NAME: __________________________________________

(Please print)

- Do not open the exam until instructed.

- Draw a circle or box around your final answers.

- All answers should include units (e.g., V, mA, kΩ) where appropriate. **For frequencies, use Hz (or kHz, or MHz), not radians/second.**

- If you want partial credit on incorrect answers, *show your work on the pages you turn in!* If you choose to turn in any sheets of scratch paper, *write your name on those sheets!*

- Don’t spend all of your time on one difficult problem. Don’t be afraid to skip ahead if you get stuck. You don’t have to work the problems in order.

- The use of wireless devices is prohibited during the exam.
1. (20 points) (a) We have an amplifier with a dc gain of 100 dB and (normal) poles at 100 Hz and 1 MHz. Draw the Bode magnitude and phase plots of this amplifier below.

(b) What is the phase margin for $\beta = 0.001$? ______________

(c) What is the lowest closed-loop gain $A_f$ for which this amplifier has acceptable stability (having a phase margin of at least 45°)? $A_f =$ __________
2. (22 points) What type of feedback topology is shown below (e.g., series-series, shunt-series,…)?

Draw three pictures showing the circuit configurations used for measuring $\beta$, $R_{11}$, and $R_{22}$ for the feedback network shown, and derive expressions for $\beta$, $R_{11}$, and $R_{22}$ as a function of circuit parameters.
3. (22 points) A voltage amplifier (voltage input, voltage output) having an open-circuit gain of 200, an input resistance of 10 kΩ, and an output resistance of 100 Ω is connected in a negative-feedback loop.

(a) Which feedback topology (e.g., series-shunt, series-series, etc.) would be used in this situation?

The feedback network has an $R_{11}$ and $R_{22}$ of 5 kΩ and provides a feedback factor $\beta = 0.15$. The amplifier is fed by a voltage source having $R_S = 1$ kΩ, and a load resistance $R_L = 1$ kΩ is connected at the output.

(b) What is $A$? (Hint: It is not 200!)

(c) What is the closed-loop gain $A_f$ of the feedback amplifier?

(d) What is the feedback amplifier’s input resistance $R_{in}$?
4. (20 points) The datasheet of the PN2222A bipolar transistor contains the following information:

   - Maximum allowable junction temperature $T_{J\text{max}} = 150^\circ\text{C}$
   - Maximum power dissipation $P_{D\text{max}} = 625 \text{ mW}$ at ambient temperature $T_A = 25^\circ\text{C}$
   - Junction-to-case thermal resistance $\theta_{JC} = 80^\circ\text{C/W}$

(a) Draw an equivalent electrical circuit for this thermal system. Label all components as well as the junction temperature $T_J$, the case temperature $T_C$, and the ambient temperature $T_A$. (Note that we are not using a heat sink in this problem.)

(b) Find the case-to-ambient thermal resistance $\theta_{CA}$.

(c) Assuming an ambient temperature of 25°C, what is the case temperature $T_C$ when the transistor dissipates 500 mW?
5. (16 points) Circuit concepts.

(a) We discussed three types of power amplifiers or output stages in class: Class A, Class B, and Class AB.

Which type has the worst distortion? ________________
Which type has the highest power efficiency? ________________
Which type has the lowest power efficiency? ________________

(b) If we put a square wave into a feedback amplifier, and the output shows too much ringing for our application, is the phase margin too high or too low? ________________

(c) Name a clever circuit structure used to generate binary-weighted currents that does not require binary-weighted resistors: ________________

(d) All else being equal, which ADC consumes more power: a flash ADC or a successive-approximation ADC? ________________

(e) All else being equal, which ADC is \textit{fastest}: a flash ADC, a successive-approximation ADC, or a dual-slope ADC? ________________

(f) All else being equal, which ADC is \textit{slowest}: a flash ADC, a successive-approximation ADC, or a dual-slope ADC? ________________