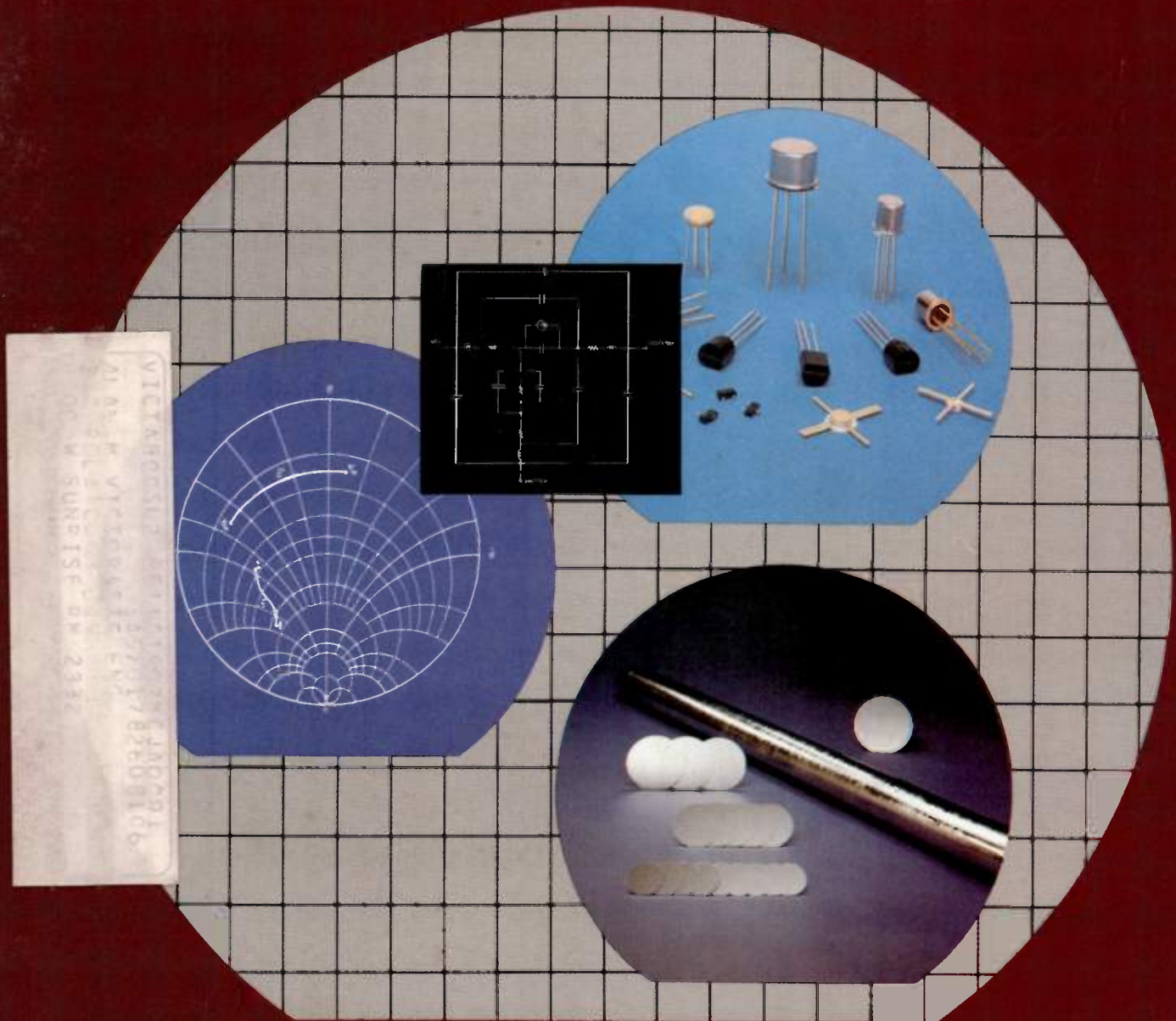


September/October 1982

A Cardiff Publication

r.f. design



Transistor Modeling • Power FETs
HV Transistors • Lowpass Filters
Electronic Tuning

IMPORTANT NOTICE
You must renew your
subscription today to
continue receiving r.f. design!
See page 9 for details



IT'S HERE!

The 1982 ANZAC Catalog. The greatest compendium of RF and microwave components in the industry: 352 pages of application notes and product specifications on low noise amps, RF log amps, mixers, switches, dividers, hybrids, couplers, and more.

Get your copy now!

Adams  Russell
ANZAC DIVISION

80 Cambridge Street • Burlington • MA 01803 • (617) 273-3333 • TWX 710-332-0258

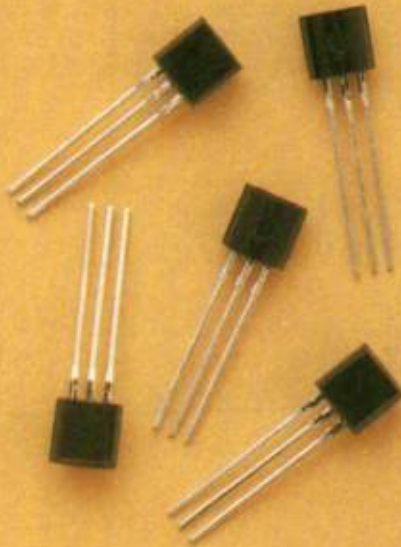
INFO/CARD 3

©1982

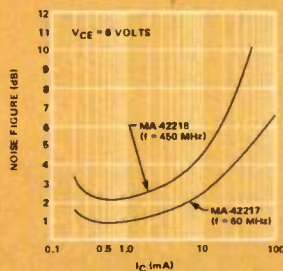
MILESTONES IN TECHNOLOGY

ONE OF A SERIES

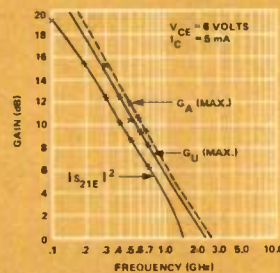
UHF Bipolar Transistors



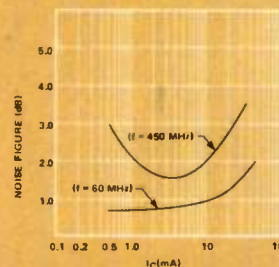
These new NPN Silicon Planar transistors offer low noise, high gain performance at significantly lower cost. As low as \$1.00 in 1k quantities. Intended for commercial UHF applications in TV, CATV, radio links, and IF amplifiers, these new transistors are packaged in a transfer-molded thermosetting plastic (TO-92) and feature planar interdigitated geometry. In addition, one series, MA-42197, is optimized for extremely wide dynamic range.



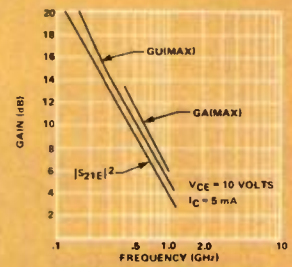
Optimum Noise Figure vs. Collector Current
@ 60 and 450 MHz



Gain Parameters vs. Frequency



Optimum Noise Figure vs. Collector Current
@ 60 and 450 MHz



Gain Parameters vs. Frequency

MA-42217,8 Series

MA-42197

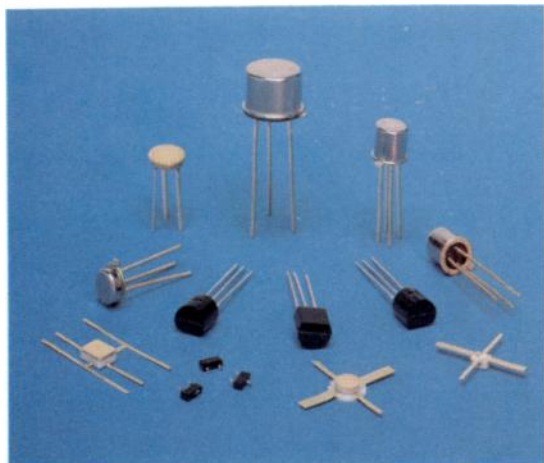
SEND FOR YOUR COPY
of *Time Standards* from our
Milestones in Technology series
along with specifications of *UHF
Bipolar Transistors* all packaged in a
handy file folder.



M/A-COM SILICON PRODUCTS, INC.

BURLINGTON, MASSACHUSETTS 01803 • (617) 272-3000
INFO/CARD 4





September/October Cover—Active devices is the editorial emphasis of this issue. The cover, courtesy of M/A-Com Silicon Products, Inc., depicts devices of importance to the active device designer.

1

Slicing S-Parameters—Refine your transistor modeling skills and use these skills to communicate your needs to the transistor supplier.

12

A High Voltage RF Bipolar Transistor for CRT Driver Applications—The design process used to develop an RF bipolar transistor with high-breakdown voltage characteristics.

22

Power FETs for RF Amplifiers: Part I—Power FETs with extended electrical ratings are competitive with power semiconductors and vacuum tubes for high-power communications equipment.

30

A Primer on Electronic Tuning Address Systems—The basics of electronic tuning with particular emphasis on PLL systems.

40

Special Lowpass Filters—Lowpass filter design using image parameter techniques for those special applications.

48

Next Month's Issue—The theme for November/December issue will be "antennas". Look for an issue featuring new antennas and new antenna applications. Also next issue will be part II of our active devices theme.

| | | | |
|-------------------|----|------------------|----|
| Letters | 6 | INFO/CARD | 67 |
| Subscription Card | 9 | Classifieds | 74 |
| Products | 56 | Advertiser Index | 74 |

September/October 1982, Volume 5, No. 5, r.f. design (ISSN 0163-321X) is published bi-monthly by Cardiff Publishing Company, a subsidiary of Cardiff Communications, Inc. 6430 S. Yosemite St. Englewood, Colo. 80111 (303) 694-1522. Copyright © 1982 Cardiff Publishing Company. Second Class postage paid at Englewood, Colorado, and additional mailing offices. Contents may not be reproduced in any form without written permission.

SUBSCRIPTIONS: r.f. design is sent free to qualified individuals responsible for the design and development of communications equipment. Other subscriptions: USA, \$15 one year, \$25 two years; International and Canada, (surface) \$25 one year, \$45 two years; International and Canada (airmail) \$40 one year, \$75 two years. If available, single copies and back issues are \$5 each. All editions of r.f. design dating from 1978 to present are available on microfilm. For details contact University Microfilms International, 300 N. Zeeb Road, Ann Arbor, MI 48106, USA, or phone (800) 521-0600.



tough flatpack mixers

...innovated by Mini-Circuits for rugged applications

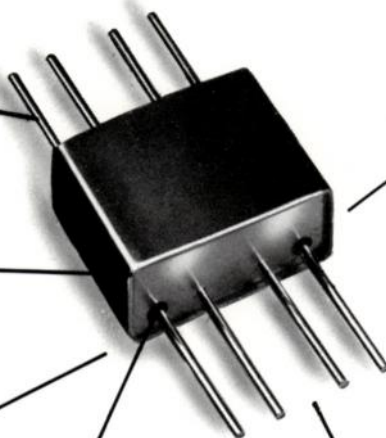
Rugged Pins
heavier 25 mil.
dia. leads resists
wire breakage

**Guaranteed
for hermeticity**
every unit must
pass MIL-STD 202
test method 112B
condition A and C

**withstands
wave soldering
punishment**
reliable pc board
assembly eliminates
open circuits common
with conventional
flatpacks. Every
unit subjected to
thermal shock testing
MIL-STD 202 method 107

**stronger
glass seals**
prevents
cracking
when leads
are bent and
handled.

**tough
competitive pricing**
only \$14⁹⁵₍₆₋₂₄₎
1/2 to 1/5
the cost of
conventional
flatpacks



Model LMX-113 Superior Electrical Characteristics

FREQUENCY RANGE, (MHz)

| | |
|--------|---------|
| LO, RF | 5-1000 |
| IF | DC-1000 |

| CONVERSION LOSS, dB | TYP. | MAX. |
|---------------------------|------|------|
| one octave from band edge | 6.2 | 7.0 |
| total range | 7.0 | 8.0 |

| ISOLATION, dB | TYP. | MIN. |
|--------------------|------|------|
| 5-50 MHz LO-RF | 50 | 45 |
| LO-IF | 45 | 40 |
| 50-500 MHz LO-RF | 40 | 30 |
| LO-IF | 35 | 25 |
| 500-1000 MHz LO-RF | 30 | 20 |
| LO-IF | 25 | 17 |

SIGNAL 1dB Compression Level
0dBm min

finding new ways...
setting higher standards

Mini-Circuits

A Division of Scientific Components Corporation
World's largest manufacturer of Double Balanced Mixers
2625 East 14th Street, Brooklyn, New York 11235 (212)769-0200
Domestic and International Telex 125460 International Telex 620156

Publisher
Bill W. Childs

Editor
Larry Brewster

Sales Manager
Ruth Breashears

Account Executives
Blair S. Meador
Suzan Myers

Editorial Review Board
Alex Burwasser
Rob Coe
Doug DeMaw
Hank Keen
Dave Krautheimer
Ed Oxner
Andy Przedpelski
Jeff Schoenwald
Raymond Sicotte

Advertising Services
Betsy Loeff

Circulation Manager
Chris Woodbury

Production Manager
Dara Hinshaw

Group Art Director
Mike Morris

Artist
Tim Gabor

Composition
Melody Benner
Sandy Bennett

Published by



Cardiff Publishing Company
Subsidiary of Cardiff Communications, Inc.
6430 S. Yosemite St.
Englewood, Colo. 80111
(303) 694-1522

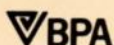
Please address subscription inquiries to:
Cardiff Publishing Circulation Service
Center, P.O. Box 1077, Skokie, IL 60077.
Postmaster: send form 3579 to the above
address.

Chairman
Stanley M. Searle

President
Robert A. Searle

Treasurer
Patrick T. Pogue

Vice Presidents
Bill W. Childs
Judy Rudrud



Alternate Procedure

Editor:

In reading "A Binary Stepped Transmission Line" in the July/August 1982 issue of "R.F. Design" magazine, I came across an HP-25 program to calculate VSWR from load and characteristic impedances. Although the program appears to calculate the VSWR, it does so with a great deal more program steps than are necessary. RPN, stack oriented calculators like those made by HP, can carry both the real and imaginary parts of a complex number in the stack. The built-in rectangular-to-polar, and polar-to-rectangular functions make it easy to convert the complex number components to forms for complex multiplication and division (polar form) or complex addition or subtraction (rectangular form). By operating in the complex domain, the 44 step program shown in the article, can be reduced to a 24 step program that not only calculates the VSWR, but also provides the complex reflection coefficient. This new, 24 step program is shown below. The input sequence is nearly like the original article:

For ZL in rectangular form: key in RL followed by ENTER
key in XL followed by R/S, VSWR returned.

For ZL in polar form: key in <ZL followed by ENTER
key in |ZL|
execute P→R
execute X<>Y followed by R/S, VSWR returned.

| STEP | KEYSTROKES |
|------|------------|
| 1 | STO 2 |
| 2 | X<>Y |
| 3 | STO 1 |
| 4 | RCL 0 |
| 5 | — |
| 6 | →P |
| 7 | STO 3 |
| 8 | X<>Y |
| 9 | STO 4 |
| 10 | RCL 2 |
| 11 | RCL 1 |
| 12 | RCL 0 |
| 13 | + |
| 14 | →P |

| STEP | KEYSTROKES |
|------|------------|
| 15 | STO/3; Γ |
| 16 | X<>Y |
| 17 | STO-4; <Γ |
| 18 | RCL 3 |
| 19 | 1 |
| 20 | + |
| 21 | RCL 3 |
| 22 | 1 |
| 23 | — |
| 24 | /; VSWR |

The register assignments are the same as in the referenced program:

RO Zo (actually Re(Zo))
R1 Re(ZL)
R2 Im(ZL)
R3 |Γ|
R4 <Γ

This same technique of treating both parts of a complex number in the stack has application beyond the calculation of VSWR. It makes network analysis and Smith Chart type calculations very easy to do on a handheld calculator.

Bruce K. Murdock
Staff Consultant
Delco Electronics

9th Grade Algebra

Dear Editor:

I like your magazine. More than half your articles are of interest to me and relate to work I do, but — — —

I distinctly feel that as printed, your articles contain more than a reasonable number of errors. I suspect many of these are due to typesetting. As one example, in the May/June 1982 issue, p. 25 equations (14) and (15) read:

$$X_2 = (X_6 + X_2) - X_6$$
$$X_4 = (X_7 + X_4) - X_7$$

Since by 9th grade algebra, these reduce to $X_2 = X_2$ and $X_4 = X_4$, which may be absolutely correct but of little use, I suspect some subscripts are mixed up.

Keeping equations, subscripts and symbols consistent and correct requires care by the author and as well as care in typesetting. Does your pro-

Rely on Dielectric

The networks do

... for assured continuous operation and proofing.



The U.S. Navy does

... for their communications, radar and fire control systems.



NASA does

... for the Space Shuttle Program and Columbia flights.



You, too, can be confident with Dielectric's RF instrumentation and components. For more than 40 years, our products have been respected by the communications industry for their exceptional reliability and accuracy.

Today, Dielectric is in the vanguard of advanced RF technology, supplying a wide variety of devices from meters and loads to waveguide for electron beam accelerators, the space shuttle program, military communications, fusion power generation, radio astronomy, and deep space satellite tracking radar. This same quality is common to all our products. That's why we offer an unprecedented 2-year warranty on our RF meters, loads and couplers.

Call us, toll-free, for the name of your local distributor. We have people 'round the globe you can rely on.

Integrity and craftsmanship . . . a New England Tradition



Dielectric now distributed by **CW ELECTRONIC SALES CO.**

800 Lincoln Street, Denver, Colorado 80203
303-832-1111/800-525-6147

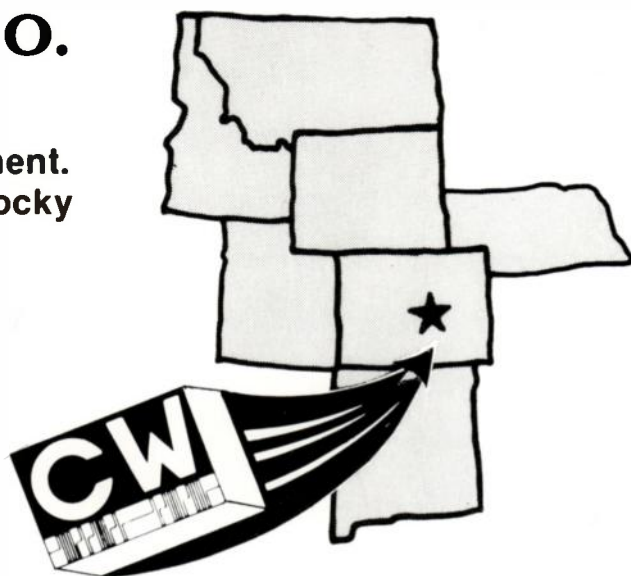
**Complete line of land mobile radio equipment.
Fully stocked warehouse serving the Rocky
Mountain territory for over 15 years.**

Represented by Marty Eichenberger



PRO-COMM MARKETING

P.O. Box 22920 Denver, Colorado 80222
303-694-4545



DIELECTRIC COMMUNICATIONS

A UNIT OF GENERAL SIGNAL
A FORTUNE 250 COMPANY



Raymond, Maine 04071, USA
207-655-4555/800-341-9678/TWX: 710-229-6890

INFO/CARD 6

Take this:



Add this:



And get this:

dc to 150 MHz
bandwidth
10 ns settling
time to 0.2%

With the revolutionary new CLC103 op amp, all you need is one gain setting resistor and $\pm V_{cc}$. The feedback resistor from output to inverting input is internal. There's no extra circuitry to design. No compensating networks either. And the bandwidth (-3dB) will hold for gain settings from one to 40, inverting or non-inverting. What's more, the CLC103 delivers an impressive 6 V/ns slew rate, flat gain-phase response from dc to over 100 MHz, plus unconditional stability...without external compensation. And in 100 piece quantities, it's priced at just \$115.

Choose from an industrial or military version. But be sure you choose the CLC103. Because you won't find a fast settling, wideband op amp that's higher performing...or easier to use.

For complete details, call (303) 669-9433. Or, write Comlinear Corporation, 2468 E. 9th St., Loveland, CO. 80537.



cess include a chance for the authors to have a "galley print" review—or at least a review by a technical editor?

J.W. Streater
Manager, Engineering
Mentor Radio Co.

Dear Mr. Streater:

I am glad to see that some people actually read all the equations. Yes, 9th grade algebra still applies! You are correct in stating that equations (14) and (15) are actually identities, and they were meant to be. Since this was a short article, I did not want to use additional equations and subscripts. You will notice that the quantity $(X_6 + X_2)$ is defined by equation (10) and X_6 by equation (3). Thus subtracting (3) from (10) gives X_2 , as stated in equation (14) and paragraph c.

I am sorry that the short cut caused some confusion. The program (and the circuit) has been used successfully mainly in IF amplifiers.

Thanks again for the comments.

Andrzej B. Przedpelski
Vice President, Development
A.R.F. Products, Inc.

TRS-80 Tuned Circuit Program

Dear Editor:

Referring to Andrzej Przedpelski's article on designing low impedance doubled-tuned circuits with the aid of an HP-41C/CV program, here is a listing for the TRS-80 that will calculate the values of the five capacitors. The program is not elegant or refined—strictly utilitarian. Nor does it plot the frequency response. The program may be rerun with a changed value by entering a variable assignment statement, then GOTO 85. For example, after solving for a set of conditions that included a coil Q of 100, type in:

QL = 150 (Enter)
GOTO = 85 (Enter)

and new values will be presented for a coil Q of 150.

Capacitor reactances are printed as positive rather than negative.

Readers that have access to a TRS-80, but not an HP-41C or CV, may be interested.

J.W. Streater
Manager, Engineering
Mentor Radio Co.

```

10 CLS: PRINT TAB(12) "DOUBLE TUNED COUPLING CIRCUIT DE-
SIGN": PRINT
20 PRINT "ENTER SOURCE RESISTANCE (RS) AND LOAD RESIST-
ANCE (RO).":
30 INPUT "RS = "; RS: INPUT "RO = "; RO
40 PRINT "ENTER LOWER AND UPPER 3 DB FREQUENCIES (F1
AND F2).":
50 INPUT "F1 = "; F1: INPUT "F2 = "; F2
70 PRINT "ENTER INDUCTOR (L) VALUE IN HENRYS. BOTH IN-
DUCTORS HAVE":
75 PRINT "SAME VALUES.":
80 INPUT "L = "; L
82 INPUT "QL = "; QL
85 F0 = SQR(F1*F2): PRINT "GEOMETRIC MEAN CENTER FRE-
QUENCY F0 = "; F0
90 XL = 6.28319*F0*L: PRINT "XL = "; "OHMS"
100 Q0 = F0/(.7*(F2-F1)): PRINT "Q0 IS"; Q0
110 X3 = XL*Q0
120 XT = X3/(Q0 - 1)
150 RL = QL*XL: PRINT "EQUIVALENT INDUCTOR SHUNT RESIST-
TOR RL = "; RL
160 RT = (Q0*XL*RL)/RL - Q0*XL)
180 R1 = RT/(1 + RT*RT/XT/XT)
200 X1 = SQR(R1*RS*RS/(RS - R1))
220 X5 = SQR(R1*RO*RO/(RO - R1))
240 X6 = RS*RS/X1/(1 + RS*RS/X1/X1)
260 QT = RT/XT:X2 = - X6 + XT*QT*QT/(1 + QT*QT)
280 X7 = RO*RO/X5/(1 + RO*RO/X5/X5)
290 X4 = X6 + X2 - X7
310 PRINT
320 PRINT "X3 = "; X3; TAB(20); 1/(6.28319* F0*X3); "FARADS"
330 PRINT "X1 = "; X1; TAB(20); 1/(6.28319* F0*X1); "FARADS"
340 PRINT "X5 = "; X5; TAB(20); 1/(6.28319* F0*X5); "FARADS"
350 PRINT "X2 = "; X2; TAB(20); 1/(6.28319* F0*X2); "FARADS"
360 PRINT "X4 = "; X4; TAB(20); 1/(6.28319* F0*X4); "FARADS"
400 END

```

TRS-80 Program.

High-Performance GaAs FETs at a Low Price? We Guarantee It!



Economical micro-X package and high-volume production now means GaAs FETs with guaranteed noise figures priced as low as \$11.00 for 3.7-4.2 GHz, and \$13.00 for 12 GHz (DBS) earth station LNAs, only from Avantek.

Avantek introduces a new line of low-cost GaAs FETs ideal for use in commercial earth station LNAs, and other applications that require guaranteed noise figures. You can count on these devices because they come from the same technology used to make our high-rel transistors for military and space applications. In fact, the ones in your amplifier are very likely from the same production line that supplied the parts for the satellite you're working with. That's quality.

Check the specs.

The 12 GHz parts (AT-10650-5 and AT-10635) and 4 GHz parts (AT-12570-5 and AT-12535) are priced at \$21.50, \$16.00, \$13.00 and \$11.00 respectively in 500 quantities. And for that price you also get Avantek-standard high reliability, with major specifications fully characterized and guaranteed.

Both the AT-106XX series and the AT-125XX series are available in hermetic, stripline packages. These 0.5 micron devices use

gold-based metalization for higher performance and increased reliability.

Available from stock.

These new, low-priced GaAs FETs are available off-the-shelf, ready to ship from the factory and distributors. Circle the bingo number if you need detailed specifications before ordering. Or, for more immediate attention, give us a call. Remember, our applications engineers are as close as the phone if you need to discuss a particular requirement.

Typical Performance

| DEVICE | FREQ. (GHz) | NOISE FIGURE (dB) | ASSOC. GAIN (dB) | P _{1dB} (dBm) | PACKAGE |
|------------|-------------|-------------------|------------------|------------------------|---------|
| AT-12535 | 4.0 | 1.2 | 11.5 | 20 | MICRO-X |
| AT-12570-5 | 4.0 | 1.2 | 12.0 | 20 | 70 MIL |
| AT-10635 | 12.0 | 2.5 | 7.5 | 17 | MICRO-X |
| AT-10650-5 | 12.0 | 2.5 | 8.0 | 17 | 50 MIL |

Avantek

3175 Bowers Avenue
Santa Clara, CA 95051
Sales: (408) 496-6710



Slicing

S-PARAMETERS

**By R. Brand and P. Ledger
MIA-COM Silicon Products, Inc.
Burlington, MA 01803**

How meaningful are your discussions with the transistor supplier when tight S-parameter tolerances are needed? Can you relate physical elements of the semiconductor to model elements or S-parameter behavior?

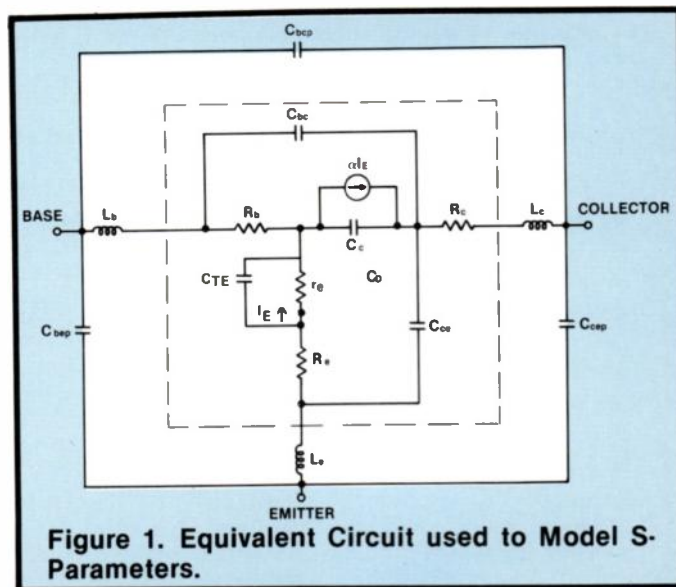
Circuit designers using S-parameters in low-noise bipolar transistor amplifier design often impose tight S-parameter tolerances on the transistor supplier so as to minimize circuit tuning during amplifier assembly. Wide-spread use of computer-aided circuit design (CAD) and automatic S-parameter measurements, coupled with prior work on modeling bipolar transistors, enable rapid determination of the critical elements required of a transistor such that it would work in a given application. Could you, given only the transistor, obtain such a model and use it both to design the amplifier and communicate your needs to the transistor supplier?

This article deals with a simple lumped element model of a state-of-the-art UHF/VHF silicon (MA42141-511) low-noise bipolar transistor chip within a package. Independent of any knowledge of the transistor chip design, we obtain close matching of modeled versus measured S-parameters and then proceed to show that the critical element values obtained are consistent with values obtained by other methods. The calculations are presented in the form of an example such that an entrant electrical engineer not familiar with transistor design methods could quickly become comfortable in using these devices in his first low-noise amplifier project, as well as effectively communicating his requirements to the transistor supplier.

We have chosen a model which has almost a one-to-one correspondence with the physical properties of the chip, given the program and final element values used in the modeling exercise. We have also included a simple description of the transistor chip structure which concentrates on its electrical properties rather than its semiconductor processing schedule.

Transistor Chip and Circuit Model

The common emitter T-equivalent model⁽¹⁾ is shown in Figure 1. The part corresponding to the transistor chip is embraced by dotted lines. The exterior elements are associ-



ated with the package which is a stripline ceramic hermetically sealed package (see Figure 2). Figure 3 shows the simplest physical chip structure in which a block of silicon has been suitably doped to create emitter, base and collector regions with wires attached to provide connection. To help the modeling process, it is useful to relate the model elements (Figure 1) to their physical location within the silicon chip (Figure 3). The base resistance, R_b , includes the contact resistance of the wire to the base (shaded dot) as well as the resistance of the P-type base region itself. The emitter transition capacitance, C_{TE} , is determined by the product of the emitter area, ABCD, and the capacitance per unit area of the emitter-base junction. The emitter resistance, r_e , depends only on the emitter-base forward bias current and is given by:

$$r_e = \frac{25.4}{I_E} \text{ ohms} \quad (1)$$

where I_E is the emitter current in milliamperes. R_b is the emitter-metal contact resistance (ABCD shaded). R_c is the collector series resistance determined by the addition of the resistance of the N+ collector region and the collector-metal contact (EFGH). The capacitance, C_c , does not have any physical relation to the structure depicted in Figure 3, and was adjusted in value only to obtain the correct S-parameters. It can be calculated⁽¹⁾ from a detailed knowledge of the base structure, but this information is not generally available to the circuit designer. Finally the common base current gain, α , used in the generator αI_E , is approximated by the single-pole expression⁽¹⁾:

$$\alpha = \frac{\alpha_o}{1 + j \frac{f}{f_b}} \exp[-j 2\pi f \tau] \quad (2)$$

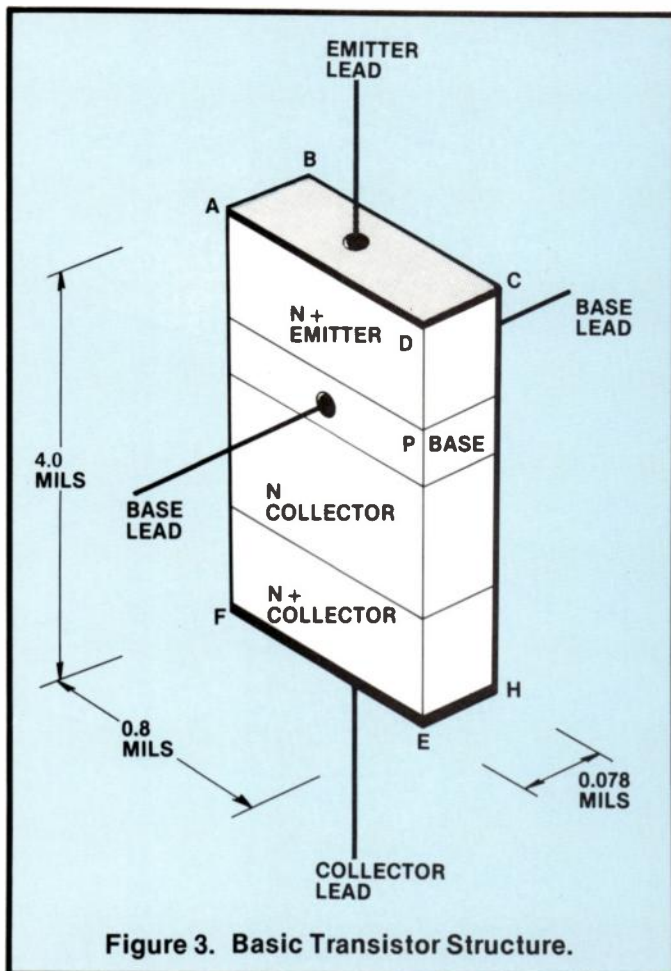
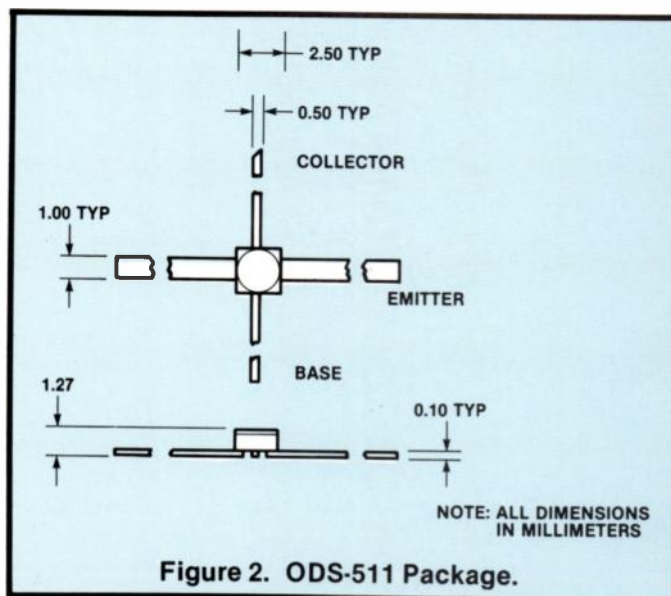
where τ is the collector depletion delay time (time for electrons to travel across the N-collector region), f_b is the base cut-off frequency which is determined by the time, τ_b , for electrons to diffuse across the P-type base region and α_o is the common base d.c. current gain.

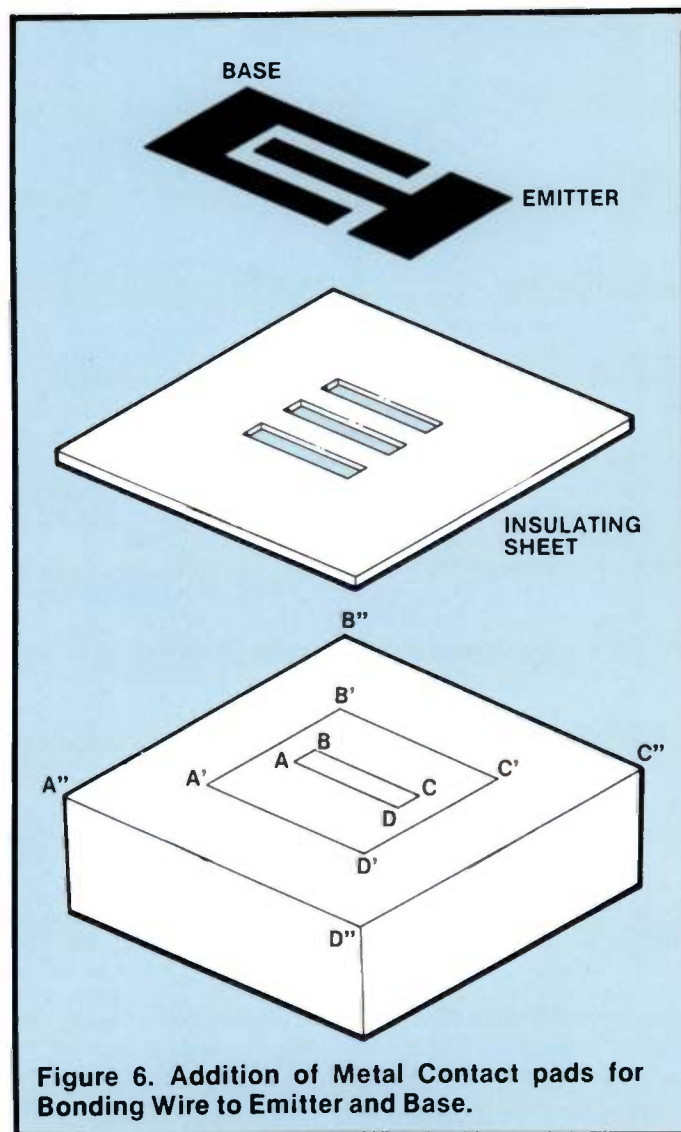
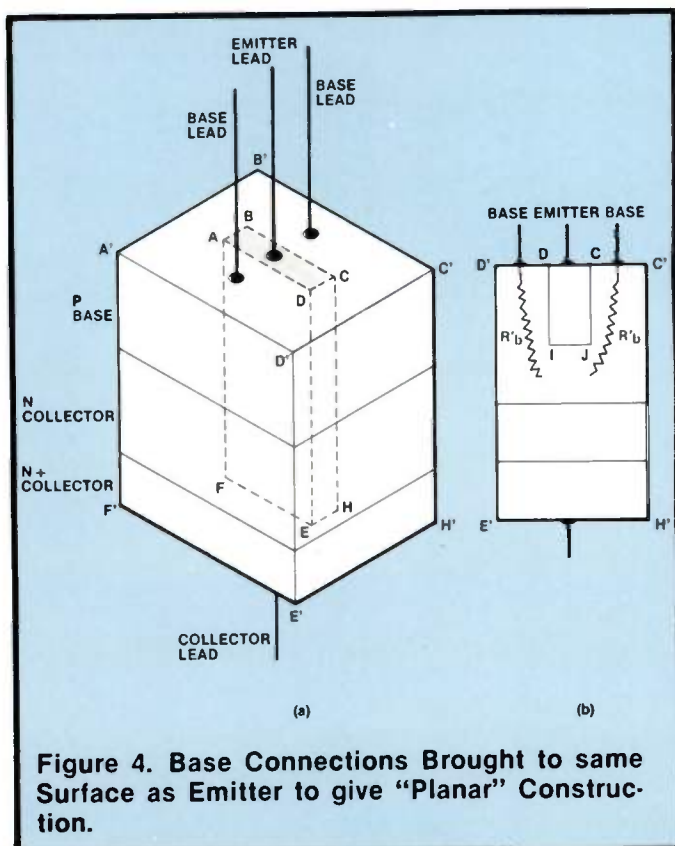
τ can be calculated for a saturation drift velocity, V_{SL} , of 8.5×10^{-6} centimeters per second, from:

$$\tau = \frac{W}{2V_{SL}} = \frac{2 \times 10^{-4} \text{ cm}}{2 \times 8.5 \times 10^{-6}} = 11.7 \text{ picoseconds} \quad (3)$$

where W is the width of the N-collector region.

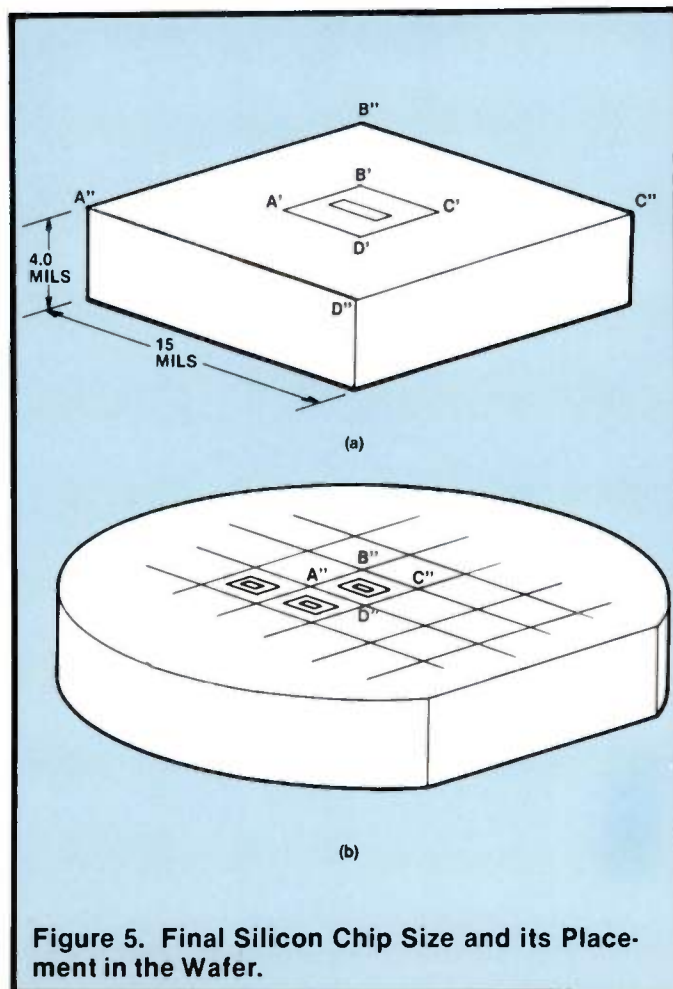
Such a transistor structure would be ideal, but it is physically too small to make the electrical connections as shown. In order to achieve the performance of the transistor under discussion, the unit cell in Figure 3 measures 0.078 mils (AB) \times 0.8 mil (BC) \times 4.0 mils (DE). This represents a volume barely visible to the naked eye for which 17,000 would pass simultaneously through the eye of a typical household needle. To circumvent the physical size limitation of the unit cell in Figure 3, the base contacts are brought to the same surface as the emitter by the addition of additional silicon [see Figure 4(a)]. Such a move, however, penalizes performance. The C_{TE} increases because of the increase in emitter area DI and DC [Figure 4(b)]. This reduces the achievable low current gain. The base resistance, R_b , increases because of the additional resistance paths R_b' [Figure





4(b)] degrading noise figure. Finally collector area has increased (to $E'F'G'H'$), which increases C_C further reducing gain. The "planar" construction of Figure 4 still lacks adequate physical size (it measures 0.23 mil \times 0.8 mil \times 4.0 mils) and lacks a practical method for attaching wires to the base and emitter regions. Additional silicon to cure the size problem can be made without further degradation of performance as shown in Figure 5(a). The silicon chip size shown in Figure 5(a) is 4.0 \times 15 \times 15 mils, more than adequate to hold while attaching wires to the chip or bonding wires or chips to packages. These chips can be positioned in a silicon wafer as shown in Figure 5(b). Since the transistor geometry is confined to one plane, they can be replicated by the thousands using standard semiconductor processing techniques.

To solve the problem of attaching wires to the emitter and base regions, metal patterns are fabricated consisting of thin fingers designed to connect to the critical regions, which in turn are attached to expanded metal areas large enough that 0.7 mil diameter gold wire can be thermo-compression bonded to them. However, as illustrated in Figure 6, a thin insulating sheet, into which has been cut suitable contact holes aligning themselves over the emitter and base regions, must be placed between the expanded metal contacts and the silicon chip in order to prevent shorting of the emitter-base and collector-base junctions by the metal stripes. This insulating sheet, which in practice



Consider the source.

HP's 8656A programmable signal generator



Consider the value.

Versatility.

The HP 8656A synthesized RF signal generator is fully HP-IB programmable. Even your most time-consuming tests can be readily automated, increasing productivity in the laboratory and throughput on the production test floor.

Performance.

With a frequency range of 100kHz to 990MHz, the 8656A's signals are accurate and stable with good spectral purity. You get 100 or 250Hz resolution, an output range of +13 to -127dBm with microprocessor-controlled unit conversion, ± 1.5 dB absolute accuracy and 0.1dB resolution. Low RFI leakage provides confidence in micro-volt

level signals. AM and FM are available from both internal and external sources and simultaneous modulation modes are easily generated. All this and reverse power protection and HP-IB are standard.

Quality.

The 8656A incorporates HP's 30 years of experience in designing and manufacturing high performance signal generators. Our reputation for designed-in quality and reliability is backed world-wide by a responsive sales and service network.

Economy.

At \$7150*, the 8656A is HP's lowest-priced programmable signal generator. It's a price-performance value that makes good economic sense for both laboratory and production environments in a broad range of applications.

Consider the exceptional value of the 8656A. You may find that it's just the right source for you. To put the 8656A to work in your particular application, or for help in choosing from our broad line of signal generators, contact your nearby HP sales office. Or write, Hewlett-Packard, 1820 Embarcadero Road, Palo Alto, CA 94303.

*U.S. domestic prices only.

Consider HP

10202



**HEWLETT
PACKARD**

INFO/CARD 9

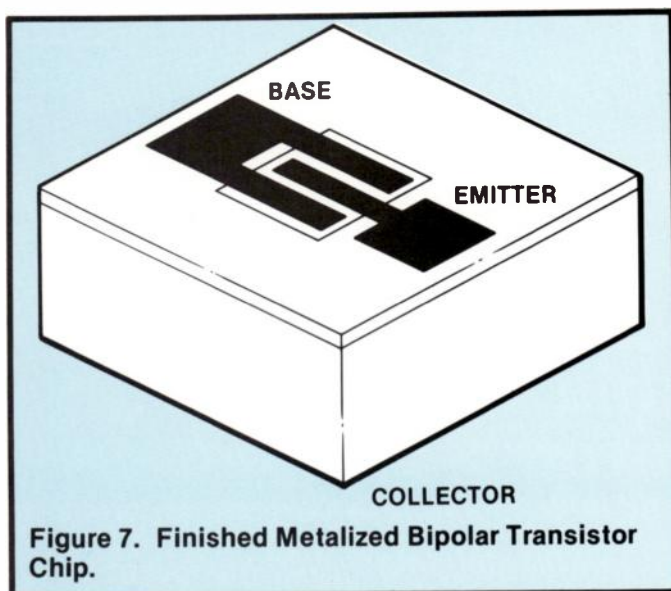


Figure 7. Finished Metalized Bipolar Transistor Chip.

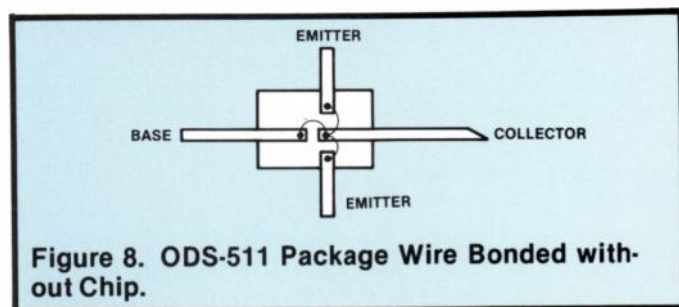


Figure 8. ODS-511 Package Wire Bonded without Chip.

is only 0.2 mils thick, appears naturally as the silicon dioxide layers grown during the semiconductor processing schedule. A consequence of this insulation system however is the creation of additional capacitance between the metal pads and semiconductor body; and these are included in the circuit model as C_{bc} (base to collector pad capacitance) and C_{ce} (emitter to collector pad capacitance). The final transistor chip is shown in Figure 7. Since wires are used to connect the metal pads to the package, they give rise to base inductance, L_b , emitter inductance, L_e , and collector inductance, L_c , which have to be taken into account for accurate prediction of S-parameter variation with frequency. Actually, for the transistor under discussion, 15 unit cells as shown in Figure 3 are connected in parallel in order to reduce the base resistance, R_b , which improves noise figure. However, connecting unit cells in parallel reduces low current gain and the trade-off between these two parameters gives rise to the proliferation of transistor geometries available today, each having its own unique combination of gain, noise figure, and S-parameter characteristics.

S-Parameter Modeling

A commercially available CAD program, COMPACT⁽²⁾, was used to calculate the S-parameters of Figure 1 over the frequency range 0.4 to 2 GHz. The COMPACT program used is given in Table 3. The purpose of this article is to develop a useful model given only the packaged transistor, access to a network analyzer and a computer, when α_o , the package elements, L_b , L_c , L_e , C_{bep} , C_{cep} , and C_{bcp} were known at the outset. The DC gain, α_o , can be measured using a standard curve tracer. The package element values can usually be obtained from the manufacturer. The most common technique for obtaining them is to measure S-parameters of an

Cost-effective, reliable filter solutions to RFI/EMI problems

LMI manufactures a broad line of high performance, long life power and communications line filters, filter panels, and power factor correction networks. These are now widely used in shielded rooms, data processing centers, communications centers, hospitals, ground support facilities, shielded cabinets and other secure or RF controlled areas. Our power line filters are



designed and manufactured to MIL-F-15733E, UL and other specs; our communications line filters exceed MIL-STD-HBK-232. All models have standard power systems, voltages, current and frequency ratings for easy interface with circuit breakers and UL and NEC requirements.

Write or call for catalog F-300. LectroMagnetics, Inc. 6056 West Jefferson Blvd. Los Angeles, CA 90016 (213) 870-9383

LMI  **LectroMagnetics, Inc.**

INEXPENSIVE SOURCE

FEATURES:

**CRYSTAL STABILITY
MIXER COMPATIBLE
COMPACT SIZE**



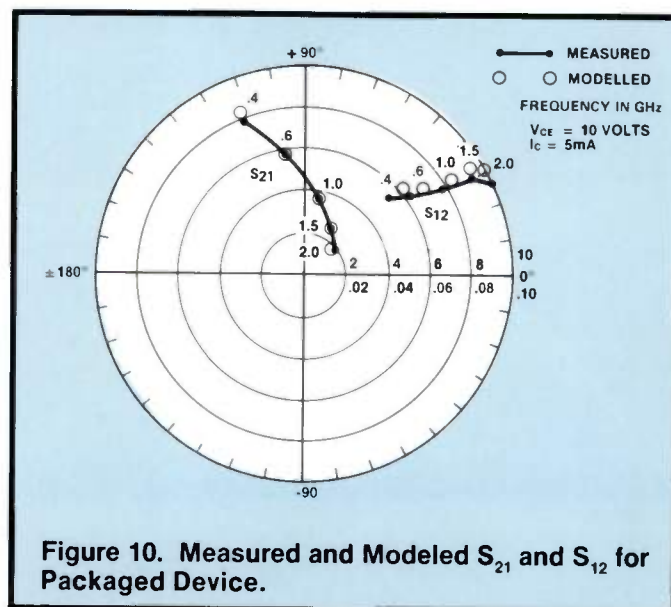
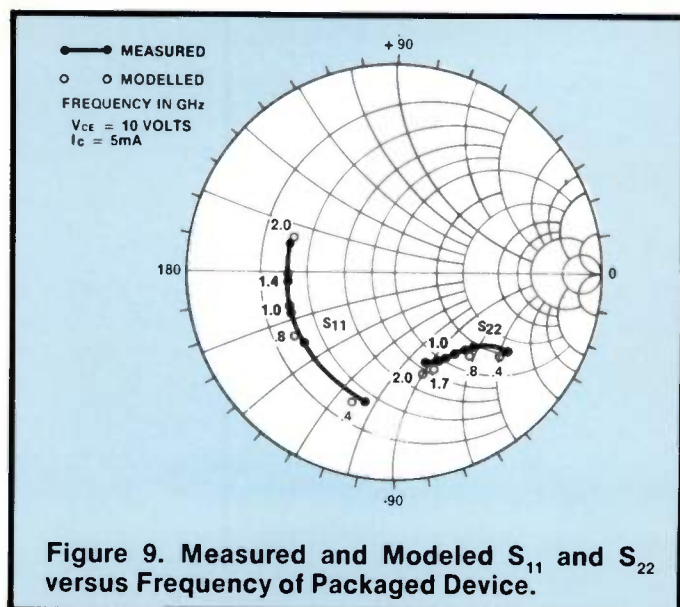
**MODEL
112**

**3-6 GHz OUTPUT
±.005% 0 to +50°C
5mw MINIMUM POWER OUTPUT
-40dBc HARMONICS
+15 VDC INPUT
4.0 x 2.0 x 2.1" HIGH
FREQUENCY ADJUSTMENT SUFFICIENT
FOR 5 YEARS AGING**

**TECHTROL CYCLONETICS, INC.
NEW CUMBERLAND, PA. 17070
(717) 774-2746**

INFO/CARD 11

September/October 1982



open package (without wires or chips) and a shorted package where wires are connected from each package lead to the collector lead (Figure 8). By matching modeled versus measured S-parameters over the frequency range of interest, values for the package elements are established. If package elements are not available from the manufacturer they can be established during the modeling exercise of the transistor itself.

S-parameters for a transistor were measured and element values in the chip model were varied until a cost match on all S-parameters over the frequency range of interest was

achieved. Measurements were made on a Hewlett-Packard Model 8542A network analyzer using a standard transistor test fixture, Hewlett-Packard Model 11608A. The results are shown in Figures 9 and 10. The final package and chip element values are given in Table 1. In addition, three of the critical circuit elements, C_{TE} , R_b and f_b were obtained independent of the modeling exercise and were found to agree with the model values. C_{TE} can be obtained by plotting the reciprocal of the common emitter cut-off frequency, f_T , against the reciprocal of emitter current, I_E . Theory predicts that:



ELECTRO-METRICS

A PENRIL COMPANY

ELECTRO-METRICS CAN SATISFY ALL YOUR EMI/EMC MEASUREMENT REQUIREMENTS...

... With Quality Instrumentation Known Worldwide for Performance and Reliability

- Complete frequency coverage from 20Hz to 40GHz
- Choice of single-unit, automated or calculator-controlled EMI/EMC Testing
- Testing per FCC/VDE/CISPR and MIL-STD 461/462 EMI/EMC specifications
- Newly available EMI Spectrum Analyzer with FCC and VDE response per CISPR bandwidths
- Complete range of options and accessories available

CCS 750 Calculator-Controlled System

100 Church Street • Amsterdam, NY 12010 • (518) 843-2600 • TWX 710-446-4798

ELECTRO-METRICS

IN TRIMMING CAPACITORS-



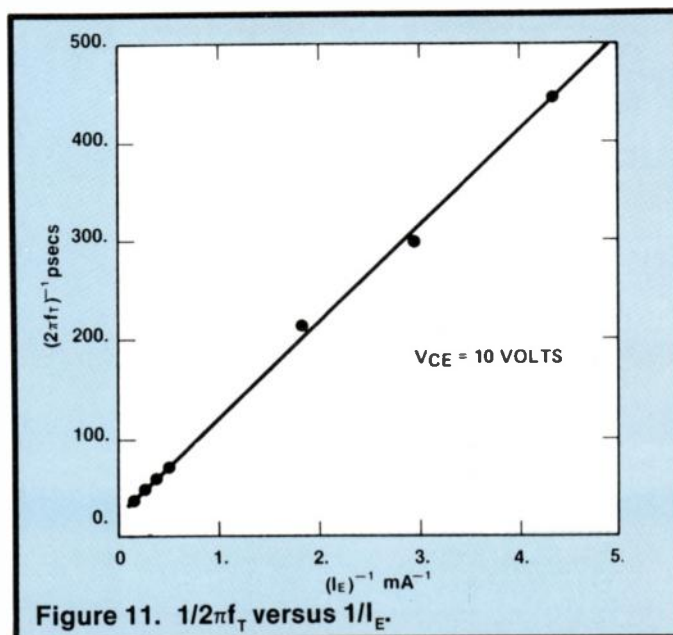
EXPERIENCE COUNTS!

Murata Erie has over 70 years of combined experience in the design and manufacture of trimming capacitors to fill virtually every application requirement—microminiature 1/8" diameter ceramic trimmers for the smallest hybrids, low cost encased ceramic trimmers for commercial and consumer applications, a complete line of 7 mm and 10 mm ceramic trimmers for communication, instrumentation and commercial applications and a broad line of multi-turn air variables that meet MIL-C-14409D.

This broad line, extensive design and manufacturing experience and enviable reputation is your assurance that the Murata Erie trimmers you select will satisfy your most challenging design requirements. For complete technical data and specifications on the Murata Erie line of trimmers write to Murata Erie North America, Inc., 1148 Franklin Rd. SE, Marietta, GA 30067 or call 404-952-9777.



MURATA ERIE NORTH AMERICA, INC.



$$\frac{1}{2\pi f_T} = \frac{25.4}{I_E} C_{TE} + \tau_b + \tau \quad (4)$$

where I_E is in milliamperes. S-parameters at 1 GHz were measured over a current range of 0.25 to 8 mA and transformed to h-parameters. f_T at each current is given by $h_{21} \times f(f = 1 \text{ GHz})$. A plot of $(2\pi f_T)^{-1}$ versus $(I_E)^{-1}$ is shown in Figure 11. The linear relation, as predicted by Equation (4), enables C_{TE} to be derived from the slope and $(\tau_b + \tau)$ from the intercept on the ordinate. The slope, obtained from a best straight-line fit to the measured values was 97.1 mA/psec. The intercept was 23.4 picoseconds, which implies a value for τ_b of 11.7 pico-seconds. f_b can be calculated from $1/2\pi f_b = \tau_b$. A comparison of model values to these measured values is shown in Table 2 and close agreement is found. Finally, optimum noise figure (at a single bias condition of $I_C = 5 \text{ mA}$ and $V_{CE} = 10 \text{ volts}$) was measured at four fre-

| PACKAGE ELEMENT VALUES | | CHIP ELEMENT VALUES | |
|------------------------|----------|---------------------|----------|
| L_b | 1.0 nH | r_e | 5 ohms |
| L_c | 0.65 nH | CTE | 4.0 pF |
| L_e | 0.225 nH | C_{ce} | 0.25 pF |
| C_{bep} | 0.2 pF | R_c | 5 ohms |
| C_{bcp} | 0.03 pF | R_e | 1 ohms |
| C_{cep} | 0.38 pF | R_b | 15 ohms |
| | | C_c | 0.016 pF |
| | | C_{bc} | 0.417 pF |
| | | α_o | 0.99 |
| | | f_b | 10 GHz |
| | | τ | 10 psecs |

Table 1.

| ELEMENT | MODEL | MEASURED |
|---------|--------|----------|
| CTE | 4.0 pF | 3.8 pF |
| f_b | 10 GHz | 13.6 GHz |

Table 2.

GILBERT ENGINEERING

ANNOUNCES



G 900™



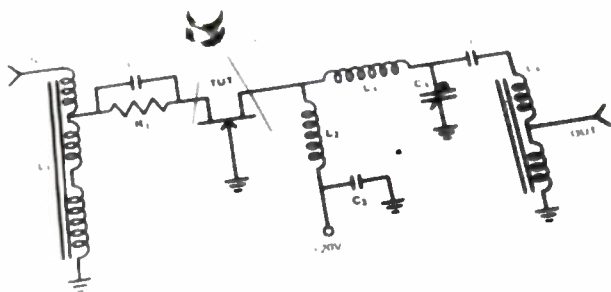
G 874™

Gilbert Engineering has acquired the GenRad (General Radio) product line of R.F. coaxial connectors, attenuators, adaptors, terminations and cable assemblies. Gilbert, a manufacturer of coaxial connectors will now produce the GR874 and GR900 series connectors.

For pricing and delivery, please write or call:

**GILBERT
ENGINEERING**

P.O. Box 23189, Phoenix, Arizona 85063-3189
5310 West Camelback, Glendale, Arizona 85301-7597
(602) 245-1050 • (800) 528-5567 • TWX 910-951-1380



High Voltage Broadband RF FET

High dynamic range RF FET now available up to 50V BVDGO for use with 24 & 32V supplies, and where higher drain voltage improves dynamic range. The CP664 (30V), CP665 (40V), and CP666 (50V) have third order intermodulation intercept $< +40$ dBm, and 50 Ohm VSWR > 1.5 to 1 over 0.5 to 50 MHz range.

**TELEDYNE
CRYSTALONICS**

147 Sherman Street, Cambridge, MA 02140
Tel: (617) 491-1670 • TWX 710-320-1196

INFO/CARD 15

EMI PROBLEMS? Let Eagle Magnetic FIND your magnetic shielding problems!



For more information write or call:
P.O. Box 24283 • Indianapolis, Ind. 46224
Phone (317) 297-1030



INFO/CARD 16

| COMPACT COMPUTER PROGRAM FOR CALCULATION OF S-PARAMETERS | |
|--|--|
| PROGRAM STEP | COMMENTS |
| RES AA SE 15 | RESISTANCE R_B , SERIES CONNECTED 15 ohms |
| CAP BB SE 4.0 | CAPACITANCE C_{TE} , SERIES CONNECTED 4 pF |
| RES CC SE 5.0 | RESISTANCE r_g , SERIES CONNECTED 5 ohms |
| RES DD SE 1.0 | RESISTANCE R_g , SERIES CONNECTED 1 ohm |
| CAP EE SE 0.250 | CAPACITANCE C_{ce} , SERIES CONNECTED 0.25 pF |
| CAP FF SE 0.016 | CAPACITANCE C_c , SERIES CONNECTED 0.016 pF |
| CAP GG SE 0.417 | CAPACITANCE C_{bd} , SERIES CONNECTED 0.417 pF |
| GEN HH CC .01 IE5 990 10000 .00001E-6 | DEFINES THE GENERATOR |
| CAP II SE 0.380 | CAPACITANCE C_{cap} , SERIES CONNECTED 0.38 pF |
| SRL JJ SE 5.0 0.86 | SERIES CONNECTED R_c , 5.0 ohms, L_c , 0.86 nH |
| CAP KK SE 0.20 | CAPACITANCE C_{bcp} , SERIES CONNECTED 0.2 pF |
| IND LL SE 1.0 | INDUCTANCE L_b , SERIES CONNECTED 1.0 nH |
| IND MM SE 0.225 | INDUCTANCE L_g , SERIES CONNECTED 0.225 nH |
| CAP NN SE 0.03 | CAPACITANCE C_{bcp} , SERIES CONNECTED 0.03 pF |
| CON AA T2 3 | CONNECTS AA BETWEEN NODES 2, 3 |
| CON BB T2 3 4 | CONNECTS BB BETWEEN NODES 3, 4 |
| CON DD T2 5 6 | CONNECTS DD BETWEEN NODES 5, 6 |
| CON EE T2 6 7 | CONNECTS EE BETWEEN NODES 6, 7 |
| CON FF T2 3 7 | CONNECTS FF BETWEEN NODES 3, 7 |
| CON GG T2 2 7 | CONNECTS GG BETWEEN NODES 2, 7 |
| CON HH T4 4 5 3 7 | CONNECTS HH BETWEEN NODES 4, 5 and 3, 7 |
| CON II T2 8 0 | CONNECTS II BETWEEN NODES 8, 0 |
| CON JJ T2 7 8 | CONNECTS JJ BETWEEN NODES 7, 8 |
| CON KK T2 1 0 | CONNECTS KK BETWEEN NODES 1, 0 |
| CON LL T2 1 2 | CONNECTS LL BETWEEN NODES 1, 2 |
| CON MM T2 6 0 | CONNECTS MM BETWEEN NODES 6, 0 |
| CON NN T2 1 8 | CONNECTS NN BETWEEN NODES 1, 8 |
| DEF AA T2 1 8 | DEFINES AA AS NODE 1 TO NODE 8 |
| PRI AA S1 50 | PRINTS S-PARAMETERS FOR NODES 1,8 |
| END | |
| 400 2000 100 | FREQUENCY RANGE 0.4 GHz to 2 GHz in 100 MHz STEPS |
| END | |

Table 3.

quencies and compared to calculated values (Figure 12). Optimum noise figure, F_{min} , is given by⁽⁴⁾:

$$F_{min} = a \frac{R_B + R_{opt}}{r_e} + \left(1 + \frac{f^2}{f_b^2} \right) \frac{1}{\alpha_o} \quad (5)$$

where the optimum source resistance, R_{opt} , is given by:

$$R_{opt} = \left\{ R_B^2 - X_{opt}^2 + \left(1 + \frac{f^2}{f_b^2} \right) \times \frac{r_g(2R_B + r_g)}{\alpha_o a} \right\}^{1/2} \quad (6)$$

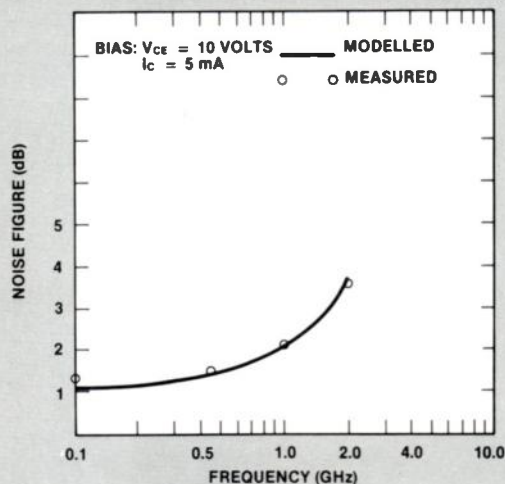


Figure 12. Measured and Modeled Minimum Noise Figure versus Frequency.

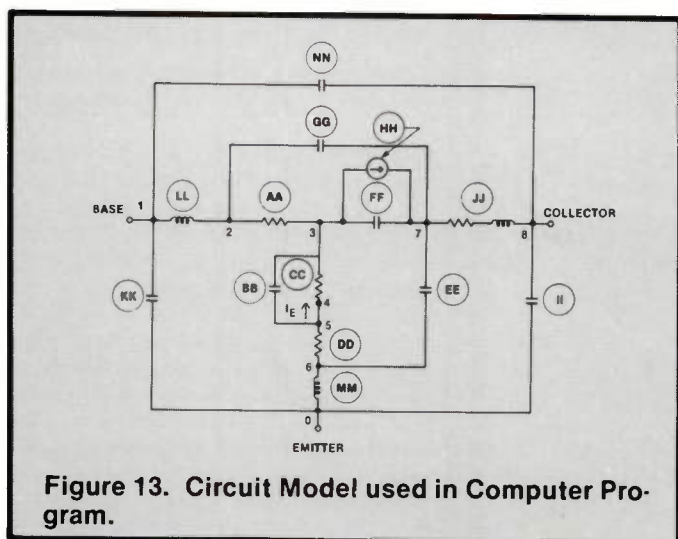


Figure 13. Circuit Model used in Computer Program.

both X_{opt} and a are given by:

$$X_{opt} = \left(1 + \frac{f^2}{f_b^2}\right) \frac{2\pi f C_{TE} r_e^2}{\alpha_o a} \quad (7)$$

and

$$a = \left\{ \left(1 + \frac{f^2}{f_b^2}\right) \left(1 + \frac{f^2}{f_e^2}\right) - \alpha_o \right\} \frac{1}{\alpha_o} \quad (8)$$

where $f_e = 1/2\pi r_e C_{TE}$. Good agreement was obtained between measured and calculated minimum noise figure, as shown in Figure 12, using the values for R_b , f_b and C_{TE} obtained from the modeling exercise.

Conclusion

With the aid of CAD programs and a simple lumped element model, low-noise bipolar transistor S-parameter behavior with frequency can be obtained which closely matches measured values. Models so derived can be used to refine the amplifier design. Furthermore, the model elements correspond to physically relatable elements of the semiconductor so that meaningful discussions with the transistor supplier can prevail when discussing applications requiring tight S-parameter tolerances. The method is flexible enough to accommodate many different package styles.

Acknowledgements

We wish to thank Dr. J.F. White, Technical Director, and Mr. W.R. Rushforth, of the M/A-COM Components Corporate Technology Center, for helpful discussions and guidance in the transistor modeling. Finally, we would like to thank D. Blanchard for preparation of the manuscript.

References

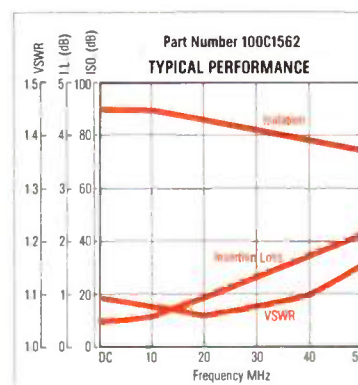
1. M.H. White and M.O. Thurston, "Characterization of Microwave Transistors", Solid-State Electronics, 1970, Vol 13, pp 523-542.
2. COMPACT™ is available from Tymshare, Inc., Cupertino, CA.
3. A.B. Phillips, Transistor Engineering, pp 303.
4. R.J. Hawkins, "Limitations of Nielsons and Related Noise Equations Applied to Microwave Bipolar Transistors and a new Expression for the Frequency and Current-Dependent Noise Figure", Solid-State Electronics, 1977, Vol 20, pp 191-196. □

r.f. design

DC THRU 50 MHz



SOLID-STATE SWITCH



Specifications
Configuration: SP3T
Frequency: DC-50 MHz
Speed: 2 μ sec. Max.
Control: 2 Line TTL
Impedance: 50 Ohms
Terminations: 50 Ohms Int.
RF Power: +25 dBm Max.
DC Supply: +15V at 10 mA
-15V at 20 mA

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



Industry Leader in
Microwave Integrated
Circuit & Connectorized
Switches, Step
Attenuators, Voltage
Control Attenuators

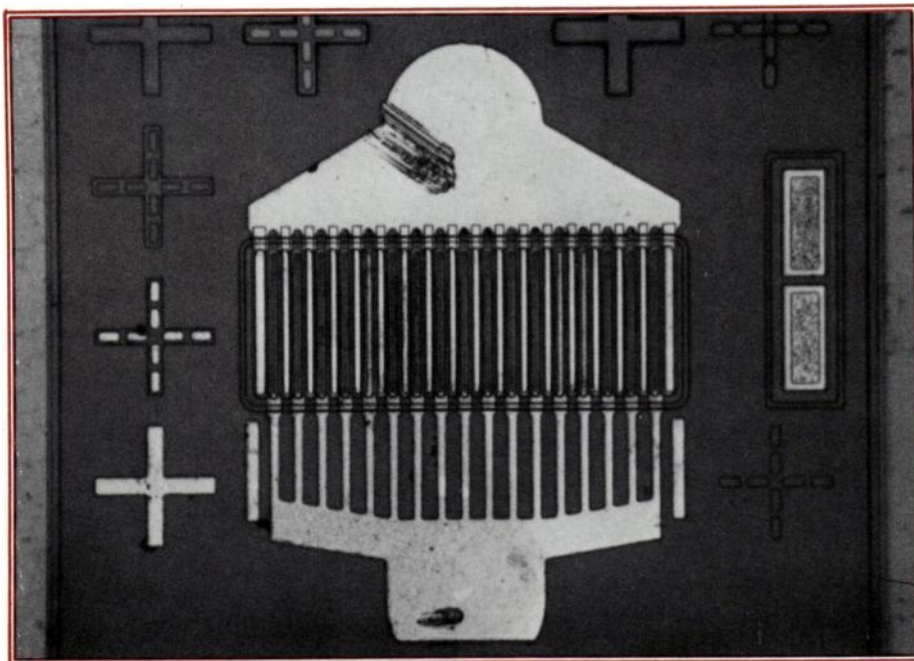
DAICO INDUSTRIES, INC.

2351 East Del Amo Blvd., Compton, Calif. 90220
Telephone: (213) 631-1143 • TWX 910-346-6741
© 1982 Daico Industries, Inc. mp82414k

INFO/CARD 17

A High-Voltage RF Bipolar Transistor

A design account of an RF bipolar transistor developed to fill the need for driver devices in the CRT display section of modern test and measurement equipment.



By Michael D. McCombs
Device Engineering Supervisor and
Chris Nixon,
Device Engineer
TRW Semiconductors
Lawndale, CA 90260

Modern test and measurement equipment often requires cathode ray tube display sections for the presentation of data or test results. Examples are oscilloscopes, spectrum analyzers, network analyzers, and digital logic analyzers. There is an evolving requirement for higher writing speeds in the CRT displays. Driving circuitry for the display must be fast, requiring semiconductor devices capable of higher switching speeds. Higher breakdown voltages in the new electrostatic CRTs are also required. Here we describe a bipolar device which meets these criteria.

In an RF transistor, the requirements for high f , as well as high break-

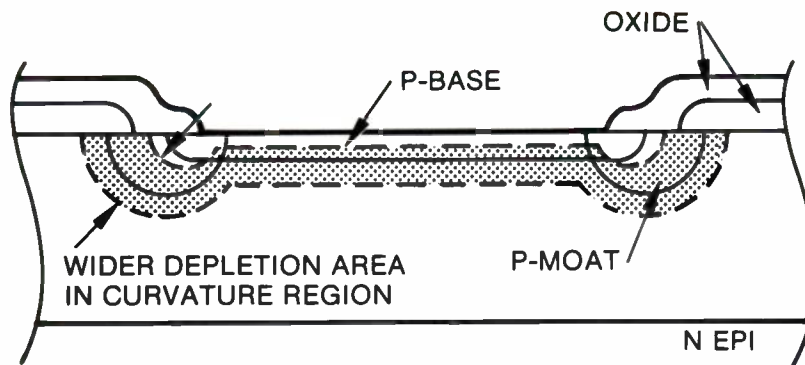


Figure 1. P-Moat Structure.

for CRT Driver Applications

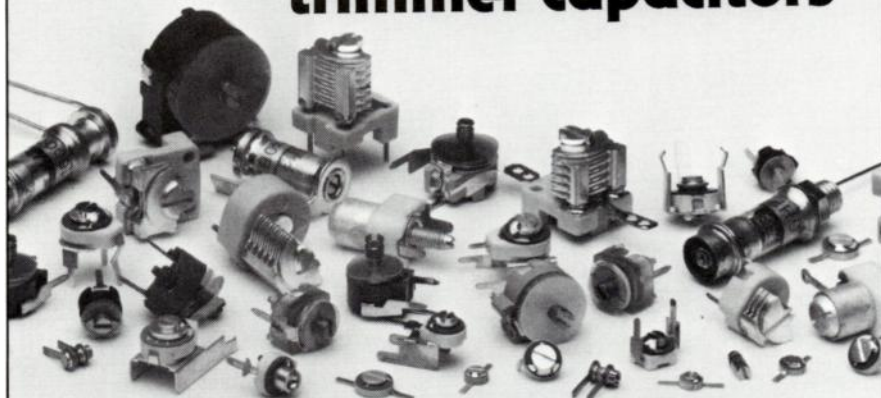
CATV 13A P- MOAT

I STEP = 1 TIME = 0.0 MINUTES.

| DEPTH (UM) | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|------------|----|-----|-----|-----|----|----|----|----|
| 0.00 | I | I | I | I | I | I | I | I |
| | I | I | I | I | I | I | I | I |
| | I | I | I | I | I | I | I | I |
| | I | I | I | I | I | I | I | I |
| | I | I | I | I | I | I | I | I |
| | I | I | I | I | I | I | I | I |
| | I | I | I | I | I | I | I | I |
| | I | I | I | I | I | I | I | I |
| 0.09 | I | *I | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I | *I | I | I | I | I | I |
| | I | I | I * | I | I | I | I | I |
| | I | I | I * | I | I | I | I | I |
| | I | I | I | *I | I | I | I | I |
| | I | I | I | I * | I | I | I | I |
| | I | I | I | I * | I | I | I | I |
| 0.50 | I | I | I | *I | I | I | I | I |
| | I | I | *I | I | I | I | I | I |
| | I | *I | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| 1.00 | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| 1.50 | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| | I | I * | I | I | I | I | I | I |
| 2.00 | I | I * | I | I | I | I | I | I |

Figure 2. SUPREM Profile of the P-Moat Structure.

When it comes to trimmer capacitors



our capacity is unlimited.

At Sprague-Goodman, our only business is trimmer capacitors. That means we devote all of our time and energy providing customers with a full range of quality trimmer capacitors. Included are sub-miniature ceramic and sapphire dielectric Pistoncaps,[®] glass Pistoncaps,[®] Filmtrims,[®] ceramic single trim and Mica compression lines.

They're all available off-the-shelf along

with our new Airtrim[®] air dielectric parallel plate trimmers. And we have custom design and manufacturing capabilities to meet any need and satisfy the most exacting specifications.

So whatever your trimmer capacitor needs may be, call us or your distributor and specify the specialist. Sprague-Goodman. The first and last name for trimmer capacitors.



Sprague-Goodman Electronics, Inc.

(An Affiliate of the Sprague Electric Company)

134 FULTON AVE. GARDEN CITY PARK, N.Y. 11040 • 516-746-1385 • TLX. 14-4533

INFO/CARD 18

down voltages are normally thought of as mutually exclusive. That is, things that improve the voltage capability of the transistor result in a loss of gain-bandwidth or switching speed performance. The device described provides both high f_t and high breakdown voltage. It combines shallow RF bipolar processing with a breakdown-enhancement technique. While production worthy, this processing doesn't add capacitance or use inordinate amounts of epi.

Performance Goals

$$H_{fe} = 20-50$$

$$BV_{CEO} = 60V \text{ min}$$

$$BV_{CBO} = 120V \text{ min}$$

$$f_t \geq 1.5\text{GHz}$$

$$C_{OB} \leq 2.5 \text{ pf @ } 10V$$

Fabrication Procedure

One requirement for this transistor was that it be manufacturable and, if possible, use existing mask sets and processes. Because of the requirement for high-breakdown voltages, it was necessary to obtain an epitaxial starting material with higher resistivity and thickness than typical materials used in RF power or linear applications. To allow for the predictable epitaxial depletion at target voltages, an epi material 9-10 μm thick with a resistivity of 3 $\Omega \text{ cm}$ was selected. The substrate was heavily doped with antimony to a level of .01 $\Omega \text{ cm}$. This type of silicon epitaxy is easily grown and is readily available from several vendors.

The mask set selected had been designed at TRW several years ago to build discrete RF transistors for the CATV marketplace and military communications applications. The mask is a basic interdigitated design. Selection was based on its relative ease of use in production. The mask uses no emitter ballasting and takes advantage of relatively "loose" 5 μm contact geometry. This makes it an extremely production-worthy mask set.

Fabrication proceeds in a straightforward manner. There are no processing "tricks." The most difficult part of the target specifications to achieve is the BV_{CBO} goal of 120V. A typical RF base process would require epi of such a high value of resistivity that the gain-bandwidth target could never be achieved. Some type of breakdown enhancement is required. We selected the P-moat process, perfected for microwave power devices requiring relatively high breakdown voltages. Low resistivity epi was previously

MATEC Pulsed R.F. Systems

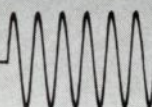
High Power Gated Amplifiers



- A versatile main frame/plug-in system
- Four gated r.f. amplifier plug-ins available collectively covering a frequency range of 100 kHz to above 120 MHz
- Peak power output 500 to above 3000 watts r.m.s. depending on amplifier used

- High amplifier on/off ratio
- Compatible with MATEC's fast recovery broadband receivers and pre-amplifiers

Please contact MATEC, INC. for more information.
60 Montebello Rd., Warwick, RI
02886 USA Tel: 401-739-9030



MATEC, INC.



INFO/CARD 19

used for higher saturated power output capability. In this case, high resistivity epi was selected because of the high BV_{CEO} requirement of the part. The moat provides a correspondingly high BV_{CBO} .

Figure 1 illustrates the principle of operation of the P-moat. Essentially, the higher breakdown is achieved by defeating curvature breakdown of the junction. This is accomplished by providing a very lightly doped p region around the edge of the base. This allows more depletion. Therefore, higher voltages are supported. Our experience shows that this process provides breakdowns of over 90% of bulk, if done correctly. In contrast, the more conventional P+ moats or depletion rings do well to give 50% of bulk.

To develop the P-moat process for this application, it was decided to

model the process first. The Stanford modeling program, SUPREM, was used. This one-dimensional process modeling program accepts inputs in the form of oxidation and diffusion and ion implantation schedules. Figure 2 shows the output of a SUPREM profile for the P-moat structure used on the device. It can be seen that SUPREM predicts a junction depth of $0.86\mu\text{m}$ and a peak doping concentration of a little over $1 \times 10^{17}\text{cm}^{-3}$. The predicted sheet is $3700\Omega/\square$. This compares very well with the experimental results described below.

Figure 3 is a schematic represent-

ation of the fabrication process. Figure 3(a) shows the formation of the P-moat by ion implantation. The moat must be deep enough to allow depletion toward the surface. This is accomplished with a 150 keV, $5 \times 10^{12}\text{a}/\text{cm}^2$ boron implant followed by an anneal cycle of 90 min @ 1100°C . Sheet resistance readings of $4000\Omega/\square$ and a junction depth of $1.0\mu\text{m}$ are obtained.

In Figure 3(b), the base structure is shown. We selected a base and emitter structure developed for TRW microwave power devices. It results in nearly 2GHz f_t performance on this chip. The base is a standard diffused process.

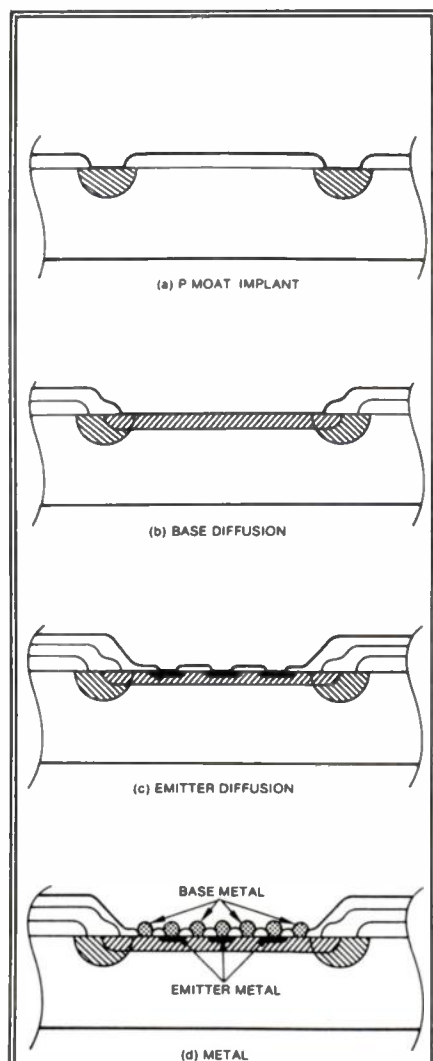


Figure 3. Wafer Fabrication Process.

r.f. design

GET 10 TIMES MORE RFI PROTECTION WITH A LINDGREN "DEI" SCREEN ROOM

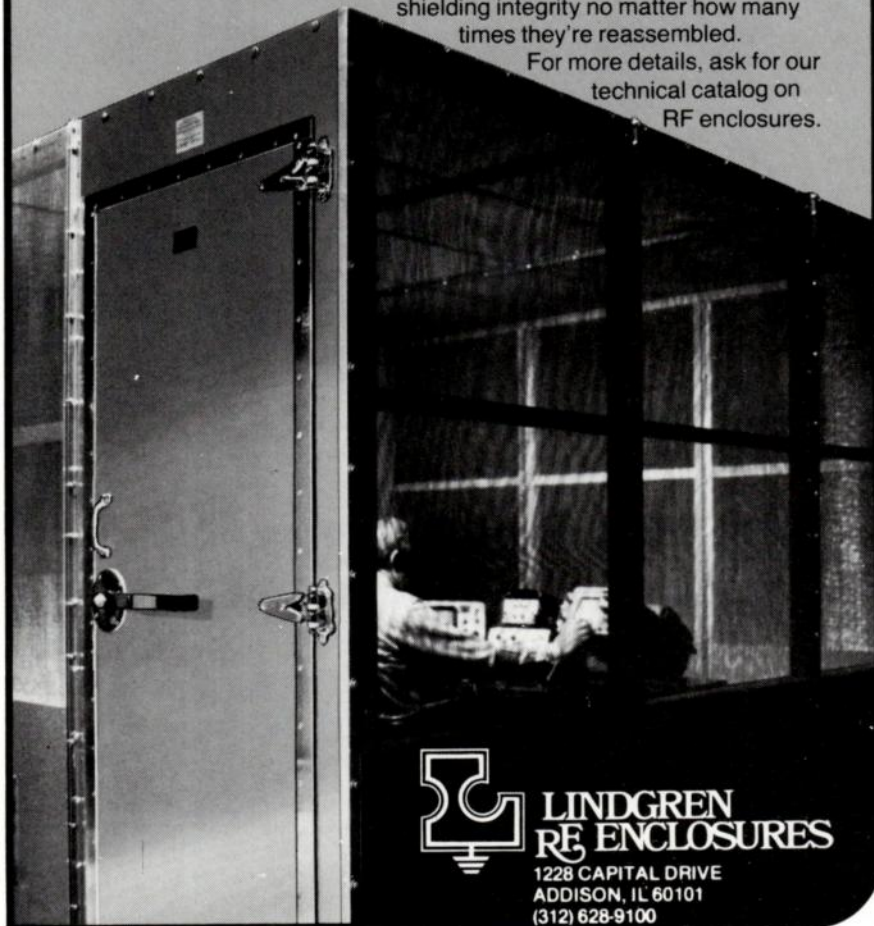
Lindgren's double-electrically-isolated (DEI) screen rooms offer 120 dB RF attenuation of electric and plane waves from 14 KHz to 1 GHz... up to 10 times more shielding than any other type of screen room.

This patented design keeps your design/test area interference-free despite rising ambient RFI levels. You get shielding equal to conventional solid-sheet-metal enclosures without sacrificing the see-through, hear-through and lighter-weight advantages of screen.

DEI design is superior because inner and outer screens of 0.011" dia. 22 x 22 bronze mesh are electrically separated, except for a single grounding point. Doors feature separate inside and outside RF seals on all four edges, with a single handle that assures an RF-tight closure by applying cam pressure at three points.

Built of panel modules, Lindgren RF enclosures can be moved, expanded or reshaped easily. Our patented overlapping pressure joints maintain full shielding integrity no matter how many times they're reassembled.

For more details, ask for our technical catalog on RF enclosures.



**LINDGREN
RF ENCLOSURES**

1228 CAPITAL DRIVE
ADDISON, IL 60101
(312) 628-9100

INFO/CARD 20

BN source wafers and a 900°C deposition cycle are followed by a 1025°C diffusion cycle. The result is a base with a junction depth of .25 μ m and a sheet resistance before emitter of 650 Ω/\square .

Figure 3(c) shows formation of the self-aligned contact scheme using LPCVD silicon nitride as a mask. Before nitride deposition, a thin layer of thermal oxide is grown. This relieves the stress created between the nitride and the silicon. The contact scheme is interdigitated with an emitter width of 1.8 μ m, a base contact width of 6.3 μ m, and a contact spacing of 2.3 μ m.

Figure 3(d) illustrates the emitter diffusion—a standard phosphorous diffusion using POC1₃ as a source. Emitter sheet resistance is approximately 30 Ω/\square , with a final base and emitter junction depth of .5 μ m and .25 μ m, respectively.

The metalization scheme uses a PtSi ohmic contact. This is followed by a Ti/W barrier with a sputtered gold final metal, which is then defined by PR and etched back. All PR uses contact technology with iron oxide working plates. The devices are passivated with Silox as a scratch protection.

Characterization

The DC characteristics of the transistors are shown in Figure 4. The breakdown goals were met, even though more margin would be desirable. The beta characteristic shows a typical value of 30, which is well within the original objective. Of course,

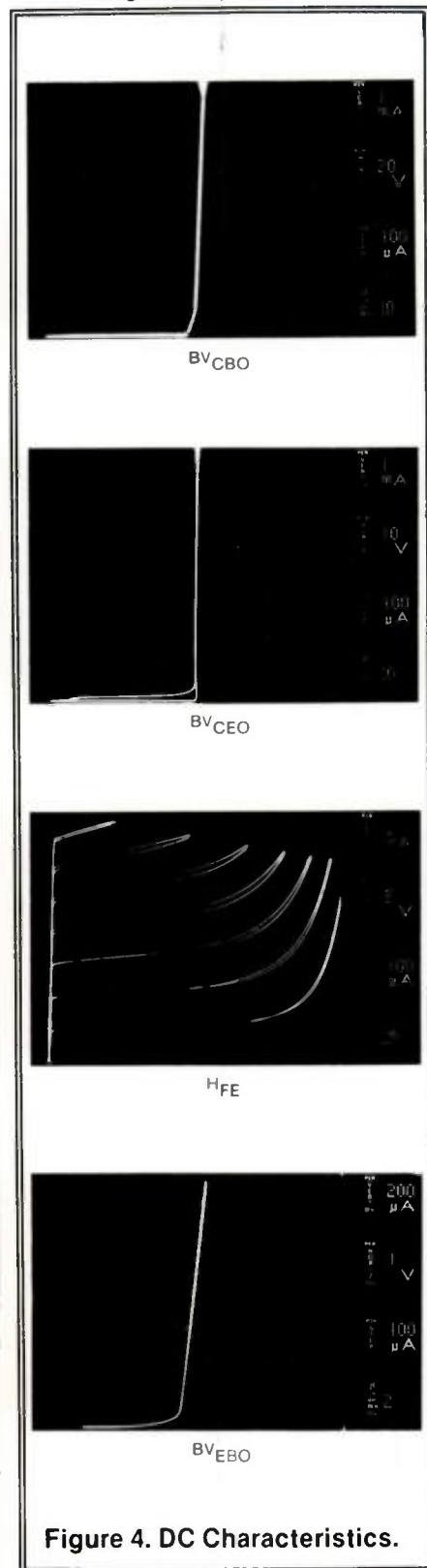


Figure 4. DC Characteristics.



AFFORDABLE SYNTHESIZERS

Thanks to computerized environmental test and quality assurance procedures, low-cost frequency synthesizers have become available from ZETA — long an industry leader in high-quality MIL Spec microwave components and subassemblies.

For example, ZETA Model 6799 offers 35.0 to 99.9 MHz coverage in 100 KHz steps, with low noise and spurious, and frequency stability of ± 5 PPM over 0° to 50°C. External reference, optional. And, just \$650 in quantities to 4, and \$370 for 100 or more units! Detailed test data is available, of course.

Call ZETA today, to review your low-cost synthesizer requirements. Award-winning ZETA quality is more affordable now, than ever!



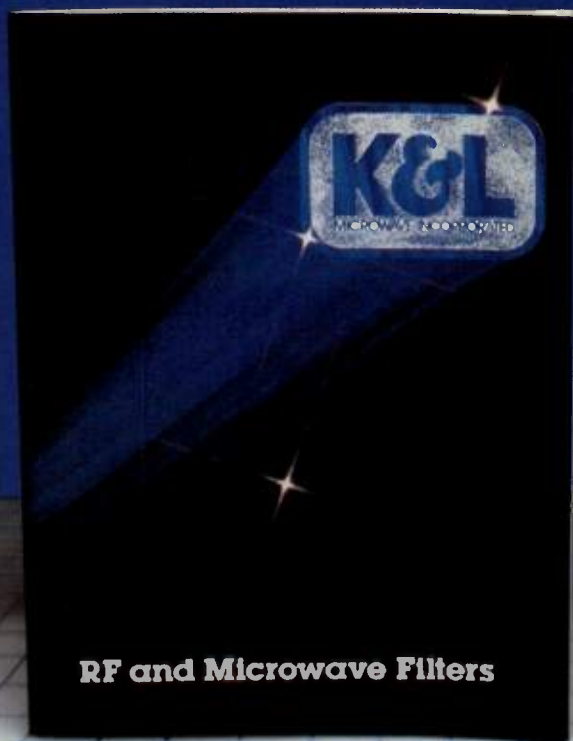
ZETA LABORATORIES, INC.

A SUBSIDIARY OF CCT

3265 Scott Blvd. Santa Clara, CA 95051

Phone: (408) 727-6001 TWX: 910-338-7336

Every filter you need for today's design specifications is in K&L's new catalog.



K&L Microwave, regarded as a world leader in the design and manufacture of RF and microwave filters, offers a new comprehensive catalog of their complete filter line.

This catalog presents a product line that covers a frequency range of 0.5 MHz to 40 GHz and features lowpass, highpass, bandpass, and bandreject filters, in LC, Tubular, Cavity and Waveguide construction. Microminiature, and tunable bandpass and bandreject filters as well as digitally controlled filters are included.

K&L can supply over 6,000 different filter styles and adaptations. And if you can't find what you need in this catalog, K&L will design a filter specially for your prototype or production order.

Look to K&L for all your filter needs.

Send for yours today

or circle the proper number
on reader service card.
INFO/CARD 22

K&L
MICROWAVE INCORPORATED

408 Coles Circle, Salisbury, Maryland 21801
301 749-2424 TWX 710-864-9683

Belgium: HEYNEN bv, Hasselt, Tel 011-210006

France: DATRON, Paris, Tel 763 8584

W. Germany: OMECON, Ottobrunn, Tel 089/6091011

Israel: M.E.L., Tel Aviv, Tel (03) 477418

Italy: TELETRON, Rome, Tel 503 6745

Japan: SOGO, Tokyo, Tel 03 309-5442

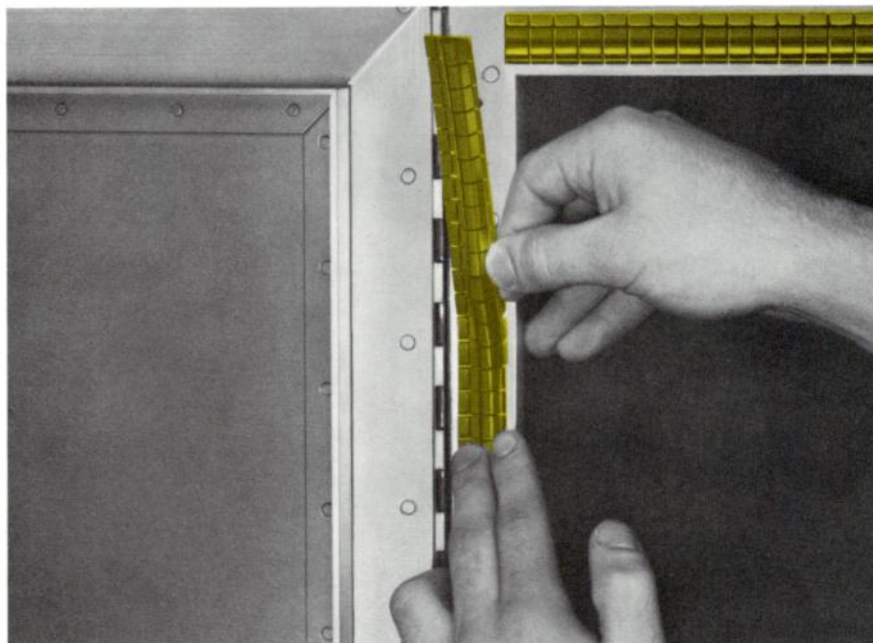
Netherlands: HEYNEN bv, Gennep, Tel 08851-1956

United Kingdom: ASPEN, Eastcote-London, Tel 01-868 1188

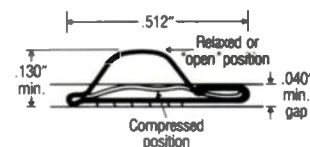
Name _____
Company _____
Address _____
City _____ State _____ Zip _____



Call Instrument Specialties **TODAY** to meet the FCC RF interference compliance date of **OCTOBER 1, 1983!**



Series 521
.512" wide



Available in widths of
.380", .512", .760".

If you're involved with Class A and/or Class B Computing Devices, as defined by the FCC, you know you have only until October 1, 1983 to comply with RFI limits.

Instrument Specialties' new Sticky-Fingers® shielding strips can help you comply. They offer attenuation of more than 102 dB at 10 GHz plane wave, and 71 dB at 14 kHz magnetic. And to attach, you need only peel off the self-adhesive backing strip and press into place. It's there to stay!

What's more, unlike other shielding strips, Sticky-

Fingers will not take a set which would reduce performance *after you felt it was satisfactory*. Sticky-Fingers *can't* absorb moisture, are not affected by air, ozone, solvents, UV light, or radiation. They can't burn or support combustion; there is nothing to outgas; they don't stretch or tear in use; and can't flake or break into small conductive particles to short out your electronics.

In short, Sticky-Fingers are the best answer to your shielding problems. For more information, write today to Dept. RF-6.



INSTRUMENT SPECIALTIES COMPANY, INC.

Delaware Water Gap, PA. 18327

Phone: 717-424-8510 • TWX: 510-671-4526

Specialists in beryllium copper since 1938

INFO/CARD 23

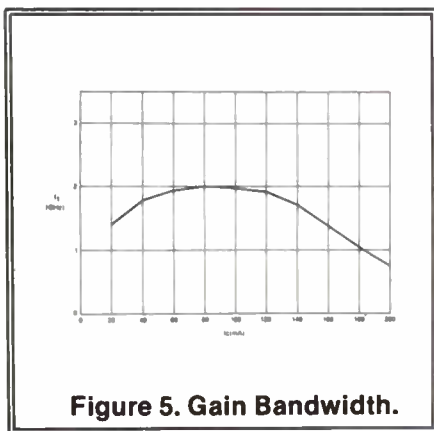


Figure 5. Gain Bandwidth.

targeting the devices for higher beta would require a sacrifice in BV_{CEO} without modifying the starting material.

The f_T vs I_c data (Figure 5) shows that the microwave process is yielding a f_T of nearly 2GHz. This is excellent for high-resistivity epitaxial material. The plot peaks out at 90 ma. The device should be operated at this level for maximum gain.

The inherent f_T performance of the vertical geometry is about 3GHz. Normally, base transit time can be a significant delay contributor in a bipolar device. In this case, a base width of 0.25 μ m contributes only about 15% of the total. The primary contributors are the emitter delay and the collector-base depletion transit time. To achieve the high BV_{CEO} breakdown voltage, we increase the collector-base transit time by 90%. The f_T value of 2GHz is lower than the theoretical level of 3GHz for this reason.

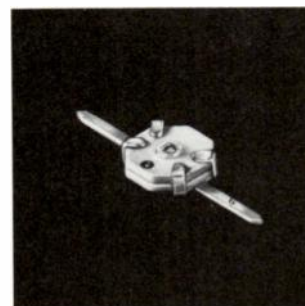
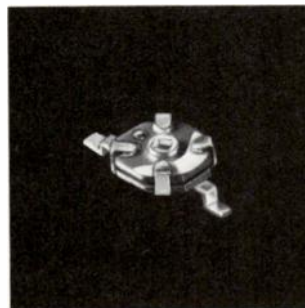
Summary

We have described a device that fills a void in present RF device technology. The design was undertaken with an emphasis on manufacturability. The horizontal geometry is 'loose' by present high frequency standards, and doesn't require any photolithographical tricks to achieve the performance goals. The vertical geometry is certainly shallow—.5 μ m—but takes advantage of a proven TRW RF technology. The metalization scheme is all gold. This offers high reliability and the option for compatibility with thin or thick film hybrid technology. Work is continuing on more devices of this type that will attain even higher performance capability.

Acknowledgements

We are grateful to Gene Brannock, Product Engineering Manager/Linear Low Noise, for device characterization and Bill Imhauser, Engineering Supervisor, for discussions on P-moat processing. □

r.f. design



Put a Johanson in your circuit.

The name Johanson has become synonymous with variable capacitors. For over 35 years our trimmer capacitors have been the industry standard of excellence.

The Thin-Trim® and Seal-Trim® capacitors are an advanced development in micro-miniaturized variable capacitors. They feature low drift rates and high Q and are ideal for high frequency applications. The Seal-Trim® is encapsulated in a moisture-proof housing which eliminates intrusion of dirt, dust, solder flux and atmospheric contamination. The two styles incorporate the Johanson square drive tuning mechanism to assure non-slip tamper proof adjustments.

Electronic Accuracy through Mechanical Precision

Johanson

Manufacturing Corporation

400 Rockaway Valley Road Boonton, New Jersey 07005
201-334-2676 TWX 710-987-8367

U.S. Patent No. 3,701,932 & U.S. Patent No. 4,179,722

INFO/CARD 24

Power FETs for RF Amplifiers

New power FETs with impressive electrical ratings finally rival not only bipolar power semiconductors but also the time-honored power vacuum tube—especially in military communications equipment where reliability and performance cannot be compromised.

By Gary Appel, Applications Engineer, and
Jim Gong, Product Manager
Siliconix, Inc.
Santa Clara, California

Motivated by the inherent and distinctly superior thermal and noise characteristics of field-effect transistors (FETs) over bipolar junction transistors (BJTs), FET suppliers have steadily optimized device performance specifically for application in high-power communications equipment. This trend is evident in the evolution of RF power FET technology summarized in Table 1, which is marked by periodic improvements in power-handling capability at high frequencies.

Recently reported developments are a laboratory demonstration of an RF power FET delivering 100W at an operating frequency of 1GHz (Semiconductor Research Institute of Japan) and a commercially available device introduced this year that has a 150W rating at 100MHz. This latter device, the Siliconix DVD150T, also has the highest supply voltage (80 to 120V) and drain-to-source breakdown voltage (260V, typical) ratings yet available.

Many RF power FETs are already used in high-power, broadband VHF military communications amplifiers, such as the ECCM frequency-hopping SINCGARS (Single Channel Ground/Airborne Radio Subsystems). With performance on a par with that of power vacuum tubes, FETs bring the potential benefits of reduced system size, weight and cost plus the physical ruggedness necessary for service in hostile military environments.

This article, the first of a two-part series, compares MOSFET and BJT performance characteristics in RF power applications. The second article details procedures for designing a broadband amplifier using RF power FETs.

Advantages of MOSPOWER FETs

RF MOS power FETs, now commercially available from at least six major semiconductor manufacturers, are used increasingly in the design of RF power amplifiers. Growing preference for MOSFETs over traditional bipolar transistors is based on the many advantages offered by the RF power MOSFET.

Inherent Thermal Stability: The current gain (beta) of a typical bipolar power transistor increases with temperature. This positive temperature coefficient is responsible for the occurrence of "thermal runaway" in a bipolar amplifier. In contrast, the transconductance of a power FET has a nega-

tive temperature coefficient: An increase in device temperature decreases transconductance. As a result, a power FET tends to shut down as device temperature increases.

This characteristic is most easily observed on the device level, however, it also occurs across the transistor die; hotter portions of the die tend to shut themselves down. The overall result is the prevention of destructive phenomena characteristic of bipolar devices: current hogging, hot-spotting and second breakdown. Also, no source ballasting resistors are required with their inherent gain reduction, increased parasitic capacitance, and increased fabrication costs. Moreover, several power FETs can be connected in parallel without the added expense of meticulous selection to match device parameters.

Low Noise: One of the most serious challenges in designing an RF power amplifier is the avoidance of spurious signal generation, which can result either from inadvertent generation of undesired mixing products or simply from the presence of broadband noise.

The transfer characteristic for a typical power FET displays no abrupt changes in shape, but instead varies slowly and smoothly with gate-to-source voltage (see Characteristics of the DVD150T). A power series expansion of this transfer characteristic would yield small values for the higher-order coefficients. This property, which is attributed to the square-law variation of drain current at low gate voltage, results in less generation of high-order intermodulation products than that of a similar bipolar transistor biased under Class AB conditions. Similarly, drain characteristics coupled with the high value of reverse isolation (-35dB) result in excellent back-intermodulation characteristics which is ideal for co-site and combat environments.

A power FET also generates far less broadband noise, typically 10 to 15dB better than a comparable bipolar transistor. Reduced noise generation is due partially to the absence of a forward-biased junction and its associated shot noise. The low noise generation of RF power FETs together with the benefits of reduced levels of high-order intermodulation and back-intermodulation distortion products lead to an increased dynamic range. Finally, ultralinear amplification is possible by employing Class A operation in combination with feed-forward techniques.

Reduced Feedback: Yet another advantage of power FETs is a reduction in the internal feedback paths. High gate impedance results in a gate waveform with amplitudes as high as 20V peak-to-peak. In contrast, the base of a typical bipolar transistor is unlikely to reach 5V peak-to-peak.

The higher gate voltage has two benefits. First, the voltage induced across the common lead (source) inductance affects the FET input voltage about one-fourth as much as it does the input voltage of the bipolar transistor, substantially reducing the unwanted feedback. Second, the effect of reverse transfer capacitance, already low in the power FET, is further reduced by the lower voltage gain. The end result is reduced Miller effect of the FET amplifier. Gain degeneration and slope are reduced due to the reduced common-lead feedback, while stability and input VSWR are less affected by load VSWR.

Circuit Design Simplicity: The unique properties of a power FET can contribute to simplified amplifier circuit design. The negative temperature coefficient allows the use of a fixed bias voltage in Class A and AB operation. No complex temperature compensation is required. Small leakage current, which is in the nanoampere or even picoampere range, results in virtually no power consumption in the gate bias supply. Consequently, a low-power bias supply can be used. Moreover, low gate current allows the power FET to have narrower gate metalization and thus reduced input capacitance.

Another circuit simplification results in the input matching network of a broadband amplifier design. The power FET gate, essentially a MOS capacitor, must be externally shunted by a resistor to properly terminate the input matching network. This combination results in the well-behaved input VSWR and flat gain response of the matching network used. No feedback or frequency compensation is required to control the input impedance or flatten the gain response. The higher input impedance of the power FET simplifies the design of matching networks.

The capacitive input of the device is an attractive feature for distributed amplifier applications. These circuits traditionally are designed around vacuum tubes whose capacitances are integrated with other circuit components. Power FET input capacitance can be exploited in the same manner.

Finally, the absence of minority-carrier storage time in power FETs is ideal for high efficiency amplification or applications with critical phase-tracking requirements.

Reliability: Many of the previously discussed power FET properties increase device reliability. For example, the negative MOSFET temperature coefficient prevents thermal runaway, and minimal internal feedback paths lessen the chance of destructive oscillation. Device reliability is further enhanced by the reduced gate current, which results in less metal migration. Then because input impedance is high, internal impedance-matching components are not required, thus further preserving reliability. Power FET reliability is further enhanced by the lack of a reverse diode breakdown possibility (base-emitter) and its associated degradation in gain (McDonald effect).

High Operating Voltage: Additional advantages become apparent in the design of a high-power amplifier when operating voltage is increased. As the supply voltage is doubled, the current demand is halved and impedance levels increase fourfold. Increased impedance results in several significant benefits.

One improvement is the reduced effect of parasitic inductance elements, especially the common-lead inductance. The inductive elements in the matching network now be-

| | FET | BIPOLAR |
|------|--|--|
| 1968 | -DMOS by Bell Laboratory -Planar, 5W @ 10MHz by ECOM (Signal Corps Electronic Command at Ft. Monmouth) | -80W @ 30MHz, 28V -20W @ 400MHz, 28V -2W @ 3.0GHz, 28V |
| 1969 | -VMOS concept reported in <i>Electronics</i> by Japan | -30W @ 400MHz, 28V |
| 1972 | -VMOS, 10W @ 1.5GHz by Office of Naval Research with Westinghouse R & D center | -50W @ 400MHz, 28V -Internal matched. |
| 1973 | -MOSFET, 10W @ 200MHz (KP901A) by Russian | -80W @ 175MHz, 28V -70W @ 30MHz, 12V |
| 1975 | -VMOS, 10W @ 200MHz (VMP1) by Siliconix, U.S.A. | -100W @ 30MHz, 12V -100W @ 400MHz, 28V |
| 1976 | -VMOS, 10W @ 200MHz (VMP4), first commercial RF VMOST | -100W @ 175MHz, 28V -Balance Transistors. |
| 1978 | -VMOS, 100W @ 175MHz, 35V (BF100-35) by CTC, U.S.A. | -20W @ 2.0GHz, 22V |
| 1980 | -VMOS, 80W @ 175MHz, 28V (DV2880T) by Siliconix, U.S.A. | -16W @ 2.3GHz, 22V |
| 1981 | -DMOS, 22W @ 1.1GHz, 28V (lab results) by Hitachi, Japan -VMOS, 120W @ 175MHz, 28V (DV28120T) and 60W @ 175MHz, 12V by Siliconix, U.S.A. -DMOS, 120W @ 100MHz, 80V (2SK317) Hitachi, Japan | -6.0W @ 4.0GHz, 22V |
| 1982 | -VMOS, 150W @ 100MHz, 100V (DVD150T) Siliconix, U.S.A. | |

Table 1.

| | Min. | Typ. | Max. |
|---|------|---------|-------|
| Breakdown voltage, BV_{DSS} | 220V | 260V | |
| Supply voltage, V_{DD} | 80V | | 120V |
| Output power (100MHz, 17dB gain) | 150W | | |
| Transconductance ($I_D = 5A$) | | 1.5 mho | |
| Transconductance ($I_D = 0.5A$) | | 0.6 mho | |
| Input capacitance, C_{iss} (1MHz, 30V) | | 340pF | 400pF |
| Output capacitance, C_{oss} (1MHz, 30V) | | 75pF | 100pF |
| Reverse transfer capacitance, C_{rss} (1MHz, 30V) | | 10pF | 15pF |

Table 2. Device Characteristics.

C₁, C₅, C₆ ARCO #462 5 TO 80 pF TRIMMER CAPACITOR
 C₂, 30 pF SEMCO POWER CAPACITOR
 C₃, ARCO #422 4 TO 40 pF TRIMMER CAPACITOR
 RFC, 13-TURNS #18 AWG CLOSE WOUND ON 0.3" DIA.
 L₁, 3-TURNS #12 AWG ON 0.3" DIA.
 L₂, 5-TURNS #12 AWG ON 0.3" DIA.

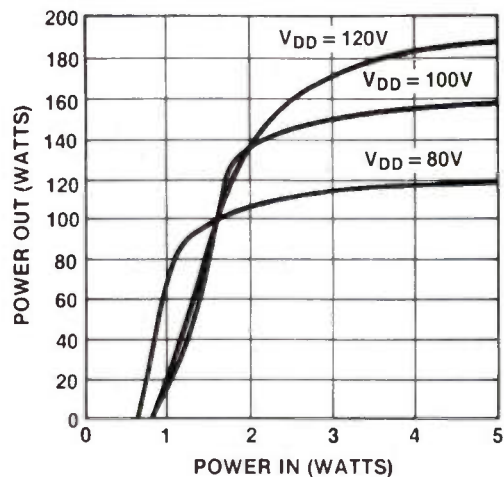
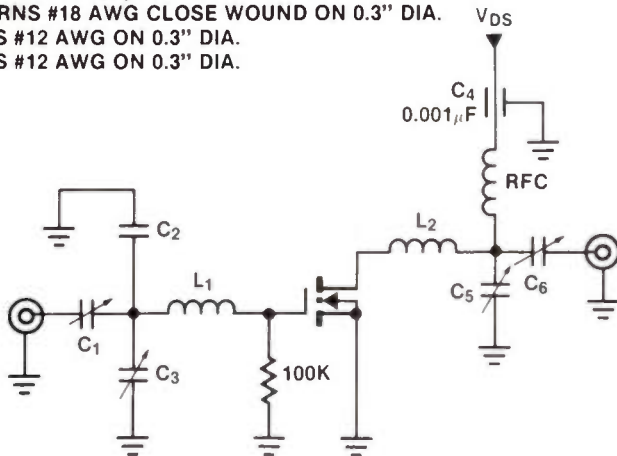


Figure 1. Test fixture and power measurements for 100MHz operation.

come lengths of wire, instead of the length of a bond leads inside the device package.

Capacitor reactance values also become more realistic. At higher operating voltages the reactance of a capacitor used as a matching element is more easily measured, and a half ohm of internal capacitor resistance will not generate destructive heat levels. Using RF bypass capacitors at the appropriate points now becomes a textbook design procedure instead of an art.

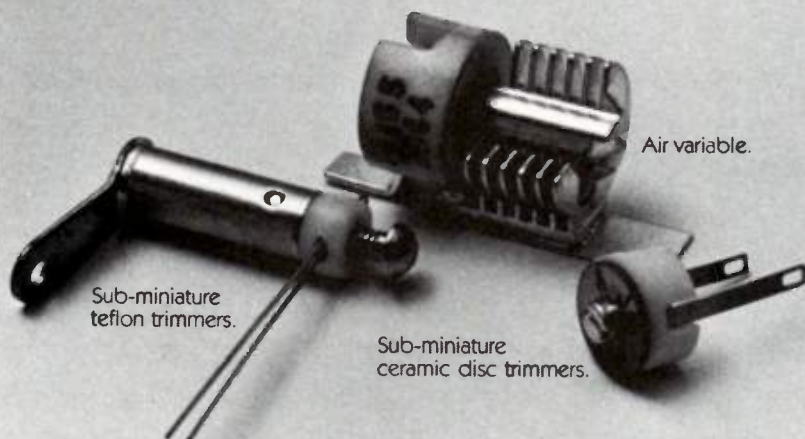
Finally, the increased impedance values allow easy con-

struction of broadband transformers resembling ideal components with minimal parasitic effects.

Device Characterization

The RF power FET discussed in the remainder of this article is the Siliconix DVD150T, which has the highest ratings available for supply voltage, drain-to-source breakdown voltage and VHF output power, Table 2. The input and output capacitances shown in the table are determining

Our capacitors help trim costs.



Available in every size and mounting style. For a free catalog, phone (507) 835-6222 or write E. F. Johnson Co., 299 10th Avenue Southwest, Waseca, Minnesota 56093.



JOHNSON

TXW 910-565-2161

E. F. JOHNSON COMPANY, WASECA, MINN. 56093

TLX 290470

INFO/CARD 25



Sub-Miniature L-C FILTERS

ALLEN AVIONICS Sub-Miniature Passive L-C Lowpass, Highpass and Bandpass Filters range from 5 MHz to 500 MHz. The filters are offered in a 50 ohm impedance with SMA connectors or terminals for PC mounting. Several different shape factors are available. Units range in size from .8 x .5 x .5 to 1.25 x .5 x .5 inches.

PHONE/WRITE FOR FILTERS AND DELAY LINES CATALOGS

ALLEN AVIONICS, INC.

224 East 2nd St., Mineola, NY 11501
 Phone: 516-248-8080

INFO/CARD 26

Looking for the world leader in solid state RF/Microwave power?

You've found it!



RF/Microwave products for telecommunications, defense electronics, laboratory instrumentation and test—frequencies from less than 1 MHz up to 8.4 GHz—power outputs from less than 1 watt up to several kilowatts—all solid state—that's the world of MPD. It's a world that's getting wider every day, with a constantly growing spectrum of commercial, industrial and military applications:

Space Satellite Amplifiers

- Class A linear or Class C
- 1500 to 2300 MHz
- "Space-Qualified" transmitters

Satellite Ground Stations

- GaAs FET power amplifiers, up to 8.4 GHz
- 1 and 5 MHz distribution amplifiers, up to 26 outputs
- FM carrier baseband video distribution amplifiers
- IF amplifiers, 70, 700 and 1100 MHz

Terrestrial Microwave Amplifiers

- Microwave LOS, 100 watts
- High power troposcatter, L-band, 1000 watts
- Microwave and UHF radio relay, 1000 watts

Broadcast

- UHF/VHF color TV transmitters, up to 1.5 KW peak synch
- Airborne TV visual/sound power amplifiers
- FCC type-accepted driver amplifiers
- UHF TV internal 3-tone amplifiers

Avionics

- FAA and MIL TACAN transmitter systems— power amplifiers, modulators, synthesizers, power supplies
- L-band digital transmitters (JTIDS)
- Data link transmitters
- Up/down converters
- Airborne pulse amplifiers

Missile Systems

- Command/destroy transmitters
- Guided weapon data link amplifiers
- Military drone transmitters

Radar Amplifiers

- L-band transmitters
- S-band pulse drivers for 3-D radar
- Shipboard drivers for AN/SPS-48 radars

Electronic Warfare

- Communication jammers
- Class A linear power amplifiers
- Linear AB wideband jammers
- Jamming simulators

Military Communications Amplifiers

- Long-pulse data links
- Communication command links
- UHF transceiver amplifiers/modulators
- MIL RF power boosters (ECCM)

Laboratory Instrumentation/Test

- Class A linear amplifiers
- RFI/EMI test amplifiers
- Power meter calibration systems
- Commercial and MIL power supplies— high efficiency, compact packaging, up to 6000 watts
- DC-DC converters



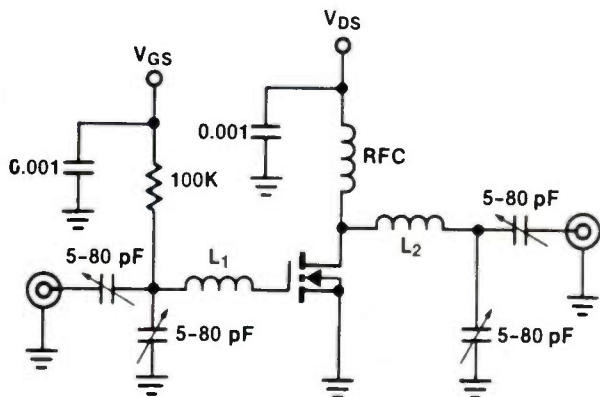
A MICOM COMPANY

MICROWAVE POWER DEVICES, INC.

330 Oser Avenue, Hauppauge, N.Y. 11788
Tel. 516-231-1400 • TWX 510-227-6239

INFO/CARD 27





L_1, L_2 1 1/2 TURNS #12 AWG 5/16" DIA.
RFC 10 TURNS = 20 AWG 1/4" DIA.

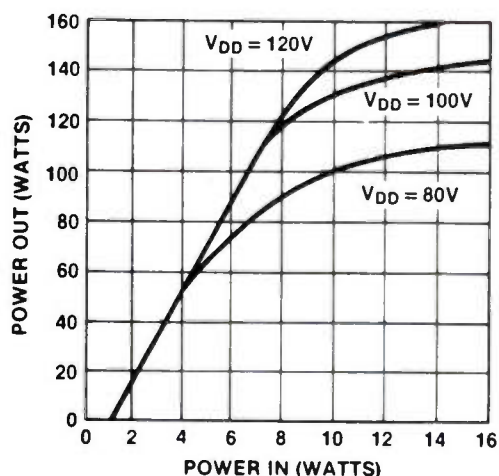


Figure 2. Test fixture and power measurements for 175MHz operation.

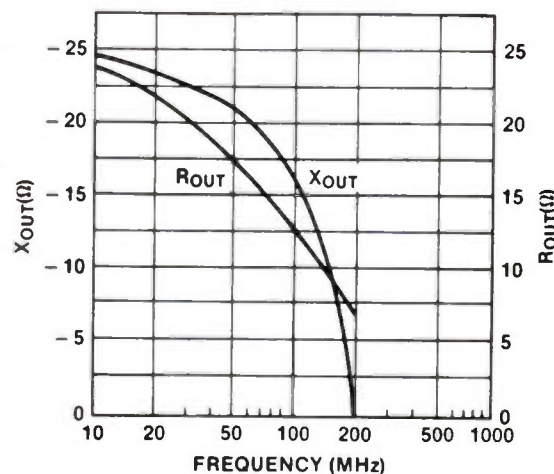
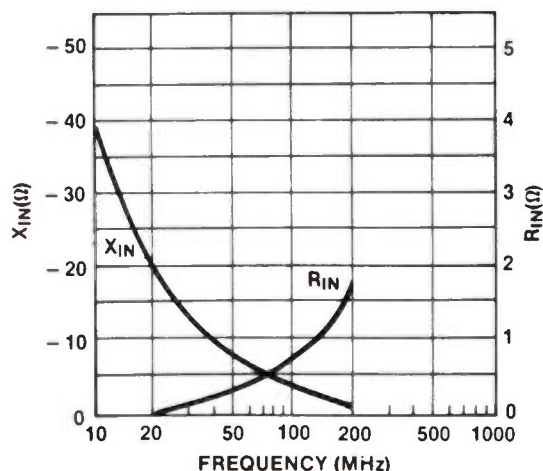
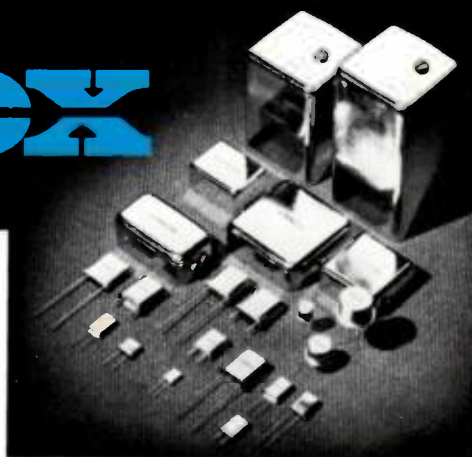


Figure 3. Plots of series equivalent input and output impedance vs. frequency used for constructing a device model.

CINOX

- Channel Crystals
- Precision Crystals
- TCXO's
- VCXO's
- OXCO's



**COMPETITIVE PRICING
HIGH QUALITY
FAST DELIVERY**

Applications for:

- Mobile Portable Base Station
- Land Mobile Communications
- Instrumentation
- Marine Communication and Navigation Equipment

CINOX CORPORATION
4914 GRAY RD., CINCINNATI, OH 45232
PHONE 513/542-5555 TWX 810 461 2749

factors in the design of broadband input and output matching networks.

The DVD150T has been characterized for Class C ($V_{GS} = 0$) operation at both 100 MHz and 175 MHz. The 100 MHz test fixture and results are shown in Figure 1. A supply voltage of 100V yielded a 150W output at a gain of 17dB. Drain efficiency measured at this point was 65%.

In the 175 MHz test fixture, Figure 2, the device was operated at zero gate voltage and with a 100V drain supply. This circuit produced an output power level of 140W at a gain of 10dB and a 64% drain efficiency.

Input and Output Models

In designing an amplifier around the DVD150T, it is important to have an adequate device model. For this purpose, the input and output impedances* are shown in Figure 3 for frequencies between 10 and 200 MHz. The capacitive nature of the input impedance as well as the small frequency-dependent resistive component are evident in this plot. The output impedance of the FET is basically identical to that of a similar bipolar transistor.

For simplified input and output matching network design, the device must be modeled in terms of electrical components. This task is relatively simple for an RF power FET. The input model is merely a series resonant circuit with capacitive, resistive and inductive elements, Figure 4a. The most significant component is the input capacitance C_{in} , which is the combined gate-to-source capacitance and Miller capacitance. Input inductance L_{in} is the combined bond-wire and lead inductances in the gate and source paths. Input resistance R_{in} is a parasitic element due to losses and power feedthrough to the output circuit. For many HF and VHF applications the input can be modeled simply by the input capacitance.

Figure 4b is a broadband matching network for an RF power FET incorporating the input model. A simplified high-frequency equivalent circuit is shown in Figure 4c. Neglecting the affect of R_{in} and L_{in} , this network is a combination of a low-pass filter and an ideal transformer. Ob-

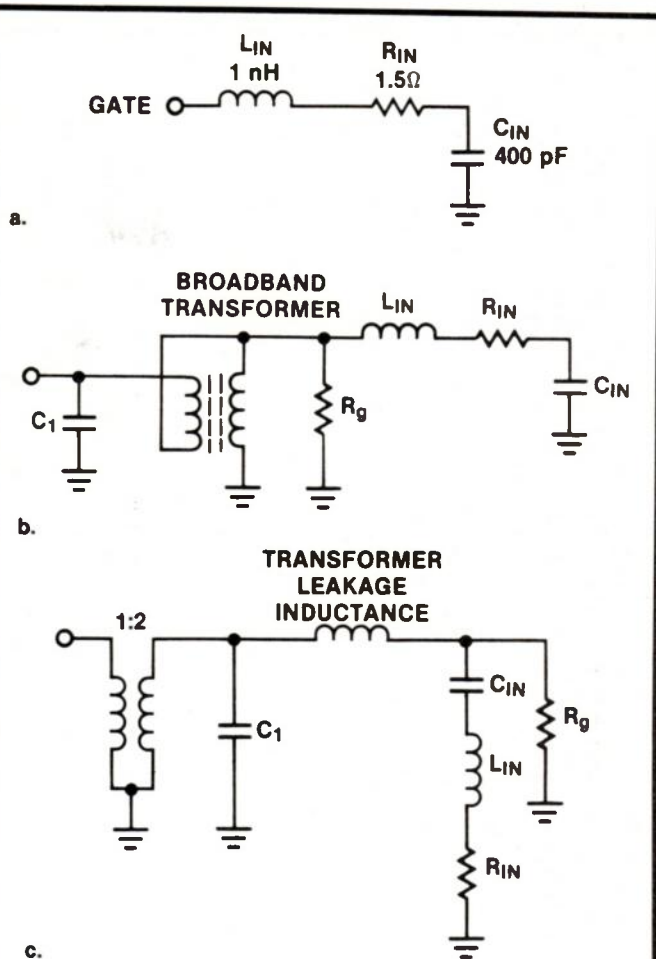


Figure 4. Applying the device input model to broadband matching network design: approximate input model, a; input model with the broadband matching network, b; and the simplified network illustrating the low-pass structure, c.

*The term "output impedance" here refers to the conjugate of the load impedance.

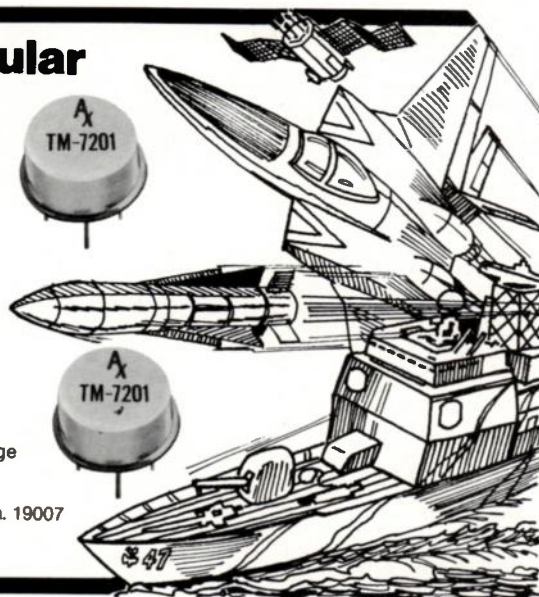
LOW COST, Multi-Stage IF/RF Modular Amplifiers, Satisfy MIL-STD-883B.

| MODEL | TM-7201 | TM-7202 | TM-7203 |
|------------------|--------------|--------------|--------------|
| Frequency: | 5-250 MHz | 5-250 MHz | 5-250 MHz |
| Gain, Min: | 28 dB | 26 dB | 28 dB |
| Gain Flatness: | ± 0.7 dB | ± 0.7 dB | ± 0.7 dB |
| Noise Fig., Max: | 5 dB | 6 dB | 3.5 dB |
| 1 dB CP min: | + 7 dBm | + 15 dBm | + 7 dBm |
| VSWR: | 2:1 | 2:1 | 2:1 |
| DC @ + 15VDC | 35 | 85 | 35 |
| Price: 1-9 | \$22 | \$30 | \$25 |

• Guaranteed specifications • Other amplifiers to 1 GHz • High Reliability • TO-8 package

Amplifonix

220 Route 13, Bristol, Pa. 19007
(215) 788-2350



INFO/CARD 29

Try Texas on for Size!

Big opportunities for RF Design Engineers.

Especially in the cable television industry, one of the fastest growing fields in the '80s. Texas is expanding steadily and is home of one of the leading cable television companies, GTE CATV in El Paso. If you want to be a part of something big, give us a call and see how you might fit into one of our current openings.

CATV Distribution Systems

You will design broadband amplifiers, filters, equalizers and other RF circuit components in the 5 to 500 MHz frequency range. This position requires three years' engineering experience with one to two years' RF circuit design background.

CATV Subscriber Systems

Responsible for the design of tuners, modulators, demodulators and other RF circuit components in the 5 to 500 MHz frequency range. Five years' RF engineering experience required.

Production Support Engineer

You will be working with CATV converters, being responsible for implementing minor design changes and general problem solving on sophisticated CATV converter products. This includes power supply microprocessor, frequency synthesis, descrambler, addressability and tuner circuits. Working closely with engineering and manufacturing groups to achieve improved productivity and other tasks. A BSEE or equivalent and three to five years' experience in CATV, TV or related consumer electronics products will qualify you.

We offer an excellent salary and benefits package, a pleasant working environment, life in the sunny climate of the Southwest and potential for advancement for the suitable candidates.

Please call Anita Rodriguez TOLL-FREE at (800) 351-2345, or send her your resume at GTE Products Corporation, CATV Division, 10841 Pellicano Drive, El Paso, TX 79935.

SYLVANIA CATV Transmission Systems is an equal opportunity employer, m/f/h.

SYLVANIA CATV Transmission
Systems

GTE

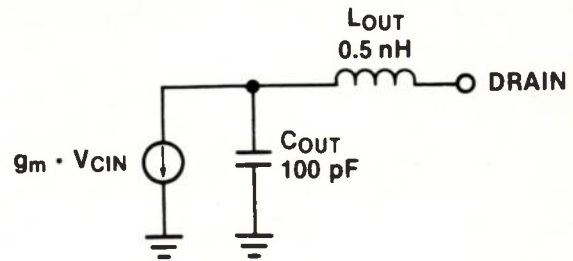


Figure 5. Approximate device output model.

taining the desired VSWR response is simply a matter of choosing the correct element values and absorbing device elements into the filter structure.

The input network is primarily responsible for the gain-bandwidth tradeoff in an RF power FET amplifier. In order to extend the cutoff frequency of the low-pass filter, the termination resistance must be lowered since C_{in} is fixed. At the same time, however, the RF voltage swing on the gate decreases, as does amplifier gain.

Two precautionary measures must be exercised when developing an input matching network. First, the amount of inductance in series with the gate lead must be minimized. The input network is basically a series resonant circuit whose resonant frequency, in most cases, lies well above the desired operating frequency. However, external series inductances can lower this resonant frequency into the operating band with a resultant gain peak followed by a declining gain response. This problem is avoided by making sure that the input termination resistor is placed as close to the device as possible.

Second, it is poor practice to operate a power FET without the input termination resistor—except near the maximum rated operating frequency. The potential problems include poor input VSWR, excessive ripple in the gain response, gate oxide puncture from excessive gate voltage and oscillation due to high-gain existing at low frequencies.

The output requirements for an RF power FET are identical to those for a bipolar transistor. The classical equation for determining the required load resistance,

$$R_L = \frac{(V_{DS} - V_{sat})^2}{2P_{out}}$$

applies equally well to a FET amplifier.

In the output model for an RF power FET, Figure 5, the capacitor and inductor can again be absorbed into a low-pass filter circuit to optimize the output bandwidth. Assuming a load resistance of 25 ohms and an output capacitance of 100pF, an output bandwidth of approximately 60 MHz should be obtainable by properly choosing the output filter network components.

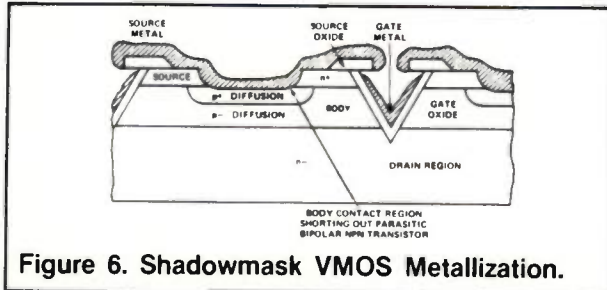
This filter network must be a singly terminated design since the device output does not provide any resistive loading at the filter input. An attempt to increase the output bandwidth by lowering the load resistance will result in reduced gain and efficiency plus possible reduction of the saturated output power.

The transconductance of the circuit in Figure 5 is relatively flat with frequency, but varies with bias conditions and drive level. These characteristics produce the flat gain response of the FET amplifier and account for the low levels of intermodulation products under Class AB bias conditions.

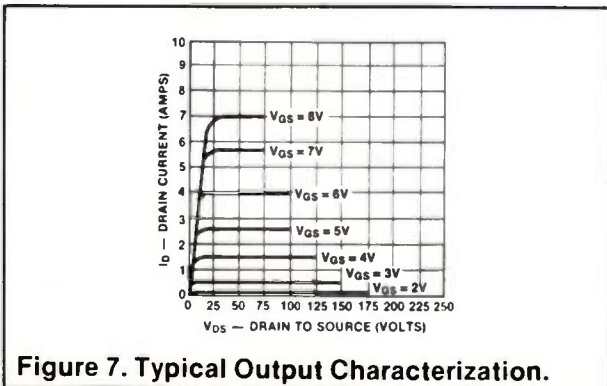
The second article of this two-part series shows how to apply the characteristics of the DVD150T power FET in the design of a broadband push-all RF amplifier.

Characteristics of the DVD150T

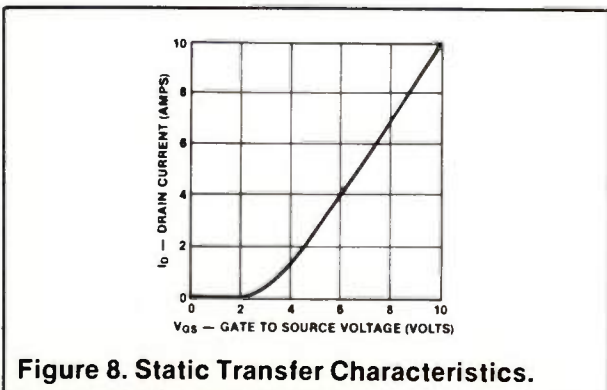
Development of the DVD150T was based on work done during 1981 for NADC regarding RF power MOSFET design and application in linear broadband high-frequency circuits. The product of this development is industry's highest power and voltage ratings for RF power FETs. Device electrical characteristics shown here, combined with favorable thermal and noise properties, are particularly beneficial for designing RF amplifiers used in communications equipment.



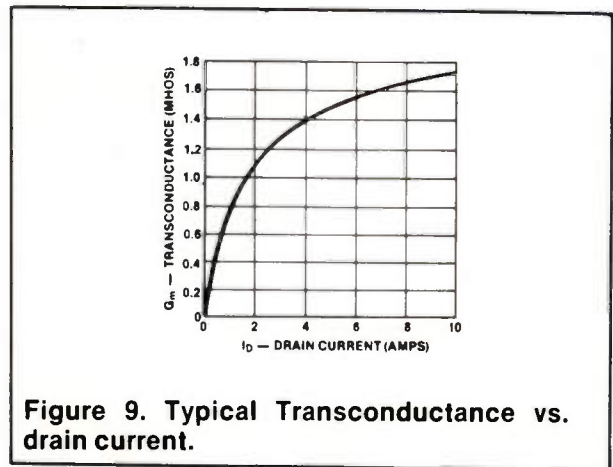
The DVD150T is fabricated with state-of-the-art processes, including shadow-mask structures that minimize gate capacitance and ion implantation that provides uniform electrical characteristics across the entire chip.



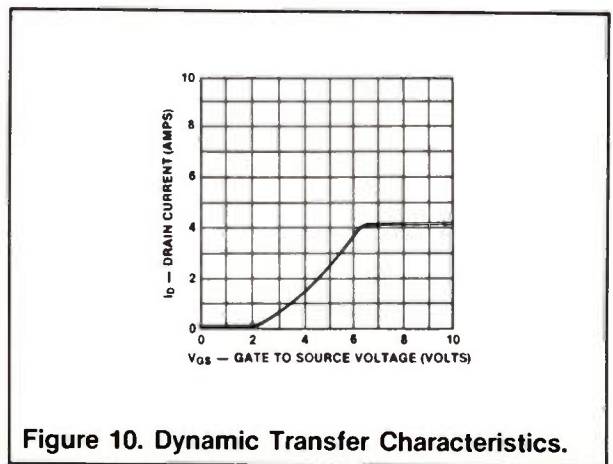
DC output characteristics exhibit the high output impedance and square-law behavior at low gate voltages typical of power FETs.



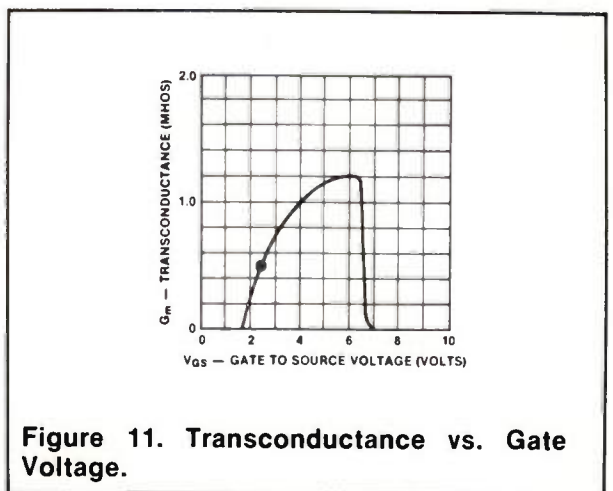
Static transfer characteristics follow the square law at low gate voltages and become linear at increased current levels—an ideal response for Class AB amplification.



The variation of transconductance with drain current is typical of RF power FETs.



This plot of the dynamic transfer characteristics is developed from the dc output characteristic by assuming a quiescent current of 500mA and a 100V supply, and by superimposing a 25-ohm load line.



In the transconductance vs. gate-voltage plot for a 25-ohm load line, the drop in transconductance just past 6V is due to device saturation. The dot on the curve indicates the recommended bias point for Class AB amplification. □

IMD ANNOUNCES: CLASS C MATCHED DEVICE AVAILABILITY: STOCK TO 30 DAYS MAX.

***Frequencies: Up to 2.7 GHz
Power Out: Up to 20 Watts
Collector Efficiency: Up to 50%
Quality: The Highest Reliability
Price: Extremely Competitive***

Engineers:

***Check the product listing on the next page...
And select the devices for YOUR SYSTEM...then contact***

**International Microwave Devices, Inc.,
51 Chubb Way, Somerville, N.J. 08876
(201) 231-1990 TELEX: 833293 IMD SVI.**

BIPOLAR MICROWAVE POWER TRANSISTORS CLASS C MATCHED DEVICES

| IMD TYPE | FREQ. (GHz) | PIN (WATTS) | POUT (WATTS) | COLL. EFF. (%) | V _{CC} (VOLTS) | θ _{JC} (°C/W) | CLASS | PKG |
|-------------|----------------|----------------|-----------------|----------------------|----------------------------|---------------------------|-------|------|
| IMD 1416-1 | 1.4-1.6 | 0.2 | 1.5 | 50 | 24 | 22.0 | C | MF-4 |
| IMD 1416-3 | 1.4-1.6 | 0.5 | 3.0 | 50 | 24 | 15.0 | C | MF-4 |
| IMD 1416-6 | 1.4-1.6 | 1.0 | 6.0 | 50 | 24 | 9.0 | C | MF-4 |
| IMD 1416-12 | 1.4-1.6 | 2.0 | 12.0 | 45 | 24 | 5.5 | C | MF-3 |
| IMD 1416-20 | 1.4-1.6 | 4.5 | 20.0 | 45 | 24 | 3.5 | C | MF-3 |
| IMD 1618-1 | 1.6-1.8 | 0.2 | 1.0 | 50 | 24 | 22.0 | C | MF-4 |
| IMD 1618-3 | 1.6-1.8 | 0.5 | 3.0 | 50 | 24 | 15.0 | C | MF-4 |
| IMD 1618-6 | 1.6-1.8 | 1.0 | 6.0 | 45 | 24 | 9.0 | C | MF-4 |
| IMD 1618-12 | 1.6-1.8 | 2.2 | 12.0 | 45 | 24 | 5.5 | C | MF-3 |
| IMD 1618-20 | 1.6-1.8 | 4.5 | 20.0 | 45 | 24 | 3.5 | C | MF-3 |
| IMD 1720-1 | 1.7-2.0 | 0.2 | 1.0 | 50 | 24 | 22.0 | C | MF-4 |
| IMD 1720-3 | 1.7-2.0 | 0.5 | 3.0 | 50 | 24 | 15.0 | C | MF-4 |
| IMD 1720-6 | 1.7-2.0 | 1.0 | 6.0 | 45 | 24 | 9.0 | C | MF-4 |
| IMD 1720-12 | 1.7-2.0 | 2.2 | 12.0 | 40 | 24 | 5.5 | C | MF-3 |
| IMD 1720-20 | 1.7-2.0 | 4.5 | 20.0 | 42 | 24 | 3.5 | C | MF-3 |
| IMD 1821-1 | 1.8-2.1 | 0.2 | 1.5 | 45 | 24 | 22.0 | C | MF-4 |
| IMD 1821-3 | 1.8-2.1 | 0.5 | 3.0 | 50 | 24 | 15.0 | C | MF-4 |
| IMD 1821-6 | 1.8-2.1 | 1.0 | 6.0 | 45 | 24 | 9.0 | C | MF-4 |
| IMD 1821-10 | 1.8-2.1 | 2.2 | 10.0 | 40 | 24 | 5.5 | C | MF-3 |
| IMD 1821-18 | 1.8-2.1 | 4.5 | 18.0 | 40 | 24 | 3.5 | C | MF-3 |
| IMD 1922-1 | 1.9-2.2 | 0.2 | 1.0 | 45 | 24 | 22.0 | C | MF-4 |
| IMD 1922-3 | 1.9-2.2 | 0.5 | 3.0 | 50 | 24 | 15.0 | C | MF-4 |
| IMD 1922-6 | 1.9-2.2 | 1.0 | 6.0 | 45 | 24 | 9.0 | C | MF-4 |
| IMD 1922-10 | 1.9-2.2 | 2.2 | 10.0 | 40 | 24 | 5.5 | C | MF-3 |
| IMD 1922-18 | 1.9-2.2 | 4.5 | 18.0 | 40 | 24 | 3.5 | C | MF-3 |
| IMD 2023-1 | 2.0-2.3 | 0.2 | 1.0 | 45 | 24 | 22.0 | C | MF-4 |
| IMD 2023-3 | 2.0-2.3 | 0.5 | 3.0 | 50 | 24 | 15.0 | C | MF-4 |
| IMD 2023-6 | 2.0-2.3 | 1.0 | 6.0 | 45 | 24 | 9.0 | C | MF-4 |
| IMD 2023-10 | 2.0-2.3 | 2.2 | 10.0 | 40 | 24 | 5.5 | C | MF-3 |
| IMD 2023-16 | 2.0-2.3 | 4.0 | 16.0 | 40 | 24 | 3.5 | C | MF-3 |
| IMD 2223-18 | 2.2-2.3 | 4.5 | 18.0 | 40 | 24 | 3.5 | C | MF-3 |
| IMD 2327-1 | 2.3-2.7 | 0.25 | 1.0 | 40 | 24 | 22.0 | C | MF-4 |
| IMD 2327-3 | 2.3-2.7 | 0.5 | 2.5 | 40 | 24 | 15.0 | C | MF-4 |
| IMD 2327-5 | 2.3-2.7 | 1.0 | 5.0 | 40 | 24 | 9.0 | C | MF-4 |
| IMD 2327-10 | 2.3-2.7 | 3.0 | 9.0 | 30 | 24 | 5.5 | C | MF-3 |
| IMD 2327-15 | 2.3-2.7 | 5.0 | 15.0 | 30 | 24 | 3.5 | C | MF-3 |

INFO/CARD 30

INTERNATIONAL MICROWAVE DEVICES



51 CHUBB WAY, SOMERVILLE, N.J. 08876 TEL. 201-231-1990 • TLX. 833293 IMD SVI

A Primer on Electronic Tuning Address Systems

Higher and higher degrees of integration keep changing communications tuning systems. This article gives the basics of electronic tuning address systems with particular emphasis on PLL systems.

*By Leonard I. Suckle
Market Development Manager
World Strategic Marketing
Motorola Semiconductor Products Sector*

Introduction

For many years the selection of a desired frequency by a tuning system had been performed by mechanically varying the LC ratio of a tuned circuit. Correct tuning was determined by means of a "feedback loop" which included the human operator in a procedure of adjustment and decision based on visual readout or, as in the case of tuning a radio, non-distorted audio output.

The advent of voltage variable capacitors (VVC) permitted the replacement of the sometimes cumbersome mechanical variable capacitor with a potentiometer to control a voltage, but this system still required the same human interface feedback system.

Further developments in characterization of the VVC voltage-to-capacitance relationships permitted the design of tuning systems which stored reference voltages that corresponded to the required capacitance for the desired frequency(s). The storage and selection medium generally consisted of a bank of switches and presettable variable resistors. Each desired frequency was preset with a potentiometer and an automatic frequency control (AFC) circuit was used to maintain correct tuning over temperature and component variations. This system was the forerunner of Electronic Tuning Address Systems (ETAS) and represented an electronic variation of the mechanical pushbutton selector commonly used in automobile radios.

A more sophisticated version of this system in use today utilizes a digital memory and D/A converter to provide voltages that correspond to the desired frequencies. These voltages are initially programmed to approximate the cor-

rect corresponding frequency. An AFC circuit may be used to update the digital information to the exact frequency, correcting for temperature and other variations. Unfortunately this system and the previously described system are dependent upon the reproducibility of the voltage-to-capacitance characteristics of the VVC, thereby creating a problem in a production environment. Furthermore, digital entry of the desired frequency may only be approximated due to the unpredictability of the characteristics of the components in the system.

Frequency Synthesis

Frequency synthesis refers to a technique that can generate many different frequencies with the use of a few reference frequencies. By appropriately defining the system, a multitude of specific frequencies may be generated by supplying corresponding digital information. This concept may be applied in a receiver where the digitally defined frequency is used as the local oscillator to heterodyne the desired incoming signal to the intermediate frequency (IF) circuits. The capabilities of frequency synthesis provide a means of tuning by switch closure or by the use of a microprocessor. Features such as digital frequency selection via keypad and frequency display are easily implemented.

How Does Frequency Synthesis Work?

The two most popular methods for frequency synthesis use either a phased locked loop (PLL) or a frequency locked loop (FLL); however, operation of both PLL and FLL systems is similar. A basic frequency synthesis system is shown in Figure 1. A reference frequency, f_r , equal to the desired output frequency, f_o , is applied to the detector X. This detector

typically represents a phase comparator in a PLL system or a frequency comparator in a FLL system. When the two input signals to the detector are equal in either phase or frequency (dependent upon the type of system), the error voltage V_E will be at reference zero. If the output frequency deviates from the reference frequency, an appropriate error voltage will be generated and fed back to the VCO which generates the output frequency. By means of this feedback loop, the output frequency is continually and automatically adjusted to be identical to the reference frequency.

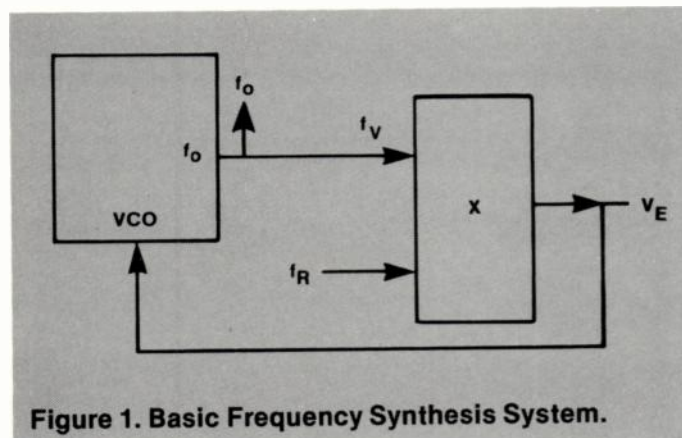
PLL Vs. FLL

The difference between a phase locked loop and a frequency locked loop system lies primarily in the type of detector used to generate the error feedback voltage (X in Figure 1). In the PLL system, a phase comparator is used which compares the phase of the two incoming signals. This is most often performed "digitally", where the incoming signals are squared and the leading edges are compared. The comparison is made on a cycle by cycle basis, which results in a fast response time to changes.

The FLL detector most often consists of some form of counter which determines the number of cycles of signal occurring in a fixed period and generates the error voltage based on the deviation of this count to the desired count. For example, the incoming comparator signal, f_v , would be applied to the clock input of a counter. The counter would be enabled for some fixed period of time, T_p , at which time the count would be compared to a value equal to the number of cycles of reference frequency, f_R , which would occur in T_p . If, after the reference period was completed, the count differed from that associated with f_R , then an appropriate error voltage would be generated.

Both of these methods have their advantages and disadvantages. The PLL has a fast response time where the error voltage is updated on a cycle by cycle basis at the reference frequency. This fast response results in a disadvantage that the error voltage will contain varying amplitudes of frequency at multiples of the reference frequency which must be filtered before it is applied to the VCO. As will be shown later, the reference frequency must be chosen as a compromise, to provide the tuning resolution required as well as to be at a frequency that may be adequately filtered.

The FLL system may be implemented by using a counter



or even an MPU instead of the phase comparator required in a PLL system. Furthermore, the residual frequency components in the error voltage are very easily filtered, independent of tuning resolution. The main disadvantage of FLL is slower response time, since the error voltage may only be updated at the rate of the sample period, T_p . This sample period, as with the case of reference frequency in PLL, is chosen as a compromise to provide sufficient tuning resolution while also providing adequate response time.

PLL Frequency Synthesis

PLL is the most commonly used frequency synthesis method in use today. The remainder of this article will be devoted to this particular method.

The addition of programmable counters, C_N , C_P and C_R as shown in Figure 2, provides a means of programming for a variety of desired output frequencies. These counters may be programmed to divide their input frequency by a count of N, P or R, respectively. In this system, the reference frequency f_R is equal to the clock frequency f_{CLK} divided by R. Also, the detector input frequency, f_v , is now equal to the output frequency, f_o , divided by the product of P and N. The feedback operation described for Figure 1 is identical in this system, and the error voltage adjusts the VCO until f_v equals f_R . In terms of the clock frequency and the output frequency,

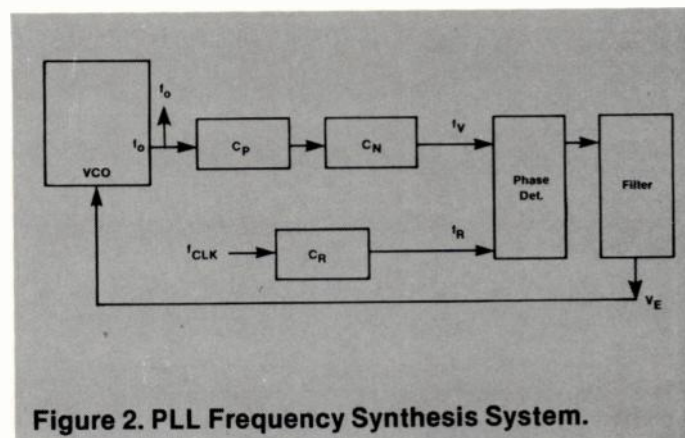
$$f_o = (N)(P)(f_{CLK})/R$$

It should follow that a wide selection of frequencies may be generated by correctly programming the three counters.

System Components

Each system component shown in Figure 2 must be chosen to create a system which meets the design specification and capabilities of existing available products.

Counter C_P is called a prescaler. It is generally a non-programmable counter and has the function of reducing the desired output frequency, f_o , to a value which can be handled by the programmable counter C_N , since programmable counters typically have lower clock speeds, generally in the range of 20 to 30 MHz. If an f_o of 500 MHz is required, a prescaler with this frequency capability and a count value of greater than 25 would be required. High frequency prescalers are presently available for operation at 1 GHz and above.



Counter C_N is a programmable counter that provides the capability of selecting the output frequency. To determine the value of this counter, we must first determine the reference frequency to be applied to the PLL. The reference frequency selected is dependent upon the required tuning resolution. Referring once again to Figure 2, it may be seen that the phase comparator frequency, f_v , will be equal to the output frequency, f_o , divided by the prescaler count P , and also divided by whatever count, N , that has been programmed into C_N . If we let $N = 1$, then $f_v = f_o/P$. As we increase the value of N in unit increments, f_v will increase in increments of f_o/P . The finest resolution to which we can adjust f_o is equal to $(f_v)(P)$. But the feedback system will always adjust f_v to equal f_R . Thus, the actual resolution of our system is

$$\text{Resolution} = (f_R)(P)$$

Since the required resolution is specified by the application, and the prescaler value is determined by the maximum frequency of operation and the electrical limitations of programmable counters, the reference frequency may be

determined using the above equation. Once this frequency is derived, C_N may be determined by

$$N(\text{max}) = f_o(\text{max}) / ((P)(f_R))$$

Counter C_R is used to derive the required reference frequency. Generally clock oscillators are available in a system, or oscillators of certain frequencies are easier or more cost effective to produce than the actual reference frequency required. The divide value R of C_R is appropriately chosen.

Single Vs. Dual Modulus

The system shown in Figure 2 has been shown to develop an output frequency equal to the reference frequency times the product of the prescaler and programmable counters. This type of system is called "single modulus" because for any specific frequency, N and P are fixed and always reset to the same designated value. The tuning resolution of the system has been shown to equal $(f_R)(P)$, and to increase the resolution either the value of P or the reference frequency must be reduced. Reducing the value of P may exceed the input frequency capabilities of C_N . Reducing the value of the reference frequency lowers the residual frequency at the output of the phase comparator, which increases the difficulty of adequately filtering the error voltage.

An alternate system is shown in Figure 3. This is called a "dual modulus" system because the moduli of the frequency counters C_P and C_N change on alternating resets. A special dual modulus prescaler is required for this system. The prescaler will count either to P or $P + 1$, depending on a modulus control input. Furthermore, the programmable counter C_N in Figure 2 is replaced by two programmable counters, C_A and C_N .

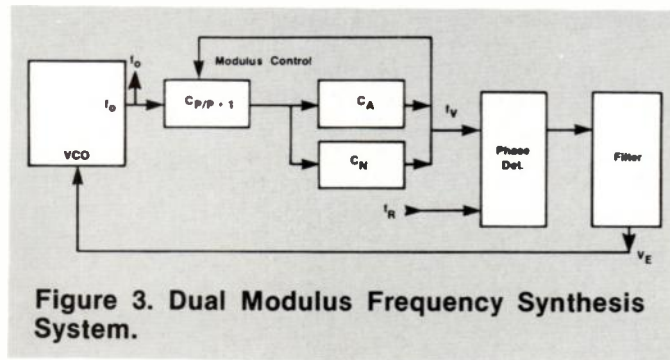
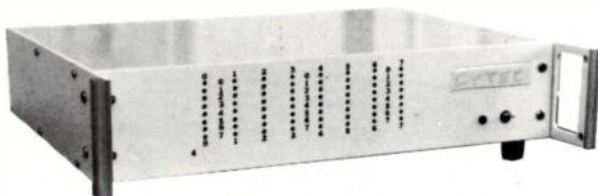


Figure 3. Dual Modulus Frequency Synthesis System.

FOR TOTAL SWITCHING CAPABILITY

CX SERIES

PROGRAMMABLE MATRICES AND MULTIPLEXERS



CX 8x8 MATRIX

STANDARD FEATURES INCLUDE:

- D.C. TO 100 MHz SIGNAL SWITCHING
- 50 OHM CHARACTERISTIC IMPEDANCE LINES
- LATCH, UNLATCH OR CLEAR SELECTED SWITCHES
- LED INDICATION OF SWITCH STATUS

OPTIONS INCLUDE:

- IEEE 488 BUS INTERFACE
- RS 232 REMOTE CONTROL & VERIFICATION
- MICROPROCESSOR AND STD BUS COMPATIBLE
- FRONT PANEL MANUAL CONTROL

MODULAR

FOR CUSTOM CONFIGURATIONS

YTEC CORP.

107 N. Washington St.
E. Rochester, N.Y. 14445
(716) 381-4740

INFO/CARD 31

Frequency control products by *erc*

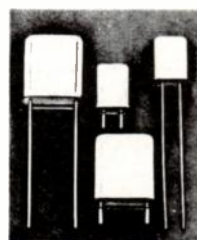
Crystal Oscillators/Quartz Crystals

CRYSTAL OSCILLATORS



ERC has available a wide variety of crystal oscillators from 1Hz to 300-MHz. Ovenized crystal oscillators utilize DC proportional controlled ovens with a unique construction which results in low power requirements and improved reliability. Temperature Compensated Crystal Oscillators (TCXO), are manufactured under exacting controlled conditions resulting in improved frequency stability specifications versus temperature.

QUARTZ CRYSTALS



Complete frequency range from 10KHz to 200MHz with Q.P.L. approval on Military crystals to Mil-C-3098. Precision coldweld crystals are available for applications requiring improved long term and short term stability. Crystal units are available in various case sizes and configurations depending on frequency and mounting requirements. ERC offers complete flexibility in specifying crystals and assistance for their applications.

erc

Call or Write

electronic research company

7618 Wedd, Overland Park, Kansas 66204
TWX: (910) 749-6477 • Telephone: (913) 631-6700

INFO/CARD 32

September/October 1982



tough attenuators

from **\$11.95**
(1-49)

the world's lowest-priced coax attenuators
3, 6, 10 or 20 dB...from DC to 1500 MHz
one-piece design defies rough handling

Check these features:

- ✓ Solid one-piece tubular construction
- ✓ Available with BNC, N, SMA, TNC connectors
- ✓ Male/female connectors standard
- ✓ Connector series intermixing available
- ✓ 2 watts max. power (except 0.5W for SMA)
- ✓ Excellent temperature stability, .002 dB/°C
- ✓ Low-cost, only \$11.95 BNC (1-49 qty.)
attenuation values may be combined
- ✓ Delivery, from stock
- ✓ Exclusive one-year guarantee

| Model | Attenuation, dB | Attenuation Tolerance | Frequency MHz | Attenuation Change over Frequency Range, MHz | | VSWR Max. (50 ohms) | |
|--------|-----------------|-----------------------|---------------|--|-----------|---------------------|-----------|
| | | | | DC-1000 | 1000-1500 | DC-1000 | 1000-1500 |
| —AT—3 | 3 | ±0.2dB | DC-1500 | 0.6dB | 1.0dB | 1.3:1 | 1.5:1 |
| —AT—6 | 6 | ±0.3dB | DC-1500 | 0.6dB | 0.8dB | 1.3:1 | 1.5:1 |
| —AT—10 | 10 | ±0.3dB | DC-1500 | 0.6dB | 0.8dB | 1.3:1 | 1.5:1 |
| —AT—20 | 20 | ±0.3dB | DC-1500 | 0.6dB | 0.8dB | 1.3:1 | 1.5:1 |

— Add prefix **C** for BNC (\$11.95), **T** for TNC (\$12.95),
N for Type N (\$15.95), **S** for SMA (\$14.95)

finding new ways...
setting higher standards

 **Mini-Circuits**

A Division of Scientific Components Corporation
World's largest manufacturer of Double Balanced Mixers
2625 East 14th Street, Brooklyn, New York 11235 (212)769-0200
Domestic and International Telex 125460 International Telex 620156

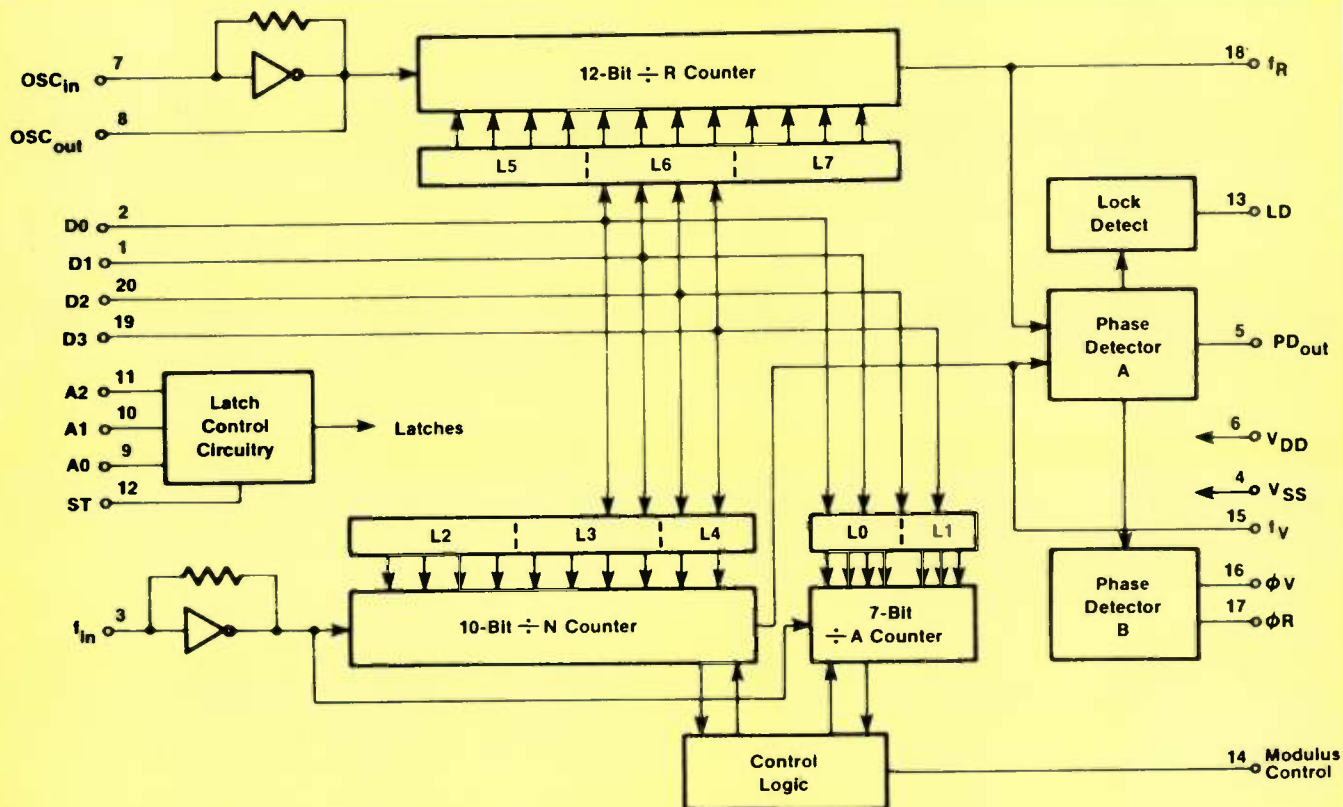


Figure 4. Motorola MC 145146 Dual Modulus Frequency Synthesizer.

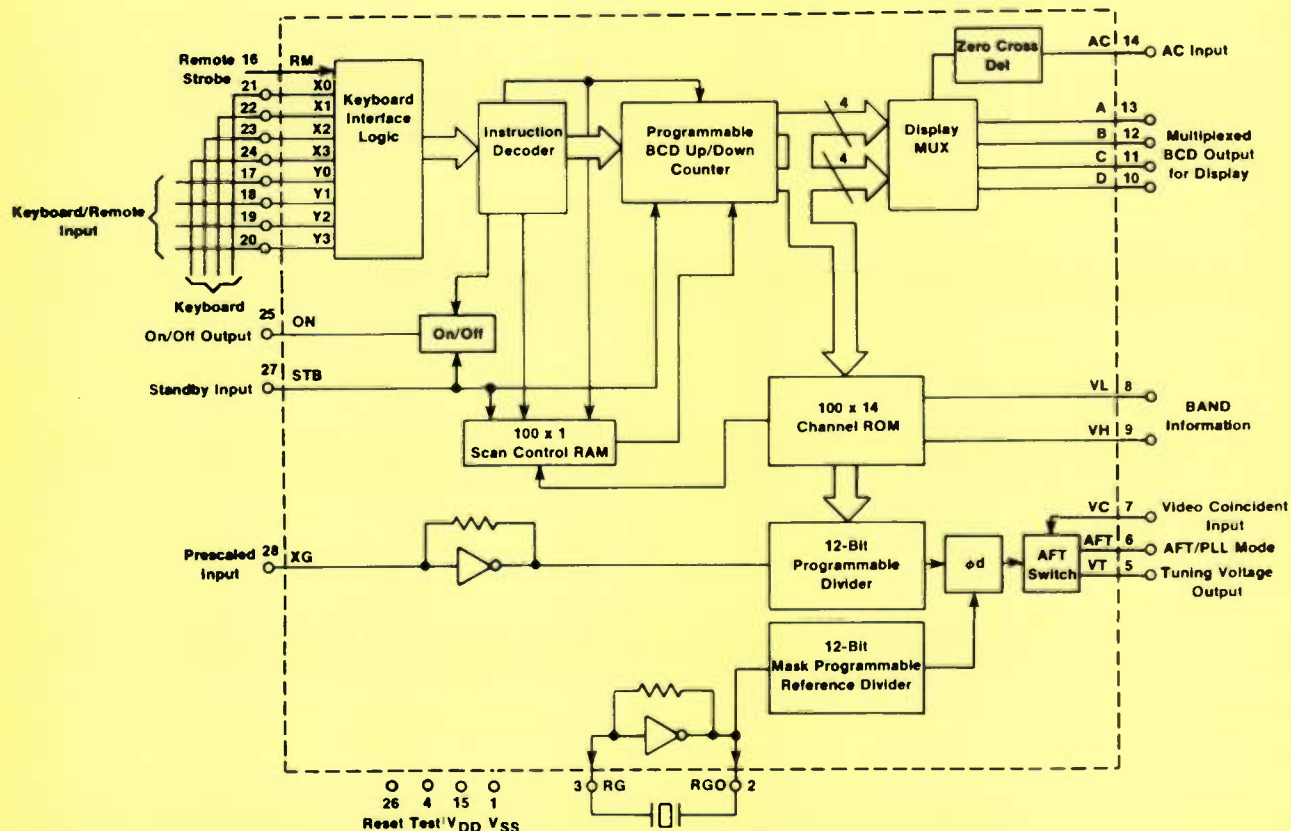


Figure 5. Motorola MC 6191 Frequency Synthesizer Block Diagram.

If nine to five finds you between 1 MHz and 1 GHz, we just made your job a lot easier. Because your new partner, the Wavetek Model 1080 Sweep Generator, is a real workhorse.

It sweeps from 1 to 1000 MHz without a band change. That's in the full sweep mode, where you have a continuously adjustable marker. The other modes are CW and ΔF , where you have a variable sweep width centered around the

marker frequency. Output is also continuously adjustable, from +13 to -70 dBm. And the sweep rates go from 10 milliseconds to 100 seconds.

You'll find Model 1080 easy to understand. There are digital readouts for frequency and output power level. Plus a simplified control panel.

Model 1080 is ready to go to work the moment it's out of the box. No mainframe to mess with, just plug it into the wall.

And it's inexpensive. Just \$2225 including 1, 10 and 100 MHz harmonic comb markers.

To get better acquainted with the Model 1080 Sweep Generator, contact: Wavetek Indiana, Inc., 5808 Churchman, P.O. Box 190, Beech Grove, IN 46107. Phone Toll Free 800-428-4424. In Indiana (317) 787-3332. TWX 810-341-3226.

WAVETEK[®]

Demonstration: INFO/CARD 1
Literature: INFO/CARD 2

Great news for anyone who sweeps for a living!



Very easy solutions



to very tough problems.

Building military systems means facing problems. Problems we at M/A-COM OSW with MIC GaAs FET amplifiers have been helping to solve for years.

Our solutions are simple.

We build amplifiers in the 2 GHz to 18 GHz range to fit **your specs**... and to fit **your package**. We are rigid on quality, but flexible on design. We have the expertise, the experience and the proven production capability. Plus, we are organized to provide special responsiveness to your specific needs.

We can build discrete or hybrid MIC GaAs FET amplifiers in the bandwidth you select; give your system high reliability while giving yourself a cost competitive edge.

With our packaging we can second source any amplifier in the 2 GHz to 18 GHz range;

With our performance we out do them all.

Whether you are seeking a first, second, or only source look to M/A-COM OSW your source for microwave MIC GaAs FET amplifiers. Give us a call for an easy solution to your toughest problem.

FEATURES:

Limiting amplifiers/Electronic gain control-EGC/
Multiple inputs and outputs/Detector outputs/Fault
detection or BIT/Protection from RF levels up to 200W



M/A-COM OSW, INC. Microwave Subsystems Division

2626 S. Hardy Drive, Tempe, AZ 85282, (602) 966-1471, TWX: 910-950-1296

INFOCARD 34

SPECIAL LOW

A return to "Old-fashioned" image parameter design methods for those special applications.

By Andrzej B. Przedpelski
A.R.F. Products, Inc.
Boulder, Colorado

An ideal filter (let's discuss only the amplitude characteristics) is one which passes the frequencies of interest and attenuates the unwanted frequencies the minimum required amount—and no more. Unneeded attenuation (or passband) only complicates the design and its execution.

When a lowpass filter is required, an engineer will usually look for a Chebyshev, Butterworth, or, maybe, an elliptic design. These, in a large number of applications, are very inefficient and costly. These applications include any basically fixed frequency signal which contains harmonics, which are undesirable. Typical examples are fixed frequency transmitter output and converting a square wave signal to a sine (such as after frequency division).

While the above mentioned filter types may be "Modern Network Theory", the "old-fashioned" image-parameter design may be more suitable in this case. In an m -derived filter,⁽¹⁾ the value of m can be chosen so that the maximum pass frequency is the desired frequency and the second harmonic (for instance) frequency is the frequency of maximum attenuation. The third and higher harmonics will be attenuated less, but that is what is usually required in these applications. Unfortunately, the values for m become un-

reasonable (0.87 for second harmonic attenuation and 0.94 for third, where about 0.6 is preferred).

A much better approach is to start from the beginning and analyze the problem systematically. Let's start with a simple pi type lowpass filter section, as shown in Figure 1(a). In addition, it has been shown that this configuration is also suitable for matching two unequal characteristic impedances ($R_i \neq R_o$). The component reactances, at the pass frequency, (F_o), are⁽²⁾:

$$X_a = -\frac{R_i}{Q} \quad (1)$$

$$X_b = \frac{R_i \left[Q + \sqrt{\frac{R_o}{R_i} (1 + Q^2)} - 1 \right]}{1 + Q^2} \quad (2)$$

$$X_c = -\sqrt{\frac{R_o}{R_i} (1 + Q^2)} - 1 \quad (3)$$

where Q is any value equal to or higher than Q_{\min} :

$$Q_{\min} = \sqrt{\frac{R_i}{R_o} - 1} \quad (4)$$

At the stop frequency, (F_∞), we would like to make the circuit look like Figure 1(b), which would give infinite attenu-

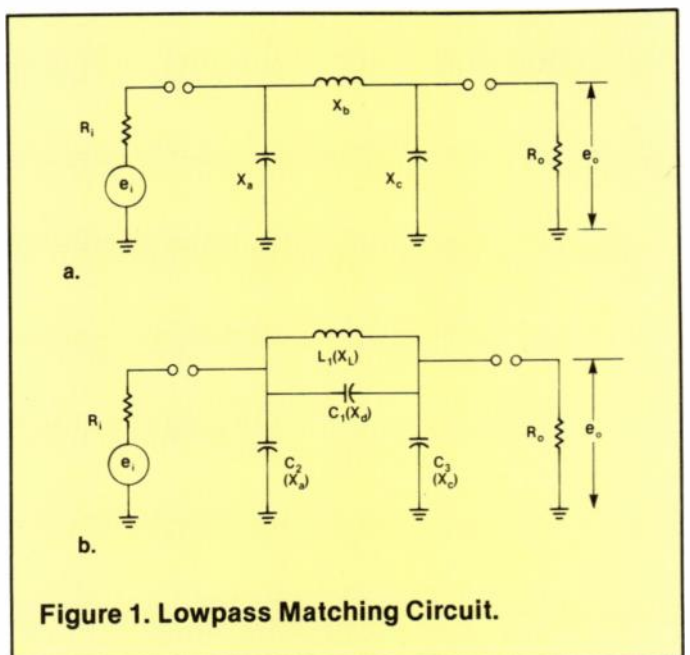


Figure 1. Lowpass Matching Circuit.

PASS FILTERS

ation at that frequency, using lossless components. Since F_{∞} is larger than F_o , this is a feasible requirement. Starting with:

$$X_L = -X_d \text{ at } F_{\infty} \quad (5)$$

we obtain:

$$L_1 = \frac{1}{(2\pi F_{\infty})^2 C_1} \quad (6)$$

Since the two circuits of Figure 1 have to be equivalent

$$\frac{1}{\frac{1}{2\pi F_o L_1} - 2\pi F_o C_1} = X_b \quad (7)$$

Substituting (6) into (7) and equating to (2), the value of C_1 can be calculated:

$$C_1 = \frac{F_o(1 + Q^2)}{2\pi R_i(F_{\infty}^2 - F_o^2)[Q + \sqrt{\frac{R_o}{R_i}(1 + Q^2) - 1}]} \quad (8)$$

C_2 can be calculated from (1):

$$C_2 = \frac{Q}{2\pi F_o R_i} \quad (9)$$

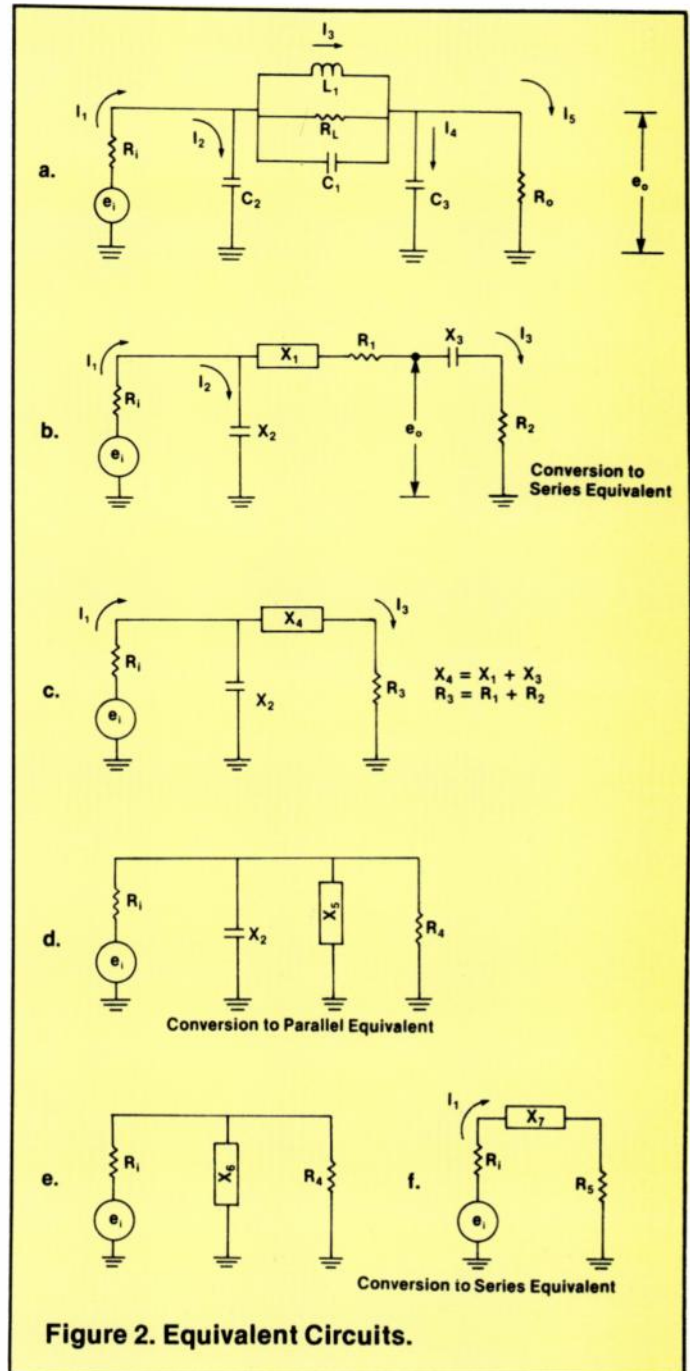
and C_3 from (3):

$$C_3 = \frac{\sqrt{\frac{R_o}{R_i}(1 + Q^2) - 1}}{2\pi F_o R_o} \quad (10)$$

Equations (8), (6), (9) and (10) thus give component values for a filter which passes F_o , attenuates F_{∞} and provides maximum power transfer from the source (R_i) to the load (R_o) at the pass frequency.

An HP-41 C/V program which calculates all the circuit values is shown in Table I. The program calculates Q_{min} and asks for a value for Q (given R_i , R_o , F_o and F_{∞}). Any value equal to Q_{min} or higher can be used. The significance of the chosen Q will be discussed later. R_i has to be larger than R_o for the component calculation. However, the filter is bilateral and can be used in either direction.

Once the filter is designed its performance should be checked to see if it satisfies the performance requirements. This can be done using the program of Table II. If only non-lossy components were used, the task of calculating the insertion loss would be easy. The reflection coefficient could be calculated and, from it, the insertion loss⁽³⁾. However, to make the program more versatile a lossy inductor was included, which is more representative of the actual circuit. This necessitates a different method of insertion loss calculation⁽⁴⁾. This method is shown in Figure 2. In this case either R_i or R_o can be larger. The program will calculate the correct step-down or step-up insertion loss.



NEC

SHATTERS

The GaAs FET Price Barrier

Introducing the 700 Series

| NE700 | f (GHz) | NF (dB) | G _a (dB) |
|---|------------|------------|------------------------|
| | | TYPICAL | TYPICAL |
| V _{DS} = 3V, I _{DS} = 10mA | 4 | 0.7 | 14.0 |
| | 8 | 1.2 | 11.0 |
| | 12 | 1.9 | 9.0 |

| NE720 | f (GHz) | NF (dB) | G _a (dB) |
|---|------------|------------|------------------------|
| | | TYPICAL | TYPICAL |
| V _{DS} = 3V, I _{DS} = 10mA | 4 | 1.0 | 13.0 |
| | 8 | 1.7 | 9.0 |

The NE700 and NE720 are NEC's newest low cost recessed gate GaAs FETs. The NE700 is a 0.5 micron device featuring low noise figure and high associated gain through 18 GHz. The NE720 is a 1.0

micron device offering low noise figure and high associated gain through 8 GHz. These devices are available in chip form or in a hermetically sealed stripline package. Both devices have glassivated gate and

channel areas and all bonding pads use a Ti-Pt-Au metallization structure. The NE700 and NE720 series are the answer to your low cost GaAs FET needs.



CALIFORNIA EASTERN LABORATORIES, INC.

Exclusive sales agent for **NIPPON Electric Co., Ltd.** Microwave Semiconductor Products.

Headquarters, Santa Clara, CA 95050, 3005 Democracy Way, (408) 988-3500 • Burlington, MA 01803, 3 New England Executive Park, (617) 272-2300 • Cockeysville, MD 21030, 12 Galloway Ave., (301) 667-1310 • Kansas City, MO 64118, 6946 North Oak Street, (816) 436-0491 • Scottsdale, AZ 85251, 7336 E. Shoeman Lane #116W, (602) 945-1381 • Irvine, CA 92715, 2182 Dupont Drive, Suite #24, (714) 752-1665 • Los Angeles, CA 90045, 6033 W. Century Blvd., Suite 840, (213) 645-0985 • Tigard, OR 97223, 7100 S.W. Hampton St., Suite 137, (503) 684-1687 • Richardson, TX 75081, 1101 E. Arapaho Road, Suite 139, (214) 644-3689.

Using

$$I_1 = \frac{e_i}{R_1 + R_5 + jX_7} \quad (11)$$

and

$$e_o = I_3(R_2 + jX_3) \quad (12)$$

and

$$\frac{I_3}{I_1} = \frac{R_5 + jX_7}{R_3 + jX_4} \quad (13)$$

the circuit gain can be calculated:

$$\frac{e_o}{e_i} = \frac{I_3(R_2 + jX_3)}{I_1(R_1 + R_5 + jX_7)} = \frac{(R_5 + jX_7)(R_2 + jX_3)}{(R_3 + jX_4)(R_1 + R_5 + jX_7)} \quad (14)$$

which can be expressed in dB:

$$\frac{e_o}{e_i} = 20 \log \left| \frac{R_5 + jX_7(R_2 + jX_3)}{(R_3 + jX_4)(R_1 + R_5 + jX_7)} \right| \text{ dB} \quad (15)$$

This gain includes the transformation gain, circuit losses and the effect of source impedance (i.e., a lossless circuit with $R_1 = R_o$ will give a gain of -6 dB).

An example will show the advantages of this circuit compared to the usual lowpass filter. Let's assume that a signal, at a 500 ohm impedance level, has a second harmonic content of -20 dBc and a third harmonic of -30 dBc. An output, at 50 ohms, with a harmonic content of less than -60 dBc is required. Dissipative insertion loss cannot exceed 1 dB and the circuit should be matched for maximum power transfer.

Using a lossless standard Butterworth lowpass filter, an 8-pole design is needed. In addition, an impedance transformation network is required. With a lossless 1 DB ripple Chebyshev design only 5 poles are required in addition to

"Leader in the Placement
of RF Engineering Professionals"
Call Toll Free 1-800-433-2160

RF Design Engineer (252)

5+ yrs. exp. + BSEE req. Design RF circuits, RF amps of 10-900 MHz. Knowledge of Basic or Fortran a real plus. Excellent N.E. Loc. with salary to 35K.

RF Design Engineer (250)

BSEE + 1 yr. min. wideband exp. req. Design RF amps for next generation CATV. Salary 35-40K plus excellent Calif. loc. with big name company.

RF Design Engineer (247)

Strong R&D background + GaAs FET exp. + min. 2 yrs. RF design. N.Y. loc. with salary to 50K.

RF Design Engineer (249)

5+ yrs. desired with salary in high 40's in beautiful scenic Arizona location.

RF Staff Engineer (185)

Work in relaxed broadband engr. group designing state-of-the-art CATV components in excellent New England location. Salary 35-45K with lots of benefits.

RF Systems Engineer (172)

1+ yrs. exp. in evaluation and specifications of analog and digital microwave satellite transmission. N.E. location with salary in high 30's.

Advanced Technology Engineer (171)

1+ yrs. exp. in design, analysis & installation of video/audio digital & voice transmission. Salary in 40's, New England loc.

Fees Paid—Confidential & Professional

JIM YOUNG & ASSOCIATES

One Young Plaza, Weatherford, TX 76086

Call for information about these and our many other opportunities nationwide.

IN TEXAS CALL COLLECT (817) 599-7623

EAS

ELECTROLINE'S ADDRESSABLE SYSTEM

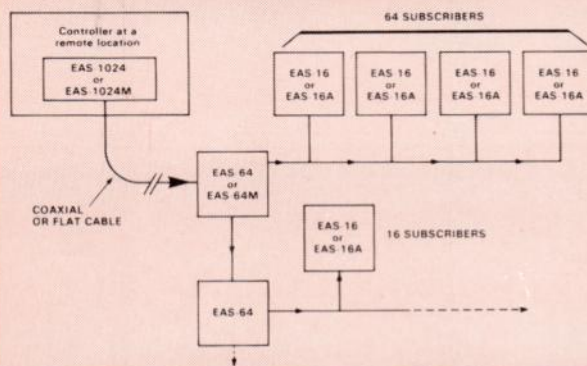
*A cost-effective system
offering maximum security
with ease of control for
multi-unit buildings.*

EAS

Designed to control access or premium service to subscribers in multidrop buildings. The system is modular in

design. Security is maintained by means of continuous scanning. EAS is ideal for apartments, hotels, hospitals or other such location where constant control is needed and to provide visual audit of each subscriber's status.

ADDRESSABLE SYSTEM



EAS

The above system is composed of 3 units — a microprocessor control (EAS-1024); a decoder (EAS-64); and a wide-band, multitap switch assembly (EAS-16). The system can be installed in 2 alternative configurations and is most compatible with other systems.

Illustrated folder with specifications upon request.

et

ELECTROLINE Television Equipment Inc.

8750, 8th Avenue, St-Michel
Montreal, Que. H1Z 2W4

or phone **collect**
(514) 725-2471

Representatives across
Canada and the U.S.A.

- ☐ TAPS
- ☐ FILTERS
- ☐ COUPLERS
- ☐ SPLITTERS
- ☐ SPECIAL AMPLIFIERS
- ☐ SWITCH-TRANSFORMERS

INFO/CARD 36

RF ENGINEERS

E-Systems Melpar Division, a growth oriented electronics firm, is currently seeking experienced RF Engineers interested in helping continue to create the technology of tomorrow. These positions will involve design, development and testing of RF, IF and baseband circuits and subsystems. RF frequency to 2500 MHz covered. Low cost, light weight design techniques are essential. Must have 3 years' applicable experience.

If you qualify, rush your resume to:
E-Systems, Inc., Melpar Division,
7700 Arlington Blvd., Falls Church,
VA 22046.

U.S. Citizenship Required.

An equal opportunity employer, M/F, H, V.
We practice and support affirmative action.



NOW! HIGH LEVEL RETURN LOSS MEASUREMENTS

EAGLE Return Loss Bridges allow high performance SWR measurements from 50kHz to 500mHz. All bridges include RF output at test port and a precision internal reference. Our five watt power rating is unmatched by anyone; This allows the bridge to be used to directly drive power amplifiers or measure amplifier output return loss under dynamic conditions! The directivity of the bridges is 40db minimum with typical performance of 50db. A rugged nickel plated brass enclosure assures excellent durability and shielding. These units are available from stock in the following ranges:

RLB 150-1 50kHz to 150mHz

RLB 150-2 10mHz to 500mHz

All units are tested using an automatic test set with data supplied at no extra charge. Price starts at \$129.00

NEED MORE INFORMATION? PLEASE CALL OR WRITE!

EAGLE
(714) 728-6000

300 N. MAIN ST.

FALLBROOK, CA 92028

INFO/CARD 37

```
01*LBL "TRAF"
02 SF 21
03 RCL 12
04 RCL 13
05 /
06 1
07 -
08 SORT
09 "MIN Q = "
10 ARCL X
11 RVIEW
12 "Q = ?"
13 PROMPT
14 "Q = "
15 ARCL X
16 RVIEW
17 ENG 2
18 STO 14
19 2
20 /
21 PI
22 /
23 RCL 15
24 /
25 RCL 12
26 /
27 RND
28 STO 19
29 "C2 = "
30 ARCL X
31 RVIEW
32 RCL 13
33 RCL 12
34 /
35 RCL 14
36 X+2
37 1
38 +
39 *
40 1
41 -
42 SORT
43 STO 18
44 2
45 /
46 PI
47 /
48 RCL 15
49 /
```

STORE:
R₁₂ - R₁
R₁₃ - R₀
R₁₅ - R₀
R₁₆ - F₀₈

Table I.

```
01*LBL "LPTR"
02 FS? 00
03 CTO 00
04 "F=? "
05 PROMPT
06 VIEW X
07*LBL 00
08 ST+ X
09 PI
10 *
11 STO 21
12 FIX 2
13 RCL 17
14 *
15 STO 25
16 1/X
17 RCL 18
18 RCL 21
19 *
20 -
21 1/X
22 RCL 25
23 RCL 26
24 *
25 X<Y
26 1/X
27 X<Y
28 1/X
29 R-P
30 1/X
31 P-R
32 STO 24
33 X<Y
34 STO 25
35 RCL 13
36 RCL 20
37 RCL 21
38 *
39 CHS
40 X<Y
41 1/X
42 R-P
43 1/X
44 STO 22
45 X<Y
46 STO 23
47 X<Y
```

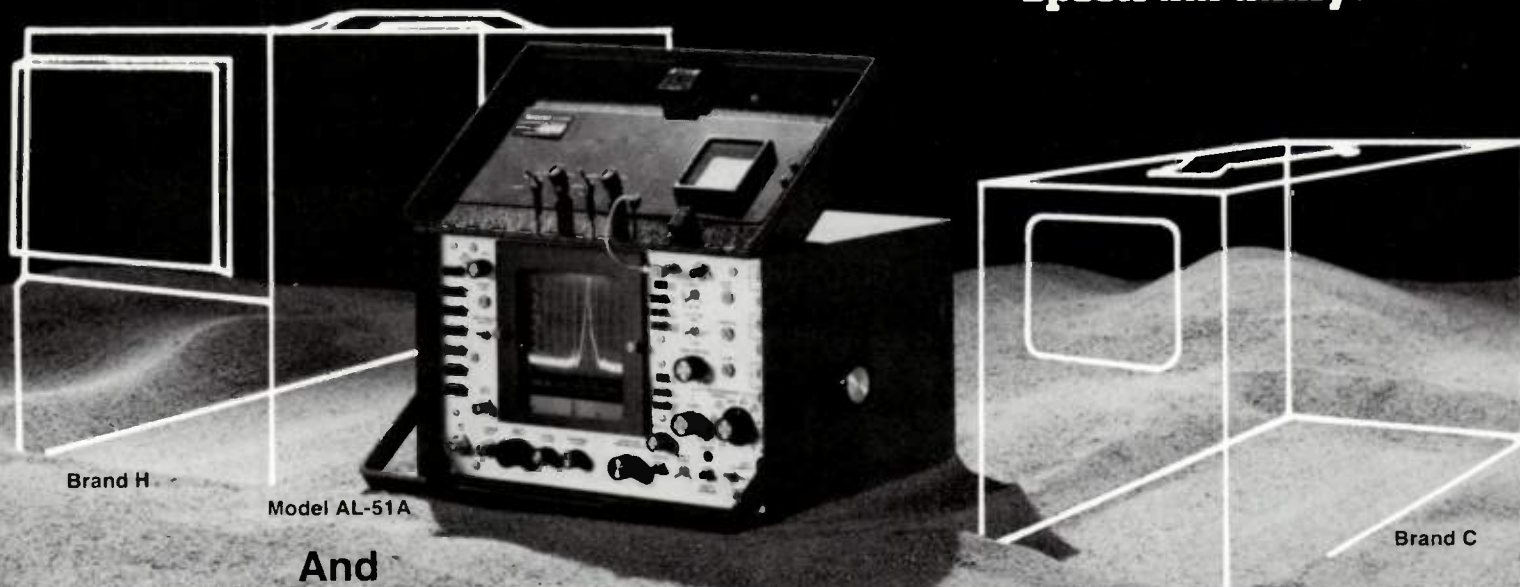
STORE:
R₁₂ - R₁
R₁₃ - R₀
R₁₇ - R₁
R₁₈ - C₁
R₁₉ - C₂
R₂₀ - C₃
R₂₆ - Q_L

Table II.

SET FLAG 00
FOR PRPLOT

the rugged truth

Texscan is the world leader in portable spectrum analyzers



And here's proof . . .

| SPECIFICATION | BRAND H* | TEXSCAN'S AL51A | BRAND C* |
|---|-----------------------------|----------------------------|-------------------|
| FREQUENCY RANGE | 0.1—1500 MHz | 0.4—1000MHz | 1—1000MHz |
| DISPERSION | 50KHz—1000MHz | 20KHz—1000MHz | 100KHz—100MHz |
| FREQUENCY ACCURACY | 2% of dispersion \pm 5MHz | \pm 0.01% | \pm 5MHz |
| AMPLITUDE DYNAMIC RANGE | 70dB | 60dB | 70dB |
| AVERAGE NOISE LEVEL | -107dBm (10KHz resolution) | -118dBm (10KHz resolution) | NOT SPECIFIED |
| ACCURACY (total worst case) | \pm 3.5dB | \pm 4dB | \pm 3dB |
| RESOLUTION (min) | 1KHz | 500Hz | 2KHz |
| STABILITY | | | |
| SHORT TERM P/P | 1KHz | 500Hz | NOT SPECIFIED |
| LONG TERM | NOT SPECIFIED | 25KHz/10 min | 50KHz/5 min |
| NOISE SIDEBANDS | -65dB 50KHz away | -70dB 50KHz away | -70dB 50 KHz away |
| OPERATING POWER | 115/230vac | 115/230vac 12 v dc | 115/230 vac |
| SIZE CUBIC INCHES | 2059 | 1092 | 1503 |
| WEIGHT LBS | 40lbs | 27lbs (incl battery) | 30lbs |
| FEATURES | BRAND H* | TEXSCAN'S AL51A | BRAND C* |
| INTERNAL BATTERY | NOT OFFERED | STANDARD | NOT OFFERED |
| EXTERNAL 12v ac oper | NOT OFFERED | STANDARD | OPTIONAL |
| PHASELOCK | NOT OFFERED | STANDARD | NOT OFFERED |
| AUDIO | NOT OFFERED | OPTIONAL | STANDARD |
| FREQUENCY MARKERS | NOT OFFERED | STANDARD | NOT OFFERED |
| DIGITAL STORAGE | OPTIONAL | OPTIONAL | NOT OFFERED |
| PRESET FREQUENCY BANDS | NOT OFFERED | STANDARD | NOT OFFERED |
| TWO LOG RANGES | STANDARD | STANDARD | NOT OFFERED |
| RUGGED CARRYING CASE WITH FRONT PANEL COVER | OPTIONAL | STANDARD | OPTIONAL |

*Information obtained from manufacturer's published data.

We've given you the facts . . . Call us now with your order

Texscan Corporation
2644 North Shadeland Ave.
Indianapolis, IN 46219
(317) 367-6781

Texscan Instruments Ltd.
One Northwidge Road
Barnhampton, Dorsetshire, UK
P.O. 04427/7113g

Texscan GmbH
Postfach 11
D-8500 München 53, W. Germany
P.O. 03657/1045

Texscan

3-5991
©Texscan Corporation 1981

INFO/CARD 34

MIN Q = 3.00
Q = 4.00
C2 = 1.27E-9
C3 = 2.66E-9
C1 = 373.E-12
L1 = 17.0E-6

1,000,000.00
RESP= -16.30 DB
2,000,000.00
RESP= -76.45 DB
3,000,000.00
RESP= -46.19 DB

$Q_L = \infty$

MIN Q = 3.00
Q = 4.00
C2 = 1.27E-9
C3 = 2.66E-9
C1 = 373.E-12
L1 = 17.0E-6

1,000,000.00
RESP= -16.02 DB
2,000,000.00
RESP= -94.04 DB
3,000,000.00
RESP= -46.19 DB

$Q_L = 100$

MIN Q = 3.00
Q = 5.00
C2 = 1.59E-9
C3 = 4.03E-9
C1 = 440.E-12
L1 = 14.4E-6

1,000,000.00
RESP= -16.38 DB
2,000,000.00
RESP= -79.90 DB
3,000,000.00
RESP= -49.82 DB

$Q_L = 100$

Table III. Results Using Different Values of Circuit Q and Inductor Q_L .

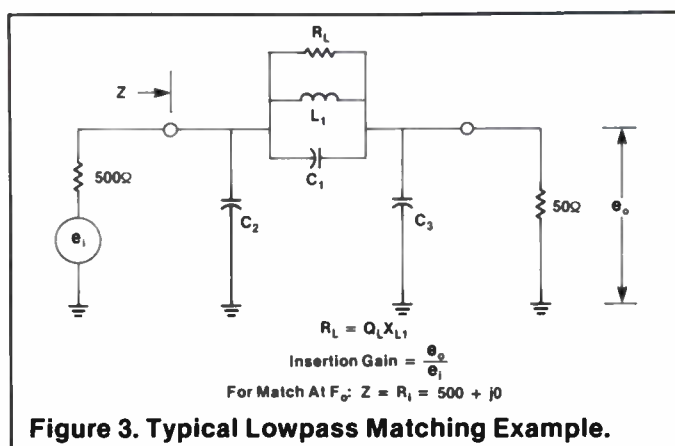


Figure 3. Typical Lowpass Matching Example.

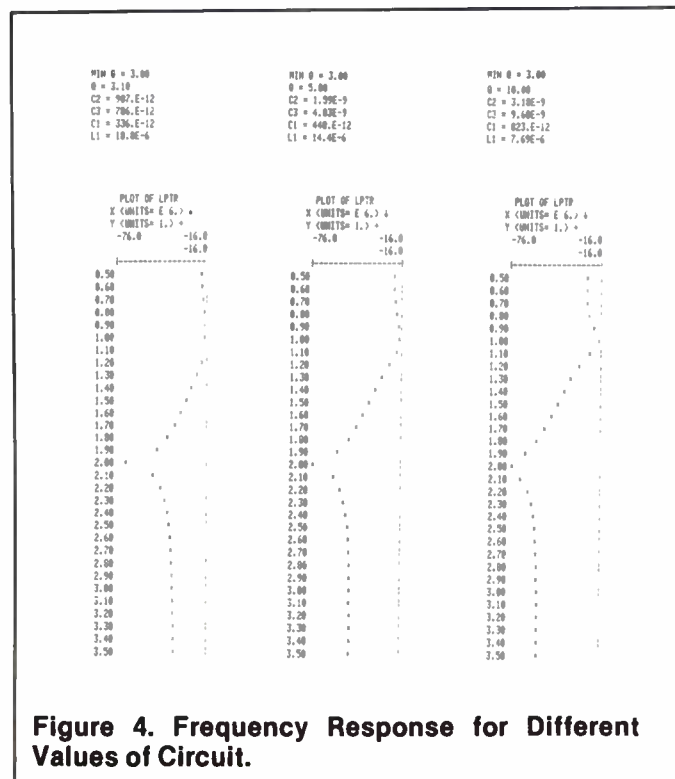


Figure 4. Frequency Response for Different Values of Circuit.

the impedance transformation. The impedance transformation can be incorporated in the basic filter design, but these impedance matching filters are not "off-the-shelf" designs. Using the filter shown in Figure 3 the required filtering and matching can be easily accomplished using 4 components in a non-critical configuration. Program I (of Table I) calculates the component values and Program II (Table II) calculates the frequency response. The finite value of the Q of the inductor, Q_L , can be used to calculate the response including circuit losses (capacitors usually have much higher Q values.) Using the example of Figure 3, the circuit values and the response at the second and third harmonics were calculated (Table III). The first column shows that using a lossless inductor, a circuit Q of 4 will provide barely adequate attenuation at the third harmonic. When a reasonable inductor loss is used ($Q_L = 100$), the difference in response at third harmonic and fundamental is not enough, by a fraction of a dB, as shown in the second column. Column three shows that using a circuit Q of 5 provides adequate attenuation for the harmonics even using $Q_L = 100$. The insertion loss due to the 10:1 step-down is 16.02 dB and the loss in the inductor is 0.36 dB, or less than the maximum desired of 1 dB.

Figure 4 shows the frequency response of the circuit of Figure 3 for different values of circuit Q. In all cases a Q_L of 100 was used. While higher values of circuit Q give higher attenuation at frequencies above cut-off, the passband at F_0 becomes smaller and the circuit may become more critical. The plots were obtained using the HP-41C/V PRPLOT routine and FS 00.

In general, the circuit is quite useful (and easy to use) where a narrow range of desired frequencies is present and both power matching and harmonic attenuation are needed.

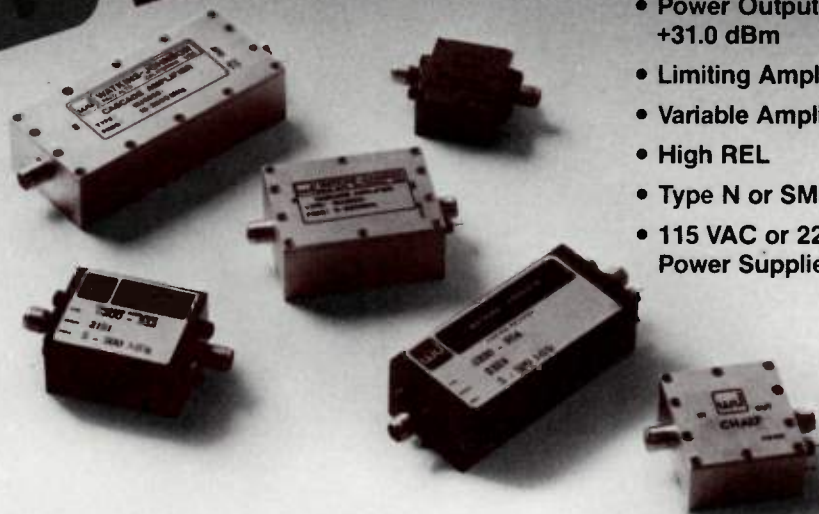
References

1. F.E. Terman, "Radio Engineer's Handbook", McGraw-Hill Book Co., N.Y., 1943, p. 228.
2. A. Przedpelski, "Simplify conjugate bilateral matching of complex impedances", Electronic Design, March 1, 1978.
3. A. Przedpelski, "Eliminate bandwidth calculation drudgery with a universal calculator program", Electronic Design, Oct. 11, 1979.
4. A. Przedpelski, "Low Impedance Double Tuned Circuit", r.f. design, May/June 1982.

**Cascaded
Amplifiers
that meet
requirements
from**

5 to 4200 MHz

WATKINS-JOHNSON



- Noise Figure as Low as 1.5 dB
- Power Output as High as +31.0 dBm
- Limiting Amplifiers
- Variable Amplifiers
- High REL
- Type N or SMA Male Connectors
- 115 VAC or 220 VAC Integral Power Supplies

Watkins-Johnson has created a truly flexible and versatile product line of high-performance amplifiers, the WJ-6200 Series, which covers the frequency range of 5 to 4200 MHz. The major building blocks used in these cascaded amplifiers are the W-J TO-8 Thin-Film Cascadable amplifiers.

By careful selection of the right TO-8 components, W-J

has optimized performance for noise figure, gain and power output. The net result is over 400 different amplifiers to choose from. Also, W-J can tailor an amplifier to your specific needs. For more information contact the W-J sales office in your area or telephone Components Applications Engineering in Palo Alto, California, at (415) 493-4141, ext. 2637.

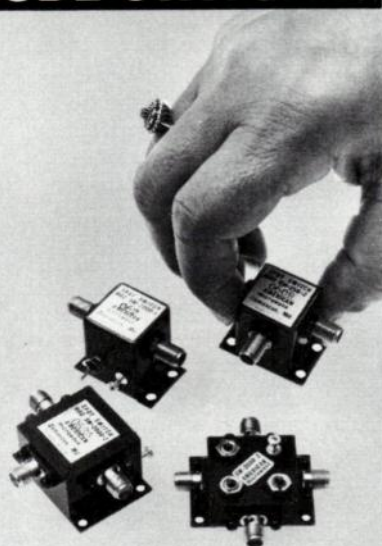


Watkins-Johnson—U.S.A.: • California, San Jose (408) 262-1411; El Segundo (213) 640-1980 • Florida, Fort Walton Beach (904) 863-4191 • Georgia, Atlanta (404) 458-9907 • Illinois, Palatine (312) 991-0291 • Maryland, Gaithersburg (301) 948-7550 • Massachusetts, Lexington (617) 861-1580 • Texas, Dallas (214) 234-5396 • New York, Jericho (516) 822-8883 • **United Kingdom:** Dedworth Rd., Oakley Green, Windsor, Berkshire SL4 4LH • Tel: (07535) 69241 • Cable: WJUKW-WINDSOR • Telex: 847578 • **Germany,** Federal Republic of: Manzingerweg 7, 8000 Muenchen 60 • Tel: (089) 836011 • Cable: WJDBM-MUENCHEN • Telex: 529401; Burgstrasse 31, 5300 Bonn 2 • Tel: 35 30 91 or 35 30 92 • Telex: (886) 9522 • **Italy:** Piazza G. Marconi, 25, 00144 Roma-EUR • Tel: 592 45 54 or 591 25 15 • Cable: WJ ROM I • Telex: 612278

INFO/CARD 39



MINIATURE WIDEBAND PIN DIODE SWITCHES



Now you can select the state-of-the-art miniature wideband pin diode switch you need from our stock. AMC Series SW-2000 pin switches (SPST and SPDT) measure only 1" H x 1.2" W x 0.75" L. And, hundreds of these units have already been used to solve solid state switching design problems in communication, aerospace, microprocessor and surveillance applications.

Check these specifications:

- SPST through SP5T Configurations Available
- Frequency: 2-2000 MHz (usable to 4000 MHz)
- Switching Time: 5 μ sec Typical
- Insertion Loss: 1.5 dB, maximum (SPDT)
- Isolation: 40 dB, minimum
- SMA Connectors
- RFI Control Terminals
- RF Power 1 watt CW
- Available with **one load** TTL Drivers

Standard models and quantities available from stock. Special switches designed to your specifications.

For solutions in solid state switching contact:

**AMERICAN
MICROWAVE CORP.**

6835 Olney-Laytonville Road
Gaithersburg, Maryland 20879
(301) 948-6800

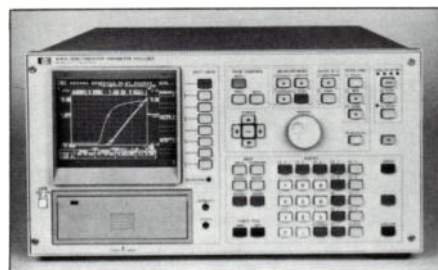


Programmable Semiconductor Parameter Analyzer

A new development in semiconductor analysis called a semiconductor parameter analyzer has been introduced by Hewlett-Packard.

The HP Model 4145A stimulates voltage and current-sensitive semiconductor devices and measures their resulting current and voltage responses. This new type of curve tracer is designed especially for electrical engineers and scientists who design, study, use or process semiconductor devices.

Stimulus-measuring units (SMUs) are the heart of the new HP 4145A. Each SMU is the equivalent of four instruments. Four built-in SMUs can act alternately as a voltage source/current monitor or current source/voltage monitor.



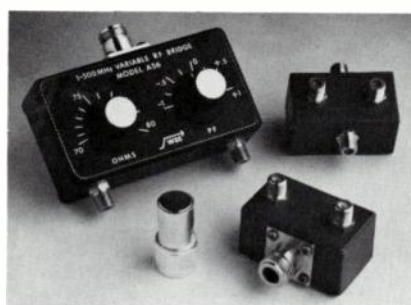
This innovative new HP instrument saves measurement setup time and reduces setup errors by storing complex dc test sequences on floppy discs.

In addition, the HP 4145A can manipulate measurement data and display such parameters as h_{FE} vs I_C and g_m vs V_{GS} , adding up to a fast and complete analysis of semiconductor dc characteristics.

The U.S. price is \$19,220. Call local **Hewlett Packard sales office or circle INFO/CARD #140.**

Monolithic Filters

What are believed to be the world's first monolithic filters for RF applications were unveiled by Thincor Division of Hull Corp. Three devices were introduced: A high pass Butterworth filter, a low pass Butterworth filter, and a simple bypass filter. Full characteristics of the units are still being evaluated. Size of the high pass and low pass filters is 0.140" x 0.180" x 0.025". The high pass and low pass filters can be furnished with cut-off frequencies between 60 and 400 MHz. The bypass filter is available in two sizes. The smaller, the LC-55, measuring 0.077" x 0.116" x 0.025", has inductances from 30 to 240 nH, and



RF BRIDGES

Fixed or Variable
Directivity (balance) 40 or
50 dB options.

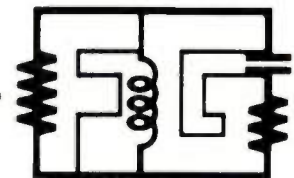
1-900 MHz RF Instruments

- RF Amplifiers
- RF Analyzers
- RF Comparators
- RF Switches
- Hybrid Divider/Combiners
- RF Detectors
- Impedance Transformers
- Precision Terminations
- Precision DC Block
- Filters
- Available 50 or 75 Ohms

WIDE BAND ENGINEERING COMPANY, INC.

P.O. Box 21652, Phoenix, Arizona 85036, U.S.A. Telephone (602) 254-1570

INFO/CARD 41



ENGINEERING

SMS GOES • GMS METEOSAT



FG-701 WEFAX RECEIVER

A complete triple conversion Microwave Receiver with a built-in LNA that mounts on the antenna and drives a Facsimile Machine or Computer Display System with NO ADDITIONAL EQUIPMENT, and NO SET-UP OR TUNING. Simply plug it in and get imagery. This is a QUALITY and RELIABLE unit in a rugged, weatherproof, pressurized housing. It will withstand severe environmental conditions. Computer programmable for channel, bandwidth, and demodulation selection.

| | |
|--------------|---------------------|
| FREQUENCY | 1691 and 1694.5 MHz |
| NOISE FIGURE | 1.5 or 2.5 dB |
| BANDWIDTH | 30 and 270 KHz |
| DEMODULATION | FM or PM |
| TEMPERATURE | -40 to +70°C |
| VIDEO OUT | 0.5 to 5 Vpp |
| AGC OUT | 0 to 5 VDC |
| SUPPLY INPUT | 11 to 14 VDC, 0.4 A |

NUMEROUS OPTIONS AVAILABLE

FG ENGINEERING CO. • Box 476 • Fredonia, AZ 86022 • [602] 643-2375

INFO/CARD 42

WRH

Projects that require special quadrature hybrids or couplers sometimes cause perplexing design difficulties. Namely, how can you fit that hybrid into the system's design, rather than tailoring the design to accommodate the hybrid? There is a solution. Wireline® hybrids. The beauty of Wireline is that it handles like wire, but performs like a machined hybrid. You get the design flexibility you want for do-it-yourself hybrid and coupler applications, and you get it at a tremendous reduction in cost.

The success of our original 100 Watt CW power Wireline led to the new braided copper and seamless copper tube Wireline that handles 200 Watt CW power. Each Wireline can be soldered into your system easily, and the new copper-jacketed style retains the shape you put it

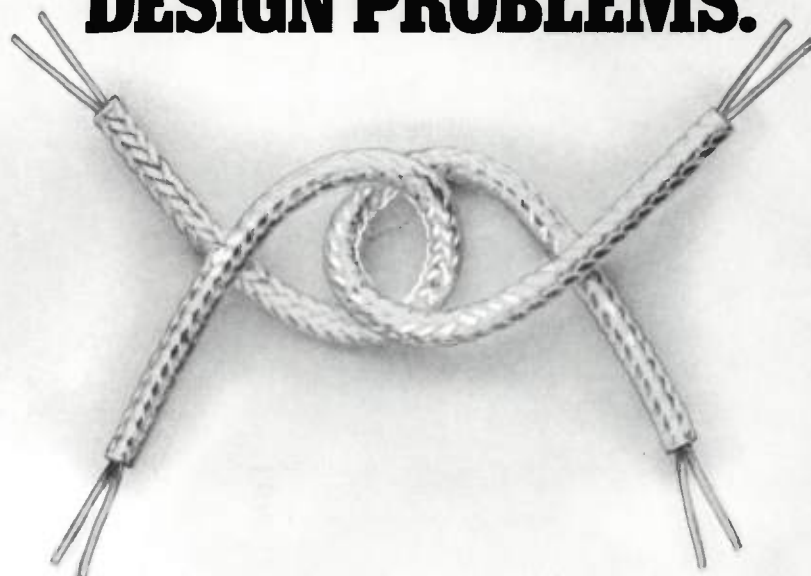


in. For each of the five Wireline styles the tightest nominal coupling is 3dB (quadrature hybrid at midband), obtained with a length equal to a quarter-wavelength. Shorter lengths yield looser coupling.

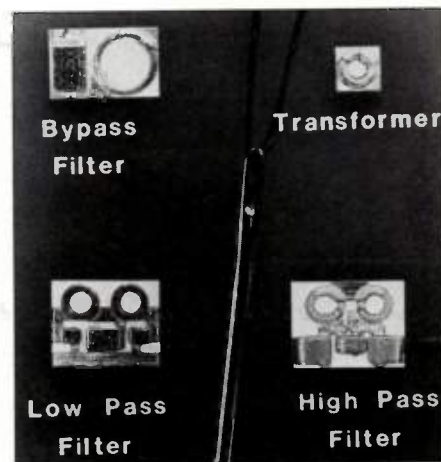
Wireline can be supplied pre-cut and trimmed in lengths of 26" to 1.08", and in a frequency range of 50-2400 MHz. Or in bulk lengths if you prefer to make your own units. Either way, Wireline hybrids offer unmatched design flexibility, convenience, and cost savings. The next time you're trying to solve a puzzling design problem, bend a little Wireline... instead of your mind.

For additional information about Wireline, and a complimentary sample of each Wireline, write or call Sage Laboratories.

WIRELINE® HYBRIDS. THE PERFECT SOLUTION TO PUZZLING DESIGN PROBLEMS.



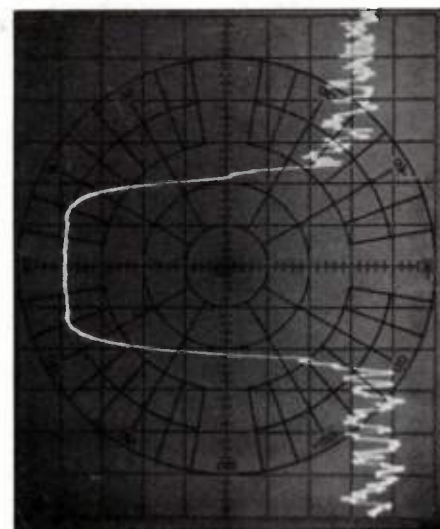
sage
LABORATORIES, INC.
3 HURON DRIVE • NATICK, MA 01760
(617) 653-0844 • TWX: 710-346-0390



capacitances from 12 to 110 pF. The larger, model LC-100, measuring 0.114" x 0.177" x .025", has inductances from 215 to 540 nH, and capacitances from 50 to 500 pF. **Thinco Div., Hull Corp., Hatboro, PA 19040, (215) 675-5000 or INFO/CARD #139.**

Wideband Saw Filters

Sawtek Inc. has announced a new family of 70 MHz surface acoustic wave (SAW) wideband filters. Designed primarily for use in home satellite receiver systems, these new filters

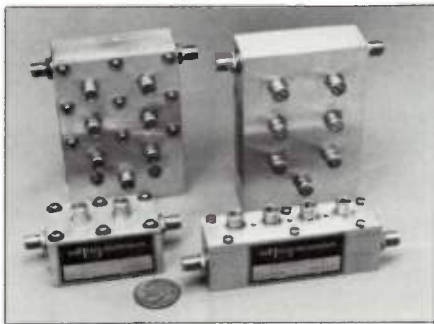


are available with bandwidths in the 18 to 36 MHz range. This new SAW design has a shape factor (40 dB to 3 dB) as low as 1.4 to 1 with 60 dB ultimate rejection. An insertion loss of 20 to 25 dB is achieved with no matching or with a single inductor. **Sawtek, Inc., 2541 Shader Rd., P.O. Box 7756, Orlando, FL 32854, (305) 299-4441 or INFO/CARD #138.**

Dielectric Resonator Bandpass Filters from 3.3 to 12.4 GHz

The AT-BPF100 series of bandpass filters use high dielectric constant,

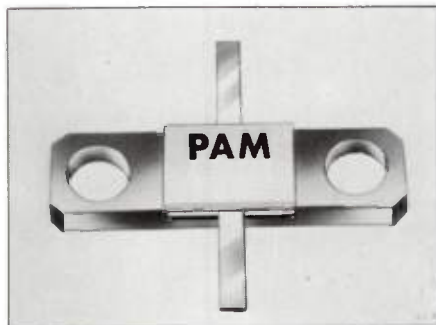
temperature stabilized, dielectric resonators to obtain fixed performance comparable to waveguide bandpass filters at the same frequency. Two to eleven pole designs are available having 3 dB bandwidths up to 6%. The filters are capable of handling up to 12 watts of CW power. Insertion loss, in most cases, is negligibly higher than their waveguide counterparts. These dielectric resonator filters offer superior frequency vs. temperature stability (2 PPM/°C) than traditional filters while being physically smaller and less expensive. Among many available options are a wide operating temperature range of -54°C to +85°C, constant group delay and different package form factors. Typically deli-



very is 30-60 days ARO in small quantities. Contact R.C. Havens, **AD-TECH MICROWAVE, INC.** 7755 E. Redfield Rd., S-500, Scottsdale, AZ 85260, (602) 998-1584 or INFO/CARD #137.

Compact Attenuator

KDI Pyrofilm announces a new compact attenuator module PAM—(db) for use in stripline and microstrip circuits. This low VSWR attenuator module is available in db values from 1 thru 10 db and is useable thru X-Band with a VSWR of 1.30:1 at 4 GHz, and 1.50:1 at 12.4 GHz in .025 thickness microstrip line with a dielectric



constant of 10. **KDI Pyrofilm Corp.**, 60 S. Jefferson Road, Whippany, N.J. 07981, (201) 887-8100 or circle INFO/CARD #136.

Communications Receivers

The new VIGILANT SR-501 and SR-

r.f. design

THE SHORTEST DISTANCE BETWEEN TWO POINTS ISN'T ALWAYS A STRAIGHT LINE.



Narrow-Band Wireline® Hybrids

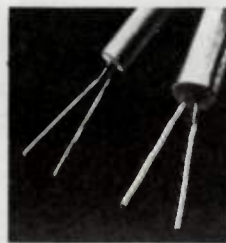
Sage's new space-qualified, form-fitting 3dB Wireline hybrids give you the design flexibility you need and the performance you demand for all your narrow-band applications. You get the handling characteristics of wire with the performance of a manufactured hybrid.

For years, engineers have enjoyed the flexibility and performance of Sage Wireline with coupling values chosen to minimize unbalance over an octave bandwidth. Now, Sage has developed two new styles of Wireline: HCP5 (100 W rated) and JCP7 (200 W rated) with configurations optimized for narrow-band applications.

Recommended for bandwidths from 0-30 percent, these new units

offer $\pm .25$ dB maximum unbalance at center frequency and feature seamless copper jacket construction that prevents leakage. And, Wireline will retain the shape you position it in.

Wireline can be supplied pre-cut and trimmed in lengths of 26 in. to 1.08 in. and in a frequency range of 50 MHz to 2400 MHz; or in bulk lengths (5 ft.) if you prefer to make your own units. Discover the flexibility, convenience and cost efficiency



of Sage narrow-band Wireline on your next puzzling design problem. Bending a little Wireline is easier than altering a design.

For additional information about Wireline and a

complimentary sample of each Wireline, write or call Sage Laboratories.

sage
LABORATORIES, INC.
3 Huron Drive • Natick, MA 01760
(617) 653-0844 • TWX: 710-346-0390
INFO/CARD 44

REF LEVEL

INPUT ATTEN

LOG SCALE

10 dBm

10 dB ATTEN

10 dB

PTS 500

now... 500 MHz of low-noise signals...
0.2 Hz resolution... 20 μ s switching...
choice of BCD par. or GPIB... modular...
proven PTS direct system... under \$7,500.



PTS

FREQUENCY SYNTHESIZERS
INFO/CARD 45

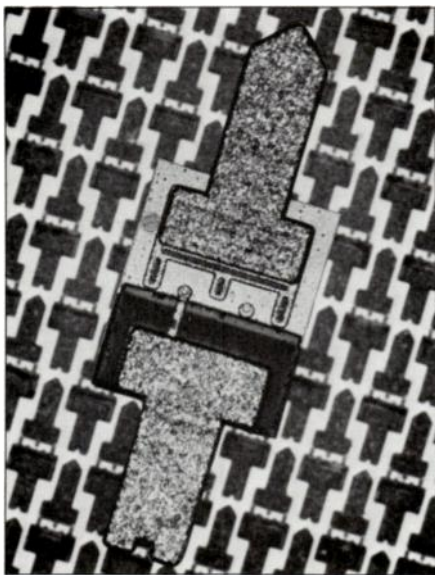
Littleton, MA, 617-486-3008



511 synthesized H.F. Communications Receivers are available for fixed and transportable H.F. Communications. They provide reception of SSB (LSB and USB), CW, AM, RTTY or FSK modes of operation. Requiring no pre-selection at the antenna input, unusually high-performance specifications are guaranteed repeatable between 50 KHz and 30 MHz at temperatures from -15°C to $+55^{\circ}\text{C}$. These professional quality equipments currently offered at attractively low prices; SR-501 at \$2,995 and SR-511 at \$4,995. **Hamilton Communications Systems, Inc., Suite 4545, One World Trade Center, New York, NY 10048, (212) 466-1400 or INFO/CARD #118.**

Microwave Schottky Diodes

With a choice of 20 different part numbers, an array of new beam lead Schottky diodes well suited for test automation is offered the microwave designer by Hewlett-Packard. The HSCH-5300 series beam lead diodes



are RF and DC tested and available in low or medium barrier. Three capacitance selections also are available for single or batch-matched versions. With repeatable RF characteristics through K_u band, the HSCH-5300 series diodes may be used in strip-line or microstrip circuits. Pricing and delivery information is available through authorized Hewlett-Packard components distributors or circle INFO/CARD #133.

r.f. design

CRYSTAL FILTERS... DELAY CORRECTED

Alpha Components...filters made by state-of-the-art technology. But our reputation doesn't stop there. We're leaders where constant time delay, combined with low shape factors are required.

Our current production includes high performance specifications such as...C.F.—455KHz*, 3db BW 3200Hz min, 60 db BW 4300Hz max, amplitude variation over 1db BW—1db max, Delta time delay over 85% of 3 db BW—200 us max. Spurious level 60 db to C.F. $\pm 100\text{KHz}$. Operating temp range 0 to 60 C. Size 82.3 x 25.4 x 55.9 mm, LxWxH. (*available in 1.4 to 2MHz range with size adjustment.)

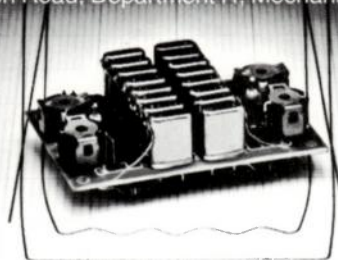
So send us your specs...LC or crystal. Chances are we'll give you production estimates in one working day from a design in our filter library.

For further technical information please call...

717/697/8595 or TWX: 510/650/4930.

**ALPHA
COMPONENTS, INC.**

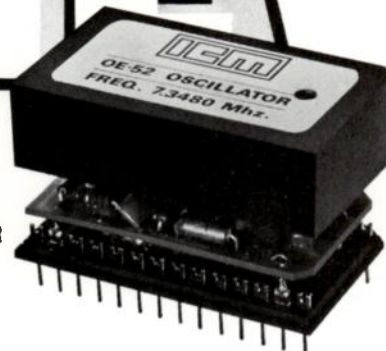
1106 E. Simpson Road, Department R, Mechanicsburg, PA 17055



INFO/CARD 46

NEW

EXPLODED
PHOTOGRAPH
OF OSCILLATOR
SHOWN LARGER
THAN ACTUAL
SIZE!



COMPLETE
OSCILLATOR
AND CRYSTAL
IN A 28 PIN
DIP PACKAGE

28 Pin DIP Oscillator . . . TTL Compatible . . . 2 to 20 Mhz.

New packaging format for greater design flexibility. Temperature compensated for tolerances to .0002%. Other output types are available. Output voltage 5.5 V PP, 2.9 V RMS

Trim range ± 10 ppm minimum. Input voltage 5 volts. Other types and frequencies available to meet most any design requirement. Size 1.45X.795X.400"

*For additional information, please
write or call our sales department.*

**International Crystal
Manufacturing Company, Inc.**

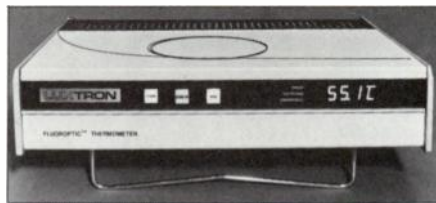
10 North Lee Oklahoma City OK 73102 (405) 236 3741



INFO/CARD 47

Optical Fiber Probe Thermometer

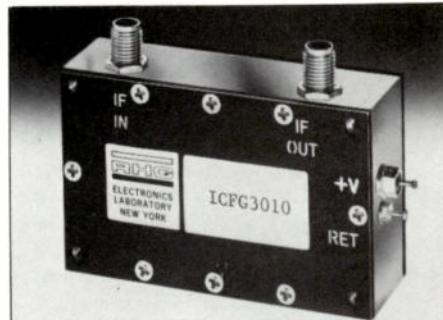
Luxtron Corporation introduces a patented new technology for temperature measurement with the Model 1000A Fluoroptic Thermometer. The Model 1000A employs a single optical fiber probe which allows measuring temperature accurately in an RF environment. A new optical technique for measurement of temperature using the ratio of intensities of fluorescent emission lines of certain rare earth phosphors. Makes possible the measurement of temperatures



from -50°C to 200°C (392°F) to 0.1°C precision with total electrical isolation and minimum thermal perturbation. Uses a small, inert optical fiber probe which is non-metallic, non-conducting and non-contaminating. Luxtron, 1060 Terra Bella Ave., Mountain View, CA 94043, (415) 962-8110 or INFO/CARD #132.

Variable Bandwidth IF Preamplifiers

A new series of variable bandwidth IF preamplifiers which enable receiver designers to electronically vary system IF bandwidth is available from RHG Electronics Laboratory, Inc. The new RHG preamplifiers are designated as the ICFG series for fixed gain models



and the ICFK series for variable gain models. Four models, covering operating frequencies of 21, 30, 45, and 60 MHz, are listed for each series. ICFG units maintain gain at 20 dB as the bandwidth is varied. On ICFK units, the gain varies inversely with the bandwidth providing a constant gain bandwidth product and the resulting constant "grass" level seen on an "A" type display. Model ICFG3010 is priced at \$795 each; and Model ICFK6020C at \$750 each. Delivery of either is 90 days ARO. RHG Electronics Laboratory, Inc., 161 East Industry Court, Deer Park, N.Y. 11729, (516) 242-1100 or INFO/CARD #131.

Communications Receiver

The Comer Communications R30K is an extremely small general coverage communications receiver, measuring only 2 inches by 4 inches by 6 inches. Despite this small size the R30K is able to perform equally if not better than most receivers occupying 18 times the volume. Frequency coverage is from 50 KHz to 30 MHz, and selection is by means of a five digit push wheel switch giving 1 KHz resolution, a VFO is provided to interpolate between the 1KHz steps. Reception modes are AM, LSB, USB and CW. Comer Communications, 609 Washington Drive, San Marcos, California 92069, (714) 744-3215 or INFO/CARD #130.



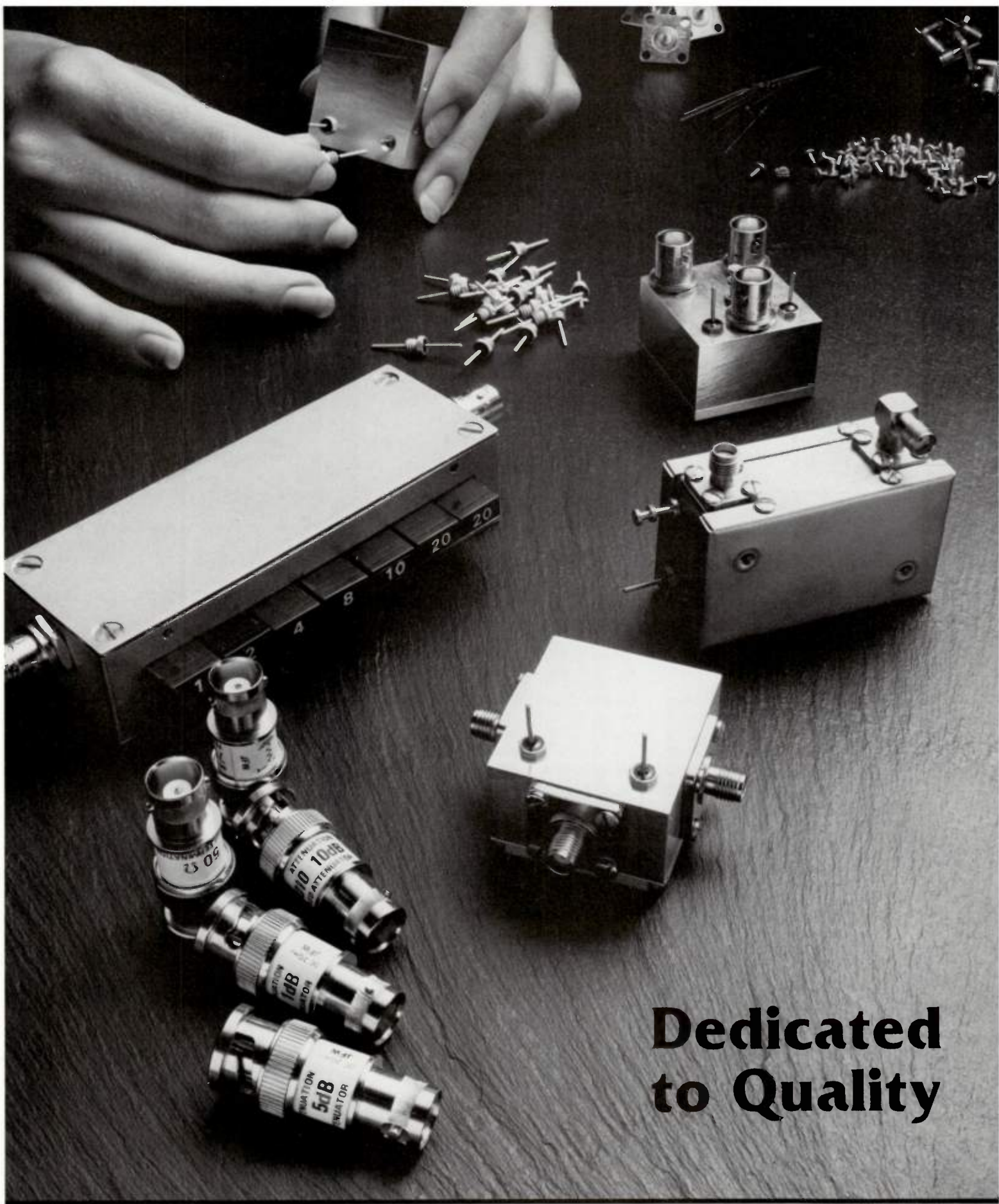
Some Packages Work Better Than Others.

MODPAK,[™] the modern packaging system, provides all the protection your RF circuit will ever need. Sturdy, shielded enclosures with a choice of four connectors in more than a dozen standard sizes or custom fabricated in virtually any size. Top and bottom covers are easily removed for access to circuit board. And it doesn't take all the king's horses and all the king's men to put them back together again. Just a screwdriver and four screws. Simplicity in both function and design.

Send for our new 1980 catalog and find out how Modpak can work better for you.

Adams & Russell
MODPAK DIVISION

80 Cambridge St., Burlington, MA 01803 (617) 273-3330



Dedicated to Quality



JFW Industries, Inc.
2719 E. Troy Avenue
Indianapolis, Indiana 46203
(317) 783-9875

Fixed Attenuators • DC to 2000 MHz • From \$11.00
Pushbutton Attenuators • DC to 1000 MHz • From \$80.00
Solid-State Coaxial Switches • .5 MHz to 1000 MHz • From \$70.00
Solid-State Attenuators • 100 KHz to 1500 MHz • From \$175.00
INFO/CARD 49

New Literature

LogiMetrics Catalog

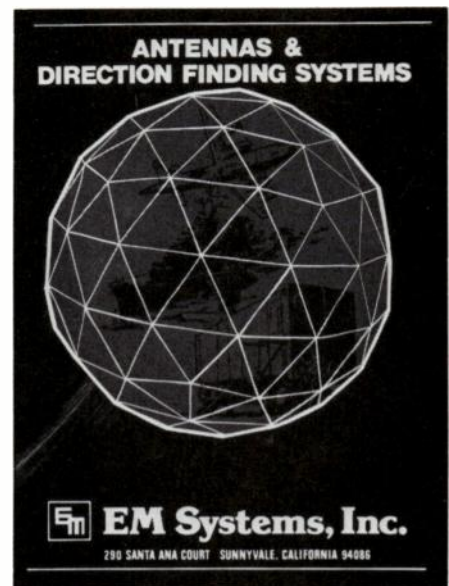
LogiMetrics has announced the availability of a new 60 page publication presents details on the company's product lines including: Traveling Wave Tube Amplifiers, Signal Generators, Electromagnetic Field Generating Systems, EW Systems and High Voltage Power Systems. Contact J. Deutsch, LogiMetrics, Inc., 121-03 Dupont Street, Plainview, N.Y. 11803, or INFO/CARD #104.

Variable Capacitor Design Manual

New 20-page catalog includes a wide selection of variable capacitors, microwave tuning elements, microwave diode holders, and prototyping kits. Easy-to-use format tabulates by part number, photo, and characteristics the types and styles available. **Johanson Manufacturing Corporation, 400 Rockaway Valley Road, Boonton, N.J. 07005, (201) 334-2676 or INFO/CARD #114.**

Antenna Catalog

EM Systems' new antenna catalog



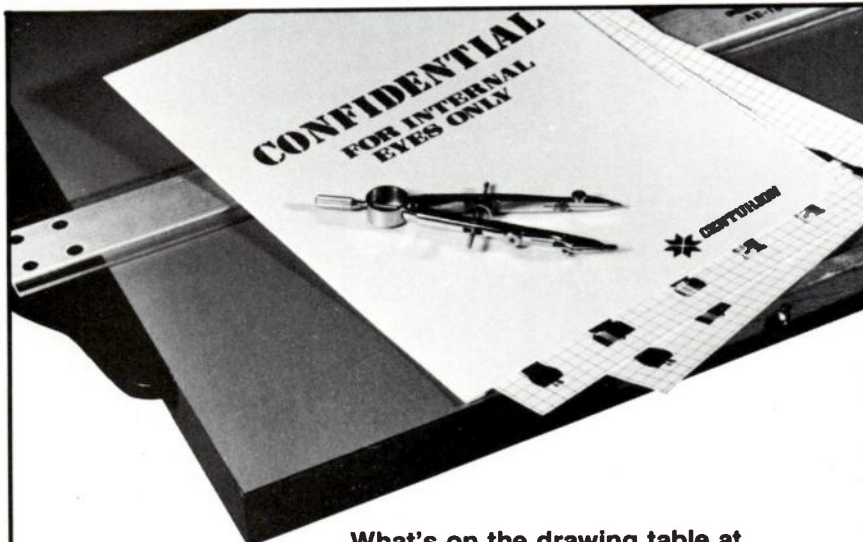
presents the company's EW antennas and direction finding systems. It's fifty pages describe high technology antenna products ranging from the classic dual polarized horn through wide-band directional and omnidirectional log periodics, spirals and bi-conical antennas to sophisticated rotary direction finding systems as well as multi element arrays for mono-pulse direction finding systems. **EM Systems, Inc., 290 Santa Ana Court, Sunnyvale, CA 94086, (408) 733-0611 or INFO/CARD #113.**

Transformers For Telecommunications

The Midcom Unit of Midland-Ross Corporation announces the publication of a totally new transformer catalog. This 24-page catalog, *Transformers for Telecommunications*, features vital information on products, test procedures, and terminology. **Midland-Ross Corporation, Midcom Unit, P.O. Box 3328, North Mankato, MN 56001, (507) 625-6521 or INFO/CARD #112.**

Design Booklet

A new booklet is available from Magnecraft with methods for solving coil design problems. New formulae compare wire gage to coil resistance, coil turns, power dissipation and ampere turns. Applications meet many



What's on the drawing table at Centurion? The competition would love to know! Since its beginning, Centurion has produced the most imitated products in the hand-held radio antenna business. And for good reason; the products have truly been innovations.

Like Centurion's introduction of the first mini "rubber duck" antennas (Style M) and the first flexible antennas for pagers (Style P), the first $\frac{1}{4}$ wave cable VHF antenna (Style V) and the first UHF gain antenna (Style G) for hand-held radios and..... the list goes on.

But Centurion realizes an innovative company cannot sit back and reflect on past successes. An innovative company must realize that past history will repeat itself only if its engineers and designers look to the future of technology. Centurion engineers are constantly at work designing and improving antennas for the radios of today and tomorrow, while the competition fights to keep up.

It is for this reason that most of the world's leading hand-held radio manufacturers insist on Centurion for the best-looking, best-performing antennas and products for their equipment. Why should you settle for less?

Contact us for a free catalog.



402/467-4491
P.O. Box 82846
Lincoln, Nebraska 68501-2846

TUF DUCK



SECOND ANNUAL

Test & Measurement World Expo

May 2-5, 1983

San Jose Convention Center • San Jose, CA

Areas of test & measurement technology covered by technical program & exhibit:

Subassembly/System ATE

Test Software

VLSI Test

Component Test

Test Instruments

Communications Test

Microwave Test

Economics of Testing

Process Monitoring

Test/Analysis/Services

Optical Inspection & Failure Analysis

Microelectronics Measurement

Fiber Optics Test

RFI & EMI Evaluation

Precision Instruments

Production/QA/ATE

Test Hardware

Technical
Conference &
Equipment
Exhibit

Produced by

Test & Measurement World
magazine

Test & Measurement World Expo.

215 Brighton Avenue, Boston, MA 02134
617/254-1445

For more information, fill out and send coupon below.

Yes, I'm interested.

- ☐ Please send me detailed information on the 1983 Test & Measurement World Expo technical program as soon as it is available.
- ☐ Please send me information about exhibiting at Test & Measurement World Expo.

Name _____

Title _____

Company _____

MS/Dept. _____

Address _____

City/State/Zip _____

Telephone (_____) _____

Return coupon to: Test & Measurement World Expo,
215 Brighton Avenue, Boston, MA 02134

INFO/CARD 51

requirements for relays, solenoids and transformers. **Magnecraft Electric Company**, 5575 North Lynch Avenue, Chicago, Illinois 60631 or circle INFO/ Card #110.

Microwave Handbook

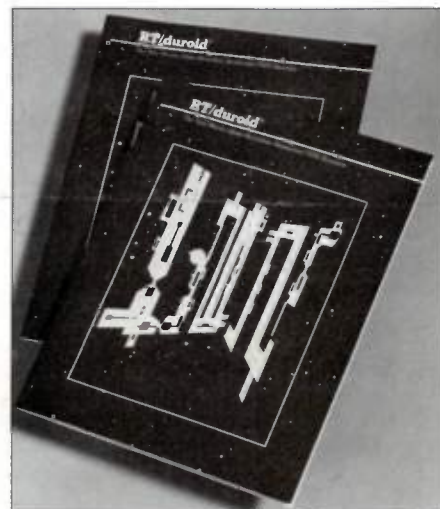
WILTRON's new 64-page catalog not only describes a complete line of microwave measurement instruments and systems, it also includes helpful technical information on applications and measurement techniques. Products described cover the 100 kHz to 40 GHz range and include Automated

Scalar Network Analyzer Systems, Programmable Sweep Generators, Tracking Sweeper Controllers, Network Analyzers, 1-1500 MHz RF Test Systems, SWR Autotesters, Detectors, Digital Phase Meters, and Precision Air Lines, Adapters, and Terminations. Contact **Walt Baxter, WILTRON Company**, P.O. Box 7290, 805 E. Middlefield Road, Mountain View, CA 94042-7290, (415) 969-6500 or INFO/CARD #111.

Microwave Materials Brochure

Literature describing RT/duroid®

microwave laminate materials is now available from Rogers. The four-page illustrated brochure outlines RT/duroid material specifications, processing



advantages, and design characteristics. **Rogers Corporation, Microwave Materials Division**, P.O. Box 700, Chandler, AZ 85224, (602) 963-4584 or INFO/CARD #109.

RF and Microwave Components Brochure

A 53-page brochure of RF and microwave components made by the Swiss corporation **Huber + Suhner AG** is available from **Uniform Tubes, Inc.**, Collegeville, PA. The catalog illustrates



and lists full specifications of more than 250 components. A comprehensive line of connectors, adapters, terminations, attenuators, EMP protectors, filters, detectors and other components are offered. **Micro-Delay Division of Uniform Tubes, Inc.**, Collegeville, PA 19426, (215) 539-0700 or INFO/CARD #108.

(Continued on page 70.)

September/October 1982

RF Telemetry Links with state-of-the-art performance and reliability

Communitronics new family of low cost receivers and transmitters is available in high or low band VHF and UHF models. They're designed to telemeter voice, low speed digital information and tone signals for such applications as Data Links, Status Control, Supervisory Control, Alarm Systems, Monitoring Systems, Pipeline Control and Low Power Repeaters, to name a few. Besides our standard models, which are available with optional RF connectors, we can also design and produce custom units to meet your exact requirements.

So, if you want the latest in RF telemetry links, write or call Communitronics for detailed specifications and pricing.



- TRANSMITTER**
- 1½ and 4 watt powers
 - Rated continuous duty
 - Compact size

- RECEIVER**
- Dual Conversion
 - Low standby current for battery operation
 - Compact size



COMMUNITRONICS LTD.

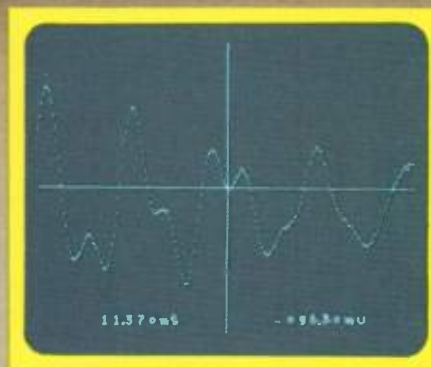
160 Wilbur Place, Bohemia, N.Y. 11716 • (516) 567-8320
INFO/CARD 52



See things you've never seen before.

Nicolet digital oscilloscopes offer you resolution, precision, dynamic range and transient capture capabilities unobtainable on analog oscilloscopes. *They are simple to operate and yet extremely versatile.*

Signals can be viewed live, continuously compared to a reference waveform or stored for detailed examination. Continuous, normal and pre-trigger operation are offered as standard and in all modes cursor-interactive time and voltage coordinates can be displayed concurrently with the signal. Stored waveforms can be displayed or plotted in XY or YT format, transferred to internal disk memory for permanent storage or output to other



Expansion of selected area in above photo, for detailed analysis.



computing devices via industry standard interfaces.

In addition to offering you the performance you would expect from the industry leader, Nicolet digital oscilloscopes are extremely well proven with thousands in effective use throughout the world.

Find out how Nicolet can help you solve problems and see things you've never seen before.

For more information, simply circle the reader service card or call 608/271-3333. Or write: Nicolet Instrument Corporation, 5225 Verona Road, Madison, Wisconsin 53711.



**NICOLET
INSTRUMENT
CORPORATION**
OSCILLOSCOPE DIVISION
Sales and Service Offices Worldwide

Digital Nicolet Oscilloscopes

Immediate need: INFO/CARD 62
Literature: INFO/CARD 66

VCXOs, TCXOs: Unmatched Versatility.

Damon continues to be recognized as the leader in the design and production of low noise VCXOs/TCXOs. Backed by the technical expertise of our engineering team, Damon offers VCXOs and TCXOs with unique performance characteristics.

VCXOs Highest Modulation Rate — Modulation Rate: DC to 2 MHz! Peak Deviation: .03% of C. F. Center Frequency: 1 to 140 MHz. F. M. Distortion: Less than 5%.

Widest Deviation Bandwidth — Peak Deviation: 0.5 to 300 KHz. Linearity: $\pm 3\%$. Center Frequency: 0.1 to 60 MHz. Frequency Stability: Less than 100 PPM, 0° to 50°C.

Exceptional Spectral Purity — Center Frequency: 40 to 120 MHz (overtone VCXO). Peak Deviation: 10 to 30 KHz. Linearity: $\pm 1\%$.

TCXOs

| Temp. Range | Standard | High Stability |
|---------------|----------|----------------|
| 0° to +50°C | 0.5-5PPM | to 0.1PPM |
| -20° to +71°C | 2-10PPM | to 0.5PPM |
| -55° to +85°C | 4-20PPM | to 1.0PPM |

Damon Electronics: The recognized leader in state-of-the-art, dependable VCXOs and TCXOs plus a high-quality line of crystal filters.

For further information, write or call Ed Doherty, (617) 449-0800



DAMON/ELECTRONICS DIVISION

80 WILSON WAY, WEST WOOD, MASS. 02090, TEL: (617) 449-0800

INFO/CARD 53

DRAMATICALLY INCREASE YOUR PRODUCT YIELD!

NEW CLEAN ROOM OVENS



- MEET MIL. STD. CLASS 100 AIR REQUIREMENTS.
- 99.97% EFFECTIVE IN FILTERING PARTICLES AS SMALL AS 0.3 MICRONS
- NEW PUSH-BUTTON PRECISION-CALIBRATED DIGITAL READOUT CONTROL

State-of-the-art anti-contamination engineering provides a work chamber as free from impurities as is possible. New TOUCH-MASTER* Digital Readout Control provides pinpoint calibration and repeatability, solid-state SCR proportioning performance, push-button operating ease.

Other features include: digital overtemperature protection; electropolished stainless interiors; enclosed motors; stainless blower wheels and sealed shafts; nitrogen system; stainless tap water cooling coil for operation below +100°C. and rapid cooldown.

The chambers, rated at +250°C. (+482°F.) come in five popular bench and floor sizes.

If your production is hurt by contaminants look into Blue M Clean Room Ovens. You'll see nothing — except increased yield. For details, contact: Blue M, A Unit of General Signal; Blue Island, Illinois 60406. Telephone (312) 385-9000.

*Patents pending



BLUE M

A UNIT OF GENERAL SIGNAL

INFO/CARD 54

Selection Guide of RF And Power Semiconductors

A 22-page Selection Guide from TRW Semiconductors describes the company's complete line of RF and power semiconductors. TRW Semiconductors, 14520 Aviation Blvd., Lawndale, CA 90260, (213) 679-4561 or INFO/CARD #107.

Newark Electronics Catalog

Catalog 106 is now in production and scheduled for release this fall. The Newark catalog features products from 190 major manufacturers. It is a custom produced catalog and all items listed are stocked. Catalog 106 is free and you may now order in advance of publication. Newark Electronics, Catalog Dept. NR, 500 N. Pulaski Road, Chicago, Ill. 60624 or INFO/CARD #106.

Filter Catalog

This 16-page catalog (BTV/82) features filters, traps and channel combiners designed to eliminate interference in broadcast TV systems and to combine several transmitters to one antenna. Microwave Filter Company, Inc., 6743 Kinne St., East Syracuse, NY 13057, 1-800-448-1666 (toll-free) or INFO/CARD #105.

New Books

Microwave Semiconductor Engineering

By Joseph F. White

This book analyzes the complex field of semiconductor microwave engineering. Explained are the essentials of the physics of semiconductors, reliability estimates, driver circuits, matrix theory, computer-aided design and how to use filter theory with microwave semiconductor networks, complete with examples. Included is information that saves time on the job: the basis of the Smith Chart, tables and charts on microstrip, stripline, coax and waveguide and the properties of materials needed in semiconductor microwave design.

Partial Contents: The PN junction, PIN diodes and the theory of microwave operation, practical PIN diodes, binary state transistor drivers, fundamental limits of control networks, mathematical techniques and computer-aided design (CAD), limiters and duplexers, switches and attenuators,

MOBILE COMMUNICATIONS

RF POWER TRANSISTORS



TH 430
2 → 30 MHz – 250 W PEP



SD 1441
130 → 175 MHz – 150 W
SD 1468
225 → 400 MHz – 70 W
SD 1499
450 → 512 MHz – 65 W



SD 1414
806 → 947 MHz – 50 W

YOU MAY DEPEND ON US, WE'RE NEVER FAR-AWAY...

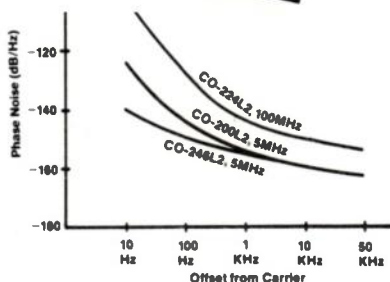


THOMSON-CSF
COMPONENTS

THOMSON-CSF COMPONENTS CORPORATION

SEMICONDUCTOR DIVISION - P.O. BOX 1454 CANOGA PARK CALIFORNIA 91304 / 6660 VARIEL AVENUE
CANOGA PARK CALIFORNIA 91303 USA. TEL.: (213) 887-1010 - TWX 910 494 1954 - TELEX 69 8481

Low Noise Crystal Oscillators



HF MODELS

Series: CO-200L2 CO-246L2
Frequency: 4-25 MHz 5 MHz (opt. to 100 MHz)
Aging: 1x10⁻⁹/day 1x10⁻¹⁰/day
3x10⁻⁷/year 3x10⁻⁸/year

Phase noise: at 5 MHz
@ 100 Hz: -145 dB/Hz -150 dB/Hz
@ 1 KHz: -155 dB/Hz -155 dB/Hz
@ 50 KHz: -163 dB/Hz -163 dB/Hz

VHF MODELS

Series: CO-224L2 CO-220L2
Frequency: 25-300 MHz 25-125 MHz
Aging: 1x10⁻⁹/day 1x10⁻⁹/day
2x10⁻⁸/year 3x10⁻⁷/year

Phase noise: at 100 MHz
@ 100 Hz: -130 dB/Hz -120 dB/Hz
@ 1 KHz: -145 dB/Hz -130 dB/Hz
@ 50 KHz: -155 dB/Hz -140 dB/Hz

Write, phone or TWX today
for complete details...

From the world's largest
and most respected full line
manufacturer of crystal oscillators...



VECTRON LABORATORIES, INC.
The Crystal Oscillator Company
166 Glover Avenue, Norwalk, Connecticut 06850
Telephone: 203/853-4433 TWX: 710/468-3796

phase shifters and time delay networks, and appendices.

Available from Van Nostrand Reinhold Co., 135 West 50th St., New York, N.Y. 10020 576 pages, \$28.50, Hardcover, Nov. 1981.

GaAs FET Principles And Technology

Edited by James DiLorenzo and Deen Khandelwal.

Drawing on contributed material from experts throughout the international community, this work is intended to provide the reader with a complete look at the science and art of design, fabrication, and application of GaAs FETs. Included are chapters on material technology, device technology, microwave circuit technology, digital integrated circuit technology and new physics concepts.

Partial Contents: Semi-insulating GaAs Substrates. Implantation into GaAs. Low Noise GaAs FET's. High Power GaAs FET's. GaAs MOSFET Technology. Thermal Design Consideration of GaAs FETs. Reliability of LN and HP GaAs FET's. Circuit Applications. SD FET Logic. A Look Into The Future.

Available from Artech House, Inc.,

610 Washington St., Dedham, MA 02026. \$45.00, Hardcover, 1982.

Introduction to Radio Frequency Design

By W.H. Hayward

This comprehensive yet basic treatment of the fundamental methods used in radio frequency design is intended for engineers, technicians and advanced radio amateurs. It prepares the reader to design HF, VHF and UHF equipment and to read and understand much of the current literature in this field. An emphasis is placed on simplicity of presentation. Frequent examples are used and comprehensive lists of references and suggested readings are provided at the ends of individual chapters. Mathematics is used as required to develop reader intuition for r.f. circuits and systems. Structured equation sets aid the reader in writing programs for small computers or hand-held programmable calculators. The book reviews traditional material from the perspective of the r.f. designer.

Contents: Low frequency transistor models, filter basics, coupled resonator filters, transmission lines, two-port networks, practical amplifiers and

LOWEST PRICED, HIGHEST QUALITY ATTENUATORS - BNC \$11.00, SMA \$14.00, T-9EA AND TERMINATIONS - BNC \$5.60, SMA \$5.60, MIL-HI-REL NETWORKS

| Model Number (2) | Impedance Ohms (Power W) | Frequency Range | BNC | TNC | N | SMA | UHF | PC |
|---|--------------------------|--------------------|-------|-------|-------|-------|-------|-------|
| Fixed Attenuators, 1 to 20 dB | | | | | | | | |
| AT-50(3) | 50 (5W) | DC-1.5GHz | 14.00 | 20.00 | 18.00 | 18.00 | — | — |
| AT-51 | 50 (5W) | DC-1.5GHz | 11.00 | 18.00 | 15.00 | 14.00 | — | 12.00 |
| AT-52 | 50 (1W) | DC-1.5GHz | 14.50 | 20.50 | 20.50 | 18.50 | — | — |
| AT-53 | 50 (25W) | DC-3.0GHz | 14.00 | 17.00 | — | 15.00 | — | — |
| AT-54 | 50 (25W) | DC-4.8GHz | 14.00 | — | — | 18.00 | — | — |
| AT-75 or AT-90 | 75 or 93 (5W) | DC-1.5GHz (750MHz) | 4.00 | 20.00 | 20.00 | 18.00 | — | — |
| Detector, Zero Bias Schottky: | | | | | | | | |
| CD-81 | 50 | 0.1-4.2GHz | — | — | — | 54.00 | — | — |
| Resistive Impedance Transformers, Minimum Loss Pads | | | | | | | | |
| RT-50/75 | 50 to 75 | DC-1.5GHz | 10.50 | 18.50 | 18.50 | 17.50 | — | — |
| RT-50/93 | 50 to 93 | DC-1.0GHz | 13.00 | 19.50 | 19.50 | 17.50 | — | — |
| Terminations: | | | | | | | | |
| CT-50 (2) | 50 (5W) | DC-4.2GHz | 11.50 | 15.00 | 15.00 | 17.50 | — | — |
| CT-51 | 50 (5W) | DC-4.2GHz | 9.50 | 12.00 | 12.00 | 9.50 | — | — |
| CT-52 | 50 (1W) | DC-2.5GHz | 10.50 | 15.00 | 15.00 | 13.00 | 15.50 | — |
| CT-53 M | 50 (5W) | DC-4.2GHz | 9.50 | 10.00 | — | 8.00 | 10.00 | — |
| CT-54 | 50 (2W) | DC-2.0GHz | 14.00 | 18.00 | 15.00 | 17.50 | — | — |
| CT-75 | 75 (25W) | DC-2.5GHz | 10.50 | 15.00 | 15.00 | 13.00 | 15.50 | — |
| CT-93 | 93 (25W) | DC-2.5GHz | 13.00 | 15.00 | — | — | 15.50 | — |
| Mismatched Terminations, 105:1 to 3:1, Open Circuit, Short Circuit: | | | | | | | | |
| MT-51 | 50 | DC-3.0GHz | 25.50 | 25.50 | — | 25.50 | — | — |
| MT-75 | 75 | DC-3.0GHz | — | — | 25.50 | — | — | — |
| Feed thru Terminations, shunt resistor | | | | | | | | |
| FT-50 | 50 | DC-1.0GHz | 10.50 | 18.50 | 18.50 | 17.50 | — | — |
| FT-75 | 75 | DC-500MHz | 10.50 | 18.50 | 18.50 | 17.50 | — | — |
| FT-90 | 93 | DC-150MHz | 13.00 | 18.50 | 18.50 | 17.50 | — | — |
| Directional Coupler, 30 dB | | | | | | | | |
| DC-500 | 50 | 250-500MHz | 80.00 | — | — | — | — | — |
| Resistive Decoupler, sense resistor or Capacitive Coupler, series capacitor: | | | | | | | | |
| RD or CC-1000 | 1000 (1000PF) | DC-1.5GHz | 12.00 | 18.00 | 18.00 | 17.00 | — | — |
| Adapters: | | | | | | | | |
| CA-50 (N to SMA) | 50 | DC-4.2GHz | — | — | 13.00 | 13.00 | — | — |
| Inductive Decouplers, series inductor: | | | | | | | | |
| LD-R15 | 0.15H | DC-500MHz | 12.00 | 18.00 | 18.00 | 17.00 | — | — |
| LD-R68 | 6.8H | DC-55MHz | 12.00 | 18.00 | 18.00 | 17.00 | — | — |
| Fixed Attenuator Sets, 3, 6, 10, and 20 dB in plastic case | | | | | | | | |
| AT-50-SET (3) | 50 | DC-1.5GHz | 80.00 | 84.00 | 84.00 | 78.00 | — | — |
| AT-51-SET | 50 | DC-1.5GHz | 48.00 | 84.00 | 84.00 | 80.00 | — | — |
| Reactive Multicouplers, 2 and 4 output ports | | | | | | | | |
| TC-125-2 | 50 | 1.5-125MHz | 54.00 | — | 57.00 | 57.00 | — | — |
| TC-125-4 | 50 | 1.5-125MHz | 57.00 | — | 81.50 | 81.50 | — | — |
| Resistive Power Dividers, 3, 4 and 9 ports | | | | | | | | |
| RC-2-30 | 50 | DC-2.0GHz | 54.00 | — | — | 54.00 | — | — |
| RC-3-30 | 50 | DC-500MHz | 54.00 | — | — | 54.00 | — | — |
| RC-8-30 | 50 | DC-500MHz | — | — | — | 84.50 | — | — |
| Double Balanced Mixers: | | | | | | | | |
| DBM-1000 | 50 | 5-1000MHz | 61.00 | — | 71.00 | 61.00 | — | — |
| DBM-500PC | 50 | 2-500MHz | — | — | — | — | — | 34.00 |
| RF Fuse, 1/8 Amp and 1.16 Amp: | | | | | | | | |
| FL-50 | 50 | DC-1.5 GHz | 12.00 | 18.00 | — | 17.00 | — | — |
| FL-75 | 75 | DC-1.5 GHz | 12.00 | 18.00 | — | 17.00 | — | — |

NOTE: 1) Critical parameters fully tested and guaranteed. Fabricated from Mil Spec High Rel. resistors. 2) See catalog for complete Model. 3) Price subject to change without notice. Shipping \$5.00 Domestic or \$15.00 Foreign on Prepaid Orders. Delivery is stock to 30 days ARO.

Send for Free Catalog on your Letterhead.
Elcom SYSTEMS INC. 305-994-1774
4032 CLINT MOORE ROAD, BOCA RATON, FL 33431

INFO/CARD 57

mixers, oscillators and frequency synthesizers, the receiver: an RF system.

Available from Prentice-Hall, Inc., Englewood Cliffs, NJ 07632, 400 pages, \$27.95, Hard cover, 1982.

Practical RF Design Manual

By Doug Demaw

A plain language solid-state design text that emphasizes circuit explanation, anomalies and performance traits. Explains solid state design of RF communications circuits for transmitters and receivers from low frequency through UHF. Design approaches given along with practical examples of proven circuits with assigned component values. The text is built on practical experiences in design and laboratory testing as opposed to the singular theoretical treatment found in similar books. There is minimal emphasis on mathematics and strong emphasis on circuit explanation and performance traits.

Contents: Preface. Transmitter and Receiver Fundamentals. Frequency-Control Systems. Small-Signal RF Amplifiers. Large-Signal Amplifiers. Frequency Multipliers. Mixers, Balanced Modulators, and Detectors. IF Amplifiers, Filters and AGC Systems.

Available from Prentice-Hall, Inc., Englewood Cliffs, NJ 07632. 272 pages, \$24.95, Hardcover, 1982.

Power FETs And Their Applications

By Edwin S. Oxner

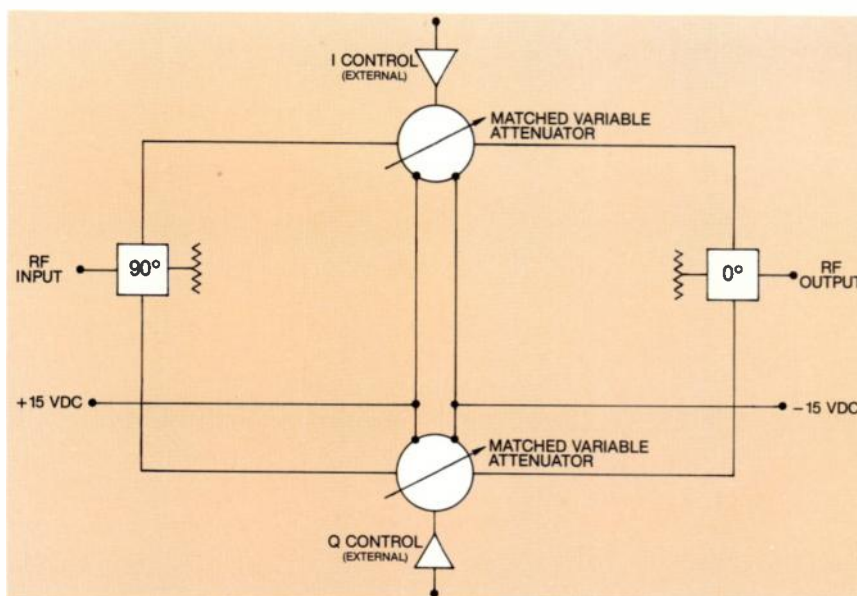
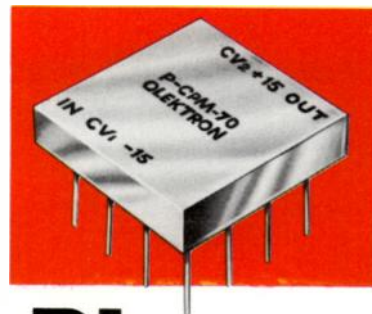
This book covers the technology and applications of power Field-Effect Transistors. The book begins by comparing FETs with several power semiconductors and gives a brief history of power FET development. Numerous types of power FETs with their features, performance and characteristics are compared. A chapter on characterization and modeling should give the designer a better understanding of the performance of power FETs. The remainder of the book is dedicated to applications ranging across a wide range of interests.

Partial Contents: Types of power FETs. Fabrication of power FETs. Characterization and modeling of power FETs. Using the power FET in switching power supplies . . . audio power amplifiers . . . motor control . . . logic control . . . as a switch . . . in high frequency applications. Selecting the right FET for the right job.

Available from Prentice-Hall Inc., Englewood Cliffs, NJ 07632, 315 pages, \$24.95, Hardcover, 1982. □

r.f. design

New P-Series Complex Phasor Modulators(CPM)



Olektron's P-CPM Series of modulators perform linear amplitude and phase control in a single package.

These modulators provide dynamic phase and amplitude control in signal processing systems and interface directly with control signal operational amplifiers.

Inputs required for 360 degree phase control and 40 dB amplitude control are:

| | |
|-----------------|---------------------------------|
| I and Q Control | ± 10V, 1000 ohms load impedance |
| RF Input | + 5 dBm @ 50 ohms |
| Power Supply | ± 15 VDC @ 10 mA |

Typical Specifications:

| | |
|----------------------------|--------------------------------------|
| Carrier Frequency | 10 to 500 MHz (available in octaves) |
| Modulation Rate | 0 to 1 MHz |
| Phase Range | 0 to 360 degrees |
| Amplitude Range | - 6 to - 46 dB |
| Impedance | 50 ohms |
| VSWR | 1.5 to 1 |
| Standard Temperature Range | 0 to 70C |

The unit measures 1"x1"x.25". For complete data write or call today. Tel: (617) 943-7440

•Product catalog (52-page) available on your company letterhead.

OLEKTRON
CORPORATION

61 Sutton Road/Webster, Mass. 01570

YOUR CHALLENGE IS OUR PROGRESS

INFO/CARD 58

Classifieds

CLASSIFIED ADVERTISING RATES

(priced by column inch; earned rates available)

ONE TIME RATE: \$90/in. • THREE TIME RATE: \$80/in. • SIX TIME RATE: \$70/in.

Confidential box numbers are available with any ad for \$5.00

Mail inquiries to *RF Design Magazine*, 6430 S. Yosemite, Englewood, CO 80111, or call Betsy Loeff at (303) 694-1522.

Professional Resume Services

1125 South Cedar Crest Boulevard, Allentown, Pennsylvania 18103. We provide complete resume preparation for RF design professionals. Prompt. Confidential. Call collect or write. (215) 433-4112.

ATC

NUMBER ONE IN CABLE COMMUNICATIONS

ELECTRONIC ENGINEER

American Television & Communications Corporation, the nation's largest and fastest growing cable television company located in the "mile high" Denver area, has an immediate need for an Electronic Engineer.

Position requires BSEE with 4+ years experience in RF and video circuit design. Good oral and written communication skills essential.

ATC offers an excellent compensation package, and the opportunity to work with the communications technology of the future. For prompt consideration, please send detailed resume and salary history to:

MANAGER OF EMPLOYMENT

AMERICAN TELEVISION & COMMUNICATIONS CORPORATION
160 INVERNESS DRIVE WEST
ENGLEWOOD, COLORADO 80112

An Equal Opportunity Employer M/F/H/V

R.F. DESIGN ENGINEERS

Cubic Communications, a leader in HF and VHF communications systems with equipment installed worldwide, is expanding its commercial product line to include a new generation of high performance radio communications products. We are looking for several talented R.F. design engineers to participate in our growth. If you are experienced in the design of one or more of the following areas, we will have an interest in you.

- Receiver and Exciter Circuits
- Frequency Synthesizer Circuits
- Processor Controlled Transceivers
- Solid State Power Amplifiers
- HF Antenna Couplers

We are located in sunny Southern California but away from the smog and congestion of the big cities. We are a small company with the backing of our much larger parent corporation. We offer the usual assortment of fringe benefit packages plus an opportunity to share in our success through our profit sharing plan.

If you are interested, please send your resume and salary history to our Director of Engineering at:



CUBIC COMMUNICATIONS

A Member of the Cubic Corporation
Family of Companies
305 Airport Road, Oceanside CA 92054
An Equal Opportunity Employer

ALS MINIATURE CURRENT PROBE

The Solution to Wideband Current Measurement

Applications: GaAs Lasers/LEDs
RF/Video Amps

Insertion Impedance:

.02 Ω shunted by 4 μ h

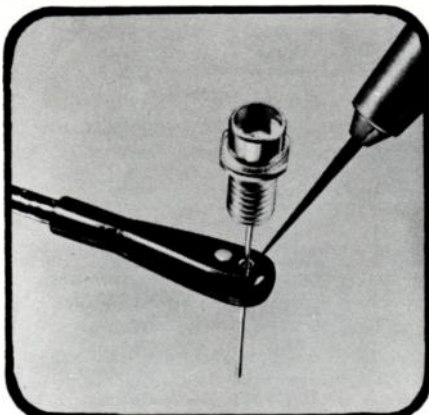
Risetime: 3.5ns

Bandwidth: 8KHz to 100MHz

Signal Response: up to 100A

Sensitivity: 1mV/mA \pm 2%

Price: \$85 US



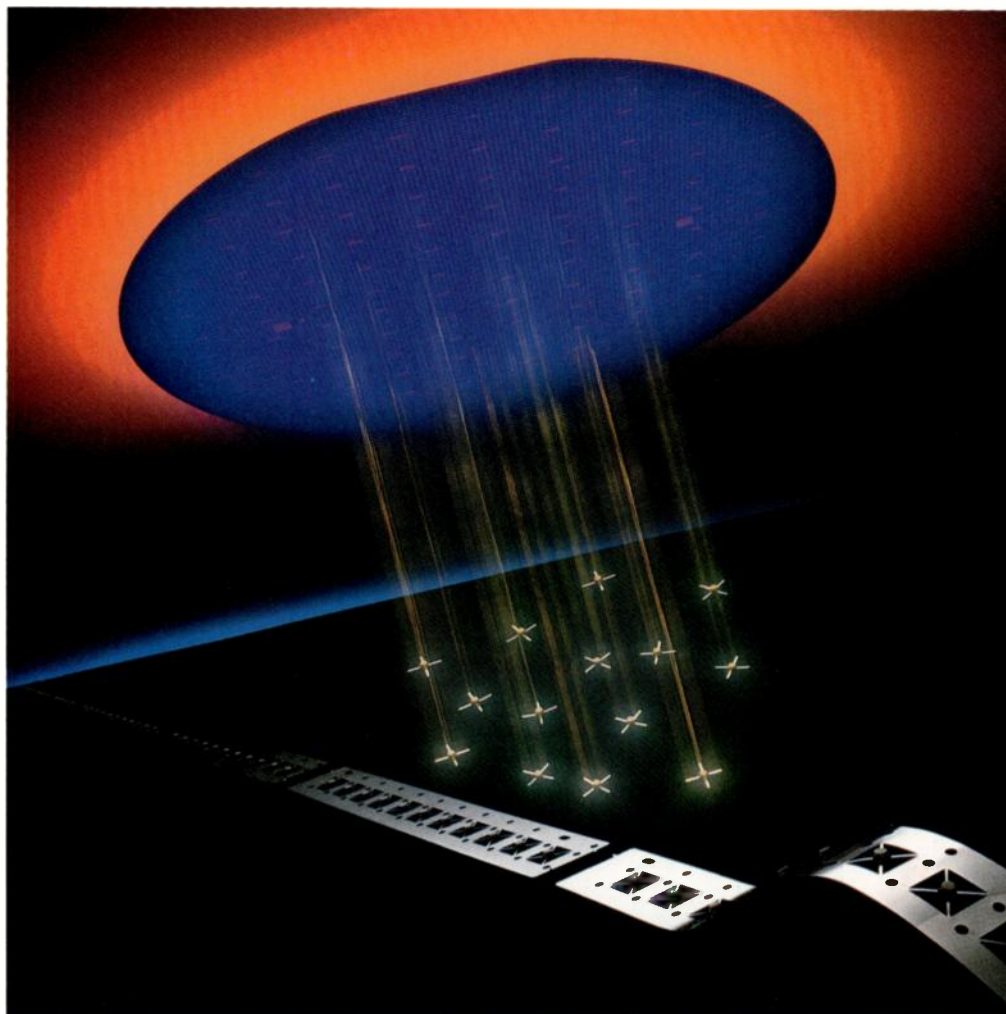
AMERICAN LASER SYSTEMS, INC.
106 James Fowler Road, Goleta, CA 93117
Phone (805) 967-0423

INFO/CARD 59

Advertiser Index

| | | | |
|---------------------------------------|--------|-------------------------------------|--------|
| Adams Russell-Anzac Div. | 2 | International Microwave | |
| Adams Russell-Modpak Div. | 62 | Devices, Inc. | 38-39 |
| Allen Avionics | 32 | JFW Industries | 63 |
| Alpha Components | 61 | Johanson Mfg. Corp. | 29 |
| American Laser Systems | 74 | E.F. Johnson Co. | 32 |
| American Microwave Corp. | 56 | K & L Microwave | 27 |
| Amplifonix | 35 | LectroMagnetics, Inc. | 16 |
| Avantek, Inc. | 11 | Lindgren RF Enclosures | 25 |
| Blue M, A Unit of General Signal | 70 | M/A-COM OSW, Inc. | 47 |
| California Eastern Labs | 50 | M/A-COM Silicon Products, Inc. | 3 |
| Centurion International | 64 | Marlee Switch Co. | 67 |
| Cinox Corp. | 34 | Matec, Inc. | 24 |
| Comlinear Corp. | 8 | Microwave Power Devices | 33 |
| Communitronics, Ltd. | 66 | Mini Circuits | 5, 43 |
| Cytec Corp. | 42 | Murata Erie North America | 18 |
| Daico Industries, Inc. | 21 | Nicolet Instrument Corp. | 69 |
| Damon/Electronics, Div. | 70 | Olektron Corp. | 73 |
| Dielectric Communications | 7 | Polarad Electronics | 76 |
| E Systems Melpar Div. | 52 | Programmed Test Sources, Inc. | 60 |
| Eagle Consultants | 52 | Sage Laboratories | 58, 59 |
| Eagle Magnetics Co. Inc. | 20 | Sprague-Goodman Electronics | 24 |
| Elcom Systems | 72 | Techtrol Cyclonetics, Inc. | 16 |
| Electroline | 51 | Teledyne Crystallonics | 20 |
| Electro-Metrics | 17 | Test & Measurement World Expo. | 65 |
| Electronic Research Co. | 42 | Texscan Corp. | 53 |
| FG Engineering | 57 | Thompson-CSF Components Corp. | 71 |
| GTE Corp. | 36 | Jim Young & Associates. | 51 |
| Gilbert Engineering Co. Inc. | 19 | Vectron Laboratories. | 72 |
| Hewlett Packard | | Watkins-Johnson | 55 |
| Company | 15, 75 | Wavetek Indiana, Inc. | 45 |
| Instrument Specialties Co. Inc. | 28 | Wide Band Engineering | 56 |
| International Crystal | 61 | Zeta Laboratories | 26 |

SURPRISE!



HP's new JEDEC bipolars offer high performance at low cost.

HP's newest bipolars are designed for those VHF and UHF applications that require both low cost and performance guaranteed to match data sheet specifications. Choose from either of two cost-effective transistors:

The general purpose 2N6838* HXTR-3103 features a minimum gain bandwidth product of 5000 MHz, a maximum noise figure of 2.3dB, and a minimum transducer gain of 13.5dB at 1000 MHz. The linear power model, 2N6839* HXTR-3104 provides minimums of 4000 MHz gain

bandwidth product, and 19dBm power output with 14dB gain at 1dB gain compression at 1000 MHz. Since both of these transistor products are JEDEC registered, you're always assured of getting repeatable and predictable RF performance for lower design and manufacturing costs — key to maintaining your competitive edge.

In 100 piece quantities, the 2N6838* HXTR-3103 is priced from \$7.35, and the 2N6839* HXTR-3104 from \$9.35. For immediate off-the-shelf

delivery, call your authorized HP components distributor. In the U.S., contact Hall-Mark, Hamilton/Avnet, Pioneer Standard, Schweber, or the Wyle Distribution Group. In Canada, call Hamilton/Avnet or Zentronics, Ltd.

*Registration numbers assigned by the Joint Electron Device Engineering Council (JEDEC) certifying Hewlett-Packard Company as the originator of standards for these solid state product types, and exclusive holder of associated type designations. U.S. domestic prices only.

When performance must
be measured by results



HEWLETT
PACKARD

INFO/CARD 60

CLEARER, SHARPER PICTURES.

Polarad's new 600B Series Spectrum Analyzers offer enhanced signal resolution for close-in analysis.

Polarad has developed a series of higher resolution filters for close-in measurements of carrier and/or signals offered as "Option - 6".

And with Polarad, you get the digital memory that's far superior to variable persistence types... high resolution with continuously updated displays — without blooming, fading or smearing.

Polarad's 600B Series of Spectrum Analyzers...the performance, ease of use and versatility you need, at a price you can afford.

Call us for a demonstration and quotation today or write for further information and specifications.

INFO/CARD 61

4 kHz signal separation with 60 dB of dynamic range is provided by the new "-6 filter option"



Polarad's internal digital memory lets you recall a display at the push of a button.

SEE US AT
WESCON BOOTHS 1450/52.

Selection Guide

| Model | Frequency |
|--------|---------------|
| 632B-1 | 100 kHz-2 GHz |
| 630B-1 | 3 MHz-40 GHz |
| 640B-1 | 3 MHz-40 GHz |