MAHARASHTRASTATE BOARD OF TECHNICAL EDUCATION

(Autonomous)

(ISO/IEC - 27001 - 2005 Certified)

22423

MODEL ANSWER

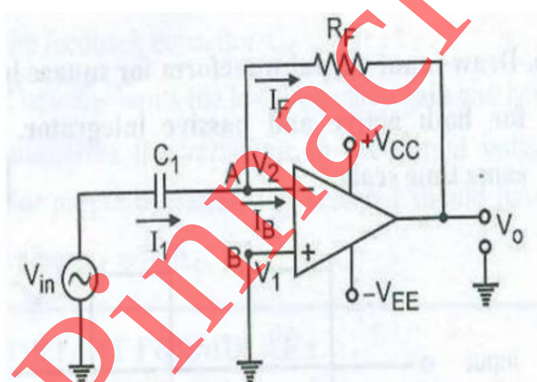
SUMMER– 19 EXAMINATION

Subject Title: Linear Integrated Circuits **Subject Code: 22423**

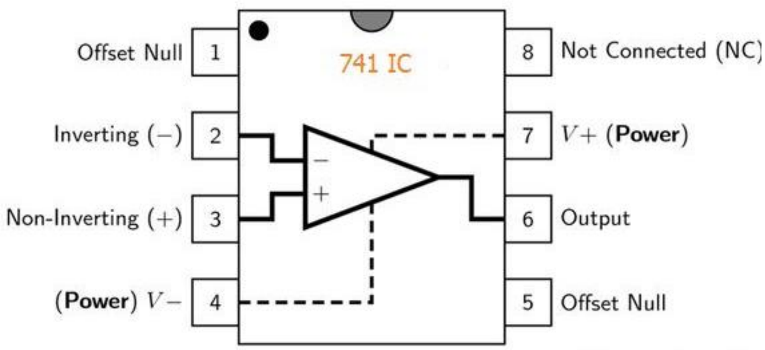
Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for anyequivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q.N.	Answer	Marking Scheme
Q.1		**Attempt any Five :**	**10-Total Marks**
	a)	**State ideal value of given parameters for Op-Amp IC 741:** **(i) Slew rate** **(ii) SVRR**	**2M**

		(iii) Input bias current **(iv) Gain bandwidth product.**	
	Ans:	The ideal value of given parameters for Op-Amp IC 741 is given by: i) Slew rate= ∞ (ii)SVRR= 0 (iii)Input bias current= 0 (iv)Gain bandwidth product=∞	**(Each value ½ mark)**
	b)	**Draw circuit diagram of OP- AMP based basic differentiator.**	**2M**
	Ans:	**Circuit diagram of differentiator:-** 	**1M** **labeling 1M**
	c)	**State the merits of active filter over passive filter.**	**2M**
	Ans:	**Merits of active filter over passive filter are:** 1. Less cost due to the variety of cheaper op-amp and absence of costly inductors. 2. Gain and frequency adjustment flexibility since the op-amp is able to providing gain; the input signal is not attenuated as in case of passive filters. 3. Active filter is easier to tune or adjust as compare to passive filters. 4. No loading problem because active filter provides excellent isolation between individual stages due to high input impedance. 5. Active filters are small in size and less bulky (due to absence of "L") and rugged. **6.** Non floating input and output.	**(Any two merits : 1 Mark each)**
	d)	**Define following terms related with filter:** **(i) Roll off Rate** **(ii) Pass band**	**2M**

	Ans:	(i) **Roll off Rate:** The rate at which gain falls off rapidly in stop band is called Roll off rate **(ii) Pass band:** A pass band is the range of frequencies that can pass through a filter.	**1M each**
	e)	**State the function of IC 555.**	**2M**
	Ans:	The 555 timer IC is an integrated circuit (chip) used in a variety of timer, pulse generation, and oscillator applications. The 555 can be used to provide time delays, as an oscillator, and as a flip-flop element.	**Any 2** **1M each**
	f)	**Give classification of filter based on components used.**	**2M**
	Ans:	Classification of filter based on components used are: 1. Active filters(components such as transistor, OP-AMP) 2. Passive filters(components such as R,L,C)	**1 M each**
	g)	**Define order of filter with suitable example.**	**2M**
	Ans:	**Order of the filter:-** It depends on the rate at which filter's gain decreases or increases after or before cut off frequency. **For example:** 1. If gain of the filter is reduced by -20 dB / decade or increases by +20 dB / decade then the filter is of 1^{st} order. 2. If gain of the filter is reduced by -40 dB / decade or increases by +40 db / decade then the filter is of 2^{nd} order and so on.	**1M** **1M**
Q 2		**Attempt any Three :**	**12M**
	a)	**Draw pin diagram of IC 741 and state the function of each pin.**	**4M**
	Ans:		

		 741 Op-Amp IC	2M
		Explanation **Pin 1 and Pin 5 (Offset Null):** Since the op-amp is the differential type, input offset voltage must be controlled so as to minimize offset. Offset voltage is nulled by application of a voltage of opposite polarity to the offset. An offset null-adjustment potentiometer may be used to compensate for offset voltage. The null-offset potentiometer also compensates for irregularities in the operational amplifier manufacturing process which may cause an offset. **Pin 2 (Inverted Input):** All input signals at this pin will be inverted at output pin 6. **Pin 3 (Non-Inverted Input):** All input signals at this pin will be processed normally without inversion. **Pin 4 (-V):** The (-V) pin (also referred to as Vss) is the negative supply voltage terminal. Supply-voltage operating range for the 741 is -4.5 volts (minimum) to -18 volts (max), and it is specified for operation between -5 and -15 Vdc. The device will operate essentially the same over this range of voltages without change in timing period. **Pin 6 (Output):** Output signal´s polarity will be the opposite of the input´s when this signal is applied to the op-amp´s inverting input. For example, a sine-wave at the inverting input will output a square-wave in the case of an inverting comparator circuit. **Pin 7 (+V):** The +V pin (also referred to as Vcc) is the positive supply voltage terminal of the 741 Op-Amp IC. Supply-voltage operating range for the 741 is +4.5 volts (minimum) to +18 volts (maximum), and it is specified for operation between +5 and +15 Vdc. **Pin 8 (NC):** The ´NC´ stands for ´Not Connected´. There is nothing connected to this pin, it is just there to make it a standard 8-pin package.	2M
	b)	**Draw and explain the working of wein bridge oscillator using IC 741.**	**4M**
	Ans:	**(Diagram 2 M, Explanation 2 M)**	

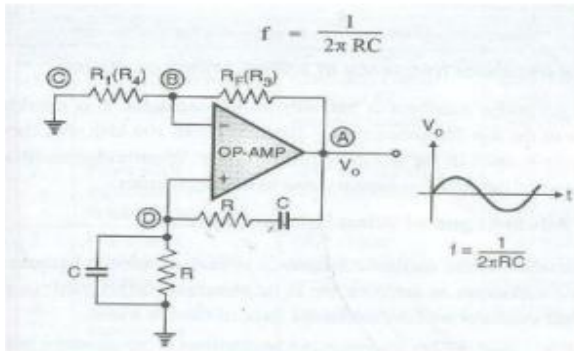
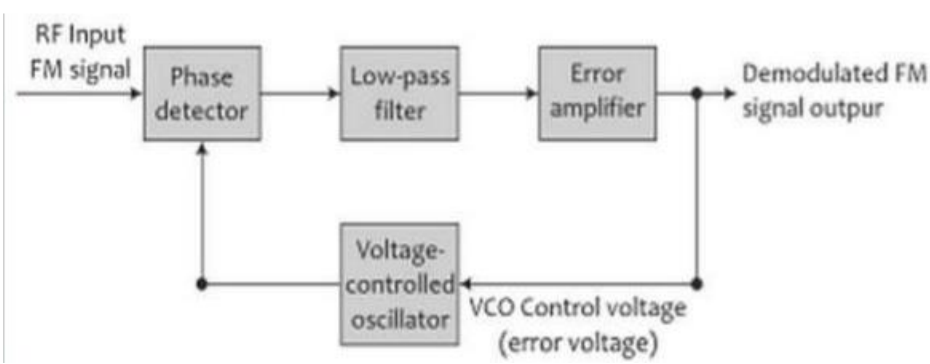


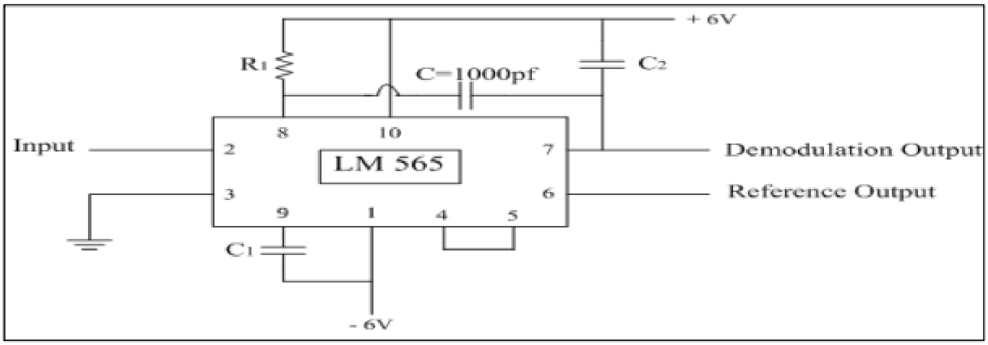
Fig: Wein bridge oscillator using OP-AMP

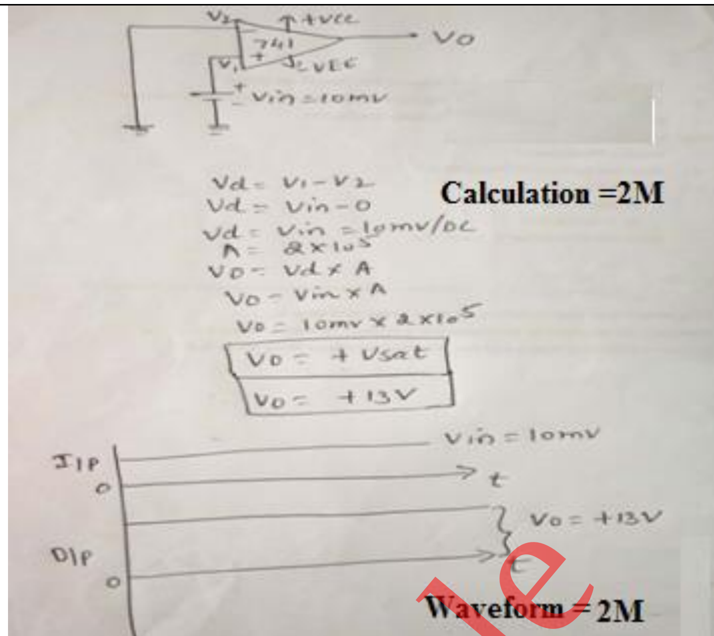
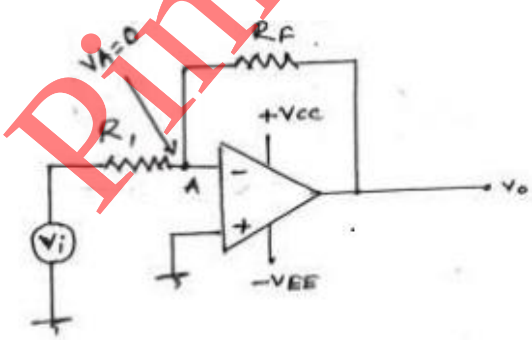
Explanation:-

- The feedback signal in this oscillator circuit is connected to the non-inverting input terminal so that the op-amp works as a non-inverting amplifier.
- The condition of zero phase shift around the circuit is achieved by balancing the bridge, zero phase shift is essential for sustained oscillations.
- The frequency of oscillation is the resonant frequency of the balanced bridge and is given by the expression fo = 1/2πRC
- At resonant frequency (ƒo), the inverting and non-inverting input voltages will be equal and "in-phase" so that the negative feedback signal will be cancelled out by the positive feedback causing the circuit to oscillate.
- From the analysis of the circuit, it can be seen that the feedback factor β= 1/3 at the frequency of oscillation. Therefore for sustained oscillation, the amplifier must have a gain of 3 so that the loop gain becomes unity.
- For an inverting amplifier the gain is set by the feedback resistor network R_f and R_i and is given as the ratio $-R_f/R_i$.

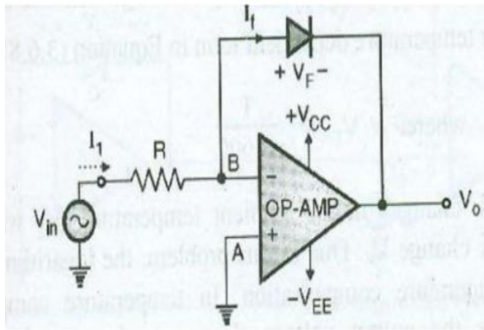
c)	**Describe the operation of FM Demodulator using PLL with block diagram.**	**4M**
Ans:	**(Any one Diagram 2 M, Explanation 2 M)**	



		OR  **1 .**FM demodulator detects the demodulation signal & it is constructed using PLL. 2. The above diagram shows the FM demodulator using PLL. 3. The FM signal which is to be demodulated is applied at the input of the PLL. 4. As the PLL is locked to the FM, the VCO starts tracking the instantaneous frequency in the FM input signal. 5. The error voltage produce at the output of the amplifier is proportional to deviation of input frequency from the center frequency of FM. Thus the ac component of the error voltage represents the modulating signal. Thus at the error amplifier output we get demodulated FM output. 6. The FM modulator using PLL ensures a high linearity between the instantaneous input frequency & VCO control voltage.	
	d)	**Calculate the output voltage for open loop non inverting amplifier if V_{in}=10 mv/dc. Also draw input output waveform.**	**4M**
	Ans:	**(Calculation = 2M & waveform = 2M)**	

			
Q.3		**Attempt any three:**	**16M**
	a)	**Explain virtual ground concept of an op-amp.**	**4M**
	Ans:	**Virtual ground is a concept related to the negative feedback in an op amp.**  **Explanation of Virtual ground concept:-** In circuit point V_A is virtual ground. Figure shows inverting amplifier using op-amp. In this circuit non-inverting terminal is connected to the actual ground. Due to this potential of inverting terminal become zero. Thus, inverting terminal is not actually connected to the ground. There after its potential is zero. Thus point V_A is known as virtual ground point. This phenomenon of having zero potential without actually grounding is known as virtual ground concept.	**2 M** **2M**
	b)	**Draw the circuit diagram of logarithmic amplifier using diodes and obtain the expression for its output voltage.**	**4M**

	Ans:	**(Diagram =2M & Derivation=2M)**	**2M**



(NOTE: Any related other Derivation can be considered)

Derivation:- **2M**

The expression for the current passing through diode is always given by,

$$I_F = I_O\left(e^{\frac{V_F}{V_T \eta}} - 1\right)$$

Where,

$$I_F = Feedback current through diode$$

$$I_O = Reverse saturation current$$

$$V_F = Forward voltage drop$$

η = constant i.e. 1 for Ge& 2 for Si

$$V_T = \frac{KT}{q}$$

K = Boltzmann's constant = 1.38 * 10^{-23}

T = Temperature in Kelvin [$273K = 0°C$]

q = Electric charge = 1.692* 10^{-19} C

As $e^{\frac{V_F}{V_T \eta}} \gg 1$

$$\therefore I_F = I_O\left(e^{\frac{V_F}{V_T \eta}}\right)$$

$$\frac{I_F}{I_O} = \left(e^{\frac{V_F}{V_T \eta}}\right)$$

Taking natural log on both side,

$$log_e\left(e^{\frac{V_F}{V_T \eta}}\right) = log_e\left(\frac{I_F}{I_O}\right)$$

$$\frac{V_F}{\eta V_T} log_e e = log_e\left(\frac{I_F}{I_O}\right)$$

As $log_e e = 1$

$$\therefore \frac{V_F}{\eta V_T} = log_e\left(\frac{I_F}{I_O}\right)$$

$V_F = \eta V_T log_e\left(\frac{I_F}{I_O}\right)$……………….. (1)

Now from figure,

$$V_F = V_B - V_O$$

$V_F = -V_O$ (Since $V_B = 0\ fromvirtualgroundconcept$)

$$-V_F = V_O$$

$\therefore V_O = -\eta V_T log_e\left(\frac{I_F}{I_O}\right)$ ……………. (2)

Now apply KCL at node B,

$$I_1 = I_B + I_F$$

$$\therefore I_1 = I_F$$

$$\therefore \frac{V_i - V_B}{R_i} = I_F$$

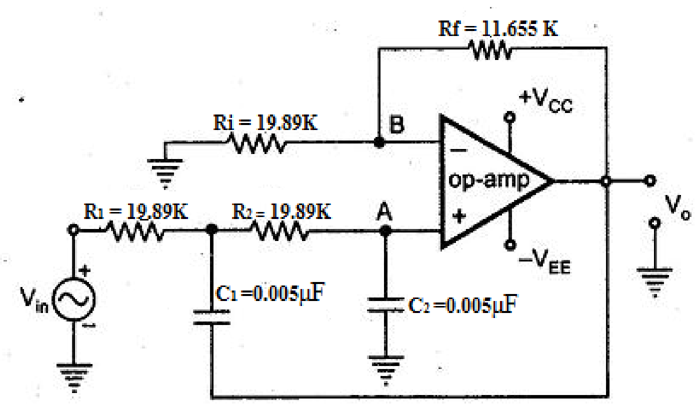
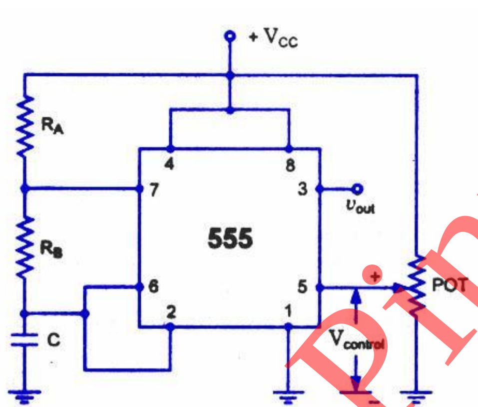
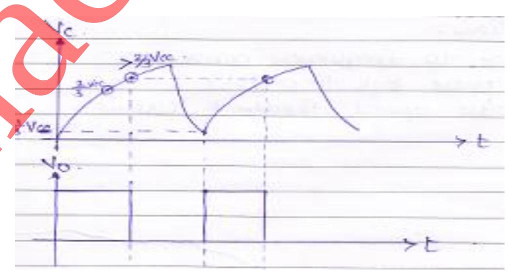
$\therefore I_F = \frac{V_i}{R_i}$ (Since $V_B = 0\ fromvirtualgroundconcept$)

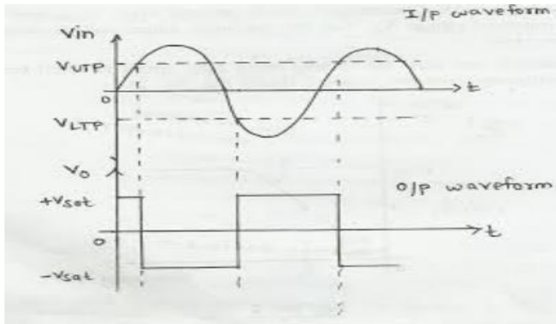
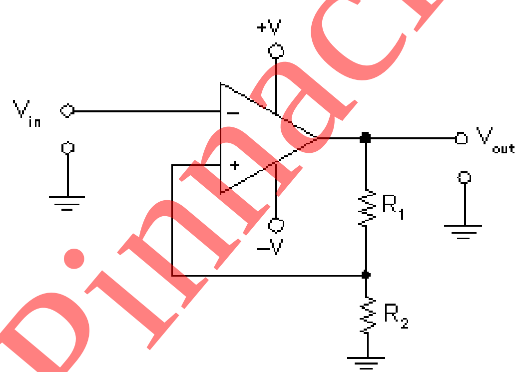
Put this into eqn 2

$$V_O = -\eta V_T log_e\left(\frac{V_i}{R_i I_O}\right)$$

$$\therefore V_O \propto log_e V_i$$

c)	**Sketch a second order low-pass butter worth filter with higher cut-off frequency of 1.6 kHz and voltage gain of 1.586.**	**4M**
Ans:	**Given data:** F_H = 1.6KHz A_V = 1.586 **Solution:** Let $C_1 = C_2$ = 0.005µF **(NOTE: Any assumed values can be consider and accordingly Calculations changes.)** $R_1 = R_2 = \frac{1}{2\pi F_H C} = \frac{1}{2\pi 1.6K\ 0.005\mu}$ = 19.89KΩ --------------**½ M formula & ½ calculation** $A_V = 1 + \frac{R_F}{R_i}$ .... **½ M** $1.586 = 1 + \frac{R_F}{R_i}$ $\frac{R_F}{R_i} = 0.586$ $R_F = 0.586\ R_i$ Let, $R_i = 19.89K\Omega$ $R_F = 11.655K\Omega$ .... **½ M** **Designed Circuit:**	**2M** **2M**

			
	d)	**Explain the working of voltage controlled oscillator using IC555. Also draw related waveform.**	**4M**
	Ans:	**Circuit diagram and waveforms:**  **Working:** • It is constructed using astable multivibrator by connecting one potentiometer to pin no.5, V_{CC} & ground. • This circuit is also called as frequency converter or frequency changer. • By connecting pot at pin no.5, the D.C voltage at this pin is not equal to 2/3 V_{CC}. But it is variable depending on position of pot wiper. • If control voltage is increased above 2/3 V_{CC} then capacitor has to charge higher voltage to change the state of output. • Therefore capacitors will take a longer time to change to required voltage. Similarly it will take longer time to discharge. Thus T= T_{ON} + T_{OFF} will also increase. • Therefore the output frequency of astable multivibrator is the function of control voltage applied at pin 5. Hence it works as voltage control oscillator.	**2M & 1M w/f** **1M**
Q.4	**A)**	**Attempt any THREE :**	**12 M**

	a)	**Identify the following waveforms. Label the circuit name and draw the circuit diagram for the same (Refer Fig.No.1).**  Fig. No. 1	**4M**
	Ans:	**Identification:** The circuit which provides given Waveforms is **Schmitt Trigger using Op-amp.** **Circuit Diagram:** 	**2M** **2M**
	b)	**What is the use of level shifter stage? Draw its circuit diagram.**	**4M**
	Ans:	**Use of level shifter stage:** Level shifting stage is used to bring the dc level to zero volts w. r. t. ground. Op-amp is a direct coupled amplifier, So when input is zero or at ground potential, the output of op-amp will be at some positive DC level which is an error voltage called as offset voltage. So in order to pull this o/p DC offset voltage to zero, the DC level shifter is used. **Circuit Diagram:**	**2M** **2M**

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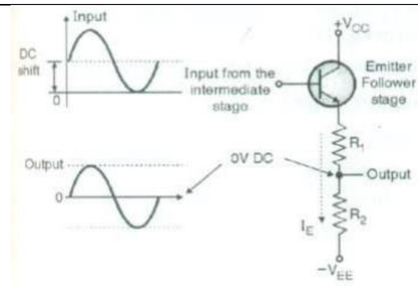
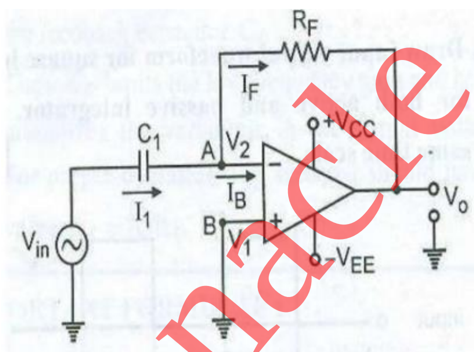
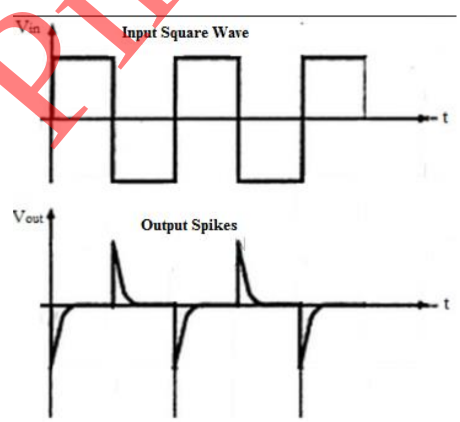
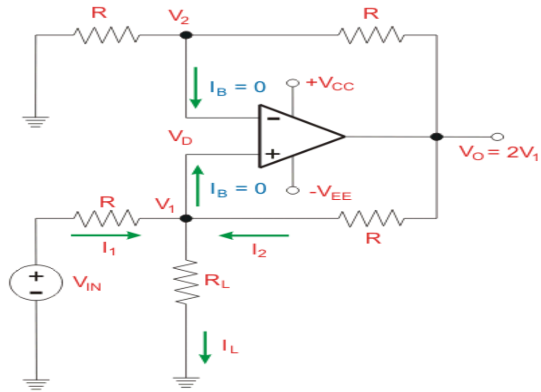
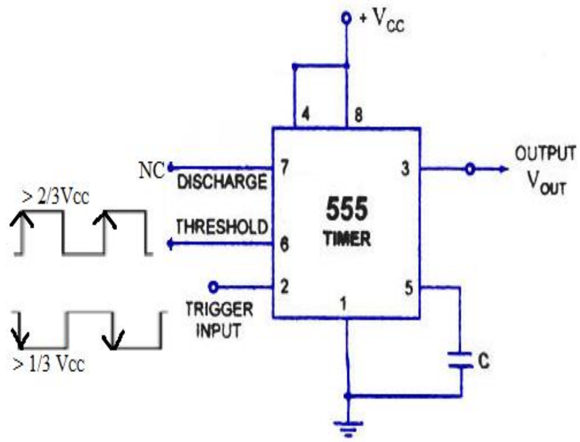
<tr><td></td><td></td><td>
</td><td></td></tr>
<tr><td></td><td>c)</td><td>For the following equation sketch the circuit diagram and output waveform for square wave input $V_o = R_1 C_1 (d_{vin}/d_t)$</td><td>4M</td></tr>
<tr><td></td><td>Ans:</td><td>Circuit Diagram of Differentiator:


Waveforms:

</td><td>2M

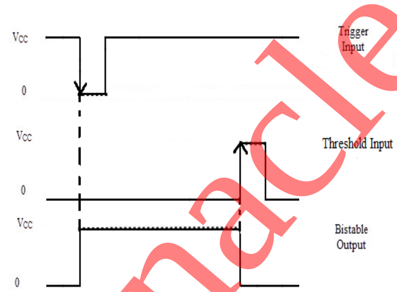
2M</td></tr>
<tr><td></td><td>d)</td><td>Draw voltage to current converter with grounded load and derive the expression.</td><td>4M</td></tr>
</table>

	Ans:	**Circuit Diagram :**  **Derivation:** **Apply KCL at node V_1** $I_1 + I_2 = I_L + I_B$ $I_1 + I_2 = I_L$ ………………… $(I_B = 0)$ $\frac{V_{in} - V_1}{R} + \frac{V_O - V_1}{R} = I_L$ $V_{in} + V_O - 2V_1 = I_L R$ $V_1 = \frac{V_{in} + V_O - I_L R}{2}$ As non-inverting mode is used , $A = 1 + \frac{R}{R} = 2$ $\therefore V_O = 2V_1$ $V_O = V_{in} + V_O - I_L R$ $V_{in} = I_L R$ $I_L = \frac{V_{in}}{R}$	**2M** **2M**
	e)	**Describe the working of bistable multivibrator with circuit diagram and waveform using IC555.**	**4M**
	Ans:	**Circuit Diagram:**	**2M**



1M

Waveforms:



Working:

1M

1. When negative going pulse is applied at pin no.2, it is more negative than 1/3 Vcc of lower comparator,

∴Output of lower comparator is high.

∴S=1

∴ output of flip flop Q = 1

∴ Final output =1

2. When positive going pulse is applied at pin no.6, it is more positive than 2/3 Vcc of upper comparator,

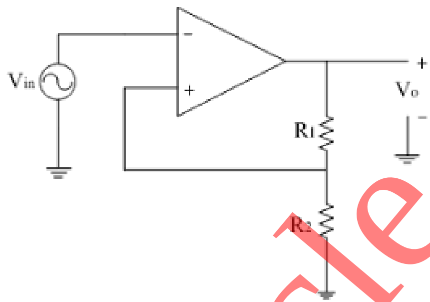
∴Output of upper comparator is high.

∴R=1

∴ output of flip flop Q = 0

∴ Final output =0

Q.5		**Solve any TWO :**	**12 M**

	a)	**If R_1=47Ω,R_2=27k Ω ,V_{out}=0.5 V_{pp} square wave for op-amp based inverting Schmitt trigger circuit with supply voltage ± 15V .Determine threshold voltages V_{UTP} , V_{LTP} and hysteresis voltage VH. For 741 maximum output voltage swing is ± 14V.**	**6M**
	Ans:	**Given data:-** R_1=47Ω,R_2=27k Ω Vout =0.5Vpp Vsat = ±14V For an inverting Schmitt Trigger  **(Diagram is Optional)** **Note: - The labeling of R_1 & R_2 Can be interchanged in the configuration so the formula is changed for calculating UTP & LTP.** **Upper Threshold Voltage V_{UTP}** = (R_1/R_1+R_2) * +V sat = $(47/47+27*10^3)$ * 14 = **0. 02433V OR 24.33mV** **OR** **Upper Threshold Voltage V_{UTP}** = (R_2/R_1+R_2) * +V sat = $(27/47+27*10^3)$ * 14 = **13.97V** **Lower Threshold Voltage V_{LTP}** = (R_1/R_1+R_2) * -Vsat = $(47/47+27*10^3)$ *(- 14) = **- 0. 02433V OR - 24.33mV** **OR**	**2M each**

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Lower Threshold Voltage V_{LTP} = (R_2/R_1+R_2) * -Vsat
= $(27/47+27*10^3)$ *(- 14)
= **- 13.97mV**
Hysteresis Voltage = V_{UTP} - V_{LTP}
= 24.33 - (- 24.33)mV
= **48.66mV**
OR
Hysteresis Voltage = V_{UTP} - V_{LTP}
= 13.97 - (- 13.97)V
= **27.94V**

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<tr><td></td><td>b)</td><td>

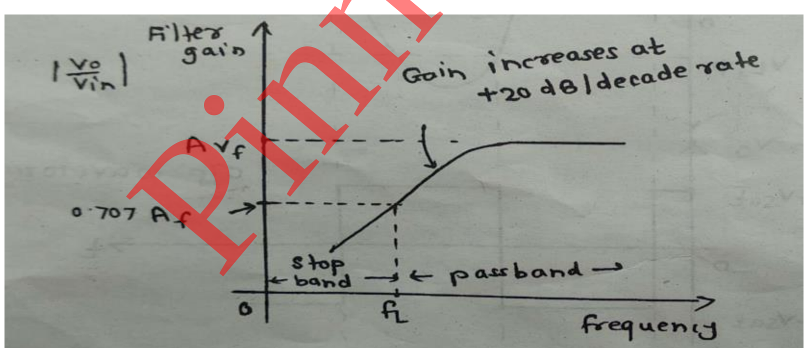
Identify and draw the op- amp based filter circuit to fulfill the following frequency response.


Fig. No. 2

</td><td>6M</td></tr>
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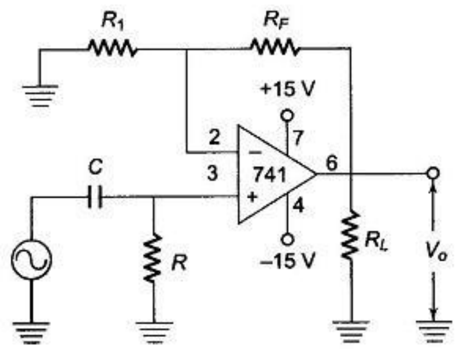
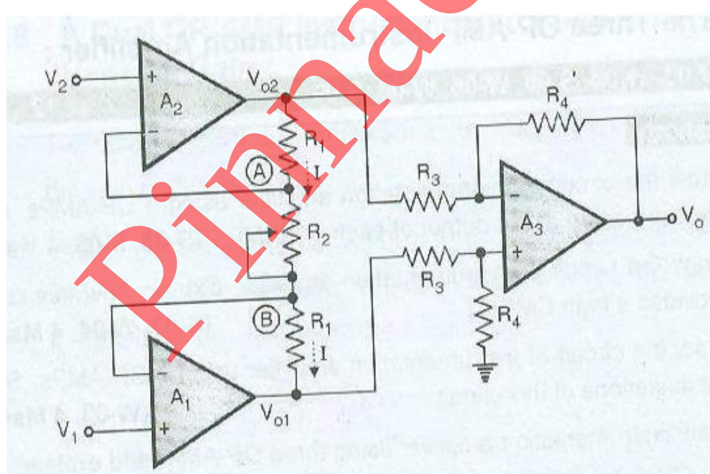
	Ans:	The given frequency response is of first order butter worth high pass filter **Circuit diagram of first order butter worth high pass filter:-** 	**2M** **4M**
	c)	**Explain working of op-amp as an instrumentation amplifier with neat diagram.**	**6M**
	Ans:	**Circuit diagram of Instrumentation amplifier:-** ***(NOTE:- Instrumentation amplifier using 1 or 2 OPAMP also can be given the marks)***  **Explanation:-** Fig: Instrumentation amplifier using three Op- Amp 1. The high impedance instrumentation amplifier using cross coupled difference amplifiers is as shown in fig. 2. A_1 and A_2 in Figure are basically non inverting amplifiers with their inverting (-) terminal connected to resistors R_2 instead of connecting it to ground. 3. As the input impedance of all OP- AMP's used in assumed to be infinite their input current is zero. Therefore current flowing through the resistors R1, R2 and R3 is same i.e. 4. The overall gain of Av of the three Op-Amp instrumentation amplifier is given by	**3M** **3M**

$$Av = \left[1 + \frac{2R1}{R2}\right] x \frac{R4}{R3}$$

Av = Av1 x Av2 Therefore,

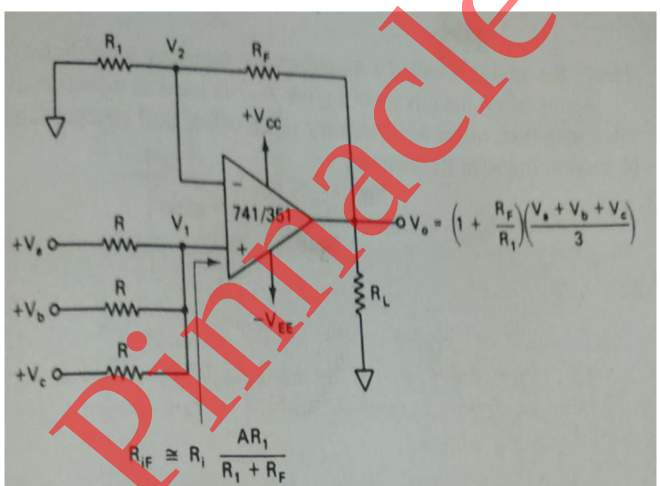
5. Hence by using a variable resistor R_2 the overall gain can be easily and linearly varied.
6. The output is then given by Vo = Av * $(V_1 - V_2)$

Q.6 **Attempt any TWO:** **12M**

a) **Draw the designed circuit for getting output voltage**

V_o= $(V_a + V_b + V_c)$ / 3 and suggest modifications for converting into scaling amplifier. **6M**

Ans: **Diagram:-** **2M**



Explanation:- **2M**

The output voltage is equal to the average of all the input voltages times the gain of the circuit (1+Rf / R1) hence the averaging amplifier. If gain (1+Rf / R1) = 1 then the output voltage will be equal to average of all the input voltages.

$$Vo = \frac{Va + Vb + Vc}{3}$$

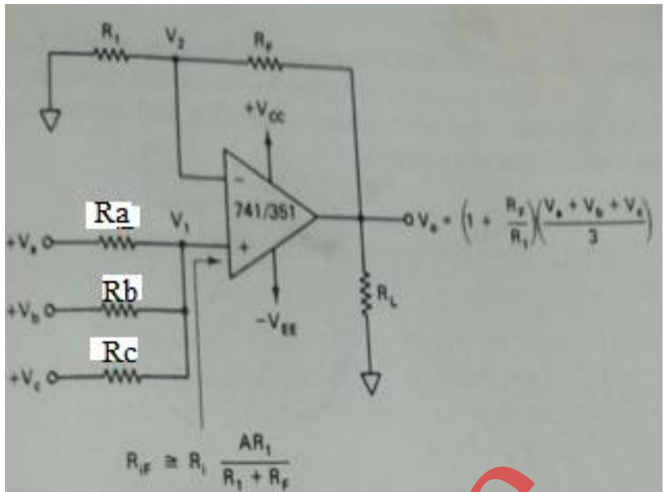
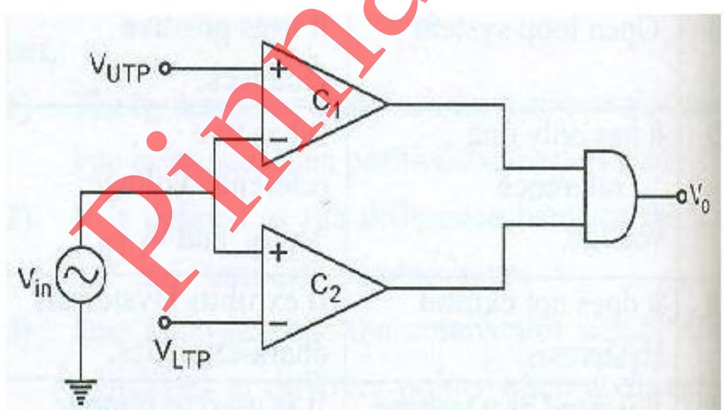
2M

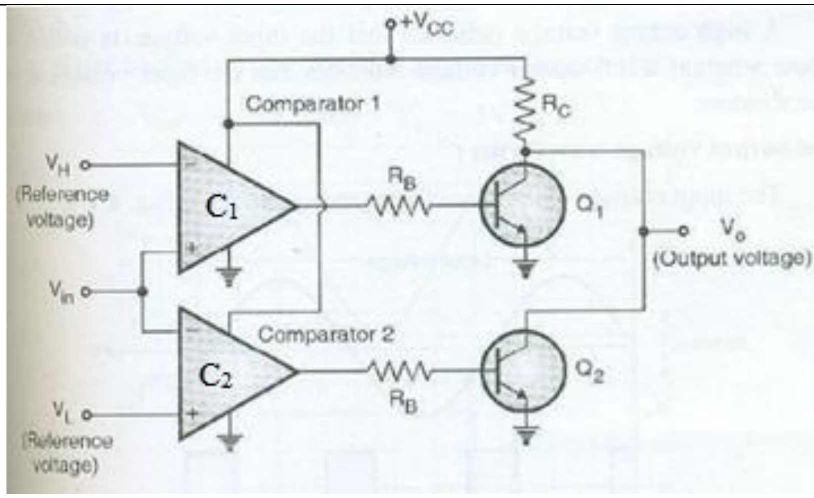
Modification to convert averaging amplifier into the Scaling amplifier:-

This can be accomplished by selecting the value of three input resistors of different value thus the output voltage of scaling amplifier is

Vo = (R_f / R_a* V_a + R_f / R_b* V_b + R_f / R_c*V_c)

Where

		$R_f / R_a \neq R_f / R_b \neq R_f / R_c$ 	
	b)	**Explain working of window detector with neat diagram. Draw input and output waveforms.**	**6M**
	Ans:	**Diagram:-**  **OR**	**2M**



3M

Working:-

indow detector uses two comparators C_1 and C_2. The reference voltage of inverting comparator C_1 is V_{UTP} and the reference voltage of the non inverting comparator C_2 is V_{LTP}. Assume $V_{LTP} < V_{UTP}$.

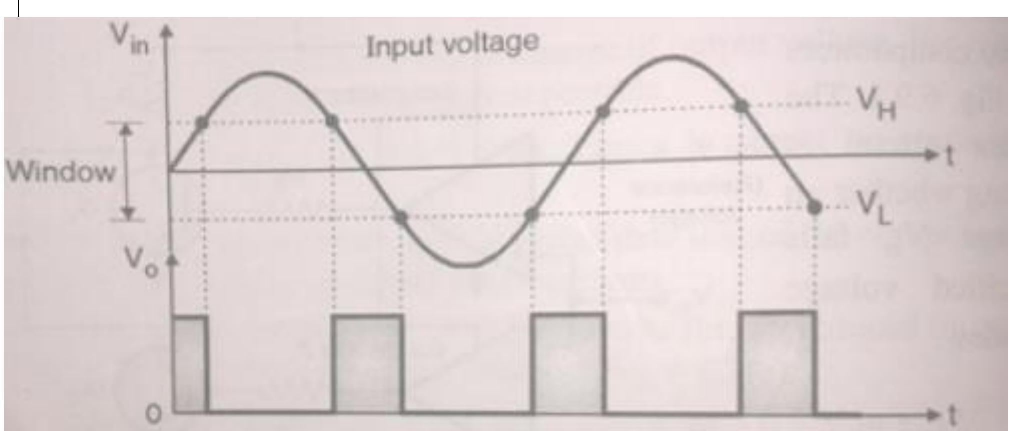
I: When Vin < V_{LTP} (V_L)then the differential voltage of C_2 is negative. Hence outputofC_2 is low. Vin is also less than V_{UTP}. Hence output of C_1 is high and output Vo of gate is low.

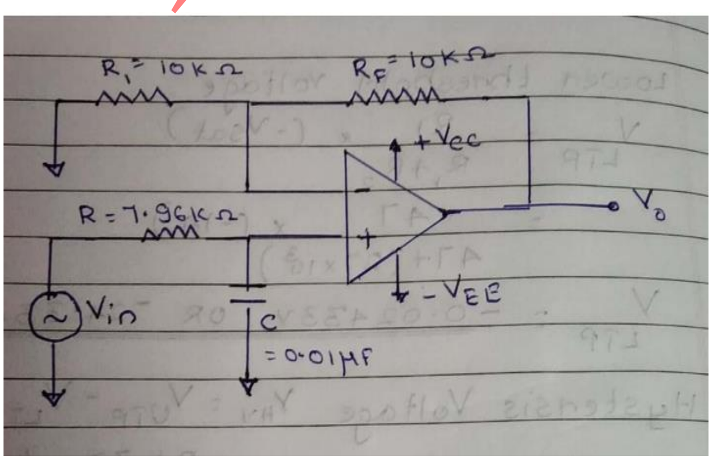
I: When Vin > V_{UTP}(V_H), then the differential input voltage of C_2 is high. The differential input voltage of C_1 is negative. The differential input voltage of C_1 is negative. output of C_1 is low and output Vo of AND gate is low.

II: When V_{LTP}< Vin< V_{UTP}, OR V_L< Vin< V_H the differential input voltage of C_1 and C_2 is positive and output is high. The output of AND gate is high.

1M

forms:-



	c)	**Design a first order low pass butter worth filter with cut-off frequency of 2 kHz and ass band gain of two. Draw the designed circuit.**	**6M**
	Ans:	**Given data: Pass band gain (A_f) = 2; Cut-off Frequency (fc) = 2 kHz;** **Calculations:** **(NOTE:- The assumption of any value will be considered. According to that calculated final answer will change.)** Pass band Gain (Af) is given by the formula: **$A_f = 1 + R_F / R_1$**--. **(1M)** Here $A_F = 2$ Therefore **$2 = 1 + R_F / R_1$** --**(1M)** So, $1 = R_F / R_1$ Therefore, $R_F = R_1$ Let $R_F = 10k\Omega$, Therefore **$R_1 = 10k\Omega$**--**(1M)** **Assume C= 0.01 µF** But $Fc = 1/2\pi RC$ But Fc= 2kHz Therefore, $2\text{ kHz} = 1/2\pi RC$ $R = 1/2\pi \times 2 \times 10^3 \times 0.01 \times 10^{-6}$ Therefore, **$R = 7.96\ k\Omega$** --**(1M)** **Designed circuit:-** 	 **4M** **2M**
