Roeback's Final Project_EECT111

Using MultiSim, Excel and hand calculations create a set of notes that show how to:

1.) Combine multiple resistors in series and parallel.

2.) By example calculate RT, IT, PT, and all the nodal voltages, branch currents and power dissipation of a resistor network.

3.) By example calculate the Thevenin Resistance and Voltage of a resistor network.

4.) Multiple capacitors combine in series and parallel.

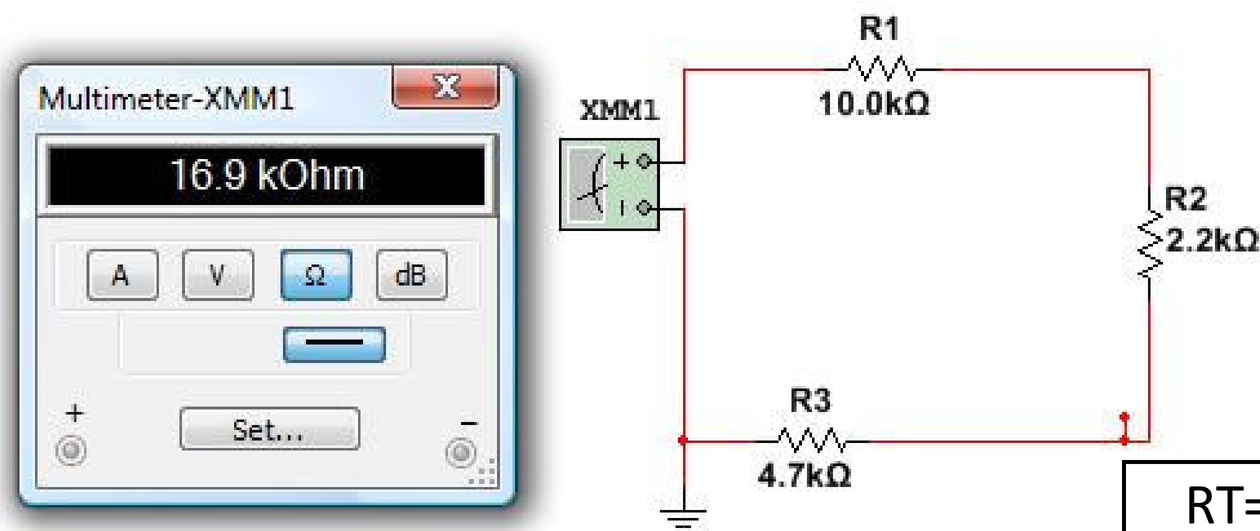
5.) Using a simple RC circuit determine the
- a.) Time Constant
- b.) Create a graph that shows the RC time constant as a function of time
- c.) Determine XC at a fixed frequency
- d.) Create a graph that shows how XC changes as a function of frequency

6.) Multiple inductors combine in series and parallel.

7.) Using a simple RL circuit determine the
- a.) Time Constant
- b.) Create a graph that shows the RL time constant as a function of time
- c.) Determine XL at a fixed frequency
- d.) Create a graph that shows how XL changes as a function of frequency

Combining Resistors in Series

The sum of all resistor values in a series circuit equals total resistance.



RT=	R1+R2+R3……	
R1=	10.0E+3	Ω
R2=	2.2E+3	Ω
R3=	4.7E+3	Ω
RT=	16.9E+3	Ω

Combining Resistors in Parallel

3 approaches can be taken to calculate total resistance in parallel.

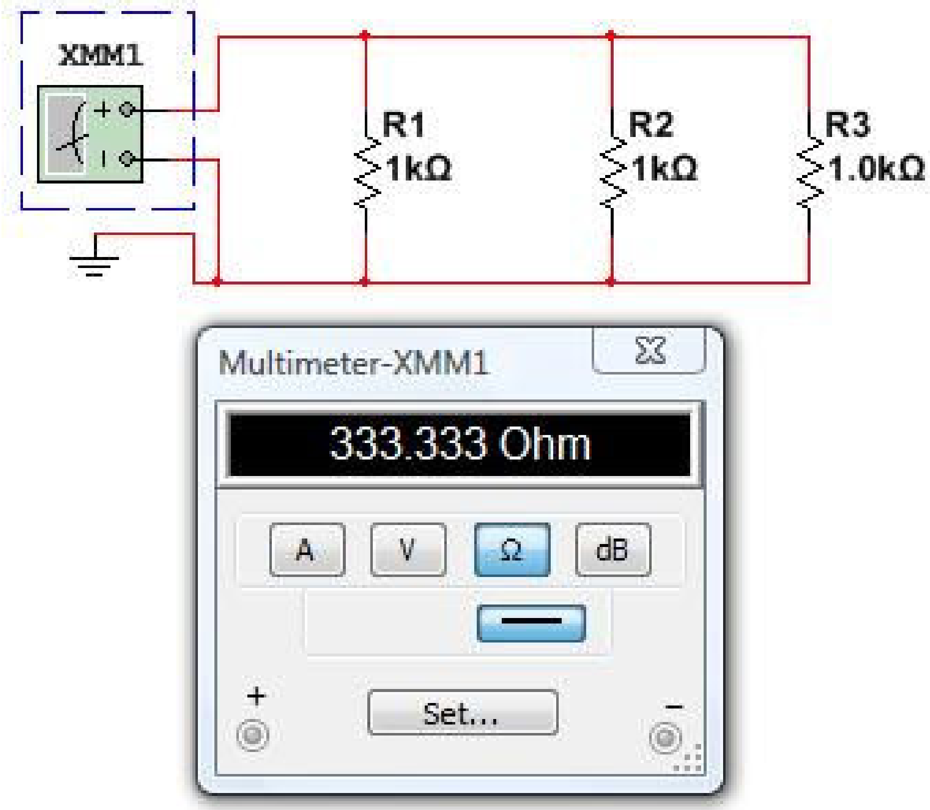
- For two or more resistors of equal value [R1/Rn]
  (Any Resistor value / # of Resistors) can be used.

- For two resistors of any value [(R1+R2)/(R1*R2)]
  (Product of both resistor values / sum of both resistor values).

- For 3 or more resistors of any value use the reciprocal of the sum of the reciprocal of all resistor values.
  [1/(1/R1)+(1/R2)+(1/R3)…]

Any Resistor Value over the Number of Resistors

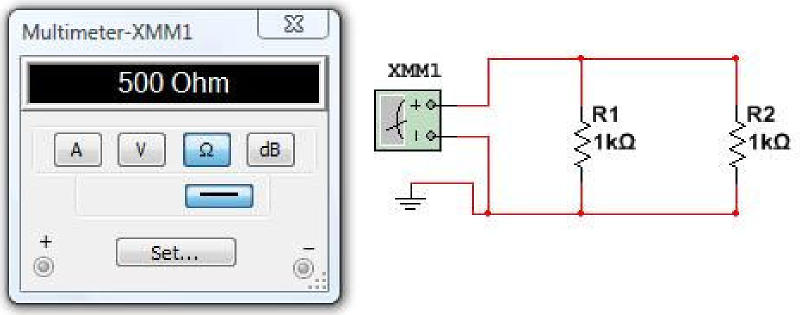
This Method only works with equal value resistors in a parallel circuit.

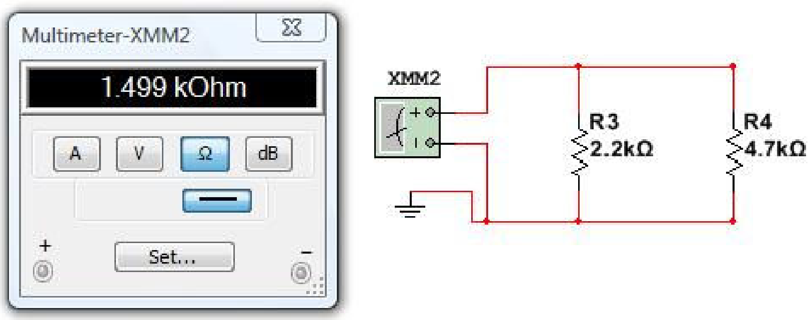


RT=	R1/Rn	
R1=	1.0E+3	Ω
R2=	1.0E+3	Ω
R3=	1.0E+3	Ω
RT=	333.333E+0	Ω

Product over Sum Method

This method works for two resistors of equal or different values.



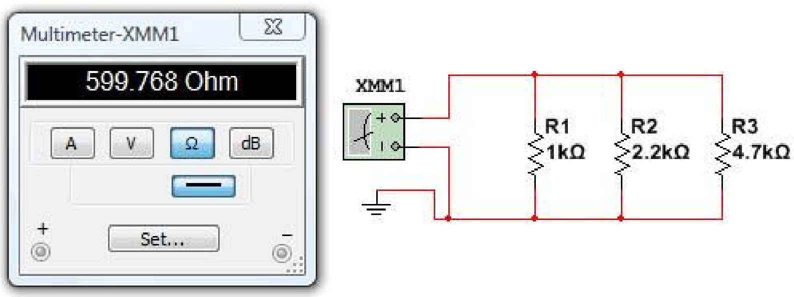


RT=	(R1*R2)/(R1+R2)	
R1=	1.0E+3	Ω
R2=	1.0E+3	Ω
RT=	500.0E+0	Ω

RT=	(R1*R2)/(R1+R2)	
R3=	2.2E+3	Ω
R4=	4.7E+3	Ω
RT=	1.499E+3	Ω

The Reciprocal of the Sum of the Reciprocal Resistor Values

This method works for calculation all parallel resistor circuits



RT=	1/[(1/R1)+(1/R2)+(1/R3)+....]	
R1=	1.0E+3	Ω
R2=	2.2E+3	Ω
R3=	4.7E+3	Ω
RT=	599.768E+0	Ω

•In a Series circuit total circuit resistance will always be great then the value of any single resistor within that same circuit.

•Regardless of a resistor's value within a parallel circuit, the total circuit resistance is always less.

• In a Series-Parallel circuit, the resistance of the individual parallel sub-circuits must be figured out first before figuring total circuit resistance.

The Usage of Watt & Ohm's Law

Calculating RT, IT, PT, and all the nodal voltages, branch currents and power dissipation of a resistor network.

- If V=Volts, R=Resistance in Ohms & I=Current in Amperes
- Ohm's Law states: V=I*R then:
  - V/R=I and V/I=R
- The Watt (Power or P) = V*I so:
  - $P=V^2/R$ or $P=R*I^2$
- With the use of these formulas the chart to the right can be made.

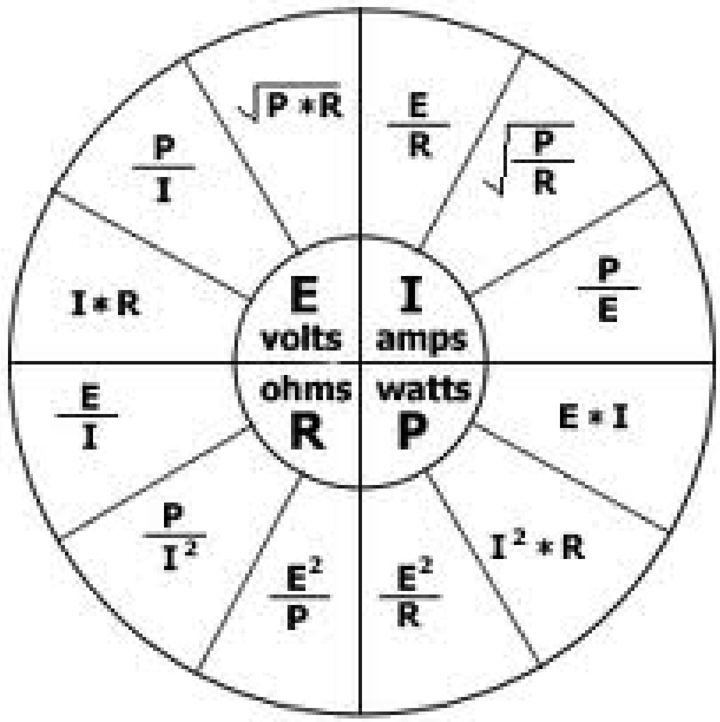
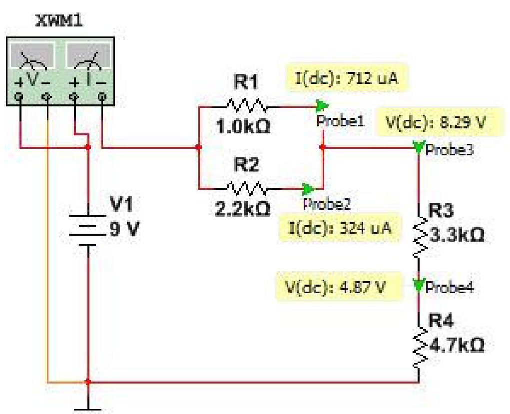
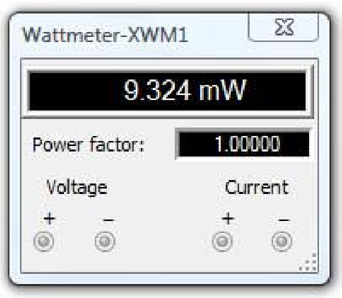


Photo Courtesy of http://www.freesunpower.com/watts_power.php

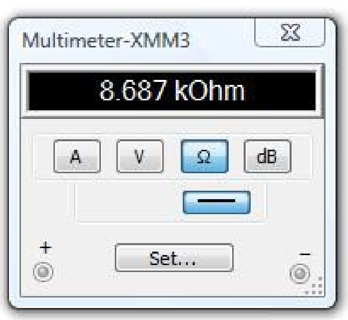
Ohm's Law in Series-Parallel Circuits

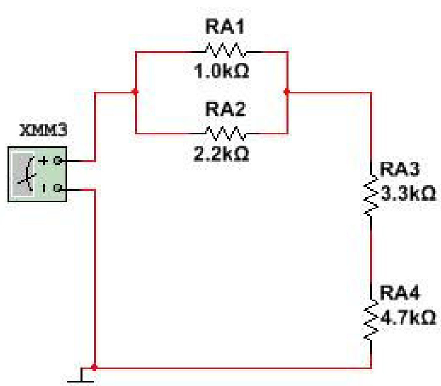
The simulation proves that using the formulas (in the chart on the previous slide) we can calculate each resistors behavior within the circuit and sub-circuits.

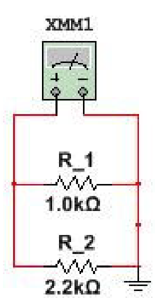


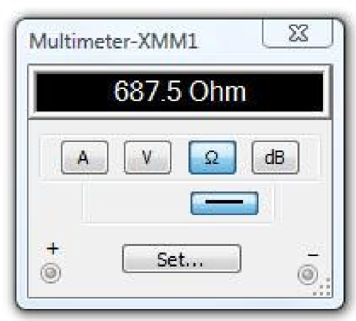


V1=	9	V	Amps Across	Voltage Drop	Power Consumed (W)
R1=	1.0E+3	Ω	712E-6	See Parallel Circuit	507.27E-6
R2=	2.2E+3	Ω	324E-6		230.58E-6
R3=	3.3E+3	Ω	1.036E-3	3.4E+0	3.54E-3
R4=	4.7E+3	Ω	1.036E-3	4.9E+0	5.04E-3
R12=	687.5E+0	Ω	1.036E-3	712.2E-3	737.85E-6
R34=	8.0E+3	Ω	1.036E-3	8.3E+0	8.59E-3
RT=	8.688E+3	Ω	1.036E-3	9.0E+0	9.324E-3
IT=	1.036E-3	A	SUM(R1-R4) & R12+R34		TRUE
PT=	9.324E-3	W	Power=PT		



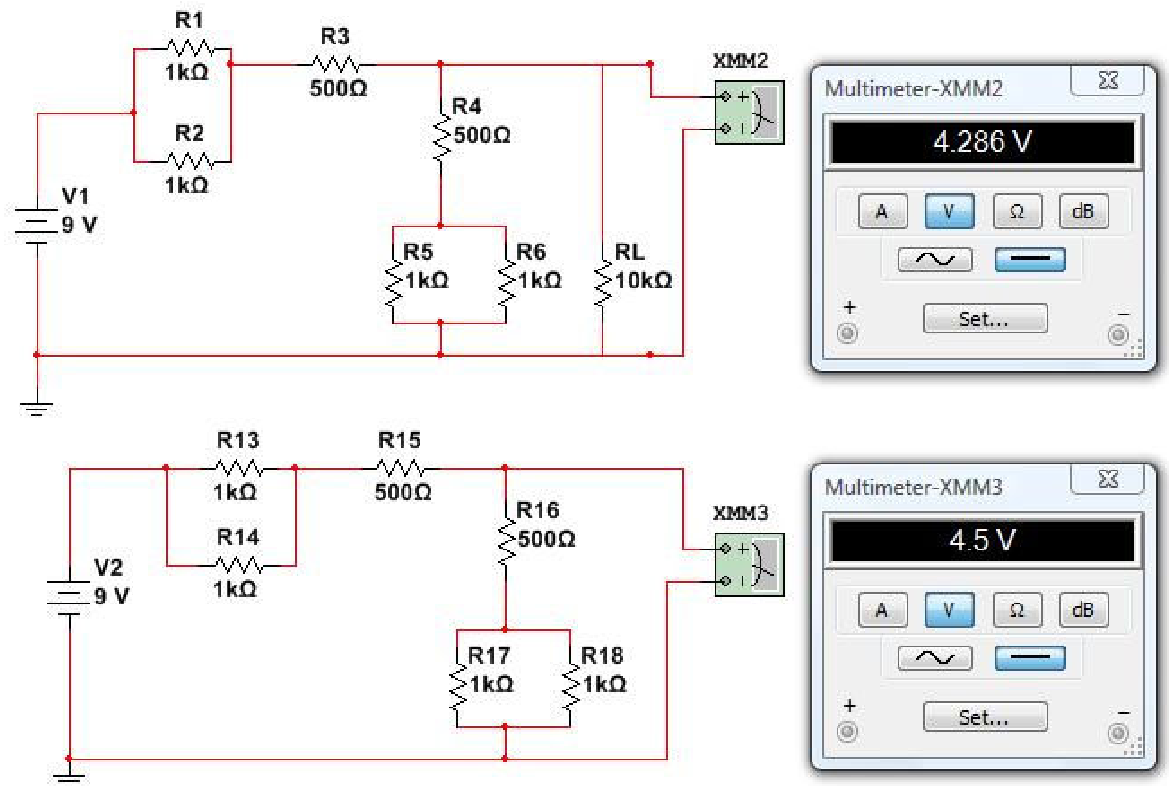






Thevenin Resistance and Voltage of a resistor network.

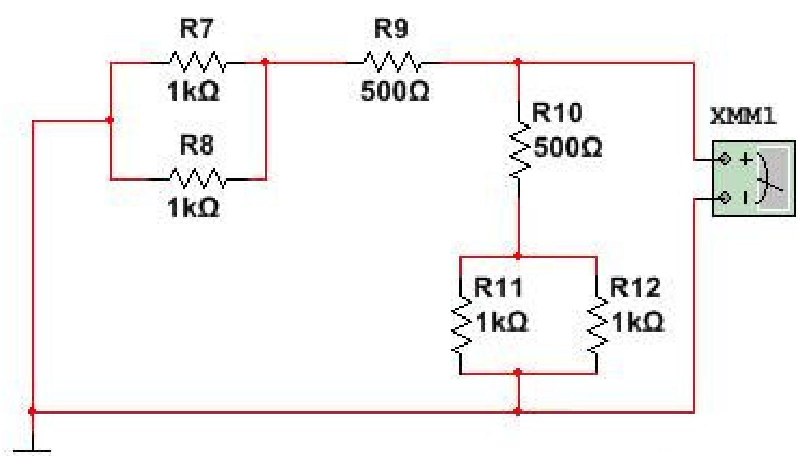
To predict Thevenin Resistance and Voltage first Calculate or Measure; voltage across the existing circuit at the point of the load with the load applied then again with the load removed.

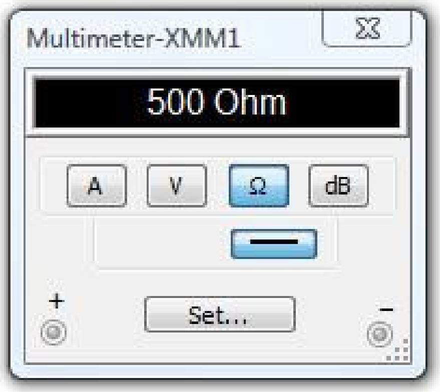


R1=	1E+3	Ω
R2=	1E+3	Ω
R3=	500E+0	Ω
R4=	500E+0	Ω
R5=	1E+3	Ω
R6=	1E+3	Ω
R12=	500E+0	Ω
R123=	1E+3	Ω
R56=	500E+0	Ω
R123456=	500E+0	Ω
R456	1E+3	Ω
RL=	10E+3	Ω
R456L=	909.091E+0	Ω
RT=	1.909E+3	Ω
V1=	9	V
Va=	4.286E+0	V
RTH=	500.0E+0	Ω
VTH=	4.5	V
VaTH=	4.286E+0	Ω
B19=B16	True	

Applying Thevenin Theorem

Then remove the supply power and load. Short across the points the supply power was previously located and Measure or Calculate the circuit resistance at the point were the load once resided.



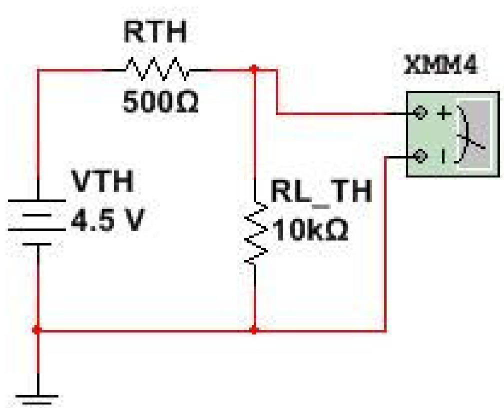


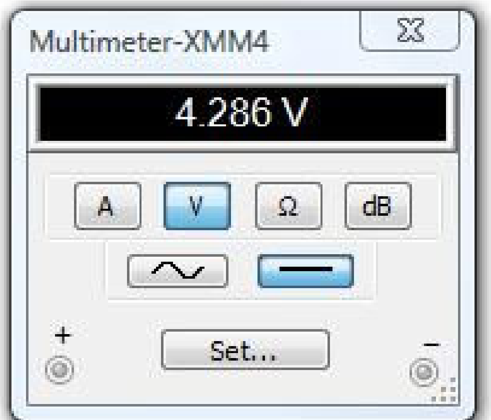
R1=	1E+3	Ω
R2=	1E+3	Ω
R3=	500E+0	Ω
R4=	500E+0	Ω
R5=	1E+3	Ω
R6=	1E+3	Ω
R12=	500E+0	Ω
R123=	1E+3	Ω
R56=	500E+0	Ω
R123456=	500E+0	Ω
R456	1E+3	Ω
RL=	10E+3	Ω
R456L=	909.091E+0	Ω
RT=	1.909E+3	Ω
V1=	9	V
Va=	4.286E+0	V
RTH=	500.0E+0	Ω
VTH=	4.5	V
VaTH=	4.286E+0	Ω
B19=B16	True	

Proving Thevenin Theorem

The circuit is replace with a single resistor equal to that of Thenenin Resistance and the supply power is replace with the Thevinin Voltage.

The simulation supports the calculations.

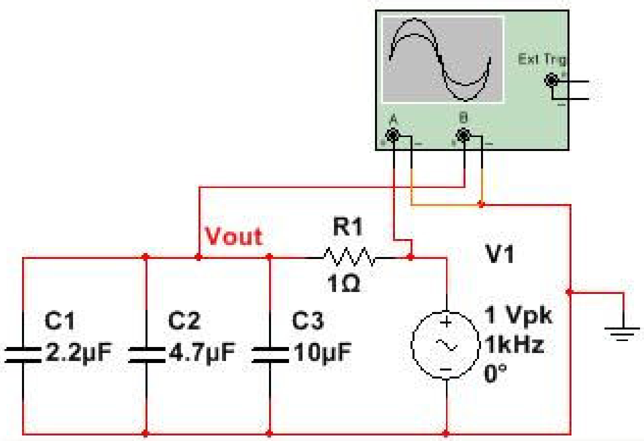




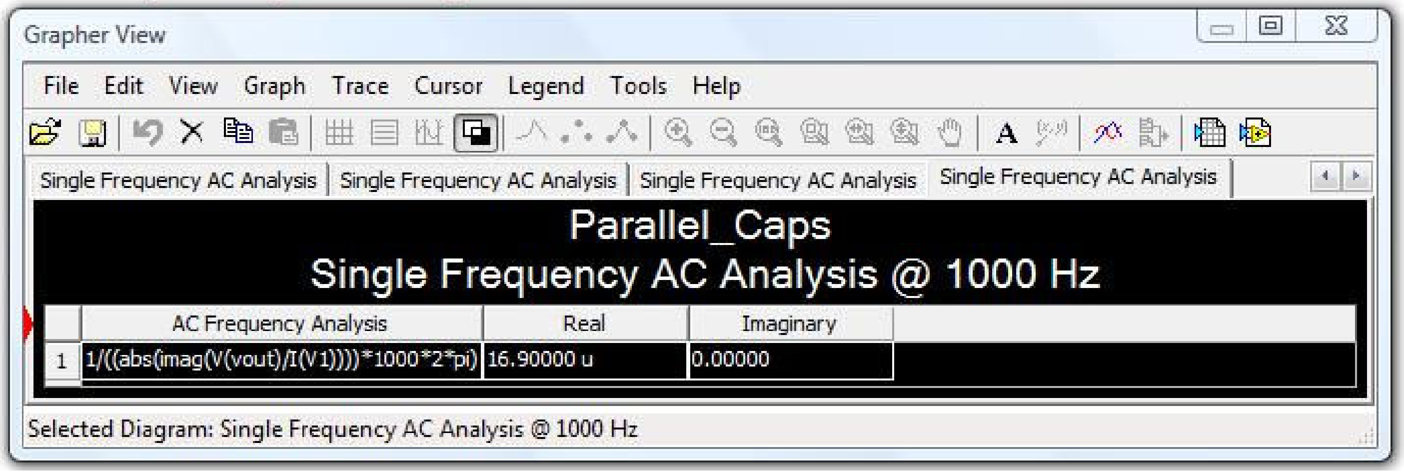
R1=	1E+3	Ω
R2=	1E+3	Ω
R3=	500E+0	Ω
R4=	500E+0	Ω
R5=	1E+3	Ω
R6=	1E+3	Ω
R12=	500E+0	Ω
R123=	1E+3	Ω
R56=	500E+0	Ω
R123456=	500E+0	Ω
R456	1E+3	Ω
RL=	10E+3	Ω
R456L=	909.091E+0	Ω
RT=	1.909E+3	Ω
V1=	9	V
Va=	4.286E+0	V
RTH=	500.0E+0	Ω
VTH=	4.5	V
VaTH=	4.286E+0	Ω
B19=B16	=True	

Combining Capacitors in Parallel

The sum of all capacitor values in parallel equals total capacitance.



The total capacitance of all capacitors in parallel is always greater then the largest capacitor value.



Capacitors in Parallel		
C1=	2.2E-6	F
C2=	4.7E-6	F
C3=	10.0E-6	F
CT=	16.900E-6	F

Combining Capacitors in Series

3 approaches can be taken to calculate total capacitance in series.

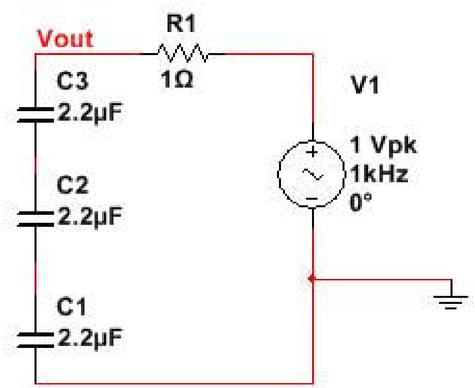
- For two or more capacitors of equal value [C1/Cn] (Any capacitor value / # of capacitors) can be used.

- For two capacitors of any value [(C1+C2)/(C1*C2)] (Product of both capacitor values / sum of both capacitor values).

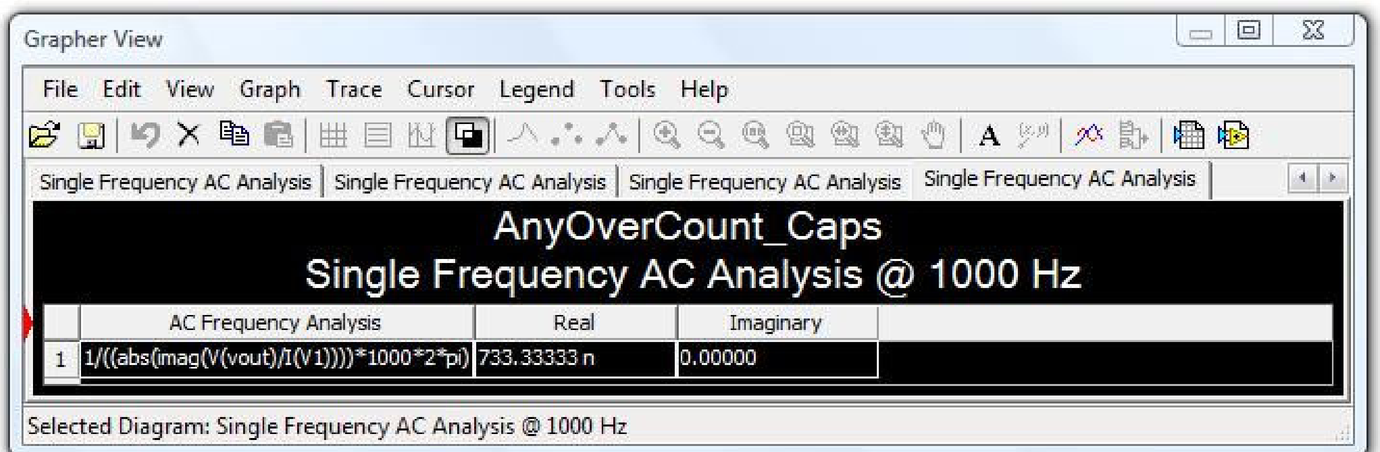
- For 3 or more capacitors of any value use the reciprocal of the sum of the reciprocal of all capacitor values. [1/(1/C1)+(1/C2)+(1/C3)…]

Capacitors of same value in Series

Calculate total capacitance by dividing the value of one capacitor by the number of capacitors in the series circuit.

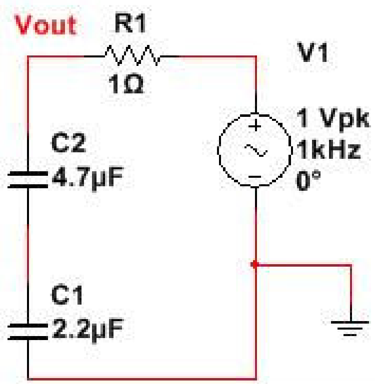


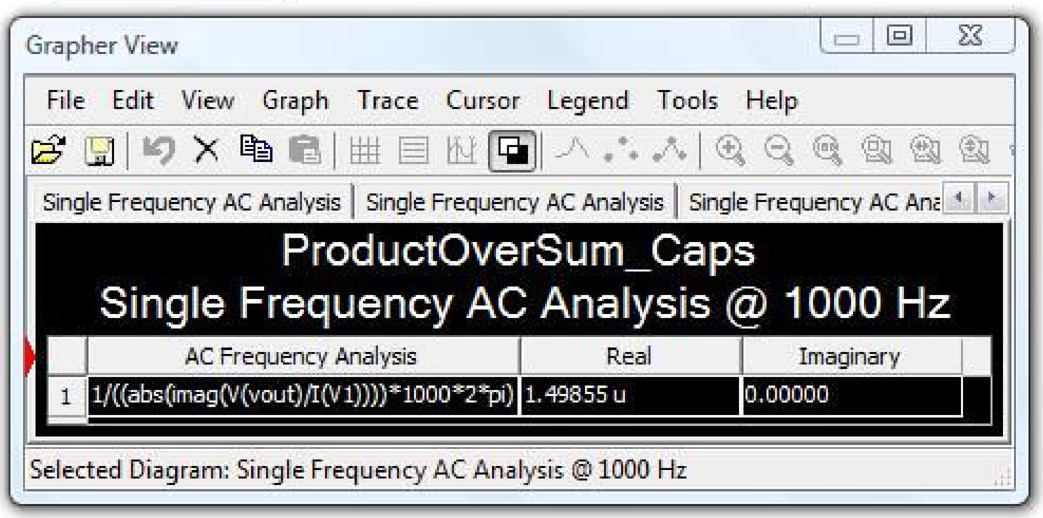
Farads=F	Anyone/Count	
C1=	2.2E-6	F
C2=	2.2E-6	F
C3=	2.2E-6	F
CT=	733.333E-9	F



Two Capacitors of Different Values

To calculate two capacitors of the same or different values use the product divided by the sum method.

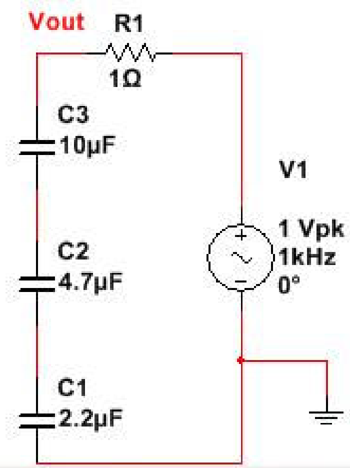




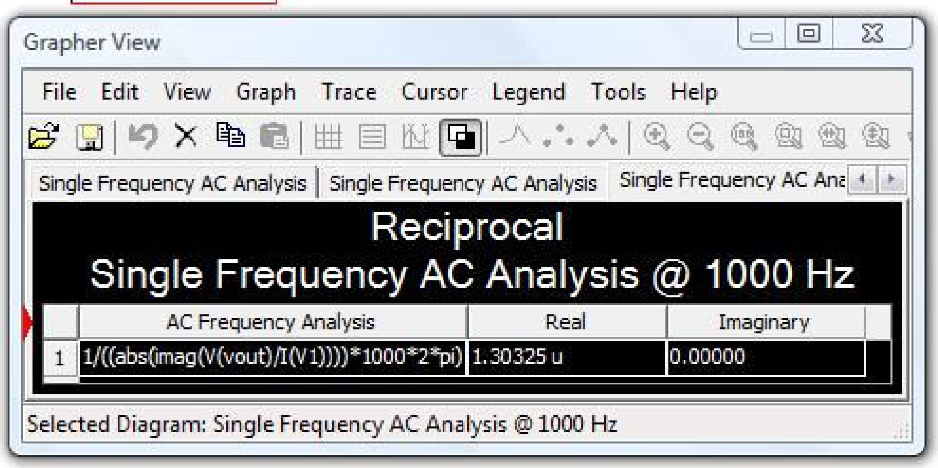
(C1*C2)/(C1+C2)		
C1=	2.2E-6	F
C2=	4.7E-6	F
CT=	1.499E-6	F

The Reciprocal of the Sum of the Reciprocal Capacitor Values

This method works for calculating all series capacitor circuits.



The total capacity of all capacitors in series is always less then the smallest capacitor value.



1/SUM(Reciprocals of all)		
C1=	2.2E-6	F
C2=	4.7E-6	F
C3=	10.0E-6	F
CT=	1.303E-6	F

RC Time Constant

The RC time constant, also called tau (τ), is the time constant (in seconds) of a RC circuit.

- $\tau = R*C$
  - R = resistor’s value (in Ohms)
  - C = capacitor’s value (in Farads)
- The Charge and Discharge rate are inversely logarithmic and are explained in greater detail on the next slide.

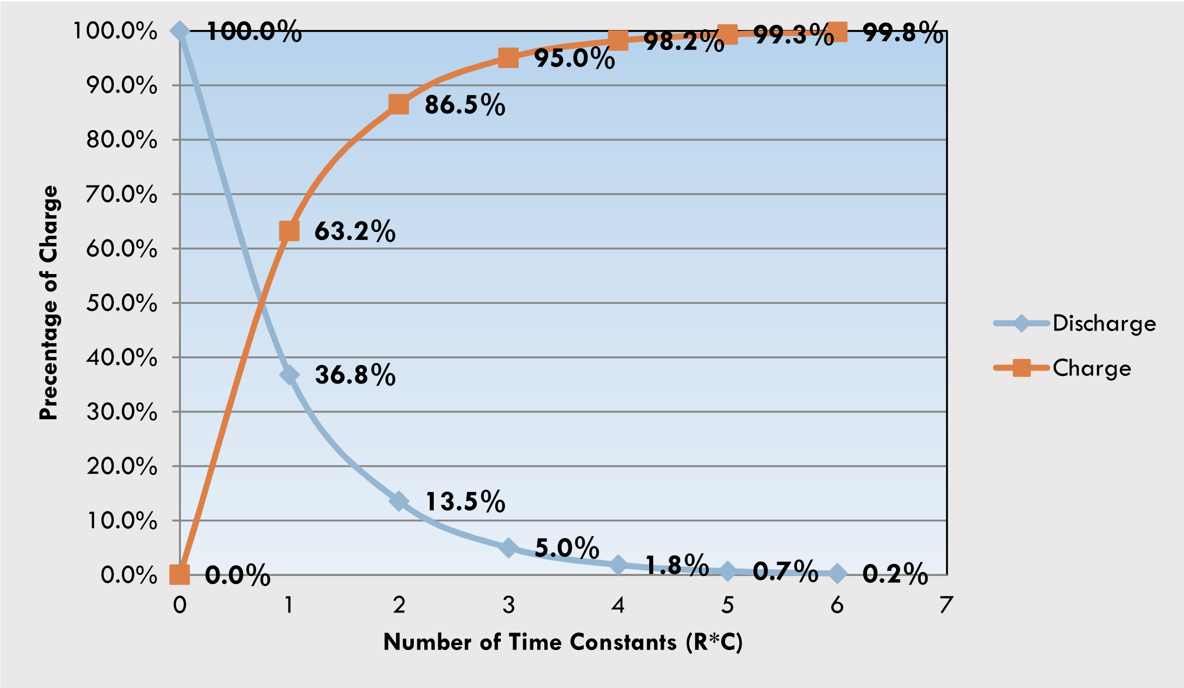
Charging $V(t) = V_0(1 - e^{-t/\tau})$

Discharging $V(t) = V_0(e^{-t/\tau})$

Picture Courtesy of http://en.wikipedia.org/wiki/RC_time_constant

RC Time Constant as a Function of Time.

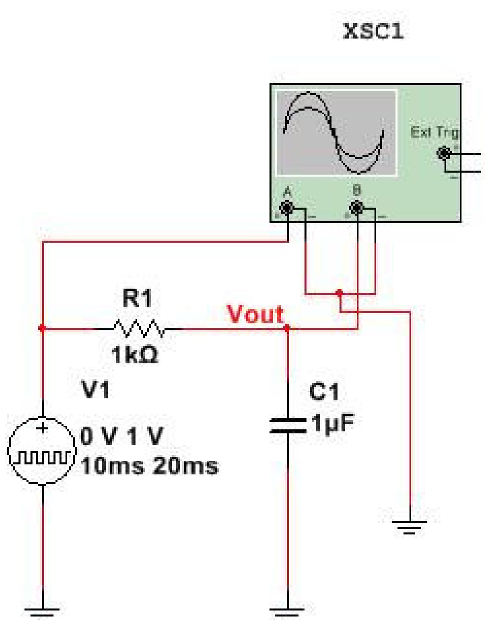
As the voltage difference between the supply and the capacitor reduces, so does current. This has an inverse effect on the charge rate. This means it get closer to 100% charged as it gets closer to infinite time. The discharge rate is just as consistent, giving us predictability. As you can see from the chart, it takes about 5 Time Constants for the capacitor to reach about 99% of full charge or about 1% from full discharge.

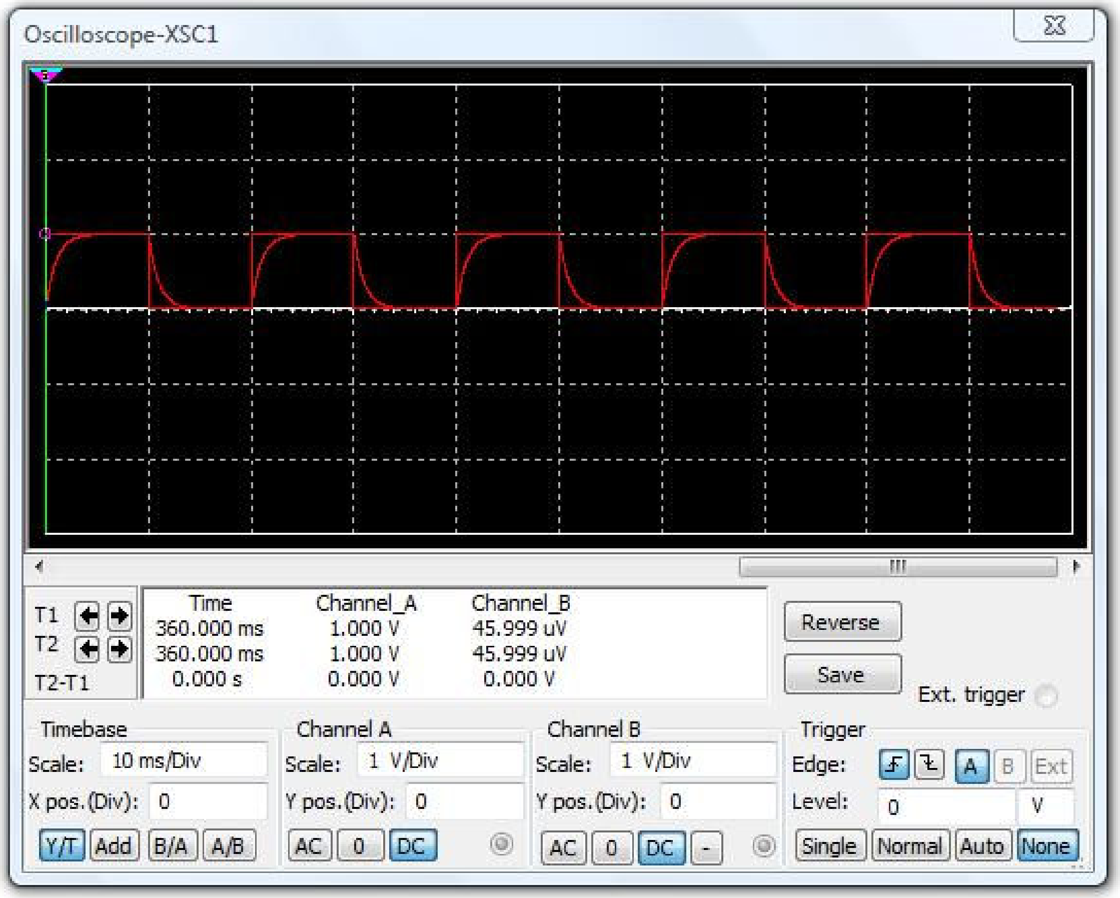


Vs=	1	VDC
R=	1.0E+3	Ω
C=	1.0E-3	Farads
(R*C=τ) τ=	1	
RC Time Constant		
(tc)	Discharge	Charge
0	100.0%	0.0%
1	36.8%	63.2%
2	13.5%	86.5%
3	5.0%	95.0%
4	1.8%	98.2%
5	0.7%	99.3%
6	0.2%	99.8%

RC Circuit Reaction to Pulsating VDC

The simulation curve mimics that of the calculated charge and discharge curve.





Xc at a Fixed Frequency.

Capacitive Reactance (Xc) is the opposition (resistance in ohms) of a charge across the capacitor. Xc is inversely proportional to frequency and capacitance within the circuit.

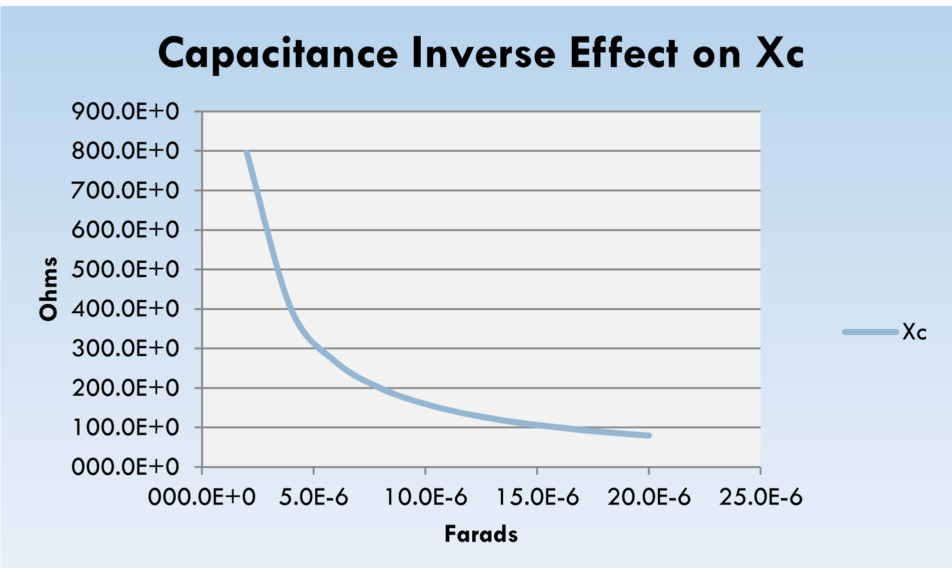
$$X_C = \frac{1}{2\pi f C}$$

Where,

X_C = Inductive reactance in ohms

f = Frequency in hertz

C = Capacitance in farads

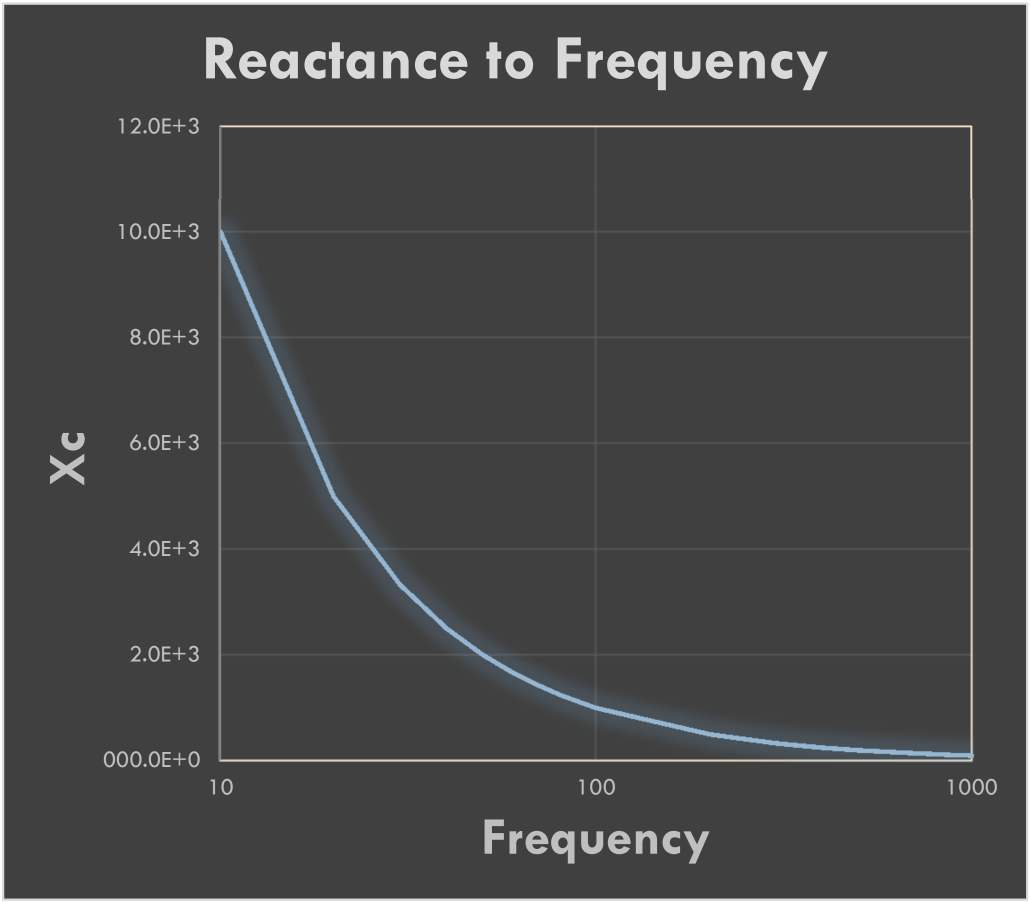


Xc=1/(2πfC)	
R=	1000
Input Hz=	100
Capacitance	Xc
2.0E-6	795.8E+0
4.0E-6	397.9E+0
6.0E-6	265.3E+0
8.0E-6	198.9E+0
10.0E-6	159.2E+0
12.0E-6	132.6E+0
14.0E-6	113.7E+0
16.0E-6	99.5E+0
18.0E-6	88.4E+0
20.0E-6	79.6E+0

Picture Courtesy of http://www.faqs.org/docs/electric/Ref/REF_1.html

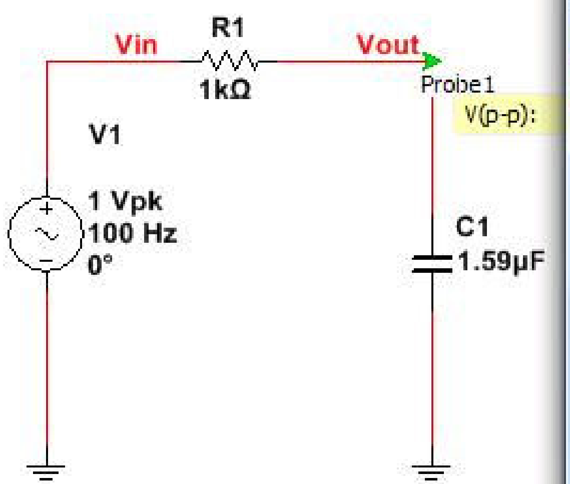
Xc Reactance of Frequency

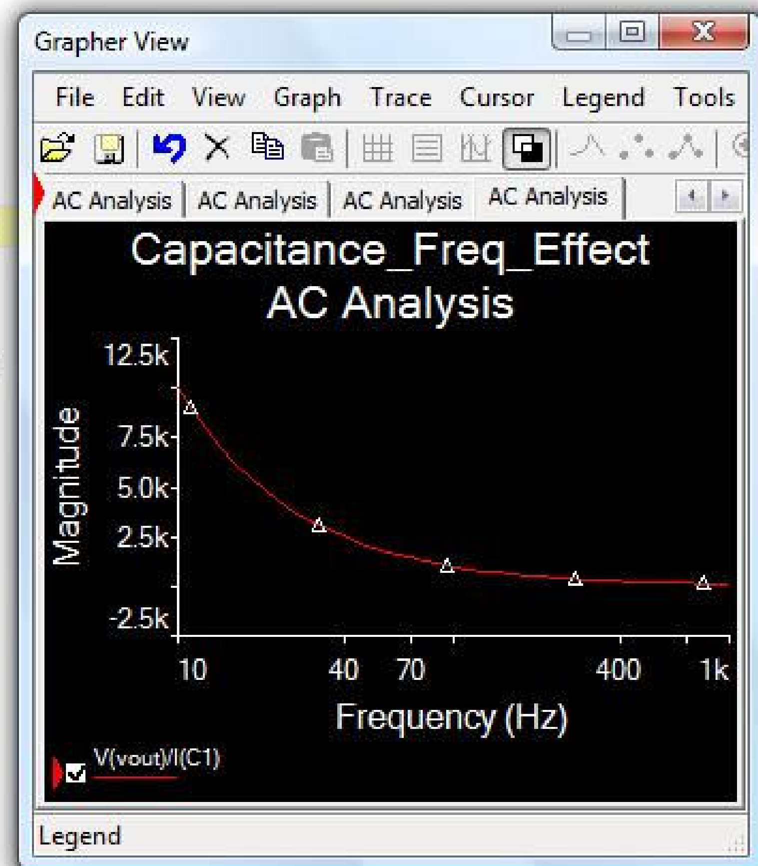
As stated in the previous slide, Xc has an inverse reaction to frequency.



Frequency	Xc for 1.59µF
10	10.0E+3
20	5.0E+3
30	3.3E+3
40	2.5E+3
50	2.0E+3
60	1.7E+3
70	1.4E+3
80	1.3E+3
90	1.1E+3
100	1.0E+3
200	500.0E+0
300	333.3E+0
400	250.0E+0
500	200.0E+0
600	166.7E+0
700	142.9E+0
800	125.0E+0
900	111.1E+0
1000	100.0E+0

Xc Reactance of Frequency Cont.

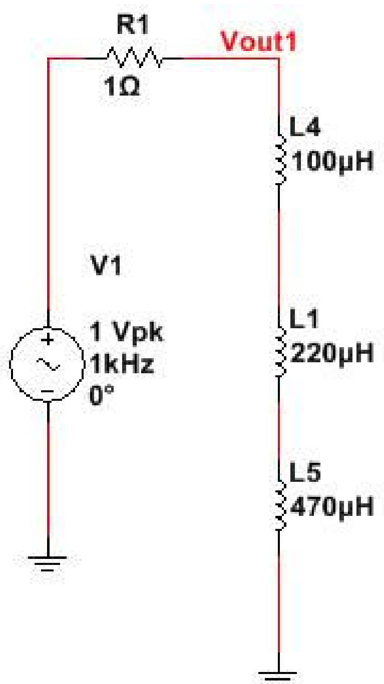


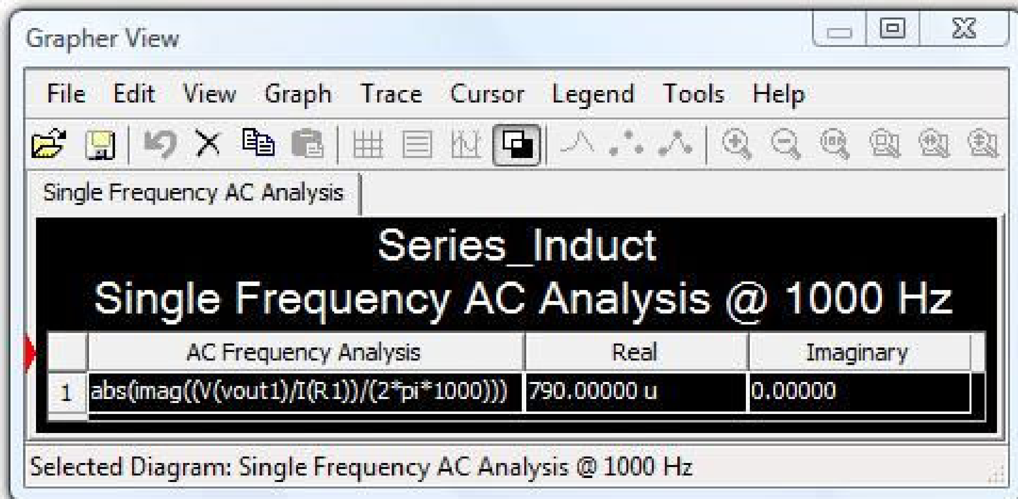


Frequency	Xc for 1.59µF
10	10.0E+3
20	5.0E+3
30	3.3E+3
40	2.5E+3
50	2.0E+3
60	1.7E+3
70	1.4E+3
80	1.3E+3
90	1.1E+3
100	1.0E+3
200	500.0E+0
300	333.3E+0
400	250.0E+0
500	200.0E+0
600	166.7E+0
700	142.9E+0
800	125.0E+0
900	111.1E+0
1000	100.0E+0

Combining Inductors in Series

The sum of all inductor values equals total inductance when in series.





LT=L1+L2+L3...	
L1=	100.0E-6
L2=	220.0E-6
L3=	470.0E-6
LT=	790.0E-6

The total inductance of all inductors in series is always greater then the largest inductor value.

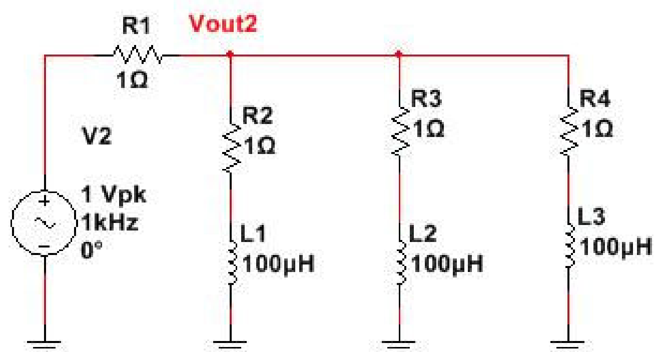
Combining Inductors in Parallel

3 approaches can be taken to calculate total inductance in parallel.

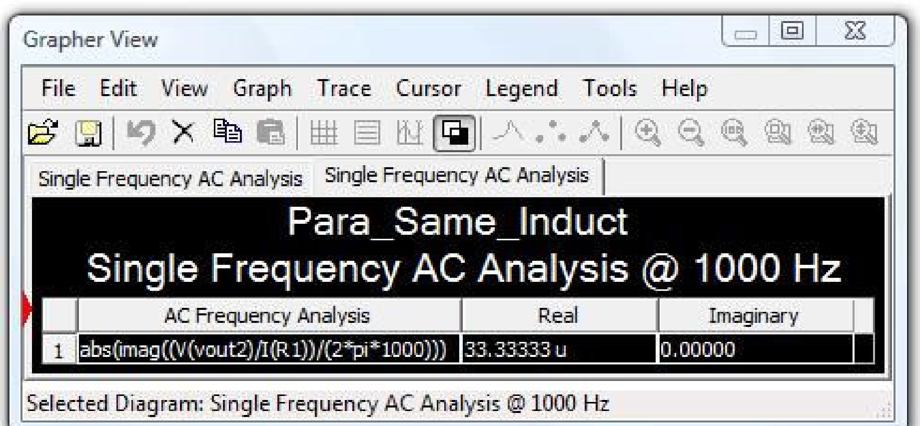
- For two or more Inductors of equal value [L1/Ln] (Any Inductor value / # of Inductors) can be used.
- For two Inductors of any value [(L1+L2)/(L1*L2)] (Product of both Inductor value values / sum of both Inductor value values).
- For 3 or more Inductors of any value use the reciprocal of the sum of the reciprocal of all Inductor value values. [1/(1/L1)+(1/L2)+(1/L3)…]

Inductors of same value in Parallel

Calculate total inductance by dividing the value of one inductor by the number of inductors in the parallel circuit.



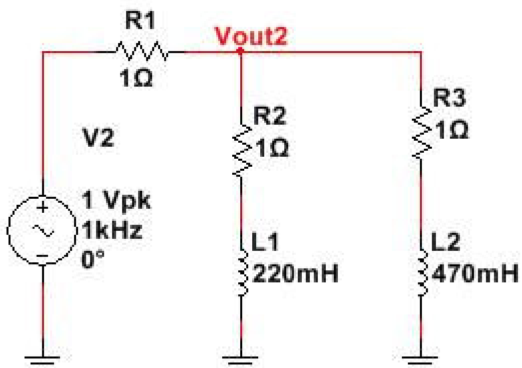
The total inductance of all inductors in series is always less then the smallest Inductor value.

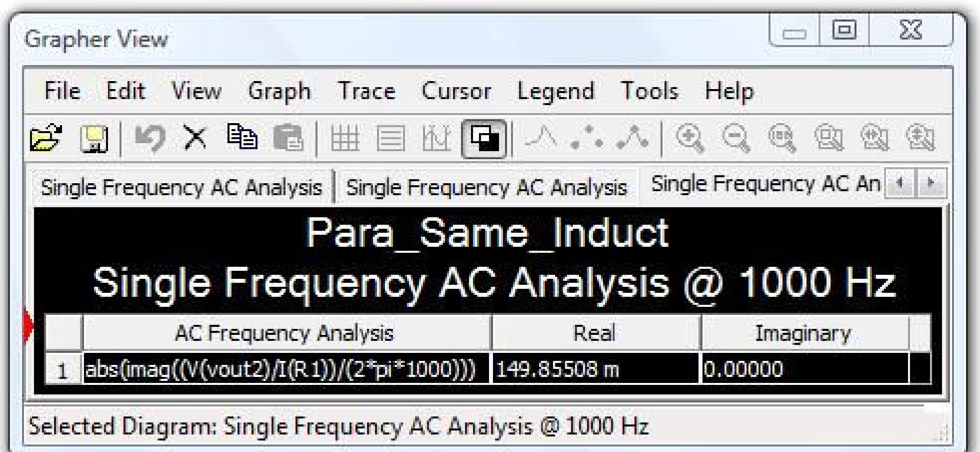


LT=AnyL/CountL	
L1=	100.0E-6
L2=	100.0E-6
L3=	100.0E-6
LT=	33.3E-6

Two Inductors of Different Values

To calculate two inductors of the same or different values within a parallel circuit use the product divided by the sum method.

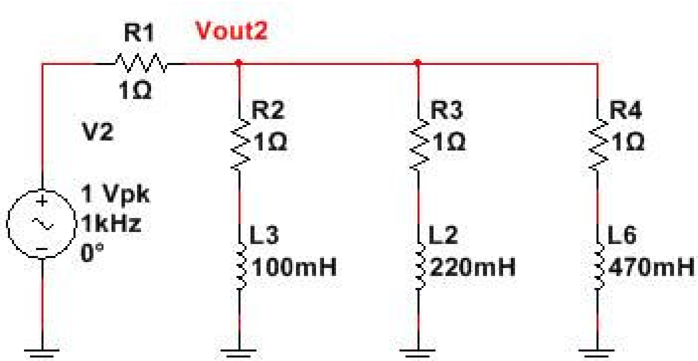


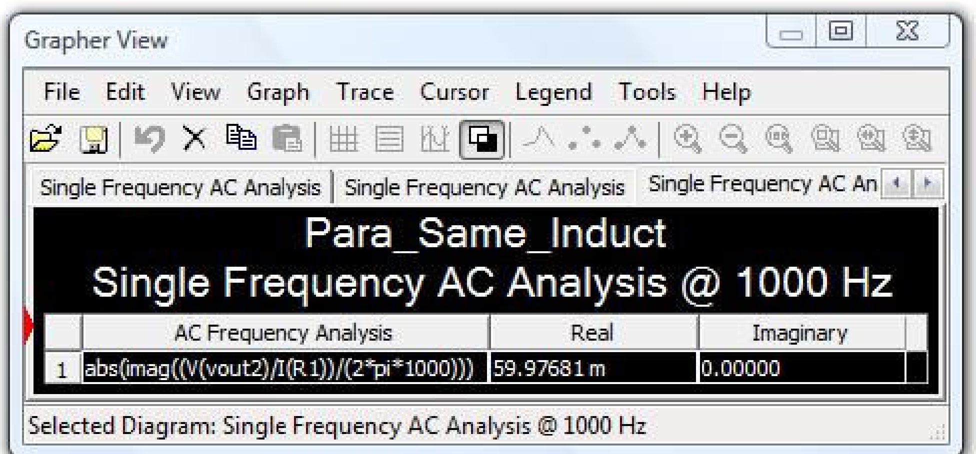


LT=(L1*L2)/(L1+L2)	
L1=	220.0E-3
L2=	470.0E-3
LT=	149.9E-3

The Reciprocal of the Sum of the Reciprocal Inductors Values

This method works for calculating all parallel inductor circuits





LT=1/((1/L1)+(1/L2)+(1/L3)..)	
L1=	100.0E-3
L2=	220.0E-3
L3=	470.0E-3
LT=	59.98E-3

RL Time Constant

The RL time constant, also called tau (τ), is the time constant (in seconds) of a RL circuit.

- $\tau = L/R$
  - R = resistor's value (in Ohms)
  - L = Inductor's value (in Henrys)
- The Charge and Discharge rate are inversely logarithmic and are explained in greater detail on the next slide.

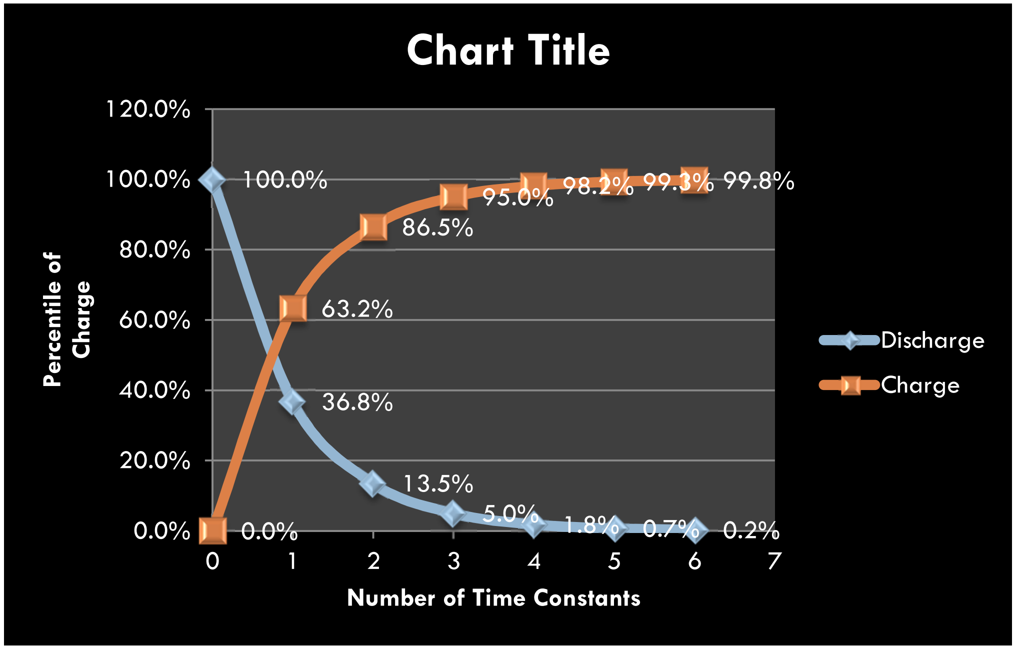
Charging $V(t) = V_0(1 - e^{-t/\tau})$

Discharging $V(t) = V_0(e^{-t/\tau})$

Picture Courtesy of http://en.wikipedia.org/wiki/RC_time_constant

RL Time Constant as a Function of Time.

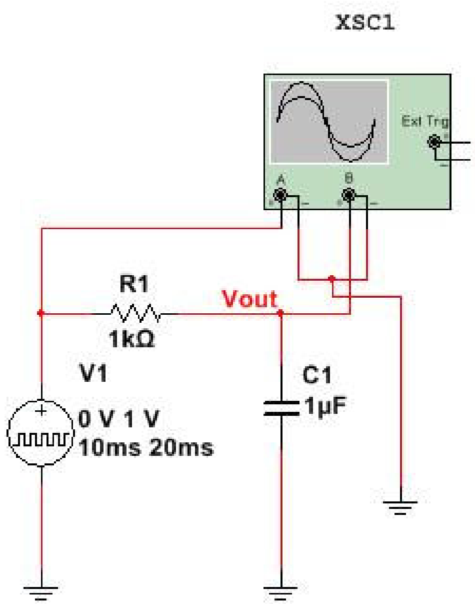
An inductor is similar to a capacitor as it stores a charge but has a different approach. An inductor stores the charge in an electrical magnetic field (EMF) around its coil and in a core if present. As the current flows though the coil a back EMF (CEMF) is generated that opposes the charge. This gives an inverse charge-rate and discharge-rate, like a capacitor it will never reach 100% or 0%.

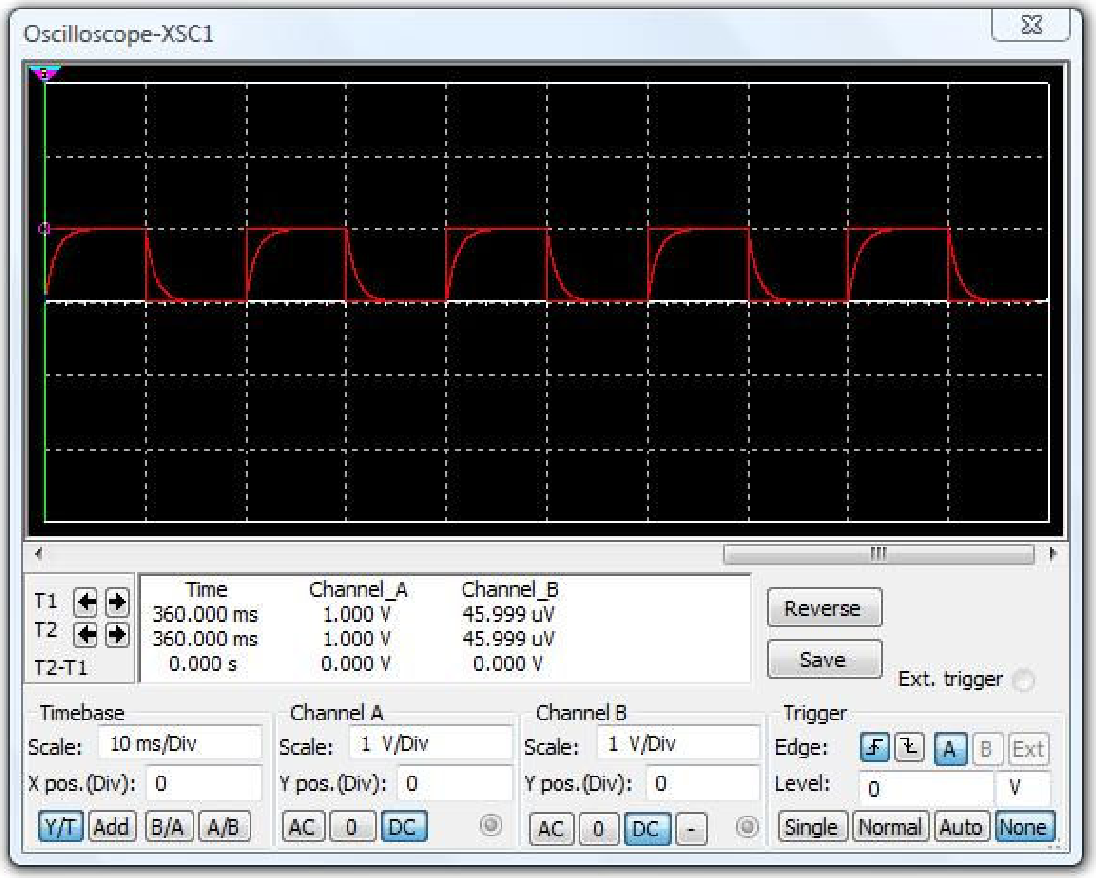


Vr=Vs(e^-(t/τ))/Vr=Vs*(1-e^-(t/τ))*		
Vs=	1	VDC
R=	1.0E+3	Ω
L=	1.0E+3	Henrys
(L/R=τ) τ=	1.0E+0	
RL Time Constant		
(tc)	Discharge	Charge
0	100.0%	0.0%
1	36.8%	63.2%
2	13.5%	86.5%
3	5.0%	95.0%
4	1.8%	98.2%
5	0.7%	99.3%
6	0.2%	99.8%

RL Circuit Reaction to Pulsating VDC

The simulation curve mimics that of the calculated charge and discharge curve.





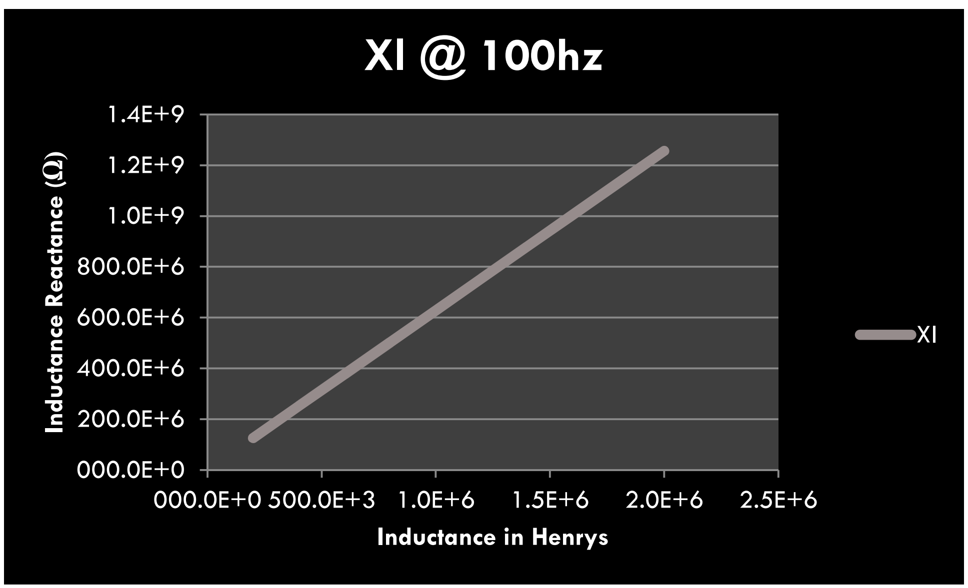
Xl at a Fixed Frequency.

Inductive Reactance (Xl) is the opposition (resistance) of a charge across the inductor. Xl is linear proportional to frequency and inductance within the circuit.

$$X_L = 2\pi f L$$

Where:

X_L = the inductive reactance in ohms
f = the frequency in hertz
L = the inductance in henries
π = 3.1416

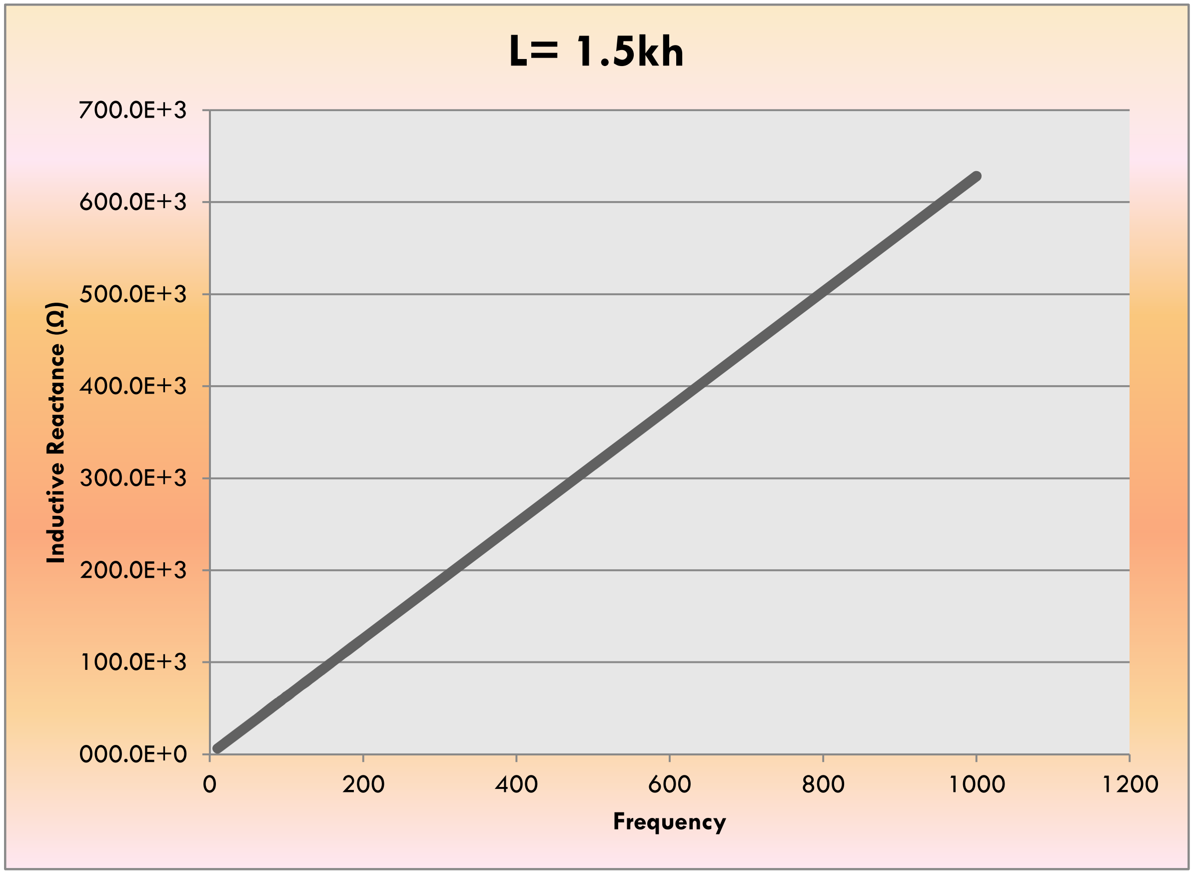


Xl=2πfL	
R=	1000
Input Hz=	100
Inductance	Xl
200.0E+3	125.7E+6
400.0E+3	251.3E+6
600.0E+3	377.0E+6
800.0E+3	502.7E+6
1.0E+6	628.3E+6
1.2E+6	754.0E+6
1.4E+6	879.6E+6
1.6E+6	1.0E+9
1.8E+6	1.1E+9
2.0E+6	1.3E+9

Picture Courtesy of http://www.tpub.com/neets/book9/34a.htm

Xl Reactance to Frequency

As stated in the Previous Slide, Xl has a linear Reaction to Frequency.



Va= 1	R= 1kΩ
Frequency	L= 1.5kh
10	6.3E+3
20	12.6E+3
30	18.8E+3
40	25.1E+3
50	31.4E+3
60	37.7E+3
70	44.0E+3
80	50.3E+3
90	56.5E+3
100	62.8E+3
200	125.7E+3
300	188.5E+3
400	251.3E+3
500	314.2E+3
600	377.0E+3
700	439.8E+3
800	502.7E+3
900	565.5E+3
1.0E+3	628.3E+3