Oscillators

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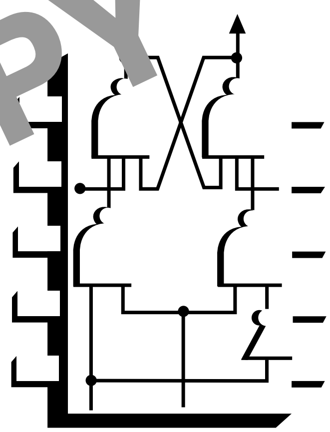
OSCILLATORS

Lesson One

Introduction to Oscillators



TPC Training Systems

25401

Lesson

1 Introduction to Oscillators

TOPICS

Oscillation
Oscillators and Amplifiers
Classes of Oscillators
LC (Tuned) Circuits
RC (Phase-Shift) Oscillators
Crystal Oscillators
Comparison of Oscillators
Common Oscillator Circuits

OBJECTIVES

After studying this Lesson, you should be able to…

- Describe the conditions needed to start and to sustain oscillation.
- Explain how positive feedback affects oscillation.
- Name three kinds of feedback networks used in oscillators.
- Discuss the advantages and disadvantages of tuned circuits, phase-shift oscillators, and crystal oscillators.
- Describe several common oscillator circuits.

KEY TECHNICAL TERMS

Sinusoidal 1.01 having the shape of a sine wave
Positive feedback 1.03 a portion of an amplifier output signal that is fed back to the amplifier input to reinforce the output signal
Positive saturation 1.04 the condition in which a further increase in the input signal no longer produces an increase in the output signal
Negative saturation 1.05 the condition in which a further decrease in the input signal no longer produces a decrease in the output signal
Feedback fraction 1.06 the amount of feedback compared to the total output
Tank circuit 1.13 a circuit in which an inductor and a capacitor are connected in parallel
Nomogram 1.20 a chart that permits estimating a value if other values are known

In many industrial applications, alternating current (ac) signals are needed in order to transfer information or to begin a process. These ac signals usually are generated by electronic circuits called oscillators. Basically, an oscillator generates an ac signal at a frequency determined by the circuit components and characteristics.

This Lesson explains how oscillators work. It describes several of the most common kinds of oscillators and compares the advantages and disadvantages of each.

Oscillation

1.01 To *oscillate* is to move back and forth. For example, an oscillating fan moves back and forth to provide maximum air circulation. The periodic back-and-forth motion is called *oscillation*. Periodic means that the motion repeats in equal periods of time. Many kinds of oscillation are sinusoidal. *Sinusoidal* motion, one kind of periodic motion, is shown on a graph as a sine wave.

1.02 Figure 1-1 shows a periodic sinusoidal waveform. One electrical cycle consists of 360°—that is, it starts at 0°, proceeds to maximum positive (90°), moves back through the starting point (180°) and down to maximum negative (270°), then proceeds back to the starting point (0° or 360°). In an electronic oscillator, the motion in electrical degrees represents a variation in potential or current from zero to one extreme, back to zero, to the opposite extreme, and then back to zero.

Oscillators and Amplifiers

1.03 An oscillator is an amplifier circuit that produces an ac signal output from a dc supply. How does an oscillator produce the back-and-forth motion? And how does an oscillator differ from other amplifier circuits? The answer to both of these questions is *positive feedback*, an arrangement by which part of the output signal is fed back to the input in a way that reinforces the output signal. Positive feedback is always directly proportional to the output signal, regardless of whether the output signal is positive-going or negative-going.

1.04 As the output signal increases, or becomes more positive, the feedback signal also increases. This increase, in turn, causes the output signal to increase further until the transistor reaches saturation. At *positive saturation*, an additional increase in the input signal no longer produces an increase in the output signal.

1.05 Now positive feedback causes the output to increase in the negative direction until the transistor reaches negative saturation. At *negative saturation*, a continued decrease in the input signal no longer produces a decrease in the output signal. From negative saturation, the amplifier again cycles toward positive saturation. Thus the amplifier output oscillates between its maximum positive voltage or current and its maximum negative voltage or current.

1.06 Although different kinds of oscillators may use different kinds of feedback networks and amplifiers, they all work according to the principle of positive feedback. The amount of feedback compared to the output is called the *feedback fraction*. Oscillator operation depends on the product of its amplification (A) and its feedback fraction (B). For an oscillator to work, the product of A and B must be greater than unity (1) to start the oscillation and equal to unity to sustain it. The circuit also must have a 0° or 360° phase shift around the loop.

1.07 Figure 1-2 on the following page shows a block diagram of a typical oscillator. Suppose that the circuit is opened at X, and a signal with a waveform like that shown in waveform 1 is introduced into the circuit at point 1. The value of AB is greater than 1

Fig. 1-1. Periodic sinusoidal waveform

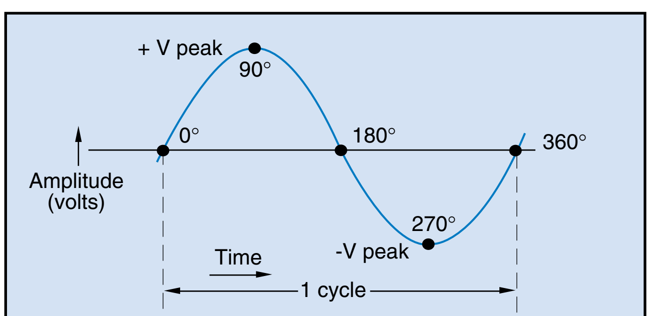
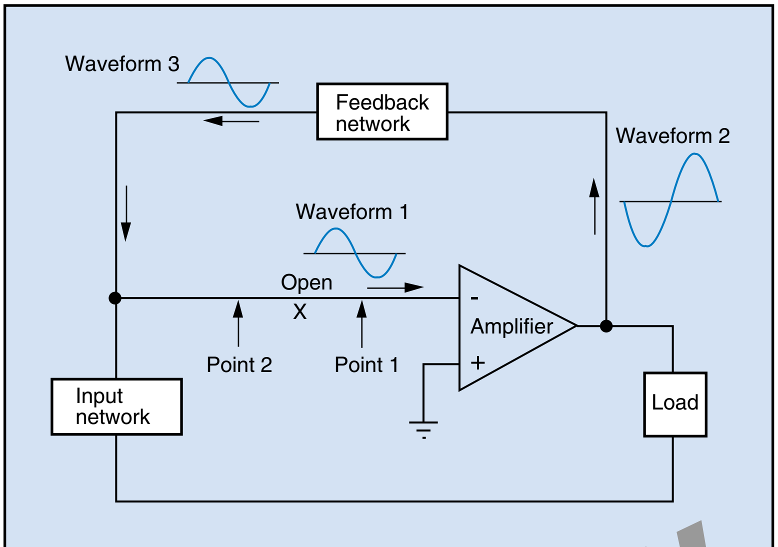


Fig. 1-2. Block diagram of typical oscillator

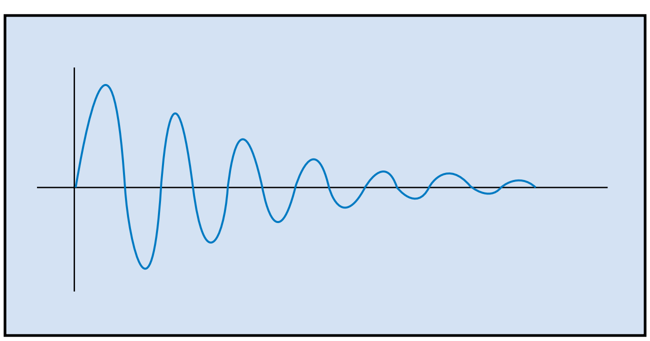


when the power is first turned on. The small dc supply voltage applied to the input terminals causes the output voltage to increase. The amplitude of the oscillation also increases until the output voltage reaches a desired level, after which the value of *AB* automatically decreases to 1 by reduction of either *A* or *B*.

1.08 The amplifier produces an amplified and inverted output signal as shown in waveform 2. As shown by waveform 3, a portion of the output signal is returned to point 2. Two different results can occur, depending on the phase and gain of the signal in the loop.

- If *AB* is equal to 1, and if the signal at point 2 is in phase with the signal at point 1, oscillation is possible. If the circuit is reconnected at X, the feedback signal at point 2 reinforces the output and the circuit is able to sustain oscillation.

Fig. 1-3. Damped oscillation



- If *AB* is less than 1, oscillation still may occur, but it will be *damped*. That is, if power is applied to the circuit, oscillations begin but decrease in amplitude until they disappear. Figure 1-3 shows what a damped oscillation waveform looks like.

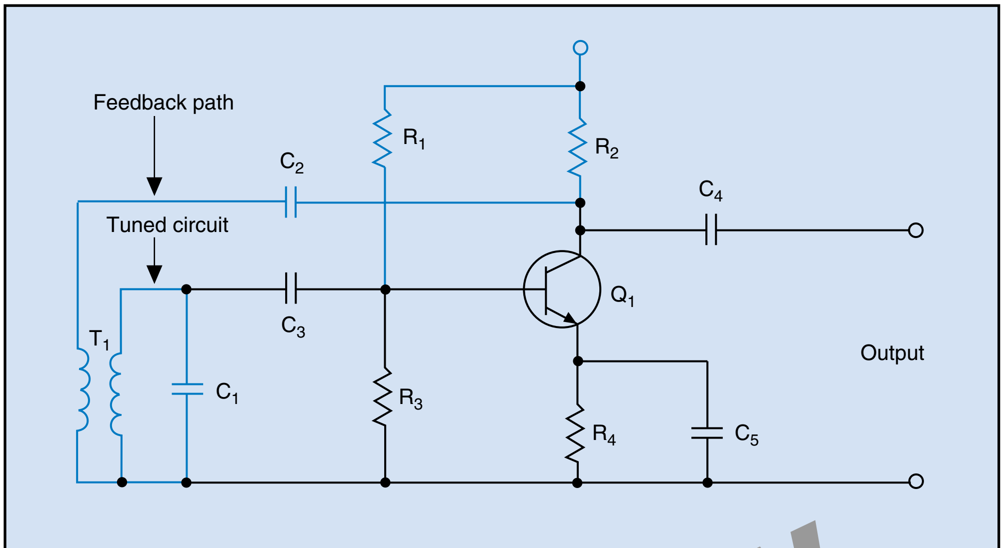
1.09 An oscillator in which the feedback path is connected in parallel with the transistor input is referred to as a *shunt-fed* oscillator. The *Armstrong* oscillator, shown in Fig. 1-4, is a kind of shunt-fed oscillator that uses a transformer for the feedback signal. The feedback path (C_2 and the primary of T_1) is in parallel with the transistor input.

1.10 To analyze the circuit in Fig. 1-4, assume that a small dc voltage is applied to the transistor. The transistor output voltage increases. The increased voltage is fed through C_2 to the primary of T_1. The secondary voltage, when applied to the transistor base, reinforces the original change in collector voltage. Because of positive feedback, the circuit oscillates.

Classes of Oscillators

1.11 There are a great many variations of oscillator circuits. Those that provide a rectangular output are discussed in later Lessons in this Unit. The oscillators discussed in this Lesson provide a sinusoidal output. Most of these oscillators can be divided into three general classifications:

Fig. 1-4. Shunt-fed oscillator



- LC
- RC
- quartz crystal.

These classifications are based on the components in the feedback network. Each of these is discussed in the paragraphs that follow.

LC (Tuned) Circuits

1.12 LC circuits are *resonant* (tuned) circuits. The "L" indicates an inductor and the "C" indicates a capacitor. These oscillators are normally used for higher frequencies (above 1 MHz). The shunt-fed oscillator in Fig. 1-4 is an example of an LC tuned circuit. Capacitor C_1 and the T_1 secondary winding connected in parallel produce an oscillation that is part of the input to transistor Q_1.

1.13 A circuit in which an inductor and a capacitor are connected in parallel is called a *tank circuit*. An LC tank circuit is shown in Fig. 1-5. Recall that the voltage across a capacitor cannot change instantly. Nor can the current through an inductor change instantly. If the capacitor is fully charged (if it is at its maximum voltage), all the energy in the tank circuit is stored in the capacitor. The capacitor then discharges into the inductor, transferring the energy stored in the capacitor to the magnetic field of the inductor until all the energy is in the inductor.

1.14 The process of energy transfer then reverses. The energy is transferred from the inductor back to the capacitor. This back-and-forth transfer of energy results in sine wave current and voltage changes in the tank circuit.

1.15 If the inductor and the capacitor were ideal components, energy transfer and oscillation would continue indefinitely. However, all real inductors and capacitors have some resistance, which causes some of the electrical energy to be lost in each cycle. Thus, without feedback, the oscillations would decrease and eventually cease.

1.16 Look again at the shunt-fed oscillator shown in Fig. 1-4. Recall that the tank circuit consists of C_1 and the secondary winding of transformer T_1. Note that, although the tank circuit in this example is on

Fig. 1-5. Tank circuit

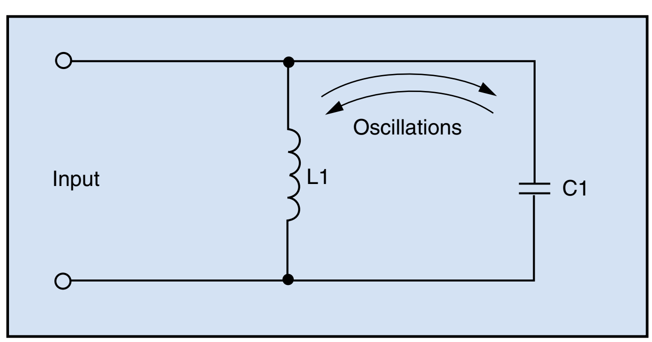
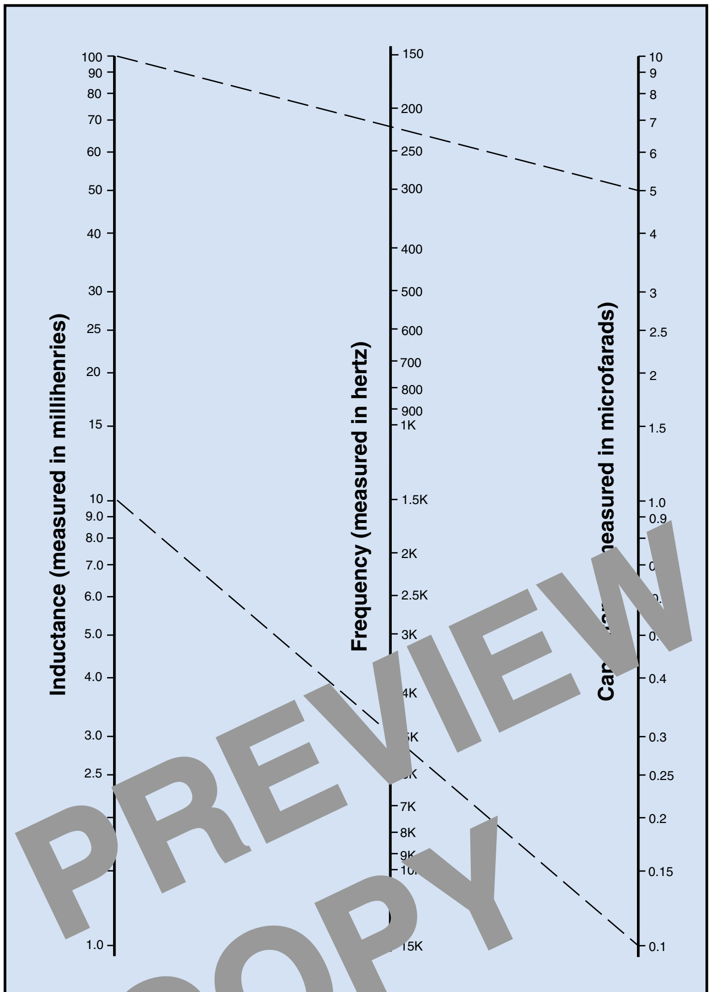


Fig. 1-6. Nomogram



the secondary, it is often on the primary side of the transformer. As the tank circuit oscillates, some of the voltage change is coupled through C_3 to the base of the transistor, where it is amplified. A portion of the amplified signal is fed back through C_2 to the primary of T_1.

1.17 The windings of transformer T_1 are polarized in such a way that a portion of the feedback signal is coupled into the tank circuit in phase with the oscillation, replacing the energy lost due to resistance in the tank circuit. This arrangement enables the circuit to sustain oscillation.

1.18 Recall that, in the circuit in Fig. 1-4, L is the inductance of the secondary winding. The coupling, and therefore the mutual inductance, is small. The following equation is used to calculate the frequency of the oscillator if the values of the inductor and the capacitor are known:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

where f = frequency in hertz (Hz)

L = inductance in henries (H)

C = capacitance in farads (F)

π = 3.14159

For example, suppose that the inductance is 100 mH (100×10^{-3} H) and the capacitance is 5 mF (5×10^{-6} F). Then the frequency is calculated as follows:

$$f = \frac{1}{2 \times 3.14159\sqrt{(100 \times 10^{-3}) \times (5 \times 10^{-6})}}$$

$$= 225 \text{ Hz}$$

1.19 If you know the frequency and need to calculate the values for *L* and *C*, you can select a value for L and then solve the equation for *C*—or you can select a value for *C* and then solve the equation for *L*. However, calculating a range of values for *L* and *C* by this method takes a great deal of time.

1.20 Using a nomogram is much faster. Shown in Fig. 1-6, a *nomogram* is a chart that enables you to estimate a value when other values are known. To use a nomogram, you place a straightedge across the nomogram. The three intersection points are the values for *L*, *C*, and *F*. For example, the lower line drawn across the nomogram shows that a 0.1-μ*F* capacitor used with a 10.0-mH inductor produces a frequency of about 5 kHz. If you use these values in the equation, the calculated value of the frequency is 5.033 kHz.

1.21 To use the nomogram for the calculation in paragraph 1.18, place the ruler across 100 mH and 5 μ*F*. The upper line drawn across the nomogram shows that the frequency is approximately 225 Hz. Nomograms can help you select components quickly for various applications.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of the book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. An oscillator is a(n) ________ with a positive feedback network.	1-1. AMPLIFIER Ref: 1.03
1-2. The output voltage in an oscillator circuit is driven back and forth between positive and negative ________.	1-2. SATURATION Ref: 1.04, 1.05
1-3. For oscillations to begin, the product of an oscillator's amplification and feedback fraction must be ________.	1-3. GREATER THAN UNITY Ref: 1.06
1-4. To sustain oscillation, the product of amplification and the feedback fraction must be ________.	1-4. UNITY Ref: 1.06
1-5. An LC oscillator circuit is a(n) ________ circuit.	1-5. TUNED or RESONANT Ref: 1.12
1-6. A(n) ________ circuit uses an inductor and capacitor connected in parallel.	1-6. TANK Ref: 1.13
1-7. In each cycle of an LC tuned circuit, some energy is lost due to the ________ of the inductors and capacitors.	1-7. RESISTANCE Ref: 1.15
1-8. The use of a(n) ________ allows you to find frequency, capacitance, or inductance quickly if you know the other two.	1-8. NOMOGRAM Ref: 1.20

RC (Phase-Shift) Oscillators

1.22 Like the LC oscillator, the RC oscillator sustains its oscillations by means of a feedback loop, but the RC loop consists of a resistor (R) and a capacitor (C). RC circuits are phase-shift circuits. In order for oscillation to occur, the phase shift around the loop must be 0° (or 360°). RC oscillators generally are used for frequencies less than 1 MHz.

1.23 Figure 1-7 shows an RC phase-shift network with a plot of its gain and phase characteristics:

- At low frequencies, the capacitor has a high impedance with very little attenuation (decrease) in the output signal. The phase shift is close to 0°.

- At high frequencies, the capacitor impedance is low and the output signal is attenuated. The decreased output signal causes a decrease in gain at higher frequencies. The phase shift is near 90°.

The simple RC oscillator shown in Fig. 1-8 includes three phase-shift networks similar to the circuit shown in Fig. 1-7.

1.24 In Fig. 1-8, the transistor circuit increases the input signal and inverts it. The inversion is a 180° phase shift. Each RC section of the feedback network attenuates the collector signal somewhat and causes an additional phase shift. At a certain frequency, which depends on the values of the components, the phase shift of each section is 60°. The three networks together produce a shift of 180° (3 × 60).

1.25 Remember that the phase shift around the loop must be 0° (or 360°) in order for oscillation to occur. If the gain of the transistor amplifier is enough to overcome the decrease in feedback at the frequency that produces a 180° phase shift, then oscillation can be sustained. By selecting components with different values, you can control the gain and frequency of oscillation.

Fig. 1-7. RC phase-shift network

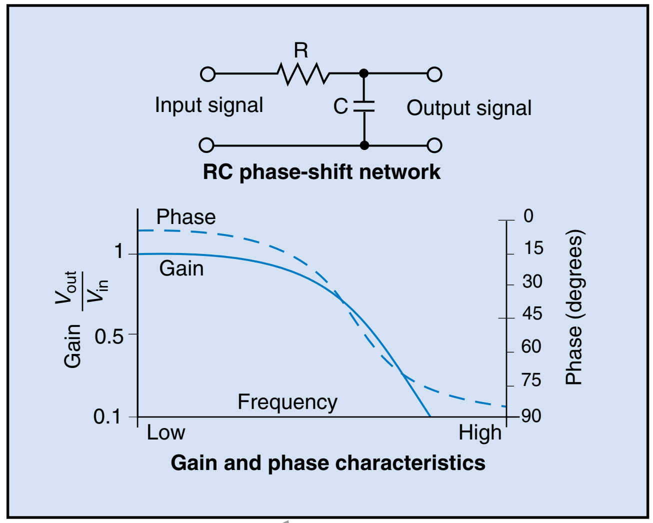
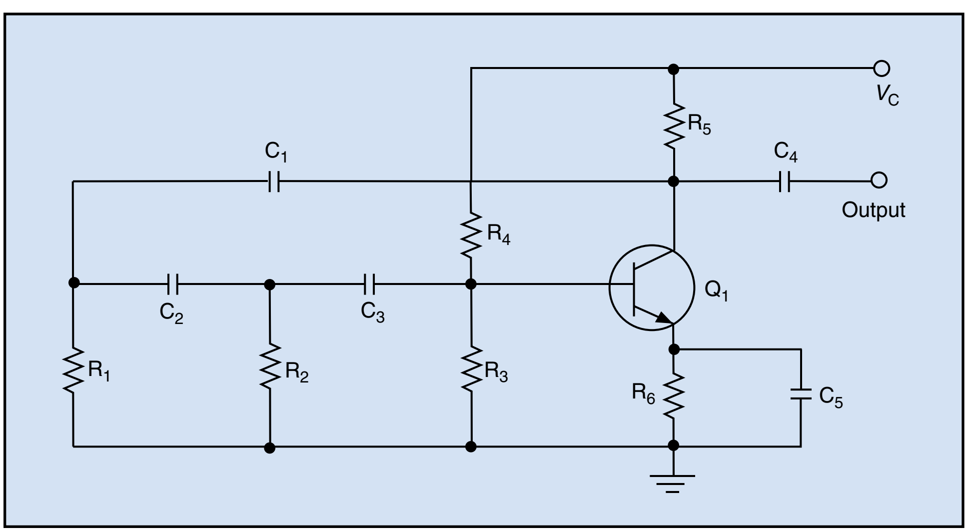


Fig. 1-8. RC phase-shift oscillator



Crystal Oscillators

1.26 Oscillators also are made with *piezoelectric* crystals, usually quartz. If a certain ac voltage is applied to a crystal that exhibits the piezoelectric effect, the crystal vibrates at the frequency of the applied voltage, much like a pendulum. The crystal component is connected into the feedback circuit.

1.27 The crystal has a natural mechanical frequency, which depends on the thickness and shape of the crystal. This frequency is known as the *resonant frequency*. An applied voltage at the resonant frequency produces maximum vibrations and a 0° phase shift. Crystals produce very stable frequencies in simple oscillator circuits.

1.28 The application of voltages at frequencies close to the resonant frequency sharply changes both the gain and the phase shift of the circuit. However, the application of voltage at exactly resonant frequency changes neither the gain nor the phase shift. Thus, you can tell exactly when the resonant frequency is reached. By knowing the exact resonant frequency, you can choose components with values that stabilize the gain and phase shift of the circuit.

1.29 Crystals are ground to a precise specified size and shape. In fact, it is possible to grind a crystal with an accuracy of a single hertz in several million hertz. For example, the crystal for a television color-burst oscillator is ground to a frequency of 3,579,545 Hz.

1.30 Operating temperature affects the resonant frequency of the crystal. A typical crystal may vary about 0.001% over the temperature range of -25 to +85°C. This variation is much smaller than in resistors, capacitors, and inductors, but it still may be too great for some applications. In order to reduce the variation even further, crystals occasionally are placed in temperature-controlled ovens that maintain frequency at about ±2 Hz out of 10 MHz, which is considered very stable.

Comparison of Oscillators

1.31 This Lesson has described three kinds of oscillators—the LC circuit, the RC circuit, and the crystal oscillator. Each kind of oscillator has its strengths and weaknesses, as discussed in the paragraphs that follow. The characteristics of each kind of oscillator are summarized in Table 1-1.

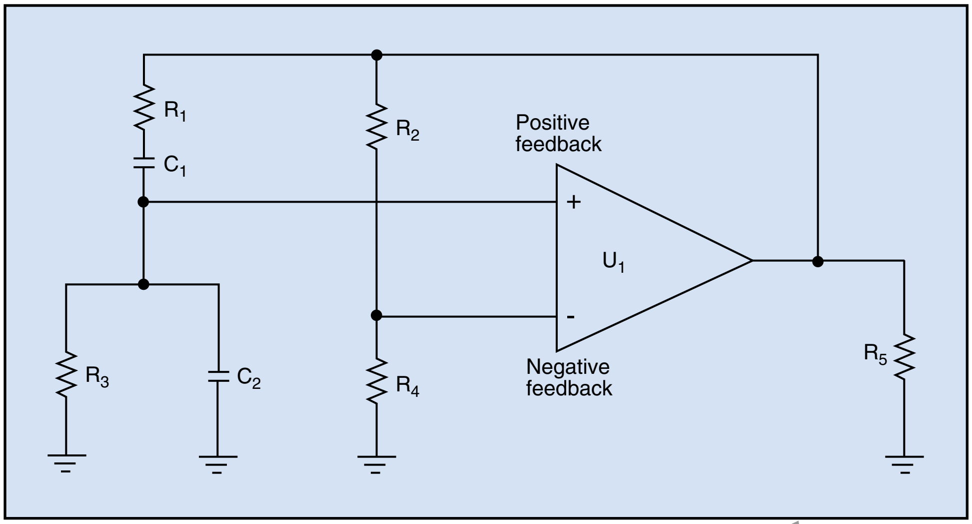
1.32 **LC circuits.** The advantage of tuned-circuit oscillators is that they provide a fairly stable frequency. With these circuits, a small change in frequency causes a large phase shift. The circuit can operate only at the frequency that causes an exact 360° (or 0°) phase shift around the loop. These oscillators can be tuned over a wide range of frequencies by using variable capacitors or inductors. They have good short-term frequency stability once they are tuned.

1.33 The main disadvantages of LC tuned-circuit oscillators are that they are relatively complex, bulky, and expensive. Inductors are large and expensive compared to resistors or crystals, especially in low-frequency oscillators where the inductance is large. Inductors can be affected by external stray magnetic fields. Inductors also can emit electromag-

Table 1-1. Comparison of oscillator characteristics

Characteristic	LC tuned-circuit oscillators	RC phase-shift oscillators	Crystal oscillators
Stability	Medium	Least stable	Most stable
Size	Largest	Smallest	Small
Cost	Highest	Lowest	Medium
Ease of adjustment	Good	Easiest	Unadjustable except over very narrow range

Fig. 1-9. Wien-bridge oscillator



netic interference if the coils are not properly shielded, and shielding adds to the bulk and expense of inductors.

1.34 **RC circuits.** The main advantages of RC circuits are that they are relatively small and inexpensive and also are easily adjusted by means of variable capacitors or resistors. The main disadvantage of RC oscillators is that they are limited to frequencies below about 2 MHz. Also, their frequency is not as stable as LC tuned circuits or crystal oscillators.

1.35 **Crystal oscillators.** The main advantage of crystal oscillators is excellent stability (both short-term and long-term) over a wide temperature range. Even small, inexpensive crystal oscillators can provide excellent stability over a wide temperature range.

1.36 The disadvantage of using crystal oscillators is that they are not tunable except over a very narrow range. That is, they can be used only in applications that require precise, fixed frequencies. If a different frequency is desired, a different crystal must be used.

Common Oscillator Circuits

1.37 It is important to remember that each of the oscillators described in this Lesson can be used with any kind of amplifying device, including vacuum tubes, transistors, or op amps. Oscillators are selected according to the feedback method, not the kind of amplifier.

1.38 Many kinds of oscillators are available. The remainder of this Lesson discusses a few of the most common oscillator circuits.

1.39 **Wien-bridge oscillator.** The Wien-bridge oscillator, shown in Fig. 1-9, is the most common of the RC oscillators. In this example, the gain element of the oscillator is an op amp. The feedback network operates differently at different frequencies:

- At frequencies below resonance, the feedback network acts as a lead network (+90° phase shift).
- At resonant frequency, the feedback network has a 0° phase shift.
- At frequencies above resonance, the feedback network acts as a lag network (-90° phase shift).

1.40 The Wien-bridge oscillator often uses a tungsten filament. In Fig. 1-9, the RC network provides a feedback fraction of $^1/_3$ at resonance. Therefore, R_2 should be two times R_4 to give a feedback fraction of $^1/_3$ on the inverting input. However, to start the oscillation, R_4 initially should be smaller than its final value. Using a tungsten filament for R_4 fulfills this requirement, because resistance increases as the filament heats slightly.

1.41 **Null network oscillators.** The feedback circuit is called a *null* network if the phase shift at the resonant

Fig. 1-10. Parallel-tee network

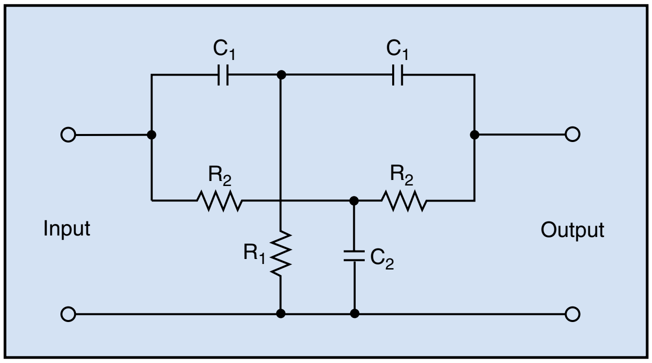
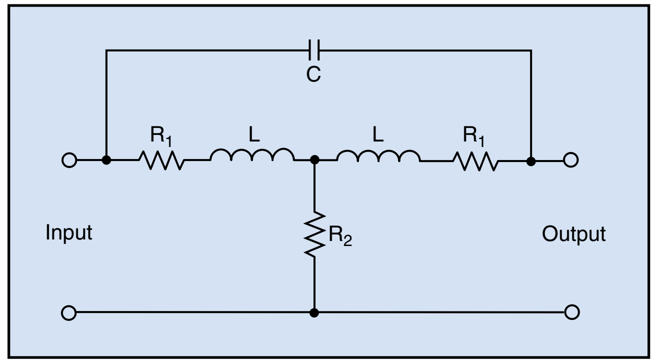


Fig. 1-11. Bridged-tee network



frequency is 0°. The Wien-bridge oscillator is one example of a null network. Other null networks used in oscillators are the *parallel-tee* network (sometimes called a *twin-tee* network) and the *bridged-tee* network. These networks are similar to the Wien bridge because they have a 0° phase shift at resonant frequency and a rapid phase shift as the frequency varies from resonance. A parallel-tee network is shown in Fig. 1-10. A bridged-tee network is shown in Fig. 1-11.

1.42 **Pierce oscillator.** A Pierce oscillator is a crystal-controlled oscillator that operates similarly to an RC phase-shift oscillator. A simple Pierce oscillator with one transistor is shown in Fig. 1-12. The signal at the base of transistor Q_1 is inverted in its collector circuit (a 180° phase shift). Because of the crystal in the feedback, the additional 180° phase shift is produced by two phase-shift sections rather than the three sections that were needed by the phase-shift oscillator.

1.43 The circuit in Fig. 1-12 oscillates at a frequency slightly higher than resonance. The crystal impedance and C_2 provide one phase-shift network. R_1 and C_1 provide the other phase-shift network. This circuit oscillates at the frequency at which the phase shift of these two networks equals 180°.

1.44 The frequency of a Pierce oscillator can be adjusted a small amount by varying either C_1 or C_2. However, because of the stability of the crystal, changes to these components have a very small effect on the frequency. This is what makes the Pierce oscillator so stable. As the discrete components in the feedback network change value due to age or temperature variations, the oscillation frequency remains almost the same.

1.45 A variation of the Pierce oscillator uses a single-stage integrated circuit (IC) inverter. This oscilla-

Fig. 1-12. Pierce oscillator

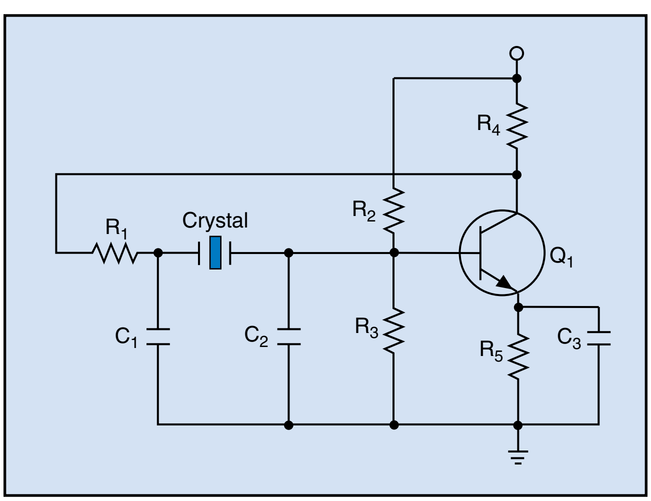
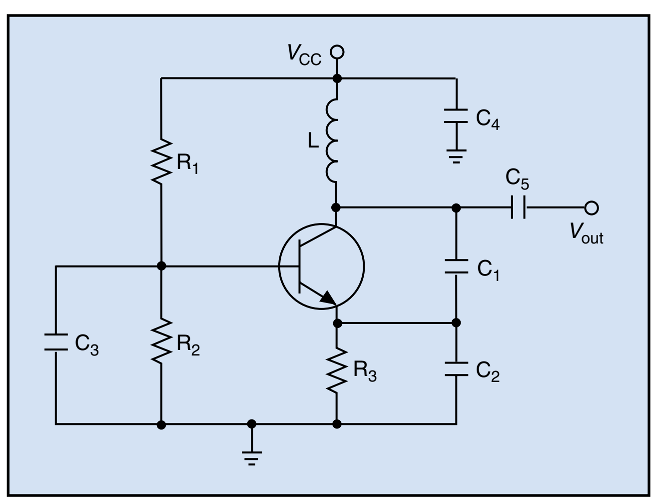


Fig. 1-13. Colpitts oscillator



tor is a little less stable than the regular Pierce oscillator because of wide variations in the inverter's output impedance. Even so, this circuit is still much more stable than an RC phase-shift oscillator.

1.46 Pierce oscillators are available in a wide range of frequencies. Crystals are available with resonant frequencies from several kHz to over 50 MHz. Varieties of Pierce oscillators cover this entire range.

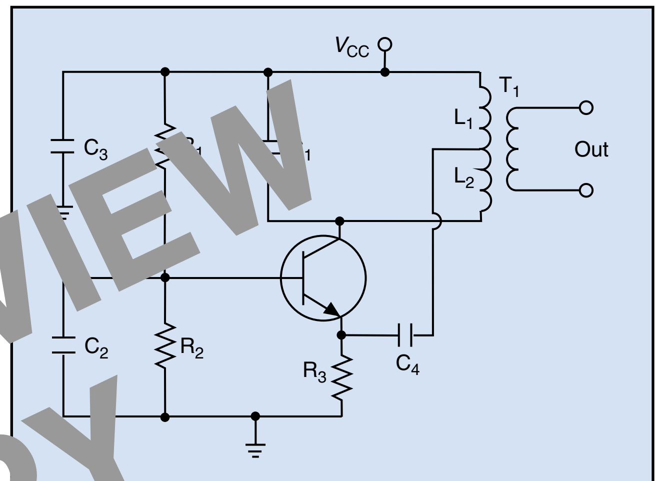
1.47 **Colpitts oscillator.** The Colpitts oscillator is the most common kind of LC oscillator. You can recognize a Colpitts oscillator, shown in Fig. 1-13, by the capacitive voltage divider formed by C_1 and C_2, which maintains the proper feedback ratio needed to sustain oscillation. The frequency of a Colpitts oscillator can be adjusted if a ganged variable capacitor arrangement replaces C_1 and C_2.

1.48 One small capacitor is sometimes inserted in series with the inductor in the tank circuit. The frequency can then be adjusted with this one capacitor, while leaving C_1 and C_2 fixed. This arrangement, a refinement of the Colpitts, is called a Clapp oscillator.

1.49 **Hartley oscillators.** The Hartley circuit and the Colpitts circuit are very similar in that both of them make use of LC tank circuits. The Hartley oscillator uses a tapped inductor in the tuned circuit to provide the feedback. The Hartley circuit shown in Fig. 1-14 uses the tapped primary of T_1 as the inductance. The output of the oscillator is taken from the transformer's secondary winding.

1.50 The Hartley oscillator was used in low audio-frequency oscillators before RC oscillators were developed. Hartley oscillators also are used less today because of other developments in technology, including low-cost crystals for fixed-frequency applications and electronically tunable oscillators.

Fig. 1-14. Hartley oscillator



1-9. RC oscillators generally are used for frequencies ________ than 1 MHz.	1-9. LESS Ref: 1.22
1-10. To sustain oscillation in a phase-shift oscillator, the total phase shift around the loop must be ________°.	1-10. 0 or 360 Ref: 1.22
1-11. If ac voltage is applied across a piezo-electric crystal, the crystal vibrates at the ________ of the applied voltage.	1-11. FREQUENCY Ref: 1.26
1-12. The natural frequency of a piezoelectric crystal is referred to as its ________.	1-12. RESONANT FREQUENCY Ref: 1.27
1-13. Variable capacitors or inductors permit ________ oscillators to be tuned over a wide range of frequencies.	1-13. LC Ref: 1.32
1-14. The main advantages of RC oscillators are that they are relatively ________ and ________.	1-14. SMALL, INEXPENSIVE Ref: 1.34
1-15. The main advantage of crystal oscillators is excellent ________.	1-15. STABILITY Ref: 1.35
1-16. To provide feedback, a(n) ________ oscillator uses a capacitive voltage divider, but a(n)________ oscillator uses a tapped inductor.	1-16. COLPITTS; HARTLEY Ref: 1.47, 1.49

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. Unlike other amplifiers, an oscillator

- ☐ a. produces a dc output
- ☐ b. requires an ac supply voltage
- ☐ c. uses no feedback
- ☐ d. uses positive feedback

1-2. To sustain oscillation, the product of amplification and the feedback fraction must be equal to 1 and the circuit must have

- ☐ a. a precisely ground quartz crystal
- ☐ b. a 0 or 360° phase shift around the loop
- ☐ c. damped waveforms
- ☐ d. polarized windings

1-3. Oscillation in a tank circuit is determined primarily by

- ☐ a. an inductor and a capacitor
- ☐ b. a piezoelectric crystal
- ☐ c. a resistor and a capacitor
- ☐ d. temperature

1-4. When a tank circuit oscillates, some energy is lost during each cycle due to

- ☐ a. capacitance
- ☐ b. inductance
- ☐ c. resistance
- ☐ d. saturation

1-5. If an RC phase-shift oscillator has three RC sections in its feedback circuit, each section must shift the input signal

- ☐ a. 60°
- ☐ b. 90°
- ☐ c. 180°
- ☐ d. 360°

1-6. In a crystal oscillator, an applied voltage at resonant frequency produces ________ vibrations and a phase shift of ________.

- ☐ a. maximum; 0°
- ☐ b. maximum; 90°
- ☐ c. minimum; 0°
- ☐ d. minimum; 90°

1-7. The main advantage of a crystal-controlled oscillator is its

- ☐ a. ease of tuning
- ☐ b. low cost
- ☐ c. simplicity
- ☐ d. stability

1-8. At frequencies below resonance, the feedback network in a Wien-bridge oscillator has a phase shift of

- ☐ a. -90°
- ☐ b. 0°
- ☐ c. +90°
- ☐ d. +180°

1-9. Varieties of ________ oscillators are available from several kHz to over 50 MHz.

- ☐ a. Clapp
- ☐ b. Colpitts
- ☐ c. Pierce
- ☐ d. Wien-bridge

1-10. Two oscillators that use LC tank circuits are the

- ☐ a. Clapp and bridged tee
- ☐ b. Colpitts and Hartley
- ☐ c. null network and twin tee
- ☐ d. Pierce and Wien bridge

SUMMARY

An oscillator is an amplifier circuit that produces an ac signal output from a dc supply by means of positive feedback. To sustain oscillation, a circuit must have a 0° (or 360°) phase shift and the product of amplification (*A*) and the feedback fraction (*B*) must be equal to 1. *AB* must be greater than 1 for oscillation to start. Once a certain output voltage is reached, the value of *AB* automatically decreases to 1 by reduction of either *A* or *B*.

In general, oscillators can be grouped according to the components in their feedback networks. The three kinds of oscillators discussed in this Lesson are LC circuits, RC circuits, and crystal oscillators. LC circuits are resonant (tuned) circuits, and RC circuits are phase-shift circuits. A tank circuit is an LC circuit in which an inductor and a capacitor are connected in parallel. An oscillator's frequency, inductance, or capacitance can be determined from a nomogram if the other two values are known. Values also can be calculated mathematically.

LC circuits are more stable than RC circuits, but crystal oscillators are the most stable of all. LC circuits can be tuned over a wide range of frequencies by means of variable capacitors or inductors. RC circuits are easily adjusted by means of variable capacitors or resistors. Crystal oscillators can be used only at the resonant frequency and therefore are not tunable except over a very narrow range. Crystal and RC oscillators are small and inexpensive, but LC circuits are bulky and fairly expensive.

The Wien-bridge is the most common RC oscillator, and the Colpitts is the most common LC oscillator. The Pierce oscillator is a crystal-controlled oscillator that operates like an RC phase-shift oscillator. The Armstrong oscillator is an RC oscillator that uses a transformer. Colpitts and Hartley oscillators both use LC tank circuits. The Colpitts uses a capacitive voltage divider and the Hartley uses a tapped inductor to provide the feedback. The Clapp oscillator is a variation of the Colpitts oscillator.

Answers to Self-Check Quiz

1-1. d. Uses positive feedback. Ref: 1.03

1-2. b. A 0° or 360° phase shift around the loop. Ref: 1.06

1-3. a. An inductor and a capacitor. Ref: 1.13

1-4. c. Resistance. Ref: 1.15

1-5. a. 60°. Ref: 1.24

1-6. a. Maximum; 0°. Ref: 1.27

1-7. d. Stability. Ref: 1.35, Table 1-1

1-8. c. +90°. Ref: 1.39

1-9. c. Pierce. Ref: 1.46

1-10. b. Colpitts and Hartley. Ref: 1.49