

Final Exam
C. DiMarzio, Northeastern University
EECE2150, Fall 2022
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Solutions

1 Short–Answer Questions

If two wires are made of the same material and have the same length, the thicker wire will have a higher resistance.

False

Capacitances in parallel add; *e.g.* $C = C_1 + C_2$.

True

The effect called “Jacob’s Ladder” is the result of trying to make

- an instantaneous change in voltage on a capacitor.
- an instantaneous change in current through a capacitor.
- an instantaneous change in voltage on an inductor.
- an instantaneous change in current through an inductor.

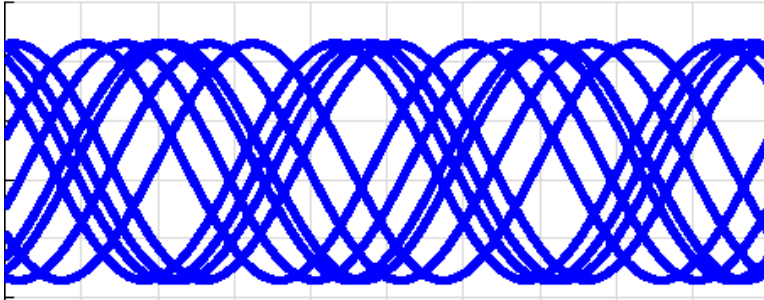
In an ideal inductor, the average power is

- $\frac{V^2}{L}$ $\frac{V^2}{2L}$ Indeterminate 0

To find the steady–state solution of a circuit,

- Short the capacitors and inductors
- Open the capacitors and short the inductors
- Short the voltage sources and open the current sources
- Open the voltage sources and short the current sources

If you observed the following signal on an oscilloscope, which of the settings would you change?



- Channel 1 Settings Horizontal Sweep Speed
 Trigger Settings

On an oscilloscope, I see a sine wave with a voltage, V peak-to-peak. What voltage will I read on a multimeter?

- V $\frac{V}{2}$ $\frac{V}{\sqrt{2}}$ $\frac{V}{2\sqrt{2}}$

I have a signal in which I know the highest frequency is 1 kHz. In order to obtain all the information in this signal I need to sample at

- < 1 Hz > 500 Hz > 1 kHz > 2 kHz

A capacitor...

- has a positive reactance that increases in magnitude with increasing frequency.
 has a positive reactance that decreases in magnitude with increasing frequency.
 has a negative reactance that increases in magnitude with increasing frequency.
 has a negative reactance that decreases in magnitude with increasing frequency.

The largest voltage that can be output by an op-amp is limited by the power rails.

True

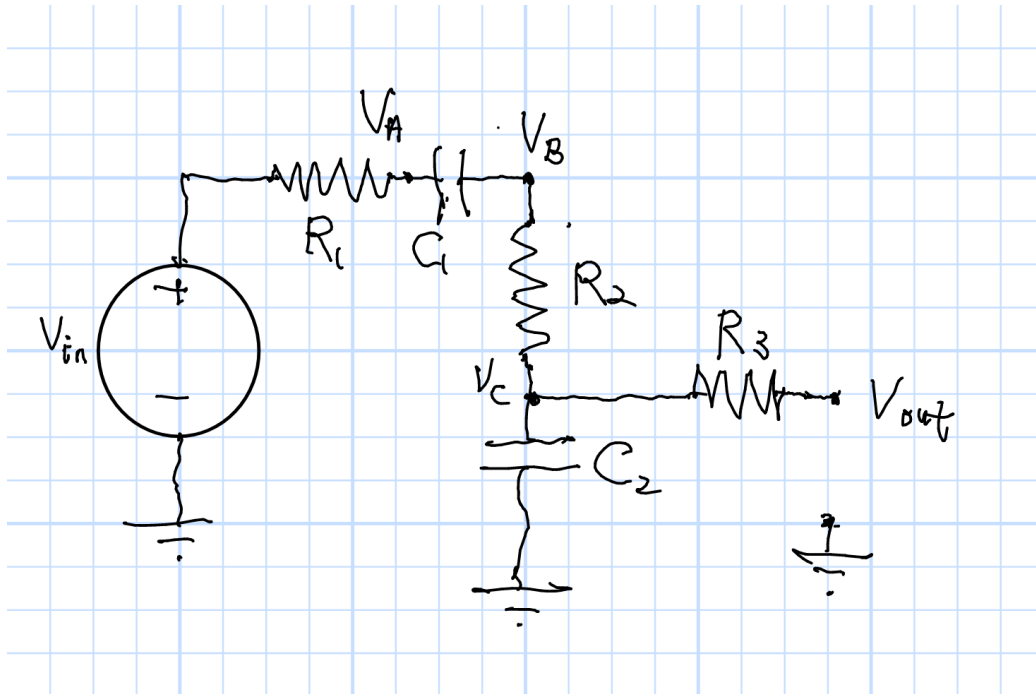
If two signals are multiplied in the time domain, then in the frequency domain, they are...

also multiplied. **X** convolved. autocorrelated. added.

A time domain signal is real valued. In the frequency domain, the voltage is $V(f)$ for positive frequencies. For negative frequencies... (Check All correct answers).

X $ReV(-f) = ReV(f)$ $ReV(-f) = -ReV(f)$
X $ImV(-f) = -ImV(f)$ $ImV(-f) = ImV(f)$

2 Current and Voltage



Consider the circuit in the figure. Here $V_{in} = 5$ at $f = 1 \text{ kHz}$, $R_1 = 4 \text{ K}\Omega$, $R_2 = 1 \text{ K}\Omega$, $R_3 = 1 \text{ K}\Omega$, $C_1 = 20 \mu\text{F}$, and $C_2 = 1 \mu\text{F}$.

Solutions Attached

For now the output is not connected to anything. Calculate the voltages and express in rectangular form;

$$V_A = \underline{\hspace{10em}}$$

$$V_B = \underline{\hspace{10em}}$$

$$V_C = \underline{\hspace{10em}}$$

Now, let's calculate the Thévenin equivalent circuit as seen at the output. First, what is the open-circuit voltage?

$$V_{OC} = \underline{\hspace{10em}}$$

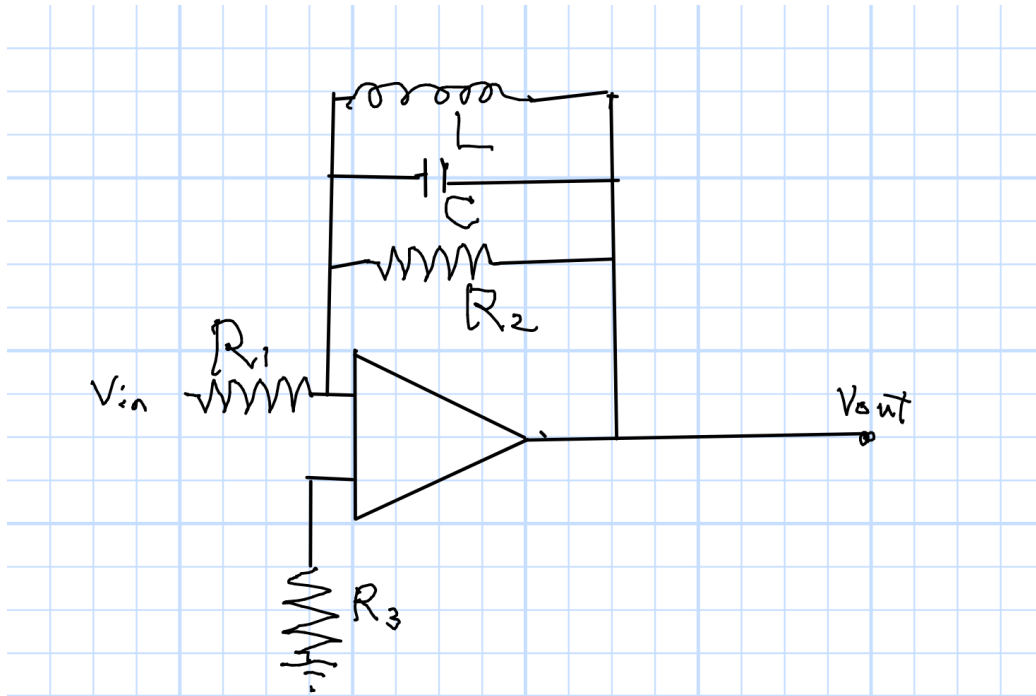
What is the short-circuit current?

$$I_{SC} = \underline{\hspace{10cm}}$$

What is the Thévenin Impedance?

$$Z_T = \underline{\hspace{10cm}}$$

3 Filter



Consider the filter in the circuit. Here $R_1 = 940 \Omega$, $R_2 = 4.7 \text{ k}\Omega$, $R_3 = 4.7 \text{ k}\Omega$, $L = 5 \text{ mH}$, and $C = 225 \text{ pF}$.

What type of filter is this?

- Low Pass
 High Pass
 Band Pass
 Band Stop

Solutions Attached

At what frequency is the gain highest? Hint: The feedback impedance is highest when the reactance is zero.

$$f_c = \underline{\hspace{4cm}}$$

What are the reactances of the capacitor and inductor at this frequency?

$$X_C = \underline{\hspace{4cm}}$$

$$X_L = \underline{\hspace{4cm}} \text{ ces in parallel add; e.g. } C = C_1 + C_2.$$

True False

What is the gain in dB at this frequency?

Gain= _____ dB.

What is the phase of the gain in degrees at this frequency?

Phase= _____ Degrees.

What is the input impedance of this amplifier?

Z_{in} = _____

Now change the frequency to 250 kHz.

What are the reactances of the capacitor and inductor at this frequency?

X_C = _____

X_L = _____

What is the gain in dB at this frequency?

Gain= _____ dB.

What is the phase of the gain in degrees at this frequency?

Phase= _____ Degrees.

4 Fourier Transform

Consider two input signals, 5 Volts $\angle 0$ deg at $f_1 = 1$ kHz and 7 Volts $\angle 45$ deg at $f_1 = 2.5$ kHz.

Solutions Attached

Draw the spectrum of the sum of these signals. Use frequency axes that cover an appropriate range of positive and negative frequencies. Plot the real part with the symbol “o” and the imaginary part with “x,” and the absolute value with a “+”. Label the axes and show numbers.

If I want to digitize this result, at what frequency must I sample?

$f_{sample} > \underline{\hspace{4cm}}$

I have a device, called a mixer, that multiplies two signals. If I use these two signals as inputs, at what frequencies do I expect to see signals in the output?

If I want to digitize this result, at what frequency must I sample?

$f_{sample} > \text{_____}$

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```
% /home/chuck/Documents/working/12458/ex2.m
% Tue Dec 6 13:42:05 2022
R1=4000;C1=20e-6;R2=1000;C2=1e-6;R3=1000;Vin=5;f=1e3;
```

```
omega=2*pi*f;
```

```
ZC1=1/(1j*omega*C1)
```

```
ZC2=1/(1j*omega*C2)
```

```
ZC1 =
```

```
0.0000 - 7.9577i
```

```
ZC2 =
```

```
0.0000e+00 - 1.5915e+02i
```

Open circuit

```
Z1122=R1+ZC1+R2+ZC2
```

```
I=Vin/Z1122
```

```
VA = Vin*(Z1122-R1)/Z1122
```

```
VB=Vin*(R2+ZC2)/Z1122
```

```
VC=Vin*ZC2/Z1122
```

```
Voc=VC
```

```
Z1122 =
```

```
5.0000e+03 - 1.6711e+02i
```

```
I =
```

```
9.9888e-04 + 3.3385e-05i
```

```
VA =
```

```
1.0045 - 0.1335i
```

```
VB =
```

```
1.0042 - 0.1256i
```

```
VC =
```

```
0.0053 - 0.1590i
```

```
Voc =
```

```
0.0053 - 0.1590i
```

Short circuit

```
Z11223=R1+ZC1+R2+par(R3,ZC2)
```

$$I = V_{in} / Z_{11223}$$

$$I_{sc} = I * Z_{C2} / (R_3 + Z_{C2})$$

$$Z_{11223} = 5.0247e+03 - 1.6318e+02i$$

$$I = 9.9404e-04 + 3.2282e-05i$$

$$I_{sc} = 2.9568e-05 - 1.5350e-04i$$

Thevenin Equivalent

$$Z_T = V_{oc} / I_{sc}$$

$$Z_T = 1.0051e+03 - 1.5899e+02i$$

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```

% /home/chuck/Documents/working/12458/ex1.m
% Exam question on filters
R1=940;R2=4700;L=5e-3;C=225e-12;
omegac=1/sqrt(L*C);
fc=omegac/2/pi

XLc=omegac*L
XCc=-1/omegac/C
ZLc=1j*XLc;
ZCc=1j*XCc;
Zc=1/(1/R2+1/ZLc+1/ZCc)

Ac = -Zc/R1
AAc=abs(Ac)
AAcdb=20*log10(AAc)
PAc=angle(Ac)*180/pi

f2=250e3;omega2=2*pi*f2

XL2=omega2*L
XC2=-1/omega2/C
ZL2=1j*XL2;
ZC2=1j*XC2;
Z2=1/(1/R2+1/ZL2+1/ZC2)

A2 = -Z2/R1
AA2=abs(A2)
AA2db=20*log10(AA2)
PA2=angle(A2)*180/pi

fc =
    1.5005e+05
XLc =
    4.7140e+03
XCc =
   -4.7140e+03
Zc =
    4.7000e+03 - 1.1975e-12i
Ac =
   -5.0000 + 0.0000i
AAc =
     5
AAcdb =
    13.9794
PAc =
    180
omega2 =
    1.5708e+06
XL2 =
    7.8540e+03
XC2 =
   -2.8294e+03

```

Z2 =
2.2073e+03 - 2.3457e+03i
A2 =
-2.3482 + 2.4954i
AA2 =
3.4265
AA2db =
10.6970
PA2 =
133.2591

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```

% /home/chuck/Documents/working/12458/ex3.m
% Tue Dec 6 15:30:19 2022
f1=1e3;f2=2.5e3;
V1=5;V2=7/sqrt(2)*(1+1j);

faxis=[-2.5,-1,1,2.5];
Y=[conj(V2),V1,V1,V2];
ffaxis=[];YY=[];
for n=1:length(faxis);
    ffxaxis=[ffaxis, repmat(faxis(n),1,3)];
    YY=[YY,0,Y(n),0];
end;
cxplot(ffaxis,YY);grid on;
xlabel('f, Frequency, kHz');
ylabel('V, Voltage');

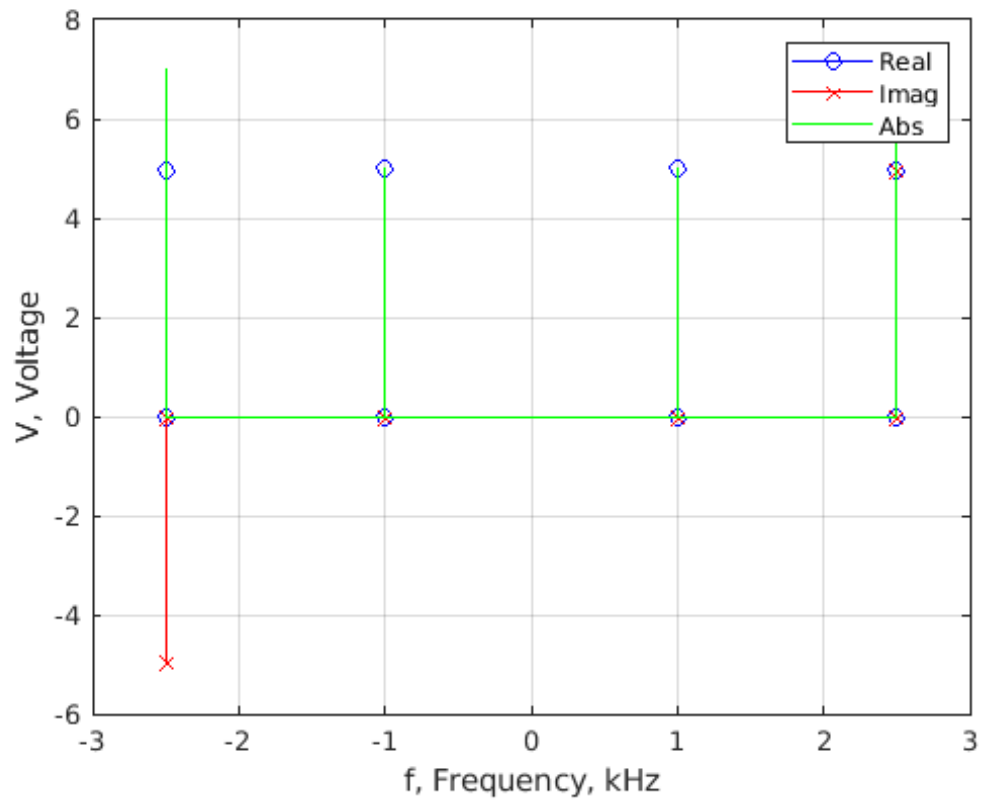
samplefrequency=2*max([f1,f2])

disp('Product frequencies are +/-f1 +/- f2');

samplefrequency=2*(f1+f2)

samplefrequency =
    5000
Product frequencies are +/-f1 +/- f2
samplefrequency =
    7000

```



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