CSE251: Electronic Devices and Circuits

Lecture 1

Course Information, Historical and Top-level view of computer hardware

Prepared By:

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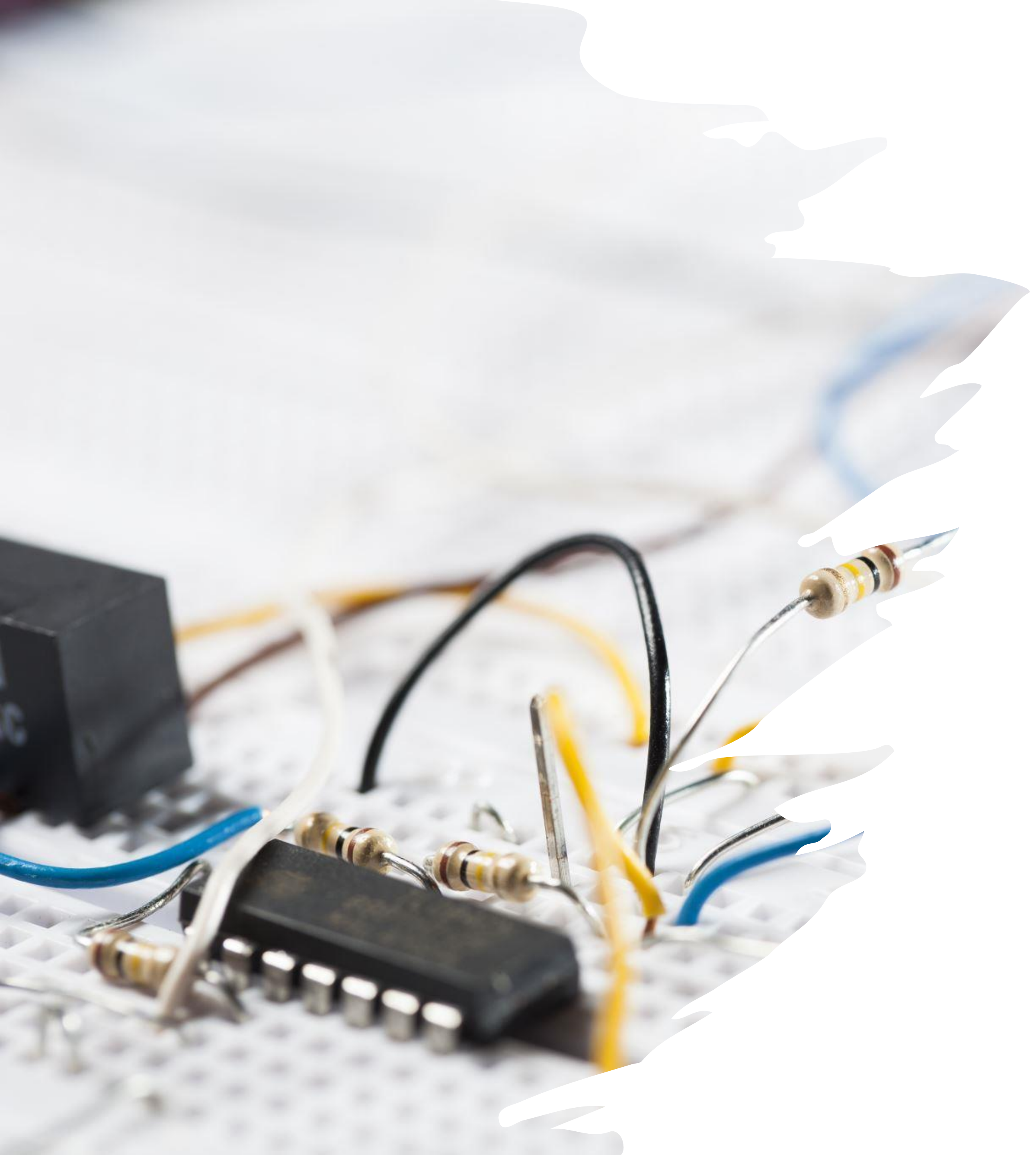
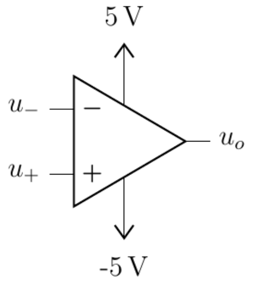


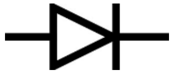
Course outline

Basically, study **four types** of devices.
(Application centric usage)

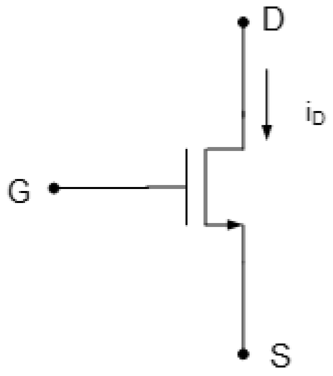
- OP-AMP



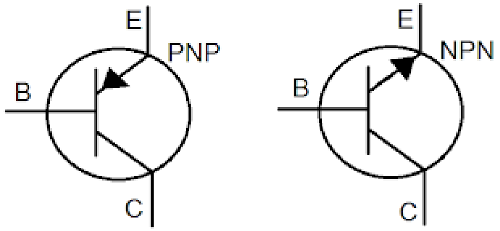
- Diodes



- MOSFET

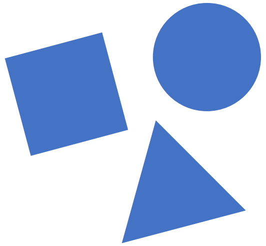


- BJT



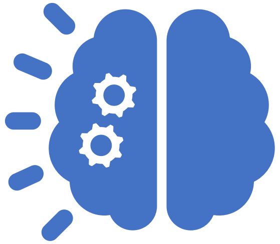
Application: Amplification and Switching

Course Outcome



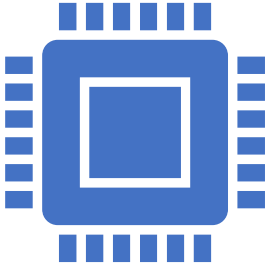
CO1

Understand and compare the **characteristics** and **operation** of electronic devices



CO2

Analyze electronic circuits made from these devices



CO3

Design various electronic circuits for power-generation and analog signal-processing applications.

A list of application (non-exhaustive)

- **Switching**
  - Rectifiers
  - Analog-to-digital (ADC)
  - Digital-to-analog conversion (DAC)
  - Arithmetic operations on analog Signals, e.g, summing, subtracting, exponentiation and generating voltage waveforms of different shapes.

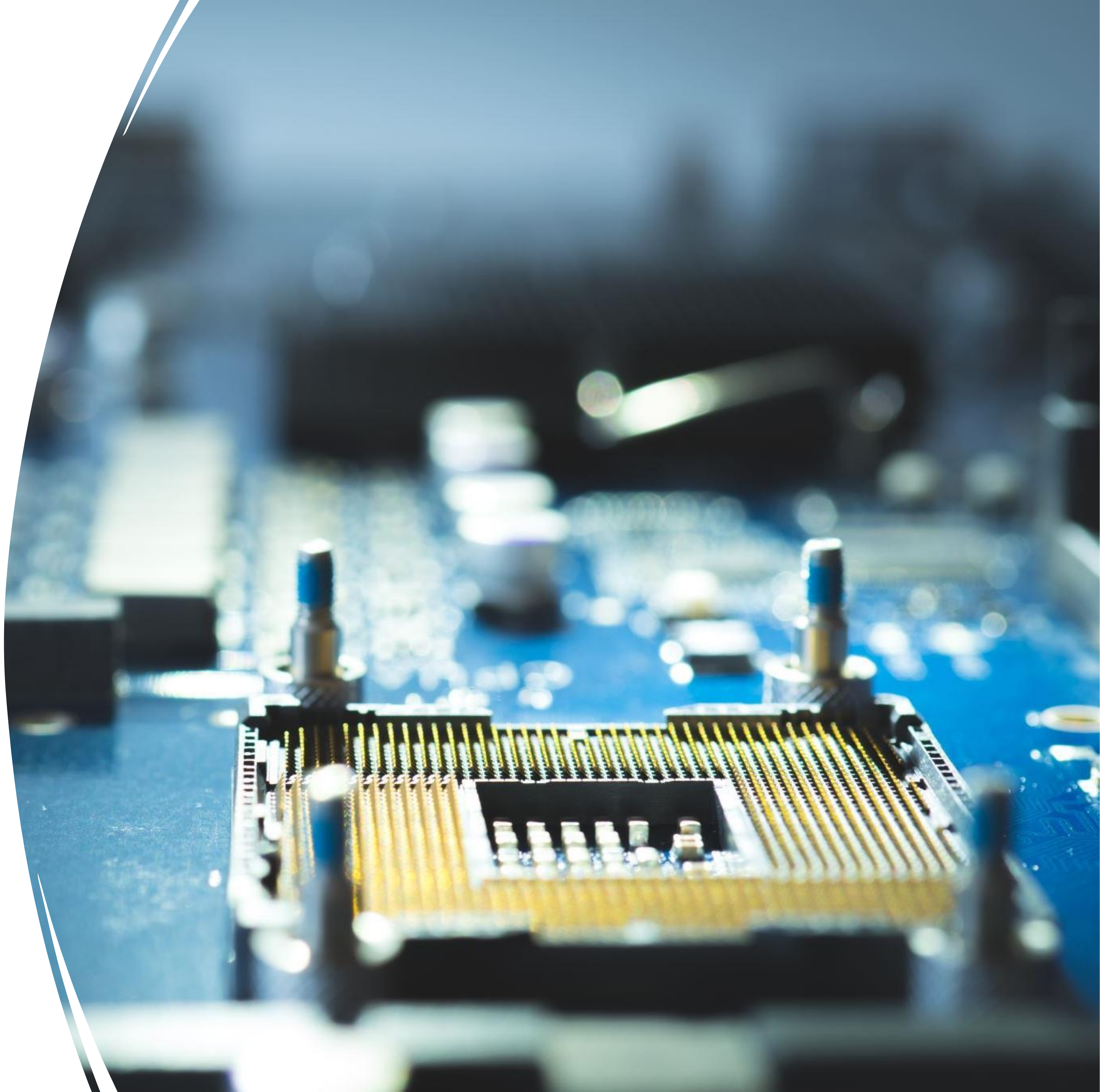
- **Amplification**
  - Regulators
  - Small-signal Amplifiers

Marks Distribution

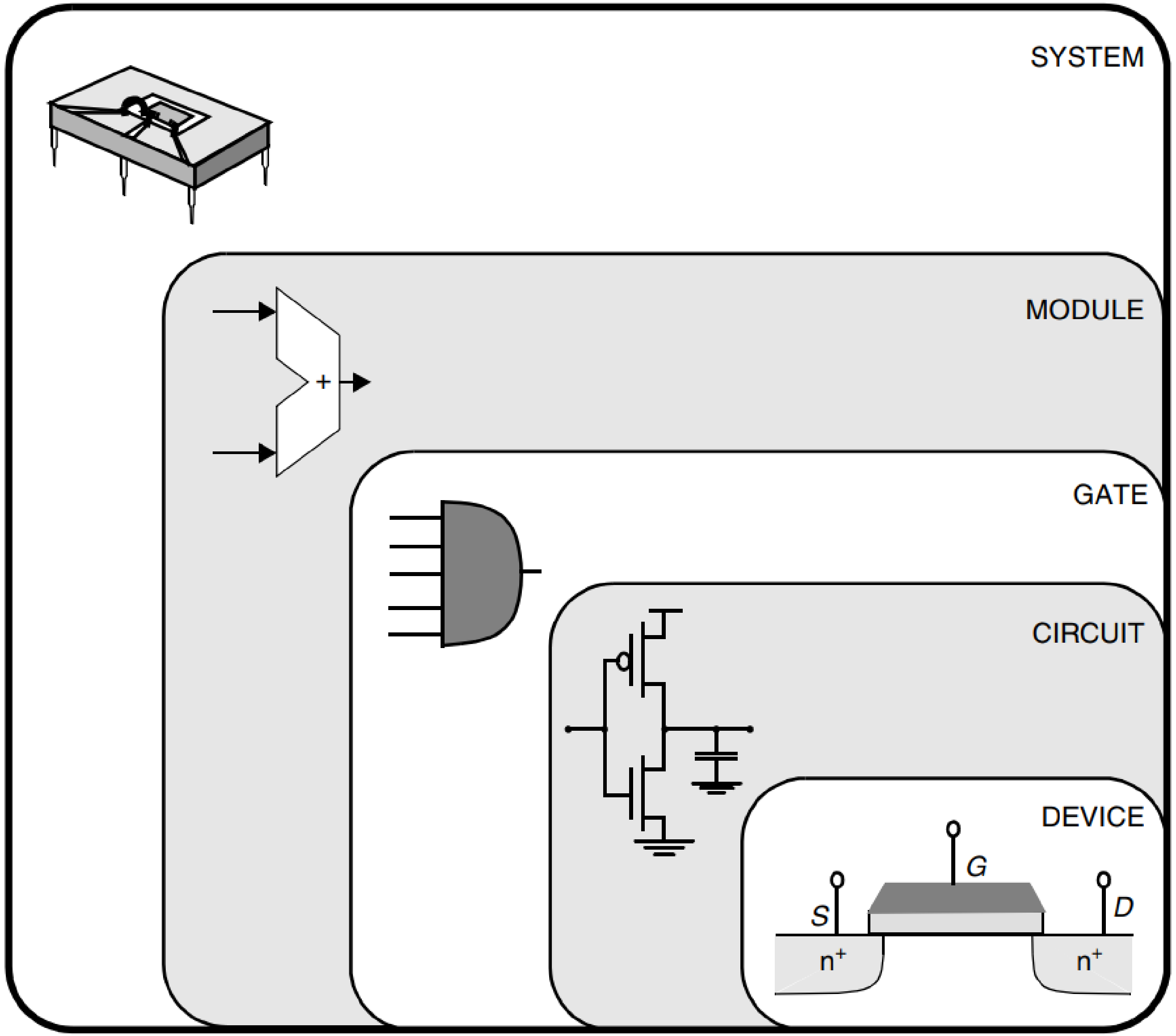
Assessment	**Percentage**	**Total number of assessments**	**Number of assessment to be graded**
Attendance	8%	-	-
Assignment	12%	6	Best N-1
Quiz	15%	4	Best N-1
Midterm	20%	1	1
Final	20%	1	1
Lab	25%	-	-

A top-down decomposition of a computer

- System
- Module
- Logic gates
- Circuits
- Electronic Devices (Process technology)



Abstraction Levels



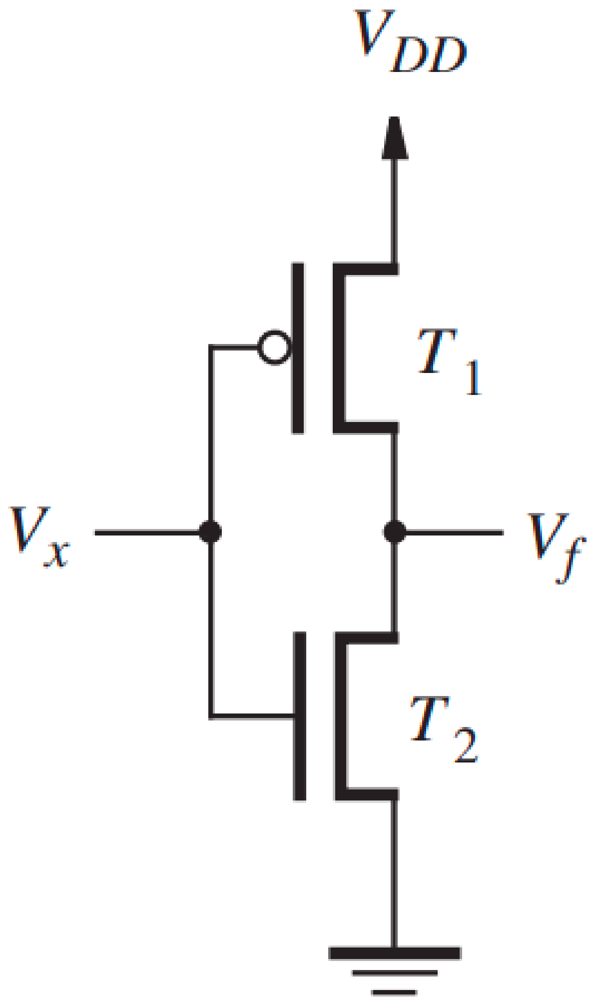
J. M. Rabaey, A. P. Chandrakasan, and B. Nikolić, *Digital integrated circuits: a design perspective*, 2. ed., Internat. ed. in Prentice Hall electronics and VLSI series. Upper Saddle River, NJ: Pearson Education, 2003.

Logic gates –> Electronic Devices

Electronic Devices:

1. Transistors (BJT/MOSFET/ JFET/**FinFET**)
2. Diodes

Amplification and **Switching**



MOSFET realization of a NOT gate.

S. D. Brown and Z. G. Vranesic, *Fundamentals of digital logic with Verilog design*, Third edition. New York: McGraw-Hill Higher Education, 2014.

Historical Perspective

Mechanical gears
(1822 - Difference Engine, Analytical Engine)

- Has it always been like this?
- Eras of Computer evolution:

Electrical switches and
mechanical relays
(1944 - Harvard Mark 1)

1. Gen 1: Mechanical to **Vacuum Tubes** (17th -1940s):
2. Gen 2: **Transistors** (BJT) (1950s): Short-lived

   (1951 – 1959)
   Switchover to ***transistors*** from ***vacuum Tubes***

3. Gen 3: **Integrated Circuitry** (1960s - Present)

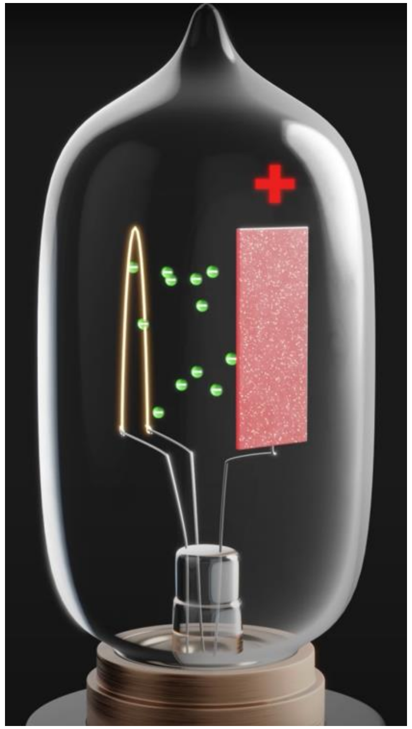
   VLSI

Microcomputers -> Laptops, Smartphones

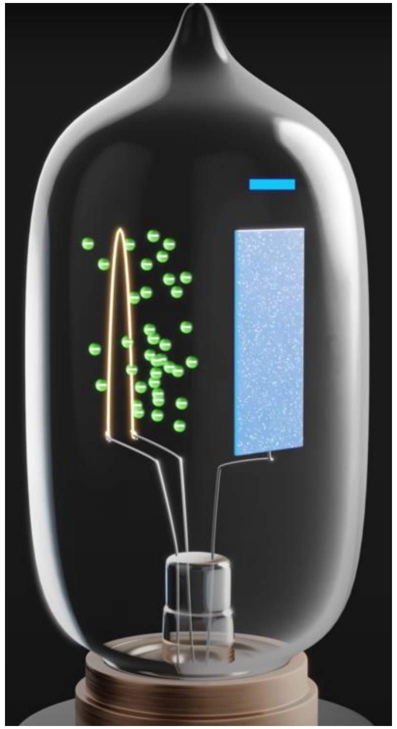
WWI: 1914 - 1918
WWII: 1939 - 1945

History of Computers (uah.edu)

Vacuum Tubes (1946 - ENIAC)



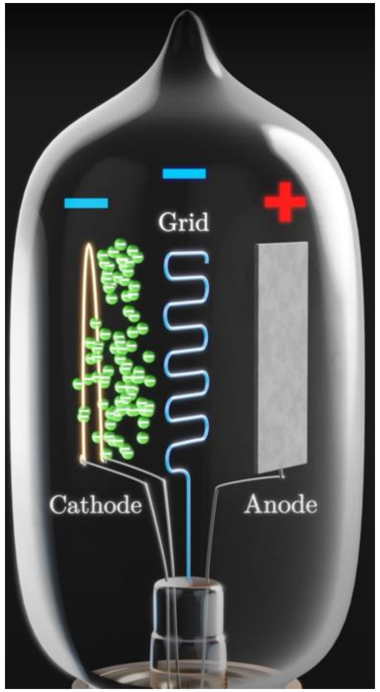
Electron Flow ON

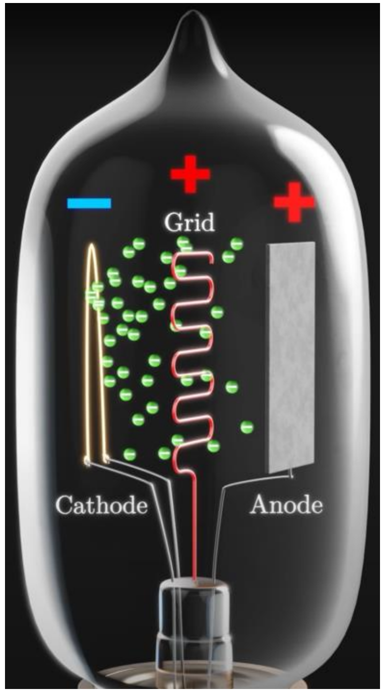


Electron Flow OFF

Thermionic <u>Di</u>ode

SWITCHING





Small changes in ***Grid*** voltage translate to large voltages at the Anode

Thermionic <u>Tri</u>ode

AMPLIFICATION

Computer Systems /Processors with BJT (60s)

Computer System	Year
IBM System/360	1964
DEC PDP Series	1960 (PDP-1), 1965 (PDP-8), 1970 (PDP-11)
Control Data Corporation 6600	1964
IBM System/370	1970
Cray-1	1976

IBM System/360 hybrid BJT circuit

Computer Systems /Processors with MOSFET (70s - Present)

Intel® 4004

1971

10 μm

Intel ® 8086

1978

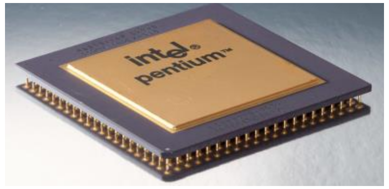
3 μm

65 nm

Intel® Core™2 Duo

2006

0.8 μm



Intel® Pentium®

1993

22 nm

Intel® Core™

2010

7 nm

AMD Ryzen 5000

2021

Intel® Core™ 12th gen

2021

10 nm

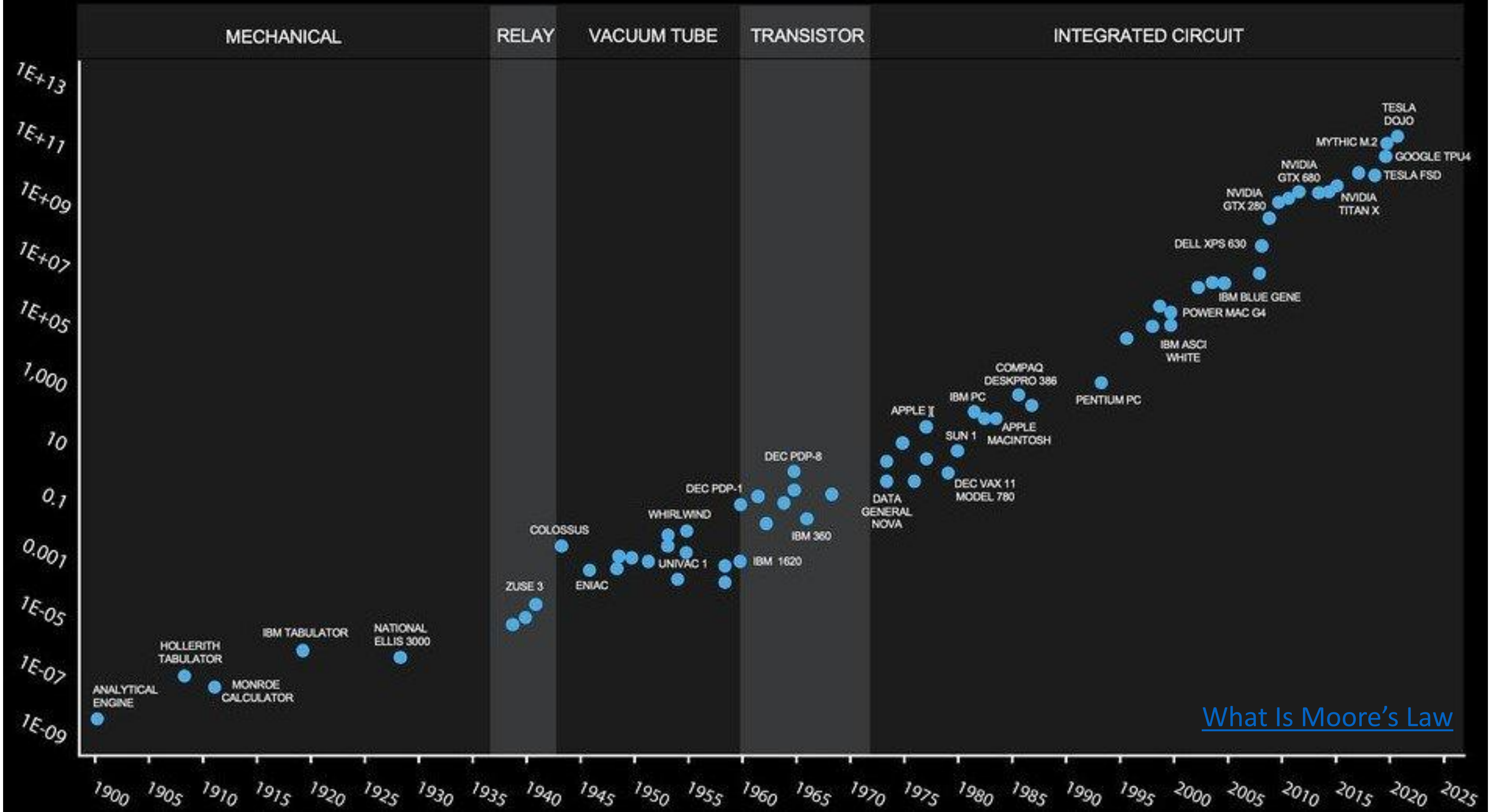
Processor evolution

(Red: Feature size)

Moore’s Law

The number of transistors in a microchip doubles every two years

122 YEARS OF MOORE'S LAW



[What Is Moore's Law]

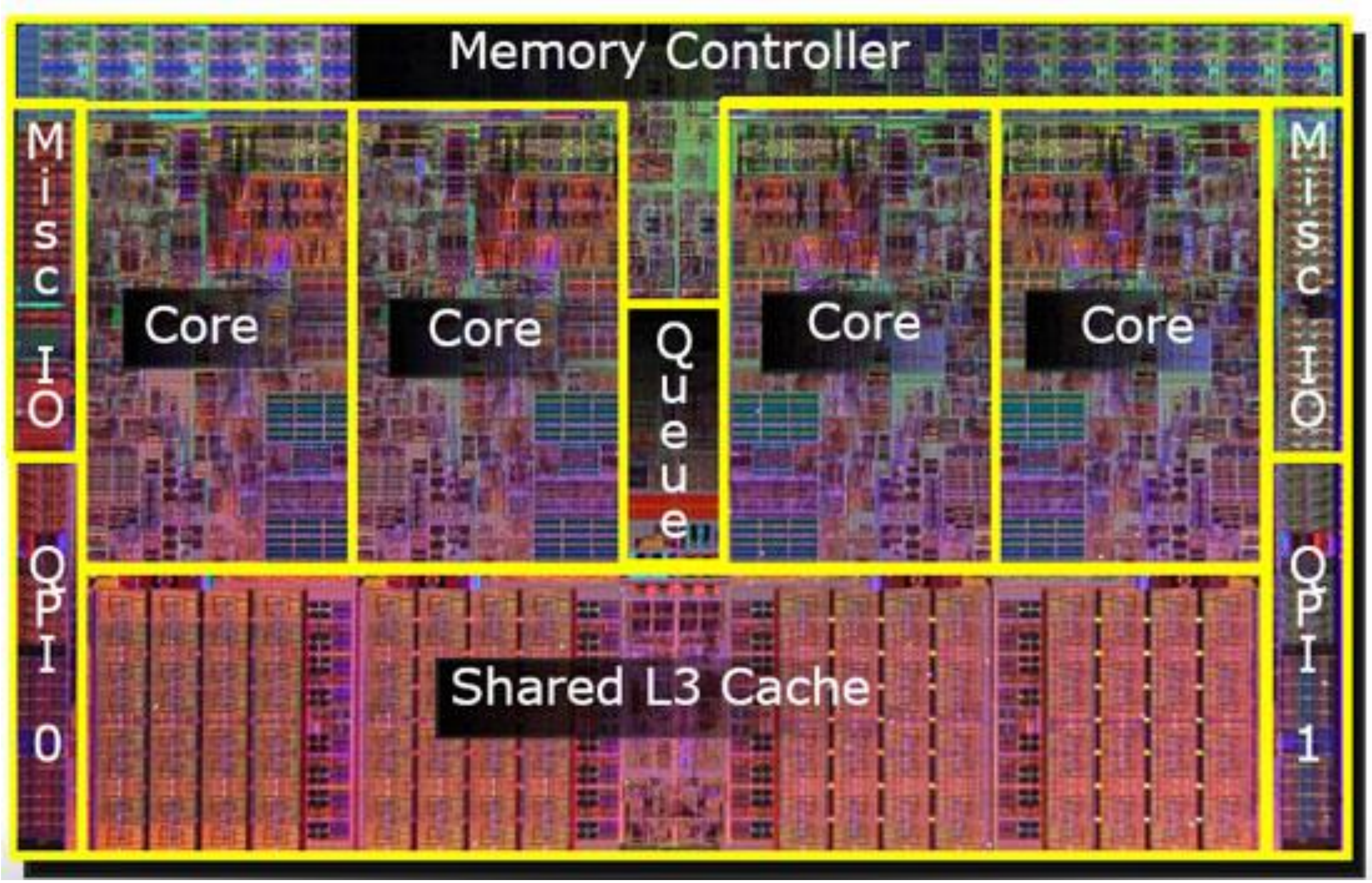
Current scenario and the future

- Ongoing chip shortage!
- Two type of companies:
  1. **Fabless** design companies: AMD, Apple etc.
  2. **Foundries**: Intel, TSMC, Samsung, Global Foundries

Moore's Law is approaching an end.
Possible alternatives for the future:

1. Quantum Computing
2. Neuromorphic Computing
3. Optical Computing

An Integrated Circuit Layout of a Processor



Appendix 1

PROCESSOR DETAILS

NEW SKU's

PROCESSOR NUMBER	BASE CLOCK SPEED (GHZ)	INTEL TURBO BOOST TECHNOLOGY 3.0 MAXIMUM SINGLE CORE TURBO FREQUENCY (GHZ)	INTEL TURBO BOOST TECHNOLOGY 3.0 MAXIMUM ALL CORES TURBO FREQUENCY (GHZ)	CORES/ THREADS	THERMAL DESIGN POWER	INTEL SMART CACHE	LITHOGRAPHY	MEMORY SUPPORT	PROCESSOR GRAPHICS	SOCKET SUPPORT	CODE NAME	RCP PRICING (USD)
10th Gen Intel® Core™ i3-10100	3.7	4.4	4.2	4 / 8	65W	7 MB	14+++ nm	Two channels DDR4-2933	Intel® UHD 730	FCLGA1159	Products formerly Comet Lake	129$
10th Gen Intel® Core™ i3-10300	3.8	4.5	4.3	4 / 8	62W	9 MB	14+++ nm	Two channels DDR4-2933	Intel® UHD 730	FCLGA1159	Products formerly Comet Lake	149$
10th Gen Intel® Core™ i3-10320	4.0	4.7	4.5	4 / 8	91W	9 MB	14+++ nm	Two channels DDR4-2933	Intel® UHD 730	FCLGA1159	Products formerly Comet Lake	159$
10th Gen Intel® Core™ i3-10350K	4.1	4.8	4.6	4 / 8	91W	9 MB	14+++ nm	Two channels DDR4-2933	Intel® UHD 730	FCLGA1159	Products formerly Comet Lake	179$
10th Gen Intel® Core™ i5-10400	3.0	4.4	4.2	6 / 12	65W	12 MB	14+++ nm	Two channels DDR4-3200	Intel® UHD 730	FCLGA1159	Products formerly Comet Lake	179$
10th Gen Intel® Core™ i5-10500	3.1	4.6	4.4	6 / 12	65W	12 MB	14+++ nm	Two channels DDR4-3200	Intel® UHD 730	FCLGA1159	Products formerly Comet Lake	199$
10th Gen Intel® Core™ i5-10600	3.2	4.8	4.6	6 / 12	65W	12 MB	14+++ nm	Two channels DDR4-3200	Intel® UHD 730	FCLGA1159	Products formerly Comet Lake	229$
10th Gen Intel® Core™ i5-10600K	3.7	4.9	4.7	6 / 12	95W	12 MB	14+++ nm	Two channels DDR4-3200	Intel® UHD 730	FCLGA1159	Products formerly Comet Lake	269$
10th Gen Intel® Core™ i7-10700	3.1	4.9	4.6	8 / 16	65W	16 MB	14+++ nm	Two channels DDR4-3200	Intel® UHD 730	FCLGA1159	Products formerly Comet Lake	339$
10th Gen Intel® Core™ i7-10700K	3.6	5.1	4.8	8 / 16	95W	16 MB	14+++ nm	Two channels DDR4-3200	Intel® UHD 730	FCLGA1159	Products formerly Comet Lake	389$
10th Gen Intel® Core™ i9-10800F	2.7	5.0	4.2	10/ 20	65W	20 MB	14+++ nm	Two channels DDR4-3200		FCLGA1159	Products formerly Comet Lake	409$
10th Gen Intel® Core™ i9-10900F	3.2	5.1	4.4	10 / 20	95W	20 MB	14+++ nm	Two channels DDR4-3200		FCLGA1159	Products formerly Comet Lake	449$
10th Gen Intel® Core™ i9-10900KF	3.4	5.2	4.6	10 / 20	105W	20 MB	14+++ nm	Two channels DDR4-3200		FCLGA1159	Products formerly Comet Lake	499$

List of resources used in this slide

- Course Handout
- Abstraction levels diagram
- History of Computers
- More about Vacuum Tubes – Veritasium YouTube
- More information about Semiconductor chip industry
- Moore’s Law

CSE251: Electronic Devices and Circuits

Lecture 1

Alt. Representation, CSE250 Review, IV Characteristics

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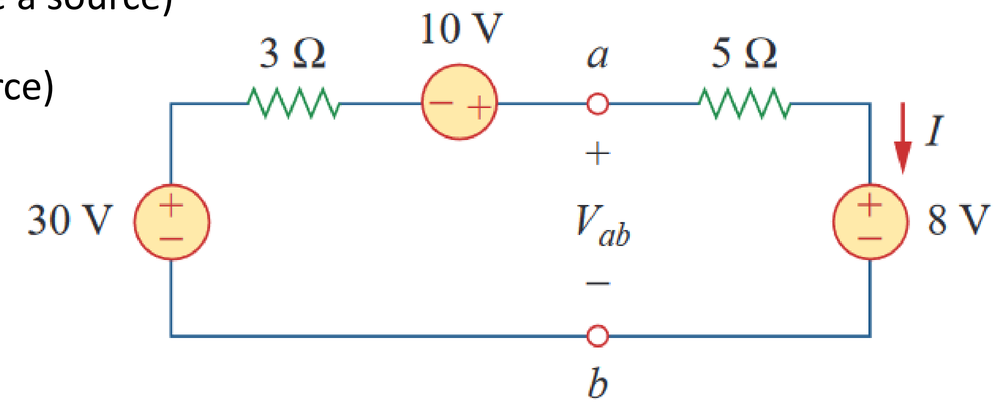
Alternative Circuit Representation: Line diagrams

Steps to decompose circuits to line diagram

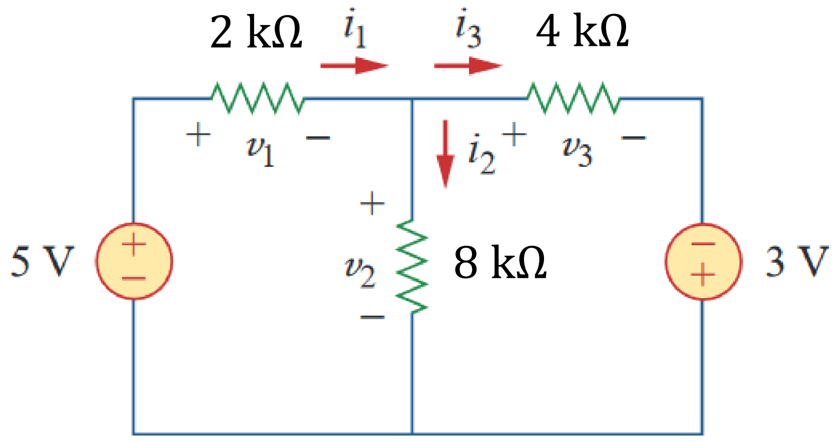
1. Set a ground so that number of **floating voltage** sources are minimized.
2. Detach the ground
3. Convert the non-floating voltage sources (~~current sources~~) into:
   - Arrow : ($\rightarrow$) **Fixed/Constant voltage source**
   - Open circle dot: ($-$o) Input/Output node voltage (may or may not be a source)
   - Filled circle dot: ($-$●) Known node voltage (may or may not be a source)
4. Keep passive elements as they are.

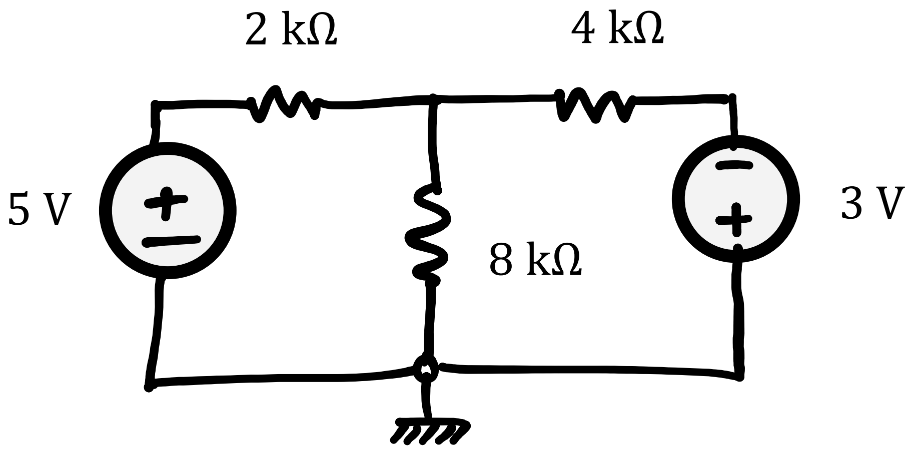
Floating voltage sources:

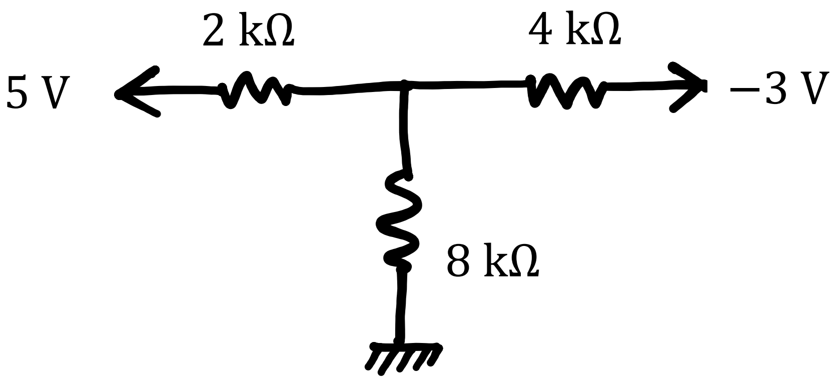
Voltage sources which are **not connected the ground** terminal. In the diagram, the $\mathbf{10\ V}$ voltage source is floating



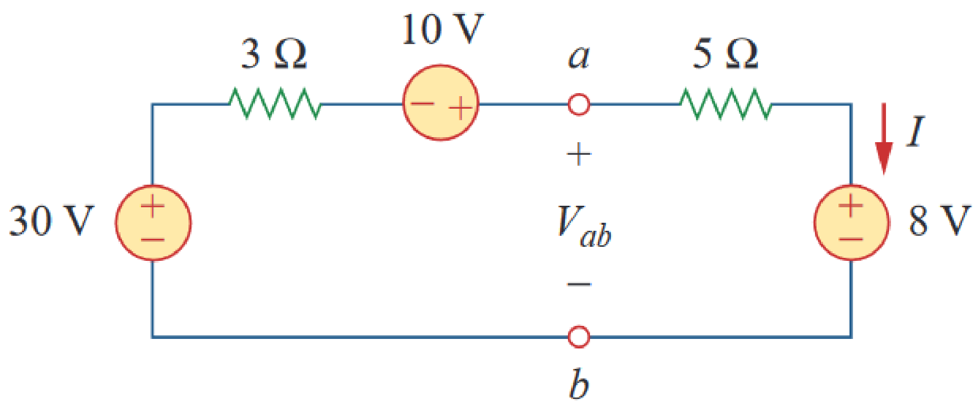
Line diagrams: Example 1

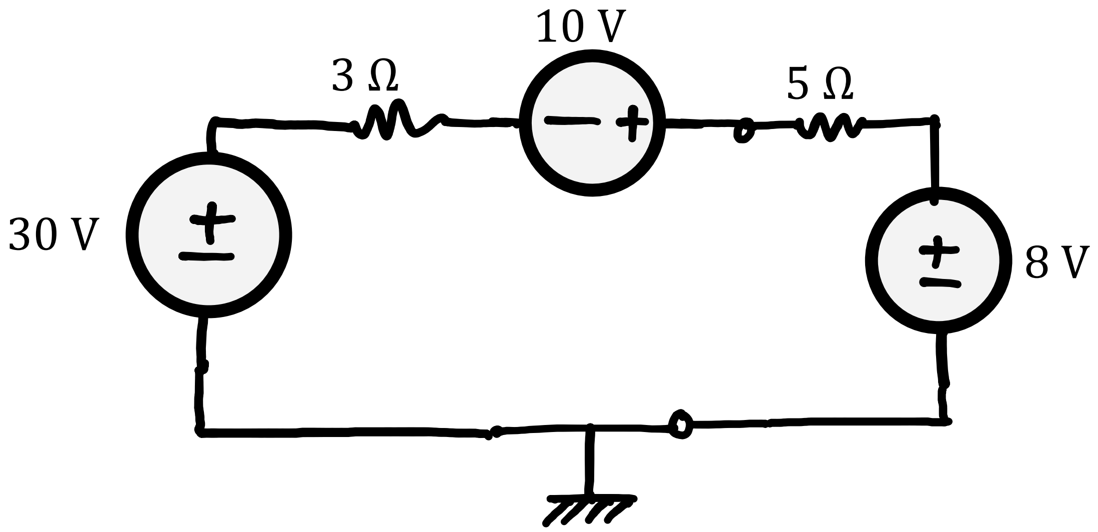


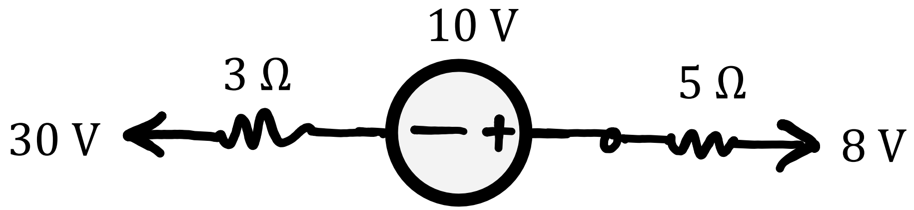




Line diagrams: Example 2

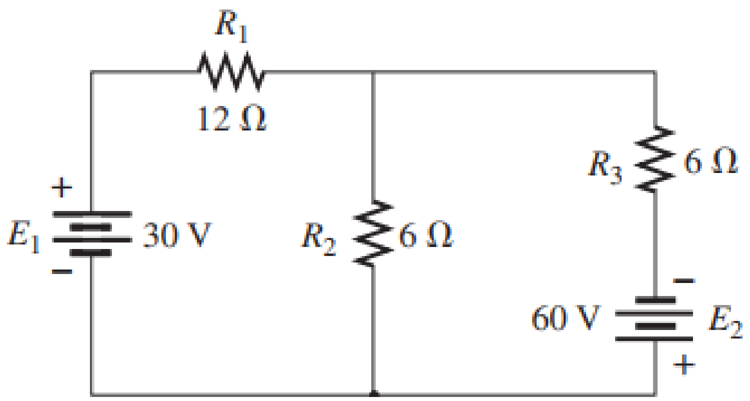






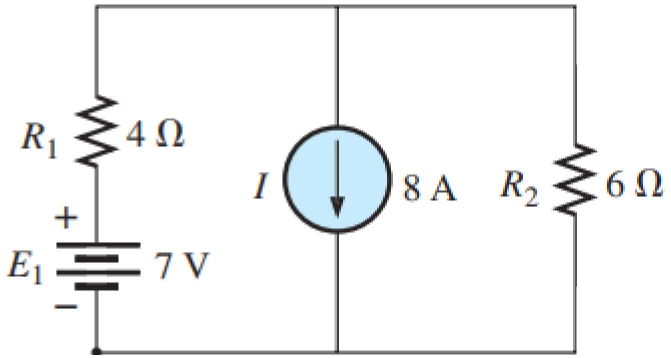
More Examples

Difficulty : 2/5



Example: 2

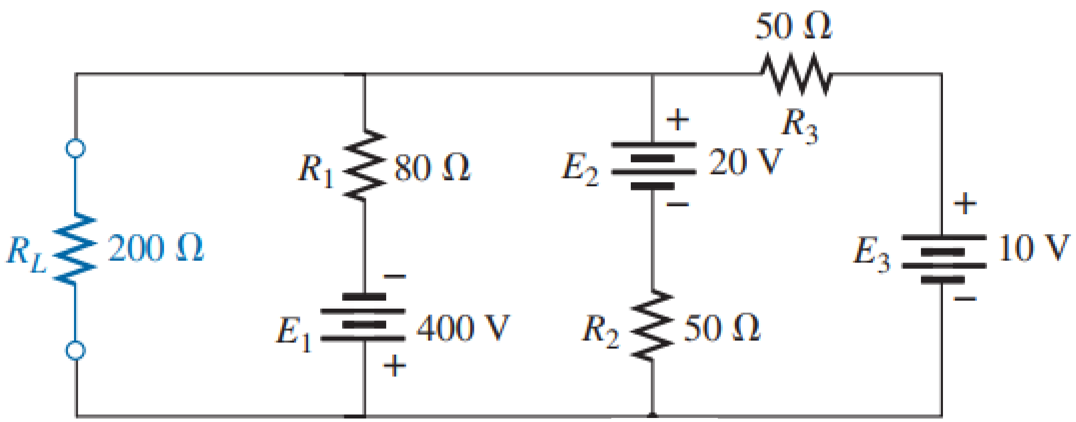
Difficulty : 3/5



Example: 3

More Examples

Difficulty : 4/5



Example: 4

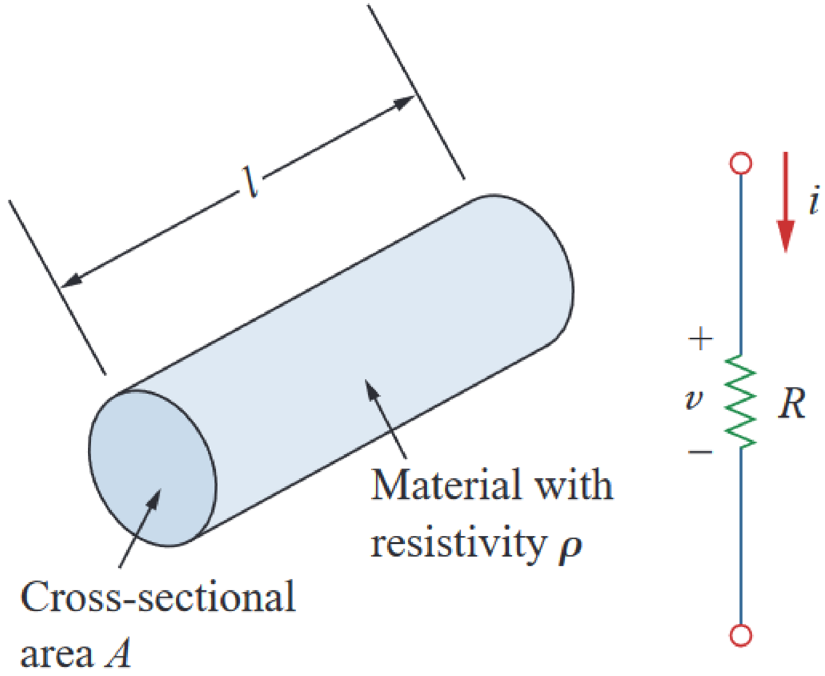
Step – (4) Make all the active elements (dc/ac type, voltage/~~current~~ sources) into single terminals (arrows/circles) using the voltages you wrote as much as you can [***<u>THERE MIGHT BE CASES WHERE YOU CAN'T DO THAT</u>***]

The fundamentals …

Ohm's Law –

- the voltage v across a resistor is **directly proportional** to the current i flowing through the resistor (R)

$$v \propto i$$
$$v = iR$$



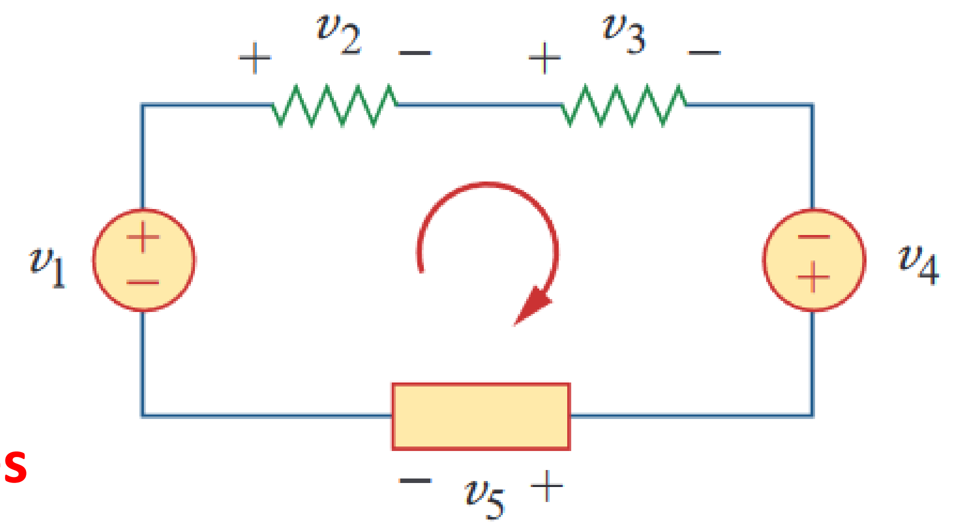
KVL: Kirchhoff’s voltage law

The algebraic sum of all **voltages** around **a closed path (or loop)** is zero.

$$-\boldsymbol{v_1} + v_2 + v_3 - \boldsymbol{v_4} + v_5 = 0$$

$$v_2 + v_3 + v_5 = \boldsymbol{v_1} + \boldsymbol{v_4}$$

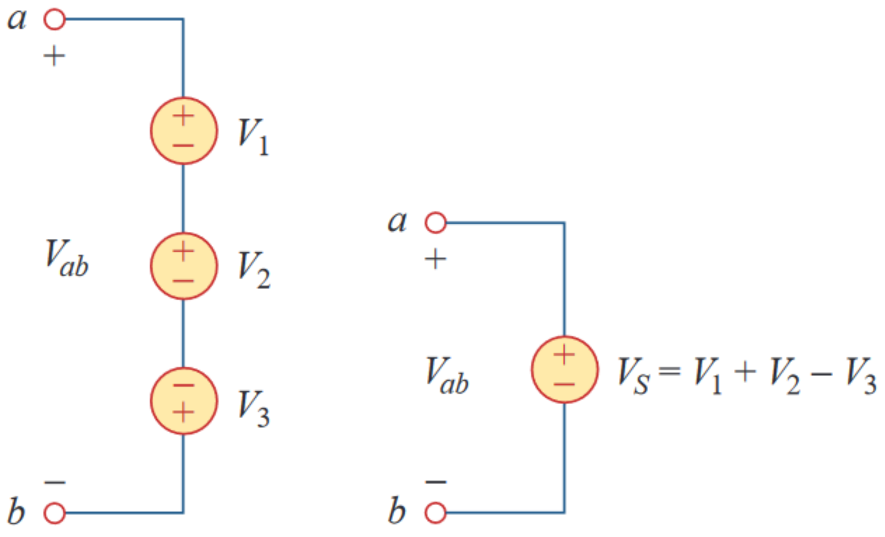
Sum of voltage drops = **Sum of voltage rises**



KVL: Kirchhoff's voltage law

$$-V_{ab} + V_1 + V_2 + V_3 = 0$$

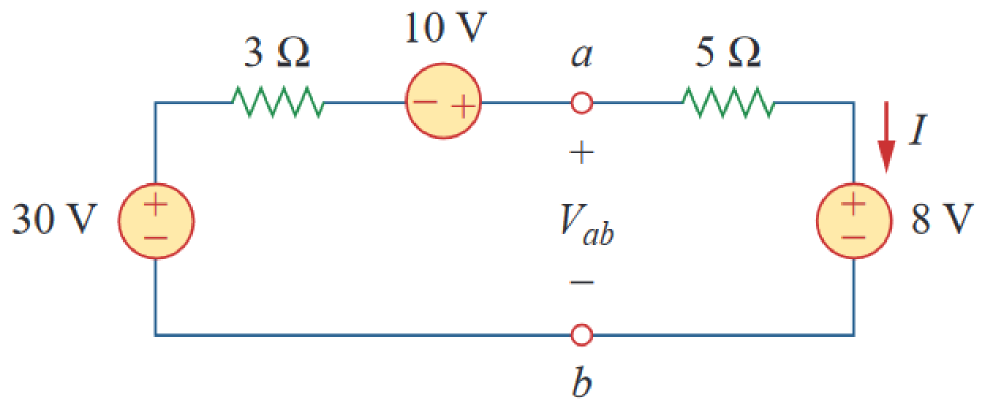
$$V_{ab} = V_1 + V_2 + V_3$$



Equivalent Circuits

KVL – Example 1

Find $\boldsymbol{I}$ and $\boldsymbol{V_{ab}}$ in the circuit



Solution:

KVL

$$-30 + 3\boldsymbol{I} - 10 + 5\boldsymbol{I} + 8 = 0$$

$$\boldsymbol{I} = \frac{32}{8}\,\mathrm{A} = 4\ \mathrm{A}$$

KVL

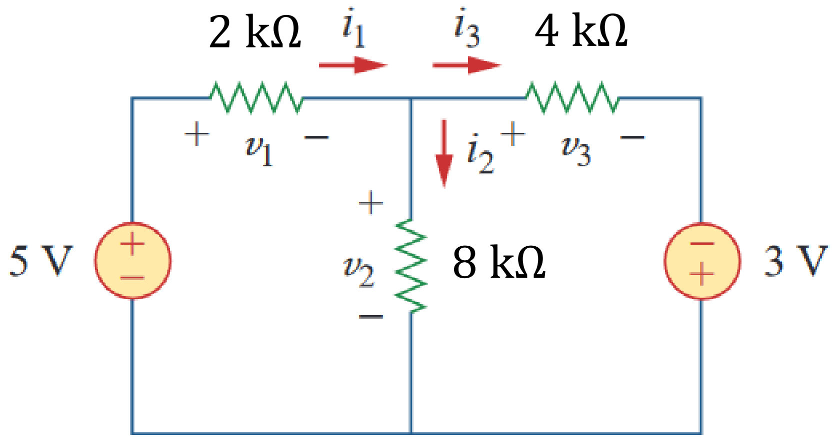
$$-V_{ab} + 5\boldsymbol{I} + 8 = 0$$

$$\boldsymbol{V_{ab}} = 28\ \mathrm{V}$$

Tip: If you find resistance values in **kΩ** instead of **Ω**, don't convert the **kΩ** values to **Ω**. Just find currents in **mA** instead of **A**.

KVL – Example 2

Find $\boldsymbol{v_1}, \boldsymbol{v_2}, \boldsymbol{v_3}, \boldsymbol{i_1}, \boldsymbol{i_2}$ and $\boldsymbol{i_3}$ in the circuit



Solution:

KVL in first loop

$$-5 + 2\boldsymbol{i_1} + 8(\boldsymbol{i_1} - \boldsymbol{i_3}) = 0$$

$$10\boldsymbol{i_1} - 8\boldsymbol{i_3} = 5$$

KVL in second loop

$$-8(\boldsymbol{i_1} - \boldsymbol{i_3}) + 4\boldsymbol{i_3} - 3 = 0$$

$$-8\boldsymbol{i_1} + 12\boldsymbol{i_3} = 3$$

Solving:

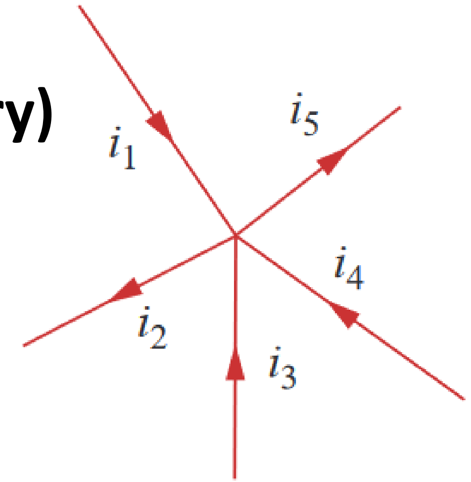
$$i_1 = 1.5 \text{ mA}$$
$$i_3 = 1.25 \text{ mA}$$
$$i_2 = i_1 - i_3 = 0.25 \text{ mA}$$

$$v_1 = 3 \text{ V}$$
$$v_2 = 2 \text{ V}$$
$$v_3 = 5 \text{ V}$$

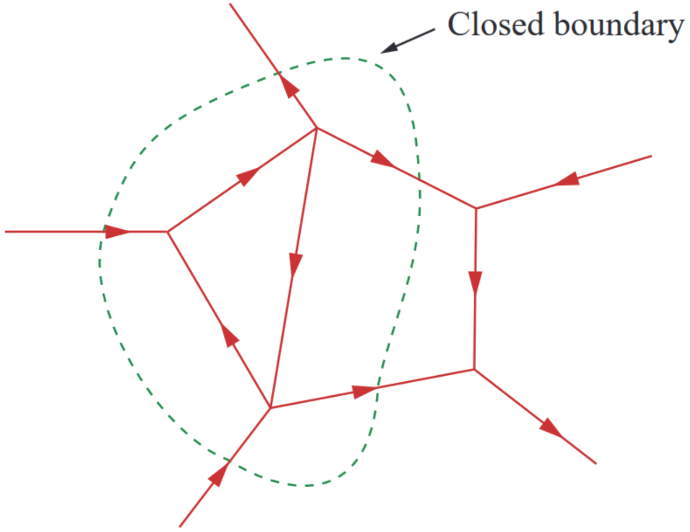
Tip: If you find resistance values in **kΩ** instead of **Ω**, don't convert the **kΩ** values to **Ω**. Just find currents in **mA** instead of **A**.

KCL: Kirchoff's Current Law

The algebraic sum of the **currents** entering a **node (closed boundary)** is equal to the sum of the currents leaving the node.



$$i_1 + (-i_2) + i_3 + i_4 + (-i_5) = 0$$

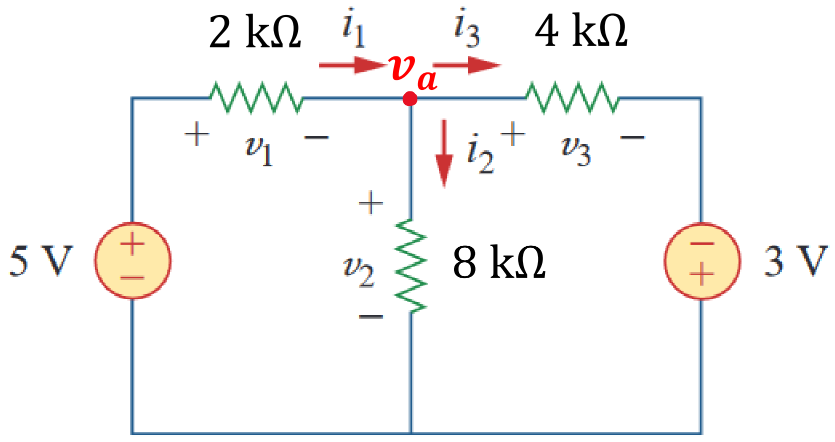


Current Entering node: **Positive**
Current Exiting node: **Negative**

Or vice versa…

KCL- Example 1

Find $\boldsymbol{v_1, v_2, v_3, i_1, i_2}$ and $\boldsymbol{i_3}$ in the circuit



Solution:

KCL in node $\boldsymbol{v_a}$. (PS: $\boldsymbol{v_a = v_2}$)

$$\frac{5-\boldsymbol{v_2}}{2}-\frac{\boldsymbol{v_2}-(-3)}{4}-\frac{\boldsymbol{v_2}-0}{8}=0$$

$$v_2\left(-\frac{1}{2}-\frac{1}{4}-\frac{1}{8}\right)=-\left(\frac{5}{2}-\frac{3}{4}\right)$$

$$\boldsymbol{v_2}=\frac{7}{4}\cdot\frac{8}{7}\text{ V}=2\text{ V}$$

$$\boldsymbol{v_1}=5-v_2=3\text{ V}$$

$$\boldsymbol{v_3}=v_2-(-3)=5\text{ V}$$