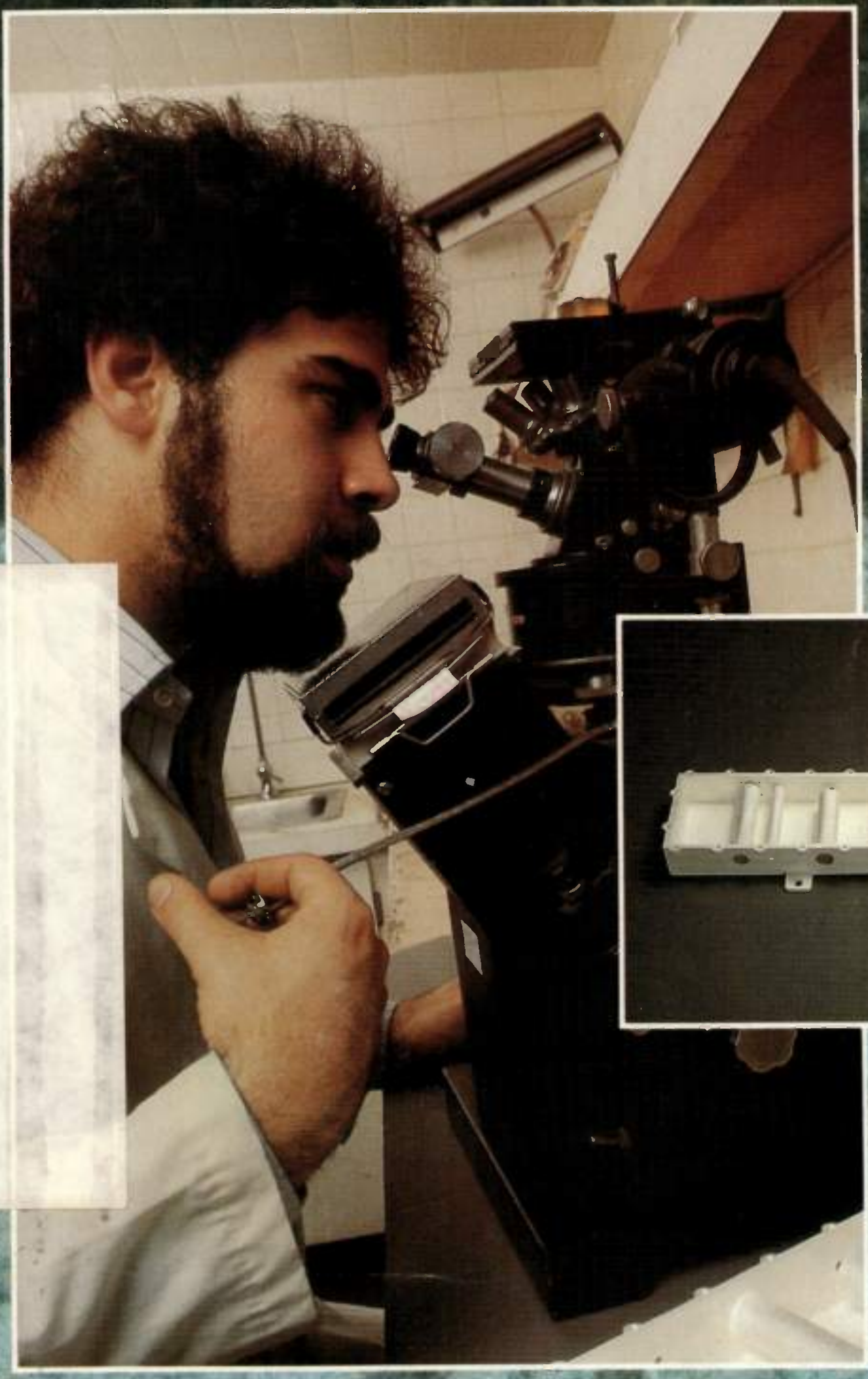
rf design

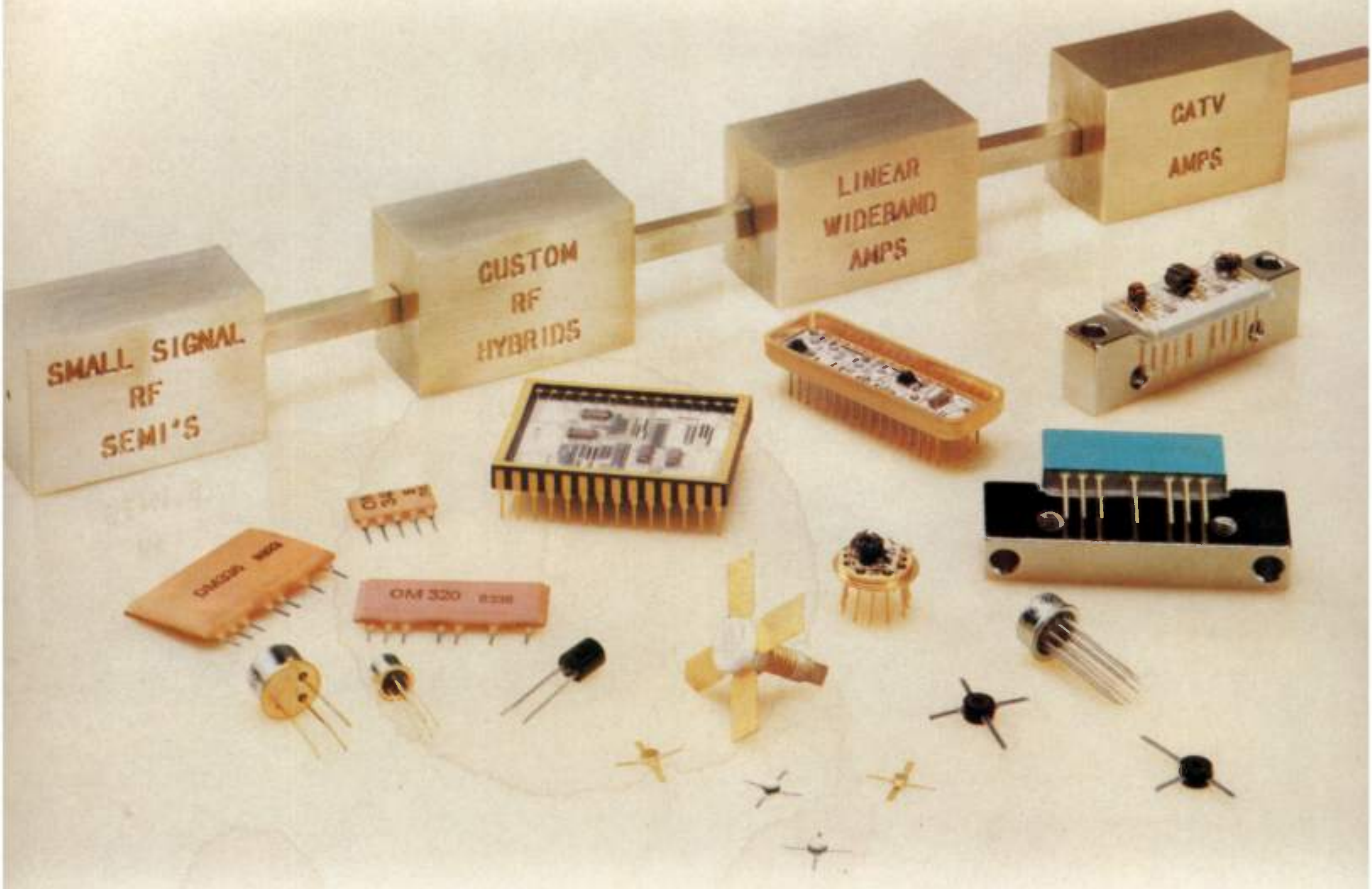
ideas for engineers

July 1985



Special Report:
The New Look in RF Circuits – Materials

In advanced RF products, one name stands out.



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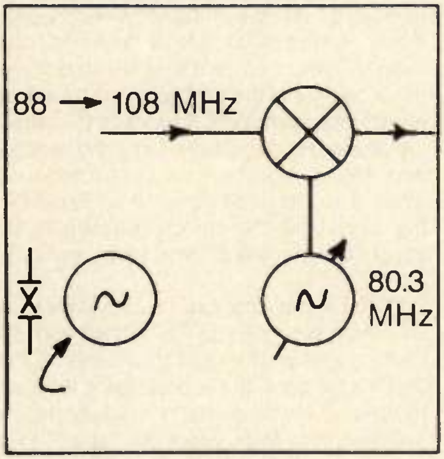
ACRIAN

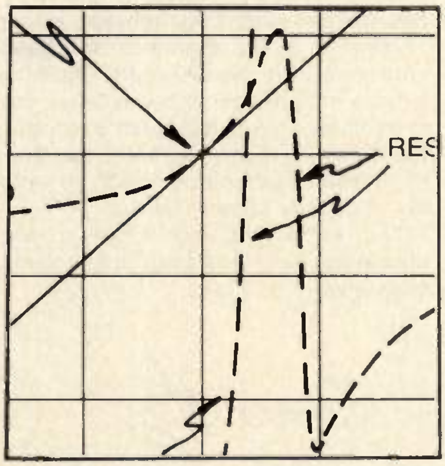
rf design

July 1985

Cover

The composite cover of this month's issue denotes the theme of the Special Report. This month we take a first look at materials used in RF circuits. The photograph shows a cellular radio interdigital filter after silver plating by Cohan-Epner Company's High-Q process. A metallurgist examines the three plating layers of electroless nickel, copper and High Q silver over the aluminum casting.





Features

Departments

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rf editorial

Helping Engineers Solve Problems

On a recent visit to a major electronics company I was asked by a marketing executive, "How is your magazine different from the others?" It was an unexpected question, but an easy one to answer.

The difference between RF Design and the other electronics trade publications is much more than the obvious — that we concern ourselves primarily with below-microwave frequency devices and designs. The important difference is the nature of our technical articles. They are not written primarily to keep readers informed about new developments. They are written by engineers to share some way the author has found to make the circuit design process easier or faster or to explain the operation of some new type of component.

My explanation to the marketing executive came down to a simple phrase, "We help engineers solve problems." We have written before about how difficult it is for RF design engineers to find the kind of information that appears every month in RF Design. Some of it simply is not available anywhere else, or it is available in such theoretical and mathematical complexity that it is of little use to the busy engineer. The technical articles in RF Design may seem mysterious to people not trained in this field, but to the engineers who read them they are direct, practical and helpful. We know this because they constantly tell us so.

RF Design has another purpose, too. We have written before about the lack of analog circuit design education in our colleges and the problems faced by electrical engineers who find themselves working in this area without sufficient knowledge. It is primarily for them that the special reports and other departments are written. In those pages we discuss more basic design principles and provide fundamental information that may be well known to the more experienced design engineers.

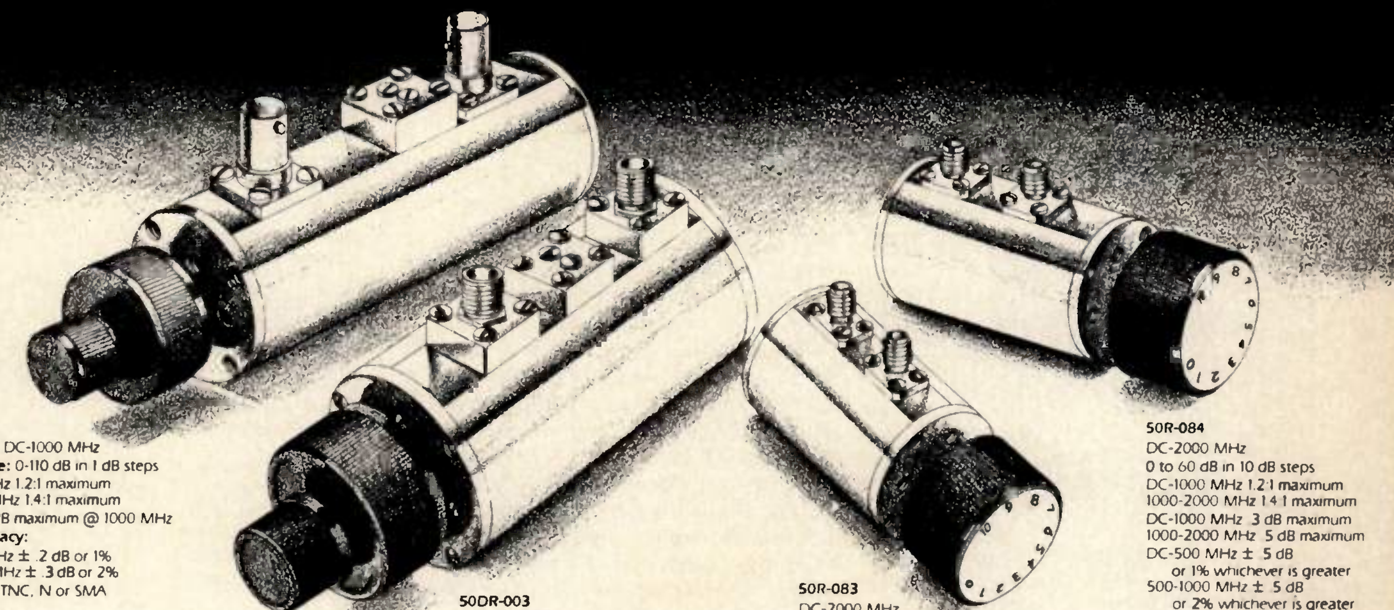
In this expanding and changing field, however, it is difficult for even the experienced engineer to keep up with new products and developments. So in the special reports we emphasize recent products and design ideas to keep our readers aware of trends while also mentioning some of the problems with currently available products. Last month, thinking of the trend toward interfacing analog and digital equipment, we turned the special report pages over to an expert in the digital field for an explanation of an important standard data bus configuration.

A statistical analysis of attendance at RF Technology Expo '85 convinced us that we are on the right track. We found that 45 percent of the engineers who attended that conference had been in engineering five years or less. The percentage dropped rapidly as experience increased, as might be expected for a conference emphasizing fundamentals. What is surprising, however, is that 17 percent of the attendees had been engineers more than 20 years. Statistics can be interpreted in different ways, but to us these figures represent a recognition by experienced engineers that they must keep learning to keep up with developments in their field.

That is what RF Design is for — to help engineers keep learning and solving problems.

James N. MacDonald

ROTARY ATTENUATORS



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BNC, TNC, N or SMA

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1000-2000 MHz 1.4:1 maximum
DC-1000 MHz .2 dB maximum
1000-2000 MHz .4 dB maximum
DC-1000 MHz ± .2 dB maximum
1000-2000 MHz ± .4 dB maximum
SMA female

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1000-2000 MHz 1.4:1 maximum
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INFO/CARD 6

The Secret Ingredient

Keith Aldrich
Publisher

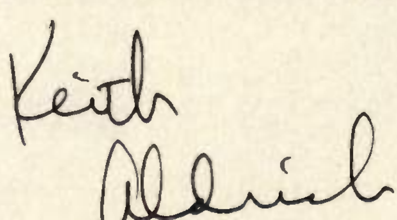
The cover story on materials in this month's issue is the first in a 3-part series on "the new look in RF circuits." We undertook to report on this sweeping topic so that you, the RF engineer, might be fully aware of all the new developments that are available to you in the quest for better performance in less space for your RF design. In the process of our investigations we uncovered a rather eye-opening central fact: the main ingredient in the quest is not a magical new material or package, but something known simply as good engineering.

Certainly it is important for you to know what is available, in the same way that a professional in any field must know the latest tools of his or her trade. In the next issue, for instance, you will see news of a monolithic gallium arsenide cell array from Harris Microwave Semiconductor that will make it possible for you to design, say, a synthesizer, replacing analog devices taking much more space. Neither this nor any other development, however, will change the need for creative engineering when you start trying to put it to work. When you have saved a lot of space, for instance, by using that monolithic chip, you are immediately faced with new challenges. What exactly are you going to do with the new space? How are you going to dissipate the extra heat that is generated? These are questions that your supplier can only vaguely help you with. The answers ultimately have to come from your ingenuity.

These points came home to us with force when we visited the folks from a company called North Hills Electronics, during the MTT-S International Symposium in St. Louis, June 4th to June 6th. This company, located in Glen Cove, New York, makes a living by fabricating RF and microwave circuits, basically; but as a matter of practical fact what they sell is good engineering. In their promotions they call it "integrated engineering." That's a fine term for it, and they can show you many fine fruits of it: amplifiers, dividers, and other products they have packaged in limited runs for companies like yours, in cases where the companies chose to "go outside" rather than do it themselves. In each case North Hills' engineers were able to point to the successful realization of objectives like reduced size and increased performance — but we looked in vain for the technological "breakthroughs" that made it possible. There was no magic. Just very judicious judgments at each step. One component is bought, another manufactured on the premises. . .so that the total design, the interconnections, the transmission lines, all fit together and work together extremely well.

Simple? Yes, amazingly so — but not that easy to achieve, as you well know. At North Hills Electronics, they attribute it to something like high morale among their engineers. Ingenuity, creativity, and individual achievement are highly prized, praised, and I assume rewarded.

It's a heartening sign, I think, for all of us. In a time when dehumanization looms large, RF engineering offers challenges that mainly depend on an individual's resourcefulness. It's a good field to be in.



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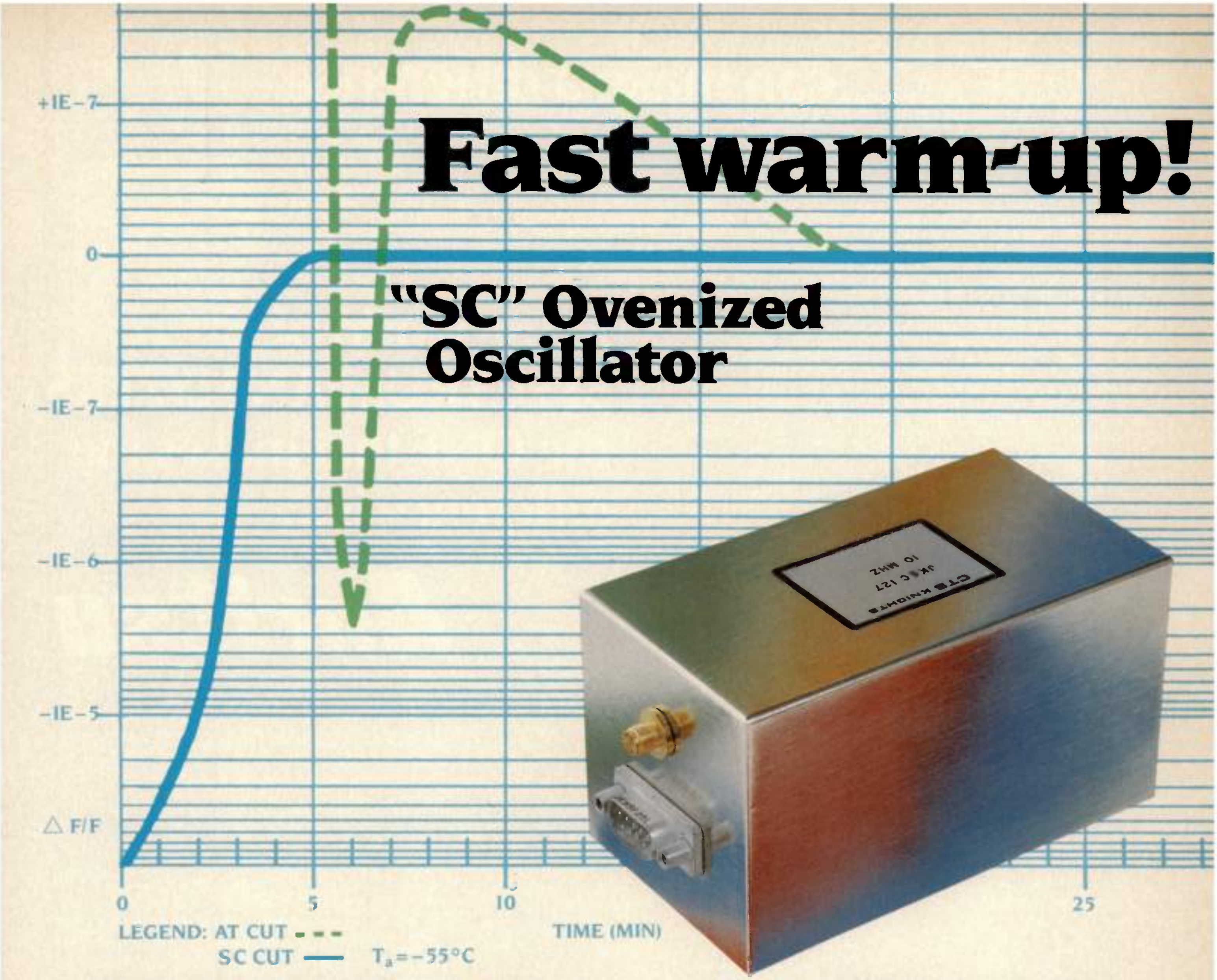

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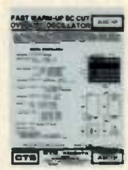

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Input Power	Oven @ turn-on 1.2 A maximum @ +28 V Oven @ 25°C 125 mA typical @ +28 V Oven @ −55°C 240 mA typical @ +28 V Oscillator 20 mA maximum @ +15 V
Frequency Stability Vs. Temperature	±5 x 10^{-9} from −55°C to +71°C
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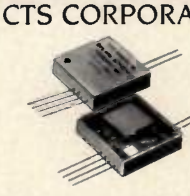

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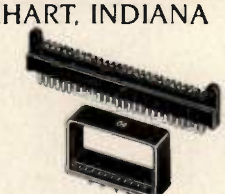

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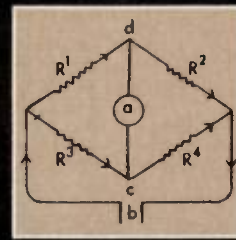
In the world of electrical measurement that one was S.H. Christie who, in 1833, devised a bridge, (Wheatstone) to compare electrical resistances, inductance and capacitance.



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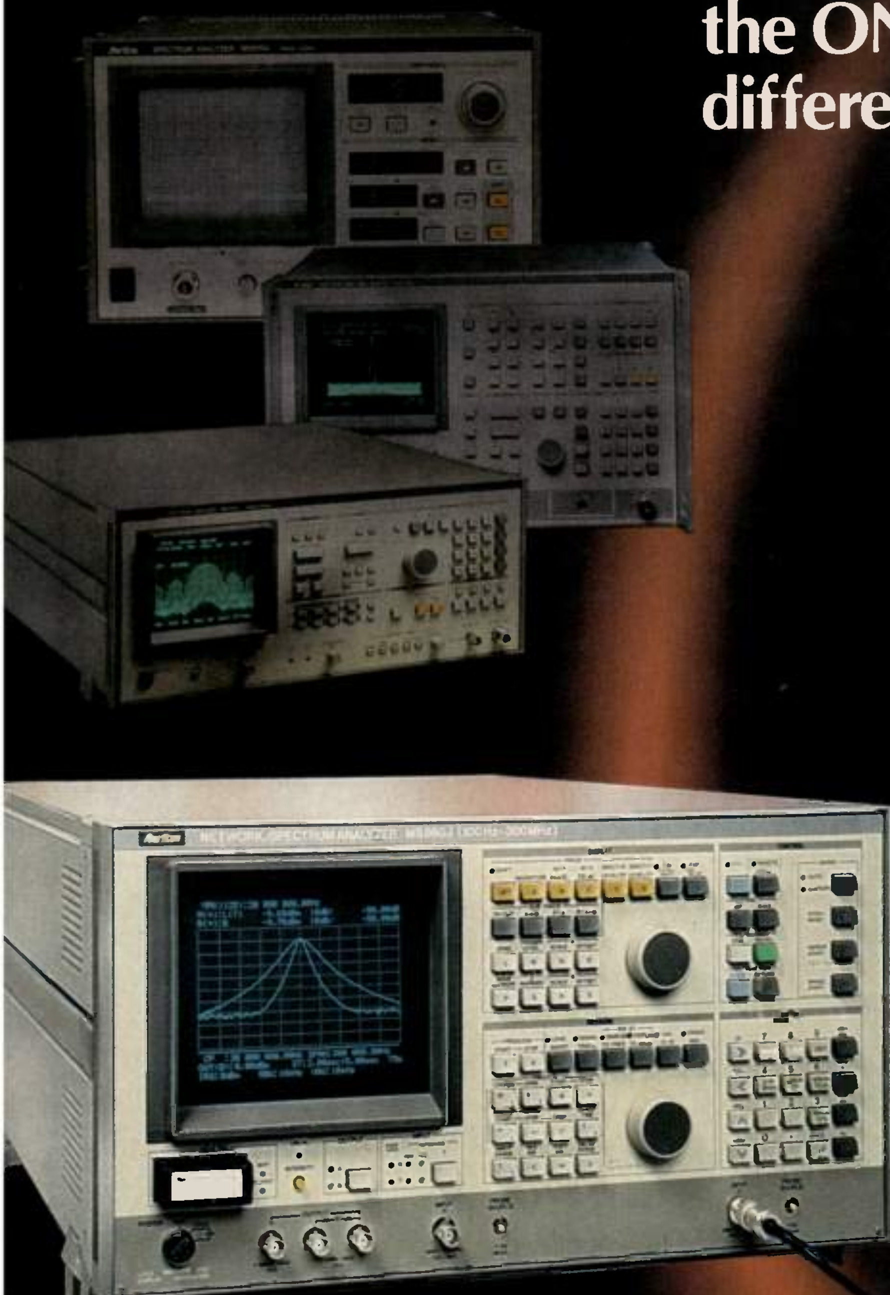

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Editor:

The article in the May, 1985 issue "Transistor Parameter Conversion" by Mr. Stanley Novak, pages 49-51, prompted me to write to inform you that Mr. Novak has "re-invented the wheel," however his wheel is less than completely circular.

Refer to the enclosed copy of an article from Electronic Design of September 17, 1974, titled "Convert two-port circuit parameters" by Mr. Robert P. Arnold which does more than Mr. Novak's. I have enclosed a copy of my adaptation (the modifications are indeed slight) of Mr. Arnold's program for use on a VAX 11/780 computer. Note that Mr. Arnold's program includes g-parameters and also can go from any parameter-form directly to any other parameter-form which is a distinct advantage. There is no need for interim stops at an unwanted parameter. Sample input data produces outputs which do agree from program to program.

Is there anything you can do to introduce Mr. Arnold's article and program to your readers? I would like to see it mentioned in "Letters to the editor" as a minimum.

Thanks for your consideration and I wish you success with your efforts to continually improve *RF Design*.

Ronald L. Wood
Principal Engineer
E.F. Johnson Co.
Waseca, MN 56093

Readers may contact Mr. Wood for information about his adaptation of Mr. Arnold's program. — editor.

Editor:

(In reference to the article in) April 1985, page 46 "BASIC Program Computes Values for 14 Matching Networks:" Line 270 X2 has to be changed to X3

Line 410 one parenthesis has to be removed

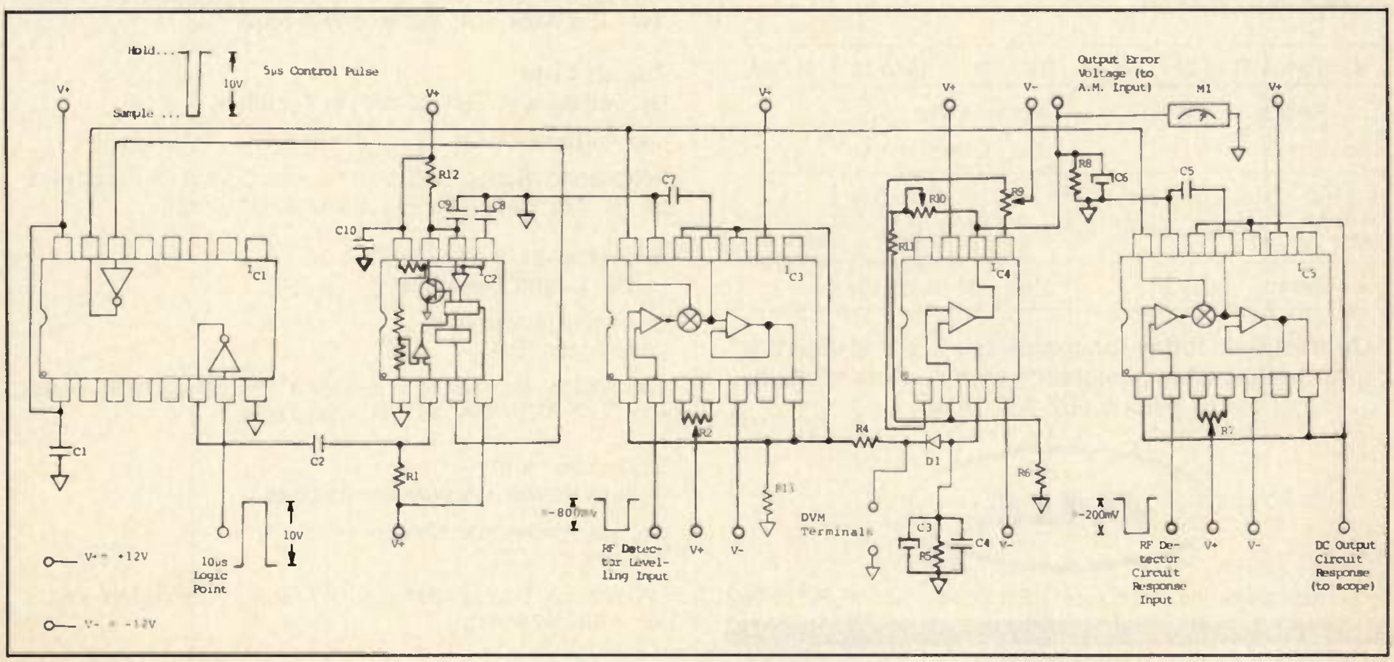
The other on statements will not run on the TI99. They were changed to IF statements. I hope that will help someone else.

```
170 IF (SGN(X1) = 1 THEN 200 :  : IF SGN (X1) = 0 THEN 190
210 IF SGN(X2) = 1 THEN 240 :  : IF SGN(X2) = 0 THEN 230
260 IF SGN(X3) = 1 THEN 290 :  : IF SGN(X3) = 0 THEN 280
270 F3 = (1/(6.28*FO*X3) )*-1
410 X1 = RS*(SQR(RL/RS) / (Q ∧2 + 1 - (RL/RS) ) )*-1
1345 IF SGN(X1) = 1 THEN 1370 :  :IF SGN(X1) = 0 THEN 1360
1380 IF SGN(X2) = 1 THEN 1410 :  : IF SGN(X2) = 0 THEN 1400
1430 IF SGN(X3) = 1 THEN 1460 :  : IF SGN(X3) = 0 THEN 1450
```

Kurt Bittman
Centereach, N.Y.

Author Alan LaPenn says the program should run on the TI99 as printed. That is what he wrote it on. — editor.

We have received several requests to reprint the circuit diagram from the article "Broadband Leveling in Pulsed Operation" in the May issue. Since part of the figure ended up in the binding and could not be seen, it is reprinted here, reduced to fit one page. — editor.



rf calendar

August 27-29
Quartz Devices Conference & Exhibition

The Westin Crown Center
Kansas City, MO

Information: Convention Manager, Westin Crown Center, Kansas City, MO.

September 11-12
Mid-Atlantic Electronics Design & Production Exhibition

Valley Forge Convention Center
King Of Prussia, PA

Information: International Mktg. Services Ltd., 1719 S. Clinton St., Chicago, IL; Tel: (312) 421-7000.

October 8-10
Electronic Imaging Expo

Sheraton Boston
Boston, MA

Information: Kathie Hallberg, IGC, 375 Commonwealth Ave., Boston, MA; Tel: (617) 267-9425.

rf courses

July 9-11
EMC design of Power Supplies

Sunnyvale, CA

Information: Susan Goff, Interference Control Technologies, St. Rt. 625, Gainsville, FL; Tel: (703) 347-0030.

July 15-19
Linear Circuit Design I

University of Maryland
Washington, DC

Information: Microwave Educational Programs, 1109 Russell Ave., Los Altos, CA; Tel: (415) 960-0536.

August 13-15
Grounding and EMI Control in Facilities

Los Angeles, CA

Information: Susan Goff, Interference Control Technologies, St. Rt. 625, Gainsville, FL; Tel: (703) 347-0030.

August 16-21
Linear Circuit Design II

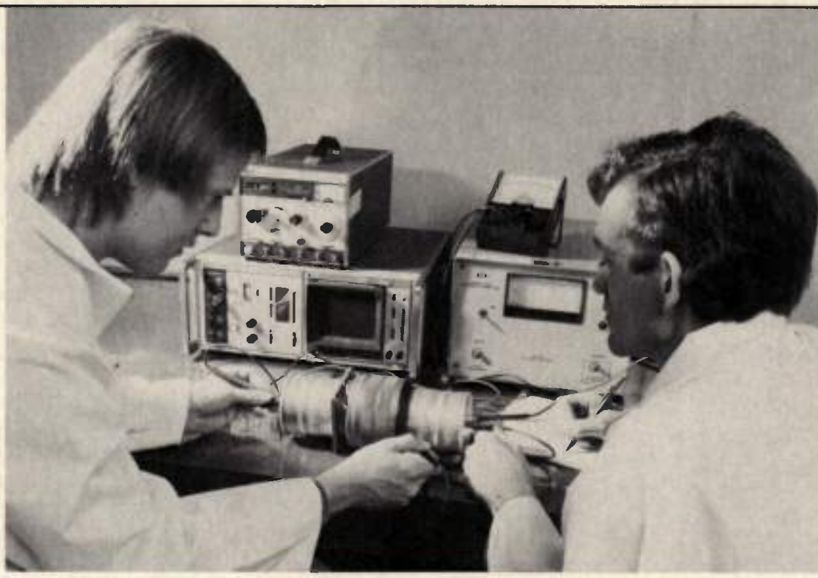
University of Maryland
Washington, DC

Information: Microwave Educational Programs, 1109 Russell Ave., Los Altos, CA; Tel: (415) 960-0536.

September 9-10
Cellular Radio Telecommunications

George Washington University
Washington, DC

Information: Darold Aldridge, GW Univ., Washington, DC; Tel: 1-800-424-9773.



German Firm Opens U.S. Plant

Stettner Electronics, Inc., the American subsidiary of Stettner & Co. of West Germany, is pleased to announce the opening of its first manufacturing facility in the United States. Located on a four acre site near the company headquarters in Chattanooga, Tenn., this modern production facility is designed for the manufacturing of ceramic multilayer chip capacitors. At the present time ceramic multilayer chip capacitors in NPO and X7R ceramic materials are in full production with additional types under development and in planning for the future. Stettner Electronics, Inc. intends to market a complete line of ceramic multilayer chip capacitors and has room to expand as the need develops.

The opening of the Chattanooga production facility represents a major commitment by Stettner & Co. towards the American market. Stettner & Co., one of Europe's largest ceramic manufacturers, has been marketing its product line in the United States since 1968. This is their first attempt to manufacture their electronic components here. An international company, Stettner & Co. has manufacturing plants in West Germany, Austria, France, Brazil, Malaysia and now, the United States. Stettner & Co. enjoys a world wide reputation for the excellent quality of its ceramic electronic components.

TRW Invests in Sybase, Inc.

TRW Inc. signed development and investment agreements with Sybase, Inc., a privately-held software company in Berkeley, California.

Under terms of the investment agreement, TRW has purchased one-third of the preferred stock of Sybase for an undisclosed amount of cash, with rights to make additional investments at a later date. Venture capital firms Hambrecht & Quist and Kleiner Perkins Caufield & Byers also purchased a like amount in the same agreement. Each company has nominated one individual to serve on Sybase's Board of Directors.

Under terms of the TRW/Sybase development agreement, the two companies will jointly develop unique database capabilities especially suited to the needs of TRW's Defense Systems Group customers. TRW expects to become one of Sybase's OEMs. Sybase will market a commercial version of their database server software to major OEMs and systems integrators.

"Sybase has developed a unique approach to database management systems," says Robert D. Williams, vice president and assistant general manager of TRW's Defense Systems Group. "Their software will be fully transportable, and is written in a higher level language adaptable to most major computers."

He noted that this will promote network architectures in which database management functions are provided by dedicated servers, thereby avoiding the degradation experienced by systems which combine applications software and database management on a single host computer. He said that the Sybase approach also enables end users to select the mix of equipment they prefer, rather than being required to invest in a dedicated central processing unit for the database management system.

Navy Gives Hughes $24 Million Award to Build Torpedo

The U.S. Navy has awarded a $24.4 million contract to Hughes Aircraft Company to begin production of a new submarine-launched, heavyweight torpedo that will counter surface and sub-surface threats through the 1990s.

The contract calls for the purchase of long lead time items, design and building of test equipment, and planning and logistics for the Advanced Capability (ADCAP) Mk-48 torpedo.

Contract options which could be exercised before the end of this year call for building, testing and delivery of several torpedoes and training systems, and the production of spare parts. The value of the award would increase to $175 million this year, if all options are exercised.

Hughes plans to build a 100,000 sq. ft. torpedo-production facility at its Ground Systems Group's anti-submarine warfare center in Buena Park, Calif. Construction is scheduled to begin this summer.

Improvements in the wire-guided ADCAP torpedo will enable it to run faster and deeper than the Mk-48 version that ADCAP is replacing.

Honeywell Establishes New Viking Labs Facility

Viking Labs/Honeywell, an operation of Honeywell's Test Instruments Division, has established a satellite facility in Tucson, Ariz., to conduct component and product testing.

The new testing lab will occupy 13,575 square feet in the Tucson Business Park.

"Because several of our major customers are close to the Tucson site, they will no longer have to rely as heavily on outside shipping services," said Bill Dover, manager of Viking Labs/Honeywell's Test Services Division. "In addition, our Mountain View, Calif., headquarters facility can be expanded to expedite service to our other customers."

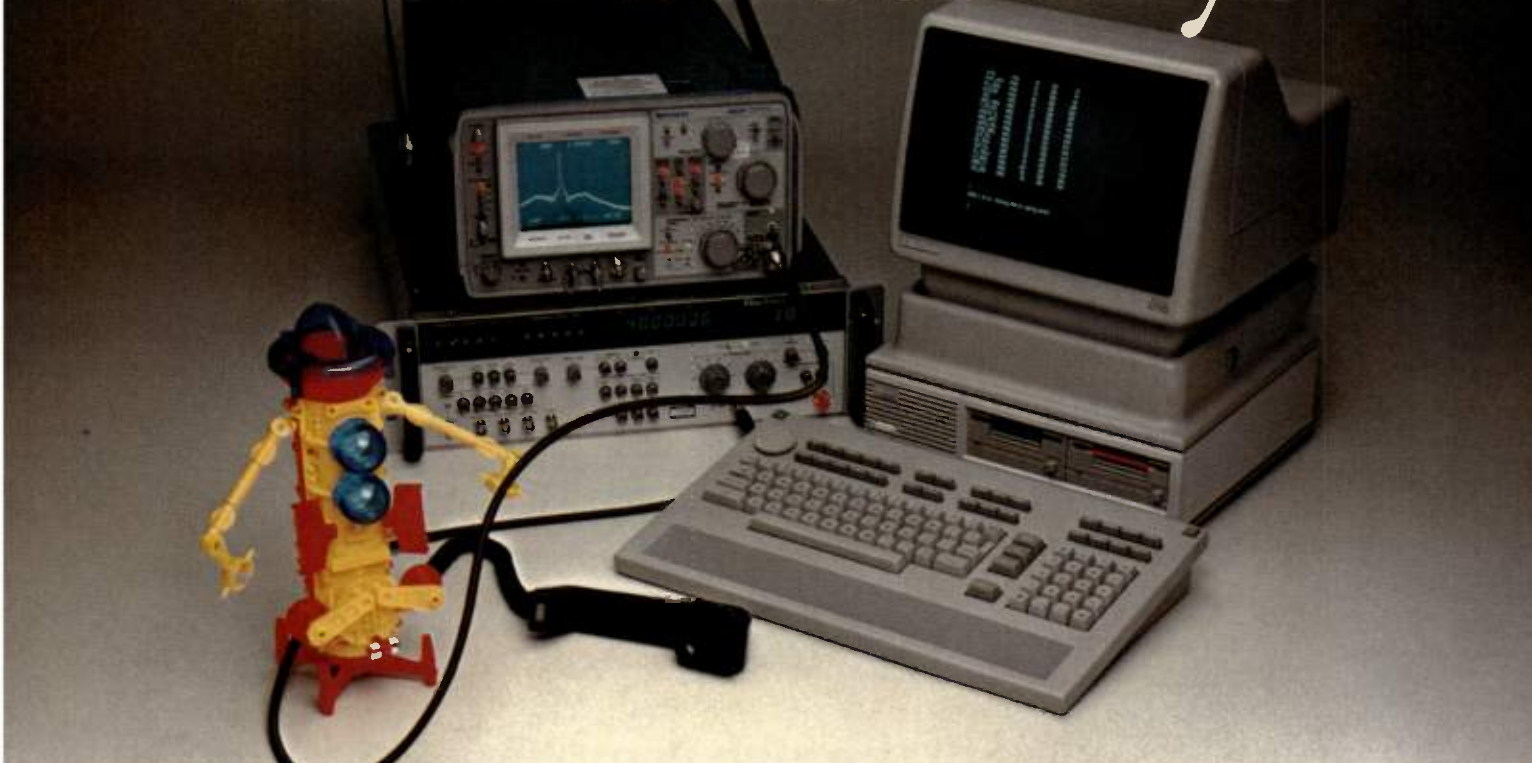
Equipment to be installed includes standard burn-in systems, environmental and burn-in ovens, and temperature cycle-type board burn-in systems being made by Enseco. Future equipment will include salt spray, temperature/humidity, shock, vibration and fine- and gross-leak test apparatus.

Viking Labs/Honeywell simulates conditions in earth, space and underwater environments and offers extensive product-reliability and component testing and environmental and metrology services.

James E. Sterrett Elected First Avantek Fellow

The Board of Directors of Avantek, Inc., Santa Clara, Calif., has named James E. Sterrett to the position of Vice President and Fellow of Avantek. The title of Avantek Fellow has been instituted by the Board of Directors to recognize an individual for significant and extraordinary technical contributions over an extended period of time. Mr. Sterrett is the first recipient of

From Test to Toys



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

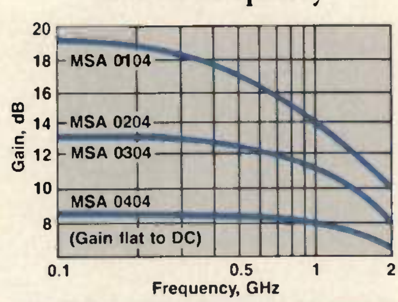
Avantek's series of MODAMP™ silicon monolithic microwave integrated circuit amplifiers are ready to drop into your 50-ohm circuit, with no design problems — virtually no concern for what comes before or after. These MMICs are unconditionally stable and provide cascadable gain blocks at any frequency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

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

Available in volume.

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

Gain vs. Frequency



*price in 10,000 piece quantities.

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

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

CENTRAL

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

Peak Distributors
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(312) 255-0707

Thorson Dist.
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Spirit Electronics
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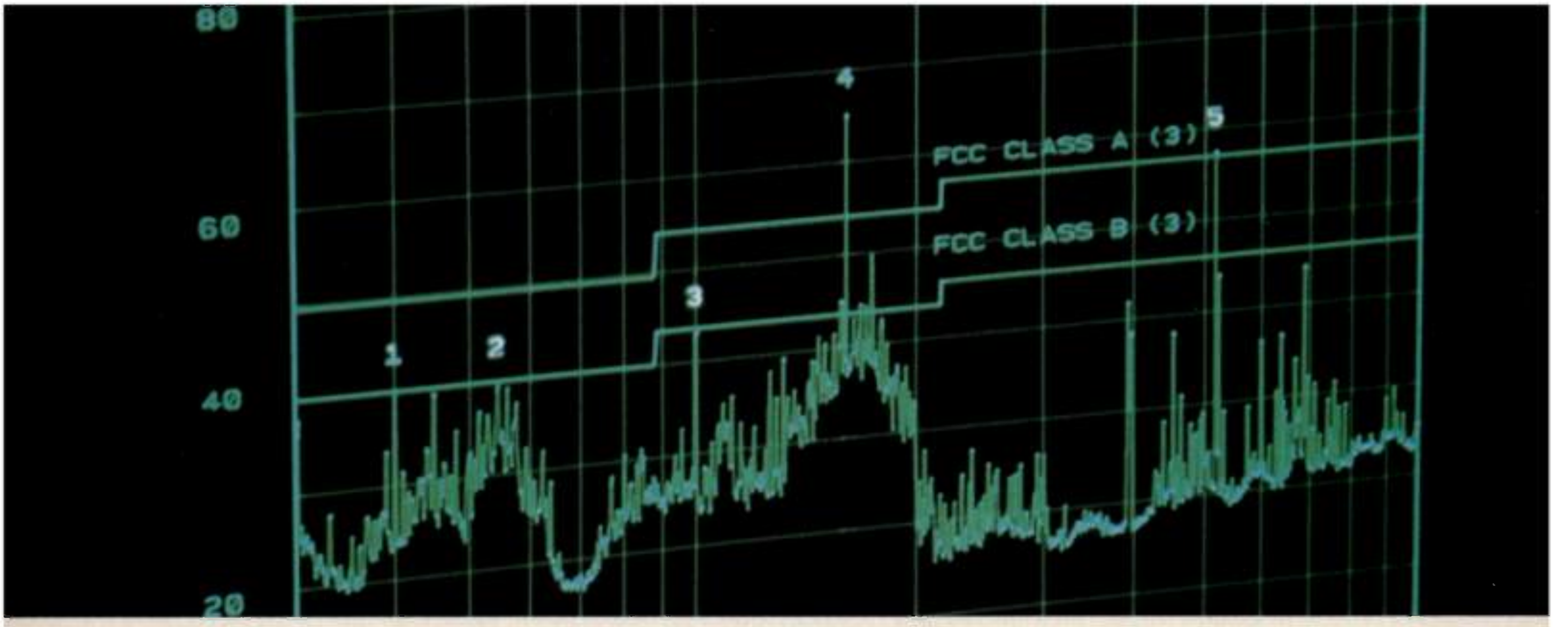
Sales: (408) 496-6710

INFO/CARD 16



CONFIDENCE

From design through compliance testing, HP's Spectrum Analyzer/EMI Receiver delivers unprecedented versatility and CISPR receiver accuracy.

Your complete EMI measurement solution.

HP's new Spectrum Analyzer/EMI Receiver delivers fast, accurate EMI compliance measurements *and* complete EMI diagnostic capabilities—all for the price of an EMI receiver alone.

Featuring the new HP 85685A RF Preselector—with improved sensitivity and overload protection—this versatile spectrum analyzer-based EMI receiver is designed to CISPR* Publication 16 recommendations and meets the measurement requirements for military and commercial standards, including FCC and VDE. Which makes it the ideal instrument to conduct your final open-site EMI compliance tests with complete confidence.

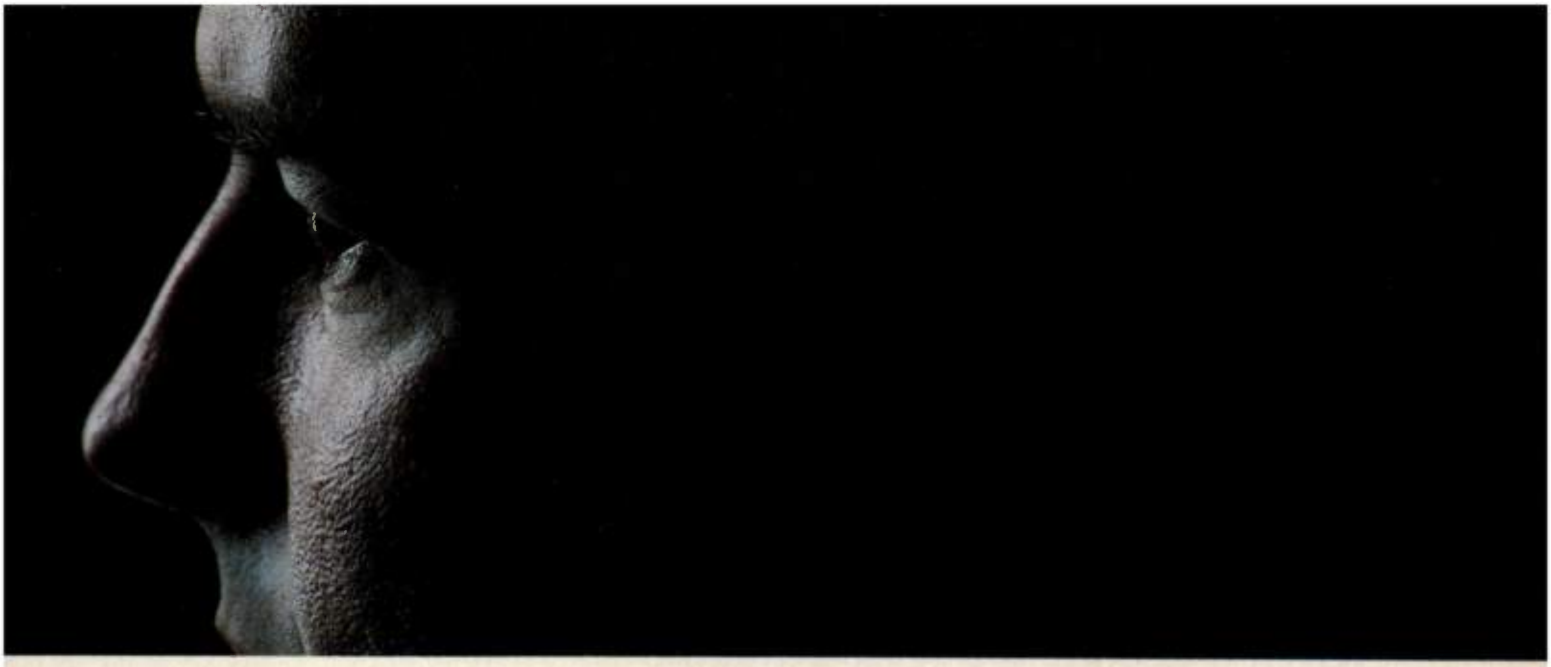
And unlike EMI receivers that are dedicated solely to compliance testing, the HP Spectrum Analyzer/EMI Receiver is also an indispensible EMI diagnostic aid throughout your product's design and evaluation stages.

The ideal EMI diagnostic tool.

Using the HP8566B or 8568B Spectrum Analyzer and simple probes, you can quickly locate problem emissions and evaluate potential solutions. These powerful analyzers sweep quickly over a broad 100Hz to 1.5 GHz or 22 GHz frequency range, instantly displaying measurement results on the easy-to-read CRT, or as hard copy plots. Built-in capabilities include: multiple-trace digital storage for instant A vs. B comparison, frequency and amplitude markers, maximum hold for capturing elusive intermittents, and direct plotter control—to name just a few.

Perform open-site tests with confidence.

When it's time for final compliance testing, the same HP spectrum analyzer used during the design and evaluation stages can be combined with



the HP85685A RF Preselector and the HP85650A Quasi-Peak Adapter. The result is an EMI receiver system with the sensitivity, overload protection and ±2 dB amplitude accuracy you'll need for both indoor and outdoor compliance testing.

System features include multiple detection modes with peak detection for the fastest possible measurement time, quasi-peak detection for compliance with CISPR Publication 16 recommendations, and average detection for discrimination between narrowband and broadband signals.

Automate your EMI measurements for increased productivity.

With the HP85864B EMI Measurement Software, featuring an easily understood menu structure, you'll be able to quickly automate your commercial and military emission measurements. Choose from a library of FCC, VDE and MIL-STD emission tests, or design your own. Test results can be annotated and notes generated as part of the test documentation.

Consider the HP advantage.

Now is the time to discover the distinct advantages of HP's Spectrum Analyzer/EMI Receiver, a total solution for EMI measurements. After all, why invest in both an EMI receiver for compliance testing *and* an additional spectrum analyzer for design/evaluation, when you can accomplish both tasks confidently with a single, versatile system that costs far less?

For more information, call the Instrument department of your local HP sales office listed in the White Pages. Or write Hewlett-Packard, 1820 Embarcadero Road, Palo Alto, CA 94303.

*CISPR (Comite International Special Des Perturbations Radioelectriques) Publication 16 is the "CISPR specification for radio interference measuring apparatus and measurement methods."

HEWLETT PACKARD

INFO/CARD 17

5301500

this highly esteemed award.

A founder of Avantek, Mr. Sterrett was instrumental in developing the technology and initial products that successfully launched the company. Throughout Avantek's 20 year history, he has provided the company with continuing technical leadership.

Among his many accomplishments, Mr. Sterrett designed the original Avantek amplifier products and was responsible for getting them into production. He developed a practical RF/microwave amplifier design that was cascadable without loss of performance or bandwidth, a concept that was patented and ultimately resulted in Avantek's still-successful series of thin-film hybrid amplifier modules. He was jointly responsible for changing thin-film circuit production from sapphire to alumina ceramic substrates, developed the first laser drilling and scribing procedures at Avantek, the first air bridge transistor geometries, and the metal system that is currently used for both bipolar transistors and GaAs FETs.

He was a member of the founding group of Avantek in September, 1965, and has held the positions of Corporate Secretary, Technical Director, Amplifier Circuit Development Engineer, Thin-Film Process Development Manager, manager of Semiconductor R&D and Vice President of Semiconductor R&D.

Mr. Sterrett holds a BSEE from Grove City College (1955), and the degrees of MSEE (1956) and Engineer, E.E. from Stanford University (1962). He is a member of Sigma Xi, the American Physical Society, the Electrochemical Society and the IEEE.

Adams-Russell Acquires A.I. Grayzel

Adams-Russell Co., Inc. has acquired A.I. Grayzel, Inc., a manufacturer of RF and microwave frequency multipliers, sources and synthesizers. A.I. Grayzel, founded in 1976, will become part of Adams-Russell's Anzac Division and form the nucleus of the division's frequency generation product line. A.I. Grayzel is located in Needham, Massachusetts.

The Anzac Division of Adams-Russell is a major supplier of military RF and microwave components and subassemblies. This acquisition will further expand its presence in the frequency generation market as well as broaden its subassembly capabilities.

TRW Joins Rockwell Team For Space Station Work

The TRW Electronic Systems Group and TRW Defense Systems Group with subcontractor Hughes Aircraft Company have joined the Rockwell International Space Station Systems Division team for the definition study of the National Aeronautics and Space Administration's (NASA) Space Station Program work at the Johnson Space Center, Houston, Texas.

TRW will support the Rockwell team with systems engineering for the Space Station Information System, consisting of communications and tracking systems as well as the data management systems. The study will include the overall information system architecture between a space station, its users and other NASA communications networks, and provide recommendations on how to best integrate them.

INFO/CARD 18

According to Phil Walker, TRW Space Station program manager, "the opportunity to work with Rockwell on Space Station studies continues a long relationship TRW has enjoyed in previous space programs such as our work on the Space Shuttle communication system for S-band and Ku-band."

Roland L. Benner, Rockwell Space Station Systems Division vice president and program manager said in announcing the agreement that TRW was invited to join the Rockwell team, "because they offer the best expertise in the country for this kind of technical challenge."

Filter Market Expected to Grow

The U.S. market for electronic filters, which stood at close to 88 million units, worth just over $1 billion in 1984, will double by 1989 according to a new report titled: "Electronic Filters", published by Worltech Reports Inc., a high-technology research firm based here. The increase represents a 15% annual growth rate, in both bolume and value, during this period.

According to the report, many segments of the electronic filter market will demonstrate growth rates far above the market average between 1984 and 1989. Included in this group are crystal filters for NAVSTAR GPS receivers; microstrip, suspended substrate, and dielectric resonator microwave filters; ceramic filters for TVRO; SAW filters; and EMI AC power line filters.

Foreign competition in the electronic filter market is minimal, and domestic competition is very fragmented, says Worltech. Opportunities for companies with the necessary technical expertise and marketing skills to increase their market share are therefore quite numerous.

The report is available from Worltech Reports Inc. at 44 Woodbine Avenue, P.O. Box 212, Northport, New York 11768, USA (516) 757-9444.

New High-Speed Transistors Rely on Hot Electrons

Scientists at Philips Research Laboratories (PRL), Redhill, United Kingdom, have shown that a new type of transistor can be made which uses hot electrons to obtain transistor action in a semiconductor. Hot electrons move at higher velocities than the average electron in the semiconductor and the advantage of this transistor structure compared with the FET or bipolar transistor is that it provides amplification and power at very much higher frequencies.

Hot-electron transistors already have a long history. Some twenty years ago it was proposed that a metal base should be used with a semiconductor on either side. The transistor action could then be obtained by injecting hot electrons into the metal via a Schottky barrier. It has proved impossible, however, to obtain any current gain from this structure because the collection of the hot electrons is a very inefficient process.

The solution to the problem of obtaining an efficient hot-electron collector became apparent with the invention of a new form of diode at PRL named a bulk unipolar diode. This diode has an extremely fast response time (>1000 GHz) and is formed in the body of a semiconductor but more importantly, it is a very efficient collector and generator of hot electrons. Two of these diodes can therefore be used to form a hot electron transistor, one for the emission and one for the collection of hot electrons.

A New Dimension in Portable, Digital Spectrum Analyzers!

The A-7550 Spectrum Analyzer

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

Two powerful microprocessors, menu driven display modes and single function keyboard entry aid the user in the operation of all analyzer functions.

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.

Features...Performance...Dependability... The A-7550 portable Spectrum Analyzer by IFR—innovative accomplishments in design.

Impressive Standard Features Include:

▪ 100 kHz to 1 GHz frequency coverage ▪ VRS™ (Vertical Raster Scan) CRT display ▪ Single function keyboard entry ▪ Menu driven display modes ▪ Automatic amplitude calibration ▪ Selectable linear/log display modes ▪ Digital storage of all displayed parameters ▪ 70 dB dynamic range ▪ 300 Hz resolution bandwidth ▪ 16 selectable scan widths ▪ Accurate center frequency readout ▪ Direct center frequency entry ▪ Automatically scaled electronic graticule ▪ Variable top scale reference (+30 to −95 in 1 dB steps) ▪ IF gain in 1 dB steps ▪ Line, bar, average and compare display modes ▪ 300 Hz and 30 kHz video filters

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

Contact your local IFR authorized distributor for a demonstration.

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The New Look in RF Circuits — Materials

The electronics industry began with radio, but for the last 15 years RF engineers have watched their colleagues in the digital field produce devices that made RF technology seem tame. While RF design engineers struggled with the complexity of analog circuits the new generation of engineering students dreamed of computers and their seemingly endless potential.

Perhaps the development of computers was a stimulus the RF world needed. Driven by military requirements, computer designers moved from discrete components to hybrid circuits to integrated circuits, then on to larger and larger scale integration. Everything kept getting smaller and lighter and faster. Now RF circuitry is going the same way.

Even within the analog world the lower frequencies have lagged behind the microwave frequencies in the more exciting developments. In general, military weapon and communication research has emphasized the higher microwave frequencies, while traditional RF served the commercial market, but RF engineers have been noticing higher frequency design improvements sponsored by the military and adapting some of that technology to the commercial market.

The RF design engineer is benefiting not just from advances in microwave technology that were financed by the military but from a new military interest in the lower frequencies, as well. In some instances lower frequency devices are being studied as replacements for microwave devices.

This is the first article in a three-part series on the new look in RF circuits. We are talking to engineers and marketing specialists from coast to coast to learn what is new in RF circuit design and what may be coming soon and we will report our findings to you. This first article looks at some materials in current use, some that are new and some that are not yet on the market.

Although editorial space in RF Design magazine usually deals with designs below 3 GHz, some of the devices mentioned in this three-part special report will be higher frequency microwave devices, because the microwave design technology involved either is or we think soon may be found in lower frequency designs.

Semiconductors

The most interesting newer semiconductor material, often written about lately, is gallium arsenide. Currently used in digital and microwave circuitry, GaAs generally has been too expensive for RF commercial use. Its major advantages over silicon are higher electron mobility, lower noise and better radiation hardness. Higher electron mobility, important for operating speed in digital processing, and radiation hardness, important for protection of satellites, have not been major concerns in RF design. Lower noise output is an attractive feature, but the higher cost of GaAs has made it more practical to deal with the noise of silicon transistors in other ways. Anyway, below 200 MHz GaAs noise increases.

M/A-Com Advanced Semiconductor Operations, Inc., Lowell, Mass., has developed a GaAs FET monolithic amplifier designed to operate from 50-1800 MHz, and the company is looking at the RF market for this device. More will be said about the device in next month's special report.

Substrates

The most universal trend in RF circuit design today is miniaturization. Hybrid circuit designers are striving continually to make components smaller and mount them closer together. As hybrid and integrated circuit devices become smaller the thermal expansion difference between materials becomes more critical. Films can separate from substrates and surface mounted components can crack or dislodge. As components are mounted closer together heat dissipation becomes a more serious problem. All the requirements associated with these design challenges have greatly increased the importance of the substrate and packaging material.

For many years the most common substrate materials have been silicon, alumina and beryllia. Silicon is the workhorse of the industry and probably will not be replaced soon as an active substrate. The ceramics also have been quite satisfactory, but new materials are being studied to replace them, at least, partially. As circuits become smaller the thermal expansion or heat dissipation properties of these ceramics become less satisfactory.

A promising new passive substrate material is aluminum nitride, which has higher thermal conductivity than alumina, a high electrical resistance and a coefficient of thermal expansion close to that of silicon. Thermal conductivity of aluminum nitride is not as good as beryllia, but this disadvantage may be outweighed by the health hazard associated with manufacturing beryllia substrates. Beryllia dust, created when the substance is ground for a smooth surface, can be highly toxic. Some persons exposed to minute quantities develop a debilitating lung disease. Only dust-size particles seem to be hazardous, so the finished product can be handled safely, but manufacturing beryllia substrates is difficult and expensive.

One problem with aluminum nitride is that available metalization pastes are made for oxide ceramics. Some work on aluminum nitride and some do not. In a paper delivered to the 35th Electronics Components Conference in Washington, DC, May 20, Waltraud Werdecker and Fritz Aldinger reported on tests they had run on commercial thick film metalizations. They found that some thick film metalizations they tested and most thin films worked satisfactorily. This was a laboratory study, however, and adherance of currently available metalization to aluminum nitride is one of the problems with this substrate material.

Metaramics, Sunnyvale, Calif., is a major user of beryllia and alumina substrates. A wholly owned subsidiary of W.R. Grace & Co., Metaramics benefits from research done at Grace's Washington Research Center, which is investigating aluminum nitride and other new substrate material. Metaramics builds custom and specialized packages, gallium arsenide and indium phosphide packages, metalized substrates, brazed ceramic-metal assemblies and high thermal dissipation IC packages. More will be said about this company in the third part of this series.

Laminates

Printed circuit board materials have not changed much in recent years, but there have been some developments worth noting. Generally, improvements have been made to accommodate higher frequencies, but RF design engineers may find strength and high dielectric constant in laminates important as circuits become smaller.

Modern laminates are made of Teflon and either woven or non-woven fiberglass sandwiched according to requirements and pressed together under high pressure and temperature. Copper plating is then fused to one or both surfaces. Woven fiberglass laminates begin with either fine, medium or coarse weaves of fiberglass cloth. The cloth is impregnated with Teflon through immersion in a bath containing a high concentration of Teflon particles. The concentration of Teflon particles in the bath determines the dielectric constant of the final laminate. These layers are fused together to the desired thickness.

Non-woven fiberglass laminates are made in a process similar to paper making. Particles of fiberglass and Teflon are mixed in a slurry. A screen picks up a layer of the materials and the liquid is sucked away from them. The dried and pressed material is layered as with the woven glass process. With this process the glass particles are non-aligned and the Teflon content is higher, making a lower dielectric constant. Alignment of the glass particles is more important at high microwave frequencies than at the usual RF frequencies.

A newer form of laminate combines woven fiberglass and Teflon separately. Layers of fiberglass are interspaced with layers of Teflon to make a stronger and less expensive product. Such a product has a more predictable dielectric constant than the other laminate types.

Oak 605, a laminate of this type made by Oak Materials Group, Laminates Division, Hoosick Falls, New York, is the first laminate to have a milspec for stability.

A New Portable

IFR, Inc., Wichita, Kan., has introduced a low cost portable spectrum analyzer. Company literature says the A-7550 has two powerful microprocessors, menu driven display modes and single function keyboard entry for easy use.

The spectrum analyzer has a range from 100 kHz to 1 GHz in 100 Hz steps and a frequency span range from 1 kHz to 100 MHz/div with an accuracy of +/−5% of frequency separation. Measurement range is −117 dBm to +30 dBm. Third order intermodulation products are less than 70 dBc for two

Non-woven fiberglass based laminate will shrink during processing where the copper has been etched away. Oak 605 will not shrink, the company says. The solid Teflon layers allow this board to withstand temperatures as high as 260 degrees C. It is a low loss material useful for narrow bandwidth tuning in receivers.

Rogers Corp., Chandler, AZ., recently introduced a non-woven glass fiber laminate with a dielectric constant transition temperature other than room temperature. The company says devices and circuit elements which are sensitive to temperature related dielectric constant shifts can be designed on RT/Duroid 5500 without resorting to complex and costly temperature compensation methods.

Rogers has introduced two new high-dielectric substrates particularly designed for miniaturizing RF circuits. RT/Duroid 6006 and 6010 are non-woven laminates with characteristics like ceramic substrates.

A recent innovation in substrates is the flexible circuit substrate. These are film laminates upon which metal foil circuits can be attached by deposition or adhesive. Circuits printed on these lightweight laminates can be bent to fit smaller spaces than those on rigid boards. Keene Laminates Div., East Providence, R.I., makes flexible films as well as the rigid laminates.

As might be expected, 3M Corp. makes a flexible substrate, used for ribbon type cables. The company's Electronic Products Div., Austin, Texas, also has a full line of rigid, copper clad laminates. A recent addition to their line are the Epsilam products, which they offer as a substitute for alumina as a substrate. Epsilam is a ceramic-filled Teflon compound the company says has a substantial total cost savings over alumina.

As this article went to press we received an announcement from ICI Americas Inc., Wilmington, Del., that they would be unveiling their "latest technological innovations in the area of *true* 3-D termoplastic molded circuit boards with *copper* circuitry" at NEPCON EAST, June 20. We will try to provide details of this product in the next issue.

Spectrum Analyzer

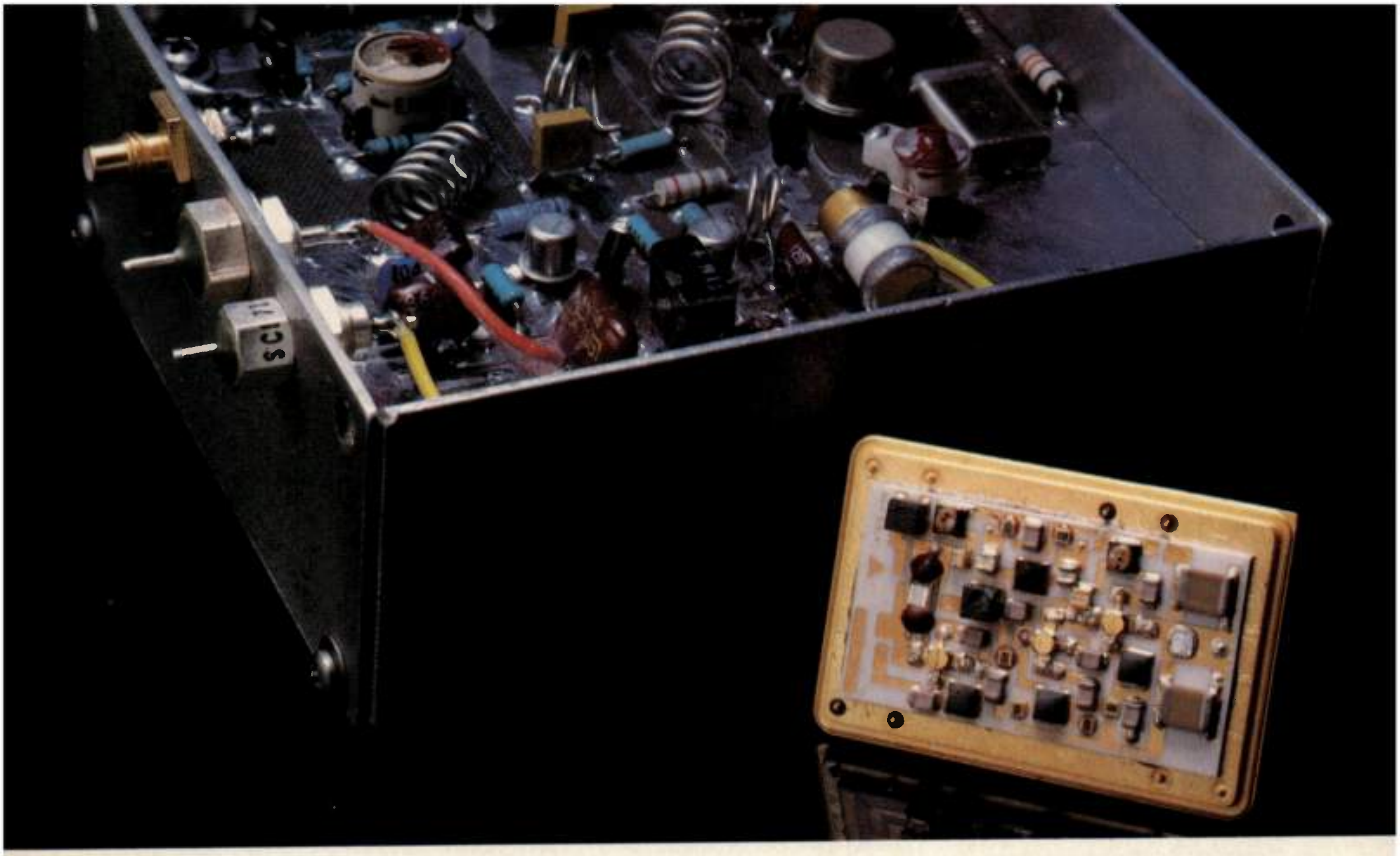
signals displayed and 10 dB down from the top reference level.

A unique digitized vertical raster scan CRT system is used as the display for the A-7550. This system allows the operator to view most analyzer parameters simultaneously while monitoring an active or stored trace, the company says.

RF frequencies may be manually entered via the front panel numeric keyboard for immediate center frequency selection from 100 kHz to 1 GHz, or by use of the frequency slewing keys for convenient analyzer operation. The absolute rate of the frequency slewing keys is automatically programmed for the analyzer's center frequency without drift or wobble.

IFR says the A-7550 microprocessor system automatically selects and optimizes bandwidth sweep rate, center frequency display resolution and the rate of the frequency slewing keys. An operator override is also provided so non-standard settings can be selected.

For additional information circle INFO/CARD #89.



Until now, you had to go to great lengths to produce an oscillator this good.

Now you can simply buy a source-on-a-chip.

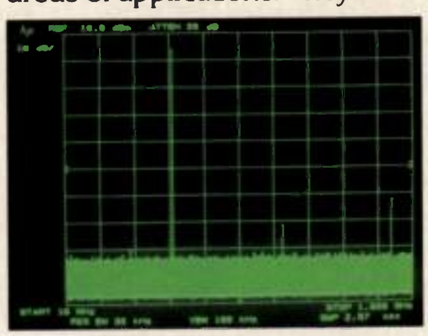
That's what an Andersen SAW oscillator is: a compact fundamental-mode device that operates from 100 MHz to 1.1 GHz without the need for multiplier chains. As a result you get superior performance in a fraction of the space, often at a lower overall cost.

Fundamentally Better

Since Andersen SAW oscillators are fundamental-mode devices, they produce a spurious-free signal. They are also alignment-free. No tuning or optimization is required.

These compact devices are also more rugged than any comparable source. Just plug them into your system. They're available in standard industry packaging for PC mounting.

Andersen SAW oscillators are the perfect source for hundreds of applications. They're also capable of functioning as VCO's. The output frequency can be modulated or locked to another reference for applications such as a PLL.



Frequency spectrum of Andersen Model SO-314-600-V Oscillator over 0 to 1 GHz range. Fundamental frequency is 314 MHz. Second harmonic is −65dBc, third harmonic is −55dBc. Spurious responses are essentially nonexistent.

Make It Easy On Yourself

We'll supply oscillators to your specific frequency requirements without a tooling charge. We can do that because of our unique CAD SAW design facility—and the versatility of our oscillator design.

Save money, save time, simplify your circuit design. Incorporate an Andersen SAW oscillator in your system today. Send for more information right now. Or give us a call at (203) 242-0761.

ANDERSEN LABORATORIES

Andersen Laboratories, Inc., 1280 Blue Hills Avenue, Bloomfield, CT 06002 Telephone (203) 242-0761/TWX 710-425-2390

Andersen SAW products are available in the United Kingdom and Europe through our sister company, Signal Technology Ltd., Swindon, Wiltshire, UK.

INFO/CARD 22

You'll Find Our New ECM-85 Can Beat FR-4 In Processibility, Performance, and Price.

At last there's a viable alternative to FR-4—a laminate that's strong yet easy on drilling tools, stands up to the most demanding electrical requirements, and offers you a price advantage.

It's an all-glass laminate from Cincinnati Milacron called ECM-85 (IPC-designated CRM-5).

In processing, ECM-85 virtually eliminates PTH barrel cracks, consistently provides smooth & smear-free holes, and features the best solderability in the industry.

In electrical performance, it provides more stable long-term insulation resistance; lower and more stable dielectric constant and dissipation factor; and wider safety margins in arc resistance, tracking resistance, and high current ignition resistance.

And in price, ECM-85 is more cost-effective than FR-4 in most applications.

If this new laminate looks attractive to you, call Milacron for samples, information, and the name of your nearest ECM-85 approved fabricator. Getting a second opinion could really pay off.

Direct inquiries to Steve Hayden or Arlyne Adams, Cincinnati Milacron Marketing Company, P.O. Box 246, Blanchester, Ohio 45107

1-800-221-7084

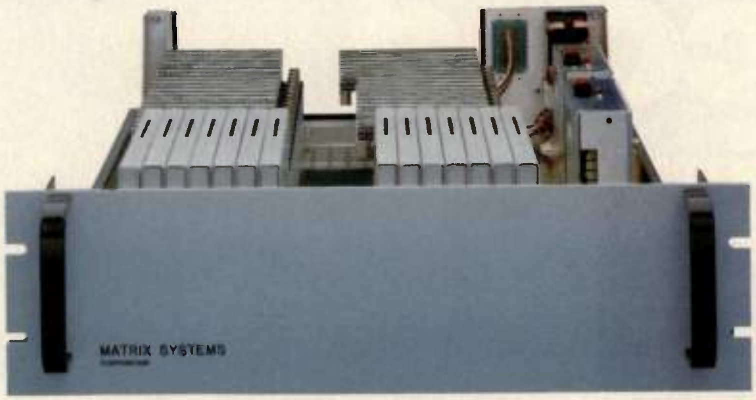
(in Ohio call 513-783-2464)

CINCINNATI
MILACRON

Electronic Circuit Materials Division

INFO/CARD 23

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



MATRIX MAKES SWITCHING A SNAP

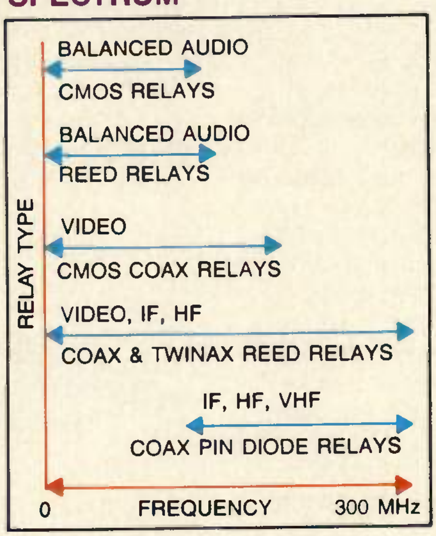
Whether you're switching VHF, HF, IF, video, audio or DC, Matrix Systems makes it a snap. That's because we can tailor a system to your exact needs using Reed, CMOS, or Pin Diode relays. The chart tells the story.

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

BUILT TO YOUR SPECS

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

MATRIX COVERS THE WHOLE FREQUENCY SPECTRUM



COMPUTER COMPATIBILITY

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

NEW PRODUCTS

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

LEAVE THE SWITCHING TO US

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

MATRIX SYSTEMS CORPORATION

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

Southwall Technologies, Palo Alto, Calif., makes a flexible printed circuit called Etch-A-Flex. Southwell uses sputter deposition to fix copper to the plastic substrate. The company says the process allows finer lines and denser circuit designs than systems using adhesives. They say the copper bond is stronger than that achieved with other adhesiveless systems.

Plating

Plating is an important consideration in any discussion of materials. Thin and thick film substrate plating will be discussed in the third article, emphasizing packaging. For plating entire surfaces, such as connector mating surfaces, a new material has been developed by DuPont as a substitute for gold. The company says GXT palladium nickel plating outwears and outperforms gold. The plating consists of a 50 microinch nickel undercoat, a palladium-nickel alloy coating either 15, 30 or 50 microinches thick, depending on the application, and a thin gold overflash.

Company data indicates GXT is superior to gold in porosity test performance, environmental corrosion resistance, creep corrosion resistance, solderability, bend ductility and wear resistance. They say it is equivalent to gold in contact resistance and classical corrosion test resistance.

Photographs for this month's cover were provided by Cohan-Epner Co., Brooklyn, New York. The company has developed a process to assure uniform plating in the recessed areas of large devices with complex shapes. Shown is a newly-developed interdigital filter designed by a major telecommunications company to work in the cellular radio frequencies.

Since parts of the filter are recessed, there is a danger that the silver in the plating solution will be depleted in the corners of the recesses and not replenished by circulation of the solution. Cohan-Epner places silver mesh in these recessed areas to feed silver into the depleted solution.

Other Materials

Looking beyond the circuits, some interesting new materials have been developed for RF shielding. Southwall Technologies has developed a shielding architectural window. The company says their window provides EMI shielding while allowing visible light transmission.

Facilities which have to be shielded against EMI usually are built without windows. Floors, ceilings and walls are made of metal and grounded. Standard glass windows pass electromagnetic waves and cannot be used in secure facilities.

Southwall says their window looks like an ordinary window but stops electromagnetic waves. The shielding comes from a conductive but highly transparent thin metal film sputtered onto an optical grade polyester. The thin film is suspended in the airspace between two panes of glass and grounded to the metal window frame, which is grounded to the building structure.

The company, a manufacturer of double insulating glass solar control windows, says the EMI shielding window also provides solar control. Each window is custom built.

This has been a brief look at some of the new materials being used in RF circuit design and related technologies. More will be said about new materials in relation to specific devices mentioned in the next two articles.

We are grateful to Roy Rice and Kevin Bennett, of W.R. Grace's, Washington Research Center, for background information on some of the new substrate materials being studied there and elsewhere, and to Ray Johnson, of Oak Materials Group, for an explanation of the fiberglass laminate manufacturing process.

The following companies produce the products mentioned in this special report. For additional information from these companies circle the corresponding number on the reader info card included with this issue.

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Helical-Resonator Filter Design

By Vincent G. Heesen
Microcom Corp.
Warminster, Penn.

Helical coil resonators fill the need for small, highly selective bandpass filters exhibiting low insertion loss in the VHF and UHF ranges. A helical resonator consists of a shielded resonate section of transmission line. The center conductor is a helically wound coil. The coil is securely affixed to the shield (outer-conductor) at one end while the other end is open-circuited. In practice, the open circuited end is often terminated in a small trimmer capacitor which serves as a frequency adjustment and mechanical support.

The shield may be cylindrical or square in shape. Shields of square cross section yield unloaded Qs that are 20 percent higher than cylindrical shields of the same diameter to width. This program will compute the insertion loss of the more probable square shield design, which is easier to make. (An alternate approach, not factored into this program, is to reduce the square shield width by 20 percent of the computed diameter of the cylindrical shield. This will result in the same unloaded Q value; but without the reduction in insertion loss.) Many dimensional variables are found in helical resonator design; however, a number of optimum designs have been developed (1). These designs used in this program define shield/coil diameter-to-length ratio.

Butterworth filters exhibit lower insertion loss than Chebyshev filters of the same Q and bandwidth. Since reduced size and insertion loss are the desirable features of the helical resonator, the program computes the insertion loss of the preferred Butterworth designs. Consult the attenuation curves for Butterworth filters (2) to determine the number of poles (resonators) required to yield the desired rejection outside the passband. The program will accept from two to seven poles.

Coupling into or out of the resonator may be accomplished with probes or coupling loops placed in proximity of the coil or tap directly attached to the coil. Inductive coupling of adjacent coils is often achieved through openings in their common shield wall. Determination of the size and location of these apertures defies

```
100 CALL CLEAR
110 PRINT "  ***HELICAL RESONATORS***": : :
120 REM W.MACALINE. R.SCHILDKNECHT-1959 :A.Zverev-1967 & V.Heesen-1983
130 PRINT "THIS PROGRAM CALCULATES THE":"PHYSICAL and ELECTRICAL":"PROPERTIES of
 HELICAL COIL":"RESONATERS.": :
140 FO=0 :: ZO=0 :: BW=0 :: RT=0 :: FL=0
150 PRINT :: INPUT "ENTER RESONATE FREQUENCY     IN MHz ":FO :: IF FO<5 OR FO>500
0 THEN 960
160 PRINT :: INPUT "ENTER RESONATOR IMPEDANCE    IN ohms ":ZO :: IF ZO<200 OR ZO>
5000 THEN 950
170 D=98*10^3/(FO*ZO):: IF D<1 THEN 180 ELSE DS=INT(D*100)/100 :: U$="inches" ::
 GOTO 190
180 DS=INT(D*1000):: U$="mils"
190 LS=1.5*DS :: IF D>1 THEN LS=INT(LS*100)/100 ELSE LS=INT(LS)
200 DC=.55*DS :: IF D>1 THEN DC=INT(DC*100)/100 ELSE DC=INT(DC)
210 L=1.5*DC :: IF D>1 THEN L=INT(L*100)/100 ELSE L=INT(L)
220 N=1900/(FO*D):: N=INT(N*100)/100 :: IF N<3.5 OR N>100 THEN 960
230 QU=50*D*SQR(FO):: QU=INT(QU)
240 QUS=QU*1.2 :: QUS=INT(QUS)
250 SP=(FO*(D^2))/2300 :: SP=INT(SP*100000)/100
260 SD=(2.606/SQR(FO))
270 WN=.4*SP :: WN=INT(WN*100)/100
280 WX=.6*SP :: WX=INT(WX*100)/100 :: IF WX<(5*SD)THEN 960
290 CALL CLEAR :: PRINT
300 PRINT TAB(6):".--------------.  ---"
310 PRINT TAB(6):"|-----Ds-------|   |"
320 PRINT TAB(6):"|   |--Dc--|":TAB(20):"|   |"
330 PRINT TAB(6):"|":TAB(10):"_______":TAB(17):"/   |-  |"
340 PRINT TAB(6):"|  (_______    ||  |"
350 PRINT TAB(6):"|    ":TAB(10):"_______)- ||  Ls"
360 PRINT TAB(6):"|  (_______ sp|Lc |"
370 PRINT TAB(6):"|":TAB(10):"_______)- ||  |"
380 PRINT TAB(6):"|  (_______    ||  |"
390 PRINT TAB(6):"|":TAB(10):"_______)  ||  |"
400 PRINT "TAP-----(__________|-  |"
410 PRINT TAB(6):"|":TAB(20):"|   |"
420 PRINT TAB(6):"|______________|  ___"
430 PRINT "Fo=":FO:"MHz":TAB(16):"Zo=":ZO:"ohms"
440 PRINT :"SHIELD DIA.(Ds)=":DS:U$
450 PRINT "SHIELD LGTH(Ls)=":LS:U$
460 PRINT "COIL DIA.  (Dc)=":DC:U$
470 PRINT "COIL LGTH. (Lc)=":L:U$
480 PRINT "WIRE SPACE.(SP)=":SP:"mils"
490 PRINT "QU(round shield)=":QU
500 PRINT "QU(square shield)=":QUS
510 PRINT :: INPUT "ENTER BW(3DB) IN MHz ":BW3 :: QL=FO/BW3 :: QO=QUS/QL
520 PRINT :"WIRE DIA.(MIN.)=":WN:"mils"
530 PRINT "WIRE DIA.(MAX.)=":WX:"mils"
540 PRINT "NUMBER of TURNS=":N
550 PRINT :: INPUT "ENTER No.of POLES (2-7)":NP :: IF NP>7 THEN 550
560 ON NP GOTO 550,570,580,590,600,610,620
570 Q1=1.4142 :: IL=20*LOG((1.4142/QO)+1)/LOG(10):: GOTO 630
580 Q1=1 :: IL=20*LOG((2/QO^2)+(2/QO)+1)/LOG(10):: GOTO 630
590 Q1=.7654 :: IL=20*LOG((2.62/QO^3)+(3.41/QO^2)+(2.62/QO)+1)/LOG(10):: GOTO 63
0
600 Q1=.618 :: IL=20*LOG((3.24/QO^4)+(5.23/QO^3)+(5.23/QO^2)+(3.24/QO)+1)/LOG(10
):: GOTO 630
610 Q1=.518 :: IL=20*LOG((3.84/QO^5)+(7.42/QO^4)+(9.11/QO^3)+(7.43/QO^2)+(3.84/Q
O)+1)/LOG(10):: GOTO 630
620 Q1=.445 :: IL=20*LOG((4.46/QO^6)+(10/QO^5)+(14.5/QO^4)+(14.6/QO^3)+(10/QO^2)
+(4.46/QO)+1)/LOG(10)
630 PRINT :"INSERTION LOSS=":INT(IL*100)/100:"DB"
640 PRINT :: INPUT "ENTER IMPEDANCE OF TAP ":RT
```

— A BASIC Program

mathematical analysis and they are, therefore, determined empirically. On the bright side, the location of taps can be calculated with reasonable accuracy. The program will compute the tap location in terms of turns or degrees from the grounded end of the coil.

The application of helical resonators has two practical limitations. One occurs when the required number of turns is less than three. Here the pitch of the helix is less than its radius and it ceases to be a helix. The other limit, encountered at low frequencies, is when the required wire diameter falls below five times the skin depth for that frequency. The program displays an error message on the screen if the design is not within these practical limits.

Dimensional relationships for helical inductors have been compiled and evaluated experimentally in a number of laboratory models (1). These equations and those for computation of insertion loss of Butterworth responses (2) and unloaded Q of resonators with copper inner and outer conductors constitute the program's design integrity.

Written in BASIC on a TI 99/4A computer, the program has been run successfully on several models of microcomputers without modification. Memory is limited to less than 5K bytes and display width need not exceed 30 columns. Conversion from radians to degrees and natural log to log base 10 has been accomplished where necessary. Those without printers or not requiring hard copies may delete lines 710 through 940.

```
670 SNN=ATN(SN)*RAD
680 TLN=(N*SNN)/90 :: TLN=INT(TLN*1000)/1000
690 TLD=N*SNN*4 :: TLD=INT(TLD)
700 PRINT :"TAP LOCATION=":TLN:"TURNS OR":TLD:"DEGREES FROM GROUND."
710 PRINT :: INPUT "HARD COPY REQUIRED (Y/N)":P$
720 IF P$<>"Y" THEN 950 ELSE OPEN #3:"PIO"
730 PRINT #3: :TAB(25):"***HELICAL RESONATOR DESIGN***" :: IF FL=1 THEN 880
740 PRINT #3: :"PROJECT:____________________________________________":TAB(56):
"DATE:________________": :
750 PRINT #3: :TAB(6):".--------------.  ---":TAB(30):"NOTES: 1. BW(3DB)=":BW3:":
 No.POLES=":NP
760 PRINT #3:TAB(6):"|-----Ds-------|    |":TAB(37):"2. Q (square shield) used for
 INS. LOSS."
770 PRINT #3:TAB(6):"|  |--Dc--|":TAB(20):"|    |"
780 PRINT #3:TAB(6):"|":TAB(10):"_______":TAB(17):"/ |-  |"
790 PRINT #3:TAB(6):"|  (_______    ||  |"
800 PRINT #3:TAB(6):"|    ":TAB(10):"_______)- ||  Ls"
810 PRINT #3:TAB(6):"|  (_______ sp|Lc |"
820 PRINT #3:TAB(6):"|":TAB(10):"_______)- ||  |"
830 PRINT #3:TAB(6):"|  (_______    ||  |"
840 PRINT #3:TAB(6):"|":TAB(10):"_______)  ||  |"
850 PRINT #3:"TAP-----(__________|-  |"
860 PRINT #3:TAB(6):"|":TAB(20):"|    |"
870 PRINT #3:TAB(6):"|______________|  ___" :: FL=1
880 PRINT #3: :"RESONATE FREQUENCY=":FO:"MHz: IMPEDANCE=":ZO:"ohms: INSERTION LO
SS=":INT(IL*100)/100:"DB"
890 PRINT #3: :"SHIELD DIA.(Ds)=":DS:U$:TAB(35):"SHIELD LGTH. (Ls)~":LS:U$
900 PRINT #3:"COIL DIA.   (Dc)=":DC:U$:TAB(35):"COIL LENGTH. (Lc)=":L:U$
910 PRINT #3:"WIRE SPACING (SP)=":SP:"mils":TAB(35):"QU=":QU:"or":QUS:"(square s
hield)"
920 PRINT #3:"NUMBER of TURNS=":N:TAB(35):"WIRE DIA.(MIN.) =":WN:"mils"
930 PRINT #3:"TAP IMPEDANCE  =":RT:"ohms":TAB(35):"WIRE DIA.(MAX.) =":WX:"mils"
940 PRINT #3:"TAP POSITION =":TLN:"TURNS OR":TLD:"DEGREES FROM GROUNDED END." ::
 CLOSE #3
950 PRINT :: INPUT "RERUN PROGRAM? (Y/N)":R$ :: IF R$="Y" THEN 100 ELSE END
960 PRINT :"THIS DESIGN IS INADVISABLE!!" :: GOTO 950
EXAMPLE:

                          ***HELICAL RESONATOR DESIGN***

PROJECT:_Channel 78I Pilot Filter________  DATE:__1-12-85___

     .--------------.  ---      NOTES: 1. BW(3DB)= 4 : No.POLES= 2
     |-----Ds-------|    |              2. Q (square shield) used for INS. LOSS.
     |  |--Dc--|    |    |              3. Butterworth rejection ≈19 dB @ ±6mHz
     |   _______/   |-   |
     |  (_______    ||   |
     |   _______)-  ||   Ls
     |  (_______ sp |Lc  |
     |   _______)-  ||   |
     |  (_______    ||   |
     |   _______)   ||   |
TAP-----(__________|-    |
     |              |    |
     |______________|  ---

RESONATE FREQUENCY= 499.25 MHz: IMPEDANCE= 390 ohms: INSERTION LOSS= 2.02 DB

SHIELD DIA.(Ds)= 503 mils          SHIELD LGTH. (Ls)~ 754 mils
COIL DIA.   (Dc)= 276 mils         COIL LENGTH. (Lc)= 414 mils
WIRE SPACING (SP)= 54.98 mils      QU= 562 or 674 (square shield)
NUMBER of TURNS= 7.55              WIRE DIA.(MIN.) = 21.99 mils
TAP IMPEDANCE  = 75 ohms           WIRE DIA.(MAX.) = 32.98 mils
```

References

1. Macalpine, W.W. and Schildkenecht, R.O., Coaxial Resonators with Helical Inner Conductors, Proceedings of the IRE, Vol. 47, No. 12, p.2100, December, 1959.
2. Zverev, A.I., Handbook of Filter Synthesis, John Wiley & Sons, New York, 1967.

About the Author

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Introduction to Electromagnetic Pulse

By Kendall Childers
Senior Scientist

There are electromagnetic disturbances associated with the detonation of chemical explosives; therefore it was no surprise that there were electromagnetic disturbances associated with nuclear explosives. What was a surprise was the extent of the geographical coverage, the bandwidth of the energy spectrum and the amplitude of some of the disturbances. The nuclear induced disturbance is called Nuclear Electromagnetic Pulse (NEMP) or simply Electromagnetic Pulse (EMP).

EMP is caused by electrons ejected from materials by gamma-rays and X-rays emitted from the nuclear explosions. EMP goes by a variety of aliases; High altitude EMP (HEMP), Low altitude EMP (LEMP), Source Region EMP (SREMP), System Generated EMP (SGEMP), Internal EMP (IEMP), etc. The names identify the source of the EMP and are a "shorthand" used to indicate the characteristics of the EMP of interest. This article will deal exclusively with HEMP, the most serious threat to telecommunication systems.

Generation of HEMP

When the gamma-rays from an exo-atmospheric nuclear explosion descend to an altitude of about 40 km, the air becomes sufficiently dense that there are significant interactions. By the time the gamma-rays penetrate to an altitude of about 20 km, they are completely absorbed in the atmosphere. The primary interaction, Compton collision, results in an ejected electron and a scattered gamma-ray. The ejected electrons are turned by the earth's magnetic field (similar to the deflection [turning] of the electron beam in a TV tube by the yoke). The process of accelerating (deflecting) charged particles generates electromagnetic radiation.

The HEMP area of coverage is determined by the area of the spherical cap enclosed by the tangent drawn from the point of the explosion to the surface of the earth. An easy set of numbers to remember is: HEMP from a nuclear explosion at an altitude of 300 miles above the surface of the earth will illuminate a 3,000 mile diameter region on the surface of the earth.

The gamma-rays from a nuclear explosion are emitted in a burst with a duration of around 10 nanoseconds. Therefore, HEMP is a pulse. The risetime of the pulse is related to the duration of the burst of gamma-rays, a few to around 10 nanoseconds. The decay of the pulse is caused by very complicated processes, which result in pulse lengths from about 1/10th to about one microsecond. The frequencies of interest when one is dealing with pulses are determined by taking the Fourier transform of the pulse. HEMP is typically "full energy rich" up to about 1 MHz and has significant energy content up to at least 100 MHz.

The degree of deflection of the ejected electrons by the earth's magnetic field depends on the direction of the electron trajectory compared to the direction of the earth's magnetic field. If the directions are perpendicular, deflection is maximized; if they are parallel, deflection is minimized. The amount of electromagnetic radiation is related to the degree of deflection, the larger the deflection the greater the radiation. The gamma-rays travel radially outward from the explosion, and the electrons are ejected "primarily in the forward direction", i.e., radially outward from the explosion. The declination of the earth's magnetic field means that (in the northern hemisphere) north of the explosion there is a region where the ejected electrons are parallel to the earth's magnetic field — in that direction there will be no HEMP. Likewise there will be a region south of the explosion where the ejected electrons are perpendicular to the earth's magnetic field — in that direction the EMP will be the maximum possible, usually characterized by a peak electric field strength of 50,000 volts/meter. In other directions HEMP will have intermediate amplitudes.

The precise characteristics of HEMP depend on the size of the nuclear explosion and the geometric relationship between the position of the explosion, the observer and the earth. Since it is not possible to specify a unique set of parameters, a composite "worst case" waveform is used. The "worst case" threat retains the nastiest characteristics of the various forms of HEMP, namely; the fastest risetime — less than 10 nanoseconds, the maximum peak electric field strength — about 50,000 volts/meter, and the longest pulse duration — about one nanosecond. The electric field strength for "worst case" HEMP is described with a double exponential (1):

$$E(t) = E_o \left[e^{-t/t1} - e^{-t/t2}\right]$$

where:
- E(t) = electric field strength as a function of time
- Eo : related to peak electric field strength, about 52,500 volts/meter
- t = time
- t1 : related to pulse width, about 250 nanoseconds
- t2 : related to rise time, about 2 nanoseconds

HEMP is a plane wave with a wave impedance of 377 ohms, therefore the corresponding magnetic field strength is given by: $H(t) = E(t)/377$
The peak "worst case" magnetic field strength is about 133 amps/meter.

The energy density in HEMP is small, about 1 joule/m^2 but the power density is large, about 7 megawatts/m^2. Whereas a significant power is incident on small (square meter) structures, significant energy is incident only on truly large (many square meter) structures.

One of the advantages of describing HEMP with a double exponential is that the Fourier transform is trivial. The transform is constant from zero hertz up to a frequency of $1/(2\pi\ t1)$ = 640 kHz where it starts to roll off at 20 dB/decade up to a frequency of $1/(2\pi\ t2)$ = 76 MHz where it starts to roll off at 40 dB/decade.

The recommended procedure for protecting modern systems is to use Faraday cage inside of Faraday cage inside Faraday case. . . until sufficient shielding is accomplished that the system survives (2). The Faraday cage inside Faraday cage scenario requires single point grounding between neighboring cages, separation of signal and power cables between cages, shielding of cables between cages and "terminal protection" where the cables penetrate the cages. The key feature of this scenario is that the shielding is distributed, no single shield is required to provide an inordinate amount of shielding.

References:

1. R. Sherman et al, "EMP Engineering and Design Principles", Bell Telephone Laboratories, Inc., 1975
2. J. Miletta et al, "Defense Switched Network Design Practices for Protection Against High-Altitude Electromagnetic Pulse", HDL-SR-82-2, Harry Diamond Laboratories, Adelphi, MD, 1982

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SAS-200/518	1000 - 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
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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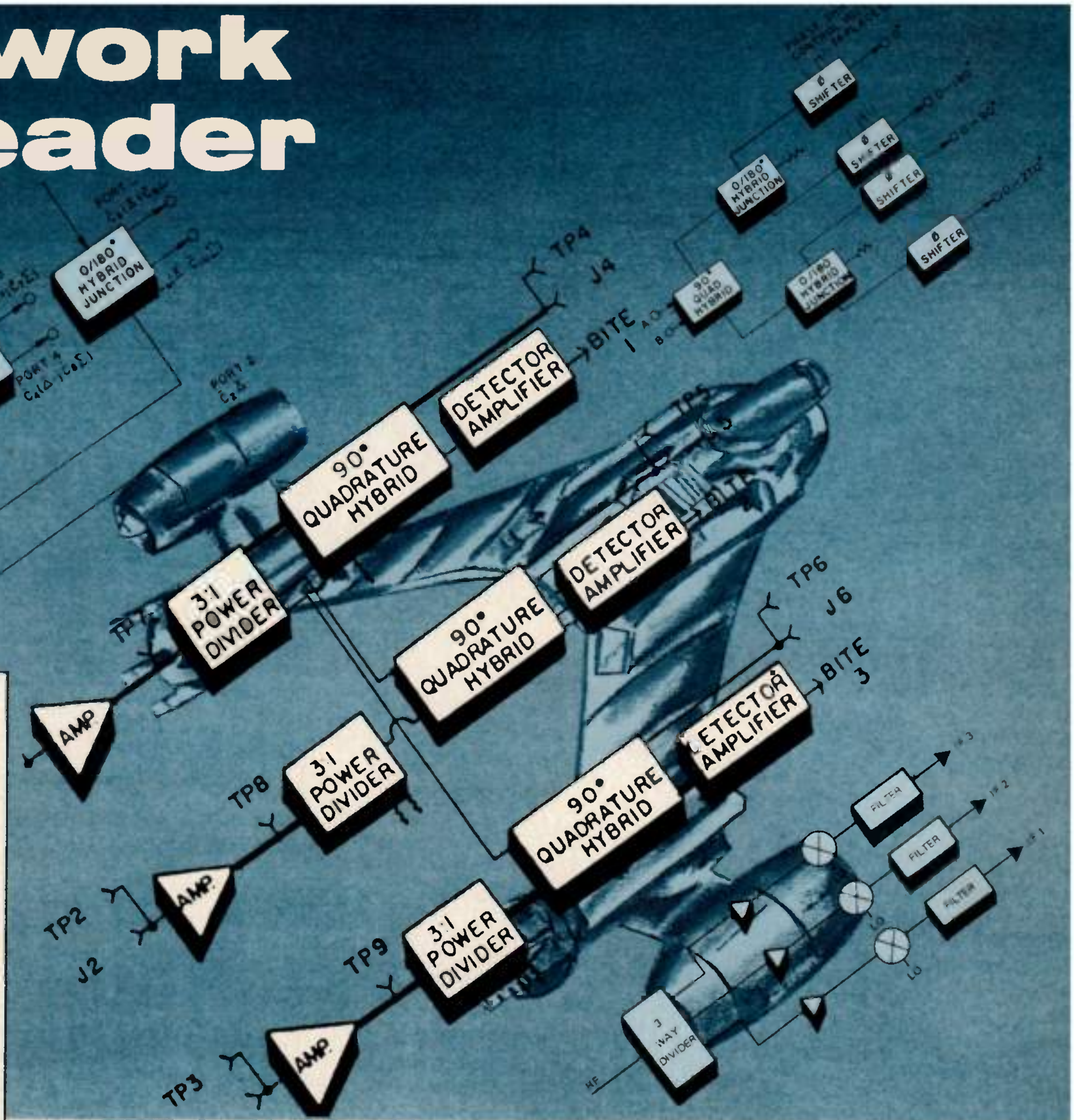
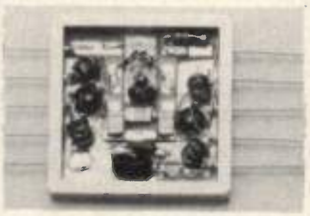
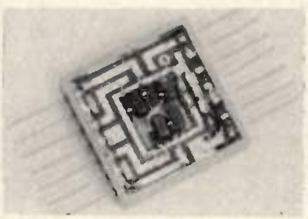
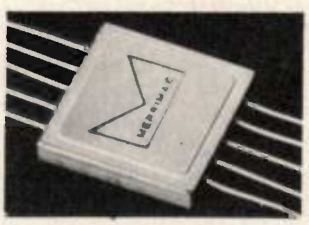



IQF-2-70 — I&Q Networks


PDF-5E-1000 — Power Divider


DMF-2A-2000 — Mixer



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A Computer Algorithm for Mixer Spurious Analysis

By Alan Victor
Motorola Communications Division

The analysis and the computer algorithm which follow allow the prediction of various mixer spurious, including general harmonic analysis, cross-over spurious location and self-quieting analysis. The approach outlined is applicable to receiver designs, synthesizers and other systems that use a multitude of mixers, oscillator sources and intermediate frequencies (IFs).

A number of mixer stages, fixed sources or sweeping sources are present in the design of receivers or frequency synthesizers. In receiver design, selection of the IF is critical in minimizing unwanted responses. A similar problem exists when a multiple loop approach is used in frequency synthesizers. In this case, the IF is analogous to the synthesizer loop bandwidth. Just as in a receiver, if a spurious response is present in the IF of a frequency synthesizer, no additional selectivity will reduce the level of spurious. One could narrow the loop bandwidth or sidestep around the interfering condition to reduce the level of spurious, but this is at the expense of increased lock time or VCO phase noise degradation. It is better to select the right oscillator frequency, IF and mixer type (1).

First, we shall define some of the most prevalent types of mixer spurious as they occur in a communications receiver. The ideal mixer would behave as a perfect product multiplier, and if the input signals (local oscillator and RF source) are sinusoidal the only IF components are the sum and difference frequencies. Simple low-pass or high-pass filtering selects the desired IF frequency. Unfortunately, the sources are rarely perfect and the mixer is not a perfect product multiplier. The mixer output consists of harmonic multiples of the local oscillator source, the RF source and any other fixed or sweeping source that might couple with the mixer inputs. The harmonic multiples at the mixer output have an integer relationship with the various mixer input signals, and the IF output can be expressed as:

$$f\ IF = N^{*}f\ RF + M^{*}f\ LO + K^{*}f\ X \qquad (1)$$

where N, M and K are integer values which are plus or minus and can be zero. The term f X is any third frequency present and might represent a fixed source or a sweeping one.

Equation 1 can be extended to any number of sources and IFs. Proper choice of the source coefficients N, M and K permit both high and low side oscillator injection (local oscillator source is either above or below the RF signal) into the mixer. Therefore, up conversion or down conversion can be analyzed. Consider the case in Equation 1 where f X is absent. If N = + 1 and M = –1 we have low side injection and the desired mixing term is:

$$f\ IF = f\ RF - f\ LO \qquad (2)$$

For N = –1 and M = +1 we have high side injection but f IF remains the same. In each case Equation 1 gives the desired result and the other result is the image frequency. A particularly troublesome spurious is given by M = N = 2 and is referred to as the ½ IF spurious. This spurious lies one half IF above or below the desired RF (depending on whether high or low side injection is used) and is difficult to filter if a wideband receiver is contemplated.

Troublesome spurious occurs for M = N ±1 or N = M ±1. When N and M differ by only an integer value close-in spurious can occur. These undesired signals, too, are close to the desired RF receive frequency and are difficult to filter. Proper selection of the IF as well as the mixer type helps reduce the level of this spurious.

Equation 1 can be handled graphically (2, 3) but quickly becomes a nightmare as the number of sweeping

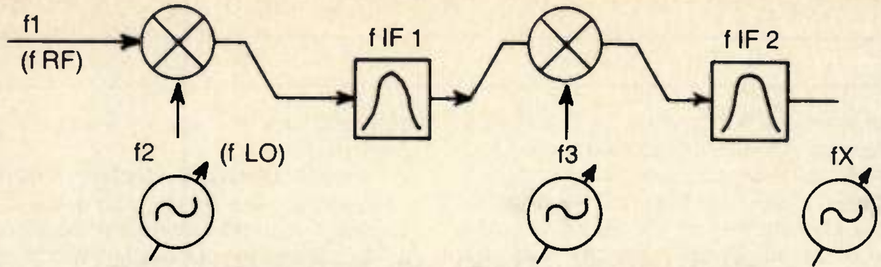

Figure 1. Three source, dual IF (dual conversion) system.

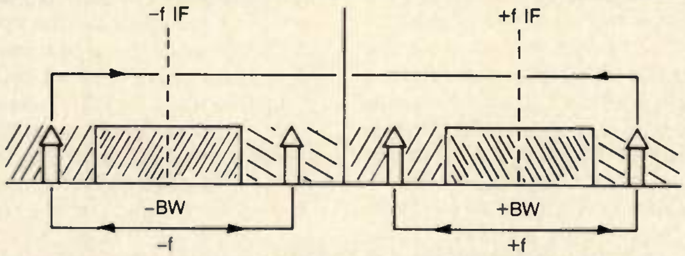

Figure 2. Movement of f IF which might constitute a crossover spurious is detected by monitoring the sign of f IF and setting and clearing flags. Arrows show possible direction of movement for generating a spurious frequency detect.

sources:	f5	f4	f3	f2	f1
	0	0	0	0	0
	0	0	0	0	1
	0	0	0	1	1
	0	0	0	1	0
	0	0	1	1	0
	0	0	1	1	0
	0	0	1	0	1
3 sources:	0	0	1	0	0
combinations	1	1	1	0	0
	1	1	1	0	1
	1	1	1	1	1
	1	1	1	1	0
	1	1	0	1	0
	1	1	0	1	1
	0	1	0	0	1
4 sources:	0	1	0	0	0
combinations	1	1	0	0	0
	1	1	0	0	1
	1	1	0	1	1
	1	1	0	1	0
	1	1	1	1	0
	1	1	1	1	1
	1	1	1	0	1
	1	1	1	0	0
	1	0	1	0	0
	1	1	1	0	1
	1	1	1	1	1
	1	1	1	1	0
	1	1	0	1	0
	1	1	1	1	1
	1	1	1	0	1
5 sources:	1	0	0	0	0
combinations					

Figure 3. Grey-Code Sequence for Multiple Signal Sources

Every zero accompanied by a one indicates that the frequency term (f1 through f5) is stepped from a minimum frequency to the maximum. If a one is accompanied by a zero then the frequency term is stepped back from f maximum to f minimum. The program routine includes three sources, but any number is handled by this technique.

sources or IFs increases. This computer program handles the above equation and allows all three sources to be swept. Two IFs are checked in the computer routine, but any number of IFs as well as any number of swept sources can be accommodated.

Figure 1 illustrates the system under consideration. To keep the number of possible spurious signals reasonable the IF bandwidth or the search range is made adjustable. Additional reduction in the number of M, N and K spurious response data points is possible if selectivity or mixer suppression is factored into the program (4). The starting and ending values for the coefficients of each source are independent and also adjustable in range.

Several problems are addressed in the program to allow all possible spurious to be detected without an undue increase in computation time. Crossover spurious, for example, can be particularly troublesome, especially if swept sources are used. These spurious signals can move through the IF and, therefore, can have zero offset from the specified IF center frequency. Instead of trying to calculate where these crossovers occur precisely, we need only determine that a crossover spurious does exist.

Figure 2 illustrates the technique used. The program checks the sign of the calculated IF and notes whether the signal produced by the spurious lies within the IF, above it or below it. This calculation is done for the extreme end frequencies of each swept source. Clearly, if the spurious produces an IF signal within the specified search range, the spurious condition is met. If the signal lies below the IF range, a negative flag is set; otherwise, a positive flag is set. The state of the flag is checked on each calculation as the swept sources are moved to their next extreme frequency point. If any of these set flags change sign from one calculation to the next, the IF signal produced by the spurious must cross over the IF center frequency and a spurious condition exists.

Note that equation 1 is really quite general. The algorithm does not care what the signal terms are, and it is up to the individual to determine what will be identified as the RF signal, the LO and the IF.

The program will handle a multitude of signal sources and IF frequencies. The routine being discussed will handle three sources and two IF frequencies. All of the sources can be swept or fixed. The program steps the sources in a Grey-Code sequence, given in Figure 3. Thus, each source is essentially swept one at a time and the program looks for a valid spurious condition.

Given three oscillators, 16 possible mixing conditions exist. These conditions take into account the sweeping of the three oscillators as well as the type of mixing, i.e., sum mixing or difference mixing. In addition, we need to consider both high and low side injection. Since we can take the absolute value of the result for high or low side injection and arrive at the same spurious response, only eight combinations are necessary. In addition, four combinations are needed to account for the kind of mixing, i.e. sum or difference.

To save computation time the four mixing combinations are presented in a menu and the user is asked to select the appropriate case type, one through four, or case five, which selects all combinations. The main subroutine in the program is SEARCH, which increments the coefficients of the three oscillators, f1, f2 and f3, using the alpha variables N, M and K. The mixing "type" is selected by the variables X, Y and Z and is controlled by selecting the desired case routine.

The spurious analysis does not actually sweep the three oscillators but instead makes a spurious computation at both band edges for f1, f2 and f3. The four subroutines IFRANGE, FLAGSET, FLAGTEST and SPUR compute whether a spurious response falls exactly in our specified IF bandwidth. Not only the IF bandwidth but also the mirror image of the IF is checked, since this represents a valid response. Since the IF band and the mirror image IF band are used in a calculation, we are able to check for spurious which could move through the IF from a small change in any one of the signal source frequencies. Crossover spurious are checked in this manner.

The subroutine IFRANGE checks for in-band spurious. The program requests the desired IF bandwidth or search range. The subroutines FLAGSET and FLAGTEST monitor the movement of the IF spurious as the sign of the spurious changes from one side of the IF to the other; i.e. the spurious passes through either the image IF or the IF. The last major subroutine is SPUR, which gives the final result. This routine recognizes whether a single conversion analysis is being performed or a general harmonic analysis is requested. In the latter case, all three sources can be present and may be swept or fixed in frequency.

In single conversion analysis only one IF is allowed. A single conversion analysis is possible using a swept RF source (f1), a swept LO source using f2, and a fixed IF, f IF (2). The analysis using the IF and the image IF detects spurious at the RF image frequency, the half IF frequency and at many M and N frequencies where M and N differ by only unity. The significance of these spurious signals is that they occur close to the desired RF receive frequency, f1. Portions of the subroutine SPUR calculate the location of these spurious signals and the RF range over which they move. The designer is then presented with a good picture of how much RF filtering is required.

The computer routine is written in BASIC, and two versions are now complete. One is written for the series 200 HP desktop personal computer and the other for the APPLE II. A three-source, 30th order spur search takes less than 60 seconds on a personal computer, even faster if few spurious are found.

Examples

Equation 1 can be expanded to consider all possible mixing situations and account for the sweeping of sources one, two and three. Using variables N, M and K as the multiple coefficients for the three sources and variables X, Y and Z to account for the mixing type (sum mixing or difference mixing) we have the following:

$$f\ IF\ (1)\ \text{or}\ f\ IF\ (2) = N{*}X{*}f1 + M{*}Y{*}f2 + K{*}Z{*}f3 \qquad (3)$$

Since $f\ IF = ABS\ (-f1\ -f2\ -f3) = (f1 + f2 + f3)$, only half of the 16 possible sweeping cases need to be analyzed. So, we have the following equations:

$$\begin{aligned} f\ IF\ (1)\ \text{or}\ f\ IF\ (2) &= N{*}X{*}f1\ min + M{*}Y{*}f2\ min + K{*}Z{*}f3\ min \\ &= N{*}X{*}f1\ min + M{*}Y{*}f2\ min + K{*}Z{*}f3\ max \\ &= N{*}X{*}f1\ min + M{*}Y{*}f2\ max + K{*}Z{*}f3\ max \qquad (4) \end{aligned}$$

and the remaining five terms follow the Grey-Code sequence generated by Figure 3.

As an aid in understanding the spurious problem, some examples are shown in Figure 4 which illustrate the material covered.

Consider an FM receiver covering 88-108 MHz. The first IF is 10.7 MHz and the second IF is 455 kHz. A microprocessor (μP) is used to obtain a clock display function and control tuning of the receiver. The

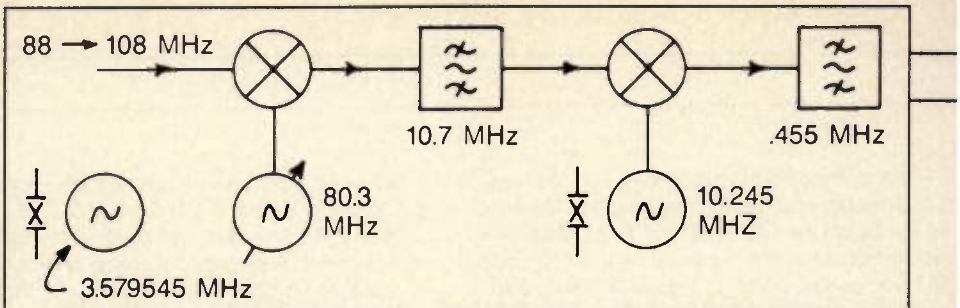

Figure 4(a). An 88-108 MHz FM Receiver Tuned to 91 MHz.

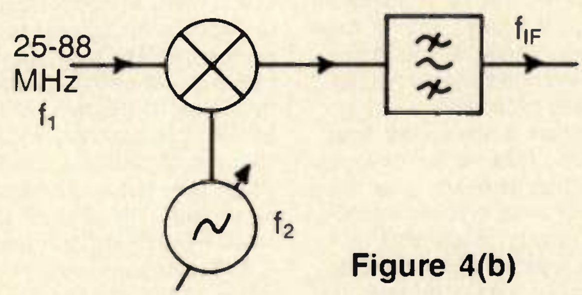

Figure 4(b)

μP oscillator is a 3.579545 MHz (f3) crystal. Using the program we find that the general spurious analysis ponts out a self-quieting condition (the receiver will essentially be quieted by its own internal oscillators) at 3*f3 which is 38.6 kHz below the 10.7 MHz IF. Clearly, this is a potential problem, especially with the first IF over 100 kHz wide. Other spurious are noted, including some which also effect the second IF.

Consider a communications receiver for the 25-88 MHz band (Fig. 4b). Low-side injection is used with up-conversion and the first IF is 90 MHz. A single conversion spurious analysis points up a number of harmonic related spurious, indicating the need for sub-octave band-pass filters. A low order N, M spur exists (2,1) but is at least 46 MHz away from the desired receive frequency. A (1,2) spur also exists and is more troublesome as it is within 2 MHz of the desired receive frequency. If high side injection is used, this spurious is no longer present The (1,2) or 3rd order spurious is removed and a higher order spurious (3,2) or 5th order, becomes present. However, the increased order allows a well-designed mixer to suppress the spurious, perhaps sufficiently so that less RF filtering is necessary.

Finally, a VHF receiver is contemplated. Several IF frequencies were chosen and low- and high-side injection tried. The resultants shown in Figures 4c,d indicate the trend. An optimum IF is about 1/7 the desired receive frequency when the M, N spurious differ by unity. If a wideband receiver is contemplated, the image frequency and half IF frequency could be more of a problem than the M, N spurious. Higher IFs allow these spurious to be moved out while the M,N spurious move in closer to the desired RF frequency. High-side injection raises the order of the M + N spurious and makes the filtering task easier.

These analyses can be re-evaluated as other sources become involved. Trade-offs will be required, but the computer algorithm and approach outlined for handling these conditions should make the job a bit easier.

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3. Capraro, G.T. and Perini J., A Graphical Approach to the Intermodulation and Spurious Response Problem, *IEEE Electromagnetic Compatibility*, February 1974, pp. 38-43, Vol. 16, No. 1.

4. Meixner, Raymond R., Basic Computer Algorithm Spots Spurious Responses, *Microwaves,* March 1977, pp. 42-46.

About the Author

Alan Victor is a Senior Staff Engineer at the Motorola Communications Sector, 8000 W. Sunrise Blvd., Plantation, FL 33322. He received his BSEE degree from the University of Florida in 1971 and an MSEE from Florida Atlantic University in 1980. He has been with Motorola since 1971, and is a member of the Motorola Science Advisory Board.

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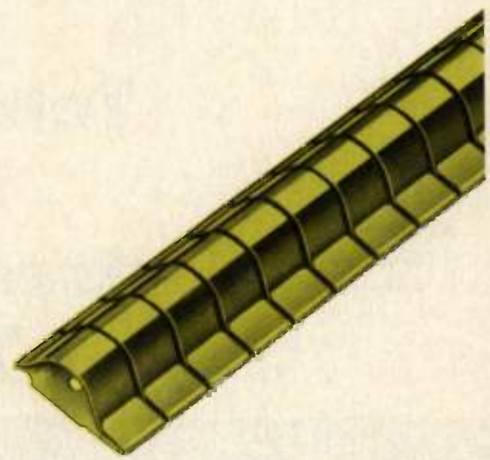

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*******************************
*         SPURSEARCH          *
*                             *
* GENERAL SPURIOUS ANALYSIS   *
*        VERSION  1.9         *
*   A.M. VICTOR   8/17/84     *
*******************************

COMPUTING CASE 1 (+,-,-)

N*F1             M*F2            K*F3
 0                0               3

DELTA IF1                    DELTA IF2

-38.6 KHZ                    -10300 KHZ

COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

N*F1             M*F2            K*F3
 1                4               8
DELTA IF1                    DELTA IF2

 16.4 KHZ                    -10200 KHZ

COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

N*F1             M*F2            K*F3
 1                5               8
DELTA IF1                    DELTA IF2

 10300 KHZ                    16.4 KHZ
```

LOW SIDE INJECTION 25-88
(90 MHz IF)

```
                 N*F1            M*F2            K*F3
                  2               1               0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 46 Mhz TO 77.5 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 46 Mhz TO 77.5 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 25 Mhz TO-12.5 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 205 Mhz TO 167.5 Mhz
                 COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                 N*F1            M*F2            K*F3
                  1               2               0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 94 Mhz TO 88 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 2 Mhz TO 3 Mhz
```

```
SPURIOUS RANGE FOR F1 (Using negative I.F.)
 25 Mhz TO 40 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 122.5 Mhz TO 115 Mhz

**********************************************

                 COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                 N*F1            M*F2            K*F3
                  2               2               0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 47 Mhz TO 88 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 45 Mhz TO 45 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 25 Mhz TO 20 Mhz
**********************************************

                 COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                 N*F1            M*F2            K*F3
                  3               2               0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 31.3333333333 Mhz TO 73.3333333333 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 60.6666666667 Mhz TO 81.6666666667 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 25 Mhz TO 13.3333333333 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 147.5 Mhz TO 141.6666666667 Mhz
**********************************************
```

LOW SIDE INJECTION 25-88
(90 MHz IF)

```
*******************************
*         SPURSEARCH          *
*                             *
* GENERAL SPURIOUS ANALYSIS   *
*        VERSION  1.9         *
*   A.M. VICTOR   8/17/84     *
*******************************
COMPUTING CASE 1 (+,-,-)
 COMPUTING CASE 1 (+,-,-)

                 N*F1            M*F2            K*F3
                  2               0               0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

Crossover at infinity: M or N equals zero
Simple harmonic multiple of RF equals IF
 45 Mhz TO 45 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 127.5 Mhz TO 110 Mhz
Crossover at infinity: M or N equals zero
Simple harmonic multiple of RF equals IF

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 25 Mhz TO-45 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 147.5 Mhz TO 200 Mhz
**********************************************
```

```
                 N*F1            M*F2            K*F3
                  3               0               0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

Crossover at infinity: M or N equals zero
Simple harmonic multiple of RF equals IF
 30 Mhz TO 30 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 142.5 Mhz TO 125 Mhz
Crossover at infinity: M or N equals zero
Simple harmonic multiple of RF equals IF

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 25 Mhz TO-30 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 147.5 Mhz TO 185 Mhz
**********************************************

                 N*F1            M*F2            K*F3
                  1               1               0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 92 Mhz TO 88 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 0 Mhz TO 4 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 25 Mhz TO-25 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 180 Mhz TO 180 Mhz
**********************************************

                 COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                 N*F1            M*F2            K*F3
                  3               4               0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 163.433333333 Mhz TO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 27.4333333333 Mhz TO 30.075 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 151.5 Mhz TO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 15.5 Mhz TO 21.125 Mhz
**********************************************
**********************************************

                 COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

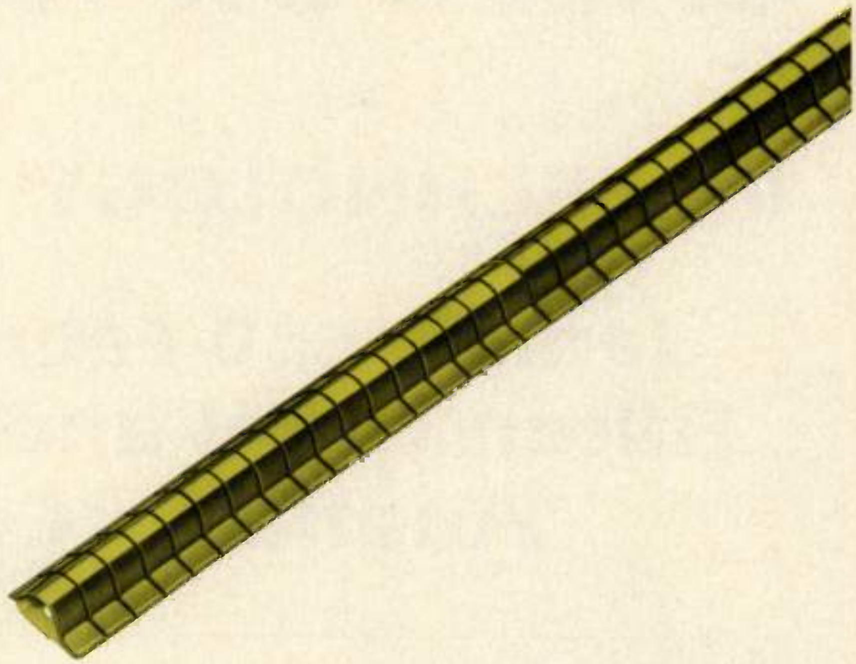
                 N*F1            M*F2            K*F3
                  4               5               0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 152.1 Mhz TO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 16.1 Mhz TO 20.48 Mhz

SPURIOUS RANGE FOR F1 (Using negative I,F.)
 143.15 Mhz TO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 7.15 Mhz TO 13.32 Mhz
**********************************************
```

17.9 IF
LOW SIDE INJECTION

...or this narrower strip...



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****************************************************

        COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                  N*F1            M*F2           K*F3
                   5               4              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 157.1 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 11.625 MhzTO 16.9 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 149.94 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 20.575 MhzTO 24.06 Mhz
****************************************************


                   6               5              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 162.9 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 5.72 MhzTO 11.1 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 156.933333333 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 12.88 MhzTO 17.0666666667 Mhz
****************************************************

                  N*F1            M*F2           K*F3
                   7               6              0
 SPURIOUS RANGE FOR F1 (Using plus I.F.)

  136 MhzTO 167.042857143 Mhz
 DELTA SPURIOUS F1 FROM DESIRED F1
  1.78333333333 MhzTO 6.95714285714 Mhz

 SPURIOUS RANGE FOR F1 (Using negative I.F.)
  136 MhzTO 161.928571429 Mhz
 DELTA SPURIOUS F1 FROM DESIRED F1
  7.75 MhzTO 12.0714285714 Mhz
 ****************************************************
```

17.9 IF
HIGH SIDE INJECTION

```
 ********************************
 *          SPURSEARCH          *
 *                              *
 * GENERAL SPURIOUS ANALYSIS    *
 *          VERSION  1.9        *
 *    A.M. VICTOR    8/17/84    *
 ********************************
     COMPUTING CASE 1 (+,-,-)
      COMPUTING CASE 1 (+,-,-)

                  N*F1            M*F2           K*F3
                   1               1              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 139.5 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 0 MhzTO 0 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 134.7 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 42.8 MhzTO 42.8 Mhz
****************************************************

                  N*F1            M*F2           K*F3
                   2               2              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 166.8 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 10.7 MhzTO 10.7 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 145.4 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 32.1 MhzTO 32.1 Mhz
****************************************************

        COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                  N*F1            M*F2           K*F3
                   2               3              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 187.85 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 48.35 MhzTO 43.7333333333 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 166.45 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 26.95 MhzTO 29.4666666667 Mhz
****************************************************
****************************************************

        COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                  N*F1            M*F2           K*F3
                   3               4              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 164.6 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 25.1 MhzTO 27.45 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 150.333333333 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 10.8333333333 MhzTO 16.75 Mhz
****************************************************
```

21.4 IF
LOW SIDE INJECTION

```
****************************************************

                  N*F1            M*F2           K*F3
                   3               2              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 137.4 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 35.9 MhzTO 36.6 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 123.133333333 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 57.3 MhzTO 50.8666666667 Mhz
****************************************************
****************************************************

                  N*F1            M*F2           K*F3
                   4               3              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 151.9 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 16.8 MhzTO 22.1 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 141.2 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 31.0666666667 MhzTO 32.8 Mhz
****************************************************
****************************************************

                  N*F1            M*F2           K*F3
                   5               4              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 160.6 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 7.25 MhzTO 13.4 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 152.04 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 17.95 MhzTO 21.96 Mhz
****************************************************
****************************************************

                  N*F1            M*F2           K*F3
                   6               5              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 166.4 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 1.52 MhzTO 7.6 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 159.266666667 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 10.08 MhzTO 14.7333333333 Mhz
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```

21.4 IF
HIGH SIDE INJECTION

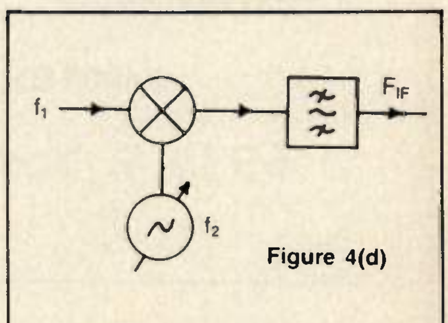

Figure 4(d)

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

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

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

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

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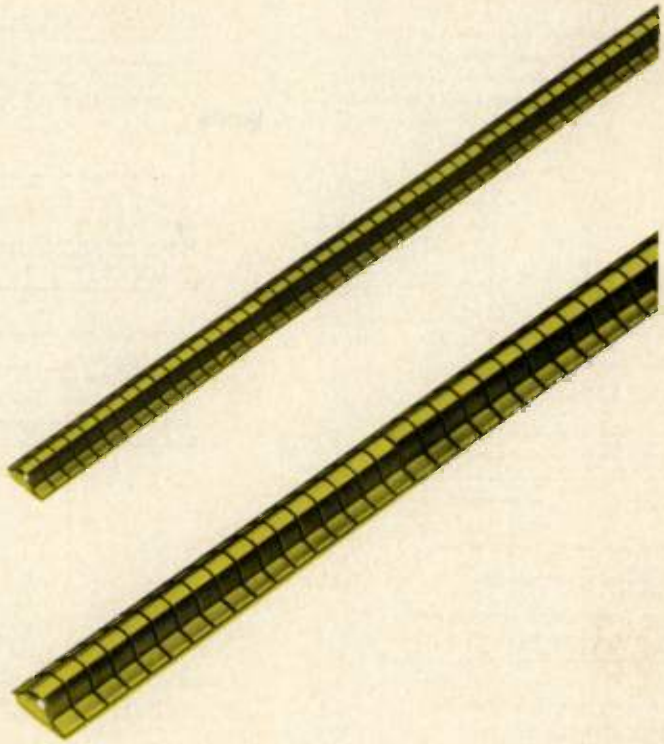

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               ******************************
               *         SPURSEARCH         *
               *                            *
               * GENERAL SPURIOUS ANALYSIS  *
               *        VERSION  1.9        *
               *   A.M. VICTOR   8/17/84    *
               ******************************
              COMPUTING CASE 1 (+,-,-)
               COMPUTING CASE 1 (+,-,-)

          N*F1            M*F2             K*F3
           1               1                0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 166 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 0 MhzTO 0 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 76 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 90 MhzTO 90 Mhz
**************************************************

          N*F1            M*F2             K*F3
           1               2                0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 227 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 91 MhzTO 64.5 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 137 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 1 MhzTO 19.5 Mhz
**************************************************

          COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

          N*F1            M*F2             K*F3
           2               2                0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 143.5 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 22.5 MhzTO 22.5 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 98.5 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 67.5 MhzTO 67.5 Mhz
**************************************************
```

45.0 IF
HIGH SIDE INJECTION

```
               ******************************
               *         SPURSEARCH         *
               *                            *
               * GENERAL SPURIOUS ANALYSIS  *
               *        VERSION  1.9        *
               *   A.M. VICTOR   8/17/84    *
               ******************************
              COMPUTING CASE 1 (+,-,-)
               COMPUTING CASE 1 (+,-,-)

          N*F1            M*F2             K*F3
           1               1                0
SPURIOUS RANGE FOR F1 (Using plus I.F.)
```

```
 226 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 90 MhzTO 90 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 0 MhzTO 0 Mhz
**************************************************

          COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

          N*F1            M*F2             K*F3
           2               2                0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 203.5 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 67.5 MhzTO 67.5 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 158.5 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 22.5 MhzTO 22.5 Mhz
**************************************************

          N*F1            M*F2             K*F3
           3               2                0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 161 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 .5 MhzTO 13 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 131 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 45.5 MhzTO 43 Mhz
**************************************************
```

45.0 IF
HIGH SIDE INJECTION

```
High Side Injection 25-88 (90 mhz. IF)

**************************************************

          COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

          N*F1            M*F2             K*F3
           2               1                0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 102.5 MhzTO 88 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 77.5 MhzTO 92 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 25 MhzTO 44 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 25 MhzTO 44 Mhz
**************************************************

          COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

          N*F1            M*F2             K*F3
           2               2                0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 160 MhzTO 88 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 135 MhzTO 135 Mhz
```

```
SPURIOUS RANGE FOR F1 (Using negative I.F.)
 70 MhzTO 88 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 45 MhzTO 45 Mhz
**************************************************

          N*F1            M*F2             K*F3
           3               2                0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 106.66666667 MhzTO 88 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 81.66666667 MhzTO 91 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 46.66666667 MhzTO 88 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 21.66666667 MhzTO 1 Mhz
**************************************************

          COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

          N*F1            M*F2             K*F3
           8               1                0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 25.625 MhzTO 33.5 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 .625 MhzTO 54.5 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 25 MhzTO 11 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
```

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High Side Injection 136-174 (45 mhz IF)

               ******************************
               *         SPURSEARCH         *
               *                            *
               * GENERAL SPURIOUS ANALYSIS  *
               *        VERSION  1.9        *
               *   A.M. VICTOR   8/17/84    *
               ******************************
              COMPUTING CASE 1 (+,-,-)
               COMPUTING CASE 1 (+,-,-)

          N*F1            M*F2             K*F3
           1               1                0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 226 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 90 MhzTO 90 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 0 MhzTO 0 Mhz
**************************************************

          COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

          N*F1            M*F2             K*F3
           2               2                0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 203.5 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 67.5 MhzTO 67.5 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 158.5 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 22.5 MhzTO 22.5 Mhz
**************************************************
```

```
                m*F1              m*F2              K*F3
                 3                 2                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MHzTO 161 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 .5 MHzTO 13 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 131 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 45.5 MHzTO 45 MHz
------------------------------------------------

                COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 3                 3                 0

                    Low Side Injection 136-174 (45 mhz. IF)

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                    *          SPURSEARCH          *
                    *                              *
                    * GENERAL SPURIOUS ANALYSIS    *
                    *         VERSION  1.9         *
                    *   A.M. VICTOR    6/17/84     *
                    --------------------------------
                   COMPUTING CASE 1 (+,-,-)
                    COMPUTING CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 1                 1                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 0 MHzTO 0 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 84 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 90 MHzTO 90 MHz
------------------------------------------------

                COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 1                 2                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 227 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 91 MHzTO 64.5 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 137 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 1 MHzTO 19.5 MHz
------------------------------------------------

                m*F1              m*F2              K*F3
                 2                 2                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MHzTO 151.5 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 22.5 MHzTO 22.5 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 106.5 MHz
DELTA SPURIOUS F1 FROM DESTRED F1
 67.5 MHzTO 67.5 MHz
------------------------------------------------

                m*F1              m*F2              K*F3
                 2                 3                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

                    136-174  Low Side Injection (21.4 mhz IF)

                    --------------------------------
                    *          SPURSEARCH          *
                    *                              *
                    * GENERAL SPURIOUS ANALYSIS    *
                    *         VERSION  1.9         *
                    *   A.M. VICTOR    6/17/84     *
                    --------------------------------
                   COMPUTING CASE 1 (+,-,-)
                    COMPUTING CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 1                 1                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 0 MHzTO 0 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 131.2 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 42.8 MHzTO 42.8 MHz
------------------------------------------------

                COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 2                 2                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MHzTO 163.3 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 10.7 MHzTO 10.7 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 141.9 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 32.1 MHzTO 32.1 MHz
------------------------------------------------

                COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 2                 3                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 182.6 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 46.6 MHzTO 43.7333333333 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 161.2 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 25.2 MHzTO 29.4666666667 MHz
------------------------------------------------

                m*F1              m*F2              K*F3
                 3                 3                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

                    136-174 Low Side Injection   (21.4 mhz IF)

 174 MHzTO 159.7333333333 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 14.2666666667 MHzTO 14.2666666667 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 145.4666666667 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 28.5333333333 MHzTO 28.5333333333 MHz
------------------------------------------------

                COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 3                 4                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 159.9333333333 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 23.9333333333 MHzTO 27.45 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 145.6666666667 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 9.6666666667 MHzTO 16.75 MHz
------------------------------------------------

                COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 4                 4                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MHzTO 157.95 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 16.05 MHzTO 16.05 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 147.25 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 26.75 MHzTO 26.75 MHz
------------------------------------------------

                m*F1              m*F2              K*F3
                 4                 5                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 148.6 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 12.6 MHzTO 17.68 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 157.9 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 1.9 MHzTO 9.12 MHz
------------------------------------------------

                    136-174 High Side Injection (21.4 mhz IF)

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                    *          SPURSEARCH          *
                    *                              *
                    * GENERAL SPURIOUS ANALYSIS    *
                    *         VERSION  1.9         *
                    *   A.M. VICTOR    6/17/84     *
                    --------------------------------
                   COMPUTING CASE 1 (+,-,-)
                    COMPUTING CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 1                 1                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 178.8 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 42.8 MHzTO 42.8 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 0 MHzTO 0 MHz
------------------------------------------------

                COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 2                 2                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 168.1 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 32.1 MHzTO 32.1 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 146.7 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 10.7 MHzTO 10.7 MHz
------------------------------------------------

                m*F1              m*F2              K*F3
                 3                 2                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MHzTO 137.4 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 53.9 MHzTO 36.6 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 123.1333333333 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 57.3 MHzTO 50.8666666667 MHz
------------------------------------------------

                COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 3                 3                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

                    136-174 mhz High Side Injection  (21.4 mhz IF)

 164.5333333333 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 28.5333333333 MHzTO 28.5333333333 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 150.2666666667 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 14.2666666667 MHzTO 14.2666666667 MHz
------------------------------------------------

                m*F1              m*F2              K*F3
                 4                 3                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MHzTO 151.9 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 16.8 MHzTO 22.1 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 141.2 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 31.0666666667 MHzTO 32.8 MHz
------------------------------------------------

                COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 4                 4                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 162.75 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 26.75 MHzTO 26.75 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 122.05 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 16.05 MHzTO 16.05 MHz
------------------------------------------------

                m*F1              m*F2              K*F3
                 5                 4                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MHzTO 160.6 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 7.25 MHzTO 13.4 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 152.04 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 17.95 MHzTO 21.96 MHz
------------------------------------------------

                COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 5                 5                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 161.68 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 25.68 MHzTO 25.68 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 152.12 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 17.12 MHzTO 17.12 MHz
------------------------------------------------

                m*F1              m*F2              K*F3
                 6                 5                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MHzTO 166.4 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 1.52 MHzTO 7.6 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 129.2666666667 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 10.08 MHzTO 14.7333333333 MHz
------------------------------------------------

                    136-174 Low Side Injection (17.9 mhz IF)
------------------------------------------------
                    --------------------------------
                    *          SPURSEARCH          *
                    *                              *
                    * GENERAL SPURIOUS ANALYSIS    *
                    *         VERSION  1.9         *
                    *   A.M. VICTOR    6/17/84     *
                    --------------------------------
                   COMPUTING CASE 1 (+,-,-)
                    COMPUTING CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 1                 1                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 0 MHzTO 0 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 138.2 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 35.8 MHzTO 35.8 MHz
------------------------------------------------

                COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 2                 2                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MHzTO 165.05 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 8.95 MHzTO 8.95 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 147.15 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 26.85 MHzTO 26.85 MHz
------------------------------------------------

                COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 2                 3                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 186.1 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 50.1 MHzTO 46.0666666667 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 168.2 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 32.2 MHzTO 34.1333333333 MHz
------------------------------------------------

                m*F1              m*F2              K*F3
                 3                 3                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

                    136-174 Low Side Injection (17.9 mhz IF)

 176 MHzTO 162.0666666667 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 11.9333333333 MHzTO 11.9333333333 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 150.1333333333 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 23.8666666667 MHzTO 23.8666666667 MHz
------------------------------------------------

                COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                m*F1              m*F2              K*F3
                 3                 4                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 163.4333333333 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 27.4333333333 MHzTO 30.075 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 151.5 MHzTO 174 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 15.5 MHzTO 21.125 MHz
------------------------------------------------

                m*F1              m*F2              K*F3
                 4                 4                 0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MHzTO 160.575 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 13.425 MHzTO 13.425 MHz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MHzTO 151.625 MHz
DELTA SPURIOUS F1 FROM DESIRED F1
 22.375 MHzTO 22.375 MHz
------------------------------------------------
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```
                 COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                 N*F1           M*F2           K*F3
                  4              3              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 152.1 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 16.1 MhzTO 20.48 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 143.15 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 7.15 MhzTO 12.22 Mhz
***************************************************

                 N*F1           M*F2           K*F3
                  5              5              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)


                 136-174 High Side Injection (17.9 mhz IF)

 136 MhzTO 159.68 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 14.22 MhzTO 14.22 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 152.52 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 21.46 MhzTO 21.48 Mhz
***************************************************

                        ********************************
                        *         SPURSEARCH           *
                        *                              *
                        * GENERAL SPURIOUS ANALYSIS    *
                        *         VERSION 1.9          *
                        *    A.M. VICTOR   6/17/84     *
                        ********************************
                      COMPUTING CASE 1 (+,-,-)
                       COMPUTING CASE 1 (+,-,-)

                 N*F1           M*F2           K*F3
                  1              1              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 171.8 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 35.8 MhzTO 35.8 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 0 MhzTO 0 Mhz
***************************************************

                 COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                 N*F1           M*F2           K*F3
                  2              2              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 162.85 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 26.85 MhzTO 26.85 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 144.95 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 8.95 MhzTO 8.95 Mhz
***************************************************

                 N*F1           M*F2           K*F3
                  3              3              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 159.8666667 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 23.8666667 MhzTO 23.8666667 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 147.9333333 MhzTO 174 Mhz


                 136-174 High Side Injection (17.9 mhz IF)

DELTA SPURIOUS F1 FROM DESIRED F1
 11.9333333 MhzTO 11.9333333 Mhz
***************************************************

                 COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                 N*F1           M*F2           K*F3
                  4              3              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 148.4 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 21.4666667 MhzTO 25.6 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 139.45 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 33.4 MhzTO 34.55 Mhz
***************************************************

                 N*F1           M*F2           K*F3
                  4              4              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 158.375 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 22.375 MhzTO 22.375 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 149.425 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 13.425 MhzTO 13.425 Mhz
***************************************************

                 COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                 N*F1           M*F2           K*F3
                  5              4              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 157.1 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 11.625 MhzTO 16.9 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 149.94 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 20.575 MhzTO 24.06 Mhz
***************************************************

                 COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                 N*F1           M*F2           K*F3
                  5              5              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 157.48 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 21.48 MhzTO 21.48 Mhz

                 136-174 High Side Injection (17.9 mhz IF)

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 [illegible] MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 14.22 MhzTO 14.22 Mhz
***************************************************

                 N*F1           M*F2           K*F3
                  6              5              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 160.9 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 5.72 MhzTO 11.1 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 156.9333333 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 12.88 MhzTO 17.6666667 Mhz
***************************************************

                 COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                 N*F1           M*F2           K*F3
                  7              5              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 139.628571429 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 32.92 MhzTO 34.3714285714 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 134.514285714 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 40.08 MhzTO 39.4857142857 Mhz
***************************************************

                 COMPUTED SPURIOUS FOR CASE 1 (+,-,-)

                 N*F1           M*F2           K*F3
                  6              6              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136.8833333 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 20.8833333 MhzTO 20.8833333 Mhz

SPURIOUS RANGE FOR F1 (Using negative I.F.)
 150.9166667 MhzTO 174 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 14.9166667 MhzTO 14.9166667 Mhz
***************************************************

                 N*F1           M*F2           K*F3
                  7              6              0
SPURIOUS RANGE FOR F1 (Using plus I.F.)

 136 MhzTO 167.042857143 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 1.7833333 MhzTO 6.95714285714 Mhz


SPURIOUS RANGE FOR F1 (Using negative I.F.)
 136 MhzTO 161.928571429 Mhz
DELTA SPURIOUS F1 FROM DESIRED F1
 7.75 MhzTO 12.0714285714 Mhz
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Preventing Unwanted Oscillations in Crystal Oscillators Part II

By James W. Wieder
Westinghouse Defense &
Electronics Center

Part II discusses non-crystal controlled oscillations and crystal spurious oscillations. It then concludes with a discussion of six design verification tests useful in uncovering potential unwanted oscillations.

A non-crystal controlled oscillation does not rely on the quartz blank for the requirements of oscillation. The unwanted oscillation is unrelated to the desired oscillation and will have poor frequency stability. There are several possible causes of non-crystal controlled oscillation.

a) The oscillation may occur via a reactance which shunts the quartz blank. The shunting reactance may be the crystal's CO. Oscillation via CO usually occurs at a frequency well above the desired oscillation. In series resonant oscillators where an inductor (LO) is used to parallel resonate out CO (at the desired frequency of oscillation), the LO may shunt the quartz blank at frequencies well below the desired oscillation.

b) A larger portion of the oscillator may be shunted by a stray impedance. The shunting path generally occurs from a low impedance point in the circuit to a high impedance point. The high impedance point is generally due to a parallel LC resonance (possibly due to stray reactance).

c) Oscillation may occur due to a sustaining stage instability. The transistor or amplifier becomes unstable due to certain combinations of impedances loading the amplifier input and/or output.

Unwanted Oscillation Via CO or LO

A typical value of CO for AT-cut crystals above 1 MHz is 2 to 6 pF. Figure 1 compares the reactance of CO with the crystal motional resistance. Above about 60 MHz, the reactance of CO is no longer very large compared with the crystal motional resistance. At 150 MHz, for example, the reactance of 5 pF (around 210 ohms) is only about twice the motional resistance ($R1_7$) of a seventh overtone AT-cut crystal. At higher frequencies (say 500 MHz), the reactance of CO may be less than the motional resistance of the crystal's desired overtone.

Unwanted oscillation via the crystal CO may occur at an unintended peak of the overtone select filter or for oscillators above 60 MHz within the overtone select bandpass. Oscillation via CO within the overtone select passband can be prevented by parallel resonating an inductor (LO) with CO at the desired overtone frequency. Depending on CO, this is usually done for oscillators above 60 to 120 MHz. The effect of LO on a seventh overtone 175 MHz AT-cut crystal is shown in Figure 2.

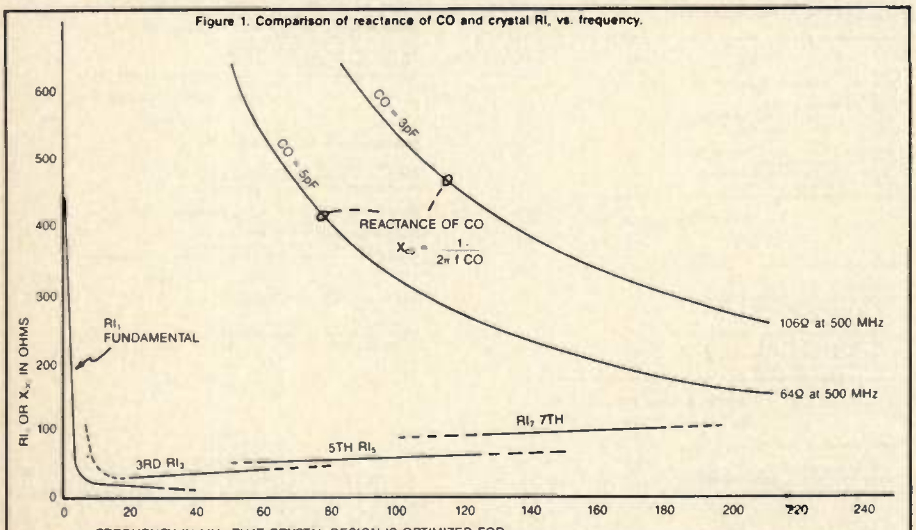
It is important that the sharpness (Q) of the CO-LO parallel resonance be significantly lower than that of the overtone select filter. This assures that the impedance of the CO-LO parallel combination remains large over the overtone select passband. In some cases, the CO-LO Q must be deliberately lowered by using resistance in series with the inductor.

Note that the CO-LO resonance is only useful in preventing oscillation via CO from occurring within the overtone select bandpass. At frequencies well above the CO-LO resonance, the CO-LO combination will still appear as CO and hence a low impedance. At frequencies well below the CO-LO resonance, the CO-LO combination will appear as LO and a low impedance. If an unintended peak exists, non-crystal controlled oscillation may occur via CO or LO above or below (respectively) the desired overtone.

A second reason for parallel resonating out CO is to increase an oscillator's trim range. As shown in Figure 3, CO has a significant effect on the 175 MHz crystal's effective reactance and resistance near series resonance. The increasing effective resistance limits the frequency adjustment range to 4 or 5 KHz above series resonance. As shown in Figure 3, parallel resonating out CO with LO dramatically increases the possible trim range by maintaining a constant effective resistance over a wider frequency range.

To determine if a non-crystal controlled

Figure 1. Comparison of reactance of CO and crystal Rl, vs. frequency.



oscillation is due to either CO or LO shunting of the crystal blank, remove the crystal from the circuit and replace it with a capacitance equal to CO (while keeping LO in the circuit). In a properly designed circuit, no oscillation should occur.

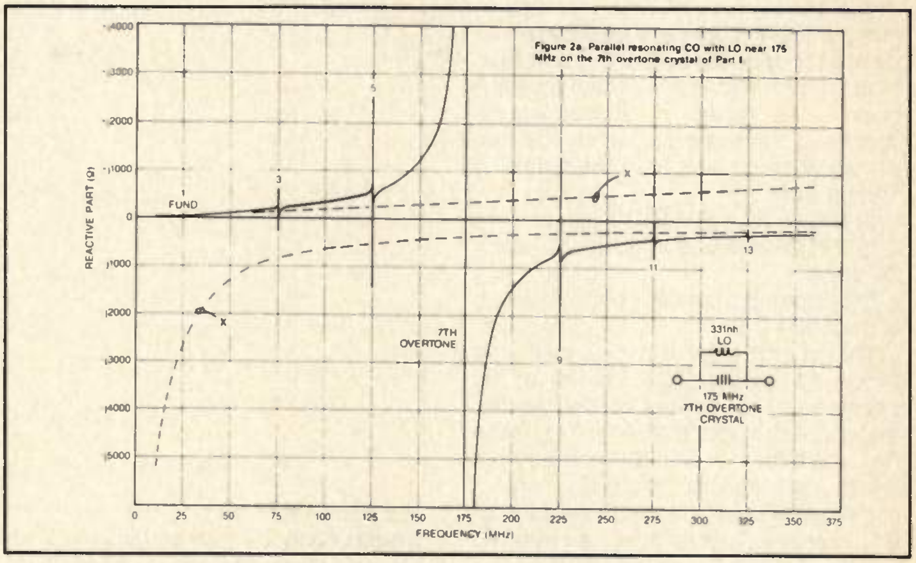


Figure 2a. Parallel resonating CO with LO near 175 MHz on the 7th overtone crystal of Part I.

Unwanted Oscillation due to Sustaining Stage Instability.

All transistors and amplifiers in addition to their forward gain also exhibit an internal reverse gain (loss). It is this internal reverse gain that can lead to a sustaining stage instability. For certain combinations of transistor (or amplifier) source and load impedances, the transistor may become unstable at a frequency which is unrelated to the desired frequency of oscillation. The oscillation is independent of the transfer function H (f) of the feedback stage. The oscillation, however, is influenced by the input impedance of the feedback stage since this represents the transistor load impedance. The oscillation is also influenced by the output impedance of the feedback stage since this represents the transistor source impedance. This type oscillation will occur when the circuit is reconfigured as shown in Figure 4. No signal source needs to be applied in Figure 4 for the unwanted oscillation to occur.

The reverse gain characteristics differ with the transistor type. Even if two transistors are biased to the same forward gain, one type may be unstable while another type works fine. References 2 and 3 discuss a method of determining if any linear 2-port is unconditionally stable at each frequency (stable for any combination of source and load impedances). This method is based on S-parameter (scattering parameter) device characterization. A method of determining the source and load impedances where the linear 2 port is stable at a given frequency (referred to as conditionally stable) is also shown.

The transistor can generally be stabilized by modifying the input or output impedance of H (f). When the frequency of the transistor instability is away from the desired crystal frequency, it may be possible to modify the input and output impedances of H (f) at the unstable frequency without affecting the desired H (f) transfer function. If the circuit can be accurately modeled, both the SPICE and COMPACT simulation programs can provide insight into a sustaining stage instability.

Oscillation at a Crystal Spurious Response

In addition to the fundamental and the odd overtone responses, quartz crystals exhibit spurious responses unrelated to the desired response. This is because the quartz blank is capable of vibrating in many different modes and directions. The number of spurious responses and their frequency locations are unique for each crystal. The model for a spurious response is the same as the crystal fundamental responses, with the following differences:

a) $R1_S$ of the spurious is higher

b) Q of the spurious is higher (L1 larger, C1 smaller)

c) Temperature stability of the spurious is generally poor

The quartz crystal is designed and screened so the $R1_S$ values of all spurious in the vicinity of the desired response are larger than $R1_d$. ($R1_d$ is the $R1_n$ value for the desired response.) A crystal specification normally lists a minimum allowed value for the ratio of $R1_S$ over $R1_d$. This ratio is often referred to as the spurious resistance ratio. For fundamental and third overtone AT-cut crystals (where $R1_d$ is small), a spurious resistance ratio of 4:1 or larger is obtainable. At higher overtones, $R1_d$ is larger and the spurious resistance ratio will be lower. For the seventh overtone, a ratio of only 2:1 may be feasible. A low spurious resistance ratio is one of the factors that limits the production use of crystals to the fifth or seventh overtone.

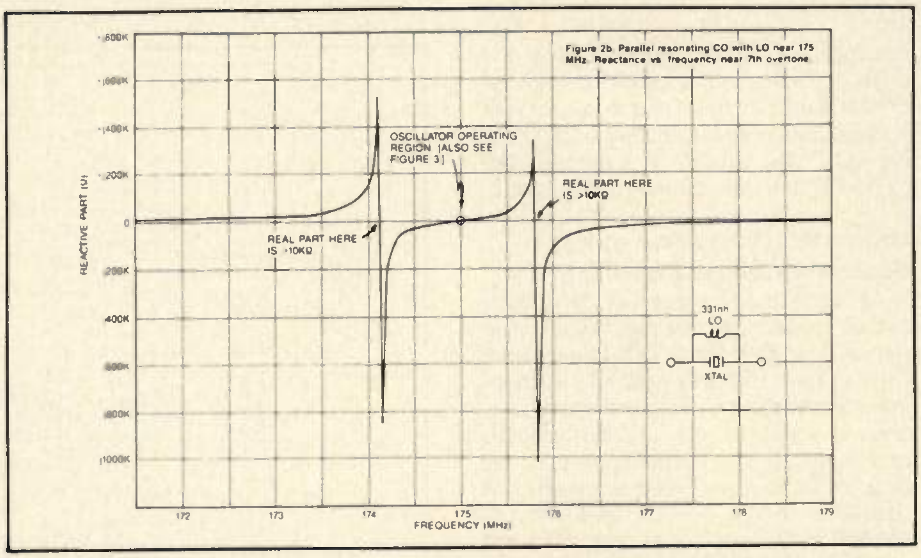


Figure 2b. Parallel resonating CO with LO near 175 MHz. Reactance vs frequency near 7th overtone.

Oscillation at a crystal spurious might occur in one of two ways.

a) Oscillation may occur at a spurious located within the overtone select bandpass (near the desired response).

b) Oscillation may occur at a spurious which happens to be located at an unintended peak. In this case, the spurious will be located well away from the desired response. The crystal manufacturer normally screens only for spurious that are near the desired response. To prevent

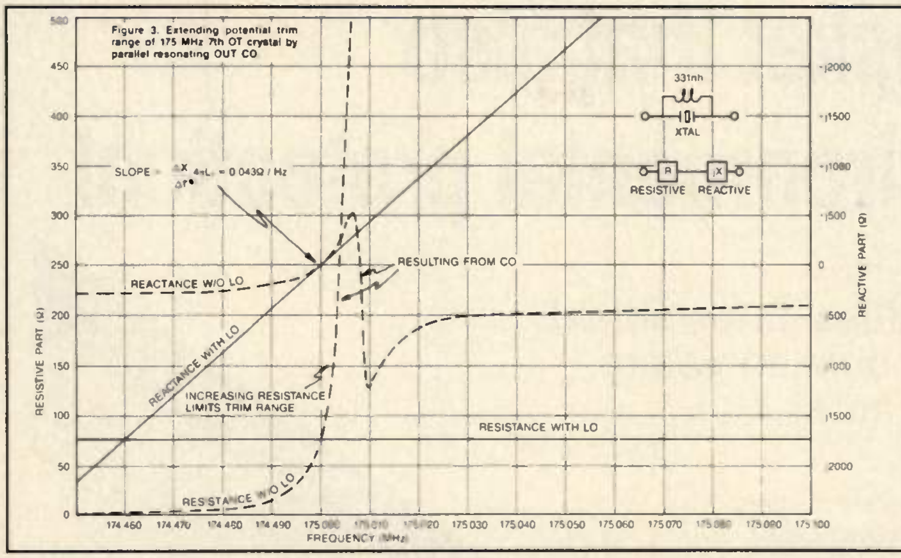


Figure 3. Extending potential trim range of 175 MHz 7th OT crystal by parallel resonating OUT CO

oscillation at a spurious located outside the screen range you must verify that unintended peaking does not occur.

For spurious located near the desired response, oscillation can be prevented by assuring that oscillation will not occur with the minimum $R1_S$ value the crystal specification would allow. This can be checked by adding resistance in series with the crystal to determine the R1 value where the desired oscillation will not start up. The minimum value of $R1_S$ should be larger than this R1 value.

Note that specifying a minimum allowed spurious resistance ratio may not adequately specify the minimum allowed spurious resistance ($R1_S$). If a particular crystal in a batch has a low value of $R1_d$, the spurious resistance ratio allows the spurious $R1_S$ to also have a low value — low enough that the requirements of oscillation might also be met by the spurious. For this reason, a minimum allowable value of $R1_S$ should also be specified where practical. For the higher overtone crystals, a minimum $R1_S$ value significantly larger than the maximum value of $R1_d$ can only be obtained at a very low crystal yield. For these crystals the specification of a minimum allowed $R1_S$ value may not be practical.

The higher the overtone used, the more likely oscillation may occur at a crystal spurious. This is because:

a) The close $R1_d$ and $R1_S$ values make it difficult to prevent the requirements of oscillation from being satisfied at a spurious, and

b) A sharper overtone bandpass must be used. This makes it more likely that this bandpass may discriminate against the desired overtone in favor of a spurious. It is important that the overtone bandpass not be made any sharper than is necessary. The effect of tuning on

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possible bandpass discrimination should also be considered.

Many VHF oscillators end up employing a design where the requirements for oscillation may also be satisfied at a spurious but start-up domination by the desired response is used. For a random noise start-up, domination by the desired frequency is aided by two factors.

a) The lower $R1_d$ value of the desired response results in a larger gain at the desired frequency. This helps the desired oscillation to build up faster than a spurious.

b) The higher Q of the spurious means the closed loop spurious bandwidth is narrower. The resulting spurious group phase delay will be larger. This causes the spurious oscillation to build up slower than the desired oscillation.

When relying on start-up dominance, the following should be considered.

a) Another frequency source (with frequency near a spurious) might leak into an oscillator during start-up and allow the spurious to build up faster than the desired response. The isolation between oscillators should be maximized. When crystal switching or oscillator switching is used, the first oscillation should be allowed to die out before the next oscillation is allowed to start up.

b) An oscillator could have a non-crystal controlled oscillation near a crystal spurious. The non-crystal controlled oscillation may start up more quickly than the desired oscillation. The non-crystal controlled oscillation may then run synchronously with the crystal spurious oscillation.

Testing to Uncover the Problems

The causes of unwanted oscillations are numerous. Experience in selecting the oscillator type, its design and layout can minimize potential problems, but due to the complex interaction of oscillator components, design oversight is possible. The ability of a computer simulation to reveal potential unwanted oscillations is limited by the extent to which stray reactances are accounted for and by the sophistication of the transistor (amplifier) model. Testing the oscillator in its normal oscillating configuration is of limited use in determining if the requirements of oscillation are met at more than one frequency. The desired oscillation may dominate the unwanted oscillation for the particular oscillator and unit being tested. Variations in either the test conditions or oscillator components could result in an unwanted oscillation becoming a problem. The following tests are useful in uncovering potential unwanted oscillations.

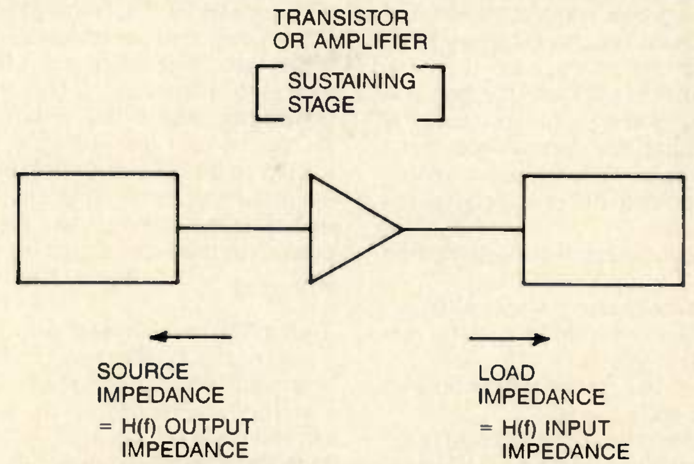

Figure 4. Reconfiguration of the oscillator circuit so a sustaining stage instability can occur with the loop opened.

Test 1. Open Loop Amplitude Response

A reliable method of detecting many potential unwanted oscillations is to open the loop and examine the gain (and in some cases the phase) response. Since the layout can be significant, the open loop response should be performed on the actual production layout. Conducting this test during the development phase may prove useful in establishing the suitability of the oscillator circuit type and may provide insight into the desired final layout.

A frequency synthesizer can be used along with a vector voltmeter, spectrum analyzer or network analyzer.

The following guidelines should be considered.

a) To see the crystal response, the frequency synthesizer should be swept in 100 Hz or finer steps in the vicinity of each crystal overtone.

b) The cause of any circuit peaking should be determined. As was previously shown, a minor circuit modification may turn a small peak into a significantly larger peak. In some situations the phase variation of a small peak may be more observable than the amplitude variation.

c) Open loop response should be examined at several trim capacitor values across the trim range.

d) Measuring the open loop response over temperature and voltage helps verify the needed excess gain at the desired oscillator frequency.

e) Use signal levels representative of oscillation start-up. Typical excess gain at start-up should be 2 to 6 dB.

f) Final oscillation level can be checked by increasing the signal level to the point where unity gain at the desired frequency is reached.

g) Carefully choose the point where the loop is to be broken.

h) Load the input and output of the open loop with the same (powered) circuit it will normally be seeing. Portions of two other oscillator boards can be interconnected using short leads.

i) To minimize standing waves on the cable, use a 10 dB attenuator at the point where the frequency synthesizer is applied to the circuit.

j) Use probes to observe the loop input and output. The probe input impedance should be large enough to prevent significant loading of the circuit being tested.

k) The impedance loading the input and output of the transistor (or amplifier) should be the same as for the closed loop.

The open loop response measurements can be used to improve the computer modeling of the various stray reactances. In the ideal, the measured response would closely match that of the open loop computer model.

Test 2. Closed Loop Amplitude Response

In this test the overtone select filter is deliberately detuned so oscillation at the desired overtone does not occur. No other oscillation should be observed. A frequency synthesizer is used to apply a signal to the loop, perhaps via what is normally the oscillator output. A probe is placed at various points in the closed loop to detect amplitude peaking as the frequency synthesizer is swept. The circuit should be detuned both above and below the desired overtone. The amount of detuning necessary to prevent the desired oscillation provides a feel for the amount of excess gain. The advantages of this method over the previous are:

a) It is easier to configure the test, and

b) If probe loading is not too great the transistor input and output load impedance may be closer to the actual circuit, making it easier to observe a sustaining stage instability.

The disadvantages of this test method are:

a) Amplitude peaking which might occur at the trim values in the normal trim range will be missed,

b) Check of excess gain at the desired overtone is limited, and

c) Limited information is obtained to improve the computer model.

Test 3. Determine Resistance Where Desired Oscillation Ceases

This should be done with with either or both of the previous two tests; it provides a feel for the circuit's excess gain. Basically, resistance (RA) is added in series with the crystal until the desired oscillation will no longer start up. This test can be done over temperature, voltage and trim range. If the resistance where oscillation stops (R1 + RA) is more than two or three times the maximum crystal motional resistance, the circuit gain is probably too high and should be decreased. Additionally, to assure that oscillation at a crystal spurious is not possible, R1 + RA should be less than the minimum crystal spurious resistance. This test is not as useful as the previous two tests but is commonly done because it is so easy to do.

Test 4. Replace Crystal with CO (Max)

The crystal is removed from the circuit and replaced with CO (MAX). If the circuit has an inductor (LO) to parallel resonate with CO, leave LO in the circuit. With the crystal removed, the desired oscillation does not occur and will not dominate the non-crystal controlled oscillations. If the circuit is properly designed, no oscillation should occur over the full trim range with temperature and voltage variations. As a minimum, this test should be run at the conditions where the active device(s) have their maximum gain. To check for margin, use a capacitor larger than CO (MAX) and also use LO values on either side of the design LO value. Since the crystal is removed, unwanted oscillations at adjacent overtones or spurious are not addressed with this test.

Test 5. Place Additional Capacitance Across the Crystal

A capacitor is placed in parallel with the crystal to simulate the maximum value of crystal CO (plus additional margin). This test provides a feel for the circuit's susceptibility to oscillation (non-crystal controlled) via the crystal shunt capacitance (CO). The oscillator should be started up several times for each trim condition. No oscillation other than the desired one should be observed. No scope edge jitter or spectrum analyzer modulation sidebands should be observed. This test is easy to do but is of limited usefulness, since the desired oscillation may be suppressing all other oscillation.

Test 6. Replace Crystal with Resistor (Series Resonant Oscillator Only)

In series resonant crystal oscillators (tuned on series resonance), the crystal is essentially resistive (of value R1). If the crystal is replaced by a resistor between the minimum and maximum value of R1, an oscillation should be seen within several MHz of the crystal series resonant frequency. This provides an indication of the overtone select filter peak location. Since oscillation is not stabilized by the crystal's large $\Delta X/\Delta f$, the frequency counter will only have around four digits of short term stability.

With the resistor in place of the crystal no other oscillation frequency should be observed over the full trim range. This test, too, is of limited usefulness since the unwanted oscillations may be suppressed.

Conclusion

The choice of the start-up excess gain at the desired frequency of oscillation is critical. If the gain is too low, some oscillators will not start-up due to amplifier, crystal or reactive component variations. In some cases oscillation may stop or not start-up at certain temperatures or voltages. When the gain is made too large, unwanted oscillations are more likely. In addition, the resulting severe non-linear operation of the active device allows low frequency flicker noise to modulate onto the oscillation frequency, increasing phase noise. An oscillator design that minimizes the variation in the closed loop gain at the desired frequency is advantageous since a low gain can be used while still assuring start-up will always occur.

Even if oscillator gain at the desired frequency is optimum an unwanted oscillation may still occur due to one or more of the causes discussed in this article. In general, the higher the oscillator frequency and the higher the amplifier high frequency cut-off, the greater the chance of having an unwanted oscillation. The possibility of an unwanted oscillation in a given design or layout cannot always be seen in advance. Performing verification tests on the final circuit configuration and layout that can uncover these specific problems is an important part of the design process.

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About the Author

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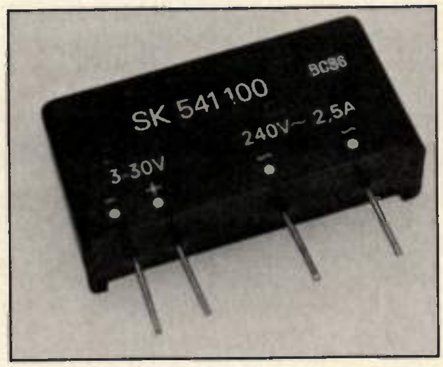
Low Distortion Programmable Oscillator

Racal-Dana Instruments Inc. announces the introduction of an ultra low distortion programmable oscillator, the Model 9085. By using an analog, two integrator loop technique, the Model 9085

achieves an output distortion of 0.01%. The Model 9085 uses a microprocessor to provide program control for ATE use in addition to providing operational flexibility for bench applications. The frequency range covered extends from 9 GHz to 330 kHz with output amplitude levels of 660 microvolts to 7 volts RMS. The output status is clearly indicated on a front panel custom four digit liquid crystal display. **Racal-Dana Instruments Inc., Irvine, Calif., INFO/CARD #175.**

Miniature Solid State Relays

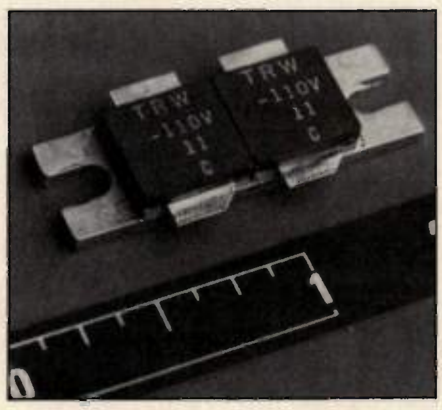
Mouser Electronics announces the availability of a quality solid state relay in



a miniature, PC-mounting design. The model ME433-SK541100 relay has all the quality features of higher-priced solid state types. It has an optocoupler input, triac output, and switches on at zero crossover voltage. Designed for low power consumption, the relay has a permanent current maximum of 2.5A. It can handle an overload of 90A (10mS) and remains energized at less than 50mA. **Mouser Electronics, Santee, Calif., INFO/CARD #173.**

Bipolar Push-Pull Power RF Amplifier

A broadband, push-pull high power, class "AB" bipolar RF amplfiier for military communications and ECM (electronic countermeasures) applications is now available from the RF Devices Division of TRW Electronic Components Group. The MRT0204-110V device provides 110 watts of CW linear power in broadband applications. Gain is 7 dB minimum at 400 MHz and 28 volts. The device is usable over a 225 to 400 MHz frequency range. The MRT0204-110V can withstand a ∞:1 VSWR (Voltage Standing Wave Ratio)



load pull at 225 MHz with a power output of 110W. **TRW Electronics Componentts Group, El Segundo, Calif. INFO/CARD #174.**

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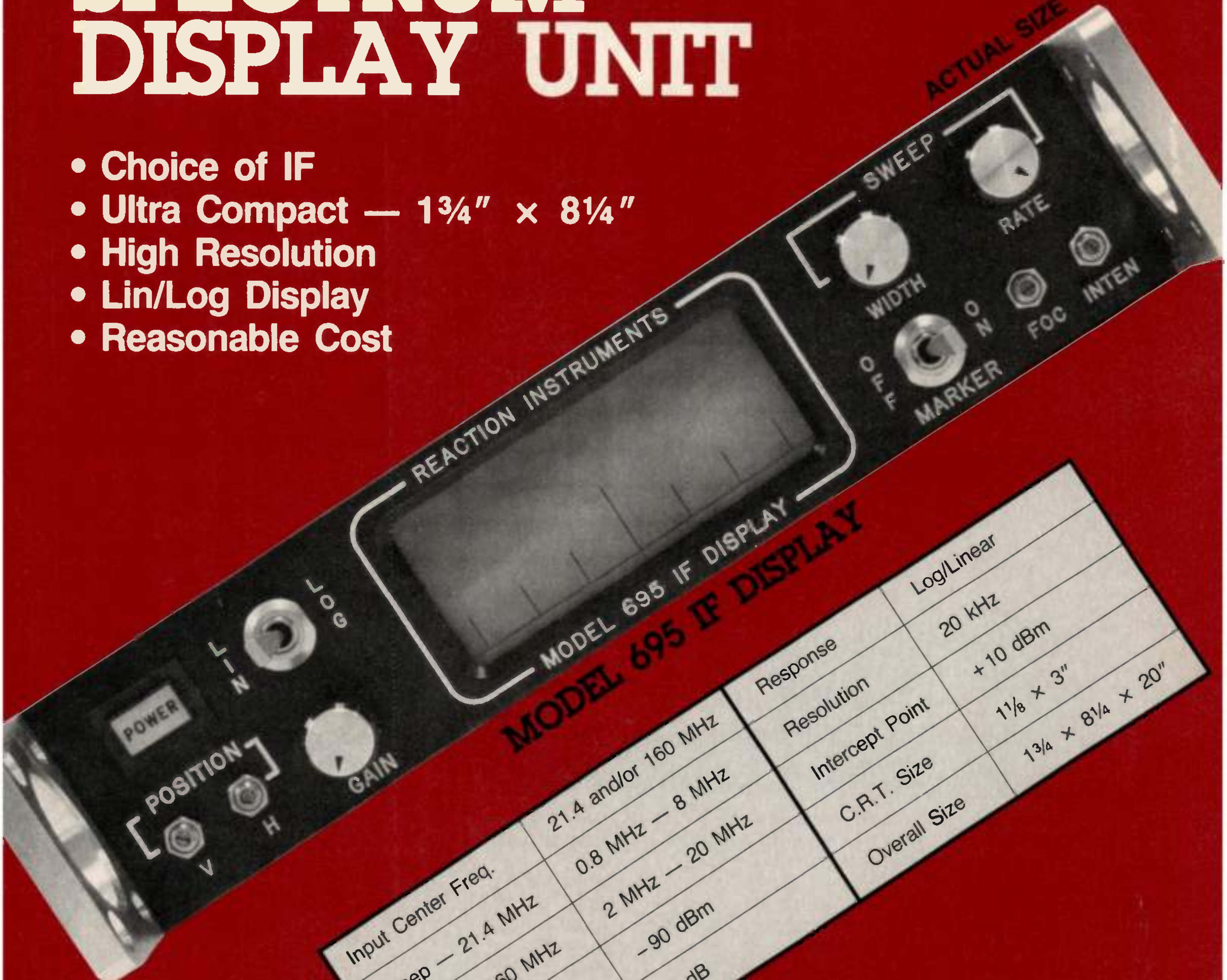

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REACTION INSTRUMENTS

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Hybrid Transmitter

RF Monolithics, a leader in SAW technology, recently introduced the SAW resonator stabilized hybrid transmitter, the only oscillator to meet FCC Part 15 regulations for low power UHF transmitters. The dedicated device offers 15.100 and 15.200 output levels using either pulse of FSK modulation. The oscillator is fully compatible with 9 volt battery operation and encoder chip drive levels. The SAW

resonator stabilized hybrid transmitter was designed for use in wireless security products, garage door openers and other remote control devices. **RF Monolithics, Dallas, Tex., please circle INFO/CARD #171.**

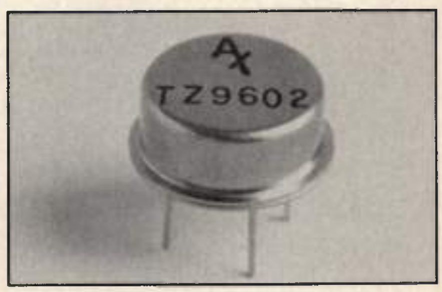
Touchstone Version 1.3

Version 1.3 of the Touchstone computer-aided engineering progrm brings new technical capabilities to the microwave and RF design engineering task. New

capabilities of the program include enhanced noise figure analysis, Monte Carlo yield prediction, HP 8510 Network Analyzer support, generalized scattering parameters based upon frequency dependent source and load impedances, Touchstone's new ability to read one and two-port Y, A, G, and H-parameters, new elements: bipolar transistor, broadside coupled lines in stripline, and rectangular waveguide termination. Voltage gain analysis for 2-port networks with 50 ohm as well as non 50 ohm source and load terminations. **EEsof, Westlake Village, Calif., INFO/CARD #170.**

RF Amplifier Model 9602

Amplifonix has announced a new RF Hybrid Amplifier, Model TZ9602 in a TO-8 hermetic package. This new design provides a gain of 11 dB typical over the frequency range of 900-1500 MHz. Other specifications include: Noise figure, 7.3



dB; Power out at 1 dB comp., +4 dBm; Max. VSWR (In/Out), 3:1/2:1; current at 15V, 36 mA temperature range; –55°C to +100°C. All units meet MIL-STD-883B screening.

Amplifonix, Inc., Bristol, Penn., **INFO/CARD #169.**

10-Watt Power Amplifier

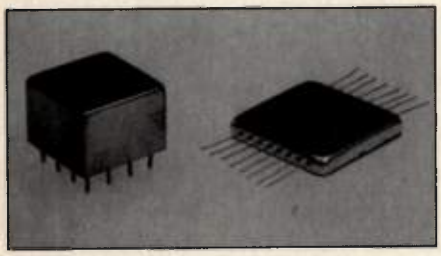
Acrian Inc. announces a 10-watt TWT replacement power amplifier that operates across the 1.0-2.0 GHz frequency range. The new amplifier, called the MB1020-10, is a solid state power module with a high output power to bandwidth ratio. The MB1020-10 features an ALC loop that allows leveling of output power. Critical specifications of the MB1020-10 include ±1 dB gain ripple (unleveled), ±.4 dB (leveled), 40 dB power gain, 20 percent efficiency, minimum 22 volt supply voltage, 2.5 A supply current, and an operating temperature range of -35 to +70 degrees C. **Acrian Inc., San Jose, Calif., please circle INFO/CARD #164.**

Coaxial Switches

RLC Electronics has introduced a line of terminated single-pole, double-throw coaxial switches for termination of the unused switch port. Electrical characteristics feature low insertion loss of .3 dB max., VSWR of 1.3 max. and isolation of 60 dB min. over the entire frequency range of DC-18 GHz. **RLC Electronics, Inc., Mt. Kisco, N.Y., please circle INFO/CARD #146.**

High Level Mixers

Synergy Microwave has introduced a new high-level mixer, giving excellent all-around performance. Model CMP-A12 covers .5-1200 MHz. Driven with a nominal +7 dBm LO, it yields typically 6 dB conversion loss and 3rd-order intercepts of typically +25 dBm (in a 50 ohm system), and is an 8-pin relay header. **Synergy Microwave Corporation, Paterson, N.J., INFO/CARD #168.**



SAW Bandpass Filters

Surface Acoustic Wave (SAW) bidirectional bandpass filters are available at frequencies from 10 MHz to 1000 MHz. Fractional bandwidths from 0.1% to 60% are produced with insertion loss that is typically 15 dB to 30 dB depending upon the substrate material chosen and other parameters. Shape factors as low as 1.15:1 are achieved and linear phase response is maintained. Rejection of at least 50 dB to 70 dB is typical in all bidirectional filters. **March Microwave, Ltd., Essex, England, INFO/CARD #167.**

High Power Lowpass Filters

CIR-Q-TEL, Inc. has developed (design patent applied for) a full line of "Ultra-Compact" high power lowpass filters. These devices generally have a low profile and are supplied with removeable connectors making them suitable as a mounting base for easy attachment of integratable sub-system components. Connectors may be: N, SC, LT and LC or other suitable high power connectors. Both Chebishev and the Levy A-Z pseudo-lowpass response and shapes are available. Applications include jamming/countermeasures, communications radar and broadcast — mobile, airborne or fixed/ground station. **CIR-Q-TEL, Kensington, Md., INFO/CARD #166.**

Model 7802-3A Receiver

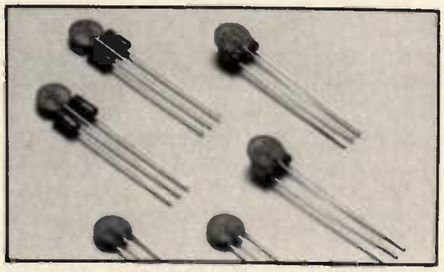
Interad Ltd. announces the availability of a frequency synthesized VHF/UHF Receiver. The Model 7802-3A Receiver has the following major features: RF input frequency — 20 MHz to 999.999 MHz; third order input — referenced to antenna input; intercept point — +5 dBm typical, 0 dBm minimum; incidental FM — 20 Hz peak; synthesizer speed — 40 μs continuous tune, 500 μs worst case. **Interad Ltd., Gathersburg, MD, please circle INFO/CARD #172.**

200 Megasample/Second Transient Recorder

A 200 megasample/sec sampling frequency, 8-bit resolution and a large, segmentable memory combine to make the recently introduced LeCroy Model TR8828C Transient Recorder an extraordinarily powerful addition to the LeCroy modular digital oscilloscope family. The PC based DSO is multichannel, multitimebase, with full waveform acquisition, viewing and archiving capabilities. The LeCroy WAVEFORM-CATALYST software package takes full advantage of the TR8828C programmability and features in providing a user friendly interface. The TR8828C saves memory by providing a means to record only selected portions of the signal, and can have memory lengths from 32K words to more than half a megaword. The TR8828C allows any graph, instrument setup, or operations sequence to be stored and recalled from disk, or output to a graphics printer. Up to 100 digitizers can be housed in benchtop or rackmounted mainframes, each with independent trigger, memory, and time/sample characteristics. The high resolution graphics permit simultaneous viewing of up to four "live" or previously stored traces, each with its own timebase and grid. **LeCroy Research Systems Corporation, Spring Valley, N.Y., please circle INFO/CARD #165.**

Disc Type PCB Mountable EMI Filters

The new DS/DSS/DST 310 series, 3-leaded, disc type, PC board mountable EMI filters are now available from Murata Erie North America, Inc. These new EMI filters not only suppress EMI over a wide



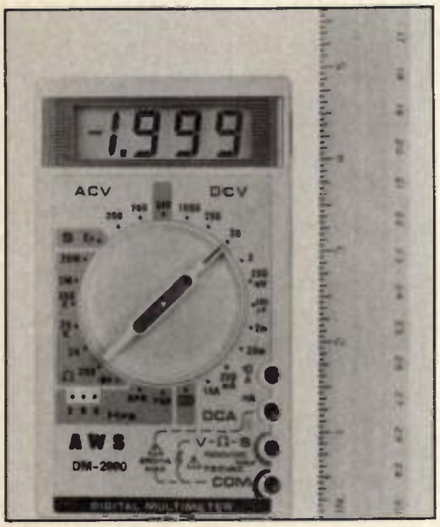
frequency range but also permit, by selection of the capacitance of the filter, the tuning of the self-resonant frequency to the frequency to be suppressed. Their DC current capacity is large, reliability is high and they can be flow-soldered. Applications include: noise suppression for electronic engine controls, electronic cash registers, car radios, digital equipment and computer peripheral equipment; and bypass/decoupling for UHF and VHF tuners and UHF receiver front ends. **Murate Erie North America, Inc., Marietta, Ga., INFO/CARD #163.**

High Power-Over the Horizon Radar

CIR-Q-TEL has developed a very rugged, high-reliability line of high power (4) filters spanning the over the horizon radar bands, 5-28 MHz; General specifications include: Power passbands: (1) 5-8.3 MHz; (2) 7.5-12.5 MHz (3) 11.5-18.8 MHz and (4) 17-28 MHz Power; 6.5 KW into 2.5:1 VSWR load continuous Power protected into infinite VSWR for 100 mS and continuous 2.5 kW into infinite VSWR; VSWR (matched load) greater than 1.25:1; Loss (matched load) greater than 0.2 dB; Rejection: less than 55 dB (2nd harmonic); 57 dB (3rd harmonic) less than 60 dB thru 15th harmonic or 300 MHz; less than 40 dB to 20th harmonic or 500 MHz. **CIR-Q-TEL, Inc. Kensington, Md., INFO/CARD #161.**

Rotary-Switch, Digital Multimeter

A.W. Sperry Instruments, Inc. announces the introduction of their new 3½-digit, rotary-switch, digital multimeters, Models DM-1000 and DM-3000. This family of DMM's, which includes the AWS DM-2000, offers a choice of features including pocket size, overload protection, 10A current readings, large, .5"-digit, easy-to-read LCD and 200 hr. battery life. the DM-1000 incorporates 6 functions on 17 ranges; the DM-2000: 8 functions on 22 ranges and the DM-3000: 9 functions on 28 ranges. All three models include: DCV, ACV, DCA, OHMS, diode test and battery test; DM-2000 adds conductance and HFE test; DM-3000 adds HFE tests, continuity buzzer and ACA. **A.W. Sperry Instruments, Inc., Hauppauge, N.Y., please circle INFO/CARD #160.**



Audio Test Automation

Tektronix has packaged a complete solution for many audio tests that includes a test program generation (TPG) tool, as well as stimulus, measurement and control capabilities. The MP 2902 audio measurement package provides a means of developing customized system software in a minimal time — without programming knowledge. MP 2902 hardware includes an AA5001 programmable distortion analyzer, a SG5010 programmable 160 kHz oscillator, a TM5006 power mainframe; a 4041 instrument controller and a 4105 color graphics display. **Tektronix, Inc., Beaverton, Ore., INFO/CARD #158.**

RF Amplifier

Amplifonix has announced a new RF hybrid amplifier, Model TM 7279 in a TO-8 hermetic package. This new design provides a gain of 13.5 dB typical over the frequency range of 5-250 MHz. Other specifications include: noise figure, 4.5 dB

power output at 1 dB comp., +23 dBm; max VSWR (In/Out), 2.01 current at 15V, 88 mA temperature range, –55°C to +100°C. All units meet MIL-STD-883B screening. **Amplifonix, Inc., Bristol, Penn., INFO/CARD #157.**

New Literature

Leader Instruments 1985 Catalog

Leader Instruments Corporation has announced the availability of their new 1985 test and measurement catalog. This 80-page comprehensive catalog details complete features, specifications and applications on more than one hundred products, including nineteen new products. LEADER's new 35 MHz 2-Channel Digital Storage Oscilloscope and the economical 100 MHz 3-Channel Dual Time Base Oscilloscope are among the most notable of the new products presented in the catalog. New video products include a Programmable Video Generator System designed for testing monochrome and color CRT monitors normally associated with computer systems and work stations. Also, LEADER entered the GPIB compatible market with the addition of a Digital LCR Meter with GPIB interface. LEADER is also introducing a new line of Signal and Sweep Generators including a 520 MHz Synthesized Signal Generator and a 1.5 GHz Sweep/Marker Generator. **Leader Instruments Corp., Hauppauge, N.Y., please circle INFO/CARD #127.**

Expanded Noise Product Catalog

Micronetics has just issued its new, expanded catalog for noise products. Micronetics products represented range from solid state noise sources DC to 65 GHz, diodes and chips to programmable noise instruments, including basic broadband types, high output level modules, modules incorporating custom control functions, noise source instruments and precision thermal noise standards. Another recent addition to its catalog pages is Micronetics new series of Noizeg solid state dual-in-line broadband noise generators. Frequencies are from 100 Hz to 20 MHz, with 14 PIN DIP hermetically sealed packaging. Also Microwave Components Catalog, MWC/985, includes a broad line of waveguide switches, coaxial switches, dummy loads, bolometers, and coaxial crystal detectors. **Micronetics, Inc., Norwood, N.J., INFO/CARD #126.**

Ferrite Devices and Filters Brochure

This new 12 page brochure and product bulletin provides up-to-date information on Isolator, Circulator & Filter Components including iso-adapters and iso-filters for Communication, Radar and EW Systems. Photos, specifications and types available are listed plus in-house custom capability. **Ute Microwave, Inc., Asbury Park, N.J., INFO/CARD #125.**

Zener Diodes Catalog

Mouser Electronics announces a new line of Zener diodes. The ME333-1N5200 series are a line of high quality 500mW Zener diodes. These Zener diodes are in a DO-35 package and have been designed and manufactured for ultra high reliability. The ME333-1N5200 series feature a tolerance of ±5%. Call or write for your free 160 page catalog. **Mouser Electronics, Santee, Calif., INFO/CARD #124.**

Diode Switches

Norsal Industries has just released three new data sheets on 1P3T diode switches. They include a line of switches consisting of series shunt, all series and terminated configurations in the .5-18 GHz region. Featured are devices with and without integral drivers, low insertion loss and high isolation characteristics. The switches are designed for military airborne environments and operate from -54°C to +125°C. The drivers have true TTL inputs which operate at a bias voltage of +5v, -12v for standard units. **Norsal Industries, Central Islip, N.Y., INFO/CARD #123.**

Radiation Test Services Brochure

Chomerics, Inc. has published a new radiation test services brochure. Entitled "Radiation Test Services: EMI Emission problems. . .We Identify and Solve Them," the publication describes Chomerics' full scale test capability, including FCC testing to Part 15, Subpart J; VDE; TEMPEST; MIL-STD 461A/B, NACSIM 5100A; IEEE-STD 587; ESD to 25kV; and shielding effectiveness testing (14 kHz to 12.4 GHz). In addition, the brochure describes how, using their on-site test facilities and in-house manufactured shielding materials, Chomerics' engineers test equipment, design suggested changes, and bring equipment into regulation compliance. The brochure also includes the FCC rules regulating RF interference caused by Class A and Class B devices, and lists equipment types tested by Chomerics. **Chomerics, Inc., Woburn, Mass., INFO/CARD #122.**

Surface Mounting Directory Update

Purchasers of the current Surface Mounting Directory and Information Service will be receiving their mid-term update volume with more than 5,000 new component listings in addition to the 21,000 listings in the annual directory. Distributed at no cost to users of the Service by DBA Consultants and Publishers, a division of D. Brown Associates, Inc., the update provides complete specs on surface mountable components, capital equipment, materials and services which have become available since last August. DBA is also accepting new orders for the Information Service, which entitles users to a bi-monthly Electronics Packaging Newsletter with up-to-the-minute data and a special person-to-person hotline number for assistance in quickly locating important information. **DBA, Ft. Washington, Penn., please circle INFO/CARD #121.**

Power Supplies and DC/DC Converters

A 12-page product brochure provides product descriptions, electrical/mechanical specifications, and price information on Computer Products' lines of open-frame linear supplies, modular switching supplies, and DIP and modular type DC/DC converters. In all, 43 different power supplies are described with output power from 15 to 150 watts. The open frame linear supplies have from one to three different outputs and are designed for applications in small business systems, data processing equipment, office products, and industrial systems and instruments. **Computer Products Inc., Pompano Beach, Fla., INFO/CARD #120.**

New Databook Covers 75 Linear Integrated Circuits

A 600-page databook and user's guide on linear integrated circuits has been published by the Raytheon Semiconductor Division. Covering 75 different devices, the book provides details descriptions and applications guidance for engineers and electronic designers. The handbook's sections include Industry Cross Reference, Quality & Reliability, Operational Amplifiers, Voltage Comparators, Digital-to-Analog Converters, Voltage References, Voltage Regulators and Special Functions.

The handbook is free-of-charge. **Raytheon Semiconductor Division, Mountain View, Calif., INFO/CARD #119.**

Free Power Supply Catalog

A new 28-page short-form power supply catalog from the Power Conversion Group of Computer Products, Inc. provides electrical/mechanical specifications, features, and ordering information on the groups' lines of AC/DC linear and switching power supplies and DC/DC converters. **Computer Products Power Conversion, Pompano Beach, Fla. INFO/CARD #118.**

Application Note Details Microwave Switching

A new application note from Hewlett-Packard Company, AN 332, "Microwave Switching From SPDT To Full-Access Matrix," helps create custom switching interfaces for designers of microwave ATE systems. Most microwave automatic-test systems use some type of signal-switching interface unit to connect stimulus and measuring equipment in the system to the units under test. Frequently the special nature of a test situation requires that these units be custom-designed interfaces. **Hewlett-Packard, Palo Alto, Calif., INFO/CARD #117.**

Bulk Acoustic Wave Delay Device Brochure

Teledyne Microwave announces its new bulk acoustic wave delay device brochure. This 12 page brochure provides detailed information including application notes, design guidelines, configuration types and electrical performance. The brochure is especially helpful for manufacturers of frequency memory systems, radar simulation systems and altimeter calibration equipment. **Teledyne Microwave, Mountain View, Calif., please circle INFO/CARD #116.**

RF Link Catalog

Neulink, a division of Celltronics, Inc., has announced the availability of a free catalog which features RF links for the VHF, UHF, and Midband frequencies. Neulink's RF links replace hard-wire systems where voice, tone, or low speed digital information is being sent or received. **Neulink, San Diego, Calif., please circle INFO/CARD #113.**

Short Form Catalog

A new short form catalog from Ballantine Laboratories, Inc., describes key specifications and features for its broad line of precision electronic test and measuring instruments. Covered are oscilloscopes, both for portable general purpose use and laboratory units; scope calibrators; voltmeters and special purpose instruments; multimeters; counters and counter-timers; and AC calibration standards. Also included are the company's programmable instruments and automated computer-based systems for calibrating oscilloscopes and meters. **Ballantine Laboratories, Inc., Boonton, N.J., INFO/CARD #112.**

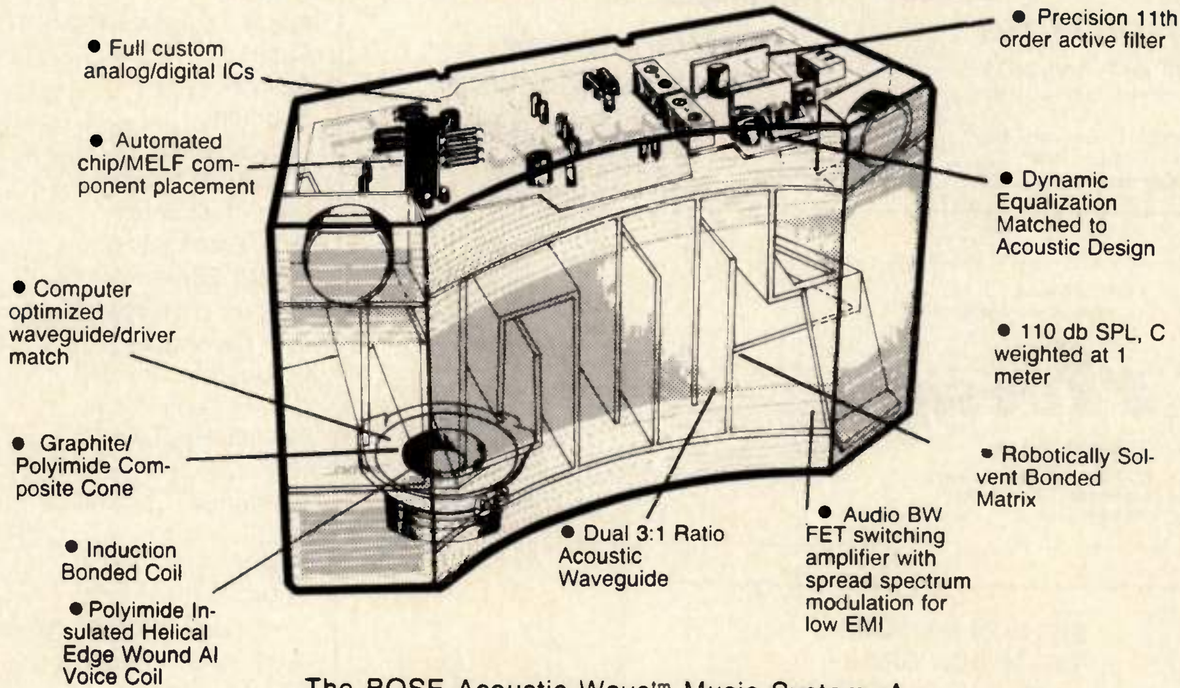
Electronics Catalog

The 176 page 1985 edition of the Mouser Electronics catalog offers over 17,000 items stocked in depth. It serves as an excellent guide for engineers, purchasing agents, or anyone needing quick access to up-to-date product data and pricing of standard stocked industrial electronic components. It includes potentiometers, capacitors, resistors, transformers, lamps, switches, battery holders, jacks, plugs, speakers, knobs, fuses, semiconductors, hardware, tools, test equipment, relays, cabinets, meters, and more. **Mouser Electronics, Santee, Calif., INFO/CARD #111.**

Low Pass EMI Filter Catalog

A new 36-page low pass EMI filter catalog is now available from Murata Erie North America, Inc. This new catalog contains complete technical information on the company's high quality EMI filters and filtering systems for MIL spec and other applications. Details on mechanical configurations, electrical specifications and environmental performance are thoroughly discussed. In addition, cross references for Military Part Numbers MIL-C-39014/16, MIL-C-39014/17, MIL-C-39014/18 and MIL-C-39014/19 with Murata Erie part numbers are given. **Murata Erie North America, Inc., Marietta, Ga., INFO/CARD #110.**

Experiment In Sound



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NEW — 112-Page Information and Product Catalog

Complete from Abrupt to Zener — 112-pages of designer data to make your life easier and your project trouble-free. Our new catalog will give you the needed information to complete even your toughest projects, by describing our broad base capabilities in silicon and gallium arsenide diodes.

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- VHF/UHF Hyperabrupt Tuning Varactors
- GaAs Tuning Varactors 15V to 60 Volts
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- Step Recovery Diodes
- Harmonic Generator Varactors
- Multi-Chip High Power Generator Varactors
- Noise Diodes
- Gunn Diodes
- Parametric Amplifier Varactors
- Control Devices — PIN and NIP Diodes
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- Power RF Switching
- Small Signal RF Diodes
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