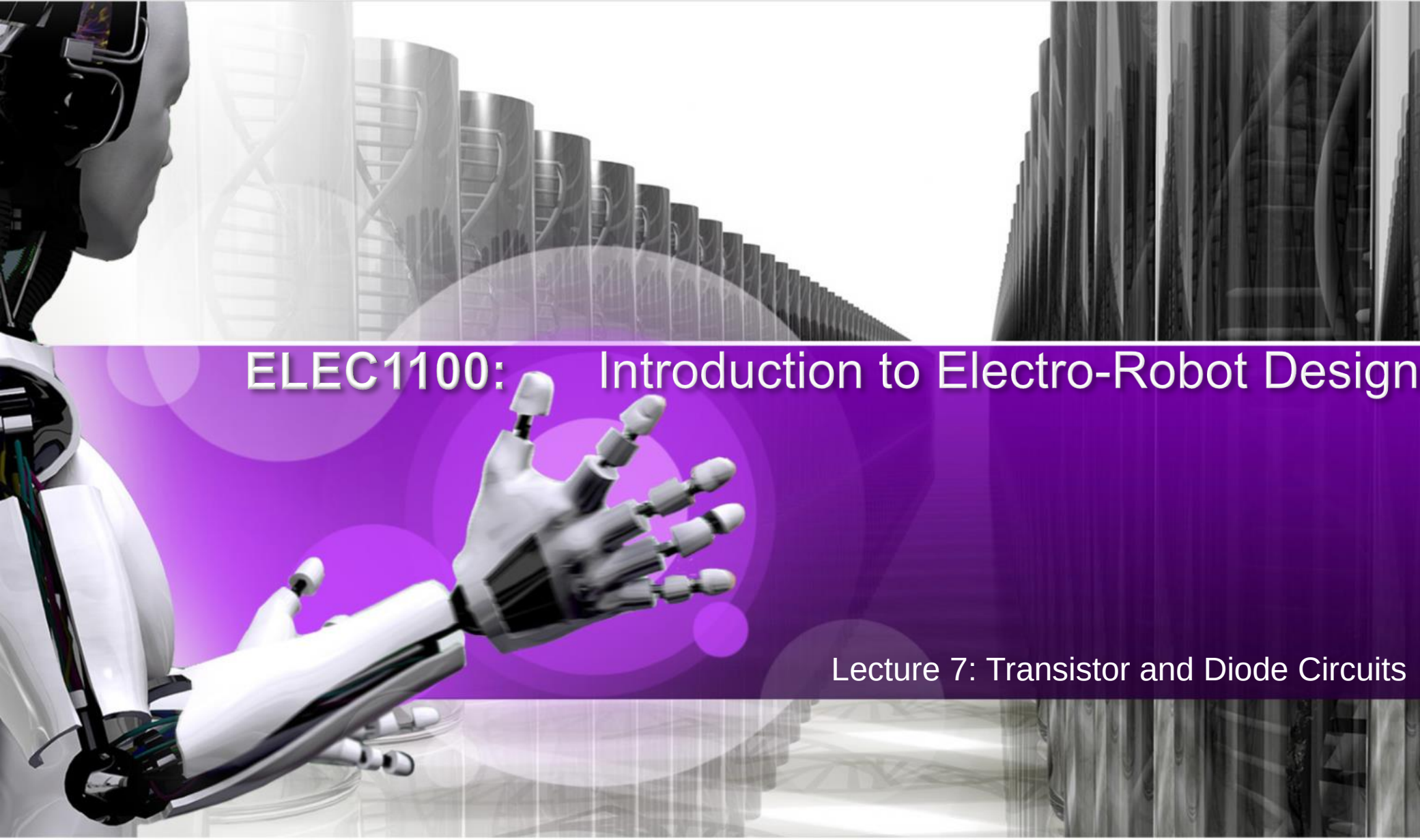

ELEC1100: Introduction to Electro-Robot Design

Lecture 7: Transistor and Diode Circuits

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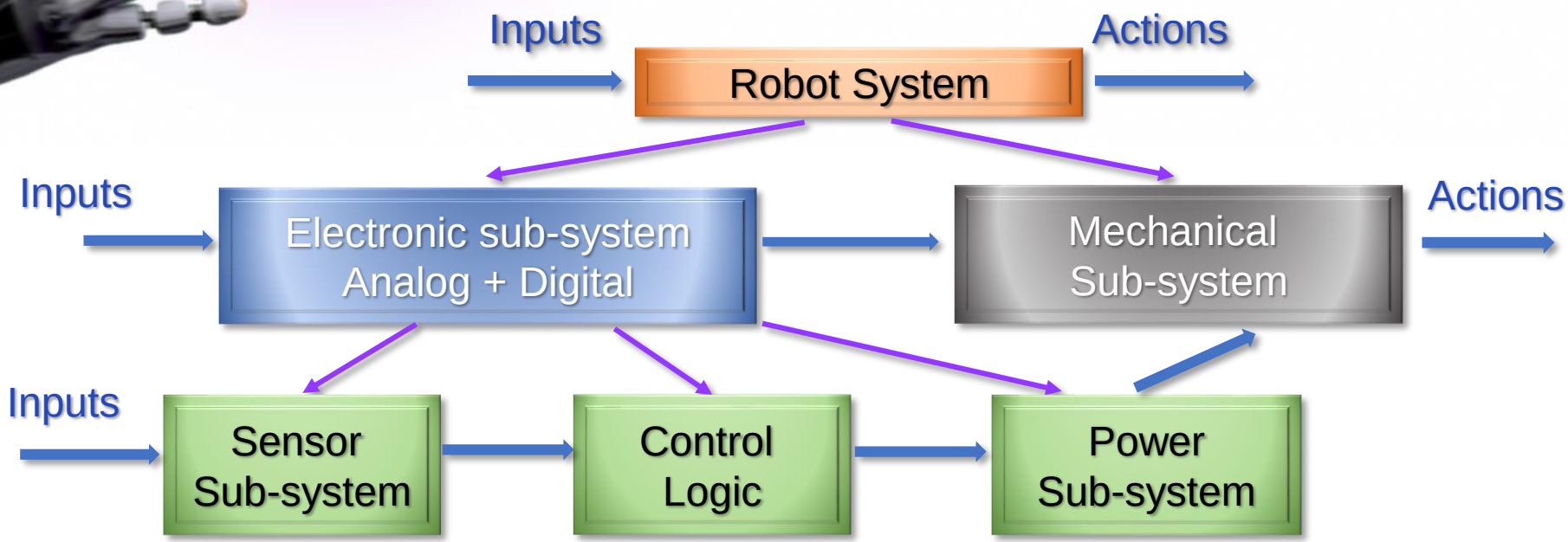
ELEC1100 ROADMAP



Basic electronics:

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

Wk2: Energy/Power and DC Sources

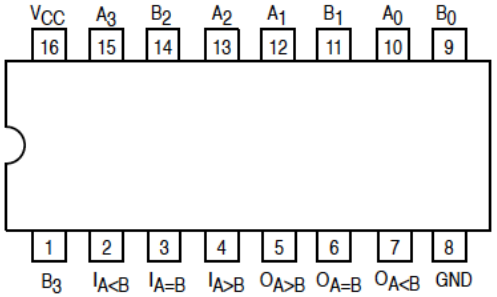
Motor Power Supply:

Wk3: Pulse Signal and PWM Control

Wk4: Transistor and H-Bridge

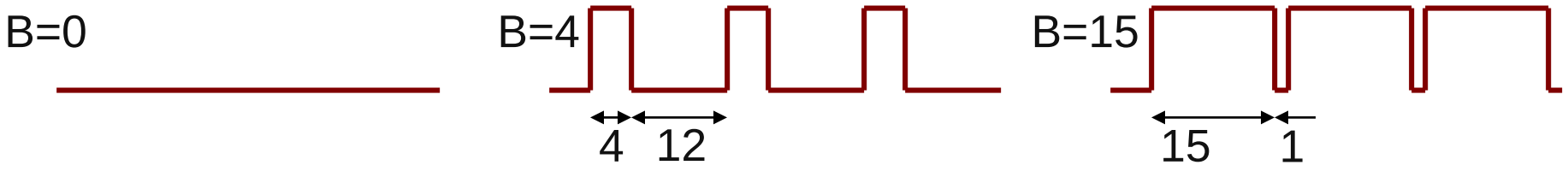
LAST LECTURE

- A comparator compares 2 binary numbers A ($=A_3A_2A_1A_0$) and B ($=B_3B_2B_1B_0$)

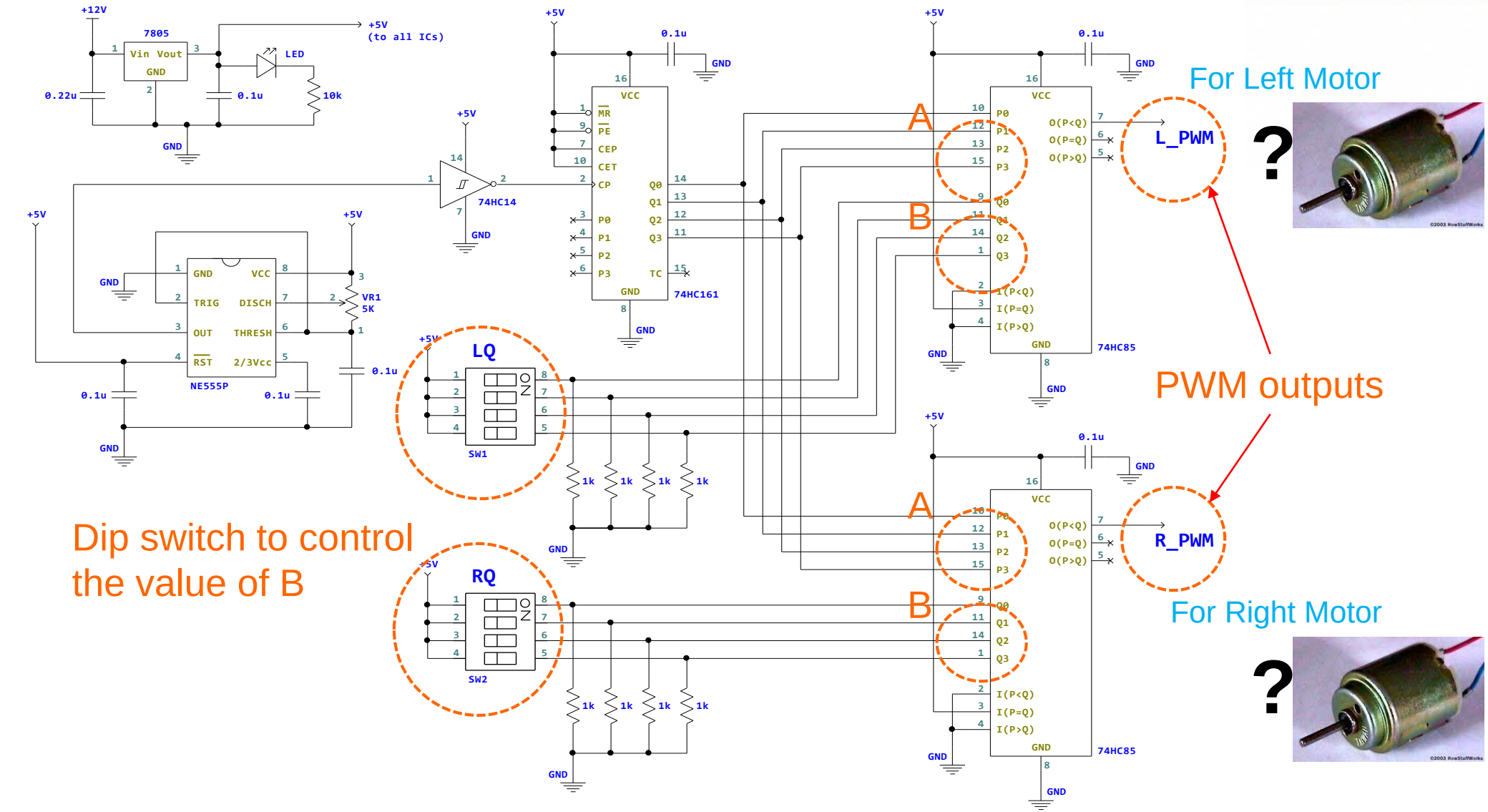


- If A < B, the pin A<B will go high and so on
- Suppose the number A comes from the counter 74HC161 and starting from 0000
- By inputting a fixed number to B, we can control the duty cycle at output of A < B

$O_{A<B}$ output



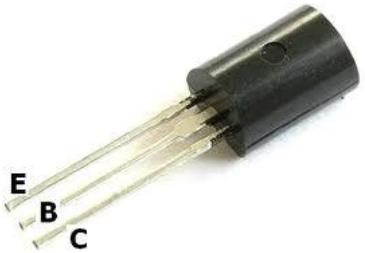
LAST LECTURE



INTERFACING PWM CIRCUIT TO THE MOTOR

- Brushed motors usually require very high current to drive it. Thus, the driving signal needs to be amplified by a transistor
- A transistor is a 3-terminal device that can be viewed as a electronic switch
- The conductivity between two of the terminals is controlled by the third terminal

Transistor



analogy

A SHORT HISTORY OF TRANSISTOR

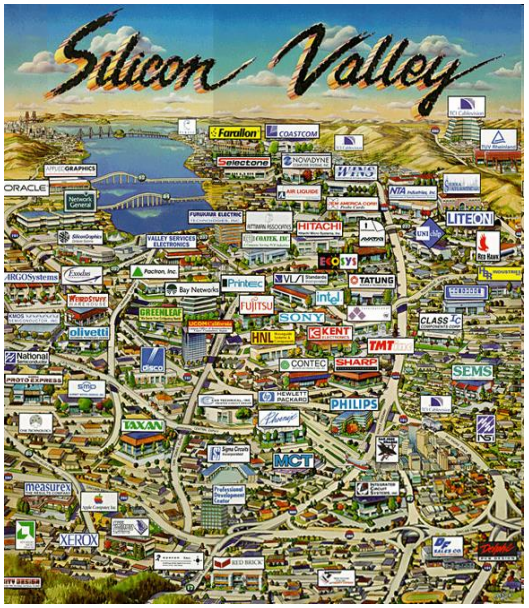
- Invented in Bell Labs by William Shockley, John Bardeen and Walter H. Brattain

- Shockley: “one of the century’s most important scientists”, Times Magazine
- Bardeen: won Nobel Prize twice !
- The three of them won the 1956 Nobel Prize in Physics for inventing the transistor

- Bardeen and Brattain made the breakthrough and Shockley put a nice ending
- However Shockley was not a good leader. Brattain refused to work for him anymore and Bardeen just quit

THE SILICON VALLEY

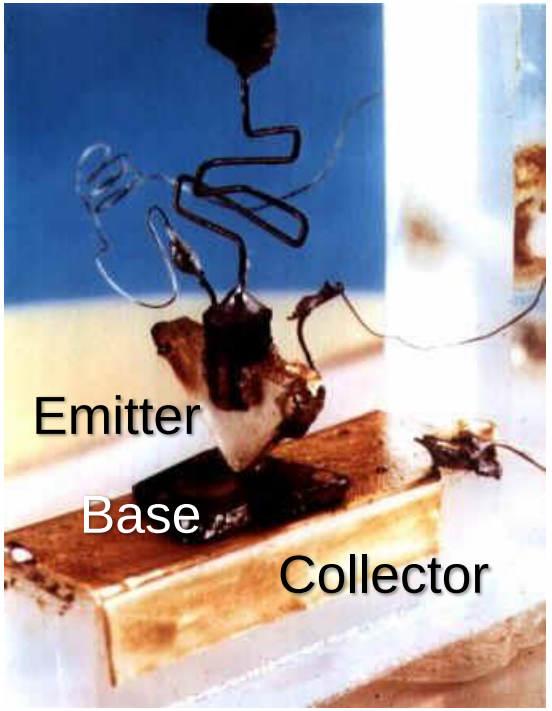
- Shockley moved to Stanford and founded Shockley Semiconductors in Palo Alto, the beginning of Silicon Valley

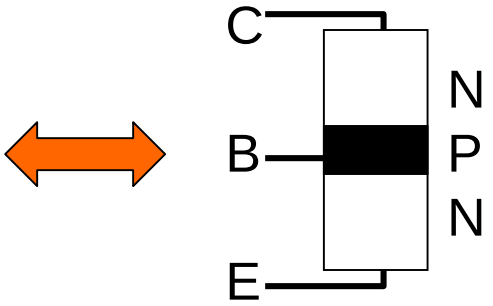


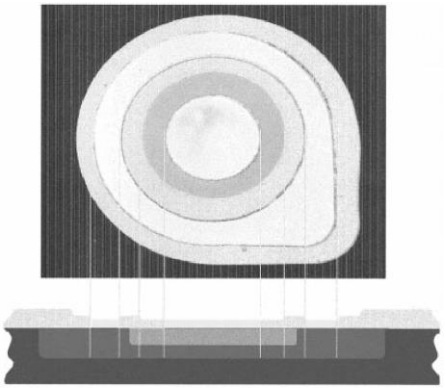
- Shockley hired the brightest scientists and engineers (e.g. Gordon Moore and Bob Noyce, founders of Intel) who founded many companies after they left Shockley

THE FIRST TRANSISTOR

- Resemble the schematic shown earlier



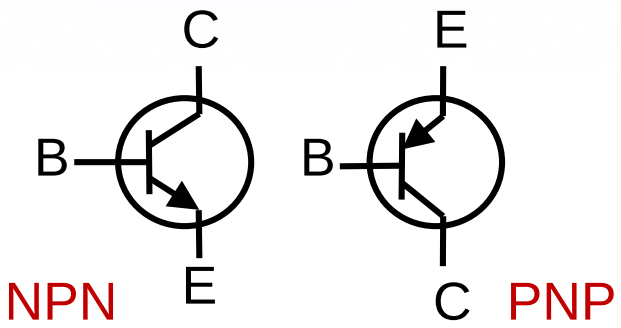


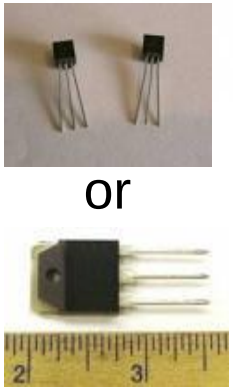


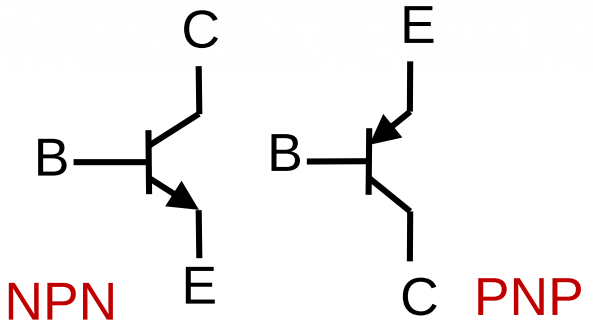
Modern planar transistors

BIPOLAR JUNCTION TRANSISTOR (BJT)

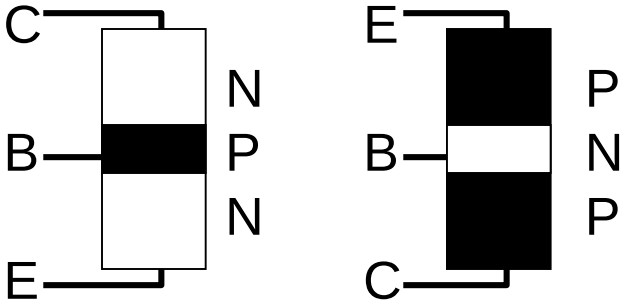
- There are two types of standard BJT





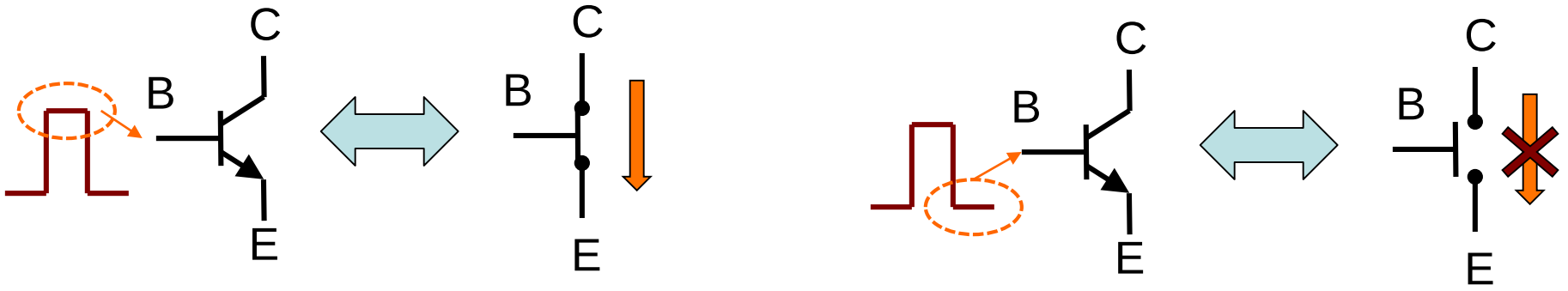


- The leads are labeled Collector (C), Base (B) and Emitter (E)
  - The N and P refers to the material type that is used to construct the transistor
- Detail operation will be covered in other courses

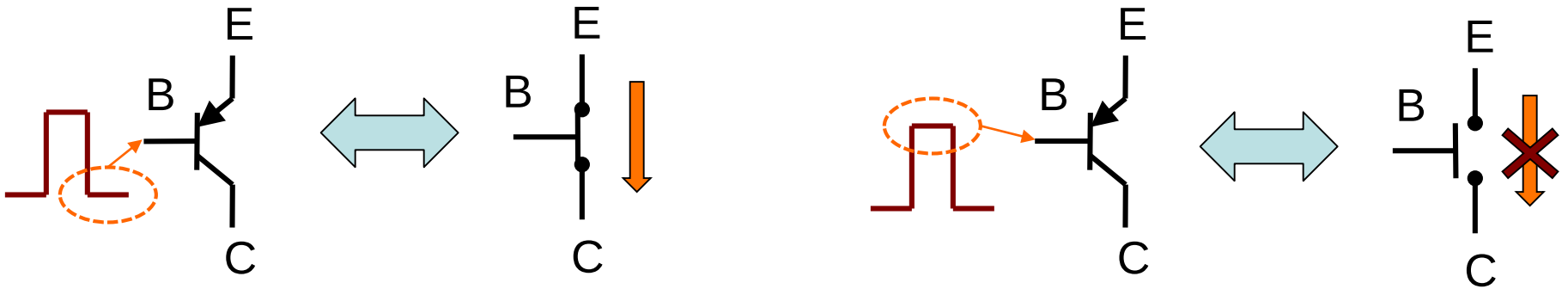


TRANSISTORS AS SWITCHES

- Simple equivalent of NPN transistors

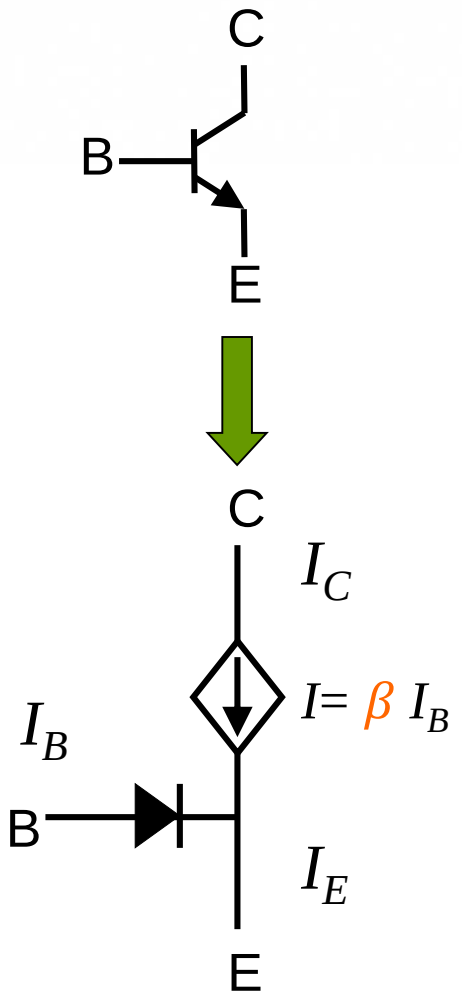


- Simple equivalent of PNP transistors



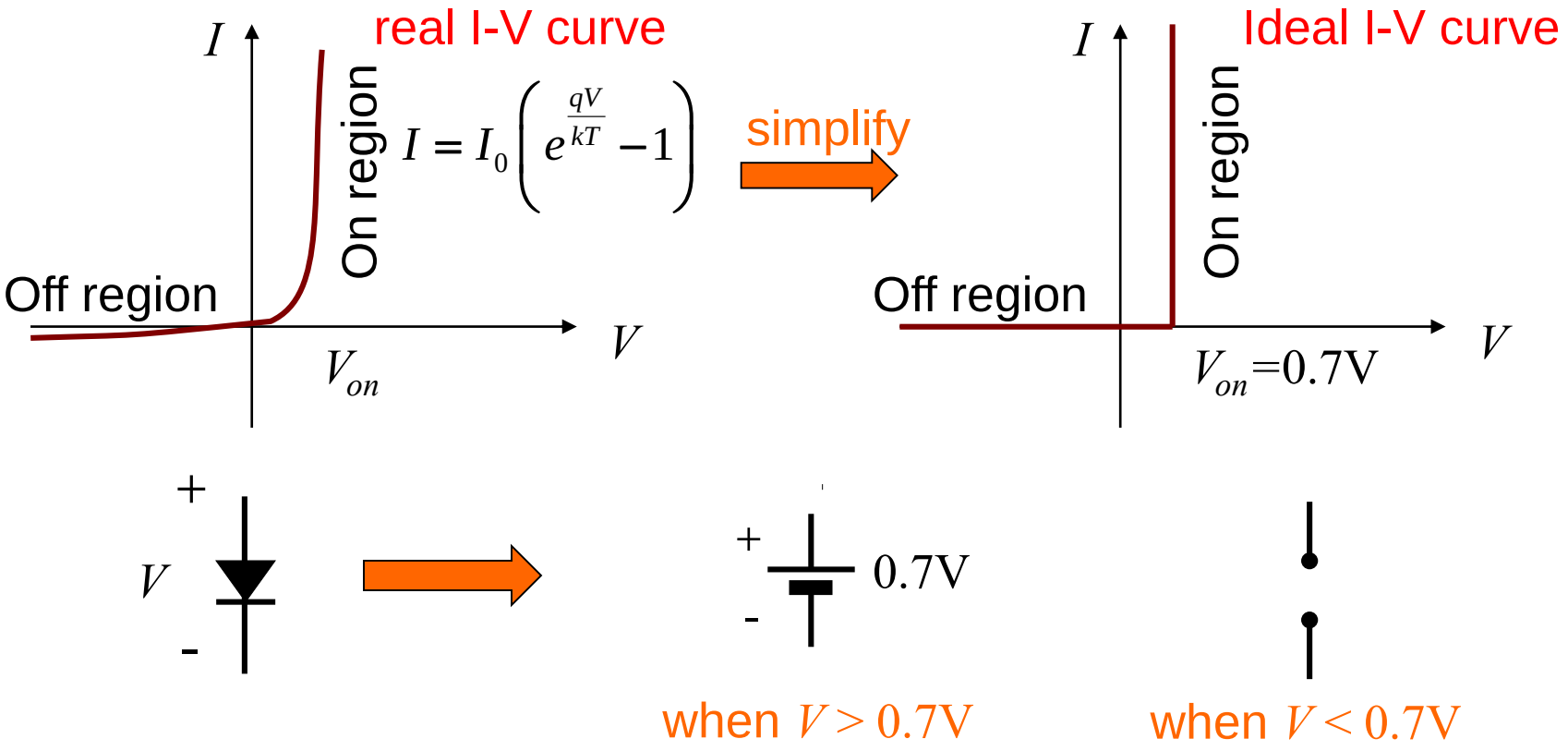
MORE REALISTIC OPERATION OF A BJT

- The B-E terminal of a BJT is actually behaving like a diode
- A base current I_B flows only when the voltage V_{BE} across the base-emitter junction is about 0.7V
- Collector current is proportional to the base current, i.e., $I_C = \beta I_B$ where β is the current gain.
- β is in the range of 20-200, leading to an amplification of current



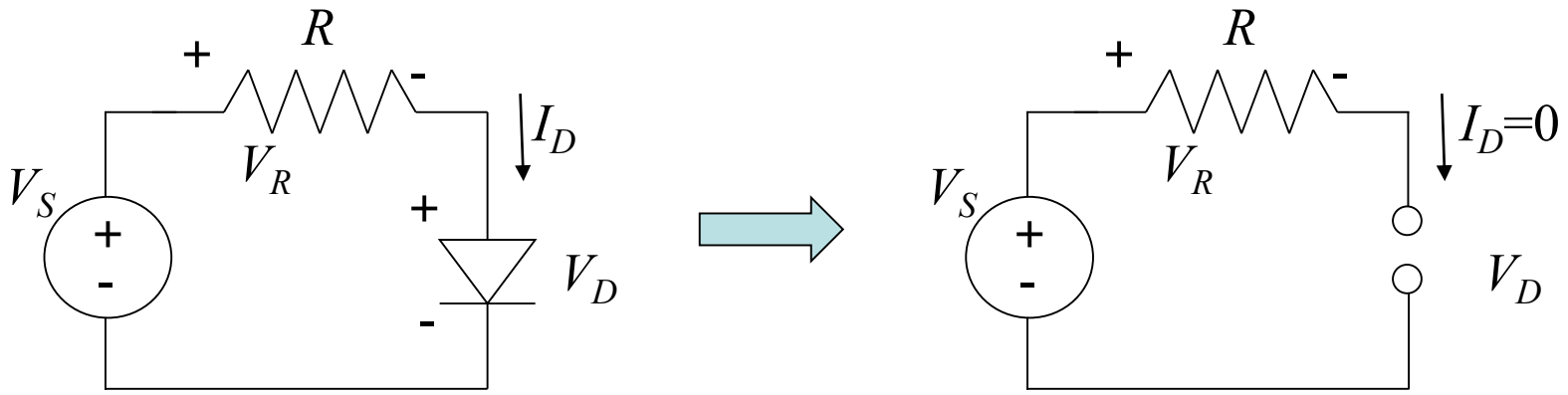
DIODE CIRCUIT ANALYSIS

- To understand transistor operation, one needs to first understand diode circuits



EXAMPLE OF DIODE CIRCUITS

- Assume off region, replace it with the equivalent model

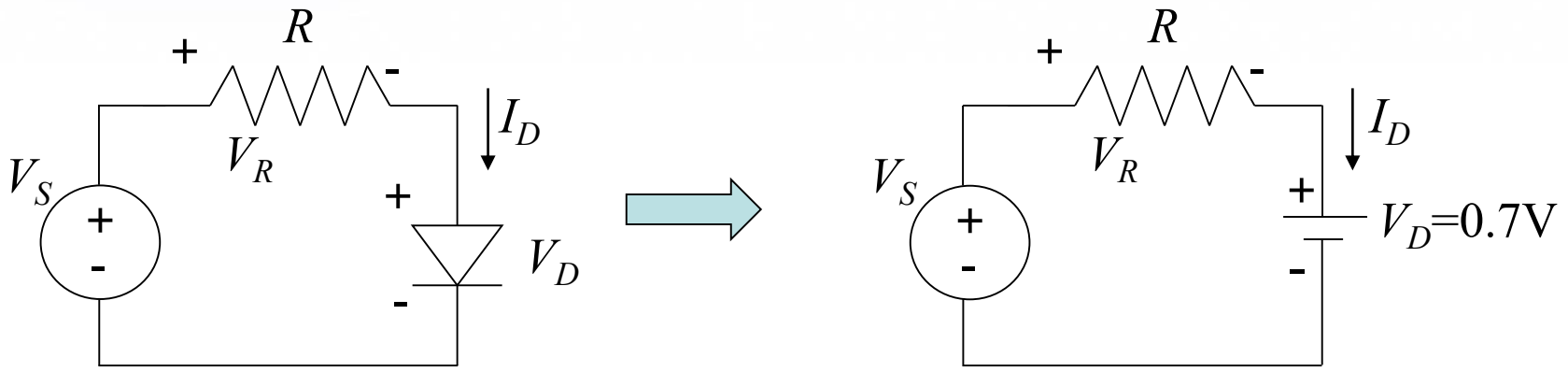


$$I_D = 0 \Rightarrow V_R = 0 \Rightarrow \boxed{V_D = V_S}$$

- If V_S<0.7V, the assumption is correct and answer found
- Otherwise, assumption is wrong and we try the other case

CURRENT THROUGH THE DIODE

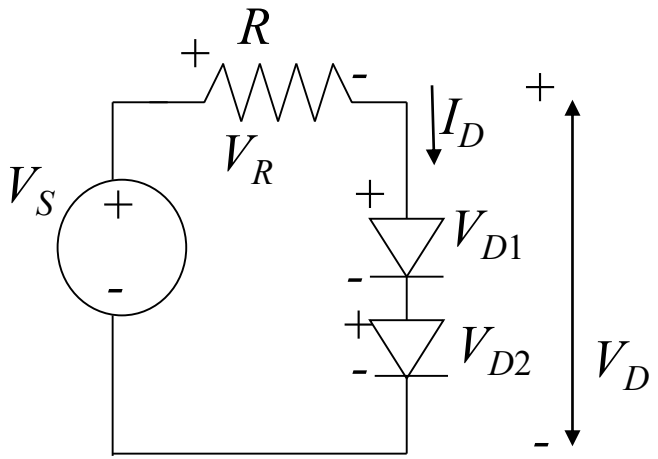
- When $V_S > 0.7\text{V}$

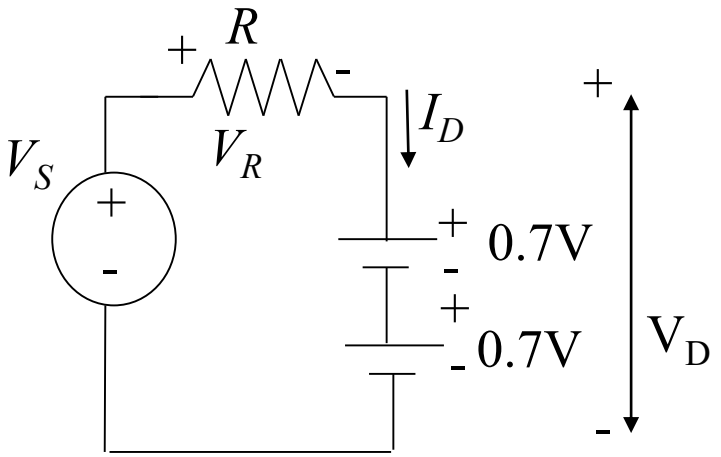


- We can obtain $V_S - 0.7 = V_R \Rightarrow I_D = \dfrac{V_S - 0.7}{R}$
- If the condition is incorrect (or $V_S < 0.7\text{V}$), $I_D < 0$
- It is important to have a resistance in series with a diode, or the current can be very large

CIRCUIT WITH TWO DIODES

- Circuit with two diodes can be solved in the same approach



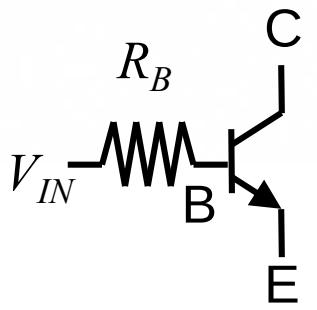


- It is simple and leave it to you as an exercise

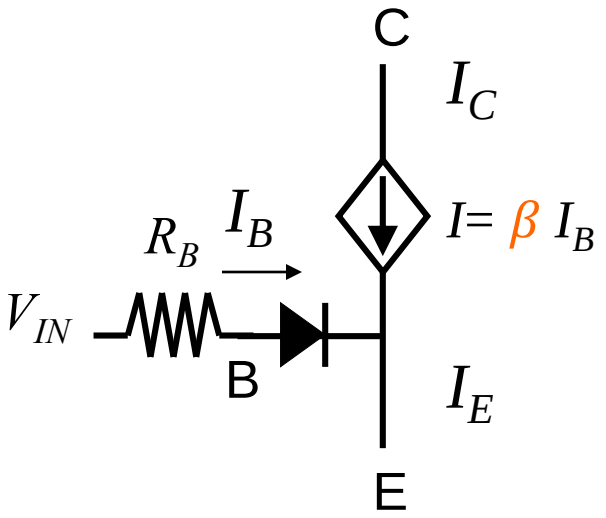
BACK TO TRANSISTOR

- A resistor is always needed at the base to avoid a very high current

$$I_B = \frac{V_{IN} - 0.7}{R_B}$$



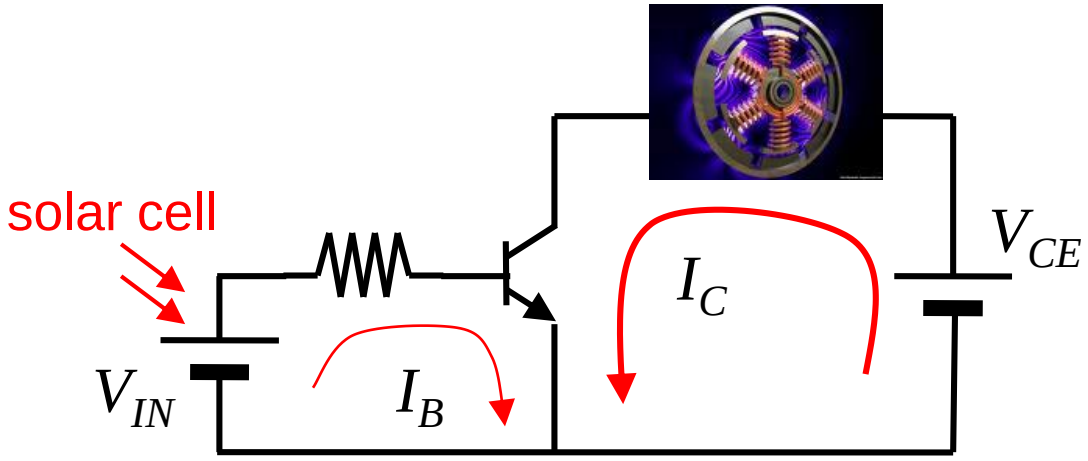
  - I_B=0, transistor is off
  - I_B small: active mode with transistor partially on
  - I_B large: transistor fully on



- As long as the input voltage V_{IN} is larger than 0.7V, you can consider the transistor is on (either partially or fully)

CIRCUIT EXAMPLE: LIGHT ACTIVATED SWITCH

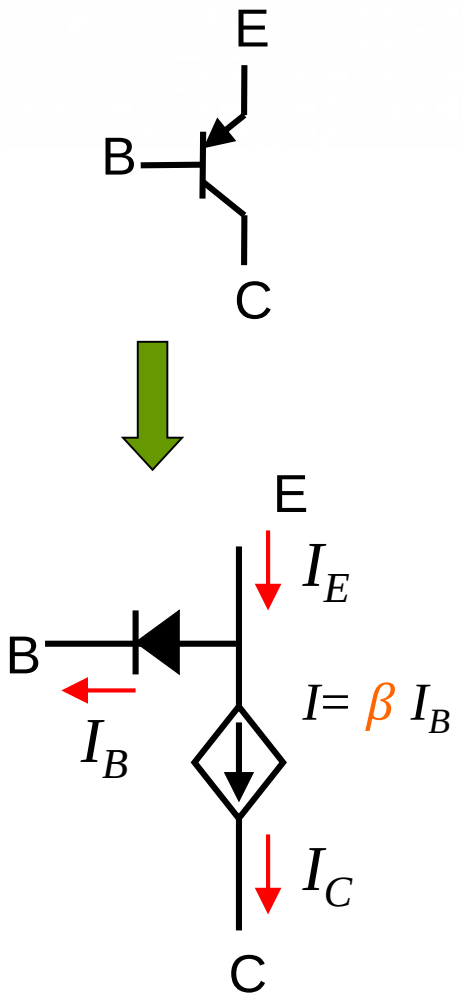
- Consider a circuit to turn on a fan under strong light
- You may simply connect the fan to a solar cell, but the solar cell is not powerful enough to drive the motor
- Consider using a solar cell to give the V_{BE} of a NPN transistor



- Can use a small power to control the delivery of a large power
- A transistor can be used as an “amplifier”

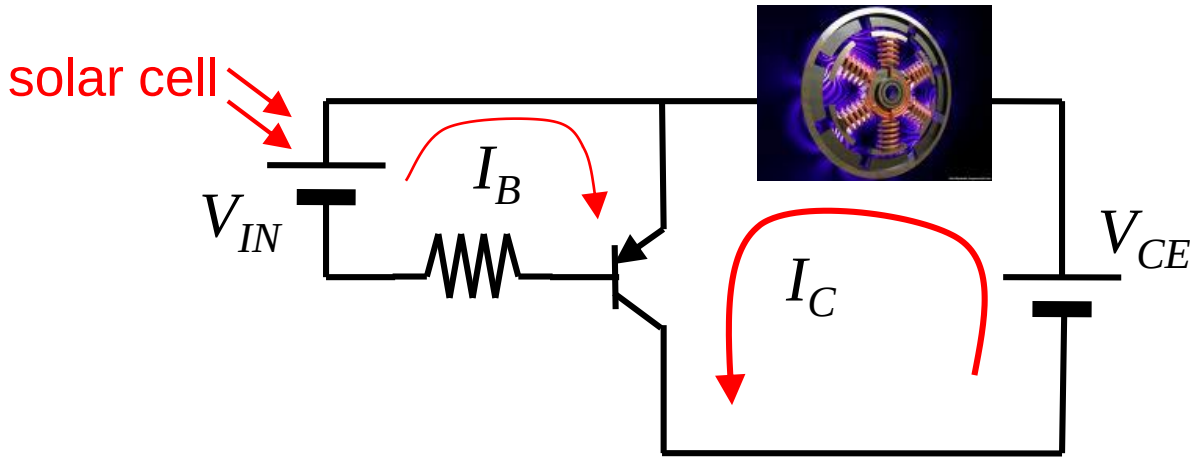
PNP TRANSISTOR

- PNP transistor is similar to NPN, but the diode is between the power supply and the input
- As long as $V_{BE} < -0.7\text{V}$, you may consider the transistor to be on
- Allow a switch to be turned on with low voltage



CIRCUIT EXAMPLE WITH PNP TRANSISTORS

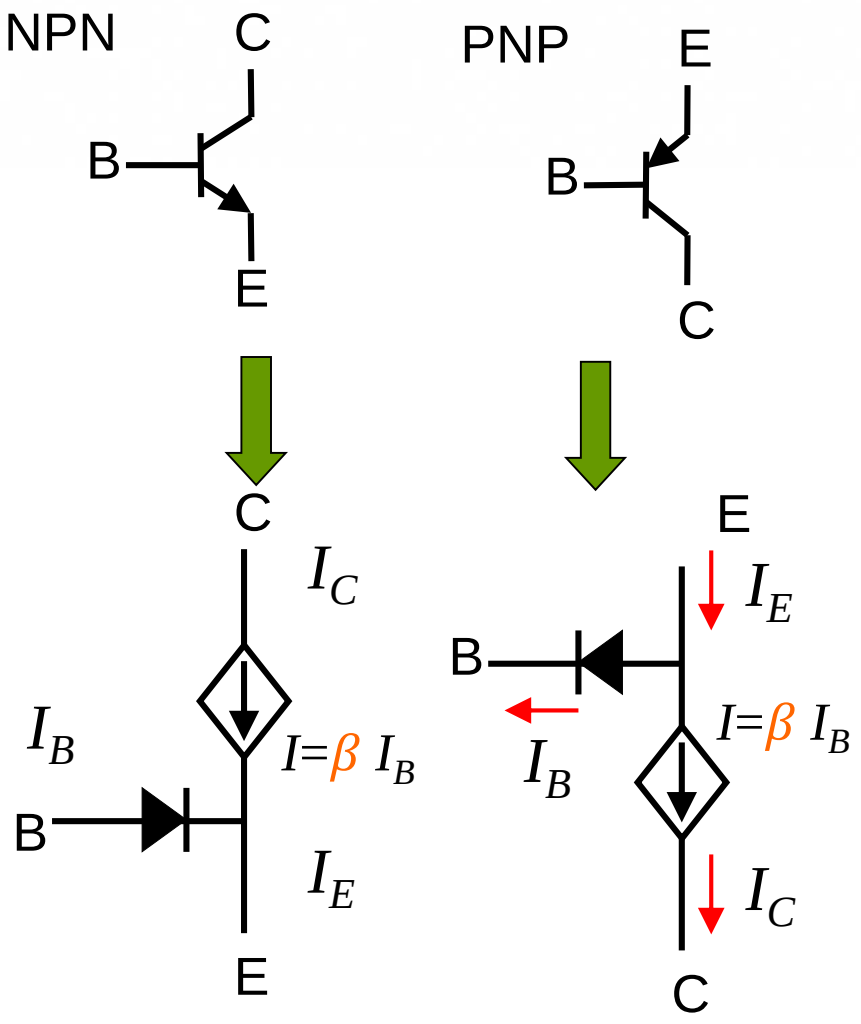
- For the same circuit to turn on a fan under strong light using PNP transistor looks like the following:



- The performance is exactly the same as the NPN case

LECTURE SUMMARY

- NPN and PNP transistors and their equivalent circuits
- Calculating diode current by assuming it is either a battery or an open circuit
- Transistors can be used as a switch or an amplifier



NEXT LECTURE

- Transistors as motor control switches
- H-bridge circuit
- Transistor as an amplifier

QUESTIONS?