tested. Other control outputs from the 4051 change wave length in the experiment. This method makes the testing virtually automatic.

Dr. Liu chose the 4051 Graphic System for this test system because of its high-resolution graphics and its GPIB capabilities. The 4051 draws data from the experiments back through the GPIB and manipulates it to provide useful results. These results take the form of several different graphs of the characteristics of solar cells and solar cell materials. Some typical outputs are Spectral Response curves, Voltage vs. Current, and plots of the conversion efficiency curve of the cells. In addition to the plotted curves, the 4051 will provide a list of all of the experimental data.

This test system is still being refined at Jet Propulsion Laboratory. As it stands, the system already provides a quantum leap in speed and efficiency over the previous data gathering methods. As an example, prior to setting this system in place, current vs. voltage data was laboriously gathered and plotted by hand, point by point. This method took between one and two hours to gather and plot 20 data points. The test system can gather 50 data samples in two **minutes**. As another example, Dr. Liu cited the plotting of Spectral Response curves. This operation previously took an entire morning of gathering data by hand, followed by subsequent computer reduction. The 4051-based test system completes the entire operation, including graphic outputs, in nine minutes. Time savings and high resolution graphics: that's what the 4051 is all about.

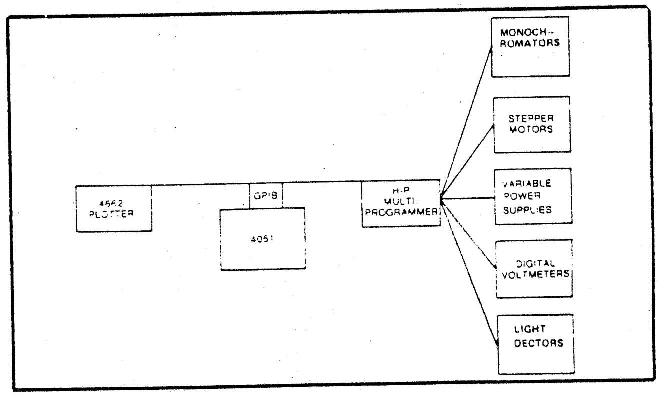

Fig. 1. Solar Cell Test System.

PLOT 50 EE Vol. 1 Speeds Circuit and System Design from Audio to Microwave Frequencies

by Dave Barnard

PLOT 50 Electrical Engineering Vol. 1 software permits interactive modeling and analysis of circuit designs in the frequency domain. From audio to microwave frequencies, whether a prospective circuit is to perform amplification, filtering, or impedance matching, this powerful package will predict circuit performance and assist designers in making decisions. A specialist working at microwave frequencies will find the interactive Smith Chart plots, impedance mapping and matching network design routines particularly helpful; this is a major emphasis in the software package. Audio and communications equipment designers can use many of the general purpose routines, as the article in TEKniques Vol. 1 No. 8 pointed out.

Extensive two-port manipulating capabilities allow anything that can be modeled as a linear two-port network to be analyzed. Circuits of active and passive elements can be constructed from a menu of elementary two-ports. The payoff is the ability to simulate a proposed design quickly with a stand-alone 4051 system. Results may be copied from the screen using a 4631 Hard Copy Unit or plotted on a 4662 Interactive Digital Plotter. Graphically portraying performance of circuits makes the trade-offs obvious to the designer. It doesn't replace engineering intuition; it complements it.

4051 BASIC programming ability is not required as a prerequisite to using EE Vol. 1. Function keys and an overlay make software operation easy. Errors may be edited out and changes made simply. Error messages are in plain language rather than in error number format.

For an engineer with BASIC programming experience, EE Vol. 1 makes a good companion to the collection of routines that are probably already on hand.

You can get started with EE Vol. 1 by simply inserting the tape and pressing AUTO LOAD. Whether the problem is simple or complex, the ease of operation won't let the program get in the way; there is sufficient power to handle demanding tasks.

Construct your circuits from the menu of two-ports which includes elementary series or parallel resistors, capacitors, and inductors. Tank circuit models—RLC—are included. Current or voltage controlled I or V sources permit modeling active device configurations. Specify transmission line models by either physical or electrical length plus impedance, dielectric and loss coefficients.

If a device (a transistor for example) has known parameters, they can be entered simply and interactively. The program converts the parameters to or from any form desired. Transistor configurations can be converted to or from common emitter, common base, or common collector.

Example

TEKniques Vol. 1 No. 8 first introduced EE Vol. 1 software to you. Let's suppose that the design of a high frequency amplifier (Fig. 1) was started following the example discussed in that article.

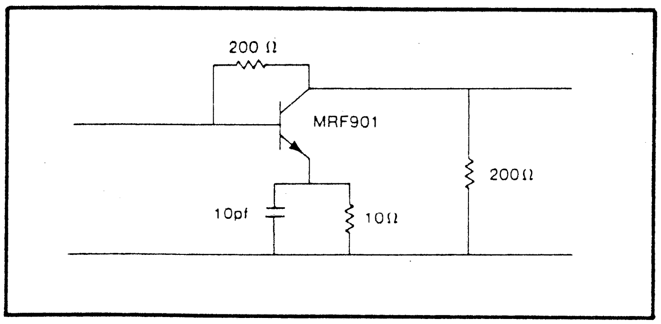

Fig. 1. Amplifier from TEKniques with MRF901 Transistor.

Analyzing amplifier performance with a different transistor requires entering the device parameters via the ENTER DATA function key. Fig. 2 shows how easily this may be done. Data for the MRF901 was taken from the Motorola **RF DATA Manual** and entered as shown.

```
ENTER DATA
Frequency Units (GHZ, MHZ, KHZ, or HZ)?          GHZ
Parameters (S, Y, Z, H, G, 1/S, 1/Y, or 1/Z)?    S
Polar, DB, or Rectangular form (P, D, or R)?     P
Enter FREQ and 11, 12, 21, and 22 data
 1:  0.2 .45 -115 .02 53 17.2 114 .57 -33
 2:  0.5 .45 -162 .04 55  7.7  90 .40 -31
 3:  1.0 .47  166 .07 64  4.0  71 .35 -35
 4:  1.5 .51  148 .10 67  2.6  58 .34 -47
 5:  2.0 .53  135 .13 68  2.0  46 .33 -62
 6:
```

Fig. 2. Device data entry.

Once entered, the S-parameters may be recorded on the 4051 internal magnetic tape by using the DATA ON TAPE function key.

Assuming data is saved in File 2, the code to analyze the circuit should refer to that file as shown in line 5 (Fig. 3).

```
ENTER CODE
  1:  GHZ COP
  2:  FE .1 10 20
  3:  RP 10 CA
  4:  CP 10 SE
  5:  DAT 2 PA
  6:  RS 200 CA
  7:  RP 200 EQ
  8:  NEXT
  9:  GAM G21-LO
 10:
 11:
LIST CODE
  1:  GHZ COP
  2:  FE .1 10 20
  3:  RP 10 CA
  4:  CP 10 SE
  5:  DAT 2 PA
  6:  RS 200 CA
  7:  RP 200 EQ
  8:  NEXT
  9:  GAM G21-LO
 10:
Code length = 84.  Simple diagnostic (Y or N)?  Y
Diagnostic completed.  Errors are noted above.
```

Fig. 3. Code entry for an amplifier.

By executing this code the entire circuit is reduced to a single set of two-port parameters which may be saved on tape for future reference (Data File 4, for example) as the circuit is built up.

A listing of gammas (Fig. 4) was requested to facilitate design of input and output impedance matching networks.

	FREQUENCY GHZ	K	GMAX DB	GAMMA MS MAG	GAMMA MS ANGLE	GAMMA ML MAG	GAMMA ML ANGLE
1:	0.10	1.322	8.466	0.148	56.559	0.151	172.198
2:	0.13	1.318	8.495	0.155	58.650	0.154	169.135
3:	0.16	1.313	8.536	0.165	61.066	0.160	165.568
4:	0.21	1.307	8.586	0.179	64.365	0.167	161.175
5:	0.26	1.304	8.592	0.204	72.132	0.173	155.419
6:	0.34	1.298	8.631	0.240	81.763	0.183	148.964
7:	0.43	1.281	8.734	0.299	94.037	0.198	142.694
8:	0.55	1.237	9.268	0.334	107.717	0.229	136.311
9:	0.70	1.210	9.665	0.476	119.977	0.261	127.345
10:	0.99	1.190	10.217	0.587	139.198	0.294	113.358
11:	1.13	1.164	10.573	0.636	153.364	0.336	90.514
12:	1.44	1.167	10.847	0.763	-173.542	0.410	66.772
13:	1.83	1.160	9.973	0.790	-154.255	0.495	58.513
14:	2.34	1.196	8.237	0.777	-145.223	0.470	55.855
15:	2.98	1.208	8.200	0.771	-141.358	0.457	49.707
16:	3.79	1.219	8.074	0.762	-139.169	0.446	44.347
17:	4.83	1.229	7.908	0.751	-136.947	0.437	40.216
18:	6.16	1.237	7.737	0.740	-135.254	0.430	37.257
19:	7.85	1.244	7.580	0.730	-133.395	0.424	35.213
20:	10.00	1.250	7.445	0.721	-133.069	0.420	33.317

Fig. 4. Listing of amplifier gammas, gain and stability.

The graphic display of gain (G_{21}) permits rapid comparison with the previous design to aid the design decision making process (Figs. 5 and 6).

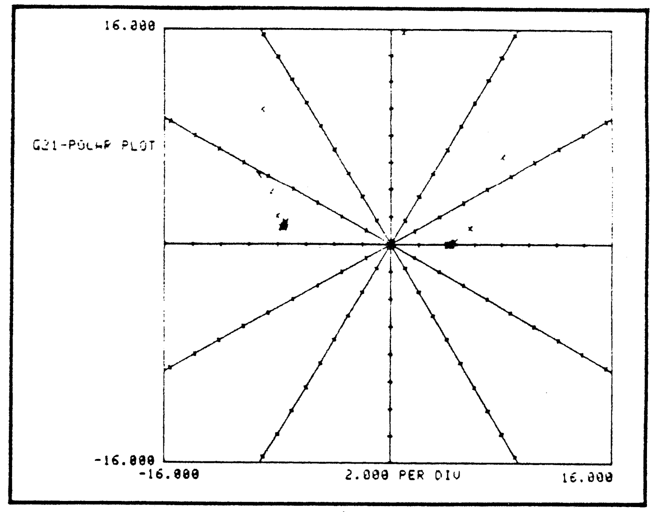

Fig. 5. Gain magnitude and angle.

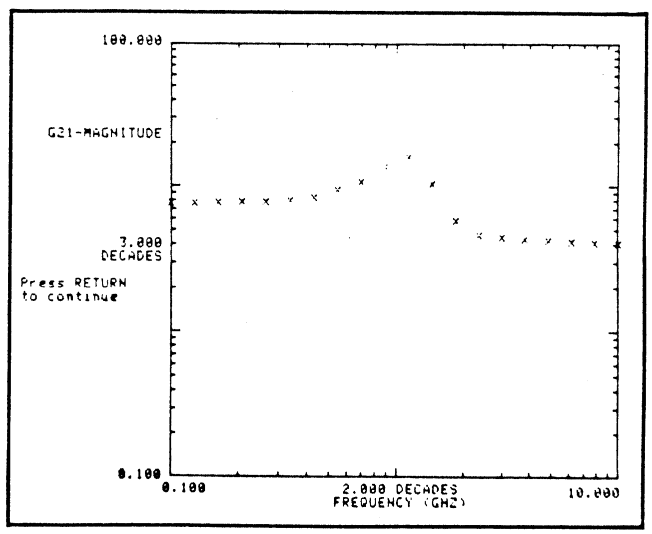

Fig. 6. Gain—vs—Frequency.

Matching network design is as simple as depressing the UTILITY function key and following the menu (Fig. 7 and Fig. 8). From two to four realizations of series and shunt elements are given.

```
MATCHING NETWORK DESIGN
Enter Frequency in GHZ          1.0
PORT 1
Termination (ZS, ZP, or GAM)?  ZS
Enter R and X (ohms)           50 0
PORT 2
Termination (ZS, ZP, or GAM)?  GAM
Enter Magnitude and Angle      .696 -163.364
L1 SHUNT  =  3.7656 NH                X = 23.6599 OHMS
C2 SERIES =  12.9808 PF               X = -12.2608 OHMS
C1 SHUNT  =  6.7268 PF                X = -23.6599 OHMS
L2 SERIES =  4.282 NH                 X = 26.4019 OHMS
Press RETURN to do another design
```

Fig. 7. Input impedance matching network.

```
MATCHING NETWORK DESIGN
Enter Frequency in GHZ          1.0
PORT 1
Termination (ZS, ZP, or GAM)?  GAM
Enter Magnitude and Angle      .336 -98.614
PORT 2
Termination (ZS, ZP, or GAM)?  ZS
Enter R and X (ohms)           50 0
L1 SERIES =  1.544 NH                 X = 9.7014 OHMS
L2 SHUNT  =  15.5277 NH               X = 97.5631 OHMS
L1 SERIES =  8.0039 NH                X = 50.2899 OHMS
C2 SHUNT  =  1.6313 PF                X = -97.5631 OHMS
L1 SHUNT  =  7.9104 NH                X = 49.7023 OHMS
C2 SERIES =  6.4124 PF                X = -24.8198 OHMS
L1 SHUNT  =  37.9985 NH               X = 238.7015 OHMS
L2 SERIES =  3.9502 NH                X = 24.8199 OHMS
Press RETURN to do another design
```

Fig. 8. Output impedance matching network.

Using the results of this utility routine yields the circuit shown (Fig. 9). Obtaining these results takes only a few moments.

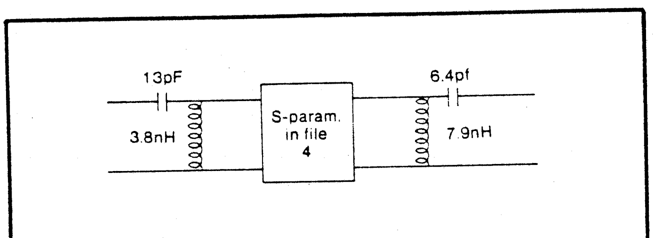

Fig. 9. Amplifier with matching networks.

To predict overall performance only requires cascading the networks just designed with the composite S-parameter black box previously saved. By building the circuit up a step at a time and saving intermediate steps, designed decisions are aided, steps may be re-traced and other designs tried with a minimum of coding. The total configuration (Fig. 9) is coded in a few steps (Fig. 10).

```
LIST CODE
 1:  GHZ
 2:  FE .1 10 20
 3:  LP 3.7656 CA
 4:  CS 12.9808 CA
 5:  DAT 4 CA
 6:  CS 6.4124 CA
 7:  LP 7.9104 EQ
 8:  NEXT
Code length = 83.  Simple diagnostic (Y or N)?
```

Fig. 10. Simulation code for circuit (Fig. 9).

The end result can be the input and output S-parameters S_{11} and S_{22} as shown (Fig. 11, and 12) or gain versus frequency (Fig. 13).

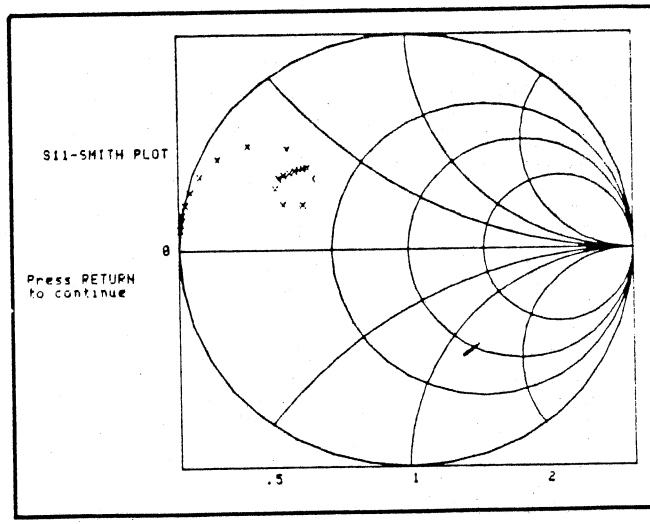

Fig. 11. Input S-parameter.

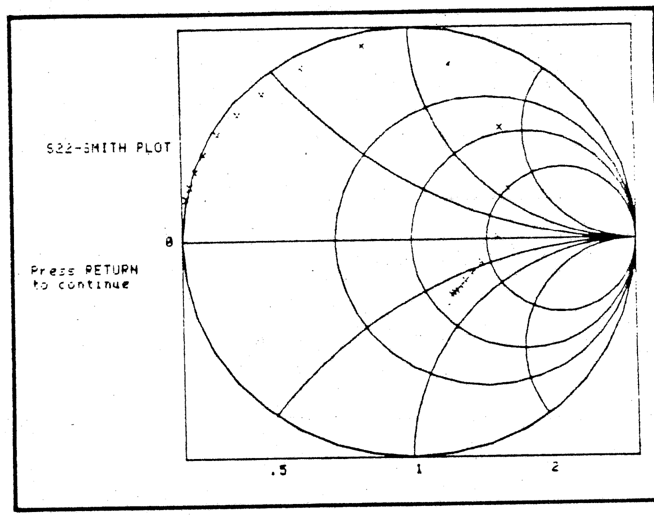

Fig. 12. Output S-parameters.

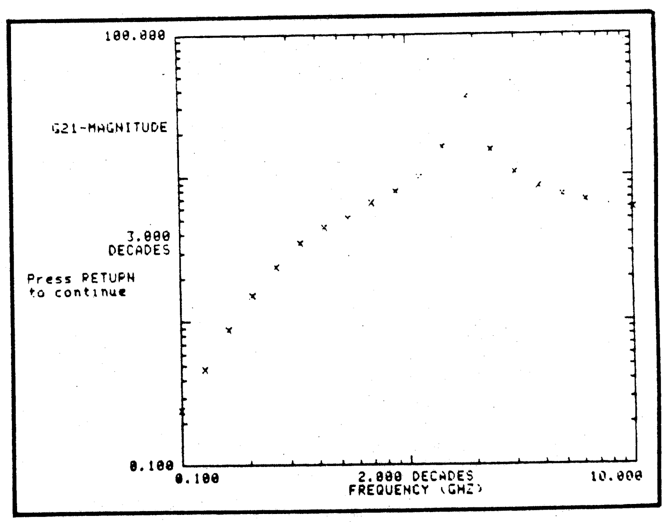

Fig. 13. Gain—vs—Frequency for whole amplifier.

Plot 50 EE Vol. 1 also contains routines that permit including transmission lines in place of the lumped impedance matching networks just designed, if better bandwidth is desired. But this article's purpose has been to illustrate the ease of use and interactiveness of the program, which permits design iterations to be made simply.

In addition to this illustrated example, Plot 50, EE Vol. 1 (4050 A06) can facilitate:

- Filter design
- Impedance matching network design
- Minimum noise figure design
- Transmission line and strip line analysis

Is there enough room on the tape that comes with EE Vol. 1 for data, code and results? The answer depends on how much data must be saved. The tape can store 25 different two-ports (of 30 lines each), and 25 coded circuits plus 5 different sets of results. Storage is easily expanded with a blank tape cartridge and the file marking and transfer utility routines accessible via the function keys.

Don't ignore EE Vol. 1 if your application doesn't approach the daylight bands of modern microwave circuit design. Simulating designs before breadboarding saves significant time even at audio frequencies.

Finally, if the task isn't an EE problem but one which can be solved as an analogue of the electrical models, EE Vol. 1 could do the job. For example, the elementary tank circuit (RLC) has a well known mechanical analogue consisting of spring, mass, and friction elements.

We'd like to hear from anyone using EE Vol. 1 to simulate mechanical, acoustical or other systems using the electrical models only as analogues of the original problem. Send a description of whatever you are modeling and sample analysis using EE Vol. 1 to TEKniques. Our address is on the back of each issue.

The 4051R06 Editor: Searching Operations

by Cathy Cramer

In the last issue of TEKniques, we talked about the 4051R06 EDITOR and its applications. This time, we'll describe some special searching operations you can perform using the EDITOR.

The 4051R06 EDITOR is a ROM pack. Installing the ROM pack and typing CALL "EDITOR" turns the 4051 into an ASCII text editor that can handle text of any kind. While the EDITOR is in control, you have 29 commands at your disposal. All are specially designed for easy text handling, but the most powerful are the searching commands.

Searching commands simplify the editing process. They quickly locate occurrences of a particular string of characters in the text, and simultaneously replace, edit, or delete those characters. Searching commands can make one correction, or many corrections at once. They're ideal for major changes to programs and text. But they also make simple everyday editing tasks go a lot faster and easier.

The 4051R06 EDITOR has two searching commands, SEARCH and NLSEARCH (No List SEARCH). Each has several forms that share the same keyword, but differ in syntax and function. SEARCH has four forms: SEARCH and List Line, SEARCH and Replace String, SEARCH and Edit Line, and SEARCH and Delete Line. NLSEARCH has two forms: NLSEARCH and Replace String, and NLSEARCH and Delete Line. The two forms of NLSEARCH are like the equivalent forms of SEARCH, but don't provide a listing of the changed or deleted lines. Table 1 summarizes the forms of the SEARCH and NLSEARCH commands.

Command	What it Does	Example
SEARCH and List Line	Lists lines that contain the string. You can send the listing to any tape storage or printing device by specifying a device number.	S "SET"
SEARCH and Replace String	Replaces occurrences of the string with another string, and lists the changed lines. You can send the listing to any tape storage or printing device.	S "PRINT", "PRINT#33:"
SEARCH and Edit Line	Recalls lines containing the string to the line buffer for editing. The lines are recalled and displayed one at a time.	S 1,10 "Mr.";
SEARCH and Delete Line	Deletes lines containing the string, and lists the deleted lines. You can send the listing to any tape storage or printing device.	S #33:"NO REPLY"*
NLSEARCH and Replace String	Replaces occurrences of the string with another string. (Does not list changed lines.)	NL "ON ERROR", "ON SIZE"
NLSEARCH and Delete Line	Deletes lines containing the string. (Does not list deleted lines.)	NL "TRACE"*

TABLE 1

Note: You can include line numbers in any SEARCH or NLSEARCH command, to specify the portion of the text you want to search.

Both SEARCH and NLSEARCH search the text, or some portion of the text, for any character string you want. You enter S for SEARCH or NL for NLSEARCH, then the string you want, enclosed in quotation marks. Additional entries tell the EDITOR which form of the command you want. (For example, a SEARCH command that ends with an asterisk is the SEARCH and Delete Line form of the command. A SEARCH com-