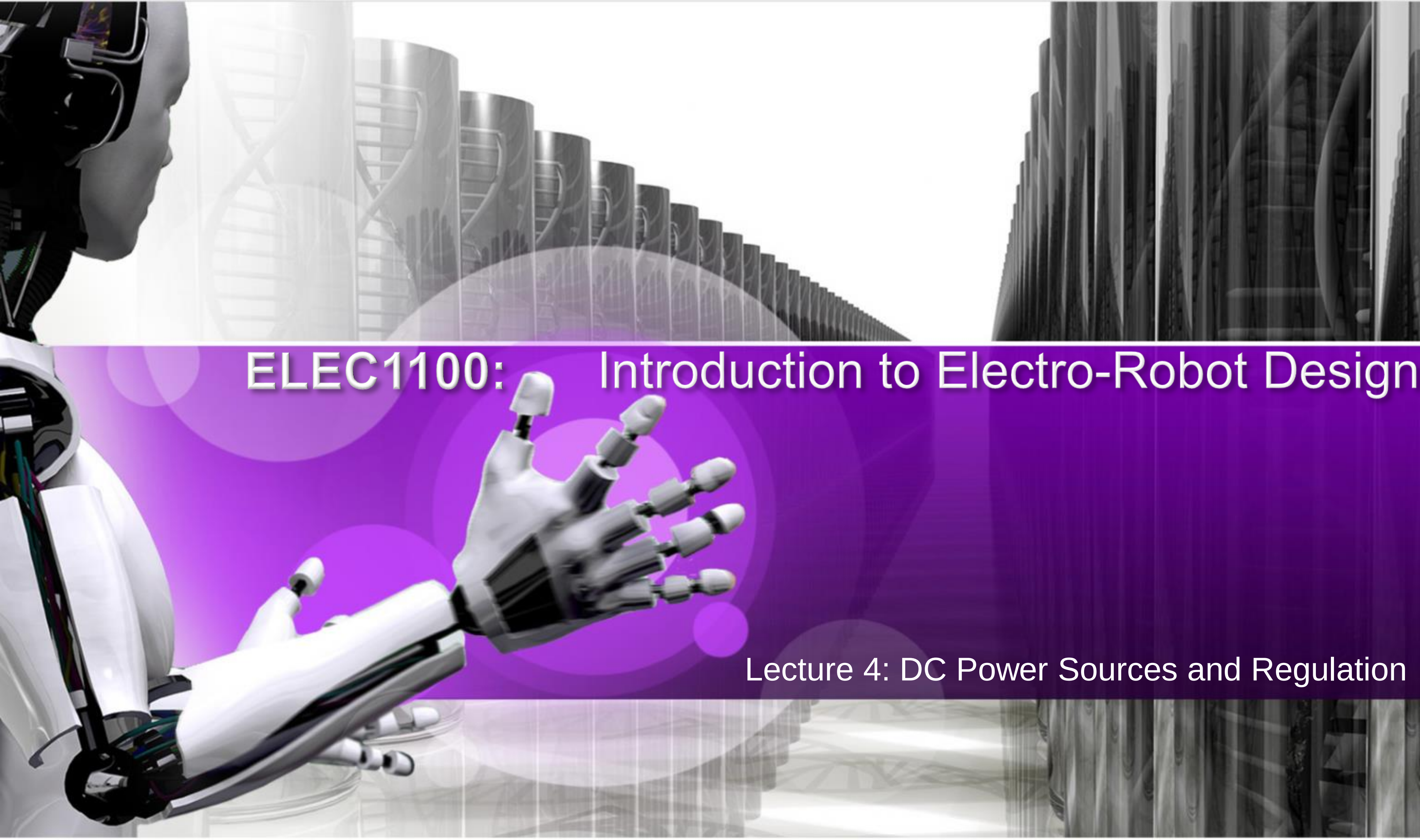
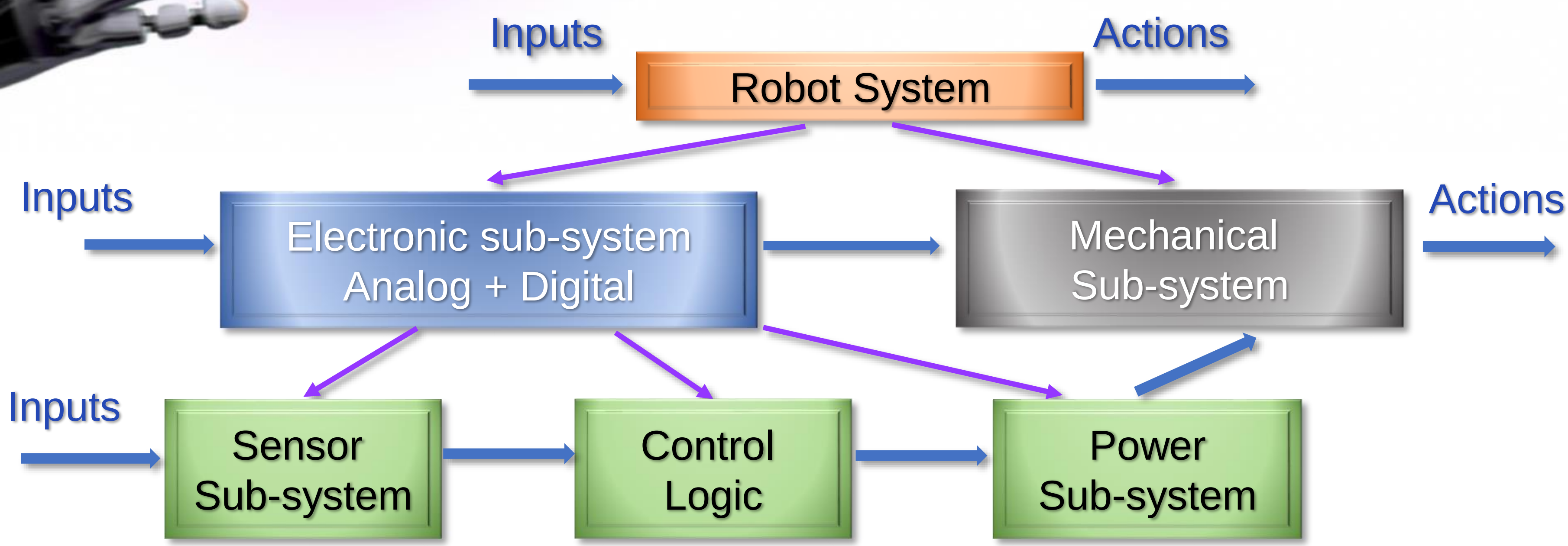


ELEC1100: Introduction to Electro-Robot Design

Lecture 4: DC Power Sources and Regulation

SONG Shenghui and MURCH Ross, Dept. of ECE, HKUST

ELEC1100 ROADMAP

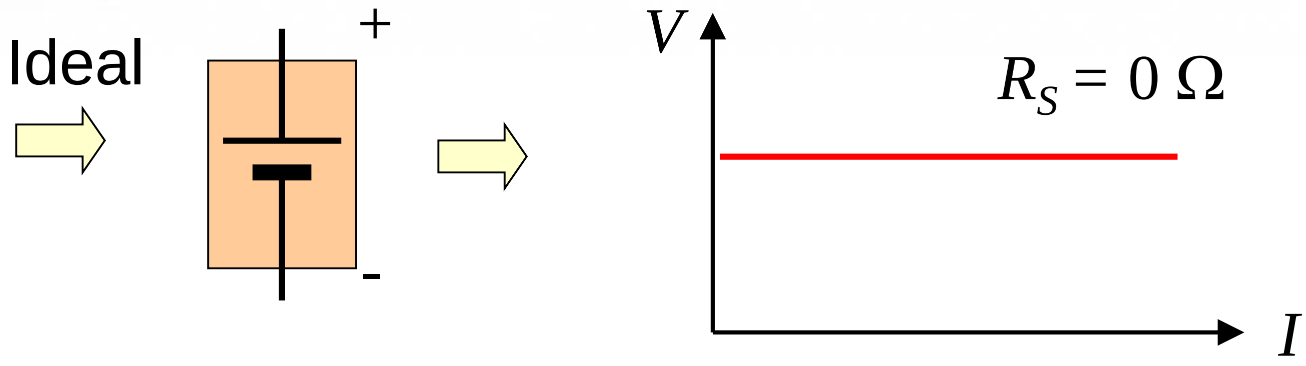


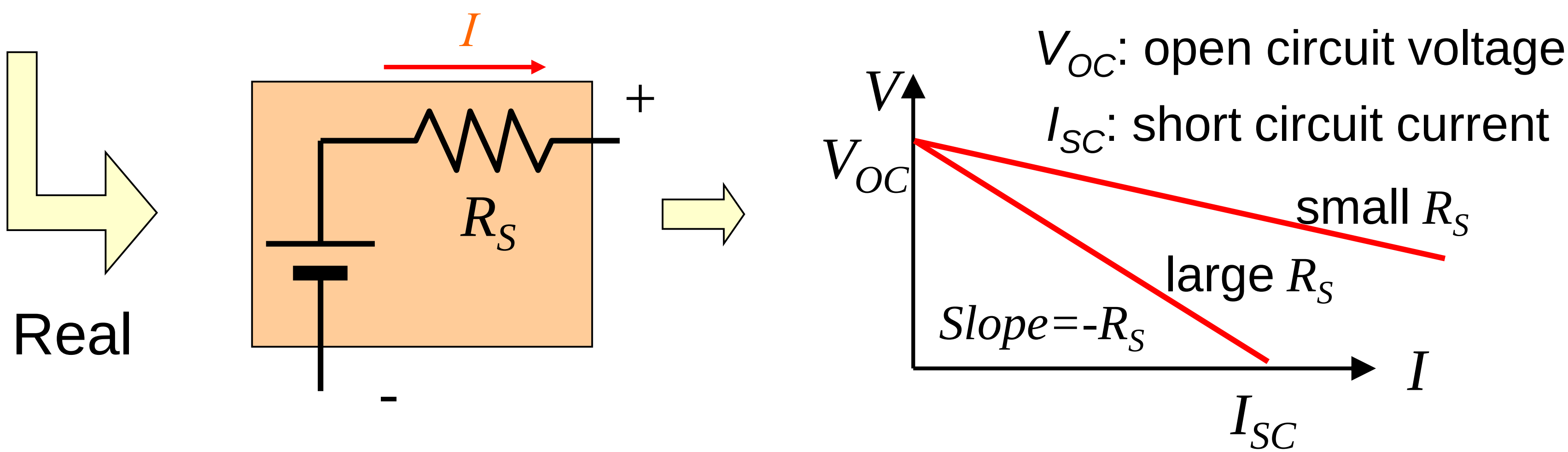
Basic electronics:

Wk1: Basic Electronics - Charge/Current/Voltage/Resistor

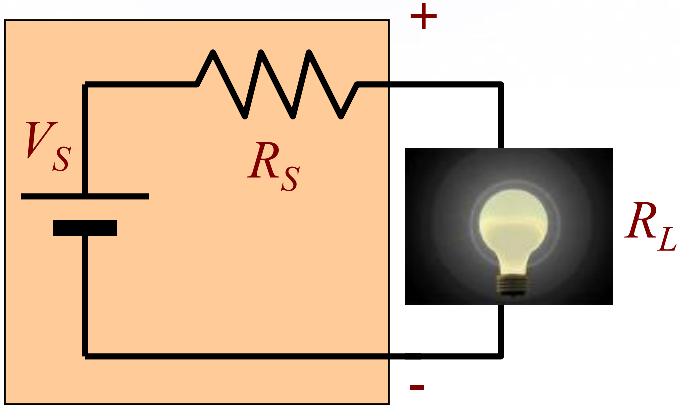
Wk2: Energy/Power and DC Sources

IDEAL AND NON-IDEAL BATTERY





POWER EFFICIENCY [1]



Current through the circuit: $I = \dfrac{V_S}{R_S + R_L}$

$P_S = R_S\left(\dfrac{V_S}{R_S + R_L}\right)^2$ Power consumed by R_S

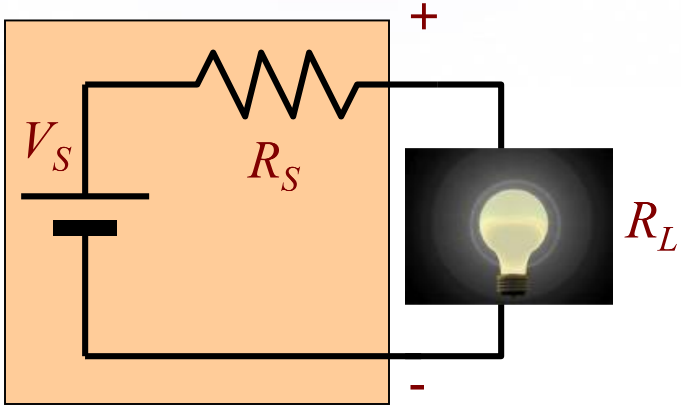
$P_L = R_L\left(\dfrac{V_S}{R_S + R_L}\right)^2$ Power consumed by R_L

- To maximize P_L, we take the derivative of P_L with respect to R_L

$$\frac{d(P_L)}{d(R_L)} = \frac{d\left(\dfrac{V_S^2}{(R_S+R_L)^2}R_L\right)}{d(R_L)} = V_S^2 \cdot \frac{(R_S+R_L)^2 - R_L(2R_S+2R_L)}{(R_S+R_L)^4}$$

Let $\dfrac{d(P_L)}{d(R_L)} = 0 \Rightarrow (R_S+R_L)^2 - R_L(2R_S+2R_L) = 0 \Rightarrow R_S^2 - R_L^2 = 0 \Rightarrow R_S = R_L$

POWER EFFICIENCY [2]

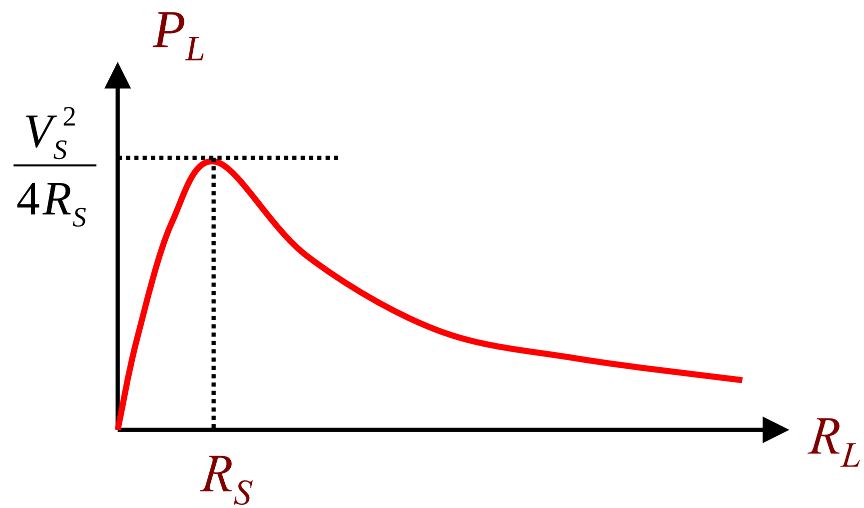


Current through the circuit: $I = \dfrac{V_S}{R_S + R_L}$

$$P_S = R_S\left(\frac{V_S}{R_S + R_L}\right)^2$$ Power consumed by R_S

$$P_L = R_L\left(\frac{V_S}{R_S + R_L}\right)^2$$ Power consumed by R_L

- Observation
  - maximum deliverable power occurs when $R_S = R_L$
  - maximum $P_L = \dfrac{V_S^2}{4R_S}$

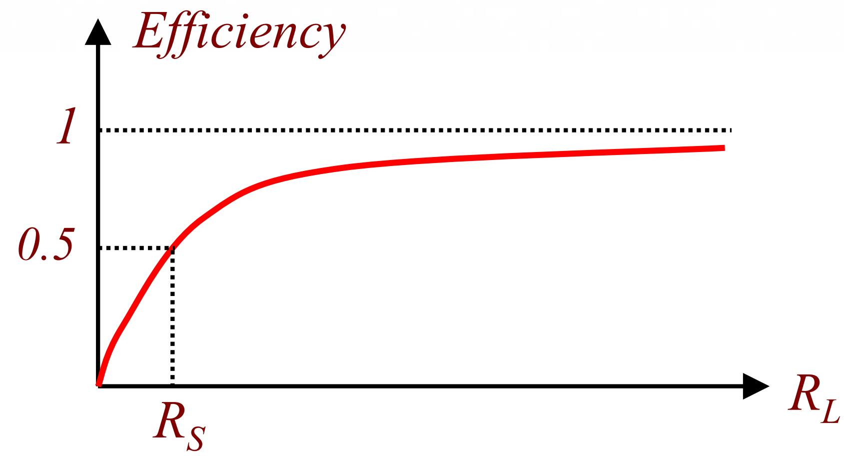


POWER EFFICIENCY [3]

- Max efficiency

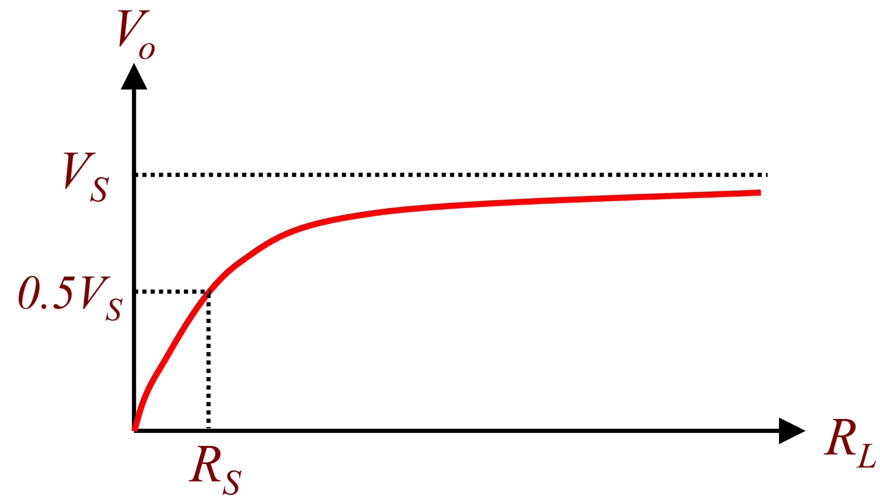
$$\text{efficiency} = \frac{P_L}{P_L+P_S} = \frac{I^2 \cdot R_L}{I^2 \cdot R_L + I^2 \cdot R_S}$$

$$= \frac{R_L}{R_L+R_S} = \frac{1}{1+\frac{R_S}{R_L}}$$



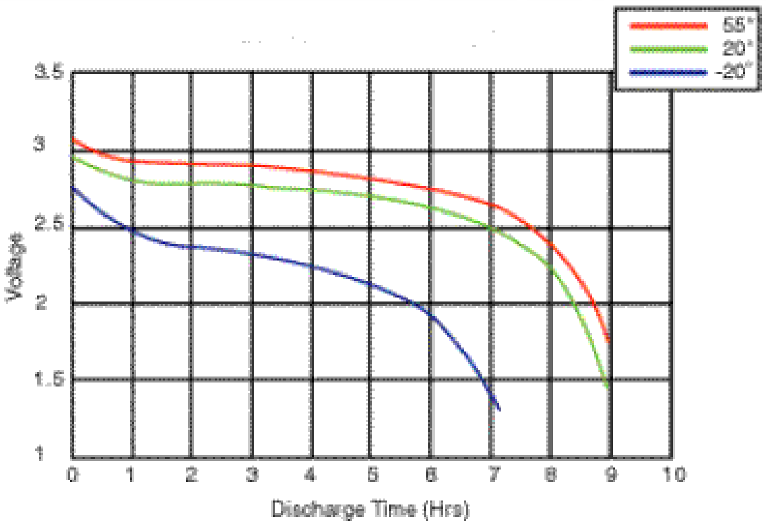
- The output voltage versus R_L

$$V_o = V_L = V_S \cdot \frac{R_L}{R_L + R_S} = V_S \cdot \left(\frac{1}{1+\frac{R_S}{R_L}}\right)$$



BATTERY CHARACTERISTICS

❖ Battery voltage is not constant



Li battery characteristics at different temperature versus time

❖ Need to stabilize the voltage to provide predictable performance

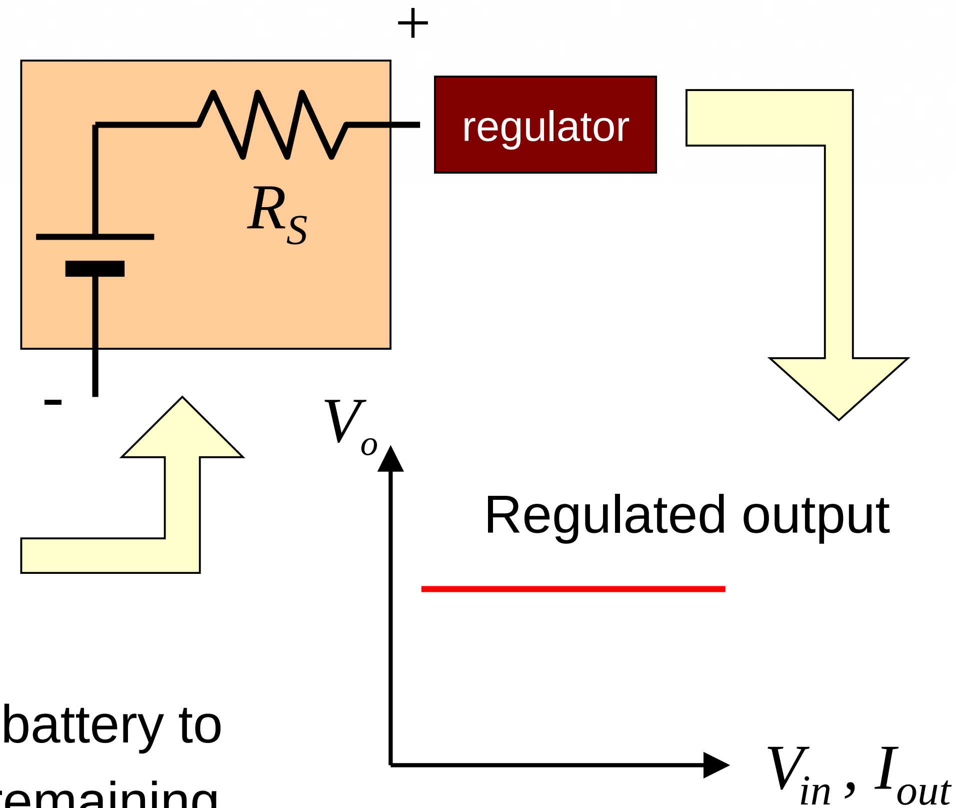
BATTERY TYPES

Primary Battery	Voltage	Energy (MJ/kg)	Remarks
Zinc chloride/carbon	1.5V	0.13	Inexpensive
Alkaline	1.5V	0.4-0.59	Most commonly used
Silver oxide	1.55V	0.47	Very expensive, only used in button cells
Lithium manganese dioxide	3.0V	0.83-1.01	Expensive and slow discharge For high drain usage only
Mercury oxide	1.35V	0.5	Constant voltage, but banned in most countries because of health concerns

Rechargeable	Voltage	Energy (MJ/kg)	Remarks
NiCd	1.2V	0.14	Inexpensive, but with “memory” effect
Lead–acid	2.1V	0.14	High discharge rate and environmental hazard
NiMH	1.2V	0.36	Heavy and high discharge rate
NiZn	1.6V	0.36	Newly introduced in 2009 and limited size only
Lithium ion	3.6V	0.46	Low discharge and volatile (explode if short circuit)

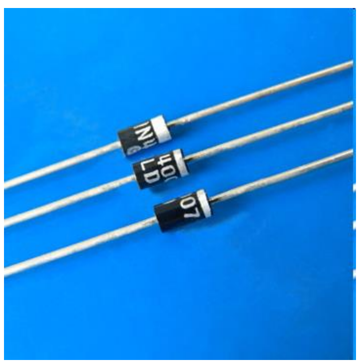
REGULATED OUTPUT

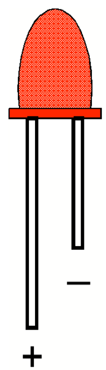
- Most battery-operated systems need a regulator to provide a constant voltage
- Regulators can also provide different voltages to different parts of a system
- Example: you will use 12V from the battery to drive the motor and 5V to drive the remaining circuits

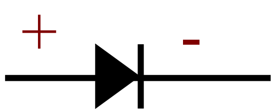


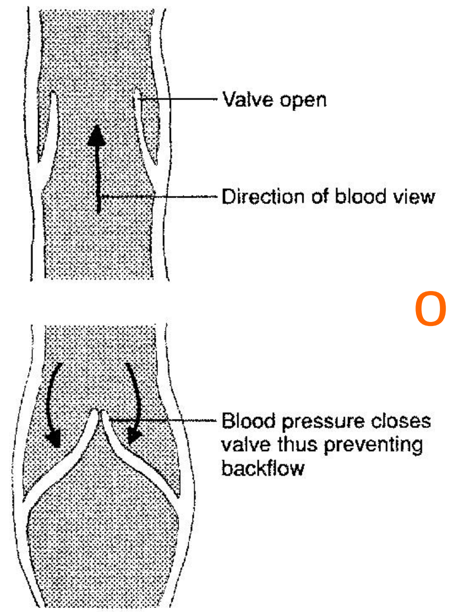
DIODE

- A diode is a device that only allows current to flow in one direction (e.g. LED)
- Symbol and characteristics









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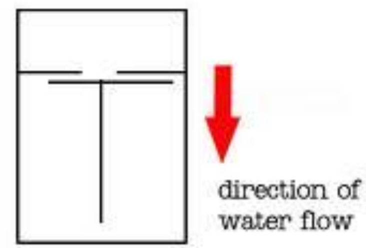
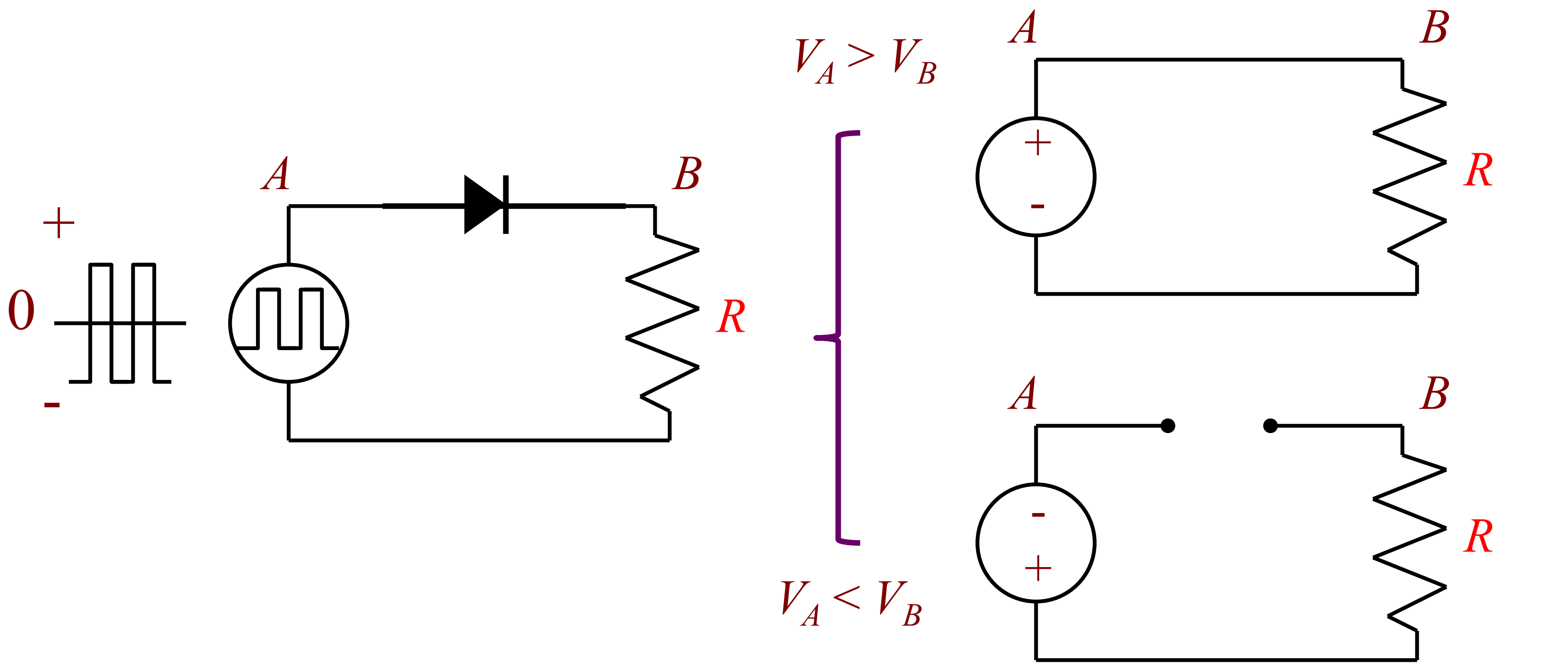


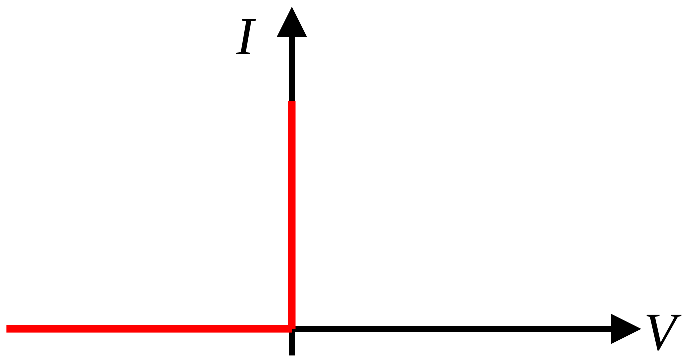
DIODE EQUIVALENT CIRCUIT

❖ A diode becomes a short circuit under forward bias and open circuit when reverse biased

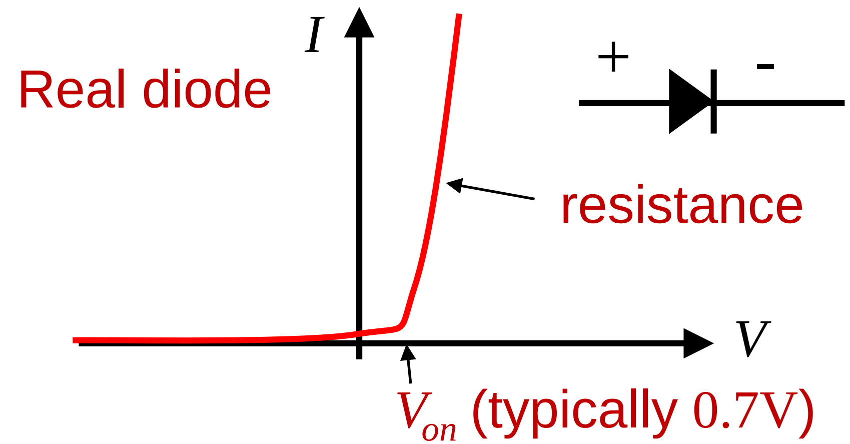


DISCRIPTION OF DIODE CHARACTERISTICS

❖ I-V characteristics of a typical diode



I-V curve for an ideal diode

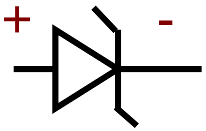


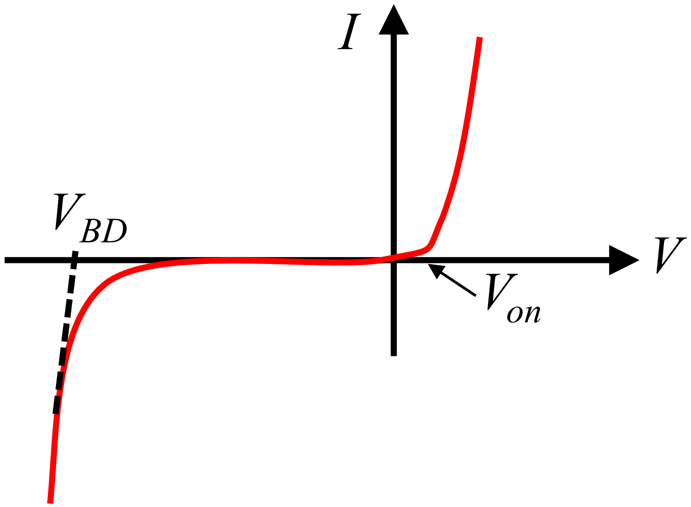
❖ At reverse voltage, current is zero (no current)

❖ At forward voltage, current is infinite (or any current)

ZENER DIODE

- Similar to a diode, but it also allows current to flow when reverse voltage is larger than a certain value
- Symbol and characteristics

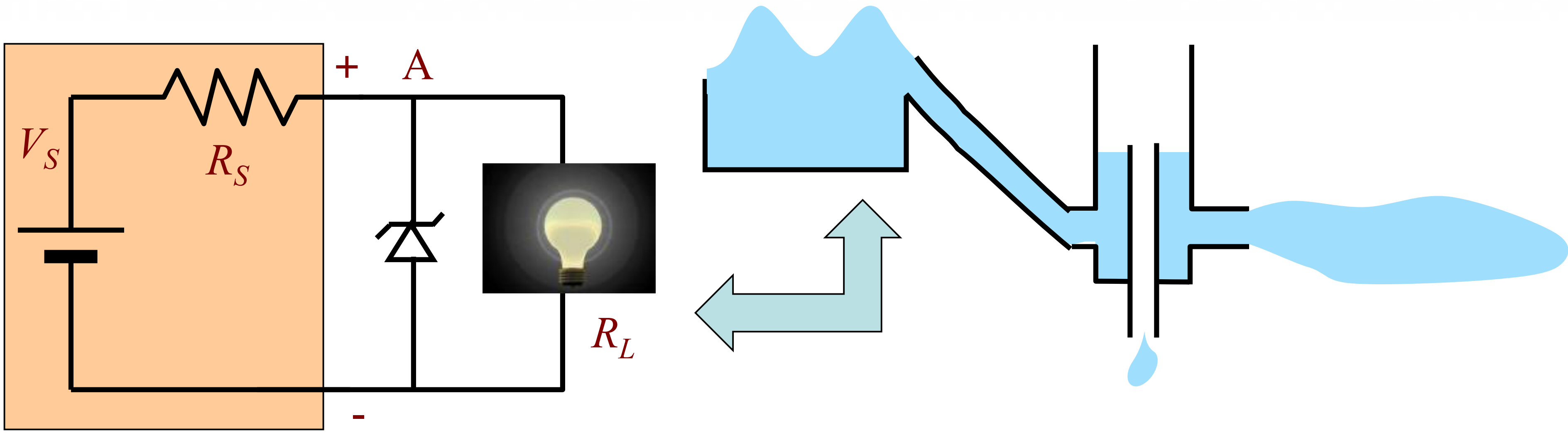




- Allow conduction when $V < V_{BD}$ or $V > V_{on}$
- Typical value $V_{BD} = \text{-5.7 V}$ or $V_{on} = 0.7\text{ V}$

CONNECTING A ZENER DIODE

❖ Circuit construction with Zener diodes

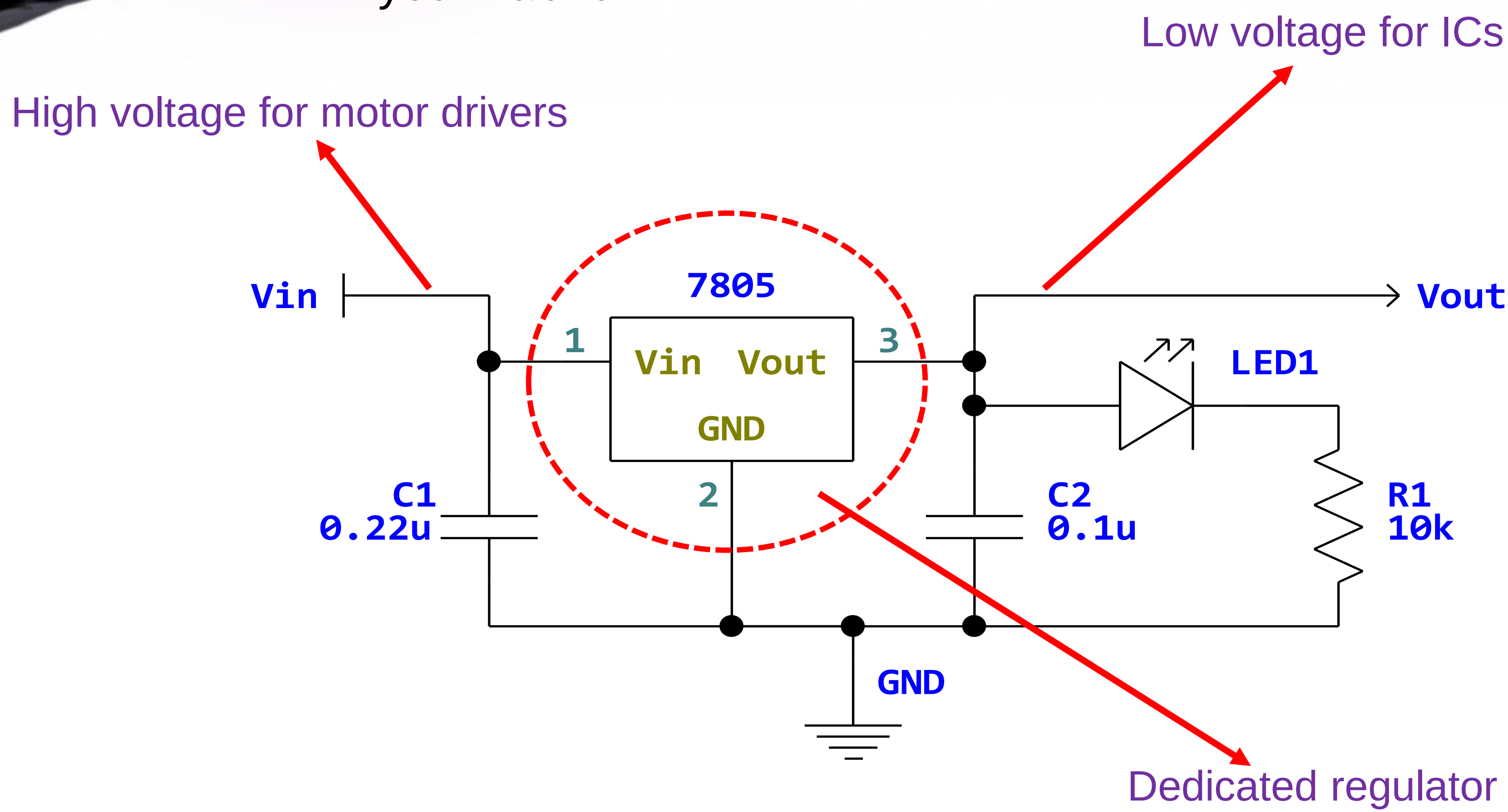


❖ When $V_A > |V_{BD}|$, the Zener diode will clamp the voltage to V_{BD} to protect the circuit.

❖ Problem: power waste

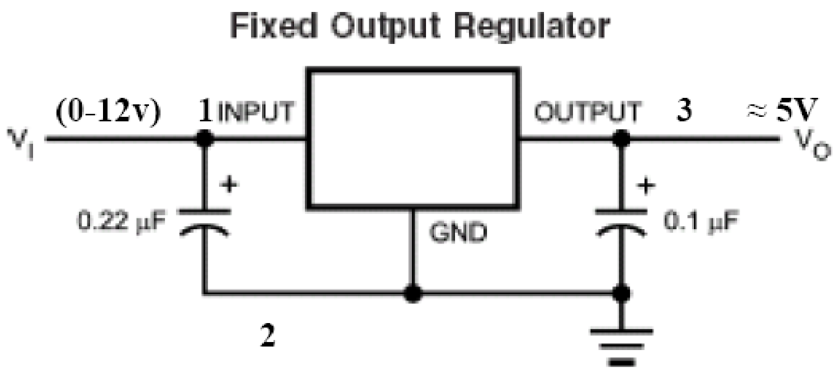
DEDICATED VOLTAGE REGULATOR

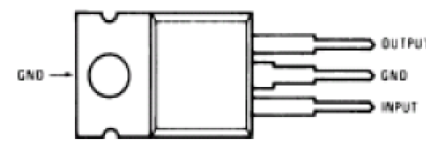
- In your Lab#02:



LM7805

- It is the Integrated Circuit (IC) to be used in your lab





LM7805

- No need to understand the internal circuit (as you need to take more advanced courses)
- Only IC Function knowledge is needed
- A capacitor is commonly used to stabilize the input

MEASURE OF A REGULATOR PERFORMANCE

- Line regulation
  - It measures how stable the output voltage is with respect to the change of the input voltage

$$\text{Line regulation} = \frac{\Delta V_O}{\Delta V_I}$$

  - Ideally, it is equal to zero

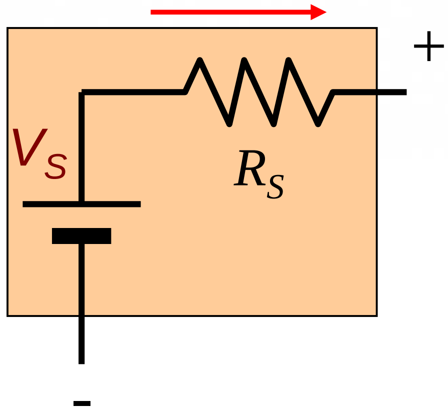
- Load regulation
  - It measures how stable the output voltage is with respect to the change of output current

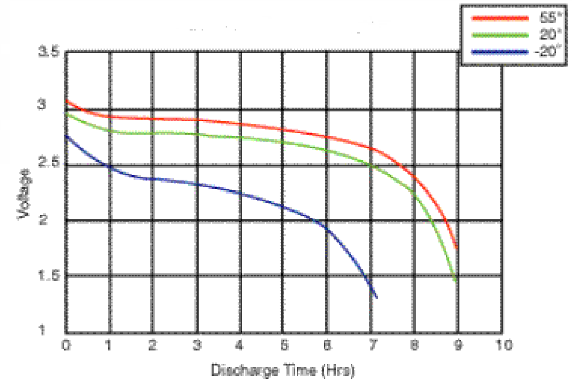
$$\text{Load regulation} = \frac{\Delta V_O}{\Delta I_O}$$

  - Ideally, it is equal to zero

LECTURE SUMMARY

- Battery characteristics





- New element learned

Diode

- The importance of voltage regulation
- LM7805 voltage regulator

NEXT LECTURE

- Integrated circuits
- Pulse generation

QUESTIONS?