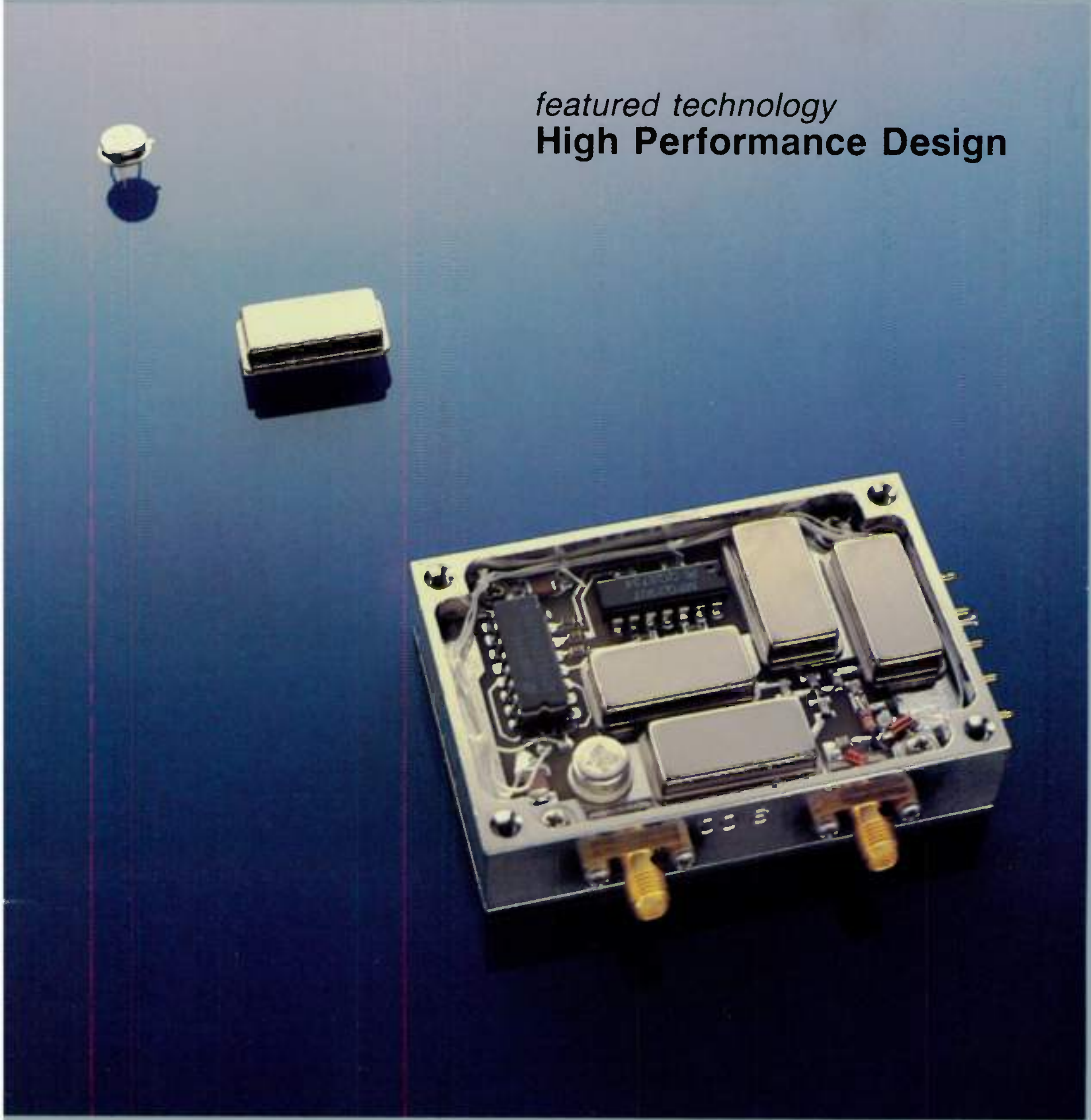
RF design

engineering principles and practices

November 1990



featured technology
High Performance Design

official show issue
RF Expo East

reader survey
Test Instruments

New from Narda

The SMART solution to radiation hazard.

SMARTS™ operates very much like a smoke alarm. Except it detects non-ionizing radiation. And it costs half as much as conventional monitoring equipment.

SMARTS installs in minutes on a ceiling or wall. Then stays on the job continuously to monitor potentially hazardous RF radiation from 0.5-18 GHz. An audible, visual and TTL alarm tells you immediately if ambient radiation exceeds the factory set threshold.

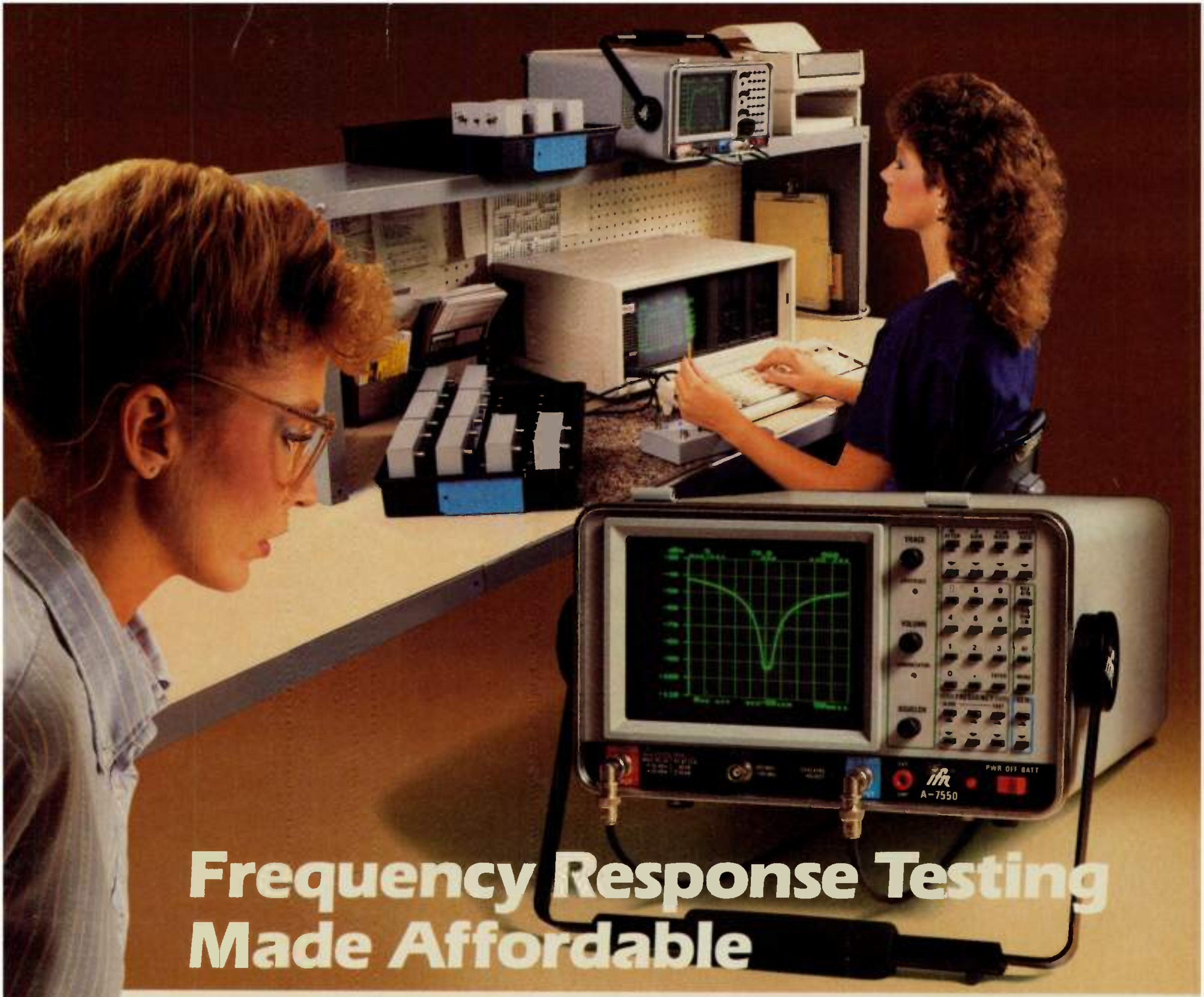
SMARTS gives you ideal protection for high power test stands, military communications shelters, satellite teleports and other situations where radiation leakage can be a problem.

SMARTS operates from a 9V lithium battery which lasts more than a year. There are no plug-ins. No adjustments. It comes already calibrated. And you can maintain calibration with a field-replaceable, pre-calibrated monitoring element.

For more information, call or write Loral Microwave-Narda, 435 Moreland Road, Hauppauge, NY 11788. Tel: (516) 231-1700. Fax: (516) 231-1711.

LORAL
Microwave-Narda

INFO/CARD 1



A-7550 Spectrum Analyzer with Built-in Tracking Generator

The IFR A-7550 Spectrum Analyzer with its optional built-in Tracking Generator may be all the test equipment you need to test the frequency response of any frequency selective device between 10 kHz and 1000 MHz. For higher frequency devices, the A-8000 Spectrum Analyzer with its optional built-in Tracking Generator can characterize frequency responses up to 2600 MHz.

With either analyzer you get a rugged, portable instrument that is equally at home in the field, on the manufacturing floor, or in the laboratory.

Other standard features of both the A-7550 and A-8000 include a synthesized RF system, +30 dBm to −120 dBm amplitude measurement range, 1 kHz per division frequency span, and 300 Hz resolution bandwidth. These features give the A-7550 and the A-8000 superior amplitude and frequency measurement capability previously unavailable on spectrum analyzers in this price range.

In addition to the Tracking Generator, other available options—such as an Internal Rechargeable Battery Pack, AM/FM/SSB Receiver, RS-232 or IEEE-488 Interfaces, and Quasi-Peak Detector—allow the A-7550 and A-8000 to be custom configured to solve many other RF testing needs.

For more information or a demonstration, contact your local IFR distributor or representative, or contact IFR directly at 316/522-4981.

INFO/CARD 2

IFR SYSTEMS, INC.

10200 West York Street / Wichita, Kansas 67215-8935 U.S.A.
Phone 316/522-4981 / TWX 910-741-6952 / FAX 316/524-2623

Our continued growth has created openings for Engineering Professionals. Please contact IFR for information.

Please see us at RF Expo East, Booth #421.

CRAFTED WITH PRIDE IN USA

WRH

DAICO 7-BIT ATTENUATORS

FOUR-OF-A-KIND

Part No.	DA0285	DA0295	DA0617	DA0375	Units
Frequency	30-500	30-500	45-250	45-75	MHz
LSB/Range	0.5/63.5	0.5/63.5	0.5/63.5	0.1/12.7	dB
Switching Speed	5	5	0.025	0.020	50% TTL to 90% RF μsec
Transition Time	3	3	0.007	0.005	10%/90% RF μsec
Control	CMOS	TTL	TTL	TTL	
DC Power	30	50	400	400	mA at +5VDC

DAICO 7-bit attenuators provide a full range of solutions to your RF needs. With 0.1 and 0.5dB LSB's and attenuation ranges up to 63.5dB in a 38-pin hermetically-sealed MIC: these packages are a perfect deal for your RF attenuator applications.

You can choose a lightning fast DA0617 or DA0375 with 25 nanosecond switching-speed, or a low current DA0285 or DA0295.

All Daico MIC attenuators are available with MIL Screening and in connectorized packages.

Call our Application Engineering Department for further information.

DAICO INDUSTRIES, INC.
2453 East Del Amo Boulevard
Compton, CA 90220
Telephone 213/631-1143
FAX 213/631-8078

©1988 Daico Industries, Inc. mp88477R

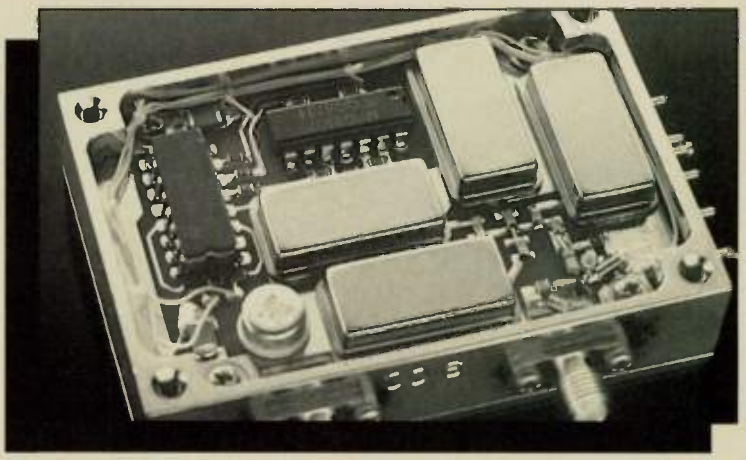
INFO/CARD 3

WRH

RF design

contents

November 1990



featured technology

emc corner

design awards

departments

Cover photo courtesy of RF Monolithics, Inc.

R.F. DESIGN (ISSN: 0163-321X USPS: 453-490) is published monthly plus one extra issue in September. November 1990. Vol. 13, No. 12. Copyright 1990 by Cardiff Publishing Company, a subsidiary of Argus Press Holdings, Inc., 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111 (303) 220-0600. Contents may not be reproduced in any form without written permission. Second-Class Postage paid at Englewood, CO and at additional mailing offices. Subscription office: 1 East First Street, Duluth, MN 55802. Domestic subscriptions are sent free to qualified individuals responsible for the design and development of communications equipment. Other subscriptions are: $36 per year in the United States; $45 per year in Canada and Mexico; $49 (surface mail) per year for foreign countries. Additional cost for first class mailing. Payment must be made in U.S. funds and accompany request. If available, single copies and back issues are $4.00 each (in the U.S.). This publication is available on microfilm/fiche from University Microfilms International, 300 Zeeb Road, Ann Arbor, MI 48106 USA (313) 761-4700.

SUBSCRIPTION INQUIRIES: (218) 723-9355.

POSTMASTER & SUBSCRIBERS: Please send address changes to R.F. Design, P.O. Box 6317, Duluth, MN 55806.

HIGH POWER COMBINER

FEATURES:

- LOW LOSS
- HIGH ISOLATION
- EXTERNAL TERMINATIONS

4 WAY COMBINER MODEL

D2650	54-88 MHz
D2685	88-108 MHz
D2655	174-216 MHz

TYPICAL SPECIFICATIONS

INS. LOSS	0.15db
ISOLATION	25db
VSWR	1.2:1
POWER	2Kw
Connectors	
input	N
output	1-5/8 EIA

WERLATONE has an extensive line of 2 and 4 way combiners covering the TV and FM bands

1965 - 1990
25 years in business

WERLATONE
decades ahead

WERLATONE, INC.
P.O. Box 47
Brewster, NY 10509
Tel: (914) 279-6187
FAX: (914) 279-7404

INFO/CARD 4

Trends in the Industry

Gary A. Breed
Editor

Every once in a while, I notice a change in the emphasis of RF engineers' work. The questions you ask, the products you want to know about, the articles submitted for publication, papers for the RF Expos, and our monthly surveys all tell me what you are working on. It is fascinating to watch the "hot topics" change as engineers make the effort to learn about new technology, develop it, then move on to the next challenge.

Here are some of the things that a significant number of RF engineers are currently working on. I'll be asking about these applications at RF Expo East, since many of the papers to be presented in Orlando cover these topics:

Part 15 Spread Spectrum. Recent rule changes setting the standards for spread spectrum consumer and commercial products have generated a lot of activity. Wireless computer peripherals and wireless data transmission for networking and remote input devices seem to be the leading applications. Audio and video consumer products are being actively pursued, as well.

Susceptibility Testing. While not far into the implementation stage, engineers are getting up to speed in this area. The primary motivation is Europe 1992 and the proposed immunity requirements for electronic products. Another reason is simply a growing awareness of the problems that sensitive electronics face — partly because of the growing use of high-speed (broadband RF!) computing devices, and partly due to slowly growing pressure from the government, military, and consumer groups. One more active area involves safety considerations as electro-mechanical components are replaced with electronics in automotive and industrial equipment.

Analog and Digital Signal Processing. Included in this group are engineers working on the A/D and D/A conversion process for RF and IF applications, high performance radar, medical imaging, and ultra-wideband video, and advanced consumer products. Analog designers are looking closely at technology which only recently reached radio frequencies, such as monolithic analog switching and multiplexing, op amps, and active filters.

Scientific Research. Although I haven't completely determined the reasons, it is apparent that a lot of RF work is in research. Plasma generators, laser drivers, plus medical imaging and treatment are a significant part, but particle physics is the biggest. It seems that a number of institutions are building new modest-sized linear accelerators and cyclotrons, or upgrading existing facilities with superconducting magnetics and new RF accelerating sources. There are efforts to develop commercial markets for small particle accelerators.

Broadband Data Networks. Both coaxial and fiber optic networks are seeing lots of engineering work. Some time ago, this work shifted from "learning how it works" to developing operating systems, but the quantity of work is substantial. Applications include everything from hospital patient monitoring networks to replacing cable bundles in military aircraft. Advanced fiber optics and high-density office systems represent major efforts.

It will be interesting to see where some of these engineering efforts lead, and when they become well-understood, what new avenues will be opened for exploration. As new ideas develop, *RF Design* will be here to see that engineers have a place to share the results of their efforts. **RF**

Noise Com: Quality. Performance. Service.

From the leader in noise sources.

No one delivers noise performance like Noise Com. And no one delivers it on time, time after time, like Noise Com. We've built a solid reputation for quality, performance, and service that is unmatched in the industry.

Noise Com offers the industry's broadest spectrum of noise products — from diode chips to hermetically-sealed noise diodes to precision coaxial and waveguide noise sources, and manual, automated, and high-power noise generating instruments.

Noise Com also designs custom subassemblies that combine noise technology with passive and active components. We have constructed fast-switching frequency-hopping generators, extremely stable noise generating subsystems, frequency-agile jammers, and secure communications subsystems.

Quality products and the industry's most responsive service and support have made Noise Com the leader in noise technology.

Put our resources to work for you.

Call **Gary Simonyan** at Noise Com, (201) 261-8797.

For Noise Com's complete line of products see the Microwaves & RF Product Data Directory

Wideband noise-generating instruments for the bench

NC 6000 Series

DC to 18 GHz

- Rugged design
- Precision attenuator
- Crest factor 5:1
- Excellent flatness

The NC 6000 Series are rugged noise generating instruments designed for applications on the test bench, or in test stations in which an NC 6000 Series unit is incorporated with other equipment to provide a wide variety of functions.

Programmable broadband noise-generating instruments

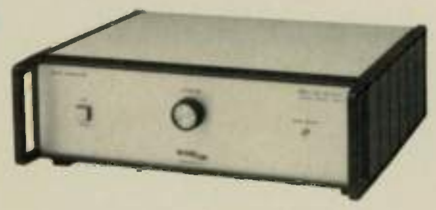
NC 7000 Series

DC to 18 GHz

- Completely programmable— from front panel or IEEE-488 bus
- Non-volatile memory for measurement parameters
- Front panel display
- Fast-switching 127-dB attenuator
- +13 dBm or +30 dBm (1 W) white Gaussian noise output

The NC 7000 Series can be used alone to perform a programmed series of noise measurements, or they can be bus-controlled, for running a battery of tests automatically via any instrument controller.

High-power, broadband noise-generating instruments



NC 8000 Series

500 Hz to 500 MHz

- High power—up to 1 W (30 dBm)
- Uniform response— ±-2 dB
- Precision attenuator—100 dB in 10-dB steps (10 dB in 1-dB steps optional)
- Can be configured for custom requirements

The NC 8000 Series offers 1 W (+30 dBm) power output for applications such as EMC testing, broadband jamming, jamming simulators, in secure communications channels, and any other area requiring high-level noise.

NOISE/COM

Number One in Noise Sources.

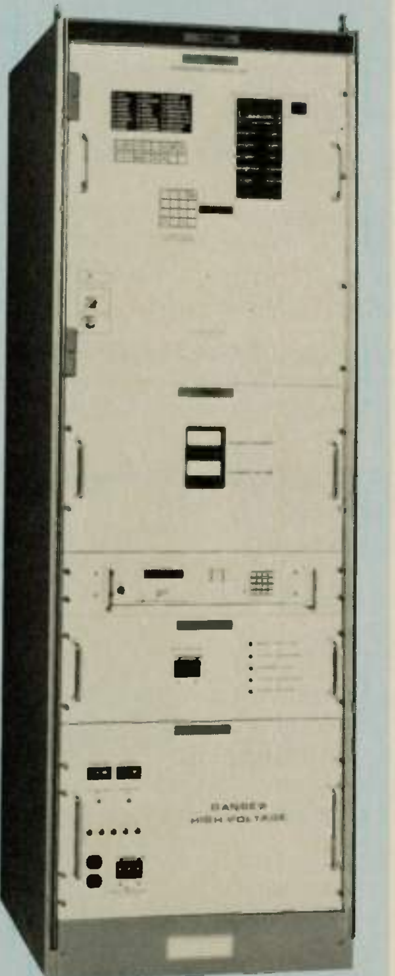
E. 64 Midland Avenue, Paramus, New Jersey 07652

(201) 261-8797 • FAX: (201) 261-8339

INFO/CARD 99

GLOBAL SUPPORT FOR GLOBAL COMMUNICATIONS

Microprocessor Controlled Klystron High Power Amplifiers


Microprocessor amplifier shown

Field-proven and recognized for wide spectrum coverage and consistent, reliable output, MCL's Microprocessor Controlled (and Standard Logic) Klystron High Power Amplifiers (SATCOM C-Band and Ku-Band) are accepted and proven by communications experts worldwide. MCL Series 10000 Klystron Amplifiers are designed to withstand variable environmental and mechanical conditions and are engineered for minimum maintenance and repair.

MCL's SATCOM Series 10000 Amplifier Systems feature a host of standard equipment and options, including:

- full microprocessor (or CMOS Logic) system control panel
- modular assembly for rapid sub-assembly access
- Motorized Channel Selectors available
- RS232, RS422, IEEE488, or Contact Remote Interfaces
- electrical/mechanical "no-step" or SCR AC line regulator drawer
- Beam Supply on casters; all other assemblies on slides
- ruggedization for transportable applications
- and more!

MCL is the leader in the field of amplifiers and allied equipment for the field of satellite communications. MCL offers a complete line of products, at competitive prices, quality-tested and proven to provide *unexcelled performance.*

Write or call MCL today and request your FREE copy of Brochure #1001 (Microprocessor Logic) or Brochure #9009 (Standard CMOS Logic) for details and technical specifications.

MCL

MCL, INC.
501 S. Woodcreek Road
Bolingbrook, IL 60440-4999
708-759-9500 #TWX: 910-683-1899
FAX: 708-759-5018

Manufacturers of TWT and Klystron Amplifiers for Satellite Communications.
24-Hour Sales and Technical Support for Immediate Service Worldwide.

INFO/CARD 6

RF design

a Cardiff publication Established 1978

Main Office:
6300 S. Syracuse Way, Suite 650
Englewood, CO 80111 • (303) 220-0600
Fax: (303) 773-9716

Publisher
Kathryn Walsh

Editor
Gary A. Breed

Assistant Editor
Liane Pomfret

Assistant Editor
Charles Howshar

Consulting Editor
Andy Przedpelski

Associate Sales Manager
Bill Pettit

Account Executive
Maryanne Averill
Main Office

Account Executive
Cindy Wieland
Main Office

Editorial Review Board
Alex Burwasser, Doug DeMaw, Dave Krautheimer, James W. Mize, Jr., Robert J. Zavrel, Jr., Ed Oxner, Andy Przedpelski, Jeff Schoenwald, Raymond Sicotte

Advertising Services
Tisha Hill

Secretary
Theresa Maier

Convention Manager
Kristin Hohn

Registration Coordinator
Barb Binge

Customer Service Representative
LeAnn Nowacki

Associate Production Managers
Matt Park, Maurice Lydick

Artists
Kim Austin, Joyce Fields, Brad Fuller, Paul Rivera, Shelley Moore, Sheri Ryder

Composition
Mike C. Moore, Marcie Tichenor

Published by
CARDIFF PUBLISHING COMPANY, INC.

BPA

President
Robert A. Searle

Vice President — Production
Cherryl Greenman

Vice President — Convention Management
Kathy Kriner

Treasurer
Jennifer Burger

Circulation Director
Patricia Shapiro

Credit Manager
Patti McManness

Please address subscription inquiries to RF Design, Cardiff Publishing Company, PO Box 6317, Duluth, MN 55806
Postmaster: send form 3579 to the above address.

Noise Com: Quality. Performance. Service.

From the leader in noise sources.

No one delivers noise performance like Noise Com. And no one delivers it on time, time after time, like Noise Com. We've built a solid reputation for quality, performance, and service that is unmatched in the industry.

Noise Com offers the industry's broadest spectrum of noise products — from diode chips to hermetically-sealed noise diodes to precision coaxial and waveguide noise sources, and manual, automated, and high-power noise generating instruments.

Noise Com also designs custom subassemblies that combine noise technology with passive and active components. We have constructed fast-switching frequency-hopping generators, extremely stable noise generating subsystems, frequency-agile jammers, and secure communications subsystems.

Quality products and the industry's most responsive service and support have made Noise Com the leader in noise technology.

Put our resources to work for you.

Call **Gary Simonyan** at Noise Com, (201) 261-8797.

For Noise Com's complete line of products see the Microwaves & RF Product Data Directory

Amplified noise modules

NC 1000 Series

DC to 2000 MHz

- High power—up to 13 dBm
- Minimum crest factor 5:1
- Flat response— ±-0.75 dB
- Operating temperature -35 to +100° C
- Storage temperature -65 to +150° C

The NC 1000 Series amplified noise modules are designed for applications that require injection of noise at high levels, and are available with a wide variety of options.

Calibrated coaxial noise sources

NC 3000 Series

10 kHz to 40 GHz

- Noise output rise and fall times less than 1 µS
- 6, 15.5, 30 dB ENR and higher outputs available
- Noise output variation with temperature less than 0.01 dB/° C
- Noise output with voltage less than 0.1 dB/% Δ V
- Operating temperature -55 to +85° C
- Storage temperature -65 to +125° C
- Maximum input power +28 VDC at 20 mA

The NC 3000 Series are well suited for receiver testing, noise figure measurements, and any application requiring broad bandwidth, and fast switching time with coaxial connections.

Calibrated millimeter-wave waveguide noise sources

NC 5000 Series

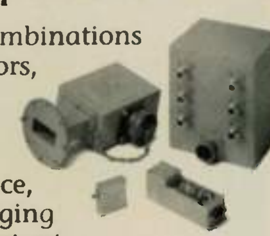
18 to 110 GHz

- Narrow or wideband performance with low or high output
- Noise output rise and fall times less than 1 µS
- VSWR less than 1.35:1
- Noise output variation with temperature less than 0.01 dB/° C
- Noise output with voltage less than 0.1 dB/% Δ V
- Operating temperature -55 to +85° C
- Storage temperature -65 to +125° C
- Maximum input power +28 VDC at 20 mA (+15 VDC available)

The NC 5000 Series noise sources feature outstanding stability, switching speed, and ripple-free response over standard waveguide bands.

Custom noise subsystems

Special products for unique applications



- Custom combinations of connectors, operating voltages, electrical performance, and packaging
- Multiple outputs
- Instruments for NPR testing
- Switched noise sources
- Space-qualified noise sources
- High-power noise sources
- Noise sources with filtering, and adjustable power level and clipping

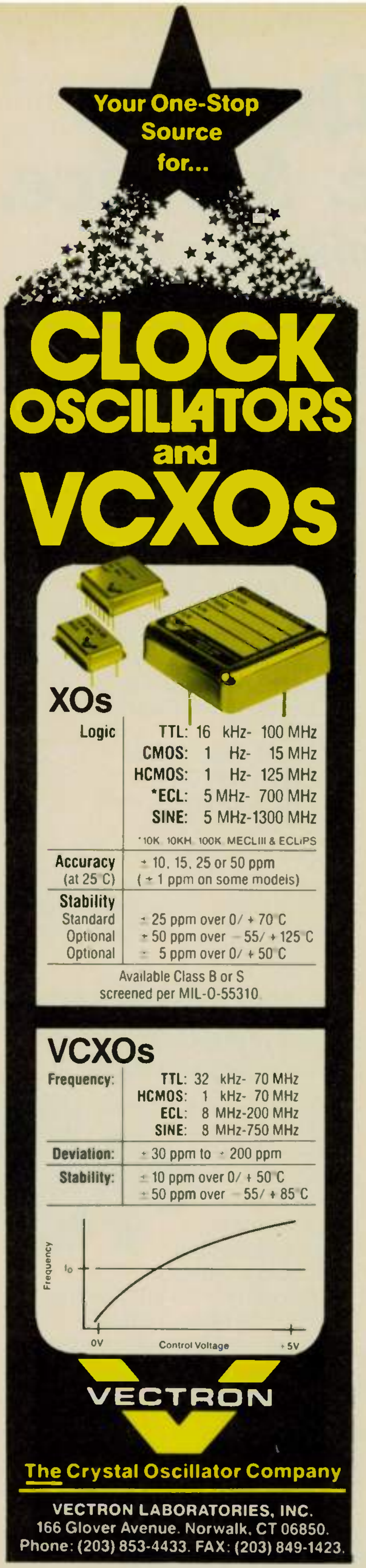
NOISE/COM

Number One in Noise Sources.

E. 64 Midland Avenue, Paramus, New Jersey 07652

(201) 261-8797 • FAX: (201) 261-8339

INFO/CARD 7



INFO/CARD 8
Please see us at RF Expo East Booth #512.

RF calendar

November

13-15 **RF Expo East 90**
Marriott Orlando World Center, Orlando, FL
Information: Kristin Hohn, Cardiff Publishing Company, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111. Tel: (303) 220-0600; (800) 525-9154.

27-28 **Technology 2000**
DC Hilton Hotel, Washington, DC
Information: Bill Schnirring or Joe Pramberger, NASA Tech Briefs' Editor at NASA Tech Briefs, 41 East 42nd St., Suite 921, NY, NY 10017. Tel: (212) 490-3999.

27-29 **Federal High Tech '91**
Boston Park Plaza Hotel & Towers, Boston, MA
Information: Federal High Tech '91, c/o E.H. Pechan & Associates, Inc., 5537 Hempstead Way, Springfield, VA 22151. Tel: (703) 941-4490.

December

4-6 **Twenty-Second Annual Precise Time and Time Interval Applications and Planning Meeting**
Sheraton Premiere Hotel, Tysons Corner, VA
Information: Paul F. Kuhnie, MS/298-100, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109. Tel: (818) 354-2715.

5-7 **Ultrasonics Symposium**
Honolulu Hilton, Honolulu, HI
Information: LRW Associates, 1218 Balfour Drive, Arnold, MD 21012. Tel: (301) 647-1591.

9-12 **1990 IEEE International Electron Devices Meeting**
San Francisco Hilton, San Francisco, CA
Information: Melissa Widerkehr, IEDM, Suite 300, 655 15th Street, NW, Washington, DC 20005. Tel: (202) 347-5900. Fax: (202) 347-6109.

January

14-16 **4th Annual International Superconductor Applications Convention**
Red Lion Hotel, San Diego, CA
Information: SCAA, 27692 Deputy Circle, Laguna Hills, CA 92653. Tel: (800) 854-8263 or (714) 362-9701. Fax: (714) 362-9803.

15-17 **ATE & Instrumentation West**
Disneyland Hotel, Anaheim, CA
Information: Tel: (800) 223-7126 or (617) 232-3976.

22-24 **Hyper 91, Microwave Technology Exhibition and Congress**
Palais des Congres, Paris, France
Information: B.I.R.P., 25 rue d'Astorg, 75008 Paris, France. Tel: 33-(1)-4742-2021. Fax: 33-(1)-4742-7568.

28-31 **Communications Networks '91**
Washington Convention Center, Washington, DC
Information: Michael Sullivan. Tel: (508) 820-8268.

Noise Com: Quality. Performance. Service.

From the leader in noise sources.

No one delivers noise performance like Noise Com. And no one delivers it on time, time after time, like Noise Com. We've built a solid reputation for quality, performance, and service that is unmatched in the industry.

Noise Com offers the industry's broadest spectrum of noise products — from diode chips to hermetically-sealed noise diodes to precision coaxial and waveguide noise sources, and manual, automated, and high-power noise generating instruments.

Noise Com also designs custom subassemblies that combine noise technology with passive and active components. We have constructed fast-switching frequency-hopping generators, extremely stable noise generating subsystems, frequency-agile jammers, and secure communications subsystems.

Quality products and the industry's most responsive service and support have made Noise Com the leader in noise technology.

Put our resources to work for you.

Call **Gary Simonyan** at Noise Com, (201) 261-8797.

For Noise Com's complete line of products see the Microwaves & RF Product Data Directory

Hermetically sealed noise diodes

NC 100 through NC 400 Series

DC to 110 GHz

- Chips and five package options
- Flat output
- Operating temperature -55 to +125° C
- Storage temperatures -65 to + 150° C
- Meet MIL-STD-750
- 50-ohm impedance
- Wide variety of packages

Drop-in noise modules for BITE applications

NC 500 Series

200 kHz to 5 GHz

- Drop-in TO-8 packages
- Economical solution to BITE
- 31 dB ENR output minimum
- Minimum crest factor 5:1
- Operating temperature -55 to +85° C
- Storage temperature -65 to + 175° C
- Temperature coefficient 0.01 dB/° C
- 50-ohm output impedance

Amplified noise modules

NC 1000 Series

DC to 2000 MHz

- High power—up to 13 dBm
- Minimum crest factor 5:1
- Flat response— ±0.75 dB
- Operating temperature -35 to +100° C
- Storage temperature -65 to +150° C

Plug-in amplified noise modules

NC 2000 Series

100 Hz to 300 MHz

- 24-pin packages
- Minimum crest factor 5:1
- High-end roll off 6 dB per octave
- Operating voltage of +15 VDC, +12 VDC optional
- Storage temperature -65 to +125° C
- Operating temperature -55 to +85° C
- Temperature coefficient 0.025 dB/° C

Custom noise subsystems

Special products for unique applications

- Custom combinations of connectors, operating voltages, electrical performance, and packaging
- Multiple outputs
- Instruments for NPR testing
- Switched noise sources
- Space-qualified noise sources
- High-power noise sources
- Noise sources with filtering, and adjustable power level and clipping

NOISE/COM

Number One in Noise Sources.

E. 64 Midland Avenue, Paramus, New Jersey 07652

(201) 261-8797 • FAX: (201) 261-8339

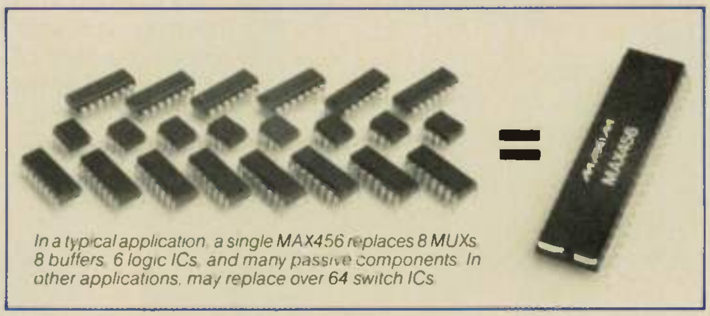
INFO/CARD 9

8×8 VIDEO CROSSPOINT SWITCH WITH BUFFERS -ONLY $2.50*/CHANNEL

Connects Any Input to Any Output

Maxim's new **MAX456** is the **first** monolithic 8×8 video crosspoint switch that routes standard video signals (NTSC, PAL, SECAM). With a digitally controlled 8×8 switch matrix, control logic, and eight 35MHz output buffers together in a 40-pin DIP or 44-pin PLCC, the MAX456 significantly reduces component count, board space and cost over discrete designs. Applications include video surveillance, imaging, visual automation, and video editing.

MAX456 Eliminates Over 20 Components



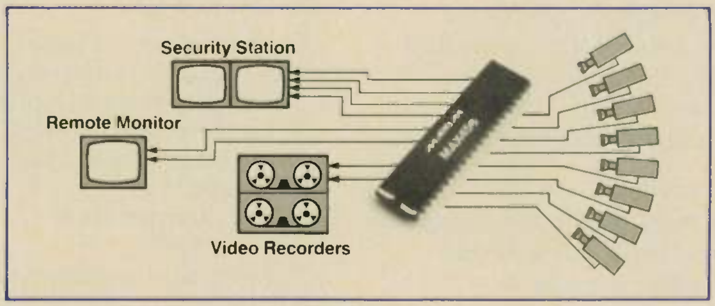
In a typical application, a single MAX456 replaces 8 MUXs, 8 buffers, 6 logic ICs, and many passive components. In other applications, may replace over 64 switch ICs.

- Reduces Board Space up to 5X
- Reduces Cost 5X Compared to Discrete Designs
- Reduces Design and Layout Time
- Reduces Stray Capacitances
- Improves Reliability

Build Larger Crosspoint Arrays

Each MAX456 buffer output can be disabled under logic control. With three-state outputs, multiple MAX456s can be paralleled to form larger switch networks.

- Eight Internal Buffers
  - 250V/μs Slew Rate
  - 35MHz Bandwidth
  - Buffer Disable Saves Power
- ±5V Power Supplies
- 80dB Off Isolation at 5MHz
- 70dB Crosstalk at 5MHz
- Serial or Parallel μP Interface



MAX456 and MAX457s Drive 75Ω Loads

Maxim also offers the MAX457, a dual 70MHz unity gain stable video amplifier. The MAX456 teams up with the MAX457 to drive 75Ω loads efficiently. Special pricing is available for MAX456/MAX457 combination purchases.

Call your Maxim representative or distributor today for applications information, data sheets, and free samples. Or, contact Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086, (408) 737-7600, FAX (408) 737-7194

* MAX456CPL $19.98 1000-up FOB USA price

MAXIM

Distributed by Arrow, Bell/Graham, Hall-Mark, Nu Horizons, Pioneer, and Wyle. Authorized Maxim Representatives: Alabama (205) 830-0498, Arizona (602) 730-8093, California (408) 248-5300, (619) 278-8021, (714) 261-2123, (818) 704-1655, Colorado (303) 799-3435, Connecticut (203) 384-1112, Delaware (609) 778-5353, Florida (305) 426-4601, (407) 682-4800, Georgia (404) 447-6124, Illinois (312) 577-9222, Indiana (317) 921-3450, Iowa (319) 393-2232, Kansas (816) 436-6445, Louisiana (214) 238-7500, Maryland (301) 644-5700, Massachusetts (617) 329-3454, Michigan (313) 583-1500, Minnesota (612) 944-8545, Mississippi (205) 830-0498, Missouri (314) 839-0033, Montana (503) 292-8840, Nebraska (816) 436-6445, Nevada (408) 248-5300, New Hampshire (617) 329-3454, New Jersey (609) 778-5353, New Mexico (505) 268-4232, New York (201) 428-0600, (607) 754-2171, North Carolina (919) 846-6888, Ohio (216) 659-9224, (513) 278-0714, (614) 895-1447, Oklahoma (214) 238-7500, Oregon (503) 292-8840, E. Pennsylvania (609) 778-5353, W. Pennsylvania (919) 851-0010, South Carolina (919) 851-0010, Tennessee (404) 447-6124, Texas (214) 238-7500, (512) 835-5822, Utah (801) 561-5099, Virginia (801) 644-5700, Washington (206) 823-9535, Wisconsin (414) 792-0920, Canada (416) 238-0366, (613) 225-5161, (604) 439-1373, (514) 337-7540

Maxim is a registered trademark of Maxim Integrated Products © 1990 Maxim Integrated Products

INFO/CARD 10

RF letters

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

Transmission Line Matching Circuits

Editor:

In reference to "Design of Transmission Line Matching Circuits" by Stanislaw Rosloniec, *RF Design*, February 1990 and Letter to the Editor from Wolfgang Wiebach, *RF Design*, September 1990, I would like to clarify what I believe is a misunderstanding in Mr. Wiebach's "correction" to the design formulas given by Mr. Rosloniec.

Having worked through the equations involving the impedance transformation of a load impedance by a transmission line, it was straightforward to verify that Mr. Rosloniec's equations 1 and 2 were indeed correct. Furthermore, it became evident how Mr. Wiebach came up with his incorrect "correction" to Mr. Rosloniec's equation 2 for the electrical length of the line.

Mr. Wiebach argues that the formula given by Mr. Rosloniec for the electrical length of the line is incorrect and goes on to give a numerical example to verify the correctness of the alternate formula. However, the confusion lies in the fact that the formula given by Mr. Rosloniec pertains to the complex conjugate match for Z_1 (for maximum power transfer) whereas the "corrected" formula given by Mr. Wiebach pertains to an impedance match to Z_1, i.e., for a minimum reflection coefficient ($S_{11} = 0$). In general, for complex load impedances, the maximum power transfer condition and the minimum reflection coefficient conditions are distinct.

John K. Daher
Georgia Tech Research Institute
Atlanta, GA

Editor:

In the September issue of *RF Design* magazine, I found a comment on my paper "Design of Transmission Line Matching Circuits." Hence, I would like to express my gratitude to Mr. Wolfgang Wiebach from Harry Diamond Laboratories for his interest in my paper. I am sorry to say, however, that his conclusion regarding equation 2 is untrue and therefore I am obliged to reject it. In my paper it is said unequivocally that Z_1 and Z_2 denote the impedances that are to be matched. In other words, the input impedance, see Figure 1, is $Z_1^* = R_1 - jX_1$. Consequently, in Wiebach's numerical example, the input impedance should be assumed (50 − j20) ohms instead of (50 + j20) ohms. Let us consider the following numerical example. For Z_1 = (50 − j20) ohms and Z_2 = (30 − j10) ohms (in this case the input impedance Z_1^* = (50 + j20) ohms) from equation 2 we obtain $\theta = 1.4550$ radians. A similar result is obtained for the following data: Z_g = (50 − j20) ohms, Z_1 = (30 − j10) ohms, Z_{0max} = 43.02 ohms, if the computer program MN-2 (distributed by the *RF Design* Software Service) is used. The above examples confirm once more that equation 2 does not contain any errors, of course, if the notation shown in Figure 1 is used. Finally, I would like to stress again that the design formulas given in Przedpelski's (Reference 5) and my papers are correct. With best regards.

Stanislaw Rosloniec
Institute of Radioelectronics
Warsaw Technical University

Editor:

As many RF engineers, Wolfgang Wiebach had made the common mistake of using "impedance transformation" instead of "impedance matching." Both terms refer to changing one of the terminations by a cascade network to a new value. However, transformation means "changing Z_1 to become *equal* to Z_2" while matching implies "changing Z_1 to become the *complex conjugate* of Z_2."

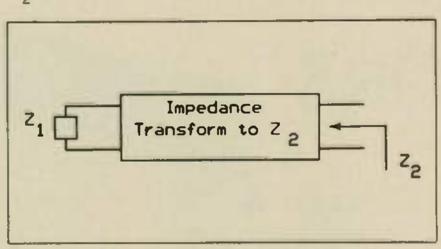


Figure 1. Impedance transform.

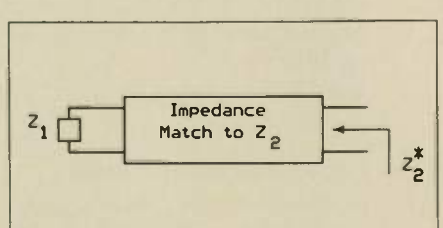


Figure 2. Impedance match.

If both terminations Z_1 and Z_2 are real, $X_1 = X_2 = 0$, then the two methods give the same results. When the terminations are complex, confusing the two methods casues erroneous results.

To conclude, the expression for θ was correct as published. Nevertheless, Mr. Wiebach was right about his second point. The proper lenght of the transmission line in Table 1 is 84 degrees (1.46 radian) instead of the 2.45 radian stated in the original article.

Les Besser
Besser Associates
Los Altos, CA

"BAND" Program

Editor:

For those who have read the *RF Design* review of Philip Geffe's "BAND" Filter design software and are interested in reading Geffe's PRINTME file which is included on disk with "BAND", please note that I have Philip Geffe's permission to provide a free copy of his PRINTME file to anyone sending me a stamped self-addressed, business size envelope at the address given below. The "BAND" PRINTME file is equivalent to about four pages of text, and it may be of interest to those considering purchasing this software.

Edward E. Wetherhold
1426 Catlyn Place
Annapolis, MD 21401

CAD Program Clarification

In Thomas Cefalo's article, "Microstrip CAD Program", October, 1990, Figure 4 was inadequately labeled. The figure is repeated below for clarification.

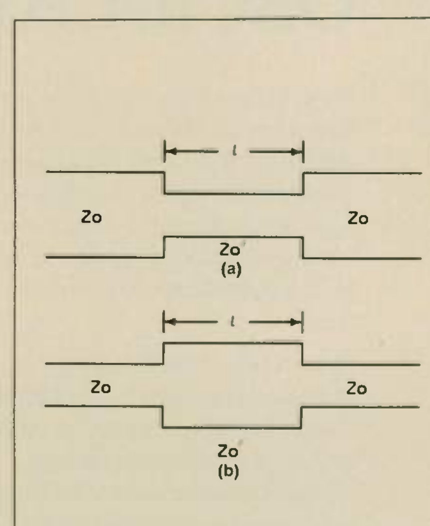


Figure 4. Microstrip inductor (a) and capacitor (b).

IF YOU THINK AN ISOLATOR HOU

You could be missing quick, reliable solutions to your design needs. We've been producing a broad line of microwave and RF components for 30 years. And they're in programs like AIM-7, ALQ-172, ALR-67, ALQ-131, ELS, RAPPORT, TCAS, and more. Just consider the samples on these pages.

THINK MULTIPLIERS

These drop-in multipliers demonstrate our capability in miniature frequency multipliers. They incorporate both lumped element filter techniques and new processes for miniaturizing combline filters.

	#1	#2	#3
Output frequency:	480 MHz	960 MHz	11.00 GHz
Multiplication factor:	X4	X2	X11
Size (nominal):	1.6 x 0.8 x 0.4 in. (41 x 20 x 10 mm)	1.6 x 0.8 x 0.4 in. (41 x 20 x 10 mm)	2.1 x 0.7 x 0.4 in. (53 x 18 x 10 mm)
Input power: (nom.)	+10 dBm	+10 dBm	+10 dBm
Output power: (nom.)	+5 dBm	+5 dBm	+7 dBm
Harmonics/Spurs	-91 dBc -65 dBc	10 to 250 MHz from 250 Mhz	

THINK OSCILLATORS

Think high stability, low noise, and high-rel in a small package. Like our 100 MHz crystal-controlled oscillator, developed for our own synthesizer applications, available with or without comb generator. Or, using your specs, we'll custom design whatever you need.

Phase Locked Oscillator:
This oscillator is small — substantially smaller than others we found on the market. This model requires an external reference source, but we can easily modify it to include an internal reference without a large size increase.

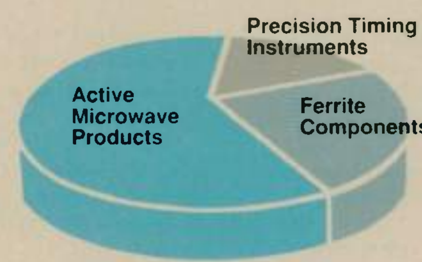
Output frequency:
Customer-specified between 100 and 1200 MHz
Reference frequency: Between 5 and 10 MHz
Size: 2.75 x 1.00 x 0.75 in. (70 x 25 x 19 mm) nominal

Ovenized Crystal Oscillator:
Designed especially for low phase noise under vibration, this new family of oscillators provides real improvements in both phase noise and frequency stability, and they come to you in a small package with only a minor cost difference. You may choose from 10 mW or 100 mW minimum output power.

Output frequency: Customer-specified between 60 and 1200 MHz
Crystal frequency: Factory selected between 60 and 125 MHz
Output power: (a) 10 to 14 dBm
(b) 20 to 24 dBm
Vibrational sensitivity: 1×10^{-9}/g maximum; 5×10^{-10}/g typical
Size: 1.33 x 1.33 x 0.56 in. (34 x 34 x 14 mm) nominal

TRAK IS JUST SE... THINK AGAIN!

THINK MULTI-FUNCTION ASSEMBLIES



TRAK's in-house engineering talent, combined with our own MIC and thin film labs, allows us to pack more functions into a package, while reducing weight and volume. Custom designs are a specialty.

Switched Filter Bank
Covers 10 to 20 GHz in three bands. Switching times as fast as 100 nanoseconds are possible, with frequency ranges customer-selected from UHF to 20 GHz.

	Band 1	Band 2	Band 3
Frequency Range: (Passband)	10-12.6 GHz	12.6-16 GHz	16-20 GHz
Rejection:	DC-7 GHz	DC-8 GHz	DC-10 GHz
(-50 dB min.)	15-26 GHz	19-26 GHz	24-26 GHz

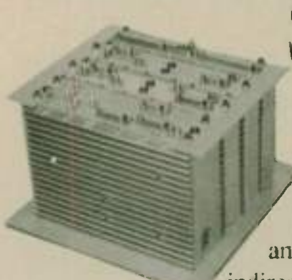
Size: 3.5 x 1.6 x 0.48 in. (89 x 41 x 12 mm) nominal

Higher Stability Crystal Controlled Oscillator/Comb Generator
A brand new type, developed for our own synthesizer applications, providing improved noise and lower vibrational sensitivity. It has both a 100 MHz oscillator ouput and a comb generator output.

Oscillator output frequency: 100 MHz
Comb spacing: 600 MHz
Comb output frequencies: 1.8 to 5.4 GHz
Size (approx.): 2.40 x 1.60 x .45 inches (61 x 41 x 11 mm) nominal

And if all this isn't enough to convince you TRAK does more than isolators, please call or write for our Free Components Catalogs. See EEM or MPDD for other TRAK military products.

THINK SYNTHESIZERS



Think modular, high resolution, digital or analog, direct or indirect. We make the smallest, most capable synthesizers in the business. Thin-film and MIC technologies are in-house. So is our materials lab for ferrites and dielectrics.

High Resolution Indirect Synthesizer
Frequency: 1.6 to 2.8 GHz
Step size: 100 Hz
Switching speed: 350 μsec., typical
Spurious: -68 dBc
Size: 7.5 x 7.25 x 5.25 in. (190 x 184 x 133 mm) nominal
Weight: 13 lbs. max.

TRAK MICROWAVE CORPORATION
Microwave Sales
4726 Eisenhower Blvd.
Tampa, Florida 33634-6391
Phone: (813) 884-1411
TLX: 52-827
FAX: 813-886-2794

TRAK MICROWAVE LTD.
Microwave Sales
3/4 Lindsay Court
Dundee, Scotland DD21TY
Phone: (44) 382-561509
TLX: (851) 76266
FAX: (44) 382-562643

TRAK MICROWAVE CORPORATION

THINK TRAK

TRAK MICROWAVE CORP. 30 ANNIVERSARY

INFO/CARD 11

Please see us at RF Expo East, Booth #503.

Far-Field, Anechoic Chamber, Compact and Near-Field Antenna Measurements
November 27-30, 1990, Atlanta, GA
Phased-Array Antennas: Theory, Design and Technology
November 27-29, 1990, Atlanta, GA
Information: Education Extension, Georgia Institute of Technology. Tel: (404) 894-2547.

IEEE UK&RI Comm/SP Chapter AGM and Evening Lecture
November 28, 1990, London, England
Information: The Institute of Electrical and Electronic Engineers, Chris Shepherd. Tel: 44 (0) 794 833393.

Modern Frequency-Time & Spatial-Time Signal Processing
December 3-6, 1990, College Park, MD
Information: Applied Technology Institute, Jim Jenkins. (301) 997-6814.

RF and Microwave Simulation Tools
November 29, 1990, College Park, MD
Information: Compact Software, Helen Shapiro. Tel: (201) 881-1200. Fax: (201) 881-8361.

Improving the Software Testing Process
November 19-20, 1990, Denver, CO
December 3-4, 1990, Atlanta, GA
December 6-7, 1990, Washington, DC
December 10-11, 1990, Boston, MA
December 13-14, 1990, Chicago, IL
Information: Data-Tech Institute. Tel: (201) 478-5400. Fax: (201) 478-4418.

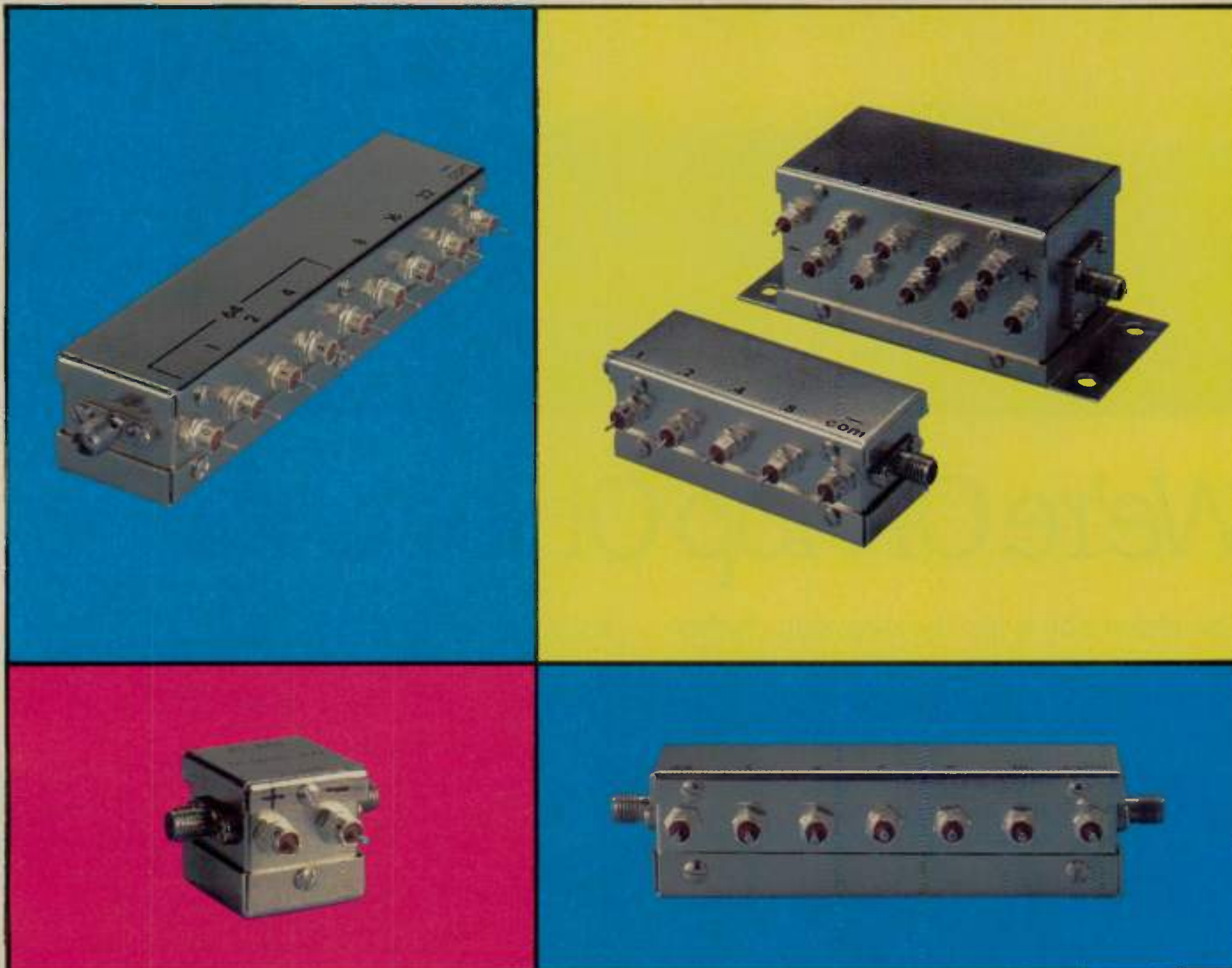
Microwave High-Power Tubes and Transmitters
November 12-16, 1990, Orlando, FL
February 25-March 1, 1991, Washington, DC
Modern Radar System Analysis
November 12-16, 1990, Orlando, FL
December 10-14, 1990, San Diego, CA
Satellite Communications Engineering Principles
November 19-21, 1990, Washington, DC
Ionospheric Radio Propagation for System Planners
November 27-30, 1990, Washington, DC
Spread Spectrum Communications Systems
December 3-7, 1990 Washington, DC
Electronic Countermeasures
December 3-7, 1990, San Diego, CA
New HF Communications Technology: Advanced Techniques
December 3-7, 1990, San Diego, CA
December 17-21, 1990, Washington, CA
Communication and Radar Signals: Detection, Estimation and Geolocation Techniques
January 9-11, 1991, Washington, DC
Hazardous Radio Frequency Electromagnetic Radiation: Evaluation, Control, Effects, and Standards
January 16-18, 1991, Washington, DC
Introduction to Radar ECM and ECCM Systems
February 20-22, 1991, Washington, DC
Antennas: Radiation and Scattering
March 11-12, 1991, Washington, DC
Information: George Washington University, Merril Ferber. Tel: (800) 424-9773; (202) 994-6106. Fax: (202) 872-0645.

Introduction to Fiber Optic Communications
November 27-30, 1990, Dallas, TX
December 11-14, 1990, Los Angeles, CA
December 11-14, 1990, Washington, DC
Digital Signal Processing: Techniques and Applications
November 27-30, 1990, San Diego, CA
December 11-14, 1990, Washington, DC
January 8-11, 1991, Los Angeles
January 15-18, 1991, Boston, MA
Introduction to Datacomm and Networks
December 4-7, 1990, Washington, DC
December 11-14, 1990, Los Angeles, CA
January 8-11, 1991, Washington, DC
Troubleshooting Datacomm and Networks
November 27-30, 1990, Los Angeles, CA
December 4-7, 1990, San Francisco, CA
December 4-7, 1990, Washington, DC
Introduction to Telecommunications
November 27-30, 1990, San Diego, CA
December 11-14, 1990, Albuquerque, NM
January 8-11, 1991, San Diego, CA
January 8-11, 1991, Washington, DC
Information: Learning Tree International, John Valenti. Tel: (800) 421-8166; (213) 417-8888. Fax: (213) 410-2952.

DSP Without Tears™ for Engineers
December 11-13, 1990, Orlando, FL
Information: Right Brain Technologies. Tel: (404) 420-3834. Fax: (404) 252-4122.

Basic Network Measurements Using the HP8510B Network Analyzer
November 13-15, 1990, Dallas, TX
November 27-29, 1990, Boston, MA
November 27-29, 1990, Los Angeles, CA
December 11-13, 1990, San Francisco, CA
December 17-19, 1990, Boston, MA
January 14-16, 1991, Los Angeles, CA
Microwave Fundamentals
January 8-11, 1991, Los Angeles, CA
HP11776A Waveform Generation Language User Course
January 10-11, 1991, Los Angeles, CA
Programming the HP8510 Network Analyzer
January 17-18, 1991, Los Angeles, CA
Information: Hewlett-Packard Company. Tel: (800) 472-5277.

Introduction to EMI/RFI/EMC
November 13-15, 1990, Philadelphia, PA
February 20-22, 1991, Orlando, FL
Grounding and Shielding
December 3-7, 1990, Las Vegas, NV
January 22-25, 1991, Orlando, FL
Practical EMI Fixes
January 28-February 1, 1991, San Francisco, CA
EMI Control Methodology and Procedures
December 11-14, 1990, Las Vegas, NV
February 25-28, 1991, Orlando, FL
EMI Diagnostics and Fixes
December 11-13, 1990, Philadelphia, PA
January 28-February 1, 1991, Orlando, FL
Information: Interference Control Technologies, Registrar. Tel: (703) 347-0030.



Precise. Fast. Durable. Programmable.

For top performance use our programmable attenuators. Select our miniature or standard series. Models as accurate as ±0.1dB. Switching speed of 6 milliseconds and switch life of 10 million selections per bit.

Attenuation as high as 150dB and steps as small as .1dB. 12 models, some useful to 2 GHz. All display flat frequency response and low VSWR.

Call us TOLL FREE today for the programmable attenuators that will meet your specific requirements.

Alan Industries, Inc.
745 Greenway Drive, P.O. Box 1203, Columbus, Indiana 47202
Phone: 812-372-8869 **CALL TOLL FREE: 800-423-5190**
FAX: 812-372-5909

Alan

Manufacturers of...

Attenuators: Programmable • Rotary • Manual Switch • Fixed • Continuously Variable
Accessories: Loads • Dividers • Terminations • RF Fuses • Bridges

INFO/CARD 12

Please see us at RF Expo East, Booth #517.

We're On Top Of Technology.

Our philosophy is like the mountain climber who won't stop until the summit. And standing on the summit, sees there's something beyond. Something else to set sights for.

At Ericsson GE, we may be on top of technology. But it's only a start.

When L.M. Ericsson of Sweden and General Electric joined forces in 1989, a merging of mind and muscle sparked a team ready to take technology to the edge. A team with the resources to make its mark as the high tech-knowledgeable℠ leader.

At Ericsson GE, we're setting the standard with state-of-the-art digital systems, subscriber phones and Mobitex® mobile data network. From high-tech trunked to custom-designed conventional, cellular and micro-cellular systems, we're striving to advance the best into the better.

At Ericsson GE, we know what it feels like to reach a summit. But we're ready to set our sights for another.

If you'd like to learn more about our company philosophy, check into a challenging opportunity currently available at our Research Triangle Park, North Carolina, and Lynchburg, Virginia, sites. Here, you can enjoy the advantages of living in one of two of the country's most beautiful, exciting and affordable areas. Call on your experience for a position in:

Radio Frequency	Digital Signal Processing
Microcircuitry Design	Software Development
Hardware Electronics	Mechanical Engineering
Applied Research	

For information contact:
Ernie Leskovec, Ericsson GE, One Triangle Drive,
P.O. Box 13969, Mail Drop FR11
Research Triangle Park, NC 27709;
(919) 549-7530.

Principals only—please, no agency referrals.

ERICSSON | GE

For The High Tech-Knowledgeable℠

An equal opportunity employer

INFO/CARD 13

Engineers Awarded Emmy for Klystrode Tube

The Academy of Television Arts and Sciences recently awarded Merrald Shrader and Don Preist of Varian an Emmy for their work in developing the

Klystrode[R] tube and transmitter for UHF-TV broadcast. The tube, developed at Varian Power Grid & X-ray Tube Products, cuts transmitter power consumption by 50 percent and correspondingly the television station's power bills. The first 60 kW Klystrode tube was introduced in 1987 and there are currently nine UHF television stations with the tubes in operation.

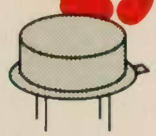
Japanese Literature Bulletin Available from Department of Commerce — The Japanese Technical Literature Program from the Office of International Technology Policy and Programs publishes the Japanese Technical Literature Bulletin. The bulletin provides abstracts of the latest in Japanese scientific and technical developments for U.S. business and industry. To obtain a copy of the publication contact: JTLP, Room 4817 HCHB, 14th & Constitution Ave., Washington, DC 20230. Tel: (202) 377-1288. Fax: (202) 377-4498.

Funding for Advanced Television Standards —The Advanced Television Standards Act of 1990 (H.R. 4933) would provide $4.65 million over two fiscal years and create funding to ensure that the FCC would be able to select a broadcast NTSC-compatible advanced television standard. The act would allow "full U.S. participation in the world HDTV marketplace," according to Sidney Topol, chairman of the EIA Advanced Television Committee. While the EIA supports the bill, there is concern that the National Telecommunications and Information Administration's (NTIA) role in the standard-setting process would be diminished thereby leading to "delays and oversights which would be detrimental to U.S. interests."

U.S. Electronics Trade Deficit Drops — For the first half of 1990, U.S. exports of electronics products reached close to $36 billion, more than a 14 percent increase of last year's exports. The current electronics trade balance represents a $2.2 billion deficit or a reduction of over 60 percent as compared to the same period in 1989. Electronics Industries Association Presi-

Stalking GaAs Performance?

Prowl through a Cougar Components catalog.



This cat tracks only the highest performance, and **Cougar's** GaAs FET TO-8 amplifiers deliver that performance with . . .

HIGH DYNAMIC RANGE

Guaranteed Specifications: 0 to 50 °C

Model	Frequency Range MHz	Gain dB Typ.	Gain dB Min.	Noise Figure dB Typ.	Noise Figure dB Min.	Power Output Min.	I. P.3 dBm	D. C. Volts Nom.	D. C. mA Typ.
PARTIAL SELECTION CHART									
AC2078	10-2000	10.0	9.0	4.0	4.8	19.5	34	15	100
AC2566	200-2500	18.5	17.5	3.5	4.0	17.0	31	15	114
AC3046	10-3000	10.5	10.0	3.5*	5.0	16.0	31.5	15	56
AC3055	10-3000	10.5	10.0	3.5*	4.5	18.0	31	5	56
AP2038	200-2000	10.7	10.0	3.6	4.5	23.0	36	15	150
AP2039	10-2000	10.7	10.0	5.0	5.5	24.5	38.5	15	175
AP2048	200-2000	9.0	8.0	4.8	5.5	23.0	39	15	150
AP2648	200-2600	7.5	6.5	5.5	6.0	23.0	37	15	150
AR1268	10-1200	18.0	17.0	3.8	4.5	20.0	35	15	180

* <3.0 dB from 1000-3000 MHz; >5.0 dB below 100 MHz.

All Cougar Components products are manufactured using materials and processes that meet or exceed MIL-STD-883 requirements.

To satisfy your hunger for GaAs performance, immediate assistance, and a _free catalog_ please call 408-492-1400, or Fax 408-492-1500.

COUGAR COMPONENTS

2225-K Martin Ave.
Santa Clara CA. 95050

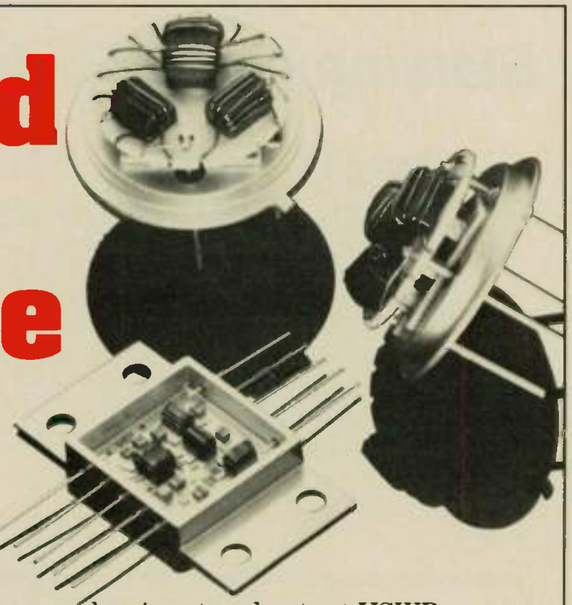
INFO/CARD 14

Please see us at RF Expo East, Booths #115, 117.

dent Peter McCloskey indicated that the figures were very encouraging and exporting is helping to sustain the industry's overall growth.

Georgia Tech Opens Microelectronics Center —The Georgia Institute of Technology recently opened a 100,000 square foot addition to their Microelectronics Research Center. The addition will allow Georgia Tech to expand their research efforts in areas such as compound semiconductor materials, advanced silicon solar cells, superconducting thin films and wires, new semiconductor processing techniques and analog silicon circuits. According to Center Director Dr. Richard Higgins, "We are positioning ourselves for the 'next wave' in the electronics industry, which includes electro-optics and integrated optics — devices which communicate to and from optical fibers. Georgia Tech has developed basic strengths that make it possible for us to develop very fundamental new advances as well as practical applications in these areas." The Center is looking for partnerships with industry to develop new technologies which may otherwise be prohibitively expensive. The new building features a "photon corridor" for optical research and 7,000 square feet of clean room space, 40 percent of it ultra-clean Class 10. Also included is laboratory, office and conference room space for 40 researchers and 80 students.

Avoid the Noise



Q-bit Corporation amplifiers are low on noise, high on performance.

These amplifiers utilize our patented Power Feedback™ technology providing a very low input and output VSWR, extremely flat gain response over a wide bandwidth and unconditional stability for any source and load impedance.

Noise figure, 1 dB compression point, reverse isolation, third and second order intercept points are specified and GUARANTEED over the full military temperature range (-55°C to +85°C).

Rather than give up performance characteristics for low noise figure, specify Q-bit amplifiers in your commercial and military RF designs.

Guaranteed -55°C to +85°C Performance

Model Number	Frequency Range (MHz)	Gain (dB)	Gain Flatness (dB) Rm	Temp	1dB Compression (dBm) Rm	Temp	Noise Figure (dB) Rm	Temp	Reverse Isolation (dB) Rm	Temp	Output Intercept 3rd/2nd (dBm) Rm	Temp	Power (V/mA) Rm	Temp	Price For Quantity 1-9
QBH-117	5-100	16.5	0.4	0.8	4.5	3.0	1.5	1.8	35	34	17/24	16/22	15/11	11	$80
QBH-118	3-100	16.3	0.4	0.8	13.0	11.0	1.9	2.1	35	35	27/38	25/35	15/21	22	$80
QBH-120	5-500	14.5	0.6	1.0	2.0	1.0	2.0	2.3	26	26	14/18	13/17	15/11	11	$95
QBH-841	5-100	19.0	0.5	0.7	4.5	3.0	1.5	1.8	35	34	17/24	16/22	15/11	11	$85
QBH-838	50-500	15.0	0.6	1.0	1.0	0.0	1.5	1.8	25	24	14/18	13/17	15/9	9	$95

Q-bit standard product TO-8 designs, like the amplifiers above, are also available in a flatpack with leads formed for surface-mounting as an option.

Call us for a catalog available on a PC compatible data disk.

Q-bit Corporation

2575 PACIFIC AVENUE NE, PALM BAY, FL 32905

TELEPHONE (407) 727-1838 TWX (510) 959-6257 • FAX (407) 727-3729

INFO/CARD 15

Please see us at RF Expo East, Booth #305.

Inexpensive Frequency Calibration Service Available — The NIST Automated Computer Time Service (ACTS), a dial-up service begun in 1988, can also act as an inexpensive frequency calibration service. NIST researchers have found that a frequency calibration accuracy of better than one part in a billion is readily available from a single long telephone call or from a sequence of short calls averaged over a few days. The system will work with modems at 300 bits/second or 1200 bits/second. Modems at 300 bits/seconds seem to offer better stability. Paper no. 44-90 describes the service and is available from Jo Emery, Div. 104, NIST, Boulder, CO 80303. The cost of hardware and software for ACTS is only about $100. Access ACTS by dialing (303) 497-4774. Software can be obtained for $36 from the Standard Reference Materials Program, Rm. 204, Bldg. 202, NIST, Gaithersburg, MD 20899. Tel: (301) 975-6776. Ask for Automated Computer Time Service, Rm. 8101.

U.S.-Japan Program Exceeds Goals — A joint U.S.-Japan cooperative R&D effort has recently achieved a significant accomplishment in fusion energy research at the Japan Atomic Energy Research Institute. The effort is being carried out by JAERI of Japan, Toshiba, General Atomics and Varian Associates. A prototype tetrode tube, set a world record for power generation by providing 1.7 megawatts of power for 5.4 second pulses at 131 MHz, exceeding the goal of 1.5 MW for five second pulses at 130 MHz established by the U.S. Department of Energy and JAERI. This goal was established to meet the next-generation requirements of their experimental fusion energy programs.

Development of the tube and the recently completed tests were sponsored by the U.S. DOE and JAERI. The tetrode, developed by Varian, offers enhanced anode dissipation which allows the tube to work in a much wider variation of load conditions, opening up a greater range of experimental possibilities.

M/A-COM Division Established — The Solid State Products Division and the Passive Component Division of M/A-COM have been consolidated into the Control Components Division. Their 100,000 square foot facility has been renovated and now has three class 10 clean rooms. Some of the technologies now available are: CAD/CAM, Computer Integrated Manufacturing and Statistical Process Control in addition to the division's Total Quality Management program.

Alford Manufacturing Acquired by Teleplex — The Alford Manufacturing Company has been acquired by Teleplex. Teleplex is currently supplying an adaptive FM broadcast antenna array to Broadcast Services. The antenna system will serve four full power FM stations at a time. Teleplex will continue to supply the Alford broadcast antenna systems, transmission line components, precision test equipment and other telecommunications products. Dr. Andrew Alford, the founder of Alford Manufacturing will remain as a consultant to the company.

Advanced Absorber Incorporated into Arlon Microwave Materials — Bairnco Corporation, the parent company of Arlon and Advanced Absorber has announced the merger of two of its subsidiaries. Advanced Absorber manufactures broadband, carbon loaded film products, tuned frequency magnetic and dielectric absorbing materials, loaded honeycomb, radar absorbing structures and radomes. Arlon manufactures PTFE laminates for high-yield circuit production. All engineering, manufacturing, research and development, quality control and customer service functions will continue to operate from Advanced Absorber's facility. Marketing and sales will be handled through Arlon.

Scientific-Atlanta SEDAT™ Technology to be Used for Satellite System Upgrade — Scientific-Atlanta's new digital-audio satellite transmission technology has been chosen by the ABC Radio Network to triple their channel capacity on the SATCOM F1R satellite and to send compact disk quality transmissions to its affiliates. Spectrum Efficient Digital Audio Technology (SEDAT) allows transmission of up to 80 CD-quality (20 kHz) channels per typical satellite transponder. It can also lower transmission costs by as much as 75 percent over analog systems. ABC Radio Network will convert its broadcast network to SEDAT-based hardware.

EEsof Announces Move — EESof recently announced their move to larger facilities. Their new address is: 5601 Lindero Canyon Road, Westlake Village, CA 91362-4020. Their phone and fax numbers remain the same.

126 YEARS

More Than
A Century Of
State-Of-The-Art
Advances In
Solid State
RF/Microwave Power Amplifiers & Sub-Systems

(L-R): Lou Scanapico, Sr. Systems Engr.; Tom Dowling, VP Eng'g.; Bill Liebman, VP Marketing; Walter Koprowski, VP Operations; Bob Vitkovich, Dir. Eng'g.; Dan Myer, RF Engr.; Dick Sheloff, Asst. to Pres.

These are some of the key people behind PST's outstanding record since its founding. Prior to that, their combined man-years of experience spanned the 1970's and 80's, when they all made significant contributions to the growth and reputation of what was then the industry's leading pioneer in solid state power amplifiers.
Now, they're here at PST, continuing to advance the state-of-the-art with a full array of amplifiers and sub-systems — Class A, AB, C; power output to 10 KW; frequencies up to 4000 MHz; CW, FM, AM, pulse and phase modulation — for a myriad of high performance, cost-effective applications including EW, communication, radar, satellites, troposcatter, laboratory and RFI/EMI testing.
May we suggest that you give them a call, to check out your application requirements — or just to say hello.

PST
A COMTECH COMPANY

POWER SYSTEMS TECHNOLOGY INC.
63 OSER AVE., HAUPPAUGE, NY 11788
TEL. 516-435-8480 • FAX 516-435-4805 • TELEX 221234
Please see us at RF Expo East, Booths #101, 103.

INFO/CARD 16

TFL HAS YOUR OSCILLATORS

MOXO
Miniature Oven Controlled Crystal Oscillator

Frequency Range:
8 – 20 MHz
Frequency Stability:
$\pm 1 \times 10^{-7}$ in temp range
Operating Temp. Range:
0° to +50°C
(optional −20°C to +70°C)
Aging Short Term Stability:
8×10^{-10} at 1 Sec
Long Term Stability:
$< 1 \times 10^{-6}$/year
Warm Up:
< 20 seconds to $\pm 1 \times 10^{-7}$
Input Voltage: 15 V ±5%
5 V (TTL)
Input Power:
< 0.5 W During Warm-up
0.38 W Stabilized at Room-Temp.
Size: 1.26″ × 1.26″ × 0.7″
Output Waveform:
TTL (optionally Sine)

OCXO
Oven Controlled Crystal Oscillator

Frequency Range:
to 50 MHz
Short Term Stabilities:
up to 5×10^{-12} (1 sec)
Warm-Up Time:
As low as 1 min
Temperature Stability:
$\pm 5 \times 10^{-10}$
(0° to +50°C)
Low Aging Rate:
$< 5 \times 10^{-11}$/Day
Low Noise:
< −157 dBc@
10 kHz Offset
Low Vibration Sensitivity:
3×10^{-10}/g
Temperature Range:
−55° to +120°C

TCXO
Temperature Controlled Crystal Oscillator

Frequency Range:
0.02 Hz to 20 MHz
Frequency Stability:
± 0.8 PPM
(−40° to +85°C)
Aging: ± 1.0 PPM/yr typ.
Supply Voltage:
2 to 15 Vdc
Supply Current:
As low as 1.0 mA
Size:
Standard:
1.5″ × 1.5″ × 0.5″
As small as:
0.960″ × 0.5″ × 0.2″

CXO
Crystal Clock Oscillator

Frequency Range:
TTL: 10 Hz to 100 MHz
C-MOS: 1 Hz to 5 MHz
ECL: 5 MHz to 500 MHz
Sinewave: 1 Hz-1 GHz
Frequency Stability:
Typ. ± 50 PPM (−20° to +70°C, Industrial)
Typ. ± 50 PPM (−55° to +125°C, Military)
Up to ± 10 PPM available (−20° to +70°C)
Aging:
± 10 PPM/yr (Industrial)
± 5 PPM/yr (Military)
Outputs: TTL, C-MOS, ECL, Sinewave
Packages: TO-5, TO-8, DIP, Hermetically Sealed Metal Case

Complete line of quartz crystals are also available.
All oscillators can be manufactured to meet MIL-O-55310, MIL-STD-202, and MIL-STD-810.

TFL

At TFL The Quality Is Crystal Clear.

Time & Frequency Ltd.
2315 N.W. 107 Avenue, Miami, FL 33172
305-593-0752

INFO/CARD 17

Watkins-Johnson Wins Subsystems Contract — Watkins-Johnson recently announced they have been awarded a $12.3 million contract by Hughes Aircraft Company, Missile Systems Group. The contract is for radio frequency processors and data-link receivers for the Advanced Medium-Range Air-to-Air Missile.

Harris RF Delivers Command and Control Center — Harris RF Communications has just completed construction and delivery of a Mobile Command Center for a Middle East customer. The center consists of a custom communications shelter on a four-wheel drive vehicle, with a companion generator trailer, providing a totally self-sufficient system. Data communications are controlled by Harris' Universal HF Modem, which provides data rates up to 2400 bps over HF channels under a variety of link conditions. The modem supports both frequency shift keying and time differential phase shift keying techniques, and can be used for full or half-duplex operation, with synchronous or asynchronous data terminals.

ASM Software Changes Name — ASM Software Inc., recently changed their name to Artwork Conversion Software Inc. to avoid confusion with software of the American Society for Metals. Their product line remains the same.

Hughes Microwave Now Offering GaAs MMICs — Gallium arsenide monolithic microwave integrated circuits are now being designed and fabricated for outside customers at Hughes Aircraft Company's new GaAs design center and foundry. While the Torrance facility has been producing MMICs for internal use for the past year, they are just now offering similar services to outside customers. It currently produces circuits for such applications as phased-array radar, automotive radar and mobile satellite communications. For more information, contact: Hughes Microwave Products Division, PO Box 2940, Torrance, CA 90509. Tel: (213) 517-6600.

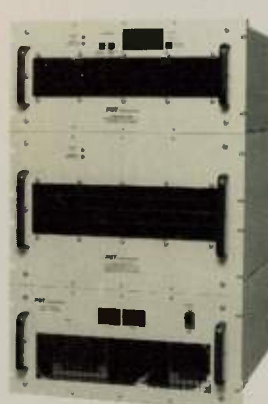
Hamilton Engineering Wins Shielding System Contract — Bechtel National recently awarded a $140,000 contract to Hamilton Engineering to assist them in designing, building and testing an electromagnetic (radio frequency) shielding system for a new Titan IV Mobile Service Tower at Cape Canaveral, FL. Hamilton will design the electromagnetic shielding seals for the tower's doors, some of which are 120 feet high. They will also devise methods of testing the entire structure for electromagnetic leakage.

M/A-COM Awarded Navy Subcontract — M/A-COM Microwave Power Devices, Inc. has received a $16.5 million contract from Raytheon's Equipment Division, for a major portion of the solid state transmitter on the U.S. Navy Relocatable Over-the-Horizon Radar (ROTHR). ROTHR is a bistatic, ionosphere backscatter radar system that can track approaching naval and airborne threats. The system has all solid state transmitters and is more automated than other over-the-horizon systems making it suitable for siting in remote locations.

1,000 WATTS

Solid State Air-Cooled

High Power Amplifiers, Frequencies to 1800 MHz



- Class AB Linear
- Wide Bandwidth
- Thermal Protection
- Load VSWR Protection
- Input/Output Overdrive Protection
- Graceful Degradation
- Low MTTR
- Built-in Test Diagnostics
- IEEE 488 Bus (optional)
- High Frequency Switching Power Supply

Series BHE/BHC amplifiers are available in a full selection of frequency ranges: 1.5-30, 20-100, 20-500, 100-500, 200-400, 225-400, 400-1000, 500-1000, 850-1450 and 1400-1800 MHz, with output powers from 100 to 1000 watts. All circuit elements are connectorized modules — pre-aligned and field-replaceable. Their wide bandwidths make them ideal for use in multi-octave, frequency-agile systems, totally unattended or remotely computer controlled. Typical applications include: EW/ECM systems, RFI/EMI testing, TWT replacements, communication systems, AM/FM transmitter boosters, high power testing.

Write or call for complete BHE/BHC information — ask for Product Data 2010 — or to inquire about our wide choice of other standard and custom designs: Class A, C, narrow band and pulsed; power output up to 10 KW; frequencies up to 4000 MHz.

PST

POWER SYSTEMS TECHNOLOGY INC.

A COMTECH COMPANY

63 OSER AVE., HAUPPAUGE, NY 11788

TEL. 516-435-8480 • FAX 516-435-4805 • TELEX 221234

Please see us at RF Expo East, Booths #101,103.

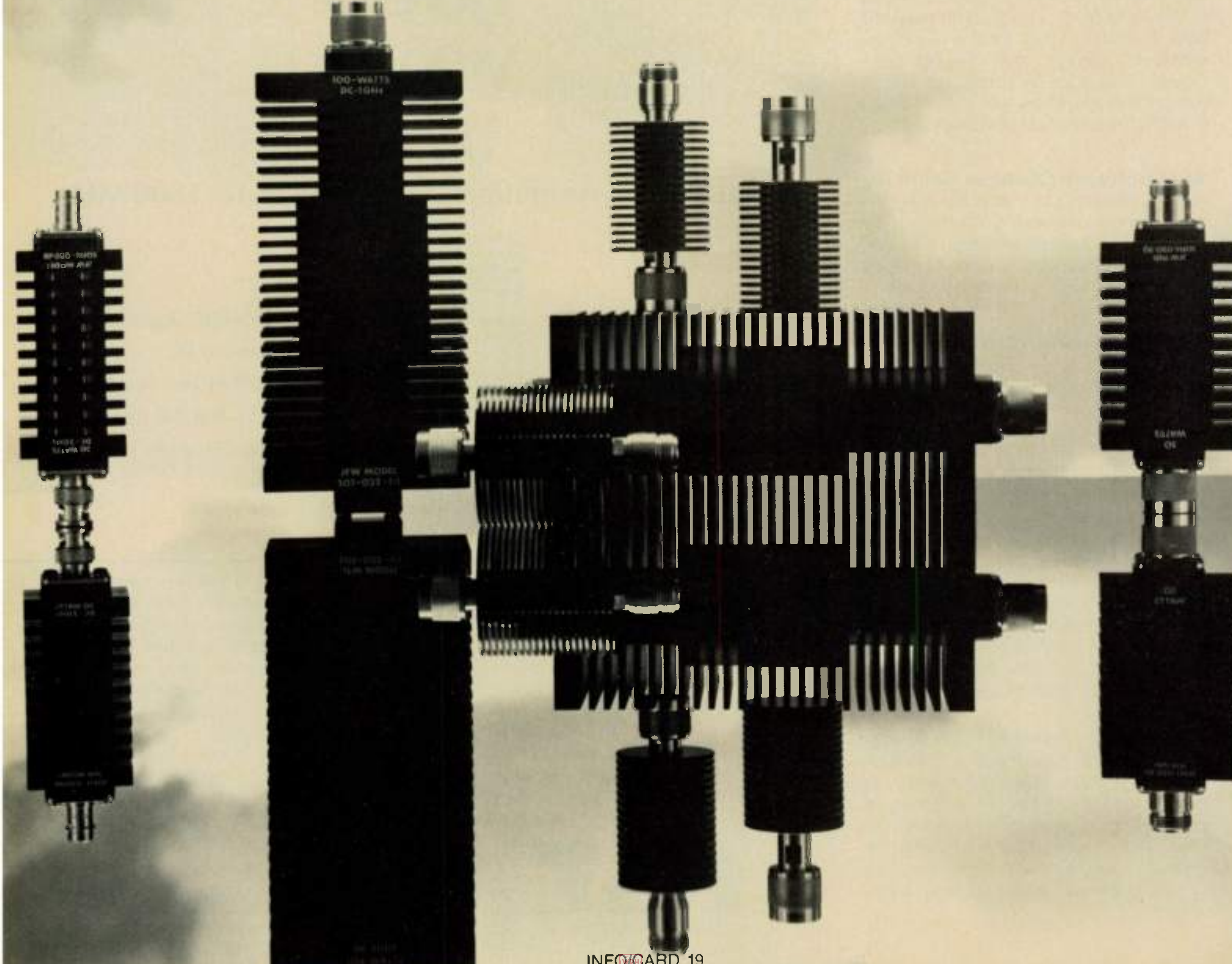
INFO/CARD 18

INVINCIBLE POWER!

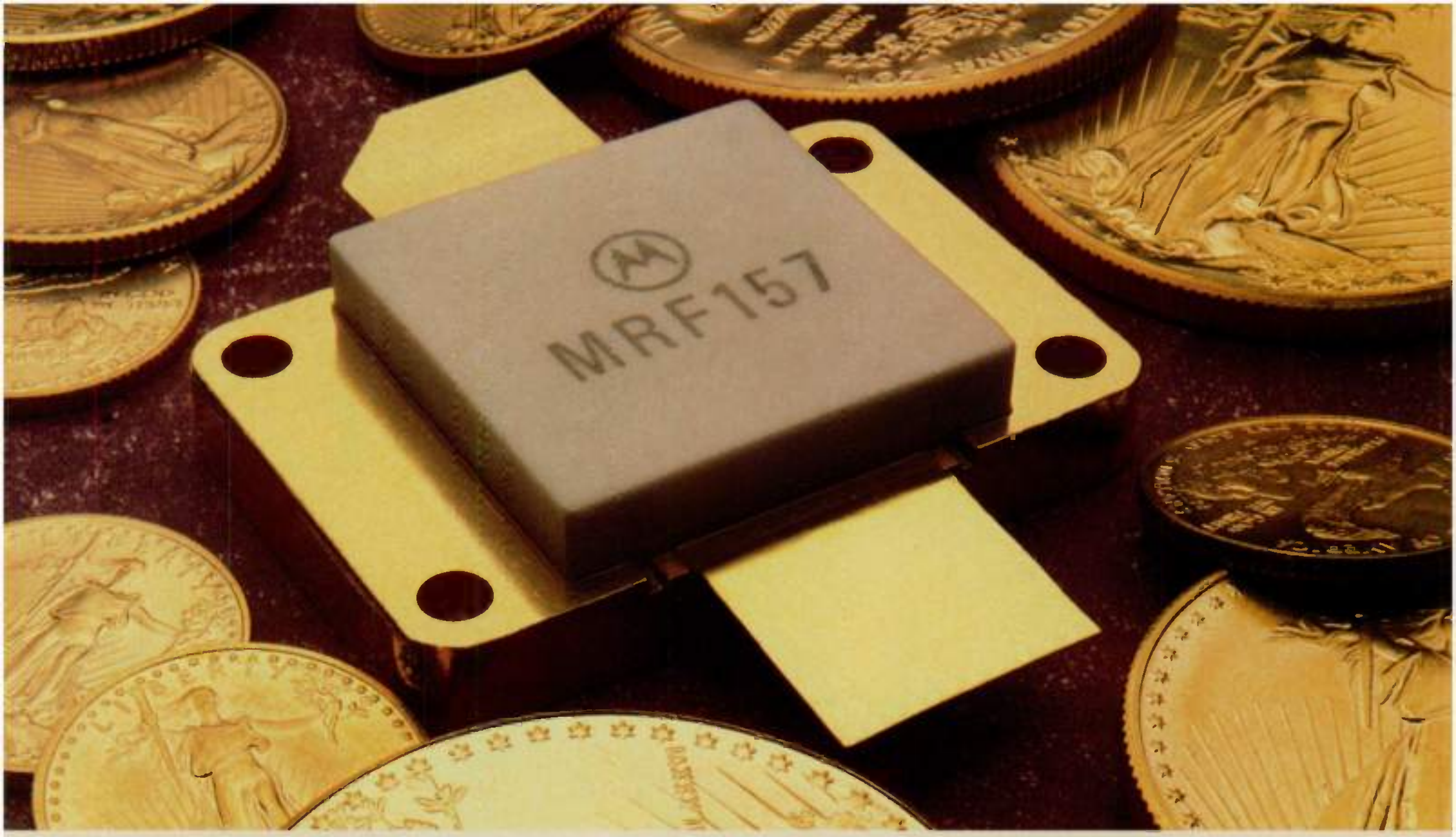
Attenuators and Loads

Power Range From 1 To 300 Watts

JFW Industries, Inc.
5134 Commerce Square Drive, Indianapolis, Indiana 46237
(317) 887-1340   Fax: (317) 881-6790



INFO/CARD 19
Please see us at RF Expo East, Booth #618.



A gold standard you can build on.

For second-generation RF Power MOSFETs, Motorola sets the standard.

Only Motorola could set the standard for performance and reliability by building a 600 watt RF Power MOSFET with gold top metal to MIL specs. Only Motorola has pioneered technology that's made it the leader in RF products world-wide. And only Motorola can put that technology and experience into a line of commercial 500 MHz RF transistors.

1990 will be a very good year.

An even dozen new Motorola RF Power MOSFETs are announced for 1990. Eight are already introduced and available. All are 100% electrical Ruggedness tested at their rated output power.

Most are in the Flange-style push-pull Gemini package, case 375-01. Others are in the 1/2" Flange, case 211-11. Coming later in the year are parts in the case 412-01 Small Gemini P-P, case 29-05 TO39CS and CS12, case 319-06.

Part #	Top Metal	P_O Watts	Frequency MHz	Gain	V_{DD} Volts
MRF157[1]	AU	600	30	20	50
MRF141G	AI	300	175	14	28
MRF151G	AI	300	175	16	50
MRF175GU	AI	150	400	12	28
MRF176GU	AI	150	400	14	50
MRF141	AI	150	175	10	28
MRF151	AI	150	175	13	50
MRF164W[2]	AI	20	400	17	28
MRF166C[2]	AI	20	400	17	28
MRF160R[2]	AI	4	400	20	28
MRF158R[2]	AI	2	400	20	28

[1] Currently being supplied as customer special. [2] To be introduced in Q1, 91.

As you have the right to expect, great new RF Power MOSFETs are available from the world's leading creator of RF Semiconductors.

For additional information, send the completed coupon or write to Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, AZ 85036. To fill an immediate need, call toll free 1-800-521-6274 during weekday business hours.

MOTOROLA

To: Motorola Semiconductor Products, Inc., P.O. Box 20912, Phoenix, AZ 85036

Please send me more information on Motorola RF Power MOSFETs.

455 RFD110090

Name ____________________

Title ____________________

Company ____________________

Address ____________________

City ____________________

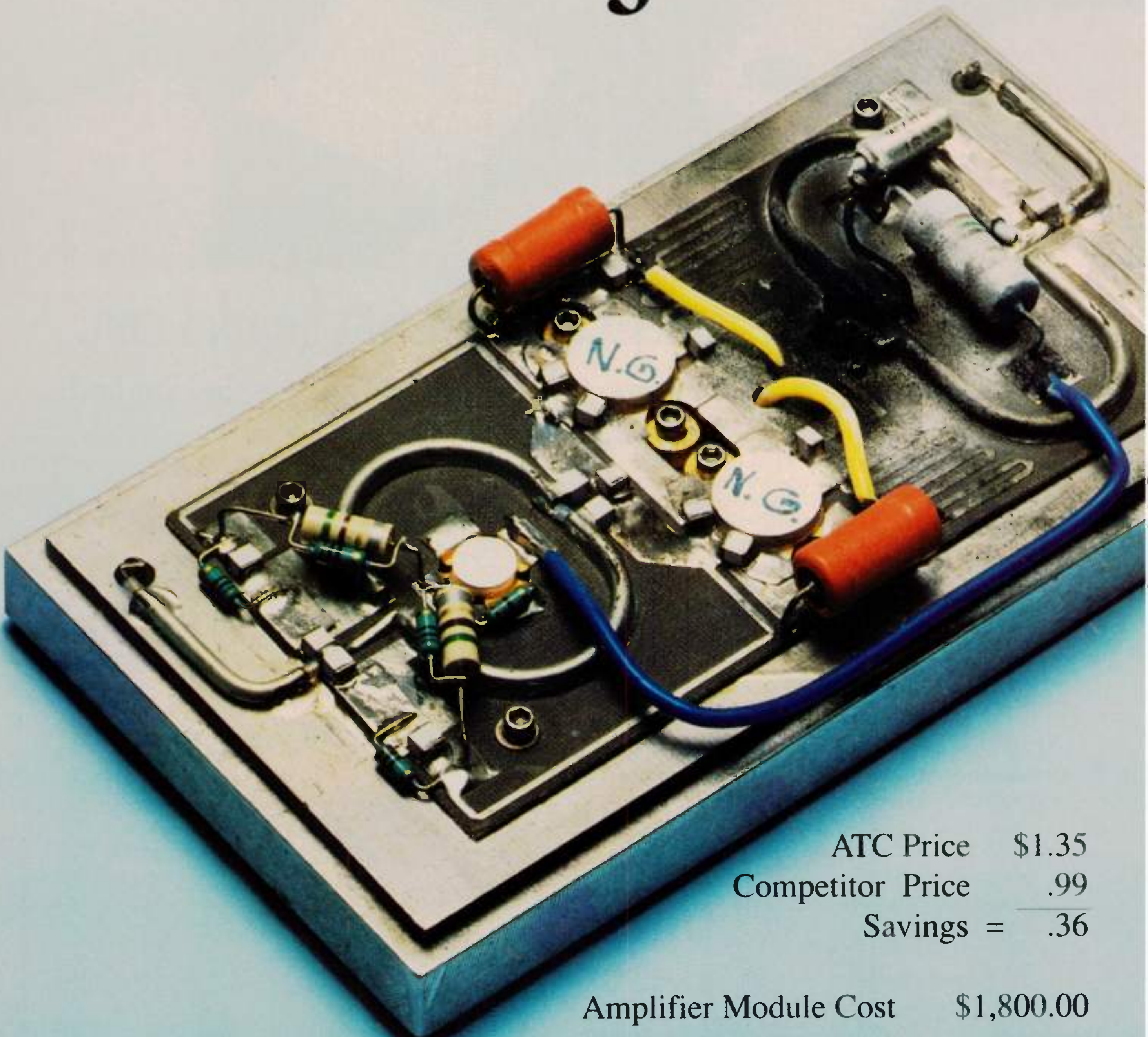
State ____________________ Zip __________

Call me (______) ____________________

INFO/CARD 20

Please see us at RF Expo East, Booths #102, 200, 201, 202.

. . . "But they just as



ATC Price	$1.35
Competitor Price	.99
Savings =	.36
Amplifier Module Cost	$1,800.00
Amplifier Replacement Costs	2,600.00
Minus Savings —	.36
Total Loss =	$2,599.64

WRH

told me it was good as ATC"

Did you ever stop and wonder why everyone claims to be equal to or better than ATC? We view it as an honor . . . can you afford to view them as the same?

A recent independent survey of capacitor suppliers ranked American Technical Ceramics number one for the tenth consecutive year for quality, service and technical support.

American Technical Ceramics. . . producing the highest quality RF/Microwave Capacitors since 1964.

american technical ceramics CORP.
one norden la., huntington sta., n.y. 11746-2102 usa
phone 516-547-5700 • telex 825707 • fax 516-547-5748

INFO/CARD 21

Please see us at RF Expo East, Booth #418.

K&L's Switched Filter Banks...

Excellence Is Standard!

**Don't custom design every filter bank.
K&L Standard PIN Diode Switched Filter Banks feature in-stock assemblies to allow quick delivery without sacrificing technology or performance.***

- 2 to 8 channels
- Frequencies 0.05 to 18GHz (18 to 26.5 GHz option)
- Overall Bandwidth 4:1 (full band option)
- VSWR: 1.6:1
- Isolation: 70 -f(GHz)
- Hermetic (laser) seal
- Switching speed 100nS (faster possible)
- Insertion Loss = filter loss + 2 + $\frac{f(GHz)}{5}$

- Package Size:
  - 2 channel 2.15" x 1" x 0.75"
  - 3 channel 2.75" x 1.5" x 0.75"
  - 4 channel 2.75" x 1.85" x 0.75"
  - 5 channel 3" x 2.25" x 0.75"
  - 6 channel 3" x 2.65" x 0.75"
  - 7 channel 3.25" x 3.45" x 0.75"
  - 8 channel 3.25" x 3.45" x 0.75"
- Typical supply voltages: -5V @ 100mA., +5V @ 60mA x no. of channels

***NRE: Not applicable on standard units.**

K&L
MICROWAVE INCORPORATED
A DOVER TECHNOLOGIES COMPANY

INFO/CARD 22

408 Coles Circle ♦ Salisbury, Maryland 21801 ♦ TWX: 710-864-9683 ♦ FAX: 301-749-5725 ♦ PHONE: 301-749-2424

Military Subsystems: A Waiting Game

By Liane Pomfret and Charles Howshar, Assistant Editors

While there has been a great deal of talk lately concerning the loss of funding for the military budget, the RF military subsystems industry has been largely unaffected. Subsystems have not suffered the same fate as major programs like the B-2 Bomber or the Strategic Defense Initiative. Andy Przedpelski, Vice President, Development at ARF Products observes, "Future contracts, -SDI, B-2, etc., will be cut because of the warming relations in Eastern Europe. The urgency for them has been reduced." However, since subsystem uses are more widespread, they are more resilient in the face of changes in the defense industry.

Military customers are realizing the advantages of integrating a multifunction assembly into a system. It saves them both time and money. Carl Schraufnagl, Vice President of Marketing for KDI/Triangle Electronics points out, "Customers are recognizing the benefits of subsystems versus individual components." "We do see the trend towards vertical integration as well as the need to reduce package size," he adds. There are some problems with this, however. "Systems houses are trying to do subsystem work themselves and those using SAW products are not always successful because they don't know the technology very well. They seem to be forcing the engineers to do subsystem integration without training them. This can be frustrating for customers trying to upgrade their systems," observes Maura Fox, Director of Marketing for Thomson-ICS.

Training has become necessary as more companies move from component design to subassembly design. Engineers and companies are learning that the better their training, the better the product and productivity. Henry Eisenson, President of Sciteq believes that, "A year from now the average performance of our engineering community will be substantially improved, because the engineers comprising the lowest 40% will be gone." Companies are no longer looking for specialists; they're looking for engineers who are capable of designing a subsystem. "You need hybrid people for hybrid devices," remarks Peter Campbell, Avantek's Product Marketing Manager for Amps and Assemblies.

Some companies are feeling the pinch from the industry's slowdown. According to Tom Roberts, Senior Vice President/Marketing Director for TRAK Microwave, "The impact is already here. Because of delays in contracts, we're not getting the trickle down (subcontracts) that we used to. However, there will be a lot of upgrading of systems, so there is an alternative." David Chambers, Engineering Vice President at K&L Microwave points out, "We've been going month to month waiting for the crunch but it hasn't come. It's the hardest it's ever been to predict these things."

Despite a gloomy forecast from industry watchdogs, the military subsystems market is still showing some growth. Among several reasons for this is the fact that retrofitting or upgrading older systems is a constant necessity. Start-up costs for new systems are too high and, in a time of mandatory budget cuts, there is very little money to be found for new projects. According to Henry Eisenson, "I think we're going to see upgrades to existing systems as opposed to new systems." Peter Campbell agrees, "It will be difficult for anyone to start new projects." Frank Perkins, Vice President of Marketing at RF Monolithics comments on the possible effects of a Mideast crisis, "If we were to have a military conflict in the Gulf, it could have an effect on the military market -all the way down to spare parts, and it could cause a dramatic increase in demand for subsystems."

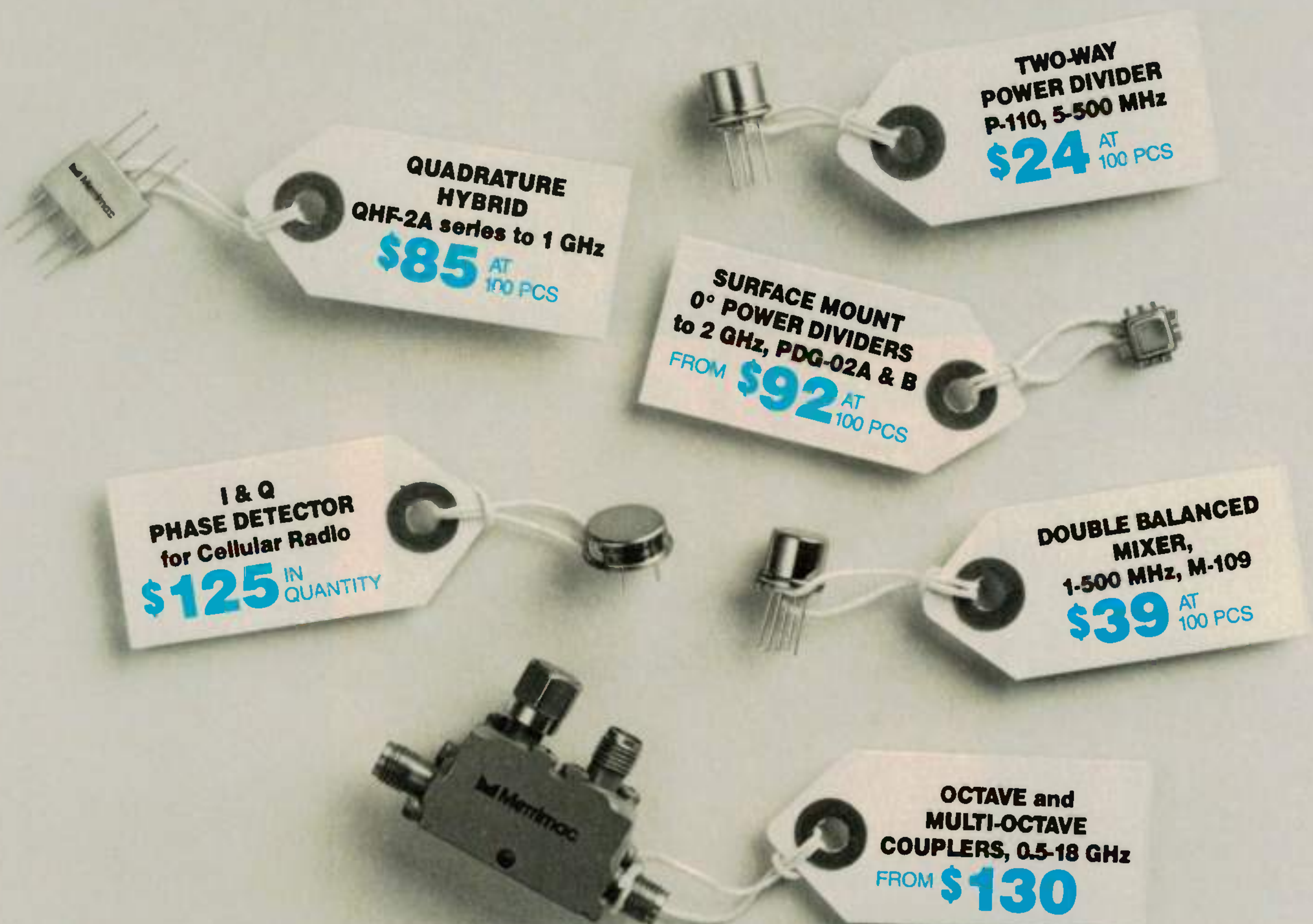
The most active areas are in the communications and radar sectors. As the need for weapons subsystems decreases, the demand for information has been increasing; a trend that has surprised few people. Across the board companies see communications, or in some cases C^3I as the most promising area. "There's still a lot of need for communications," says Frank Sasselli, Engineering Manager at Microwave Modules and Devices. Dave Krautheimer, Director of Marketing at RHG concurs, "Some areas will get better — mostly in communications and ELINT."

One advantage in the industry is size. Smaller seems to be better in these days of financial uncertainty. By all appearances, the smaller companies are doing better than their big brothers. Since their overhead is smaller, they are better able to adjust to changes in the market. P. Wahi, President of Antenna Research comments, "Smaller companies have been gearing down for the cuts, shifting their product line. Larger companies wanted to take a bigger risk. Now it's a difficult situation for them. If they don't get the contracts it will be a big deception for them." Gary Simonyan, President of Noise Com notes, "As a small company we're excited by what is happening. We're so busy, we can't keep up with the orders," — a promising sign for a company that has been in the military subsystems market for just over six months. Sandy Edberg, Division Sales Manager for the Microwave Product Division at Hughes Aircraft has seen the same trend, "We are working with a number of small businesses that indicate they are profitable in the first year of operation."

Despite these signs, companies are hedging their bets by moving into the commercial sector. "The long term solution to the RF industry is finding a commercial application for military products, so that the industry is not subject to the 5 to 7 year cycles of the defense industry," says P. Wahi. But there are difficulties in finding commercial applications for military subsystems in that the cost of a device is so high that commercial production is often unfeasible.

The number of unknown variables -the changing political climate of Europe, the Mideast crisis, the U.S. budget -makes it difficult to predict the future of the military subsystems market. There is no doubt that there are large changes on the horizon, but what they will lead to is still unknown. **RF**

MERRIMAC MEANS HIGH QUALITY, NOT HIGH PRICE



- Rely On The MERRIMAC Stock Delivery Program of Catalog Components
- Rely on MERRIMAC Engineering For Support and Custom Requirements
- Rely On The Reputation Earned By MERRIMAC For Proven Quality, Dependability and Value

Merrimac

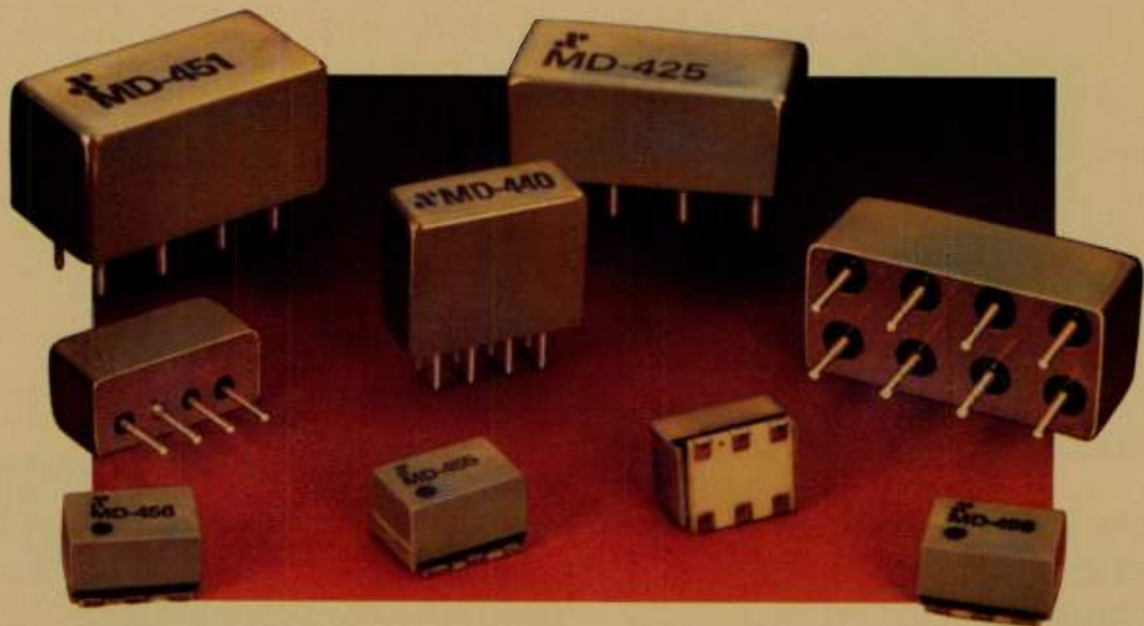
- For Further Details On The Stock Delivery Program And To Receive Your Copy Of The Latest Catalog, Call or Write: MERRIMAC, 41 Fairfield Place, West Caldwell, NJ 07006 (201) 575-1300 • FAX: (201) 575-0531

Above Prices For USA

INFO/CARD 24

Please see us at RF Expo East, Booths #304, 306.

ANZAC DELIVERS *The Alternative*



ANZAC's MD-400 Series of Mixers — The Quality Alternative.

Until now, buying a low cost mixer may have meant receiving a low quality device. With ANZAC's new MD-400 Series of mixers you get everything you'd expect from an ANZAC product at prices you might expect from the other guy.

Performance

Model No.	Frequency Range RF/LO (MHz)	IF (MHz)	Conv. Loss (dB) Typ	Isolation (dB) Typ LO-RF	LO-IF	Comp. Point (dBm) Typ	LO Drive (dBm)
MD-405	0.1-250	DC-250	5.0	48	45	+13	+17
MD-401	0.2-400	DC-400	6.0	50	45	0	+7
MD-428	1-400	DC-400	5.5	55	45	-1	+7
MD-410	0.5-500	DC-500	5.0	50	40	-2	+7
MD-413	0.5-500	DC-500	6.0	50	45	+9	+17
MD-411	0.6-500	DC-500	5.0	50	35	-2	+7
MD-426	1-500	DC-500	5.5	50	40	0	+7
MD-455	1-500	DC-500	7.0	50	45	+1	+7
MD-403	2-500	DC-500	6.5	50	45	+13	+17
MD-441	2.5-500	DC-500	6.0	60	45	+1	+7
MD-450	5-500	DC-500	6.5	45	45	+17	+23
MD-435	0.5-600	DC-600	5.5	55	45	+2	+7
MD-440	1-1000	DC-1000	5.5	45	40	-1	+7
MD-400	1-1000	DC-1000	6.5	50	45	+2	+7
MD-412	1-1000	0.5-500	5.0	40	30	-1	+7
MD-414	2-1000	DC-1000	6.5	45	35	+9	+17
MD-404	5-1000	DC-1000	6.5	48	45	+14	+17
MD-456	5-1000	DC-1000	7.0	40	35	+2	+7
MD-427	10-1000	5-500	5.5	50	40	+1	+7
MD-406	5-1200	DC-1200	7.5	45	40	+13	+17
MD-402	5-1250	DC-1250	6.5	45	40	+2	+7
MD-415	2-2000	0.5-500	7.0	45	35	+5	+10
MD-425	5-2000	10-600	8.0	45	35	+2	+7
MD-407	10-3000	10-800	7.5	40	25	+5	+10
MD-416	10-3000	10-1000	7.5	35	25	+10	+17

Specs per Adams-Russell Components Group 1989 RF & Microwave Signal Processing Components catalog. For more information contact the factory.
*MD-426 1-24 units (higher quantity pricing available)

Quality

MD-400 Series mixers meet stringent military standards and come with ANZAC's 1 year warranty.

Competitive

Series 400 mixers start as low as **$5.90*** and are available **FROM STOCK**, in a variety of relay header and surface mount package styles.

Call today for more information about our complete line of quality, low cost mixer alternatives.

ANZAC
A DIVISION OF ADAMS-RUSSELL

Dedicated to Your Satisfaction

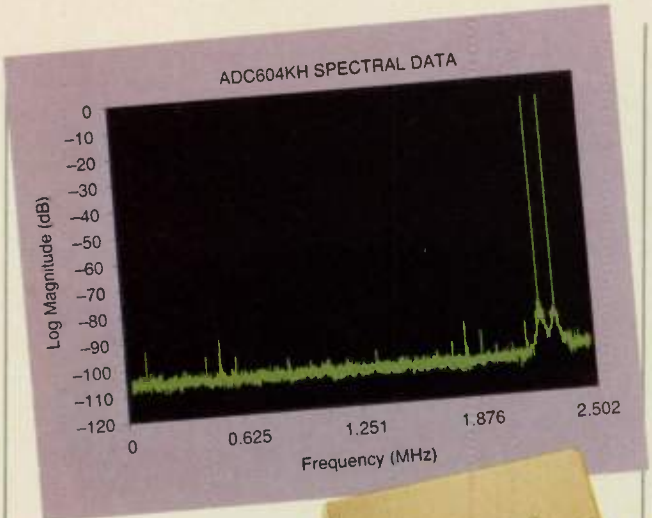
80 Cambridge Street Burlington, MA 01803
(617) 273-3333 FAX: (617) 273-1921

A M/A-COM COMPANY

INFO/CARD 25

Please see us at RF Expo East, Booths #315, 317.

New 5MHz Sampling A/D Converter Tops 83dB Spurious-Free Dynamic Range



Sets Dynamic Performance Standards

ADC604 is our new, complete 12-bit, 5MHz sampling A/D converter. It offers designers unmatched dynamic range for spectrum analysis and digital receiver applications requiring high sampling speed. Its excellent linearity results in near **14-bit distortion performance.**

Key Specifications

- 83dB SFDR
- 68.6dB SNR
- −83dBc THD
- −83dBc IMD
- 12-bit Resolution
- DC - 5MHz Sampling Rate
- ±1.25V Input Range
- ±0.4LSB DLE

ADC604 is a hybrid subsystem containing ADC, sample/hold amp, precision voltage reference, and timing and error-correction circuitry. To insure the highest performance, high grade (KH) units are not only thoroughly DC and AC tested, but they are also shipped with FFT and Swept-Power (see Figure 1) test data at no additional charge.

Need more speed? ADC604 is pin-compatible with our 12-bit, 10MHz ADC603; it's easy to make speed and dynamic range trade-offs by simply plugging in an ADC603 or ADC604. Both devices dissipate 6W and are available in 46-pin ceramic and metal DIPs.

More High Speed, High Performance Products

We offer a full line of linear products designed for high speed, high resolution applications. These include current- and voltage-feedback op amps, 12- to 16-bit ADCs and DACs, sample/hold amps, PC-based ADC design and test systems, and a selection of demonstration boards to aid in product evaluation. Our new *High Speed Linear Products* brochure describes our line and contains valuable test and applications tips. Ask your Burr-Brown representative for a free copy, or call **1-800-548-6132** for immediate assistance.

Burr-Brown Corp.
P.O. Box 11400
Tucson, AZ 85734 USA

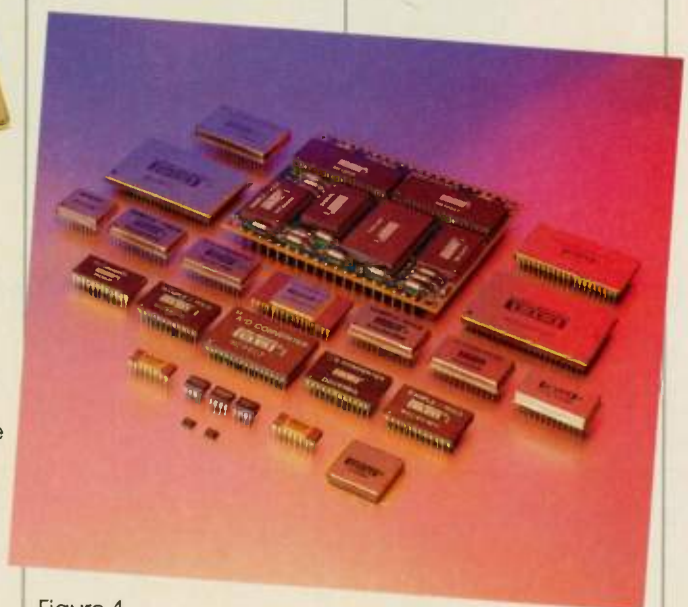
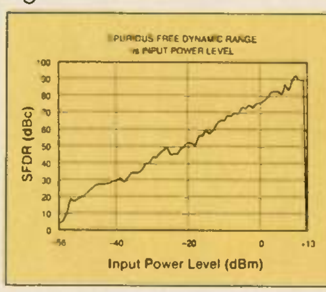


Figure 1



Typically, an A/D's spurious signal levels show a variation with input signal power. Swept-Power testing demonstrates that these spurs remain at levels acceptable over the complete range of input signal amplitudes. The test measures "worst-case" spurious signal levels as the input is decreased in very small increments from an over-driven amplitude to near the ADC noise level.

BURR-BROWN®

INFO/CARD 26

Please see us at RF Expo East, Booth #104.

Yes, I'm interested in Kay Attenuators.

Kay Elemetrics Corp. can supply you with the right Attenuator to fit your applications. We have both 50Ω and 75Ω models from DC-3GHz.

- ✓ **Programmable**
- ✓ **In-Line Step**
- ✓ **Continuously Variable**
- ✓ **50Ω & 75Ω**
- ✓ **Bench and OEM**
- ✓ **Surface Mount Components**
- ✓ **Custom Models**
- ✓ **DC-3GHz Range**

Fill out and mail this card today to receive more information.

Name ______________________ Position ______________

Company ______________________ Dept. ______________

Address ____

City ______________________ State ________ Zip ________

Phone ____

"Attach Business Card Here"

INFO/CARD 27

RF design — FREE SUBSCRIPTION REQUEST

To receive *RF Design*
Answer all questions, sign, date and mail today.

✓ I wish to receive *RF Design* free of charge ☐ yes ☐ no

✓ **Signature** ______________________ **Date** __________
required

NAME		
TITLE		
COMPANY NAME		
ADDRESS		
BLDG. NO.	M/S	
CITY	STATE	ZIP

The above is my ☐ company address ☐ home.

1. Please check the one category which best describes your business.

- 25 ☐ CATV & broadcast equipment
- 45 ☐ Land mobile equipment
- 140 ☐ Video, audio equipment
- 142 ☐ Data transmission, computer systems
- 60 ☐ Instruments & test equipment
- 144 ☐ Medical electronics equipment
- 146 ☐ Industrial controls & power supplies
- 70 ☐ Consumer electronics equipment
- 80 ☐ Components & subsystems
- 15 ☐ Aviation, marine, navigation systems
- 112 ☐ Satellite & space systems
- 114 ☐ EW, ECM & radar systems
- 116 ☐ Military communications systems
- 118 ☐ Government agency (non-military)
- 90 ☐ Lab or consultant
- 150 ☐ User of electrical equipment
- 180 ☐ Library or school
- Other ______________ (please specify)

2. Please check the one category which best describes your title.

- 01 ☐ Engineering manager
- 02 ☐ Engineer (Design, R&D, Project, MTS)
- 03 ☐ Engineering Service Titles (Standards, Reliability, QC, Test Engineers)
- 04 ☐ President, Owner/Operator, Vice President, General or Plant Manager
- 05 ☐ Other — please specify ______________

RFD 11-90

RF design — Reader INFO CARD

November 1990, Expires February 1991.

For information on products or services from the manufacturer, simply fill in the card and circle INFO/CARD numbers below.

Name ______________________ **Title** ______________

Company ____

Address ____

City/State/Zip ____

Telephone ____

Signature ______________________ **Date** __________

1	11	21	31	41	51	61	71	81	91	101	111	121	131	141	151	161	171	181	191	201	211	221
2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192	202	212	222
3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193	203	213	223
4	14	24	34	44	54	64	74	84	94	104	114	124	134	144	154	164	174	184	194	204	214	224
5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195	205	215	225
6	16	26	36	46	56	66	76	86	96	106	116	126	136	146	156	166	176	186	196	206	216	226
7	17	27	37	47	57	67	77	87	97	107	117	127	137	147	157	167	177	187	197	207	217	227
8	18	28	38	48	58	68	78	88	98	108	118	128	138	148	158	168	178	188	198	208	218	228
9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199	209	219	229
10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL

FIRST CLASS PERMIT NO. 12 PINE BROOK, NJ

POSTAGE WILL BE PAID BY ADDRESSEE

KAY

Kay Elemetrics Corp
12 Maple Avenue
Pine Brook, NJ 07058-9798

Place Stamp Here

RFdesign

Cardiff Publishing Company

5615 W. Cermak Rd.
Cicero, IL 60650

Place Stamp Here

RFdesign

Cardiff Publishing Company

P.O. Box 5286
Pittsfield, MA 01203-5286

THE ADVANCED PHOTON SOURCE AT ARGONNE NATIONAL LABORATORY

Argonne's APS Project is a $456 million dollar development. Its completion will allow scientists to explore the very heart of matter and to aid in the development of new materials—impacting industries worldwide. Professionals with a background in RF technologies are invited to join us in this ground-breaking project.

ELECTRICAL ENGINEER—RF CIRCUITS & SUB-SYSTEMS

Requirements include considerable knowledge of RF circuitry and techniques, system specifications, design review and budgetary restraints. A B.S.E.E. and 7-12 years of RF circuitry experience, including a minimum of 2-5 years directing technicians, is necessary. A Master's degree and experience directing other engineers is a plus. **(Box #36626)**

ELECTRICAL ENGINEER—HIGH POWER KLYSTRON AND WAVEGUIDE SYSTEMS

We require a B.S. or M.S. in E.E. and 5-12 years experience to include a minimum of 2-5 years experience directing technicians. In addition, considerable knowledge of CW multikilowatt, megawatt klystron and waveguide techniques; and a good understanding of related vacuum and mechanical design principles are also necessary. **(Box #82896)**

ENGINEER—ACCELERATOR BEAM DIAGNOSTICS

We seek applicants with an M.S. or Ph.D. in E.E. or Engineering Physics with experience in accelerator diagnostics systems. Knowledge of fast electronics logic theory, digital electronic computing, and fabrication and machining of materials is required. Skill in interpreting drawings, designing, and analytical and electrical techniques is also necessary. **(Box #31745)**

ASSISTANT ENGINEER/PHYSICIST

A Ph.D. in E.E. and considerable knowledge of electromagnetic theory and boundary value problems, electrodynamics, RF techniques, microwave circuits and measuring equipment are mandatory for success in this capacity. **(Box #82897)**

ASSISTANT ENGINEER

Requirements include a Ph.D. in E.E. and knowledge of electromagnetic theory and boundary value problems, RF techniques, microwave circuits and measuring equipment. **(Box #0004)**

ENGINEERING ASSISTANT

Applicants for this entry-level position should possess a B.S.E.E. and knowledge of RF techniques, microwave circuits and general E.E. principles. **(Box #82815)**

PHYSICIST—VACUUM & MECHANICAL ENGINEERING

Candidates should possess comprehensive knowledge of ultra-high vacuum physics and technology, surface physics and experimental techniques of surface science, as well as safety practices. **(Box #31735)**

Ron Johns, Manager, Human Resources-APS and Jim Bridges, RF Technical Coordinator-APS, will be available for interviews on November 13, 14, 15, & 16, 1990, at the Orlando World Center Hotel. Please leave a message with the hotel operator and we will arrange a confidential interview.

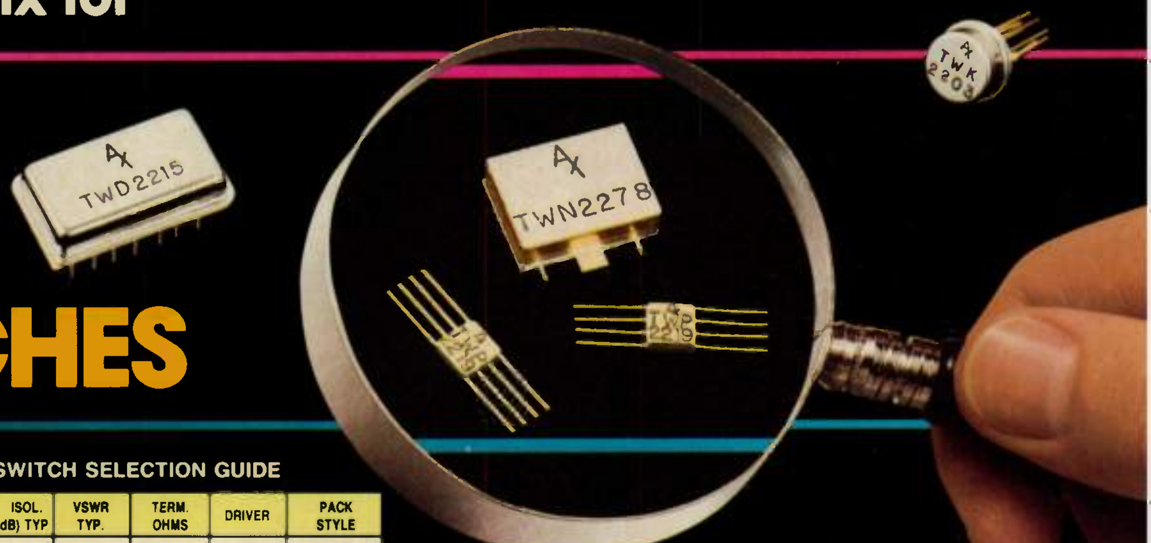
If unable to interview, please send resume to **Walter D. McFall, Box-J-APS-(Box#)-4E, Employment and Placement, ARGONNE NATIONAL LABORATORY, 9700 South Cass Avenue, Argonne, IL 60439.** Argonne is an equal opportunity/affirmative action employer. (Use your PC to learn more about ANL and other available opportunities. Dial (508) 263-3857 and key in the password ARGON.)

ARGONNE NATIONAL LABORATORY • UNIVERSITY OF CHICAGO •

TAKE A CLOSER LOOK...

Now the switch is on to Amplifonix for

GaAs FET SWITCHES



AMPLIFONIX GaAs SWITCH SELECTION GUIDE

MODEL. NO.	TYPE	FREQ. (MHz)	I.L. TYP.	ISOL. (dB) TYP	VSWR TYP.	TERM. OHMS	DRIVER	PACK STYLE
TWK2203	SPDT	DC-3000	0.8	50	1.15	50	0/-5V	TO5-3
TWP2204	SPDT	DC-3000	0.8	50	1.15	50	0/-5V	FTPACK
TWD2205	SPDT	5-3000	1.2	55	1.2:1	50	TTL	DIP
TWD2206	SPDT	5-3000	1.2	55	1.2:1	50	CMOS	DIP
TWP2209	SPST	DC-3000	0.7	45	1.15:1	50	0/-5V	FTPACK
TWK2213	SPST	DC-3000	0.7	55	1.15:1	50	0/-5V	TO5-3
TWP2214	SPST	DC-3000	0.7	55	1.15:1	50	0/-5V	FTPACK
TWD2215	SPST	5-3000	1.0	60	1.2:1	50	TTL	DIP
TWD2216	SPST	5-3000	1.0	60	1.2:1	50	CMOS	DIP
TWD2217	SPDT	5-2000	1.0	55	1.2:1	OPEN	TTL	DIP
TWD2218	SPDT	5-2000	1.0	55	1.2:1	OPEN	CMOS	DIP
TWP2219	SPDT	DC-3000	0.5	40	1.15:1	OPEN	0/-5V	FTPACK
TWK2224	SPDT	DC-2000	0.6	40	1.15:1	OPEN	TTL	TO5-3
TWP2231	SPST	5-3000	1.0	55	1.2:1	50	TTL	FTPACK
TWP2232	SPST	5-3000	1.0	55	1.2:1	50	CMOS	FTPACK
TWP2233	SPDT	5-2000	1.0	50	1.2:1	50	TTL	FTPACK
TWP2234	SPDT	5-2000	1.0	55	1.2:1	OPEN	TTL	FTPACK
TWP2238	SPDT	5-3000	0.9	50	1.2:1	OPEN	CMOS	FTPACK
TWD2241	SP3T	5-2000	1.0	60	1.2:1	50	TTL	DIP
TWD2242	SP3T	5-2000	1.0	60	1.2:1	OPEN	TTL	DIP
TWD2244	SP3T	5-2000	1.0	60	1.2:1	50	CMOS	DIP
TWD2245	SP3T	5-2000	1.0	60	1.2:1	OPEN	CMOS	DIP
TWP2247	SP3T	5-2000	1.0	55	1.2:1	50	TTL	FTPACK
TWP2248	SP3T	5-2000	1.0	55	1.2:1	OPEN	TTL	FTPACK
TWP2251	SP3T	5-2000	1.0	55	1.2:1	50	CMOS	FTPACK
SWP2252	SP3T	5-2000	1.0	55	1.2:1	OPEN	CMOS	FTPACK
TWD2254	SP4T	5-2000	1.0	55	1.2:1	50	TTL	DIP
TWD2255	SP4T	5-2000	1.0	55	1.2:1	OPEN	TTL	DIP
TWD2257	SP4T	5-2000	1.0	55	1.2:1	50	CMOS	DIP
TWD2258	SP4T	5-2000	1.0	55	1.2:1	OPEN	CMOS	DIP
TWP2261	SP4T	5-2000	1.0	55	1.2:1	50	TTL	FTPACK
TWP2262	SP4T	5-2000	1.0	55	1.2:1	OPEN	TTL	FTPACK
TWP2264	SP4T	5-2000	1.0	55	1.2:1	50	CMOS	FTPACK
TWP2265	SP4T	5-2000	1.0	55	1.2:1	OPEN	CMOS	FTPACK
TWN2278	SPST	5-3000	0.9	55	1.1:1	50	0/-5V	SURFMT

- DC to 3 GHz; SPST through SPNT
- Ultra-fast switching speeds
- Broad band frequency response
- Unit pricing starts as low as $29

High speed, broadband, GaAs FET switches are now available from Amplifonix. Some units are available with built-in TTL or CMOS drivers. All units operate over the temperature range from −54°C to +85°C and can be screened to the tables of MIL-STD-883.

For a closer look, call or write today for more information.

Amplifonix

2010 CABOT BLVD. WEST • LANGHORNE, PA 19047 • 215-757-9600 • FAX: 215-757-0378

INFO/CARD 29

Experiments with Primitive FET Mixers

By Wes Hayward
Microwave Division,
TriQuint Semiconductor

The Field-Effect Transistor has been used as a mixer since it first became available in discrete form. Both junction FETs and dual-gate MOSFETs are popular, usually as active mixers. Port-to-port isolation improves when balance is incorporated in the design. Although discrete FET mixers are common, integrated Gallium Arsenide circuits are also of interest, especially at microwave frequencies. Integration of multiple circuit functions on a single chip, including mixers, offers size and cost advantages in some receivers. Integration can also improve performance, usually through better transistor matching and reduced parasitic reactance.

The fabrication of an integrated circuit is an ever-evolving process. It is never casual, especially when compared with the methods we use with discrete components. A typical turnaround time through processing is seldom less than six weeks. Clearly, the IC design process should incorporate all available design tools.

The most powerful available tool is computer simulation. However, mixers are considerably more complicated than linear amplifiers, making them more difficult to simulate. Not only is the mixer intrinsically nonlinear, but our interest is often dominated by deviations from the normal, nonlinear behavior. It is not enough to determine conversion gain. We also wish to predict the mixer performance with regard to gain compression, LO drive dependance, noise figure, and intermodulation distortion.

SPICE (1) is a major nonlinear design tool used at TriQuint. Programs using harmonic balance (2) are growing in acceptance. Both program types depend upon the availability of accurate device models (3).

While computer simulation methods continue to grow, they do not replace experimental circuits. Early breadboards of FET mixers are built with off-the-shelf components. Testing often occurs at low frequency where measurements are less complicated and instrumentation is readily available. Detailed data is not as important as the understanding of circuit topology that comes from a primitive study.

In the next phase of breadboarding, traditional circuits offering promise are rebuilt with discrete versions of normally integrated components. FETs of various types and sizes, integrated resistors, capacitors, and inductors are built in unused corners of routine wafers. The wafers are then cut into small die, cataloged, and stored for later use. The chip components are attached to a package and interconnected with a wire bonder. The resulting "IC" is used in circuit construction. The resulting circuit performance is usually less than that available from a monolithic IC, but useful information is still gained.

The final test of an idea occurs after fabricating and packaging a monolithic integrated circuit. We frequently build "Multiple Project Chips," which provide a convenient method to test several integrated ideas. The MPC also replenishes our supply of breadboarding components.

All of these methods have been used in our quest for improved mixers. This paper emphasizes breadboarding experiments. Some of the mixers presented are easily integrated.

A test fixture, shown in Figure 1, was assembled from available components. Crystal controlled HF oscillators are

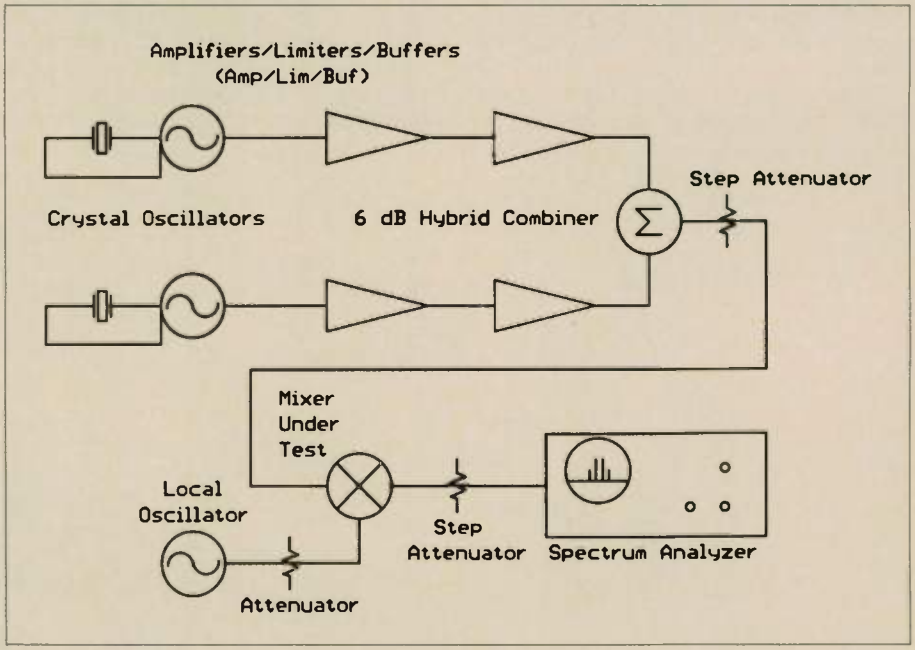


Figure 1. Test fixture.

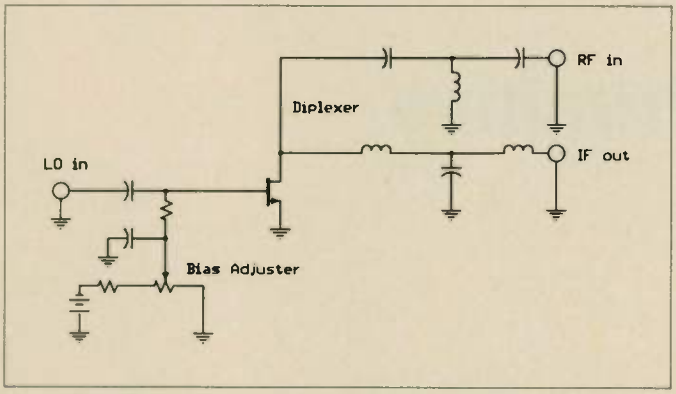


Figure 2. Mixer derived from Maas' X-band design.

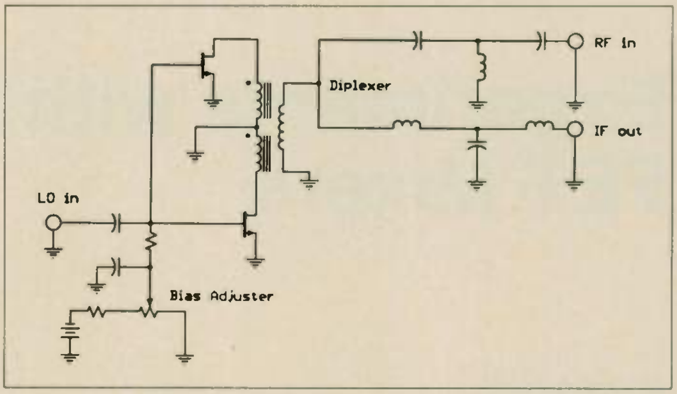


Figure 3. Single-balanced mixer with over 60 dB LO to IF isolation.

amplified, buffered, limited, and combined in a 6 dB hybrid combiner. The result is a two-tone source with an available output of +9 dBm per signal. Another source is a local oscillator with available output power up to +23 dBm. Numerous attenuators are available to control power levels. Mixer output is observed in a spectrum analyzer using commercially available high level diode ring mixers.

Single FET Mixers

The most common FET mixers are the familiar active, unbalanced JFET or dual-gate MOSFET designs. These have been widely discussed in the receiver literature (4, 5, 6). The less familiar passive circuits also offer promise. Although apparent in the literature, they have not found the widespread application of the active mixers. This paper emphasizes our results with passive mixers.

Figure 2 shows the first circuit examined. This topology is adapted from an X-band design by Maas (7). The circuit offers benefits beyond the obvious simplicity. The FET functions as a shunt resistor with a value that varies at the local oscillator rate (8, 9). Both RF and IF energy appear at the FET drain terminal. A diplexer separates the RF and IF components.

Several different FETs were tried in this circuit, with results summarized in Table I. Conversion gain and intermodulation distortion (third-order input intercept) are similar to those of diode rings. The unexpected feature is the LO to IF and LO to RF suppression. Because the FET has no bias, there is no gain at the LO frequency. Hence, the LO is suppressed by 15 dB or more at the other ports.

Although not included in Table I, we have measured and simulated GaAs FETs in this circuit. A single 1×300 micron depletion mode FET shows an insertion loss of 6 to 8 dB. Performance depends on FET width and geometry. Measured results are consistent with computer simulations.

Balanced Mixers with Shunt FETs

The single ended design is extended with the addition of a second FET, shown in Figure 3. The LO signal is applied, in phase, to both FET gates. The two drain voltages are out-of-phase, forced by a trifilar ferrite transformer. A diplexer isolates the IF and RF ports. Some results are shown in Table II. This circuit is especially simple, requiring but one IF/RF transformer. Excellent LO to IF isolation (over 60 dB) and reasonable gain are available. The circuit is not suitable for conversion to baseband, however.

A wideband singly balanced mixer is shown in Figure 4 with results presented in Table III. This mixer requires differential LO drive, but no diplexer is needed. LO to IF suppression is similar to that of Figure 3. The mixer is suitable for direct conversion to baseband. Both circuits offer low IMD if the optimum devices and LO voltage are used.

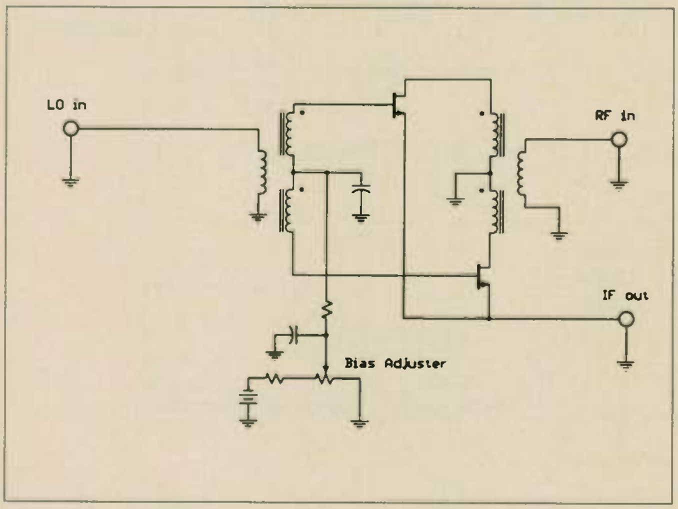


Figure 4. Wideband single-balanced mixer.

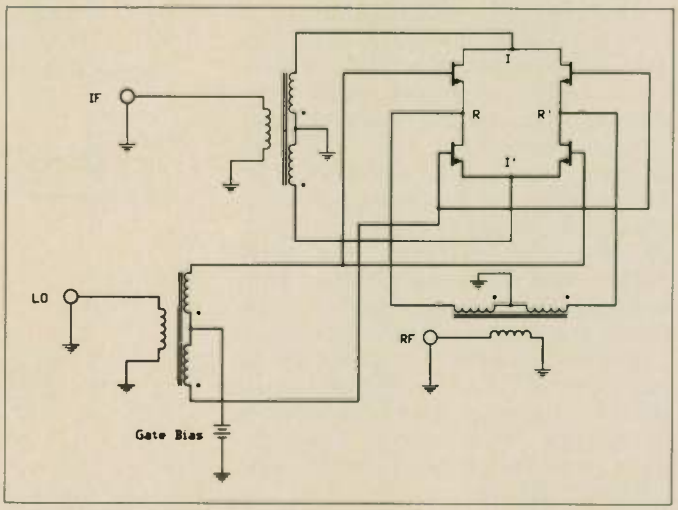


Figure 5. Oxner's FET ring mixer.

Coilcraft Designer's Kits

First they save you time. Then they save you money.

These kits make it easier than ever to pick the right coils, chokes and other magnetics for your project.

Why waste hours calling around for samples or trying to wind them yourself. Coilcraft's low-cost kits put dozens of values right at your fingertips!

You not only save time on engineering. You also save money when you go into production because we stock just about all the parts in our kits at low off-the-shelf prices.

Call in today, and you can have your kit tomorrow!

To order, phone **800/322-COIL**.

"Unicoil" 7/10 mm Tuneable Inductors
.0435 µH - 1.5 µH
49 shielded, 49 unshielded (2 of each)
Kit M102 $60

"Slot Ten" 10 mm Tuneable Inductors
0.7 µH - 1143 µH
18 shielded, 18 unshielded (3 of each)
Kit M100 $60

Surface Mount Inductors
4 nH - 33 µH
48 values (10 of each)
Kit C100 $125

Axial Lead Chokes
0.1 µH - 1000 µH
25 values (5 of each)
Kit F101 $50

Horizontal Mount Inductors
Tuneable and fixed
Inductance: 31.5 - 720nH
33 Values (6 of each)
Kit M104 $60

Common Mode Data Line Filters
Attenuation bandwidth: 15 dBm,1.5-30 mHz
DC current capacity: 100 mA
2, 3, 4 and 8 line styles (4 of each)
Kit D101 $65

Common Mode Line Chokes
Current: .25 - 9 amps RMS
Inductance: 508 µH - 10.5 mH
8 styles (2 of each)
Kit P202 $100

Current Sensors
Sensing range: 0.5-35 amps
Freq. resp.: 1 - 100 kHz, 50 - 400 Hz
Transformer and sensor-only versions
8 styles (15 total pieces)
Kit P203 $50

Base/Gate Driver Transformers
Inductance: 1.5 mH Min.
Frequency: 10 - 250 kHz
2 single, 2 double section (2 of each)
Kit P204 $50

Mag Amp Toroids
Current: 1, 5 amps
Volt-time product: 42 - 372 V-µsec
6 styles (2 of each)
Kit P206 $100

Power Filter Chokes
Current: 3, 5, 10 amps
Inductance: 5 - 300 µH
18 styles (48 total pieces)
Kit P205 $75

Axial Lead Power Chokes
Current: .03-4.3 amps
Inductance: 3.9 µH - 100 mH
60 styles (2 of each)
Kit P209 $150

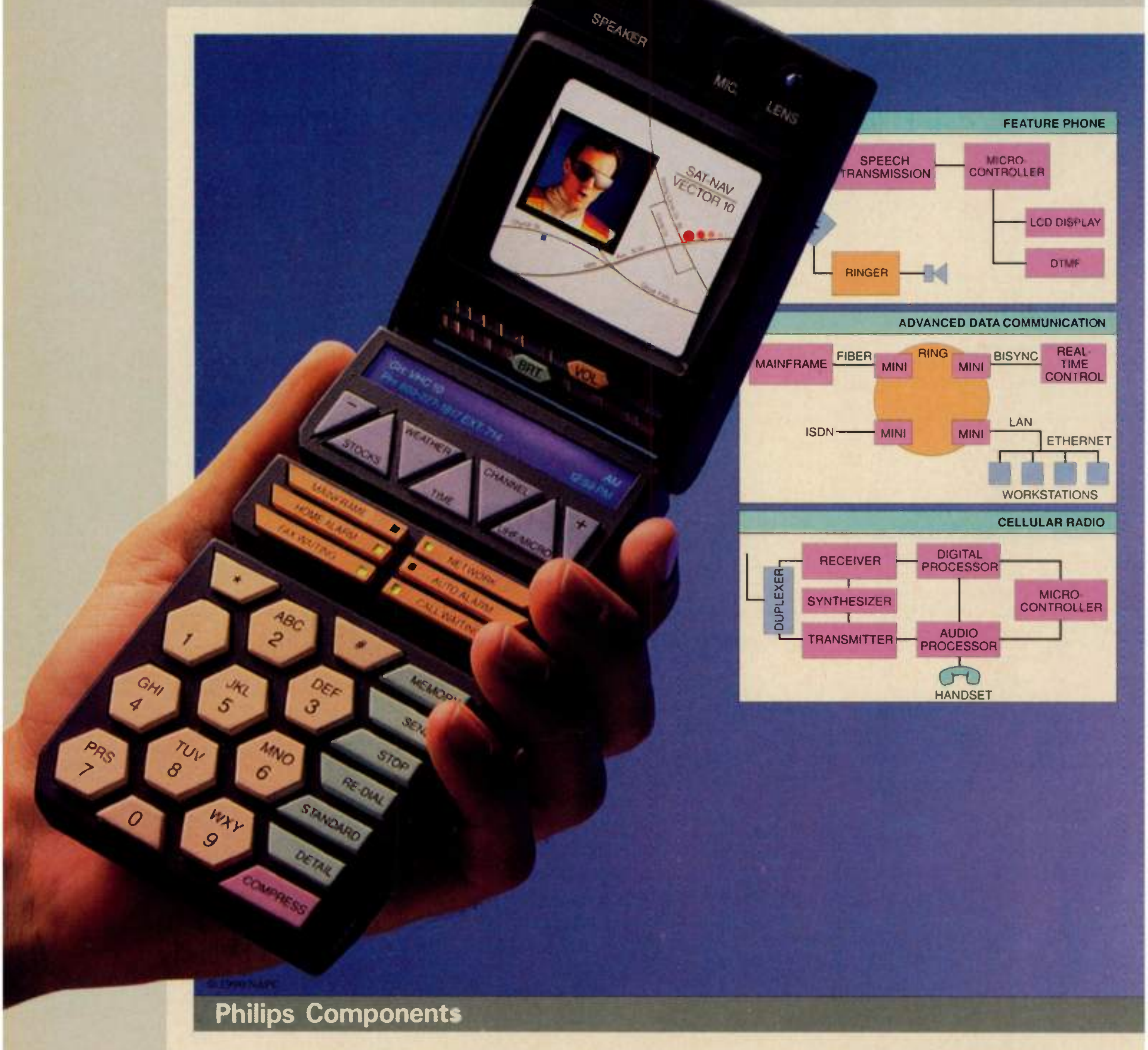
Coilcraft

eem electronic engineers master See our catalog in Vol. A, Section 1800

1102 Silver Lake Rd., Cary IL 60013 800/322-COIL Fax 708/639-1469

INFO/CARD 32

Signetics. Because today's
tomorrow's communi



remote possibilities are
ation breakthroughs.

FOR DESIGN INNOVATIONS, YOU NEED A FULL–SYSTEM SUPPLIER WITH NO STRINGS ATTACHED.

When it gets down to the wire, there's no better solution for your telephone, cellular, wireless or computer connectivity designs than Philips Components–Signetics.

We offer a complete range of high-performance ICs to tackle your ever-changing needs.

For compact radio designs, choose from a complete range of RF products. Including RF amplifiers, mixers and IF stages. As well as our fully programmable, low-power synthesizer with an RF divide from 400 MHz to over 1 GHz.

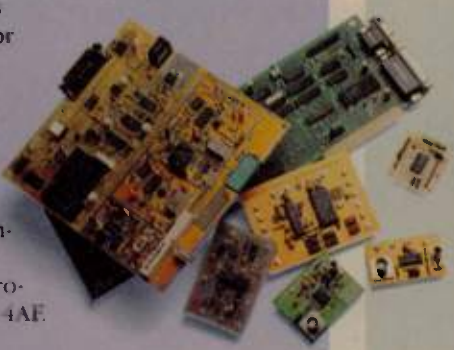
Plus there's our fully integrated cellular chip set. It includes demo-boards, software and software support and is the only complete solution for designing cellular radio applications. With it you can reduce the size of your portable product by reducing your chip count by up to 90%.

And for advanced feature phones, we offer a complete telephone solution including transmission circuits and feature circuits.

Or for high-speed computer connectivity there's our advanced Ethernet® chip set and 100 Mbit fiber optic transceiver chip set. We also offer ICs that handle all popular protocols, including DUSCCs and UARTs.

We're building a broad base of state-of-the-art products utilizing our advanced, world-class BiCMOS process QUBiC. Combining the best features of Bipolar and CMOS, we're now creating new classes of high-performance devices within all our product families.

Each communication IC is an example of how Philips Components–Signetics is designing smarter devices to meet tomorrow's needs. Including the need for military products. So whether you're designing your first product or a new generation of products, remember that at Philips Components–Signetics we always keep the lines of communication open. Call now for your communications brochure: 800-227-1817, ext. 714AF.



Ethernet is a trademark of Xerox Corp.

Signetics

EXTENDING THE DIMENSIONS OF PERFORMANCE

PHILIPS

PHILIPS

Please see us at RF Expo East, Booths #204, 206.

FET Type	Gc, dB	P-LO-av dBm	IP3in dBm	Bias Volts	Note #
SD21ODE	-10	+8	+15	+4.11	
VMP-4	-5.0	+8	+9	+1.77	
J310	-8.5	+8	+15.5	negative	(a)
TIS-88	-10	+8	+9	0	(b)
2N7000	-5.0	+8	+11	+1.92	
3N211	-12	+8	+12	0.1	
IRF-511	-9	+8	+8.5	+2.85	

(a) 2:1 turns ratio transformer used to increase gate LO voltage.
(b) TIS-88 is similar to a 2N4416.

Table I. Single-Ended FET Mixers with Diplexer.

FET Type	Gc, dB	P-LO-av dBm	IP3in dBm	Bias Volts
SD21ODE	-11	+8	+16	—
	—	+11	+21	—
	—	+17	+25.5	—
	—	+23	+31.5	—
J310	-8	+11	+21	negative
	-7	+17	+23	negative

Table II. Singly Balanced Narrowband FET Mixer with Diplexer.

FET Type	Gc, dB	P-LO-av dBm	IP3in dBm	Bias Volts	Note #
SD210	-9.5	+11	+17.5	—	
	-7.0	+23	+31.0	—	(a)
M, 1mm	-4.6	+8	+17	-1.54	
	-5.1	-2	+9	-1.54	
E, 1mm	-5.9	-5	+8	+0.58	

(a) Performance with SD211 essentially edentical to SD210.

Table III. Singly Balanced Wideband FET Mixer.

FET Type	Gc, dB	P-LO-av dBm	IP3in dBm	Bias Volts	Note #
Si8901	-10	—	+31	Approx. +2	(a)
	-11	+11	+22	—	(b)
	-9.5	+17	+30	—	
	-9.5	+23	+34	—	
4X M-1mm	-6.0	-2	+13	-1.55	(c)
	-5.6	+2	+17.5	-1.57	
	-5.2	+4	+21	-1.54	
	-5.1	+8	+22.5	-1.53	
4X HA-0.3mm	-9.7	+7	+17.2	—	(d)

(a) Siliconix Ring operated with 2N3904 differential amplifier at LO port, 15 mA total current. 1:1 Current Balun at RF, DC coupled I-F.
(b) Ring operated with 1:1:1 voltage balun at LO port. 1:1 Current balun at RF port, DC coupled I-F.
(c) Monolithic Ring, 1 x 300 Micron HA FETS, 1:1:1 voltage balun at LO, 1:1 Current Balun at RF. DC Coupled I-F.

Table IV. FET Ring Mixer.

TCXO's in DIP packages

ALL Logic Families available in 4- or 14-pin DIP .5"x.8"x.375"

OSCILLATEK M84 SERIES

ACTUAL SIZE

SPECIFICATIONS

Voltage stability: Vcc ± 5%, Δ F < 1PPM
Vcc ± 10%, Δ F < 12PM

Aging: 5 PPM first year; 2PPM per year thereafter

Frequency Adj.: Control voltage in range of 0 to 5V (variable capacitor optional)

STABILITY TEMPERATURE RANGE	FREQUENCIES AVAILABLE
±1PPM, 0°C to +50°C	HCMOS/TTL 1KHz to 32MHz
±2PPM, 0°C to +70°C; −20°C to +70°C	CMOS 1KHz to 10MHz
±5PPM, 0°C to +50°C; −20°C to +70°C; −40°C to +85°C	ECL 10MHz to 32MHz
±10PPM, −20°C to +70°C; −40°C to +85°C; −55°C to +105°C	SINE 10MHz to 32MHz

K&L OSCILLATEK

620 N. Lindenwood Drive • Olathe, Kansas 66062
FAX: (913) 829-3505 • TELEX: 437045
Phone: (913) 829-1777

INFO/CARD 30

QUARTZTEK

QUARTZ CRYSTALS*
CRYSTAL FILTERS

• DISCRETE • MONOLITHIC •
SUPERIOR AGING*

*ANOX. CRYSTALS
EXCELLENT FREQ.
CONTROL

SOLUTIONS NOT PROBLEMS

WITH YOUR FREQUENCY CONTROL DESIGNS.

CALL OR FAX YOUR CRYSTAL OR CRYSTAL FILTER REQUIREMENTS TO THE QTEK ENGINEERING STAFF AND LET THEM HELP YOU WITH

THE SOLUTION

QUARTZTEK
20 S. 48TH AVE.
PHOENIX, AZ. 85043
602-272-7944 FAX: 233-2440

INFO/CARD
31 CRYSTALS 102 FILTERS

Table III includes some GaAs FET data. The FETs had a channel width of 1 mm, larger than usually found in an integrated circuit. Two FET types were used. The first is an "M," a depletion mode device with a typical pinchoff of −2 volts. The other, the "E" FET, functions in the enhancement mode with a threshold of +0.15 volt. A third type from the same process is the "D" FET, a depletion mode device with a typical pinchoff voltage of −0.6 volt. Mixer performance with the D is intermediate between that obtained with the M and the E (10). The integral gate-source diodes of a MESFET limit the LO voltage. Silicon MOSFETs have no diodes at their gate. Hence, they will withstand higher gate voltage to produce higher 3rd order input intercepts. The low conversion loss, less than 5 dB, is characteristic of the GaAs FETs.

FET-Ring Mixers

Wideband port-to-port isolation is enhanced with doubly balanced mixers. A popular circuit is the FET ring mixer described by Oxner, shown in Figure 5 (11). This design features especially low intermodulation distortion, but is restricted to HF and VHF application. Transformers occur at all three ports, making this mixer difficult to integrate.

The traditional diode ring achieves double balance with only two transformers. This is also possible with FETs, shown in Figure 6. One corner of the ring is grounded with a single-ended IF signal extracted from the opposite corner. A voltage balun supplies the local oscillator to the gates while RF energy reaches the ring through a current balun. The transformer forms are vital to proper operation. Specifically, a voltage balun will not work at the RF port. Individual transformer windings are paralleled by a FET; the transistor will then short circuit the balun.

The RF balun in Figure 6 forces equal currents in the two windings, but allows arbitrary voltages at the R-R′ port. The 1:1 current balun used is especially simple. A bifilar winding on a ferrite core is used at HF while a ferrite bead or sleeve over a twisted pair serves for higher frequencies. Pick a bead with a hole diameter large enough to accommodate the twisted pair, but no larger.

We studied the circuit of Figure 6 with the Siliconix Si8901 and with a variety of GaAs rings. Some of this data is presented in Table IV. The device of greatest interest is the 1 mm M-FET. The ring was built with discrete FETs from the same processing run, with no other attempt at matching. The ring results are an extension of those of the singly-balanced mixers. Conversion loss under 6 dB occurred with the large width GaAs FETs. The third-order input intercept was +22 dBm. This performance was available with low LO power. Much larger input intercepts were available with the Si8901, but conversion loss was higher. The dependance of intercept upon LO power is similar to that reported by Oxner.

An Integrated Ring

Figure 7 shows a partial schematic of an integrated ring mixer with on-chip active baluns. This circuit has been built with 100 micron enhancement mode GaAs FETs in the ring. The small FET

Application Specific Bipolars

Need quality, reliability and performance for your specific application? Start here and save yourself a search.

We offer a wide selection of NEC Bipolar Transistors screened for Space and Military requirements—as well as commercial devices in chip form and a variety of packages, including Micro-X and tape and reel.

Part Series	Description
NE647/648	K-Band oscillators over MIL Temp ranges
NE645/681	Low Noise, Cost Effective for L/S Bands
NE333	700mW Class A, 1.25W Class C L/S-Band amps
NE567	High Gain C-Band amps, C/X-Band oscillators
NE856	High Gain, Low Cost, Low Noise for L-band
NEL2300	Consistent 3W Class A output in S-Band
NE243	630mW for high C-Band oscillators
NE568	Medium Power, High Gain for S-Band amps

CEL can also provide the support and characterization data you need to accurately determine your circuit's performance using NEC parts.

FREE DATA FOR DESIGNERS
For a product selection catalog, call, write or circle the number below.

NEC

California Eastern Laboratories

Headquarters (408) 988-3500 FAX (408) 988-0279
4590 Patrick Henry Drive, Santa Clara, CA 95054
Western (408) 988-7846 Eastern (301) 667-1310
Central (708) 655-0089 Canada (613) 726-0626

© 1989 California Eastern Laboratories

INFO/CARD 92

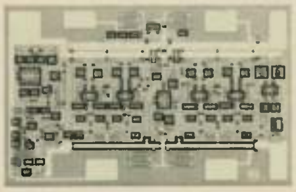
Please see us at RF Expo East, Booth #407.

NOW PUT A LITTLE AVANTEK MAGIC IN YOUR SYSTEM

Avantek MagIC™ High Speed ICs Enable Superior System Designs

magIC™

The new MagIC™ series of silicon bipolar MSI integrated circuits offer the best performance available from silicon ICs yet. The broadband, high frequency performance of these high-speed silicon ICs make them cost-effective alternatives to more expensive GaAs ICs. Avantek MagIC silicon ICs are manufactured with Avantek's proprietary 10-15 GHz F_t, 25 GHz F_{max} Isosat™ process for unsurpassed integration and performance at microwave frequencies. Avantek's MagIC series ICs presently consists of four product families: low noise amplifiers, active mixers, variable gain control amplifiers, and prescalers. These low-cost, high-speed silicon ICs are Avantek's magic solutions to your RF, microwave and lightwave system performance and cost problems.



High Performance, High Speed, Low Cost . . .

The INA-series of two-stage low-noise amplifiers presently consists of three models, offering:

- 3 dB bandwidths to 2.8 GHz
- Gains as high as 32 dB
- Noise figures as low as 1.7 dB
- Prices as low as $22.00 each* in hermetic 70 mil surface mount package

The IAM-series of active mixer/amplifiers presently consists of two models, offering:

- RF and LO frequency range of .05 to 5.0 GHz
- Conversion gain as high as 15 dB
- LO power as low as −10 dBm
- Prices as low as $16.00 each* in hermetic 180 mil surface mount package

The IVA-series of variable gain control amplifiers presently consists of two models, offering:

- 3 dB bandwidths to 3.0 GHz
- 30 dB gain control range
- Gains as high as 26 dB
- Prices as low as $28.50 each* in hermetic 180 mil surface mount package

The IFD-series low phase noise static prescalers offer:

- Divide-by-4 to 5 GHz
- Low 125 mW Power Consumption
- Prices as low as $18.50 each* in hermetic 100 mil surface mount package

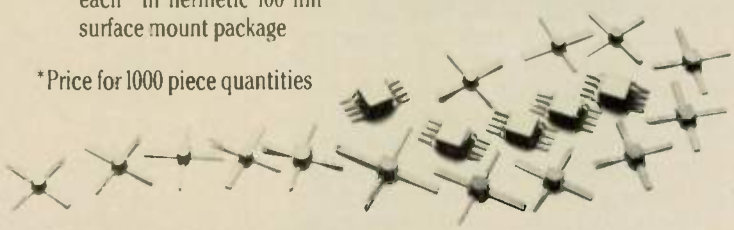
*Price for 1000 piece quantities

MagIC™ ICs Are Available in Quantity for Volume Applications

Avantek presently produces more than 1,000,000 MMICs per month. So you can be assured the MagIC high speed ICs you need will be available to support your volume production programs. And, all MagIC silicon ICs are in stock at your local Avantek distributor.

For additional information, or the name and address of your local distributor, contact the regional sales office nearest you.

Regional Sales Offices
North America
Eastern: (301) 381-2600
Central: (312) 358-8963
Western: (805) 373-3870
European: (44) 276-685753



Magic Solutions in Silicon

AVANTEK

INFO/CARD 28

Please see us at RF Expo East, Booth #417.

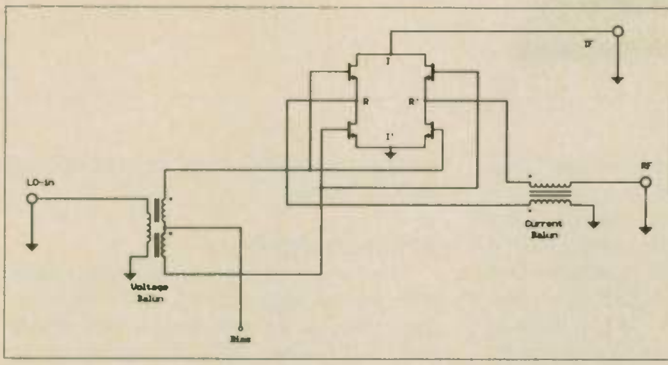


Figure 6. FET ring mixer with two transformers.

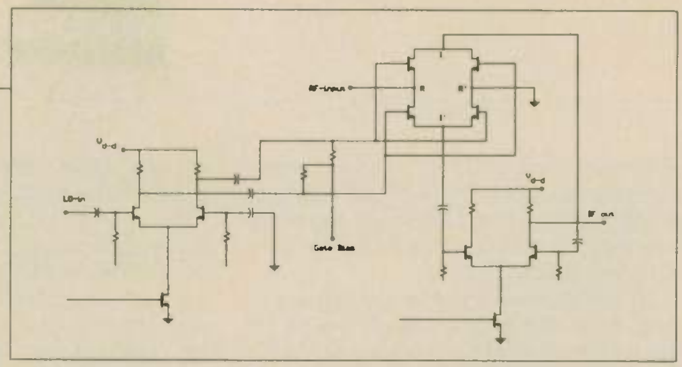


Figure 7. Partial schematic of an integrated ring mixer with on-chip active baluns.

width and active IF balun both compromise intermodulation distortion performance. However, local oscillator drive is less than that required by larger FETs. The enhancement mode FETs have low thresholds, further easing the LO drive problems. The active IF balun is a high impedance load for the ring. The high impedance makes it tempting to apply rings with small FETs when IMD is not critical. Unfortunately, noise figure could also suffer. The ring of small FETs has low available conversion gain.

Recall that "available power gain," rather than "power gain" or "transducer gain" is the important gain that affects noise figure (12). Available power gain is defined as the ratio of the power available from a network to the power available from the source. Hence, it is calculated by conjugately matching the network output while leaving the input unchanged. Available power gain of a nonlinear network is easily extracted from SPICE simulations. The active IF balun is replaced with a floating resistive load to speed calculations. A transient analysis is then performed. A LO sinusoid differentially drives the gates while another excites the RF port. The intermediate frequency component is filtered with a Fourier Transform (usually a part of SPICE) and the IF power delivered to the resistor is calculated. The process is repeated with a variety of load resistors to find a maximum. This value establishes the available power gain. With a 50 Ohm driving source impedance, the available power gain of the ring of 100 micron FETs was −14 dB. This improves to −10 dB with a higher driving impedance. Available power gain in a ring mixer improves with larger FETs, but the improved performance is accompanied by higher LO power requirements.

The simulations are confirmed with noise figure measurements. SPICE can also be used to evaluate the noise performance of the active baluns and other amplifiers. In spite of the noise problem, the mixer with small FETs (Figure 7) is still useful, offering LO to

New!
2.8 GHz Prescalers...
in Silicon!

By directly synthesizing frequencies up to 2.8GHz our new low priced prescalers help you simplify your designs, minimize the number of components, and reduce board space.

What does your application call for? Low cost plastic packages? Chips or ceramic packages that can be MIL or Space screened? Low voltage devices for battery powered designs?

MODEL	FREQUENCY	V_{CC}	I_{CL}	DIVISION RATIO
UPB581	0.5–2.8GHz	5V	30mA	2
UPB582	0.5–2.8GHz	5V	45mA	4
UPB584	0.5–2.5GHz	5V	18mA	2
UPB585	0.5–2.5Ghz	5V	26mA	4
UPB587	0.05–1GHz	2.2 to 3.5V	5.5mA	2, 4, 8

Call today. We'll work with you engineer-to-engineer to see that you get the parts you need, at a price that's right. And in most cases, we can ship directly from stock.

NEC technology and quality—and CEL service. It's a powerful combination. Put it to work for you.

FREE DATA FOR DESIGNERS

For data sheets and a full line Si MMIC specifications brochure, call, write or circle the number below.

NEC®

California Eastern Laboratories

Headquarters (408) 988-3500 FAX (408) 988-0279
4590 Patrick Henry Drive, Santa Clara, CA 95054
Western (408) 988-7846 Eastern (301) 667-1310
Central (708) 655-0089 Canada (613) 726-0626

©1989 California Eastern Laboratories

INFO/CARD 34

Please see us at RF Expo East, Booth #407.

IF suppression of 30 dB. Current consumption was only 10 mA from a single 5 volt supply. The LO power required was only −5 dBm and net down conversion gain was 8 dB.

All of the mixers presented require a fixed bias. The gate-source of the FETs are biased to be at pinchoff or threshold. The LO then causes low resistance on the positive half cycle, and a high value on the other half. Most of the data presented was obtained at HF and low VHF. Some of the ring mixers were investigated at higher frequency. A ring of 1 mm M-FETs had relatively flat conversion gain up to 500 MHz. Insertion loss increased at 1 GHz, but could be regained with increased LO power, suggesting limitations in the balun. LO port tuning may also prove useful. The smaller, monolithic rings functioned well up to 1.6 GHz.

Acknowledgments

The writer gratefully acknowledges discussions with colleagues at TriQuint, especially those with Angus McCamant and Jeff Damm. Special thanks go to Ed Oxner at Siliconix for numerous discussions. *RF*

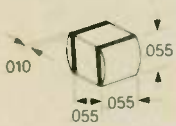
Sample our Hi-Q, Porcelain COG Chip Capacitors!

There's no longer a need to settle for P90 temperature characteristics in circuits requiring high Q capacitors. Murata Erie's new MA58 and MA68 porcelain chips provide both high Q and a COG (NPO) temperature coefficient at very competitive prices. They meet MIL-C-55681 specifications, too.

Try them.

Just order one of our Design Engineering Kits listed below at a special introductory price of only $49.95 and find out how COG TC's can make your life a lot easier.

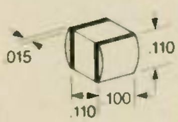
CASE 1



KIT MA58-001 (5 each of 15 values)

Cap.	Tol.	Cap.	Tol.	Cap.	Tol.	Cap.	Tol.
1.0pF	B	4.7pF	D	12pF	K	47pF	K
1.8pF	C	5.6pF	D	15pF	K	56pF	K
2.7pF	D	6.8pF	K	22pF	K	100pF	K
3.3pF	D	10pF	K	33pF	K		

CASE 2



KIT MA68-001 (5 each of 15 values)

Cap.	Tol.	Cap.	Tol.	Cap.	Tol.	Cap.	Tol.
1.0pF	C	6.8pF	D	33pF	J	470pF	M
2.2pF	D	10pF	J	47pF	J	680pF	M
3.6pF	D	15pF	J	68pF	J	1000pF	M
5.6pF	D	27pF	J	100pF	J		

To order your kit, call 814-237-1431. Ask for Hi-Rel/Hi-Q Customer Service. (VISA accepted.)

State College Operations
1900 W. College Avenue
State College, PA 16801
Tel: 814-237-1431
Panafax: 814-238-0490

muRata ERIE
MURATA ERIE NORTH AMERICA

INFO/CARD 35

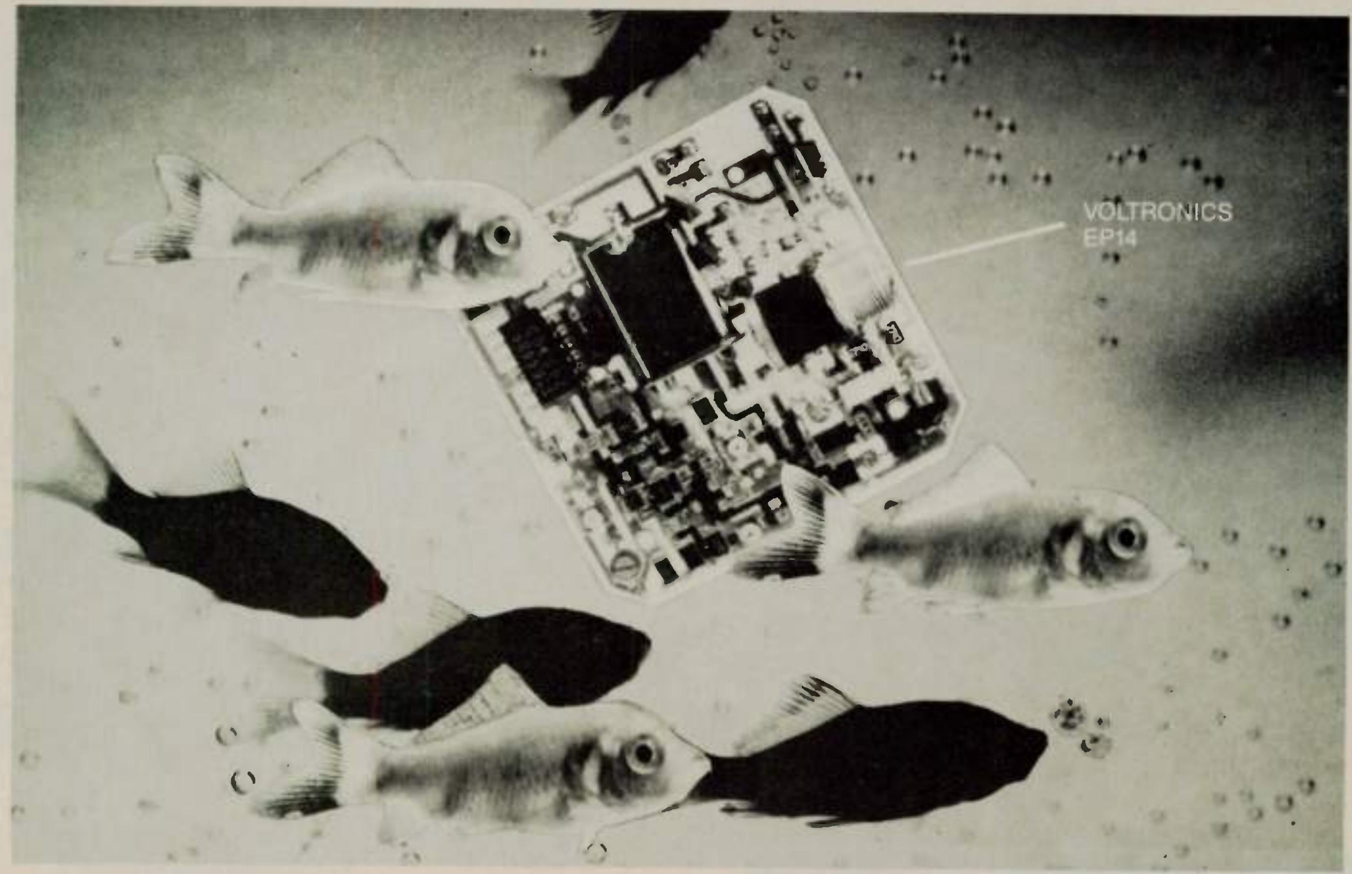
Please see us at RF Expo East, Booth #210.

References

1. Banzhaf, *Computer-Aided Circuit Analysis using SPICE*, Prentice-Hall, Englwood Cliffs, N.J. 1989.
2. Harmonic Balance programs, Compact Software, 483 McLean Blvd and 18th Ave, Paterson, N.J. 07504, EEsof, Inc., 5795 Lindero Canyon Road, Westlake Village, CA 91362.
3. McCamant, McCormack, and Smith, "An Improved GaAs MESFET Model for SPICE," Paper submitted to IEEE Trans. on MTT.
4. Rohde and Bucher, *Communications Receivers Principles & Design*, McGraw-Hill, New York 1988
5. Sabin & Schoenike, *Single-Sideband Systems & Circuits*, McGraw-Hill, New York 1987
6. Hayward, *Introduction to Radio Frequency Design*, Prentice-Hall, 1982.
7. Maas, "A GaAs MESFET Mixer with Very Low Intermodulation," *IEEE Transactions on Microwave Theory & Techniques*, Vol. MTT-35, No.4, April, 1987
8. Maas, *Microwave Mixers*, Artech House, Dedham, MA 1986.
9. Maas, *Nonlinear Microwave Circuits*, Artech House, Dedham, MA 1988.
10. Oxner, "A Commutation Double-Balanced Mixer of High Dynamic Range," *Proceedings of RF Technology Expo 86*, Anaheim, Calif., pp 309-323.
11. Oxner, "Commutation Mixer Achieves High Dynamic Range," *RF Design*, February, 1986, pp47-53.
12. Gonzalez, *Microwave Transistor Amplifiers*, Prentice-Hall, Englewood Cliffs, N.J., 1984.

About the Author

Wes Hayward received his Bachelor of Science degree in Physics from Washington State University and his MSEE from Stanford. He is currently a Senior Engineer for the Microwave Products Division at TriQuint Semiconductor, P.O. Box 4935, Group 700, Beaverton, OR 97076. His telephone number is (503) 644-3535.



Today's Board Washing Is Really Tough. Can Your Trimmer Capacitor Handle This?

Internal O-ring and sealed case resist water, flux, cleaning solvents and vapors

- No loose caps or leaky press fits
- Surface mount versions of all styles
- High reliability screening available
- Capacitance ranges from 0.3 - 1.2pF to 2 - 250pF
- Multi-turn tuning resolution
- Air, sapphire, glass, quartz, and Teflon® dielectrics

Voltronics trimmer capacitors are proven in the most rigorous applications such as: aircraft radios, satellite communication equipment, manpack radios, radar sets, cable TV transmission gear, fiber optics circuits and numerous other military and commercial RF to Microwave circuits.

Voltronics engineers respond quickly to requests for modifications or "specials". Call us and see how easy it is to find the perfect trimmer for your application.

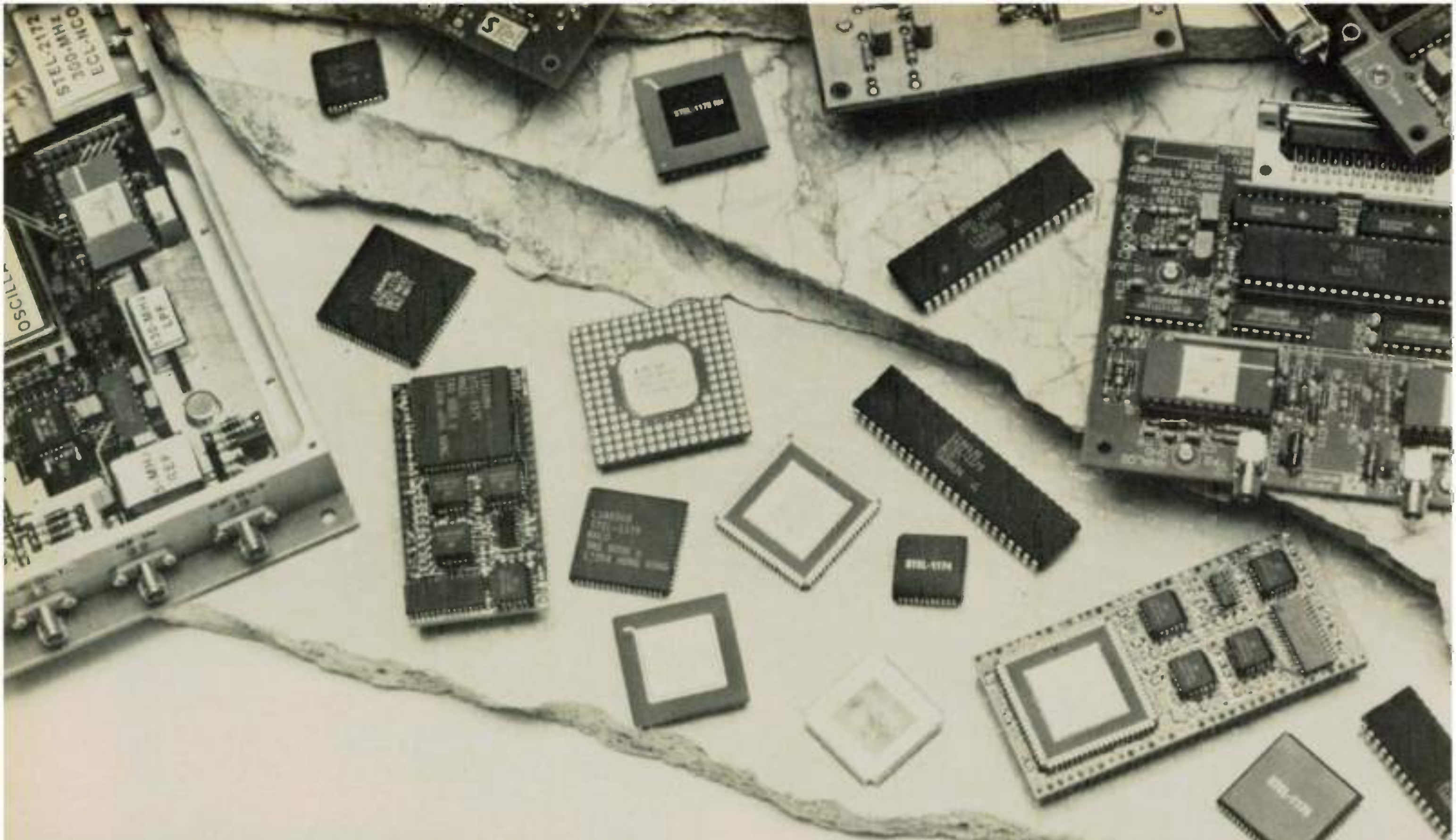
Quick Ship
72 hour delivery available
for up to 200 pieces of most parts

Voltronics offers a complete line of high performance trimmer capacitors

Voltronics CORPORATION
WEST STREET ■ P.O. BOX 476
EAST HANOVER, NEW JERSEY 07936
(201) 887-1517 ■ FAX 201-887-3349

INFO/CARD 36

Please see us at RF Expo East, Booth #516.



PRODUCTS FOR DIRECT DIGITAL SYNTHESIS

DDS

STANFORD TELECOM offers the most comprehensive selection of numerically controlled oscillators (NCOs), DDS boards and chassis assemblies in the industry.

In addition, a comprehensive set of digital integrated circuits for spread spectrum and forward error correction is also offered.

We can provide data sheets, application notes, and even handbooks. Please call, fax, or write the ASIC & Custom Products Group for additional information.

Telephone: (408) 980-5684 • Fax: (408) 727-1482

2421 Mission College Boulevard
Santa Clara, CA 95054-1298

STANFORD TELECOM

MONOLITHIC NCOS

STEL-1172B	50 MHz, 32-bit, Quadrature
STEL-1173	50 MHz, 48-bit, High Resolution
STEL-1174	50 MHz, 16-bit, Low Cost
STEL-1175	60 MHz, 32-bit, Phase Modulated
STEL-1176	80 MHz, BCD/Decimal, high speed CMOS
STEL-1177	60 MHz, 32bit, full PM, FM, & Quadrature
STEL-2172	300 MHz, ECL, 28-bit
STEL-2173	1 GHz, GaAs, 32-bit, BPSK, QPSK

BOARD LEVEL DDS

STEL-1272	based on 1172B, 0-20 MHz
STEL-1273	based on 1173, 0-20 MHz
STEL-1275	based on 1175, 0-25 MHz
STEL-1375A	miniature assembly based on 1175
STEL-1376	miniature assembly based on 1176
STEL-1377	miniature assembly based on 1177
STEL-1277	based on 1177, 0-25 MHz
STEL-2272	based on 2172, 0-130 MHz
STEL-2273	based on 2173, 0-400 MHz

CHASSIS-LEVEL DDS

STEL-9272	based on 2172
STEL-9273	based on 2173

ASIC & Custom Products Group

INFO/CARD 37

Dynamic Evaluation of High Speed, High Resolution D/A Converters

By James J. Colotti
CSD/Telephonics

Practically speaking, the all-digital receiver will never exist. Yet, as digitally uncharted waters dwindle, many traditionally analog functions are being replaced by their digital counterparts — augmenting the performance of the remaining analog components and thus the overall system. One interface device that merges these two technologies is the high speed, high resolution digital-to-analog converter (DAC or D/A Converter). Two potential applications of DACs are shown in Figure 1. While DAC applications are not limited to receiver design, virtually all high speed/high resolution applications require careful evaluation of potential candidates to assure that the appropriate device is selected. Although most manufacturers provide a comprehensive set of characterization data, the device will often not be specified under the specific conditions called for in an application.

To alleviate this uncertainty, the D/A dynamic evaluation techniques outlined in this article were developed. Through a trio of tests: single tone, two tone, and noise power ratio (NPR), the performance of a potential D/A can be comprehensively analyzed. While this article will focus on RF applications, these tests are applicable to the dynamic characterization of most any DAC.

The Test Set Up

As depicted in Figure 2, the DAC under evaluation receives digital inputs that are generated as follows: A TTL clock of the required sampling frequency, f_s, drives a counter chain which generates addresses for the high speed memory (EPROM or RAM). Contained in the memory is the look-up table of codes that generate the appropriate test tone or tones. The sampling frequency will often dictate the memory type that is employed. EPROMs can provide a convenient storage medium, however, they typically exhibit slower access times than RAMs. One drawback to

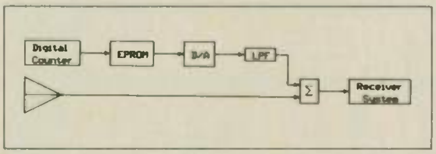


Figure 1a. A built-in test tone injection application for a high speed, high resolution DAC.

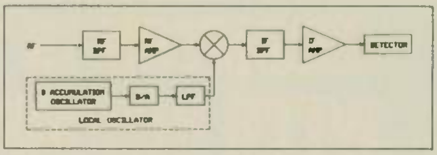


Figure 1b. A superheterodyne receiver with digitally generated local oscillator.

using RAMs however, is the continual need for the download hardware.

Wave generation software is used to create and download the look up table data to the memory devices. The software also loads in a reset command that will clear the counter chain, once the final data point is read. This allows the counter to continuously run from 0 to some maximum value, N-1. Data output from the memory is latched to minimize erroneous transitional data, and then presented to the D/A converter. This look-up table generation technique is preferred over other approaches by virtue of its ease of implementation and multi-tone generation capability.

The analog output of the DAC is presented to the spectrum analyzer where the frequency spectrum is monitored. Due to the high image frequencies contained in the D/A output, it is sometimes necessary to limit the bandwidth with a low pass filter depending on the test equipment limitations.

Each test of the trio is useful for examining various D/A performance parameters. For example, harmonic distortion (HD) and signal to quantization noise performance are readily accomplished with the single tone test. Since the resulting spectrum is relatively uncluttered, as compared to the other tests, the single tone analysis is also useful for characterizing other DAC parameters, such as power supply rejection and gain accuracy.

Harmonic distortion is characterized by products that occur at integer multiples of the fundamental frequency. Often, the second and third products of a DAC are most prominent.

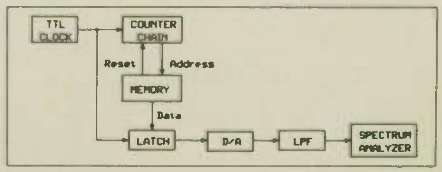


Figure 2. DAC test set up.

The two tone test is useful for examining intermodulation products, a nonlinearity characterized by distortion products that occur at sums and differences of integer multiples of the two primary frequencies. Typically, the dominant IM products are among the second order components located at f_2-f_1 and f_1+f_2, and the third order components located at $2f_1-f_2$ and $2f_2-f_1$. Although this test can also be used for signal to noise ratio evaluation, it is limited to less than full scale testing due to saturation problems that would arise if the instantaneous amplitude of the combined signals exceeded the full scale limit. For example, if two equal amplitude tones are considered, the level of each must be at least 6.02 dB below the D/A full scale level to avoid saturation.

The NPR test, considered the most stringent of the three, is used to evaluate a converter's ability to replicate wide band signals such as those encountered in spread spectrum communication. This test entails generating a comb of uniformly spaced frequencies over a range dictated by the application. The comb is then characterized by a narrow notch that is usually located in the center of the frequency range.

Inside the notch, below the lower frequency limit, and above the upper frequency limit would appear the culmi-

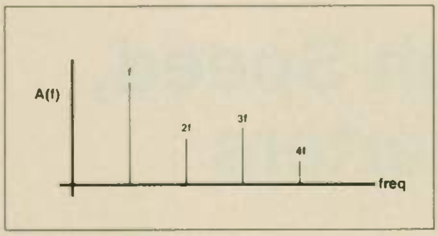


Figure 3. Harmonic distortion.

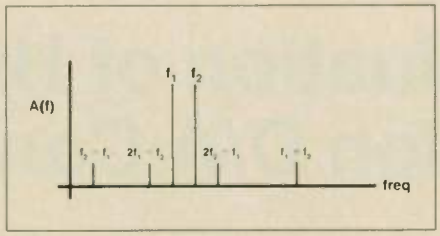


Figure 4. Intermodulation products.

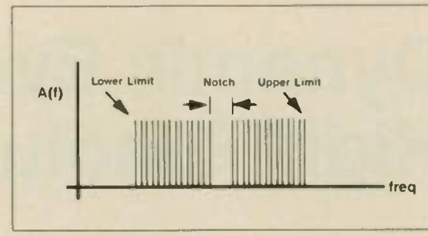


Figure 5. NPR signal.

BOONTON IS SYNONYMOUS WITH RF/RMS VOLTMETERS!

Boonton (bo͞on' tŭn) *n.*, New Jersey manufacturer of quality electronic instrumentation for over 40 years. Famous for sensitive and highly accurate RF/RMS Voltmeters.

This tradition is continued with the two latest Boonton models that find wide acceptance in telecommunications, cable TV, and military applications. The digital 9200B offers the widest frequency and level ranges available, 10 Hz to 2.5 GHz and 100 μV to 3 V (300 V with 100:1 divider.) Selected display indication may be made in mV or dB relative to selected impedances between 5Ω and 2500Ω, or to a voltage or power reference. Calibration data for eight interchangeable probes stored in non-volatile memory. Options include a second input channel for gain/loss measurements and GPIB or MATE compatibility. The low-cost analog 92EA, with the same voltage range, covers frequencies from 10 Hz to 1.2 GHz with a choice of optional meter scales.

Both instruments feature:
- ☐ Low noise, passive RMS detection with microvolt sensitivity
- ☐ Detachable and replaceable probe cables of any length
- ☐ Complete family of accessories, including 100:1 voltage divider and terminated or through-line adapters for both 50Ω and 75Ω applications.

BOONTON

Boonton Electronics Corporation

791 Route 10, Randolph, NJ 07869, Telephone: (201) 584-1077, FAX: (201) 584-3037

Signal Generators ■ Modulation Analyzers ■ RF Power Meters ■ RF/RMS Voltmeters ■ Scalar Network Analyzers ■ Impedance Meters and Bridges ■ Audio Test Instruments ■ Sweep Generators/Synthesizers

INFO/CARD 38

Please see us at RF Expo East, Booth #423.

nation of the nonlinear products generated by the converter. Often, the discrete products of these nonlinearities are so numerous that a wide band noise appearance is created — which is particularly noticeable in the notch. This test can be especially useful since manufacturers rarely evaluate the NPR performance of their devices.

The wave generation software mentioned earlier, also contains a fast fourier transform (FFT) algorithm that allows the look-up table data to be viewed in the frequency domain prior to downloading. This useful reference illustrates the performance of an ideal DAC of the desired resolution. Use of the FFT algorithm however, restricts the number

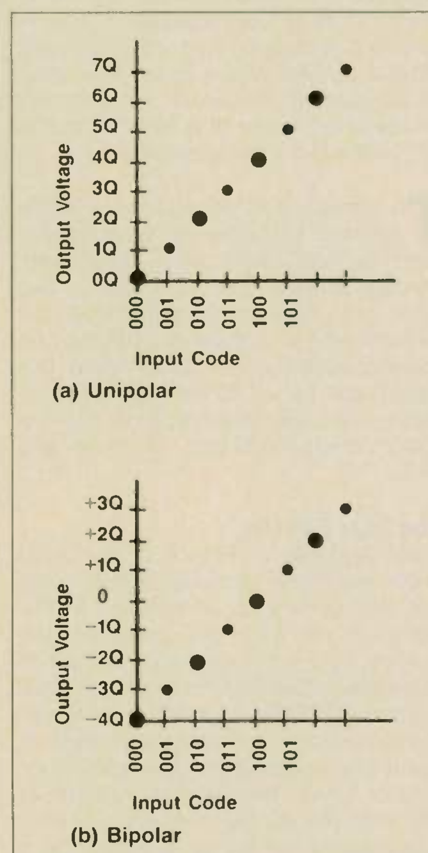


Figure 6. Ideal 3 Bit DAC transfer function.

Patented QUALCOMM Noise Reduction Circuit actually reduces spurious noise.

Change frequencies in 0.007 Hz increments (30 MHz clock).

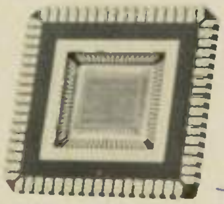
Built-in quadrature step control.

Fast FSK and PSK modes included.

At $35, the Q2334 DDS is a steal (20 MHz version, quantity 1000).

$25 8-bit DAC provides similar spurious performance as a $75 10-bit DAC (Sony CX20202) using patented noise reduction circuit.

TWO DDSs in one package allow fully independent outputs or any phase/frequency offset.



Can't wait? Order Q0310-1 DDS Evaluation Board for fast-turn prototyping and low volume applications.

QUALCOMM Q2334 DDS + Q3036 1.6 GHz PLL for hybrid DDS/PLL synthesizers.

Fine tune your phase modulation with over 4 billion step resolution.

MIL 883 screened DDS available.

Notice there's no external ROM in this ad? Patented on-chip algorithmic sine-lookup reduces board space and spurious noise.

Industry standard 68-pin PLCC package. Other packages also available.

20, 30, 50 MHz clock speeds. Your choice, all kept in stock.

DDS BY QUALCOMM
WHY COMPROMISE?

At QUALCOMM, we believe compromise leads to mediocrity.

That's why our family of Q2334 Direct Digital Synthesizers (DDS) are full-custom designs. In fact, they are the world's *first* commercially available full-custom DDS.

Full custom means we painstakingly placed each transistor and gate on silicon, instead of settling for a DDS design handcuffed to a silicon foundry's limitations.

A QUALCOMM full-custom DDS means *you* needn't compromise in performance, price or lead time. With a full-custom DDS, you can have more performance in less space (and with silicon, space is money). QUALCOMM has qualified its full-custom design with multiple foundries, so there's no worry about sole source.

After all, who would you rather have design your DDS? Someone else's foundry or QUALCOMM--the name behind CDMA digital cellular telephone and OmniTracs®, the world's first and most successful two-way mobile satellite communications system.

If you don't like to compromise, call or FAX us. We're here to help.

VLSI Products Division
10555 Sorrento Valley Road San Diego, CA 92121 USA
TEL: 619-587-1121 x540 • FAX: 619-452-9096

QUALCOMM INCORPORATED

"the elegant solution"

QUALCOMM DDS Patents 4,901,265; 4,905,177. ©1990 QUALCOMM, Inc.

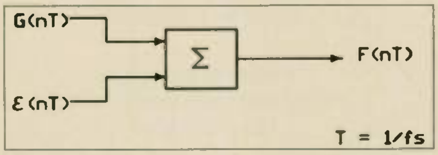


Figure 7. Ideal DAC quantization error representation.

of data points to powers of 2, which can yield a cumbersome resolution frequency (discussed in a following section) depending on the sampling rate.

A Focus on D/A Dynamic Errors

The transfer function of an ideal DAC is characterized by a linear relationship, where the analog output is proportional to the digital input code. For example, the transfer function of an ideal 3 bit DAC is shown in Figure 6.

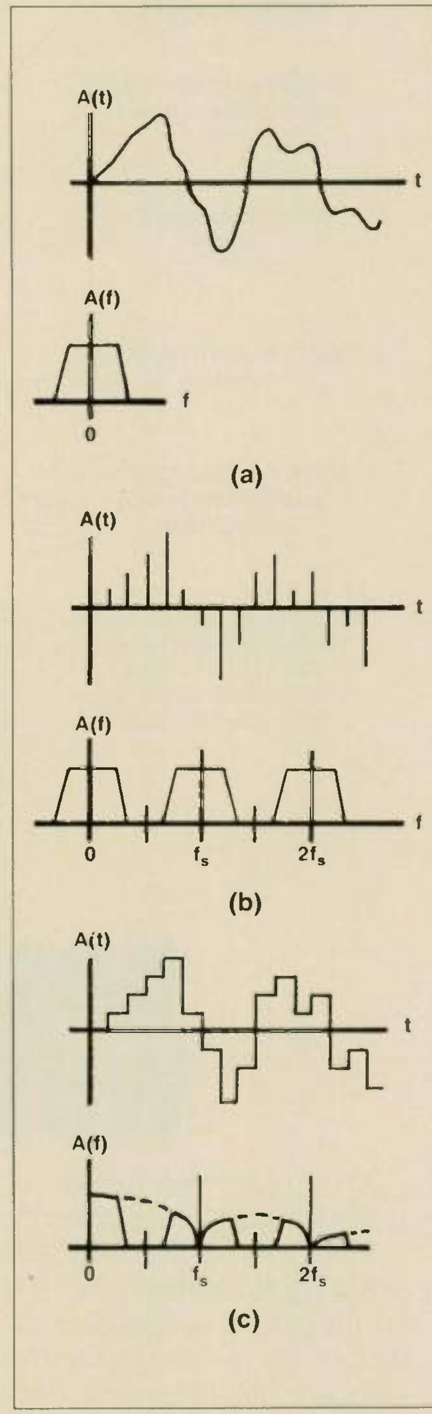


Figure 8. Time and frequency domain of a sampled signal a) original waveform, b) sampled representation, c) staircased representation.

Q refers to the weight or value that corresponds to 1 least significant bit (LSB).

$$Q = \frac{V_{FS}}{2^N} \qquad (1)$$

Collins Bandpass Mechanical Filters

LOW COST SERIES

Fits in the space!
Fits in your budget!

SETTING NEW STANDARDS FOR IF FILTERS

- Low Cost (100 Piece Unit Price is $30)
- Compact Design
- Center Frequency: 455 kHz
- Bandwidths: 500 Hz, 2.5 kHz, 6 kHz
- 7 and 8 Pole Selectivity
- Rugged
- Excellent Quality & Reliability

Rockwell International

Filter Products
Rockwell International
2990 Airway Avenue
Costa Mesa, CA 92626
(714) 641-5311
FAX: (714) 641-5320
TELEX: 685532 (COLLINS CSMA)

INFO/CARD 40

FAST DELIVERY
MANY MODELS ARE IN STOCK

WHEN YOU CONSIDER ...

• Performance • Delivery • Price

AND ADD

• MITEQ's long-term warranty and the long list of custom-selectable options, you will realize that MITEQ's bipolar amplifiers offer unparalleled bargains. Study the data and make your own decision.

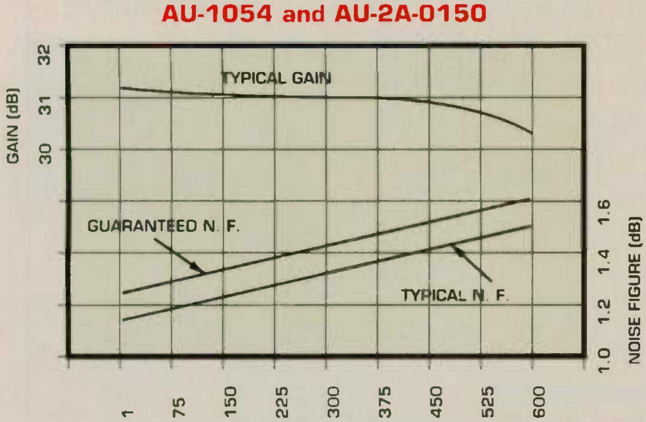
OPTIONS

- Integral input limiter
- Bias supplied via the output port
- Low-loss input "bias tee" for photo diodes
- Low frequency operation to below 10 kHz
- Fast recovery from input overloads
- Amplitude and phase matching
- Lower guaranteed noise figure

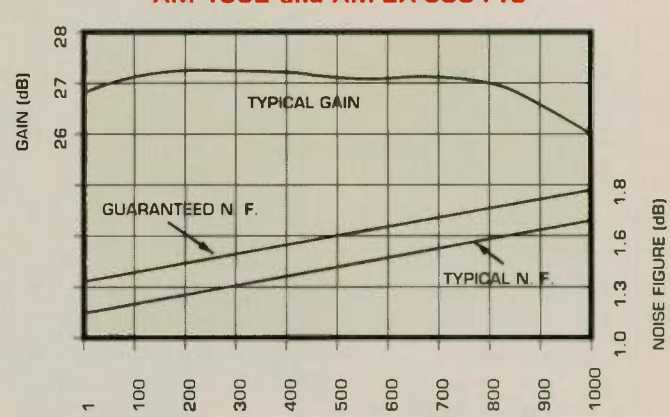
Model Number	Frequency (MHz)	Gain (Min.) (dB)	Gain Var. (Max.) (±dB)	Noise Figure (Max.) (dB) Low End	Mid Band	High End	VSWR (Max.)	Dynamic Range 1 dB Gain Comp. Output (Min.,dBm)	Nom. DC Power (+15V, mA)
AU-1054	1-500	30	0.5	1.25	1.4	1.5	2:1	+8	55
AU-2A-0150	1-500	30	0.5	1.25	1.4	1.5	2:1	+8	55
AU-3A-0150	1-500	45	0.5	1.25	1.4	1.5	2:1	+10	67
AU-1149	10-180	15	0.5	4.5	5.5	6.5	2:1*	+18	75
AU-1291	.015-500	60	0.75	1.25	1.4	1.5	2:1	+8	90
AM-1300	.01-1000	25	0.75	1.4	1.6	1.8	2:1	+6	50
AM-1052	1-1000	26	0.75	1.4	1.6	1.8	2:1	+6	50
AM-2A-000110	1-1000	27	0.75	1.4	1.6	1.8	2:1	+8	50
AM-1299	1-1000	38	0.75	1.4	1.6	1.8	2:1	+9	75
AM-3A-000110	1-1000	37	0.75	1.4	1.6	1.8	2:1	+9	75

* 75 ohm impedance level

AU-1054 and AU-2A-0150



AM-1052 and AM-2A-000110



For additional information, please call Bill Pope at (516) 436-7400, on extension 282.

MITEQ

100 Davids Drive, Hauppauge, New York 11788
Tel: (516) 436-7400 • Fax: (516) 436-7430 • Telex:6718148

INFO/CARD 41

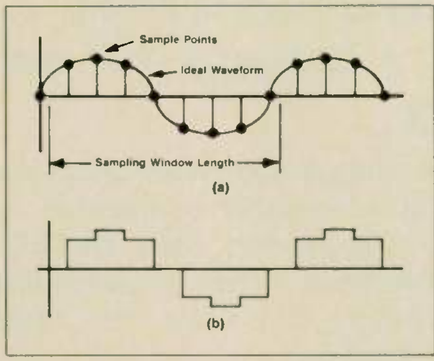


Figure 9. A limited number of DAC codes are exercised when the fundamental is a non-prime multiple of the resolution frequency a) sampled data points of the ideal waveform, b) DAC staircased output.

DAC Characteristic	Impact on AC Performance
Monotonicity	Code Dependent Spurs
Differential Non Linearity	Increased Quantization Noise
Integral Non Linearity	IM and HD Distortion
Glitch Impulse	Spurious
Digital Feed-through	Spurious
Power Supply Rejection	Spurious
Settling Time	Spurious, also dictates maximum f_s
Slew Rate	IM and HD Distortion
Gain	Amplitude error
Offset	Usually none, if AC Coupled

Table 1. DAC characteristics and their impact on AC performance.

Where:

V_{FS} = Full scale peak-to-peak voltage
N_b = Number of bits

Due to this finite resolution, even the ideal DAC would exhibit a fundamental quantization error of ± Q/2. Higher DAC resolution (i.e. more bits) yields a smaller quantization error, allowing greater fidelity in the reconstruction of a desired signal. Calculating the theoretical DAC noise produced by this quantization error, begins by modeling the DAC output, F(nT) as the sum of the exact sequence of sampled values G(nT) corrupted by an error component, ε(nT), which shifts the exact value to the nearest quantization level.

The maximum sine wave mean square value that can be generated before clipping is:

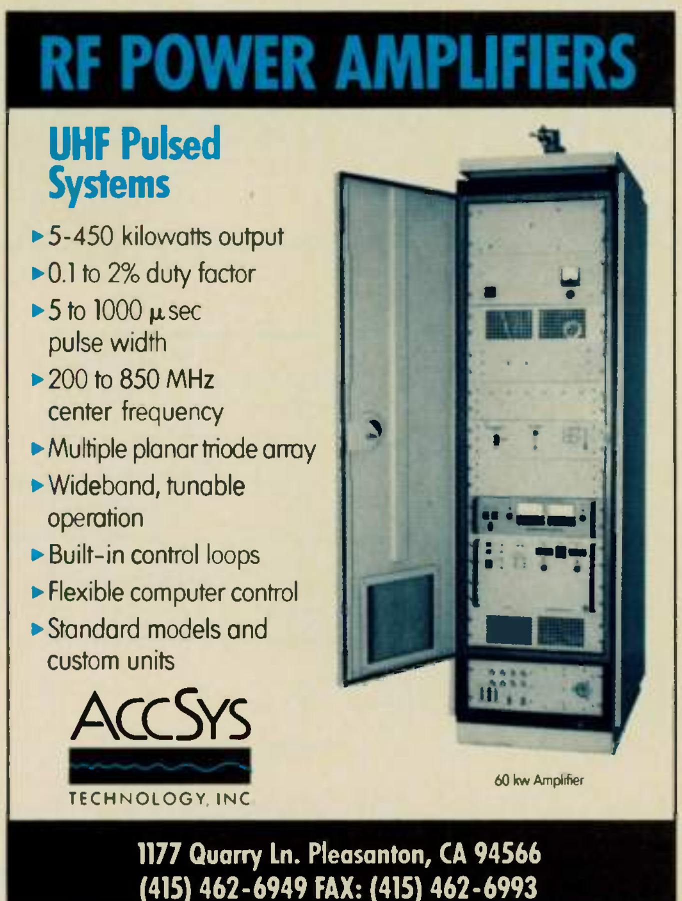
$$P_{Max} = \left[\frac{Q(2^{N_b-1})}{\sqrt{2}}\right]^2 = 2^{2N_b-3}Q^2 \qquad (2)$$

Based on the assumption that ε is a uniformly distributed and uncorrelated random variable over the range of $-Q/2 \leqslant \varepsilon \leqslant +Q/2$, its variance "power" is given by:

$$P_\varepsilon = \frac{\left[\frac{Q}{2} - \left(\frac{-Q}{2}\right)\right]^2}{12} = \frac{Q^2}{12} \qquad (3)$$

The sought after DAC dynamic range (maximum sine level to quantization noise over the Nyquist bandwidth) is calculated by simply taking the ratio of the two powers:

$$DR = 10\,\mathrm{Log}_{10}\left[\frac{2^{2N_b-3}Q^2}{\frac{Q^2}{12}}\right] = 6.02\,N_b + 1.76 \qquad (4)$$



INFO/CARD 42

INFO/CARD 43

Please see us at RF Expo East, Booths #222, 224.

Resolution Bandwidth	Dynamic Range
100 kHz	96.3 dB
30 kHz	101.5 dB
10 kHz	106.3 dB

Table 2. Theoretical dynamic range of a 12 bit DAC converting at 34 MHz, at three typical spectrum analyzer resolution bandwidths.

Since the quantization noise is uniformly distributed over the Nyquist bandwidth, determination of the dynamic range in a smaller bandwidth, f_{bw}, is simply:

$$DR = 6.02\ N_b + 1.76 + 10\ \mathrm{Log}_{10}\left[\frac{f_s}{2f_{bw}}\right] \quad (5)$$

Ideally, reconstruction of an analog signal from its samples would be represented in the frequency domain as the convolution of the original analog signal spectrum and a train of impulse functions. The resulting spectrum, as depicted in Figure 8b, would consist of the original signal spectrum plus its images centered at integer multiples of the sampling frequency, f_s.

Since an impulse function would place unrealistic slew rate demands on a real world DAC, its output is instead characterized by a "staircase" function as depicted in Figure 8c. Although the resulting frequency spectrum of the staircased waveform also contains the original spectrum and images, the envelope is attenuated by a sine x/x roll off:

$$\mathrm{Atten} = 20\ \mathrm{Log}_{10}\left[\frac{\sin\left(\frac{\pi f}{f_s}\right)}{\frac{\pi f}{f_s}}\right] \quad (6)$$

where f = Output frequency
f_s = DAC sampling rate

Typically in DAC applications, only the spectrum from DC to the Nyquist Frequency ($f_s/2$) would be of interest, thus the higher frequency images are filtered with an LPF. The sine x/x roll-off however, will attenuate a signal at the Nyquist limit by 3.92 dB as compared to frequencies at the low end of the spectrum. Demanding applications would digitally correct this problem by placing an inverse sine x/x filter before the DAC.

In addition to the fundamental considerations of quantization noise and sine x/x roll-off, DACs also exhibit other characteristics which must be carefully considered in high speed applications. Some of these characteristics and their associated impact on AC performance are listed in Table 1.

Monotonicity indicates whether or not the analog output will consistently increase with increasing input code. Only when the signal passes through the non-monotonic portion of the transfer function, will it be tainted. Depending on where this discontinuity exists the resulting spurs may be signal level (code) dependent. As an example, if a non-monotonic point existed at BFO (Hex code of a 12 bit converter), smaller signals that did not exercise this code are unaffected, while larger signals that pass through this point will be corrupted. Fortunately, monotonicity is virtually always guaranteed by DAC manufacturers over the applicable temperature range, and is not usually a consideration.

Differential non-linearity, usually expressed in LSB weights, refers to the incremental accuracy of the DAC transfer function. Since this parameter dictates an increase in spread of quantization error, the resulting noise floor increase is readily predictable. Integral non-linearity pertains to the overall deviation of the DAC transfer function. Often characterized as a "bowing" deviation, this type of error will create distortion products in the DAC output. Glitch impulse, sometimes referred to as glitch energy, is a measure of the

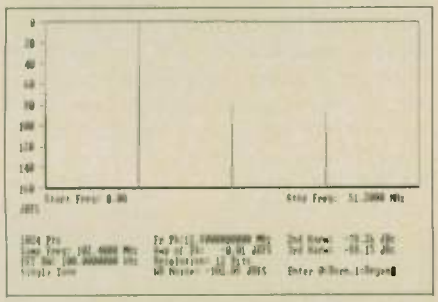


Figure 10a. FFT spectrum of quantized noise-extreme case.

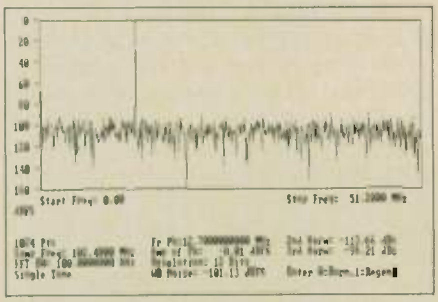


Figure 10b. FFT spectrum of quantized noise-even distribution.

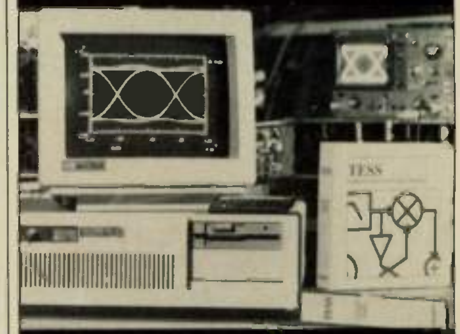
TESS

BLOCK DIAGRAM SIMULATION ON YOUR PC

RF/Digital Time Simulation
Spectrum Analysis
OrCAD Graphical Entry
FAST and EASY to Use
Free Upgrade & Support

What Can TESS Do For You?

Use TESS to quickly test modems, radios, signal processors and radars. Build systems of up to 800 blocks chosen from over 55 high level models. (includes filters, mixers, VCOs, A/D, D/A, logic etc.) Do tests in hours which would take weeks of breadboarding in the lab. See the effects of nonlinearities, bandlimiting, phase



noise and adjacent channels. Test PLL stability. Add noise and measure BER. Super high speed lets you simulate modulated carriers. Add your own models to TESS easily with the optional MODGEN model generator.

FREE APPLICATION NOTE
CALL FOR DEMO DISK

Not copy protected. TESS simulator $695. MODGEN option $495. Symbols for ORCAD/SDT® $195. For PCAD PCCAPS® $295. VISA, MasterCard and PO's accepted.

TESOFT
PO BOX 305 Roswell GA 30077
404-751-9785 FAX 404-664-5817

INFO/CARD 44

glitch area that is created by switching transients between updates. Although it is sometimes possible to de-skew the most significant bits (MSBs) to reduce the glitch impulse area, the efficacy of this technique is very limited, usually to about a 40 or 50 percent reduction. If needed, a much more effective method in reducing glitch area is to employ a sample and hold amplifier (SHA) at the DAC output. The SHA would maintain the proper analog level while the DAC is transitioning to the next value, buffering the output from the glitch activity. The DAC-02315 and DGL-02316 manufactured by Data Device Corporation is a good example of a DAC/SHA pair which is specifically intended for this purpose.

Digital feed-through pertains to the isolation that exists between the digital signals and the analog output. This feed-through is most problematic in high speed applications where high slew rate logic often carries higher frequency ripple components. Since this parameter is very dependent on circuit layout and implementation, it is often unspecified by manufacturers. Latching the digital data will limit coupling of extraneous noise riding on the logic signals, but will do nothing to prevent logic edge coupling. Maximizing the distance between the digital and analog circuitry will minimize capacitive coupling, while minimizing loop areas of both the analog and digital circuitry will minimize inductive coupling. Unfortunately, even the most carefully executed layout will not reduce the stray coupling capacitance that exists between the chip boundaries of the DAC, which is typically on the order of 0.2 pF. Manufacturers usually limit this capacitance by placing the digital signal pins as far away as practical from the analog pins. One method of reducing the effect of this coupling capacitance is to incorporate a Faraday shield around the DAC package — this will be discussed in more detail in the test results section.

Power supply rejection ratio (PSRR), frequently specified only at DC, is expressed in terms of percent of full scale change for a DC percent change in power supply voltage. Although this is helpful for determining amplitude variation over a given supply voltage range, this DC specification will provide little information about high frequency rejection. In high speed applications, judicious use of the proper bypass capacitors and filter inductors will complement the PSRR to maintain the proper noise immunity. Providing a capacitor pair consisting of a 0.001 – 0.1 uF ceramic and ~5 uF tantalum on each supply pin helps stabilize the voltage over a wide frequency range. The capacitors can be augmented by series inductors to further cleanse the supply lines.

Settling time of a DAC is traditionally defined as the time from the digital input transition to the time the DAC output has settled to within a certain error band, usually ± 1/2 LSB. A portion of this delay may be attributed to a fixed "pipeline" delay due to latch and switch propagation times, during which the analog output is unchanged. Therefore, in AC applications DAC settling time may be redefined in terms of the output alone: i.e., as the time the output leaves a ±1/2 LSB error band to the time the output

A Whole World of
IF/RF/Microwave Filters and Multiplexers
Custom-Built to Your Specifications.

IF/RF/Microwave Filters and Multiplexers for:
- Military
- Space
- Communications

Functions:
- Frequency Domain
- Transitional
- Time Domain

Frequencies:
- DC to 26.5 GHz

Technologies:
- Miniature Lumped Element
- Miniature Cavities
- Miniature Helicals
- Suspended Substrate
- Waveguide
- Tuneable
- Combline
- Interdigital
- High Power
- Switched Filter Banks

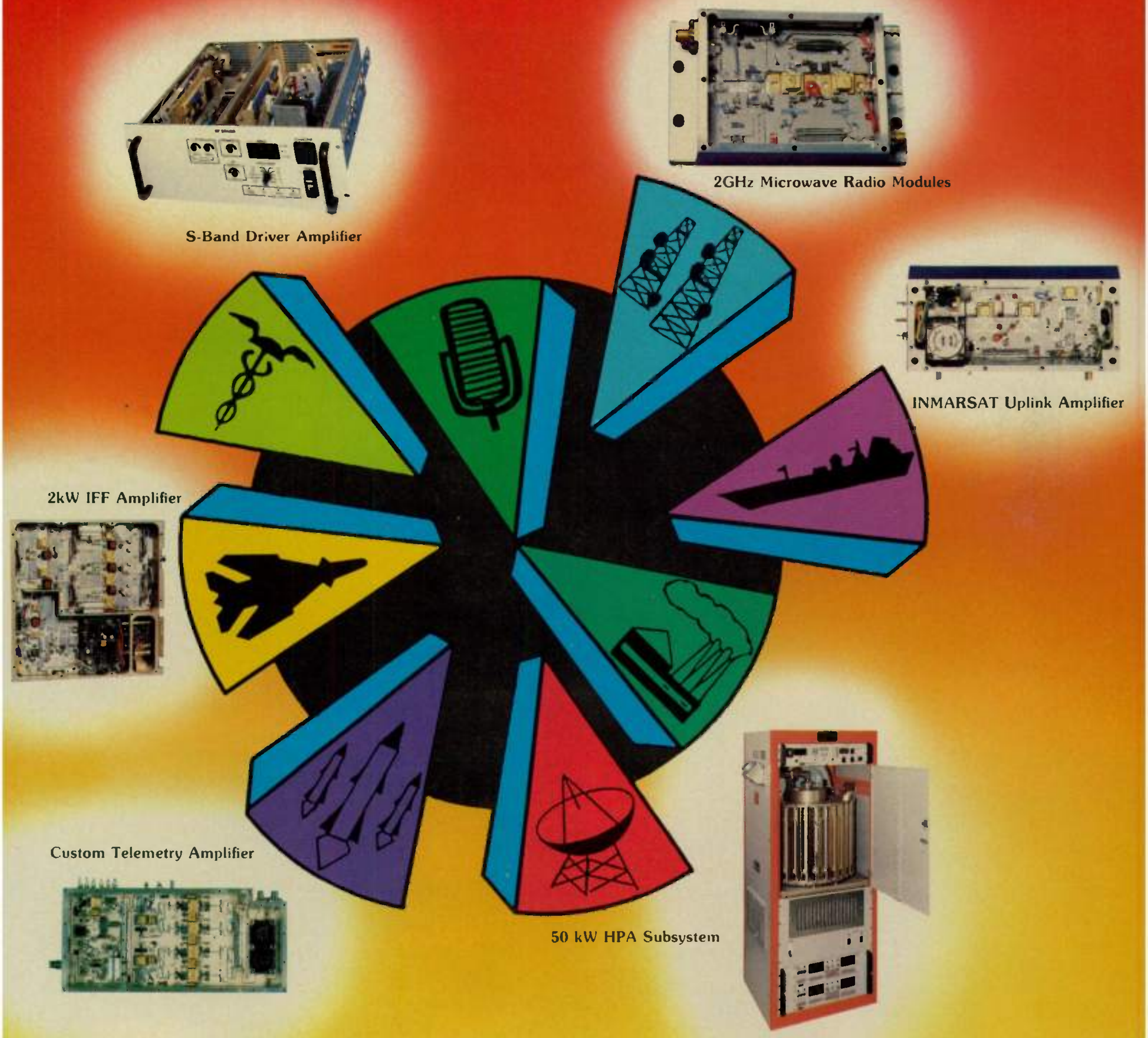
Computer-Aided Services:
- Synthesis
- Design
- Engineering
- Manufacturing
- Testing

INTEGRATED MICROWAVE ™
3422 Tripp Court
San Diego, CA 92121-1009 USA
Tel. (619) 259-2600
FAX: (619) 755-8679

International Rep. inquiries invited

INFO/CARD 45

NO MATTER WHAT THE APPLICATION . . .



SGS-THOMSON Microelectronics has the capability and experience to design, develop & manufacture RF & microwave power amplifiers and high power amplifier (HPA) subsystems to your exact needs. From straightforward power amplifier modules for INMARSAT terminals or microwave radios to complex Medical, Industrial, Radar or Avionics subsystems with built-in test functions, power supplies and other accessory features. Need a power amplifier for your application?

Look to the people with more than 20 years RF experience-

SGS-THOMSON MICROELECTRONICS

SGS-THOMSON Microelectronics
Commerce Drive
Montgomeryville, Pennsylvania 18936-1002
Tel. (215) 362-8500 Fax (215) 362-1293

Please see us at RF Expo East, Booths #403, 405. INFO/CARD 46


When connections are critical, depend on Omni Spectra.
When you need subminiature connectors, depend on the company who makes more of them than anyone else. More people buy SMA's from Omni Spectra because we don't compromise on quality.
Our totally integrated capabilities, coupled with state-of-the-art SPC, assure the highest degree of quality. We control the critical processes of machining, plating, brazing and glass sealing in-house.
When you really need to get small, think big. Depend on Omni Spectra.
For more information, call or write:
M/A-COM Omni Spectra, Inc.
140 Fourth Avenue. Waltham, MA 02254
Tel: USA (617)890-4750
UK (0734)580833
Japan 03(226)1671
Omni Spectra
A M/A-COM COMPANY
INFO/CARD 47
Please see us at RF Expo East, Booths #315. 317.

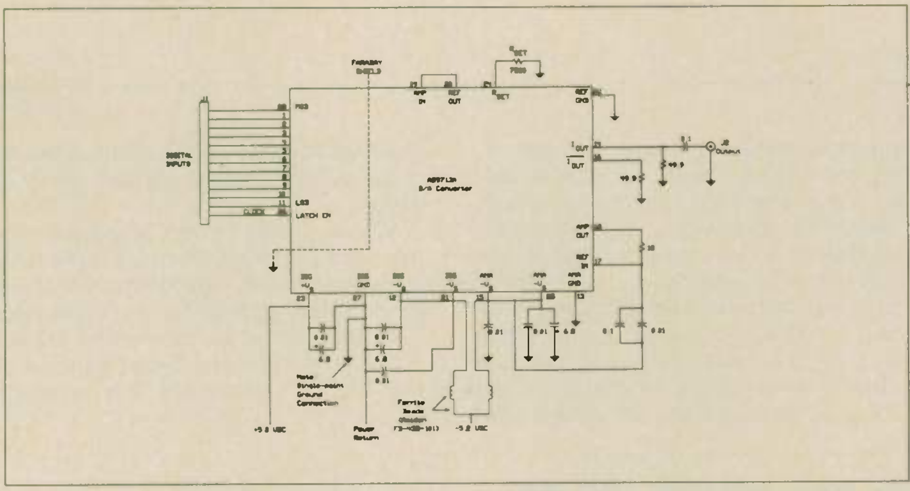


Figure 11. AD9713A test schematic.

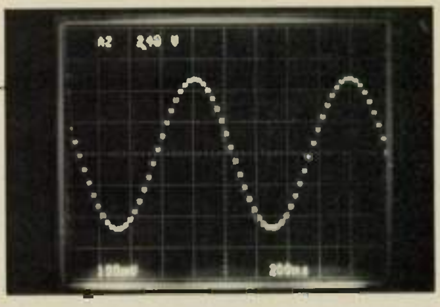


Figure 12a. Single tone test, time domain.

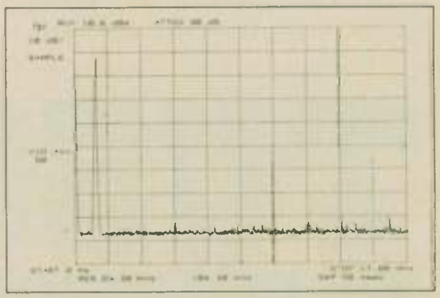


Figure 12b. Single tone test, frequency domain.

settles to within a ±1/2 LSB band. Ideally, a DAC should be chosen with a settling time that is much shorter than the sampling period.

The remaining DAC parameters: slew rate, gain and offset are relatively straightforward. DAC slew rate limitations are similar to that of other analog components, where the maximum output frequency is limited to:

$$f_{max} = \frac{SR}{2\pi V_p} \qquad (7)$$

where V_p = Maximum peak voltage level
SR = Slew rate (V/S)

Gain error, often expressed as a percent of the full scale (FS) output, relates to the amplitude accuracy of the DAC output. For example a 0.1 percent of FS gain error would dictate an amplitude error of less than 0.01 dB. Small gain errors are common, and are therefore not of significant concern in AC applications. Offset, which is also expressed as a percent of full scale output pertains to the resulting output level that would appear at the DAC output when it is instructed to output 0 volts. The offset is usually not significant, and is easily removed with AC coupling.

Test Considerations

Before discussing actual D/A test results, a few items should be addressed concerning the test parameters. The sampling window that contains the digital waveform must embody an integral number of cycles. Failure to assure this will result in discontinuities when the transition from the end of the data period to the start of the new one occurs.

The frequency resolution is simply:

$$f_{res} = \frac{f_s}{N} \qquad (8)$$

where: f_s = sampling frequency
N = Length of the sampling window (number of points)

Need extra copies of the *RF Design* 1990/91 Directory?

Make **check** payable to: RF Design
6300 S. Syracuse Way, #650
Englewood, CO 80111

☐ One copy .... $19 95 ea ☐ 5-24 copies .... $15 00 ea
☐ 2-4 copies .... $18 00 ea ☐ 25 or more .... $10 00 ea

I need ______ copies
______ books $______ plus $______ (*postage) $______ TOTAL
*(add $2 00 postage if outside U S)

Please **charge** my ☐ AMEX ☐ VISA ☐ MC

No ______ Exp ______

Sig ______

PRINT NAME First ______ Middle Initial ______ Last ______

Title ______ Company ______

Address ______ Telephone ______

City ______ State ______ Zip ______

Country ______

1990/91
RF Design Market Directory

The **RF Directory** is a compilation of over 1200 RF product vendors, with listings organized by individual product categories. RF engineers have grown to depend on it as being accurate, comprehensive, and efficient because it specifically and exclusively covers RF products. Each year's issue is more popular than the last as the dynamic RF market continues to grow and new products are developed.

The **Directory** is also unique to the RF field in that product advertisements and data sheets are adjacent to the appropriate product listings, putting all pertinent data in one place.

The **RF Directory** is the fastest way to locate the latest RF products and services needed for cost-effective, competitive designs.

Avoiding the discontinuity requires that the fundamental frequency be an integer multiple (m) of the resolution frequency:

$$f_t = m\, f_{res} = m\, \frac{f_s}{N} \qquad (9)$$

Other considerations should also be heeded. To maximize the number of DAC codes exercised, the sampling window length, N, should be as long as practical while the integer multiple, m, chosen in the above equation should be odd and prime. The problems associated with choosing a small sampling window or a non-prime multiple can be visualized by examining the following example: consider a sampling frequency of f_s = 102.4 MHz that generates a tone at f_t = 12.8 MHz. Regardless of how large the sampling length is, under these conditions there will always exist exactly 8 samples per cycle which would utilize a very limited number of DAC codes.

When viewed in the frequency domain, the quantization errors of the tone are concentrated at the harmonics of the fundamental as depicted in Figure 10a. This anomaly yields misleading results concerning the true HD performance of the DAC — a problem that is easily

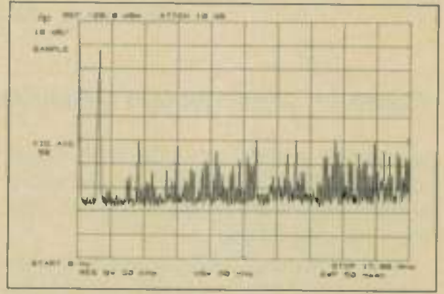


Figure 13a. -30 dB full scale test-without Faraday shield.

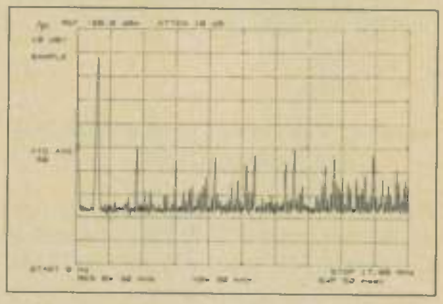


Figure 13b. -30dB full scale test-with Faraday shield.

solved by allowing the largest length (N) that is practical and by selecting the fundamental to be an odd and prime multiple on the resolution frequency. This would slightly offset subsequent cycles, maximizing the number of codes exercised —"spreading" the quantization error. Referring back to the example, by reselecting the fundamental to be 12.7 MHz (which is an odd and prime multiple of the resolution frequency of 0.1 MHz) the resulting frequency domain plot, Figure 10b, depicts an evenly distributed quantization noise floor.

An interesting consideration that arises during DAC evaluation is the performance limitations of the test equipment. Recall that the theoretical DAC dynamic range (defined as the full scale sine amplitude to the quantization noise floor ratio) is:

$$DR = 6.02\, N_b + 1.76 + 10\, \mathrm{Log}\left(\frac{f_s}{2f_{bw}}\right) \qquad (10)$$

where: N_b = converter resolution (num-

TUSONIX

If you're looking for a reliable source for EMI Filters and Custom Filter Assemblies . . .

Tusonix, as a QPL source, is proud of its JIT performance

Miniature EMI/RFI ceramic filters and filter capacitors attenuate most frequency ranges in a wide variety of QPL approved styles. Most are available from stock in production quantities, ready for immediate shipment.

When it comes to custom packaging EMI/RFI feed-thru filters and/or filter capacitors, Tusonix offers a complete in-house custom assembly capability. Our expertise in the manufacture and array assembly of quality EMI/RFI filters and filter capacitors results in substantially improved efficiency. The result is a reliable, economic assembly that satisfies your unique needs.

So let Tusonix supply your filter requirements in discrete filters and assemblies. Write for literature TODAY . . . or please call us at:

Phone: 602-744-0400

TUSONIX

P.O. Box 37144, Tucson, AZ 85740-7144
Phone: 602-744-0400 Telex: (RCA) 299-640
FAX: 602-744-6155

INFO/CARD 48

ber of Bits)

f_s = Sampling frequency

f_{bw} = Measurement bandwidth

Considering, for example, a 12 bit DAC converting at 34 MHz, the resulting theoretical dynamic ranges for some typical spectrum analyzer bandwidths are listed in Table 2.

Measuring instantaneous dynamic ranges of greater than 80 or 90 dB generally place formidable demands on a spectrum analyzer. Therefore, some tests encountered in the evaluation of a quality high speed, high resolution DAC, will be limited by the test equipment. Fortunately, techniques frequently exist to circumvent this problem — as will be discussed in the following section.

Test Results

The AD9713A by Analog Devices was characterized at 34 MHz with the test trio to determine its suitability in various applications. The schematic of the DAC test circuit is shown in Figure 11. The unipolar current source DAC output is specified for a full scale level of 20.65 mA, with a set resistor of 7.5 kohms. Placing the 50 ohm resistor at the output creates a 50 ohm Thevenin 1.033 unipolar voltage source. This dictates an available power of −1.8 dBm into an AC coupled 50 ohm load. Applications requiring higher level outputs can be accommodated with a high speed transconductance amplifier, such as the AD9617.

The Faraday shield was constructed with 3 mil copper tape wrapped around the length of the IC package and connected to the board ground plane. Except where noted in the single tone case, the Faraday shield was used in all the following tests.

DAC characterization for a 1.01270 MHz local oscillator is accomplished with the single tone test. The time domain and frequency domain results are shown in Figures 12a and 12b respectively. Note that in the time domain, the duration of the switching transients between updates are substantially shorter than the update period. The staircased appearance is easily smoothed with an LPF. In examining the frequency domain, it is important to note that the observed noise floor is that of the spectrum analyzer which masks the quantization noise and all but the most ornery of DAC spurs. Being consistent with the data sheet specification, these spurs and HD products are observed to be at least 68 dBm down from the full scale carrier. Note also that with the peak amplitude of −1.8 dBm, the theoretical quantization noise floor in the resolution bandwidth of 30 kHz will be 101.5 dB below the peak at −103.3 dBm, well below the analyzer's noise floor. Reducing the analyzer's internal attenuator from 30 to 20 dB will improve its effective noise figure, but will create misleading harmonic products as the front end of the spectrum analyzer will add distortion to the signal.

Digitally reducing the signal to −30 dBFS (below full scale) reduces the instantaneous dynamic range requirement of the spectrum analyzer, allowing for a more comprehensive observation of the DAC performance, as depicted in Figures 13a and 13b. However, depending on the application the digital level reduction may not be a valid test since the DAC spurious content will likely be signal level dependent. In such a case, it would be more meaningful to attenuate the fundamental in the analog domain with a notch filter, to reduce the analyzer instantaneous dynamic range requirement. However, careful implementation of the filter is required to assure that it does not generate distortion products that would create misleading test results.

The numerous spurs are caused by both capacitive coupling of the digital data to the analog circuitry and DAC nonlinearities. Although careful layout can limit the coupling problem, it can do little for the coupling that exists within the DAC itself, as discussed in a previous section. Use of the Faraday Shield can attenuate the effect of the coupling capacitance (as illustrated in a comparison of the Figures 13a and 13b), though its efficacy is limited since its proximity to the die is constrained by the package. Nevertheless, most of the spurs and harmonics are attenuated, some by as much as 8 dB. Ignoring the discrete spurs, Figure 13 reveals a noise floor of −96 dBm which again is limited by spectrum analyzer performance.

Although many manufacturers do specify harmonic distortion, the single tone HD test is useful in situations where data sheet test conditions do not parallel the specific application. Additional uses for this test include: verifying the DAC circuit configuration and characterization of other DAC parameters such as power supply rejection.

Frequently unspecified by a manufacturer, intermodulation distortion (IMD) is another important DAC parameter which is useful for example, in evaluating a

Mil-Spec
RF Microcircuits

5 MHz to 1500 MHz

RF Amplifiers, Switches, Attenuators & Subassemblies for Military, Communication or Space Application

* Low Noise
* High Efficiency
* High Gain

- Standard and Custom Design
- Cascade Assemblies with a Variety of Connectors
- TO-8, TO-12 and 4 Pin DIP Plug-In Modules
- Full Military Temperature Range
- Varying Gain, NF and Power Outputs
- Screened to MIL-STD Specifications
- Full One Year Warranty
- Competitive Pricing

AYDIN VECTOR

P.O. Box 328, Newtown, PA 18940-0328

(215) 968-4271

FAX 215 - 968 - 3214

INFO/CARD 49

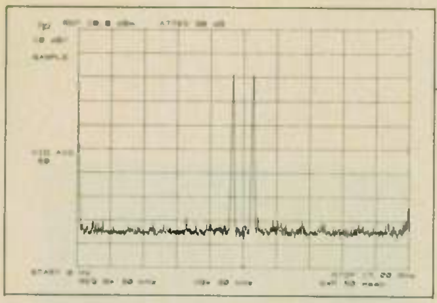


Figure 14. Two tone DAC performance.

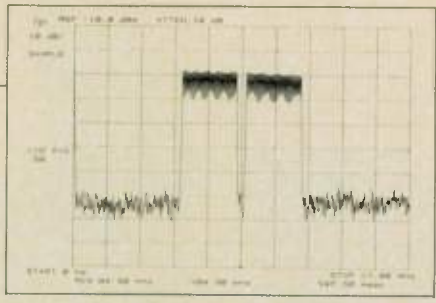


Figure15a. NPR DAC performance DC to 17 MHz.

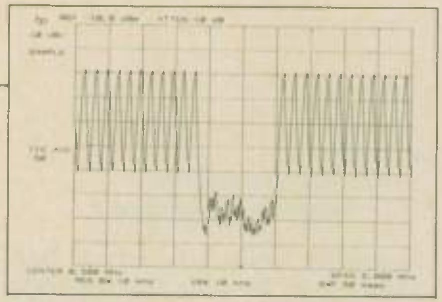


Figure 15b. NPR DAC performance, focus on notch.

DAC intended to inject a built-in-test (BIT) signal consisting of two tones. Figure 14 illustrates the DAC performance in generating a two tone signal at approximately 7.952 and 8.981 MHz. To avoid saturation, the amplitude of each signal is at −8 dBm, slightly less than half the full scale amplitude of −1.8 dBm.

Note that the largest of the IM components is the second order product at 16.933 MHz which is at −64 dBm (56 dBc).

The final and most stringent test of the trio is the noise power ratio, which is especially useful in DAC characterization in wide band applications. In the following example, the NPR test was used to characterize potential DACs for use in the IF output generation of a ground based satellite receiving system. Since the IF consisted of a PN modulated 6 MHz bandwidth carrier centered at 8.5 MHz, the NPR test was developed using a comb of frequencies ranging from approximately 5.5 to 11.5 MHz with a void from approximately 8.25 to 8.75 MHz. The discrete frequencies were spaced at four times the resolution frequency of 16.6 kHz, providing about 82 components. Randomizing the phases of each signal is necessary to minimize the peak-to-RMS voltage ratio, thus maximizing the number of DAC codes exercised.

Actual NPR performance of the AD9713A is depicted in Figure 15. Note the noise floor of −85 dBm depicted in Figure 15a, falls far short of the theoretical level of −103 dBm. In actuality the noise floor is a culmination of the numerous HD and IMD products of each of the frequency components that make up the NPR test, as anticipated previously. The 2 MHz frequency span of Figure 15b details the notch spectrum. Note that the individual frequency components, spaced at 66.4 kHz, are easily resolved in this figure. Although the DAC performance is impressive, under these conditions it will only yield an instantaneous dynamic range equivalent to that of an ideal 9 Bit converter. Depending on the application requirements, this may not be a significant limitation since as the NPR signal is digitally attenuated, the noise floor decreases.

It is interesting to note the slight decline in signal amplitude at the higher NPR frequencies. This is not due to the frequency response of the physical part, but is rather a consequence of the sine x/x attenuation discussed earlier.

Summary

Most manufacturers do an excellent job specifying DAC performance. Unfortunately, data sheet specifications often reflect operation under conditions unlike those called for in a specific application — or worse a desired parameter such as IM performance, may not be specified at all. Dynamic evaluation with the single tone, two tone and NPR tests will help define DAC uncertainties, providing an efficient means to characterize and evaluate DACs for a wide variety of applications. ***RF***

References

1. High Speed Design Seminar, Analog Devices, 1990.
2. Alen Oppenheim, *Digital Signal Processing*, Prentice-Hall, 1975.

About the Author

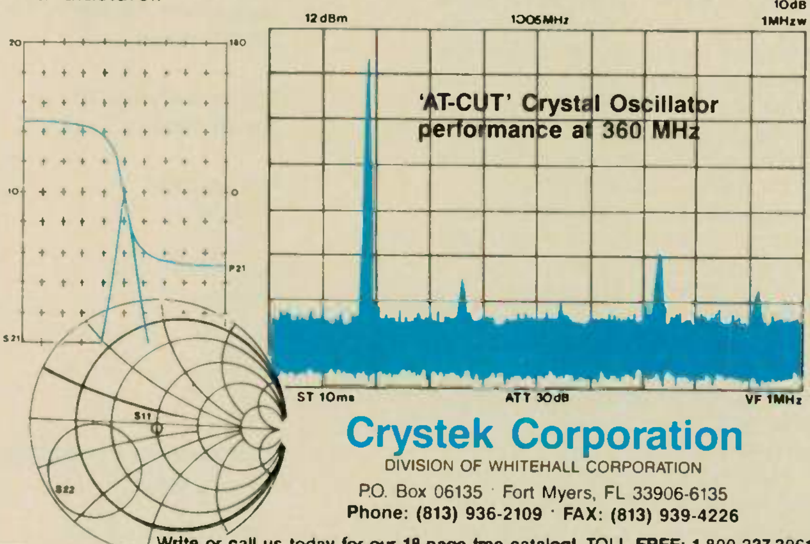
James Colotti is an Analog Design Engineer for CSD/Telephonics. He may be reached at: Command Systems Division, 815 Broad Hollow Road, Farmingdale, NY 11735.

The pulse of dependable communications.

Crystek manufactures Frequency Control Products that span the entire Frequency spectrum needed for today's system designer, whether the requirement is for a Crystal at 1.000 Megahertz or an Oscillator at 1.000 Gigahertz.

With our in-house Quartz Crystal manufacturing we have the ability to respond quickly and accurately to your requirements and develop unique oscillator designs to fit the ever changing electronic technology.

Call CRYSTEK today with your required specifications and if we are not able to provide you with the specific device we will recommend another manufacturer.



Crystek Corporation

DIVISION OF WHITEHALL CORPORATION

P.O. Box 06135 · Fort Myers, FL 33906-6135

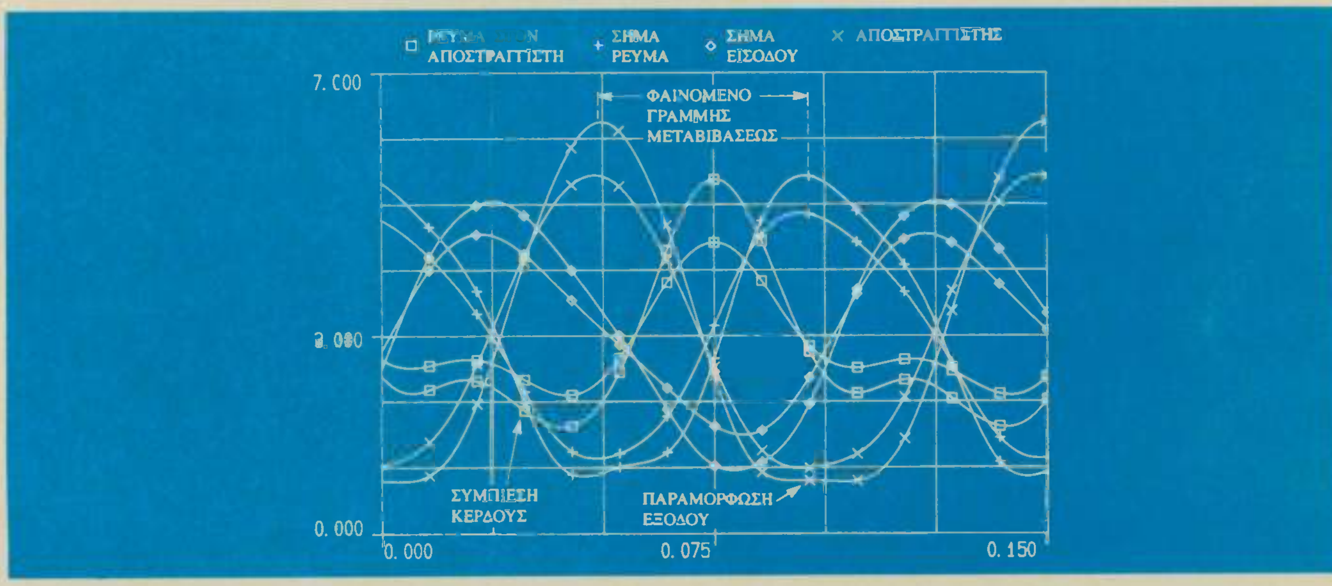
Phone: (813) 936-2109 · FAX: (813) 939-4226

Write or call us today for our 18-page free catalog! TOLL FREE: 1-800-237-3061

INFO/CARD 50

BESSER ASSOCIATES

If modern circuit design looks like this to you,



call us for assistance.

New design tools can speed up project development. However, what you learned in school yesterday may not be sufficient in today's world.

New graduates soon discover that university education provides only the foundation of what is realistically needed to perform well in the industry.

Experienced engineers have problems too. Studies reveal that within each 3-5 year period, one-half of an engineer's technical knowledge becomes obsolete.

Continued training is a must for survival in today's competitive market. With increasing emphasis on commercial application, modernization of the design laboratory and production floor is critical.

Application of modern computer-aided engineering to RF and microwave circuit and system design is vital to manufacturing products with high quality and yield.

A well-planned continuing education program will enable your company to meet these goals.

As a recognized international leader, Besser Associates is totally dedicated to continuing education of RF and microwave professionals. Our instructors are top-notch design engineers, skilled in both technology and the art of teaching. We can customize our courses to meet your specific needs.

For more information on how these training programs can work for you, contact:

Besser Associates
4600 El Camino Real
Suite 210
Los Altos, CA 94022

Phone: (415) 949-3300
Fax: (415) 949-4400

INFO/CARD 51

Spread Spectrum At Your Finger Tips.

HIGHEST PERFORMANCE VITERBI DECODER
At 20 Mbps with 4-bit soft decision the STEL-2020 is the highest performance K=6 and K=7 Viterbi decoder in the industry.

HIGHEST FLEXIBILITY PN CODER
At 30 Mcps and up to 32 taps per coder the STEL-1032 Triple PN Coder has the flexibility to generate a wide variety of codes for many spread spectrum applications.

HIGHEST PERFORMANCE DIGITAL FILTER
The STEL-3310 64-Tap Complex Matched Filter provides the highest performance in a single package for signal despreading applications.

GPS CODER
The STEL-1023 generates the C/A (Clear/Acquisition) coding and timing for GPS receivers in a single chip.

LOWEST PRICE VITERBI DECODER
At less than $100 (qty. 1000) the STEL-5269 K=7 Viterbi decoder has the most attractive price in the industry, with industry standard polynomials and a 256 Kbps data rate.

HIGHEST SPEED ACCUMULATOR
With a 70 Msamples/sec. accumulation rate the STEL-2410 is the industry's highest speed signal accumulator for spread spectrum applications.

HIGHEST PERFORMANCE BIT SYNCHRONIZER/ DEMODULATOR
The STEL-2110A is a digital bit synchronizer and PSK demodulator, providing high performance in spread spectrum BPSK and QPSK applications.

FASTEST BURST DATA ACQUISITION
The STEL-2210 Block Phase Estimator allows burst signals to be acquired rapidly and demodulated coherently when used in conjunction with the STEL-2110A.

HIGHEST PERFORMANCE QUADRATURE NCO
The STEL-1177 Quadrature NCO has a 60 MHz clock frequency and incorporates linear PM and FM capabilities as well as providing quadrature 12-bit outputs for –75 dBc purity.

SIGNAL QUALITY ESTIMATOR
The STEL-2330 Signal Quality Estimator provides front-end processing to allow the E_b/N_o of signals to be calculated at up to 15 Msamples/sec.

STANFORD TELECOM proudly offers the industry's most complete line of Spread Spectrum VLSI Products for any occasion.

STANFORD TELECOM... the leader in Spread Spectrum, also offers products for Direct Digital Synthesis applications. In addition, we specialize in the development of custom ASIC solutions for your specific requirements.

For immediate support, please write or call:

STANFORD TELECOM

ASIC & Custom Products Group
2421 Mission College Blvd., Santa Clara, CA 95054
Tel: (408) 980-5684 • Fax: (408) 727-1482

INFO/CARD 52

Measurement of Analog-to-Digital Converter Settling Time with Equivalent Time Sampling

By Thomas Hack
Comlinear Corporation

Analog-to-Digital converter (ADC) settling time is an important specification in a variety of applications. In pulse applications the settling characteristic may set the resolution. In applications where a multiplexer (MUX) is used in front of an ADC, it allows the designer to calculate the channel-to-channel crosstalk, and optimize MUX/ADC timing. Systems where settling time may become an issue include time-domain reflectometers (optical and wire), medical-imaging equipment, infra-red and visible light video applications, as well as traditional IQ systems such as radar and ultrasound.

Unfortunately, settling time has been difficult if not impossible to measure in high-speed ADCs. Flash converters invariably use a sampled-comparator topology and comparators determine the settling time. Most subranging converters include a track and hold amplifier whose output may or may not be observed without degrading performance. Either way, the signal may not be available in an analog form at a point in the ADC converter signal path where settling time is established or it may be corrupted by the measuring process. This means that in many situations the only way settling time could be deduced is from the digital samples that the ADC produces. But if the analog-to-digital converter performs well at its maximum sample rate, its settling time should be expected to be less than 1 clock period-and this isn't good enough when other parts in the system (such as MUXs) also contribute to total settling time.

Fortunately, if a highly repetitive test signal is used, equivalent-time sampling can be used. Figure 1 illustrates this approach. A Hewlett-Packard 3326 two channel synthesizer supplies a clock to the ADC under test and a square wave analog test signal. A diode waveshaping network removes any anomalies from the test signal before it enters the ADC. Settling time will be measured to approximately 1 part in 8000 in a 12 bit ADC. The analog-to-digital converter samples the test signal at a clock frequency slightly lower than the analog test signal frequency producing a series of digital words that are placed in memory on board a personal computer. The data is then displayed and printed for analysis purposes.

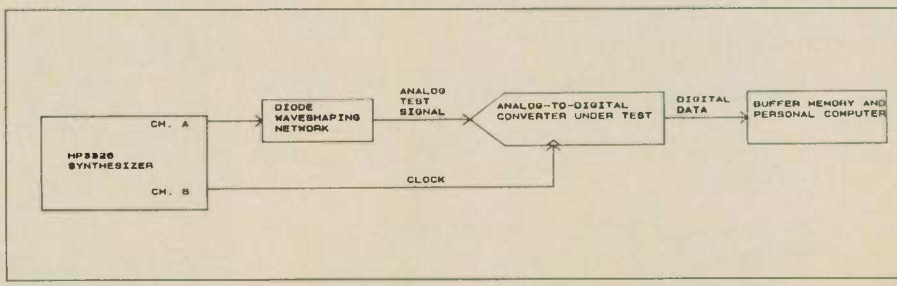


Figure 1. Analog-to-digital converter settling time test setup.

If the analog test signal is repeatable from one cycle to the next, one sample on a large number of cycles is taken and one or more cycles of the ADC's response to the test signal is reconstructed with very high apparent sampling frequency (Figure 2). For best results a low phase-noise synthesizer (such as the HP 3326) should generate the clock and analog test signal and the clock and the test signal should be derived from the same reference oscillator (by phase locking or other means). Without further signal processing tricks, settling time to 1/2 LSB can be observed (this assumes reasonable analog-to-digital converter signal to noise ratio and synthesizer noise performance).

A Comlinear CLC925 12 Bit, 10 MSPS ADC is used as an example. Starting with a 5 MHz test signal-this gives 100 ns for the low state and 100 ns for the high state. Since this converter has a 200 ns minimum clock period, this is a suitable choice.

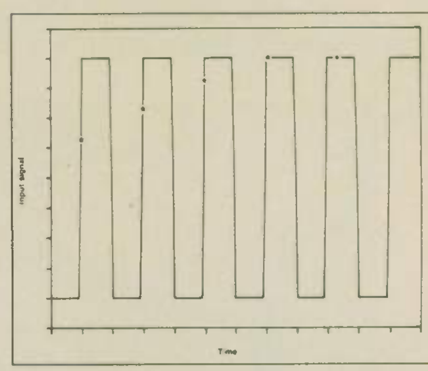


Figure 2. Sequential equivalent time sampling. Asterisks denote actual sample points.

It is assumed that 4096 samples will be taken to represent 1 cycle of this waveform. This works out to a real time increment of:

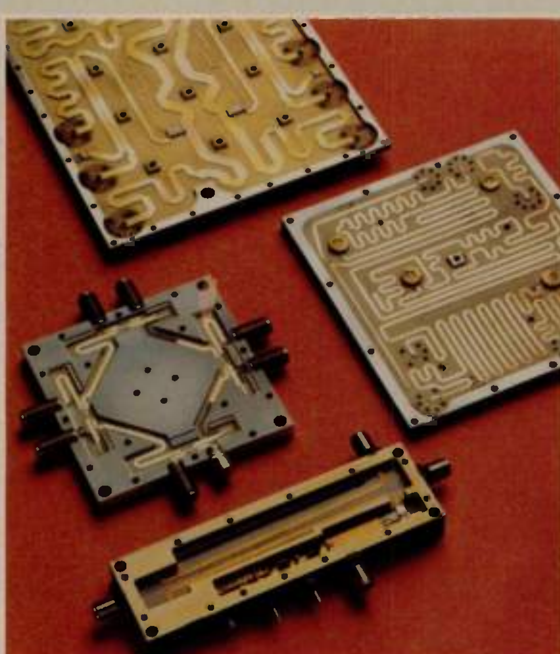
$t = (200 \times 10^{-9})/4096 = 48.83$ ps between consecutive samples.

Using 50 picoseconds as an apparent sampling time interval will give slightly more than 1 cycle of the analog test signal in the 4096 sample record.

Stripline Solutions

Couplers, Power Dividers, Hybrids

- 0.5 to 50 GHz, Octave and Multi-Octave Bandwidths
- Rugged Stripline Construction
- Small Lightweight Designs
- Meet MIL-E-5400 and MIL-E-16400 Environments, Operation from −65° to +125°C
- Power Handling to 100 Watts CW
- 3, 6, 10, 20 and 30 dB Couplers In Stock
- 2-, 3-, 4- and 8-Way Power Dividers In Stock
- Mil-Spec Equivalents In Stock
- 90°, 180°, Magic "T", Crossover, Non-Crossover Hybrids In Stock



- Phase and Amplitude Matched Units
- Customized and Multi-Function Designs
- Space Qualified Units

M/A-COM Control Components Division offers the industry's broadest line of standard and custom Couplers, Power Dividers and Hybrids.

Find your Stripline Solution. Call or write today for our NEW Passive Component Catalog.

M/A-COM Control Components Division
21 Continental Blvd., Merrimack, NH 03054
Tel: 603-424-4111 Fax: 603-424-6580

M/A-COM

INFO/CARD 53

Please see us at RF Expo East, Booths #315, 317.

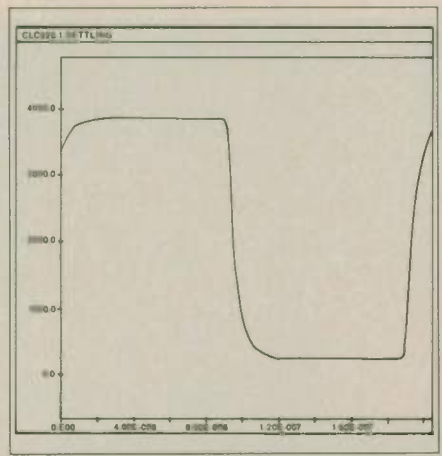


Figure 3a. CLC925 analog-to-digital converter settling time.

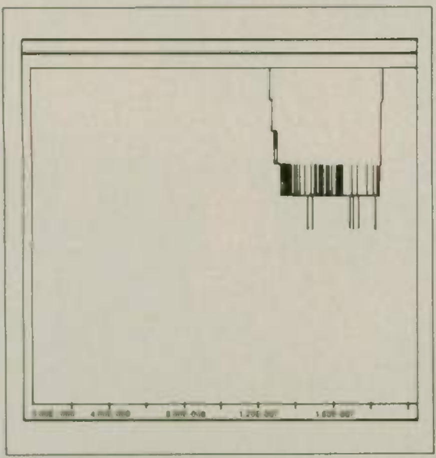


Figure 3b. CLC925 settling-expanded view.

To make the clock period 50 picoseconds longer than the analog test signal period:

clock period = 1/(5 MHz) + 50 ps = 200.05 ns.

The clock frequency then is:

clock frequency = 1/(200.05 ns) = 4,998,750.312 Hz

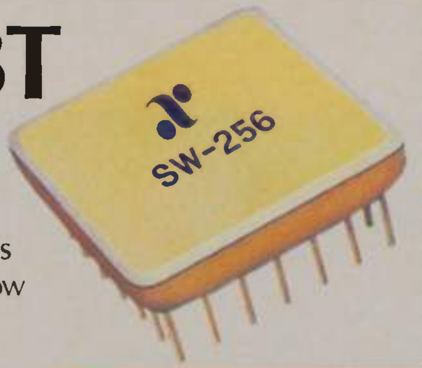
The clock frequency can also be twice this value and every other ADC sample used to reconstruct the waveform. This allows the analog-to-digital converter settling time to be measured near the CLC925's maximum clock frequency. In practice, the settling time numbers are indisguisable.

Figure 3a shows the signal that was acquired through the converter. Figure 3b is the same waveform expanded so that only codes 235 and 246 are depicted on the vertical axis. The spikes in Figure 3b are one quantization level high. They occur in any ADC as it settles and are due to the analog signal being very close to a transition. As the converter settles to a point approximately midway between two transitions, the spiking is greatly reduced. Measured settling time is approximately 50 nanoseconds. This number includes not only the settling time of the analog-to-digital converter but also the settling time of the synthesizer and waveshaping circuit. As a result, the settling time is actually somewhat less. ***RF***

About the Author

Thomas Hack is an Applications Engineer with the Data Conversion Group of Comlinear Corporation. He received his BSEE from Cooper Union, his MSEE from Rensselaer Polytechnic Institute, and his MBA from the University of Colorado. He can be reached at (303) 226-0500 and his address is 4800 Wheaton Drive, Fort Collins, CO 80525.

GaAs SP3T Switch



ANZAC is having a sale and it's one you shouldn't miss. Act now and save over $100.00 on the SP3T that features:

- A 5-1000 mHz Frequency Range
- 1.2 dB Insertion Loss
- 50 ns Switching Speed
- 2.2 mA DC Power Consumption

was $249.95 now only $129.95

Plus. . .

- An integrated CMOS driver (TTL Compatible)
- ANZAC's full guarantee, and of course. . .
- **IMMEDIATE DELIVERY** from stock.

Supplies at this price are limited. Act now by calling **617-273-3333** and save over $100. on this unique device.

ANZAC
A DIVISION OF ADAMS-RUSSELL
A M/A-COM COMPANY

INFO/CARD 54

Please see us at RF Expo East, Booths #315, 317.

CRYSTAL FILTERS

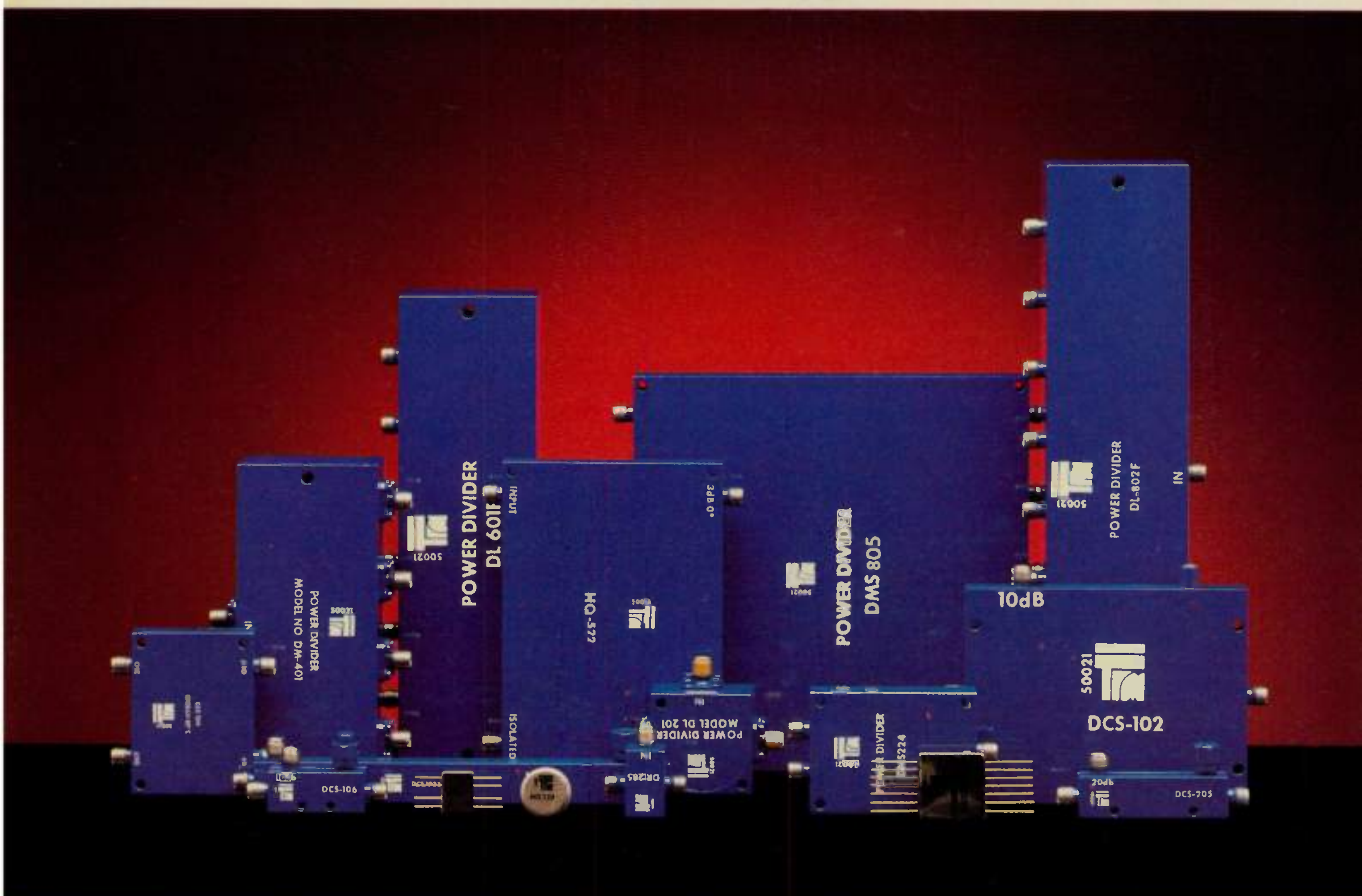
• MONOLITHIC • DISCRETE •

TEMEX ELECTRONICS is a manufacturer of Crystal Filters, Discriminators, L/C Filters and Crystals. TEMEX designs to custom specifications as well as the 10.7 MHz and 21.4 MHz standards. We take pride in fast response and the support of our customers. • PHONE • FAX • MAIL •

TEMEX ELECTRONICS, INC.
5021 N. 55th Ave. #10 Glendale, Az. 85301
(Tel) 602-842-0159 (Fax) 602-939-6830

INFO/CARD 55

BROADBAND POWER DIVIDERS



FULL AND MULTI-OCTAVE APPLICATIONS, DC-20GHz

When it comes to broadband power dividers, TRM offers more than 100 different designs covering virtually any application in the .125-20GHz range and encompassing both full and multi-octave band performance. Standard models, which are available in a variety of power divisions, can be modified or repackaged to meet specific operating requirements.

As a leading developer of microwave power dividers for over 20 years, TRM has established a well deserved reputation for providing solutions that are totally engineered to meet the most demanding specifications. The results are apparent in the breadth of our product line and in the number of major MIL Spec programs that utilize our technology. Contact us for more information regarding both. And send for a free catalog today!

TRM... We'll change your mind about microwave components.

TRM, Inc.
Grenier Field
401 Kelly Ave.
Manchester
NH 03103
603-627-6000 FAX 603-627-6025

INFO/CARD 56

Please see us at RF Expo East, Booth #614.

SPECIFICATIONS (2N, 3N, 4N)

MODEL NO.	FREQUENCY RANGE (GHz)	INSERTION LOSS (dB MAX.)	ISOLATION (dB MIN.)	VSWR IN (MAX.)	VSWR OUT (MAX.)	AMPLITUDE BALANCE (dB MAX.)	PHASE BALANCE (DEG. MAX.)	INPUT POWER (WATTS MAX.)	OUTLINE
DMS 221	2–18	1.00	20	1.50:1	1.50:1	0.40	6	30	1
DMS 347	6–18.5	1.00	15	2.00:1	1.70:1	0.50	5	5	3
DMS 421	2–18	1.75	20	1.50:1	1.50:1	0.50	8	30	2
DMS 447	6–18.5	1.25	15	1.60:1	1.60:1	0.30	8	30	1

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ **Announcing the 1991** ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

RF Design Awards Contest

NOW WITH TWO ENTRY CATEGORIES! ...AND TWO PRIZE PACKAGES!

The DESIGN Contest

GRAND PRIZE: HP 8751A Spectrum Analyzer
9 kHz-1.7 GHz coverage, synthesized, portable spectrum analyzer for bench or field use.
...provided by Hewlett-Packard Company

SECOND PRIZE: TESS System Design Software & Accessories
Speed up your system design with this block diagram simulator, plus ORCAD/SDT III and FORTRAN.
...provided by TESOFT

THIRD PRIZE: Package of RF Components
Popular ANZAC signal processing components.
...provided by Adams-Russel, ANZAC Div.

RULES:

1. Entries shall be RF circuits containing no more than eight single active devices, or six integrated circuits, or be passive circuits of comparable complexity.

2. The circuit shall have an obvious RF function and operate in the below-3 GHz frequency range.

3. Circuits shall be the original work of the entrant, not previously published. If developed as part of the entrant's employment, entries must have the employer's approval for submission.

4. Components used must be generally available, not obsolete or proprietary.

5. Submission of an entry implies permission for publication in *RF Design*. All prize winning entries will be published, plus additional entries of merit.

6. Winners are responsible for any taxes, duties, or other assessments which result from the receipt of their prizes.

7. Entries must be postmarked no later than March 30, 1991, and received no later than April 10, 1991.

8. All entries will remain confidential until the publication of the July 1991 issue of *RF Design*.

SPECIAL PRIZE (Both Contests) — RSG-10 1 GHz Signal Generator
Everyone has a chance for a major prize in this contest — a full-feature synthesized signal generator with 100 Hz resolution, AM/FM modulation, and 20-setup memory. One name will be drawn at random from all non-winning entries to receive this instrument.
...provided by Ramsey Electronics

Every engineer who enters will get a special RF Design Awards T-Shirt — include your size when you enter! ...compliments of TESOFT

The PC SOFTWARE Contest

GRAND PRIZE: Macintosh SE/30 System and RF Designer Software
Analyze, synthesize, and optimize your circuits on your own Macintosh system, with hard disk and printer.
...provided by ingSOFT Ltd.

SECOND PRIZE: Passive/Filter Design Software
"Student edition" of S/FILSYN filter design program, passive module, and utilities with plenty of software performance.
...provided by DGS Associates

THIRD PRIZE: Package of RF Components
Another package of ANZAC RF components — stock your lab. ...provided by Adams-Russell, ANZAC Div.

RULES:

1. Each entry shall consist of a computer program that assists in the design of RF circuits. Programs for test or control of RF circuits will also be accepted.

2. Programs must operate on computers compatible with either PC/MS-DOS, or Apple Macintosh operating systems. Note any special hardware requirements (memory, graphics, etc.).

3. Programs written in languages other than GWBASIC or BASICA should be supplied in both compiled, executable form, and uncompiled source code.

4. Entries shall be submitted on disk, accompanied by supporting documentation, including theoretical explanations and references, and instructions for operation of the program. A printed copy of the source code is required.

5. Programs must be the original work of the entrant, and must not be previously published or distributed (including distribution by open BBS or shareware). If developed as part of the entrant's employment, entries must have the employer's approval.

6. Submission of an entry implies permission for publication in *RF Design* and distribution by the RF Design Software Service. All prize winning entries will be published, plus other entries of merit. (Some restrictions on publication and distribution of source code may be acceptable.)

7. Winners are responsible for any taxes, duties, or other assessments which result from the receipt of their prizes.

8. Entries must be postmarked no later than March 30, 1991, and received no later than April 10, 1991.

9. All entries remain confidential until publication of the July 1991 issue of *RF Design*.

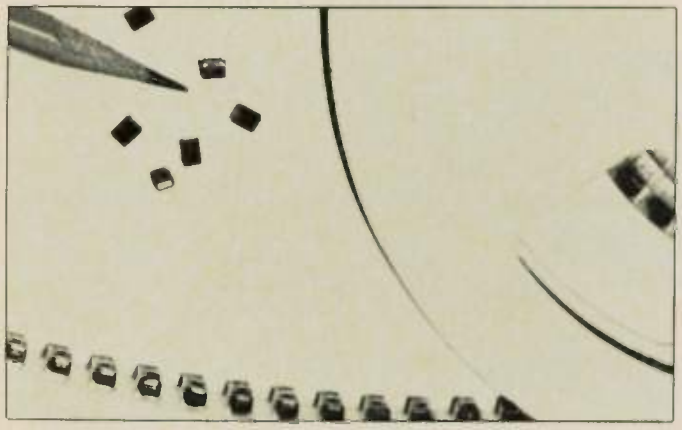
Send entries to: RF Design Awards Contest
***RF Design* magazine**
6300 S. Syracuse Way, Suite 650
Englewood, CO 80111

★ ★

Surface Mount Inductors

J. W. Miller Division has produced new surface mount inductors from 0.1 μH through 1000 μH. Current ratings from 740 mA/0.1 μH through 30 mA/1000 μH are available for operation over the −20 to +85 degrees Celsius temperature range. The units are for use over the 2.5 to 250 MHz frequency range. Packaged in bulk, 500-piece reels or on tapes, the inductors measure 3.2 mm long by 2.5 mm wide by 1.3 mm high. Minimum Q is 30 for inductors less than 1 μH or greater than 100 μH and 40 for inductors between those two values. Precise dimensions and excellent flow soldering terminal strength facilitate automated production. These inductors have internally welded connections and are resistant to solvents per MIL 202 E. Their solderabililty is per MIL STD 202 Method 208, and they are resistant to a soldering temperature of 250 degrees Celsius for 10 seconds. Tinned copper is used for the terminals and the core is ferrite.

J. W. Miller Division
INFO/CARD #200



Frequency Counter/Finder

The Model UTC 8030 universal counter-timer is a benchtop frequency counter and portable frequency finder from Optoelectronics. It makes direct and prescaled frequency, period, and time interval measurements, and calculates and displays frequency ratios. An external jack is provided for lab reference clocks more accurate than the instrument's ±1 PPM. Display resolution is 1 Hz in 600 MHz. As a frequency finder for use in the

field, UTC 8030 features a 10 Hz to 2400 MHz operating range and sensitivity better than 1 mV up to 500 MHz. and better than 10 mV at 2400 MHz. The unit features a 16-segment LCD signal strength bargraph, with each segment representing 3 dB. The UTC 8030 is priced at $579 each, and optional ±0.1 PPM time base is $125; NiCad battery pack is $75; LCD backlight is $40.

Optoelectronics, Incorporated
INFO/CARD #199

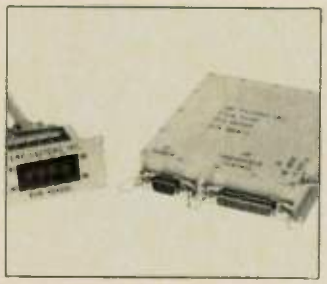
Ferrite EMI Attenuators Evaluation Kit

Chomerics, Inc. is offering a CHO-SORB® EMI Attenuators Evaluation Kit for design and test engineers. The kit contains 15 ferrite configurations including cylindrical and split cylindrical for round cables, and split rectangular for flat ribbon cables. Both plastic and metal clamps are included in the kit to facilitate installation for split configurations. Chomerics CHO-SORB attenuators are made of a specially formulated ferrite material of nickel zinc/iron oxide, and reduce EMI in cabling applications. Typical properties of CHO-SORB material are initial permeability of 850, with a maximum of 5000, and volume resistivity of 10^5 ohm-cm. They are used on computers, printers, keyboards, radio and television receivers and other high frequency devices.

Chomerics, Incorporated
INFO/CARD#198

Frequency Synthesizer

The Series 400 Frequency Synthesizer from EMF Systems has a frequency range of 1200 to 2400 MHz with options up to 10 GHz and a bandwidth up to 500

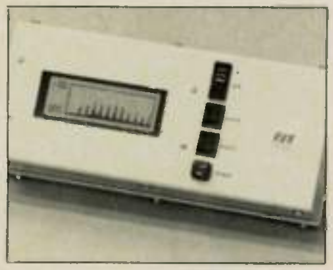


MHz. Its step size is 1 MHz with other step sizes available, and an output power of +13 dBm minimum. The seriers 400 has a switching speed of 1ms for a 1MHz step size. Phase noise is −85 dBc at 10 kHz, −105 dBc at 100 kHz, and −125 dBc at 1 MHz. Harmonics are −15 dBc maximum and discrete spurious signals are −60 dBc. The Series 400's operating temperature range is −20 to +70 degrees Celsius and MIL environments are optional. Options include external reference frequencies of 1 MHz or 10 MHz, TTL level external reference input, internal reference, output power to +20 dBm, thumbwheel switch and cable assembly, and AFC. The synthesizer is 4.2" × 4.8" × 1.5" plus a mounting flange.

EMF Systems, Incorporated
INFO/CARD #197

Spectrum Display Unit

Microdyne has introduced the CSD-SDU Spectrum Display Unit. The portable unit is designed for use in satellite earth station installations, alignments, and system check out. The CSD-SDU operates in the L band (950 - 1459 MHz) and displays the spectrum on an LCD graphics screen. The unit can be used for both C and Ku band dish alignment, and for L band network setup and maintenance. It also provides three display modes: bar graph mode that displays 24 vertical bars which correspond to the dBm levels for each C band transponder; spectrum mode (5 MHz steps); and oversample mode that removes the level fluctuation due to vertical sync modulation in the bar graph mode. The CSD-SDU has a self-contained, rechargeable battery pack good for three



hours of continuous operation or two hours when powering an LNB. An internal, low-battery indicator monitors the rechargeable power supply.

Microdyne Corporation
INFO/CARD #196

VCXO/ECL Oscillators

Connor-Winfield has developed four crystal oscillators for use with fiber optics transmission lines. The 51.840 MHz CMOS VCXO (HV54/64-160) and the 155.520 MHz ECL (EO1-453/463) are available with ±20 PPM center frequency stability over the temperature ranges of −40 to +85 and 0 to +70 degrees Celsius. The EO1-453/463 also features dual complimentary outputs. The HV54/64-160 models run $87.95 each, and the EO1-453/463 models run $82.70 each, in ten piece quantities.
Connor-Winfield Corporation
INFO/CARD #195

Low Noise Frequency Synthesizers

The PTS Model 0 in the ×10 series covers the 10 kHz to 10 MHz frequency band with 1 Hz resolution. Performance specifications include −35 dBc harmonic distortion, −60 dBc spurious outputs, and −132 dBc SSB phase noise at 1 kHz offset. The 160R-type OEM synthesizer covers the 0.1 to 160 MHz range with various DDS options for phase-continuous switching available.
Programmed Test Sources, Incorporated
INFO/CARD #194

Miniature Wideband Current Probe

Model 711 Miniature Wideband Current Probe from American Laser Systems has a bandwidth of 8 kHz to 100 MHz and a risetime of less than 3.5 ns. It adds only 0.2 ohms shunted by 4 μH to the circuit being measured. The price is $85 for 1 to 9 down to $53 for 75 to 100 pieces.
American Laser Systems, Incorporated
INFO/CARD #193

Broadband Noise Generator

Noise Com has released the NC 8110, a noise generator that delivers 1 W of white Gaussian noise from 2 to 500 MHz. It contains a precision noise source capable of delivering a broadband signal as well as an amplifier with excellent amplitude flatness. Several options are available including 10 dB and 110 dB attenuators calibrated in 1 dB steps.
Noise Com
INFO/CARD #192

S-Band LNA

An S-Band LNA has been released by California Amplifier with an input frequency from 2.1 to 2.7 GHz, a noise figure of 1.5 dB at 23 degrees Celsius, and output power of +10 dB minimum at 1 dB compression. Part C308872 is the high gain unit (25 dB), and part C30947 is the low gain unit (20 dB). The price per unit is $60.
California Amplifier
INFO/CARD #191

Bandpass Filters

Model 9000 Series DRF Filters from have tunable frequency ranges of 20 - 40 MHz, 40 - 80 MHz, 80 - 160 MHz, 160 - 320 MHz, and 320 - 520 MHz. They have a bandwidth of 4 to 10 percent and VSWR of 2:1 maximum.
Interad Ltd.
INFO/CARD #190

GPS Marine Antenna

The Model AN-712 is a low loss, commercial GPS antenna that provides hemispherical coverage at the L1 operating frequency. Gain is 0 dBic minimum at zenith, −3 dBic nominal at the horizon, and −10 dBic minimum at 15 degrees below the horizon.
Antenna and Microwave Div. of Adams-Russell
INFO/CARD #189

Fiber Optic Link

Lite Link™ is a fiber optic system for land mobile and other communications released by Decibel. A DBFST11P-G Optical Transmitter converts a 850-890 MHz analog signal to 1300 nm light and transmits it over a single mode optical fiber to a Decibel 50, 100, or 150 watt tower top Optical Receiver/Power Amplifier which converts the light back to RF and amplifies it for radiation by the antenna.
Decibel
INFO/CARD #188

Wide Bandwidth Delay Lines

These passive 30.0 MHz video delay lines are designed to delay 30.0 MHz signals with a

9385 SERIES
CERAMIC TRIMMER CAPACITORS

- Tiny, rugged construction
- Microwave capability
- PC or SL mounting
- 5 ranges: 1.2-3 through 4-30 pF

Johanson
MANUFACTURING CORPORATION
Rockaway Valley Road
Boonton, N.J. 07005
(201) 334-2676 FAX: 201-334-2954

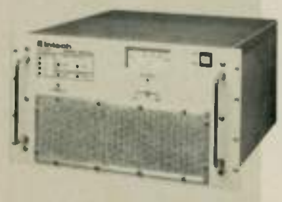
INFO/CARD 57

When you need TTL Clock Oscillators
FAST
or quality Crystals
FAST
call 800-333-9825

Comclok Inc.
Cal Crystal Lab., Inc.
FAX 714-491-9825

INFO/CARD 58

PA2-400 POWER AMPLIFIER



(Power supply not show)

200 watts
2-400MHz

intech

Design Features

- ☐ Microprocessor Controlled
- ☐ Continuous Duty Cycle
- ☐ Front Panel Power Meter
- ☐ Front Panel LED Status
- ☐ Self Protection
- ☐ Solid State
- ☐ MOS FET
- ☐ Modularized Design
- ☐ Compact Size
- ☐ Light Weight

With off the shelf products
or products built to your specifications

INTECH Incorporated
AMPLIFIERS — COMMUNICATIONS

Com/Nav Division	TEL	(408) 727-0500
2270 Martin Avenue	TWX	(408) 910-338-0254
Santa Clara CA 95050	FAX	(408) 748-9489

INFO/CARD 59

Performance In a Pinch

- Fundamental Crystals to 125 MHz
- ECL Clock Oscillators to 500 MHz (4-pin DIP) (size)
- VCXOs to 200 MHz (4-pin DIP)
- Clock Oscillators to 200 MHz (4-pin DIP)
- V.C.O. Oscillators to 500 MHz (4-pin DIP)
- Tubular Crystals
- Tubular Filters
- 4-pole on One Blank
- Complete Military Screening
- Surface Mount Capabilities

SCP
Sokol
Crystal Products, Inc.
Since 1975

Manufacturing: 121 Water Street, P.O. Box 249, Mineral Point, WI 53565
Phone (608) 987-3363, Fax (608) 987-3882
Sales: 3001 Latham Drive, Madison, WI 53713
Phone (608) 273-0222, Fax (608) 273-0577

INFO/CARD 60

Please see us at RF Expo East, Booth #505.

maximum delay time of 200 ns without cascading. The range of eight lines with delay times from 10 ns to 200 ns can be further programmed by users in units of 2, 4, 8, 16, and 32 ns.
RF Technology, Incorporated
INFO/CARD #187

Class A 500 Watt HF Transmitter

Harris RF Communications has introduced a new Class A 500 Watt HF transmitter, designed for use in environments where multiple transmitters and receivers are collocated. The RF-1135 provides 500 watts of RF output power over a bandwidth of 2 to 30 MHz in 10 Hz increments.
RF Communications Group
Harris Corporation
INFO/CARD #186

Miniature Frequency Synthesizers

A family of low cost miniature frequency synthesizers covering frequencies from 200 to 1600 MHz with bandwidths up to an octave has been released by Pulsar Microwave. Phase noise at 1 kHz offset is greater than −78 dBc and −95 dBc minimum at 100 kHz offset.
Pulsar Microwave Corporation
INFO/CARD #185

Miniature Switches

Model #CT33S6C internally terminated SPDT features 1.4:1 maximum VSWR, insertion loss of 0.4 dB maximum, and 60 dB minimum isolation from DC to 12 GHz, and Model #HS-35S50-1T features 1.2:1 maximum VSWR, insertion loss of 0.2 dB maximum, and minimum isolation of 80 dB.
Teledyne Microwave
INFO/CARD #184

Dual Receiver

Watkins-Johnson has introduced the WJ-8700, a compact dual VLF/HF receiver designed to monitor or search the 5 kHz to 32 MHz frequency range. AM, FM, CW, and SSB demodulation modes are available. Numerous options are available, including: 21.4 MHz signal monitor output, IEEE-488 or RS-232 remote interface bus, and independent sideband.
Watkins-Johnson Company
INFO/CARD #183

Cellular Panel Base Station Antenna

Six cellular panel antennas with adjustable beamwidths have been introduced by Antenna Specialists. The antenna Series ASPD990J has been designed for the 824 to 896 MHz cellular band and offers a horizontal beamwidth that may be set to 60, 90, or 110 degrees without radome removal. Gain ranges from 10.5 to 12.5 dB and VSWR is 1.5:1 maximum.
Antenna Specialist Company
INFO/CARD #182

20 dB Coupler

Sage Laboratories has released the Model FC4545-3 20 dB ± 1 dB coupler. This unit operates over the 1810-1830 MHz range, has an insertion loss of less than 0.25 dB, VSWR of 1.15:1, and greater than 40 dB of isolation. The coupler is designed for airborne applications and weighs 1.1 ounces.
Sage Laboratories, Incorporated
INFO/CARD #181

Surface Mount Filter Packages

IMpac™ Surface Mount Filter Packages feature Mil-spec lumped element miniature filter technology. The packages contain miniature low-, band-, and high-pass designs in a variety of transfer functions. The filters have isolation of 70 dB, impedance of 50 ohms, and a frequency range of DC to 5000 MHz.
Integrated Microwave
INFO/CARD #180

Mica Capacitors

A family of subminiature precision RF capacitors is now available from Cornell Dubilier Electronics. The units work up to 1 GHz and are available in 191 standard ratings with tolerances down to ±0.5 pF or ±0.5 percent.
Cornell Dubilier Electronics
INFO/CARD #179

450 MHz DAC

Plessey Semiconductors is now offering a 450 MHz, 8-bit DAC. The SP98608 has settling times of 2.2 ns, ± 1/2 LSB. The unit is capable of driving doubly terminated 50 ohm lines. Pricing is $49.95 in quantities of 1000 and is available now.

Imagine A Single Source For Every Frequency Control Need...

Now Imagine What That Source Can Do For You.

With CTS, you can specify from one of the broadest lines of frequency control products available anywhere—crystals, clock oscillators, VCXO's, TCXO's and ovenized oscillators. If a standard product won't do, our engineers will design one that meets the requirements of your application. But there are more reasons for making CTS your single source for frequency control products.

Our cutting-edge technology assures you of the most advanced frequency control products. The in-house production of crystals, precision designs and strict quality control give you an added margin of reliability. Additionally, our technical support teams provide a problem solving capability that can be a real asset for your design and engineering teams.

Get the product your application requires, plus technical services and reliability proven in the most demanding military, instrumentation, telecommunication and data processing applications. All from a single source. Call now for the name of your CTS Sales Representative.

CTS
CORPORATION

Around The World,
Your Single Source For Excellence℠

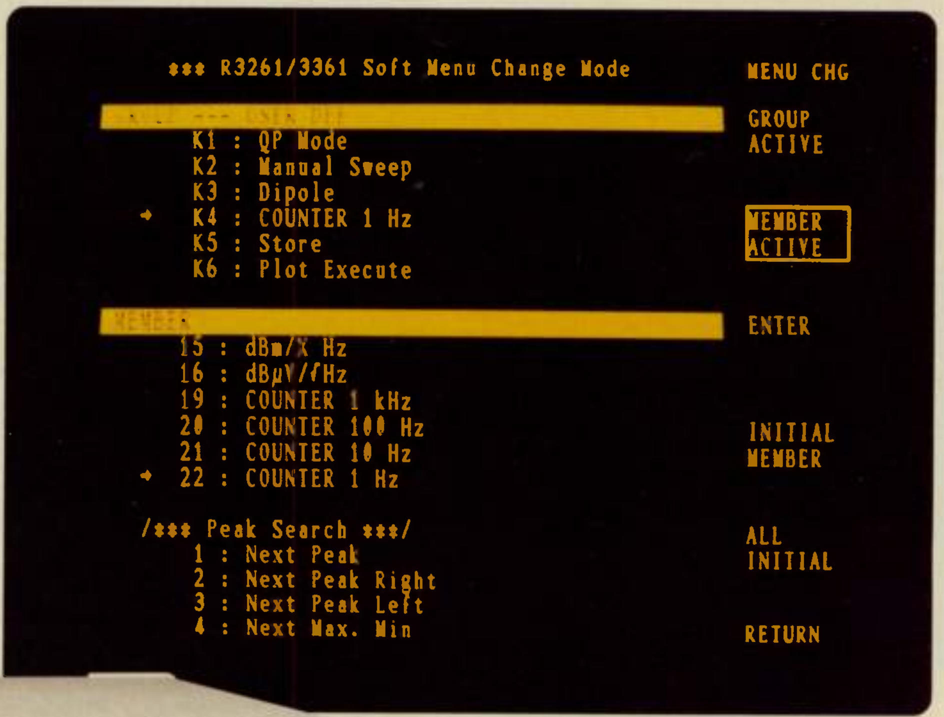
CTS Frequency Control Division,
400 Reimann Ave., Sandwich, IL 60548, Tel: 815/786-8411, Fax: 815/786-9743

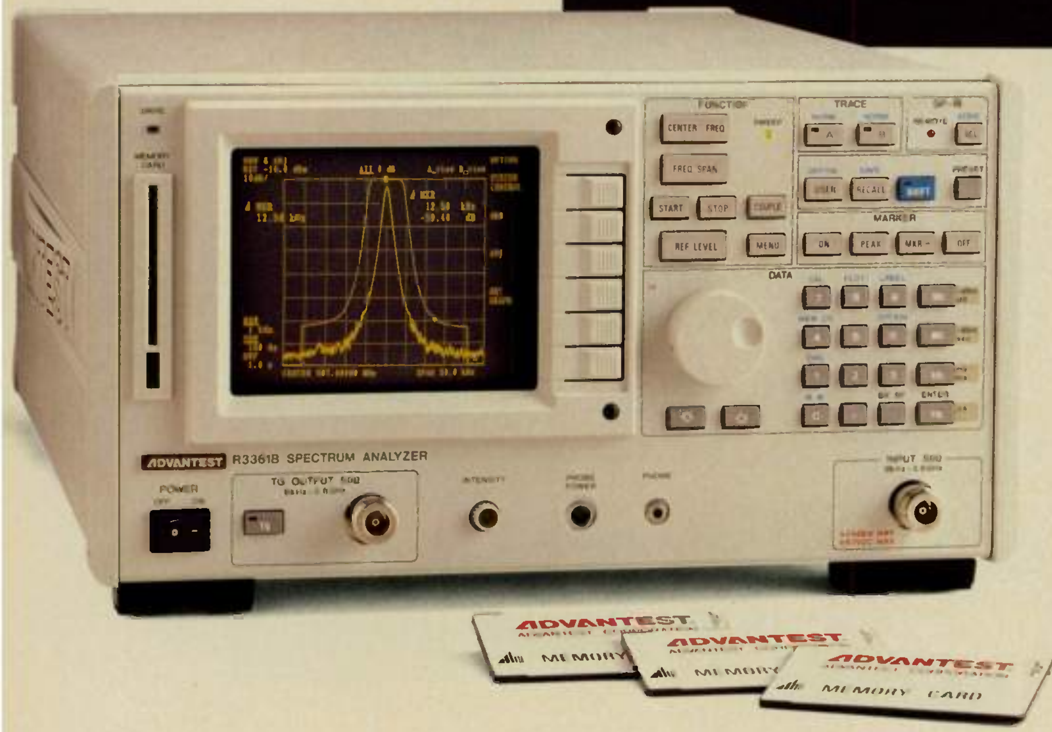
See us at Wescon Booth #3059 and RF Expo Booth #323. INFO/CARD 61 **Please see us at RF Expo East, Booth #323.**

User Defined Functions Customize and Speed Operation.

A measuring window and IC memory card functions make ADVANTEST ideal for the lab or production.

Quick and easy operation: The R3261/3361 Series features a user-defined function that enables selection of the functions needed at the touch of a key. The USER key operates the same way as the FUNCTION key on a personal computer, so personalized menus can be created quickly and easily. Pick the R3261/3361 Series for all the right reasons — for speedy panel settings, a DEFINE function that can be used to replace the software menu, a measuring window function and the flexibility of IC memory card functions.





- Frequency range: 9kHz to 3.6GHz (R3261B/3361B) 9kHz to 2.6GHz (R3261A/3361A)
- Built-in tracking generator and 120dB display "display dynamic range. . ." range (R3361A/3361B)
- Synthesis technique used for 1Hz-resolution setting and measurements "Total level accuracy of 1dB (Typ.)."
- Quasi-peak measurements 70dB dynamic range
- Measuring window function
- Built-in "controller function." (option)

R3261/3361 Series Spectrum Analyzer

ADVANTEST®

ADVANTEST CORPORATION Shinjuku-NS Building, 4-1, Nishi-Shinjuku 2-chome, Shinjuku-ku, Tokyo 163, Japan Phone (03)342-7500 Facsimile (03)342-7410 Telex 232-4914 ADVAN J

Advantest America, Inc. 300 Knightsbridge Parkway, Lincolnshire, IL 60069, U.S.A. Phone:(708)634-2552 Facsimile:(708)634-2872

Advantest UK Limited CI Tower, St.Georges Square, High Street, New Malden, Surrey, KT3 4HH, U.K. Phone:(081)336-1606 Facsimile:(081)336-1657

INFO/CARD 62

Please see us at RF Expo East, Booth #609.

Plessey Semiconductors
INFO/CARD #178

Wideband Limiters

Model LCPM-8-160/50-M features very low AM to PM conversion over the 2-200 MHz range, and model LCPM-8-30/15 is a wideband limiter with a bandpass filter to meet a user-specified bandwidth in the 2-200 MHz range. It also features a power amplifier at the output capable of delivering up to +20 dBm.
Miteq
INFO/CARD #177

Manual SP2T Switch

Loral Microwave-Wavecom has introduced the Model 020-EM2-A4S-6CO, a manual SP2T RF coaxial switch that operates from DC to 26.5 GHz. The switch has VSWR of 1.6:1 or less, insertion loss of 0.6 dB or less, and isolation of 50 dB minimum. It meets MIL-S-3928 and MIL-E-5400.
Loral Microwave-Wavecom
INFO/CARD #176

Surface Mount Clock Oscillators

Toyocom has released surface mount clock oscillators in the frequency range from 1.5 to 32 MHz. They are offered in a plastic 4 pin SOJ package and models compatible with TTL logic or high speed CMOS are available. Current pricing is $2.70 in 1000 piece lots.
Toyocom
INFO/CARD #175

8-Channel Switched Filter Bank

The 8-channel switched filter bank from K&L Microwave, covers the 20 MHz to 1020 MHz frequency range and has channel bandwidths that range from 30 to 60 percent. Isolation is 70 dB from DC to 1300 MHz, insertion loss is 5 dB maximum, and VSWR over the 3 dB channel bandwidths is 1.7:1.
K&L Microwave
INFO/CARD #174

RF Design Software Service

Computer programs from *RF Design*,
provided on disk for your convenience.
All disks are MS-DOS/PC-DOS compatible, unless otherwise noted.

Disk RFD-1190: November 1990
"Broadband Impedance Matching by Polynomial Synthesis" by David Lang. Generates a polynomial equalizer function directly from S-parameters, and synthesizes matching networks. (BASIC, source listing and compiled versions)

Disk RFD-1089: October 1990
"Microstrip CAD Program," by Thomas Cefalo of MITRE Corp. Computes microstrip impedance, delay, inductance, capacitance, and other factors. (BASIC, compiled)

Disk RFD-0990: September 1990
"Split Tee Power Divider" from article by S. Roslonlec. Performs matrix computations for analysis of this type of circuit (BASIC)

Still Available: RFD-1989-SET
All 11 disks from 1989 issues of *RF Design* — $74.00 (5¼") or $82.00 (3½"). Price includes postage. Foreign orders add $8.00 (outside U.S. and Canada)

Send for a complete listing of available programs, or circle Info/Card below.

Disks are $9.00 each (5¼ in.) or $10.00 (3½ in.). Outside U.S. and Canada, add $8.00 per order. Foreign checks must be in U.S. funds, and must be payable in the U.S. Prices include postage and handling.

Annual subscriptions are available, providing 13 disks for $90.00 (5¼ in.) or $100.00 (3½ in.). Specify starting date. For subscribers outside the U.S. and Canada, add $50.00.

Payment must accompany order...specify disks wanted...send check or money order to:

RF Design Software Service
P.O. Box 3702
Littleton, Colorado 80161-3702
Questions and comments should be directed to *RF Design* magazine.

INFO/CARD 84

Eight reasons why

Here are eight models from our broad line of broadband antennas and TEM cells, offering field strength up to 1,000 volts/meter.

1-800-933-8181

will get you the best antenna/amplifier selection advice for your rf susceptibility testing. When you dial our toll-free number you'll talk direct with one of our applications engineers.

ar amplifier research

160 School House Road, Souderton, PA 18964-9990 USA
215-723-8181 • TWX 510-661-6094 • FAX 215-723-5688

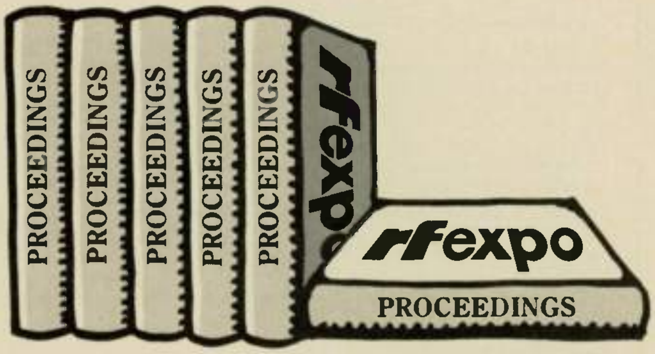
417

INFO/CARD 63

Please see us at RF Expo East, Booths #504, 506.

RF TECHNOLOGY EXPO
and
RF EXPO EAST

Proceedings Available



Successful engineers like yourself rely on the RF EXPO PROCEEDINGS to keep them informed on the latest RF technological advances. The proceedings contain the best papers presented at *RF Design's* trade shows. Written by industry experts, these papers let you share the expertise to update your circuit design.

Topics include:

* filter design * frequency synthesis * power amplifiers * antennas * receiver design * phase-locked loops * transmissions systems * oscillator design * and many other important topics.

Give yourself the designing edge...order your copies of the RF EXPO PROCEEDINGS today!

Hurry, supplies are limited.

Please send me the following Proceedings:

☐ RF Technology Expo 90
☐ RF Technology Expo 89
☐ RF Technology Expo 88
☐ RF Technology Expo 87
☐ RF Technology Expo 86
☐ RF Expo East 89
☐ RF Expo East 87
☐ RF Expo East 86

Name
Title Phone
Company Name
Address
Bldg. No. M/S
City State ZIP
Country Postal Code

Price:

$125 each — outside U.S. add $30.00 to total order for shipping charges.

Save 20% Take all 8 for $800.00 A savings of $200.00

Payment: (Payment must accompany order)

☐ Check enclosed

☐ Bill my: ☐ VI ☐ AE ☐ MC

Card # Exp.
Signature Date

SEND TO: RF EXPO PROCEEDINGS
6300 S. Syracuse Way, Suite 650
Englewood, CO 80111

1190

Application of Shielded Cables

By Thomas A. Jerse
Hewlett-Packard Signal Analysis Division

Shielded cables play an important role in the design of RF and microwave equipment. One need only look through a cable manufacturer's catalog to gain an appreciation of the many different types of shielded cables available. This article explores the differences in shielding characteristics among shield types. But no matter how good its theoretical shielding, a cable is only as good as the way in which it is grounded. Thus, the implications of cable grounding on the shielding effectiveness of a cable will also be discussed.

Conductors are shielded for two basic reasons: to prevent the coupling to other electronic circuits of the signal carried by the conductor and to protect against the coupling of external electric and magnetic fields to the conductor. In most applications, the cable shield also provides a return path for the current flowing in the conductor. In this way, a shielded cable serves as transmission line, providing a path with a well-controlled characteristic impedance for the propagation of the signal from one circuit to another.

A properly grounded cable shield forms a barrier against both electric and magnetic fields. A grounded shield ideally provides a low-impedance, low-potential surface for terminating the flux lines of an electric field. Good magnetic-field shielding is obtained when both the signal current and all its return current flow inside the cable.

When a cable drives a balanced load, as in Figure 1a, all the signal current, I_1, must return in the cable shield as I_s. Because the current loop is contained inside the cable, a minimum amount of magnetic field is radiated. But balanced loads are often costly to implement in practice. As a result, most loads are unbalanced as in Figure 1b; the source and the load are both connected to a ground system, in this example, a chassis. This situation presents the signal current flowing through the load with two possible return paths. The current can flow back down the cable shield as I_s, or it can flow along the chassis as I_g. The cable provides the best magnetic shielding when all the signal current flowing through the load returns along the shield; i.e., $I_1=I_s$. The chassis path is much less desirable because the magnetic flux produced by the return current is unshielded.

The proportion of current flowing in the two paths depends on the relative impedances presented by the chassis and the cable shield. At low frequencies, the current divides according to the resistance presented by each path. The chassis generally presents significantly less resistance than the cable shield so that the bulk of the low-frequency current returns through the chassis.

At high frequencies, most of the return current flows in the cable shield because magnetic-field coupling between the inner conductor and the shield makes this the path of least inductance (1). Consider the simplified model of Figure 2 where a source drives a load through a shielded cable. The cable shield is represented by the series combination of its inductance, L_s, and its resistance, R_s. The concentric geometry of the cable prescribes strong magnetic field coupling between the inner conductor and the shield. Because every magnetic-flux line produced by current flowing in the shield encircles both the shield and the inner conductor, the mutual inductance, M, between the shield conductor and the center conductor equals the self-inductance of the shield, L_s.

The relationship between I_1 and I_s can be determined by setting the sum of the voltage drops around the shield loop equal to zero.

$$I_s(R_s + j\omega L_s) - I_1 j\omega M = 0 \quad (1)$$

After rearranging the terms and observing that L_s=M, the relationship between load and shield current can be written

$$\frac{I_1}{I_s} = \frac{j\omega L_s}{R_s + j\omega L_s} \quad (2)$$

This transfer function, plotted in Figure 3, asymptotically approaches unity at high frequencies. Here, the cable supplies the most effective magnetic shielding. The breakpoint of this high-pass function is given by

$$\omega_c = \frac{R_s}{L_s} \quad (3)$$

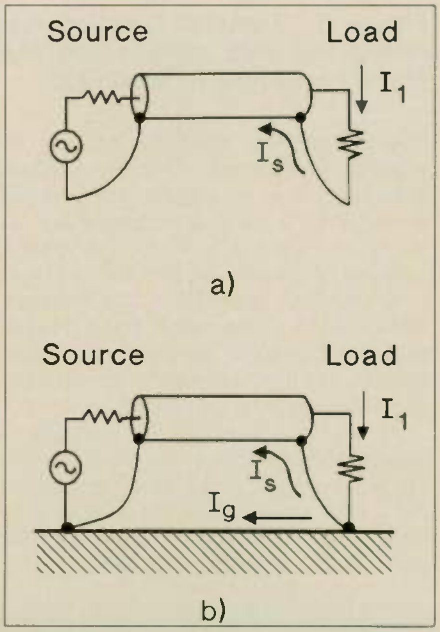


Figure 1. a) Balanced load circuit, b) Unbalanced load circuit - this gives the returning current two paths to the source.

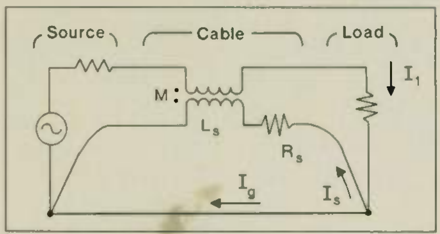


Figure 2. Equivalent circuit to evaluate current flow in a shielded cable.

and is known as the shield cutoff frequency. This parameter depends on the physical characteristics of the cable and varies among cable types from a few hundred hertz to a few kilohertz. Because the shield cutoff frequency represents the 3-dB point where only 70.7 percent of the signal current returns in the shield, a general rule-of-thumb is that $5\omega_c$ marks the lower limit of good magnetic shielding.

Cable Transfer Impedance

The ability of a shielded cable to protect its circuit against external inter-

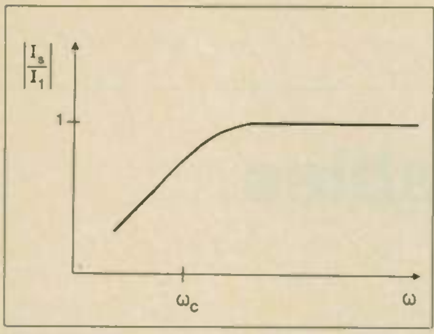


Figure 3. Transfer function between the load current and the current returning in the shield.

ference can be characterized by its transfer impedance. Transfer impedance is a useful measure of the isolation provided by a cable shield because, as shown in Figure 4, it relates the voltage induced on the inside of a cable shield to a current flowing on the outside. Because the voltage drop along a cable is proportional to its length, transfer impedance measurements are ordinarily normalized to a unit length.

At high frequencies, the skin effect separates the differential-mode return current flowing on the inner surface of the cable shield from the interference current flowing on the outer surface. The skin effect describes the tendency of high-frequency current to flow on the surface of conductors. This phenomenon is quantified by a skin depth, which represents the distance below a conductor surface where the current density falls to 1/e of the surface current. Skin depth depends on frequency and the material properties of the conductor according to

$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}} \tag{4}$$

where ω is the frequency of the current, μ is the permeability of the conductor ($4\pi \times 10^{-7}$ H/m for non-magnetic material), and σ is the conductivity of the conductor.

One would expect cable transfer impedance to decrease with frequency as the skin depth becomes shallower. The transfer impedance of a rigid or semi-rigid cable that uses a solid, tubular shield has this characteristic and takes the form

$$Z_T = R_0 \frac{(1 + j)\,\frac{t}{\delta}}{\sinh\left[(1 + j)\,\frac{t}{\delta}\right]} \tag{5}$$

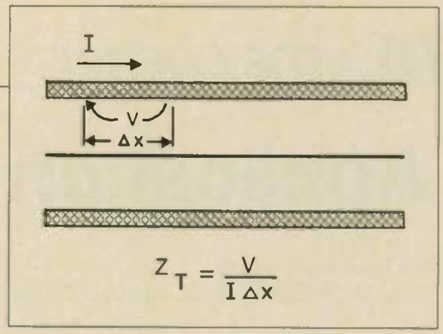


Figure 4. The concept of transfer impedance in a shielded cable.

where t is the shield thickness. R_0 represents the DC resistance of the cable shield and depends on the shield parameters as

$$R_0 = \frac{1}{2\pi a\sigma t} \tag{6}$$

with the outer radius of the cable shield denoted by a. The variation with frequency of the transfer impedance, plotted in Figure 5, shows that there is virtually no communication between currents flowing on the inside and the outside of a solid shield at high frequencies. The transfer impedance of a solid shield, given in equation 5, is also described as a diffusion impedance, Z_d,

INFO/CARD 93

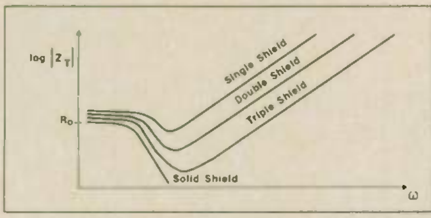


Figure 5. Typical effect of shield type on transfer impedance.

because it represents the ability of the signal to propagate directly through a metal shield.

Flexible cables find the widest use because they are more convenient than semi-rigid cables. A flexible shield is formed by weaving together a number of groups of fine wires. Woven shields exhibit a regular pattern of rhombic apertures which serve as pathways for field coupling through the shield. In most high-frequency applications, magnetic field coupling dominates so that the transfer impedance of a flexible cable is usually expressed as

$$Z_T = Z_d + j\omega M_{12} \qquad (7)$$

where M_{12} represents the mutual inductance between the outside of the shield and the inner conductor. M_{12} depends on the physical parameters of the cable shield, such as the number and size of the wires used in the weave, the angle of the weave, and so on (2). The diffusion impedance, Z_d, is proportional to the DC resistance of the woven shield and diminishes with frequency in accordance with equation 5.

Equation 7 reveals that, at lower frequencies, the principal mechanism for leakage through the cable shield is diffusion. At higher frequencies, the dominance of the reactive term indicates the greater efficiency of magnetic coupling through the rhombic apertures in the shield.

The shielding effectiveness of a cable can be improved by laying a second woven shield over the first. A second layer typically lowers the resistance, R_0, and hence the diffusion impedance, by about a factor of two. This change translates to approximately a 6-dB improvement in shielding effectiveness at low frequencies. The real benefit of a second shield accrues at high frequencies because the extra layer significantly reduces the mutual inductance by covering a large percentage of the rhombic apertures in the weave. The increase in high-frequency shielding effectiveness due to the second shield can exceed 40 dB. Adding a third shield layer further improves the shielding effectiveness of a cable. Figure 5 illustrates typical differences in the transfer impedance among cable types.

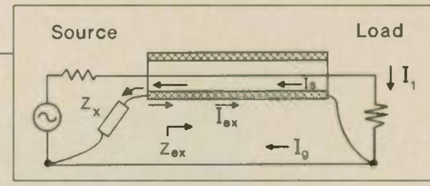


Figure 6. Excitation of common-mode current flow, I_{ex}, by poor shield grounding.

Cable Grounding

In practice, the effectiveness of a shielded cable is often determined by the way it is grounded. Inductance or resistance in the leads between the end of the cable shield and the load or the signal source driving the cable can increase the emissions radiated from it. The circuit in Figure 6 represents a poor ground at the source end of the cable with the impedance Z_x. Above the shield cutoff frequency, nearly all the load

RF Circuit Designers

Mask Software CAD Translators

Reduce turnaround time and cut mask costs when you use our software postprocessors to directly photoplot board artwork. Stop cutting and peeling Rubylith®. Our postprocessors convert AutoCAD, EGS, Generic CADD, or Calma drawings into Gerber photoplotter code.

PHOTOPLOTTERS

ACS 500 DXF to Gerber
ACS 600 GDSII to Gerber
ACS 700 HP EGS to Gerber

TRANSLATORS

ACS 800 EGS to AutoCAD DXF
ACS 1000 MiCAD to AutoCAD
ACS 3500 AutoCAD to GDSII
ACS 3600 EGS to GDSII

Call or write for our application notes describing how to photoplot hybrid circuits directly from your CAD database.

ARTWORK CONVERSION SOFTWARE, INC.
1320 Mission St. #5, Santa Cruz, CA 95060
408/ 426-6163 Fax: 408/ 426-2824

INFO/CARD 64

LOWEST PRICED, HIGHEST QUALITY ATTENUATORS - BNC $15.00 1-9 EA., SMA $15.00 1-9 EA.
AND TERMINATIONS - BNC $5.60 10 EA., SMA $5.60 10 EA. MIL. HI-REL. NETWORKS

Model Number (2)	Impedance Ohms (Power W)	Frequency Range	BNC	TNC	N	SMA	UHF	SMB	PC
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Send for Free Catalog on your Letterhead
Elcom SYSTEMS INC. TEL. 407-994-1774 FAX. 407-994-1770
932 CLINT MOORE ROAD BOCA RATON FL 33487

INFO/CARD 65

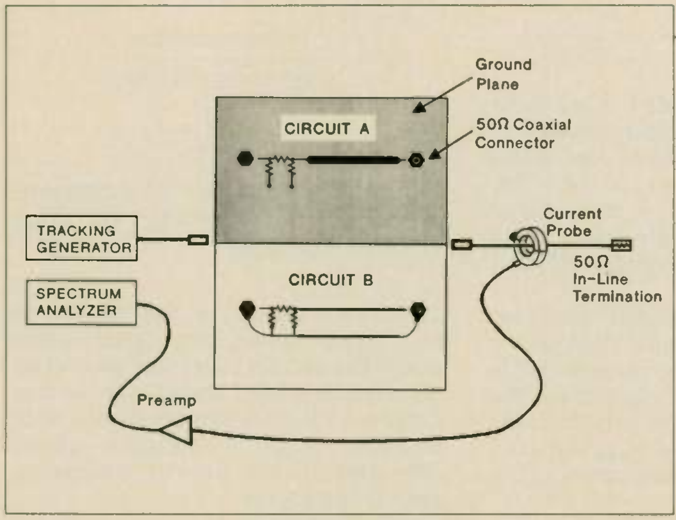


Figure 7. Experiment demonstrating the benefit of maintaining the proper characteristic-impedance in the circuitry driving a cable.

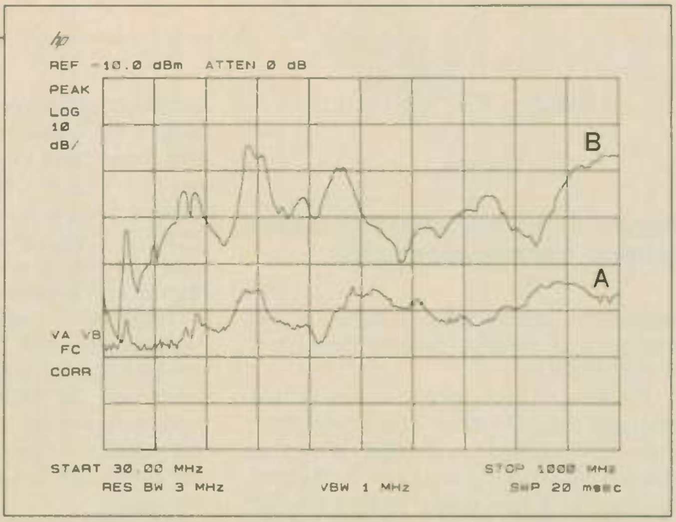


Figure 8. Qualitative comparison of common-mode current produced by the two different cable grounding schemes shown in Figure 7.

current would return in the shield of a well-grounded cable. However, the grounding impedance, Z_x, makes it less attractive for the return current to flow down the cable shield as I_s and more attractive for the current to return in the ground system as I_g.

At high frequencies, where the skin depth is somewhat shallower than the thickness of the shield, Z_x causes common-mode current to flow along the outside of the cable. Above the shield cutoff frequency, the skin effect forces the return current to flow on the inner surface of the shield because that surface has the strongest coupling to the center conductor. When the return current reaches the source end of the cable, it has two possible paths to return to its source: it can flow through Z_x back to the source; or, it can flow along the outside of the cable shield as I_{ex}. The latter path represents an unshielded common-mode current flow which ex-

HI-POWER RF

AMPLIFIERS, TRANSMITTERS AND POWER GENERATORS

No matter what your application needs, Henry Radio can solve your RF requirements. 10 to 10,000 watts! 2 to 500 MHz frequency range. If we don't have it in stock, we'll make one to fit your needs.

TYPICAL APPLICATIONS:

- NMR, Nuclear Magnetic Resonance
- PLASMA Generation
- MEDICAL Applications
- NUCLEAR Magnetic Imaging
- COMMUNICATIONS Applications

Over a half-century of reliability in communications

HENRY RADIO

2050 S. Bundy Dr., Los Angeles, CA 90025, TOLL FREE: 1-800-877-7979, FAX: 1-213-826-7790

INFO/CARD 66

HIGH ENERGY CORP
CERAMIC RF CAPACITORS
C-D/SANGAMO
MICA RF CAPACITORS

JENNINGS
A LEAR SIEGLER COMPANY
VACUUM CAPACITORS
VACUUM RELAYS

SURCOM ASSOCIATES, INC.
2215 Faraday Avenue, Suite A
Carlsbad, California 92008
TEL (619) 438-4420
FAX (619) 438-4759

INFO/CARD 67

cites radiated emissions from the cable. Let Z_{ex} represent the impedance looking down the outside of the cable. The current divider formed between Z_x and Z_{ex} governs the proportion of return current that flows as common-mode current.

$$I_{ex} = I_s \frac{Z_x}{Z_x + Z_{ex}} \qquad (8)$$

The skin effect physically separates the currents flowing on the inner and outer surfaces of the cable shield. Thus, at high frequencies a cable shield actually serves as two conductors.

The best way to curtail I_{ex} is to ground the cable well; that is, to minimize Z_x. The other design option involves increasing the external cable impedance, Z_{ex}, often implemented by wrapping the cable around a ferrite toroidal core so that the common-mode current encounters a lossy inductance.

The relationship between cable grounding and common-mode current flow can be demonstrated by the experiment diagramed in Figure 7. A printed-circuit board contains two different structures. In circuit A, a trace above a ground plane forms a microstrip transmission line with a characteristic impedance of 50 ohms. Circuit B does not have a ground plane; the circuit is formed by two parallel traces creating a high-impedance transmission line. Each circuit includes a 6-dB pad to provide a good input match. A spectrum analyzer combined with a tracking generator was used to evaluate the relative emissions from each circuit. The tracking generator drove the circuit input, while a terminated 50 ohm cable was connected to the output. A wide-band current probe connected to the spectrum analyzer through a preamplifier sensed the common-mode current flowing through the cable. The results illustrated in Figure 8 show that the relatively inductive impedance of the open wire line in circuit B causes a significant increase in common-mode current. The radiated emissions from the cable would be as much as 30-dB higher at some frequencies.

Summary

Shielded cables are most effective when the load current returns entirely in the cable. Above about five times the shield cutoff frequency, mutual coupling between the center and outer conductor of a shielded cable causes most of the return current to flow in the shield. However, poor cable grounding can cause common-mode current flow on the outside of the cable shield. Maintaining a matched characteristic impedance from the cable connector back to the source of current can effectively minimize the radiated emissions from a cable. ***RF***

References

1. H.W. Ott, *Noise Reduction Techniques in Electronic Systems*, 2nd ed., John Wiley, New York, 1988, pp. 42-52.
2. E.F. Vance, *Coupling to Shielded Cables*, John Wiley, New York, 1978.

About the Author

Tom Jerse is an R&D Project Manager at Hewlett-Packard Company, 1212 Valley House Drive, Rohnert Park, CA 94928. He also serves as a part-time lecturer at the University of California Davis.

WBE

RF COMPARATORS

Model A49 is a totally solid state, dual channel RF Comparator for comparison of gain, loss, and impedance with an attenuator or master reference -- the technique used in the more advanced network analysers. Model A49 has the stability and high isolation required for measuring insertion loss in steps of .01 dB to SRL and shielding effectiveness testing beyond -80 dB! With both ports balanced, measurement error can be reduced to that of the Standard alone without compensating for errors resulting from dual trace scopes, detector tracking, scale accuracy, linearity, drift, etc..

Model	Freq. Range	Switch Config.	VSWR	Flatness	Isolation	Loss	Path Selection	Channel Match	Phase Control	Size	Weight
A49	1-500	DPDT (2 separate SPDT heads)	1.05:1 typical	±.1 dB typical	45 dB min. 50 dB typical	1 dB per switch typical	Path A only, Path B only, Path A & B simultaneous at 30 Hz line locked switch rate	.1 dB max.	Rear Chassis mounted phase adjust and phase reverse controls	EIA Panel 3 1/2" x 19" 4" chassis depth	4 1/2 lbs.
A49/6	1-600										
A49U	1-900										

POWER: 115 VAC, 60 Hz, 15W

WIDE BAND ENGINEERING COMPANY, INC.

P.O. BOX 21652, PHOENIX, AZ 85036 TELEPHONE: (602) 254-1570

INFO/CARD 68

RF & MICROWAVE AMPLIFIERS FOR CELLULAR SYSTEMS

For over 10 years, Trontech has pioneered a variety of products for Cellular Systems, from engineering custom design through production. Today, our amplifiers can be found in nearly all of AT&T's Cellular Radio Cell Site Systems.

Trontech is recognized as an industry innovator and leading edge source in advanced amplifier design. We can offer you a wide range of capabilities and applications such as:

- Ultra low noise amplifiers.
- High dynamic range receive amplifiers.
- High power amplifiers for transmit applications.
- Custom designs for test systems.
- L & S band high power amplifiers for Cell Site Microwave Communications Links.

We have literally thousands of designs for production type amplifiers on file. They're available as is, or we can customize them by adjusting virtually any parameter. Now you can specify precisely to maximize system performance. From single units to high volume production, get it all at standard amplifier prices! The chart illustrates several existing product areas for both US and European standards.

All Trontech products are manufactured to MIL-I-45208. In-house environmental testing capabilities offer rapid and economical testing of new designs to system requirements.

Specify the source that offers a real choice, field-proven designs and a successful track record in quality, performance, price and delivery — Trontech! Call or write for more detailed information or applications assistance.

Product Area	Freq. Range	Description
Low noise	10 — 4200 MHz	Noise Figures under 1.2 dB for superior receiver sensitivity
Wide dynamic range amplifiers	400 — 1000 MHz	Low noise amplifiers with typical gain under 20 dB and 3rd order intercept points greater than +35 dBm
High power linear	400 — 1000 MHz	Amplifiers up to 80 Watts Linear for transmit applications
High power linear	1.7 — 2.3 GHz	GaAs Power Amplifiers for Cellular Radio Microwave Links

TRONTECH INC.

63 Shark River Road, Neptune, New Jersey 07753 U.S.A.
Tel: (201) 922-8585 FAX: (201) 922-3903 TELEX 13 2445

INFO/CARD 69 Please see us at RF Expo East, Booth #616.

Contact factory for your local representative.
Trontech is represented in the following countries: Switzerland, Italy, Holland, West Germany, India, England, Japan, Canada, Israel, France, Sweden.

Log Fidelity Test Fixture

By James D. English
ABC Circuit Design

The log fidelity test fixture is used to observe the transfer function error of a logarithmic amplifier in real time. The technique used is based on the principle that when an exponential waveform is operated upon by the logarithmic function, the result is a linear function. In this specific case, the exponential signal is a function of time, therefore, the generated function is also linear with time. Since accurate linear functions of time are easily generated, the output of the device under test is then subtracted from the generated linear function. The result is the transfer error.

The following set of goals were used to design the test fixture:

- The unit would allow a test range of 100 dB to correspond with 10 divisions across on a typical display device. This will allow a horizontal sensitivity of 10 dB per division.
- The unit would produce at least 0 dBm into 50 ohms.
- The RF output impedance would be 50 ohms with a broadband match.
- The unit would operate on +5 volts.
- The output error sensitivity would be 0.2V/dB.
- The output sweep would be 2V full scale or 0.2V/10dB of display range.

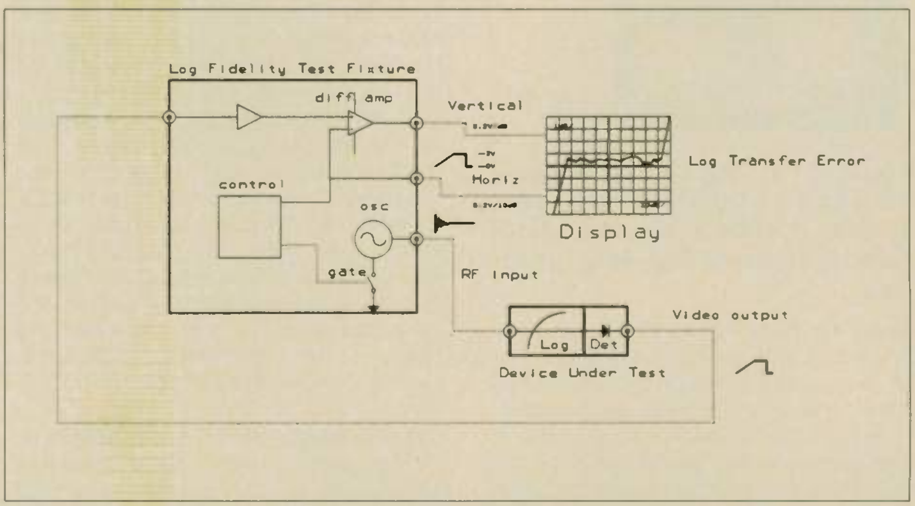


Figure 1. Block diagram of log fidelity test fixture.

- A log video input range of 0.5 volts full scale to 5 volts full scale of either polarity would be accommodated.

Circuit Operation

The fixture is intended to be used with an external oscilloscope display as shown in the block diagram in Figure 1. The sweep output is fed into the horizontal input and the scale factor is set for 0.2V/division. The video output is directed to the display vertical input. The scale factor is set to 0.2V/division. This arrangement will allow 1 dB/division vertical error over a 100 dB logging range.

Operation of the fixture requires that the video output of the logarithmic amplifier under test be connected to the video input connector on the front panel. The position of the polarity switch may have to be changed depending on the

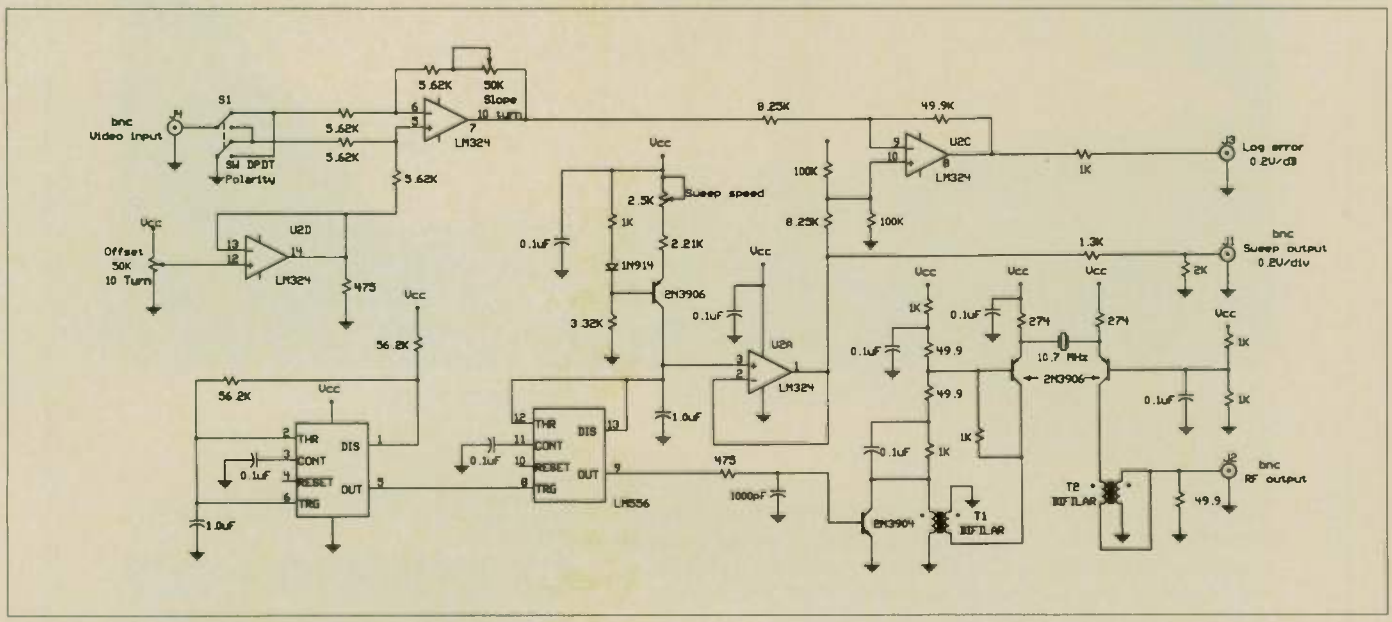


Figure 2. Logarithmic amplifier test fixture.

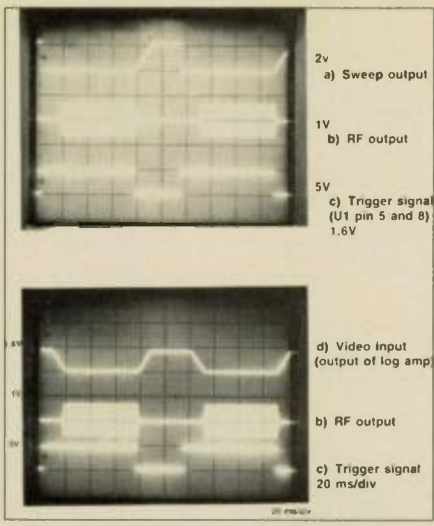


Figure 3. a) Sweep b) Decaying RF signal c) Control signal used to gate oscillator on and off d) Video output of log amp under test.

sensitivity of the video. The input common mode range is about 4 volts. The RF output of the fixture is then routed to the input of the logarithmic amplifier. It may be convenient to place a set of step attenuators in series (such as the HP355C&D) to limit the maximum signal available to the logarithmic amplifier under test. Also, this may be necessary to match up the dynamic window of the log amp under test.

RF log amplifiers are generally of the bandpass type. That is, they work at an intermediate frequency. The exponential device is a resonator with a specific and well controlled loaded Q, (Q_L). The Q_L of the circuit is defined as the ratio of the energy stored to the energy lost per half cycle scaled by π (1). To charge the resonator with energy, the circuit is allowed to oscillate with the resonator as the frequency control device. The oscillation loop is then broken but the resonator Q_L is maintained. The resonator will then start to lose $2\pi/Q_L$ of its energy per cycle. Or $10\text{Log}(1+2\pi/Q_L)$ dB per cycle. When the oscillation loop is broken, a linear ramp is started, the difference between this ramp and the output of the logarithmic amplifier is then displayed as the transfer error.

Crystal Resonator Considerations

The quartz crystal is not an ideal one port device. In-harmonic modes (crystal spurs) can cause problems when de-

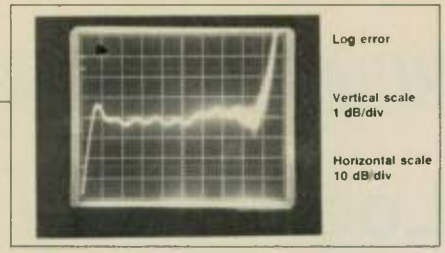


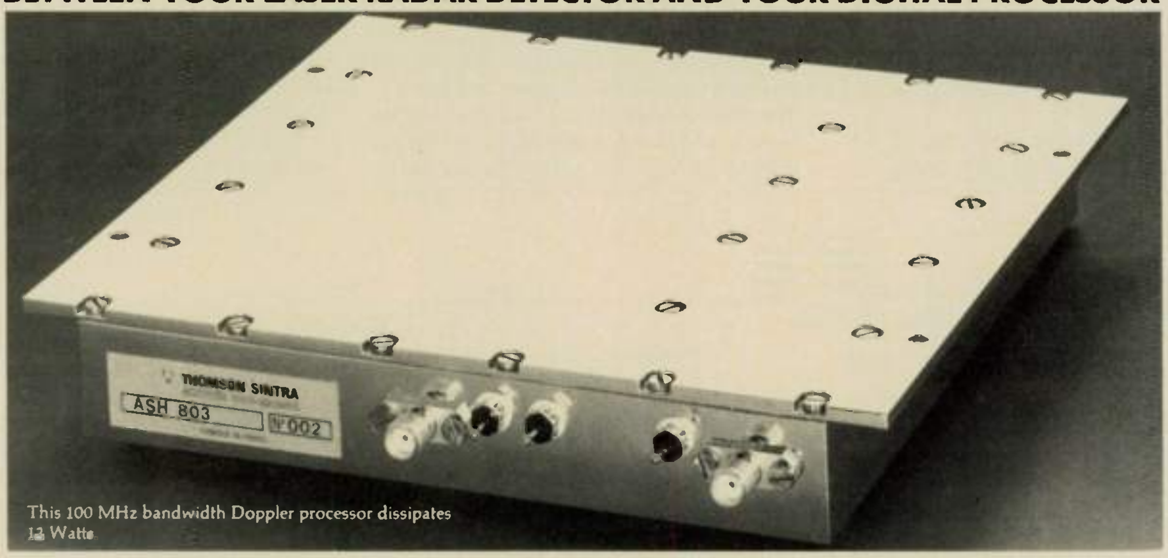
Figure 4. Log error.

signing circuits to test log amps. The problem comes about when resonant responses other than the main mode are excited. This is a problem because spurious modes generally have a much higher loaded Q than the main mode. This causes the decay rate for the spurious modes to be less than that of the main mode. Even if the spurious mode is 30 dB below the main mode at the beginning of the decay, it can actually be greater than the main mode before it reaches the −100 dBc point. This will show up as an error in the log transfer function. Therefore, the proper crystal must be specified for the job.

Another crystal consideration is the resistance change with drive level. This is a common problem with quartz resonators used in low phase noise oscillators and narrow band filters. As the power in the resonator is increased or decreased, a change will be observed

THE MISSING BLOCK

BETWEEN YOUR LASER RADAR DETECTOR AND YOUR DIGITAL PROCESSOR



POLARIS EXPANSION

Using state-of-the-art SAW and DIGITAL technology, THOMSON-SINTRA offers.

RF-TO-DIGITAL DOPPLER ANALYSERS

Perfect for processing the Doppler information of CO2 and YAG laser velocimeters. These compact low powered modules are connected to the laser radar detector output. They generate the spectrum signal in digital format ready for additional processing. For complete information on real time SAW Spectrum Analyzers and other SAW products, contact:

THOMSON-SINTRA
ACTIVITES-SOUS-MARINES-DTAS
B.P. 38 - 06561 - VALBONNE - CEDEX - FRANCE
Tel.: (33)92.94.31.79 - Fax: (33)92.94.31.90
For USA and Canada:
THOMSON-ICS CORPORATION
Route 57. Feeding Hills Road. SOUTHWICK, Ma-01077/0229
(413) 569-0575

THOMSON-CSF

THE BRAINPOWER. THE WILLPOWER. THE WINPOWER.

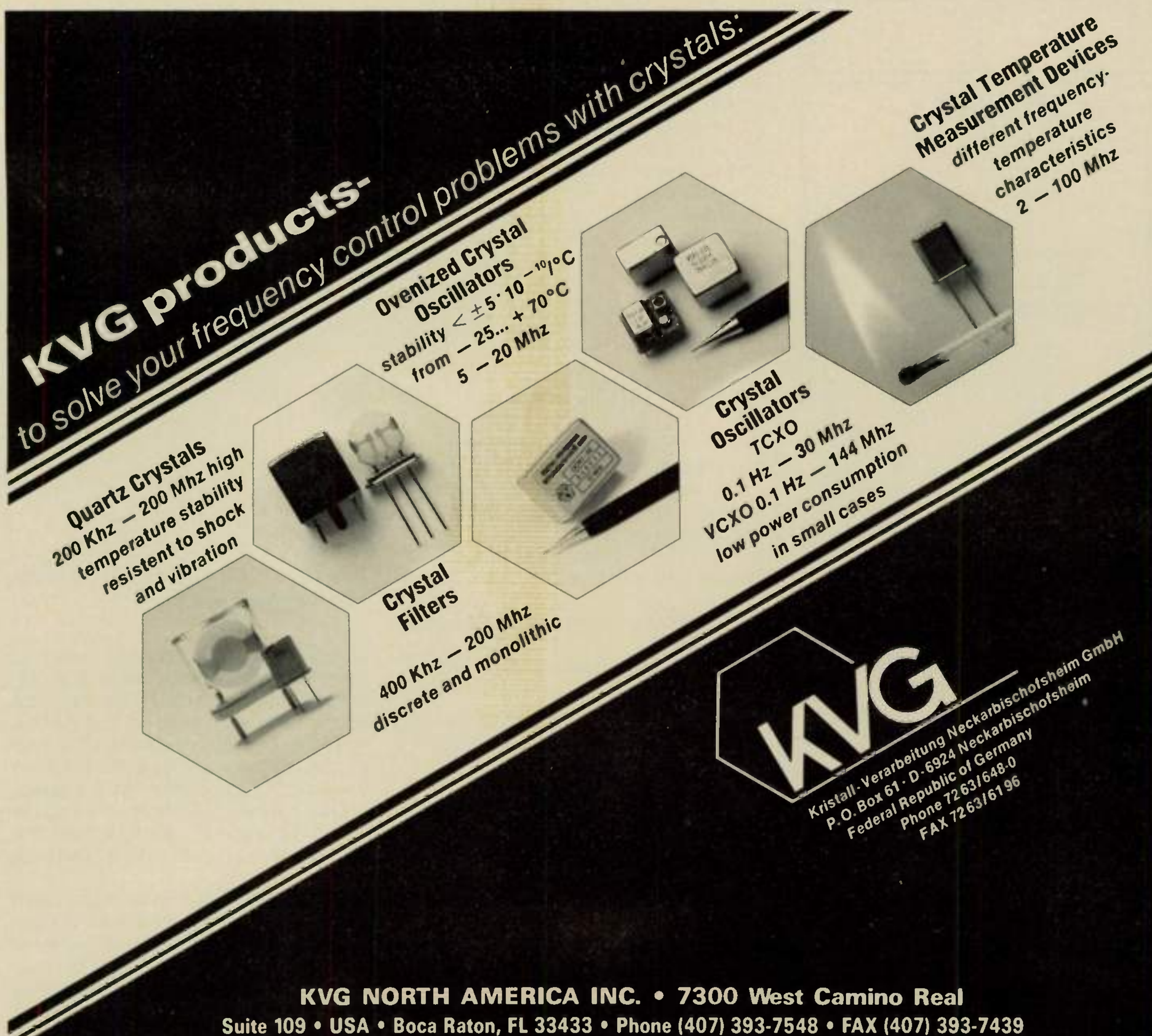
INFO/CARD 70

in the series resistance. Obviously, this effect is very undesirable. This phenomena is often nonlinear and not repeatable. It is possible to build some very good crystals and some very bad ones. This phenomena can be caused by contamination in the fabrication process. For this test fixture, a very good crystal must be chosen.

The resonator that loses a quantity of energy every cycle can be used to test log amps. The dual to this is the use of a log amp to determine the amount of excess gain or negative resistance in an oscillator. As an oscillator turns on, the percentage of the energy gained per cycle by the total resonator energy will remain constant until limiting occurs. The parameters of the resonator and load must be known a priori. The slope of the log of the turn on waveform will yield a value for Q for the circuit. This value will be negative as the total R_s must be negative for the oscillator to start. After the R_s is calculated, the resistance of the source and load are subtracted to yield the net negative resistance of the oscillator. The excess gain is the ratio of the total positive resonator and load resistance by the total negative resistance.

Circuit Description and Design Considerations

Oscillator. The RF oscillator (Figure 2) has a PNP transistor (Q4) connected as a negative resistance amplifier. The collector of the transistor is fed into the bifilar wound transformer (T1), which inverts the phase of the current by 180 degrees. The output is then fed into the base through a voltage divider to control the amount of positive feedback. By controlling the amount of feedback, the negative impedance presented by the

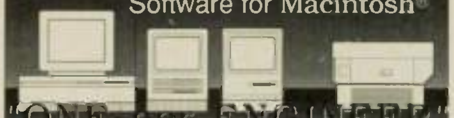


Quartz Crystals INFO/CARD 102 Crystal Filters INFO/CARD 103 Ovenized Crystal INFO/CARD 104

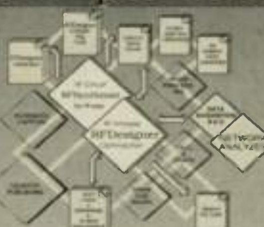
Crystal Oscillators INFO/CARD 105 Crystal Temperature INFO/CARD 106

ingSOFT Limited

High Performance Engineering Software for Macintosh®

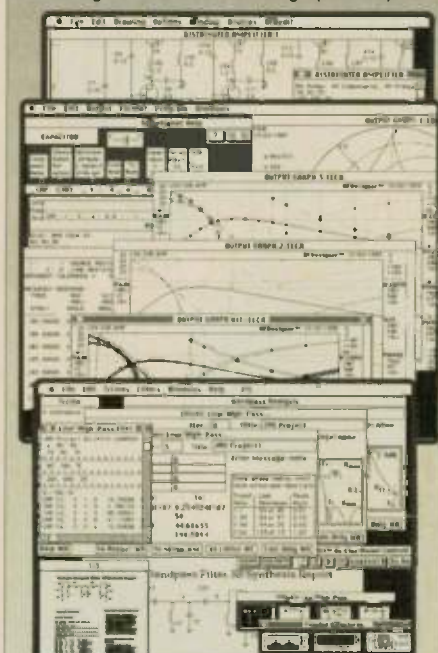


"ONE-per-ENGINEER"



THE FIRST COMPLETE RF & MW DESIGN SOLUTION

Friendly and intuitive user's interface with easy exchange of information among all applications. Direct high-resolution text and graphic outputs.



RFSynthesist™ ...a computer aided synthesis tool for **lumped** and **distributed** structures, providing the first step in circuit design.

RFDesigner™ ...a powerful and easy-to-use analog simulator. Saves money and time in design of RF & MW circuits. **Gradient**, **Random** and **Yield** optimizers allow optimization of any number of circuit components.

SCHEMATIC CAPTURE: full-featured, digital simulation included, produces run-ready files, used for data entry and as a project data base.

PCB LAYOUT CAD with programing capabilities, essential for design of RF & MW PCB layouts.

NETWORK ANALYZER INTERFACE: sw/hw (SCSI to IEEE488) for S-parameter data acquisition.

Comprehensive User Support: printed and **automatic On-Line Manuals**, **RFDesigner Newsletter**, and active consulting. ingSOFT software runs on **all Macintosh models** with 1 MB RAM min. (4 to 8 MB recommended).

IngSOFT Limited

213 Dunview Ave., Willowdale, Ont. M2N-4H9, Canada
TEL: (416) 730-9611 FAX: (416) 733-3884

RFSynthesist RFDesigner ingSOFT Limited DesignWorks Capilano Computing Systems Ltd Macintosh Apple Computer Inc

INFO/CARD 72

emitter can be adjusted to the proper value. The resonator for the oscillator is the crystal. The equivalent series resistance (R_s) of the crystal was measured to be 10.3 ohms. The resonator is embedded between the negative resistance port of Q4 and the emitter of Q3, a common base stage. The common base stage has a net input resistance of 4.9 ohms at 10.7 MHz. Therefore, to sustain oscillation, Q4 needs to present at least a negative resistance of −15.2 ohms. Actually this value needs to be somewhat more negative than that or the oscillator will take a long time to come to value. It may seem funny, but the useful output of the oscillator circuit is when it is shut off! The NPN transistor, Q2, is used to shunt the transformer T1. This effectively removes the positive feedback without upsetting the DC bias of the oscillator transistor. When the negative resistance is removed, the impedance looking into Q4 is about 3.5 ohms. This causes a total loop impedance of 18.7 ohms. At the moment the negative resistance is removed, there is potential energy in the resonator that must be dissipated by the loop resistance. This energy will be dissipated at the rate of $(2\pi)/Q_L$ per cycle or $10\text{Log}(1 + 2 \times \pi/Q_L)$ dB per cycle. The loaded Q (Q_L) of the circuit is given by:

$$Q_L = 2\pi \times F_s \times L_m/(Re_1 + R_s + Re_2)$$

Where: F_s is the series resonant frequency of the crystal resonator.

Re_1 is the real part of the impedance looking into the negative resistance stage, Q4, when it is shut off.

Re_2 is the real part of the impedance looking into the common base stage, Q3.

R_s is the equivalent series resistance of the crystal.

L_m is the equivalent motional inductance of the crystal.

$$Q_L = 2\pi \times 10.7\times10^6 \times 9.36\times10^{-3}/(3.5 + 10.3 + 4.9) = 33651$$

$$\text{dB loss per cycle} = 10 \times \text{Log}(1 + 2 \times \pi/Q_L)$$

$$= 10 \times \text{Log}(1 + 2 \times \pi/33651)$$

$$= 810\times10^{-6} \text{ dB/cycle}$$

The limit mechanism in the oscillator is the current standing in the Q4 transistor. The equilibrium point will be where the negative resistance of the oscillator is equal to the 15.2 ohms of the crystal in series with the common base stage

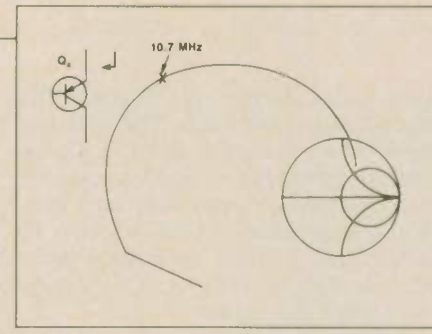


Figure 5. Simulated Re_1, negative R.

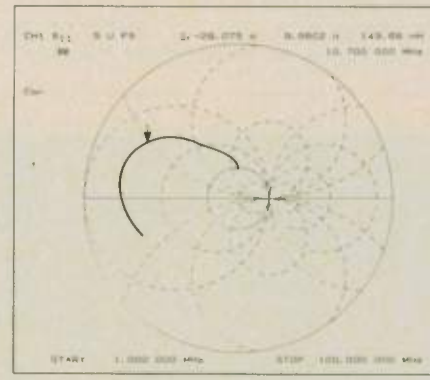


Figure 6. Measured Re_1, negative R stage (turned on).

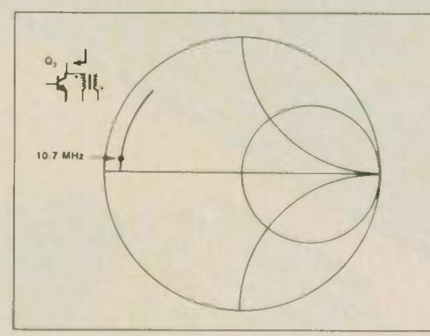


Figure 7. Simulated RF switch "on" impedance.

emitter. When the transistor switch is opened, the negative resistance is presented to the crystal. The net loop resistance is very negative. The thermal noise of the loop resistance will cause an oscillation to build up at the resonant frequency of the crystal. As the power in Q4 increases, the negative resistance at the emitter will decrease until the equilibrium point of −15.2 ohms is reached.

Circuit simulation tools have been around for some time. However, the use of Spice as an RF design tool has some very serious limitations. One of these is the inability to model a circuit that uses a resonator with a very large disparity in the values of the energy storage elements. The motional elements of a

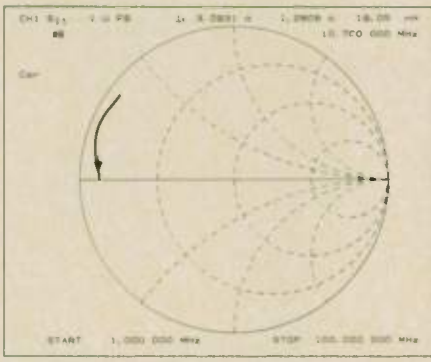


Figure 8. Measured RF switch (turned on).

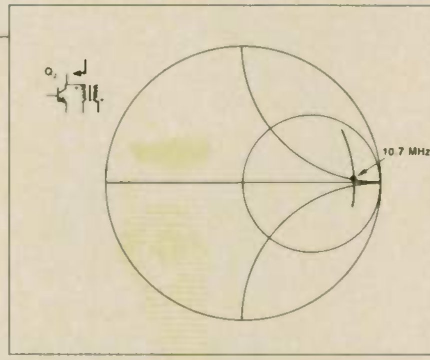


Figure 9. Simulated RF switch "off" value.

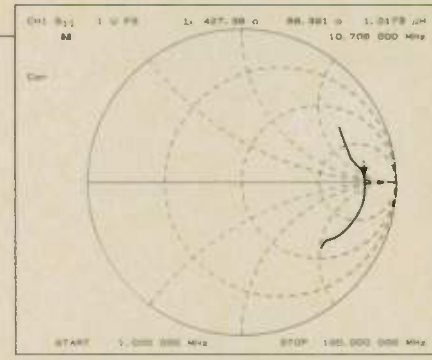


Figure 10. Measured RF switch (turned off).

quartz crystal are an example. Still, even with these limitations, it is useful to use Spice as an analysis tool to help design the negative resistance stage. In this situation, the negative resistance model for Spice was arranged such that the scattering parameters for the one port could be extracted (3). In this way, the results could be correlated with real network analyzer measurements directly.

The goal was to design a negative resistance oscillator that met the following criteria:

- The oscillator was to use a single 5 V supply.
- It was to include a gate to switch the oscillator on and off rapidly.
- The act of switching the oscillator on or off was not to upset the bias or cause a glitch in the output waveform.
- It was to use standard, garden variety components.
- When switched off, the resonator must be able to release the stored energy to the output load in a well controlled load impedance.
- The limit mechanism must be abrupt and well defined.
- The oscillator was to be cheap, easy to build, and easily duplicated by others skilled in the art.

After experimenting with several oscillator topologies, the idea for a negative resistance type came about. In this arrangement, the resonator is external. By using a negative resistance circuit, all the design goals were met. The circuit essentially contains two feedback mechanisms, one negative and one positive. The negative feedback was added for two reasons. First, when the positive feedback is removed, then the negative feedback will force a lower output impedance. The second reason was to help dampen any spurious oscillations that may occur near the F_t of the device. The bifilar wound transformer reverses the sense of the collector current thus causing the feedback to be positive. This forces the base current to be 180 degrees out of phase with the collector. The current is shunted by the 49.9 ohm resistor that will bring the amount of positive down to an acceptable level (too much is almost worse than not enough). In this manner, the amount of positive and negative feedback can be accurately and independently controlled. When the oscillator is in the switched off state, the bifilar wound transformer is shunted by Q2, which is used as an RF switch. This has the effect of removing enough positive feedback such that the emitter resistance is positive (around 3.5 ohms).

Multivibrator. The repetition rate, at which the RF oscillator is gated off and the sweep is started, is controlled by the multivibrator consisting of U3A. The discharge time allowed is about one third of the charge time. The reciprocal of the sum of the charge and discharge times is the overall repetition rate. The discharge time is such that the oscillator has plenty of time to lose its energy. The total energy lost during the discharge time is described below. These are the design equations for the 555/556 timers (2).

rep rate = $(1.49)/((R_a + 2R_b) \times C)$

Since $R_a = R_b$

rep rate = $(1.49)/(3 \times 56.2{\times}10^3 \times 10^{-6})$

= 8.83 Hz

Discharge time = 1/(rep rate × 3) = 1/(8.83 × 3)

= 37.75 ms

total decay (dB) = discharge time × dB loss per cycle × F_s

The dB loss per cycle has been previously shown to be $810{\times}10^{-6}$ dB per cycle.

Therefore, the total decay (dB) = $37.75{\times}10^{-3} \times 810{\times}10^{-6} \times 10.7{\times}10^6$

total decay (dB) = 328 dB

Since the steady state oscillator amplitude is about 0 dBm, the final decay amplitude would be −328 dBm, way below the thermal noise of the circuit.

Ramp Generator. The sweep ramp is generated by the current source Q1 charging the capacitor C3. When the ramp reaches 2/3 V_{cc} and the trigger input signal goes high, the timer U3B will discharge C3. The control of the timer is done by the multivibrator U3A.

The total sweep time required can be calculated from the loaded Q of the resonator and the desired test range.

The test range specified by the design goal is to be 100 dB. Therefore, the sweep time is the test range in dB divided by the time it takes the oscillator circuit to decay by 100 dB. Thus, the following equation is derived:

Sweep time = (Test range)/ (dB loss per cycle × F_s)

= $100/(810{\times}10^{-6} \times 10.7{\times}10^6)$ = 11.5 ms

Sweep and Display Amplifier. The opamp (U2A) is used to buffer the sweep for use of the display amplifier and the difference amplifier.

The amount of charge current needed is calculated from the sweep time requirement.

i = C × dv/dt

Since dv/dt is time invariant, the equation can be solved directly.

$i = 10^{-6} \times 3.333/11.5 \times 10^{-3}$ = 289uA

Since there is 1 volt between the emitter of Q1 and V_{cc}, the required resistor is 1V/289uA or 3.45 kohms. This is the 2.21 kohm resistor in series with the 2.5 kohms potentiometer adjusted to its mid-range.

Video Scaling Amplifier. The video input voltages from the various logarith-

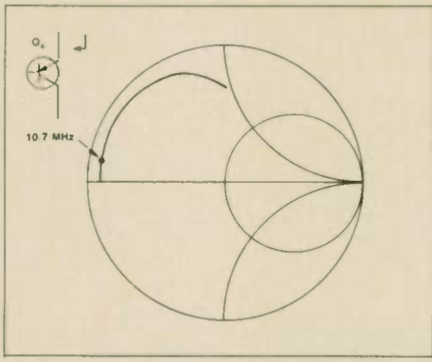


Figure 11. Simulated negative R stage switch off.

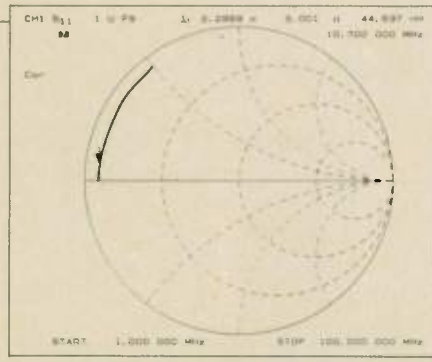


Figure 12. Measured Re_1 negative R (shut off).

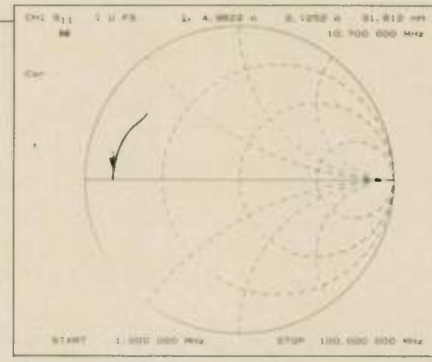


Figure 13. Measured Re_2 common base stage.

mic amplifiers can vary from unit to unit in amplitude, offset and polarity. Therefore, it was a design goal to accommodate a 10:1 input amplitude change, a 5 volt offset range, and both polarities. The scaling and offset is done by U2B. Sw1 is the polarity switch.

Difference Amplifier. The difference between the scaled video input and the sweep is done by U2C. The gain required is equal to the sweep range in volts divided by the test range in dB. This is 33.3 mV per dB. The design goal is to display an error of 0.2V/dB, therefore, the gain of the difference amplifier should be 0.2V/dB divided by 33.3 mV/dB or, in this case, a gain of 6.

Performance

The one port S_{11} measurements made with Spice predicted that the output impedance real part of the negative resistance stage would be −21 ohms (Figure 5). The measured negative resistance was −29 ohms (Figure 6). The discrepancy is in the model used for the transformer T1 and the active device Q4. Good agreement was found for the measured RF switch and transformer for both the on and off states (Figures 7, 8, 9 and 10). The predicted value for the negative resistance amplifier in the off state agreed nicely with the measured results (Figure 11 and 12). Lastly, the impedance looking into the common base output stage (Figure 13) came very close to the 4.9 ohms predicted.

Figure 3c depicts the control signal that is used to gate the oscillator on and

Precise Quality

SINGLE LAYER

Microwave Chip Capacitors

CERAMIC SUBSTRATES NOW AVAILABLE!

SINGLE-LAYER CAP GAP-CAP BINERY & CUSTOM BAR-CAP

For years our diversified expertise in producing the finest in microchips has created a reputation of being second to none in precise quality.

With our state-of-the-art know-how, Compex Corp can provide the low profile, small size and low series inductance to minimize losses and maximize value.

Call now, find out why more and more companies agree ... Compex for PRECISE QUALITY!

■ 609/596-9388
■ Fax 609/596-3482

COMPEX CORP

Taunton Professional Parke
238 Taunton Blvd. Medford, NJ 08055

INFO/CARD 73

Please see us at RF Expo East, Booth #606.

High Reliability Precision OCXO

FTS 9000 SERIES

Frequency: 4 to 160 MHz

Radiation Hardened

Military and Space qualified designs

Aging/day to 1×10^{-11} (5 MHz)

Low Phase Noise

FTS

FREQUENCY AND TIME SYSTEMS, INC.
34 Tozer Road
Beverly, MA 01915
(508) 927-8220

INFO/CARD 74

off. In Figure 3b, the decaying RF signal is shown. The sweep is shown in Figure 3a. Notice how the sweep starts at the moment that the oscillator starts to decay. The video output of the log amplifier under test is shown in Figure 3d. The video output of the particular log amp under test is inverted. Notice how the log amp output continues to rise long after the decaying RF signal appears to be gone. This is because the log amp under test has about 80 dB of dynamic range while the linear display of the RF has only about 25 dB of range. Also notice that when the control signal gates the oscillator on (Figure 3c) that it takes about 8 ms to observe the output on the log amp (Figure 3d). This is because when the oscillator is switched on, the noise floor is several tens of dB below that of the minimum signal that the log amp can display.

Figure 4 shows the difference between the internally generated ramp and the output of the log amp. This is the desired final output. The vertical scale is 1 dB per division and the horizontal scale is 10 dB per division. In this example, no provisions were made for retrace blanking. If this is desired, then the trigger signal in Figure 3c could be used.

Performance Enhancements

This fixture is intended to demonstrate an alternative for testing logarithmic amplifiers. It is not intended to be the last word on the subject. Several performance enhancements are possible. Temperature stabilization of the oscillator could be done by using current sources in the emitters that are proportional to absolute temperature (PTAT). This would stabilize the temperature dependent load impedance. The possibility exists to provide an absolute calibration through a feedback circuit that will adjust the sweep rate to compensate for variations in decay rate during the non-decay time. An embedded controller could be added to keep track of these additional functions. The addition of a fast programmable synthesizer with a heterodyne scheme would allow the system to work over a range of frequencies. This would allow three dimensional log error plots to be displayed.

Often times the success of a project can be measured in how many experiments per unit time can be done. One is more likely to make an experimental change in a circuit if the performance can be immediately evaluated. This testing apparatus is intended to provide the incentive to make such changes to a circuit as their effect is shown immediately. ***RF***

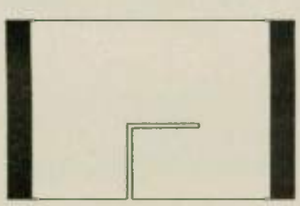
References

1. Simon Ramo and John R. Whinnery, *Fields and Waves in Modern Radio*, John Wiley and Sons, Inc., 1956.
2. *Signetics Linear Data Manual*, Volume 2, 1987 Signetics Corporation.
3. Thomas B. Mills, "S Parameters in Spice," *RF Design*, p. 45, June 1989.

About the Author

James English is a private consultant specializing in analog and RF circuit design. He may be reached at ABC Circuit Design, 19705 SW Johnson, Aloha, OR 97006. Tel: (503) 642-3803.

FIND RESISTANCE AND CAPACITANCE OF IRREGULAR SHAPES



LASER TRIMMING: L-cuts, Vernier Trims, and Others. **RESISTOR LAYOUT**: "Dogbone" Resistor Heads, Resistor Bends. **TRANSMISSION LINES**: L, C, V_p, and Z_0 for Microstrip, Stripline, Flex Circuits, Ribbon Cable, and Roll-Your-Own. **IC INTERCONNECTIONS**: Capacitance of 1st and 2nd Metal, Coupling Between Lines, Effect of Nitride versus Oxide Dielectrics, Sloped Line Edges, Multilayer Dielectrics, Fringing Capacitance. **IC PACKAGE CAPACITANCE.**

EASY PROBLEM SETUP. ACCURATE. RUNS ON IBM PC/AT™ and compatibles with math coprocessor. $450. 60-page User Guide and Applications Book. Money-Back Guarantee.

GRID Software Corp.

P.O. Box 20070, Bloomington, MN 55420 • (612) 891-2674

INFO/CARD 75

LODESTONE PACIFIC

THROUGH HOLE AND SURFACE MOUNT

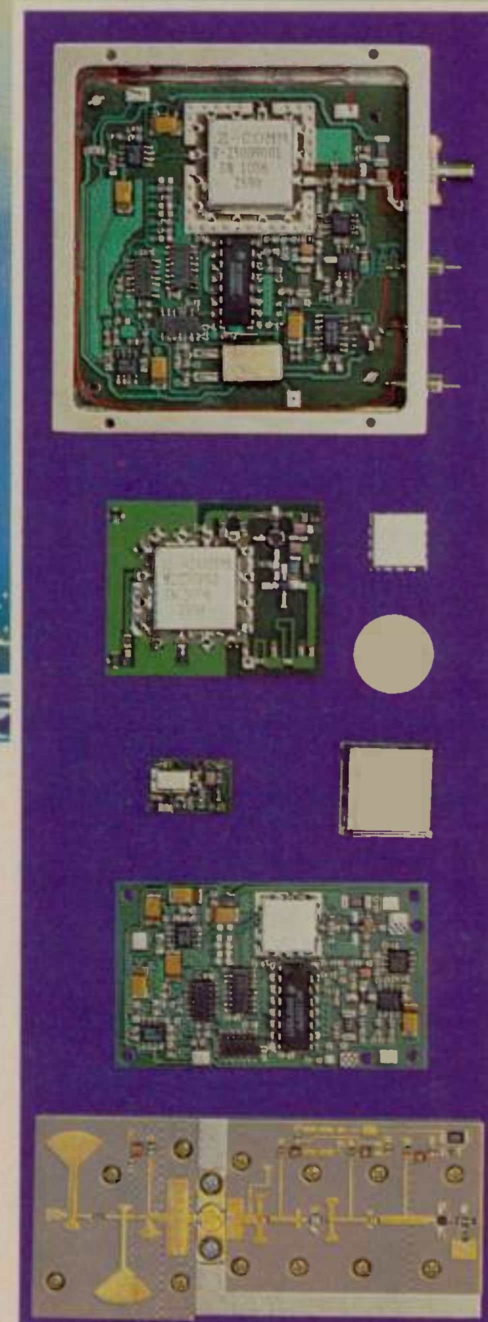
Component and toroid mounts moulded from cost effective thermoplastic or thermoset plastic for high temperature performance. All mouldings meet UL-94 VO. All leads plated to solderability MIL STD 202 Method 208. Send for our catalog of stock configurations.

MOUNTING HARDWARE

4065 E. La Palma Ave., Bldg. G • Anaheim, CA 92807 • (714) 630-1343 • FAX (714) 630-8480

INFO/CARD 76

The GREAT WAVES are made by Nature ...and Z-COMM™



VCO'S AND SYNTHESIZERS ARE OUR BUSINESS

We have been producing "The great VCO's since the beginning."

Pioneering high performance, low cost, high volume products and earning the title of the world's largest and the most diversified VCO manufacturer.

Where there is application such as Fiber Optic Telecommunications, LAN, VSAT, Mobile Sat Com Terminals, Medical and RF/Microwave Instrumentation, Frequency Hopping, Spread-Spectrum, Cellular Phones and Base Stations, Microwave Relay Links, Aircraft Communication, Video transmission or any other of the numerous applications in 30 MHz to 3 GHz spectrum the Z-COMM™ "Great Wave" VCO's or Synthesizers can be found.

At Z-COMM™ innovation never stops. The "Great Wave" new products such as Leadless chip carrier VCO's "Mini-C," not bigger than the outline of the TO-8 can (.5" x .5") smaller than a dime, is readily available in a number of the different frequencies from 100 MHz to 3 GHz. Our low power 5Vdc, 5 mA coaxial resonator VCO is one of the first of its kind on the market today, covering frequencies from 800 MHz to 1,000 MHz. Z-COMM™ frequency sources F-Series with internal reference, covering frequencies from 500 MHz to 3 GHz, offer our customer quick, high performance reliable LO at 3-5 times lower cost than the nearest competitor.

We back our "Great Wave" VCO products with Engineering "know-how" and manufacturing process which are the best in the industry. We are utilizing the latest CAE/CAD tools and fully automated surface mount (SMT) and ATE production lines. Z-COMM™ people strive to provide "zero defect" products and services to all our customers.

New 1990 VCO/Synthesizer Product Catalog

Over 150 Standard VCO & Synthesizer Models:

- **Frequency Ranges from 30 MHz to 3 GHz**
- **Quick Reference Guides & Product Locators**
- **Low Phase Noise, High Performance, High Volume Products**
- **Application Notes With Schematic & Layout Examples**

For more information and the catalog on Z-COMM's "Great Wave" VCO's and Synthesizer products
CALL: 305-735-1000 • FAX 305-735-1094

Z-Communications, Inc.

5450 N.W. 33rd Avenue • Fort Lauderdale, FL 33309

INFO/CARD 77

New Products Featured at RF Expo East

Digital Signal Processing/ADC Test and Development System

The new Burr-Brown DSP-SYS604 PC-based digital signal processing system offers designers a cost-effective way to test, evaluate and develops applications for the high dynamic range ADC604 A/D converter. The system may be used to analyze device performance, measure specification profiles, or for high speed signal conversion for a DSP processor. The DSP-SYS604 system comes complete with analog signal input system, 50 MHz DSP32C processor board, digital input buffer, dynamic signal analysis software, digital signal processing code generation software, and power supply.
Burr-Brown Company
INFO/CARD #160

Class AB Linear Amplifier

Model BHE 4819-500 is a solid state, 500 watt amplifier operating in the 400-1000 MHz frequency range featuring class AB operation, 600 MHz bandwidth, 57 dB of overall minimum gain and is fully protected.
Power Systems Technology, Inc.
INFO/CARD #159

Miniature Surface Mount Filter Packages

Piezo Technology has developed miniature, leaded and leadless surface mount filter packages. The user is required to supply the input and output impedance matching networks. The leadless packages may contain two to four poles of selectivity, and the leadless technology has been integrated into a leaded configuration that incorporates the matching networks.
Piezo Technology, Inc.
INFO/CARD #158

Long Pulse Microwave Power Transistor

Motorola has released the MRF10120, a long pulse microwave power transistor. It will deliver 120 watts of peak power for typically less than 15 watts of peak RF input power over the frequency band from 960 to 1215 MHz. The MRF10120 is supplied in a hermetic metal-ceramic package and is aimed at both military applications (specifically JTIDS) and commercial applications such as Mode S transmitters.
Motorola
INFO/CARD #157

Microwave Reflection Analyzer

The BEKISCAN® CP from Millimeter Wave Technology quantifies shielding effectiveness of conductive stainless steel fibre loaded plastic parts. It has an operating frequency of 10.525 GHz with frequency stability of ±25 MHz.
Millimeter Wave Technology, Inc.
INFO/CARD #156

Low Phase Noise OCXO

Part Number 2900082 is a low profile, low phase noise OCXO that utilizes Piezo's SC cut crystals. The frequency range is 5 to 15 MHz, and typical phase noise at 10 MHz is −110 dBc/Hz at 10 Hz, −140 dBc/Hz at 100 Hz, and −160 dBc/Hz at 1 kHz.
Piezo Crystal Company
INFO/CARD #155

Hybrid Plug-In Programmable Attenuators

JFW Industries has introduced a new line of hybrid plug-in programmable attenuators available in 50 ohm terminations in the frequency range of 50 to 500 MHz. The attenuation range for these items are 0-31 dB in 1 dB steps, and their switching speed is 5 microseconds.
JFW Industries, Inc.
INFO/CARD #154

75 Ohm Component Analyzer

The HP 8752B RF Network Analyzer is a fully integrated RF component test system for 75 ohm applications, including CATV components and cables. It gives the characterizations of gain, impedance, phase and group delay for components in the 300 kHz to 3 GHz frequency band.
Hewlett Packard Company
INFO/CARD #153

EMI Suppression Filter Sample Kit

Murata Erie has released sample kit #EK115A, which contains 220 chip EMI filter components for filtering EMI/RFI. Included are a wide variety of Murata Erie's BLM series solid ferrite devices and the NFM series of EMI filters.
Murata Erie North America
INFO/CARD #152

Microwave IC Libraries

EEsof's SMART libraries combine an electrical simulation model for MMIC circuit elements with the corresponding element's physical layout model, linking simulation and layout. SMART libraries work with EEsof's Touchstone® and Libra® circuit simulators.
EEsof, Inc.
INFO/CARD #151

Variable Voltage Switching Power Supplies

Component Distributors has released a line of three and four output variable voltage switching power supplies manufactured by Zenith. Also available are switching power supplies with five and six outputs.
Component Distributors, Inc.
INFO/CARD #150

AT LAST,
ALL TOGETHER, IN ONE HANDY VOLUME THE BEST ARTICLES FROM *RF DESIGN*, ON OSCILLATOR DESIGN.

No more clipping, no more copying, no more scavanging for back issues. No more trying to remember where you read it. This handy booklet contains our best original articles featuring oscillator design...compiled from current issues of RF Design *magazine.*

This complete section of articles will tutor beginners, and keep current designers up to date on the latest techniques. It includes articles that will solve day-to-day design problems...help with analysis and specification...and help even the most skilled engineer improve the efficiencies and versatilities of his designs.

And, best yet, if we receive your order by November 1st, you will receive this softbound booklet for as little as $10.95 per copy. . .**a savings of up to 37%. But you must order today. . .quantities are limited.** *(In a rush? Call our "circulation" department at 303/220-0600, and order today.)*

PRICING:

Quantity 1-9 @ $14.95 each, plus $3.50 total shipping*.
Quantity 10-49 @ $12.95 each, plus $7.00 total shipping*.
Quantity 50-UP @ $10.95 each, plus $12.00 total shipping*.

*NON U.S. ORDERS, PLEASE DOUBLE SHIPPING CHARGE. ALL ORDERS SHIPPED SURFACE MAIL.

— — — — — — — — COUPON — — — — — — — — COUPON — — — — — — — —

RFD 1190

YES, SHIP ME (QTY) __________ OSCILLATOR BOOKLETS TODAY @ $__________ EACH, PLUS $__________ SHIPPING/HANDLING, **TOTAL ENCLOSED $**__________.

( ) BILL MY COMPANY, SIGNED COMPANY PURCHASE ORDER ENCLOSED.
( ) CHECK ENCLOSED PAYABLE TO *RF DESIGN*
( ) MC ( ) VISA ( ) AMEX EXP. DATE __________

CARD #__________ SIGNATURE __________

SHIP TO:

NAME __________ COMPANY __________

ADDRESS __________ MS __________

CITY __________ STATE __________ ZIP __________

TELEPHONE ( ) __________

MAIL ORDERS TO:
RF DESIGN, T. MAIER, 6300 S. SYRACUSE WAY, #650, ENGLEWOOD, CO 80111.

Multi-layer Adjustable Chip Capacitor Kit

American Technical Ceramics is offering a design kit for STA-TUNE™ Multilayer Adjustable Chip Capacitors. The kit contains 22 values ranging from 1 to 68 pF, with adjustment ranges of 0.15 pF to 3 pF. The kit (ST2001) is priced at $199.95.
American Technical Ceramics Corporation
INFO/CARD #149

140 MHz SAW Filters

Sawtek has announced a new line of 31 standard SAW filters at a center frequency of 140 MHz in addition to its line of 70 MHz devices. Bandwidths range from 0.25 MHz to 80.0 MHz.
Sawtek Inc.
INFO/CARD #148

Circuit Simulation

SuperStar Professional Extension is a high speed real-time circuit simulation, tuning and optimization package. The professional extension version includes Monte Carlo statistical analysis and microwave models.
Eagleware Corporation
INFO/CARD #147

High-Frequency Digital Clock

The HC1253 is a high-frequency digital clock for computer graphics by RF Monolithics. This clock operates at 262.074 MHz. Small quantity pricing for the HC1253 is $150 each.
RF Monolithics
INFO/CARD #146

Surface Mount Trimmer Capacitors

Sprague-Goodman Electronics has announced the addition of gull-wing leaded models to their line of Surftrim® surface mounting ceramic dielectric trimmer capacitors. Seven capacitance ranges (from 1.7-3.0 pF to 13.0-50 pF) are available.
Sprague-Goodman Electronics, Inc.
INFO/CARD #145

Two-way Power Divider

Model #SDL 260 is a two-way power divider which operates over the 1 MHz -600 MHz frequency range. Max insertion loss is 0.6 dB, and VSWR (output) is 1.4:1.
TRM Incorporated
INFO/CARD #144

High Power Amplifier

Part number P1020-43-PS is a 20 Watt, class A, linear power amplifier covering the 1000 to 2000 MHz range. Specifications for the unit include output power at 1 dBc of 43 dBm minimum and VSWR of 1.5:1 typical.
Trontech
INFO/CARD #143

Miniature Low Noise Ultra-Stable Crystal Oscillator

Type CO-705SL2 provides aging of 5 × 10^{-10} per day and 1 × 10^{-7} per year. Temperature stability is ±1 × 10^{-9} over the 0 to +50 degree Celsius range. Phase noise is −130 dBc/Hz at 10 Hz.
Vectron Laboratories, Inc.
INFO/CARD #142

Ceramic EMI Filters

Ceramic Devices is offering a line of monolithic ceramic EMI filters in both solder-in and screw-in configurations. These filters come in C, L, Pi, and T circuits with up to 10,000 pF of capacitance at 50 VDC.
Ceramic Devices
INFO/CARD #141

Feed-Through Capacitors and Pi-Filter Arrays

Stetco now manufactures a wide assortment of ceramic feed-through capacitor and Pi-filter arrays which are used in a variety of RFI suppression applications.
Stetco Incorporated
INFO/CARD #140

Programmable Attenuator

Trilithic has released a programmable attenuator that covers the DC to 1 GHz range for 50 ohm loads and the DC to 650 MHz range for 75 ohm loads. It has insertion loss as low as 0.15 dB per cell and accuracy as good as ±0.1 dB. Prices start at $138 each.
Trilithic Incorporated
INFO/CARD #139

Linear Voltage Variable Attenuator

The QBH-723 is a hybrid linear voltage variable attenuator in a 5-pin, TO-8 package. The unit operates over a frequency range of 20 to 500 MHz with a typical VSWR of 1.5:1 on the input and output ports and a linear range (db/V) of at least 11.0 dB.
Q-bit Corporation
INFO/CARD #138

Circuit Optimizer Upgrade

Nedrud Data Systems has released DragonWave 2.0, a graphical design and optimizing software package for RF circuits on Macintosh computers. Black box data can be entered in Y-and Z-parameters as well as S-parameters.
Nedrud Data Systems
INFO/CARD #137

Direct Digital Synthesizer

Sciteq Electronics has introduced the DDS-1, a multi-mode DDS on one square inch, with digital phase and amplitude control. The waveformer dissipates 1.5 watts and fits a standard 84-pin chip carrier.
Sciteq Electronics, Inc.
INFO/CARD #136

750 Watt Amplifier

Model 750HB is a broadband amplifier that delivers a minimum of 750 watts CS through a bandwidth of 400 to 1000 MHz. Minimum gain is 59 dB, flatness is ±1.5 dB at 1 mW input, input and output impedance is 50 ohms, and VSWR is 2.0:1.
Amplifier Research
INFO/CARD #135

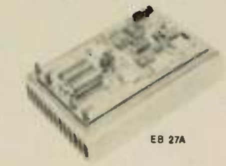
Low Cost Modulation Meter

The Boonton Model 8220 Modulation meter has a carrier range of 10 MHz to 1.3 GHz and a level meter from −27 to +19 dBm with 0.01 dB resolution. The Model 8220 is priced at $5,995.
Boonton Electronics Corporation
INFO/CARD #134

Miniature Diplexers

TTE has just released a line of miniature diplexers that cover the frequency range of 20 kHz to 100 MHz. The lowpass frequency cased is 2" × 5.75" × 0.75" while the packages for units above 100 kHz is 2" × 4.75" × 0.5".
TTE Incorporated
INFO/CARD #133

HF LINEAR AMPLIFIERS - BROADBAND TRANSFORMERS


EB 27A

HF AMPLIFIERS per MOTOROLA BULLETINS
Complete Parts List for HF Amplifiers Described In the MOTOROLA Bulletins

AN758 300W $160.70
AN762 140W $ 93.25
AN779L 20W $ 83.79
AN779H 20W $ 93.19
AR313 300W $403.00
EB63 140W $ 88.65
EB27A 300W $139.20
EB104 600W $448.15
AR305 300W $383.52

NEW!! 1K WATT 2-50 MHz Amplifier

100 WATT 420-450 MHz PUSH-PULL LINEAR AMPLIFIER — SSB-FM-ATV
KEB67—PK (Kit)........$159.95
KEB67—PCB (PC Board)........$ 18.00
KEB67—I (Manual)........$ 5.00

We also stock Hard—to—Find parts
CHIP CAPS—Kemet/ATC
METALCLAD MICA CAPS—Unelco/Semco
RF POWER TRANSISTORS
MINI—CIRCUIT MIXERS
SBL—1 (1—500Mz)........$ 6.50
SBL—1X (10—1000Mz)........$ 7.95

ARCO TRIMMER CAPACITORS
VK200—20/4B RF Choke........$ 1.20
56—590—65—3B Ferrite Bead........$ .20
Broadband HF Transformers
Add $ 3.50 for shipping and handling.

2 METER VHF AMPLIFIERS
35 Watt Model 335A........$ 79.95 Kit
75 Watt Model 875A........$119.95 Kit
Available in kit or wired/tested

POWER SPLITTERS and COMBINERS 2—30MHz
600 Watt PEP 2—Port........$ 69.95
1000 Watt PEP 2—Port........$ 79.95
1200 Watt PEP 4—Port........$ 89.95

For detailed information and prices, call or write for our free catalog.

We ship worldwide.
VISA
CCI Communication Concepts Inc.
508 Millstone Drive • Xenia, Ohio 45385 • (513) 426—8600
FAX (513) 429-3811
master charge
WE SHIP WORLDWIDE

INFO/CARD 78

100 MHz Digital Storage Oscilloscope

The Tek 221A, a 100 MHz analog and digital storage oscilloscope from Tektronix, achieves a 100 megasamples/second sampling rate simultaneously on each of two channels. It is priced at $3995 and is available immediately.
Tektronix
INFO/CARD #132

Prototyping Card for VXIbus

Model 7065 allows RF and microwave instruments and subsystems to be designed into the VXIbus format. The card features an enclosure which ensures an EMI sealed environment while providing efficient heat dissipation. Prices begin at $2495.
Racal Dana Instruments, Inc.
INFO/CARD #131

Microwave Laser Photo Plotter

The model N524000-MLPP system plots a mask from an AutoCAD drawing file in less than one-half hour, with no post processing. It accommodates up to a 6" x 6" substrate size and plots a 0.001" line and space.
Newport Electro-Optics Systems, Inc.
INFO/CARD #130

Ultrafast GaAs MMIC Switch

Anzac's newest GaAs MMIC switch (SW-256) works in the 5-1000 MHz frequency range and switches in 50 nsec typically. It consumes 2.2 mA of DC power typically, and isolation is 35 dB minimum from 5-1000 MHz and 50 dB minimum from 5-500 MHz. The SW-256 is priced at $129.95.
M/A-COM, Anzac Division
INFO/CARD #129

Four Channel Simultaneous Sampling ADC

The AD7874, a monolithic four-channel simultaneous sampling ADC from Analog Devices, has 71 dB minimum SNR at 29 ksps. Maximum peak spurious noise, intermodulation distortion, and total harmonic distortion are each 80 dB. Prices begin at $28 in 100s.
Analog Devices
INFO/CARD #128

Bulk Injection Current Probes

Models 95236-1, 95252-1, and 95235-1 are designed for EMC and EMP testing. Model 95252-1 operates over the frequency range from 400 to 1000 MHz; Model 95236-1 operates over the 0.01 to 100 MHz range; and Model 95235-1 operates over the 10 to 450 MHz range.
Eaton Corporation
INFO/CARD #127

Coaxial Assemblies

W. L. Gore & Associates has introduced the CX Series GORE-TEX[R] RF coaxial cable assemblies for low-frequency applications to 1000 MHz. These assemblies are 30 percent lighter than RG type cables and have VSWR of 1.2:1.
W. L. Gore & Associates, Inc.
INFO/CARD #126

800 MHz Si MMIC Amplifier

Avantek is now offering an advanced silicon bipolar low noise, high gain amplifier with a 3 dB bandwidth of DC to 800 MHz. The INA-02184 and INA-02186 amplifiers offer 31 dB gain, 2 dB noise figure, and +11 dBm output power at 1 dB compression.
Avantek, Inc.
INFO/CARD #125

Spectral Linewidth Analyzer

The MS9602A is an optical linewidth analyzer from Anritsu that measures the spectral width of light sources operating in the 1.3 and 1.55 um bands. The analyzer has resolution of 20 kHz. Linewidth measurement range is 20 kHz to 100 MHz for heterodyne measurements and 1 to 500 MHz for homodyne measurements. It costs $45,090.
Anritsu America, Inc.
INFO/CARD #124

NEW SURPLUS

	10-99	100-249	250-up
RFI Line Filter, Corcom, IVRI	$ 8.00	$ 4.80	$ 3.65
24V C.T. 1 AMP Xformer, TRIAD, F-374P	$ 5.75	$ 4.50	$ 2.50
1.8432 MHz Xtal, NRC		$ 1.35	$ 0.95
RF Relay, OMRON, G5Y154P-DC12	$ 5.75	$ 4.85	$ 3.25
0.2 uh VAR. Inductor, Coilcraft, 144-07J12S		$ 1.25	$ 0.60
SPDT RF Switch, Minicircuits, PSW1211	$18.95	$15.95	$12.95
UART, RCA, CDP65C51E2	$ 2.25	$ 1.75	$ 1.25
41.25 MHz SAW, Plessey, SY212	$ 2.25	$ 1.70	$ 1.15

D & P MANUFACTURING, INC.
P.O. BOX 107
CHALFONT, PA 18914
(215) 997-1200
FAX (215) 997-1200

Phased Coded Correlators

Thomson-CSF has developed a full range of phased coded correlators for satellite communications and group and airborne radars. The CP603 in particular has a digital signal centered at 120 MHz, and insertion loss is lower than 25 dB.
Thomson-ICS Corporation
INFO/CARD #123

Acrian Equivalent Resistors and Attenuators

Florida RF Labs introduces a new line of Acrian equivalent resistors, terminations, attenuators. These new components meet or exceed Acrian power ratings while maintaining low VSWR and capacitance.
Florida RF Labs, Inc.
INFO/CARD #122

NMR Amplifier

The NMR-300L/50M produces 300 watts of pulse power over the frequency range of 5-220 MHz, reducing to 150 watts up to 250 MHz, and 50 watts from 200-600 MHz. It is available for $12,500.
ENI
INFO/CARD #121

Industrial RF Power Supply

ETO has introduced the PG-5DW, a fully automatic, water cooled 5 kW industrial RF power supply/amplifier for excitation of CO_2 lasers and other plasma applications. It operates on any factory set frequencies between 10 and 90 MHz.
Ehrhorn Technological Operations, Inc.
INFO/CARD #120

MMIC LED Driver

The UPC1684 MMIC LED Driver from NEC has high speed current switching —to 300 Mb/s NRZ, 1.4 nsec fall time, and 1.0 nsec rise time. It accepts standard ECL level inputs and is available in a hermetically sealed package or in chip form.
California Eastern Laboratories, Inc.
INFO/CARD #119

Dielectric Filters

Toko America has introduced 2-pole and 3-pole dielectric bandpass filters for spread spectrum applications. These filters feature a passband from 902-928 MHz. Insertion loss is 1.8 dB max and VSWR is 2.0 max.
Toko America, Inc.
INFO/CARD #118

MIC Hybrid Amplifiers

JCA Technology has released a MIC hybrid 20-22 GHz amplifier line. The amplifiers can be manufactured to military specifications with gain levels from 15 dB to 40 dB and output power is +10 dBm at 1 dB compression.
JCA Technology
INFO/CARD #117

Shielding Integrity Monitor

Lindgren RF Enclosures has released a self-testing automatic RF integrity tester for permanent installation, with fiber optic control and status lines, and an optional search loop antenna for RF leakage source location.
Lindgren RF Enclosures
INFO/CARD #116

Clock Oscillator with Tri-State Capability

The CXO-63GAU clock oscillator from CTS is available up to 110 MHz and offers CMOS/TTL compatible output with tri-state capability. Symmetry is 48 percent/52 percent typical (at 50 percent level).
Frequency Control Division
CTS Corporation
INFO/CARD #115

Wideband Variable Gain Amplifier

The NE5209 wide band variable gain amplifier from Signetics has a gain bandwidth out to 1.5 GHz and a linear gain control range that allows precise AM modulation. It can be used to simplify automatic gain control applications.
Philips Components—Signetics
INFO/CARD #114

RF Series Attenuators

This series of attenuators from Compac Development has attenuation at or above 80 dB out to 20 GHz. The attenuators are avaiable off the shelf or can be customized to client specifications.
Compac Development Corporation
INFO/CARD #113

Miniature 200 Watt Amplifier

LCF Enterprises has released a miniature 200 Watt amplifier featuring 55 percent efficiency over the 150-250 MHz frequency band. Compressed gain is 37 dB with variable control. The package size is 4.84" × 2" × 1" without a heat sink.
LCF Enterprises
INFO/CARD #112

Low Cost Switches

Micronetics Electronics Division has introduced low cost SP1T and SP2T switches for commercial applications. Typical isolation is 50 dB with insertion loss of 0.75 dB up to 4 GHz. Prices are $49 and $69 in quantities.
Micronetics, Inc.
INFO/CARD #111

Spectrum Analyzers

The R3261/R3361 Series of synthesized spectrum analyzers offer frequency ranges of 9 kHz to 2.6 GHz and 9 kHz to 3.6 GHz, depending on the model. The analyzers have a display dynamic range of 120 dB and an overall accuracy level of 1 dB.
Advantest America, Inc.
INFO/CARD #109

Who says nobody loves trimmer capacitors?

When it comes to small size, low cost and SMT requirements, engineers are flowery in their praise of Sprague-Goodman's Ceramic Dielectric Trimmers.

It's no wonder. Our ceramics have a way of making everything look rosy. They come in a broad variety of sizes, shapes and capacitance ranges, including Surftrim® SMT, and sealed models. All are of the highest quality, sensibly priced and readily available.

For more information, call or write for Engineering Bulletin SG-305A, plus data on other trimmer capacitors for virtually every requirement.

SPRAGUE GOODMAN

SEE US AT RF EXPO EAST BOOTH 215

The World's Broadest Line Of Trimmer Capacitors
134 FULTON AVENUE, GARDEN CITY PARK, NY 11040-5395
TEL: 516-746-1385 • FAX: 516-746-1396 • TELEX: 14-4533

INFO/CARD 80

STATEMENT OF OWNERSHIP, MANAGEMENT AND CIRCULATION (Required by 39 U S C 3685)
1 Title of Publication RF DESIGN
1B Publication No 453490
2 Date of Filing Sept 28, 1990
3 Frequency of Issue Monthly plus one extra issue in September
3A No of issues published annually 13
3B Annual Subscription Price $36 00
4 Complete Mailing Address of Known Office of Publication Cardiff Publishing Co Inc , 6300 S Syracuse Way, Ste 650 Englewood, CO 80111
5 Complete Mailing Address of the Headquarters of General Business Offices of the Publisher Cardiff Publishing Co Inc , 6300 S Syracuse Way, Ste 650, Englewood, CO 80111
6 Full Names and Complete Mailing Address of Publisher, Editor and Managing Editor
Publisher Kathryn Walsh, 6300 S Syracuse Way, Ste 650, Englewood, CO 80111.
Editor Gary Breed, 6300 S Syracuse Way, Ste 650, Englewood, CO 80111
7 Owner (if owned by a corporation, its name and address must be stated and also immediately thereunder the names and addreses of stockholders owning or holding 1 percent or more of total amount of stock If not owned by a corporation, the names and addresses of the individual owners must be given If owned by a partnership or other unincorporated firm, its name and address, as well as that of each individual must be given If the publication is published by a nonprofit organization, its name and address must be stated) (item must be completed) Cardiff Publishing Co Inc is a subsidiary of Argus Press Holding Inc , 6255 Barfield Road, Atlanta, GA 30328-4369
8 Known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages or other securities (if there are none, so state) None

9 Extent and nature of circulation	Average No copies each issue during preceding 12 months	Actual No copies of single issue published nearest to filing date
A Total No Copies (Net Press Run)	43,630	43,554
B Paid and/or requested circulation		
1 Sales through dealers and carriers, street vendors and counter sales	None	None
2 Mail subscription (Paid and/or requested)	39,516	40,795
C Total paid and/or requested circulation (Sum of 9B1 and 9B2)	39,516	40,795
D Free distribution by mail, carrier or other means (samples, complimentary and other free copies)	2,698	1,009
E Total Distribution (Sum of C and D)	42,214	41,804
F Copies not distributed		
1 Office use, left over, unaccounted, spoiled after printing	1,416	1,750
2 Return from News Agents	None	None
G TOTAL (Sum of 3 F1 and 2 — should equal net press run shown in A)	43,630	43,554

10 I certify that the statements made by me above are correct and complete
(Signed) Robert A Searle, President/Publisher

A Review of the Program BAND

By David C. Greene
Philips Consumer Electronics

This review is presented for the information of our readers, and does not imply an endorsement of this product by RF Design. *If you would like to see more independent reviews of RF software or hardware products in the future, write us and let us know.*

BAND is a low-cost computer program for the design of LC bandpass filters, written for IBM PC or MS-DOS compatible personal computers. BAND accomplishes the bandpass filter design by performing a lowpass to bandpass transformation. Reviewing this transformation, recall that a bandpass filter with center frequency f_0, lower 3 dB frequency f_1, and upper 3 dB frequency f_2 is obtained from the lowpass prototype filter by the transformation

$$S = \frac{1}{a}\left(\frac{s}{f_0} + \frac{f_0}{s}\right) \quad (1)$$

where

$$a = \frac{f_2 - f_1}{f_0} \quad (2)$$

is the relative bandwidth. The normalized frequency is then

$$\Omega = \frac{1}{a}\left(\frac{f}{f_0} - \frac{f_0}{f}\right) \quad (3)$$

and as a consequence of this transformation, f_0 is the geometric mean of f_1 and f_2.

$$f_0 = \sqrt{f_1 \times f_2} \quad (4)$$

From these equations it is clear that a frequency ratio in the LP case corresponds to a bandwidth ratio in the BP case, thus relating the shape factors of the LP and BP attenuation responses.

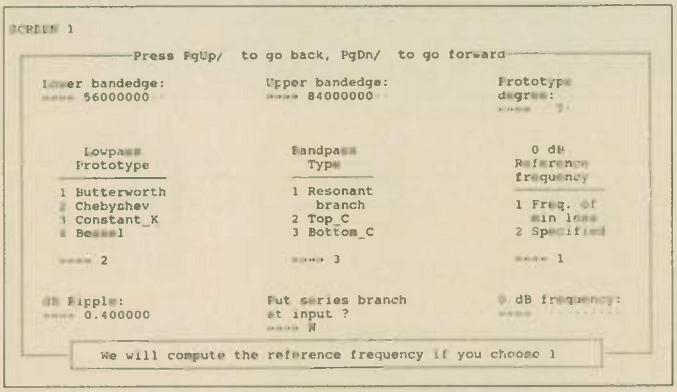


Figure 1. First data input screen for BAND.

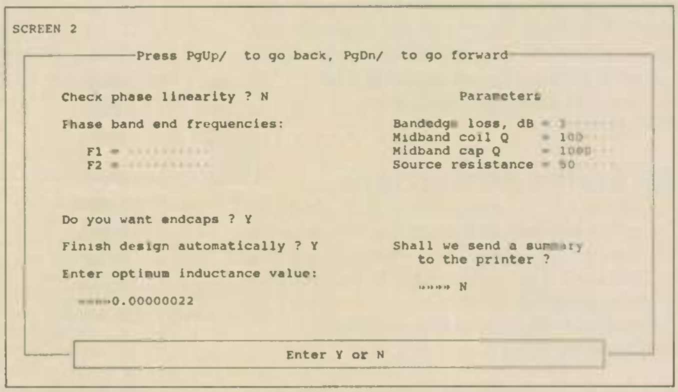


Figure 2. Second data input screen for BAND.

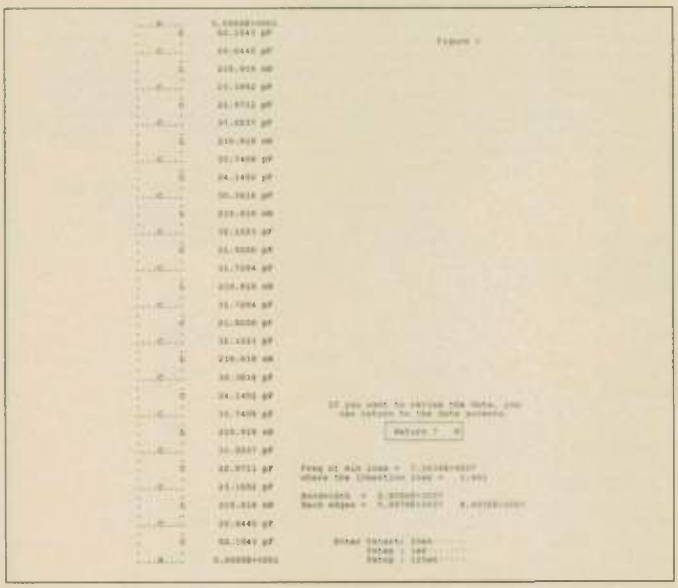


Figure 3. This screen appears when calculations are complete.

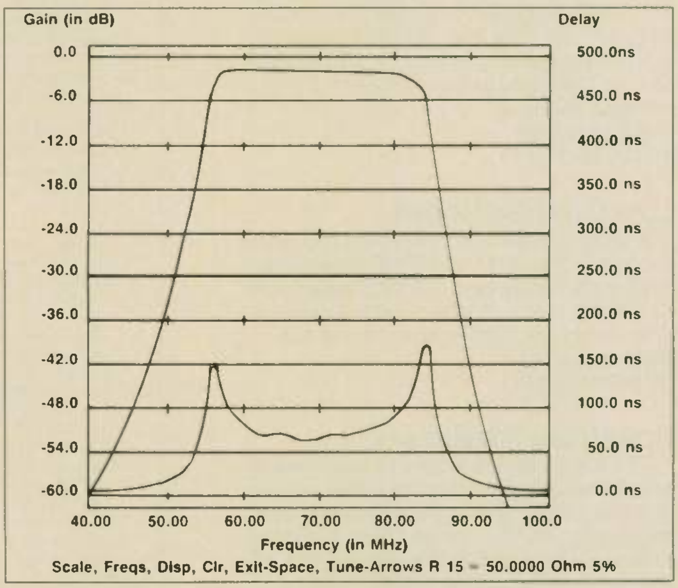


Figure 4. Results analyzed by Spice and graphed.

```
....R....      2.0000E+0002
.       C       1.36457 nF
....C....       77.9559 pF
.       L       56.0032 uH
....C....       19.1337 pF
.       C       23.0540 pF
....C....       89.1725 pF
.       L       56.0032 uH
....C....       20.6532 pF
.       C       135.429 pF
....C....       43.9797 pF
.       L       56.0032 uH
....C....       11.9372 pF
.       C       208.953 pF
....R....      1.3061E+0003

          If you want to revise the data, you
           can return to the data screen.

                    Return ?   N

   Freq of min loss =  3.5915E+0006
   where the insertion loss =  -2.781

   Bandwidth  =  9.9984E+0005
   Band edges =  3.0802E+0006   4.0800E+0006
   The best (least squares) line is:
              Slope =  1.97E-0004 degrees/Hertz
          Intercept = -4.91E+0002 degrees
   Max deviation is  4.85E+0000 degrees.
        Enter Fstart: 2.08
              Fstop : 1e5
              Fstop : 5.08
       (Press Esc when data is in)
```

Figure 5. Generated output.

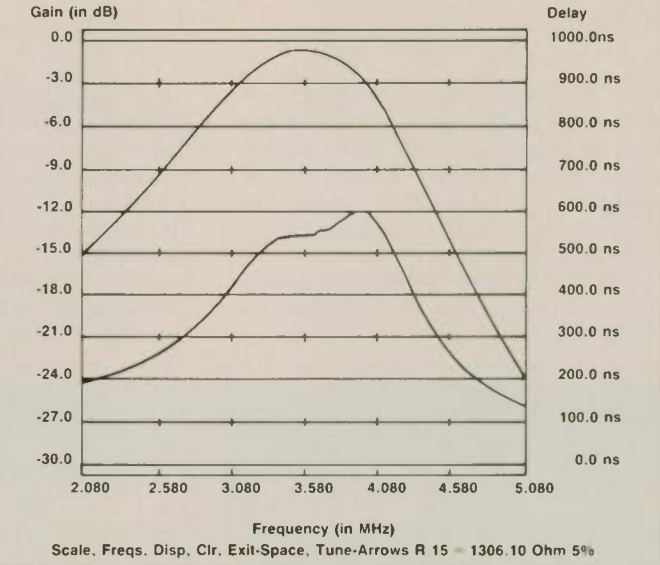


Figure 6. Graphical output of analyzed network.

The frequencies f_a and f_b correspond to the LP frequencies Ω_a and Ω_b, respectively and are related to f_0 by

$$f_0 = \sqrt{f_a - f_b} \tag{5}$$

forming the bandwidth

$$B = f_b - f_a \tag{6}$$

then the following is true

$$|\Omega_a| = \Omega_b = \frac{f_b - f_a}{f_2 - f_1} \tag{7}$$

then

$$f_b = f_0\left(\sqrt{1 + \left(\frac{B}{2 \times f_0}\right)^2} + \frac{B}{2 \times f_0}\right) \tag{8}$$

and

$$f_a = f_0\left(\sqrt{1 + \left(\frac{B}{2 \times f_0}\right)^2} - \frac{B}{2 \times f_0}\right) \tag{9}$$

The BP element values are obtained by replacing each LP inductor L_n with a series LC combination resonating at f_0, with the inductor value $L_n/(\omega_2 - \omega_1)$ and the capacitor value $a/(L_n \times \omega_0)$. Each LP capacitor C_n is replaced by a parallel LC combination resonating at f_0, with the inductor value of $a/(C_n \times \omega_0)$ and the capacitor value of $C_n/(\omega_2 - \omega_1)$. For more information see Reference 1.

The lowpass filter prototypes available are, 1) Butterworth, 2) Chebyshev, 3) Constant K, 4) Bessel. These lowpass prototypes are of the all-pole type, placing all poles at infinite frequency, thus they contain no finite loss poles in the stopband. This means that BAND can not handle elliptic bandpass filter designs. For the design cases where the above mentioned approximation types are adequate then BAND can quickly perform the necessary design equations.

The best way to illustrate the program is to design a bandpass filter using BAND. In the first example, a 70 MHz bandpass filter with 3 dB corner frequencies of 56 MHz and 84 MHz is specified. By using the Chebyshev approximation with a passband ripple of .4 dB and choosing a 7th order lowpass prototype it is possible to obtain over 30 dB of stopband suppression at 50 MHz and 90 MHz. Such a filter could be used for

SAWING QUARTZ?

ELECTRO ABRASIVES ARE YOUR No. 1 ANSWER.

Sawing and lapping quartz into timing devices, and other precision lapping and polishing of components require precision abrasives: the type produced at our new Buffalo powder plant.

Our new generation powders are your best choice:

- Electrocarb® Silicon Carbide
- Brown Fused Aluminum Oxide Optical Powders
- White Precision Alumina

For these reasons:

- Sized to rigid FEPA standards
- Water classified with state-of-the-art technology
- Used daily in production sawing of quartz
- In stock for immediate shipment

Request Descriptive Product Literature.

Contact Al Ramming for assistance in grit-size selection and the name of your nearest Electro distributor.

ELECTRO ABRASIVES

ELECTRO ABRASIVES CORPORATION • 701 Willet Road • Buffalo, N.Y. 14218
Tel: 800-284-GRIT Fax: 716-822-2858

INFO/CARD 81

the IF of a TVRO receiver. The choice of lowpass prototype type and order must be made based on either experience, tables such as Zverev (2), or computer programs (3, 4), since this program contains no provisions for calculation of order.

The data is input to BAND by means of two screens. The first appears as shown in Figure 1.

We have entered the lower corner frequency of 56 MHz, the upper corner frequency of 84 MHz, and chosen the Chebyshev type lowpass prototype with a passband ripple of 0.40 dB specified. This program uses a lookup table for the Bessel LP prototype normalized g(n) values, for the Butterworth and Chebyshev LP prototype, the g(n) values are calculated using Dr. H. J. Orchard's equations (3, 4). Another LP prototype very rarely seen anymore is the constant K type design that is based on image parameter design, based on transmission line theory, discovered by Dr. Otto Zobel in 1923 (2). BAND will accommodate LP prototypes of order 1 to 20 except Bessel which must be of order 2 to 11.

Continuing with our example, the bottom C type configuration is chosen and the reference frequency is specified as the one of minimum loss. By moving on to the next screen (see Figure 2) we can enter the rest of the necessary data for this design.

In Figure 2 we have elected not to check phase linearity, and specified the band edges as the 3 dB attenuation points. The coil Q is set to 100, the capacitor Q is set to 1000, and a source resistance of 50 ohms is specified.

BAND uses an iterative algorithm to accurately set the specified band edges at the specified attenuation, (usually 3 dB). The BP network is calculated and the frequencies of the specified band edges are determined by a nodal analysis program. If these frequencies are in error then a corrected network is calculated and again analyzed. This process continues until agreement within some tolerance, (0.1 percent), is obtained. Thus BAND automatically sets the band edges to the specified frequencies using the lossy coils and capacitors, with this loss being specified by component Q.

End caps and automatic finish are selected with a coil value of 0.22 μH. By specifying these options the program will use Norton's transformations to set the coil values equal. The improper selection of configuration and values at this point can result in negative component values being generated using Norton's transformations (2).

When this screen is left, the calculations to generate the LC network start. A "working" message fills the screen while the program runs, and can be quite annoying. The time it takes for these calculations depends on the complexity of the filter and the computer's speed. Machines equipped with a math co-processor will be much faster, but typically calculations only take from 2 to 20 seconds.

If you answer NO to the prompt then the screen shown in Figure 3 is displayed, giving the frequency of minimum loss, insertion loss, bandwidth, and band edge frequencies. The prompt for F start, F step, and F stop allows these values to be entered and, once entered,

INFO/CARD 82

when the Esc key is pressed a frequency analysis will be performed. The LC network designed and shown in Figure 3 was analyzed using Spice and these results graphed. This graph is shown in Figure 4 and shows good agreement with this program. Please note that this program contains no provisions for graphics output or graphing of data.

To conclude, a second design example is presented; a Bessel linear phase bandpass filter with a passband of 3.08 MHz to 4.08 MHz, such as might be used to take chroma off of a composite video NTSC television signal. The Bessel lowpass prototype of order 3 is chosen and the bottom C configuration is chosen with end caps and auto finish with a coil value of 56 μH. Figure 5 shows the output obtained and Figure 6 shows the graphical output of this network analyzed using Spice. Note that for this network the terminations are unequal, this is common with this type of filter and some care must be exercised to prevent negative elements from appearing in the design. Also note the group delay distortion which results from the distortion of phase encountered in the LP to BP transformation.

There are many other possible configurations, but these two examples should provide an indication of the operation and performance of the program. The price of BAND is $99 post paid and may be obtained by contacting Phil Geffe's FILTERWARE, 503 Williamsburg Road, Cincinnati, OH 45215. Interested readers can also circle Info/Card #110. ***RF***

References

1. Herman J. Blinchikoff & Anatol I. Zverev, *Filtering in the Time and Frequency Domains*, John Wiley & Sons, Inc., 1976.
2. Anatol I. Zverev, *Handbook of Filter Synthesis*, John Wiley & Sons, Inc., New York, NY, 1967.
3. David C. Greene, "A Design Program for Butterworth Lowpass Filters," *RF Design*, March, 1989.
4. David C. Greene, "Chebyshev Lowpass Filter Design", *1990 RF Design Directory*, Fall 1989 P. 70.

About the Author

David Greene is a Project Engineer in the Advanced Development Engineering group at Philips Consumer Electronics, One Philips Drive, P.O. Box 14810, Knoxville, TN 37914-1810.

Presenting . . .

Sawtek's Standard 70 MHz and 140 MHz SAW Filters

3 dB BW	Part Number
0.25	851541
0.50	851542
0.75	851543
1.0	851544
1.5	851545
2.0	851546
2.5	851547
3.0	851548
3.5	851549
4.0	851550
4.5	851551
5.0	851552
5.5	851553
6.0	851554
6.5	851555
7.0	851556
7.5	851505
8.0	851557
8.5	851558
9.0	851559
9.5	851560
10.0	851475
11.0	851841
12.0	851842
13.0	851843
14.0	851844
15.0	851845
16.0	851846
18.0	851847
20.0	851848
22.0	851849
24.0	851850
26.0	851851
28.0	851852
30.0	851853
32.0	851854
34.0	851855
36.0	851856
38.0	851857
40.0	851858

Available for Immediately Delivery!

To order fewer than 100 of any of the 70 MHz or 140 MHz SAW filters listed, contact Penstock at **1-800-PENSTOC**, or write: Penstock Inc., 520 Mercury Drive, Sunnyvale, California 94086-4018. FAX: 408-730-4782. For custom-designed filters or orders over 100 pieces, please contact Sawtek at 407-886-8860.

3 dB BW	Part Number
0.25	851900
0.50	851901
0.75	851902
1.0	851903
1.48	851904
2.0	851905
2.5	851906
3.0	851907
4.0	851909
5.0	851911
6.0	851913
7.0	851915
8.0	851917
9.0	851919
10.0	851921
12.0	851923
14.0	851925
16.0	851927
18.0	851929
20.0	851931
24.0	851933
28.0	851935
32.0	851937
36.0	851939
40.0	851941
44.0	851943
48.0	851945
56.0	851947
64.0	851948
72.0	851949
80.0	854101

SAWTEK INCORPORATED

PENSTOCK™ INC
IF/RF/MICROWAVE DISTRIBUTION

INFO/CARD 83

Please see us at RF Expo East, Booths #107, 109.

Broadband Impedance Matching By Polynomial Synthesis

By David R. Lang
Consultant

When used to design broadband matching networks, standard CAD programs such as Touchstone[R] can find optimum component values only if the assumed network topology is approximately correct. However, the choice of a suitable matching network (equalizer) topology may not be obvious when the source and load impedances to be matched are defined by measured or model-derived S-parameters that represent networks more complex than the simple RL or RC terminations assumed by analytic matching theory.

The program MATCHD, described here, operates under MS-DOS, and is loosely based on a procedure outlined by Yarman (1) for generating a polynomial equalizer reflection coefficient function directly from source and load S-parameters. One or more topologically unique equalizer networks, all exhibiting the same response, can then be synthesized from this function.

MATCHD accomplishes this synthesis as follows. First, an optimum equalizer response is obtained by minimizing one of two selected error functions over the optimization frequency band. The first function simply minimizes the average equalizer insertion loss; the second minimizes the difference between the equalizer loss and a desired frequency-gain profile, and can be used to incorporate gain slope compensation into the interstage networks of cascade amplifiers. The computed equalizer loss vs. frequency is then displayed in a numeric or graphic format. Finally, a driving point impedance function is generated from the optimized reflection coefficient function, and from this the network components of the equalizer(s) are extracted, using elementary pole removal operations.

When using MATCHD, the complex source and load are each defined only by S-parameter files. The source and load data file frequency bands must, of course, overlap, but MATCHD provides linear interpolation in case the data frequencies do not match. The format of these S-parameter files is not restrictive, and Touchstone-compatible data files can be read directly.

Theory

MATCHD will always realize the equalizer as a minimum reactance, lumped element ladder network. Transmission zeros at other than DC or infinity are not included in the response, since the improvement in gain is generally small and for practical matching circuits the consequent circuit complexity is rarely justified.

The S-parameters of a passive, lossless and reciprocal two port can be represented as ratios of polynomials (2) as follows:

$$S_{11} = \frac{h(s)}{g(s)} \qquad (1)$$

$$S_{21} = S_{12} = \frac{s^P}{g(s)} \qquad (2)$$

$$S_{22} = \frac{-(-1)^P h(-s)}{g(s)} \qquad (3)$$

where

$$h(s) = A_N s + A_{N-1} s^{N-1} + \ldots A_1 s + A_0 \qquad (4)$$

and $(s = j\omega)$

$$g(s) = B_N s + B_{N-1} s^{N-1} + \ldots B_1 s + B_0 \qquad (5)$$

All of the coefficients A(*) and B(*) are real, and the reference impedance for both ports equals 1.0 ohm.

For lumped element realizations of the 2-port, N is the total number of reactances, and P is the number of DC transmission zeros (shunt inductors or series capacitors). The S-parameter matrix is thus defined independently of the specific component sequence of subsequently realized equalizers.

To minimize computation time, equations 1-3 can be further simplified to the following sequence:

$$\text{ang}(S_{11}) = \text{ang}(h(s)) - \text{ang}(g(s)) \qquad (6)$$

$$\text{ang}(S_{21}) = \text{ang}(S_{12}) = (90 \times P) - \text{ang}(g(s)) \qquad (7)$$

$$\text{ang}(S_{22}) = -(180 - 2 \times \text{ang}(S_{21})) - \text{ang}(S_{11}) \qquad (8)$$

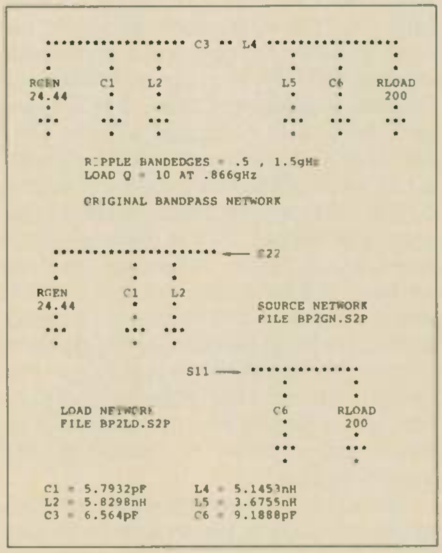


Figure 1. 0.5-1.5 GHz bandpass equalizer example.

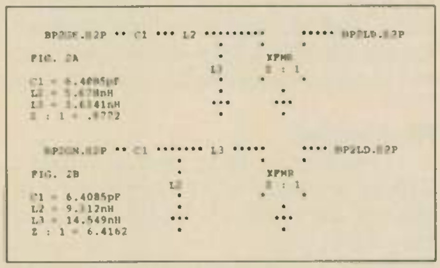


Figure 2. MATCHD equalizers for the 0.5-1.5 GHz bandpass example.

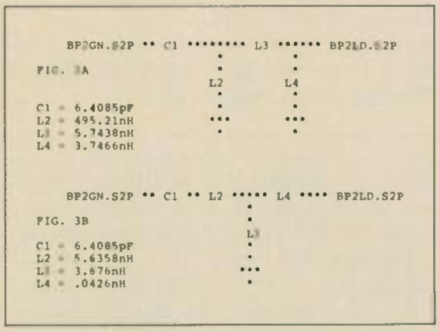


Figure 3. Bandpass example equalizers using Norton transformers.

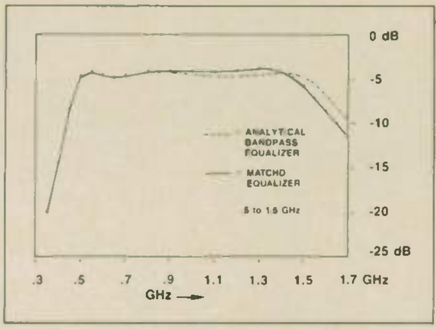


Figure 4. MATCHD broadband response versus original bandpass network response.

$$\mathrm{mag}(S_{12}) = \mathrm{mag}(S_{21}) = \mathrm{mag}\ \frac{s^P}{g(s)} \tag{9}$$

$$\mathrm{mag}(S_{22}) = \mathrm{mag}(S_{11}) = \mathrm{mag}\ \frac{h(s)}{g(s)}$$

The transducer gain (loss) G_t of the equalizer is:

$$G_T = \frac{|S_{21}|^2(1-|\Gamma_S|^2)(1-|\Gamma_L|^2)}{|(1-\Gamma_S S_{11})(1-\Gamma_L S_{22}) - \Gamma_S\Gamma_L S_{12}S_{21}|^2} \tag{11}$$

where Γ_S and Γ_L are the reflection coefficients of the source and load terminations, respectively, and $G_t \leqslant 1.0$ since the equalizer is passive. Now define

$$H(\omega) = h(-s) \times h(s) \tag{12}$$

$$= C_{2N}\omega^{2N} + C_{2N-2}\omega^{2N-2} + \ldots C_0$$

$$G(\omega) = g(-s) \times g(s) \tag{13}$$

$$= D_{2N}\omega^{2N} + D_{2N-2}\omega^{2N-2} + \ldots D_0$$

The coefficients C_m and D_m are then related as follows:
pure lowpass (LP): $P = 0$
pure highpass (HP): $P = N$
in all cases: $N \geqslant P \geqslant 0$

$$D_m = C_m + 1 \quad \text{for } m = 2P \tag{14}$$

$$D_m = C_m \quad \text{for } m \neq 2P \tag{15}$$

The polynomials h(s) and g(s) are thus indirectly related by their respective squared-magnitudes H(ω) and G(ω). During optimization, H(ω) and G(ω) are directly generated from the best estimated h(s). The roots of g(s), and subsequently g(s), are created from the left hand plane (LHP) roots of G(ω) to ensure the realizability of the equalizer response.

The subroutine used to extract the complex roots of G(ω) is a modified version of the general polynomial root extraction algorithm of Moore (3, 4). The MATCHD version is faster, but is limited to extracting roots of real-coefficient polynomials of real variables (even powers of jω).

If the pure HP or LP response is chosen, one can also choose to include or omit an ideal transformer in the design. If the transformer is omitted, the overall design is simpler but the performance (the bandpass gain) may in some cases suffer since the optimization loses a degree of freedom. In this case the additional constraint is:

$$\text{LP case: } h_O = 0 \tag{16}$$

$$\text{HP case: } h_N = 0 \tag{17}$$

When $N > P > 0$, a transformer is always included. As shown in the example below, a Norton transformer can generally be realized to replace the ideal transformer. The addition of the extra component in the Norton transformer does not change the effective number of N or P and does not alter the original equalizer response.

Optimization Detail

This part describes how the program finds an optimum equalizer response. The only information required by the program prior to optimization is supplied by the user in steps (a) and (b) below. The error-minimizing instruction loop comprises steps (c) to (j).

a) user specifies: N, P, the optimization frequency bandedges, number of frequency steps, the data file names, the decision to use an ideal transformer or not, and the goal: maximum flat gain or loss curve matching. In MATCHD the number of elements is arbitrarily limited to $1 \leqslant N \leqslant 6$, which should be more than sufficient for most matching requirements.

b) create an initial choice of the coefficients of h(s). This choice can be user-defined if desired, but is normally executed entirely within MATCHD.

c) generate H(ω) from h(s)

d) generate G(ω) from H(ω) using rules 14 and 15

e) find the roots of G(ω)

f) switch the Re and Im components of the root pairs (e)

g) generate g(s) from the LHP roots of (f)

h) compute the equalizer S-parameters using equations 6-10.

i) compute the transducer gain G_t over the normalized optimization band. In this step, each frequency in the original optimization band is scaled so that the normalized geometric mean frequency equals 1.0 radian.

j1) for maximizing the gain over the defined band, the error function is:

$$E_1 = \frac{1}{M}\sum_{1}^{M}(1 - G_t(k))^2 \tag{18}$$

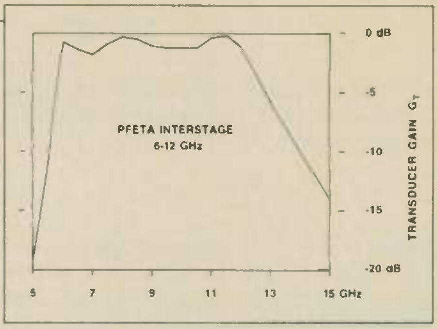


Figure 5. Response of Ku-band interstage example, (file PFETA.S2P).

j2) for forcing the response to fit (if possible) the user-defined gain profile values Td(k), the mean square error function is:

$$E_2 = \frac{1}{M}\sum_{1}^{M}(10 \times \log(G_t(k)) - T_d(k))^2 \tag{19}$$

for k=1 to M optimization frequency steps.

Steps (c)-(j) are repeated using a new set of coefficients for h(s), until successive changes in the error function are smaller than 1 percent of the error function. The new h(s) coefficients A(*) are generated using the nonlinear optimization procedure described below.

The circuit response outside of the optimization bandwidth does not contribute directly to the error functions E1 or E2. Normally, when the gain over the optimization band is maximized using E1, the out-of-band gain will also be minimized. When the generator and load impedances exhibit complex behavior over a wide optimization bandwidth, and the specified N is large, more than one choice of A(*) will yield a local gain maximum. Under these conditions the coefficients near an optimum point may be strongly interdependent, i.e. if we change an "optimum" coefficient, A(j), we might be able to find new A(k≠j) so that the average gain is nearly unchanged. In this case, gradient optimization methods may require an excessive number of iterations to find a solution.

MATCHD uses Nelder-Mead simplex function minimization (3) which is a direct search method and does not utilize gradients. The simplex is a set of N+1 points in N-space, each representing a different h(s). During optimization the simplex migrates through N-space, its average radius gradually shrinking onto the h(s) which yields the smallest E1 or E2.

Component Extraction

After convergence is achieved, the

normalized generator end driving point impedance of the equalizer is obtained directly from

$$Z_{rlc} = \frac{h(s) + g(s)}{g(s) - h(s)} \qquad (20)$$

When $N > P > 0$, several networks can be realized directly from this driving point impedance using elementary pole removal operations; the number depends on the class of response originally chosen. The component values are then denormalized back to the original S-parameter reference impedance (usually 50 ohms) and bandcenter frequency before being displayed.

Program Operation

A detailed description of commands for the MATCHD program is included on the program disc in a README.EXE file, and will not be duplicated here.

MATCHD was created for use on AT-compatible (286/386) personal computers, and is provided in a Turbobasic compiled version directly executable under DOS versions 2.0 to 3.3, and also in the original uncompiled version. The compiled version (MATCHD.EXE) file size is 91K, and an EGA, CGA, or VGA display is required. When a (287) coprocessor is used, solution of an N=3 network will require about 60 seconds.

MATCHD always assumes that the specified data files are for 2-ports (.S2P), although it uses only S_{22} of the generator file and S_{11} of the load file for the optimization. The data must be in a Touchstone or equivalent format (i.e. the frequency and the four S-parameters comprise 9 numbers per line). The DOS text editor EDLIN can also be used to create and edit these data files.

Most of the program's execution time is spent finding the complex roots of $G(\omega)$ after a new set of h(s) coefficients is chosen. The computation of the gain or error function is much faster, thus the overall execution time is practically independent of the number of sample frequencies within the optimization bandwidth.

Several simple examples will demonstrate the use of the program. For comparison purposes, we first design a six element bandpass matching network using Green's classic analytical method (6). By this approach, the resistance and bandcenter "Q" of a parallel RC load are specified, along with the desired ripple bandedge frequencies (0.5 and 1.5 GHz); these directly determine the ripple magnitude and generator resistance from the Fano limits (6). This response is optimum in the restricted sense that the maximum value of passband attenuation is minimized. The resulting final bandpass network is shown in Figure 1.

Next, the bandpass network is trisected as shown and the reflection coefficient looking into each from the interior side is computed over 0.3 - 2.0 GHz and stored in two separate S-parameter files. MATCHD is then used to design an equalizer for these two source and load networks, using an N=3, P=2 response to maximize the gain over 0.5 to 1.5 GHz in 100 MHz steps.

The resulting two equalizers are shown in Figure 2a and 2b. The element values of Figure 2a are close to those of the original network. We can also realize two Norton transformer solutions, as shown in Figure 3a and 3b. The broadband response of all four MATCHD circuits is identical, and is plotted along with the original bandpass network response in Figure 4.

As a final example, we create interstage matching networks between two identical small signal, Ku-band packaged GaAs FETs. The data sheet for this device listed the S-parameters in 1 GHz steps from 1 to 18 GHz (file PFETA.S2P). Again, we arbitrarily choose to maximize the flat gain over 6 to 12 GHz in 500 MHz steps, using an N=4, P=3 response. The final response is shown in Figure 5. The equalizer configurations (not including the Norton transformers) which all yield this response are detailed in Figures 6a, 6b and 6c.

In contrast to numerous other CAD broadband matching procedures, MATCHD does not require the source and load port S-parameter data to be classified or modeled using equivalent lumped or distributed networks. It optimizes a transfer function rather than physical component values, consequently one or more topologically distinct matching networks are realizable from a single optimized transducer gain response.

Techniques for converting the final lumped element equalizer to its distributed or transmission line equivalent were not discussed; this topic is covered in detail in (6).

Several examples of optimized equalizer were shown. For the same terminating impedances, both the gain response and the element values of a MATCHD equalizer were close to those of an analytically optimum equalizer.

This program is available on disk from the RF Design Software Service. See page 77 for ordering information. ***RF***

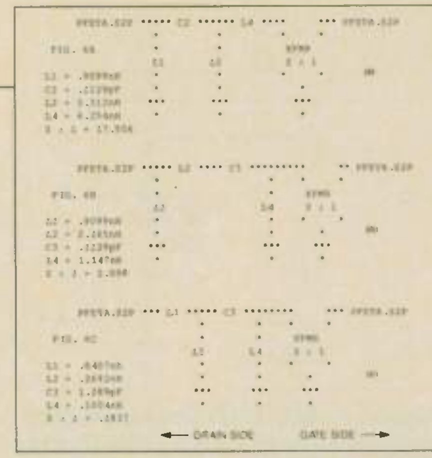


Figure 6. FET interstage equalizers, (PFETA.S2P).

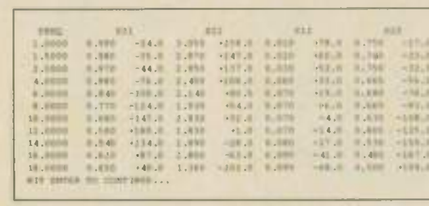


Figure 7. Ku-band packaged GaAs FET data, Vds = 3V, Ids = 10ma, (PFETA.S2P).

References

1) B.S. Yarman, "A Simplified Real Frequency Technique for Broadband Matching a Complex Generator to a Complex Load," *RCA Review*, vol. 43, Sept. 1982, pp. 529-541.

2) V. Belevitch, "Topics in the Design of Insertion Loss Filters," *IRE Trans. Circ. Theory*, Dec. 1955, pp. 337-346.

3) J.B. Moore, "A Convergent Algorithm for Solving Polynomial Equations," *Journal of the Association for Computing Machinery*, vol. 14, no. 2, Apr. 1967, pp. 311-315.

4) T.R. Cuthbert, *Circuit Design Using Personal Computers*, John Wiley & Sons, 1983.

5) J.A. Nelder and R. Mead, "A Simplex Method for Function Minimization," *The Computer Journal*, vol. 7, no. 3, Oct. 1964, pp. 308-313.

6) Matthaei, Young and Jones, *Microwave Filters, Impedance-Matching Networks, and Coupling Structures*, Artech House, 1980, pp. 120-162,

About the Author

David R. Lang is a consultant specializing in RF/Microwave design. His address is: 7301 N. Mockingbird Lane, Paradise Valley, Arizona 85253.

RF software

Silicon Circuit Design Software

EEsof's new Bipolar Junction Transistor (BJT) model simulates both the small-signal and large-signal performance of RF and microwave silicon devices. The model has Libra™, Touchstone®, Microwave SPICE®, and Xtract™ simulators included. The different packages range in price from $14,000 to $26,000 and are available on IBM PCs and compatibles using OS/2 and on Apollo, HP, and Sun workstations using UNIX.

EEsof, Incorporated
INFO/CARD #210

Filter Design Package

ACTIVE, a design package for active filters, has been introduced by Tatum Labs. It calculates poles, plots the frequency and time responses, and other characteristics. ACTIVE also finds the component values for the filter. ACTIVE runs on IBM PC/XT/ATs and compatibles, with Hercules, CGA or EGA graphics and costs $745.

Tatum Labs, Incorporated
INFO/CARD #209

Antenna Simulator

Compact Software has released an antenna simulator, I-NAC-3, for the HP9000 Series 3xx and 8xx platforms. I-NAC-3 is an antenna design system for frequency domain and time domain analysis and synthesis of complex 2D and 3D objects modeled by linear segmented wire-frame structures. It works for the frequency range from 10 kHz to 10 GHz.

Compact Software
INFO/CARD #208

Indoor Radio System Design Software

SIRCIM is a multipath indoor radio channel simulator developed at Virginia Tech. It can be used to study channel access, handoff, co-channel interference, equalization, diversity and modulation performance, and bit error rates in emerging indoor radio systems. The software is priced at $1500 for general purchases and $400 for universities.

Virginia Polytechnic Institute
INFO/CARD #207

FET Simulation Software

S-MINIMOS5 is a software tool for the numerical simulation of MOSFETs and MESFETs. It is capable of two-dimensional simulation of planar structures and three-dimensional simulation of planar and nonplanar structures. In S-MINIMOS5, the fundamental set of semiconductor equations are solved using techniques which allow comparatively low computational costs. It is available for the Sun, Apollo, HP, Sony, and DEC families of workstations, and supports UNIX, MSDOS, ULTRIX, and VMS operating systems. S-MINIMOS5 is priced at $25,000.

SILVACO International
INFO/CARD #206

Active Filter Design Update

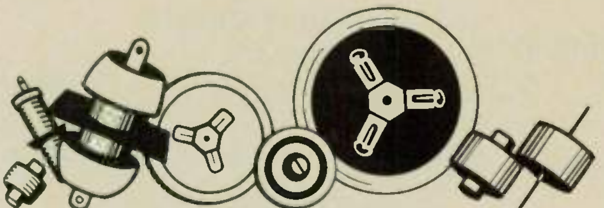
RLM Research has introduced an updated version of AFDPLUS. The program now has expanded file conversion support for simulation programs. The transfer function feature now allows the user to add, subtract, cascade, or divide filters to simulate more complex systems. The upgraded version of AFDPLUS is priced at $850 and the upgrade for older version is priced at $175.

RLM Research
INFO/CARD #205

Down Converter Software

Tektronix Federal Systems has announced the Down Converter Software product (S2MG160) which can automate measurements in the 100 Hz to 21 GHz frequency range. It can be used for radar testing, SATCOM, RF, ATE, and otehr applications. The price is $500.

Tektronix Federal Systems, Inc.
INFO/CARD #204



POWER CAPACITORS

...for high power density applications

Plate, barrel and feed-through capacitors for a wide range of applications such as solid state RF generators, RF suppression and HF transmitters.

Capacitance: 1.5-10,000 pF · Voltage: 2-30 kVp
Power: 2-150 kVA · Current: 5-50 Arms.

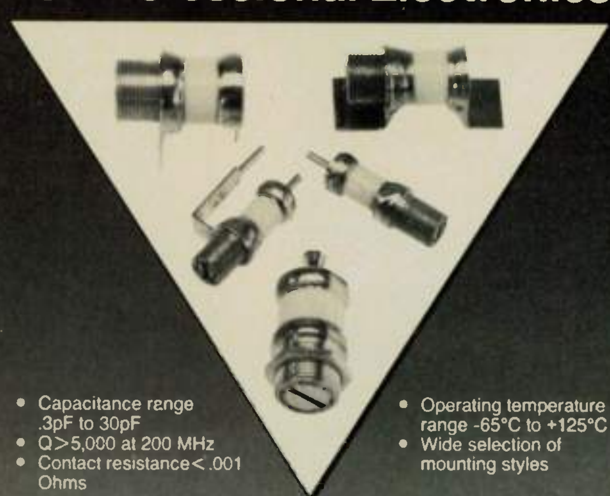
Manufactured by Draloric GmbH. Call now for information including special design assistance.

109 Alfred Street, Biddeford, ME 04005-2526 · Phone: (207) 284-5695

A COMPANY OF VISHAY DALE

INFO/CARD 85

For Professional Electronics



- Capacitance range .3pF to 30pF
- Q>5,000 at 200 MHz
- Contact resistance<.001 Ohms
- Operating temperature range -65°C to +125°C
- Wide selection of mounting styles

Trim-Tronics' air dielectric tubular trimmers offer High Q and a wide variety of capacitance ranges. Our unique rotor design provides smooth, uniform torque and excellent rotor-to-bushing contact resulting in low contact resistance. All metal surfaces are gold plated as a standard feature of our products.

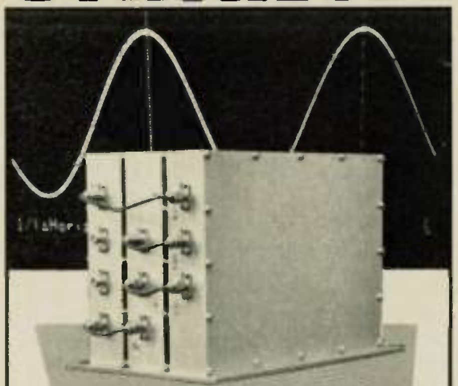
TRIM-TRONICS INC

A subsidiary of Alfred Tronser GmbH

Route 20 East, Cazenovia, NY 13035 Tel: (315) 655-9528 TFX: 315-655-2149
Outside USA and Canada contact Alfred Tronser GmbH, Phone 49 07 082/3007

INFO/CARD 86

FREQUENCY SYNTHESIS

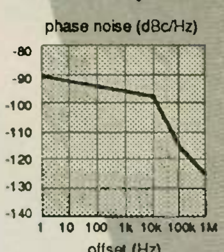


VDS-1400

DDS+PLL

VHF/UHF SYNTHESIZER

- 20-235MHz
- any octave BW
- 1Hz steps
- 5 msec switching
- -60dBc spurs



for

- automatic test equipment
- clock generators
- core of higher frequency units
- downconverters
- radar
- SATCOM (70MHz or 140MHz)
- simulators
- NMR
- navigation
- HF/VHF/UHF/ Tx and Rx

SCITEQ ELECTRONICS, INC.
8401 Aero Drive
San Diego, CA 92123
TEL 619-292-0500
FAX 619-292-9120
TLX 882008

INFO/CARD 87

Please see us at RF Expo East, Booth #209.

RF literature

Test Equipment Catalog

Rohde & Schwarz has released a catalog covering their traditional electronic test equipment along with two new signal generators with extended high frequency range to 4.32 GHz, a 1 Hz to 260 kHz synthesized oscillator, and the Model FSB spectrum analyzer with an upper frequency limit of 5.2 GHz and an inherent noise level less than −145 dBm.

Rohde & Schwarz
INFO/CARD #230

Frequency Management Components

Raltron Electronics has a new catalog covering crystals, crystal oscillators, crystal filters, and ceramic resonators. The catalog also describes a line of tight tolerance and stability crystals between 1 and 300 MHz for telecommunications applications.

Raltron Electronics Corporation
INFO/CARD #229

Digital Signal Processing Handbook

Digital Signal Processing Applications is a handbook that bridges the gap between digital signal processing algorithms and their real-world implementations. Each chapter focuses on a specific application topic, describing the algorithm and its implementation.

Analog Devices
INFO/CARD #228

Programmable Attenuators

JFW Industries has released a catalog of programmable attenuators that come with BNC, SMA, or N female connectors to meet any requirements. Most items are 50 ohm although many units are now available for 75 ohm systems.

JFW Industries
INFO/CARD #227

Crystal Filters Manual

A new technical manual for engineers who design and specify crystal filters has been published by McCoy Electronics. The manual includes performance charts, graphs, photographs, and technical information.

McCoy Electronics Company
INFO/CARD #226

EMI/RFI AC Power Line Filters

Included in this catalog from Murata Erie are filters with UL, CSA, and TUV listings, common mode choke coils in a variety of configurations, filtered AC line socket assemblies and filters for telephone lines.

Murata Erie North America
INFO/CARD #225

Broadcast Tower Protection

This report provides information that can assist stations in managing an existing FM or television tower and in maintaining the physical factors related to AM, FM, and TV towers or a directional array. It also contains a checklist of factors to consider in determining tower fees and insurance considerations. The price is $15 for members and $30 for non-members.

National Association of Broadcasters
INFO/CARD #224

Voltage Controlled Oscillators

Vari-L Company has released a catalog of VCOs with frequency ranges of 20 MHz - 10 GHz. The VCO lines exhibit improved harmonic performance, increased modulation bandwidths, and improved phase noise. The catalog also contains complete design application notes and test definitions tables for the VCOs.

Vari-L Company, Inc.
INFO/CARD #223

SMART Analog™ ICs

Crystal Semiconductor has announced a catalog of their full range of integrated circuits. Included are analog receivers, jitter attenuators, DTMF receivers, ethernet/cheapernet ICs, and other products. Product information includes specifications, block diagrams, theories of operation, and application information.

Crystal Semiconductor Corporation
INFO/CARD #222

Miniature Coaxial Connectors

With a frequency range up to 2 GHz, the NIM-CAMAC miniature coaxial connectors are a new line of connectors from Lemo USA. This catalog illustrates over 30 different shell designs to meet a variety of applications as well as adapters linking LEMO connectors to BNCs. Technical data includes materials, plating, electrical and mechanical characteristics, and recommended cables.

Lemo USA, Incorporated
INFO/CARD #221

Electronic Enclosure Catalog on Disk

Equipto Electronics has released a floppy diskette, for any IBM compatible PC, featuring their modular electronic cabinets and computer furniture. Selections are engineered to meet EMI/RFI, FCC, military, TEMPEST, and EMP requirements.

Equipto Electronics Corporation
INFO/CARD #220

Metallized Products

Kyocera's metallized division is offering a new brochure describing the company's line of ceramic packages for RF and microwave applications. Also presented are ceramic lids and windows, and metallized substrates.

Kyocera America, Incorporated
INFO/CARD #219

RF engineering opportunities

IOWA MIDWEST
· ENGINEERS · DESIGN
· MANAGERS · SYSTEMS
PROFESSIONAL ENGINEERING RECRUITING
TOP COMPANIES — RADIO · COMMUNICATIONS · AVIONICS
DON GALLAGHER, MSEE, PRESIDENT
Gallagher & Associates
1145 LINN RIDGE RD MT. VERNON, IA 52314
(319) 895-8042 (319) 895-6455 FAX
35 Years Engineering Exper. — Co. Paid Fees

Advertising Index

FREQUENCY SYNTHESIS

SATCOM

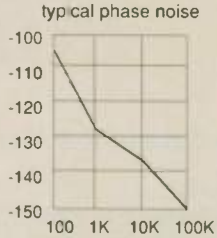
Crystal Replacement Synthesizer

The VDS-100 uses a proprietary architecture to achieve excellent spectral purity and fine frequency steps. The unique design minimizes adjustments and operates all components with wide margin to enhance reliability and producibility.

It is a form/fit/function replacement for existing units that may not meet reliability or performance requirements, and should be considered as a first choice in new applications. SMT throughout!

• Operating range	50-150 MHz (any 15%)
• Step size	1/384MHz, or as req
• Control	15 bit BCD
• Spurious	-95dBc typ
• Power	<10W

Consult Sciteq for other combinations of bandwidth and step size.



SCITEQ Electronics, Inc.
8401 Aero Drive
San Diego, CA 92123
TEL 619-292-0500
FAX 619-292-9120 TLX 882008

INFO/CARD 88
Please see us at RF Expo East, Booth #209.

THE PENSTOCK FAMILY IS GROWING . . .

NOW AVAILABLE: HEWLETT-PACKARD
Microwave Semiconductors & Components

Amplifiers
Attenuators
Bias Tee
Comb Generators,

Detectors
Diodes
Mixers
MMIC Components

Step Attenuators
Switches:
EM, PIN, MMIC
Transistors

INVENTORY IN STOCK
(800) PENSTOCK

Corporate Office: 520 Mercury Drive, Sunnyvale, Calfiornia 94086-4018 • FAX: (408) 730-4782

Sales Offices:

SO. CALIFORNIA: 213-383-6100
NORTHWEST: 206-454-2371
CANADA: 604-662-3475

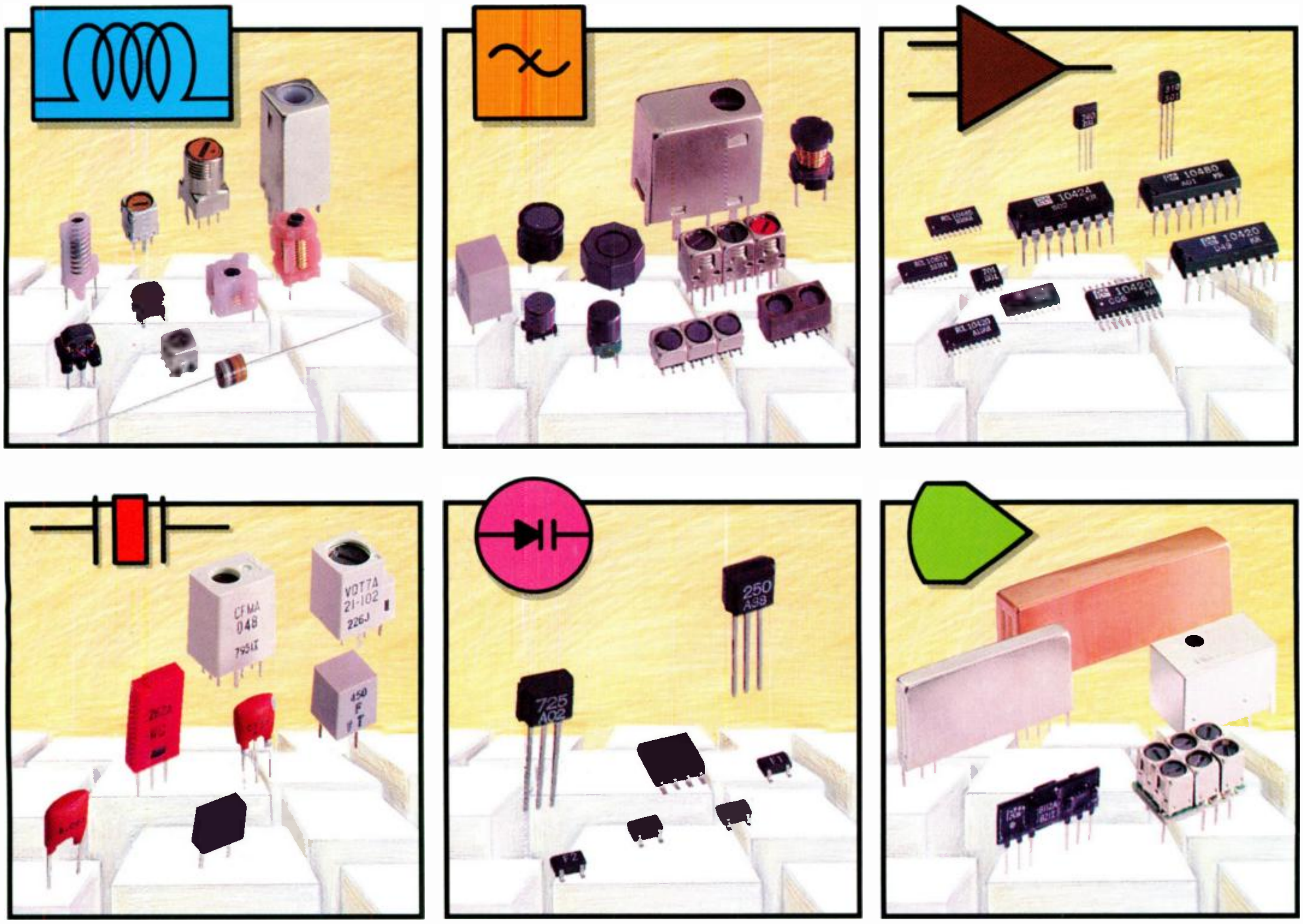
ILLINOIS: 708-934-3700
INDIANA: 317-784-3870
KANSAS: 913-829-9330

NEW YORK: 516-271-8415
PENNSYLVANIA: 215-383-9536
NEW JERSEY: 201-459-5323

PENSTOCK
RF Microwave Distribution

HEWLETT PACKARD
Authorized Distributor

INFO/CARD 89



RF Design Simplified. Use Toko's RF Building Blocks and Stop Going to Pieces!

Now you can reduce your RF design and component sourcing problems with just one phone call. Toko can supply more than 75% of the components required for most RF design projects, with "building blocks" that save time and space.

Toko is the world's largest manufacturer of small coils, with radial and axial leaded-inductors and SMT inductors—adjustable or fixed, in single or multiple coil configurations. We have what you're looking for.

Why design a complex LC or helical filter when Toko already makes it! We offer a wide variety from 4mm SMT styles to helical filters large enough to handle RF power signals—all in single or multiple configurations.

For I-F amplification and detection, Toko offers a variety of ICs to simplify design and reduce product size. Other available types include: compandors for noise reduction, equalizers, analog switches and voltage regulators.

For I-F or oscillator circuits, Toko ceramic filters and oscillating elements are an alternative to more costly technology. These High Q devices are also extremely compact and stable.

With over 36 stock types in a wide range of capacitance values, Toko has the varactor diodes you need, in SMT or SIP packages. An exclusive manufacturing process eliminates tracking errors in matched sets.

The fastest way to design and produce your next RF design project is with Toko RF modules. Utilizing the latest hybrid circuit technology, these circuits will also save space and cost. Custom variations are also available.

COIL PROTOTYPE/SAMPLE KITS

Toko sample kits give you more choices and cost less!

- Molded Sample Kit: 82 values (123 parts) 30MHz-150MHz; 0.0393-1.173 μH
- 7mm Sample Kit: 54 values (108 parts), 70kHz-50MHz; 0.1-220 mH
- 10mm Sample Kit: 68 values (136 parts), 79kHz-75MHz; 0.08 μH-56 mH

PRICED AT ONLY $49 EACH. ORDER TODAY!

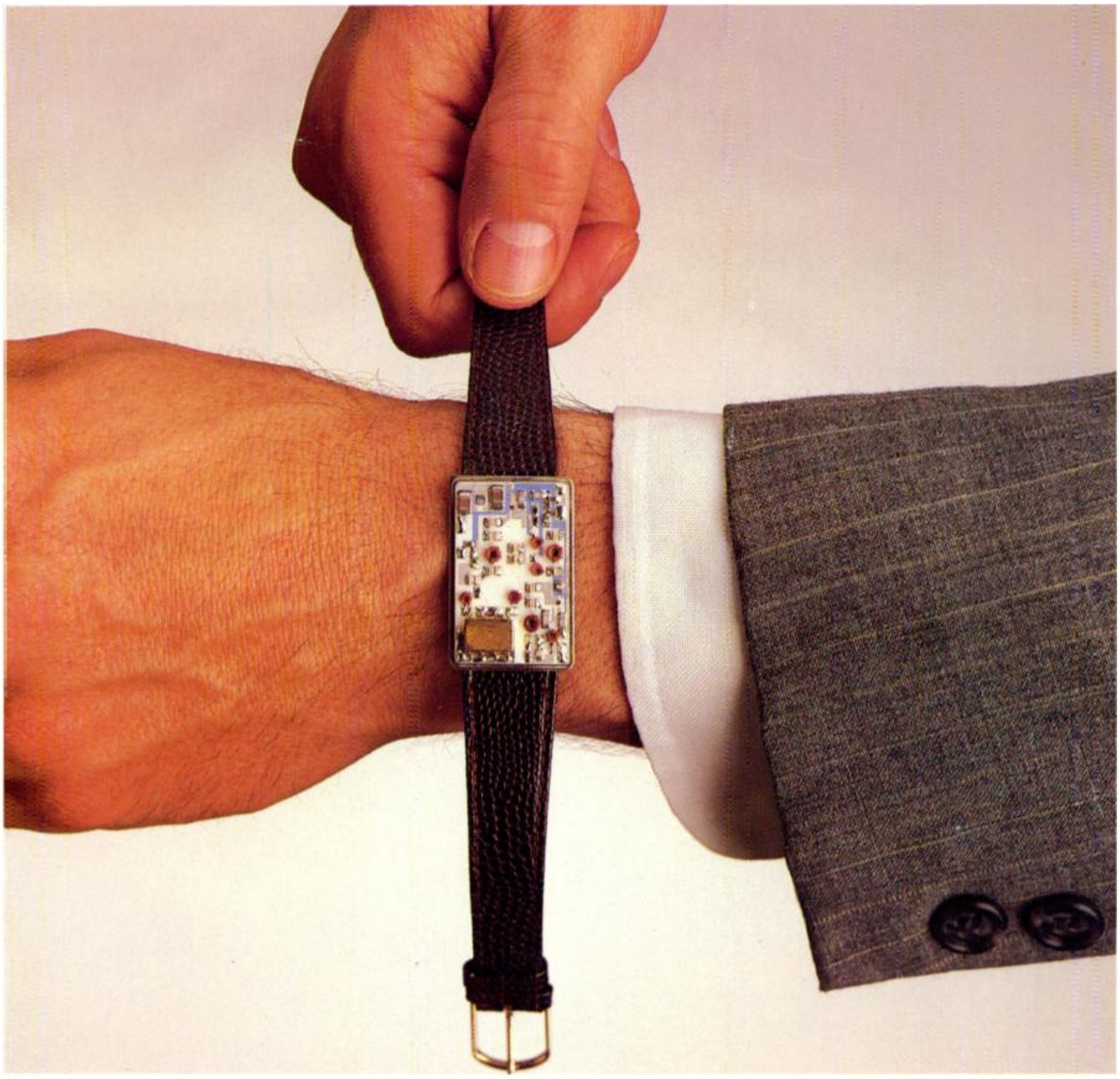
Let Toko put the pieces together for you. For a free catalog or information on samples, contact Toko America today. (708) 297-0070; FAX (708) 699-7864.

TOKO
TOKO AMERICA, INC.

Your strategic partner. . . for all the right reasons.

INFO/CARD 90

Please see us at RF Expo East, Booth #515.



You can't buy a better precision timepiece for under 2.4 GHz.

If you're operating in a frequency range from 100 MHz to 2.4 GHz, you can't buy a better oscillator than an Andersen VCO. It gives you the highest spectral purity with the lowest spurious (> -60dB). And typical single sideband phase noise of > -119dBC @1 KHz offset.

It's compact. It's rugged. It operates in temperatures up to 100°C. It can be tuned up to 1.5 MHz or phase-locked to a reference. Plus, its low mass and low profile make it ideal for surface-mount technology, DILS or flatpaks.

Isn't it about time you discovered the precision, the versatility and simplicity of designing with Andersen oscillators? Contact Andersen Laboratories, 45 Old Iron Ore Road, Bloomfield, CT 06002. Telephone (203) 286-9090/FAX 203-242-4472.

ANDERSEN LABORATORIES

INFO/CARD 91