
Al's Electronic Class Room

Understanding Voltage

AC Voltage

- AC Voltage Current flows in Both Directions.
- The Voltage that is brought into our home, 120 RMS VAC at 60 Hz
- Easier to transport over long distance Then DC Voltage

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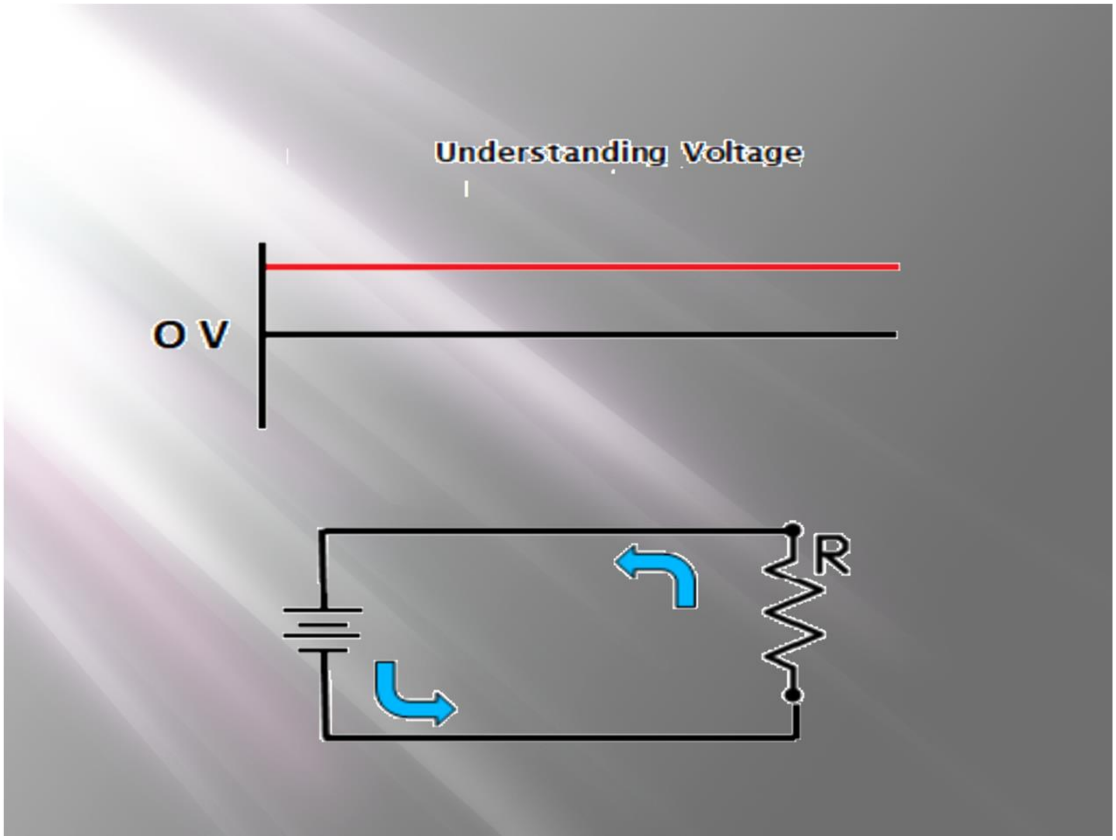
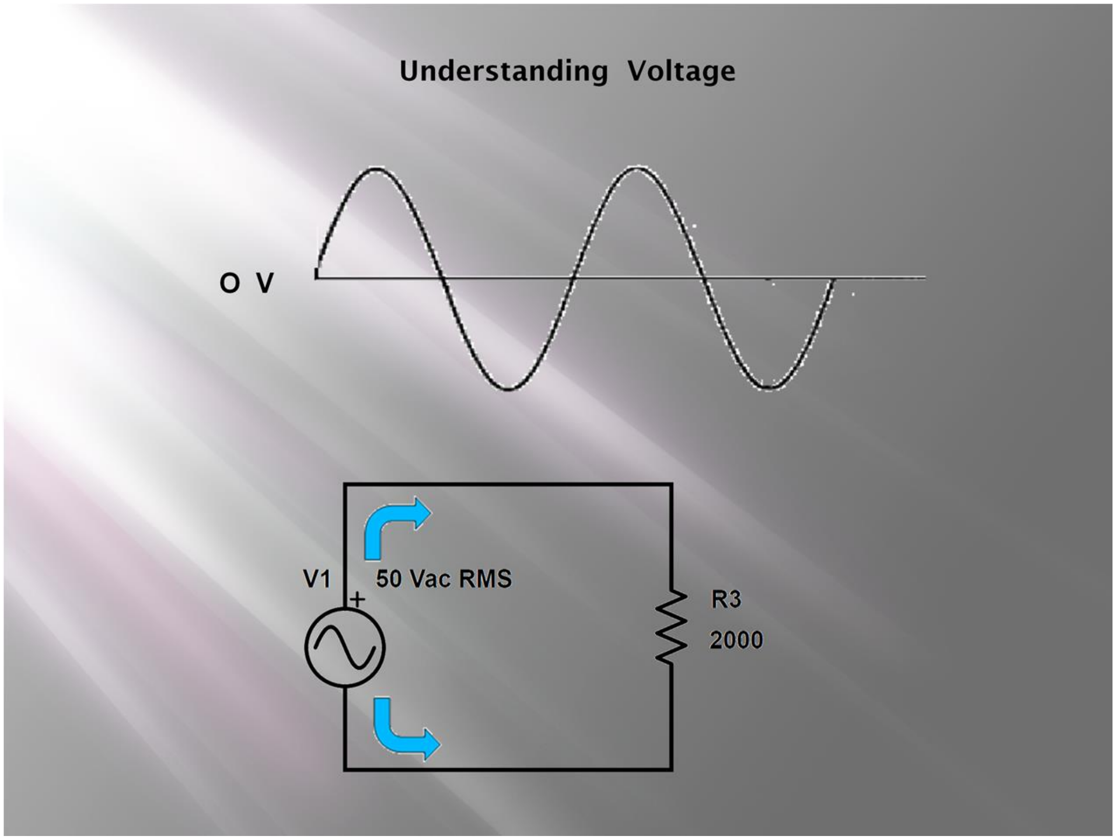
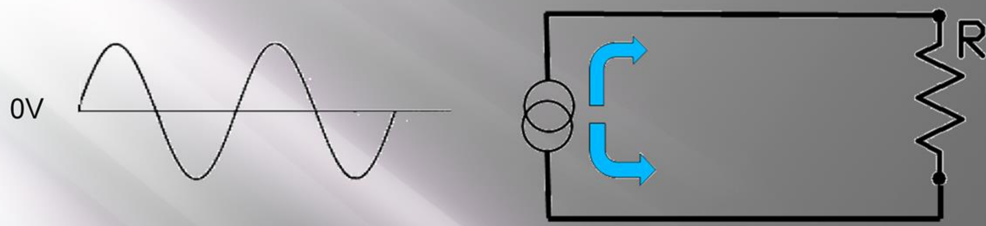

Understanding Voltage
O V
R


Understanding Voltage
O V
V1
50 Vac RMS
R3
2000

Understanding Voltage



- The hertz (symbol: Hz) is the derived unit of frequency is defined as one cycle per second.
- It is named for Heinrich Rudolf Hertz, the first person to provide conclusive proof of the existence of electromagnetic waves.
- Hertz are commonly expressed in multiples: kilohertz (kHz), megahertz(MHz),gigahertz (GHz), and terahertz (THz).

Understanding Voltage

What is RMS Voltage AC ?

Root-Mean-Square

- **Take The Square of each Individual Value (Square).**
- **Adding the Squares Dividing the Sum by the Number of Values (Mean).**
- **Take the Square Root of this Value is the RMS Value (Root)**

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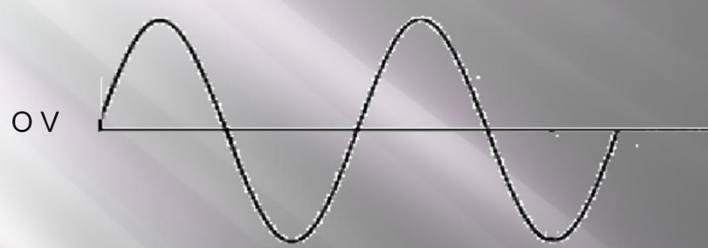
Understanding Voltage



Understanding Voltage,

What is RMS Voltage AC ?

Root-Mean-Square

Example: Find the RMS Value of 2,3,4

- **Take The Square of Each Value $2^2 = 4$, $3^2 = 9$, $4^2 = 16$**
- **Find the Mean (Average) , 4 + 9 + 16 / 3= 29/3= 9.67**
- **Root Square Root of 9.67, $\sqrt{9.67}$ = RMS Value 3.11**

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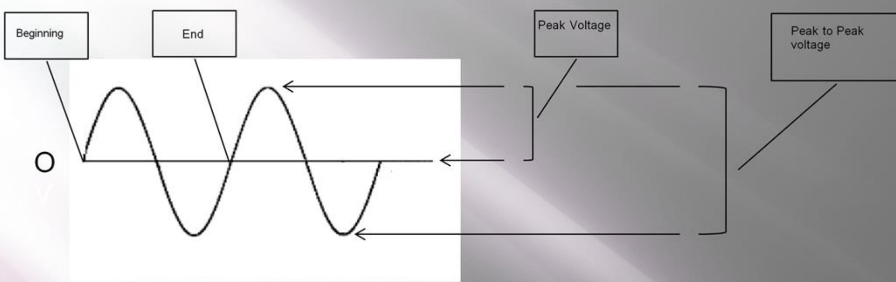
Understanding Voltage



- 120 VAC RMS at 60 Hz.
- Peak Voltage Equals 1.414 x RMS
- Peak to Peak Voltage equals 2.828 x RMS or 2 x Peak Voltage
- RMS Voltage Equals .707 x Peak Voltage
- 1/T = F & 1/F = T

Understanding Voltage

- 120 VAC RMS at 60 Hz.
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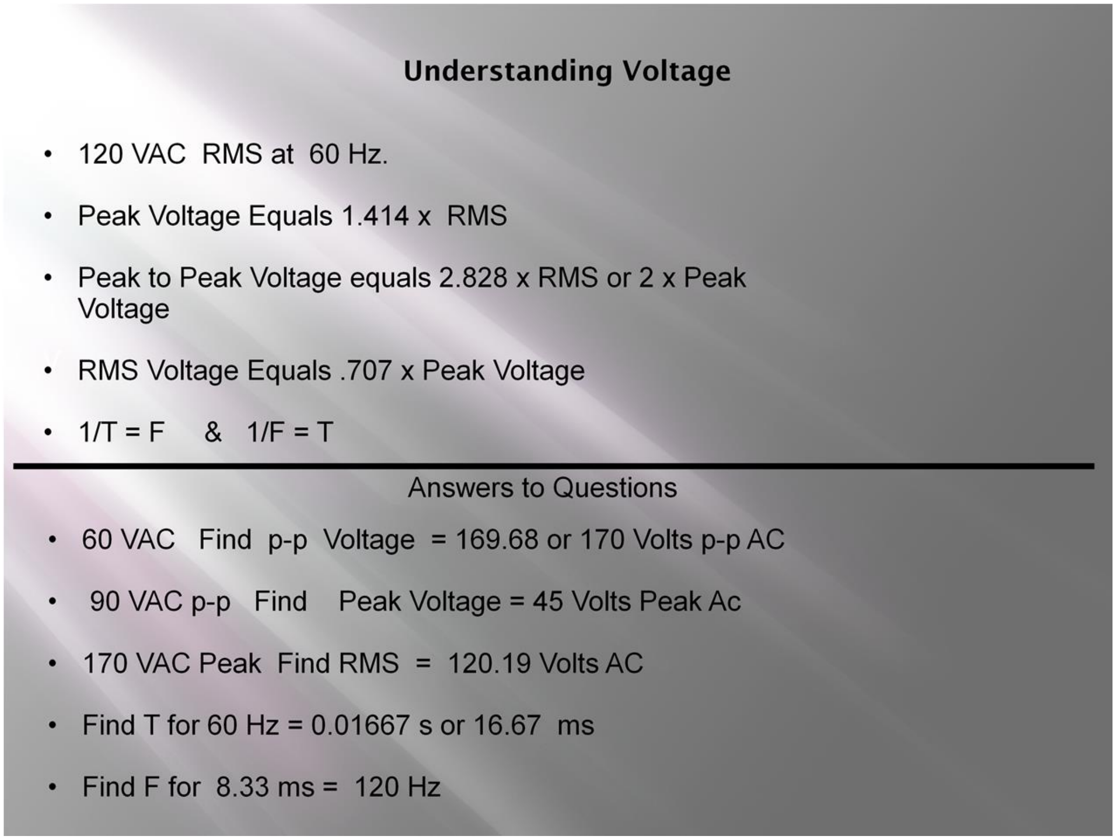
- RMS Voltage Equals .707 x Peak Voltage
- 1/T = F   &   1/F = T

Questions

- 60 VAC   Find p-p Voltage =
- 90 VAC p-p   Find   Peak Voltage =
- 170 VAC Peak Find RMS =
- Find T for 60 Hz =
- Find F for 8.33 ms =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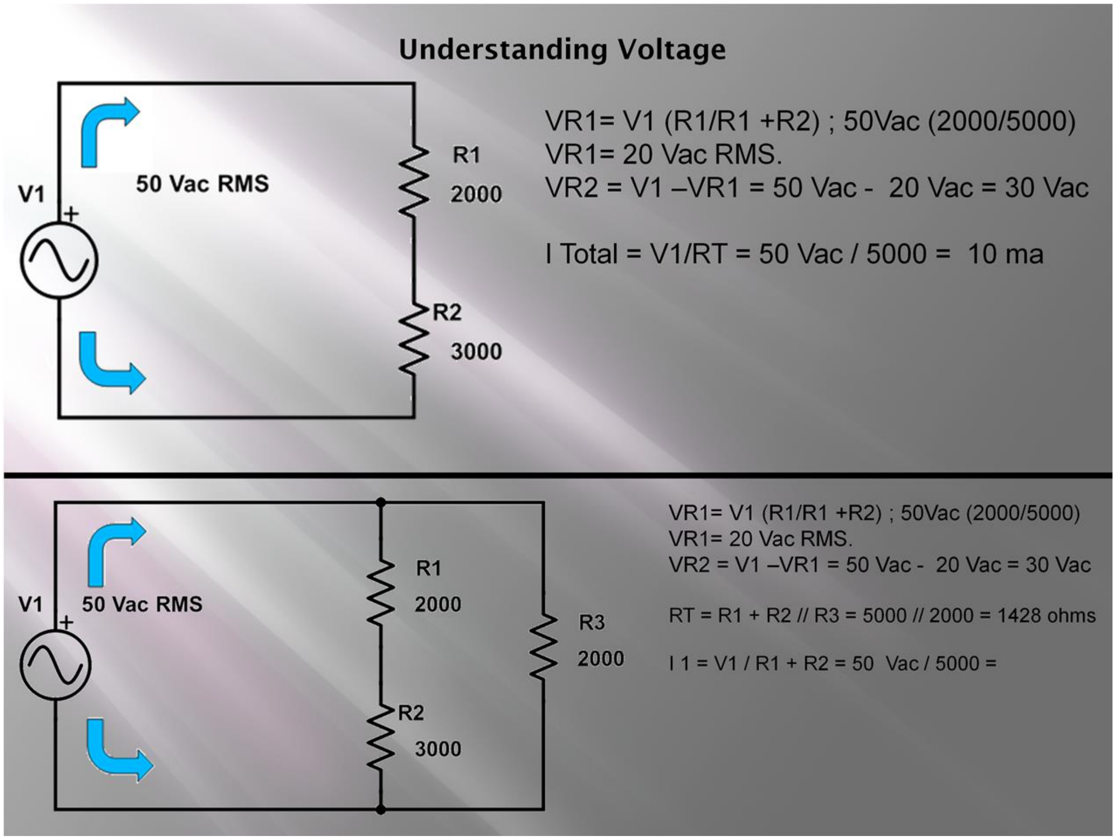
• 1/T = F & 1/F = T
Answers to Questions
• 60 VAC Find p-p Voltage = 169.68 or 170 Volts p-p AC
• 90 VAC p-p Find Peak Voltage = 45 Volts Peak Ac
• 170 VAC Peak Find RMS = 120.19 Volts AC
• Find T for 60 Hz = 0.01667 s or 16.67 ms
• Find F for 8.33 ms = 120 Hz


Understanding Voltage
V1
50 Vac RMS
R1
2000
R2
3000
VR1= V1 (R1/R1 +R2) ; 50Vac (2000/5000)
VR1= 20 Vac RMS.
VR2 = V1 –VR1 = 50 Vac - 20 Vac = 30 Vac
I Total = V1/RT = 50 Vac / 5000 = 10 ma
V1
50 Vac RMS
R1
2000
R2
3000
R3
2000
VR1= V1 (R1/R1 +R2) ; 50Vac (2000/5000)
VR1= 20 Vac RMS.
VR2 = V1 –VR1 = 50 Vac - 20 Vac = 30 Vac
RT = R1 + R2 // R3 = 5000 // 2000 = 1428 ohms
I 1 = V1 / R1 + R2 = 50 Vac / 5000 =

Understanding Voltage

Conversions:

1 Volt = 1000 milli Volts or 1000000 u Volts or Micro Volts;

Powers of 10; $1x10^{-3}$ is milli; $1x10^{-6}$ μ or micro

1000 Volts = 1 Kilo Volts ; 1 KV Powers of 10 : $1x10^{+3}$

1000000 Volts = 1 Mega Volts : Powers of 10 : $1x10^{+6}$

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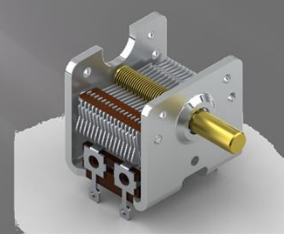
Capacitance

- Capacitors have two Metal plates as shown in the diagram
- Dielectric Material (which is a type of insulator is placed in between the plates).
- Types of Dielectric Materials are air, Mica or Paper.
- Free Electrons cannot flow thru a insulator the Capacitor holds a charge.

Schematic Symbols of a Capacitor

Non Polarized **Polarized** **Variable**



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Capacitance

Type of Dielectrics:

DIELECTRIC MATERIALS
Air
Alsimag 196
Bakelite
Cellulose
Fiber
Formica
Glass
Mica
Mycalex
Paper
Plexiglass
Polyethylene
Polystyrene
Porcelain
Pyrex
Quartz
Steatite
Teflon

- Capacitor will Charge instantly
- The Voltage Across the Capacitor Equals the Voltage Source.
- Electrons are redistributed on the Capacitor

Charge on the Capacitor is $Q=CV$

Where: Q is Coulombs

C is the Value Of Capacitance Measured in Farads

V is the voltage across the capacitor

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Charge on the Capacitor is   Q=CV
Where: Q is Coulombs
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V is the voltage across the capacitor

1 Coulomb of Charge is defined of having an imbalance of Electrons on a capacitor of 6.25×10^{18} Electrons.

Capacitors are measured in Micro Farads Abbreviated *u*f (10^{-6}) & Pico Farads *p*F (10^{-12}), Also Capacitors have a working Voltage rating. Ex 47 uf 50WVDC

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Capacitance

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Charge on the Capacitor is   Q=CV
Where: Q is Coulombs
C is the Value Of Capacitance Measured in Farads
V is the voltage across the capacitor

Problem: Charge Stored In a 2 uF capacitor at 50 VDC across it.
Q= 2×10^{-6} x 50 VDC = 100×10^{-6} = 100×10^{-6} Coulombs
Problem: Charge Stored In a 2 uF capacitor at 50 VDC across it.
Q= 40×10^{-6} x 50 VDC = 2000×10^{-6} = 2000×10^{-6} Coulombs

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Charge on the Capacitor is Q=CV
Where: Q is Coulombs
C is the Value Of Capacitance Measured in Farads
V is the voltage across the capacitor

I = Q/t
Where: I is Current
t is Time
Q is Charge in Coulombs

Problem:

2 *u*A of Current Charges a Capacitor for 20 Seconds
Find Q: Q = I x t ; 2 x 10 $^{-6}$ x 20 = 40 x 10 or 40 *u*C

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Capacitance

Schematic Symbols of a Capacitor

Dielectric

1 Coulomb of Charge is defined of having an imbalance of Electrons on a capacitor of 6.25×10^{18} Electrons.

Capacitors are measured in Micro Farads Abbreviated *uf* (10^{-6}) & Pico Farads *nF* (10^{-12})

I = Q/t
Where: I is Current
t is Time
Q is Charge in Coulombs

Charge on the Capacitor is Q=CV
Where: Q is Coulombs
C is the Value Of Capacitance Measured in Farads
V is the voltage across the capacitor

Problem:

2 *u*A of Current Charges a Capacitor for 20 Seconds
Find Q: Q = I x t ; $2 \times 10^{-6} \times 20 = 40 \times 10$ or 40 *u*C

Find value of Capacitance from above Problem; v = 20 Vdc
C= Q/V ; $40 \text{ X } 10^{-6}$ / 20 Vdc = 2×10^{-6} ; 2 *u*F

Current of 5 ma Charges a10 uf for 1 sec. Find V across the Capacitor: Q= I x t ; $5 \times 10^{-3} \times 1 = 5 \times 10^{-3}$ Coulombs.
Q/C = V ; $5 \times 10^{-3} / 10 \times 10^{-6} = 0.5 \times 10^{3}$ 500 volts

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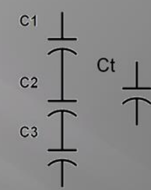
Capacitance

- **Capacitors in Series add Indirectly**

C1= 10 uF ; C2 = 10 uF ; C3 = 5 uF

$$\frac{1}{\frac{1}{C1}+\frac{1}{C2}+\frac{1}{C3}} = \frac{1}{\frac{1}{10x10^{-6}}+\frac{1}{10x10^{-6}}+\frac{1}{5\,x10^{-6}}} = 2.\,5 \text{ uf}$$

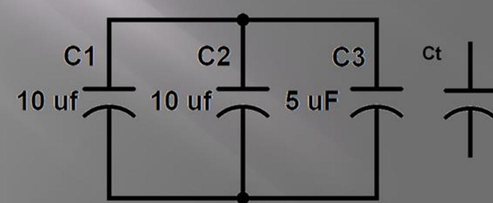


- **Capacitors in Parrallel add directly**

C1= 10 uF ; C2 = 10 uF ; C3 = 5 uF

$$C1 + C2 + C3 = Ct$$

10uf + 10 uf + 5 uf = 25 uf



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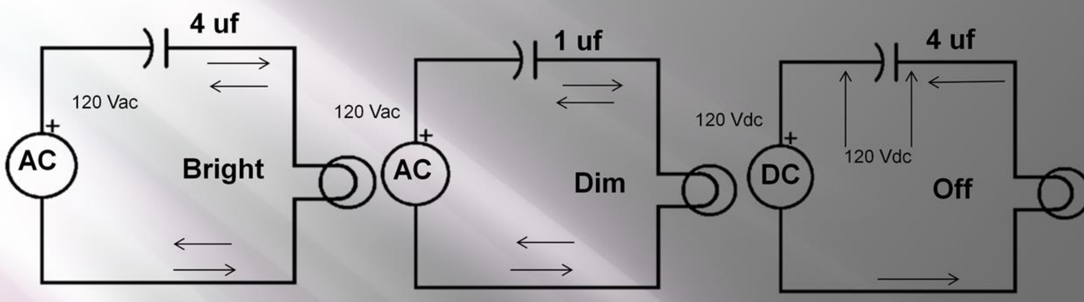
Capacitance

$$\frac{1}{2\pi fc} = X_c \;;\; \pi = 3.14$$

Capacitance Reactance



$$\frac{1}{2\pi fc} = \frac{1}{6.28\,(60)(4 \times 10^{-6})} = 663\ \Omega$$

$$\frac{1}{2\pi fc} = \frac{1}{6.28\,(60)(1 \times 10^{-6})} = 2652\ \Omega$$

Open Circuit

- Alternating current flows in a capacitive circuit with ac voltage applied.
- A smaller capacitance allows less current, which means more Xc with more ohms of opposition.
- Lower Frequencies for the applied voltage results in less current and more Xc. With DC voltage which has a frequency of “0” Xc is infinite and no current flows in circuit.

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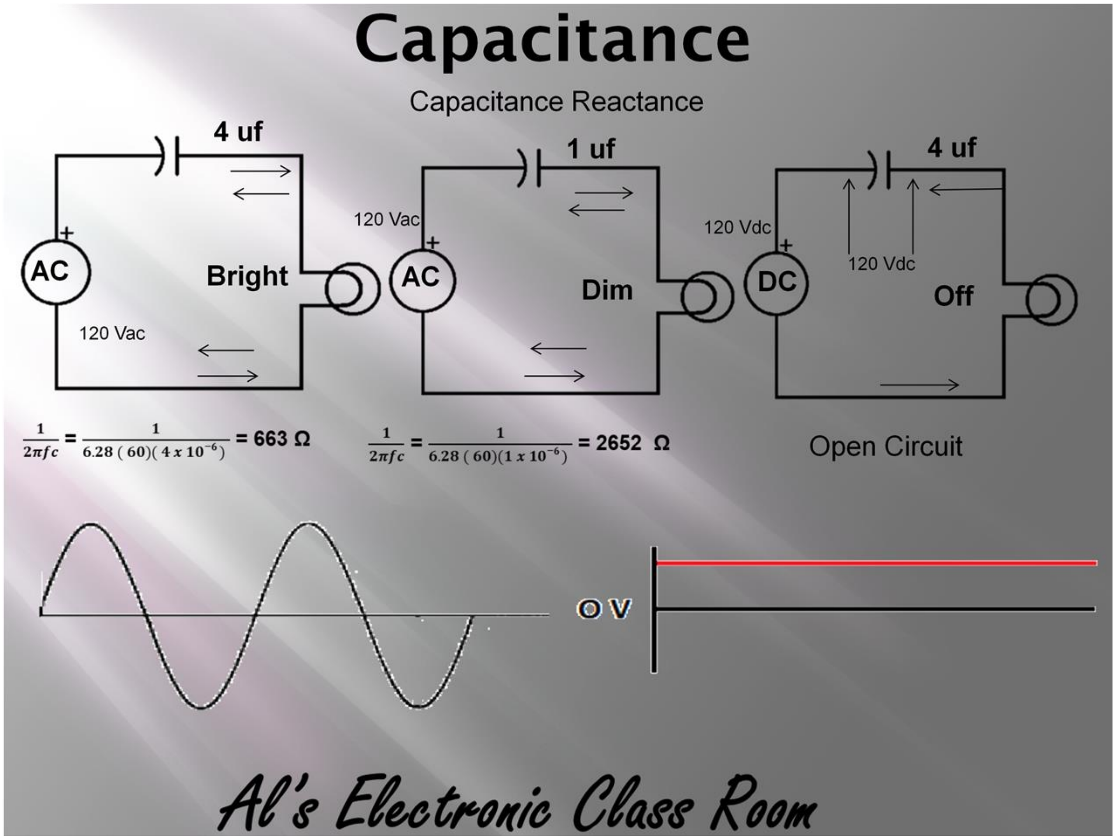
Capacitance
Capacitance Reactance
4 uf
AC
+
Bright
120 Vac
1 uf
120 Vac
AC
+
Dim
4 uf
120 Vdc
DC
+
120 Vdc
Off
$\frac{1}{2\pi fc} = \frac{1}{6.28\,(60)(4 \times 10^{-6})} = 663\ \Omega$
$\frac{1}{2\pi fc} = \frac{1}{6.28\,(60)(1 \times 10^{-6})} = 2652\ \Omega$
Open Circuit
O V
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Capacitance

Capacitance Reactance

$Xc = \frac{1}{2\pi f c}; \frac{1}{(6.28) f c} = \left(\frac{0.159}{1}\right)\left(\frac{1}{f c}\right) = \frac{0.159}{f c}$

- *Frequency f & Capacitance C are Inversely Proportional to Xc*

Problems: Find Xc

- C = 0.1*u*f, *f* = 1000 *Hz* *Xc= ?*
- C =1*u*f, *f* = 1000 *Hz* *Xc= ?*
- C = 100*p*f, *f* = 1 *MHz* *Xc= ?*
- C = 100*p*f, *f* = 10 *MHz* *Xc= ?*
- C = 240*p*f, *f* = 41.67 *KHz* *Xc= ?*

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Capacitance

Capacitance Reactance

$Xc = \frac{1}{2\pi f c}$; $\frac{1}{(6.28) f c} = \left(\frac{0.159}{1}\right)\left(\frac{1}{f c}\right) = \frac{0.159}{f c}$

- *Frequency f & Capacitance C are Inversely Proportional to Xc*

Problems: Find Xc

- C = 0.1*u*f, *f* = 1000 *Hz* *Xc =1591* Ω
- C =1*u*f, *f* = 1000 *Hz* *Xc = 159* Ω
- C = 100*p*f, *f* = 1 *MHz* *Xc = 1591* Ω
- C = 100*p*f, *f* = 10 *MHz* *Xc = 159* Ω
- C = 240*p*f, *f* = 41.67 *KHz* *Xc = 15914* Ω

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Capacitance

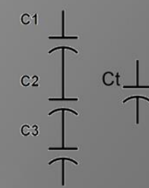
Capacitance Reactance

- **Capacitors Reactance in Series add directly**

C1= 10 uF ; C2 = 10 uF ; C3 = 5 uF ; 100 Hz

Xc1 + Xc2 + Xc3 =Xct ; 159 Ω + 159 Ω + 318 Ω = 636 Ω

Ct = 636 Ω



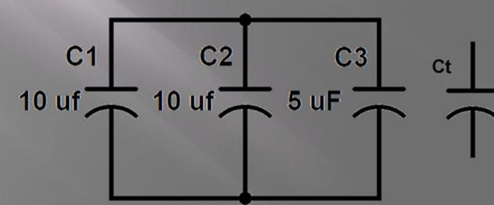
- **Capacitors in Parrallel add indirectly**

C1= 10 uF ; C2 = 10 uF ; C3 = 5 uF

$$C1 + C2 + C3 = Ct$$

10uf + 10 uf + 5 uf = 25 uf

$$\frac{1}{\frac{1}{Xc1}+\frac{1}{Xc2}+\frac{1}{Xc3}} = \frac{1}{\frac{1}{159\,\Omega}+\frac{1}{159\,\Omega}+\frac{1}{318\,\Omega}} = 63.6\ \Omega$$



Ct = 63.6 Ω

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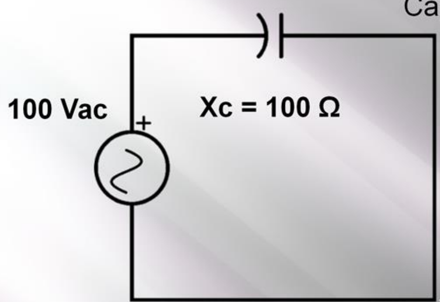
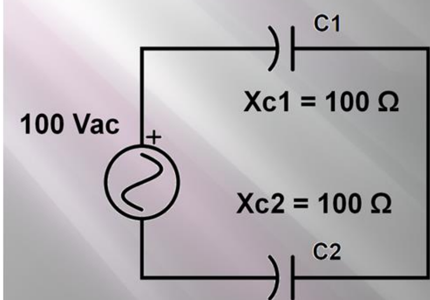
Capacitance

Capacitance Reactance



$$I\ ac = \frac{VAC}{XC1} = \frac{100\ VAC}{100\ \Omega} = 1\ A\ ac$$



$$I\ ac = \frac{VAC}{Xc1 + Xc2} = \frac{100\ VAC}{200\ \Omega} = 0.5\ A\ ac$$

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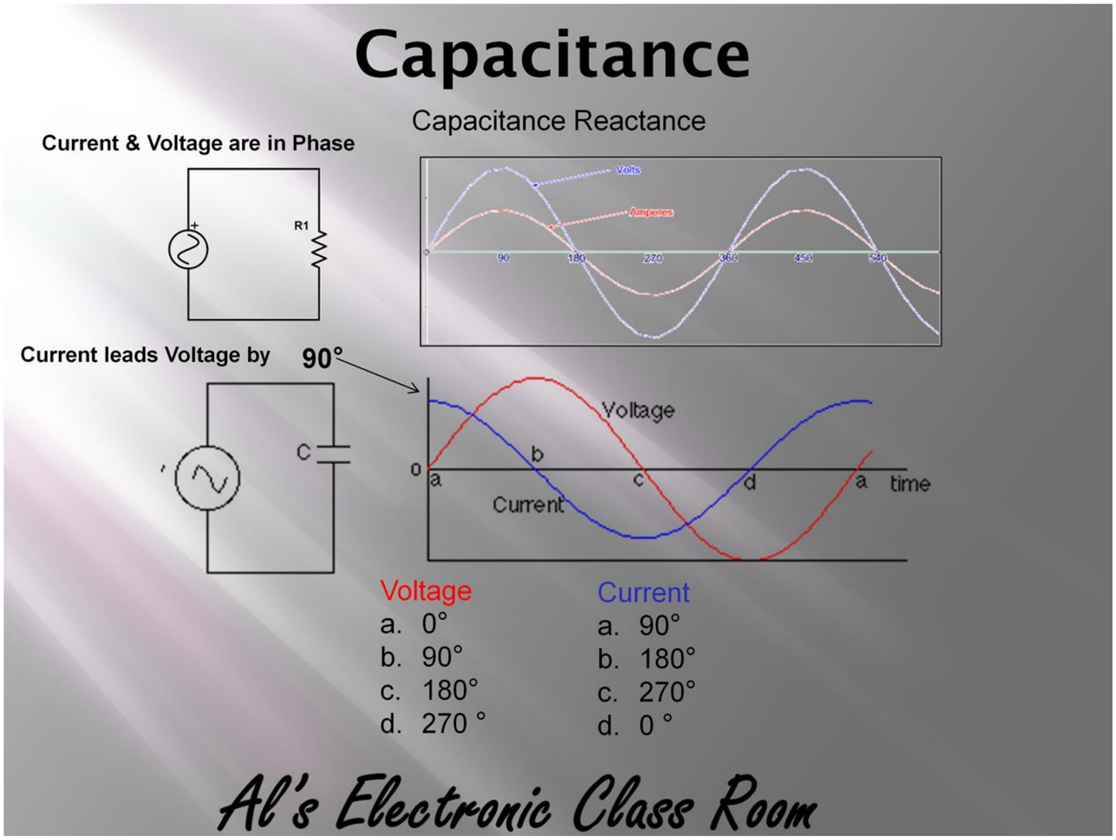
Capacitance
Capacitance Reactance
Current & Voltage are in Phase
R1
Volts
Amperes
90
180
270
360
450
540
Current leads Voltage by
90°
C
Voltage
0
a
b
c
d
a
time
Current
Voltage
a. 0°
b. 90°
c. 180°
d. 270 °
Current
a. 90°
b. 180°
c. 270°
d. 0 °
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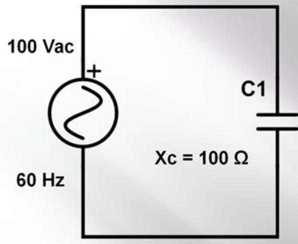
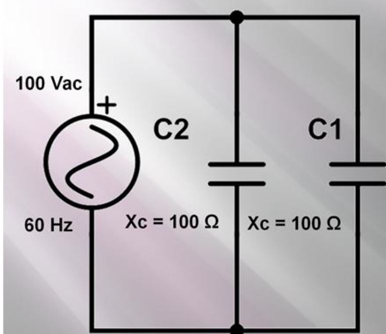
Capacitance



Capacitance Reactance

$$I\ ac = \frac{Vac}{XC1} = \frac{100\ Vac}{100\ \Omega} = 1\ ac\ Amp$$

- **Capacitive Series Circuit I is the Same**
- **Voltage is the same across the capacitors**
- **Frequency is the the same for Voltage and Current**



$$I\ ac = \frac{Vac}{Xct} = \frac{100\ Vac}{50\ \Omega} = 2\ ac\ Amp$$

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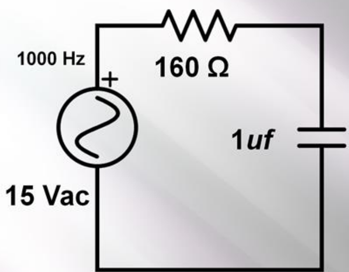
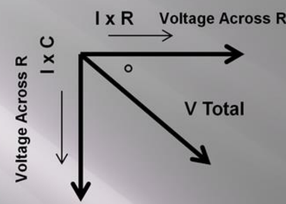
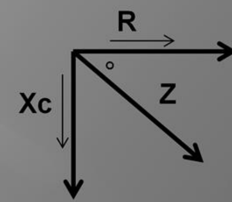
Capacitance=

Capacitance Reactance







- Xc = $\frac{1}{2\pi fc} = \frac{1}{6.28\,(1000)(1x\,10^{-6})} \cong 160\ \Omega$
- Z= $\sqrt{R^2 + Xc^2}$ = $\sqrt{160^2 + 160^2}$ = 226 Ω
- *It* = $\frac{Vac}{Z} = \frac{15\ Vac}{226\ \Omega} = 0.0663\ Ac\ amps$
- VR = 160 Ω x 0.0663 Ac amps = 10.6 Vac
- Vc = 160 Ω x 0.0663 Ac amps = 10.6 Vac
- Vt = $\sqrt{VR^2 + VC^2}$ =$\sqrt{10.6^2 + 10.6^2} = \sqrt{224.72}$ = 14.99 Vac
- Find °; Tan° = $\frac{Xc}{R} = \frac{160}{160}$ = 1 = 45° (Use Tan $^{-1}$ function on Calculator)

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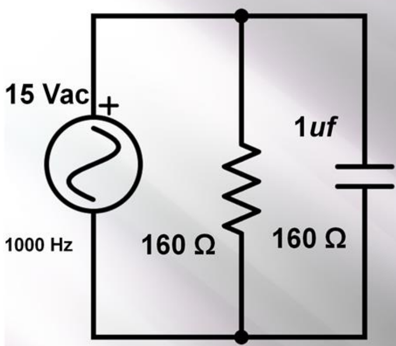
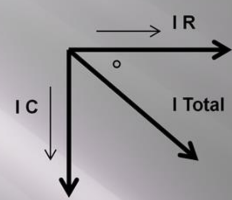
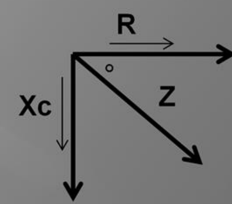
Capacitance



Capacitance Reactance





- Xc = $\frac{1}{2\pi fc} = \frac{1}{6.28\,(1000)(1x\,10^{-6})} \cong 160\,\Omega$
- *IC* = $\frac{Vac}{Xc} = \frac{15\ Vac}{160\,\Omega} \cong 94\ ma$; *IR*= $\frac{15\,VAC}{160\,\Omega} \cong 94\,MA$
- *It* = $\sqrt{IC^2 + IR^2} = \sqrt{94ma^2 + 94ma^2} \cong$ 133 Ma
- Z = $\frac{Vac}{It} = \frac{15\,Vac}{133\,ma} = 112\,\Omega$
- Find °; Tan° = $\frac{Ic}{IR} = \frac{94\,ma}{94\,ma}$ = 1 = 45° (Use Tan $^{-1}$ function on Calculator)

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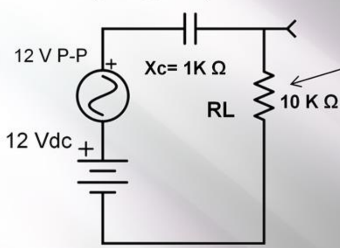
Capacitance

Capacitance Reactance

Coupling Capacitor *Cc*



Input Resistance for AC Coupling Amplifier

- **Capacitor Cc will block Dc Voltage and allow Ac signal to Pass**
- **Criteria Pass Frequencies of 100 Hz above.**

- **Xc wants to be 1/10 of RL; Xc = 1kΩ**
- **Xc** $= \frac{0.159}{fc}$; $C = \frac{0.159}{(Xc)f} = \frac{0.159}{1000\,\Omega\,(100\,Hz)} = \frac{0.159}{100000} = 1.6\,uf\ @\ 36\,Wvdc$
- $Xc = \frac{0.159}{fc} = \frac{0.159}{(1000)(1.6\,x\,10^{-6})} \cong 100\ \Omega$

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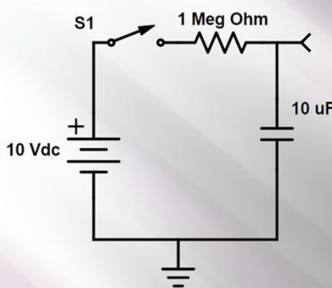
Capacitance

Resistor & Capacitor time Constant(s), ***RC time constant(s)***



- **RC Time Constants ;** $R \times C = \ time\ of\ one\ time\ constant.$
- **Five time Constance to approximately Charge to Supply Voltage.**
- **Each time Constant Charges to 63 % of Supply Voltage**

$$1\,TC = R \times C\,;\,1\,Meg\,\Omega \times 10uf\,;\,(1 \times 10^{6}) \times (10 \times 10^{-6})$$
$$1\,TC = 10\,Seconds$$

Time Constant	RC Value	Percentage of Maximum	
		Voltage	Current
0.5 time constant	0.5RC	39.3%	60.7%
0.7 time constant	0.7RC	50.3%	49.7%
1.0 time constant	1RC	63.2%	36.8%
2.0 time constants	2RC	86.5%	13.5%
3.0 time constants	3RC	95.0%	5.0%
4.0 time constants	4RC	98.2%	1.8%
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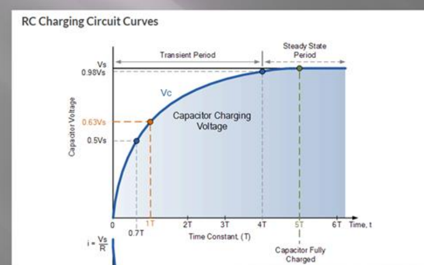
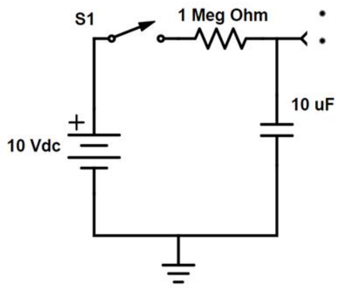


Al's Electronic Class Room

Capacitance

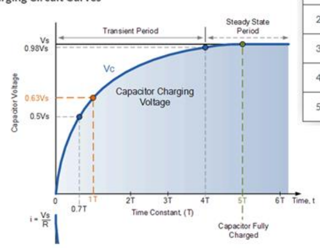
Resistor & Capacitor time Constant(s), *RC time constant(s)*

- **RC Time Constants ;** $R \times C = \; time\ of\ one\ time\ constant.$
- **Five time Constance to approximately Charge to Supply Voltage.**
- **Each time Constant Charges to 63 % of Supply Voltage**



$$1\,TC = R \times C\,;1\,Meg\,\Omega \times 10uf\,;(1 \times 10^{6}) \times (10 \times 10^{-6})$$
$$1\,TC = 10\,Seconds$$

RC Charging Circuit Curves



Time Constant	RC Value	Percentage of Maximum	
		Voltage	Current
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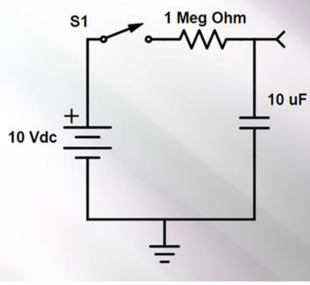
Capacitance

Resistor & Capacitor time Constant(s), *RC time constant(s)*



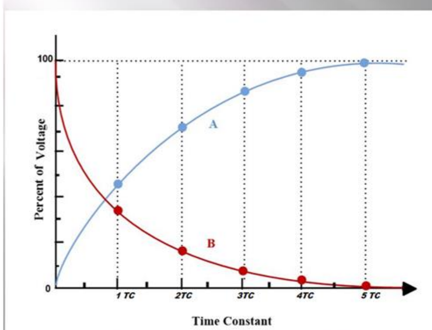
- RC Time Constants ; $R \times C = $ *time of one time constant.*
- Five time Constance to approximately Charge to Supply Voltage.
- Each time Constant Charges to 63 % of Supply Voltage

$1\,TC = R \times C\,; 1\,Meg\,\Omega \times 1\,uF;\ (1 \times 106) \times (10 \times 10^{-6})$

$1\,TC = \ 10\,Seconds$

Voltage Across Capacitor

0.5 TC x 10 Sec = 5 Sec ; 0.393 x 10 VDC = 3.93 Volts
0.7 TC x 10 Sec = 7 Sec ; 0.503 x 10 VDC = 5.03 Volts
1 TC x 10 Sec = 10 Sec ; 0.632 x 10 VDC = 6.32 Volts
2 TC x 10 Sec = 20 Sec ; 0.865 x 10VDC = 8.65 Volts
3 TC x 10 Sec = 30 Sec ; 0.95 x 10 VDC = 9.5 VDC
4 TC x 10 Sec = 40 Sec ; 0.982 x 10VDC = 9.82 VDC
5 TC x 10 Sec = 50 Sec ; 0.993 x 10 VDC = 9.93 VDC



Voltage Across Resistor

Vs-Vc =VR
10Vdc – 3.94 VDC = 6.06 Vdc
10Vdc – 5.03 VDC = 4.97 Vdc
10Vdc – 6.32 VDC = 3.68 Vdc
10Vdc – 8.65 VDC = 1.35 Vdc
10Vdc – 9.5 VDC = 0.5 Vdc
10 Vdc- 9.82 VDC = 0.18 Vdc
10 Vdc – 9.93 VDC =0.07 Vdc

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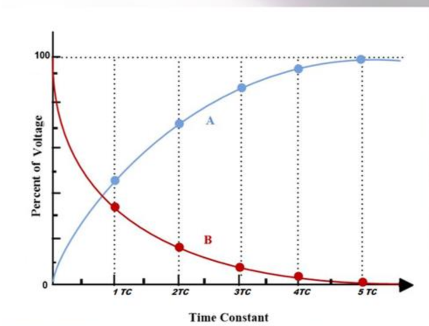
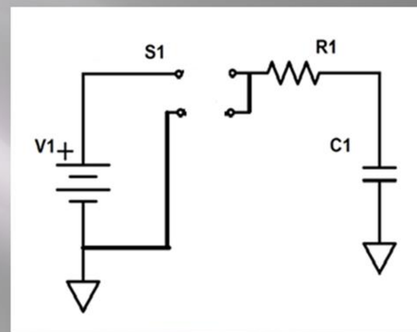
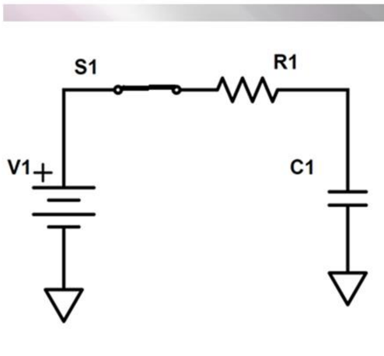
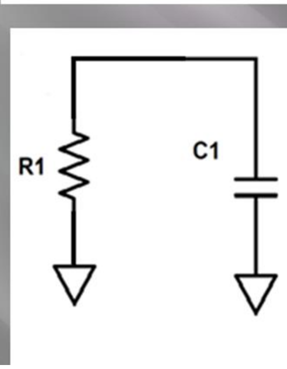
Capacitance

Resistor & Capacitor time Constant(s), *RC time constant(s)*









Capacitance

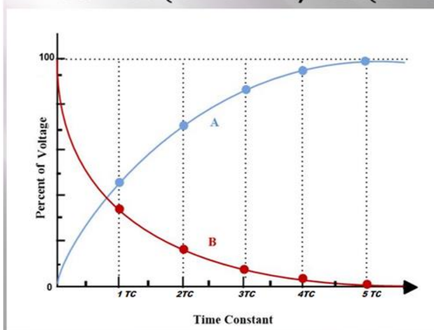
Resistor & Capacitor time Constant(s), ***RC time constant(s)***

Where:

- Vc is the voltage across the Capacitor.
- Vs is the supply voltage.
- T is the elapsed time since the application of the supply voltage.
- RC is the *time constant* of the RC charging circuit.

$$Vc = Vs(1 - e^{-t/RC})$$ **Use Calculator**

$Vc = Vs(1 - e^{-t/RC})$ **=** $10(1 - e^{-\frac{1}{1}})$ **= 10(1 - 0.367) = 10(0.663) = 6.63 Volts**



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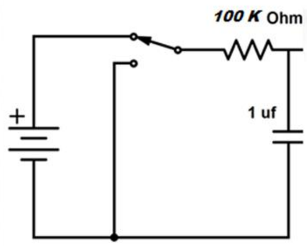
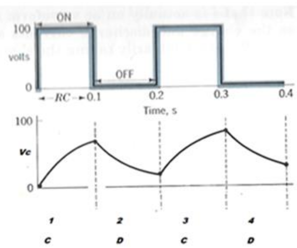
Capacitance

Resistor & Capacitor time Constant(s), *RC time constant(s)*





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5.0 time constants	5RC	99.3%	0.7%

- TC = R x C; $(100 \times 10^{3}) \times (1 \times 10^{-6})$
  TC = 0.1 Seconds

Capacitor

1. 0.632 x 100 = 63.2 Volts
2. 63.2 – (0.632 x 63.2) volts = 23.23 Volts
3. ((100 – 23.23) x 0.632) + 23.23 = 71.7 Volts
4. 71.7 – (0.632 x 71.7) Volts = 26.4 Volts

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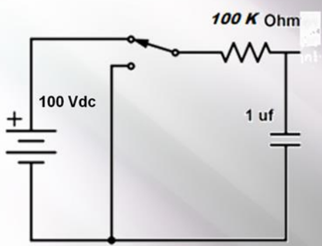
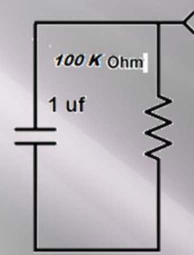
Capacitance

Resistor & Capacitor time Constant(s), *RC time constant(s)*





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- TC = R x C; (100 x10 ^{3}) x (1 x 10 $^{-6}$)
  TC = 0.1 Seconds

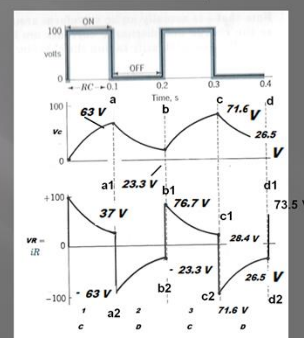
Capacitor

a) 0.632 x 100 = 63.2 Volts
b) 63.2 – (0.632 x 63.2) volts = 23.3 Volts
c) ((100 – 23.23) x 0.632) + 23.23 = 71.7 Volts
d) 71.7 – (0.632 x 71.7) Volts = 26.4 Volts

Resistor

a1 100 Volts- 63 Volts = 37 Volts
b1 100 Volts- 23.3 Volts = 76.7 Volts
c1 100 volts -71.6 Volts = 28.4 Volts
d1 100 volts – 26.5 Volts = 73.5 Volts

a2 37 Volts – 100 Volts = - 63 Volts
b2 76.7 Volts – 100 Volts = - 23.3 Volts
c2 28.4 Volts – 100 Volts = -71.6 Volts
d2 73.5 Volts – 100 Volts = 26.5 Volts



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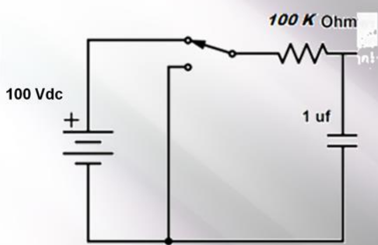
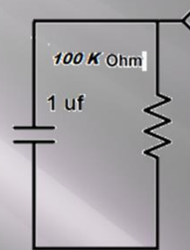
Capacitance

Resistor & Capacitor time Constant(s), *RC time constant(s)*





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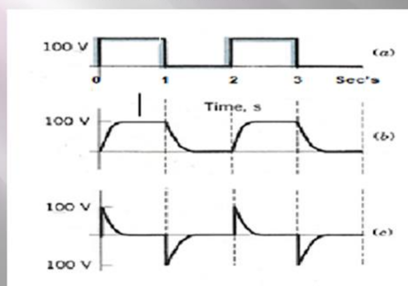

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Capacitance

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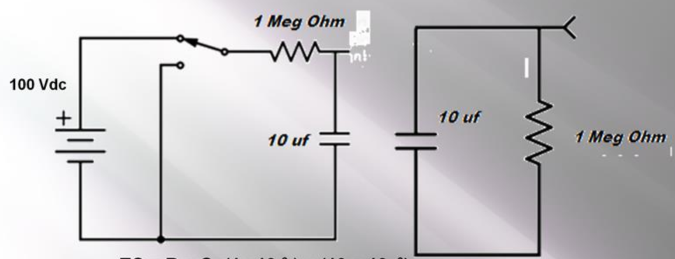

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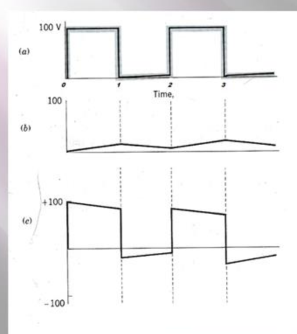
  TC = 10 Seconds



$$VC = VS(1 - e^{-t/RC})$$

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