MISR UNIVERSITY FOR SCIENCE AND TECHNOLOGY
COLLEGE OF ENGINEERING
MECHATRONICS DEPARTMENT

MTE 506 DIGITAL CONTROL

LAB 5 – SPRING 2019

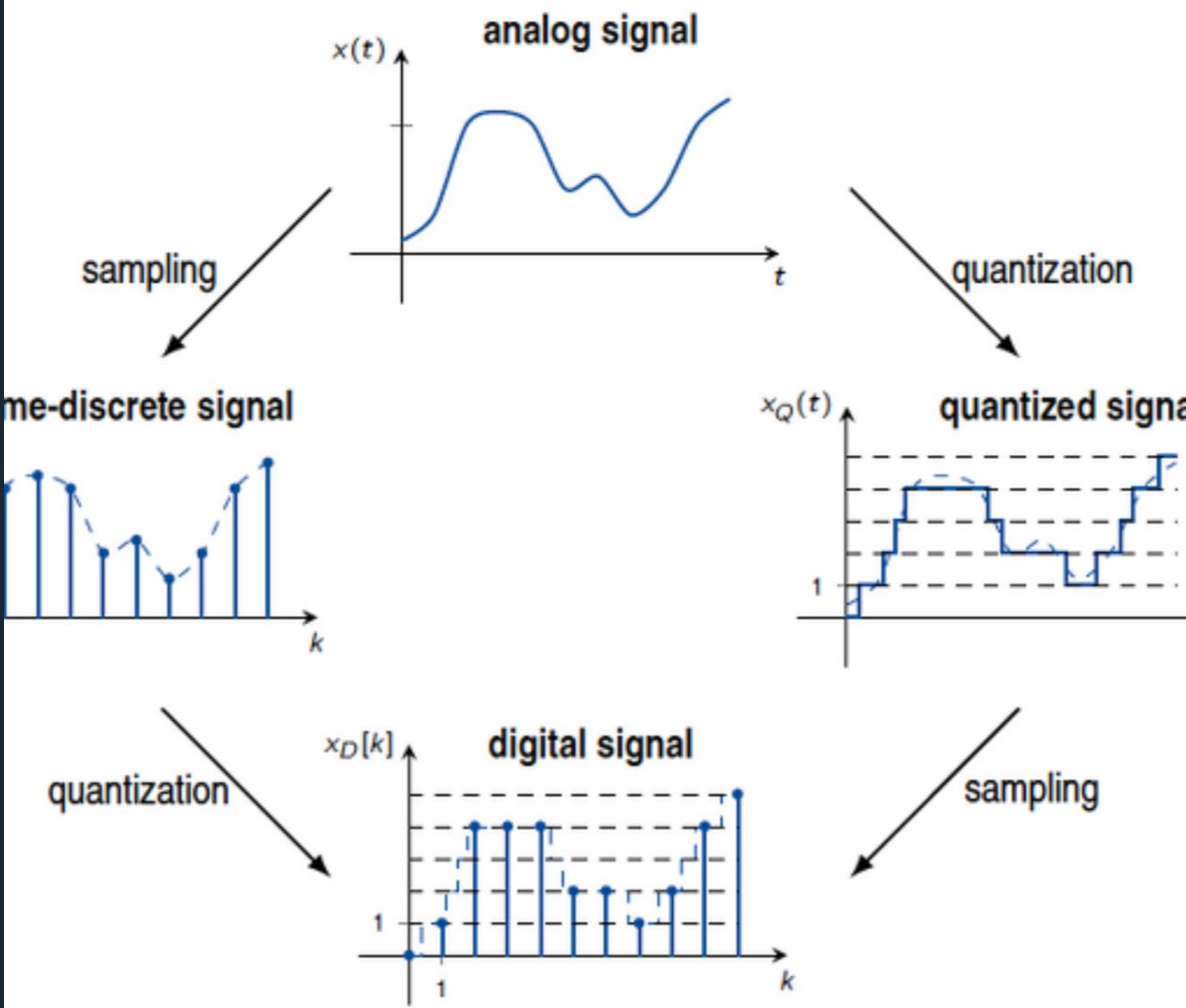
Lab 5

Goals of The Lab

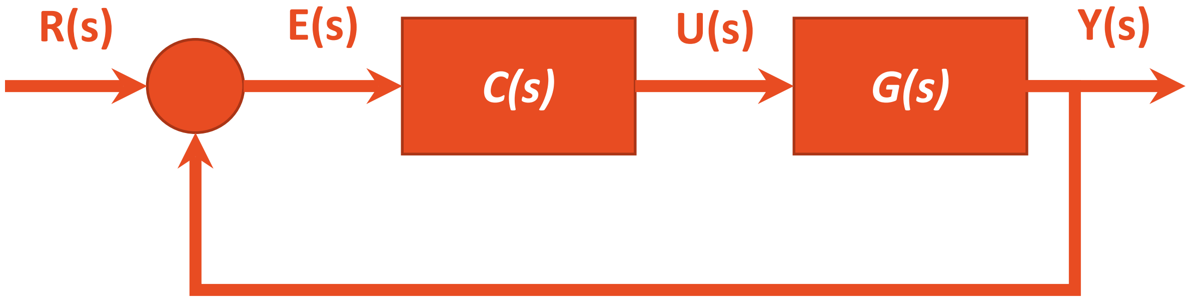
- Studying the PID terms on system response
- Computing steady state for each term

Lab 5

Continuous vs. Discrete Systems



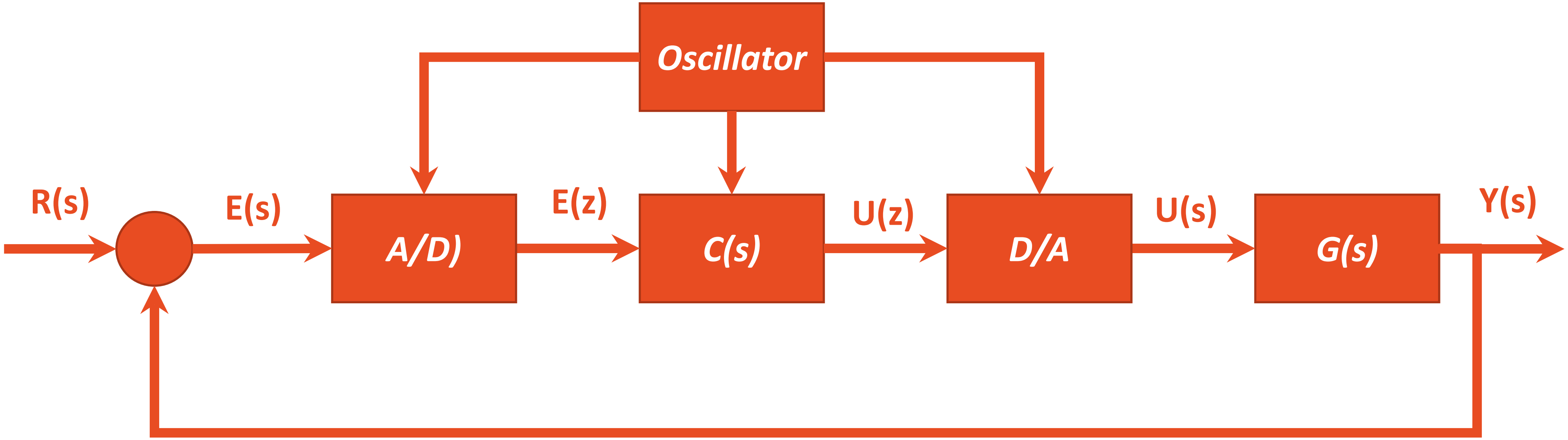
Continuous System vs. Discrete System



$R(s)$ ... *Stimulation signal*
$E(s)$ ... *Error signal*
$C(s)$ ... *Controller*
$U(s)$ ... *Control Action*
$Y(s)$ ... *Sensor Output*

Lab 5

Continuous System vs. **Discrete System**



$R(s)$ … *Stimulation signal*

$E(s)$ … *Error signal*

$C(s)$ … *Controller*

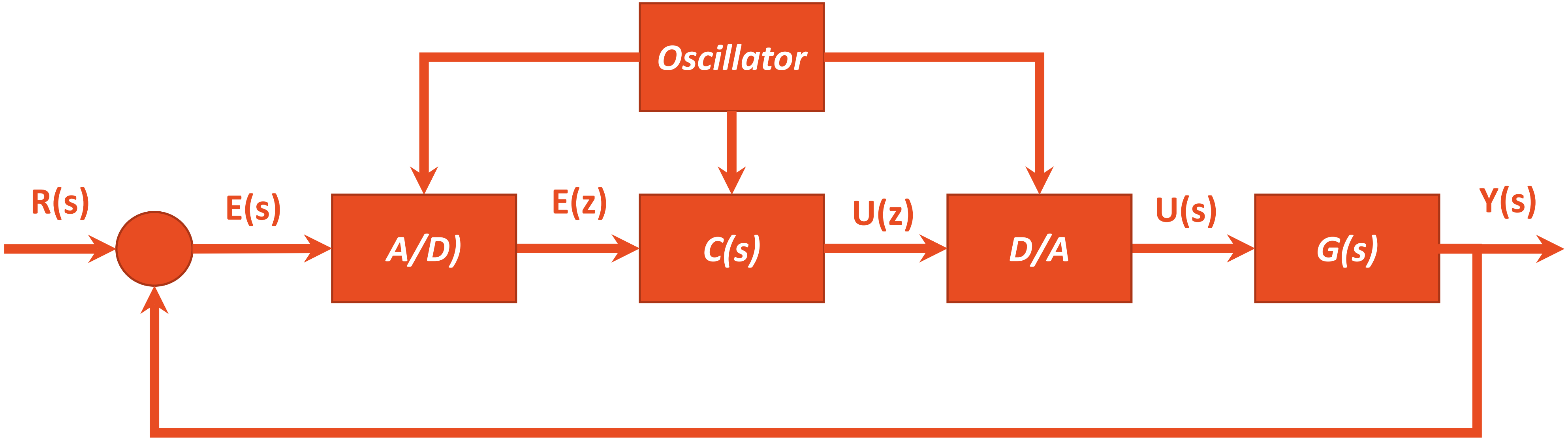
$U(s)$ … *Control Action*

$Y(s)$ … *Sensor Output*

$E(z)$ … *Discretized error signal*

$U(z)$ … *Discretized Control Action*

Continuous System vs. **Discrete System**



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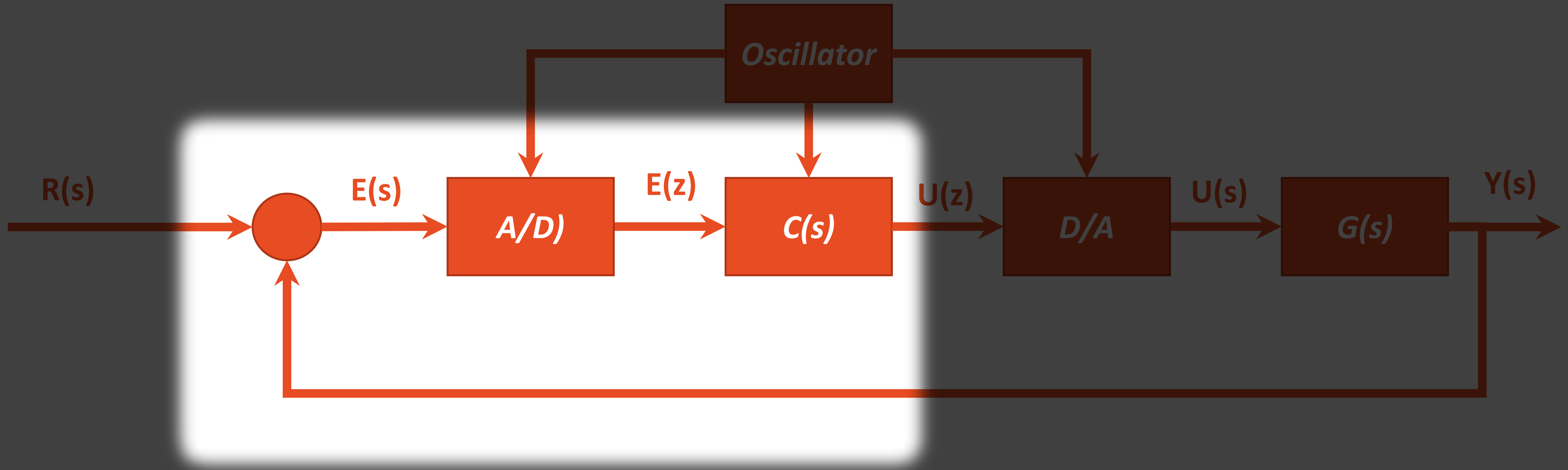
Continuous System vs. **Discrete System**



Modern Controllers

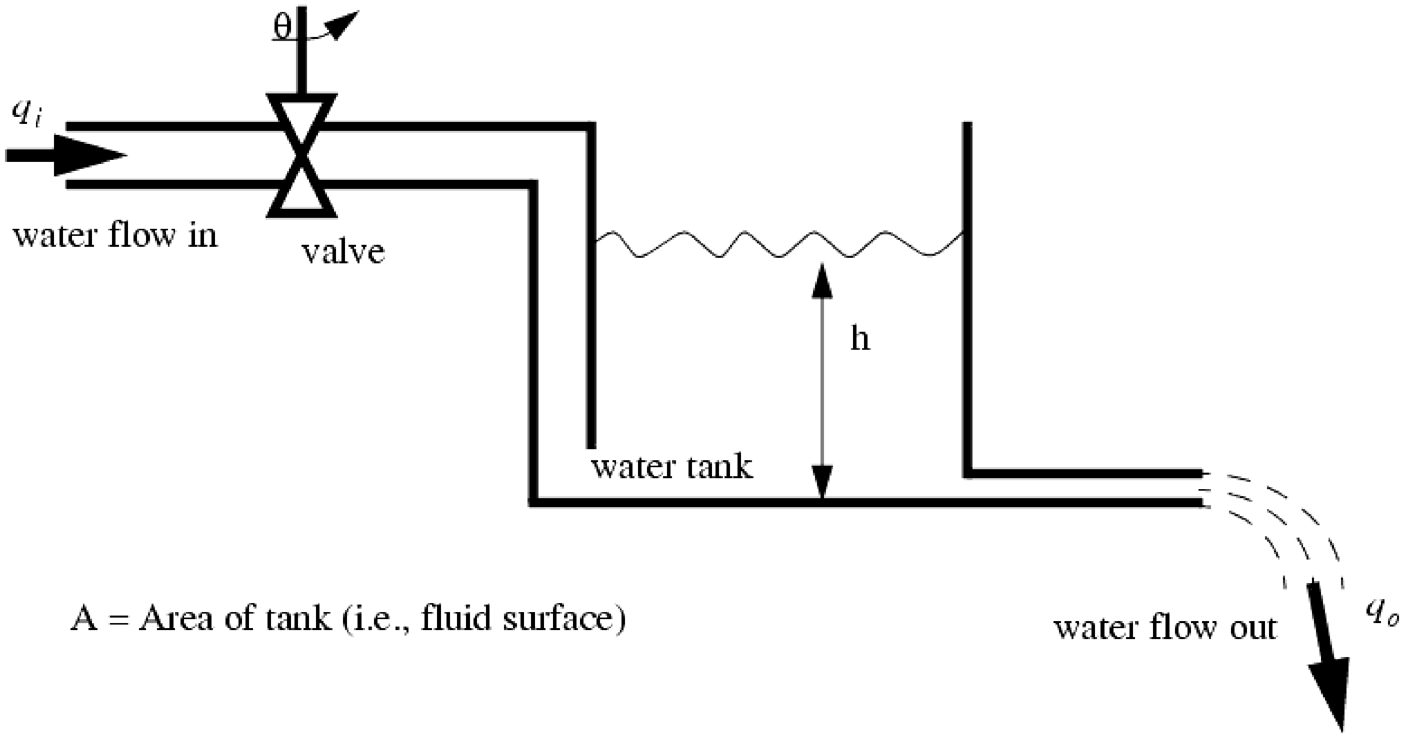
Lab 5

Simulating Water Tank

Revisited

Conversion to Discrete System

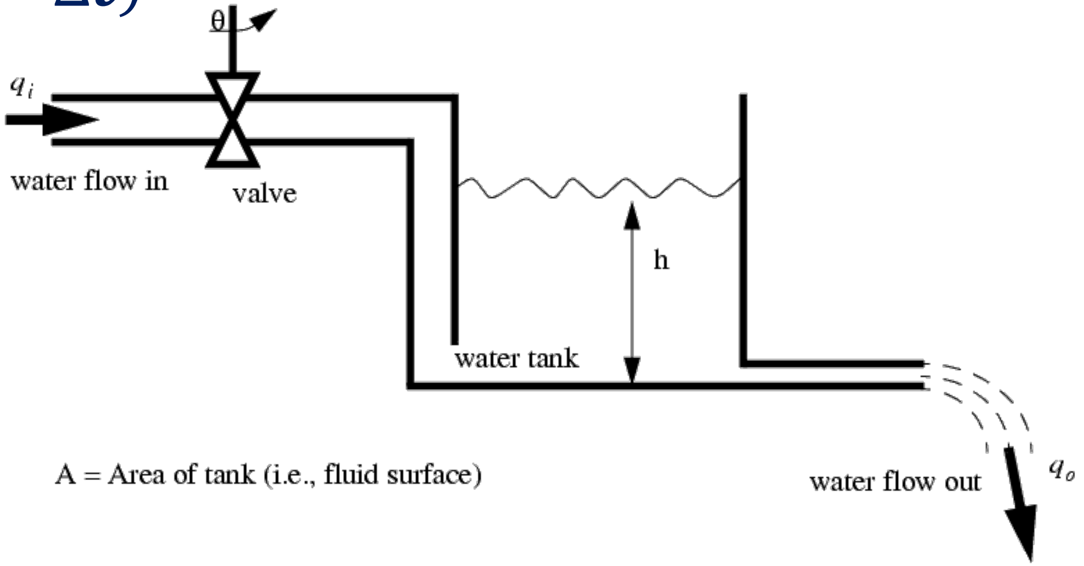
Difference Equation



In Lab 1 ....

$$h(t) = \frac{\Delta t \, * (k * h(t - \Delta t) - \, q_i(t))}{A} + h(t - \Delta t)$$

Δt ... *Sampling time* $q_i(t)$ ... *Excitationsignal*



Let Δt *be* T *(textbook term)*

Samples:

$T\,, 2T\,, 3T\ \ldots\ldots kT\,, \qquad k > 0$

$$h(kT) = \frac{T \, * (k * h(kT - 1) - \, q_i(kT))}{A} + h(kT - 1) \; [\mathit{Difference\ Equation}]$$

Difference Equation

$$h(kT) = \frac{T * (k * h(kT-1) - q_i(kT))}{A} + h(kT-1)$$

$iF\ T = 1\ second\ (most\ problems\ assuming\ this\ for\ simplicty$

$$h(k) = \frac{(k * h(k-1) - q_i(t))}{A} + h(k-1)$$

$$A[h(k) - h(k-1)] - k * h(k-1) = -q_i(t)$$

$$A * h(k) - A * h(k-1) - k * h(k-1) = -q_i(t)$$

$$A * h(k) - [A+k] * h(k-1) = -q_i(t)$$

$$\boxed{[A+k] * h(k-1) - A * h(k) = q_i(t) \quad [Difference\ Equation]}$$

Lab 5

Difference Equation

$$\underbrace{[\boldsymbol{A}+\boldsymbol{k}] * \boldsymbol{h}(\boldsymbol{k}-\mathbf{1}) - \boldsymbol{A} * \boldsymbol{h}(\boldsymbol{k})}_{\text{System Output}} = \underbrace{\boldsymbol{q}_{\boldsymbol{i}}(\boldsymbol{t})}_{\text{System Input}}$$

$$\boldsymbol{if}\ \boldsymbol{k}=\mathbf{0} \ \rightarrow \boldsymbol{h}(\boldsymbol{k}-\mathbf{1})=\boldsymbol{h}(\mathbf{0})$$

Difference Equation

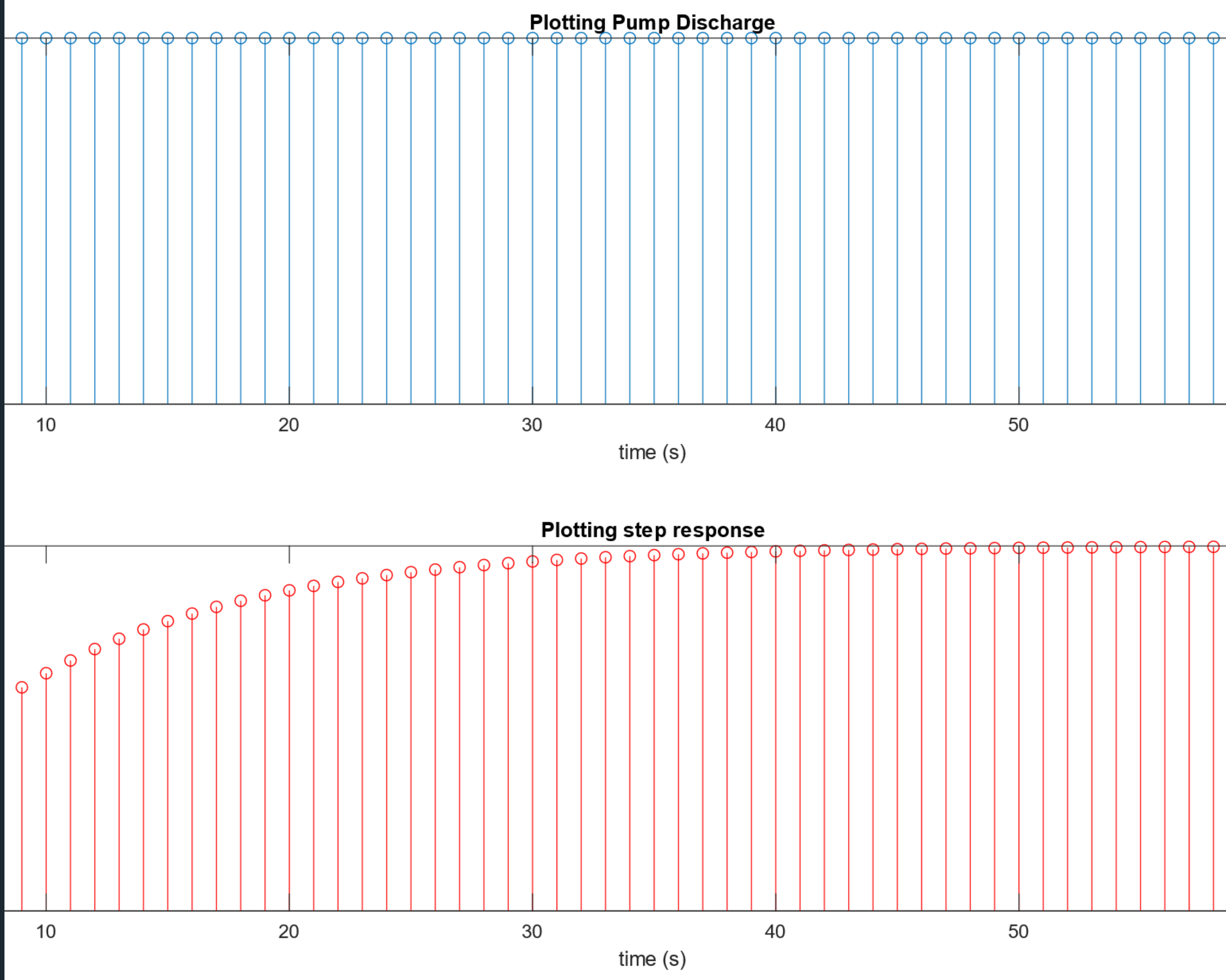
Remember

$$\frac{dh}{dT} = h(t) - h(t - \Delta t) = h(kT) - h(kT - 1)$$

Lab 5

Exercise 1

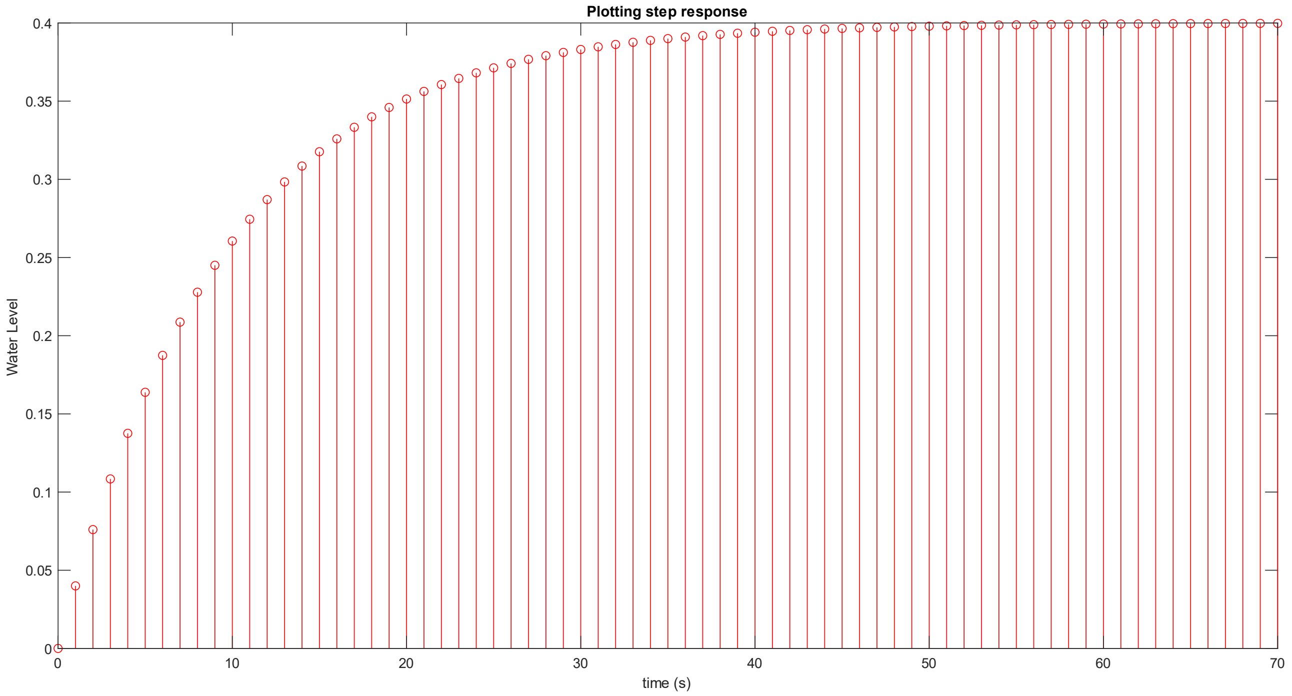
Representation of discrete response using MATLAB



Lab 5

MATLAB command

$$stem\ (t, y)\ \ldots plots\ discretized\ \ (SAMPLED) data$$



Lab 5

Solved Example

Difference Equation

me system shown in Figure 12.7.

$k = 0, 1, 2, \ldots,$ then the system

. This text studies only the class

s can be described by linear differe

ch as

$$+ 2y(k + 1) - y(k) = 2u(k +$$

$$- 1) - y(k - 2) = 2u(k - 1)$$

Difference Equation Example

$$3y(k+2)+2y(k+1)-y(k)=2u(k+1)-3u(k)$$

Find y value after 3 seconds assuming 1 s sampling interval

Solution

Rearranging equation terms by changing future term to past:

$$y(k+2) \rightarrow y(k) \text{ (present)} \rightarrow \text{replace k with k} - 2$$

$$\therefore 3y(k)+2y(k-1)-y(k-2)=2u(k-1)-3u(k-2)$$

Difference Equation Example

$$\therefore 3y(k) = 2u(k-1) - 3u(k-2) - 2y(k-1) + y(k-2)$$

$$\therefore y(k) = \frac{1}{3}[2u(k-1) - 3u(k-2) - 2y(k-1) + y(k-2)]$$

Initial conditions needed

$$y(-2) = 1\,,\, y(-1) = -2 \text{ and } \mathrm{u(k)} = 1 \text{ [unit step]}$$

We need to compute $y(0) \rightarrow y(1) \rightarrow y(2) \rightarrow \mathrm{y}(3)$

Difference Equation Example

$$y(-2) = 1\ ,\ y(-1) = -2 \text{ and } \mathrm{u}(\mathrm{k}) = 1 \text{ [unit step]}$$

$$y(0) = \frac{1}{3}[2u(-1) - 3u(-2) - 2y(-1) + y(-2)]$$

$$= \frac{1}{3}[2 * (0) - 3 * (0) - 2 * (-2) + (1)] = \frac{5}{3}$$

$$y(1) = \frac{1}{3}[2u(0) - 3u(-1) - 2y(0) + y(-1)]$$

$$= \frac{1}{3}\left[2 * (1) - 3 * (0) - 2 * \left(\frac{5}{3}\right) + (-2)\right] = -\frac{10}{9}$$

Difference Equation Example

$$y(-2) = 1\,, y(-1) = -2 \text{ and } \mathrm{u}(\mathrm{k}) = 1 \text{ [unit step]}$$

$$y(2) = \frac{1}{3}[2u(1) - 3u(0) - 2y(1) + y(0)]$$

$$= \frac{1}{3}\left[2 * (1) - 3 * (1) - 2 * \left(-\frac{10}{9}\right) + \left(\frac{5}{3}\right)\right] = \frac{26}{27}$$

$$y(3) = \frac{1}{3}[2u(2) - 3u(1) - 2y(2) + y(1)]$$

$$= \frac{1}{3}\left[2 * (1) - 3 * (1) - 2 * \left(\frac{26}{27}\right) + \left(-\frac{10}{9}\right)\right] = -\frac{109}{27}$$

Lab 5

Asignment

$$3y(k+2)+2y(k+1)-y(k)=2u(k+1)-3u(k)$$

$Write\ a\ MATLAB\ script\ to\ calculate\ y(k)\ given\ k, y(-1), y(-2)\ assuming\ unit\ step\ input$

$Due\ date\ (today\ 11{:}59\ PM)$

$Send\ to : waleed.elbadry@must.edu.eg$

Don’t forget to pull the lab update from.

http://github.com/wbadry/mte506

Waleed El-Badry

END OF Lab 5