Huazhong University
of Science & Technology

Electronic Circuit of Communications

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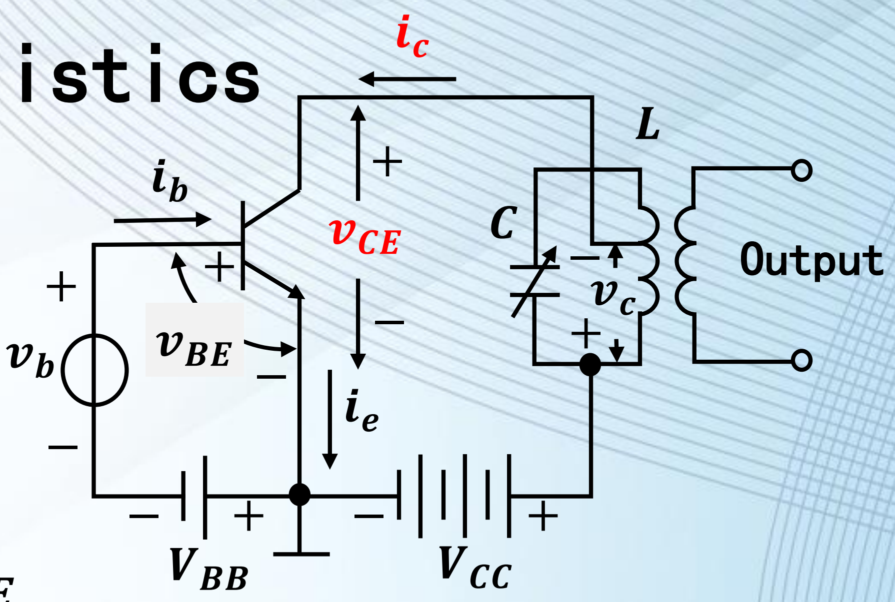
Dynamic Characteristics

RF Power Amplifier-Dynamic Characteristics

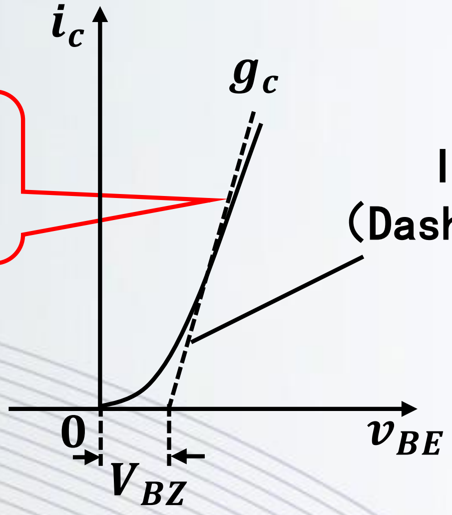


- Static Characteristics: No Load

If has load, i_c ↑, R_L has voltage, v_{CE} changes

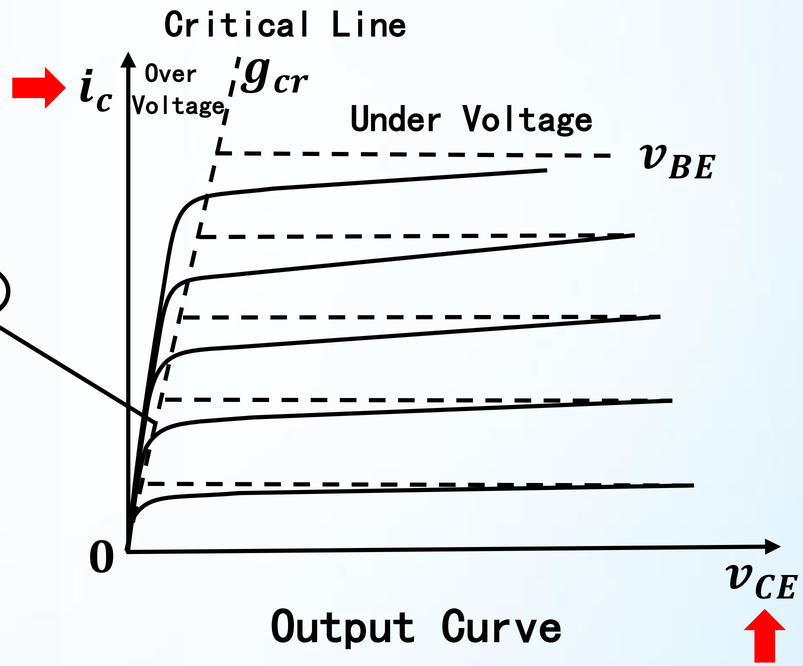
- **Dynamic Characteristics:** Curve between i_c & v_{CE}

$i_c = g_c(v_{BE} - V_{BZ})$
Transfer Equation



Transfer Curve

Ideal
(Dashed Line)



Output Curve

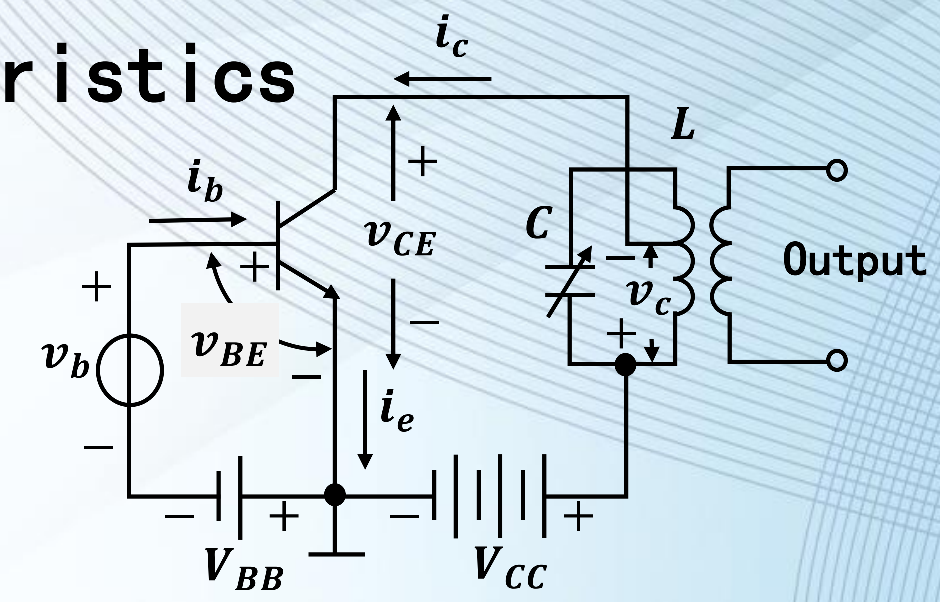
RF Power Amplifier-Dynamic Characteristics

➢ When resonant, we have 2 circuit equations:

$$\begin{cases} v_{BE} = -V_{BB} + V_{bm}\cos\omega t \\ v_{CE} = V_{CC} - V_{cm}\cos\omega t \end{cases}$$

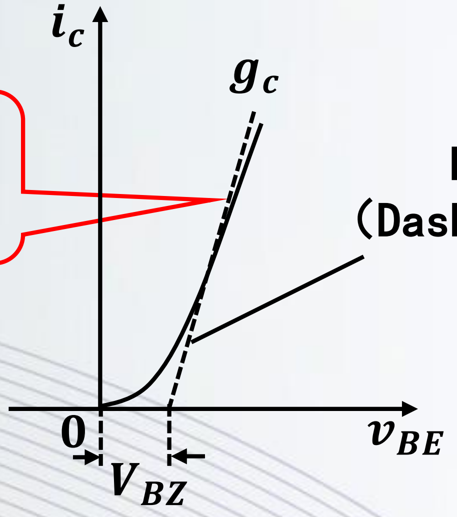
Cancel $\cos\omega t$, Obtain

$$v_{BE} = -V_{BB} + V_{bm}\frac{V_{CC} - v_{CE}}{V_{cm}}$$

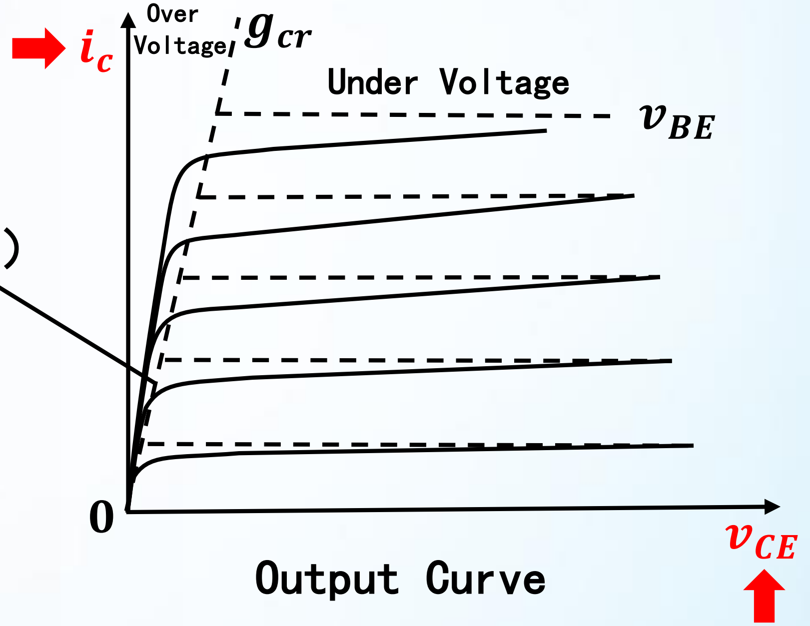


$i_c = g_c(v_{BE} - V_{BZ})$

Transfer Equation



Transfer Curve



Output Curve

RF Power Amplifier-Dynamic Characteristics

$i_c = g_c(v_{BE} - V_{BZ})$ Transfer Equation

$$v_{BE} = -V_{BB} + V_{bm}\frac{V_{CC} - v_{CE}}{V_{cm}}$$

Obtain Dynamic Curve on i_c–v_{CE} Plane:

$$i_c = g_c\left[-V_{BB} + V_{bm}\frac{(V_{CC} - v_{CE})}{V_{cm}} - V_{BZ}\right]$$

$$= \boxed{-g_c\left(\frac{V_{bm}}{V_{cm}}\right)}\left[v_{CE} - \boxed{\frac{V_{CC}V_{bm} - V_{BZ}V_{cm} - V_{BB}V_{cm}}{V_{bm}}}\right]$$

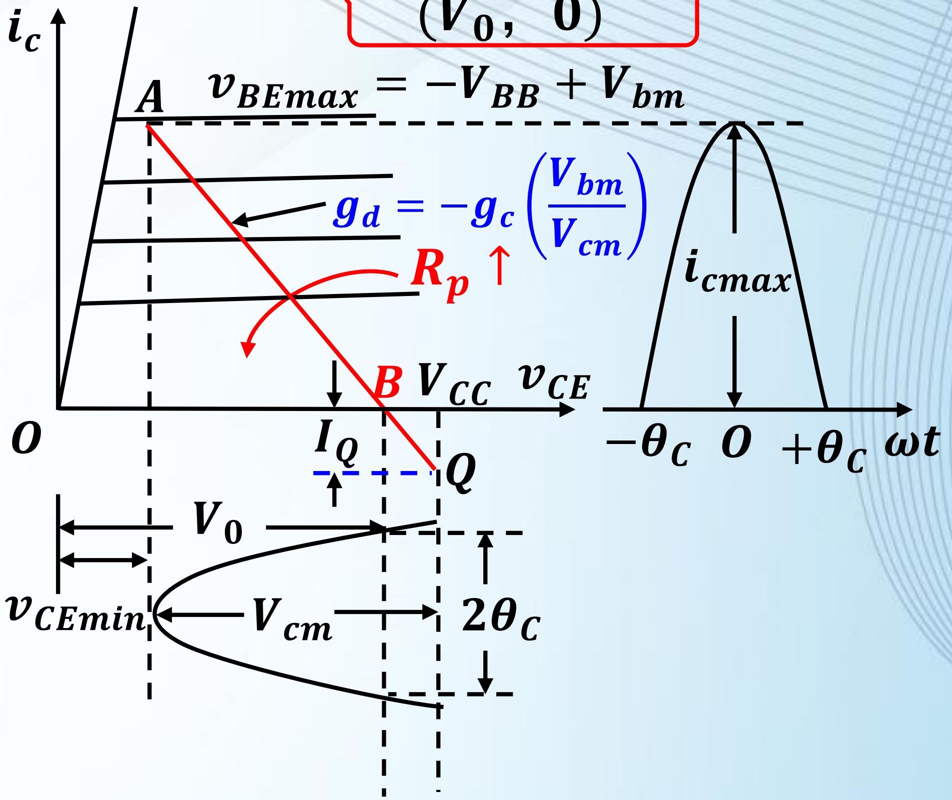
$$= g_d(v_{CE} - V_0)$$

Intercept: V_0

Slope: $g_d = -g_c\left(\frac{V_{bm}}{V_{cm}}\right) = -g_c\frac{V_{bm}}{I_{cm1}R_p}$

➢ Method 1: Line with slope g_d, goes through B Point

$(V_0,\ 0)$



i_c–v_{CE} Dynamic Curve

➢ **Negative Slope**: Negative Resistance, AC Energy Generator

RF Power Amplifier-Dynamic Characteristics

- Method 2: Line pass points A & Q

$$\begin{cases} v_{BE} = -V_{BB} + V_{bm}\cos\omega t \\ v_{CE} = V_{CC} - V_{cm}\cos\omega t \end{cases}$$

$(v_{CEmin},\ i_{cmax})$

① A : $\omega t = 0$, $i_c = i_{cmax}$

$$\begin{cases} v_{BE} = -V_{BB} + V_{bm} \Rightarrow i_{cmax} = g_c(-V_{BB} + V_{bm} - V_{BZ}) \\ v_{CE} = V_{CC} - V_{cm} = v_{CEmin} \end{cases}$$

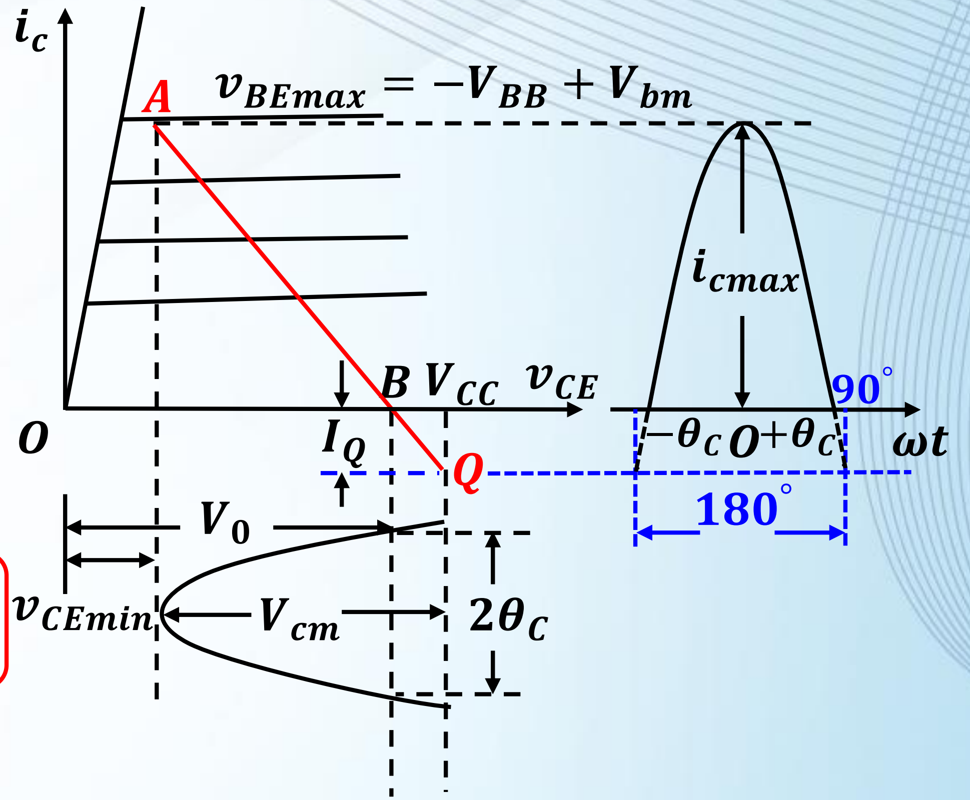
$i_c = g_c(v_{BE} - V_{BZ})$
Transfer Equation

$(V_{CC},\ I_Q)$

② Q: $\omega t = 90^\circ$, $i_c = I_Q$

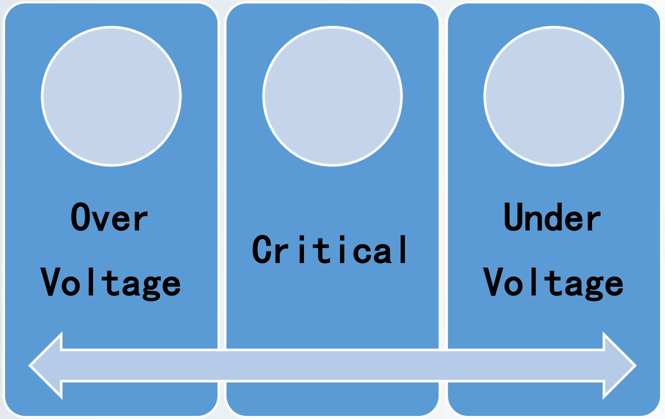
$$\begin{cases} v_{BE} = -V_{BB} \quad \Rightarrow I_Q = g_c(-V_{BB} - V_{BZ}) \\ v_{CE} = V_{CC} \end{cases}$$

$i_c = g_c(v_{BE} - V_{BZ})$



i_c–v_{CE} Dynamic Curve

RF Power Amplifier-Dynamic Characteristics

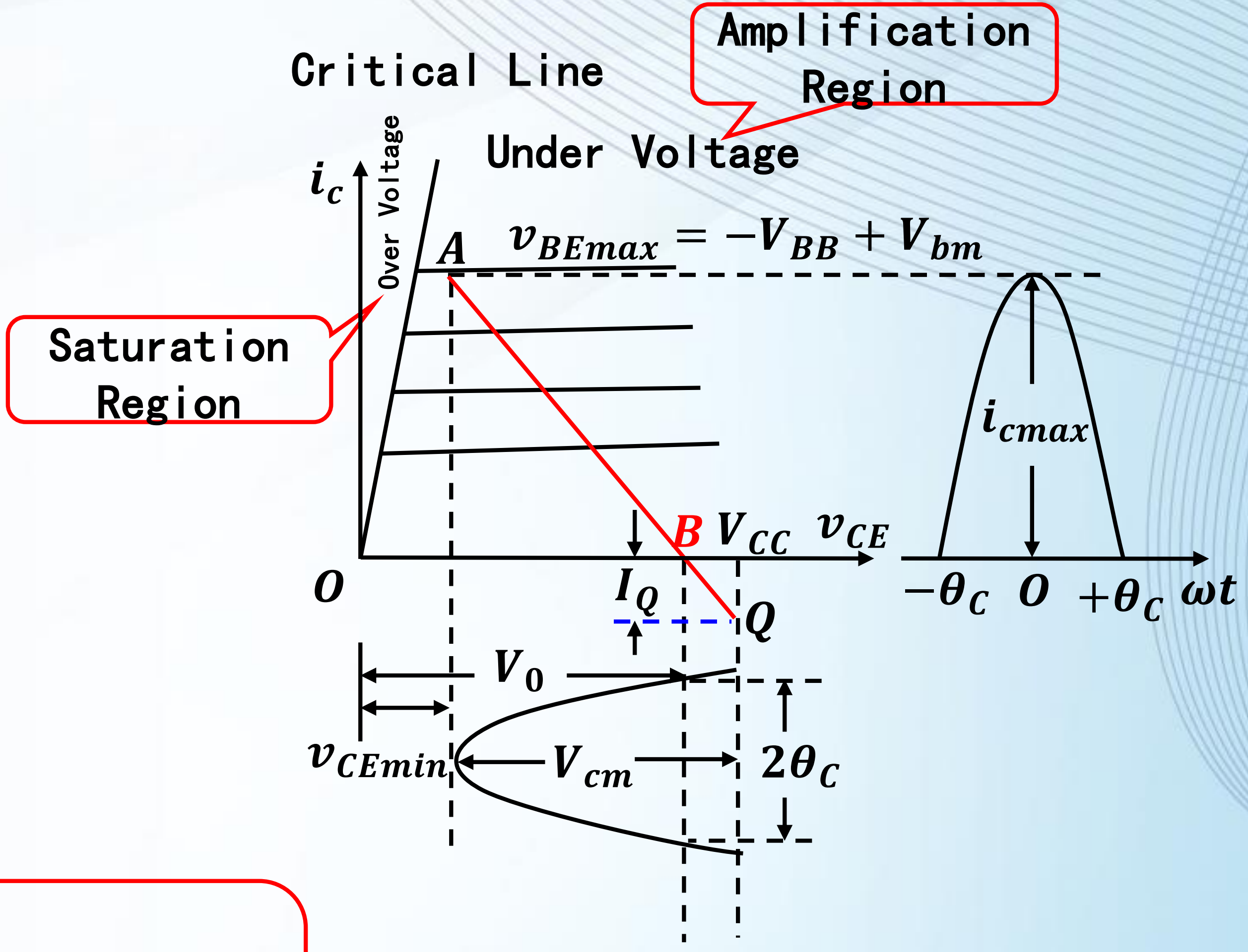


- Only change R_p
- Only change V_{CC}
- Only change $V_{bm}(V_{BB})$

Load Characteristics

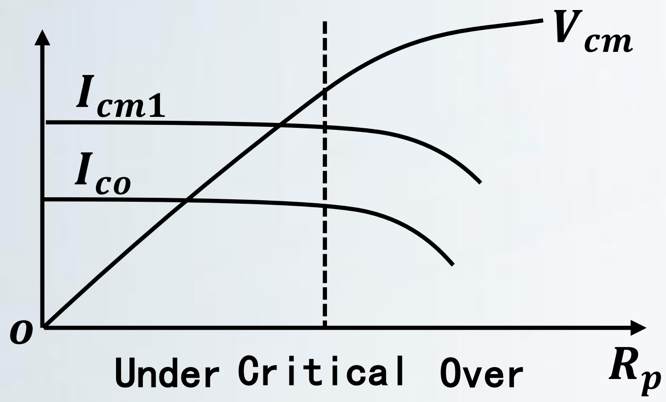
If V_{CC}、$V_{bm}(V_{BB})$ do not change,

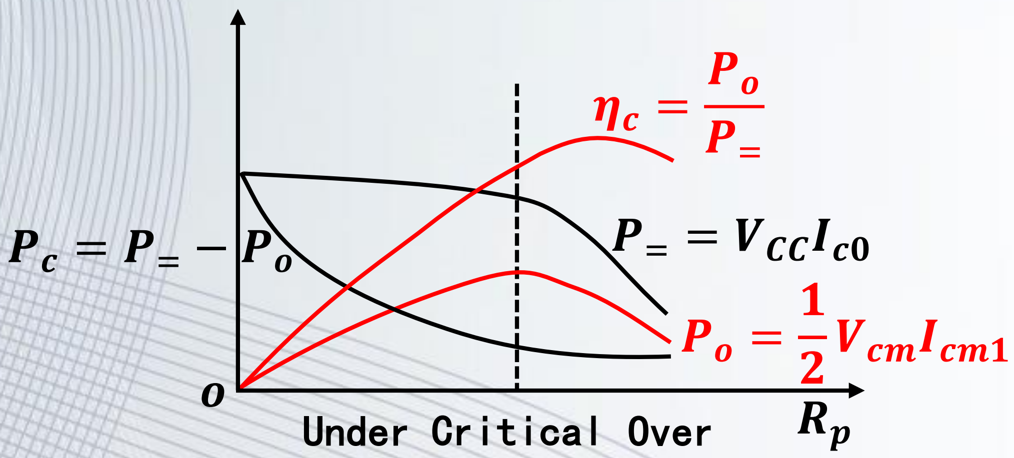
Current/Voltage/P_o/η_c will change with R_p

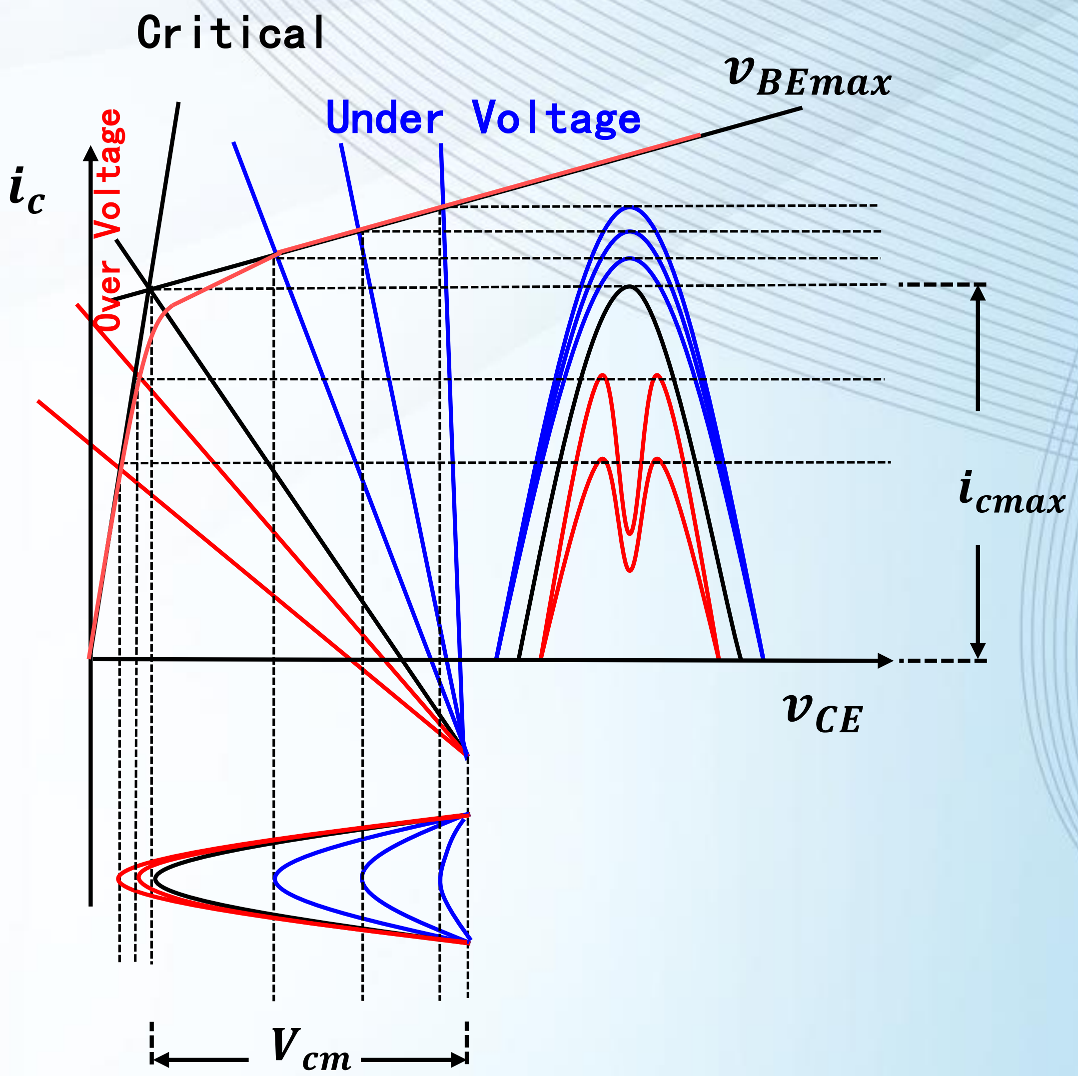


i_c-v_{CE} Dynamic Curve

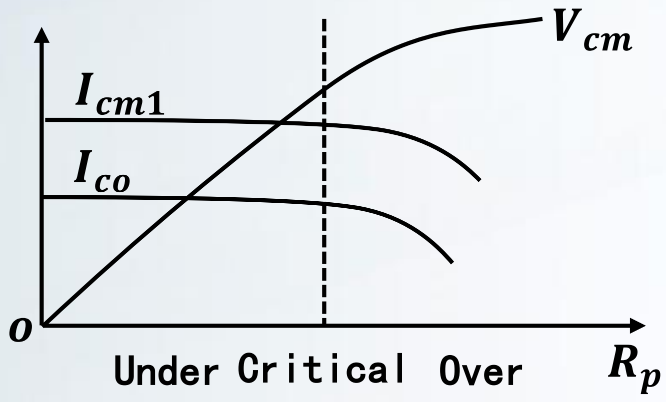
RF Power Amplifier-R_p

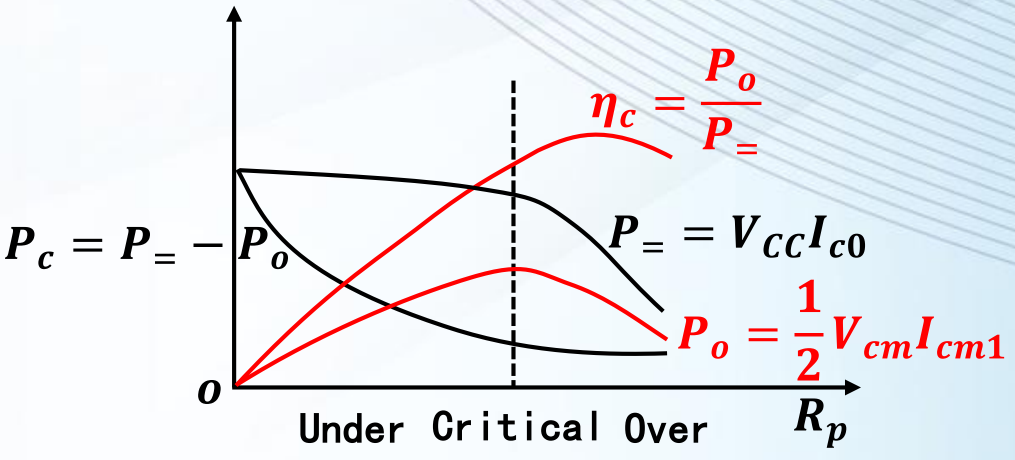






RF Power Amplifier-R_p



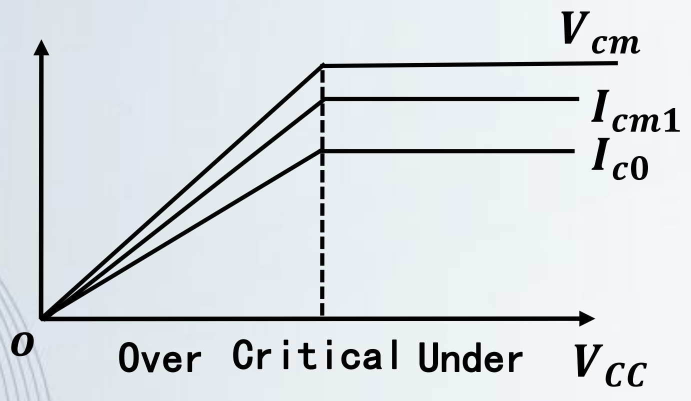


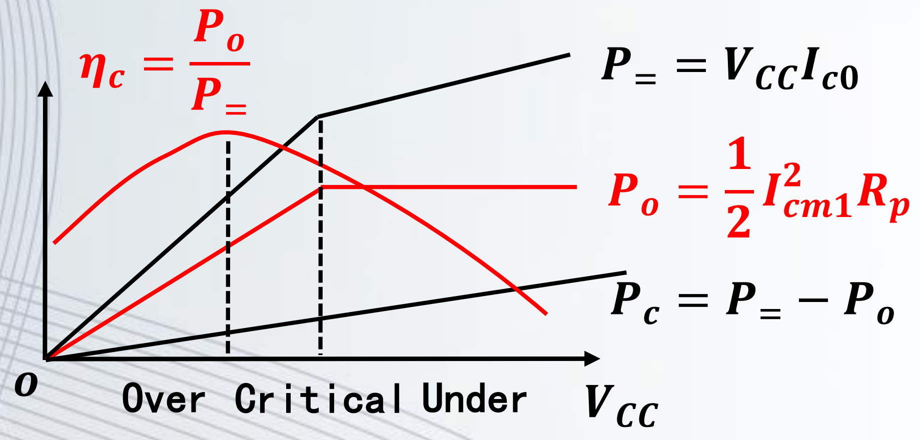
- Features of Working State:
  - Under Voltage State: Constant Current, $P_o\downarrow$, $\eta_c\downarrow$, $P_c\uparrow$;
  - Over Voltage State: Constant Voltage, $P_o\downarrow$, η_c max; Middle Stage
  - Critical State: P_o max, η_c high; Last Stage

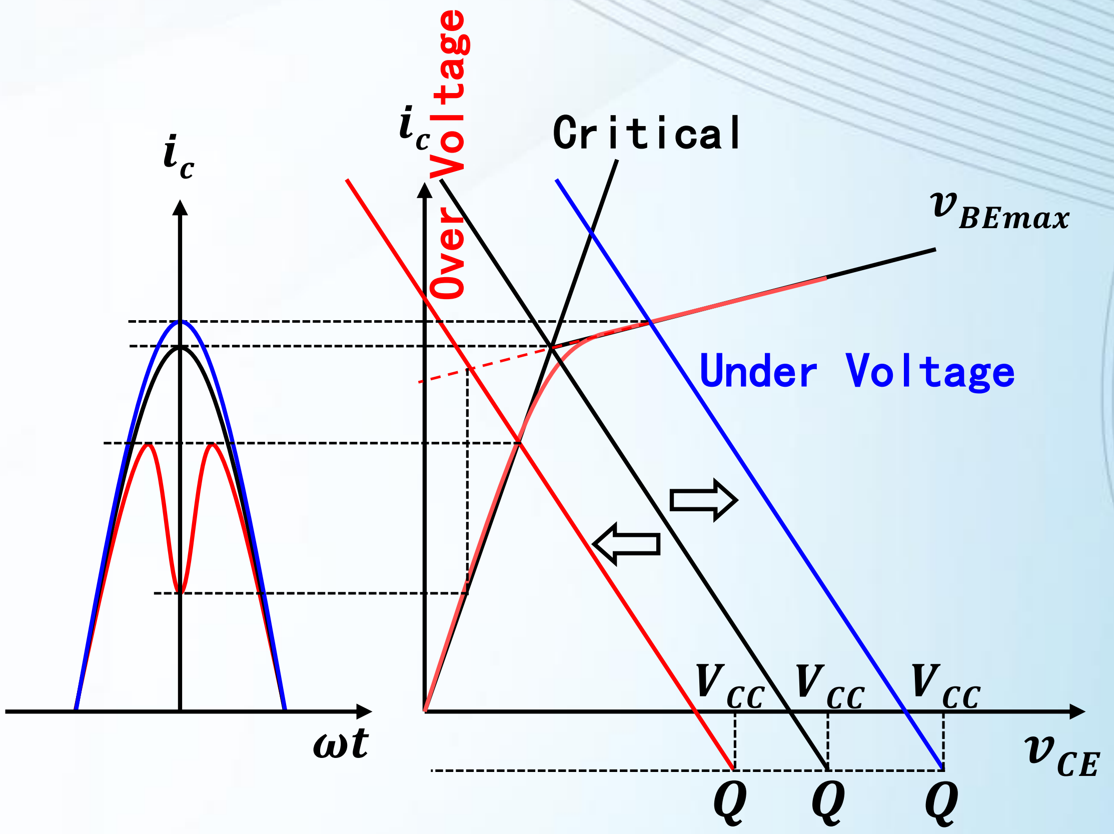
Best State

RF Power Amplifier (Dynamic Characteristics) —V_{CC}

- R_p、$V_{bm}(V_{BB})$ no change, V_{CC} $vs.$ Over Voltage、Under Voltage

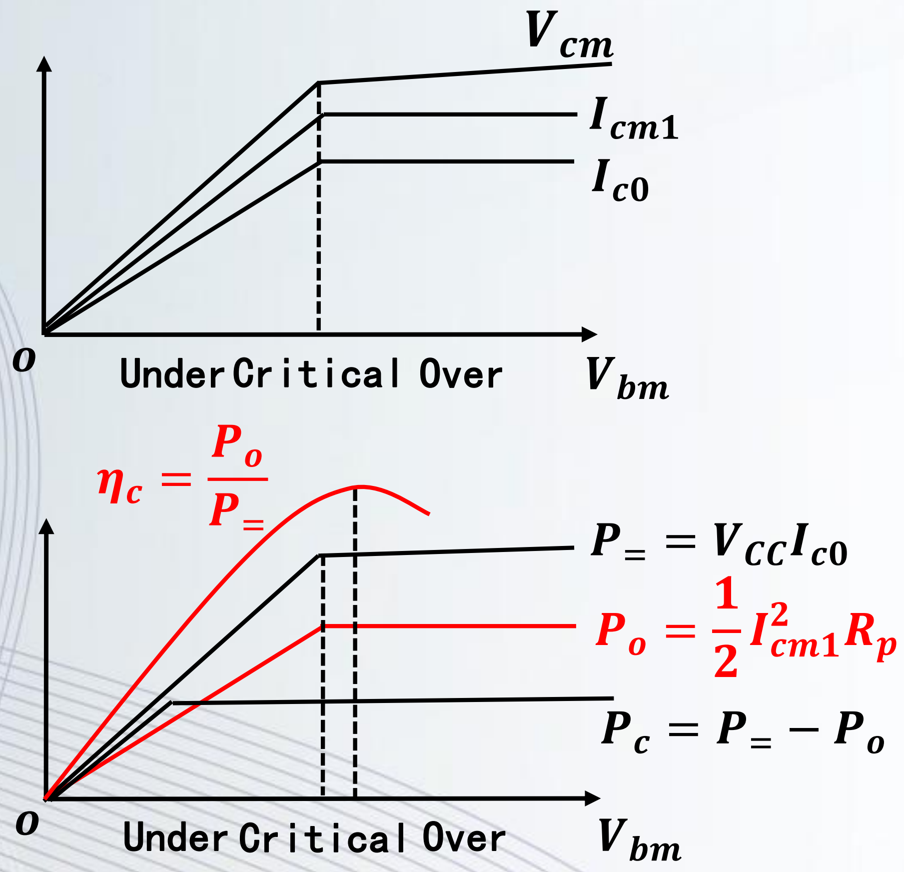


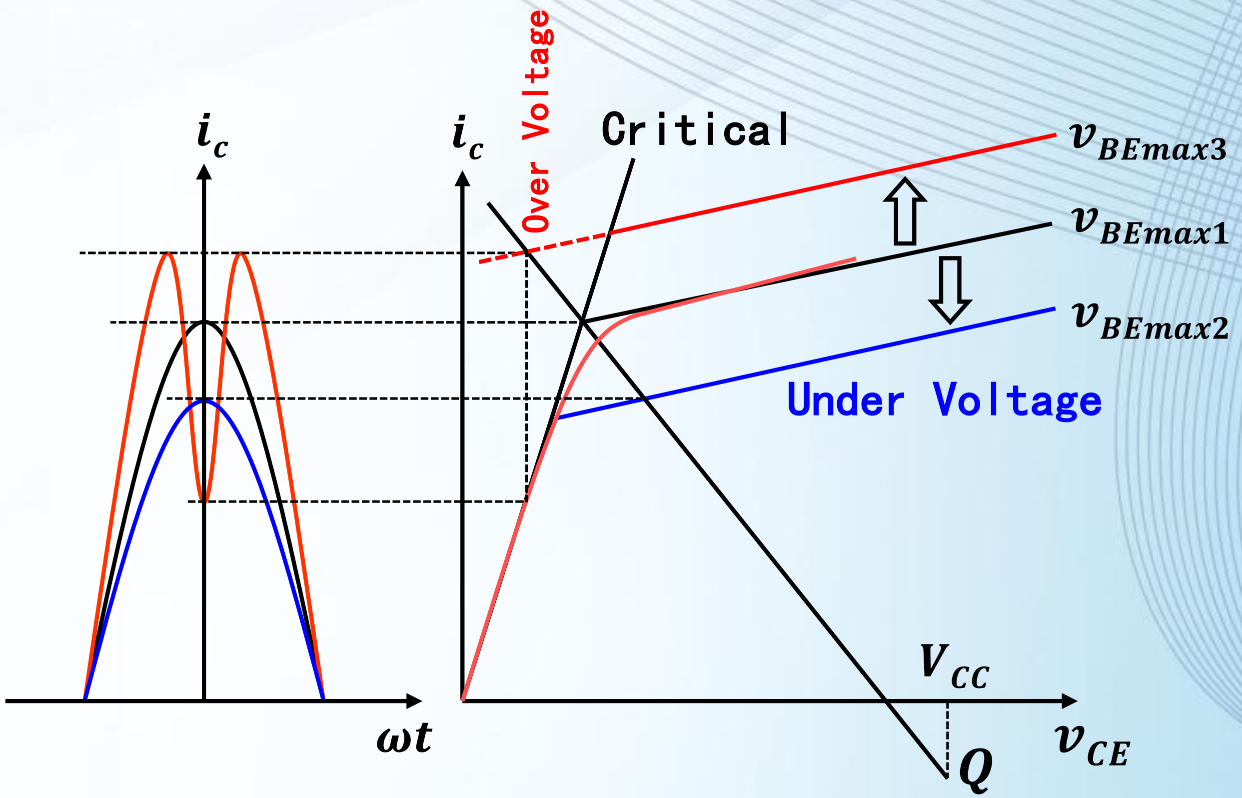




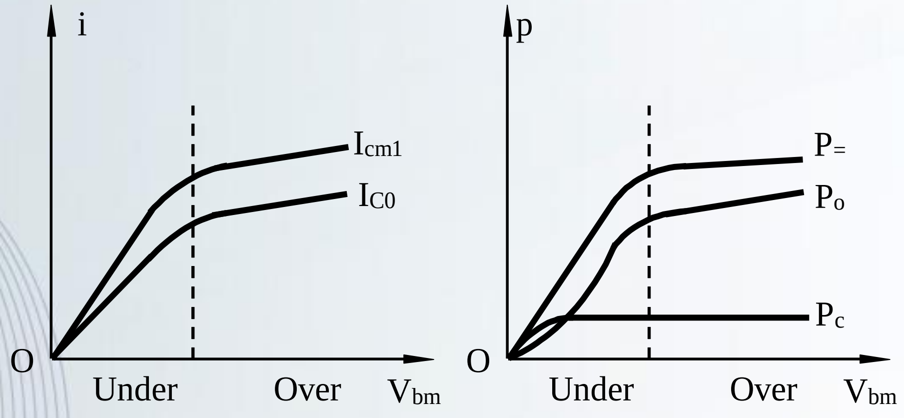
RF Power Amplifier (Dynamic Characteristics) —V_{bm}

- R_p、V_{BB}、V_{CC} no change, V_{bm} $vs.$ Over Voltage、Under Voltage

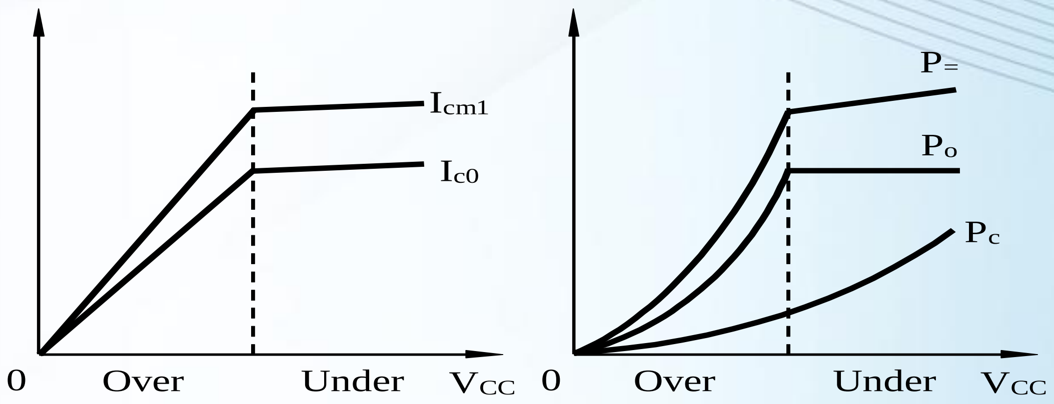




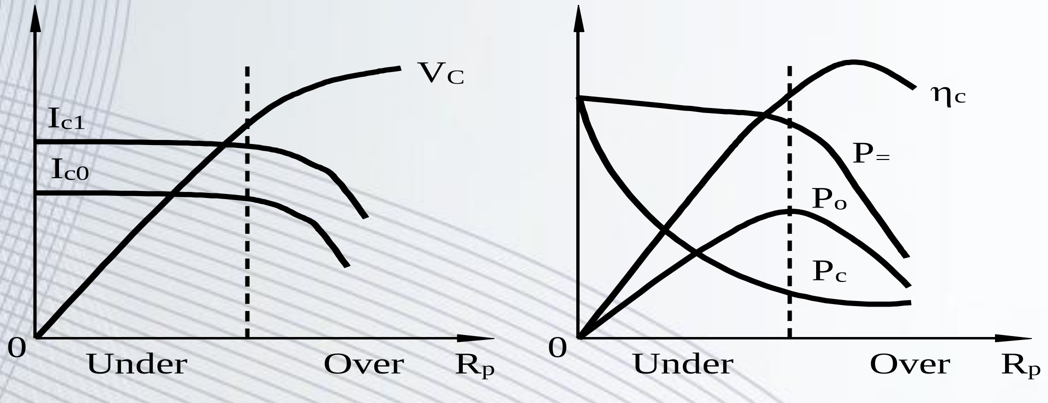
Ex 4-1 For a RF power amplifier, it is not effective to improve P_o by means of increasing V_{bm}. Analyze its reason and how to improve P_o effectively?



(a) (b)



(a) (b)



Load Curve

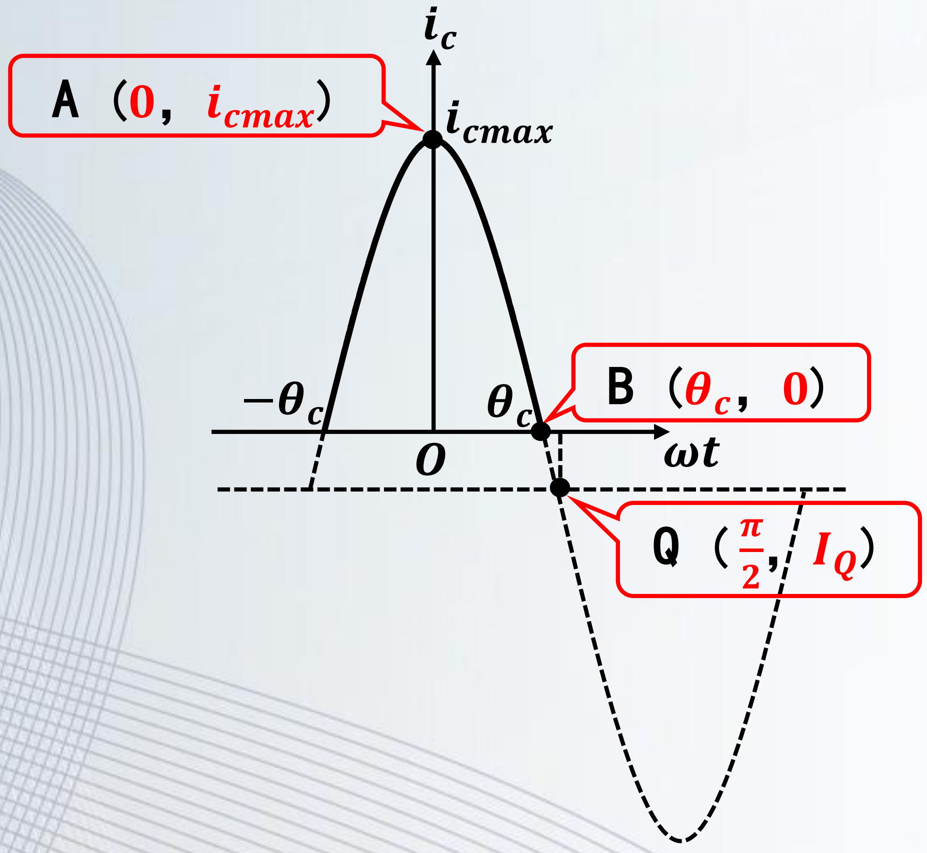
$V_{bm}\uparrow \rightarrow P_o\uparrow$ Ineffectively

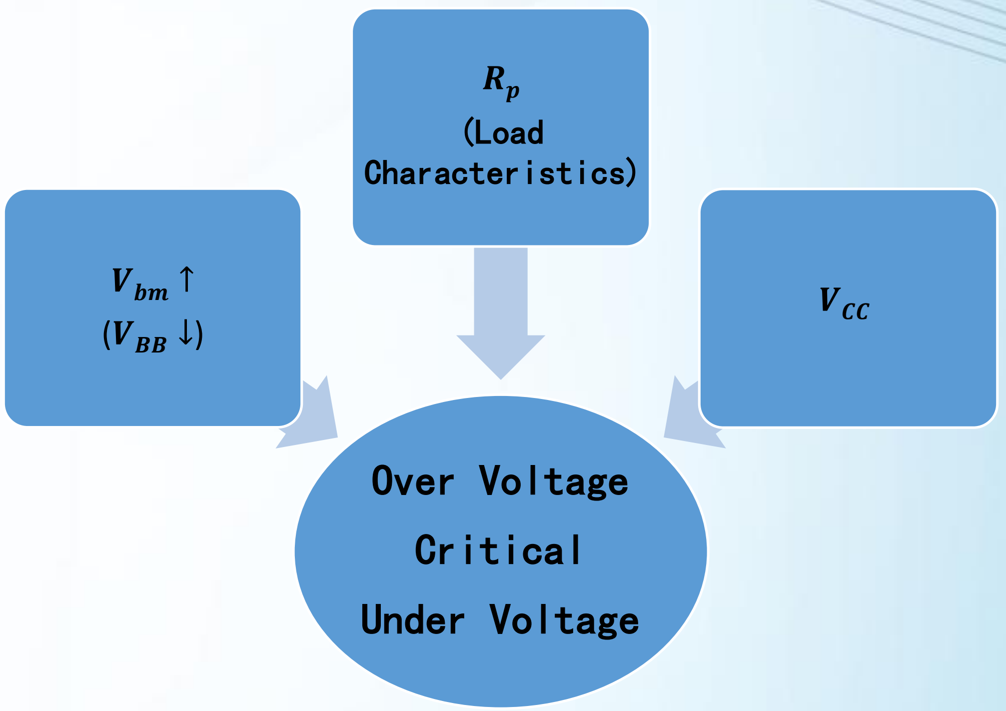
$\Longrightarrow$ Over Voltage State

$\Longrightarrow P_o\uparrow$ by $\uparrow V_{CC}$ & $\downarrow R_p$

Summary

➢ Dynamic Characteristics (A B Q)





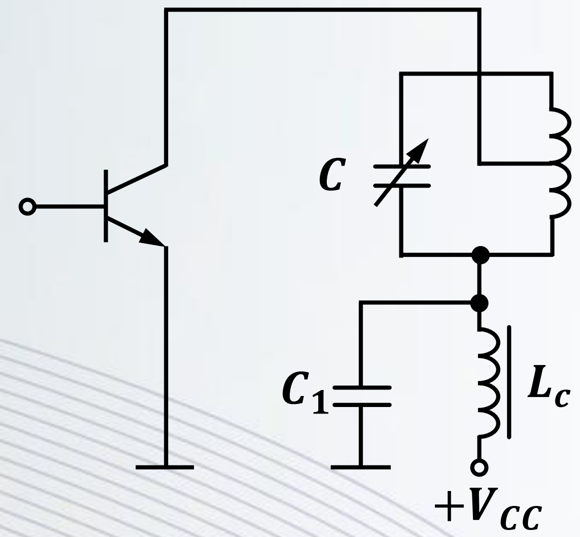
Power Amplifier Circuit

RF Power Amplifier—DC Power Supply Circuit

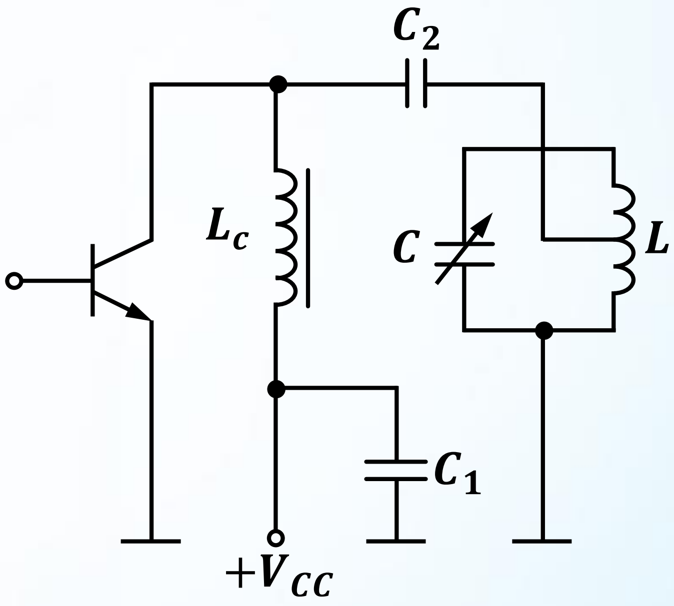
- DC Power Supply
  - Collector Bias Circuit
    - Series-fed
    - Parallel-fed
  - Base Bias Circuit
    - Series-fed
    - Parallel-fed

RF Power Amplifier—Collector Bias Circuit

- Include Series-fed & Parallel-fed



Series-fed

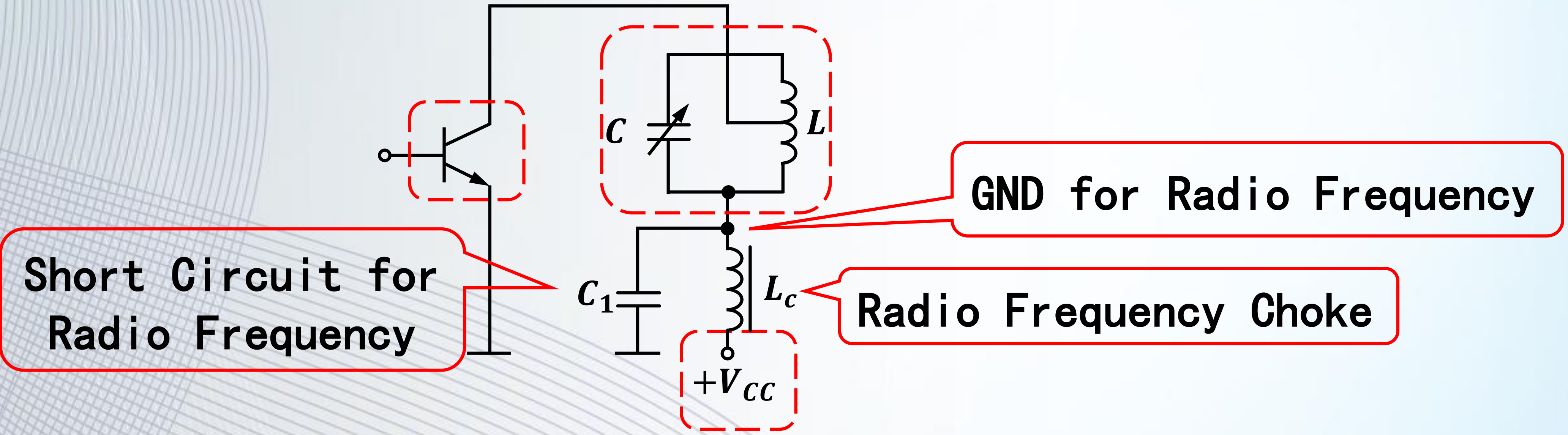


Parallel-fed

RF Power Amplifier—Collector Bias Circuit(Series-fed)

- **Series-fed Circuit:**

V_{CC} + Parallel Resonance + Power Amplifier Transistor

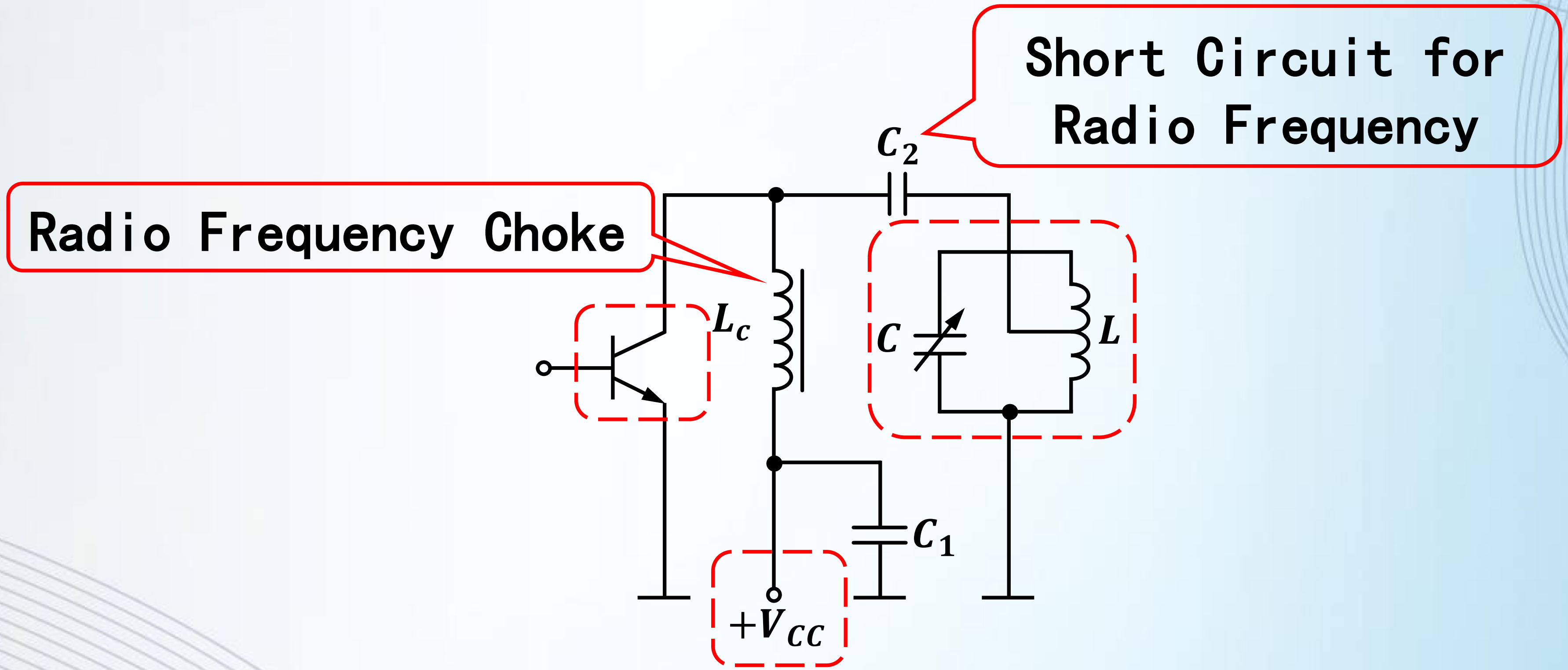


Series-fed

RF Power Amplifier—Collector Bias Circuit(Parallel-fed)

- **Parallel-fed Circuit:**

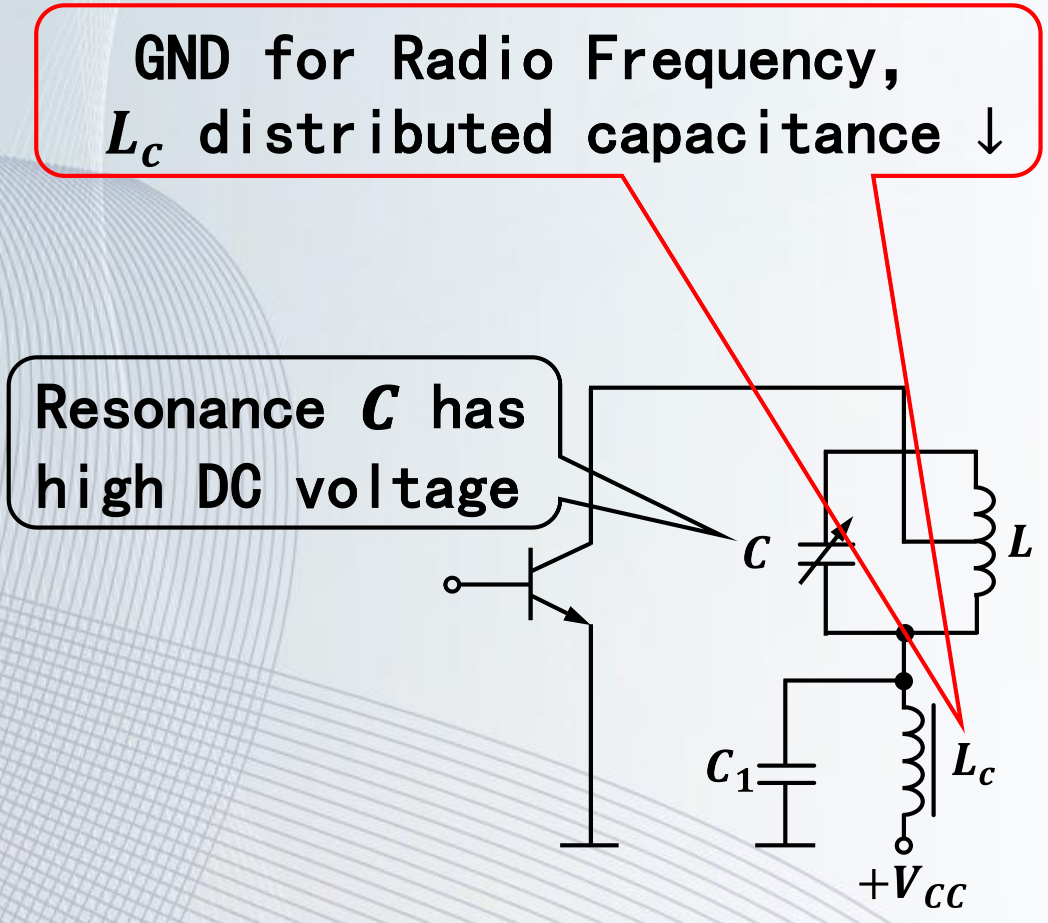
  V_{CC} // Parallel Resonance // Power Amplifier Transistor



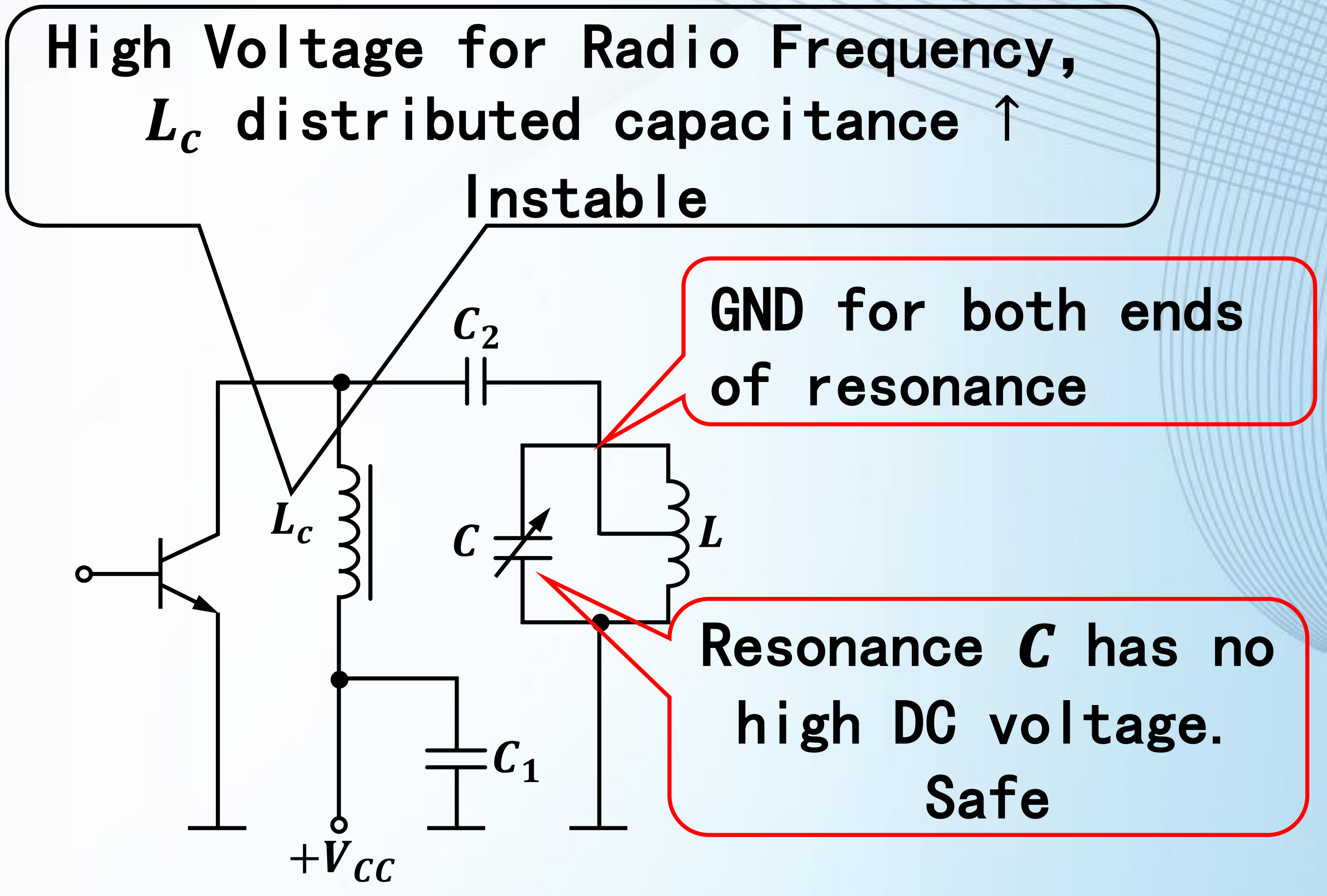
Parallel-fed

RF Power Amplifier—Collector Bias Circuit(Comparison)

- Series-fed *vs.* Parallel-fed



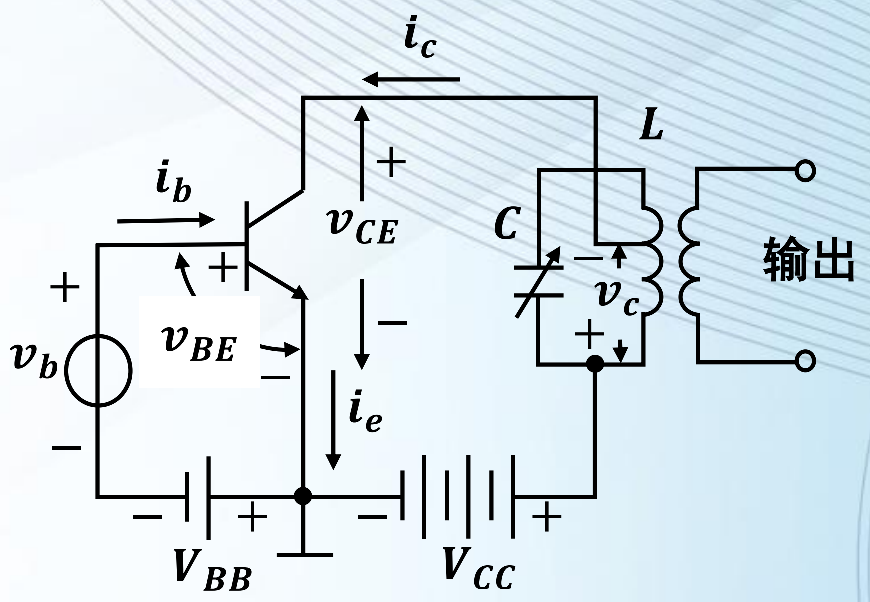
Series-fed

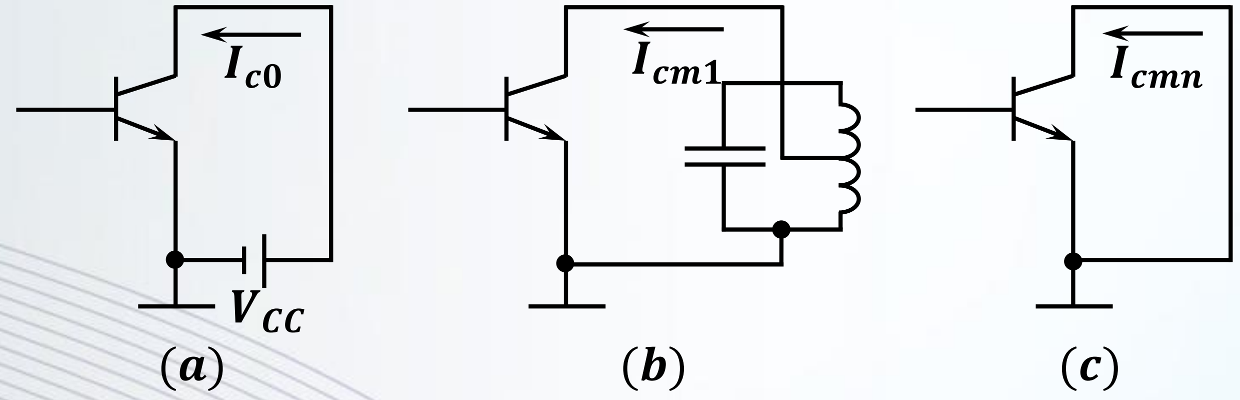


Parallel-fed

RF Power Amplifier—Collector Bias Equivalent Circuit

- Fig. (a) : DC Power Supply
- Fig. (b) : $1\times$ Harmonic Frequency
- Fig. (c) : $\geq 2\times$ Harmonic Frequency

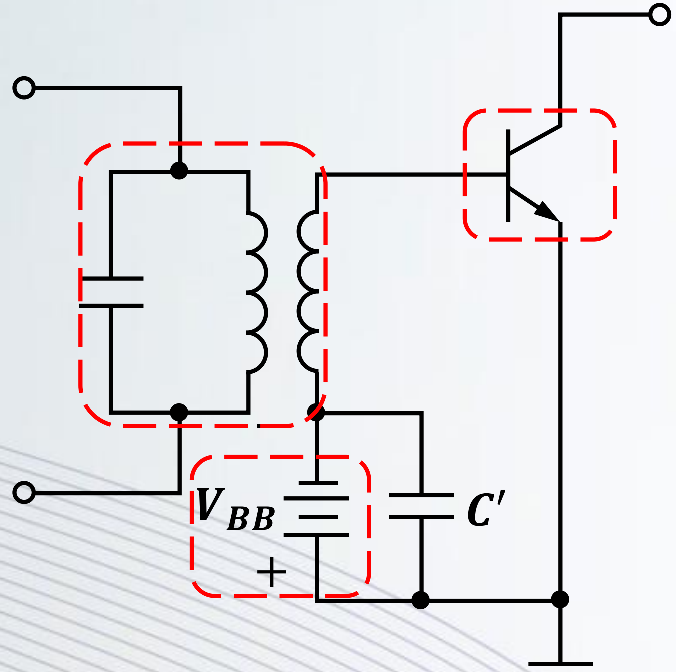




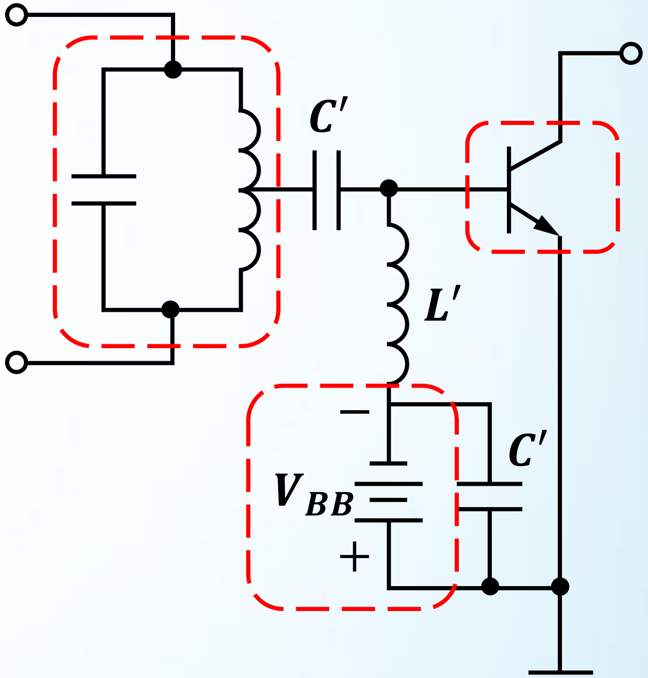
Collector Bias Equivalent Circuit for Different Frequency

RF Power Amplifier—Base Reverse Bias Circuit

- Series-fed: V_{BB} + Source + Power Amplifier Transistor
- Parallel-fed: V_{BB} // Source // Power Amplifier Transistor

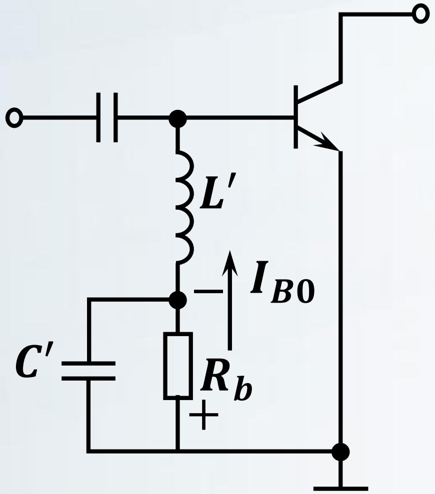


Series-fed

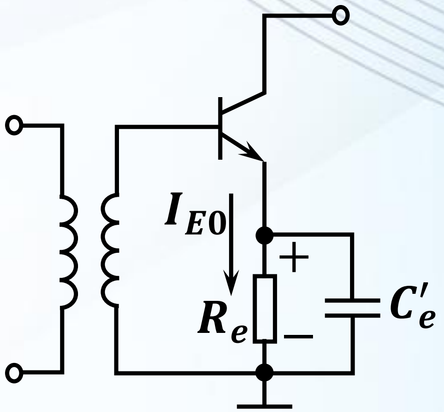


Parallel-fed

RF Power Amplifier—Base Reverse Bias Circuit (Self-Bias)



(a)



(b)

- Fig(a):Base current I_{BO} on R_b to generate reverse bias voltage V_{BB}
- Fig(b):Emitter current I_{EO} on R_e to generate reverse bias voltage V_{BB}
  - Self Reverse Bias + Negative FeedBack, (For Stability)

C Frequency Multiplier

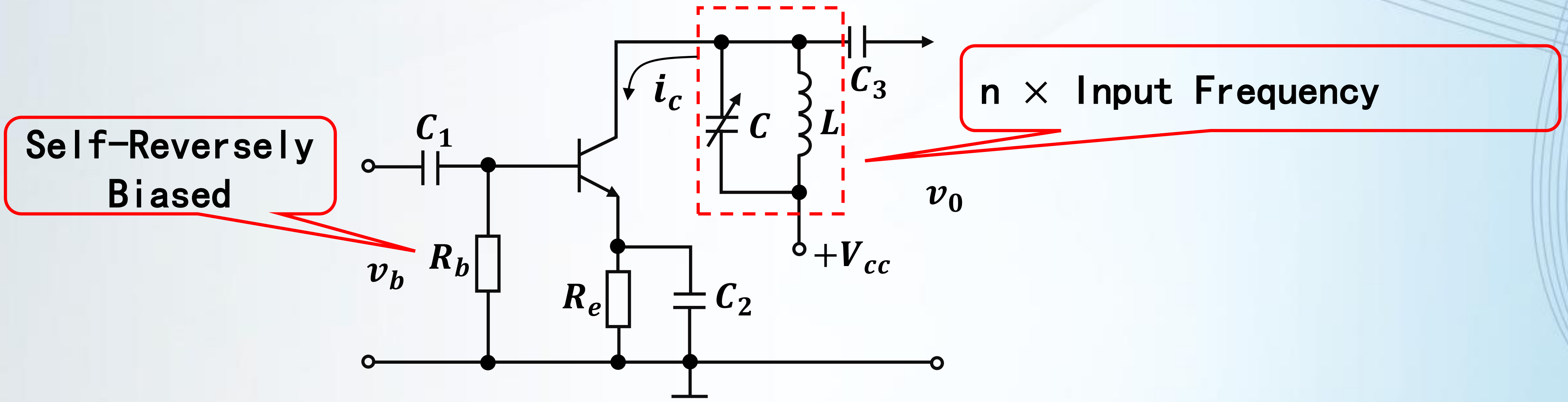
Class C Frequency Multiplier

- Objectives
  - Decrease frequency of master oscillators, increase stability of frequency
  - Obtain higher frequency as quartz crystal oscillators have upper limits
  - Decrease intercoupling between input & output frequency, increase stability of frequency
  - Increase frequency deviation (FM, PM)
  - Increase bandwidth

- Method
  - Class C Frequency Multiplier

Class C Frequency Multiplier—Principle

- Similar as RF Power Amplifier: Class C, Reversely Biased
- Different: Parallel Resonant on n Times of Input Frequency

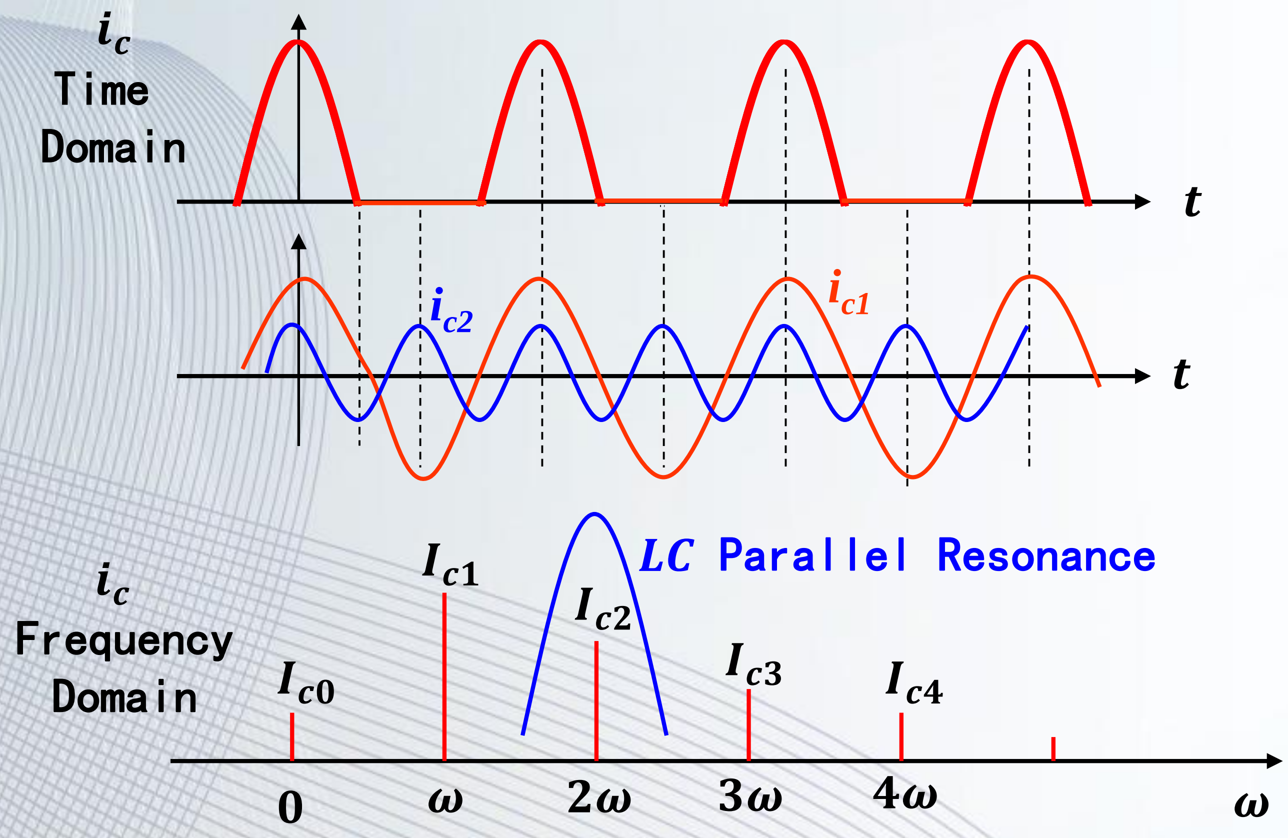


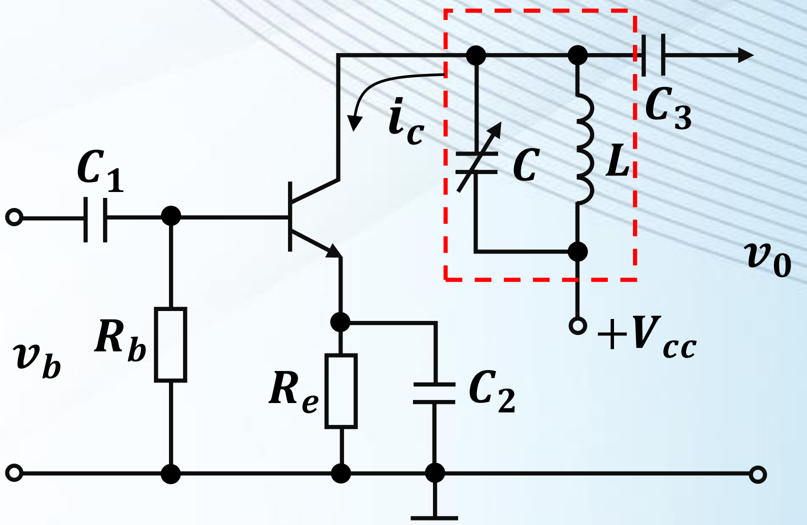
Class C Frequency Multiplier

$$i_c = I_{c0} + I_{cm1}\cos\omega t + I_{cm2}\cos 2\omega t + \cdots + I_{cmn}\cos n\omega t + \cdots$$

Class C Frequency Multiplier—Time & Frequency Domain

- 2 × Input Frequency

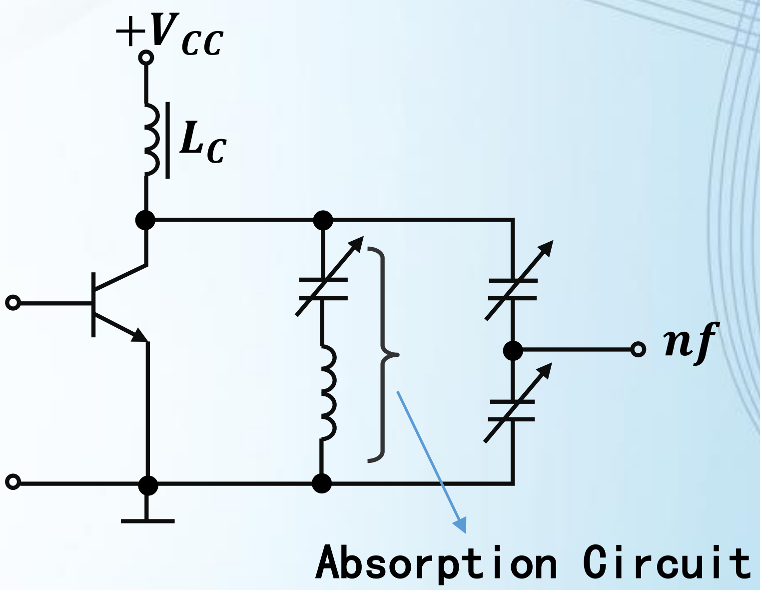


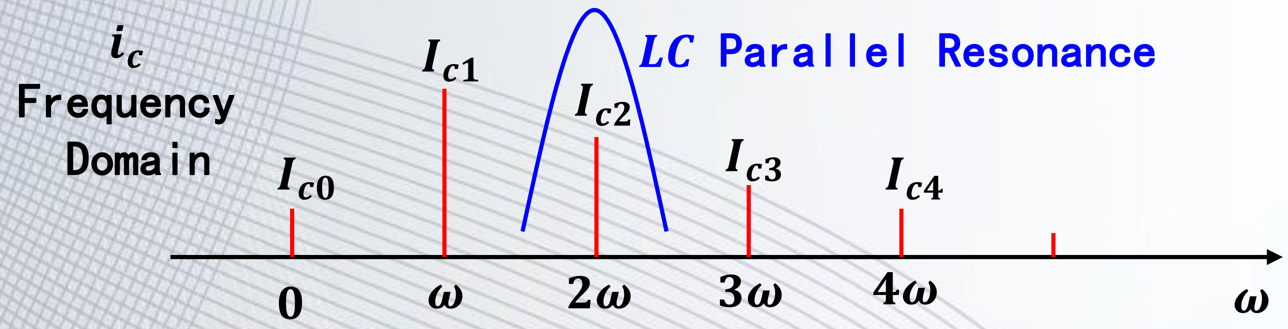


Class C Frequency Multiplier

Class C Frequency Multiplier— Filtering

- For C Power Amplifier, easy to remove high frequency
- For C Frequency Multiplier, not easy to remove low frequency
- Increase Filtering Performance:
  (1) Increase Q
  (2) Adopt Absorption Circuit
  (3) Increase Selectivity of BPF

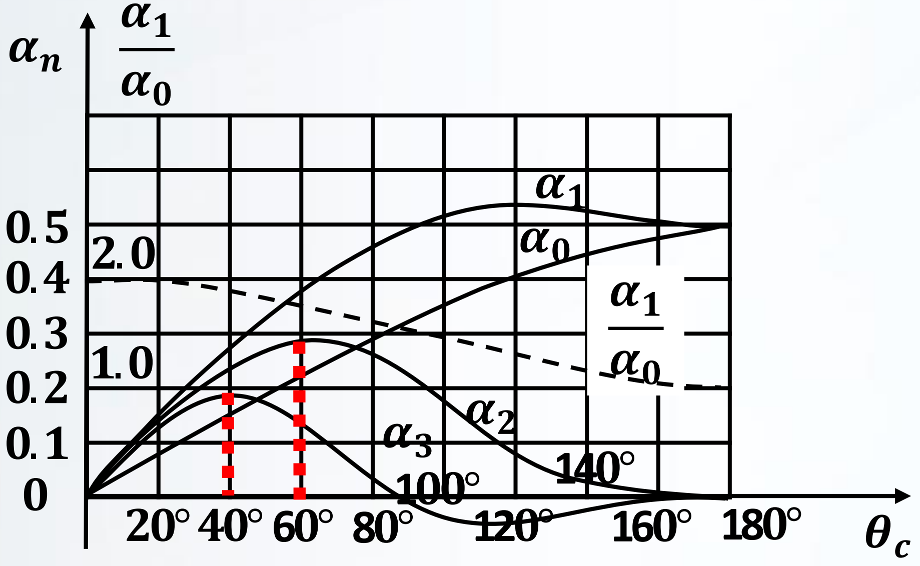




Class C Frequency Multiplier—θ_c

- How to determine θ_c

  Depend on Multiplier n



- n=2 θ_c round 60°
- n=3 θ_c round 40°