Department of Applied Analysis
and Computer Science
University of Waterloo

Technical Report CS-73-20
May, 1973

A Tutorial Guide to Superplot
APL Routines for Plotting Functions

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Introduction

The author has spent many frustrating hours trying to sketch the graphs of functions both for himself and for students. Even though plotters are available at most computer sites, including the one here at the University of Waterloo, it takes more expertise and time to use them then most people can afford. However, the APL programming language, and 2741 terminals are generally available and easy to use. Add to these facts the existence of a special IBM high resolution typeball, the fast formatting function *ΔFMT* from I. P. Sharp's distributed version of APL-Plus, and a program to use all these items together, and you have a reasonably easy to use method of plotting wide classes of functions.

The reader should already know the basics of how to sign on to a time-sharing terminal, and how to define functions in APL. The following pages present a tutorial guide to the use of the plotting functions available in library 701, workspace Superplot, on the APL-Plus service offered by the Computing Centre at the University of Waterloo.

The overall design of the workspace consists of one main user function called PLOT, which does the actual computation of the graph, and a large selection of variables which can be reset to change the size, or labelling, or density, or type of plotting done by the main function. When the author proudly presented the fledgling version of these routines to a friend for testing, some months ago, the first test function used was of the form

$$F(X,Y) = 0 \quad \text{(Cartesian Twoplot)}$$

and, of course, the author had anticipated only functions of the form

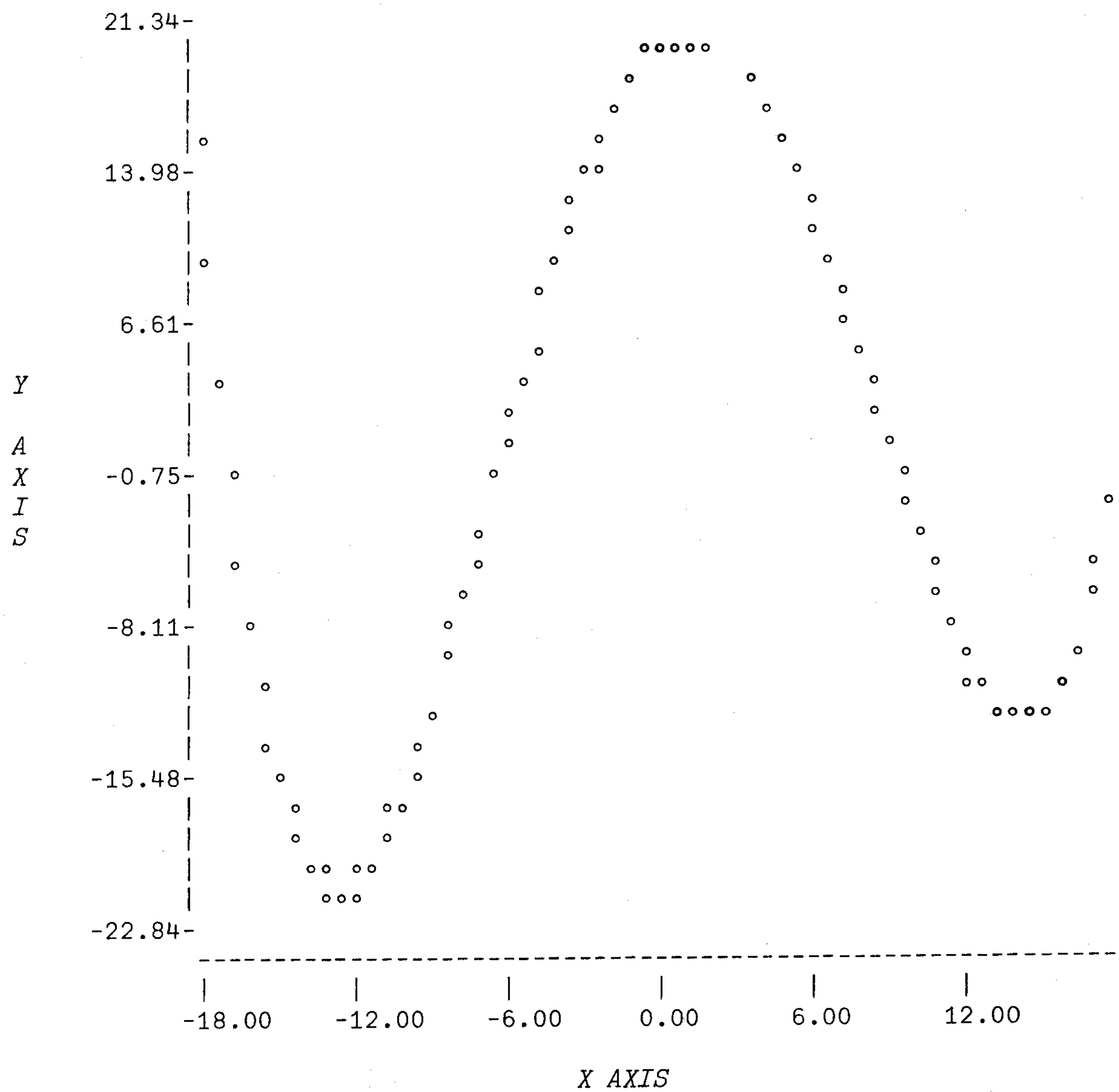
$$Y = F(X) \quad \text{(Cartesian Oneplot)}$$

So, in an effort to avoid further embarrassments of the same nature, the present version will plot any function definable in the APL language of both of the above types, as well as the corresponding types for Polar and Parametric equations involving two variables. The facilities to accumulate graphs and to plot a matrix using the first column as abscissas were added as afterthoughts.

WORKSPACE 701 SUPERPLOT

THIS WORKSPACE IS DESIGNED TO PLOT GRAPHS FOR ANY FUNCTIONS DEFINABLE IN THE APL LANGUAGE. HERE IS AN EXAMPLE FROM A TYPICAL TERMINAL SESSION - WHICH YOU CAN, AND PERHAPS SHOULD, DUPLICATE FOR YOURSELF.

```
      )LOAD 701 SUPERPLOT
SAVED 21.59.46  25/02/73

      PLOT

⎕:

      (.00114×X*4)+(¯.0049×X*3)+(¯.405×X*2)+(1.178×X)+19.125
```



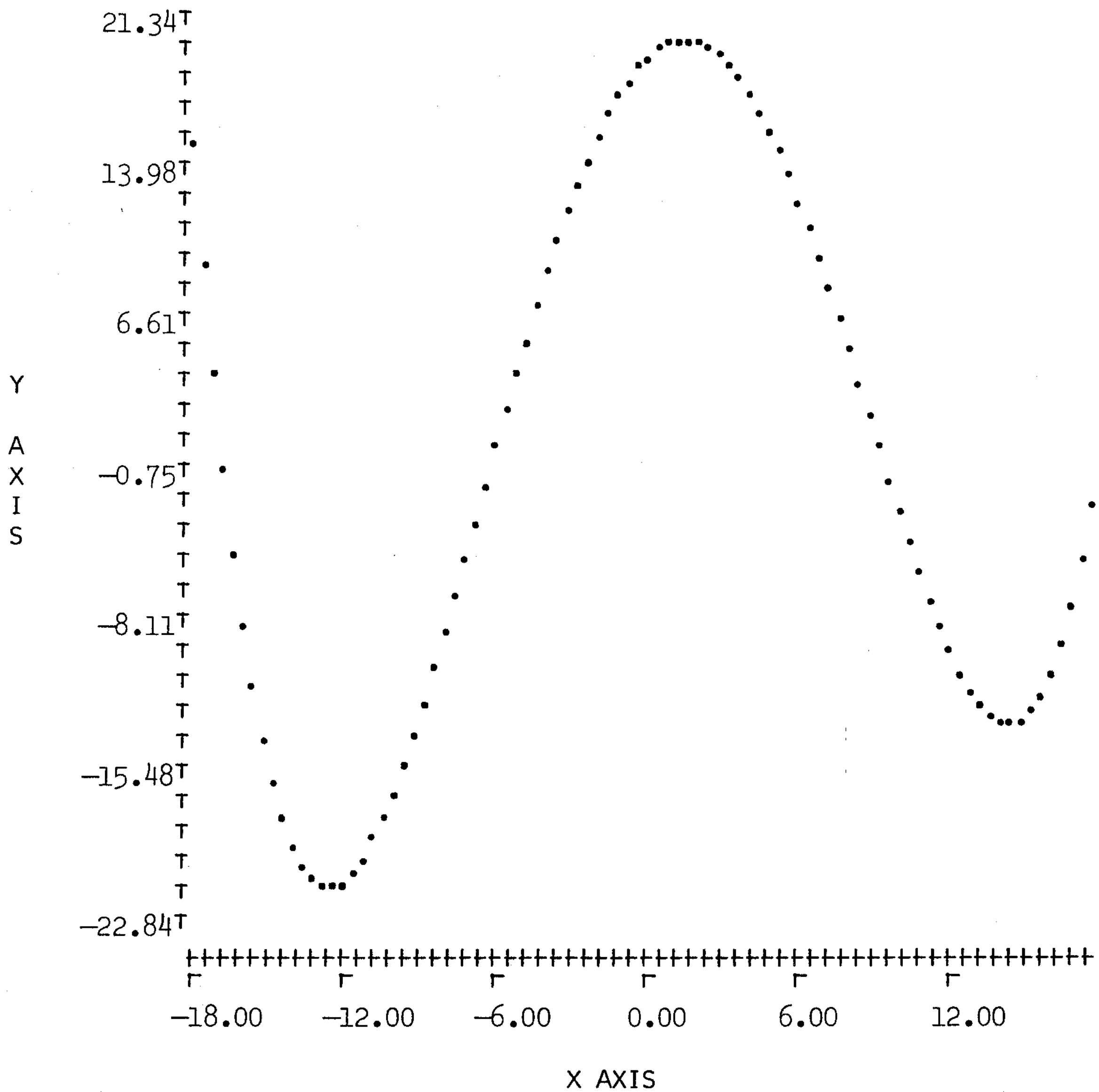
NICE AS THIS GRAPH IS, IT COULD BE NICER. FOR EXAMPLE, WE MIGHT LIKE A MUCH SMOOTHER PLOT. BY USING THE IBM HIGH RESOLUTION TYPEBALL, IF YOU ARE LUCKY ENOUGH TO HAVE ONE, WE PROCEED TO PLOT THE SAME GRAPH. BUT FIRST WE TURN ON THE FINEPLOT OPTION BY TYPING

FINEPLOT

NOW WE CALL THE PLOT FUNCTION AGAIN: THEN CHANGE THE TYPEBALL ONLY AFTER TYPING IN THE FUNCTION, AND BEFORE PRESSING THE CARRIAGE RETURN.

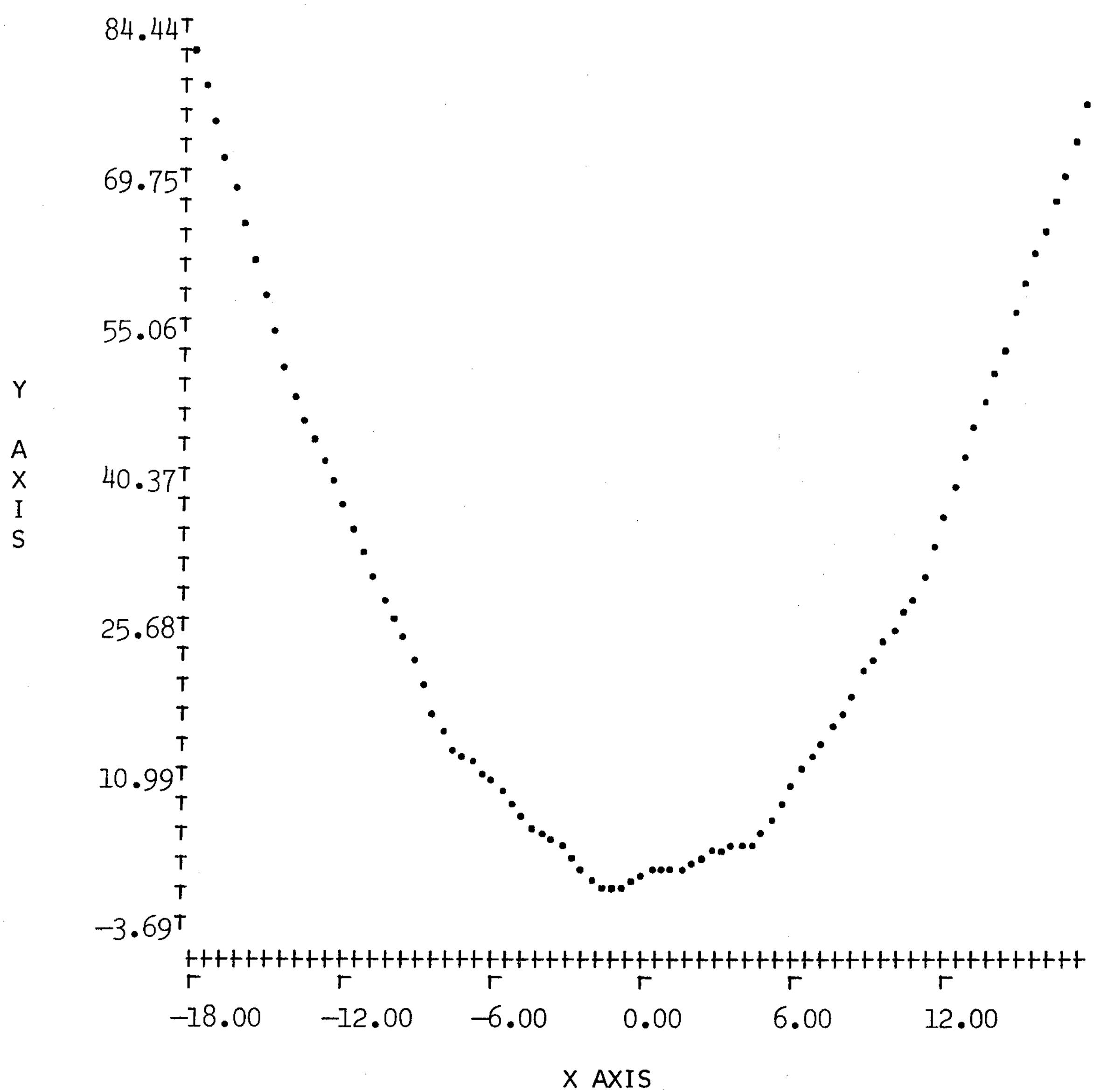
PLOT

```
⎕:

      (.00114×X*4)+(¯.0049×X*3)+(¯.405×X*2)+(1.178×X)+19.125
```



THESE LAST EXAMPLES HAVE BEEN QUITE ARTIFICIAL AND DISHONEST. MOST OF THE TIME YOUR FIRST PLOT WILL NOT BE VERY SATISFACTORY - FOR MANY REASONS. WATCH WHAT HAPPENS WITH SOMETHING MORE TYPICAL, SAY WITH THE EQUATION

```
Y = (SIN X) + .5(COS 2X) + .25(X*2)

⍝THE FINEPLOT OPTION IS STILL IN EFFECT.
⍝TO CANCEL FINEPLOT TYPE  REGULAR

⍝NOTE THAT SIN X  IS 1○X  AND COS 2X  IS 2○2×X  IN APL

PLOT

⎕:

(1○X)+(.5×2○2×X)+.25×X*2
```

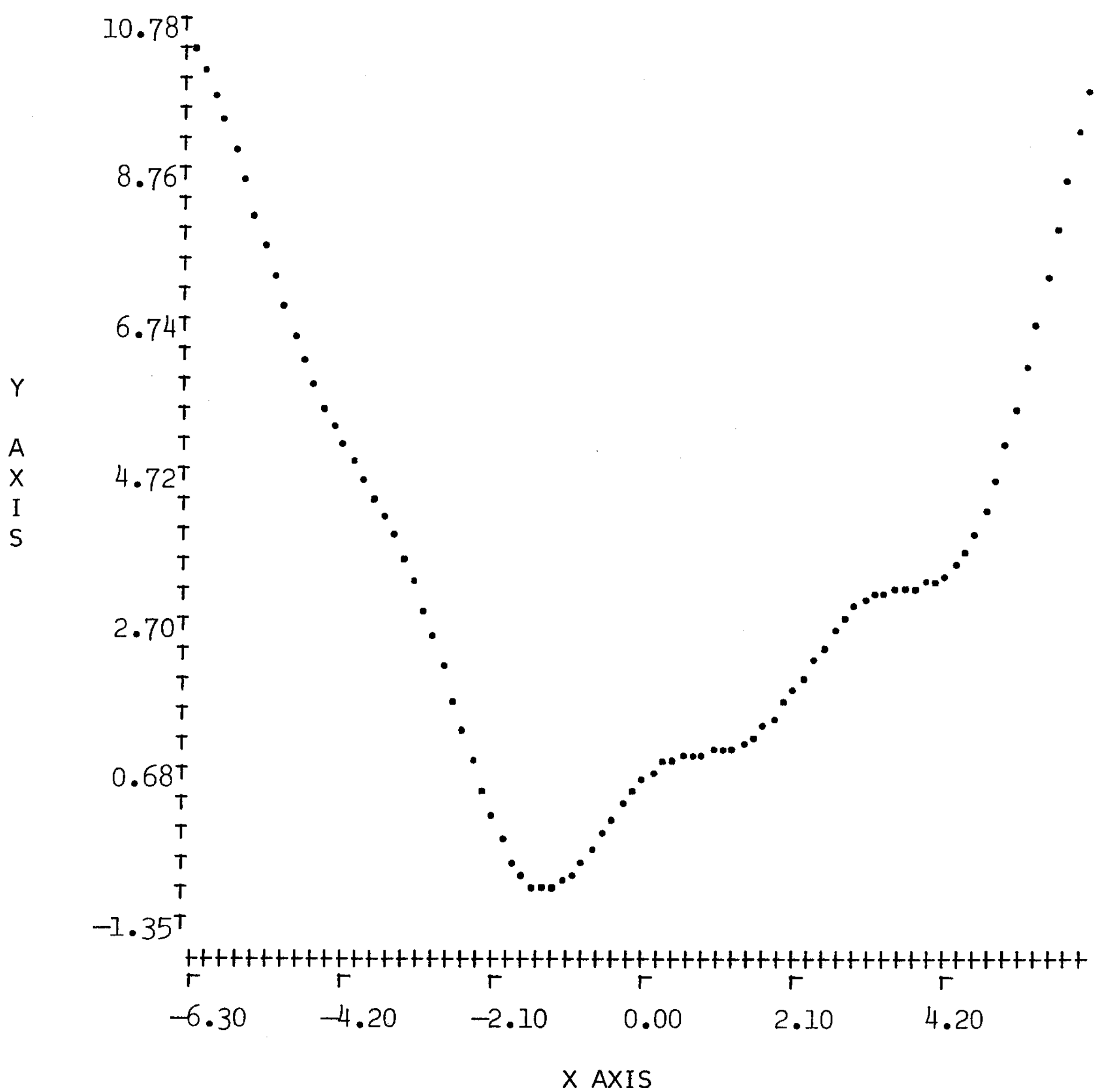


THE MOST INTERESTING PART OF THIS LAST GRAPH IS ABOVE THE X-AXIS IN THE REGION WHERE X = 0. BUT WE CAN'T BE SURE IF THOSE WIGGLES ARE PRINT IRREGULARITIES OR TRUE GRAPHICAL VARIATIONS. TO MAGNIFY THAT PORTION OF THE GRAPH WE RESET OUR X AND Y LIMITS ON THE AXES AS FOLLOWS:

```
⍝TO RESET THE MAX AND MIN VALUE OF THE X-VALUES

XMI←¯6.3
XMA←6.3

⍝AND NOW TO REPLOT BY CALLING THE PLOT FUNCTION

PLOT
```

⎕:

(1○X)+(.5×2○2×X)+.25×X*2



OBVIOUSLY THE GRAPH WAS MISBEHAVING AND NOT THE TYPEWRITER! NOW IT LOOKS LIKE THERE MAY OR MAY NOT BE A RELATIVE EXTREMA AT ABOUT X=3.6. *LET'S TAKE A REALLY CLOSE LOOK AT THAT PART OF THE GRAPH UNDER A MAGNIFYING GLASS. FIRST WE RESET OUR LIMITS*

```
XMI←3.59
XMA←3.65
```

BEFORE WE PLOT NOTE THAT THE RATE OF RISE OF THE GRAPH BETWEEN THESE TWO X LIMITS IS NOT VERY GREAT. IN FACT THE CHANGE IN THE Y VALUE IS FROM 3.100336 *TO* 3.107019. *SO WE WILL NEED MORE DECIMALS SHOWING IN THE VALUES ALONG THE Y-AXIS. WE GET THEM BY TYPING*

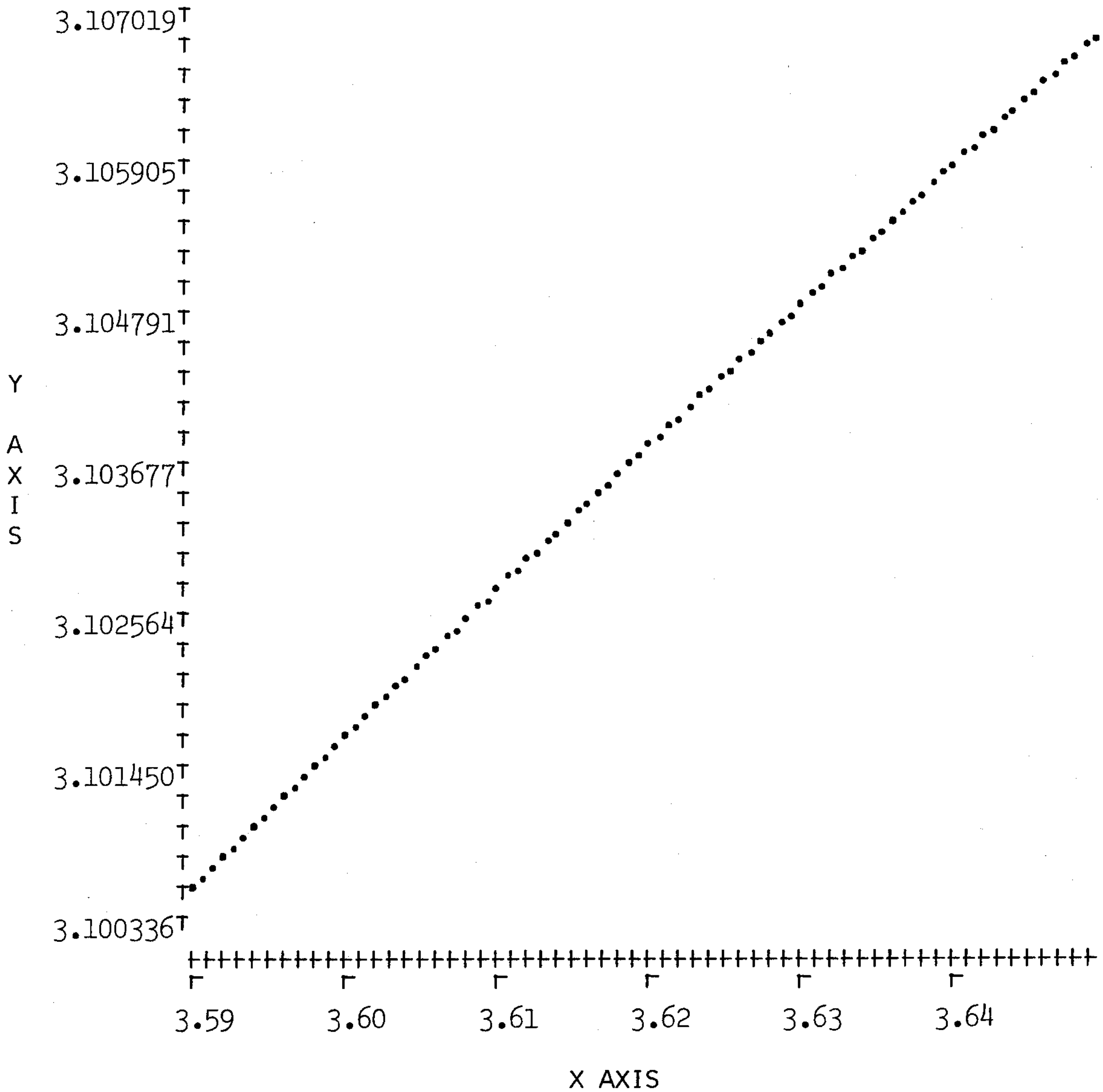
```
YFORMAT '10.6'
```

WHICH WILL GIVE US 10 *PLACES FOR EACH Y VALUE, AND* 6 *DECIMALS. AND NOW WE REPLOT*:

```
PLOT
```

⎕:

```
(1○X)+(.5×2○2×X)+.25×X*2
```


3.107019
3.105905
3.104791
3.103677
3.102564
3.101450
3.100336
Y AXIS
3.59
3.60
3.61
3.62
3.63
3.64
X AXIS

CLEARLY THIS GRAPH HAS NO EXTREMA IN THE GIVEN RANGE! AS A VARIATION, WE MIGHT LIKE TO FIND THE INTERSECTIONS OF THIS LAST GRAPH WITH THE CURVE

8 - *X*⋆2 - 2*X* - *COS X*

TO DO THIS WE FIRST RESET OUR LIMITS AND THE Y FORMAT:

```
XMI←¯6
XMA←6
YFORMAT '10.2'
```

AND WATCH CAREFULLY TO SEE HOW WE GET BOTH CURVES TOGETHER!

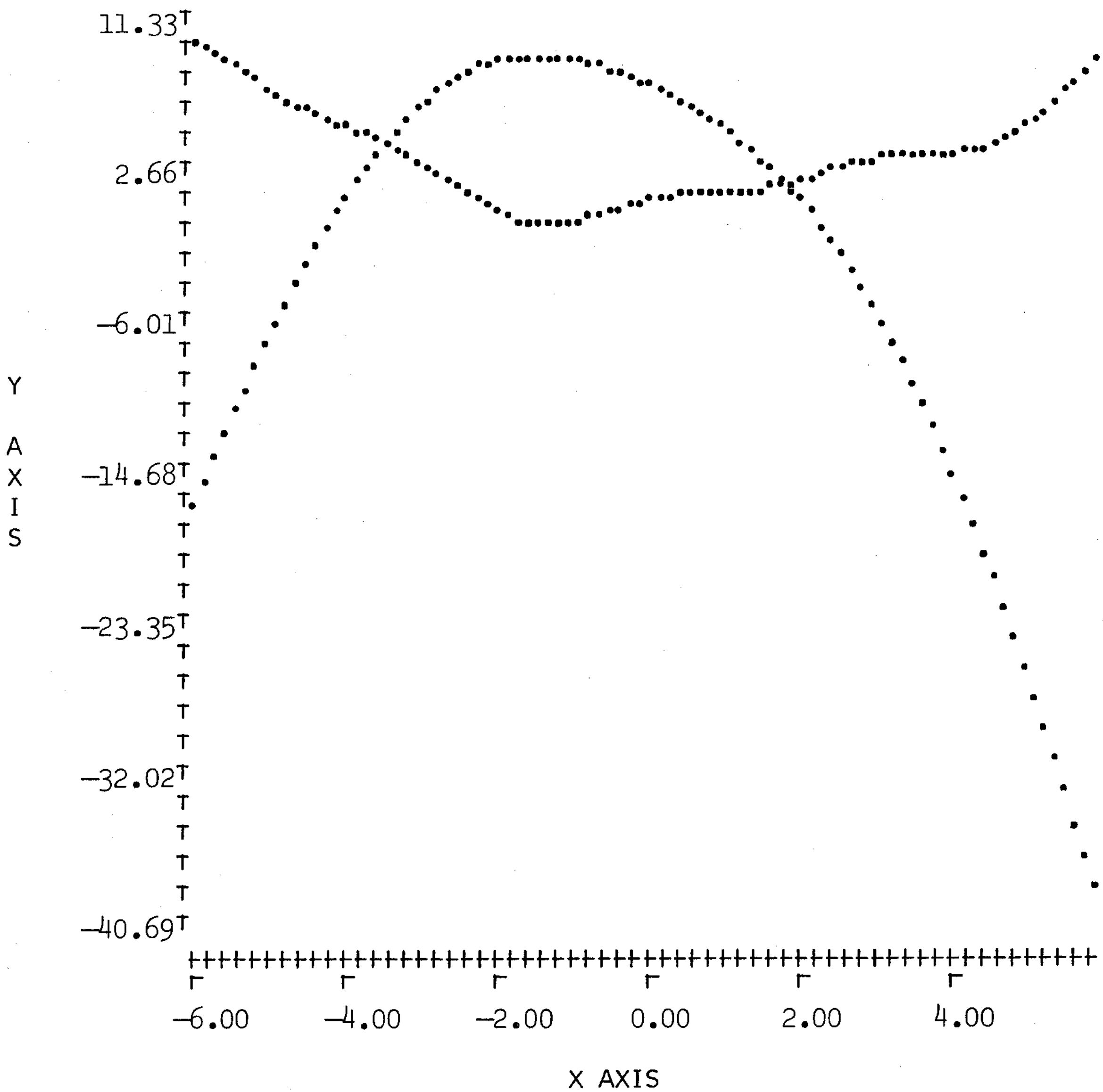
```
PLOT
```

⎕:

```
⎕,((1○X)+(.5×2○2×X)+(.25×X⋆2))
```

⎕:

```
(8+(-X⋆2)+(¯2×X)+(-2○X))
```


11.33
2.66
-6.01
-14.68
-23.35
-32.02
-40.69
Y AXIS
-6.00
-4.00
-2.00
0.00
2.00
4.00
X AXIS

WHEN YOU USE THIS DEVICE, REMEMBER ALWAYS TO ENCLOSE YOUR ENTIRE FUNCTION IN EACH LINE WITHIN BRACKETS, JUST AS WE DID ABOVE, OTHERWISE YOU WILL GET GARBAGE OUT. THE INTERSECTION POINTS OF THESE TWO GRAPHS APPEAR TO BE AT ABOUT AN X VALUE OF -3.5 *AND* 1.8. *BY REPLOTTING THE CURVE, WHICH WE WILL NOT DO, AND RESETTING THE LIMITS FOR X YOU COULD PLOT THESE POINTS EVEN MORE ACCURATELY.*

CARTESIAN TWOPLOT

IF WE NOW PLOT THE FUNCTION

```
(10×X*2) + (5×Y*2) + (¯14×X×Y) - 1 = 0
```

THIS IS HOW WE PROCEED.

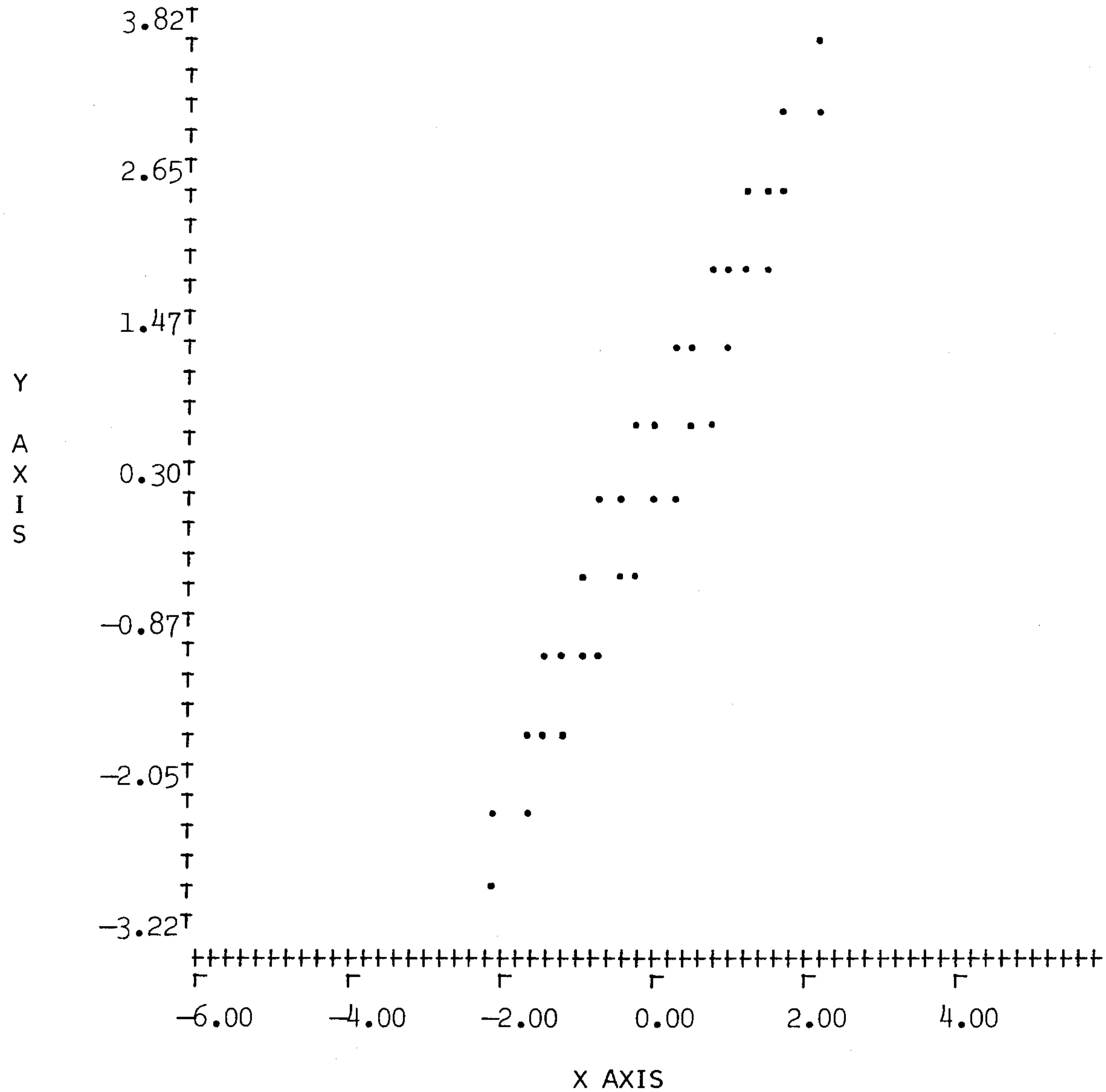
```
      CARTESIAN TWOPLOT
```

NOW DEFINE A FUNCTION

```
      ∇ R ← FCN X
[1]   R ← YOUR FUNCTION OF VARIABLES X AND Y ∇
```

AND THEN TYPE PLOT

```
      ∇ R ← FCN X
[1]   R ← (10×X*2)+(5×Y*2)+(¯14×X×Y)-1∇

      PLOT
```

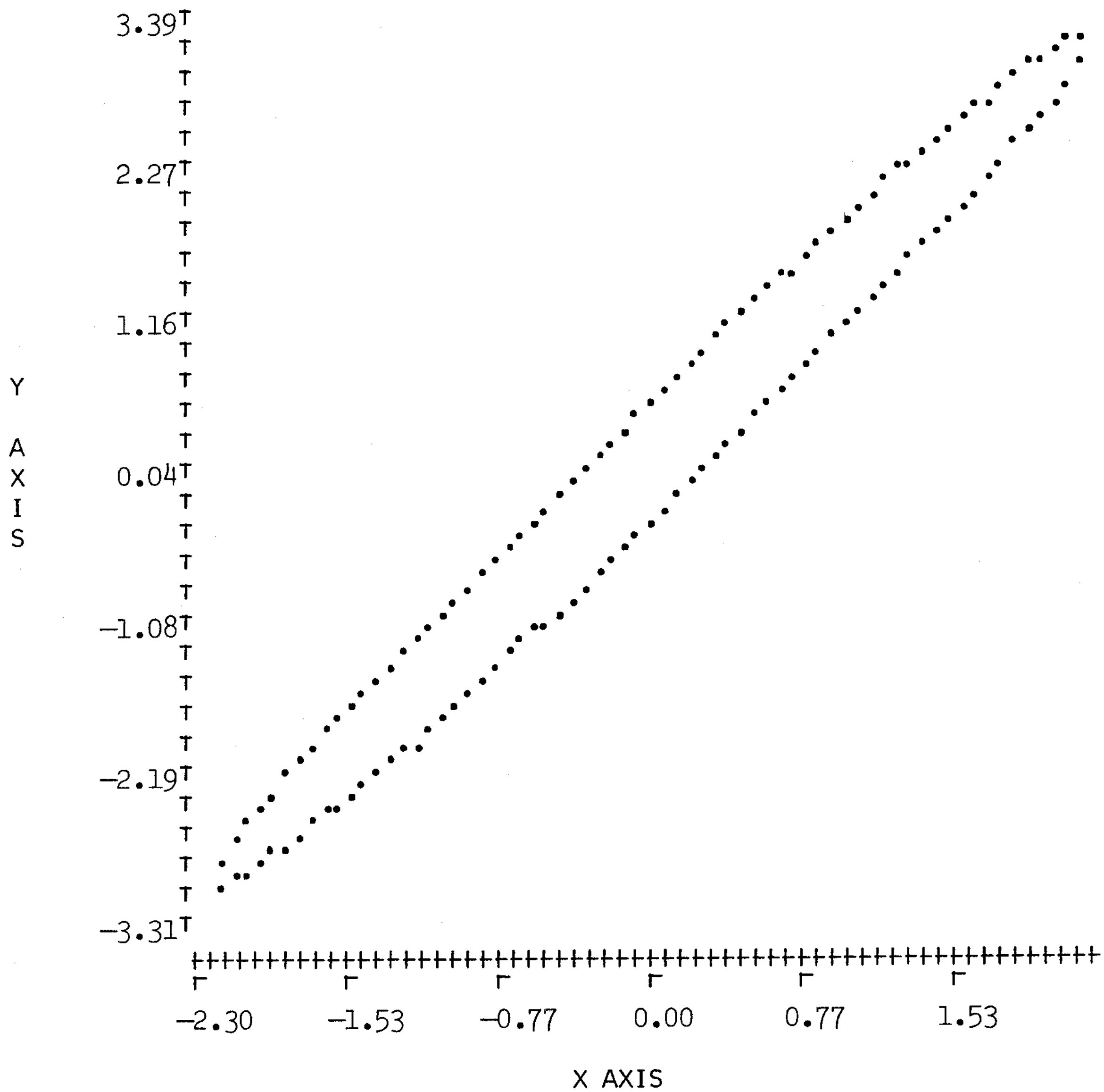

3.82
2.65
1.47
0.30
-0.87
-2.05
-3.22
Y AXIS
-6.00
-4.00
-2.00
0.00
2.00
4.00
X AXIS

THIS GRAPH IS TERRIBLY BAD, AND CAN BE GREATLY IMPROVED BY RESETTING OUT LIMITS TO

```
      XMI←¯2.3
      XMA←2.3
```

AND INCREASING THE PLOTTING DENSITY BY TYPING

```
      DENSITY 7
WAS 5

      PLOT
```



PARAMETRIC ONEPLOT

TO PLOT EQUATIONS SUCH AS THE FOLLOWING

$$X = .3T - SIN\ T$$
$$Y = .3 - COS\ T$$

WE WOULD PROCEED AS FOLLOWS. OUR FIRST COMMAND RESETS ALL THE OPTIONS AND PARAMETERS TO THEIR ORIGINAL DEFAULT VALUES.

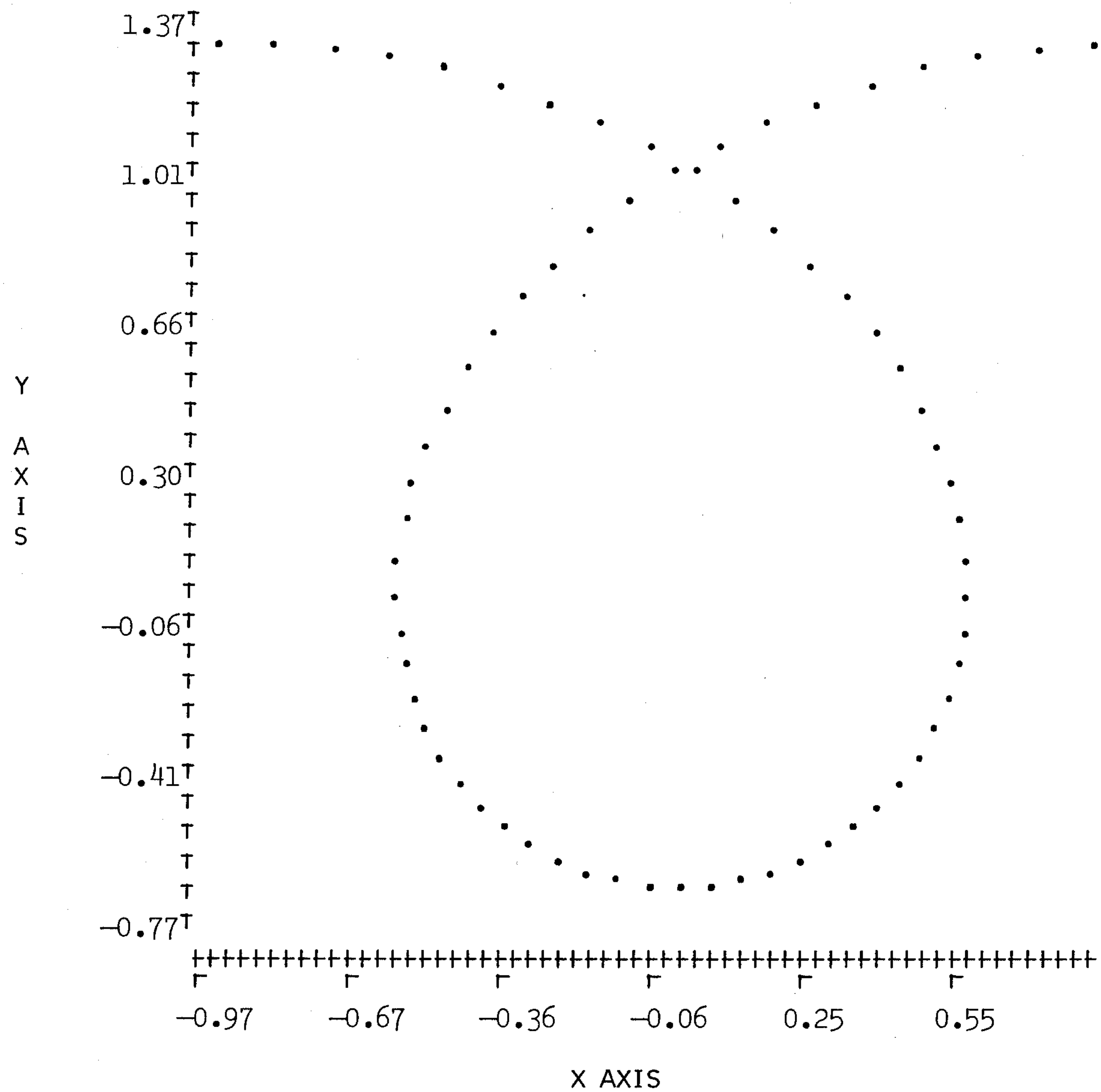
```
DEFAULT
FINEPLOT
PARAMETRIC ONEPLOT
```

NOW DEFINE A FUNCTION

```
     ∇PFN
[1]  X ← YOUR FUNCTION OF THETA
[2]  Y ← YOUR FUNCTION OF THETA ∇
```

SO WE NOW GO AHEAD TO DEFINE THE FUNCTION JUST AS REQUESTED.

```
     ∇PFN
[1]  X ← (.3×THETA)-1○THETA
[2]  Y ← .3-2○THETA ∇

     PLOT
```

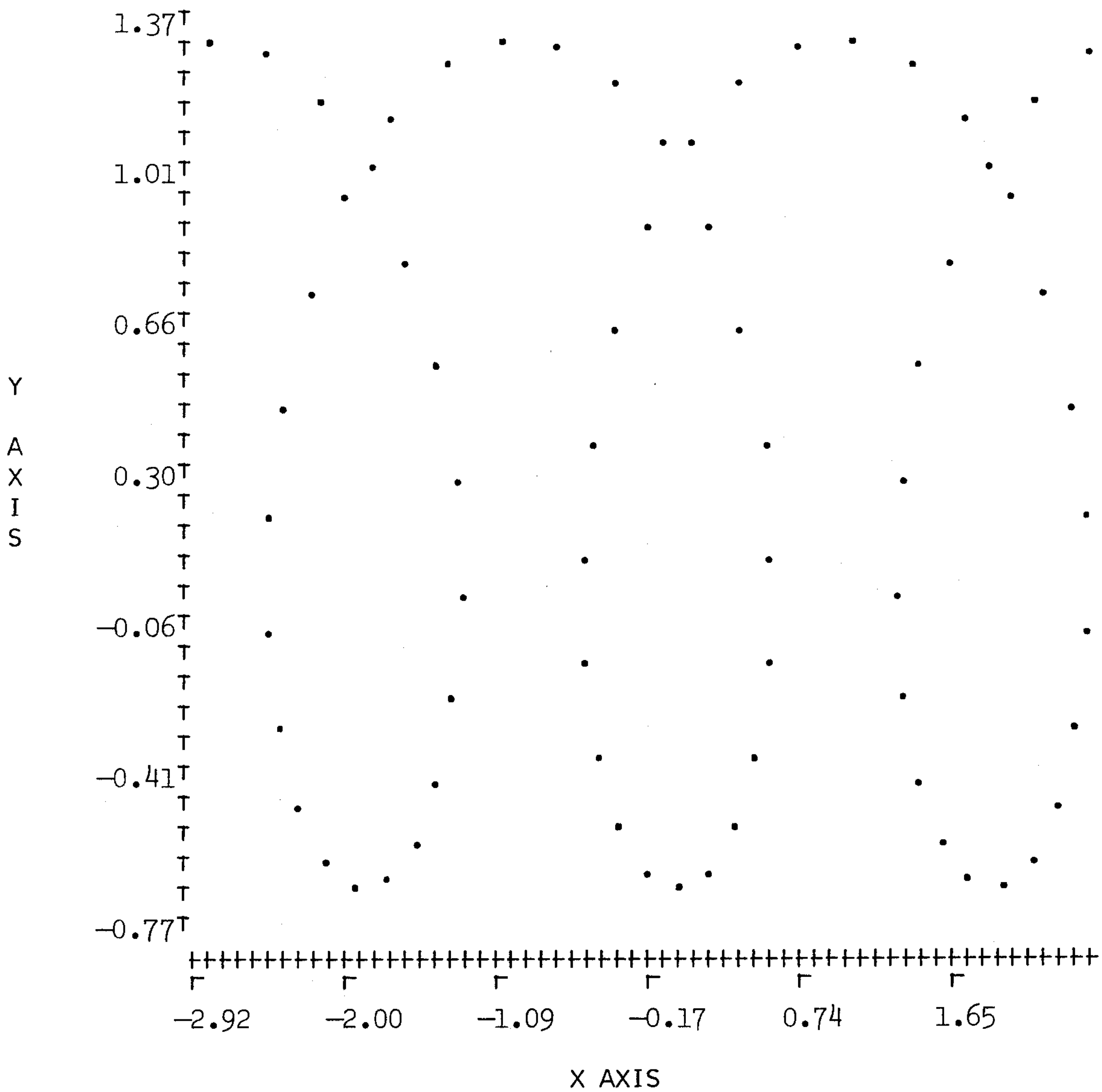

1.37
1.01
0.66
0.30
-0.06
-0.41
-0.77
Y AXIS
-0.97
-0.67
-0.36
-0.06
0.25
0.55
X AXIS

IF YOU MIGHT LIKE A PICTURE OF MORE OF THIS GRAPH, WE WOULD HAVE TO RESET THE DEFAULT LIMITS ON THE PARAMETER THETA FROM ¯3.14 *AND* 3.14 *TO SOMETHING LIKE THE FOLLOWING, SAY*

```
TMI←¯9.5
TMA←9.5
```

AND THEN PLOT AGAIN

```
PLOT
```

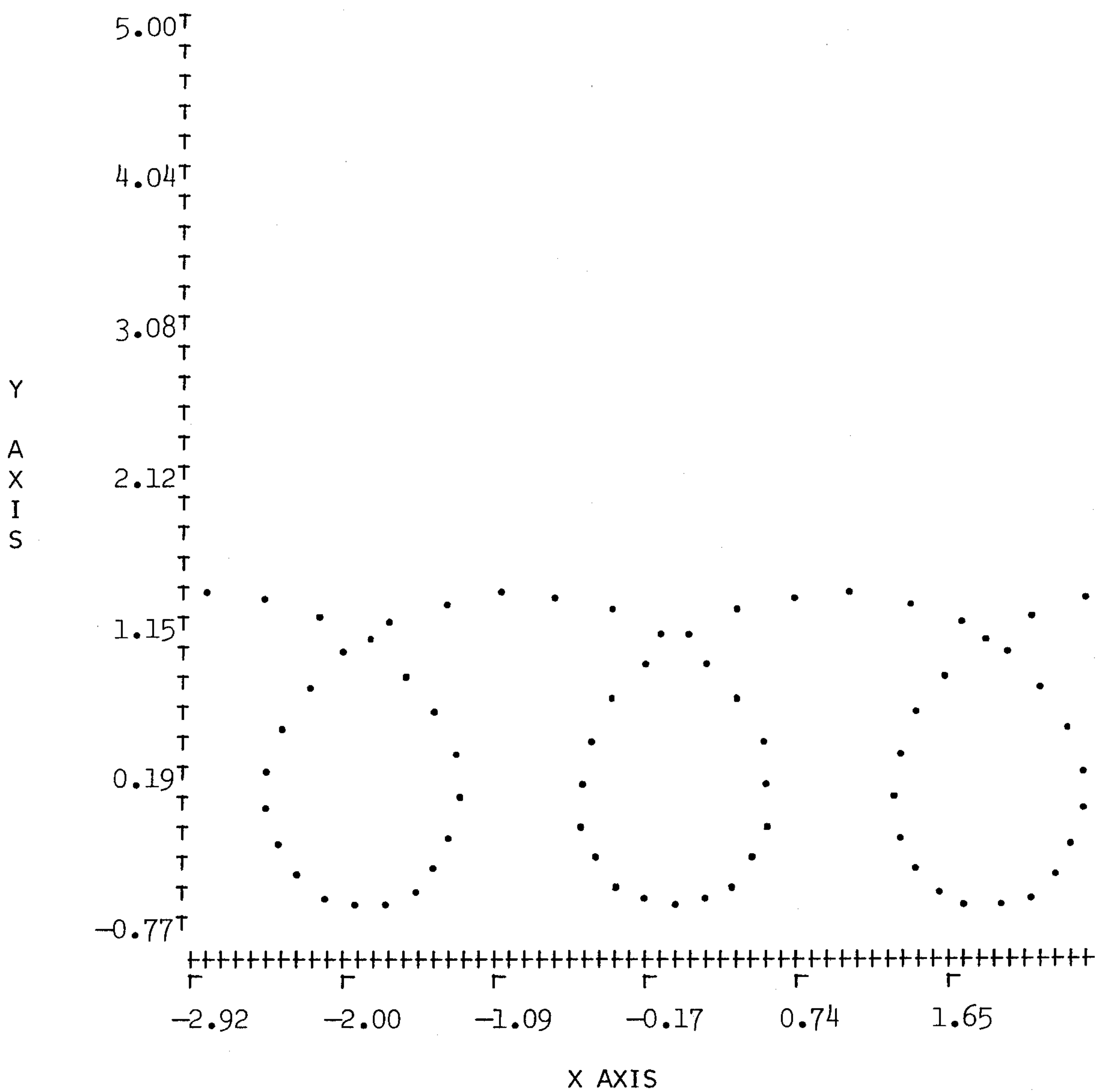


FINALLY, WE OBSERVE THAT THE SCALING ON THE Y-AXIS IS GROSSLY EXAGGERATED. TO MAKE THE X AND Y AXIS SCALING APPROXIMATELY EQUAL WE TURN OFF THE AUTOMATIC SCALING FOR THE Y-AXIS BY TYPING

```
AUT←0
```

AND THEN RESET THE Y-AXIS LIMITS TO THE MORE REALISTIC VALUES OF

```
YMA←5
YMI←¯.77

PLOT
```



PARAMETRIC TWOPLOT

TO PLOT EQUATIONS OF THE FORM

$$X(1+T*3) - 3T = 0$$
$$Y(1+T*3) - 3T*2 = 0$$

WE PROCEED AS FOLLOWS:

```
      DEFAULT

      FINEPLOT

      PARAMETRIC TWOPLOT
```

NOW DEFINE A FUNCTION

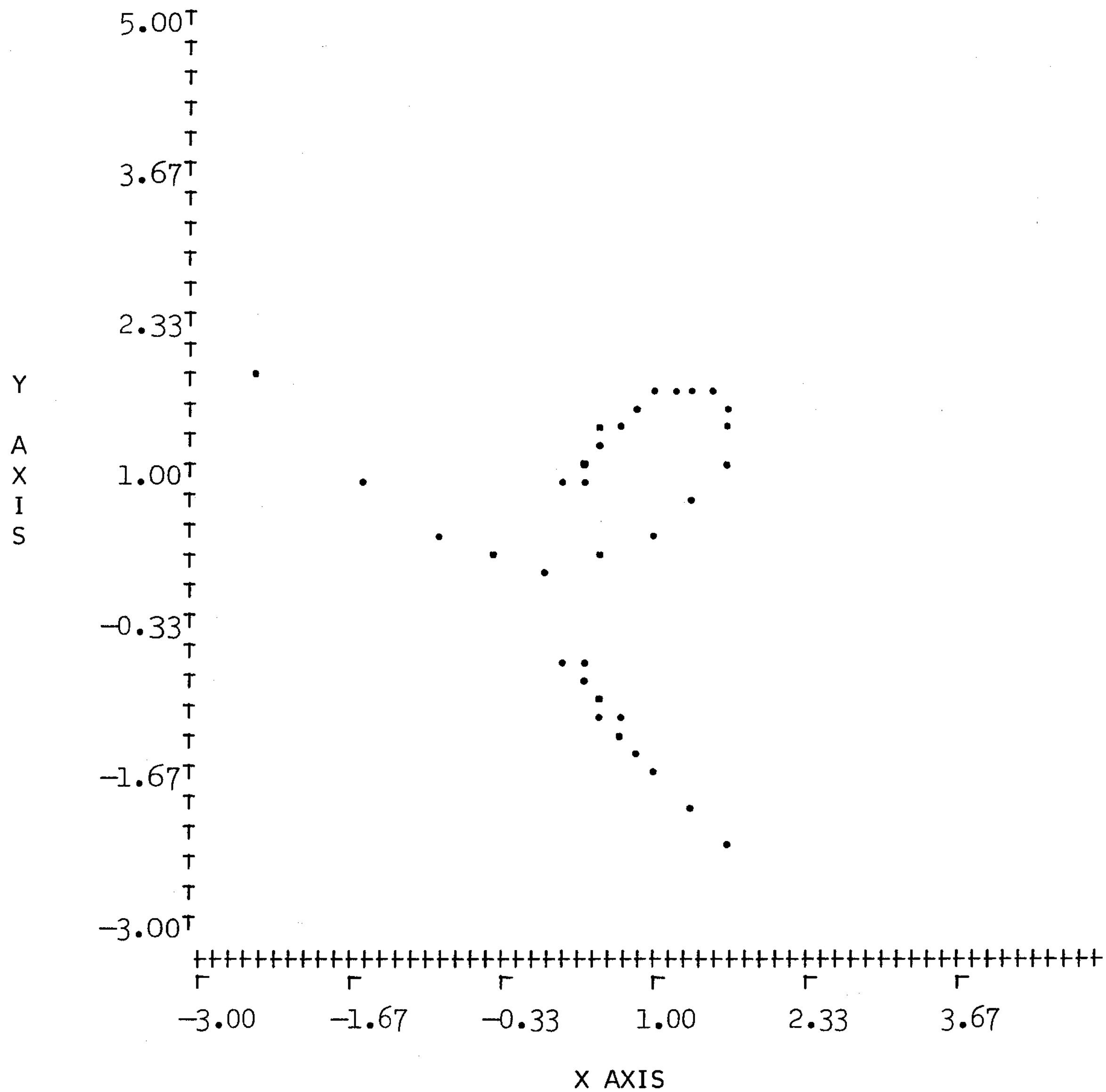
```
      ∇ PPP THETA
[1]  TX ← YOUR FUNCTION OF VARIABLES X AND THETA
[2]  TY ← YOUR FUNCTION OF VARIABLES Y AND THETA ∇
```

AND WE NOW DEFINE THE FUNCTION PPP AS REQUESTED:

```
      ∇PPP THETA
[1]  TX ← (X×1+THETA*3)-3×THETA
[2]  TY ← (Y×1+THETA*3)-3×THETA*2 ∇
```

OUR PREPARATION IS COMPLETED, SO WE CALL THE PLOTTING FUNCTION:

```
      PLOT
```

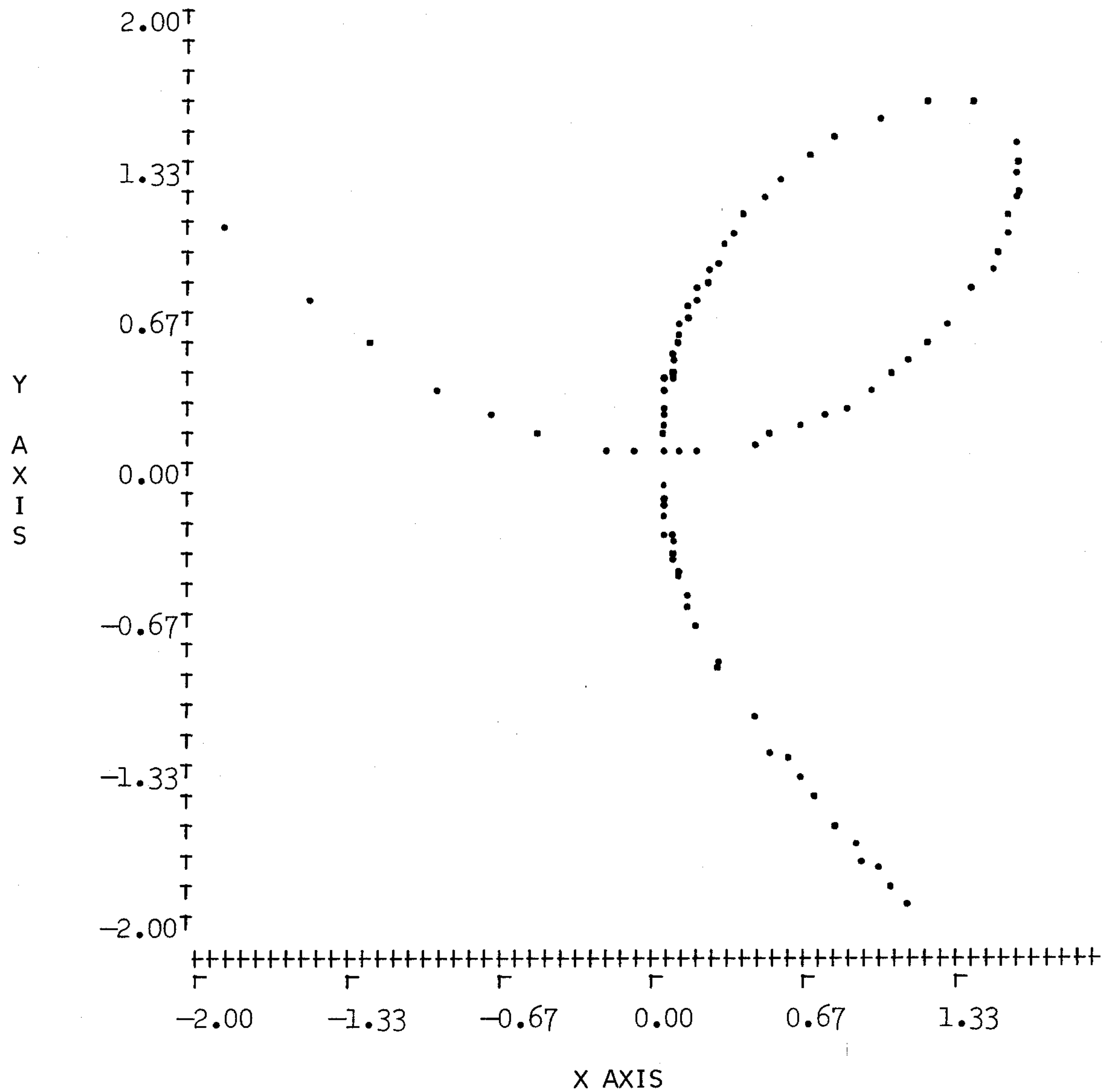

5.00
3.67
2.33
1.00
-0.33
-1.67
-3.00
Y AXIS
-3.00
-1.67
-0.33
1.00
2.33
3.67
X AXIS

THIS GRAPH IS CERTAINLY NOT VERY SATISFACTORY. ANALYZING OUR EQUATIONS WE CAN EASILY SEE THAT THE X AND Y VALUES ARE NOT EVENLY DISTRIBUTED WITH RESPECT TO THE DISTRIBUTION OF THE VALUES OF THE PARAMETER THETA. IN ORDER TO GET A BETTER DISTRIBUTION OF POINTS WE PREDETERMINE THE VALUES OF THETA TO BE USED IN PLOTTING:

```
      TGRID
REPLACE OLD THETA OR CATENATE?
REPLACE
ENDPOINTS?
⎕:
      ¯20 ¯10
HOWMANY SUBDIVISIONS?
⎕:
      10
ENDPOINTS?
⎕:
      ¯10 ¯2
HOWMANY SUBDIVISIONS?
⎕:
      15
ENDPOINTS?
⎕:
      ¯2 ¯1.5
HOWMANY SUBDIVISIONS?
⎕:
     10
```

AND WE KEEP THIS UP TO GET 10 *POINTS IN* ¯1.5 *TO* ¯1.1, 5 *POINTS IN* ¯1.1 *TO* ¯.9, 10 *POINTS IN* ¯.9 *TO* ¯.1, 10 *POINTS IN* ¯.1 *TO* .1, 10 *POINTS IN* .1 *TO* .5, 15 *POINTS IN* .5 *TO* 3, 10 *POINTS IN* 3 *TO* 9, 10 *POINTS IN* 9 *TO* 10,30 *POINTS IN* 1 *TO* 10, *AND* 5 *POINTS IN* 10 *TO* 30. *WE EXIT FROM THE TGRID PROGRAM SIMPLY BY ENTERING THE NUMBER* 0 *ALONE TO THE ENDPOINTS QUERY. NOW WE RESET OUR LIMITS AND REPLOT:*

```
      XMI←YMI←¯2
      XMA←YMA←2
      AUT←0
      ⍝THIS LAST COMMAND TURNS OFF THE AUTOMATIC SCALING
      PLOT
```


2.00
1.33
0.67
0.00
-0.67
-1.33
-2.00
Y AXIS
-2.00
-1.33
-0.67
0.00
0.67
1.33
X AXIS

POLAR ONEPLOT

TO PLOT POLAR CURVES OF THE FORM R = F(THETA), FOR EXAMPLE:

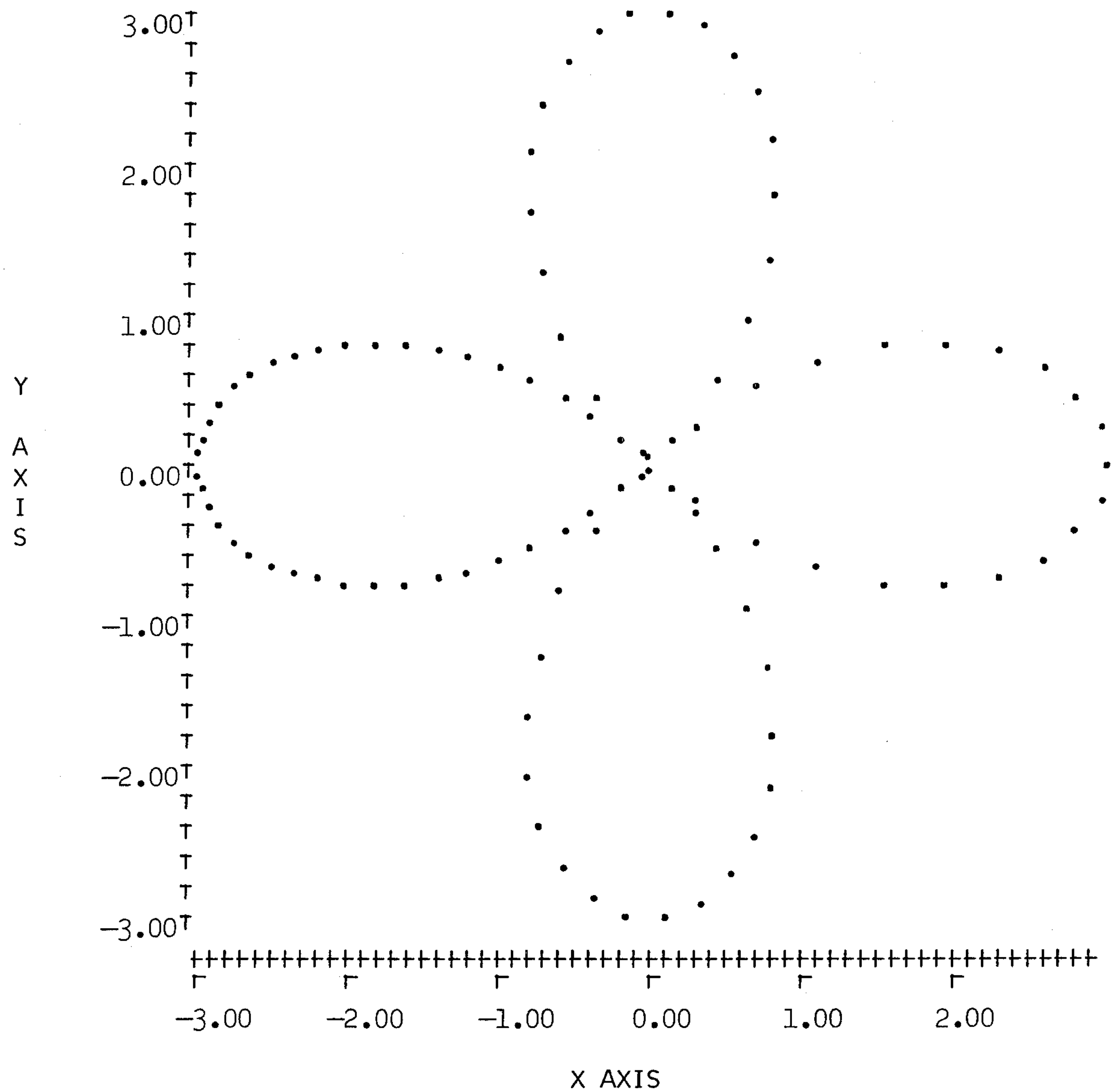
R = 3(*COS 2THETA*)

WE PROCEED IN THE FOLLOWING FASHION. FIRST WE SET THE POLAR PLOTTING OPTIONS:

```
      POLAR ONEPLOT
```

NOW INPUT YOUR FUNCTION OF THE VARIABLE THETA AFTER TYPING PLOT

```
      XMI←YMI←¯3
      XMA←YMA←3
      TGR←0
      ⍝THIS LAST COMMAND SHUTS OFF THE TGRID OPTION SWITCH
      AUT←0
      DENSITY 10
WAS 5
      PLOT
⎕:
      3×2○2×THETA
```


3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
Y AXIS
-3.00
-2.00
-1.00
0.00
1.00
2.00
X AXIS

POLAR TWOPLOT

AS A FINAL EXAMPLE, WE TACKLE POLAR EQUATIONS SIMILAR TO THE FOLLOWING EXAMPLE:

(*R*⋆2) - 4*SIN 2THETA* = 0

AND WE PROCEED AS FOLLOWS:

```
      POLAR TWOPLOT
```

NOW DEFINE A FUNCTION

```
      ∇Z ← PPF THETA
[1]  Z ← YOUR FUNCTION OF VARIABLES R AND THETA ∇
```

AND THEN TYPE PLOT

AND AS REQUESTED WE NOW DEFINE OUR FUNCTION:

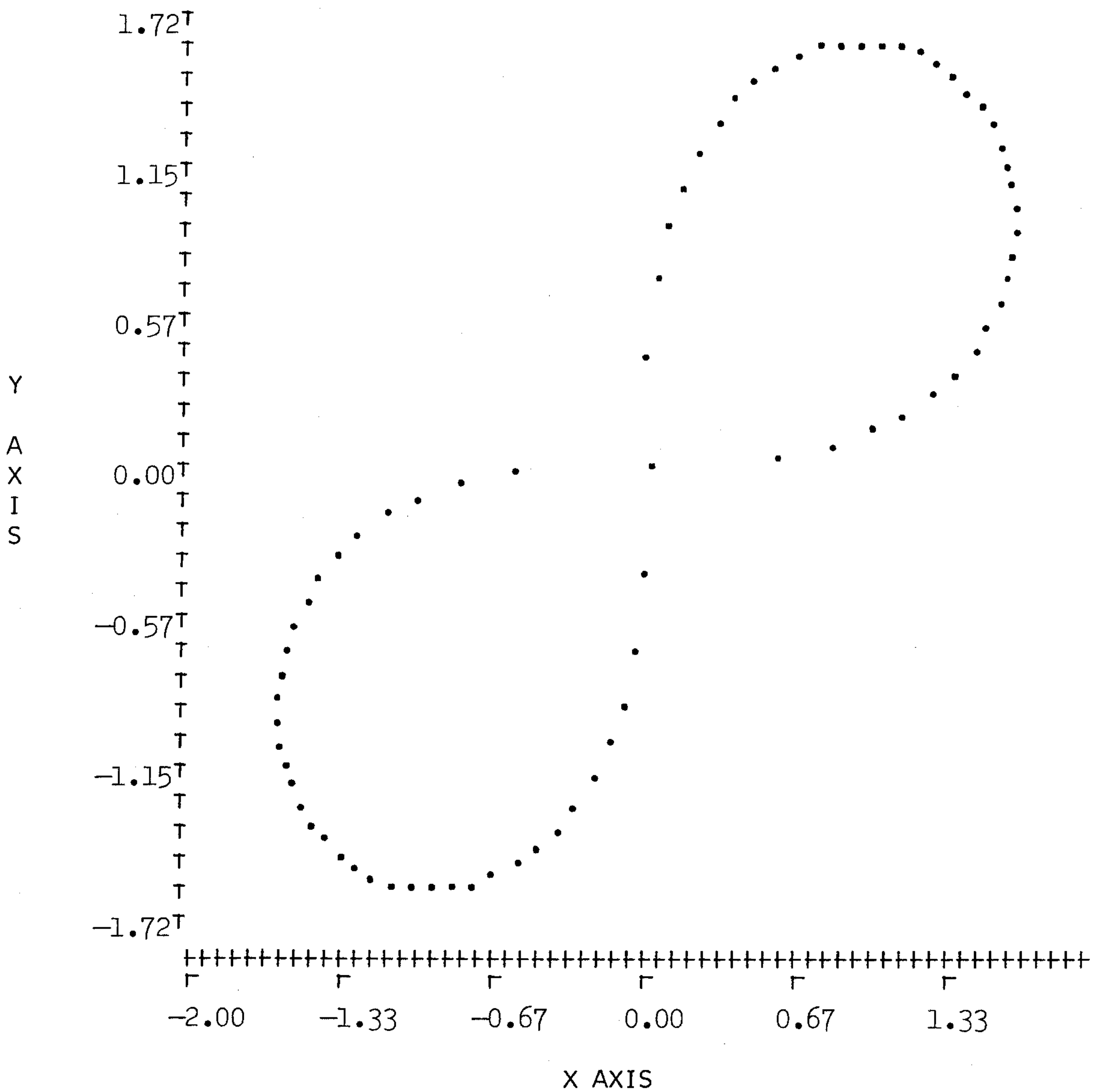
```
      ∇Z ← PPF THETA
[1]  Z ← (R⋆2)-4×1○2×THETA ∇
```

AND SINCE WE ARE GOING TO DO A GRID SEARCH ON R AND THETA, WE NOW SET LIMITS AS FOLLOWS:

```
      AUT←1
      RMI←0
      RMA←2.1
      TMI←0
      TMA←○2
```

THESE LAST TWO LINES SET THE MAX AND MIN FOR THETA AT 0 *AND* 2×*PI RESPECTIVELY:*

```
      DENSITY 15
WAS 10
      PLOT
```


1.72
1.15
0.57
0.00
-0.57
-1.15
-1.72
Y AXIS
-2.00
-1.33
-0.67
0.00
0.67
1.33
X AXIS

PLOTTING A MATRIX

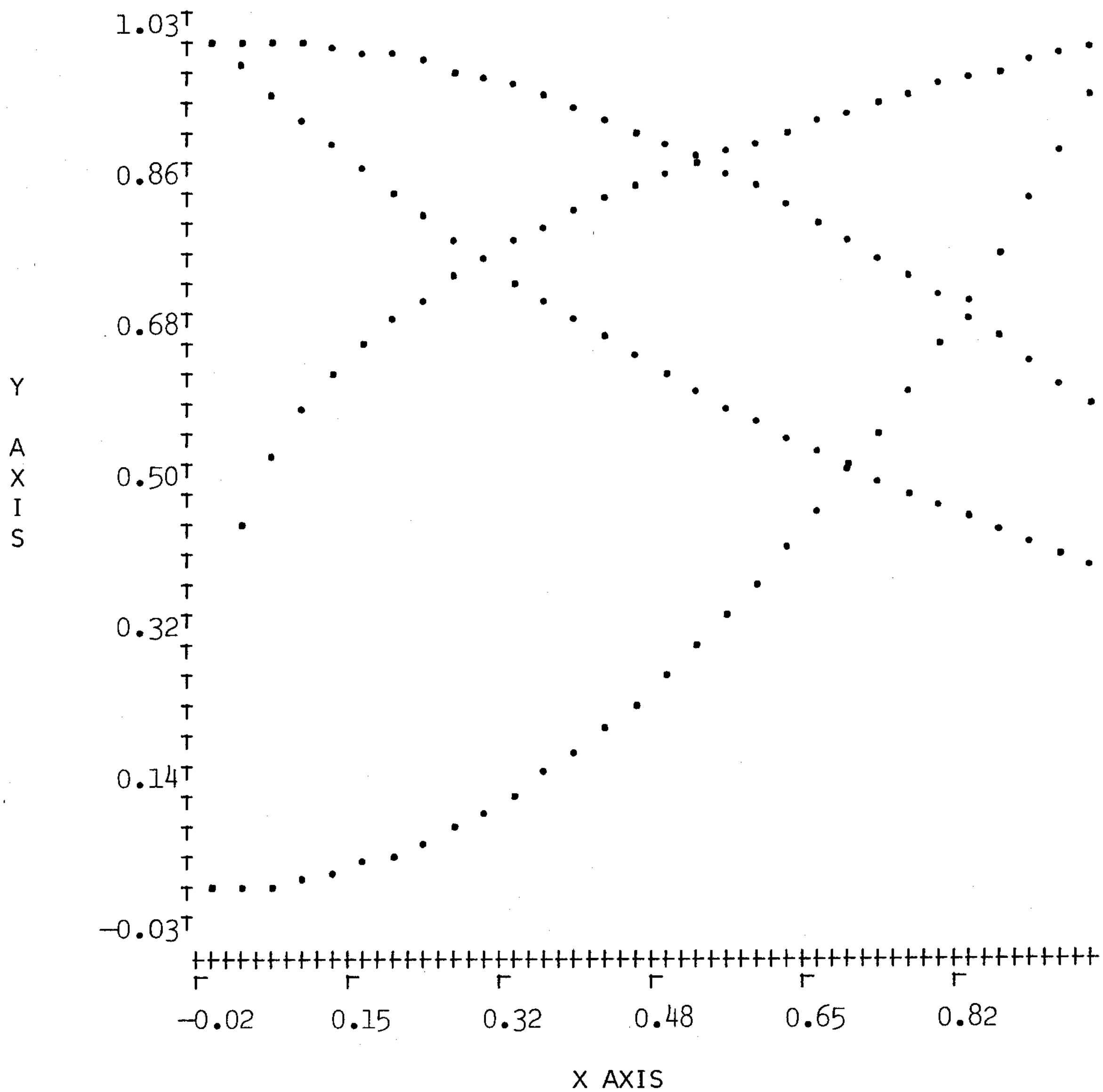
IF YOU HAVE A MATRIX CONTAINING INFORMATION YOU WOULD LIKE TO PLOT, THE FOLLOWING DEVICE WILL GIVE YOU A GRAPH. THE VALUES IN THE FIRST COLUMN OF THE MATRIX ARE USED AS X-VALUES. THE CORRESPONDING ENTRIES IN THE REMAINING COLUMNS (ANY NUMBER OF REMAINING COLUMNS MAY BE USED) ARE USED AS Y-VALUES FOR THAT VALUE OF X IN THE FIRST COLUMN. AS AN EXAMPLE, SUPPOSE WE WISH TO PLOT THE CURVES

Y = X⋆2 Y = X⋆.25 Y = EXP -X Y = COS X

FOR 30 VALUES OF X BETWEEN 0 AND 1. WE PROCEED AS FOLLOWS

```
⍝WE FIRST SELECT 30 VALUES BETWEEN 0 AND 1
D←30 1⍴(¯1+⍳31)÷30

⍝WE NOW ADD COLUMNS TO D, 1 COLUMN FOR EACH FUNCTION ABOVE
D←(((D,D[;1]⋆2),D[;1]⋆.25),⋆-D[;1]),2○D[;1]

⍝NOW TO PLOT THE MATRIX D
CARTESIAN ONEPLOT
FINEPLOT
PLOT
```

```
⎕:
      MATRIX D
```


1.03
0.86
0.68
0.50
0.32
0.14
-0.03
Y AXIS
-0.02
0.15
0.32
0.48
0.65
0.82
X AXIS

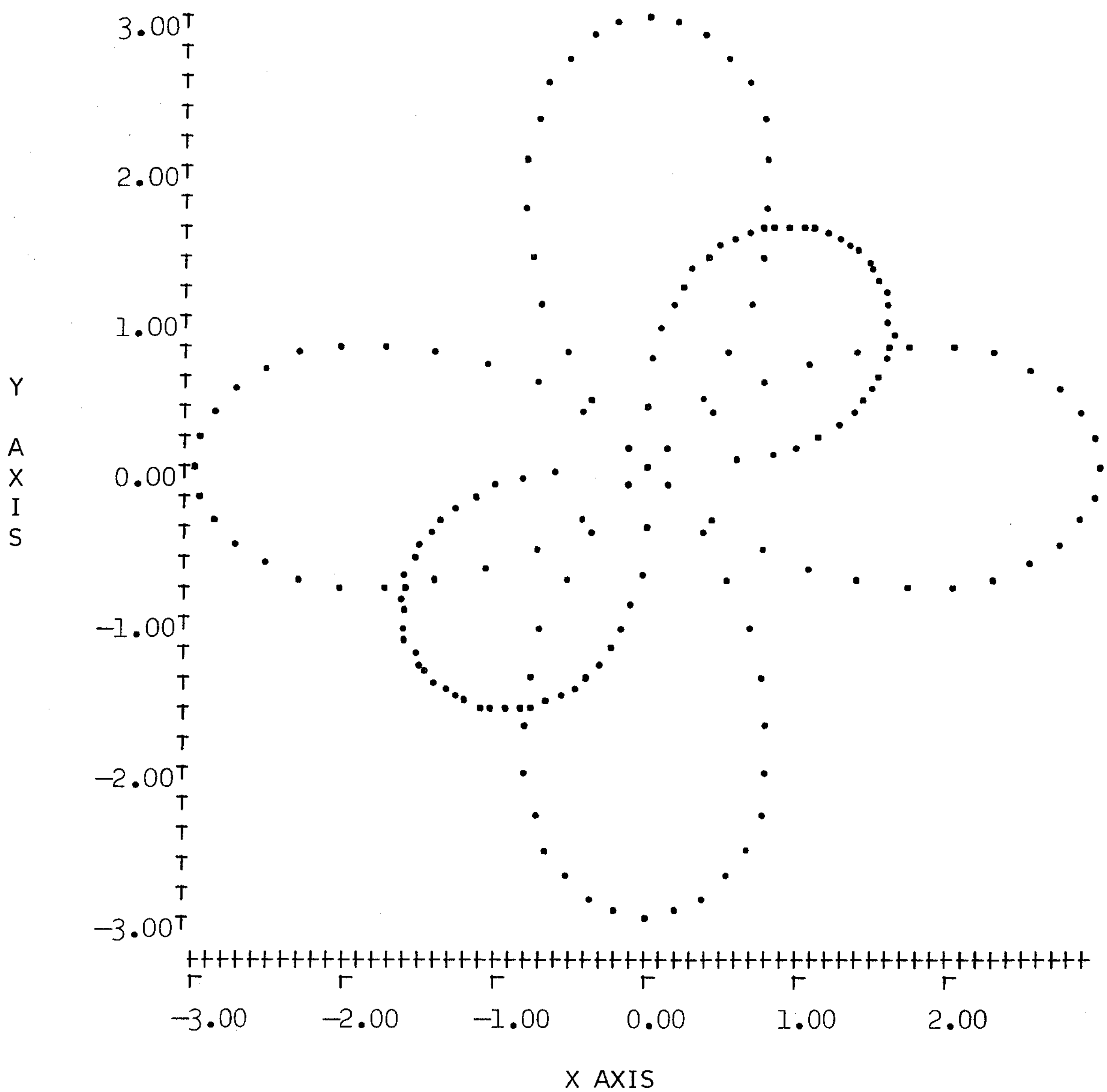
PLOTTING SEVERAL FUNCTIONS TOGETHER

IF YOU WANT TO SAVE THE DATA FROM SEVERAL PLOTS, AND THEN PLOT THE DATA IN ONE SINGLE PLOT, SIMPLY SET THE SAVE OPTION ON BY TYPING

SAVE

THE X AND Y COORDINATES FROM ANY FOLLOWING USES OF THE PLOT FUNCTION WILL THEN BE SAVED. IF, FOR EXAMPLE, THE LAST 2 PLOT EXAMPLES HAD BEEN PRECEDED BY THIS COMMAND, WE WOULD NOW TYPE IN THE FOLLOWING COMMANDS. NOTE THAT THE USE OF THE WORD SAVED SIMPLY SUBMITS ALL OUR SAVED COORDINATES TO THE PLOT FUNCTION.

```
        CARTESIAN ONEPLOT

        PLOT

⎕:
        SAVED
```


3.00
2.00
1.00
0.00
−1.00
−2.00
−3.00
Y AXIS
−3.00
−2.00
−1.00
0.00
1.00
2.00
X AXIS

FOR THE APL ADEPT WE PRESENT THE FOLLOWING BRIEF DESCRIPTIONS OF THE FUNCTIONS AND VARIABLES IN THIS WORKSPACE. BY SKILLFUL USE OF THESE OPTIONS MANY ELEGANT AND USEFUL PLOTS CAN BE QUICKLY AND EFFORTLESSLY PRODUCED, WE HOPE!

FUNCTIONS

CARTESIAN-*SETS OPTION SWITCHES FOR THE PLOTTING OF FUNCTIONS OF THE FORM*

Y = F(X) [*CARTESIAN ONEPLOT*]
F(X,Y) = 0 [*CARTESIAN TWOPLOT*]

DEFAULT- *SETS ALL OPTION SWITCHES BACK TO THEIR DEFAULT VALUES AND THIS GIVES THE CARTESIAN ONEPLOT OPTION.*

DENSITY- *DETERMINES THE FINENESS OR NUMBER OF POINTS FOR X AND Y GRIDS. TYPE DENSITY* 10 *AND YOU GET A DENSITY OF* 10, *ETC.*

FINEPLOT- *SETS THE OPTION SWITCHES FOR THE USE OF THE IBM HIGH RESOLUTION TYPEBALL.*

LP *NOT MEANT TO BE USED ON A STANDALONE BASIS.*

MATRIX- *THIS FUNCTION IS USED TO PLOT A MATRIX USING THE FIRST COLUMN AS X-VALUES, AND THE OTHER COLUMNS AS CORRESPONDING Y-VALUES. FIRST YOU MUST CONSTRUCT THE MATRIX D, AND THEN TYPE THE FOLLOWING:*

```
          CARTESIAN ONEPLOT
          PLOT
    ⎕:
          MATRIX D
```

AND YOUR PLOT WILL APPEAR AS IF BY MAGIC!

NOPRINT- *ERASES THE PREVIOUS CONTENT OF THE GLOBAL VARIABLE OPT, AND STORES THE RESULT OF THE NEXT USE OF THE PLOT FUNCTION INTO THIS VARIABLE OPT. NO GRAPH IS PRINTED FOR ANY FOLLOWING USE OF THE PLOT FUNCTION UNTIL THE COMMAND PRINT IS ISSUED.*

PARAMETRIC- *SETS OPTIONS FOR PLOTTING FUNCTIONS OF THE FORM*

X = F(THETA)
Y = G(THETA) [*PARAMETRIC ONEPLOT*]

F(X,THETA) = 0
G(Y,THETA) = 0 [*PARAMETRIC TWOPLOT*]

PLOT *THE MAIN FUNCTION USED FOR PLOTTING, AFTER ALL OPTIONS HAVE BEEN SET.*

POLAR - *SETS OPTIONS FOR PLOTTING FUNCTIONS OF THE FORM*

R = F(THETA) [*POLAR ONEPLOT*]
F(R,THETA) = 0 [*POLAR TWOPLOT*]

PRINT- *SETS OPTIONS TO PRINT GRAPHS AS THEY ARE COMPUTED, LINE BY LINE. THE PLOT IS NOT SAVED, AND IS COMPLETELY LOST IF PRINTING IS INTERRUPTED. FOR THIS REASON IT IS STRONGLY RECOMMENDED THAT EACH PLOT BE DONE BY TYPING*

```
NOPRINT
PLOT
OPT
```

SO THAT THE PLOT IS ALWAYS STORED IN THE VARIABLE OPT. THE FUNCTION NOPRINT ALWAYS ERASES THE CONTENTS OF OPT, SO BE SURE TO SAVE OPT IN ANOTHER VARIABLE BEFORE TYPING NOPRINT - IF YOU WANT TO SAVE THE GRAPH CURRENTLY IN OPT.

REGULAR- *PRINTS THE GRAPH USING THE STANDARD IBM APL TYPEBALL.*

SAVE *CLEARS THE BUFFERS SAVX AND SAVY, SETS THE SAVE OPTION ON AND SAVES ALL COORDINATES FROM THE PLOT FUNCTION.*

SPECIAL- *PRINTS THE GRAPH USING A SECOND SPECIAL CHARACTER SET ON THE IBM HIGH RESOLUTION TYPEBALL.*

STATE- *THIS FUNCTION PRINTS OUT ALL THE OPTIONS CURRENTLY IN EFFECT, AND THEIR CURRENT VALUES. IF YOUR GRAPHS LOOK AWFUL, ONE OF THESE OPTIONS IS PROBABLY NOT SET PROPERLY, SO THAT LOOKING AT THE RESULT OF THIS FUNCTION CAN BE HELPFUL.*

TGRID- *A CONVERSATIONAL PROGRAM DESIGNED TO CONSTRUCT A VECTOR OF VALUES FOR THE VARIABLE THETA, TO BE USED IN A GRID SEARCH FOR POINTS TO PLOT IN POLAR AND PARAMETRIC PLOTTING.*

YFORMAT- *SETS THE NUMBER OF PLACES AND DECIMALS USED IN PRINTING VALUES ON THE Y-AXIS. FOR EXAMPLE, THE COMMAND YFORMAT* '11.4' *WILL PRINT Y-AXIS VALUES IN* 11 *PRINT POSITIONS WITH* 4 *DECIMAL PLACES.*

XFORMAT- *SETS THE NUMBER OF PLACES AND DECIMALS USED IN PRINTING VALUES ON THE X-AXIS. FOR EXAMPLE, THE COMMAND XFORMAT* '8.5' *WILL PRINT X-AXIS VALUES IN* 8 *PRINT POSITIONS WITH* 5 *DECIMALS.*

NOSAVE *SHUTS OFF THE SAVE OPTION.*

VARIABLES

THE FOLLOWING VARIABLES ARE USED TO CONTROL THE OPTIONS IN THE PLOT FUNCTION. ALL OF THEM MAY BE SET DIRECTLY BY THE USER. SIMPLY TYPE THE VARIABLE NAME, FOLLOWED BY AN ARROW ←, FOLLOWED BY THE VALUE THAT YOU WANT THE VARIABLE TO HAVE, FOR EXAMPLE

AUT ← 0

SETS THE VARIABLE AUT TO 0, *AND SO TURNS OFF THE AUTOMATIC SCALING OF THE Y-AXIS VALUES.*

AUT — *AUTOMATIC SCALING OF THE Y-AXIS VALUES*
[0 *OFF*]
[1 *ON*]

BKSP — *BACKSPACE CHARACTER. NEVER RESET!*

CHR — *CHARACTER SET BEING USED.*
[1 *IBM HIGH RESOLUTION TYPEBALL DOTS*]
[2 *REGULAR APL TYPEBALL CIRCLES*]
[3 *IBM HIGH RESOLUTION TYPEBALL CUTS*]

CODE — *A RANK* 3 *ARRAY OF CHARACTERS USED FOR PLOTTING*

CR — *CARRIAGE RETURN CHARACTER. NEVER RESET!*

DNX — *DENSITY OF GRID FOR X AND Y VALUES, R AND THETA VALUES.*

NPR — *NOPRINT OPTION SWITCH*
[0 *NOPRINT*]
[1 *NOPRINT*]

NX — *INTERNAL FUNCTION DENSITY. NX* = 10÷*DNX*

ONEPLOT — *A VALUE OF* 0. *NEVER RESET.*

OPT — *A GLOBAL VARIABLE USED TO STORE THE OUTPUT OF PLOT*

PAR — *PARAMETRIC PLOTTING OPTION SWITCH*
[0 *OFF*]
[1 *ON*]

RMA — *MAXIMUM VALUE FOR R IN POLAR PLOTTING*

RMI — *MINIMUM VALUE FOR R IN POLAR PLOTTING*

SAV — *OPTION SWITCH FOR SAVING COORDINATES*
[0 *NOSAVE*]
[1 *SAVE*]

TGR — *THETA GRID OPTION SWITCH*
[0 *OFF*]
[1 *ON*]

TMA — *MAXIMUM VALUE FOR THETA IN PARAMETRIC OR POLAR PLOTTING*

TMI — *MINIMUM VALUE FOR THETA IN PARAMETRIC OR POLAR PLOTTING*

TWOPLOT — *A VALUE OF* 1. *NEVER RESET!*

WARN — *WARNING MESSAGE*

WH — *PHYSICAL HEIGHT OF THE PRINTED GRAPH IN TYPEWRITER SPACES. ''WINDOW HEIGHT''*

WW — *PHYSICAL WIDTH OF THE PRINTED GRAPH IN TYPEWRITER SPACES. ''WINDOW WIDTH''*

XF — *X-AXIS FORMAT SPECIFICATION FOR ∆FMT. USE THE FUNCTION XFORMAT TO RESET THIS VARIABLE.*

XMA — *MAXIMUM VALUE FOR VARIABLE X IN ANY PLOT.*

XMI — *MINIMUM VALUE FOR VARIABLE X IN ANY PLOT.*

XNN — *INTERNAL VALUE USED TO PRINT THE NUMBERED TICS ON THE X-AXIS. XNN IS ALWAYS EQUAL TO THE INTEGRAL PART OF THE XFORMAT SPECIFICATION.*

XT — *A CHARACTER VECTOR OF TEXT TO BE PRINTED UNDER THE X-AXIS VALUES.*

XTC — *AFTER PLOTTING XTC IS THE VALUE OF ONE ''X-TIC''*

XYF — *OPTION SWITCH FOR TWOPLOTTING*
[0 *OFF*]
[1 *ON*]

YF — *Y-AXIS FORMAT SPECIFICATION FOR ∆FMT. USE THE FUNCTION YFORMAT TO RESET THIS VARIABLE.*

YMA — *MAXIMUM VALUE FOR VARIABLE Y IN ANY PLOT.*

YMI — *MINIMUM VALUE FOR VARIABLE Y IN ANY PLOT.*

YNN — *EVERY YNN'TH TIC ON THE Y-AXIS WILL BE NUMBERED. AND IF YNN* = 0 *ONLY THE TOP TIC IS NUMBERED.*

YT — *A CHARACTER VECTOR OF TEXT TO BE PRINTED ALONG THE Y-AXIS.*

C̲H — *A CHARACTER VECTOR CONTAINING* '0123456789'

P̲OLAR — *POLAR PLOTTING OPTION SWITCH*
[0 *OFF*]
[1 *ON*]

T̲HETA — *A USER SPECIFIED VECTOR OF VALUES FOR THETA TO BE USED IN A GRID SEARCH. TGR MUST BE SET TO* 1. *USE TGRID.*