Experiment No. 12

RC PHASE SHIFT OSCILLATOR USING BJT

AIM

To design RC phase shift oscillator.

THEORY

An oscillator is essentially a source of emf. Its output may be a sine wave, a square wave, a triangular wave or a ramp. It is possible to vary the frequency and amplitude of the output. In this experiment we will be concerned only with sine wave oscillators.

Feedback is said to exist in an amplifier if a part of its output is brought back into the input circuit. Consider the situation in figure 1. A fraction β ($\beta < 1$) of the output V_o is brought back into the input circuit.

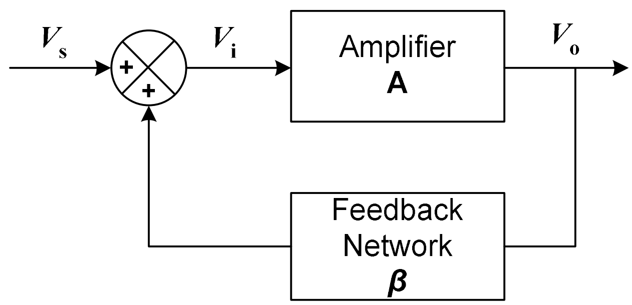

Fig 1. Basic oscillator block diagram

The net input V_i to the amplifier can then be written in two different ways.

$$V_i = V_s + \beta V_o \qquad (1)$$

where V_s is an external input

In equation (1) the feedback is said to be positive. Both V_s and βV_o drive the input terminal. So, this is positive feedback.

If A is the voltage gain of the amplifier.

$$V_o = AV_i \qquad (2)$$

From equation (1) and (2)

$$\frac{V_o}{A} = V_s + \beta V_o$$

Hence gain Ar of the whole circuit including the feedback network is given by

$$Ar = \frac{V_o}{V_s} = \frac{A}{(1 - A\beta)}$$

Thus, positive feedback increases the gain from A to Ar. If Vs is reduced to 0 and Vo made equal to V_i, we get an amplifier that supplies its own input. An output voltage is obtained even in the absence of an external input. This happens when $A\beta = 1$.

An amplifier that supplies its own input is an oscillator. Then relation $A\beta = 1$ is called Barkhausen criterion for oscillators. It implies that βV_o must have the same magnitude and the same phase as the input. In general, A is complex. This means that the output of an amplifier is different from the input not only in magnitude but also the phase of the output. In the CE amplifier with a resistive load, the output and input have opposite phases. The feedback network must reduce the output to V_o/A and introduces a further change of 180^0 in phase.

In a CE amplifier with a resistive load, the output and input have opposite phases. The feedback network must reduce the output to V_o/A and introduces a further change of 180^0 in phase. An initial external input is required by an oscillator to start functioning. Noise signal present in the circuit may start the initial oscillation.

The amplifier part is a CE amplifier using voltage divider bias. The output is 180^0 out of phase with the input. The input network has three identical sections. Each section consist of a capacitor C and resistor R. The feedback network must produce a phase shift of 180^0. Each section must therefore, produce a phase shift of 60^0.

DESIGN

From the transistor data sheet, for BC107,

$h_{fe} = \beta = 110$, $I_{c\,\mathrm{max}} = 100$ mA, $V_{\mathrm{CE\,max}} = 45$V

Let $V_{CC} = 12$V, $I_c = 2$mA. Since the quiescent point is in the middle of the load line for the amplifier, $V_{CE} = 50\%$ of $V_{CC} = 6$V.

$V_{RE} = 10\%$ of $V_{CC} = 1.2$ V

Assuming $I_C = I_E$, $\qquad V_{RE} = I_C R_E = I_E R_E$

$$1.2 = 2\times10^{-3}\times R_E$$

$$R_E = \frac{1.2}{2\times10^{-3}} = 600\ \Omega$$ Select standard value of resistance 560 Ω.

Voltage across collector resistance, $V_{RC} = V_{CC} - V_{CE} - V_{RE}$

$$= 12 - 6 - 1.2 = 4.8\ \text{V}$$

$$R_C = \frac{V_{RC}}{I_C} = \frac{4.8}{2\times10^{-3}} = 2.4\ \text{k}\Omega$$ Select standard value of 2.2 kΩ

Base current, $I_B = \dfrac{I_C}{\beta} = \dfrac{2\times10^{-3}}{110} = 18.2\ \mu\text{A}$

Take $I_2 = I_B$ then $I_1 = 10I_B + I_B = 11I_B$

Base voltage, $V_B = V_{RE} + V_{BE} = 1.2 + 0.6 = 1.8$ V

$$R_2 = \frac{V_B}{I_2} = \frac{1.8}{10\times18.2\times10^{-6}} = 9.9\ \text{k}\Omega$$ Select standard value of 10 kΩ

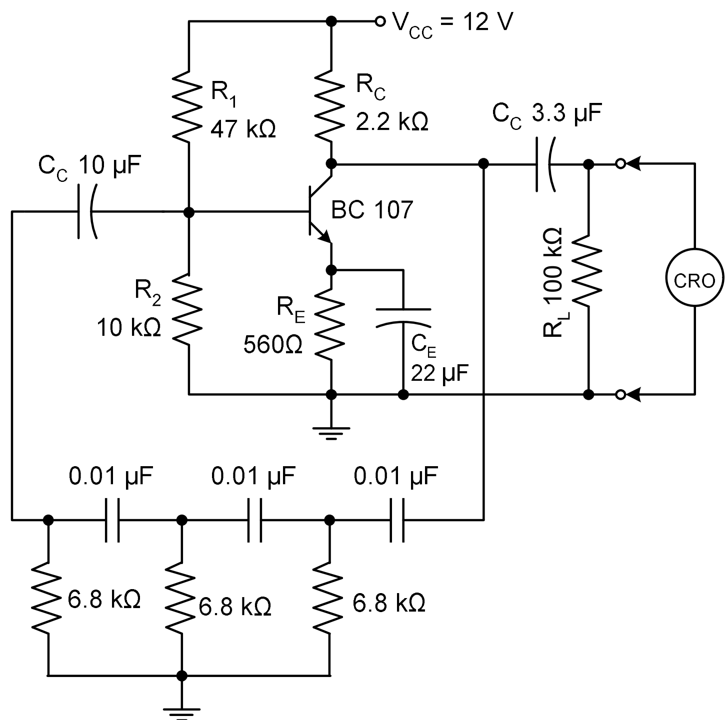

Fig1 g. Circuit Diagram of RC Phase shift Oscillator

$$R_1 = \frac{V_{CC} - V_B}{I_1} = \frac{12 - 1.8}{11 \times 18.2 \times 10^{-6}} = 51\,\text{k}\Omega \qquad \text{Select standard value of } 47\,\text{k}\Omega$$

Design of coupling capacitors C_{C1} and C_{C2}

X_{C1} should be less than the input impedance of the transistor. Here, R_{in} is the series impedance.

Then $X_{C1} \leq \frac{R_{in}}{10}$

Here $R_{in} = R_1 \,||\, R_2 \,||\, h_{FE}\, r_E = 47\text{k}\Omega \,||\, 10\,\text{k}\Omega \,||\, 110 \times 12.5\,\Omega = 1.17\,\text{k}\Omega$

We get R_{in}=1.17 kΩ. Then $X_{C1} \leq 117\ \Omega$.

For a lower cut off frequency of 200 Hz, $C_{C1} = \frac{1}{2\pi f X_{C1}} = \frac{1}{2\pi \times 200 \times 117} = 6.8\,\mu\text{F}$

Select standard value of 10 µF for C_{C1}

Similarly, $X_{C2} \leq \frac{R_{out}}{10}$ where $R_{out}=R_C$. Then $X_{CE} \leq 220\Omega$.

So, $C_{C2} = \frac{1}{2\pi f X_{C2}} = \frac{1}{2\pi \times 200 \times 220} = 3.6\,\mu\text{F}$

Select standard value of 3.3 µF for C_{C2}

Design of bypass capacitors C_E

To bypass the lowest frequency (say 200 Hz), X_{CE} should be much less than or equal to the resistance R_E.

$$X_{CE} \le \frac{R_E}{10}$$

$$X_{CE} \le \frac{560}{10} \qquad \text{ie. } X_{CE} \le 56$$

Apply value of f such that the amplifier has good gain at a lower cutoff frequency of 200 Hz

$$C_E \ge \frac{1}{2\pi f X_{CE}} = \frac{1}{2\pi \times 200 \times 56} = 14.2\ \mu\text{F}$$

Select standard value of 22 μF for C_E

Design of feedback network

The circuit consists of an amplifier stage and a feedback network to provide an additional 180^0 phase shift, approximately depending upon the frequency of operation. The RC phase shift network must provide 180^0 or an average of 60^0 phase shift/lag of RC network

RC phase shift factor, $k = V_S/V_0$.

For one stage of RC network

$$V_o = I\,R \qquad V_C = I\,X_C$$

$$\tan\Phi = \frac{V_C}{V_o} = \frac{I\,X_C}{I\,R} = \frac{1}{(2\pi f\,C)R}$$

$$f = \frac{1}{2\pi RC\,\tan\Phi}$$

If these are three sections, each must give, approximately $\Phi = 60^0$ then $\tan 60 = \sqrt{3}$

$$f = \frac{1}{2\pi RC\,\sqrt{3}}$$

This gives the approximate frequency of oscillation of a phase shift with three RC sections.

In the above phase relationship, between voltage and current in the RC network, the additional current I that flow through C for the other sections so that V_C is larger than the value indicated which means that f is smaller than the value obtained in the above equation. A transfer function analysis of the three-stage network would give a more accurate expression for frequency of oscillation as below.

$$\boxed{f = \frac{1}{2\pi RC\,\sqrt{6}}}$$

Assume f = 1000 Hz and C = 0.01 μF

$$1000 = \frac{1}{2\pi R \times 0.1 \times 10^{-6} \times \sqrt{6}}$$

$$R = \frac{1}{2\pi \times 1000 \times 0.01 \times 10^{-6} \times \sqrt{6}} = 6.5\ \mathrm{k}\Omega$$

Select nearest standard value of 6.8 kΩ for R

The three-stage feedback network would have an attenuation of $\left(\frac{1}{29}\right)$ and to satisfy the Barkhausen criterion for oscillation, the amplifier should have a gain of 29 or more. If the gain is just above 29, a pure sine wave will be generated. If the gain is too high, there may be distortions in the output waveform. The circuit in figure 1 is having gain of more than 29 by default. A quick method to adjust the voltage gain is to adjust the load resistance R_L.

PROCEDURE

Set up the circuit as shown in figure. Display the output signal in a CRO. Measure the frequency and amplitude.

RESULT

Observed the waveform and measured the frequency of oscillations.

Frequency of output waveform = ……… kHz

QUESTIONS

1. What are the requirements for oscillations?
2. How is feedback accomplished in the RC oscillator?
3. Explain in detail a method for making frequency measurements.
4. Wien Bridge oscillator is more stable than RC oscillator. Why?