BENHA UNIVERSITY
FACULTY OF ENGINEERING AT SHOUBRA

ECE-312
Electronic Circuits (A)

Lecture # 12
Oscillators (LC Circuits)

Instructor:
Dr. Ahmad El-Banna

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Agenda

- The Colpitts Oscillator
- The Clapp Oscillator
- The Hartley Oscillator
- The Armstrong Oscillator
- Crystal-Controlled Oscillators

THE COLPITTS OSCILLATOR

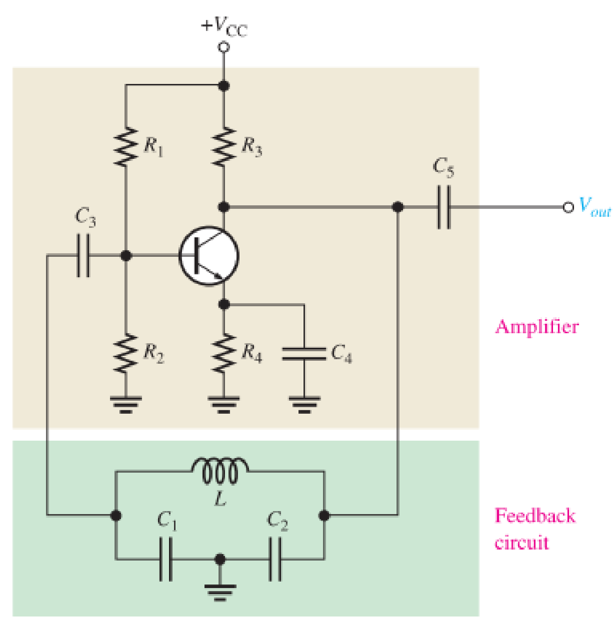
Colpitts Oscillator

- LC feedback elements are normally used in oscillators that require higher frequencies of oscillation.
- Also, because of the frequency limitation (lower unity-gain frequency) of most op-amps, discrete transistors (BJT or FET) are often used as the gain element in LC oscillators.

- Colpitts oscillator uses an LC circuit in the feedback loop to provide the necessary phase shift and to act as a resonant filter that passes only the desired frequency of oscillation.

$$f_r \cong \frac{1}{2\pi\sqrt{LC_T}}$$

$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$



Conditions for Oscillation and Start-Up

$$B = \frac{V_f}{V_{out}} \cong \frac{IX_{C1}}{IX_{C2}} = \frac{X_{C1}}{X_{C2}} = \frac{1/(2\pi f_r C_1)}{1/(2\pi f_r C_2)}$$

$$B = \frac{C_2}{C_1} \qquad A_v = \frac{C_1}{C_2}$$

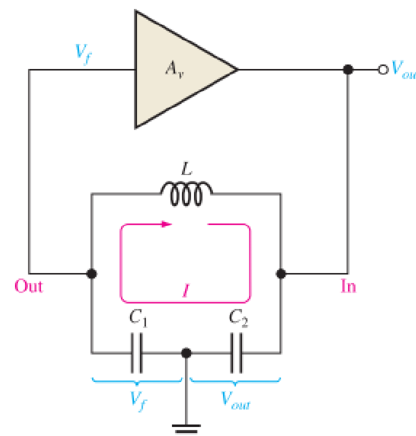


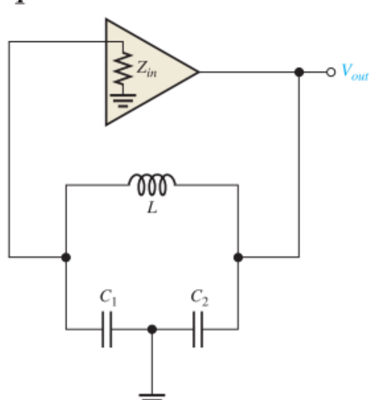
FIGURE 16–17

The attenuation of the tank circuit is the output of the tank (V_f) divided by the input to the tank (V_{out}). $B = V_f/V_{out} = C_2/C_1$. For $A_vB > 1$, A_v must be greater than C_1/C_2.

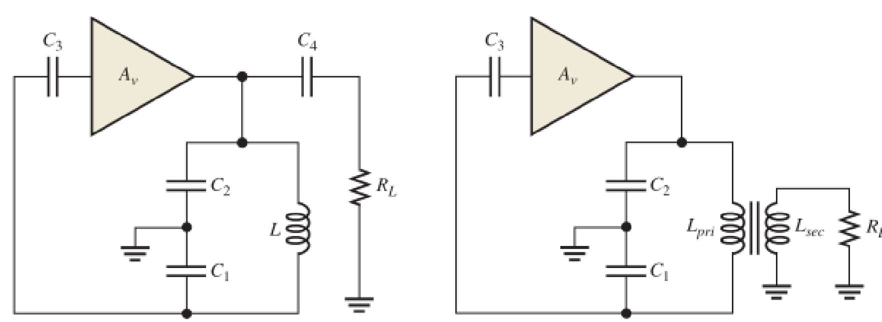
- Loading of the Feedback Circuit Affects the Frequency of Oscillation

→ Z_{in} of the amplifier loads the feed-back circuit and lowers its Q, thus lowering the resonant frequency.

$$f_r = \frac{1}{2\pi\sqrt{LC_T}}\sqrt{\frac{Q^2}{Q^2 + 1}}$$



→ A FET can be used in place of a BJT, as shown in Figure 16–19, to minimize the loading effect of the transistor's input impedance.



(a) A load capacitively coupled to oscillator output can reduce circuit Q and f_r.

(b) Transformer coupling of load can reduce loading effect by impedance transformation.

FIGURE 16–20

Oscillator loading.

THE CLAPP OSCILLATOR

Clapp Oscillator

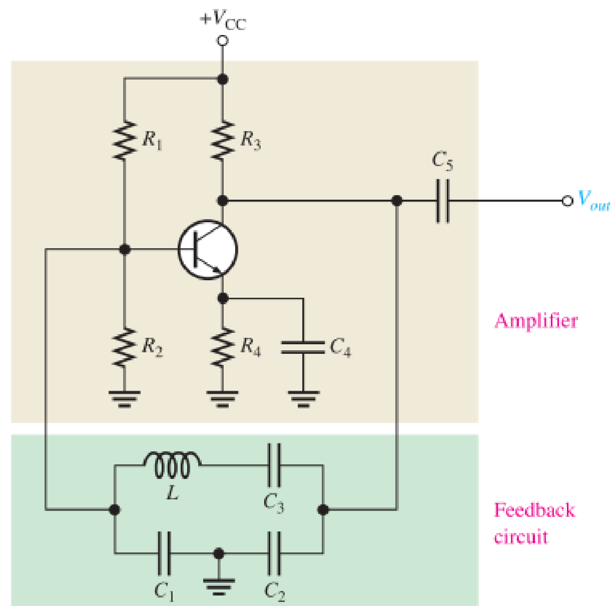
- The Clapp oscillator is a variation of the Colpitts with addition of C_3.

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

$(Q > 10) \longrightarrow \quad f_r \cong \frac{1}{2\pi\sqrt{LC_T}}$

If C_3 is much smaller than C_1 and C_2,

$$(f_r \cong 1/(2\pi\sqrt{LC_3})).$$



- Since C_1 and C_2 are both connected to ground at one end, the junction capacitance of the transistor and other stray capacitances appear in parallel with C_1 and C_2 to ground, altering their effective values.
- C_3 is not affected, however, and thus provides a more accurate and stable frequency of oscillation.

THE HARTLEY OSCILLATOR

Hartley Oscillator

- The Hartley oscillator is similar to the Colpitts except that the feedback circuit consists of two series inductors and a parallel capacitor

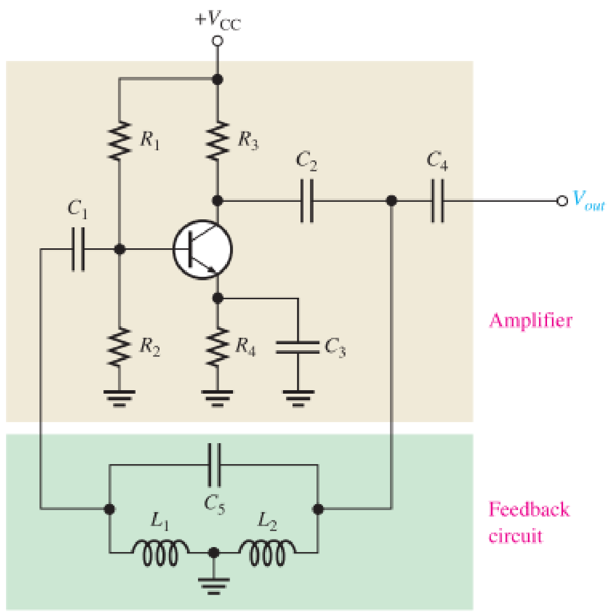
$Q > 10$

$$f_r \cong \frac{1}{2\pi\sqrt{L_T C}}$$

$$L_T = L_1 + L_2.$$

$$B \cong \frac{L_1}{L_2}$$

$$A_v \cong \frac{L_2}{L_1}$$



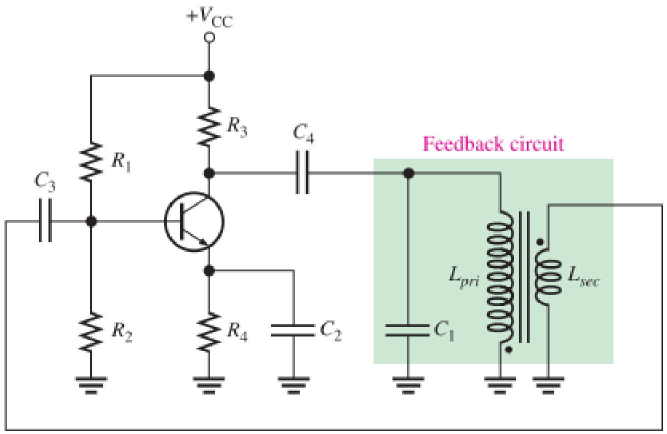
- Loading of the tank circuit has the same effect in the Hartley as in the Colpitts; that is, the Q is decreased and thus f_r decreases.

THE ARMSTRONG OSCILLATOR

Armstrong Oscillator

- This type of LC feedback oscillator uses transformer coupling to feed back a portion of the signal voltage.
- It is sometimes called a “tickler” oscillator in reference to the transformer secondary or “tickler coil” that provides the feedback to keep the oscillation going.
- The Armstrong is less common than the Colpitts, Clapp, and Hartley, mainly because of the disadvantage of transformer size and cost.

$$f_r = \frac{1}{2\pi\sqrt{L_{pri}C_1}}$$



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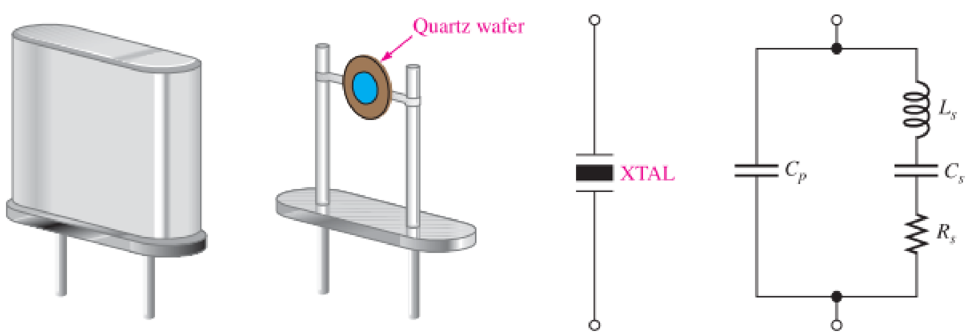
CRYSTAL-CONTROLLED OSCILLATORS

Crystal-Controlled Oscillators

- The most stable and accurate type of feedback oscillator uses a **piezoelectric crystal** in the feedback loop to control the frequency.
- Quartz is one type of crystalline substance found in nature that exhibits a property called the piezoelectric effect.
- When a changing mechanical stress is applied across the crystal to cause it to vibrate, a voltage develops at the frequency of mechanical vibration.
- Conversely, when an ac voltage is applied across the crystal, it vibrates at the frequency of the applied voltage.
- The greatest vibration occurs at the crystal's natural resonant frequency, which is determined by the physical dimensions and by the way the crystal is cut.



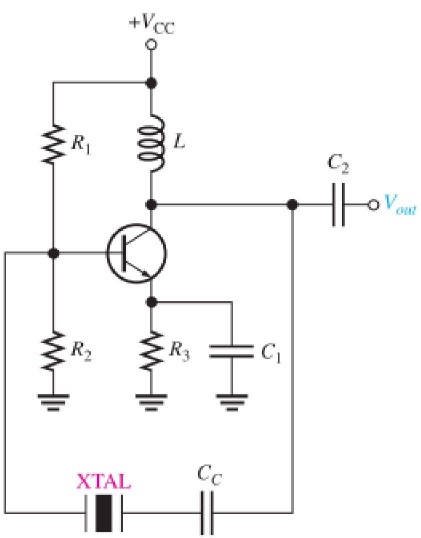
(a) Typical packaged crystal (b) Basic construction (without case) (c) Symbol (d) Electrical equivalent

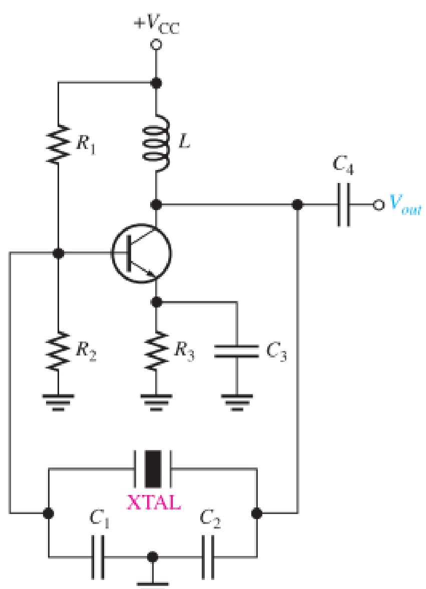
Basic crystal oscillators

- A great advantage of the crystal is that it exhibits a very high Q.
- The impedance of the crystal is minimum at the series resonant frequency, thus providing maximum feedback.
- a crystal is used as a series resonant tank circuit.
- The crystal tuning capacitor, C_c is used to "fine tune" the oscillator frequency by "pulling" the resonant frequency of the crystal slightly up or down.

Modes:

- Piezoelectric crystals can oscillate in either of two modes—fundamental or overtone.
- The **fundamental** frequency of a crystal is the lowest frequency at which it is naturally resonant.
- The fundamental frequency depends on the crystal's mechanical dimensions, type of cut, .. etc.
- Usually it's less than 20 MHz.
- **Overtones** are approximate integer multiples of the fundamental frequency.
- Many crystal oscillators are available in integrated circuit packages.





- For more details, refer to:
  - Chapter 16 at T. Floyd, **Electronic Devices**,9th edition.
  - http://www.electronics-tutorials.ws/oscillator/rc_oscillator.html
  - http://www.electronics-tutorials.ws/oscillator/oscillators.html
- The lecture is available online at:
  - http://bu.edu.eg/staff/ahmad.elbanna-courses/11966
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