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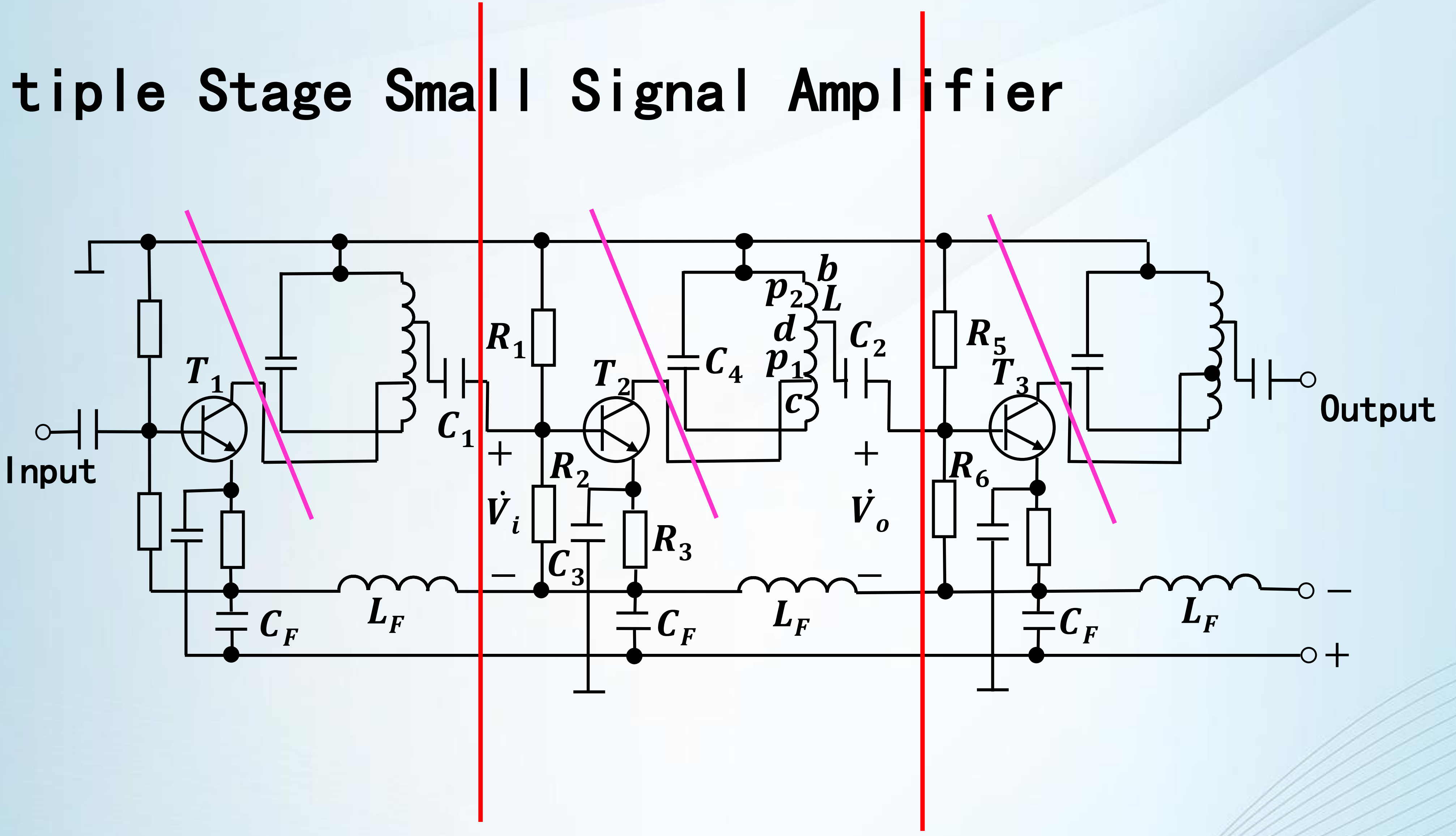
Multiple Stage Amplifier

Multiple Stage Small Signal Amplifier



Divide and Conquer

（1） m-stage Gain

- Amplifier with m stages, A_{V_1}、$A_{V_2}\cdots\cdots A_{V_m}$， respectively

  m-stage Gain： $A_m = A_{V_1} \cdot A_{V_2} \cdot \cdots\cdots \cdot A_{V_m}$

- If every stage has equal A_{V_1}

$$A_m = A_{V_1}^m$$

(2) m-stage Bandwidth $(2\Delta f_{0.7})_m$

If equal stage gain:
$A_m = A_V^m$

$$\frac{A_m}{A_{m_0}} = \frac{1}{\left(\sqrt{1+\left(\frac{Q_L}{f_0}2\Delta f\right)^2}\right)^m} = \frac{1}{\sqrt{2}}$$

$\Rightarrow$Total bandwidth: $(2\Delta f_{0.7})_m = \sqrt{2^{\frac{1}{m}}-1} \cdot 2\Delta f_{0.7}$

1-stage gain

Factor < 1, $X = \sqrt{2^{\frac{1}{m}}-1}$

Note:

- Total Bandwidth < Single Bandwidth

(3) m-stage Selectivity (Rectangle Coefficient)

$$\frac{A_m}{A_{m_0}} = \frac{1}{\left(\sqrt{1+\left(\frac{Q_L}{f_0}2\Delta f\right)^2}\right)^m} = 0.1$$

$$\Rightarrow (2\Delta f_{0.1})_m = \sqrt{100^{\frac{1}{m}} - 1} \cdot 2\Delta f_{0.7}$$

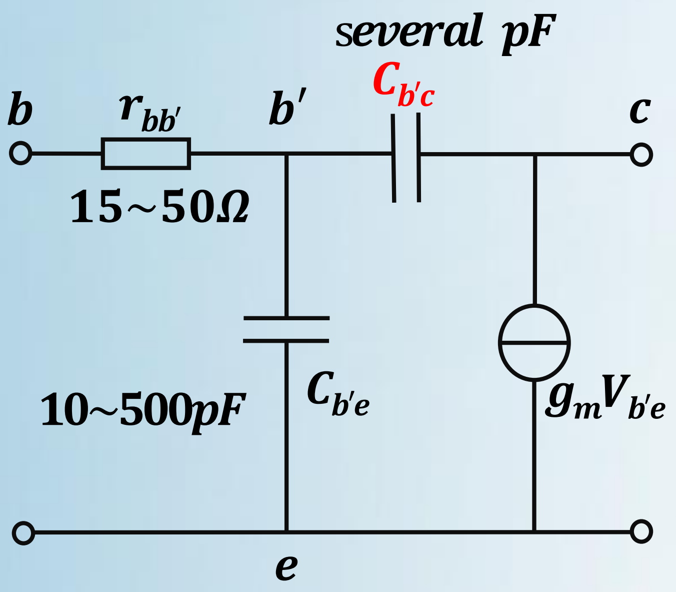
$$\Rightarrow K_{r0.1} = \frac{(2\Delta f_{0.1})_m}{(2\Delta f_{0.7})_m} = \frac{\sqrt{100^{\frac{1}{m}} - 1}}{\sqrt{2^{\frac{1}{m}} - 1}}$$

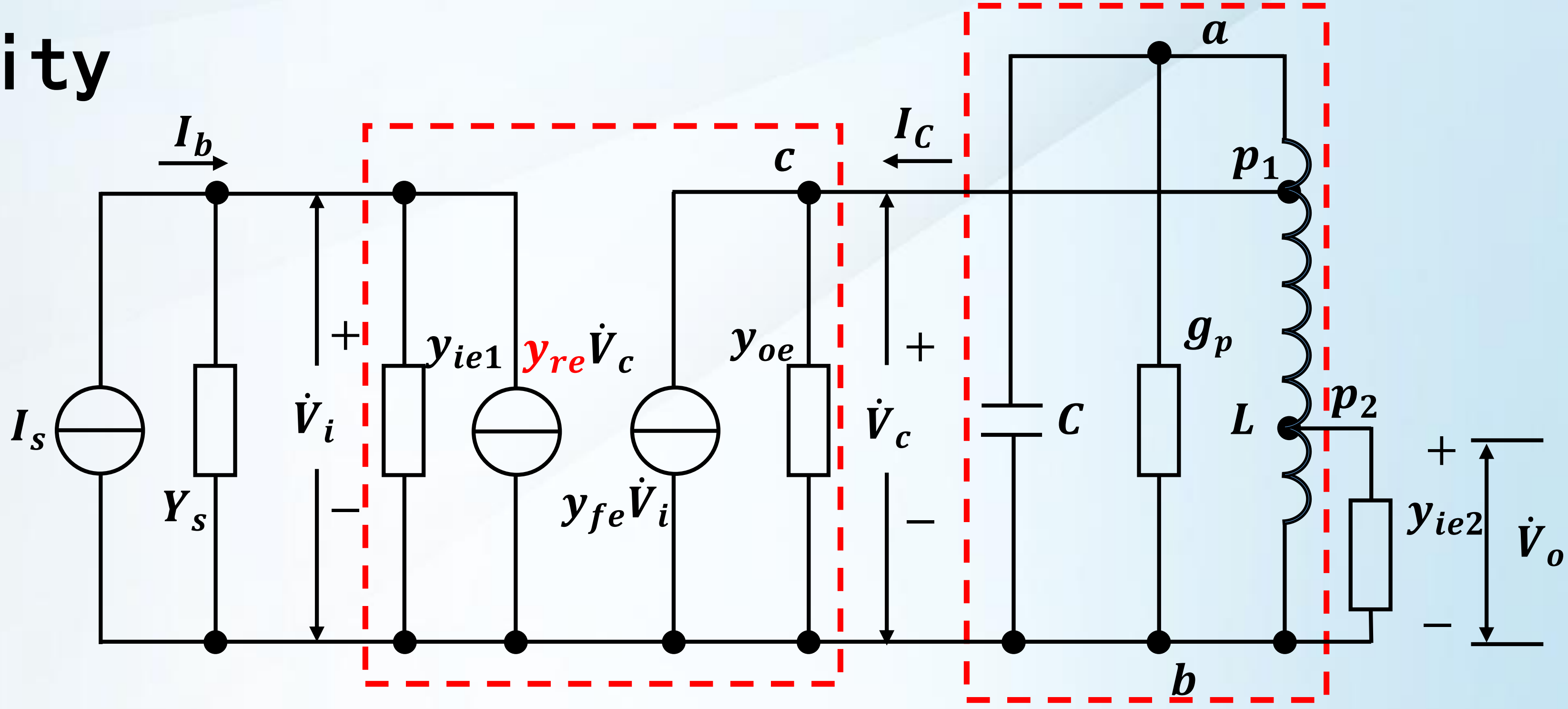
Note: Far away from ideal 1

m	1	2	3	4	5	6	7	8	9	10
$K_{r0.1}$	9.9499	4.6613	3.7430	3.3805	3.1886	3.0703	2.9902	2.9324	2.8888	2.8547

Instability

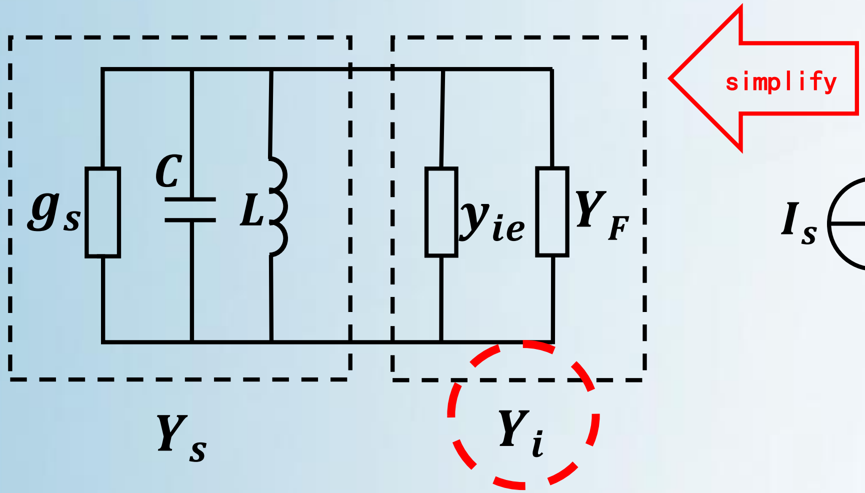
Reason of Instability

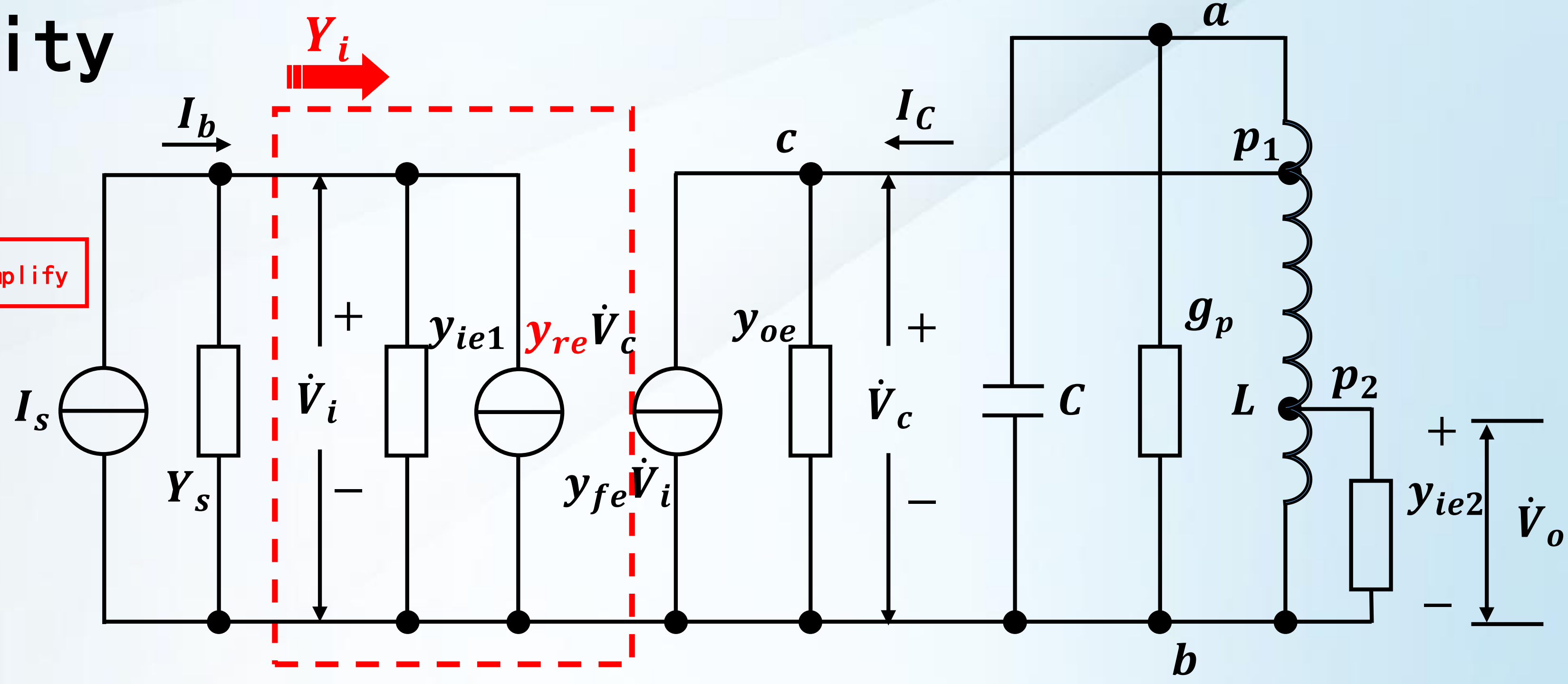




- Hybrid π: $C_{b'c} \neq 0$ → Bi-directional → Instable
- Y parameter: $y_{re} \neq 0$

Reason of Instability





- Consider g_Σ of $Y_s + Y_i$

$$Y_i = y_{ie} - \frac{y_{fe} y_{re}}{y_{oe} + Y_L'} = y_{ie} + Y_F$$

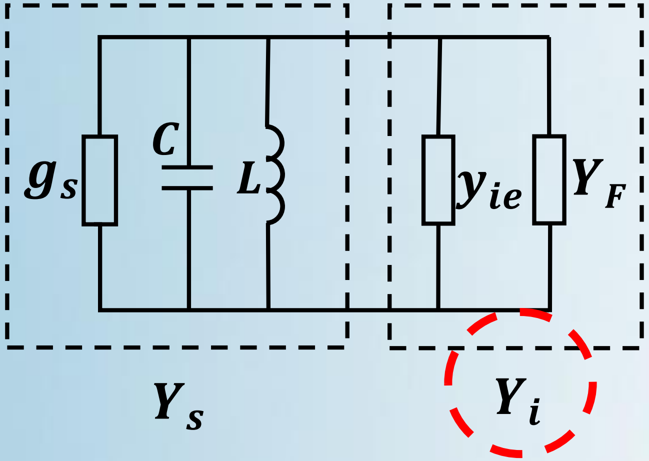
$$\boxed{Y_F = g_F + jb_F}$$

$$g_\Sigma = g_s + g_{ie} + g_F$$

$\Rightarrow g_F$ (function of frequency) <0 → $g_\Sigma = 0$

$\Rightarrow Q_L = \dfrac{\omega_0 C_\Sigma}{g_\Sigma} \to \infty$ Amplifier disabled

Condition of Instability



If $Y_s + Y_i = 0$, $g_\Sigma = 0$ Instable

$$Y_s + Y_i = Y_s + y_{ie} - \frac{y_{fe}y_{re}}{y_{oe} + Y_L'} = 0 \quad \Rightarrow \quad \frac{(Y_s + y_{ie})(y_{oe} + Y_L')}{y_{fe}y_{re}} = 1$$

y_{re}↑, Feedback↑, Left equation↓, Close to 1 → Instable
y_{re}↓ , Feedback↓, Left of equation↑→ Stable

Stability Coefficient $S = \dfrac{(Y_S + y_{ie})(y_{oe} + Y_L')}{y_{fe}y_{re}}$

If $S = 1$, Instable
If S>>1 , Stable ($S = 5$~10)

Relation between A_{V_o} and S

If $S = 5$, $(A_{V_o})_s = \sqrt{\dfrac{|y_{fe}|}{2.5\omega_0 C_{re}}}$

$$A_{V_o} \le (A_{V_o})_s$$

Note:

① $f\uparrow$ $(A_{V_o})_s\downarrow$

② Choose bigger $\dfrac{|y_{fe}|}{C_{re}}$

③ $(A_{V_o})_s$ only consider inner feedback, not outside feedback

Solutions

Clue:

$y_{re} \neq 0$ ($C_{b'c} \neq 0$) $\Rightarrow$ Bi-directional Device

⇒Unidirectionalize

1

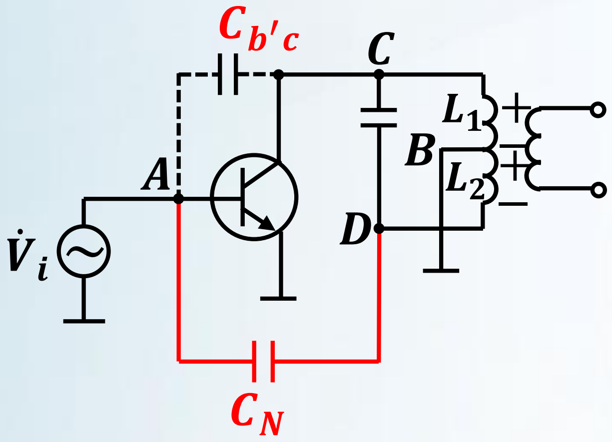
Neutralization

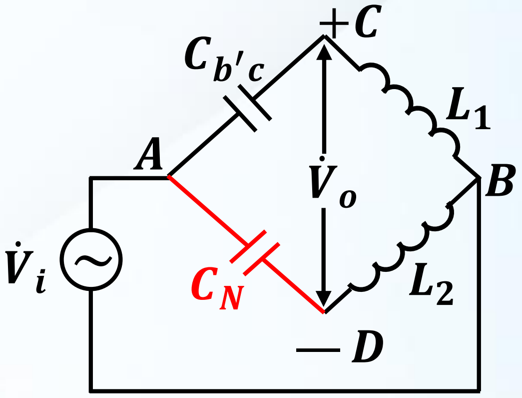
2

Mismatch

(1) Neutralization:

- To add C_N to construct bridge





- Balancd Bridge, CD ($\dot{V}_0$) does not feedback to AB
- Balancd Bridge, impedance ratio are same

Output not affact input

$$\therefore \frac{\omega L_1}{\omega L_2} = \frac{\dfrac{1}{j\omega C_{b'c}}}{\dfrac{1}{\omega C_N}} \qquad \Rightarrow C_N = \frac{L_1}{L_2} C_{b'c}$$

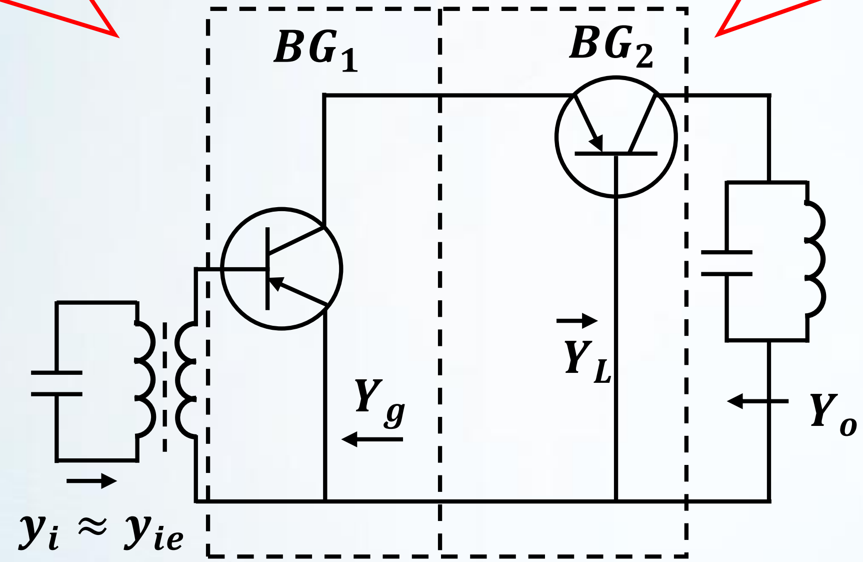
(2) Mismatch:

Gain↓ Stability↑

- Clue: Mismatch ⇒ Output↓ ⇒ Feedback↓ ⇒ Stable

Common Emitter
r_{in}↑; r_{out}↑

Common Base
r_{in}↓; r_{out}↑



Darlington

(3) Comparisons

- **Neutralization**

Pros: Simple, High Gain

Cons: ① not for wideband amplifier

② not effective for changes of tempreture

③ not suitable for batch production

- **Mismatch**

Pros: ① wideband amplifier

② effective for changes of many factors

③ suitable for batch production

Cons: gain ↓