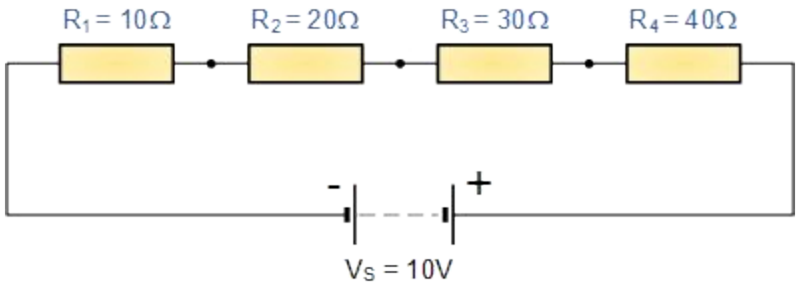
Introduction

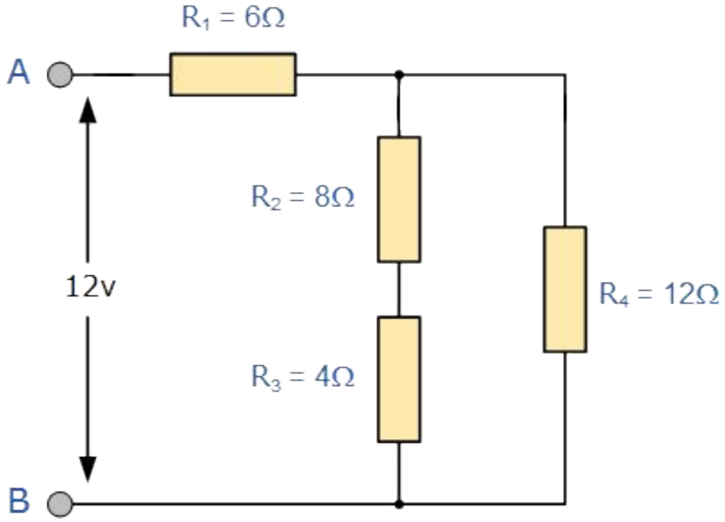
Electrical & Electronic Circuits and Elements

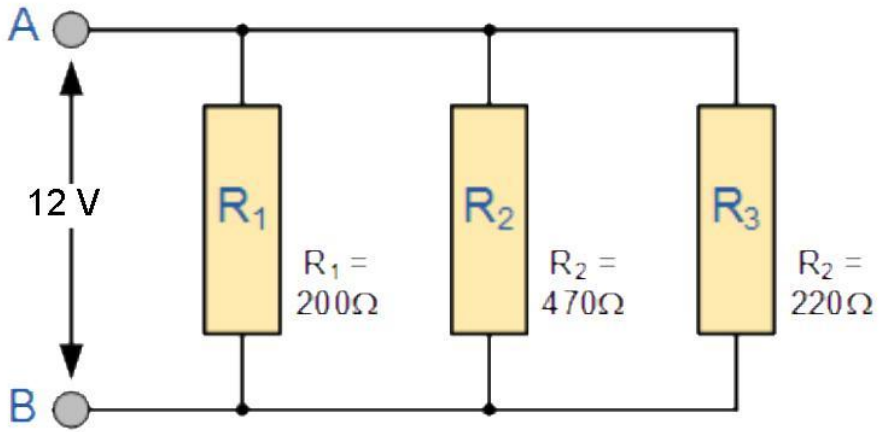
Embedded Systems & Embedded Programming

Fundamentals of Electric Circuits (Resistors)

- ❖ Some applications of KVL, KCL and Ohm's law
  - ➢ Calculate the current and voltage of every resistor
  - ➢ Calculate the power consumed by every circuit







- ❖ Calculate the internal resistance of a 5V battery which can deliver max 10W power

Fundamentals of Electric Circuits (Resistors)

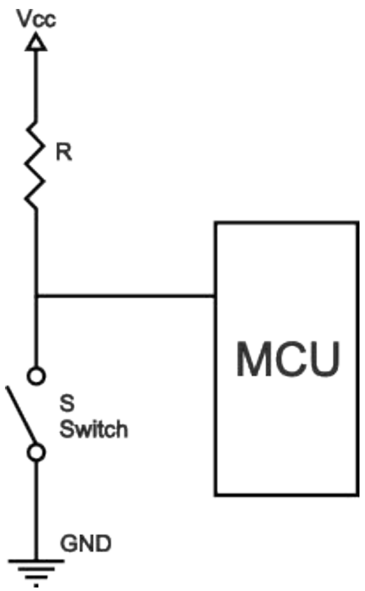
❖ Pull up resistor / Pull down resistor

➢ Logic states of digital circuits

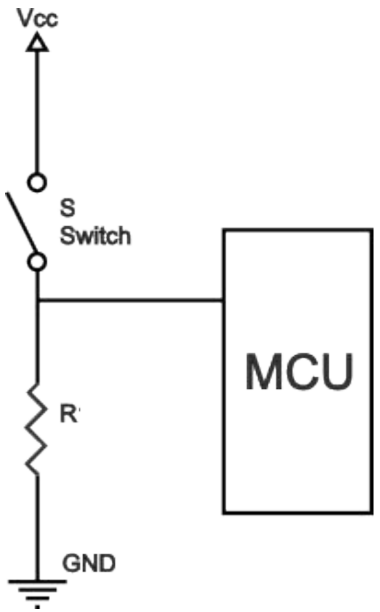
- High (e.g. 2.3 - 3.3 V)
- Low (e.g. 0 - 1.1 V)
- Floating (high impedance)

➢ Resistance value depends on

- Power dissipation
- High/Low of signals level
- Input leakage current
- Speed of the circuit (RC circuit)
- A rule of thumb: at least 10 times smaller than the impedance of the input pin
- 4.7 kΩ is a common pull up resistor



Pull-up resistor



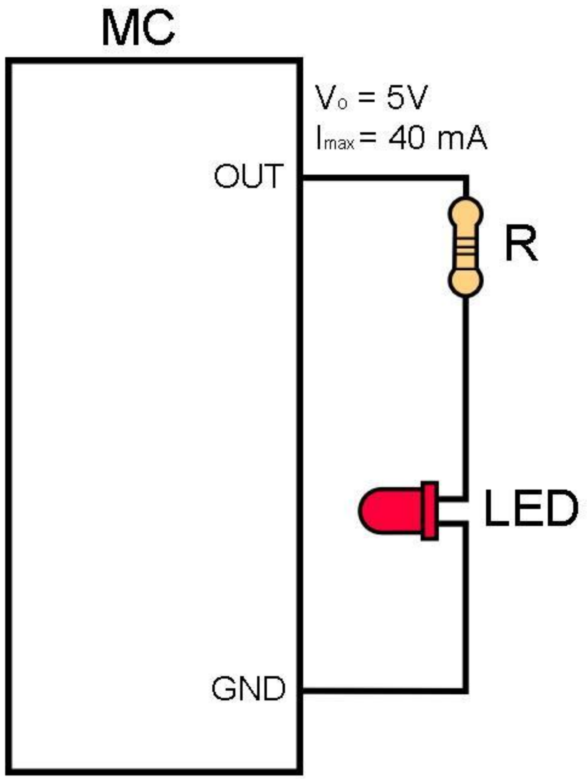
Pull-down resistor

Pull Up Resistor Tutorial   Calculate pull up/down resistors

Fundamentals of Electric Circuits (Resistors)

- LED (Light-Emitting Diode)
  - Why do we need a resistor
    - To limiting the current
  - Why should we have a series circuit
    - To dividing the voltage
  - Calculate the resistance of the resistor
    - If the forward current is 17 mA
    - And forward voltage is 2 V

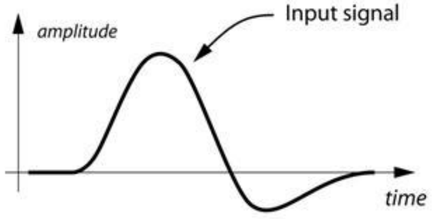
Answer: 176 Ω

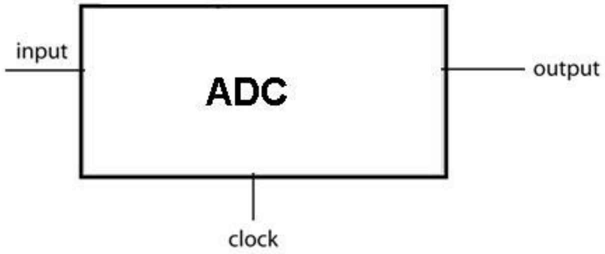


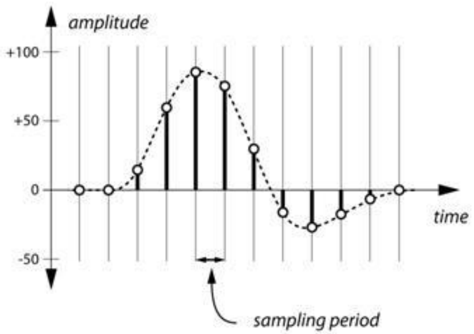
[Datasheet of the LED]

Fundamentals of Electric Circuits (Resistors)

❖ ADC(Analog to Digital Convertor)

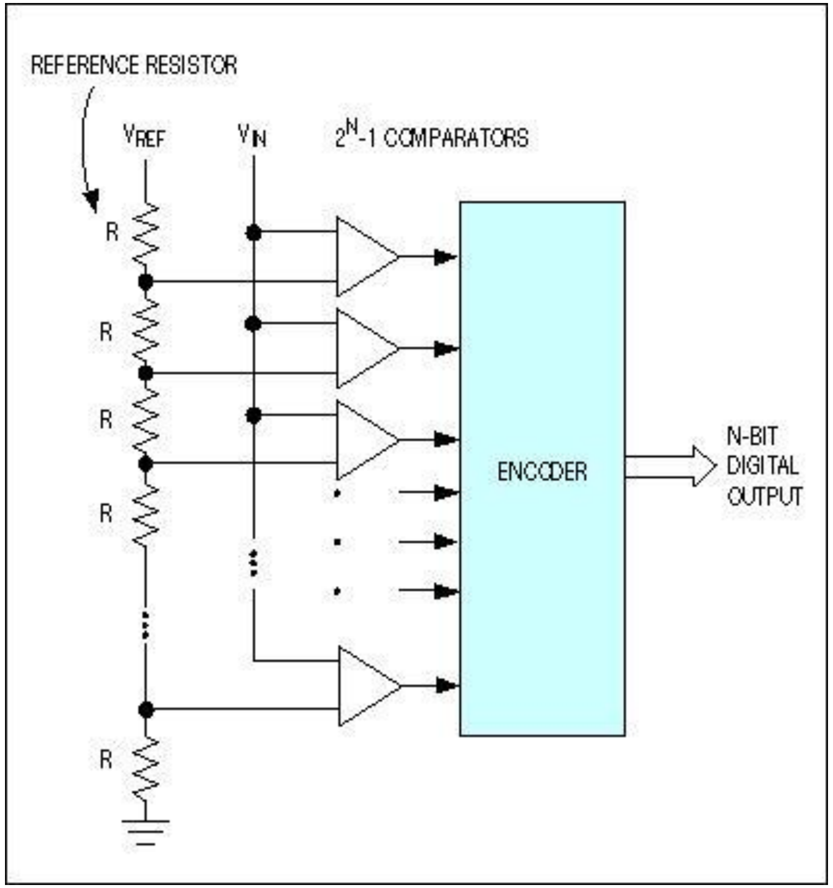






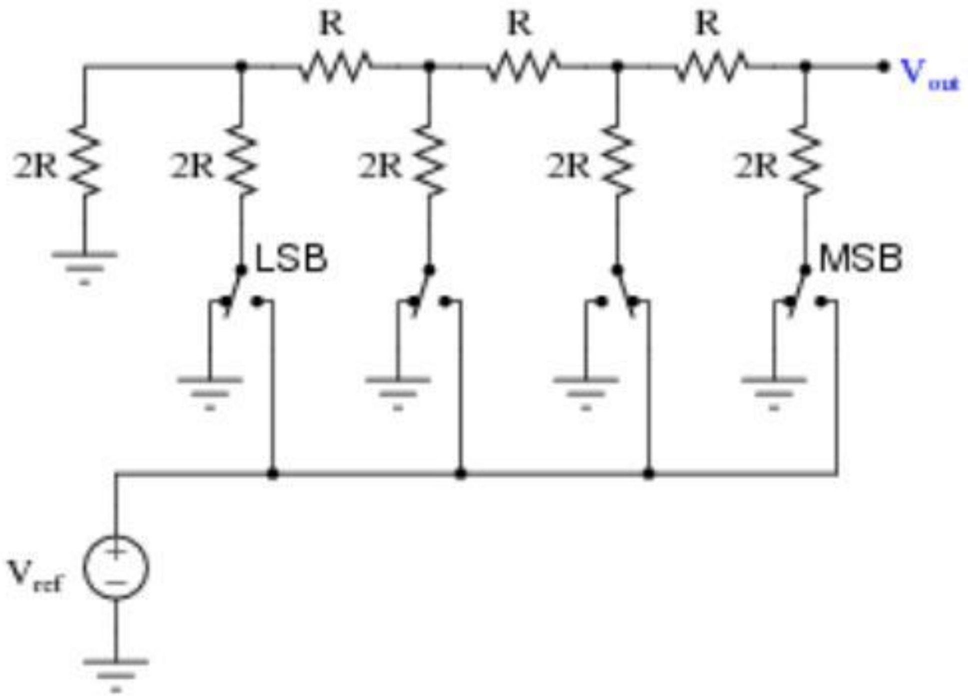
⇨ Sequence of numbers

{…, 0, 0, +15, +60, +85, +72, +28, -17, -30, -21, -8, -1, …}



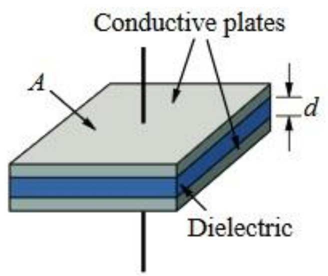
Fundamentals of Electric Circuits (Resistors)

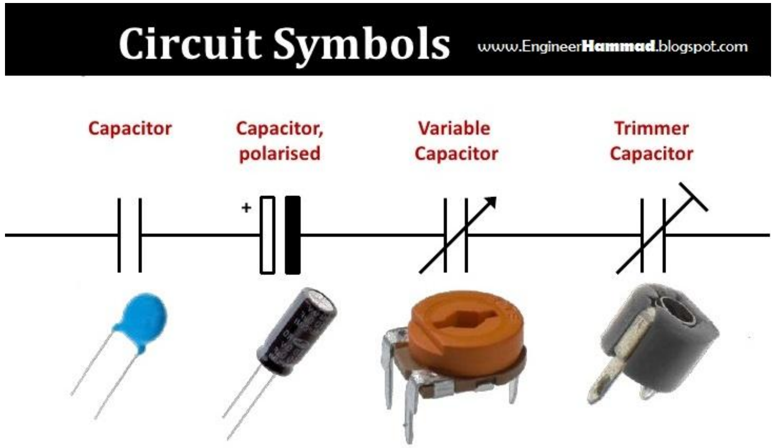
- R-2R ladder network **D**igital to **A**nalog **C**onvertor (DAC)
- Calculate the out voltage
  - If the digital value is 0100
  - If the digital value is 1001
  - Suppose that V_{ref} is 4V



Fundamentals of Electric Circuits (Capacitor)

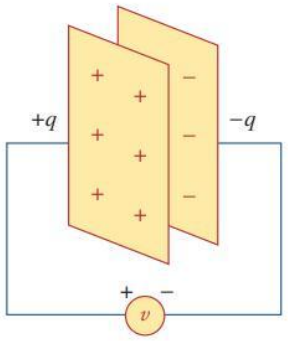
- Is a **passive element** which can **store energy** in its **electric field**
- Consists of two conducting **plates** separated by a **dielectric** (insulator)
- Air, ceramic, electrolyte etc. are used as dielectric
- Application
  - Capacitors in Series
  - Capacitors in Parallel
  - Coupling and Decoupling Capacitors
  - Energy Storage
- Types
  - Fixed Capacitors (the conducting surfaces are not adjustable)
  - Variable Capacitors (their capacitance can be changed mechanically or electronically, e.g. keypad)





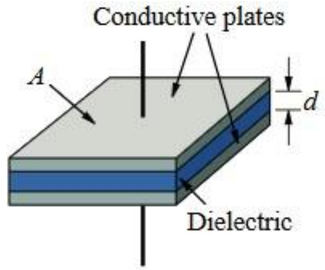
Fundamentals of Electric Circuits (Capacitor)

- By connecting to a voltage source it stores charge on the plates
- The amount of stored charge (q) is directly proportional to the applied voltage (v)
- Capacitance (C)
  - The amount of stored charge per plate for a unit voltage difference in a capacitor
  - More capacitance means more capacity to store charge
  - Its unit is **farads** (F) and can be measured by a **capacitance meter**
  - Depends on the permittivity of the dielectric and the physical dimensions of the capacitor



$$C = \varepsilon A/d$$

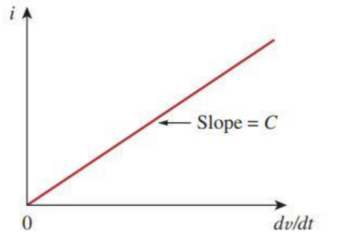
C: capacitance (F)
ε: permittivity of the dielectric
A: plate area
d: distance between the plates



$$q \propto V \longrightarrow q = CV$$

$$\frac{dq}{dt} = C\frac{dv}{dt} \longrightarrow I(t) = C\frac{dv}{dt}$$

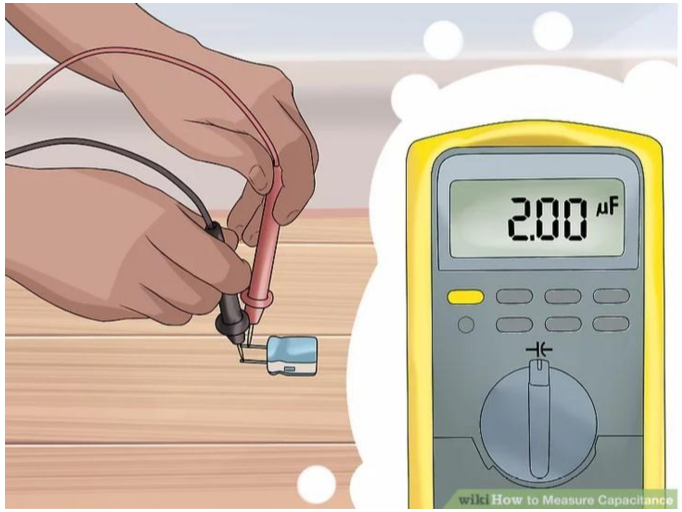
$$W_C(t) = \frac{1}{2}Cv_C^2(t)$$ Energy stored in a capacitor (J)

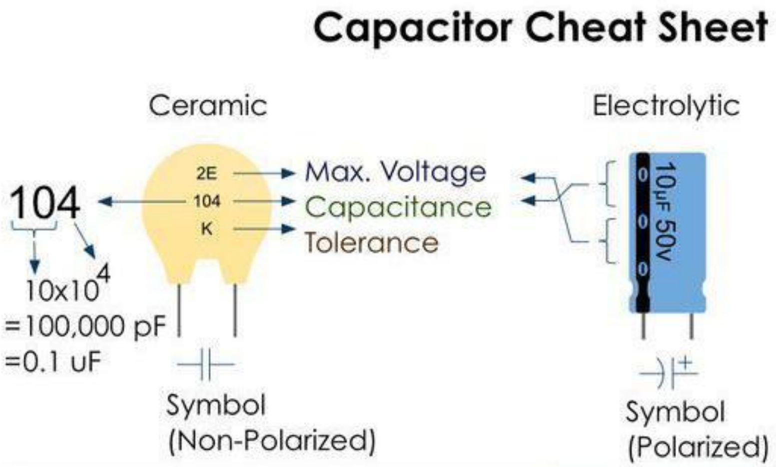


Current-voltage relationship of a capacitor.

Fundamentals of Electric Circuits (Capacitor)

- Capacitance (C) can be measured by
  - A capacitance meter
  - [Online calculator]
  - A cheat sheet





Capacitance Conversion Values

Microfarads (µF)	Nanofarads (nF)	Picofarads (pF)
0.000001 µF	0.001 nF	1 pF
0.00001 µF	0.01 nF	10 pF
0.0001 µF	0.1 nF	100 pF
0.001 µF	1 nF	1,000 pF
0.01 µF	10 nf	10,000 pF
0.1 µF	100 nF	100,000 pF
1 µF	1,000 nF	1,000,000 pF
10 µF	10,000 nF	10,000,000 pF
100 µF	100,000 nF	100,000,000 pF

Tolerance

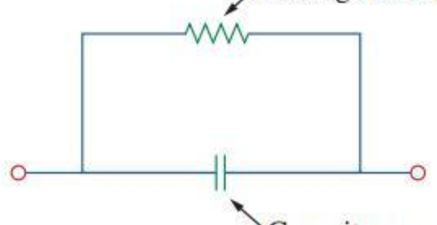
Code	Percentage
B	± 0.1 pF
C	±0.25 pF
D	±0.5 pF
F	±1%
G	±2%
H	±3%
J	±5%
K	±10%
M	±20%
Z	+80%, -20%

Max. Voltage

Code	Max. Voltage
1H	50V
2A	100V
2T	150V
2D	200V
2E	250V
2G	400V
2J	630V

Fundamentals of Electric Circuits (Capacitor)

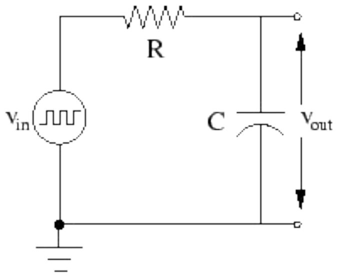
- ❖ A capacitor is an open circuit to dc voltage ($i = 0$)
- ❖ The voltage on a capacitor cannot change suddenly
  - ➢ Discontinuous change in the voltage requires an infinite current
- ❖ The ideal capacitor does not consume energy
  - ➢ Takes power from the circuit when storing energy (charging)
  - ➢ Returns previously stored energy when delivering power to the circuit (discharging)
- ❖ A real capacitor has a parallel-model leakage resistance (100 MΩ)

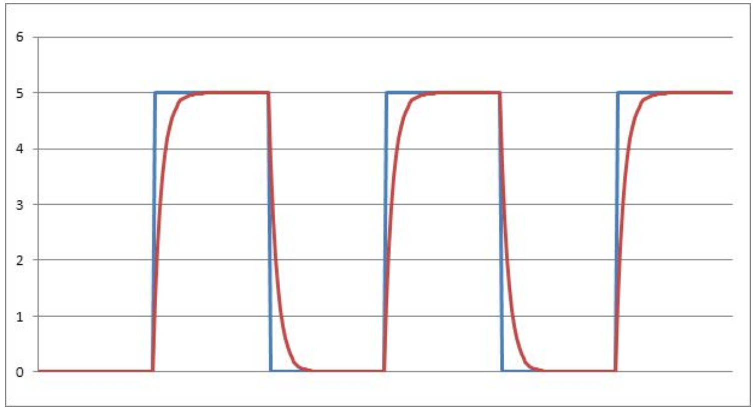


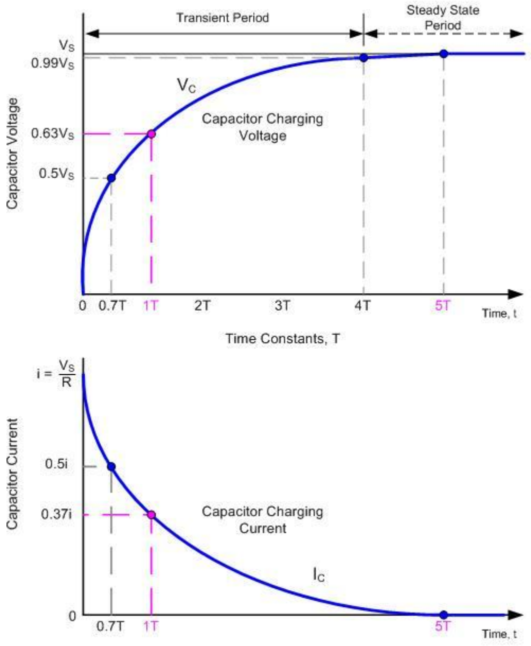
Circuit model of a nonideal capacitor.

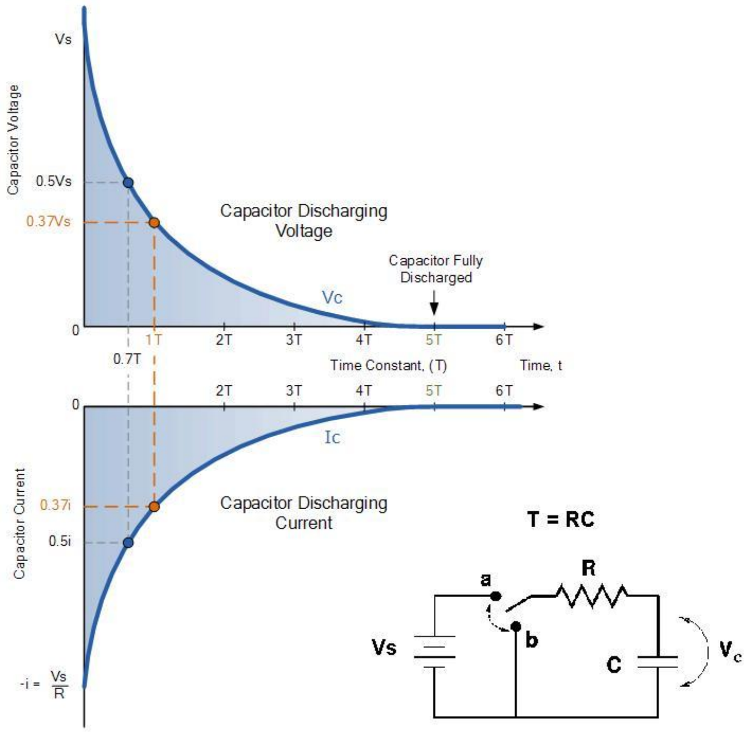
Fundamentals of Electric Circuits (Capacitor)

- ❖ Charge and discharge
- ❖ AC, puls and noise responses





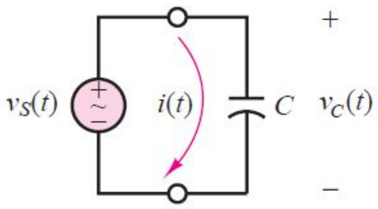




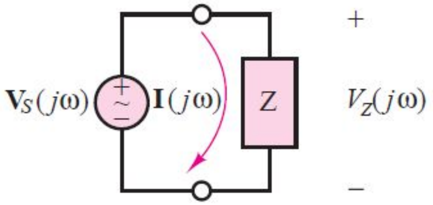
[Capacitors and Capacitance](#)

Fundamentals of Electric Circuits (Capacitor)

- Impedance (or complex resistance)
  - Is the **frequency-dependent** resistance of a load
  - Is the generalized version of the ohm's law
  - Is the i-v relationship of a load
  - Is measured in ohm(Ω)
  - Is represented by **Z** (Z = R + jX, X is the reactance)
- Impedance of a resistor is **R** and impedance of a capacitor is $\dfrac{1}{sC}$
  - Where ***s*** is the complex frequency of the source signal
  - ***s*** for a **DC** signal is **0** and for a **sinusoidal AC** signal is ***jω***
    - $\omega = 2\pi f$ where f is the frequency of the signal



AC circuits

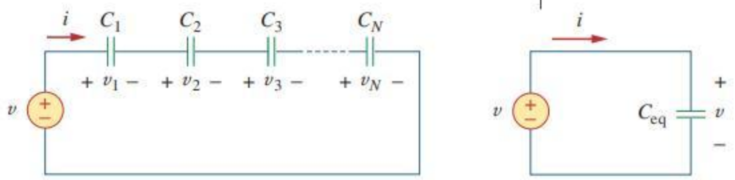


AC circuits in phasor/impedance form

Fundamentals of Electric Circuits (Capacitor)

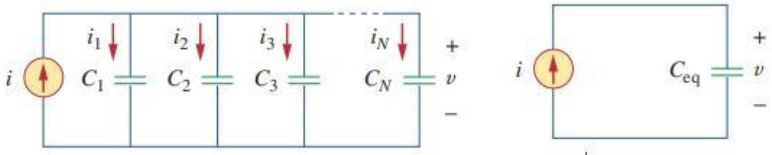
- ❖ Capacitors in Series
  - ➢ Capacitive voltage divider
  - ➢ Filter out the DC component in a signal (Coupling capacitors)
- ❖ Capacitors in Parallel
  - ➢ DC power supplies
  - ➢ Filter out the AC component (decoupling/bypass capacitors)
- ❖ Capacitors used for energy storage
  - ➢ Audio equipment, UPS, camera flash etc.

[Read more about capacitors at Capacitor Guide]



$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots + \frac{1}{C_N}$$

$$Q_{total} = Q_1 = Q_2 = \ldots = Q_n$$



$$C_{eq} = C_1 + C_2 + C_3 + \cdots + C_N$$

$$V_1 = V_2 = \ldots = V_n$$

$$Q = Q_1 + Q_2 + \ldots + Q_n$$

Yrkes Akademin
Vi hjälper dig att lyckas!

Fundamentals of Electric Circuits

- References

  - Fundamentals of Electric Circuits, 5th Edition, Charles K. Alexander and Matthew N.O. Sadiku, ISBN 978-0-07-338057-5
  - Fundamentals of Electrical Engineering, First Edition, Giorgio Rizzoni, ISBN 978-0–07–338037–7

  - ***Most of the images have been copied from these two books***

- Some useful links
  - Light-Emitting Diodes (LEDs)
  - Decoupling Capacitors
  - 5 Lighting Terms You Should Know
  - Impedance and Reactance

The SI prefixes.

Multiplier	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a