September/October 1983

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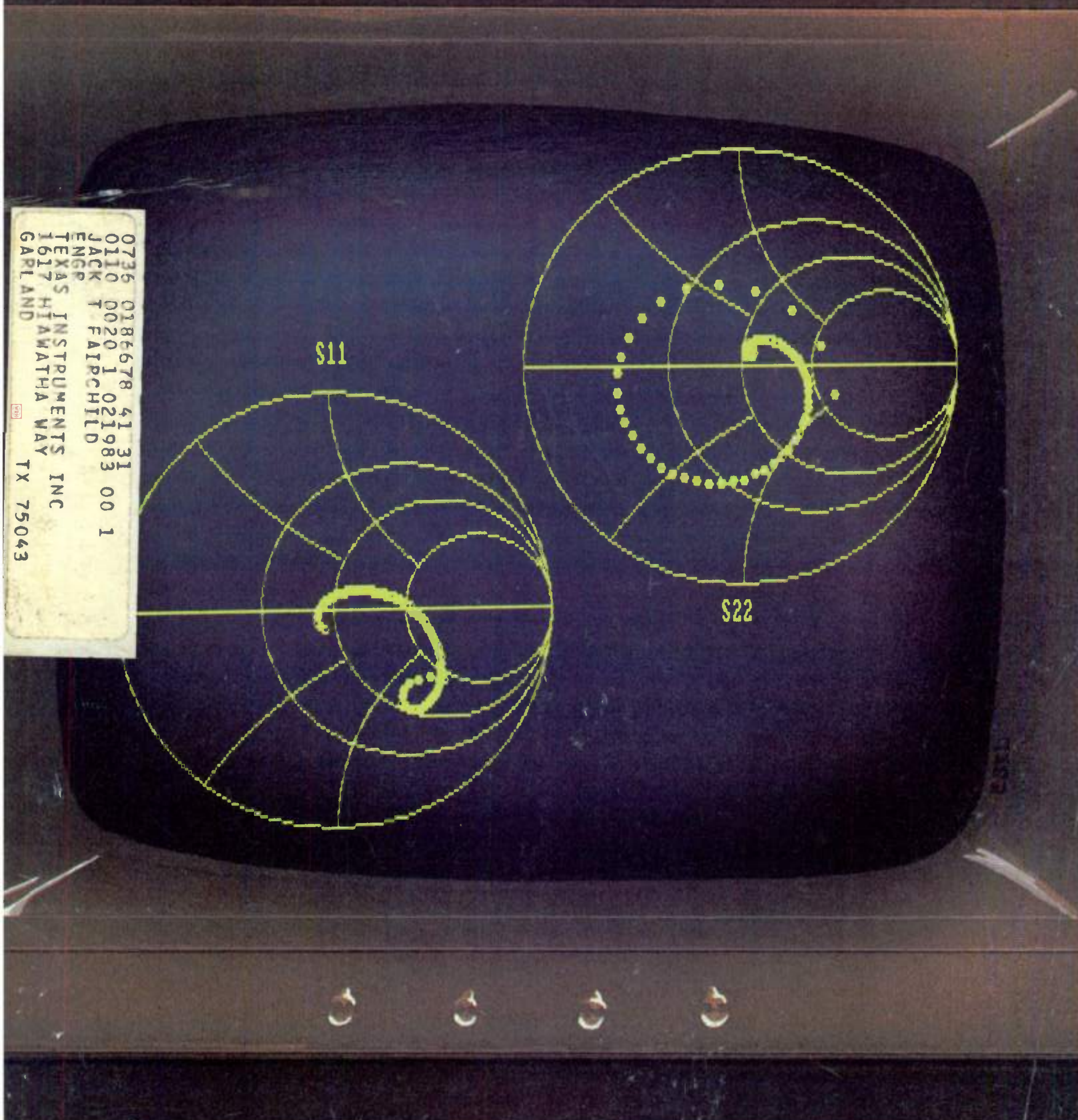
rf design



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900 MHz	MOBILE APPLICATIONS				
Type	Power (W)	Freq. (MHz)	Gain (db) min.	VCC (V)	Package
BLU98	0.5	900	9.0	12.5	SOT-103 E1
BLV90	1	900	7.5	12.5	SOT-172
BLV91	2	900	6.5	12.5	SOT-172
BLU99	4	900	7.3	12.5	SOT-122
BLV92	4	900	8.0	12.5	SOT-171
BLV93	8	900	6.0	12.5	SOT-171
BLV94	15	900	6.0	12.5	SOT-171

400 to 512 MHz	MOBILE APPLICATIONS				
BLU60/12	60	175	4.8	12.5	SOT-119
BLU45/12	45	175	5.1	12.5	SOT-119
BLU30/12	30	175	6.0	12.5	SOT-119
BLU20/12	20	175	6.5	12.5	SOT-119
BLW82	30	175	5.0	12.5	SOT-119
BLW81	10	175	6.0	12.5	SOT-122
BLU99	5	175	10.5	12.5	SOT-122
BLW80	4	175	8.0	12.5	SOT-122
BLW79	2	175	9.0	12.5	SOT-122
BLX65	2	175	6.0	12.5	TO-39

175 MHz	MOBILE APPLICATIONS				
BLV75/12	75	175	7.0	12.5	SOT-119
BLV45/12	45	175	6.5	12.5	SOT-119
BLV30/12	30	175	8.2	12.5	SOT-119
BLW60C	45	175	5.0	12.5	SOT-120
BLW31	28	175	9.5	12.5	SOT-120
BLY89C	25	175	6.0	12.5	SOT-120
BFQ43	4	175	12.0	12.5	TO-39E
BFQ42	2	175	10.5	12.5	TO-39

30 to 900 MHz	BASE STATIONS				
Type	Power (W)	Freq. (MHz)	Gain (db) min.	VCC (V)	Package
BLW96	200	30	13.5	50	SOT-121
BLV25	175	108	10.5	28	SOT-119
BLV80/28	80	175	6.5	28	SOT-119
BLV33F	85	225	10.5	28	SOT-119
BLV36	120	225	10.0	28	SOT-161
BLU53	100	400	6.5	28	SOT-161
BLV97	30	860	6.5	24	SOT-171
BLV57	38	860	6.5	25	SOT-161

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Type	Freq (MHz)	P In (MW)	P Out (W)	VCC	Package
BGY32	68-88	100	20	12.5	SOT-132
BGY33	80-108	100	20	12.5	SOT-132
BGY35	132-156	150	20	12.5	SOT-132
BGY36	148-174	150	20	12.5	SOT-132
BGY43	148-174	150	13	12.5	SOT-132B
BGY40A	400-440	100	7.5	12.5	SOT-132C
BGY41A	400-440	150	13	12.5	SOT-132C
BGY40B	440-470	100	7.5	12.5	SOT-132C
BGY41B	440-470	150	13	12.5	SOT-132C
BGY40A	470-512	100	7.5	12.5	SOT-132C
BGY41C	470-512	150	13	12.5	SOT-132C
BGY45A	68-88	150	30	12.5	SOT-301-A-03
BGY45B	144-175	150	30	12.5	SOT-301-A-03
BGY46A	400-440	30	1.5	9.6	SOT-26NC
BGY47A	400-440	45	2.2	9.6	SOT-26NC
BGY47B	430-470	45	2.2	9.6	SOT-26NC
BGY47C	460-512	45	2.2	9.6	SOT-26NC
BGY22	380-512	50	29	12.5	SOT-75A
BGY23	380-480	2.5 WATTS	7	12.5	SOT-75A

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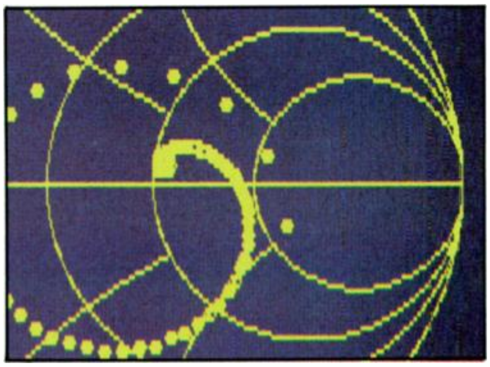
INFO/CARD 1

WRH

r.f. design

September/October 1983



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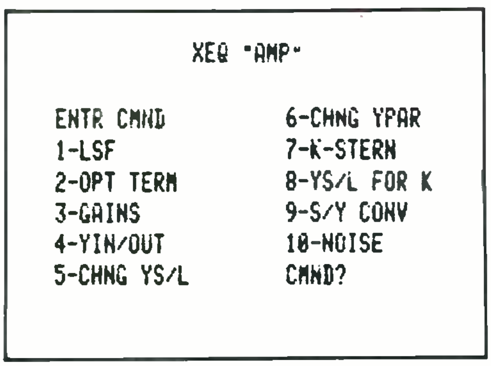
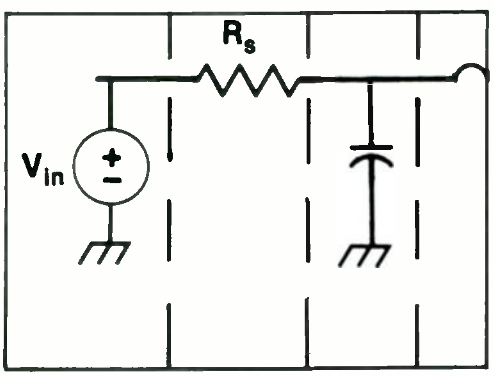


Low Noise Amplifier Design, P. 10



GP Ladder Analysis, P. 32

Cover

Features

Departments

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Dear Sir:

We very much appreciate having had a nice review of our book *70 Years of Radio Tubes and Valves* in your recent issue, but a typographical error has caused us to have to write some rather embarrassing letters — I thought you'd want to know about this.

Harvey Roehl
The Vestal Press Ltd
Vestal, New York 13850

Unfortunately, the magazine made a typographical error in the price of the book, and it is not $12.95, it is $21.95. Ed.

Feedback on PLL Article

Several readers have commented on Andrzej Przedpelski's article on PLL. Specifically on the subject of "divide by N delay." The following is the author's response to these questions. ED.

The divider delay concept has been bothering several people for some time now. The delay, as presented in the *r.f. design* PLL article, has been arrived at by at least two investigators: Scott Wetenkamp of Watkins-Johnson (as referenced in the article) and Stan Goldman of Texas Instruments.

Let me comment on some of your comments:

1). There seems to be a general agreement that there is a delay in the divider circuit. The most valid approch, in my opinion, is that any transition (at the output frequency) does not "arrive" at the phase comparator until N transition later. Let's take a conceptual example: a 10 MHz synthesizer with N = 10,000. The delay in the divider is 1 millisecond. This delay, at a loop frequency of let's say 1 KHz, would be equivalent to 360 degrees of phase shift; at 100 Hz, 36 degrees, etc. The phase margin would be decreased by the same amount.

2. The expression e^{-sT} expresses a delay T in the frequency domain. It satisfies the assumed conditions: the gain is unity at all frequencies and the phase changes continuously with frequency (as shown in Figs. 19 and 20). This is confirmed by your correct statement that the above expression can be expressed as an infinite series with an infinite number of poles (as done by Wetenkamp in a truncated form). The fact that there are an infinite number of poles is taken into account in the article. Any PLL has a very large number of spurious poles, such as the op-amp and VTO response, stray reactances, etc., not usually accounted for in the more common PLL analyses. As I stressed before, there is no such thing as "second order" PLL, although that seems to be the usual example used. Your comment that these poles would make the loop hard to stabilize is correct in cases of loops with large bandwidths and large N, *if this effect is not taken into account.* The consideration of all these effects, not usually taken into account, *and their use in optimizing the loop,* were the main reason for these articles.

Your comments are appreciated and comments from other readers would be also welcome, whether positive or negative. I hope that the above analysis could be someday confirmed exactly by rigorous experimental tests. So far, some of the latest actual designs indicate that the overall analysis is correct.

Andrzej B. Przedpelski

QSL Cards

Dear Editor:

Help ! I've been buried in a pile of coupons requesting free QSL cards *(Ad:Mar/Apr 83).* Please tell your readers RCA is making every effort possible to promptly fill all requests. My initial QSL card print order will not be sufficient and I've had to increase the order eightfold. This will cause some delay in our ability to respond to the requests. Please pass my apologies on to your readers for the extended waiting time they may experience.

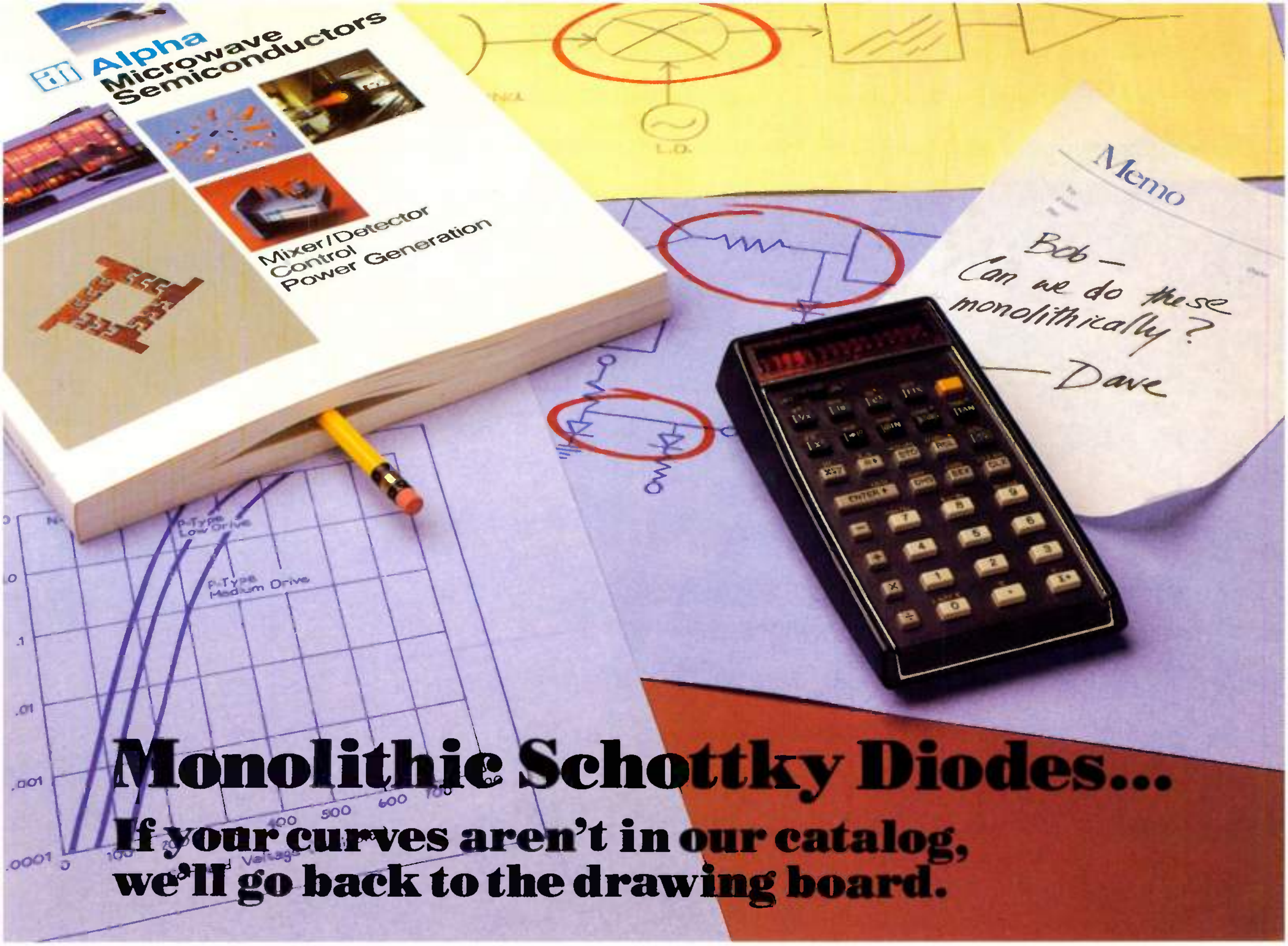
Sincerely,

Tom Bluesteen
RCA Government Communications

"Basic, The Universal Language"?

Dear Sir:

Occasionally you publish programmable calculator programs to solve particular design problems. At the risk of impertinence, may I suggest the programmable calculator is obsolete, having been replaced by the personal computer. You should



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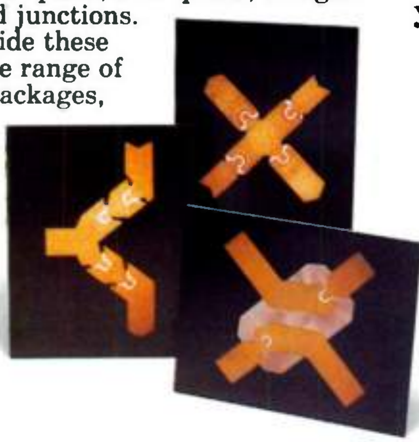

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INFO/CARD 4

publish program listing in BASIC, the universal language of personal computers. From a purely practical point of view, an article with HP-41 or TI-59 listing is of interest to only a small subset of your readers, while a BASIC program is available on all personal computers and nearly all time-sharing systems, and usually requires trivial translation for any machine from Apple to ZX-81. At the same time, few journals have provided a forum for publishing RF design programs, and your magazine could continue its leadership by filling this lack — but not by publishing calculator programs; these belong with the "short cuts on your slide rule" articles!

Sincerely,
V.P. O'Neil II
Member of Technical Staff
Motorola, Inc.

Errors in Stub Matching Article

Dear Sir:

I would like to express my thanks to Mr. Lev for the feedback (Letters July/August 1983) pointing out that several errors are present in the article, "Calculator Aided Stub Matching." Please inform your readers of the following typographical mistakes and the corrections.

$$\frac{Y(x)}{Y_o} = \frac{Y_T/Y_o + j\tan\beta x}{1 + j(Y_T/Y_o)\tan\beta x} \quad (4)$$

$$X = \frac{\lambda}{2\pi}\tan^{-1}\left\{\frac{\frac{G(x)}{Y_o}B_{Tn} \pm \sqrt{G_{Tn}\left[\frac{G(x)}{Y_o}\left|Y_{Tn}\right|^2 - \left(\frac{G(x)}{Y_o}\right)^2 - G_{Tn} + \frac{G(x)}{Y_o}\right]}}{\frac{G(x)}{Y_o}(|Y_{Tn}|^2) - G_{Tn}}\right\} \quad (6)$$

Neither of these errors appear in the program. Equation (7) is in error and should read as follows:

$$\frac{B(x)}{Y_o} = \pm\sqrt{\frac{G(x)\left[1 + \left|Y_{Tn}\right|^2 - \frac{G(x)}{Y_o}G_{Tn}\right] - G_{Tn}}{G_{Tn}}} \quad (7)$$

This error does occur in the program "MAT", and as pointed out by Mr. Lev causes a very small error to occur for the calculation of the stub lengths. The program should be modified as follows: Lines 142 thru 155 should be deleted and the following lines 142 thru 154 inserted in their place.

Program Corrections For "MAT"

```
140 X↑2
141 +
142 1
143 +
144 RCL 04
145 RCL 09
146 *
147 CHS
148 +
149 RCL 09
150 *
151 RCL 04
152 -
153 RCL 04
154 /
155 SQRT
```

I apologize for any inconvenience.

Sincerely,

Alan Victor

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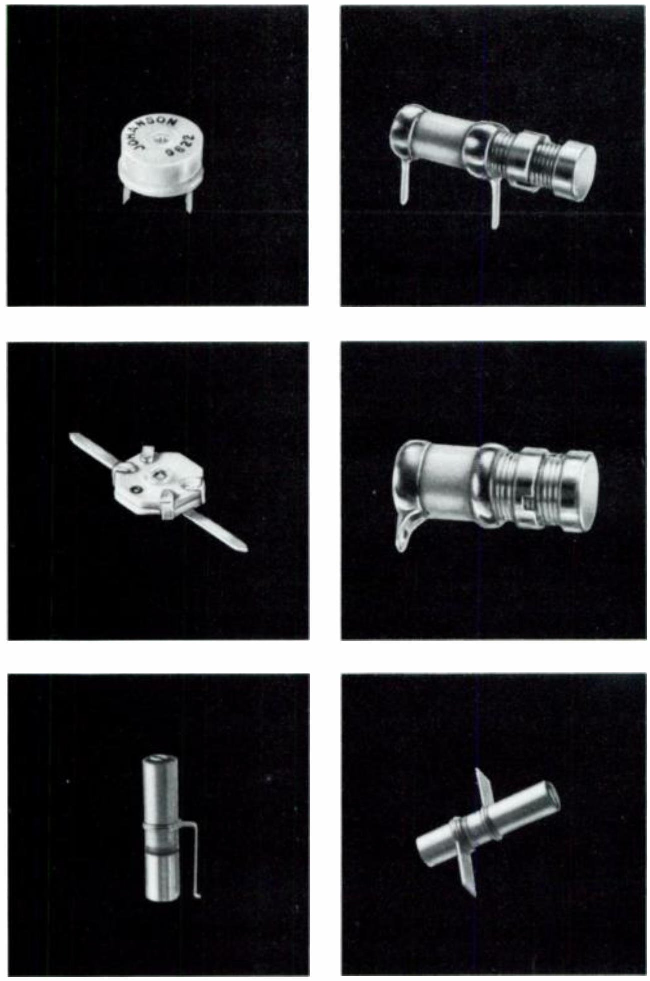

Low Noise Amplifier Design

This low-noise program for the HP-41 calculator is intended to be an addition to the general amplifier design package previously published in the March/April 1983 issue. Also a version of the program is now offered for the TI-59 calculator.

By D. R. Hertling and R. K. Feeney
School of Electrical Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

Both TI-59 and HP-41 programs are given to calculate termination admittances, as shown in Figure 1, for low noise devices whose Y or S parameters are known. The programs work with both inherently stable and potentially unstable devices.

Background

For optimum low noise performance, both the source conductance and susceptance must be specified. Most manufacturers, however, specify only the source conductance. Sometimes, although rarely, both G_s and B_s are given. If neither low noise termination is given, the procedure developed by Nielsen, can be used to find the optimum source conductance. The optimum source susceptance can then be determined experimentally. Several other references describe procedures for calculating both the source conductance and susceptance for low noise [2, 3, 4]. These procedures, however, are tedious and depend upon experimentally determined quantities.

Even if both G_s and B_s are known, the designer may choose to also calculate the B_s which yields maximum gain. The overall noise figure of a multistage system is a function of both the noise figure and gain of the first stage. It is therefore possible that even if the noise figure of the first stage is increased by altering B_s, its gain could be increased by a large enough factor to decrease the overall noise figure of the system. The designer may therefore choose to use the value of B_s which maximize the gain of the stage. If the device is inherently stable, the designer is only concerned with optimizing either the noise performance or gain of the amplifier. If, however, the device is potentially unstable, the designer must first provide an adequate degree of stability.

A device is inherently stable if the Linvill stability factor, C, is less than one or greater or equal to zero. In terms of Y parameters, the Linvill stability factor is given by

$$C = \frac{|y_f y_r|}{2g_i g_o - \mathrm{Re}(y_f y_r)} \qquad (1)$$

If the device is inherently stable, there are two cases to consider: (1) only G_s specified, and (2) both G_s and B_s specified for low noise performance. For both cases the designer will want to find the unspecified terminations which optimize the amplifiers's performance.

Design for the second case is straightforward since, with G_s and B_s specified, the designer need only conjugately match the output port to maximize the gain. The calculator programs handle this case as follows; after the Y parameters of the device are entered, the Linvill stability factor is calculated. Even if the device is potentially unstable, it is possible that the mismatch at the input port caused by the low noise terminations will make the circuit stable. The programs, therefore, then calculate the output admittance of the amplifier and check to see if its real part is greater than zero. If the output conductance is positive, then the optimum load termination is simply found by taking the complex conjugate of the output admittance. If the real part of the output admittance, G_{put}, is negative, a different procedure which is described later must be used. Next, the input admittance is calculated to check if its real part, G_{in}, is negative. Finally, the transducer gain, G_T, is calculated in decibels.

Design for the first case requires slightly more work. It can be shown that the source susceptance, B_s, for maximum gain is the same as it would be if the source conductance, G_s, had not been specified. The expression for this optimum value for B_s is:

$$B_s = -b_i + \frac{\mathrm{Im}(y_f y_r)}{2g_o} \qquad (2)$$

The programs handle this case as follows; after calculating the Linvill stability factor, the source susceptance is calculated from equation (2). Then with both G_S and B_S now known, execution is identical to the second case. Again both the input and output admittances are calculated to check if their real parts are negative.

If the output conductance with the low noise source termination is negative, an approach must be taken which first ensures stability. Stern developed a procedure using Y parameters for designing amplifiers with potentially unstable devices. The Stern stability factor, K is given by:

$$K = \left[\frac{2(g_i + G_s)(g_o + G_L)}{|y_f y_r| + \mathrm{Re}(y_f y_r)}\right] \qquad (3)$$

If K is greater than unity the circuit is stable. The larger the K, the more stable the amplifier, however, the lower the amplifier gain. In other words, gain is exchanged for stability. A Stern factor from approximately 4 to 10 is adequate for most situations.

The source conductance for optimum noise performance is given by the manufacturer. With G_s known, the designer can choose a Stern factor, K, and then solve equation (3) for the load conductance G_L. Similar to the design procedure for inherently stable devices, there are two cases to consider: only G_s specified, and both G_s and B_s specified for low noise performance.

Design for the second case is straightforward since with both G_s and B_s known, the output admittance of the amplifier can be calculated. The real part of Y_L is no consequence since the load conductance has already been determined from equation (3) to yield the chosen degree of stability. The desire load susceptance, B_L, is the one which yields maximum gain. B_L should therefore be chosen to be the negative of the imaginary part of the calculated output admittance.

It should be noted that both ports of this amplifier have been purposely mismatched. The input port is mismatched to yield optimum low noise performance and the output port has been mismatched to ensure an adequate margin of stability.

Design for the first case requires more work since the source susceptance must also be determined. The programs use a modified Stern's procedure involving an iterative method of successive approximations. The real part of the source and load terminations are determined as in case two. The imaginary parts are determined as follows; B_L is first chosen to be the negative of b_o. (b_o is the imaginary part of y_o.) Next, using the previously determined value of G_L and the first guess for B_L, the input admittance of the amplifier is calculated. B_s is then taken to be the negative of the imaginary part of the input admittance. Using the given value for G_s and the first guess for B_s, the output admittance for the amplifier is calculated. The second guess for B_L is then taken to be the negative of the output susceptance. This procedure continues until the new value for B_L is within .1 percent of its value from the previous iteration. A very appealing feature of this iterative procedure is its similarity to experimental optimization of an amplifier. Experimentally the circuit would be optimized by alternatively adjusting B_s and B_L until maximum gain is realized.

The TI-59 Software

The TI-59 software is split into three programs. The first one is for inherently stable devices and requires only the Y parameters, the source conductance, and if known, the source susceptance for low noise. If the output conductance or the net input conductance ($G_{in} + G_s$) is negative then the second program should be run. The second program requires the device Y parameters, G_s, B_s (if known), and a Stern factor. Both programs use the same registers for the Y parameters and the source and load terminations. Thus it is unnecessary to re-enter this data when going from one program to the other. Also direct addressing is not used in any of the programs to facilititate any program additions or modifications. If the designer wishes to use S parameters, the third program which converts S → Y parameters should be executed first. This program is compatible with the other two in that the device parameters are entered in the same order and the resulting Y parameters are automatically stored in the proper registers for execution of either of the other two programs.

The following examples illustrate the use of the programs.

Example 1 (TI)

Find the unknown terminations for the device whose Y parameters are given. The optimum source termination is $Y_s = 2.0 - j25.0$ mmhos.

$$[y] = \left[\begin{array}{cc} 8.5 + j3.5 & 0 - j.2 \\ \hline 40 - j20 & .35 - j.75 \end{array}\right] \text{ all mmhos}$$

This example will be solved two ways. The first solution will assume that only G_s is known. For the second solution it will be assumed that both G_s and B_s are known. Procedure:

(1) Read side 1 and side 2 of magnetic card #1. (Inherently stable device program.)
(2) Press E to initialize the program.

(3) Enter y_i, y_r, y_f and y_o in order using the following procedure:

Enter g_i
Press A
Enter b_i
Press A
.
.
.
Enter b_o
Press A

(4) Enter G_s
Press B

(5) Press A' if a printout is desired.

(6) Press C

The following printout is obtained.

```
 8.5-03
 3.5-03
  0.  00
-2. -04
  4. -02
-2. -02
 3 5-04
-7.5-04
```

```
 0.8989218      C
     0.002     GS
.0149285714     BS
.0001447849     GL
.0002114586     BL
20.59568013     GT
```

If the printer is not used, the calculator will stop with C displayed. Successive pressings of R/S will display G_s, B_s, G_L, and G_T in dB in that order.

To do this example for both G_s and B_s known, all that is necessary is to enter B_s, press B' and then press C. The way the program is written, flag 2 is set when B_s is entered. Therefore flag 2 should be reset if it is desired to again run the program with only G_s given. For $B_s = -25.0$ mmhos, the following printout is obtained:

```
 0.8989218      C
     0.002     GS
    -0.025     BS
.0001229258     GL
.0004530568     BL
17.54641583     GT
```

[It should be noted that flag 1 is set if a printout is desired, therefore, if RST is pressed, which resets all flags, the program will also not print the results.]

Example 2 (TI)

This example illustrates design using a potentially unstable device which is not stabilized by the low noise mismatch at the input port.

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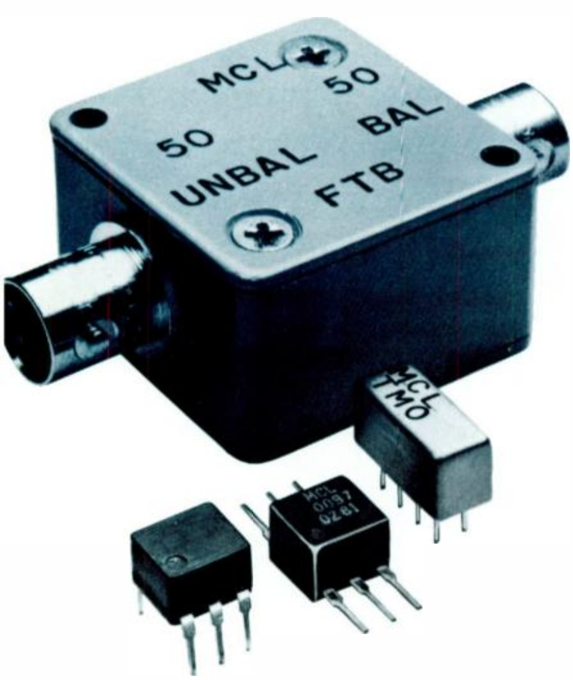

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Model No.	TMO1-1T	TMO2-1T	TMO2.5-6T	TMO3-1T	TMO4-1		TMO5-1T	TMO13-1T
Imped. Ratio	1	2	2.5	3	4	4	5	13
Freq. (MHz)	.05-200	.07-200	.01-100	.05-250	.2-350	8-350	.3-300	.3-120
T Model (10-49)	$3.95	$4.25	$4.25	$3.95	$2.95	$4.95	$4.25	$4.25
TMO model (10-49)	$6.45	$6.75	$6.75	$6.45	$4.95		$6.75	$6 75

UNBALANCED PRIMARY & SECONDARY

	T2-1	T3-1	T4-2	T8-1	T14-1
Model No.	TMO2-1	TMO3-1	TMO4-2	TMO8-1	TMO14-1
Imped. Ratio	2	3	4	8	14
Freq. (MHz)	.025-600	.5-800	.2-600	.15-250	.2-150
T model (10-49)	$3.45	$4.25	$3.45	$3.45	$4.25
TMO Model (10-49)	$5.95	$6.95	$5.95	$5.95	$6.75

FT FTB

Model No.	FT1.5-1	FTB1-1	FTB1-6	FTB1-1-75
Imped. Ratio	1.5	1	1	1
Freq. (MHz)	.1-400	.2-500	.01-200	.5-500
(1-4)	$29.95	$29.95	$29.95	$29.95

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INFO/CARD 9

59 Rev. B

$$[y] = \begin{bmatrix} 1.5 + j3.5 & 0 - j.3 \\ 56 - j11 & .1 + j.75 \end{bmatrix} \begin{array}{l} \text{all} \\ \text{mmhos} \end{array}$$

G_s = 2.0 mmhos, B_s unknown

To do this example, simply repeat steps (1) through (6) of Example 1.

```
         1.5-03
         3.5-03
          0. 00
         -3.-04
         5.6-02
        -1.1-02
          1.-04
         7.5-04
-.0000980193     GOUT
```

The calculator prints a negative value for G_{out}. Thus, with the given source conductance, the real part of the output admittance is negative indicating that the circuit is potentially unstable. If the printer is not used, this negative value for G_{out} would be displayed. The second program should now be run.

Procedure:

(1) Read side 1 and side 2 of the second magnetic card. (Potentially unstable device program.)

(2) Since the Y parameters and G_s are already stored in the proper registers, simply enter a Stern factor (4 is used for this example.)

(3) Press C

The following printout is obtained.

```
          4.       K
       0.002       GS
 -.0053394657      BS
  0.007797737      GL
 -.0048994022      BL
  24.66890426      GT
```

If B_S is also known, simply enter its value and press B′ prior to entering K and running the program. Assuming B_s = −10.0 mmhos, the following printout is obtained.

```
        4. 00      K
        2.-03      GS
       -1.-02      BS
   7.797737-03     GL
  -2.2224771-03    BL
   1.9999671 01    GT
```

Example 3 (TI)

This example uses S parameters to demonstrate the S → Y parameter conversion program.

$$[S] = \begin{bmatrix} .792\angle -107.4° & .07\angle 26° \\ 1.995\angle 81.1° & .659\angle -60.8° \end{bmatrix}$$

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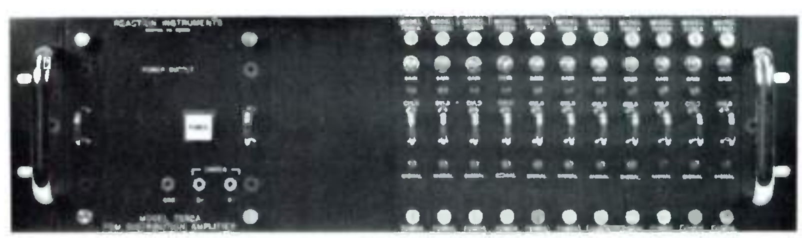

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(Example 3 continued)

The chosen device is an HP 2N6680 GaAs FET and the parameters are for 4 GHz. The optimum reflection coefficient Γ_o = .618 ∠98° which corresponds to an optimum source termination $Y_{s\ opt}$ = 10.22 – j20.23 mmhos. This termination should yield a noise figure F_{min} = 1.6 dB (1.45).

Procedure:

(1) Read side (1) and side (2) of the third magnetic card. (The S → Y conversion program.)
(2) Press E to initialize the program.
(3) Enter S_{11}, S_{12}, S_{21}, and S_{22} in order as follows.
$|S_{11}|$
Press A
$\angle S_{11}$
Press A
.
.
.
$\angle S_{22}$
Press A
(4) Press B
(5) After execution halts, read side (1) and side (2) of the first magnetic card. (Inherently stable program.)
(6) Enter G_s
Press B
(7) Enter B_s
Press B′
(8) Press A′ if a printout is desired.
(9) Press C

The following printout is obtained.

```
        0.792
       -107.4
         0.07
          26.
        1.995
         81.1
        0.659
        -60.8
  1.287686117    C
      0.01022    GS
     -0.02023    BS
  0.006749021    GL
 -.0142927572    BL
  11.84801243    GT
```

In order to see if the B_s which yields maximum gain would possibly provide better overall performance, rerun the program as follows.
(1) Press INV SF 2 (this resets flag 2 so that the value of B_s which yields maximum gain is calculated.)
(2) Press C

The following printout is obtained.

```
  1.287686117    C
      0.01022    GS
 -.0349985274    BS
  .0024186614    GL
 -0.014608277    BL
  14.67647499    GT
```

In order to see which solution provides the best overall noise figure, calculate the new noise figure of the device from:

$$F = F_{min} + \frac{R_N}{G_s}[(G_s - G_o)^2 + (B_s - B_o)^2] \qquad (4)$$

$F_{min} = 1.44$, $G_s = 10.22$ mmhos, $B_o = -20.23$ mmhos.

R_n is given in the data sheet. $R_n = 23.14$ ohms. From equation (4):

$F = 1.93$

The designer therefore has the choice between:

$F = F_{min} = 1.44$ and $G_T = 11.85$ dB (15.31)

and

$F = 1.93$ and $G_T = 14.68$ dB (29.37)

The overall noise figure of a two stage system is given by:

$$F = F_1 + \frac{F_2 - 1}{G_1} \qquad (5)$$

where F_1 and G_1 are the noise figure and gain of the first stage and F_2 is the noise figure of the second stage expressed as ratios. Using equation (5) it can be shown that the lower noise figure and gain are superior as long as the noise figure of the second stage is less than or equal to 16.97 (12.3 dB).

The HP-41 Software

The low-noise program for the HP-41 is intended to be an addition to the general amplifier design package previously described in r.f. design[5]. One additional subroutine is added to the software and minor modifications are made to two existing subroutines. One of the minor changes adds a new item (NOISE) to the "menu" while the other change is in the Stern stability factor routine.

Since the user will probably wish to make gain and other calculations in addition to finding the best termination for noise performance, he will probably wish to modify the previous programs and add the extra routines to the calculator. If this is done, the S-parameter routine cannot be simultaneously loaded into the HP-41CV main memory. If S-parameters are used, one of the longer routines, say, the gain calculation subprogram, should temporarily be deleted or copied to extended memory. With the S-parameter module deleted and the noise program in place, a minimum size of 030 is needed leaving 43 registers unused.

The details of using the program were discussed previously. All routines are executed by entering the appropriate command from the command menu. If a printer is not present, it is recommended that flag no. 21 be set manually before using the programs. If this flag is set, the calculator will stop whenever a print or prompt command is executed. Pressing R/S will continue the program. The HP-41 program is almost completely automatic. If both G_s and B_s are known, they should be entered. When B_s is not known, enter zero.

The program tests for the various cases and automatically does the appropriate calculations.

Example 1 (HP)

Start the calculator by executing program AMP. The command menu is printed.

```
                XEQ "AMP"
ENTR CMND
1-LSF
2-OPT TERM
3-GAINS
4-YIN/OUT
5-CHNG YS/L
6-CHNG YPAR
7-K-STERN
8-YS/L FOR K
9-S/Y CONV
10-NOISE

CMND?
                   10    RUN
```

Enter command number 10. The program requests the device y-parameters. The Linvill stability factor is automatically calculated.

```
ENTER Y-PARAMS

GI=?
             6.5-03    RUN
BI=?
             3.5-03    RUN
GR=?
                  0    RUN
```

```
BR=?
          -.2-03    RUN
GF=?
           40-03    RUN
BF=?
          -20-03    RUN
GO=?
           .35-03   RUN
BO=?
          -.75-03   RUN

L. S. F. = 898.9E-3
```

Next, enter the optimum source termination. Since B_s is not known, enter zero.

```
GS=?
           2-03     RUN
BS=?
              0     RUN
```

Once the source termination is entered, the HP-41 program proceeds automatically and prints the results including all of the amplifier gains.

```
GS= 2.000E-3
BS= -14.93E-3

GL= 144.8E-6
BL= 211.5E-6
```

```
OPERATING GAIN
GP= 20.14E0 dB

AVAILABLE GAIN
GA= 20.60E0 dB

TRANSDUCER GAIN
GT= 20.60E0 dB


CMND?
```

After completing the calculations, the calculator prompts for another command. Again, enter 10 to do the second part of example one.

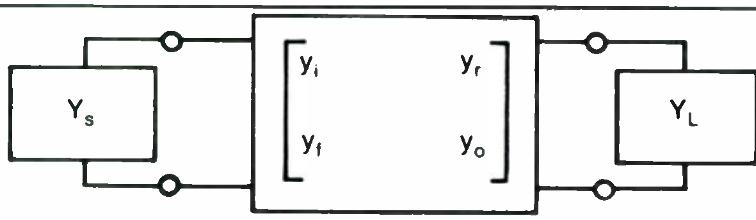
```
CMND?
              10    RUN

L. S. F. = 898.9E-3

GS=?
            2-03    RUN
BS=?
          -25-03    RUN

GS= 2.000E-3
BS= -25.00E-3

GL= 122.9E-6
BL= 453.1E-6
```



$Y_S = G_S + jB_S$ $\qquad$ $Y_L = G_L + jB_L$

$$\begin{bmatrix} y_i & y_r \\ y_f & y_o \end{bmatrix} = \begin{bmatrix} g_i + jb_i & g_r + jb_r \\ g_f + jb_f & g_o + jb_o \end{bmatrix}$$

Figure 1. Definitions of quantities used.

```
OPERATING GAIN
GP= 22.79E0 dB

AVAILABLE GAIN
GA= 17.55E0 dB

TRANSDUCER GAIN
GT= 17.55E0 dB


CMND?
```

This completes example one. Examples two and three, done using the same procedure, are summarized in Figure 2.

References

1. E.G. Nielsen, "Behavior of Noise Figure in Junction Transistors," *Proc. IRE,* vol. 45, pp. 957-963, July 1957.
2. H. Fukui, "The Noise Performance of Microwave Transistors," *IEEE Trans. on Electron Dev.,* vol. ED-13, pp. 329-341, March 1966.
3. R.Q. Lane, "The Determination of Device Noise Parameters," *Proc. IEEE,* vol. 57, pp. 1461-1462, Aug., 1969.
4. M. Sannino, "On the Determination of Device Noise and Gain Parameters," *Proc. IEEE,* vol. 67, pp. 1364-1366, Sept. 1979.
5. R.K. Feeney and D.R. Hertling, "RF Amplifier Design Program," *r.f. design,* pp. 32-47, March/April, 1983.

Figure 2A
HP-41 Example 2

```
                 XEQ "AMP"

ENTR CMND
1-LSF
2-OPT TERM
3-GAINS
4-YIN/OUT
5-CHNG YS/L
6-CHNG YPAR
7-K-STERN
8-YS/L FOR K
9-S/Y CONV
10-NOISE

CMND?
                 10     RUN

ENTER Y-PARAMS

GI=?
            1.5-03     RUN
BI=?
            3.5-03     RUN
GR=?
                 0     RUN
BR=?
            -.3-03     RUN
GF=?
             56-03     RUN
BF=?
            -11-03     RUN
GO=?
             .1-03     RUN
BO=?
            .75-03     RUN

L. S. F. = 4.756E0

GS=?
              2-03     RUN
BS=?
                 0     RUN
K=?
                 4     RUN

GS= 2.000E-3
BS= -5.339E-3

GL= 7.798E-3
BL= -4.899E-3

OPERATING GAIN
GP= 25.25E0 dB

AVAILABLE GAIN
DOES NOT EXIST

TRANSDUCER GAIN
GT= 24.67E0 dB

CMND?
                 10     RUN

L. S. F. = 4.756E0

GS=?
              2-03     RUN
BS=?
            -10-03     RUN
K=?
                 4     RUN

GS= 2.000E-3
BS= -10.00E-3

GL= 7.798E-3
BL= -2.222E-3


OPERATING GAIN
GP= 24.13E0 dB

AVAILABLE GAIN
DOES NOT EXIST

TRANSDUCER GAIN
GT= 20.00E0 dB


CMND?
```

Figure 2B.
HP-41 Example 3.

```
XEQ "AMP"

ENTR CMND
1-LSF
2-OPT TERM
3-GAINS
4-YIN/OUT
5-CHNG YS/L
6-CHNG YPAR
7-K-STERN
8-YS/L FOR K
9-S/Y CONV
10-NOISE

CMND?
              9     RUN
MS11=?
           .792     RUN
AS11=?
         -107.4     RUN
MS12=?
            .07     RUN
AS12=?
             26     RUN
MS21=?
          1.995     RUN
AS21=?
           81.1     RUN
MS22=?
           .659     RUN
AS22=?
          -60.8     RUN

CMND?

             10     RUN

L. S. F. = 1.288E0

GS=?
       10.22-03     RUN
BS=?
      -20.23-03     RUN

GS= 10.22E-3
BS= -20.23E-3

GL= 6.749E-3
BL= -14.29E-3

OPERATING GAIN
GP= 14.48E0 dB

AVAILABLE GAIN
GA= 11.85E0 dB

TRANSDUCER GAIN
GT= 11.85E0 dB

CMND?
                10      RUN

L. S. F. = 1.288E0

GS=?
          10.22-03      RUN
BS=?
                 0      RUN

GS= 10.22E-3
BS= -35.00E-3

GL= 2.419E-3
BL= -14.61E-3

OPERATING GAIN
GP= 17.36E0 dB

AVAILABLE GAIN
GA= 14.68E0 dB

TRANSDUCER GAIN
GT= 14.68E0 dB

CMND?
```

Program #1 (TI) Inherently

000	91	R/S
001	76	LBL
002	11	A
003	72	ST*
004	09	09
005	99	PRT
006	69	OP
007	29	29
008	91	R/S
009	76	LBL
010	16	A'
011	86	STF
012	01	01
013	91	R/S
014	76	LBL
015	12	B
016	42	STO
017	23	23
018	91	R/S
019	76	LBL
020	17	B'
021	86	STF
022	02	02
023	42	STO
024	24	24
025	91	R/S
026	76	LBL
027	13	C
028	43	RCL
029	12	12
030	42	STO
031	01	01
032	43	RCL
033	13	13
034	42	STO
035	02	02
036	43	RCL
037	14	14
038	42	STO
039	03	03
040	43	RCL
041	15	15
042	42	STO
043	04	04
044	36	PGM
045	04	04
046	13	C
047	42	STO
048	18	18
049	53	(
050	24	CE
051	33	X²
052	85	+
053	32	X:T
054	42	STO
055	29	29
056	33	X²
057	54	)
058	34	√X
059	42	STO
060	19	19
061	53	(
062	24	CE
063	55	÷
064	53	(
065	02	2
066	65	×
067	43	RCL
068	10	10
069	65	×
070	43	RCL
071	16	16
072	75	-
073	43	RCL
074	18	18
075	54	)
076	54	)
077	42	STO
078	20	20
079	87	IFF
080	02	02
081	30	TAN
082	53	(
083	43	RCL
084	11	11
085	94	+/-
086	85	+
087	43	RCL
088	29	29
089	55	÷
090	02	2
091	55	÷
092	43	RCL
093	16	16
094	54	)
095	42	STO
096	24	24
097	76	LBL
098	30	TAN
099	43	RCL
100	18	18
101	42	STO
102	01	01
103	43	RCL
104	29	29
105	42	STO
106	02	02
107	53	(
108	43	RCL
109	10	10
110	85	+
111	43	RCL
112	23	23
113	54	)
114	42	STO
115	03	03
116	53	(
117	43	RCL
118	11	11
119	85	+
120	43	RCL
121	24	24
122	54	)
123	42	STO
124	04	04
125	36	PGM
126	04	04
127	18	C'
128	43	RCL
129	16	16
130	42	STO
131	03	03
132	43	RCL
133	17	17
134	42	STO
135	04	04
136	36	PGM
137	04	04
138	10	E'
139	36	PGM
140	04	04
141	17	B'
142	42	STO
143	25	25
144	42	STO
145	35	35
146	32	X:T
147	42	STO
148	36	36
149	94	+/-
150	42	STO
151	26	26
152	00	0
153	32	X:T
154	22	INV
155	77	GE
156	23	LNX
157	43	RCL
158	18	18
159	42	STO
160	01	01
161	43	RCL
162	29	29
163	42	STO
164	02	02
165	53	(
166	43	RCL
167	16	16
168	85	+
169	43	RCL
170	25	25
171	54	)
172	42	STO
173	03	03
174	53	(
175	43	RCL
176	17	17
177	85	+
178	43	RCL
179	26	26
180	54	)
181	42	STO
182	04	04
183	36	PGM
184	04	04
185	18	C'
186	43	RCL
187	10	10
188	42	STO
189	03	03
190	43	RCL
191	11	11
192	42	STO
193	04	04
194	36	PGM
195	04	04
196	10	E'
197	36	PGM
198	04	04
199	17	B'
200	42	STO
201	33	33
202	32	X:T
203	42	STO
204	34	34
205	53	(
206	43	RCL
207	10	10
208	85	+
209	43	RCL
210	23	23
211	54	)
212	42	STO
213	01	01
214	53	(
215	43	RCL
216	11	11
217	85	+
218	43	RCL
219	24	24
220	54	)
221	42	STO
222	02	02
223	53	(
224	43	RCL
225	16	16
226	85	+
227	43	RCL
228	25	25
229	54	)
230	42	STO

Stable Device

231	03	03
232	53	(
233	43	RCL
234	17	17
235	85	+
236	43	RCL
237	26	26
238	54	)
239	42	STO
240	04	04
241	36	PGM
242	04	04
243	13	C
244	42	STO
245	27	27
246	32	X:T
247	42	STO
248	28	28
249	43	RCL
250	12	12
251	42	STO
252	01	01
253	43	RCL
254	13	13
255	42	STO
256	02	02
257	43	RCL
258	14	14
259	42	STO
260	03	03
261	43	RCL
262	15	15
263	42	STO
264	04	04
265	36	PGM
266	04	04
267	13	C
268	94	+/-
269	44	SUM
270	27	27
271	32	X:T
272	94	+/-
273	44	SUM
274	28	28
275	53	(
276	53	(
277	43	RCL
278	27	27
279	33	X²
280	85	+
281	43	RCL
282	28	28
283	33	X²
284	54	)
285	35	1/X
286	65	×
287	04	4
288	65	×
289	43	RCL
290	23	23
291	65	×
292	43	RCL
293	25	25
294	65	×
295	53	(
296	43	RCL
297	14	14
298	33	X²
299	85	+
300	43	RCL
301	15	15
302	33	X²
303	54	)
304	54	)
305	53	(
306	24	CE
307	28	LOG
308	65	×
309	01	1
310	00	0
311	54	)
312	42	STO
313	32	32
314	87	IFF
315	01	01
316	24	CE
317	43	RCL
318	20	20
319	91	R/S
320	43	RCL
321	23	23
322	91	R/S
323	43	RCL
324	24	24
325	91	R/S
326	43	RCL
327	25	25
328	91	R/S
329	43	RCL
330	26	26
331	91	R/S
332	43	RCL
333	32	32
334	91	R/S
335	43	RCL
336	33	33
337	91	R/S
338	76	LBL
339	24	CE
340	22	INV
341	52	EE
342	98	ADV
343	98	ADV
344	01	1
345	05	5
346	69	OP
347	04	04
348	43	RCL
349	20	20
350	69	OP
351	06	06
352	02	2
353	02	2
354	03	3
355	06	6
356	69	OP
357	04	04
358	43	RCL
359	23	23
360	69	OP
361	06	06
362	01	1
363	04	4
364	03	3
365	06	6
366	69	OP
367	04	04
368	43	RCL
369	24	24
370	69	OP
371	06	06
372	02	2
373	02	2
374	02	2
375	07	7
376	69	OP
377	04	04
378	43	RCL
379	25	25
380	69	OP
381	06	06
382	01	1
383	04	4
384	02	2
385	07	7
386	69	OP
387	04	04
388	43	RCL
389	26	26
390	69	OP
391	06	06
392	02	2
393	02	2
394	03	3
395	07	7
396	69	OP
397	04	04
398	43	RCL
399	32	32
400	69	OP
401	06	06
402	29	CP
403	43	RCL
404	33	33
405	22	INV
406	77	GE
407	22	INV
408	23	LNX
409	43	RCL
410	32	32
411	91	R/S
412	76	LBL
413	23	LNX
414	98	ADV
415	98	ADV
416	22	INV
417	52	EE
418	69	OP
419	00	00
420	02	2
421	02	2
422	03	3
423	02	2
424	04	4
425	01	1
426	03	3
427	07	7
428	69	OP
429	04	04
430	43	RCL
431	25	25
432	69	OP
433	06	06
434	91	R/S
435	00	0
436	35	1/X
437	76	LBL
438	22	INV
439	02	2
440	02	2
441	02	2
442	04	4
443	03	3
444	01	1
445	69	OP
446	04	04
447	43	RCL
448	33	33
449	98	ADV
450	69	OP
451	06	06
452	69	OP
453	00	00
454	91	R/S
455	76	LBL
456	15	E
457	01	1
458	00	0
459	42	STO
460	09	09
461	81	RST

Program #2(TI) Potentially Unstable Device

000	91	R/S
001	76	LBL
002	11	A
003	72	ST*
004	09	09
005	99	PRT
006	69	OP
007	29	29
008	91	R/S
009	76	LBL
010	16	A'
011	86	STF
012	01	01
013	91	R/S
014	76	LBL
015	12	B
016	42	STO
017	23	23
018	91	R/S
019	76	LBL
020	17	B'
021	86	STF
022	02	02
023	42	STO
024	24	24
025	91	R/S
026	76	LBL
027	13	C
028	98	ADV
029	98	ADV
030	42	STO
031	20	20
032	43	RCL
033	12	12
034	42	STO
035	01	01
036	43	RCL
037	13	13
038	42	STO
039	02	02
040	43	RCL
041	14	14
042	42	STO
043	03	03
044	43	RCL
045	15	15
046	42	STO
047	04	04
048	36	PGM
049	04	04
050	13	C
051	42	STO
052	18	18
053	53	(
054	24	CE
055	33	X²
056	85	+
057	32	X:T
058	42	STO
059	29	29
060	33	X²
061	54	)
062	34	√X
063	42	STO
064	19	19
065	43	RCL
066	10	10
067	42	STO
068	22	22
069	43	RCL
070	16	16
071	42	STO
072	21	21
073	71	SBR
074	33	X²
075	42	STO
076	25	25
077	87	IFF
078	02	02
079	39	COS
080	61	GTO
081	23	LNX
082	76	LBL
083	33	X²
084	53	(
085	53	(
086	43	RCL
087	20	20
088	65	×
089	53	(
090	43	RCL
091	19	19
092	85	+
093	43	RCL
094	18	18
095	54	)
096	54	)
097	55	÷
098	53	(
099	02	2
100	65	×
101	53	(
102	43	RCL
103	10	10
104	85	+
105	43	RCL
106	23	23
107	54	)
108	54	)
109	75	-
110	43	RCL
111	16	16
112	54	)
113	92	RTN
114	76	LBL
115	23	LNX
116	43	RCL
117	17	17
118	94	+/-
119	42	STO
120	26	26
121	76	LBL
122	42	STO
123	43	RCL
124	18	18
125	42	STO
126	01	01
127	43	RCL
128	29	29
129	42	STO
130	02	02
131	53	(
132	43	RCL
133	16	16
134	85	+
135	43	RCL
136	25	25
137	54	)
138	42	STO
139	03	03
140	53	(
141	43	RCL
142	17	17
143	85	+
144	43	RCL
145	26	26
146	54	)
147	42	STO
148	04	04
149	36	PGM
150	04	04
151	18	C'
152	43	RCL
153	10	10
154	42	STO
155	03	03
156	43	RCL
157	11	11
158	42	STO
159	04	04
160	36	PGM
161	04	04
162	10	E'
163	36	PGM
164	04	04
165	17	B'
166	32	X:T
167	94	+/-
168	42	STO
169	24	24
170	76	LBL
171	39	COS
172	43	RCL
173	18	18
174	42	STO
175	01	01
176	43	RCL
177	29	29
178	42	STO
179	02	02
180	53	(
181	43	RCL
182	10	10
183	85	+
184	43	RCL
185	23	23
186	54	)
187	42	STO
188	03	03
189	53	(
190	43	RCL
191	11	11
192	85	+
193	43	RCL
194	24	24
195	54	)
196	42	STO
197	04	04
198	36	PGM
199	04	04
200	18	C'
201	43	RCL
202	16	16
203	42	STO
204	03	03
205	43	RCL
206	17	17
207	42	STO
208	04	04
209	36	PGM
210	04	04
211	10	E'
212	36	PGM
213	04	04
214	17	B'
215	32	X:T
216	42	STO
217	30	30
218	87	IFF
219	02	02
220	38	SIN
221	53	(
222	53	(
223	24	CE
224	85	+
225	43	RCL
226	26	26
227	54	)
228	55	÷
229	43	RCL
230	26	26
231	54	)
232	50	I×I
233	32	X:T
234	93	.
235	00	0
236	00	0
237	01	1
238	22	INV
239	77	GE
240	34	√X
241	43	RCL
242	30	30
243	76	LBL
244	38	SIN
245	94	+/-
246	42	STO
247	26	26
248	61	GTO
249	35	1/X
250	76	LBL
251	34	√X
252	43	RCL
253	30	30
254	94	+/-
255	42	STO
256	26	26
257	61	GTO
258	42	STO
259	76	LBL
260	35	1/X
261	53	(
262	43	RCL
263	10	10
264	85	+
265	43	RCL
266	23	23
267	54	)
268	42	STO
269	01	01
270	53	(
271	43	RCL
272	11	11
273	85	+
274	43	RCL
275	24	24
276	54	)
277	42	STO
278	02	02
279	53	(
280	43	RCL
281	16	16
282	85	+
283	43	RCL
284	25	25
285	54	)
286	42	STO
287	03	03
288	53	(
289	43	RCL
290	17	17
291	85	+
292	43	RCL
293	26	26
294	54	)
295	42	STO
296	04	04
297	36	PGM
298	04	04
299	13	C
300	42	STO
301	27	27
302	32	X:T
303	42	STO
304	28	28
305	43	RCL
306	12	12
307	42	STO
308	01	01
309	43	RCL
310	13	13
311	42	STO
312	02	02
313	43	RCL
314	14	14
315	42	STO
316	03	03
317	43	RCL
318	15	15
319	42	STO
320	04	04
321	36	PGM
322	04	04
323	13	C
324	94	+/-
325	44	SUM
326	27	27
327	32	X:T
328	94	+/-
329	44	SUM
330	28	28
331	53	(
332	53	(
333	43	RCL
334	27	27
335	33	X²
336	85	+
337	43	RCL
338	28	28
339	33	X²
340	54	)
341	35	1/X
342	65	×
343	04	4
344	65	×
345	43	RCL
346	23	23
347	65	×
348	43	RCL
349	25	25
350	65	×
351	53	(
352	43	RCL
353	14	14
354	33	X²
355	85	+
356	43	RCL
357	15	15
358	33	X²
359	54	)
360	54	)
361	53	(
362	24	CE
363	28	LOG
364	65	×
365	01	1
366	00	0
367	54	)
368	42	STO
369	32	32
370	87	IFF
371	01	01
372	24	CE
373	43	RCL
374	20	20
375	91	R/S
376	43	RCL
377	23	23
378	91	R/S
379	43	RCL
380	24	24
381	91	R/S
382	43	RCL
383	25	25
384	91	R/S
385	43	RCL
386	26	26
387	91	R/S
388	43	RCL
389	32	32
390	91	R/S
391	76	LBL
392	24	CE
393	02	2
394	06	6
395	69	OP
396	04	04
397	43	RCL
398	20	20
399	69	OP
400	06	06
401	02	2
402	02	2
403	03	3
404	06	6
405	69	OP
406	04	04
407	43	RCL
408	23	23
409	69	OP
410	06	06
411	01	1
412	04	4
413	03	3
414	06	6
415	69	OP
416	04	04
417	43	RCL
418	24	24
419	69	OP
420	06	06
421	02	2
422	02	2
423	02	2
424	07	7
425	69	OP
426	04	04
427	43	RCL
428	25	25
429	69	OP
430	06	06
431	01	1
432	04	4
433	02	2
434	07	7
435	69	OP
436	04	04
437	43	RCL
438	26	26
439	69	OP
440	06	06
441	02	2
442	02	2
443	03	3
444	07	7
445	69	OP
446	04	04
447	43	RCL
448	32	32
449	69	OP
450	06	06
451	91	R/S
452	76	LBL
453	15	E
454	01	1
455	00	0
456	42	STO
457	09	09
458	81	RST

Program #3 (TI) S → Y Parameter Conversion

```
000  91 R/S      103  44 SUM      206  65  ×
001  76 LBL      104  36  36      207  43 RCL
002  11  A       105  43 RCL      208  14  14
003  72 ST*      106  35  35      209  55  ÷
004  09  09      107  32 X:T      210  43 RCL
005  99 PRT      108  43 RCL      211  35  35
006  69 OP       109  36  36      212  54  )
007  29  29      110  22 INV      213  32 X:T
008  91 R/S      111  37 P/R      214  53  (
009  76 LBL      112  42 STO      215  43 RCL
010  12  B       113  36  36      216  15  15
011  60 DEG      114  32 X:T      217  75  -
012  53  (       115  42 STO      218  43 RCL
013  43 RCL      116  35  35      219  36  36
014  10  10      117  01  1       220  54  )
015  65  ×       118  42 STO      221  37 P/R
016  43 RCL      119  37  37      222  42 STO
017  16  16      120  43 RCL      223  15  15
018  54  )       121  10  10      224  32 X:T
019  32 X:T      122  42 STO      225  42 STO
020  53  (       123  39  39      226  14  14
021  43 RCL      124  94 +/-      227  01  1
022  11  11      125  44 SUM      228  42 STO
023  85  +       126  37  37      229  37  37
024  43 RCL      127  43 RCL      230  43 RCL
025  17  17      128  11  11      231  39  39
026  54  )       129  42 STO      232  44 SUM
027  37 P/R      130  40  40      233  37  37
028  42 STO      131  94 +/-      234  43 RCL
029  28  28      132  42 STO      235  40  40
030  32 X:T      133  38  38      236  42 STO
031  42 STO      134  43 RCL      237  38  38
032  27  27      135  16  16      238  43 RCL
033  53  (       136  44 SUM      239  16  16
034  43 RCL      137  37  37      240  94 +/-
035  14  14      138  43 RCL      241  44 SUM
036  65  ×       139  17  17      242  37  37
037  43 RCL      140  44 SUM      243  43 RCL
038  12  12      141  38  38      244  17  17
039  54  )       142  43 RCL      245  94 +/-
040  32 X:T      143  27  27      246  44 SUM
041  53  (       144  94 +/-      247  38  38
042  43 RCL      145  44 SUM      248  43 RCL
043  15  15      146  37  37      249  27  27
044  85  +       147  43 RCL      250  94 +/-
045  43 RCL      148  28  28      251  44 SUM
046  13  13      149  94 +/-      252  37  37
047  54  )       150  44 SUM      253  43 RCL
048  37 P/R      151  38  38      254  28  28
049  94 +/-      152  43 RCL      255  94 +/-
050  44 SUM      153  37  37      256  44 SUM
051  28  28      154  32 X:T      257  38  38
052  32 X:T      155  43 RCL      258  43 RCL
053  94 +/-      156  38  38      259  37  37
054  44 SUM      157  22 INV      260  32 X:T
055  27  27      158  37 P/R      261  43 RCL
056  43 RCL      159  32 X:T      262  38  38
057  27  27      160  53  (       263  22 INV
058  42 STO      161  24 CE       264  37 P/R
059  35  35      162  55  ÷       265  32 X:T
060  43 RCL      163  43 RCL      266  53  (
061  28  28      164  35  35      267  24 CE
062  42 STO      165  54  )       268  55  ÷
063  36  36      166  32 X:T      269  43 RCL
064  43 RCL      167  53  (       270  35  35
065  10  10      168  24 CE       271  54  )
066  32 X:T      169  75  -       272  32 X:T
067  43 RCL      170  43 RCL      273  53  (
068  11  11      171  36  36      274  24 CE
069  37 P/R      172  54  )       275  75  -
070  42 STO      173  37 P/R      276  43 RCL
071  11  11      174  42 STO      277  36  36
072  32 X:T      175  11  11      278  54  )
073  42 STO      176  32 X:T      279  37 P/R
074  10  10      177  42 STO      280  42 STO
075  43 RCL      178  10  10      281  17  17
076  16  16      179  53  (       282  32 X:T
077  32 X:T      180  02  2       283  42 STO
078  43 RCL      181  94 +/-      284  16  16
079  17  17      182  65  ×       285  01  1
080  37 P/R      183  43 RCL      286  00  0
081  42 STO      184  12  12      287  32 X:T
082  17  17      185  55  ÷       288  76 LBL
083  32 X:T      186  43 RCL      289  22 INV
084  42 STO      187  35  35      290  05  5
085  16  16      188  54  )       291  00  0
086  01  1       189  32 X:T      292  22 INV
087  44 SUM      190  53  (       293  64 PD*
088  35  35      191  43 RCL      294  09  09
089  43 RCL      192  13  13      295  69 OP
090  10  10      193  75  -       296  39  39
091  44 SUM      194  43 RCL      297  43 RCL
092  35  35      195  36  36      298  09  09
093  43 RCL      196  54  )       299  77 GE
094  16  16      197  37 P/R      300  22 INV
095  44 SUM      198  42 STO      301  91 R/S
096  35  35      199  13  13      302  76 LBL
097  43 RCL      200  32 X:T      303  15  E
098  11  11      201  42 STO      304  01  1
099  44 SUM      202  12  12      305  00  0
100  36  36      203  53  (       306  42 STO
101  43 RCL      204  02  2       307  09  09
102  17  17      205  94 +/-      308  81 RST
```

HP-41 Main Program AMP

This program has been modified by the addition of the NOISE calculation to the menu.

```
01♦LBL "AMP"
02 CF 04
03 CF 03
04 ADV
05 "ENTR CMNG"
06 AVIEW
07 "1-LSF"
08 AVIEW
09 "2-OPT TERM"
10 AVIEW
11 "3-GAINS"
12 AVIEW
13 "4-YIN/OUT"
14 AVIEW
15 "5-CHNG YS/L"
16 AVIEW
17 "6-CHNG YPAR"
18 AVIEW
19 "7-K-STERN"
20 AVIEW
21 "8-YS/L FOR K"
22 AVIEW
23 "9-S/Y CONV"
24 AVIEW
25 "10-NOISE"
26 AVIEW
27♦LBL 00
28 ADV
29 FIX 0
30 "CMND?"
31 PROMPT
32 ENG 3
33 GTO IND X
34♦LBL 01
35 FC? 03
36 XEQ "PARA"
37 ADV
38 XEQ "LINV"
39 GTO 00
40♦LBL 02
41 FC? 03
42 XEQ "PARA"
43 XEQ "OPT"
44 GTO 00
45♦LBL 03
46 FC? 03
47 XEQ "PARA"
48 FC? 04
49 XEQ "YS/L"
50 XEQ "YI/O"
51 XEQ "GP"
52 XEQ "GA"
53 XEQ "GT"
54 GTO 00
55♦LBL 04
56 FC? 03
57 XEQ "PARA"
58 FC? 04
59 XEQ "YS/L"
60 XEQ "YI/O"
61 "GIN= "
62 ARCL 23
63 AVIEW
64 "BIN= "
65 ARCL 22
66 AVIEW
67 ADV
68 "GOUT= "
69 ARCL 25
70 AVIEW
71 "BOUT= "
72 ARCL 24
73 AVIEW
74 ADV
75 GTO 00
76♦LBL 05
77 XEQ "YS/L"
78 GTO 00
79♦LBL 06
80 XEQ "PARA"
81 GTO 00
82♦LBL 07
83 FC? 03
84 XEQ "PARA"
85 FC? 04
86 XEQ "YS/L"
87 XEQ "STN"
88 ADV
89 "K-STERN= "
90 ARCL 17
91 AVIEW
92 GTO 00
93♦LBL 08
94 FC? 03
95 XEQ "PARA"
96 XEQ "ITR"
97 ADV
98 XEQ "S/LPR"
99 GTO 00
100♦LBL 09
101 XEQ "SPAR"
102 XEQ "PAR1"
103 GTO 00
104♦LBL 10
105 FC? 03
106 XEQ "PARA"
107 XEQ "NOISE"
108 ADV
109 XEQ "S/LPR"
110 ADV
111 XEQ "YI/O"
112 XEQ "GP"
113 XEQ "GA"
114 XEQ "GT"
115 ADV
116 GTO 00
117 END
```

HP-41 Subroutine NOISE

This routine determines the source and load terminations for the best noise figure according to the equations in the text. Various situations, such as potential instability, are handled automatically.

```
01♦LBL "NOISE"
02 SF 04
03 ADV
04 XEQ "LINV"
05 "GS=?"
06 PROMPT
07 STO 19
08 "BS=?"
09 PROMPT
10 STO 18
11 FS? 00
12 GTO 01
13 RCL 18
14 X=0?
15 XEQ 05
16 XEQ "YI/O"
17♦LBL 03
18 RCL 24
19 CHS
20 STO 20
21 RCL 25
22 STO 21
23 RTN
24♦LBL 01
25 X=0?
26 GTO 04
27 XEQ "YI/O"
28 FC? 02
29 GTO 03
30 XEQ 06
31 RCL 24
32 CHS
33 STO 20
34 RTN
35♦LBL 04
36 XEQ 05
37 XEQ "YI/O"
38 FC? 02
39 GTO 03
40 XEQ 06
41 SF 08
42 XEQ "ITR"
43 RTN
44♦LBL 06
45 "K=?"
46 PROMPT
47 STO 17
48 RCL 11
49 RCL 12
50 +
51 RCL 17
52 *
53 RCL 03
54 RCL 19
55 +
56 /
57 2
58 /
59 RCL 05
60 -
61 STO 21
62 RTN
63♦LBL 05
64 RCL 10
65 RCL 05
66 /
67 2
68 /
69 RCL 02
70 -
71 STO 18
72 .END.
```

HP-41 Subroutine STN

This subroutine calculates the Stern Stability Factor or specifies terminations for a given K. The routine has been modified for the NOISE program. One additional flag, no. 8, has been added. This allows the noise routine to skip the part of the calculation that generates G_S and G_L.

```
01•LBL "STN"
02 CF 07
03 RCL 03
04 RCL 19
05 +
06 X<0?
07 SF 07
08 RCL 05
09 RCL 21
10 +
11 X<0?
12 SF 07
13 *
14 2
15 *
16 RCL 11
17 RCL 12
18 +
19 /
20 STO 17
21 FC? 07
22 RTN
23 ABS
24 CHS
25 STO 17
26 RTN
27•LBL "ITR"
28 FS? 08
29 GTO 06
30 "k=?"
31 PROMPT
32 STO 17
33 RCL 11
34 RCL 12
35 +
36 *
37 2
38 /
39 RCL 03
40 RCL 05
41 *
42 ABS
43 /
44 STO 27
45 RCL 03
46 RCL 05
47 *
48 X<0?
49 GTO 02
50 RCL 03
51 X<0?
52 GTO 03
53 RCL 27
54 SQRT
55 1
56 -
57 GTO 05
58•LBL 02
59 RCL 27
60 1
61 +
62 SQRT
63 GTO 05
64•LBL 03
65 RCL 27
66 SQRT
67 1
68 +
69•LBL 05
70 STO 26
71 RCL 03
72 ABS
73 *
74 STO 19
75 RCL 26
76 RCL 05
77 ABS
78 *
79 STO 21
80•LBL 06
81 CF 05
82 CF 06
83 RCL 02
84 STO 22
85 RCL 04
86 STO 24
87•LBL 01
88 RCL 22
89 CHS
90 STO 18
91 RCL 24
92 CHS
93 STO 20
94 XEQ "YI/O"
95 RCL 22
96 RCL 18
97 +
96 RCL 22
99 /
100 ABS
101 1 E-4
102 X>Y?
103 SF 05
104 RCL 24
105 RCL 20
106 +
167 RCL 24
108 /
109 ABS
110 1 E-4
111 X>Y?
112 SF 06
113 FS? 05
114 GTO 04
115 GTO 01
116•LBL 04
117 FC? 06
118 GTO 01
119 SF 04
120 BEEP
121 CF 08
122 END
```

General Purpose Ladder Analysis With The Hand-Held Calculator

A programmable calculator allows analysis of a circuit before it is built. Analysis takes a little time up-front but it can save considerable amounts in the long run.

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Many filters encountered by the rf designer may be treated as ladder networks of alternating series impedances and shunt admittances. There is frequently a need to analyze the performance of these filters, usually as a means of confirming the synthesis methods used during design. A general purpose program is offered in this paper to calculate filter transducer gain as a function of frequency.

Owing to the frequent occurrence of ladder networks, programs for their analysis have special requirements. The programs should be easy to use without external documentation. Of greater significance, the programs should be efficient, offering rapid execution. It is tempting to generate programs that will evaluate as many circuit element types as possible. However, this will often compromise the speed and ease-of-use goals. The program presented here is kept purposefully simple.

Complicated ladder circuits may be evaluated with ROM based software available for the HP-41C calculators. One suitable program is the ladder analysis in the "Circuit Analysis" pack, offered by Hewlett Packard. Another is Handy-Compact[1]. Both programs are powerful and very useful. Both are also slow.

A Basis for Analysis

The concept used in this program, "General Purpose Ladder Analysis", (GPLA), is illustrated by the 5th order low pass filter shown in Fig. 1. The circuit is segmented into planes, marked "a" through "f" in the figure. The immittance (impedance or admittance) at any plane looking toward the load is easily calculated. An infrequently used, but essentially trivial form of the so called ladder method shows that the output voltage is given as a product of the calculated immittances.[2] For the example of Fig. 1., $V_{out} = V_{in} Z_a Y_b Z_c Y_d Z_e Y_f$. A simple rule makes this form especially convenient: An impedance is used in the product when looking into a shunt element. Conversely, an admittance appears in the product to correspond to planes looking into a series element. All planes from the generator to the load are included. This simple rule allows the transfer function of an arbitrary LC ladder to be written by inspection.

Although GPLA is written for the HP-41C calculator family, similar forms are easily written for other

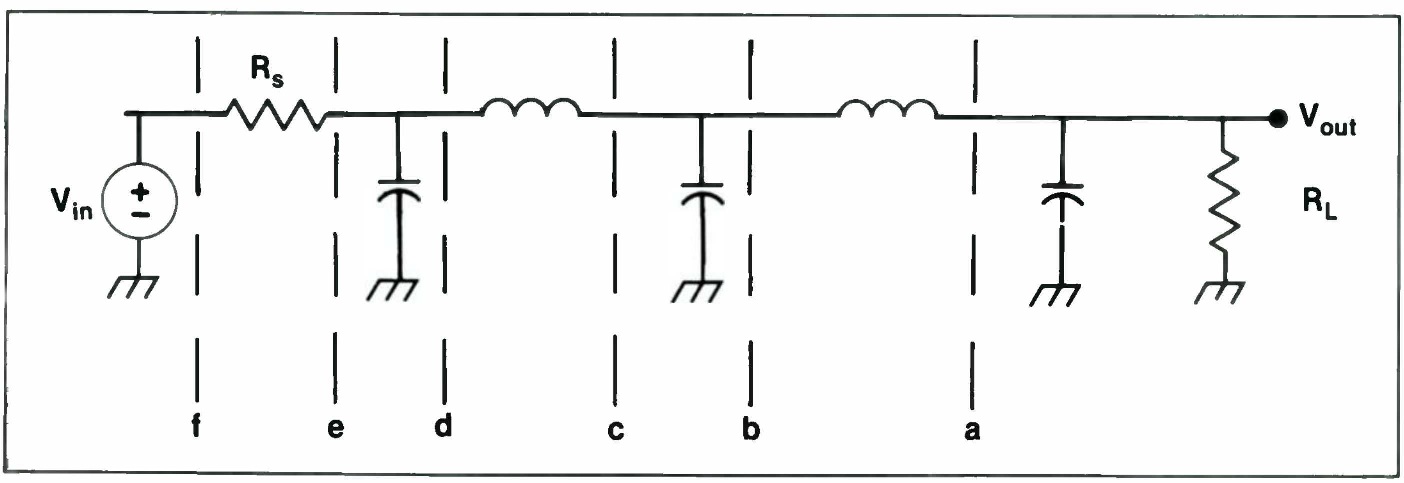


Figure 1 — Fifth order low pass filter illustrating the method used for ladder analysis. The network response is given by $V_{out} = V_{in} Z_a Y_b Z_c Y_d Z_e Y_f$ where immitance is evaluated from the defining plane looking toward the load.

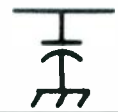
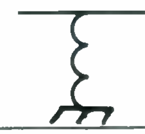
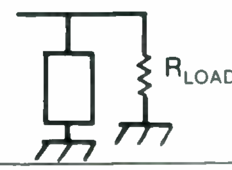
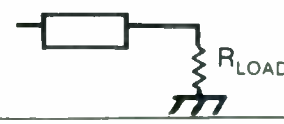
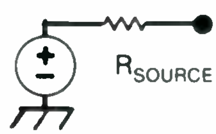
	Y-to-Z or Z-to-Y Conversion: Without:	With:	
Parallel Capacitor	**01**	**06**	
Series Capacitor	**02**	**07**	
Series Inductor	**03**	**08**	
Parallel Inductor	**04**	**09**	
Load End	**00**		
	11		
Source End	**10**		

Table 1. Subroutines used for construction of the "User Defined" portion of the General Purpose Ladder Analysis program.

"machines" including the desk top computer. The writer will supply versions for the HP-15C and the TI-58/59 calculators to interested readers[3]. The rules presented are used to generate the programs. Further, the method may be adapted to existing software. For example, the ladder analysis available with Handy-Compact is designed to find only the input impedance of a ladder. Gain is limited to lossless filters using $|S_{21}|^2 = 1 - |S_{11}|^2$. However, the immittance is available during program execution for each plane of a network. Lossy networks may be analyzed for gain by multiplying the immittance magnitude into a register at each plane. Additional modifications will supply angle information with GPLA (at the cost of speed).

Program Structure

The program presented is a collection of subroutines. This is followed by a short program segment written by the user to correspond to the filter being studied. The main subroutine resides at LABEL 05 and serves to convert an impedance to an admittance, or an admittance to an impedance. The magnitude of the immittance, after conversion, is multiplied into a register (R_{09}), forming the required products. The common way to write this subroutine uses the polar to rectangular (and back) conversions. Data is maintained in rectangular form in this program. The subroutine is longer and less obvious but execution speed is significantly shorter.[4]

Four subroutines serve to add to the immittance of capacitors or inductors, series or shunt, to the existing immittance in the x and y registers. Four additional routines are identical except that they also initiate the immittance conversion routine. An appropriate resistive term is also added to account for losses when an inductor is included in the ladder. A uniform, frequency independent Q_u is assumed for all inductors.

One of two available routines are

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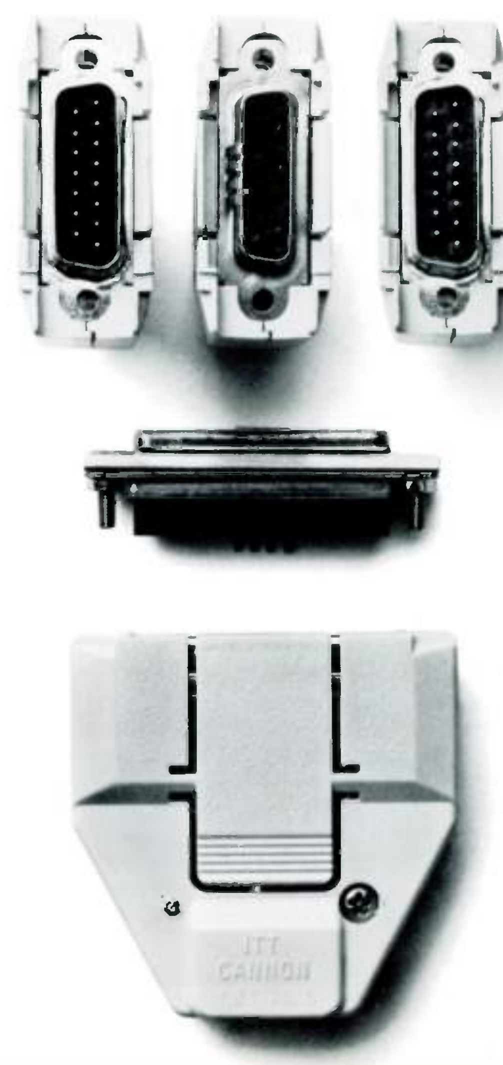
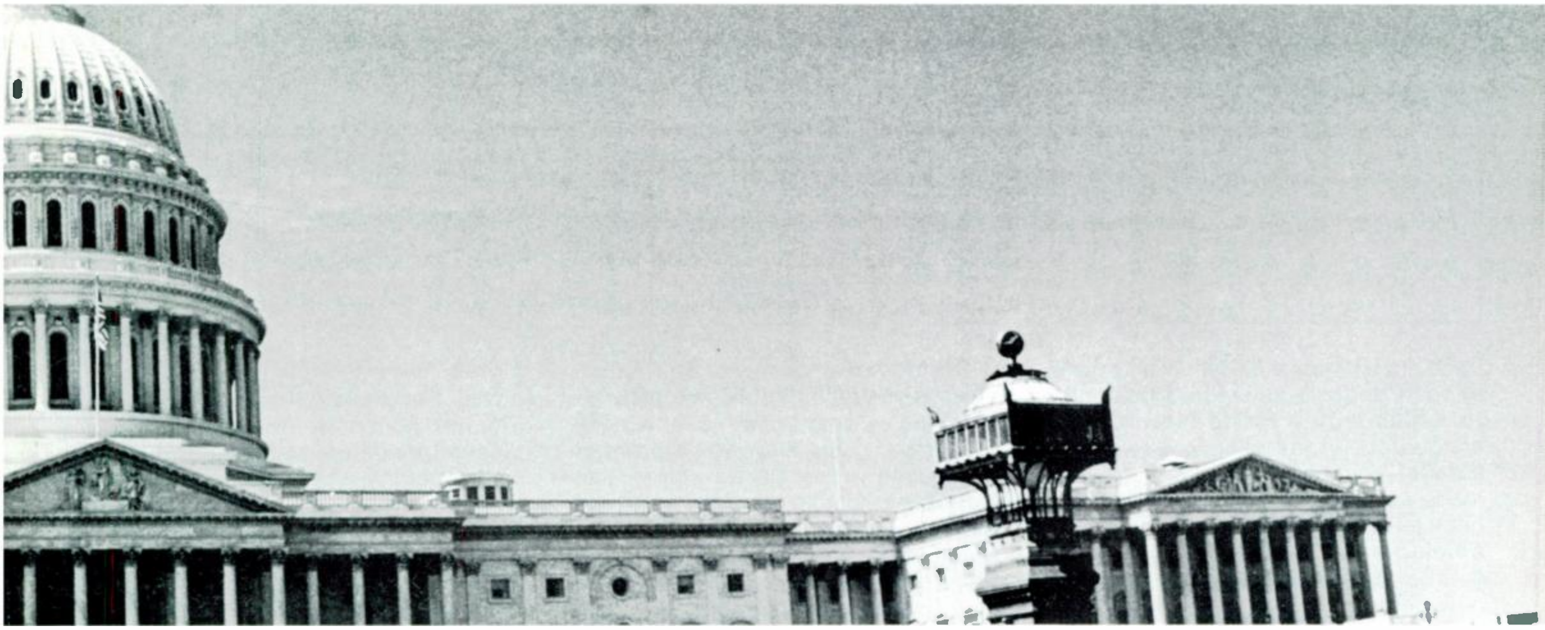
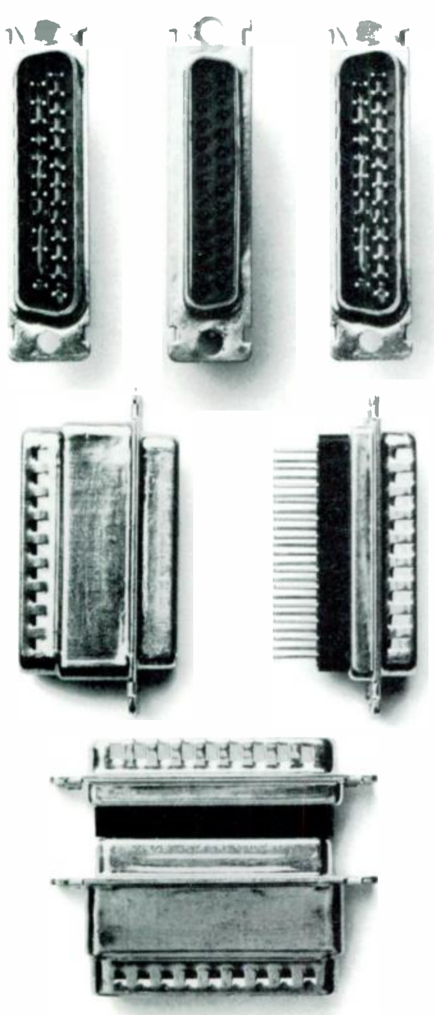
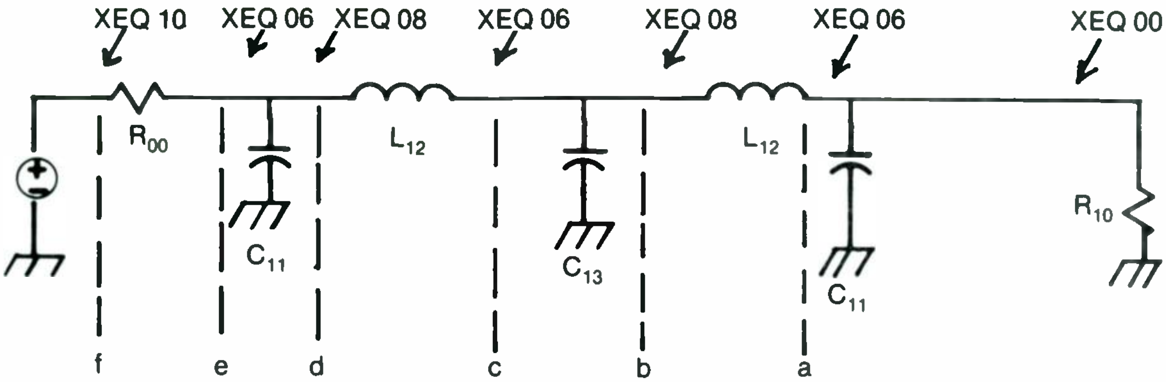









```
XEQ 00
RCL 11
XEQ 06
RCL 12
XEQ 08
RCL 13
XEQ 06
RCL 12
XEQ 08
RCL 11
XEQ 06
XEQ 10
```

Figure 2(A)

used to initialize filter evaluations at each frequency. One corresponds to a filter with a series first reactive element while the other is used for a parallel reactance adjacent to the load. After all reactive elements have been assembled during a calculation, a final routine adds the effect of the source resistance and calculates the network transducer gain. The display is prepared and the frequency is incremented before looping back for the next evaluation.

Besides the operational routines needed for calculation, the program contains a modicum of "window dressing." This allows the program to be used without extra notes. This feature is available only for the HP-41C version of GPLA.

Application

The program, listed at the end of the paper, is loaded into the calculator and the circuit to be analyzed is sketched. The components are labeled with arbitrary indicies of 11 or higher, corresponding to data registers. See the examples that follow. The component values are manually placed in memory at the proper locations using units of Farads and Henrys. The value of Q_u is placed in R_{03}. A very large Q_u value (1×10^9) is used for lossless filters. Source resistance is placed in R_{00} while the load is in R_{10}, both in ohms. The program is then run using XEQ "GPLA".

The first section is a series of prompts that remind the user of the application rules. This section is viewed with repeated pressing of the Run/Stop key. Finally, the user is prompted to write the "user defined" portion of the program. The program mode is entered and the following steps are used:

1) The first program step is XEQ 00 if the first reactance at the load is a parallel element. XEQ 11 is used if the first reactance at the load is a series connection.

2) The first L or C at the load end is recalled from memory. This is followed by XEQ nn where nn is a code from Table 1. Note that nn will be from 01 to 04 if the immittance is to be added without a following Y-to-Z or Z-to-Y conversion. Code nn will range from 06 to 09 if the conversion is desired. The conversion is required whenever a transition from a series branch to a parallel one is encountered.

3) Step 2 is repeated for each network element.

4) The user defined part of the program is finished with XEQ 10 when all elements have been taken into account.

5) Flag 00 should be set at the beginning if each data point is to be read for an extended time. The program is then continued with a Run/Stop. Normally, with Flag 00 cleared, the program displays results while doing the calculation for the next frequency. The display shows the frequency in MHz and the transducer gain in dB.

6) The immittance looking toward the load may be evaluated with a R/S in the user defined program immediately following the calculation that adds the corresponding reactance at that plane. Note that the program uses the "x" register for the imaginary part of the immittance with "y" containing the real part.

7) Exit the program mode after writing the user defined part of the program. Enter the user mode and press user "F" to enter the frequency in MHz, a R/S, the frequency step in MHz, and another R/S to begin calculations. User F may be used at any time after a R/S in the program to change a frequency. This routine is slightly different than the traditional HP-41C "Prompt". The user is prompted for frequency. However, during the viewing of the alpha command, the user may press CLX, causing the present frequency or step to be viewed.

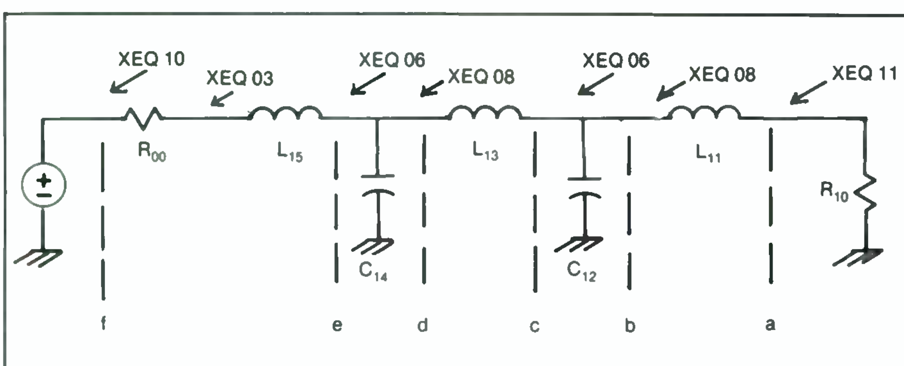
Program application is illustrated with the following examples.

Example 1.

The first filter evaluated is the 5th order low pass presented earlier, now shown in Fig. 2A. A symetrical circuit is assumed with equal end capacitors and equal inductors. The first reactance adjacent to the load is a parallel element, so the user defined program begins with XEQ 00. Figure 2 is labeled with the planes used for immittance inversion and with the appropriate subroutines. Execution time is about six seconds per frequency for this example.

Example 2.

Another 5th order low pass filter is examined. This circuit, Fig. 2B, is



(B)

Figure 2B — Fifth order low pass filters analyzed in Examples 1 and 2. The planes of immittance inversion are shown, "a" through "f". Program subroutines used in analysis are presented above the circuit at the points in the circuit where they are utilized. All immitances are looking toward the load end, R_{10}.

```
XEQ 11    XEQ 06    RCL 15    STOP      R-in
RCL 11    RCL 13    XEQ 03    X<>Y
XEQ 08    XEQ 08    X<>Y      STOP      X-in
RCL 12    RCL 14    CLD       XEQ 10    Gt, dB
          XEQ 06
```

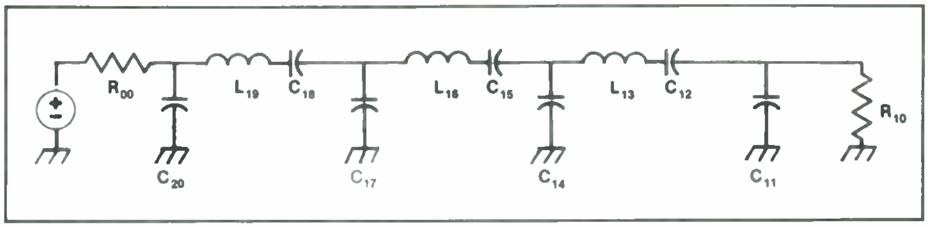


Figure 3—Third order bandpass filter analyzed in Example 3. Series resonators are used in this circuit.

XEQ 00	RCL 13	RCL 16	RCL 19
RCL 11	XEQ 08	XEQ 08	XEQ 08
XEQ 06	RCL 14	RCL 17	RCL 20
RCL 12	XEQ 06	XEQ 06	XEQ 06
XEQ 02	RCL 15	RCL 18	XEQ 10
	XEQ 02	XEQ 02	

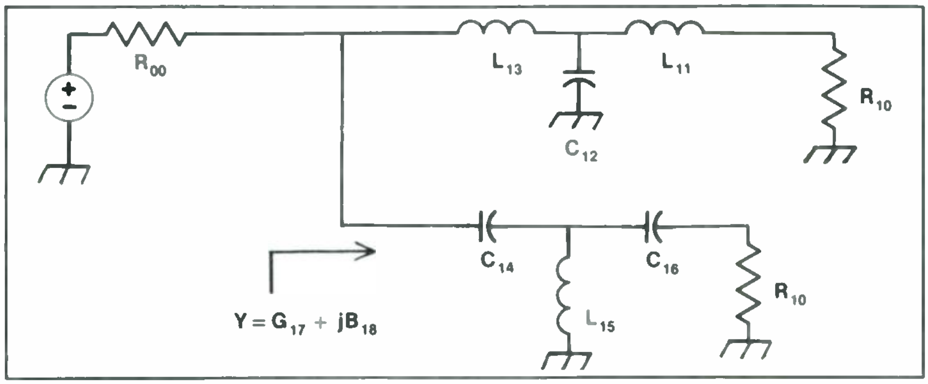


Figure 4. Diplexer network analyzed in Example 4.

	STO 18	RCL 13	XEQ 05
XEQ 11	X<>Y	XEQ 08	CLD
RCL 16	STO 17	RCL 18	X<>Y
XEQ 07	XEQ 11	+	STOP
RCL 15	RCL 11	X<>Y	X<>Y
XEQ 09	XEQ 08	RCL 17	STOP
RCL 14	RCL 12	+	XEQ 10
XEQ 07	XEQ 06	X<>Y	

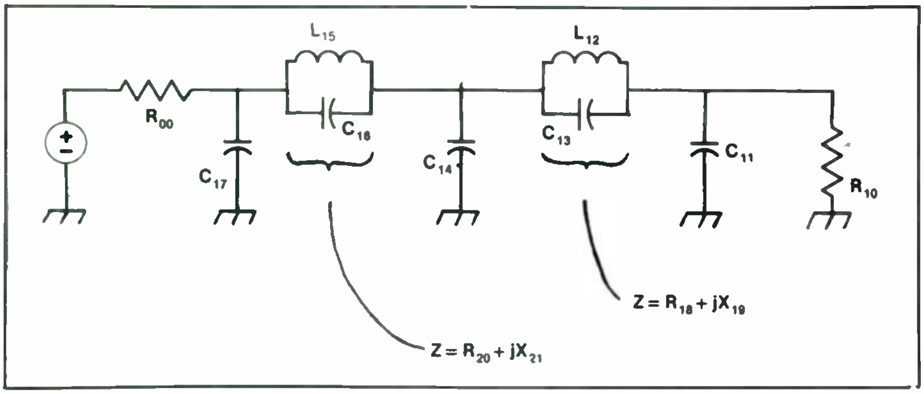


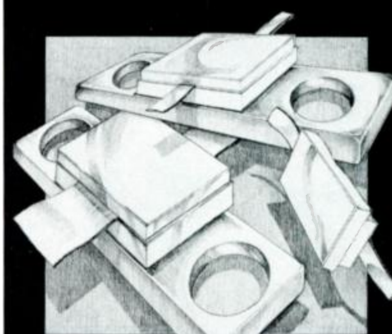
Figure 5—Elliptic low pass filter analyzed in Example 5.

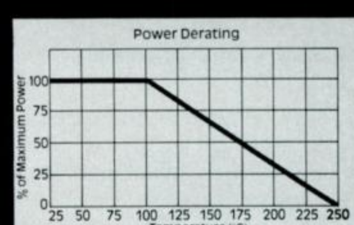
the dual of the first and requires a slightly different user defined program segment. The first step is XEQ 11, for the first reactive element next to the load is a series one. The last reactance, at the source end of the filter, is also a series component. But, the impedence of the source is yet to be taken into account when the filter input is encountered. XEQ 03 follows RCL 15 (to recall L_{15}) rather than XEQ 08 which would perform an undesired Z-to-Y conversion.

Two R/S steps are included within the program to allow the filter input resistance and reactance to be viewed. The display must be cleared with a "CLD" statement in the order defined

```
XEQ 00
CLST
RCL 12
XEQ 04
RCL 13
XEQ 06
STO 19
X<>Y
STO 18
CLST
RCL 15
XEQ 04
RCL 16
XEQ 06
STO 21
X<>Y
STO 20
XEQ 00
RCL 11
XEQ 06
RCL 19
+
X<>Y
RCL 18
+
X<>Y
XEQ 05
RCL 14
XEQ 06
RCL 21
+
X<>Y
RCL 20
+
X<>Y
XEQ 05
RCL 17
XEQ 06
XEQ 10
```


INFO/CARD 40





INFO/CARD 34

segment prior to viewing the impedance.

Example 3.

The next circuit examined is the third order bandpass filter using coupled series resonators shown in Fig. 3. The tuned circuits consist of series elements with no intervening shunt capacitors. The program required nine seconds per frequency for evaluation. An earlier version of GPLA using the polar to rectangular conversions took 16 seconds per frequency for the same filter.

Example 4.

The program is generally used for simple LC ladder networks. More complicated circuits may be examined though. Figure 4 shows a diplexer consisting of combined low pass and high pass filters. The high pass filter is considered to be a parallel branch with the low pass being the through path. The program begins as if the response of the high pass filter were being evaluated. Once the branch point is reached, the resulting admittance is stored in memory. The program is again initiated at the load for the low pass branch. When the high pass branch is reached, the data in memory is recalled and added. Program stops provide the composite input impedance as well as the transfer response of the low pass branch.

Example 5.

The final example further illustrates the utility of GPLA with more complicated filters. An elliptic low pass circuit, Fig. 5, is examined. The first step in the user defined program segment is XEQ 00. This is required only to calculate the angular frequency. The stack is then cleared with a CLST command to ensure that a termination will not alter the calculated impedance of a series element. The admittance of L_{12} and C_{13} is calculated. The result is converted to an impedance and stored in memory. The procedure is repeated with L_{15} and C_{16}. The program then begins again with XEQ 00. The "trap" impedances are added when encountered. Note that XEQ 05 is used explicitly for Z-to-Y conversion in this and the previous example. It is usually called only from other subroutines with simple filters.

Conclusion

The program presented is rather simple with only 143 lines of HP-41C code. It is still extremely useful for the evaluation of many networks encountered in rf design. The utility of the program comes from the use of a modified form of the traditional ladder method. Program speed is enhanced with a careful choice of programming methods. Results correspond well with those obtained with more exhaustive computer methods.

While GPLA is limited in application, the method may be expanded to describe networks of a more complicated nature. For example, a similar program has been written for the analysis of crystal ladder filters. The concepts are identical to those presented here. Execution speed is much faster than obtained with more versatile programs using scattering parameters or the ABCD matrix. Speed is the reward of the worker willing to write programs that are no more complicated than really required.

Acknowledgements

The writer gratefully acknowledges the comments of R. Culter and Dr. D. Morton. He also would like to thank his sons, Ron and Roger, who translated the program to the HP-15C and TI-58/59 formats.

References

1. Handy-Compact is the registered trademark of CGIS, a COMSAT Company.

2. W.H. Hayward, *Introduction to Radio Frequency Design,* Prentice-Hall, 1982. See Chapter 2 for a discussion of the ladder method.

3. GPLA is available from the author for HP-15C and the TI-58/59 calculators. The interested reader should specify the calculator type and write to the author at 7700 S.W. Danielle Ave., Beaverton, OR 97005. A self-addressed stamped envelope would be appreciated.

4. T.R. Cuthbert, Jr., *Circuit Design Using Personal Computers,* Chapter 4, Wiley Interscience, 1983.

Table 2. HP-41C Program Listing for GPLA

```
01 LBL "GPLA"              15 PROMPT
02 SF27                    16 "SER:11"
03 SF27(alpha space)       17 PROMPT
04 ASTO 05                 18 "TERM:00.10"
05♦LBL E                   19 PROMPT
06 "PCY=01,06"             20 "Q=03"
07 PROMPT                  21 PROMPT
08 "SCZ=02,07"             22 GTO 12
09 PROMPT                  23♦LBL F
10 "SLZ=03,08"             24 RCL 01
11 PROMPT                  25 "F, MHZ"
12 "PLY=04,09"             26 PROMPT
13 PROMPT                  27 STO 01
14 "PAR:00"                28 RCL 04
```


INFO/CARD 37

INFO/CARD 38

```
29 "STEP"
30 PROMPT
31 STO 04
32 GTO A
33♦LBL 00
34 RCL 01
35 2 E6
36 *
37 PI
38 *
39 STO 02
40 4
41 STO 09
42 CLST
43 RCL 10
44 1/X
45 X<>Y
46 FS? 01
47 XEQ 05
48 RTN
49♦LBL 01
50 RCL 02
51 *
52 +
53 RTN
54♦LBL 02
55 RCL 02
56 *
57 1/X
58 -
59 RTN
60♦LBL 03
61 XEQ 01
62 X<>Y
63 LASTX
64 RCL 03
65 /
66 +
67 X<>Y
68 RTN
69♦LBL 04
70 XEQ 02
71 X<>Y
72 LASTX
73 RCL 03
74 /
75 +
76 X<>Y
77 RTN
78♦LBL 05
79 ENTER↑
80 X↑2
81 ENTER↑
82 RCL T
83 X↑2
84 +
85 ST/ 09
86 ST/ Z
87 ST/ Y
88 RDN
89 CHS
90 RTN
91♦LBL 06
92 XEQ 01
93 XEQ 05
94 RTN
95♦LBL 07
96 XEQ 02
97 XEQ 05
98 RTN
99♦LBL 08
100 XEQ 03
101 XEQ 05
102 RTN
103*LBL 09
104 XEQ 04
105 XEQ 05
106 RTN
107*LBL 10
108 X<>Y
109 RCL 00
110 +
111 X<>Y
112 XEQ 05
113 RCL 09
114 RCL 10
115 /
116 RCL 00
117 *
118 LOG
119 10
120 *
121 STO 06
122 CLA
123 CLD
124 FIX 2
125 ARCL 01
126 ARCL 05
127 ARCL 06
128 AVIEW
129 FS? 00
130 STOP
131 RCL 04
132 ST+ 01
133 GTO A
134♦LBL 11
135 SF 01
136 XEQ 00
137 RTN
138♦LBL 12
139 CF 27
140 "USER PGM:"
141 LBL A
User
Defined
Part
of
Program
END
```

Storage:

00	Source R
01	Frequency, MHz
02	Angular Freq., rad.
03	Unloaded Q of inductance
04	Freq. Step, MHz
05	alpha space
06	G-t, dB
09	Vout^2
10	Load R

Computer Analysis of C Band Thin Film Attenuators

Computer Aided Design (CAD) is used to accurately predict the phase, VSWR and attenuation of thin film attenuators

By Paul Schneider
Norden Systems

Meeting the difficult phase balance requirements of today's phased array antenna systems places ever more difficult requirements on phase sensitive components such as low-loss step attenuators, switch-line phase shifters, and switchable filter banks. To meet the technical challenge of these components Norden has investigated the use of computer aided design (CAD) to accurately predict the phase, VSWR, and attenuation of thin film attenuators.

To accomplish this a microwave circuit design software program called Super-Compact* was used. This CAD program, developed specifically to accurately analyze microwave integrated circuits, can now also accurately predict the phase, VSWR and attenuation of lossy thin film MIC networks such as used in attenuators. It is believed that Norden was the first company to evaluate Super-Compact's ability to accurately predict microwave characteristics of thin film attenuator networks.

Analysis of 6 dB and 12 dB Step Attenuators

The physical dimensions of Norden designed 6 dB and 12 dB thin film step attenuators were carefully measured using a shadowgraph instrument. Using these measured dimensions a data file was written on Super-Compact for the Norden attenuators. The data file and schematic for a typical microstrip attenuator is shown in Figure 1 and Figure 2. When the analysis was performed on Super-Compact there was close correlation between computer predicted results and laboratory measurements proving that Super-Compact could accurately analyze thin film attenuators for phase, amplitude, and return loss. The phase of these step attenuators is defined as the difference in phase between the attenuator line and the low loss lines which are connected by two PIN diode SPDT switches. The computer-predicted phase differences between the low loss and attenuator lines were within 2 degrees of the measured results, as shown below.

Optimization of the 6 dB, 12 dB And 24 dB Attenuators

In addition, 6 dB, 12 dB and 24 dB step attenuators were also optimized using Super-Compact for VSWR, attenuation and phase difference between the low loss line and the attenuator line. The chart below summarizes the results of computer optimization of these attenuators indicating maximum phase difference, VSWR, and attenuation flatness expected for a C band step attenuator.

In the process of optimizing the step attenuators, the ground return dimensions for the shunt resistors of the attenuators were varied by computer. It is interesting to note that, without the computer, this task would have been time consuming and costly requiring many prototypes of different ground plane dimensions to be built and tested. In-

(Continued on page 47.)

Maximum Phase Difference of the 6 dB and 12 dB Thin Film Attenuators

		Frequency			
		F_1 GHz		F_2 GHz	
Maximum Attenuation	Film Resistor Material	Measured Phase Difference	Computer Predicted Phase Difference	Measured Phase Difference	Computer Predicted Phase Difference
6 dB	100 ohms/square	1°	2°	2°	3°
12 dB	100 ohms/square	6°	8°	12°	13.5°

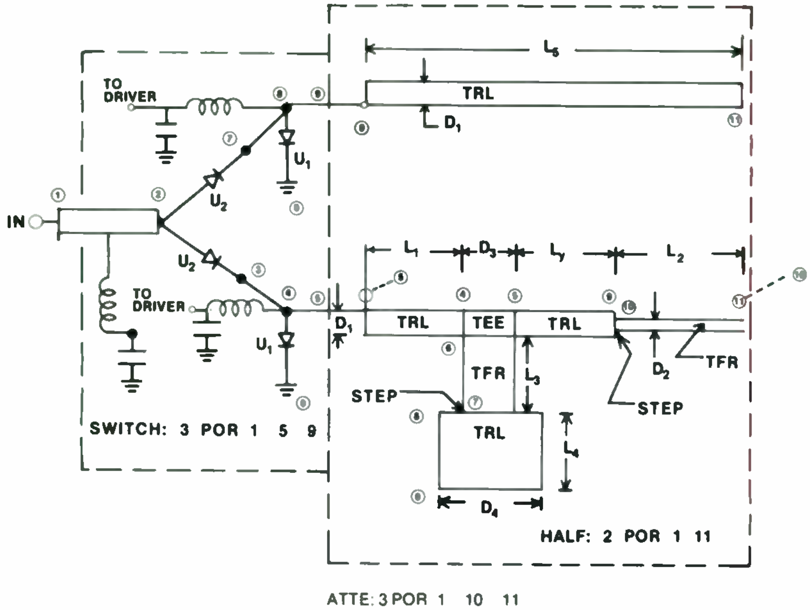


Figure 1—Schematic of left half of step attenuator.

Note: Right half of step attenuator is the mirror image of the left hand side.

U_1—PIN diode
$C_j = .15$ pf
$R_s = .5$ ohms

U_2—NIP diode
$C_j = .05$pf
$R_s = 1.5$ ohms

```
D1: D1MIL
D2: D2 MIL
D3: D3 MIL
D4: D4 MIL
L1: L1 MIL
L2: L2 MIL
L3: L3 MIL
L4: L4 MIL
LY: LY MIL
*Create half-circuit for symmetrical connection
BLK
TRL 1 4 W = D1 P = L1 SUB
TEE 4 5 6 W1 = D1 W2 = D1 W3 = D3 SUB
TFR 6 7 W = D3 P = L3 RS = 100 SUB
STEP 7 8 W1 = D3 W2 = D4 SUB
TRL 8 0 W = D4 P = L4 SUB
TRL 5 9 W = D1 P = LY SUB
STEP 9 10 W1 = D1 W2 = D2 SUB
* Note—L2 is half of the physical length.
TFR 10 11 W = D2 P = L2 RS = 100 SUB
HALF: 2POR 1 11
END
* Creating SPDT
BLK
TRL 1 2 W = 15 MIL P = 50 MIL SUB
RES 2 3 R = 1.50H
IND 3 4 L = .3NH
CAP 4 0 C = 15PF
IND 4 5 L = 2NH
CAP 2 7 C = .05PF
IND 7 8 L = .3NH
RES 8 0 R = 50H
IND 8 9 L = .2NH
SWITCH: 3POR 1 5 9
END
* Attach switch to line
BLK
HALF 5 10
TRL 9 11 W = D MIL P = L5 MIL SUB
SWITCH 1 5 9
ATTE: 3POR 1 10 11
END
BLK
ATTE: 1 10 11
ATTE: 12 10 11
ATTEN: 2POR 1 12
END
* Cascade two half circuits
FREQ
STEP F1 E 9 F2 5E8
END
OUT
PRI ATTEN S
END
DATA
SUB: MS H = 15MIL ER = 9.8 MET1 = NI 1500A MET2 = AU
   3MIL
END
```

Optimized Microstrip Step Attenuators

Attenuator	6 dB	12 dB	24 dB
Maximum VSWR	1.07	1.10	1.11
Maximum Deviation of Attenuation	+ .06 dB	+ .05 dB	+ .12 dB − .09 dB
Maximum Phase Difference Between Low Loss and Attenuator Line	+ 1°	+ 2°	+ 1°

(Continued from page 44.)
stead, in less than one hour the computer analysis showed how the ground plane dimensions for the shunt resistors of the optimized attenuators affected the return loss and phase response of the attenuators.

To achieve on the bench, computer predicted performance, it is very important to undertake a tolerance study of the device under development. A successful completion of this tolerance study allows the engineer to select device dimensions with maximum tolerance dimensions and pin point those dimensions which are most critical for success.

A computer analysis of another Norden designed attenuator whose dimensions were measured with a shadowgraph measurement instrument showed a flat 23 dB of attenuation which agreed with the measured results. The phase between low loss and attenuator line was +4 degrees maximum compared to ±5 degrees when the step attenuator was measured on the bench. One of the reasons for the differences in phase results could be the fact that Super-Compact is not capable of analyzing the phase differential due to the coupling between the low loss and attenuation lines.

Conclusion

It is obvious from these results that Super-Compact is able to predict attenuation and phase performance accurately and thus should be considered an important tool in the design of microwave step attenuators, time delay phase shift networks, and other thin film networks where accurate phase response is required.

Acknowledgements

The author would like to thank Steve March and Les Besser of CGIS for their technical advice and assistance and Larry Gross and Harold Shnitkin of Norden for their support. Thanks also to Walter Macie, Charlie Brown, and Mary Nault for their expertise.

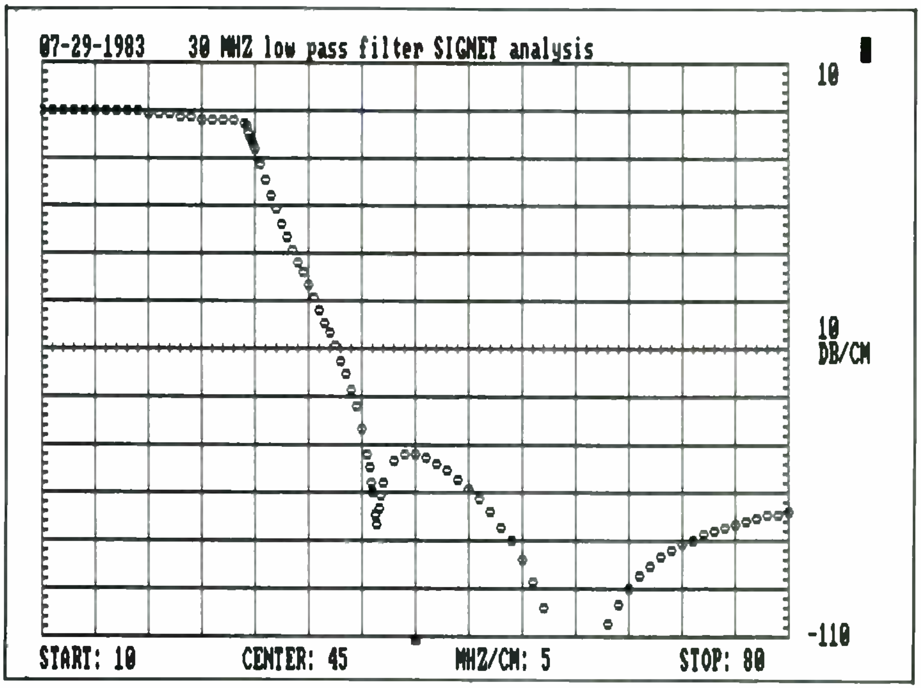
* Super-Compact is the registered trademark of CGIS, a COMSAT Company.

Circuit Design/Analysis Software for IBM-PC

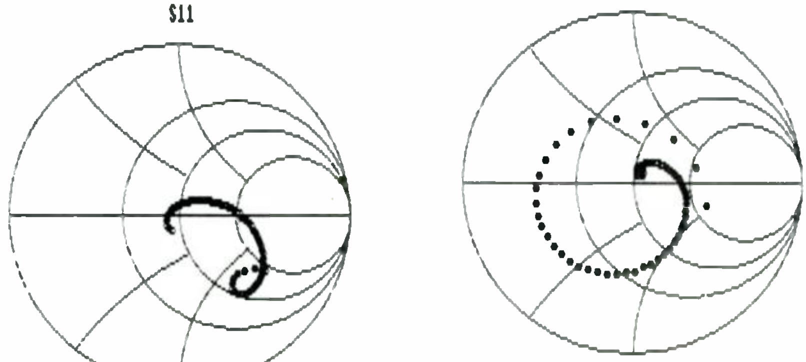
SIGNET is a moderately priced circuit design/analysis program written for the RF engineer who appreciates speed and efficiency. SIGNET handles lumped, distributed, active and passive components (e.g., design a three stage, 6 GHz microstrip amplifier). A major feature is a routine which provides component values for LC low-pass, high-pass, band-stop, and several different types of band-pass filters. Analysis can provide magnitude and angle of S-parameters, group delay, stability factor, gain etc. Speed is excellent owing to the machine language run format and optional 8087 co-processor chip support. Ease of use comes from sympathy for the new or infrequent user who may not be a seasoned computer "hack" or instruction manual fan.

Features include semi-automatic design optimization, component value sensitivity analysis, extensive on-line help text, data and circuit file storage, active device library, printable screen graphics, and a unique "scratch pad" facility for frequently encountered side calculations (e.g., conversion from L and C to transmission line equivalents).

Hardware requirements are an IBM, Compaq, or similar 8088 computer with 128K of memory and one disk drive. An 8087 co-processor chip, graphics display, and dot-matrix printer are optional. SIGNET purchase price $1,790. Prospective buyers may purchase a copy of SIGNET which has been "patched-up" to be of limited usefulness; demo disk $20.00 (may be used as credit for later purchase). **Dr. M. Martin & J. Mastropole, 1067 Leigh Mill Road, Great Falls, Virginia 22066, or INFO/CARD #106.**

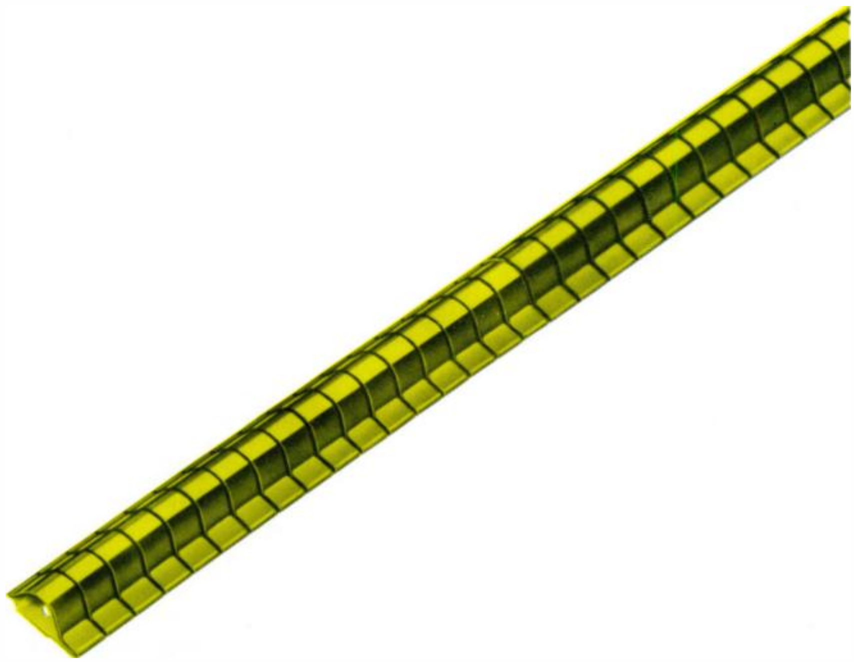


S11



S22

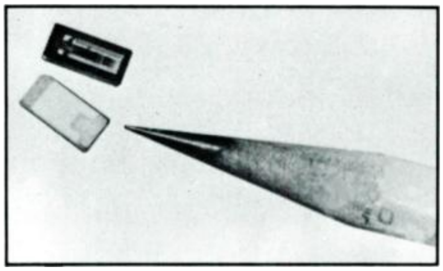
...or this narrower strip...



```
SIGNET copyright 1982 by James W. Mastropole, 1067 Leigh Mill Rd.
Great Falls, Virginia 22066   TEL 703-759-3976

VERSION 1.2/IBMPC

--A license to use this program has been issued to ############--

Posession or use of this software is strictly limited to the above
licensee.

SIGNET is an electronic circuit analysis tool which has been
optimized for the RF designer. Unlike most other sophisticated
computer programs, it requires little -if any- time with an
instruction manual in order for one to become a productive user.

REMEMBER:
* SIGNET only accepts commands in CAPITAL LETTERS.
* Prompts which are accompanied with a 'beep'sound may be answered
  with any of 14 command words (which are listed when you respond
  with the 'HELP' command) even though numerical data is expected.
* Most prompts may be answered by depressing only the ENTER key if
  you desire to move ahead into the program or avoid an action.

Do you need more information, Y/N?

SIGNET units:   MHZ, OHMS, HENRYS, FARADS, CENTIMETERS

SWEEP PROMPT MAY BE ANSWERED WITH ANY ONE OF THE FOLLOWING:
     MAP    to use constant freq, component value scan mode
     XMAP   to exit MAP mode
     SAVE   to save circuit data file
     LIST   to list current circuit data file
     HELP   to get this information
     NEW    to erase circuit data file
     CALC   to do some common circuit calculations
     FILT   to design filters
     PLOT   to enter plot/graphics mode
     XPLOT  to exit PLOT mode
     EDIT   to modify current circuit file
     SFILE  to save calculated data
     TITLE  to add date, time, and title to display
     QUIT   to exit SIGNET

Enter circuit file names using A: or B: as required;
do not add an extension, this is done automatically.

MORE Y/N?  Y

CIRCUIT ELEMENT LIBRARY:
RSE, RSH    series or shunt resistor
LSE, LSH    series or shunt inductor
CSE, CSH    series or shunt capacitor
       T    transformer by impedance ratio; EX-'T50/300'(50 TO 300)
       N    transformer by turns ratio;  EX-'N4' (1:4)
       XSE  parallel combination of R, L, and C used as a series
            circuit element; EX-'XSE1E4/.22E-6/470E-12'
            (R=10K, L=.22UH, C=470PF) C=0 is OK here
       XSH  series combination of R, L, and C used as a shunt
            circuit element; EX-'XSH10/.22E-6/470E-12'
       R    attenuator; EX-'R3' (3DB)
       S    S-parameter file; up to three different files may be
            used in a circuit. Open files with an 'S/' command at
            the beginning of the circuit list. EX-'S/MRF901/D1'
            (opens files MRF901 and D1). S1 and S2 will then
            represent the respective devices.
       V    V1, V2, or V3 precedes a circuit element, referring
            to one of the three parameters of that element which
            is to be varied while in the 'MAP' mode. Only one 'V'
            may be used in a circuit file (ignored when not in MAP).

MORE Y/N? Y
       WSE  series transmission line
       WTS  shunt transmission line; shorted at end
       WTO  shunt transmission line; open at end
       WSS  shorted transmission line used as a series element
       WSO  open transmission line used as a series element

       EX-'WSE75/15'  (series 75 Ohm line, 15cm long in air)

HOLD, USE and F circuit file operators:
       H    groupings of one or more circuit elements may be saved
            by following that grouping with H0, H1, ... or H9.
            The main circuit model is zeroed after an H command.
       U    circuits which have been saved by an H command may
            be recalled by U0, U1, ... or U9.
       F    the feedback command forms a new circuit element by
            combining two circuits which have been saved by H commands.
            Classical Series or Parallel feedback connections are
            allowed.   EX-'FP01' (parallel combination of H0 and H1)
                       EX-'FS27' (series combination of H2 and H7)
MORE Y/N? Y

OUTPUT OPTIONS:
       M    magnitude of S-parameters
       A    angle of S-parameters
       G    magnitude of S-parameters in Db
       D    group delay (omitted for first freq in a scan)
       K    stability factor

Desired output options must be grouped on a single line, without
the use of commas. SIGNET will ignore any file entrys beyond that
point, allowing you to add a title or any other text on subsequent
lines in the file.

An '*' in the printout indicates that SIGNET has
had to use interpolated S-parameters in its calculations.

HIT <RETURN> WHEN READY

CIRCUIT FILE NAME (or enter 'HELP')? SIG1
START/STOP/INCREMENT (mhz)? 20/40/2

FREQ mhz        S11         S21         S12         S?
 20          -12.877      -0.354      -0.354     -13.123    DB
 22           -8.831      -0.781      -0.781      -9.052    DB
 24           -5.829      -1.554      -1.554      -5.979    DB
 26           -4.347      -2.318      -2.318      -4.506    DB
 28           -5.916      -1.812      -1.812      -7.392    DB
 30           -1.084      -8.261      -8.261      -1.723    DB
 32           -0.155     -20.923     -20.923      -0.295    DB
 34           -0.076     -31.691     -31.691      -0.128    DB
 36           -0.055     -41.800     -41.800      -0.076    DB
 38           -0.043     -52.455     -52.455      -0.050    DB
 40           -0.036     -66.422     -66.422      -0.035    DB
07-29-1983   LOW PASS FILTER
```

"Chip" Crystals

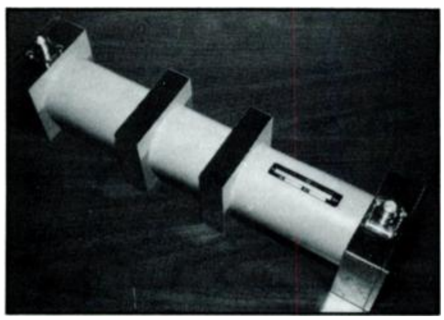
A broad range of leadless quartz crystals for surface mounting and capable of utilizing fully automated soldering techniques has been introduced by Statek Corporation. They withstand temperatures used in vapor



phase reflow soldering processes at 215°C and wave soldering processes up to 260°C. Designated the CX-1-SM series, these crystals are available in any frequency in the range 10 kHz to 2.0 MHz. **Statek Coproration, Orange, CA 92668, or INFO/CARD #124.**

High Power Lowpass Harmonic Rejection Filter

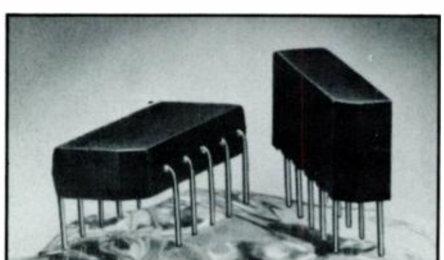
CIRQTEL Inc. announces the introduction of a full range (2MHz to 2GHz) lowpass harmonic rejection filter. Models are available for 100,



200, 500W, 1, 2.5 and 10KW continuous power. **CIRQTEL Inc., Kensington, Maryland 20795 or INFO/CARD #123.**

Capacitor Arrays

United Chemi-con Inc. has announced the introduction of a new packaging concept for its capacitor products known as Capacitor Arrays. This new product is a resin molded package which utilizes insert molding techniques to place 2 to 5 aluminum electrolytic elements into a capacitor array to maximize the concept of high density board mounting. Units are de-



signed for automatic insertion on PC boards. Electrically, these capacitor arrays have a capacitance range of 0.1 to 10 uF and are available with a voltage range of 6.3 to 50V. Price: Typical cost; .28 each for unit with 3 capacitors, 50 VDC working voltage, in 1000 quantity. **United Chemi-con Inc., Rosemount, IL 60018, or INFO/CARD #122.**

Mini-Amplifier

Trilectric introduces a series of miniature RF power amplifiers. The Mini-Amps are available in VHF (140-174 MHz) and UHF (450-512 MHz). Designed for applications that have limited mounting space, the amplifiers

measure 5-3/4"Lx 3"Wx1-3/4"H. Power output on VHF is 20-40 watts with 2-4 watt input. UHF is 10-20 watts output with 2-4 watt input. The amplifiers feature sturdy annodized aluminim alloy case construction housing an advanced single stage microstrip amplifier design. **Trilectric, Las Vegas, NV 89109, or INFO/CARD #121.**

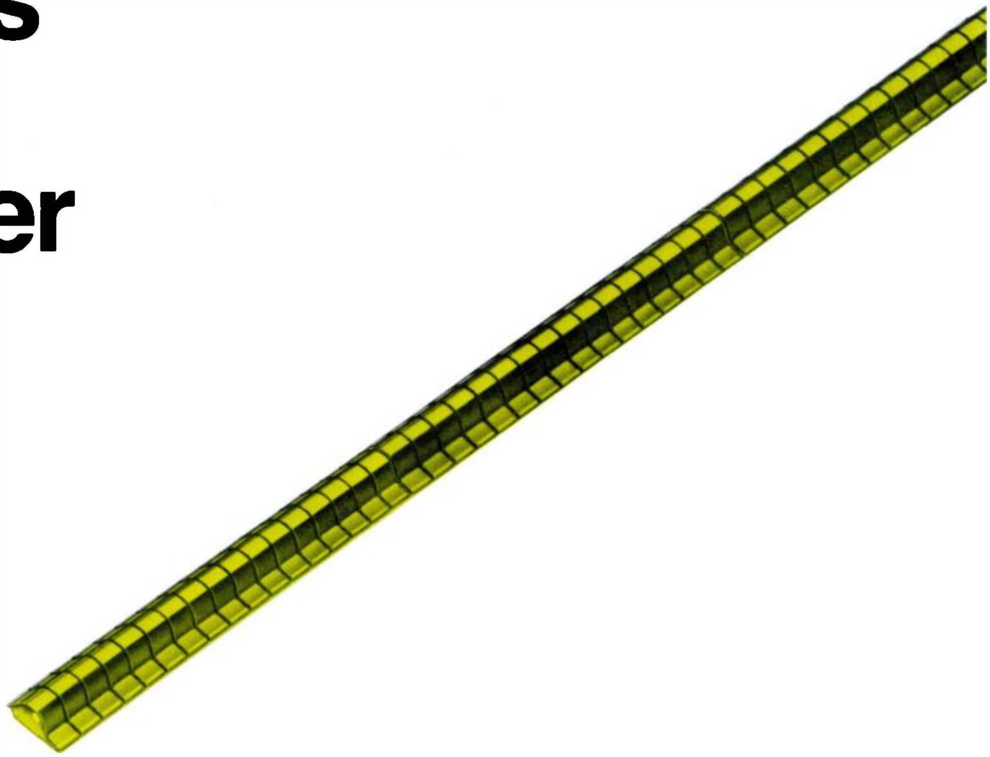
RF/Microwave Amplifier in Flatpack Configuration

Alpha Industries, Inc., Microelectronics Division now offers a complete line of RF/Microwave Amplifiers in flatpack packages as well as our standard TO-8, TO-12, TO-3 and 4 PIN DIP enclosures. These new products will be designated as the FP Series and will cover the ranges of 5 to 4200 MHz in numerous design configurations with output powers up to + 24 dbm and noise figures as low as 2db. The units are designed to provide broad frequency coverage, flat gain response, unconditional stability and low input/output VSWRS for a wide variety of applications. As with all of our modular products they can be cascaded to fulfill various system requirements. **Alpha Industries, Inc., Colmar, PA 18915, or INFO/CARD #120.**

Coaxial Attenuators, DC to 18.0 GHz, up to 100 Watts!

Weinschel Engineering announces new additions to its high power attenuator line. The model 46 has a power rating of 25 watts, 200 watts peak and is available in the following standard attenuation values: 3, 6, 10, 20, 30 and 40 dB. Models 47 and 48

...or this even narrower strip...



have standard attenuation values of 10, 20, 30 and 40 and are rated for 50 watts, 500 watts peak and 100 watts, 1000 watts peak, respectively. **Weinschel Engineering, Gaithersburg, Maryland 20877, or INFO/CARD #119.**

RF Transformers

Synergy Microwave has announced the availability of its new line of RF transformers for all broadband impedance matching applications. Forty-five standard models appear in the Synergy Microwave Master Catalog, covering impedance ratios of 1:1, 1:1.5, 1:2 and 1:4, in all possible balanced/unbalanced configurations. Each model is additionally available in three package types . . hermetic 8-pin miniature headers, hermetic tinplated flatpacks, and non-hermetic plastic flatpacks. **Synergy Microwave Corp., Fairfield, N.J. 07006, or please circle INFO/CARD #118.**

Low-Cost Frequency Counters

Two new frequency counters from Hewlett-Packard, the HP 5384A and HP 5385A, offer new levels of accuracy and resolution in economy-priced systems counters covering the frequency range of 10 Hz to 1 GHz. High input sensitivity coupled with extensive input-signal conditioning

result in enhanced performance in R&D testing. Additionally, low-priced systems capability is available in either HP-IB (Hewlett-Packard Interface Bus), which is standard, or HP-IL (Hewlett-Packard Interface Loop), which is optional. Frequency range for the HP 5384A is 10 Hz to 225 MHz. For the HP 5385A, it is 10 Hz to 1 GHz. Key specifications common to both units include: measurement resolution is 9 digits per second minimum; four- to 11-digit display resolution is front-panel selectable to simplify readings; input sensitivity is a high 10 mV rms (typical); and three gate time selections (0.1, 1.0 and 10 seconds) are provided. The HP 5384A is priced at $1,400 and the HP 5385A is priced at $1,700. Delivery for both counters is four weeks ARO. **Hewlett Packard Co., Palo Alto, CA 94303, or please circle INFO/CARD #117.**

High -"Q" GaAs Tuning Diode Chips

Alpha Industries now offers passivated abrupt gallium arsenide tuning diodes in chip form. Manufactured by Alpha's Semiconductor Divison, these GaAs Chips are ideally suited for frequency tuning applications from X through KA band. They can be used to tune filters, phase shifters, Gunn-Impatt-transistor oscillators, upconnectors, and low order multipliers. Passivation, in conjunction with other processes, results in high reliability and leakage currents less than 10 nanoamps. Variations from square law are minimized while maintaining high tuning ratios and highest Q by a careful selection of eqitaxial GaAs and by tightly controlled anode


REF LEVEL
10 dBm
INPUT ATTEN
10 dB ATTEN
LOG SCALE
10 dB/
When your automated test system requires precision frequencies, fast switching, quick settling, and low noise with GPIB or BCD-parallel control, PTS Synthesizers deliver, with proven reliability.
In their automated crystal processing facility General Electric's Mobile Communications Division use PTS 200 Synthesizers.
If you need VHF-UHF Synthesizers for precision frequency control, specify PTS.
PTS
FREQUENCY SYNTHESIZER MODELS
40 MHz, 160 MHz, 200 MHz, 500 MHz
PTS 500
PTS
PROGRAMMED TEST SOURCES, INC.
Littleton, MA, 617-486-3008
INFO/CARD 46

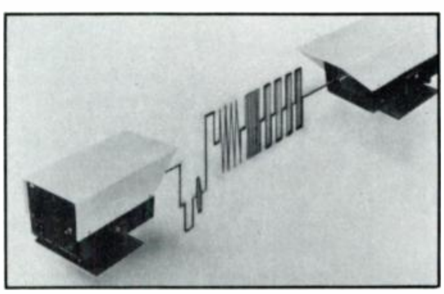
diffusions. **Alpha Industries, Inc., Woburn, MA 08101, or INFO/CARD #116.**

High Output RF Linear Hybrid Amplifiers Offered In Single-In-Line Packages

17 RF linear hybrid amplifiers offered in a new hermetic single-in-line package are available from TRW Semiconductor Division. Known as the SIP series, these hermetic hybrids exhibit output power up to 2 watts with bandwidths up to 1 GHz and noise figures as low as 3dB. A second series, the GPA's (general purpose amplifiers) are low cost, high performance cascadable amplifiers in TO-8 packages. With output as high as +20dBm and bandwidths up to 1500 MHz, the GPA's supply internal bias as well as external bias components. The GPA series may be cascaded alone or in tandem with the SIP series for higher output capability without sacrificing bandwidth. Both series are designed for a wide variety of receiver, transmitter and instrumentation applications. The SIP series are priced from $50-65 in quantities of 100. Prices range from $25-86 in quantities of 100 for the GPA series. **TRW Semiconductor Division, Lawndale, CA 90260 or INFO/CARD #115.**

Optical Infrared System

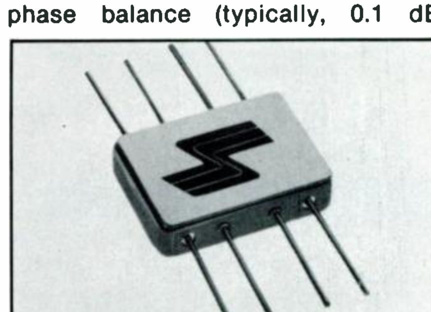
Recent advances now allow transmission of excellent quality color or black and white video signal and audio signal to distances increased by 25% and with greater reliability on a free space optical infrared transmission system. The model 761, consisting of one transmitter and one receiver, transmits line of sight on an invisible infrared beam of light with-



out the need for FCC licensing. Built-in alignment telescopes assist in quick and easy installation for temporary or permanent sites. New circuitry insures dependable, high-quality transmission. For broadcast applications, NTSC, PAL, and SECAM quality signals can be attained at distances of 2500 FT. (.8KM) with a signal to noise ratio of 54DB. Applications include ENG, microwave to studio, camera to microwave and more. **American Laser Systems, Inc., Goleta, CA 93117, or please circle INFO/CARD #105.**

RF/Digital Modulators

Synergy Microwave has announced the availability of its comprehensive line of Bi-phase and QPSK (quadriphase) modulators. The Bi-phase modulators are broadband (5-1250 MHz) and exhibit excellent amplitude balance (typically 0.1 dB) and phase balance (typically, 0.5° to 100 MHz, 1.0° to 500 MHz, and 3° to 1250 MHz). The QPSK modulators are specified at 10% bandwidths and are available at frequencies up to 1500 MHz. Catalog models are listed with center frequencies of 30, 60, and 70 MHz. Aside from excellent amplitude and phase balance (typically, 0.1 dB



1 degree) the Synergy QPSK's offer absolute "insertion phase" balance. This is critical in a QPSK device yielding (when used as a demodulator) maximum DC output when both input signals (modulated and CW) are exactly in-phase. Both Bi-phase and QPSK modulators are available with standard 10 mA DC current logic, or with integral ECL drivers. Other integral logic is available on request. The catalog QPSK models are listed in Flatpacks, the Bi-phase models in Flatpacks and TO-8 packages. **Synergy Microwave Corp., Fairfield NJ 07006, or INFO/CARD #104.**

Bandpass Filter Suppresses TVRO Interference

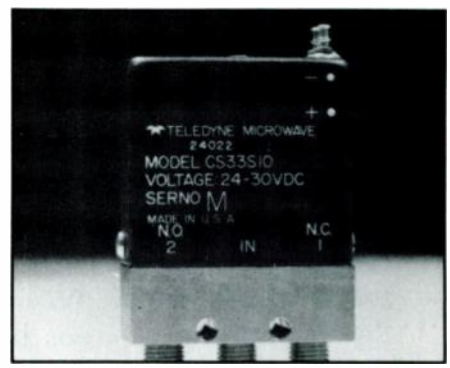
The model #4352 coaxial bandpass filter passes the 3.7-4.2 GHz TVRO band with less than 0.8 db insertion loss (maximum) and 1.5 VSWR (maximum). Attenuation is at least 20 dB at 3.5 and 4.4 GHz, the closest allocated interference. Typical suppression is approximately 30 and 50 dB on the public carriers, 2.1 and 6.5 GHz, respectively. The weather-sealed filter has type N connectors and inherent D.C. passing for LNA power. Price and delivery are $115 and 5 days, respectively. **Microwave Filter Co., Inc., East Syracuse, NY 13057, or please circle INFO/CARD #103.**

SPDT Diode Switch

Engelmann Microwave, a KDI Company, has announced the addition of a SPDT Diode Switch which operates over the full frequency range of 0.1 to 18 GHz. The Model SW 2218 has a speed of 30 nsec. max. for 10-90% points. It is priced at $350 per unit and is available from stock. **Engelmann Microwave, Whippany, NJ 07981, or INFO/CARD #102.**

SPDT Coaxial Switch

Teledyne Microwave provides full band performance over the DC-18 GHz range, now with special inboard



mounting configuration. These SPDT, latching and failsafe switches are mounted conveniently by holes between the ports in the RF portion of the switch. Both inboard and outboard mounting can be provided on the same switch for increased versatility. Insertion loss performance is 0.5 dB max., isolation is 60 dB min., and VSWR is 1.50 max. across the full band with improved performance in the DC-6 GHz range. Actuators can be supplied with 12, 15, 24-30 VDC, and 115 VAC coils. **Teledyne Microwave, Mountain View, CA 94043, or please circle INFO/CARD #101.**

High Power Coaxial Switches

RLC Electronics announces an improved series of high power coaxial switches. By the use of heat conducted dielectrics, the SRP Series of electro-mechanical switches have the ability of handling high CW power levels in a frequency range of DC-6GHz. Typical power capability would be 1500 watts CW @ 1000MHz. These switches are available with SC, HN or Type N connectors with standard options of indicator circuits, latching operation, and TTL drivers. They are available in single-pole, double-throw through single-pole, six-throw. Prices start at $425 in unit quantity for the single-pole, double-throw. Delivery is from stock to eight weeks. **RLC Electronics, Inc., Mount Kisco, N.Y. 10549, or please circle INFO/CARD #100.**

Ultra Low Phase Noise Oscillator

Greenray has announced a new ultra low phase noise oscillator Model YH1202-1. It features the combination of low phase noise, low aging and high stability in one oscillator. Specifications include: Frequency range, 25 MHz to 100 MHz; Output Type, Sine Wave; Output power, 0 dBm (minimum) into 50 ohms; Temperature range, 0 to 50°C; Temperature stability, 5×10^{-8}ppm; Aging, 1×10^{-9}/day; Input voltage, + 15 vdc.

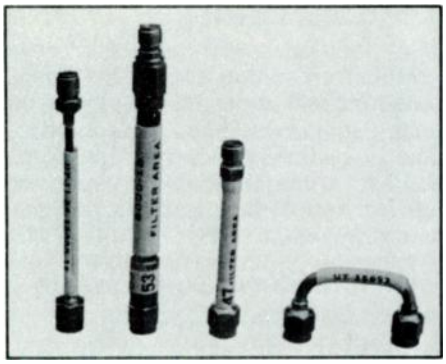
Phase Noise: (At 100 MHz)

Offset From Carrier	db/Hz
100 Hz	-120
1kHz	-130
50 kHz	-140

Greenray Industries, Inc., Mechanicsburg, PA 17055, or INFO/CARD #99.

Micro-Coax Low Pass Filters

Higher frequency capabilities for Low Pass Filters in semi-rigid coaxial



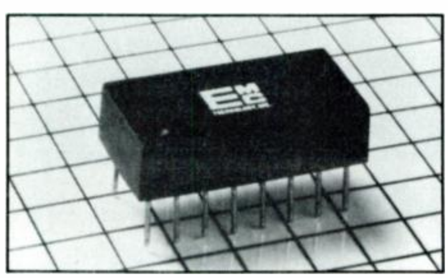
cable have been achieved by the MicroDelay Division, Uniform Tubes, Inc., Collegeville, PA. In 0.0865" O.D. cable, the frequency range is 1.0 GHz to 30.0 GHz. In 0.141" O.D. cable, the range is 200 MHz to 18.5 GHZ. In 0.250" O.D. cable, the range is 200 MHz to 8.0 GHz. **Uniform Tubes, Inc., Collegeville, PA 19426, or INFO/CARD #114.**

Chipless™ Circuits for RFI/EMI Suppression

KDI Pyrofilm's Chipless™ Capacitor Circuits and Chipless™ RC Circuits can provide effective interference suppression. These low cost circuits, available in both Single-in-Line and Dual-in-Line configurations can be effective in helping designers meet FCC Article 15 requirements. **KDI Pyrofilm Corporation, Whippany, NJ 07981 or INFO/CARD #113.**

16-Pin Dual-In-Line Attenuator

A new dual-in-line attenuator package from EMC Technology offers a unique approach to obtaining the correct attenuation values for adjust at test applications, and is said to be the first microwave attenuator offered



in a standard DIP configuration. The Model 1248 attenuator plugs into an ordinary 16-pin dual-in-line socket, and operates from DC to 1 GHz (usable to 2GHz). Four separate attenuators are incorporated in the package, each of which may be used independently or jumpered to achieve desired attenuation up to 15dB in increments of 1dB. Cost for the new DIP attenuator is $25, and delivery is from stock. **EMC Technology, Inc., Cherry Hill, NJ 08034, or please circle INFO/CARD #111.**

New Literature

Ceramic Capacitor Catalog

PACCOM recently announced the availability of an 8-page ceramic Capacitor Catalog describing the company's full range of miniature ceramic capacitors. Included in the catalog are complete electronic and mechanical specifications for temperature compensating, high dielectric, semi-conductor type, high voltage, and taped ceramic capacitors. **Paccom, Redmond, Wa 98052, or INFO/CARD #150.**

Attenuator Catalog

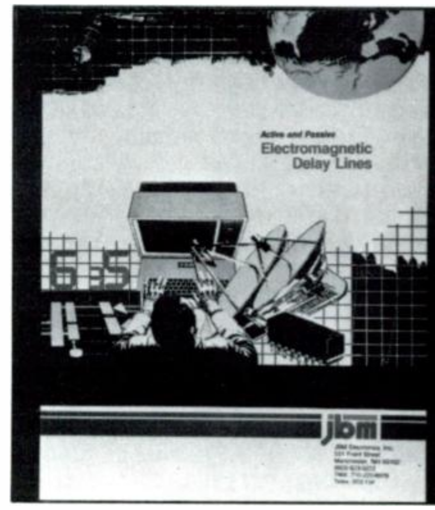
JFW Industries announces a new Attenuator Catalog containing specifications and prices on wide range of units, including fixed attenuators, coaxial switches rotary attenuators, solid state programmable attenuators and others. **JFW Industries, Indianapolis, IN 46203, or INFO/CARD #149..**

Millimeter Wave Components and Subsystems Catalog

Alpha Industries announces its new comprehensive Active Millimeter Wave Components and Subsystems catalog. The 40-page catalog describes Alpha's latest developments in millimeter wave technology. Featured are detailed specification charts, graphs, and complete ordering information for balanced mixers, upconverters, harmonic mixers, detectors, frequency multipliers, phase-locked sources, PIN diode switches, and modulators. Alpha's capabilities of custom-developed millimeter wave subsystems and radar antennas are also included. **Alpha Industries, Woburn, MA, 01801 or INFO/CARD #148.**

Electromagnetic Delay Lines

A 16-page illustrated catalog describing a broad line of active (TTL and DTL-compatible) and passive electromagnetic delay lines has been published by JBM Electronics, Inc. The



new publication includes information on specifying and testing delay lines, as well as dimension data, circuit diagrams and specifications for approximately 200 standard DIP and SIP-packaged modules. Information on custom and military types is also included. **JBM Electronics, Inc., Manchester, NH 03102, or please circle INFO/CARD #147.**

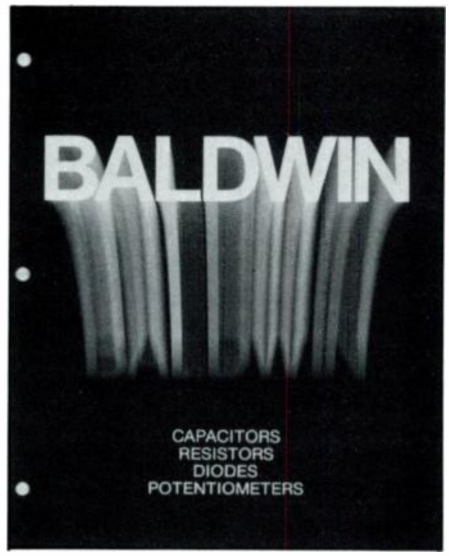
Antenna Systems Catalog

Andrew Corporation, a supplier of antenna equipment to the telecommunications industry since 1937, recently published a new edition of its general catalog — Antenna Systems/Catalog 32. Andrew catalogs traditionally have been valued not only for their product listings, but also for the extensive technical information and system planning data that they provide. The new catalog includes many new features and products. The coaxial cable and power rating sections are reorganized to facilitate applications-oriented comparison. The book has been expanded to 208 pages with increased coverage of broadcast and earth

station products. GRASIS® towers and equipment shelters appear in the catalog for the first time since Andrew Corporation acquired Grasis Corporation in 1983. **Andrew Corporation, Orland Park, IL 60462, Please circle INFO/CARD #146.**

Passive Components Catalog

A new 60-page two-color catalog on capacitors, resistors, diodes and potentiometers is available free from Baldwin Components Center, Inc. The components described in the catalog are available in all standard values and are maintained in a computerized inventory for shipment in 24 hours. Components with non-standard values are available on special order. Many of the components are in currently-desired miniature and sub-miniature designs to assure optimum use of board space, and have high-precision, ultra-high precision and MIL ultra-high precision capabilities. **Baldwin Components Center, Inc., Deer Park, N.Y. 11729, or please circle INFO/CARD #144.**



Microwave Signal Sources Brochure

M/A-COM OSW, Inc., M●A●T●S Divison, San Jose, California, presents their all new Mrcrowave Signal Sources Brochure. Included in the attractive four-color brochure is a company profile highlighting Product Engineering by M●A●T●S's design oriented engineering team, a Quality Assurance team with the lowest return rate in the industry, and Guaranteed Reliability including computerized test data provided with each unit.Featured in the Standard Sources section are details on the Free Running Cavity Sources (FR Series), Phase-Locked Sources (PL Series), Automatic Phase-Locked Sources (FM Series), Mechanically

Air Force Strategic Communications Embedded Computer Systems–Ada Language

For the Air Force E-4B Airborne Command Post and Minuteman Missile Weapons System.

Now is your opportunity to work for the industry leader in Ada Software applications in major weapons systems. Sonicraft's upgrade of the Air Force 487L Strategic Low Frequency Communications System will employ state-of-the-art VLF/LF Receiver and Microprocessor System Technology. This will be the first major defense system to use the new MIL-STD-1815A Ada Language in a multiprocessor, real-time environment.

Join a company that recognizes and rewards performance. We have immediate career opportunities in the following areas:

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Program Managers
Program Administrator
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Training Specialist
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R/F Analog Circ. Designers
Software Reliability Engin. Analyst
Software Quality Spec. Writer
Sr. Electronic Technicians
Logistic Engineering Supervisor
Maintenance Engineer
Logistics Support Supervisor
Sr. Software Engineers
Sr. Digital Hardware Dev. Engineer
Sr. ATE Hardware Design Engineer
Systems Engineer
Components Engineer
Reliability Engineer
Software Quality Engineer
Manufacturing Engineer
Security Officer

Candidates should have 5 years or more military R&D or software engineering experience, and be U.S. citizens. We offer excellent compensation commensurate with your ability and experience and a full range of company benefits including relocation package. For immediate and confidential consideration, please send resume to:

DRE Program Manager,
Dept. MZ-46

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(PRINCIPALS ONLY PLEASE)

Tuned Synthesizers (SN Series), Automatic Locking Synthesizers (SA Series), Crystal Oscillators (XO Series), and Frequency Multipliers (XM Series). Also included are Features, Center Frequency, Typical Output Power by Source Series, and Options Available. **M/A-COM OSW, Inc., MA Telecommunication Sources Division, San Jose, CA 95112, OR INFO/CARD #142.**

Selection Guide on Consumer IC'S

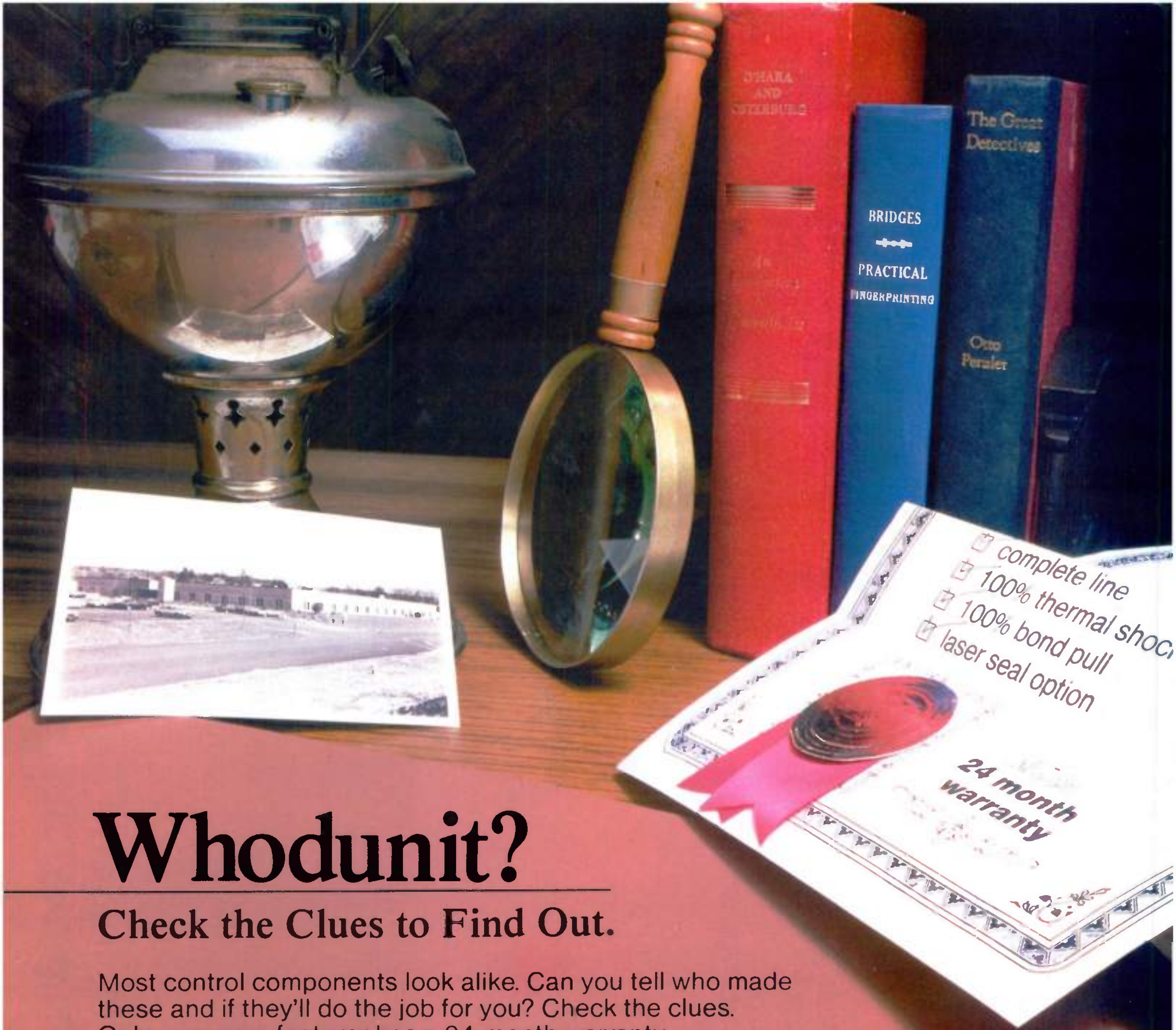
A new 45-page selection guide outlining Siemens "consumer" integrated products has recently been released. The "consumer" classification includes those integrated circuits for use in television receivers, satellite receivers, television cable converter systems, home and automobile radios, infrared remote control of television, CATV converters, radio and general applications. The color brochure contains a summary of IC types, block diagrams and package, function and electrical characteristics. Additional product literature and applications information are also available. **Siemens Components, Inc., Iselin, N.J. 08830, or INFO/CARD #140.**

RF Components Catalog

A new RF Components Catalog has just been released by KDI Pyrofilm. This 40 page catalog details KDI Pyrofilm's line of RF AND MICROWAVE RESISTIVE COMPONENTS for military and commercial applications in the frequency range of DC to 26.5 GHz. The KDI Pryofilm RF Components Catalog also includes sections on: Chip Resistor Applications; Installation/RF Matching-Power Terminations, and Temperature Calculations. **KDI Pyrofilm Corporation, Whippany, New Jersey, 07981, or INFO/CARD #141.**

Quartz Crystal Clock Oscillators

Frequency Control Products has released new, comprehensive literature describing its full line of Hi Reliability Quartz Crystal Clock Oscillators. The four page brochure gives complete details on their miniature low profile DIP types, available in both commercial and military versions including the TTL Series, covering a frequency range from 1kHz to 100MHz and the CMOS Series, covering a frequency range from 10kHz to 15MHz. Complete descriptions, features, environmental data, mechanical specifi-

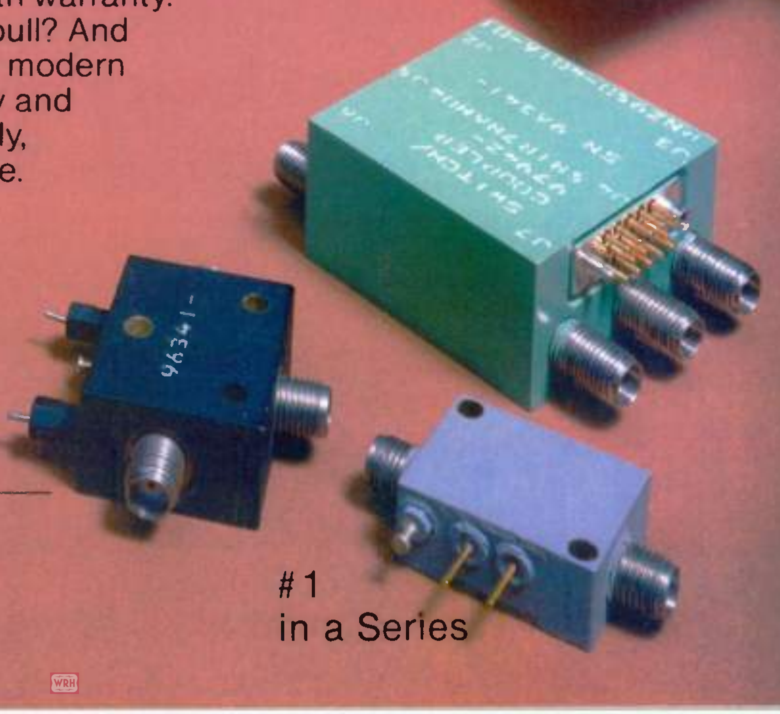


Whodunit?

Check the Clues to Find Out.

Most control components look alike. Can you tell who made these and if they'll do the job for you? Check the clues. Only one manufacturer has a 24-month warranty. What about thermal shock and bond pull? And laser-welded seals? Who has the new modern facility with complete Hi-Rel capability and a large manufacturing capacity? Finally, check the logo and company signature. Whodunit? We did!

Send for complete catalog of single and multi-throw switches, limiters, attenuators and phase shifters.



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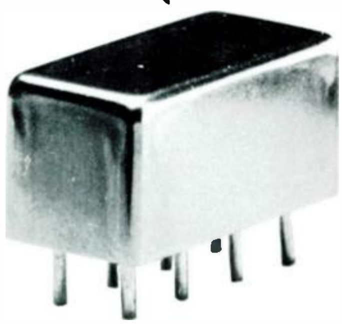
INFO/CARD 58

#1
in a Series



cations, a screen test options chart, mechanical outlines, electrical specifications for both series, and ordering information are all detailed. **Frequency Control Products, Inc., Woodside, N.Y. 11377, or INFO/CARD #145.**

Capacitor Catalog

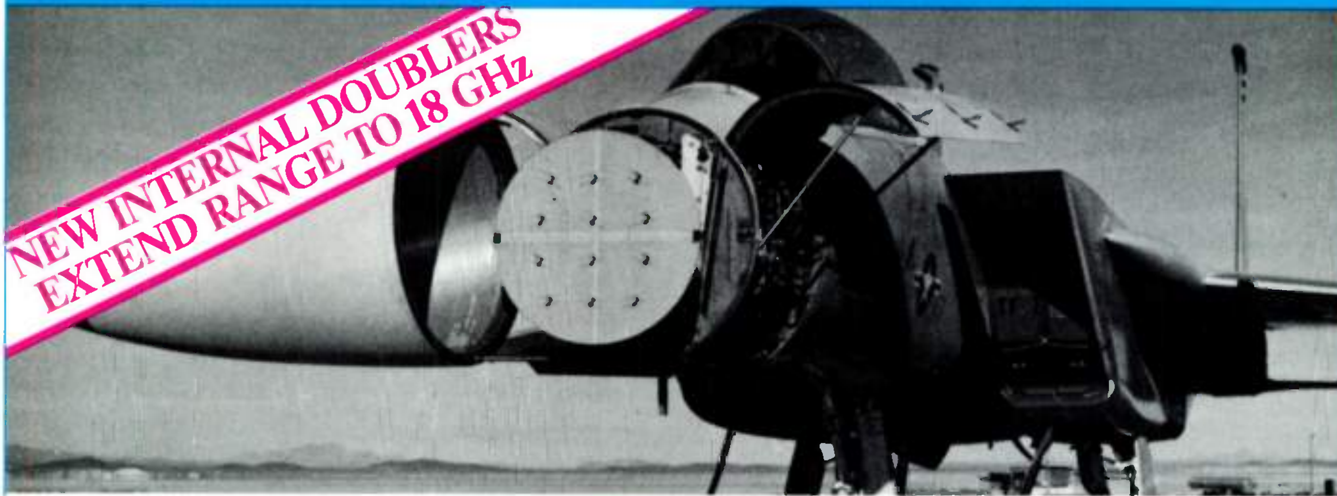
Republic Electronics Corp., announces availability of its new 1983 Catalog U-1 (12 pages), describing its complete line of MUCON Subminiature Ceramic capacitors. A complete line of Microwave capacitors CDR11 thru CDR14 and CDR21 thru CDR25 QPL to MIL-C-55681 are included; CY81 thru CY87 QPL to MIL-C-11272. NPO capacitors in styles CCR05 thru CCR09, CCR13 thru CCR19 and CCR75 thru CCR79 QPL to MIL-C-20. Also available is a complete line of temperature compensating capacitors with coefficients from NPO thru N5600. **Republic Electronics, Paterson, N.J. 07524, or INFO/CARD #139**

Booklet on Solving Coil Design Problems

Magnecraft has developed an original graphical method for solving coil design problems. Basically, it is a "short-cut to determine coil resistance for the entire range of wire sizes-and eliminates the hit-or miss need for winding many trial coils."

New formulae compares wire gage to coil resistance, coil turns, power dissipation and ampere turns. Applications meet many requirements for relays, solenoids and transformers. **Magnecraft Electric Company, Chicago, Il 60630, or INFO/CARD #138.**

Advertiser Index



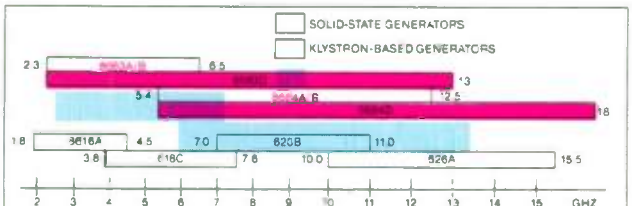
HP 8684B 5.4 to 12.5 GHz: AM, FM, Pulse

HP 8683A 2.3 to 6.5 GHz: AM, FM

NEWEST CAPABILITY: DOUBLER FREQUENCY RANGES

New from HP: truly portable high performance signal generators.

Now it's easy and economical to do high performance receiver testing almost anywhere. Weighing under 40 lbs., HP's 8680 Series of rugged, compact signal generators give you the frequency stability and spectral purity inherent in cavity tuned oscillators, with typical non-harmonic spurious below −85 dBc.



Extended application range of 8680 Series Signal Generators gives strong price performance advantage

NEW 8683D Radar/EW 2.3—13 GHz
8684D Radar/EW 5.4—18 GHz

Innovative microprocessor enhancements provide output level accuracy of ±2.5 dB, improved tuned frequency accuracy, and automatic compensation for cable loss. Solid state reliability delivers a demonstrated 6000 hours MTBF. And powerful diagnostic capability is built in for field service.

These outstanding signal generators feature low distortion FM and metered AM over a dynamic range from +10 to −130 dBm![1] They come in four frequency ranges providing 18 GHz, almost triple the coverage of Klystron-based units. Communications versions are priced at $12,000.* Radar/EW versions—including an internal pulse modulator/generator with >80 dB on/off ratio, and <10 ns rise/fall times—are priced at $15,000.* For detailed information, contact your nearby HP sales office, or write Hewlett-Packard, 1820 Embarcadero Rd., Palo Alto, CA 94303. Price for new 8683D/8684D doubled version $19,000.*

[1] 8683/84D generators: −3 to −130 dBm standard. +10 to −130 dBm available with opt. 001 after March 84.

0401202C

*U.S. domestic prices only.

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