

EXPERIMENT 1

RF OSCILLATORS

1.1 EDUCATIONAL OBJECTIVES:

- ❖ Understanding the operation and characteristics of radio-frequency (RF) oscillators.
- ❖ Designing and implementing oscillators.

1.2 REFERENCE READINGS:

- ❖ Kennedy G., Electronic Communication Systems, McGRW-Hill, Third Edition, 1994,
- ❖ D. Roddy and J. Coolen, Electronic Communications, Prentice Hall of India, 1995.
- ❖ Young Paul H., Electronic Communication Techniques, Merrill Publishing Company, Third Edition 1990.
- ❖ Haykin Simon, Communication Systems, John Wiley, 4th Edition, 2001.

1.3 BACKGROUND INFORMATION:

An oscillator is simply a signal generator converting its dc supply voltage into a continuously repeating ac output signal without any input signal. Oscillators play very important roles in communication systems. An oscillator generates the carrier or local oscillation signal used in any communication system.

Fig.1-1 shows the basic block diagram of oscillator. It includes an amplifier and a feedback network constructed by the resonator. When dc power is

first applied to the circuit, noise will appear in the circuit and is amplified by the amplifier and then fed to the input through the feedback network that is a resonant circuit with filter function.

The feedback network permits the signal frequency equaling the resonant frequency to pass and rejects other frequencies. The feedback signal will be amplified and fed back again. If the feedback signal is in phase with the signal at input and voltage gain is enough, the oscillator will be operation.

For proper operation, an oscillator must meet Barkhausen criterion.

Barkhausen criterion is the relationship between the amplifier's gain A and the oscillator's feedback factor $\beta(s)$ and should be equal to 1. That is

$$A\beta(s) \geq 1 \quad (1-1)$$

where

A : amplifier's gain

$\beta(s)$: oscillator's feedback factor.

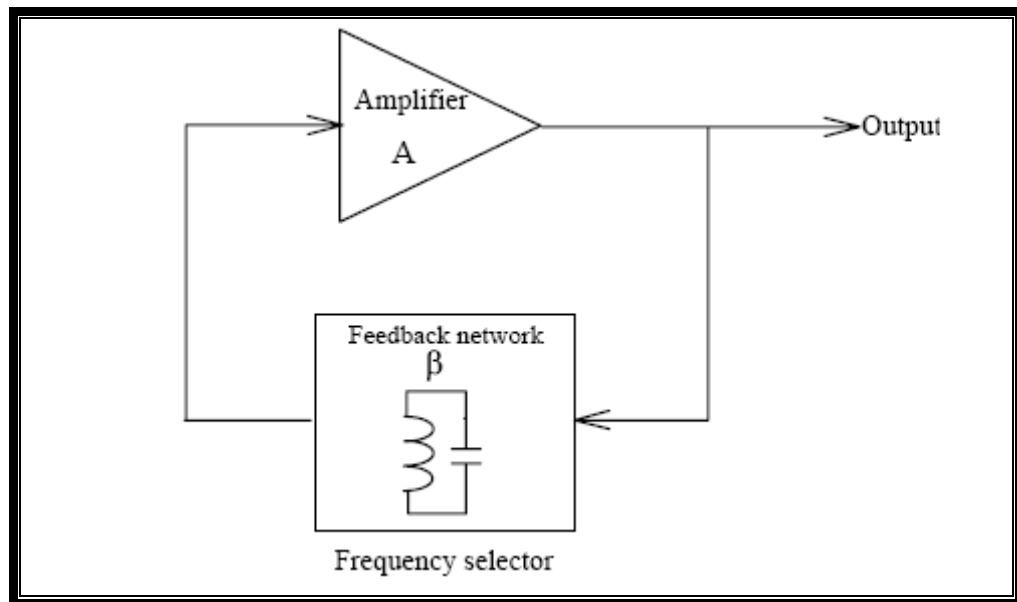


Fig.1-1 Basic block diagram of an oscillator

Transistor oscillators will be used in our experiments. A transistor amplifier with nonlinear i_c - v_{be} characteristic serves as an amplitude limiter. An oscillator with limiter function is also called a self-limiting oscillator when its

loop gain equals 1. Therefore such an oscillator circuit is no need to append other amplitude limiters.

- **Colpitts Oscillator:**

An ac equivalent circuit of Colpitts oscillator is shown in Fig. 1-2. Since the LC parallel-resonant circuit is connected between the base and the collector of transistor, partial feedback voltage is fed to the emitter through the voltage divider constituted by C1 and C2. In this circuit, the R represents the sum of the output resistance of transistor, load resistance and the equivalent resistance of inductor and capacitor. If the frequency is not very high, the internal capacitances of transistor can be neglected and the oscillating frequency of Colpitts oscillator can be calculated by the formula

$$f_o = \frac{1}{2\pi \sqrt{L \left(\frac{C_1 C_2}{C_1 + C_2} \right)}} \quad (\text{Hz}) \quad (1-2)$$

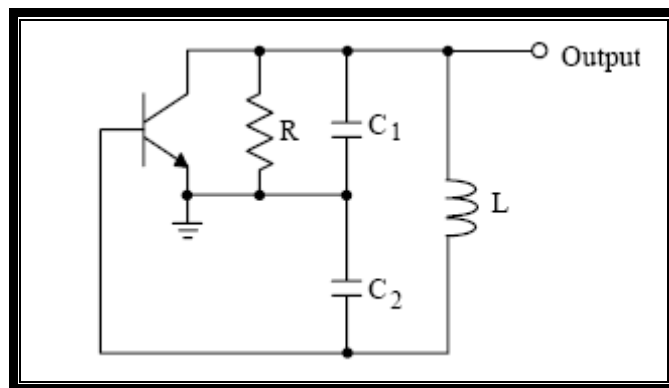


Fig.1-2AC equivalent of Colpitts oscillator

In Colpitts oscillator circuit, the feedback factor β is C_1/C_2 and the voltage gain A is $g_m R$. By Eq. (1-1)

$$A\beta(S) = 1$$

We obtain

$$g_m R \frac{C_1}{C_2} = 1$$

Or

$$g_m R = \frac{C_2}{C_1}$$

For starting oscillation, the loop gain should be at least 1 so that the oscillation condition can be expressed by

$$g_m R \geq \frac{C_2}{C_1}$$

(1-3)

Fig. 1-3 shows a practical Colpitts oscillator circuit. The resistors R_1 , R_2 , R_3 and R_4 determine the bias of transistor. C_1 is the coupling capacitor and C_2 is the bypass capacitor. The frequency of oscillation is determined by the values of C_3 , C_4 and L_1 .

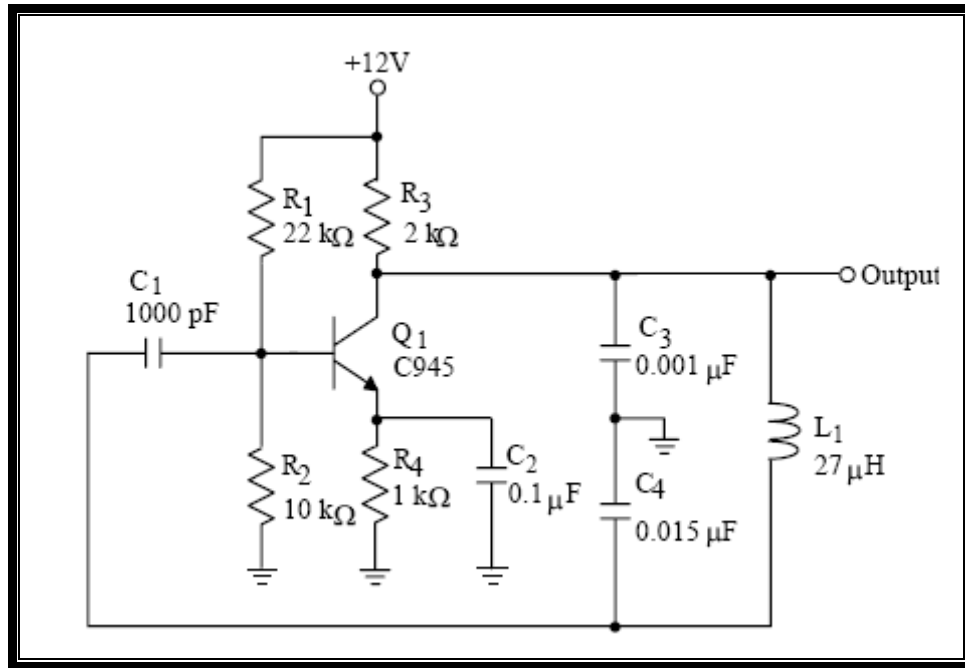


Fig.1-3 Colpitts oscillator circuit

• Hartley Oscillator

The ac equivalent circuit of Hartley oscillator, shown in Fig. 1-4, is similar to the Copitts oscillator. The parallel LC resonant tank is connected between the collector and base; however, two conductors L1 and L2 are used instead of two capacitors. The R represents the sum of transistor's output resistance, load resistance and the equivalent resistance of inductors and capacitor.

If operating frequency is not very high, the spray capacitance of transistor can be neglected and the oscillating frequency is determined by the component values of parallel-resonant circuit and can be calculated by the formula

$$f_0 = \frac{1}{2\pi\sqrt{(L_1 + L_2)C}} \quad (\text{Hz})$$

(1-4)

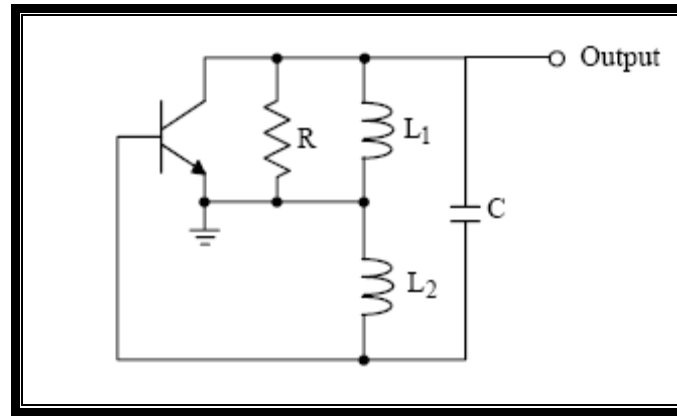


Fig.1-4 A C equivalent of Hartley oscillator

In Hartley oscillator circuit, the feedback factor E is L_2 / L_1 and the voltage gain A is $g_m R$. By Eq. (1-1)

$$A\beta(s) = 1$$

we obtain

$$g_m R \frac{L_2}{L_1} = 1$$

Or

$$g_m R = \frac{L_1}{L_2}$$

For starting oscillation, the loop gain should be at least 1 so that the oscillation condition can be expressed by

$$\beta_m R \geq \frac{L_1}{L_2}$$

(1-5)

Fig. 1-5 shows a practical Hartley oscillator circuit. Resistors R1, R2 and R3 provide the bias for transistor. C1 is the couple capacitor and C2 is the bypass capacitor. C3, L1 and L2 form a resonant circuit for determining the operating frequency.

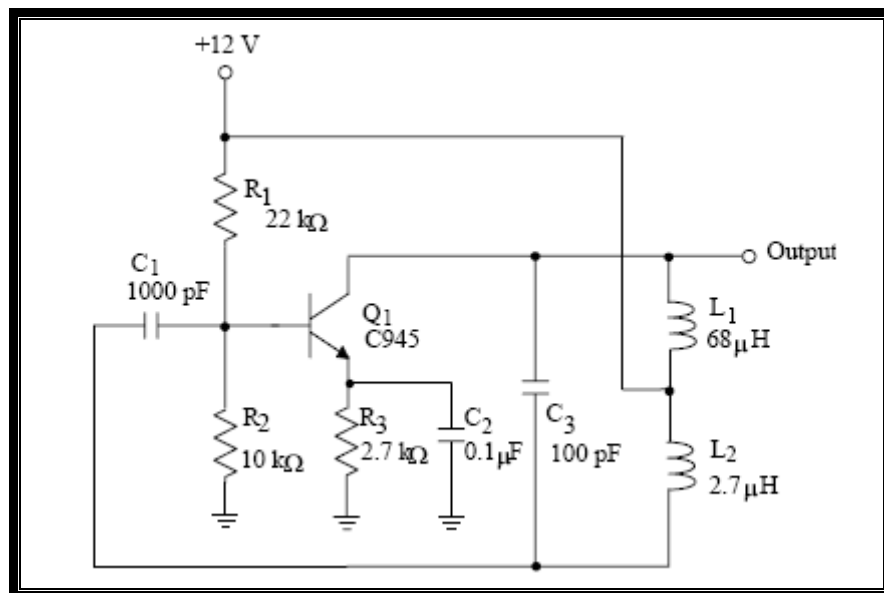


Fig.1-5 Hartley oscillator circuit

Excepting the oscillators mentioned above, there are many other types of oscillators in practical applications: such as RC phase-shift and Wein bridge oscillators for low frequency requirement, Clapp and Pierce oscillators for high stability. In general, Pierce oscillator is the most common use in high-frequency applications due to the use of crystal that has low power consumption and very high and stable Q.

1.4 EQUIPMENT REQUIRED

1. Module KL-92001
2. Module KL-93001
3. Oscilloscope
4. LCR Meter

1.5 TASKS TO STUDY

Experiment 1-1 Colpitts Oscillator:

1. Locate Colpitts Oscillator circuit on Module KL-93001. Insert connect plugs in J1 and J3 to set $C3 = 0.001 \mu\text{F}$, $C4 = 0.015 \mu\text{F}$ and $L1 = 27 \mu\text{H}$.
2. Set the vertical input of oscilloscope to AC position and connect to output terminals (O/P). Observe and record the waveform and frequency in Table 1-1. If the circuit operates improperly, recheck the dc bias of transistor.
3. Remove the connect plugs from J1 and J3. Using the LCR meter, measure the values of C3, C4 and L1 and record the results in Table 1-1, and then calculate the output frequency.
4. Insert connect plugs in J2 and J4 to change C3 to C5(100 pF), C4 to C6(1000 pF), and L1 to L2(2.7 μH). Repeat steps 2 and 3.

Experiment 1-2 Hartley Oscillator:

1. Locate Hartley Oscillator circuit on Module KL-93001. Insert connect plugs in J1 and J3 to set $L1 = 68 \mu\text{H}$, $L2 = 2.7 \mu\text{H}$, and $C3 = 100 \text{ pF}$.
2. Set the vertical input of oscilloscope to AC position and connect to output terminals (O/P). Observe and record the waveform and frequency in Table 1-2. If the circuit operates improperly, recheck the dc bias of transistor.
3. Remove the connect plugs from J1 and J3. Using the LCR meter, measure the values of C3, C4 and L1 and record the results in Table 1-2, and then

calculate the output frequency.

4. Insert connect plugs in J2 and J4 to change C3 to C4(150 pF), L1 to L3(47 μ H), and L2 to L4(470 μ H). Repeat steps 2 and 3.

Table 1-1

	C ₃	C ₄	L ₁	Output Waveform
Nominal Value	0.001 μ F	0.015 μ F	27 μ H	
Measured Value				
				Calculated $f_o =$ Measured $f_o =$
Nominal Value	100 pF	1000 pF	2.7 μ H	
Measured Value				
				Calculated $f_o =$ Measured $f_o =$

Table 1-2

	L_1	L_2	C_3	Output Waveform
Nominal Value	68 μH	2.7 μH	100 pF	Calculated $f_o =$ Measured $f_o =$
Measured Value				
Nominal Value	470 μH	47 μH	150 pF	Calculated $f_o =$ Measured $f_o =$
Measured Value				

1.5 QUESTIONS:

- 1.** In experiments 1-1 and 1-2, do the calculated and measured values of output signal agree? Explain.
- 2.** What is the function of each capacitor or inductor in Colpitts oscillator circuit shown in Fig. 1-3
- 3.** Determine the values of C_3 , L_1 and L_2 of Hartley oscillator shown in Fig.1-5 for the oscillating frequency of 5MHz.
- 4.** When the operating frequency is in radio-frequency range, why we must pay attention to the layout of circuit and the length of wire?