ELEC50001 EE2 Circuits and Systems

Problem Sheet 2

(Operation Amplifier Applications – Lectures 4 to 6)

1. Figure 1 shows the macro model of AP431i voltage reference in SPICE format.

   (i) Sketch the part of the circuit involving R1, R2 and I1 only.

   (ii) What is the meaning of the line for E1?

   (iii) Figure 1b) is a partially completed full model circuit for AP431i. Complete the circuit by filling in the missing component.

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*  SPICE MACRO MODEL FOR AP431i VOLTAGE REFERENCE
*  CREATED BY: Peter Cheung, Imperial College London
*  VERSION: 1.0
*  DATE 29 SEP 2024
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.SUBCKT AP431i REF CATHODE ANODE
I1 ANODE vref 1m
R2 vref ANODE 2.5k
R1 ANODE REF 1.25Meg
R3 N2 N3 0.1
D1 CATHODE N1 DMOD1
D2 ANODE CATHODE DMOD1
E1 ANODE N3 REF vref 750
V1 N2 N1 1.4
.model DMOD1 D (Ron=1m Roff=1meg vfwd=1m vrev=40)
.end
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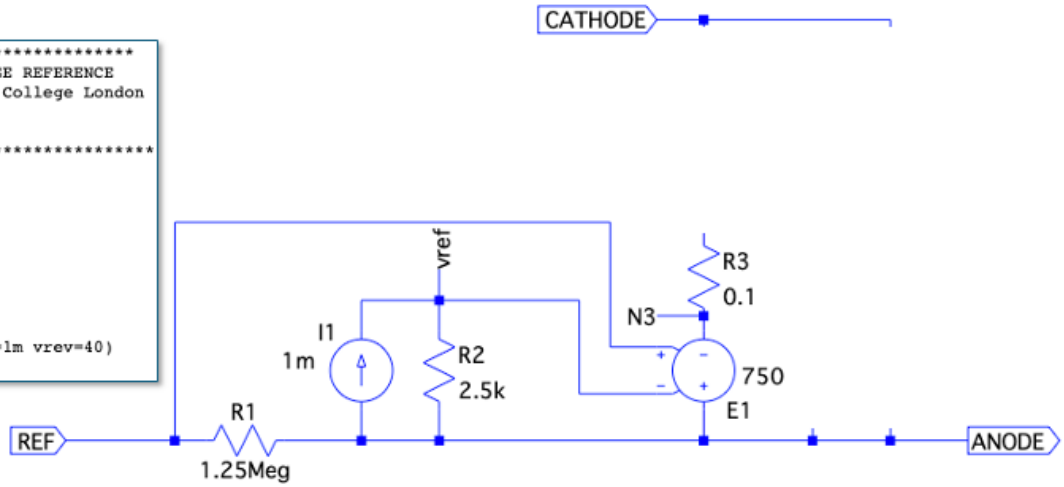

Figure Q1

2. Based on information provided in the datasheet of the MCP601 op-amp (see Problem sheet 1), draw only the input stage of the macro model for this op-amp.

3. Use the datasheet for MCP601 again, complete the missing component values in this model that specify: (i) the open-loop gain, (ii) the gain-bandwidth product, (iii) the slew-rate, (iv) output impedance, and (v) maximum output current, of this op-amp as shown in Figure Q3. (Input stage not shown here.)

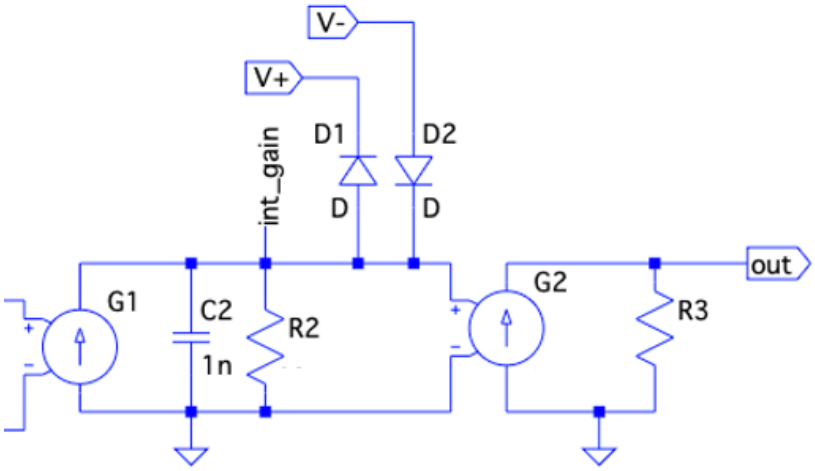

Figure Q3

4. Derive an equation for the closed-loop gain G = Y/X for the circuit shown in Figure Q4 below assuming that the open-loop gain of the op-amp is A_1 and the feedback factor is K.

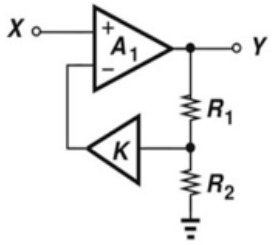

Figure Q4

5. *Figure Q5* shows two different analogue comparators with hysteresis (also known as Schmidt Trigger circuits) that compare the input voltage V_{IN} to some switching thresholds. Calculate the switching thresholds for each circuit in terms of V_{REF}, R_1 and R_2.

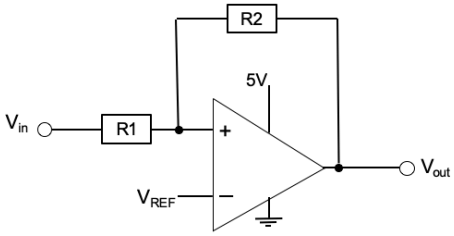

Figure Q5a

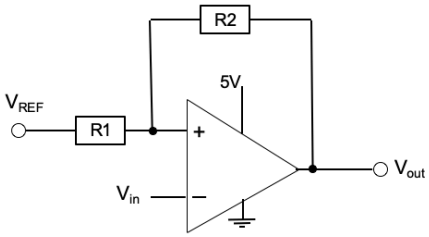

Figure Q5b

6. For the circuit shown in Figure Q6, derive the transfer function $H(s) = V_{out}(s)/V_{in}(s)$.

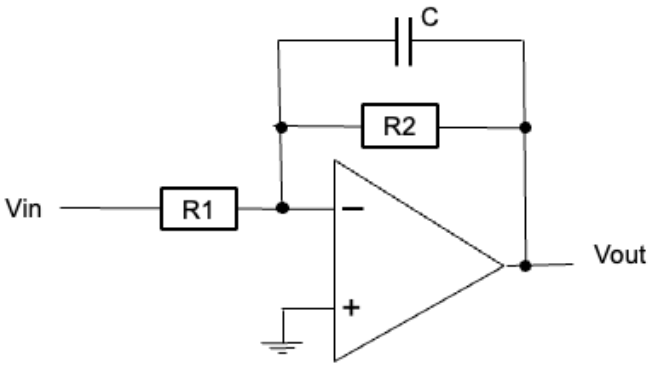

Figure Q6

7. *Figure Q7* shows a function generator that produces a square wave and a triangular wave. Calculate the amplitudes of and frequency of the signals.

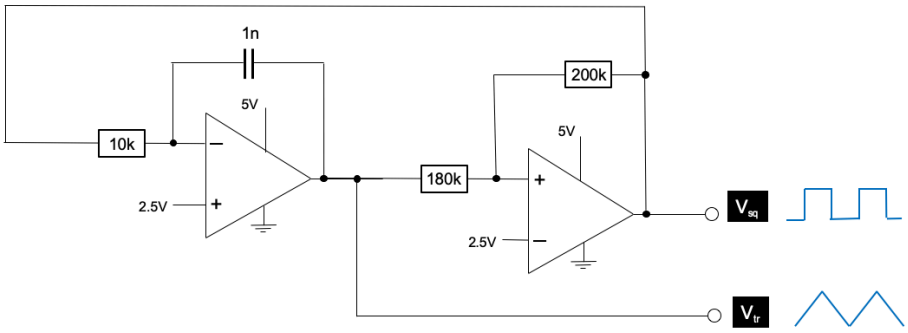

Figure Q7

8. Using the method described in Lecture 6 slide 11, design a Butterworth lowpass filter with a cutoff frequency of 5kHz and an attenuation rate of -80dB per decade.

9. *Figure Q9* shows a 2nd order lowpass filter implemented using an op-amp configured as a unity gain amplifier. Assume that C1 = C2 = C and that R1 = R2 = R, derive the transfer function $H(s) = V_{out}(s)/V_{in}(s)$. If C = 100pF, determine the value of R such that the corner frequency is 10kHz. What is the Q of the filter?

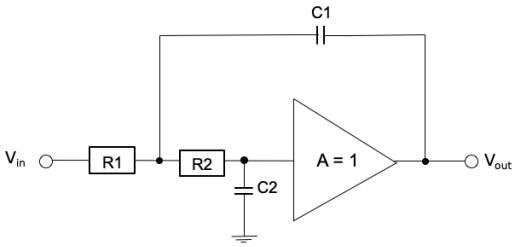

Figure Q9

10. The triangular signal from Q7 is connected the negative input of an op-amp and an analogue voltage Vin is applied to the positive input as shown in Figure Q10. Derive an equation relating the average voltage of V_{pwm} to V_{in} and the conditions under which this equation applies. Design a circuit to extract the average voltage from V_{pwm}.

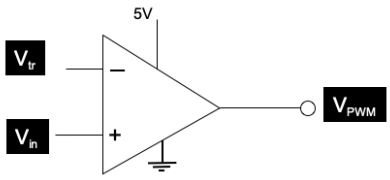

Figure Q10