The University of Sheffield
Department of Electronic and Electrical Engineering

Electronic Devices in Circuits Tutorial Sheet

Operational Amplifiers

Q1 An operational amplifier is connected as shown in figure 1. The input offset voltage, v_{os}, is 5mV, the input offset current, i_{os}, is 200nA and the input bias current, which flows into the amplifier inputs, is 400nA.

(i) What range of output voltages could occur if v_i is grounded? (1.005V to -0.205V)

(ii) If both v_{os} and i_{os} were zero what would the output voltage be? (0.4V)

(iii) What value of resistor should be connected between the non-inverting input and ground to make the answer to part **(ii)** = 0? (9.9kΩ)

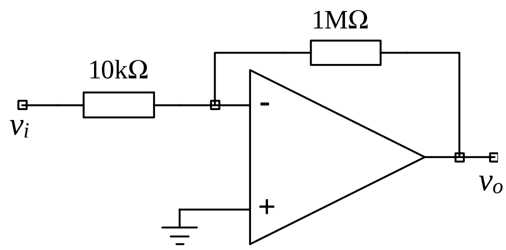

Figure 1

(iv) If the resistor calculated in part **(iii)** is connected, suggest a modification to the values of all three resistors in the circuit such that the circuit gain remains unchanged but the effects of i_{os} are reduced by a factor of 10. (1kΩ, 100kΩ, 990Ω)

(v) If the bipolar input op-amp of figure 1 was replaced by a FET input op-amp, which of the terms, v_{os}, i_b and i_{os} would be the dominant contributor to the output offset voltage?

Q2 Derive an expression for the gain-bandwidth product of the circuit of figure 2. (*You should find that this inverting amplifier connection behaves slightly differently from the non-inverting case covered in the lecture notes.*)

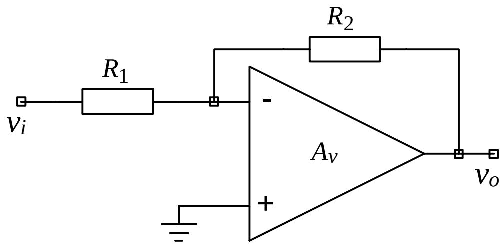

Figure 2

Q3 In medical impedance imaging systems small voltages on the surface of a body are sensed by buffer amplifiers with a very high input impedance. If an op-amp voltage follower circuit is to be used as a sense amplifier which must not introduce a phase error greater than 0.1^o at a frequency of 50kHz, what gain-bandwidth product is required of the op-amp? (28.6MHz)

Q4 A particular op-amp for which you have no data is observed to have a step response of the form:

$$k\ (1 - e^{-t/2.8\times10^{-6}})$$

when wired to give a non-inverting gain of 250V/V.

(i) What is the gain-bandwidth product of the op-amp? (14.2MHz)

(ii) What 3dB bandwidth would you expect for a non-inverting gain of 10V/V? (1.42MHz)

(iii) What circuit risetime would you expect for the non-inverting gain of 10V/V? (246ns)

Q5 A non-inverting amplifier circuit with a gain of 10V/V uses an op-amp with a slew rate of 25V/µs and a gain-bandwidth product of 15MHz.

(i) Evaluate $|\text{gain}|$ and phase shift of the amplifier at a frequency of 5MHz. (2.87, -73^{o})

(ii) What is the maximum frequency at which a 20V pk-pk sinusoidal output can be supported in undistorted (ie purely sinusoidal) form? (398kHz)

(iii) At what amplifier circuit gain would the exponential shape of the rising and falling edges of a 15V pk-pk "square wave" output begin to be affected by the amplifier's slew rate capabilities? Would the exponential shape of the edges be affected by a gain of half this value? (56, Yes)

(iv) Why is the answer to part **(iii)** independent of the fundamental frequency of the square wave?

Q6 For the circuit of figure 6, show that

$$v_o = \frac{2}{CR}\int v_i\,dt$$

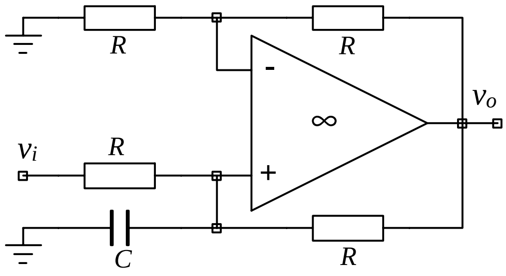

Figure 6

Q7 Demonstrate that the finite gain defect of the op-amp in figure 7a can be represented by the equivalent circuit of figure 7b where the op-amp is ideal. (*This process expresses the effects of finite A_v in terms of normal circuit elements and thus makes them easier to interpret.*) ***Hint:*** *approach the problem by showing that both circuits have the same transfer function.*

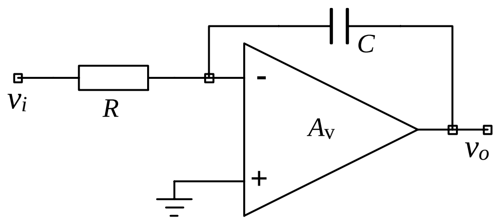

Figure 7a

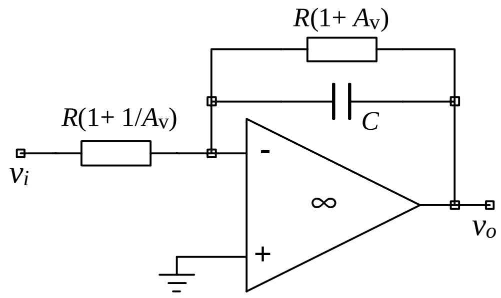

Figure 7b

Q8 Choose values of R_2, R_3, and C in figure 8 to give pole and zero frequencies of 10Hz and 500Hz respectively and a high frequency gain of 10V/V. Sketch the amplitude and phase response of the system. (4.99MΩ, 91.6kΩ, 3.13nF)

If an *RC* low pass circuit with a time constant of 79µs is attached to the op-amp output, sketch the overall frequency response of the circuit. (*The overall response is a close approximation to the equalisation characteristic necessary to get a flat response from a magnetic record player cartridge.*)

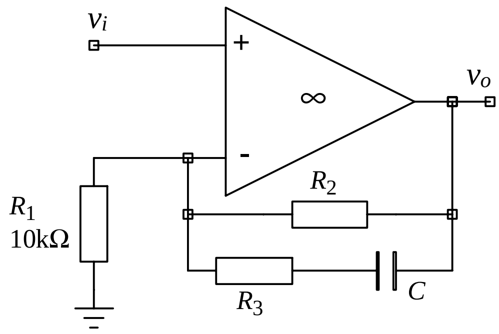

Figure 8