# Electronics
# EECE2412 — Spring 2017
# Exam #1

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File:12198/exams/exam1

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Name: solutions

**General Rules:**

- 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 line for numerical answers or box for plots or drawings. 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.

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2 pts each
+3 free

# 1 Short–Answer Questions

What is the ratio of peak–to–peak voltage to RMS voltage?

☐ $\sqrt{2}$ ☐ 2 ☒ $2\sqrt{2}$

What is the ideal input impedance for a voltage amplifier?

$\infty$

What is the ideal output impedance for a transconductance amplifier?

$\infty$

An amplifier has a voltage gain of $A_V = -20$. What is the gain in dB?

☐ 20 dB ☒ 26 dB ☐ 28 dB

$20 \log_{10}(20)$

The output of an operational amplifier can be limited by

☐ The power supply voltage ☐ The current the amplifier is capable of producing ☒ Either of the above

Two ampifiers are used in series to create a higher gain. The first has a bandwidth of 100 kHz and the second has a bandwidth of 10 MHz. What is the bandwidth of the combination?

100 kHz (the lower one)

The typical forward voltage of a silicon diode is

☐ 25 mV ☐ 0.5 V ☒ 0.7 V

The intrinsic carrier density $n_i$ is typically

☒ $10^{10}$ cm$^3$ ☐ $10^{12}$ cm$^3$ ☐ $10^{14}$ cm$^3$

Increasing the donor concentration

☐ increases ☒ decreases

the hole concentration, $p$.

If a positive voltage is applied to the anode of a diode, the diode is forward biased.

☒ True ☐ False

In a diode, forward current flows from the cathode to the anode.

☐ True ☒ False

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# 2 Differential Amplifier

bench +1

The figure shows a differential amplifier.

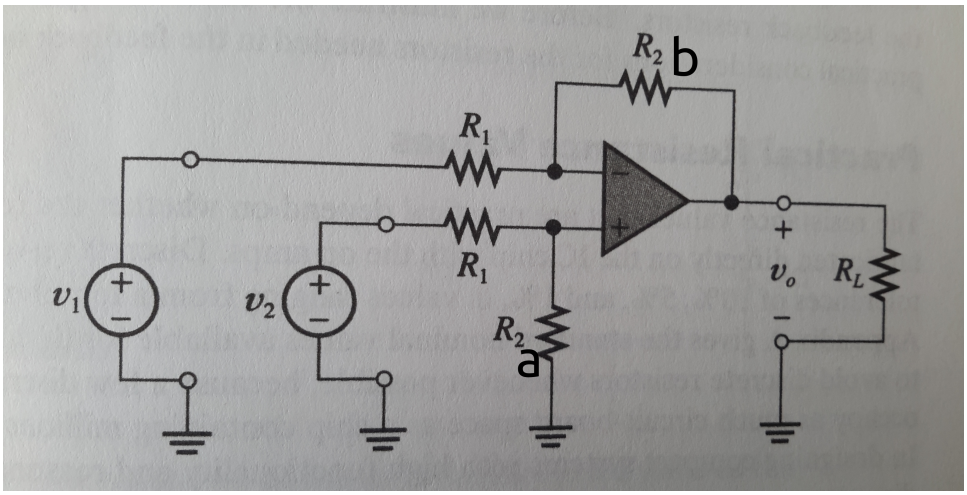


Figure from Hambley, *Electronics, 2nd Ed.*

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## 2.1 Equations

Write an equation for the non–inverting input voltage, $v_+$ as a function of $v_2$.

$$V_+ = V_2 \frac{R_{2a}}{R_1 + R_{2a}}$$

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Write an equation for the inverting input voltage, $v_-$ as a function of $v_1$ and $v_0$.

$$V_- = V_o \frac{R_1}{R_1 + R_{2b}} + V_1 \frac{R_{2b}}{R_1 + R_{2b}}$$

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## 2.2 Differential Gain

We will set $R_1 = 1$ kOhm and for now $R_{2a} = R_{2b} = 10$ kOhm.

With these values, what is the differential gain? That is, what is the ratio of $v_o$ to $v_1 - v_2$?

$V_- = V_+$ $\quad R_{2a} = R_{2b} = R_2$

$$V_o \frac{R_1}{R_1 + R_{2b}} = V_2 \frac{R_{2a}}{R_1 + R_{2a}} - V_1 \frac{R_{2b}}{R_1 + R_{2b}}$$

$$V_o = \frac{R_2}{R_1}(V_2 - V_1) = \frac{10k}{1k}(V_2 - V_1)$$

$$-10$$

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## 2.3 Tolerances

We discussed in class that the common mode gain is zero. That is, if we let $v_1 = v_2$, the ouptut is zero. Your equations above should show this.

Now suppose that the resistor in the negative feedback circuit, $R_{2b}$ is actually high by 5 percent and all the rest are correct. What is the common mode gain now? That is, for $v_1 = v_2$, what is the ratio of $v_o$ to $v_1$, with $v_1 = v_2$?

10500 Ω

$$V_o = \frac{R_1 + R_{2b}}{R_1}\left[\frac{R_{2a}}{R_1 + R_{2a}} - \frac{R_{2b}}{R_1 + R_{2b}}\right] V_{1 \text{ or } 2}$$

$$\frac{11500}{1000}\left[\frac{10000}{11000} - \frac{10500}{11500}\right]$$

$$-0.045$$

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## 2.4 Bandwidth

Assume that the op–amp in this circuit has an open–loop gain of $2 \times 10^5$ and an open–loop bandwidth of 10 Hz. What is the bandwidth of this circuit?

$A_v f_b = A_{vol} f_{bol}$

$10 f_b = 2 \times 10^5 \times 10 Hz$

$f_b = 2 \times 10^5 Hz$

200kHz

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# 3 Rectifier Circuit

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Consider the simple rectifier in the figure below.

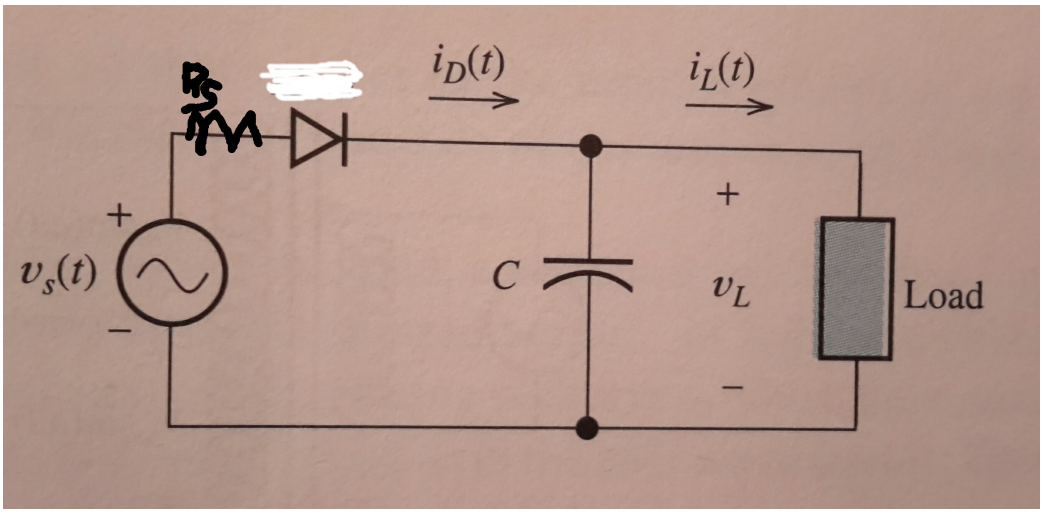



Figure from Hambley, *Electronics, 2nd Ed.*

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 0.7 V (CVD Model). The source has an internal series resistance of $R_s = 10$ ohms. The load is 300 Ohms, and the capacitor is 1000 $\mu$F.

Now let's assume that the input voltage is a square wave at 50 Hz with 100 Volts peak–to–peak.

50 −50 t

## 3.1 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.

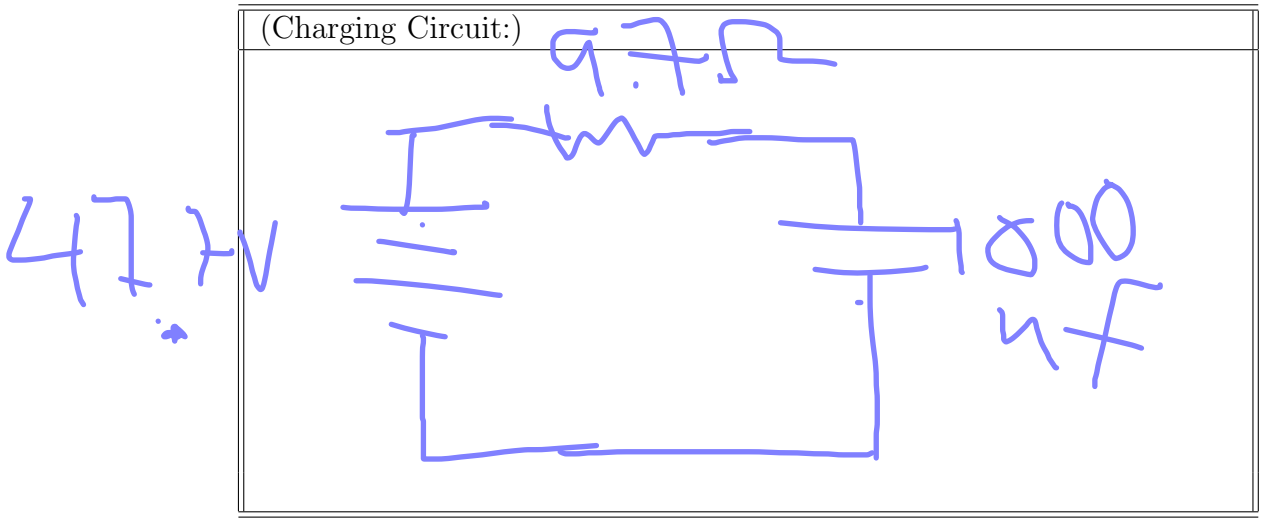
10 0.7 50V 300

$V_{oc} = 49.3\,V$ $\frac{300}{310}$ $= 47.7\,V$

$i_{sc} = \frac{49.3\,V}{10\,\Omega} = 4.93\,A$

$R_{TH} = \frac{V_{oc}}{i_{sc}} = 9.7\,\Omega$ (or $300 \| 10$)

(Charging Circuit:)




What is the RC time constant of the charging circuit?

$9.7\Omega \times 10^{-3} F = 9.7 \times 10^{-3} s$

Time Constant: 9.7ms

What is the maximum voltage on the capacitor?

47.7V

Maximum Voltage: 47.7V

## 3.2 Discharging

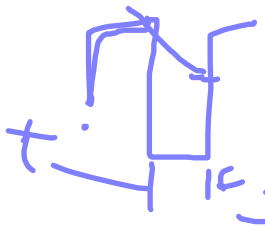
Draw the circuit model for the "discharging" state.

(Discharging Circuit:)


What is the RC time constant of the discharging circuit?

$300\Omega \times 10^{-3} F = 0.3s$

Time Constant: 300 ms




$V(t) = V(0)\, e^{-(t/\tau)}$

$= 47.7\, e^{-10^{-2}/0.3}$

$= 46.1$ Ripple is 1.6 V

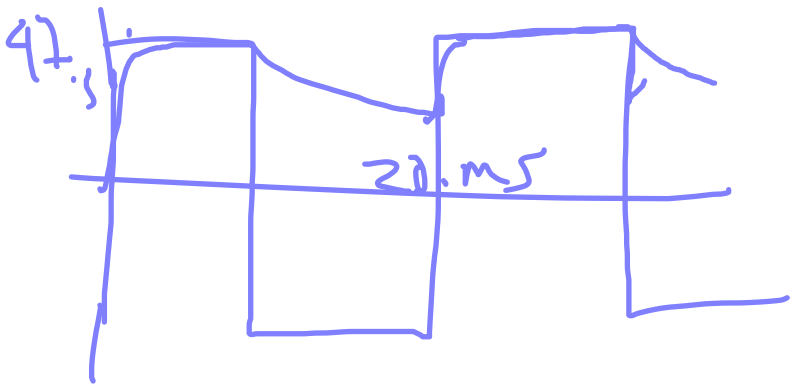
What is the magnitude of the ripple?

Ripple: 1.6 V Volts

## 3.3 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.

(Voltage Plots:)



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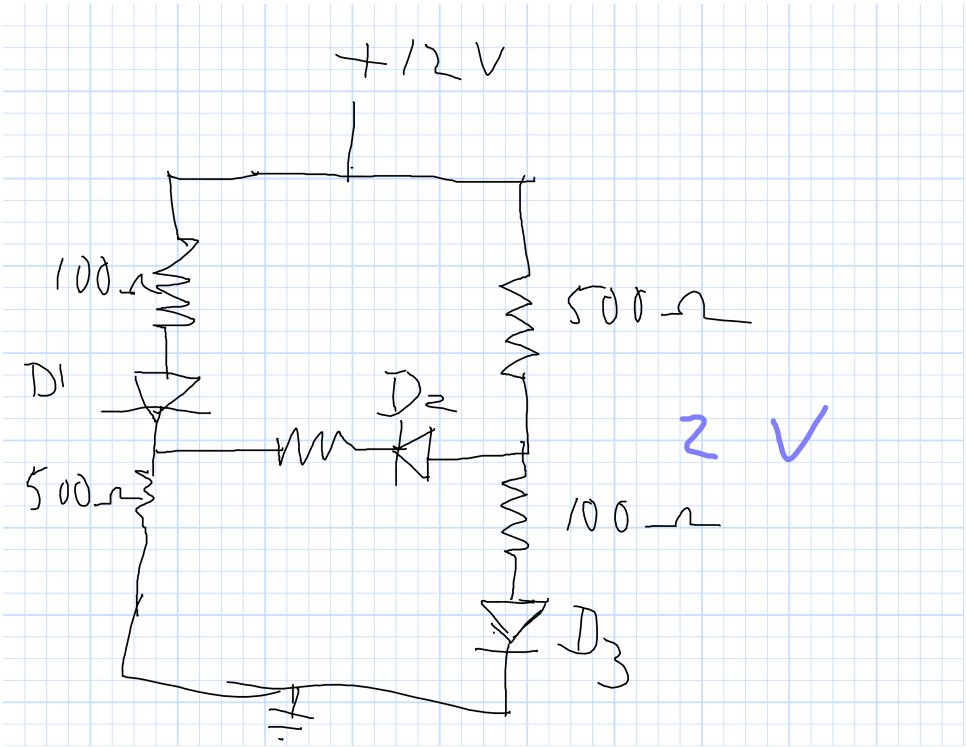
# 4 Diode Circuit

Consider the following circuit with 3 diodes. Determine which diodes are on and off, and the current drawn from the DC supply.




10 V

2 V

Guess 1 & 3 on:
works if 2 is off

Which diodes are on?

☒ 1 ☐ 2 ☒ 3

$\frac{12\text{ V}}{(600 \| 600)\,\Omega} = 0.04\text{ A}$

What is the total current from the 12 Volt source?

40 mA