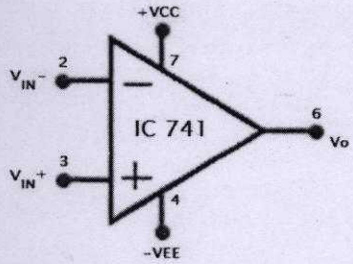
EXPERIMENT #4 SQUARE AND TRIANGULAR WAVEFORM GENERATOR

I OBJECTIVES

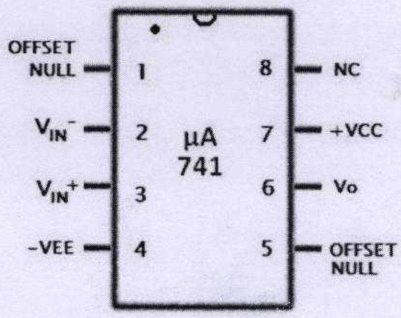
The broad objective of this experiment is to familiarize the student with some general ideas concerning the generation of waveforms which employ op amp.

II COMPONENTS AND INSTRUMENTATION

The general purpose op amp μA 741 will be used. You require two supplies, ±15 V for short. As well, you need a variety of resistors. For measurement, use a bench multimeter, a two channel oscilloscope and a waveform generator.



(a) Symbol



(b) Pin diagram

Fig 4.1. OP-AMP μA 741

III PREPARATION

Formulae used in design calculations

$$R_1 = \frac{R_3}{4 * f * R_2 * C} \qquad R_3 = \frac{2 * R_2 * V_{SAT}}{V_{o(P-P)}}$$

Q1. In the circuit of Fig.4.2., $V_{z1}=V_{z2}=6.3V$, $V_F=0.7V$, $R_1=5k\Omega$ and $R_f=100k\Omega$. Find the expression for output voltage when

i) $V_{in}=0.3\sin t$ ii) $V_{in}=0.6\sin t$ iii) $V_{in}=3\sin t$

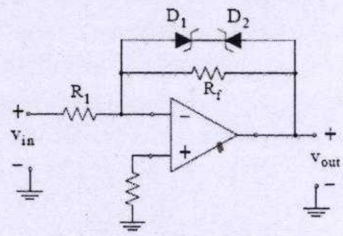


Fig.4.2

Q2. What are the nominal limiting levels at node V_{01} of the circuit of Fig 4.3. What frequency of oscillation do you expect if $R_1=4.7k\Omega$, $R_2=10k\Omega$, $R_3= 30k\Omega$ and $C=0.2\mu F$?

Q3. What simple change would double the frequency while maintaining the amplitude at node V_0?

Q4. What simple change would double the frequency and half the amplitude at node V_0?

IV EXPERIMENTATION

4.1 – Square and Triangular Waveform Generator

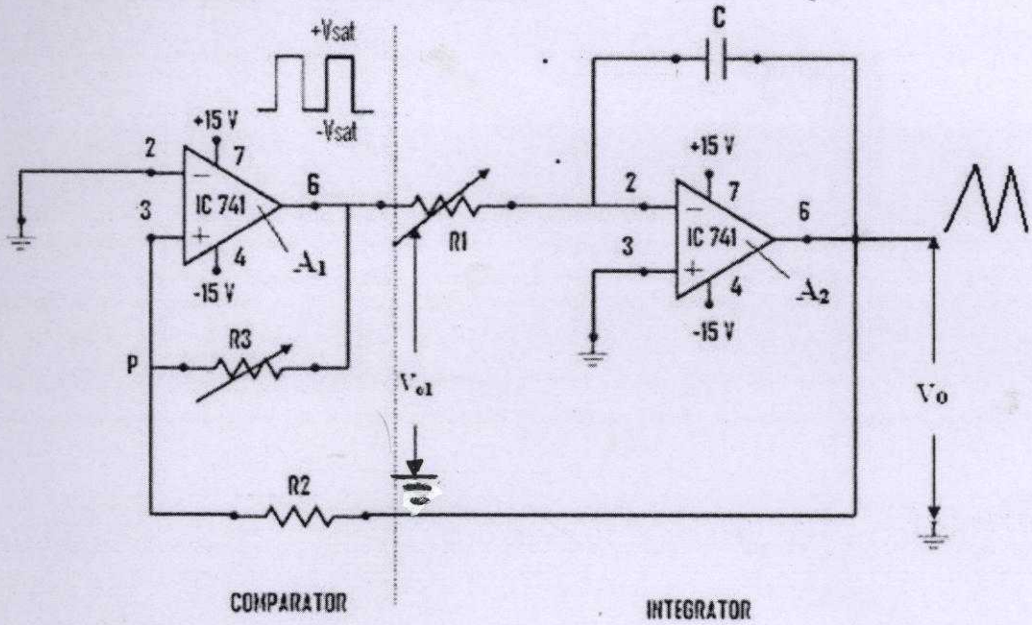


Fig 4.3. Circuit Diagram of Square and Triangular waveform generator

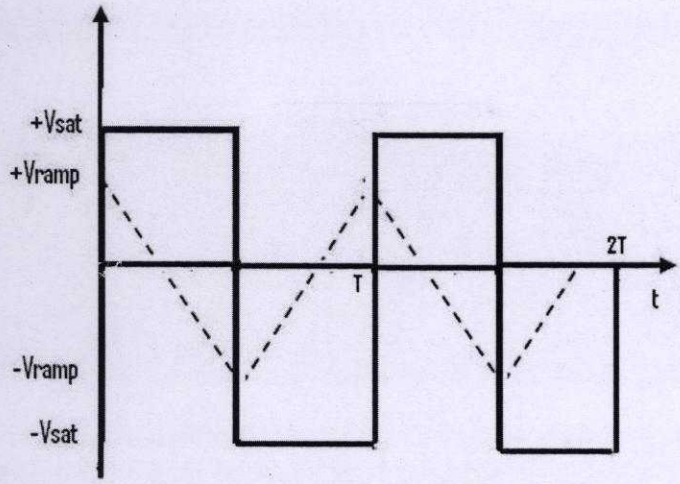


Fig 4.4 Typical waveforms

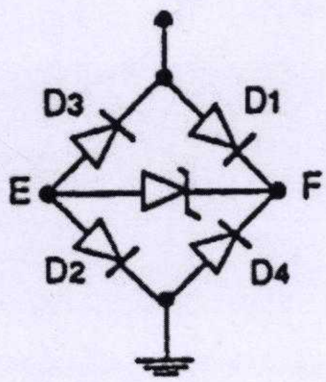


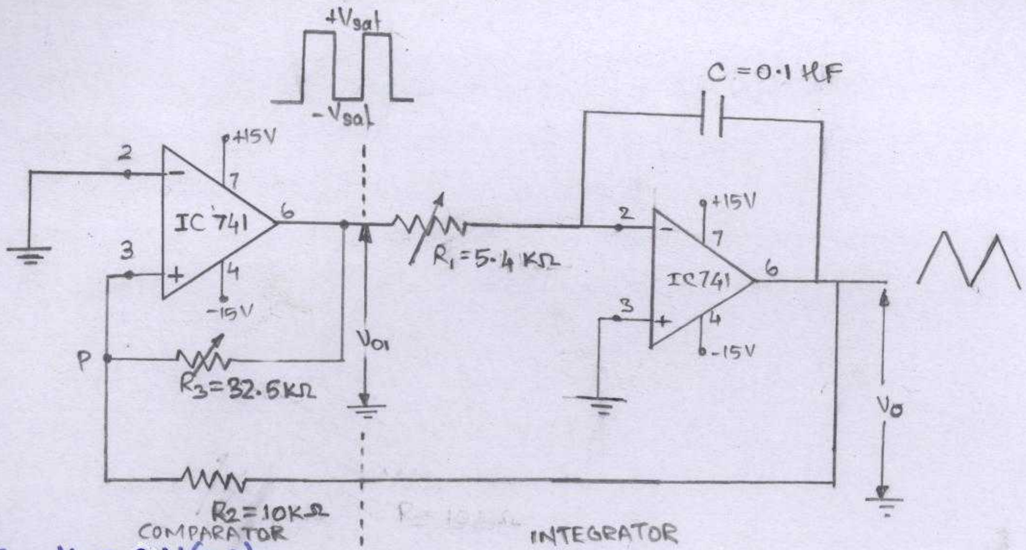
Fig 4.5 Voltage limiting circuit

4.2

Design the circuit of triangular waveform generator for ___8___V (peak to peak of triangle waveform) at _1500__Hz. Draw the circuit diagram in the space provided and indicate the component values.

Use C= 0.1μF , R_2 =10KΩ

Zener voltage = 5V zener



$f = 1500\,Hz$, $V_o = 8\,V(p\text{-}p)$

$C = 0.1\,\mu F$

$R_3 = \frac{2R_2(13)}{8} = \frac{26}{8} R_2$

$R_1 = \frac{32.5\times10^3}{4\times1500\times10\times10^3\times0.1\times10^{-6}} = 5.4\,K\Omega$

if $R_2 = 10K\Omega$,

$R_3 = 32.5\,K\Omega$

1) Build the circuit.

2) Observe the signals at nodes V_{01} and V_0. Note the two waveforms, their peak to peak values and the frequency.

Signal	Measured		Calculated	
	Peak to peak (V)	Frequency (Hz)	Peak to peak (V)	Frequency (Hz)
V_{01}	22	1562	26	1500
V_0	7.6	1562	8	1500

3) In turn, shunt R_1, R_2, C by components of equal value, and note the effects on signal amplitudes and frequencies.

R_1 Shunted by equal value ($R_{1effective}$= 2.7KΩ)

Signal	Measured		Calculated	
	Peak to peak (V)	Frequency (Hz)	Peak to peak (V)	Frequency (Hz)
V_{01}	22	2941	26	3000
V_0	7.6	2941	8	3000

R_2 Shunted by equal value ($R_{2effective}$= 5KΩ)

Signal	Measured		Calculated	
	Peak to peak (V)	Frequency (Hz)	Peak to peak (V)	Frequency (Hz)
V_{01}	22	2777.7	26	3000
V_0	4	2777.7	4	3000

C_1 Shunted by equal value ($C_{effective}$= 0.2μF)

Signal	Measured		Calculated	
	Peak to peak (V)	Frequency (Hz)	Peak to peak (V)	Frequency (Hz)
V_{01}	22	769.2	26	750
V_0	7.8	769.2	8	750

Comment on your observations:

From the empirical relation : $f = \frac{R_3}{4R_1R_2C_1}$ and $V_{o(p-p)} = \frac{2R_2V_{sat}}{R_3}$

- If R_1 is reduced to half, frequency would double, $V_{o(p-p)}$ remains same.
- If R_2 is reduced to half, frequency would double, $V_{o(p-p)}$ reduces by half.
- If C_1 is doubled, frequency reduces to half, $V_{o(p-p)}$ remains same.

This is because if a resistor is shunted, net resistance reduces.
If capacitor is shunted, net capacitance increases.

4) Connect the sub circuit shown in the Fig. 4.5 at the output of the comparator and note the amplitude and frequency.

Signal	Peak to peak (V)	Frequency (Hz)
V_{01}	11	1562.5
V_0	4.2	1562.5

5) While displaying the waveforms at nodes V_0 and V_{01}, short-out the zener Z intermittently, noting the changes in amplitude and frequency.

Signal	Peak to peak (V)	Frequency (Hz)
V_{01}	2.4	1470.5
V_0	0.96	1470.5

6) While displaying nodes V_0 and V_{01}, open circuit the zener and observe the overall effect. Note that without zener the operation depends on the relative saturation voltages of A_1 and A_2. Comment on **the effect of zener.**

Signal	Peak to peak (V)	Frequency (Hz)
V_{01}	22	1538.4
V_0	7.6	1538.4

- When V_{01} has a positive peak, diodes D_1 and D_2 are turned on, thus due to zener action, V_{01} is not allowed to rise above 5V (peak). When V_{01} has a negative peak, diodes D_3 and D_4 are turned on, thus V_{01} is not allowed to fall below −5 V (peak). However, V_0 also reduces proportionately.
- When Z is shorted, V_{01} would carry two diode drops → (0.6V + 0.6V) = 1.2V (peak)
- When Z is removed, V_{01} falls back to ±13V (peak) → saturation levels.

Consider the variety of waveforms available and the means for control. Prepare an organized and well-labeled timing sketch, including at least the three node voltages P, V_0, V_{01}. (Use the ordinary graph sheet provided).

V INFERENCE \ CONCLUSIONS

- The circuit of a square / triangular wave has been designed and constructed.
- The empirical relations are verified:

$$\left[f \propto \frac{1}{R_1 R_2 C_1}\right] \quad \text{and} \quad \left[V_{0(p-p)} \propto R_2\right]$$

- To limit the voltage after 1st stage (V_{01}), zener is used as shown in the voltage limiting circuit.
- When shorted, it leads to a drastic fall in both V_{01} and V_0.

Integrated Circuits Lab	Credit	Maximum Marks
Preparation	5	5
Experimentation	9½	10
Reporting	5	5
Total Marks	19.5	20

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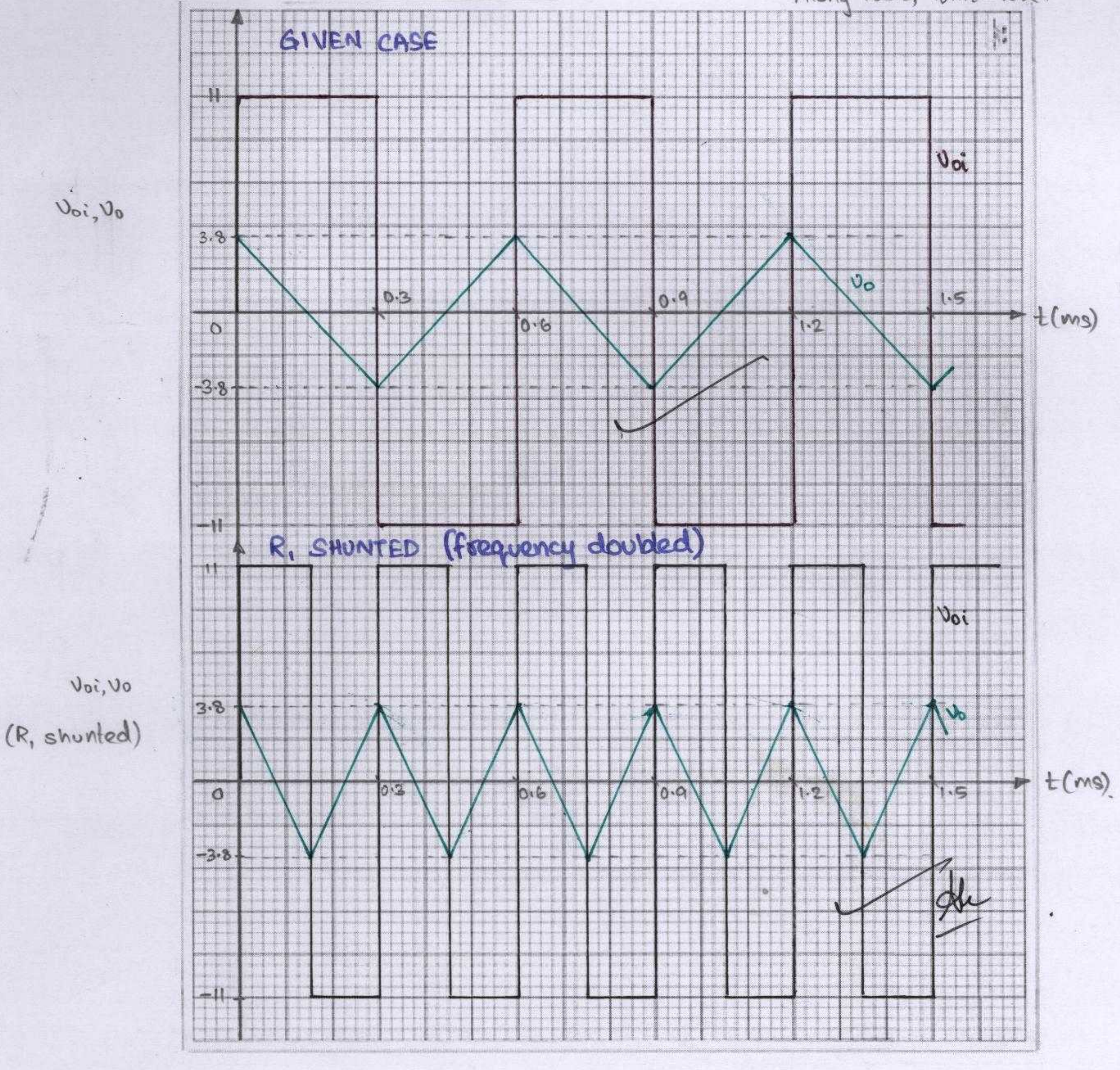
OUTPUT OF SQUARE AND TRIANGULAR WAVE GENERATOR

SCALE
Along X axis, 1unit = 0.1 ms
Along Y axis, 1unit = 2.2V



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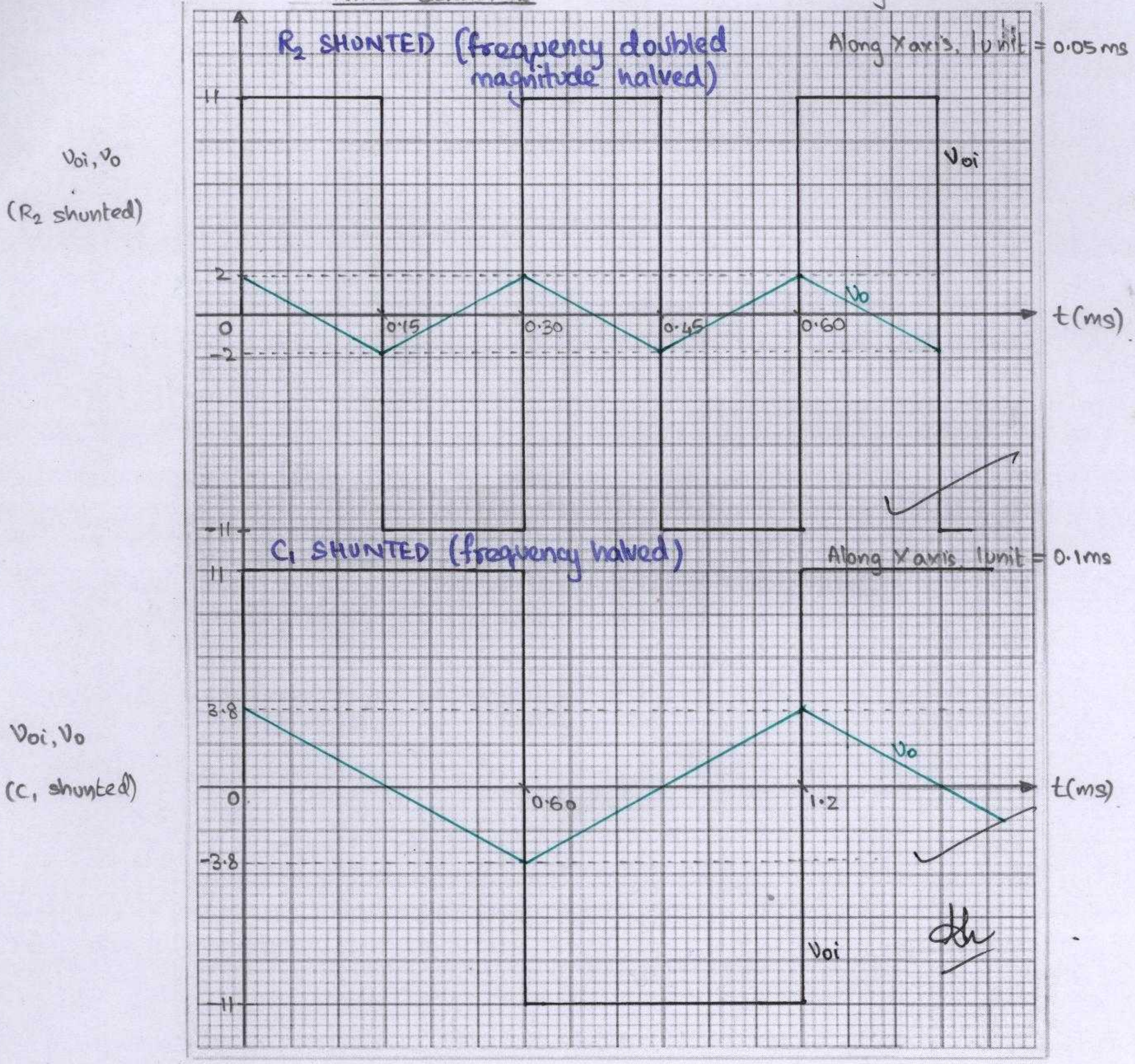
OUTPUT OF SQUARE AND TRIANGULAR WAVE GENERATOR

SCALE
Along Y axis, 1unit = 2.2 V



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WITH VOLTAGE LIMITING CIRCUIT

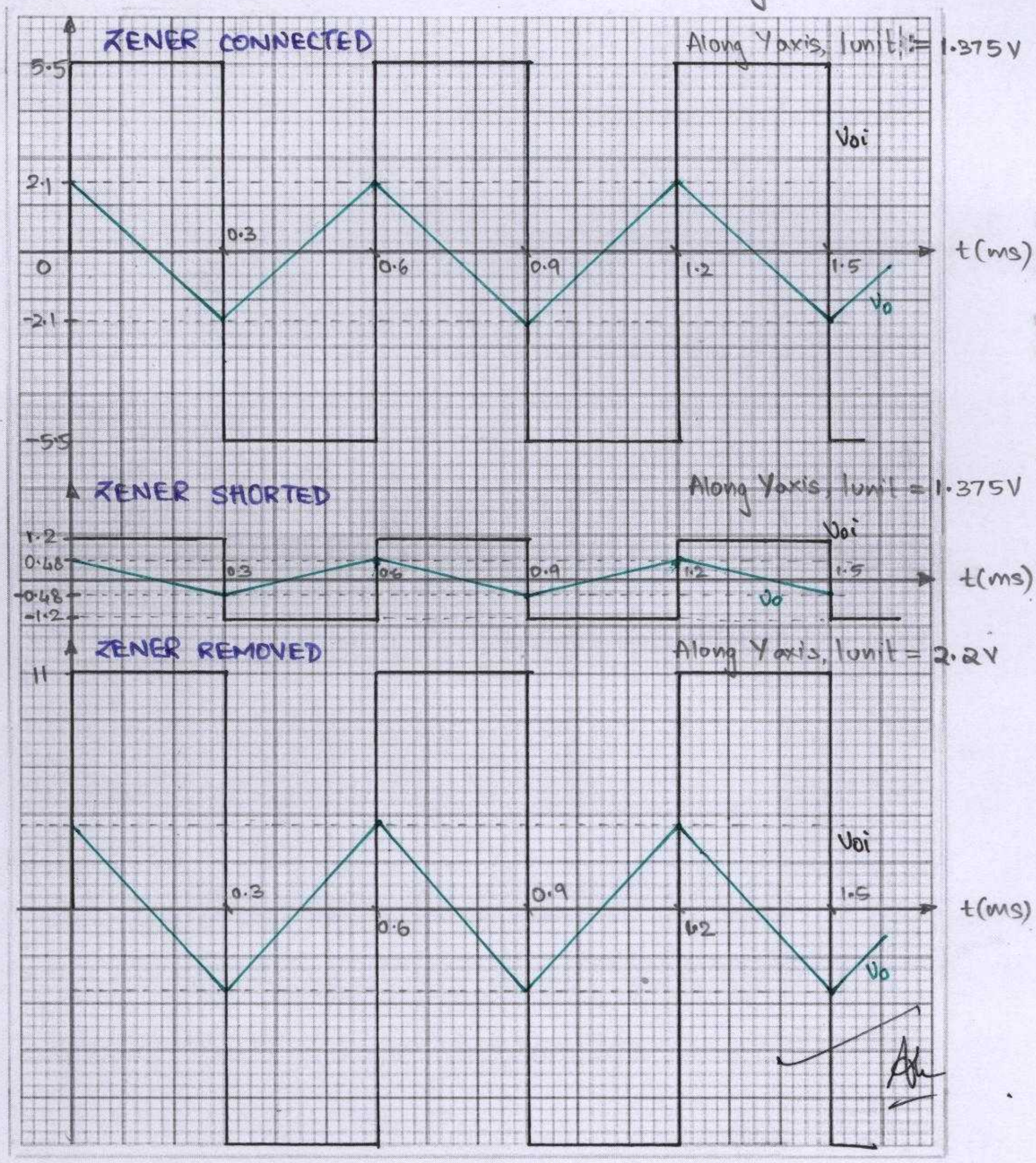
SCALE

Along X axis, 1unit = 0.1ms

Voi, Vo (Zener connected)

Voi, Vo (Zener shorted)

Voi, Vo (Zener removed)



Formolae :

$$R_1 = \frac{R_3}{(4 f R_2 C)} \quad \text{and} \quad R_3 = \frac{2 R_2 V_{SAT}}{V_0 (p-p)}$$

Question 1:

In the given circuit, $V_{Z1} = V_{Z2} = 6.3V$, $V_F = 0.7V$, $R_1 = 5k\Omega$, $R_f = 100k\Omega$.
Find the expression for output voltage when

i) $V_{in} = 0.3 \sin t$

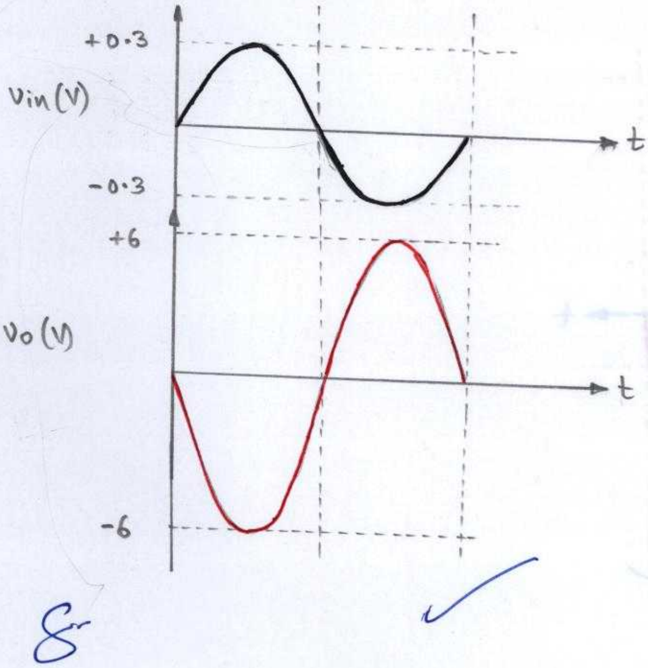
(ie) $V_{in} = 0.6V (p-p)$

$$V_{out} = \left(-\frac{R_f}{R_1}\right) V_{in}$$

$$= -20 \times 0.6$$

$$= -12V (p-p)$$

However, the zeners dont have sufficient reverse bias (6.3V or above) to maintain constant voltage. thus

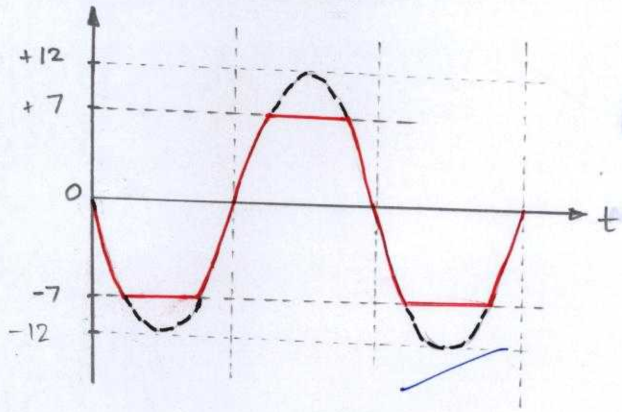


ii) $V_{in} = 0.6 \sin t$.

$V_{out} = \pm 12V$ (peak)

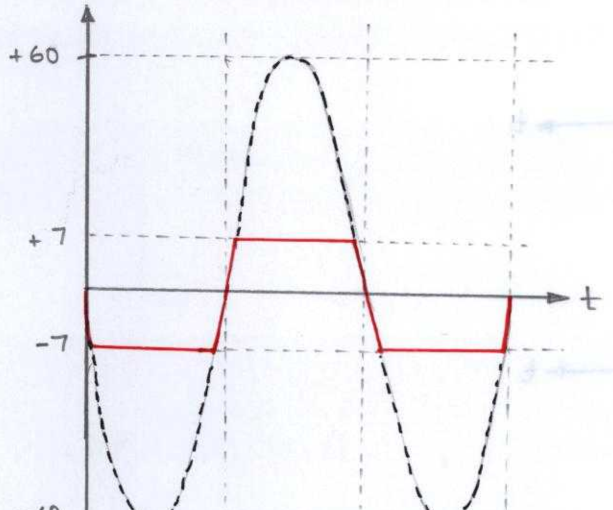
During +ve half, D_2 maintains 6.3V, during -ve half D_1 maintains 6.3V, only if i/p magnitude is higher than minimum voltage required for zener operation

∴ Total voltage $= (6.3+0.7)$
$= 7V$.



iii) $V_{in} = 3 \sin t$

$V_{out} = \pm 60V$ (peak).



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Question 2:

What are the nominal limiting levels at node V_{01}. What frequency of oscillation do you expect if $R_1 = 4.7\,K\Omega$, $R_2 = 10\,K\Omega$, $R_3 = 30\,K\Omega$, $C = 0.2\,\mu F$?

$$f = \frac{R_3}{4R_1R_2C}$$

$$= \frac{30\times10^3}{4(4.7\times10^3)(10\times10^3)(0.2\times10^{-6})}$$

$$f = 797.87\ Hz$$

Upper limiting level $= +V_{sat} = +13V$

Lower limiting level $= -V_{sat} = -13V$

Question 3:

What simple change would double the frequency while maintaining the amplitude at node V_0.

We know, $f = \dfrac{R_3}{4R_1R_2C}$ & $V_0(p\text{-}p) = \dfrac{2R_2V_{sat}}{R_3}$

$R_1' = R_1/2$, $\therefore f' = 2f$.

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Question 4:

What simple change would double the frequency and half the amplitude at node v_o?

Replace R_3 by $2R_3$.

(ie) $R_3' = 2R_3$, thus $f' = 2f$ and $v_o'(p\text{-}p) = \frac{v_o(p\text{-}p)}{2}$

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