# Capacitor

Young Won Lim
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Please send corrections (or suggestions) to youngwlim@hotmail.com.

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# Charge

**Before**

**Initial**

**Final**

No more electrons to leave

$V_0$

$V_0$

+ + + + +

– – – – –

crowded electrons prevent
other electrons from arriving

*Energy stored in Electric Field*
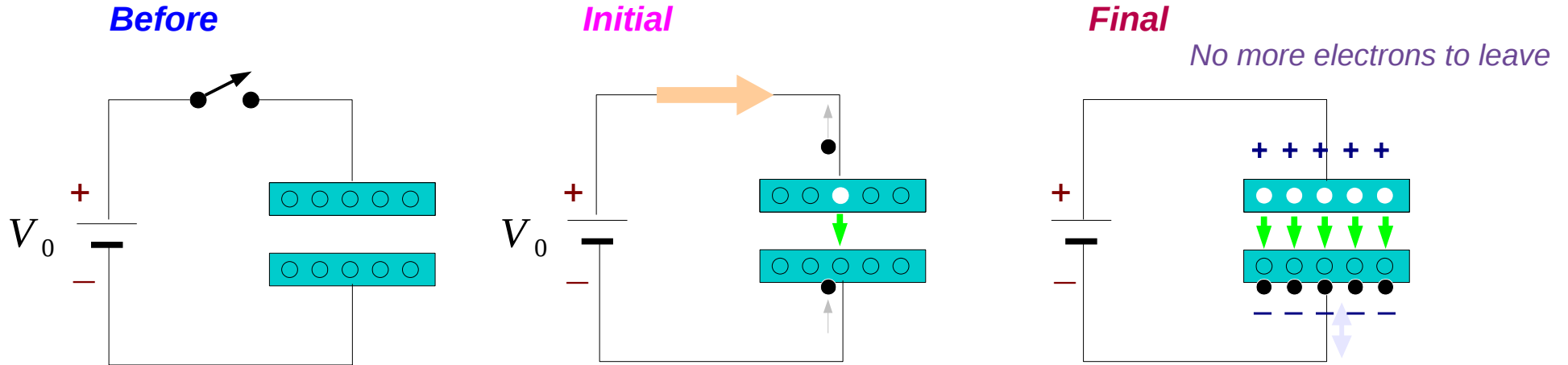
$$i_c = C \cdot \frac{d v_c}{d t}$$

$$v_c(0^-) = v_c(0^+)$$    *unyielding voltage*

$$i_c(0^-) \neq i_c(0^+)$$    *current jump*

$$v_c(\infty) = V_0$$
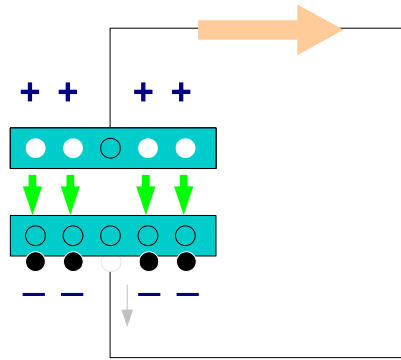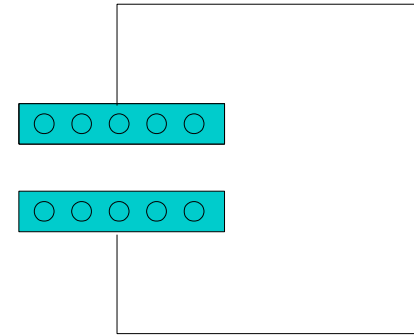
$$i_c(\infty) = 0$$

# Discharge
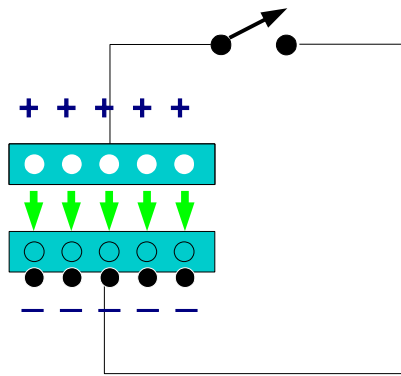
**Initial**

**Final**

No more electrons moving
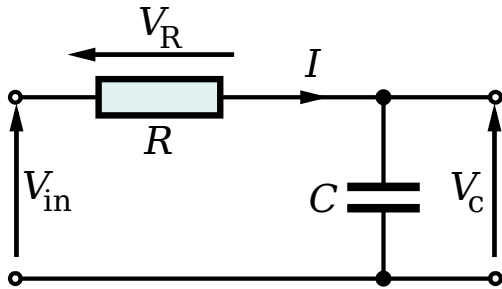
$$i_c = C \cdot \frac{d\,v_c}{d\,t}$$

$v_c(0^-) = v_c(0^+)$     *unyielding voltage*

$v_c(\infty) = 0$

$i_c(0^-) \neq i_c(0^+)$     *current jump*
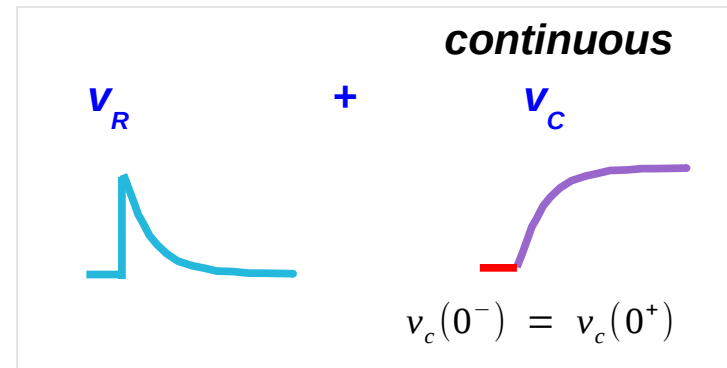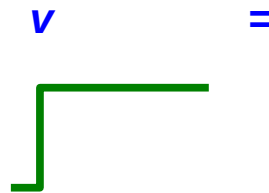
$i_c(\infty) = 0$

# Charge



$$i_c = C \cdot \frac{d v_c}{d t}$$

*unyielding voltage*

*current jump*

$v$ = $v_R$ + **continuous** $v_C$

*the capacitor voltage slowly follows the shape of the applied step input voltage*

$$v_c(0^-) = v_c(0^+)$$

$i$ = $i_R$ = $i_C$ **jump**

*the capacitor current changes abruptly by the applied step input voltage and then slowly becomes zero*

$$i_c(0^-) \neq i_c(0^+)$$

**Capacitor**

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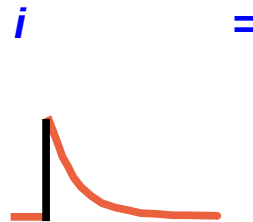06/15/2017
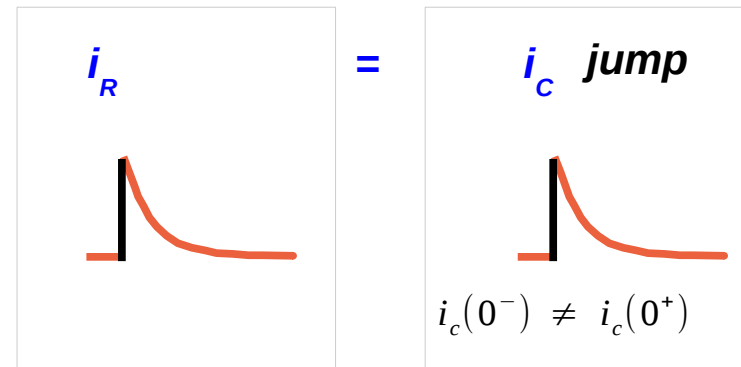
# Discharge



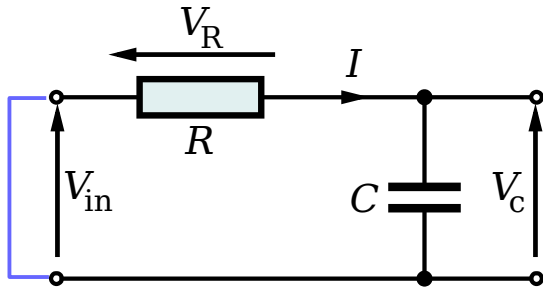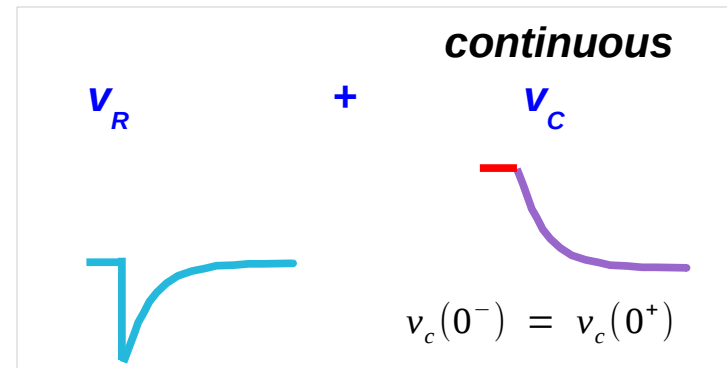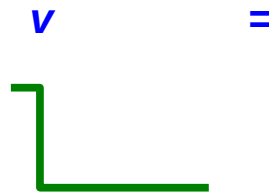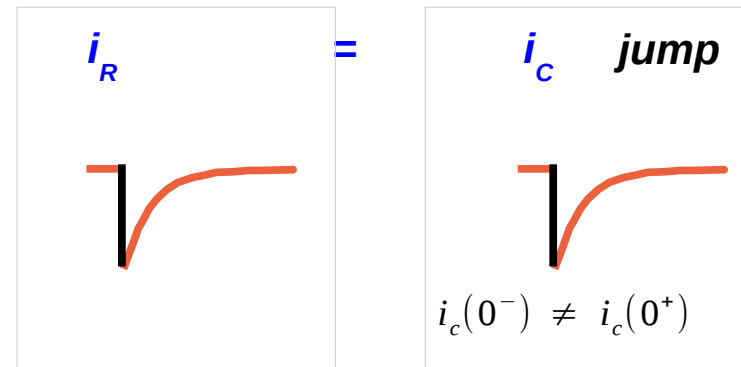$$i_c = C \cdot \frac{d v_c}{d t}$$

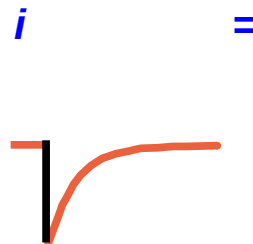*unyielding voltage*

*current jump*

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the capacitor voltage slowly follows the the shape of the applied step input voltage

**continuous**

**v** = **v$_R$** + **v$_C$**

$$v_c(0^-) = v_c(0^+)$$

---

the capacitor current changes abruptly by the applied step input voltage and then slowly becomes zero

**i** = **i$_R$** = **i$_C$**  **jump**

$$i_c(0^-) \neq i_c(0^+)$$

# Pulse

$$v \quad = \quad v_R \quad + \quad v_C$$

$$i \quad = \quad i_R \quad = \quad i_C$$

# Pulse
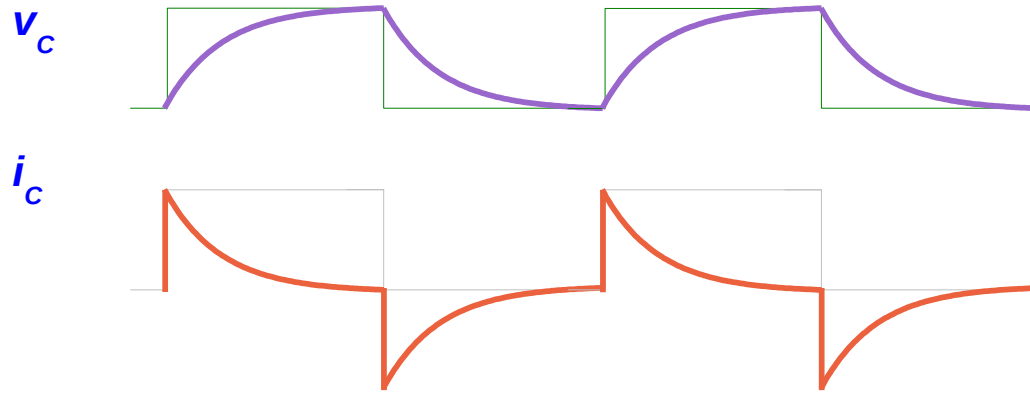
$v_C$

$i_C$

$$i_C = C \frac{d v_C}{d t}$$

$\omega$ ↑   $i_c$ ↑   $X_c$ ↓

$v_C$

$i_C$

$v_C$

$i_C$

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# Everchanging signal pairs

decreasing    increasing    decreasing    increasing    decreasing    increasing

$$\frac{d}{dt}$$

$v_C$

$i_L$

$i_C$

$v_L$

negative    positive    charge   discharge    negative    positive

charge   discharge

# Capacitor Current

positive charge
(positive ions)

insulator

negative charge
(free electrons)
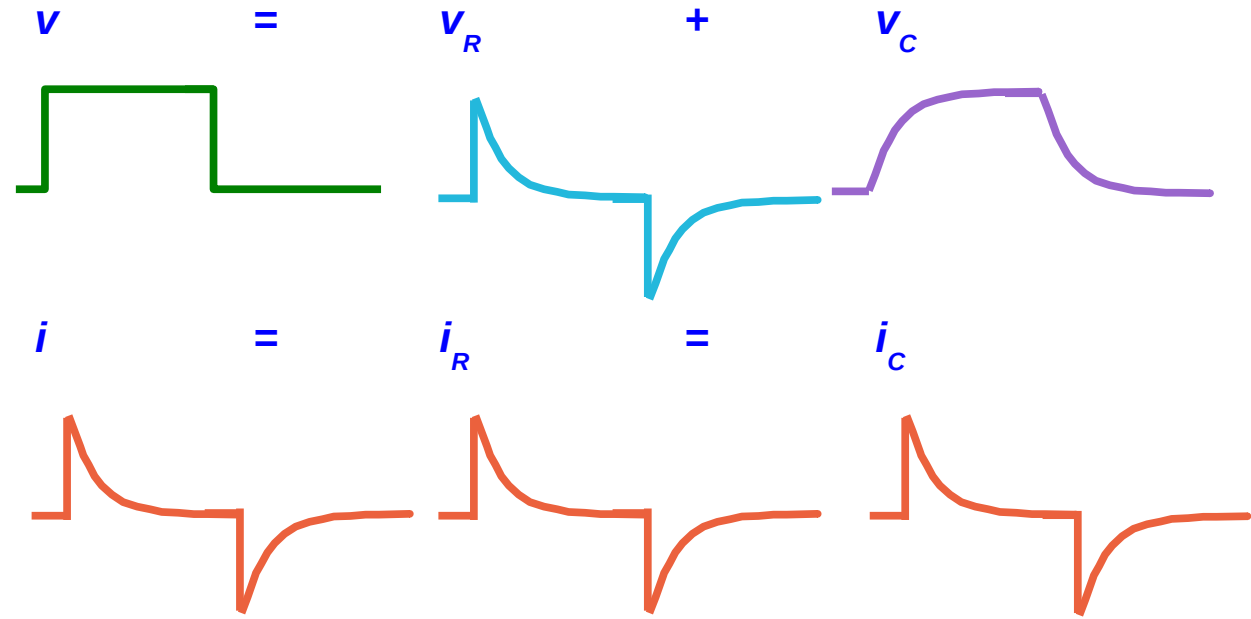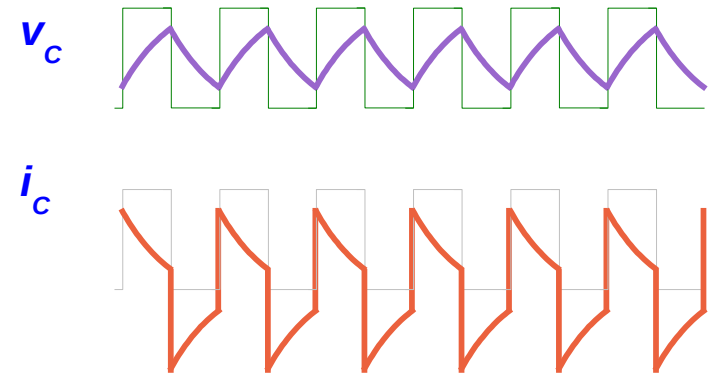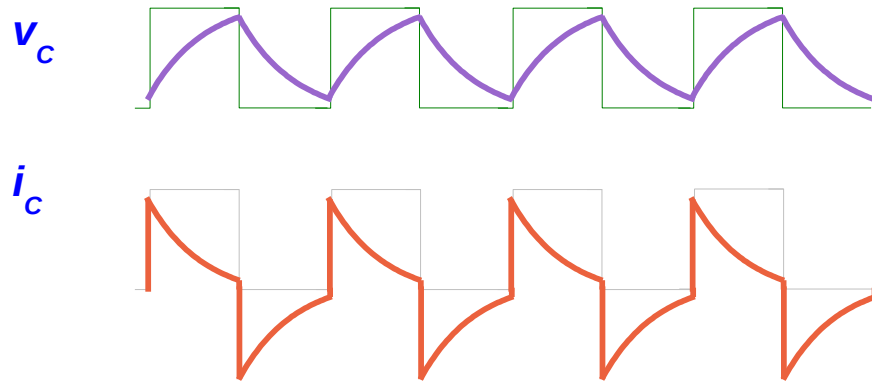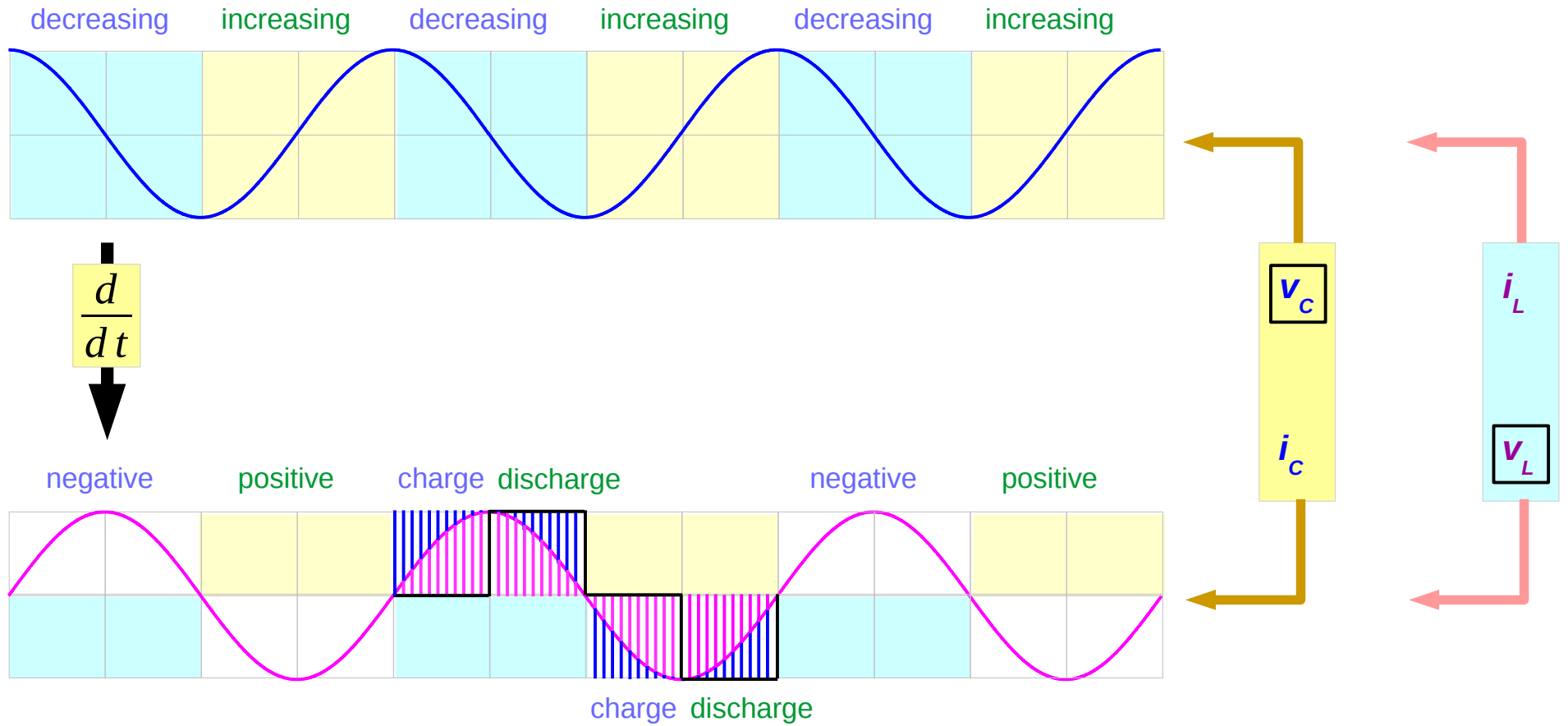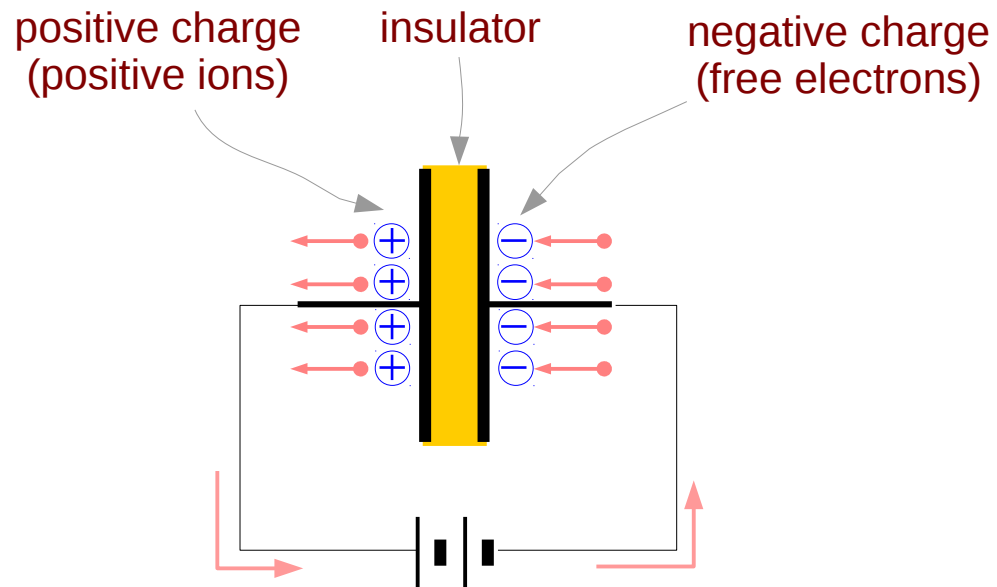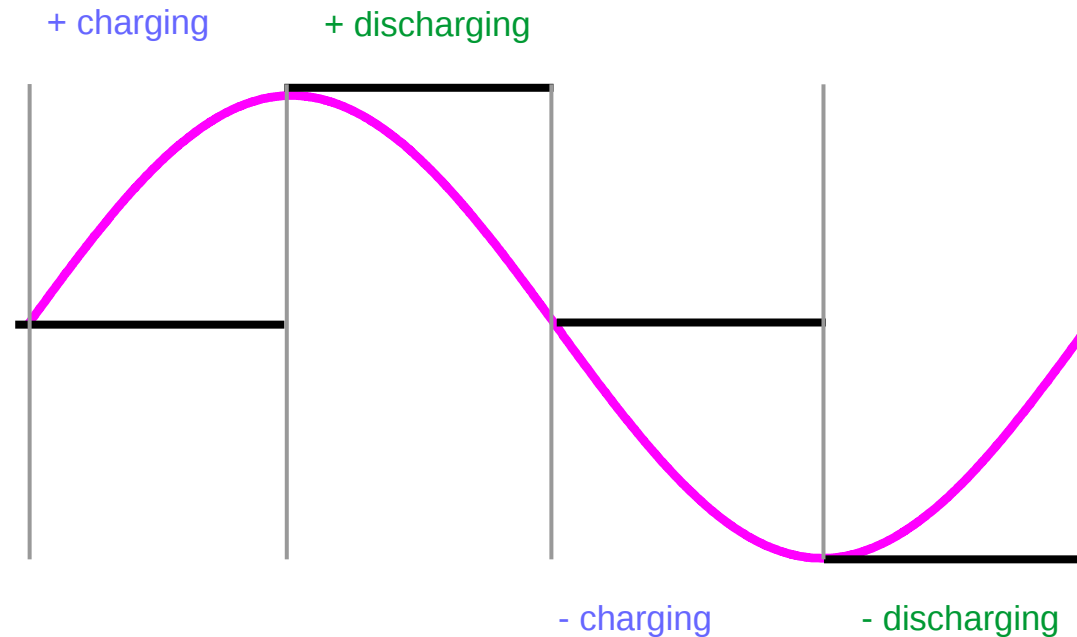
Think as    electrons move to the left
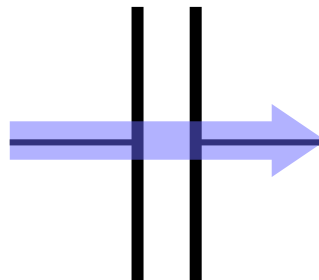
**Displacement Current**

# Continuous Charing and Discharging Operations

**Incremental Voltage Increment** ➡ **Continuous Charging**

**Incremental Voltage Decrement** ➡ **Continuous Discharging**

+ charging      + discharging

- charging      - discharging
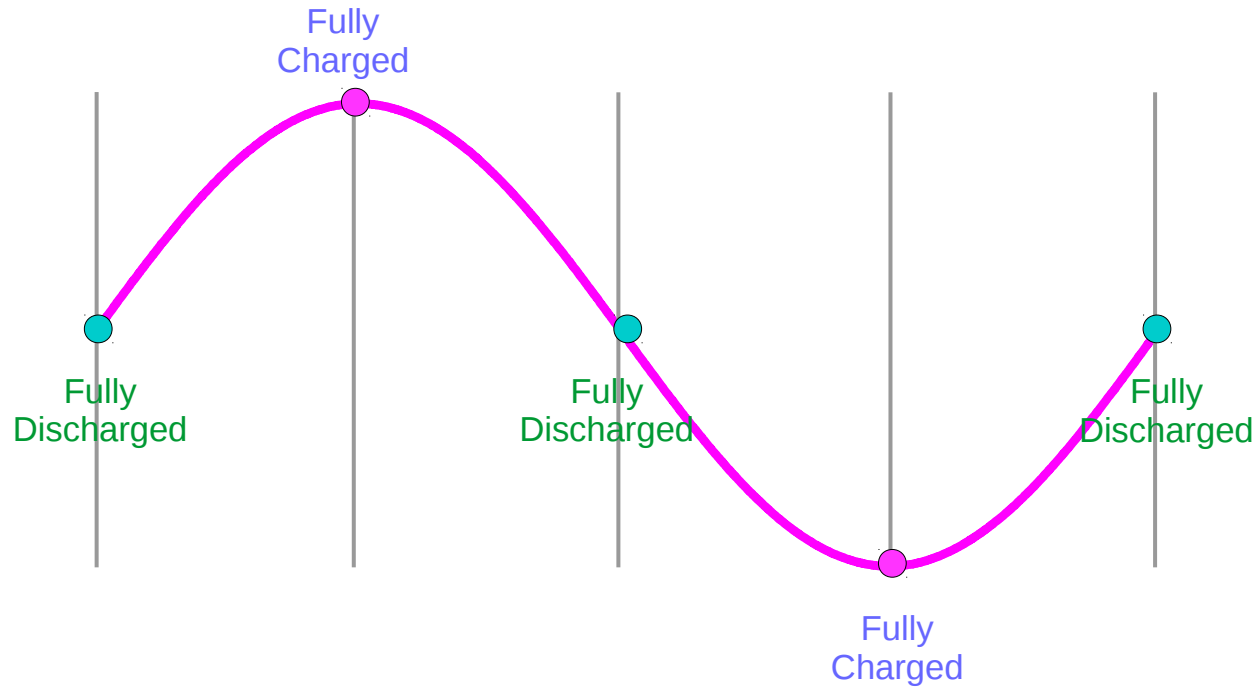
# Fully Charged and Fully Discharged

**Incremental Voltage Increment** ➡ **Continuous Charging**

**Incremental Voltage Decrement** ➡ **Continuous Discharging**

Fully charged

Fully
Charged

Fully
Discharged

Fully
Discharged

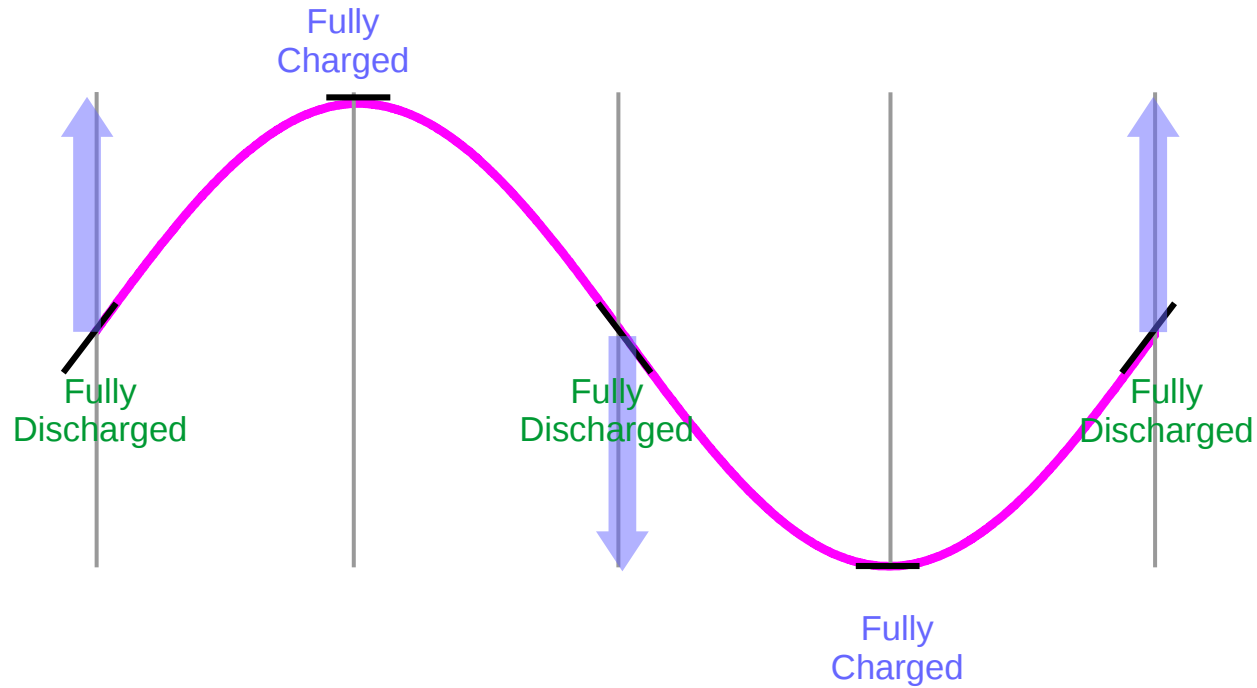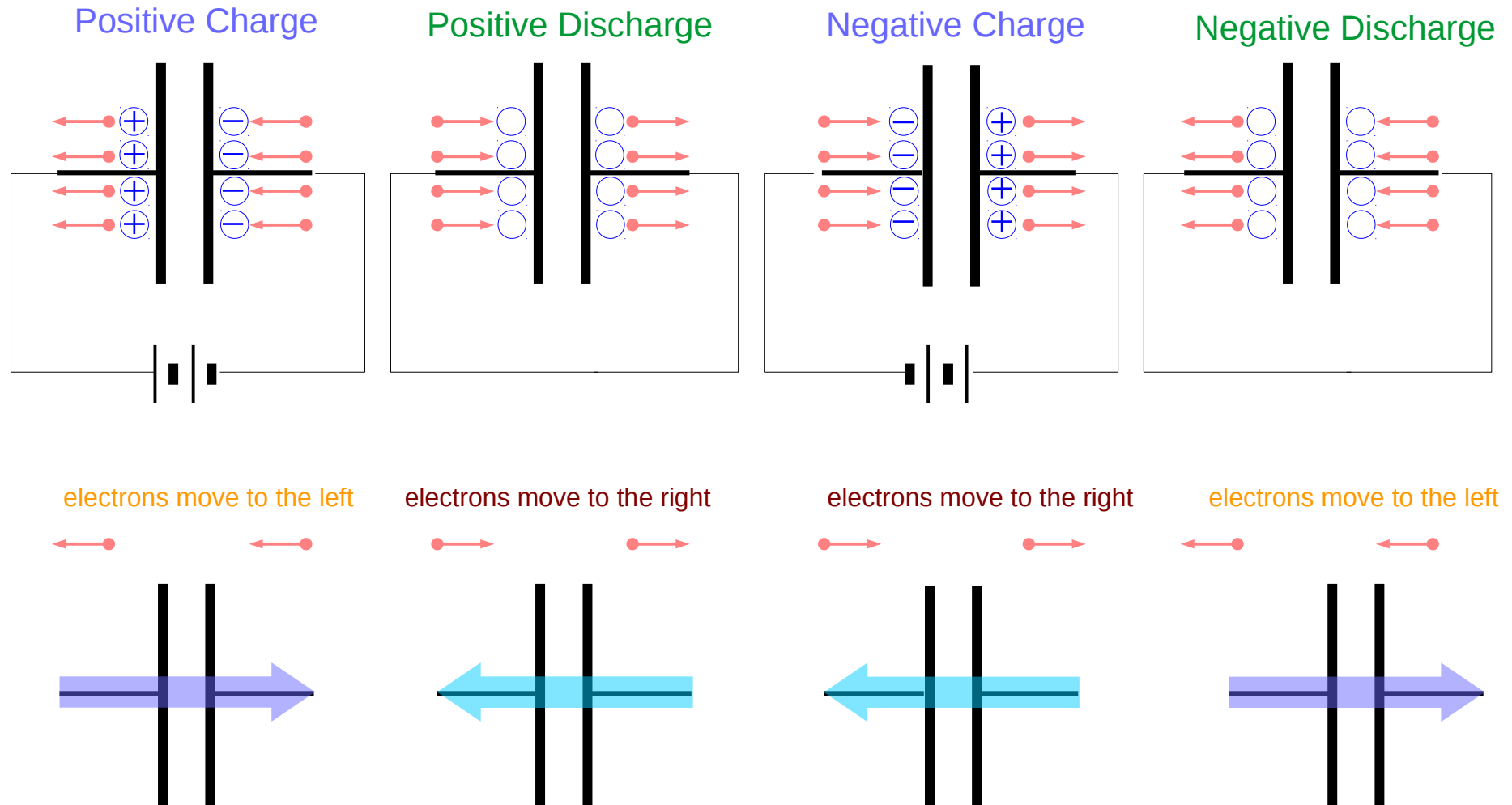Fully
Discharged

Fully
Charged

# Fully Charged and Fully Discharged

**Incremental Voltage Increment** ➡ **Continuous Charging**

**Incremental Voltage Decrement** ➡ **Continuous Discharging**
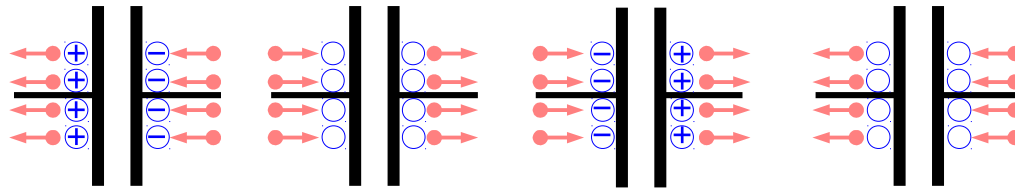
Fully charged

Fully
Charged

Fully
Discharged

Fully
Discharged

Fully
Discharged

Fully
Charged

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# Everchanging signal pairs

Positive Charge

Positive Discharge

Negative Charge

Negative Discharge

electrons move to the left

electrons move to the right
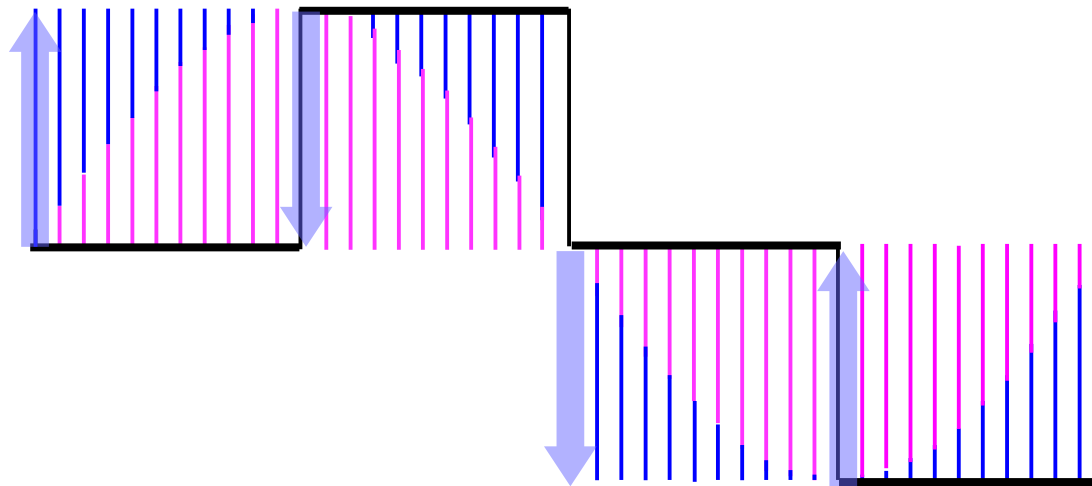
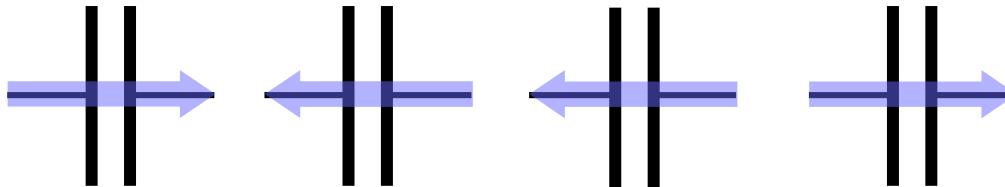electrons move to the right

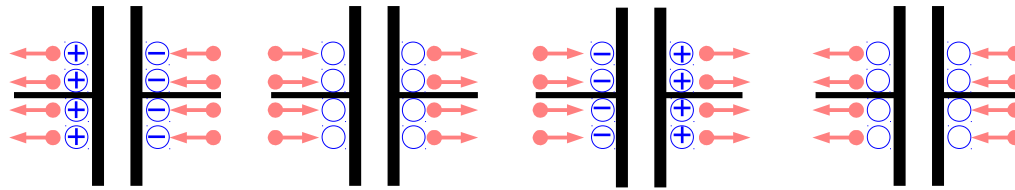electrons move to the left

# Everchanging signal pairs

charge

discharge

charge

discharge

# Everchanging signal pairs

charge            discharge

charge            discharge
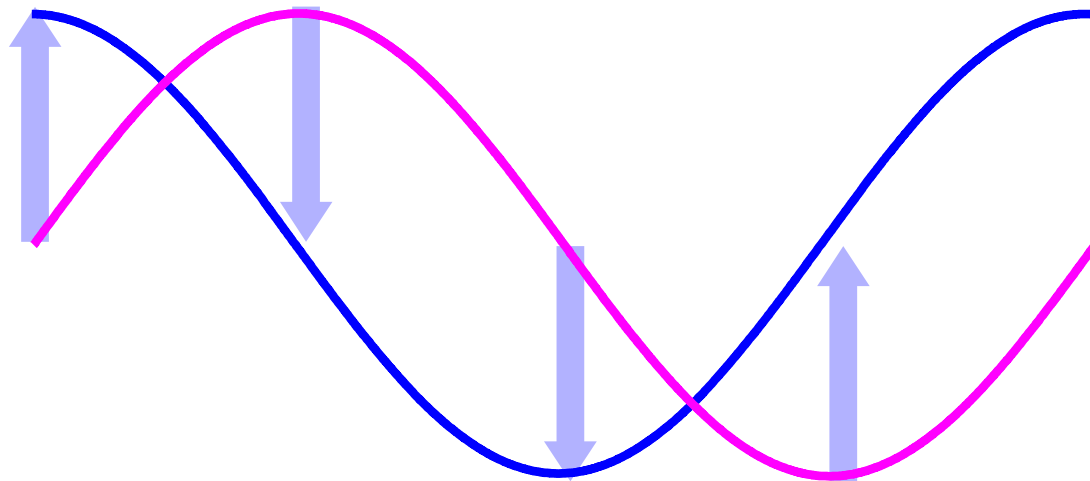
# Everchanging signal pairs
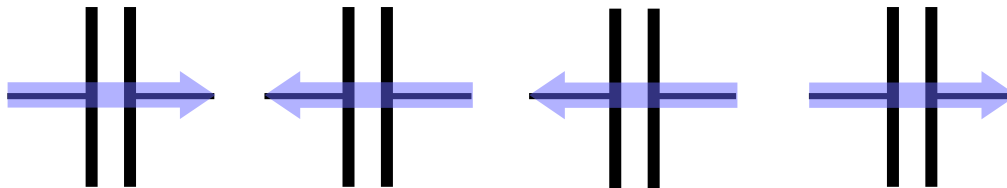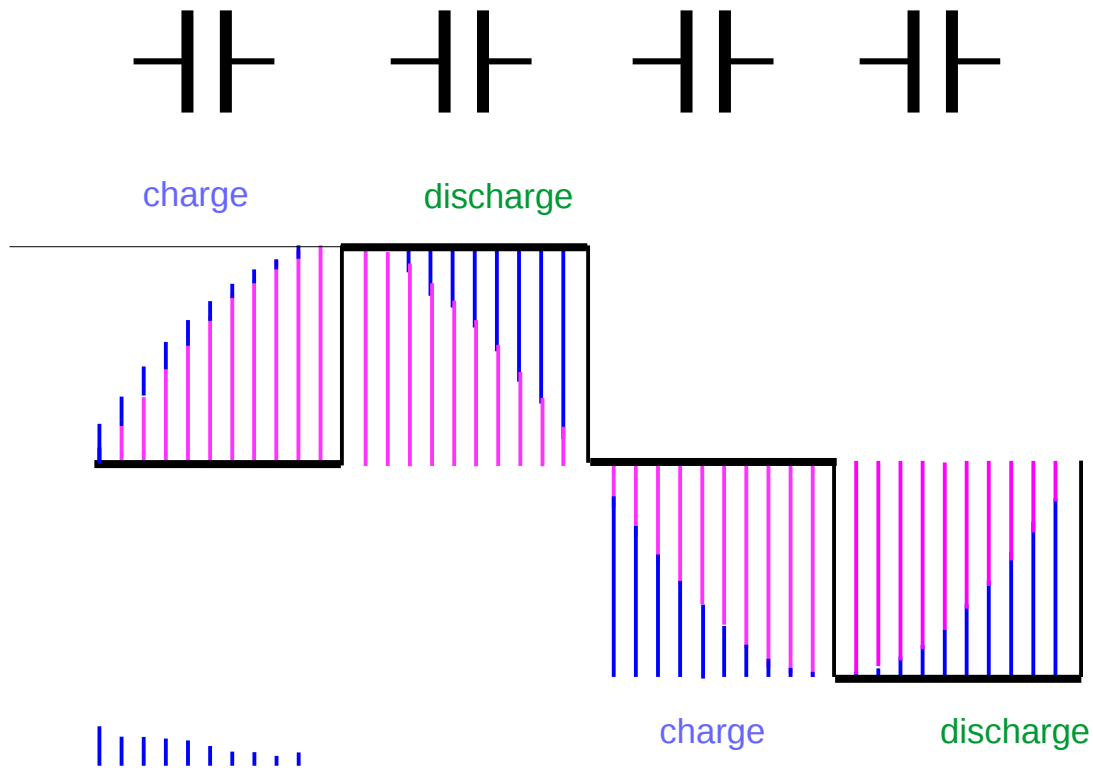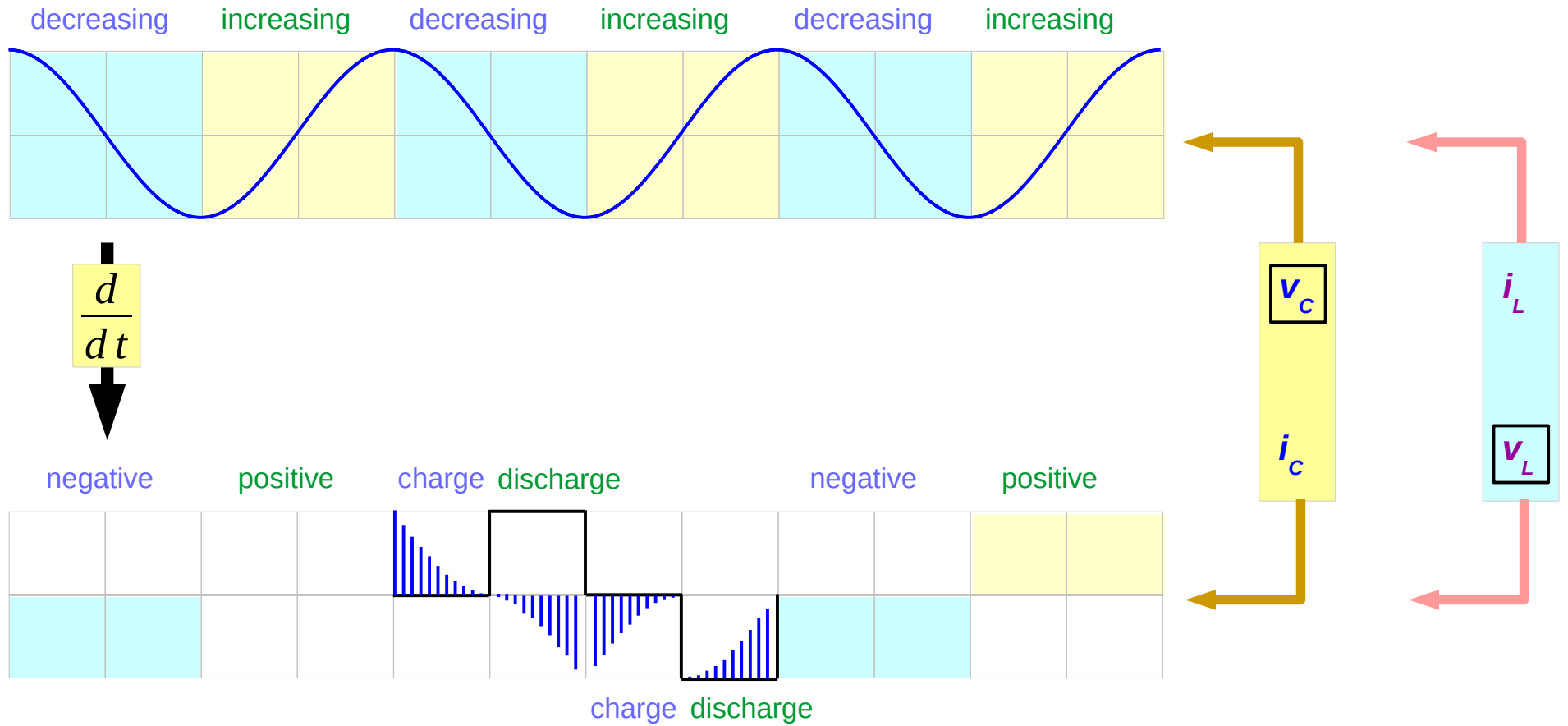


charge    discharge

charge    discharge

# Everchanging signal pairs
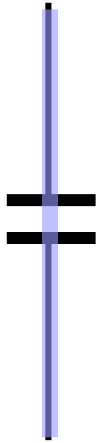
decreasing     increasing     decreasing     increasing     decreasing     increasing

$$\frac{d}{dt}$$

negative     positive     charge   discharge     negative     positive

charge   discharge

$v_C$

$i_C$

$i_L$

$v_L$

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# I leads V by 90°

**Initial charge**

**Full charge**

*I*   *V*

**SHORT**

**OPEN**

*V = 0*

*I = 0*

*I : peak*
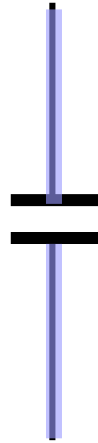
*V : peak*

## References
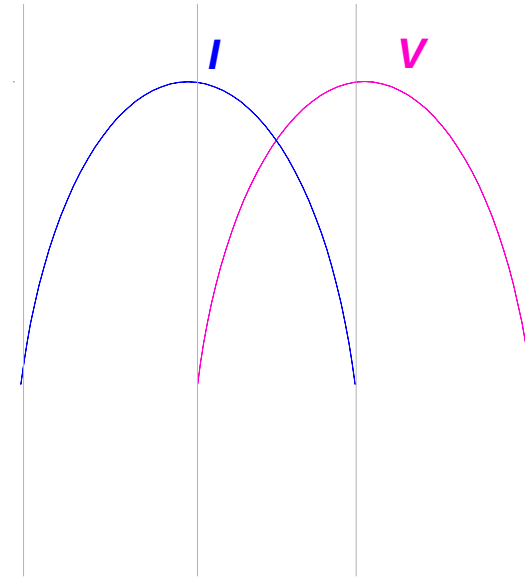
[1]  http://en.wikipedia.org/
[2]  J.H. McClellan, et al., Signal Processing First, Pearson Prentice Hall, 2003