ECE4435 Homework
Physical Characteristics of Op-Amps

1. An op-amp has the low-frequency open-loop gain $A_0 = 10^5$. The op-amp is to be used in an inverting amplifier with a gain of -2000. (a) What is the required ratio R_F/R_1? [2040.8] (b) For the value of R_F/R_1, how much larger is the input resistance than R_1? [$1.0204R_1$]

2. An op-amp has the low-frequency open-loop gain $A_0 = 10^5$. The op-amp is to be used in a non-inverting amplifier. The theoretical gain is calculated assuming that the op-amp is ideal. What is the highest theoretical gain that gives an error between the theoretical gain and the actual gain that is less than 5%? [5263.2]

3. At low frequencies, an op-amp has an open-loop gain $A_0 = 10^5$ and an open-loop output resistance $R_0 = 150\ \Omega$. The op-amp is to be used in a non-inverting amplifier having a voltage gain of 200. If the amplifier is designed with the assumption that the op-amp is ideal and the input resistance to the feedback network is to be 100 kΩ, calculate the actual gain of the circuit and its output resistance. [199.60, 0.29940 Ω]

4. At low frequencies, an op-amp has an open-loop gain $A_0 = 10^5$ and an open-loop output resistance $R_0 = 150\ \Omega$. The op-amp is to be used in an inverting amplifier having a voltage gain of -200. If the amplifier is designed with the assumption that the op-amp is ideal with an amplifier input resistance of 1 kΩ, calculate the actual gain of the circuit and its output resistance. [-199.6, 0.301 Ω]

5. An op-amp has the gain-bandwidth product $f_x = 1.5$ MHz. The op-amp is to be used in a non-inverting amplifier circuit. Calculate the highest gain that the amplifier can have if the half-power or -3 dB bandwidth is to be 30 kHz or greater. [-50]

6. Two non-inverting op-amp amplifiers are operated in cascade. Each amplifier has a gain of 20. If each op-amp has the gain-bandwidth product $f_x = 1.5$ MHz, calculate the half-power or -3 dB bandwidth of the cascade amplifier. [48.3 kHz]

7. An op-amp has the gain-bandwidth product $f_x = 1.5$ MHz. Compare the bandwidths of an inverting and a non-inverting amplifier which use the op-amp if the dB values of the voltage gain magnitude A_{0f} are 0 dB, 10 dB, 20 dB, and 30 dB. [Non-inverting: 1.5 MHz, 4.74 kHz, 150 kHz, 47.4 kHz, Inverting: 750 kHz, 360 kHz, 136 kHz, 46 kHz]

8. An op-amp has a dc gain $A_0 = 10^5$ and a gain bandwidth product $f_x = 1.5$ MHz. The op-amp is used in an inverting amplifier with the element values $R_1 = 1.5$ kΩ and $R_F = 75$ kΩ. Calculate the dc gain of the amplifier, the upper cutoff frequency, and the value of the elements in the equivalent circuit for the input impedance. [-49.98, 29.4 kHz, $R_2 = 0.75\ \Omega$, $L = 7.96$ mH]

9. The op-amp in the preceding problem has an open-loop output resistance $R_0 = 150\ \Omega$. Calculate the value of the elements in the equivalent circuit for the output impedance. [$R_2 = 150\ \Omega$, $L = 811\ \mu$H]

10. An op-amp has the saturation voltages $V_{SAT}^{+} = V^{+} - 3$ V and $V_{SAT}^{-} = V^{-} + 3$ V, where $V^{+} =$ 15 V and $V^{-} = -15$ V. The current limited output current is $I_M = 30\,$mA. (a) Determine the lowest load resistance that can be driven to full output without current limiting. (b) Determine the peak output voltage for a load resistance of 75 Ω. (c) The op-amp is used

to realize a non-inverting amplifier with a gain of 5. The input waveform is a square wave with a peak value of 1 V. Sketch the plot of the output voltage waveform for a capacitive load of value $C_L = 1\ \mu$F. Assume that the op-amp does not slew. [400 Ω, 2.25 V, slopes are $\pm 3 \times 10^4$ V/s]

11. The op-amp in the preceding problem has a slew rate of 0.75 V/μs. (a) Calculate the full-power bandwidth of the op-amp. (b) Calculate the peak value of the largest amplitude sine-wave that the op-amp can put out at frequency of 30 kHz if it is not to slew. (c) Calculate the largest peak-to-peak signal that the op-amp can put out at 30 kHz. Hint, assume that the amplitude of the input signal is increased until the output voltage waveform is fully converted into a triangle wave. [9.95 kHz, 6.25 V]

12. A non-inverting amplifier with feedback resistors R_F and R_1 has a resistor R_2 in series with its non-inverting input. The op-amp has the input bias current I_B. Solve for the dc component of the output voltage due to I_B. Assume that $A_0 \to \infty$, $I_{OS} = 0$, and $V_{OS} = 0$. $[(1 + R_F/R_1)\, I_B\, (R_2 - R_1 \| R_F)]$

13. A non-inverting op-amp with feedback resistors $R_F = 100$ kΩ and $R_1 = 1$ kΩ has a dc offset voltage of 1 V at its output when $v_I = 0$. (a) If the input offset current and input bias current can be neglected, calculate the input offset voltage V_{OS}. (b) If the input offset voltage and input bias current can be neglected, calculate the input offset current I_{OS}. (c) If the input offset voltage and input offset current can be neglected, calculate the input bias current I_B. (d) The op-amp has the low-frequency open-loop gain $A_0 = 10^5$. When either power supply voltage is changed by 1 V, the dc offset at the op amp output changes by 0.5 V. Calculate the power supply rejection ratio in μV/V. [9.9 mV, 20 μA, 10 μA, 5 μV/V]

14. A non-inverting amplifier has a resistor R_1 in series with the + input and feedback resistors R_2 and R_F. A series resistor R_3 and capacitor C are connected between the + and − inputs. Show that the effective open-loop transfer function is given by

$$A'(s) = A(s)\,\frac{1 + R_3 C s}{1 + (R_1 + R_2 \| R_F + R_3)\, C s}$$

Thus the $R_3 - C$ network adds a pole-zero pair to the transfer function. Using a Bode plot, show how this can improve the stability of an amplifier when $A(s)$ has more than one pole below the unity-gain frequency.

15. An op-amp has the low-frequency open-loop differential gain $A_0 = 10^5$. The op amp is used as a non-inverting amplifier with the feedback ratio $v_F/v_O = 0.0001$. The gain with feedback is found to be $v_O/v_I = 9100$. Calculate the common-mode rejection ratio ρ. (955 or 59.6 dB)