Physics 334, Winter Quarter 2012, Examination #2

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1 /25
2 /25
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TOTAL /100

Exam notes: Don’t turn over the exam until the starting-buzzer and stop writing at the closing-buzzer. The exam is closed-book. You may use a calculator, but not smart phones, iPads or laptops. You may not use your own equation sheet. Please check that you have a total of 5 pages, including this page. You can make reasonable assumptions based on standard component tolerances of 5%, which may save you some time and effort. You may write in the margins, on scratch paper or on the back page of the exam, but that won’t be graded. Sloppy or disorganized work may be downgraded.

Possibly useful equations and information:

Ideal op-amp golden rules: (1) inputs source or sink no current; (2) the open-loop output voltage is \((V^* - V)\) times an arbitrarily large gain; (3) if properly negatively fed-back, the inputs \((V^*\) and \(V)\) are at the same voltage.

The transconductance of a FET is the change in the drain current divided by a change in the gate-to-source voltage.

The “3 dB” frequency of a RC high- or low-pass filter is \(1/(2\pi RC)\)
1. (25 points total) "Bad circuits." Each circuit below has a glaring fault that makes it bad. To the immediate right of each circuit, (i) explain in 10 words or less why the circuit is bad and, (ii) after correcting the fault, sketch a corrected "good" circuit.

a. (6 points) Transistor switching a light-bulb

b. (6 points) AC-coupled emitter-follower

c. (6 points) Zener-diode and emitter-follower voltage regulator

d. (7 points) Current source supplying a varying load $R_{load}$
2. (25 points total) Consider an AC-input-coupled source-follower, shown below, made from a n-channel JFET. Its drain current $I_D$ versus $V_{DS}$ curves for various values of gate-to-source voltage $V_{GS}$ are also shown below.

![Diagram of a source-follower circuit with a JFET, resistor $R$, and capacitor $C$.]

- a. (6 points) Suppose you'd like the quiescent (no-signal) current to be approximately 1 mA; what's an appropriate value of $R_S$? Look at curves of $I_D$ vs $V_{GS}$ for $I_D = 1$ mA, $V_{GS} = -0.6$ V.

  Hence $R_S = \frac{0.6}{1} = 600 \Omega$

- b. (6 points) With respect to the quiescent current $I_D$, should the value of $R$ be (circle one) (i) much larger than $R_S$; (ii) much smaller than $R_S$; (iii) about equal to $R_S$; or (iv) the value of $R$ relative to $R_S$ doesn't much matter. Since no current flows into the gate, $V_S \approx 0$.

- c. (7 points) Further suppose you'd like the follower to pass 100 Hz signals with only 3 dB attenuation. Find appropriate values for $R$ and $C$. (This following is a detail, so don't let it trip you up, but you can assume the transconductance $g_m$ is very large compared to $1/R_S$ for all $I_D$.)

  $$\alpha_{3db} = \frac{1}{R_C} \Rightarrow \alpha_{3db} = 2 \pi f$$

  For $R$, for example, $f = 100$ Hz, $C \approx 1.6 \mu F$.

- d. (6 points) How much amplitude can the input signal have before the output becomes seriously clipped, exhibits other pathological behavior or otherwise is no longer a good follower? Explain your answer in 10 words or less.

  When $V_{GS} \leq -1.2$ V, $I_D \to 0$ (transistor shut off).

  Hence $|(-1.2) - (-0.6)| \approx 0.6$ V.

  Note: 0.6 V is smaller than the voltage that causes gate conduction: $0.7V - (V_{GS} \approx -0.6V) \approx 1.3V$.  

3. (25 points total) Consider the 311 comparator circuit below. (Recall the 311 has both open-collector and uncommitted-emitter outputs.) $V^+$ is a test-point where you'll measure a voltage.

![Comparator Circuit Diagram]

a. (8 points) When $V_{\text{in}} = +15 \text{ V}$, what's $V_{\text{out}}$ and $V^+$?

$$V_{\text{out}} = -15 \text{ V} \quad V^+ = \approx -1 \text{ V}$$

b. (8 points) When $V_{\text{in}} = -15 \text{ V}$, what's $V_{\text{out}}$ and $V^+$?

$$V_{\text{out}} = +15 \text{ V} \quad V^+ = \approx +1 \text{ V}$$

c. (9 points) Consider an input-voltage excursion of $V_{\text{in}}$ from -15 V to +15 V then back to -15 V. Draw below the hysteresis curve for this excursion. That is, make a neat and careful plot of $V_{\text{in}}$ on the horizontal axis and $V_{\text{out}}$ on the vertical axis for the excursion. Where the plot exhibits hysteresis, indicate the direction of the excursion with arrows. Ensure you indicate and show values for input voltages where the output makes transitions.
4. (25 points total)
Shown below are six op-amp circuits with input voltage of either +1 V or -1 V as shown. On each circuit drawing, write at V\text{out} the output voltage for each circuit. Assume the op-amps are ideal and the output level can swing anywhere between the +15 V and -15 V op-amp power supply voltages. You may also assume ideal diodes with forward voltage drop 0.7 V.

![Circuit Diagrams](image)

- **First Circuit:**
  - Input: +1 V and -1 V
  - Output: V\text{out} = -15 V (at rail)

- **Second Circuit:**
  - Input: +1 V
  - Output: V\text{out} = +1 V

- **Third Circuit:**
  - Input: +1 V and -1 V
  - Output: V\text{out} = -15 V (at rail)

- **Fourth Circuit:**
  - Input: +1 V
  - Output: V\text{out} = +1 V + 0.7 V = 1.7 V

- **Fifth Circuit:**
  - Input: -1 V and +1 V
  - Output: V\text{out} = +15 V (at rail)

- **Sixth Circuit:**
  - Input: -1 V
  - Output: V\text{out} = -15 V (at rail)