TI PPC NOTES

NEWSLETTER OF THE TI PROGRAMMABLE CALCULATOR CLUB

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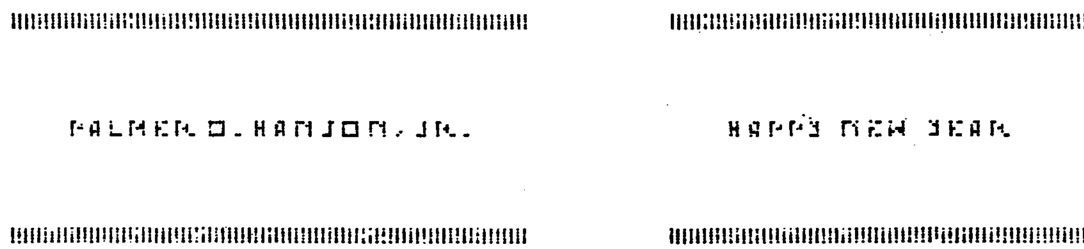
Mini-banner - See page 6



With this issue we have completed the fifth year of our newsletter. It has been a busy year, where the dominant theme has probably been high resolution graphics. The illustration above is one more example of inventive use of the technique. For the future the newsletter will continue to emphasize the TI-58/59 and PC-100, with expanding coverage of the CC-40 and TI-66 if member interest so indicates. Page 3 of this issue adds 28 PPX programs to the list published with V9N5, and even more are available to be listed in a future issue. I encourage other members to make the programs they hold available.

For 1985 there will be two changes. The first reflects my continuing marginal health and other committments. You are well aware that most issues for 1984 were late, with this final 1984 issue being mailed two months into 1985. I have concluded that I can not reasonable expect to catch up in 1985, and it would be folly to pretend that I can. I have therefore decided to reduce the number of issues for 1985 to four, with about 24 to 28 pages per issue. The second change is necessary since our membership has fallen to a level where bulk rate mailing can no longer be provided. Accordingly, only first class subscriptions can be made available in 1985. I have concluded that a reasonable rate for delivery in the US and Canada for the four issues is sixteen dollars. For overseas members the air mail rate is reduced to twenty dollars for the four 1985 issues. Should you decide not to subscribe for 1985 I would appreciate a note to that effect. If you know of someone who might wish to become a member send the name and address and I will send introductory information.

ERRATA:

Copying the Display into the T Register - V9N5P15 - Robert Prins wrote to remind me that Patrick Acosta had reported that h54 could be used to copy the t register into the display in V6N9/10P14.

Myer Boland's Bells/Shells Brainteaser - V9N5P5 - There was an inadvertent misprint in the statement of the brainteaser. In order to avoid giving away the answer the problem should be restated as:

> When I took the number of bells from the number of shells and then followed through I got 2.788875116 . Explain.

FOR BI-LINGUALS - George Thomson discussed weighted linear least squares problems in V8N1P27. Page 107 of Volume 84, Number 26 of Government Reports Announcements carries the announcement at the right for a weighted curve-fitting program for the HP-67/97. A hard copy is $7.00. A microfiche copy is $4.50. But note the caution "Portions are illegible in microfiche products." I have not obtained a copy of this program, but my experience with documents from GRA suggests that potential buyers really heed that caution.

467,315
DE84015475 **PC A02/MF A01**
Kansas State Univ., Manhattan. Dept. of Physics.
Weighted Curve-Fitting Program for the HP 67/97 Calculator.
M. P. Stockli. 1983, 2p DOE/ER/02753-210, CONF-830706-12
Contract AC02-76ER02753
13. international conference on the physics of electronic and atomic collisions (ICPEAC), Berlin, F.R. Germany, 27 Jul 1983.
Portions are illegible in microfiche products.

The HP 67/97 calculator provides in its standard equipment a curve-fit program for linear, logarithmic, exponential and power functions that is quite useful and popular. However, in more sophisticated applications, proper weights for data are often essential. For this purpose a program package was created which is very similar to the standard curve-fit program but which includes the weights of the data for proper statistical analysis. This allows accurate calculation of the uncertainties of the fitted curve parameters as well as the uncertainties of interpolations or extrapolations, or optionally the uncertainties can be normalized with chi-square. The program is very versatile and allows one to perform quite difficult data analysis in a convenient way with the pocket calculator HP 67/97. (ERA citation 09:042520)

MANY DIGITS OF e - V9N4P24 presented a program by Patrick Johansson which would find 480 digits of e. V9N5P4 had a program by Robert Prins which was an adaptation of a program by Bjorn Gustavsson which would find 1300 digits of e. Larry Leeds reminds me that the November/December 1981 issue of PPX Exchange included his program which would find 440 digits of e.

HELP! - V9N4P10 discussed TI-59 malfunctions, and reported that A. Krufka had been able to eliminate keyboard problems by rearranging the foam under the keys. Others have reported similar experience with the TI-59. My problem is with the TI-55II, the TI-57LCD and the BA-55, all of which have very similar construction. Each of the units operated satisfactorily at the time of purchase; but in a few months each unit developed some sort of key bounce which causes multiple entries for a single intended keystroke. I have taken the units apart, rearranged the foam, etc., to no avail. Has anyone had any success in clearing this type of problem?

MORE PPX PROGRAM AVAILABILITY - V9N5P18 set up an informal program exchange to provide access to programs which were in PPX Exchange. Over six hundred programs were listed. The following table lists 28 more programs.

C	068006	- Standard Queue Model M/M/C
C	068009	- Transit System Modelling
C	098012	- Advanced Cash Register
C	108007	- Straight Line/Declining Balance Depreciation
C	148024	- Electric Utility Billing II
1	178012	- Federal Income Tax
C	198012	- Net Cash Flow and Rate of Return
C	268047	- List and Plot Data Distribution
C	308085	- Traveling Salesperson Problem
C	378001	- Multiple Server Queuing
1	388002	- 4 Variable Optimizing Pattern Search
C	398226	- Volume, Area and Circumference
C	398285	- Coordinate Rotation
C	628061	- Open Channel Flow
1	638003	- EBCDIC Code Converter
1	638004	- ASCII Code Converter
1	638005	- ASCII and EBCDIC Encoder
1	638007	- TMS 9900 Disassembler
C	698030	- Fire Sprinkler System Design
C	718003	- Illumination at a Point in Interior Space
C	718006	- Lighting Calculations (Watts/Square Foot Method)
C	718010	- Lighting Calculatons (Zonal Cavity Method)
C	738015	- Air Conditioning and Heating System
C	738020	- Solar Gain Analysis
C	778043	- Hasty Survey
C	908047	- Expanded Memory
C	908150	- Sequential Operations, Data Array
C	908210	- Utility Charges

Code 1 means the programs are available on a loan basis from TI PPC Notes. Send one dollar (two dollars overseas) for each program that you wish to borrow. It is understood that the programs will be returned promptly to be available for other members.

Code C means the programs are available from Robert Ericson, 32 Ferncrest Blvd., North Providence, RI 02911. He will send copies anywhere for four dollars per program.

BOOK REVIEW - Engineering Statistics with a Programmable Calculator. by William Volk. McGraw Hill Book Co., 1221 Avenue of the Americas, New York, N.Y. 10020. 363 pages. Subjects covered include statistical parameters, probability distributions, t function, chi-squared function, analysis of variance, regression and correlation. Programs are in both RPN and AOS. The book is also available from Educalc (Stock # E-110) for $26.95.

Member Goerge Booth reports that this book contains twenty-five programs which are very useful. He suggests that members who know of other calculator references which might be of interest to our club should outline the information for publication in our newsletter. See pages 2 and 10 for other examples.

MODULO 210 SPEEDY FACTOR FINDER IN BASIC - Laurance Leeds

V8N4P12 reported that the speed of the prime factor program in the Mathematics module for the CC-40 was only ten to forty percent faster than the fastest TI-59 programs, and substantially slower than the speeds reported for the HP-41. Laurance Leeds recently obtained a Radio Shack Model 100. One of his first programs was a modulo 210 factor finder which yields some truly impressive execution times.

The program at the right is a modification of Laurance's program to accommodate the single line display of the CC-40.

```
100 DIM X(12),Y(12),E(53)
110 DATA 2,3,5,7,11,2,4,2,4,6,2,6,4,
2,4,6,6,2,6,4,2,6,4,6,8
120 DATA 4,2,4,2,4,8,6,4,6,2,4,6,2,6
,6,4,2,4,6,2,6,4,2,4,2,10,2,10
130 FOR I=1 TO 53:READ E(I):NEXT I
140 PRINT "Modulo 210 Factors Progra
m":PAUSE 2
200 INPUT "N = ";N:N0=N
210 PRINT "Busy Factoring"
220 FOR I=1 TO 5
230 D=E(I)
240 IF INT(N/D)*D=N THEN GOSUB 400
250 NEXT I
300 IF N/D<=SQR(N)THEN X(K)=N:Y(J)=1
:GOTO 500
310 FOR I=6 TO 53
320 D=D+E(I)
330 IF INT(N/D)*D=N THEN GOSUB 400
340 NEXT I
350 GOTO 300
400 X(K)=D:S=S+1:N=N/D
410 IF N=1 THEN X(K)=D:Y(J)=S:GOTO 5
00
420 IF INT(N/D)*D=N THEN 400
430 Y(J)=S:K=K+1:J=J+1:S=0:RETURN
500 DISPLAY BEEP:FOR I=0 TO 12
510 IF X(I)=0 THEN 600
520 PRINT "F("&STR$(I+1)&") ="&STR$(
X(I))&"^"&STR$(Y(I))
530 PAUSE:NEXT I
600 PRINT "N was ";
610 PRINT USING"##############",N0:P
AUSE
620 FOR I=0 TO 12:X(I)=0:Y(I)=0:NEXT
 I : S = 0
630 J=0:K=0:GOTO 200
```

After entering the program, press RUN and see the words "Modulo 210 Factors Program" in the display after about four seconds. During that time the increments used in the program are transferred from the data statements to the E array. In a few more seconds the prompt "N = _ " appears in the display. Enter the value to be factored and press ENTER. The display will read "Busy Factoring" until the process is complete. Then, the display will contain the first factor and multiplicity. Press ENTER to display the remaining factors. When the last factor has been displayed, one more ENTER will return the input value to the display. Another enter prepares the program for another problem and stops with the prompt "N = _" in the display.

Sample execution times for programs with comparable capability of twelve digits or more using the same benchmark problems used previously are:

Program/machine	111111111111	987654321	9999999967
TI-59 M/U Module	43 sec	215 sec	
TI-59 13 Digit Mod 210	34 sec	61 sec	3 hr 15 min
CC-40 Mathematics Module	11 sec	41 sec	1 hr 55 min
CC-40 (this program)	4 sec	9 sec	23 m 15 sec
Model 100 program (next page)	3 sec	7 sec	18 m 08 sec

Modulo 210 Speedy Factor Finder in BASIC (cont)

The program for the Model 100 is reproduced below. Laurance wrote an even faster factor finder program which did not recall the increments from an array, but rather used in-line techniques such as those used in the faster TI-59 programs. That program will declare 9999999967 to be prime in only 15 minutes 11 seconds. If you would like a copy of that program send a SASE. Finally, a reduced copy of the CC-40 program is presented below to obtain a comparison of legibility. CC-40 users are invited to comment.

Model 100 Program

```
100 DIM R(12), S(12), E(53)
110 DATA 2,3,5,7,11,2,4,2,4,6,2,6,4,2,4,6,6,2,6
,4,6,2,4,6,2,6,6,4,2,4,6,2,6,4,2,4,2,10,2,10
,4,2,6,4,6,8,4,2,4,2,4,8,6
120 FOR I = 1 TO 53:READ E(I):NEXT I
130 PRINT"FACTORS, N=14 DIGITS,MODULO 210 PGM"
200 PRINT:INPUT"N=";N
205 T1$=TIME$
210 PRINT "BUSY FACTORING"
220 FOR I = 1 TO 5
230 D = E(I)
240 IF INT(N/D)*D=N THEN GOSUB 700
250 NEXT I
300 IF N/D<=SQR(N) THEN R(K)=N:S(J)=1:GOTO 750
310 FOR I = 6 TO 53
320 D = D + E(I)
330 IF INT(N/D)*D=N THEN GOSUB 700
340 NEXT I
350 GOTO 300
700 R(K)=D:S=S+1:N=N/D
710 IF N=1 THEN R(K)=D:S(J)=S:GOTO 750
730 IF INT(N/D)*D=N THEN 700
740 S(J)=S:K=K+1:J=J+1:S=0:RETURN
750 T2$=TIME$
800 H=0
810 IF R(H) = 0 THEN 900
820 PRINT R(H)CHR$(94)S(H),
830 IF R(H+1) = 0 THEN 900
840 PRINT TAB(19)R(H+1)CHR$(94)S(H+1)
850 H=H+2:GOTO 810
900 PRINT:PRINT T2$:PRINT T1$
910 END
```

CC-40 Program

```
100 DIM X[12],Y[12],E[53]
110 DATA 2,3,5,7,11,2,4,2,4,6,2,6,4,
2,4,6,6,2,6,4,2,6,4,6,8
120 DATA 4,2,4,2,4,8,6,4,6,2,4,6,2,6
,6,4,2,4,6,2,6,4,2,4,2,10,2,10
130 FOR I=1 TO 53:READ E[I]:NEXT I
140 PRINT "Modulo 210 Factors Progra
m":PAUSE 2
200 INPUT "N = ";N:N0=N
210 PRINT "Busy Factoring"
220 FOR I=1 TO 5
230 D=E[I]
240 IF INT[N/D]*D=N THEN GOSUB 400
250 NEXT I
300 IF N/D<=SQR[N]THEN X[K]=N:Y[J]=1
:GOTO 500
310 FOR I=6 TO 53
320 D=D+E[I]
330 IF INT[N/D]*D=N THEN GOSUB 400
340 NEXT I
350 GOTO 300
400 X[K]=D:S=S+1:N=N/D
410 IF N=1 THEN X[K]=D:Y[J]=S:GOTO 5
00
420 IF INT[N/D]*D=N THEN 400
430 Y[J]=S:K=K+1:J=J+1:S=0:RETURN
500 DISPLAY BEEP:FOR I=0 TO 12
510 IF X[I]=0 THEN 600
520 PRINT "F["&STR$[I+1]&"] ="&STR$[
X[I]]&"^"&STR$[Y[I]]
530 PAUSE:NEXT I
600 PRINT "N was ";
610 PRINT USING"###############",N0:P
AUSE
620 FOR I=0 TO 12:X[I]=0:Y[I]=0:NEXT
 I : S = 0
630 J=0:K=0:GOTO 200
```

PRIME FACTOR PRINTOUTS WITH THE CC-40 AND HX-1000 PRINTER

The CC-40/HX-1000 combination provides a printout capability on demand. Use of the Call SETLANG command before entering the prime factors program even provides the annotation for the printout in the chosen language. See the examples at the right.

```
FACTEURS PREMIERS

Nb a Decomposer= 987654321

F1=3
F2=3
F3=17
F4=17
F5=379721
```

```
PRIMZAHLEN

Zahl= 987654321

F1=3
F2=3
F3=17
F4=17
F5=379721
```

MINI-BANNER - Denis Paye of the Central African Republic. This clever program permits the generation of a miniature banner lengthwise along the printer paper, where the height of the characters is equal to the width of a normal print character. Mr. Paye's program uses the high resolution graphics mode to truncate selected print characters, and combines the truncated characters in a manner that provides all the letters of the alphabet, all the numbers, and selected other characters. See the table on page 7. (PPX program 908015 also permitted the user to generate a banner length-wise along the printer paper, where the letters are 20 characters high.)

Instructions:

Two options are available, for long or short banners. For either option it is necessary to generate the data to select the characters starting at register 10. Each character is composed of up to three segments. Five segments make up the contents of each register. Leading blank characters will print as blanks. An example will illustrate the process. Suppose we wish to print the words HAPPY NEW YEAR. From the table on page 7 we find that the required codes are 37-67 for H, 16-67 for A, 10-62 for P, 26-67 for Y, 00 for blank, 10-55-67 for N, and so on. We will use a single blank between characters, and three blanks between words. We start in register 10 and assemble the code as shown in the left hand column below. The center column is the printout of the assembled data. Of course, the leading zeroes are neither stored or printed. The right hand column contains the code for a banner PALMER O. HANSON, JR. where only two blanks are used between words.

```
37-67-00-16-67
00-10-62-00-10
62-00-26-67-00
00-00-10-55-67
00-37-23-00-77
02-67-00-00-00
26-67-00-37-23
00-16-67-00-10
60-27-00-00-00
```

3767001667.	10
10620010.	11
6200266700.	12
105567.	13
37230077.	14
267000000.	15
2667003723.	16
16670010.	17
6027000000.	18

1062001667.	10
6270010.	11
6267003723.	12
10602700.	13
32236700.	14
2700003767.	15
16670010.	16
5567002710.	17
32236700.	18
1055670056.	19
276700.	20
1060270027.	21

To obtain the long option, enter the program as shown in the left four columns of the program listing, and set up the h85 codes used for graphics mode with the following sequence:

GTO 005 LRN Op 05 Sto 83 Bst Bst A

LRN 9 Op 17 Pgm 12 SBR 444 R/S Dms LRN Ins LRN RST

GTO 009 LRN GTO 024 0 Op 05 A SUM Bst LRN Pgm 12 SBR 444 R/S Dms LRN

Ins LRN RST GTO 017 LRN Del Del 6 Op 17 10 STO 00 LRN GTO 093 R/S

At the final R/S the program will run and print the banner. To get a second banner with the same letters simply press GTO 093 R/S. To get a banner with different letters enter the new control code and press GTO 093 R/S. If you print the program after hexadecimal code initialization you will see the code in the fifth column of the program listing followed by the code in the second through fourth columns.

Mini-Banner (cont)

To get the short option enter the baseline program (columns 1 through 4) and implant the hex codes with the following sequence:

GTO 007 LRN STO 83 Bst

LRN 9 Op 17 Pgm 12 SBR 444 R/S Dms LRN Ins LRN RST GTO 007 LRN 0 SST

GTO 024 0 Op 05 A SUM Bst LRN Pgm 12 SBR 444 R/S Dms LRN

Ins LRN RST GTO 017 LRN Del Del 6 Op 17 10 STO 00 LRN GTO 093 R/S

The program after initialization will be the code in the sixth column of the program listing, followed by the code in columns two through four.

Program Listing:

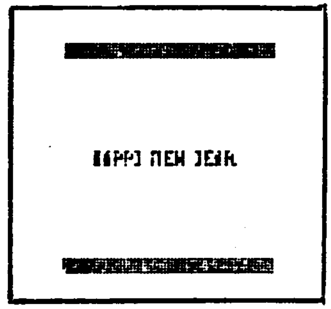
000	61	GTO	028	67	EQ	056	43	RCL	084	69	OP	000	61	GTO	000	61	GTO
001	00	00	029	00	00	057	29	29	085	21	21	001	00	00	001	00	00
002	09	09	030	74	74	058	69	OP	086	43	RCL	002	09	09	002	09	09
003	00	0	031	55	÷	059	02	02	087	01	01	003	00	0	003	00	0
004	00	0	032	43	RCL	060	25	CLR	088	67	EQ	004	00	0	004	00	0
005	00	0	033	00	00	061	61	GTO	089	00	00	005	69	OP	005	00	0
006	00	0	034	22	INV	062	00	00	090	17	17	006	05	05	006	00	0
007	00	0	035	28	LOG	063	13	13	091	25	CLR	007	11	A	007	00	0
008	00	0	036	95	=	064	01	1	092	91	R/S						
009	00	0	037	22	INV	065	00	0	093	22	INV	009	61	GTO	009	61	GTO
010	00	0	038	59	INT	066	42	STO	094	52	EE	010	00	00	010	00	00
011	00	0	039	65	×	067	00	00	095	69	OP	011	24	24	011	24	24
012	00	0	040	02	2	068	01	1	096	00	00	012	00	0	012	00	0
013	00	0	041	22	INV	069	44	SUM	097	06	6	013	69	OP	013	69	OP
014	00	0	042	44	SUM	070	01	01	098	07	7	014	05	05	014	05	05
015	00	0	043	00	00	071	61	GTO	099	69	OP	015	11	A	015	11	A
016	00	0	044	01	1	072	00	00	100	01	01						
017	00	0	045	00	0	073	56	56	101	69	OP	017	06	6	017	06	6
018	00	0	046	00	0	074	00	0	102	03	03	018	69	OP	018	69	OP
019	00	0	047	95	=	075	69	OP	103	09	9	019	17	17	019	17	17
020	00	0	048	59	INT	076	02	02	104	42	STO	020	01	1	020	01	1
021	00	0	049	42	STO	077	97	DSZ	105	01	01	021	00	0	021	00	0
022	00	0	050	29	29	078	00	00	106	61	GTO	022	42	STO	022	42	STO
023	00	0	051	43	RCL	079	00	00	107	00	00	023	00	00	023	00	00
024	00	0	052	00	00	080	13	13	108	17	17	024	00	0	024	00	0
025	32	X:T	053	67	EQ	081	01	1				025	32	X:T	025	32	X:T
026	73	RC*	054	00	00	082	00	0				026	73	RC*	026	73	RC*
027	01	01	055	64	64	083	32	X:T				027	01	01	027	01	01

Print Code Table:

Character	Code	Character	Code	Character	Code
A	16-67	T	53-10	5	67-61
B	37-30-74	U	06-56-67	6	01-02
C	01-26	V	06-10	7	25-37
D	32-66	W	77-02-67	8	37-50-67
E	37-23	X	66-01	9	26-66
F	37-25	Y	26-67	0	01-66
G	01-61	Z	25-37-27	%	53-06
H	37-67	.	27	+	47-24
I	50-32	,	56	x	51-73
J	27-67	:	51	/	67
K	37-01	?	25-70	-	47-47
L	06-27	!	67	(	01
M	10-62-67	"	25	)	66
N	10-55-67	'	53	o	65
O	32-23-67	Blank	00	[	32
P	10-62	1	50-06	]	50-67
Q	32-30-27	2	61-66-56	Σ	30-37-23
R	10-60-27	3	23-73		
S	27-10	4	07-77		

Mini-Banner (continued)

A sample of the output obtained from the short option appears at the right. The printout used the same control data as for the HAPPY NEW YEAR banner which appears on page 1.



Segment Definition Table:

Printed dots are shown as x's. Blanks are shown as periods.

Code	Segment	Code	Segment	Code	Segment
00	....	26	x...x x..x.	60	..x.. .xxx.
01	.xxx. x...x	27	x.... x....	61	xx... xx..x
02	..x.. .xx..	30	x...x xx.xx	62	..x.. ..xx.
05	...x. ..xx.	32	xxxxx x...x	65	..xx. ..xx.
06	xxxxx x....	37	xxxxx ..x..	66	....x .x.x.
07	..xx. .x...	47	....x..	67	xxxxx .....
10	xxxxx x	50	..... x...x	70	xxx.. ...x.
14	xxxx. x...x	51	..... .x.x.	73	..x.. .x.x.
16	xxxx. .x..x	52	.xxxx .x...	74	xxxxx .x.x.
23	x...x x...x	53	x	77	xxxxx .x...
24	.xxx. ..x..	55	....x ...x.		
25	....x x	56	x.... .x...		

Editor's Note: There are other options available with this program. I will discuss them in a coming issue, after my middle school daughter and I have managed to complete the translation from French to English.

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52 FACTORIAL FOR THE TI-57 - Robert Prins

First there was Reginald van Genechten's program for 34 factorial (V8N3P12). Robert Prins responded with a program for 44 factorial in V9N4P5. Now, Robert has provided a wrap-around calculation which uses the positions assigned to the trailing zeroes to extend the capability to 52 factorial.

```
00  66         X=T
01  01           1
02  32 0       STO 0
03  08           8
04  84         +/-
05 -18    INV  LOG
06  32 1       STO 1
07  86 0       LBL 0
08  4            (
09  07           7
10  38 0       EXC 0
11  75           +
12  61 2       SBR 2
13  86 1       LBL 1
14  33 1       RCL 1
15 -49    INV  INT
16  38 1       EXC 1
17  49         INT
18  42          EE
19  08           8
20  84         +/-
21 -42    INV   EE
22  38 1       EXC 1
23  38 7       EXC 7
24  38 6       EXC 6
25  38 5       EXC 5
26  38 4       EXC 4
27  38 3       EXC 3
28  38 2       EXC 2
29  34 1       SUM 1
30  56         DSZ
31  51 1       GTO 1
32  00           0
33  44           )
34  32 0       STO 0
35  56         DSZ
36  51 0       GTO 0
37  08           8
38 -18    INV  LOG
39  86 2       LBL 2
40  39 1       PRD 1
41  39 2       PRD 2
42  39 3       PRD 3
43  39 4       PRD 4
44  39 5       PRD 5
45  39 6       PRD 6
46  39 7       PRD 7
47  00           0
48 -61    INV  SBR
```

Instructions:

1. Enter the program.
2. Press INV C.t. RST.
3. Enter the the number n and press R/S. When the calculations are complete a 0. will be in the display. Approximate execution times are:

34!	5 min 30 sec
44!	7 min 5 sec
52!	8 min 20 sec

4. For n ≤ 44 the results are read out from data registers 1 through 7, with the highest digits in R7 and the lowest digits in R1, with all trailing zeroes indicated.

   For 45 ≤ n ≤ 52 the most significant digits are read from the locations which would otherwise have trailing zeroes. examples will illustrate the process, the output for 48!, 50! and 52! :

48!	50!	52!	
15592536	1713378	43878571	RCL 7
7267086	4361260	66063685	RCL 6
22890473	81660647	64037669	RCL 5
73375038	68844377	75289505	RCL 4
52148635	64156896	44088327	RCL 3
46777600	5120003	78248065	RCL 2
124139	4140932	81751709	RCL 1

Factorials from 45 through 49 have ten trailing zeroes. Thus, the last two digits from R2 for 48! are zeroes, and all eight digits from R1 would be zeroes but for the wraparound feature. The digits 124139 are the most significant digits, and, therefore, 48! = 12413915592536072670862289047373375038521486354677 76E+10 .

Factorials from 50 through 52 have twelve trailing zeroes. Thus, for 50! the last four digits of R2 and all eight digits of R1 would be zeroes but for the wraparound. The nine most significant digits of 50! are 304140932, which are then followed by 01713378 from R7, and so on, with a multiplier of E+12.

For 52! the wraparound fills the twelve spaces which would otherwise contain trailing zeroes; the most significant digits are 8065817 ... ... and the multiplier is E+12.

<u>MICROSTRIP DESIGN</u> - Robert Leaman. V9N4P25 reported the publication of a program for microstrip design in the July 1984 issue of Microwaves & RF. Bob tried the original program by E. Simon. He found that the data entry procedure was inconvenient: (1) the parameters could be entered only in a prescribed sequence, and (2) a change in one of the entered parameters required that the entire set be reentered. He rewrote the program to eliminate those deficiencies. In the process he also reduced the program to fit on one magnetic card (see the program listing on page 12). The resulting program also runs slightly faster.

The iterative solution in the Simon program is replaced by use of the Zeroes of Functions routines from the Master Library (ML-08). That routine finds a real root for a function in user memory defined by user defined label A'. Bob's program uses flag 1 to allow the A' label to be used as a data entry key and as the start of the function to be used by ML-08. Steps 104 through 108 then define the f(x) = 0 function for use by ML-08.

When used with residual data not equal to zero in data registers 01 through 06 ML-08 can create errors. Steps 168 through 171 eliminate this potential problem by using the linear regression initialization routine from ML-01 to clear those registers. Those registers are also used by calculations which must occur after the iterative calculation has been completed (Lbl D' and Lbl E).

Flag 7 is the error director for the Lbl D sequence. Since this sequence ends with a RST, flag 7 is always cleared without the use of any additional program steps. Steps 211 to 225 make sure that the operating frequency is not too large, a feature not provided in the Simon program. The normalized line width (w/h) is not displayed since it is of secondary importance. It can be found in register 09 if it is needed. The normalized line width is flashed to reveal the progress of the iterative solution by the Pause at step 016.

Sample Calculation:

The article in Microwaves & RF includes a sample calculation for the "givens":

Line Impedance	Z	=	50 ohms
Substrate Dielectric Constant	ϵ_r	=	9.7
Substrate Thickness	h	=	0.635 mm
Metalization Resistivity	ρ	=	0.00000127 ohm-cm
Metalization Thickness	t	=	0.008 mm
Substrate Dissipation Factor	$\tan\delta$	=	0.0001
Operating Frequency	f	=	1 Ghz

Since different iterative solution methods are used by the Simon and Leaman programs, there will be slight differences in the outputs:

Parameter	Simon	Leaman
w/h	9.6022310-01	9.6022306-01
w	6.0974167-01	6.0974165-01
λ_g	1.1636365+02	1.1636365+02
V_{ph}	1.1636365+02	1.1636365+02
α_c	1.0845967-03	1.0845966-03
α_d	2.2206595-05	2.2206595-05

For this problem the execution time to solve for the line width requires about 2 minutes 57 seconds with the Simon program and 2 minutes 50 seconds with the Leaman program. Replacement of the Pause at location 016 with a Nop will reduce the execution time of the Leaman program to 2 minutes 40 seconds.

Microstrip Design - (cont)

Instructions:

Procedure	Enter	Press	Display
1. Initialization		E'	0.
2. Enter input parameters in any order:			
a. Required line impedance	Z	A	Z.
b. Substrate dielectric constant	ϵ_r	B	ϵ_r
c. Substrate thickness (mm)	h	C	h
Skip to step 3 if losses are not relevant.			
d. Metalization resistivity (ohm-cm)	ρ	A'	ρ
e. Metalization thickness (mm)	t	B'	t
f. Substrate dissipation factor	tan δ	C'	tan δ
3. Calculate line width		D	w(mm)

A flashing display indicates that the specified impedance, Z, is out of range. Press CLR, enter a new impedance at A and then press D.

Procedure	Enter	Press	Display
4. Calculate guide wavelength: Enter operating frequency (GHz)	f	E	λ_g (mm)
a. Calculate phase velocity		R/S	V_{ph} (mm/ns

If steps 2d, 2e, or 2f were omitted then the program ends, if the data was entered, continue with step 5.

Procedure	Enter	Press	Display
5. Calculate conductor losses		D'	α_c(dB/mm)
a. Calculate dielectric losses		R/S	α_d(dB/mm)

Step 4A must follow Step 4 and Step 5a must follow Step 5! Display flashes during Step 4 when the entered operating frequency is too great. Press CLR, enter a new f and continue.

The relative permeability of the substrate must be unity for the calculations to be valid.

Data Register Assignments:

R00 - Entry indirect index
R01 - used
R02 - used
R03 - used
R04 - used, R_S (conductor skin resistance)
R05 - used, $\partial w/\partial t$
R06 - used, λ (wavelength of operating frequency)
R07 - used, f (operating frequency, GHz)
R08 - used, w (line width, mm)
R09 - w/h (normalized line width)
R10 - Z_o (free-space line impedance)
R11 - Z (specified line impedance)
R12 - ϵ_r (substrate dielectric constant)
R13 - h (substrate thickness, mm)
R14 - ρ (metalization resistivity, ohm-cm)
R15 - t (metalization thickness, mm)
R16 - tan δ (substrate dissipation factor)
R17 - $(u_o/\epsilon_o)^{\frac{1}{2}}$
R18 - $(\epsilon_{re})^{-\frac{1}{2}}$
R19 - ϵ_{re} (effective dielectric constant)

Microstrip Design - (cont)

Program Listing:

000	76	LBL
001	81	RST
002	92	RTN
003	61	GTO
004	81	RST
005	76	LBL
006	10	E'
007	29	CP
008	01	1
009	00	0
010	42	STO
011	00	00
012	25	CLR
013	81	RST
014	42	STO
015	09	09
016	66	PAU
017	43	RCL
018	12	12
019	85	+
020	01	1
021	54	)
022	55	÷
023	02	2
024	85	+
025	53	(
026	24	CE
027	75	-
028	01	1
029	54	)
030	65	×
031	53	(
032	01	1
033	85	+
034	01	1
035	00	0
036	55	÷
037	43	RCL
038	09	09
039	54	)
040	35	1/X
041	34	√X
042	95	=
043	42	STO
044	19	19
045	35	1/X
046	34	√X
047	42	STO
048	18	18
049	01	1
050	32	X:T
051	43	RCL
052	09	09
053	77	GE
054	00	00
055	71	71
056	55	÷
057	04	4
058	85	+
059	35	1/X
060	65	×
061	02	2
062	54	)
063	23	LNX
064	55	÷
065	02	2
066	55	÷
067	89	π
068	61	GTO
069	00	00
070	95	95
071	85	+
072	53	(
073	35	1/X
074	94	+/-
075	85	+
076	01	1
077	54	)
078	45	Y^X
079	06	6
080	85	+
081	02	2
082	93	.
083	04	4
084	02	2
085	75	-
086	93	.
087	04	4
088	04	4
089	65	×
090	43	RCL
091	09	09
092	35	1/X
093	54	)
094	35	1/X
095	65	×
096	43	RCL
097	17	17
098	95	=
099	42	STO
100	10	10
101	65	×
102	43	RCL
103	18	18
104	75	-
105	43	RCL
106	11	11
107	95	=
108	92	RTN
109	76	LBL
110	18	C'
111	69	OP
112	20	20
113	76	LBL
114	17	B'
115	69	OP
116	20	20
117	76	LBL
118	16	A'
119	87	IFF
120	01	01
121	00	00
122	14	14
123	69	OP
124	20	20
125	76	LBL
126	13	C
127	69	OP
128	20	20
129	76	LBL
130	12	B
131	69	OP
132	20	20
133	76	LBL
134	11	A
135	69	OP
136	20	20
137	72	ST*
138	00	00
139	48	EXC
140	00	00
141	01	1
142	00	0
143	48	EXC
144	00	00
145	61	GTO
146	81	RST
147	76	LBL
148	14	D
149	86	STF
150	01	01
151	04	4
152	52	EE
153	05	5
154	65	×
155	89	π
156	55	÷
157	08	8
158	93	.
159	08	8
160	05	5
161	04	4
162	01	1
163	06	6
164	95	=
165	34	√X
166	42	STO
167	17	17
168	36	PGM
169	01	01
170	71	SBR
171	25	CLR
172	01	1
173	01	1
174	36	PGM
175	08	08
176	12	B
177	35	1/X
178	36	PGM
179	08	08
180	11	A
181	01	1
182	52	EE
183	07	7
184	94	+/-
185	36	PGM
186	08	08
187	14	D
188	36	PGM
189	08	08
190	15	E
191	69	OP
192	18	18
193	87	IFF
194	07	07
195	02	02
196	00	00
197	25	CLR
198	35	1/X
199	81	RST
200	42	STO
201	09	09
202	65	×
203	43	RCL
204	13	13
205	95	=
206	42	STO
207	08	08
208	81	RST
209	76	LBL
210	15	E
211	32	X:T
212	07	7
213	05	5
214	55	÷
215	43	RCL
216	13	13
217	55	÷
218	53	(
219	43	RCL
220	12	12
221	75	-
222	01	1
223	54	)
224	34	√X
225	95	=
226	77	GE
227	02	02
228	33	33
229	32	X:T
230	85	+
231	95	=
232	81	RST
233	02	2
234	09	9
235	09	9
236	93	.
237	07	7
238	09	9
239	02	2
240	09	9
241	03	3
242	55	÷
243	32	X:T
244	42	STO
245	07	07
246	54	)
247	42	STO
248	06	06
249	55	÷
250	43	RCL
251	19	19
252	34	√X
253	95	=
254	92	RTN
255	65	×
256	43	RCL
257	07	07
258	95	=
259	81	RST
260	76	LBL
261	19	D'
262	89	π
263	65	×
264	02	2
265	54	)
266	65	×
267	35	1/X
268	32	X:T
269	53	(
270	43	RCL
271	07	07
272	65	×
273	43	RCL
274	14	14
275	54	)
276	34	√X
277	95	=
278	42	STO
279	04	04
280	43	RCL
281	09	09
282	77	GE
283	02	02
284	94	94
285	04	4
286	65	×
287	89	π
288	65	×
289	43	RCL
290	08	08
291	61	GTO
292	02	02
293	98	98
294	02	2
295	65	×
296	43	RCL
297	13	13
298	55	÷
299	43	RCL
300	15	15
301	54	)
302	23	LNX
303	65	×
304	89	π
305	35	1/X
306	95	=
307	42	STO
308	05	05
309	01	1
310	32	X:T
311	43	RCL
312	09	09
313	77	GE
314	03	03
315	64	64
316	22	INV
317	86	STF
318	00	00
319	35	1/X
320	85	+
321	87	IFF
322	00	00
323	03	03
324	27	27
325	24	CE
326	65	×
327	43	RCL
328	05	05
329	85	+
330	01	1
331	54	)
332	65	×
333	87	IFF
334	00	00
335	81	RST
336	53	(
337	43	RCL
338	09	09
339	35	1/X
340	65	×
341	08	8
342	75	-
343	35	1/X
344	65	×
345	02	2
346	54	)
347	55	÷
348	53	(
349	43	RCL
350	10	10
351	55	÷
352	06	6
353	00	0
354	54	)
355	22	INV
356	23	LNX
357	65	×
358	01	1
359	00	0
360	55	÷
361	61	GTO
362	04	04
363	03	03
364	71	SBR
365	03	03
366	17	17
367	53	(
368	01	1
369	85	+
370	93	.
371	04	4
372	04	4
373	65	×
374	43	RCL
375	09	09
376	35	1/X
377	33	X^2
378	85	+
379	06	6
380	65	×
381	43	RCL
382	09	09
383	35	1/X
384	33	X^2
385	65	×
386	53	(
387	01	1
388	75	-
389	43	RCL
390	09	09
391	35	1/X
392	54	)
393	45	Y^X
394	05	5
395	54	)
396	55	÷
397	89	π
398	55	÷
399	07	7
400	02	2
401	00	0
402	65	×
403	43	RCL
404	10	10
405	55	÷
406	43	RCL
407	13	13
408	65	×
409	43	RCL
410	04	04
411	65	×
412	43	RCL
413	19	19
414	34	√X
415	55	÷
416	89	π
417	55	÷
418	01	1
419	00	0
420	23	LNX
421	95	=
422	92	RTN
423	02	2
424	00	0
425	65	×
426	71	SBR
427	04	04
428	16	16
429	65	×
430	43	RCL
431	16	16
432	55	÷
433	43	RCL
434	06	06
435	65	×
436	43	RCL
437	19	19
438	34	√X
439	65	×
440	53	(
441	43	RCL
442	19	19
443	71	SBR
444	04	04
445	50	50
446	55	÷
447	53	(
448	43	RCL
449	12	12
450	35	1/X
451	75	-
452	01	1
453	95	=
454	61	GTO
455	81	RST

CALCULATORS IN NAVIGATION - P. Hanson. In accordance with the suggestion of George Booth, Robert Prins and others I have decided to publish some lists of documentation on the use of hand-held calculators in various disciplines. I will start in this issue with an index of articles on the use of calculators in navigation.

The Journal of Navigation (British), The Royal Institute of Navigation, at The Royal Geographic Society, 1 Kensington Gore, London SW7 2AT:

1. "The Calculation of Position Line Data with a Computer Calculator", by H. L. Podmore, Vol. 28, No. 1, January 1975, pp 101-104.

2. "Air Navigation with a Pocket Electronic Calculator", J. D. Proctor, Vol. 28, No. 1, January 1975, pp 104-109.

3. "The Use of Hand-held Pocket Calculators for Navigation", a discussion chaired by G. E. Beck, Vol. 28, No. 4, October 1975, pp 466-476.

4. "Further Comments on the Calculation of Position Line Data with a Computer Calculator", by John A. Read, Vol. 29, No. 1, January 1976, pp 97-98.

5. "Using a Hand-held Calculator for Ships Position Comparison", by T. R. Meaden, Vol. 29, No. 3, July 1976, pp 296-298.

6. "Navigational Almanacs for Small Computers and Calculators", D. H. Sadler, Vol. 32, No. 1, January 1979, pp 11-24.

7. "Calculators for Marine Navigation", by Basil d'Oliveira, Vol. 34, No. 3, September 1981, pp 452-461.

NAVIGATION: Journal of the Institute of Navigation (U.S.A.), Suite 832, 815 15th Street NW, Washington, DC 20005. I have received permission from the ION (U.S.A.) to provide limited copies of the articles below. Send one dollar for each article to cover the cost of copying and handling.

1. "The Use of the HP-35 Calculator for Sight Reduction", by S. Rigby, Vol. 21, No. 1, Spring 1974, pp 44-45.

2. "Direct Methods of Latitude and Longitude Determination by Mini-computer", by Crocker Wight, Vol. 23, No. 2, Summer 1976, pp 149-156.

3. "Finding Latitude and Longitude by Calculator", by C. Fox, Vol. 22, No. 4, Winter 1975-1976, pp 293-301.

4. "Two Body Fixes by Calculator", by M. F. A'Hearn and G. S. Rossano, Vol. 24, No. 1, Spring 1977, pp 59-66.

5. "A New Method of Celestial Navigation", by R. C. Ogilvie, Vol. 24, No. 1, Spring 1977, pp 67-71.

6. "A Completely Programmable Method of Celestial Navigation", by C. T. Daub, Vol. 26, No. 1, Spring 1979, pp 59-62.

7. "Three Point Fix by Pocket Calculator", by C. Blair, National Marine Meeting, November 1979, pp 18-22.

8. "Hand-held Collision Avoidance Aid", J. Luse, Vol. 28, No. 1, Spring 1981, pp 17-21.

9. "K12 Method by Calculator: A Single Program for All Celestial Fixes, Directly or by Position Lines", by S. Kotlaric, Vol. 28, No. 1, Spring 1981, pp 17-21.

10. "Mathematical 3-Arm Protractor", by W. Ruhnow, Vol. 31, No. 1, Spring 1984, pp 38-46.

<u>MORE ON ACCURACY OF THE LN FUNCTION</u> - Laurance Leeds and Palmer Hanson. The table on page 15 compares the natural logarithm function for several computers for selected Ln(1+x) problems where x is small. The table entries show that the Model 100 and the TI-66 are clearly superior.

V9N4P9 discussed alternate methods of evaluating Ln(1+x) where x is near zero. One method which is described in the HP-15C Advanced Functions Handbook provided improved results for the Bob Fruit benchmark test with the HP-11, the TI-66 and the Model 100. The results with the CC-40 were only slightly improved, and the results with the TI-59 were degraded.

Laurance Leeds provided a 52 step TI-59 routine to improve the calculation of Ln(1+x) where x is near zero (see the left hand listing below). With an input of x, in two seconds the program will provide Ln(1+x) to the accuracy shown in the next to the bottom row on page 15. A 25 step program can provide identical results, but with requires four seconds execution time (see the center listing below). The advantage of this program is that the number of iterations, and hence the accuracy, can be increased with very little penalty in program steps. If the 5 at location 005 is changed to a 7, then the results in the last five columns of the next to last row on page 15 are unchanged, but the results for larger x are much improved:

Ln(1.1) = 0.0953101809524 which is correct to 8 figures, and
Ln(1.01) = 0.00995033085317 which is correct to 12 figures.

An BASIC program which is the equivalent of the shorter TI-59 program, but which accepts (1+x) rather than x, is shown at the right below. Twelve iterations are used for the CC-40 since the response time is still nearly instantaneous. The results are in the bottom row on page 15. The Ln(1.1) is correct to 13 significant figures.

```
000  76 LBL      026  03   3
001  11  A       027  65   x
002  42 STO      028  02   2
003  00  00      029  65   x
004  55  ÷       030  43 RCL
005  05  5       031  00  00
006  65  x       032  95   =
007  04  4       033  94 +/-
008  95  =       034  85   +
009  94 +/-      035  01   1
010  85  +       036  95   =
011  01  1       037  55   ÷
012  95  =       038  02   2
013  55  ÷       039  65   x
014  04  4       040  43 RCL
015  65  x       041  00  00
016  03  3       042  95   =
017  65  x       043  94 +/-
018  43 RCL      044  85   +
019  00  00      045  01   1
020  95  =       046  95   =
021  94 +/-      047  65   x
022  85  +       048  43 RCL
023  01  1       049  00  00
024  95  =       050  95   =
025  55  ÷       051  92 RTN
```

```
000  76 LBL
001  11  A
002  94 +/-
003  42 STO
004  00  00
005  05  5
006  42 STO
007  01  01
008  25 CLR
009  76 LBL
010  12  B
011  85  +
012  43 RCL
013  01  01
014  35 1/X
015  95  =
016  65  x
017  43 RCL
018  00  00
019  95  =
020  97 DSZ
021  01  01
022  12  B
023  94 +/-
024  92 RTN
```

```
1000 IMAGE .######
########^^^^

1000 IMAGE .######
########^^^^
1010 INPUT Z
1020 Z=1-Z
1030 F=0
1040 FOR I=12 TO 1
 STEP -1
1050 F=Z*(F-1/I)
1060 NEXT I
1070 PRINT USING 1
000;F:PAUSE
1080 GOTO 1010
```

Suppose that we use these routines for Ln(1+x) to improve the accuracy of the solutions for Bob Fruit's benchmark test.

Exact Solution	2260.48792 47960 86067 ...
TI-59 (5 iterations)	2260.48972 4844
TI-59 (7 iterations)	2260.48792 4793
CC-40 (12 iterations)	2260.48972 4796

where the CC-40 solution is correct to 13 significant figures.

More on Accuracy of the Ln Function - (cont)

	1e2*Ln(1.1)	1e3*Ln(1.01)	1e4*Ln(1.001)	1e5*Ln(1.0001)	1e6*Ln(1.00001)	1e7*Ln(1.000001)	1e8*Ln(1.0000001)
Exact	9.53101 79804 3248	9.95033 08531 6808	9.99500 33308 3533	9.99950 00333 3083	9.99995 00003 3333	9.99999 50000 0333	9.99999 95000 0003
M-100	9.53101 79804 323	9.95033 08531 677	9.99500 33308 351	9.99950 00333 305	9.99995 00003 332	9.99999 50000 030	9.99999 94999 999
TI-66	9.53101 79804 32	9.95033 08531 68	9.99500 33308 35	9.99950 00333 30	9.99995 00003 33	9.99999 50000 04	9.99999 95000 05
EL-512	9.53101 79804	9.95033 08532	9.99500 33308	9.99950 00333	9.99995 00003	9.99999 5	9.99999 95
HP-11	9.53101 7980	9.95033 0853	9.99500 3331	9.99950 0033	9.99995	9.99999 5	9.99999 95
TI-59	9.53101 79804 3	9.95033 08532	9.99500 3331	9.99950 003	9.99995	9.99999 5	10.
CC-40	9.53101 79804	9.95033 0853	9.99500 333	9.9995	9.99994 9	10.	10.0001
TI-57	9.53101 798	9.95033 08	9.99500 2	9.9995	10.	10.	10.
TI-55II	9.53101 798	9.95033 09	9.99500 3	9.9995	9.9999	10.	9.99
Comm 64	9.53101 797	9.95033 072	9.99500 669	9.99950 29	9.99979 339	10.00431 22	9.98978 747
Color C	9.53101 807	9.95033 104	9.99500 024	9.99950 29	9.99979 34	9.99947 063	9.98978 747

Alternate Programs for Ln(a) where a is near 1:

TI-59	9.53103 33333 4	9.95033 08533 4	9.99500 33308 4	9.99950 00333 4	9.99995 00003 4	9.99999 50000 1	9.99999 95000 1
CC-40	9.53101 79804 32	9.95033 08531 681	9.99500 33308 35	9.99950 00333 309	9.99995 00003 33	9.99999 50000 034	9.99999 95

The table lists the output from the natural logarithm function for a range of hand-held programmable calculators and personal computers. In the table the Radio Shack Model 100 is clearly superior, closely followed by the TI-66. It seems to be a well-kept secret that the TI-66 mechanization seems to have fixed all of the deficiencies of the TI-59 such as non-commutative multiply, $\sin\theta \neq \cos(90-\theta)$, etc. The Sharp EL-512 also does very well. The last two rows show the results obtained using the programs on page 14 to improve the solution for the natural logarithm when the argument is near unity.

BINARY/DECIMAL/HEXADECIMAL CONVERSIONS - Lem Matteson. In V9N1P12 a fast mode decimal/octal conversion program was provided by David Mah. Lem has found that hexadecimal conversions are useful in machine language programming and submitted the following conversion program. The program uses three banks. The listings are on pages 17 and 18.

Instructions: A printer is required.

A For decimal to binary enter a decimal number up to 1023 and press A.

```
      101.    DEC
 110.0101     BIN
```

B For decimal to hexadecimal enter a decimal number up to 1,048575 and press B.

```
  543210.     DEC
  849EA       HEX
```

C For hexadecimal to binary enter a hexadecimal number up to 3FF and press C. You must enter the number equivalent of A through F. The hexadecimal code is printed before the binary code.

```
       7.    ?HEX
       7      HEX
     111.     BIN
```

D For hexadecimal to decimal enter a hexadecimal number up to FFFFF and press D. You must enter the number equivalent of A through F. The hexadecimal code is printed before the decimal equivalent.

```
910111213.   ?HEX
   9ABCD      HEX
  633805.     DEC
```

E For 2's complement enter a binary number up to 11111111 and press E.

```
11001100.     BIN
  110100.     NEG
```

A' For binary to decimal enter a binary number up to 11111111 and press A'.

```
  110100.     BIN
      52.     DEC
```

B' For binary to hexadecimal enter a binary number up to 11111111 and press B'.

```
 1010110.     BIN
      56      HEX
```

D' For conversion of the numerical equivalent of hexadecimal code to hexadecimal code enter the numerical equivalent and press D'.

```
1513110907.  ?HEX
   FDB97      HEX
```

E' For 1's complement enter a binary number up to 11111111 and press E'.

```
11001100.     BIN
  110011.    1 CP
```

This program does not include a comprehensive check for an acceptable range of input. If you exceed the ranges defined above you may obtain erratic results.

HARDWARE AVAILABILITY - Frank Gebhardt has the following equipment for sale: TI-59, PC-100C, modules and manuals for Business Decisions, Securities Analysis, and Real Estate Investment. He would like to sell the equipment in one lot. You can write to

Frank C. Gebhardt
140 East 29th Street
Erie PA 16504

Binary/Decimal/Hexadecimal Conversions - (cont)

Bank 1 Listing:

000	98	ADV	040	76	LBL	080	10	10	120	49	PRD	160	02	2	200	49	PRD
001	00	0	041	14	D	081	55	÷	121	11	11	161	75	-	201	12	12
002	92	RTN	042	42	STO	082	01	1	122	43	RCL	162	59	INT	202	97	DSZ
003	76	LBL	043	07	07	083	06	6	123	11	11	163	42	STO	203	00	00
004	10	E'	044	32	X:T	084	75	-	124	61	GTO	164	10	10	204	01	01
005	86	STF	045	03	3	085	59	INT	125	03	03	165	95	=	205	83	83
006	01	01	046	69	OP	086	42	STO	126	24	24	166	65	×	206	03	3
007	76	LBL	047	17	17	087	10	10	127	76	LBL	167	02	2	207	22	INV
008	15	E	048	61	GTO	088	95	=	128	11	A	168	95	=	208	28	LOG
009	32	X:T	049	05	05	089	65	×	129	32	X:T	169	44	SUM	209	33	X^2
010	71	SBR	050	07	07	090	01	1	130	71	SBR	170	11	11	210	49	PRD
011	04	04	051	76	LBL	091	06	6	131	04	04	171	01	1	211	12	12
012	55	55	052	12	B	092	95	=	132	46	46	172	00	0	212	03	3
013	32	X:T	053	86	STF	093	44	SUM	133	01	1	173	22	INV	213	69	OP
014	69	OP	054	02	02	094	11	11	134	04	4	174	49	PRD	214	17	17
015	06	06	055	32	X:T	095	01	1	135	03	3	175	11	11	215	43	RCL
016	42	STO	056	71	SBR	096	00	0	136	03	3	176	97	DSZ	216	12	12
017	00	00	057	04	04	097	00	0	137	06	6	177	00	00	217	61	GTO
018	03	3	058	46	46	098	22	INV	138	32	X:T	178	01	01	218	04	04
019	69	OP	059	01	1	099	49	PRD	139	77	GE	179	57	57	219	80	80
020	17	17	060	00	0	100	11	11	140	04	04	180	06	6	220	76	LBL
021	61	GTO	061	04	4	101	69	OP	141	64	64	181	42	STO	221	17	B'
022	05	05	062	08	8	102	20	20	142	69	OP	182	00	00	222	86	STF
023	68	68	063	05	5	103	29	CP	143	06	06	183	43	RCL	223	01	01
024	76	LBL	064	07	7	104	43	RCL	144	42	STO	184	10	10	224	86	STF
025	13	C	065	06	6	105	10	10	145	10	10	185	55	÷	225	02	02
026	32	X:T	066	32	X:T	106	22	INV	146	00	0	186	02	2	226	76	LBL
027	03	3	067	77	GE	107	67	EQ	147	42	STO	187	75	-	227	16	A'
028	00	0	068	04	04	108	00	00	148	11	11	188	59	INT	228	42	STO
029	08	8	069	64	64	109	79	79	149	42	STO	189	42	STO	229	10	10
030	00	0	070	69	OP	110	43	RCL	150	12	12	190	10	10	230	75	-
031	00	0	071	06	06	111	00	00	151	04	4	191	95	=	231	59	INT
032	00	0	072	42	STO	112	65	×	152	42	STO	192	65	×	232	95	=
033	00	0	073	10	10	113	02	2	153	00	00	193	02	2	233	29	CP
034	32	X:T	074	00	0	114	95	=	154	71	SBR	194	95	=	234	67	EQ
035	77	GE	075	42	STO	115	22	INV	155	04	04	195	44	SUM	235	02	02
036	04	04	076	00	00	116	28	LOG	156	55	55	196	12	12	236	43	43
037	64	64	077	42	STO	117	52	EE	157	43	RCL	197	01	1	237	01	1
038	86	STF	078	11	11	118	22	INV	158	10	10	198	00	0	238	00	0
039	03	03	079	43	RCL	119	52	EE	159	55	÷	199	22	INV	239	33	X^2

Bank 2 Listing:

240	33	X^2	280	39	39	320	35	35	360	28	LOG	400	22	INV	440	07	7
241	49	PRD	281	67	EQ	321	32	X:T	361	52	EE	401	67	EQ	441	04	4
242	10	10	282	02	02	322	69	OP	362	22	INV	402	04	04	442	04	4
243	71	SBR	283	92	92	323	06	06	363	52	EE	403	11	11	443	69	OP
244	04	04	284	65	×	324	42	STO	364	22	INV	404	02	2	444	04	04
245	55	55	285	02	2	325	10	10	365	49	PRD	405	01	1	445	92	RTN
246	43	RCL	286	45	Y^X	326	42	STO	366	11	11	406	44	SUM	446	01	1
247	10	10	287	43	RCL	327	11	11	367	01	1	407	08	08	447	06	6
248	69	OP	288	09	09	328	00	0	368	00	0	408	61	GTO	448	01	1
249	06	06	289	95	=	329	42	STO	369	00	0	409	04	04	449	07	7
250	55	÷	290	44	SUM	330	00	00	370	49	PRD	410	16	16	450	01	1
251	04	4	291	11	11	331	42	STO	371	08	08	411	85	+	451	05	5
252	22	INV	292	97	DSZ	332	08	08	372	49	PRD	412	03	3	452	69	OP
253	28	LOG	293	00	00	333	43	RCL	373	11	11	413	95	=	453	04	04
254	33	X^2	294	02	02	334	10	10	374	43	RCL	414	44	SUM	454	92	RTN
255	95	=	295	67	67	335	55	÷	375	11	11	415	08	08	455	01	1
256	42	STO	296	43	RCL	336	01	1	376	75	-	416	97	DSZ	456	04	4
257	10	10	297	11	11	337	00	0	377	22	INV	417	00	00	457	02	2
258	08	8	298	52	EE	338	00	0	378	59	INT	418	03	03	458	04	4
259	42	STO	299	22	INV	339	75	-	379	42	STO	419	67	67	459	03	3
260	09	09	300	52	EE	340	22	INV	380	11	11	420	71	SBR	460	01	1
261	42	STO	301	87	IFF	341	59	INT	381	95	=	421	04	04	461	69	OP
262	00	00	302	01	01	342	95	=	382	32	X:T	422	37	37	462	04	04
263	00	0	303	00	00	343	42	STO	383	09	9	423	43	RCL	463	92	RTN
264	42	STO	304	72	72	344	10	10	384	32	X:T	424	08	08	464	32	X:T
265	11	11	305	71	SBR	345	69	OP	385	77	GE	425	69	OP	465	03	3
266	29	CP	306	04	04	346	20	20	386	03	03	426	02	02	466	01	1
267	01	1	307	46	46	347	29	CP	387	96	96	427	69	OP	467	02	2
268	00	0	308	43	RCL	348	43	RCL	388	85	+	428	05	05	468	02	2
269	49	PRD	309	11	11	349	10	10	389	01	1	429	00	0	469	04	4
270	10	10	310	69	OP	350	22	INV	390	95	=	430	87	IFF	470	00	0
271	43	RCL	311	06	06	351	67	EQ	391	44	SUM	431	02	02	471	69	OP
272	10	10	312	81	RST	352	03	03	392	08	08	432	04	04	472	04	04
273	75	-	313	76	LBL	353	33	33	393	61	GTO	433	78	78	473	32	X:T
274	22	INV	314	19	D'	354	43	RCL	394	04	04	434	92	RTN	474	85	+
275	59	INT	315	86	STF	355	00	00	395	16	16	435	07	7	475	85	+
276	42	STO	316	02	02	356	65	×	396	32	X:T	436	01	1	476	69	OP
277	10	10	317	32	X:T	357	02	2	397	01	1	437	02	2	477	06	06
278	95	=	318	71	SBR	358	95	=	398	05	5	438	03	3	478	25	CLR
279	69	OP	319	04	04	359	22	INV	399	32	X:T	439	01	1	479	81	RST

Binary/Decimal/Hexadecimal Conversions - (cont)

480	29	CP	520	55	÷	560	32	X:T	600	95	=	640	01	1	680	75	-
481	22	INV	521	01	1	561	71	SBR	601	29	CP	641	01	1	681	59	INT
482	67	EQ	522	00	0	562	04	04	602	22	INV	642	07	7	682	42	STO
483	04	04	523	00	0	563	46	46	603	67	EQ	643	02	2	683	01	01
484	94	94	524	75	-	564	32	X:T	604	06	06	644	02	2	684	95	=
485	02	2	525	59	INT	565	69	OP	605	08	08	645	69	OP	685	67	EQ
486	22	INV	526	42	STO	566	06	06	606	01	1	646	04	04	686	06	06
487	28	LOG	527	07	07	567	81	RST	607	85	+	647	93	.	687	73	73
488	33	X^2	528	95	=	568	00	0	608	00	0	648	02	2	688	43	RCL
489	49	PRD	529	65	×	569	42	STO	609	95	=	649	32	X:T	689	01	01
490	11	11	530	01	1	570	01	01	610	44	SUM	650	42	STO	690	85	+
491	61	GTO	531	00	0	571	08	8	611	01	01	651	05	05	691	93	.
492	04	04	532	00	0	572	42	STO	612	01	1	652	55	÷	692	01	1
493	99	99	533	65	×	573	02	02	613	00	0	653	01	1	693	95	=
494	58	FIX	534	53	(	574	29	CP	614	22	INV	654	00	0	694	65	×
495	04	04	535	01	1	575	43	RCL	615	49	PRD	655	75	-	695	43	RCL
496	43	RCL	536	06	6	576	00	00	616	01	01	656	59	INT	696	03	03
497	12	12	537	45	Y^x	577	22	INV	617	97	DSZ	657	95	=	697	22	INV
498	85	+	538	43	RCL	578	59	INT	618	02	02	658	67	EQ	698	28	LOG
499	43	RCL	539	09	09	579	67	EQ	619	05	05	659	06	06	699	95	=
500	11	11	540	95	=	580	05	05	620	91	91	660	67	67	700	69	OP
501	95	=	541	44	SUM	581	91	91	621	43	RCL	661	43	RCL	701	06	06
502	69	OP	542	11	11	582	43	RCL	622	01	01	662	05	05	702	98	ADV
503	06	06	543	69	OP	583	00	00	623	65	×	663	69	OP	703	91	R/S
504	22	INV	544	29	29	584	65	×	624	04	4	664	06	06	704	00	0
505	58	FIX	545	43	RCL	585	04	4	625	22	INV	665	98	ADV	705	02	2
506	81	RST	546	07	07	586	22	INV	626	28	LOG	666	91	R/S	706	00	0
507	43	RCL	547	22	INV	587	28	LOG	627	33	X^2	667	00	0	707	00	0
508	07	07	548	67	EQ	588	95	=	628	95	=	668	42	STO	708	01	1
509	71	SBR	549	05	05	589	42	STO	629	42	STO	669	03	03	709	05	5
510	03	03	550	18	18	590	00	00	630	01	01	670	93	.	710	03	3
511	18	18	551	43	RCL	591	43	RCL	631	87	IFF	671	01	1	711	03	3
512	29	CP	552	11	11	592	00	00	632	01	01	672	32	X:T	712	69	OP
513	00	0	553	52	EE	593	55	÷	633	07	07	673	69	OP	713	04	04
514	42	STO	554	22	INV	594	01	1	634	04	04	674	23	23	714	43	RCL
515	11	11	555	52	EE	595	00	0	635	85	+	675	43	RCL	715	01	01
516	42	STO	556	87	IFF	596	75	-	636	01	1	676	01	01	716	69	OP
517	09	09	557	03	03	597	59	INT	637	95	=	677	55	÷	717	06	06
518	43	RCL	558	01	01	598	42	STO	638	32	X:T	678	01	1	718	47	CMS
519	07	07	559	44	44	599	00	00	639	03	3	679	00	0	719	81	RST

HEX$ IN THE COLOR COMPUTER - P. Hanson. With an almost universal requirement to generate hexadecimal conversions it would seem that computer manufacturers would provide such a capability. The only one I have seen so far is the HEX$ command in the Extended BASIC of the Radio Shack Color Computer. The user can simply enter PRINT HEX$(n) where n is a decimal number between 0 and 65535 and the computer returns the hexadecimal equivalent between 0 and FFFF. We could use more help like that!

PROGRAMS SIMPLIFY SYSTEMS ANALYSIS - T. C. Steidel. Maurice Swinnen called my attention to this pair of programs which appear on pages 103-106 of the January 1985 issue of Microwaves & RF. Quoting from the article: "The first program, Input Cascade, prompts the user to provide element parameters, stage by stage, as it successively cascades noise figure and intercept points. The final results are the cascaded input noise figure, intercept points, and the bandwidth. A second program, Noise Cascade, provides information that helps the designer identify the stages that contribute most to the system's noise figure." Equations and instructions are listed in the article. To obtain the program listing you must send a stamped, self-addressed envelope to Thomas C. Steidel, P.O. Box 197, Pine Grove Mills, PA 16868. FORTRAN and MBASIC versions are also available.

<u>ML-02 WITH DOUBLE DIVIDES</u> - Palmer Hanson. V9N2P15 and the following pages discussed the non-commutative multiply quirk with the TI-59, and described a workaround using the idea of double divides replacing multiplies. Use of the technique with the Nick/Ristanovic "Gauss" method and Robert Prins' modification of the Programbiten method for solving simultaneous equations showed two orders of magnitude of improvement for the 7 x 7 sub-Hilbert problem which we have used as a benchmark (See V9N2P18). An obvious question was whether double divides would provide a similar improvement in the Master Library program for solving simultaneous equations (ML-02).

I downloaded the ML-02 program and proceeded to replace multiplies and products with double divides and inverse products. An example of a "double divide", actually the combination of a divide and a 1/x, appears at locations 236-240 in the listing below. An example of a "double divide" replacing a product, actually the combination of an inverse product and a 1/x, appears at locations 178-184. Some multiplies do not need to be changed, for example the multiplies used in program control such as the one at location 008. The resulting listings for ML-02 modes A through A' fit on three card sides.

<u>Program Listing</u>:

<u>Program ABC</u> (Record it in banks 1 and 2 with partitioning 8-Op-17.

000	76	LBL	049	38	38	098	42	STO	147	94	+/-	196	42	STO	245	02	02
001	19	D'	050	76	LBL	099	02	02	148	49	PRD	197	02	02	246	17	17
002	85	+	051	13	C	100	73	RC*	149	06	06	198	85	+	247	01	1
003	53	(	052	43	RCL	101	02	02	150	43	RCL	199	43	RCL	248	22	INV
004	24	CE	053	07	07	102	50	IxI	151	07	07	200	05	05	249	44	SUM
005	75	-	054	42	STO	103	32	X:T	152	85	+	201	75	-	250	05	05
006	01	1	055	05	05	104	22	INV	153	01	1	202	43	RCL	251	43	RCL
007	54	)	056	85	+	105	97	DSZ	154	95	=	203	04	04	252	05	05
008	65	×	057	33	X²	106	05	05	155	42	STO	204	95	=	253	32	X:T
009	43	RCL	058	85	+	107	01	01	156	05	05	205	42	STO	254	43	RCL
010	07	07	059	07	7	108	33	33	157	73	RC*	206	03	03	255	04	04
011	85	+	060	95	=	109	01	1	158	02	02	207	73	RC*	256	67	EQ
012	07	7	061	42	STO	110	44	SUM	159	63	EX*	208	03	03	257	02	02
013	95	=	062	01	01	111	02	02	160	03	03	209	55	÷	258	62	62
014	92	RTN	063	43	RCL	112	73	RC*	161	72	ST*	210	73	RC*	259	61	GTO
015	76	LBL	064	05	05	113	02	02	162	02	02	211	02	02	260	01	01
016	11	A	065	72	ST*	114	50	IxI	163	43	RCL	212	95	=	261	93	93
017	42	STO	066	01	01	115	22	INV	164	07	07	213	42	STO	262	01	1
018	07	07	067	01	1	116	77	GE	165	44	SUM	214	01	01	263	44	SUM
019	99	PRT	068	22	INV	117	01	01	166	02	02	215	72	ST*	264	04	04
020	98	ADV	069	44	SUM	118	04	04	167	44	SUM	216	03	03	265	43	RCL
021	92	RTN	070	01	01	119	32	X:T	168	03	03	217	43	RCL	266	07	07
022	76	LBL	071	97	DSZ	120	43	RCL	169	97	DSZ	218	07	07	267	32	X:T
023	12	B	072	05	05	121	07	07	170	05	05	219	44	SUM	268	43	RCL
024	75	-	073	00	00	122	85	+	171	01	01	220	02	02	269	04	04
025	32	X:T	074	63	63	123	43	RCL	172	57	57	221	44	SUM	270	67	EQ
026	01	1	075	01	1	124	05	05	173	43	RCL	222	03	03	271	02	02
027	95	=	076	42	STO	125	85	+	174	04	04	223	33	X²	272	76	76
028	65	×	077	04	04	126	08	8	175	19	D'	224	85	+	273	61	GTO
029	43	RCL	078	42	STO	127	95	=	176	42	STO	225	08	8	274	00	00
030	07	07	079	06	06	128	42	STO	177	01	01	226	95	=	275	80	80
031	85	+	080	43	RCL	129	03	03	178	73	RC*	227	32	X:T	276	19	D'
032	08	8	081	04	04	130	61	GTO	179	01	01	228	43	RCL	277	42	STO
033	95	=	082	85	+	131	01	01	180	35	1/X	229	03	03	278	01	01
034	42	STO	083	07	7	132	04	04	181	24	CE	230	77	GE	279	73	RC*
035	01	01	084	95	=	133	43	RCL	182	22	INV	231	02	02	280	01	01
036	32	X:T	085	42	STO	134	03	03	183	49	PRD	232	47	47	281	35	1/X
037	92	RTN	086	03	03	135	32	X:T	184	06	06	233	43	RCL	282	24	CE
038	99	PRT	087	75	-	136	43	RCL	185	29	CP	234	01	01	283	22	INV
039	72	ST*	088	43	RCL	137	04	04	186	67	EQ	235	94	+/-	284	49	PRD
040	01	01	089	07	07	138	85	+	187	02	02	236	55	÷	285	06	06
041	92	RTN	090	75	-	139	07	7	188	84	84	237	73	RC*	286	43	RCL
042	32	X:T	091	08	8	140	95	=	189	43	RCL	238	02	02	287	06	06
043	01	1	092	95	=	141	67	EQ	190	07	07	239	35	1/X	288	98	ADV
044	44	SUM	093	42	STO	142	01	01	191	42	STO	240	24	CE	289	99	PRT
045	01	01	094	05	05	143	73	73	192	05	05	241	95	=	290	98	ADV
046	32	X:T	095	43	RCL	144	42	STO	193	43	RCL	242	74	SM*	291	92	RTN
047	61	GTO	096	04	04	145	02	02	194	04	04	243	03	03	292	00	0
048	00	00	097	19	D'	146	01	1	195	19	D'	244	61	GTO	293	00	0

ML-02 With Double Divides - (cont)

Program DEA' (Record it in bank 1 with partitioning 8-Op-17)

000	69	OP	040	73	RC*	080	01	01	120	05	05	160	07	07	200	04	04
001	31	31	041	01	01	081	73	RC*	121	75	-	-161	85	+	201	32	X:T
002	43	RCL	042	55	÷	082	01	01	122	43	RCL	162	01	1	202	43	RCL
003	07	07	043	73	RC*	083	22	INV	123	07	07	163	54	)	203	07	07
004	22	INV	044	02	02	084	67	EQ	124	85	+	164	33	X^2	204	77	GE
005	44	SUM	045	35	1/X	085	00	00	125	07	7	165	95	=	205	01	01
006	02	02	046	24	CE	086	78	78	126	95	=	166	42	STO	206	56	56
007	92	RTN	047	61	GTO	087	43	RCL	127	42	STO	167	01	01	207	98	ADV
008	22	INV	048	00	00	088	07	07	128	02	02	168	75	-	208	01	1
009	97	DSZ	049	31	31	089	44	SUM	129	00	0	169	43	RCL	209	92	RTN
010	05	05	050	92	RTN	090	01	01	130	71	SBR	170	07	07	210	76	LBL
011	00	00	051	00	0	091	01	1	131	00	00	171	75	-	211	16	A'
012	30	30	052	00	0	092	44	SUM	132	08	08	172	43	RCL	212	85	+
013	75	-	053	00	0	093	05	05	133	85	+	173	04	04	213	32	X:T
014	69	OP	054	76	LBL	094	43	RCL	134	01	1	174	42	STO	214	07	7
015	21	21	055	14	D	095	03	03	135	44	SUM	175	05	05	215	85	+
016	43	RCL	056	42	STO	096	72	ST*	136	01	01	176	95	=	216	43	RCL
017	07	07	057	05	05	097	01	01	137	73	RC*	177	42	STO	217	07	07
018	44	SUM	058	92	RTN	098	99	PRT	138	01	01	178	02	02	218	65	×
019	02	02	059	42	STO	099	92	RTN	139	95	=	179	00	0	219	53	(
020	73	RC*	060	03	03	100	61	GTO	140	72	ST*	180	71	SBR	220	24	CE
021	01	01	061	43	RCL	101	00	00	141	01	01	181	00	00	221	85	+
022	55	÷	062	07	07	102	59	59	142	01	1	182	31	31	222	01	1
023	73	RC*	063	33	X^2	103	76	LBL	143	44	SUM	183	85	+	223	54	)
024	02	02	064	85	+	104	15	E	144	04	04	184	71	SBR	224	95	=
025	35	1/X	065	07	7	105	01	1	145	43	RCL	185	00	00	225	42	STO
026	24	CE	066	95	=	106	42	STO	146	04	04	186	00	00	226	01	01
027	61	GTO	067	42	STO	107	04	04	147	32	X:T	187	73	RC*	227	32	X:T
028	00	00	068	01	01	108	43	RCL	148	43	RCL	188	01	01	228	92	RTN
029	08	08	069	43	RCL	109	07	07	149	07	07	189	95	=	229	73	RC*
030	92	RTN	070	05	05	110	85	+	150	77	GE	190	55	÷	230	01	01
031	22	INV	071	32	X:T	111	33	X^2	151	01	01	191	73	RC*	231	99	PRT
032	97	DSZ	072	43	RCL	112	85	+	152	08	08	192	02	02	232	92	RTN
033	05	05	073	07	07	113	07	7	153	01	1	193	95	=	233	01	1
034	00	00	074	22	INV	114	95	=	154	42	STO	194	72	ST*	234	44	SUM
035	50	50	075	77	GE	115	42	STO	155	04	04	195	01	01	235	01	01
036	75	-	076	00	00	116	01	01	156	07	7	196	01	1	236	61	GTO
037	71	SBR	077	58	58	117	43	RCL	157	85	+	197	44	SUM	237	02	02
038	00	00	078	01	1	118	04	04	158	53	(	198	04	04	238	29	29
039	00	00	079	44	SUM	119	42	STO	159	43	RCL	199	43	RCL	239	00	0

Instructions:

All the instructions for modes A through A' on pages 9 through 12 of the Master Library manual apply, except that you must remember to enter the second part of the program when you want to perform modes D through A'.

1. Load the two card sides for the first part, program ABC.
2. Enter the order of the matrix and press A.
3. Enter a "1" and press B. A 1 is returned to the display. Enter the elements of the matrix column by column pressing R/S to enter each element. The input elements are printed.
4. Press C to find the determinant. The determinant is printed.
5. Enter a "1" and press D. A 1 is returned to the display. Enter the elements of the vector, pressing R/S to enter each value.
6. Press CLR and E to solve. When complete a 1 is returned to the display.
7. Enter a "1" and press 2nd-A' . A 1 is returned to the display. Read out the solution by pressing R/S repetively. Comparative performance for benchmark programs is discussed on page 24.

SOLUTION OF SIMULTANEOUS LINEAR EQUATIONS BY ORTHOGONAL HOUSEHOLDER METHODS

George Wm Thomson. Recent methods for matrix inversion and solution of simultaneous equations described in TI PPC Notes have been variations of classical elimination methods where the variables are successively eliminated by the addition of multiples of rows and/or columns. Good accuracy has been obtained by skilled programming and the use of internal tests to determine good "pivoting" elements. A different group of ways based on the use of n-dimensional vector rotations have been found to give much better results than the elimination methods, especially for large matrices. Most are based on orthogonal vector transformations using A. S. Householder's methods. This program applies these ideas to the TI-59 using an algorithm due to Eugene Golub and programmed in FORTRAN by his collaborator Peter A. Businger of Bell Laboratories. The two part, 7 EE Fast Mode program is based on a copy of Businger's program sent in 1970 and previously tested on an IBM 360/30. The program uses Palmer Hanson's "double-divide" fix for the faulty TI-59 multiply throughout, and is extensively trapped against the entry of zero values as part of the input.

<u>Program</u> <u>Listing</u>:

<u>Part</u> <u>A</u> - Record it in banks 1 and 2 using partitioning 8-Op-17.

000	91	R/S	054	74	74	108	70	70	162	08	08	216	08	08	270	61	GTO
001	76	LBL	055	01	1	109	35	1/X	163	25	CLR	217	73	RC*	271	02	02
002	18	C'	056	44	SUM	110	95	=	164	42	STO	218	75	75	272	62	62
003	86	STF	057	75	75	111	82	HIR	165	74	74	219	55	÷	273	76	LBL
004	08	08	058	97	DSZ	112	05	05	166	29	CP	220	43	RCL	274	12	B
005	01	1	059	08	08	113	73	RC*	167	73	RC*	221	74	74	275	01	1
006	42	STO	060	00	00	114	70	70	168	76	76	222	94	+/-	276	76	LBL
007	70	70	061	43	43	115	22	INV	169	55	÷	223	95	=	277	17	B'
008	25	CLR	062	43	RCL	116	74	SM*	170	53	(	224	74	SM*	278	85	+
009	43	RCL	063	74	74	117	67	67	171	73	RC*	225	76	76	279	09	9
010	70	70	064	99	PRT	118	82	HIR	172	75	75	226	01	1	280	85	+
011	85	+	065	75	-	119	18	18	173	67	EQ	227	44	SUM	281	82	HIR
012	09	9	066	43	RCL	120	32	X:T	174	01	01	228	75	75	282	18	18
013	85	+	067	72	72	121	43	RCL	175	81	81	229	01	1	283	65	×
014	43	RCL	068	95	=	122	70	70	176	54	)	230	44	SUM	284	43	RCL
015	71	71	069	77	GE	123	67	EQ	177	35	1/X	231	76	76	285	71	71
016	65	×	070	00	00	124	02	02	178	95	=	232	97	DSZ	286	95	=
017	53	(	071	85	85	125	49	49	179	44	SUM	233	08	08	287	61	GTO
018	43	RCL	072	98	ADV	126	85	+	180	74	74	234	02	02	288	02	02
019	70	70	073	43	RCL	127	01	1	181	25	CLR	235	17	17	289	60	60
020	75	-	074	70	70	128	95	=	182	01	1	236	01	1	290	68	NOP
021	01	1	075	65	×	129	42	STO	183	44	SUM	237	44	SUM	291	76	LBL
022	95	=	076	01	1	130	78	78	184	75	75	238	78	78	292	11	A
023	42	STO	077	01	1	131	82	HIR	185	01	1	239	97	DSZ	293	82	HIR
024	67	67	078	95	=	132	18	18	186	44	SUM	240	09	09	294	08	08
025	42	STO	079	99	PRT	133	75	-	187	76	76	241	01	01	295	42	STO
026	75	75	080	98	ADV	134	43	RCL	188	97	DSZ	242	39	39	296	71	71
027	43	RCL	081	43	RCL	135	70	70	189	08	08	243	01	1	297	01	1
028	71	71	082	74	74	136	95	=	190	01	01	244	44	SUM	298	52	EE
029	85	+	083	99	PRT	137	42	STO	191	67	67	245	70	70	299	02	2
030	01	1	084	91	R/S	138	09	09	192	82	HIR	246	61	GTO	300	00	0
031	75	-	085	43	RCL	139	25	CLR	193	15	15	247	00	00	301	94	+/-
032	43	RCL	086	74	74	140	43	RCL	194	55	÷	248	08	08	302	42	STO
033	70	70	087	34	√X	141	67	67	195	53	(	249	43	RCL	303	72	72
034	95	=	088	72	ST*	142	42	STO	196	43	RCL	250	71	71	304	22	INV
035	42	STO	089	70	70	143	75	75	197	74	74	251	82	HIR	305	57	ENG
036	68	68	090	73	RC*	144	85	+	198	67	EQ	252	07	07	306	43	RCL
037	42	STO	091	67	67	145	43	RCL	199	02	02	253	98	ADV	307	71	71
038	08	08	092	22	INV	146	71	71	200	36	36	254	25	CLR	308	91	R/S
039	25	CLR	093	77	GE	147	65	×	201	54	)	255	81	RST	309	42	STO
040	42	STO	094	01	01	148	53	(	202	95	=	256	76	LBL	310	71	71
041	74	74	095	01	01	149	43	RCL	203	42	STO	257	14	D	311	91	R/S
042	29	CP	096	73	RC*	150	78	78	204	74	74	258	01	1	312	76	LBL
043	73	RC*	097	70	70	151	75	-	205	43	RCL	259	00	0	313	13	C
044	75	75	098	94	+/-	152	43	RCL	206	67	67	260	42	STO	314	93	.
045	67	EQ	099	72	ST*	153	70	70	207	42	STO	261	08	08	315	01	1
046	00	00	100	70	70	154	95	=	208	75	75	262	43	RCL	316	34	√X
047	55	55	101	43	RCL	155	42	STO	209	43	RCL	263	08	08	317	33	X²
048	55	÷	102	74	74	156	76	76	210	66	66	264	91	R/S	318	35	1/X
049	73	RC*	103	75	-	157	42	STO	211	42	STO	265	72	ST*	319	86	STF
050	75	75	104	73	RC*	158	66	66	212	76	76	266	08	08			
051	35	1/X	105	67	67	159	43	RCL	213	43	RCL	267	99	PRT			
052	95	=	106	55	÷	160	68	68	214	68	68	268	69	OP			
053	44	SUM	107	73	RC*	161	42	STO	215	42	STO	269	28	28			

Solution of Linear Equations by Orthogonal Householder Methods (cont)

Part B - Record it it banks 1 and 2 using partitioning 8-Op-17.

000	91	R/S	054	73	RC*	108	75	75	162	76	76	216	00	00	270	08	08
001	76	LBL	055	75	75	109	43	RCL	163	55	÷	217	85	+	271	06	6
002	18	C'	056	55	÷	110	74	74	164	73	RC*	218	06	6	272	06	6
003	86	STF	057	73	RC*	111	42	STO	165	00	00	219	05	5	273	42	STO
004	08	08	058	78	78	112	76	76	166	95	=	220	95	=	274	09	09
005	01	1	059	35	1/X	113	43	RCL	167	72	ST*	221	42	STO	275	73	RC*
006	42	STO	060	95	=	114	79	79	168	79	79	222	79	79	276	09	09
007	78	78	061	82	HIR	115	42	STO	169	82	HIR	223	73	RC*	277	99	PRT
008	82	HIR	062	05	05	116	08	08	170	18	18	224	75	75	278	91	R/S
009	18	18	063	25	CLR	117	73	RC*	171	75	-	225	55	÷	279	69	OP
010	42	STO	064	42	STO	118	75	75	172	01	1	226	53	(	280	29	29
011	09	09	065	77	77	119	55	÷	173	95	=	227	73	RC*	281	97	DSZ
012	29	CP	066	73	RC*	120	43	RCL	174	42	STO	228	79	79	282	08	08
013	43	RCL	067	76	76	121	77	77	175	09	09	229	67	EQ	283	02	02
014	78	78	068	55	÷	122	95	=	176	43	RCL	230	02	02	284	75	75
015	85	+	069	53	(	123	74	SM*	177	09	09	231	38	38	285	25	CLR
016	09	9	070	73	RC*	124	76	76	178	85	+	232	54	)	286	81	RST
017	85	+	071	75	75	125	01	1	179	82	HIR	233	35	1/X	287	76	LBL
018	82	HIR	072	67	EQ	126	44	SUM	180	16	16	234	95	=	288	11	A
019	17	17	073	00	00	127	75	75	181	95	=	235	22	INV	289	82	HIR
020	65	×	074	80	80	128	01	1	182	42	STO	236	44	SUM	290	08	08
021	53	(	075	54	)	129	44	SUM	183	76	76	237	77	77	291	99	PRT
022	43	RCL	076	35	1/X	130	76	76	184	73	RC*	238	25	CLR	292	91	R/S
023	78	78	077	95	=	131	97	DSZ	185	76	76	239	69	OP	293	82	HIR
024	75	-	078	44	SUM	132	08	08	186	42	STO	240	30	30	294	07	07
025	01	1	079	77	77	133	01	01	187	77	77	241	97	DSZ	295	99	PRT
026	54	)	080	25	CLR	134	17	17	188	82	HIR	242	08	08	296	65	×
027	95	=	081	01	1	135	25	CLR	189	18	18	243	01	01	297	82	HIR
028	42	STO	082	44	SUM	136	01	1	190	42	STO	244	99	99	298	18	18
029	73	73	083	75	75	137	44	SUM	191	00	00	245	43	RCL	299	85	+
030	42	STO	084	01	1	138	78	78	192	75	-	246	09	09	300	09	9
031	75	75	085	44	SUM	139	97	DSZ	193	43	RCL	247	85	+	301	95	=
032	82	HIR	086	76	76	140	09	09	194	09	09	248	06	6	302	82	HIR
033	17	17	087	97	DSZ	141	00	00	195	95	=	249	05	5	303	06	06
034	85	+	088	08	08	142	13	13	196	42	STO	250	95	=	304	92	RTN
035	01	1	089	00	00	143	82	HIR	197	08	08	251	42	STO	305	00	0
036	75	-	090	66	66	144	18	18	198	29	CP	252	79	79	306	00	0
037	43	RCL	091	82	HIR	145	42	STO	199	43	RCL	253	43	RCL	307	00	0
038	78	78	092	15	15	146	00	00	200	09	09	254	77	77	308	00	0
039	95	=	093	55	÷	147	85	+	201	85	+	255	55	÷	309	00	0
040	42	STO	094	53	(	148	82	HIR	202	09	9	256	73	RC*	310	00	0
041	79	79	095	43	RCL	149	16	16	203	85	+	257	09	09	311	00	0
042	42	STO	096	77	77	150	95	=	204	82	HIR	258	95	=	312	76	LBL
043	08	08	097	67	EQ	151	42	STO	205	17	17	259	72	ST*	313	13	C
044	43	RCL	098	01	01	152	76	76	206	65	×	260	79	79	314	93	.
045	78	78	099	35	35	153	06	6	207	53	(	261	97	DSZ	315	01	1
046	85	+	100	54	)	154	05	5	208	43	RCL	262	09	09	316	34	√X
047	82	HIR	101	95	=	155	85	+	209	00	00	263	01	01	317	33	X²
048	16	16	102	42	STO	156	43	RCL	210	75	-	264	76	76	318	35	1/X
049	95	=	103	77	77	157	00	00	211	01	1	265	76	LBL	319	86	STF
050	42	STO	104	68	NOP	158	95	=	212	95	=	266	99	PRT			
051	74	74	105	43	RCL	159	42	STO	213	42	STO	267	82	HIR			
052	42	STO	106	73	73	160	79	79	214	75	75	268	18	18			
053	76	76	107	42	STO	161	73	RC*	215	43	RCL	269	42	STO			

Instructions:

The purpose of the program is the solution of NDATA equations for N unknowns where N may range from 2 through 7 and the maximum NDATA is a function of N. NDATA may not be less than N.

Variables	N	2	3	4	5	6	7
Equations	$NDATA_{max}$	18	14	11	9	8	7

When NDATA exceeds N the solution is obtained by the method of least squares assuming that the N X-variables are error free.

Partitioning 8-Op-17 is used throughout.

Solution of Linear Equations by Orthogonal Householder Methods (cont)

1. Load banks 1 and 2 of program A.
2. Enter the number of variables (N) and press A. Enter the number of equations (NDATA) and press R/S. Note: N can be considered as the number of columns and NDATA as the number of rows.
3. Press D to start data entry. Enter each element and press R/S starting in the first column, and proceeding to subsequent columns until all the X data has been entered. The input data is stored sequentially beginning at register 10. The input data is printed. As each element is entered the calculator stops with the location where the next element will be stored in the display. No processing is performed as a part of data entry; therefore, you can print out the input data with 10-INV-2nd-List, and can correct erroneous entries with STO commands to the appropriate register.
4. Press C and see a flashing "10." Press 7 and EE to enter fast mode. At stop press RST.
5. Press B to start data entry for the right hand side or B-vector. The register number where the first element will be stored will be returned to the display. Enter each element in order and press R/S, but stop loading when 60 appears in the display. Any B values in registers 60 and above will be deleted when bank 2 of program is entered.
6. Press CLR. Load banks 1 and 2 of program B. Repeat step 2 above.
7. If any B values were not loaded in step 5 because storage would have been into registers 60 and above, load them using STO-XX .
8. Press C and see a flashing "10." Press 7 and EE to enter fast mode. At stop the first variable will be printed and displayed. Press R/S as many times as needed to print and display the remaining variables. Note: The first variable is stored in register 66 with the remaining variables in sequence in the subsequent registers.
9. To solve for a different right hand side (set of B-values) and the same N and NDATA, repeat steps 6 through 8.

Note: The values of the summations of squares which are printed in mode C with program A (step 4 above) are indications of the progress of the solution. Values of this sum less than 1e-20 lead to a warning stop. The matrix may be singular. Press R/S and continue at your own risk.

Sample Problems:

One sample problem is the 7 x 7 sub-Hilbert which we have used as a benchmark to evaluate other methods of solution of simultaneous equations (see V8N6P18). The results from that problem are compared with the results obtained with ML-02 and ML-02 with double-divides on page 24. It will be seen that the Householder program yields better results than ML-02, but poorer results than ML-02 with double-divides.

The second sample problem is a least squares polynomial curve fit with degree 3 (matrix order 4) which was used as the example in James A. Walston's "Least-Mean-Square Fit of a Polynomial" program (PPX 398010) and repeated in Palmer Hanson's "Polynomial Curve Fit with Errors" (PPX 208059); that is, to fit a third degree polynomial to the data

X	-7	-4	0	2	5
Y	-81	27	3	27	243

Solution of Linear Equations by Orthogonal Householder Methods (cont)

where the x and y values correspond exactly to the euqation

$$y = 3 - 2x + 5x^2 + x^3$$

The columns for the left hand side (step 3) must include the values of x raised to the zero, first, second and third power. Thus, the first column is all ones, the second column is the x values, the third column is the x values squared, and the fourth column is the x values cubed. N is 4 and NDATA is 5. The right hand side (step 5) is made up of the y values. The results from three methods of solution including all thirteen digits are:

ML-02 (PPX 398010)	Householder	ML-02 plus Double-divide
2.99999998722	2.99999999751	3.00000000000
-1.99999999804	-1.99999999989	-2.00000000002
5.00000000045	5.00000000003	4.99999999999
.9999999999972	1.000000000000	.9999999999996

where the solution with the ML-02 plus double-divide was obtained by recovering the appropriate sums from the printout accompanying the PPX 398010 execution, and entering them appropriately. For the 7 x 7 sub-Hilbert problem the results, again to all thirteen digits, are:

Exact	ML-02	Householder	ML-02 Plus
56	56.00818974480	56.00205338452	55.99917749600
-1512	-1512.189567429	-1512.048402327	-1511.980645638
12600	12601.38627848	12600.35696822	12599.85720361
-46200	-46204.53435755	-46201.17229239	-46199.53040737
83160	83167.37180486	83161.90927078	83159.23383982
-72072	-72077.82742612	-72073.51019112	-72071.39284591
24024	24025.78601210	24024.46282921	24023.81357950

If the solution vector is combined with the original matrix in the manner discussed on V9N2P18 the results placed vertically in-line with the corresponding solution above, are:

1	1.000000052	1.000000031	0.999999997
1.000000003	1.000000007	1.000000001	1.000000006
1	1.000000019	0.999999998	0.999999996
1	1.000000019	1.000000002	1.000000001
1.000000001	1.000000019	1.000000007	1.000000003
1	1.000000003	1.000000002	1.000000002
1	1.000000013	1.000000004	1.000000002

where due to truncation in the calculator, even the exact solution combined with the original matrix yields some error.

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Magnetic card service and card reader cleaning cards continue to be available at the rates formerly quoted.

RCR