## 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.

- A differential equation is not instant.

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

- 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:


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

## 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:



## Simulink：Differential Equations．

－To insert the Step and Scope blocks we do：


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## 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.

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## 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.




## Simulink: Laplace Transform.

- Working with DE is not easy. Laplace Transform allows avoid DE.
- Also, it allows us to have an analytic relation input/output!!

$$
\begin{gathered}
R C \dot{y}+y=x \\
R C \frac{d y}{d t}+y(t)=x(t)
\end{gathered}
$$

- Aplying Laplace:

$$
R C s Y(s)+Y(s)=X(s)
$$

## Simulink: Laplace Transform.

- Operating:

$$
\begin{aligned}
& Y(s)(R C s+1)=X(s) \\
& Y(s)=\frac{1}{R C s+1} X(s)
\end{aligned}
$$

- We could easily implement this in Simulink!!!
- The multiplier of $X(s)$ is called Transfer Function.

$$
H(s)=\frac{1}{R C s+1}
$$

## Simulink: Laplace Transform.

- Double click on Transfer Fcn to open options as shown below:
- Simulating:




## End of Class

