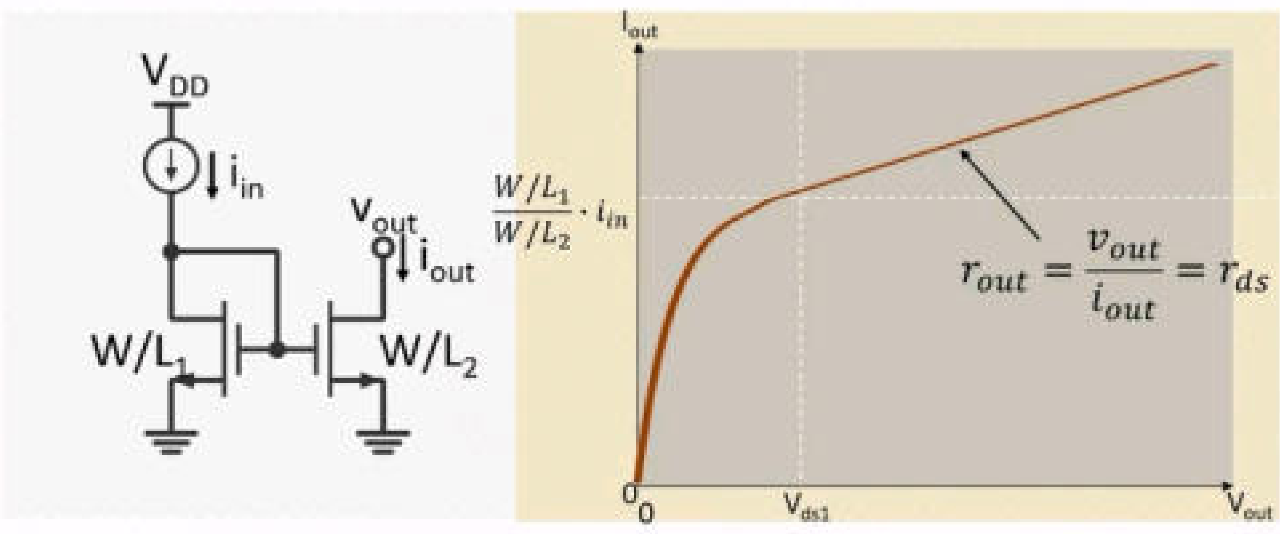
Recall

Topology	Gain	Rout	Rin
CM source	high	high	high
CM gate	high	high	low
CM drain	low	low	high

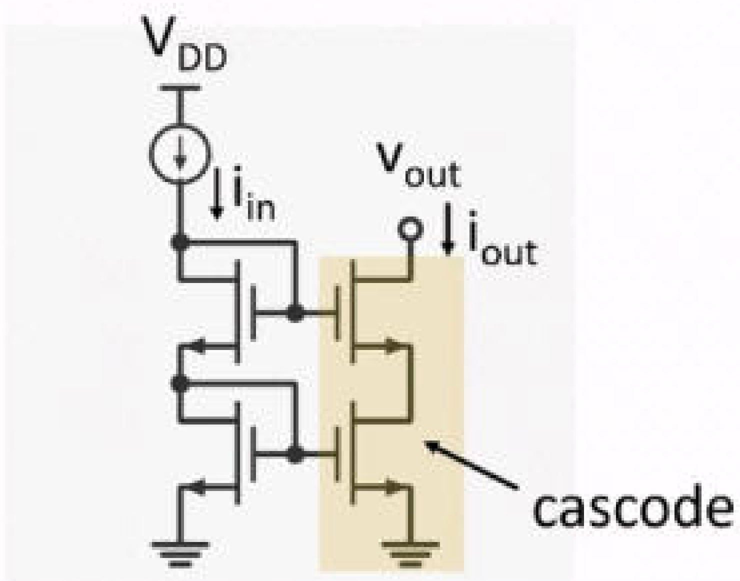
Basic Current Mirror



For an ideal current mirror the output current is independent of V_{out}.

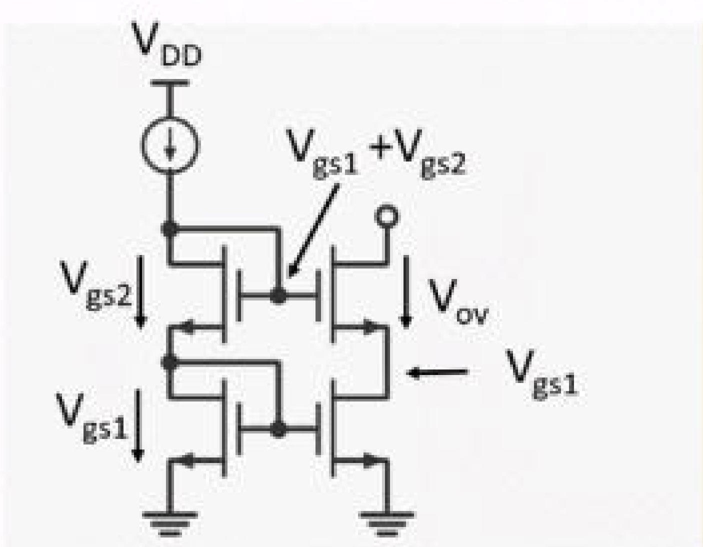
➡ large r_{out} desired

Cascode Current Mirror



Increased output resistance due to cascoding.

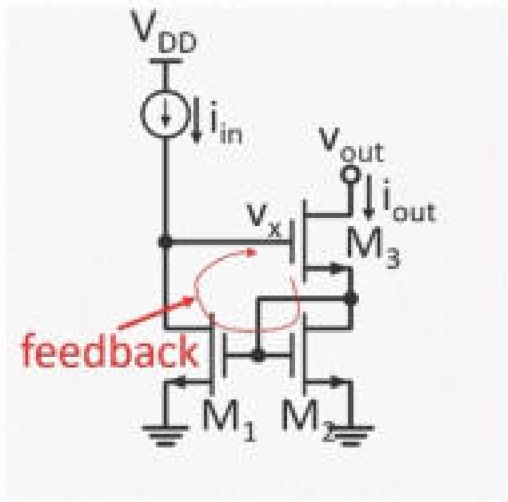
Cascode Current Mirror



$$V_{out} > V_{gs1} + V_{ov} = V_{th} + 2V_{ov}$$

Reduced swing compared to basic current mirror.

Wilson Current Mirror



标角解释

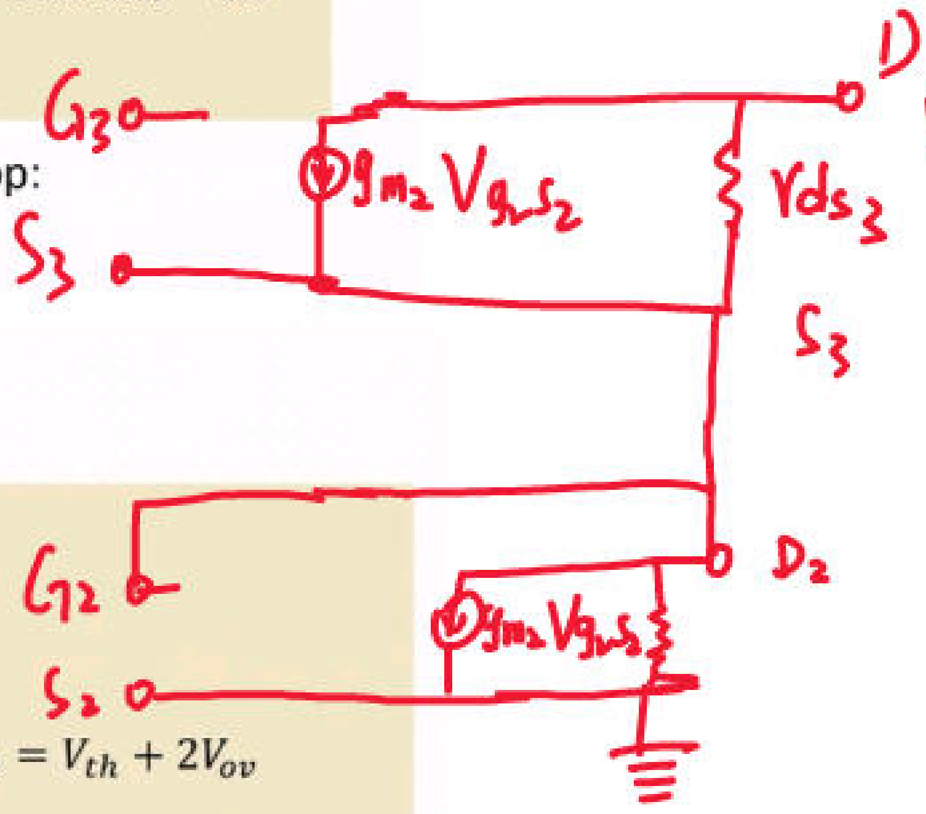
$$i_{out} = \frac{v_{out}}{r_{ds3} + 1/g_{m2}} - \underbrace{i_{out} r_{ds1} g_{m3}}_{\text{feedback}}$$

反馈量

$$\Rightarrow r_{out} \approx \frac{v_{out}}{i_{out}} = (1 + g_{m3} r_{ds1}) \cdot r_{ds3}$$

Output resistance increased via feedback loop:

$V_{out}\uparrow \rightarrow I_{out}\uparrow \rightarrow v_x\downarrow$

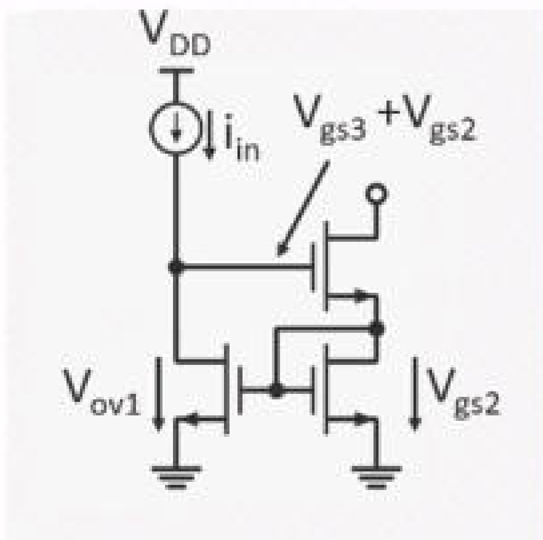


$g_{m2}V_{g_2s_2}$ 是一个电流源，内阻很大，故并联后，等效成一个 r_{ds3}

$G_2 = D_2$ 即 $g_{m2}V_{g_2s_2}$ 是一个等效电阻 $R' = \frac{V_{g_2s_2}}{g_{m2}V_{g_2s_2}} = \frac{1}{g_{m2}}$

综上 未反馈时 $i_{out} = \frac{V_{out}}{r_{ds3} + \frac{1}{g_{m2}}}$

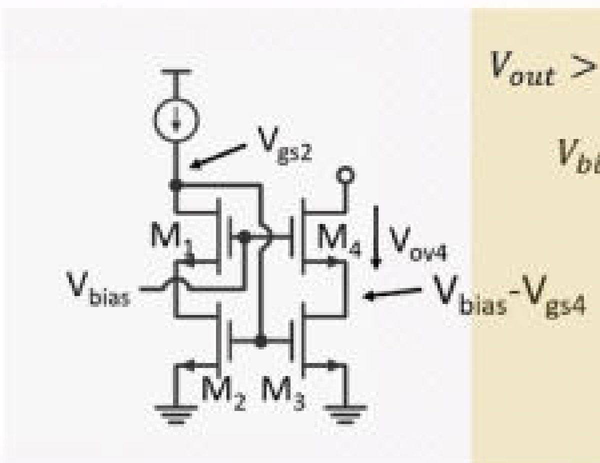
Wilson Current Mirror



$$V_{out} > V_{gs2} + V_{ov3} = V_{th} + 2V_{ov}$$

How to increase the output swing?

High Swing Cascode Current Mirror



$$V_{out} > V_{bias} - V_{gs4} + V_{ov4} = V_{bias} - V_{th}$$

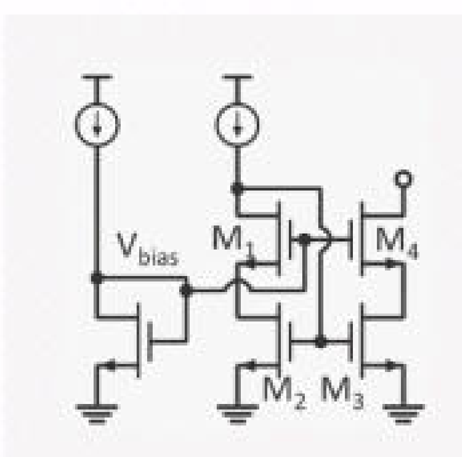
$$V_{bias} > V_{gs1} + V_{ov2}$$

$$\Rightarrow V_{out} > V_{ov1} + V_{ov2} = 2V_{ov}$$

Output swing increased by V_{th}.

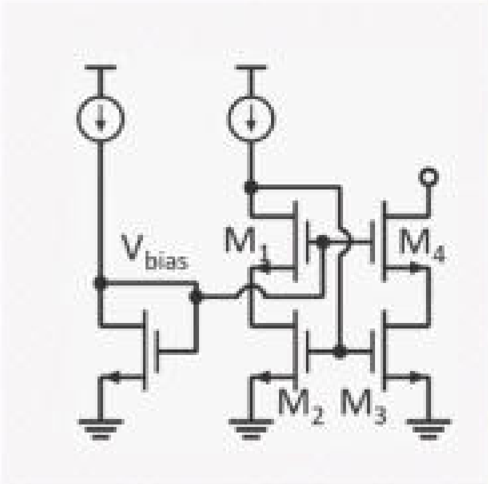
How to generate V_{bias}?

High Swing Cascode Current Mirror



Use long (L > W) diode connected transistor to generate V_{bias}.

High Swing Cascode Current Mirror



$$V_{bias} > V_{ov2} + V_{gs1}$$

Use long (L > W) diode connected transistor to generate V_{bias}.

Recall

Current Mirror	Rout	Swing
Basic	-	++
Cascode	+	-
Wilson	+	-
High Swing	+	+

反馈(Feedback)

Effects of Poles & Zeros on Frequency Response(1)

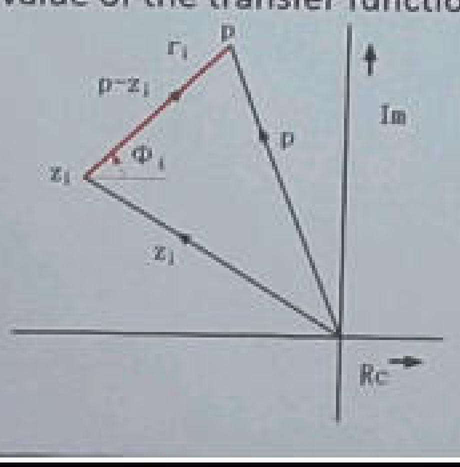
- Consider a general system transfer function:

$$H(s)=\frac{P(s)}{Q(s)} = b_0\frac{(s-z_1)(s-z_2)\cdots(s-z_N)}{(s-\lambda_1)(s-\lambda_2)\cdots(s-\lambda_N)}$$

zeros at $z_1\ z_2 \cdots z_N$

poles at $\lambda_1\ \lambda_2 \cdots \lambda_N$

- The value of the transfer function at some complex frequency s=p is:



$$H(s)|_{s=p} = b_0\frac{(p-z_1)(p-z_2)\cdots(p-z_N)}{(p-\lambda_1)(p-\lambda_2)\cdots(p-\lambda_N)}$$

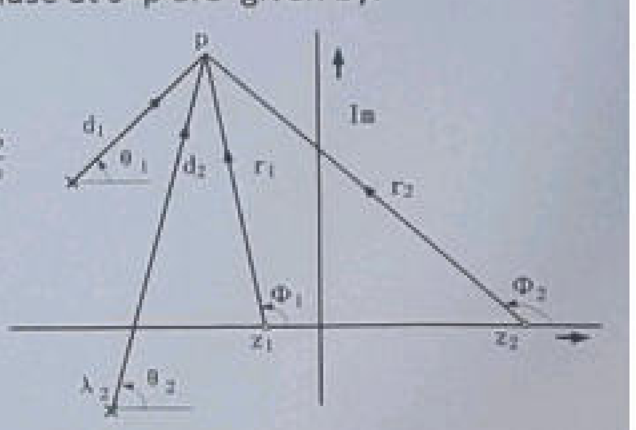
$$= b_0\frac{(r_1e^{j\phi_1})(r_2e^{j\phi_2})\cdots(r_Ne^{j\phi_N})}{(d_1e^{j\theta_1})(d_2e^{j\theta_2})\cdots(d_Ne^{j\theta_N})}$$

Effects of Poles & Zeros on Frequency Response(2)

- Therefore the magnitude and phase at s=p are given by:

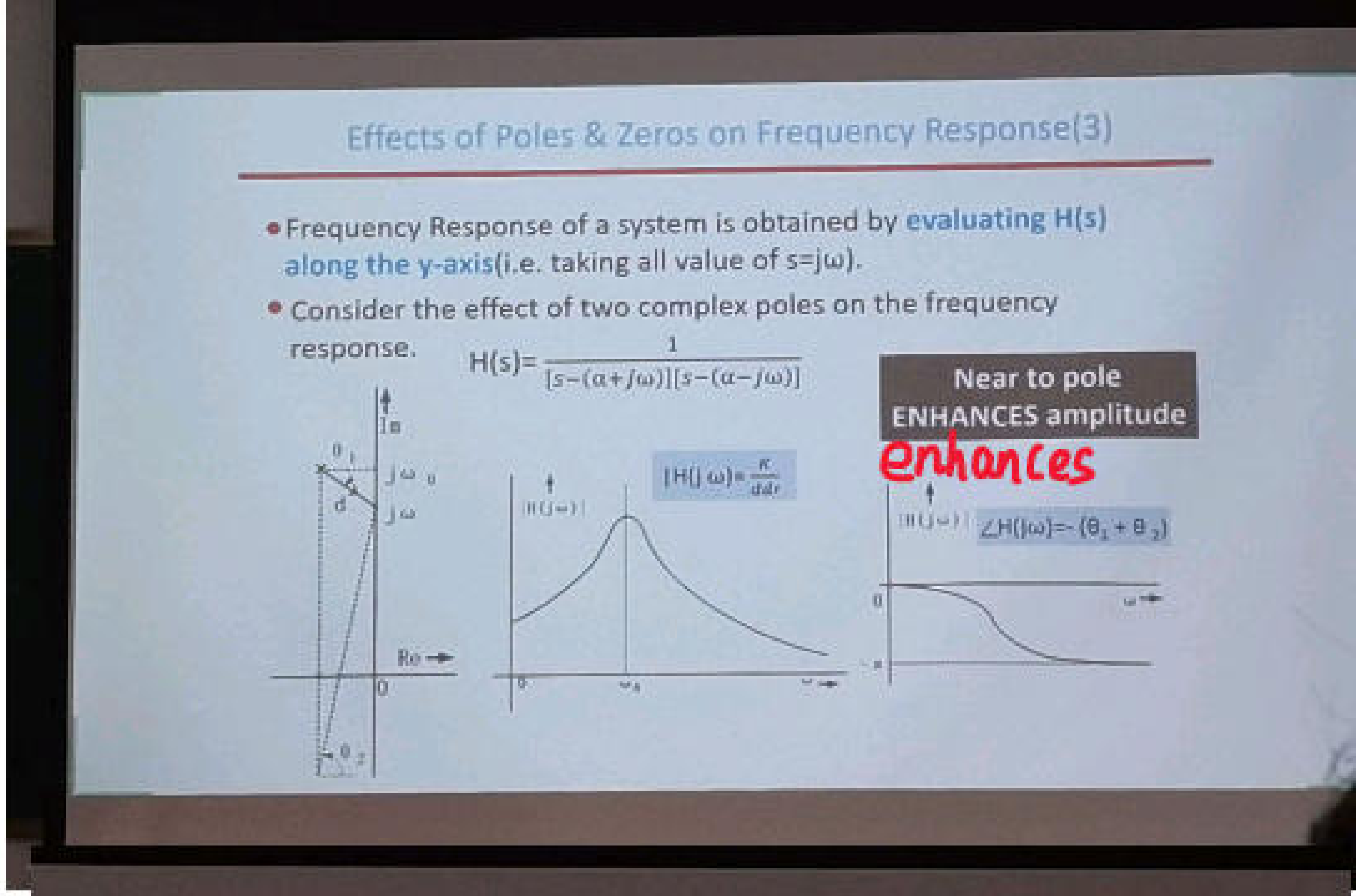
$$H(s)|_{s=p} = b_0\frac{r_1r_2\cdots r_N}{d_1d_2\cdots d_N}$$

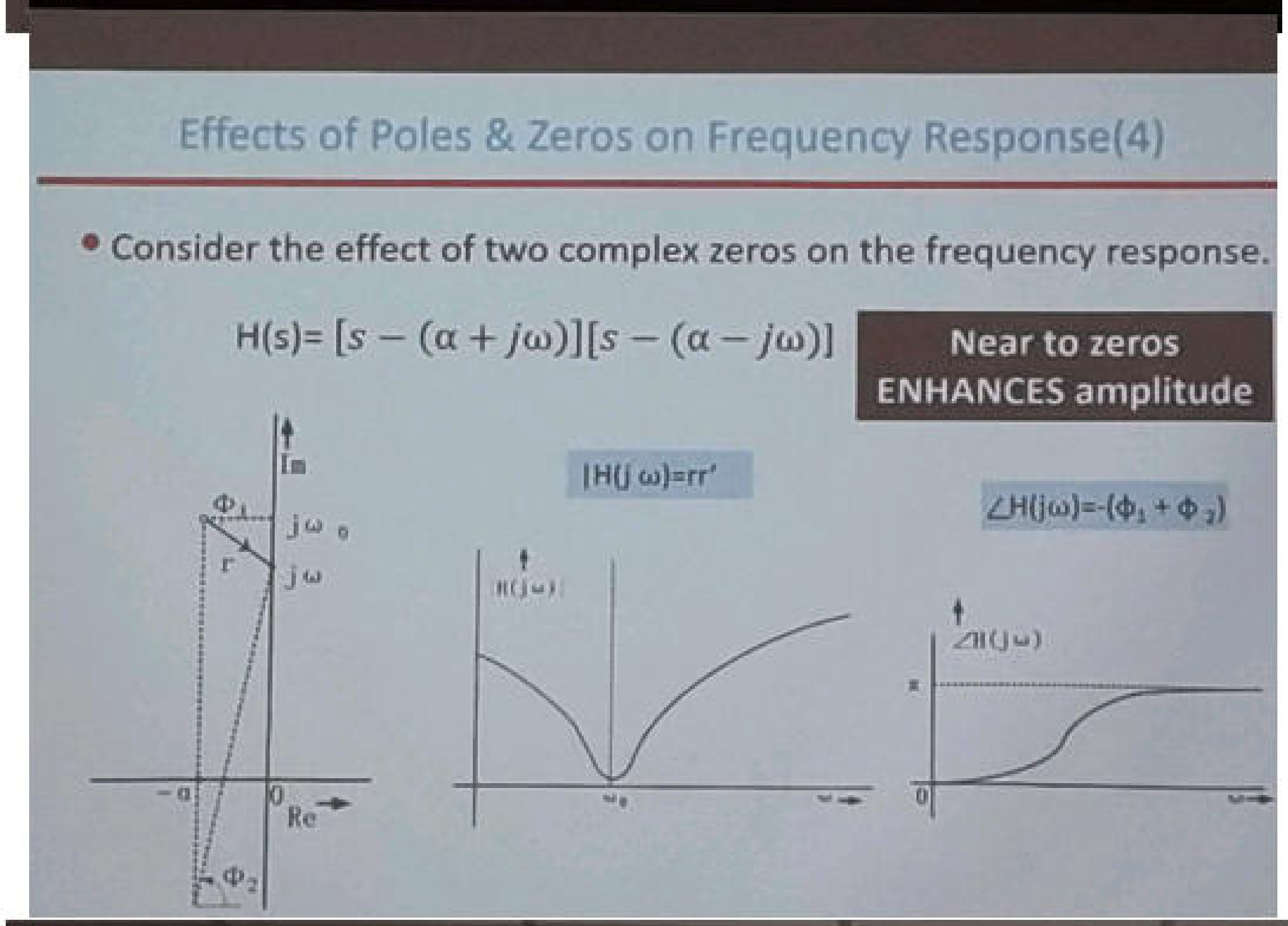
$$= b_0\frac{\text{product of the distances of zeros to p}}{\text{product of the distances of poles to p}}$$

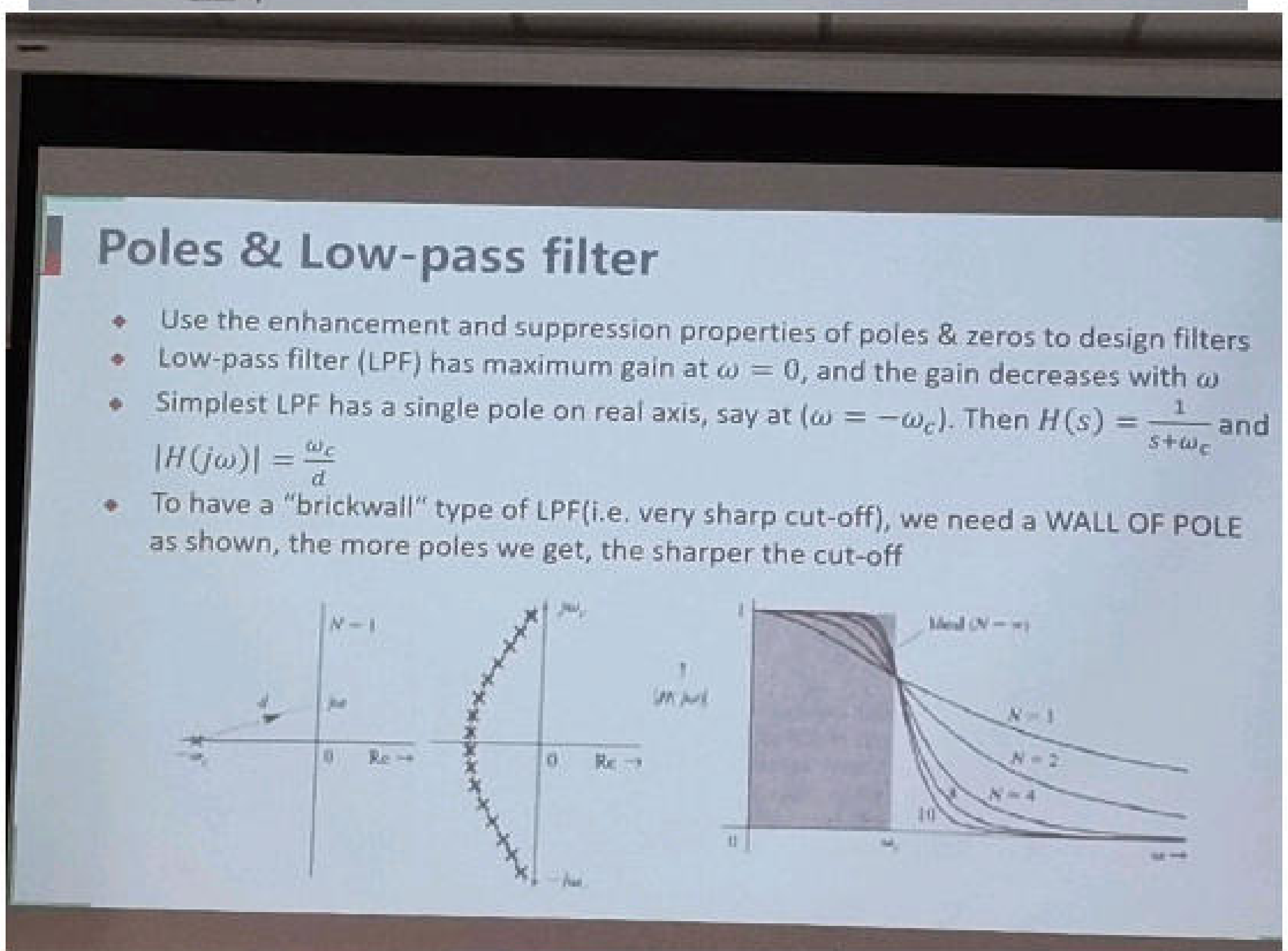


$$\angle H(s)|_{s=p} = (\Phi_1+\Phi_2+\cdots+\Phi_N) - (\theta_1+\theta_2+\cdots+\theta_N)$$

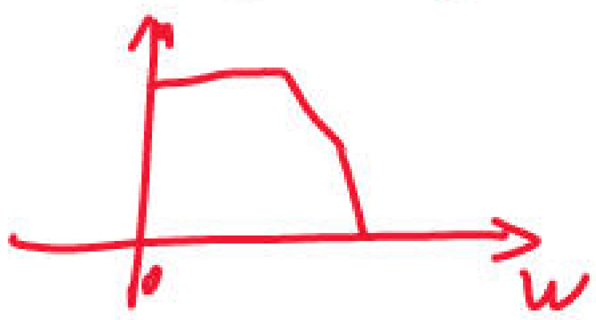
=sum of zero angles to p − sum of pole angles to p

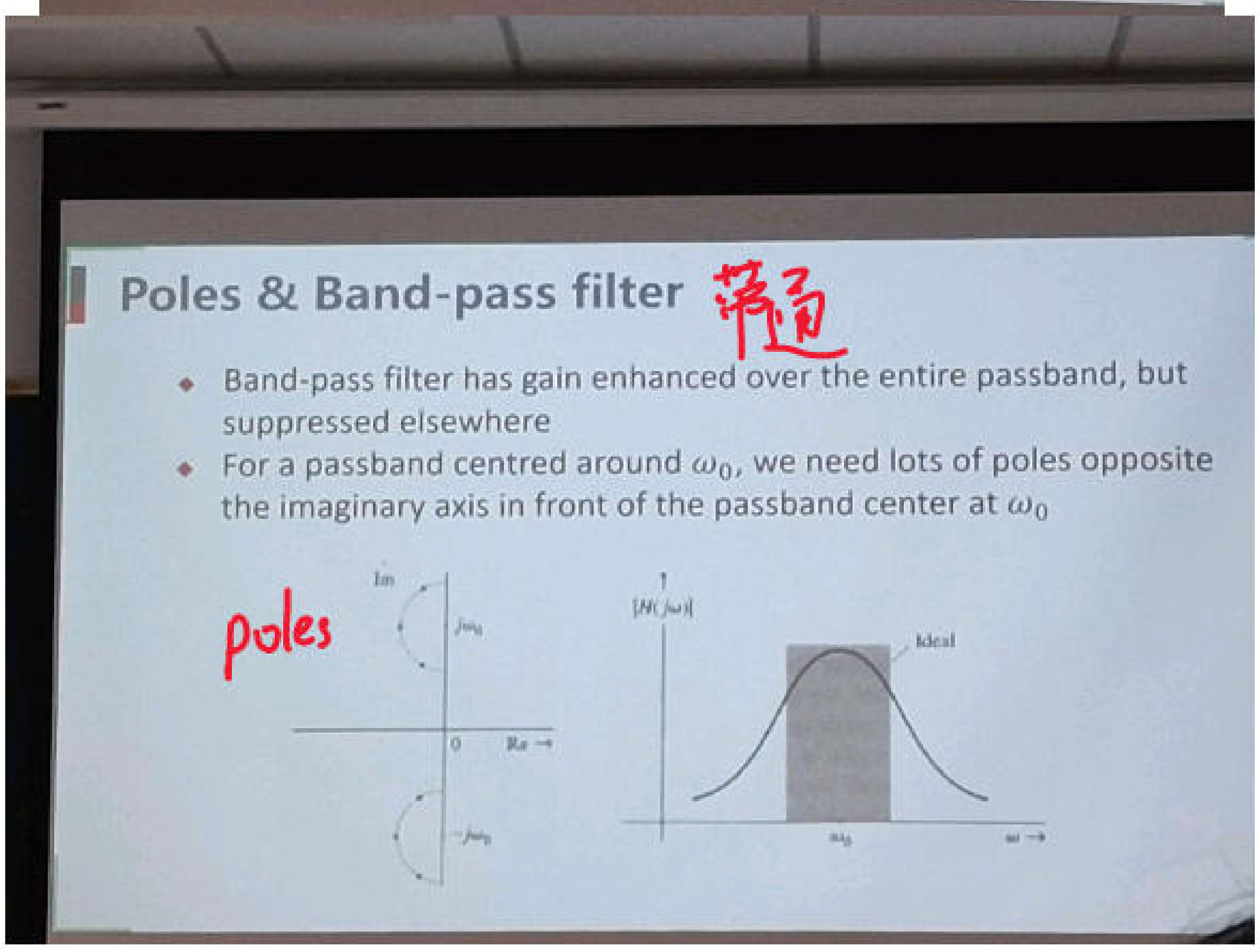


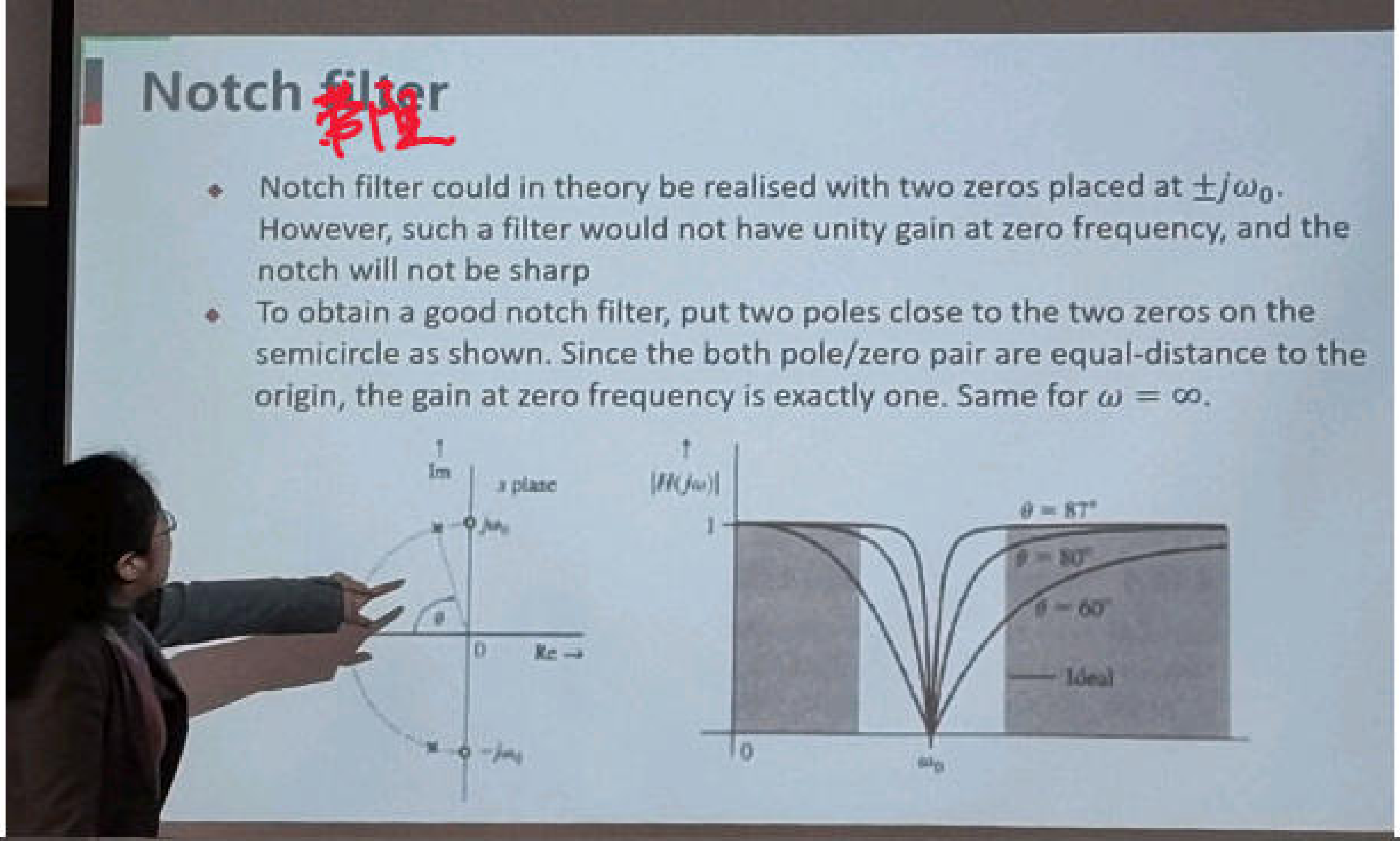


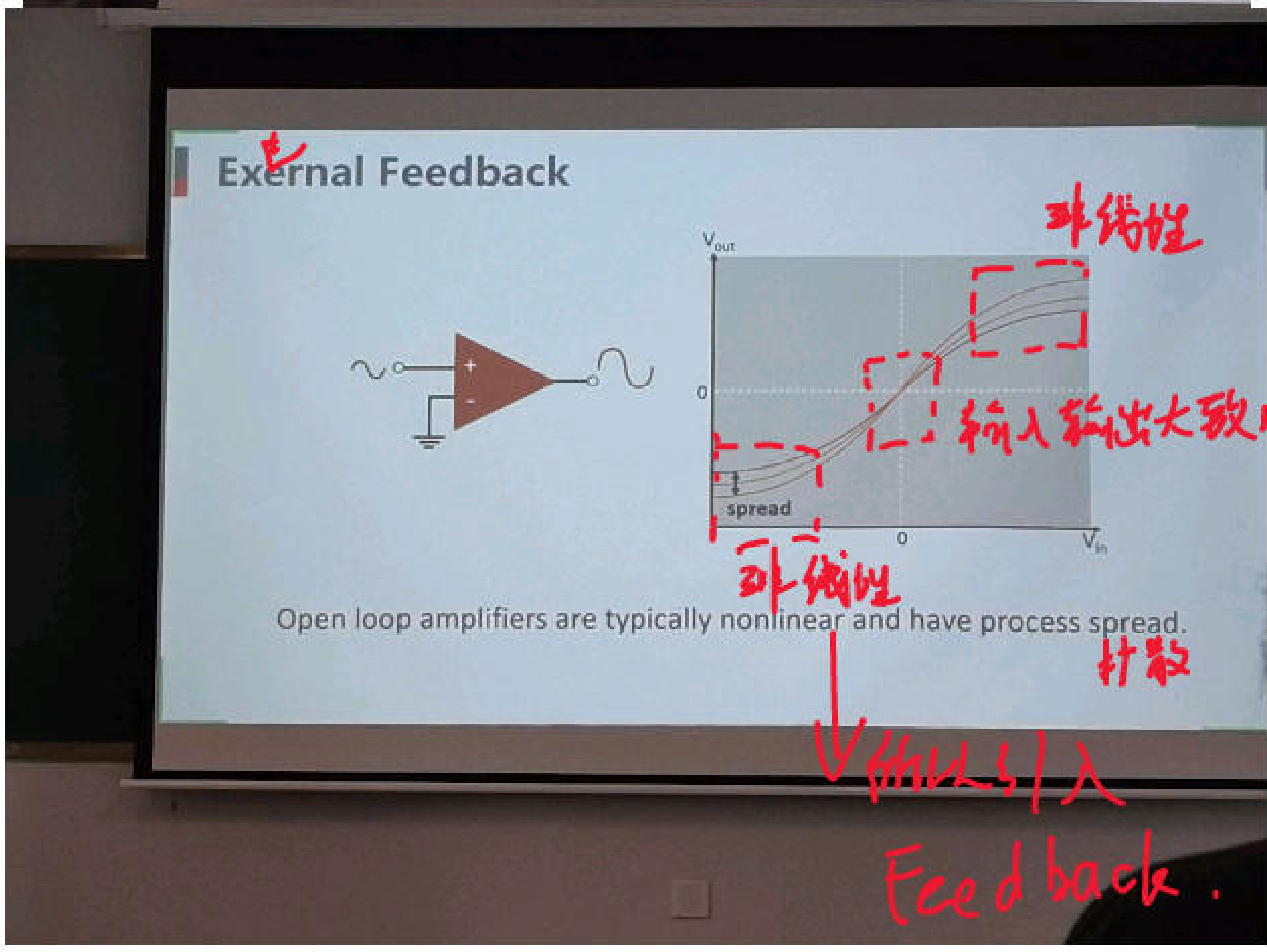


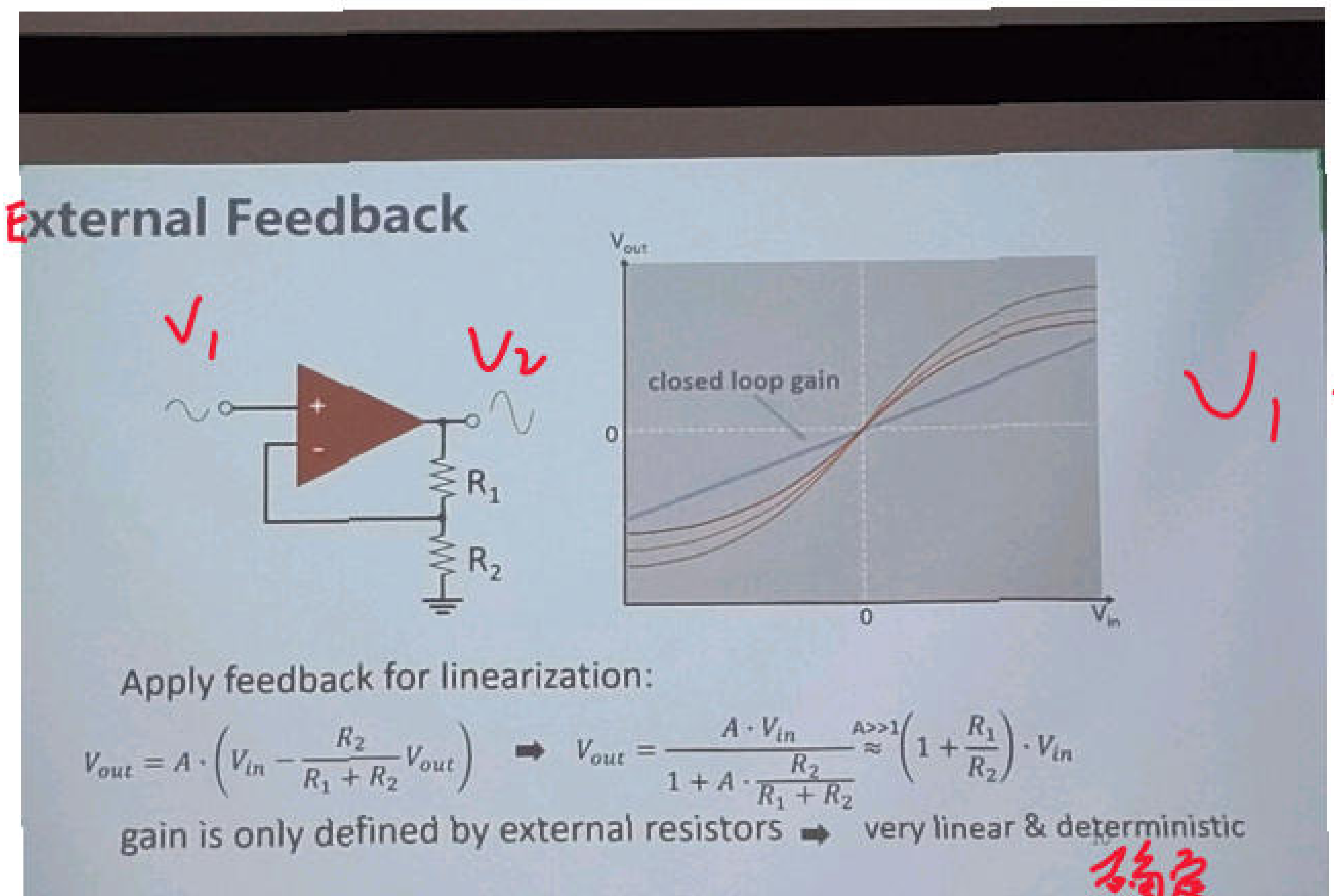
低通滤波器
在分母做极点
$$H(s)=\frac{1}{(s-a)(s-b)}$$





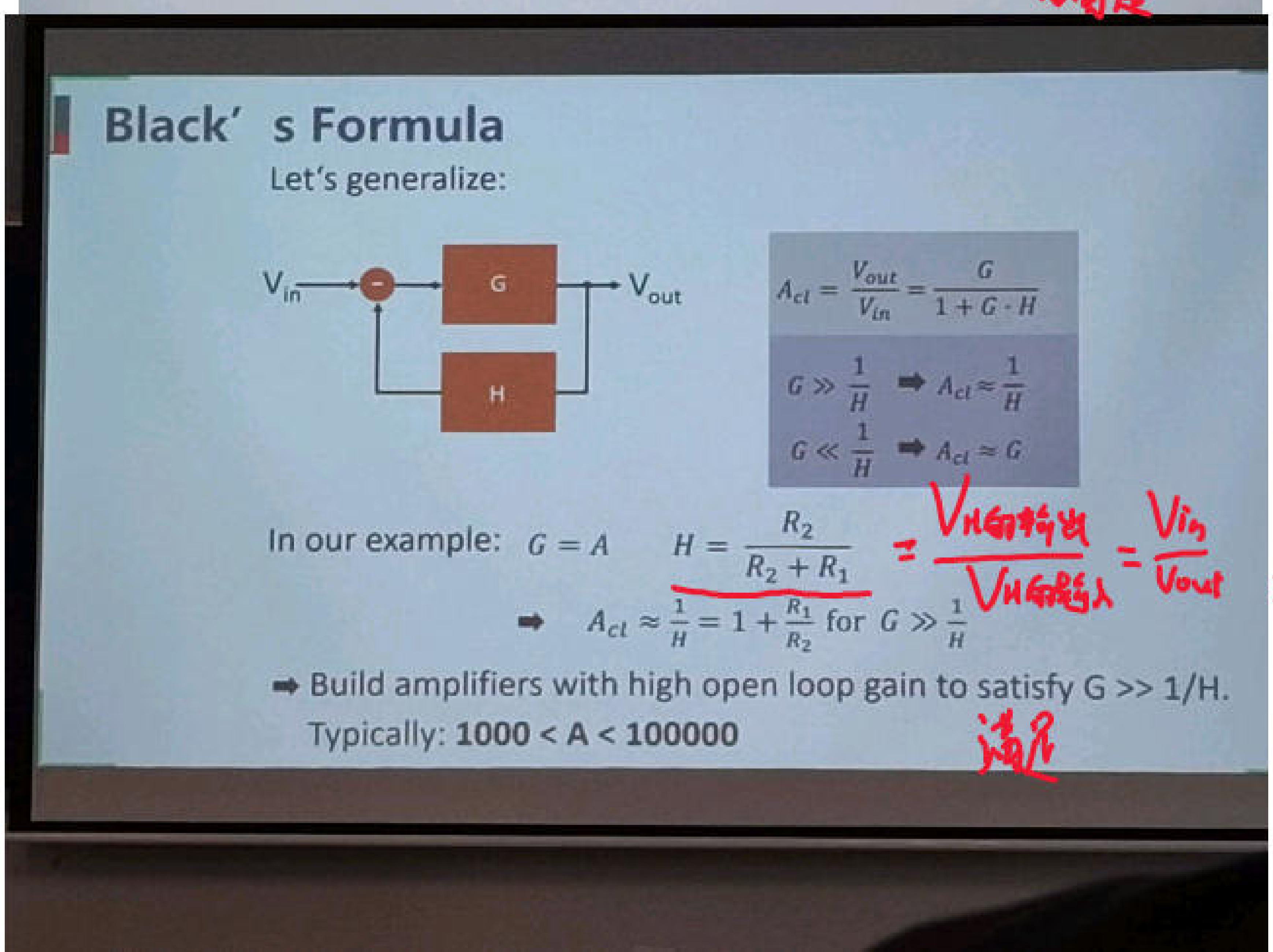






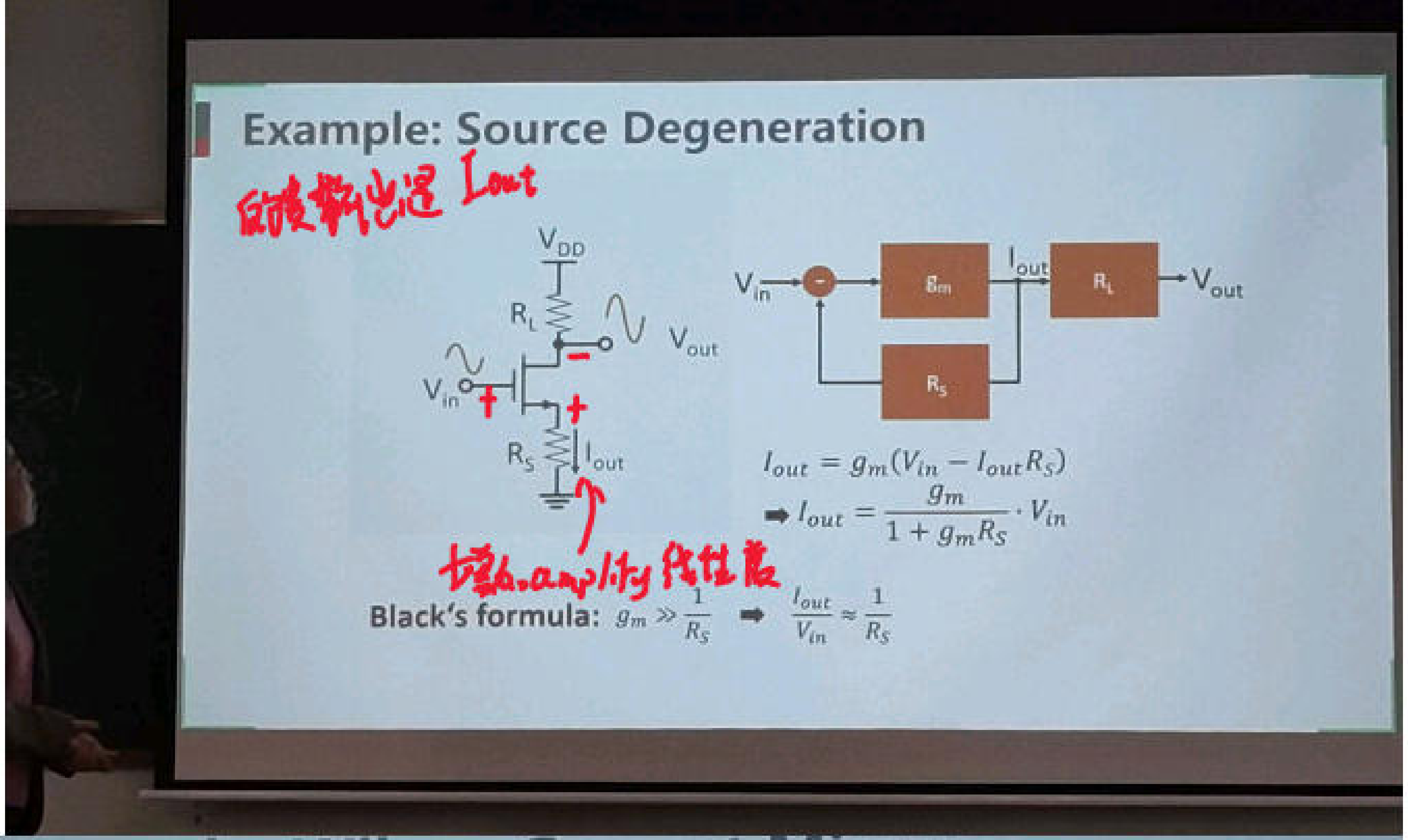
$$V_1 = V_2 \cdot \frac{R_2}{R_1+R_2}$$

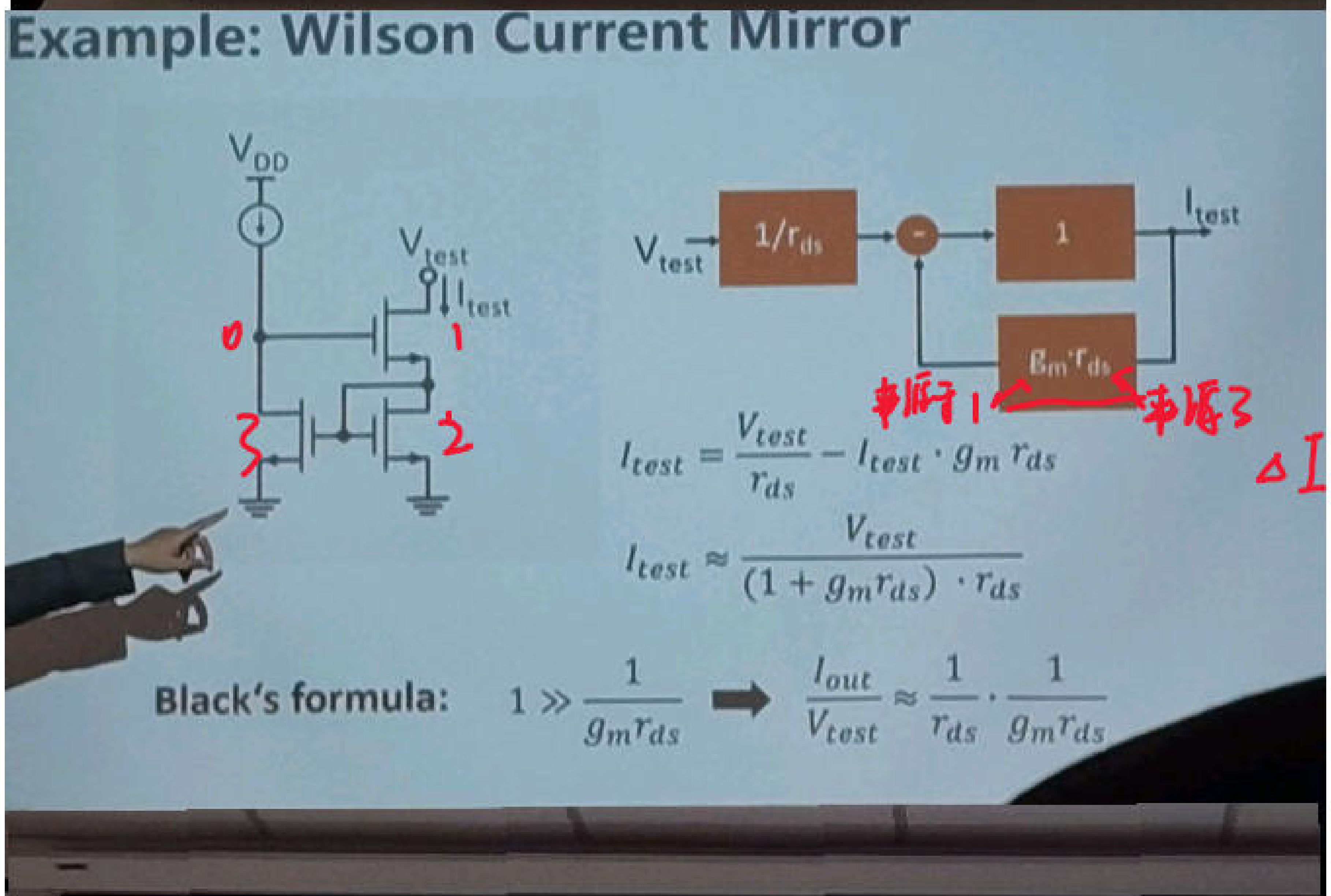
$$\frac{V_2}{V_1} = \frac{R_1+R_2}{R_2} = 1+\frac{R_1}{R_2}$$



GH
环路增益

1+GH
反馈深度

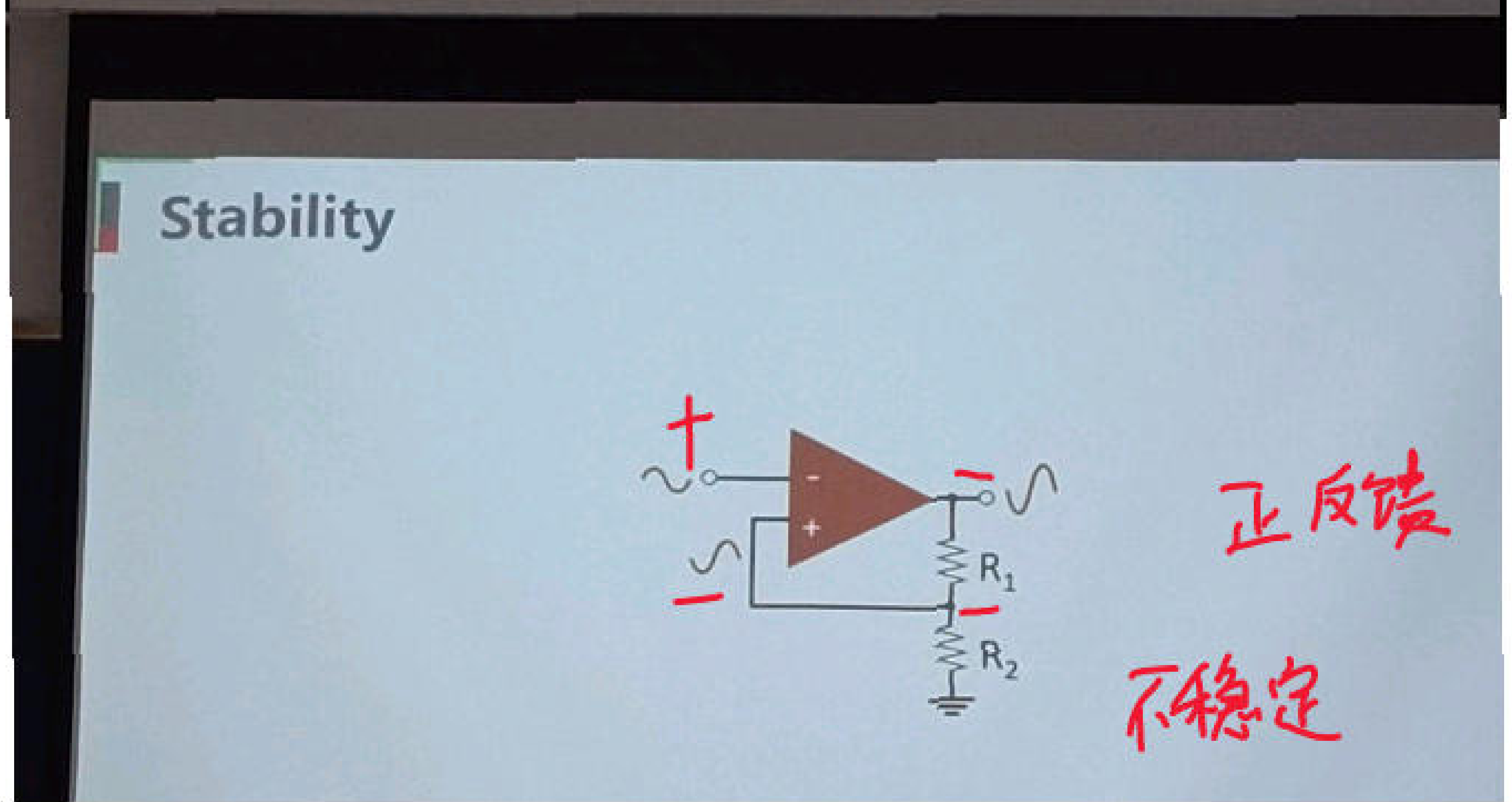


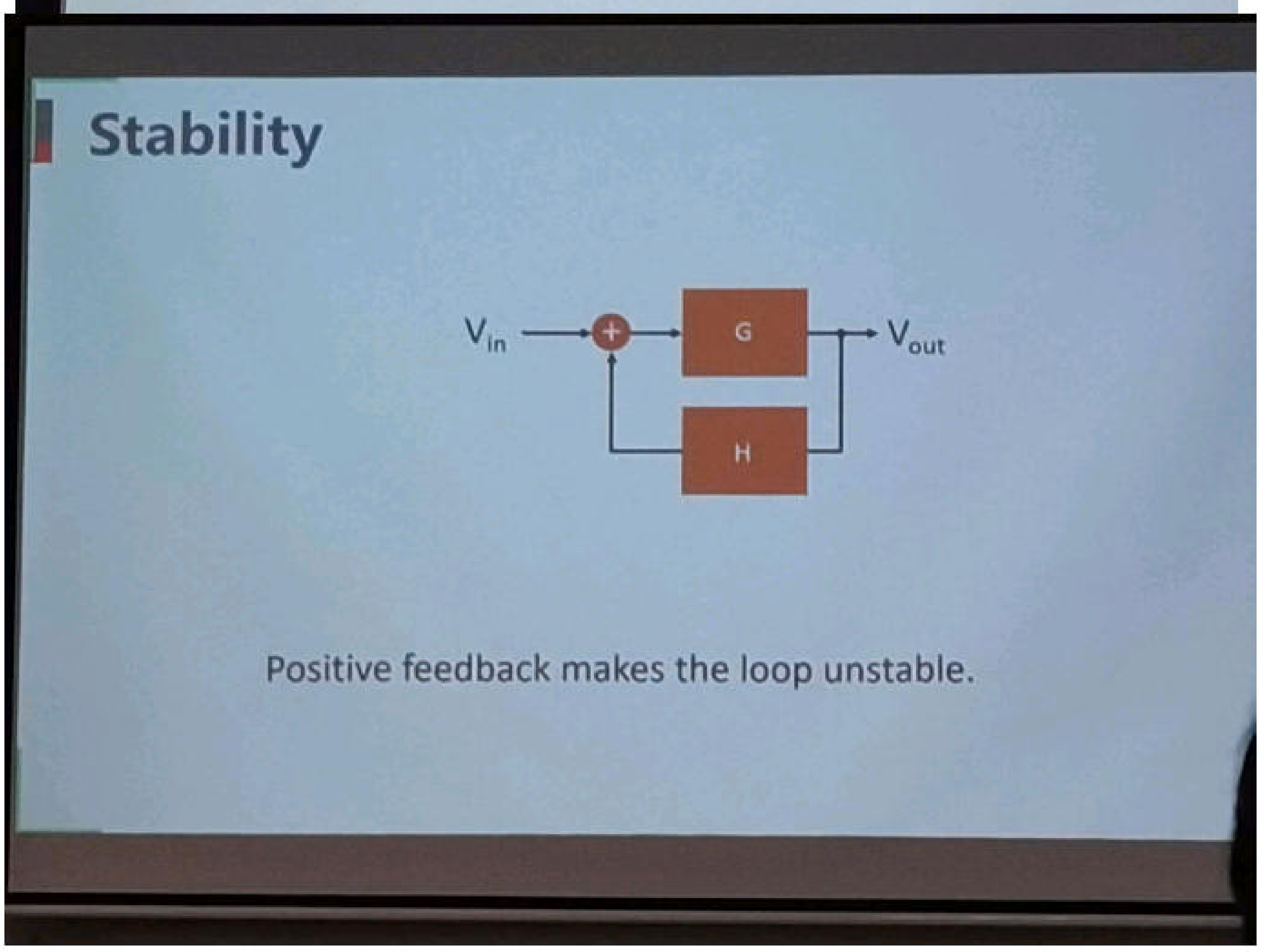


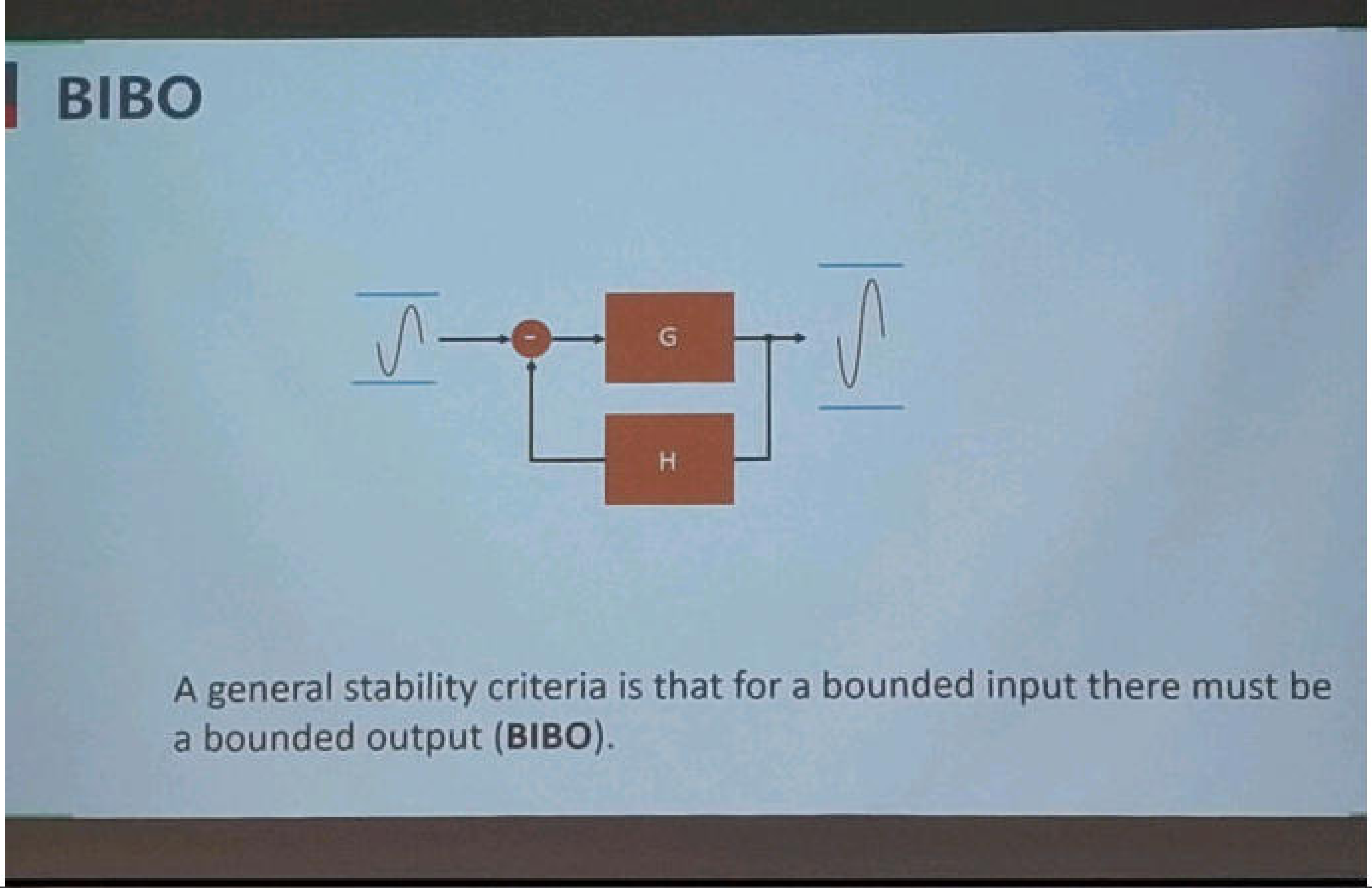
ΔI

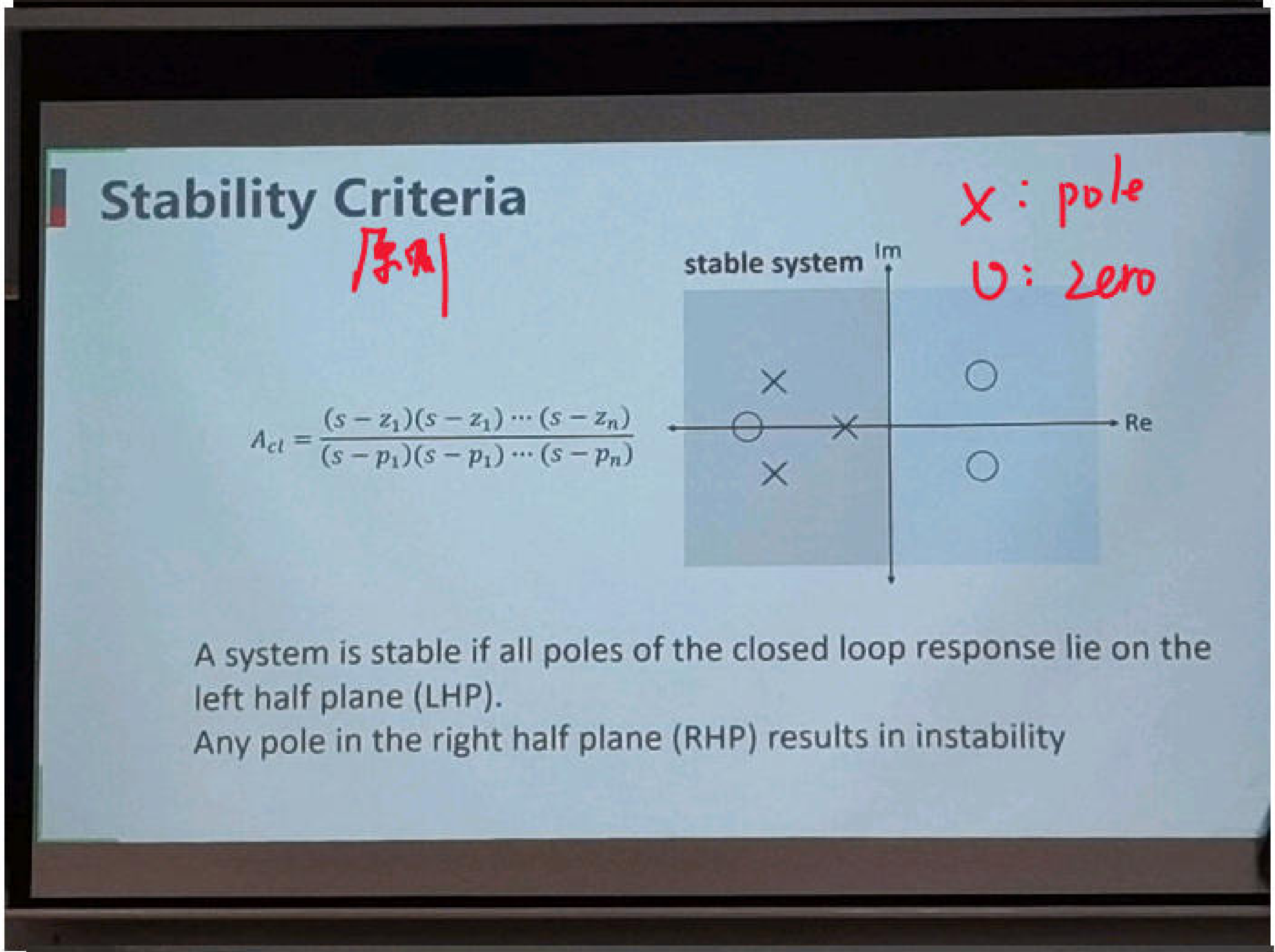
$V_{ds3} = \Delta V_0$

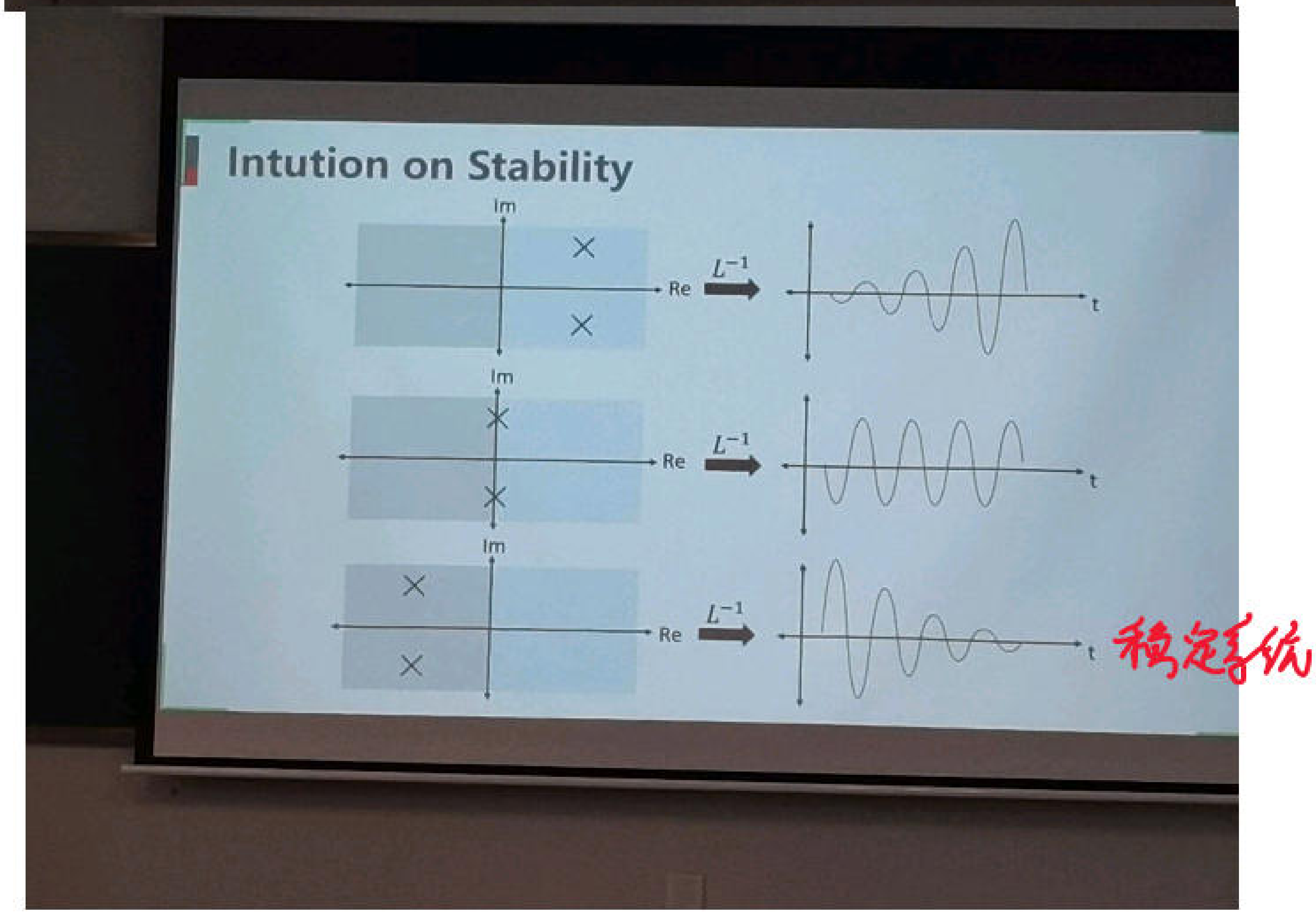
$\Delta V_0 g_m = \Delta I$



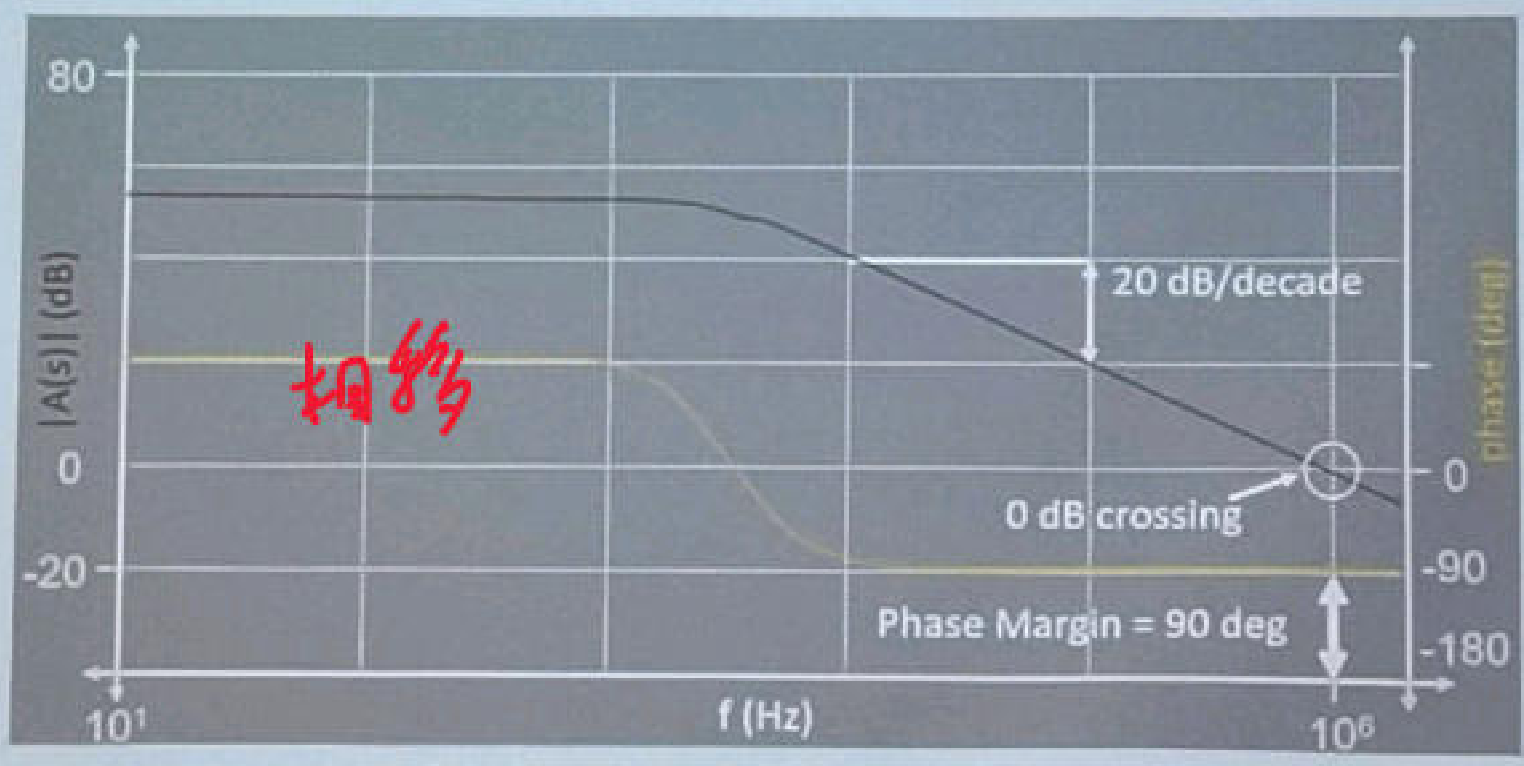


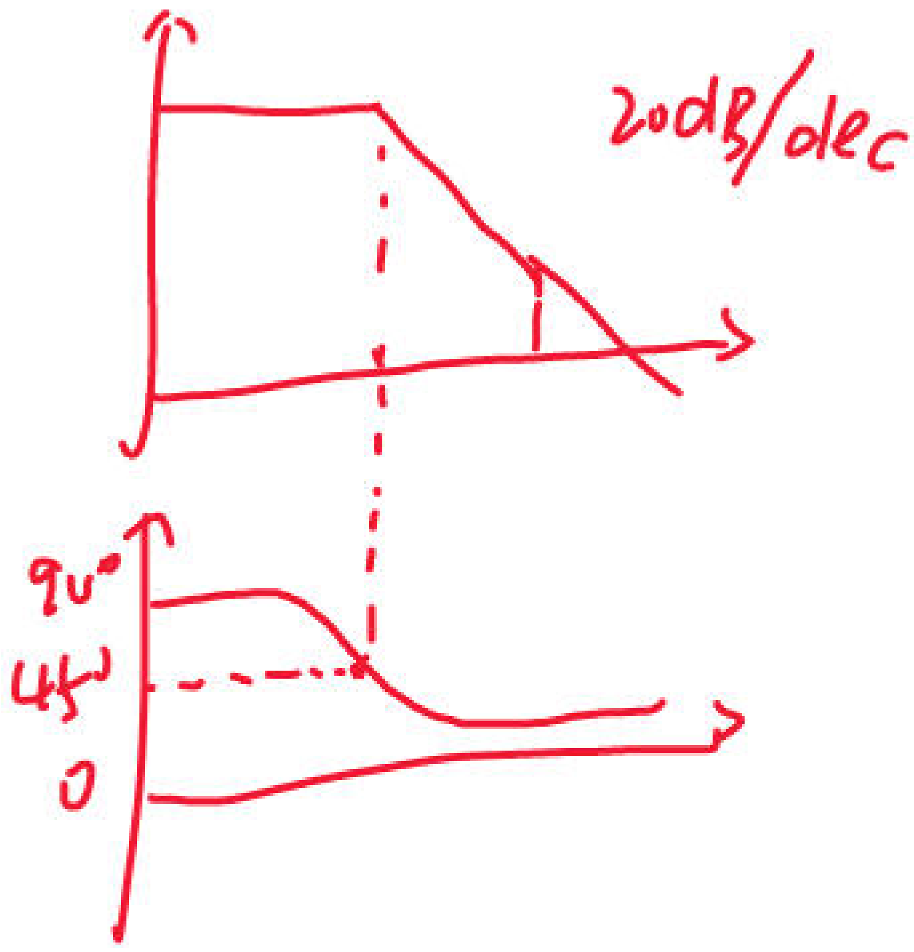

BIBO
G
H
A general stability criteria is that for a bounded input there must be a bounded output (BIBO).


Stability Criteria
原则
x : pole
o : zero
stable system
Im
Re
$A_{cl} = \frac{(s-z_1)(s-z_1)\cdots(s-z_n)}{(s-p_1)(s-p_1)\cdots(s-p_n)}$
A system is stable if all poles of the closed loop response lie on the left half plane (LHP).
Any pole in the right half plane (RHP) results in instability


Intution on Stability
Im
Re
L^{-1}
t
稳定系统

Bode Plot



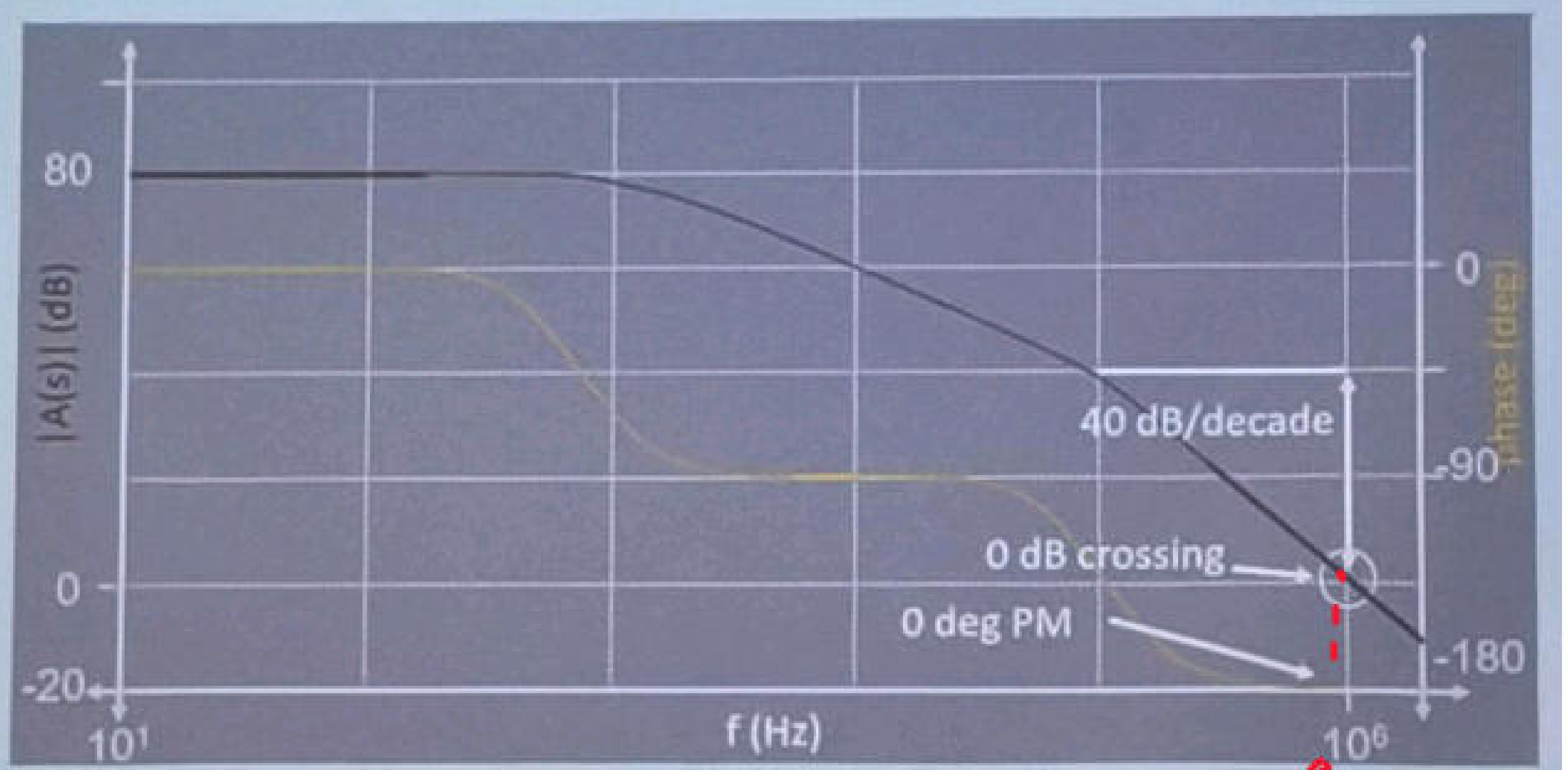


There is a more intuitive way to check on the Bode Plot of the **open loop** response:
phase margin > 0 @ 0 dB crossing

一个pole产生90°相移

位于坐标轴上的

Bode Plot



2nd order roll-off creates low phase margin.

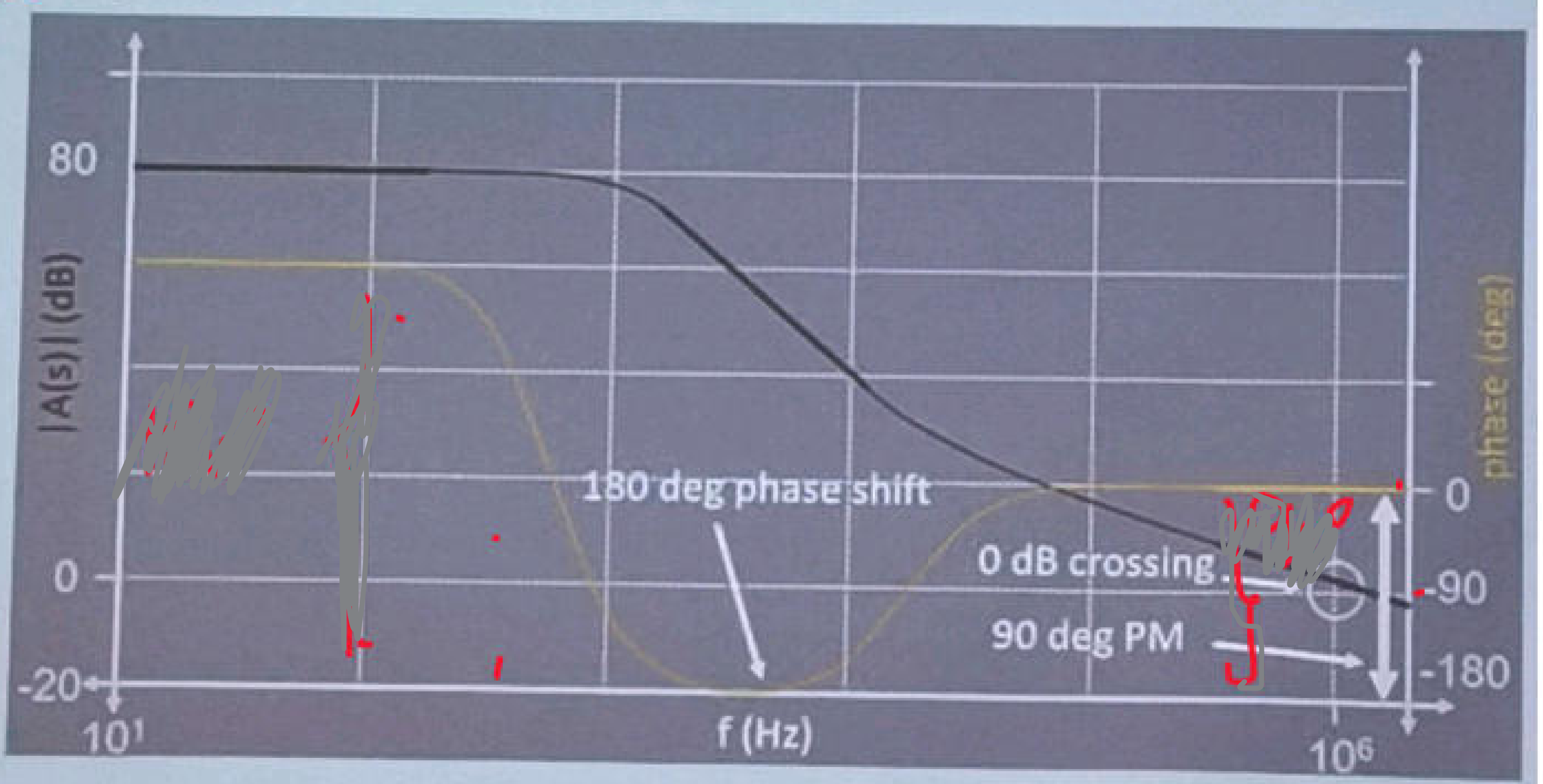
增益为1 频率点

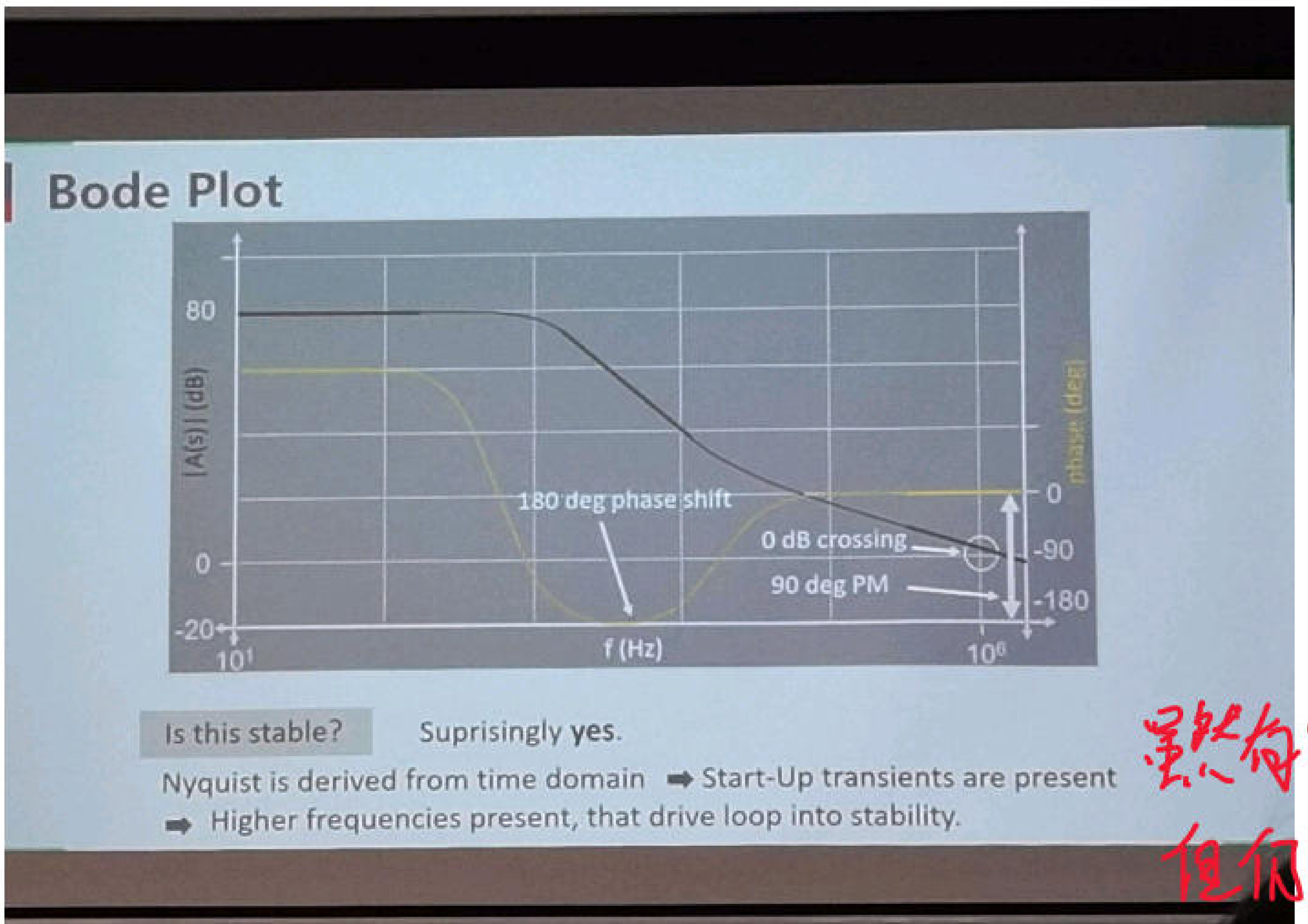
gain=1 时.

相位裕度

Bode Plot

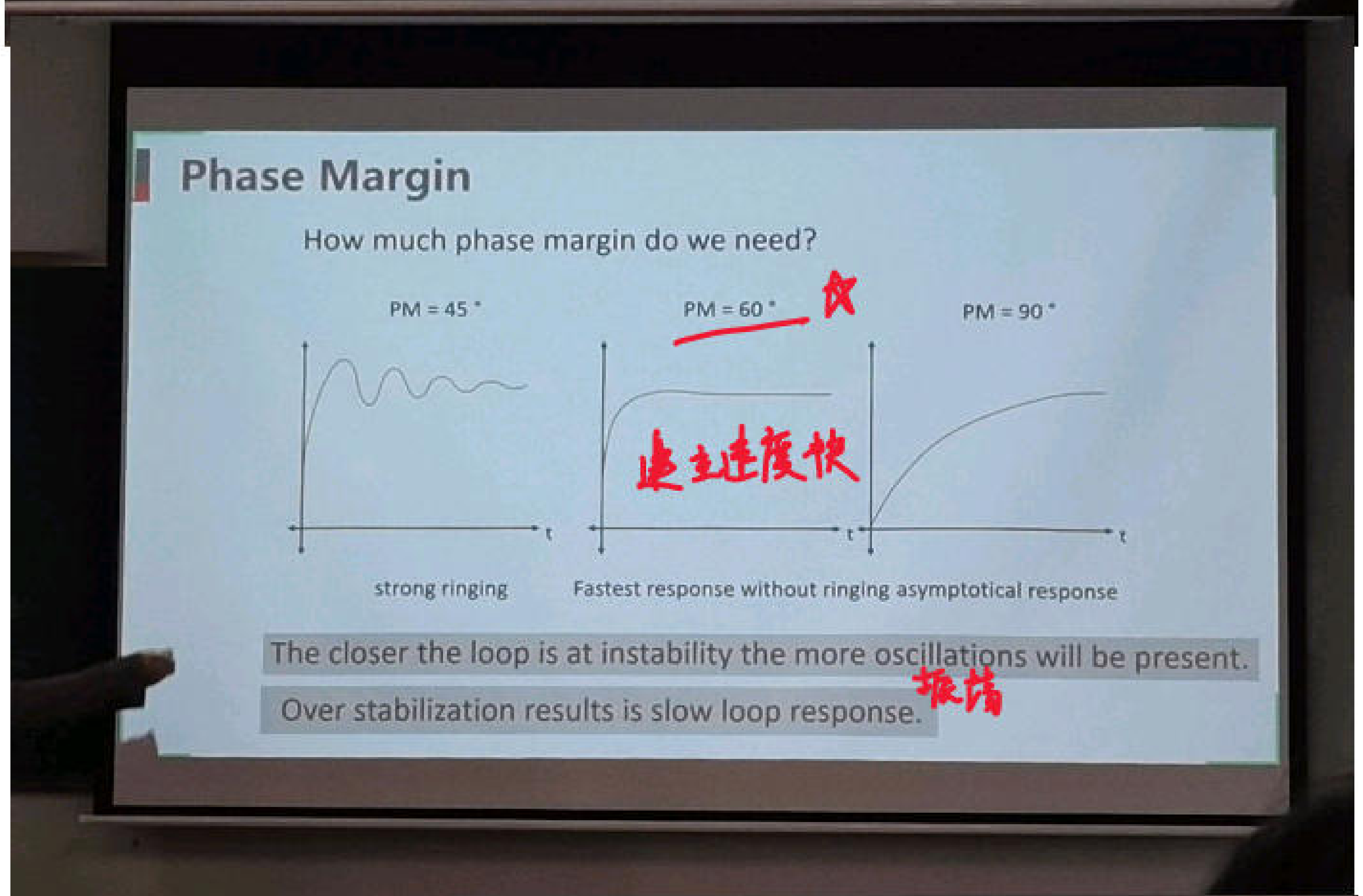
两组复pole + 一组复zero





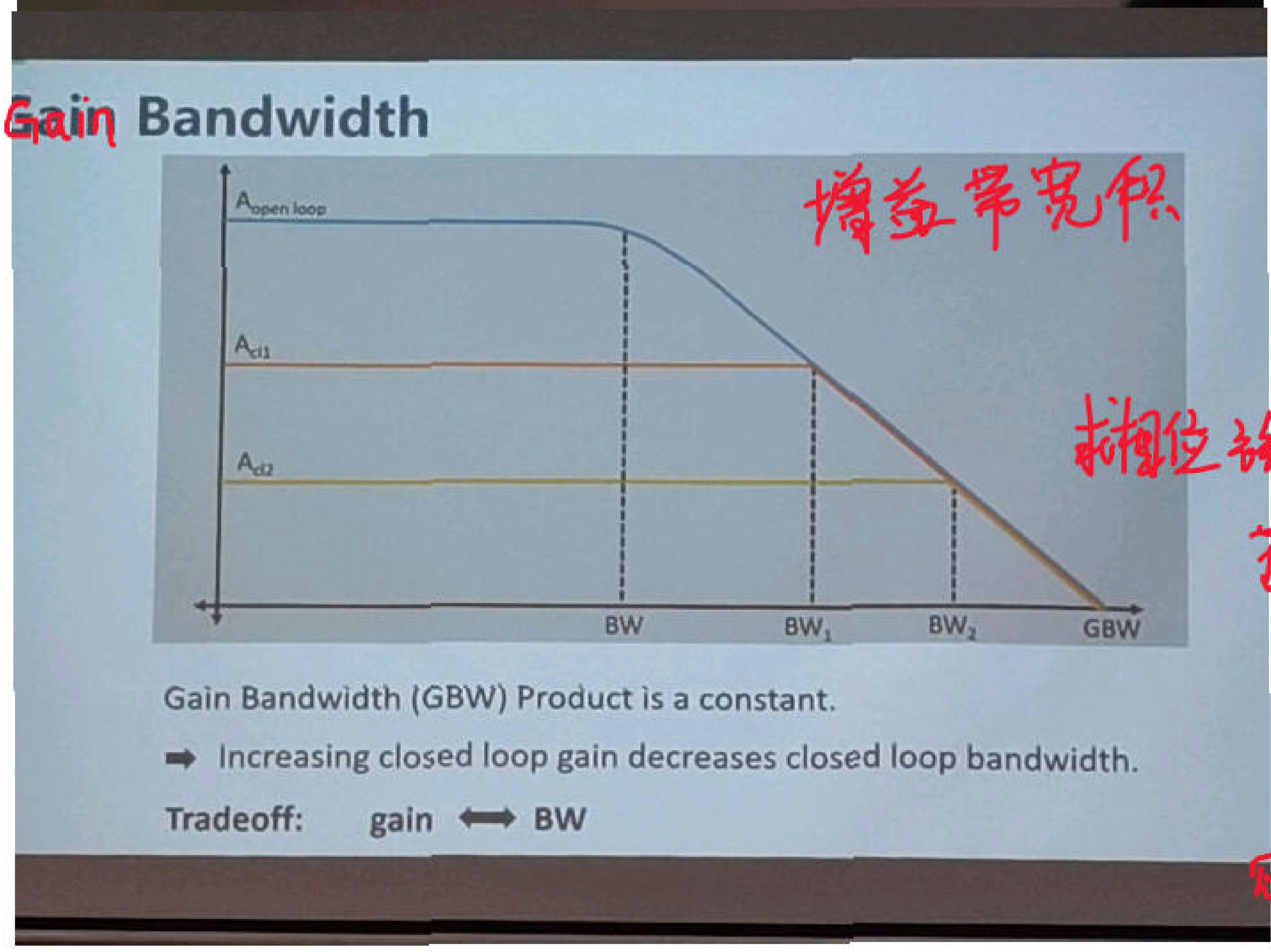
settle time is long

虽然有90°的marge
但仍是稳定的



速度快

振荡



Gain

增益带宽积

相位裕度看 feedback.

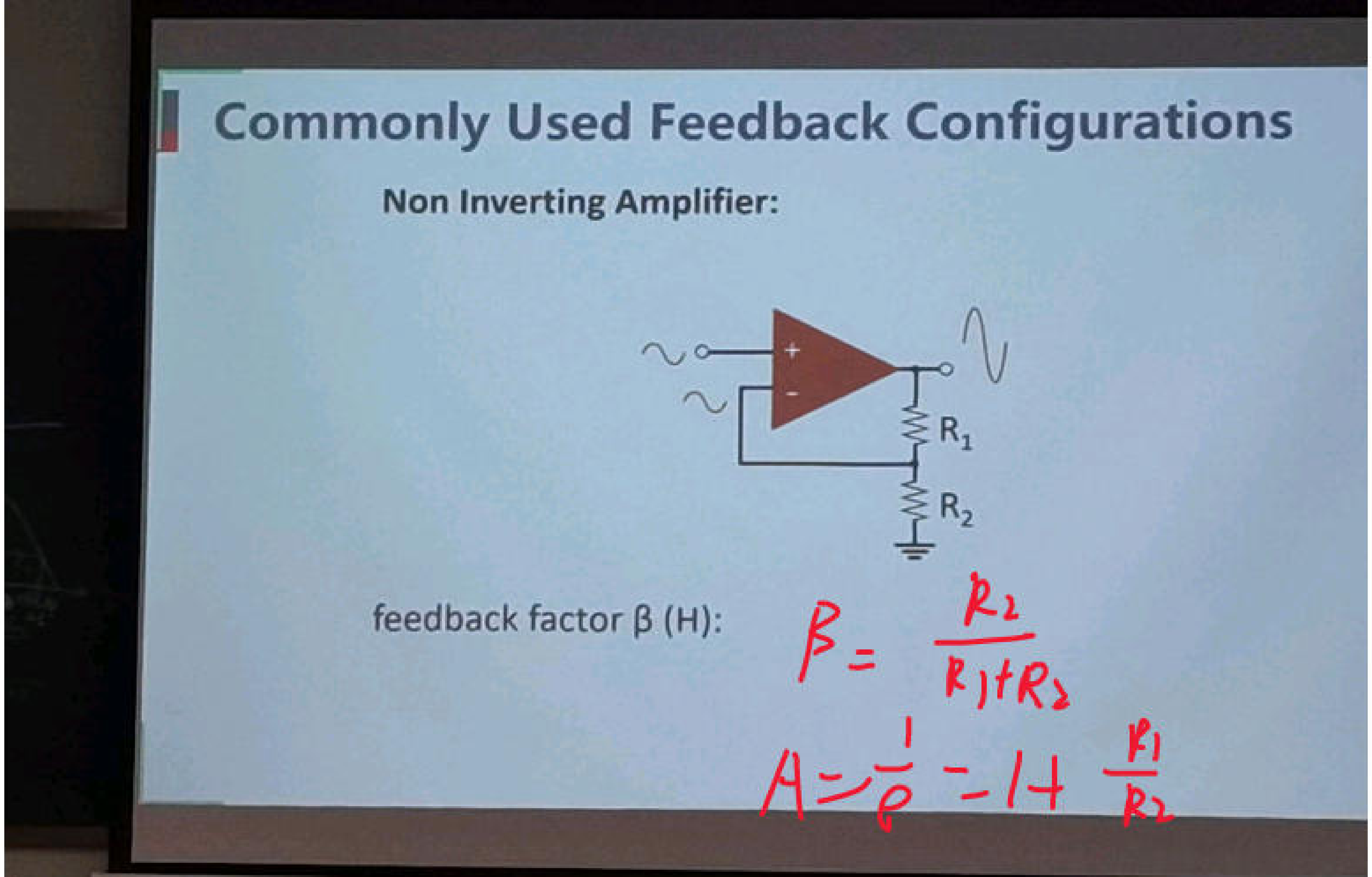
若 feedback $= \frac{R_2}{R_1+R_2}$

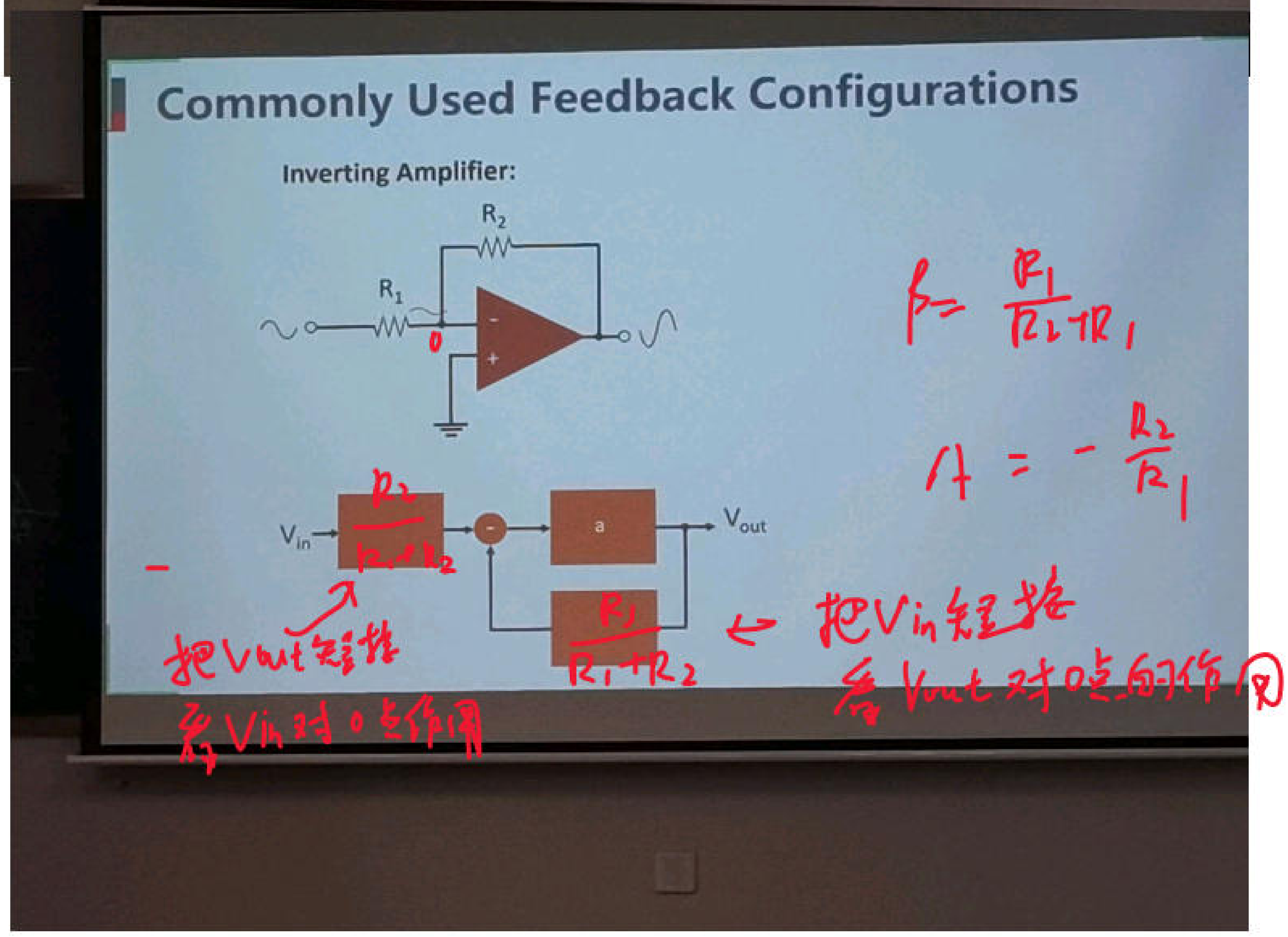
$A = 1+\frac{R_1}{R_2} > 1$,

取不到 GBW.

则 裕度可取到 $A = 1+\frac{R_1}{R_2}$

处的相位裕度


Commonly Used Feedback Configurations
Non Inverting Amplifier:
+
-
R_1
R_2
feedback factor β (H):
$\beta = \frac{R_2}{R_1+R_2}$
$A = \frac{1}{\beta} = 1 + \frac{R_1}{R_2}$


Commonly Used Feedback Configurations
Inverting Amplifier:
R_2
R_1
0
-
+
V_{in}
$\frac{R_2}{R_1+R_2}$
a
V_{out}
$\frac{R_1}{R_1+R_2}$
$\beta = \frac{R_1}{R_2+R_1}$
$A = -\frac{R_2}{R_1}$
-
把Vout短接
看Vin对0点作用
把Vin短接
看Vout对0点的作用