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CHAPTER TWO

PLOTTING COMMANDS

2.1 GRAPH FUNCTIONS

MATLAB has built-in functions that allow one to generate bar charts, x-y, polar, contour and 3-D plots, and bar charts. MATLAB also allows one to give titles to graphs, label the x- and y-axes, and add a grid to graphs. In addition, there are commands for controlling the screen and scaling. Table 2.1 shows a list of MATLAB built-in graph functions. One can use MATLAB's help facility to get more information on the graph functions.

Table 2.1
Plotting Functions

FUNCTION	DESRIPTION
axis	freezes the axis limits
bar	plots bar chart
contour	performs contour plots
ginput	puts cross-hair input from mouse
grid	adds grid to a plot
gtext	does mouse positioned text
histogram	gives histogram bar graph
hold	holds plot (for overlaying other plots)
loglog	does log versus log plot
mesh	performs 3-D mesh plot
meshdom	domain for 3-D mesh plot
pause	wait between plots
plot	performs linear x-y plot
polar	performs polar plot
semilogx	does semilog x-y plot (x-axis logarithmic)
semilogy	does semilog x-y plot (y-axis logarithmic)
shg	shows graph screen
stairs	performs stair-step graph
text	positions text at a specified location on graph
title	used to put title on graph
xlabel	labels x-axis
ylabel	labels y-axis

2.2 X-Y PLOTS AND ANNOTATIONS

The plot command generates a linear x-y plot. There are three variations of the plot command.

(a) **plot(x)**

(b) **plot(x, y)**

(c) **plot(x1, y1, x2, y2, x3, y3, ..., xn, yn)**

If x is a vector, the command

```
plot(x)
```

will produce a linear plot of the elements in the vector x as a function of the index of the elements in x. MATLAB will connect the points by straight lines. If x is a matrix, each column will be plotted as a separate curve on the same graph. For example, if

```
x = [ 0 3.7 6.1 6.4 5.8 3.9 ];
```

then, **plot(x)** results in the graph shown in Figure 2.1.

If x and y are vectors of the same length, then the command

```
plot(x, y)
```

plots the elements of x (x-axis) versus the elements of y (y-axis). For example, the MATLAB commands

```
t = 0:0.5:4;
y = 6*exp(-2*t);
plot(t,y)
```

will plot the function $y(t) = 6e^{-2t}$ at the following times: 0, 0.5, 1.0, …, 4 . The plot is shown in Figure 2.2.

To plot multiple curves on a single graph, one can use the plot command with multiple arguments, such as

```
plot(x1, y1, x2, y2, x3, y3, ..., xn, yn)
```

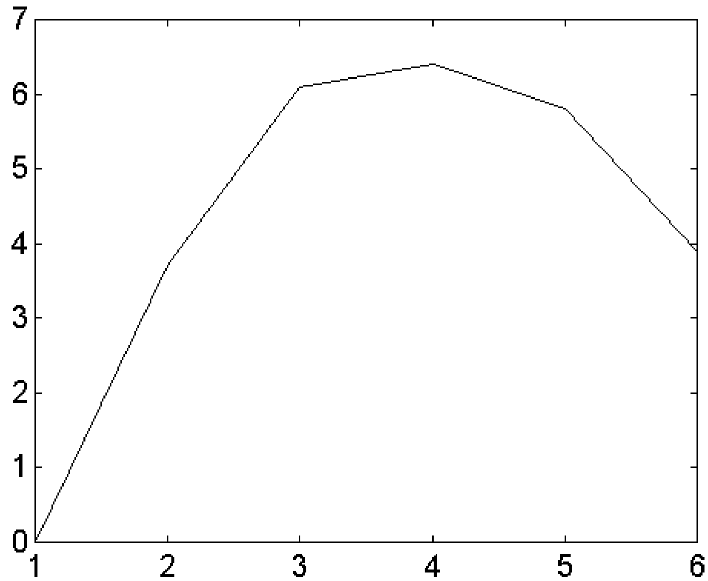

Figure 2.1 Graph of a Row Vector x

The variables x1, y1, x2, y2, etc., are pairs of vector. Each x-y pair is graphed, generating multiple lines on the plot. The above plot command allows vectors of different lengths to be displayed on the same graph. MATLAB automatically scales the plots. Also, the plot remains as the current plot until another plot is generated; in which case, the old plot is erased. The **hold** command holds the current plot on the screen, and inhibits erasure and rescaling. Subsequent plot commands will overplot on the original curves. The **hold** command remains in effect until the command is issued again.

When a graph is drawn, one can add a grid, a title, a label and x- and y-axes to the graph. The commands for grid, title, x-axis label, and y-axis label are **grid** (grid lines), **title** (graph title), **xlabel** (x-axis label), and **ylabel** (y-axis label), respectively. For example, Figure 2.2 can be titled, and axes labeled with the following commands:

```
t = 0:0.5:4;
y = 6*exp(-2*t);
plot(t, y)
title('Response of an RC circuit')
xlabel('time in seconds')
ylabel('voltage in volts')
grid
```

Figure 2.3 shows the graph of Figure 2.2 with title, x-axis, y-axis and grid added.

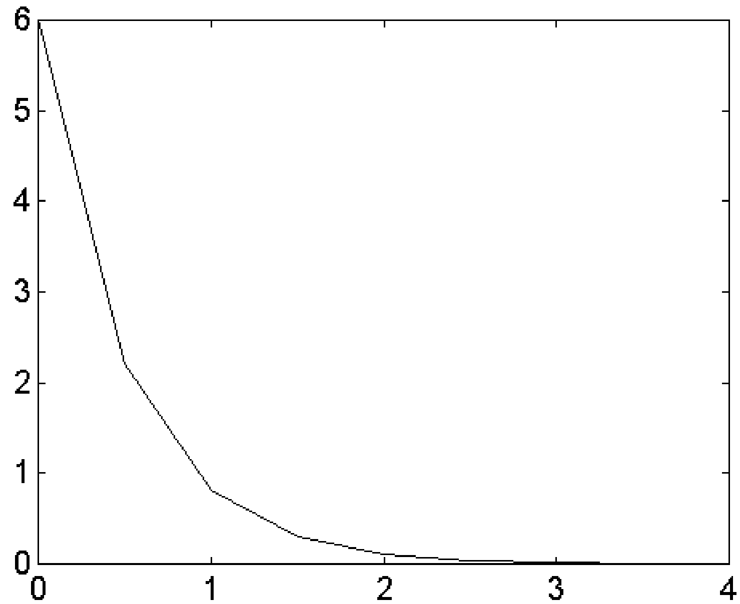

Figure 2.2 Graph of Two Vectors t and y

To write text on a graphic screen beginning at a point (x, y) on the graphic screen, one can use the command

text(x, y, 'text')

For example, the statement

```
text(2.0, 1.5, 'transient analysis')
```

will write the text, transient analysis, beginning at point (2.0,1.5). Multiple text commands can be used. For example, the statements

```
plot(a1,b1,a2,b2)
text(x1,y1,'voltage')
text(x2,y2,'power')
```

will provide texts for two curves: a1 versus b1 and a2 versus b2. The text will be at different locations on the screen provided x1 $\neq$ x2 or y1 $\neq$ y2.

If the default line-types used for graphing are not satisfactory, various symbols may be selected. For example:

plot(a1, b1, '*')

draws a curve, a1 versus b1, using star(*) symbols, while

plot(a1, b1, '*', a2, b2, '+')

uses a star(*) for the first curve and the plus(+) symbol for the second curve. Other print types are shown in Table 2.2.

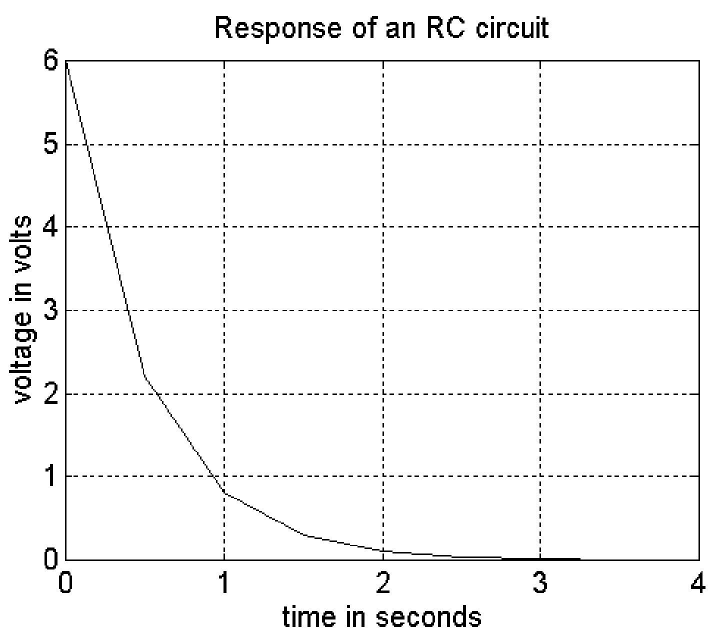

Figure 2.3 Graph of Voltage versus Time of a Response of an RLC Circuit

For systems that support color, the color of the graph may be specified using the statement:

plot(x, y, 'g')

implying, plot x versus y using green color. Line and mark style may be added to color type using the command

plot(x, y, '+w')

The above statement implies plot x versus y using white + marks. Other colors that can be used are shown in Table 2.3.

Table 2.2
Print Types

LINE-TYPES	INDICATORS	POINT TYPES	INDICATORS
solid	-	point	.
dash	--	plus	+
dotted	:	star	*
dashdot	-.	circle	o
		x-mark	x

Table 2.3
Symbols for Color Used in Plotting

COLOR	SYMBOL
red	r
green	g
blue	b
white	w
invisible	i

The argument of the plot command can be complex. If z is a complex vector, then plot(z) is equivalent to plot(real(z), imag(z)). The following example shows the use of the plot, title, xlabel, ylabel and text functions.

Example 2.1

For an R-L circuit, the voltage $v(t)$ and current $i(t)$ are given as

$$v(t) = 10\cos(377t)$$

$$i(t) = 5\cos(377t + 60^0)$$

Sketch $v(t)$ and $i(t)$ for $t = 0$ to 20 milliseconds.

Solution

MATLAB Script

```
% RL circuit
% current i(t) and  voltage v(t) are generated;  t is time
t = 0:1E-3:20E-3;  v  = 10*cos(377*t);
a_rad = (60*pi/180);  % angle in radians
i = 5*cos(377*t + a_rad);
plot(t,v,'*',t,i,'o')
title('Voltage and Current of an RL circuit')
xlabel('Sec')
ylabel('Voltage(V) and Current(mA)')
text(0.003, 1.5, 'v(t)');
text(0.009,2, 'i(t)')
```

Figure 2.4 shows the resulting graph. The file ex2_1.m is a script file for the solution of the problem.

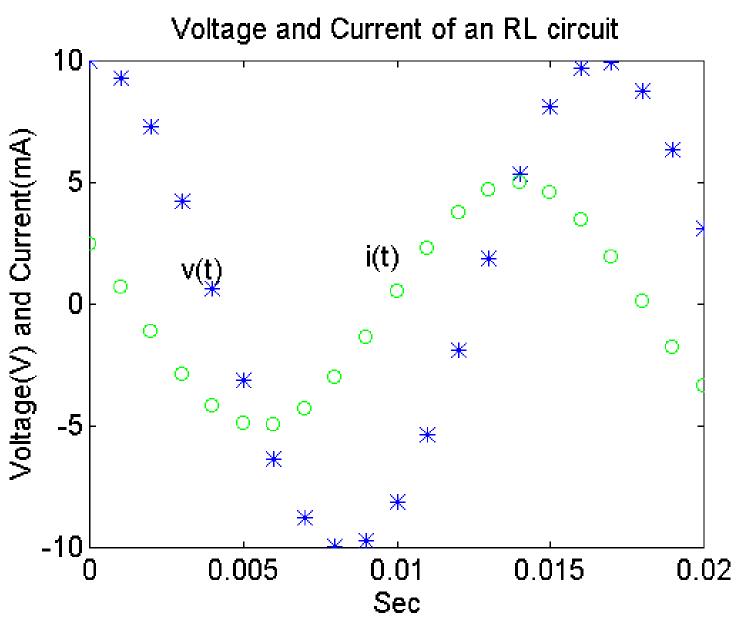

Figure 2.4 Plot of Voltage and Current of an RL Circuit under Sinusoidal Steady State Conditions

2.3 LOGARITHMIC AND POLAR PLOTS

Logarithmic and semi-logarithmic plots can be generated using the commands **loglog, semilogx, and semilogy**. The use of the above plot commands is similar to those of the plot command discussed in the previous section. The description of these commands are as follows:

loglog(x, y) - generates a plot of $\log_{10}(x)$ versus $\log_{10}(y)$

semilogx(x, y) - generates a plot of $\log_{10}(x)$ versus linear axis of y

semilogy(x, y) - generates a plot of linear axis of x versus $\log_{10}(y)$

It should be noted that since the logarithm of negative numbers and zero does not exist, the data to be plotted on the semi-log axes or log-log axes should not contain zero or negative values.

Example 2.2

The gain versus frequency of a capacitively coupled amplifier is shown below. Draw a graph of gain versus frequency using a logarithmic scale for the frequency and a linear scale for the gain.

Frequency (Hz)	Gain (dB)	Frequency (Hz)	Gain (dB)
20	5	2000	34
40	10	5000	34
80	30	8000	34
100	32	10000	32
120	34	12000	30

Solution

MATLAB Script

```
% Bode plot for capacitively coupled amplifier
f = [20 40 80 100 120 2000 5000 8000 10000 ...
    12000 15000 20000];
g = [ 5 10 30 32 34 34 34 34 32 30 10 5];
semilogx(f, g)
```

```
title('Bode plot of an amplifier')
xlabel('Frequency in Hz')
ylabel('Gain in dB')
```

The plot is shown in Figure 2.5. The MATLAB script file is ex2_2.m.

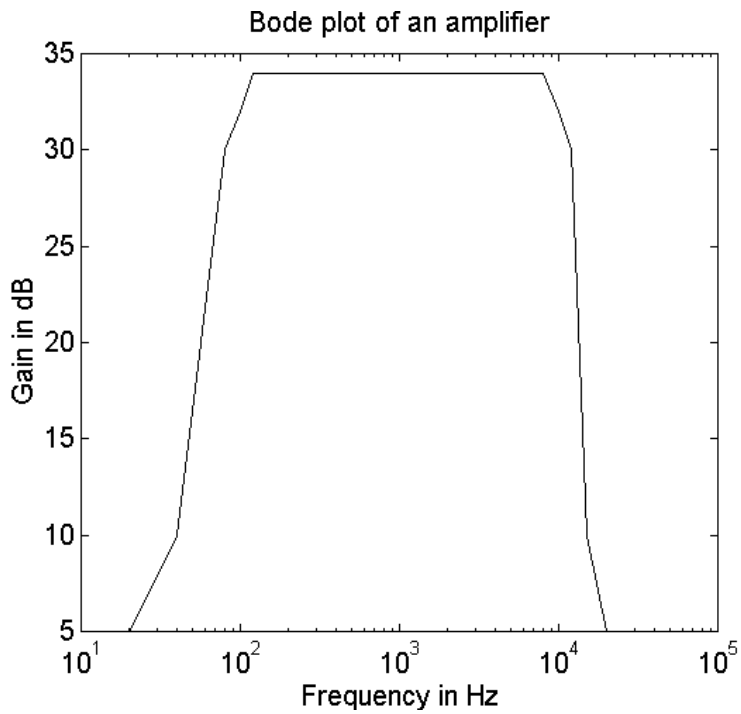

Figure 2.5 Plot of Gain versus Frequency of an Amplifier

A **polar** plot of an angle versus magnitude may be generated using the command

polar(theta, rho)

where,

theta and rho are vectors, with the theta being an angle in radians and rho being the magnitude.

When the grid command is issued after the polar plot command, polar grid lines will be drawn. The polar plot command is used in the following example.

Example 2.3

A complex number z can be represented as $z = re^{j\theta}$. The n^{th} power of the complex number is given as $z^n = r^n e^{jn\theta}$. If r = 1.2 and $\theta = 10^0$, use the polar plot to plot $|z^n|$ versus $n\theta$ for n = 1 to n = 36.

Solution

MATLAB Script

```
% polar plot of z
r = 1.2;  theta = 10*pi/180;
angle = 0:theta:36*theta;  mag = r.^(angle/theta);
polar(angle,mag)
grid
title('Polar Plot')
```

The polar plot is shown in Figure 2.6.

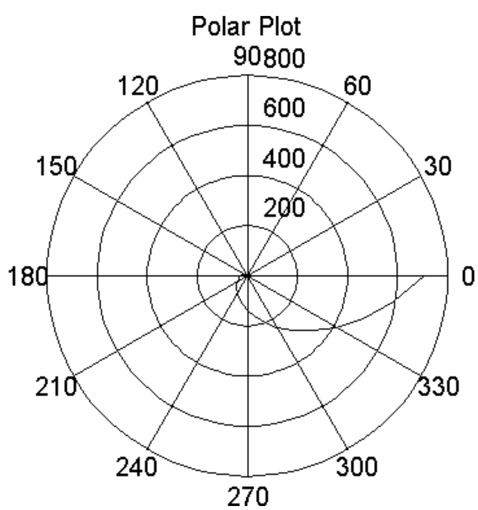

Figure 2.6 Polar Plot of $z = 1.2^n e^{j10n}$

2.4 SCREEN CONTROL

MATLAB has basically two display windows: a command window and a graph window. The hardware configuration an operator is using will either display both windows simultaneously or one at a time. The following commands can be used to select and clear the windows:

shg	-	shows graph window
any key	-	brings back command window
clc	-	clears command window
clg	-	clears graph window
home	-	home command cursor

The graph window can be partitioned into multiple windows. The **subplot** command allows one to split the graph window into two subdivisions or four subdivisions. Two sub-windows can be arranged either top or bottom or left or right. A four-window partition will have two sub-windows on top and two sub-windows on the bottom. The general form of the subplot command is

subplot(i j k)

The digits *i* and *j* specify that the graph window is to be split into an i-by-j grid of smaller windows. The digit *k* specifies the k^{th} window for the current plot. The sub-windows are numbered from left to right, top to bottom. For example,

```
%
x = -4:0.5:4;
y = x.^2; % square of x
z = x.^3; % cube of x
subplot(211), plot(x, y), title('square of x')
subplot(212), plot(x, z), title('cube of x')
```

will plot $y = x^2$ in the top half of the graph screen and $z = x^3$ will be plotted on the bottom half of the graph screen. The plots are shown in Figure 2.7.

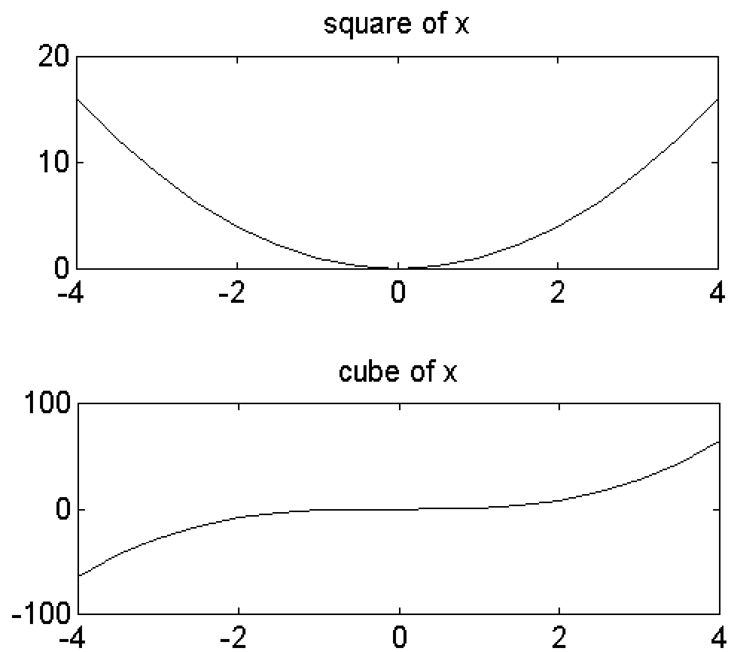

Figure 2.7 Plots of x^2 and x^3 using Subplot Commands.

The coordinates of points on the graph window can be obtained using the **ginput** command. There are two forms of the command:

[x y] = ginput

[x y] = ginput(n)

- [x y] = ginput command allows one to select an unlimited number of points from the graph window using a mouse or arrow keys. Pressing the return key terminates the input.

- [x y] = ginput(n) command allows the selection of n points from the graph window using a mouse or arrow keys. The points are stored in vectors x and y. Data points are entered by pressing a mouse button or any key on the keyboard (except return key). Pressing the return key terminates the input.

SELECTED BIBLIOGRAPHY

1. MathWorks, Inc, *MATLAB, High-Performance Numeric Computation Software*, 1995.

2. Biran, A. and Breiner, M. *MATLAB for Engineers*, Addison-Wesley, 1995.

3. Etter, D.M., *Engineering Problem Solving with MATLAB*, 2nd Edition, Prentice Hall, 1997.

EXERCISES

2.1 The repulsive coulomb force that exists between two protons in the nucleus of a conductor is given as

$$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$$

If $q_1 = q_2 = 1.6x10^{-19}$ C, and $\frac{1}{4\pi\varepsilon_0} = 8.99x10^9\ Nm^2 / C^2$, sketch a graph of force versus radius r. Assume a radius from $1.0x10^{-15}$ to $1.0x10^{-14}$ m with increments of $2.0x10^{-15}$ m.

2.2 The current flowing through a drain of a field effect transistor during saturation is given as

$$i_{DS} = k(V_{GS} - V_t)^2$$

If $V_t = 1.0$ volt and $k = 2.5mA / V^2$, plot the current i_{DS} for the following values of V_{GS} : 1.5, 2.0, 2.5, ..., 5 V.

2.3 Plot the voltage across a parallel RLC circuit given as

$$v(t) = 5e^{2t} \sin(1000\pi t)$$

2.4 Obtain the polar plot of $z = r^{-n} e^{jn\theta}$ for θ = 15^0 and n = 1 to 20.

2.5 The table below shows the grades of three examinations of ten students in a class.

STUDENT	EXAM #1	EXAM #2	EXAM #3
1	81	78	83
2	75	77	80
3	95	90	93
4	65	69	72
5	72	73	71
6	79	84	86
7	93	97	94
8	69	72	67
9	83	80	82
10	87	81	77

(a) Plot the results of each examination.

(b) Use MATLAB to calculate the mean and standard deviation of each examination.

2.6 A function $f(x)$ is given as

$$f(x) = x^4 + 3x^3 + 4x^2 + 2x + 6$$

(a) Plot $f(x)$ and
(b) Find the roots of $f(x)$

2.7 A message signal m(t) and the carrier signal $c(t)$ of a communication system are, respectively:

$$m(t) = 4\cos(120\pi t) + 2\cos(240\pi t)$$
$$c(t) = 10\cos(10{,}000\pi t)$$

A double-sideband suppressed carrier $s(t)$ is given as

$$s(t) = m(t)c(t)$$

Plot $m(t), c(t)$ and $s(t)$ using the subplot command.

2.8 The voltage v and current I of a certain diode are related by the expression

$$i = I_S \exp[v / (nV_T)]$$

If I_S = $1.0x10^{-14}$ A, n = 2.0 and V_T = 26 mV, plot the current versus voltage curve of the diode for diode voltage between 0 and 0.6 volts.