**UNIVERSITY OF SWAZILAND**

**FACULTY OF SCIENCE**

**DEPARTMENT OF PHYSICS**

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| **MAIN EXAMINATION** | **:** | **2009/2010** |
| **TITLE OF PAPER** | **:** | **ELECTRONICS II** |
| **COURSE NUMBER** | **:** | **P312** |
| **TIME ALLOWED** | **:** | **THREE HOURS** |
| **INSTRUCTIONS** | **:** | **ANSWER ANY FOUR OUT OF FIVE QUESTIONS** |
| | | **EACH QUESTION CARRIES 25 MARKS** |
| | | **MARKS FOR DIFFERENT SECTIONS ARE SHOWN IN THE RIGHT-HAND MARGIN.** |

**THIS PAPER HAS 6 PAGES, INCLUDING THIS PAGE.**

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## QUESTION 1

(a) Calculate and sketch the output voltage of an op-amp integrator as a function of time for the input voltage shown in Fig. 1. Label the diagram. (6 marks)

(b) Fig. 2 shows the circuit diagram of a non-inverting op-amp. Derive the following expression to show that the overall voltage gain of the circuit is independent of the open-loop gain.

$$A_f = \frac{R_1 + R_2}{R_1}$$ (7 marks)

(c) Use operational amplifiers to design a circuit which corresponds to the following ideal relationship between the output voltage, $v_{out}$ and the input voltages, $v_1$ and $v_2$.

$$v_{out} = 1000\int v_1 dt + \left(4 \times 10^{-3}\right)\frac{dv_2}{dt}$$ (12 marks)

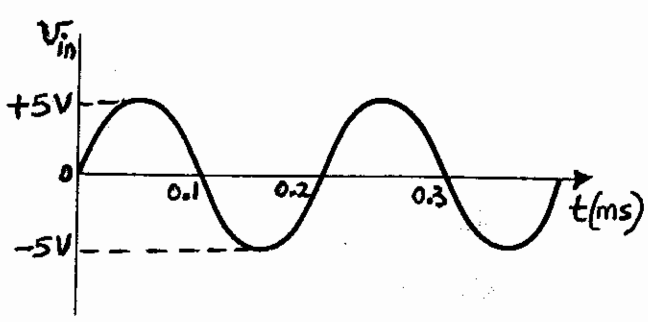


Fig. 1

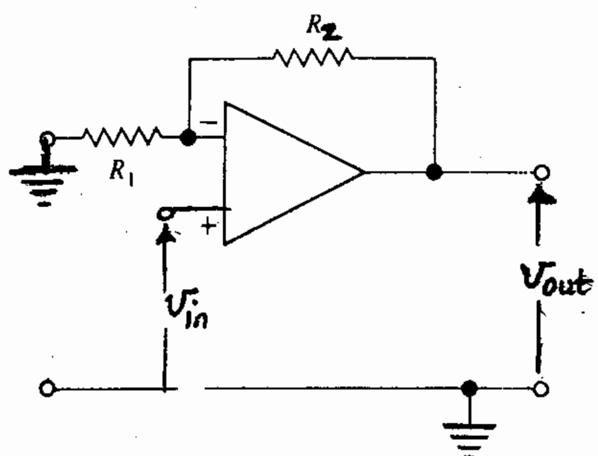


Fig. 2

**QUESTION 2**

(a) The magnitude of the transfer function of the bandpass filter is given by the following equation:

$$|T(s)| = \left[1 + \left(\frac{\omega}{\omega_0}Q_S - \frac{\omega_0}{\omega}Q_S\right)^2\right]^{-\frac{1}{2}}$$

where the symbols have the usual meaning.

(i) Use this relationship to sketch graphs of $|T(s)|$ against frequency, f for small and large values of $Q_S$. Show how the graph points are derived. (8 marks)

(ii) Use the equation for $|T_S|$ given above to derive expressions for the lower and higher cut-off frequencies, $f_1$ and $f_2$ of the bandpass filter and to show that

$$f_1 = \frac{f_0}{2}\left[\left(\frac{1}{Q^2}\right) + 4\right]^{\frac{1}{2}} - \frac{f_0}{2Q_S}$$ and that

$$f_2 = \frac{f_0}{2}\left[\left(\frac{1}{Q^2}\right) + 4\right]^{\frac{1}{2}} + \frac{f_0}{2Q_S}.$$ (10 marks)

(b) A first-order RC low-pass filter is to be designed to give a cut-off frequency of 1 kHz.

(i) What capacitance would be required if the resistance, R is 1 kΩ? (2 marks)

(ii) By how much would the output voltage of the filter be attenuated at the cut-off frequency (in decibels)? Show the calculations. (3 marks)

(iii) What would be the phase difference between the output and input voltages at the cut-off frequency? (2 marks)

## QUESTION 3

(a) A voltage amplifier has an open-loop gain of -900. If 0.5% of the output voltage is fed back to the input as negative feedback, what will be the percentage change in the gain with feedback when the open-loop gain decreases by 20%, due to changes in device parameters? (11 marks)

(b) Consider a bipolar junction transistor amplifier. The a.c. current gain of the transistor is $h_{fe} = 200$. The input resistance of the amplifier is 1 kΩ and the collector load resistor, $R_C$ is 3 kΩ.

(i) Find the voltage gain of the amplifier (i.e. without feedback). (2 marks)

(ii) Find the voltage gain of this amplifier when negative feedback is applied and the feedback factor is 0.02. (3 marks)

(c) (i) A simple bistable multivibrator utilises two bipolar junction transistors connected to one another. Sketch the circuit diagram of the multivibrator. (2 marks)

(ii) The bistable multivibrator has two stable states. Discuss, briefly, the principle of operation of this multivibrator and mention the action that would be required to change the states at the collector of each transistor, that is, from high to low or vice versa.

(7 marks)

**QUESTION 4**

(a) State the functions of logarithmic and antilog amplifiers. (4 marks)

(b) (i) Sketch the circuit diagram of a logarithmic amplifier which utilises a pn diode. (2 marks)

(ii) Derive an expression to show that the output voltage, $V_0$ of a logarithmic amplifier is proportional to the logarithm of the input voltage, $V_i$ as follows:

$$V_0 = -2.303\eta V_T \log_{10}\left(\frac{V_1}{I_0 R}\right)$$

where the symbols have the usual meaning. (8 marks)

(c) Use an operational amplifier to design a circuit which corresponds to the following ideal relationship between the output and input voltages.

$$v_{out} = -\left(v_1 + 2v_2 + 8v_3\right)$$ (6 marks)

(d) Design an op-amp differentiator that gives an output of -5 V for an input rate of change of +10 V/s. (5 marks)

## QUESTION 5

Consider a Wien-bridge oscillator which utilises bipolar junction transistors.

(a) Draw a complete circuit diagram of this oscillator. (3 marks)

(b) Explain how the oscillator works. State the conditions that must be satisfied by a circuit in order to sustain oscillations?

(10 marks)

(c) Derive an expression for the attenuation or feedback factor with the aid of the Wien network, and show that the attenuation is one-third at resonance. (10 marks)

(d) Determine the frequency of oscillation of this oscillator if the frequency-determining resistors and capacitors are each 50 kΩ and 0.002 μF, respectively.

(2 marks)