## EE 1130

## Freshman Eng. Design for

 Electrical and Computer Eng.Class 3

Signal Processing Module (DSP).

- Differential Equations.
- Laplace Transform. Transfer Function.
- Simulink with Transfer Functions. Zeros, Poles.


## Simulink: Differential Equations.

- Any Linear Time Invariant system could be modeled as the solution of a differential equation (DE) .
- In the case of Low Pass RC filter shown in next figure:

- The Differential Equation is:

$$
R C \dot{y}+y=x
$$

## Simulink: Differential Equations.

- Next is an algebraic equation (instant equation).

$$
y(t)=2 x(t)
$$

- A differential equation has into account velocities!!!

$$
K \frac{d y}{d t}+y(t)=2 x(t)
$$

## Simulink: Differential Equations.

- The circuit analysis is shown in next figure:


$$
i_{R}(t)=\frac{v_{R}(t)}{R}
$$

$$
\begin{array}{r}
v_{C}(t)=\frac{1}{C} \int_{0}^{t} i_{C}(t) d t \\
i_{C}(t)=C \frac{d v_{C}}{d t}
\end{array}
$$

## Simulink: Differential Equations.

- The circuit analysis is s

$$
x(t)=\left(C \frac{d y}{d t}\right) R+y(t)
$$

$$
R C \frac{d y}{d t}+y(t)=x(t)
$$

## Simulink: Differential Equations.

$$
R C \dot{y}+y=x
$$

- Where $y$ with the dot is the first derivative of $y(t)$ and $x$ is $x(t)$. $R$ and $C$ are the values of the Resistor and Capacitor respectively.
- The Differential Equation could be simulated with Simulink.
- However, the Differential Equation must be modified to an Integral Equation, since integrator blocks are more used than derivative blocks.

$$
\int(R C \dot{y}+y) d t=\int x d t
$$

## Simulink: Differential Equations.

- The integral is linear:

$$
\begin{gathered}
R C \int \dot{y} d t+\int y d t=\int x d t \\
R C y=\int x d t-\int y d t \\
y=\frac{1}{R C} \int(x-y) d t \\
y=\int\left(\frac{1}{R C} x-\frac{1}{R C} y\right) d t
\end{gathered}
$$

## Simulink: Differential Equations.

- The block diagram could be implemented from this equation:

$$
y=\int\left(\frac{1}{R C} x-\frac{1}{R C} y\right) d t
$$



## Simulink: Differential Equations.

- To insert the Step and Scope blocks we do:




## Simulink: Differential Equations.

- To insert the Integrator block we do:



## Simulink: Differential Equations.

- Once all elements in the Model, we make the connections:

- To flip the Gain1 block we type control+I



## Simulink: Differential Equations.

- Double click on each gain block and change the 1 to $1 /(\mathrm{R} * \mathrm{C})$ at the first block and $-1 /(\mathrm{R} * \mathrm{C})$ at the second.
- Type $\mathrm{C}=1$ and $\mathrm{R}=1$ at the command window to define the variables $R$ and $C$.



## Simulink: Differential Equations.

- To see both traces in one scope we add the MUX.

| Simulink Library Browser | $-\square \times$ |
| :---: | :---: |
| File Edit View Help |  |
| $\square \square>$ Enter search term |  |
| Libraries | y: Simulink/Signal Routing $\mid$ \| |
| Sirmulink <br> Commonly Used Blocks <br> Continuous <br> Discontinuities <br> Discrete <br> Logic and Bit Operations <br> Lookup Tables <br> Math Operations <br> Model Verification <br> Model-Mide Utilities <br> Ports \& Subsystems <br> Signal Attributes <br> Signal Routing <br> .- Sinks <br> Sources <br> User-Defined Functions <br> . Additional Math \& Discrete <br> Aerospace Blockset <br> Communications System... <br> Computer Vision System... <br> Control Systern Toolbox <br> DSP Systern Toolbox <br> Data Acquisition Toolbox <br> EDA. Sirmulator Link <br> Embedded Coder <br> Fuzzy Logic Toolbox <br> Gauges Blockset | [A] <br> [A\} <br> Merge <br> Multiport Swito <br> Mux <br> Selector |

## Simulink: Differential Equations.

- Once all connected, variables defined in command window, we hit play and double click on the scope block to open the scope screen.




## End of Class

