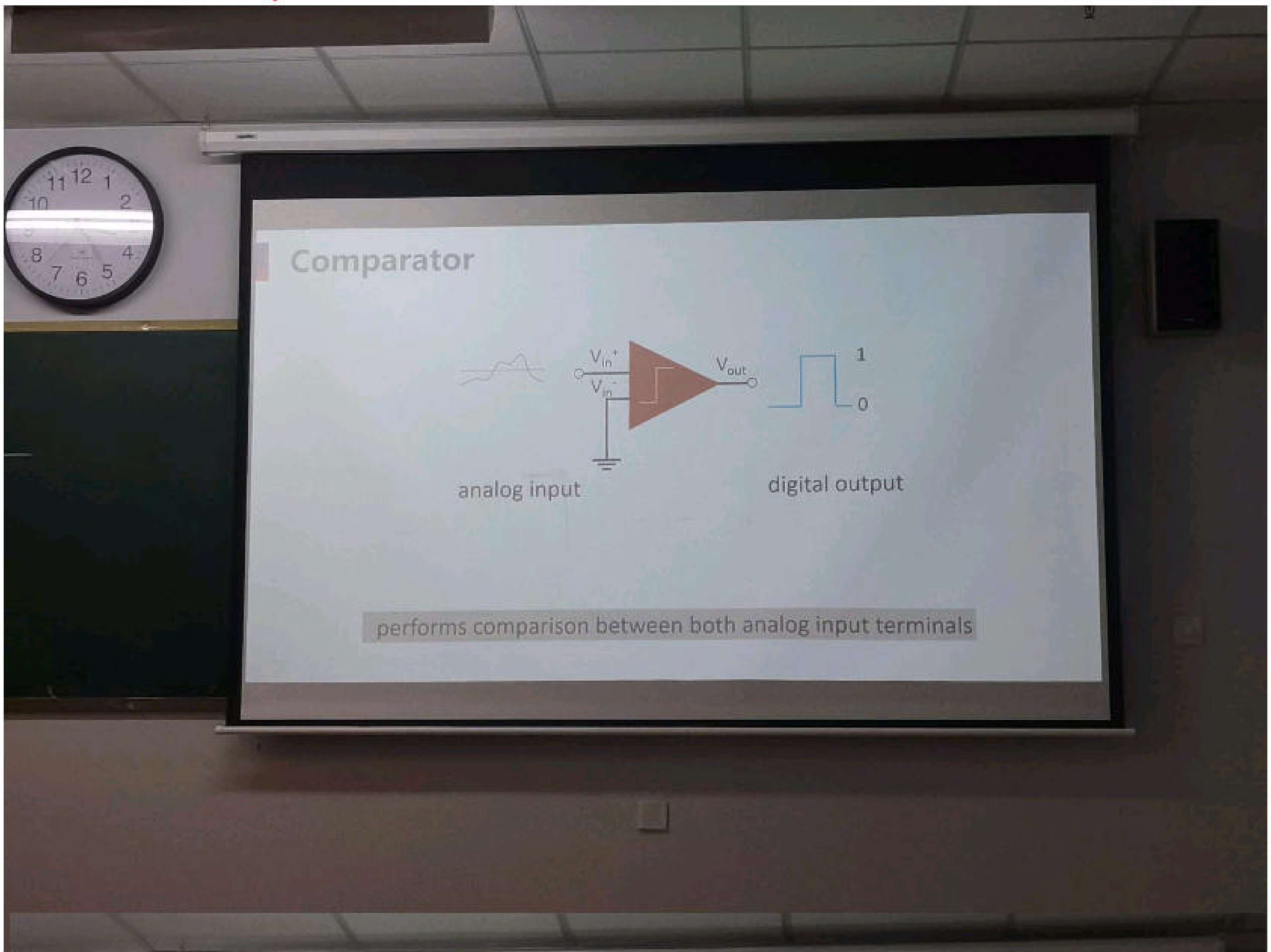
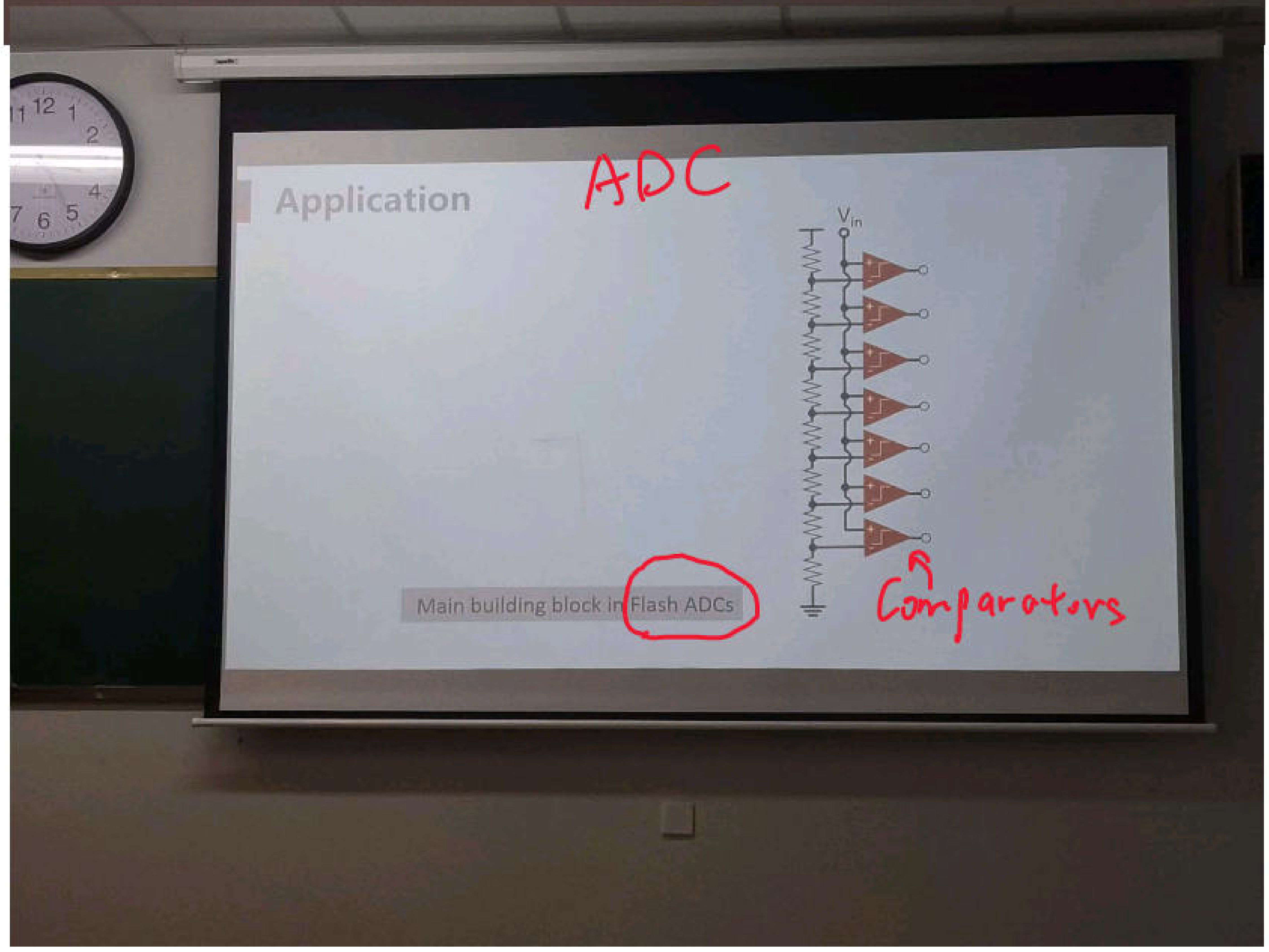
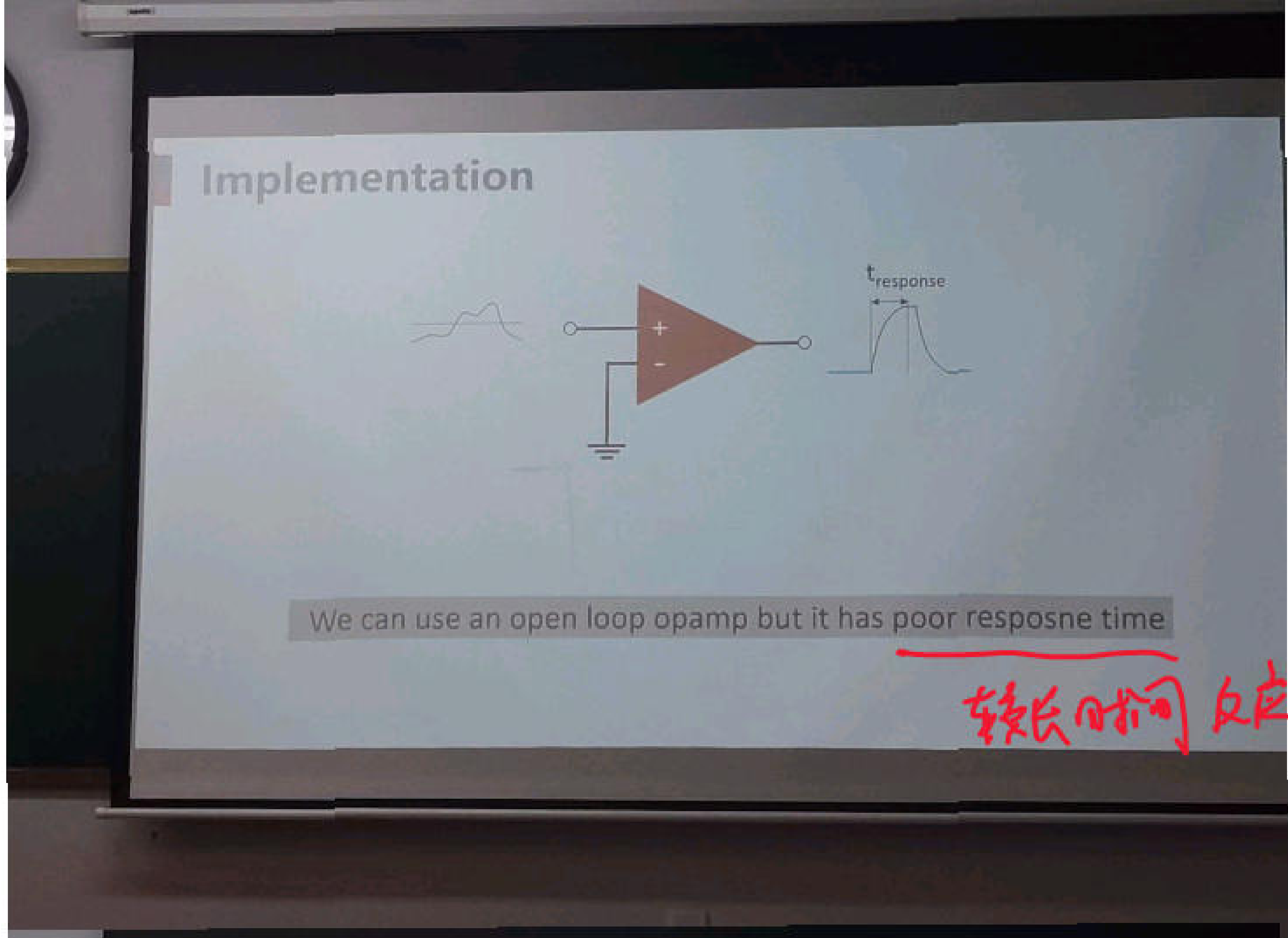
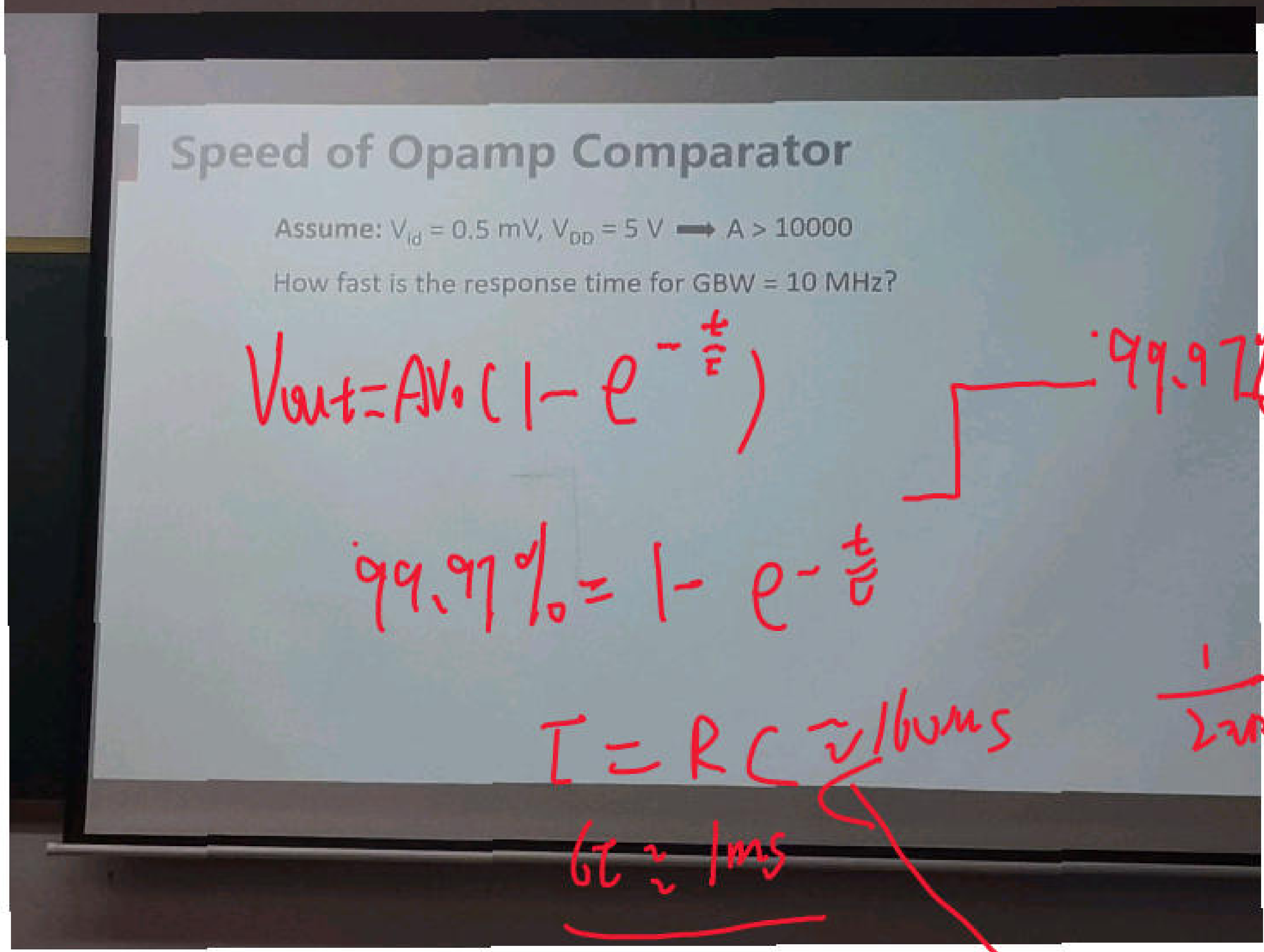
Comparators 比较器







较长时间反应



$V_{out} = A_{V0}(1 - e^{-\frac{t}{\tau}})$

99.97% ~ $6\tau \sim 7\tau$

$99.97\% = 1 - e^{-\frac{t}{\tau}}$

$\tau = RC \approx 160\mu s$

$6\tau \approx 1ms$

$\frac{1}{2\pi RC} = \frac{10\times10^{6}}{10^{4}}$

$= 10^{3}$

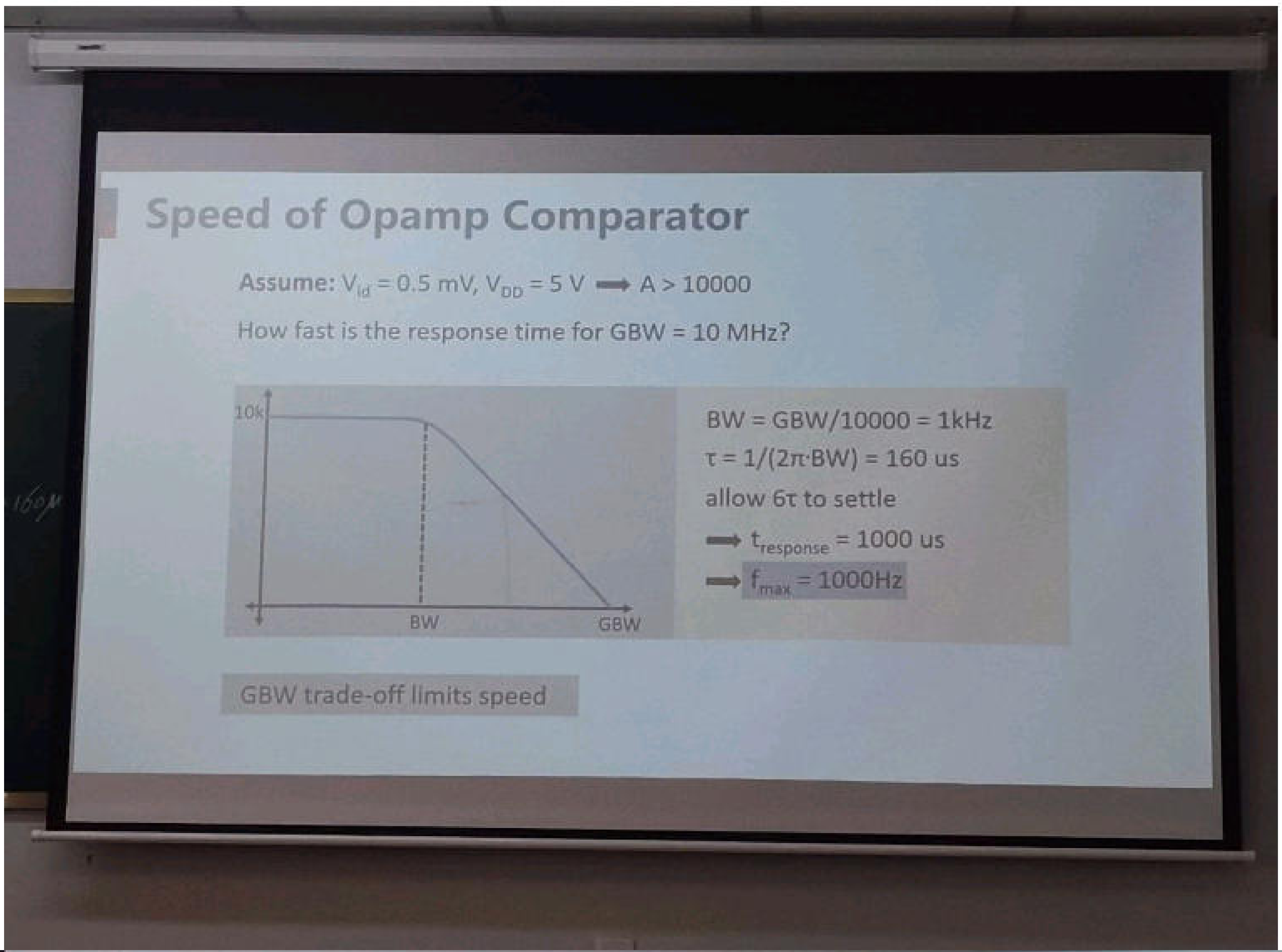
$RC = \frac{1}{2\times10^{3}\pi}$

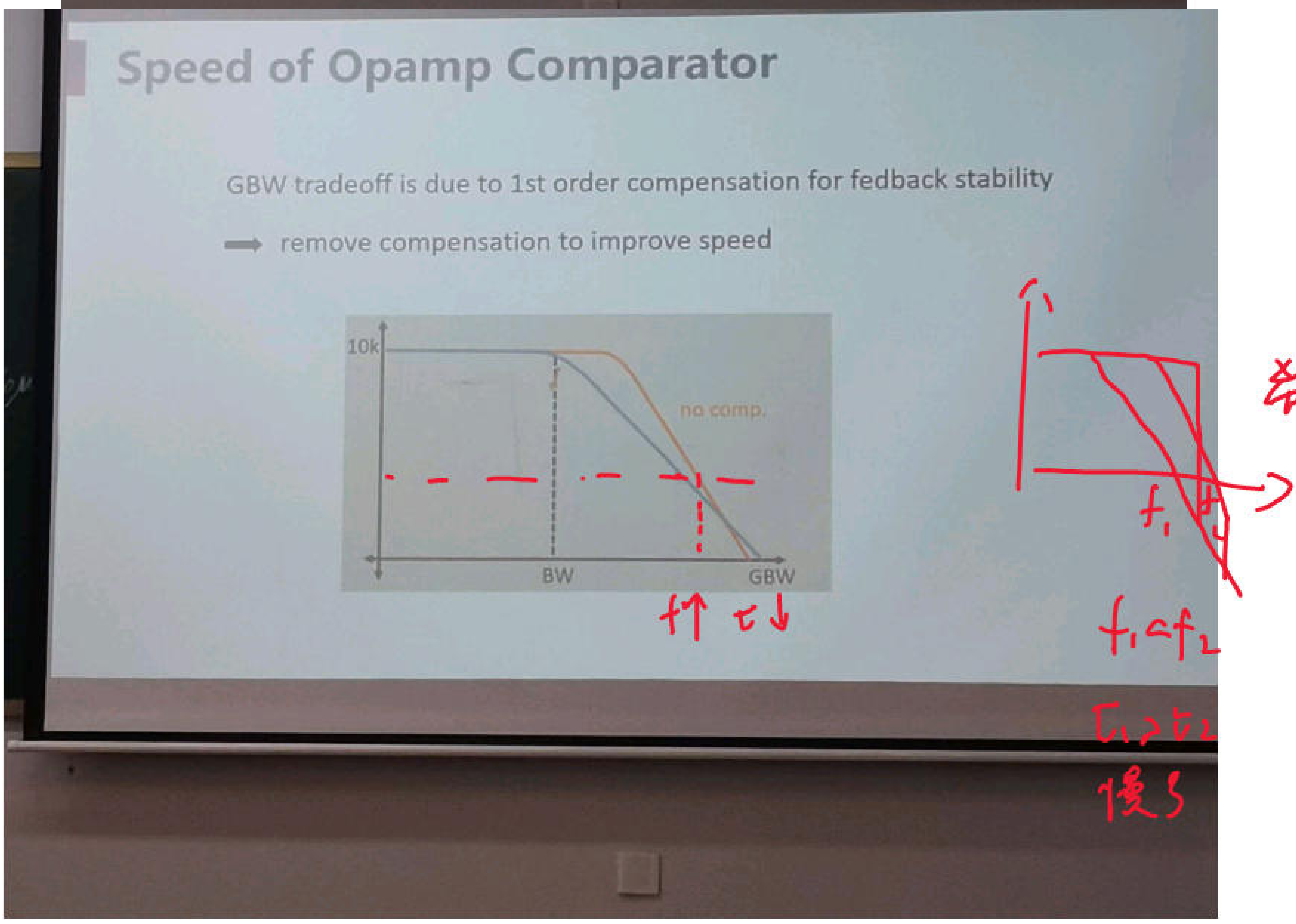
$f = \frac{1}{6\tau} = 1kHz$

吻合.

故一般99.97%

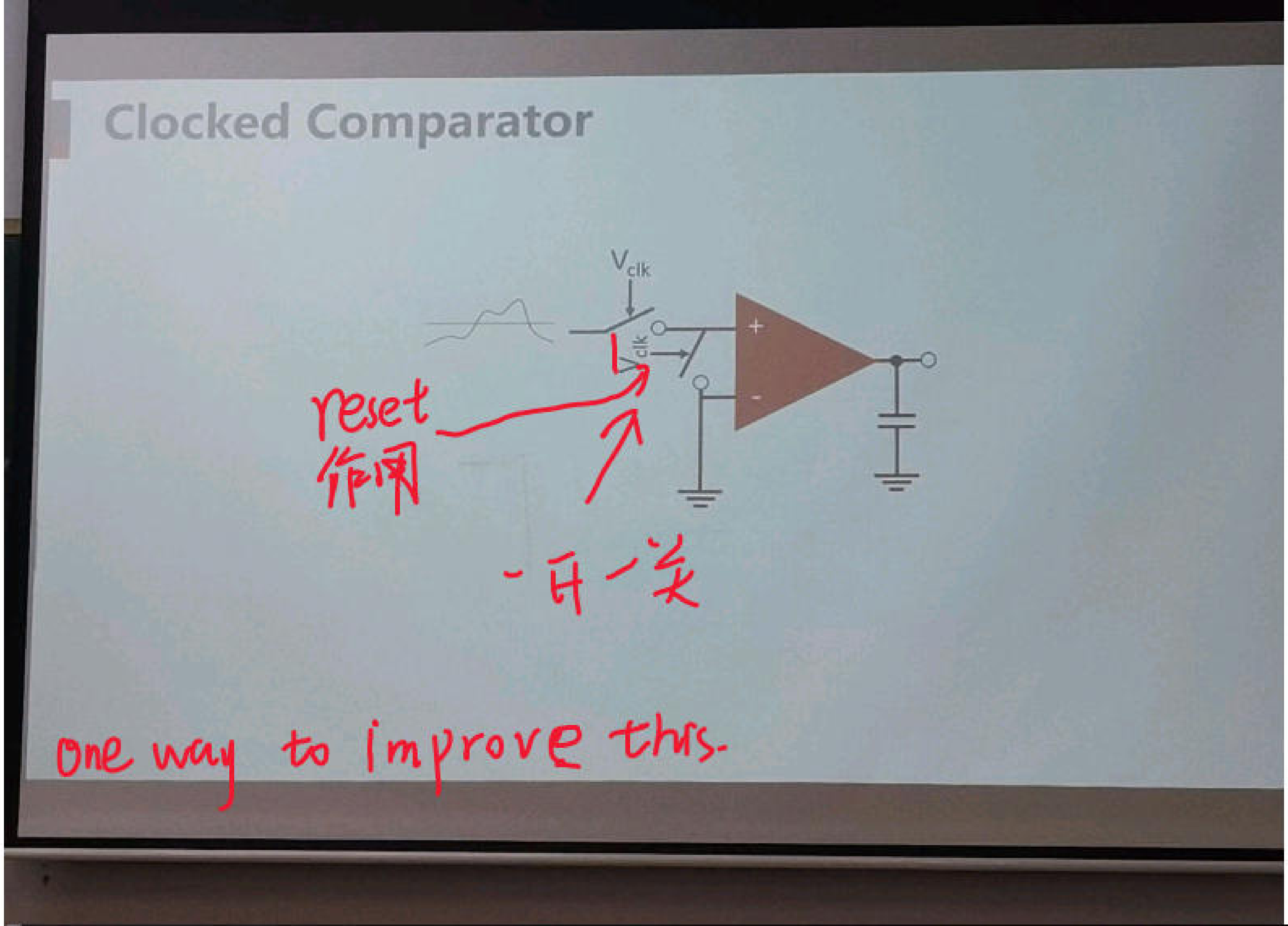
建立时间最快为6τ.

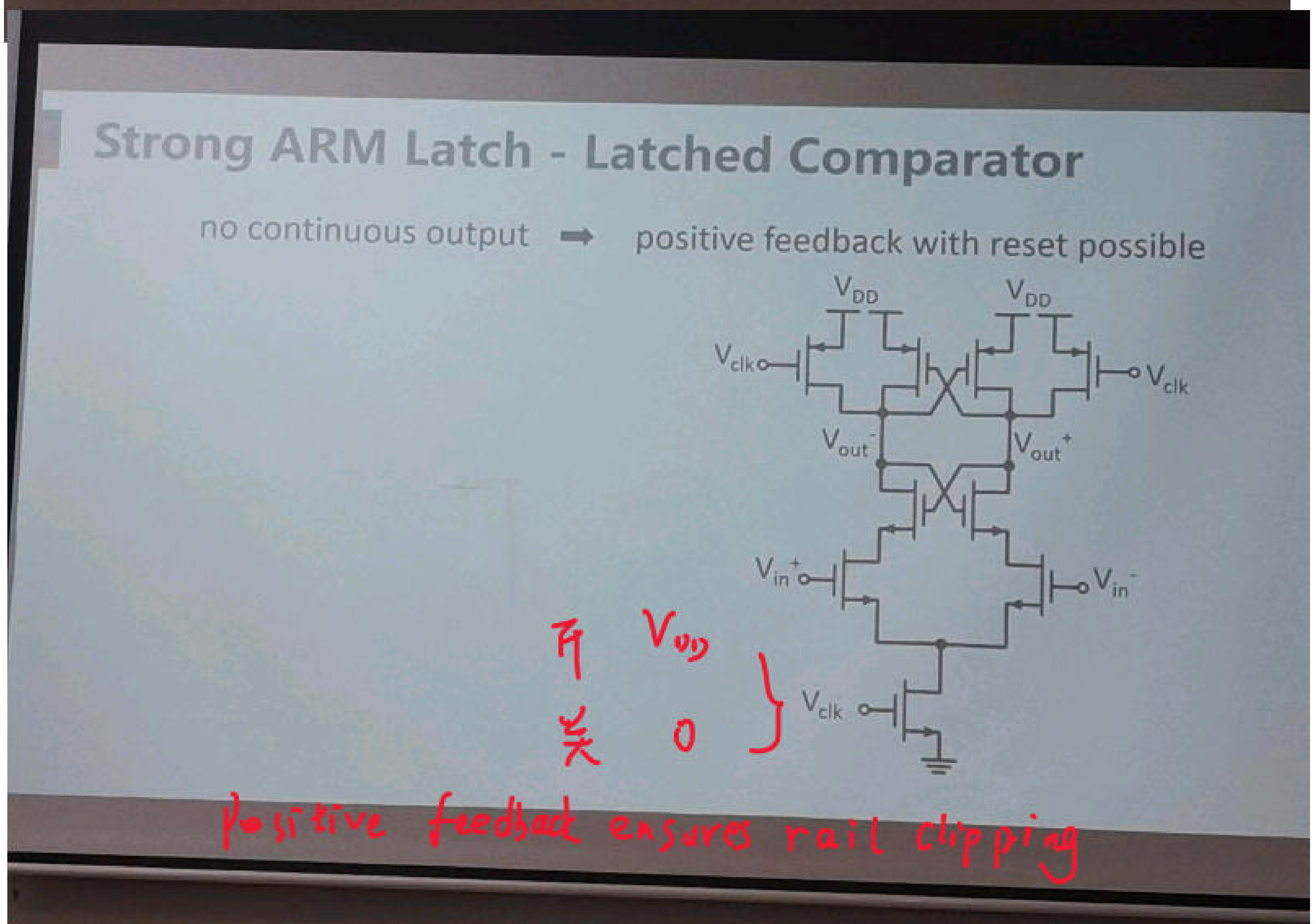


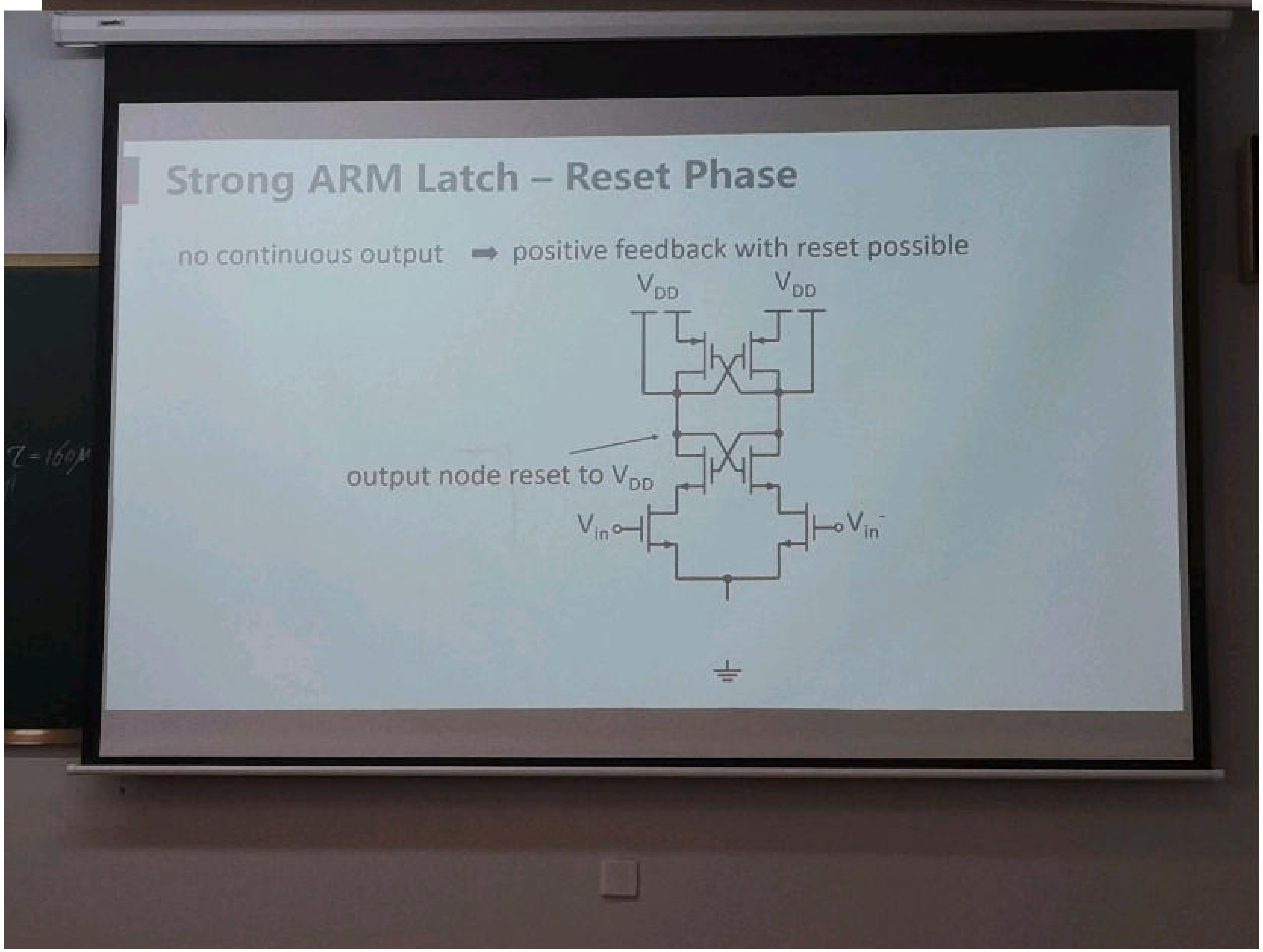


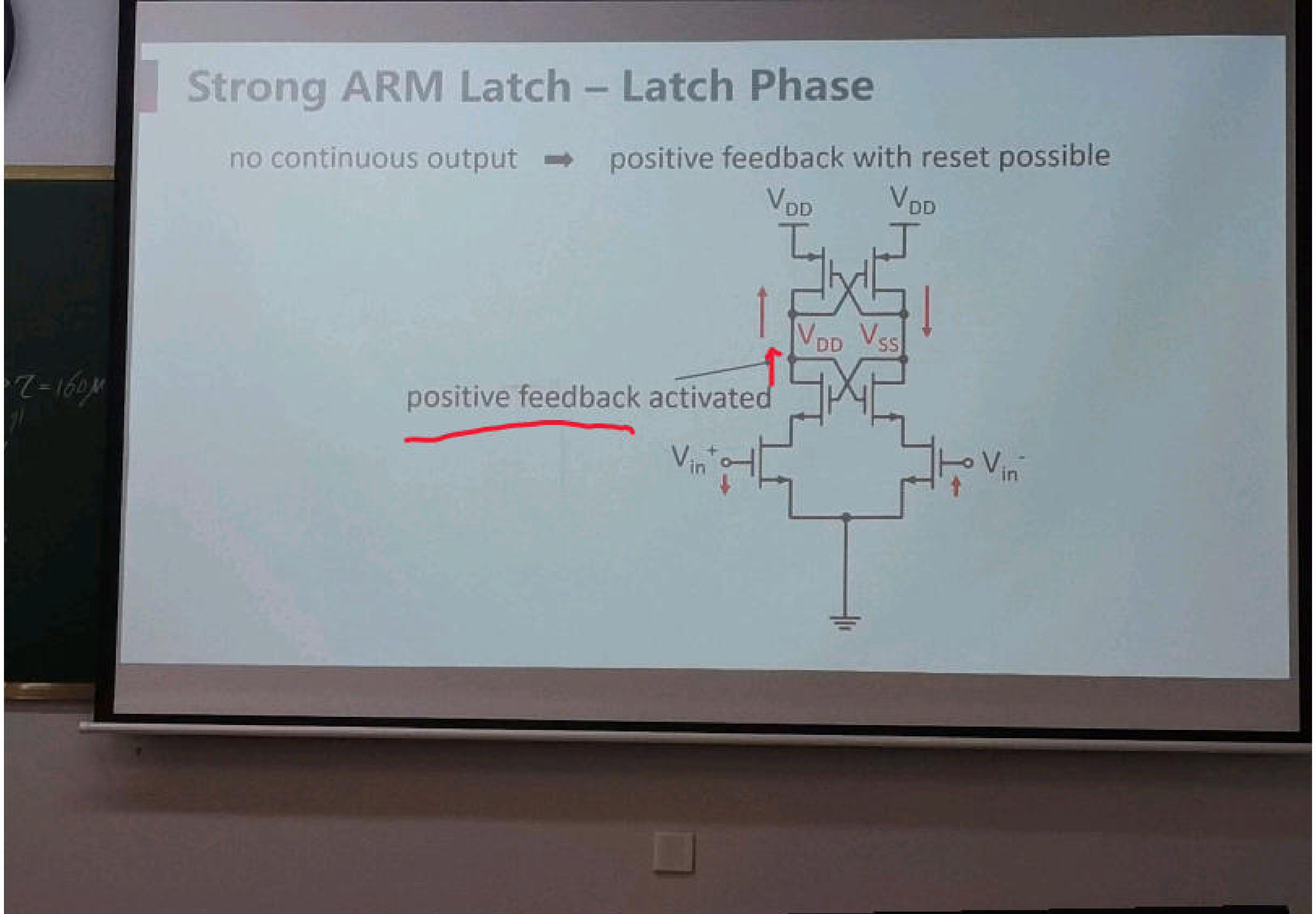
pole点,
希望近一些、
f大, τ小
加速

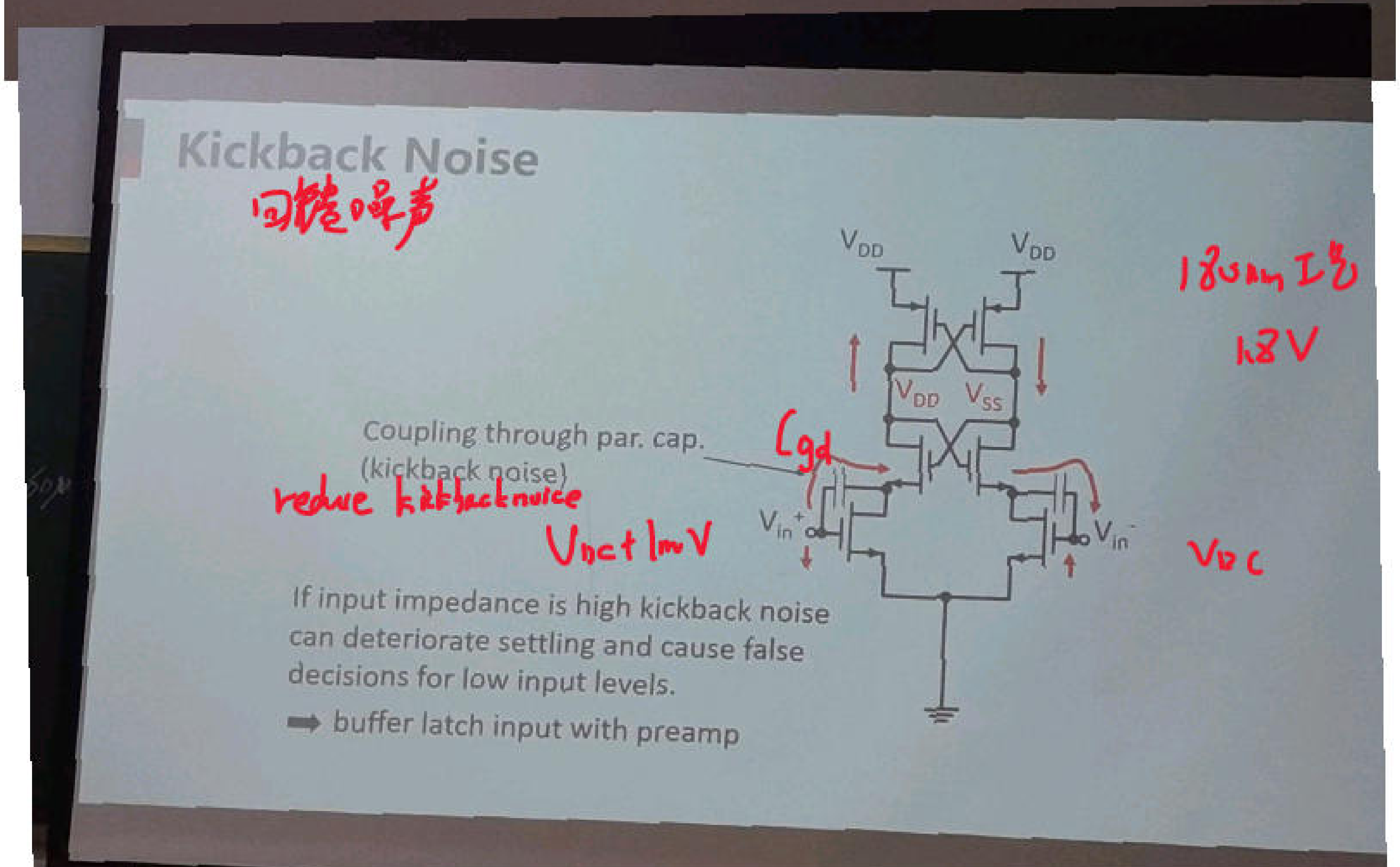
$f_1 < f_2$
$\tau_1 > \tau_2$
慢了

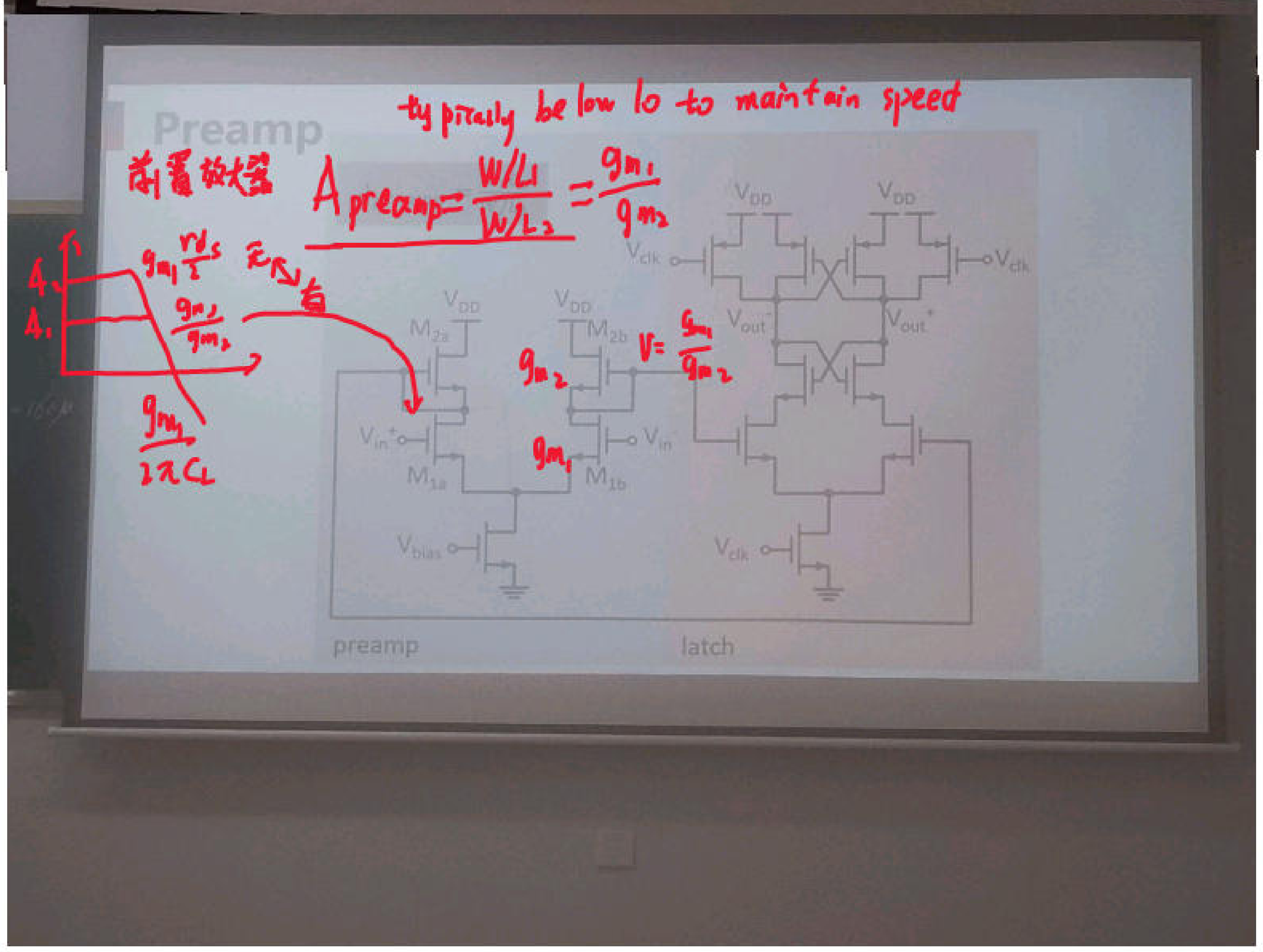

Clocked Comparator
V_{clk}
V_{clk}
+
-
reset
作用
一开一关
one way to improve this.

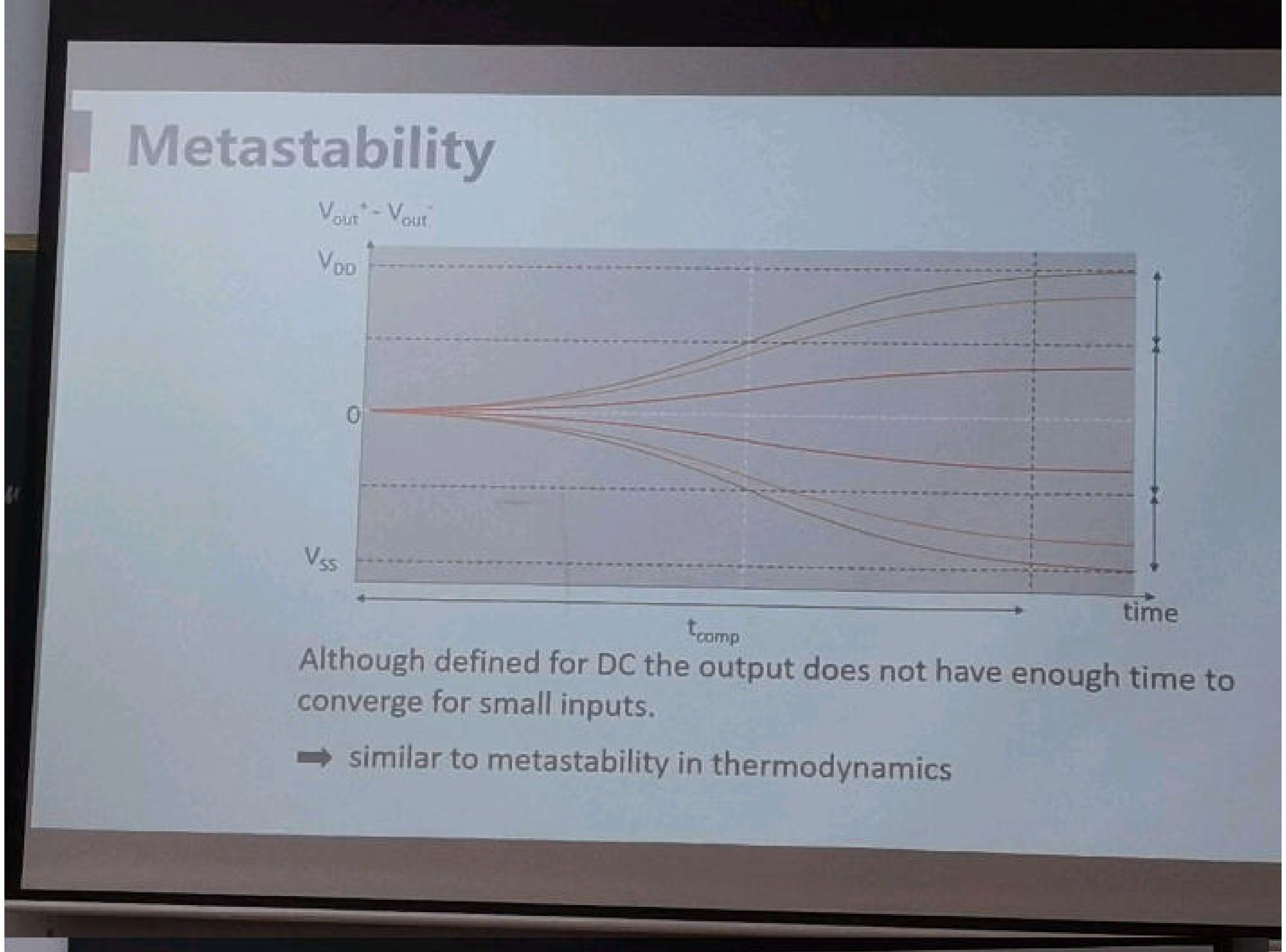

Strong ARM Latch - Latched Comparator
no continuous output ➡ positive feedback with reset possible
V_{DD}
V_{DD}
V_{clk}
V_{clk}
V_{out}^-
V_{out}^+
V_{in}^+
V_{in}^-
开 V_{DD}
关 0
V_{clk}
positive feedback ensures rail clipping

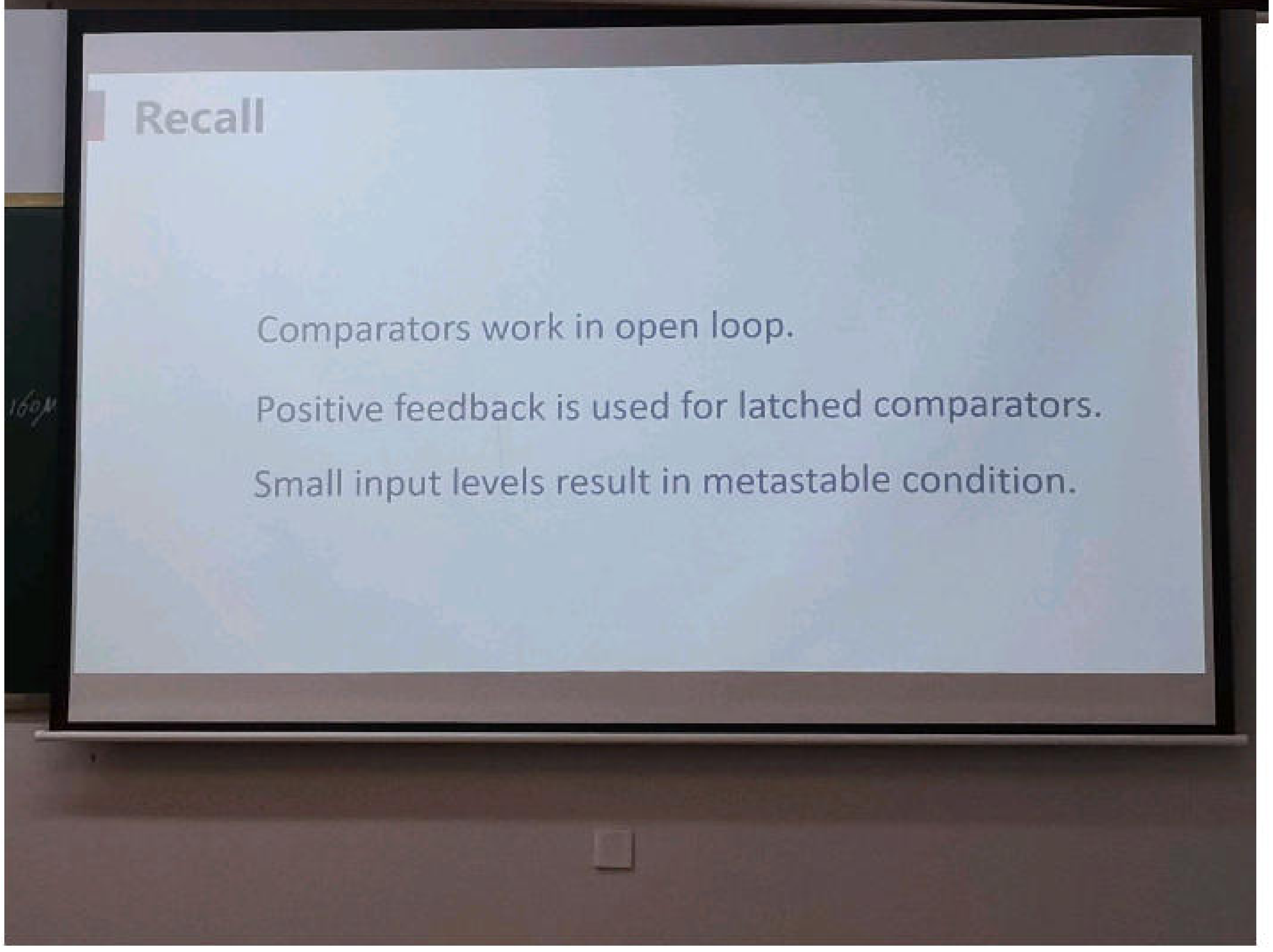

Strong ARM Latch – Reset Phase
no continuous output ➡ positive feedback with reset possible
V_{DD}
V_{DD}
output node reset to V_{DD}
V_{in}
V_{in}^-

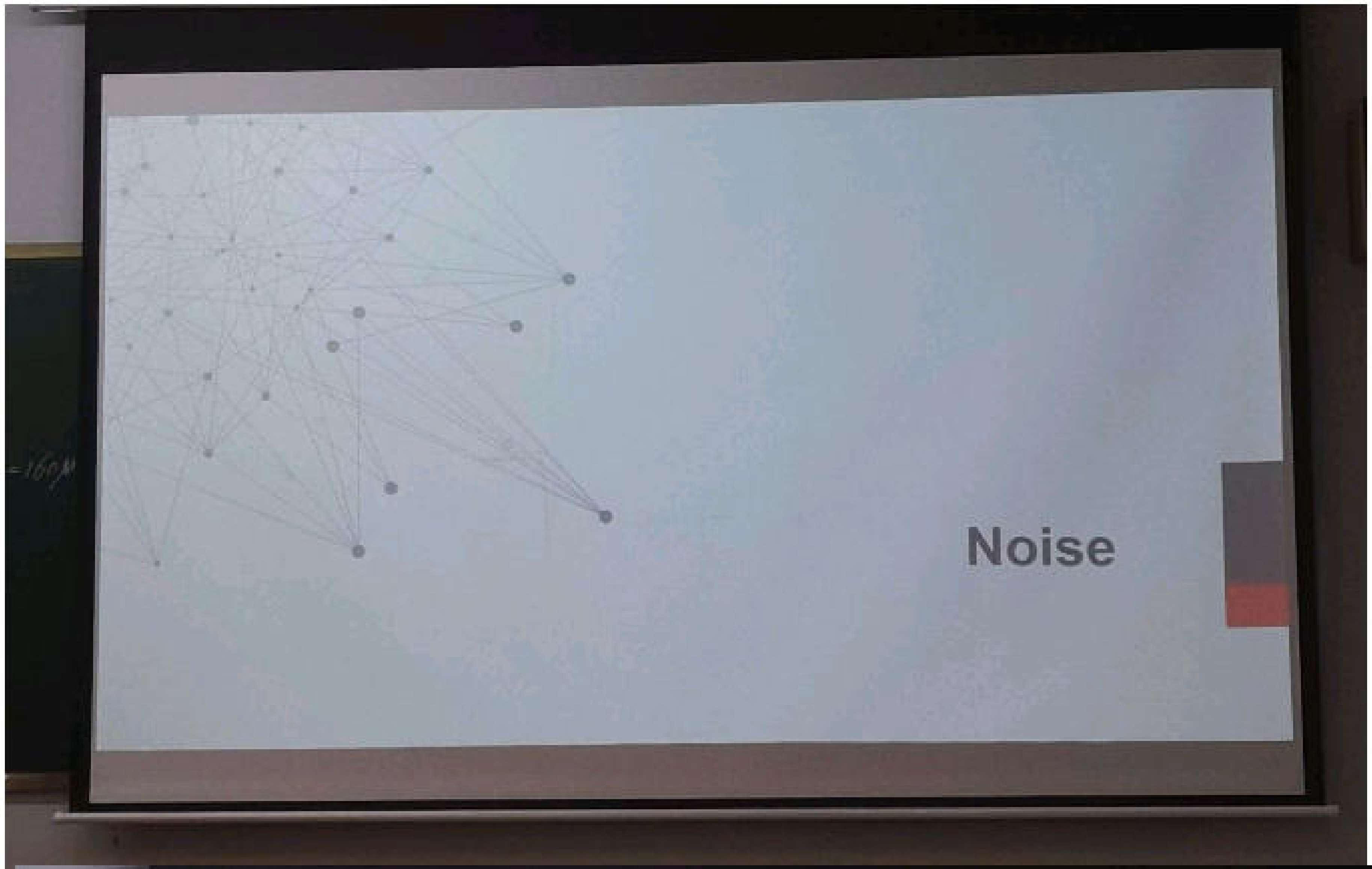

Strong ARM Latch – Latch Phase
no continuous output ➡ positive feedback with reset possible
VDD
VDD
VDD
VSS
positive feedback activated
Vin+
Vin-

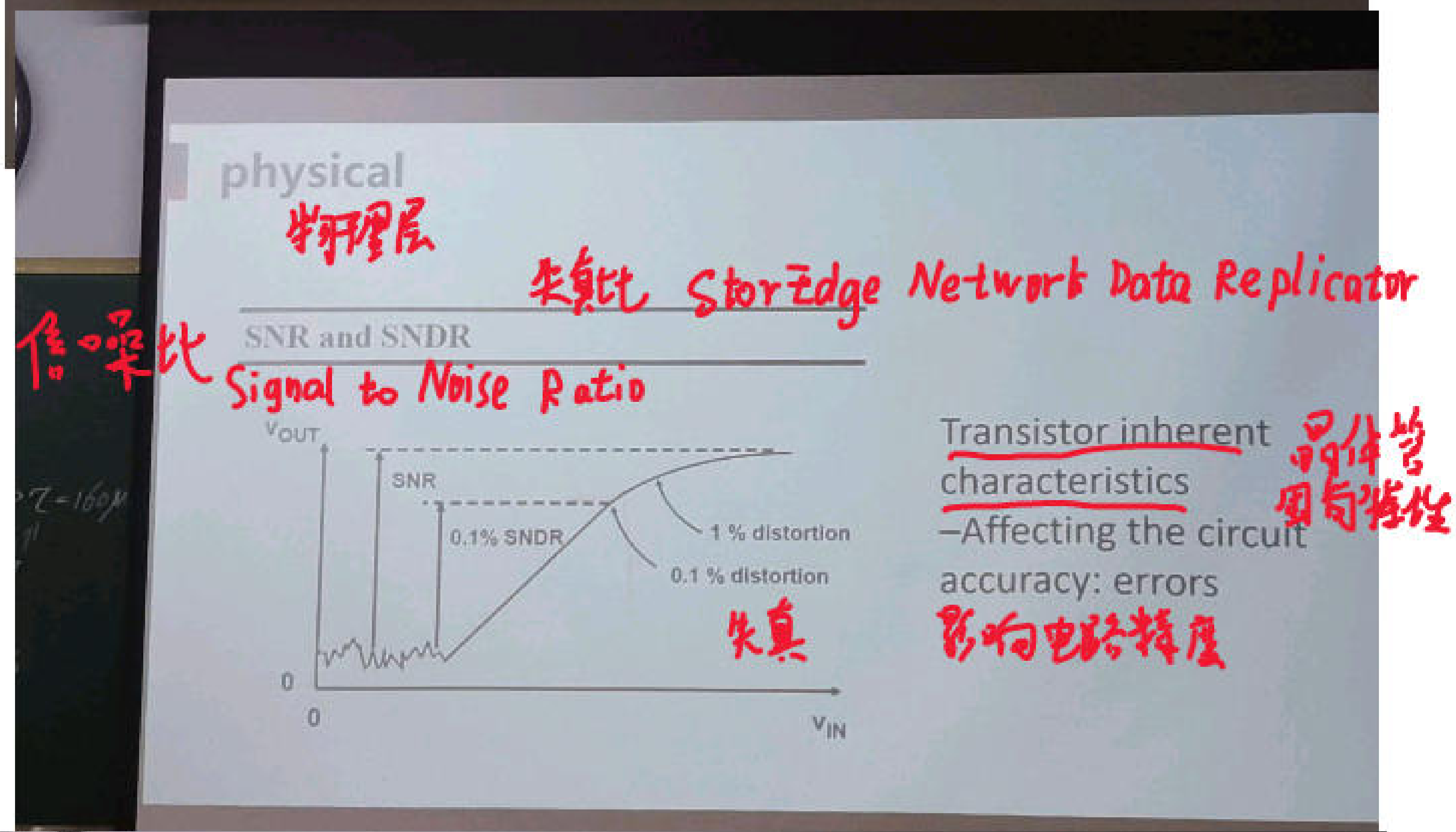

Kickback Noise
回馈噪声
VDD
VDD
VDD
VSS
180nm 工艺
1.8V
Cgd
Coupling through par. cap.
(kickback noise)
reduce kickback noise
Vin+
Vin-
VDC
If input impedance is high kickback noise can deteriorate settling and cause false decisions for low input levels.
➡ buffer latch input with preamp

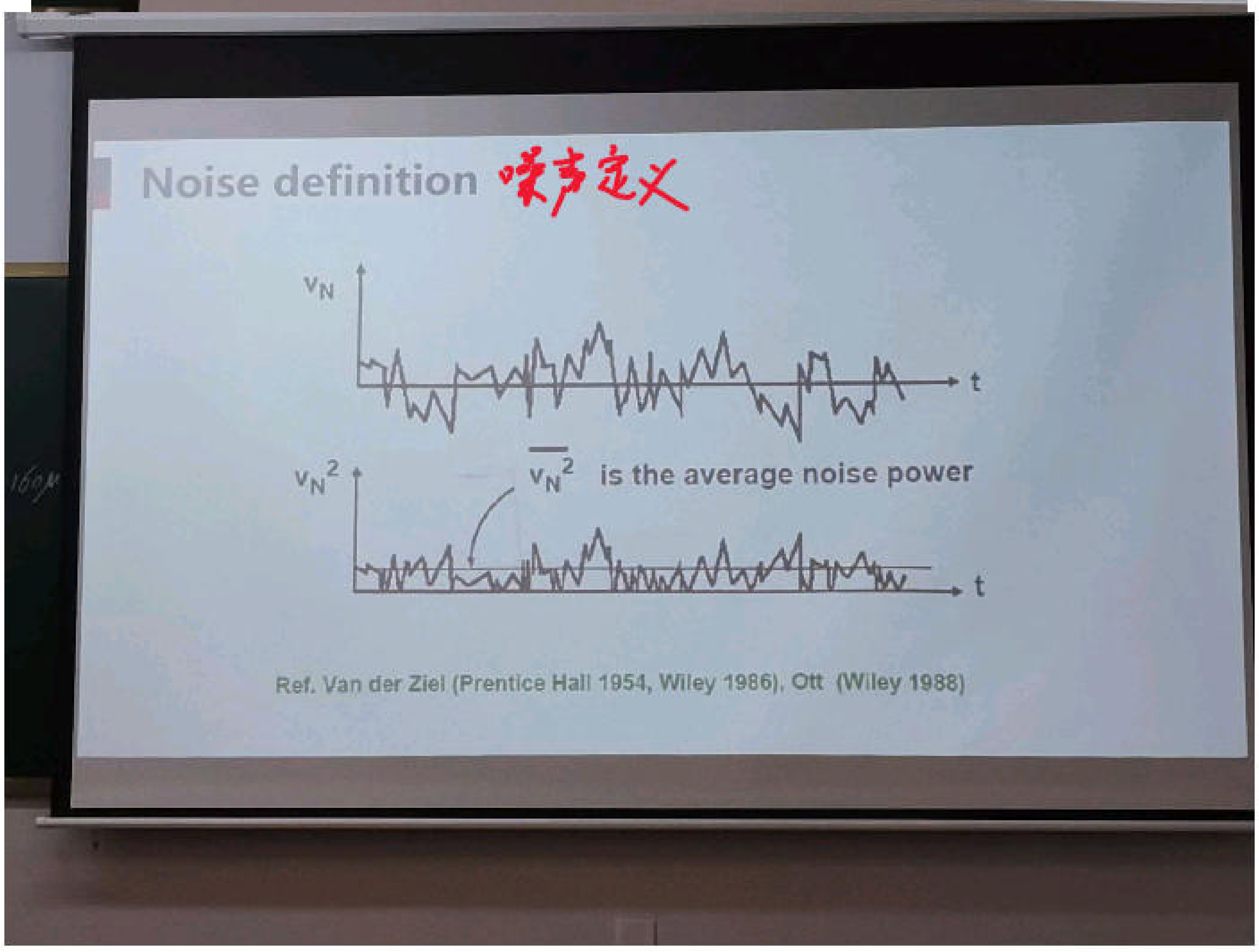

Preamp
前置放大器
typically below 10 to maintain speed
A preamp = W/L1 / W/L2 = gm1 / gm2
VDD
VDD
Vclk
Vclk
Vout-
Vout+
M2a
M2b
M1a
M1b
Vin+
Vin-
Vbias
Vclk
preamp
latch


Metastability
V_out+ - V_out-
V_DD
0
V_SS
time
t_comp
Although defined for DC the output does not have enough time to converge for small inputs.
➡ similar to metastability in thermodynamics


Recall
Comparators work in open loop.
Positive feedback is used for latched comparators.
Small input levels result in metastable condition.


Noise

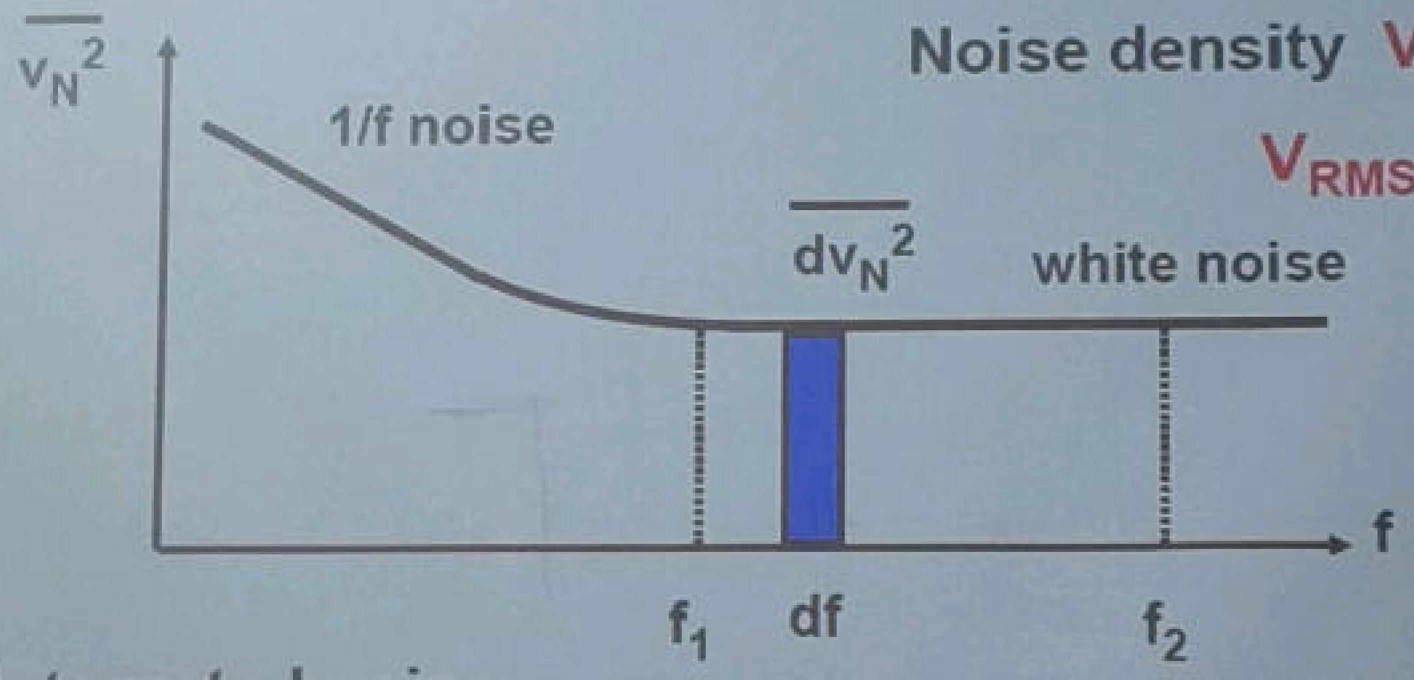

physical
物理层
失真比 Storedge Network Data Replicator
信噪比
SNR and SNDR
Signal to Noise Ratio
VOUT
SNR
0.1% SNDR
1 % distortion
0.1 % distortion
失真
0
0
VIN
Transistor inherent characteristics
晶体管固有特性
–Affecting the circuit accuracy: errors
影响电路精度


Noise definition 噪声定义
vN
t
vN2
vN2 is the average noise power
t
Ref. Van der Ziel (Prentice Hall 1954, Wiley 1986), Ott (Wiley 1988)

Noise versus frequency

Noise density V^2/Hz

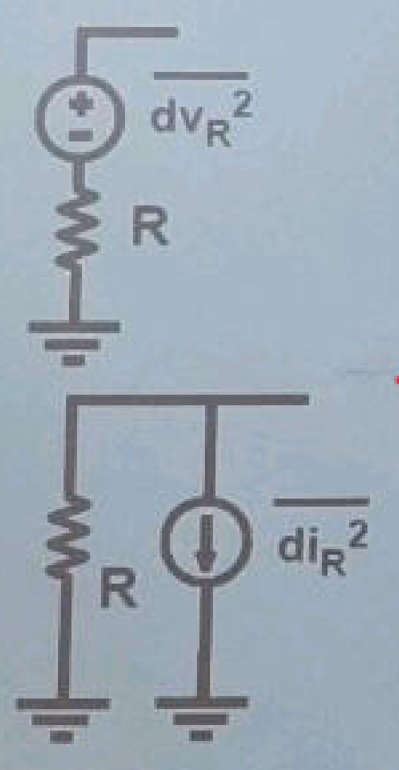
$V_{RMS}/\sqrt{Hz}$



Integrated noise

V_{RMS} $$\overline{v_{12}} = \sqrt{\overline{v_N^2}} = \sqrt{\int_{f_1}^{f_2} \overline{dv_N^2}\, df} = \sqrt{(f_2 - f_1)\, \overline{dv_N^2}}$$

Noise of a resistor is thermal noise



$\overline{dv_R^2} = 4kT\,R\,df$ is white 热噪声

depends on T, not on I_R

for R = 1 kΩ ① $\sqrt{\overline{dv_R^2}} = 4\ nV_{RMS}/\sqrt{Hz}$ 4n V/√Hz 4纳伏/√Hz

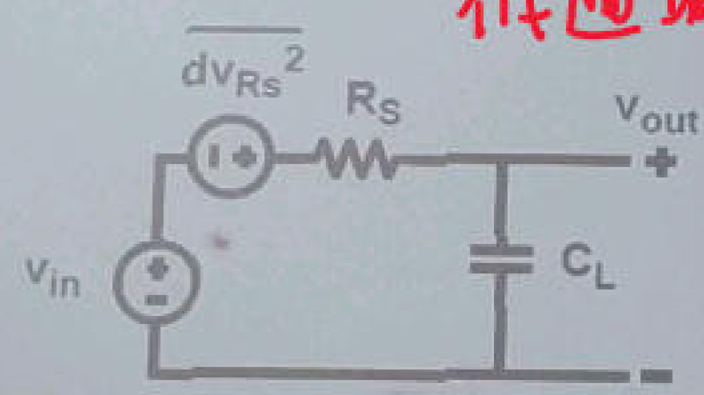
at T = 300 K or 27°C ③

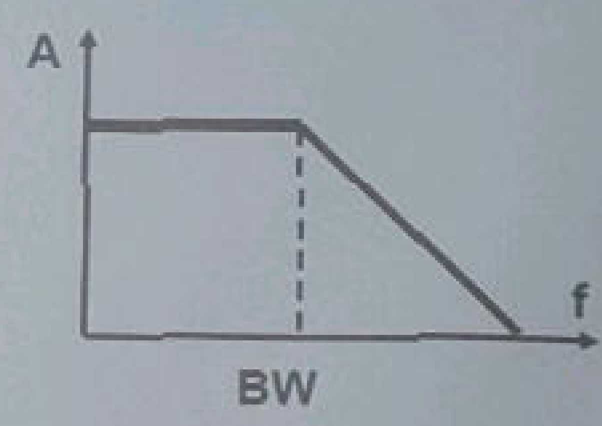
记住 ☆

$$\overline{di_R^2} = \frac{\overline{dv_R^2}}{R^2} = \frac{4kT}{R}\,df \quad \text{is white}$$

Integrated Noise of Resistor -1

低通滤波





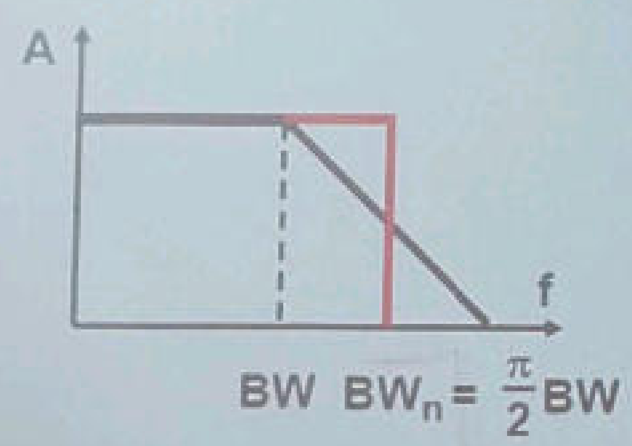
$\overline{dv_{Rs}^2} = 4kT\,R_S\,df$

$$\overline{v_{Rs}^2} = \int_0^\infty \frac{\overline{dv_{Rs}^2}}{1 + (f/BW)^2}$$

$$BW = \frac{1}{2\pi R_S C_L}$$

0 → ∞

Integrated Noise of Resistor -2



$$\overline{v_{Rs}^2} = \int_0^\infty \frac{\overline{dv_{Rs}^2}}{1+(f/BW)^2}$$

$$\boxed{\int_0^\infty \frac{dx}{1+x^2} = \frac{\pi}{2}}$$

$$\overline{v_{Rs}^2} = 4kT\,R_S BW \frac{\pi}{2}\,df$$

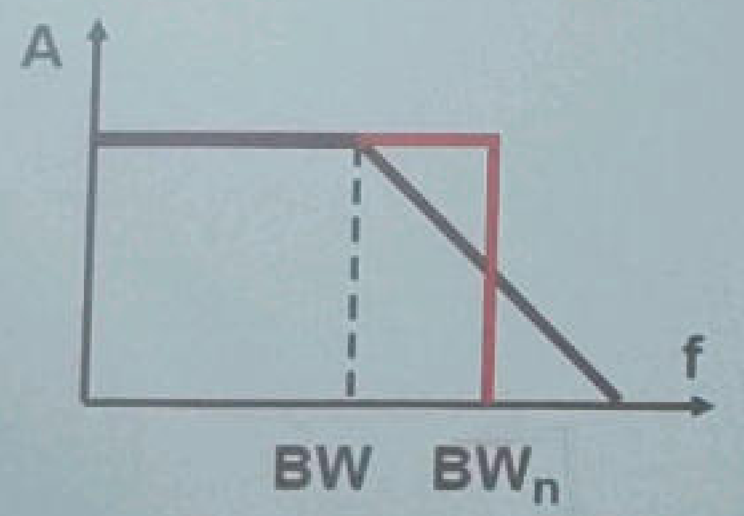
$$\overline{v_{Rs}^2} = \frac{kT}{C_L}$$

$BW = \frac{1}{2\pi R_S C_L}$

C_L = 1pF v_{Rs} = 65 μV_{RMS}

$C_L \uparrow \rightarrow$ Square $\rightarrow$ speed $\downarrow$.

Noise density vs integrated noise



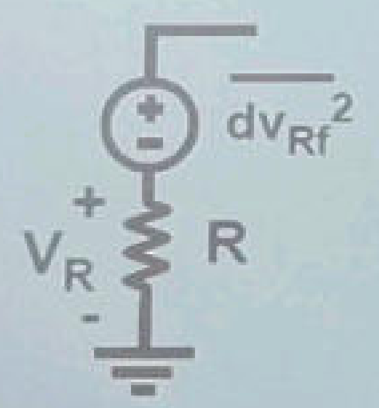
$$\overline{dv_{Rs}^2} = 4kT\,R_S\,df$$

$$\overline{v_{Rs}^2} = \int_0^\infty \frac{\overline{dv_{Rs}^2}}{1+(f/BW)^2} = \frac{kT}{C_L}$$

Noise density (V^2/Hz) ~ R_S (or $1/g_m$)

Integrated noise (V_{RMS}) ~ $1/C_L$

A resistor also has 1/f noise $\sim \frac{1}{\sqrt{f}}$



$$\overline{dv_{Rf}^2} = V_R^2 \frac{KF_R R_\square}{A_R} \frac{df}{f} \quad \text{is 1/f}$$

$$KF_{RSi} \approx 2\times 10^{-21}\ \text{Scm}^2$$

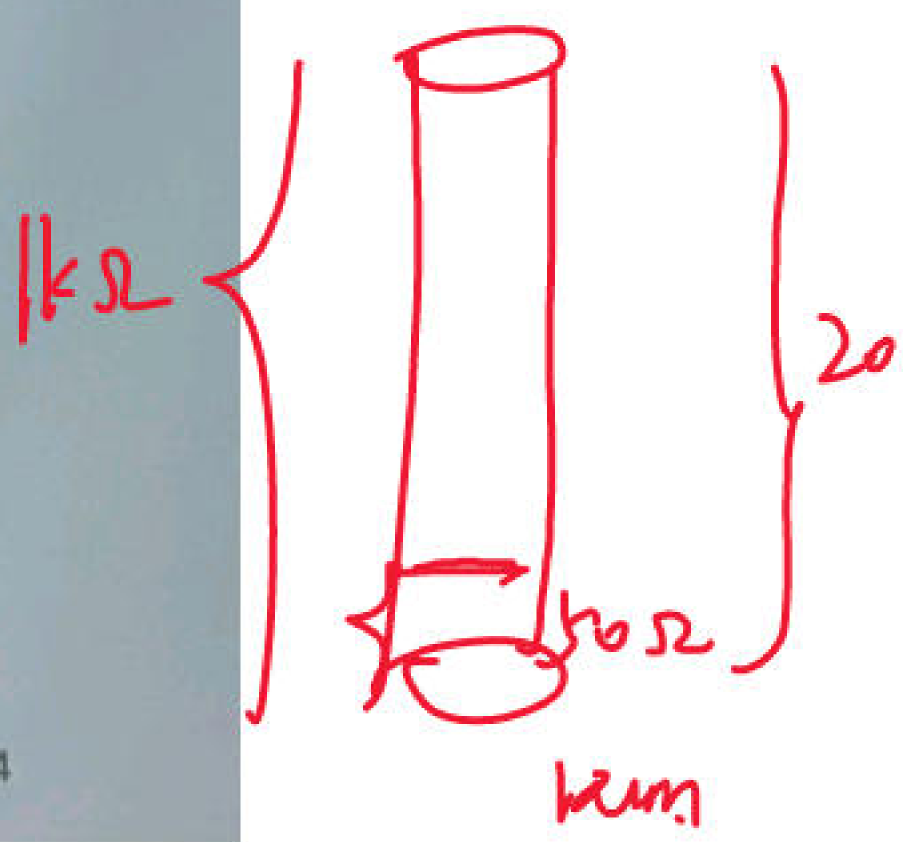
$$KF_{Rpoly} \approx 10\ KF_{RSi}$$

for R = 1 kΩ with 20 □'s of 50 Ω/□ and 1 μm wide and V_R = 0.1 V

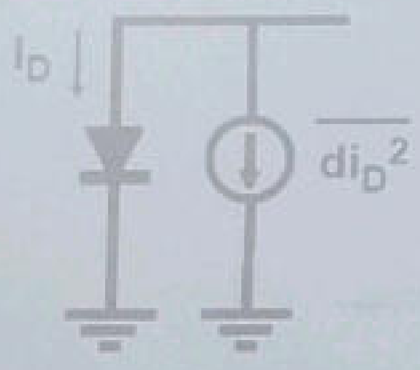
1um 1um

$\sqrt{\overline{dv_{Rf}^2}}$ = 16 $nV_{RMS}/\sqrt{Hz}$ at 1 Hz

Ref. Vandamme, ESSDERC '04



Noise of a diode is shot noise



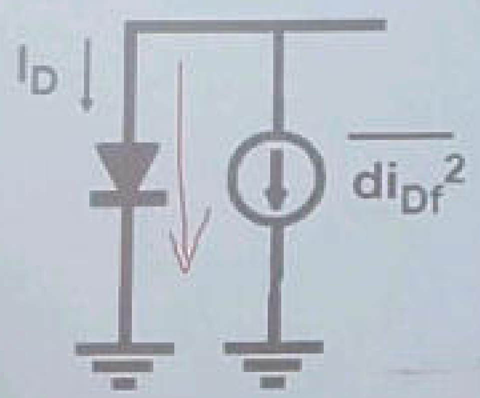
$\overline{di_D^2} = 2q\, I_D\, df$ is white

$q = 1.6 \times 10^{-19}$ C

depends on I_D, not on T

for $I_D = 50\ \mu A$ $\sqrt{\overline{di_D^2}} = 4\ pA_{RMS} / \sqrt{Hz}$

A diode also has 1/f noise



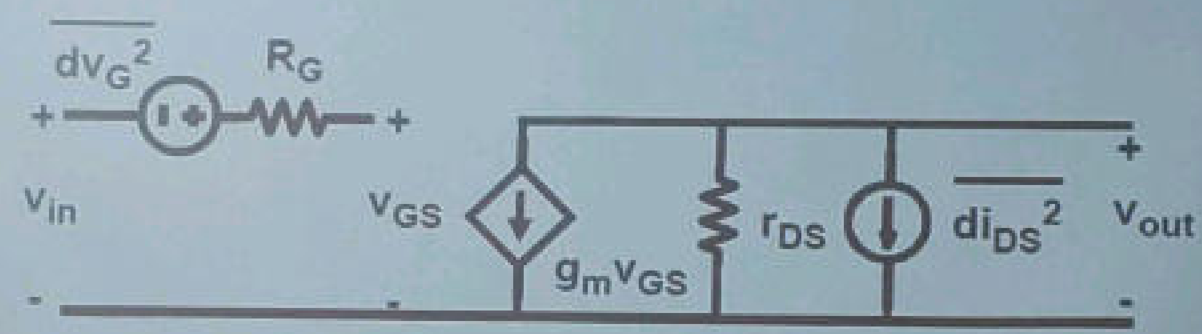
$\overline{di_{Df}^2} = I_D \dfrac{KF_D}{A_D} \dfrac{df}{f}$ is 1/f

$KF_D \approx 10^{-21}$ Acm^2

For a diode of $A_D = 5 \times 2\ \mu m = 10\ \mu m^2$ and $I_D = 0.1$ mA

$\sqrt{\overline{di_{Df}^2}} = 1\ nA_{RMS} / \sqrt{Hz}$ at 1 Hz

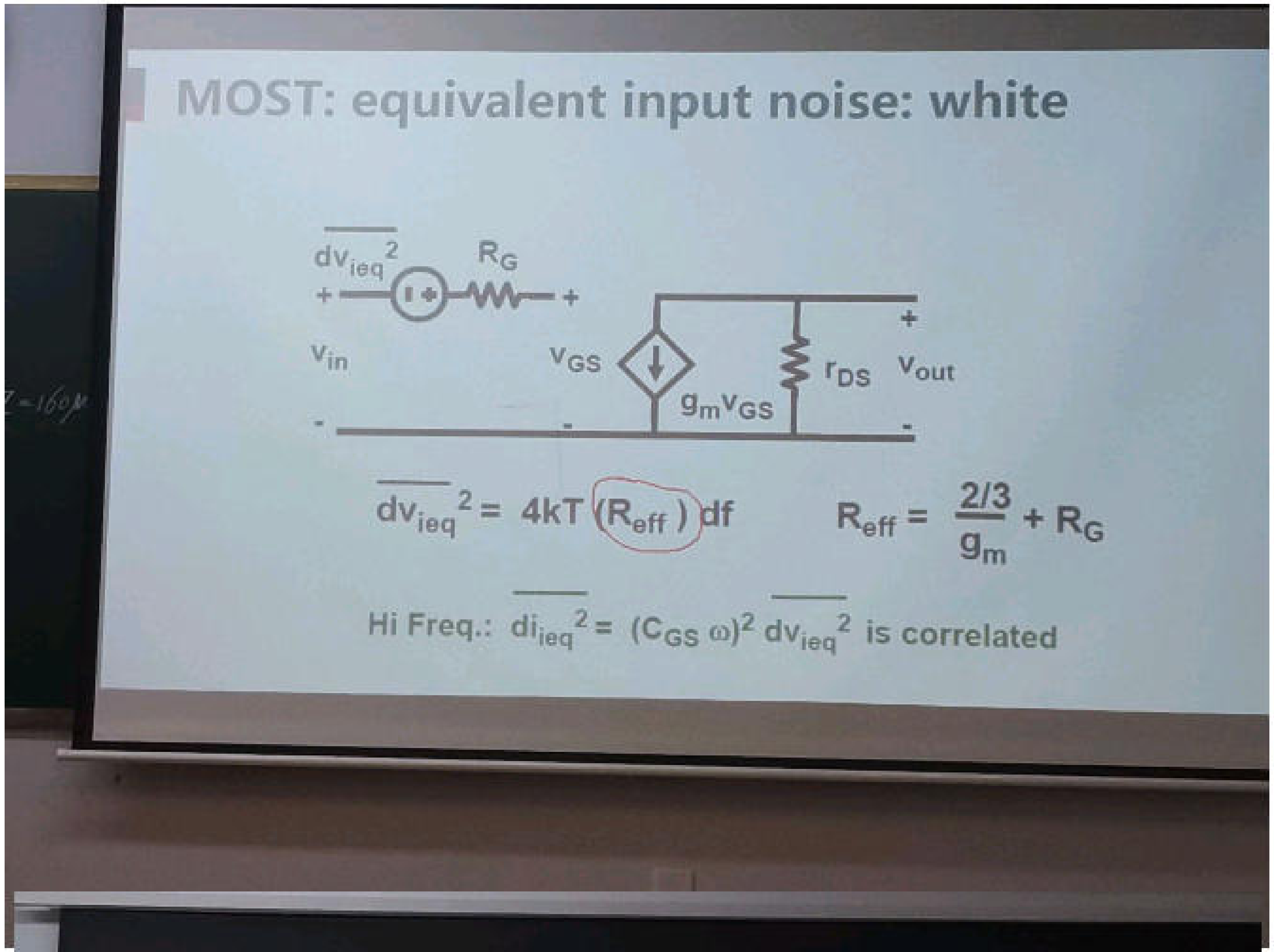
Noise of a MOST

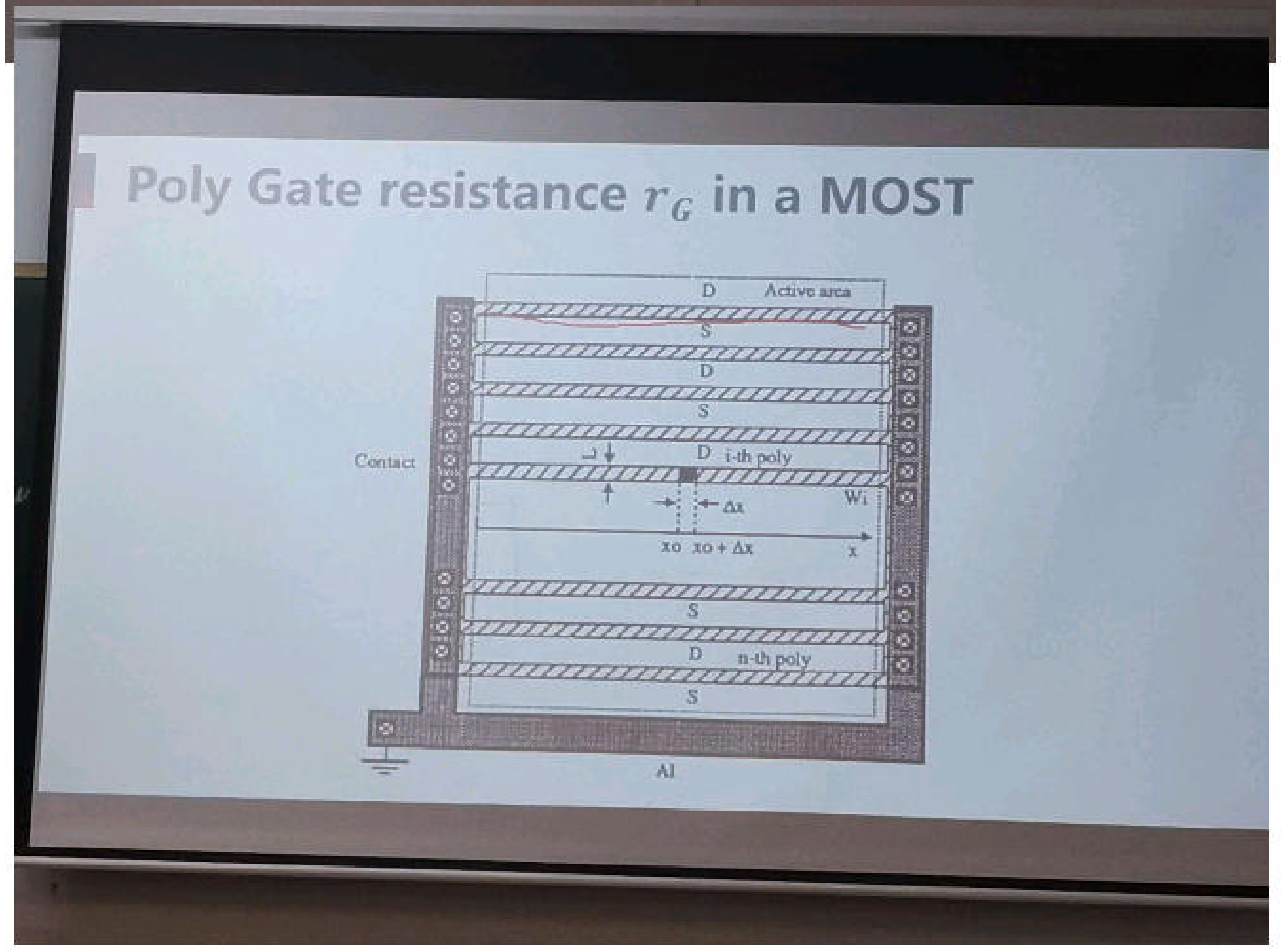


$\overline{dv_G^2} = 4kT\, R_G\, df$

$\overline{di_{DS}^2} = \dfrac{4kT}{R_{CH}}\, df = 4kT \dfrac{2}{3} g_m\, df$

Ref. Van der Ziel, Prentice Hall 1954, Wiley 1986.


MOST: equivalent input noise: white
$\overline{dv_{ieq}^2}$
R_G
v_{in}
v_{GS}
$g_m v_{GS}$
r_{DS}
v_{out}
$\overline{dv_{ieq}^2} = 4kT\,(R_{eff})\,df$
$R_{eff} = \frac{2/3}{g_m} + R_G$
Hi Freq.: $\overline{di_{ieq}^2} = (C_{GS}\,\omega)^2\,\overline{dv_{ieq}^2}$ is correlated


Poly Gate resistance r_G in a MOST
D
Active area
S
D
S
Contact
D
i-th poly
Δx
W_i
x_0
$x_0 + \Delta x$
x
S
D
n-th poly
S
Al