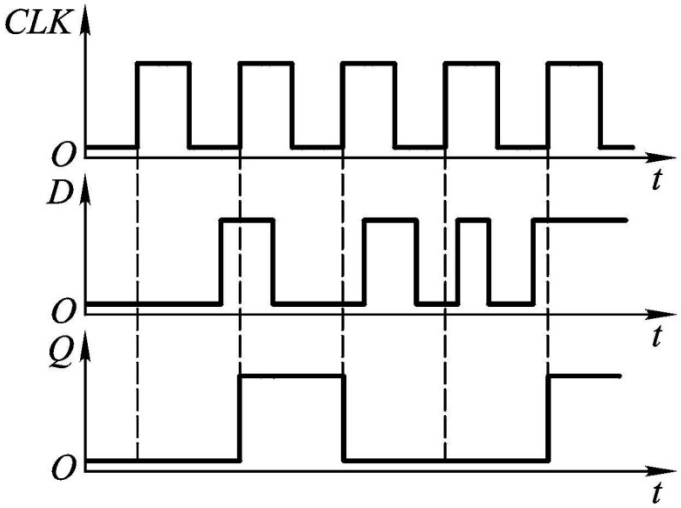
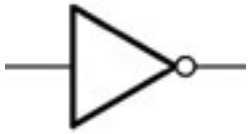
课程内容

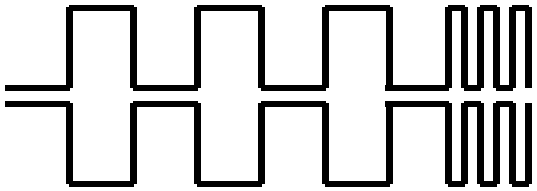
- 数制与码制(第一章)
- 逻辑代数基础(第二章)
- 组合逻辑电路(第四章)
- 半导体存储电路（第五章）
- 集成门电路(第三章)



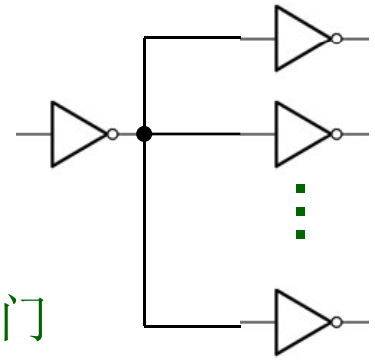
问题1：低电平---0；高电平---1
几伏为高电平？几伏为低电平？

问题2：输出跟着输入变化，能变多快？
1MHz？500MHz?1GHz?





问题3：理想情况，一个门能驱动无数个负载，实际上不能，为什么？



TTL门，CMOS门

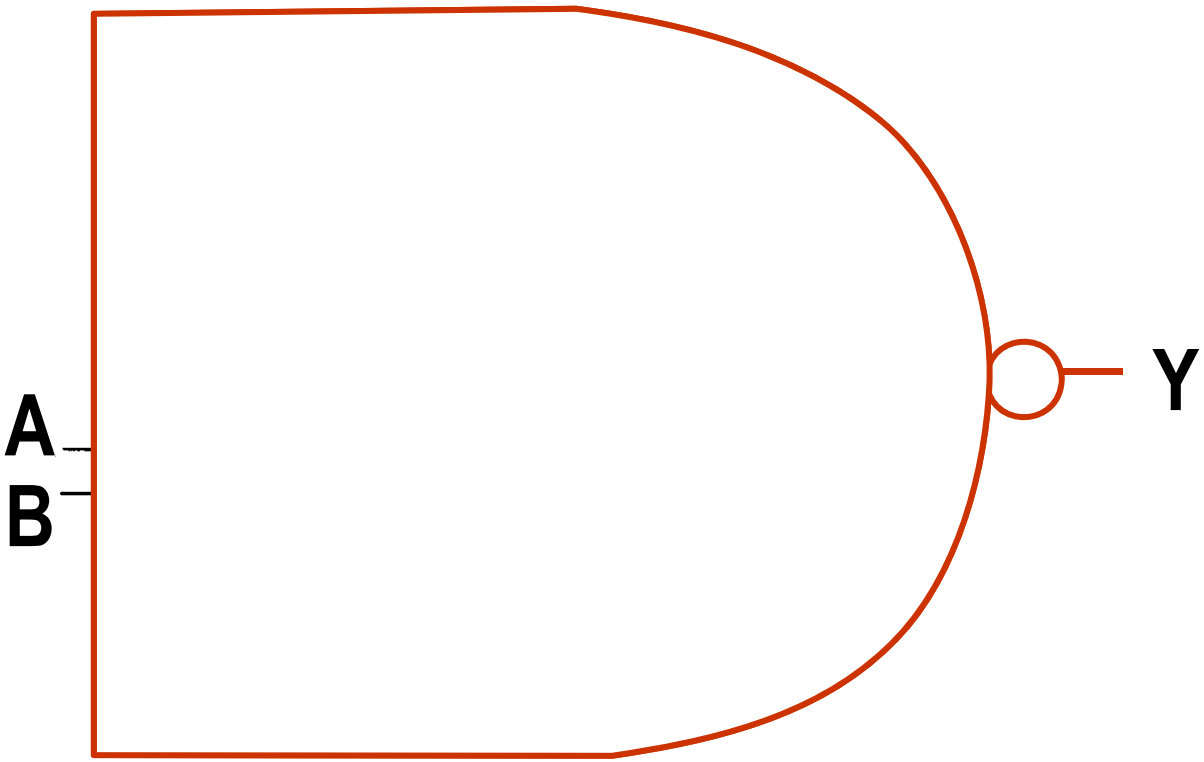
第三章　集成门电路

概述

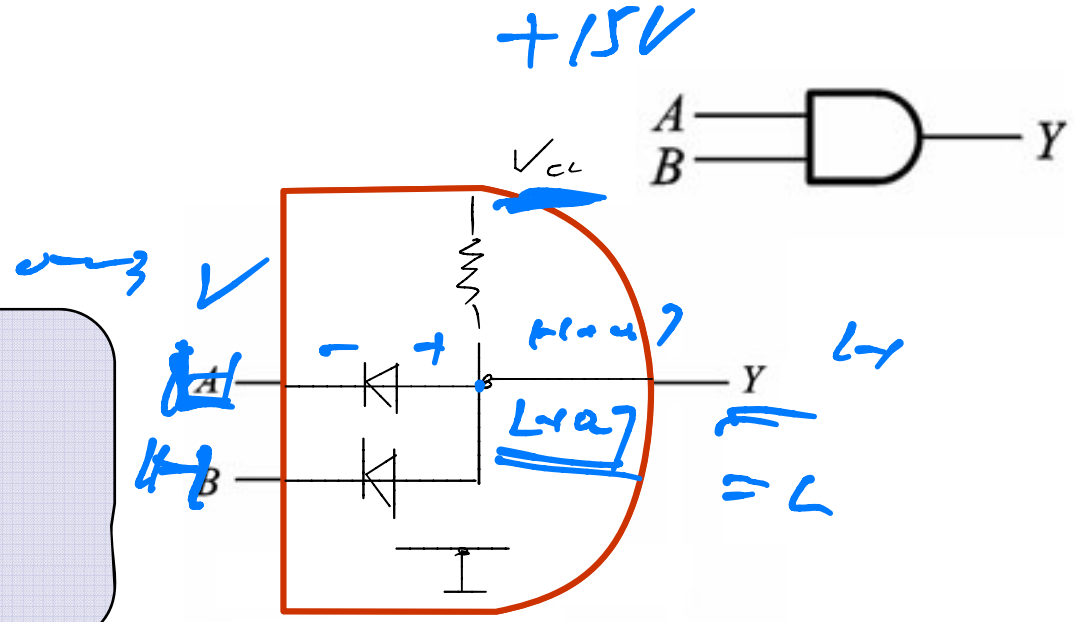
半导体二极管门电路

TTL门电路(Transistor-Transistor Logic)

CMOS门电路


A
B
Y

二极管与门



设V_{CC} = 5V
二极管导通时　V_D=0.7V

A	B	Y
0V	0V	0.7
0V	3V	0.7
3V	0V	0.7
3V	3V	3.7

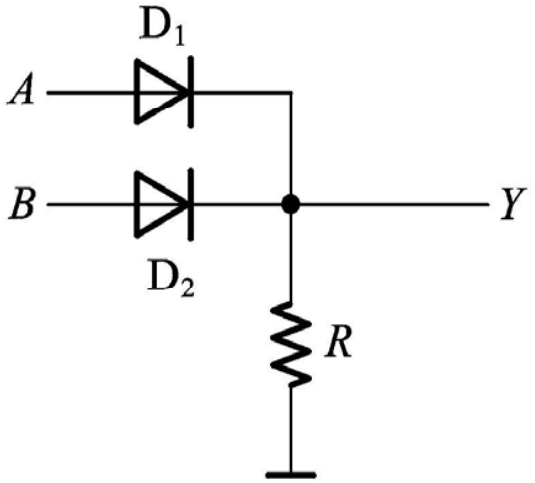
规定3V以上为1

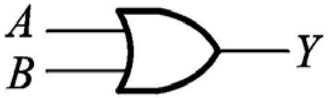
0.7V以下为0

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

二极管或门

设V_{CC} = 5V，
加到A、B端
V_{IH}=3V，V_{IL}=0V
二极管导通时V_D=0.7V





A	B	Y
0V	0V	0 V
0V	3V	2.3V
3V	0V	2.3V
3V	3V	2.3V

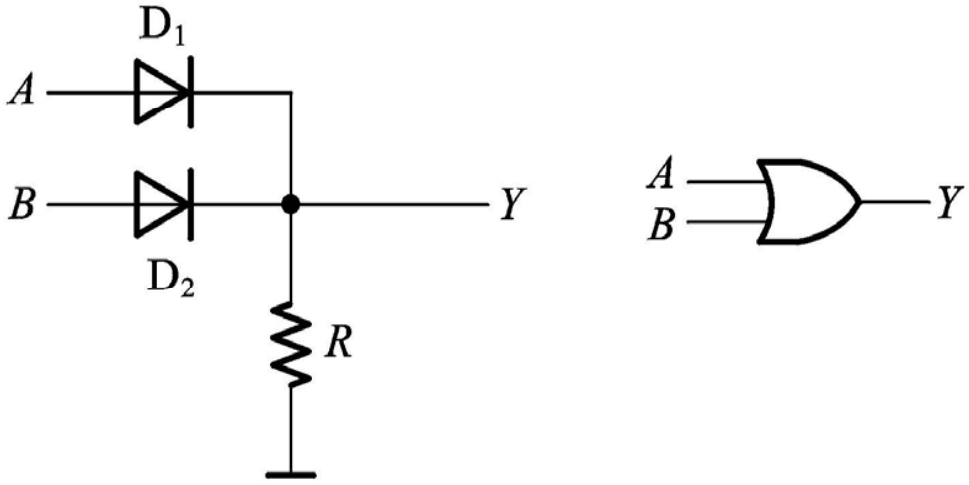
规定2.3V以上为1

0V以下为0

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

二极管或门

设V_{CC} = 5V，
加到A、B端
V_{IH}=3V，V_{IL}=0V
二极管导通时V_D=0.7V

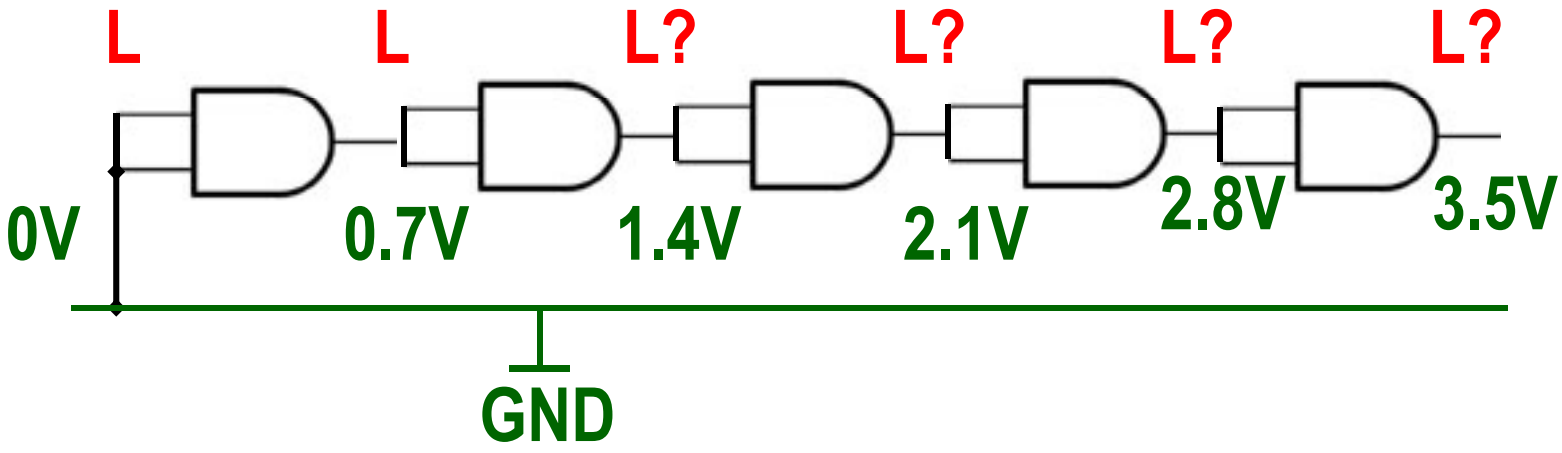


A	B	Y
0V	0V	0 V
0V	3V	2.3V
3V	0V	2.3V
3V	3V	2.3V

规定2.3V以上为1
0V以下为0

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

二极管门电路的缺点



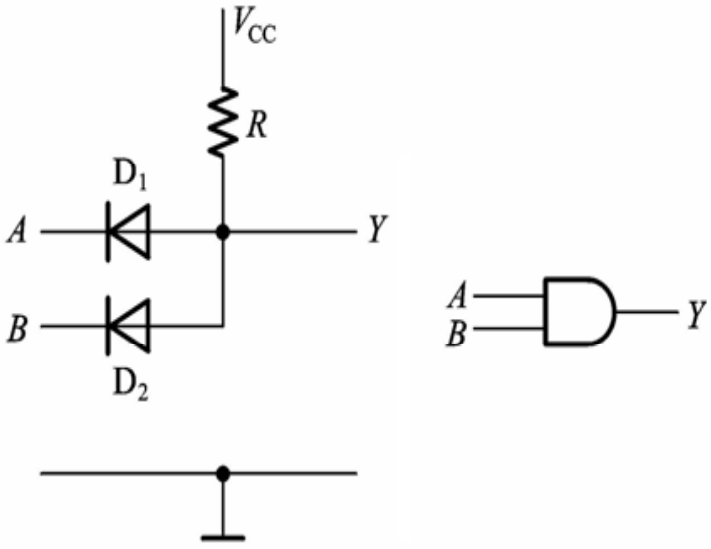
缺点1. 电平有偏移

缺点2. 功耗大

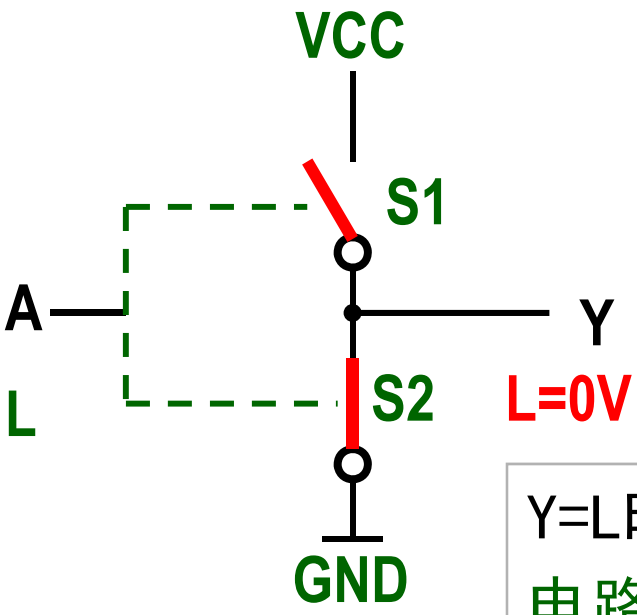
A=B=L, Y=L;

消耗在电阻R上的功耗

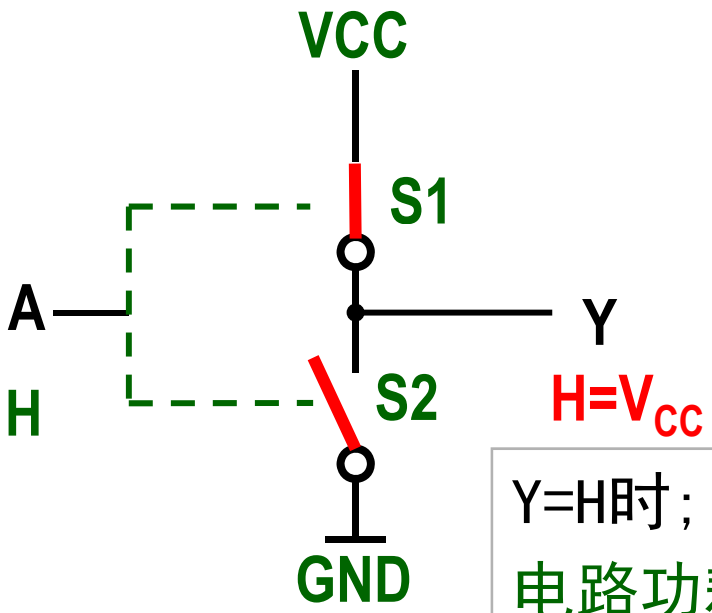
$=V_{CC}\cdot I=V_{CC}(V_{CC}-0.7)/R=V_{CC}^2/R$



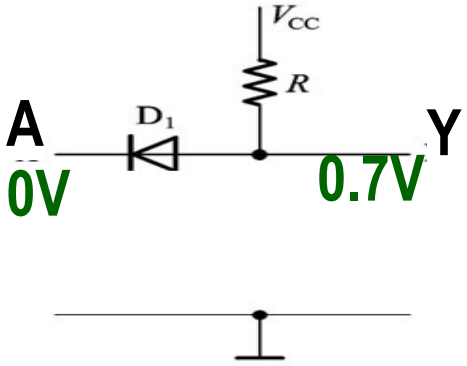
怎样降低门电路的功耗？互补开关电路



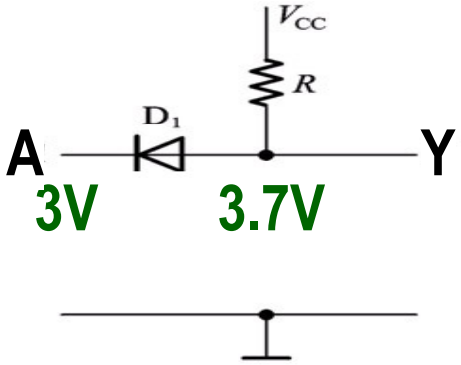
Y=L时；
电路功耗
$=V_{CC}\cdot I=0$



Y=H时；
电路功耗
$=V_{CC}\cdot I=0$

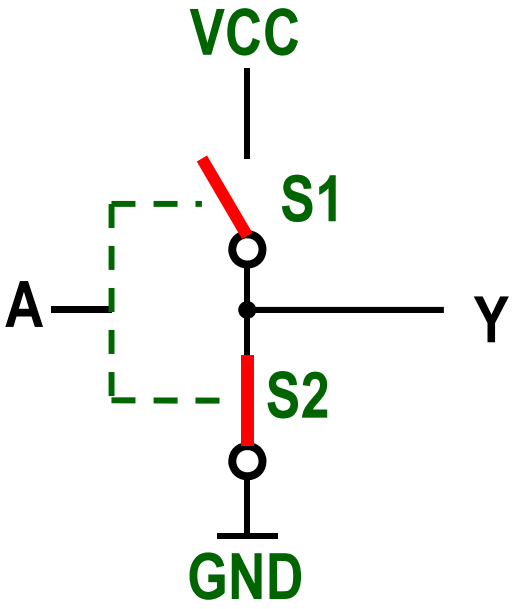


Y=L时；电路功耗$=4.3^2/R$

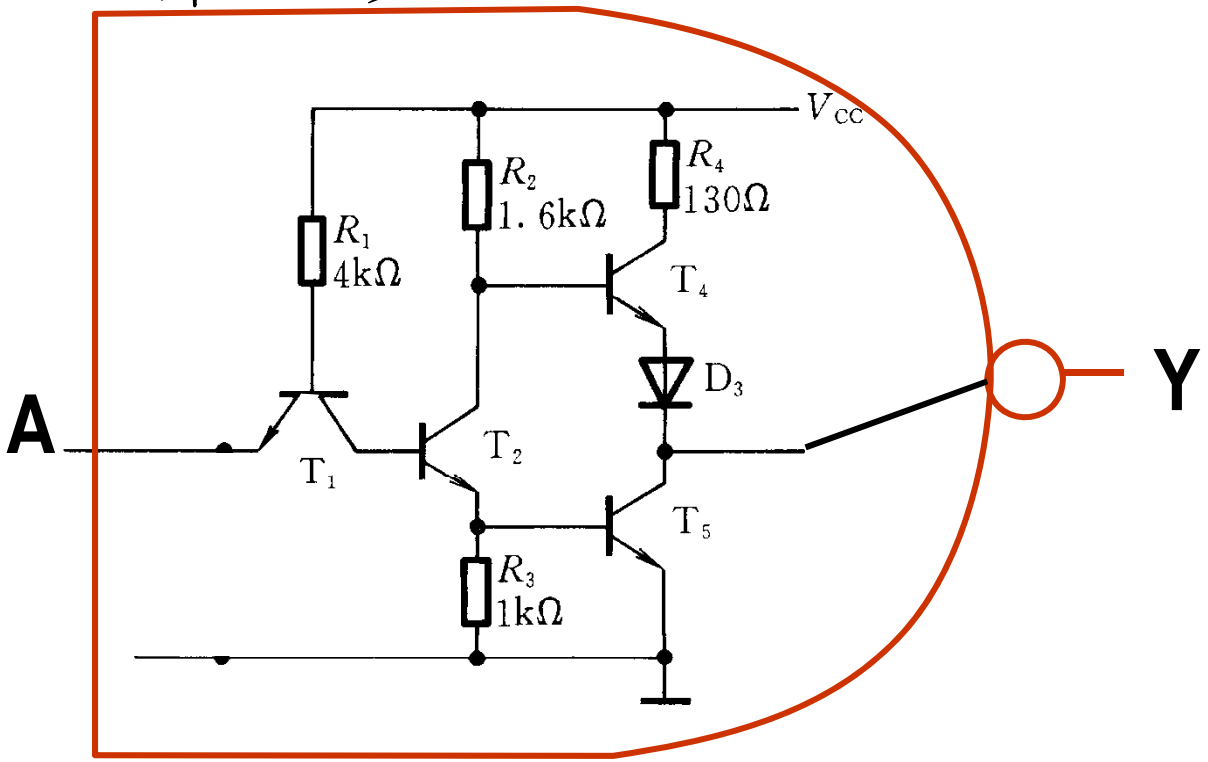


Y=H时；电路功耗$=1.3^2/R$

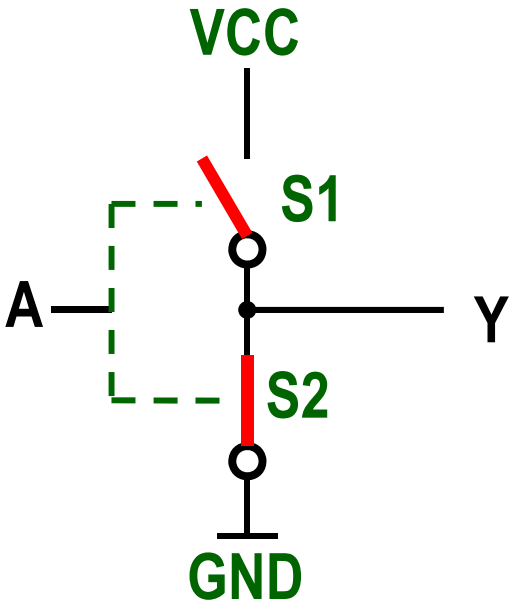
TTL非门

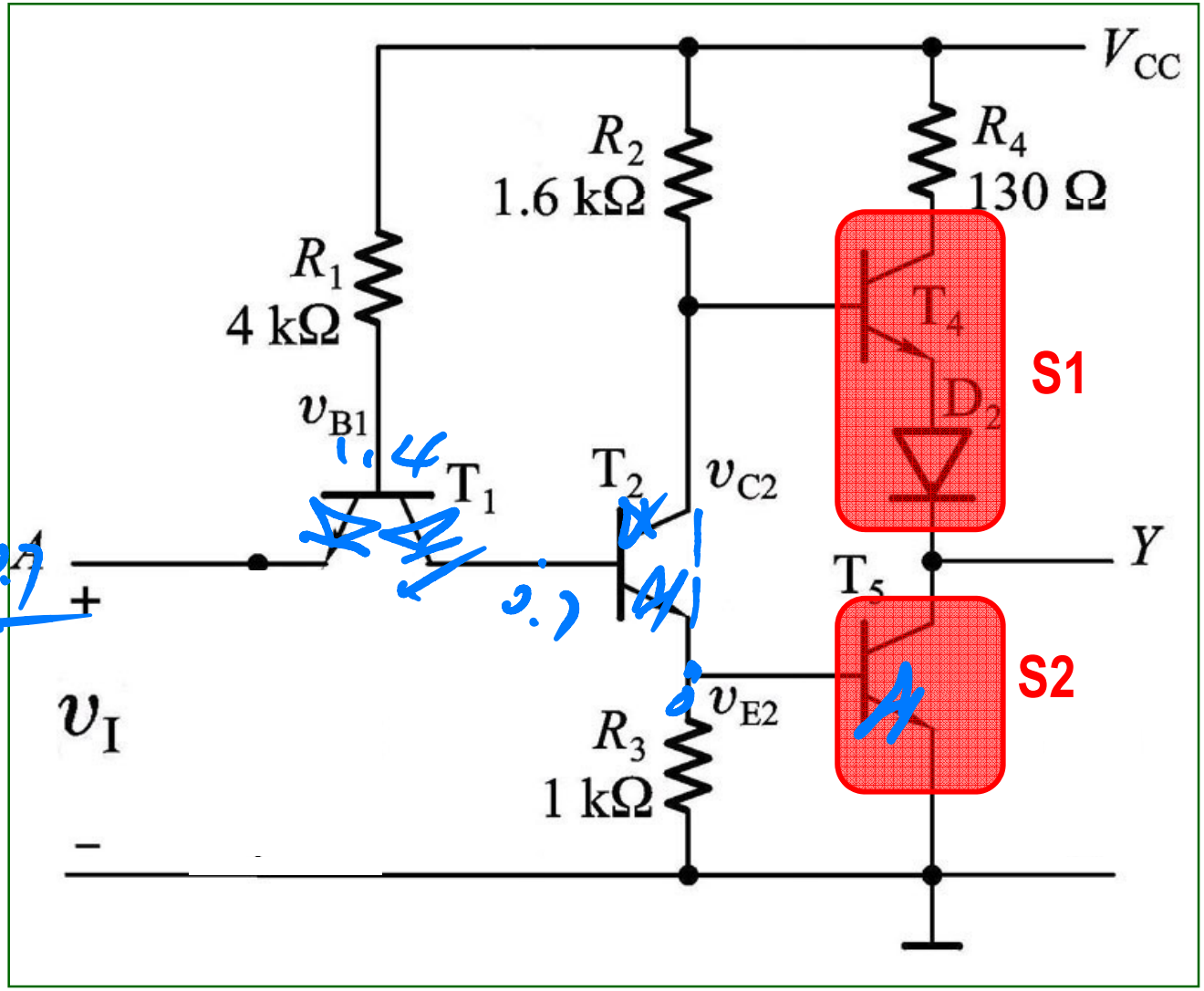


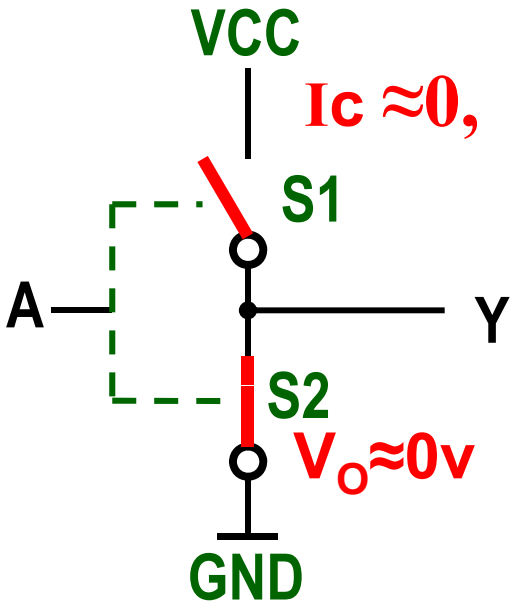
逻辑门电路



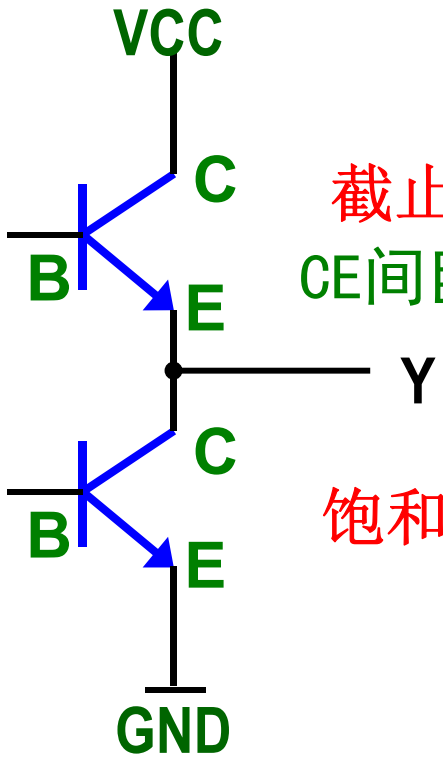
TTL非门


VCC
S1
A
Y
S2
GND


V_{CC}
R_2
1.6 kΩ
R_4
130 Ω
R_1
4 kΩ
T_4
D_2
S1
v_{B1}
T_1
T_2
v_{C2}
Y
T_5
+
v_I
S2
v_{E2}
R_3
1 kΩ
–



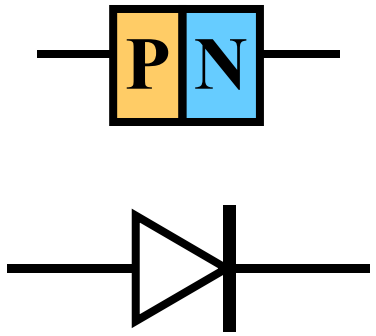
理想开关
功耗为0

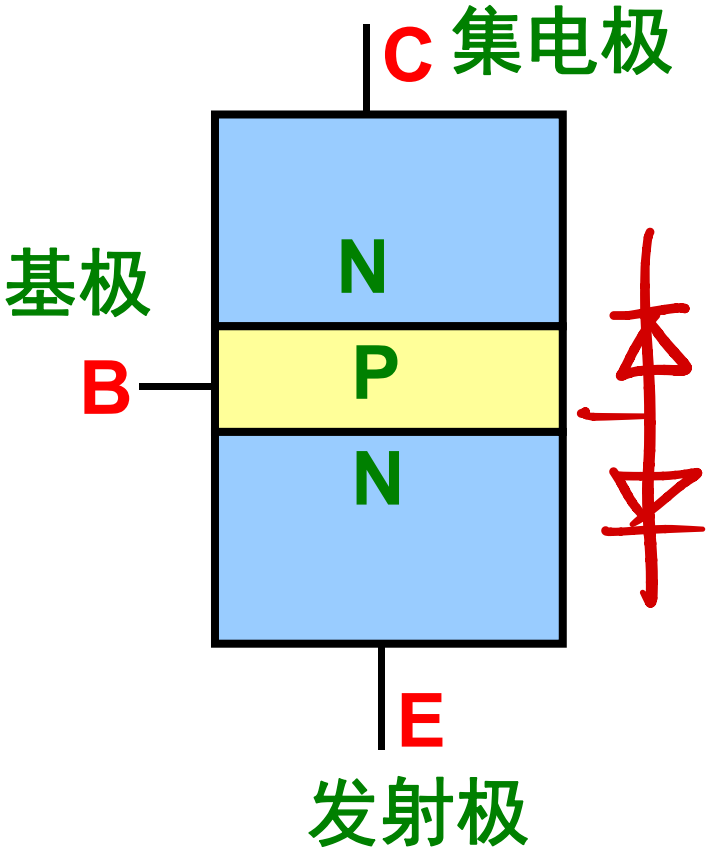


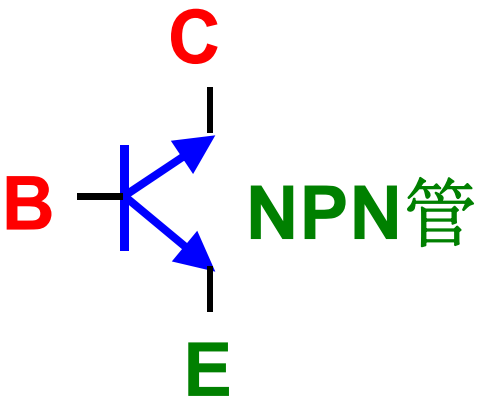
截止,Ic ≈0,
CE间巨大电阻
断开

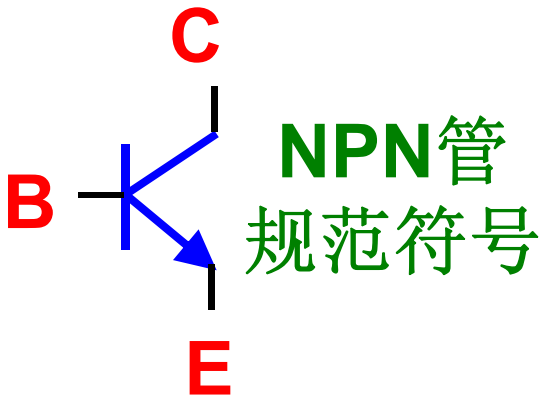
饱和，V_{CE}≈0.1v 闭合

三极管开关
尽可能接近
理想开关

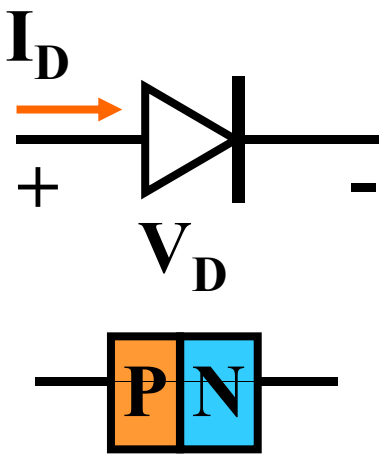


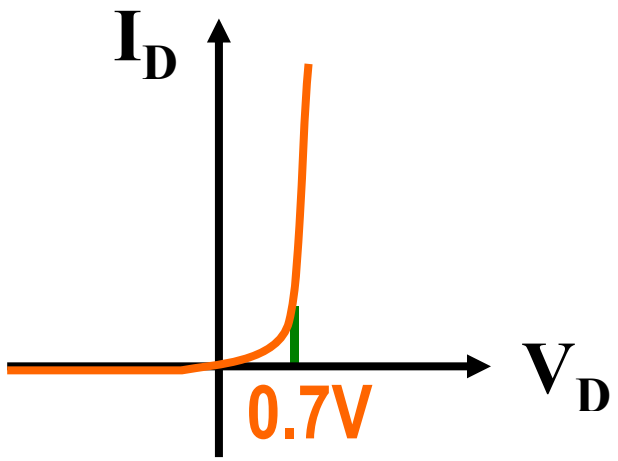




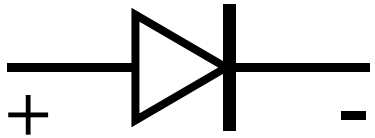


基极

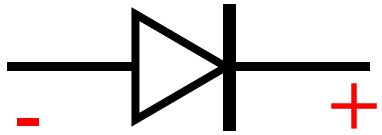




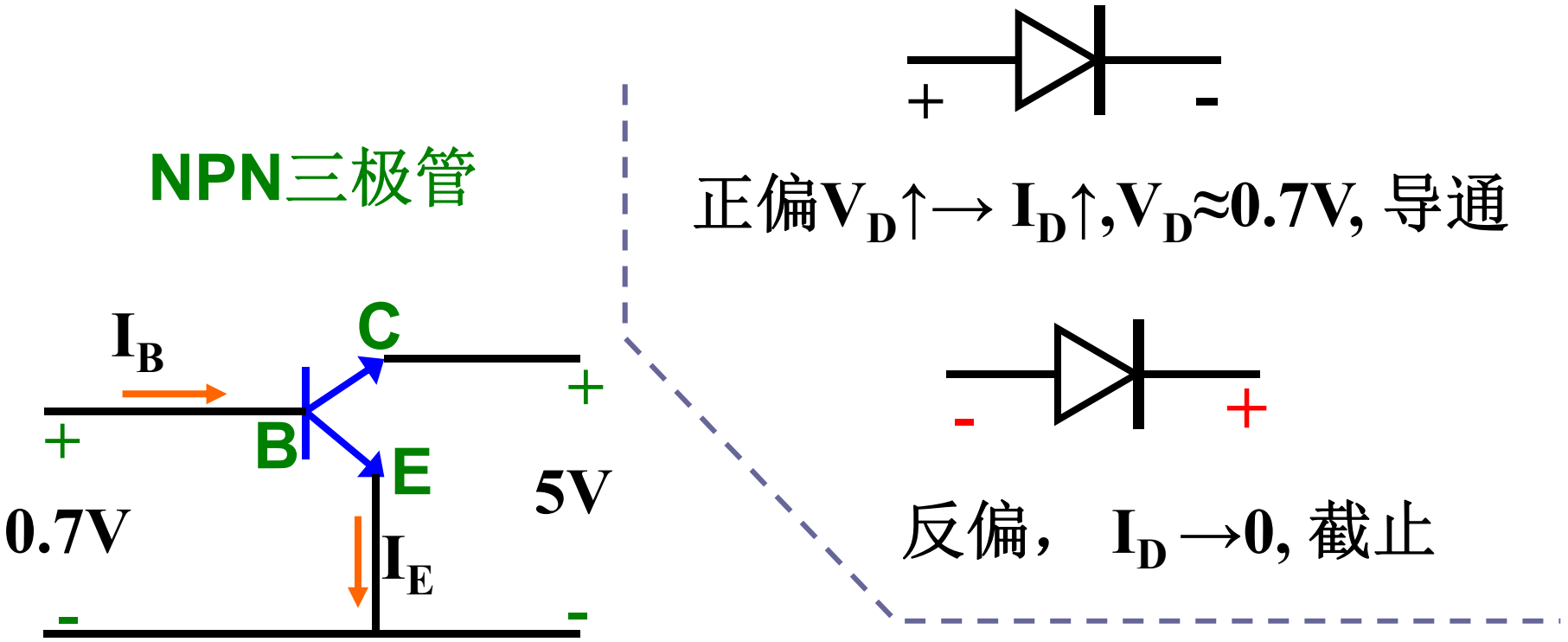
二极管的伏安特性



正偏V_D↑→I_D↑,V_D≈0.7V时,导通，电阻小



反偏，I_D→0,截止，电阻大

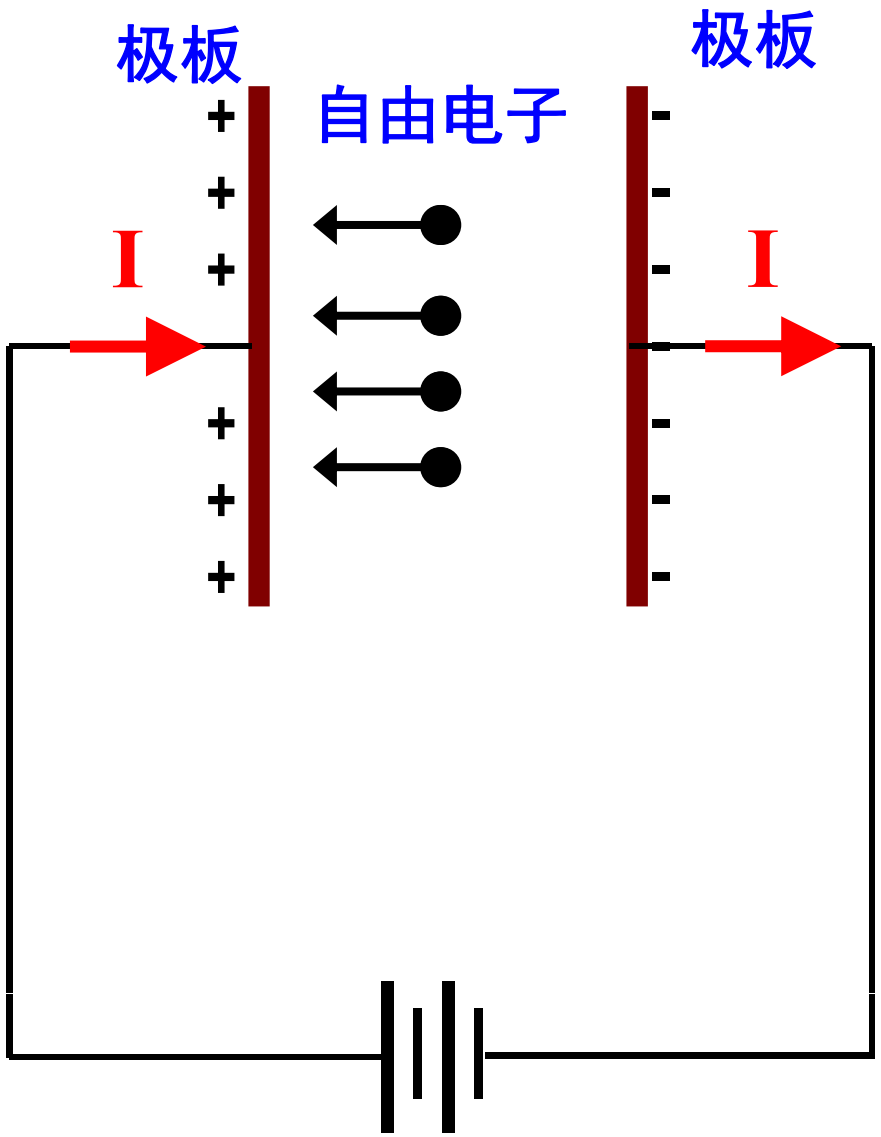


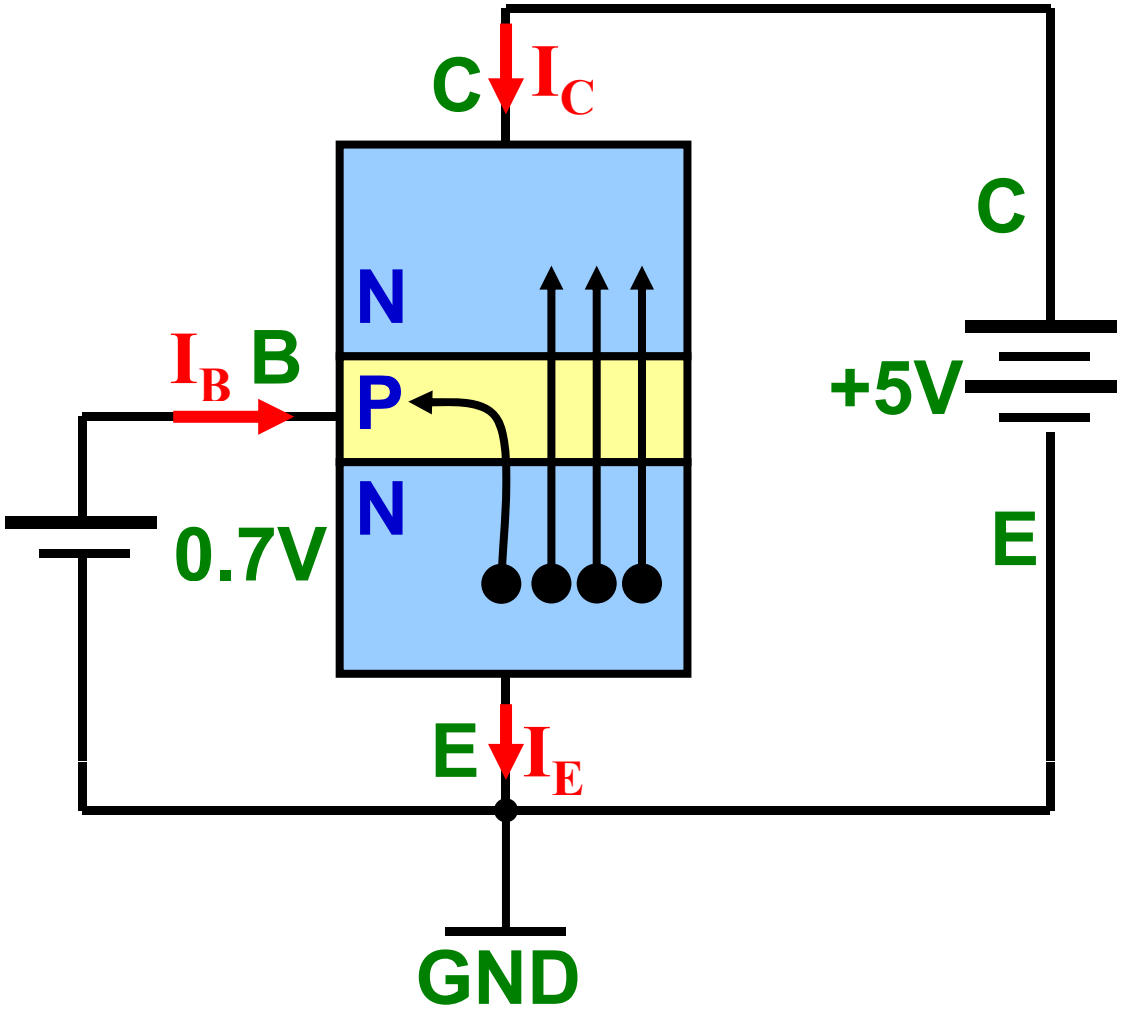
BE结正偏， V_{BE} = 0.7V时, BE结导通， I_B , I_E产生

V_{BC} = 0.7V – 5V = - 4.3V, BC结反偏， I_C →0, 截止?

三极管 ≠二极管 + 二极管

电场


极板
自由电子
极板
I
I



放大：

BE正偏，

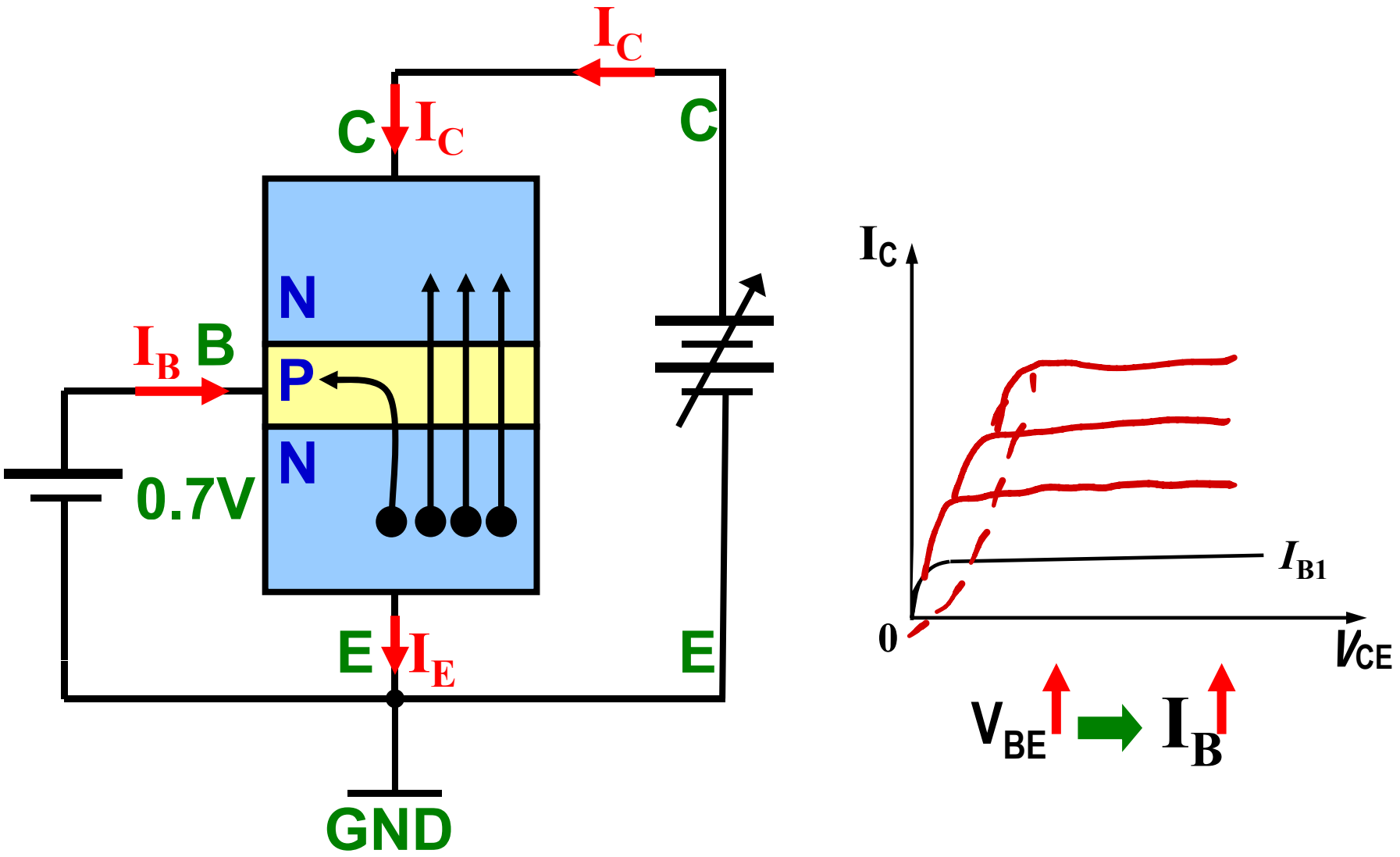
BC反偏

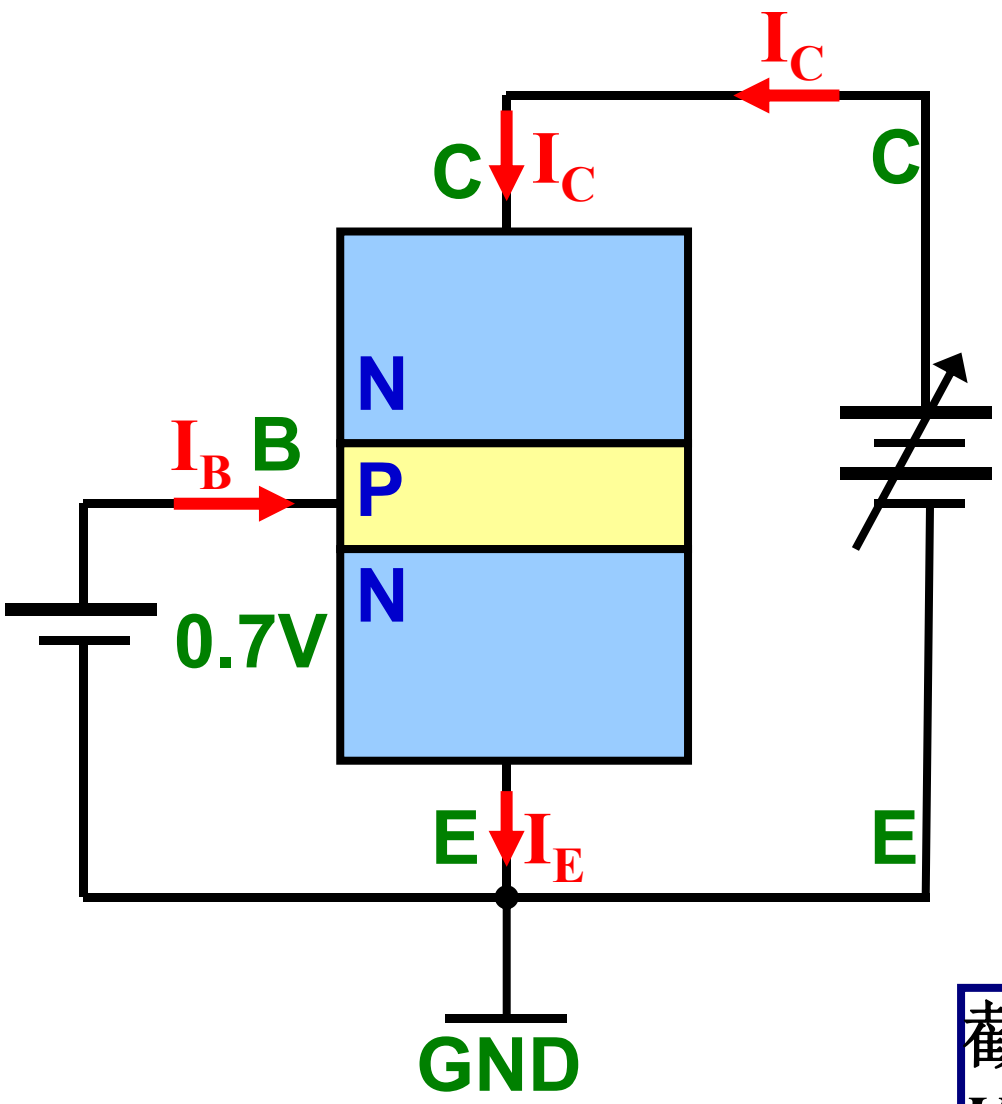
V_{BC}= - 4.3V

放大倍数

$$I_C=\beta I_B$$

$$I_E=I_B+I_C$$


I_C
C
I_C
C
N
I_B B
P
N
0.7V
E
I_E
E
GND
I_C
I_{B1}
0
V_{CE}
V_{BE}
I_B



饱和区

BE正偏

BC正偏

V_{BC}:0.6V~0.7V

V_{CE}:0.1V~0.0V

$I_C < \beta I_B$

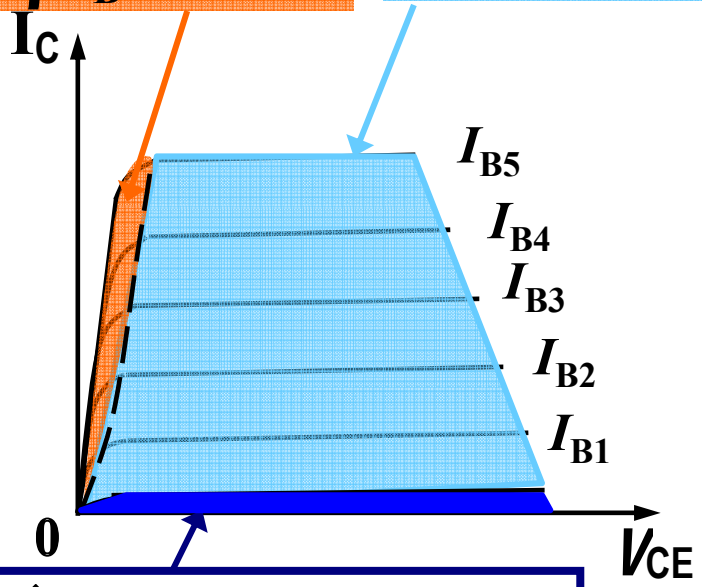
E,C同等电位

放大区

BE正偏

BC反偏

$I_C = \beta I_B$

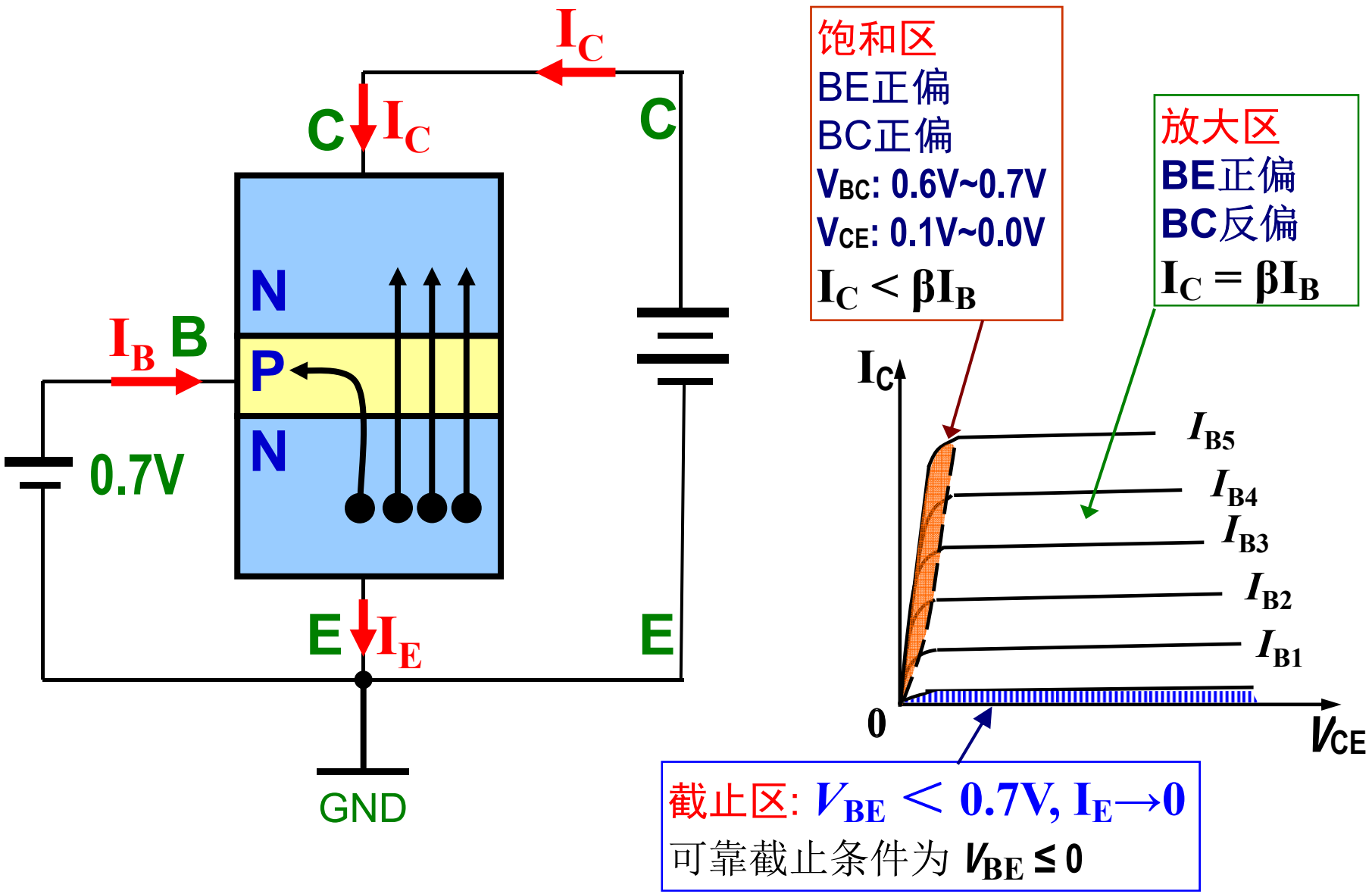


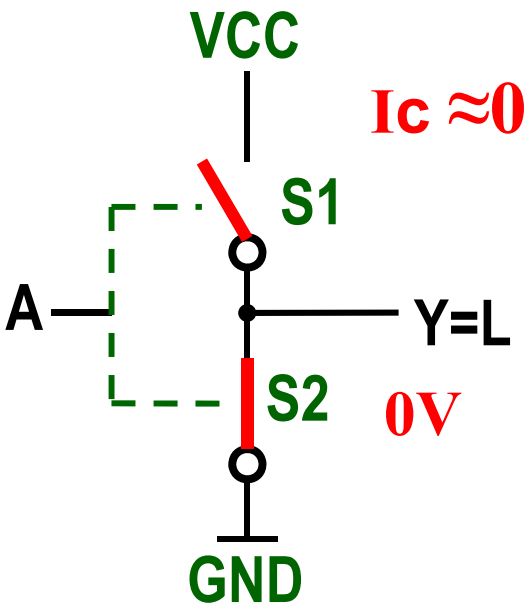
截止区

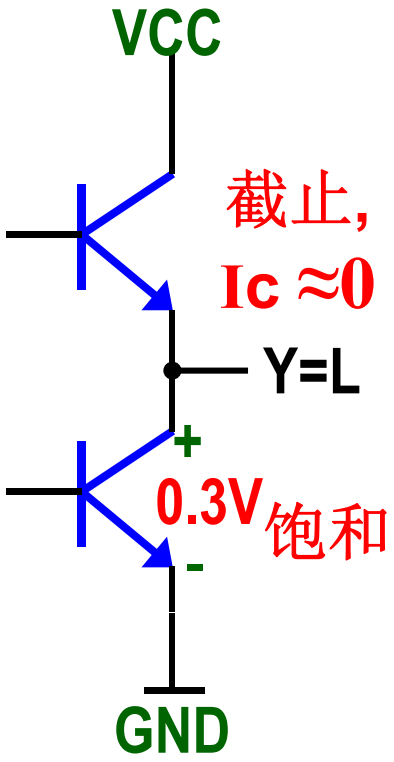
V_{BE} < 0.7V，$I_E \rightarrow 0$

可靠截止条件为 $V_{BE} \leq 0$

V_{BE}小于0.7v或反偏=>截止

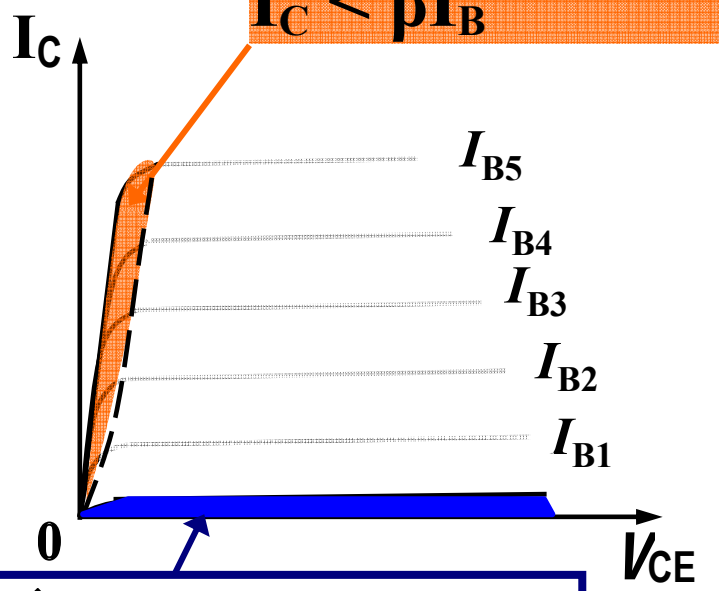

I_C
C
I_C
C
N
I_B B
P
N
0.7V
E
I_E
E
GND
饱和区
BE正偏
BC正偏
V_{BC}: 0.6V~0.7V
V_{CE}: 0.1V~0.0V
$I_C < \beta I_B$
放大区
BE正偏
BC反偏
$I_C = \beta I_B$
I_C
I_{B5}
I_{B4}
I_{B3}
I_{B2}
I_{B1}
0
V_{CE}
截止区: $V_{BE} < 0.7V$, $I_E \rightarrow 0$
可靠截止条件为 $V_{BE} \leq 0$



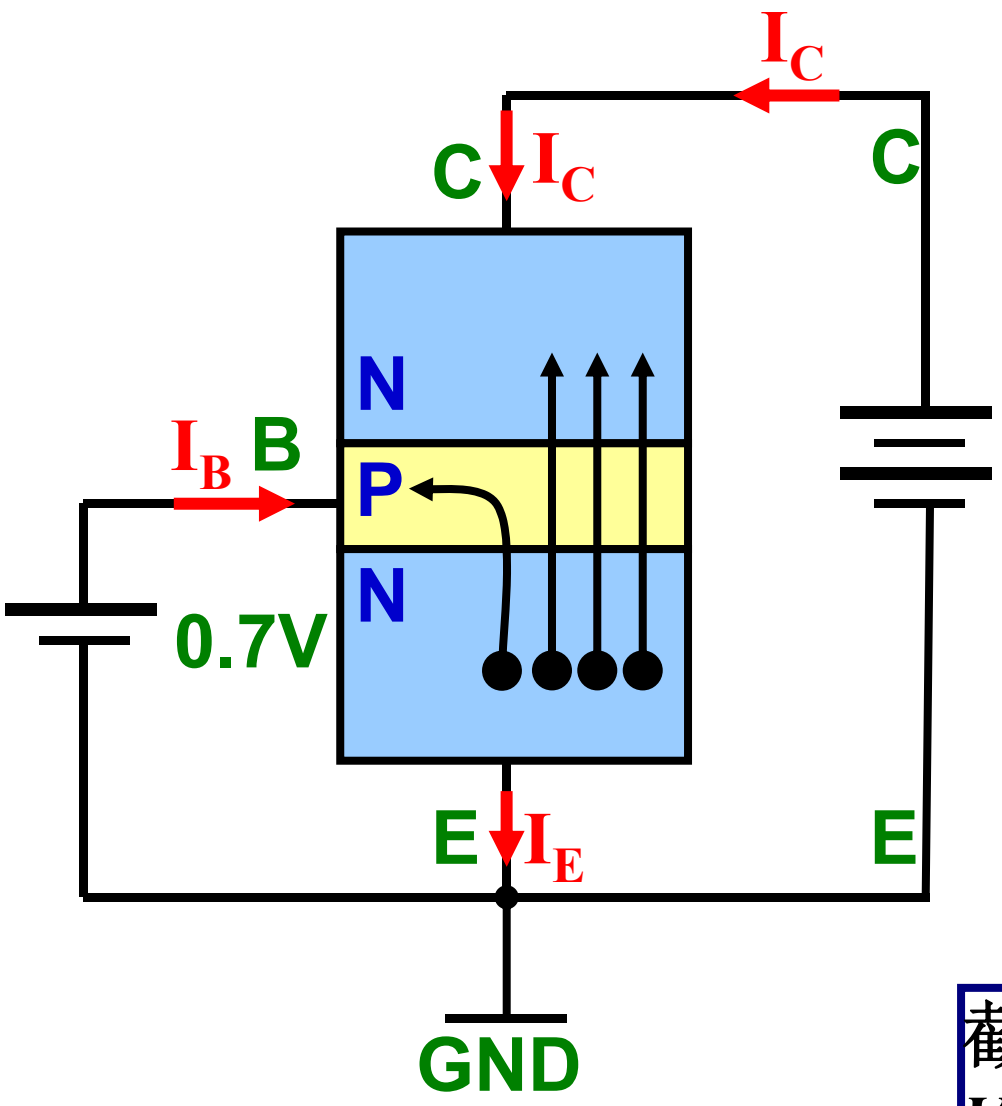


门电路
饱和
截止
放大 → 逻辑错误，不高不低

饱和区
BE正偏
BC正偏
V_{BC}:0.6V~0.7V
V_{CE}:0.1V~0.0V
$I_C < \beta I_B$



截止区
V_{BE} < 0.7V，$I_E \to 0$
可靠截止条件为 $V_{BE} \leq 0$
V_{BE}小于0.7v或反偏=>截止



怎样使三极管工作在饱和或截止状态呢？

饱和区

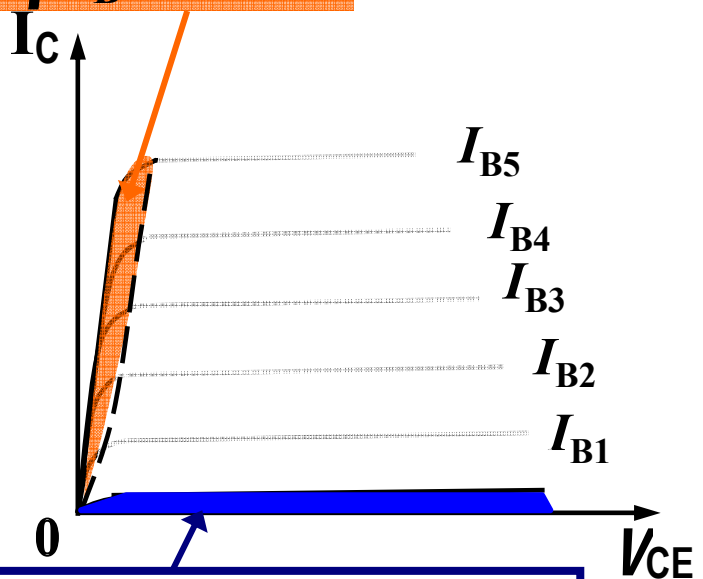
BE正偏

BC正偏

V_{BC}:0.6V~0.7V

V_{CE}:0.1V~0.0V

$I_C < \beta I_B$

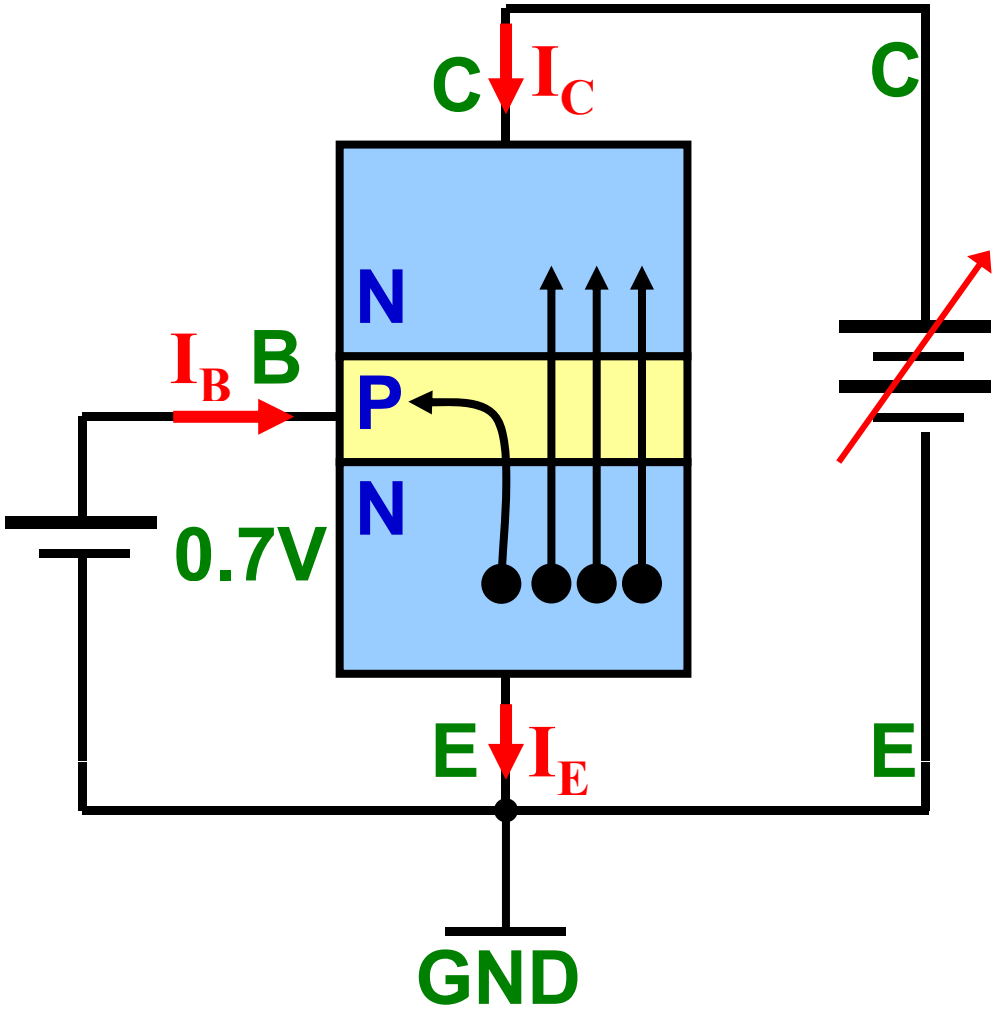


截止区

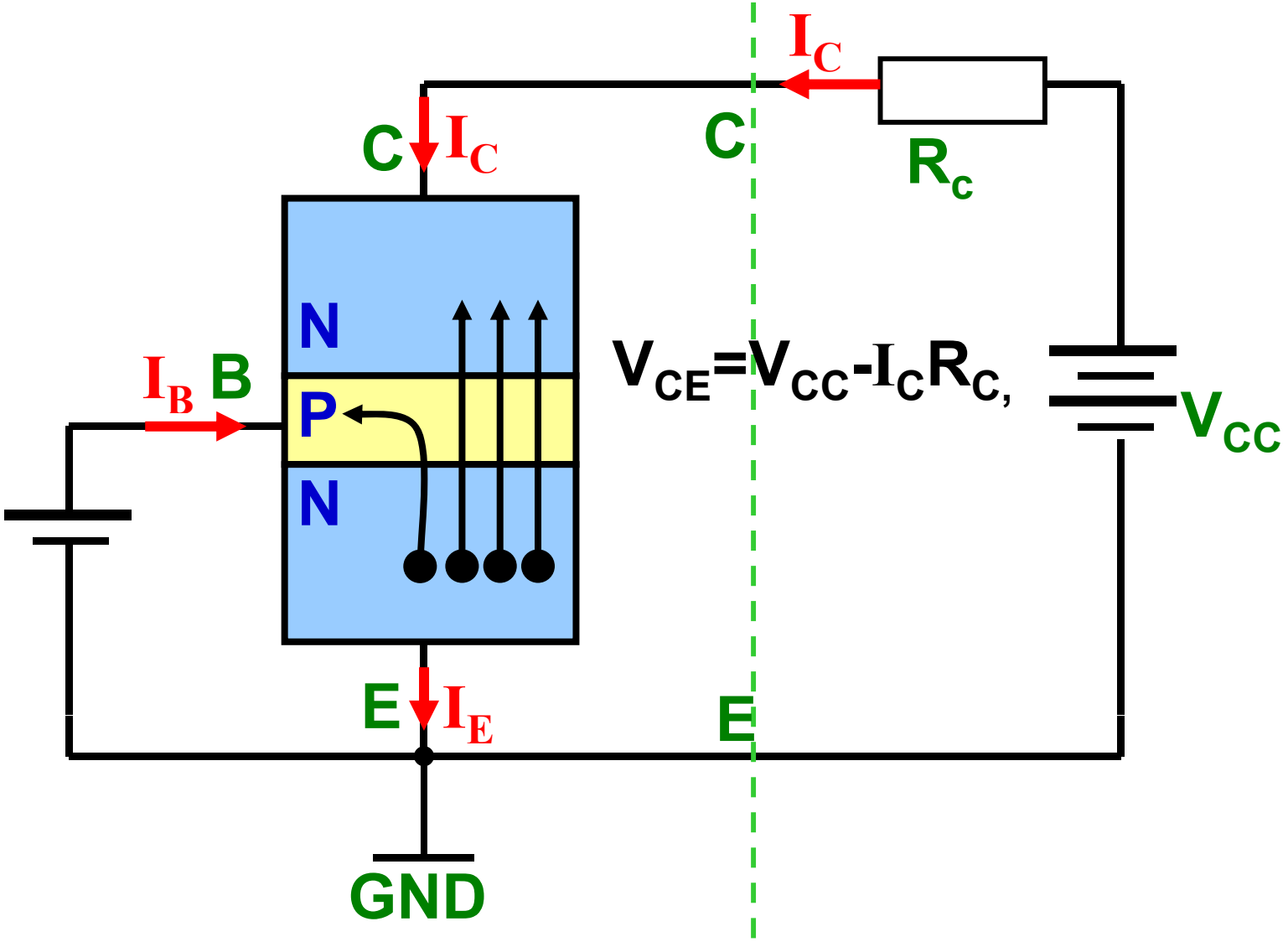
V_{BE} < 0.7V，$I_E \rightarrow 0$

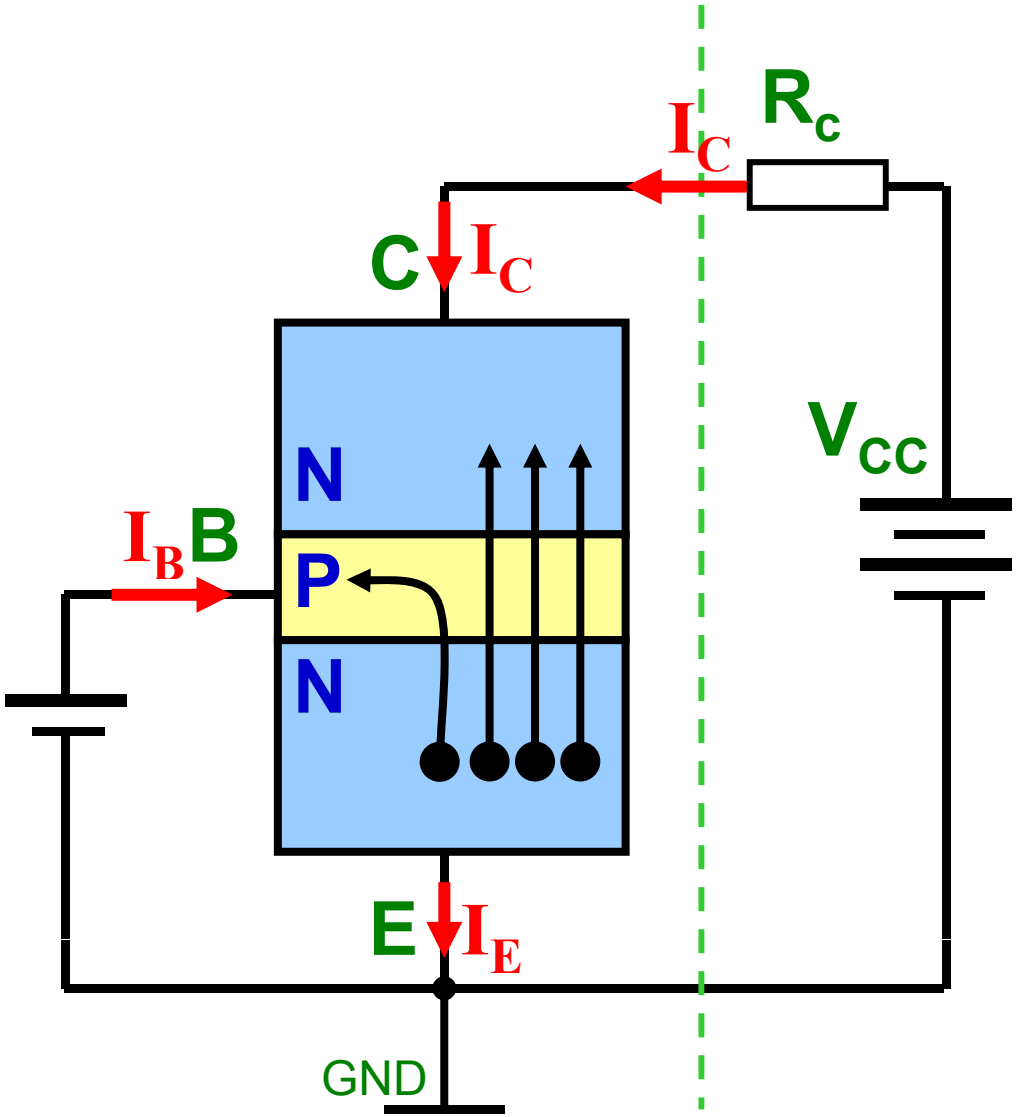
可靠截止条件为 $V_{BE} \leq 0$

V_{BE}小于0.7v或反偏=>截止


C
I_C
C
N
I_B B
P
N
0.7V
E
I_E
E
GND

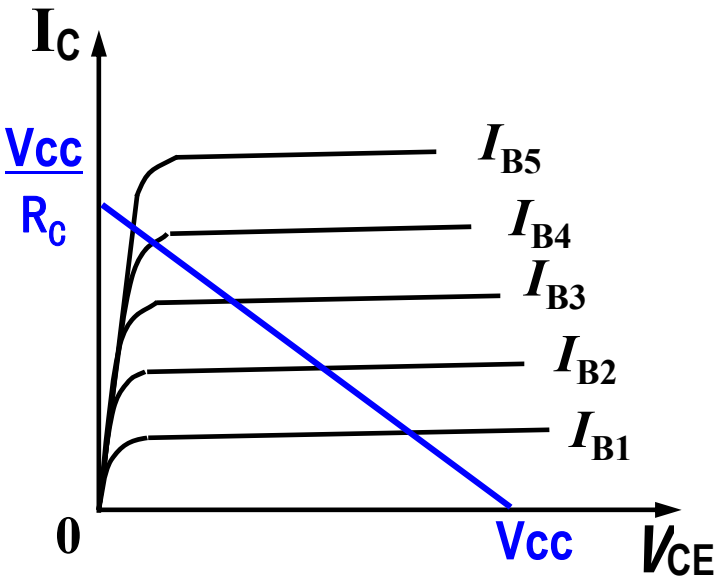
$I_C=(V_{CC}-V_{CE})/R_C$,

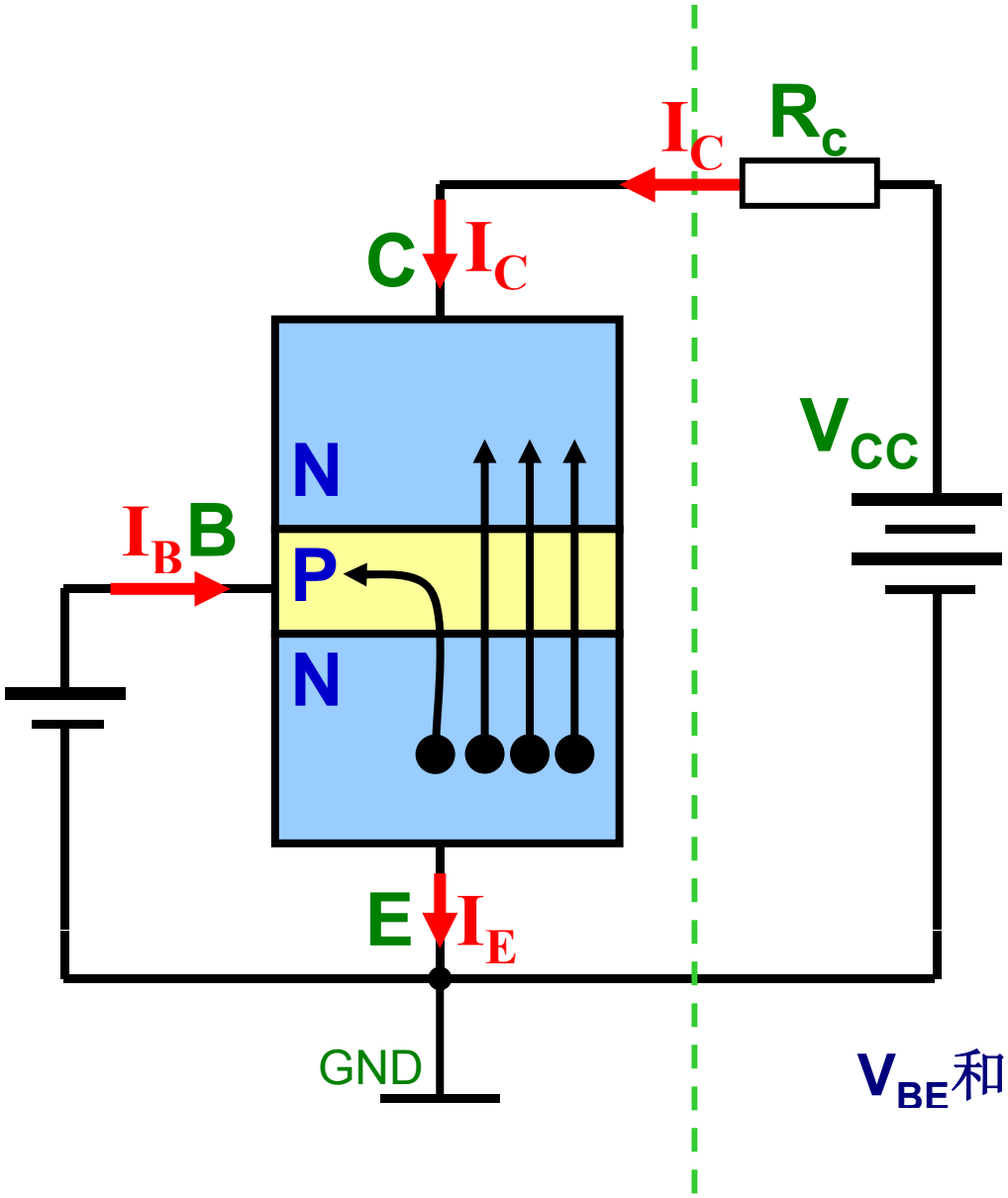




$$V_{CE}=V_{CC}-I_CR_C,$$

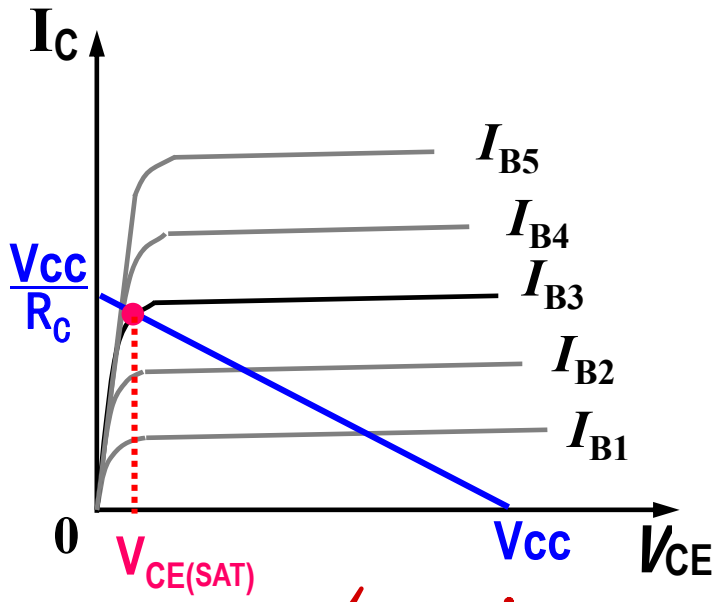
$$I_C=(V_{CC}-V_{CE})/R_C,$$





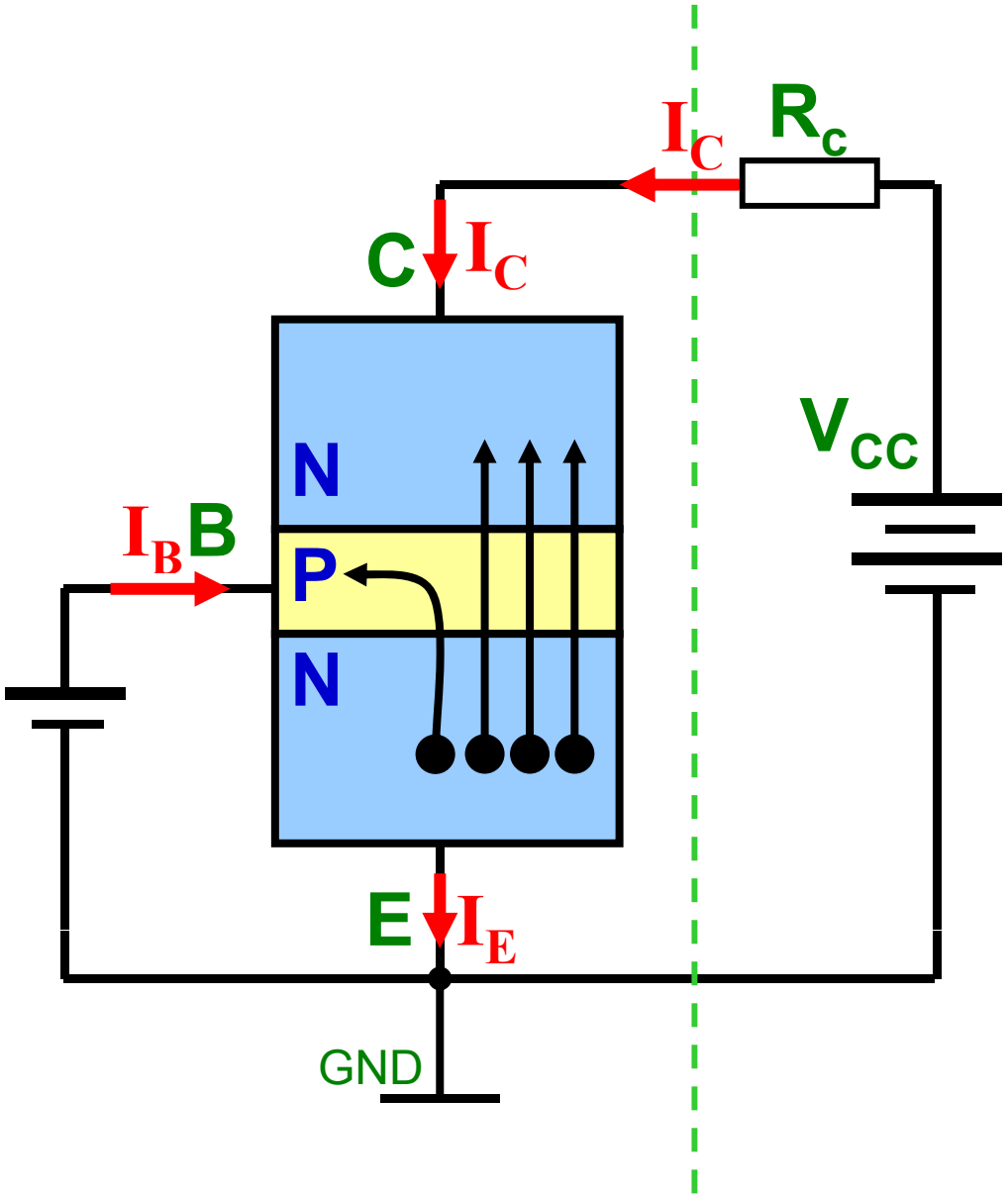
$V_{CE}=V_{CC}-I_CR_C$,

$I_C=(V_{CC}-V_{CE})/R_C$,



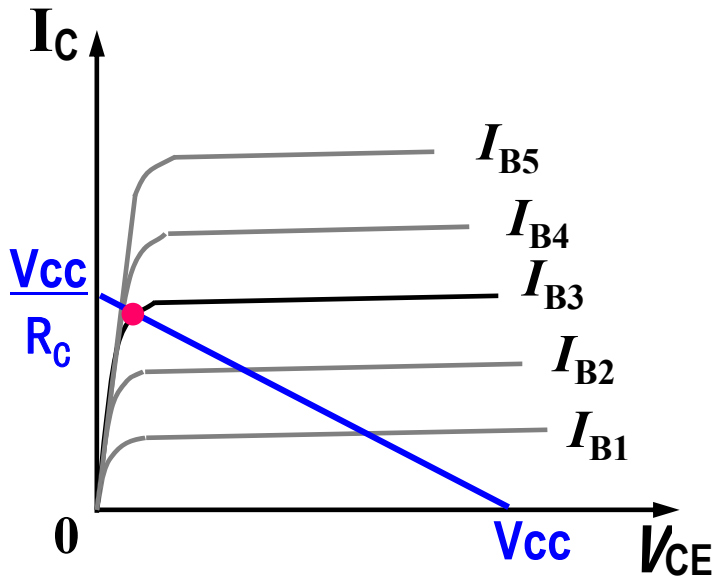
0.1 ~ 0.3V (闭合)

V_{BE}和R_C取值合适, 三极管进入饱和



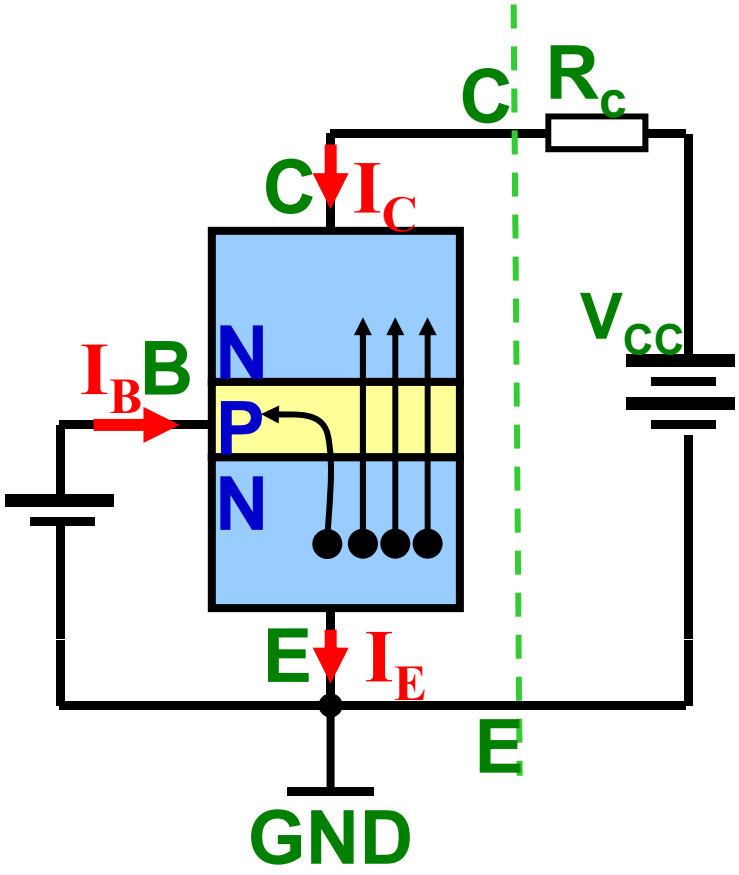
$V_{CE}=V_{CC}-I_CR_C$,

$I_C=(V_{CC}-V_{CE})/R_C$,



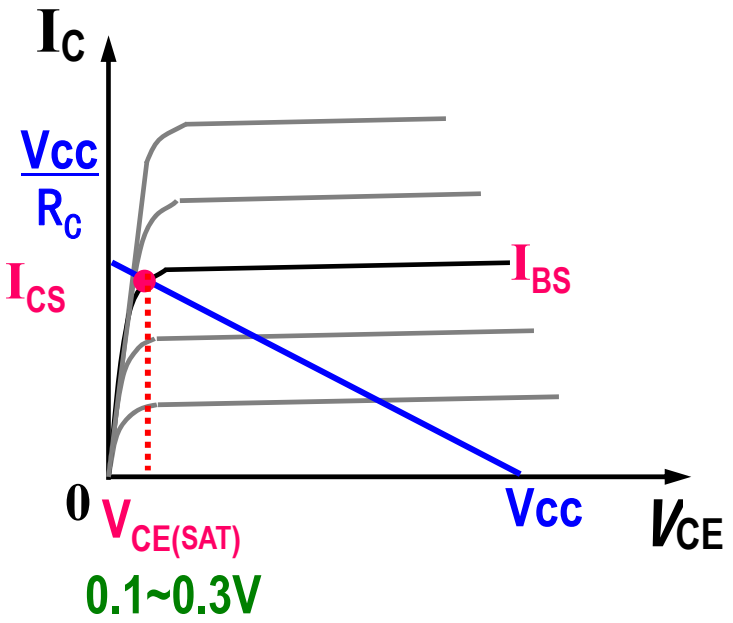
V_{BE}取值多大合适呢？

V_{BE}←→i_B



V_{BE}和R_C取值合适，三极管进入饱和

V_{BE}取值多大合适呢？



$$I_C \approx I_{CS} = \frac{V_{CC} - V_{CE(sat)}}{R_C} \approx \frac{V_{CC}}{R_C}$$

$$I_{BS} = \frac{I_{CS}}{\beta} \approx \frac{V_{CC}}{\beta R_C}$$

饱和时，$V_{CE}=V_{CE(sat)}$

0.1~0.3V

$V_{CE}=V_{CE(sat)}=V_{CC}-I_{CS}R_C$

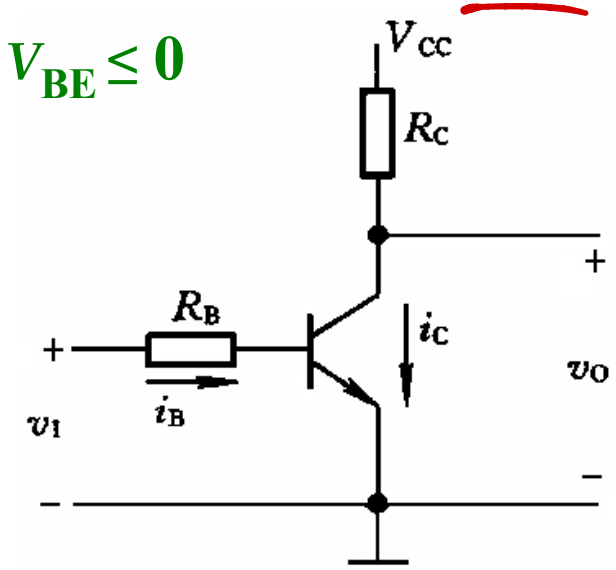
三极管工作于开关状态的条件

截止条件

$V_{BE} < 0.7V$ ➡ $I_E \to 0$

可靠截止条件BE反偏

$V_{BE} \leq 0$



截止时，$I_E \to 0$，

一定有$I_C \to 0$吗？

饱和条件

$I_B > I_{BS}$ (一定的R_C取值下)

I_B 愈大于 I_{BS} 饱和愈深。饱和

饱和区

BE正偏

BC正偏

V_{BC}:0.6V~0.7V

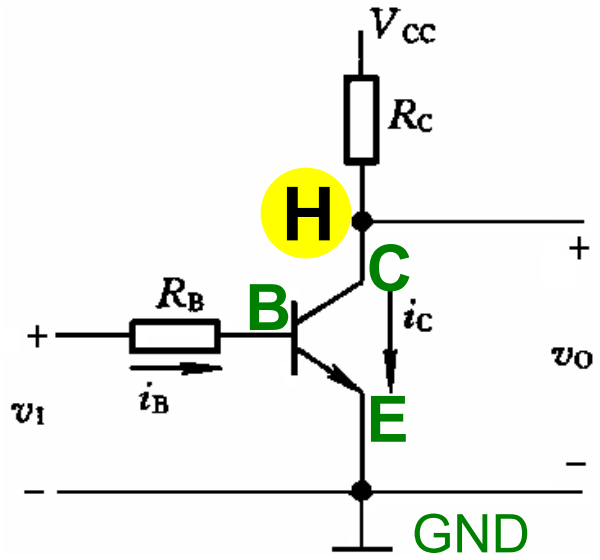
V_{CE}:0.1V~0.0V

$I_C < \beta I_B$

三极管工作于开关状态

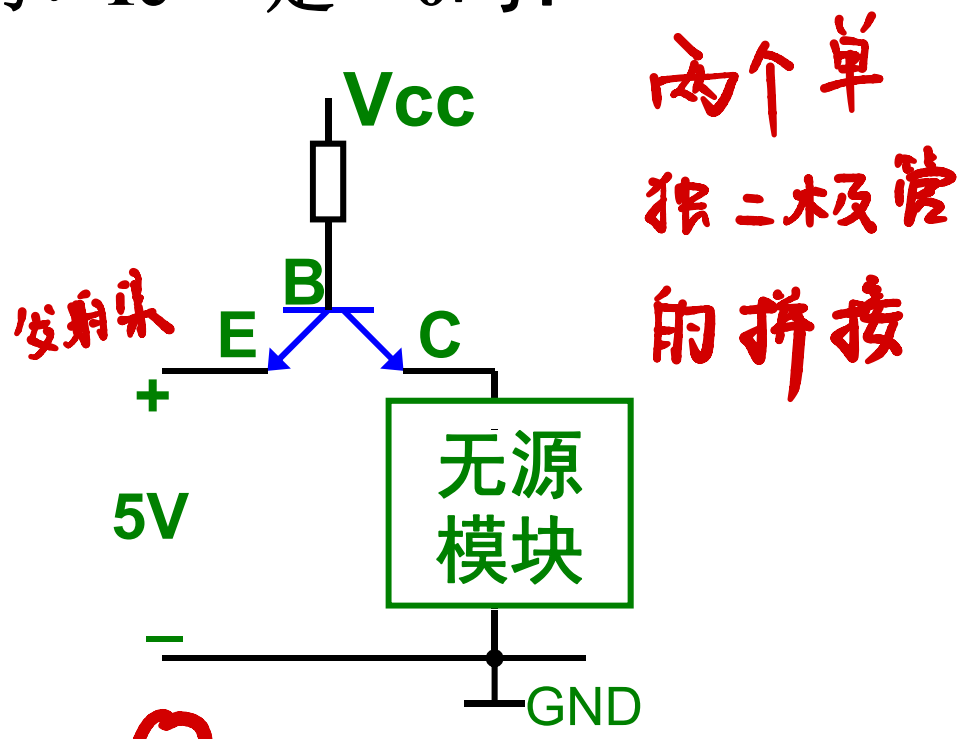
V_{BE}<0.7v，或V_{BE}反偏，三极管截止，$I_E \rightarrow 0$,

截止时，BC结一定反偏吗？Ic 一定→0吗？



BC反偏，

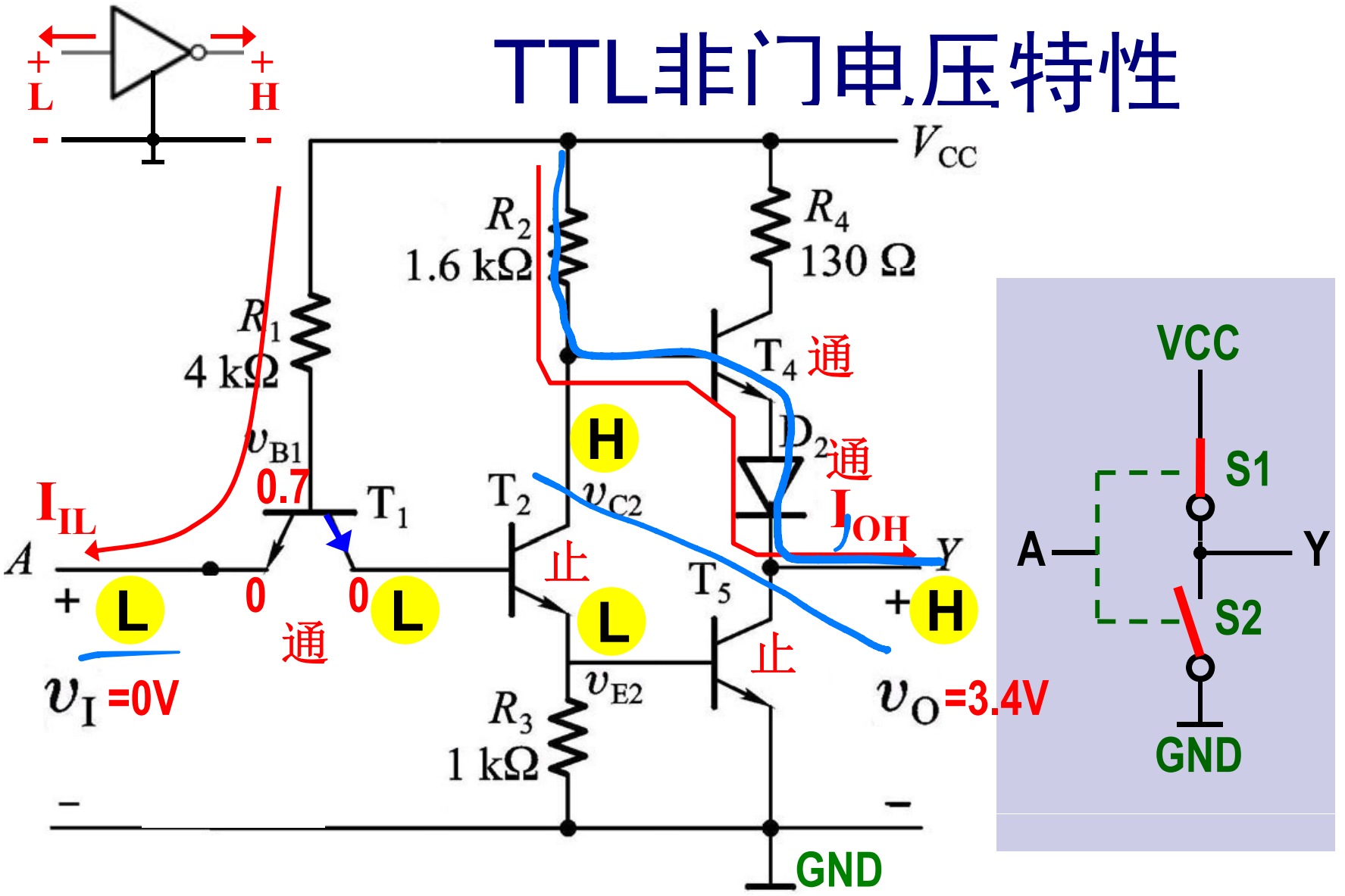
反向二极管的 $I_C \rightarrow 0$



BC正偏，

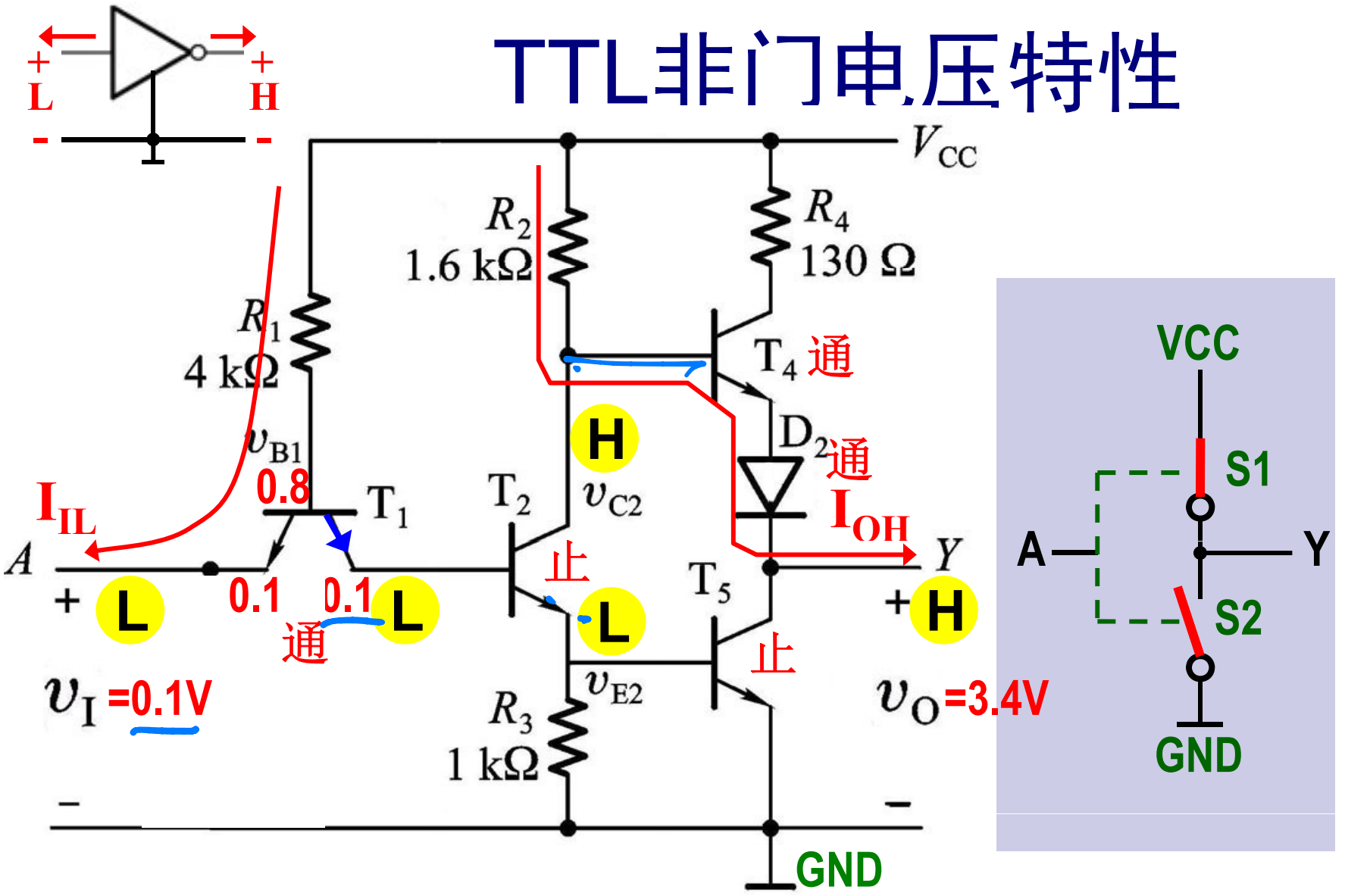
正向二极管，Ic 不一定→ 0

TTL非门电压特性



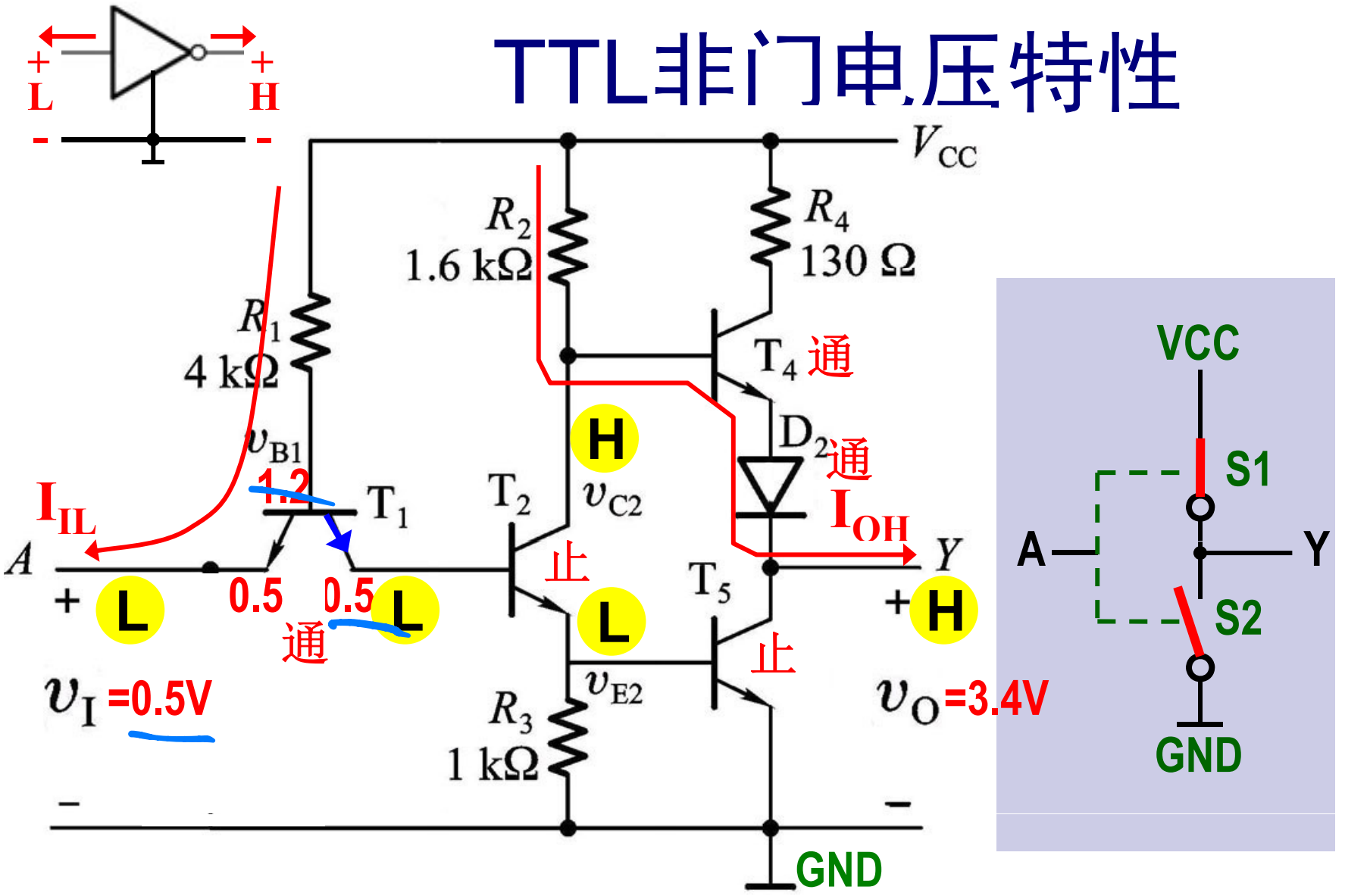
$$V_O = V_{CC} - V_{R2} - 0.7 - 0.7 = 3.6 - V_{R2} = 3.4V$$

TTL非门电压特性



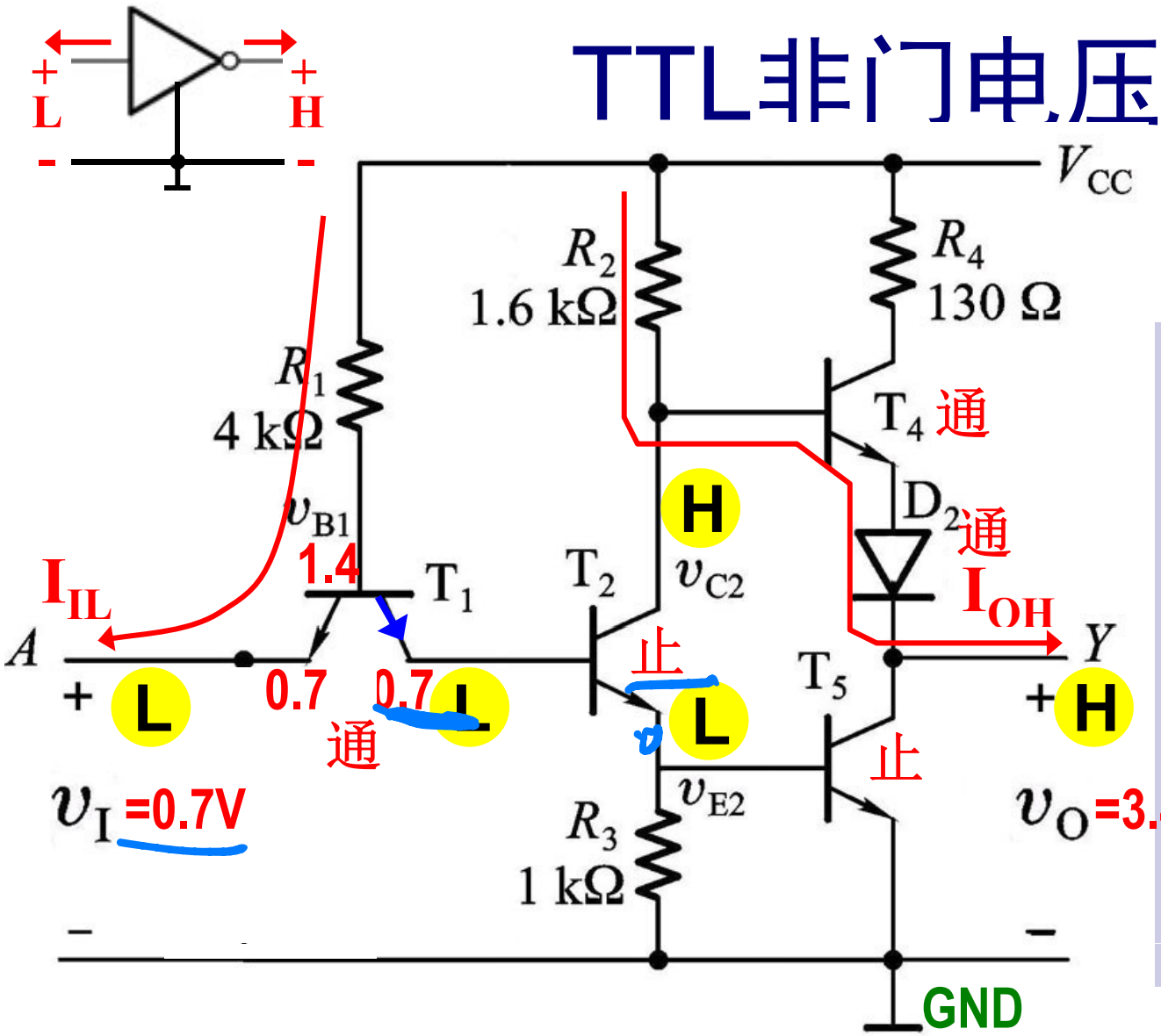
$$V_O = V_{CC} - V_{R2} - 0.7 - 0.7 = 3.6 - V_{R2} = 3.4V$$

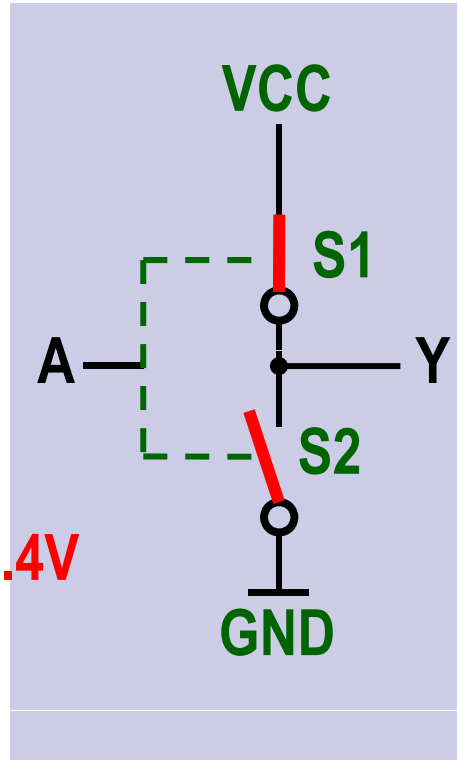
TTL非门电压特性



$$V_O = V_{CC} - V_{R2} - 0.7 - 0.7 = 3.6 - V_{R2} = 3.4V$$

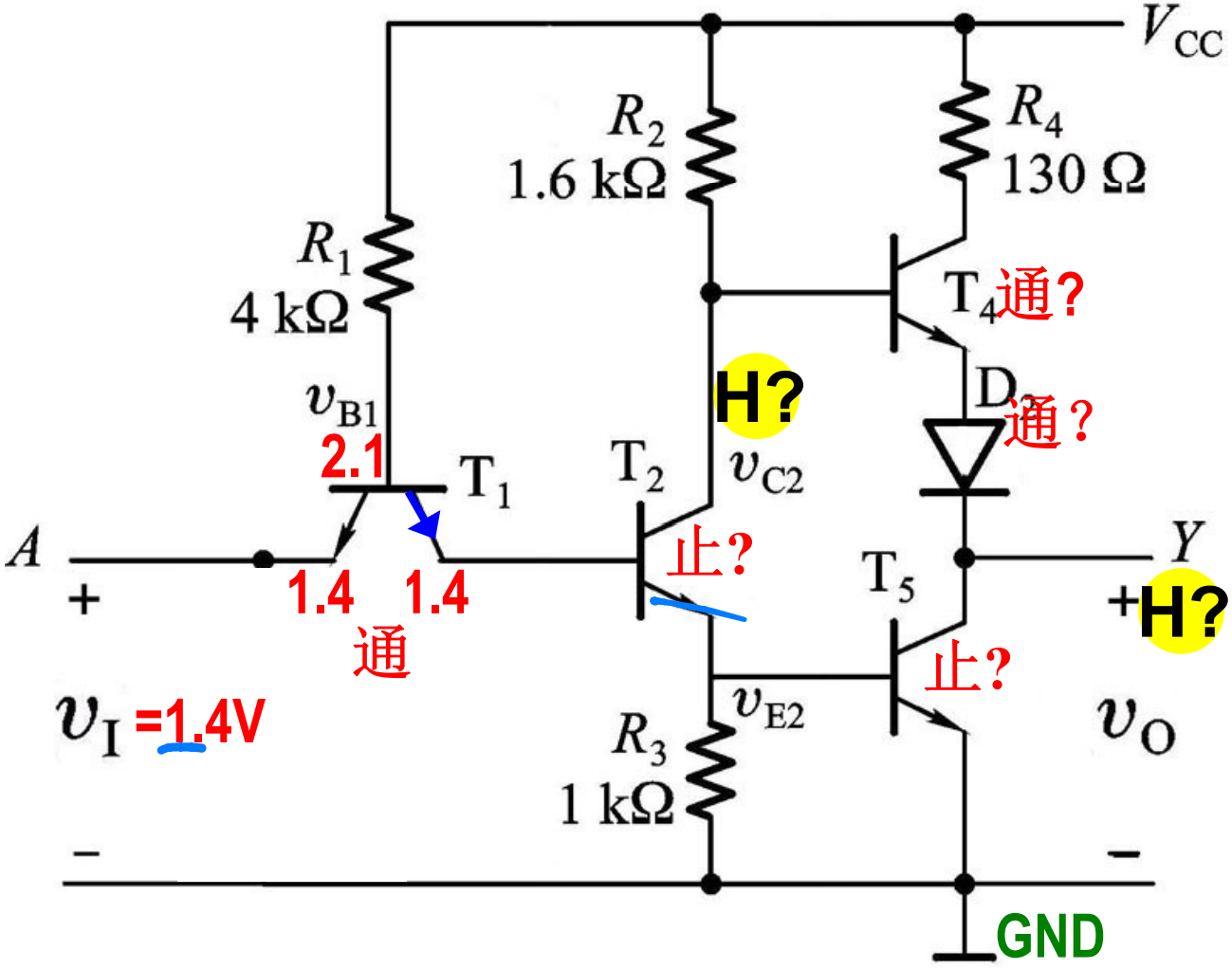
TTL非门电压特性

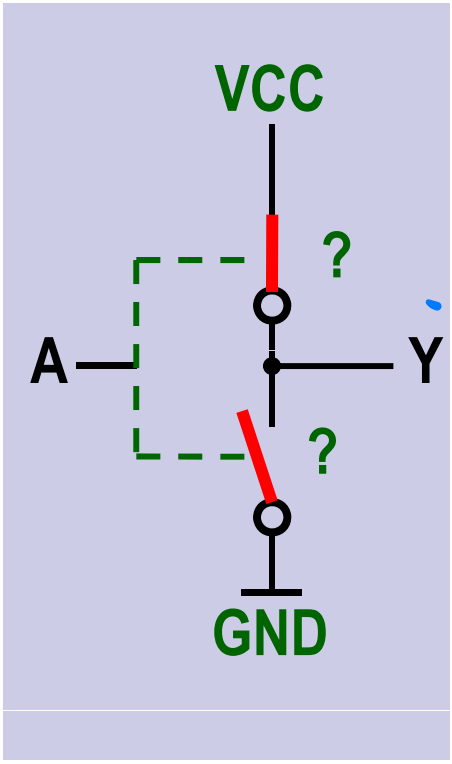




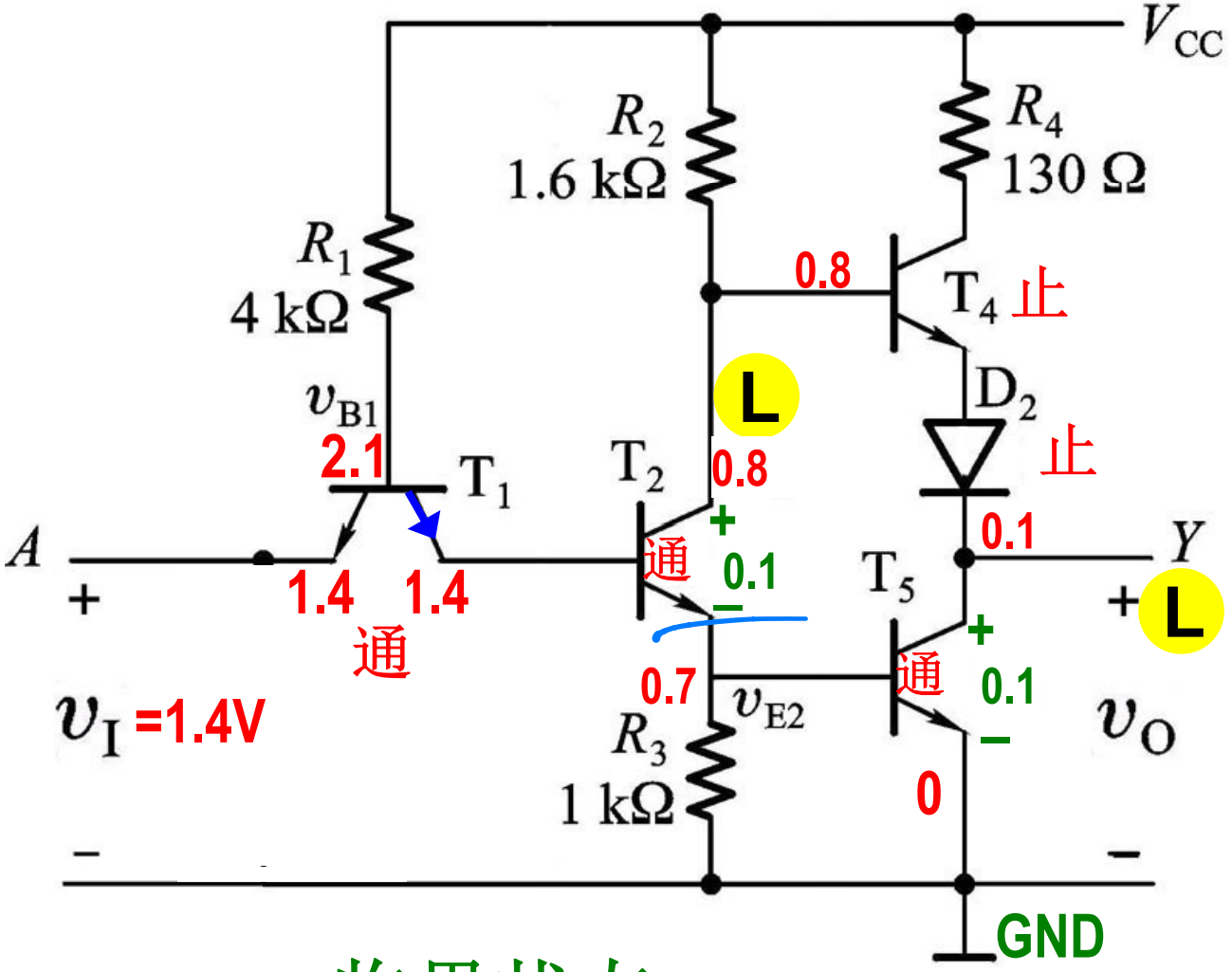
$$V_O = V_{CC} - V_{R2} - 0.7 - 0.7 = 3.6 - V_{R2} = 3.4V$$

TTL非门电压特性

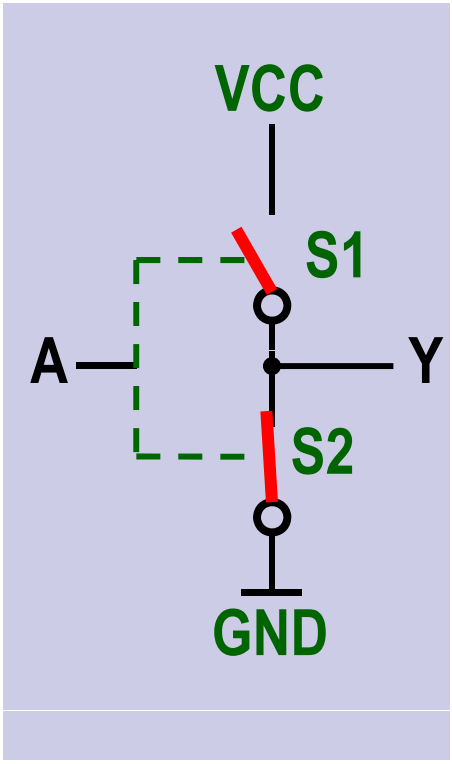

V_{CC}
R_2
1.6 kΩ
R_4
130 Ω
R_1
4 kΩ
T_4通?
D
通?
H?
v_{B1}
2.1
T_1
T_2
v_{C2}
A
+
1.4
1.4
通
止?
T_5
Y
+H?
v_I =1.4V
v_{E2}
v_O
R_3
1 kΩ
–
–
GND
GND


VCC
?
A
Y
?
GND

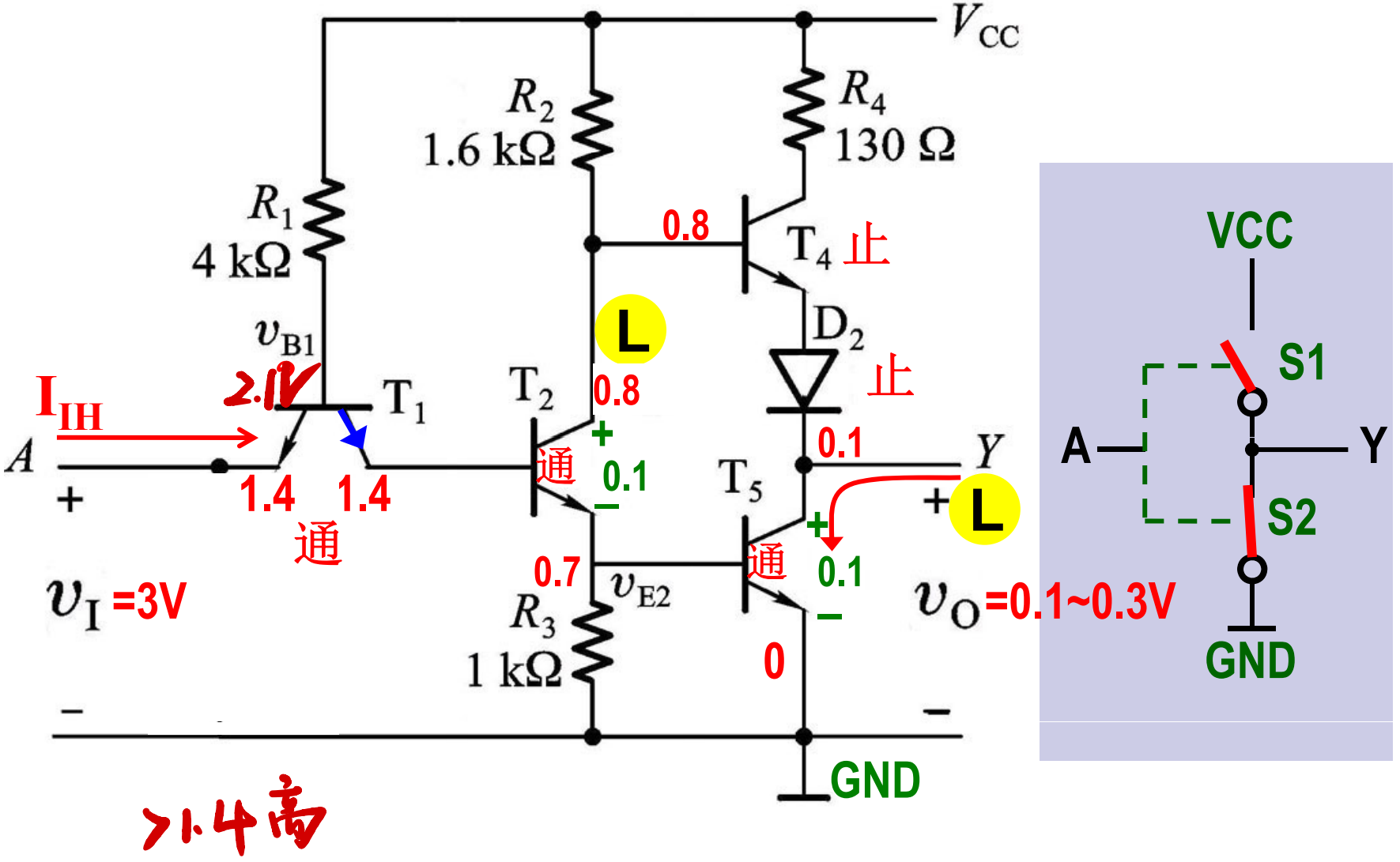
TTL非门电压特性



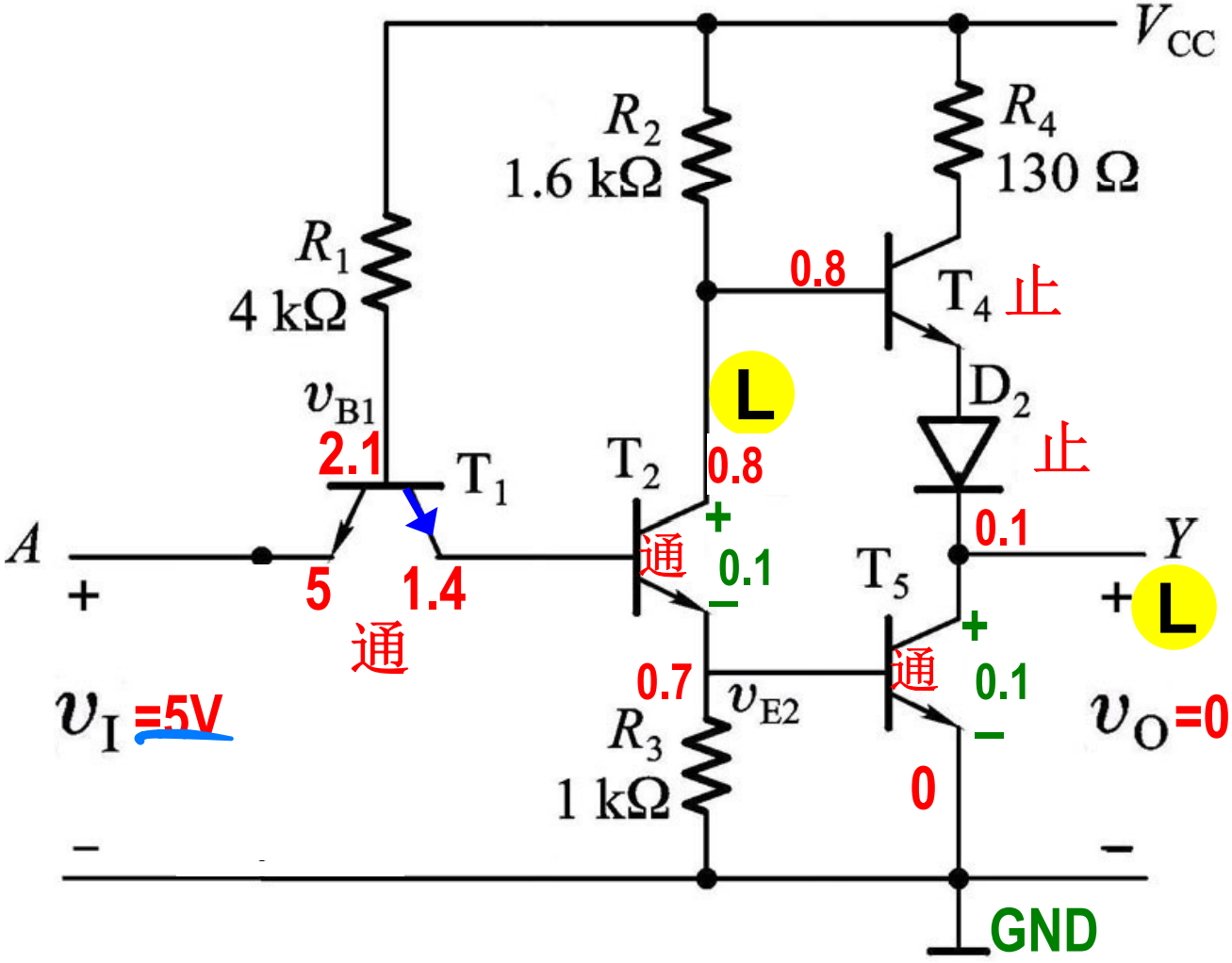
临界状态

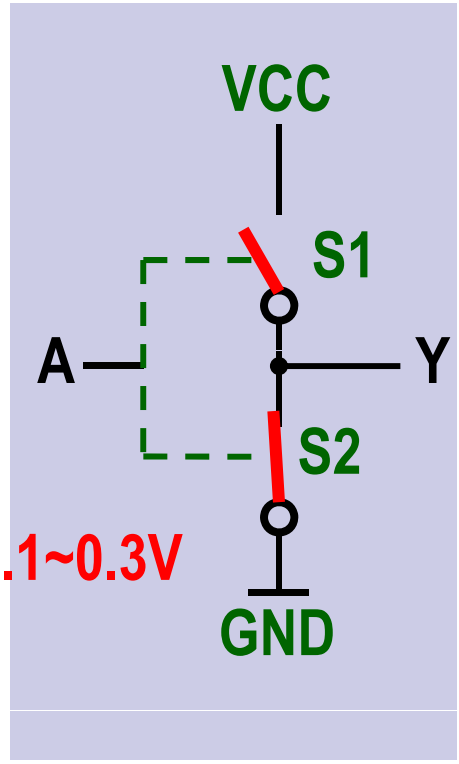


TTL非门电压特性

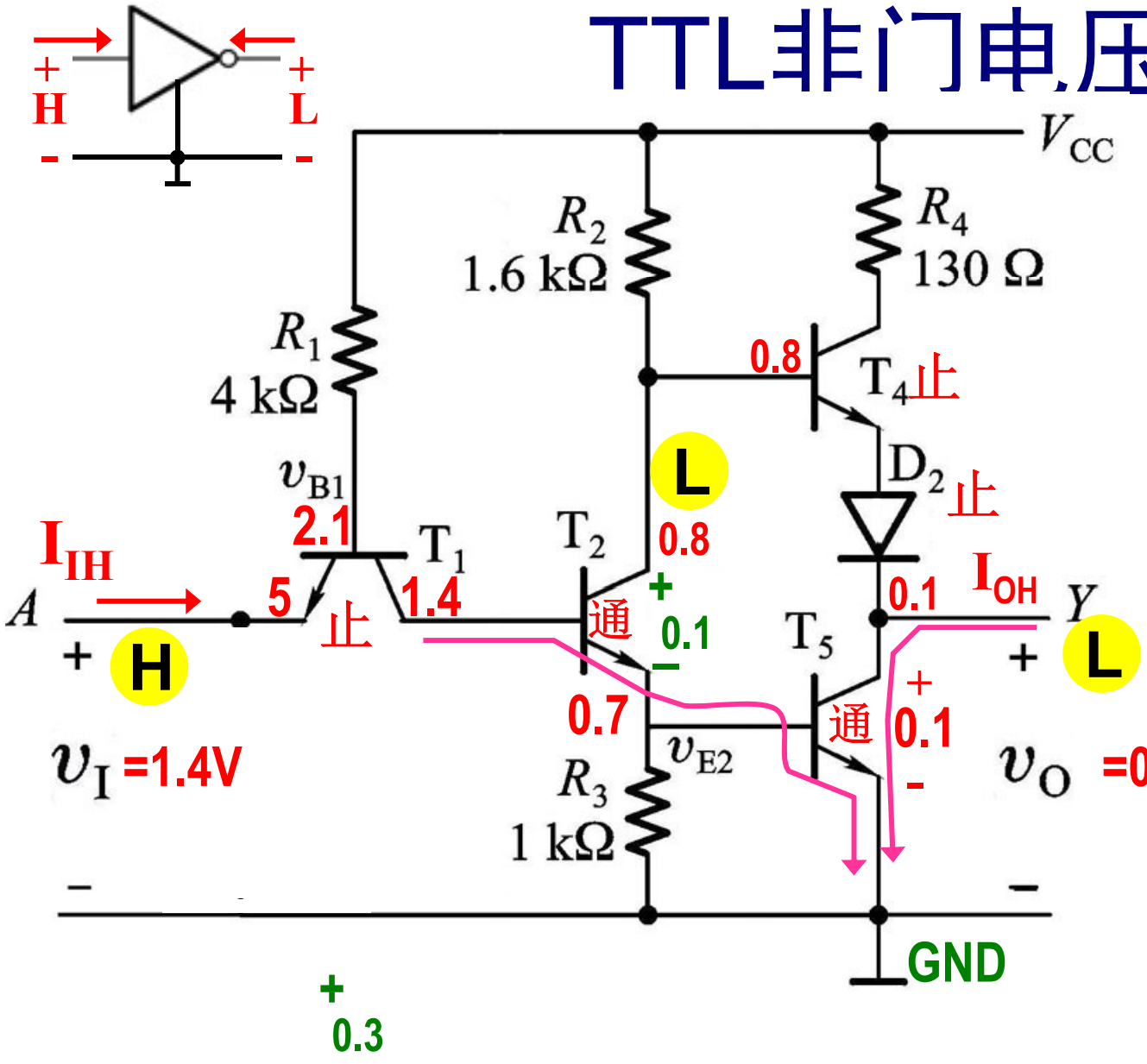

V_{CC}
R_2
1.6 kΩ
R_4
130 Ω
R_1
4 kΩ
0.8
T_4 止
D_2
止
v_{B1}
2.1V
L
T_1
T_2
0.8
I_{IH}
A
+
1.4
1.4
通
通
0.1
0.1
T_5
Y
+
L
0.7
v_{E2}
通
0.1
v_I =3V
R_3
1 kΩ
0
v_O=0.1~0.3V
–
–
GND
>1.4高
VCC
S1
A
Y
S2
GND

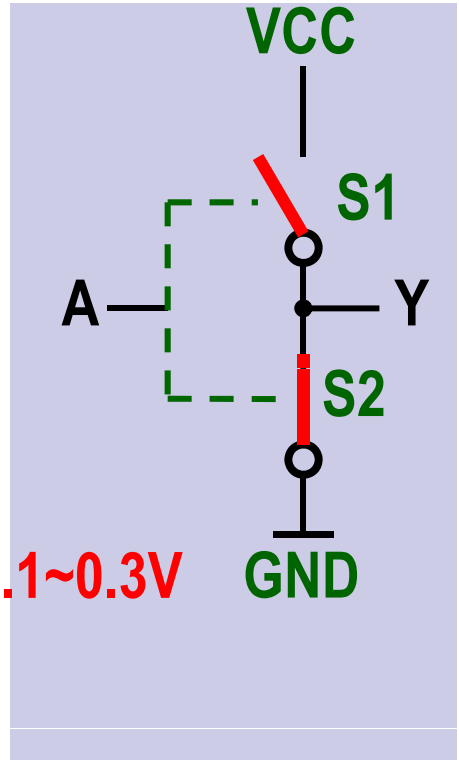
TTL非门电压特性


V_{CC}
R_2
1.6 kΩ
R_4
130 Ω
R_1
4 kΩ
0.8
T_4 止
v_{B1}
2.1
T_1
T_2
0.8
L
D_2
止
A
+
5
1.4
通
通
0.1
0.1
T_5
Y
+
L
0.7
v_{E2}
通
0.1
v_I =5V
R_3
1 kΩ
0
v_O=0.1~0.3V
GND


VCC
S1
A
Y
S2
GND

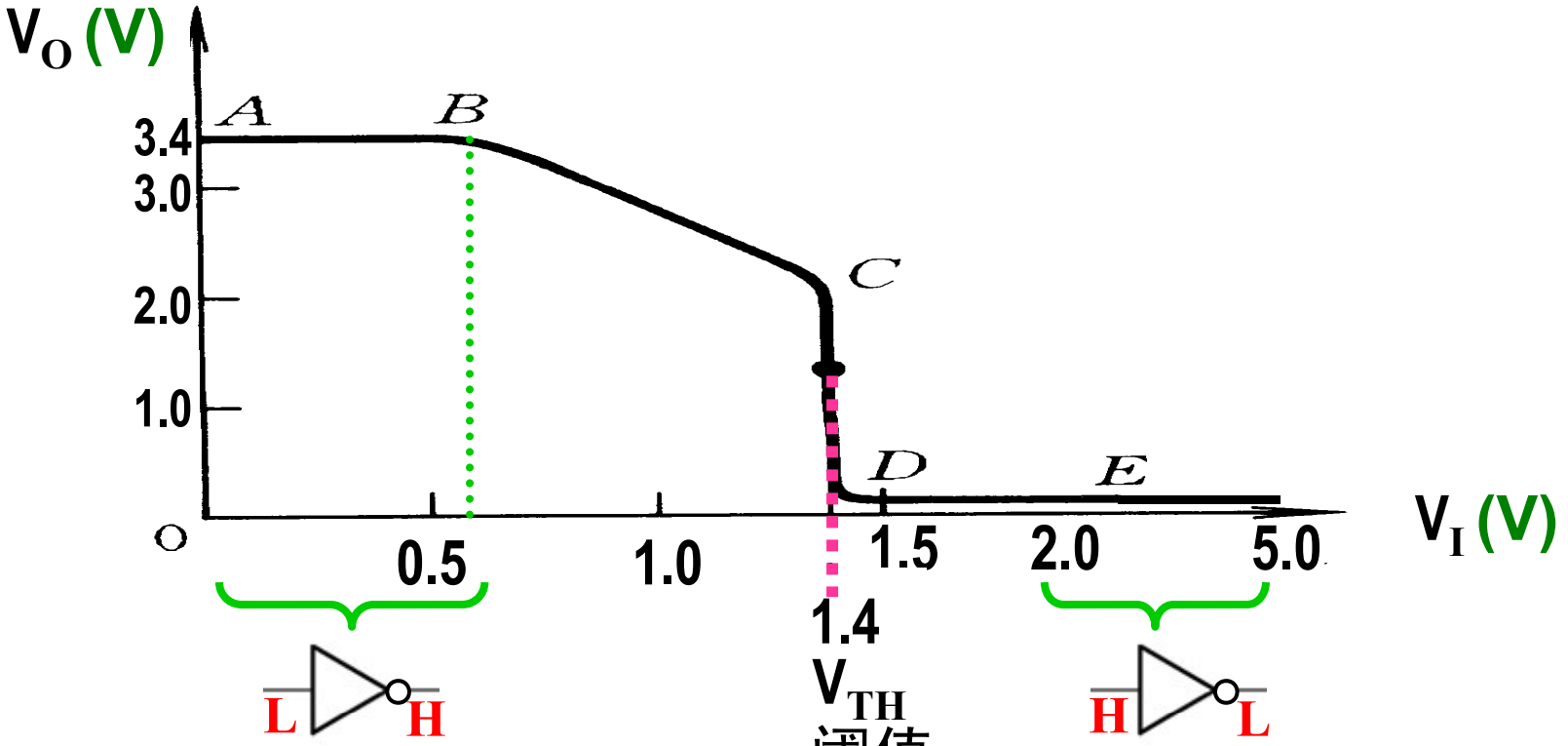
TTL非门电压特性





V_O= 0.1V~0.3V

TTL非门电压传输特性曲线 page117



输入电压多少算低电平？

0～0.8V 很

$V_{IL(max)}$=0.8V

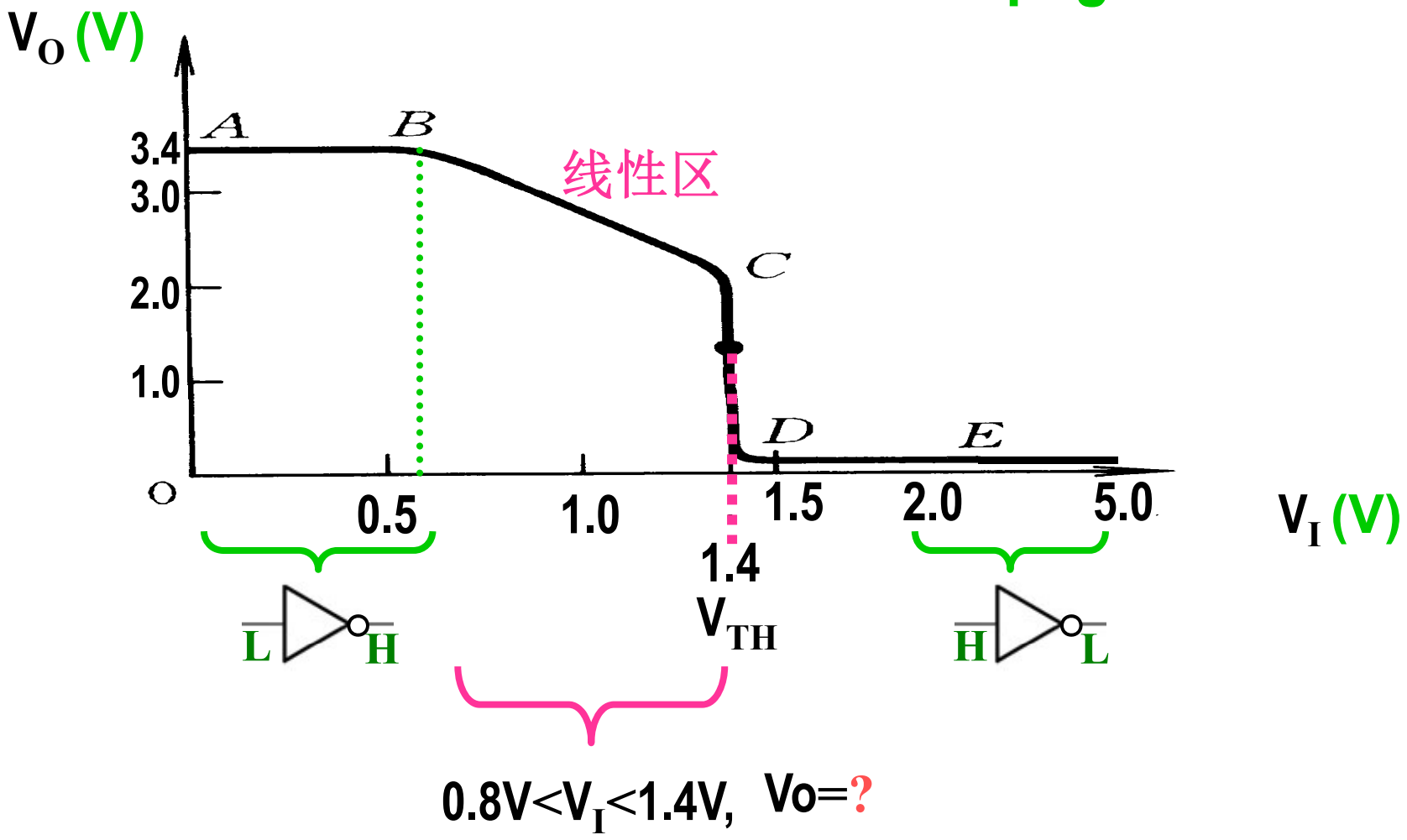
输入多少算高电平？

2.0～5.0V

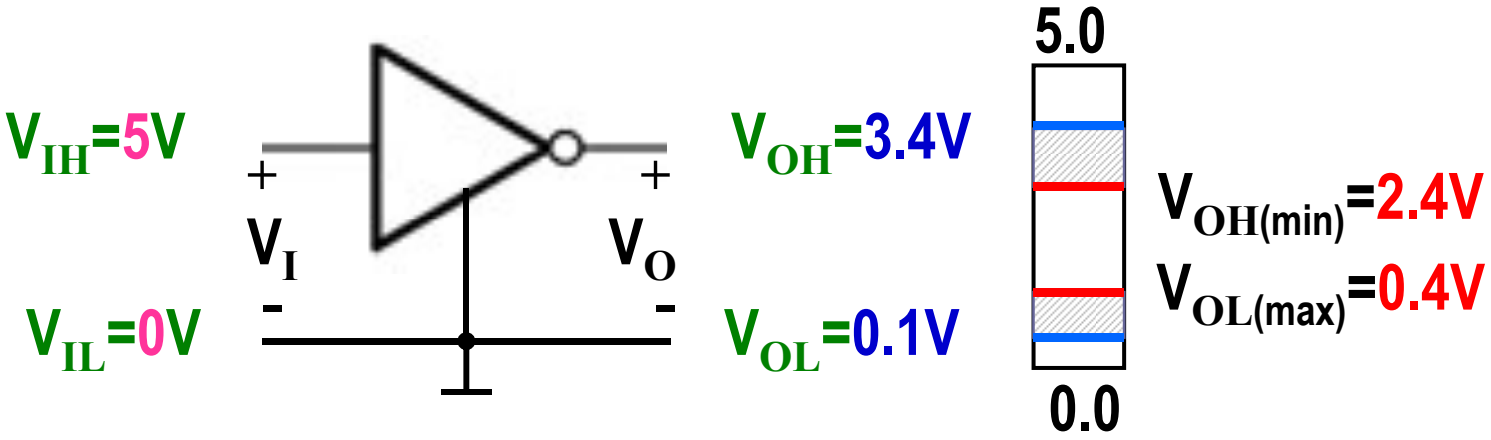
V_{IH}>1.4V时，T2,T5导通
实际要求V_{IH}>2.0V

$V_{IH(min)}$=2.0V

TTL非门电压传输特性曲线 page117



TTL 反相器的输入端噪声容限



V_{IH}=3.4V

V_{IL}=0.1V

输入高电平噪声容限 V_{NH}

$$V_{NH} = V_{OH(min)} - V_{IH(min)}$$

2.4V　　2.0V

74系列的标准参数：

$V_{OH(min)}$=2.4V，　$V_{OL(max)}$ =0.4V

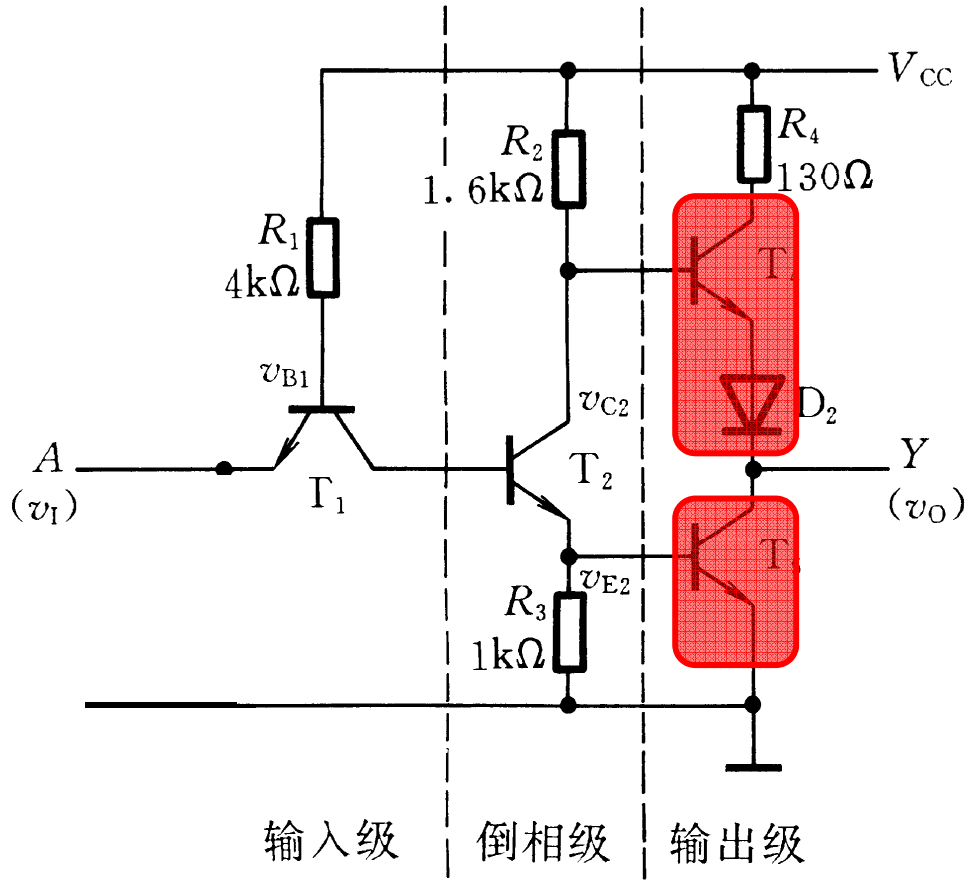
$V_{IH(min)}$=2.0V，　$V_{IL(max)}$ =0.8V

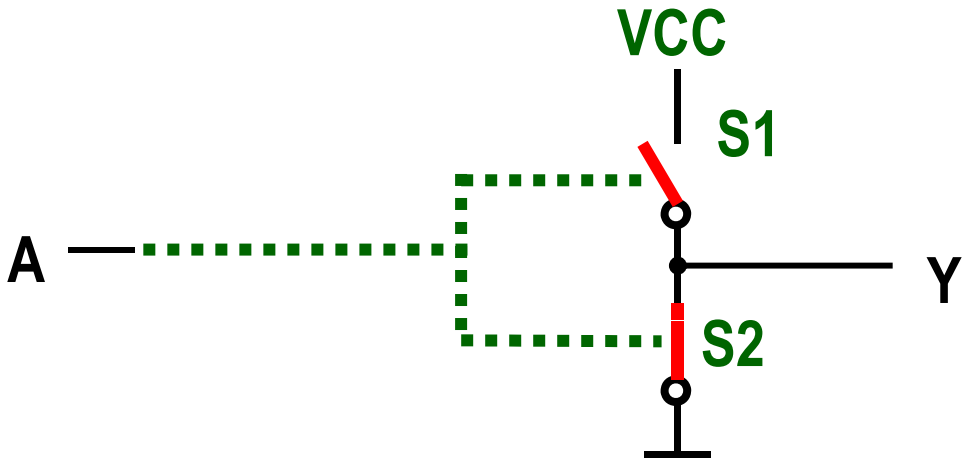
输入低电平噪声容限 V_{NL}

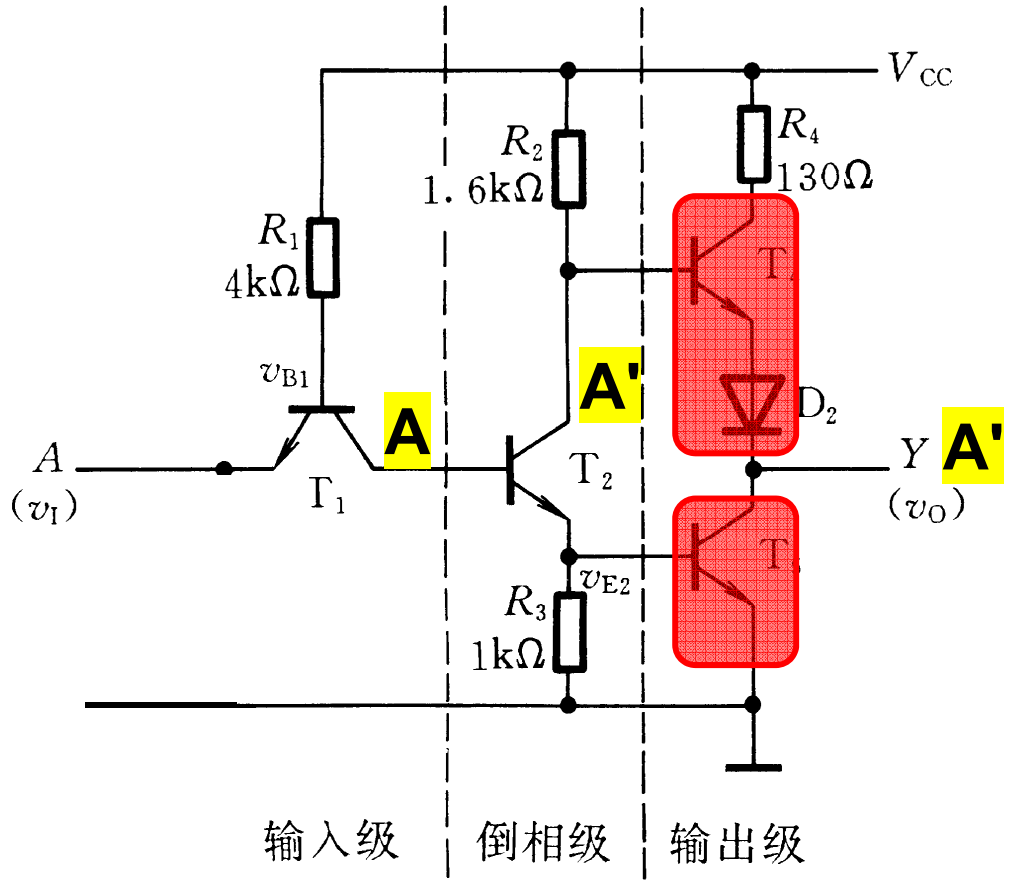
$$V_{NL} = V_{IL(max)} - V_{OL(max)}$$

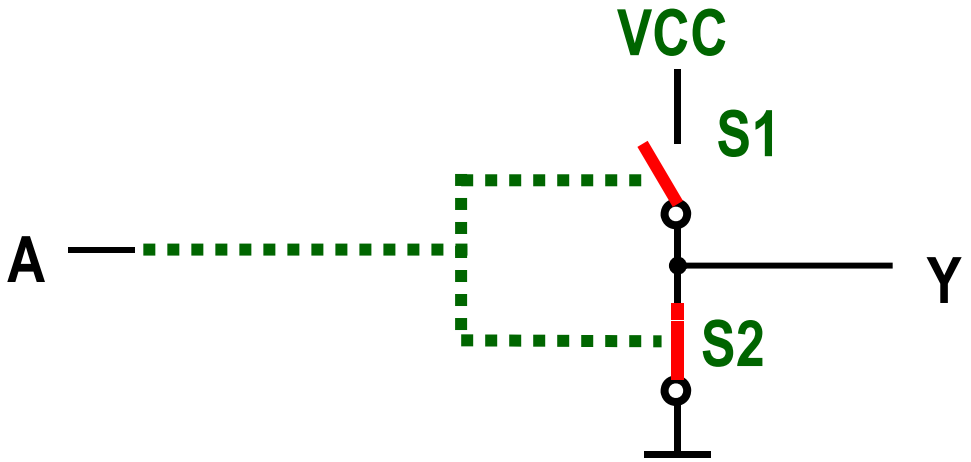
0.8V　　0.4V

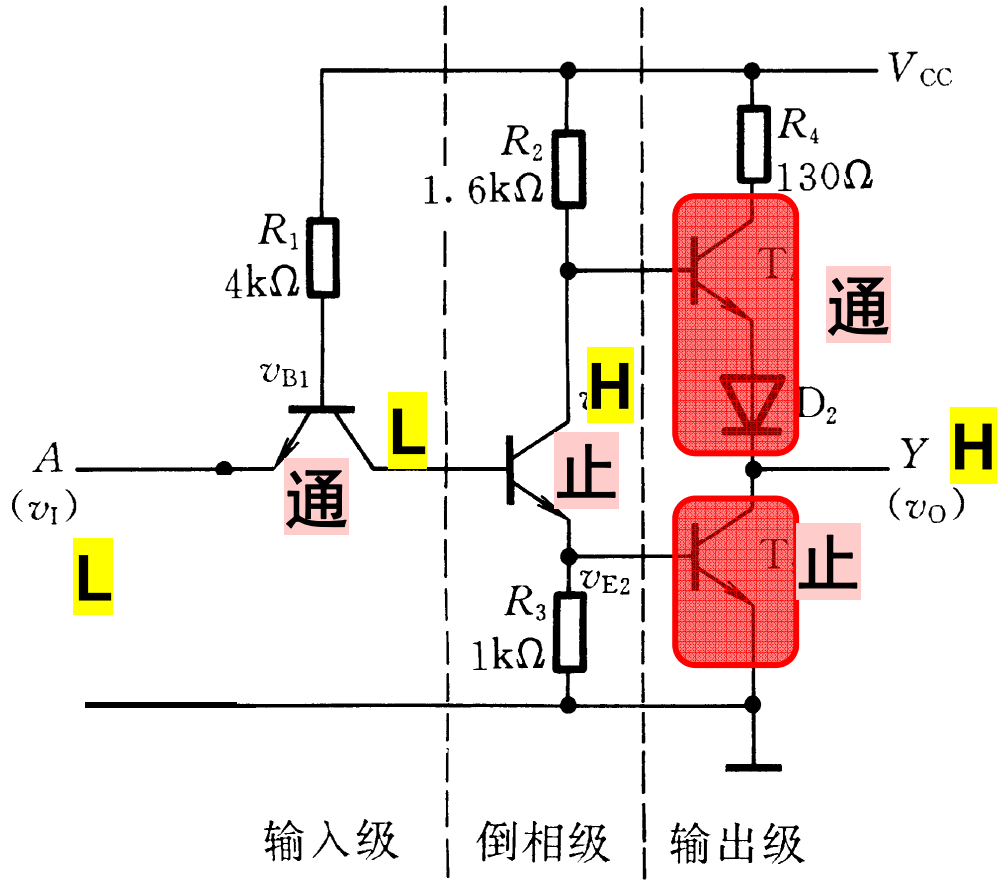
TTL 非门

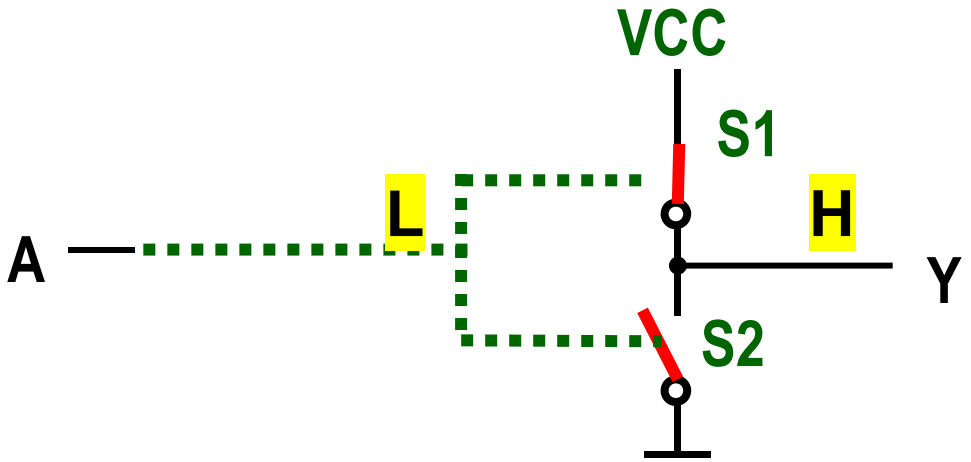

V_{CC}
R_2
1.6kΩ
R_4
130Ω
R_1
4kΩ
v_{B1}
v_{C2}
D_2
A
(v_I)
T_1
T_2
Y
(v_O)
v_{E2}
R_3
1kΩ
输入级
倒相级
输出级

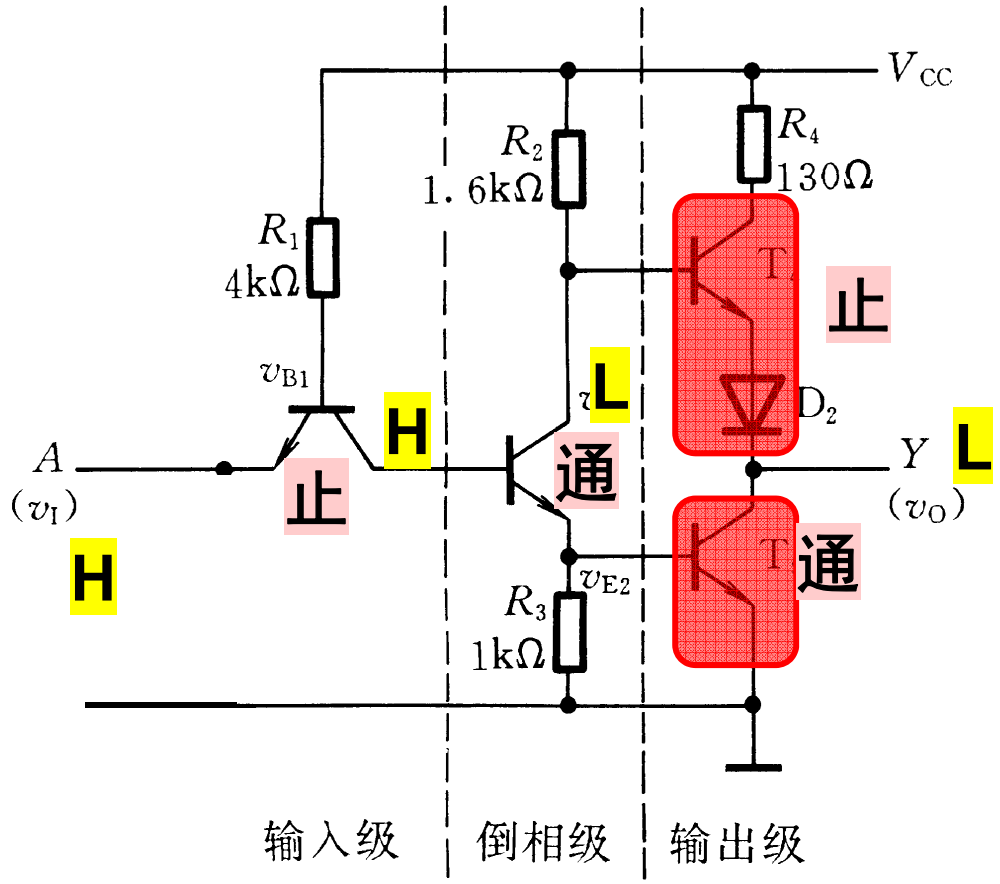

VCC
S1
A
Y
S2

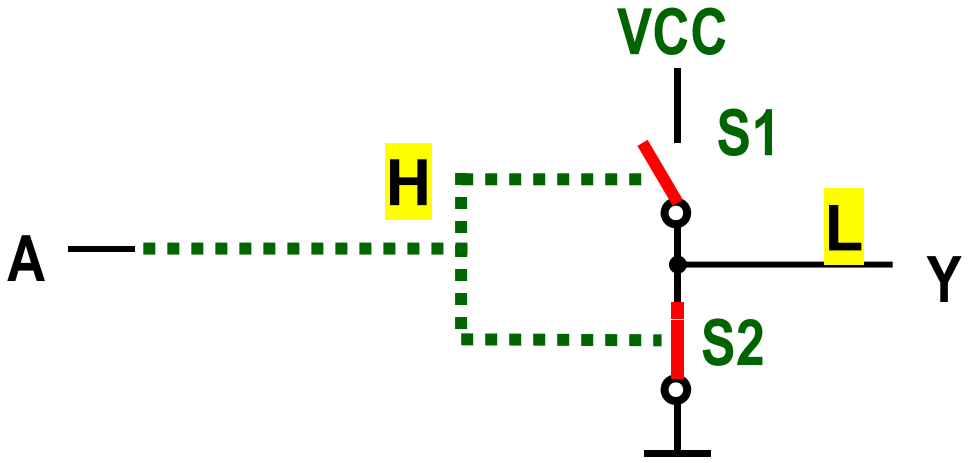

V_{CC}
R_2
1.6kΩ
R_4
130Ω
R_1
4kΩ
T
v_{B1}
A'
A
D_2
A
(v_I)
T_1
T_2
Y
A'
(v_O)
T_3
v_{E2}
R_3
1kΩ
输入级
倒相级
输出级


VCC
S1
A
Y
S2

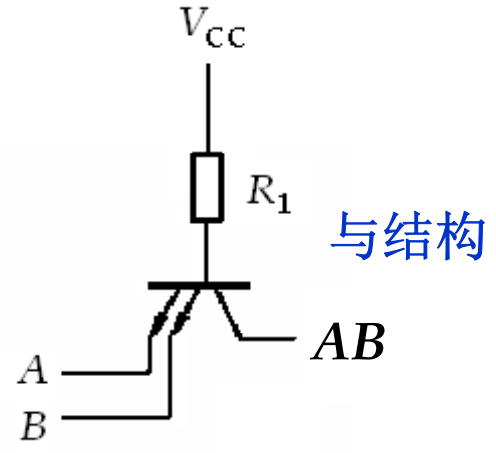

V_{CC}
R_2
1.6kΩ
R_4
130Ω
R_1
4kΩ
T
通
v_{B1}
H
D_2
L
A
(v_I)
通
止
Y
H
(v_O)
L
T
止
v_{E2}
R_3
1kΩ
输入级
倒相级
输出级


VCC
S1
L
H
A
Y
S2

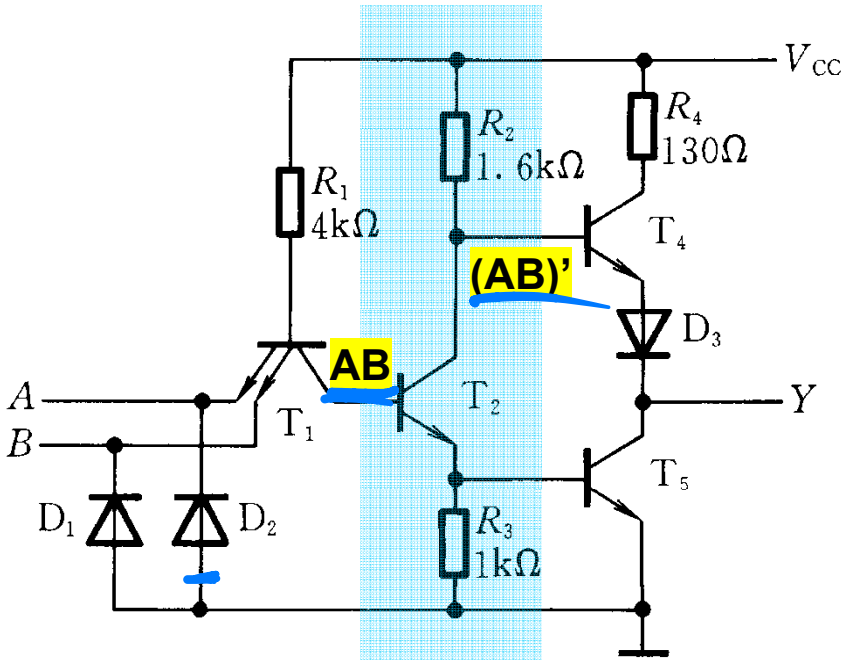

V_{CC}
R_2
1.6kΩ
R_4
130Ω
R_1
4kΩ
T
止
v_{B1}
L
H
通
D_2
A
(v_I)
止
Y
L
(v_O)
H
T
通
v_{E2}
R_3
1kΩ
输入级
倒相级
输出级


VCC
S1
H
L
A
Y
S2

其他类型的TTL门电路

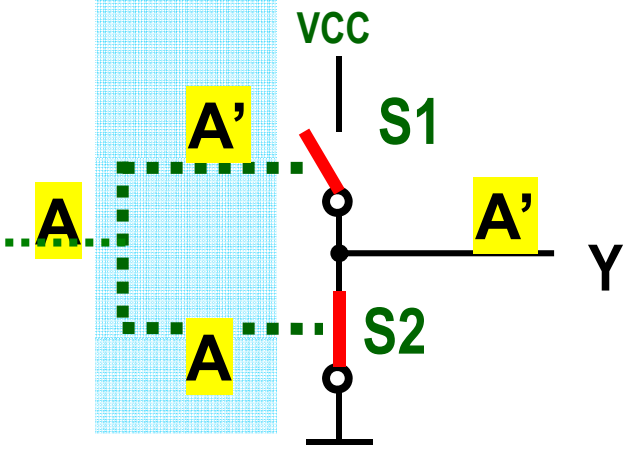


与结构

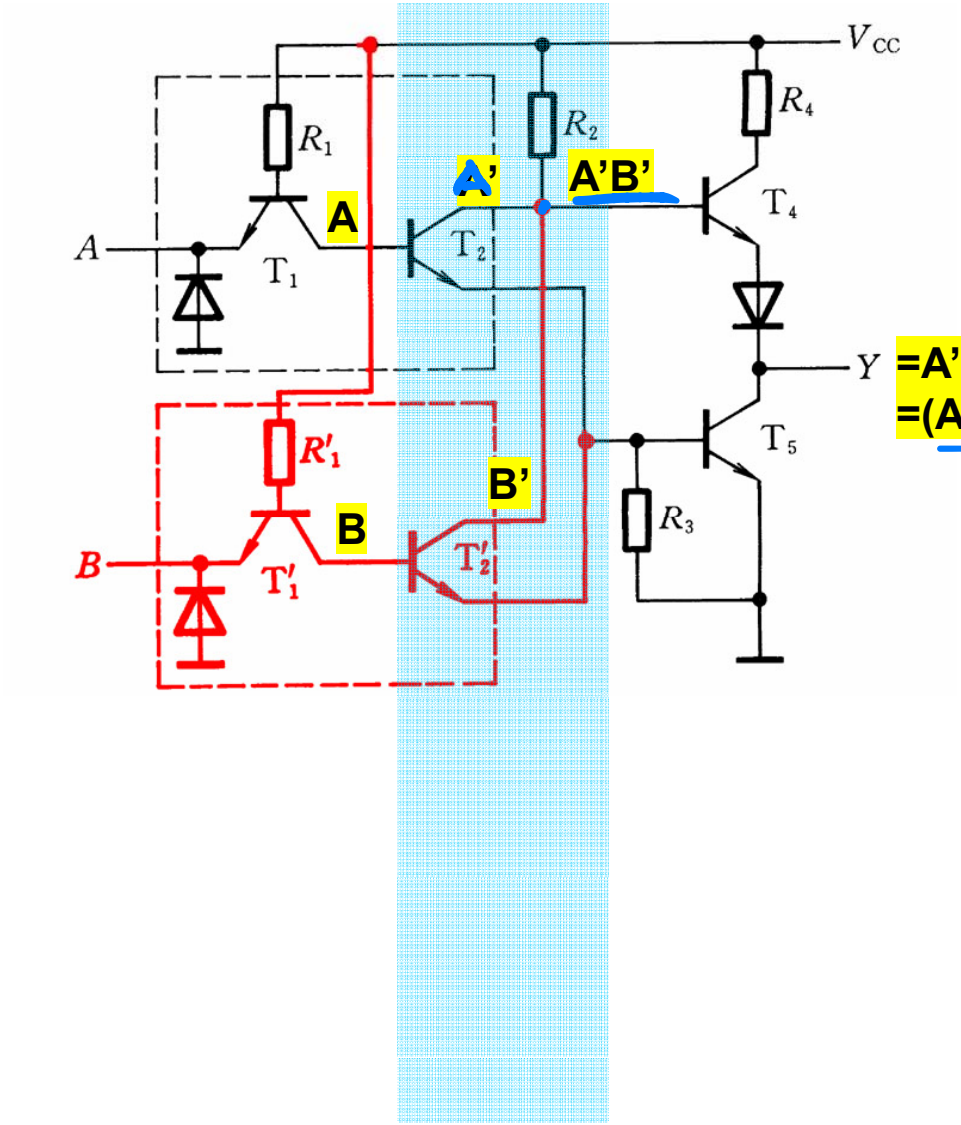


$=(AB)'$

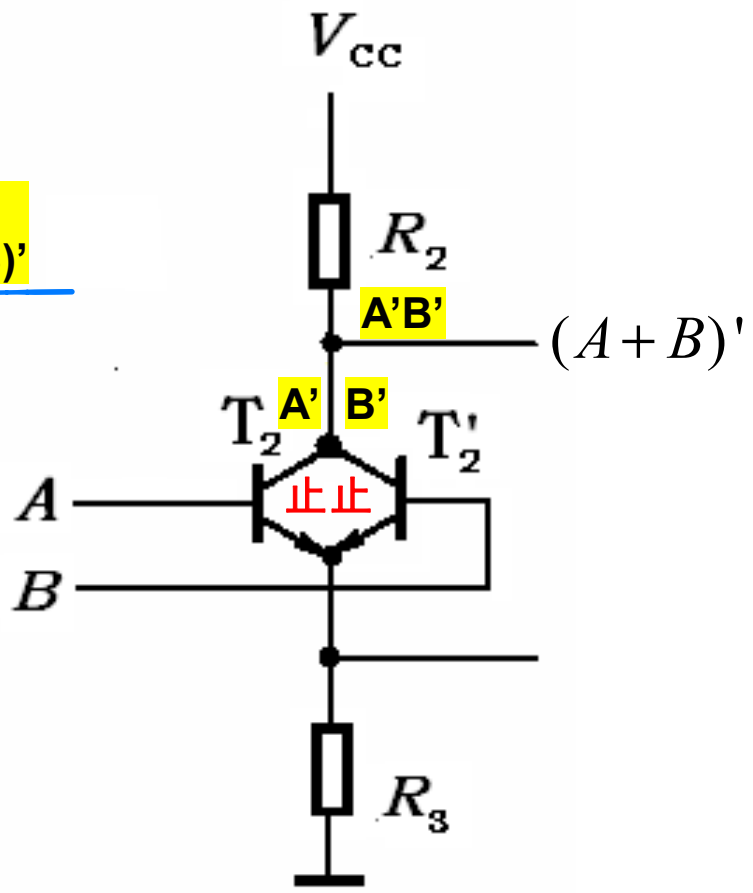
与非门



其他类型的TTL门电路

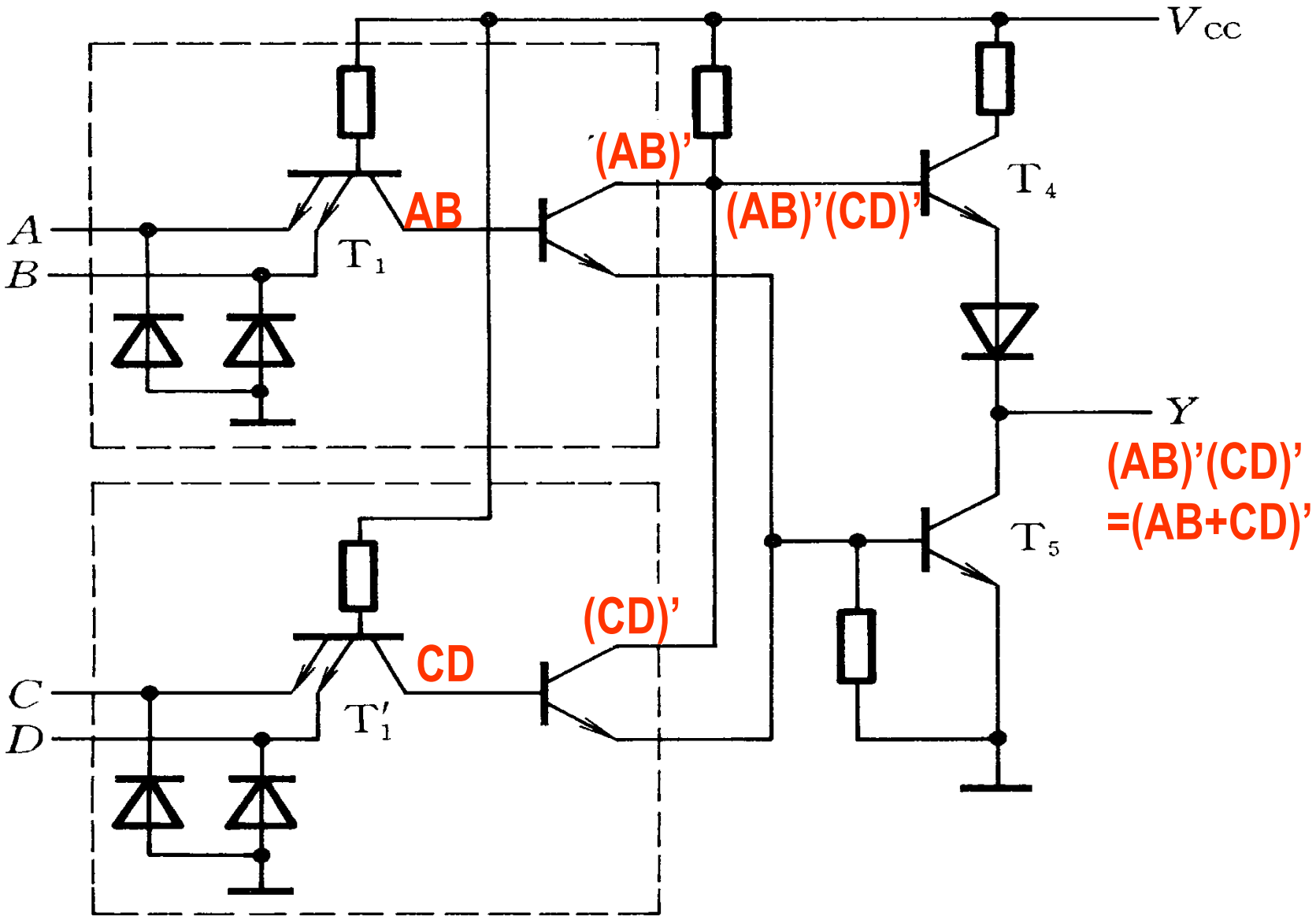


=A'B'
=(A+B)'

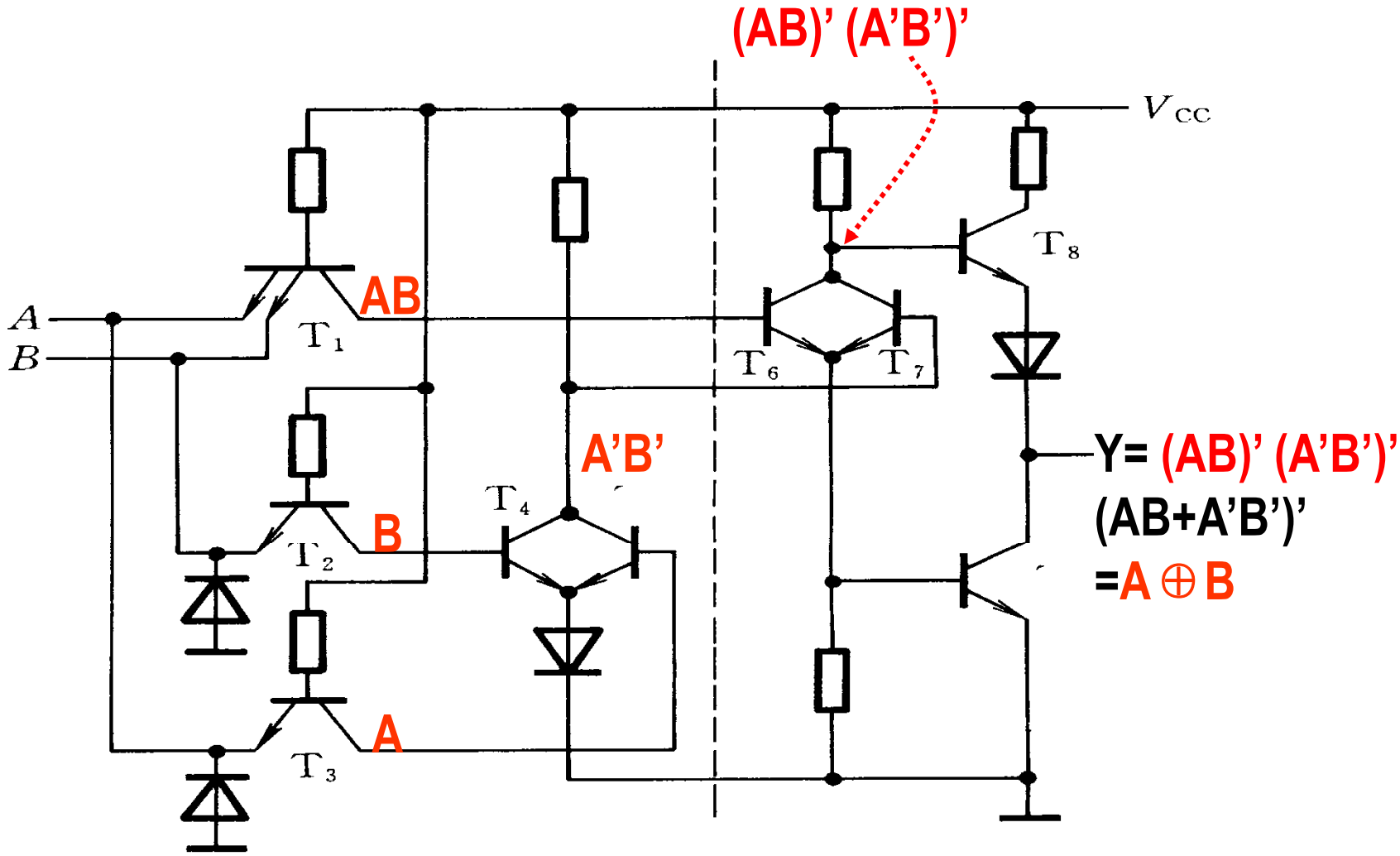


或非结构

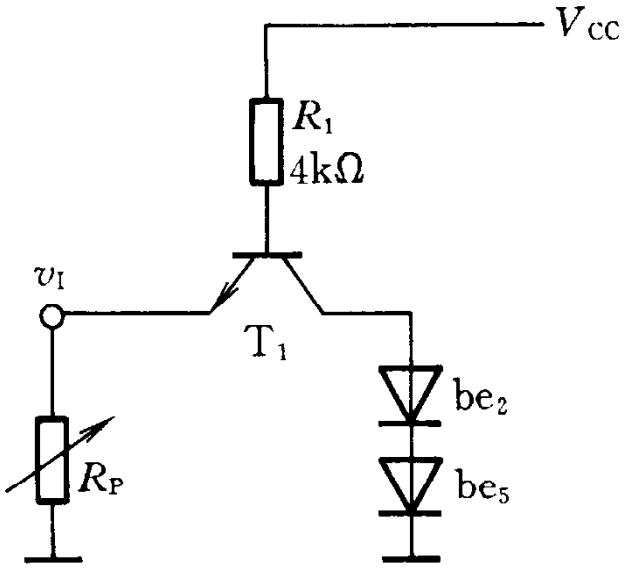
其他类型的TTL门电路



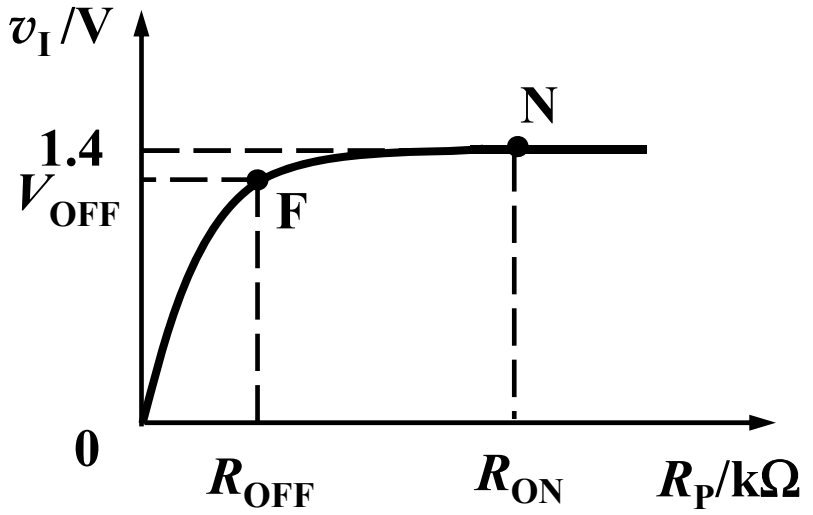
其他类型的TTL门电路



TTL门输入负载特性



输入负载特性测试电路

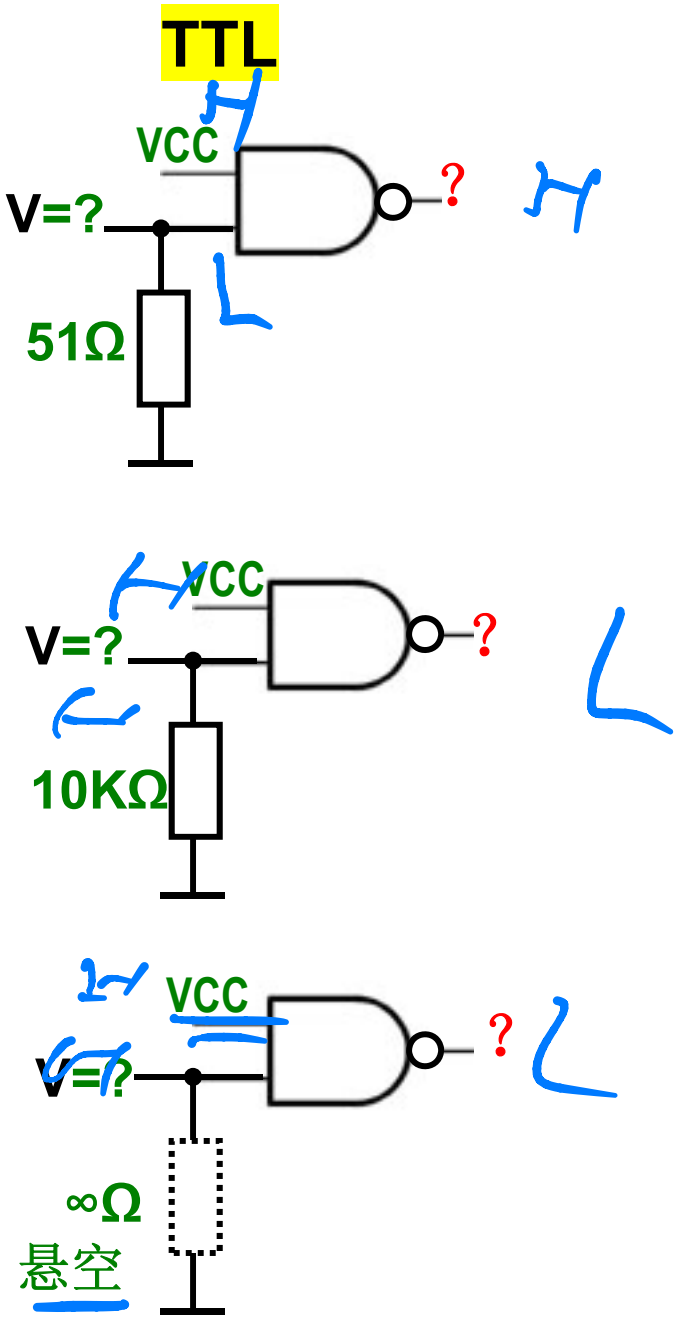


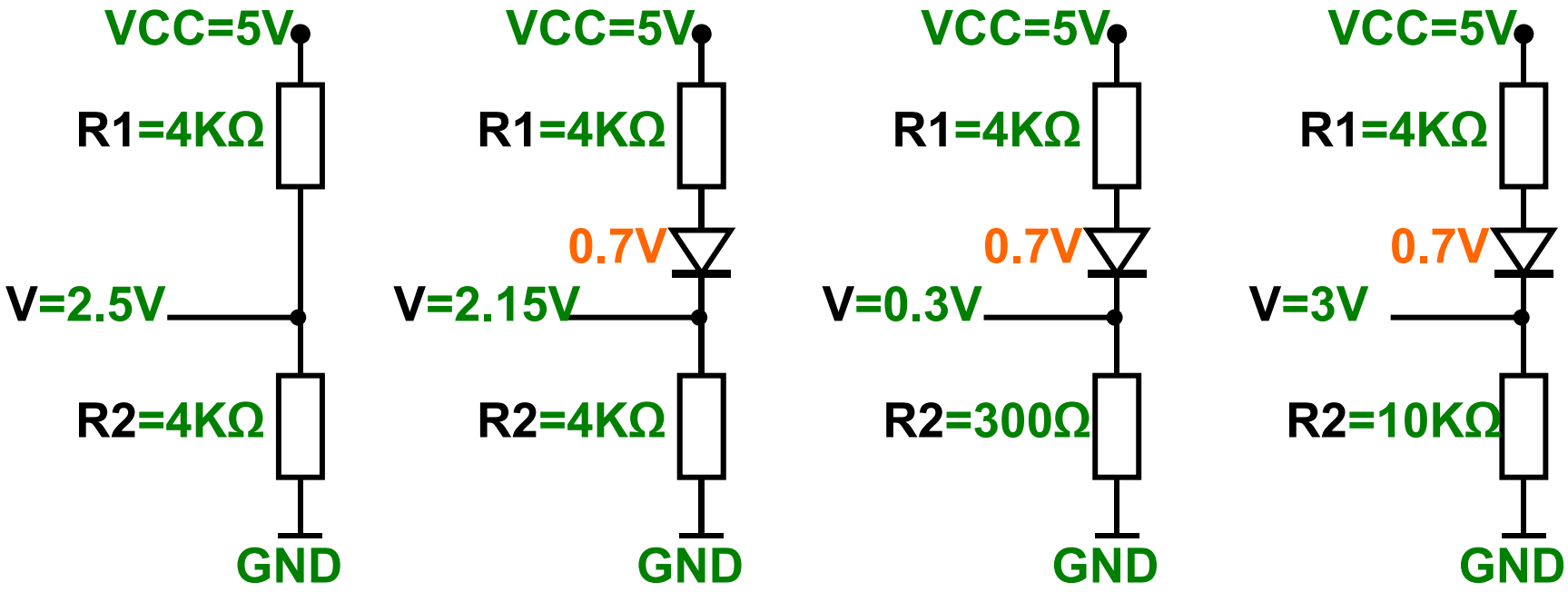
输入负载特性曲线

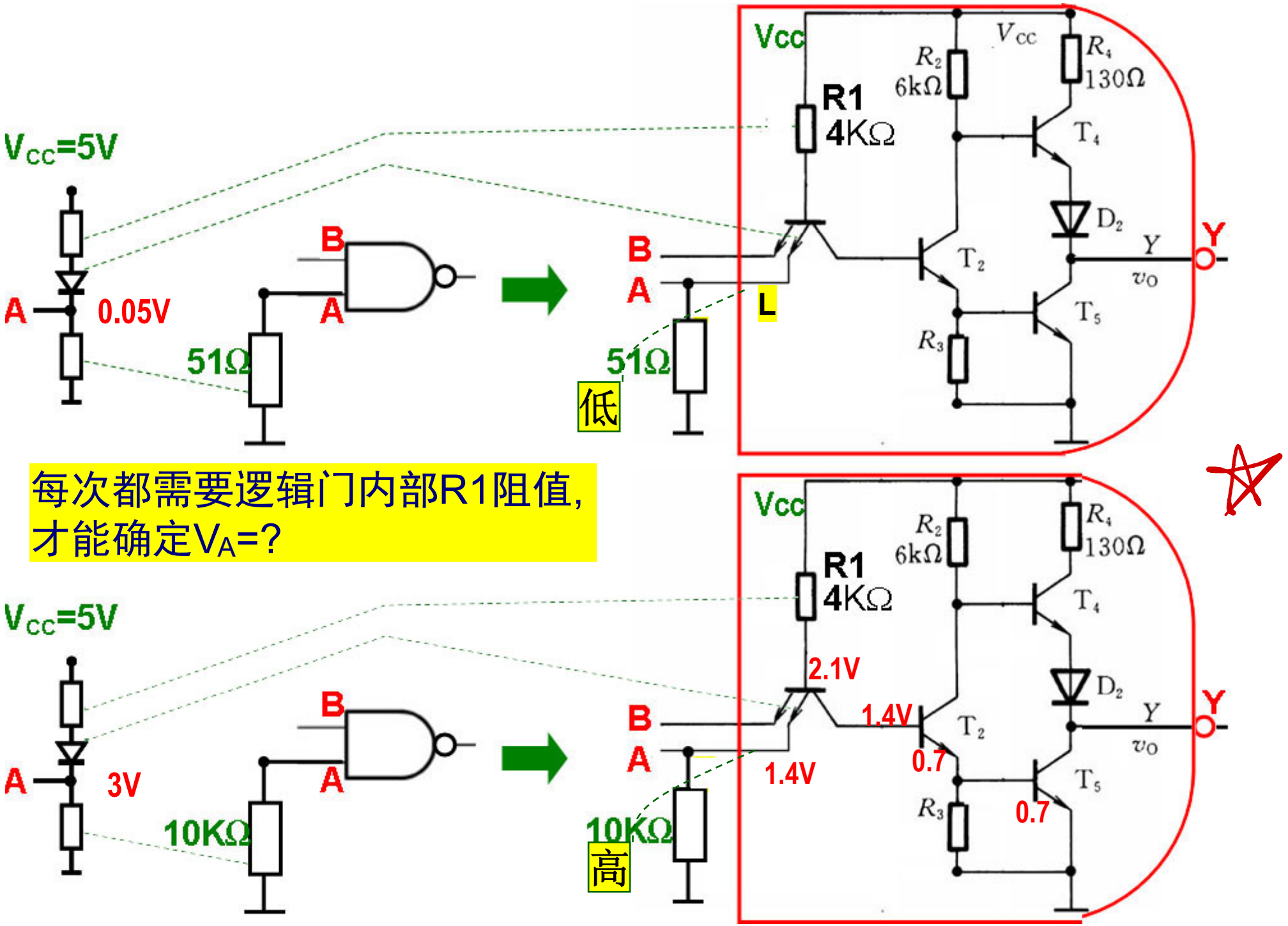
$$v_i = \frac{R_P}{R_1 + R_P}(V_{CC} - v_{BE1})$$

$R_I < R_{OFF}$ 时，相应输入端相当于输入低电平。对 TTL 系列，$R_{OFF} \approx 700\ \Omega$。

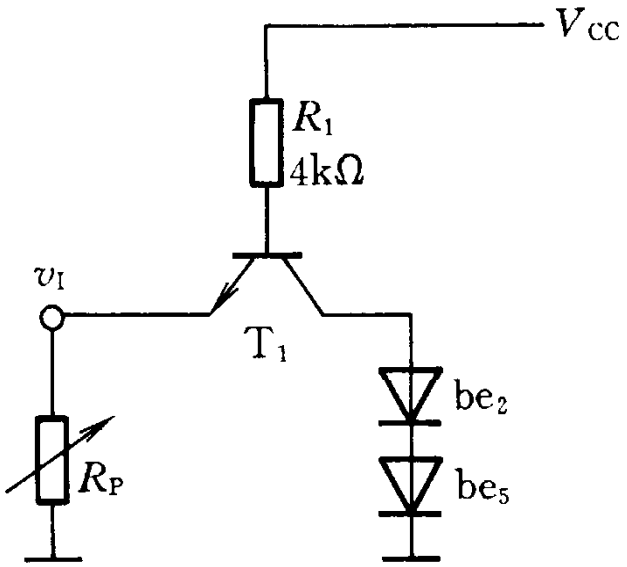
$R_I > R_{ON}$ 时，相应输入端相当于输入高电平。对 TTL 系列，$R_{ON} \approx 2.5\ \text{k}\Omega$。


TTL
VCC
V=?
?
51Ω
VCC
V=?
?
10KΩ
VCC
V=?
?
∞Ω
悬空

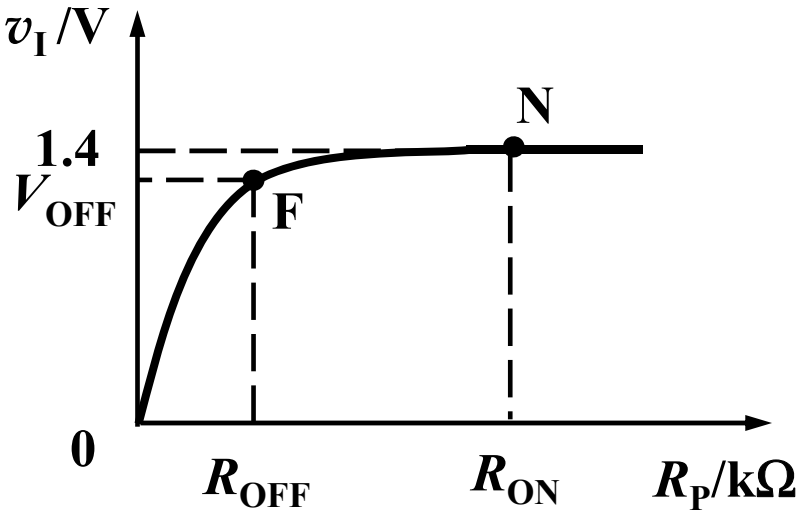

VCC=5V
R1=4KΩ
V=2.5V
R2=4KΩ
GND
VCC=5V
R1=4KΩ
0.7V
V=2.15V
R2=4KΩ
GND
VCC=5V
R1=4KΩ
0.7V
V=0.3V
R2=300Ω
GND
VCC=5V
R1=4KΩ
0.7V
V=3V
R2=10KΩ
GND


V_{CC}=5V
A
0.05V
51Ω
B
A
B
A
51Ω
低
L
Vcc
R1
4KΩ
R_2
6kΩ
V_{CC}
R_4
130Ω
T_4
D_2
T_2
Y
v_O
Y
T_5
R_3
每次都需要逻辑门内部R1阻值,
才能确定V_A=?
V_{CC}=5V
A
3V
10KΩ
B
A
B
A
10KΩ
高
Vcc
R1
4KΩ
R_2
6kΩ
R_4
130Ω
T_4
2.1V
D_2
1.4V
T_2
Y
v_O
Y
1.4V
0.7
T_5
R_3
0.7

TTL门输入负载特性



输入负载特性测试电路



输入负载特性曲线

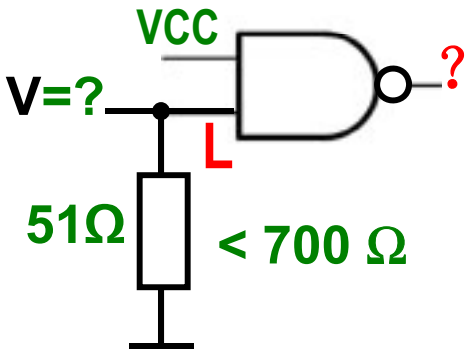
厂商参数

$$v_i = \frac{R_P}{R_1 + R_P}(V_{CC} - v_{BE1})$$

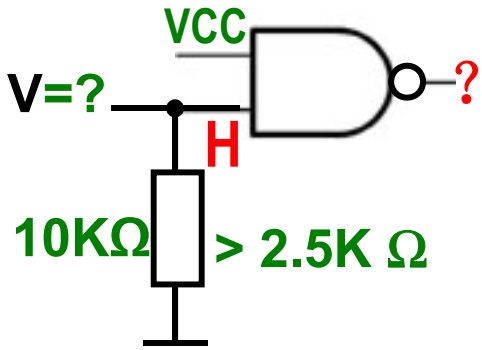
$R_I < R_{OFF}$ 时，相应输入端相当于输入低电平。对 TTL 系列，$R_{OFF} \approx 700\ \Omega$。

$R_I > R_{ON}$ 时，相应输入端相当于输入高电平。对 TTL 系列，$R_{ON} \approx 2.5\ k\Omega$。

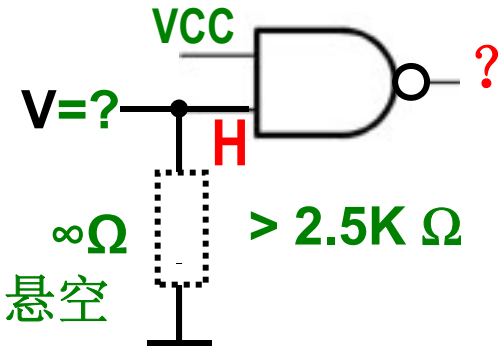
TTL逻辑门，已知， $R_{OFF} \approx 700\ \Omega$， $R_{ON} \approx 2.5\ k\Omega$



Y=H

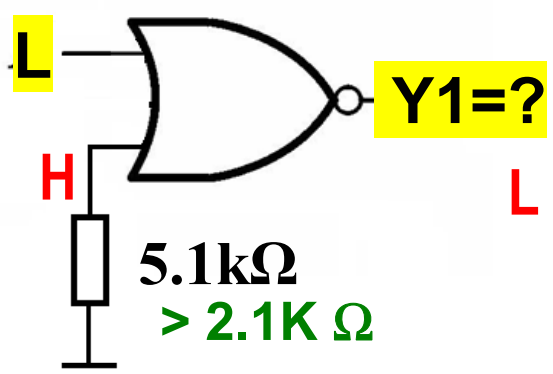


Y=L



Y=L

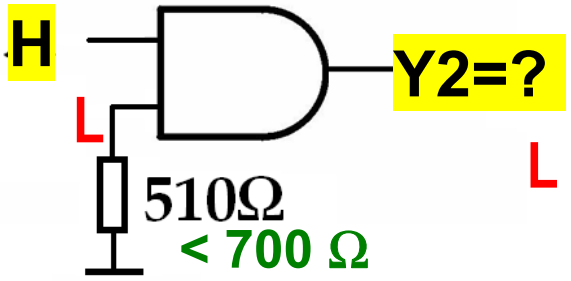
TTL门，已知$R_{OFF} \approx 700\ \Omega$，$R_{ON} \approx 2.1\ k\Omega$，问输出？



5.1K Ω > R_{ON}，

相应输入端相当于输入高电平

所以Y1=L

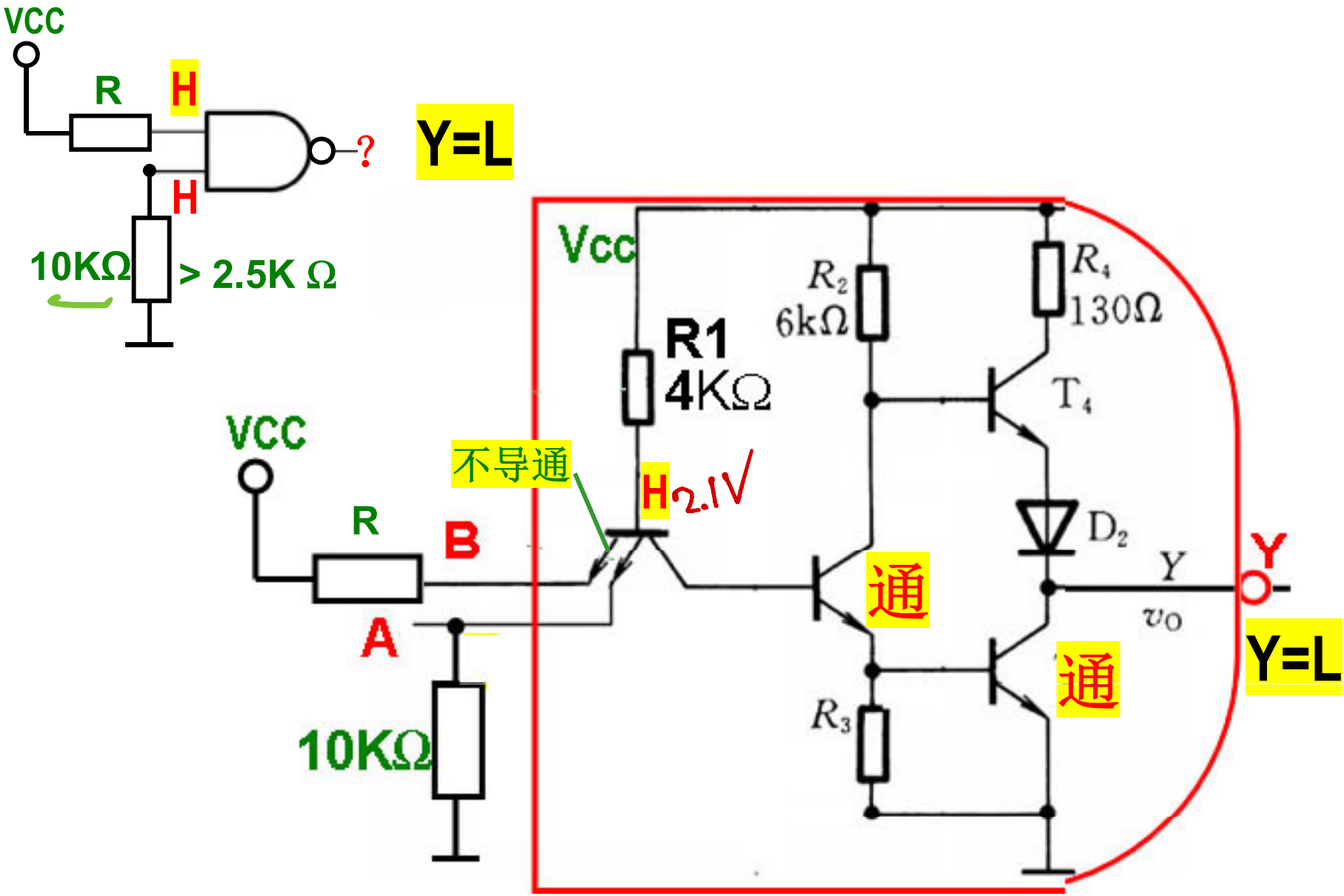


510Ω < R_{OFF}

相应输入端相当于输入低电平

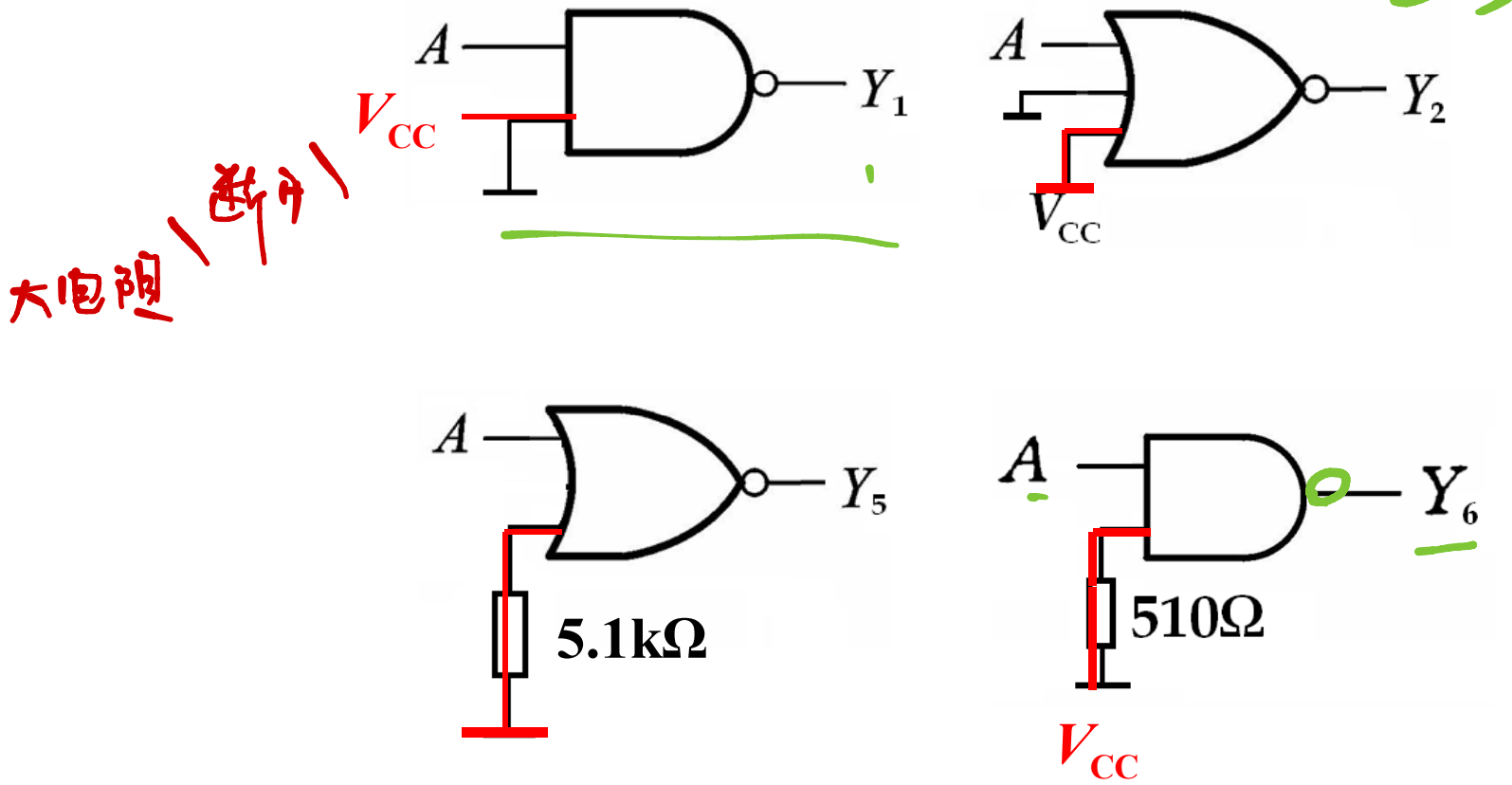
所以Y2=L

TTL逻辑门，已知， $R_{OFF} \approx 700\ \Omega$， $R_{ON} \approx 2.5\ k\Omega$



［例］欲用下列电路实现非运算，试改错。

($R_{OFF} \approx 700\ \Omega$，$R_{ON} \approx 2.1\ k\Omega$)



作业

3.3、与非门，或非门，异或门能用作非门吗？

3.8（不做，下次做，因为有三态门，OC门）

3.13 (a,b)已知内部电路，判断是什么逻辑门

3.14(1,2,3,4,5,6,7,8)逻辑门输入端连接大电阻、小电阻、悬空，输出=?

3.15 电压表，测试逻辑门，电压值=?（提醒电压表内阻很高）

3.14