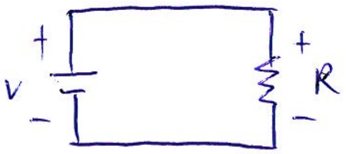
L5: Motor Basics & Pulse Signal

Review: By far, we have learned how to provide energy to a device and do power control.



$$P = \frac{V^2}{R}$$

Next, we look at how to drive a moter.

Battery ⟶ Circuit ⟶ Motor

Battery ↓ Chemical Energy

Circuit ↓ Electrical Energy

Motor ↓ Mechanical.

1. Motor Basics

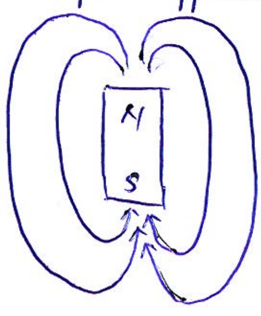
The "relationship" between electrical field & Magnetic field.

1) Magnetic Field

a. Two Poles: S/N

b. Like poles repel & opposite attract

c.



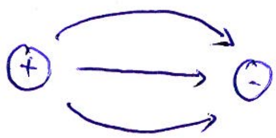
d. Magnetic monopole was "Created" in lab but not yet found in nature.

2) Electric Field

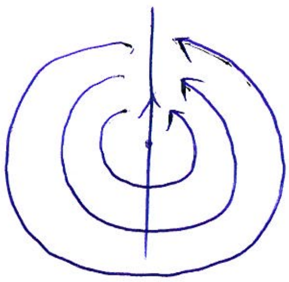
a. Two charges "+"/"−"

b. Like charges repel & opposite attract.

c.



2) Electro-magnet : letting a current go through a wire.



Right-Hand-Rule

3) Electro-magnet interaction.

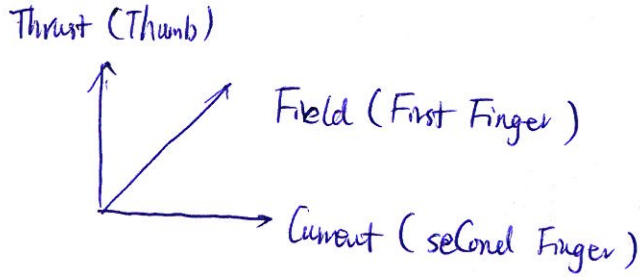
Poles repel/attract } → putting a wire with current in a magnet field ?
Electro-magnet

The wire will experience a force "Lorentz Force"

$F = I L B$ ⟶ Magnet Field.

I ↓ current

L ↘ length of the wire

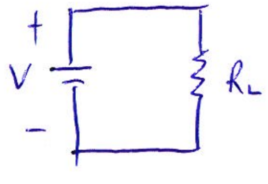


Direction : Left-Hand-Rule.

4) Electric Motor has two parts { Stator : permanent magnet poles
Rotor : windings connected to a mechanical commutator.

5) Types of motors { Brushed DC Motor
Brushless DC "
Stepper DC "
Micro Motor.

2. Power Control : $P_R = V \cdot I = \frac{V^2}{R}$ How to control P_R ?



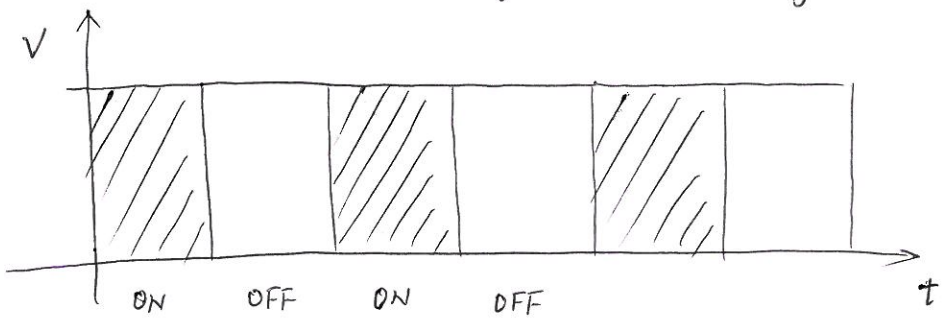
Change V ?
Change R ? Not practical !

1) Can we get any other ideas from our daily life?

Now, think about how we walk or run on the ground.

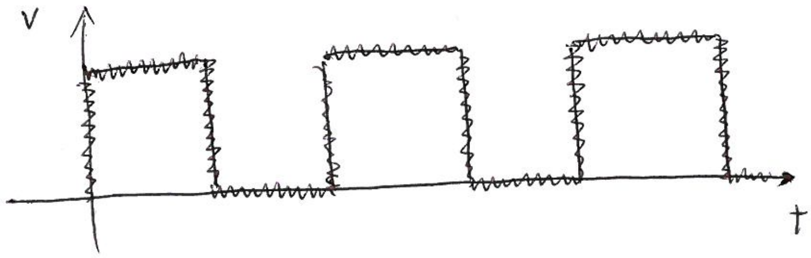
Do we provide "power" to our body continuously? Obviously, not.

Then, consider a DC voltage. If we can't change the voltage value, can we control the time over which we provide the voltage?

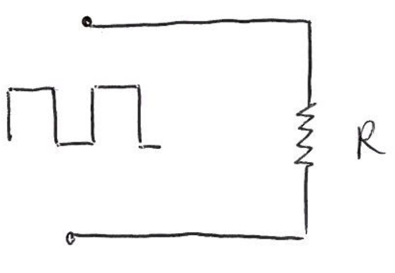


We can control the voltage to be ON/OFF, and then control the power.

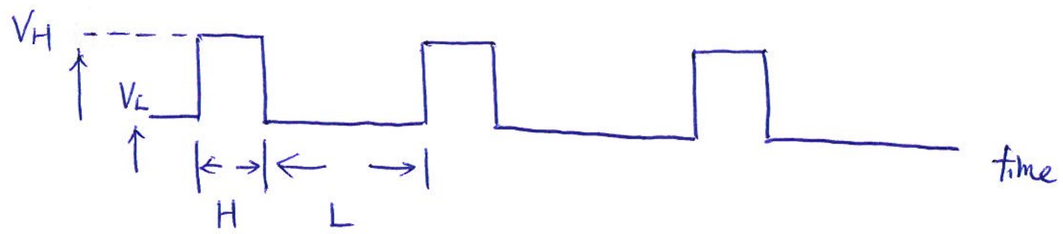
This is what we call a pulse signal.



Then, what is the power provided by a pulse signal to a load?



2) Pulse signal is in the form :



A continuous well defined train of pulses is also called "clock".

"Terms" :

- Clock high time $= H$
- " Low " $= L$
- " period $T = H + L$
- Frequency $f = 1/T$
- Duty Cycle : $= H/T$.
- Pulse Height $= V_H - V_L$

※ Average voltage of a pulse signal :

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

For the case $V_L = 0$, $V_{ave} = \frac{H}{H+L} V_H$.

※ Then, is the power provided by a pulse signal equal to that provided by a DC source with voltage V_{ave} ?

Let's first determine the average power.

$$P_{ave} = \frac{\text{Energy in clock high} + \text{Energy in clock low}}{H + L}$$

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

$$= \frac{H}{H+L} \cdot \frac{V_H^2}{R} + \frac{L}{H+L} \frac{V_L^2}{R} \qquad (1)$$

What is the power provided by V_{ave}?

Not equal.

$$P'_{ave} = \frac{V_{ave}^2}{R} = \frac{(HV_H + LV_L)^2}{R(H+L)^2}$$

In fact, if we want to find an equivalent voltage to provide the same power

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

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

What can we see from equation (1)?

The average power is governed by V_H, V_L and also <u>H and L</u> !!

Normally, adjusting H & L is much easier than adjusting V_H, V_L, especially for digital circuit !!

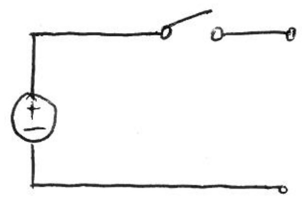
In your project, you will adjust H & L to adjust the power provided to the motor !

Consider the special case with $V_L = 0$. We can get

$$P_{ave} = \frac{H}{H+L} \frac{V_H^2}{R} = \frac{H}{T} \cdot \frac{V^2}{R}$$ where $\frac{H}{T}$ is the duty cycle.

3. Pulse generation

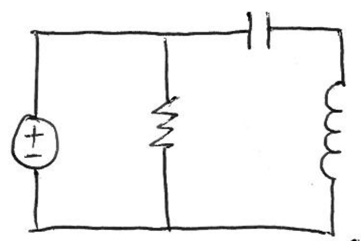
Method 1 : Switch



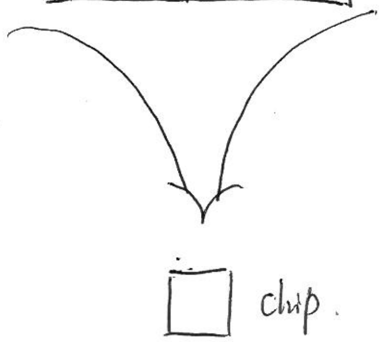
OK, but mechnical way.

Method 2 : Digital method by using IC.

1) Discrete circuit



2) Integrated Circuit



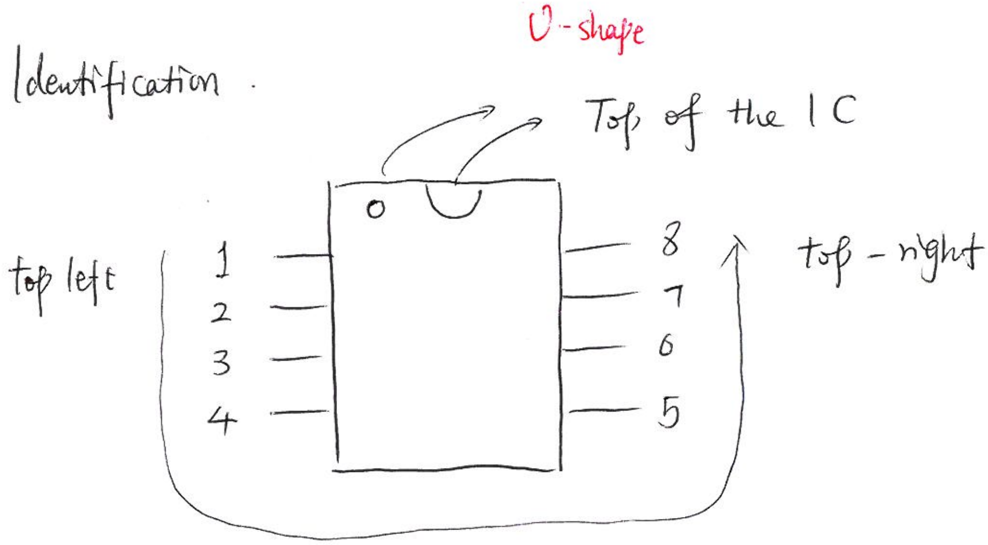
chip.

3) Pulse generation

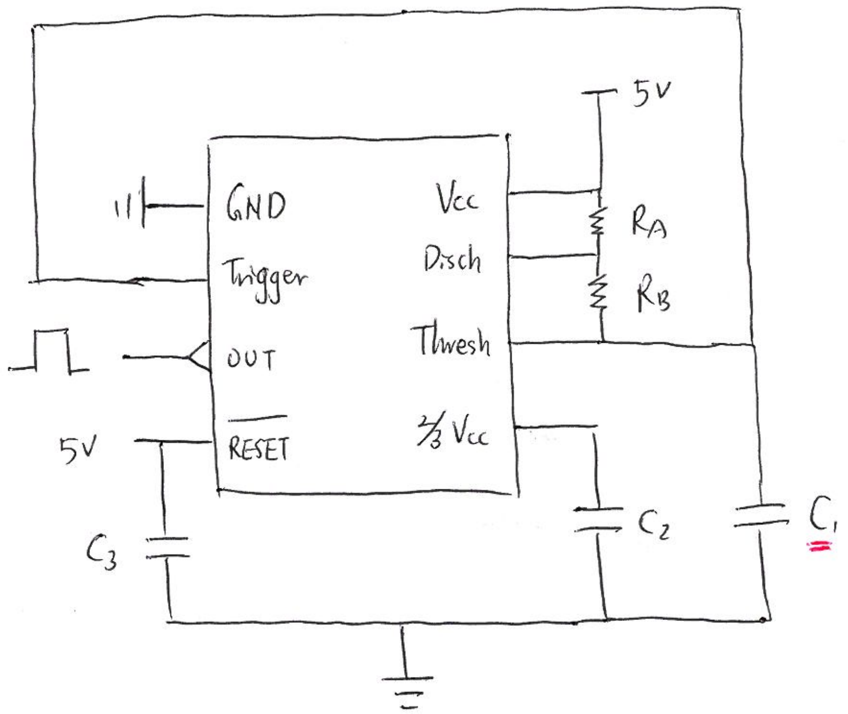
NE555.

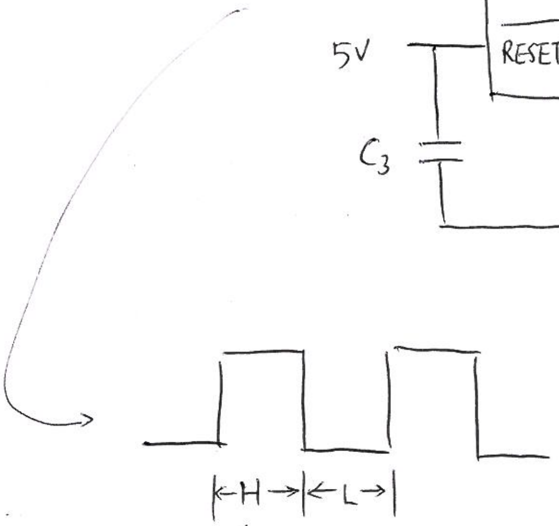
IC Pin Identification.

NE555



Connection :





$H = 0.7\,(R_A + R_B)\,C_1$

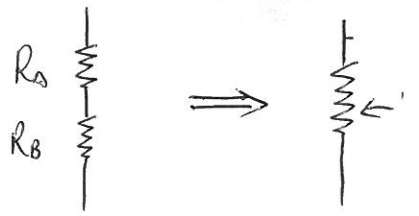
$L = 0.7\,R_B\,C_1$

$T = H + L = 0.7\,(R_A + 2R_B)\,C_1$

$f = 1/T$

$$H/T = \frac{R_A + R_B}{R_A + 2R_B}$$

How can we change the duty-cycle ?



Variable resistor.

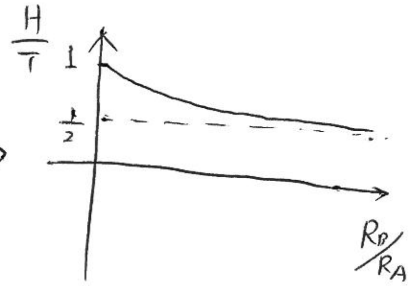
Can we get any duty-cycle we want ?

$$\frac{H}{T} = \frac{R_A + R_B}{R_A + 2R_B} = \frac{1 + R_B/R_A}{1 + 2\,R_B/R_A}$$

$$\nearrow \quad \frac{R_B}{R_A} = 0 \Rightarrow \frac{H}{T} = \frac{1}{1} = 1$$

$$\searrow \quad \frac{R_B}{R_A} = \infty \Rightarrow \frac{H}{T} = \frac{1}{2}.$$

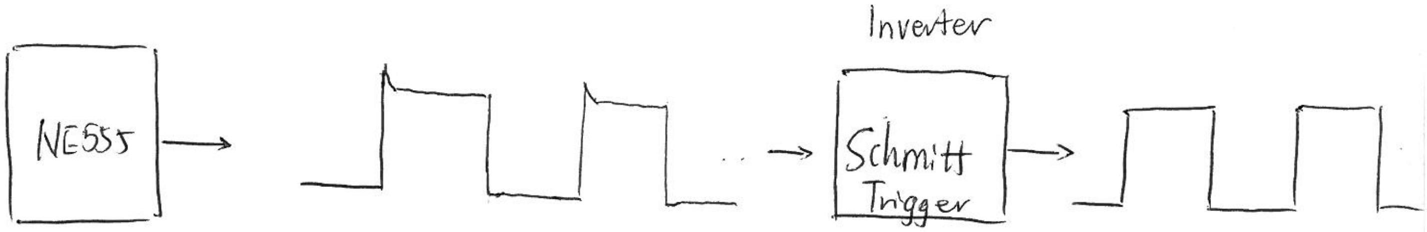
$$f(x) = \frac{1+x}{1+2x} \qquad \frac{df(x)}{dx} = \frac{1+2x-2(1+x)}{(1+2x)^2} = \frac{-1}{(1+2x)^2} \Rightarrow$$



Minimum $\frac{H}{T} = \frac{1}{2}$.

Then, how can we get any duty-cycle we want ? (Later!)

4) Waveform Regeneration



5) Controlling pulse width with R_A, R_B & C_1 still requires mechanical intervation, thus an analog process.

In the next lecture, we will develop a digital method for pulse control.