Pearson BTEC Level 4 Higher Nationals in Engineering (RQF)

Unit 22: Electronic Circuits and Devices

Unit Workbook 3

in a series of 4 for this unit

Learning Outcome 3

Oscillators

Contents

INTRODUCTION

Examine the operation and application of oscillators

- Types of oscillators such as Wien bridge, Twin-T, R-C ladder, L-C coupled, transistor, operational amplifier, crystal
- Frequency, stability, frequency drift, distortion, amplitude and wave shapes

GUIDANCE

This document is prepared to break the unit material down into bite size chunks. You will see the learning outcomes above treated in their own sections. Therein you will encounter the following structures;

Purpose — Explains *why* you need to study the current section of material. Quite often learners are put off by material which does not initially seem to be relevant to a topic or profession. Once you understand the importance of new learning or theory you will embrace the concepts more readily.

Theory — Conveys new material to you in a straightforward fashion. To support the treatments in this section you are strongly advised to follow the given hyperlinks, which may be useful documents or applications on the web.

Example — The examples/worked examples are presented in a knowledge-building order. Make sure you follow them all through. If you are feeling confident then you might like to treat an example as a question, in which case cover it up and have a go yourself. Many of the examples given resemble assignment questions which will come your way, so follow them through diligently.

Question — Questions should not be avoided if you are determined to learn. Please do take the time to tackle each of the given questions, in the order in which they are presented. The order is important, as further knowledge and confidence is built upon previous knowledge and confidence. As an Online Learner it is important that the answers to questions are immediately available to you. Contact your Unit Tutor if you need help.

Challenge — You can really cement your new knowledge by undertaking the challenges. A challenge could be to download software and perform an exercise. An alternative challenge might involve a practical activity or other form of research.

Video — Videos on the web can be very useful supplements to your distance learning efforts. Wherever an online video(s) will help you then it will be hyperlinked at the appropriate point.

3.1 Oscillators

Oscillators systems that will output a repeating A.C signal with only a D.C supply. The output of the oscillator (shape and amplitude) are determined by the design and component choices. The amplitude is typically constant, but frequency can be altered through the use of variable resistors.

Oscillators are classed into three different types, dependent on their wave output:

- Sine wave oscillators produce sine waves
- Relaxation oscillators produces rectangular waves.
- Sweep Oscillators produce "sawtooth" waves.

Fig.3.1 shows a graphic output of each oscillator type.

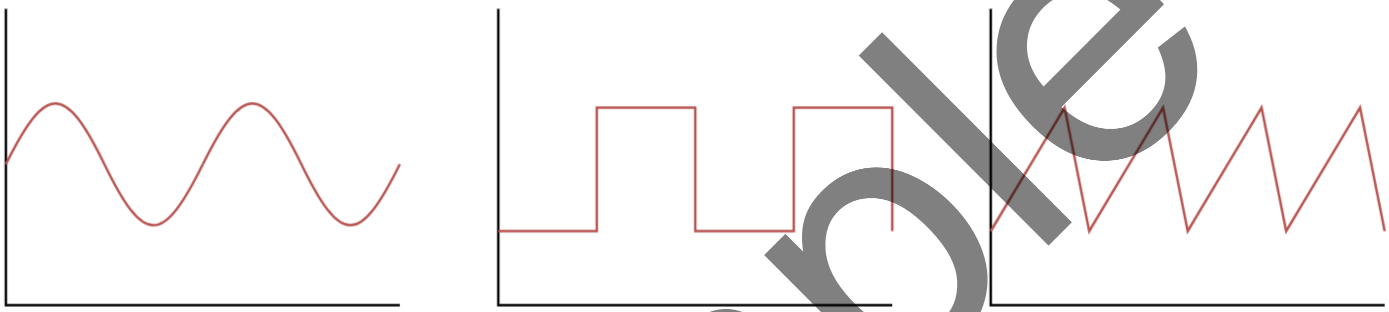

Fig.3.1: Different oscillation outputs: sine wave (left), rectangular wave (centre), sawtooth wave (right)

3.2 Sine Wave Oscillators

Sine wave oscillators are used to generate radio or audio frequencies from a DC supply. These can be classified further:

- Hartley oscillator,
- Colpitts oscillator,
- RC ladder oscillator,
- Crystal sine wave oscillator.

3.2.1 LC Coupling Oscillator

The design can either incorporate two inductors and one capacitor (Hartley), or two capacitors and one inductor (Colpitts). The defining feature of LC coupling oscillators are the "tank" circuits. The two oscillators have different resonant frequencies, which are discussed later. These types of oscillators are however, prone to drifting when there are small changes in the supply voltage.

Hartley Oscillators incorporate a tank circuit that consists of two coils and a capacitor, shown in more detail in Fig.3.2. It is difficult to tune the oscillator to the required frequency, as if the coupling between $\mathrm{L_1}$ and $\mathrm{L_2}$ is too small, the feedback will drop to zero, if the coupling is too great the oscillations will continue to grow and distort. Tuning the feedback loop accurately, however, produces constant amplitude oscillations.

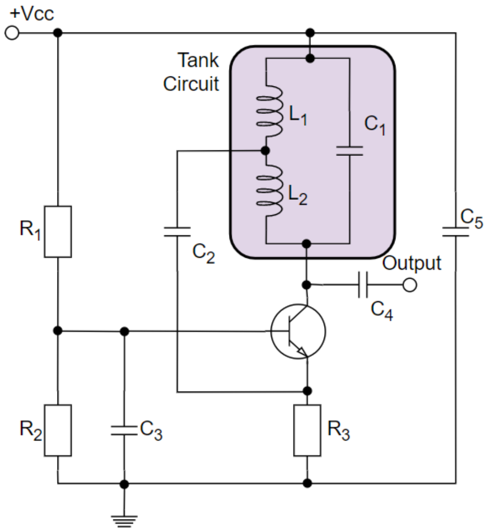

Fig.3.2: Hartley oscillator

Hartley oscillators resonant frequency is calculated using Eq.3.1, where L and C are the inductance and capacitance of the tank circuit, respectively.

$$f_r = \frac{1}{2\pi\sqrt{LC}}, \text{ where } L = L_1 + L_2 \qquad \text{(Eq.3.1)}$$

Colpitts Oscillators are a very similar design to the Hartley oscillator design but could be considered to be its exact opposite. In this case, the tank circuit uses two capacitors and one inductor, by eliminating some of the self-inductance within the tank circuit, the Colpitts has an improved stability, as well as a simpler design. At higher frequencies, the lower impedance path of the capacitors will produce a more accurate sine wave. A schematic of the Colpitts oscillator is shown in Fig.3.3 below.

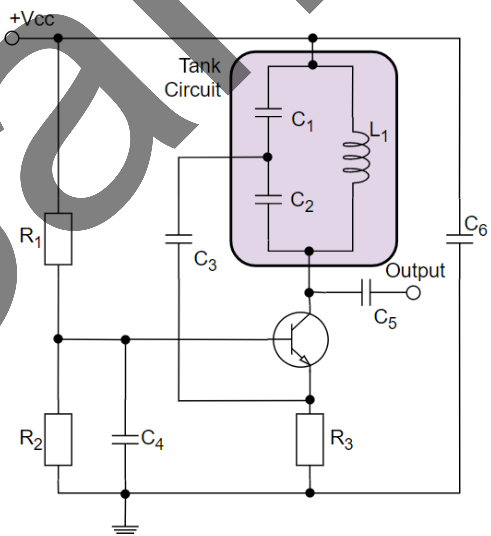

Fig.3.3: Colpitts oscillator

Colpitts oscillators resonant frequency is calculated using Eq.3.2, Colpitts oscillators are much better at maintaining high frequency stability.

$$f_r = \frac{1}{2\pi\sqrt{LC}}, \text{ where } C = \frac{C_1 \times C_2}{C_1 + C_2} \qquad \text{(Eq.3.2)}$$

3.2.3 Crystal Oscillator

Crystal oscillators are also LC oscillators but use a crystal in the system to promote frequency stability. The crystal is normally quartz, which is a piezo-electric device. A piezo-electric device will bend and produce a mechanical stress when it is subjected to a voltage, and so when the quartz is stressed, it will produce a voltage. Therefore, by inducing a voltage in pulses, the piezo-electric device will reinforce the pulses and oscillate in phase with the pulses. The equivalent circuit of a quartz crystal can be shown in Fig.3.4.

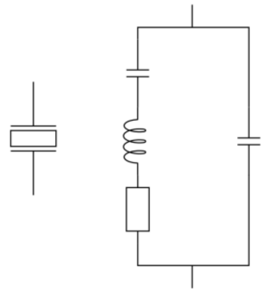

Fig.3.4: The symbol for a piezo-crystal (left) and it's equivalent circuit (right)

The frequency at which the reinforcing effect occurs is also the resonant frequency of the crystal, which is dependent on the size of the crystal and the atomic structure. A well-prepared crystal will act oscillate in an underdamped fashion (the oscillations will take a long time to die out). Fig.3.5 shows both a Hartley and Colpitts oscillator with a crystal configuration incorporated.

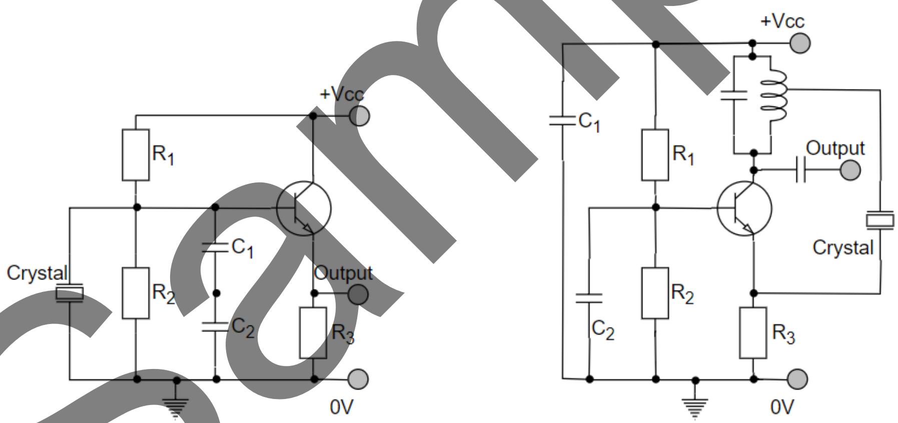

Fig.3.5: A crystal incorporated Colpitts (left) and Hartley (right) oscillator

3.2.4 RC Ladder

RC ladders are a method used to develop a sine wave, with each RC point developing 60° phase the sine wave, so the initial amplified stage (180°) is generated, and the inverted signal is also developed (giving the whole 360° of the sine wave). Fig.3.3 shows an RC ladder circuit, it is important that the capacitors and resistors in the ladder are equal, otherwise the amplification will not be even across the wave, which will cause a signal distortion.