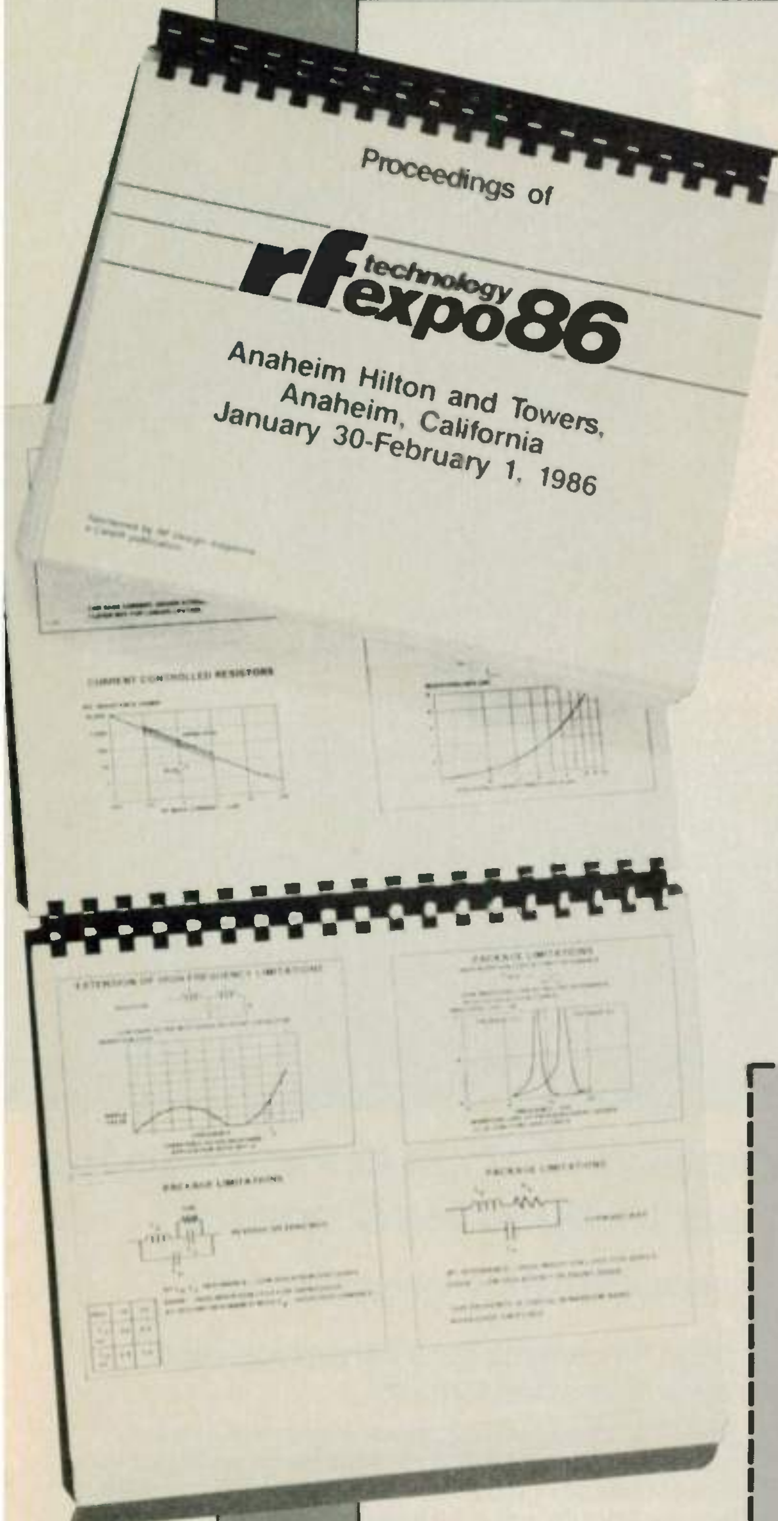


portion of this band. The T-201S01 complies with MIL-STD-E5400 and is magnetically and EMI shielded in a steel case and operates over −40°C to +80°C. Circulators are also available as drop-in units with tabs or pins. **Mica Microwave, Santa Clara, Calif. INFO/CARD #160.**

TACSATCOM Antenna Features Rapid Deployment

The Advanced Lightweight Tactical Antenna (ALTA) is a compact 8-foot diameter remote controlled antenna for severe environment DSCS satellite communications. The nine piece carbon composite reflector and a low profile cross-elevation over elevation axes positioner weigh less than 280 pounds. A two-person crew can

assemble the antenna, without tools, in under ten minutes. The ALTA is directly compatible with the USASATCOMA C-10273/TSC Dual Capability Servo Control Unit and has RF performance characteristics identical to that of the AS-3036 TACSATCOM antenna. The subsystem packs into two transit cases designed to fit in the narrow aisleway of an S-250 communications shelter. Total shipping weight is 330 pounds compared to the 1700 pounds for the AS-3036. **Datron Systems, Inc., Simi Valley, Calif. INFO/CARD #159.**



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RFD 5-86

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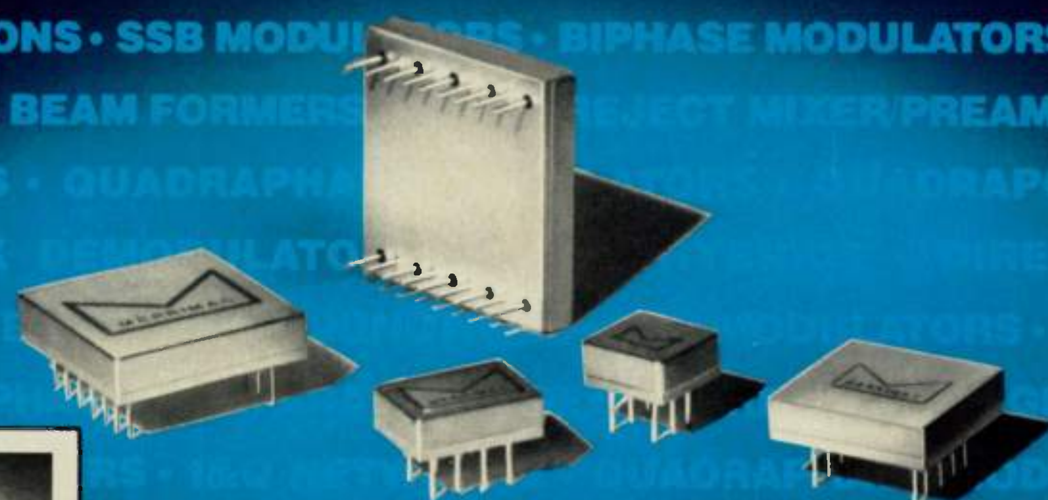
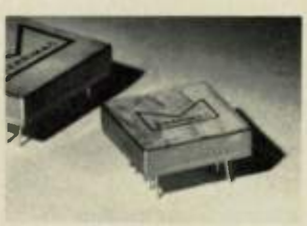
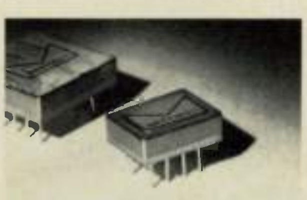


1" sq. Mixer with Pre-Amp

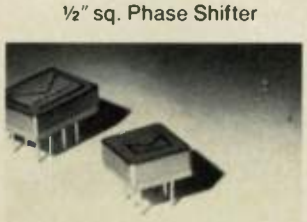
8/10" sq. Phase Comparator



⅝" sq. Complex Weight Network



½" sq. Phase Shifter



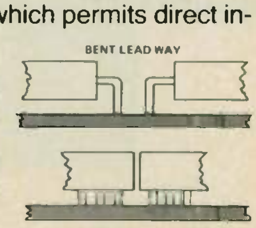
⅜" sq. Broadband Mixers

High Performance IF Signal Processing Networks in up to 50% less space

- **Save on real estate and also obtain low profile 0.20" height package**
- **Compatible package for computerized parts placement**
- **Increase yields by avoiding lead forming**

Merrimac's Meri-pac provides you with a new way to save space in dense PCB requirements for all your IF signal processing needs *up to 3.5 GHz*. **When you have flat packs on your mind — consider Meri-pacs instead** — you'll eliminate wasted space and lead breakage problems. Plus you have the advantage of a package which permits direct insertion into PCB by computer control parts placement.

The *gold-plated* **Meri-pacs** give you not only real estate savings, but also environmental integrity—package is hermetically sealed, seam welded ... no solder, therefore no solder balls.



Merrimac's extensive Hi-Rel product experience in RF and IF signal processing is available in every configuration; flat pack, low profile TO cans, relay packages, discrete connectorized SMA or OSP low profile packages, and NOW in new Meri-pac.

Call us on your next project. We want to help.

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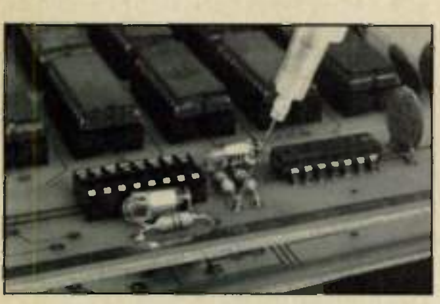
INFO/CARD 40

Solderless Conductive Products for Circuit Assembly, Repair

A series of products that can replace solder in circuit assembly operations is being offered by Emerson & Cuming, Inc. These "heatless solder" materials promote simplified processing through savings on time, labor and equipment costs. They include a variety of products from E&C and Amicon, the latter made possible through the recent formation of Grace's Polymer & Electronic Materials



(PEM) unit. The Eccobond® line features products that can create conductive paths, relieve ESD and establish ground planes, particularly in heat-sensitive applications. The Amicon product line features a broad range of conductive assembly and polymer thick film materials, including a new generation of conductive SMD adhesives. **Emerson & Cuming, Inc., Woburn, Mass. INFO/CARD #158.**

LAN Bandpass Filter Accommodates Ether Net and Sytek

The 4803 bandpass filter allows simultaneous reception of DEC's Ether Net (54-72 MHz) and Sytek's Group A broadband modem by limiting the Sytek band (73-76 MHz) on cable connected computer local area networks. The bandpass filter prevents the DEC Ether Net signals from being retransmitted through the Sytek translator and causing interference.

Placed on the input to the Sytek modem, the 4803 passes 11 of its 300 kHz channels occupying the 73-76 MHz band and rejects the 54-72 MHz band used by the DEC Ether Net system to a minimum of 40 dB. Inband variation of insertion loss is 1 dB maximum. Return loss is 18 dB minimum. Impedance is 75 ohms with type F connectors and the filter comes mounted on a standard 19" rack panel. Price is $1,500. **Microwave Filter Company, Inc., East Syracuse, N.Y. Please circle INFO/CARD #157.**

Family of PC-Mount BNCs is Introduced

Automatic Connector, Inc. has developed a complete family of BNC type PCB mount receptacles. The connectors may, within the same installation, also be mounted through a bulkhead for external interconnections as the design incorporates a standard rear mounting "D" hole

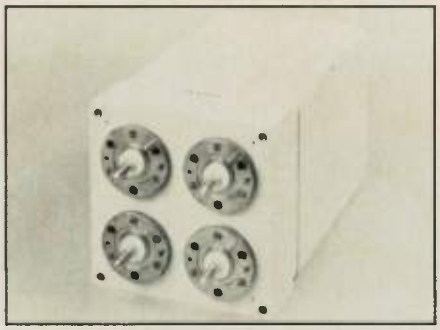
feature. This new line of BNC-PCB receptacles is designed to be isolated from ground utilizing a black (white optional) valox body. Production quantities of the BNC-PCB isolated from ground receptacles are available at an average price of $1.67 each. **Automatic Connector, Inc., Commack, N.Y. INFO/CARD #156.**

Miniature Soldering Iron Designed for Precision Assembly

An industrial grade miniature soldering iron for precision electronic assembly and manufacturing operations is available from M.M. Newman Corporation. The Antex Model G/3U features slide-on tips that are directly grounded. Heating up to 725°F in only 45 seconds, over 40 different tip styles are available including a .012" tapered needle point for precision electronics assembly. The Model G/3U Miniature Soldering Iron complete with a #8 tapered needle point tip sells for $17.95 (retail). **M.M. Newman Corporation, Marblehead, Mass. INFO/CARD #155.**

Coaxial Switch Handles 2 kW up to 4 GHz

RLC Electronics, Inc. introduces the Model SR-T-7/8-D-I-L remote latching transfer switch, a new high-speed coaxial switch for use with high power 7/8 EIA equipment. This is the first switch in the industry accommodating 7/8 EIA connectors which will transfer in 100 milliseconds. These switches feature low inser-



tion loss and VSWR over the DC-4 GHz range with high isolation. The latching feature eliminates current drain after switching has been accomplished. At 4 GHz, the insertion loss is .14 dB maximum, and isolation is 60 dB minimum. Prices start at $1,875.00 in unit quantities, plus options including indicator circuitry, TTL control, a choice of power voltage and connector. **RLC Electronics, Inc., Mt. Kisco, N.Y. INFO/CARD #162.**

Microwave Miniature BPFs Come in T05, T08 & Rectangular Packages

RLC Electronics announces the expansion of its line of Micro Miniature Band Pass Filters. The MBP Series covers the range of 10 MHz to 12.4 GHz. High Q devices are used in a microstrip mode with standard units utilizing low ripple Chebychev design. Other responses are avail-

able when desired, as well as rectangular, T05 and T08 mechanical configurations, with printed circuit board mounting pins, tabs or SMA connectors. Prices start at $270.00 in unit quantities. **RLC Electronics, Inc., Mt. Kisco, NY. Please circle INFO/CARD #186.**

GaAs MSI ICs Are Based on Standard Cell Library

TriQuint Semiconductor, Inc. announces a new line of GHz GaAs MSI components based on their Q-LOGIC™ depletion-mode standard cell library. The series will initially include a line of 1 to 3 GHz counters, but will soon be extended to include other components such as multiplexers and demultiplexers. TriQuint is also planning to introduce a workstation-based Q-LOGIC Standard Cell design package. The first component available in the Q-LOGIC series is the TQ1111 4-bit ripple counter. Available in 2.0, 2.5 and 3 GHz ranges. Prices are $89, $119 and $199 (100's) for the three speeds. **TriQuint Semiconductor, Inc., Beaverton, Ore. INFO/CARD #185.**

ESD Test System Simulates Static Discharge Events

IMCS Corporation introduces the model 3000 automated ESD Sensitivity Test System, designed to simulate static discharge events in IC devices and provide visual and/or printed results indicating ESD voltage thresholds. The Model 3000 can test devices with up to 192 pins and up to 15,000 volts. The basic system is capable of testing up to 64 pins at up to 10,000 volts and consists of a microprocessor-based controller and a separately enclosed ESD test console. The Model 3000 meets Mil-Std-883, Method 3015. **ICMS Corporation, Mountain View, Calif. Please circle INFO/CARD #184.**

TVRO Spectrum Analyzer

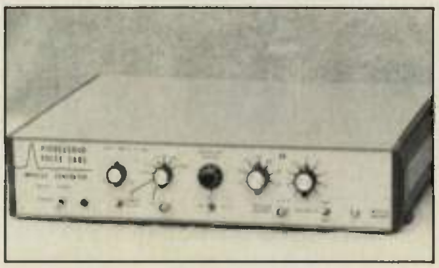
AVCOM's PSA-35 Portable Spectrum Analyzer is designed for the TVRO industry, and offers frequency coverages of 10 and 1500 MHz and 3.7 to 4.2 GHz for checking signal strength, inband attenuations, terrestrial interference, filter alignment, faulty connectors, LNAs, feedhorn isolation. and cable loss at all commonly used frequencies in the TVRO industry, including 12 GHz downconverters. The PSA-35 features a built-in DC block with +18 VDC for powering LNAs and BDCs, calibrated signal amplitude display and rechargeable internal battery with recharger. The price is $1965.00. **AVCOM of Virginia, Inc., Richmond, Va. Please circle INFO/CARD #187.**

GaAs Gate Array

Honeywell has introduced its first gallium-arsenide (GaAs) gate array. The 2,000-gate HGG-2020 supports clock speeds up to 1 GHz, with typical internal gate delays of 230 picoseconds. Gate feature size is 1.0 micron. The total equivalent gate count of the HGG-2020 is 1,950 gates. Additionally, 56 I/O cells can be configured as input or output for either 5 volt TTL/CMOS or ECL options. The I/O cells can be programmed selectively to interface with these technologies. **Honeywell, Gallium Arsenide IC Product Center, Richardson, Tex., please circle INFO/CARD #183.**

Impulse Generator

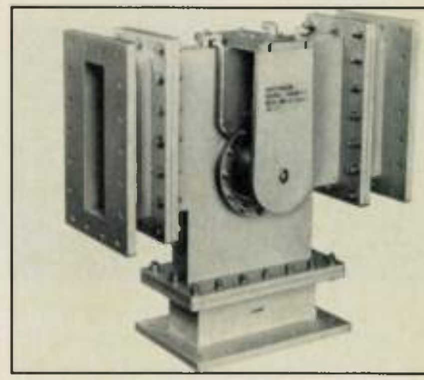
Picosecond Pulse Labs Inc. pulse generators have been redesigned for faster rise times and greater amplitude. The Model 3500C now produces impulses of >10 V amplitude and <60 ps FWHM (50 percent) duration. The spectrum amplitude is 61 dBuV/MHz and



useable to at least 10 GHz. The Model 4500B produces a fast rise, 20 ns (or 200 ns optional) step function. The Model 4600A features a switch selectable step or impulse waveform. The step from either of these generators is available in several options with amplitudes from 10 V to 35 V and 10-90 percent risetimes from 50 ps to 85 ps. **Picosecond Pulse Labs, Inc., Boulder, Colo., INFO/CARD #182.**

Ferrite Circulator

Raytheon has introduced a new ferrite circulator specifically designed to protect microwave tubes in the power output stages of microwave industrial heating and drying equipment. Model CUH214 is



a high power UHF circulator, featuring a very low insertion loss of 0.15 dB max. at 915 MHz. Power output is 50 kW continuous wave into a 10:1 mismatch, while isolation is 25 dB min. at 915 MHz. **Raytheon Company, Special Microwave Devices Operation, Northborough, Mass., INFO/CARD #181.**

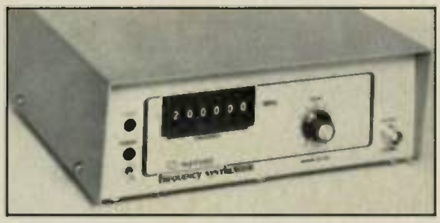
Frequency Halvers

Telemus Electronics Systems, Inc. has introduced a line of low cost, half octave frequency halvers between 1 to 4.5 GHz. Based on a subharmonic generation technique produced by two varactors in a non-linear circuit, these devices can be

used to divide microwave signals in the feedback loops of synthesizers. The halvers exhibit low phase noise, are simple to use and require a bias of 20 mA at 5 volts. The output can be used to drive ECL dividers for further RF division. These halvers are also offered in an integrated cascaded version with division ratios of divide by 4, 8 and 16. **Telemus Electronic Systems, Inc., Nepean, Ontario, Canada, INFO/CARD #180.**

Frequency Synthesizer

The SI-105 frequency synthesizer has been announced by Syntest Corporation. The SI-105 is an advanced 4¾ digit synthesizer, providing 1 MHz to 32 MHz TTL and ECL signals with 500 Hz resolution into a 50 ohm load with low phase noise



and spurious signals. Stability is ±10 PPM over a temperature range of 0° to 50°C; spurious outputs are –60 dBC; and settling time is 50 msec to within 10 percent of step. The price is $673.00 in unit quantities. **Syntest Corporation, Marlboro, Mass., INFO/CARD #179.**

Prototype PC Machine

Girard Electronics, Inc., has developed a non-chemical system for generating flexible prototype circuits which the user can laminate into double-sided PCBs, multilayer circuits and boards for standard or surface-mount components. PROTOFLEX-III uses optical-mechanical technology to produce prototype circuits. An optical system scans circuit artwork mounted on the right side of a drum within the machine, then PROTOFLEX-III machines circuits from 1 oz. copper sheeting on a polymide base affixed to the left side of the drum. **Girard Electronics, Afton, Minn., INFO/CARD #178.**

RF Shielded Cabinets

A line of new all-wielded RF shielded cabinets for EMI/RFI requirements have been introduced by LectroMagnetics, Inc. (LMI). Performance exceeds the 100 dB level typically required for Tempest; other applications include FCC, VDE and MIL-STD-461. Minimum 14-gauge shielding steel ensures maximum attenuation levels and structural integrity. Accessories include fiber optic feed-throughs, waveguides, RF filters, RF shielded honeycomb air vents for ventilation, coaxial connector panels, equipment racks and cooling fans. **LectroMagnetics, Inc., Los Angeles, Calif., INFO/CARD #177.**

TriQuint GaAs Cell Array Design Software

TriQuint Semiconductor, Inc. and Tektronix CAE Systems Division have announced a software module that provides a complete electrical design system for TriQuint's Q-CHIP™ GaAs GHz cell array product offered on the Division's engineering WorkSystem™ family. System designers can use the Q-CHIP/CAE Systems library for schematic capture, logic simulation, and test vector generation in Q-CHIP circuit personalization development. The Q-CHIP is a 140 equivalent gate, 24 input/output, configurable cell array device suited for MSI applications with clock rates in the 100 to 2000 MHz range. The design software costs $4,000 and is available within 30 days. **TriQuint Semiconductor, Inc., Beaverton, Ore. INFO/CARD #140.**

Phase-Noise Measurement System

EASY-L, a software-measurement program for characterizing carrier phase noise from 10 MHz to 18 GHz, is available from Hewlett-Packard Company. The measurements are based on the HP 11729C carrier-noise test set (10 MHz to 18 GHz). Two measurement techniques are supported by the software: the phase-detector method and the frequency-discriminator method. Product note 11729C-3, "A User's Guide for Automatic Phase Noise Measurements," accompanies the disks and describes how to assemble the system and operate the software. EASY-L, in either 3½-inch or 5¼-inch format, is $95. **Hewlett-Packard Company, Palo Alto, Calif. Please circle INFO/CARD #139.**

Terrain Dependent Radio System Design

John Murray Associates has released Radio System Planning Techniques (RSPT) Version 2.0, a design package including digitized topographic terrain files and advanced propagation loss techniques for broadcast, land-mobile (including cellular), paging, tactical, and point-to-point applications. RSPT provides the user with radio signal level estimates, path profiles and terrain obstruction identification, path profile file development, FCC average terrain calculations, and radio data base. RSPT runs on IBM-compatible machines with 512K memory and a color graphics adapter. A demonstration copy is available for $30. **John Murray Associates, Boulder, Colo. Please circle INFO/CARD #137.**

Public Domain Software on 3½" Floppy Disks

Multipath, Inc., a distributor of public domain software for personal computers, has available over a thousand programs for the MS-DOS, PC-DOS, CP/M-80 and CP/M-86 operating systems on 3½" floppy disks. The software is recorded in a disk format that matches the computer specified by the customer, including most lap top, portable and desk top computers which use a 3½" disk drive. All programs are also available for computers using 5¼" and 8" disk drives, with over 150 DOS and CP/M recording formats to choose from. **Multipath, Inc., Montville, N.J. INFO/CARD #138.**

rf literature

Design and Drafting Kit

Bishop Graphics, Inc. has announced a complete "learn-by-doing" kit for beginners and professionals seeking to develop or advance their skills in analog printed circuit board design and drafting. The kit consists of a 430-page text and a companion kit of design and drafting aids that teach the intricacies of analog printed circuit design and drafting by doing actual PCB design and artworks. The *Analog Printed Circuit Design & Drafting* combination text and drafting aids package is available from dealers or from Bishop Graphics for $149.95. Both the book and design aids package can be ordered separately. **Bishop Graphics, Inc., Westlake Village, Calif. INFO/CARD #154.**

Test Instrumentation Catalog

Marconi Instruments has issued a master catalog covering its complete line of test instrumentation. The 350-page catalog includes full descriptions, specifications, illustrations, operational features, and ordering information on: signal generators, radio test systems, modulation meters, power meters, signal sources and sweep generators, counter timers, analyzers, digital communication test equipment, FDM test equipment and television test equipment. Application notes and technical publications available from Marconi are also described. **Marconi Instruments, Allendale, N.J. INFO/CARD #153.**

Arbitrary-Waveform Synthesizer Note

A new application note from Hewlett-Packard Company entitled "Receiver Testing with the HP 8770S Arbitrary-Waveform Synthesizer System" (AN 314-1) describes the use of real-life waveforms in RF, IF and baseband-processing testing phases. The note introduces some new receiver-testing concepts, now practical with generators capable of providing signal coverage from DC to 50 MHz. The new HP 8770S arbitrary-waveform synthesizer provides 125 megasamples per second for an equivalent bandwidth of DC to 50 MHz with an amplitude resolution of 12 bits. **Hewlett-Packard Company, Palo Alto, Calif. Please circle INFO/CARD #152.**

PDB Bonding Film

A note describing MPC Bonding Film is available from Microwave Printed Circuitry, Inc. The bonding film is a thermally-stabilized, irradiated polyolefin copolymer designed for bonding single- or multi-deck microwave stripline circuit boards. Use of the film seals the circuit interface, eliminating inner air gaps, and distributes mechanical stress more evenly. **Microwave Printed Circuitry, Lowell, Mass. INFO/CARD #151.**

Power Amplifier Catalog

A catalog describing the complete line of power amplifiers is available from ENI. The catalog describes amplifiers up to 1000 watts output for applications in laboratory test, communications, ultrasonics, NMR, EMC testing, linear accelerators and cancer hyperthermia. Also described are ENI's power multicouplers, wideband transformers and special purpose amplifier modules. **Electronic Navigation Industries, Inc., Rochester, N.Y. Please circle INFO/CARD #150.**

High Voltage Capacitor Catalog

A new catalog provides information on KD Components' high voltage ceramic capacitors. All KD ceramic capacitors are manufactured under the quality control requirements of MIL-I-45208. The capacitors are made with NPO or X7R material formulated for high voltage applications. Performance characteristics for the two dielectrics are included. The catalog contains specifications and ordering information for multilayer ceramic capacitors, high voltage ceramic chips, high voltage ceramic discs and multiplier stacks, and new low corona capacitors. **KD Components, Santa Ana, Calif. INFO/CARD #149.**

Continuing Education Brochure

Besser Associates, Inc. has published a brochure detailing the company's capabilities in continuing education for the RF/Microwave international engineering community. Details on the availability of various on-site seminars, workshops and videotapes covering the latest RF and microwave advancements for designers, managers and technicians are outlined. **Besser Associates, Inc., Palo Alto, Calif. INFO/CARD #148.**

Test Equipment Guide

United States Instrument Rentals has published its 1986/87 Product Guide. This 368-page hardbound catalog contains a complete listing of the 4,351 different models of electronic test and measurement equipment that USIR has available for rent. Among the types of products listed are analyzers, CAE/CAD equipment, microprocessor development systems, counters, desktop controllers, generators, meters, oscilloscopes, recorders, signal modifiers and telecommunications devices. **United States Instrument Rentals, San Mateo, Calif. INFO/CARD #147.**

Analog Multiplier Application Note

A new 6-page application note outlines a two-chip approach to building a low-cost 50 MHz voltage-controlled amplifier (VCA) and a fast, low feedthrough video switch. The two chips are the AD539JN analog multiplier and the 5539N wideband op amp. The note outlines the basic principles of analog multiplication and the advantages of two-quadrant multiplication in gain-control applications. Both circuit layouts are clearly diagrammed along with six graphs plotting response, phase and gain. **Analog Devices, Norwood, Mass. INFO/CARD #146.**

Cable and Connector Sourcebook

Marshall Electronics announces the publication of a sourcebook for video, audio and broadcast communications which features connectors, wire and cable, cable assemblies and installation accessories. The catalog features superflexible cables, connectors, video camera and audio interconnect cables, patch bay connectors and panels, video switching consoles, RF amplifiers and coaxial relays. **Marshall Electronics, Inc., Culver City, Calif. INFO/CARD #145.**

GaAs FET Amplifier Brochure

A new catalog describing Celeritek's line of GaAs FET microwave amplifiers is now available, describing the company's line of more than 100 different 0.5 GHz to 18 GHz microwave amplifiers. The catalog describes the firm's facilities and operating philosophy, and their ability to provide custom products and second sourcing services. **Celeritek, San Jose, Calif. Please circle INFO/CARD #144.**

Test and Measurement Catalog

Wavetek Corporation announces its 1986 test and measurement instrumentation catalog, containing descriptions, specifications, prices and ordering information for Wavetek's generator and measurement equipment along with related special equipment and components. **Wavetek Corporation, San Diego, Calif. INFO/CARD #143.**

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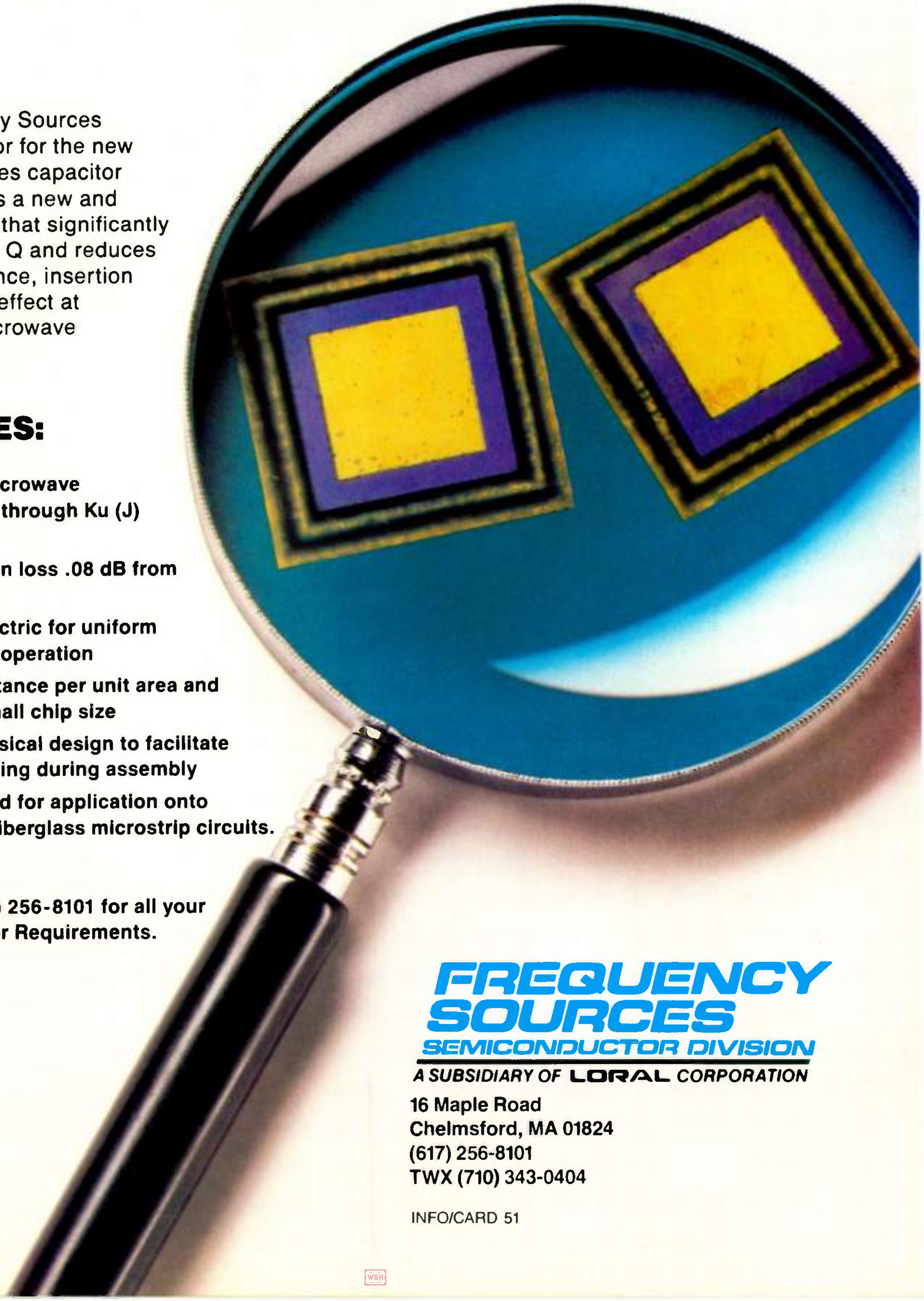
Advertiser's Index



SAW Questions and Andersens.

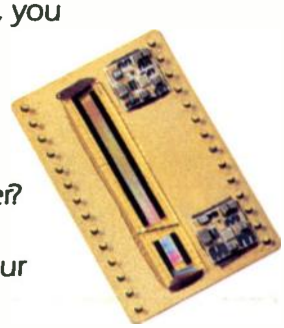
Bandpass filters:

QUESTION: I have an application that requires filters. Why should I consider SAW devices?

ANDERSEN: Want to eliminate tuning? Need very sharp passband skirts (i.e. low shape factor) with high close-in rejection? Low ripple? Phase that can be linear or non-linear, as you choose? Small size? Highly repeatable characteristics? These are the areas where SAW filters excel. If any of these factors are important, you should be looking at SAW's.

QUESTION: What about hybridizing?

ANDERSEN: This may be a very smart move. With our in-house hybrid facility, we can deliver maximum performance in a minimum space. Buying a zero-loss SAW filter module or an entire hybridized Andersen IF section may improve your system performance, reduce size, increase reliability and fully exploit the advantages of SAW technology.



QUESTION: How expensive and how long will it take to get my filter?

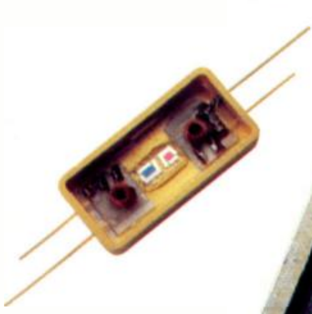
ANDERSEN: That depends on your specs. But we have hundreds of stock designs to choose from (we're the oldest SAW manufacturer), so it's very possible we already have one that meets your specs. If not, with our recent major staff increase we offer one of the largest groups of SAW designers of any U. S. company to meet your needs fast and at aggressive new pricing.

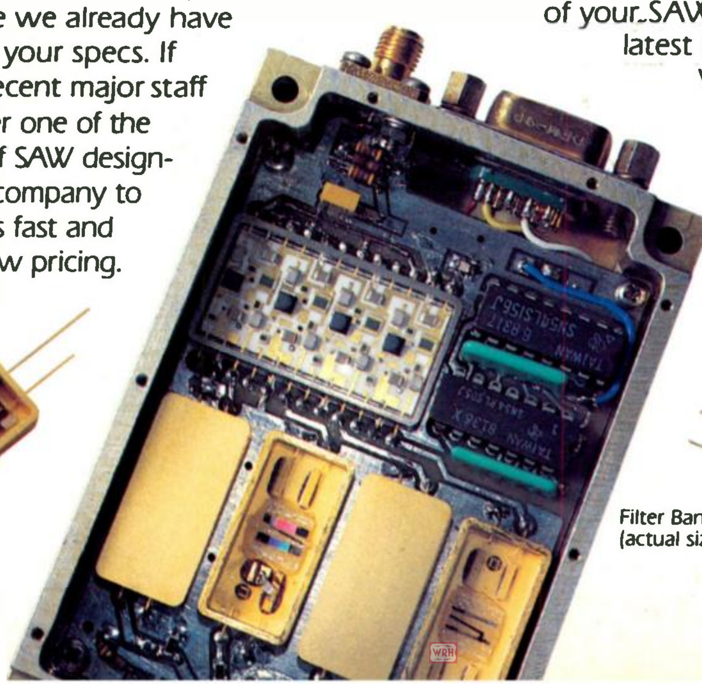
QUESTION: How do I get started?

ANDERSEN: Just give us a call. We'll do everything we can to meet your needs.

Or, if you simply want more information, send for Volume I of our comprehensive handbook on Acoustic Signal Processing. In it, you'll find the right Andersen to most of your SAW questions—and specs on the latest models.

Write to Andersen Laboratories,
1280 Blue Hills Avenue,
Bloomfield, CT 06002.
Or phone (203) 242-0761/
TWX 710 425 2390.





Filter Bank
(actual size)

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When it's a question of SAW, Andersen is the answer.

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