rf design

engineering principles and practices

August 1988

1978 1988 10th Anniversary

Inside —
An RF Special Edition:
Quartz Technology

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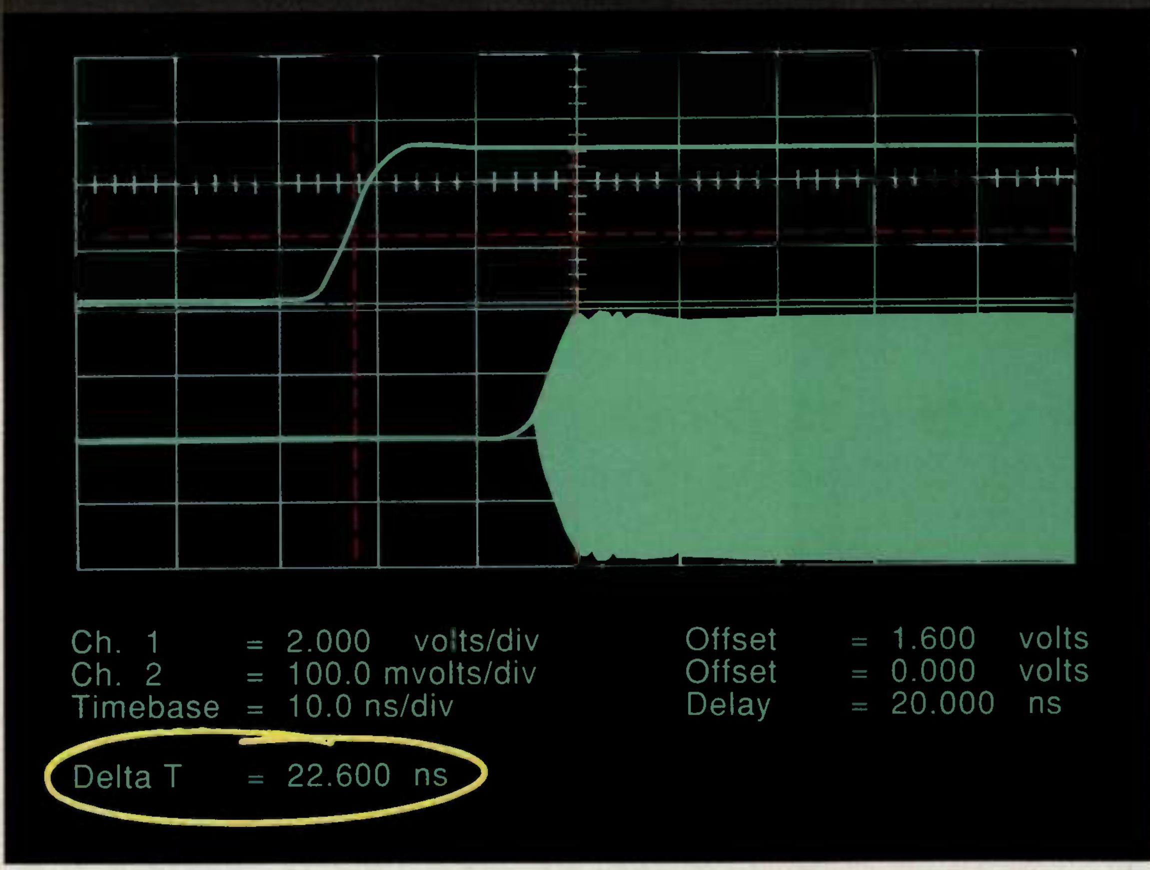

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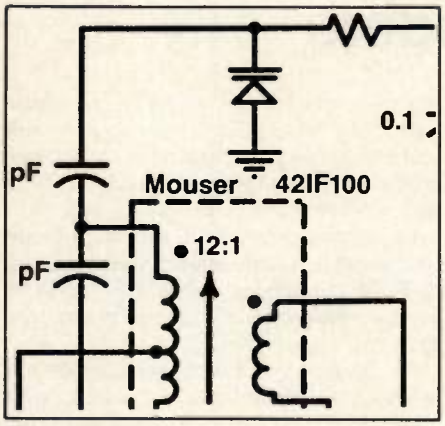
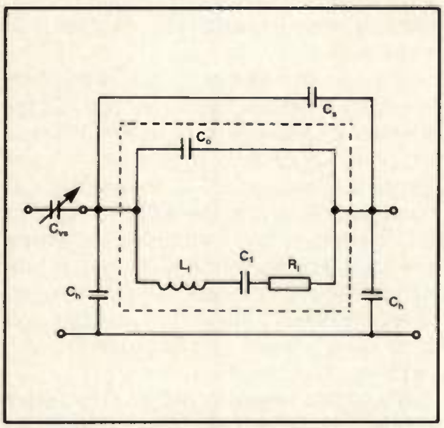
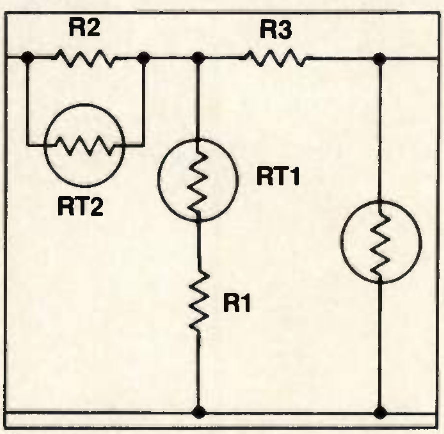


Page 23 — Loran-C Front End



Page 42 — Quartz Crystals and Oscillators



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Cover Story

Featured Technology

Quartz Technology — RF Special Edition

Departments

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rf editorial

Don't Wear Blinders

By Gary A. Breed
Editor

Being one of very few people in the RF industry that has to keep up with *everything,* I sometimes get frustrated. Every one I talk to knows far more about their own specialty than I do. Yet, most of the time I find myself giving those same people advice about developments outside their area of focus. Often, the discussion leads to the discovery of components, techniques or applications that directly affect their work.

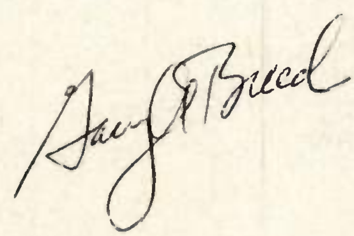
Of course, the intense work required for much of science and engineering doesn't leave much room for 'broadening our horizons.' However, many opportunities come up where one branch of technology can help another. These opportunities are missed if we get involved in a project so deeply that no time is spent keeping up with the rest of the world.

Examples are easy to find. We will soon publish an article from Directed Energy on the application of a new line of power switching MOSFETs. This company set out to improve performance of high power pulse amplifiers for laser drivers, TWTs or other pulse modulation needs. When it was pointed out that the switching times and repetition rates were suited for Class D/E RF amplifiers in the HF range, a whole new group of possible customers became apparent.

In January, we highlighted Comlinear's high speed operational amplifiers, with one application being an RF active filter. This line of components was developed primarily for data acquisition, not RF, but a look beyond that market made it clear that the parts solved design problems in other areas.

I discovered this principle in my own tinkering. The new multi-function ICs for VHF FM pager, cellular radio and cordless telephone applications seemed to have attributes useful for SSB or CW applications. By modifying the decoupling and feedback circuitry, I was able to reduce the hard limiting in the IF stages to the point where linearity could be maintained over a significant range. These results led to a very simple and inexpensive HF amateur radio receiver design.

My simple message is this: Don't wear blinders. Make sure you stay as aware as you can of developments in other branches of engineering. You just might find the solution to your own design problems.



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a Cardiff publication Established 1978
Main Office:
6300 S. Syracuse Way, Suite 650
Englewood, CO 80111 • (303) 220-0600

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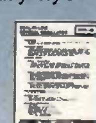

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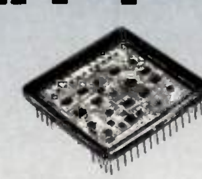

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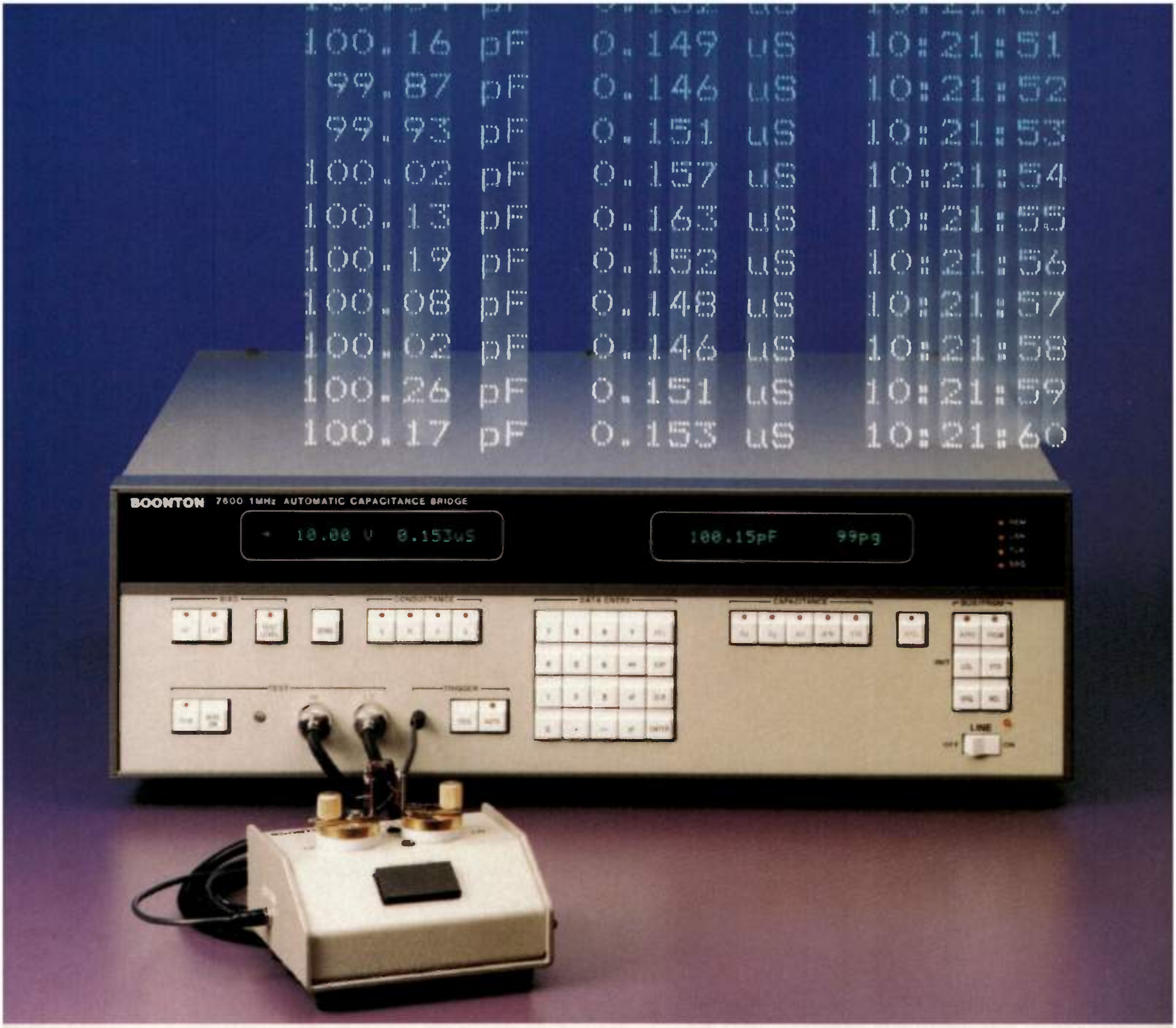

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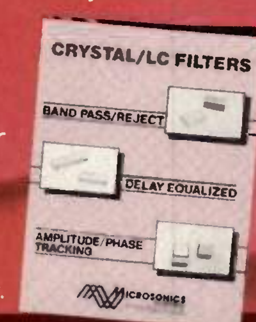

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INFO/CARD 11

rf letters

Letters should be addressed to: Editor, *RF Design*, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111

Microstrip Comments

Editor:

I really enjoy your magazine and have built 2 to 4 RF circuits with little or no problems from your articles. However, one thing has been bugging me for over a year and that is microstrip PC boards. In your June issue you gave a good tutorial right out of all the microstrip texts I have examined. However, in a practical design such as the MMIC doubler in the same issue, ground plane is often left on the microstrip signal side of the PC board albeit with a gap about the width of the microstrip line on each side.

I recently built a wideband 20-150 MHz swtichable gain amplifier with four stages of 15 dB each using Avantek amplifiers and Teledyne relays. It worked reasonably well up to about 45 dB gain but the microstrip seemed capacitive when laid out with ground plane on the same side even with a gap that was wider than the microstrip, which was 0.1" (about right for 1/16" G10). I also noted that Motorola's RF Data Book had similar designs. The phase shift gave me oscillation problems above 45 dB gain which were difficult to remove. It seems as though this method is not truly microstrip or truly coplanar which has not been covered in any of the texts I perused.

Please give a list of references on how to design this type of microstrip as frequently we are called on to design other circuits on the same PC board and the microstrip side ground plane helps to isolate and attenuate the RF fields surrounding the board. Even better would be an article using a high level language problem for designing such circuits. Keep up the good work.

Bob Hyde
University of Texas
Austin, TX

Editor:

I just wanted to let you know how much I appreciate your excellent articles in *RF Design*. My subscription has been going on for several years now (Please do not stop!) and I am always looking forward to entering the BASIC computer programs for engineering into my Amiga 1000 system. Whether the code is for a Commodore 64, which I used to have, or for the IBM MS-DOS machines (I have a 10 MHz XT-clone, too), it's always fun to rework the program to put out some sort of graphic presentation on the Amiga's display. If you'd like, I could send listings of some of the various filter, PLL and other *RF Design* programs which have been adapted to run on the Amiga.

The Featured Technology section of your June issue, "Microstrip Design Basics," was extremely informative. Also, of great interest was the "Fundamentals of Red/Black System Engineering" article. While the more experienced RF engineers would rather not see magazine space used this way, those of wishing to keep our knowledge of RF techniques really do appreciate the help. I'm sure many of us enjoy the flow of tutorials and design application articles.

Gerry White
General Dynamics
Electronics Division
San Diego, CA

P.S. Does anyone else have Amiga engineering programs to share?

Directory Scramble

Editor:

First let me congratulate you on your commendable work in bringing out the Directory issue. It is a wonderful idea and it caught us in a scramble for that one copy. It will of great help for your readers in India if you could send us another copy or two. It is very helpful and I am looking forward to seeing many more great ideas from *RF Design*.

P. Parthasarathy
Hindustan Aeronautics Ltd.
Hyderabad, India

Correction

The June 1988 *RF Design* article, "Principles of Microstrip Design" by Alan Tam, requires a few clarifications and corrections. First, we deeply regret a bit of mischief that resulted in the misspelling of Alan's name. The following should also be noted:

1. In Example #2, width = .75 mil (not w/t).
2. In Example #8, s = 80 mil (not 50 mil).
3. In Table 3, Example #6, and Example #11, the Loss Tangent references should be dimensionless (not inches).
4. Also, in Example #11, α_d is dimensioned in dB/in, following the form of equation (27). Plus, the expression for Q_r should be the same as that given in equation (29a). (A parenthesis and number 2 were omitted.)

We again congratulate Alan on a very concise presentation of basic microstrip design information.

UCLA Extension

Radiation Effects on Electronic Systems
October 10-14, 1988, Los Angeles, CA

Superconducting Detectors
November 1-3, 1988, Los Angeles, CA

Kalman Filtering II
November 28-December 2, Los Angeles, CA

Microwave Circuit Design I
November 28-December 2, 1988, Los Angeles, CA

Microwave Circuit Design II
December 5-9, 1988, Los Angeles, CA

Information: UCLA Extension, P.O. Box 24901, Los Angeles, CA. Tel: (213) 825-1047

The George Washington University

Tactical High Frequency Radio Communications System Planning and Engineering
September 19-23, 1988, Washington, DC

Radiowave Propagation for Communications System Engineering
September 19-23, 1988, Washington, DC
November 7-11, 1988, Orlando, FL

Microwave Radio Systems
September 22-23, 1988, Washington, DC

Introduction to Digital and Analog Modulation
October 3-7, 1988, Washington, DC

Satellite Communications Engineering Principles
October 5-7, 1988, Washington, DC

Modern Communications and Signal Processing
October 10-14, 1988, Washington, DC

New HF Communications Technology: Advanced Techniques
October 17-21, 1988, San Diego, CA
December 12-16, 1988, Washington, DC

Optical Fiber Communications
December 12-16, 1988, Orlando, FL

Information: Shirley Forlenzo, Continuing Education Program, George Washington University, Washington, DC 20052; Tel: (800) 424-9773, (202) 994-8530

Interference Control Technologies, Inc

Grounding and Shielding
September 26-30, Philadelphia, PA
October 24-28, Atlanta, GA

Information: Penny Caran, Registrar, Interference Control Technologies, Inc., State Route 625, P.O. Box D, Gainsville, VA 22056. Tel: (703) 347-0030

Besser Associates

Microwave Circuit Design I: Linear Circuits
August 15-19, 1988, Baltimore, MD

Microwave Circuit Design II: Non-linear Circuits
August 22-26, 1988, Baltimore, MD

Information: Eva Koltai, Besser Associates, Inc., 3975 East Bayshore Road, Palo Alto, CA 94303; Tel: (415) 969-3400

EEsof, Inc.

Introduction to Microwave Computer Aided Engineering
September 6-7, 1988, Westlake Village, CA
November 7-8, 1988, Westlake Village, CA

Introduction to Microwave Computer Aided Layout and Design
September 8, 1988, Westlake Village, CA
November 9, 1988, Westlake Village, CA

Advanced CAE
September 12-13, 1988, Westlake Village, CA
November 14-15, 1988, Westlake Village, CA

Advanced Microwave Computer Aided Layout and Design
September 14, 1988, Westlake Village, CA
November 16, 1988, Westlake Village, CA

Nonlinear Circuit Design
September 19-20, 1988, Westlake Village, CA
November 21-22, 1988, Westlake Village, CA

Information: Sandra Scoredos, EEsof, Inc., 5795 Lindero Canyon Road, Westlake Village, CA 91362. Tel: (818) 991-7530

TriQuint Semiconductor

Digital/Microwave Multi-Project Chip GaAs IC Design
October 9-14, 1988, Portland, OR

Information: Leslie Kasinger, TriQuint Semiconductor, P.O. Box 4935, Group 700, Beaverton, OR 97076. Tel: (503) 644-3535 ext. 4081

Bloom Associates

Modern Power Conversion Design and Analysis Methods
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Information: Bloom Associates, Inc., 115 Duran Drive, San Rafael, CA 94903-2317. Tel: (415) 492-8443

Integrated Computer Systems

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September 20-23, 1988, Los Angeles, CA
September 27-30, 1988, Washington, DC
October 25-28, 1988, Boston, MA
November 15-18, 1988, San Francisco, CA

Digital Signal Processing: Techniques and Applications
September 13-16, 1988, San Diego, CA
October 4-7, 1988, Boston, MA
October 4-7, 1988, Toronto, Canada
October 18-21, 1988, Los Angeles, CA
November 1-4, 1988, Washington, DC

Image Processing and Machine Vision
September 20-23, 1988, Washington, DC
October 4-7, 1988, San Francisco, CA
November 1-4, 1988, Los Angeles, CA

Information: Barbara Fischer, Integrated Computer Systems, 5800 Hannum Avenue, P.O. Box 3614, Culver City, CA 90321-3614; Tel: (800) 421-8166, (213) 417-8888

Design & Evaluation, Inc.

The Worst Case Circuit Analysis Training Seminar
October 17-19, 1988, San Francisco, CA

Information: Design & Evaluation, Inc., 1000 White Horse Road — Suite 304, Voorhees, NJ 08043. Tel: (609) 770-0800

rf calendar

August 30-September 1, 1988
10th Annual Quartz Devices Conference and Exposition
Westin Crown Center, Kansas City, MO
Information: Peter Walsh, Components Group, EIA, 2001 Eye St. N.W., Washington, DC 20006. Tel: (202) 457-4930

September 12-16, 1988
10th Annual Antenna Measurements Techniques Association Meeting
Atlanta Hilton and Tower Hotel
Information: Becky Clark, 1988 AMTA Symposium, c/o Scientific-Atlanta, Inc., Mail Station ATL 28-I, P.O. Box 105027, Atlanta, GA 30348.

1988 RF & Microwave Symposia
Hewlett-Packard Company
September 19, 1988, Kansas City, MO
September 21, 1988, Indianapolis, IN
September 23, 1988, Chicago, IL
Information: Contact local HP sales offices listed in the white pages of the telephone book.

September 14-15, 1988
Mountain States Electronic Expo
Denver Merchandise Mart, Denver, CO
Information: Dick Porter, Midland Exposition Group, 4501 Wadsworth Blvd., Wheat Ridge, CO 80033. Tel: (303) 424-9024

September 30, 1988
5th David Sarnoff Symposium on New Trends in Microwave, Milli-meter Wave and Photonic Device Technologies
David Sarnoff Research Center, Princeton, NJ
Information: Judy Hohman, David Sarnoff Research Center, CN5300, Princeton, NJ 08543-5300. Tel: (609) 734-2037

October 25-27, 1988
RF Expo East 88
Philadelphia Civic Center, Philadelphia, PA
Information: Linda Fortunato, Cardiff Publishing, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80110. Tel: (303) 220-0600; (800) 525-9154

October 27, 1988
3rd Annual EMC Event
Minneapolis Hilton Inn, Minneapolis, MN
Information: Diane Swenson, Tel:(612) 462-7001

November 1-3, 1988
SCAN-TECH 88
McCormick Place North, Chicago, IL
Information: AIM, 1326 Freeport Road, Pittsburgh, PA 15238. Tel: (412) 963-8588

November 8-12, 1988
Electronica '88
Munich Trade Fair Centre, Munich, W. Germany
Information: Gerald Kallman, Kallman Associates, 5 Maple Ct., Ridgewood, NJ 07450-4431. Tel: (201) 652-3898

February 14-16, 1989
RF Technology Expo 89
Santa Clara Convention Center, Santa Clara, CA
Information: Linda Fortunato, Cardiff Publishing Company, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111. Tel: (303) 220-0600; (800) 525-9154

MIT/American Superconductor to Develop Thin-Film Technology

American Superconductor has announced that it has licensed the proprietary thin-film technology developed by Dr. Yet Ming Chiang of MIT. The technology uses a polymeric precursor approach to obtain spin-coated thin films to produce uniform films of bismuth containing superconducting oxides which are able to carry currents in excess of 500,000 amps/cm^2 at 4.2 degrees K.

The thin-film approach was originally developed for rare earth superconductors such as yttrium-barium-copper oxide. In this process, homogenous citrate solutions are first formed and then polyesterfied by heating in the presence of ethylene glycol. The polymer solution is then applied to substrates using spin coating, a technique common to photolithography. The process uses relatively inexpensive materials and equipment to produce smooth films that are compositionally homogenous and work on a variety of substrates and compositions.

The current limitations for many microelectronic and communications devices are primarily the speed by which signals are transmitted. Superconducting materials offer the promise of substantially increasing the maximum speed of these devices. The barriers to implementing devices using traditional superconducting material is the impracticality of operating in a liquid helium environment. High temperature superconductors, on the other hand, eliminate this roadblock by operating in a liquid nitrogen environment, which is becoming the standard operating environment for these microelectronic devices. The challenge is to produce a cost effective material.

American Superconductor is focusing its efforts towards the improvement of electrical parameters particularly critical current and critical magnetic field properties; the improvement of mechanical properties such as fracture toughness and flexibility; and the development of manufacturing processes that yield high volumes of materials in the desired forms.

H-P Opens Atlanta Support Center

Hewlett-Packard Company recently announced the opening of its Atlanta Customer Support Center. It will provide five main support operations at a single location: Customer Network Center; Atlanta hub of the North American Response Center; Customer Education Center; Project Center; and Regional Customer Service Center, a repair depot. The 111,000 square-foot facility will house more than 350 professionals, technical and support workers who serve 16,000 customers.

Trak Expands Scottish Facility

Trak Microwave, Ltd., a subsidiary of Trak Corporation, Tampa, FL., has announced plans to add 5,000 square feet of manufacturing space to its existing Scottish manufacturing facility. In addition to an enhanced manufacturing facility, the company also plans to add personnel to accommodate anticipated growth during the next 18 months.

Amador Opens Third Open Area Test Site

Amador Corporation of Taylor Falls, Minn., announced that it is opening a third open area test site to be located approximately 20 miles northeast of Rochester, Minn. The 32 feet by 66 feet facility will feature an all-weather fiber glass upper floor with a 14 foot diameter remote controllable turntable that will hold up to 10,000 pounds. The non-metallic structure is designed to provide a protected environment for 3 to 10 meter antenna distances. The ground floor will contain support areas and instrumentation rooms for customers as well as a shipping dock and elevator.

RF Power Components to Pursue Coupler and Hybrids Market

RF Power Components, Inc. of New York has entered the marketplace with high power directional couplers and hybrids. Typical products will be in the 20 MHz to 2 GHz range with power ratings in excess of 2 kW. The address is P.O. Box 768, Melville, NY. Tel: (516) 293-6670.

Hughes Begins Work on Next Phase of Australian Satellites

Hughes Aircraft Company, a unit of GM Hughes Electronics, has begun work on Australia's next generation of commercial communications satellites, a system valued as high as $500 million. The Aussat "B" award is the first of Hughes' new line of body-stabilized HS 601 satellites. It is three times more powerful and will last twice as long as the first generation Aussat "A" satellites. Aussat B's are the first Hughes body- stabilized, three-axis, commercial satellites and use internal momentum wheels to provide stabilization once in orbit.

The HS 601 can accommodate a variety of commercial and government payloads requiring power levels from 1 kW to 6 kW. The 3,300 pound satellite will also carry a multipurpose, Ku-band frequency communications payload with 15-50 watt transponders. The satellite's three reflector antenna will generate three receive and seven transmit beams for national and regional communications distribution. The solar array on the satellite is capable of producing more than 3000 watts of power. From the tip of one solar array wing to another, the satellites are more than 66 feet long.

As part of the contract, Hughes will purchase launch vehicles and insurance and will deliver the two satellites only after they have been tested in orbit. The Ariane 4, General Dynamics Atlas Centaur, Chinese Long March 2E and Martin Marietta Titan III launch vehicles are under consideration.

The first Aussat "B" satellite will be ready for launch in late 1991.

Wiltron and H-P File Suit and Countersuit Over Vector Network Analyzers

On May 18, Wiltron Company filed suit against Hewlett-Packard Company, alleging violations of anti-trust laws, unfair marketing practices and contract interference. The companies are competitors in the communications test equipment marketplace. Wiltron, whose recently introduced Model 360 Vector Network Analyzer represents a major competitor in an area dominated by H-P products, alleges that Hewlett-Packard has engaged in illegal conduct to remain in a near-monopoly position. The suit further alleges that H-P has made false and misleading statements about Wiltron to customers, and has interfered with contracts for purchase of the Model 360.

Hewlett-Packard filed a countersuit against Wiltron on July 1, alleging Wiltron violates six H-P patents and one copyright. H-P also asked the court to dismiss the Wiltron suit, claiming that the Wiltron suit was filed after H-P notification of alleged patent infringement in an effort to obscure the infringement issue. Both the Wiltron suit and H-P countersuit seek damages and injunction against the alleged illegal activities of the other.

Mitel/Level One Sign Agreement

Level One and Mitel Corp. have announced a five-year worldwide agreement under which Level One and Mitel will jointly develop and second-source advanced transreceivers for T-1 transmission and ISDN markets. The demand for transreceivers designed for use with twisted-pair wires is estimated to reach $700 million by 1992.

Hytek Receives Contracts from Gould and TRW

Hytek Microsystems, Inc., announced that it has received a one-year contract to supply custom hybrid devices to Gould, Inc.'s Defense Electronics Division in Glen Burnie, MD. The contract is valued at $560,000. If options included in the contract are exercised, the total value will exceed $1 million.

Hytek Microsystems also announced that it received a $280,000 contract from TRW's Electronics and Defense sector, headquartered in Redondo Beach, Calif. The contract calls for complete manufacturing and testing of four distinct custom hybrid devices processed to TRW space flight requirements.

General Dynamics Awards Contract to W-J

Watkins-Johnson Company has been awarded contracts valued at more than $13 million by General Dynamics Corporation of Camden, Arkansas. The contract calls for WJ to supply microwave components and electronic assemblies for the AIM-7M Sparrow air-to-air missile. Work on the contract will be performed at the company's Palo Alto and Scotts Valley, Calif., plant.

Ericsson Receives Taiwanese Contract

Ericsson has received an order for a cellular mobile telephone system from Taiwan's Telephone Administration. The $17 billion contract is for a system that includes Ericsson AXE digital switches, radio base stations and equipment for radio coverage in tunnels. The first part of the systems is expected to be put into service in mid-1989 in Taipei, Taichung and Kaoksiung. Later, the system will be expanded to cover the greater part of Taiwan.

Australian PTT Purchases Telecommunications Equipment

Ericsson has received two large orders valued at $95 million for telecommunications equipment from Telecom Australia, the Australian PTT. The first contract, valued at $18 million, is for radio base station equipment to be used in the AXE-based Australia cellular mobile telephone network.

The other contract, valued at $77 million covers AXE digital equipment for new local, transit and trunk switches, as well as extensions to existing switches. The AXE equipment, which includes more than 160,000 local lines, will be manufactured at Ericsson Australia's Melbourne plant for delivery during 1988 and 1989.

Wilson-Fiberfil Assumes Identity of Akzo

On January 1, 1989, Wilson-Fiberfill International will complete its transition into the Akzo identity and formally become Akzo Engineering Plastics. Wilson-Fiberfill was acquired by Akzo, NV, in 1986.

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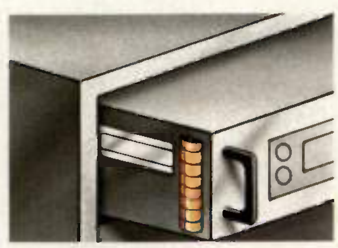

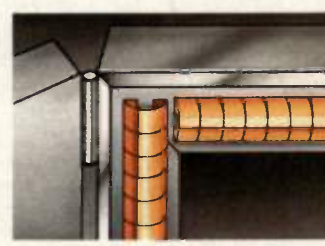

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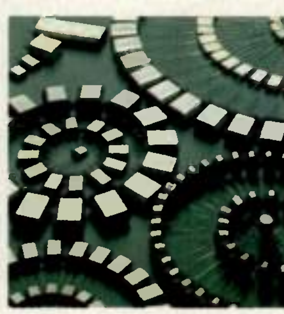

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INFO/CARD 17

EEsof and IBM in Marketing Agreement

EEsof has announced that it has entered into a marketing agreement with IBM under which IBM will market EEsof's Touchstone software. IBM can market Touchstone on IBM ATs and PS/2 computers under this cooperative software agreement. Touchstone will continue to be available directly from EEsof.

Gould Completes Sale to AEG

Gould, Inc. and AEG AG of West Germany, a member of the Daimler-Benz Group, announced that they completed the sale in escrow of the Gould Industrial Automation Systems Group to AEG on June 30, 1988. Gould said that the sale proceeds of approximately $270 million are being held in escrow pending customary regulatory approval of the United Kingdom and French governments. The balance of the announced proceeds of approximately $290 million is subject to adjustments provided for in the transfer agreement and will be determined upon satisfactory completion of remaining closing requirements.

The company noted that upon dispersal from escrow, proceeds will be used in part to further reduce debt and the balance for a stock repurchase program previously authorized by the board of directors. As announced in May 1988, Gould expects to repurchase up to 20 percent of its outstanding common stock from time to time in the open market or privately negotiated purchases, or through other means over the next 12-month period as dictated by market conditions. As of March 31, 1988, Gould had 45 million average shares outstanding.

Air Force Contract Awarded to Raytheon

Raytheon Company's Equipment Division has been awarded a $166.8 million contract by the Air Force Systems Command's Electronic System Division, Hanscom AFB, Mass. to upgrade the BMEWS (Ballistic Missile Early Warning System) Site III at Fylingdales, Yorkshire, England. This will be the second BMEWS radar upgrade built by Raytheon. The first upgrade at Thule, Greenland, provided a phased array radar that is driven by a computer. The radar system is capable of early warning against intercontinental, intermediate range and sea-launched ballistic missiles. It is also capable of keeping track of satellites and other objects presently in space.

The Fylingdales radar upgrade will differ from the one in Greenland in that it will have a third face, which will provide warning and tracking capabilities over 360 degrees of coverage. The upgrade contract includes engineering, production, integration, installation and test of hardware and software which processes and displays data from more than 2,500 antenna elements on each of the three faces.

AEL Awarded Navy Contract

AEL Industries, Inc. announced that its American Electronic Laboratories subsidiary has been awarded a $3.1 million contract by the U.S. Navy's Aviation Supply Office in Philadelphia, to produce 15 low band jammer (LBJ) amplifiers for the EA-6B Prowler aircraft. The LBJ constitutes the two lowest bands of the AN/ALQ-99, a tactical jamming system whose primary purpose is to disrupt radar. In addition to the Navy's EA-6B, the LBJ is also used on the U.S. Air Force's EF-111A aircraft. rf

Quartz Industry to Gather in Kansas City

Industry organizations play a major role in shaping many aspects of the technology they represent. Manufacturing, research, applications, supplier relationships, and customer education are just a few of those areas. The quartz industry will address these items at the 10th Quartz Devices Conference and Exhibition at Kansas City, August 30 through September 1.

The conference is sponsored by the Electronics Industries Association (EIA), through their Quartz Devices Group. Not only do manufacturers of quartz products get together, but so do their suppliers and customers. The exhibition is an opportunity for anyone involved with quartz, its production or applications to further explore the technology in a very focused manner.

Like many conferences, this one has both technical papers and an exhibition hall. The technical program, including both industry and customer applications sections, is highlighted on page 38 in the "RF Special Edition: Quartz Technology" included within this issue. The exhibition hall has space available for over 30 companies involved in crystal manufacturing, filters, SAW devices, bulk quartz production, processing equipment, and packaging.

Highlights of the show include two major awards, to be presented on Tuesday, August 30. The industry's "Man of the Year" for 1988 is one, a high honor for an important contributor to the success of the quartz industry. The 1987 Man of the Year was D. Canon Bradley, President of Colorado Crystal Corporation.

The second award winner has waited an entire year to receive it! This is the "Best Paper of the 9th QDC&E," determined by the votes of attendees at the previous years' conference. Last year, the award was given to Tim Semones of Innovative Measurement Solutions for his 1986 paper, "A Software Implementation of EIA-512."

One of the activities supported through the proceeds of the Quartz Devices Conference is university/industry research. This work involves piezoelectric resonators, oscillator and filter research, measurements, and other basic study. University participants include Northern Illinois University, Oklahoma State University and the University of Central Florida. Present and future projects include etch pipes, surface mounting and traceability of measurements.

The Role of the EIA

The Quartz Devices Group is part of the EIA, whose role in the electronics industry is clearly demonstrated by this event. This organization has several key activities. First, it is a central organization to which a large percentage of electronics manufacturers belong. As such, the EIA can keep communications open among otherwise competitive companies, and can actively promote a whole industry. The conference in Kansas City is a prime example of an industry-wide activity.

The other role that the EIA fulfills is extremely important: the establishment of technical standards for performance of electronic products. In conjunction with other organizations such as the American National Standards Insitute (ANSI), the military, and the National Bureau of Standards, the EIA is constantly working to establish specifications for its member companies that simultaneously fit customers' requirements and manufacturers' capabilities.

Congratulations to the EIA and the quartz industry for ten years' success with the Quartz Devices Conference! Many *RF Design* readers will be in Kansas City to toast their 10th Anniversary; maybe you will be one of them. rf

A Loran-C Front End Using the LM1211

RF integrated circuit can be used in low-frequency applications.

By Ralph W. Burhans
Burhans Electronics

The National Semiconductor LM1211 linear IC is an IF amplifier and product detection system for operation in the 20-80 MHz range. It is intended for data or video recovery from broadband local area networks (LAN) and other communications systems. This article decribes a low frequency application, taking advantage of the IC's flexibility.

In normal operation, the LM1211 has a SAW filter compatible input and can be gain controlled in excess of 40 dB (Figure 1). A versatile product detector is used where the input signal is multiplied by a reference derived from limiting and phase-shifting the input. The signal input is isolated from the reference path for external connections and the phase shifter is operated from DC over the 20-80 MHz IF range. The chip is also adaptable below 20 MHz to provide an RF front-end for a Loran-C receiver or as an IF strip and detector for AM-CW-SSB-FSK in simple SWL receivers.

Loran-C Time-Frequency Checking

One application for a simple Loran-C front-end is as a source of reference. This includes timing pulses for checking local crystal clock oscillator offset, drift, and aging rates. In this case, a group repetition interval (GRI) generator driven from a local crystal clock under test is compared with the same GRI as obtained from the Loran-C received pulse envelope. The pulse groups are aligned on a scope trace such that the leading edge of a particular pulse can be observed. Any drift to the right or left of this pulse edge then represents a drift of the local clock used to synchronize the scope sweep. Observations taken at selected time intervals then give the clock offset and aging rate.

Loran-C Filters

For this pulse detector, a wideband 100 kHz filter is needed in place of the SAW filter used at higher IFs. Many types of filters have been designed for Loran-C, generally with a -3 dB bandwidth of 20 kHz and -30 dB bandwidth of 50 kHz or so in order to properly pass the risetime of the transmitted pulse envelope. Most receiver filters also produce envelope delay distortion because of the finite bandwidth limitations and the problem of interference reduction at adjacent channels such as 77, 88, and 126 kHz high power military-marine VLF communications. A fixed tuned elliptic-type filter where the traps are tuned to the desired interference rejection notches is illustrated in Figures 2a and 2b.

This filter consists of standard 455 kHz IF transformers padded down with additional resonating capacitors. The filter is intended to be driven from an active E-field antenna preamplifier with a low impedance output. The circuit can be tuned by coupling to a suitable CW signal source, tuning the traps for nulls at 88 and

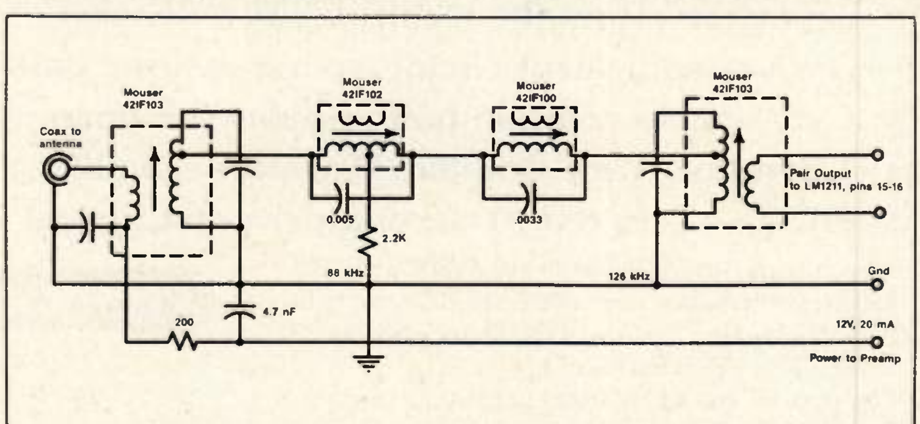

Figure 2a. Loran-C input filter circuit diagram.

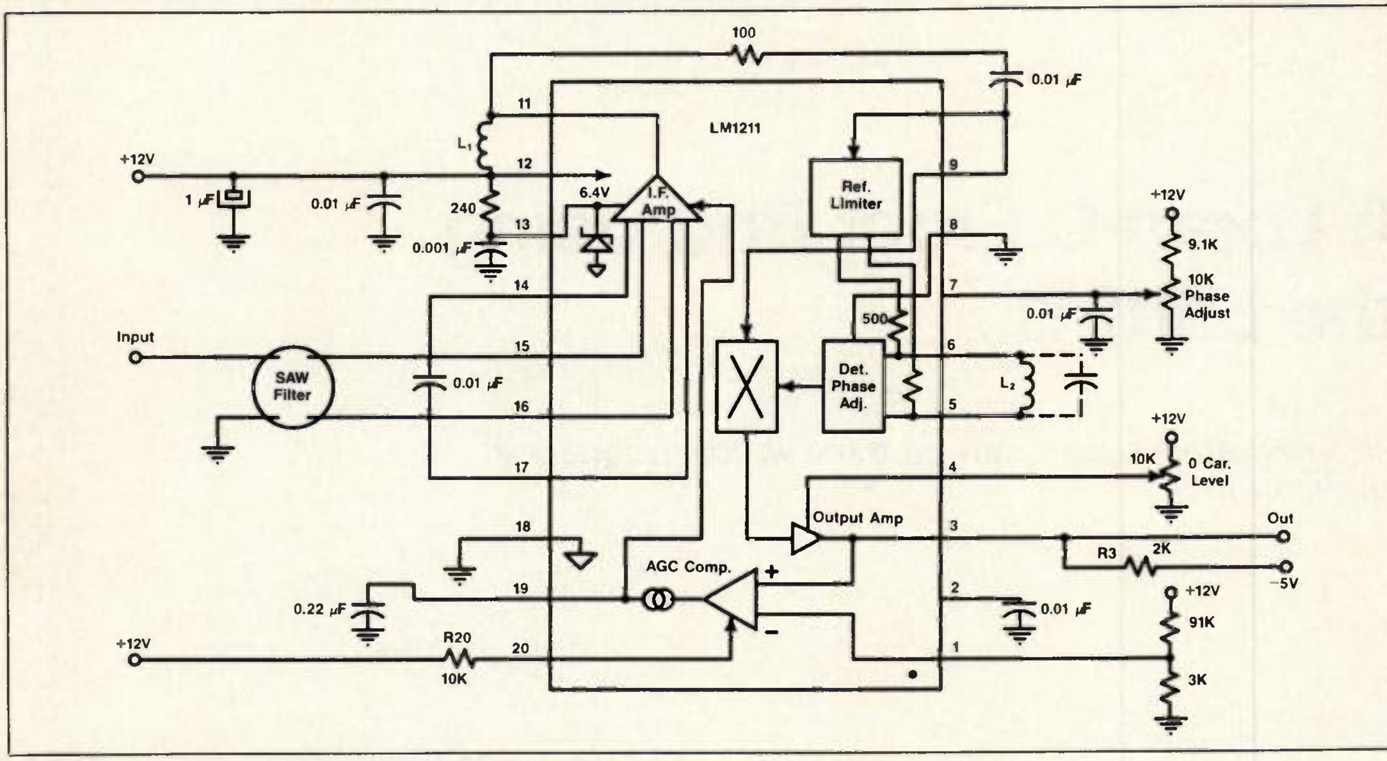

Figure 1. LM1211 broadband demodulator system.

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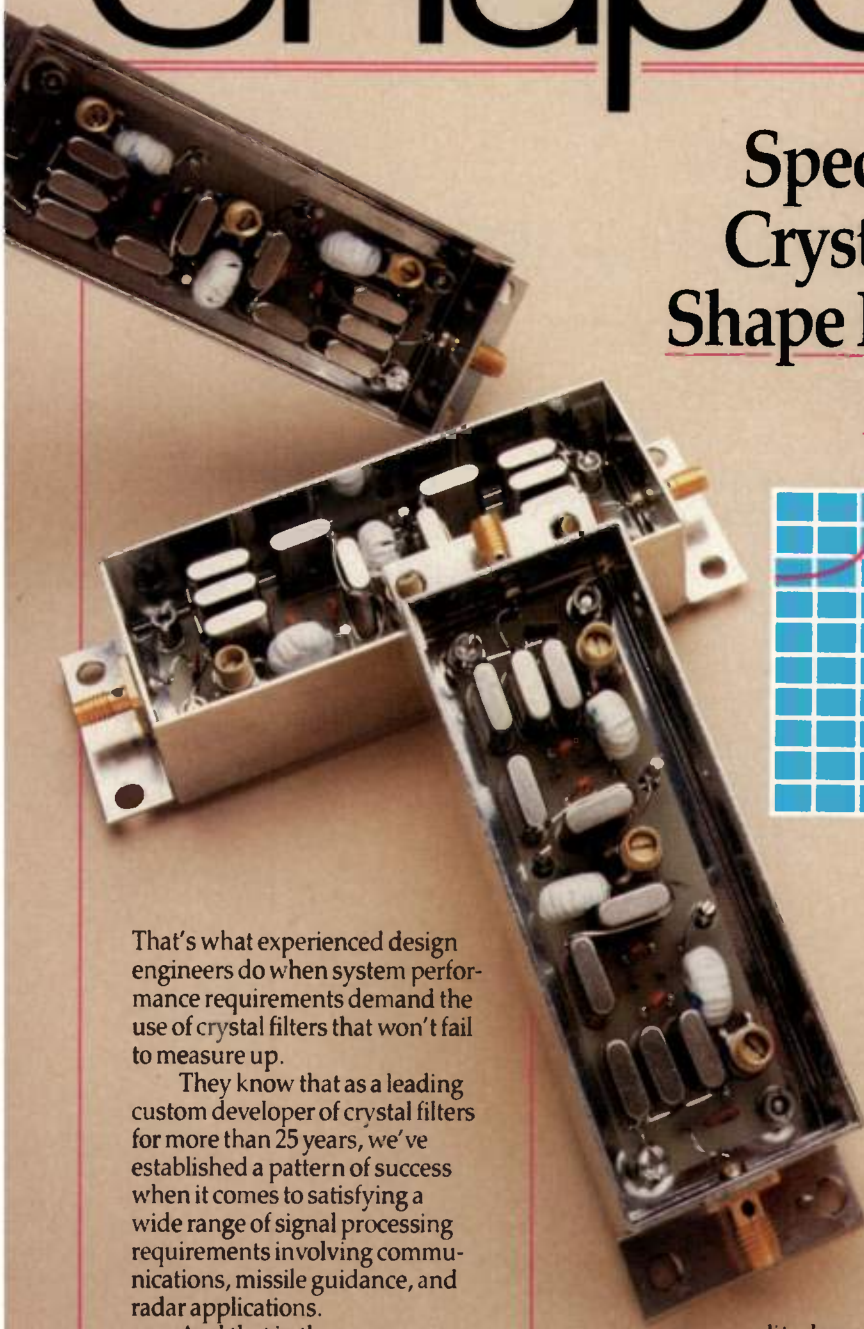

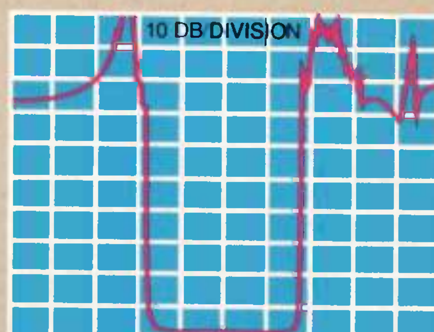

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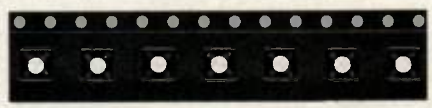

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INFO/CARD 33

126 kHz and then tuning the two end transformers for the flattest response over the 95 to 115 kHz range. The lowest frequency trap at 88 kHz is a modified bridged-T circuit with the resistor chosen to produce the deepest null.

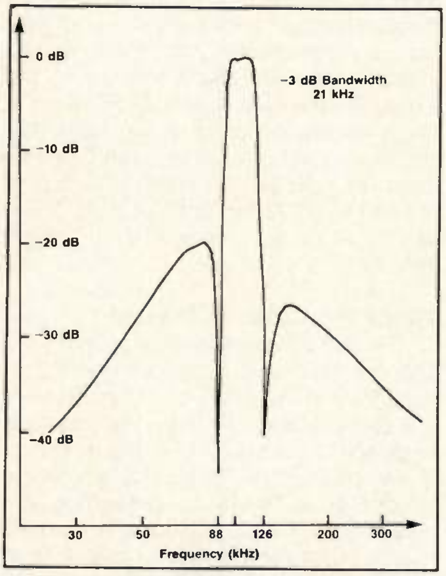


Figure 2b. Frequency response of the Loran-C input filter.

For the ideal case, the traps should be tuned well outside the 90-110 kHz range to provide the minimum envelope distortion on the received pulse and the bandwidth of the antenna preamplifier should be much wider than this input filter at the receiver.

Delay and Add Methods

Many Loran-C receiver front-ends contain an envelope detector where a delayed version of the signal is multiplied with the undelayed carrier to provide a zero crossing at the 3rd or 4th cycle of the 100 kHz carrier. The 3rd cycle of the transmitted pulse is defined as the reference point for timing and navigation purposes in the Loran-C coverage area.

A method of detecting this point is to delay and add the signal from two paths, one of which is delayed 5 microseconds with respect to the output signal from the IF amplifier. A portion of the output signal is added to the delayed signal producing a null effect at some point in the risetime of the pulse. A simple network which performs this function is a bridged-T with a resistor providing the add and a parallel resonant circuit providing the delay. The resistor is adjusted to shift the phase of

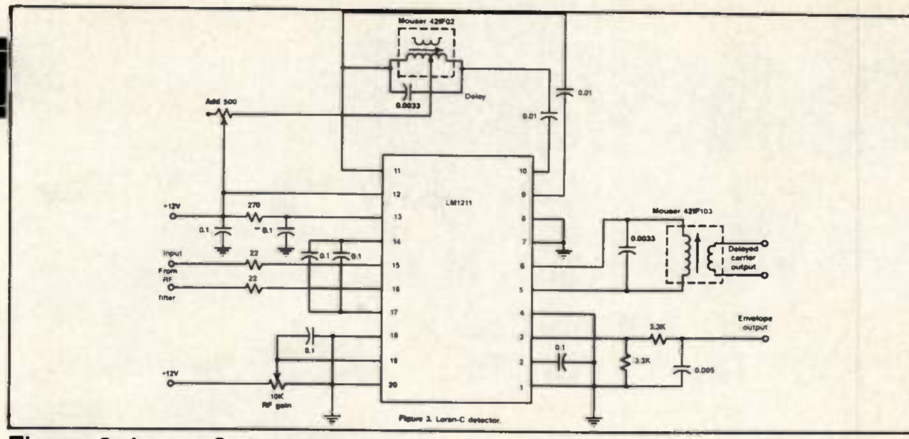


Figure 3. Loran-C detector.

the null point at the desired 3rd or 4th cycle while the tuned circuit peaks at 100 kHz.

Loran-C 100 kHz Detector

The complete detector circuit is illustrated in Figure 3 where 455 kHz IF transformers are used for the delay and add function with an isolated 100 kHz output carrier. The output from pin 3 of the LM1211 provides the envelope of the Loran-C pulse with a simple RC filter to clean up the signal for direct use in timing observations on the Loran-C envelope. The voltage gain of this system is of the order of 100 dB from the input of the RF filter to the output DC envelope limiting at 3 V_{p-p}.

Precision Loran-C Tracking

The signal from the reference port, pins 5 and 6, has an emphasized zero crossing effect at the 4th cycle. The phase of the zero crossing before the null point are opposite to the phase after the null point which could possibly be used by external processor software to determine the reference point of the original Loran-C signal pulse. The envelope output from pin 3 is much less precise in determining this reference point because of the additional process filtering in the detector. However, the envelope output is easier to observe in raw scope observations for timing checks. This envelope output could be used with processor software to estimate where to start tracking the more precise carrier crossing points from pins 5 and 6 where added limiters would provide 100 kHz carrier zero crossing points from the transformer output.

Thus, the LM1211 with relatively simple circuitry can provide both functions — input for hard limiters and envelope processing on Loran-C signals. The chip also has internal AGC functions but this is not desirable for Loran-C because strong signals of a given chain will decrease the signal for weak signals and cross chain interference from other strong Loran-C signals may activate the AGC just before a desired weak signal is to be detected. The pin 20 AGC gate is grounded in this application and a DC control pot is used as manual RF gain control. In practice, this RF gain control is set such that the antenna noise level is plainly visible on the baseline of the envelope output, but it could also be controlled with external processor software and suitable D/A converters as each envelope comes up during a known GRI interval.

455 kHz IF Strip

The LM1211 detector IC can also be used as a combination AM- CW-SSB-FSK detector with a standard 455 kHz IF system. The circuit illustrated in Figure 4 is intended for possible use in a simple communications receiver with a final IF output of 455 kHz obtained from a suitable low impedance ceramic, crystal or mechanical filter coupled to pins 15 and 16 with a suitable transformer. An IF output transformer (Mouser 42IF103) connected to pin 11 provides the drive for the linear signal input at pin 9 and also pin 10 in the AM mode. Here the detector is operating in the normal autocorrelation or quasi-synchronous mode.

BFO Circuit

For CW, SSB, and audio FSK, the limiter stage is connected with the selector switch as an oscillator circuit. This makes use of the limiting reference output on pins 5 and 6 as feedback. The transformer (Mouser 42IF100) primary low impedance tap matches the input impedance at pin 10 and the low impedance secondary winding provides a broadband match at the output pins 5 and 6. The oscillator transformer pin 6 signal is in phase with the signal on pin 10 for the correct feedback polarity. The result is a BFO signal amplitude of 200 mV p-p or more appearing at the output of reference pins 5 and 6. The BFO is tuned over a 5 kHz range centered on 455 kHz with a variable capacitance diode and voltage control pot. The BFO could also be used for audio FSK detection. When operating in the AM mode, the oscillator tuned circuit is disabled and broadly resonant at 455 kHz as required at pins 5 and 6.

AGC

A fast attack-slow decay AGC system is provided with a threshold control connected to bias pin 4. This is slightly different than the normal connection of using pin 1, and works better in this case when the pin 3 output audio is returned to ground through the 3.3 k resistor rather than returned to −5 V. Thus a single +12 V supply operates the circuit.

For maximum weak signal sensitivity it may be useful in some applications to bring the threshold control at pin 4 out as a front-panel control element. The limiting sensitivity for AM detection is about 1 μV rms with 50 percent modulation at pins 15 and 16, generating 20 mV p-p at the pin 3 audio output filter. The threshold sensitivity for narrowband CW signals is better at about 1 μV for a 50 mV p-p audio output. The ultimate sensitivity is critically dependent on the impedance match of the input filter at pins 15 and 16, the AGC threshold adjustment, and a proper circuit layout with good isolation and capacitor bypassing. rf

References

1. LM1211 Broadband Demodulator System, National Semiconductor Corporation.
2. R.W. Burhans, "Using Loran-C for Time and Frequency Checking," *Radio Electronics*, July 1983.

About the Author

Mr. Burhans is a retired research engineer and lecturer from the Avionics Engineering Center of Ohio University in Athens, Ohio. He has spent the past 20 years working on low frequency navigation receiver systems where he was a mentor in a NASA-FAA sponsored Tri-University program. He may be contacted at Burhans Electronics, 161 Grosvenor St., Athens, Ohio 45701, phone (614) 593-8207.

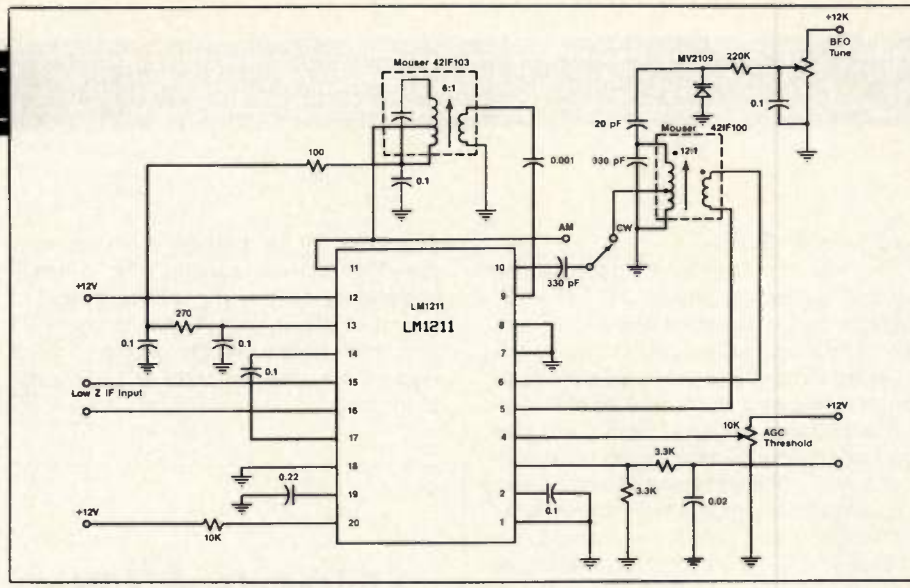
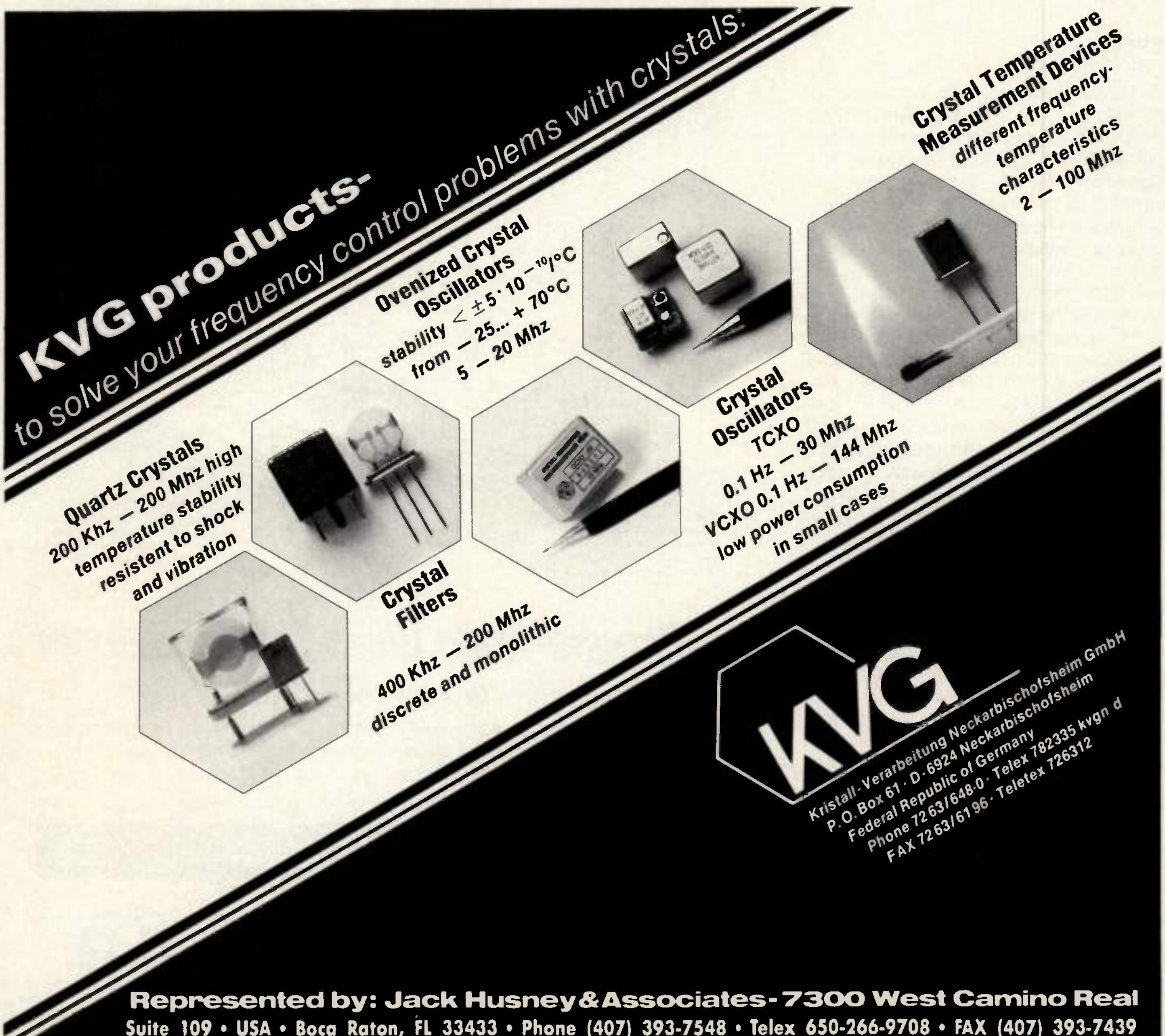


Figure 4. AM-CW-SSB detector.



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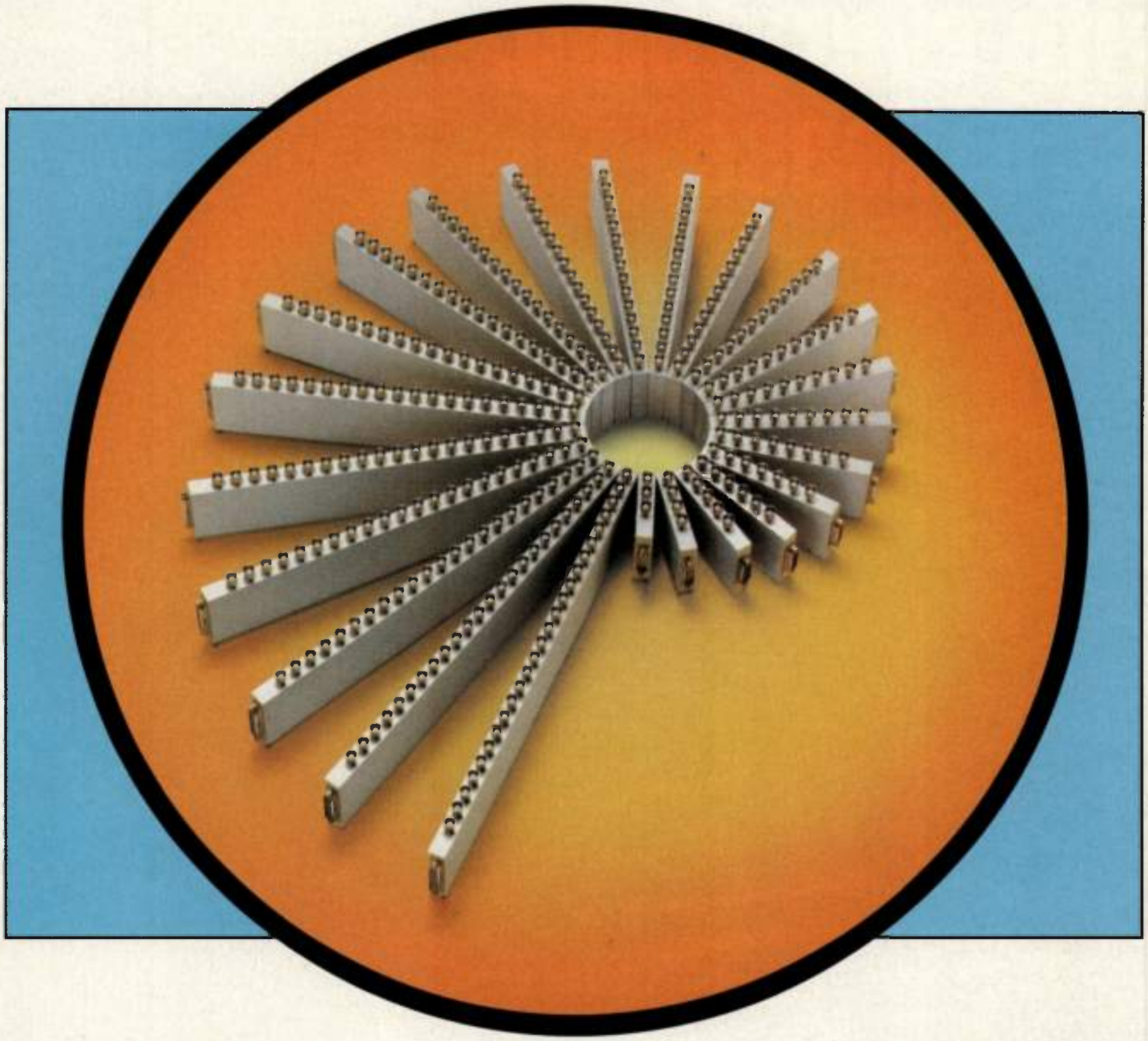

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INFO/CARD 22

EMC Organizations and Societies

By Mark Gomez
Technical Editor

This article lists the major societies in the EMC community together with brief descriptions of their charters. Many of these organization have local chapters which are not listed due to space restrictions. If your organization is not mentioned in this listing, please inform the author so that a more comprehensive list can be published at a later date.

Electronic Industries Association (EIA)

This diverse association covers the complete electronic industry which includes manufacturers and distributors. Founded in 1924 after being named "Radio Manufacturers Association" its goals include technical progress, national defense economic growth, and participating in the interests of the electronic industry. The name "Electronic Industries Association" was adopted in 1957. The main function of this organization is to produce standards which are normally certified by ANSI at the request of the EIA.

An EMC Committee, known as G-46, was born to establish a user/industry stand on Government specifications, regulations and standards. The EIA generally reviews and comments on proposed government specifications and standards before they are released.

G-46 activities include spectrum management and conservation, personnel safety and health care electronics design and usage, and installation in terms of regulated and non-regulated electromagnetic emissions and receptions. This EIA committee also assures that EMC legislation, regulations, specifications, standards, requirements and evaluation procedures are acceptable for procurement and application. When necessary, the EIA provides support to other organizations. A key task is the coordination and promulgation of information. More details can be obtained from EIA at 2001 Eye St., N.W., Washington, DC 20006, or circle INFO/CARD #219.

Telecommunications Industries Association

This association is a spin-off from the EIA. It is made up the telecommunications division previously part of the EIA and the USTS (United States Telephone Suppliers). Known as the TIA, this organization is totally independent from the EIA, even though they still share the same facilities. For more information, contact TIA at 2001 Eye St., N.W., Washington, DC 20006. INFO/CARD #218.

Institute of Electrical and Electronic Engineers

This professional society, with over 250,000 members, has various technical societies such as the EMC society which boasts a membership of 2,500. The main function of the society is to promote technical advancement through educational programs and the distribution of information.

The EMC society has 28 local chapters located in major cities in the United States; Ottawa, Canada; Tel Aviv, Israel; and Tokyo, Japan. The society is active in technical conferences and symposia through its sponsorship of the Electromagnetic Compatibility Symposium and participation in various local and international conferences and symposia. An inter-society relations committee organizes special sessions and secures invited papers for other conferences that have an EMC interest. Further details are available from the IEEE, 345 E. 47th St., New York, NY 10017. INFO/CARD #217.

Society of Automotive Engineers

The Society of Automotive Engineers is a professional society dedicated to a wide spectrum of engineers in the aerospace and automotive fields. The EMC elements are handled by SAE Committee AE-4 which is composed of technically qualified members, liaison members and consultants who are responsible for coordinating and advising on electromagnetic compatibility. It provides assistance to the technical community through standardization, design improvements and testing methodology. Also, it maintains a technical forum for the resolution of mutual problems. Engineering standards, specifications and technical reports are developed by the committee and issued by the society for the general information of industry and governments worldwide.

The AE-4 committee is comprised of seven different standing subcommittees which are the AE-4A, AE-4B, AE-4C, AE-4D, AE-4F, AE-4L and AE-4R to address the various EMC issues. Committee membership is comprised of over 170 engineers including international participants. Details on AE-4 can be procured from SAE AE-4, 400 Commonwealth Dr., Warrendale, PA 15096. Please circle INFO/CARD #216.

American Council of Independent Laboratories

This organization is made up of about 400 independent commercial labs. Approximately 10 of these labs perform EMI and telecommunication testing. The organization acts as a voice on legislation for EMC related issues (eg. MIL-STD) for these trade organizations. It does not, however, set standards. This council was the first organization to petition the National Bureau of Standards to set up the NBS National Voluntary Laboratory Accreditation Program (NVLAP). Current activities include representing the United States in the recent European hearings for achieving standardized testing before the 1992 lift on trade barriers. Further information can be obtained from ACIL, 1725 K St., N.W., Washington, DC 20006. INFO/CARD #215.

EOS/ESD Association

EOS/ESD is an acronym for Electrical Overstress/ Electrostatic Discharge. The primary field of interest of this organization is the advancement of the theory and practice of electrical overstress avoidance, with emphasis on electrostatic discharge phenomena. The technical focus includes considerations to the effects of both material and manmade electromagnetic threats (ESD, EMI, EMP, Lightning, etc.) on electronic components, subsystems and systems. The technical community includes personnel in government, industry and academic organizations involved in research and development, electronic equipment manufacturers and user, and EOS/ESD effects reduction products and methods. Further information can be received by writing EOS/ESD Association, Inc., at P.O. Box 298, Westmoreland, NY 13490. INFO/CARD #214.

Electromagnetic Energy Policy Alliance

The Electromagnetic Energy Policy Alliance (EEPA) is an association of manufacturers and users of electronic and electrical systems that utilize non-ionizing electromagnetic energy in telecommunications, broadcasting, manufacturing and consumer services. The primary objective of the alliance is to work for a responsible and rational public policy regarding electromagnetic energy. EEPA actively promotes public education, sponsors research and acts in an advisory capacity to regulatory and standard-setting bodies. Information can be obtained from Richard Ekfelt, EEPA, 1255 23rd St., N.W. Washington, DC 20037. INFO/CARD #213.

American National Standards Institute

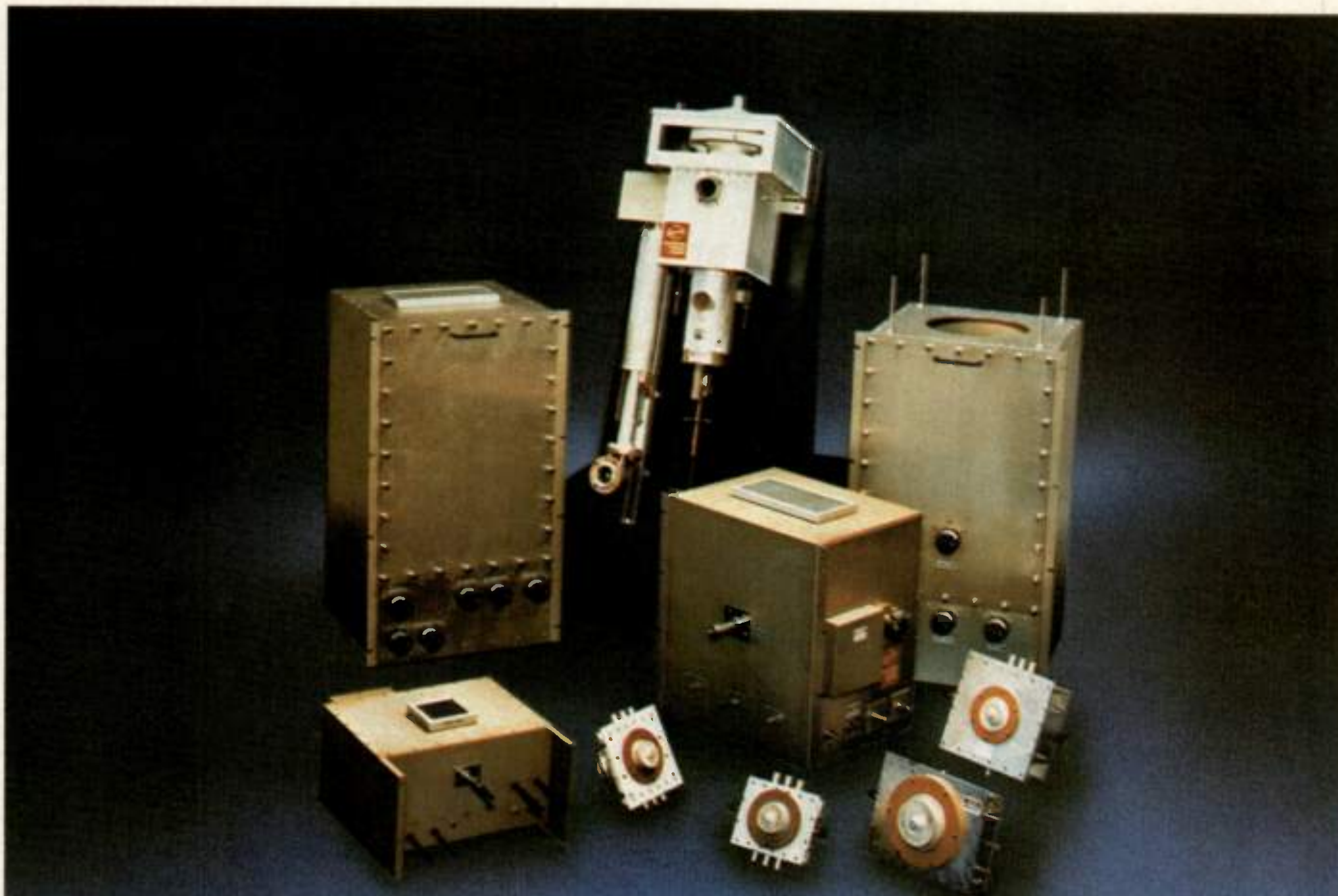
The American Standards Institute, ANSI, basically participates in coordinating standards. Among the EMC related standards committees that are part of ANSI are the C63 and C95.1.

The C63 Ad Hoc committee is concerned with interference related issues as far as consumer electronics is concerned. Recent activities include developing voluntary standards for susceptibility of VCRs and cordless telephones. The voluntary standards have been implemented, with significant manufacturer compliance. The problems of susceptibility of cordless phones has virtually been phased out and the problem with VCRs has been significantly reduced.

C95.1 is concerned with non-ionizing radiation hazards from DC to 100 GHz. The committee's main function is to prepare standards on related issues. An example of its current activity is the revision of a standard relating to human exposure. More information can be obtained from ANSI, 1430 Broadway, New York City, NY 10018. INFO/CARD #212.

Bio Electromagnetics Society

The Bio Electromagnetics Society (BEMS) is a society devoted to promote scientific effects of electromagnetic radiation within biological systems. The members are scientists and related people who are involved in parallel industries and participants in organizations that recommend and set standards. The society publishes a journal, holds annual meetings, symposiums and workshops. This non-profit organization also recommends people to organizations such as the ANSI subcommittees. Further information can be obtained from Dr. William Wisecup, 121 W. Church St., Frederick, MD 212714. INFO/CARD #211. rf



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CV-2225	4CX3500A	86–108	5 kW
CV-2240	3CX10,000U7	54–88	10 kW†
CV-2250	3CX10,000U7	170–227	10 kW†
CV-2400	8874	420–450	300/1250 W*
CV-2800	3CX400U7	850–970	225 W
CV-2810	3CX400U7	910–970	190 W

*pulsed power
†peak sync, or 2.5 kW combined in translator service

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INFO/CARD 23

Quartz Devices Conference & Exposition: The Technical Program

Papers for Industry and User Engineers Highlight the 10th Anniversary of the Conference.

Milestone anniversaries are a time to celebrate, and the 10th Quartz Devices Conference & Exhibition is no exception. This exhibition is the top event of the year for the quartz industry, offering engineers within the industry a chance to do some focused study in materials, production, measurements and regulatory matters. For their customers, the industry includes plenty of information on performance specifications, applications engineering, and new technologies.

Because quartz represents one of the oldest and most important RF technologies, *RF Design* is pleased to be part of the 10th Anniversary celebration of the Quartz Devices Conference. It is a rare RF engineer who is not involved with quartz technology. Whether it's crystal oscillators, filters, discriminators; or SAW resonators, filters and delay lines, quartz is a universal RF component.

The sponsors of the conference emphasize its "nuts and bolts" character. The technical sessions are intended to allow the attendees the maximum usage of their time and talents in areas involving both business and technology. The papers are divided into two tracks: Session A, dedicated to "Applying Current Technology," and Session B, devoted to "Improving Productivity."

Session A papers are directed to engineers who are users of quartz products, and to industry engineers who have responsibility for customer applications. The Session B topic is new this year, intended for industry engineers and managers, but valuable for anyone involved in manufacturing processes of any kind.

Here is the schedule for the conference events, including the papers for each Session, as of the date of publication (the exhibit hall is open from 2:30-7:00 p.m., Tuesday and Wednesday, 9:30 a.m.-Noon on Thursday):

Monday, August 29
5:00 p.m.-6:00 p.m.
General Registration, plus wine and cheese reception.

Tuesday, August 30
8:30 a.m.-Noon Session A
Crystal Manufacturing and Process Control
Photolithographic Techniques Applied to Quartz Resonators
Lapping, Grinding and Polishing Techniques
Production Techniques for Measuring G Sensitivity

8:30 a.m.-Noon Session B
Statistical Process Control (SPC) and Design of Experiments, Keki Bhote, Motorola, Inc.

Much of what passes for Statistical Process Control in the U.S. is either trivial, obsolete or wrong. This course will present, in non-mathematical terms, a variety of easy and low-cost but statistically powerful techniques that can be learned by all levels in a company from managers to line workers.

1:30 p.m.-5:00 p.m.
Session A (continued)

Crystal Design and Packaging
Surface Mount Packaging and LCC Packages

1:30 p.m.-5:00 p.m.
Session B (continued)
Statistical Process Control and Design of Experiments (conclusion)

5:30 p.m.-7:00 p.m.
Special Presentations
"Man of the Year"
"Best Paper of the 9th QDC&E"
Champagne toast of the 10th Anniversary

Wednesday, August 31
8:30 a.m.-Noon Session A
Measurements and Test Techniques
A Conclusion from the Round Robin Crystal Measurement Experiment
Quartz Resonator Model Measurement and Sensitivity Study
Measurement Traceability with NBS

8:30 a.m.-Noon Session B
Cycle Time Reduction — Design of World Class Operations, James Swartz, Competive Action

Attendees will learn, step by step, how to improve their operations. I the workshop, as part of a team, they will operate a simulated manufacturing operation through "real and flow analysis" that will indirectly remove obstacles.

1:30 p.m.-5:00 p.m.
Session A (continued)
Oscillator and Filter Design
Digitally Compensated Crystal Oscillators
Environmental Effects on the Stability of QuartzOscillator Designs
Impact of MIL STD 1772 on Hybrid Oscillator Manufacturing

1:30 p.m.-5:00 p.m.
Session B (continued)
Cycle Time Reduction (conclusion)

5:30 p.m.-7:00 p.m.
Hospitality Reception

Thursday, September 1
8:30 a.m.-Noon Session A
Properties of Quartz Material
Sensitivity of Quartz to Various Levels of Radiation
Quality of Quartz Measurement Standards

The conference has an excellent social calendar, as well. Tuesday and Wednesday evenings from 5:30 to 7:00 offer hospitality receptions in the exhibit hall, while Monday evening has a special treat, a jazz "Pub Crawl." Jazz lovers can take in three jazz clubs, including a barbeque dinner at the Mutual Musicians Foundation at 18th and Vine.

Registration for the Quartz Devices Conference and Exhibition should be completed by August 19th. Conference registration costs between $200 and $250, depending on the number attending and whether the company is an EIA member. The Proceedings are $50; the Jazz Lover's Pub Crawl is $30, with limited space available. rf

For registration information, please contact:

Electronic Industries Association
10th Quartz Devices Conference & Exhibition
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INFO/CARD 39

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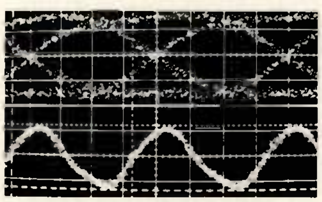

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UPG701B	Master Slave T-Type Flip Flop	400 ps	4.5 GHz
UPG702B	3-Input NOR/OR	400 ps	3.0GHz
UPG703B	Four Stage Ripple Counter	500 ps	2.5 GHz
UPG704B-15	4:1 Multiplexer	800 ps	1.5 GHz
UPG704B-20	4:1 Multiplexer	800 ps	2.0 GHz
UPG704B-25	4:1 Multiplexer	800 ps	2.5 GHz
UPG705B-15	1:4 DeMultiplexer	800 ps	1.5 GHz
UPG705B-20	1:4 DeMultiplexer	800 ps	2.0 GHz
UPG705B-25	1:4 DeMultiplexer	800 ps	2.5 GHz
UPG706B-1	High Speed Flip Flop	400 ps	4.0 Gbps
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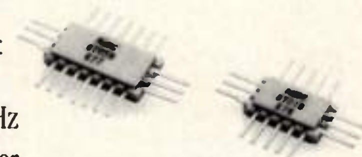

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INFO/CARD 41

Quartz Crystals and Aperiodic Oscillators in RF Systems

Part I: Specifying Crystal Parameters

By Dr. I.J. Dilworth
University of Essex

In most radio frequency systems the quartz crystal oscillator is an essential component or sub-system. This article discusses the essential parameters required when specifying quartz crystals and is centered around the AT cut crystal.

RF engineers normally use quartz crystals in oscillators and filters. In terms of the latter, efficient use depends on the associated circuitry presenting a proper impedance match. The same can be said about quartz crystals employed in oscillator circuits. The quartz crystal feedback oscillator is arranged to encourage feedback at the desired output frequency. Quartz crystals can be cut and mounted to favor operation in either their fundamental resonance mode (their lowest frequency of operation) or in a higher order mode corresponding to a multiple of the fundamental resonance. Only odd multiples (3,5,7,9 etc.) of the fundamental resonance are produced and series resonance is employed for such overtone crystals.

It is important to note that the resonances presented by the quartz are mechanical rather than electrical although the output produced by the piezoelectric effect is an electrical potential. They are Bulk Acoustic Wave devices (BAW). Their VHF/UHF equivalent are Surface Acoustic Wave devices (SAW's) which can be represented by the same equivalent circuit.

Note that all crystals can be specified to oscillate at either their series or parallel resonant frequencies. The equivalent circuit of a crystal and the equations governing the resonant frequencies are shown in Figure 1 together with the important circuit parameters and relevant equations. Note that parallel resonance is also often referred to as anti-resonant or as a series-load type. All these terms are synonymous.

Series resonant frequency

$f_s = 1/2\pi(L_1C_1)^{0.5}$ (always $< f_p$) (1)

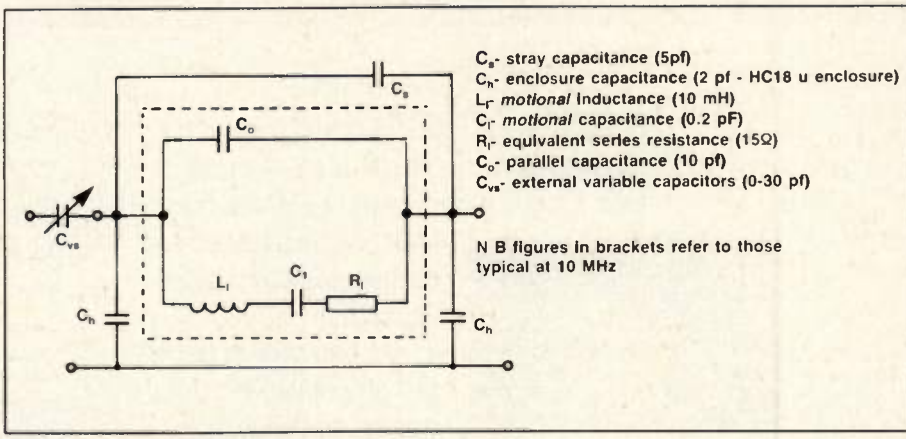

Figure 1. Crystal equivalent circuit.

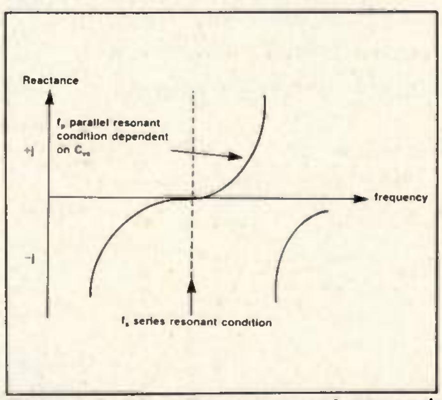

Figure 2. Reactance at and around resonance.

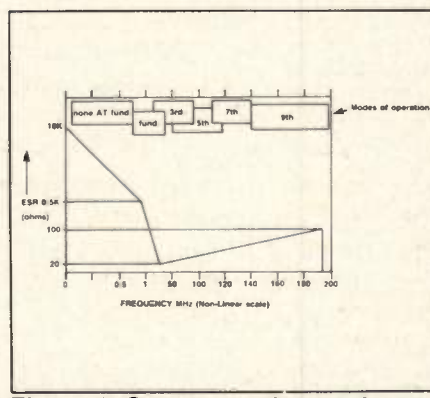

Figure 3. Summary of crystal parameters.

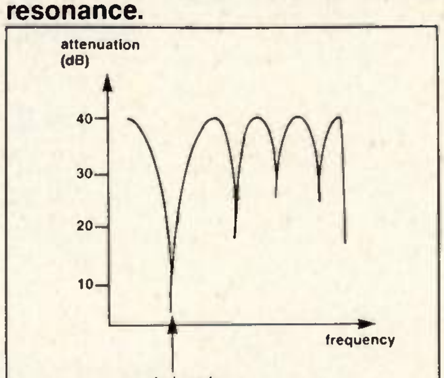

Figure 4a. Crystal attenuation versus frequency.

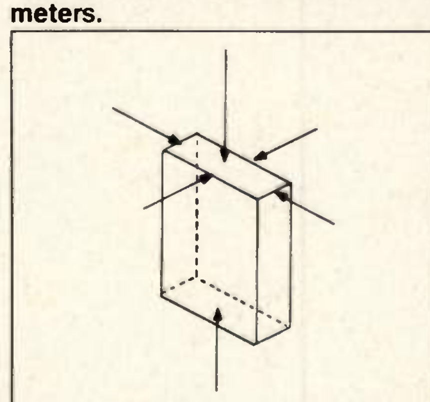

Figure 4b. Vibrations on a crystal.

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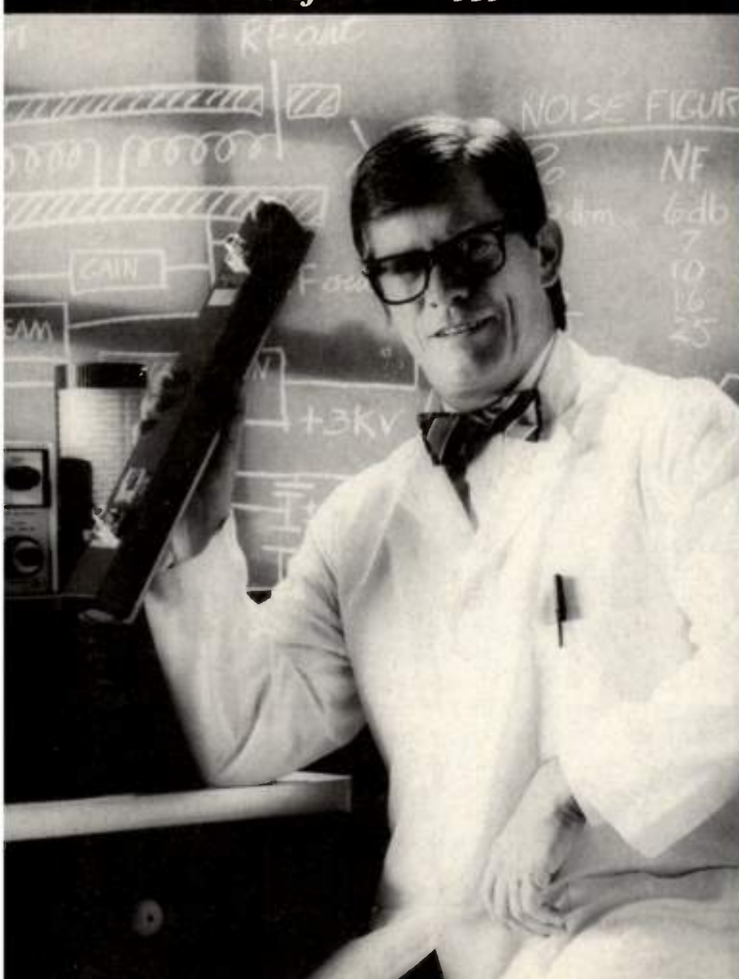


State of the art 1987.

Parallel resonant frequency

$f_p = f_s(C_1/(1 + 2(C_o + C_{vs}))$
(always $> f_s$ dependent on C_{vs}) (2)

Q factor (88,000)

$Q = 2\pi f_s L_1/R_1 = 1/2\pi f_s C_1 R_1$ (3)

Although the capacitive contributions in the resonator are small the equivalent inductive component is large. In addition the resistive contribution which occurs using a wire wound inductor of similar value is very much less, resulting in a very high Q factor when compared to that available from an L-C circuit at the same frequency. However, the effective Q when used in an oscillator configuration will always be less than the theoretical Q given by the formula. The actual operating Q is proportional to the reactance slope at resonance as discussed in Part 2 of this article and illustrated in Figure 2.

The series resonant frequency is a single point corresponding to zero reactance (Figure 2) whereas the parallel resonant frequency may be any frequency within the parallel resonant region dependant on the external load capacitance C_{vx}. Series and parallel resonant crystals are manufactured in exactly the same way except that the parallel resonant unit is always measured at the specified load capacitance — usually taken as 30 pF.

Crystals cut for fundamental operation below 500 kHz utilize modes of vibration differing from the Shear AT fundamental mode and overtone AT cut crystals used in higher frequencies. A summary of the most important parameters of typical quartz crystals for frequencies between 50 kHz and 200 MHz is shown in Figure 3.

Fundamental mode crystals are generally limited to frequencies below approximately 30 MHz since above this frequency the quartz becomes too thin to be practically useful. As observed in Figure 3, third overtone types can be specified above about 5 MHz. As will be discussed

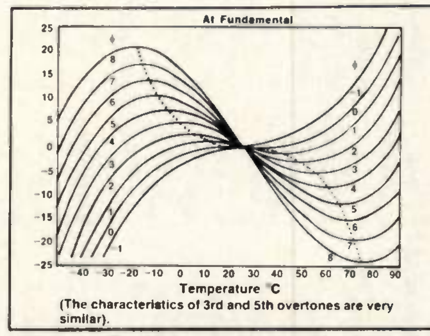
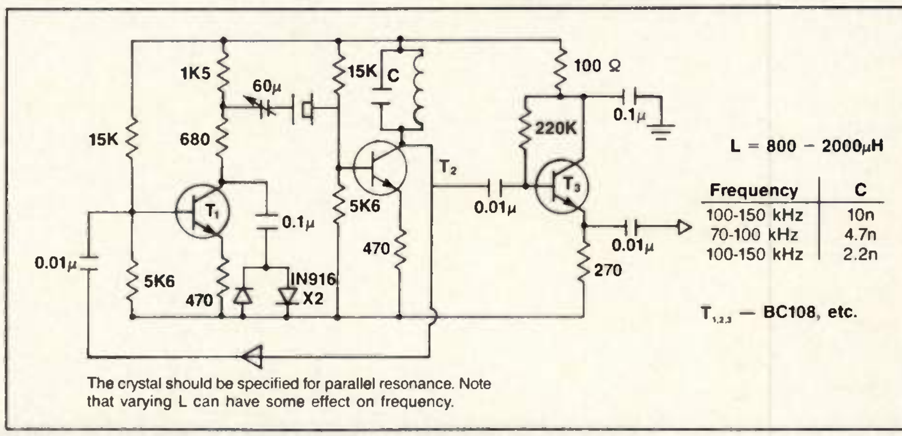


Figure 5. Temperature/frequency characteristics.



Frequency	C
100-150 kHz	10n
70-100 kHz	4.7n
100-150 kHz	2.2n

Figure 6a. Fundamental mode crystal oscillator.

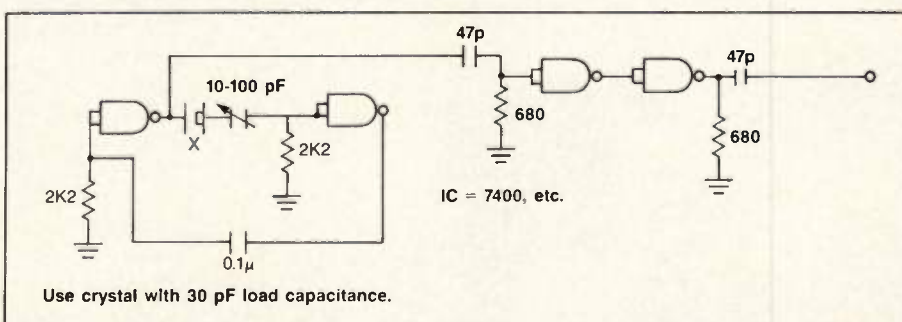


Figure 6b. Parallel mode oscillator.

later, crystals employing overtone modes are most suited to high stability applications and those requiring little frequency adjustment. This is why in the examples given the 10 MHz precision standard is specified as an overtone type. Fundamental mode crystals are more easily pulled in frequency and thus are more suitable to temperature controlled oscillators (TXO) and variable crystal oscillator (VXO) applications.

In a fundamental mode oscillator the feedback needs to be optimized for the fundamental resonant frequency of the quartz crystal. Similarly for an oscillator designed to oscillate on an overtone mode not only does the crystal need to be cut and mounted in such a way as to allow mechanical oscillation at the desired frequency but it is important to suppress any tendency to oscillation, sometimes simultaneously, in the fundamental mode. This is usually readily accomplished by putting a small (say, 1K ohm) resistor in parallel with the overtone crystal.

Note that for overtone crystals as the mode number increases (3,5,7,9), the quantity of unwanted vibrational modes increases. Although crystals can be used on any overtone they are usually designed to suppress unwanted modes and to oscillate only in the desired overtone.

Crystals for Filter Applications

As with any other asymmetric mechanically resonant system, quartz crystals exhibit many resonance phenomena or modes of vibration. For example, in a rectangular piece of crystal, there may be at least three modes of vibration, all corresponding to different bulk acoustic resonances across the three parallel wall dimensions as indicated in Figure 4b. In addition, many other more complex modes are possible within the structure (diagonally, etc.)

A typical plot of the response versus frequency of a crystal designed for an oscillator is shown in Figure 4a. A crystal is acceptable for oscillator applications when the unwanted modes are attenuated by 10 dB or more relative to the wanted mode. However, in a filter application such crystals may not be useful and may produce unexpected and unwanted responses. Crystals intended for filter applications are designed using rules which aim to minimize undesired responses. Since the resonances result from bulk acoustic effects, the shape and in particular the edges of the crystal affect these higher order undesired responses.

There are very many circuit configurations which work admirably as crystal oscillators. However, it is necessary to know a little about the requirements of the crystal for a given application before deciding which feedback configuration is best employed as an oscillator. There are the obvious requirements of frequency accuracy and stability with variation in temperature. Both quantities are usually specified in terms of ppm (parts per million). Clearly specifications for a crystal to control a microprocessor clock are likely to be very different to those required for a transmitter used in the tracking of an arctic polar bear.

Quartz is a naturally occurring substance and the crystal, typically 3-10 cm in diameter and several centimeters long, may be cut with respect to the internal crystal lattice structure in many ways. Each one of these cuts (eg., X, Y, AT, and BT) exhibits different electrical properties. These differing properties can be exploited to produce, for example, crystals with low frequency change due to external temperature effects. The curve shown in Figure 5 relates to the response of the fundamental AT and to a very close approximation overtone AT modes with temperature. In order to minimize frequency change over a given temperature range, the cut angle of the quartz needs to be carefully selected. The frequency change with temperature is a plot of:

$$\frac{\delta f}{f} = x(T - T_o) + y(T - T_o)^2 + z(T - T_o)^3 \ldots \text{etc.} \quad (4)$$

where T is the temperature and T_o is a reference temperature of x, y and z at 1st, 2nd and 3rd order temperature coefficients, respectively. Dependent on the required operating temperature range and required maximum change in frequency over this range, a given $\delta\theta$ is chosen for the cut angle to meet the specification. Note that in practice the crystal lattice angle and orientation is readily found using a simple x-ray machine.

The characteristics of 3rd and 5th overtones are very similar. To give some idea of the parameters that need to be specified, an example of the typical specification for two applications are shown in Table 1.

Generally the tighter the specification, particularly the effective series resistance (ESR) in overtone designs and parts per million per degree centigrade (ppm/C), the greater the cost. The extremes of realizable specifications depend on the frequency, cut and mode of operation. This varies between the many current manufacturers of quartz crystals. The production of crystals is very much an exact science up to a point. However, there are variabilities which naturally occur when manufacturing certain crystals, notably those with low ESR, which can result in a less than 100 percent yield. Some manufacturers employ empirical tricks of the trade during production to enhance certain desirable properties.

Because the effective series resistance of fundamental shear cut (non AT) crystals operating below 600 kHz is relatively high (Figure 3), more gain is needed to ensure reliable oscillation occurs. Circuits similar to that shown in Figure 6 can be used to good effect.

Discrete transistors may be replaced with an integrated circuit transistor array for convenience. Note that the two back to back diodes clip the oscillatory voltage through the crystal to 0.6 V peak to peak and hence limit the total current and power while providing output amplitude stabilization. Circuits using logic gates can be used in such low frequency oscillators as shown in Figure 6. However,

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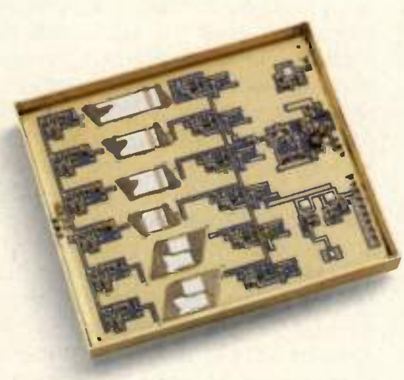

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because of the relatively high crystal drive power which can accelerate crystal aging and the random phase shift within the IC, which results in jitter or phase modulation, they are not suitable for frequency sensitive applications.

Slow changes in frequency with time are referred to as resonator aging. The changes are principally caused by contamination of the enclosure — the actual quartz changes negligibly. The result of this process is that the mechanical resonance of the cut quartz changes with time, usually higher in frequency. The change can be minimized by reducing the degree of vibration, and hence alternating current across the crystal. Unfortunately, the price paid here is that the output from the crystal has to be reduced, and consequently more amplification is needed to provide a given output. In high volume production, aging rates of 1 in 10^8 per day are achieved and the best that can be made under controlled conditions is about 5 in 10^{11} per day. Glass encapsulation can be better than metal enclosures for lack of contaminants.

Therefore, a good philosophy in design is to reduce the drive level through the crystal in order to prevent rapid aging occurring. The apparent resistance of the resonator can be a function of the crystal current. The effect is shown in Figure 7. At low drive levels many crystals exhibit a rapid and abrupt increase in resistance which can result in difficult starting. A plateau region is then reached within which an oscillator is normally designed to operate. At crystal currents greater than about 5 mA drive level effects become significant. In practice the effects of under or over driving can produce unreliable starting and operating difficulties. If the drive level is too high, flicker noise (1/f) modulated onto the sidebands of the crystal become much larger. One example of the significance of sideband noise, or off carrier noise, is that in a mixer the local oscillator sideband noise may be high enough to reduce the receiver sensitivity if the intermediate frequency is within the excess noise envelope of the local oscillator. The technique shown in Figure 7b is to make use of the high Q of the crystal used in an oscillator configuration to filter its output. Hence, reducing harmonic amplitudes and by virtue of the circuit configuration it reduces the sideband noise of the fundamental carrier output.

Choosing the Appropriate Crystal

As can be seen from Figure 3, the effective series resistance (ESR) falls steadily above about 1 MHz and less gain is required in a feedback oscillator to provide

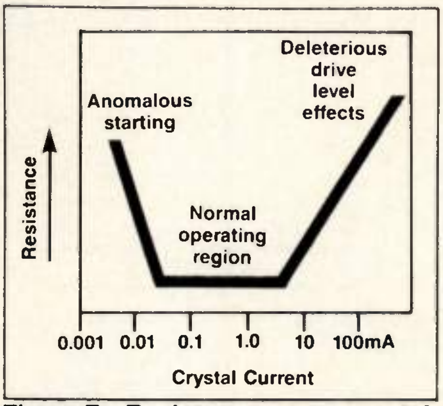
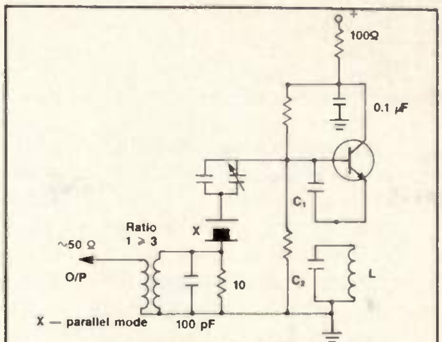


Figure 7a. Resistance versus crystal current.



Note that the crystal acts like an inductance and therefore acts as an LPF in conjunction with the capacitor and attenuates harmonics. Note also the crystal Q is reduced by the 10Ω series resistor

Figure 7b. Using the crystal in an oscillator as a filter.

reliable oscillation conditions. It is interesting to note that the actual value of the ESR is very significant in a number of applications and can actually determine the crystal and overtone used dictating whether or not frequency multiplication is required in a particular application. application.

The question then asked may be what is wrong with employing frequency multipliers? Obviously if frequencies are above 30 MHz using a fundamental mode and 200 MHz using overtone mode crystals, a multiplier is required — short of employing a more sophisticated heterodyne or phase locked loop system to provide the required output frequency. However, if possible multipliers should be avoided because they require extra components and adjustments, multiply any drift or noise generated by the crystal oscillator and consume power. However, for economic considerations, reasons of circuit simplicity and other technical reasons, frequency doubling or tripling may be the most convenient technique. Frequency multipliers are also useful if a variable frequency crystal oscillator (VXO) is required. In this case the frequency multiplier can be usefully employed to multiply the otherwise relatively small frequency swing obtainable from the fundamental mode crystal oscillator usually employed in VXO designs.

Consider an application where the power supply voltage is limited to 5 volts from batteries and the component count is severely restricted by space and weight limitations. An oscillator/signal source is required at, say, 210 MHz with the maximum output possible. Since the component count is limited and 9th overtone crystals are not available at this frequency, a multiplication stage(s) is required. The active devices used to fabricate any feedback oscillator have gain which is supply voltage dependant. Generally for any device, at a given frequency, the lower the available supply voltage the lower the available gain. As mentioned above, the higher the ESR (effective series resistance) of the crystal, the higher the gain required in the feedback oscillator to achieve oscillation and reliable starting. Therefore, in this example because of the potentially low gain available due to the relatively high frequency and low supply voltage, the designer needs to specify a

Crystal	High Precision 10 MHz 3rd overtone	Local overtone for application in section (3)
Type of enclosure —	HC18u	HC45u
Nominal frequency	10 MHz 3rd overtone	70 MHz 3rd overtone
Frequency adjustment tolerance	1×10^{-6}	1×10^{-6}
Load capacitance	30 pf parallel resonance	Series resonant
Operating temperature range	+60 to + 80°C	0 to + 40°C
Temperature coefficient	1×10^{-8}/°C	(For a drift < 1 kHz @ 70 MHz over 20°C) 7×10^{-7}/°C
Long term stability (aging)	5×10^{-10}/day	1×10^{-8}/month
Crystal drive current	≤0.1 mA	≤0.1 mA
ESR	≤55Ω	≤70Ω
Shunt Capacitance	≤ 6 pf	≤ 10 pf

Table 1. Example of typical specifications.

crystal with a low ESR — the lower the better. Note that starting is particularly important in systems which switch on and off regularly, such as those found using economizer circuits as in some portable equipment.

The lowest available ESR's are provided by fundamental mode AT cut crystals operating between 5 and 30 MHz. Since using this frequency range would require a multiplication of about 7-10 to reach the required frequency in this example; it is not a very efficient means of obtaining the required output at 210 MHz. Single device frequency multipliers, operating in class C can be approximately 50 percent efficient if used as doublers and progressively less efficient depending on the multiplication required from the stage as shown in Figure 8. Therefore, in this particular application, tripling or doubling the required frequency are the only acceptable solutions.

This implies using either a 70 MHz or 105 MHz overtone crystal. The former is available cut for either 3rd or 5th overtone modes and the latter is available in 5th overtone only. As can be seen from Figure 2, the higher the overtone the higher the ESR. Typical ESR figures for the 3rd, 5th, 7th and 9th overtones are 40, 60, 80, and 100 ohms respectively. Therefore the best choice for this application will probably be at a 3rd overtone of 70 MHz since this offers the lowest ESR and consequently potentially more reliable starting from lower gain feedback amplifier configuration. In addition, in this particular application, where the final required frequency is 210 MHz, the 3rd overtone will provide more drive power than the 5th overtone type for the following frequency multiplier. The ESR is a measure of the purity of the crystal and the cleanliness with which it has been manufactured and packaged. Crystals with ESR's below those shown in Figure 2 can be manufactured but tend to be rather specialized items and are consequently quite expensive.

Part II, to be published next month, will discuss various application circuits for crystal oscillators. rf

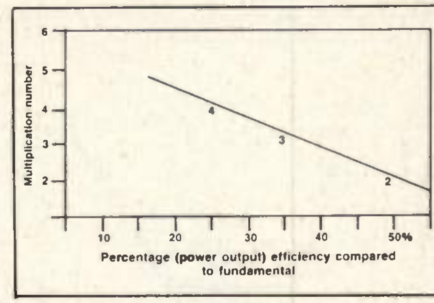


Figure 8. Multiplication factor versus percent efficiency.

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New MIL Crystal Oscillator Specification

Revision B to MIL-0-55310 Requires Caution in its Application

By Alfred Camhi
Vectron Laboratories

Revision B has just been issued to MIL-0-55310, the military specification for crystal oscillators which was written primarily to define QPL crystal oscillators with each type covered by an individual specification sheet (e.g. MIL-0-55310/16). MIL-0-55310B designates only two Product Assurance Levels, B and S. Class S, intended primarily for space applications, represents a minuscule portion of usage and thus this discussion is limited to Class B applications.

The most common industry application of MIL-0-55310 is not to define QPL products but rather as a general reference document for crystal oscillators which are not available as QPL parts. Because of the changes incorporated in Revision B, it is important to understand the implications, notably cost, of specifying MIL-0-55310 for non-QPL crystal oscillators especially with regard to parts and testing.

Parts

A. Oscillators using descrete construction (defined as discrete parts, including surface mount devices, interconnected on a printed circuit board) — MIL-0-55310B states that passive parts must be Established Reliability (level P or higher), semiconductors must be JANTX, and integrated circuits must be QPL listed or comply with MIL-STD-883. Further, discrete parts not available to these levels must be individually screened. In a complex oscillator it is likely that several parts will not be available to JANTX/ER levels. These include thermistors, small variable components and semiconductors not yet covered by MIL-S- 19500. Thus, a specification which includes the statement "oscillators shall conform to MIL-0-55310B" results in not only the cost associated with Hi-Rel components but also the potentially sizable lot charges and time delays associated with screening all non-standard parts. Therefore, it is important that each specification for a non-QPL crystal oscillator be specific in defining any parts requirements.

B.Oscillators using "custom hybrid circuit construction" (hybrid oscillators or hybrids used within a discrete crystal oscillator) — These devices must comply with MIL-M-38510, Appendix G. Thus, in addition to the 100 percent screen testing of the packaged hybrid, all active and passive components (microelectronic elements) used within the hybrid must first undergo element evaluation on an individual basis in accordance with MIL-STD-883. For those parts not normally inventoried as screened devices by the oscillator manufacturer, significant lot charges will result.

Testing

MIL-0-55310B specifies First Article (qualification) Testing, Screen Testing and Quality Conformance Testing.

A. First Article (qualification) Testing

The standard requires that if first article inspection is specified, it must be performed on an eight piece sample. The tests include such obvious choices for qualification testing as shock and vibration, but also include ambient pressure, moisture resistance and salt spray which may be of little significance for a fully sealed oscillator. Thus, if First Article (qualification) Testing is required, specifying MIL-0-55310B as the basis of such testing may not be cost effective in terms of the test sample size or tests to be performed. In addition, MIL-0-55310B states that, unless otherwise extended, First Article Approval applies only to the contract under which is was granted, implying that these qualification type tests may have to be continually repeated on a long-term multi-contract program.

B. Screen Testing

Oscillators employing discrete component construction must, on a 100 percent basis, be subjected to thermal shock, seal test and 160 hour burn-in. This impacts cost and delivery. Further, as MIL-O-55310B only recognizes fully sealed oscillators, coaxial RF or multi-terminal connectors must be sealed.

Hybrid oscillators must be 100 percent screen tested and in oscillators employing "mixed construction" (discrete construction oscillators which incorporate a hybrid), the hybrid is first screened and then following its installation into the oscillator, the entire oscillator is screened — a double impact on cost and delivery.

C. Quality Conformance Testing

1. Group A inspection: MIL-0-55310B states that Group A inspection (visual inspection and basic electrical testing) be performed on a sample basis; it does not require that any characteristics be tested 100 percent. This may be inadequate, since some characteristics of TCXOs and OCXOs should be tested on a 100 percent basis.

2. Group B inspection

This is a sample 30-day aging test. The sample size is the same whether the product ordered is a clock oscillator or ultrastable oven controlled crystal oscillator. For TCXOs (temperature compensated crystal oscillators) and OCXOs (oven controlled crystal oscillators) the data taken must be fit, using the least squares method, into a logarithmic formula which purports to project the long-term aging characteristic. Vectron's historical data indicates that this formula may be of theoretical interest but is in fact a poor predictor of future aging. Further, OCXOs which typically have stringent aging specifications should logically have aging testing imposed 100 percent. The sample basis outlined by the new standard is not sufficient.

3. Marking

MIL-0-55310B specifies that the frequency be marked on crystal oscillators using an eight-character group of seven numerals and one letter. 10 MHz would be written 10M00000, and 173.42 kHz would be written 173K4200. Should MIL-0-55310B be called out for general applicability in a specification with no further marking instructions, oscillators would not be in compliance unless designated by this new code. The user of the oscillator would likely have no idea of the oscillator's frequency based upon this marking. Therefore, it is suggested that the specifier detail how the frequency should be marked.

Conclusion

MIL-0-55310B does an excellent job providing standard definitions of terms and test methods, and its reference in specifications for non-QPL oscillators for those purposes is desirable. However, the danger lies in a blanket reference to MIL-0-55310B. Each individual non-QPL crystal oscillator specification which references MIL-0-55310B should be specific regarding parts requirements and testing. For example, further clarification is needed as to whether Hi-Rel parts are required and if so should those parts not available as JANTX/ER/883 be individually screened. More detailed explanation is also needed with regard to testing where such questions as the need for 100 percent screen testing, the adequacy of sample Group A testing and whether the oscillator should be individually first article tested rather than qualified in the purchaser's system arises. rf

About the Author

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Computing the Response of Lossy Crystal and LC Filters

Accurate Characterization is Needed for Realistic Specification of Filter Performance

By C. W. Pond
McCoy Electronics Company

In the design of a new system it is often necessary to select a response or a transfer function for a bandpass or lowpass filter. This is usually accomplished by getting the information from one of the many available filter design handbooks. Unfortunately the values listed by the handbooks are for ideal, lossless filters. In order for an engineer to accurately specify a filter, or to gain a reasonable expectation of filter performance, he must have data beyond those textbook design tables. This article describes a method for determining filter response with lossy elements, and offers a computer program for its implementation.

Figure 1 shows the increase in insertion loss and the considerable passband rounding that occurs when losses are introduced. The differences which are caused by coil or crystal losses could easily affect the system performance, so they should be identified and accounted for. Handbooks don't show the effects of this dissipation because each case is related to its unique center frequency, bandwidth and available resonator Qs. No book could be large enough to cover all possible cases.

Since the performance of the system could be degraded by this type of response, it would be valuable to accurately predict the effects for a particular design situation. The most accurate method would be to design and analyze a filter that would meet the system requirements, but this can be a long and costly process, even with the necessary design programs.

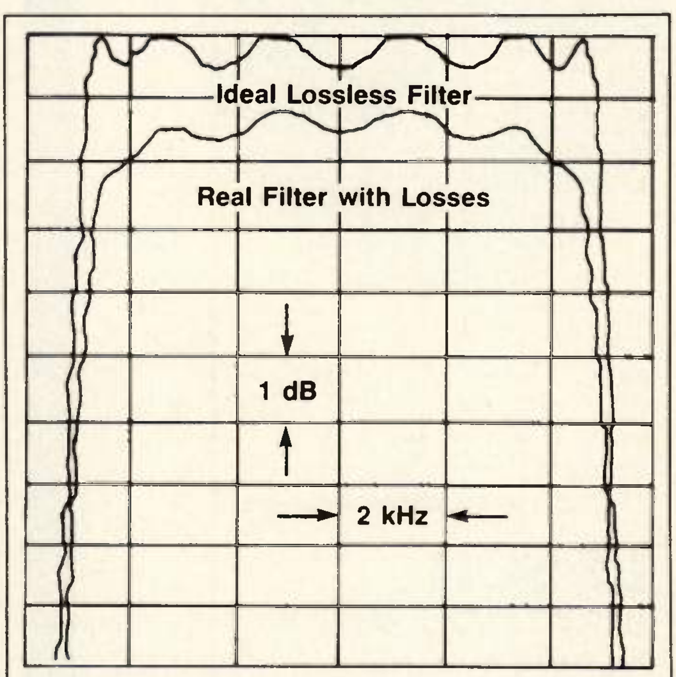

Figure 1. Lossless and lossy responses.

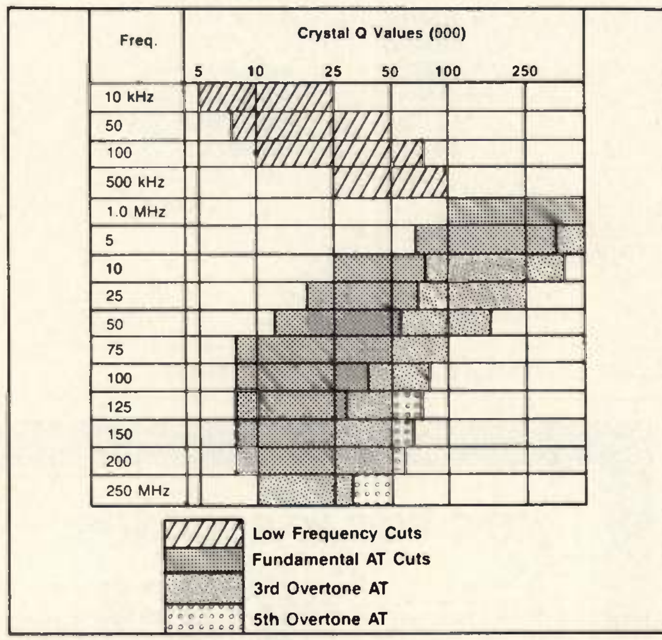

Figure 2. Typical crystal Q values.

This note provides an alternate solution and a program for computing the lossy response of LC and crystal filters. The only parameters needed are ones that are usually known: center frequency, bandwidth, number of poles, ripple, and an estimate of the resonator Q values. If the required number of poles is not known initially, rerunning the program will help establish the number needed.

Given the S-plane pole locations, the program computes both the lossless and lossy lowpass transfer functions along with the lossless and normalized attenuation, phase and delay. It then determines, from the particular center frequency, bandwidth and Q values, the new lossy pole locations and computes the denormalized and lossy attenuation, phase and delay response. Since the computation is based on the lowpass prototype, only the upper half of the passband for a bandpass filter is computed and displayed.

For readers unfamiliar with crystals, a chart of practical Qs is included in Figure 2. The values give the normal range for filter applications, but because of spurious and producibility considera-

Program Example:
values entered from the keyboard are shown underlined.

Input number of POLES and RIPPLE

6 0.25

s-Plane Pole Locations

	Real	Imaginary
1	−.093392	1.026886
2	−.255151	.751733
3	−.348543	.275153
4	−.348543	−.275153
5	−.255151	−.751733
6	−.093392	−1.026886

Lossless Transfer Function

a's	Real Part	Imag. Part
1	.132127	0.000000
2	.597280	0.000000
3	1.483038	−.000001
4	2.044640	−.000001
5	2.471860	−.000001
6	1.394173	0.000000
7	1.000000	.000000

Input Ωstart, ΔΩ, # of steps
(Default values are 0, 0.1, 21)

CR = carriage return

Normalized Response

Ω	Loss (dB)	Phase (°)	Delay (Sec)
.000	.2500	.000	4.52049
.100	.1716	26.145	4.64409
.200	.0323	53.472	4.89520
.300	.0166	81.979	5.01766
.400	.1547	110.597	4.95938
.500	.2500	139.032	5.01696
.600	.1432	168.896	5.48258
.700	.0009	−157.614	6.20043
.800	.1432	−120.728	6.61720
.900	.2066	−80.714	7.72162
1.000	.2500	−23.737	12.74360
1.100	6.0915	44.340	8.70916
1.200	14.3102	78.213	3.96605
1.300	21.1627	95.518	2.32696
1.400	26.9005	106.527	1.59757
1.500	31.8665	114.430	1.19554
1.600	36.2707	120.506	.94280
1.700	40.2445	125.385	.77000
1.800	43.8757	129.420	.64486
1.900	47.2258	132.832	.55041
2.000	50.3403	135.767	.47685

Flat Loss = .000 dB

Do you want to add DISSIPATION?
(Y or N)

Y

Figure 3. Example of program operation.

Input Fo, BW, and Q

5000000	5000	100000

Lossy Transfer Function

a's	Real Part	Imag. Part
1	.138250	0.000000
2	.627564	0.000000
3	1.545874	−.000001
4	2.144928	−.000001
5	2.543068	−.000001
6	1.454173	0.000000
7	1.000000	.000000

Response Renormalized to the Specified Fo, BW and Q's

Freq. (Hz)	Loss (dB)	Phase (°)	Delay (μSec)
5000000.	.1919	.000	288.982
5000250.	.1237	26.230	296.125
5000500.	.0052	53.534	310.666
5000750.	.0000	81.927	318.197
5001000.	.1341	110.495	316.023
5001250.	.2353	139.025	320.961
5001500.	.1681	168.999	349.369
5001750.	.0861	−157.615	392.242
5002000.	.2664	−120.901	421.317
5002250.	.4287	−80.619	495.500
5002500.	.8691	−25.011	759.558
5002750.	6.3898	38.944	544.370
5003000.	14.2104	73.302	262.899
5003250.	20.9186	91.442	155.958
5003500.	26.5914	103.041	107.179
5003750.	31.5215	111.367	80.136
5004000.	35.9031	117.761	63.124
5004250.	39.8615	122.889	51.500
5004500.	43.4815	127.126	43.093
5004750.	46.8232	130.707	36.754
5005000.	49.9311	133.784	31.822

Flat Loss = .452 dB

For bandpass filters the only part of the response that is shown is from center frequency and higher.

Figure 3. (continued).

tions, it is always best to use the lowest possible Q that will yield satisfactory results. The third and fifth overtone responses can be used only on very narrow band filters since their impedance levels are many times higher than that of the fundamental mode. If overtones are required, the design should be evaluated carefully.

Computational Information

The pole locations for a Butterworth filter are found from the following:

$$P_k = a_k + jb_k \tag{1}$$

$$a_k = \cos\left(\frac{2k + N - 1}{N} \cdot \frac{\pi}{2}\right) \tag{2}$$

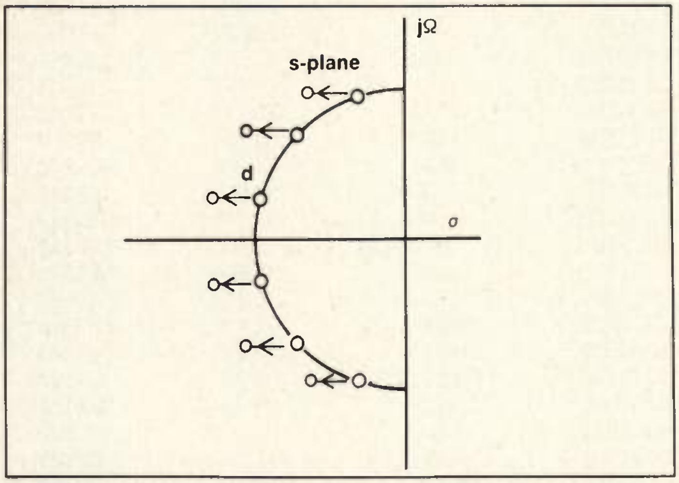

Figure 4. Determination of lossy pole locations.

$$b_k = \mathrm{SIN}\left(\frac{2k + N - 1}{N} \cdot \frac{\pi}{2}\right) \quad (3)$$

where k = 1, 2, ... , 2N.

Similarly, the Chebyshev pole locations are determined from:

$$a_k = \pm\mathrm{SINH}(\beta)\mathrm{SIN}\left(\frac{2k - 1}{N} \cdot \frac{\pi}{2}\right) \quad (4)$$

$$b_k = \mathrm{COSH}(\beta)\mathrm{COS}\left(\frac{2k - 1}{N} \cdot \frac{\pi}{2}\right) \quad (5)$$

where k = 1, 2, ... , 2N

$$\beta = \frac{\mathrm{ARCSINH}}{N}(\varepsilon) \quad (6)$$

$$\varepsilon = \frac{1}{\sqrt{10^{0.1Ap} - 1}} \quad (7)$$

The number of poles in N and the ripple is Ap. The left half plane pole locations are used to find H(s) and $|H(j\Omega)|^2$. These values are found from:

$$H(s) = \prod_{k=1}^{N}(s - p_k) \quad (8)$$

substituting s = jΩ

$$|H(j\Omega)|^2 = \mathrm{Re}[H(j\Omega)]^2 + \mathrm{Im}[H(j\Omega)]^2 \quad (9)$$

At any Ω the real and imaginary parts of H(jΩ) can be found by forming the sums:

$$\mathrm{Re}[H(j\Omega)] = \sum_{k=1}^{N/2+1} (-1)^{(k-1)} A_{2k-1} \Omega^{2(k-1)} \quad (10)$$

$$\mathrm{Im}[H(j\Omega)] = \sum_{k=1}^{(N+1)/2} (-1)^{(k+1)} A_{2k} \Omega^{(2k-1)} \quad (11)$$

$$H(s) = A_{N+1}s^N + A_N + \ldots + A_2 s + A_1 \quad (12)$$

Here the A values, which are the coefficients of the transfer function, are shown as upper case letters to avoid confusion with the real part of the pole locations. From these sums the attenuation and phase can be computed, but the derivatives of the real and imaginary parts of the transfer function are required in order to find the delay. Taking the derivative of each yields:

$$\frac{d(\mathrm{Re}[H(j\Omega)])}{d\Omega} = \sum_{k=2}^{(N/2+1)} (-1)^{(k-1)} 2(k-1) A_{(2k-1)} \Omega^{(2k-3)} \quad (13)$$

$$\frac{d(\mathrm{Im}[H(j\Omega)])}{d\Omega} = \sum_{k=1}^{(N+1)/2} (-1)^{(k+1)} (2k-1) A_{2k} \Omega^{(2k-2)} \quad (14)$$

Thus, once the transfer function is found, the analysis is reduced to computing a series of sums involving its coefficients at specified Ω values.

Program Operation

A program has been developed by McCoy to execute the above computations. A FORTRAN listing of the program is available, and instructions for obtaining a copy are given at the end of this article.

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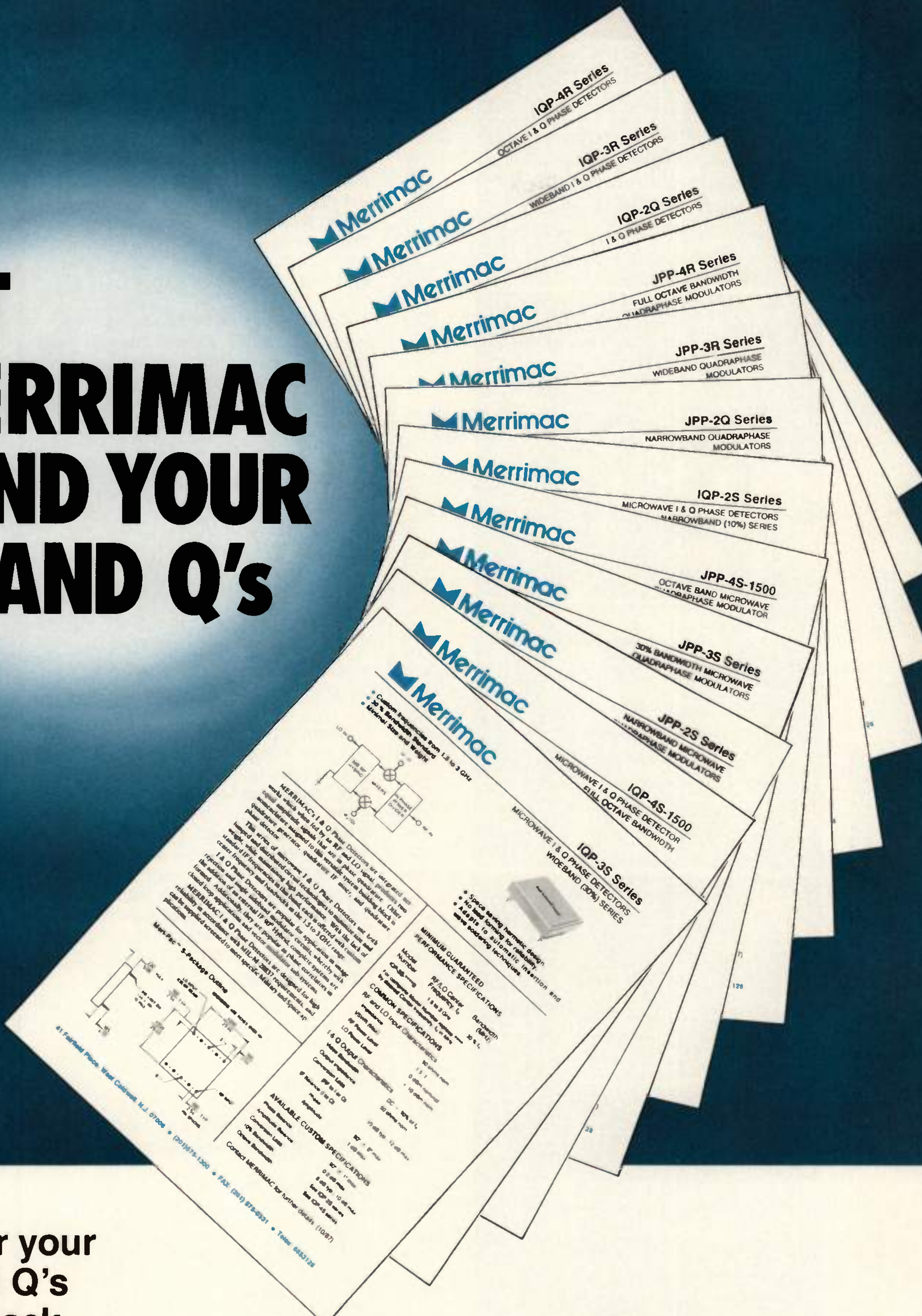

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The operation of the program shown in Figure 3. Given the number of poles and the ripple value it computes the s-plane pole locations. If a Butterworth design is desired use 0 dB for the ripple value.

The left half plane (LHP) pole values are used to construct the lossless transfer function H(s), of the form:

$$H(s) = a_{n+1}s^n + a_n s^{n-1} + \ldots + a_2 s^1 + a_1 \qquad (15)$$

Once the transfer function has been found, the program is ready to begin the lossless analysis. At this point it is necessary to supply the normalized frequency to start at (Ωstart) the size steps (ΔΩ) and the number of steps to take.

The attenuation is found from:

$$A = 10\text{LOG}[\text{Re}[H(j\Omega)]^2 + \text{Im}[H(j\Omega)]^2] \qquad (16)$$

The phase is computed using:

$$\Phi = \text{ATAN}\left[\frac{\text{Im}[H(j\Omega)]^2}{\text{Re}[H(j\Omega)]^2}\right] \qquad (17)$$

The time delay is found using:

$$\text{Delay} = \frac{d\Phi}{N} \qquad (18)$$

$$= \frac{\text{Re}[H(j\Omega)]\dfrac{d(\text{Im}[H(j\Omega)])}{d\Omega} - \text{Im}[H(j\Omega)]\dfrac{d(\text{Re}[H(j\Omega)])}{d\Omega}}{\text{Re}[H(j\Omega)]^2 + \text{Im}[H(j\Omega)]^2}$$

After computing and printing the response, the computer stops and asks if dissipation is to be added. If the answer is yes then it is necessary to input the center frequency (Fo), bandwidth (BW), and an estimate of the resonator Q values. BW is the bandwidth at the equiripple point for a Chebyshev or at the −3 dB level for a Butterworth. Q values for crystal filters may be found from Figure 2 and LC Q values may be found in manufacturers' literature.

Using the dissipation constant (d), determined from this data, a new set of s-plane pole locations are found (Figure 4) and the new lossy transfer function is computed. The new locations of the poles are a distance d left of their old positions, where d is determined from:

$$d = \frac{1}{Q} \qquad \text{(Lowpass)} \qquad (19)$$

$$d = \frac{Fo}{BW^*Q} \qquad \text{(Bandpass)} \qquad (20)$$

The frequency and delay values are changed to reflect the center frequency and bandwidth by using:

$$F_i = F_o + \frac{\Omega_i\,BW}{2} \qquad \text{(Bandpass)} \qquad (21)$$

$$F_i = \Omega_i{}^*BW \qquad \text{(Lowpass)} \qquad (22)$$

$$\text{Delay} = \frac{\text{Delay}}{BW^*\pi} \qquad (23)$$

Accuracy of Results

The example chosen is for a 6-pole 0.25 dB Chebyshev bandpass crystal filter with a center frequency of 5 MHz and a design bandwidth of 5 kHz. The resonator Q used is 100k. To evaluate the accuracy of the approximation program, a crystal filter with those same parameters was designed and analyzed using the

Freq. (Hz)	Loss (dB)	Phase (Deg.)	Delay (μSec)
5000000.	.192	−89.895	291.293
5000250.	.124	−63.653	297.392
5000500.	.007	−36.364	309.285
5000750.	.003	−7.982	316.732
5001000.	.139	20.647	317.695
5001250.	.241	49.204	325.549
5001500.	.175	79.246	353.365
5001750.	.091	112.809	392.121
5002000.	.266	149.828	432.567
5002250.	.418	−169.329	542.850
5002500.	.985	−112.459	667.610
5002750.	6.799	−49.159	537.262
5003000.	14.636	−15.752	284.614
5003250.	21.344	2.072	162.827
5003500.	27.026	13.557	109.834
5003750.	31.983	21.842	81.424
5004000.	36.389	28.213	63.840
5004250.	40.384	33.333	52.017
5004500.	44.047	37.576	43.499
5004750.	47.432	41.163	37.050
5005000.	50.586	44.245	32.106

Loss — .45 dB

Figure 5. Circuit analysis program results for example filter.

normal circuit analysis program. Comparing the results of the circuit analysis program (Figure 5) to those in Figure 3 shows that the attenuation in the passband is accurate to within 0.13 dB, and within about 0.67 dB in the stopband. The phase shift of a bandpass filter is N*45° at the center frequency and so this constant value must be added to all the values in the approximation program. When this correction factor is applied, the agreement between the two methods is within 2.5 degrees.

The delay values from the approximation program will be more accurate than those computed by the circuit analysis program because they are computed directly from the derivative of the phase of the transfer function, while the analysis program only approximates them by finding the slope from the two adjacent phase readings.

The accuracy procedure was repeated for a lowpass filter and it was found that there was even better agreement between the two methods. In fact, the differences were so slight as to be negligible.

It should be pointed out that this technique is accurate only for filters with uniform dissipation and therefore it won't give accurate results for lowpass filters that have different Qs in their inductors and capacitors or any filter that has sizable variation in the Q values of its resonators.

Summary

This calculation method allows engineers to accurately determine the passband and stopband performance of lowpass and bandpass crystal and LC filters. By introducing the lossy components without a complete design and analysis, this computation lets the designer know the 'real' performance of a filter, not just the ideal specifications found in published design tables.

For a FORTRAN listing of the filter response program described here, either write McCoy Eletronics Co. at the address below, or circle INFO/CARD #220. rf

About the Author

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CAD Simplifies TCXO Design

Technique adds temperature vs. frequency analysis to software package.

By Paul Faerber and Alan Victor
Monicor Electronic Corporation

This article presents an application of CADEC, a CAD program available from Compact Software, to aid in the analysis and optimization of a temperature compensation network for use in a temperature compensated crystal oscillator. Basic requirements for a temperature compensation network are discussed and a typical network presented. It shows how this network is modeled, analyzed, and optimized using CADEC. Finally, an example of how this technique was used is presented with experimental results.

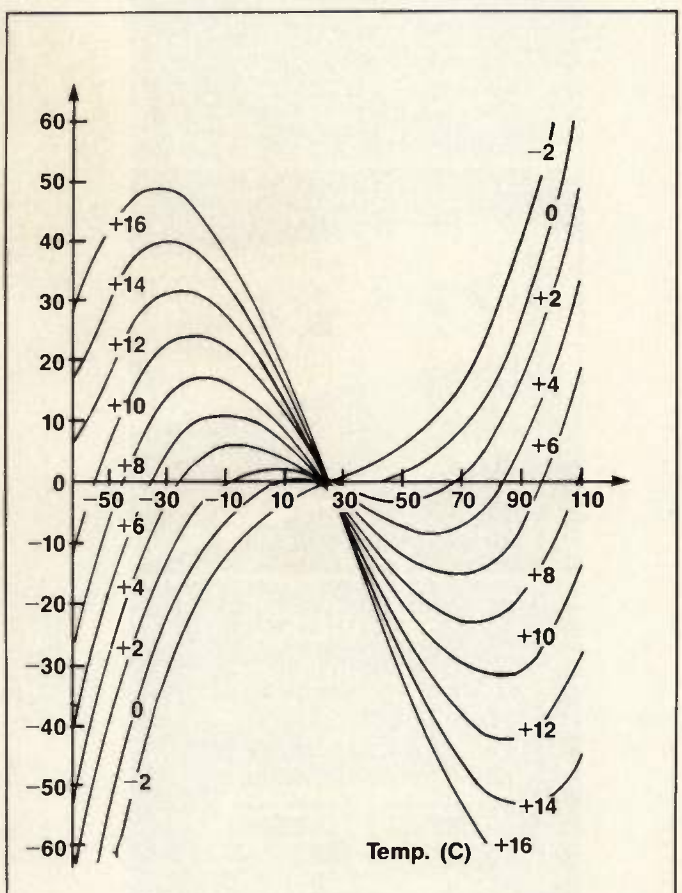


Figure 1. Temperature characteristics of AT-cut crystals.

The frequency versus temperature characteristics of typical AT-cut crystals as a function of the angle of cut is shown in Figure 1. Crystal manufacturing and crystal technology has progressed to the point where the angle of cut for the AT-cut crystal is well controlled and production crystals which match the predicted curves can be obtained. Although crystals which inherently provide frequency stability of ±5 ppm or greater over a limited temperature range are available from a number of manufacturers, when frequency stability over a broad range of temperature is required and a crystal oven cannot be used, some type of temperature compensation network is needed.

As shown in Figure 1 the frequency of a crystal, independent of the angle of cut, is a non-linear function of temperature. Although the frequency of a crystal can be made to shift by placing a reactance in series with it, since the curve exhibits both a positive and negative slope with an upper and a lower turning point, the crystal cannot be temperature compensated over a broad temperature range by the addition of single component. It requires the correct combination of components with positive and negative reactive temperature coefficients. It is possible to actually add reactive components with various temperature coefficients to the oscillator circuit but a more common solution is to place a varactor diode in series with the crystal and vary the varactor voltage in such a manner that the network provides the varying reactance to temperature compensate the oscillator. One such network which has been discussed in detail by Frerking (1) and is shown in Figure 2 (ref. 1).

By varying the voltage to the varactor in series with the crystal, the load capacitance of the crystal is changed and the frequen-

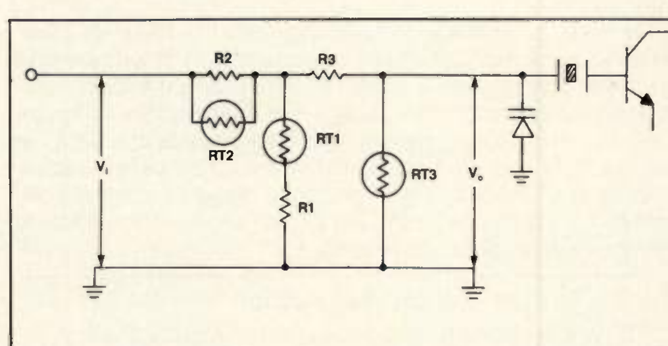


Figure 2. A temperature compensation network.

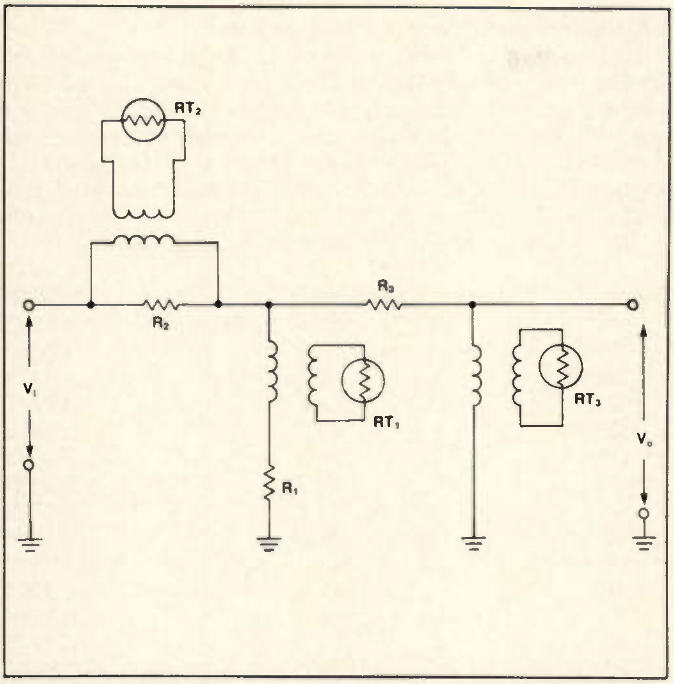


Figure 3. Frerking temperature compensation network with ideal transformers.

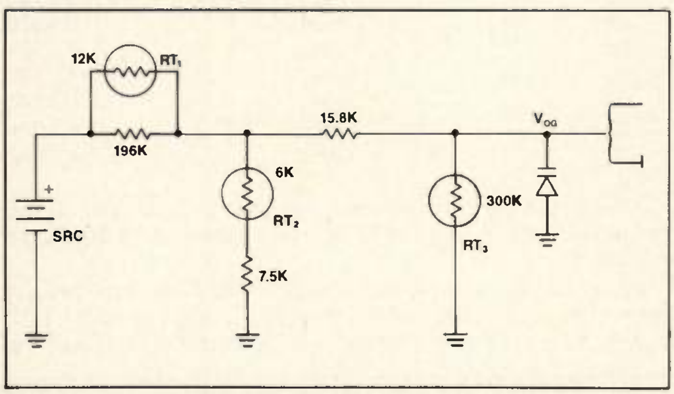


Figure 4. Optimized network with standardized component values.

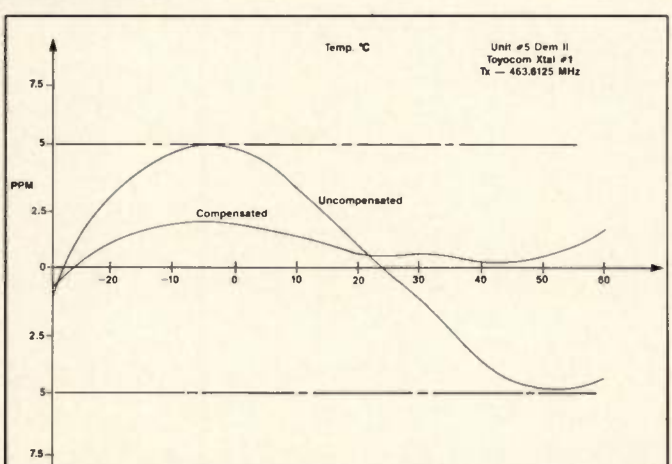


Figure 5. Oscillator performance before and after temperature compensation.

cy shifted. The non-linear voltage versus temperature function required for temperature compensation is generated by the thermistor-resistor network made up of resistors R_1, R_2 and R_3 and negative temperature coefficient thermistors RT_1, RT_2 and RT_3. The resistance of a thermistor over temperature RT is a function of β (a constant that depends on the thermistor material) and RT0, the zero power resistance at temperature T0. The equation defining this relationship is:

$$RT = RT0^{\beta(1/T - 1/To)} \quad (1)$$

The voltage transfer function of the thermistor-resistor network can then be expressed as follows:

$$\frac{V_0}{V_1} = \frac{RT_3(R_1 + RT_1)(R_2 + RT_2)}{(R_1+RT_1)(R_2+RT_2)(R_3+RT_3)+R_2RT_2[(R_1+RT_1)+(R_3+RT_3)]} \quad (2)$$

```
     PRI  FRERKING TEMPERATURE COMPENSTATION
     REM  D1 DATA FILE CONTAINS SERIES THERMISTOR DATA FOR RT2
     REM  D2&D3 DATA FILES CONTAINS PARALLEL THERMISTOR DATA FOR RT1&RT3
     REM  FREQUENCY SWEEP FROM 10 MHZ TO 120 MHZ
     REM  CORESPONDS TO A TEMPERATURE SWEEP OF -40 TO 70 DEGREES C.
     REM  WITH 75 MHZ = 25 DEGREES C.
1:   SRC       12V 1uohm
3:   LFR       10MHz  120MHz  5MHz
6:   TER       1000Gohm
7:   RS        220kohm
     .OLD D1
     ..PAR
     .OLD D2
8:   ..RP      22kohm
     ...SER
     ..CAS
9:   .RS       33kohm
     ..CAS
     .OLD D3
     ..CAS
     .OUT VOG/M
```

Table 1. CADEC circuit description.

```
     PRI  FRERKING TEMPERATURE COMPENSTATION
     REM  WITH IDEA TRANSFORMERS ADDED
     REM  DATA FILES CONTAIN PARALLEL THERMISTOR DATA FOR RT1-RT3
     REM  NORMALIZED TO 1 OHM
     REM  FREQUENCY SWEEP FROM 10 MHZ TO 120 MHZ
     REM  CORESPONDS TO A TEMPERATURE SWEEP OF -40 TO 70 DEGREES C.
     REM  WITH 75 MHZ = 25 DEGREES C.
     REM  IGNORE CADEC CONNECTION ERROR MESSAGES
1:   SRC       12V 1uohm
3:   LFR       10MHz  120MHz  5MHz
6:   TER       1000Gohm
7:   RS        220kohm
     .CON 1 0 4
8:   RS        1mohm
9:   .TRF      316.2277  1
     ..CAS
     .OLD D1
     ..CAS
     .COI 1 4 2 3
11:  RS        1 ohm
     .CON 2 0 0
     TWO 1 4
12:  .RS       1mohm
13:  ..TRF     44.72136 1
     ..CAS
     ..OLD D2
     ...CAS
     ..COI 1 2 3 4
15:  .RS        22kohm
     ..CON 2 0 0
16:  .RS       1ohm
     ..CON 3 0 0
17:  .RS       33kohm
     ..CON 1 0 5
     .TWO 1 5
     ..CAS
18:  .RS       1 mohm
19:  ..TRF     1E3 1
     ...CAS
     ..OLD D3
     ...CAS
     ..COI 1 0 2 3
21:  .RS       1ohm
     ..CON 2 0 0
22:  .RS       1 mohm
     ..CON 1 0 4
     .TWO 1 4
     ..CAS
     .OUT VOG/M
```

Table 2. Temperature compensation CADEC file.

The implementation of a TCXO design using this temperature compensation network is straight forward. First the varactor voltage versus temperature required to properly compensate the oscillator is determined. This is done by operating the oscillator with the varactor in the circuit over the desired temperature range, varying and recording the varactor voltage required to set the oscillator on frequency. This defines the required voltage transfer function for the thermistor-resistor network versus temperature. The second step in the design process is to determine values for R_1, R_2, R_3, $RT0_1$, $RT0_2$, $RT0_3$, β_1, β_2 and β_3 which provides the necessary voltage transfer function. Although the transfer function for the network is well defined, the selection of suitable values for the 9 independent variables is not trivial. The procedure often involves tedious calculations and/or a trial and error approach with the resulting network being less than optimal. Hence, CAD is used to assist in the process.

CADEC has no explicit provisions for analysis and optimization of circuits over temperature. Since the thermistor-resistor network contains no reactive components that change over frequency, the network's performance versus temperature can be represented as performance versus frequency. For example, a temperature sweep from −40° to 70°C can be represented as a frequency sweep from 10 MHz to 120 MHz. Analysis done at 75 MHz therefore, represents a temperature of 25°C. The thermistors are modeled as ABCD matrices of the appropriate parallel or series resistance entered in CADEC data files with the same substitution of frequency for temperature.

Temperature(°C)	Frequency(MHz)	Required Varactor Voltage(VDC)
-30	463.61190	2.61
-20	463.61391	2.12
-10	463.61465	1.95
0	463.61459	1.96
+10	463.61405	2.10
+20	463.61301	2.36
+25	463.61235	2.50
+30	463.61183	2.64
+40	463.61081	2.88
+50	463.61031	3.01
+60	463.61041	2.98

Table 3. Characteristics of the oscillator.

As an example, Frerking's thermistor-resistor network shown in Figure 2 was modeled and analyzed using CADEC. The CADEC circuit description is listed in Table 1. OLD D_1 contains the ABCD matrix information for RT_2 represented as a series resistor varying over frequency (temperature). OLD D_2 and OLD D_3 contain the ABCD matrix information for RT_1 and RT_3 represented as parallel resistors varying over frequency (temperature).

The results of the CADEC analysis is listed below:

Temp. C	Frequency/Hz	VOG/M
−40	10E6	4.9375
−35	15E6	4.0850
−30	20E6	3.4179
−25	25E6	2.9246
−20	30E6	2.5813
−15	35E6	2.3541
−10	40E6	2.2239
−5	45E6	2.1715
0	50E6	2.1844
5	55E6	2.2512
10	60E6	2.3696
15	65E6	2.5296
20	70E6	2.7273
25	75E6	2.9550
30	80E6	3.2045
35	85E6	3.4638
40	90E6	3.7198
45	95E6	3.9568
50	100E6	4.1594
55	105E6	4.3127
60	110E6	4.4046
65	115E6	4.4274
70	120E6	4.3782

These results (interpreted as output voltage versus temperature from −40° to 70°C) agree closely with Frerking's results.

In addition to analysis, optimization of the thermistor- resistor network is also possible if the desired VOG/M values for each temperature are inputed as optimization codes at the single fre-

```
     PRI  EXAMPLE TEMPERATURE COMPENSTATION NETWORK
     REM  WITH IDEA TRANSFORMERS ADDED
     REM  DATA FILES CONTAIN PARALLEL THERMISTOR DATA FOR RT1-RT3
     REM  NORMALIZED TO 1 OHM
     REM  FREQUENCY SWEEP FROM 10 MHZ TO 100 MHZ
     REM  CORESPONDS TO A TEMPERATURE SWEEP OF -30 TO 60 DEGREES C.
     REM  WITH 65 MHZ = 25 DEGREES C.
     REM  IGNORE CADEC CONNECTION ERROR MESSAGES
 1:  SRC       5V 1uohm
 3:  TER       1000Gohm
     REM OPTIMIZATION DATA
     OPT VOG/M =2.61/.0001
 4:  SFR       10MHz
     OPT VOG/M =2.12/.0001
 5:  SFR       20MHz
     OPT VOG/M =1.95/.0001
 6:  SFR       30MHz
     OPT VOG/M =1.96/.0001
 7:  SFR       40MHz
     OPT VOG/M =2.10/.0001
 8:  SFR       50MHz
     OPT VOG/M =2.36/.0001
 9:  SFR       60MHz
     OPT VOG/M =2.50/.0001
10:  SFR       65MHz
     OPT VOG/M =2.64/.0001
11:  SFR       70MHz
     OPT VOG/M =2.88/.0001
12:  SFR       80MHz
     OPT VOG/M =3.01/.0001
13:  SFR       90MHz
     OPT VOG/M =2.98/.0001
14:  SFR       100MHz
     OPT ZIN/RE>10E3/.001
15:  SFR       100MHz
16:  RS        195.080472308kohms
     .CON 1 0 4
17:  RS        1mohm
18:  .TRF      109.5445115 1
     ..CAS
     .OLD D1
     ..CAS
     .COI 1 4 2 3
20:  RS        1 ohm
     .CON 2 0 0
     TWO 1 4
21:  .RS       1mohm
22:  ..TRF     77.4596 1
     ..CAS
     ..OLD D2
     ...CAS
     ..COI 1 2 3 4
24:  .RS        7.45750944554kohm
     ..CON 2 0 0
25:  .RS       1ohm
     ..CON 3 0 0
26:  .RS       15.6105131604kohm
     ..CON 1 0 5
     .TWO 1 5
     ..CAS
27:  .RS       1 mohm
28:  ..TRF     547.7225575 1
     ...CAS
     ..OLD D3
     ...CAS
     ..COI 1 0 2 3
30:  .RS       1ohm
     ..CON 2 0 0
31:  .RS       1 mohm
     ..CON 1 0 4
     .TWO 1 4
     ..CAS
     .OUT VOG/M
```

Table 4. Temperature compensation network CADEC file.

quency points representing the corresponding temperature. The circuit description above only allows the optimization of resistor values R_1, R_2 and R_3. To allow the optimization of the thermistors, ideal transformers are used to connect the data files containing the thermistor data. The thermistor data for a given beta is then normalized to 1 ohm. Many thermistor manufacturers supply temperature versus resistance curves normalized to 1 ohm for the different materials they manufacture. Now by allowing CADEC to vary the turns ratio of the ideal transformer, the thermistor with the best RT0 can be selected from the family of thermistors of a given material type. After CADEC optimizes the network for the best non-linear curve fit, standard values for the resistors and thermistors can be entered and the circuit analyzed. The schematic for the circuit is shown in Figure 3 and the CADEC circuit description is listed in Table 2.

As an example of how this technique works, an oscillator with the characteristics shown in Table 3 was chosen as the starting point. The design goal is to temperature compensate this oscillator over the −30 to 60°C range. The temperature compensation network is powered by a regulated +5 volt supply. Table 4 shows the optimized CADEC circuit description, with the optimization data.

The optimized temperature compensation network with standardized component values is shown in Figure 4. The measured results are listed in Table 5. The oscillator performance before and after temperature compensation is shown in Figure 5.

Temperature(°C)	Frequency(MHz)
-30	463.61296
-20	463.61376
-10	463.61403
0	463.61393
+10	463.61372
+20	463.61338
+25	463.61288
+30	463.61293
+40	463.61265
+50	463.61256
+60	463.61297

Table 5. Measured results for the temperature compensation network.

The results of this example show how CADEC, a program normally used for RF and microwave design, can be used to optimize the DC output voltage of a temperature compensation network over temperature. This paper presented only one temperature compensation network but the same analysis and optimization technique can be applied to other networks. rf

References

1. M.E. Frerking, *Crystal Oscillator Design and Temperature Compensation*, Van Nostrand Reinhold Company, 1978.
2. CADEC User Manual, Communications Consulting Group.

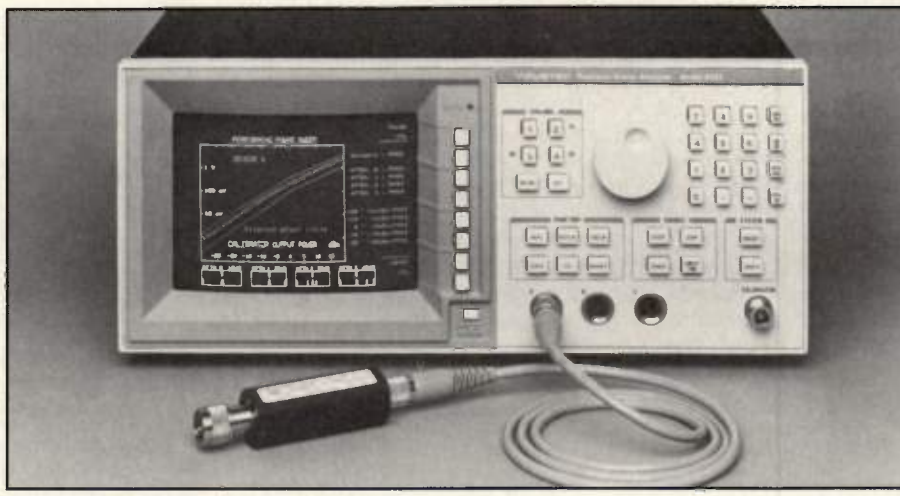
About the Authors

Alan Victor is vice president and Paul Faerber is principal engineer at Monicor Electronic Corp., 2964 N.W. 60th St., Fort Lauderdale, FL 33309. Alan holds an MSEE and previously worked for Motorola Communications Center. Paul has a BSEE from Georgia Tech. Both authors can be reached by phone at (305) 979-1907.

Wavetek Introduces a Precision Scalar Analyzer

The 8003 is a precision scalar analyzer with NBS traceable power measurement accuracy. A front panel calibrator allows the instrument to calibrate its power sensors to a linearity of ± 0.04 dB over the 90 dB dynamic range. This calibrator uses an internal thermistor bridge for good linearity while eliminating mismatch and attenuation errors during calibration by other means. With the addition of data stored in EEPROMs in the power sensors, the instrument makes corrected absolute power measurements.

Thirteen power sensors accompany the analyzer with standard units covering from 10 MHz to 40 GHz. Application oriented sensors are available for high power (1 watt) and low VSWR (<1.18 at 26.5 GHz) measurements. Capabilities include the ability to measure power-meter-accurate 1 dB compression measurements on active devices, and absolute power measurements such as the saturation output level of an amplifier or the input level from a source.

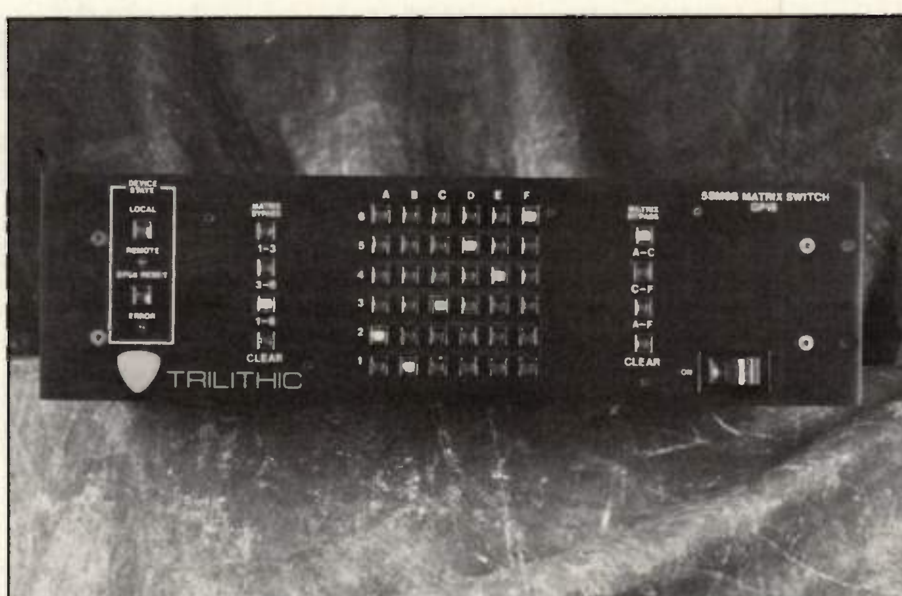


A color display is included with the 8003. This helps separate the 4 channels and makes the instrument more user friendly. A color coding scheme used with soft-key menus point-out allowable choices and highlight active modes and GPIB control is featured. Price for the scalar analyzer is $12,500 exclusive of the 13 power sensors and four return loss bridges. Sensors range in price from $75 to $3,600. **Wavetek Microwave, Inc., Sunnyvale, CA. INFO/CARD #210.**

DC to 1.2 GHz Matrix Switch From Trilithic

Model 1006B consists of a row and column array that allows all rows to be connected to all columns in any order, including crossovers. The only restriction is that a row port can only be connected to one column port at any one time or vice-versa. All ports are terminated unless connected to another port.

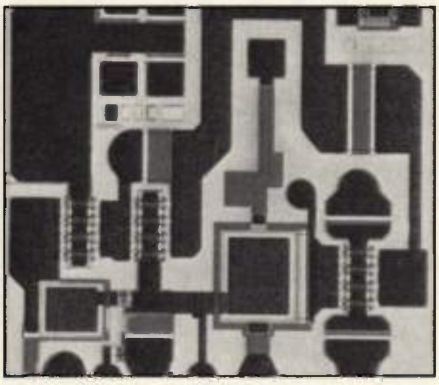
Row ports are numbered 1 through 6 and column ports are lettered A through F. Flexibility is derived from bypassing multiplexers capable of connecting any one of row ports 1, 3 or 6 to either of the other two. The same capability exists on the column side with ports A, C and F. Also, column ports can be connected to row ports in any order. The multiplexers take priority over the matrix so that if the port A port is bypassed to C, neither A nor C can be connected to the numbered row ports. A similar 8 × 8 matrix is available without the bypassing multiplexers.



This switching flexibility is available from DC to 1200 MHz with 2 ± 1 dB insertion loss, 1.5:1 VSWR and isolation of 60 ± 5 dB over the specified range. Impedance is 50 ohms and connectors are BNC with SMA and type N is available as an option. The front panel contains a 6 × 6 lightable keyboard which lights to indicate that a connection is complete after performing the required operations. In a like manner, the multiplexer keys on either side of the matrix keyboard light when the connection is made. As a programming aid, the key-lighting function continues under remote control. The unit comes with either a RS-232 or IEEE-488 interface. Model 1006B costs $11,425. **Trilithic, Inc., Indianapolis, IN. Please circle INFO/CARD #209.**

GaAs Amplifier

Texas Instruments introduces a monolithic gallium arsenide (GaAs) amplifier that operates from 100 MHz to 3.5 GHz. Three field effect transistor (FET) stages with 0.5-micron nominal gate lengths employ resistive feedback to give repeatable linear phase and amplitude characteristics. The amplifier has a 3 dB bandwidth that exceeds five octaves, a 2.4 dB



noise figure, 18 dB gain, ± 0.25 dB gain flatness from 0.1 to 2 GHz, and input and output SWR of 2:1. The device produces 15 dBm of output power at 1 dB gain compression. The TGA8061 is supplied in chip form and measures 60 × 60 × 4 mils. In quantities of 1,001 to 2,500, the amplifier is priced at $24 each. **Texas Instruments Inc., Semiconductor Group, Dallas, TX. INFO/CARD #208.**

Convection-Cooled Termination

Model T1100N is a 100 watt, DC to 800 MHz convection cooled termination. When

operated with forced air at 100 cfm, the unit is rated at 150 watts CW over an ambient temperature range of −55°C to +25°C. Maximum operating VSWR is 1.3:1. The unit is supplied with Type N male connectors per MIL-C90312 and is available with TNC or SMA connectors. Cost is $350 and the unit measures 5" × 5" × 3". **KDI/Triangle Electronics, Whippany, NJ. INFO/CARD #207.**

Video Isolation Transformer

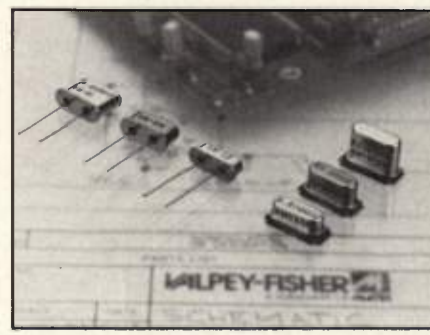
The NH-12847 video isolation transformer is designed to eliminate hum in TV and data systems. It provides 110 dB ground isolation at power line frequencies between input and output and ground. Its bandwidth of 10 Hz to 5 MHz makes it NTSC and PAL compatible. Applications include broadcast quality TV equipment, process control, CCTV, security and medical imaging systems. In small quantities, the unit is priced at $104. **North Hills Electronics, Inc., Glen Cove, NY. INFO/CARD #206.**

High Pass Filter

Microwave Filter Company unveils a filter that prevents interfering frequencies from overloading the amplifier and causing interference to HF radios. Passband is 2 to 20 MHz and maximum loss is 3 dB. Stopband is 0.5 to 1.5 MHz with rejection of 40 dB min. Impedance is 50 ohms and connectors are UHF PL-259. The case measures 1.62" × 2" × 4.25" and costs $225. **Microwave Filter Company, East Syracuse, NY. INFO/CARD #205.**

Reduced Height Crystals

A series of reduced height HC-49/U (VM-6) crystals cover from 3.5795 MHz to



75 MHz and utilize AT-cut crystal technology. All members of the series are available in metal cans and tape and reel packaging. **Valpey-Fisher Corp., Hopkinton, MA. INFO/CARD #203.**

SAW Resonators

Toshiba introduces five SAW resona-

tors. The SRU295 (295.0 MHz), SRU303 (303.5 MHz), SRU304 (303.875 MHz), SRU310 (310.5 MHz) and SRU315 (315.0 MHz) SAW resonators designed for short-range transmissions using low amplitude signals. Applications include wireless security systems, garage-door openers, and other automation uses requiring the transmission of information at low speeds using a carrier of about 300 MHz. In 1,000-piece quantities, the resonators are priced below $2.50. **Toshiba America, Inc., Deerfield, IL. INFO/CARD #160.**

Power MOSFETs

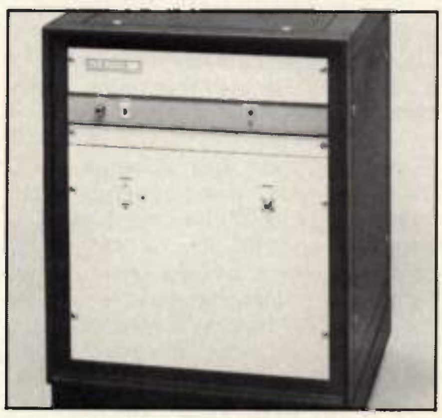
The DE-150 Series features a switching speed of less than 5 ns at frequencies over 20 MHz with 75 watt dissipation. The devices switch 1 to 2k watts of average power and 5 to 10k watts of peak power. Applications include switch mode power conversion, high speed linear amplifiers, TWT modulators, laser diodes, Impatt diodes, image intensifiers and acoustic transducers. In 1,000-piece quantities, the devices are $83. **Directed Energy, Inc., Fort Collins, CO. INFO/CARD #201.**

BAW Delay Lines

Andersen unveils bulk acoustic wave delay lines with delays from 125 ns to 2000 ns. Bandwidth in excess of 20 MHz are possible with less than 8 dB insertion loss while operating frequency extends beyond 100 MHz. **Andersen Laboratories, Inc., Bloomfield, CT. INFO/CARD #200.**

100W RF Amplifier

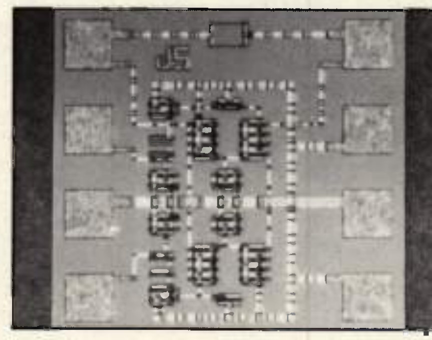
Amplifier Research introduces an amplifier that delivers up to 180 watts and a minimum of 100 watts CW from 100 to



1000 MHz. Its output at less than 1 dB gain compression is 70 watts and typical flatness is ± 1.5 dB. Features include instantaneous bandwidth and immunity to load mismatch. Applications include RFI susceptibility testing, antenna and component testing, wattmeter calibration, and general laboratory work. Model 100W1000M7 is priced at $40,000. **Amplifier Research, Souderton, PA. Please circle INFO/CARD #199.**

Active Phase Splitter

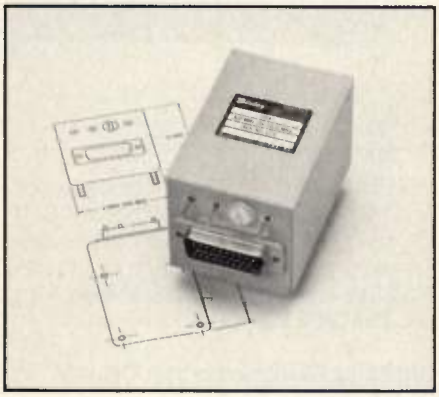
A 3.5 GHz GaAs active phase splitter has been introduced by Anadigics. The APS30010 offers a single port insertion



loss of 2.0 dB, 0.3 dB amplitude balance, and 1.0 degree phase balance. Other features include a 30 dB reverse isolation, 30 dB isolation between ports and 15 dB input return loss. Intended for microwave and digital application, the APS30010 is priced at $43.50 for the die and $65.00 for the 8-pin flatpack in 1,000-piece quantity. **Anadigics, Inc., Warren, NJ. Please circle INFO/CARD #198.**

Digitally Compensated Crystal Oscillator

Bliley introduces the D9A digitally compensated crystal oscillator with standard frequencies of 5 or 10 MHz. Optional frequencies from 10 kHz to 20 MHz are also



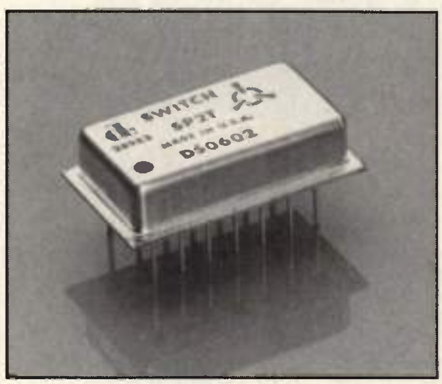
available. Frequency stability is $\pm 5 \times 10^{-8}$ between 0°C and +60°C. In addition to standard aging of 3×10^{-9}/day, a 1×10^{-9}/day aging rate is also offered. **Bliley Electric Company, Erie, PA. Please circle INFO/CARD #197.**

EMI Test Receiver

The EMC-P80 is a portable hand-held EMI test receiver for measurements in the 2 MHz to 34 MHz range. This battery unit is useful for measuring radiated interference sources and is capable of measuring transmitted field strength and antenna patterns. Average and peak detectors permit the unit to meter all types of signals including impulsive and CW. A tracking RF pre-selector reduces the instrument's vulnerability to overload and spurious responses. A built-in audio jack allows for aural monitoring of signal modulation, and a selection switch permits the operator to listen to AM or FM signals. The EMC-P80 comes with two tuner heads, Models T-81 and T-82 to provide continuous measurements from 2 MHz to 34 MHz. The T-81 covers from 2 MHz to 8 MHz while the T-82 covers from 8 MHz to 34 MHz. A whip antenna, VA-70, is also included. The instrument is priced at $4,995. **Electro-Metrics, Amsterdam, NY. INFO/CARD #196.**

GaAs SPDT Switch

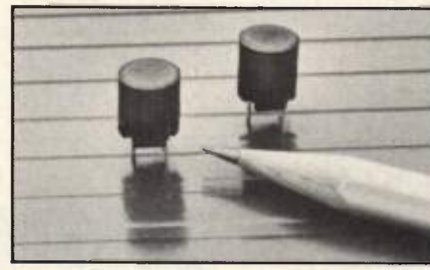
P/N DS0602 is a GaAs FET SPDT switch that operates from 5 to 2000 MHz with VSWR of 1.5:1. It draws 150 uA and switches in 26 ns. Isolation ranges from 45 dB to 65 dB depending on frequency and insertion loss is approximately 1.6 dB at the higher frequencies. Other features include internal 50 ohm terminations, 4 ns



transition time and low switching transients. The switch is available in a 14-pin DIP. **DAICO Industries, Inc., Compton, CA. INFO/CARD #195.**

Miniature Fixed Inductors

A miniature fixed inductor line for filtering and trapping, Model 8RBC, has a frequency range of 50kHz to 200 kHz with inductance range of 1 mH to 45 mH and



internal capacitance that can be specified over a 5 to 6800 pF range. In OEM quantities, the inductor is under $1.**Toko America, Inc., Mt. Prospect, IL. INFO/CARD #194**

SMT Quartz Crystal

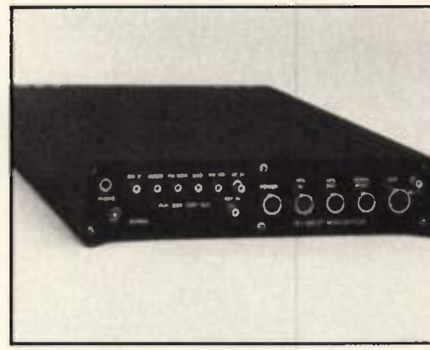
CX-AT-HT is an AT-cut, SMT, miniature quartz crystal without leads available at frequencies from 8 to 35 MHz. Standard frequencies range from 8 to 24 MHz with tolerances of ± 0.0005 percent. It is packaged in standard 7 inch reels with up to 1,000 pieces per reel. Prices in quantities of 1,000 range from $3.20 to $5.45 each depending on tolerances. **Micro Crystal Div./SMH, New York, NY. Please circle INFO/CARD #193.**

Analog Measurement System

Createc Signal Computer introduces the Scout SC-02. It uses zener and quartz references and feedback from the microcomputer through a 12-bit DAC. This two-channel, 20 MHz digital oscilloscope has a transient recorder with 46 data memories, a 1 MHz RMS multimeter, automatic frequency measurement to 7 MHz and computing functions on all input and stored waveforms. As a frequency counter the Scout performs frequency measurements from DC to 7 MHz with typical accuracy better than 0.05 percent. This instrument is priced at $2,995. **Createc Signal Computer, Santa Clara, CA. Please circle INFO/CARD #189.**

Surveillance Miniceptor

Watkins-Johnson introduces the WJ-8607 miniature receiver called the miniceptor. The range of 2 to 512 MHz is



expandable to 2000 MHz with a frequency-extender option. The design features SMT technology which results in a package measuring 1.65" × 6.50" × 10.50". **Watkins-Johnson Company, Palo Alto, CA. INFO/CARD #192.**

Digitally Compensated Crystal Oscillator

Connor-Winfield unveils a family of DCXOs with TTL fixed frequencies from 15 kHz to 25 MHz, and CMOS fixed frequencies from 250 Hz to 6 MHz. Stability

is × 0.00002 percent from 0 to 70°C and ± 0.0001 percent from −40 to 85°C. **Connor-Winfield Corp., West Chicago, IL. INFO/CARD #191.**

EMC Measurement Antenna

The Bowtop antenna has a bandwidth from 30 to 600 MHz and 2 dB variation antenna factor. It is an active antenna with two interchangeable elements — one a dipole and the other a vertical monopole. The dipole measures 30 cm across. **EMC Consulting, Tucson, AZ. Please circle INFO/CARD #190**

UHF Connector

Model RFU-602-1 is a mini UHF connector rated to 2 GHz. It is constructed of a nickel plated machined brass body, silver plated contact and delrin dielectric. **RF Industries, San Diego, CA. Please circle INFO/CARD #188.**

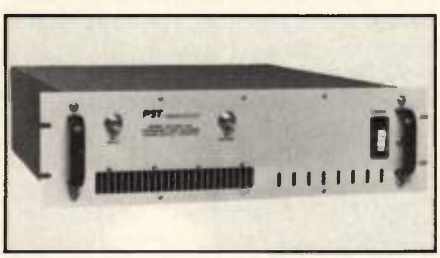
Signal Source

Model 2005 from B&K Precision is a signal source from 100 kHz to 150 MHz in six bands. The output may be AM modulated by an internal 1 kHz source or externally by any audio frequency. It

features step and variable fine output attenuation to 40 dB, variable AM modulation from 0 to 100 percent, auxiliary output for the internal 1 kHz audio source and separate outputs for the RF connection and an external frequency counter. The instrument is priced at $195. **B&K Precision, Div. of Maxtec International Corp., Chicago, IL. INFO/CARD #187.**

Microwave Instrument Amplifier

PST introduces the Model AR1929-10 instrument amplifier with frequency range of 1 to 2 GHz. Power output at 1 dB compression is 10 watts while saturated power output is 15 watts. Small signal gain is 40



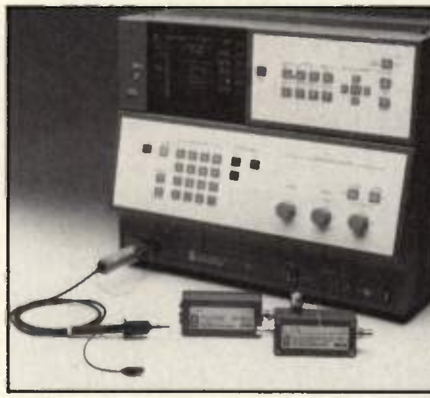
dB min. and spurious signals are measured at −60 dBc. The amplifier accepts CW, FM, pulse, AM and phase input signals. **Power Systems Technology, Inc., Hauppague, NY. INFO/CARD #186.**

Frequency Synthesizer

The Syntest Model DS-102 frequency synthesizer offers a frequency range of 0.1 to 16 MHz with internal reference oscillator having stability of ± 10 ppm. Resolution is 5½ digits and the TTL output is capable of driving 50 ohms. The DS-102 is priced at $1,485. **Syntest Corp., Marlboro, MA. INFO/CARD #185.**

Transmission System Analyzer

The TSA-2 is a systems analyzer that can handle most FDM system measurements. It combines the functions of a selective level meter with those of a spectrum and network analyzer. The frequency range of 100 Hz to 180 MHz allows for



measurements on VF channels, in the FDM baseband and the IF band of FM radio and satellite link systems. Facilities are provided for rapid tone search, SSB demodulation and measuring phase jitter to CCITT Rec. 0.91 standards. **Wandel & Goltermann, Inc., Research Triangle Park, NC. INFO/CARD #184.**

High Power Amplifiers

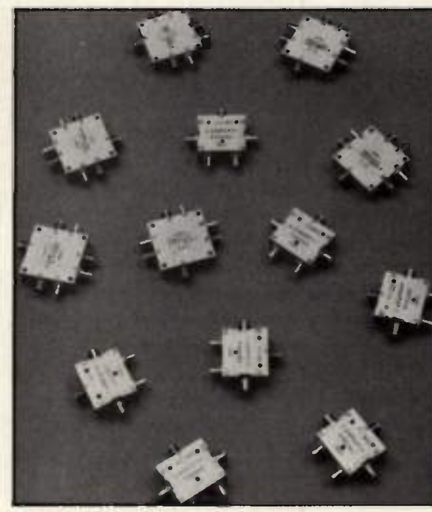
The CPS series has five models operating from 5 to 45 MHz with power outputs of 800, 1000, 2000 and 5000 W. Minimum bandwidth is 10 percent of frequency range and RF load is 50 ohms nominal. Other features include fast acting APC, automatic SWR protection, 2 percent linearity in power control, water cooling, pulse or sine wave modulation plus remote control and monitor functions. Options include internal drive reference, external frequency drive, analog or digital power display, AM or pulse modulation, RS232 interface, series or parallel interlocks and a power/control cable kit. **Comdel, Inc., Beverly, MA. Please circle INFO/CARD #193.**

Miniature Ceramic Quartz Crystal

Statek Corp introduces the CX-4 surface mountable miniature quartz crystal that measures 200 mils × 72 mils × 42 mils. First year aging is less than 10 ppm while shock survival rate is 3,000g. It is available in the 32 kHz to 100 kHz frequency range. **Statek Corp., Orange, CA. INFO/CARD #182.**

PIN Diode Switches

Sierra Microwave Technology introduces a line of PIN diode switches covering from 0.5 to 18 GHz. The switches feature multi-octave bandwidth, fast switching, integral TTL-compatible drivers, SMA removable



connectors for use in microstrip structures, and internal drop-in isolators for use in non-reflective switches. SPST through SP5T devices are available. **Sierra Microwave Technology, Rancho Cordova, CA. INFO/CARD #183.**

Capacitive Coupling Networks

The R&B Enterprises CCN-201 and CCN-202 capacitive coupling networks are used to couple high frequency EMP test signals to equipment cables for bulk-cable injection testing. CCN-201 operates from 10 MHz to 50 MHz and has a coupling efficiency of no less than −6 dB while CCN-202 has a range of 50 MHz to 100 MHz with no less than −5 dB coupling efficiency. **R & B Enterprises, West Conshohocken, PA. INFO/CARD #183.**

Planar Tunnel Diode

These germanium planar tunnel diodes are ideal for detector applications through 26 GHz where fast recovery and high temperature stability is required. Detector diodes have an I_P range of 50 to 600 uA with junction capacitance less than 0.2 pF. Switching diodes are available with $I_P \approx 50$ mA. **M-pulse Microwave, San Jose, CA. INFO/CARD #210.**

Log Amplifiers

These log amplifiers from Trontech can be specified with over frequency range of 1 MHz to 300 MHz. Dynamic range is 75

dB min., and linearity is ±75 dB from 0 to −70 dBm. The basic unit has a frequency range of 60 ±10 MHz. **Trontech, Inc., Neptune, NJ. INFO/CARD #165.**

Thin-Film Cascadable Amplifier

Model AC487 is a thin film cascadable amplifier that operates over the 10 to 400 MHz range. Typical gain is 14.5 dB (guaranteed) over the 0 to 50°C temperature range. Noise figure is 3.3 dB typ. and

4.0 max. over the same temperature range. Power output is 15.5 dBm and third order intercept is typically 32 dBm. Operating current at 15 V is 33 mA and standard packaging is 4-pin TO-8. **Cougar Components, Sunnyvale, CA. Please circle INFO/CARD #164.**

Phase Shifter

Model FPS4381 operates from DC to 2 GHz and provides 0.3 dB maximum insertion loss with VSWR of 1.25:1. The unit measures 1.5" × 4" × 0.5". Modified units

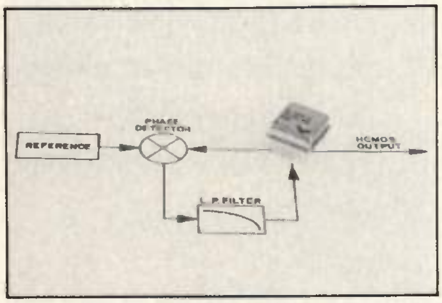
can be supplied for operation to 18 GHz. **Sage Laboratories, Inc., Natick, MA. INFO/CARD #163.**

Shielding Isolator

Sierra Microwave introduces a shielding drop-in isolator covering the 1.475 to 1.675 GHz range. Minimum isolation is 20 dB, VSWR is 1.25:1 max. and insertion loss is 0.5 dB max. The device measures 0.75" × 0.75" × 0.25" and temperature range is −54°C to +85°C. **Sierra Microwave Technology, Rancho Cordova, CA. INFO/CARD #162.**

DIP HCMOS VCXO

The CO-444V series hybrid VCXOs are designed for phase locking applications. They provide any specified center frequency from 1 kHz to 50 MHz. Deviation



over the 0 to +5 V control voltage ranges from ±30 ppm to ±200 ppm. These 0.2" high double DIP resistance welded packaged oscillators meet 10^{-8} atm/cc fine leak testing per MIL-STD-883. They also conform to MIL-O-55310 and are available level B screened. **Vectron Laboratories, Inc., Norwalk, CT. INFO/CARD #161.**

Gain Block Amplifiers

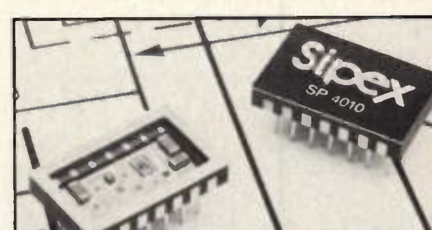
The HAMP-5001 automatic gain control (AGC) and HAMP-3001 20 dB gain block amplifiers with bandwidths from 100 kHz to 2 GHz are designed for digital communications. The amplifiers provide 15 dB and 20 dB, respectively. Power at the 1 dB compression point is 11 dBm for the 5001 and 10.6 dBm for the 3001. The 5001 has an AGC range of 31 dB and the 3001 has gain flatness of ± 0.6 dB. In quantities of 100, the 5001 is $130 and 3001 is $101. **Hewlett-Packard Company, Palo Alto, CA. INFO/CARD #204.**

Pulse Amplifier

Kalmus Engineering unveils a pulse amplifier, Model 169LP, with peak power output in excess of 4 kW at 10 percent duty cycle from 10 to 70 MHz min. Features include blanking of 1 us with signal rise and fall times better than 150 ns. The amplifier sells for $22,500. **Kalmus Engineering International, Ltd., Woodinville, WA. INFO/CARD #202.**

60 MHz Buffer Amplifier

The Hybrid Systems division of Sipex Corp. introduces FET-input beffer amplifier that uses a DI-based ASIC. The SP4010 has an accuracy of 16-bits, slew rate of 1000 V/us, 60 MHz bandwidth and settling time of 150 ns to 0.005 percent for a 10 V step. Input offset voltage is specified at 1 mV typ., 2 mV max. with voltage drift of 10 uV/degree C and input bias current of 100 pA. Its minimal harmonic distortion is −100 dB at 10 kHz and −80 dB at 1 MHz. Packaging is 14-pin ceramic DIP and price in 100-piece quantity ranges from $44.50 to $82.50 depending on temperature range and screening. **Sipex Corp., Billerica, MA. Please circle INFO/CARD #159.**



rf literature

Catalog Lists PC-Based Instruments

This catalog features a line of PC-based instruments. Included are FFT spectrum analyzers, digital scopes, logic analyzers, data acquisition cards, GPIB controller cards, stepper motor control cards and scientific data analysis software. All hardware products come with controlling software. **Rapid Systems, Inc., Seattle, WA. INFO/CARD #184.**

Used Equipment Catalog

Genstar REI introduces a catalog that includes like-new analyzers, oscilloscopes generators and desktop computers from major manufacturers. Prices, warranties and illustrations are included. **Genstar REI Sales Company, Woodland Hills, CA. INFO/CARD #161.**

Product Line Card

A line card from Penstock features 19 lines with over 48 product categories, 6000 product types, and over 200,000 components. It is available at no charge to qualified RF/Microwave component users. **Penstock, Inc., Sunnyvale, CA. Please circle INFO/CARD #160.**

Medium Power Amplifiers Featured in Brochure

A brochure describing low noise, medium power, DC to microwave amplifiers is available from Trontech. Specific types featured include silicon and GaAs FET low noise amplifiers, medium and high power RF and microwave amplifiers, ultra-wide band low noise and medium power amplifiers. Frequency response, gain flatness, noise figure, output power, saturated output, gain compression, power requirement, input power and case style specifications are given where appropriate. Also included is general information and definitions of commonly used technical terms. **Trontech, Inc., Neptune, NJ. Please circle INFO/CARD #162.**

Discrete Data Disk

The Discrete Data disk includes selector guide information on Motorola's entire line of bipolar power transistors, power MOSFETs, small signal devices, RF devices, optoelectronic devices, rectifiers, zeners, thyristors and sensors. The guide contains 58 product categories with technical information on over 7,200 devices, 20,000 cross references, 200 rf design

6300 S. Syracuse Way, Suite 650 / Englewood, Colorado 80111 (303) 220-0600

TO: RF Engineers
FROM: *RF Design* magazine
RE: RF Expo East 88

Thousands of professionals in RF engineering will converge on Philadelphia October 25-27, 1988. The reason: RF Expo East 88. This conference is targeted specifically at you and the special problems and situations you encounter daily. Note the following:

Subject: Special Courses

Since the first RF Expo East, engineers have raved about the RF Fundamentals course presented by Les Besser. 1988 promises to be no different, as once again, Les presents his extremely popular fundamentals course, RF Circuit Design Part I, October 24, 1988. And, for the first time, RF Circuit Design Part II, Advanced Topics, will be presented October 25, 1988. Both courses are sure to be highlights of the show. Another tutorial added this year is Computer Aided Filter Design, conducted by Randy Rhea of Circuit Busters, a successful software design and analysis company. This day-long tutorial in modern filter design takes place October 24, 1988 and does require pre-registration, as do both of the fundamentals courses.

Recommendation: Pre-register for all three courses on the registration card found on page 83.

Subject: Exhibiting Companies

Over 100 leading manufacturers will be on the exhibit hall floor, displaying the latest innovations in RF engineering technology and services. Meet with representatives of these companies to discuss your specific applications.

Recommendation: Comparison shop for components and materials you need in your work by visiting the exhibit hall.

Subject: Session Schedule

Program chairman Carl Erickson of McCoy Electronics and *RF Design* editor Gary Breed have selected the most current topics, including: Quartz Crystal Technology; SAW Devices; Mixer Tutorial; Radiowave Propagation; Power Amplifiers; Manufacturing and Quality Control; RF Design Awards Contest Winners.

Recommendation: If you're serious about improving your design techniques and problem solving skills, attend the sessions.

RF Expo East will be an outstanding opportunity for you to improve your skills and advance your career. The registration form is on page 83. Fill it out and mail it today.

Bottomline: Attend RF Expo East 88. Your future success depends on it.

RF Session Schedule for 1988 RF Expo East

Tuesday, October 25

Session A-1: SAW Devices

- 8:30 SAW Spectrum Analyzers
  Maura Fox, Phonon Corporation
- 9:30 SAW Products: Custom Subsystems and Fully Integrated Hybrid Modules
  — R. Hays, T. O'Shea, J. Anderson and M. Lewis, SAWTEK
- 10:30 Direct E-Beam Write of SAW Devices
  — Colin Lanzl, Alpha Industries

Session A-2: Receiver Design

- 8:30 Receiver Design — Simplified
  — Jerry Iseli, RF Monolithics, Inc.
- 9:30 Global Positioning System
  — Bruce Hammel, Rockwell International, Collins Radio Div.
- 10:30 Optical/Acoustic Receivers
  — Richard Johnson, Crystal Technology

Session A-3: Design Techniques

- 8:30 Optimum Impedance Matching Using Minimum Number of Components
  — Donald Lanzinger, Loral Systems Group
- 9:30 Complex Signals: Their Processing and Transmission
  — Noel Boutin, University of Sherbrooke
- 10:30 Unequal Splitter Design
  — Douglas K. Linhart, Micon, Inc.

EXHIBITS OPEN — 11:00 a.m.-6:00 p.m.

Session B-1: Synthesizer Topics

- 1:30 Optically Coupled VHF Voltage Controlled Oscillator
  — Albert Helfrick, Dowty RFL Industries, Inc.
- 2:30 Low Spurious Techniques for DDS Systems
  — Robert J. Zavrel, Jr., Digital RF Solutions
- 3:30 Direct Digital Synthesis
  — John Bendley, Wavetek RF Products, Inc.

Session B-2: Reliability and Quality Control

- 1:30 Failure Analysis of RF Devices
  — Andrew Blackwood, Structure Probe
- 2:30 Determination of the M.T.T.F. for Pulsed Power L-Band Microwave Transistors Used in Radars and Navigation Apparatus
  — Georges Bobin, RTC, and John C. Salvey, Amperex Electronic Corporation
- 3:30 Performance of RF Components at Low Temperatures
  — Otward Mueller, General Electric Company

Session B-3: New RF Components

- 1:30 A 150-Watt Transistor for Class AB Power Amplifier Applications in the 460-860 MHz UHF Television Band
  — John Walsh, SGS-Thomson
- 2:30 A Silicon RF Amplifier Using a Dielectrically Isolated Monolithic Microwave Integrated Circuit (DIMMIC) Process
  — P. Bachert, M. McCombs, P. Sanders, Motorola Semiconductor Product Sector
- 3:30 Applications and Measurement of Small Value Inductors in SMT and Hybrid Circuits
  — Richard Dunlap, Micoil

Wednesday, October 26

Session C-1: Radiowave Propagation Tutorial

- 8:30-11:30 (3-hour tutorial session)
  Daniel R. Dorsey, Jr., Control Data Corporation

Session C-2: Quartz Crystal Applications

- 8:30 Fundamentals & Stability of Crystal Resonators
  — Dr. John Vig, U.S. Army Electronics Technology & Devices Laboratory (LABCOM)
- 9:30 Crystal Filters
  — William Pond, McCoy Electronics Company
- 10:30 Practical Considerations in Specifying Hi-Stability Crystal Oscillators
  — Glenn Kurzenknabe, Piezo Crystal Company

Session C-3: Computer-Aided Design

- 8:30 CAC Package for RF Applications
  — Alec Clerihew, Hazeltine Corporation
- 9:30 CAD Techniques for SAW Devices
  — Dr. Donald Malocha, University of Central Florida
- 10:30 High-Speed Printed Circuit Board Analysis and Simulation in a Workstation Environment
  — J.N. Hall, S.H. Ardalan, M.S. Basel, R. Pomerleau, D.O. Riddle and M.B. Steer, North Carolina State University

EXHIBITS OPEN — 11:00 a.m.-6:00 p.m.

Session D-1: Elements of Antenna Theory

- 1:30-4:30 (3-hour tutorial session)
  — Benjamin Rulf, Lockheed Electronics Company, Inc.

Session D-2: Power Amplifiers

- 1:30 Effects of VSWR Upon Class-E Power Amplifiers
  — Dr. Frederick H. Raab, Green Mountain Radio Research Company
- 2:30 RF Hybrid Linear Power Amplifier With Diamond Heat Sink
  — Hafiz Karabudak, Aydin Vector Division
- 3:30 Development of a Linear L-Band High Power Amplifier for Satellite Applications
  — Gillis Brassard, Spar Aerospace Limited

Session D-3: Non-Linear Circuit Simulation

- 1:30 Nonlinear Circuit Simulation for Microwave and High Speed Circuits
  — P.K.U. Wang, K.T. Lin, M. Sango and C. McGuire, EEsof Inc.
- 2:30 Simulation of Nonlinear RF and Microwave Circuits
  — C.R. Chang, P.L. Heron, M.B. Steer, G.W. Rhyne, D.O. Riddle and R.S. Gyurcsik, North Carolina State University

Thursday, October 27

EXHIBITS OPEN 10:00 a.m.-2:00 p.m.

Session E-1: Mixer Tutorial

- 8:30-11:30 (3-hour tutorial session)
  — Dr. Donald Steinbrecher, Steinbrecher Corporation

Session E-2: Manufacturing-Related Topics

- 8:30 Special Requirements of RF Packaging
  — Rudy Sachs, ASPE, Inc.
- 9:30 An Inexpensive Silicon Monolithic Process for Microwave Low and Medium Power Circuits
  — Paul Sanders, Motorola Semiconductor Products Sector
- 10:30 Simulation of Complex PCB Layouts Including Coupled Tracks with Nonlinear Digital Device Termination
  — D. Winklestein, R. Pomerleau and M.B. Steer, Bell Northern Research

Session E-3: Transmission Line Topics

- 8:30 Through Symmetric Fixture: A Two-Port S-Parameter Calibration Technique
  — J.S. Kasten, M.B. Steer and R. Pomerleau, Center for Communications and Signal Processing, North Carolina State University
- 9:30 Use of Pads and Baluns for TAHQ Alignment
  — N. Ersoz, Thomson Consumer Electronics
- 10:30 The Design of a High Reliability Electronic Step Attenuator
  — M. Da Silva and D. Whipple, Hewlett-Packard

EXHIBITS OPEN — 10:00 a.m.-2:00 p.m.

rf literature *Continued*

standard package types and 130,000 parameters. It supports both parametric and part number searches. More information on the disks can be obtained by circling the reader service number. Disks costs $2 each. **Motorola, Inc., Semiconductor Products Sector, Phoenix, AZ. INFO/CARD #181.**

Tuning Devices Design Manual

Johanson introduces a catalog/design manual which features a frequency/application index to facilitate selection. The trimmer capacitor portion describes a variety of units including air dielectric trimmers, microwave sapphire dielectric trimmers, and an array of ceramic dielectric types in a variety of sizes, ranges and mounting configurations. Also included is a surface mounted trimmer capacitor which is available in tape and reel packaging. The microwave tuning device portion provides information on specifications for microwave tuning elements for filters and oscillators along with adjustable phase trimmers for microwave cable assemblies. The final section lists proto-typing kits for identifying and evaluating most of the products listed. **Johanson Manufacturing Corp., Boonton, NJ. INFO/CARD #177.**

RF Filter Brochure

This RF filter brochure covers filters from 10 MHz to 18 GHz in bandpass, lowpass, lumped, tunable, cavity and waveguide configurations. Included are attenuation curves, insertion loss curves, and other passband and stopband relationships. **Texscan Instruments, Indianapolis, IN. INFO/CARD #176.**

Op Amp Selection Guide

Raytheon has published a precision operational amplifier selection guide highlighting over 50 device types. Listed are performance specifications, packaging information, and MIL-STD-883B availability. **Raytheon Company, Mountain View, CA. INFO/CARD #175.**

Test and Measurement Instrumentation Catalog

This catalog lists test and measurement instrumentation in the Fluke/Philips alliance. Products listed are oscilloscopes, bench/system multimeters, handheld multimeters, multimeter accessories, logic analyzers, board testers and troubleshooters, calibration instruments, counters/timers, instrumentation systems, data acquisition systems, and digital thermometers. A section on customer service and ordering information is included. **John Fluke Mfg. Co., Inc., Everett, WA. INFO/CARD #180.**

Opto-Electronic Handbook

This handbook has information on photoconductive cells, photodiodes, phototransistors, photodarlingtons, light emitting diodes, opto-isolators, optical switches, opto arrays and opto chips. These sections contain descriptions, drawings and specifications for the various components and assemblies. Other sections highlight design considerations, applications of various components, definitions and interchangeability. **Clairex Electronics, Mount Vernon, NY. INFO/CARD #170.**

Fiber Optics Handbook

This handbook from Hewlett-Packard has been updated to reflect the latest technical developments in the photonics industry. Terms in the publication are organized alphabetically and numerous cross-references are given. Figures and diagrams are used is illustrate the technical language. More information can be obtained by circling the reader service

rf literature

number. The handbook is listed at $20. **Hewlett-Packard Company, Palo Alto, CA. INFO/CARD #178.**

Quartz Crystal Products Catalog

Fox Electronics introduces a brochure that describes surface mount devices, crystals, oscillators, real-time clocks, and filters. A section that describes Fox Electronics together with ordering procedures and identification information is included. The final section of this catalog lists definitions and engineering data. Crystals listed include custom, AT cut and tuning fork crystals. Oscillators highlighted encompass TTL clock, MOS, HCMOS, ECL, TCXO and VCXO. **Fox Electronics, Ft. Myers, FL. INFO/CARD #174.**

Semicustom IC Guide

The guide to semicustom integrated circuits is available from Plessey Semiconductors. It details gate array and standard cell product lines available in both CMOS and bipolar technologies including packaging and quality screening options for both commercial and military applications. A discussion of the semicustom design process using the Plessey PDS-2 design system is also provided with specifications of all interactive design tools. In addition, case histories involving four Plessey customers are discussed to illustrate the variety of problems which can be solved using Plessey Semiconductor products and expertise. **Plessey Semiconductors North America, Irvine, CA. INFO/CARD #180.**

Products Brochure

This brochure from Norsal covers phase shifters, SPST switches, SPDT switches, BPSK modulators, image reject mixers and phaseless attenuators. Specifications together with ordering information and schematics are included. **Norsal Industries, Inc., Central Islip, NY. INFO/CARD #171.**

Data Conversion Products Catalog

Micro Networks announces the availability of its 1988-1989 Data Conversion Products Catalog. It contains detailed, application oriented data sheets describing over 60 different products including sampling A/D converters, analog-to-digital converters, digital-to-analog converters, track-hold amplifiers, data acquisition systems and linear amplifiers. Tutorial sections cover A/D, D/A and T/H basics, and frequency-domain FFT testing for sampling A/D converters. **Micro Networks, Worcester, MA. Please circle INFO/CARD #179.**

rf software

RF Circuit Analysis and Optimization Program

RF Designer™ is a small signal circuit analysis program intended for the Apple Macintosh II ™ Macintosh SE™ and Macintosh Plus™ computers. The program features full nodal analysis, random and gradient optimizers, S- parameter interpolation, stability analysis, graphical outputs such as magnitude, phase, return loss, Smith chart and a variety of tabular output options such as S-parameters, gain, phase and return loss. S-parameter libraries include data for common active devices.

Component models are set up to include the effects of parasitics such as capacitor inductance, transmission line loss and coil Q. Component values can be optimized for desired performance in three independent frequency bands. The package contains the program, an S-parameter library, a folder with examples, the RF Design Tutorial — a textbook covering the basics of high frequency design, and the RF Designer Tutorial — an introduction to the program. The circuit size that can be analyzed is only limited by the available memory; 1 Mb allows 40 nodes, 60 components and 30 frequencies for S-parameter file. **JAG Electronics, Willowdale, Ontario, Canada. INFO/CARD #168.**

Active Filter Design Package

RLM Research introduces version 3.1 of the AFD (active filter design) software package. This version has the capability to perform sensitivity and worst case analysis on filter circuits. An FFT routine has been added to speed up the calculation of time domain responses. **RLM Research, Boulder, CO. Please circle INFO/CARD #166.**

Call for Papers

rf technology expo 89

February 14-16, 1989
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Your participation is requested, to continue a tradition of excellence. Topics needed include basic tutorials, project case histories, and advanced design techniques. The recognition by your engineering peers is a reward you will not forget. All speakers receive complimentary full registration and a copy of the Proceedings.

Send your proposal, including title, abstract, and author(s) information to:

Dr. Tim Healy
RF Technology Expo Program Chairman
Microwave and Communications Laboratory
Santa Clara University
Santa Clara, CA 95053
(408) 554-4482

Questions may also be addressed to:

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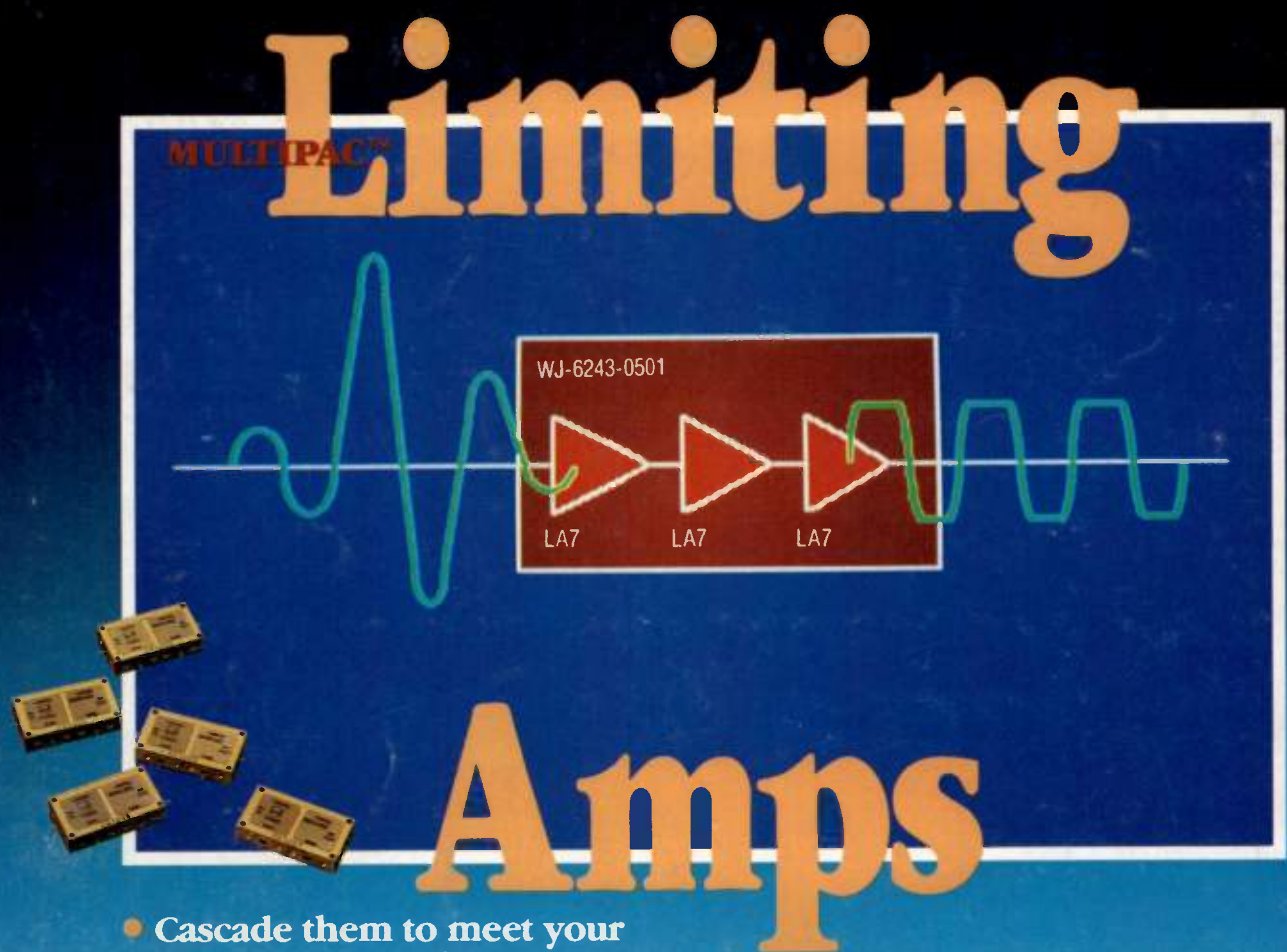

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	6243-0501	LA7/LA7/LA7	33.0	9.5	+7.0	2:1	15	162
	6243-0505	LA7/LA7/LA7	33.0	9.5	+7.0	2:1	15	162
10-1000	6242-0502	LA17/LA17	19.0	7.6	+5.0	2:1	15	110
	6243-0502	LA17/LA17/LA17	28.5	7.6	+5.0	2:1	15	165
	6243-0506	LA17/LA17/LA17	28.5	7.6	+5.0	2:1	15	165
1000-4000	6242-0503	LA45/LA45-1	21.0	10.0	+14.5	2.3:1	15	210
	6243-0503	LA45/LA45/LA45-1	30.0	10.0	+14.5	2.3:1	15	315
2000-6000	6242-0504	KLA62/KLA62	20.0	9.5	+10.0	2.3:1	12	140
	6243-0504	KLA62/KLA62/KLA62	30.0	9.5	+10.0	2.3:1	12	210

Note: 1. These models may be cascaded together for wider limiting dynamic range.

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