Practice 1:

Logistics, RC Networks, Thevenin-Norton

Course Logistics

Logistics – Times and Location

- All practice sessions are on Mondays
  - 1400-1500 – 34/109
  - 1500-1600 – 28/303
  - 1600-1700 – 28/107

- The third session will be recoded and uploaded to the course website for later viewing.

- Office Hours:
  - Monday – 1300-1400 (VLSI Center, building 95)

Logistics – Grades and Homework

- Grade composition:
  - Test – 100%
  - Optional test bonus will be given to those who turn in all homework assignments.

- Homework:
  - Several homework assignments will be designated as "tasks" on the course website (highlearn).
  - Every student is required to submit *ALL* homework assignments within 2 weeks of publication to be eligible for bonus.
  - **Submission is via highlearn**! Homework may be done in pairs, but submission has to be individual.

Logistics – Final Exam

- The test will be <u>closed book</u>.
- A formula sheet will be attached to the test. An example sheet will be published on the course website.
- The test will include all the course material that will be covered in the lectures, practices, and homework.
- Many examples of former tests are available and you are advised to use them to prepare for the test.
- The three tests will be at the same (*high!*) level. They will have **different** questions about **different parts** of the material.

Logistics – Course Website

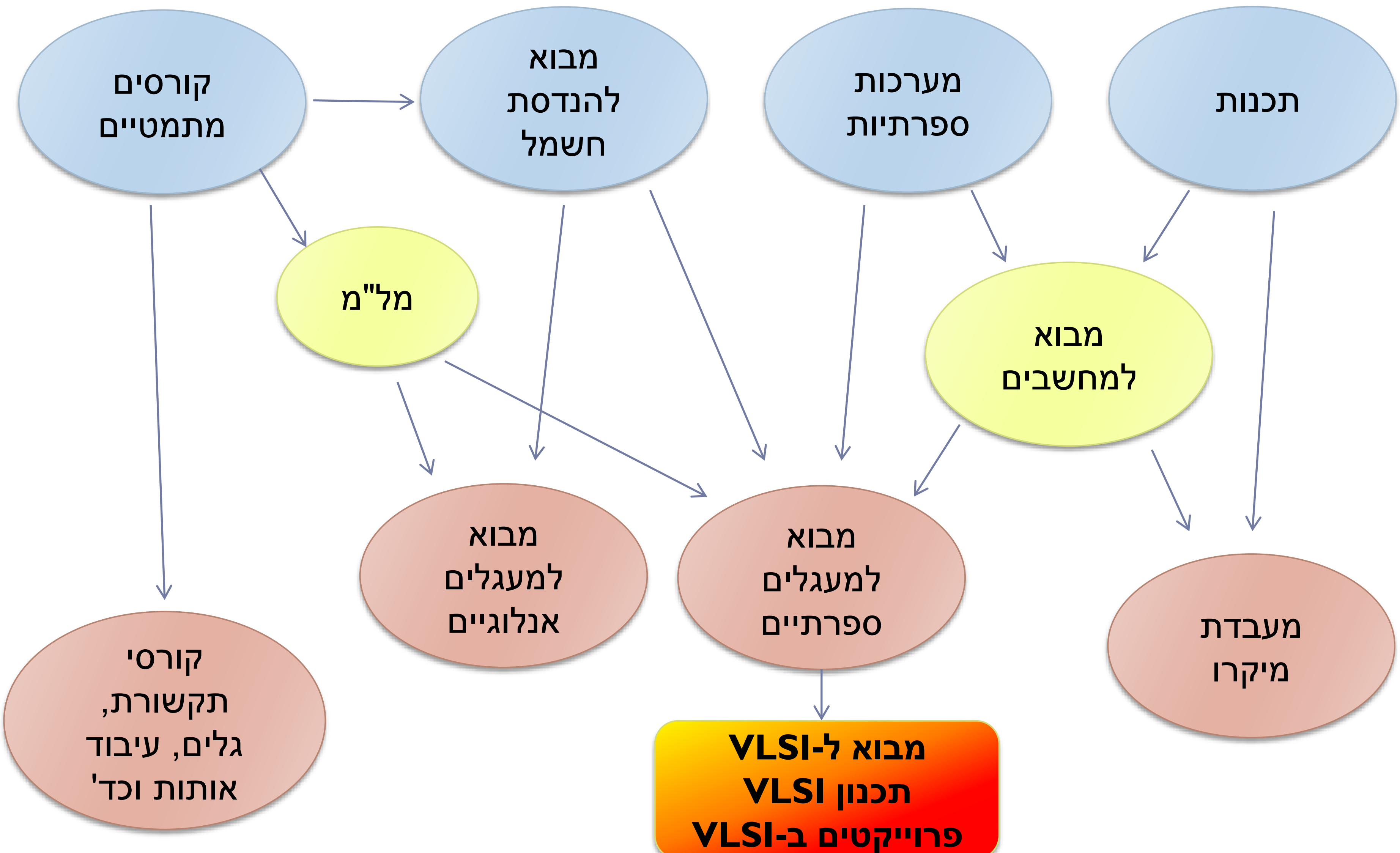
- The course website is ***highlearn***.
- All course content and discussion will be through the website:
  - **Lectures** – 4 slide per page *pdf* files will be uploaded weekly.
  - **Practices** – Full explanations and solutions in a *pdf* document will be uploaded weekly.
  - **Practices** (2) – Presentations used during practice sessions will be uploaded. (*ppt*) Following the practice session, annotated slides will be uploaded.
  - **Homework** – Will be published and submitted through the website.
  - **Discussion Forum** – Questions can be asked in the forum. If not answered by other students, we will try and answer them.
- Questions via direct emails to Dr. Fish or me will not be answered!

Logistics - Bibliography

- Rabaey, et al.:
  - Digital Electronic Circuits: A Design Perspective – 2nd Edition
- Sedra & Smith
  - Microelectronic Circuits
- Weste & Harris
  - CMOS VLSI Design: A Circuits and Systems Perspective

Short Introduction

Introduction – Where Are We?



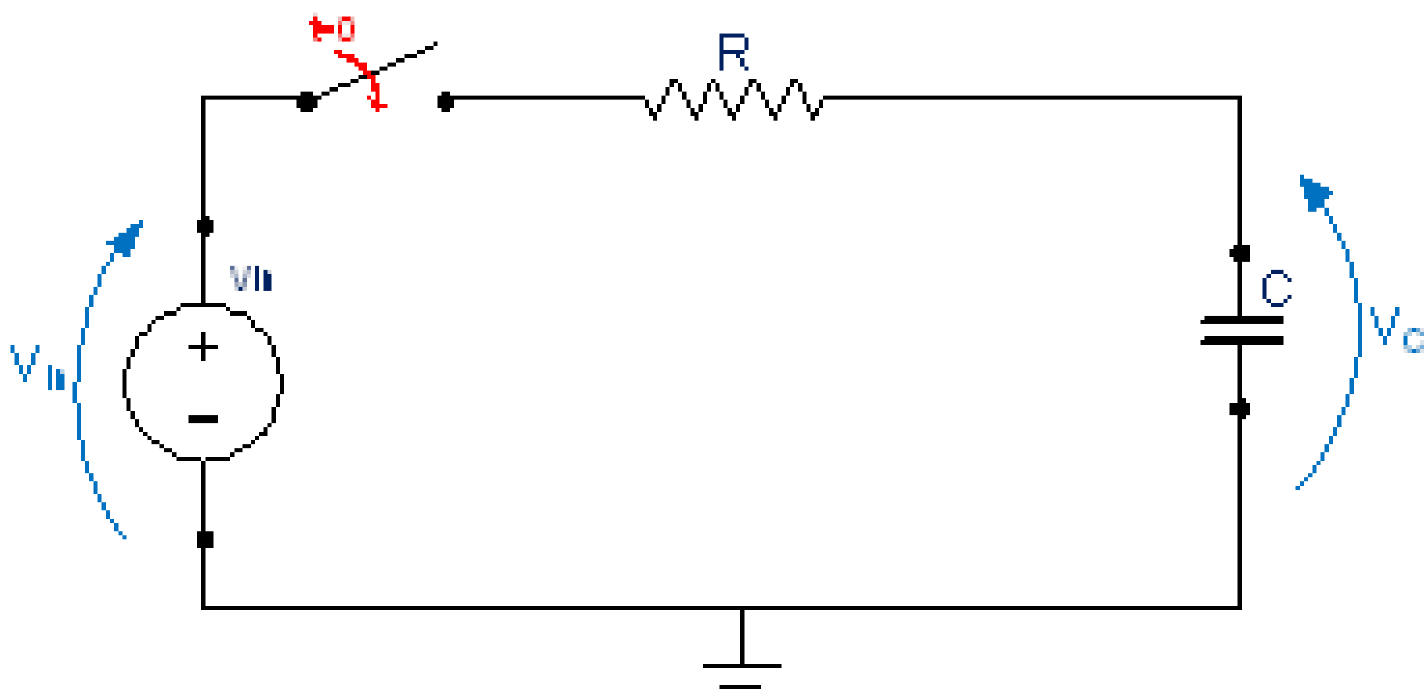
Introduction – Digital? Analog? Us?

First Order RC Circuits

RC Circuits - Motivation

RC Circuits - Example

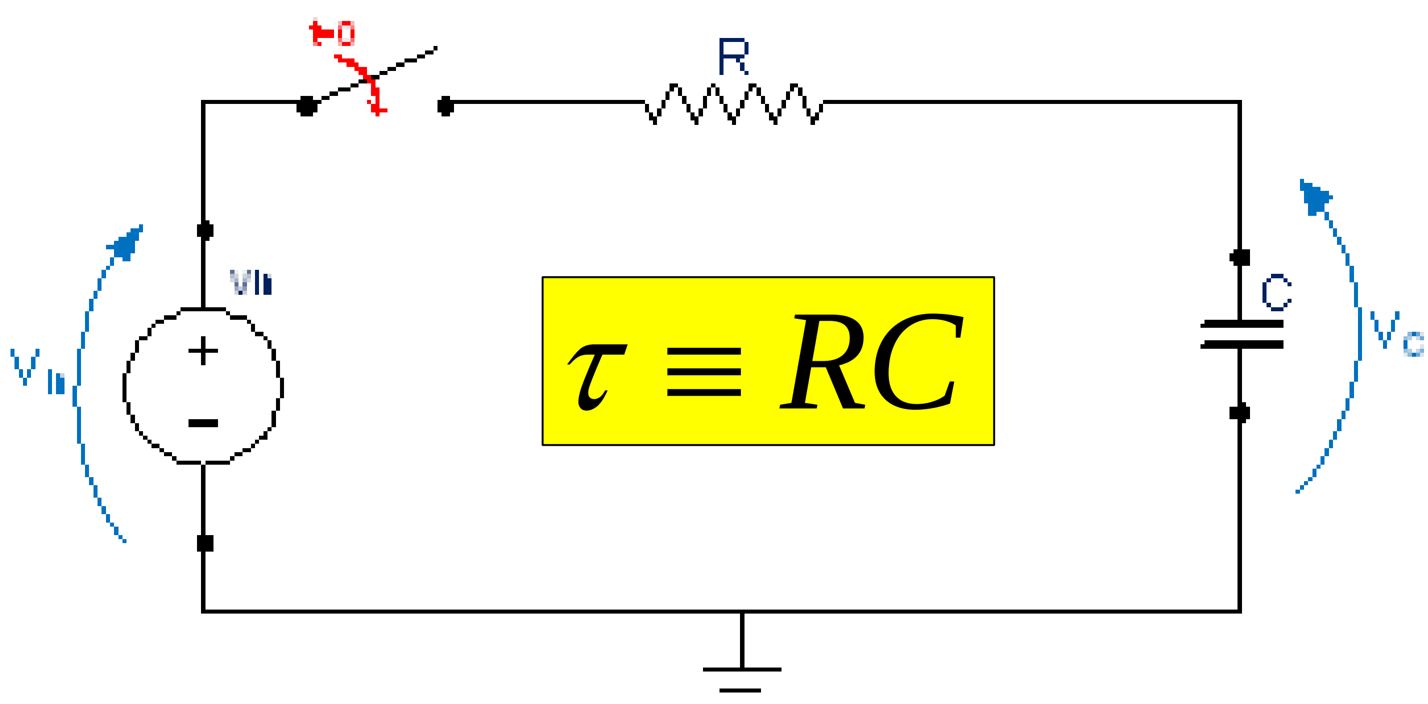
- Given:
  - R, C, Vin
  - $V_c(0)=V_0$
  - The switch closes at t=0.
- Find:
  - $V_c(t)$



RC Circuits - Example

- KVL: $$V_{in}(t) = V_c(t) + V_R(t) = V_c(t) + i_C(t)R$$

$$V_{in} = V_c + RC\mathring{V}_c = \tau\mathring{V}_c + V_c$$



RC Circuits - Example

- First Order Differential Equation:

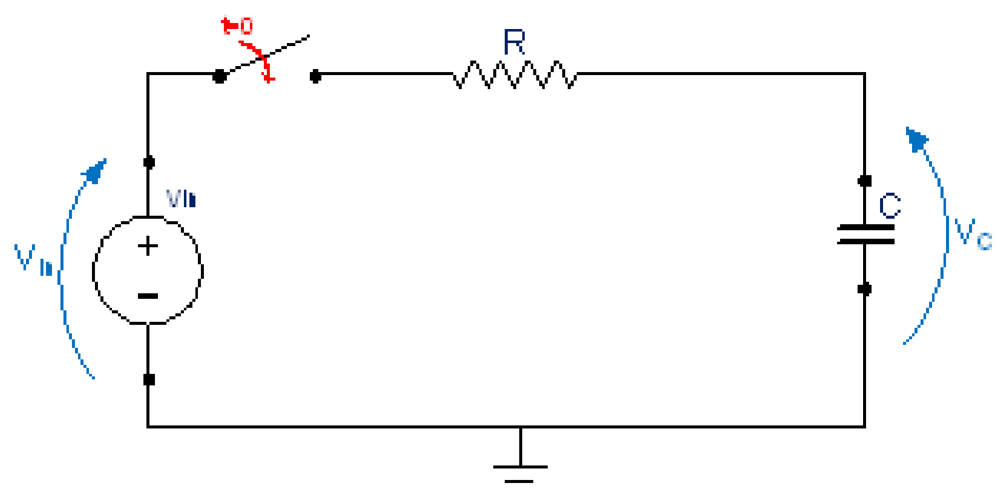
$$V_{in} = V_c + RC\overset{\circ}{V}_c = \tau\overset{\circ}{V}_c + V_c \quad \Rightarrow \quad V_c(t) = V_{ch}(t) + V_{cp}(t)$$

- Homogeneous Solution:

$$V_{ch}(t) = Ke^{-t/\tau}$$

- Particular Solution:

$$V_{cp}(t) = V_{in}$$



RC Circuits - Example

- General Solution:

$$V_c(t) = V_{ch} + V_{cp} = Ke^{-t/\tau} + V_{in}$$

$$V_c(0) = V_0 = Ke^{-0/\tau} + V_{in} = K + V_{in}$$

$$\Downarrow$$

$$K = V_0 - V_{in}$$

$$V_c(t) = (V_0 - V_{in})e^{-t/RC} + V_{in}$$

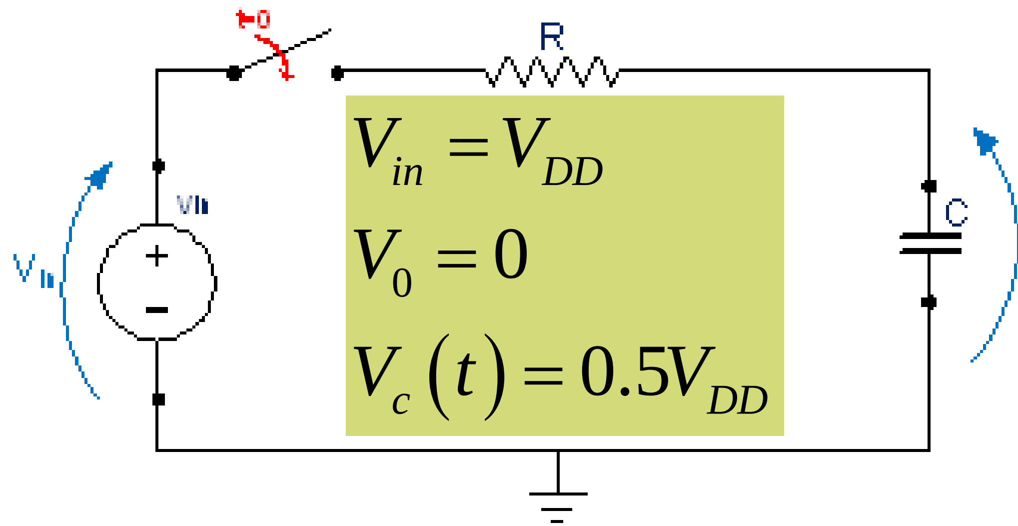
$$\boxed{= V_0 e^{-t/RC} + \left(1 - e^{-t/RC}\right)V_{in}}$$

RC Circuits – Using this solution

- How long will it take to charge the capacitor to $V_{in}/2$?

$$\boxed{V_c(t) = (V_0 - V_{in})e^{-t/RC} + V_{in}}$$

$$e^{-t/RC} = \frac{V_c - V_{in}}{V_0 - V_{in}}$$



$$V_{in} = V_{DD}$$

$$V_0 = 0$$

$$V_c(t) = 0.5V_{DD}$$

$$t = RC\ln\frac{V_0 - V_{in}}{V_c - V_{in}} \equiv \tau\ln\frac{V_c(0) - V_c(\infty)}{V_c(t) - V_c(\infty)}$$

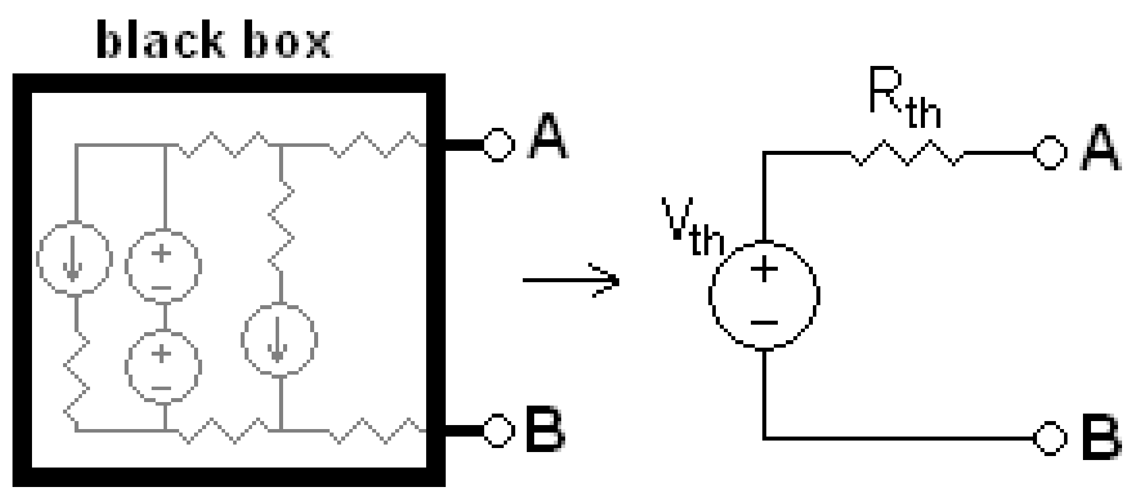
$$t = RC\ln\frac{-V_{DD}}{0.5V_{DD} - V_{DD}} = RC\ln 2$$

$$\boxed{t = 0.69\tau}$$

Thevenin-Norton Equivalents

Thevenin - Norton – A reminder…

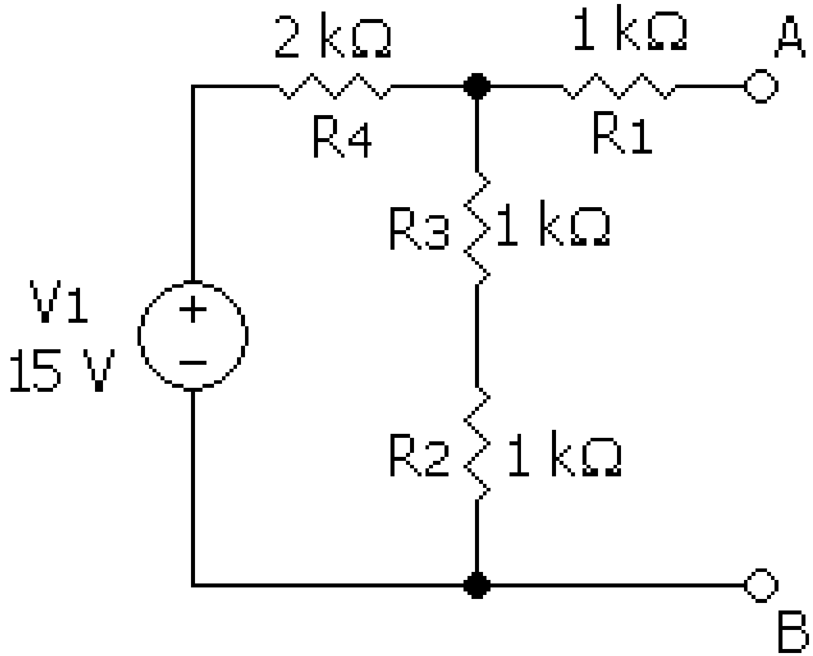
- Remember that in Introduction to Electrical Engineering you learned *Thevenin's Theorem*?
  - Any linear circuit – no matter how complex – can be simplified into a Voltage Source and Equivalent Impedance driving a load.
  - By using a Thevenin Equivalent circuit, we *don't care* what's going on inside the circuit. This simplifies the equations drastically.



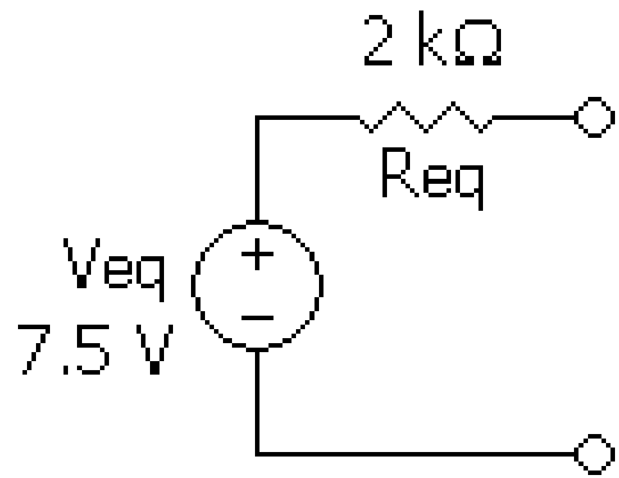
Thevenin – Calculation Method

- 1. Find the *Open Circuit Voltage* (V_{OC}):
  - Disconnect the *Load*.
  - Find the Voltage between the terminals of the load.
- 2. Find the *Short Circuit Current* (I_{SC}):
  - Short circuit the *Load*.
  - Find the Current between the load terminals.
- 3. Calculate the Thevenin Equivalent Voltage and Impedance:
  - $V_{Thevenin}=V_{OC}$
  - $R_{Thevenin}=V_{OC}/I_{SC}$

Thevenin – Example



$$V_{Thevenin} = 7.5V \quad R_{Thevenin} = 2k\Omega$$



$$V_{OC} = V_{in}\frac{R_3 + R_2}{R_4 + R_3 + R_2} = 7.5V$$

$$I_{SC} : KCL \rightarrow \frac{15 - V_X}{2k} = \frac{V_X}{1k} + \frac{V_X}{2k} \quad I_{SC} = \frac{V_X}{1k}$$

$$15 - V_X = 3V_X \quad V_X = 15/4 \quad I_{SC} = 15/4k$$

Norton – Reminder

- Norton equivalent circuits are the same as Thevenin Equivalents, but they incorporate a current source instead.
- To find the Norton Equivalent:
  - 1. The Norton Resistance is the same as the Thevenin Resistance.
  - 2. The Norton Current Source is the Short Circuit Current.