ENGI 2132 Electronics II
Practice Problems for Final Exam — Fall 2017

- Closed notes, closed books. No electronic devices allowed except non-programmable calculator
- Show calculation steps for full marks

Equations

$$
\begin{aligned}
P_{DC} &= \frac{2V_{CC}V_O}{\pi R_L} \\
P_{D,max} &= \frac{2V_{CC}^2}{\pi^2 R_L} \\
i_C &\approx I_S \exp(v_{BE}/V_T) \\
g_m &= I_C/V_T \\
r_\pi &= \beta/g_m \\
r_e &= \alpha/g_m = \beta/\left((\beta+1)g_m\right) \\
r_o &= V_A/I_c
\end{aligned}
$$

Problems

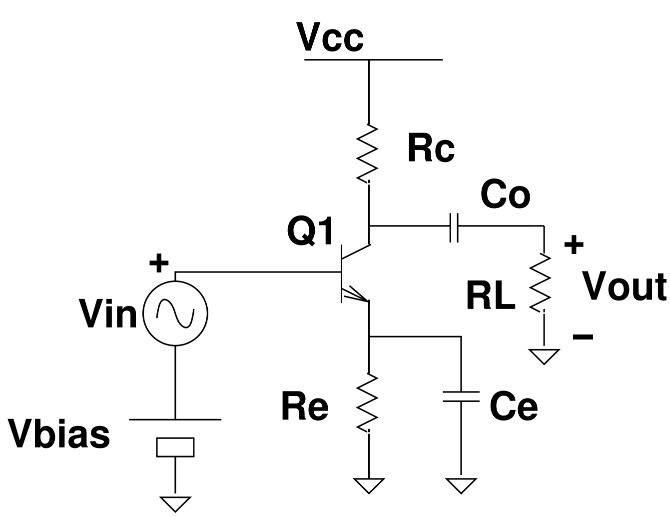
1. In the following circuit, $V_{CC} = 12$ V, $R_E = 40\ \Omega$, $R_c = 80\ \Omega$, $R_L = 200\ \Omega$. The desired collector current in Q_1 is 60 mA. Assume β of Q_1 is very large, $V_{BE,on} = 0.7$ V and $V_{CE,sat} = 0.4$ V.

   (a) Calculate the required value for V_{BIAS} and the operating point of Q_1.

   (b) Calculate maximum positive and negative voltage swing at load resistor.

   (c) Calculate DC supply power, load power and power efficiency for maximum sinusoidal output.

   (d) Q_1 has a TO-220 package with θ_{JA}=70°C/W, $T_{MAX} = 150$ °C and the ambient temperature is 27 °C. Is a heat sink required or not? Justify your answer.



2. In the following circuit, $R_S = 1$ kΩ, $v_S = 1$ V and the operational amplifier is fed with supply voltages ± 12 V.

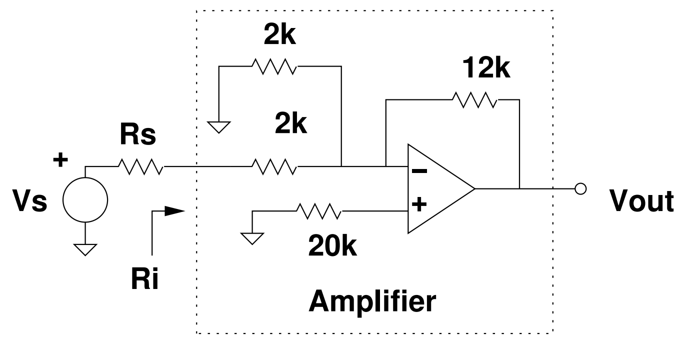
   (a) Is the feedback positive or negative?

   (b) Calculate the input resistance of the amplifier (R_i)

   (c) Calculate the current through R_S

   (d) Calculate v_{OUT}

   (e) Calculate v_{OUT} if v_S is increased to 5 V

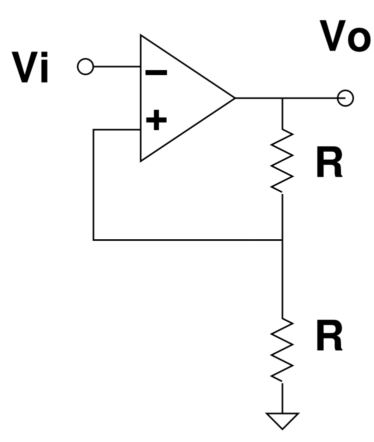


3. In the following circuit, $R = 10$ kΩ and the operational amplifier is fed with supply voltages ± 12 V.

   (a) Is the feedback positive or negative?

   (b) Plot v_O vs. v_I

   (c) Sketch the input and output voltages if v_I is a sine wave with a peak of 10 V.

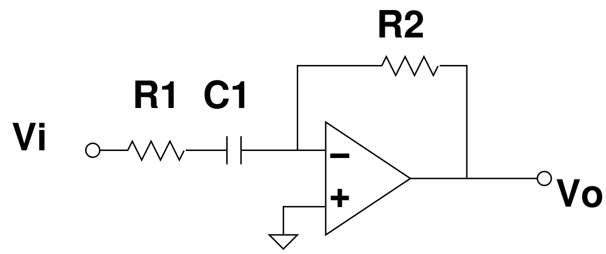


4. In the circuit below, $R_1 = 1$ kΩ, $R_2 = 50$ kΩ and the circuit is driven with an ideal voltage source (zero internal resistance).

   (a) Calculate C_1 to obtain a gain with magnitude 10 at a frequency of 10 kHz.

   (b) Is this a high-pass or a low-pass filter?

   (c) Calculate the -3 dB cutoff frequency of the circuit.

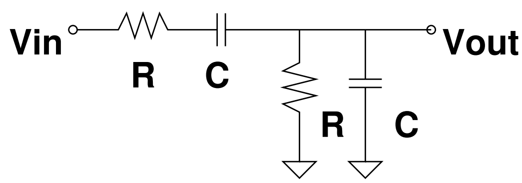


5. Refer to the network shown below.

   (a) Symbolically derive the transfer function V_{out}/V_{in}

   (b) If this network is used to build a feedback oscillator, explain how the oscillation frequency is determined (from your result in (a)) and what is the required amplifier gain.

   (c) Show an schematic diagram of the feedback oscillator that uses this network.

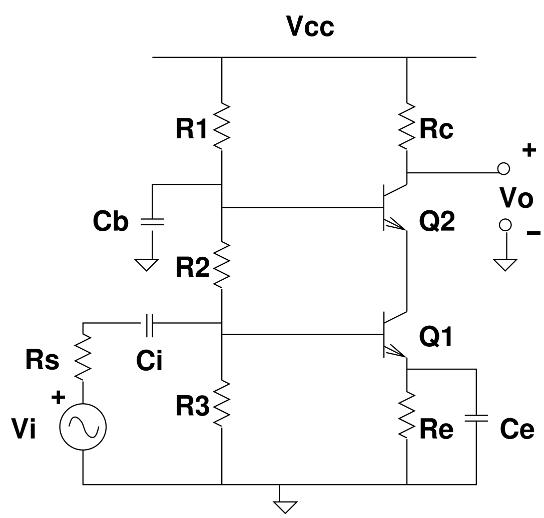


6. In the circuit below, $V_{CC} = 15$ V, $R_S = 300\ \Omega$, $R_E = 1.5$ kΩ and $R_C = 4$ kΩ. The bipolar transistors are equal with $\beta = 160$, $V_A = \infty$, $V_{BE,on} = 0.7$ V and $V_{CE,sat} = 0.3$ V. The bipolar transistors are to be biased with $I_C = 1.5$ mA and $V_{CE1} = 1.5$ V.

   (a) Design R_1, R_2 and R_3.

   (b) Draw the small-signal circuit of the amplifier. Assume capacitors are short-circuits at the frequency of operation.

   (c) Calculate the overall voltage gain v_o/v_s at mid-frequencies.



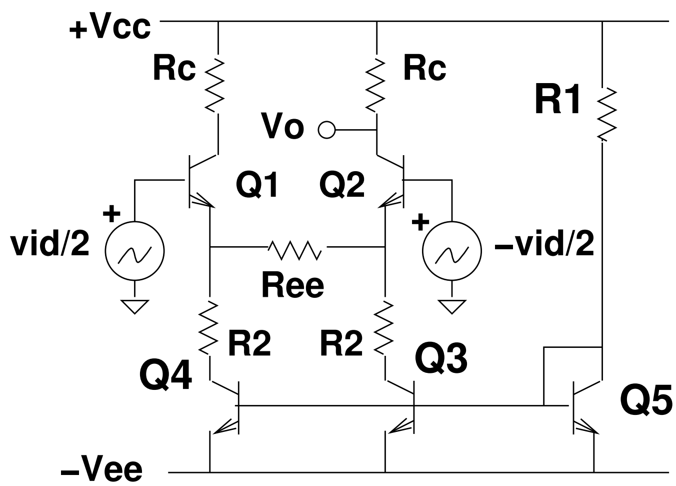
7. In the circuit below, $V_{CC} = 12$ V, $V_{EE} = 6$ V, $R_2 = 50\ \Omega$ and $R_C = 3$ kΩ. The bipolar transistors are all equal with $\beta = 200$, $V_A = 80$ V, $V_{BE,on} = 0.7$ V and $V_{CE,sat} = 0.3$ V. You can neglect base currents in DC analysis.

   (a) Calculate R_1 to make the DC component of v_O equal to 6 V.

   (b) Calculate V_{CE} in Q_1 and Q_3.

   (c) Draw the common-mode small-signal half-circuit and calculate the common-mode gain.

   (d) Draw the differential-mode small-signal half-circuit and calculate R_{EE} for a differential-mode gain equal to 10.



8. Design a voltage regulator based on the KA7809E to provide 9 V to a load of at least 15 Ω. The regulator is encapsulated in a TO-220 package with θ_{JA}=65°C/W, θ_{JC}=5°C/W (assume θ_{CS}=0.5°C/W), T_{MAX} = 125 °C and the ambient temperature is 40 °C. Refer to the attached specification table for electrical parameters. Specify the following for your design: circuit schematic, supply voltage, minimum required supply current, maximum power dissipated in regulator and maximum heat allowable sink resistance (if needed at all).

Electrical Characteristics (KA7809E / KA7809ER)

Refer to test circuit, -40°C < T_J < 125°C, I_O = 500 mA, V_I = 15 V, C_I = 0.33 µF, C_O = 0.1 µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		8.65	9.00	9.35	V
		5.0 mA ≤ I_O ≤ 1.0 A, P_O ≤ 15 W, V_I = 11.5 V to 24 V		8.60	9.00	9.40	
Regline	Line Regulation(9)	T_J = +25°C	V_I = 11.5 V to 25 V		6	180	mV
			V_I = 12 V to 17 V		2	90	
Regload	Load Regulation(9)	T_J = +25°C	I_O = 5 mA to 1.5 A		12	180	mV
			I_O = 250 mA to 750 mA		4	90	
I_Q	Quiescent Current	T_J = +25°C			5	8	mA
ΔI_Q	Quiescent Current Change	I_O = 5 mA to 1.0 A				0.5	mA
		V_I = 11.5 V to 26 V				1.3	
$\Delta V_O/\Delta T$	Output Voltage Drift(10)	I_O = 5 mA			-1		mV/°C
V_N	Output Noise Voltage	f = 10 Hz to 100 kHz, T_A = +25°C			58		µV
RR	Ripple Rejection(10)	f = 120 Hz, V_I = 13 V to 23 V		56	71		dB
V_{Drop}	Dropout Voltage	I_O = 1 A, T_J = +25°C			2		V
R_O	Output Resistance(10)	f = 1 kHz			17		mΩ
I_{SC}	Short-Circuit Current	V_I = 35 V, T_A = +25°C			250		mA
I_{PK}	Peak Current(10)	T_J = +25°C			2.2		A

Notes:

9. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
10. These parameters, although guaranteed, are not 100% tested in production.