

Diodes & Transistors

電機 26 級 陳亮宇

半導體

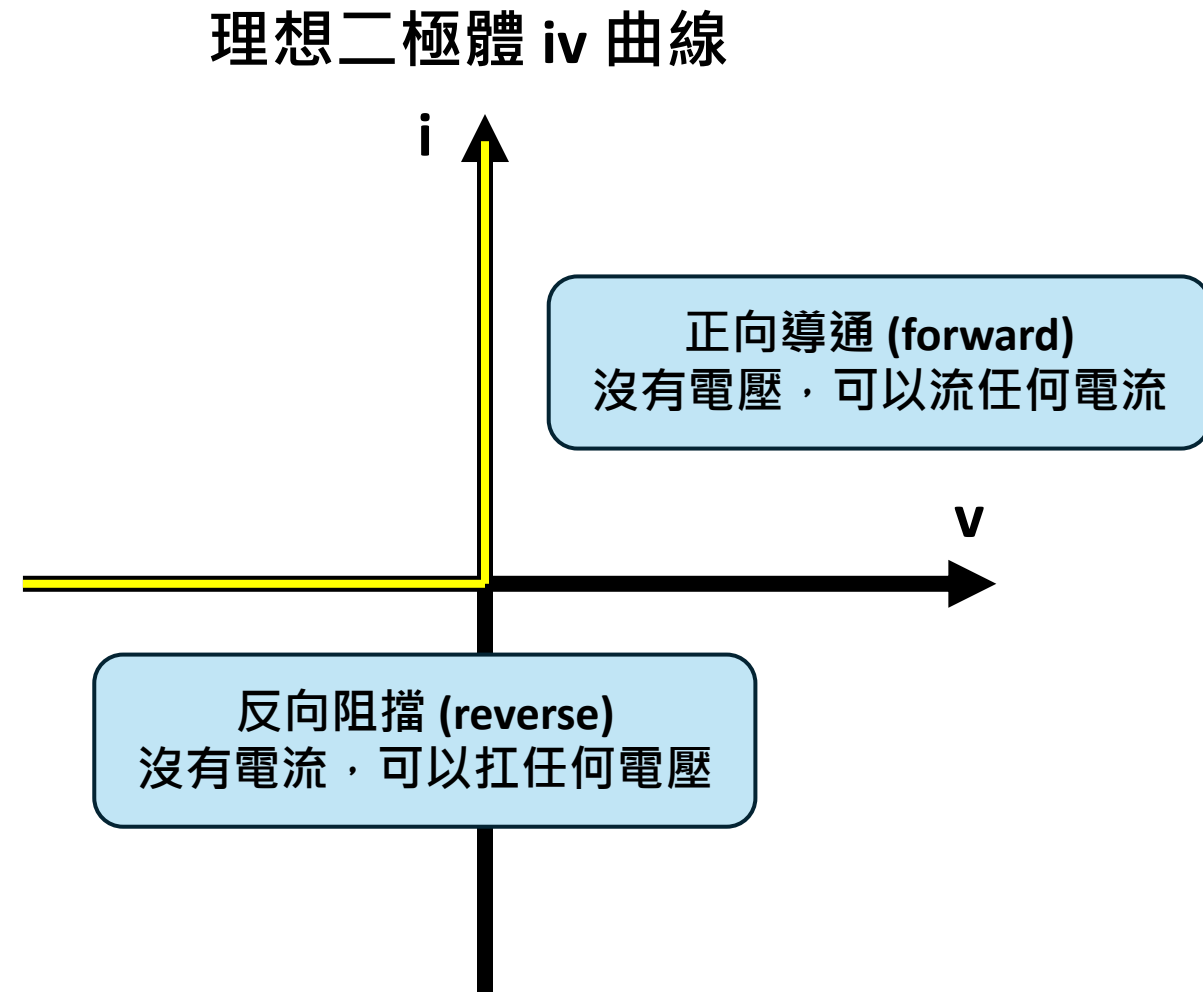
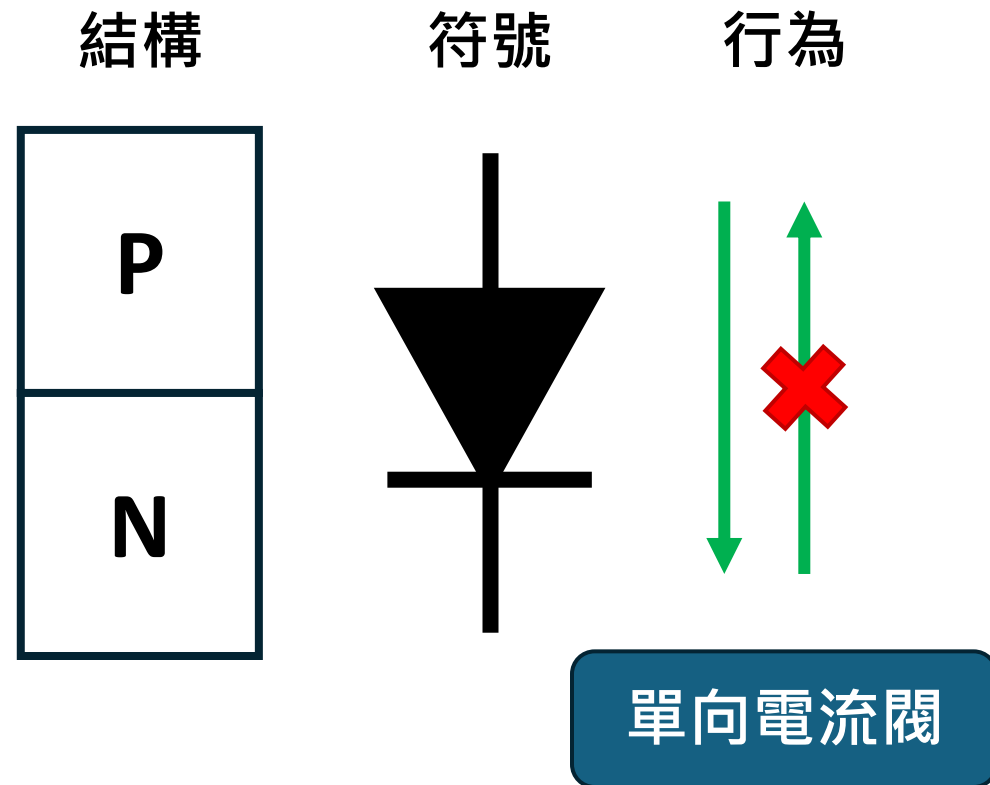
- 在矽裡面參雜 III-A 或 V-A 族元素，分別形成 P-type 和 N-type

	P-type	N-type
Doping (參雜)	III-A	V-A
Free carrier (自由載子)	Hole (電洞)	Electron (電子)
Mobility (載子遷移率)	低	高

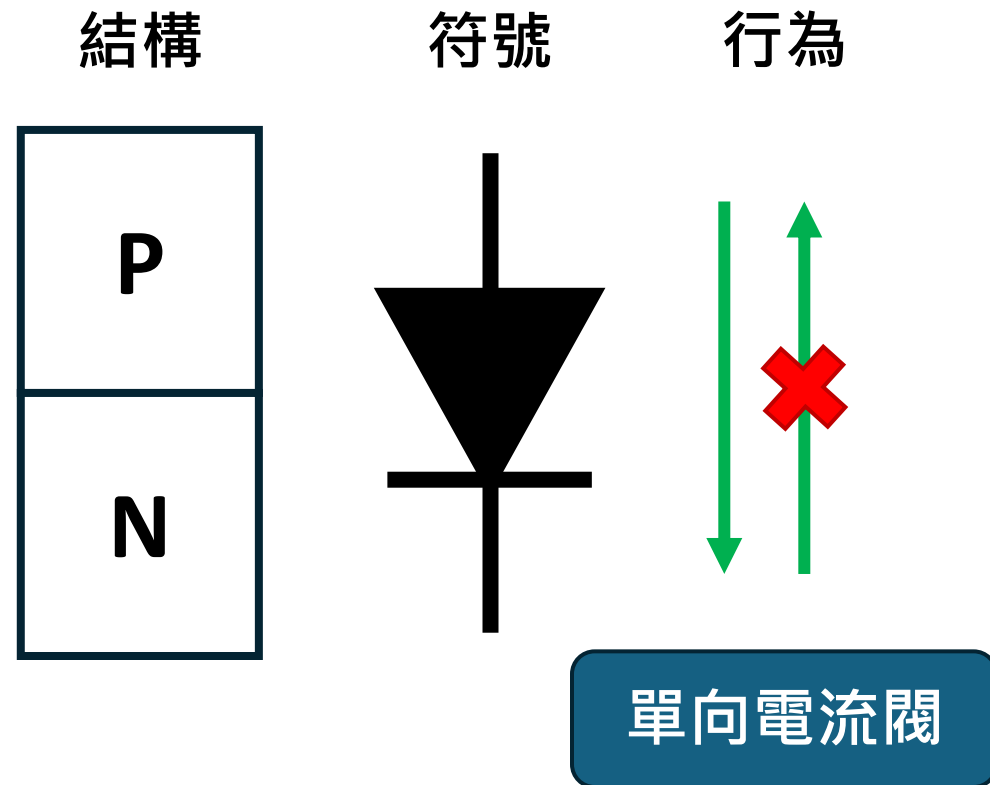
記得半導體有分 P 跟 N
就好了，剩下請見電子學

做晶片就是在矽晶圓上面
用 P 跟 N 跟 oxide 堆結構，
變成電晶體和電路

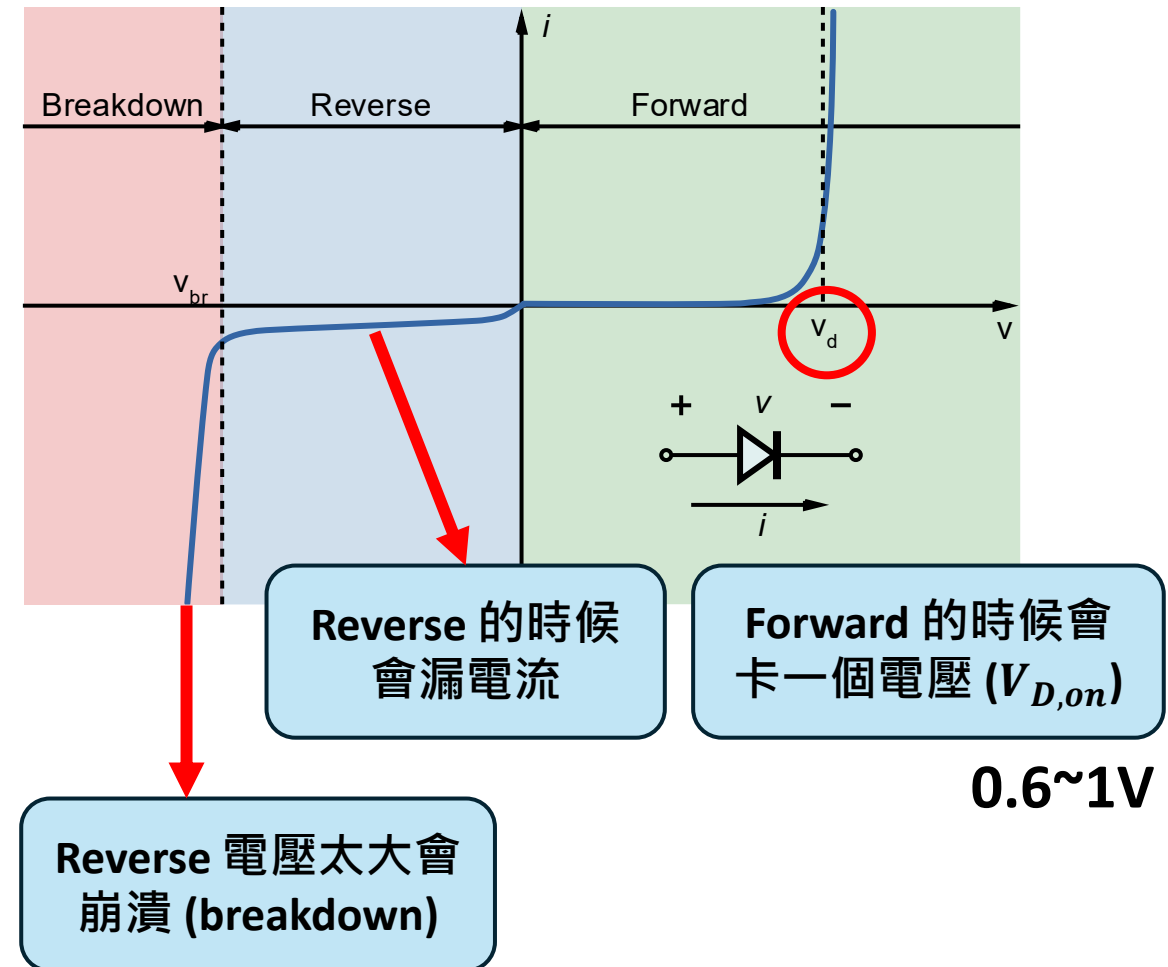
二極體 Diode



二極體 Diode



現實世界二極體 iv 曲線



Diode 規格

- Maximum forward current: 導通打開的時候電流可以多大
- Maximum reverse voltage: 關起來的時候可以扛多少電壓
- Forward voltage: 導通的時候會吃多少電壓

ABSOLUTE MAXIMUM RATINGS ($T_{amb} = 25\text{ }^{\circ}\text{C}$, unless otherwise specified)				
PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Repetitive peak reverse voltage		V_{RRM}	100	V
Reverse voltage		V_R	75	V
Peak forward surge current	$t_p = 1\text{ }\mu\text{s}$	I_{FSM}	2	A
Repetitive peak forward current		I_{FRM}	500	mA
Forward continuous current		I_F	300	mA
Average forward current	$V_R = 0$	$I_{F(AV)}$	150	mA
Power dissipation	$l = 4\text{ mm}, T_L = 45\text{ }^{\circ}\text{C}$	P_{tot}	440	mW
	$l = 4\text{ mm}, T_L \leq 25\text{ }^{\circ}\text{C}$	P_{tot}	500	mW

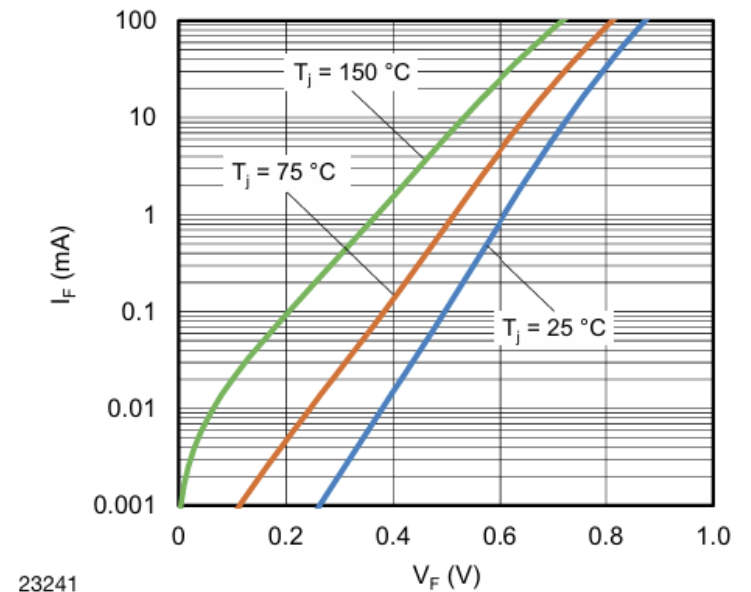
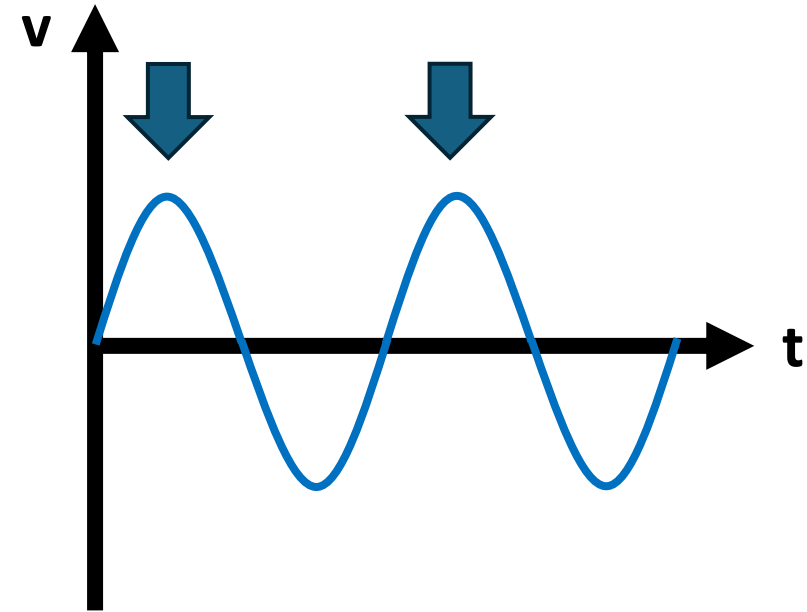
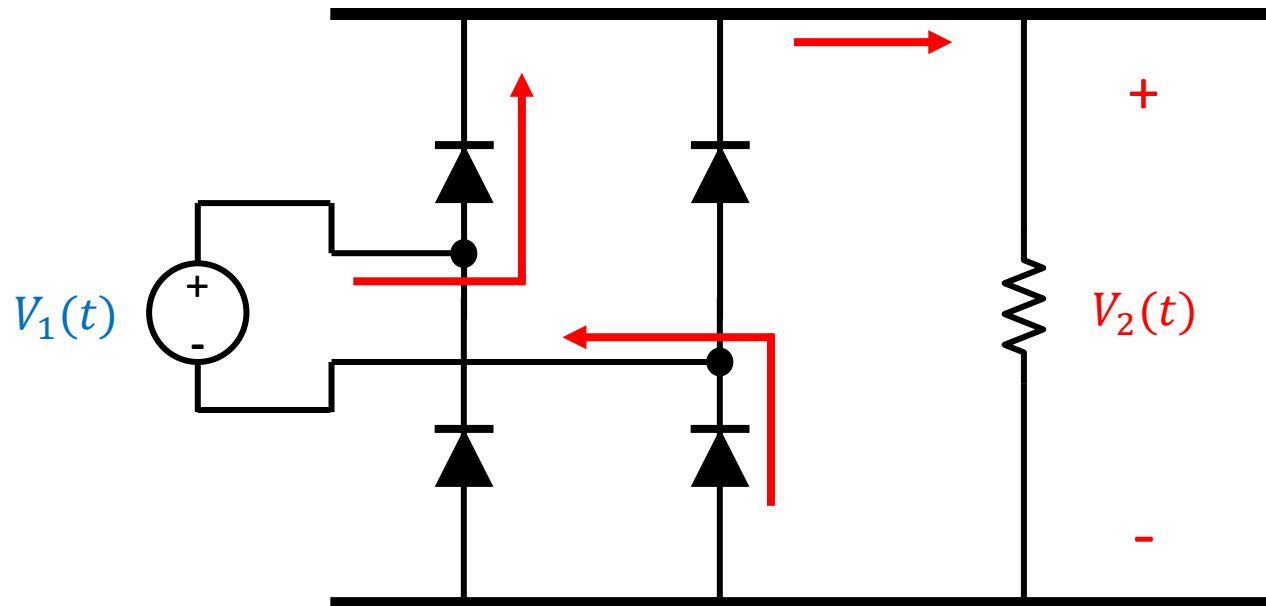


Fig. 2 - Forward Current vs. Forward Voltage

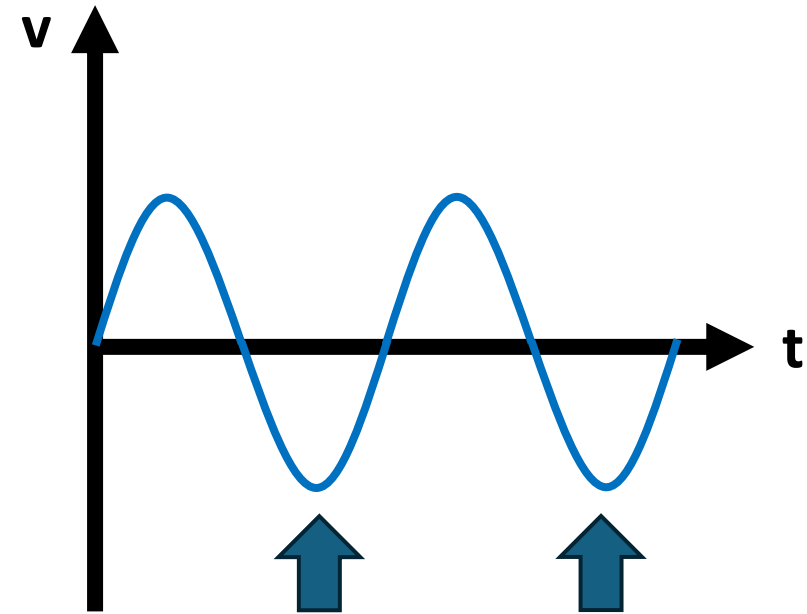
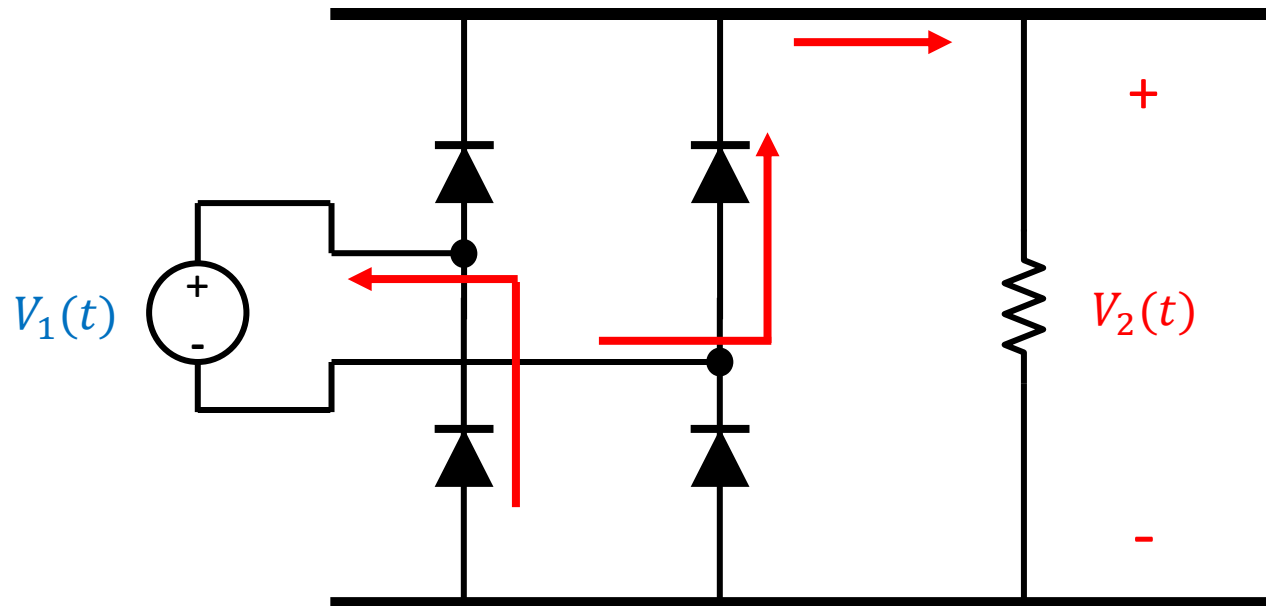
Diode 的應用

全橋整流器 (Full bridge rectifier)



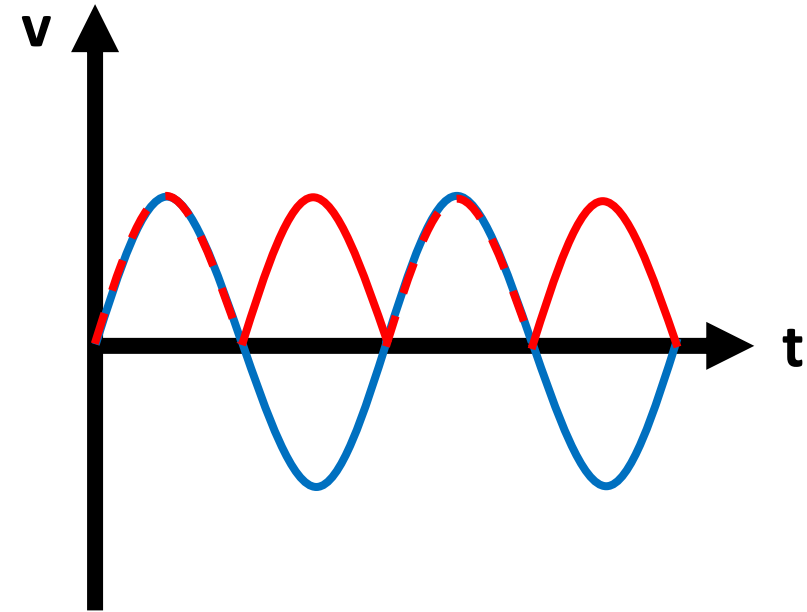
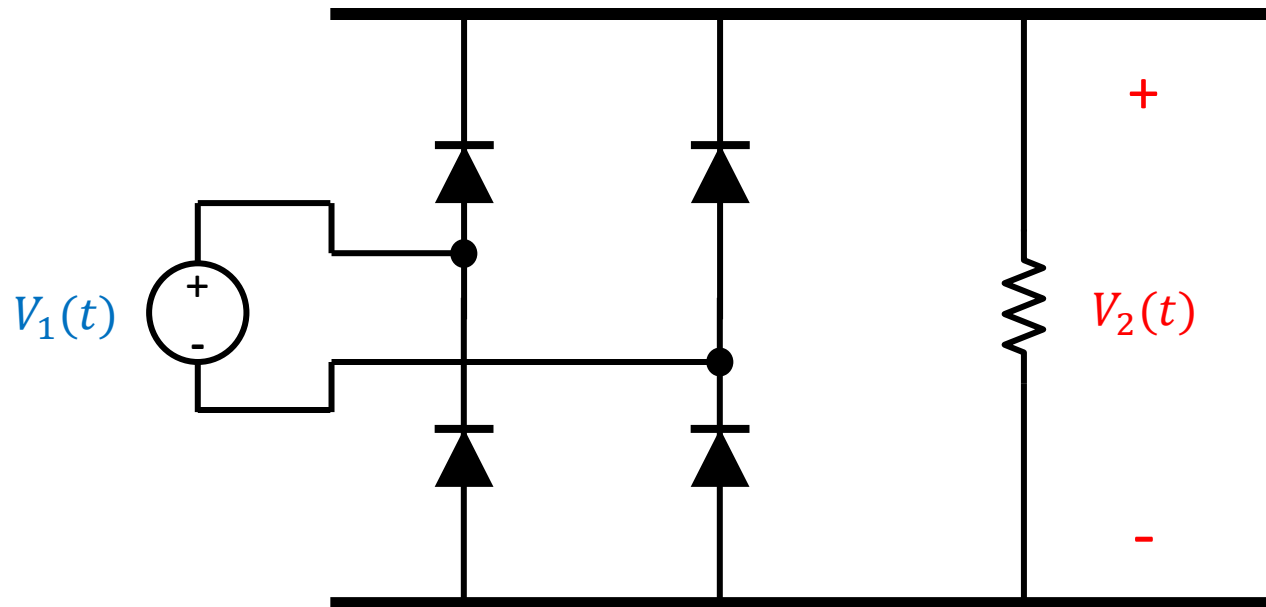
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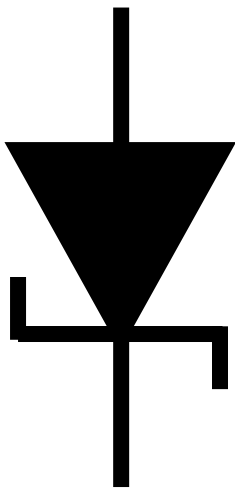
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全橋整流器 (Full bridge rectifier)



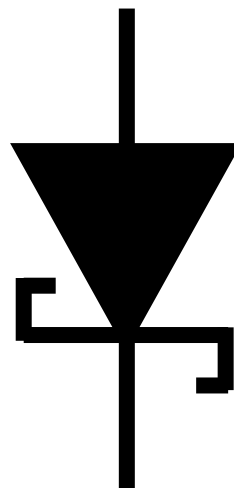
各種 Diode

Zener



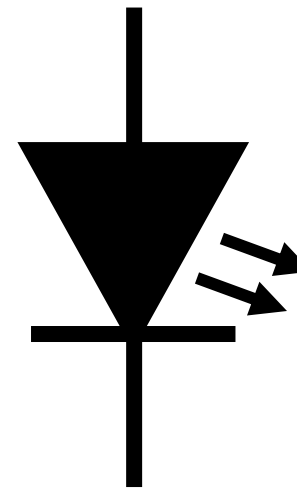
利用反向崩潰特性
來限制電壓不要超過特定數值

Schottky



順向電壓較低 ($\sim 0.3V$)
但是反向漏電較嚴重

LED



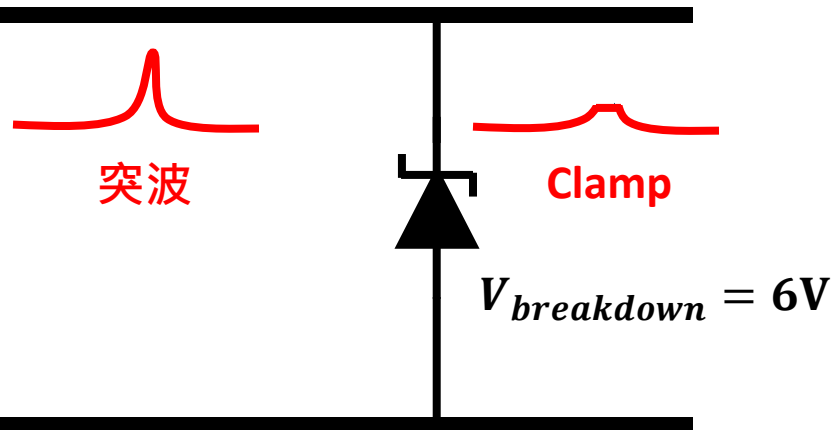
拿來發光
或是拿來當光偵測器

Zener Diode 接法

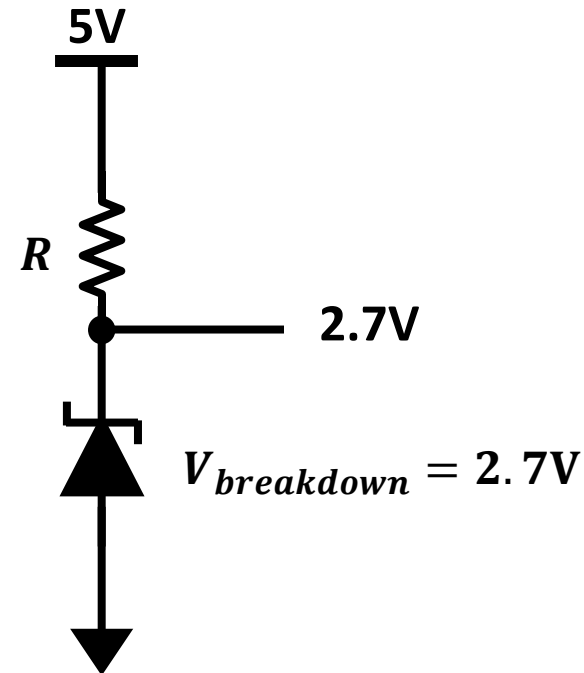
不管哪種，Zener Diode 在正常情況下都要 reverse bias

第一種：
用於防止電壓突波傷害電路

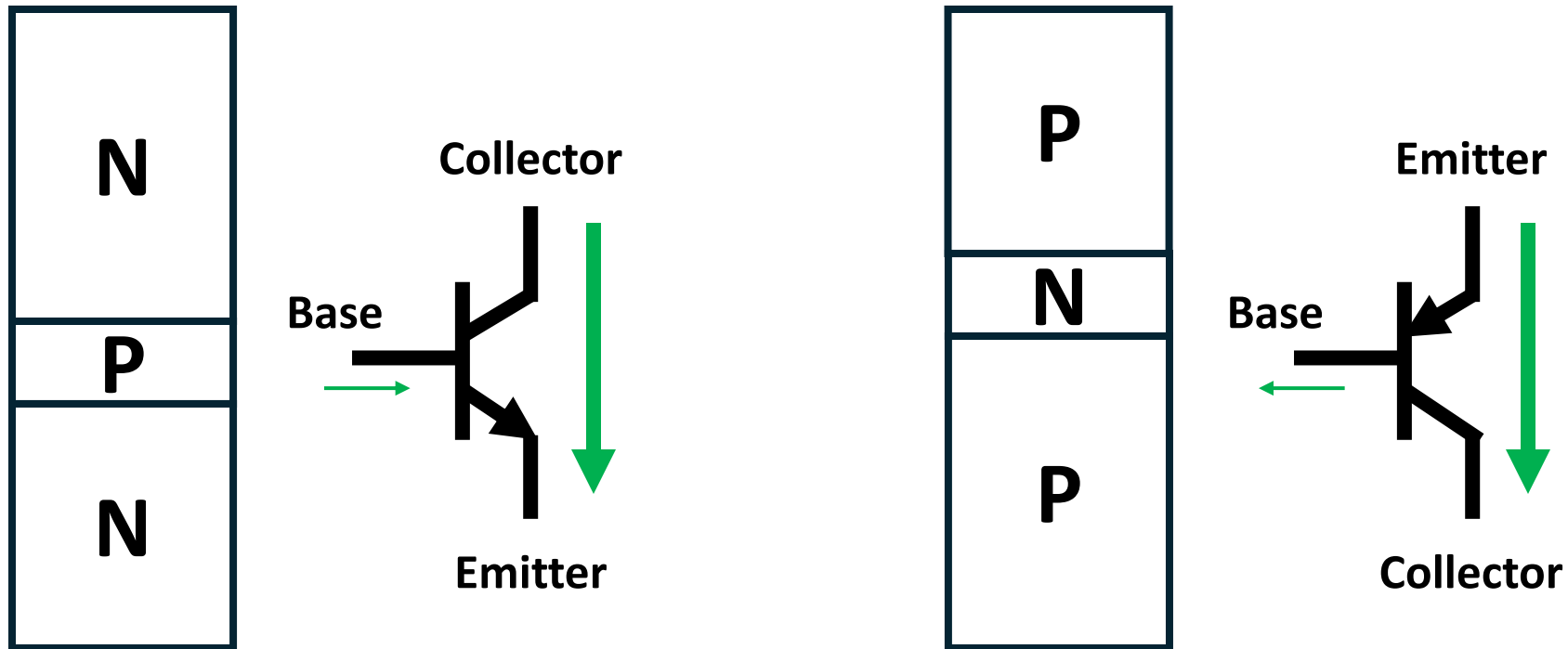
正常電壓 5V



第二種：
用於產生參考電壓 (不是很準)



Bipolar Junction Transistor (BJT)



電流放大器

$$I_C = \beta I_B$$

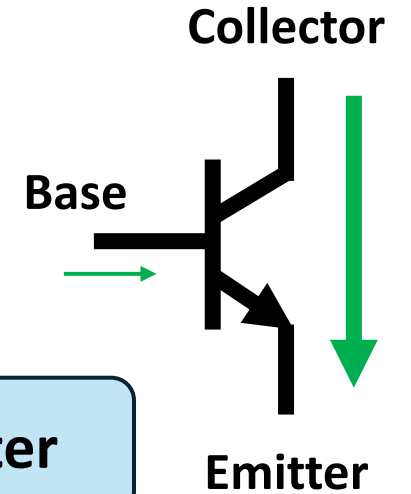
BJT 開關模型

NPN:

有小電流流進 base

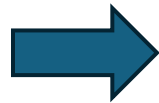


有大電流從 collector 流向 emitter

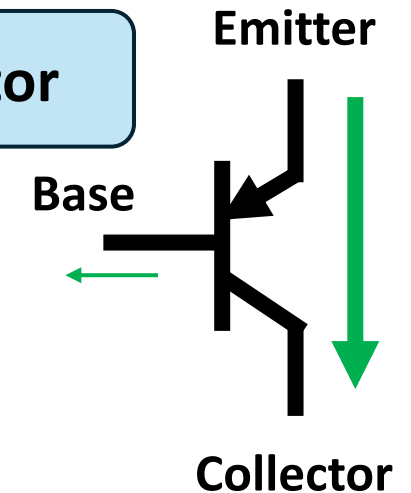


PNP:

有小電流流出 base



有大電流從 emitter 流向 collector



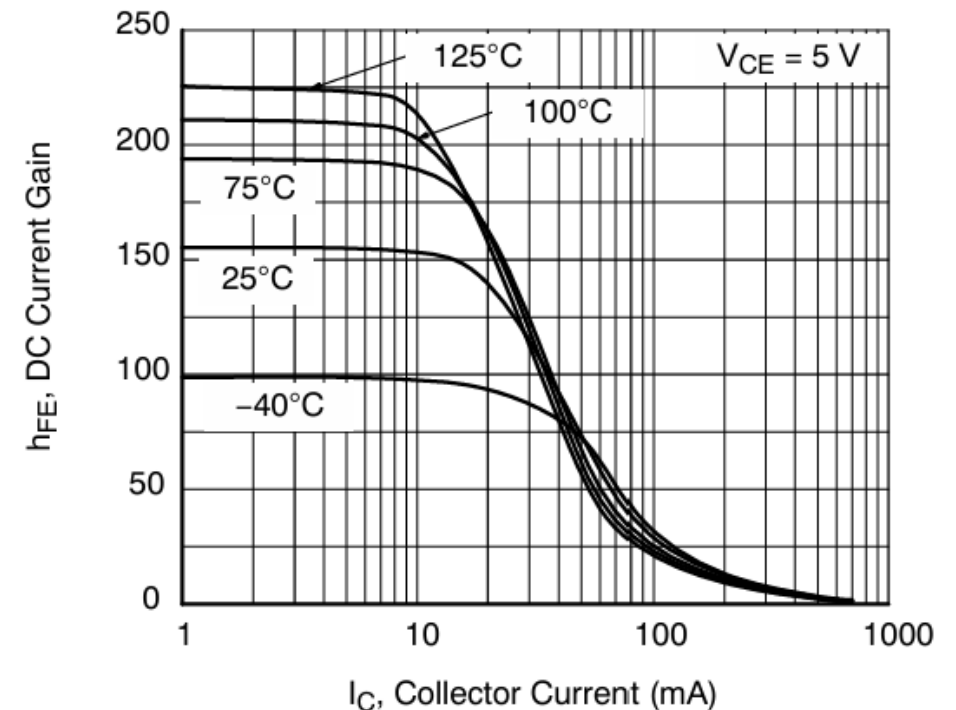
- 沒有 base 電流，BJT 就會關掉
- V_{BE} 範圍大概在 0.5~1.0V，更高的話會燒掉

BJT 規格

- Maximum collector current: 打開的時候電流可以多大
- Maximum collector-emitter voltage: 關起來的時候可以扛多少電壓
- Current gain (β , h_{fe}): 電流放大倍率

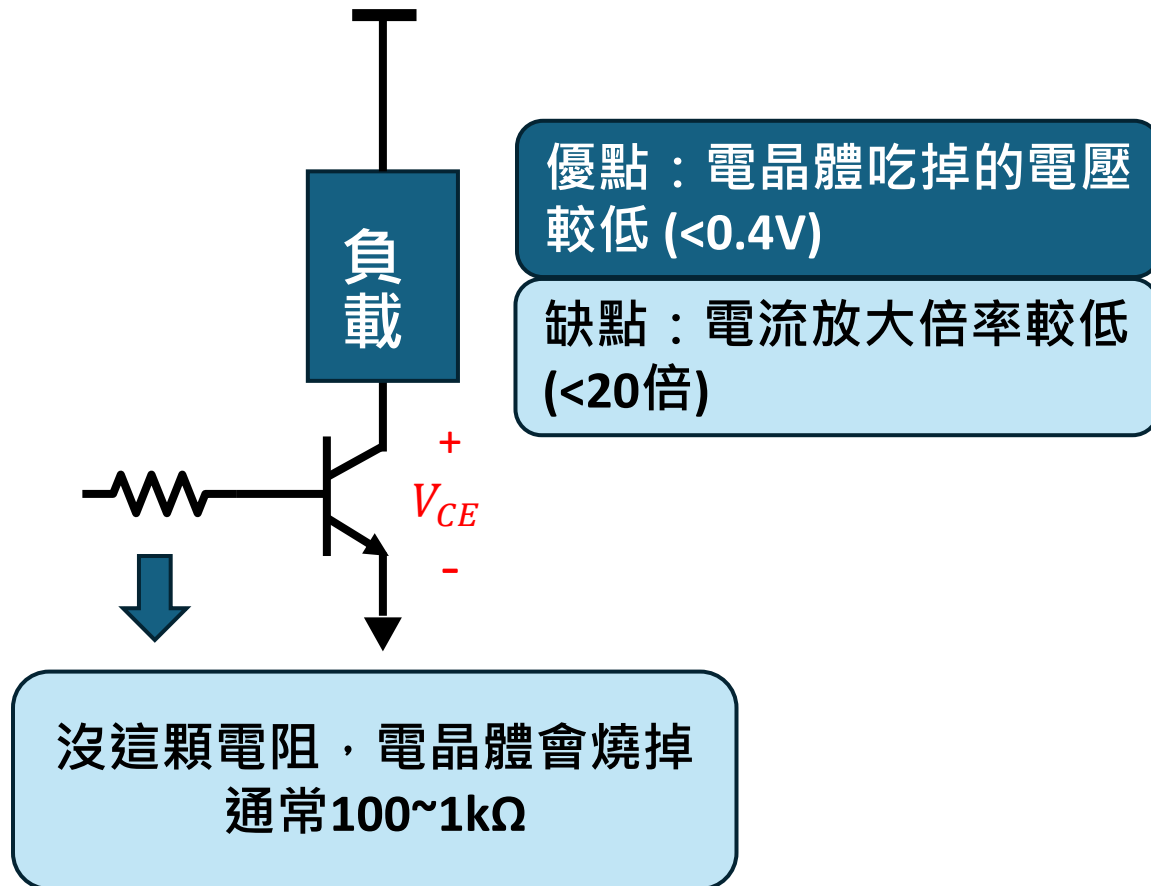
ABSOLUTE MAXIMUM RATINGS (Note 1)

Symbol	Parameter	Value	Unit
V_{CEO}	Collector-Emitter Voltage	160	V
V_{CBO}	Collector-Base Voltage	180	V
V_{EBO}	Emitter-Base Voltage	6	V
I_C	Collector Current – Continuous	600	mA
T_J, T_{STG}	Operating and Storage Temperature (Note 2)	-55 to + 150	°C

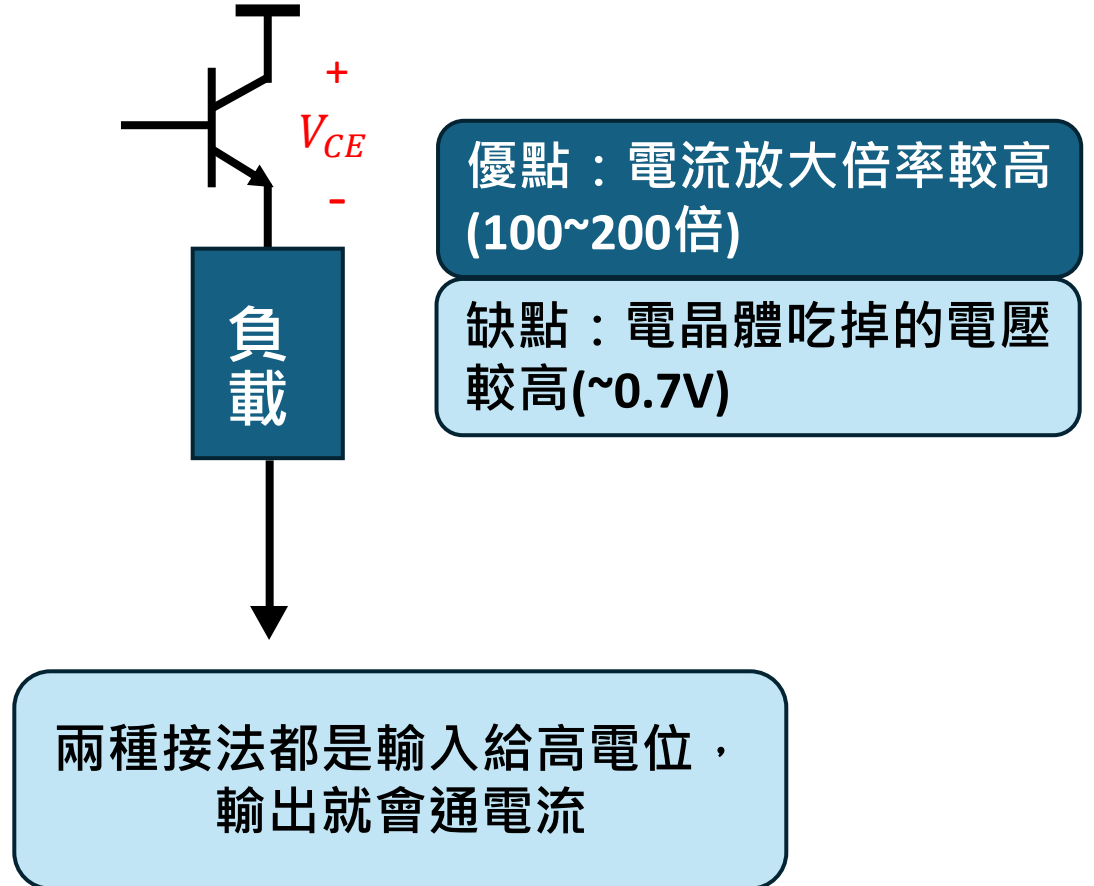


NPN BJT 開關範例電路

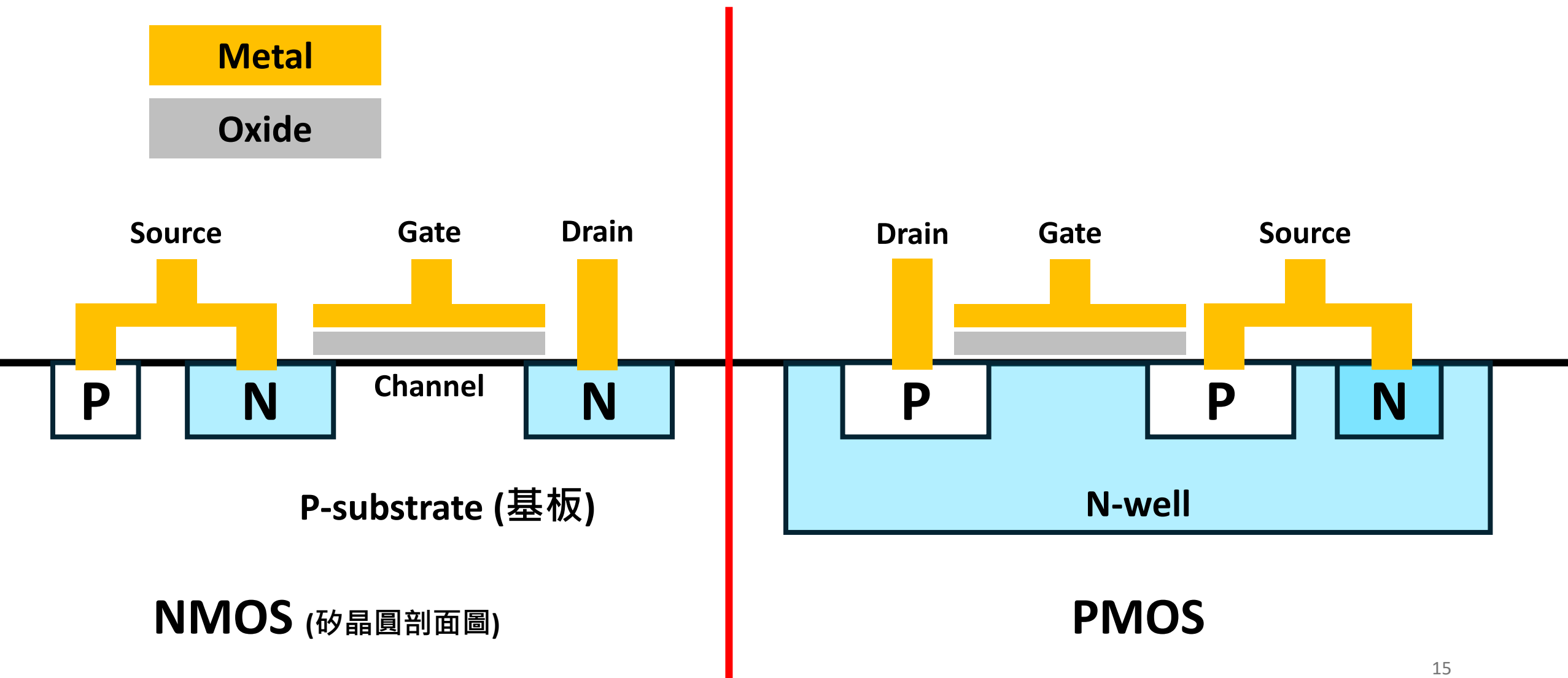
Common Emitter



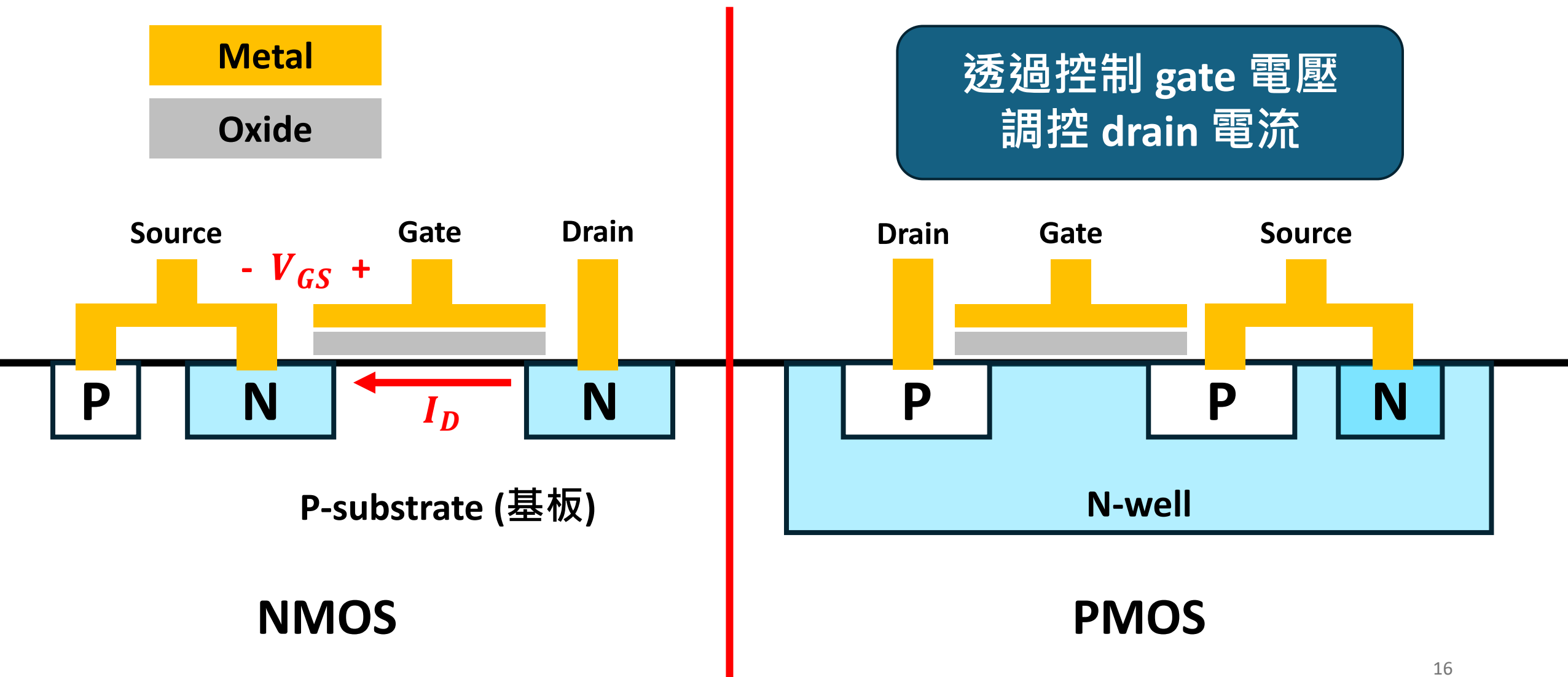
Emitter Follower



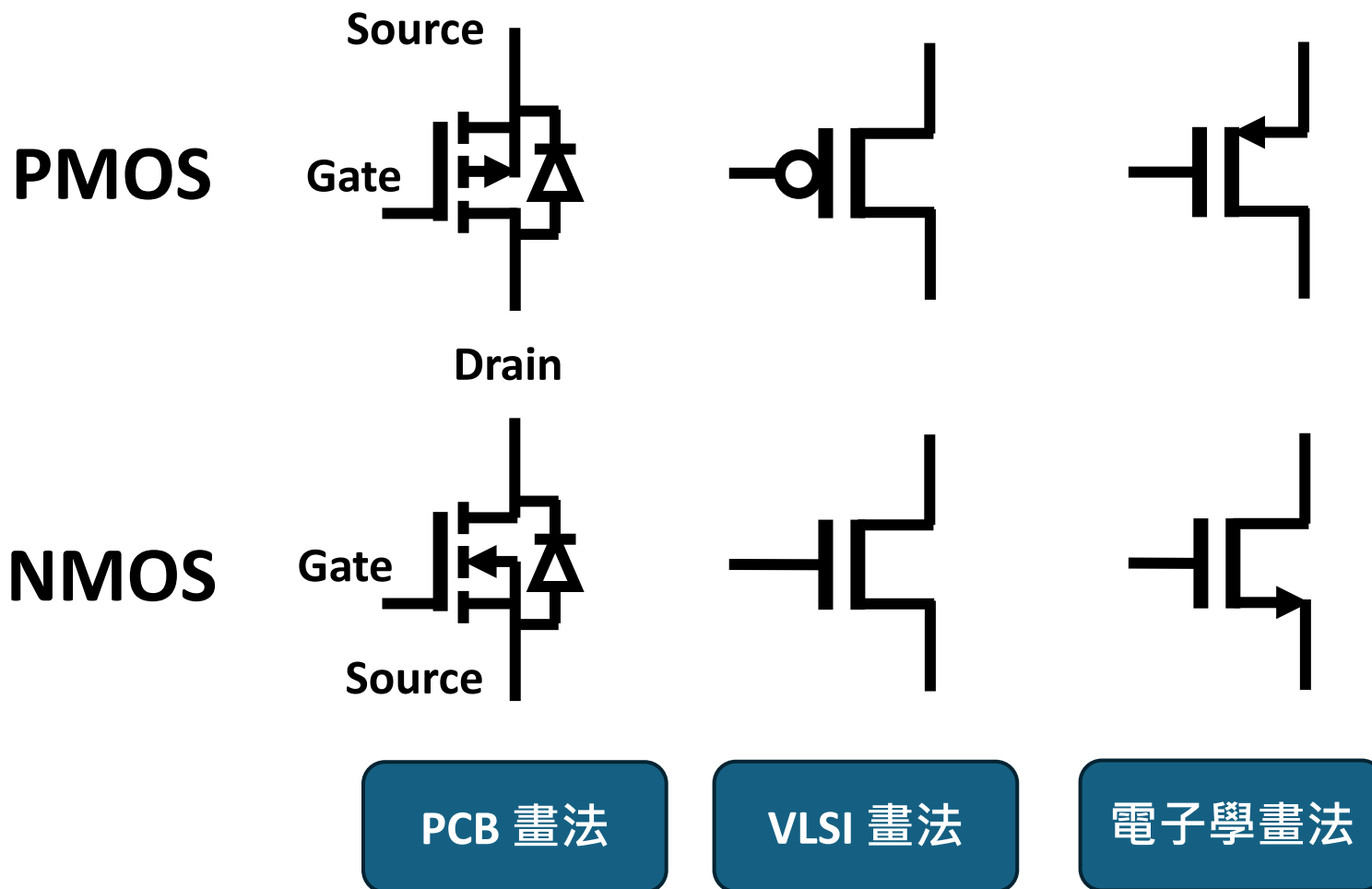
MOSFET (Metal Oxide Semiconductor Field Effect Transistor)



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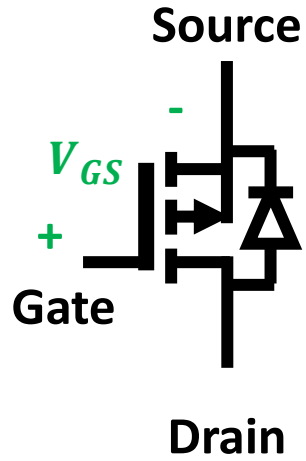
MOSFET (Metal Oxide Semiconductor Field Effect Transistor)



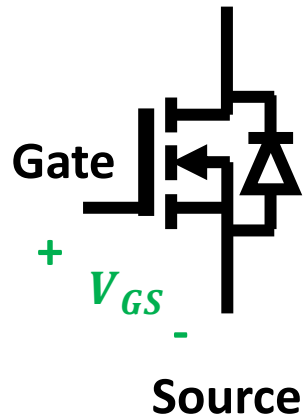
大部分的電路裡面，
NMOS 在下、PMOS 在上

MOSFET 開關模型

PMOS



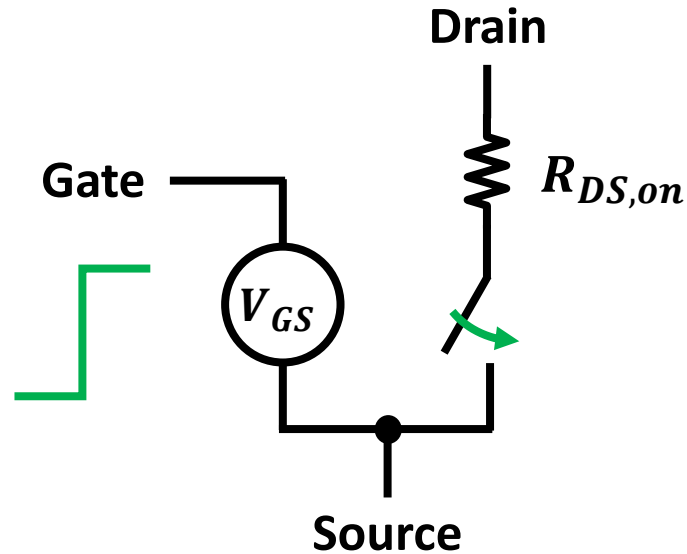
NMOS



$$|V_{GS}| > |V_{TH}|$$



Turn-on



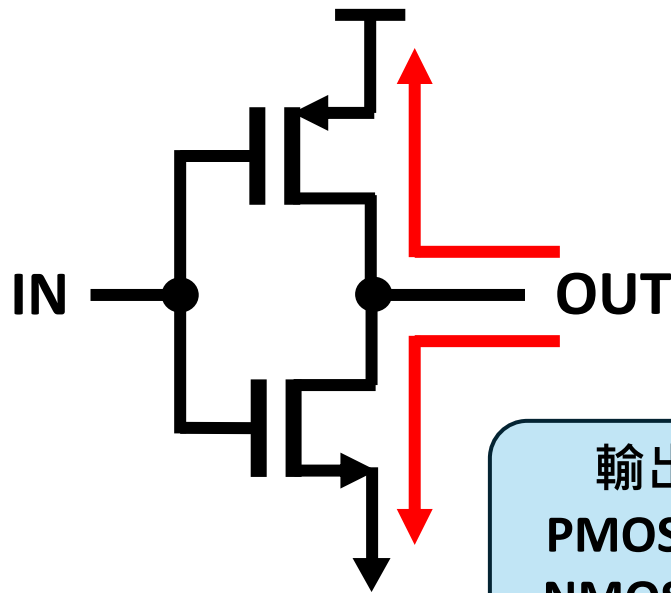
MOSFET 打開之後會有
導通電阻($\sim 0.05\Omega$)

MOSFET 開關接法



CMOS logic

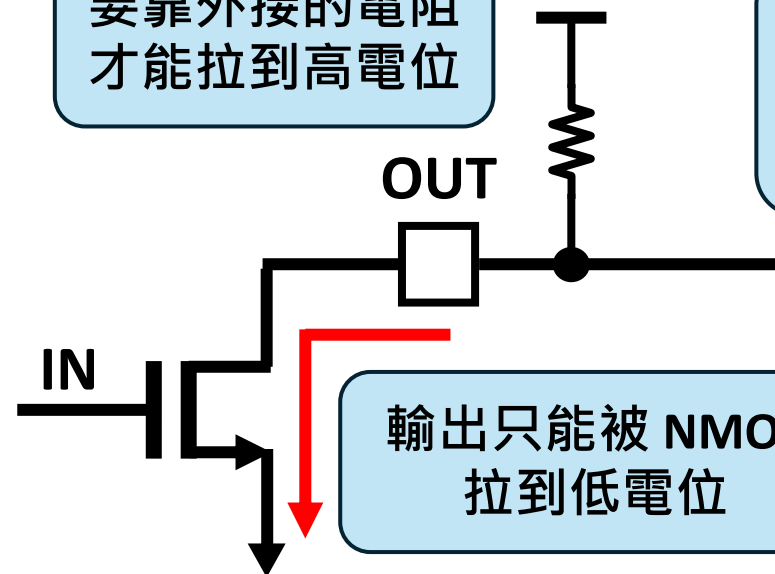
數位 IC 輸出到 pin 之前通常
是一個 inverter 的結構



輸出可以被：
PMOS 拉到高電位
NMOS 拉到低電位

也有另一種叫做 open drain

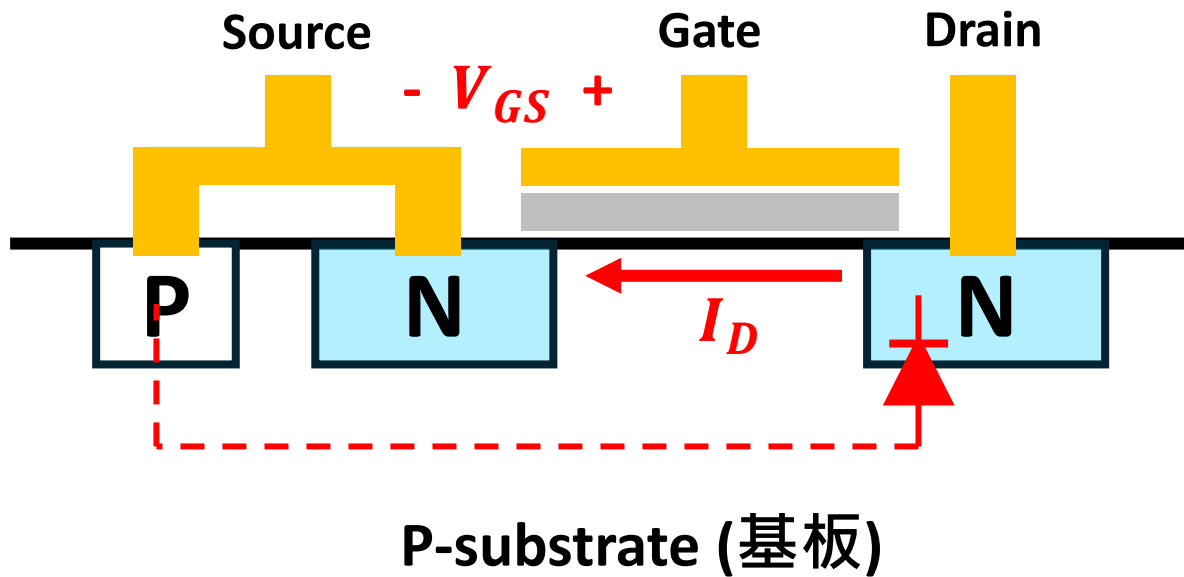
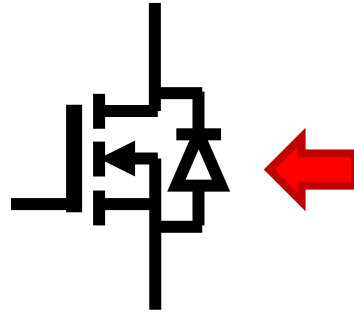
要靠外接的電阻
才能拉到高電位



輸出只能被 NMOS
拉到低電位

目的：
外面的高電位可以跟
IC 的高電位不一樣

Body diode



因為有 body diode，所以
MOSFET 只能擋一個方向的電壓

NMOS 只能 drain > source
PMOS 只能 source > drain

(Power) MOSFET 規格

- Maximum blocking voltage: 關掉的時候最高可以擋多少電壓
- Maximum drain current: 打開的時候最高可以通多少電流
- On resistance: 打開之後的電阻有多小
- Thermal resistance: 每消耗一瓦會升溫幾度

2 Thermal characteristics

Table 1 Key Performance Parameters

Parameter	Value	Unit
V_{DS}	30	V
$R_{DS(on),max}$	4.5	m Ω
I_D	63	A
Q_{OSS}	8.6	nC
$Q_G(0V..10V)$	13	nC

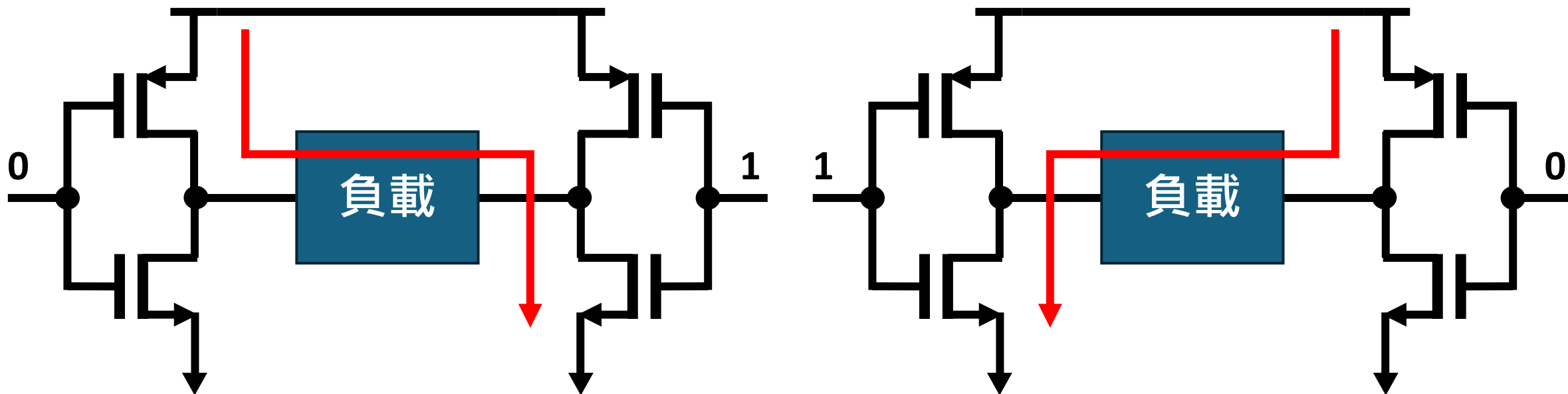
Table 3 Thermal characteristics

Parameter	Symbol	Values			Unit
		Min.	Typ.	Max.	
Thermal resistance, junction - case, bottom	R_{thJC}	-	-	4.2	K/W
Thermal resistance, junction - case, top	R_{thJC}	-	-	20	K/W
Device on PCB, 6 cm ² cooling area ¹⁾	R_{thJA}	-	-	50	K/W

MOSFET 常見電路

H-bridge

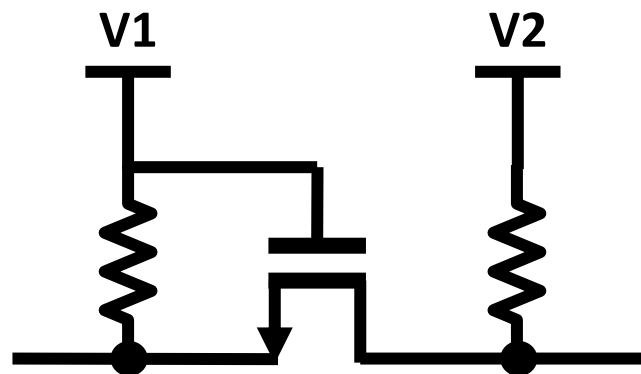
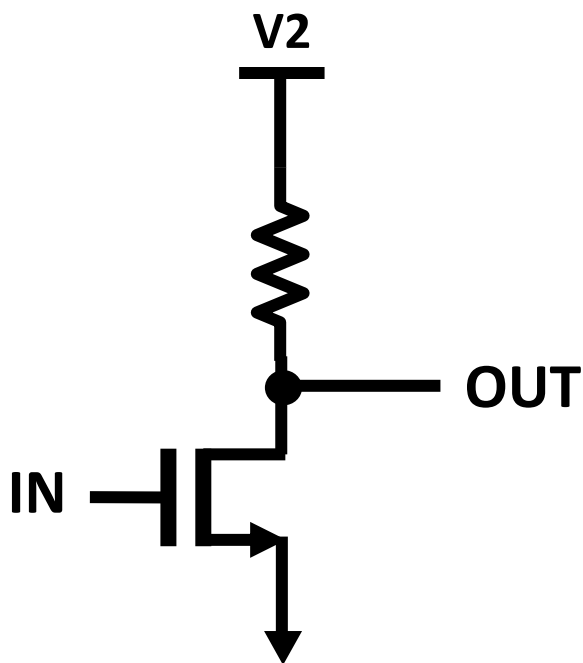
通常用來驅動馬達，可以從一組電源產生兩種不同方向的電流



MOSFET 常見電路

Level Shifter

用來做兩種邏輯電位的轉換



雙向

這兩種電路都有 0->1 很慢的問題，因為要靠電阻往上拉