

Special Report: The New Look in RF Circuits – Materials



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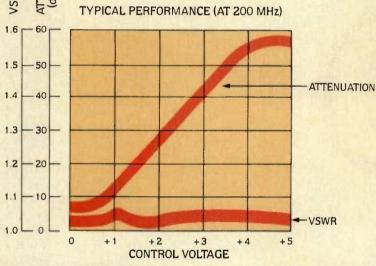


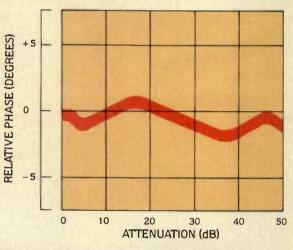
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PHASE COMPENSATED phase stable over full attenuation range 🗌 internal linearizer 🗋 internal driver Π VSWR (dB)



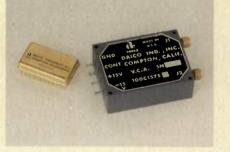


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frequency	150-250MHz			
phase stability	10° max over			
	specified attenuation			
attenuation range	40 dB min			
linearity	±2dB			
insertion loss	4 dB max			
VSWR	1.25 max			
control	0 to +5 volts			
RF power	+ 15 dBm max			
DC power	+ 15 volts @ 40 mA			
	- 15 volts @ 40 mA			
impedance	50 ohms			
size	1.5 × 2.0 × .6 in			
connectors	SMA			
part number	100C1575			

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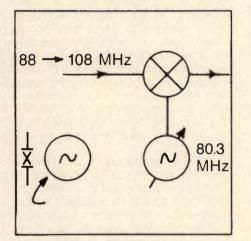
Cover

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

23 Special Report: The New Look in RF Circuits — Materials

Some of the materials commonly used in RF circuits are described in this special report, along with some new materials not yet in common use. — James N. MacDonald



A Computer Algorithm for Mixer Spurious

42 Analysis

The analysis and computer algorithm in this article allow prediction of various mixer spurious signals, including general harmonic analysis, cross-over spurious location, and self-quieting analysis. — Alan M. Victor.

54 Preventing Unwanted Oscillations in Crystal Oscillators Part II

Part II of this two-part article discusses non-crystal controlled oscillations and crystal spurious oscillations, concluding with a discussion of six design verification tests useful for uncovering potential unwanted oscillations — James W. Wieder

Departments

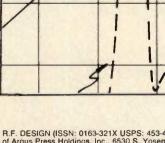
The Designer's Notebook

30 This month's Designer's Notebook describes the helical resonator filter and its uses. A BASIC CAD program is given to compute the physical and electrical properties of these filters. — Vincent G. Heesen

RFI/EMI Corner

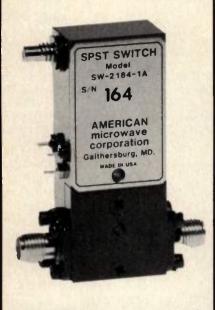
- 32 This article is a brief explanation of some of the characteristics of High altitude Electromagnetic Pulse generated by a nuclear explosion. — Kendall Childers
- 6 Editorial
- 8 Publisher's Notes
- 13 Letters
- 14 Calendar
- 14 RF Courses
- 16 News
- 35 Info/Card
- 62 New Products
- 69 New Literature
- 72 Advertisers Index

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		0.3	1.0	2.0	12.4
		to	to	to	to
Model	Characteristic	1.0	2.0	12.4	18.0
SW-2181-1A	Min Isolation (dB)	30	40	45	45
	Max Ins loss (dB)	1.0	1.0	1.6	2.0
	Max VSWR (on pos.)	1.3	1.3	1.9	1.9
SW-2183-1A	Min Isolation (dB)	40	60	70	70
	Max Ins loss (dB)	1.0	1.0	1.8	2.3
	Max VSWR (on pos.)	1.4	1.4	1.9	1.9
SW-2184-1A	Min Isolation(db)	45	70	85	80
	Max Ins loss (dB)	1.0	1.0	2.0	2.5
	Max VSWR (on pos.)	1.4	1.4	1.9	1.9

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Helping Engineers Solve Problems



rf editorial

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 belowmicrowave 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 M. Ma Donald

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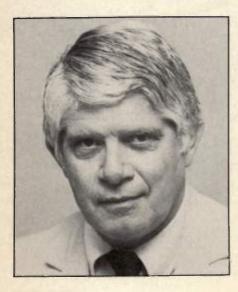


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xxx-insert attenuation value 1-30dB

rf publisher's note

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.

Publisher Keith Aldrich Editor James MacDonald

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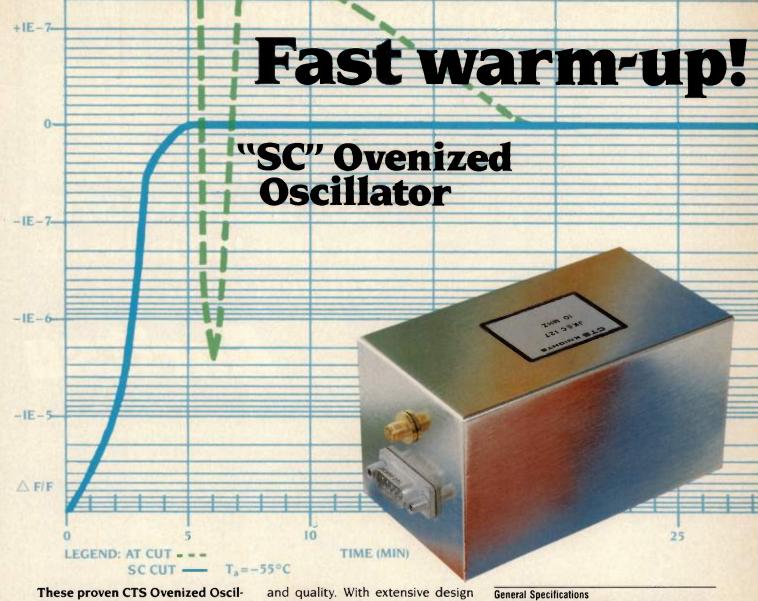
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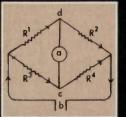
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rf Tetters

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 parameterform 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

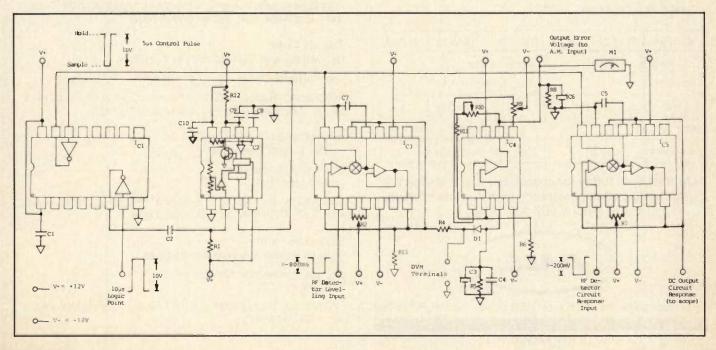
The other on statements will not run on the TI99. They were changed to IF statements. I hope that will help someone else. 170 IF (SGN(X1) = 1 THEN 200 : : IF SGN (X1) = 0 THEN 190 210 IF SGN(X2) = 1 THEN 240 : : IF SGN(X2) = 0 THEN 230 260 IF SGN(X3) = 1 THEN 290 : : IF SGN(X3) = 0 THEN 280 270 F3 = (1/(6.28*FO*X3))*-1

410 X1 = RS*(SQR(RL/RS) / (Q \land 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

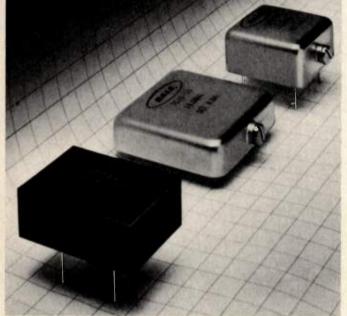
Kurt Bittman Centereach, N.Y.

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.



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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.

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INFO/CARD 15



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

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 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.

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 AD-CAP 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 cycletype 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 productreliability 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 lest to lo

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.

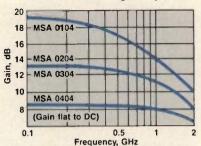
4-Pacs are small (140 mil) plastic packages suitable for PC board or stripline applications in products ranging from instrumentation to toys, from fiber optic systems to mobile communications. They're simple to use and readily available.

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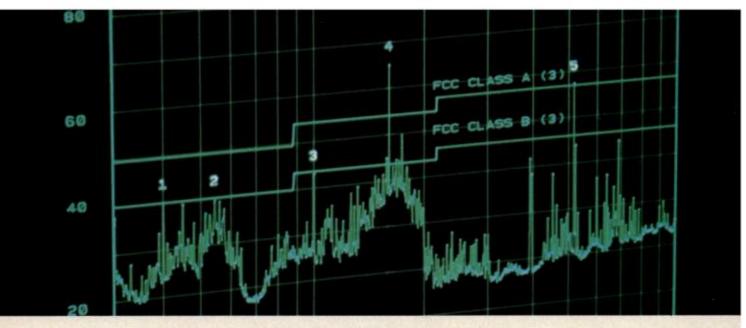
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Your complete EMI measurement solution.

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And unlike EMI receivers that are dedicated solely to compliance testing, the HP Spectrum Analyzer/EMI

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Receiver is also an indispensible EMI diagnostic aid throughout your product's design and evaluation stages.

Using the HP8566B or 8568B Spectrum Analyzer and simple probes, you

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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.

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



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

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

We gave it to the FCC.

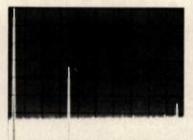
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Typical spectrum of Hybrid Transmitter



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rf special report

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. Bervllia 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

rf special report Continued

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



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INFO/CARD 21

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 highdielectric 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.,

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.

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.

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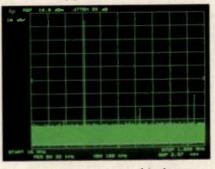
That's what an Andersen SAW oscillator is: a compact fundamental-mode device that operates from 100 MHz to 1.1 GHz without the need for multiplier chains. As a result you get superior performance in a fraction of the space, often at a lower overall cost.

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Andersen SAW oscillators are the perfect source for hundreds of applications. They're



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. also capable of functioning as VCO's. The output frequency can be modulated or locked to another reference for applications such as a PLL.

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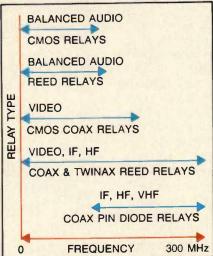
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rf special report Continued

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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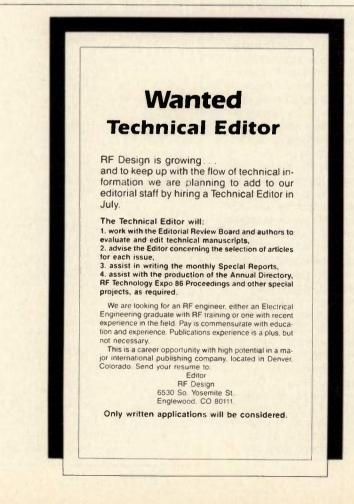
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Helical-Resonator Filter Design

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 (outerconductor) 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 FRINT " ###HELICAL RESONATORS###": : :
120 REM W.MACALINE, R.SCHILDKENECHT-1959 :A.Iverev-1957 & V.Heesen-1985
130 FRINT "THIS PROGRAM CALCULATES THE": "PHySICAL and ELECTRICAL": "FROPERTIES of
HELICAL COIL": "RESONATERS.": :
140 FD=0 :: ZD=0 :: BW=0 :: RT=0 :: FL=0
150 PRINT :: INFUT "ENTER RESONATE FREQUENCY
                                                                                                                   IN MH2 ": FO :: IF FO 5 OF FO 500
0 THEN 960
                                                                                                                 IN ohms ": 20 :: IF 20 200 DR 20
160 PRINT :: INFUT "ENTER RESONATOR IMPEDANCE
           THEN 950
170 D=98#10 3/(FD#ID):: IF D 1 THEN 180 ELSE DS=INT(D*100)/100 :: U$="inches" ::
  50TD 190
BOID 140

180 DS=INT(D41000):: U4="mils"

190 LS=1.54DS :: IF D 1 THEN LS=INT(LS+100)/100 ELSE LS=INT(LS)

200 DC=.554DS :: IF D 1 THEN DC=INT(DC+100)/100 ELSE DC=INT(DC)

210 L=1.54DC :: IF D 1 THEN L=INT(L+100)/100 ELSE L=INT(L)

220 N=1900/(FD4D):: N=INT(N+100)/100 :: IF N(3.5 DF N 100 THEN P60)

210 L=1.54DC :: N=INT(N+100)/100 :: IF N(3.5 DF N 100 THEN P60)
210 GU=50+D+SGR(FO):: GU=INT(GU)
240 GU=GU#1.2 :: GUS=INT(GUS)
250 SP=(FO+(D-2))/2300 :: SF=INT(SP+100000)/100
260 SD=(2.606/SDR(FD))
270 WN=.44SF :: WN=INT(WN#100)/100
280 WX=.6#SF :: WX=INT(WX#100)/100 :: IF WX (5#SD)THEN 960
1.11
 310 PRINT TAB(6);"| :---DC--!":TAB(20);"| | !"

320 PRINT TAB(6):"| :--DC--!":TAB(20);"| | !"

330 PRINT TAB(6):"| :TAB(10):"______":TAB(17):"/ (- !"

340 PRINT TAB(6):"| (________!! ! !"

        340 PRINT TAB(6):":
        1

        350 PRINT TAB(6):":
        ":TAB(10):"

        360 PRINT TAB(6):":
        ":TAB(10):"

      060 PRINT TAB(6): ": TAB(10): "_____)- 1: Ls"

      070 PRINT TAB(6): ": ": TAB(10): "_____)- 1: Ls"

      080 PRINT TAB(6): ": ": TAB(10): "_____)- 1: L"

      090 PRINT TAB(6): ": ": TAB(10): "_____)- 1: L"

      190 PRINT TAB(6): ": ": TAB(10): "______)- 1: L"

      400 PRINT TAB(6): ": ": TAB(10): "______)

      110 PRINT TAB(6): ": ": TAB(10): "______)

      110 PRINT TAB(6): ": ": TAB(20): ": "

420 PRINT TAB(6):":
430 PRINT "Fo=":FO:"MHz":TAB(15):"Ic=":ZO:"Ohms"
440 FRINT :"SHIELD DIA. (Ds) =":DS;U%
450 PRINT "SHIELD LGTH(Ls)~":LS:U%
400 PRINT "COIL DIA. (Dc)=":DC:U$
470 PRINT "COIL LGTH. (Lc)=":L:U$
480 PRINT "WIRE SPACE.(SP)=":SP:"mils"
 490 FRINT "DU(round shield)=":OU
500 FRINT "OU(souare shield)=":OUS
510 PRINT :: INFUT "ENTER BW(JDB) IN MHz ":BWJ :: OL=FO BWJ :: OD=OUS/OL
 520 PRINT :"WIRE DIA.(MIN.)=":WN:"mils"
530 PRINT "WIRE DIA.(MAX.)=":WX:"mils"
540 PRINT "NUMBER of TURNS=":N
 040 FRINT NUMBER OF TURNS=:N

550 FRINT :: INFUT "ENTER NO. OF FOLES (2-7)":NF :: IF NP>T THEN 550

550 ON NP GOTO 550.570,580,590,500,510,520

570 O1=1.4142 :: 1L=20#LOG(((1.4142/QO)+1)/LOG(10):: GOTO 630

580 O1=1 :: IL=20#LOG((2/QO-2)+(2/GO)+1)/LOG(10):: GOTO 630

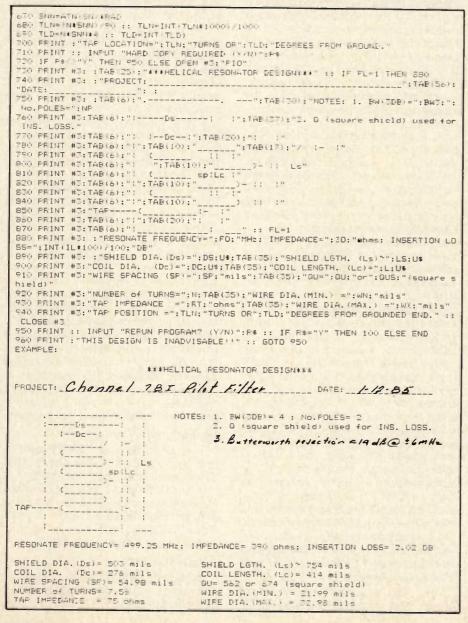
590 O1=.7654 :: IL=20#LOG((2.32/QO-3)+(3.41/QO^2)+(2.52/QO)+1)/LOG(10):: GOTO 63
  600 01=.618 :: IL=20*L05((3.24/00 4)+(5.23/00 3)+(5.23/00 2)+(3.24/00)+1)/L05(10
   ::: GOTO 630
  610 Q1=.518 :: IL=20#L05((3.84/Q0 5)+(7.42/00 4)+(9.11 Q0 3)+(7.43/Q0 2)+(3.84/Q
  0 +1) /LOG(10):: GOTO ±30
  b20 61=.445 :: IL=20*L06((4.46,00 b)+(10,00 5)+(14.5,00 4)+(14.6,00 5)+(10/00 2)
+(4.45/00)+1) L06(10)
  470 FRINT :"INSERTION LOSS=":INT(IL+100)/100:"DB"
+40 PRINT :: INPUT "ENTER IMPEDANCE OF TAP ":FT
```

– 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.

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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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31

rfi/emi corner

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 exoatmospheric 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 gammaray. 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):

 $E(t) = Eo [e^{-t/t1} - e^{-t/t2}]$

where: E(t) = electric field strength as

a function of time

- Eo : related to peak electric field strength, about 52,500 volts/meter
 - = time

t.

- 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/m² but the power density is large, about 7 megawatts/m². 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

About the Author

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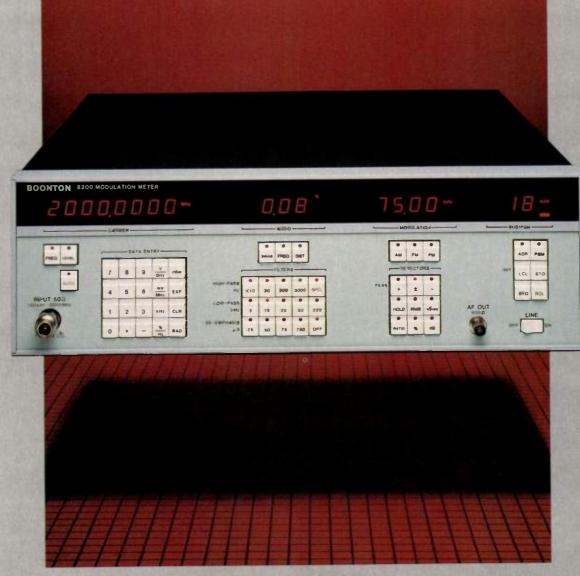
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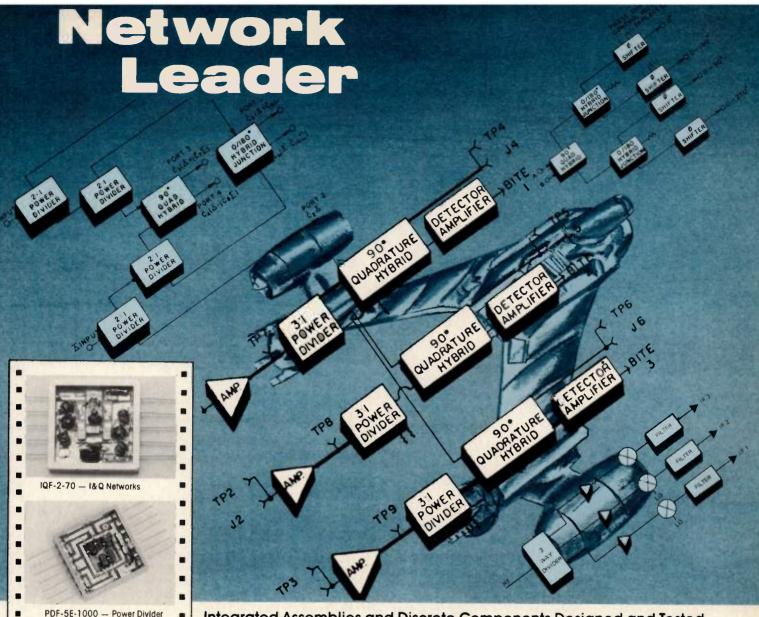
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A Computer Algorithm for Mixer Spurious Analysis

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).

number of mixer stages, fixed sourc-Ales 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:

$$f IF = N^* f RF + M^* f LO + K^* f X$$
(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.

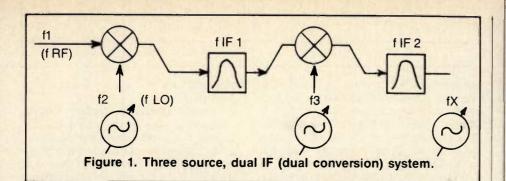
Equation 1 can be extended to any number of sources and IFs. Proper choice of the source coefficients N, M and K permit both high and low side oscillator injection (local oscillator source is either above or below the RF signal) into the mixer. Therefore, up conversion or down conversion can be analyzed. 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:

$$f IF = f RF - f LO$$
(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 $\frac{1}{2}$ 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 $M = N \pm 1$ or $N = M \pm 1$. 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



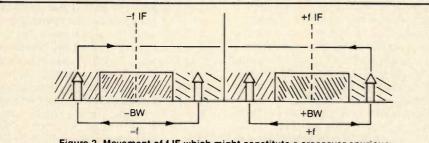
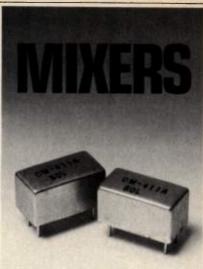


Figure 2. Movement of f IF which might constitute a crossover spurious is detected by monitoring the sign of f IF and setting and clearing flags. Arrows show possible direction of movement for generating a spurious frequency detect.

sources:	f5 0	f4 0	f3	f2	f1
Notes in the set of the			0	0	0
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	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
The second s	1	1	1	1	0
	1	1	0	1	0
	1	1	0	1	1
	Ó	1	Õ	Ó	1
4 sources:	0	1	õ	õ	ò
combinations	1	-	0	0	0
combinations	-		õ	0	1
			0	1	
		1	0	1	0
	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
The street was a street was a street of the	1	1	0	1	0
a took production to a first state of	1	1	1	1	1
	1	1	1	Ö	1
5 sources:	1	ò	ò	õ	ò
combinations		U	v	0	0
Figure 3. Grey-Code Sequer	tor t		ianal Ca	urooc	
rigure 3. Grey-Code Sequer	ice for N	nultiple 3	ngnai So	Jurces	

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.



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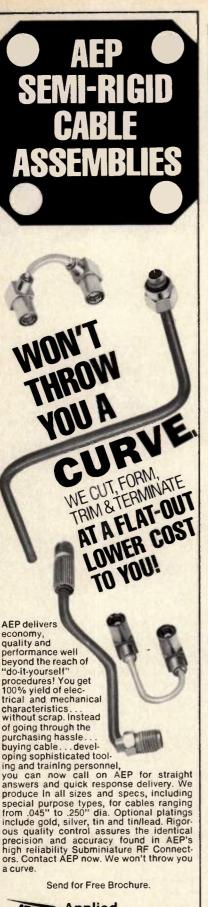
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sources or IFs increases. This computer program handles the above equation and allows all three sources to be swept. Two IFs are checked in the computer routine, but any number of IFs as well as any number of swept sources can be accommodated.

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

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Sprague-Goodman Electronics, Inc. (An atfiliare of the Sprague Electric Company) 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, FLAG-TEST 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 inband spurious. The program requests the desired IF bandwidth or search range. The subroutines FLAGSET and FLAG-TEST 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) or f IF (2) = $N^*X^*f1 + M^*Y^*f2 + K^*Z^*f3$ (3)

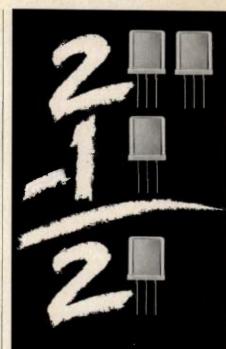
Since f IF = ABS (-f1 - f2 - f3) = (f1 + f2 + f3), only half of the 16 possible sweeping cases need to be analyzed. So, we have the following equations:

f IF (1) or f IF (2) = $N^*X^*f1 \min + M^*Y^*f2 \min + K^*Z^*f3 \min$ = $N^*X^*f1 \min + M^*Y^*f2 \min + K^*Z^*f3 \max$ = $N^*X^*f1 \min + M^*Y^*f2 \max + K^*Z^*f3 \max$ (4)

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 (μ P) is used to obtain a clock display function and control tuning of the receiver. The



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 μ P oscillator is a 3.579545 MHz (f3) crystal. Using the program we find that the general spurious analysis ponts out a selfquieting 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). Lowside 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 bandpass 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. Tradeoffs 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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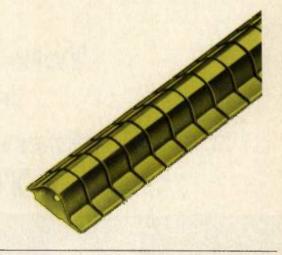
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136 MhzTO 137.4 Mhz DELTA SFURIOUS FI FROM DESIRED F1 35.9 MhzTO 36.6 Mhz	-
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Figure 4(d)

CALL FOR PAPERS RF TECHNOLOGY EXPO 86 January 30-February 1 Hilton Hotel and Towers Anaheim, Calif.

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

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

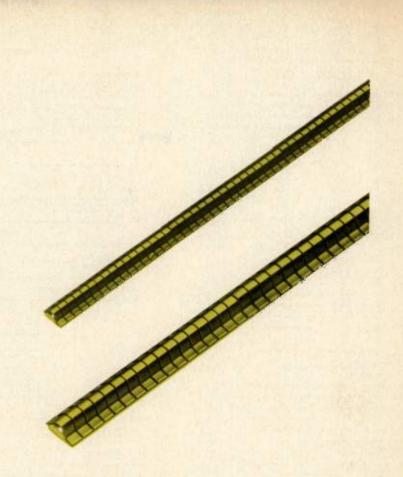
Suggested topics include, but are not limited to, RF circuit design, design techniques, components, computer aided design, EMC/EMI, digital interfacing, component mounting, antennas and testing.

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

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

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

... or these even narrower strips...



* SPURSEARCH + • GENERAL SPURIOUS ANALYSIS • VERSION 1.4 • A.H. VICTOR B/17/84 • COMPUTING CASE 1 (+,-,-) COMPUTING CASE 1 (+,-,-) N+F1 H+F2 KeF3 SPURIOUS RANGE FOR FI (Using plus I.F.) 136 Mh2TO 166 Mh2 DELTA SPURIOUS F1 FROM DESIRED F1 0 Mh2TD 0 Mh2 SPURIDUS RANGE FOR F1 (Using negative 1.F.) IDa Harto 76 Mmg DELTA SPURIDUS F1 FROM DESIRED F1 NO HmitO 90 Mmg NoF1 HeF2 KeF3 SPURIOUS RANGE FOR F1 (Using plus 1.F.) 227 Nh2TO 174 Mh2 DELTA SFURIOUS F1 FROM DESIRED F1 91 Nh2TO 64.5 Nh2 SPORIOUS RANGE FOR F1 (Using negative 1.F.) 137 Mm:TO 174 MM: DELTA SPORIOUS F1 FROM DESIRED F1 1 MM:TO 19.5 Mm: COMPUTED SPURIOUS FOR CASE & (+,-,-) NoF1 HoF2 2 2 SPURIOUS RANGE FOR F1 (Using plus 1.F.) K+#3 136 MARTO 143.5 MAR DELTA SPURIDUS FI FROM DESIRED FI 22.5 MARTO 22.5 MAR BURIOUS RANGE FOR F1 (Using negative I.F.) 134 Hn-TO 98.5 Hhz BELTA SPURIOUS F1 FROM DESIRED F1 47.3 HhzTO 47.5 Hhz 450 HF HIGH SIDE INJECTION + SFURSEARCH + • GENERAL SPURIDUS ANALYSIE • VERSION 1.• • A.N. VICTOR 0/17/04 • COMPUTING CASE 1 (+,-,-) COMPUTING CASE 1 (+,-,-) NoFS H+F2 K+F3 SFURIOUS RANGE FOR F1 (Using plus 1.F.) **RF** Design

226 Mh2TD 174 Mh2 DELTA SPURIOUS FI FROM DESIRED FI 90 Mh2TD 90 Mh2 SPUGIDUS RANGE FOR F1 (Using negative I.F.) 136 MhitO 174 Mhr DELTA SPURIOUS F1 FROM DESIRED F1 0 MhitO 0 Mhi COMPUTED SPURIOUS FOR CASE 1 (+,-,-) NOFI H+F2 K+F3 SPURIOUS RANGE FOR F1 (Using plus 1.F.) 203.5 MhzTO 174 Mhz DELTA SPURIOUS F1 FROM DESIRED F1 67.5 MhzTO 67.5 Mhz SPURIOUS FANGE FOR F1 (Using negative 1.F.) 158.5 mniT0 174 mmi DELTA SPURIOUS F1 FROM DESIRED F1 22.5 mmiT0 22.5 mmi NoF1 NoF2 3 2 SPURIOUS RANGE FOR F1 (Using plus 1.F.) K.F3 136 MhzTO 161 Mhz DELTA SPURIOUS FI FROM DESIRED FI .5 MhzTO 13 Mhz SPURIOUS RANGE FOR F1 (Using negative 1.F.) 136 MmitO 131 Mmi DELTA SPURIOUS F1 FROM DESIRED F1 45.5 MmitO 43 Mmi 45.0 IF HIGH SIDE INJECTION High Side Impection 25-mm (Wo max. 1F) COMPUTED SPURIOUS FOR LASE & LA. NºF1 mer: SPURIOUS HANGE FOR #1 LUBING DIUS 1.P.) 102.5 mato se ma DELTA SMATOUS FI FROM DESIAED FI 77.5 mato 42 mm Sfull DUE Rampe FOR F1 (Using negative 1.F.) 25 mpilo 44 mpi ELTA SPLATOUS F1 FORM DESINED F1 25 mpilo 44 mpi COMPUTED SPURIOUS FOR CASE 1 (+,+,+) NUP1 NUP 2 2 SPURIOUS NAME FOR P1 (Using plus 1.F.) nerz A PPS 140 Ph2TO BE Ph2 DELTA BPLAIDUS FI FROM DESINED FI 135 Ph2TO 135 Ph2

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	· A.F. VILIUN 8/17/84 ·
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DURIDUS PANE FOR F1 (Using blue 1.F.1) DO-124 Low Sier injection (21.4 em 217) Ordeblander	144, 94,74 94,74 94,74 94,74 94,74 35 95,74 35 97,95 35 97,9
2 2 3 0 IDENTION PARE FOR P1 (using plue 1.F.1) IDENTION FOR P1 (Using plue 1.F.1) ID	146, 26,75 14,75 14,75 16,75 15,75 1
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DURING MANGE FOR P1 (Using olive 1.F.) IDE-174 Law Size Layoncian (21.4 and 17.4 and 1.F.) IDE-174 Law Size Layoncian (21.4 and 17.4	146, 26,75 14,75 14,75 16,75 15,75 1
DURIDUE PANOE FOR P1 (using blue 1.F.) IDE-174 Law Size Layersen (21.4 em 17) IDE-174 Law Size La	144, 76,77 14,77 14,77 14,77 15,77 15,77 15,77 15,77 15,77 15,77 15,77 15,77 15,77 15,77 16,752 16,7
DURING PANOL FOR P1 (Using blue 1.F.) DURING PANOL FOR P1 (Using blue 1.F.) DO-12 Low Size layersen (21.4 em 17) DO-13 Low Size layersen (21.4 em 17) DO-14 Low Size layersen (21.4 em 17) DO-15 Low Size layersen (146, 26, 74 26, 74 36, 74 36, 74 35, 35 35, 37 35, 37, 37 35, 37, 37 35, 37, 37 35, 37, 37, 37, 37, 37, 37, 37, 37, 37, 37
DURING PANOL FOR P1 (Using blue 1.F.) DURING PANOL FOR P1 (Using blue 1.F.) DO-12 Low Size layersen (21.4 em 17) DO-13 Low Size layersen (21.4 em 17) DO-14 Low Size layersen (21.4 em 17) DO-15 Low Size layersen (144, 144,
DURIDUE PANOE FOR P1 (using blue 1.F.) IDE-174 Law Size Layersen (21.4 em 17) IDE-174 Law Size La	146, 26,75 146,75 146,75 146,75 156,75 1
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COMPUTED SPURIOUS FOR CASE 1 (+,-,-)	hufi naf2 5 5
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SPURIOUS RANGE FOR F1 (Using plus 1.F.)	
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12a must D 147.23 mms DELTA Experiedade F 1 For DESIRED F1 2.6.73 must D 2.6.73 mms	123.12 MN:TO 174 MN2 142.TA SPURIOUS F1 FHOM DEBIRED F1 17.12 MN:TO 17.12 MN2
Nof1 nof2 Kof3	Nof1 mf2
SPURIOUS READE FOR F2 (Using plus 1.F.)	SPURIOUS HANGE FOR FE Susing plus 1.F.2
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SFURICUS RANGE FOR F1 (Using negative [.F.) 137.4 multo 174 mul DELTA SFURICUS F1 FROM DESIRED F1 1.4 multo 4.12 mult	SPUEIDUE HANGE FOR F1 (Using negative 1.F.)
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130-17- high Size Importion (21 and 17)	136-175 Low Sase Ingection (17.
	• 2 ⁴ 1456ab
SPURSEINCH CEHERNL SFURIOUS	· UKRENN, SPUT IGU
• VERSION 1.0 • • N.M. VICTOR 0/17/H4 •	- VERLIDA - 4.m. VIETCH
COMPUTING CASE 1 (+) COMPUTING CASE 1 (+)	COMPUTING CASE 1 ++ COMPUTING CASE 1 +
NoF1 moF2 5+f3	New F 1
SFURIOUS NAME FOR F1 LUSING DIVE 1.F.F	EPURIOUS HANGE FOR FI LUSING DIUS I.F.
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SPURIDUE Howde FOR F1 (Using negative 1.F.)	SPIRIOUS RANGE FOR F1 (USING Desative 1.F.)
126 MR: TO 174 MR: DELTA SMURIDUS FI FROM DESIRED F1 U MR: TO 6 MR:	15e MAITO 158.2 MAI DELTA SPURIDUE F1 FROM DESIRED F1 25.8 MAITO 35.8 MAI
***************************************	COMPUTED SPURIOUS FOR CA
COMPUTED SPURIOUS FOR CASE 1 (+,+,+)	144F1 114F2
2 0 SPURIDLE RAMEE FOR F1 LUSING Disc 1.F.1	SPURIOUS RAVES FOR F1 (Using plus 1.F.)
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Not 1 Pot 2 Kar3	CONFUTED SPURIOUS FOR CA
3 2 0 SPURIDUE RANGE FOR F1 (Using plus 1.F.)	10071 mef2 2 3
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	186.1 PULTO 174 MHS DELTA BPURIOUS F1 FROM DEBIRED F1 30.1 PRUTO 44.000000007 PHS
PTURIDUE Remain POP F1 (Uning negative 1.F.) 136 marth 133::Uning negative 1.F.) 26174 SPURIOUS F1 FROM JESIAED F1 57.3 marth 250. Researces 7 MR	SPURIOUS RANGE FOR F1 (Using negative 1.F.) 168.2 micTO 174 mms DELTA SPURIOUS F1 FROM DESIRED F1
COMPUTED SPURIOUS FOR CASE 1 (+,+,+)	DELTA SPURIOUS FI FROM DESIRED FI 52.2 MMETD 34.15555553 THE
Neg Neg Keg	10071 nof2 3 3
SPURIOUS RANZE FOR FJ (Usine blue 1.F.)	SPURIOUS RANGE FOR F1 (Using plue 1.F.)
130-17- mos High Side Injection (21-+ mhz 1F)	130-176 ine bise injettion (17.
144.057577875 #4:10 174 #9: 6178 64.7525 6.4549 (482146 F) 28.85055555 #7:15 28.52755555 #6:	JTA MILTE SLE GAMMAND MIT DELTA SPURIOUS FI FRUM DESTREM FI BILFERSTREET MILTE ISLATEDITEDIT MIL
(FuRIDUS NAMES FOR F1 (Using negative 1.F.)	SPURIOUS AWGE FON FI NUESHD HEDSTIVE 1.F.: 136 Mmc10 150,100700000 Mmc
<pre>fupElugE havdE F0 f1 (Using negative L/) Co.leveness 7 mo10 (F4 m; c) F1 f2 MrA(2007 F1 f0 m) F0 f1 (F1 m) F1 f2 MrA(2007 F1 f0 m) F0 f1 (F1 m) F1 f2 m) F1 (F1 m) F1 (F1 m) F1 (F1 m) F1 (F1 m) F1 (F1 m) F1 (F1 m) F1 (F1 m) F1 (F1 m) F1 (F1 m) F1 (F1 m) F1 (F1 m) F1 (F1 m</pre>	DELTA SPURIOUS FI FLOR DESIRED FI 20. Beergeese 7 Mit TC 20. Breconse 7 Mit
Nof3 Nof2 1of3	COMPUTED SEMILOUS FOR CA
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is.8 mort0 10.1 mor SPURIOUS Rende FDR F1 lusing meastive I.F.J	142.400000000 Mill 174 MM DELTA SFURIOUS F1 FROM DESIRED F1 27.4330000000 Mm2T0 30.075 Mm2
12e Marto 141,0 Mar DELTA SFURIOUS FI FROM DESIRED FI 21.0pensenar FMITO 22.0 Mar	FUEIDUE SANGE FOR FI (UMING REDATIVE 1.F.)
	151.5 MN2TO 174 MN2 DELTA SPURIOUS F1 FROM DESIRED F1 15.5 MN2TO 21.125 MN2
COMPUTED SPURIDUS FOR CASE 1 (+,-,-)	Nof 1 Port 2
SPURICUS RANGE FOR F1 (Using slue 1.F.)	SPURIDUE RANGE FOR FI (USING PLUE 1.P.)
162.73 mst10.874 ms D&15 smattode F1 FROM DESIRED F1 Da.75 mst1026.73 mst	136 MILTO 160.575 MLL DELTA SPURIOUS P1 FROM DESIGED F1
26.75 mitlD 26.75 mit SPURIDUE RANDE FOR F1 (Using negative 1.F.)	13.425 Photo 13.425 Photo heative 1.F.)
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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.

Anon-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.

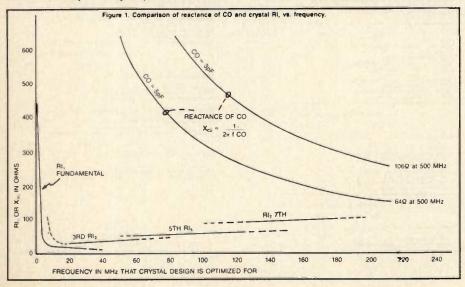
b) A larger portion of the oscillator may be shunted by a stray impedance. The shunting path generally occurs from a low impedance point in the circuit to a high impedance point. The high impedance point is generally due to a parallel LC resonance (possibly due to stray reactance).

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 (R1₇) 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.

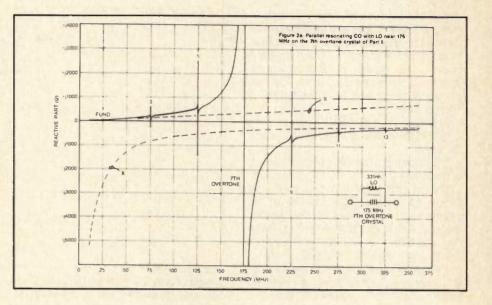
Note that the CO-LO resonance is only useful in preventing oscillation via CO from occurring within the overtone select bandpass. At frequencies well above the CO-LO resonance, the CO-LO combination will still appear as CO and hence a low impedance. At frequencies well below the CO-LO resonance, the 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 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.

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 pos-

sible 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



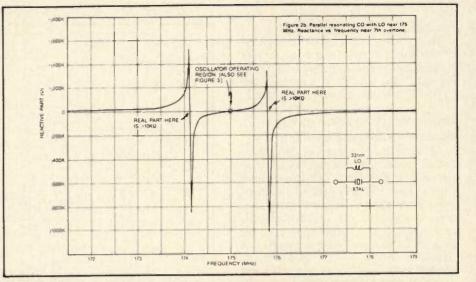
the desired response. This is because the quartz blank is capable of vibrating in many different modes and directions. The number of spurious responses and their frequency locations are unique for each crystal. The model for a spurious response is the same as the crystal fundamental responses, with the 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,



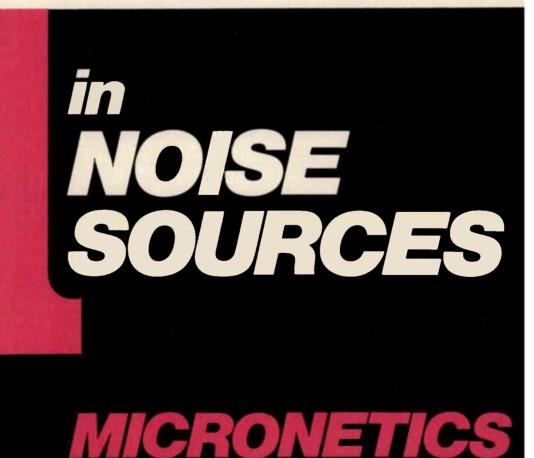
a ratio of only 2:1 may be feasible. A low spurious resistance ratio is one of the factors that limits the production use of crystals to the fifth or seventh overtone.

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

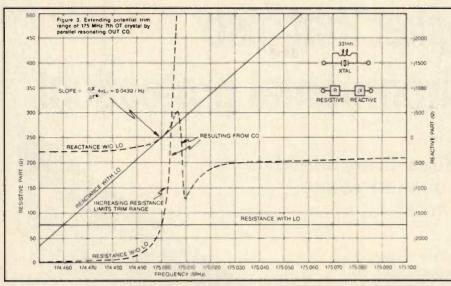
a) Oscillation may occur at a spurious located within the overtone select band-

pass (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



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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

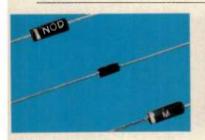
checked by adding resistance in series with the crystal to determine the R1 value where the desired oscillation will not start up. The minimum value of R1_s should be larger than this R1 value.

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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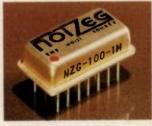
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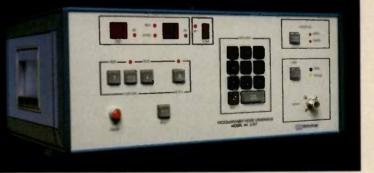
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MX5110	300MHz-1GHz	± 2.0 dB	1.5:1	- 79	
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possible bandpass discrimination should also be considered.

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.

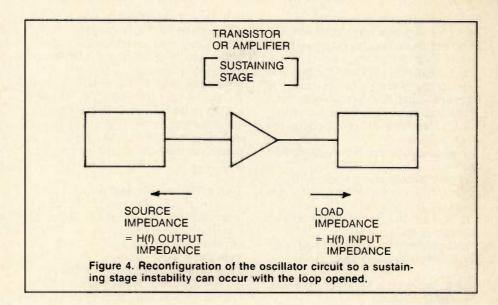
When relying on start-up dominance, the following should be considered.

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 noncrystal 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.



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 + RAshould 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

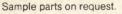
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E/M Lubricants can meet your specifications and comply with VDE and FCC requirements. We can solve your individual problems through our electrically conductive compounds of graphite, copper, nickel, silver, zinc arc spray, and electroless copper/nickel. Won't peel, chip or crack.

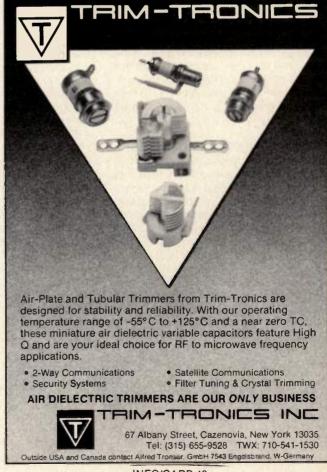
If desired, E/M Lubricants' expertise also enables us to decoratively finish-coat your part after shielding has been applied.

Custom-Coaters for over two decades. Complete coating facilities, nationwide. And all thirteen custom-coating facilities are U.L. recognized.





INFO/CARD 39



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.

References

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2) Hewlett Packard Application Note

154, "S-Parameter Design," 1973

3) Avantek, "High-Frequency Tran-sistor Primer" Parts I & II, 1975

4) T.T. Ha, "Solid-State Microwave Amplifier Design," John Wiley & Sons, 1981

5) National Bureau of Standards Monograph 140, "Time and Frequency," 1974.

6) D.K. Belcher, "Designing a High Stability VHF Oscillator," RF Design, Jan./Feb. 1983.

7) R.J. Matthys, "Crystal Oscillator Circuits for VHF" RF Design, May/June 1983.

8) Mil-C-3098 General Specification for Quartz Crystal Units.

9) SPICE Version 2F.1 User's Guide, University of California, Berkeley

10) SUPER-COMPACT User's Manual (1.6), CGIS, Inc. Palo Alto, California.

About the Author

Jim Wieder is a design engineer at Westinghouse Defense and Electronics Center, P.O. Box 1521, M.S. 3642, Baltimore, MD 21203. -1

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SFE Technologies, San Fernando

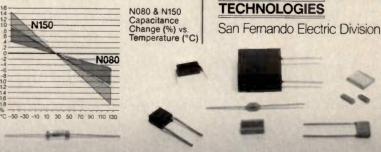
San Fernando, CA 91340-2793.

New MLCs with negative TC available from SFE Technologies combine excellent stability and tight tolerances with a wide choice of packaging.

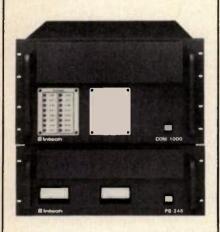
With a temperature coefficient of -80 ppm/°C and -150 ppm/°C, our negative TL MLCs span a capacitance range of 1 pF to .056 uF with tolerances to 1%, working voltages from 25 to 500 VDC, and have all other characteristics of standard NPO series ceramics. Their stable performance compared to plastic film capacitors makes them ideal replacements for polystyrene, polypropylene and polycarbonate components, in filters for modems, cable TV, RF amplifiers and other telecommunication applications. They are unaffected by high production methods of solder attachment such as wave solder. Available in leadless

chips, 2-pin DIPs, molded axials and radials, glass encased axials and conformal-coated radials. In all standard packaging methods including bulk, tape-and-reel for pick-and-place and automatic insertion.

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- · Compensates for positive TC of inductive components, giving superior filter performance over temperature changes.



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COM 1000: 1000W. Av. Power 1.6-30 MHz with PS 248 Dual Switching AC Power Supply.

Introducing the next generation of unconditionally stable POWER MOS FET Linear Amplifiers from Intech.

Combining the low order distortion of Class "A" with the high efficiency of "AB" & "C" Designs, they can withstand severe load mismatch conditions without spurious oscillation or failure.

They are capable of high speed on-off switching and are Frequency Agile over their 1.6-30 MHz range.

They are ideal for: RFI/EMI Testing, H.F. Transmitters, Linear Accelerators, N.M.R. CATSCAN, plasma equipment and diathermy.

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rf products

RF Circuit Design Program For Personal Computers

STAR 1.0 is a lost cost program written for circuit design using personal computers. It analyzes and optimizes electronic circuits including amplifiers, oscillators, filters, matching networks, hybrids, couplers and others. STAR 1.0 features: frequency domain analysis of circuits; optimization of any component values in circuit; file storage of circuits for easy recall or change: stability factor and circles; screen, printer and plot outputs; program disk with 28 application examples; complete manual; ability to handle resistors, capacitors, inductors, twoport data (for active or special devices), transformers, transmission lines, port exfor conversions, changed cascade/series/or parallel connections and many other codes; availability for IBM PC/XT/Jr., Apple II+/IIc/IIe, Commodore C-64 and Kaypro 2/2X/4/10 computers. Circuit Busters, Lilburn, Ga., IN-FO/CARD #176.

Low Distortion Programmable Oscillator

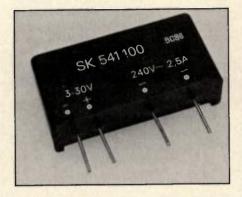
Racal-Dana Instruments Inc. announces the introduction of an ultra low distortion programmable oscillator, the Model 9085. By using an analog, two integrator loop technique, the Model 9085



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

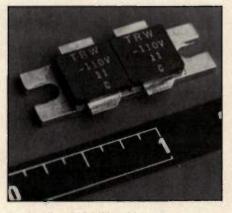
Mouser Electronics announces the availability of a quality solid state relay in



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.

SPECTRUM DISPLAY UNIT

REACTION INSTRUM

MODEL 695 IF DISPLAY

21.4 and/or 160 MHz

0.8 MHZ - 8 MHZ

2 MHZ - 20 MHZ

-90 dBm

60 dB

Response

Resolution

Intercept Point

C.R.T. Size

Overall Size

- Choice of IF
- Ultra Compact 13/4" × 81/4"

0

Input Center Freq.

Sweep _ 21.4 MHZ

Sweep - 160 MHZ

Sensitivity

Gain Control

- High Resolution
- Lin/Log Display
- Reasonable Cost



LogiLinear

20 KHZ

+ 10 dBm

11/8 + 3"

13/4 × 81/4 × 20"



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





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

A full line of accessories including antennas, probes and LISN's are available. R & S-Polarad does make it easier.



Number 1 in a Series.

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

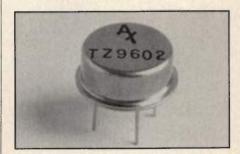
Version 1.3 of the Touchstone computeraided engineering progrm brings new technical capabilities to the microwave and RF design engineering task. New



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., IN-FO/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.

Eliminate

on your Low Band adind smiller

When two frequencies are present in a non-linear circuit, new frequencies are produced which may cause interference on other channels. With site congestion and higher power paging transmitters, especially in urban areas, the generation of intermodulation products is of increasing concern. With M/A-COM Low Band Isolators and IM Suppression Panels, you can provide maximum isolation of

transmitter intermodulation and ensure maximum protection of your transmitter. Eliminate intermodulation on your low band paging transmitter with M/A-COM solators

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INFO/CARD 58

PIEZO's Little Wonder.

Superb performance in a plug-in compatible replacement for HP 10544A/B/C or HP 10811A/B oscillators.

- □ Low phase noise
- □ Fast warm up

PIEZO's new Model Number 2810007 Series oscillators are designed for equipment requiring a compact, rugged, precision fre-quency source. The DRAT (*doubly rotated AT) stress compensated (SC cut) crystal offers the advantages of a longer life and a lower operating cost. This makes the 2810007 an ideal, cost effective oscillator for precision time keeping, instruments, communication and navigation equipment.

The PIEZO standard of quality guarantees you this kind of performance:

- Aging rates: <5 parts in 10¹⁰/day
- Phase noise: Better than 160 dbc at 10 kHz offset
- Warm up: Within 5 parts in 10° of

□ High short term stability □ Low power consumption □ Rugged construction for □ DRAT* SC cut crystal □ Fast delivery

extra shock and vibration control

- final frequency in 10 minutes
- Time domain stability: Better than 5 parts in 10¹² for a 1 second averaging time
- Power consumption: Approximately 2 watts after warm up
- Output frequency: 10 MHz or 10.23 MHz standard

We offer fast delivery, with limited orders shipped directly from stock. PIEZO Systems is an affiliate of PIEZO Crystal Company, a leader in the production of piezoelectric crystals since 1936. For more information call your nearby PIEZO representative, or write to PIEZO SYSTEMS, P.O. Box 619, Carlisle, PA 17013. Telephone (717) 249-2151.



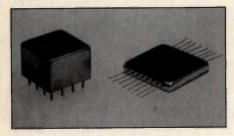
* Best aging available to date: parts in 10¹²/day!





High Level Mixers

Synergy Microwave has introduced a new high-level mixer, giving excellent allaround performance. Model CMP-A12 covers .5-1200 MHz. Driven with a nominal +7 dBm LO, it yields typically 6



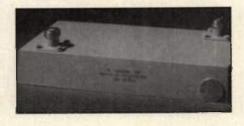
dB conversion loss and 3rd-order intercepts of typically +25 dBm (in a 50 ohm system), and is an 8-pin relay header. Synergy Microwave Corporation, Paterson, N.J., INFO/CARD #168.

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



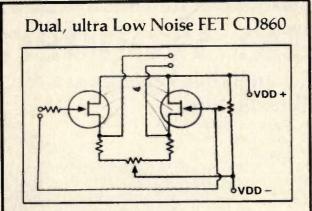
suitable high power connectors. Both Chebishev and the Levy A-Z pseudolowpass response and shapes are available. Applications include jamming/countermeasures, communications radar and broadcast — mobile, airborne or fixed/ground station. CIR-Q-TEL, Kensington, Md., INFO/CARD #166.

Model 7802-3A Receiver

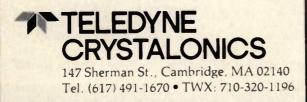
Interad Ltd. announces the availability of a frequency synthesized VHF/UHF Receiver. The Model 7802-3A Receiver



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 μ s continuous tune, 500 μ s worst case. Interad Ltd., Gathersburg, MD, please circle INFO/CARD #172.



This dual FET is designed for low level amplifiers with input noise voltage typically $1.4nV\sqrt{Hz}$ at 1 kHz. Device has min. Gm of 25,000 µMho per side, assuring voltage gain of 25 min. with 1K drain load. The 10mA operating point is easily held due to low pinch-off voltage, as source follower. CD860 has typical output impedance of 24 ohms. Gm is matched to $\pm 5\%$ and VPO to $\pm 25mV$.



HIGH DYNAMIC RANGE



Janel offers a wide variety of high dynamic range RF Amplifiers. The chart below shows a sampling of what's available. All feature high guaranteed performance and yet are competitively priced. Many models are available from stock.

M	odel	Frequency	Gain	N.F.	3rd I.P.
PI	F811A	1-32 MHz	16.5dB	4.5dB	+42dBm
PI	F841	2-32	16.5	5.0	+46
PI	F804	215-320	27.0	4.0	+32
P	F829	406-512	16.5	4.5	+38
PI	F833	800-920	26.5	2.8	+34
PI	F845	800-915	18.0	2.0	+35

In addition to RF Amplifiers, Janel manufactures a wide range of standard Power Dividers and other rf components. Custom designs can be provided for unusual applications. For detailed information, call or write Janel Laboratories, Inc., 33890 Eastgate Circle, Corvallis, OR 97333. Telephone (503) 757-1134.



INFO/CARD 47

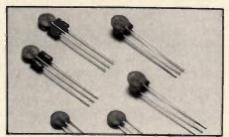
200 Megasample/Second Transient Recorder

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.

8 eighth dimension enterprises

C.A.D. RF FILTER PROGRAMS for Apple*II and Apple* IIe Computers

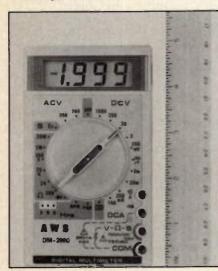
Computer Aided Design for **RF FILTERS** and **LOW PASS MICROWAVE MICROSTRIP FILTER.** The programs are **MENU DRIVEN** and are **SUPER EASY** to use. Just input (when asked by program) the information that you would use to design

a filter by the long hand method. The resultant values will produce the filter you want. NOW, with options available, you can monitor frequency response and test tolerance sensitivity of the lumped constant components. Programs are: 1, LOW PASS FILTER, DC to 1200 MHz; 2, HIGH PASS FILTER, 1 KHz to 1100 MHz; 3, BAND PASS FILTER, 10 KHz to 1000 MHz; and 4, BAND REJECT FILTER, 10 KHz to 1200 MHz. \$99.95 dollars for any one (1) of the lumped elements filters. \$349.95 dollars for all four (4). The MICROSTRIP LOW PASS FILTER is \$1499.95 dollars. All filters on one (1) diskette is \$1700.00 dollars. Send check, money order, or company purchase order to P.O. Box 62366, Sunnyvale, Ca., 94088-2366. California residents add 7.0%, 6.5%, or 6.0% depending on county. 100% 60 Day guarantee. Prices subject to change without notice. 10% discount if this ad accompanies order. *Apple is the registered trademark of APPLE COMPUTER, INC.

rf products Continued

Rotary-Switch, Digital Multimeter

A.W. Sperry Instruments, Inc. announces the introduction of their new 31/2-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, easyto-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

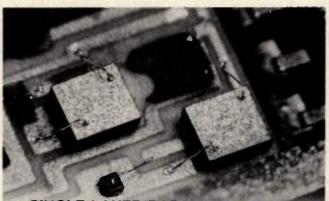


power output at 1 dB comp., +23 dBm; max VSWR (In/Out), 2.01 current at 15V, 88 mA temperature range, -55°C to +100°C. All units meet MIL-STD-883B screening. Amplifonix, Inc., Bristol, Penn., INFO/CARD #157.





BROADBAND EQUIPMENT FOR INSTRUMENTATION AND COMMUNICATIONS



SINGLE LAYER PARALLEL PLATE **CERAMIC CAPACITOR CHIPS**

Featuring a single layer dielectric construction with associated low series inductance, this family of capacitor chips are ideal for applications ranging from DC to microwave frequencies.

Available in capacitance ranges from 0.25 pf to 15,000pf voltage ratings to 15KV, their high dielectric strength makes them resistant to damage from static discharge. Precious metal terminations are compatible with epoxy, solder or wire bonding assembly techniques.



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INFO/CARD 50

In Line

Power

SW CW

10W cv 5-300 MHz)

500 cw

175 ohm limited

to 10W cw)

Coupler Type

single

single

single

dual

P O BOX 21652, PHOENIX, ARIZONA 85036 U S A

1-500

1-100

10-200

Minim

1-500

MHz

20

40

35 dE

40 dB min typica

45 dB min

35 d8 m

40 dB min typica

45 dB min

WIDE BAND ENGINEERING COMPANY, INC.

INFO/CARD 49

m Directivity

MHz

30

45

In Line

Loss (dB)

.4 max

typical

.3

.15

.3

.15

Flatness of -20 dB port (dB

-.1 5-300 MHz 1.25 1-500 MHz

TELEPHONE (602) 254 1570

VSWA

1,1:1 5-500 1,5:1 1-500

1.14

1.04:1 typica

68

Mode

A73-20

A73-20GA

A73-20GB

A73-20P

A73D-20P

A73-20PX

A73D-20P>

A73-20PA

A73D-20PA

A73-20PA X

A73D-20PAX

July 1985



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 upto-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 $\pm 5\%$. 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.**

RF Design

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 personto-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.**

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PHASE NOISE					
	MODEL ER8001 124 db				
	MODEL ER8003 135 db				
INPUT VOLTAGE _	$_12$ VDC \pm 10% STANDARD				
OUTPUT	SINE-WAVE 1VRMS INTO 50				
	ohm LOAD				
SIZE	_MODEL ER8001 and				
	MODEL ER8003				
	2" × 2" × 4" H				
	MODEL ER8005				
	2.25" × 2.25" × 4.25" H				
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INFO/CARD 51

rf literature Continued

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 hardwire 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.

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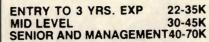
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Advertiser Index

Acrian, Inc.	4,
Adams Russell - Anzac	.12
Adams Russell - Modpak	.24
A.H. Systems	
American Microwave	6
Amperex-Slatersville	
Andersen Labs	
Anritsu	.10
Applied Engineering	.44
Austron	
Avantek	.17
Boonton	
CTS Knights	
Cincinnati Milacron	
Daico Industries	
Dale Electronics	
Eighth Dimension	
Electronic Research Co.	
E/M Lubricants	
Frequency Sources	
G & H Technology	15
Hewlett-Packard Co 1	
IFR	
Instrument Specialties 47	7 10
Instrument Specialities	3 58
Intech	62
JFW Janel Laboratories	
Johanson Dielectrics	
E.F. Johnson	
Kay Elemetrics	5 36
M/A-Com	
Marconi Matrix Systems Corp	
Matrix Systems Corp	
Merrimac	41
Metelics	6 57
Micronetics	7 29
Noisecom	65
Piezo Crystal	
Reaction Instruments	
RF Monolithics	
SFE Technologies	61
Sokol Crystal	
Solitron	
Teledyne Crystalonics	
Telonic Berkeley	
Texscan	60
Trimtronics	a 10
Vectron	5, 40
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