K.S. SCHOOL OF ENGINEERING AND MANAGEMENT, BANGALORE - 560109

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

SESSION: 2021-2022 (EVEN SEMESTER)

III SESSIONAL TEST QUESTION PAPER

SET-A

USN

Degree : B.E
Branch : Electronics and Communication Engineering
Course Title : Analog Circuits
Duration : 90 Minutes

Semester : IV
Course Code : 18EC42
Date : 01/09/2022
Max Marks : 30

Note: Answer ONE full question from each part.

Q No.	Question	Marks	K-Level	CO mapping
	PART-A			
1(a)	**Explain** working of a zero crossing detector. What are the problems incurred and solution for the same?	5	Understanding (K2)	CO4
(b)	With a neat circuit diagram, **explain** the opamp based inverting amplifier configuration for scaling and averaging circuit with relevant expressions for the output.	5	Understanding (K2)	CO4
(c)	Draw the circuit and frequency response of a first order low pass filter. **Design** a first order low pass filter to have a cutoff frequency of 1kHz with a pass band gain of 2.	5	Applying (K3)	CO5
	OR			
2(a)	**Explain** working of a Schmitt Trigger circuit with suitable input and output waveforms.	5	Understanding (K2)	CO4
(b)	With a neat circuit diagram, **explain** working of Instrumentation amplifier circuit.	5	Understanding (K2)	CO4
(c)	**Design** a second order high pass Butterworth filter and explain its operation with a neat circuit diagram.	5	Applying (K3)	CO5
	PART-B			
3(a)	In the circuit of inverting summing amplifier, Va= +1V, Vb= +2V,Vc=+3V, Ra=Rb=Rc=3KΩ, Rf=1KΩ,R_{OM}=270Ω an supply voltages=±15V. Assuming that the op-amp is initially nulled, **determine** the output voltage V_0.	5	Applying (K3)	CO4
(b)	**Draw** the circuit and waveforms for an inverting Schmitt Trigger using op-amp, with relevant expressions. For an inverting Schmitt Trigger circuit R1 = 15KΩ ; R2 = 1KΩ and Vin = 10Vp-pp sine wave. The saturation voltages are ± 14V and Vref = 2 V. i) **Determine** the threshold voltages Vut and Vlt. ii) **Find** the value of Hysteresis voltage V_{hy}.	5	Applying (K3)	CO4
(c)	**Explain** the operation of 555 timer with relevant expressions as a Monostable multivibrator.	5	Understanding (K2)	CO5
	OR			
4(a)	**Derive** the expression for input (Rif) and output (Rof) resistance of non-inverting amplifier with feedback.	5	Applying (K3)	CO4
(b)	The circuit shown in fifure is to be used as averaging amplifier with the following specifications. Va=Vb=1.5V, Vc=3V, R1=R=1.5K and V_0=5.2V. determine the required value of R_F.	5	Applying (K3)	CO4

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	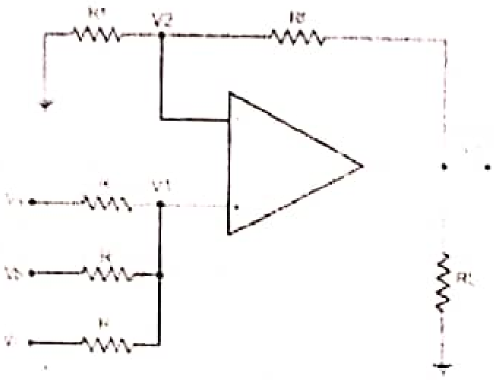 Summing amplifier non inverting configuration			
(c)	**Explain** R-2R network type DAC with relevant expressions.	**5**	**Understanding (K2)**	**CO5**

⑤

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III SESSIONAL TEST SCHEME & SOLUTION-SETA

Degree	:	**B.E**	**Semester**	:	**IV**
Branch	:	**Electronics and Communication Engineering**	**Date**	:	**01/09/2022**
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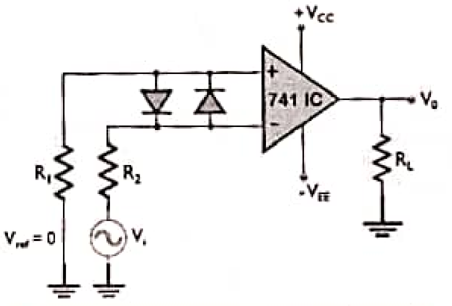
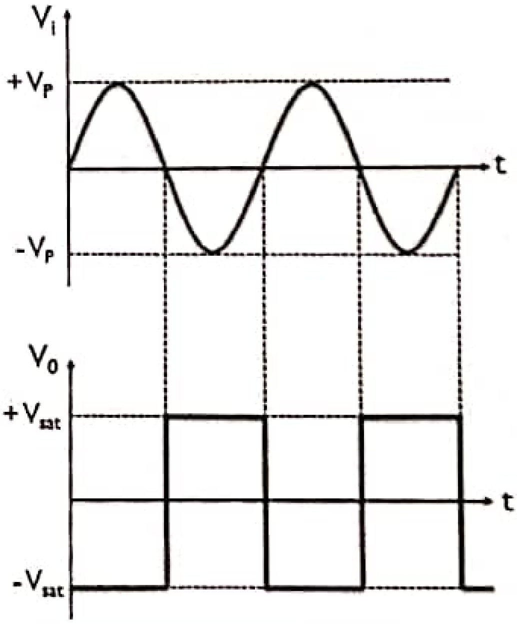
<table>
<tr><th>Q. No.</th><th>Scheme & Solution</th><th>Marks</th></tr>
<tr><td colspan="3">PART-A</td></tr>
<tr><td>1(a)</td><td>
The figure below represents the circuit of a zero crossing detector using inverting op-amp:
Here, the input signal V_i is provided to the inverting terminal of the op-amp while



Circuit Diagram of Zero-Crossing Detector

Electronics Coach



Input and Output Waveforms

Electronics Coach

the non-inverting terminal is grounded by making use of two resistors R_1 and R_2. As we can see that analog input signal is provided at the inverting terminal of the op-amp. Thus, the waveform of the signal at the output will hold reverse polarity. This we will discuss under working of the detector.

Working of Zero Crossing Detector

Let us consider the circuit given above in order to understand the working.
As we have already mentioned that the reference level is set at 0 and applied at the non-inverting terminal of the op-amp. The sine wave applied at the inverting terminal of the op-amp is compared with the reference level each time the phase of the wave changes either from positive to negative or negative to positive.

Firstly, when positive half of the sinusoidal signal appears at the input. Then the op-amp comparator compares the reference voltage level with the peak level of the applied signal.
</td><td>5</td></tr>
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(b)

Inverting Amplifier as summing, averaging and scaling amplifier:
The configuration is shown in fig. 2. With three input voltages va, vb & vc. Depending upon the value of Rf and the input resistors Ra, Rb, Rc the circuit can be used as a summing amplifier, scaling amplifier, or averaging amplifier.

Again, for an ideal OPAMP, v1 = v2. The current drawn by OPAMP is zero. Thus, applying KCL at v2 node

$$i_1+i_2+i_3=i_f$$

$$\frac{V_a}{R_a}+\frac{V_b}{R_b}+\frac{V_c}{R_c}=-\frac{V_o}{R_f}$$

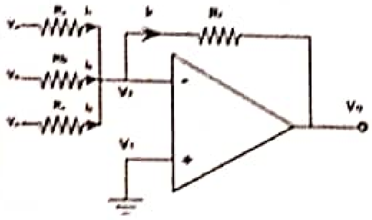
$$V_o=-\left(\frac{R_f}{R_a}V_a+\frac{R_f}{R_b}V_b+\frac{R_f}{R_c}V_c\right)$$

If in the circuit shown, $R_a=R_b=R_c=R$

$$V_o=-\frac{R_f}{R}(V_a+V_b+V_c)$$

This means that the output voltage is equal to the negative sum of all the inputs times the gain of the circuit Rf/ R; hence the circuit is called a summing amplifier. When Rf= R then the output voltage is equal to the negative sum of all inputs.
vo= -(va+ vb+ vc)

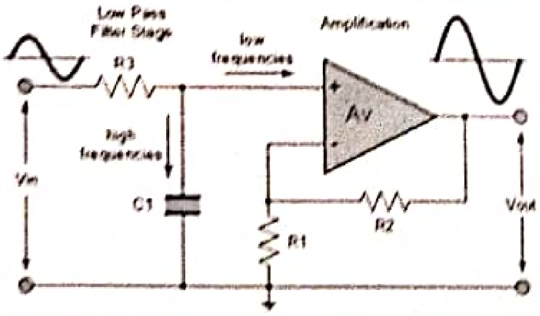
5



If each input voltage is amplified by a different factor in other words weighted differently at the output, the circuit is called then scaling amplifier.
The circuit can be used as an averaging circuit, in which the output voltage is equal to the average of all the input voltages.
In this case, $R_a= R_b= R_c = R$ and $R_f / R = 1 / n$ where n is the number of inputs.
Here $R_f / R = 1 / 3$.
$v_o = -(v_a+ v_b + v_c) / 3$
In all these applications input could be either ac or dc.

(c)

Active Low Pass Filter with Amplification



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The frequency response of the circuit will be the same as that for the passive RC filter, except that the amplitude of the output is increased by the pass band gain, A_F of the amplifier. For a non-inverting amplifier circuit, the magnitude of the voltage gain for the filter is given as a function of the feedback resistor (R_2) divided by its corresponding input resistor (R_1) value and is given as:

$$\text{DC gain} = \left(1 + \frac{R_2}{R_1}\right)$$

Therefore, the gain of an active low pass filter as a function of frequency will be:
Gain of a first-order low pass filter

$$Voltage\ Gain, (Av) = \frac{Vout}{Vin} = \frac{A_F}{\sqrt{1+\left(\frac{f}{fc}\right)^2}}$$

Where:

- A_F = the pass band gain of the filter, (1 + R2/R1)
- f = the frequency of the input signal in Hertz, (Hz)
- fc = the cut-off frequency in Hertz, (Hz)

Thus, the operation of a low pass active filter can be verified from the frequency gain equation above as:

- 1. At very low frequencies, $f < fc$ $\quad \frac{Vout}{Vin} \cong A_F$
- 2. At the cut-off frequency, $f = fc$ $\quad \frac{Vout}{Vin} = \frac{A_F}{\sqrt{2}} = 0.707A_F$
- 3. At very high frequencies, $f > fc$ $\quad \frac{Vout}{Vin} < A_F$

Thus, the **Active Low Pass Filter** has a constant gain A_F from 0Hz to the high frequency cut-off point, f_C. At f_C the gain is $0.707A_F$, and after f_C it decreases at a constant rate as the frequency increases.

OR

2(a)

Schmitt Trigger:
Schmitt trigger, circuit which is basically a comparator with positive feedback. Fig. shows an inverting Schmitt trigger circuit using OPAMP.

5

Because of the voltage divider circuit, there is a positive feedback voltage. When

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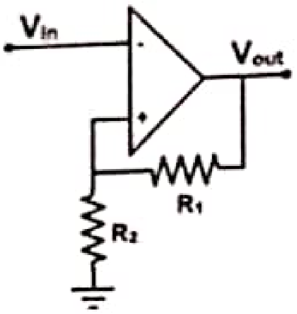
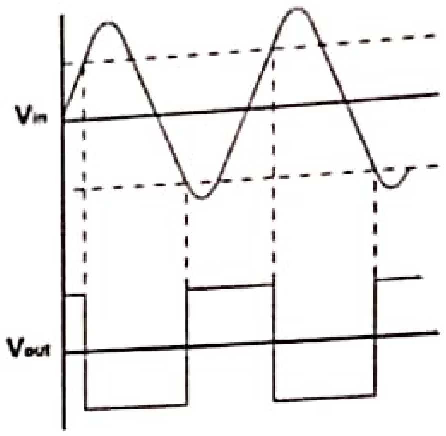
OPAMP is positively saturated, a positive voltage is feedback to the non-inverting input, this positive voltage holds the output in high stage. ($v_{in} < v_f$). When the output voltage is negatively saturated, a negative voltage feedback to the inverting input, holding the output in low state.





When the output is $+V_{sat}$ then reference voltage V_{ref} is given by

$$V_{ref} = \frac{R_2}{(R_1+R_2)} \cdot V_{sat} = (+\beta V_{sat})$$

If V_{in} is less than V_{ref} output will remain $+V_{sat}$.

When input v_{in} exceeds $V_{ref} = +V_{sat}$ the output switches from $+V_{sat}$ to $-V_{sat}$. Then the reference voltage is given by

$$V_{ref} = \frac{-R_2}{(R_1+R_2)} \cdot V_{sat} = (-\beta V_{sat})$$

The output will remain $-V_{sat}$ as long as $v_{in} > V_{ref}$.

If $v_{in} < V_{ref}$ i.e. v_{in} becomes more negative than $-V_{sat}$ then again output switches to $+V_{sat}$ and so on. Positive feedback has an unusual effect on the circuit. It forces the reference voltage to have the same polarity as the output voltage. The reference. voltage is positive when the output voltage is high ($+v_{sat}$) and negative when the output is low ($-v_{sat}$).

In a Schmitt trigger, the voltages at which the output switches from $+v_{sat}$ to $-v_{sat}$ or vice versa are called upper trigger point (UTP) and lower trigger point (LTP). the difference between the two trip points is called hysteresis.

(b) Differential Instrumentation Amplifier Transducer Bridge:

Figure shows a simplified circuit of a Differential Instrumentation Amplifier Transducer Bridge. 5

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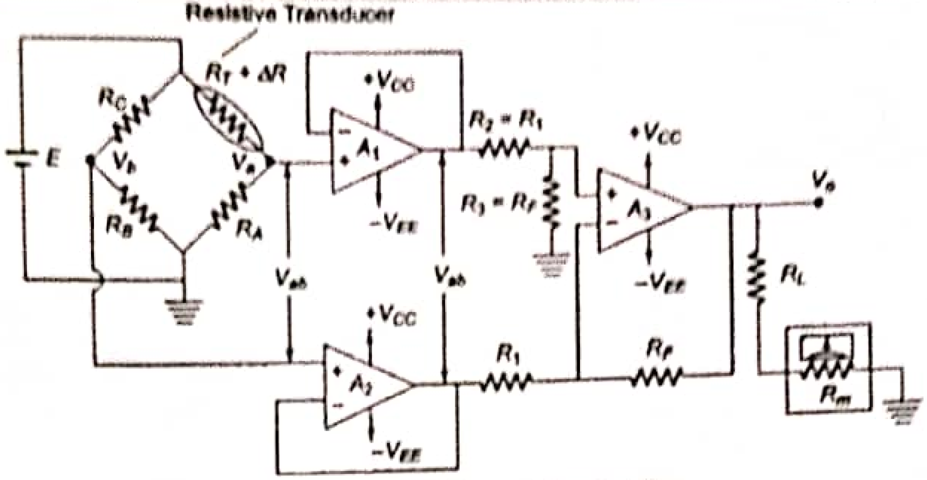

Fig. 14.25 ▬ Differential Instrumentation Amplifier using Transducer Bridge

In this circuit a resistive transducer (whose resistance changes as a function of some physical energy) is connected to one arm of the bridge.

Let R_T be the resistance of the transducer and ΔR the change in resistance of the resistive transducer. Hence the total resistance of the transducer is ($R_T \pm \Delta R$).

The condition for bridge balance is $V_b = V_a$, i.e. the bridge is balanced when $V_b = V_a$, or when

$$\frac{R_B(E)}{R_B + R_C} = \frac{R_A(E)}{R_A + R_T}$$

Therefore,

$$\frac{R_c}{R_B} = \frac{R_T}{R_A}$$

The bridge is balanced at a desired reference condition, which depends on the specific value of the physical quantity to be measured. Under this condition, resistors R_A, R_B and R_C are so selected that they are equal in value to the transducer resistance R_T. (The value of the physical quantity normally depends on the transducers characteristics, the type of physical quantity to be measured, and the desired applications.)

Initially the bridge is balanced at a desired reference condition. As the physical quantity to be measured changes, the resistance of the transducer also changes, causing the bridge to be unbalanced ($V_b \neq V_a$). Hence, the output voltage of the bridge is a function of the change in the resistance of the transducer. The expression for the output voltage V_o, in terms of the change in resistance of the transducer is calculated as follows.

Let the change in the resistance of the transducer be ΔR. Since R_B and R_C are fixed resistors, the voltage V_b is constant, however, the voltage V_a changes as a

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function of the change in the transducers resistance.

Therefore, applying the voltage divider rule we have

$$V_a = \frac{R_A(E)}{R_A + (R_T + \Delta R)} \text{ and } V_b = \frac{R_B(E)}{R_B + R_C}$$

The output voltage across the bridge terminal is V_{ab} given by $V_{ab} = V_a - V_b$.

Therefore,

$$V_{ab} = \frac{R_A(E)}{R_A + (R_T + \Delta R)} - \frac{R_B(E)}{R_B + R_C}$$

However, if

$$R_A = R_B = R_C = R_T = R, \text{ then}$$

$$V_{ab} = \frac{R(E)}{2R + \Delta R} - \frac{R(E)}{2R} = E\left(\frac{R}{2R + \Delta R} - \frac{1}{2}\right)$$

$$V_{ab} = E\left(\frac{2R - 2R - \Delta R}{2(2R + \Delta R)}\right) = \frac{-\Delta R(E)}{2(2R + \Delta R)} \qquad (14.15)$$

The output voltage V_{ab} of the bridge is applied to the Differential Instrumentation Amplifier Transducer Bridge through the voltage followers to eliminate the loading effect of the bridge circuit. The gain of the basic amplifier is (R_F/R_1) and therefore the output voltage V_o of the circuit is given by

$$V_o = V_{ab}\left(\frac{R_F}{R_1}\right) = \frac{-\Delta R(E)}{2(2R + \Delta R)} \times \frac{R_F}{R_1} \qquad (14.16)$$

It can be seen from the Eq. (14.16) that V_o is a function of the change in resistance ΔR of the transducer. Since the change is caused by the change in a physical quantity, a meter connected at the output can be calibrated in terms of the units of the physical quantity.

Applications of Instrumentation Amplifier Transducer Bridge:

We shall now consider some important applications of instrumentation amplifiers using resistance types transducers. In these transducers, the resistance of the transducer changes as a function of some physical quantity. Commonly used resistance transducers are thermisistors, photoconductor cells, and strain gauges.

(c)

Second Order High Pass Butterworth Filters:

The second order high pass Butterworth filters produces a gain roll off at the rate of + 40 dB/decade in the stop band. This filter also can be realized by interchanging the positions of resistors and capacitors in a second order low pass

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Butterworth filters. The Fig. 2.81 shows the second order high pass Butterworth filters.

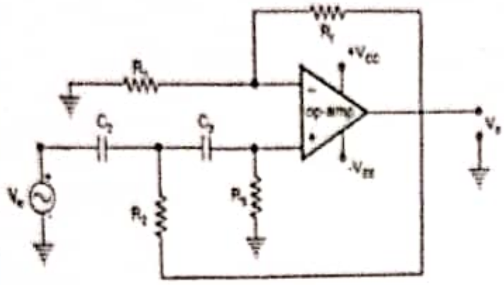


Fig. 2.81 Second order high pass Butterworth filter

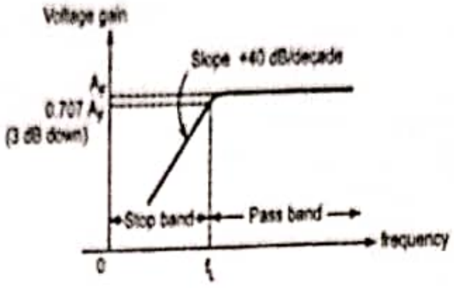


Fig. 2.82 Frequency Response

The analysis, design and the scaling procedures for this filter is exactly same as that of second order low pass Butterworth filter.

The resulting expression is given here for the convenience of the reader. The voltage gain magnitude equation for the second order high pass filter is

$$\left|\frac{V_0}{V_{in}}\right| = \frac{A_F}{\sqrt{1 + \left(\frac{f_L}{f}\right)^4}} \quad \ldots$$

where

- f = input frequency in Hz
- f_L = lower cut off frequency in Hz ≈1/2πRC
- $R_2 = R_3 = R$ and $C_2 = C_3 = C$
- A_F = passband gain
- = 1.586 to ensure second order butterworth response

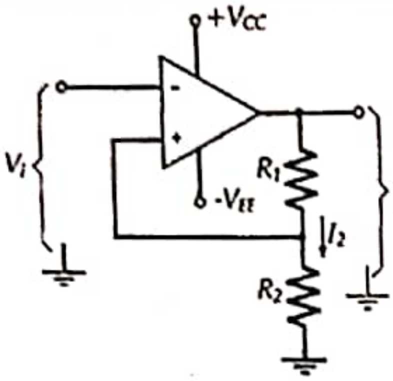
and

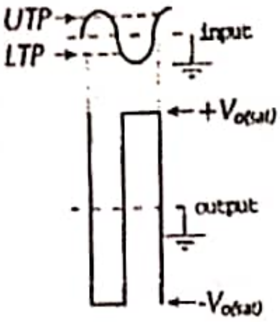
$$R_f = 0.586\ R_1$$

The frequency response of this filter is shown in the Fig. 2.82.

PART-B

3(a)	$V_o = -\frac{1\,(10^3)}{3\,(10^3)}\,(1 + 2 + 3) = -\,2\ \text{V}$	5
(b)	**Inverting Schmitt Trigger** – A Schmitt Trigger Circuit Diagram is a fast-operating voltage level detector. When the input voltage arrives at a level determined by the circuit components, the output voltage switches rapidly between its maximum positive level and its maximum negative level.	5





An op-amp inverting Schmitt Trigger Circuit Diagram is shown in Fig. together with input and output waveforms. At first glance the circuit looks like a noninverting amplifier. But note that (unlike a noninverting amplifier) the input voltage (V_i) is applied to the inverting input terminal, and the feedback voltage goes to the noninverting input. The waveforms show that the output switches rapidly from the positive saturation ($+V_{o(sat)}$) voltage to the negative saturation level ($-V_{o(sat)}$) when the input exceeds a certain positive level; the **upper trigger point** (UTP). Similarly, the output voltage switches from low to high when the input goes below a negative triggering point; the **lower trigger point** (LTP).

Note that after V_i has increased to the UTP and V_o has switched to $-V_{o(sat)}$, the output remains at $-V_{o(sat)}$ even when V_i falls below the UTP. Switch over from $-V_{o(sat)}$ to $+V_{o(sat)}$ does not occur until V_i = LTP. Similarly, after V_i has been reduced to the LTP and V_o has switched to $+V_{o(sat)}$, the output remains at $+V_{o(sat)}$ when V_i is increased above the LTP. Switch-over from $+V_{o(sat)}$ to $-V_{o(sat)}$ does not occur again until V_i = UTP.

Triggering Points:

If the output voltage to the circuit in Fig. 14-33 Is high, the voltage at the noninverting terminal is,

$$V_{R2} = \frac{+V_o \times R_2}{R_1 + R_2}$$

If the input voltage (at the inverting input terminal) is below V_{R2} (at the noninverting input), the output voltage is kept at its high positive level. For the output to switch to its low level, the input voltage must exceed V_{R2} by a very small amount (approximately 70 µV for a 741 op-amp). So, the UTP essentially equals V_{R2}.

$$UTP = \frac{+V_o \times R_2}{R_1 + R_2} \qquad (14\text{-}23)$$

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When the output is negative, the LTP can be calculated as,

$$LTP = \frac{-V_o \times R_2}{R_1 + R_2} \qquad (14\text{-}24)$$

Generally a schematic diagram of the IC 555 circuits is shown which does not include comparators, flip-flop etc. It only shows the external components to be connected to the 8 pins of IC 555. Thus, the schematic diagram of Monostable Multivibrator Using IC 555 is shown in the Fig. 2.104.

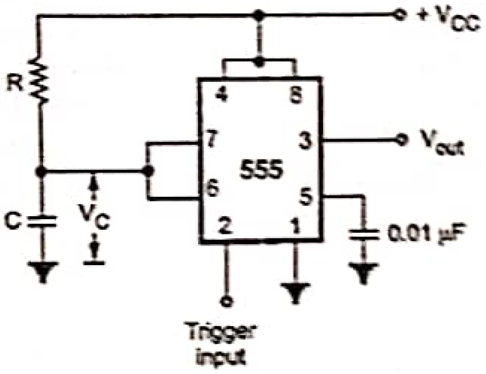


Fig. 2.104 555 timer as monostable multivibrator

The external components R and C are shown. To avoid accidental reset, pin 4 is connected to pin 8 which is supply $+V_{CC}$. To have the noise filtering of control voltage, the pin 5 is grounded through a small capacitor of 0.01 µF.

(c) The flip-flop is initially set i.e. Q is high. This drives the transistor Q_d in saturation. The capacitor discharges completely and voltage across it is nearly zero. The output at pin 3 is low. 5

When a trigger input, a low going pulse is applied, then circuit state remains unchanged till trigger voltage is greater than 1/3 V_{CC}. When it becomes less than 1/3 V_{CC}, then comparator 2 output goes high. This resets the flip-flop so Q goes low and $\bar{Q}$ goes high. Low Q makes the transistor Q_d off. Hence capacitor starts charging through resistance R, as shown by dark arrows in the Fig. 2.102.

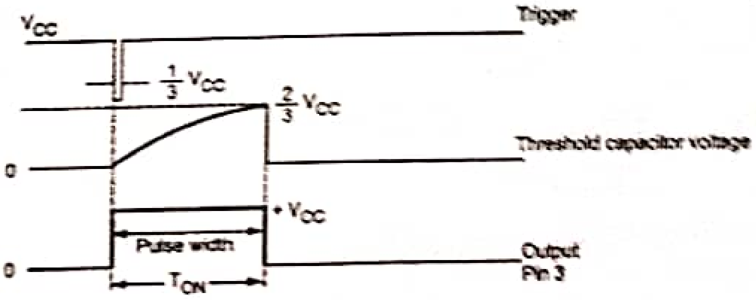


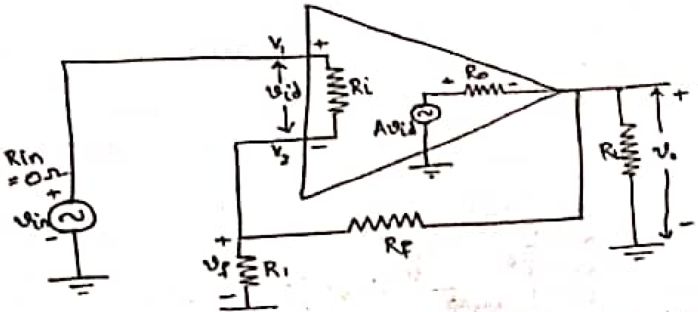
Fig. 2.103 Waveforms of monostable operation

The voltage across capacitor increases exponentially. This voltage is nothing but the threshold voltage at pin 6. When this voltage becomes more than 2/3 V_{CC}, then comparator 1 output goes high. This sets the flip-flop i.e. Q becomes high and $\bar{Q}$ low. This high Q drives the transistor Q_d in saturation. Thus capacitor C quickly discharges through Q_d as shown by dotted arrows in the Fig. 2.103.

So it can be noted that V_{out} at pin 3 is low at start. when trigger is less than 1/3 V_{CC} it becomes high and when threshold is greater than 2/3 V_{CC} again becomes low, till next trigger pulse occurs. So a rectangular wave is produced at the output. The pulse width of this rectangular pulse is controlled by the charging time of capacitor. This depends on the time constant RC. Thus RC controls the pulse width. The waveforms are shown in the Fig. 2.103.

OR

4(a)



Fig(b): Input Resistance with feedback calculations.

If R_i is the input resistance without feedback of the opamp.

Let R_{iF} be the input resistance with feedback of the opamp.

$$\therefore R_{iF} = \frac{v_{in}}{i_{in}} = \frac{v_{in}}{v_{id}/R_i}$$

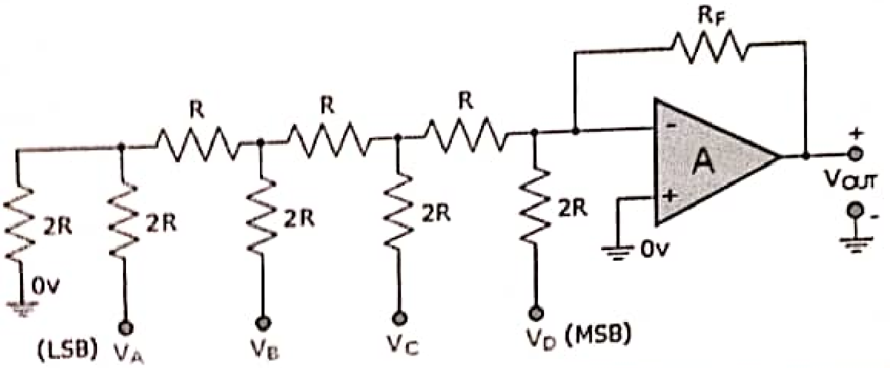
$$\text{But, } v_{id} = \frac{v_o}{A} \quad ; \quad v_o = A_F v_{in} = \frac{A}{1+AB} v_{in}$$

$$\therefore R_{iF} = \frac{A R_i v_{in}}{v_o} = \frac{A R_i}{\frac{v_o}{v_{in}}} = \frac{\cancel{A} R_i (1+AB)}{\cancel{A}}$$

$$\therefore \boxed{R_{iF} = R_i(1+AB)} \quad — (1)$$

eq^n(1) shows that the ~~f.~~ input resistance with feedback increases and is (1+AB) times of input resistance without feedback.

5

(b)	$$V_o = \left(1 + \frac{R_F}{R_1}\right) V_1 = \left(1 + \frac{R_F}{R_1}\right) \frac{V_a + V_b + V_c}{3}$$ Rf=2.4K	5
(c)	R-2R Digital-to-Analogue Converter: The digital logic circuit used to drive the D/A converter can be generated by combinational or sequential logic circuits, data registers, counters or simply switches. The interfacing of a R-2R D/A converter of "n"-bits will depend upon its application. All-in-one boards such as the Arduino or Raspberry Pi have *digital-to-analogue converters* built-in so make interfacing and programming much easier. There are many popular DAC's available such as the 8-bit DAC0808. 	5

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