Electronics
EECE2412 — Spring 2016
Exam #1

Perfect score is 90
Add 10 on the grade sheet.

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File:12140/exams/exam1

18 February 2016

Name: Solutions : Row # ________ : Seat # ________

General Rules:

- Write your name, row number, and seat number above. Row #1 is at the front. Seat #1 is to the left as viewed by the students.
- You may make use of two sheets of notes, 8.5–by–11 inches, using both sides of the page.
- You may use a calculator.
- Present your work as clearly as possible. I give partial credit if I can figure out that you know what you are doing. I do not give credit for putting down everything you know and hoping I will find something correct in it.
- Each question has a vertical black bar providing space for your work and a box for numerical answers. Please write your answer to each question clearly. If it happens to be correct, I give you points quickly and move on to the next problem. Please show your work in the space provided, or on extra pages, clearly labeled with the problem number. If the answer is wrong, this will make it easy for me to find ways to give you partial credit.
- Avoid any appearance of academic dishonesty. Do not talk to other students during the exam. Keep phones, computers, and other electronic devices other than calculators secured and out of reach.

1 Operational Amplifiers 30

The figure below shows an operational amplifier circuit. The Op–Amp in this case has an open–loop gain of 10^5, has a gain–bandwidth product of 1 MHz and is powered by positive and negative 12 Volt power supplies, but is otherwise ideal.

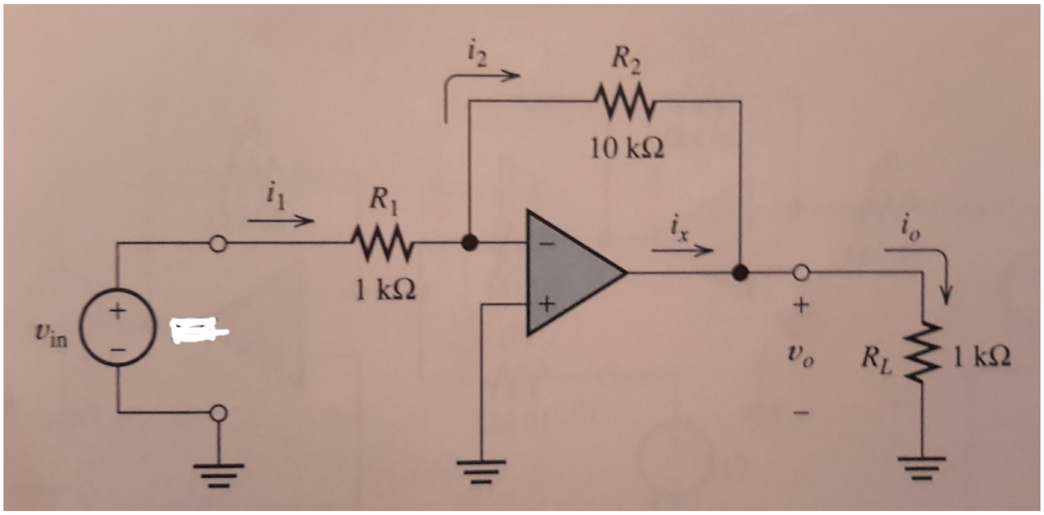


Figure from Hambley, *Electronics, 2nd Ed.*

1.1 Gain 10

What is the voltage gain in decibels? What is the phase?

$A_v = -\frac{R_2}{R_1} = -\frac{10k\Omega}{1k\Omega} = -10$

Gain: 20 dB Phase: 180 degrees

1.2 Bandwidth 10

What is the 3–dB bandwidth?

$|A_v| B = 10^6$ Hz

$B = 10^5$ Hz ✓

Bandwidth: 100 kHz ✓

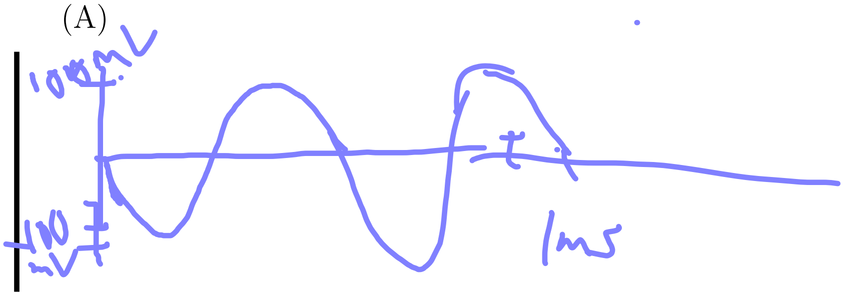
1.3 Output Waveforms

Sketch a couple cycles of each output waveform, $v_o(t)$ if the input is

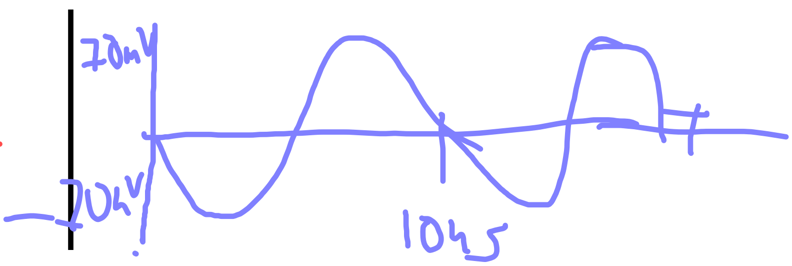
$$v_{in}(t) = (10 \text{ mV}) \times \sin(2\pi f t)$$

where (A) $f = 2$ kHz and (B) $f = 100$ kHz. Be sure to include numbers of seconds and volts on the axes.

(A)



(B)

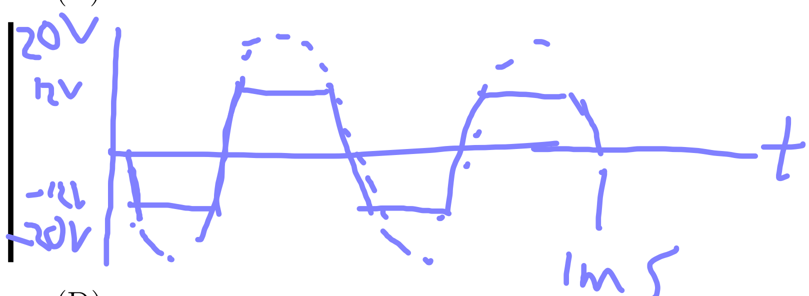


Repeat for

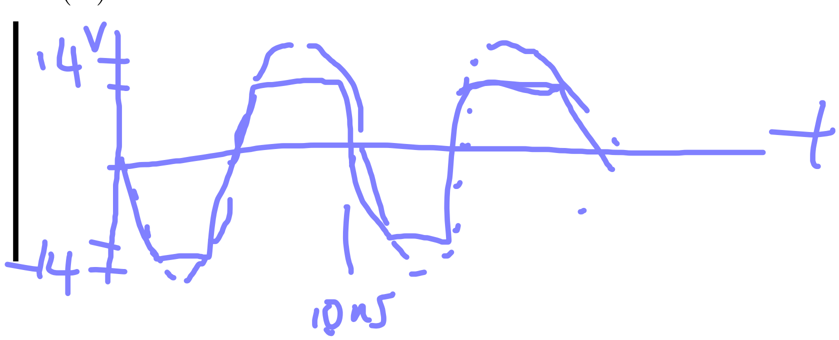
$$v_{in}(t) = (2 \text{ V}) \times \sin(2\pi f t)$$

where (C) $f = 2$ kHz and (D) $f = 100$ kHz.

(C)



(D)



2 Rectifier Circuit

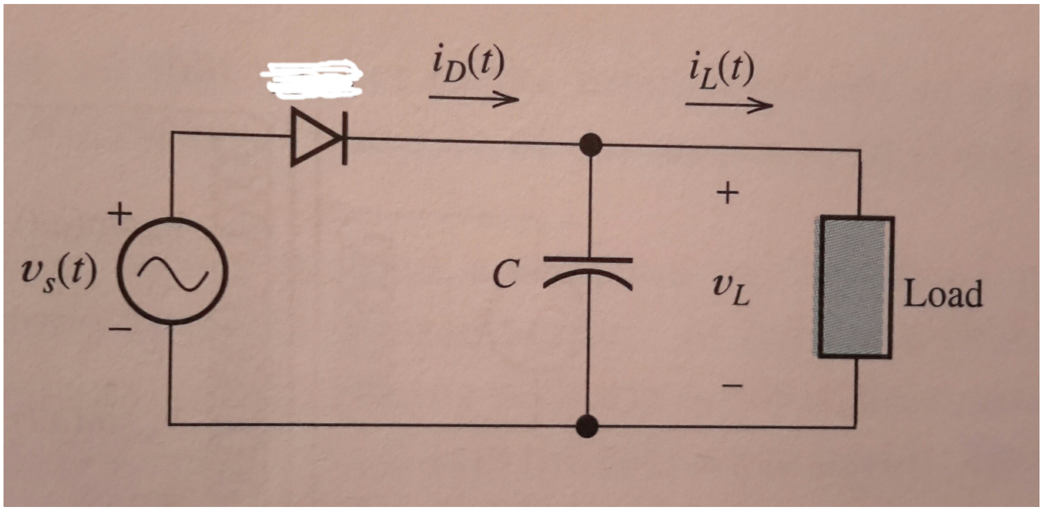
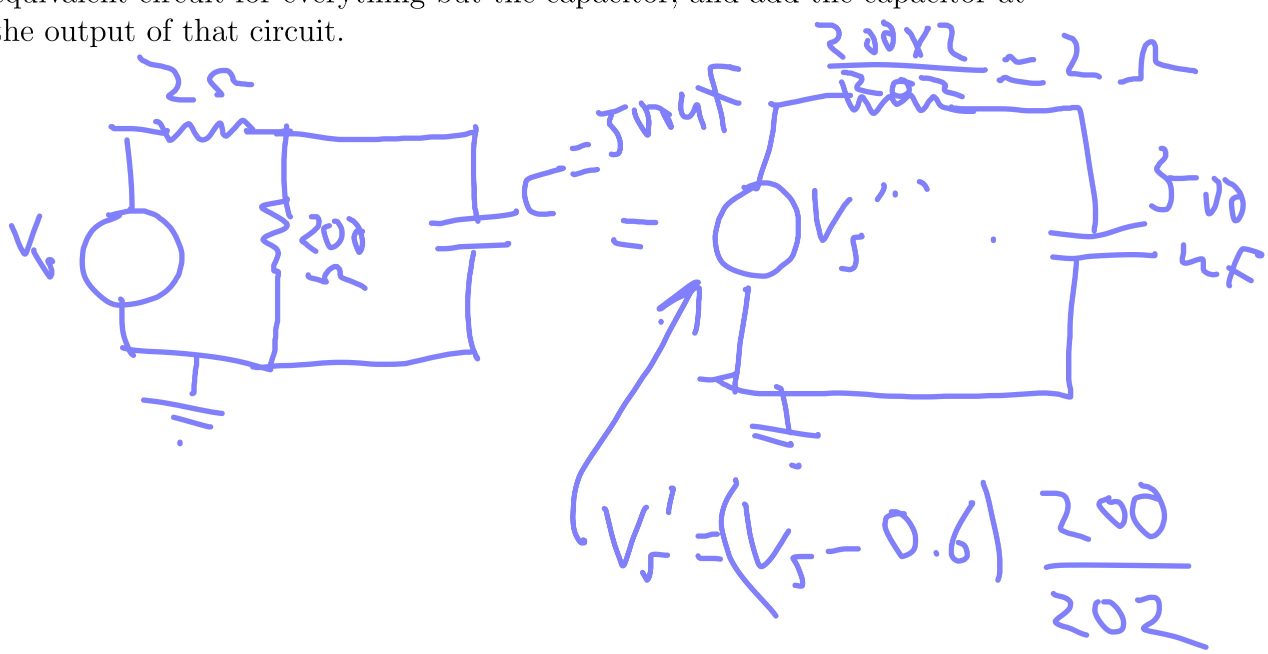


Figure from Hambley, *Electronics, 2nd Ed.*

This circuit is a simple rectifier circuit with a filter capacitor. The capacitor is said to be "charging" when the diode is "on" and "discharging" when it is "off." The diode has a forward voltage drop of 0.6 V and a series resistance of 2 Ohms. The load is 200 Ohms, and the capacitor is 500 μF.

2.1 Charging

Draw the circuit model for the "charging" state. Reduce it to a Thevenin equivalent circuit for everything but the capacitor, and add the capacitor at the output of that circuit.



What is the RC time constant of the charging circuit?

3

2Ω × 5 × 10⁻⁴ F = 10⁻³ s

Time Constant: 1 ms

What is the maximum voltage on the capacitor if the source $v_s(t)$ is a 120 V RMS sine wave?

3

$(120\sqrt{2} - 0.6)\frac{200}{202} = 167$

Maximum Voltage: 167 V

Do you think this is fast enough for the voltage on the capacitor to track the input voltage at a frequency of 60 Hz?

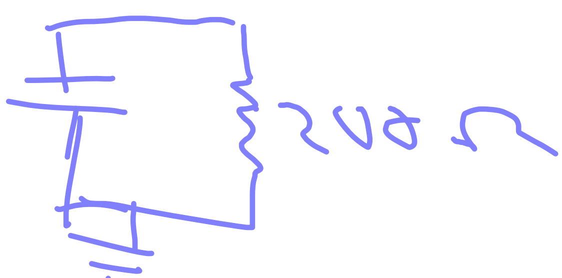
Answer: yes. half cycle is 8 time constants

10

2.2 Discharging

Draw the circuit model for the "discharging" state.

4



What is the RC time constant of the discharging circuit?

3

200 Ω × 5 × 10⁻⁴ F = 0.1 s

Time Constant: 100 ms

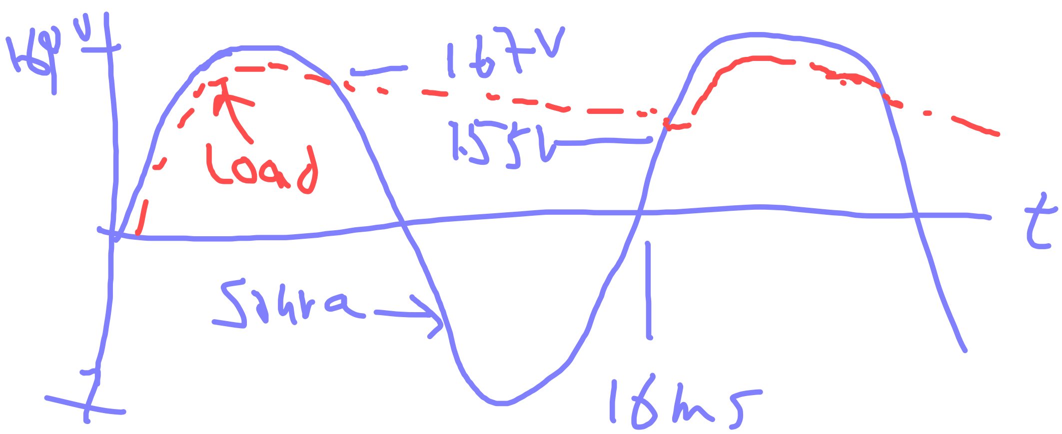
What is the magnitude of the ripple?

$(1 - e^{-(8ms/100ms)}) \times 167V = 13V$

Ripple: 13 Volts

2.3 Summary

Sketch the input voltage from the source, and the output voltage to the load quantitatively on a single plot. That is, show numbers on both axes of the graph.



3 Diode Small–Signal Model

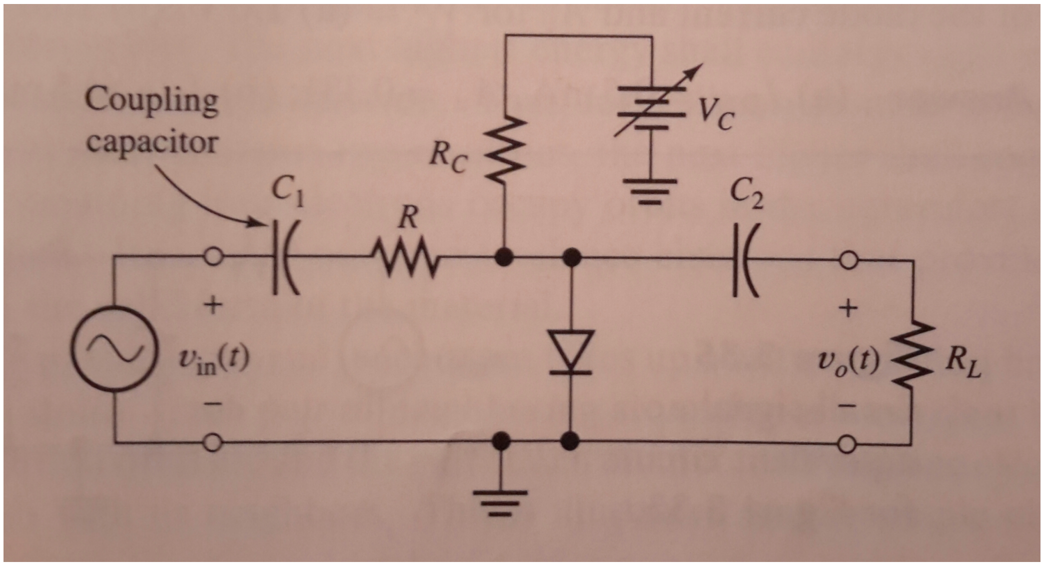


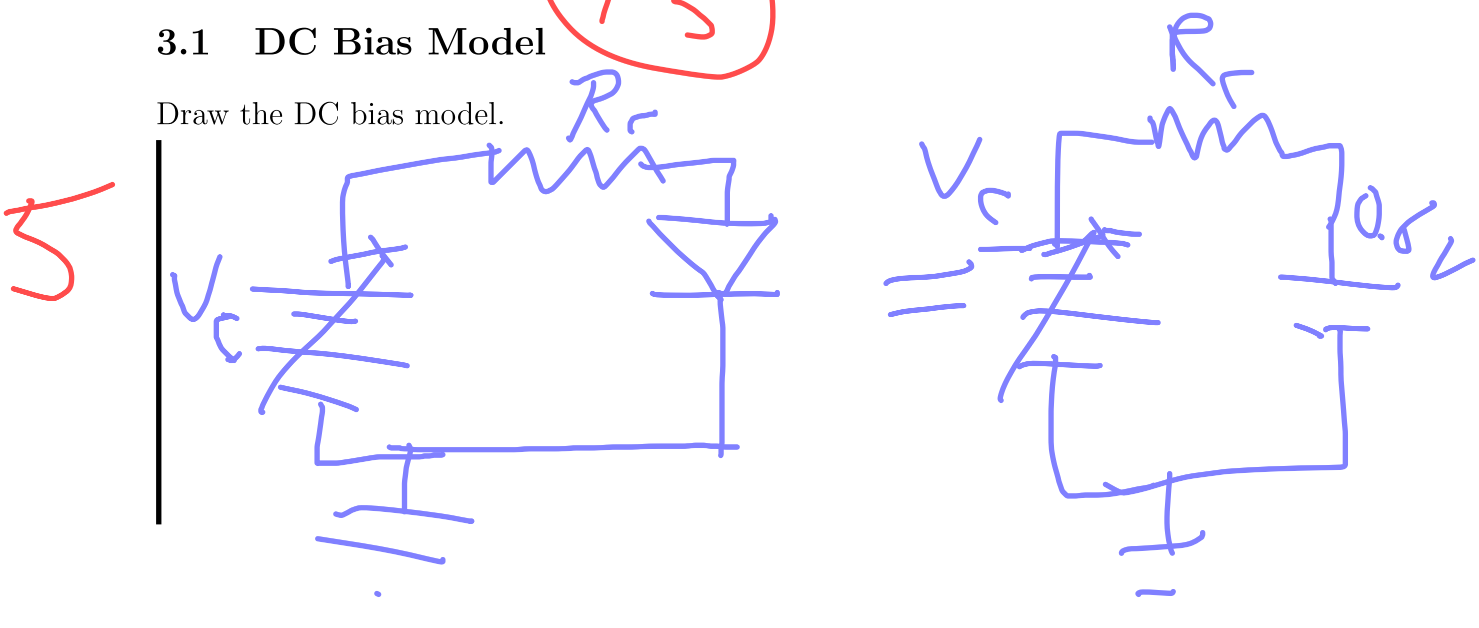
Figure from Hambley, *Electronics, 2nd Ed.*

In this model of a voltage–controlled attenuator, the capacitors are large enough to be considered short circuits at the AC frequency of the source, $v_{in}(t)$.

The diode draws 10 mA at a forward voltage of 0.6 V, and follows the Shockley equation. Resistor values are $R_C = 1$ kOhms, $R_L = 4$ kOhms,

3.1 DC Bias Model

Draw the DC bias model.



Find the control voltage required for the diode current to be (A) 10 mA and (B) 5 mA.

3

$(V_C - 0.6V) = I R_C$. $R_C = 1k\Omega$

$V_C = I R_C + 0.6V$

V_C (A): 10.6 V Volts

5

V_C (B): 5.6V Volts

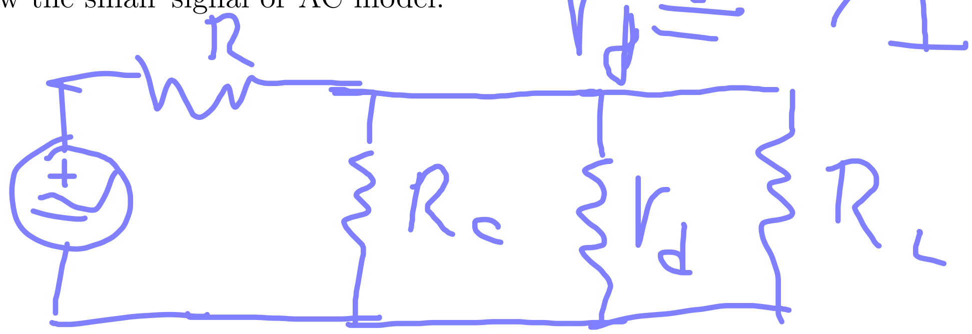
15

3.2 Small–Signal Model

Draw the small–signal or AC model.

$r_d = V_T / I$

3



What is the diode resistance, r_d for each DC current?

3

$r_d = \frac{V_T}{I} = \frac{25\,mV}{10\,mA}$

r_d (A): 2.5 Ohms

$\frac{25\,mV}{5\,mA}$

3

r_d (B): 5 Ω

What value of R will cause the circuit gain,

$$A_V = V_O(t)/V_{in}(t),$$

to be equal to 0.5 when the diode current is 10 mA (Case A)?

3

$R_C \| R_L \| r_d = R \qquad r_d \approx R$

R: 2.5 Ohms

Then, what is the gain when the diode current is 5 mA (Case B)?

3

$\frac{r_d}{r_d + R} = \frac{5}{5+2.5} = \frac{2}{3}$

A_v: 0.67