◆ *Overdrawing built-in function graphs*

Two or more different built-in functions can be drawn together on the same display. Since the range for the first graph is automatically set, all subsequent graphs on the same display are produced according to the range of the first graph (provided that all subsequent graphs are user defined graphs). The first graph is produced by using the previously mentioned operation. Subsequent graphs are produced using the variable "*x*" in the operation.

Say, the function Y1 is defined as "*Y1 = sin x*" for plotting the built-in sine curve.

Then overdraw the graph " *y = cos x*" on the graph above. To do so, the function Y2 should be defined as "*Y2 = cos x*" (variable "*x*" has to be entered in this case since "*y = cos x*" is not a built-in function).

IIIb. User Generated Graphs

User generated graphs can be divided into function graphing and parametric graphing. In function graphing, the user should input a formula in the format of *y = f(x)* while in parametric graphing, both *x = f(T)* and *y = f(T)* should be defined.

◆ *Specifying range parameters*

Unlike built-in functions, the ranges of user generated graphs are not set automatically, so graphs produced outside of the display range do not appear on the display. Range parameters are used to define the size of the graph window. The parameters consist of the following :-

Xmin :- the minimum value of the *x*-axis
Xmax :- the maximum value of the *x*-axis
Xscl :- scale of the *x*-axis (distance between hash marks)
Ymin :- the minimum value of the *y*-axis
Ymax :- the maximum value of the *y*-axis
Yscl :- scale of the *y*-axis (distance between hash marks)
T_{min} :- the minimum value of parameter "*t*" for parametric graphs
T_{max} :- the maximum value of parameter "*t*" for parametric graphs
Pitch :- the pitch value for parametric graphs

How to set the range parameters

To set the range parameters, one should press the [RANGE] key (except in the BASE-N and CMPLX mode), the range parameter setting screen appears on the display. Enter the value you want to specify for the displayed parameter and then press [=].

For example, change the range parameters on the left to those on the right as follows :-

Xmin :	0 → -5	Ymin :	-10 → -5
Xmax :	5 → 5	Ymax :	10 → 15
Xscl :	4 → 2	Yscl :	4 → 4
T_{min} :		0	
T_{max} :		10	
Pitch :		0.1	

[RANGE]

Specify -5 for Xmin.
[(-)] [5]

Press [=] to confirm and move to Xmax.

Simply press [=] since there is no change for Xmax.

Specify 2 for Xscl.
[2] [=]

Specify -5 for Ymin.
[-][5] [=]

Specify 15 for Ymax.
[1][5] [=]

No change for T_{min} , just press [=]

Specify 10 for T_{max}.
[1][0] [=]

Press [=] to confirm and move to "Pitch".

Specify 0.1 for pitch by pressing [.] [1] [=]. Meanwhile, the unit will recycle back to "Xmin".

Leave "RANGE" setting, press [RANGE] again.

Besides range values, you can also input range parameters as expressions such as 2π and these expressions are automatically converted to the values.

Remarks :-

- If you enter a value that is outside the allowable range or if you try to perform some other illegal operations, an error message appears on the display. When this happens, press [◀] or [▶] to locate the error in the calculation and make the necessary corrections.
- Inputting 0 for Xscl or Yscl doesn't set any scales.
- Inputting a maximum value that is less than the minimum value will reverse the respective axes.
- If the maximum and minimum values of an axis are equal, an error will be generated.
- When a range setting is used that does not allow display of the axes, the scale for the *y*-axis is indicated on either the left or right edge of the display, while that for the x-axis is indicated on either the top or bottom edge.
- When the range values are changed or reset, the graph display is cleared and the newly set axes only are displayed.
- If the range is set too wide or narrow, the graph produced may not fit on the display.

How to check the range parameters

If you want to check all the range parameters, you can press [RANGE] to switch to parameter setting screen. Then press [EXE] to scroll through the range parameter settings without changing them.

[RANGE]

[=]

[=]

[=]

[=]

[=]

[=]

[=]

[=]

Lastly press [RANGE] again to return to the display that was shown before entering the range display.

How to reset the range parameters

Range values are reset to their initial values by pressing [SHIFT][MCL] or [SHIFT][SCL] during range display.

The initial values are as follows :-

Xmin :	-4.6	Ymin :	-3.0
Xmax :	4.6	Ymax :	3.0
Xscl :	1	Yscl :	1
Tmin :		0	
Tmax :		2π	
Pitch :		2π/45	

◆ *Generation of Function Graphs*

After specifying the range parameters as described above, user generated graphs can be drawn simply by defining the functions (formula) in "FUNC" menu as described above.

For example, the graph for $y = 2x^2 + 3x - 4$ is to be drawn

Firstly, set the ranges to the values shown below.

Xmin = -5, Xmax = 5, Xscl = 1
Ymin = -10, Ymax = 10, Yscl = 2

Then open the "FUNC" menu, select "Y1 " and define the function formula of "Y1".

Enter the formula by keying in [2] [X,T] [x²] [+] [3] [X,T] [-] [4]

Press [=] to go back "FUNC" menu.

Draw the graph by pressing [DRAW]. The graph will be displayed as below.

◆ *Generation of Parametric Graphs*

When parametric graph has been selected in "MODE" menu, you can draw parametric graphs. Similar to function graphs, users should specify the range parameters first to define the graph window. Then he / she can input the formula in "FUNC" menu.

Press [SHIFT][FUNC] to open the "FUNC" menu. "PARAM?" is displayed instead of "FUNCT" to indicate the parametric function is to be defined.

This time, the user will be asked for two formulae which are *x = f(T)* and *y = f(T)*.

For example, the parametric graph of *x = 3θT cos 2T ,*
y = 3θT sin 2T - 9.8T ^ 2 is to be drawn

Define both *x(t) and y(t) as cos(θ)* but been defined, no curve will be plotted as the key button [DRAW] has been pressed. Only the *x-y* coordinates will be shown.

◆ *Graph Overdraw*

Two or more graphs can be overdrawn, which makes it easy to determine intersection points and solutions that satisfy all the equations.

For example, let's find the intersection points of the graph $y = 2x^2 + 3x - 4$ and $y = 2x + 3$.

First, press [SHIFT][CLS][EXE] to clear the graph screen in preparation for the first graph. Then enter the formula for the first graph in the "FUNC" menu.

Y1 = 2X² + 3X - 4

Press [DRAW] to plot Y1.

Next, overdraw the graph for *y = 2x + 3* by defining Y2 = 2*X* + 3 as well.

Press [DRAW] and the graphs are overdrawn each other as shown on the right.

In this way, it can be easily seen that there are two intersections for the two function graphs. The approximate coordinates for these two intersections can be found using "Zoom" function or the "Trace" function described in the following sections.

IIIc. Zoom Function

This function lets you enlarge or reduce the *x*- and *y*-coordinates. If you use the Trace or Plot function to locate the pointer at a specific point on the graph, the enlargement / reduction is performed using the pointer location as the center point.

How to enlarge a graph

Example :- To enlarge the graph for *y = sin x* by a factor of 1.5 on the *x*-axis and 2.0 on the *y*-axis.

Firstly, set the range parameters as below.

Xmin = -360	Ymin = -1.6
Xmax = 360	Ymax = 1.6
Xscl = 180	Yscl = 1

After specifying the range parameters, graph *y = sin x* as described above.

Then press [SHIFT][FACTOR] for the factor specification screen. (The current zoom factor is 2.)

Change the factor to 1.5 by keying in [1] [.] [5]

Press [EXE] to confirm the X-factor and move forward to Y-factor screen.

Change Y-factor to 2 by entering [2].

Press [EXE] to cycle back to "Xfact" .

Finally, press [SHIFT][FACTOR] to exit.

Whenever you try to change the factor value while a graph is displayed, the display changes to the text screen automatically. To return to the graph screen, press [G↔T].

[G↔T]

Press [SHIFT][Zoom-*f*] to enlarge the graph according to the factors specified.

When you view the range parameters again, you will find that the window size becomes as follows :-

Xmin = -240, Xmax = 240, Xscl = 180
Ymin = -0.8, Ymax = 0.8, Yscl = 1

If you press [SHIFT][Zoom-*f*] again, the graph is enlarged once more by the factors you specified. To return the graph to its original size, press [SHIFT][Zoom Org].

How to reduce a graph

Follow the same procedure as described above for enlarging a graph. After specifying the factor, press [SHIFT][Zoom-1/*f*] instead. The graph will be reduced as below.

You can take a look at the range parameters which become as :-

Xmin = -540, Xmax = 540, Xscl = 180
Ymin = -3.2, Ymax = 3.2, Yscl = 1

If you press [SHIFT][Zoom-1/*f*] again, the graph is reduced once more by the factors specified. To return the graph to its original size, press [SHIFT][Zoom Org].

IIId. Trace Function

This function lets you move a pointer around a graph and display the *x*- and *y*-coordinates of the current pointer location. The coordinates can be displayed with the use of seven digits or eleven digits. When two active graphs are overdrawn each other, you can press [▲] or [▼] to switch between the graphs. Each time you toggle between the curves, the tracing will restart from the leftmost position.

For example, graph $y = x^2 - 3$ on the screen.

Activate the Trace function by pressing [TRACE]. A blinking pointer will be located on the leftmost of the curve and the corresponding *x*-coordinate will be shown.

You can use the buttons [◀] or [▶] to move the pointer along the graph. Each press moves the cursor one point. Holding down either key moves the pointer at high speed. The corresponding coordinate reading shown on the lower right part of the screen will be updated all the way.

Press [▶] consecutively.

Besides the *x*-coordinate, you can also read the *y*-coordinate of the blinking pointer by pressing [SHIFT][X⇔Y] which will toggle the reading of *x*-coordinate and *y*-coordinate.

As you trace along the curve, either x-coordinate or y-coordinate will be shown in 7-digit mantissa plus a 2-digit exponent. If you want to get the exact value, you can press [VALUE] to read the value which will be displayed in 11-digit mantissa plus a 2-digit exponent as below.

To switch back to 7-digit mantissa, you can press [VALUE] again.

[VALUE]

To exit the Trace function, press [TRACE] again. The blinking pointer will disappear.

IIIe. Sketch Operations

You can select and perform the following functions by Sketch operations.

Plot --- Plot a point on the graph
Line --- Draw a line segment between two points
Tangent --- Draw a line segment tangent to a function
Horizontal --- Draw a horizontal line
Vertical --- Draw a vertical line

To display the Sketch menu, press [SHIFT][SKETCH]. Function "Plot" and "Line" are displayed.

Press [▶] consecutively to select the desired function.

[▶]

[▶]

[▶]

Press [▶] further to move to the end of ***SKETCH*** menu.

Pressing [◀] lets you go back to the previous item.

As you have chosen the desired function, press [EXE] for confirmation and exit from ***SKETCH*** menu.

IIIe-1. Plot Function

The Plot function is used to mark a point on the screen of a graph display. The point can be moved left, right, up and down using the cursor keys, and the coordinates for the graph displayed can be read.

Select Plot function in the ***SKETCH*** menu. The command "Plot" will be shown on the display as below.

You have to specify the *x*- and *y*-coordinates after the command "Plot".

For example :- Plot a point at *x*=2 and *y*=2 on the axes created by the following range values.

Xmin = -5, Xmax = 5, Xscl = 1
Ymin = -10, Ymax = 10, Yscl = 2

Press [SHIFT][SKETCH][EXE][2][SHIFT][,][2][EXE]

The blinking pointer is positioned at the specified coordinates. Due to limitations caused by the resolution of the display, the actual position of the pointer can only be approximate.

The pointer can be moved left, right, up and down using the cursor keys. The current position of the pointer is always shown at the bottom of the display.

[▶][▶][▶][▶][▶]

To find the *y*-coordinate value, press [SHIFT][X⇔Y].

As you move the blinking pointer upwards or downwards, the *y*-coordinate will be updated simultaneously.

[▶][▶][▶][▶][▶]

When the pointer is at the location you want, press [EXE] to plot a point. At this time, the pointer returns to the original point you specified (1.2, 2) in this example).

[EXE]

Now, you can input a new coordinate value to create a new blinking pointer without clearing the present pointer. The present pointer will become a fixed point as shown below.

[SHIFT][SKETCH][EXE][2],[0.8]
[3][EXE]

If *x-y* coordinates are not specified for the Plot function (i.e., [SHIFT][SKETCH][3][EXE]), the blinking pointer appears at the center of the screen.

IIIe-2. Line Function

The Line function makes it possible to connect two points (including the blinking pointer) created with the Plot function with a straight line. With this function, user generated lines can be added to graphs to make them easier to read.

For example, Draw perpendiculars from the point (2, 0) on the *y*-axis to its intersection with the graph for *y = 3x*. Then draw a line from the point of intersection to the *y*-axis.

Let the range values be :-

Xmin = -2, Xmax = 5, Xscl = 1
Ymin = -2, Ymax = 10, Yscl = 2

Clear the graph display and draw the graph for *y = 3x*.

[SHIFT][CLS][EXE]
[SHIFT][FUNC][EXE]
[3][X,T][EXE]
[DRAW]

Next, use the Plot function to locate a point at (2, 0).

Now plot a point at (2, 0) again and use the cursor key [↑] to move the pointer up to the graph of *"y = 3x"*.

[SHIFT][SKETCH][EXE][2],[0][EXE]
[EXE]
Press [↑] consecutively till the blinking pointer meets the graph of *y = 3x*.

Select Line function in the ***SKETCH*** menu to draw a line.

Press [SHIFT][SKETCH]→[EXE] [EXE].

Next, a perpendicular will be drawn from the same point on the graph to the *y*-axis.

Firstly, plot the point on the graph and use the cursor key [◀] to move the pointer to the *y*-axis. This can be accomplished using the command "Plot X, Y" since the current blinking pointer is actually the point on the graph and the corresponding *y-y* coordinates are stored.

[SHIFT][SKETCH][EXE][ALPHA][X],[ALPHA][Y][EXE] [EXE]

Then move the pointer to the *y*-axis by pressing [◀] consecutively.

Draw the line.
[SHIFT][SKETCH]→[EXE][EXE]

IIIe-3. Drawing a Tangent Line

First locating a point on the screen using TRACE function.

Then select the "Tangent" function from the ***SKETCH*** menu. Press [EXE] to draw the tangent line through the specified point.

IIIe-4. Draw a Horizontal Line

First plot a point on the screen as described above. Say, plot a point at (2, 0).

If necessary, use the cursor keys [◀], [▶], [▲] or [▼] to move the blinking cursor to the point through which the horizontal line is to be drawn. Finally, press [EXE] to draw the horizontal line.

Finally, press [EXE] to draw the horizontal line.

IIIe-5. Drawing a Vertical Line

First plot a point on the screen as described above. Say, plot a point at (2, 0).

If necessary, use the cursor keys [◀], [▶], [▲] or [▼] to move the blinking cursor to the point through which the vertical line is to be drawn. Finally, press [EXE] to draw the vertical line.

IIIf. Graph Scroll Function

In SD mode, single-variable statistical graphs can be drawn. Either bar graphs or normal distribution curves can be produced.

For drawing the bar graphs, *y*-coordinate represents the data range and the *y*-coordinate stands for the number of items (frequency) of each data. The number of bars ranges between 1 to 20, which is defaulted at 10 upon power up reset. If you want to change the number of bars, you can press [RANGE] to view the range parameters as described previously. The bar number selection is appended to the end of the parameter list. Hence, as you press [EXE] consecutively, you can view the parameters in the order of Xmin, Xmax, Xscl, Ymin, Ymax, Yscl, Tmin, Tmax, Pitch, Bar and cycle back to Xmin.

As you come to the bar selection screen, the display shows :-

If you want to change the bar number, enter an integer in the range of 1 to 20. Then press [EXE] to update the value. If you have entered a value out of this range, or the input value is not an integer. Ma Error will occur.

Example :- Use the following data to draw a ranked graph.

Rank No.	1	2	3	4	5	6	7	8	9	10	11
Rank	0	10	20	30	40	50	60	70	80	90	100
Frequency	1	3	2	2	3	5	6	8	15	9	2

Step 1 :- Set the range values as below.

Xmin = 0, Xmax = 110, Xscl = 10
Ymin = 0, Ymax = 20, Yscl = 2

Step 2 :- Clear the statistical memory by pressing [SHIFT][Scl][EXE].

Step 3 :- Input the data.

0 [DT]
10 [DT][DT][DT]
20 [DT][DT]
30 [DT][DT]
40 [DT][DT][DT]
50 [SHIFT][,][5 [DT]
60 [SHIFT][,][6 [DT]
70 [SHIFT][,][8 [DT]
80 [SHIFT][,][5 [DT]
90 [SHIFT][,][9 [DT]
100 [DT][DT]

Step 4 :- Press [DRAW] to draw the graph. You will be asked to select either bar chart or distribution curve by the screen display as below.

Press either [◀] or [▶] to select the type of graphs. Then press [EXE] to start the drawing. Say, bar chart has been chosen.

If normal distribution graph is to be drawn, select "Line" above and press [EXE].

Please note that the range values may be quite different from the previous data since the *y*-axis value is relatively small when compared with the bar graph.

Say, the range values are changed to those shown below.

Xmin = 0, Xmax = 110, Xscl = 10
Ymin = 0, Ymax = 0.05, Yscl = 0.01

The formula used for normal distribution curves is :-

$$y = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

where σ is the population standard deviation, $x\sigma$ σ is the mean

IIIh. Paired-Variable Statistical Graphs

Paired-variable graphs are drawn in REG mode. When data is input in LR mode, points will be displayed immediately and data is input to the statistical memory.

Example :- Perform linear regression on the following data and draw a regression line graph.

x_i	-9	-5	-3	1	4	7	
y_i	-2	-1	2	3	5	8	

Step 1 :- Specify the range values as below.

Xmin = -10, Xmax = 10, Xscl = 2
Ymin = -5, Ymax = 15, Yscl = 5

Step 2 :- Press [SHIFT][Scl][EXE] to clear the statistical memories.

Step 3 :- Input the data.

[SHIFT][(-)][SHIFT][,][SHIFT][(-)][2DT]
[SHIFT][(-)][SHIFT][,][SHIFT][(-)][1DT]
[SHIFT][(-)][SHIFT][,][2DT]
1[SHIFT][,][3DT]
4[SHIFT][,][5DT]
7[SHIFT][,][8DT]

For each data input, the point is displayed immediately on the screen. If the data value exceeds the window size, the corresponding data point will not appear on the display but the data will be stored into the statistical memory.

Step 4 :- As all the data have been input, press [DRAW] to draw the regression line.

Note:- When data input is outside the preset range values, the point will not appear.

To read the coefficients of the regression lines, A, B, or C, you can press [SHIFT][A], or [SHIFT][B], or [SHIFT][C] respectively.

IIIi. Graph Learning :-

Two functions, i.e., Shift and Change helps students to grasp the relationship between an equation and its graph. **(Only work in COMP mode.)**

Press [GRAPH LEARN] to start the learning function. The display will show as below.

If "Shift" is the function you want, press [=] and you can proceed to the "Shift" function.

IIIi-1. Shift

Shift the graph's location without changing its shape, and the change is immediately reflected in the equation on the lower right of the display.

At entering "Shift" menu, you are asked to select a built-in function for shifting.

Press the key buttons [^] or [x] to search through the functions. On the lower right corner, the symbols [^] or [x] will be ON to tell you if there are further messages on either ends.

Those functions available are :-

$y = x^2$
$y = \sqrt{x}$
$y = x^{-1}$
$y = e^x$
$y = \ln x$
$y = x^3$
$y = \sin x$
$y = \tan x$
$x^2 + y^2 = 4$

After you have found the desired function, press [=] to start the "Shift" function.
The function will be plotted on the graph with the ranges set to the optimum values.

Say, you have selected the function *"y = y² "*.

A flashing block appears on the lotus of the curve to indicate that you can press the key buttons [▲], [▼], [◀] or [▶] to shift the graph in the step of Xscl or Xscl along the *x*-axis or *y*-axis respectively.

Let Xscl = 2 and Yscl = 3.

When you have moved the graph downwards for one step, the equation will become as below.

As you move the graph further to the right for one step, the equation will be changed to *"y = (x – 2)² – 3 "*

If the new equation is too long to be shown on the lower right LCD, you can press [G↔T] to switch to text display.

[G↔T]

You can use the key buttons [◀] or [▶] to read the whole equation. To go back to the graph display, press [G↔T] again.

IIIi-2. Change :-

"Change" function is used to change the shape of the graph and the change is immediately reflected in the equation on the right side of the display.

Select "Change" in the graph learning menu. Then press [=] to proceed to the selection of the desired function.

Those functions available are :-

$y = x^2$
$y = \sqrt{x}$
$y = |x|$
$y = x^3$
$y = x^{-1}$
$y = \sin x$
$y = e^x$
$x^2 + y^2 = 4$

As you have selected the function, press [=] to start the "Change" function.

Let the function be $y = x^2$. The graph will be shown as below.

A flashing cursor will be located on the lotus of the curve. You can change the shape of the graph by pressing either [▲] or [▼] buttons as indicated. Say, the graph is moved to the lotus of *"y = 2x² "*.

Same as "Shift" function, you can press [G↔T] to switch to text display to read the whole equation.

For the function of *" r ² = r ² = r ² "*, as you press [▲] or [▼] to change the shape of the circle, the lotus of the circle should move radially.

IIIj. Graph Solving :-

Graph Solving function lets you plot the graph on the display and find the corresponding *x*-value for a specified *y*-value.

Press [GRAPH SOLVE] once and the display will be as below.

You are asked to input the desired function.

Let the function be *y = 0.25(x+2)(2x+1)(2x-5)*

As you press [=] to complete the entry, the graph will be plotted and meanwhile the message *" Y = a "* will be shown up on the lower right portion of the display.

(It is assumed that the graph is plotted on the window with the optimum range.)

After you have defined the value of a, the horizontal line Y = a will be overdrawn on the original graph and the intersection points are the roots of the equation *" 0.25(x+2)(2x+1)(2x-5)−a = 0 "*.

Let *a* be zero in this example. Hence the equation *" 0.25(x+2)(2x+1)(2x-5) = 0 "* is going to be solved. If roots have been found, flashing cursor (s) will be located at the corresponding position (s).

To read other roots, you can press either [◀] or [▶] to move the block to next root at the left or at the right of the current root.

Say, you have pressed the button [▶] , the display will become :-

Press [▶] further to read the third root.

If you press [▶] further, the graph will scroll to the right further for one window. No matter whether root or (roots) is present or not, the graph will stay on the display. Similarly, you can go to the left to search for roots by pressing [◀] or press [▶] to move the graph to the right for one window further.

(Note :- The accuracy of the roots is affected by the resolution of the scales.)