

# Capacitor in an AC circuit

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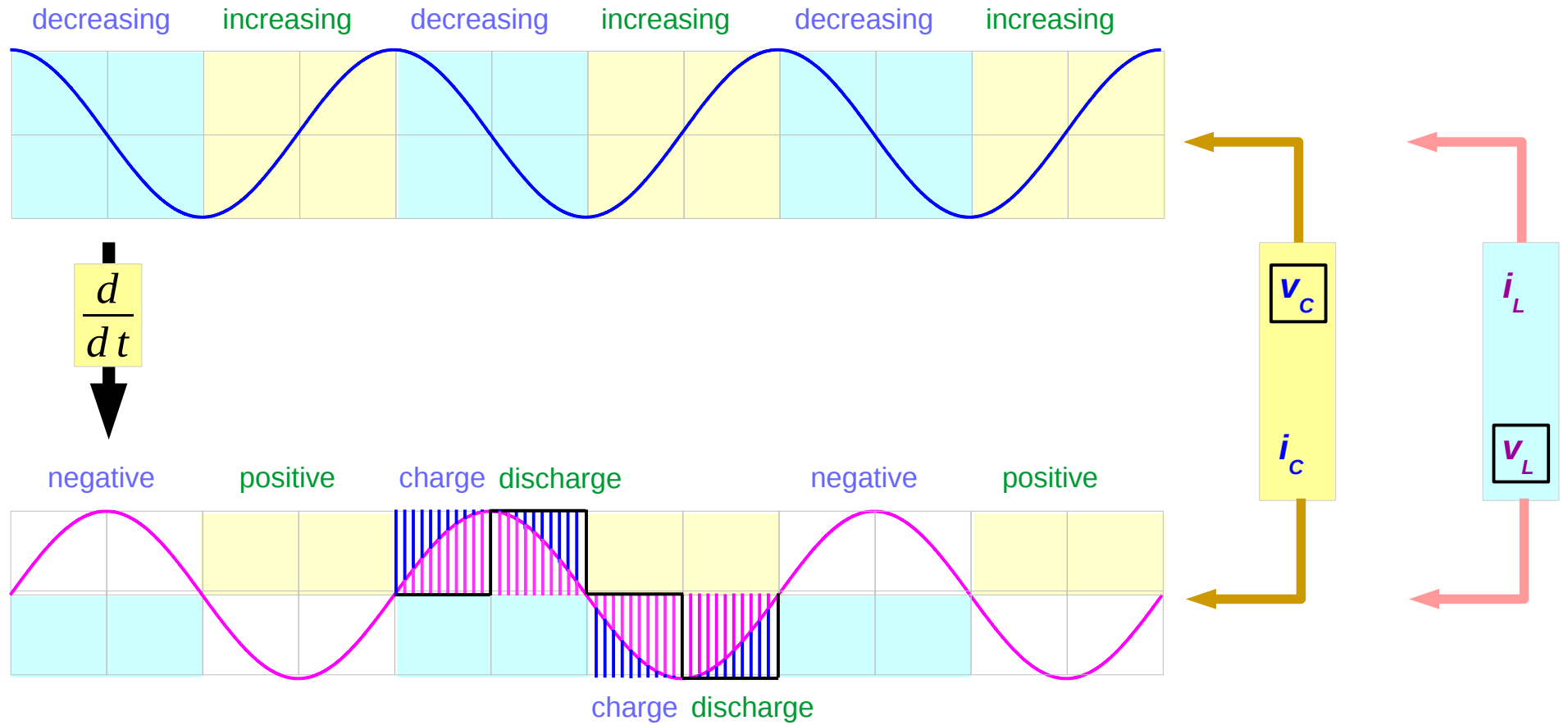
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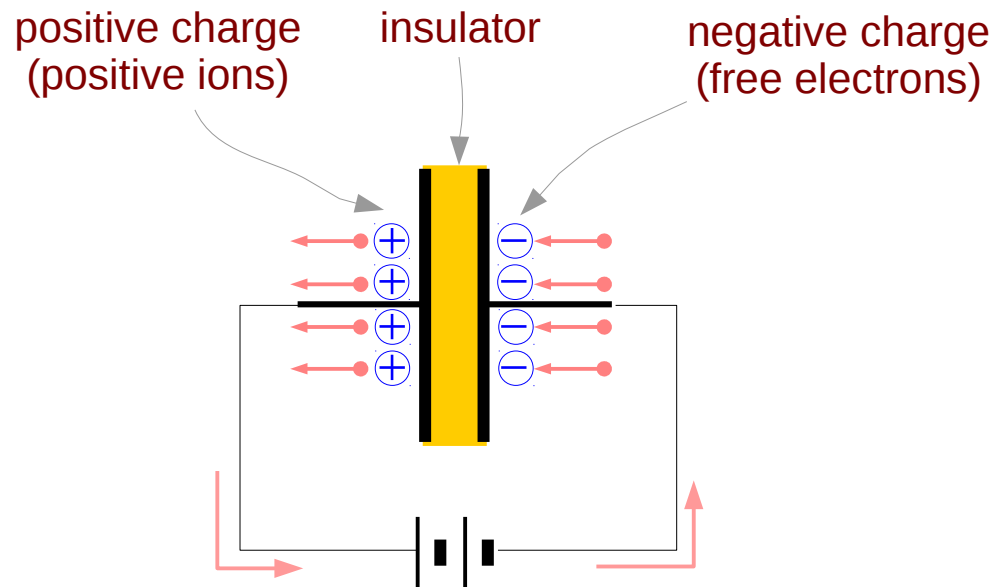
Please send corrections (or suggestions) to [youngwlim@hotmail.com](mailto:youngwlim@hotmail.com).

This document was produced by using OpenOffice and Octave.

# Everchanging signal pairs



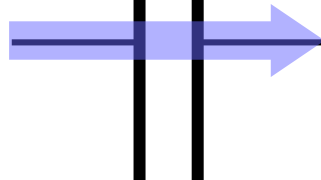
# Capacitor Current



No actual electrons movement across insulator materials



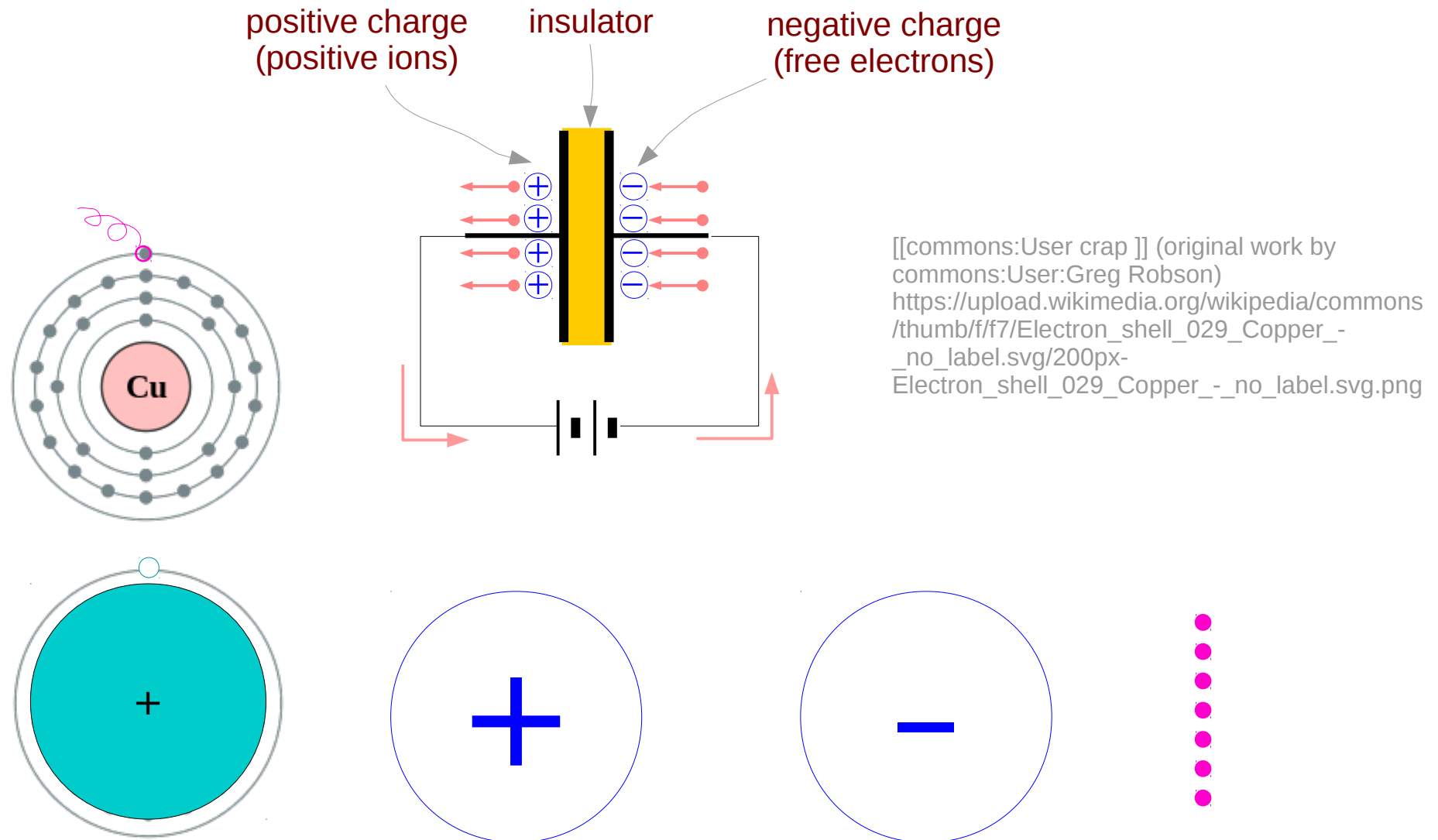
But, think as



**Displacement Current**

flows through the capacitor

# Positive ions and free electrons



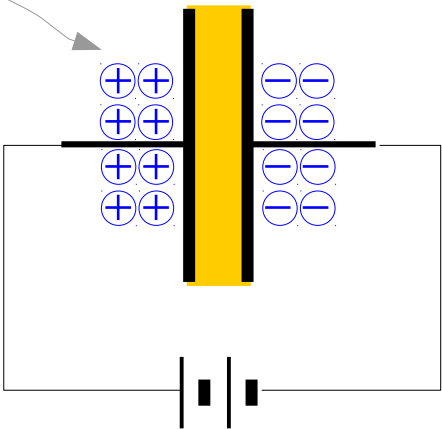
[[commons:User crap ]] (original work by commons:User:Greg Robson)  
[https://upload.wikimedia.org/wikipedia/commons/thumb/f/f7/Electron\\_shell\\_029\\_Copper\\_-\\_no\\_label.svg/200px-Electron\\_shell\\_029\\_Copper\\_-\\_no\\_label.svg.png](https://upload.wikimedia.org/wikipedia/commons/thumb/f/f7/Electron_shell_029_Copper_-_no_label.svg/200px-Electron_shell_029_Copper_-_no_label.svg.png)

# Three States

positive charge  
(positive ions)

**Positively Charged State**

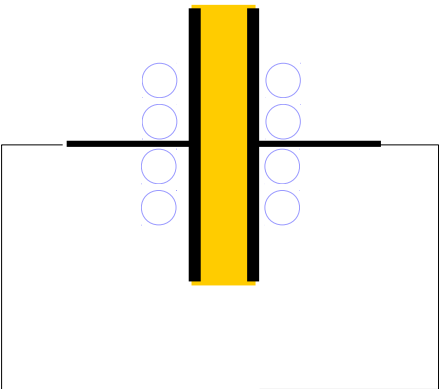
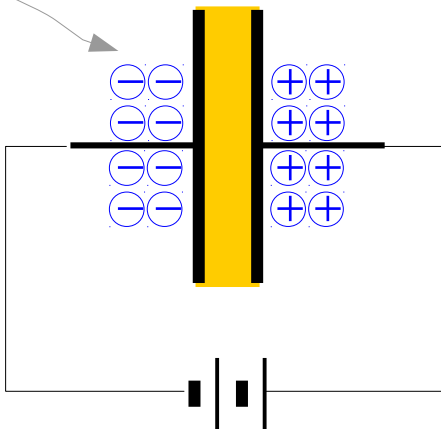
fully charged → no current



negative charge  
(free electrons)

**Negatively Charged State**

fully charged → no current

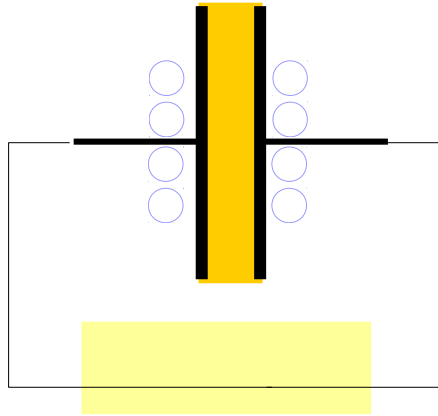


**Fully Discharged State**

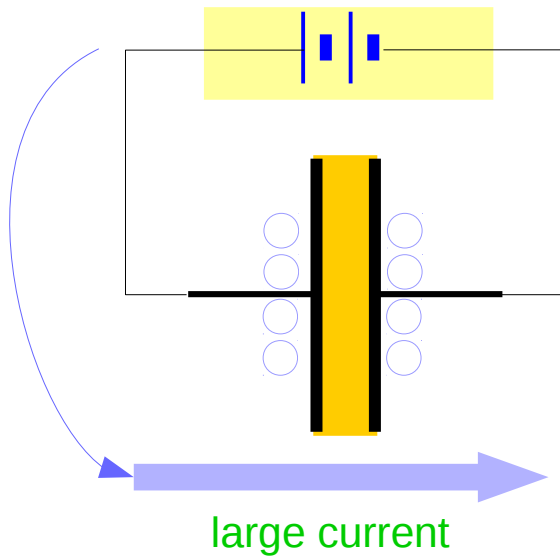
possible large current

# Currents in the Fully Discharged State

Initially no current

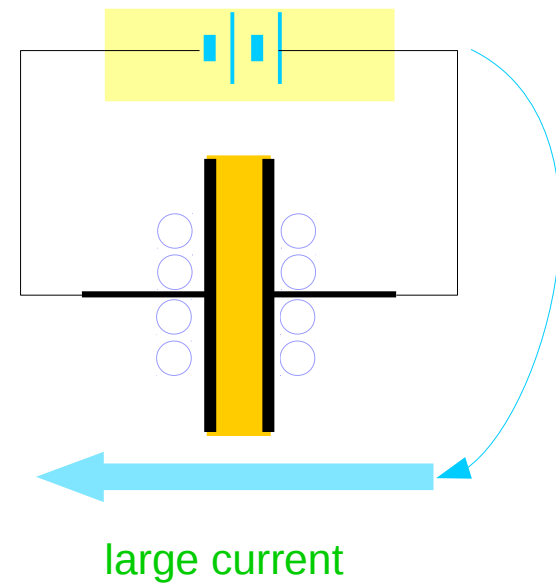


Fully Discharged State



Fully Discharged State

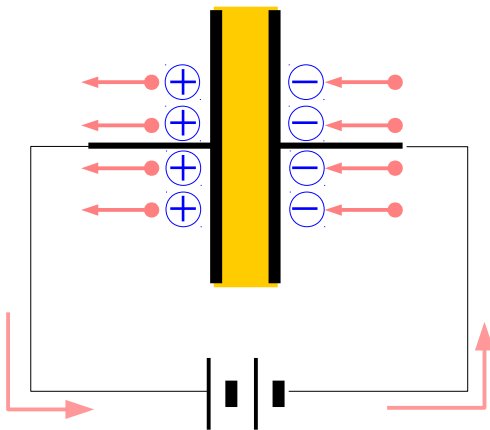
Fully Discharged State



# Inter-State Current Flowing

## Under Positively Charging

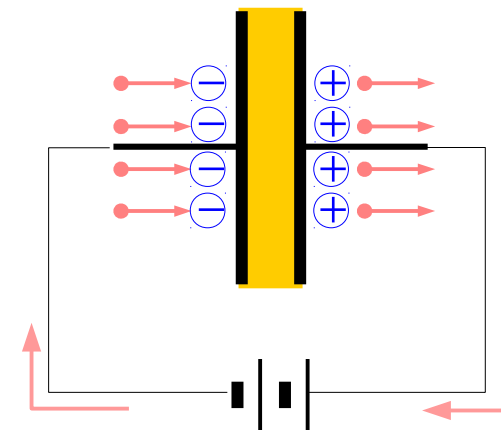
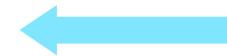
(+) current flow direction



electron flow direction

## Under Negatively Charging

(-) current flow direction



electron flow direction

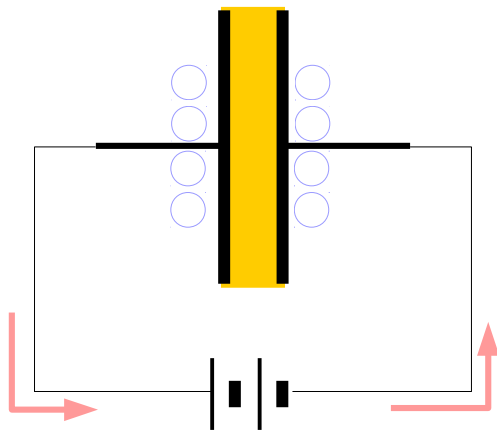


# Inter-State Current Flowing

## Fully Discharged State

Initial large current

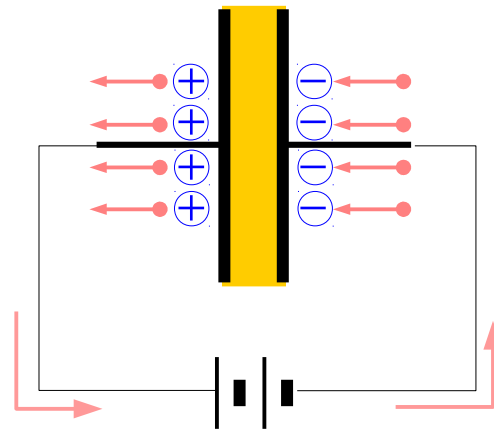
(+) current flow direction



electron flow direction

## Under Positively Charging

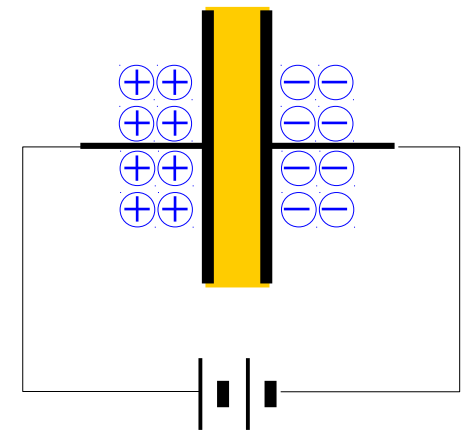
(+) current flow direction



electron flow direction

## Positively Charged State

no current



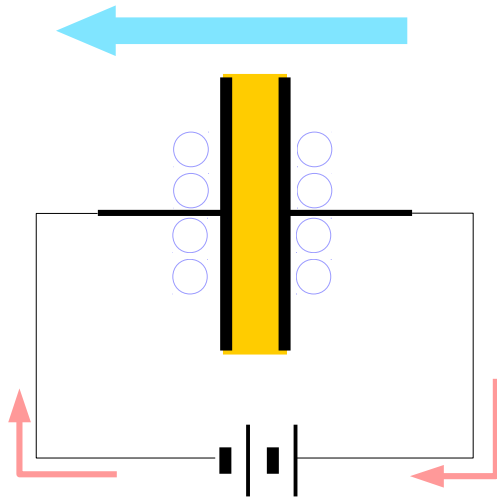
Crowded →  
No more space

# Inter-State Current Flowing

## Fully Discharged State

Initial large current

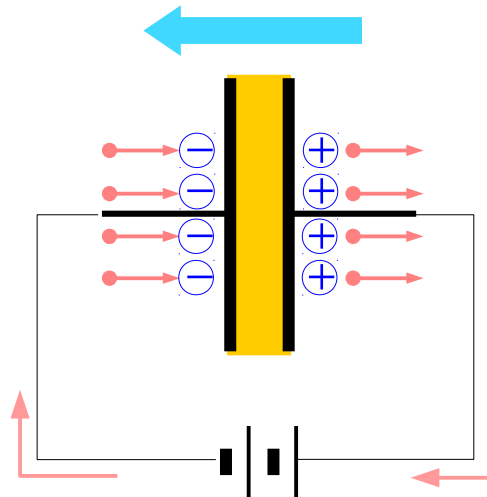
(-) current flow direction



electron flow direction

## Under Negatively Charging

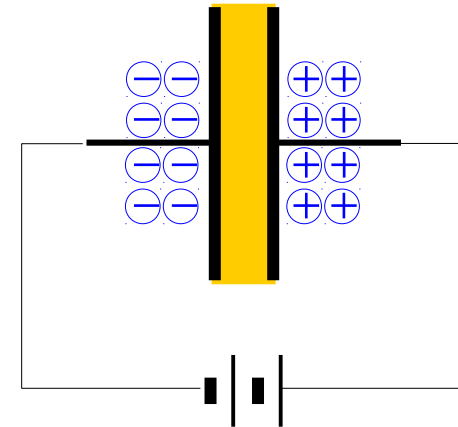
(-) current flow direction



electron flow direction

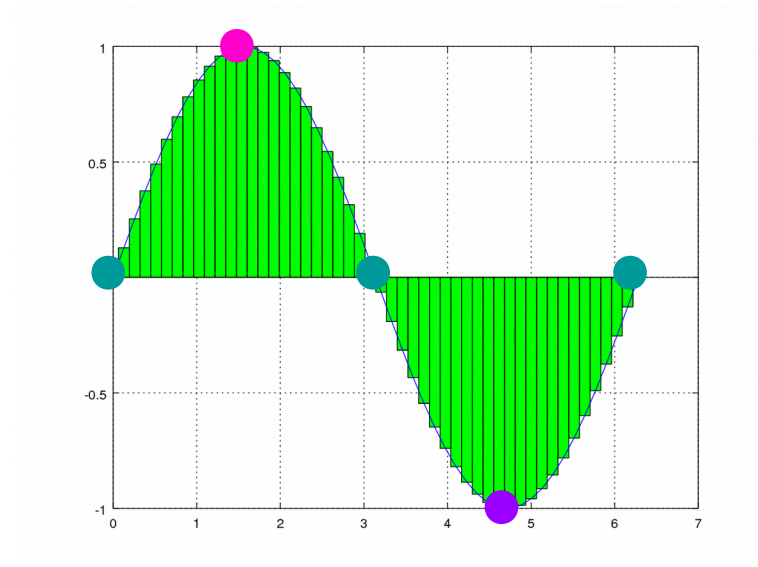
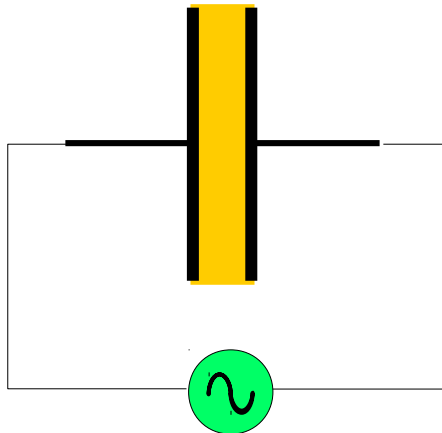
## Negatively Charged State

no current

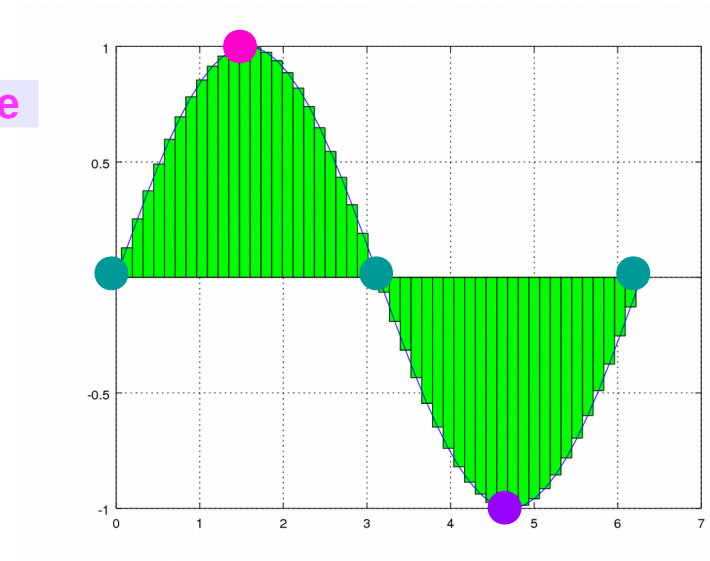
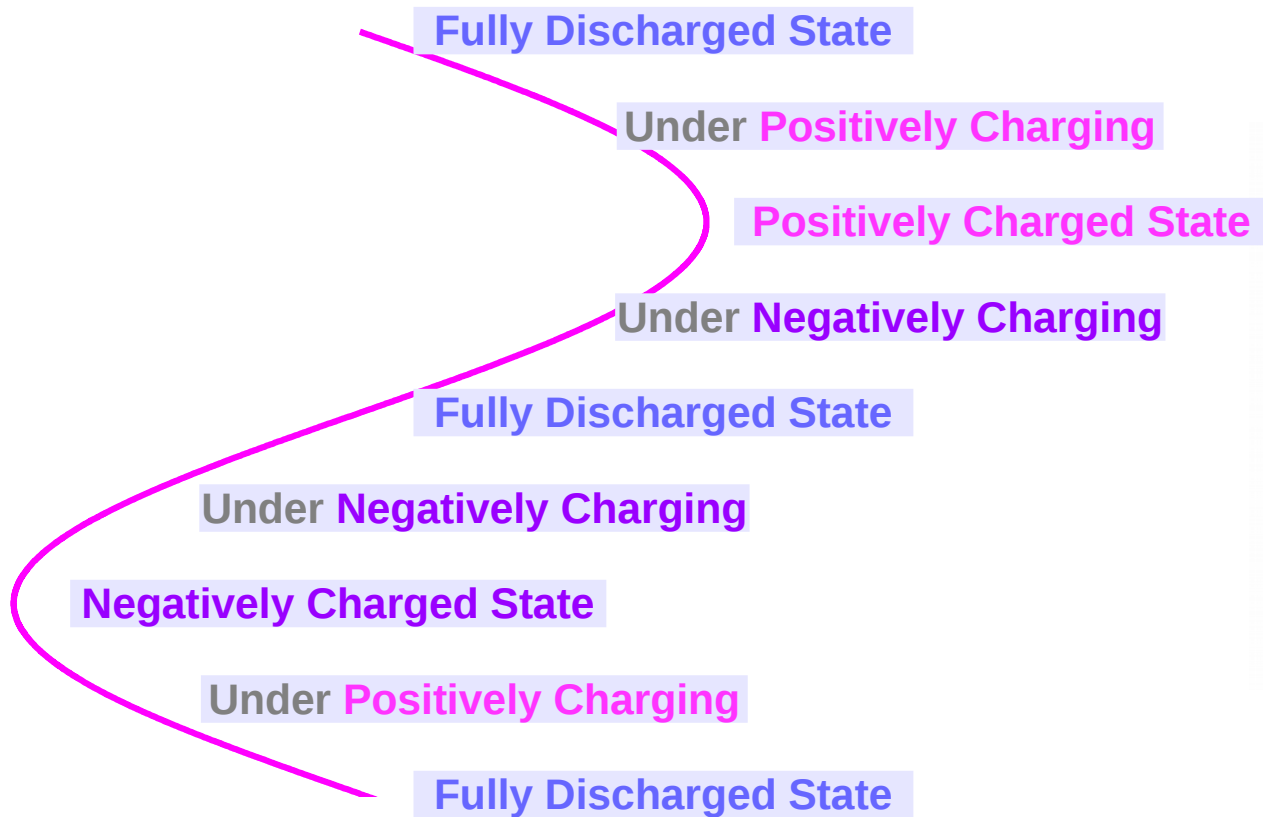


Crowded →  
No more space

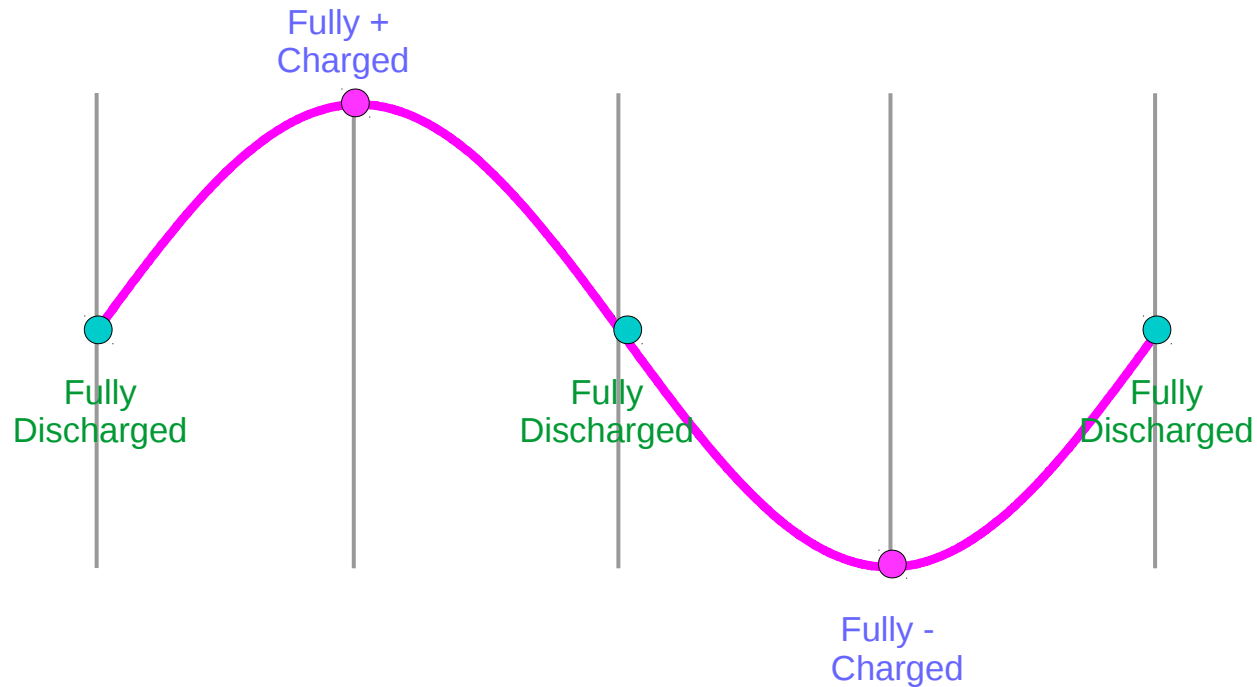
# An AC Voltage Source



# An AC Voltage Source

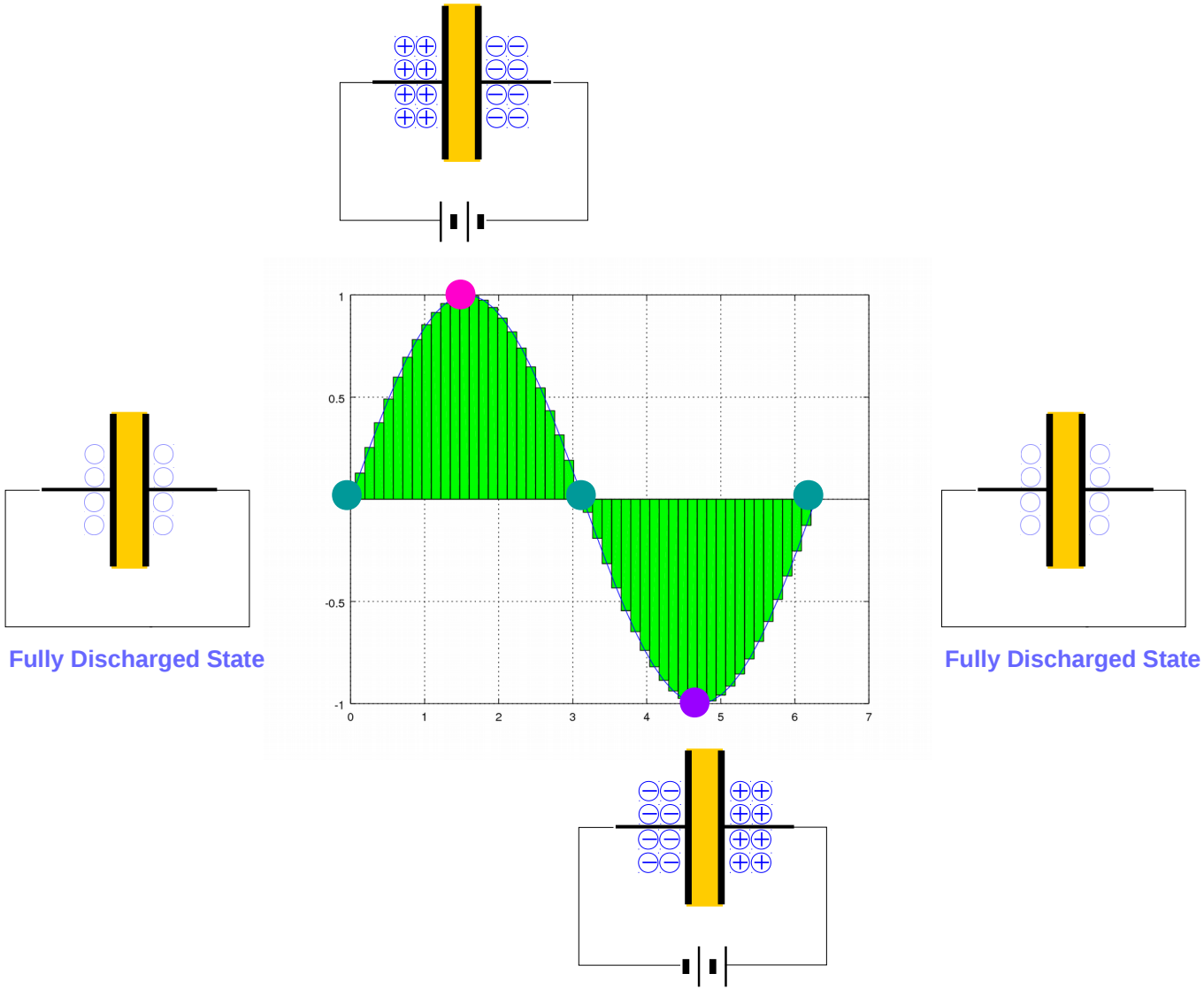


# Fully Charged and Fully Discharged

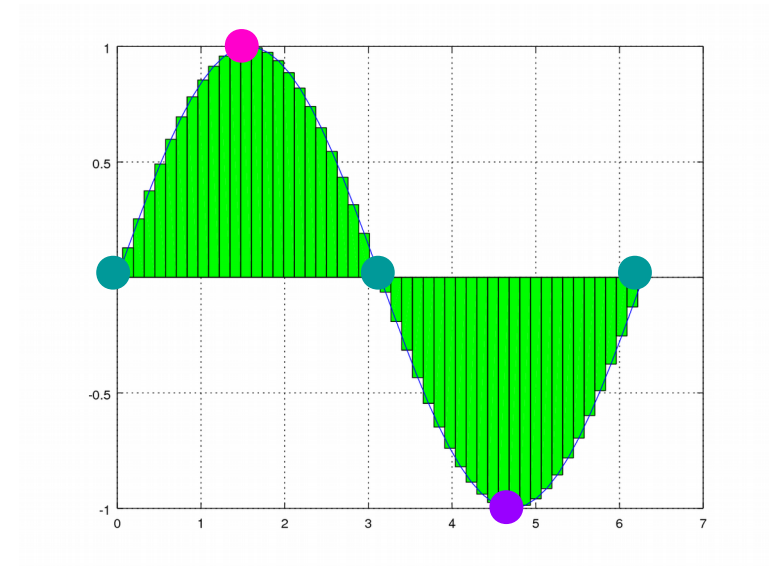
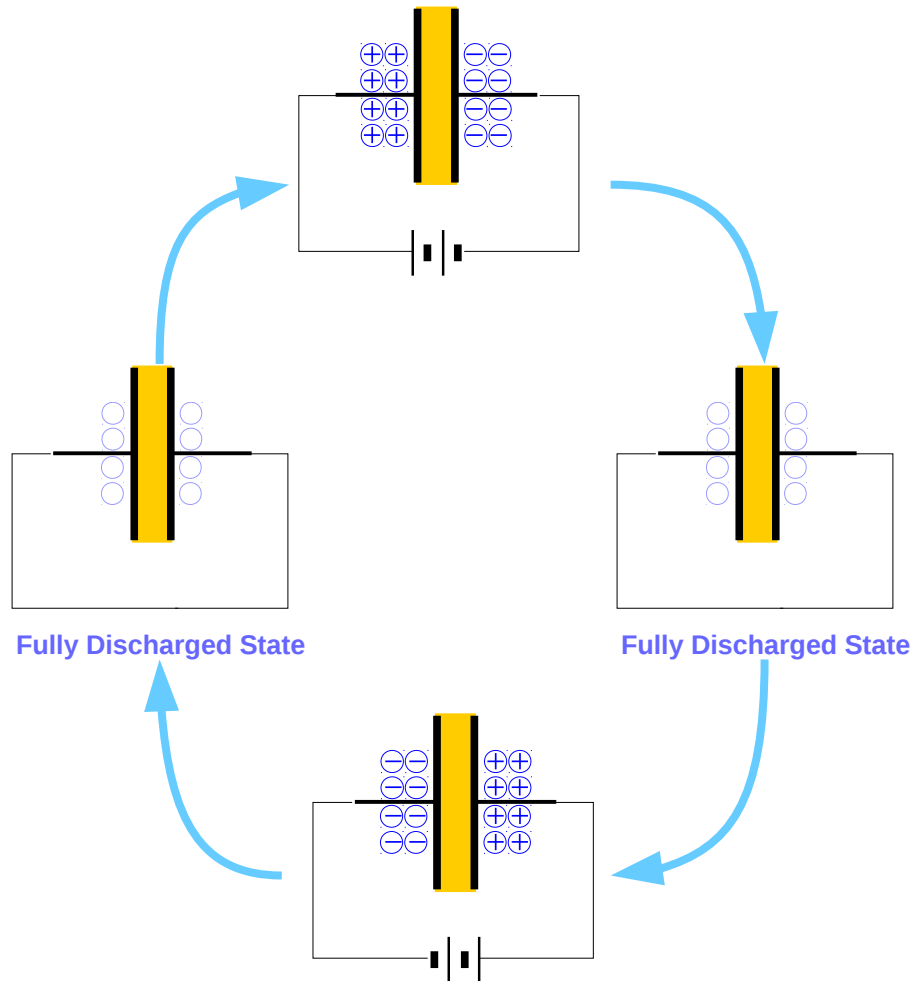


(+) Charging	(-) Charging	(-) Charging	(+) Charging
(+) current	(-) current	(-) current	(+) current
(+) Charging	(+) <b>Discharging</b>	(-) Charging	(-) <b>Discharging</b>

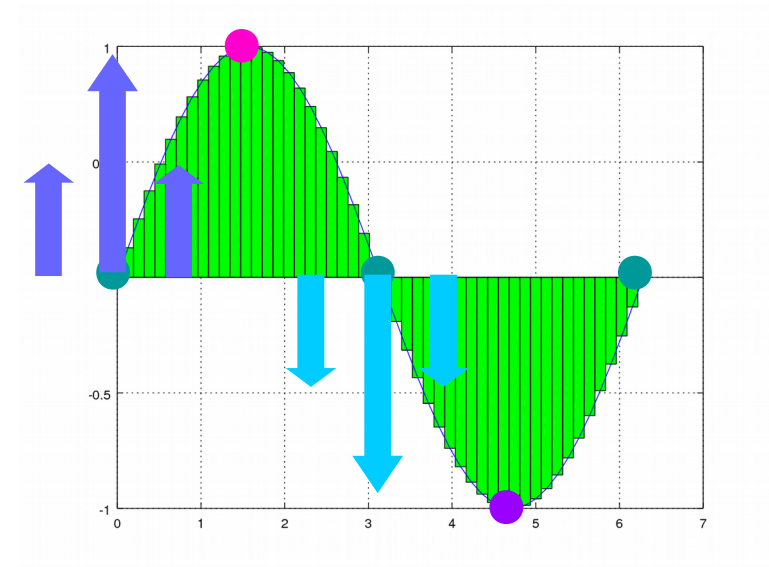
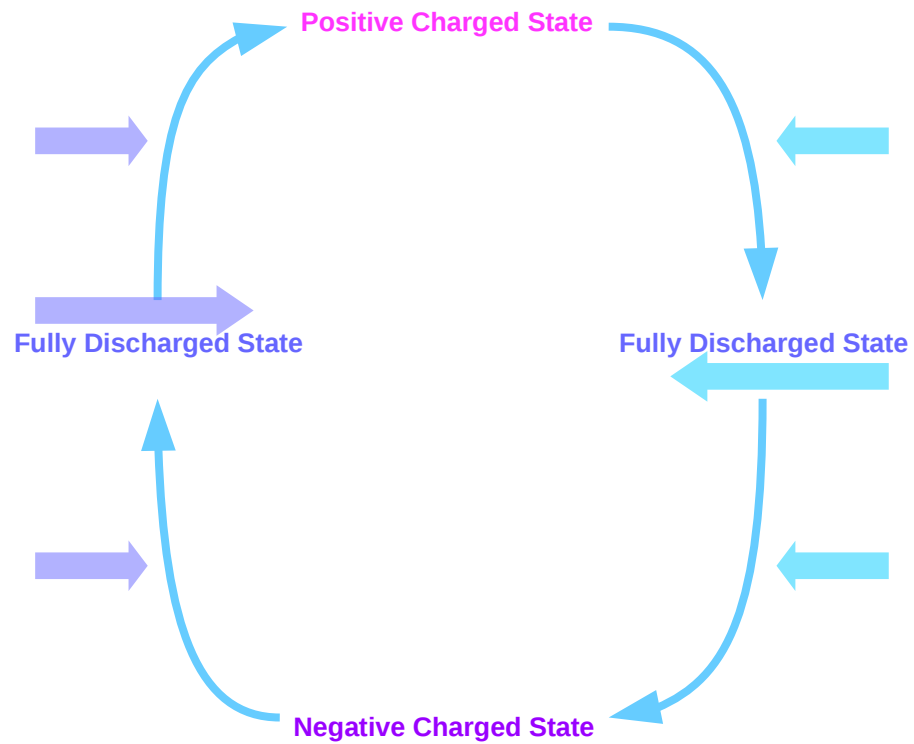
# A Cycle



# State Transition Diagram

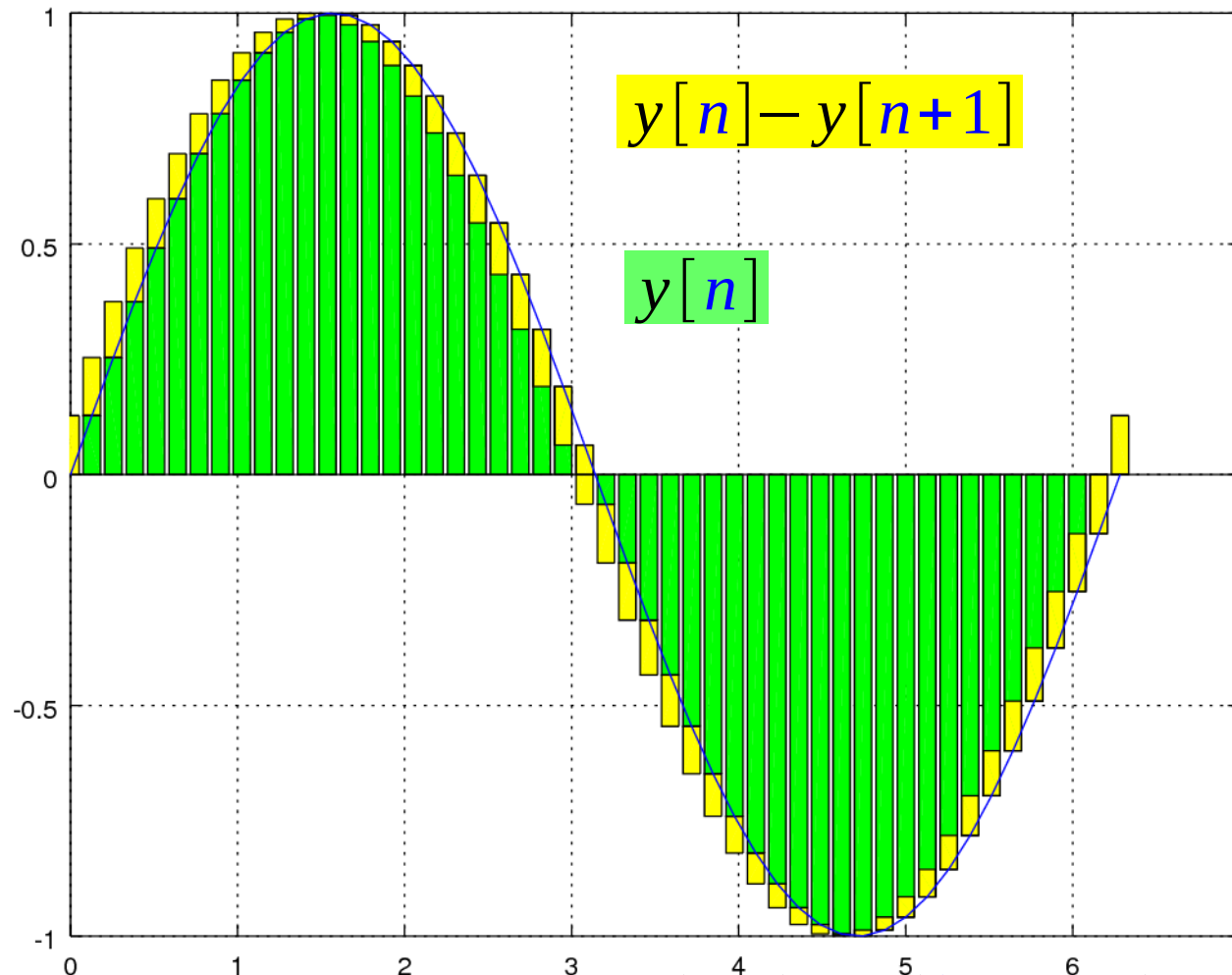


# Current Flow





# Fully Charged and Fully Discharged



```

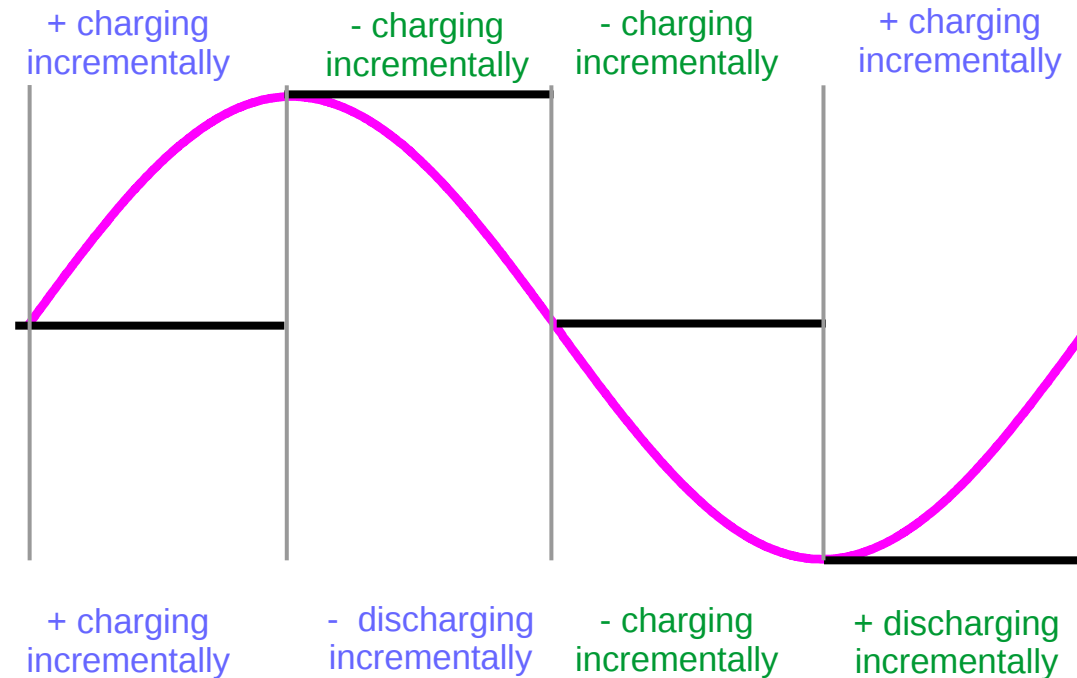
h = bar(t1, [y1' y2'],
"stacked")
set(h(1), "facecolor", "g");
set(h(2), "facecolor", "y");
hold on
plot(t1, y1)
axis([0 7 -1 1]);
    
```

$$y[n] - y[n+1] = y(nT) - y((n+1)T) = \sin(nT) - \sin((n+1)T)$$

# Continuous Charging and Discharging Operations

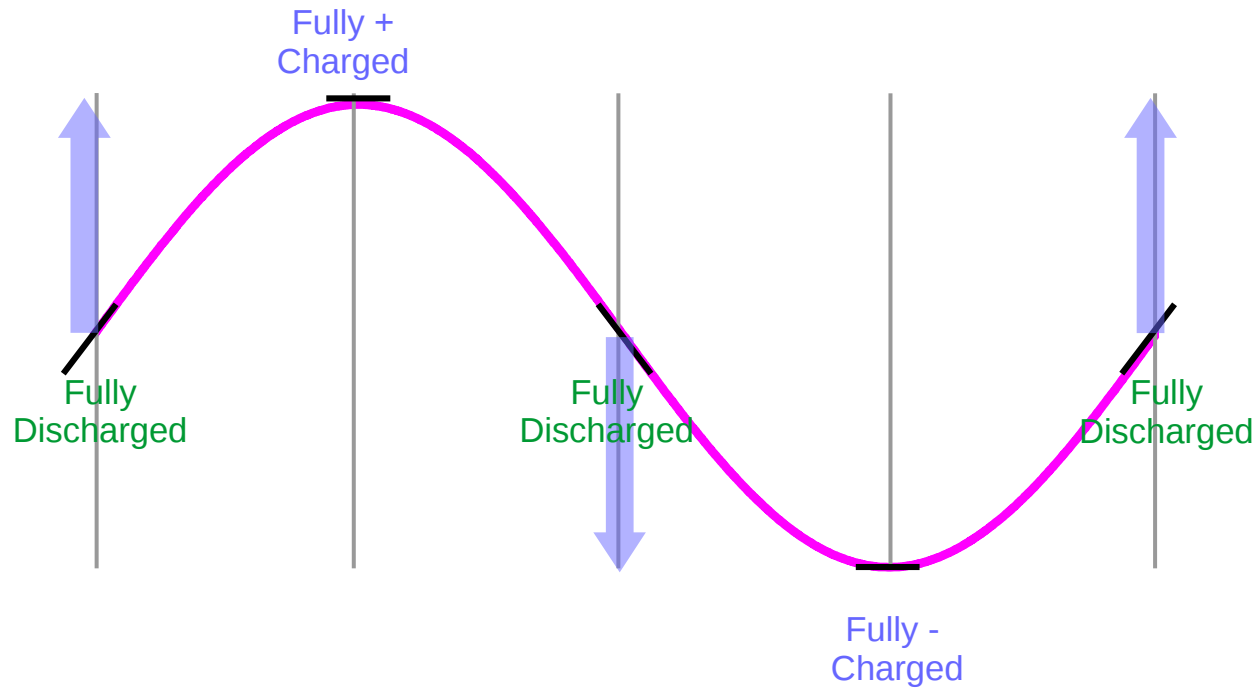
Incremental Voltage Increment  $\Rightarrow$  + Charging incrementally

Incremental Voltage Decrement  $\Rightarrow$  - Charging incrementally

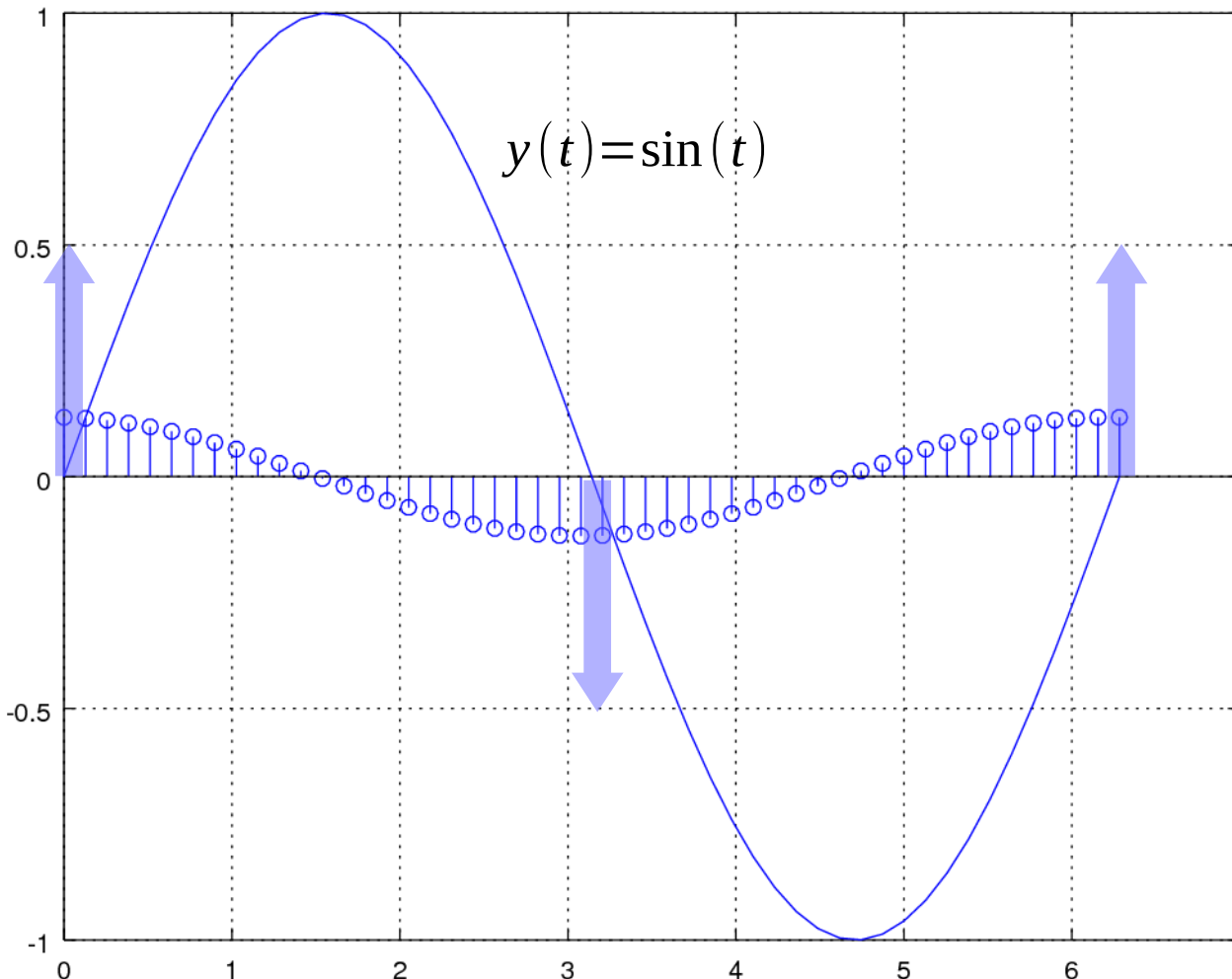


# Fully Discharged : Large Current

Incremental Voltage Increment → Continuous Charging  
Incremental Voltage Decrement → Continuous Discharging



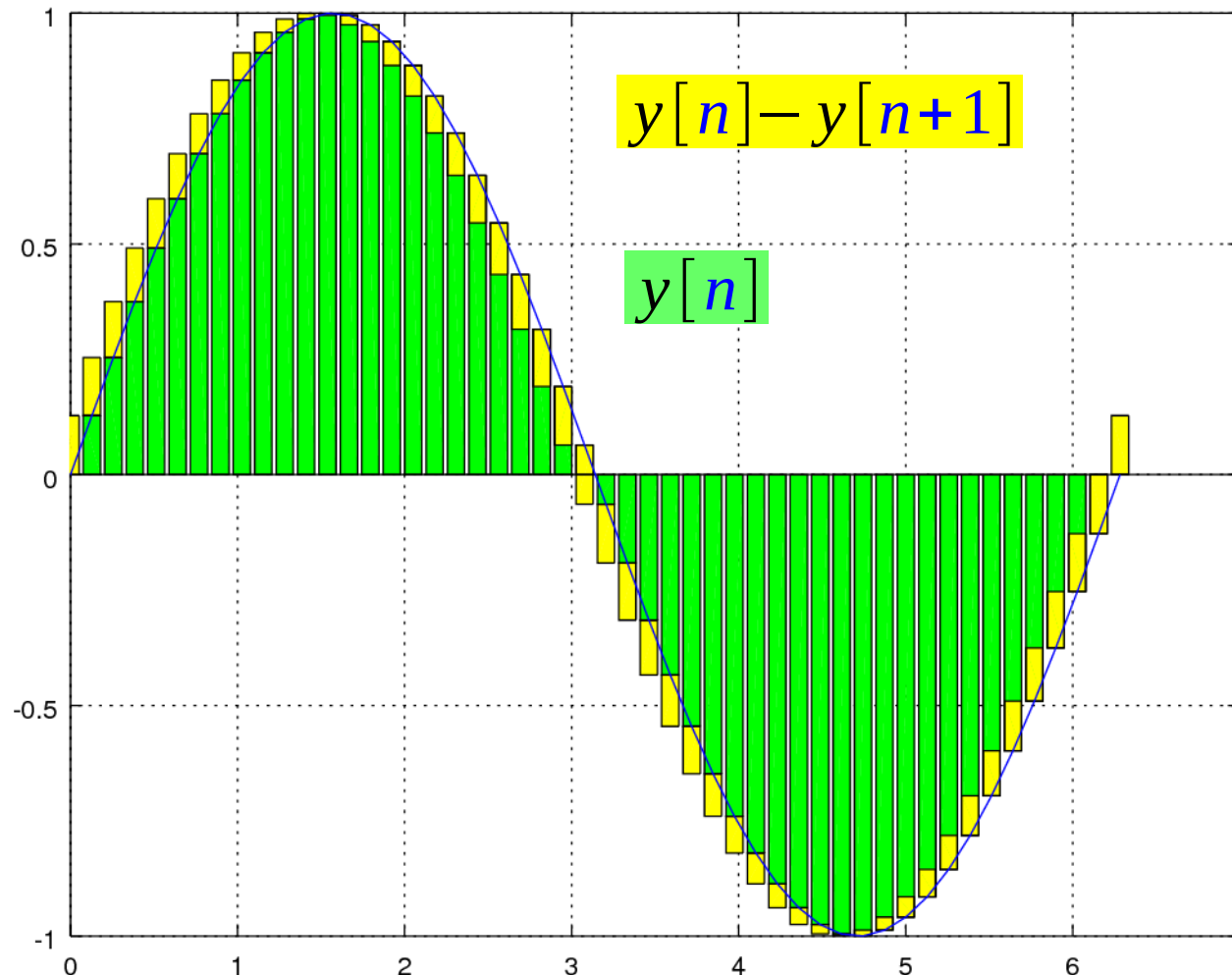
# $y[n+1] - y[n]$



```
t = linspace(0, pi*2, 50);  
t1 = t;  
t2 = t + t(2);  
y1 = sin(t1);  
y2 = sin(t2) - sin(t1);  
stem(t1, y2)  
hold on  
plot(t1, y1)
```

$$y[n] - y[n+1] = y(nT) - y((n+1)T) = \sin(nT) - \sin((n+1)T)$$

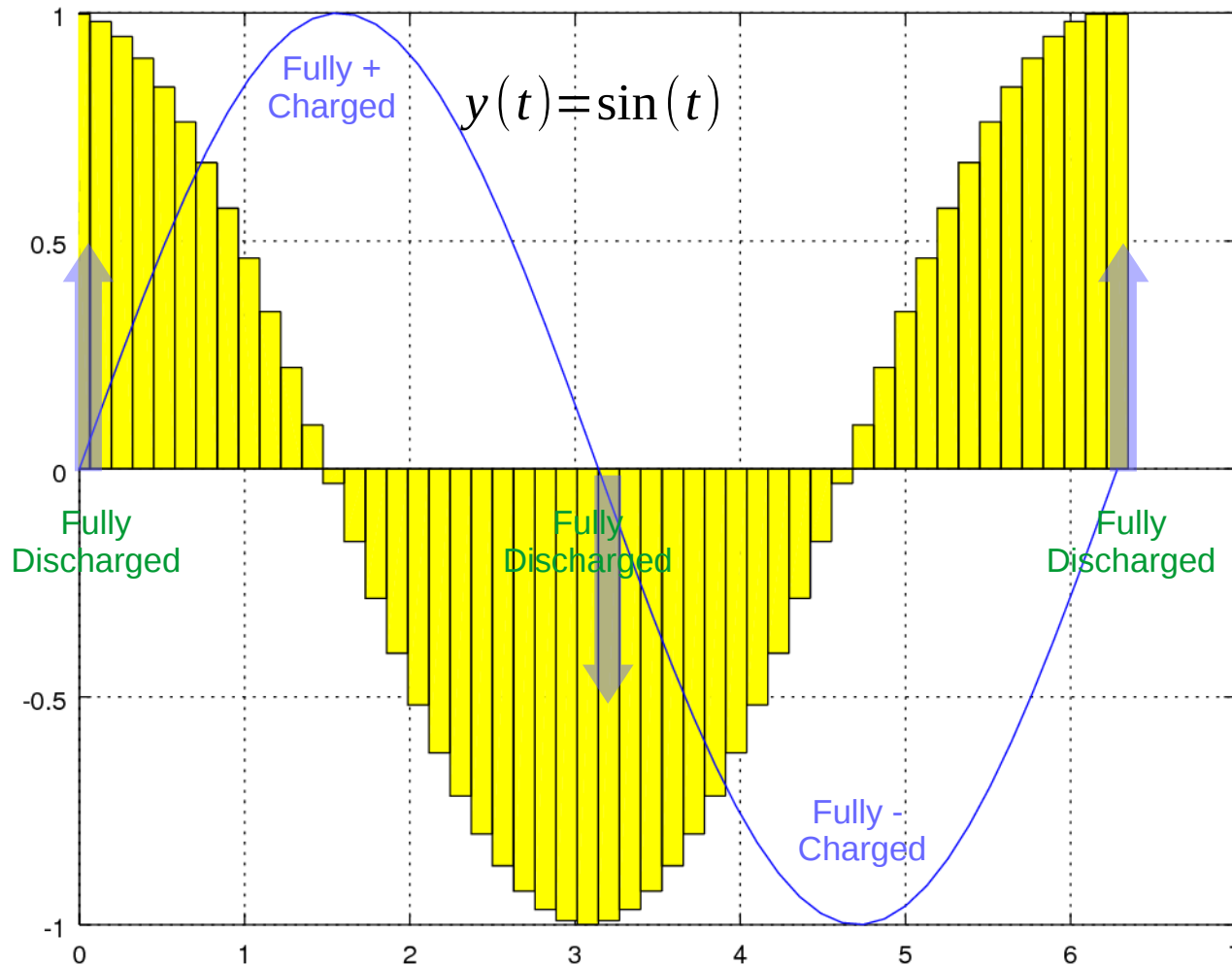
# Fully Charged and Fully Discharged



```
h = bar(t1, [y1' y2'],  
"stacked")  
set(h(1), "facecolor", "g");  
set(h(2), "facecolor", "y");  
hold on  
plot(t1, y1)  
axis([0 7 -1 1]);
```

$$y[n] - y[n+1] = y(nT) - y((n+1)T) = \sin(nT) - \sin((n+1)T)$$

# Fully Charged and Fully Discharged

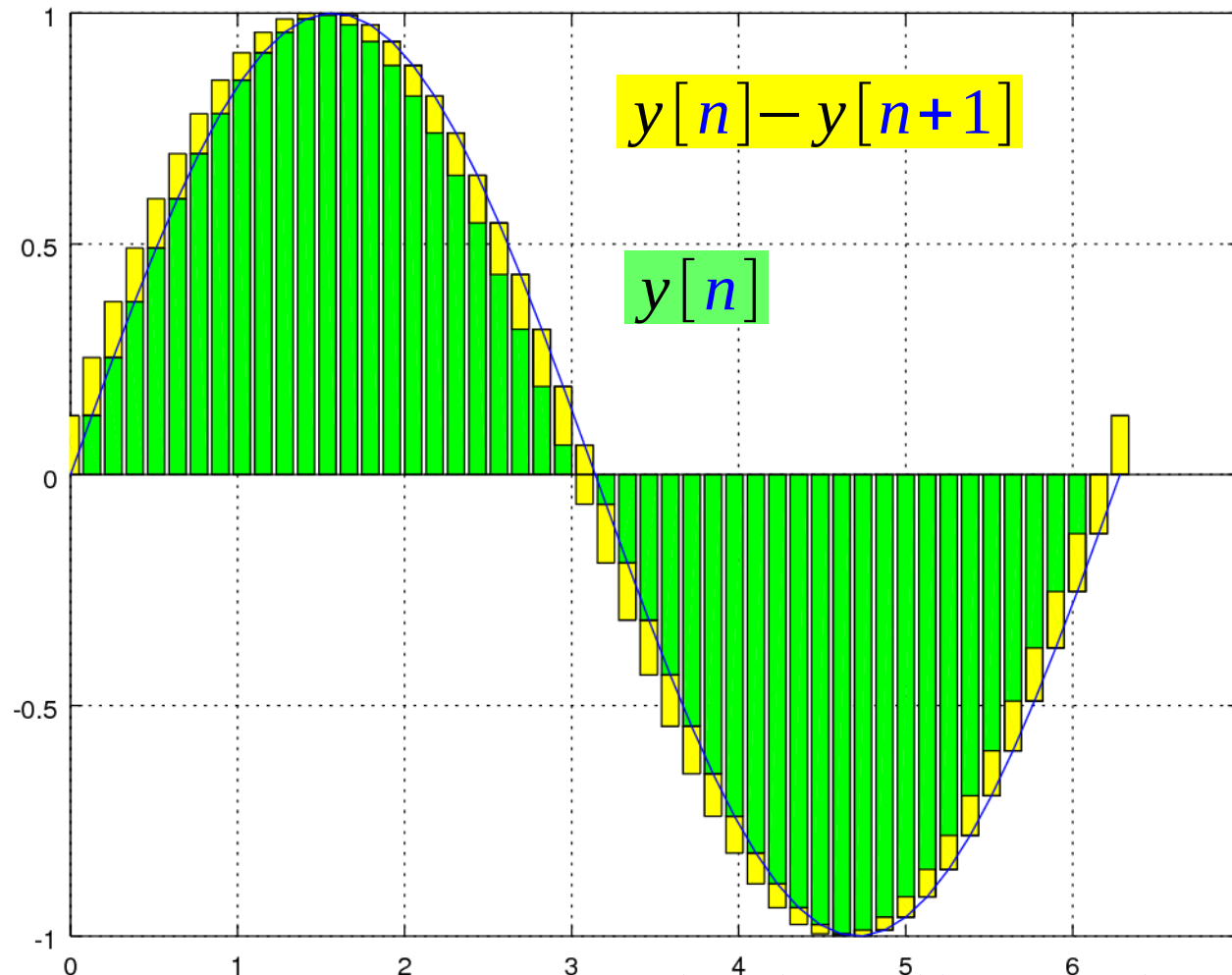


```
h = bar(t1, y2/t(2), "hist")
set(h(1), "facecolor", "y");
hold on
plot(t1, y1)
axis([0 7 -1 1]);
```

$$\frac{y[n] - y[n+1]}{T}$$

$$\propto \frac{dy}{dt}$$

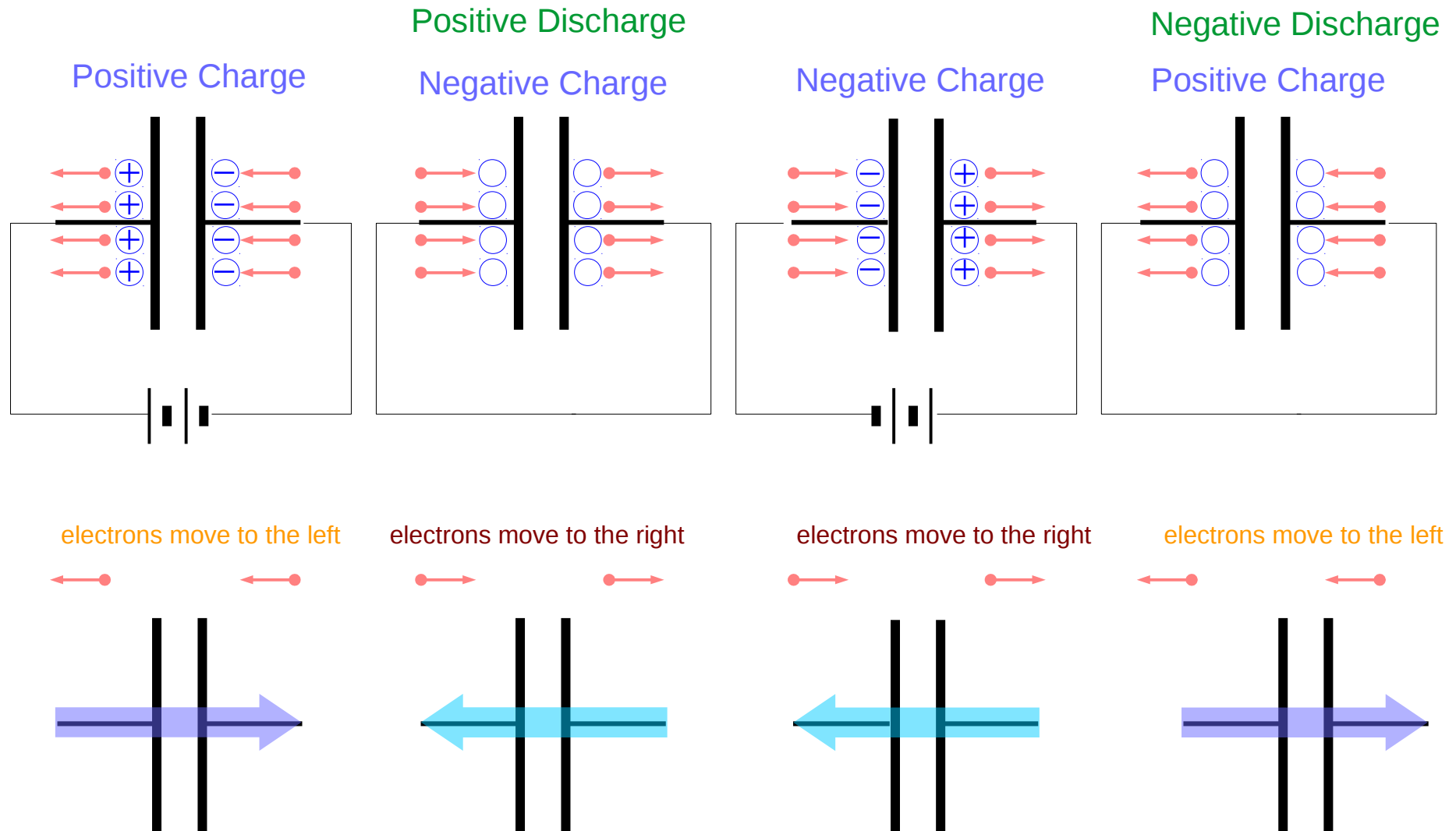
# Fully Charged and Fully Discharged



```
h = bar(t1, [y1' y2'],  
"stacked")  
set(h(1), "facecolor", "g");  
set(h(2), "facecolor", "y");  
hold on  
plot(t1, y1)  
axis([0 pi]);
```

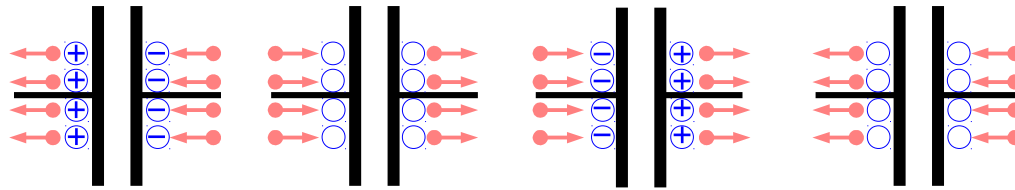
$$y[n] - y[n+1] = y(nT) - y((n+1)T) = \sin(nT) - \sin((n+1)T)$$

# Everchanging signal pairs



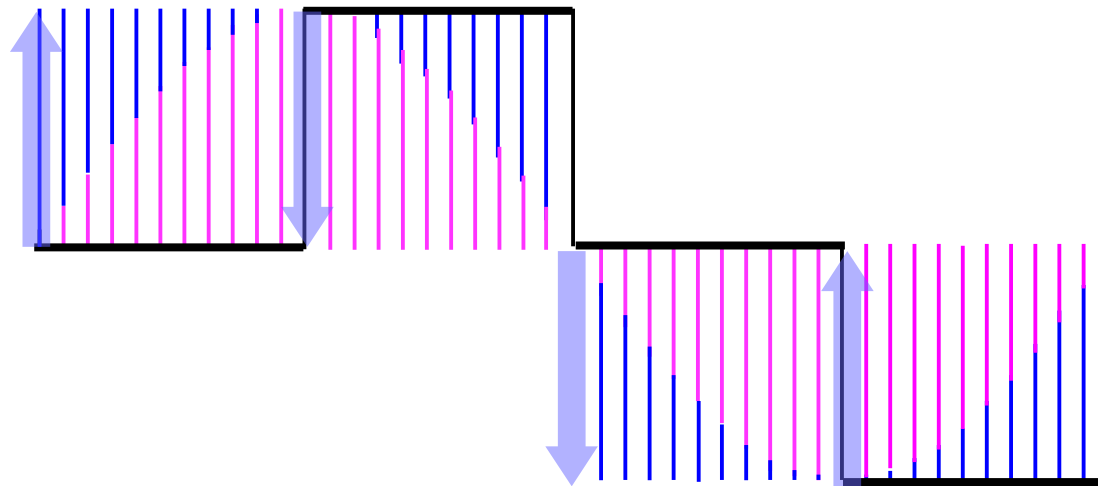


# Everchanging signal pairs



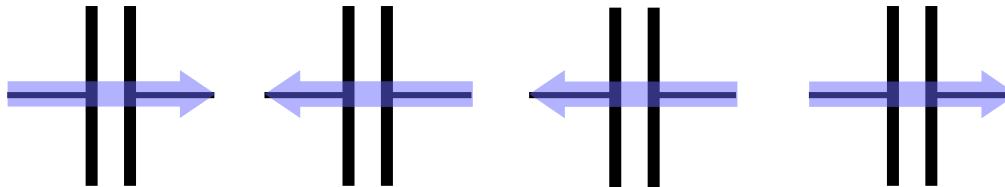
charge

discharge

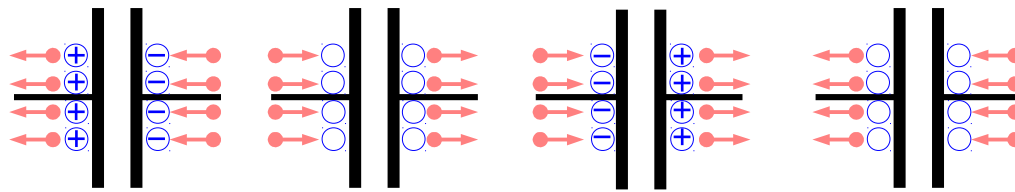


charge

discharge

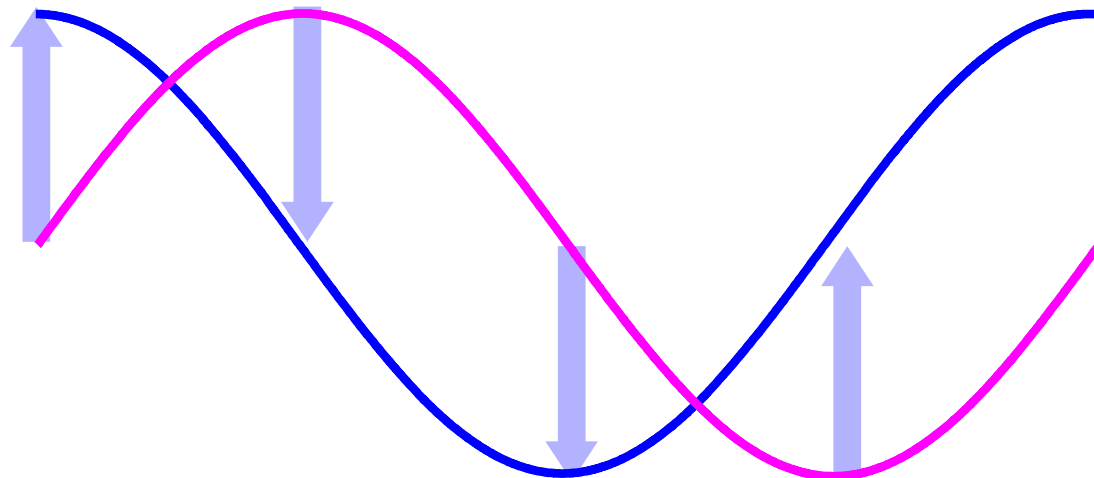


# Everchanging signal pairs



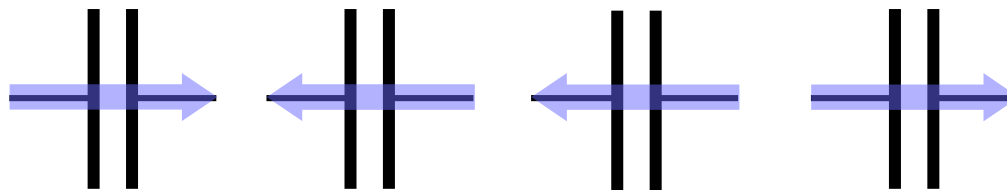
charge

discharge

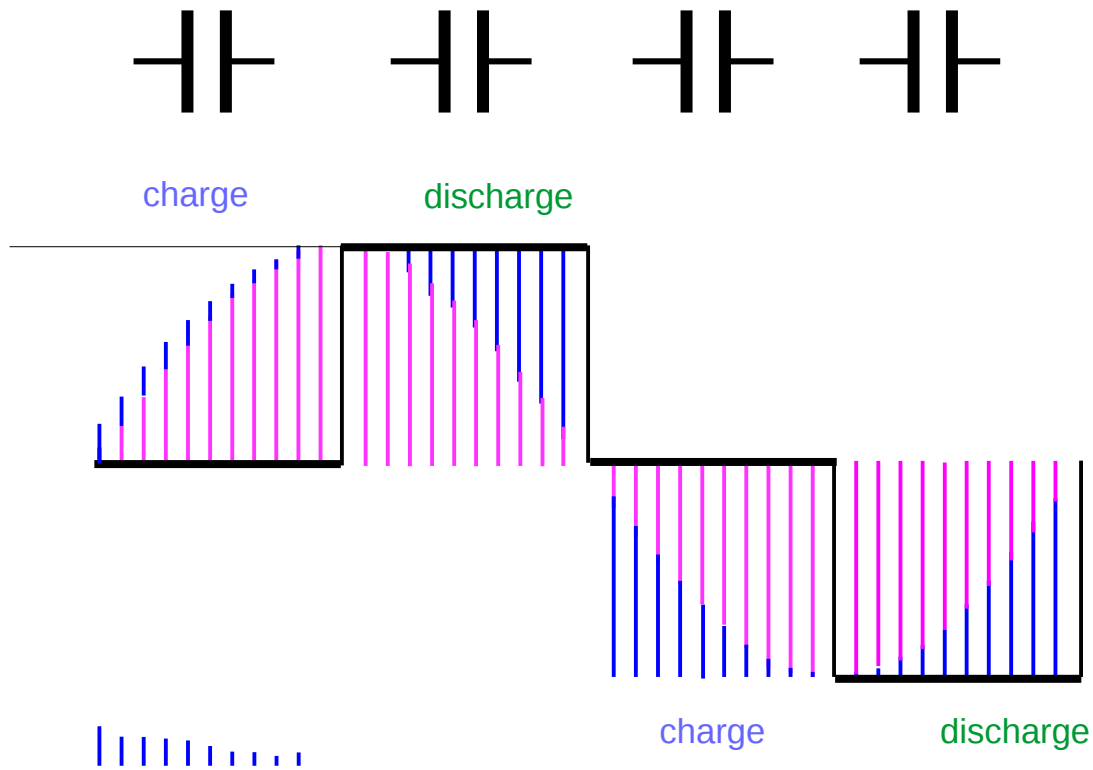


charge

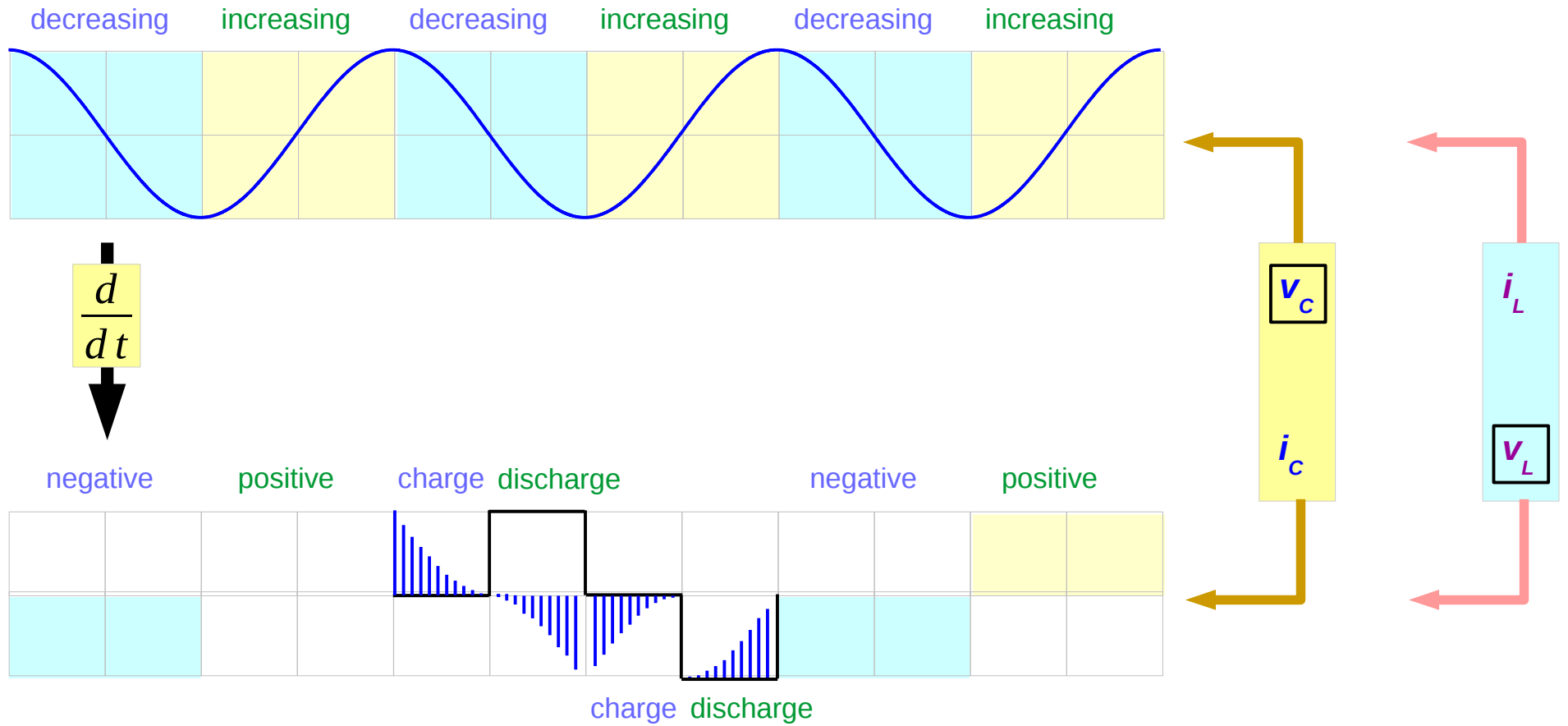
discharge



# Everchanging signal pairs

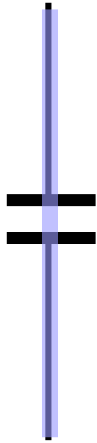


# Everchanging signal pairs



# I leads V by 90°

*Initial charge*

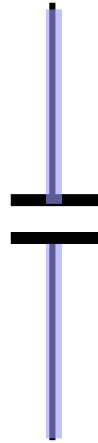


*SHORT*

*V = 0*

*I : peak*

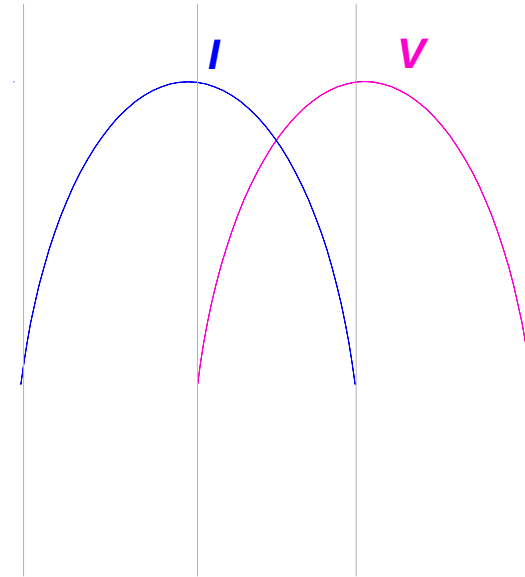
*Full charge*



*OPEN*

*I = 0*

*V : peak*



## References

[1] <http://en.wikipedia.org/>

[2] J.H. McClellan, et al., Signal Processing First, Pearson Prentice Hall, 2003