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Special Report: Software Streamlines RF Engineering

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January 1985



Special Report p.22

Cover

January Cover —

This month's front cover features Touchstone/RF, a design and analysis program intended for RF engineering. It is one one the many new products to be displayed at the RF TECHNOLGY EXPO. Photograph courtesy of EEsof.

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Special Report: Software Streamlines RF Engineering —

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Max VSWR (on pos.)	1.4	1.4	1.9	1.9
SW-2184-1A Min Isolation(db)	45	70	85	80
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INFO/CARD 4

rf editorial

A New Year, A New Frequency



Kiyoshi Akima Editor

As you read the first monthly issue of *RF Design* you will notice many changes, the most apparent ones on the front cover. In addition to a new logo, this is our first cover to show a person. This highlights our commitment not just to the field of RF, but to the *people* working in RF. But the changes don't stop there, they continue inside. There are four new departments:

 RF News. This department brings news of the RF field. This month the emphasis is on RF TECHNOLOGY EXPO 85, the first such event devoted exclusively for people working in the lower reaches of high frequency.

 RFI/EMI Corner. Lester Dant of AD-Vance Magnetics provides a background to the subject of electromagnetic compatibility and electromagnetic interference.

• The Digital Connection. John Schooley of Remcon explains how to drive light emitting diodes for displays.

• Product of the Month. This month the spotlight falls on a new modular spectrum analyzer from Hewlett-Packard.

The first special report of the new year focuses on computer software for RF engineering. The emphasis is on commercially available packages for desktop computers. These programs can aid the engineer during the various phases of the design process, from initial design and analysis to final circuit layout and even mask preparation.

Many readers have written us expressing their opinions on the "Universal Language" for programming and the merits of personal computers versus handheld programmable calculators. We side-step the matter this month by presenting one from each side. R. K. Feeney and D.R. Hertling present an HP-41 program for Feedback Amplifier Design while Richard Bain presents a BASIC program for Filter Response. Rounding out the magazine, Jim Walworth explains the Dielectric Resonator.

The special report in February will focus on modules and supercomponents. These devices, by replacing entire circuits, allow the designer to get on with the job of designing the system, instead of wasting time tweaking a component. The March report will cover new waves in oscillator design. The report in April will cover high power RF amplifiers as they surpass the kilowatt plateau. The May report will focus on new spectrum analyzers. In June the subject will be digital interfacing, as the need to communicate - with digital as well as analog instruments - continues to grow. If you or your company have any developments in these areas that would be of interest to the RF community, please let us know now so we can spread the word.

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rf publisher's note

The Curtain Goes Up: RF TECHNOLOGY EXPO Takes a Bow



Keith Aldrich Publisher

On January 23 — three days after Super Bowl Sunday — an event will begin that is destined to eclipse the one in Stanford Stadium, as far as RF engineers are concerned. On that day, in the Disneyland Hotel in Anaheim, California, RF engineers from all over the country and around the world will congregate to market the opening of the first RF TECHNOLOGY EXPO... an annual event dedicated exclusively to the work of engineers working in the lower reaches of high frequency.

For three days (through noon of January 25), those engineers will be treated to technical papers and sessions delivered by more than sixty engineering leaders of the RF community ... and to exhibits of new RF products from more than sixty leading companies in the RF industry. Many of those companies are using the event to introduce new products, even new technologies, that could change the way you design RF equipment. One of the introductions is featured in this month's cover story: a new software package by EEsof, known as "Touchstone/RF." It will be demonstrated at EEsof's booth at EXPO. Another software program - by Compact Engineering, Inc. - will be demonstrated at its booth at EXPO.

But software is only one of the areas in which RF engineers will be able to compare new product offerings. Another is the hotly competitive field of frequency synthesized signal generators; most of the makers will be displaying their instruments at EXPO exhibits. Another is the field of circuit modules, and supercomponents. Makers of low-level signal amplifiers, high power RF amplifiers, and other components, have all begun to offer more and more of the ultimate circuit function in their devices, and introductions of this sort will positively abound at EXPO - not only in exhibits, but in some technical sessions as well.

The technical program, as it nears completion (see news stories beginning on page 13), bears the stamp of its organizer, Andrzej "Andy" Przedpelski, VP of Development at ARF Products, Inc. When he undertook the chore he stoutly declared his intention to steer clear of esoteric papers on subjects which could not possibly affect the work on the boards of today's RF engineers. As a result, attendees can expect to go away from EX-PO much the wiser in such practical aspects of their work as packaging (e.g., the effect on RF work of using surface mounted devices on the circuit board). As Andy says "there's something useful for everyone," whether the attendee is designing cordless telephones or landing systems.

It's only a few weeks away. if you haven't already registered to come, please do it immediately, so we can plan for you. I suggest you place a call right now to Convention Manager Kathy Kriner, Cardiff Publishing Company, (303) 694-1522.

A lot of people have gone to a lot of work to make RF TECHNOLOGY EXPO 85 the time of your professional life. Don't let them down. See you in Anaheim.

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Everything you've read about Touchstone^Mthe new standard of microwave computer-aided engineering-applies to Touchstone/RF, the version specially tailored for RF engineers. With four exceptions: Both programs also run on the Hewlett-Packard series 200, models 9816 and 9836. Touchstone/RF costs less than half of Touchstone's price.

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rf letters

With reference to the article "Antenna Impedance Matching Using A Sweep Generator" (Sept./Oct. 1984) by Riley H. Puckett.

I have been using a sweep generator for this purpose for years. I had almost forgotten that there is another way. There is a very useful and inexpensive (about \$200) device available for the purpose, however. Its called a reflection coefficient bridge. I don't know who else makes them, but the one I have is manufactured by Texscan (model RCB-3). For this purpose, they make life much simpler.

Actually, most modern RF laboratories probably don't have a network analyzer available. It's a pauper's business, despite this month's editorial. The problem with network analyzers, as well as similar instrumentation, is they require well trained, and therefore unavailable, technicians to operate them.

William E. Yohpe Florida Fox Sarasota, FL

I would like to take a few moments to let you know how much I use and enjoy your magazine. Every issue has at least one article that has direct application to something I'm working on.

Sincerely, Wesley Grenlund Weyerhaeuser Company Tacoma, WA

Our club comprises people interested in RF electronics and is active in providing free practical and theory training to young people in radio and electronics, with the hope that some will take up electronics as a career. It is both our hobby and our contribution to the electronics future.

We try to beg or scrounge whatever we can for demonstrations and for practical use in our projects, but here in Australia it is very difficult to obtain suitable state-of-the-art components, materials and literature (or even NOT-so state of the art parts). We just do not have the industry that could provide training materials.

Could we ask, through your magazine, whether companies that have components that may otherwise by obsolete or excess stock, or do not meet specification, would consider donating a few to our cause? Obviously we would like something that could be used (and the data to allow design) but even total rejects can be useful, as an alternative to pictures in a book.

As a guide to the type of components that would be particularly helpful, we encourage our classes to build equipment for transmission and reception on the amateur frequencies so that it can be put to practical use. These frequencies include 50, 144, 435, and 1300 MHz, and perhaps soon 10 GHz, with emphasis on modern techniques. (Articles from your magazine are most helpful for the theory side.) Consequently we try to use solid state low noise and power devices, mixers, etc. and would be very grateful for any components that could either be used at these frequencies or that illustrate the type of parts being used commercially.

Yours sincerely, Colin MacKinnon Secretary Castle Hills R.S.L. Amateur Radio Club 52 Mills Road Glenhaven 2154 Australia

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RW52501	TX52501	1.5W 2GHz GP 14	Common Emitter Isolated Stud	
RW52502	TX52502	3.0W 2GHz GP 14	Common Emitter, Isolated Stud	
RW52601	TX52601	1.5W 2GHz HLP 8	Common Emitter, Grounded Flange	
NVV52002	TX52602	3.0W 2GHz HLP 8	Common Emitter, Gounded Flange	
RW53601	TX53601	1.6W 3GHz HP-14	Common Emitter, Isolated Stud	
RW54501	TX54501	0.5W 4GHz GP-14	Common Emitter Isolated Stud	-
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RF TECH EXPO Program Nears Completion

Set to bow in Anaheim Jan. 23

With over 60 technical papers scheduled for presentation during the three-day event, Program Chairman Andrzej Przedpelski, VP of Development for ARF Products, is putting the finishing touches on the program for RF TECHNOLOGY EXPO 85, to be held Jan. 23-25, Disneyland Hotel, Anaheim, Calif.

How would he describe the program? He tends to speak of its "variety" and "practicality," characteristics he was aiming for in reviewing submissions. As for variety: "The papers range from fairly sophisticated circuit presentations to fairly fundamental concepts." To illustrate sophistication he points out "Phase Noise Measurements for Very Low Frequencies," by Dr. Fred Walls of the Bureau of Standards, a recent award winner for his work in hydrogen masers. To illustrate fundamental concepts, he points to "Use of Capacitors in RF Circuits," by Elliot Goldman of Illinois Capacitor.

Practical Papers

Although these two papers vary in sophistication, they also have something in common, says Przedpelski. They are both practical. "All the papers deal with concepts, techniques and devices which the RF engineer can apply right now." There has been a "lot of complaint" among engineers, he says, "over a recent trend in technical forums to dwell on developments which will not see practical application for years, if ever."

Some of the RF TECH EXPO papers "would never be taught in college," he says, but speak to universal concerns; for



Andrzej Przedpelski

example, "Mounting Considerations for RF Low Power Plastic Packages," by Harry Swanson, of Motorola Semiconductor. Another: "Surface Mounted Components," by Martin Barton, Rockwell International.

Modules, Techniques

New modular devices, which will be prominent in exhibitor booths (See "Exhibitors use RF TECH EXPO as Launching Pad"), will be the subject of a number of papers too. Norman Dye and Jim Oakland, Motorola Semiconductor, will present "The Hybrid Amplifier Module for Cellular Telephone Designs." Ron Patston, Avantek, will present "Hybrid Varactor-Tuned Oscillator Modules: Their Practical Application in RF Communications." A speaker from Acrian will also unveil a new modular device.

Design techniques will get an updating from Hewlett-Packard's Ken Voelker, speaking on "S-Parameters and Analyzers using Crystals and SAWs"...from James Eagleson of B&B Electronics speaking on "ACSB — an Overview of Amplitude Compandored Sideband Technology"...from William Schneider of Jet Propulsion Lab, with "Application of Coherent Digital Memories to Communications Jamming."

Hot Topics

Computer-Aided Design and EMC/EMI, both hot topics in RF technology, will get a number of papers each. A paper by Kenn Atkinson, of Don White Consultants, deals withn both topics: "Use of Personal Computers in Predicting and Control of EMI." Except for that paper, all sessions on EMC/EMI are scheduled for Friday morning, so as not to conflict with a regional IEEE Conference and Exhibition on Electromagnetic Compatibility at the L.A. Airport Hilton, Wednesday, Jan. 23. (See "EMC Conference to be Staged in L.A.")

For complete information about RF TECHNOLOGY EXPO 85, contact: Kathy Kriner, Convention Manager, Cardiff Publishing Co., 6530 S. Yosemite St., Englewood, CO 80111, (303) 694-1522.

Experts Teach "Fundamentals" at RF TECHNOLOGY EXPO 85

Five instructors, each a noted expert in the area he will teach, have been named for the day-long "Fundamentals of RF Design" course to be presented both Wednesday, Jan. 23, and Thursday, Jan. 24, at RF TECHNOLOGY EXPO 85, Disneyland Hotel, Anaheim, California.



Les Besser

Les Besser, President, Microwave Educational Programs, Los Altos, Calif., will take the first half of the day teaching a mini-course developed especially for the EXPO course: "Small-signal Amplifier Design: from Smith Charts to Computer using S-Parameters."

K.Č. Gupta, Professor, University of Colorado, Boulder, will teach on "Microstrip Lines Analysis and Design."

J.H. Johnson, President, Microwave Modules and Devices, Mountain View, Calif., will present a paper on "High Power RF Amplifier Design."

John Morton, Engineering Manager, Microsonics, Inc., Weymouth, Mass., will lecture on "Criteria for Oscillator Design."

Carl A. Erikson, Jr., Director of Processing Operations, Andersen Laboratories, Bloomfield, Conn., will conclude the day with "An Introduction to SAW Devices: Design, Fabrication, Testing, Uses, and Future Trends."

Instructors and subjects will be the same on both days that the course is offered. The course is open to all registered attendees at RF TECHNOLOGY EXPO 85, as one of many technical sessions being offered in the three-day event (see 'EXPO Technical Program near Completion''). One-day registrations are available, however (\$50, if bought in advance, as opposed to the full-term \$145), to encourage attendance by those interested mainly in the "Fundamentals" course. Group rates are also available, to encourage attendance by whole engineering teams.

The five instructors in the "Fundamentals of RF Design" course are "outstanding leaders in the subjects they will teach," according to Andrzej Przedpelski, Program Chairman for RF TECH-NOLOGY EXPO 85.



Les Besser was the founder of Compact Engineering, Inc., the author of COMPACT and SPEEDY software programs and over 50 technical papers and articles, and was a recipient of the IEEE MTT Microwave Applications Award in 1983. His courses on microwave circuit design are offered nationally throughout the year.

K.C. Gupta is one of the leading author-

ities in the area of research for transmission line analysis, and has published books on microwave integrated circuits, microstrip lines and slotlines, and computer-aided design of microwave circuits. He has been visiting professor at various universities in Canada, Denmark, the USA and Switzerland.

J.H. "Joe" Johnson, as VP of Engineering for Communications Transistor Corp.

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Carl Erikson, Jr.

(CTC), was responsible for many nowfamiliar innovations in RF transistors and headed teams which twice won the *Industrial Research* magazine award for one of the most important developments of the year. He has been awarded five patents and is the author of many technical publications, articles and seminars worldwide.

John Morton is one of the industry's leading developers of oscillator products. He has headed Microsonics' program in this area since 1979, and before that worked with Texas Instruments in Lubbock, Tex., and Motorola Component Products in Franklin, III. His articles have been published in several electronics magazines.

Carl A. Erickson, Jr., has been a leader in the field of SAW device development and processing — for five years at Andersen Labs and before that at Hazeltine. He is also experienced as a designer of microelectronic circuits in RF frequencies, and is the author of three or four lectures, articles and seminars each year.

For full information about RF TECH-NOLOGY EXPO 85 and how to attend it, contact: Kathy Kriner, Convention Manager, Cardiff Publishing Co., 6530 S. Yosemite St., Englewood, CO 80111, (303) 694-1522.

Exhibitors to Use RF TECH EXPO as Launching Pad

The earliest company to tip its hand is EEsof, with the cover story in this month's issue of *RF Design* ("Software Streamlines RF Engineering"). A new software package, for use specifically by RF engineers and called "Touchstone/ RF," is announced with this exclusive story — but the *real* introduction, with hands-on demonstrations to hundreds of prospective users, will come in a few weeks at EEsof's exhibit booth in RF TECHNOLOGY EXPO 85, Disneyland Hotel, Anaheim, Calif., Jan. 23-25. EEsof is only one of more than sixty

companies exhibiting at the show and only one of many whose staff has been working around the clock to ready product introductions at the world's first conference and exhibit held specifically for RF engineers. For instance Compact Software, another program firm, is making an introduction of its own. One of the hottest competitions is expected to be among makers of low-cost, frequency-synthesized signal generators (See November/ December, "Signal Generators get Smaller and Smarter"), as Marconi, Fluke, Texscan, Wavetek, Polarad, Racal-Dana and others vie for attention. But perhaps the most clear trend will be the introduction by component makers of more and more of the ultimate circuit, generally on hybrid products they are calling "modules." Exhibitors who could be introducing such products include Acrian, Avantek, Amperex, TRW, Motorola Semiconductor, Microwave Modules and Devices, Adams-Russell/Anzac, and Watkins-Johnson.

EMC/EMI exhibitors are plentiful, with EMC Technology, A.H. Systems, Holaday Industries, Keene RayProof and others taking booths. Other exhibitors not already mentioned include: American Technical Ceramics, Amplifier Research, Andersen Laboratories, Applied Engineering Products, Austron, Bird Electronic, Cirtech, Cohan-Epner, Communications Associates, Inc.

EMC Conference to be Staged in L.A.

On Wednesday, Jan. 23, the 1985 IEEE Regional Conference and Exhibition on Electromagnetic Compatibility will be held at the L.A. Airport Hilton from 10 AM to 9 PM.

Ms. Terry Cantine, Eaton Corp., is chairman of the event. Eleven speakers are scheduled for the technical programs, which begins at 1:00 PM. Among the papers are "EMP Protection for Small Communication Systems;" "EMI Measurement Techniques;" "Shielding;" and "Free Field Site Measurements."

Chairman Cantine is also chairman of the RF TECHNOLOGY EXPO session on EMC/EMI at the Disneyland Hotel, Anaheim, Friday Jan. 25. The two events have been coordinated to avoid conflict so that attendees at one can also attend the other. Registration fee for the IEEE Regicon is \$20 at the door. For more information contact: Ms. Terry Cantine, Eaton Corp., 5340 Alla Road, Los Angeles, CA 90066.

MMD Sees \$25 Billion Market For Systems Below 2 GHz

Just months after incorporation as a maker of RF power amplifiers and func-

tion modules, with emphasis on frequencies under 4 GHz, Microwave Modules and Devices (MMD)., Mountain View, Calif., is already eyeing expansion into another market: military and commercial communications systems under 2 GHz.

Worldwide, this market presently has sales of \$25 billion, according to Joe Johnson, MMD president, and is growing at a rate of 15% a year. "Systems below

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T NEWS Continued



2 GHz comprise 65% of the total systems market," says Johnson, "and provide the fastest-growing part of the market. New directions in miliatry communications, radar and EW are emphasizing these frequencies. There are also exciting opportunities in the industrial sector, such as cellular phones, medical electronics, and broadcast transmitters."

MMD has enjoyed a highly successful

rf calendar

January 23 1985 Regional Conference on Electromagnetic Compatibility

Airport Hilton Los Angeles, CA

Information: Fred Nichols, LectroMagnetics, Inc. 6056 W. Jefferson Blvd., Los Angeles, CA 90016; Tel: (213) 870-9383.

January 23-25 RF Technology Expo 85

Disneyland Hotel Anaheim, CA

Information: Kathy Kriner, *RF Design*, 6530 S. Yosemite St., Englewood, CO 80111; Tel: (303) 694-1522 Note: To avoid conflicts, sessions on EMC/EMI will not be held on January 23.

January 28-February 1 Modern Microwave Circuit Design: Linear Circuits A Five-day Short Course UCLA

Los Angeles, CA Information: Les Besser; Tel: (415) 960-0536.

startup after spinning off from CSF-

Thomson a few months ago, and will

close out its first year with almost a million

in sales, expected to reach \$25 million in

the fifth year. Its specialty so far has been

custom designs of hybrid modules to customer specifications, typically using BeO

substrates or chip carriers to achieve per-

formance not possible with discrete de-

signs (see illustration for sample wide-

February 11-15 HF Communication Technology: Advanced Techniques A Five-Day Short Course

San Diego, CA

Information: Ron Donais; Tel: (202) 676-8523 or toll-free (800) 424-9773.

February 26-28 Nepcon West 85

Convention Center and Marriott Hotel Anaheim, CA

Information: Show Manager, Nepcon West 85, 1350 E. Touhy Ave., Des Plaines, IL 60018; Tel: (312) 299-9311.

February 26-28 Automated Design and Engineering for Electronics band capabilities). A number of standard products are also being readied for marketing.

Johnson believes the company's success has been partially due to a slowness on the part of "competent competitors" to move into the market niche chosen by MMD. Reports of more new-company activity sifting through to *RF Design* indicate that this advantage will not long prevail. The phenomenon of MMD appears to be a harbinger of a specialized market boom.

Another Firm to Enter High Power RF Amplifier Market

American Microwave Technology, Fullerton, Calif., founded a year and a half ago to develop low-cost RF transistors for such applications as microwave ovens, has turned its attention to the growing market for RF power sources in communications and other industrial markets. The company has developed an OEM module which it is now marketing to test equipment and electronic production and medical equipment manufacturers, and is looking for an opportunity to develop custom devices to manufacturer specifications. The firm is headed by Michael Long, President, formerly with Power Hybrids. Director of Engineering is Roland Lee, who designed power amplifiers for Eaton Instrumentation. For more information contact: Lowell Beezley, Marketing Director (714) 680-4936.

Hilton Hotel Anaheim, CA

Information: Show Manager, Automated Design and Engineering for Electronics, 1350 E. Touhy Ave., Des Plaines, IL 60018: Tel: (312) 299-9311.

March 11-15

Electromagnetic Interference and Control

A Five-day Short Course

Washington, DC

Information: Shirley Forlenzo, George Washington University; Tel: (202) 676-8530 or toll-free (800) 424-9773.

March 18-20 Dielectric Resonators A Three-day Short Course

University of Mississippi, Oxford Campus Oxford, MS

Information: Dr. Darko Kajfez, Department of Electrical Engineering, University, MS 38677; Tel: (601) 232-7231.

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rf special report

Software Streamlines RF Engineering

Microcomputer-based CAD can help take the black magic out of the black art of RF.

By Kiyoshi Akima RF Design

ntil IBM legitimized the microcomputer with the introduction of the PC, computer-aided design (CAD) was almost exclusively the domain of mainframes and minicomputers. In order to use CAD programs like COMPACT or SPICE the engineer had to have access to a large computer, typically through a timesharing service. While engineers had desktop computers, they were used primarily as instrument controllers and data loggers, or for more mundane tasks such as wordprocessing and accounting. Predictably, the first design tools for microcomputers were for digital work - logic analyzers, in-circuit emulators, and the like. Only later came microcomputer programs for analog, and especially RF, engineering.

Circuit Analysis and Optimization

Analysis is the process of converting the circuit topology and component parameters to actual circuit performance. Most early analysis programs were two-port models. Elementary two-ports are used as the basic building blocks, and the overall circuit is itself a two-port. This approach led to significant limitations on the allowable topologies. The next generation offered nodal analysis, which could handle virtually unlimited circuit interconnections. This makes the circuits easier to describe, but increases the complexity and running time of the program.

Circuit analysis allowed the designer to predict the circuit performance without physically constructing the circuit. If the desired performance was not achieved, changes could be made to the circuit description and the analysis repeated.

Given the circuit topology, desired performance, and initial "guesses" for the element values, the components can be "fine-tuned" to produce the desired performance using an iterative process called optimization. Due to its iterative nature, optimization is usually a time-consuming process. The amount of time required, and even the probability of achieving a solution, is dependent on many factors including circuit complexity, the quality of the initial guesses, and the desired performance.

SIGNET from Martin & Mastropole (featured in our September/October 1983 issue) runs on the IBM PC and compatibles. Its designers have chosen analysis speed over circuit description flexibility by using a two-port cascaded approach. However, previously analyzed circuits can be used as elements in another circuit, further reducing analysis time and avoiding "reinventing the wheel." Measurements include S-parameters, stability factor, and gain. Features include semi-automatic design optimization, component value sensitivity analysis, and a library of active devices. Another feature is a "calculator" mode which allows calculations without exiting the program.

Touchstone from EEsof also runs on the IBM PC and compatibles. Frequency measurements may be swept, and up to 25 variables can be optimized simultaneously. All results can be displayed in tabular form, on a rectangular grid, or on a Smith chart. Circuits can be saved and used as "black boxes" in another circuit.

The growing popularity of the IBM PC led Compact Software to introduce a version of SUPER-COMPACT for the PC. SUPER-COMPACT PC uses the two-port model, but allows much flexibility in interconnecting the two-ports. Up to fifteen variables may be optimized simultaneously. One attractive feature is the easy interface to the mainframe versions of the program. The preliminary analysis can be performed on the PC, and then uploaded to a mainframe. Compact Software also has versions of the program for the Hewlett-Packard Series 200 desktop computers and the HP-41C handheld computer as well as versions running on larger computers.

SUGAR from Systems for Automatic Test is an interactive circuit design program for the HP Series 200 computers, including the 9816, 9826, and 9836. Like Touchstone, SUGAR is based on the nodal model. For optimization the designer can specify not only the weighting factors but also the error function exponent, giving more control over the optimization. An example of its "userconsiderate" design is the ability to enter element values without an exponent; 12 picofarads can be entered as "12p" instead of "12.E-12."

Also running on the HP Series 200 is CADEC (Computer-Aided Design of Electronic Circuits) from Communications Consulting Corp. CADEC is an interactive analysis and optimization program for high-frequency and microwave active and passive circuits. It is restricted to the linear frequency domain. The nodal circuit description is reduced internally to twoport Y matrix. CADEC includes a fast Fourier transformation of calculated frequency points to a large variety of userdefined waveforms. Also available from Communications Consulting are three Design Kits for PLL, RF, and Communications.

The large installed base of HP Series 200 computers led EEsof to develop Touchstone 200 for the HP 9816 and 9836. Enhancements include support for the unique features of the Series 200 such as high resolution graphics and the Vernier wheel.

Circuit Synthesis

Both analysis and optimization require that the designer know the circuit topology before designing the circuit. Without much experience or inspiration, this is rarely the case. Synthesis is the opposite of analysis. The designer provides the circuit specifications and the program generates the circuit topology and the component values.

Synthesis is a powerful and efficient design approach, but is not without its limitations. The current crop of "silicon compilers" require more computing power than can be provided by microcomputers. They are also better suited for digital integrated circuit design than for the "black art" of RF.

Statistical Analysis

Many engineers do not do any statistical or tolerance analysis after the completion of the design. Ideally, one would include the tolerance effects from the start and optimize the "toleranced" circuit. However, this greatly increases the computational requirements.

Monte Carlo yield prediction uses the computer to simulate a number of circuit samples, with the component values randomly selected within their tolerances. After predicting the yield, the designer

Exclusively RF

Esof has introduced a specially tailored version of Touchstone for engineers working below the microwave frequency ranges: Touchstone/ RF. Touchstone/RF retains all of the features of Touchstone needed for RF while eliminating the costly microwave models such as microstrips and waveguides. As a result, the cost is less than half that of Touchstone.

More than 160 measurements can be specified on any defined network. Up to nine measurements can be taken simultaneously. These measurements can be collected and displayed on rectangular grids or Smith charts (with radii of 0.33, 1.0, or 3.0) All measurements are available as magnitude and angle, real and imaginary, and magnitude in dB. Available measurements include S-parameters, group delay, differential phase shift, and voltage gain.

An important feature is the lab-like tuner. Press a key, and a light bar appears over the data values. Simply type in the new value to change one, and if a sweep is desired, press one more key. The new results are plotted over the old results so the effect can be clearly seen. If the screen gets too cluttered, a press of the sweep key redraws the plot eliminating the old traces. The flexible, interactive optimizer achieves a global minimum of the user-defined error function. For an amplifier, for example, gain could be required to lie *within* a range in-band and *below* certain goals out-of-band. Multiple measurements may be simultaneously optimized over different frequency bands. Variables for optimization can be defined by specifying a starting value only, or constrained by also specifying upper and lower bounds.

In addition, Touchstone/RF offers the following features:

 Non-50-ohm external terminations

Monte Carlo yield prediction

• Noise analysis and optimization (two-stage and feedback)

· Logarithmic frequency sweep

• HP 8510 Network Analyzer support (Touchstone can read and analyze S-parameters from the HP 8510)

 Lange coupler analysis and synthesis

Touchstone/RF runs on IBM PCs and compatibles. It can be used with the MiCAD program to prepare camera-ready artwork, drawings, and documentation associated with the circuit. Touchstone/RF 200 is available for the HP 9816, 9836, and 9836C. Please circle INFO/CARD #128. can make economical decisions, such as whether it is better to allow tuning of components or tightening some tolerances.

Beyond Design

The design process does not end when the desired performance has been achieved. Products often must meet FCC, VDE, MIL-STD-461 or other standards. A line of programs to determine radiated emission levels is available from Don White Consultants Inc. The programs can display the radiated emission levels alongside the selected specification to pinpoint problem areas. The designer can try various ideas — such as adding an external EMI filter or floating the circuit to the cabinet ground — to see their results. The DWCI programs are available for the IBM PC and compatibles.

After the circuit has been designed, it must be constructed. For printed circuits three weeks or more might be required between the completion of the circuit design and the creation of the masks. The process usually involves several people, thus increasing the chances of human error.

EEsof's MiCAD can automatically produce camera-ready artwork from the circuit descriptions generated by their Touchstone circuit design program. When changes are made in the Touchstone circuit file, the MiCAD graphics are automatically updated. The designer can "tune" an assembly drawing with MiCAD and then re-analyze or re-optimize using Touchstone. MiCAD is available for the IBM PC and compatibles.

Conclusion

When selecting a CAD system, whether on a mainframe, microcomputer-based, or a stand-alone workstation, the unique needs of analog engineering must be taken into consideration. An advanced digital integrated circuit may use thousands of gates and flip-flops that must be laid out and connected. The computer is used primarily to aid in creating a "roadmap" of the circuit and ensuring its integrity. An advanced analog circuit, on the other hand, may contain only a few dozen discrete elements, but each must be characterized thoroughly and accurately. A single transistor, for example, requires 42 parameters to be specified.

A digital design system typically simulates just one instrument — a logic analyzer. An analog design system needs to simulate a benchful of instruments — a signal generator, oscilloscope, spectrum analyzer, and more.

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Frequency spectrum of Andersen Model SO-314-600-V Oscillator over 0 to 1 GHz range. Fundamental frequency is 314 MHz. Second harmonic is – 65dBc, third harmonic is – 55dBc. Spurious responses are essentially nonexistent. also capable of functioning as VCO's. The output frequency can be modulated or locked to another reference for applications such as a PLL.

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

Theory of Operation of the DRO

By J.H. Walworth

This article begins with a brief historical discussion drawn primarily from a paper by Plourde¹. After a brief discussion of dielectric resonator (DR) coupling techniques, feedback oscillator application and theory is discussed. Finally, two appendices are included that examine DR coupling in more depth and transistor bias analysis.

In 1939, Richtmyer² showed that unmetallized dielectric objects can function as electrical resonators, which he called dielectric resonators. The first exploratory activities on dielectric resonators followed much later in the 1960s. Practical applications in microwave components were precluded in this decade primarily due to the lack of suitable materials. TiO₂ which had a Q of 10000 at 4 GHz unfortunately had a temperature coefficient of 400 ppm/°C which is two orders of magnitude too high for practical applications.

The advantages of DRs result from the combination of properties that they possess. They offer low-cost (under \$3 in 1000 quantities), high quality resonators which are small and which approximate lumped resonant elements for use in microwave circuits. They fill a gap between waveguide and microstrip technologies by providing Qs and temperature stabilities approaching those of Invar cavity resonators along with the integrability approaching that of stripline resonators. Figure 1 is a copy from page T-98 of the 1963 Microwave Engineer's Handbook and Buyer's Guide that has added to it a curve for the DR in the TEO1 mode. The figure is useful to compare Qs of the three types of microwave resonators represented. DRs can be purchased with TCs less than ± 1ppm, and at least one oscillator has been built with a TC ±0.1 ppm³.

Before understanding the operation of a dielectric resonator oscillator (DRO) a knowledge of the basic coupling mechanisms must be investigated. Figure 2 shows the magnetic field associated with the DR in a side view and the electric field in a top view. Microstrip coupling makes







use of the magnetic field to couple energy into an adjacent microstrip line excited by a 50 ohm source and terminated in 50 ohms. This circuit can be used to characterize the DR frequency and coupling characteristics. If a 50 ohm microstrip line is constructed in a box with connectors on each end the box will look like an absorption type wavemeter when the DR is coupled to the line.

Figure 3c shows the equivalent model of a DR coupled to microstrip. The transformer ratio $N=N_2/N_1$ is a function of the distance from the line (d) to the DR height (h) above the line. The spacer dielectric constant also has a slight effect but will not be taken into account in any analysis. Appendix 1 includes some elementary analysis and some empirical data concerned with coupling coefficient k=1/N.

The spacer material has two very critical characteristics: its loss tangent and its temperature coefficient (TC). The Q factor is approximately equal to the inverse of the loss tangent, $\tan\theta$. The overall Q of the resonator in its complete environment will be higher by using spacer material with low loss tangent. The ideal environment for the DR would be to suspend it in air. The simplest mounting technique is to cement the DR directly to the top side of the pc board spaced the proper distance from the coupled line. Unfortunately most pc board materials, bonded with resins, and spacer materials made of plastics or resins, do not offer a good combination of physical TC and dielectric constant TC that is required for overall frequency TC.

"Hard" materials can provide low loss and good TC characteristics. Judging from published specs on DROs using ceramic substrates, $A1_2O_3$ is a good choice of spacer. Glass or fused quartz is another good alternative. The type most analyzed and used by Murata is Fosterite (2Mg0 SiO₂.

Figure 4a is a representative of two microstrip lines at right angles coupled to a common DR. This configuration will be used to build an analysis of a feedback type oscillator by the addition of an active device. The first line is shown terminated on both ends by its characteristic impedance. The second line is terminated on one end by a load of Z_0 ohms and a generator of R_q source impedance.

In order to analyze the coupling effect the schematic representation is shown in Figure 4b. Figure 4c is the next logical progression demonstrating an amplifier, A1, inserted showing its output as the source and its input impedance as R1. Signal flow representation is shown in Figure 4d, where $\propto L\theta$ is the gain of the amplifier in a 50 ohm system and $\beta L\theta$ is the feedback through the DR and is:

$\beta = k_1 k_2 L 180^\circ$ at resonance

The 180° phase shift is due to the orientation of the transformers as can be seen in Figure 4c. Without R_L and R_1 , the condition for oscillation is $|\alpha|x|\beta|>1$ and $\theta+\Phi=n*360$, where n=0, 1, 2...

When R_L and R_1 are considered, the loop must have enough gain to overcome the losses in R_L and R_1 . The most stable condition to consider is a matched amplifier system with feedback. Figure 4d indicates power flow by certain arrows, i.e. P_L is the power delivered to the load.

Assuming a matched system it is easy to comprehend $P_R=P_A$, if R_{in} of A_1 is equal to R_1 . Note that \propto and β have units of voltage gain as does the S_{21} of a transistor. To obtain power gain we must use α^2 and β^2 .

Assume: $P_A = P_B(1)$ Then, $2P_A = \beta^2 P_1(2)$ and $P_A = \beta^2 P_1/2$ (3) Also: $P_1 + P_L = \alpha^2 P_A$ (4) Substituting (3) into (4) gives $P_1 + P_L = \alpha^2 \beta^2 P_1/2$ and rearranging, $\alpha^2 \beta^2 = 2(1 + P_L/P_1)$

The condition for oscillation is that

 $\propto^2 \beta^2 > 2(1 + P_L/P_1)$

Again applying the assumption that the system is matched,

PL=P1

and $\alpha^2\beta^2>4$

or ∝β>2

or in terms of dB:

∝β>6dB.

Of course, the above depends on the phase being correct.

The best way to adjust phase for n x 360 around the loop is to provide some additional phase shift in the transmission lines on the input and output of A₁. For example, assume one were using a transistor or amplifier that had an S₂₁ of 7.4 dB \perp ±13°at 3.5 GHz. Since the S₂₁ is greater than 6 dB we are assured under worst case conditions that we can obtain oscillation when the phase is correct. The total phase of \propto and β is ±13°±180°=193°. To arrive at a total phase shift of 0°, we should add -193° by transmission line delay.

If GT board material is used, $\epsilon r=2.54$. A 50 ohm line on .030 material is approximately .085 inch wide and has an effective dielectric constant of $\epsilon eff=2.14$. To determine the length needed for 193° of

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DR DR Zo Re Zo Re Re Re Re Re South A Resonator coupled to two lines

phase shift we must determine the length of a wavelength in a dielectric medium with an effective dielectric constant of 2.14.

 $\lambda_{o} = \frac{11.8 \text{ in/nS}}{3.5 \text{ GHz}}$ or 3.37 inches in air and

 λ_{GT} = 3.37/ $\sqrt{2.14}$ =2.305 inches in GT

and the required length total is:

(193°/360°) x 2.305 in = 1.24 in

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If the distance from the DR tangency points to the transistor are equal, the input requires .62 and the output requires .62 inches.

Keep in mind that there have been several assumptions made in the preceding analysis and example. Therefore, this design procedure is not exact and should be used only to put one in the "ballpark." One major reason it is not exact is that S_{21} of a transistor is a small signal parameter and certainly not usually the case with oscillators. It would of course be more accurate to measure S_{21} under the desired operating conditions and then apply the preceding design procedures.

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Not much attention has been given to the coupling parameters k_1 and k_2 . These parameters are highly dependent upon the physical media surrounding the DR. Usually one does not concern himself with the absolute value of k_1 or k_2 since the optimum placement of the DR (i.e. height of spacer and distance from line) is determined in the alignment of the oscillator. (Appendix 1 contains a procedure for determining k_1 and k_2 as well as some empirical data on a DR.)

Once the initial location is determined for the transistor, an oscillator is best tuned by initially placing the DR tangent to both input and output lines and adjusting the height of the spacer. As the data in Appendix 1 points out, the resonator achieves highest Q when the spacer is largest, however k_1 and k_2 are lower.



Hence the compromise is to adjust the spacer to obtain oscillations using the thickest spacer pracitcal. Unfortunately, temperature changes the parameters of the circuit, including the transistor S_{21} angle. Therefore, a spacer that gives good performance at room temperature may result in a power loss at high temperatures. The compromise here is to make the spacer thinner, sacrificing Q for the sake of power at the high temperature.

Theoretically, only a metal top cover and metal bottom cover are required for the DR. However, as discussed by Plourde and Ren, metal walls prevent radiation losses. Remember that losses of any kind result in higher phase noise in the overall oscillator.

Appendix 1 Empirical Determination of Coupling Coefficient

Figure 3c shows the equivalent lumped circuit of a DR coupled to microstrip. The coupling coefficient k will be evaluated.

Reference [4], equation (47) gives the coupling coefficient of a DR to microstrip. Note that k will be used instead of transformer turns ratio; k=1/N.

$$k^{2} = \frac{2Z_{0}}{Q'_{0}} \left(\begin{array}{c} 1 - |S_{21}| \\ |S_{21}| \end{array} \right)$$

Where: $Z_o =$ microstrip impedance $S_{21} =$ forward transmission coefficient

$$Q'_{o} = Q_{o}/(1 + \frac{k^{2}\eta\partial}{2n})$$

 Q_o and kn are fixed parameters of the DR ∂ , η and constant function of the mutual coupling per unit length of the microstrip. Since these are constants and difficult to compute, out empirical approach will lump them together as a constant, K, and:

$$Q'_{o} = KQ_{o}$$

Substituting 2) into and rearranging 1) yields:

$$K = \frac{2Z_{o}}{k^{2}Q_{o}} \begin{pmatrix} 1 \\ |S_{21}| \\ -1 \end{pmatrix}$$
(3)

K is determined by configuring an absorption test fixture as described in Figure 3b and attempting to find the conditions for k=1. Consider Figure A1 a) and A1 b) to gain an understanding of unity coupling where k=1. Figure A1 a) is Figure 3a redrawn to show the transformer removed, since k=1.

A1 b) is the equivalent at exact resonance. Under ideal conditions with a very high Q DR, R_m would be very large compared to R_1 and no energy would be delivered to R_1 .

For practical applications the DR is positioned until the insertion loss is 20 dB at resonance. (If the test equipment will allow, a more accurate answer can be obtained by using an IL greater than 20 dB.)

If Figure a1 b) is analyzed for insertion loss (IL) to R1:



2)

$$IL = \frac{R_g + R_L}{R_g + R_L + R_m}$$

and

 $IL(dB)=20Log((R_a+R_l)/(R_a+R_L+R_m))$

Solving for
$$R_m$$
: (set $R_a + R_L = 100$)

R_=100(1011/20-1)

By varying the frequency of the signal source, the loaded Q can be determined from the 3 dB insertion loss frequencies:

$$Q_{L} = \frac{\sqrt{f_1 f_2}}{f_2 - f_1}$$

where f_1 =lower 3 dB point and f_2 =upper 3 dB point.

Reference (5) gives an equation to determine Q_o (unloaded Q) from Q_1 and R_m .

$$Q_0 = Q_1 (1 + 100/R_m)$$
 7)

Now equation 3 can be solved for K for the particular DR and microstrip line being tested. The DR is then placed different distances from and heights above the microstrip and k solved for and tabulated.

$$k^{2} = \frac{2Z_{o}}{KQ_{o}} \left(\frac{1 \cdot |S_{21}|}{|S_{21}|} \right)$$

In addition to k, L and C can be found for the DR.

$$L=\frac{R_m}{2\pi f_c Q_o k^2}$$

where
$$f_c = \sqrt{f_1 f_2}$$

$$C = \frac{1}{(2\pi f)^2 L}$$
10)

Example A1:

Assume a maximum insertion loss condition results in 20 dB insertion loss for a spacer thickness of .05". At this point k=1 and $|s_{21}|$ =.10.

from 5) $R_m = 100 (10^{20/20} - 1) = 900\Omega$

The measured -3 dB points are: $f_1=9.5247$ GHz $f_2=9.5533$ GHz

4)

5)

6)

8)

9)

Substitute K=2.46 into equation 8, then with different spacers (or distances to the line) measure the insertion loss. I.L., and the -3 dB frequencies. Use equations 5,

SPACER	IL	R _m	Q	К
.05"	20	900	366	2.46
.10"	11.5	276	1285	2.46
.15"	6.25	95	4817	2.46

6, 7, 8, 9, and 10 to complete the calculations of k, L, C for each position.

The following data was calculated from measurements on a Murata DRD055UCO24 resonator on a 50 ohm line in GT material. The spacer was placed on top of the substrate material.

K	k	L	С	fc(GHz)
2.46	1	41pH	6.8pF	9.359
2.46	.295	41pH	6.8pF	9.435
2.46	.094	41pH	6.8pF	9.386

Appendix 2 Bias Considerations

Most microwave transistors are designed for grounded emitter applications. Any resistance or reactance in the emitter path to ground acts like degenerative feedback decreasing the gain of the transistor.

Biasing with only a series base resistor is quite inadequate since the collector current will vary considerably with temperature. There is also the possibility of thermal runaway.

The most often used bias technique for grounded emitter microwave biasing is to use a current controlled current source driving the base of the microwave transistor. The bias transistor is a low cost pnp type such as a 2N2907 or equivalent.



Figure A2-1 is a schematic of the bias transistor, Q_1 , along with the microwave transistor, Q_2 .

$l_c = \beta_2 lb$ $l_s = (V_s - V_s)/B_s$	1)
$I_{e1} = (V_{cc} - V_b - V_{be})/R_e$	2) 2)
I _{e1} =I _c +I _b	3)

Solving 1) for I_b and substituting in 3),

$$I_{e1} = I_c + I_c / \beta$$

Substituting 4) into 2), yields

$$I_{c}+I_{c}\beta=(V_{cc}-V_{b}-V_{be})/R_{e}$$
 5)

solving for Ic:

$$l_c = (V_{cc} - V_b - V_{be})/R_e(1 + 1/\beta_2))$$
 6)

if $\beta_2 >> 10$, then $I_c = (V_{cc} - V_b - V_{be})/R_e$ 7)

Thus the equation for I_c has no temperature dependent terms other than

 V_{be} . V_{be} changes about -2.1 mV/deg-C which is only about 0.05%/deg-C when V_{cc} =10V. This amount of change is negligible compared to RF parameter changes verus temperature in Q_2 .

 R_3 is added for convenience of RF decoupling for Q_2 base. Since I_b will usually be less than 0.5 mA, R_3 can be in the 1K to 10K range and have no effect on the DC or RF performance.

To synthesize the bias design, choose a V_{ce2} such that the voltage drop across R_e is greater than 1 volt. Choose R_e from:

R_=VR_/I

where VR_e is the drop across R_e.

Calculate: $V_b = V_{cc} - VR_e - V_{be}$ Calculate: R_1 and R_2 to give V_b .

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Frequency, max	1000 MHz	1000 MHz	500 MHz(2)	1000 MHz	1000 MHz	1000 MHz	500 MHz	3000 MHz	400 MHz	400 MHz	400 MHz
Power Rating (CW) at 30 MHz	1000W	150W	45W	150W	150W	1000W	1000W	200W	3000W	3000W	3000W
Power Rating (CW) at max freq	350W	50W	20W	50W	50W	350W	450W	30W	850W	850W	850W
VSWR	1.3	1.2	1.3	1.3	1.3	1.3	1.2	1.4	1.1	1.1	1.1
Impedance (ohms)	50	50	75	50/75	50	50	50	50	50	50	50
Size (LxWxH, inches)(1)	3.0 x 1.16 x 1.9	1.6 x .64 x 1.67	3.0 x 1.1 x 1.35	1.88 x .75 x 1.63	1.55 x .63 x 1.2	3.0 x 2.03 x 1.75	3.0D x 1.0H	2.5 Sq x 1.4H	2.0 x 1.68 x 1.3	2.0 x 2.13 x 1.3	2.0 x 2.13 x 1.3
Approx Weight (oz)	10	4.5	10	3	3.5	12	10	12	8	12	12

⁽¹⁾Does not include connectors.
 ⁽²⁾Minimum -100 dB Isolation dc to 500 MHz.
 ⁽³⁾Special connectors producing -100 dB isolation available. Power rating is reduced to 20 CW.

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Isolation-dB, min at max freq	60	60	60	60
VSWR, max	1.5	1.5	1.5	1.5
Insertion Loss-dB, max	0.5	0.5	0.5	0.5
Size (inches)*	1.40H x 1.34L x.50W	2.2H x 2.64L x 1.09W	2.1L x 1.26 Sq	3.0L x 1.75 Sq
Approx Weight (oz)	1.5	9	6	16

*Excludes mounting bracket, terminals, and connectors.

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Feedback Amplifier Design Program

A previously published program is amplified to include feedback effects.

By R.K. Feeney and D.R. Hertling Georgia Institute of Technology

Many RF amplifiers, particularly those operating over a large bandwidth, employ some type of feedback. The HP-41 program described in this article facilitates the inclusion of feedback effects in amplifier design. The software is constructed as an addition to a program previously described.^{1, 2}

Figure 1 shows an amplifier circuit that includes both voltageshunt and current-series feedback. The circuit of Fig. 1. is redrawn as an interconnection of two port networks in Fig 2. In the usual case, the two port networks have the simple configuration of a single impedance as shown in Fig. 1. For this situation, the network N1 has the y-matrix,

$$[Y_{N1}] = \begin{bmatrix} Y_F & -Y_F \\ & & \\ -Y_F & & Y_F \end{bmatrix}$$
(1)

No inverse matrix exists for $[Y_{N1}]$ and hence the network N1 cannot be described in terms of z-parameters. The current-series feedback network N2 is defined by the z-matrix,

$$[Z_{N2}] = \begin{bmatrix} Z_F & Z_F \\ \\ Z_F & Z_F \end{bmatrix}$$
(2)

Once again, no inverse matrix exists, so the y-paramter description of the network does not exist.

We can model the overall composite amplifier by the proper combination of these networks. If the device is described by the y-parameter matrix [Y], and the composite of the three networks by the symbol [Y'], the equation defining [Y'] is,

$$[Y'] = [[Y]^{-1} + [Z_{N2}]]^{-1} + [Y_{N1}]$$
(3)

The above equation together with the single element formulations of $[Y_{N1}]$ and $[Z_{N2}]$ are implemented in the HP-41 program described below.

Use of the Program

The software consists of a new subroutine FDBK that is added to the previously described program.^{1, 2} Also, the "menu" in the main program portion of the previously described routine must be modified to include the additional function. The new software occupies about 300 bytes. Consequently, it cannot be loaded into the calculator without first removing something else. One likely candidate for removal is the NOISE subroutine. If the user has an HP-41CX or the extended memory module, it is suggested that several subroutines be moved to the extended memory and copied into the active memory space as needed.

Example of the Program Use

Given a 2N5109 transistor operating at 200 MHz, the yparameters in mmho for the transistor are:

$$y_{ie} = 22 + j9$$
 $y_{re} = 0 - j2.2$
 $y_{fe} = 40 - j185$ $y_{oe} = 1 + j8$

The transistor is connected as shown in Fig. 1 with a shunt feedback element of 0.7 - j2.3 mmho and an emitter impedance of 5 + j20 ohms. We will determine the composite Y-parameters, check stability, and calculate the optimum terminations for the feeback amplifier.

Start the analysis by executing program AMP. The program displays the command table and requests a command numbers.

	ALC: MAN	
ENTR CMND		6-CHNG YPAR 7-K-STERN
B-GAINS		9-S/Y CONV
-CHNG YS/L		11-FDBK

VEO "AMO"

CMND?

January 1985

Since feedback is present, select funtion 11. The program prompts for the y-parameters.

	11.	RUN
ENTER Y-PARA	MS	
GI = ?	22-03	RUN
BI = ?	9-03	RUN
GR = ?	0	RUN
BR = ?	-2.2-03	RUN
GF = ?	40.02	DUN
BF = ?	40-03	RUN
GO = 2	-185-03	RUN
uo - i	8-03	RUN
	FB-CONFIG	

FR-	CONF	l
P =	1	
S =	2	
B =	3	

After these are entered, it is necessary to specify which feedback is present. The number 1 indicates voltage-shunt (basecollector), feedback, the number 2 indicates current-series (emitter) feedback while 3 specifies that both types are present. For this case we enter 3 followed by the value of the feedback elements.



Figure 1. Amplifier Using Feedback.

R = ?	3	RUN
X = 2	5	RUN
G = 2	20	RUN
B = 2	.7-03	RUN
D = !	-2.3-03	RUN

The calculator now contains (registers 02-09) the y-parameters of the composite network. Execute command No. 1 to evaluate the stability of the composite network. CMND?

1. RUN L.S.F. = 871.1E-3 We note that the composite transistor is inherently stable. Therefore, maximum gain values and optimum terminations exist. These can be obtained by executing command No. 2. CMND? RUN 2.

OPTIMUM VALUES L.S.F. = 871.1E-3 GS = 3.140E - 3BS = 4.311E - 3GL = 282.4E-6BL = -738.3E - 6GMAX = 22.71E0 dB



In a like fashion, other design information can be obtained.



Figure 2. Two-Port Network Representation of the Amplifier of Figure 1.

T T					
Feedback Sub	proutine				
01+LBL -FDBK-	23+LBL 01	45 RTN	67 FS2 89	89 670 88	111 001 97
82 -FB-CONFIG	• 24 •G=?•	46+LBL 05	68 CHS	98 XFD *7**	112 XED 89
83 AVIEN	25 PROMPT	47 2.009	69 ST+ IND 26	91 ST- 28	113 CHS
84 ADV	26 ADV	48 STO 26	78 ISG 26	92 X()Y	114 STO 87
85 · P=1-	27 STO 28	49 CF 89	71 GTO 64	93 SI- 27	115 X()Y
06 RVIEW	28 -B=?-	58+LBL 84	72 RTN	94 RCI 62	116 CHS
87 · S=2-	29 PROMPT	51 EC2 18	73+1 BL -CONV-	95 STO 29	117 STG 86
08 AVIEN	30 STO 27	52 GIO 86	74 2 995	96 801 83	110 PCI AS
09 · B=3·	31 SF 10	53 RCL 26	75 ST0 26	97 STO 81	119 PCL 69
19 PROMPT	32 XED 85	54 INT	7641 R! #7	90 01: 64	120 VED 00
11 ADV	TE PIN	55.6	77 PCL IND 26	90 RCL 04	121 CHC
12 X=82	34+1 BL 82	56 -	78 150 26	100 VEO 00	122 010 00
13 RTN	35 XF0 -CONV-	57 8/87	79 010 97	101 CTO 67	122 310 07
14 3	36 -P=2-	58 CTO 86	06 VED +7++	101 510 05	123 AV71
15 8(92	77 PDOMPT	50 GTU 00	00 AEY 2+	102 61/1	124 603
16 PTN	78 610 28	CAL DI GC	01 310 20	103 310 0Z	12J 510 68
17 X()Y	79	61 DCI 27	02 A\/I 07 CTO 27	104 KUL 27	120*LDL 07
18 CTO IND Y	AR PDONDT	61 KUL 21	03 310 21	105 KUL 01	127 KUL 27
190 RI 63	41 CTG 27	62 F3? 67	04 0.007 05 CTO 2/	100 ALW 07	128 KLL 28
20 YEO 00	42 CE 10		0J 51U 20	107 510 03	129 XEW -2/-
21 450 01	47 VEO 05	04 317 INU 20	80*L8L 88	168 X()1	130 END
22 PTN	AA VEG CONU.	0J 136 20	87 KUL INI 26	109 510 04	
EL MIN	TT ALE CONT	DO RUL ZO	05 106 20	110 KLL 05	
Main Program					
81+LBL -AMP-	22 AVIEN	43 FC? 03	64 ARCL 23	85 FC? 03	196+LBL 10
82 CF 84	23 -9-S/Y CONV-	44 XEQ -PARA-	65 AVIEN	86 XEQ "PARA"	187 EC2 83
03 CF 03	24 AVIEN	45 XEQ -OPT-	66 -BIN= -	87 FC? 84	188 XEQ -PARA-
84 ADV	25 -10-NOISE-	46 GTO 88	67 ARCL 22	88 XEQ -YS/L-	109 XEQ "NOISE"
05 "ENTR CHND"	26 AVIEN	47+LBL 83	68 AVIEN	89 XEQ -STN-	110 ADV
86 AVIEN	27 -11-FDBK-	48 FC? 83	69 ADV	90 ADV	111 XEQ "S/LPR"
07 -1-LSF-	28 AVIEW	49 XEQ "PARA"	78 "GOUT= "	91 *K-STERN= *	112 ANV
08 AVIEN	29+LBL 88	50 FC? 84	71 ARCL 25	92 ARCL 17	113 XER -YI/0-
09 *2-OPT TERM*	30 ADV	51 XEQ "YS/L"	72 AVIEN	93 RVIEN	114 XEQ -CP-
10 AVIEW	31 FIX 0	52 XEQ -YI/0-	73 *BOUT= *	94 GTO 88	115 XEQ -6Q-
11 -3-GAINS-	32 "CMND?"	53 XEQ -GP-	74 ARCL 24	95+1 Bi 88	116 XED -CT-
12 AVIEW	33 PROMPT	54 XEQ "GR"	75 AVIEN	96 EC2 83	117 ANV
13 *4-YIN/OUT*	34 ENG 3	55 XEQ .GT.	76 ADV	97 YEG -POPO-	118 CTO 89
14 AVIEW	35 GTO IND X	56 GTO 00	77 GTO 88	98 YEG -ITP-	11941 RI 11
15 "5-CHNG YS/L"	36+LBL 01	57+LBL 04	78+1 BL 85	99 DNV	120 502 97
16 RVIEN	37 FC? 03	58 FC? 03	79 XEQ -YS/1 -	188 XF0 - 5/1 DD-	121 XEQ -POPO-
17 -6-CHNG YPAR-	38 XEQ -PARA-	59 XEQ -PARA-	88 GTO RA	181 CTO 49	122 YEG -EDDV-
18 AVIEN	39 ADV	68 FC2 84	81+LBL 66	19241 RI 90	127 YEO -DOD1-
19 *7-K-STERN*	40 XEQ -LINY-	61 XER -YS/I -	82 XF0 -POPO-	193 YEQ -CDAD-	124 CTO 00
26 RVIEW	41 GTO 88	62 XFQ -Y1/0-	83 GTO 84	184 YEQ -DODI-	127 GIU 00
21 -8-YS/L FOR K-	42+LBL 82	63 "GIN= "	84+1 RI . 47	195 CTO 90	ILJ END
		WW WAT			

Conclusion

We have presented a program that accounts for the effects of feedback in amplifier design. The user is encouraged to experiment with the program by investigating the effect of feedback on amplifier stability. After making such an investigation, we concluded that most of our intuitive ideas (carried over from low frequency design) as to the effect of feedback on stability were usually incorrect. RF design demands a much more quantitative approach which should be facilitated by this program.

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Filter Response Program

A BASIC program calculates the response of Butterworth or Chebyshev filters.

By Richard Bain

E-SYSTEMS/ECI Division

esign and system engineers are many times called upon to specify the amount of selectivity required in receiver or transmitter circuits. Once the selectivity required has been determined, a filter that will provide this selectivity must be selected. At this point, the engineer will probably resort to sets of curves such as those found in the ITT handbook.1 This method works fairly well for Butterworth filters though the engineer must keep the calculator close at hand to convert to and from normalized bandwidth. If the attenuation at a large number of frequencies must be obtained, it can be rather slow and tedious work. Further, the accuracy of the results are limited by the resolution of frequency and attenuation possible on a graph. In the case of the Chebyshev filter, there is an additional problem of having curves for only a few different degrees of ripple; the designer may have to interpolate between curves thus further degrading the accuracy of results. When the designer desires to find the frequency at a particular attenuation for a bandpass filter given only center frequency and bandwidth, he must resort to the quadratic equation as well as tables to solve this problem.

It occurred to me that a computer or programmable calculator ought to be able to do these tasks with speed and accuracy thus enhancing the design engineer's efficiency.

Formulas are available from several

sources^{2 3 4} to calculate the response of Butterworth and Chebyshev filters. These formulas allow calculating the filter response without evaluating the polynomial response equations. The program listed at the end of this article was written using equations from the referenced sources.

The program has the following capabilities:

1. Analyzes both Butterworth and Chebyshev filters, the latter with any degree of ripple. There are no limitations on the number of poles that can be entered.

2. Calculates either attenuation versus frequency or frequency versus attenuation. Calculates both upper and lower frequencies for bandpass or bandreject filters.

3. Calculates responses of lowpass, highpass, bandpass and bandreject filters.

Butterworth Section

Lines 60 through 710 constitute the Butterworth section of the program. This section is subdivided into four program modules. The first two modules calculate attenuation at a given frequency. The normalized bandwidth is first calculated in line 170, then the attenuation is calculated in line 190 using equation 1 of Table I. If the calculation is for a highpass filter, the reciprocal of the normalized bandwidth is calculated in line 180. The attenuation is converted to dB in line 200, then the results are printed on the display. Line 250 allows the attenuation to be calculated at another frequency for the same filter. The bandpass/bandreject module of the Butterworth section uses the same equations as the lowpass module but first converts the bandpass information to the lowpass equivalent in lines 300 through 320. The frequency (f_x) at the same attenuation as that at the given frequency (on the other side of the passband) is calculated using equation 2 of Table I.

The third module of the Butterworth section, lines 450 through 550, calculates the frequency at which a given attenuation occurs for a lowpass or highpass filter. This module uses equation 3 of Table I to obtain the normalized frequency which is then converted to the actual frequency in line 500. The fourth module also finds the frequency for a given attenuation but for a bandpass or bandreject filter. This module occupies lines 560 through 710. The actual bandwidth is obtained as in the lowpass case, then equations 4 and 2 of Table I are used in lines 650 through 660 to obtain the two frequencies above and below the center frequency of the filter using the given information.

The Chebyshev section of the program consists of four modules with the same functions as the four modules in the Butterworth section. These modules use

```
10
      PRINT "
                    FILTER ATTENUATION /FREQUENCY PROGRAM"
20
      DIM Y$[1],A$[10],B$[6]
INPUT "NUMBER OF POLES",Np
30
       INPUT "BUTTERWORTH(1) OR CHEBYSHEV(2)", Num
40
50
       IF Num=2 THEN 720
      PRINT "
60
                         BUTTERWORTH FILTER ANALYSIS"
20
      PRINT "
                               *************
      INPUT "3DB BANDWIDTH IN MHZ IS", Bw3
80
90
       INPUT "ATTEN FOR GIVEN FREQ(1) OR FREQ FOR GIVEN ATTEN(2)", Aorf
100
      IF Aorf=2 THEN 410
      INPUT "LOWPASS(1), BANDPASS(2), HIGHPASS(3) OR BANDREJECT(4)", Typ
110
120
      IF Typ=2 THEN 270
130
      IF Typ=4 THEN 270
140
      CALL Header(Np, Bw3, Typ, Fc, R, Num, Bwr)
```

Table I Butterworth Equations	Table II Chebyshev Equations					
Butterworth Equations $A = \sqrt{1 + W^{2N}}$ $F_{H} = F_{C}^{2} / F_{L}$ $N = (A^{2} - 1)^{1/2N}$ $F_{L} = 1/2(-BW_{3} + \sqrt{BW_{3}^{2}} + 4F_{C}^{2})$ $A - \text{Amplitude of filter response}$ $N - \text{Normalized bandwidth of lowpass prototype filter}$ $F_{H} - \text{Unknown frequency on high side of bandpass}$ with attenuation as F_{H} $Center frequency of bandpass or bandreiget filter$	Eq. 1 Eq. 2 Eq. 3 Eq. 4	A = $\sqrt{1} + (10^{.1R} - 1)Cn^2$ Cn = 1/2(e ^{NK} + e ^{-NK}) K = In(W + $\sqrt{W^2} - 1$) W = 1/2(e ^{K/N} + e ^{-K/N}) K = In(Cn + $\sqrt{Cn^2} - 1$) Cn = $\sqrt{(A^2 - 1)}/(10^{.1R} - 1)$ W = cos(1/N Cos ⁻¹ Cn) A — Amplitude response of t Cn — Vlaue of the Chbyshev K — Cosh ⁻¹ of Cn or W	Eq. # 1 2 3 4 5 6 7 vhe filter polynomial	Program Line # 900, 1070 890, 1060 880, 1050 1230, 1390 1220, 1380 1210, 1370 N/A		
$_{\rm C}$ — Gener nequency of bandpass of bandreject filter 3W ₃ — 3 dB bandwidth of bandpass or bandreject filter N — Number of poles		 W — Normalized bandwidth of lowpass prototype filter N — Number of poles R — Bandpass peak to peak ripple 				

some of the equations in Table I as well as those in Table II. The Chebyshev section allows the user to enter either the 3 dB bandwidth or the equiripple bandwidth to calculate response. If the 3 dB bandwidth is entered, the program calls a subroutine in line 760 to convert the 3 dB bandwidth to the equiripple bandwidth. The equiripple bandwidth is then displayed in the header.

The program was written in BASIC for a HP9836 table top computer, but it could be easily modified to run on any computer with a BASIC language capability, even home computers such as Atari, Commodore or Radio Shack. Since the main use anticipated for the program is finding the response at a few points, no attempt was made to incorporate a plotting routine. This would not be difficult to add in the Butterworth section, but the Chebyshev section presents a problem. The formula used to calculate attenuation versus frequency cannot be used inside the equiripple bandwidth of a Chebyshev filter. Inside this bandwidth, Eq. 7 of Table Il must be used. It would also be relatively easy to store values in an array as they are calculated to provide a table on the display device.

Caveats

Error trapping was not employed in the program since an error would spoil only one or two pieces of data. Certain operations can result in an overflow or division by zero while using the program:

1. Asking for attenuation at a frequency within the ripple bandwidth of a Chebyshev filter.

2. Asking for attenuation at or near center frequency on a bandreject filter.

3. Asking for the attenuation at zero frequency for a highpass filter.

Though error trapping need not be used for the program in its present form, if the response were to be plotted or that data placed in a table, the trapping would be valuable to prevent the loss of a large amount of data.

The accuracy of the result obtained with this program is better than .2% for all cases tested.

The program asks for frequency and bandwidth in MHz, but GHz, KHz or Hz could be used, so long as both frequency and bandwidth are entered in the same units. The answer will then be in the units used for frequency and bandwidth.

Conclusion

The program presented gives the design engineer the ability to quickly check filter response for a Butterworth or Chebyshev filter with any number of poles. The BASIC program can be easily modified to permit use of the program on any other computer that uses BASIC. This program should prove a valuable addition to the designer's array of analytical tools.

References

"Reference Data for Radio Engineers," Fifth Ed., Howard W. Sams & Co. Inc., 1968. 2. Herman J. Blinchikoff & Anatol I. Zverev, Filtering in the

Time and Frequency Domains, John Wiley & Sons, New York, 1976

3. Phillip R. Geffe, "Designers' Guide to: Active bandpass Filling R. Gelfe, "Designers' Guide to: Active bandpass
 Phillip R. Gelfe, "Designers' Guide to: Active bandpass

filters (Part 2)," EDN, March, 1974.

150	!#####################################
160	INPUT "FREQ IN MHZ TO CALCULATE ATTENUATION",Fofa
170	W=Fofa/Bw3
180	IF Typ=3 THEN W=1/W
190	A=SQR(1+W†(2*Np))
200	Adb=20*LGT(A)
210	PRINT "THE ATTENUATION AT";Fofa;"MHZ IS ";Adb;"dB"
220	Y\$=""
230	INPUT "ANOTHER FREQUENCY (Y OR N)",Y\$
240	IF Y\$="Y" THEN 160
250	GOTO 30
260	!#####################################
270	INPUT "CENTER FREQUENCY IN MHZ IS",Fc
280	CALL Header(Np,Bw3,Typ,Fc,R,Num,Bwr)

```
290
      INPUT "FREQ IN MHZ TO CALCULATE ATTENUATION", Fofa
300
      Fx=Fc#Fc/Fofa
310
      Bwx=ABS(Fofa-Fx)
320
      W=Bwx/Bw3
330
      IF Typ=4 THEN W=Bw3/Bwx
340
      A=SQR(1+Wt(2*Np))
350
      Adb=20+LGT(A)
360
      PRINT "THE ATTENUATION AT "; Fofa; "MHZ IS "; Adb; "dB"
370
      Y$=""
380
      INPUT "CALCULATE ATTENUATION AT ANOTHER FREQ (Y OR N)", YS
390
      IF Y$="Y" THEN 290
400
      GOTO 30
410
      INPUT "LOWPASS(1), BANDPASS(2), HIGHPASS(3) OR BANDREJECT(4)", Typ
420
      IF Typ=2 THEN 570
430
      IF Typ=4 THEN 570
440
      CALL Header(Np, Bw3, Typ, Fc, R, Num, Bwr)
450
      INPUT "
460
               dB OF ATTENUATION" , Adb
470
      A=10+(Adb/20)
480
      W = (A + A - 1) + (1 / (2 + N_p))
490
      IF Typ=3 THEN W=1/W
500
      Fofa=Bw3*W
510
      PRINT "THE FREQUENCY AT "; Adb; " dB ATTENUATION IS "; Fofa; "MHZ"
520
      Y$= ""
      INPUT "FIND FREQ AT ANOTHER ATTENUATION (Y OR N)", Y$
530
540
      IF Y$="Y" THEN 460
550
      GOTO 30
560
      570
      INPUT "CENTER FREQUENCY IN MHZ IS ",Fc
580
      CALL Header (Np, 8w3, Typ, Fc, R, Num, Bwr)
590
      Y$=""
600
      INPUT "DB OF ATTENUATION TO CALCULATE FREQ", Adb
610
      A=10+(Adb/20)
620
      Wx=(A*A-1) t(1/(2*Np))
630
      Bwx=Bw3+Wx
      IF Typ=4 THEN Bwx=Bw3/Wx
640
650
     F1=.5*(-Bwx+SQR(Bwx*Bwx+4*Fc*Fc))
660
     Fh=Fc#Fc/F1
670
     PRINT "AT AN ATTENUATION OF "; Adb; "dB THE HIGH FREQ IS "; Fh; "MHZ"
680
     PRINT "AT AN ATTENUATION OF "; Adb; "db THE LOW FREQ IS "; F1; "MHZ"
      INPUT "FIND FREQ AT ANOTHER ATTENUATION (Y OR N)", YS
690
700
     IF Y$ = "Y" THEN 590
710
     GOTO 30
720
                      CHEBYSHEV FILTER ANALYSIS"
     PRINT "
730
     PRINT "
                         **********
740
      INPUT "RIPPLE IN DB IS",R
      INPUT "TYPE 1 TO INPUT 3dB BANDWIDTH, 2 TO INPUT EQUI-RIPPLE BW",Q
750
760
      IF G=1 THEN CALL Convert(R, Bwr, Np)
770
     IF Q=2 THEN INPUT "EQUIRIPPLE BANDWIDTH IN MHZ IS", Bwr
     INPUT "ATTEN FOR GIVEN FREQ(1) OR FREQ FOR GIVEN ATTEN(2)", Aorf
780
790
     IF Aorf=2 THEN 1140
800
      INPUT "LOWPASS(1), BANDPASS(2), HIGHPASS(3) OR BANDREJECT(4)", Typ
810
      IF Typ=2 THEN 980
820
      IF Typ=4 THEN 980
830
     CALL Header(Np, Bw3, Typ, Fc, R, Num, Bwr)
840
      850
     INPUT "FREQ IN MHZ TO CALCULATE ATTENUATION", Fofa
860
     W=Fofa/Bwr
870
     IF Typ=3 THEN W=1/W
880
     K=LOG(W+SQR(W+W-1))
890
     Cn=.5*(EXP(Np*K)+EXP(-Np*K))
900
     A=SQR(1+(10†(.1+R)-1)+Cn†2)
910
     Adb=20+LGT(A)
920
     PRINT "THE ATTENUATION AT"; Fofa; "MHZ IS "; Adb; "dB"
930
     Y$="""
940
     INPUT "ANOTHER FREQUENCY (Y OR N)", YS
950
     IF Y$="Y" THEN 850
960
     GOTO 30
970
     980
     INPUT "CENTER FREQUENCY IN MHZ = ",Fc
000
     CALL Header(Np, Bw3, Typ, Fc, R, Num, Bwr)
```

```
INPUT "FREQ IN MHZ TO CALCULATE ATTENUATION", Fofa
1000
1010
     Fx=Fc*Fc/Fofa
1020
     Bwx=ABS(Fofa-Fx)
1030
     W=Bwx/Bwr
     IF Typ=4 THEN W=Bwr/Bwx
1040
1050
     K=LOG(W+SQR(W*W-1))
     Cn=.5*(EXP(Np*K)+EXP(-Np*K))
1060
1070
     A=SQR(1+(10†(.1*R)-1)*Cn†2)
1080
     Adb=20#LGT(A)
1090
     PRINT "THE ATTENUATION AT ";Fofa;"MHZ IS ";Adb;"dB"
      Y$=""
1100
      INPUT "CALCULATE ATTENUATION AT ANOTHER FREQ (Y OR N)", YS
1110
      IF Y$="Y" THEN 1000
1120
1130 GOTO 30
     INPUT "LOWPASS(1), BANDPASS(2), HIGHPASS(3) OR BANDREJECT(4)", Typ
1140
1150
     IF Typ=2 THEN 1320
     IF Typ=4 THEN 1320
1160
1170
     CALL Header(Np, Bw3, Typ, Fc, R, Num, Bwr)
     1180
     INPUT "
              dB OF ATTENUATION TO CALCULATE FREQ", Adb
1190
1200
     A=101(Adb/20)
1210 Cn=SQR((A*A-1)/(10+(.1*R)-1))
1220
     K=LOG(Cn+SQR(Cn+Cn-1))
1230
     W=.5*(EXP(K/Np)+EXP(-K/Np))
1240
     IF Typ=3 THEN W=1/W
1250
     Fofa=Bwr*W
     PRINT "THE FREQUENCY AT "; Adb;" dB ATTENUATION IS "; Fofa; "MHZ"
1260
     Y$=""
1270
1280
     INPUT "FIND FREQ AT ANOTHER ATTENUATION (Y OR N)", Y$
1290
     IF Y$="Y" THEN 1190
1300
     GOTO 30
      1310
      INPUT "CENTER FREQUENCY IN MHZ IS ",Fc
1320
1330
     CALL Header(Np, Bw3, Typ, Fc, R, Num, Bwr)
     Y$=""
1340
     INPUT "DB OF ATTENUATION TO CALCULATE FREQ", Adb
1350
1360 A=10+(Adb/20)
     Cn=SQR((A*A-1)/(10+(.1*R)-1))
1370
1380
     K=LOG(Cn+SQR(Cn+Cn-1))
1390
     W=.5*(EXP(K/Np)+EXP(-K/Np))
1400
      Bwx=Bwr #W
     IF Typ=4 THEN Bix=Bwr/W
1410
1420 F1=.5*(-Bwx+SQR(Bwx*Bwx+4*Fc*Fc))
1430 Fh=Fc*Fc/Fl
     PRINT "AT AN ATTENUATION OF ": Adb: "dB THE HIGH FRED IS ": Fh: "MHZ"
1440
      PRINT "AT AN ATTENUATION OF "; Adb; "dB THE LOW FREQ IS "; F1; "MHZ"
1450
      INPUT "FIND FRED AT ANOTHER ATTENUATION (Y DR N)", YS
1460
      IF Y$="Y" THEN 1340
1470
     GOTO 30
1480
1490
     END
1500 SUB Header(Np, Bw3, Typ, Fc, R, Num, Bur)
1510
      A$="LOWPASS"
      B$="3 dB"
1520
     IF Typ=2 THEN A$="BANDPASS"
1530
      IF Typ=3 THEN AS="HIGHPASS"
1540
        Typ=4 THEN AS="BANDREJECT"
      IF
1550
1560
     IF Num=2 THEN B$="RIPPLE"
     IF Num=2 THEN BW3=BWr
1570
                                     ":8$:" BANDWIDTH = ":8w3:"MHZ"
      PRINT Np ;" POLE ";A$ ;" FILTER
1580
1590 IF Num=2 THEN PRINT "RIPPLE=":R;"dB
                                          .....
     IF Typ=2 OR Typ=4 THEN PRINT "CENTER FREQ=":Fo:"MHZ"
1600
                      ******
1610
      PRINT "
1620
      SUBEND
      SUB Convert (R, Bwr, Np)
1630
     INPUT "3dB BANDWIDTH IN MHZ=", Bw3
1640
1650
      A=10†(3/20)
     Cn=SQR((A*A-1)/(10t(.1*R)-1))
1660
      K=LOG(Cn+SQR(Cn+Cn-1))
1670
      W=.5*(EXP(K/Np)+EXP(-K/Np))
1680
1690
      Bwr=Bw3/W
1700
      SLIBEND
```

rf digital connection

Driving LED Displays

By John L. Schooley REMCON

Using Light Emitting Diodes (LED) for displays can be accomplished very easily. Getting the most out of the display requires following some basic rules. Many times a designer can also save on circuitry and reduce power consumption by giving a little additional thought to the method used to drive the display.

Since the brightness of LEDs is determined by the current through the LED, a constant source of drive current should be used to insure the brightness is consistent from one LED to the next. Voltage drops across LEDs may vary from 1.7 volts to 3.5 volts depending on the type of processing, the manufacturer and the current used to drive the device. If 15 VDC or more is available to drive the LED, a simple dropping resistor is adequate, however a large number of LEDs driven from a higher voltage will consume a significant amount of power. LEDs can be effectively driven from 5 VDC power if a constant current source is used to supply the drive current. When multiple LEDs are connected in series to save power, the variation in forward voltage will become greater and must be considered in the current source.

Using multiple colors of LEDs can be



very effective in a display. LEDs are available in green and yellow in addition to the more common red. Specifications list the intensity of the LEDs at a specific drive current, however, apparent brightness to a viewer can vary with different ambient lighting conditions. Also, extrapolating relative brightness at other drive currents may lead one astray when using LEDs of different colors. It is advisable to test the relative apparent brightness over the expected ambient light levels before finalizing a design.

How you drive a display will depend on the source of the signals to be displayed. A time multiplexed matrix can save considerable power and wiring if the system lends itself to this approach. LEDs are very fast compared to the response of the eye, allowing time multiplexing without detectable licker or loss in brightness. A large number of LEDs might be set up in a matrix with the rows and columns determined by counters or latches such that only one (1) LED is activated at a time. The rows may be latched for a ground return through a current regulator followed on the next timing cycle to supply voltage to the columns. This technique is particularily advantageous in sequential situations where only a few LEDs are used at one time





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rfi/emi corner

First There Was Magnetic Interference

By Lester Dant AD-Vance Magnetics, Inc.

n the beginning there was earth's field. The pervasive earth's magnetic field can be a detrimental factor in some experiments, research, testing and equipment operations.

Structural steels and an abundance of other man-made ferromagnetic objects contribute to undesirable environmental magnetic conditions.

Modern building construction, with its lower ceilings and increased number of reinforced steel beams, has created magnetic problems. The lower ceilings bring steel beams closer to sensitive equipment, thereby presenting magnetic fields that effect performance. Laboratory reseachers and production technicians frequently mull over the cause of interference, especially when they had no such problem with the same equipment or identical equipment at a previous location.

Then Came Electro-Magnetic Interference

Electro-magnetic interference can originate from various sources. These sources include components such as motors, transformers, solenoids, coils, electro magnets, high current cables, power generating equipment, and a variety of mobile or nearby radiating electronic and electrical gear.

A Need for Magnetic Shielding

Magnetic shielding is a properly selected metal alloy placed around or adjacent to a circuit component to suppress radiated magnetic fields interfering with other nearby components, or vice versa.

To assure optimum performance, stray magnetic fields must be directed around critical electronic components as a rock in a river diverts running water. This is accomplished by a magnetic shield of high permeability (indicative of the ability of a material to conduct magnetic flux) which provides a low reluctance path guiding the magnetic flux around the critical area.

More and more, engineers are learning the necessity of using magnetic shielding to achieve the performance desired from components and systems. Denser packaging has incited much of the recent interest in magnetic shields. With components positioned ever closer together, and radiating components affecting adjacent components, increased electromagnetic interference frequently occurs.

To shield out a magnetic field, its source or sources must first be determined. Usually, this is not difficult, but sometimes the source seems to elude discovery. For example, interfering magnetic fields are several times greater in modern, low ceilinged concrete structures than in older, higher ceilinged buildings of different construction. This can be immensely perplexing until the realization dawns that numerous reinforcing steel beams are incorporated into concrete construction and that low ceilings bring the resulting steel beams' extraneous magnetic interference much closer to sensitive equipment than in higher ceilinged rooms of different construction.

Electro-magnetic components within the same housing must be investigated as a prime source of interference. Also, other equipment in close proximity must be considered as a possible source.

Multiple Sources of interference are often present and must be evaluated.

Once the unwelcome field's source is discovered, consideration is given whether to shield the source or the affected components. When it is practical to do so, it is preferable to shield the affected component or components, rather than the offending source.

Other factors to consider in specifying the optimum shield are the strength of the field, the number of shielding layers required, whether to use high or low permeability alloy or a combination thereof, the shape of the shield and the accessibility of the component to be shielded. It is vital that the shielding alloys selected do not saturate when properly used, do not suffer excessive permeability loss from shock, display minimum retentivity, and exhibit relatively stable permeability characteristics after final anneal, avoiding the expense and inconvenience of regularly repeated annealings.

For lighter fields, a single layer shield can suffice. Two or more layers must be used for stronger fields. The shielding material which best matches a particular application should be chosen after analyzing the field. Among the major factors considered are permeability, saturation, shock sensitivity, and proper annealing after fabrication.

After the magnetic requirements have

been established there remains the annealing, the mechanicals and the aesthetics.

Shield shapes may range from simple to quite complex. In complex applications, shields are tailored to fit exactly and can consist of many unusual configurations.

Cylindrical, conical, and box shaped configurations constitute the most common shielding enclosures. The cylindrical design is best for scan converter and photomultiplier tubes, de-gaussed rock transports, isolation chamber, storage tubes, motors, meters, and tiny vacuum tubes. Cathode ray tube shields usually are conical. The box shaped shields are suited for video recorder head assemblies, magnetic tape containers, transformers, aircraft weather radar, power supplies and reactors.

The most effective magnetic shielding enclosures are designed and fabricated to meet specific requirements.

Magnetic field interference ususally is discovered when the completed assembly is tested. Shielding becomes imperative but not enough space has been allowed by the designer. Jamming some shielding into the inadequate area helps but doesn't produce the full performance desired.

In accordance with the time tested "ounce of prevention," the shield should be incorporated at the equipment manufacturing stage whenever possible. CRTs are a good example. Retrofitting the optimum shield is often expensive and sometimes impossible if the designer hasn't allowed sufficient space. If the shield is designed into the assembly at the very beginning, optimum shielding is attained easily.

AN OUNCE OF DESIGN IS WORTH A POUND OF RETRO-FIT.

Magnetic shielding techniques are most valuable and more economical in the design and prototype stages.

Without magnetic shielding much of today's sophisticated electronic gear would be larger, less efficient and in some magnetic environments, impossible to function at all. As components are made more sensitive and packaging more dense, susceptibility to electromagnetic interaction increases dramatically even in the best engineered layouts.

Engineering assistance with your problems is available at an experienced, reputable manufacturer of magnetic shielding.

One Antenna Kit with everything, to go please.

A complete line of kits with upper limits to 18GHz that satisfy FCC, VDE, and MIL-STD 461 specifications, and more.

Antenna kits that meet your specifications of high quality and frequency response, and that are also responsive to your demands of portability and easy use. A.H. Systems offers nine different kits that fill the bill. Each comes in a single, lightweight case. Just one kit can contain all the antennas, probes and cables to perform E-Field 1KHz-18GHz, H-Field 20 Hz-50KHz and conducted 20Hz-100MHz testing. Antenna factor calibrations are provided with each antenna.

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MODEL #	FREQ. RESP.	DESCRIPTION	MODEL #	FREQ. RESP.	DESCRIPTION
SAS 200 510	300 - 1800 MHz	Log Perindic	SAS-200 511	20 300 MH	Bicolucal Folding
SAS 200 511	1000 - 12000 MHz	Log Periodic	SAS-200 550	001 - 60 MH	Active Monopole
SAS-200-512	200 - 1800 Mise	Log Periodic	SAS-200 560	per MIL-STD-461	Loop - Emission
SAS-200-518	1000 - 18000 Mite	Log Periodic	SAS-200 561	per MIL-STD 461	Loop - Radiating
SA5 700 540 SA5 700 541	20 300 MHz 20 300 MHz	Biconical Biconical Biconi Collapsible	BCP-200 510 BCP-200 511	20 Hz 1 MHz 100 KHz 100 NHz	LF Current Probe HF VHF Crist. Probe

INFO/CARD 24

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Varian EIMAC has complete cavity design and production capability. We make sure that tube and cavity are compatible. If it isn't an off-the-shelf-item, we have the designers and engineers for any specific job.

EIMAC has expertise in all disciplines including pulse, CW, FM, and TV. We match tube, power, bandwidth and operating mode to achieve optimum performance.

More information on EIMAC cavities and tubes is available in our Cavity Capability brochure from Varian EIMAC. Or for prompt consideration of your special design requirements, contact Product Manager, Var-

EIMAC Cavity	Matching EIMAC Tube	Tuning Range (MHz)	Power Output
CV-2200	4CX20,000A	86-108	30 kW
CV-2220	3CX1500A7	86-108	1.5 kW
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

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rf product of the month

New Modular Spectrum Analyzer Family

The HP 70000 family of modularmeasurement-system components includes a mainframe enclosure, two display units and a number of modules that fit into the mainframe. The first modules offered allow manual and automatic spectrum analysis from 100 Hz to 325 GHz. The company plans to introduce modules in the future that will provide additional spectrum-analysis capabilities

Comprising a single spectrum-analyzer instrument, the new system includes a minimum set of three spectrum-analyzer modules, a display unit and a mainframe. A system containing more than one independent instrument (such as a programmable signal generator) also can be configured, with the advantage of centraloperator control and monitoring of all instruments from one display unit.

A major beneift of the new measurement system is the purchaser's ability to buy only those system components required for present measurement tasks. If greater capacity is needed later, components easily can be added to provide the additional capability.

A new high-speed digital-interface bus in the system provides rapid communications among the system components. HP 70000 systems can communicate with other instruments and controllers through the Hewlett-Packard IEEE-488 interface bus (HP-IB).

The new systems can output data directly to an HP-IB plotter or printer without the use of an external controller. It also is possible to record the CRT image directly on a VCR if a continuous record of a measurement is needed.

Rapid repair is made possible by onsite replacement of faulty modules. Service diagnostics help to locate malfunctioning modules quickly, and faulty components can be replaced at the site where the system is used. On-site service for the new system is offered, or the user can stock backup modules for repair services.

The resulting high "up time," along with the modular-measurement-system's centralized control of multiple-instrument systems and built-in software-development aids, make the HP 70000 system well suited for automatic test applications.

Upgrade Economically

The HP 70000 user can upgrade performance or add new measurement functions when needed simply by adding the required components to the system. This approach saves the cost of replacing instruments (or an entire non-modular system) to meet new measurement needs.

Simple to Operate

The HP 70000 systems are manually operated by a set of 14 softkeys on the display unit, located on either side of the CRT screen. In the spectrum-analyzer systems, the softkeys give the operator access to an extensive set of built-in measurement, signal-processing and trace-manipulation functions. These functions can simplify spectrum analysis and also reduce the time required for software development.

An example of the usefulness of these functions is the spectrum analyzer's ability to perform, internal real-time amplitude correction for swept millimeter measurements.

The user also can define a personal set of softkey functions by down-loading pro-



grams to the system from a computer.

A windowing function allows current data from multiple instruments to be shown simultaneously on a single display for easy monitoring of large systems.

Software development is aided by DE-BUG and PAUSE models that help locate problems in program code, and by a CATALOG function that lists all downloaded program functions and variables.

Performance Contributions to Spectrum Analysis

The modular spectrum-analyzer systems make several performance contributions:

 broad frequency coverage RF range: 100 Hz to 2.9 GHz. Microwave range: 50 kHz to 26.5 GHz.

Millimeter range: up to 325 GHz, with as many as four bands covered simultaneously by one analyzer.

- absolute amplitude accuracy ±2.3 dB at 2.5 GHz at any place on the display.
- IF resolution bandwidth
- adjustable in 10% increments.

• Excellent millimeter amplitude accuracy and sensitivity using HP 11970 series harmonic mixers:

- ±2.7 dB accuracy at 60 GHz.
- -124 dBm sensititivy at 60 GHz
- (10 Hz resolution bandwidth).

The initial offering of the HP 70000 family includes three standard, factoryconfigured HP 71000 spectrum-analyzer systems:

- HP 71100A (100 Hz to 2.9 GHz);
- HP 71200A (50 kHz to 22 GHz); and HP 71300A (coverage depends on external mixers used).

Each system is contained in one mainframe and has an HP 70205A graphicsdisplay module.

Optional modules extend microwave coverage to 26.5 GHz, provide wider IF bandwidths, and add the HP 70300A RF tracking generator. The optional HP 70206A system graphics display has a larger, 9-inch CRT screen and can sit on top of the HP 70001A mainframe or stand alone.

Individual modules, displays and mainframes may be ordered if the customer wishes to assemble a system. Customers also may order a custom system and have it assembled by the factory.



NTEL

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

AMPLIFIERS

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

CONTROL DEVICES

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

MIXERS

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

SUBSYSTEMS

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



PASSIVES

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

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

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FM/AM Signal Generator

The generator, model VP-8177P, provides CW, frequency or amplitude modulated signals ranging between 100 kHz to 110 MHz. The output level can be set from -20 dB to 99 dB in 1-dB steps. The signal generator also boasts a modulation distortion of 0.1% or lower at AM modulation and 0.05% or lower at FM modulation. The digital frequency lock ensures the frequency to be as stable as that of a crystal oscillator. Frequency drifts or errors which pose problems to communica-



tion type radio receivers are practically reduced to zero. The built-in memory backup battery protects the preset frequency, modulation functions and attenuator settings stored in the RAM, even when the power switch is off or power to the unit is lost. Panasonic Industrial Co., Secaucus, NJ 07094. INFO/CARD #164.

Leadless Zeners

The newly introduced leadless zeners include 49 devices comprising the MLL5221 to MLL5270 family of ½-watt devices covering a zener-voltage range from 2.4 V to 91 V, and the MLL4728 to MLL4764 family of 1-watt devices, 36 units covering the 3.3 V-100 V range. the ½-watt devices may be purchased in 20%, 10%



and 5% tolerances. Special zener voltages, tighter tolerances and matched sets can be purchased on special order. Motorola Semiconductor Products Inc., Phoenix, AZ 85036. INFO/CARD #163.

RF Switches Guaranteed to 1,000,000 Cycles

One million operating cycles without noticeable performance degradation are guaranteed for a new line of RF switches. The warranty means 1,000,000 operations per switch position with no intermittent contacts in the RF or indicator circuits, less than 0.1 dB increase in insertion loss, and less than 0.5 ohm increase in indicator circuit resistance.

Currently available switch models span from SPST to SP12T and 2P2T. Standard actuating modes offered are failsafe, latching, latching reset and normally open. Available options include internal 50-ohm termination of open or unused ports, isolated DC indicator circuitry, suppression diodes, self de-energizing circuits, TTL² logic circuits and manual override. Users can choose from all popular connector types, all common operating voltages and several mounting configurations. Wavecom Marketing, Northridge, CA 91324. INFO/CARD #162.

Three Channel Oscilloscopes

The SS-5706 30 MHz and SS-5705 40 MHz oscilloscopes both offer three-channel inputs for simultaneous display. Each channel is equipped with an independent position control to increase measurement range. The SS5705 also incorporates al-



ternate sweep, so that the enlarged waveform of a delayed sweep can be displayed simultaneously with the original waveform, up to a total of six traces. Other features include an internal video signal synchronization separator to allow stable triggering of the video signals and a unique jitterless circuit which provides for steady observation of high-frequency signals. Iwatsu Instruments, Carlstadt, NJ 07072. INFO/CARD #161.

Spread Spectrum Generator

This instrument provides pseudorandom sequences that are useful for developing and testing spread spectrum and conventional data communication systems. The desired linear recursive sequence (LRS) is selected by setting the feedback pattern and the initial contents of a 16-bit shift register. The length of the LRS sequence can be varied from 1 to 2¹⁶ -1 and the internal clock can be varied from 1 Hz to 20 MHz in steps of 1-2-5. Dif-

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

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INFO/CARD 29

RF Design

51

150 WATT ATTENUATOR

DC TO 8.0 GHz

Nominal Impedance: 50 ohms

Deviation (dB): (Dependent on value of attenuation) DC-4 GHz: ± 0.4 to ± 0.5 dB

> 4-8 GHz: ±.75 to ± 1.00 dB

Standard Nominal Values (dB): 3, 6, 10, 20, 30, 40

Maximum VSWR: At 4 GHz - 1.25 At 8 GHz - 1.35

Type N Connectors

Compact Size: 3 x 5 x 7 inches

Power: 150 watts average 5 KW peak

Temperature Range: -55°C to + 125°C



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INFO/CARD 30

rf products Continues



ferent modes of operation include BPSK, QPSK, GOLD/JPL, Staggered, and Burst. Burst mode is particularly useful for wideband radar applications. For spread spectrum applications, a second pseudorandom sequence is available for use as a data source. External inputs include clock, data, and start/stop. External outputs include clock, data, LRS strobe, direct sequence, and a parallel interface to drive a frequency hopper. New Wave Instruments, San Jose, CA 95111. Please circle INFO/CARD #159.

Arbitrary Generator

The Model 5910B is a microprocessorbased, programmable, Arbitrary Waveform Generator that features a frequency accuracy of 0.05% over the range of 100 mHz to 5 MHz. By means of its internal memory and a counter, the 5910B is frequency locked to limit drift to one part in 2000. A $4V_2$ digit display allows for 20,000 counts of resolution.

The 5910B allows the user to define a waveform by entering a series of voltage levels, up to 1024 points, with an amplitude resolution of 4000 points. Points may be entered manually or via IEEE-488 bus interface. Waveforms can be scaled from 0-30vp-p and output at rates of 200 nsec. to 10,000 seconds per point.



The 5910B also provides interpolation or digital ramping allowing the user to create straight line segments between points.

The 5910B is complimented by an Auto-Programmer and a fully equipped Function Generator which include sine, square, triangle, pulse, sawtooth, haversine, and havertriangle waveforms.

AMPLIFIERS, 5MHz-1GHz MIL-STD-883B Screening MIL-STD-883B Screening MIL-STD										
Series	Freq Typ.	Noise Figure	Power Output	VS	WR	In Po	put wer	Package		
	(MHz)	(dB)	(dBm)	(dBm)	In	Out	Out	Vdc	Ima	Style
GA Single- Stage	kHz-400	13	4.5-6.0	5-15	2.0	2.0	+15 typ.	17-70 (range)	TO-12	
MHT Single-or Multi-Stage	5-1000	14	2.5-7.0	-2 to +23	2.0	2.0	+15 typ.	10-105 (range)	TO-8	
GHT Single-or Multi-Stage	5-400	13	4.0-7.0	5-15	2.0	2.0	+15 typ.	17-70 (range)	TO-8	
MHD Multi-	1-500	21	2.5-6.5	5-20	1.6	1.6	+15	50-115	4-pin	

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Avdin XX Vector



Which Instrument Specialties contact strip will solve your connector grounding problem?



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

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

¹ "off the shelf" Grounding Strips are easily installed in most common connectors by means of the self-adhesive strip or the self-contained spring clip. This style contact provides consistent interconnection grounding in mated pairs, as a result of the superior spring characteristics of the Beryllium Copper material.

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



More complete descriptions of these strips and other shielding products can be found on pages 6 and 7 of our Guide to Interference Control. Write for your free copy. Address: Dept. RF-16.

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AUSTRON MODEL 2110 DISCIPLINED FREQUENCY STANDARD



THE FIRST MICROPROCESSOR CONTROLLED DISCIPLINED FREQUENCY STANDARD.

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

The Model 2110 automatically locks the frequency of its internal oscillator to an external reference that has superior long-term stability. Through the use of a third-order servo oscillator control technique, the instrument corrects the frequency offset and aging of the internal oscillator. Should the reference fail, the Austron 2110 can limit the frequency offset to parts in 10¹² for several days.

A SOLUTION FOR DEMANDING APPLICATIONS

- in communications systems where spectral purity and redundancy are of paramount importance
- in metrology where stable frequencies to parts in 10¹² accuracy are required
- in clock systems where a stable clock with accuracies to ± 100 ns is necessary

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

OFFERING STATE-OF-THE-ART FEATURES

- microprocessor controlled
- high-stability internal oscillator
- third-order servo oscillator control system
- frequency measurement to parts in 10⁻¹² with 100 sec averaging times
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- spectrally pure output signals
- optional IEEE-488 interface
- optional dual reference frequency input allowing a choice of external references

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

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Other features include non-volatile memory for the storage, retrieval and reprogramming of up to 89 arbitrary waveforms, auto-programming programs and operating parameters. Krohn-Hite Corp., Avon, MA 02322. Please circle INFO/CARD #157.

Miniature Low Pass Filters

These units combine the latest in microcircuitry with high reliability to allow the customer the maximum filter response in the smallest size. Units are available with pins, tabs and SMA female



connectors for the widest applications. The units can be fabricated in 2-10 sections with cutoff frequencies of 10 MHz to 18 GHz. Low VSWR and insertion loss are inherent in the design. RLC Electronics, Inc., Mount Kisco, NY 10549. Please circle INFO/CARD #160.

Optical Waveguide

Superguide 1000, a large core fiber waveguide which transmits a megawatt of power through the fiber in the pulse mode, can be used as a cost-saving re-



placement for bundles in applications where sharp bend-radius is not required. It achieves very high power laser transmissions. Fiberguide Industries, Stirling, NJ 07890. INFO/CARD #158.

All-Metal Fiber Optic Connectors

These hi-performance FO connectors are zinc die-cast (thus offering greater corrosion resistance compared to other allmetal types) and are available in either Epoxy (CCAD Series) or Epoxyless (CCAD-NE Series) with typcial splice losses of less than .75 dB per connector end.

Each connector in the CCAD Series is comprised of a connector body, metal crimp sleeve, and heat shrink tubing; the



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And the amps themselves? Take the M1600 broadband power amplifier. Solid-state. Rugged. Versatile. The M1600 can be used in component testing or for broadband communciations, among many other applications. With a power output of 130W and a frequency range of 0.5-35 MHz, the M1600 has an unconditionally stable output that is fully protected, delivering the bandwidth required for the most demanding applications...Definitely, The Right Tool.

The IFI M1600 Broadband Power

Power Output: 130W minimum Frequency Range: 0.5–35 MHz Power Gain: 55 dB

Features:

Class A Operation Solid State 1 Milliwatt Input For Full Rated Output





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HYBRID SOURCES Crystal Oscillator/Multiplier 10 MHz to 6GHz Commercial or Military Quality Digital Temperature Comp Option

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5 or 10 MHz In/100 MHz Out 100 MHz In/1400 MHz Out Custom Multipliers

NAVSTAR GPS CLOCK

10.23 MHz In/ 1432.2 MHz Out

FM and PM MODULATORS

10 MHz to 6 GHz RF Output DC-6 MHz Baseband Input Digital Temperature Comp Option

NAVSTAR GPS ANTENNAS RCP Microstrip Patch Antennas Dual Patch Antenna for L1 & L2 Other Frequencies and Polarizations

GaAs FET LNA FOR NAVSTAR DOWNLINK Effective Noise Temperature

< 65°K PASSIVE DEVICES ON

DROP-IN SUBSTRATES Power Dividers, Mixers & Directional Couplers .5 to 12.4 GHz Connectorized Housings

Optional CUSTOM THICK FILM HYBRIDS Your Designs Hybridized



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INFO/CARD 35





OFTI CCAD-NE includes a connector body, crimp adapter, and heat shrink tubing and terminates very fast (less than 3 minutes!) via the crimping method to immobilize both cable and fiber. As a convenience to users, all connectors are shipped fully assembled for immediate installation. Both Series are Amphenol 905 intermateable. Optical Fiber Technologies, Inc., Nutting Lake, MA 01865--0148. INFO/CARD #156.

Function Generator

This function generator covers a wide 0.002 Hz to 2.1 MHz frequency span in seven overlapping ranges. Each multiplier setting gives a full 1000:1 frequency range, and frequency may be set with the calibrated dial, externally modulated, or swept over the three decades available per range. The Model 20 Function Generator operates directly from the line using an external transformer/battery charger, and will also operate from an external dc



or ac source. In addition, it can operate internally from NiCad batteries. Wavetek San Diego, San Diego, CA 92123. IN-FO/CARD #155.

Ultra Low Noise Crystal Oscillator

Comstron's 1014 Series Low Noise Crystal Oscillators exhibit state-of-the-art short term phase stability in the 100 MHz frequency range. The relatively high reference frequency coupled with ultra low phase noise and superior time and tem-

Number (2) Ohms (Power W) Range BNC TNC N SMA UHF PC Freed Alteroustort, I to 20 dB AT-51 50 (5W) DC-15GHz 14.00 15.00 16.00 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -	Model	Impedance	Frequency		UNIT PP	RICE (4) E	FFECTIVE	4-15-8	4
Fared Alternuationt, 1 to 20 dB AT-50(3) S0 (SW) DC 1 SGHz 14.00 20.00 16.00 - AT-51 S0 (SW) DC 1 SGHz 11.00 13.00 14.00 - 12.00 AT-51 S0 (SW) DC 1 SGHz 14.00 17.00 - 15.00 - - AT-52 S0 (TW) DC 3 GGHz 14.00 17.00 - 15.00 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - <th>Number (2)</th> <th>Ohms (Power W</th> <th>) Range</th> <th>BNC</th> <th>TNC</th> <th>N</th> <th>SMA</th> <th>UHF</th> <th>PC</th>	Number (2)	Ohms (Power W) Range	BNC	TNC	N	SMA	UHF	PC
AT-56(3) 50 (5W) OC-15GHz 14.00 20.00 18.00 - - AT-51 50 (5W) DC-15GHz 14.00 17.00 15.00 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - <	Fixed Altenual	ors. 1 to 20 dB					1000		10.50
AT-51 50 (5W) DC-15GHz 11.00 13.00 14.00 - 12.00 AT-52 50 (12%) DC-3GHz 14.30 20.50 19.50 - - 15.00 - - - 15.00 - - - 15.00 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -	AT-50(3)	50 (5W)	DC-1 5GHz	14 00	20 00	20.00	16.00		-
AT-52 50 (1W) DC 15GHr 14.30 20.50 19.50 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -	AT-51	50 (5W)	DC-1 5GHz	11.00	15.00	15 00	14.00	-	12.0
AT-53 50 (25W) DC-3.0GH+ 14.00 17.00 - 15.00 - - AT-754 50 (75W) DC-3.0GH+(75WH/174,00 70.00 20.00 18.00 - - AT-750 AT '80 75 or 93 (5W) DC-15GH+(75WH/174,00 70.00 - - 50.00 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - <t< td=""><td>AT-52</td><td>50 (1W)</td><td>DC 1 5GHz</td><td>14.50</td><td>20 50</td><td>20.50</td><td>19.50</td><td>-</td><td>-</td></t<>	AT-52	50 (1W)	DC 1 5GHz	14.50	20 50	20.50	19.50	-	-
AT-54 50 (125W) DC 4.3 GHz	AT-53	50 (25\W)	DC 30GHz	14.00	17 00	-	15.00	-	-
Al-Asi At-30 75 or 33 (5W) UC-15 GH2 (7590 H1/14 00 20 00 20.00 18.00	AT-54	50 (25W)	DC-4.2GHz	-	-	-	18.00	-	-
Detector, Zaro Bias Schottky: CD-91 50 01-4.2GHz 34.00 - - 54.00 - - Resistive (impedance Transformers, Minimum, Loss Paris) T1-50.75 50.10.75 DC-15GHz 10.50 19.50 19.50 17.50 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -	AT-75 pr AT-90	75 or 93 (.5W)	DC-1 5GHz(75)	MH2114 00	20 00	20.00	18.00	-	-
Chr 31 50 0.14.3GHz 34.00 - - 54.00 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -	Detector, Zero	Bias Schottky.							
Resultive (impedance Transformers Minimum Loss Paris) Resultive (impedance Transformers Minimum Loss Paris) RT-50/75 50 10 75 DC - 10 GHz 10.50 19.50 18.50 17.50 - TT-50/75 50 10 75 DC - 10 GHz 11.50 15.00 17.50 - - CT-50 (3) 50 (10 %) DC - 4 GHz 11.50 15.00 15.00 17.50 - - CT-51 50 (10 %) DC - 2 GHz 10.50 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00	CD-51	50	01-4 2GHz	54 00	-	-	54.00	-	-
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Terminations CT -50 (3) S0 (3W) DC -4 2GHz 11.50 15.00 17.50 - - CT -51 (3) S0 (3W) DC -4 2GHz 9.50 12.00 12.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.0	N1-20 83	50 to 93	DC-10GHz	13.00	19.50	19.50	17.50	-	-
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Bensitive Decoupler, series reserver. Bensitive Decoupler, series resider or Capacitive Coupler, series capacitor No or CC:000 (1000PF) DC:15GHz 12.00 18.00 17.00 - Abapterio DOCA:000 (1000PF) DC:15GHz 12.00 18.00 18.00 13.00 - - Abapterio DOCA:2GHz - - 13.00 13.00 - - Abapterio Doca:2GHz - - 13.00 18.00 18.00 17.00 - - Definition Decouplers, services inductor Doca:2GNHHz 12.00 18.00 18.00 17.00 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - <t< td=""><td>DC-500</td><td>50</td><td>250-500MHz</td><td>60.00</td><td></td><td>-</td><td>-</td><td>-</td><td>-</td></t<>	DC-500	50	250-500MHz	60.00		-	-	-	-
BD or CC 1000 10000 (1000PF) DC 1 SGHz 12.00 18.00 17.00 - - Adapter: Adapter: - - 13.00 13.00 - - Adapter: DC 4 2GHz - - 13.00 13.00 - - Adapter: DC 4 2GHz - - 13.00 13.00 - - Drattice Decouplers.series inducior DC 500MHz 12.00 18.00 17.00 - - Drattice Decouplers.series inducior DC 550Hz 12.00 18.00 18.00 17.00 - - Tired Attimulator Sets 3.61 Dd 20.08 inglastic case 80.00 84.00 94.00 76.00 - - Tist-SET (3) 50 DC 15GHz 46.00 - 67.00 47.00 - - Resitive Multicouplers 2 and 4 output ports - - 64.00 - - 64.00 - - - - - - - - - - - - - - - -	Resistive Decou		or Canachue Cou	nier sarins ca	nacitor				
Adapterin Definition	RD or CC-1000	1000 (1000PF)	DC-1 5GHz	12.00	18.00	18.00	17.00	-	-
Alson Mit to SMA) 50 DC 4.2GHz - - 13.00 13.00 - - Inductive Decouplers, series inducior DC 500MHz 12.00 18.00 18.00 17.00 - - ID-R15 0.17.0H DC 550MHz 12.00 18.00 18.00 17.00 - - ID-R48 6.60/H DC 550MHz 12.00 18.00 18.00 17.00 - - Itered Attempolator Sets 3.61 DAd 20.0B Inglishic Case 80.00 84.00 94.00 76.00 - - Tr3-15-EET (3) 50 DC 1.5GHz 46.00 - 67.00 67.00 - - Reactive Multicouplers 2 and 4 output pons TC - 15.125MHz 61.00 - - - - - - - - - - - - - - - - - - - - - - - - - - - -	Adapters								
An off find Sump bits Series inductor Dr Ris 0.170H DC-500Hr 12.00 18.00 17.00 - Dr Ris 0.170H DC-500Hr 12.00 18.00 17.00 - - Dr Ris 0.170H DC-500Hr 12.00 18.00 18.00 17.00 - - Dr Ris 0.170H DC-500Hr 12.00 18.00 18.00 17.00 - - Tred Attenuator Sets 3.6 10.0420 dB in plastic case - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - </td <td>CA.50 IN to SM</td> <td>1 60</td> <td>DC 4 20H+</td> <td>-</td> <td>-</td> <td>13.00</td> <td>13.00</td> <td></td> <td></td>	CA.50 IN to SM	1 60	DC 4 20H+	-	-	13.00	13.00		
nauctive Decouplers, series inductor 12.07415 0 (17.04 DC-500MHz 12.00 18.00 17.00 DC-878 6 6 40H DC-55MHz 12.00 18.00 17.00 17.00 5613 3 0 DC-15GHz 80.00 84.00 94.00 76.00 47.50-5ET (3) 50 DC-15GHz 48.00 94.00 64.00 60.00 Freative Multicouplers 2 and 4 output ports 1C-125-2 50 1.5-125MHz 64.00 - 67.00 67.00 Heastive Power Dividers 3 4 and 9 ports 4C-2-30 50 DC-20GHz 64.00 - 67.00 67.00 Heastive Fower Dividers 3 4 and 9 ports 4C-2-30 50 DC-20GHz 64.00 - 64.00 4C-8.30 50 DC-20GHz 64.00 4C-8.30 50 DC-15 GHz 12.00 18.00 - 17.00 4C-75 75 DC-15 GHz 12.00 18.00 - 17.00 4C-75 75 DC-15 GHz 12.00 18.00 - 17.00 4C-75 75 DC-15 GHz 12.00 18.00 - 17.00 4C-8.30 50 DC-15 GHz 12.00 18.00 - 17.00 4C-8.30 50 DC-15 GHz 12.00 18.00 - 17.00 4C-8.30 50 DC-15 GHz 12.00 18.00 - 17.00 4C-8.50 50 DC-15 GHz 12.00 18.00 - 17.00 4DE-4.50 50 DC-15 GHZ 12.00 18.00 - 10.00 4DE-4.50 50 DC-15 GHZ 12.00	Land Sto fre to Shin		oc + some					-	-
LD-rhis 0.17(rhi DC-500/kHz 12.00 18.00 17.00 - - First Altimulator Sels 16.10 and 20 dB in plastic case - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -	Inductive Deco	uplers series indu	clor	10.00			12 00		
Charles Deckson Deckson <t< td=""><td>LD ARA</td><td>6.8</td><td>DC-SUUMH2</td><td>12.00</td><td>18.00</td><td>18 00</td><td>17.00</td><td>-</td><td>-</td></t<>	LD ARA	6.8	DC-SUUMH2	12.00	18.00	18 00	17.00	-	-
First A lifenual or Sels 1, 6, 10, and 20 dB in plastic case		0 0014	DC-33minz	18.00	10.00	10.00	17.00		
N1-30-261 (3) 00 DC-15 GH2 60.00 64.00 64.00 76.00 - - Reactive Multicoupiers 2 and 4 output points 00 64.00 64.00 64.00 64.00 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -	Fired Attenuate	or Sels 3 6 10 ar	id 20 dB in plasti	c case					
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breakthrough in the under \$50 op amp market. Key specs that differentiate the CLC300 from other high-performance op amps include: DC-85 MHz –3dB Bandwidth; $3000V/\mu s$ Slew Rate; 4ns Rise and Fall Times; 100 milliamp Output Current.



The CLC300 is packaged in a 24-pin double wide DIP and operates over the full industrial –25 degree C to +85 degree C temperature range. One hundred piece price is \$39. Comlinear Corp., Loveland, CO 80537. INFO/CARD #153.

Four-Channel FFT Analyzer

Ideal for a variety of electronic, vibration, and acoustic signal processing applications, the 804A can be used for purposes such as servo analysis, AC impedance measurements, source triangulation, machinery diagnostics, 3-phase harmonic distortion measurements, and modal analysis. In addition, the analyzer is fully programmable for automatic operation, waveform math, calculation se-



quence, and signal synthesis. An unlimited number of test set-ups, macroprogram listings, test results and reports can be stored on disks, each of which has a capacity of up to 400 kBytes. IEEE-488 and RS232 interfaces are included for plotter control, signal triggering, tracking, and integral connection to controllers and other test equipment. Wavetek Scientific, Inc. Rockleigh, NJ 07647. Please circle INFO/CARD #152.

Single-Supply Operational Amplifiers

The MC34071 and MC34072 series of high speed, single supply operational amplifiers are single and dual versions of the MC34074 quad operational amplifier series which was introduced during the latter part of 1983. The complete family of single dual, and quad devices operate over a wide single supply voltage range of 3 volts to 44 volts (or dual supplies from ±1.5 V to ±22 V). They offer improved bandwidth, and slew rate performance an order of magnitude greater than previously available single supply amplifiers. Motorola Semiconductor Products Inc., Phoenix, AZ 85036. INFO/CARD #151.

Ceramic Capacitor Chip

This 1.0 microfarad S41 sized multilayer ceramic capacitor chip is said to have exceptional volumetric efficiency. Measuring 0.125 inches in length, 0.095 inches in width and 0.065 inches in thickness, the unit is smaller than many tantalum chip capacitors offering the same value of



capacitance. Utilizing a dielectric composition with Y5V characteristics, typical applications for the unit include use as bypass or decoupling elements in a variety of electronic circuits. With an operating voltage rating of twenty-five volts, the unit has been designated as part number 250S41Y105ZP4. Unit pricing at the 1,000 piece quantity level is \$0.224 each. Johanson Dielectrics, Inc., Burbank, CA 91505. INFO/CARD #150.

Wideband Spectrum Analyzer

Designated as the MS611A, the unit covers the audio through VH/UHF regions in a single band with a frequency range of 50 Hz to 2 GHz. An advanced synthesized local oscillator ensures stable measurement with a high resolution bandwidth ranging from 10 Hz to 3 MHz. The analyzer itself is designed with a dynamic range of 90 dB to minimize the



generation of spurious signals and provide high sensitivity, thus enabling the fast, accurate measurement of low distortion signals.

All functions are controlled by an internal microprocessor and all numerical values required in measurements are displayed on the CRT screen. The MS611A provides unique functions such as the AUTO TUNE, executable by means of a front-panel key, and the AUTO RANGE key, with access to the amplitude region that is "off the screen." Other features are the MARKET, and AUTO COUPLED functions that are provided to enhance the ease of operation. These, combined with the GP-IB function, enable simple external control of the spectrum analyzer. Anritsu America, Inc., Oakland, NJ 07436. INFO/CARD #149.



INFO/CARD 39

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Conductive Tape

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Coaxial Bias Tees

The Models 5550 and 5575 Coaxial Bias Tees are extremely broadband with -3 dB bandwidths of 100 kHz to 10 GHz and 10 kHz to 12 GHz respectively. They are used, for example, to insert DC into a coaxial circuit for powering active devices such as transistors, laser diodes



or photodiodes. Their pulse transient responses are very clean with transition durations (risetimes) of 20 ps and 28 ps. Although they were originally designed for pulse applications, they can also be used for RF and microwave applications. The prices are \$210 and \$225. They are available from stock. **Picosecond Pulse Labs**, **Boulder, CO 80306. INFO/CARD #147.**

Low Distortion Audio Signal Generator

The LAG-126S offers 5 frequency ranges covering 5 Hz to 500 kHz with output voltage calibrated in dBm or dBv. The output attenuator range is -69.9 to +10 dB in 0.1 dB increments with fine adjust for precision control of level. A front panel onoff output voltage switch is convenient for making signal to noise measurements. For balanced and unbalanced outputs, the sine wave distortion is less than 0.005% through 20 kHz. Also, square wave outputs can be produced with a rise

Electronic Energy Conversion Sources & Systems



time of less than 200 ns making the LAG-126S a perfect low frequency laboratory signal generator. Leader Instruments Corp., Hauppauge, NY 11788. Please circle INFO/CARD #146.

Programmable Noise Generator

Designated the MX-5000 series, these instruments are the next generation to the PNG-5000 line. Choice of thirteen models covering 10 Hz-2000 MHz. Completely solid state microprocessor controlled



functions. High Crest Factor (peak to RMS ratio greater than 5) 0-99 dB attenuation in 1 dB steps. Micronetics, Inc., Norwood, NJ 07648. INFO/CARD #145.

Thick-Film Hybrid Cascadable Amplifiers

The amplifier design provides a maximum noise figure of 5.5 dB, frequency availability from 10 MHz to 1200 MHz, +13.5 dB minimum power output, and a maximum input/output VSWR of 2.1:1.



Distinctive features include high gain (+23.0 dB typical), high intercept points, and high-reliability. Alpha Industries, Microelectronics Division, Colmar, PA 18915. INFO/CARD #144.

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The new bypass switch, designated the model SW-T2X, permits the direct optical bypass of the nodes or faults in fiber optic links. A new feature of this unit is that it provides a "node self test" (or wrap) path in order to permit testing the node transmitter against its receiver while the switch is in the bypass mode. Another new feature is that artificial loss can be specified as an option in the "wrap" optical path while the switch is in the bypass mode. This prevents the node transmit-





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8761B Switch

ter from saturating the node receiver while at the same time offering minimum attenuation through the switch in the optical bypass path. Frequency Control Products, Inc., Woodside, NY 11377. Please circle INFO/CARD #143.

GPS Receiver

Called the Model 9390 Time and Frequency Monitor, the unit tracks and obtains time and frequency data from NAV-STAR Global Positioning System (GPS) satellites. The receiver can serve as a stand-alone instrument or as a reference source for existing facilities. Its primary application is the calibration of timing equipment and precision clocks using the time reference (accurate to better than 100 nanoseconds) on board a GPS satellite. This reference is traceable directly to USNO, NBS and all international time standards. The Model 9390 can employ a scheduled GPS satellite for time and frequency determination after accurate antenna position coordinates are entered by the operator, or after the unit automatically acquires and tracks four satellites. Time and frequency, position, satellite data and status, and tracking schedules are dis-



played on the front panel and made available for external monitoring via an RS232C I/O port. This port also accepts remote control inputs for all front panel control functions. Datum Inc., Timing Division, Anaheim, CA 92806. Please circle INFO/CARD #140.

Manual UHF Switch

The Model FS3290 is a manually operated three pole, two throw switch. One pole is specified from 225 to 400 MHz with limits of 1.3/1 maximum VSWR, 0.2 dB



maximum insertion loss, 40 dB minimum isolation, and 200 watts CW input power. The other two poles are rated at 1 amp and 150 volts. Sage Laboratories, Inc. Natick, MA 01760. INFO/CARD #142.



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fixed gain amplifier scaling from an input of 10 volts to the rated voltage. Digital input via the IEEE-488 bus is possible. Kepco, Inc., Flushing, NY 11352. Please circle INFO/CARD #137.

Broadband Triplexer

The Model TPF 143 triplexer is designed to operate from DC to 18.0 GHz and provides passband channel bandwidths of DC to 2 GHz, 2 to 8 GHz, and 8 to 18 GHz. The triplexer exhibits 1.0 dB maximum insertion loss (to within 5% of crossover), a crossover insertion loss of 4.5 dB maximum, a 2.01:1 maximum VSWR, and rejection of 55 dB to within 15% of crossover. The low profile triplexer is 3.7 x 2.0 x 0.5 inches and uses SMA female connectors. Time Microwave, Santa Clara, CA 95050. Please circle INFO/CARD #136.

Monolithic Chip Capacitor Sample Kits

Four new sample kits for Monolithic Chip Capacitors are now available. These kits, available with either palladium-silver termination Type GR42-6; (EIA 1206 size and Type GR40; EIA 0805 size) or nickel barrier temination (Type GRM-42-6 and GRM40), consist of approximately 6500 chip capacitors of 60 different values in COG, 7R, Z5U and Y5V material. These chip capacitors feature: miniature size, wide capacitance, TC and tolerance range; and industry standard sizes. Murata Erie North America, Inc., State College, PA 16801. INFO/CARD #135.



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Points: 2nd +55 dBm 3rd +35 dBm Connectors: SMA Size: 2" x 3" x 1" Part Number: 100C1562 OTHER CONFIGURATIONS AVAILABLE

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Telecommunications Data Book

This comprehensive reference guide provides the latest, complete technical data for the design engineer. It consists of seven detailed chapters which pull together Motorola's Semiconductor products dedicated to applications in telecommunications.

This first edition offers the latest information to aid in the application of Motorola Telecommunication devices and completion of systems using these devices. Extensive data sheets provide complete specifications for each device, covering information such as pin connections, block diagrams, testing and applications, and electrical characteristics. Application Notes and technical articles are also provided to further aid understanding of systems and devices.

This definitive manual contains dimensions for each device's available packages. Package availability is indicated on the front page of the individual data sheets. Quality and reliability aspects of the Semiconductor products supplied by Motorola, as well as a glossary of terms and abbreviations found in publicaitons pertaining to Motorola Telecommunications products are also included.

Pricing for the new Motorola Telecommunications Device Data Book is \$2.80 each in quantities of 1-9; \$2.40 each for 10-24; and \$2.15 each for 25 or more. Copies of this Data Book can be obtained by calling the nearest Motorola Sales Office, or by sending the appropriate payment to Motorola's Literature Distribution Center, Broadway Bldg. #1, 616 W. 24th St., Tempe, AZ 85282.



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Components Catalog

A new, 60-page catalog covers the company's full line of electronic hardware and interconnect devices, variable capacitors, miniature coaxial connectors, spacers and tube sockets. Each product listing in Components Catalog 103 provides the engineer with complete specifications and applicable electrical ratings, detailed dimensional drawings and application information. In addition, the catalog includes an alphabetical product index and a part number to page number cross-reference. E.F. Johnson Company Components Division, Waseca, MN 56093. Please circle INFO/CARD #119.

Fiber Optic Test Guide

A new applications-oriented publication that covers most testing problems for fiber optics is now available. Called the "Fiber Optic System Testing Guide," it was originally developed as a manual for field service technicians at a major computer company. The pocket-sized guide covers testing cables, transmitters, receivers and system data transmission. It also includes

rf literature Continued

hints on making tests, a dB/watts graph and dB/% transmission table. All the techniques recommended are field-proven and are similar to those tests proposed as industry standards. Fotec Inc., Boston, MA 02118. INFO/CARD #118.

Bipolar Analog IC Catalog

The catalog, printed in multiple colors, contains representative IC layouts, layouts and cross sections of various components on Solitron analog arrays as well as a description of semi-custom and custom products including:

- · 20V, 40V and 80V Standard Semi-Custom Analog ICs
- 20V, 40V and 80V Precision Semi-Custom Analog ICs (with laser trimmed thin film resistors)
- 20V, 40V and 80V Power Semi-Custom Analog ICs (with power transistors, up to 5A per transistor)
- 20V, 40V and 80V Custom Analog ICs

(in any bipolar technology; standard, precision or power) Solitron Devices, Inc., Riviera Beach FL 33404. Please circle INFO/CARD #113.

Coaxial K Connector Brochure

By using the family of connectors, launchers, and semirigid cable described in this 10-page illustrated brochure, engineers can now design in coax from DC to 46 GHz. The K Connector advantages of excellent performance, ease of assembly, reliable operation, complete testability, and SMA compatability at surprisingly low prices are discussed. Also mentioned, the WILTRON 5669 Automated Scalar Network Analyzer System which uses K Connector components to make accurate measurements from



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INFO/CARD 52



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



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PF829	406-512	16.5	4.5	+38
PF833	800-920	26.5	2.8	+34
PF845	800-915	18.0	2.0	+35

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

JANEL LABORATORIES

INFO/CARD 54

rf literature Continued

a single test port over the 10 MHz to 40 GHz range. WILTRON Co., Mountain View, CA 94042-7290. INFO/CARD #117.





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connectors meeting dimensional requirements of MIL-C 38999. Two series of loose-piece filters and high frequency printed circuit board filters are described. EMI gaskets, commoning strips, keying plugs and mounting accessories are included. AMP Inc., Harrisburg, PA 17105. INFO/CARD #114.

Oscilloscope Brochure

Illustrating the benefits of the various features and controls that are common on their scopes, this new brochure highlights the top of the line, the LBO-518. The two latest additions to the expanding line of oscilloscopes, the 100 MHz, 3-Channel Dual Time Base LBO-516, and the 50 MHz 2-Channel Dual Time Base LBO-525L are also featured. A special section of this new brochure highlights some of the important functions of the scopes such as alternate triggering, variable hold-off, and dual time base operation. Front panel call-outs, along with complete specifications, enable the oscilloscope user to easily identify his needs and make a proper buying decision. Leader Instruments Corp., Hauppauge, NY 11788. INFO/CARD #116.

Communications Antenna Catalog

Specifications are stated in both the English and metric systems for antennas ranging from backpack sized portable units to giant arrays requiring multiple acre installation for worldwide communications. Heavy-duty antenna rotators and rotator control are also shown. When applicable, the U.S. military nomenclature and national stock numbers are included. Most products in the catalog are available for Federal G.S.A. procurement. Hy-Gain, CIM Department, Lincoln, NE 68505. INFO/CARD #115.



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Introducing the surface acoustic wave (SAW) resonator. This fundamental-mode UHF resonator is manufactured with semiconductor processing techniques using quartz as a substrate. The high-Q resonance of the SAW resonator arises from phased reflections across the surface of the device — similar mathematically to the resonance of a laser. The quartz SAW resonator makes an excellent frequency control device for UHF oscillators from 300 to over 1000 MHz. SAW resonators are used in RF applications from precision instrumentation to high-volume consumer electronics.

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Fiber-Optic Communications Devices

This product brochure contains specifications, descriptions and applications with diagrams on fiber-optic coupler/monitors, 2-, 3-, and 4-wavelength division multiplexers/demultiplexers; directional directional couplers and splitters; optical swtiches; and other fiber-optic components. The full array of devices has been designed for installation and implementation in telecommunication, cable TV, computer, local area networks, military, biomedical and industrial process. Kaptron, Inc., Palo Alto, CA 94303. Please circle INFO/CARD #112.

Microwave Frequency Chart

A new microwave frequency chart showing microwave applications by frequency has been created. The colorful chart is intended to help anyone in the microwave industry to see at a glance the major commercial and military activities in the 1 to 44 GHZ frequency spectrum. It should be particularly valuable to design engineers, product planners, design team leaders and project/program managers who can benefit from knowing their frequency domain better.

This chart identifies the satellite communication up/down links for the commercial C- and Ku-bands, military C-band, DBS and MILSTAR. Also, frequency bands for common carrier microwave linkes, L- and S-band telemetry and electronic news gathering. Radar applications include radar altimeters, weather radars and general radar bands. The chart even identifies police radar and microwave oven frequencies. The chart also shows the letter designations for both the IEEE Std 521 radar bands and the military ECM bands. This will make band translations easier, such



Similar in appearance to the A62 RF Sweep Amplifier pictured, the A52U RF Sweep Amplifier has a frequency range of 1-900 MHz. Flatness is \pm .5 dB. Gain is 30 dB nominal. Input VSWR is 1.5:1 max with typical VSWR of 1.2:1. Available in 50 or 75 ohm impedance, the unit is an excellent general purpose lab amplifier amplifying signals for receivers, frequency counters, spectrum analyzers, oscilloscopes, markers and detectors. It is rugged enough for mobile applications. Line filtering and double shielding prevent ambient and power line interference.

Wide Band Engineering Co., Inc.

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as from the radar X-band to the ECM I/J band.

On the back of the chart are the microwave products from the company, including scalar network analyzers, peak power meters, signal and sweep generators, and direct synthesizers. Also, signal switching systems and RF/Microwave components such as mixers, attenuators, filters and detectors. Wavetek San Diego, San Diego, CA 92138. INFO/CARD #111.

GaAs FET Amplifier Catalog

Standard GaAs FET amplifiers from 2-18 GHz, with gains ranging from 7 to 50 dB, are featured in a new, six-page catalog. The proven GaAs FET line has state-of-the-art specs, including very low noise figures, wide dynamic ranges, ruggedized construction, and small, lightweight, hermetically sealed enclosures. Every unit listed in the catalog can be screened to MIL-STD-883. Systron Donner Microwave Div., Van Nuys, CA 91411. Please circle INFO/CARD #110.

Telecommunications Surge Testing

Bulletin 1000 and Application Note 103 describes equipment and methods for surge testing telecommunications equipment for the effects of induced lightning and switching transients.

This literature provides complete information on testing to various industrial, national and international telecommunications specifications. Additionally, the Application Note describes the required surge waveforms, energy requriements, coupling methods, and diagnostic measurement techniques for determining pass/fail criteria. KeyTek Instrument Corp., Burlington, MA 01803. INFO/CARD #109.

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