NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA

ANALOG INTEGRATED CIRCUITS (EC321)

Lab Report

OSCILLATORS

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INTRODUCTION

Oscillators are electronic circuits that generate oscillating electronic signals generally the sine wave and the square wave. They are very important in other types of the electronic equipment which require precise, stable oscillations. Amplitude modulation radio transmitters use the oscillation to generate the carrier waveform. The AM radio receiver uses the special oscillator known as a resonator to tune a station. The oscillators are also present in computers, metal detectors and also in the guns.

1.1 Principle of Oscillators

The oscillator converts the direct current from the power supply to an alternating current and they are used in many of the electronic devices. The signals obtained from oscillators are either sine waves or square waves.

1.2 Types of Oscillators

There are two types of electronic oscillator's; linear and nonlinear. The oscillators discussed in the report are strictly linear, electronic op-amp based oscillators.

The different types of electronic oscillators are:

- Crystal Oscillator
- Hartley Oscillator
- RC Phase Shift Oscillator
- Colpitts Oscillators
- Wein Bridge Oscillator

THEORY

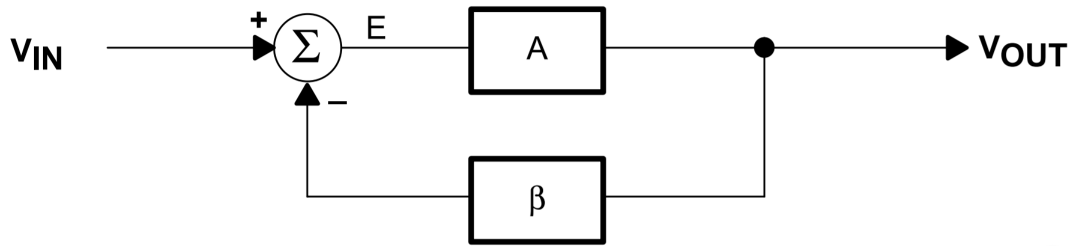


Figure 2.1: Negative Feedback Network [5]

The Transfer function of the above system can be written as

$$H(s) = \frac{A}{1 + A\beta}$$

Oscillation results when the feedback system is not able to find a stable steady-state because its transfer function cannot be satisfied. This will occur when the roots of the transfer function when plotted on the s-plane (obtained after transforming the time varying transfer function using Laplace transform) lie precisely on the Imaginary axis.

Hence the denominator of $H(s)$ must be equal to zero, or, $A\beta = -1$

This is called the *Barkhausen* criterion which states that for a system to exhibit oscillations:

1. The magnitude of the open loop gain must be equal to 1, i.e., $|A\beta| = 1$
2. The open loop gain must result in a total phase shift of 0°or 360°, i.e., $\angle\beta(j\omega) = 0$ or 360

The phase shift is introduced by passive components which exclusively constitute the β network. This is because passive components are accurate and almost drift-free and experience very limited deterioration in performance due to aging.

A single-pole RL or RC circuit contributes up to 90°phase shift per pole, and because 360°of phase shift is required for oscillation, at least two poles must be used in the oscillator design. An LC circuit has two poles, thus it contributes up to 180°phase shift per pole pair. LC and LR oscillators are not considered here because low frequency inductors are expensive, heavy, bulky, and highly non-ideal. LC oscillators are designed in high frequency applications, beyond the frequency range of voltage feedback op amps, where the inductor size, weight, and cost are less significant. [5]

So we stick to RC circuits which have more than 2 poles in order to assure a phase shift of 180°-360°.

The gain A is decided based on the β network used such that the *Barkhausen* conditions are satisfied. Active elements like opamps are used for this purpose as they provide great flexibility on deciding the gain values. For the analysis of the following circuit, it is assumed that the opamps are ideal to the effect that they provide a steady gain across the entire frequency spectrum. We thus ignore the contribution of the opamp itself to the overall phase shift.

Pursuant to the above specifications, we examine 2 circuits.

1. RC phase shift Oscillator
2. Wien Bridge Oscillator

2.1 RC Phase Shift Oscillator

The circuit shown in figure 2.2 will oscillate at the frequency for which the phase shift of the RC network is 180°. Only at this frequency will the total phase shift around the loop be 0°or 360°. The reason for using a three-section RC network is that three is the minimum number of sections (i.e., lowest order) that is capable of producing a 180°phase

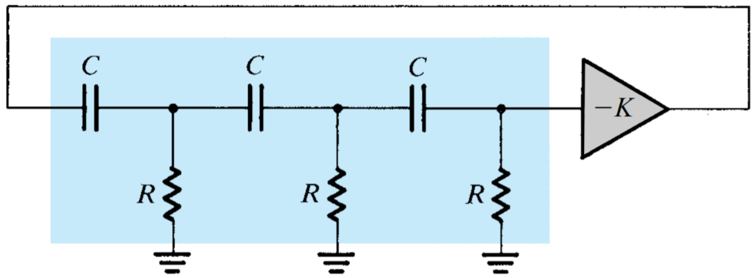


Figure 2.2: Functional Representation of an RC phase shift circuit [1]

shift at a finite frequency. For oscillations to be sustained, the value of K should be equal to the inverse of the magnitude of the RC network transfer function at the frequency of oscillation. However, to ensure that oscillations start, the value of K has to be chosen slightly higher than the value that satisfies the unity-loop-gain condition.

The contribution of each RC stage to the overall phase shift is hence equal to 60°.

Transfer function of the RC ladder

$$\angle\beta(j\omega) = \frac{-j(\omega RC)^3}{-j(\omega RC)^3 - 6(\omega RC)^2 + 5j(\omega RC) + 1}$$

Therefore,

$$\omega \text{ for which } \angle\beta(j\omega) = 180°, \Rightarrow \omega = \frac{1}{\sqrt{6}RC}$$

$$\text{Also, at } \omega = \frac{1}{\sqrt{6}RC},\ K = 29 \text{ so that } |A\beta| = -1$$

This is easy enough to build with the addition of an inverting amplifier as in Figure 2.3.

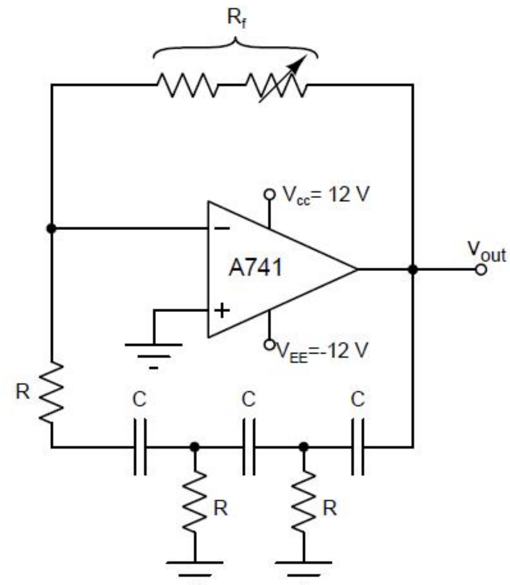
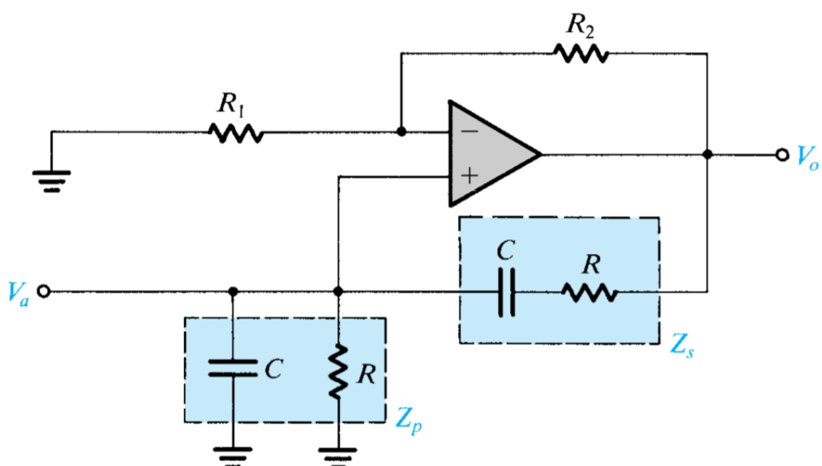


Figure 2.3: RC Phase Shift Oscillator

2.2 Wien Bridge Oscillator



Wien Bridge Oscillator [1]

The working of the Wien Bridge Oscillator as shown in the above figure can be understood from its β network which clearly operates like a voltage divider.

$$\frac{V_a}{V_o} = \beta(j\omega) = \frac{z_p}{z_p \parallel z_s}$$

$$\Rightarrow \beta(j\omega) = \frac{j\omega RC}{-(\omega RC)^2 + j3\omega RC + 1}$$

For oscillations, $|k\beta(j\omega)| = 1$

Therefore, for $\angle\beta(j\omega) = 0 \Rightarrow \omega = \dfrac{1}{RC}$

Also, since at $\omega = \dfrac{1}{RC}$, $|\beta(j\omega)| = \dfrac{1}{3} \Rightarrow k = 3$

DESIGN

3.1 RC Phase Shift Oscillator

Desired frequency of oscillation (f_c) = 2kHz
For a 3 - stage phase shift oscillator, desired frequency of oscillation is given by following equation

$$f_c = \frac{1}{2\pi RC\sqrt{2N}} \text{ where } N = 3$$

Therefore,

$$f_c = \frac{1}{2\pi RC\sqrt{6}}$$

Let C = 0.01 uF Hence, $R = 3250\Omega \cong 3.3k\Omega$

Attenuation in RC feedback circuit = $\frac{1}{29}$

Therefore, amplification factor = 29 $\Rightarrow \frac{R_f}{R} = 29$
Let R = $3250\Omega \cong 3.3k\Omega$
$R_f = 29 \times 3250 = 94250\Omega = 94.25k\Omega$

3.2 Wien Bridge Oscillator

Desired frequency (f_c) = 2 kHz
For a Wein bridge oscillator, desired frequency of oscillation is given by following equation

$$f_c = \frac{1}{2\pi RC} 2 \times 10^3 = \frac{1}{2\pi RC}$$

Let C = $0.01\mu F \Rightarrow R = 8k\Omega$

Since, attenuation due to the RC feedback circuit = $\frac{1}{3}$

$\Rightarrow$ Amplification due to the operational amplifier = 3

$$1 + \frac{R_f}{R_1} = 3 \Rightarrow R_f = 2 \times R_1$$

Let $R_1 = 1k\Omega \Rightarrow R_f = 2k\Omega$

COMPONENTS REQUIRED

Components	Quantity
uA741	2
1kΩ	2
8.2kΩ	1
3.3kΩ	3
0.01uF	3
4.7kΩ POT	1
100kΩ POT	1
Breadboard	1
Multimeter	1
Probes	2

PIN DIAGRAM of IC

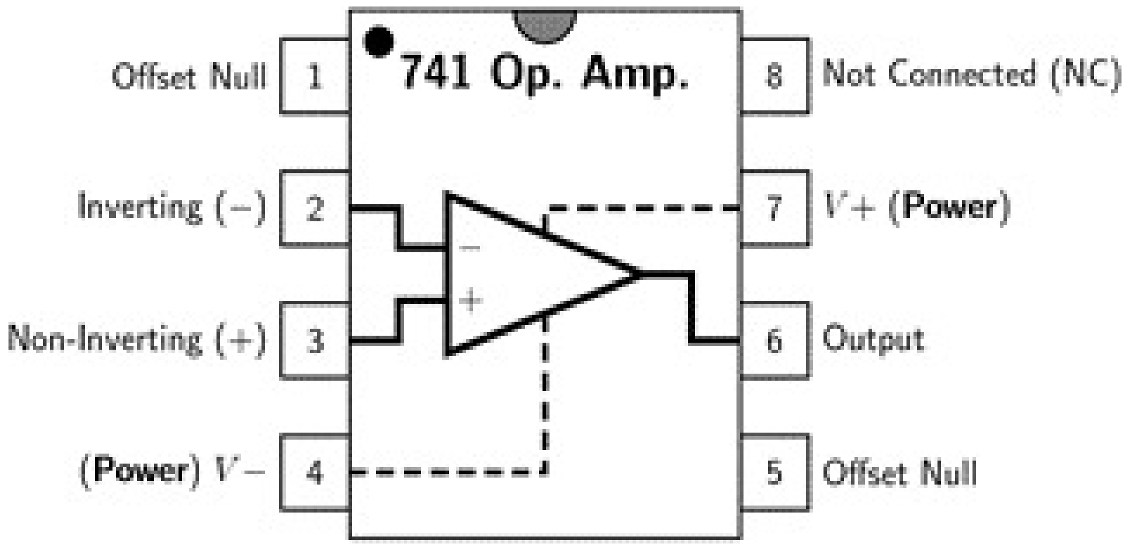
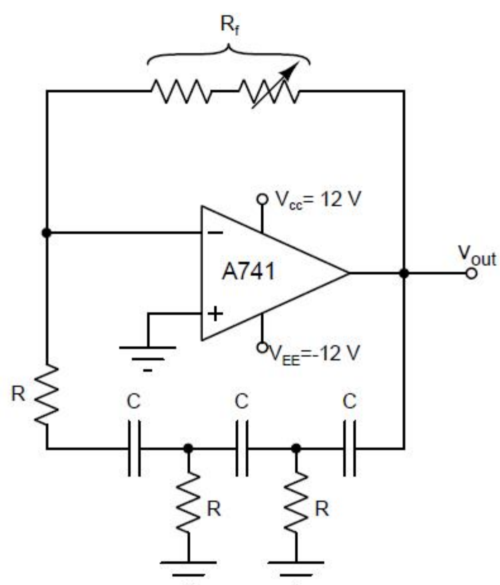
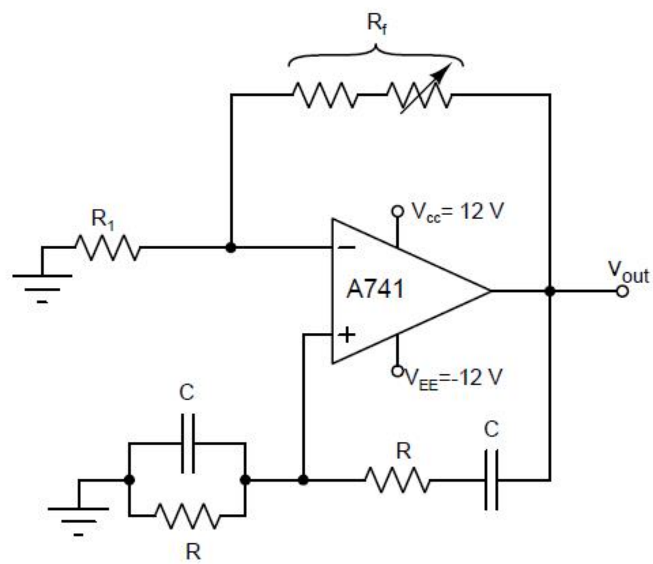


Figure 5.1: uA741 Op-Amp IC [2]

CIRCUIT DIAGRAM



(a) RC Phase Shift Oscillator



(b) Wein Bridge Oscillator

OBSERVATIONS

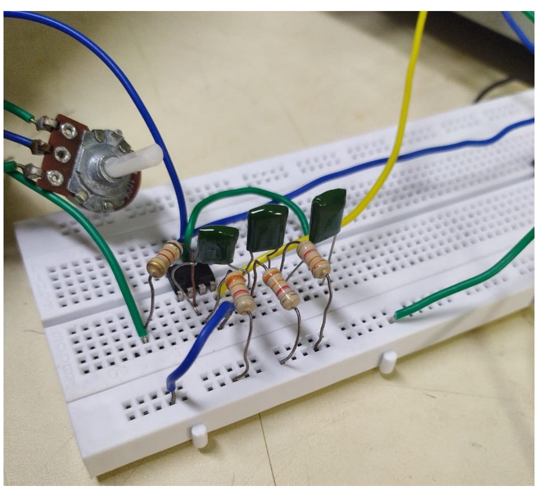
7.1 RC Phase Shift Oscillator

$V_{min} = -9.8V$
$V_{max} = 11.2V$

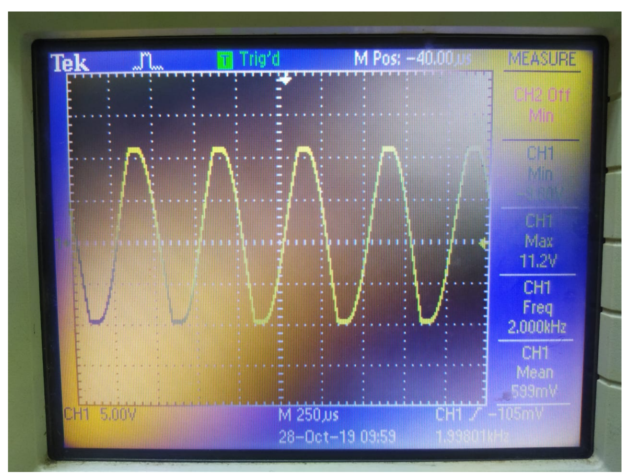
$R' = 8.2k\Omega$
$R_{100k\Omega\,POT} = 86k\Omega$

Feedback Resistor $R_f = R' + R_{100k\Omega\,POT} = 94.2k\Omega$

Obtained frequency of waveform = **2 kHz**



(a) Circuit Implementation



(b) Output Waveform

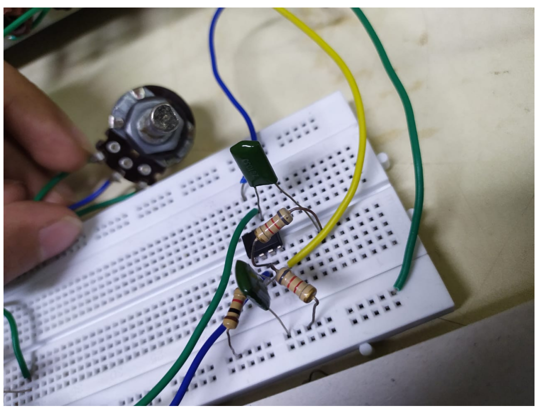
7.2 Wein Bridge Oscillator

R'=$1k\Omega$
$R_{4.7K\ POT} = 1k\Omega$

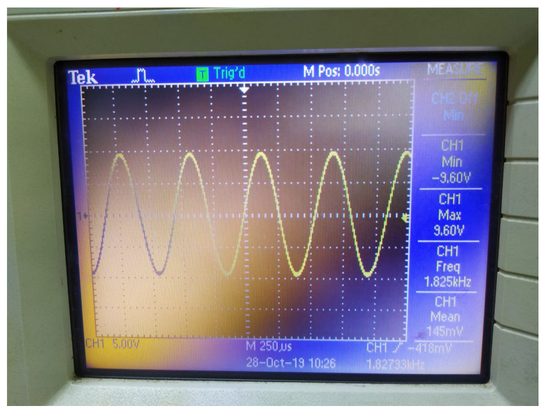
Feedback resistor value $R_f = R' + R_{4.7K\ POT} = 2k\Omega$

$V_{max} = 9.8V$
$V_{min} = -9.6V$

Obtained frequency of waveform = **1.825 kHz**



(a) Circuit Implementation



(b) Output Waveform

PRECAUTIONS

1. $+V_{CC}$ and $-V_{CC}$ voltage level must kept optimum, and shouldn't be exceeded.
2. Make sure grounding is proper.
3. Probes attenuation must be matched properly.
4. Make sure to use a resister (R') in the feedback path of amplifier in order for the potentiometer to have complete rotation without shorting the feedback circuit.

APPLICATIONS

9.1 Wien Bridge Oscillator

Wein Bridge Oscillator used in wide level of applications in the field of electronics, from finding the exact value of the capacitor, For generating 0 degree phase stable oscillator related circuitry, due to low noise level it is also a wiser choice for various Audio grade level applications where continuous oscillation is required.[4]

1. Used for distortion testing of power amplifier.
2. To supply the signals for testing filters.
3. Used to give excitation for AC bridge.
4. Fabricate pure tune.
5. Measure the audio frequency.

9.2 RC Phase Shift Oscillator

The applications of this type of phase shift oscillator include the following

1. The applications of this phase shift oscillator include voice synthesis, musical instruments, and GPS units.
2. This phase shift oscillator is used to generate the signals over an extensive range of frequency. They used in musical instruments, GPS units and voice synthesis.[3]

Bibliography

[1] Kenneth C. Smith Adel Sedra. *Microelectronic circuits*. 5th ed. Oxford University Press, 1982.

[2] Elprocus. *Op-Amp IC's – Pin Configuration, Features Working*. URL: https://www.elprocus.com/op-amp-ics-pin-configuration-features-working/.

[3] Elprocus. *RC Phase Shift Oscillator Working and Its Applications*. URL: https://www.elprocus.com/rc-phase-shift-oscillator-circuit-using-bjt-frequency/.

[4] Elprocus. *Tutorial on Wien Bridge Oscillator Circuit And It's Working*. URL: https://www.elprocus.com/wien-bridge-oscillator-circuit-working/.

[5] Ron Mancini and Richard Palmer. *Sine-Wave Oscillator Application Report*. URL: http://www.ti.com/lit/an/sloa060/sloa060.pdf.