Huazhong University
of Science & Technology

Electronic Circuit of Communications

School of Electronic Information
and Commnications

Jiaqing Huang

Oscillators Classification

- Feedback
  - RC Oscillator
  - LC Oscillator
    - Coupling Oscillator
      - Base-based
      - Emitter-based
      - Collector-based
    - LC Oscillator
      - Inductor Feedback (Hartley)
      - Capacitor Feedback(Coplitts)
      - Series Improved Capacitor(Clapp)
      - Parallel Improved Capacitor(Selier)
  - Crystal Oscillator
    - Capacitor Feedback Crystal
      - Pierce
      - Overtone Crystal
      - Series Crystal
    - Inductor Feedback Crystal
      - Series Crystal (Example)
      - Miller
- Negative-Resistance

Coupling Oscillators

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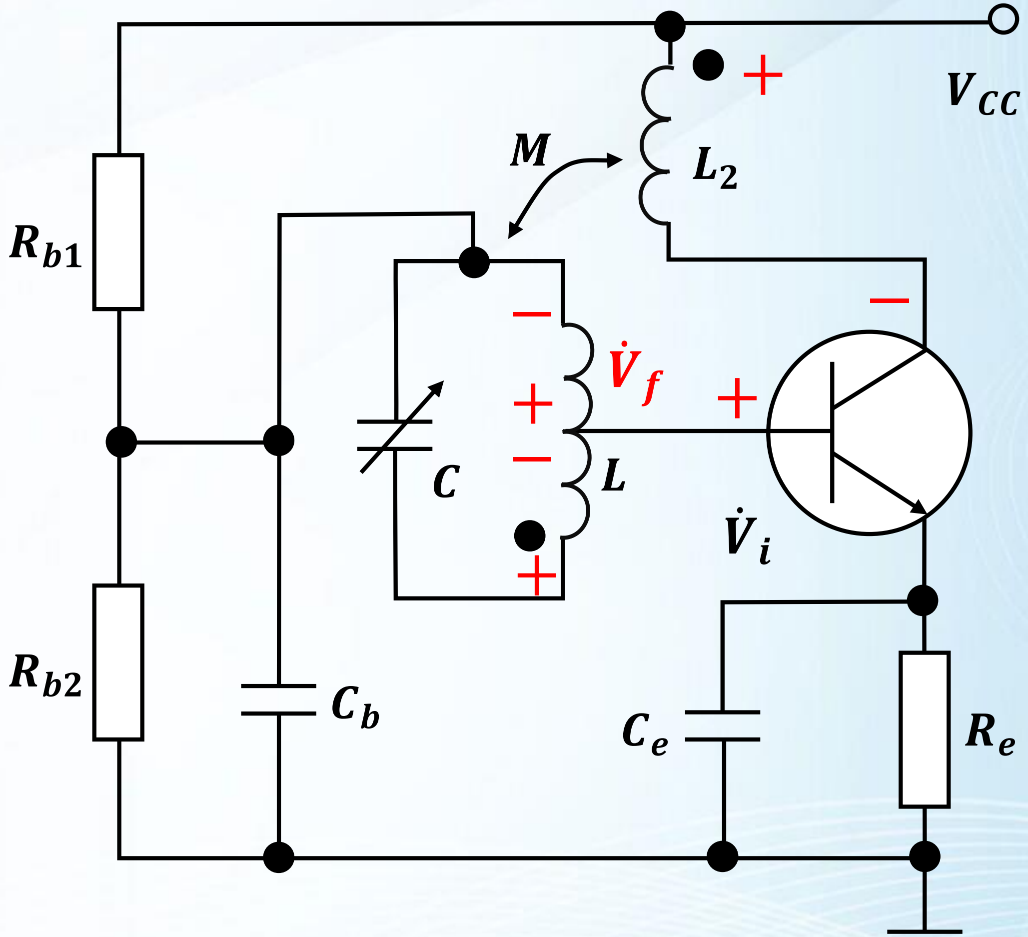
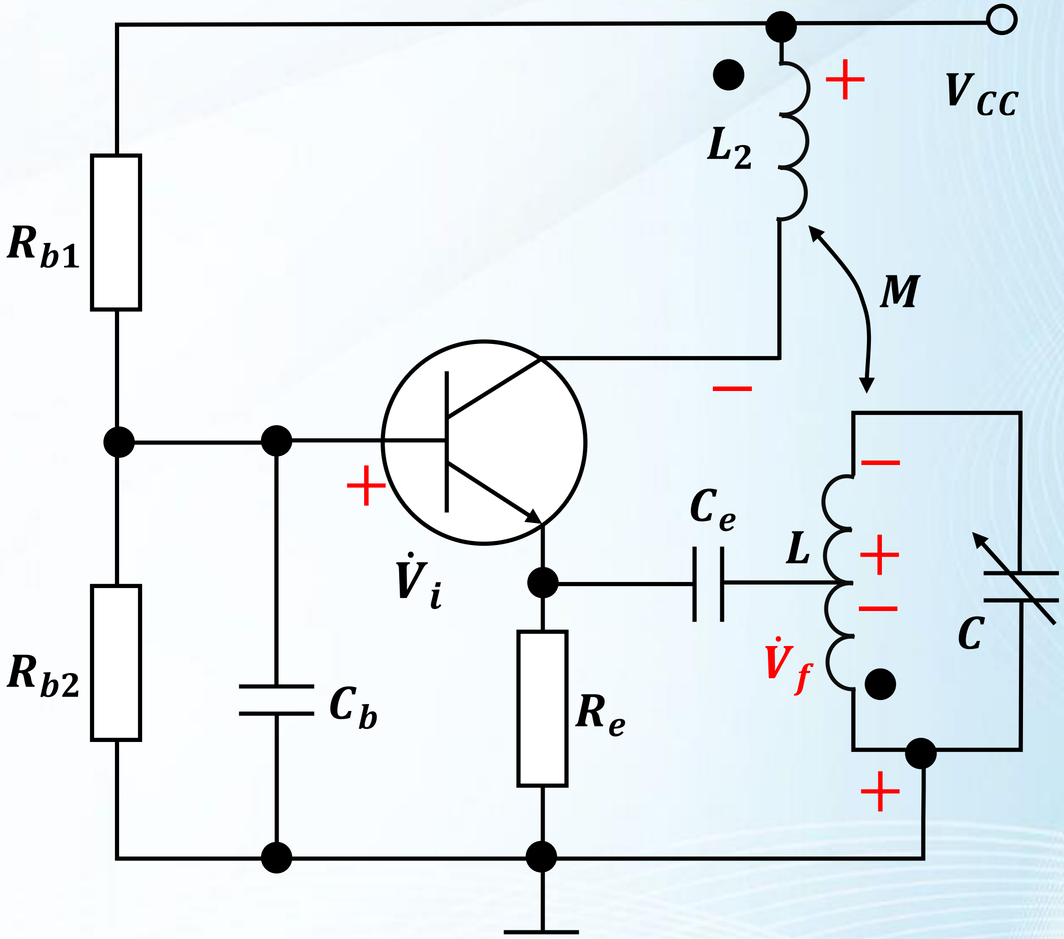
Coupling Oscillator (Base)

- R_i of b-e ↓ ⇒ Q ↓
- Tap-connected between Transistor & LC Oscillator
- Key: Determine $\dot{V}_f$ ($\dot{V}_f = \dot{V}_i$)



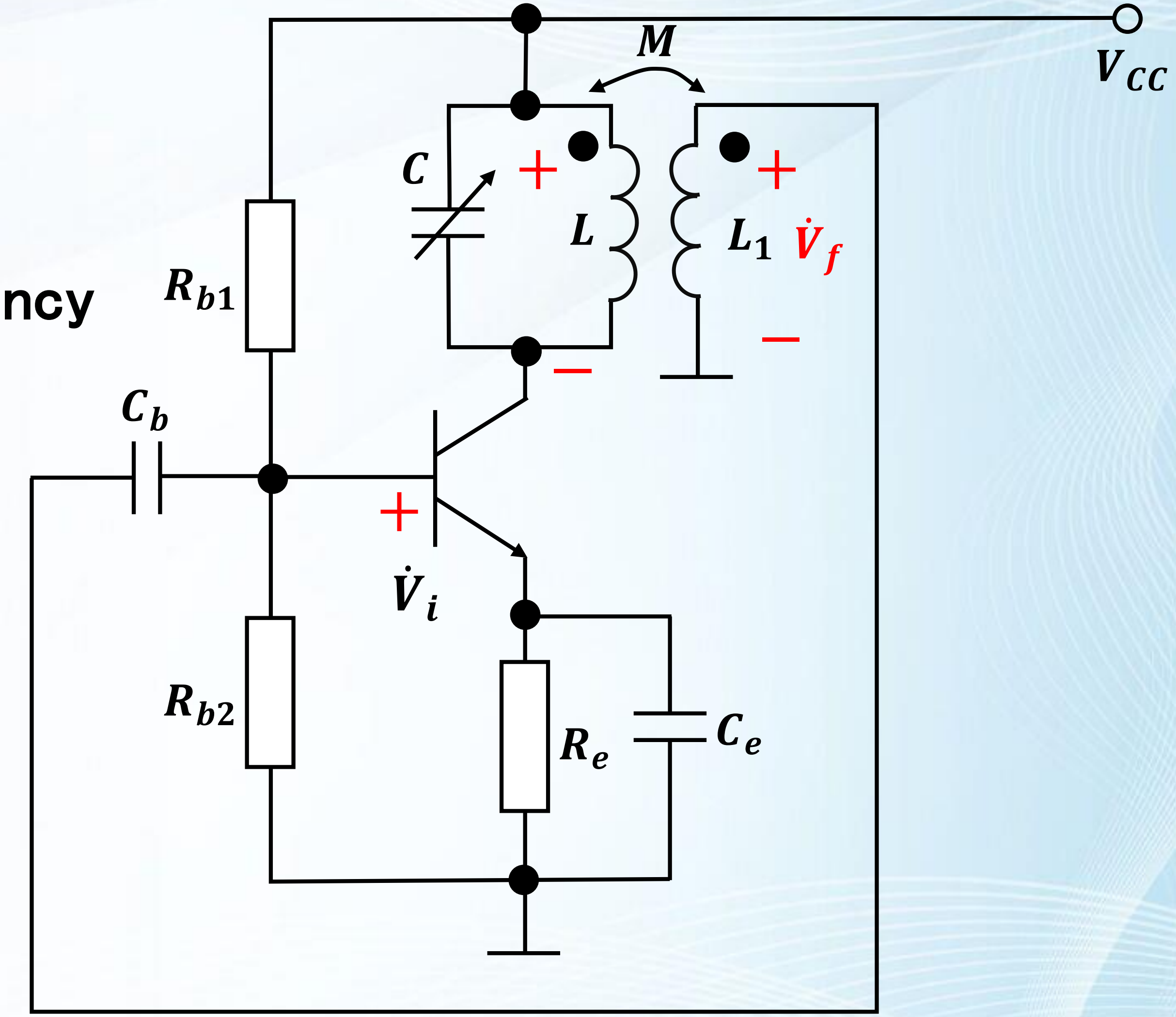
Coupling Oscillator (Emitter)



- R_i of b-e ↓ ⇒ Q ↓
- Tap-connected between Transistor & LC Oscillator
- Key: Determine $\dot{V}_f$ ($\dot{V}_f = \dot{V}_i$)

Coupling Oscillator (Collector)

- Stable output when radio frequency



- Key: Determine $\dot{V}_f$ ($\dot{V}_f = \dot{V}_i$)

Coupling Oscillator

- Oscillation Frequency：$f_0 = \frac{1}{2\pi\sqrt{LC}}$

- Advantage：
  - Adjust F（by M）$\nRightarrow f_0$

- Disadvantage：
  - Upper-bound frequency can not be high

    Reason：Distributed capaciance of transformer, unstable

Inductor Feedback Oscillators

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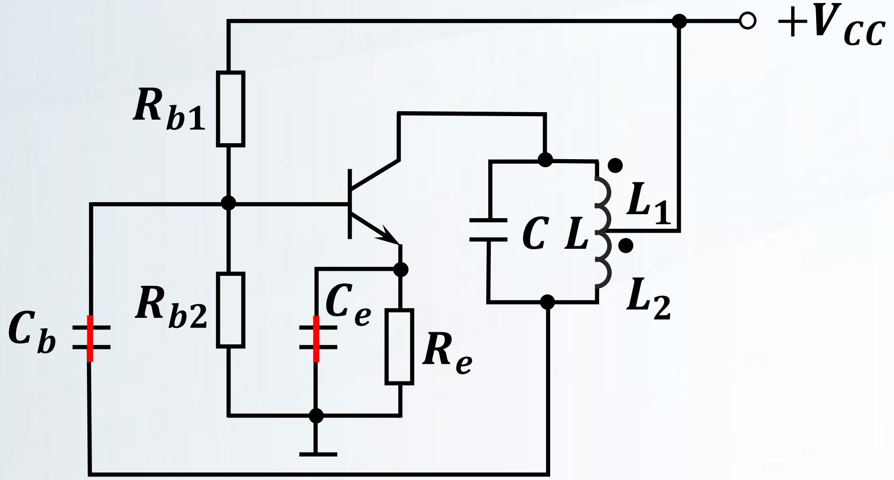
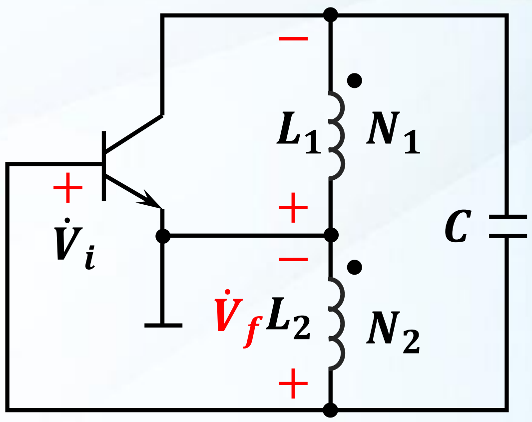
Inductor Feedback Oscillator (Hartley)



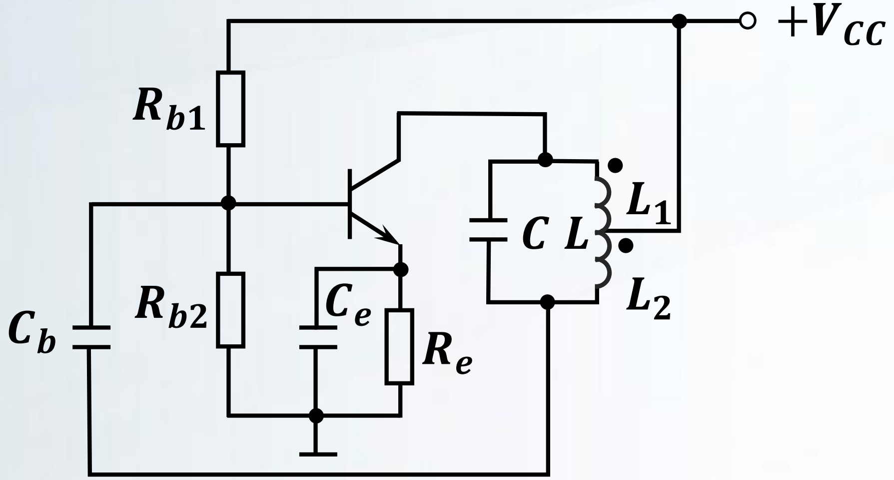
Inductor Feedback Oscillator



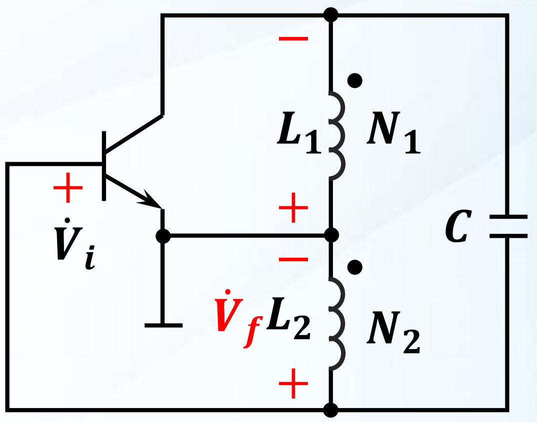
Equivalent Circuit

- RF Equivalent Circuit Principle
  - Resistor Open: R_{b1}, R_{b2}, R_e
  - Inductor Open: No RF Choke
  - Capacitor Short:
    - Bypass Capacitor: C_e
    - Coupling Capacitor: C_b
    - Power Filter Capacitor: None

Inductor Feedback Oscillator (Hartley)



Inductor Feedback Oscillator

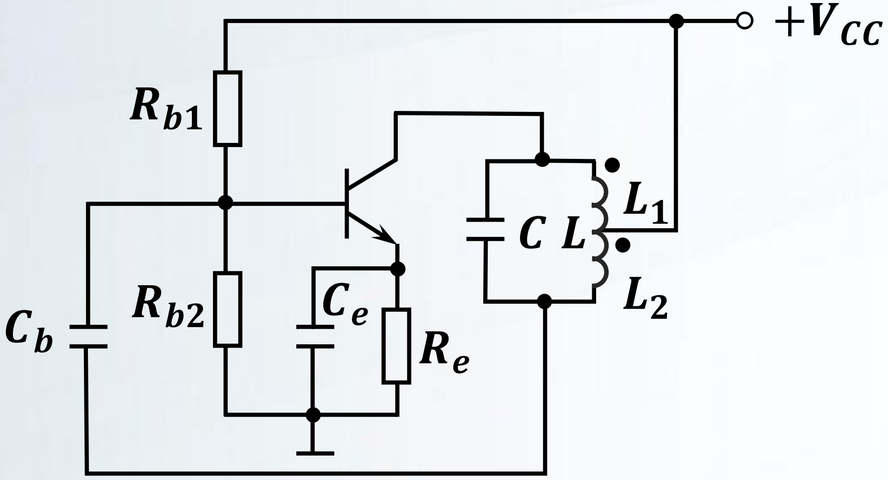


Equivalent Circuit

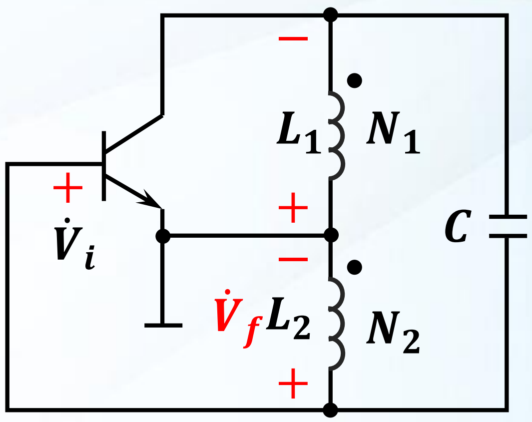
Oscillation Frequency: $f_0 \approx \dfrac{1}{2\pi\sqrt{LC}}$ $\quad L = L_1 + L_2 + 2M$

Feedback Coefficient: $F = \dfrac{L_2 + M}{L_1 + M}$

Inductor Feedback Oscillator (Hartley)



Inductor Feedback Oscillator



Equivalent Circuit

Advantage:

1) M between L_1 & L_2 is strong to start oscillation easily
2) Adjust frequency by C conveniently
3) $C \nRightarrow F$

Disadvantage:

1) Distorted oscillation waveform
   Reason: high feedback/impedence of Inductors

2) Upper-bound frequency is not high
   Reason: distributed capacitance

Capacitor Feedback Oscillators

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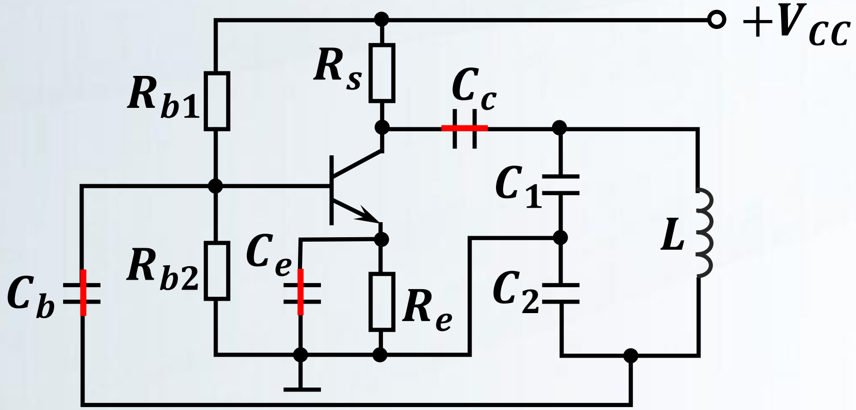
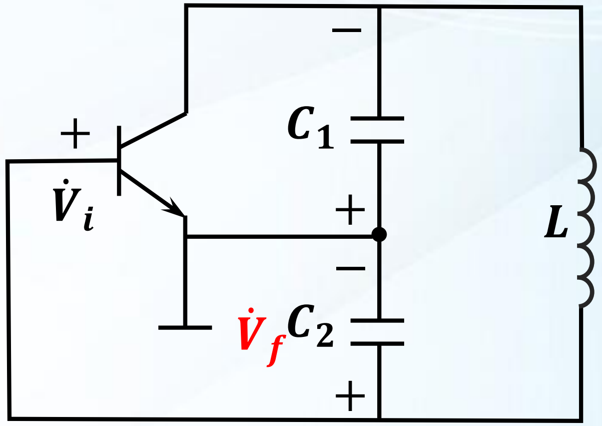
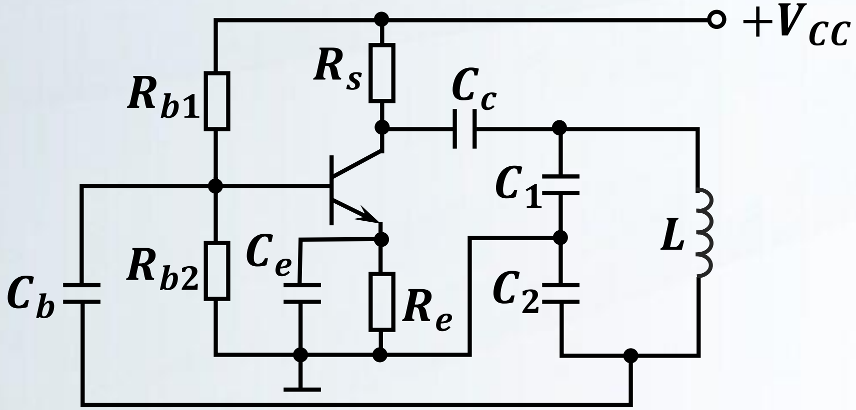
Capacitor Feedback Oscillator(Coplitts)

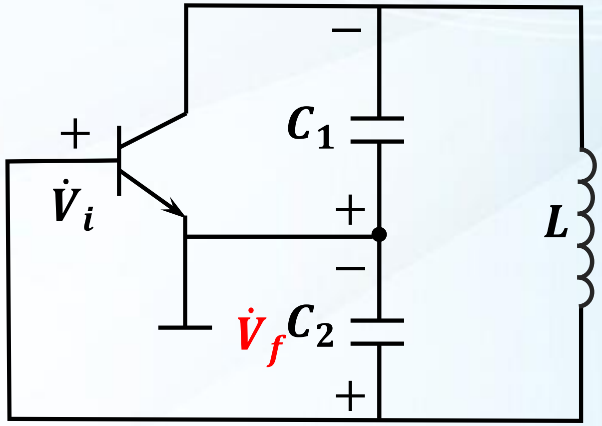




- RF Equivalent Circuit Principle
  - Resistor Open: R_{b1}、R_{b2}、R_e、R_s
  - Inductor Open: No RF Choke
  - Capacitor Short:
    - Bypass Capacitor: C_e
    - Coupling Capacitor: C_b、C_c
    - Power Filter Capacitor: None

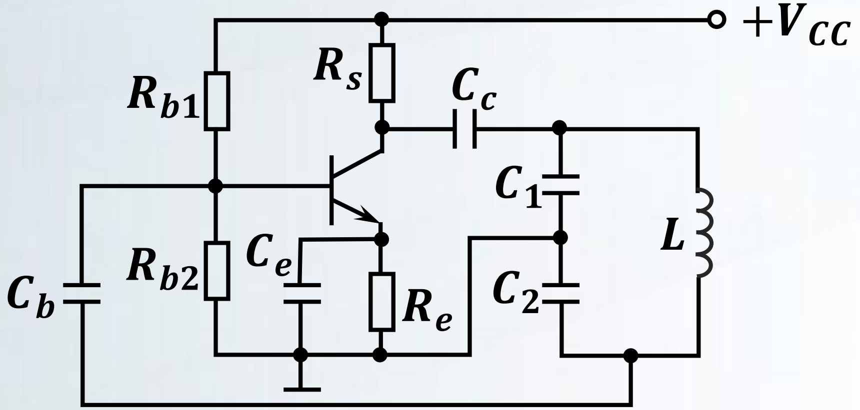
Capacitor Feedback Oscillator(Coplitts)

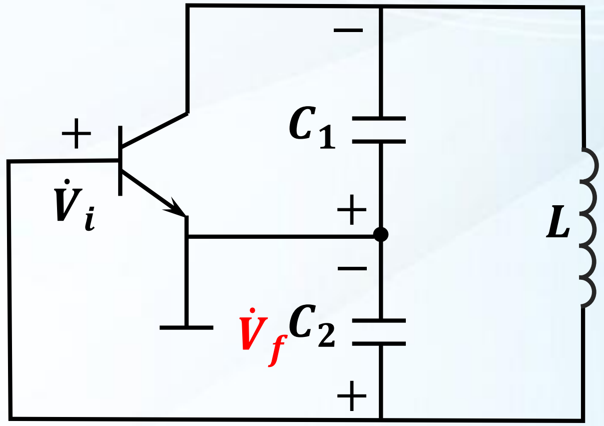




- **Advantage:**
  - Better oscillation waveform
  - Better stability
  - Higher frequency

Capacitor Feedback Oscillator(Coplitts)





Frequency $f_0 \approx \dfrac{1}{2\pi\sqrt{LC}}$ $\quad \boxed{C = \dfrac{C_1 C_2}{C_1 + C_2}}$

Feedback $\quad F = \dfrac{C_1}{C_2}$

- **Disadvantage:**
  - Adjust f_0 by C_1 or $C_2 \Rightarrow F$ (Solution: L // a capacitor)
  - $F \Rightarrow f_0$

Series Improved Capacitor Feedback Oscillators

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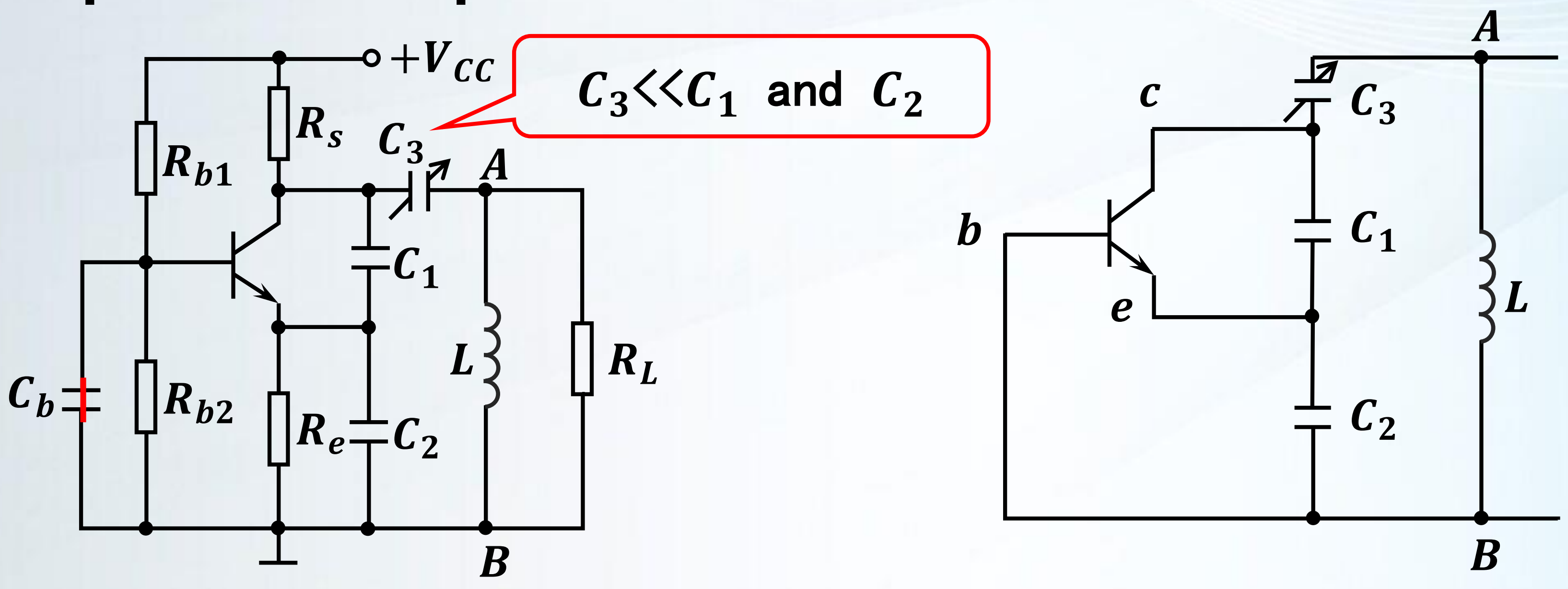
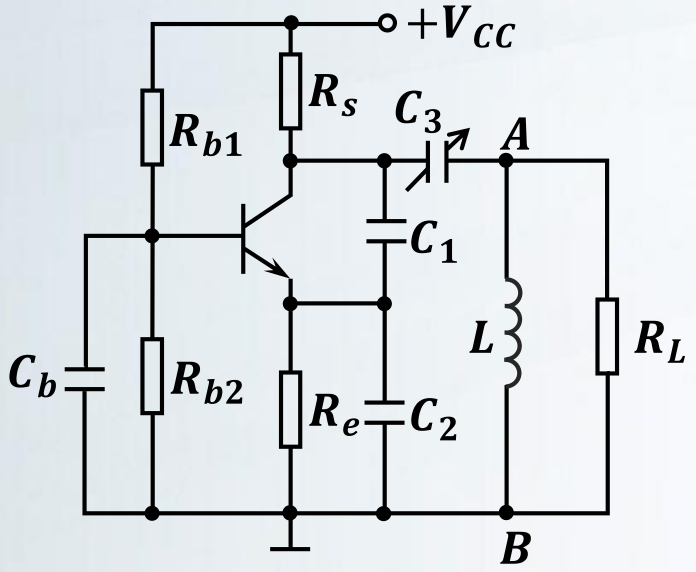
    - Overtone Crystal
    - Series Crystal
    - Series Crystal (Example)
    - Miller
    - Capacitor Feedback Crystal: Pierce, Overtone Crystal, Series Crystal
    - Inductor Feedback Crystal: Series Crystal (Example), Miller
- Negative-Resistance

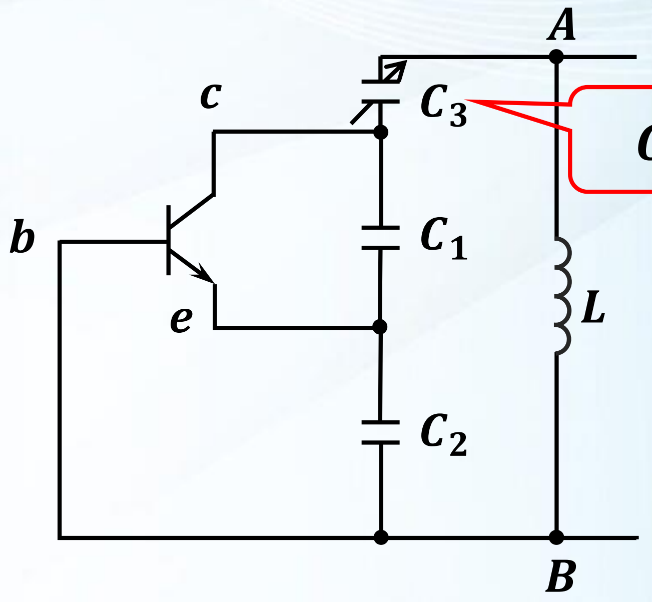
Series Improved Capacitor Feedback Oscillator(Clapp)



- Equivalent Circuit Principle
  - Resistor Open: R_{b1}、R_{b2}、R_e、R_s、R_L
  - Inductor Open: No RF Choke
  - Capacitor Short:
    - Bypass Capacitor: C_b
    - Coupling Capacitor: None
    - Power Filter Capacitor: None

Series Improved Capacitor Feedback Oscillator(Clapp)





C_3<<C_1 and C_2

$$\begin{cases} \text{Frequency} \quad f_0 \approx \dfrac{1}{2\pi\sqrt{LC}} \approx \dfrac{1}{2\pi\sqrt{LC_3}} \\ \text{Feedback} \quad F = \dfrac{C_1}{C_2} \end{cases}$$

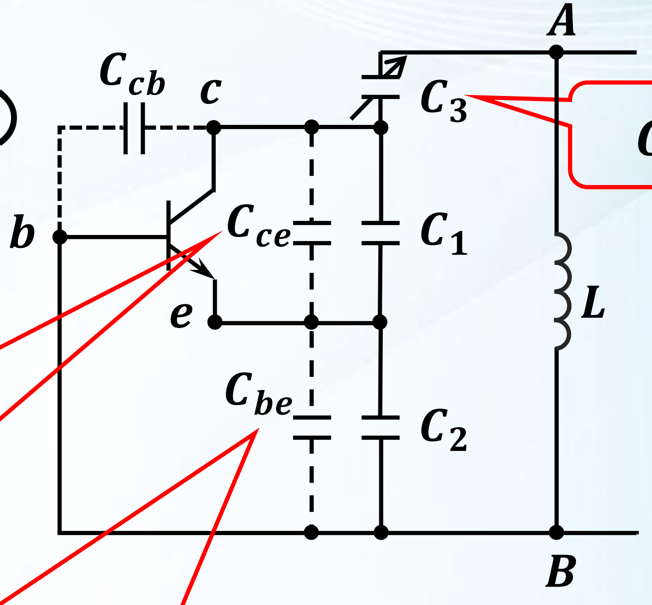
Total $C = C_1 + C_2 + C_3$

$$C = \frac{C_1C_2C_3}{C_1C_2 + C_2C_3 + C_1C_3} = \frac{C_3}{1 + \frac{C_3}{C_1} + \frac{C_3}{C_2}} \approx C_3$$

$$f_0 \nLeftrightarrow F$$

Series Improved Capacitor Feedback Oscillator(Clapp)

- Stability? (input output capacitance)
  - Clue: tap-connected



$C_3 \ll C_1$ and C_2

Access Factor: $p'_{ce} \approx \frac{C_3}{C_1} \ll 1$

Equivalent impedance of C_{ce} ↓↓

Stability↑↑

Access Factor: $p'_{be} \approx \frac{C_3}{C_2} \ll 1$

Equivalent impedance of C_{be} ↓↓

Stability↑↑

Better frequency stability

Series Improved Capacitor Feedback Oscillator(Clapp)

Key: $C_3 \ll C_1$ and C_2

- **Advantage**
  - Loose coupling (C_{ce}、C_{be} with small access factor)
  - Adjust F by C_1、C_2 $\nRightarrow$ f_0
  - Adjust f_0 by C_3 $\nRightarrow$ F

- **Disadvantage**
  - Narrow wave range (Cover factor$=\frac{f_{0max}}{f_{0min}}=1.2\sim1.3$)
  - Output amplitudes vary with frequencies

Parallel Improved Capacitor Feedback Oscillators

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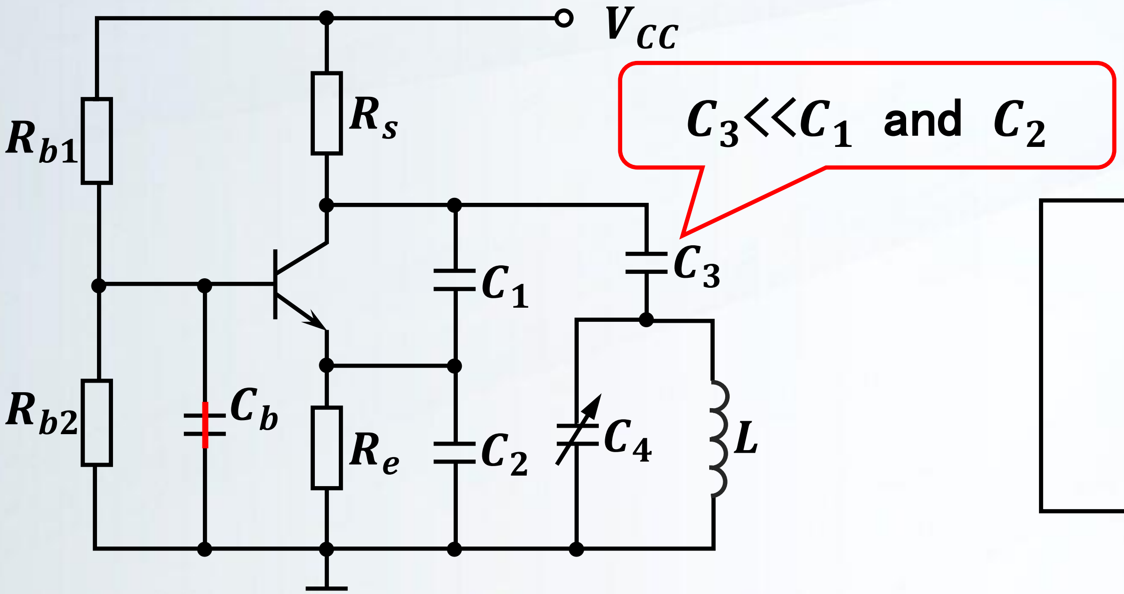
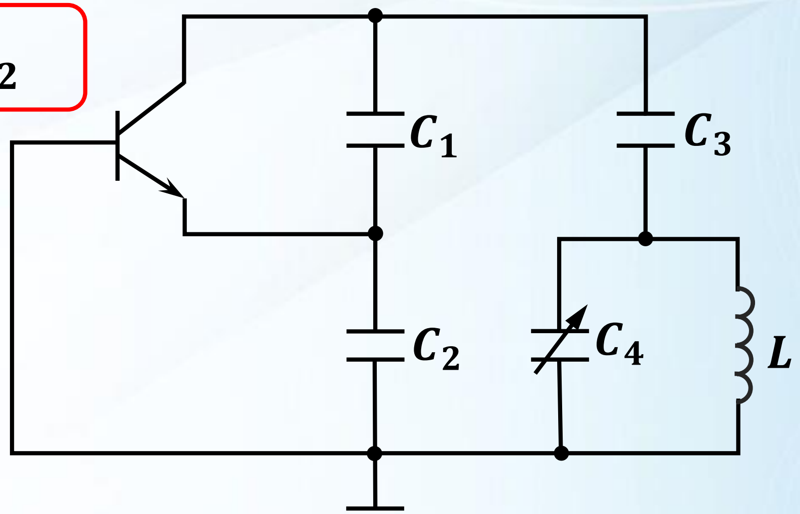
      - Miller
- Negative-Resistance

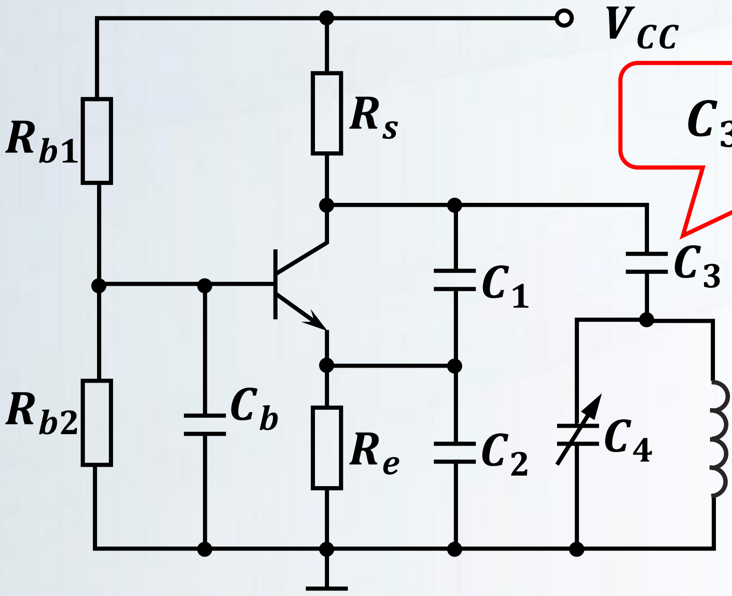
Parallel Improved Capacitor Feedback Oscillator(Seiler)



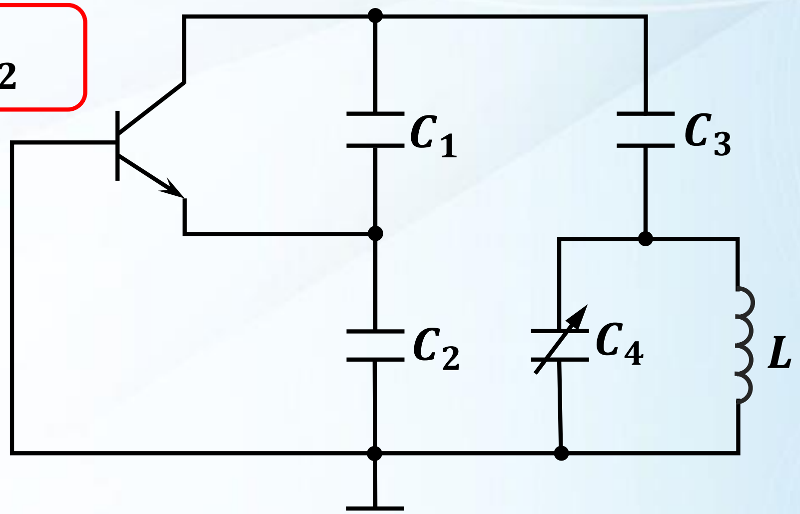


- RF Equivalent Circuit Principle
  - Resistor Open: R_{b1}、R_{b2}、R_e、R_s
  - Inductor Open: No RF Choke
  - Capacitor Short:
    - Bypass Capacitor: C_b
    - Coupling Capacitor: None
    - Power Filter Capacitor: None

Parallel Improved Capacitor Feedback Oscillator(Seiler)



$C_3 << C_1$ and C_2



Frequency $\quad f_0 \approx \dfrac{1}{2\pi\sqrt{LC}} \approx \dfrac{1}{2\pi\sqrt{L(C_3 + C_4)}}$

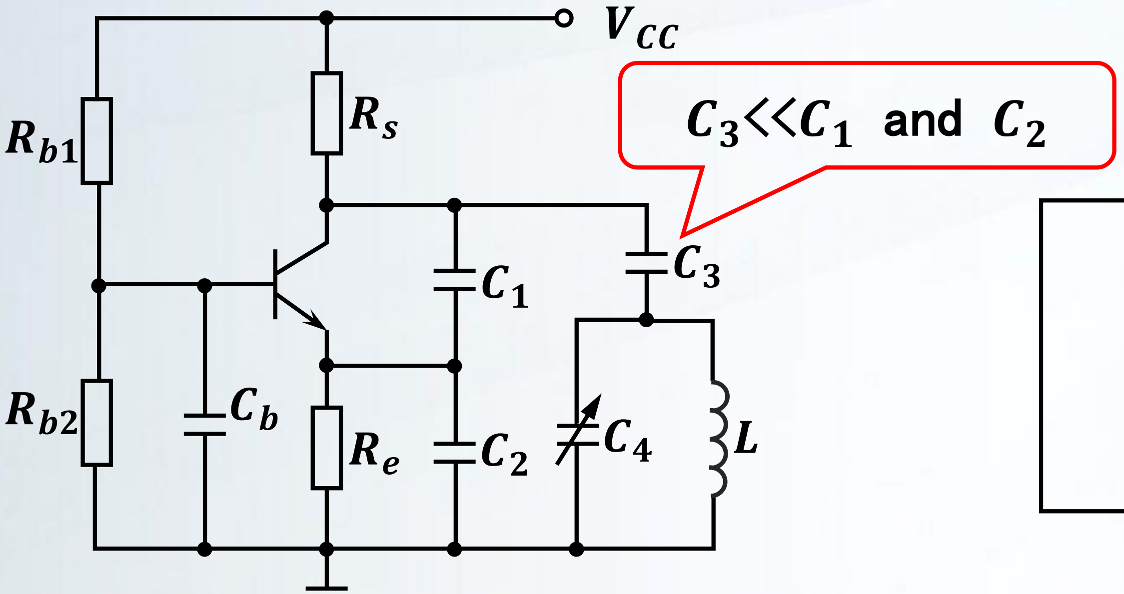
Feedback $\quad F = \dfrac{C_1}{C_2}$

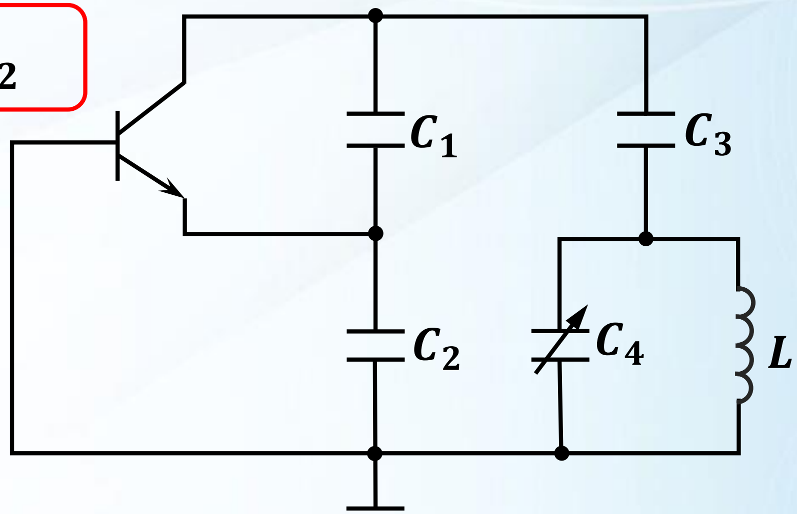
$f_0 \nLeftrightarrow F$

Total $C = (C_1 + C_2 + C_3) // C_4$

$$C = \frac{C_1 C_2 C_3}{C_1 C_2 + C_2 C_3 + C_1 C_3} + C_4 \approx C_3 + C_4$$

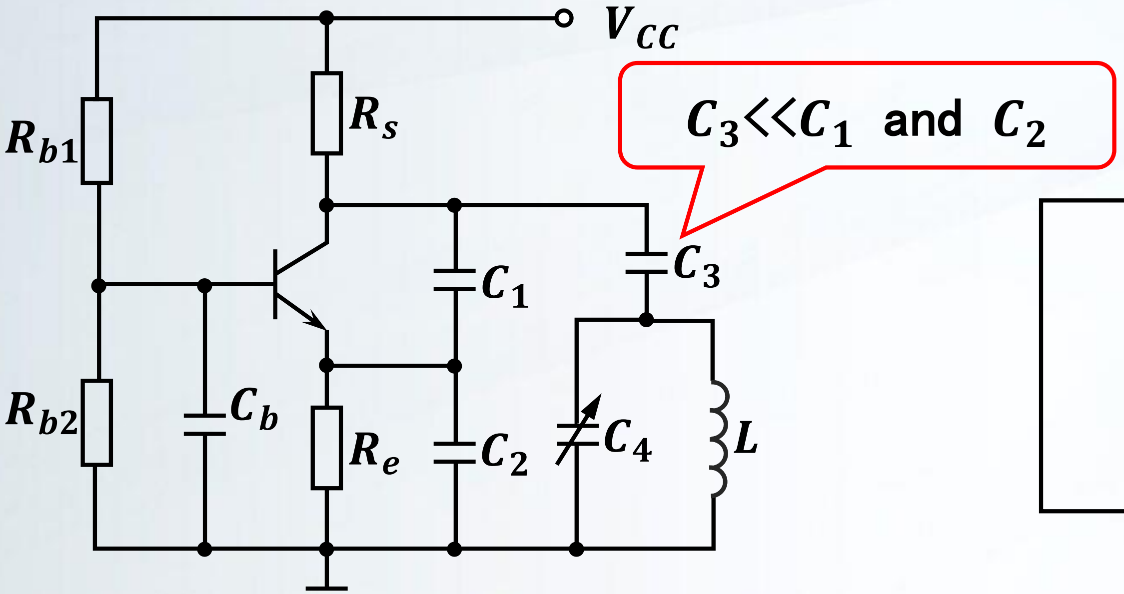
Parallel Improved Capacitor Feedback Oscillator (Seiler)

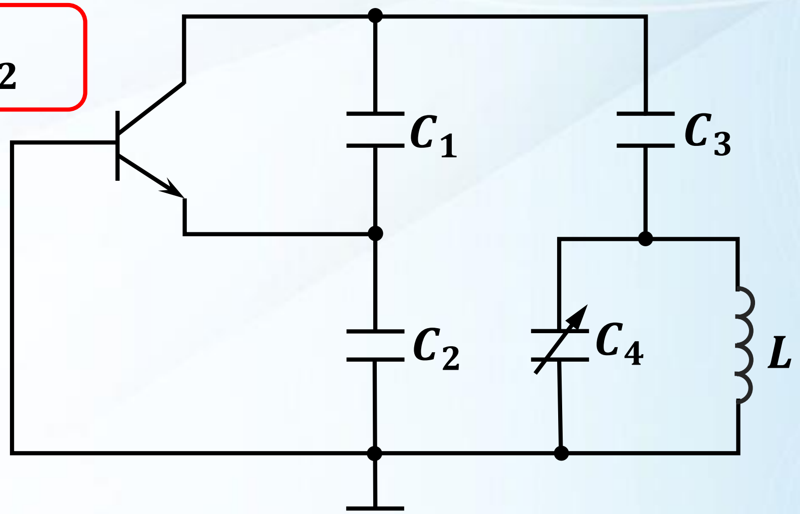




- Selection of C_3
  - C_3 too small, loosely coupling, not easy to start
  - C_3 too big, stability ↓
  - In general, decrease C_3 as much as possible when startup condition is satisfied

Parallel Improved Capacitor Feedback Oscillator(Seiler)





- **Advantage**
  - Wide wave range (Cover factor$=\frac{f_{0max}}{f_{0min}}=1.6\sim1.8$)
  - Output amplitudes are stable

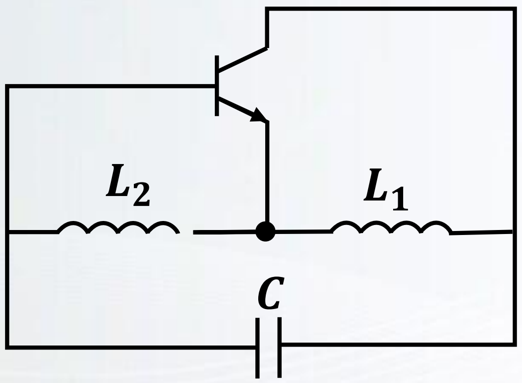
Criteria of LC Composition

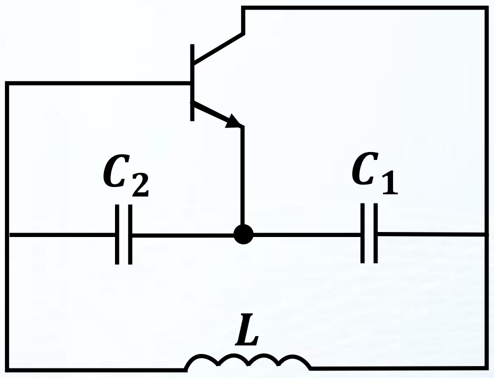
Criteria of LC Oscillator Composition

- General case?

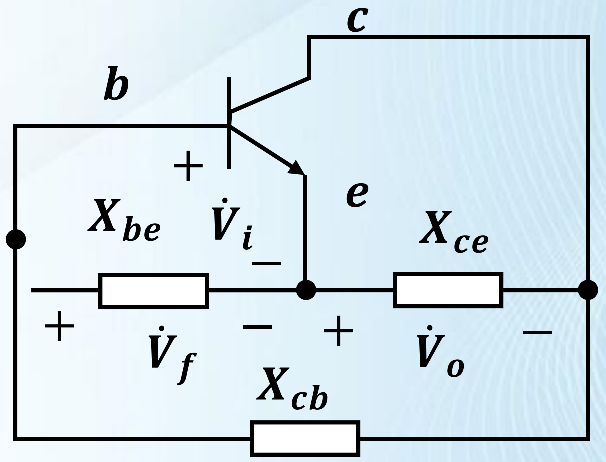
① $c-e$ and $b-e$ are same

② $b-c$ is different





Criteria of LC Oscillator Composition



- Suppose 3 reactance

$$Z_1 = jX_{ce} \qquad Z_2 = jX_{be} \qquad Z_3 = jX_{cb}$$

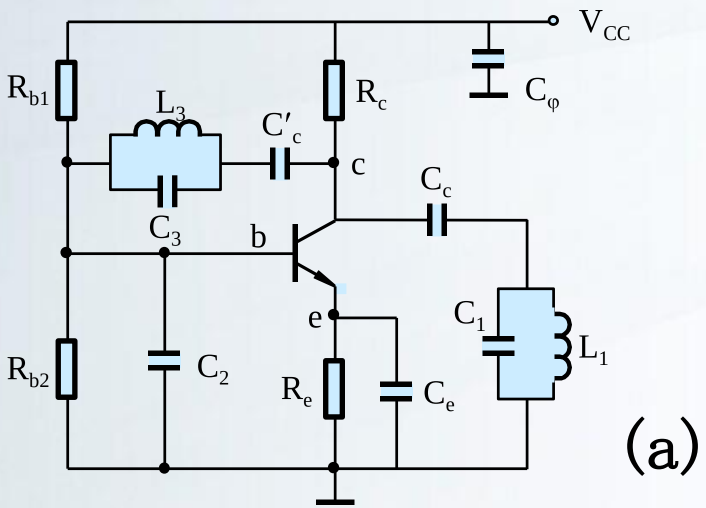
- Purely resistive when resonant

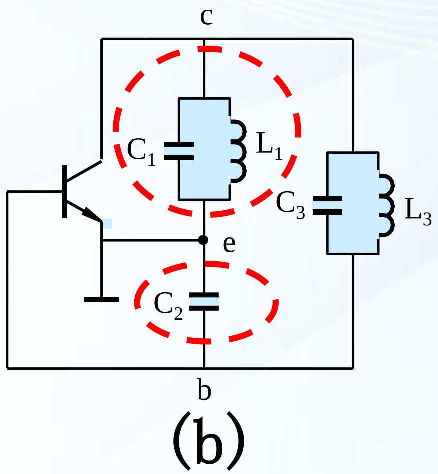
$$X_{be} + X_{ce} + X_{cb} = 0$$

- $AF = 1$, $F = 1/A > 0$
- $F = X_{be}/X_{ce} > 0$, X_{be} and X_{ce} are the same type

- Thus:
  - X_{be} and X_{ce} are the same type (both inductive or both capacitive)
  - They are different with X_{cb}

Exp 5-1 Draw AC equivalent circuit of the oscillator, determine when to start oscillation and classification.





Solution: 1) AC Equivalent circuit

2) Criteria of LC composition:

x_{be} Capacitive, x_{ce} Capacitive

x_{cb} Inductive

- L_1C_1 Capacitive→ $f_0 > f_1$ (L_1C_1 natural frequency)
- L_3C_3 Inductive→ $f_0 < f_3$
- Classification: Capacitor Feedback LC Oscillator

$$\frac{1}{2\pi\sqrt{L_1C_1}} < \frac{1}{2\pi\sqrt{L_3C_3}} \qquad L_1C_1 > L_3C_3$$