ECE 214 – Electrical Circuits Lab
Lecture 7

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Announcements

- Will be out of town next Monday and Tuesday. For lecture I am switching with ECP214, so you will have ECP214 Tuesday at 8am and ECE214 Thursday at 8am.
- This will complicate Tues and Wed labs a bit, I'll do my best to make sure you get the material in time.

Lab #7 – RLC Circuits

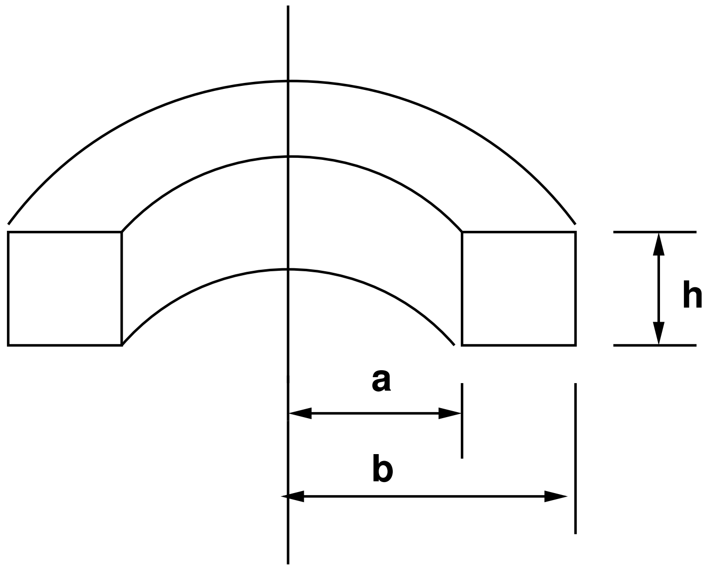
Inductors

- Impedance: $Z_L = j\omega L$
- Current lags voltage by 90^o in sinusoid
- Store energy in magnetic field.
- Measured in Henries
- Chokes – block AC while letting DC pass

Inductors – Estimating Value

- For a torroid, rectangular cross section, air filled
  Magnetic field inside: $B = \frac{\mu_0 I}{2\pi r}$
  Magnetic flux through each loop turn:
  $\Phi_B = \int_a^b Bh\, dr = \frac{\mu_0 INh}{2\pi} \int_a^b \frac{dr}{r} = \frac{\mu_0 INh}{2\pi} \ln \frac{b}{a}$
  Inductance: $L = \frac{N\Phi_B}{I} = \frac{\mu_0 N^2 h}{2\pi} \ln \frac{b}{a}$

- N = number of turns
  h = height
  b = outside radius
  a = inside radius



- For ferrite core, multiply by ferrite's μ_r which is anywhere from 16 to 640. Can you see why they use ferrite cores?

- Saturation – when have an iron core at high currents can saturate, causing big decrease in inductance.

Calculating the Series Resistance using Q

- ESR = equivalent series resistance, Q = Quality Factor
- For an Inductor, $Q = \frac{2\pi f L}{R_S}$
- For a Capacitor, $Q = \frac{1}{D} = \frac{R_S}{2\pi f C}$
  D = Dissipation Factor,

RLC Circuits – Resonance

- When impedance is at minimum (and non-imaginary) So when capacitance and inductance balance out.
- $\omega_0 = \frac{1}{\sqrt{LC}}$
- The capacitor and inductor bounce the current back and forth between each other. V on the Capacitor and V on the inductor are the same, but 180 degrees out of phase.
- Damping: whether circuit will resonate naturally. Depends on resistance. One that will are underdamped,

those that won't are overdamped.
attenuation = alpha, measured in nepers per second (decibels, but natural log)
Damping factor=$\zeta = \frac{\alpha}{\omega_0}$
Zeta = 1 is critical damping, just before oscillating.

- Resonance can be used as a filter. Bandwidth $\delta\omega = 2\alpha$

- Q factor, describes resonators. Peak energy stored in circuit divided by the average energy dissipated in it per radian at resonance. Low Q circuits are damped and lossy; high Q circuits are underdamped. Q is related to bandwidth; low Q circuits are wide band and high Q circuits are narrow band.

$Q = \frac{\omega_0}{\delta\omega}$

Series RLC, $Q = \frac{1}{\omega_0 RC} = \frac{\omega_0 L}{R}$

RLC Circuits – Series

- $\alpha = \frac{R}{2L}$ and $\omega_0 = \frac{1}{\sqrt{LC}}$

RLC Circuits – Applications

- Tuning, with variable capacitor
- Filters
- Oscillator (where R is very small)
- Voltage Multiplier – If R is small, $V_L = \frac{V}{R}\omega_0 L$
  $\frac{V_L}{V} = Q$

RLC Circuits – Analysis

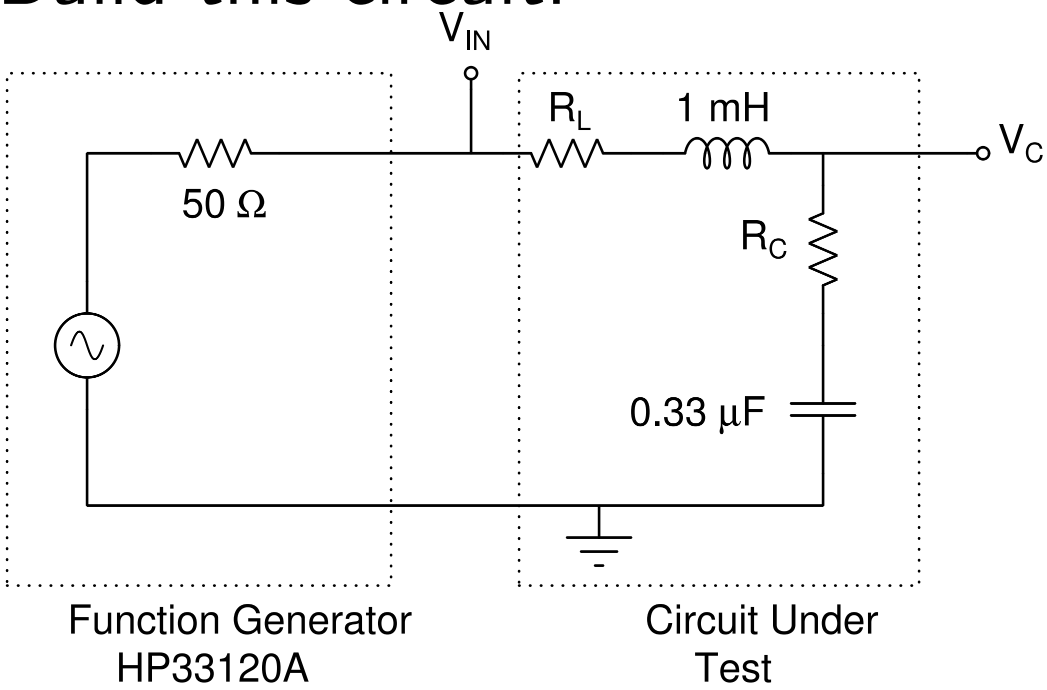
- Step function: three cases.
  $\alpha = \frac{R}{2L}$, $\omega_0 = \frac{1}{\sqrt{LC}}$, $\zeta = \frac{\alpha}{\omega_0}$
  - Overdamped $(\alpha > \omega_0)$ $(\zeta > 1)$
    Decaying exponential (after brief pulse up) $v_C(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t}$
    $s_{1,2} = -\alpha + / - \sqrt{\alpha^2 - \omega_0^2}$
  - Critically Dampled $(\alpha = \omega_0)$ $(\zeta = 1)$
    Quickly decaying exponential
    $v_C(t) = (A_1 + A_2 t)e^{-\alpha t}$

– Underdamped ($\alpha < \omega_0$) ($\zeta < 1$)
Ringing sinusoidal that gradually decays
$v_C(t) = [A_1 \cos(\omega_d t) + A_2 \sin(\omega_d t)]e^{-\alpha t}$
$\omega_d = \sqrt{\omega_0^2 - \alpha^2}$

- Sinusoidal
$v_C(t) = \frac{V_{in}}{LC} \frac{1}{\sqrt{(\frac{1}{LC} - \omega^2)^2 + (\frac{R}{L}\omega)^2}} \cos(\omega t - \tan^{-1}(\frac{\frac{R\omega}{L}}{\frac{1}{LC} - \omega^2}))$

Lab Notes

- Build this circuit:



- You will need to do some micro-cap in-lab, be sure one of your lab group has a laptop capable of doing this.

- Advanced equipment usage. As always you can check the relevant manuals, but here are some spoilers.
  - Hooking the trigger from the function generator to the external trigger on the scope. May be necessary? Co-ax cables in the closet.
  - Using the function generator in single-pulse mode: Set the signal up the way you want: (50ms, square, amplitude, offset).
    Press “shift” then “burst”

Can set number of repeats in burst with “shift” “$<$”
Now press “single” (trig) key and it will send a single pulse.

– Using the scope in to capture a single shot:
First it’s best to get the scope set up with the proper scaling settings to begin with.
Select Slope/Coupling and set the trigger level
Mode / Single
Press the Run button. It will collect on trigger but only a single shot.

- Finding phase shift in lissajous mode;

45 degree line to right means 0 degrees $\sin^{-1}(0/max)$

oval with the right ratio is 45 degrees $\sin^{-1}(\frac{\sqrt{2}}{2}$

circle is 90 degrees $\sin^{-1}(max/max)$