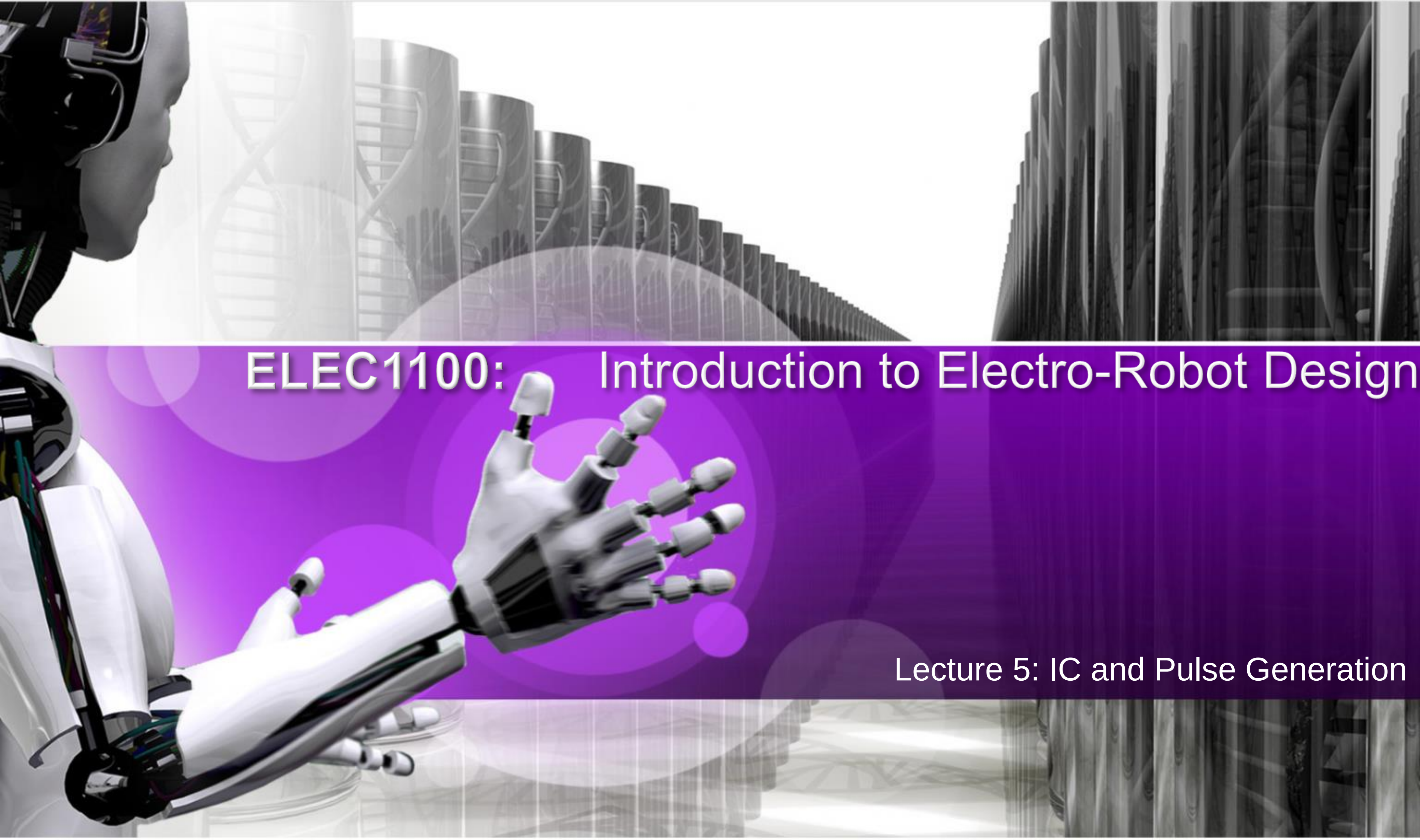
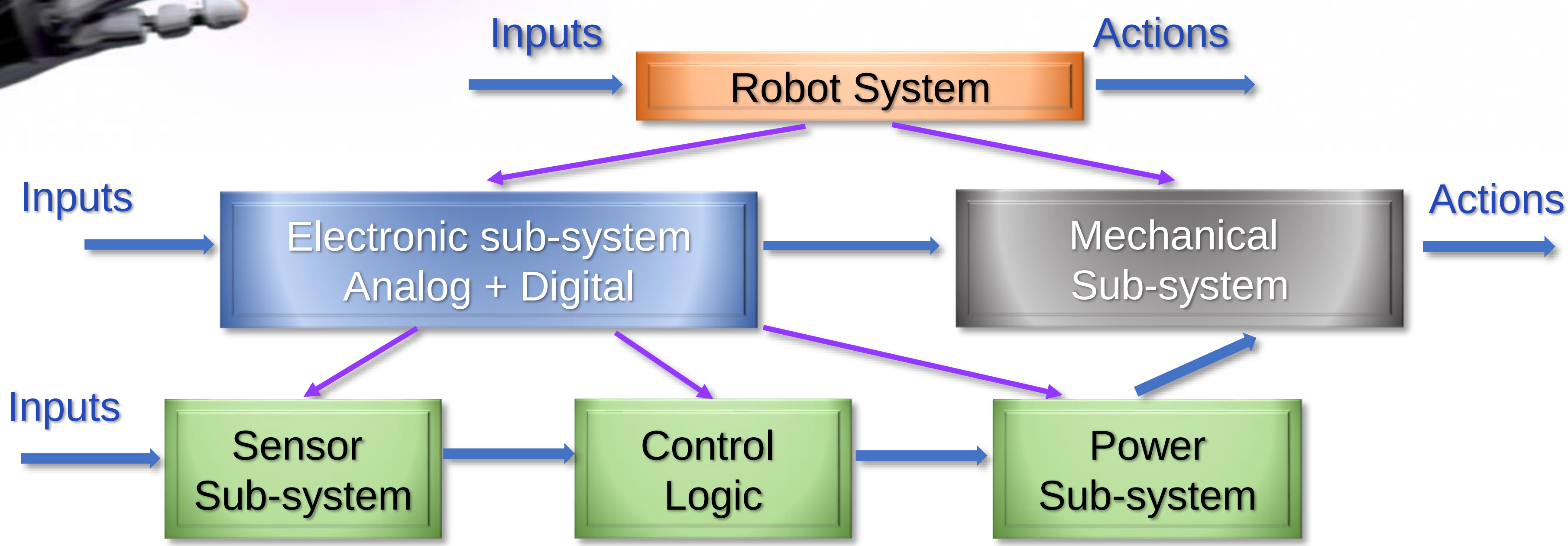


ELEC1100: Introduction to Electro-Robot Design

Lecture 5: IC and Pulse Generation

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

ELEC1100 ROADMAP



Basic electronics:

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

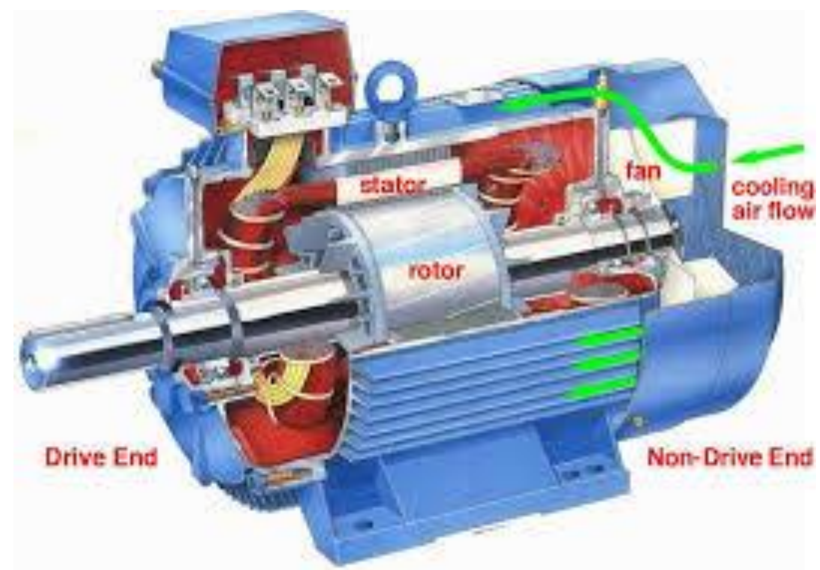
Wk2: Energy/Power and DC Sources

Motor Power Supply:

Wk3: Pulse Signal and PWM Control

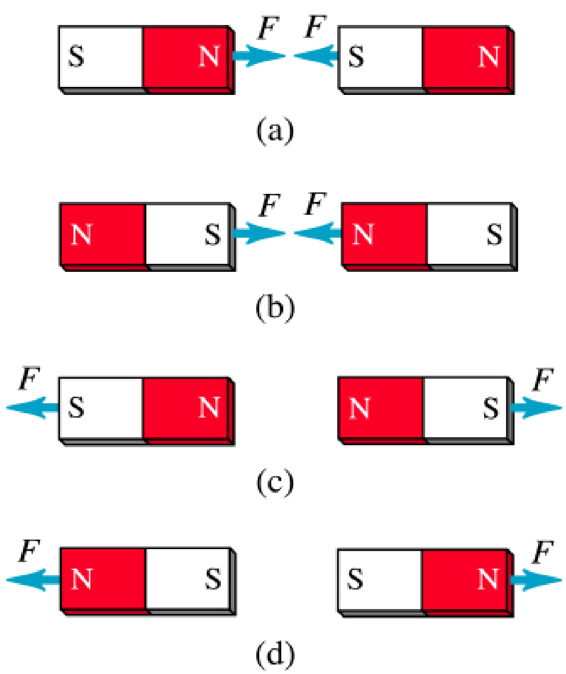
WHAT ARE MOTORS?

- ❖ A motor is an electric-mechanical device, converting electricity to mechanical motion
- ❖ A revised energy conversion leads to a generator



MAGNETIC BASICS

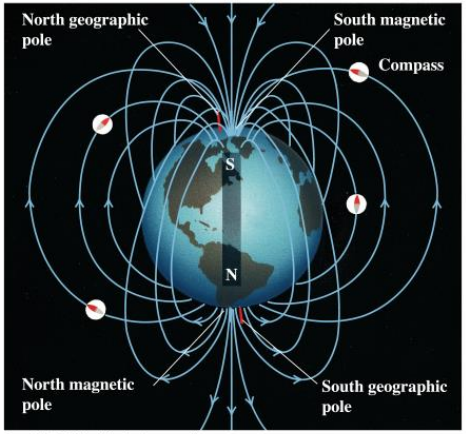
- ❖ A magnet has two poles: south and north
- ❖ Like poles repel, and opposite poles attract

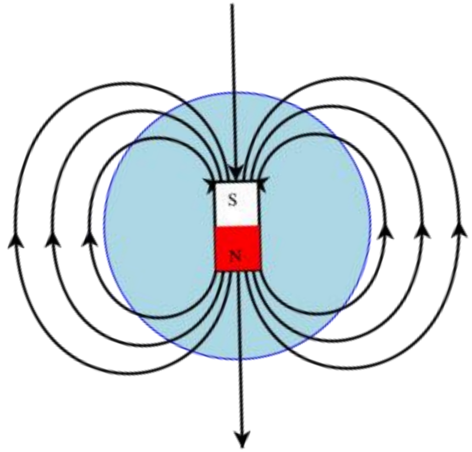


Magnetic poles always come in pairs

Magnetic monopoles are predicted to exists but with no experimental evidence yet

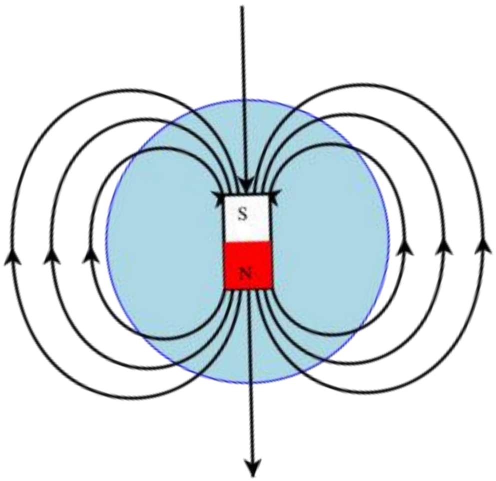
The Earth's magnetic field appears to come from a giant bar magnet, but with its south pole located up near the Earth's north pole

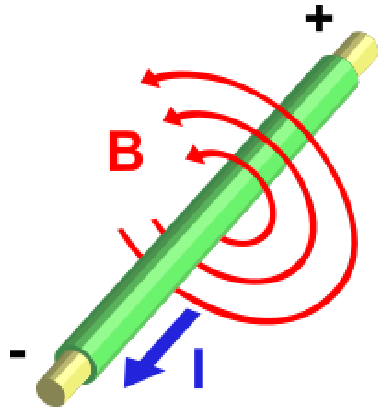


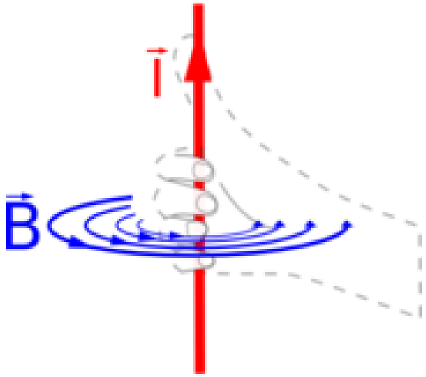


CURRENT AND MAGNETIC FIELD

- A magnet produces a magnetic field from N to S
- A current flow through a wire also creates or "induces" a magnetic field (denoted by B)
- Direction of a B-field can be found by the right-hand-rule



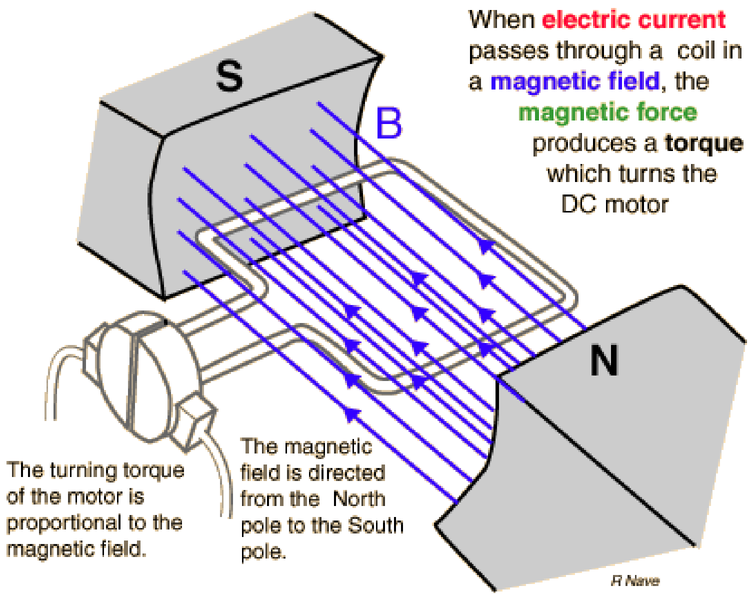


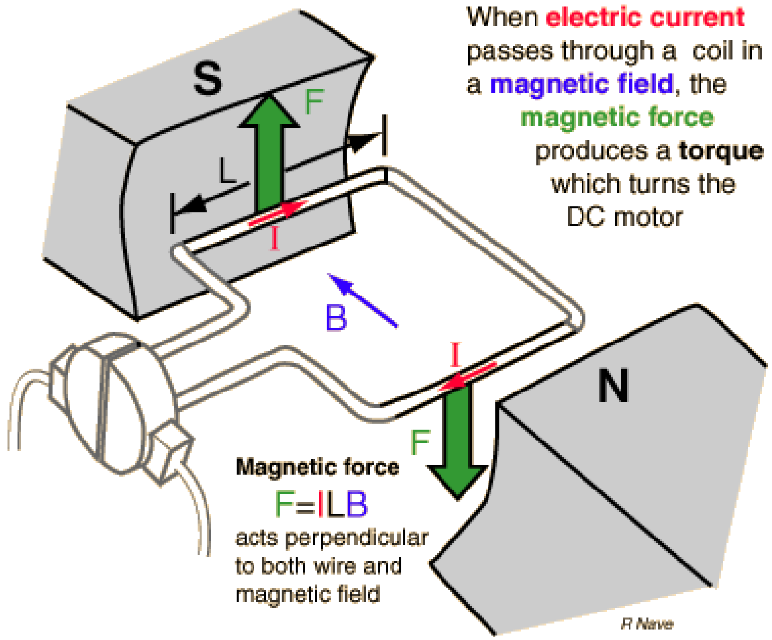


Right-Hand-Rule

ELECTRO-MAGNET INTERACTION

❖ When a wire carrying an electric current (I) is placed in a magnetic field (B), the wire will experience the Lorentz force



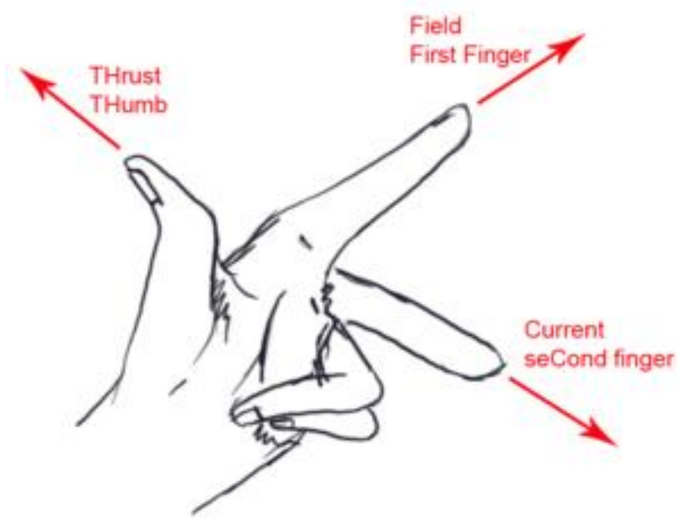


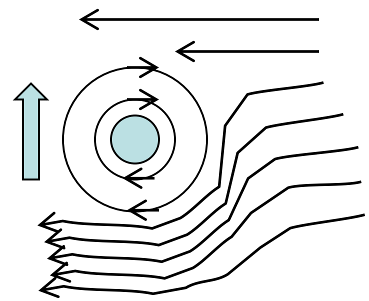
MAGNETIC FORCE TO A CURRENT CARRYING WIRE

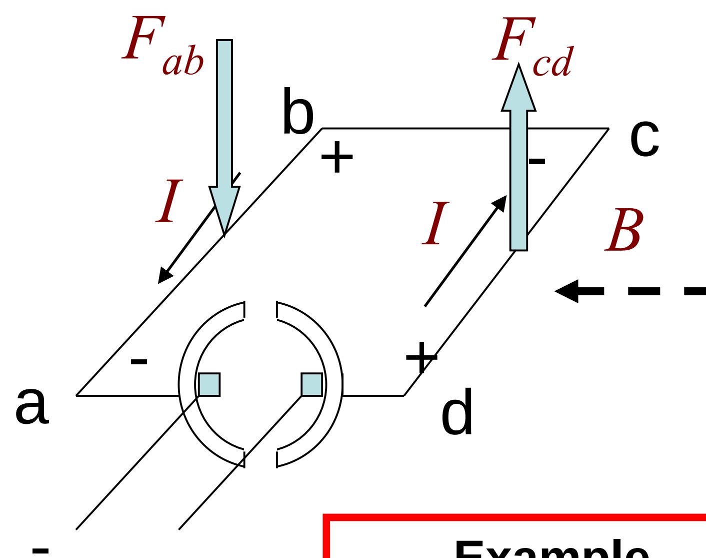
- Formula of the magnetic force on a current-carrying wire :

  $F = ILB$ (B : magnetic field L : wire Length I : current)

- Direction of the force can be determined by the Fleming's Left-Hand-Rule



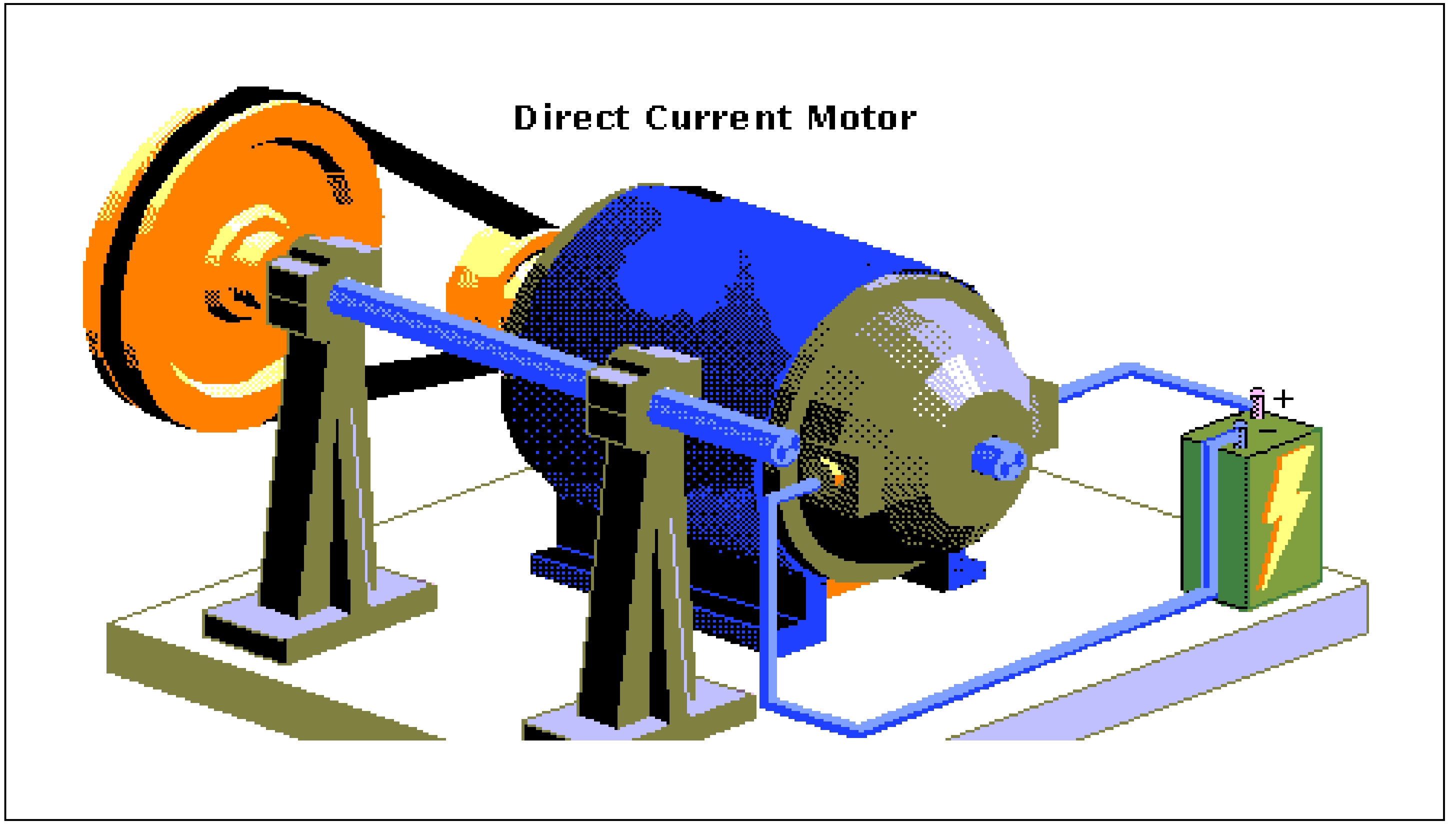




Example

ELECTRIC MOTOR

- An electric motor uses electrical energy to produce mechanical energy



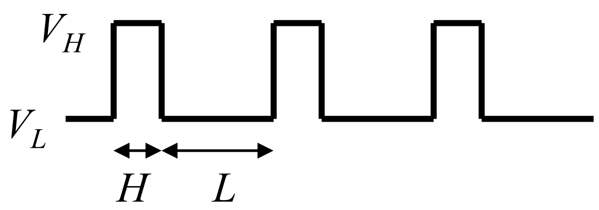
ELECTRIC MOTOR

- Electric motor consists of two parts
  - Stator: composed of two permanent magnet poles
  - Rotor: composed of windings which are connected to a mechanical commutator

- Types of electric motors
  - Brushed DC motor
  - Brushless DC motor
  - Stepper DC motor
  - Micro motor
  - …

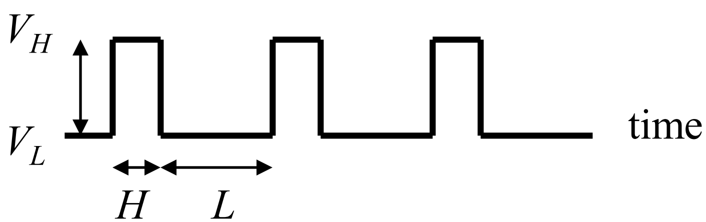
PULSE GENERATION

- Mobile robots usually have DC voltage as power source
- Pulse voltage signal also has many applications that will be described in later lectures
- Can we generate pulses with desired timing out of a DC power supply?



PULSE CHARACTERISTICS

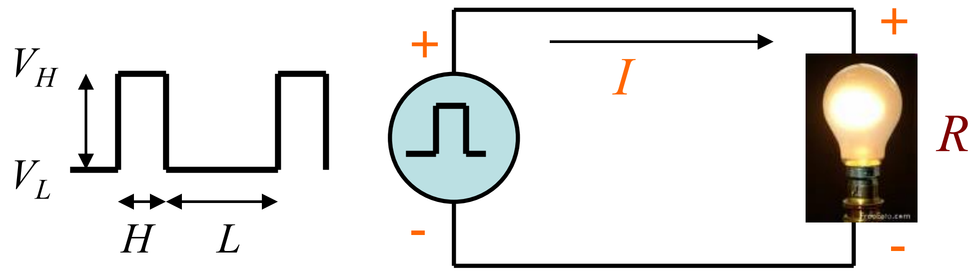
- Definition of terms
  - A continuous well defined train of pulses sometimes also called a clock
  - Clock high time = H
  - Clock low time = L
  - Clock period = $T = H + L$
  - Frequency = $1/T$
  - Duty cycle = H/T
  - Pulse height = $V_H - V_L$



AVERAGE VOLTAGE

- If you use a pulse to drive a load, what is the result?
- Average voltage

$$V_{ave} = \frac{H}{H+L}V_H + \frac{L}{H+L}V_L$$



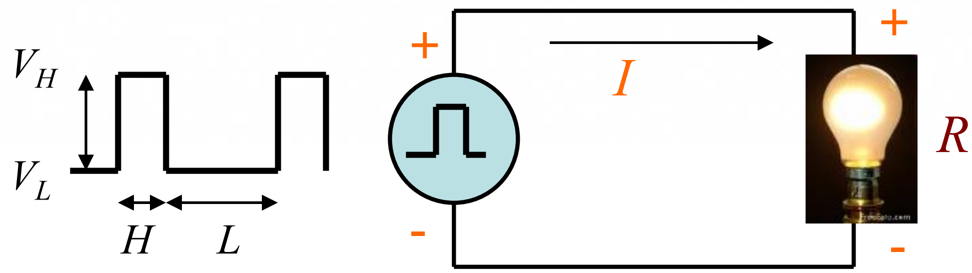
  - If $V_L = 0$, we have $V_{ave} = \frac{H}{H+L}V_H$

- Is the brightness of the light equal to the circuit with the pulse voltage replaced by a battery with $V = V_{ave}$?

AVERAGE POWER AND EQUIVALENT VOLTAGE

- Average Power

$$P_{ave} = \frac{H}{H+L}\frac{V_H^2}{R} + \frac{L}{H+L}\frac{V_L^2}{R}$$



- If the pulse voltage source is replaced by an equivalent DC voltage source with $V = V_{eq}$, we have:

$$P_{ave} = \frac{V_{eq}^2}{R}$$

- Equating the average power, we have

$$\frac{V_{eq}^2}{R} = \frac{H}{H+L}\frac{V_H^2}{R} + \frac{L}{H+L}\frac{V_L^2}{R} \Rightarrow V_{eq} = \sqrt{\frac{H}{H+L}V_H^2 + \frac{L}{H+L}V_L^2}$$

or if $V_L = 0$

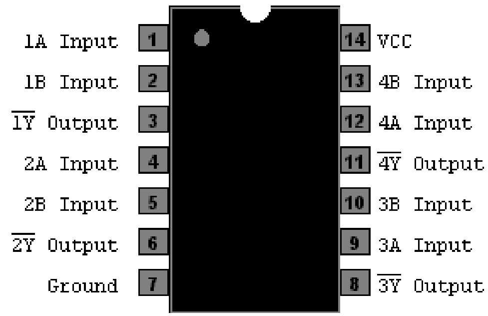
$$V_{eq} = \sqrt{\frac{H}{H+L}}V_H$$

INTEGRATED CIRCUIT

- To generate pulses, you need to use a new component called Integrated Circuit (IC).
- ICs can be made very compact in a fingernail size chip, having up to several billion transistors and other electronic components such as capacitors, resistors, diodes and etc.
- The particular IC you will use is NE555.
- The characteristics of an IC is given by the datasheet provided by the manufacturer.
- You will learn more ICs in future.

IC CONNECTION

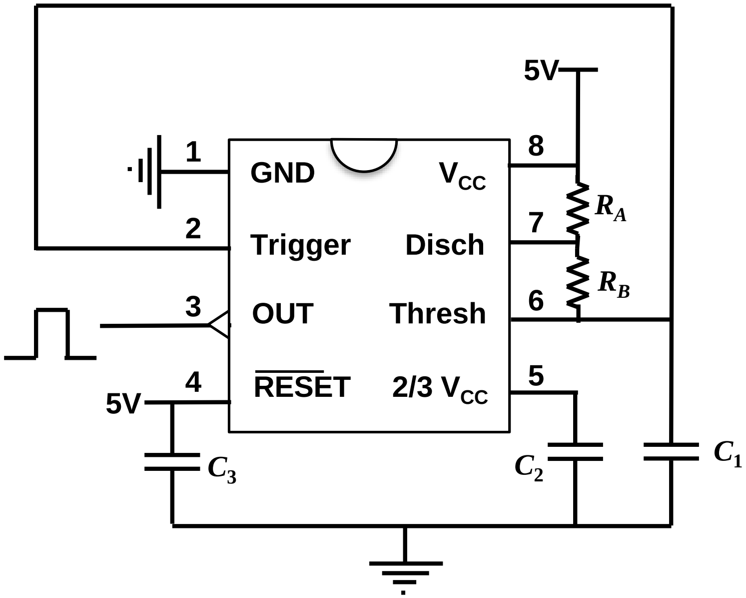
- Each IC has a U-shape mark or a circle to indicate its top



- After you identify the top of an IC, the pins are labeled starting with 1 from the top left corner going downward, then from the bottom right corner going upward

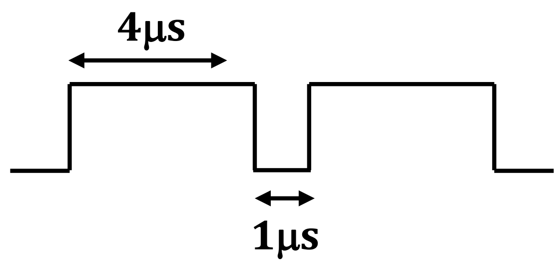
CONSTRUCTING AN NE555 CIRCUIT

- NE555 application schematic
- Based on the datasheet, we have
  - Clock high time = $0.7(R_A+R_B)C_1$
  - Clock low time = $0.7R_BC_1$
  - Clock period = $0.7(R_A+2R_B)C_1$
  - Frequency = $1/[0.7(R_A+2R_B)C_1]$
  - Duty cycle = $(R_A+R_B)/(R_A+2R_B)$



EXERCISE: PULSE SIGNAL

❖ You are given a pulse below.

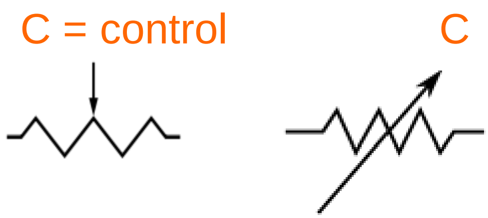


What is the value of its frequency?

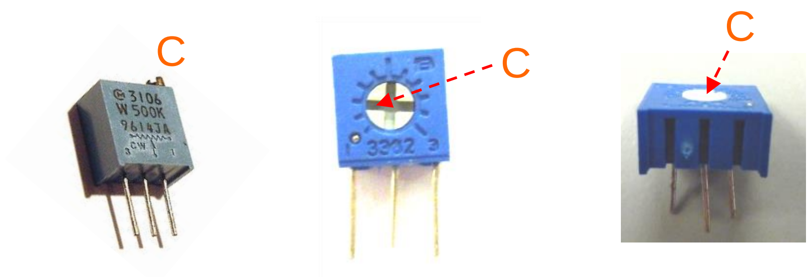
frequency = 1/**5**μs = 200kHZ

RESISTOR TUNING

- Sometimes we want to adjust the value of a resistor to achieve certain power deliver
- A variable resistor can be used



Symbol

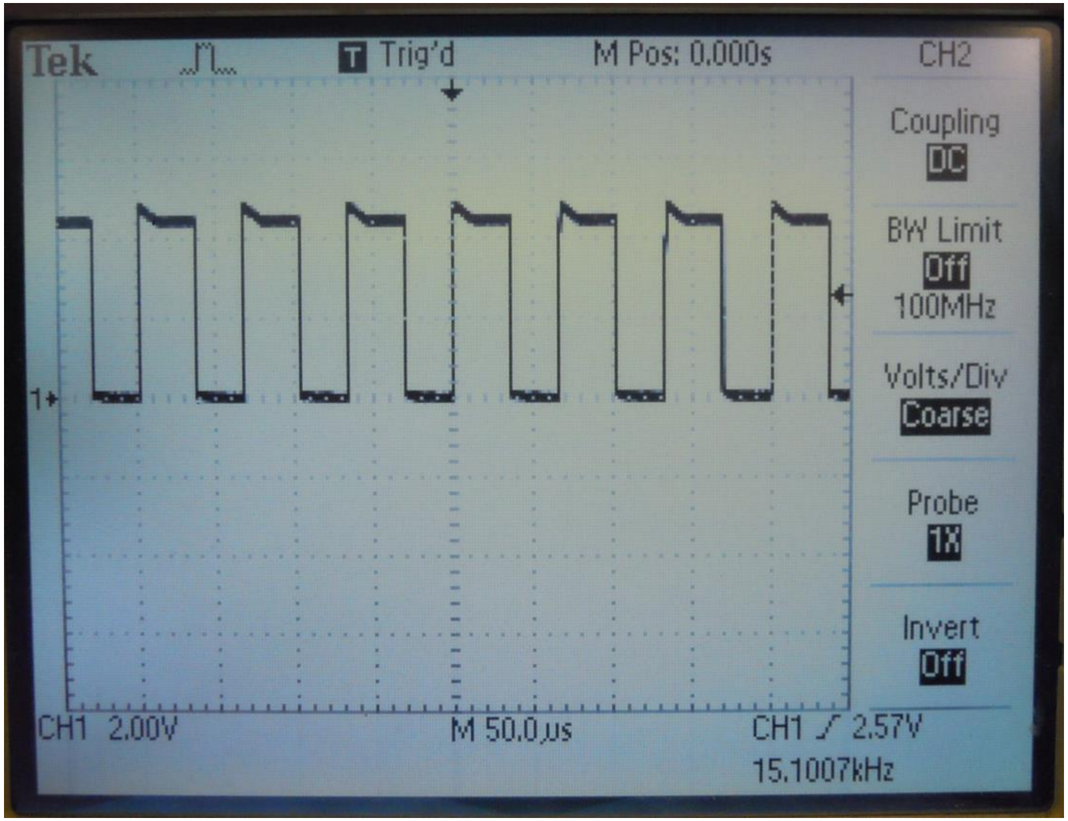


Real Object

- You will be using one of these in Lab#03

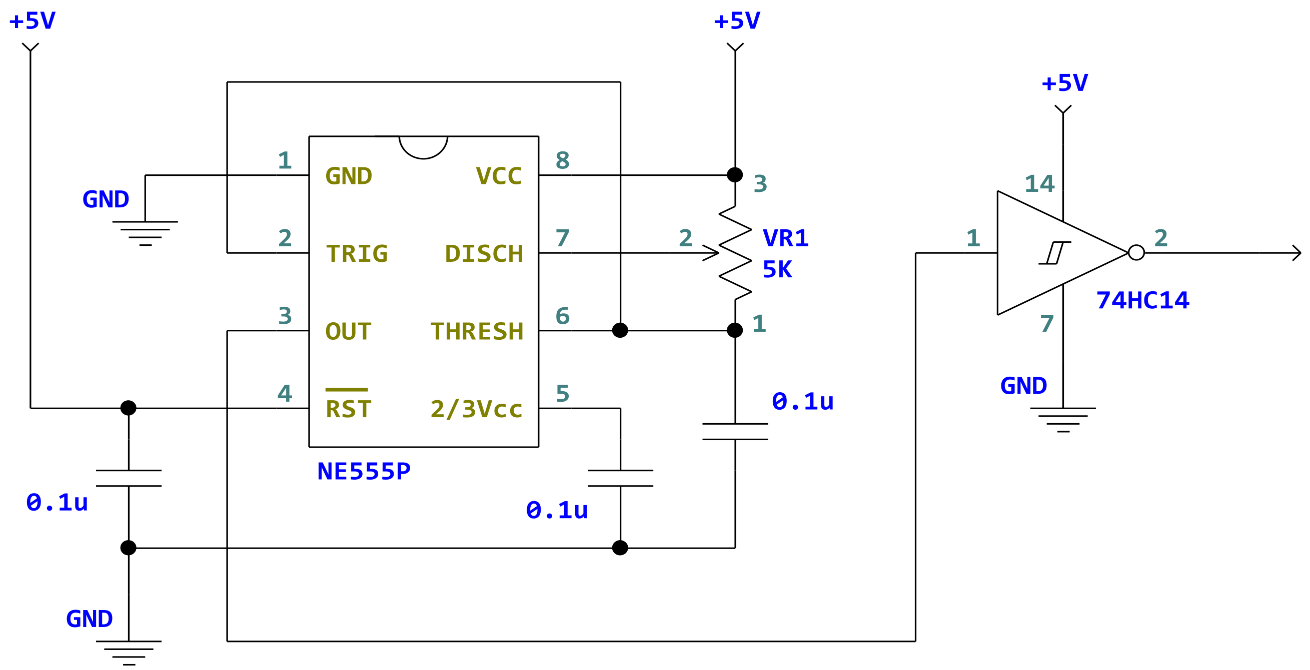
WAVEFORM RECTIFICATION

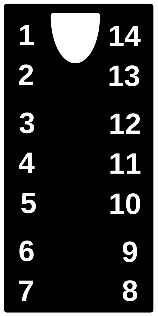
❖ Unfortunately, the output of the pulse signal from NE555 is not always perfect.



SCHMITT TRIGGER [1]

- We can use Schmitt Trigger (74HC14) to rectify the waveform

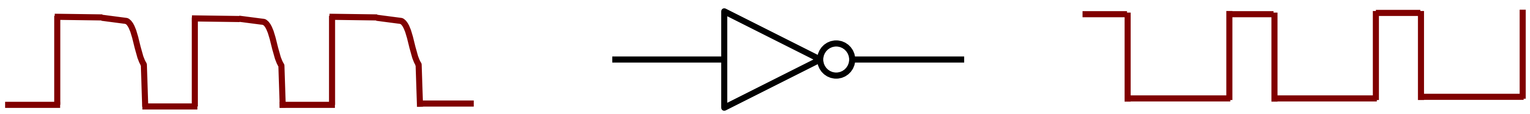


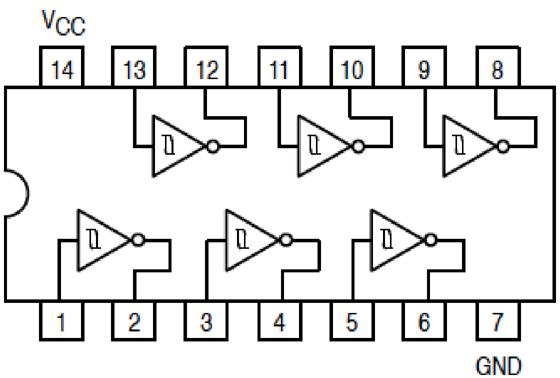


74HC14

SCHMITT TRIGGER [2]

❖ The output of 555 timer is re-shaped by the Schmitt Trigger (74HC14)

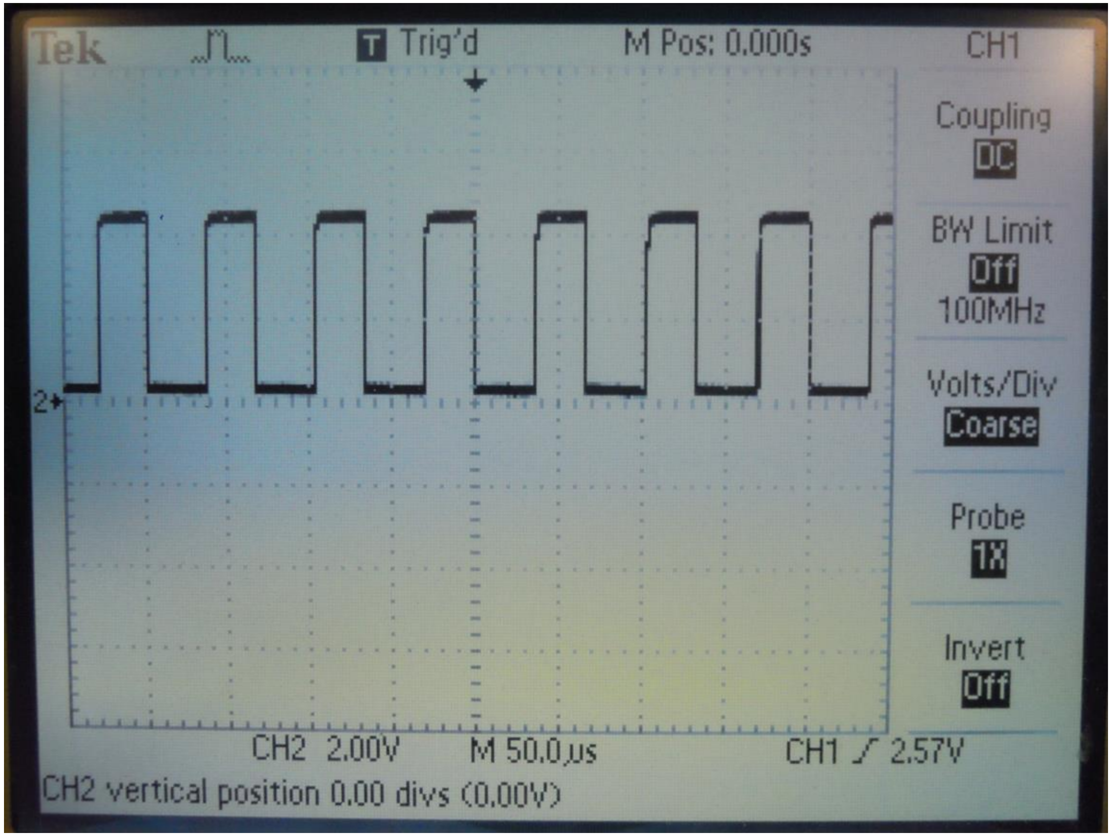




- The output is inverted
- There are 6 Schmitt Triggers and you only need to use one
- Even not shown, the V_{CC} (positive supply) and GND has to be connected to power for proper function

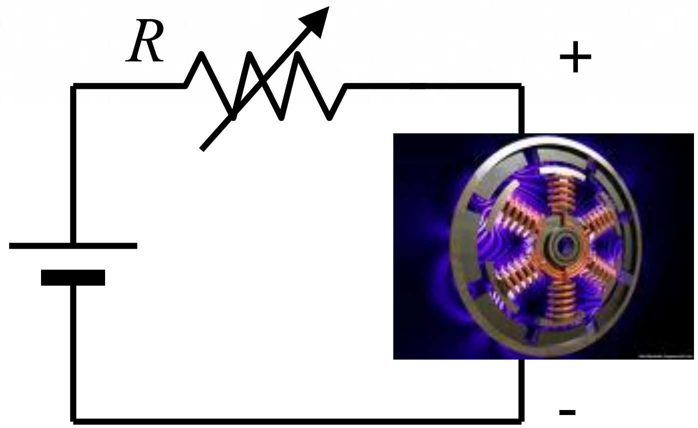
SCHMITT TRIGGER [3]

- After going through the Schmitt trigger, the waveform is clean.



GENERIC MOTOR SPEED CONTROL

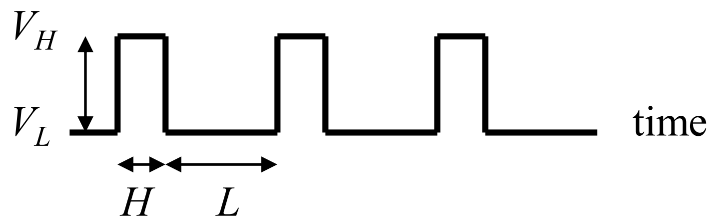
- Higher voltage leads to larger current, higher power and faster rotation
- Different voltages can be obtained by using a variable resistor



- Disadvantages:
  - It is difficult to control the speed precisely
  - Need mechanical motion to tune the resistor and not computer friendly

LECTURE SUMMARY

- Motor Basic
- IC
- Pulse signal characteristics



NEXT LECTURE

- Pulse Width Modulation (PWM)

QUESTIONS?