Theme: Introduction in Simulink.
Continuous and discrete signals. Transform Laplace. Transform Z. Typical elements.

The goal of the work:

1. To study Simulink and its library.
2. To study the mode of use the transform Laplace and Transform Z in Matlab.
3. To study the typical signals in Simulink.
4. To study the typical elements and its proprities.

Theoretical notions

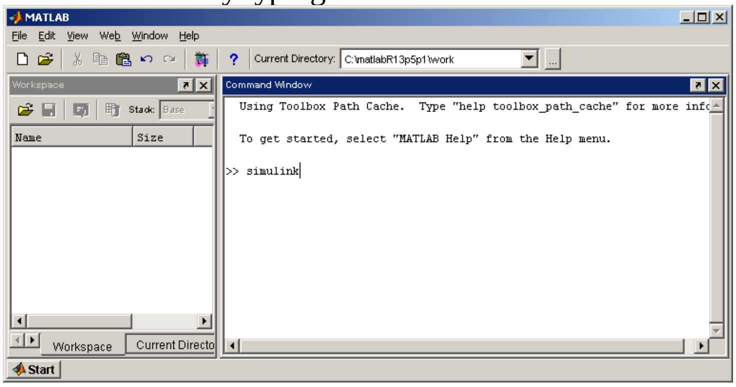
Introduction in SIMULINK

Simulink is a software package that enables you to model, simulate, and analyze systems whose outputs change over time. Such systems are often referred to as dynamic systems. Simulink can be used to explore the behavior of a wide range of real-world dynamic systems, including electrical circuits, shock absorbers, braking systems, and many other electrical, mechanical, and thermodynamic systems.

Simulating a dynamic system is a two-step process with Simulink. First, a user creates a block diagram, using the Simulink model editor, which graphically depicts time-dependent mathematical relationships among the system's inputs, states, and outputs. The user then commands Simulink to simulate the system represented by the model from a specified start time to a specified stop time.

Getting Started in SIMULINK

In MATLAB the Simulink is started by typing in command line the command **simulink**



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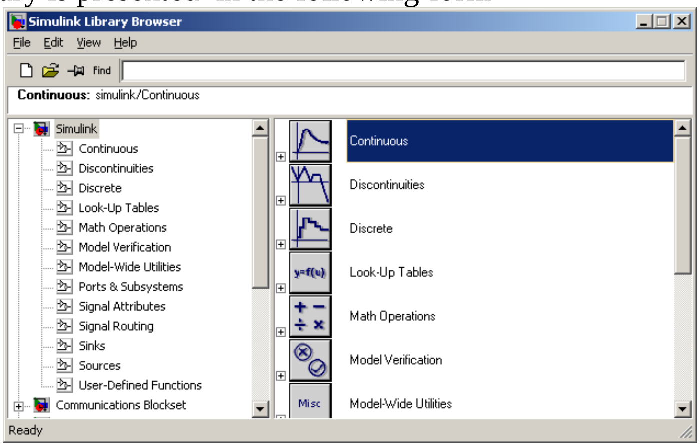
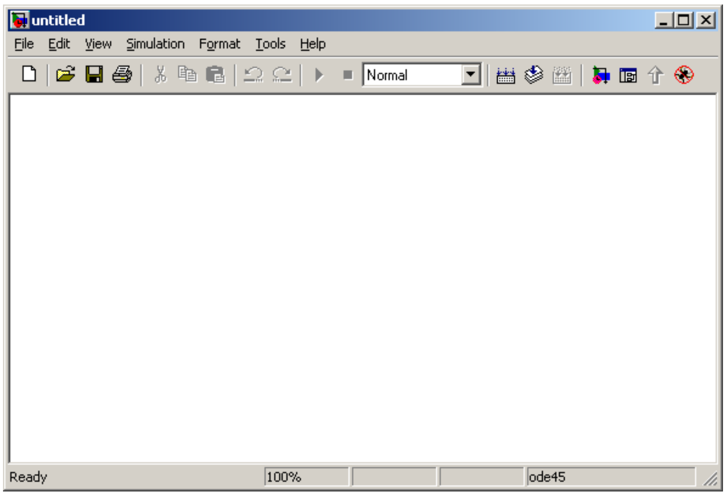
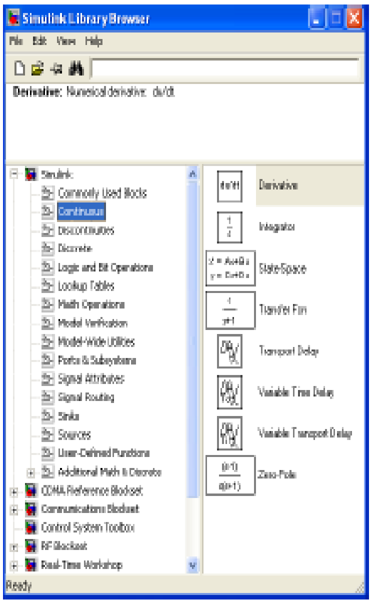
The Simulink library is presented in the following form



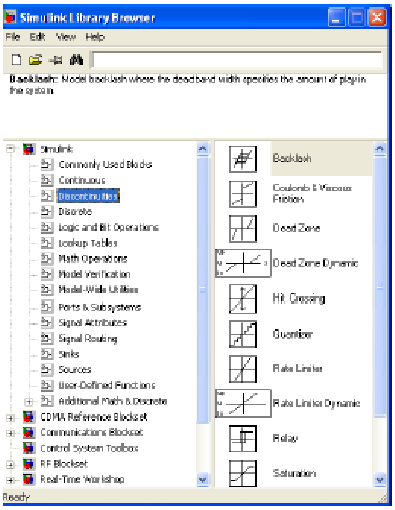
A Simulink model is a block diagram that can be created from "File->New->Model" in the Library Browser. An empty block diagram will pop up. You can drag blocks into the diagram from the library.



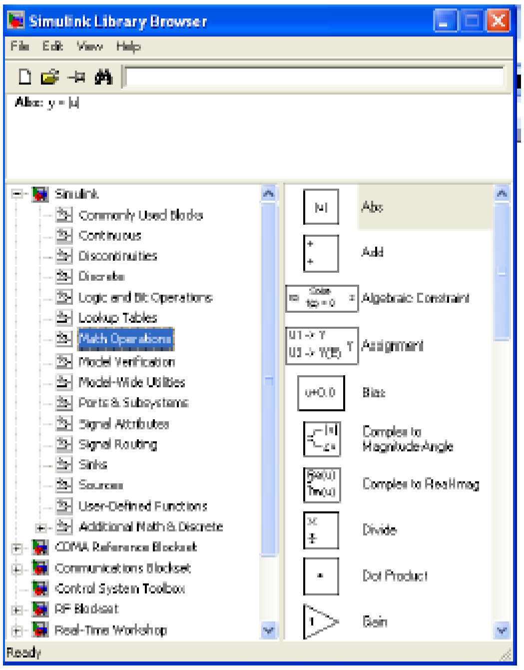
The category Continuous Elements contains continuous system model elements:



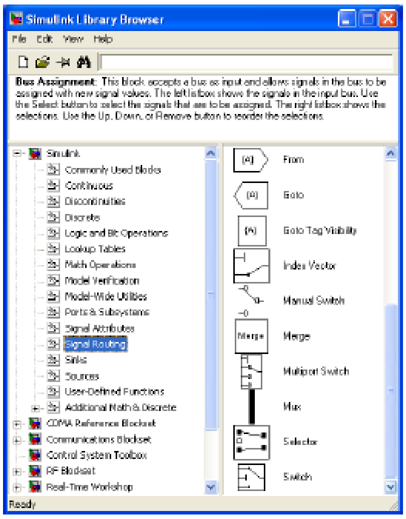
The category Discontinuous Elements contains discontinuous system model elements:



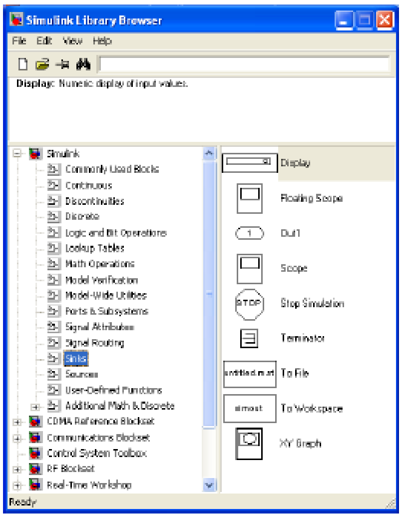
The category Math Operations contains list of math operation elements:



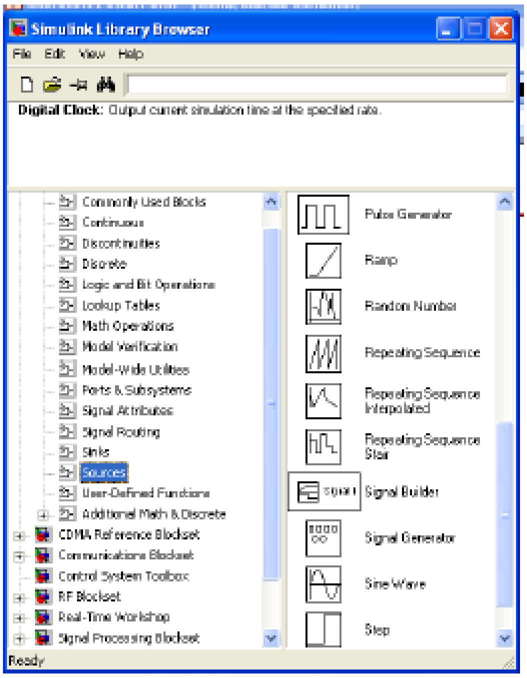
The category Signal Routing contains the signal routing elements:

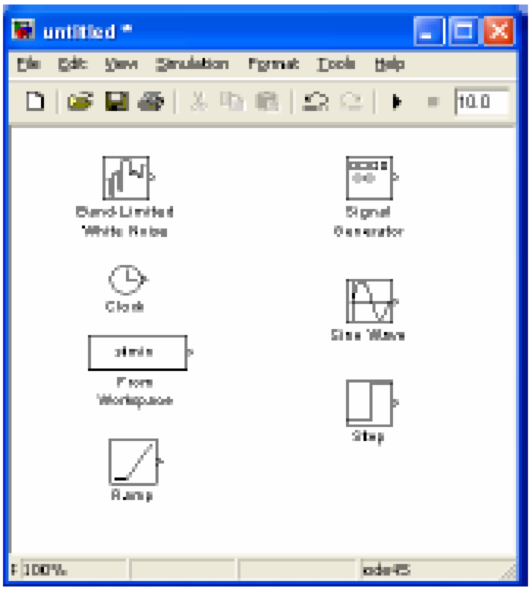


The category Sink Models contains elements that are used for for displaying simulation results:

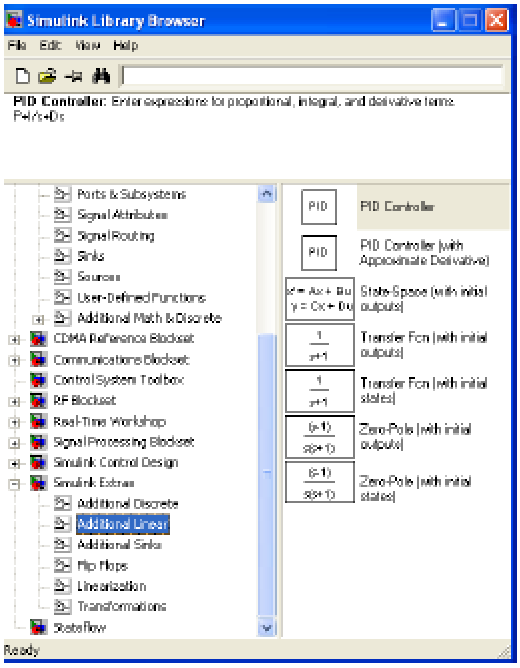


The category Signal Routing contains list of source elements used for model source functions:

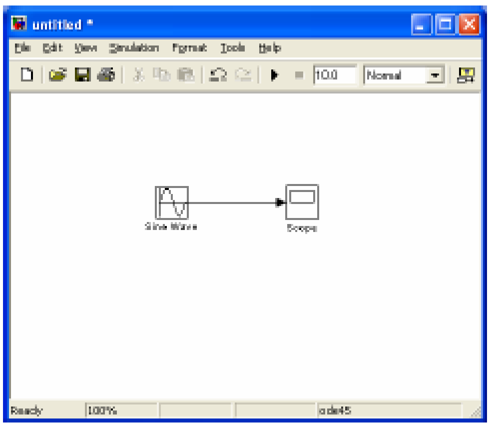




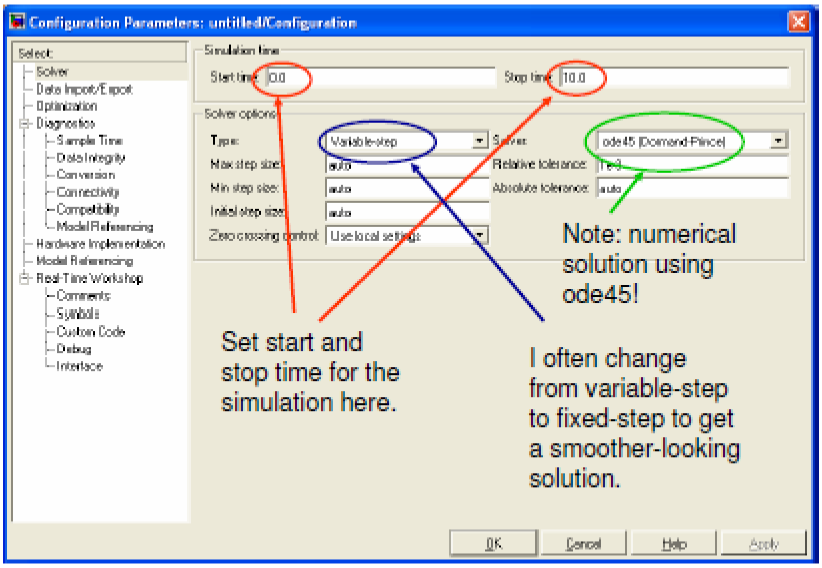
The category Simulink Extras contains additional blocks for PID controller simulation:



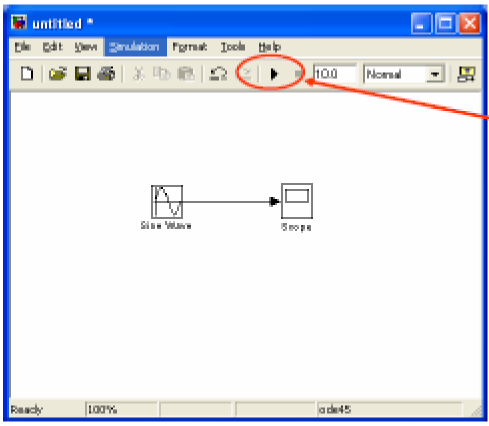
Connections of blocks:



Running the Simulation:

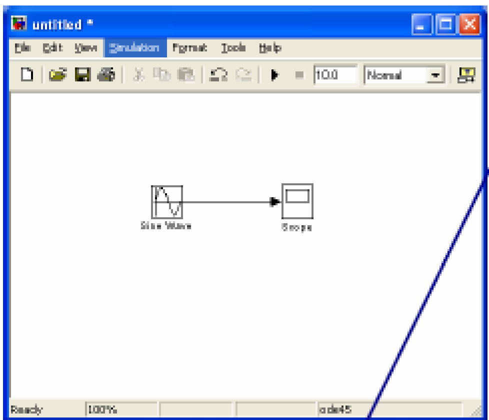


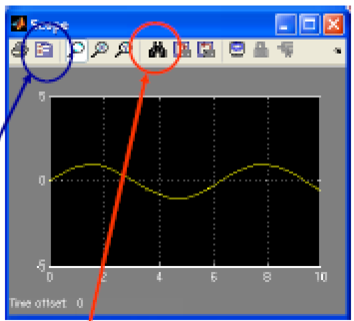
Running the Simulation:



Once the parameters are all set, click the play button to run the simulation.

Viewing Results: Scope

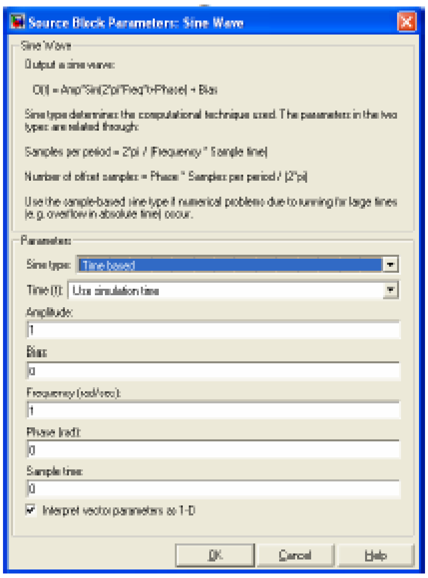




You can save data from the scope to the workspace using the "Parameters", "Data History" tab.

Double click on the scope icon to open up the viewer. You often have to zoom out using the binocular icon if the curve doesn't fit in the default axes.

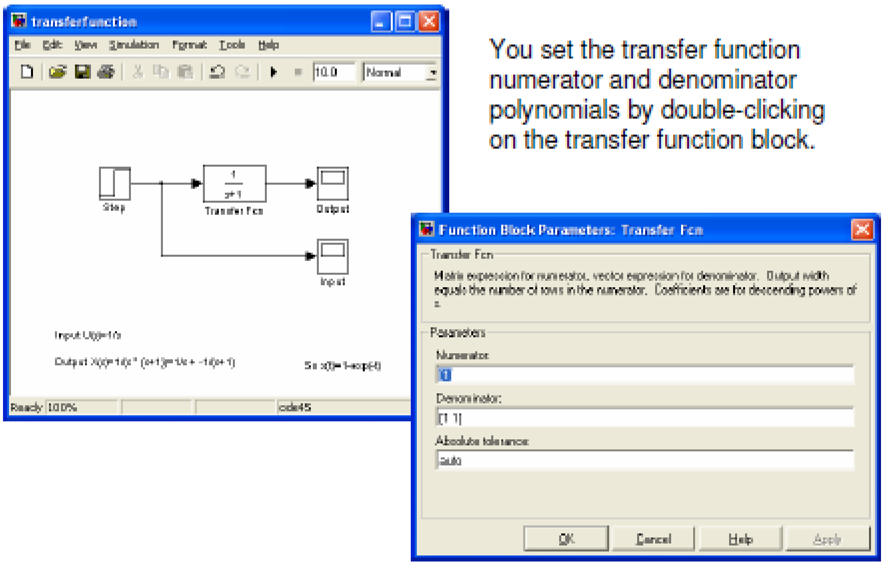
Modifying Block Properties



Double click on any block to bring up a properties box.

Here are the "sine wave" properties. If you don't know what something is… leave it alone!!!

Use the transfer functions:



You set the transfer function numerator and denominator polynomials by double-clicking on the transfer function block.

Laplace transform

A transform is a mathematical tool that converts an equation from one variable (or one set of variables) into a new variable (or a new set of variables). To do this, the transform must remove all instances of the first variable, the "Domain Variable", and add a new "Range Variable". Integrals are excellent choices for transforms, because the limits of the definite integral will be substituted into the domain variable, and all instances of that variable will be removed from the equation.

$$F(s) = \int_{0}^{\infty} f(t) e^{-ist} dt \,.$$

The transform Laplace in Matlab is calculated use the following commands:

F = laplace(f)
F = laplace (f, v)
F = laplace (f, u, v)

In the first form the variable of function f is s, and of the function F is t. In the second form the variable of function f is t and of the function F is v. In the third form the variable of the function f is u and of the function F is v.

The inverse transform Laplace is calculate by the formulae

$$f(x) = \frac{1}{2\pi i} \int_{c-i\infty}^{c+i\infty} F(s) e^{ist} ds$$

The inverse transform Laplace in Matlab is calculated use the following commands:

f = ilaplace(F)
f = ilaplace (F, u)
f = ilaplace (F, v, u)

In the first form the variable of function f is s, and of the function F is t. In the second form the variable of function f is t and of the function F is v. In the third form the variable of the function f is u and of the function F is v.

Example. Is need calculate the transform Laplace of the function

$$f(t) = e^{-at}$$

```
syms f F t s
syms a positive
f = exp(-a *t)

f =
exp(-a*t)

F = laplace(f)

F =
1/(s+a)
```

Example. Is need calculate the inverse transform Laplace of a function

$$F(s) = \frac{1}{s+a}$$

```
syms f F s t
syms a positive

F = 1/(s+a)

f = ilaplace(F)

f =
exp(-t*a)
```

Z transform

The Z transform is defined by the following expresion

$$F(z) = \sum_{n=0}^{\infty} f(n) z^{-n}$$

The Z transform in Matlab is calculated use the following commands:

F = ztrans(f)
F = ztrans(f, w)
F = ztrans(f, k, w)

In the first form the variable of function f is n, and of the function F is z. In the second form the variable of function f is n and of the function F is w. In the third form the variable of the function f is k and of the function F is w.

The inverse Z transform is calculated by the following expresion:

$$f(n) = \frac{1}{2\pi i} \oint_{|z|=R} F(z) z^{n-1} dz\,.$$

The inverse Z transform in Matlab is calculated use the following commands:

```
f = iztrans(F)
f = iztrans(F, k)
f = iztrans(F, w, k)
```

Example. Calculate the Z transform of the function

$$f(n) = \exp(-anT)$$

```
syms a n T
f = exp(-a*T*n)

f =
exp(-a*T*n)

F = ztrans(f)

F =
z/exp(-a*T)/(z/exp(-a*T)-1)
```

The inverce Z transform of F function will be

```
iztrans(F)

ans =
exp(-a*T)^n
```

Example. Calculate the inverse Z transform of the function

$$F(z) = \frac{z}{z-a}$$

```
syms a z;
F = z / (z – a);
f = iztrans(F)

f =
a^n
```

The typical elements in theory of system:

1. The *ideal element* (*proportional*), differential equation and transfer function are:

$$y(t) = kx(t),$$
$$H(s) = k$$

where k is the transfer coefficient.

2. *The integrator element*, the integral equation and transfer function are:

$$y(t) = \frac{1}{T_i}\int_0^t x(t)\ ,$$
$$H(s) = \frac{1}{T_i s} = \frac{k_i}{s}$$

where T_i is the time constant of integration, $k_i = 1/T_i$ – the inverse coefficient of time constant.

3. *The element with inertia first order*, differential equation and transfer function are:

$$T\frac{dy(t)}{dt} + y(t) = kx(t)$$
$$H(s) = \frac{k}{Ts+1}$$

where k is a transfer coefficient, T – time constant.

4. *The ideal and real derivative element* (*or element with anticipation*), differential equation and transfer function are:

- the ideal element:

$$y(t) = \frac{dx(t)}{dt},$$
$$H(s) = T_d s,$$

where T_d is a constant time.

- the real derivative element is:

$$T_p \frac{dy(t)}{dt} + y(t) = T_d \frac{dx(t)}{dt},$$
$$H(s) = \frac{T_d s}{T_p s+1} = T_d s \frac{1}{T_p s+1}.$$

5. *Damped oscillating element* (inertia second order): differential equation and transfer function are:

$$T^2 \frac{d^2 y(t)}{dt^2} + 2\xi T \frac{dy(t)}{dt} + y(t) = kx(t),$$
$$H(s) = \frac{k}{T^2 s^2 + 2\xi T s + 1} = \frac{k}{T_1 s^2 + T_2 s + 1} = k \frac{\omega_n^2}{s^2 + 2\xi \omega_n s + \omega_n^2}$$

where k transfer coefficient, T – constant time, ξ - damping coefficient, $T_1 = T^2$, $T_2 = 2\xi T$, and $\omega_n = \frac{1}{T}$ is natural.

6. *The element with delay*: differential equation and transfer function are:

$$y(t) = kx(t-\tau),$$
$$H(s) = ke^{-\tau s}$$

where k is transfer coefficient, τ – delay.

Tasks:

1. Find the presentation of functions in transform Laplace
    1. *f = sin(5wt); f=t^n+10;f=cos(wt-10)*
    2. *f = sin(10wt+2);f=5t^n+10;f=cos(3wt)*
    3. *f = sin(5wt-2t);f=t^4;f=cos(8wt-t^2)*
    4. *f = sin(wt+7t);f=5t+2;f=cos(12wt-10)*
    5. *f = sin(7wt-2);f=5t^n;f=cos(8wt)*
    6. *f = sin(2wt-6t);f=3t^4;f=cos(wt-t^2)*
    7. *f = sin(5wt+7t);f=9t+10;f=cos(12wt-10)*
    8. *f = sin(5wt-4);f=4t^n; f = sin(8wt);*
    9. *f = sin(3wt); f=t^n+1;f=cos(wt-9)*
    10. *f = sin(20wt+1);f=3t^n+10;f=cos(7wt)*
    11. *f = sin(5wt-3t);f=t^5;f=cos(8wt-t^3)*
    12. *f = sin(wt+4t);f=6t+2;f=cos(10wt-10)*
    13. *f = sin(3wt-6);f=2t^n;f=cos(3wt)*
    14. *f = sin(2wt-8t);f=t^3;f=cos(wt-t^3)*
    15. *f = sin(5wt+t);f=8t+2;f=cos(wt-10)*
    16. *f = sin(8wt-7);f=6t^n; f = sin(8wt);*

2. Find the presentation of functions in transform Z
    1. *f = sin(4wTn);f=(2Tn+10)^2;f=8Tn*
    2. *f = sin(2wTn);f=(3Tn+10)^2;f=Tn*
    3. *f = sin(3wTn);f=(4Tn+10)^2;f=5Tn+100*
    4. *f = sin(7wTn);f=(7Tn+10)^2;f=8Tn*
    5. *f = sin(6wTn);f=(9Tn+10)^2;f=10Tn*
    6. *f=(Tn+10)^2;f=10Tn+20;f = sin(8wTn-10)*
    7. *f=(Tn+10)^2;f=5Tn;f = sin(7wTn)*
    8. *f=(9Tn+15)^3;f=10Tn+10; f=20Tn*
    9. *f = sin(2wTn);f=(8Tn+10)^2;f=6Tn*
    10. *f = sin(10wTn);f=(4Tn+10)^2;f=Tn*
    11. *f = sin(13wTn);f=(2Tn+10)^2;f=5Tn+50*
    12. *f = sin(17wTn);f=(5Tn+10)^2;f=7Tn*
    13. *f = sin(16wTn);f=(7Tn+10)^2;f=2Tn*
    14. *f=(Tn+5)^2;f=15Tn+20;f = cos(8wTn-10)*

15. *f=(Tn+8)^2;f=15Tn;f = cos(6wTn)*
16. *f=(20Tn+10)^3;f=20Tn+10; f=10Tn*

3. Study the mode of use the Simulink.
4. Present the variation of typical signals, using the block Scope for the following signals:
   1. *Band-Limited White Noise*
   2. *Chirp Signal*
   3. *Pulse Generator*
   4. *Ramp*
   5. *Random Number*
   6. *Repeating Sequence*
   7. *Sine Wave*
   8. *Step*
   9. *Uniform Random Number*

Identify the parameters that characterize each signal.

5. Obtain the transient process for the:

- **ideal element;**
- **inertia element;**
- **integrator element;**
- **real derivative element;**
- **inertia element with time delay**.

Give some values for the transfer coefficient and constant time. Modify the respectively values and observe the modification of the transient process.

6. For the case of **damped oscillating element** give some value for the k and T . Modify the value of the damping coefficient in domain [0..1] (the k and T value remain constant) for every case present the transient process.