

I-NPC Module Switching Pattern (Single Phase)

Fuji Electric Co., Ltd.

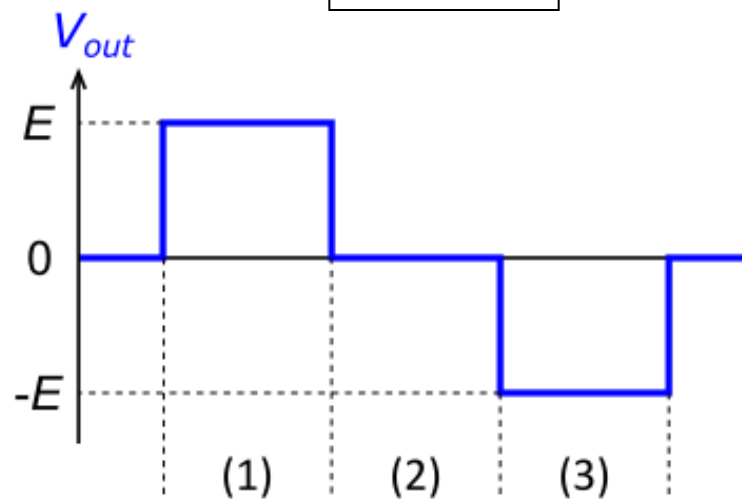
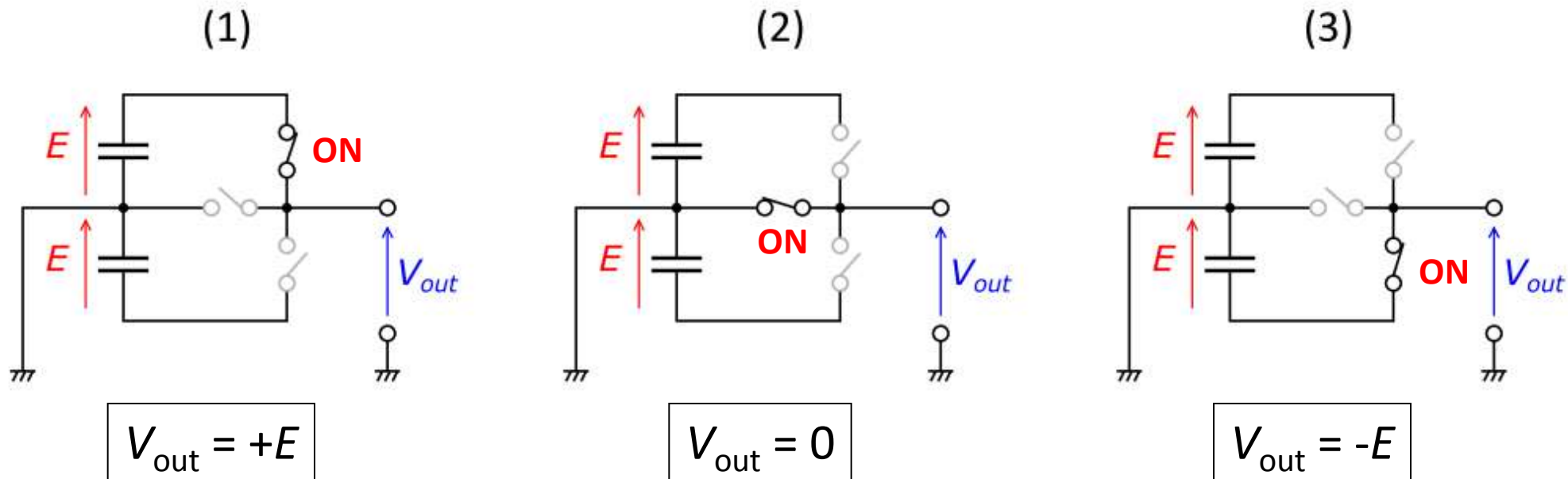
Device Application Technology Dept.

Semiconductor Div.

Sales Group

Mar, 2015

What is the “three level” ?

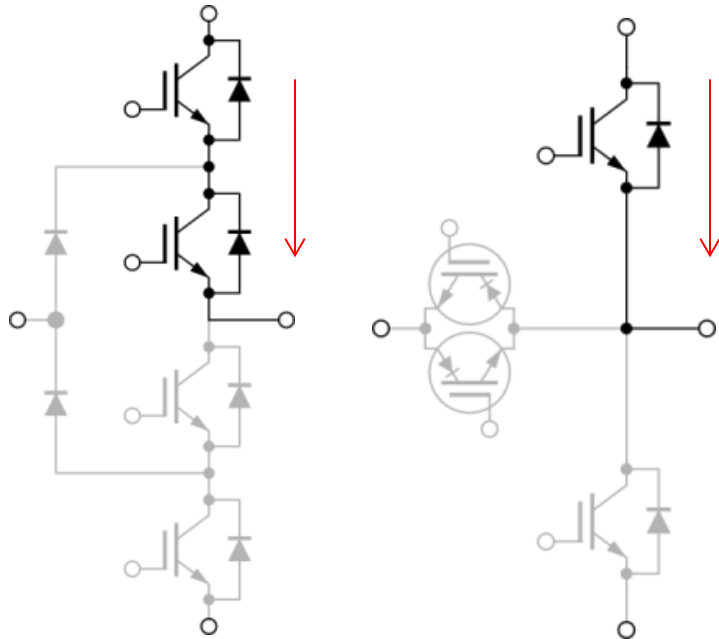
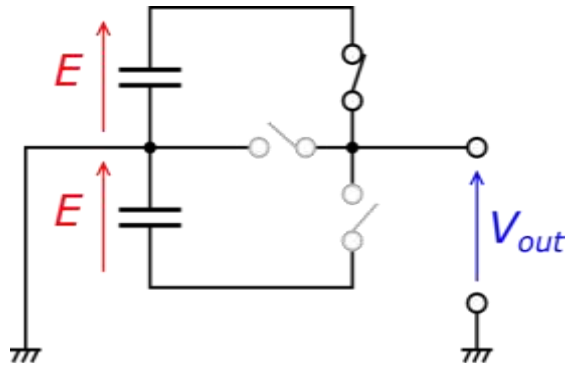


Three level outputs!
(+E, 0, -E)

NPC & T-type 3-level Configuration

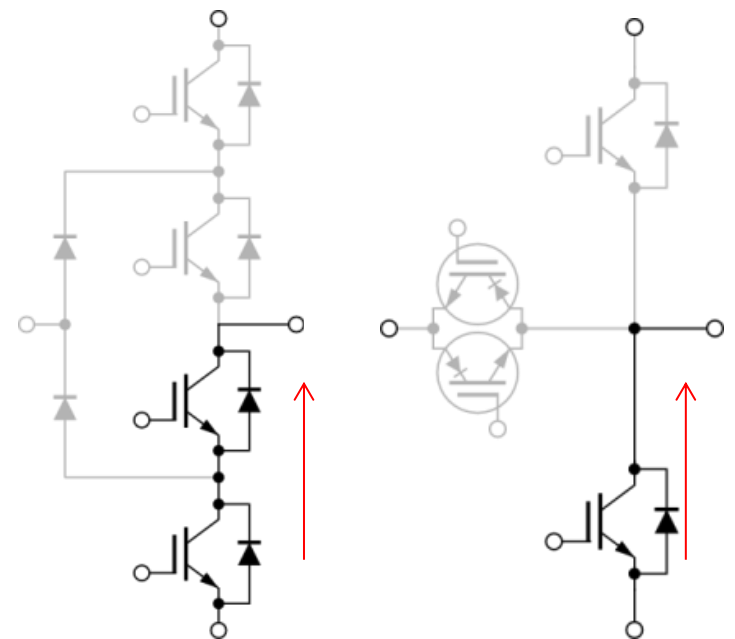
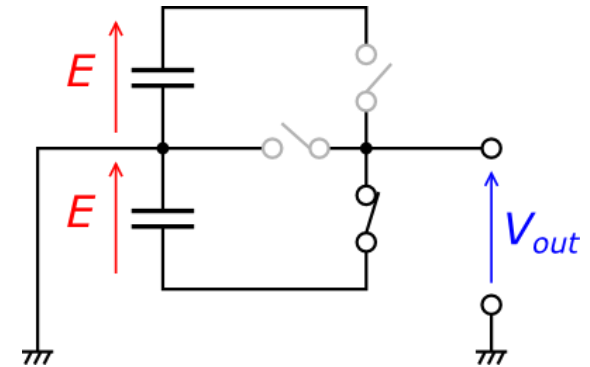
(1)

$$V_{out} = +E$$



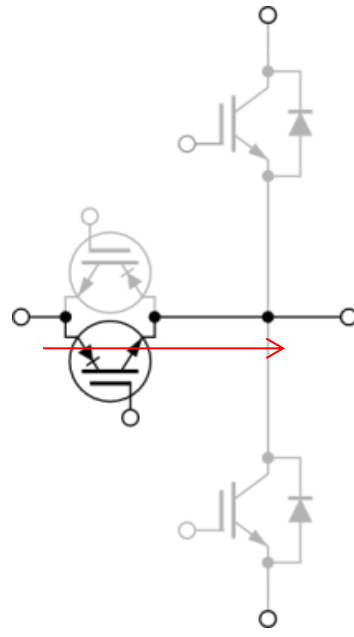
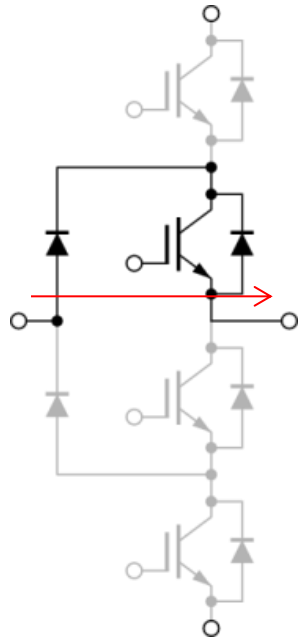
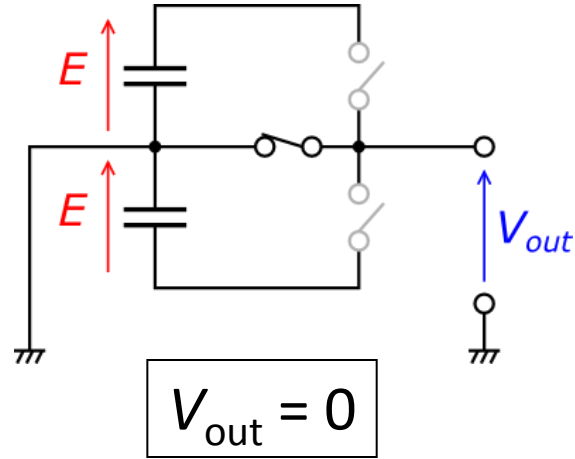
(3)

$$V_{out} = -E$$

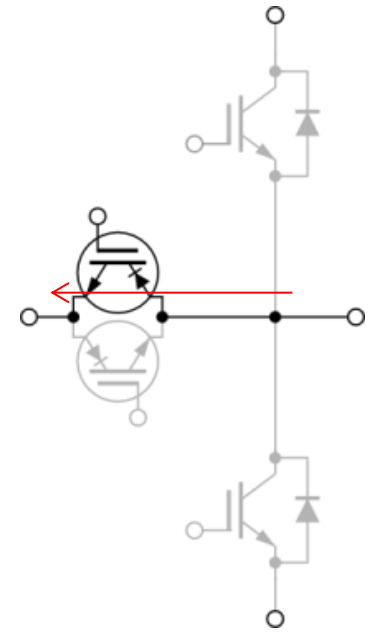
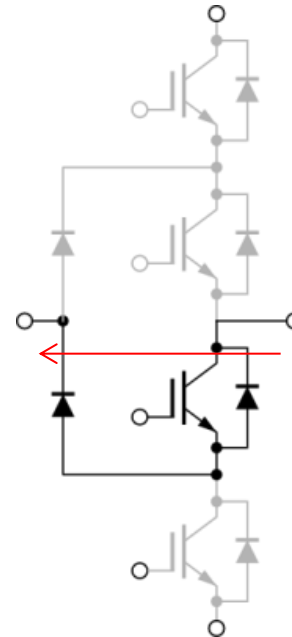


Switching Pattern

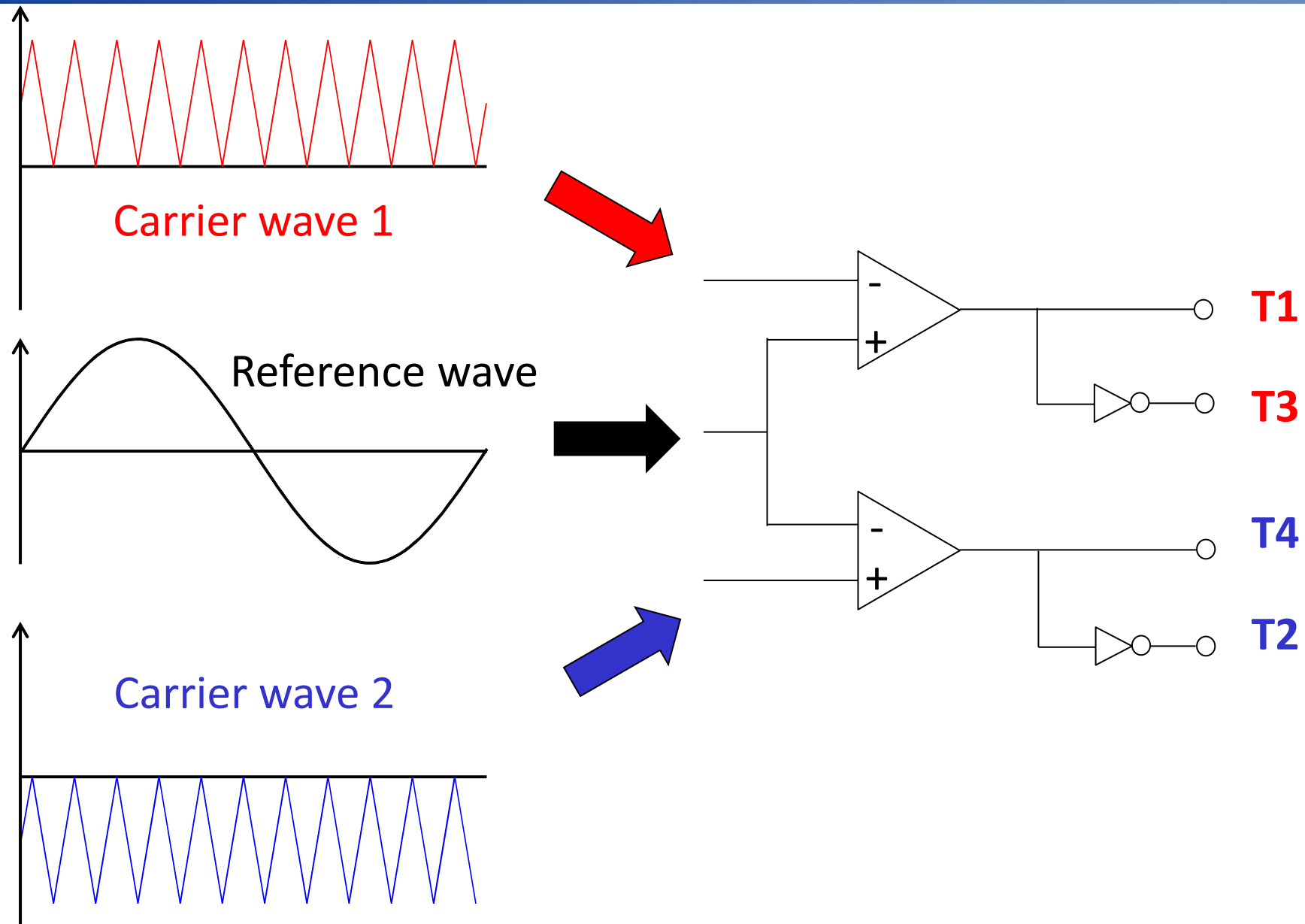
(2)



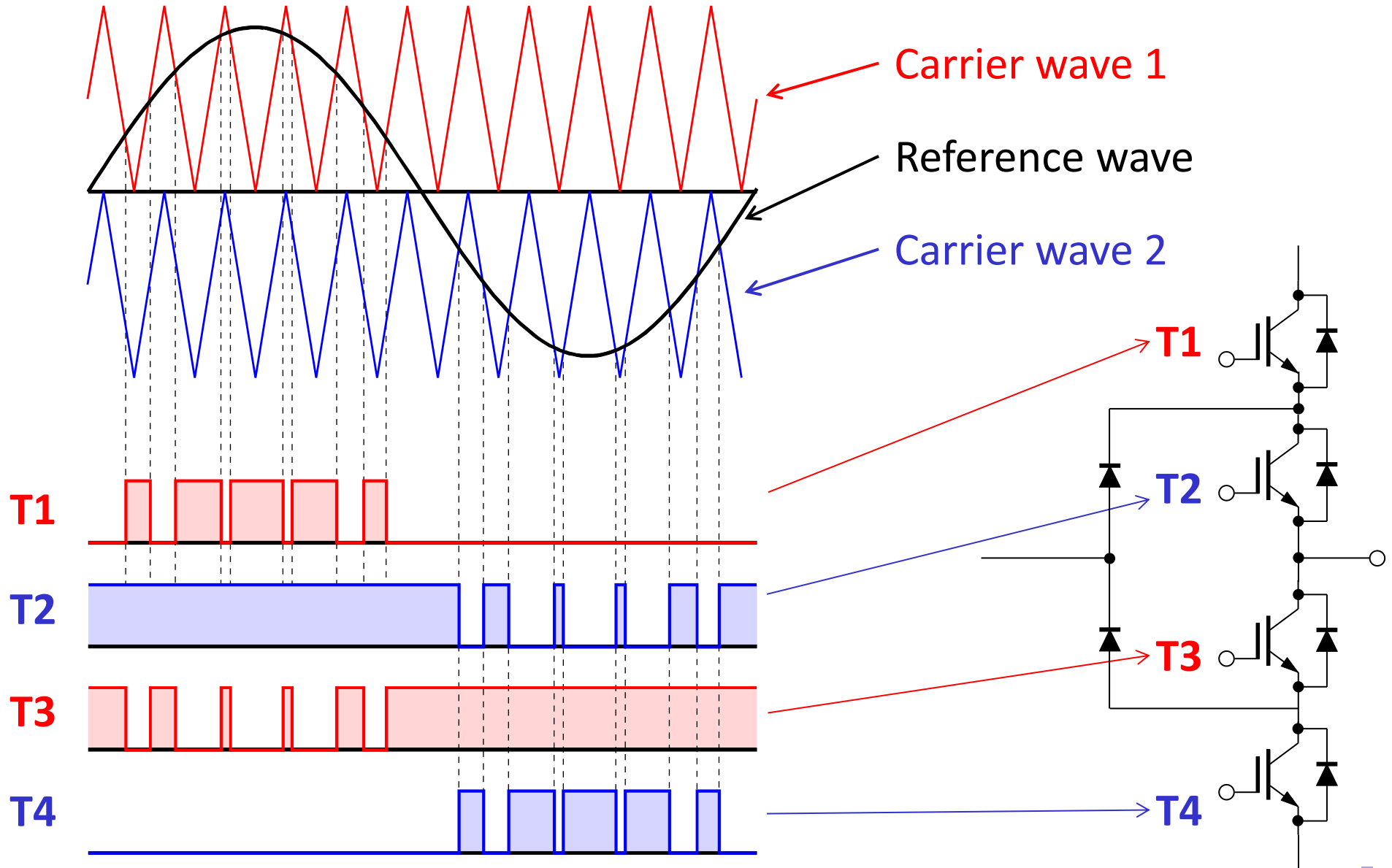
or



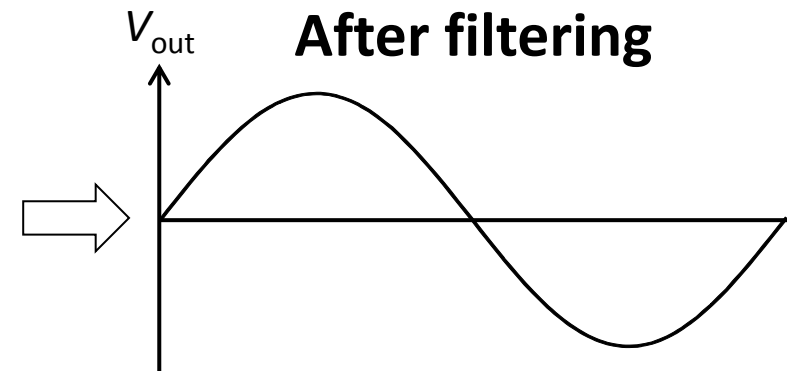
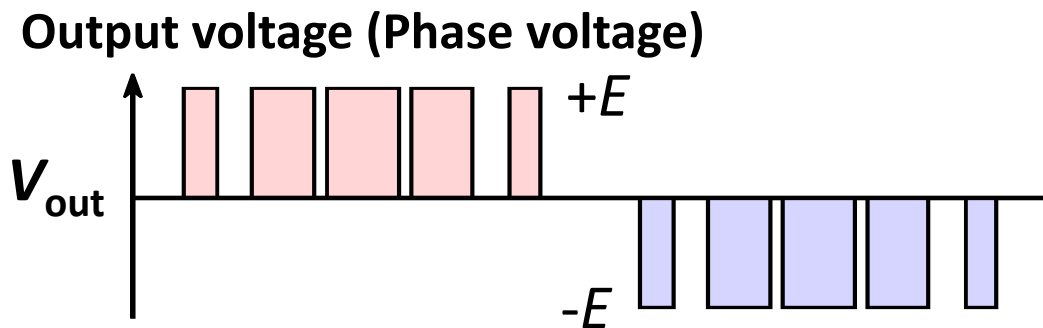
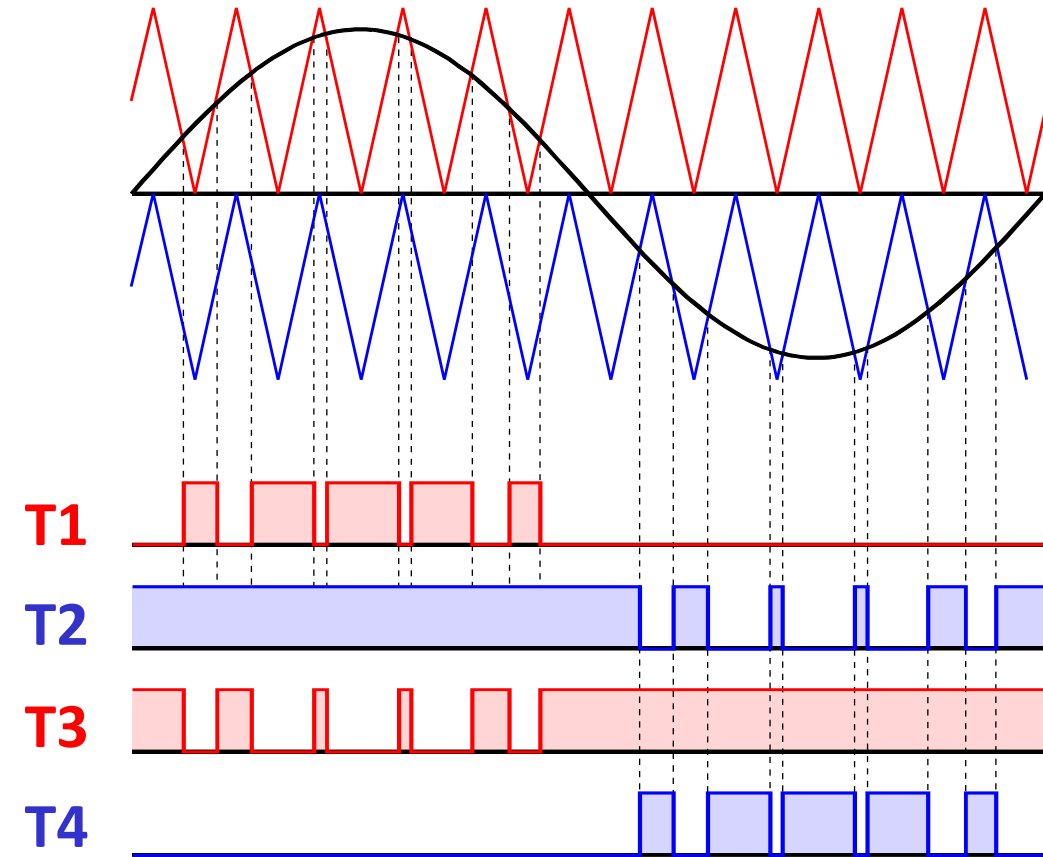
Generate PWM Pulse



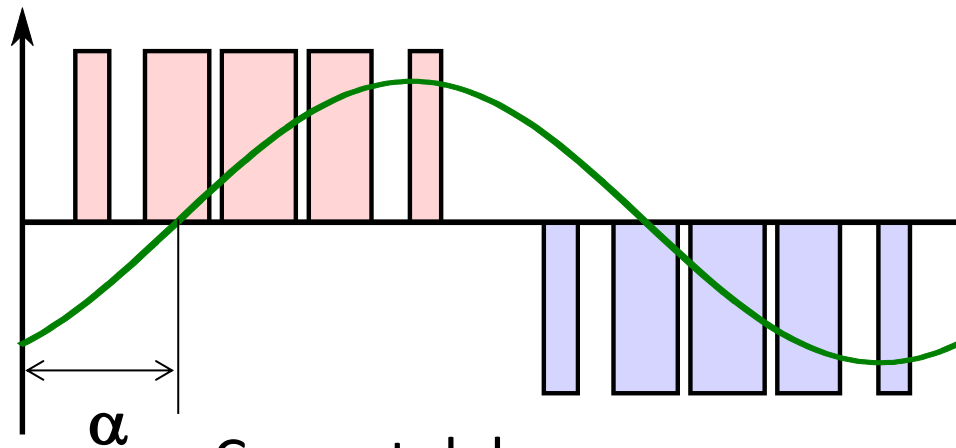
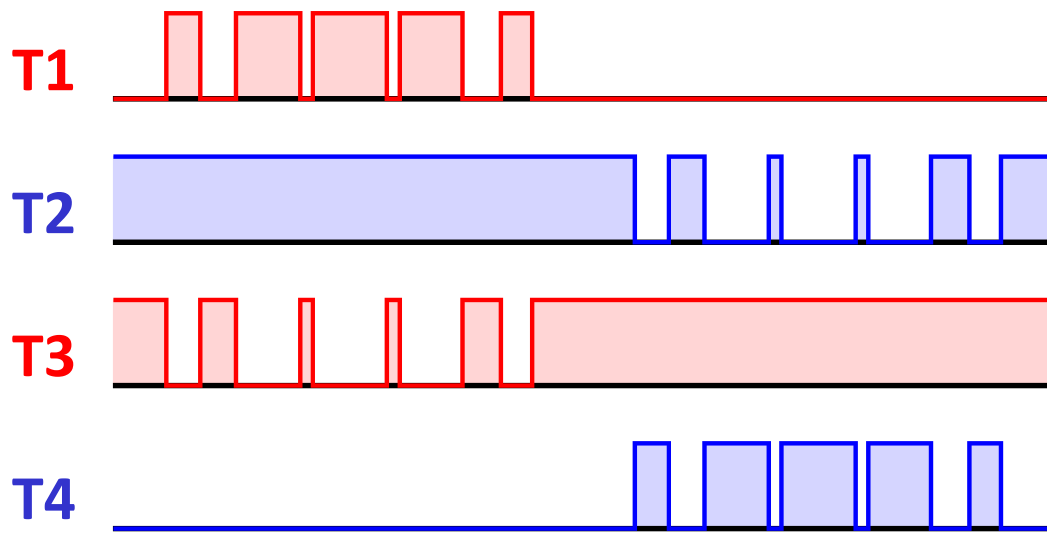
Switching Pattern (Phase Voltage)



Switching Pattern (Phase Voltage)

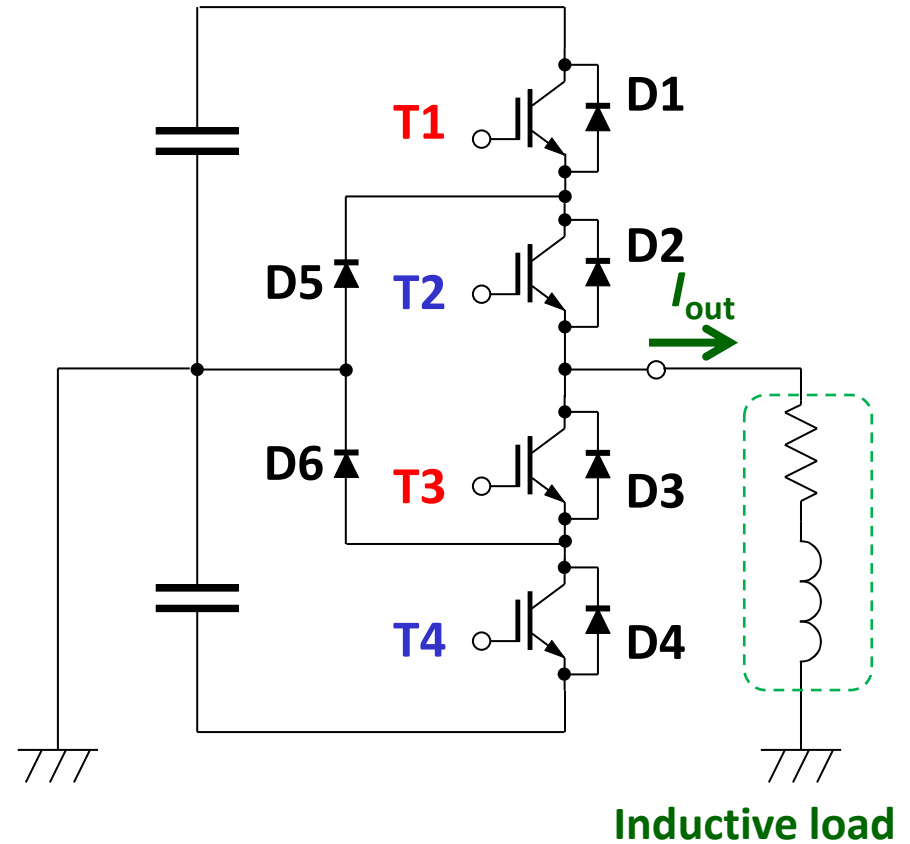


Inductive Load – Lagging Current



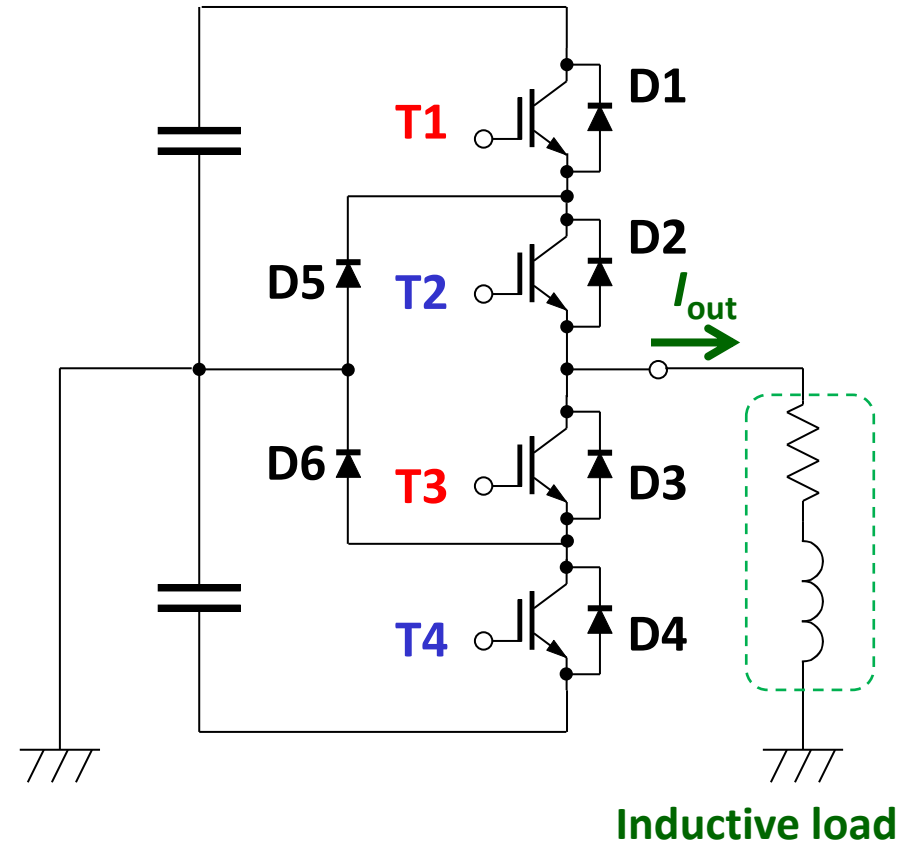
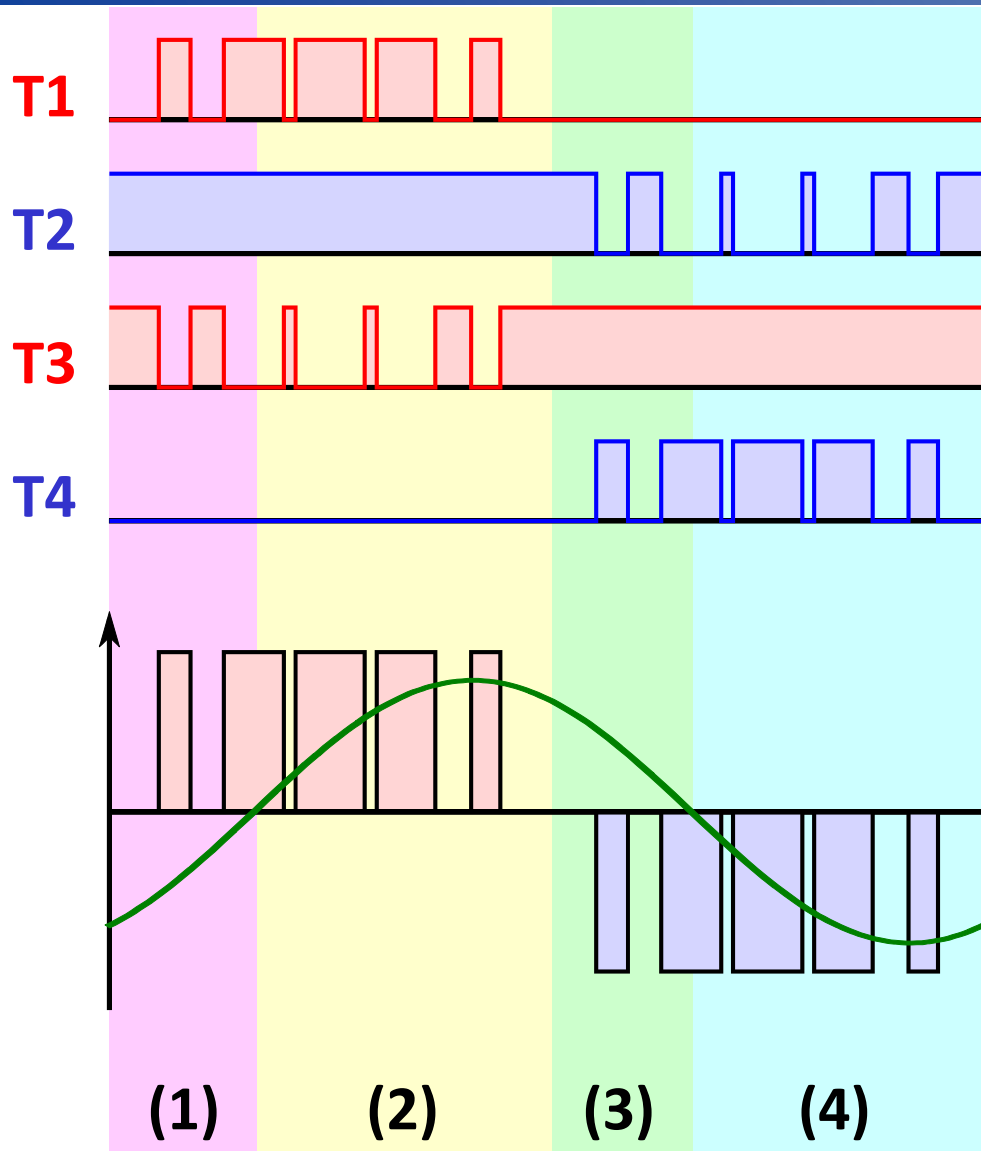
Current delay: α

Power factor: $\cos \alpha$



If an inductive load is connected, the current waveform is lagging behind the voltage waveform.

Switching Pattern

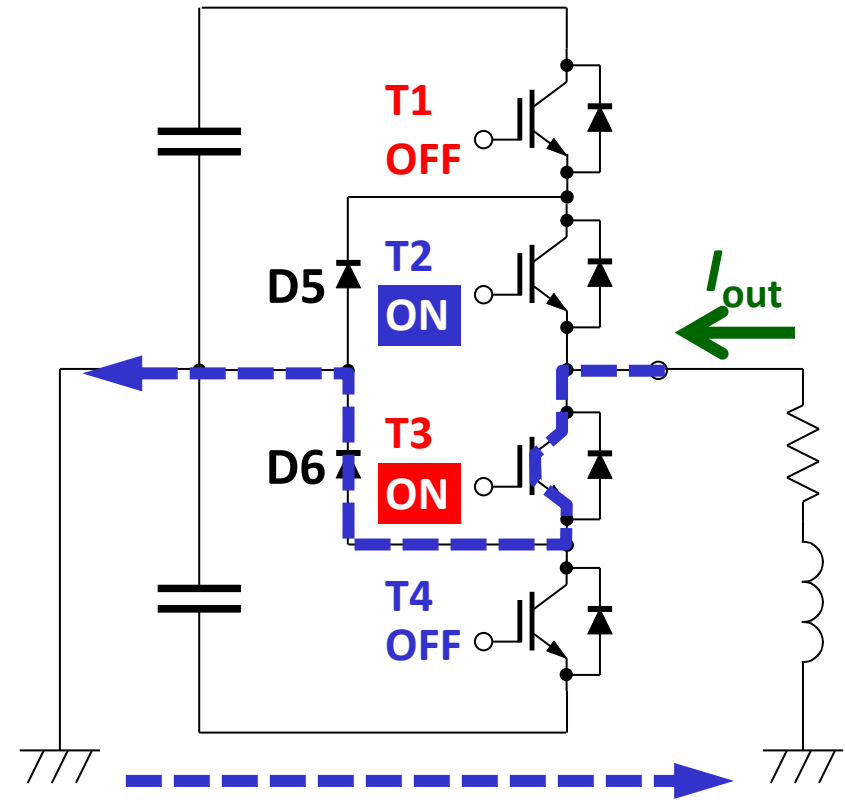
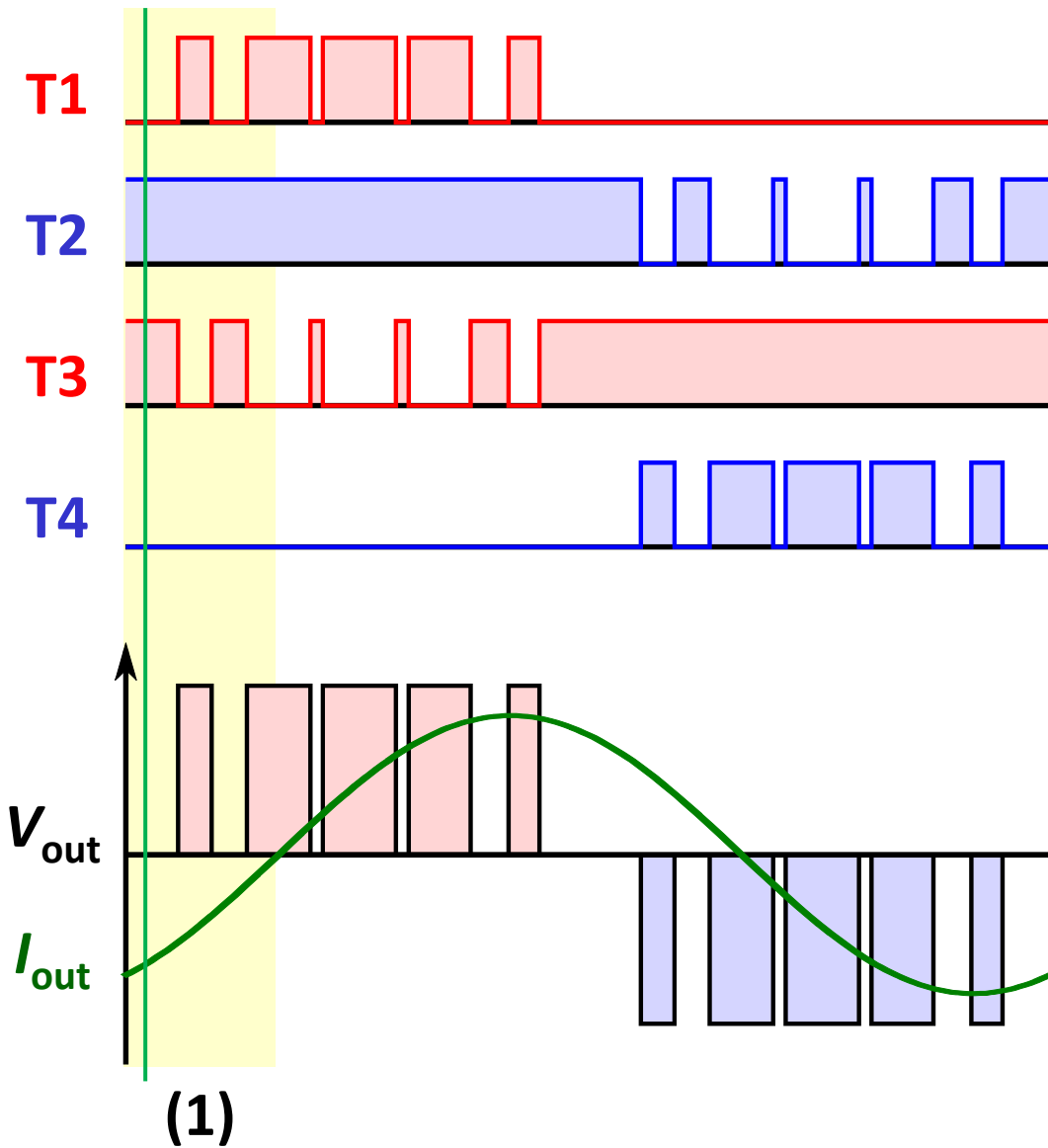


Loss Matrix

		Voltage			
		+E	0	0	-E
Current	+ I_o	(2)		(3)	
		Psat: T1 Psat: T2 ← (mode A): Eon: T1 Err: D5 → (mode A): Eoff: T1	Psat: T2 Pf: D5	Psat: T2 Pf: D5 → (mode B): Eoff: T2 ← (mode B): Eon: T2 Err: D4	Pf: D3 Pf: D4
	- I_o	(1)		(4)	
		Pf: D1 Pf: D2 ← (mode B): Eoff: T3 → (mode B): Eon: T3 Err: D1	Psat: T3 Pf: D6	Psat: T3 Pf: D6 → (mode A): Eon: T4 Err: D6 ← (mode A): Eoff: T4	Psat: T3 Psat: T4

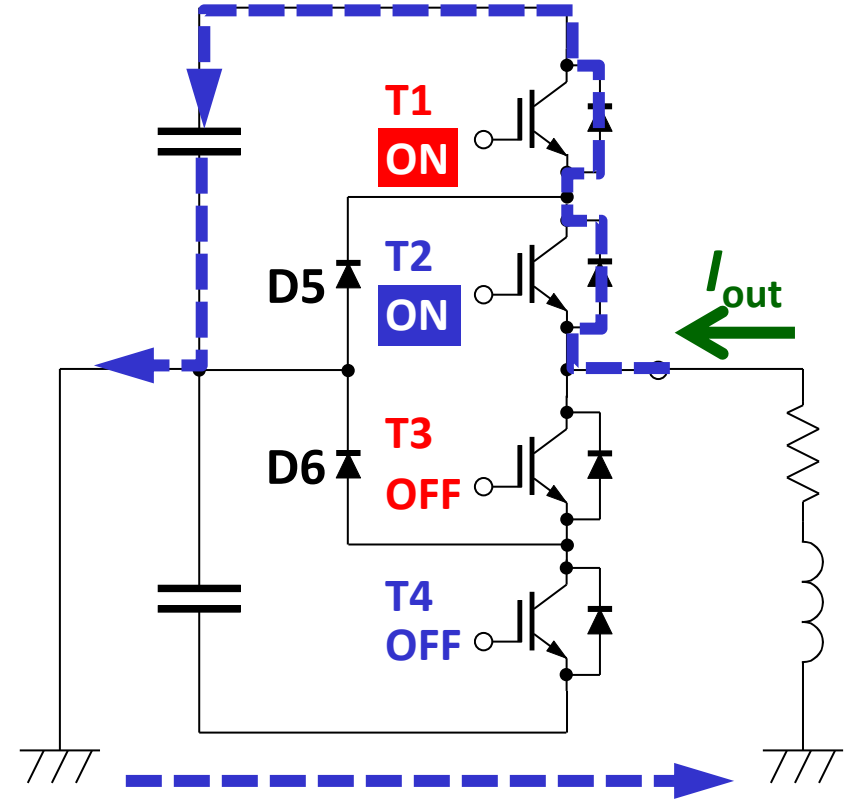
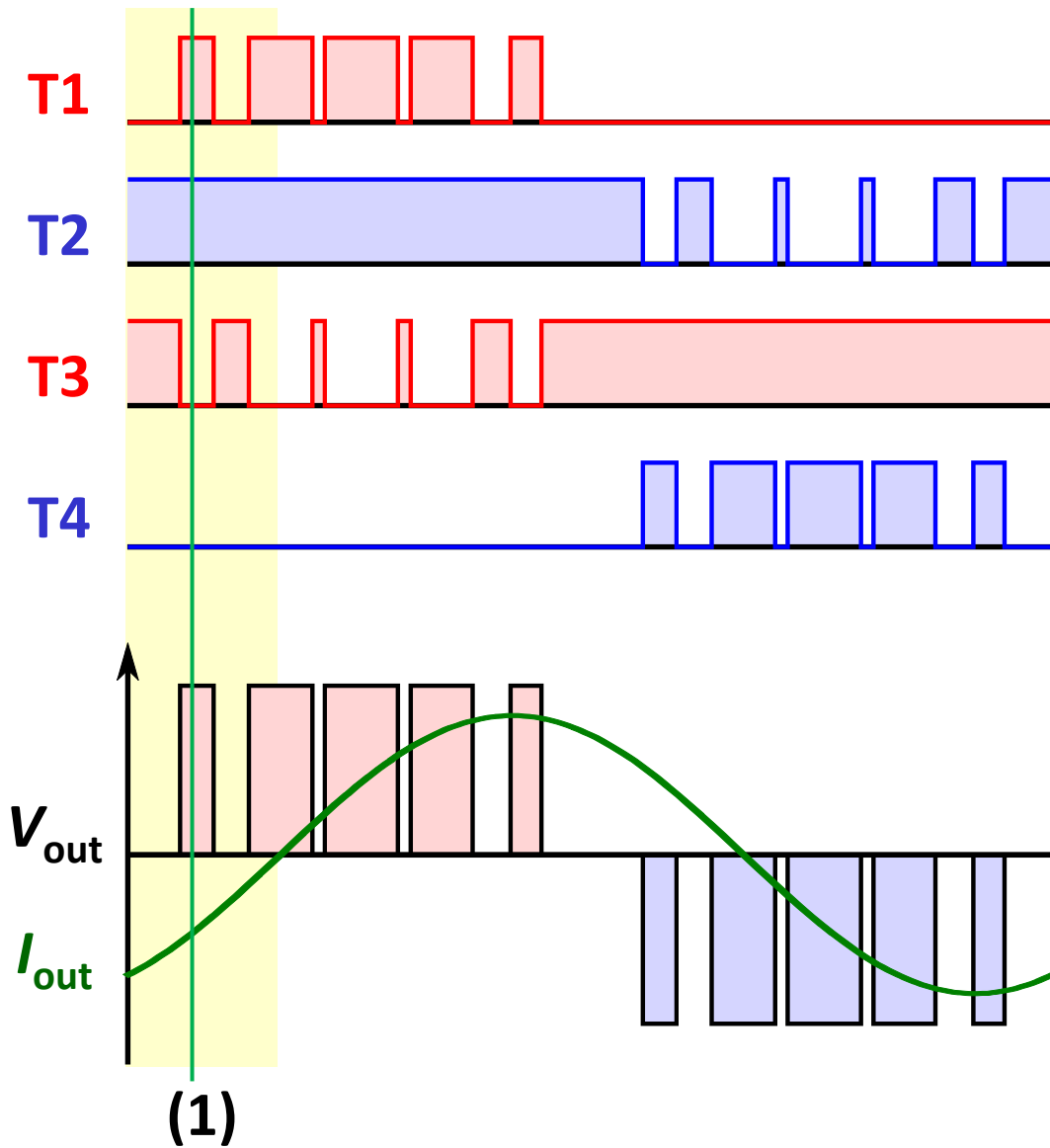
※ There is no Err on D2 and D3

Switching Pattern (1) SW mode B



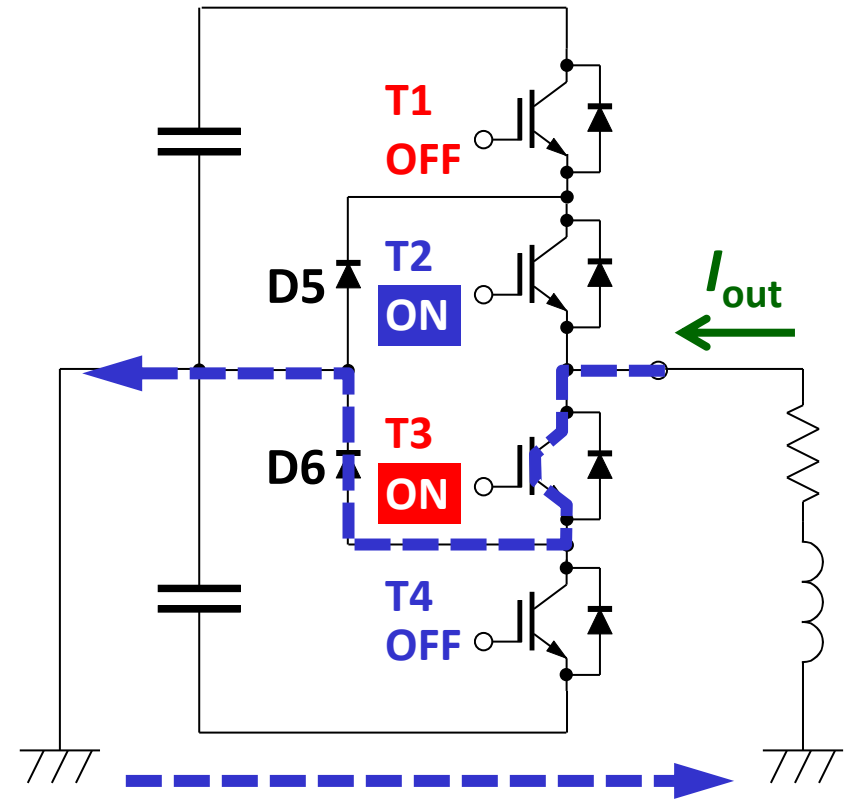
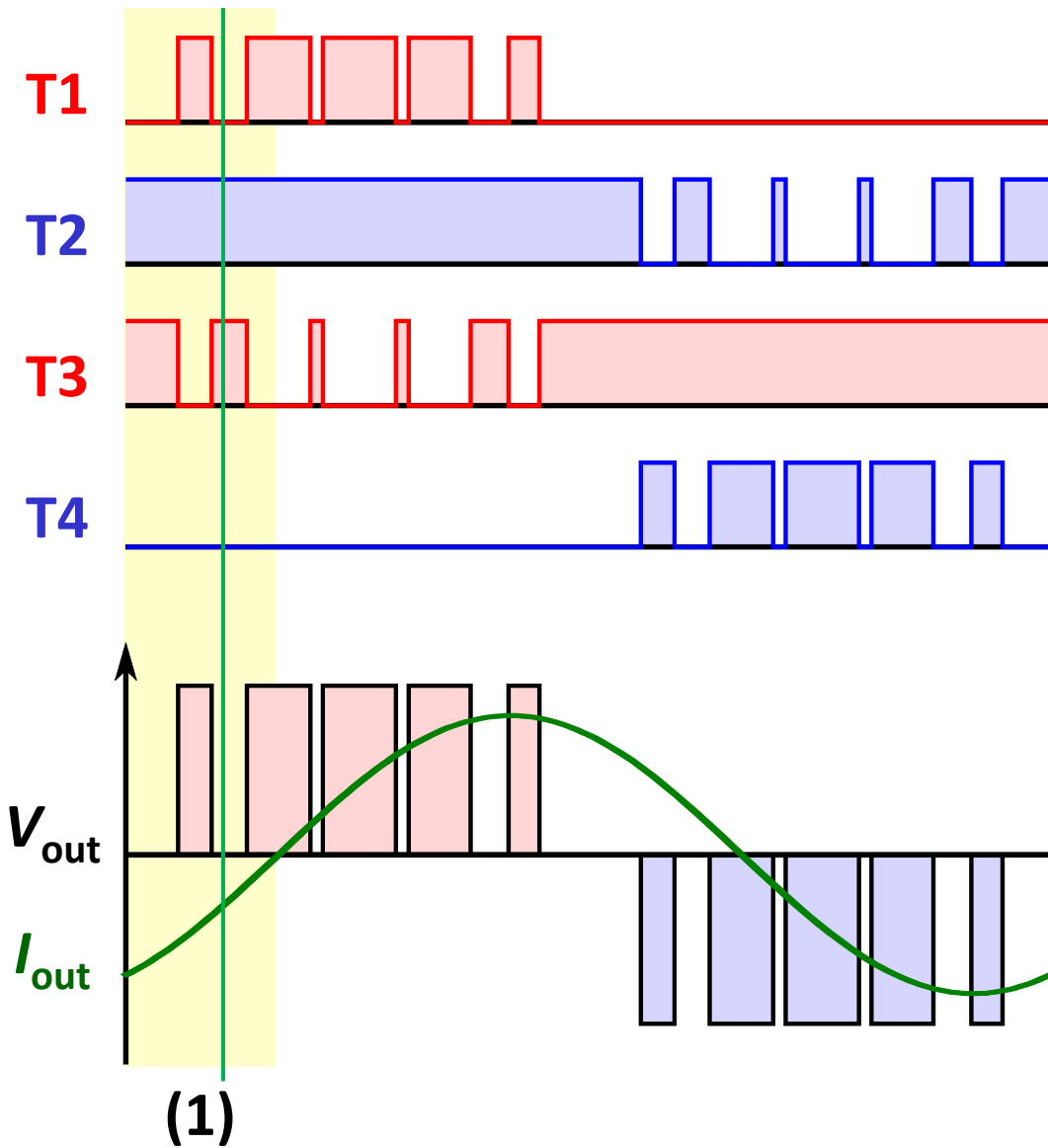
T2: ON
T3: Turn on (Free wheeling)
D6: Free wheeling

Switching Pattern (1) SW mode B



D1: Free wheeling
D2: Free wheeling
T3: Turn OFF

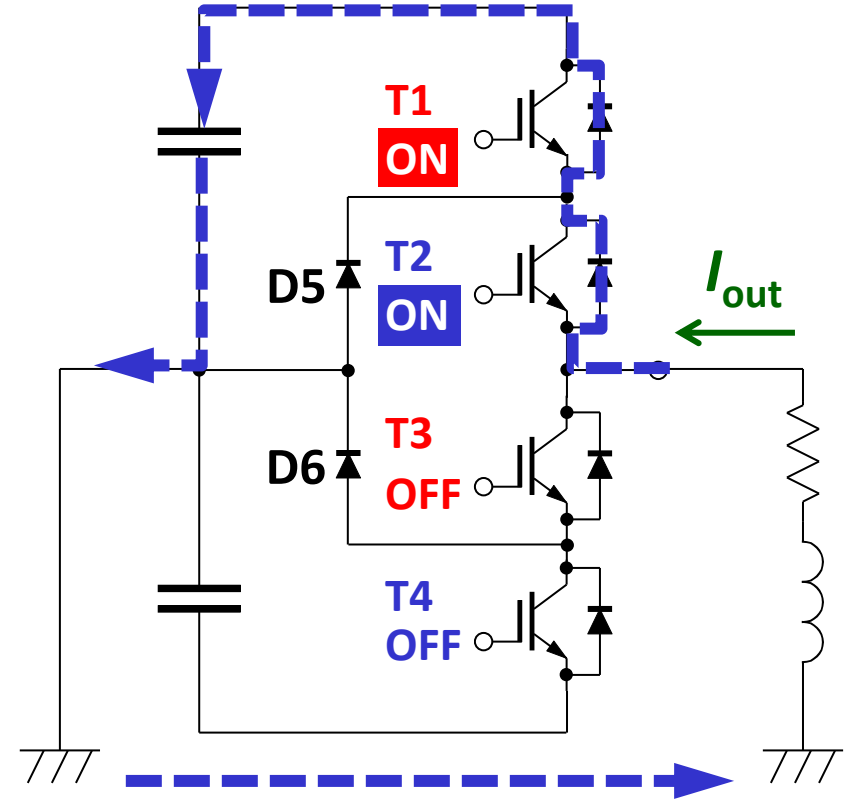
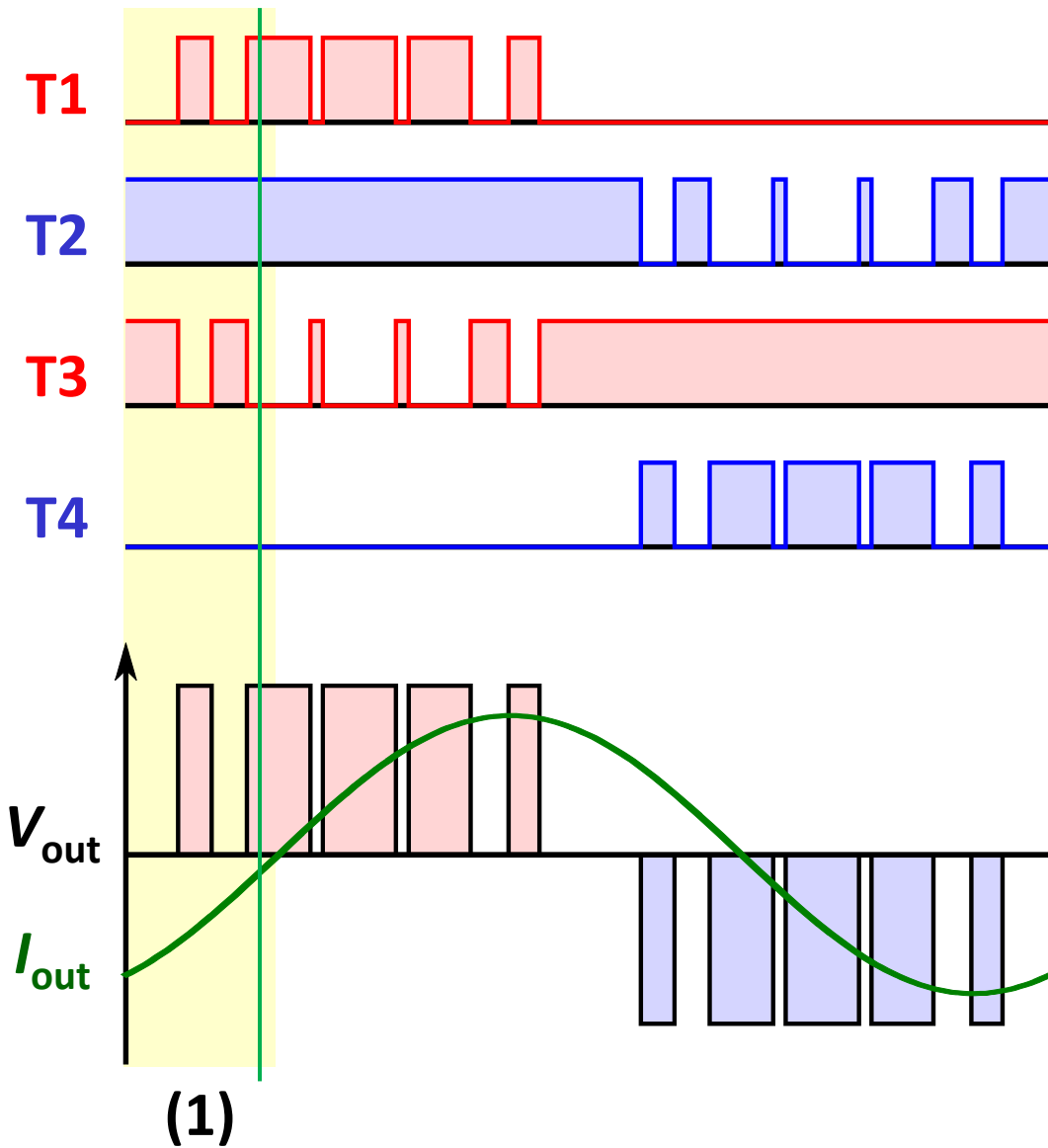
Switching Pattern (1) SW mode B



D1: Reverse recovery

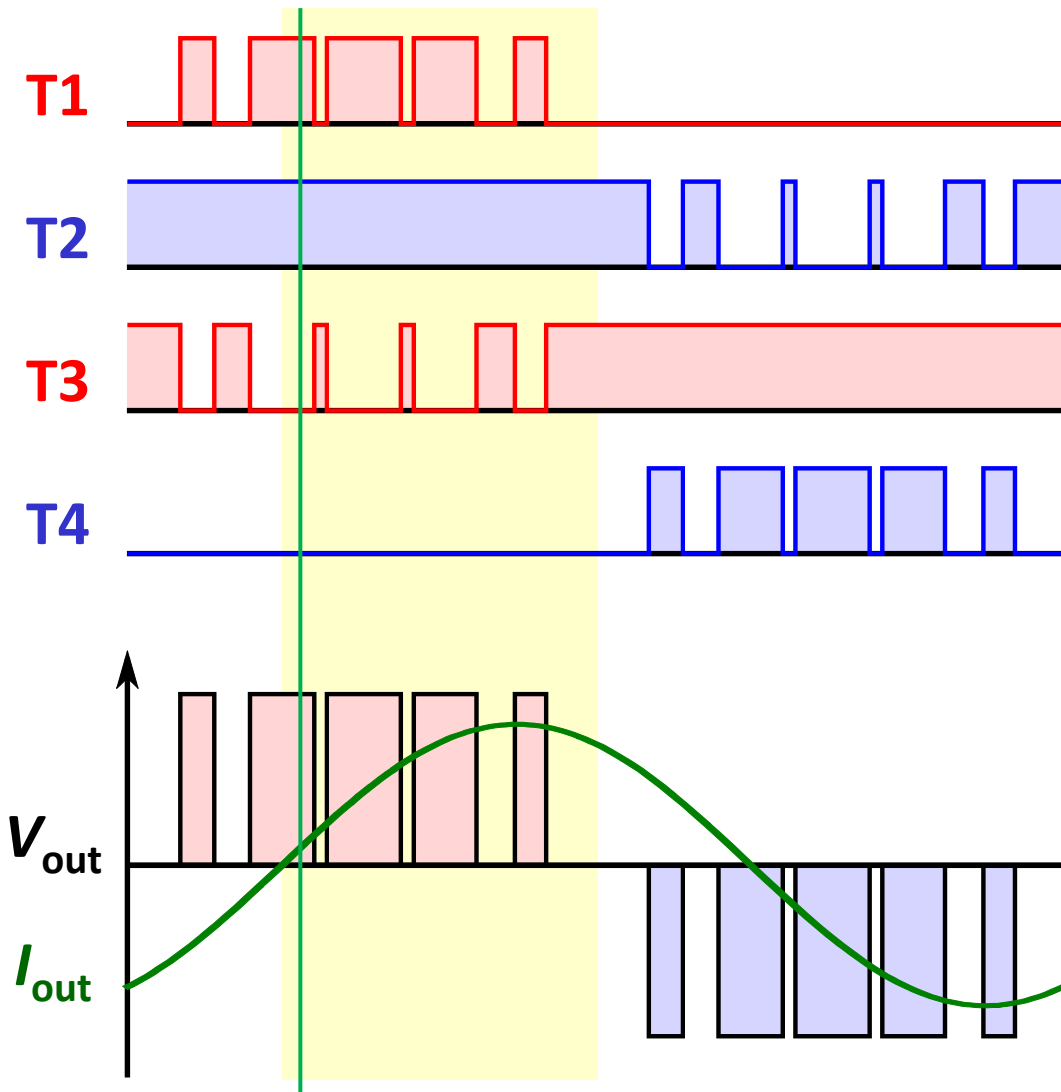
T3: Turn ON

Switching Pattern (1) SW mode B

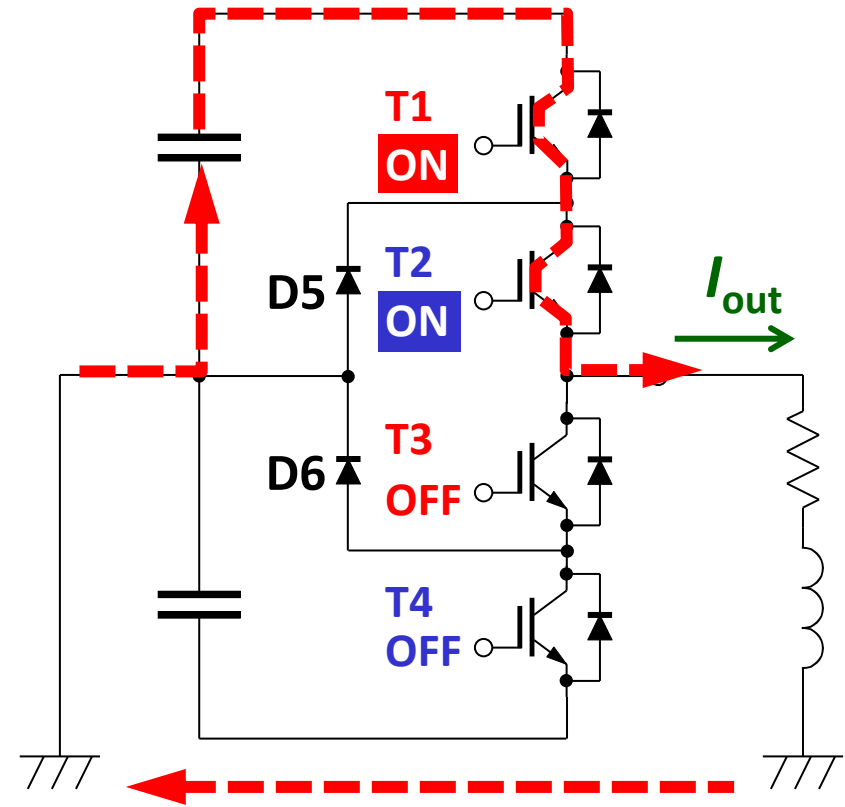


D1: Free wheeling
D2: Free wheeling
T3: Turn OFF

Switching Pattern (2) SW mode A



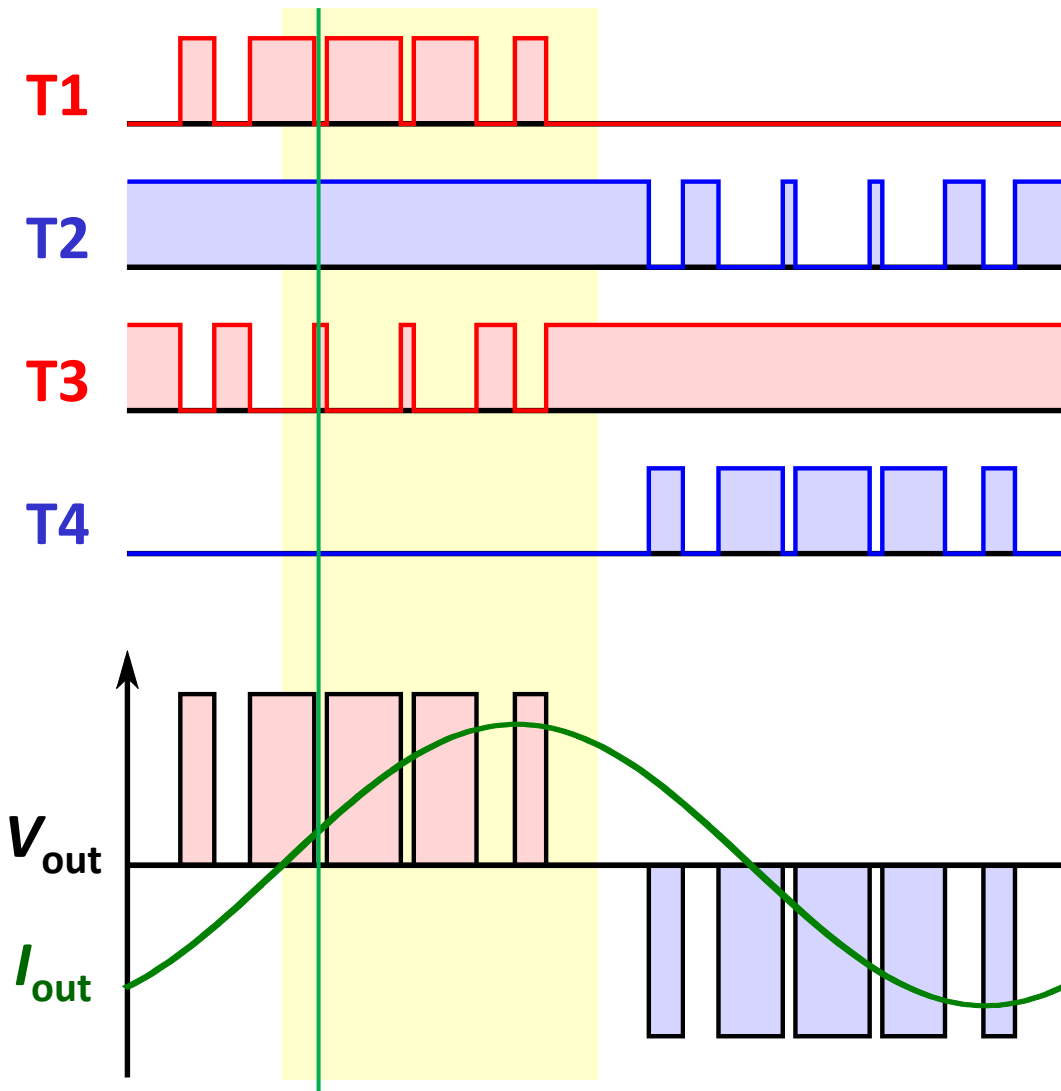
(2)



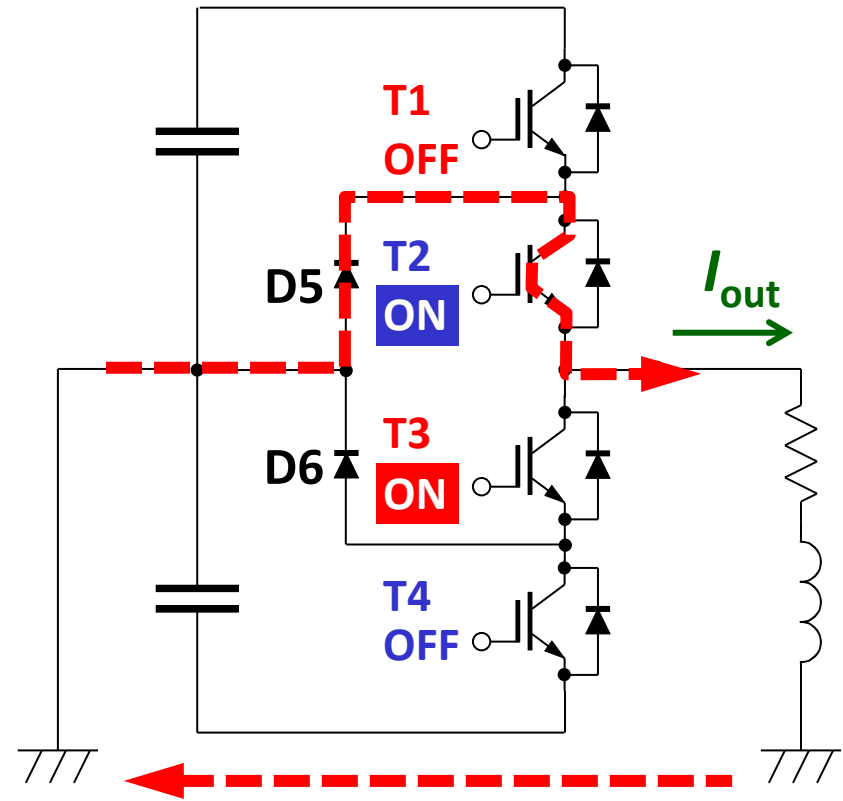
T1: ON

T2: ON

Switching Pattern (2) SW mode A

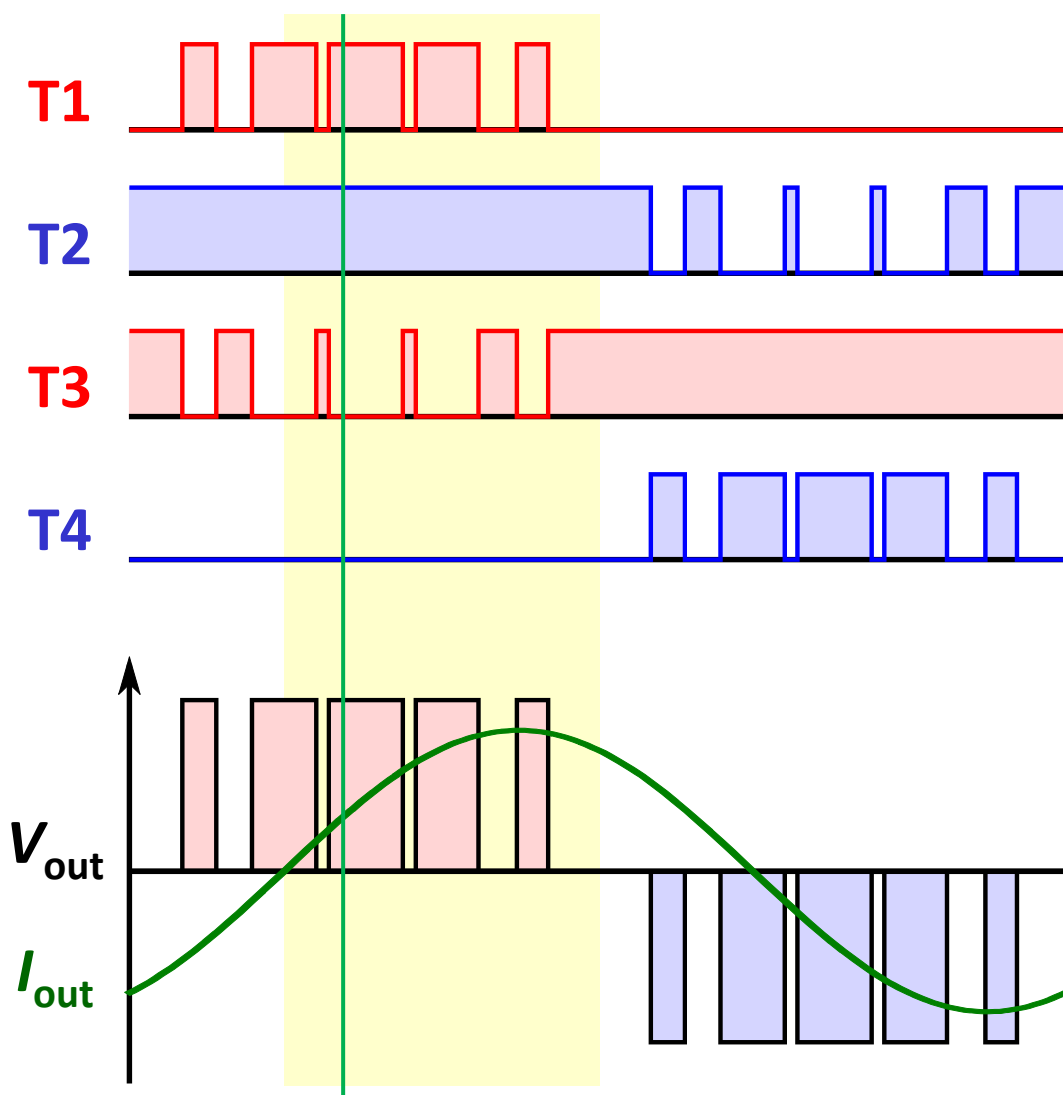


(2)

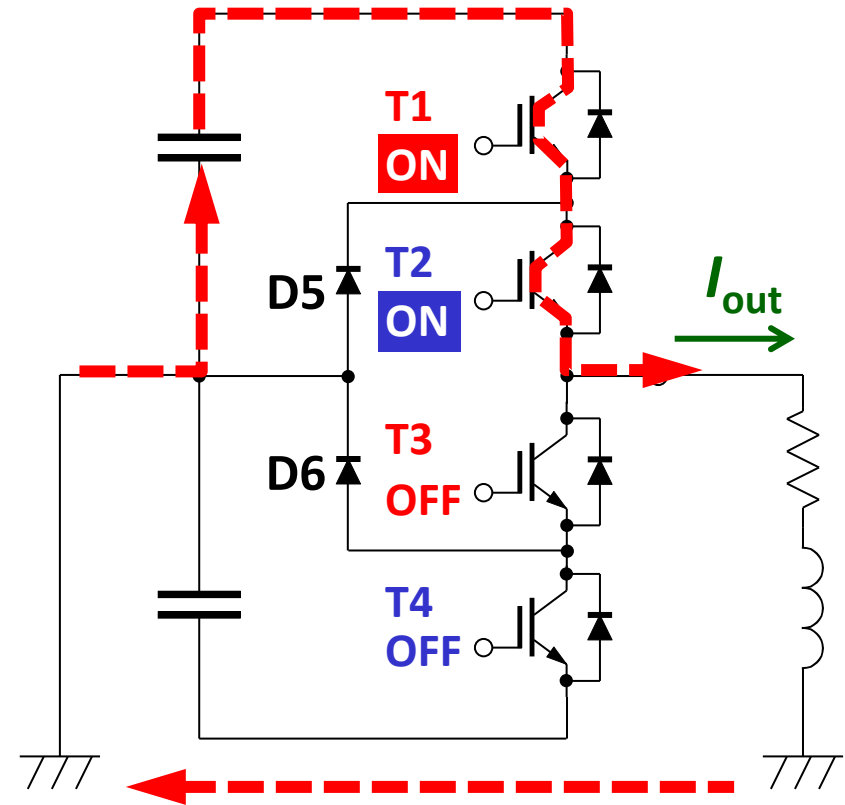


T1: Turn OFF
T2: ON
D5: Turn ON

Switching Pattern (2) SW mode A

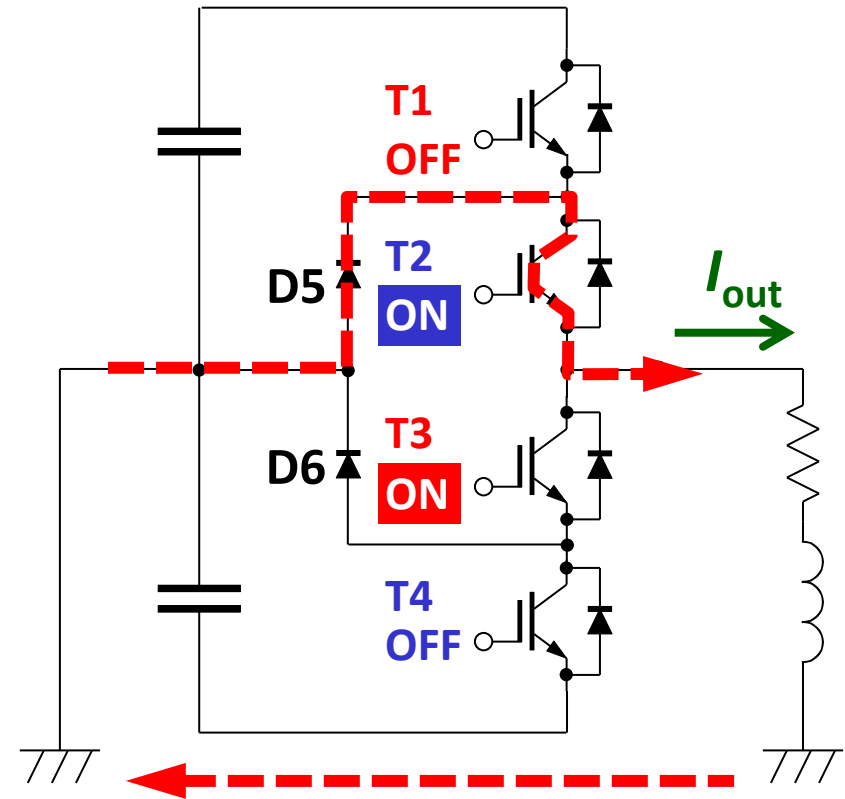
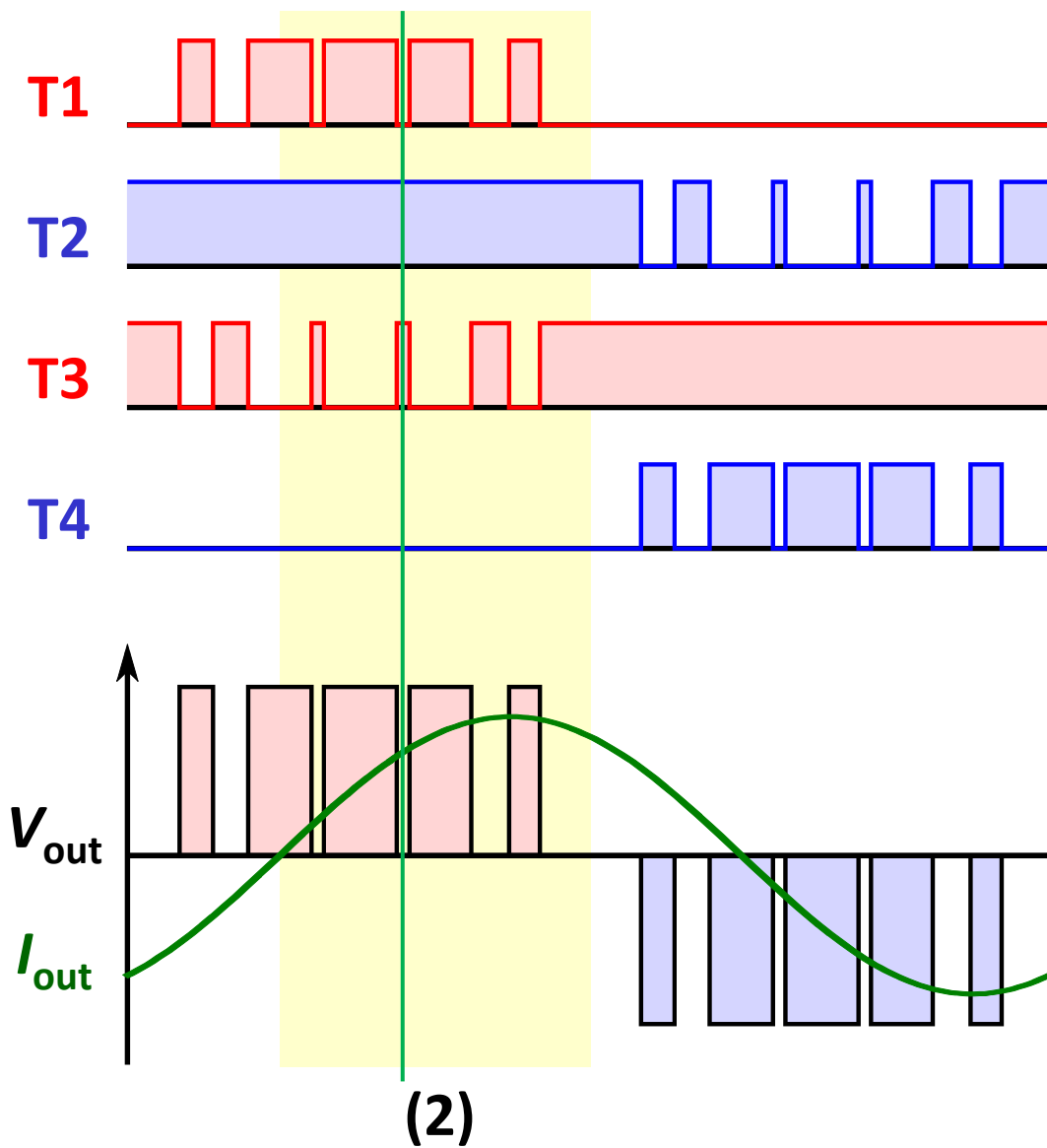


(2)



T1: Turn ON
T2: ON
D5: Reverse recovery

Switching Pattern (2) SW mode A

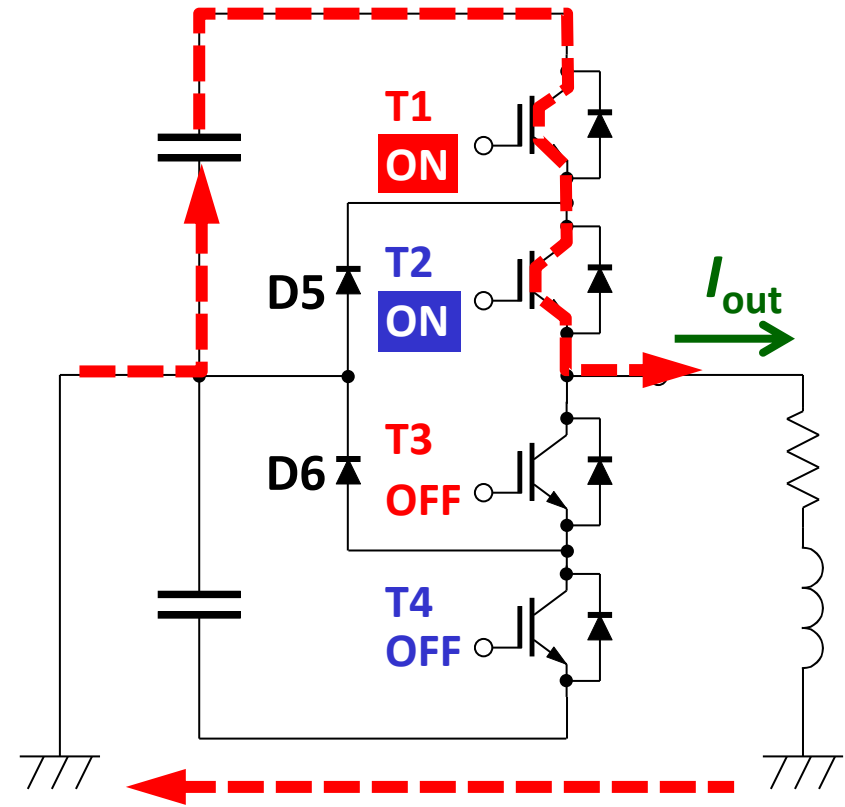
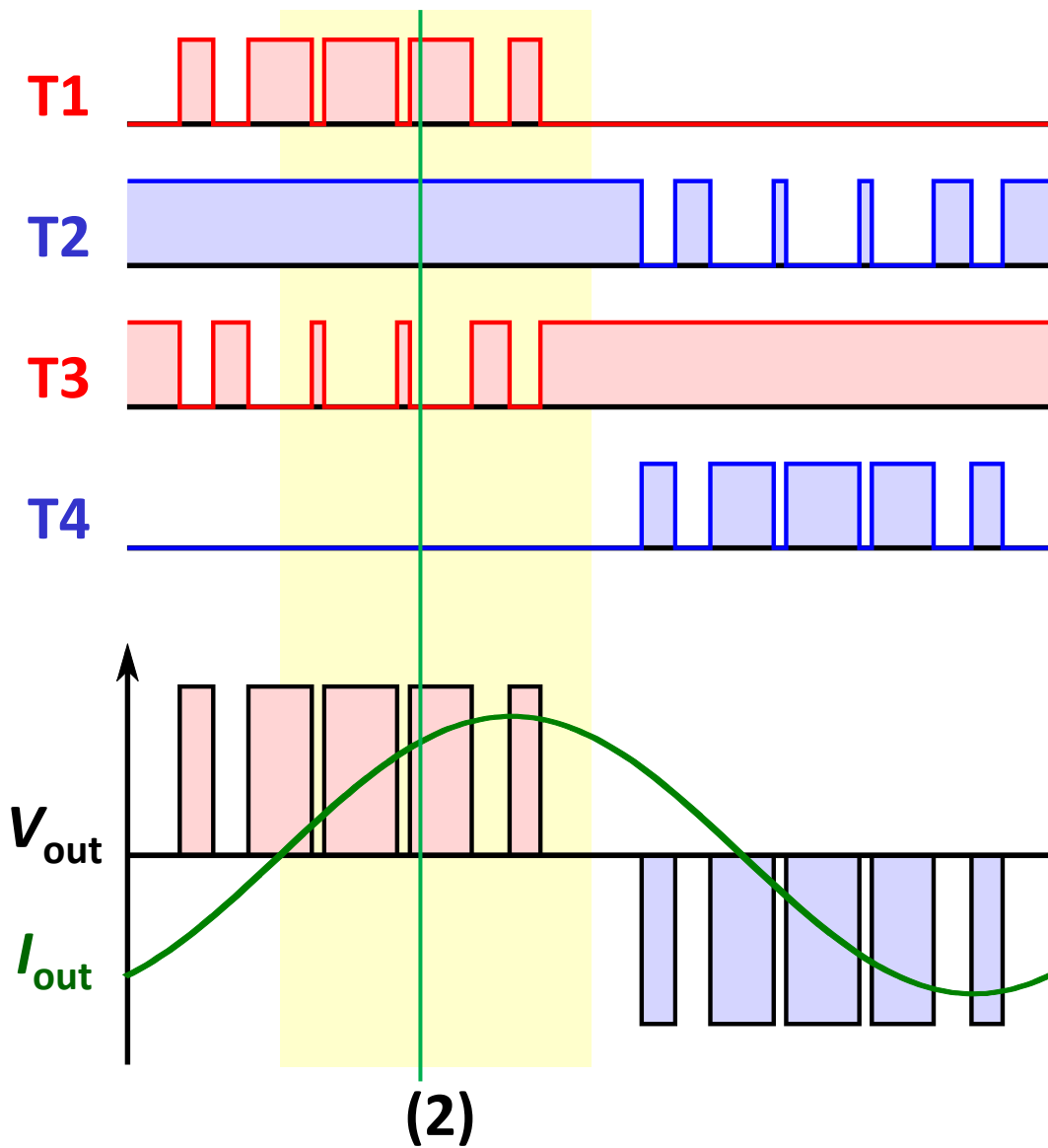


T1: Turn OFF

T2: ON

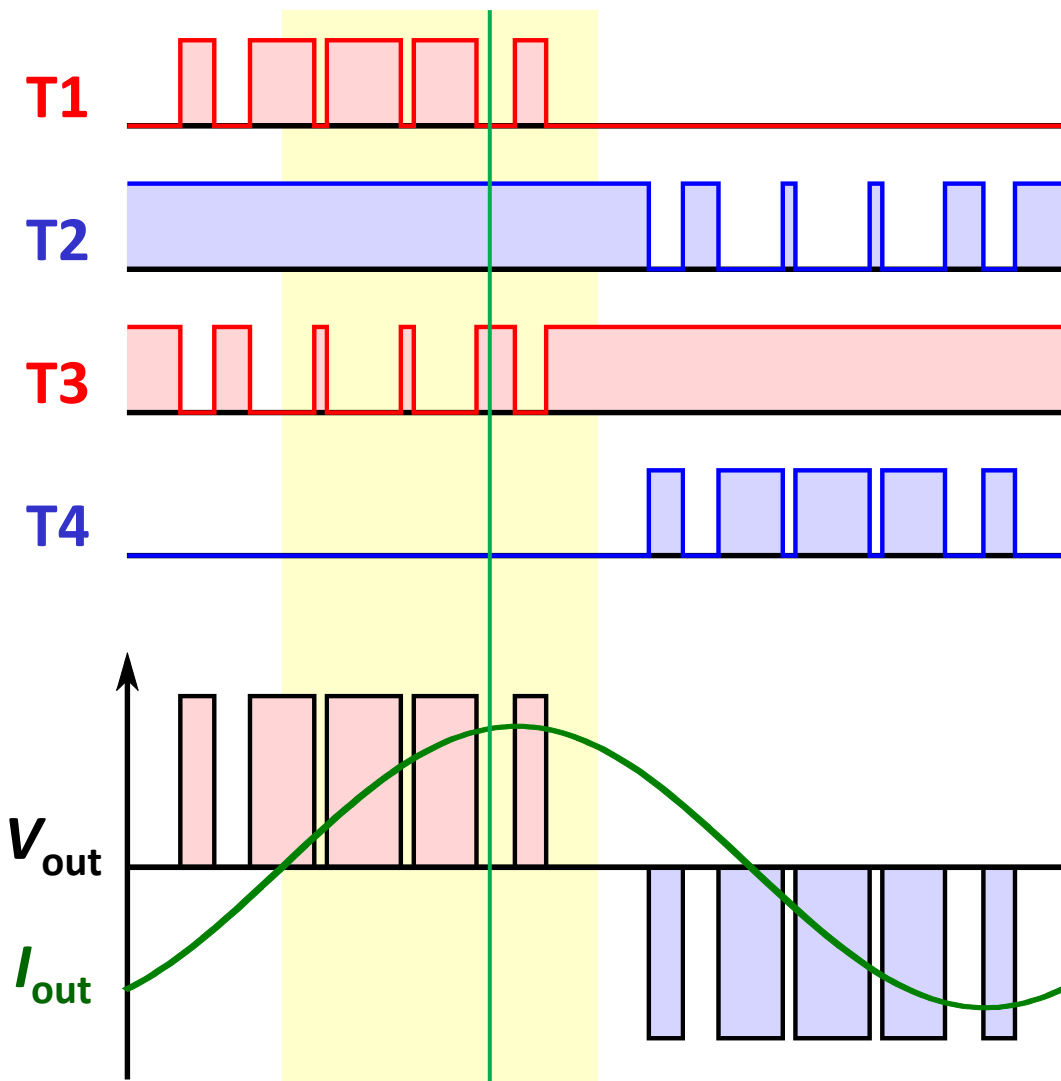
D5: Free wheeling

Switching Pattern (2) SW mode A

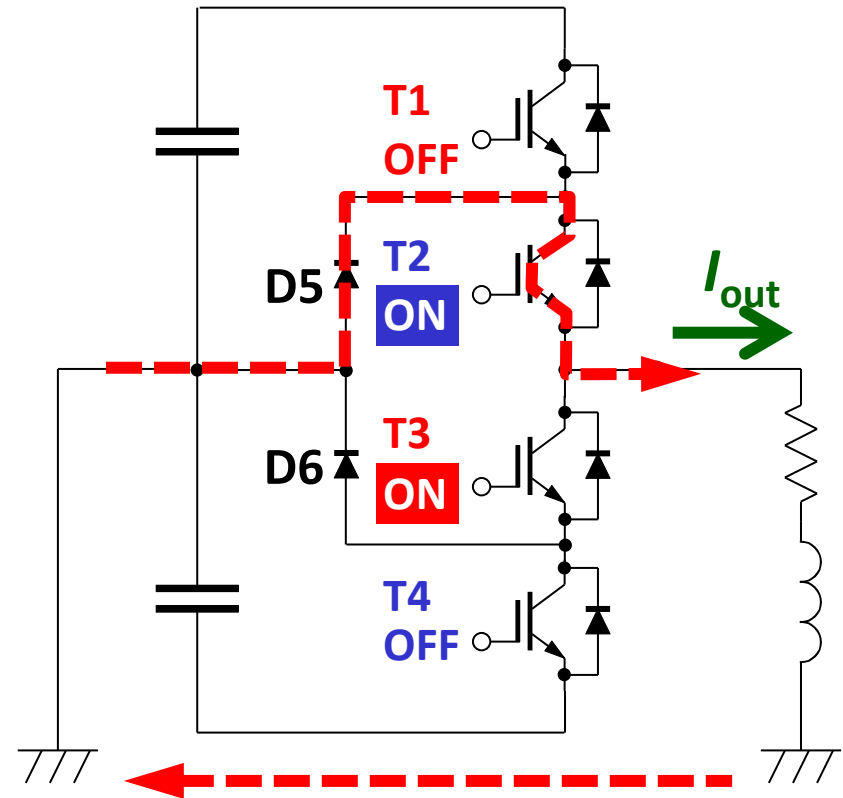


T1: Turn ON
T2: ON
D5: Reverse recovery

Switching Pattern (2) SW mode A

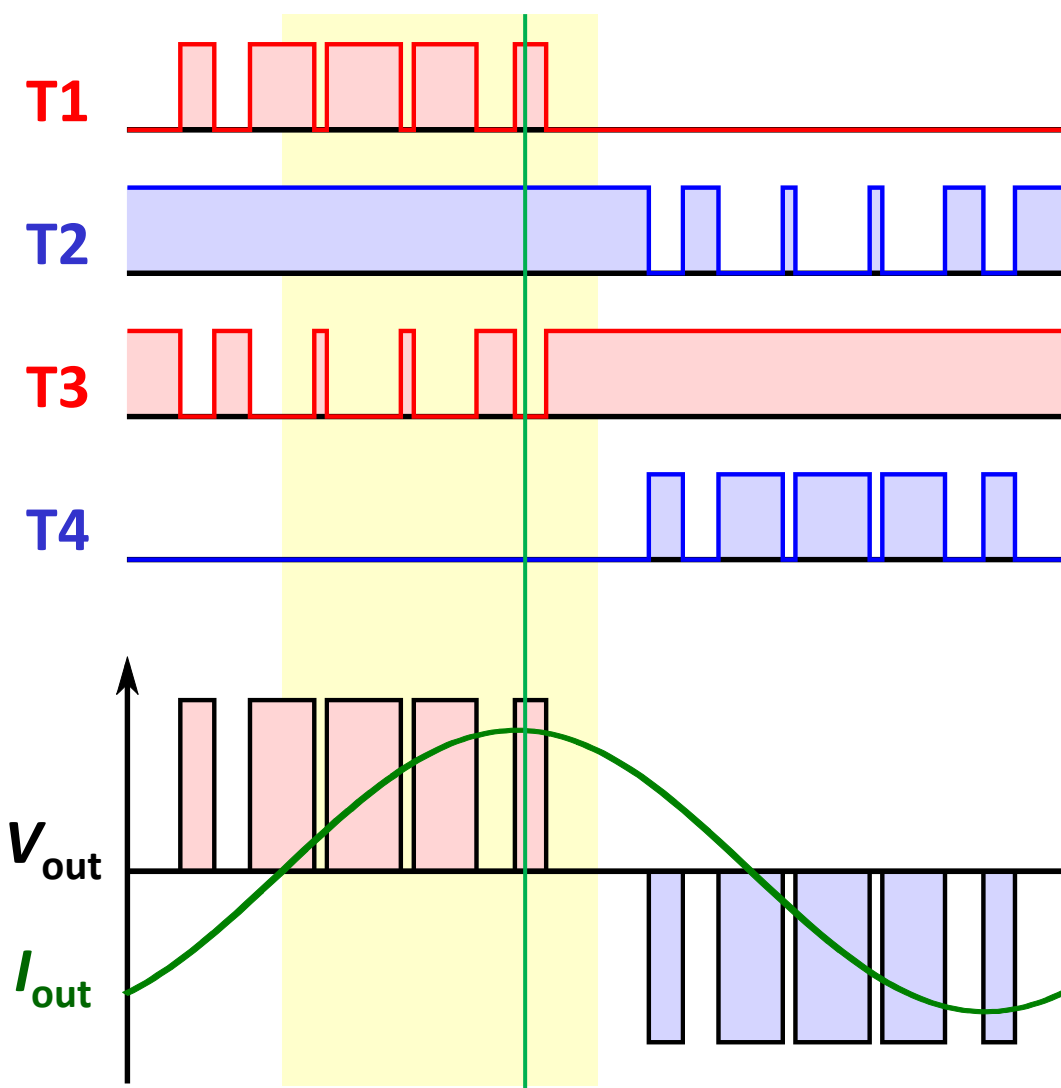


(2)

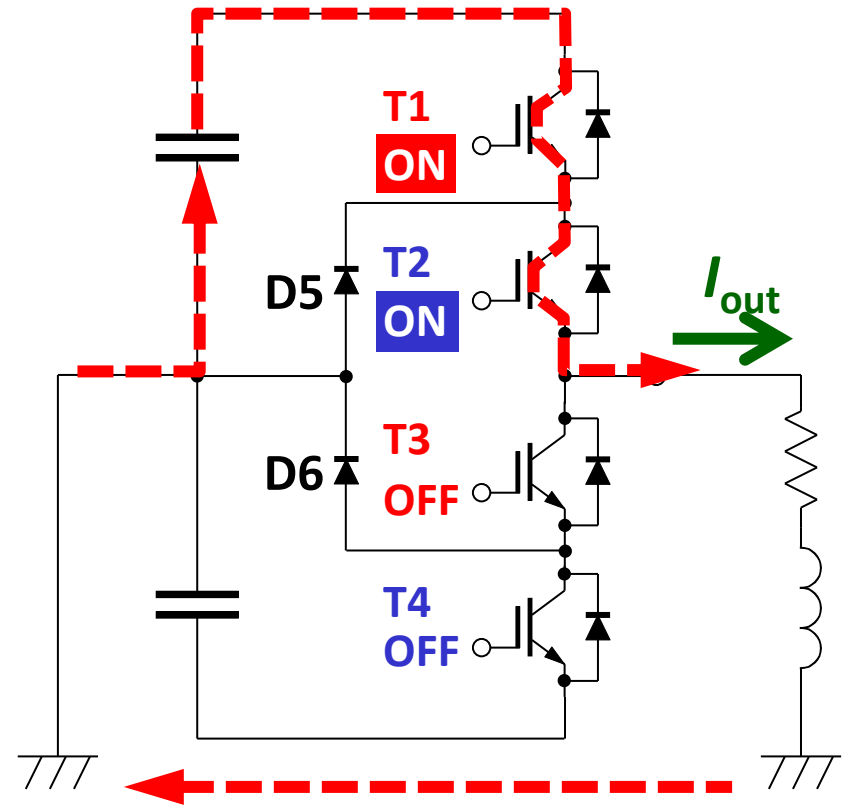


T1: Turn OFF
T2: ON
D5: Free wheeling

Switching Pattern (2) SW mode A

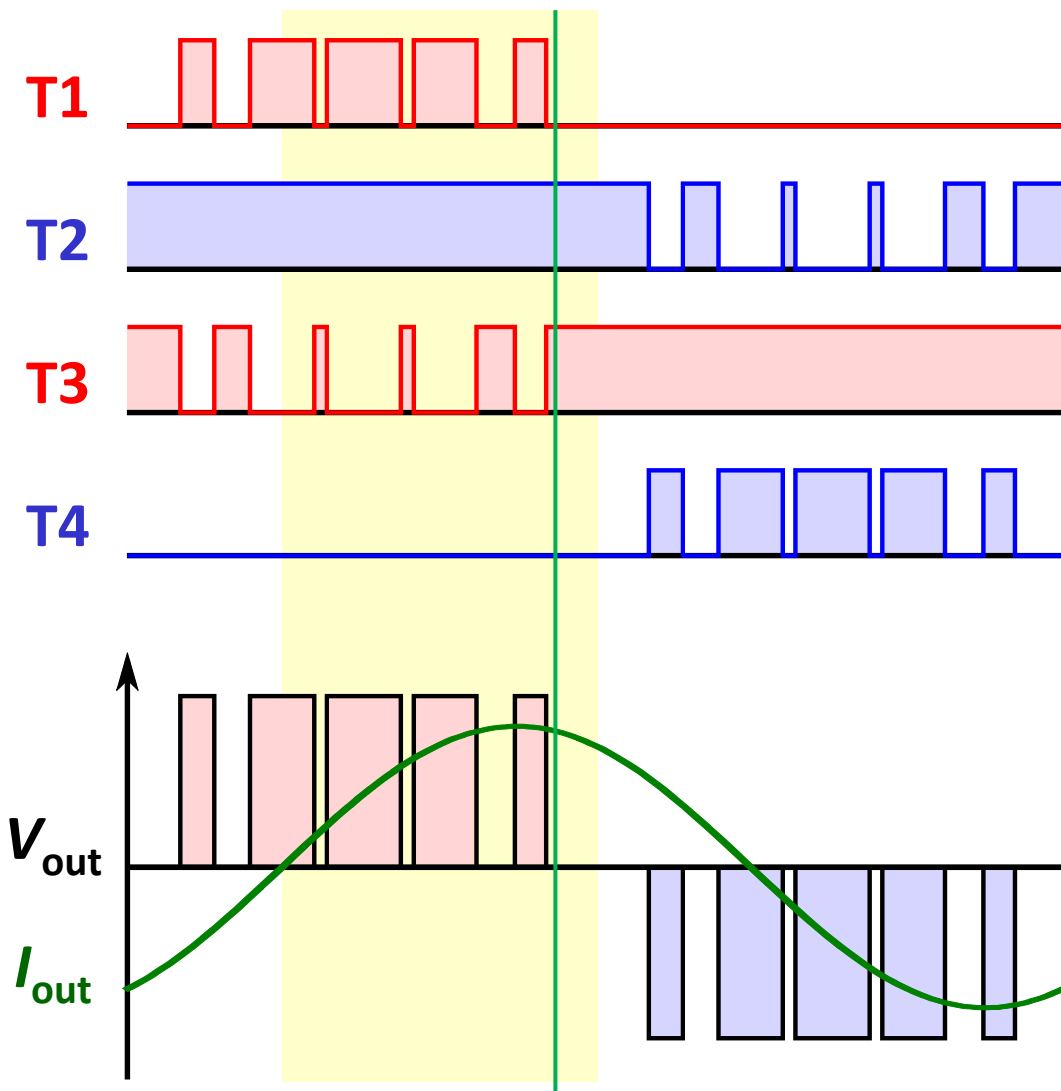


(2)

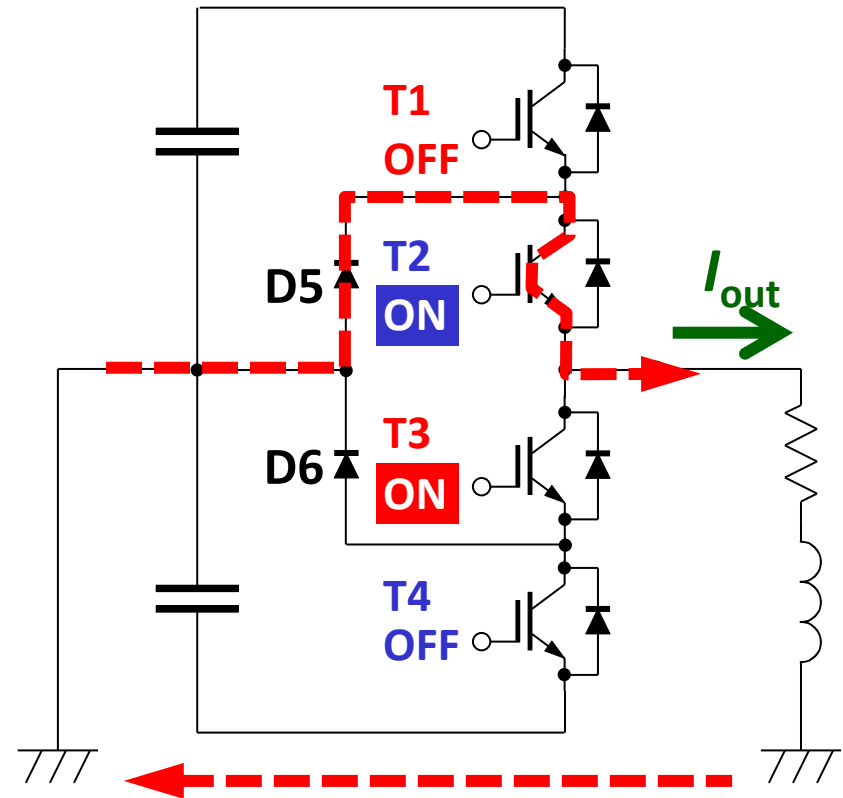


- T1: Turn ON
- T2: ON
- D5: Reverse recovery

Switching Pattern (2) SW mode A



(2)

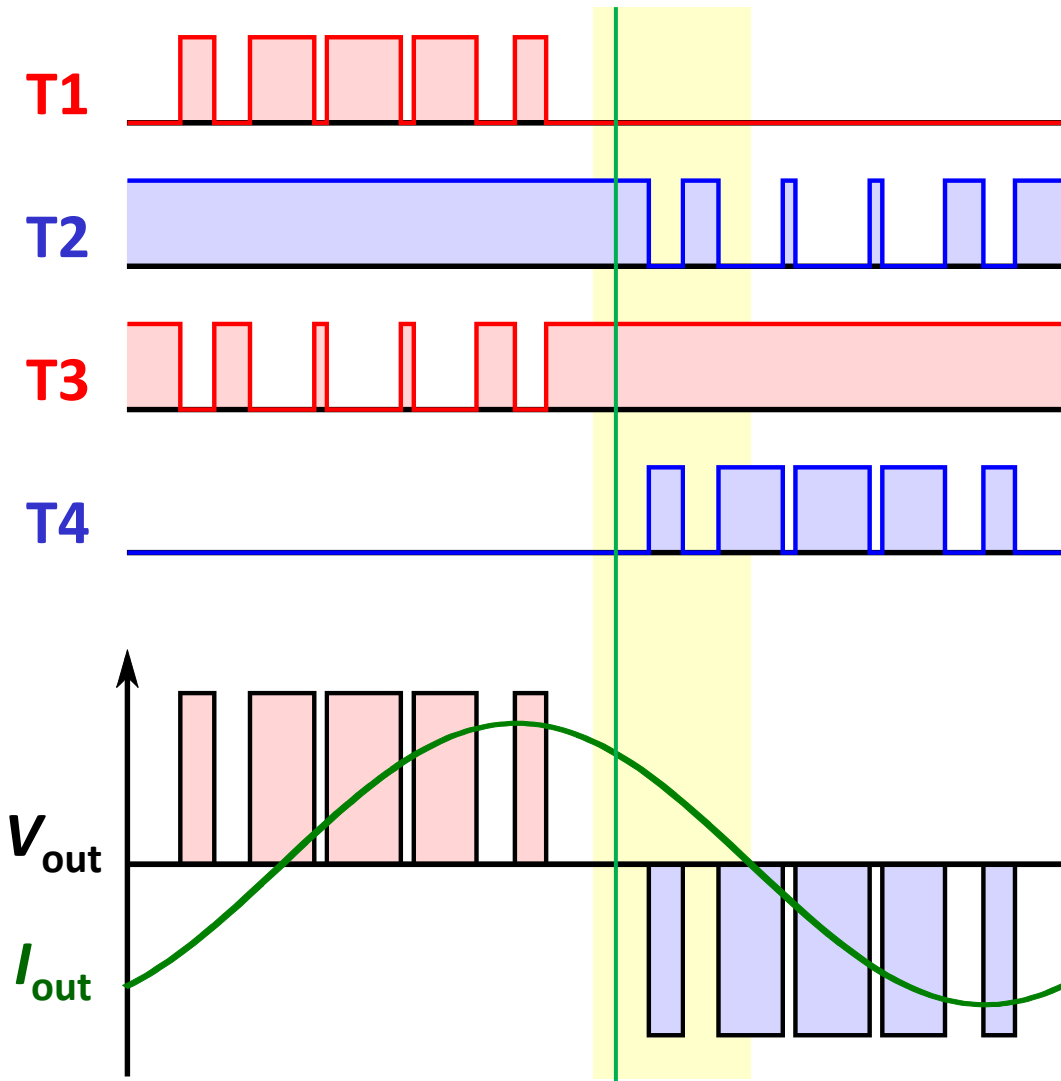


T1: Turn OFF

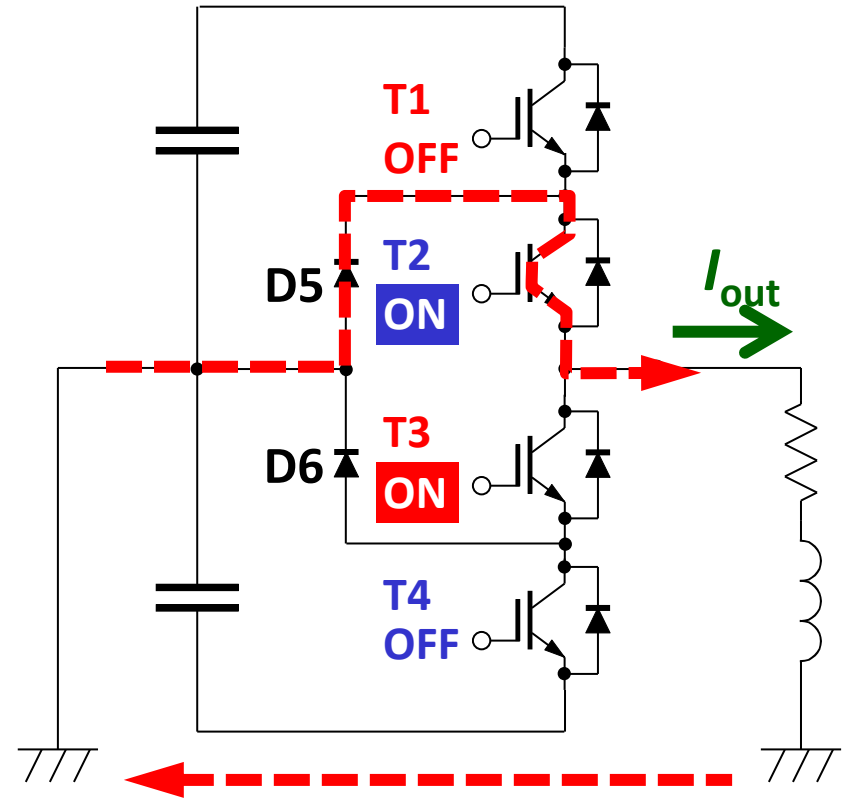
T2: ON

D5: Free wheeling

Switching Pattern (3) SW mode B'

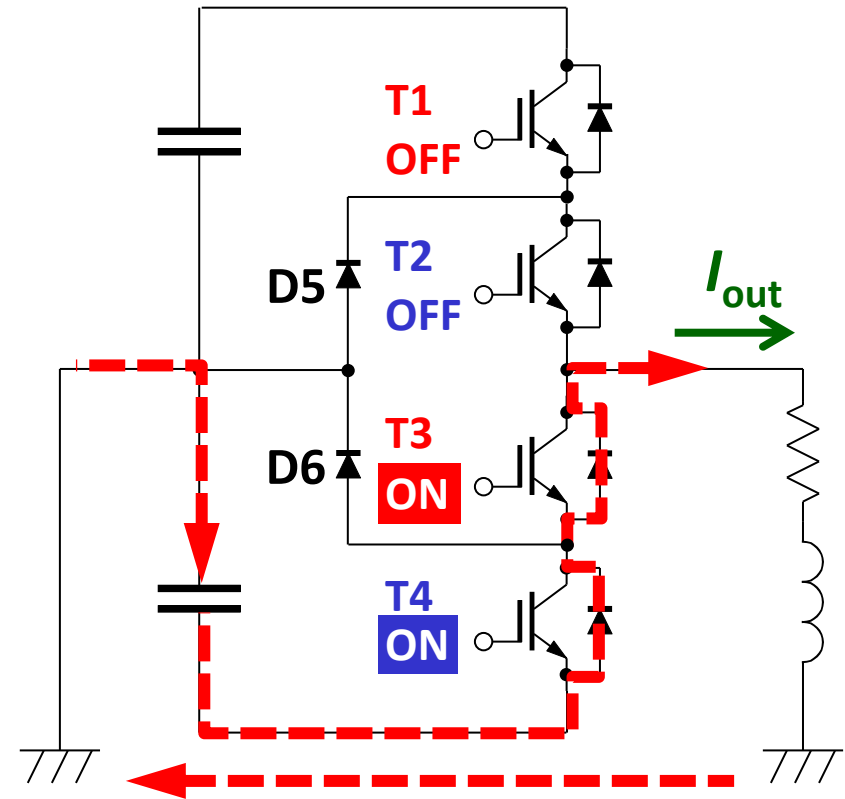
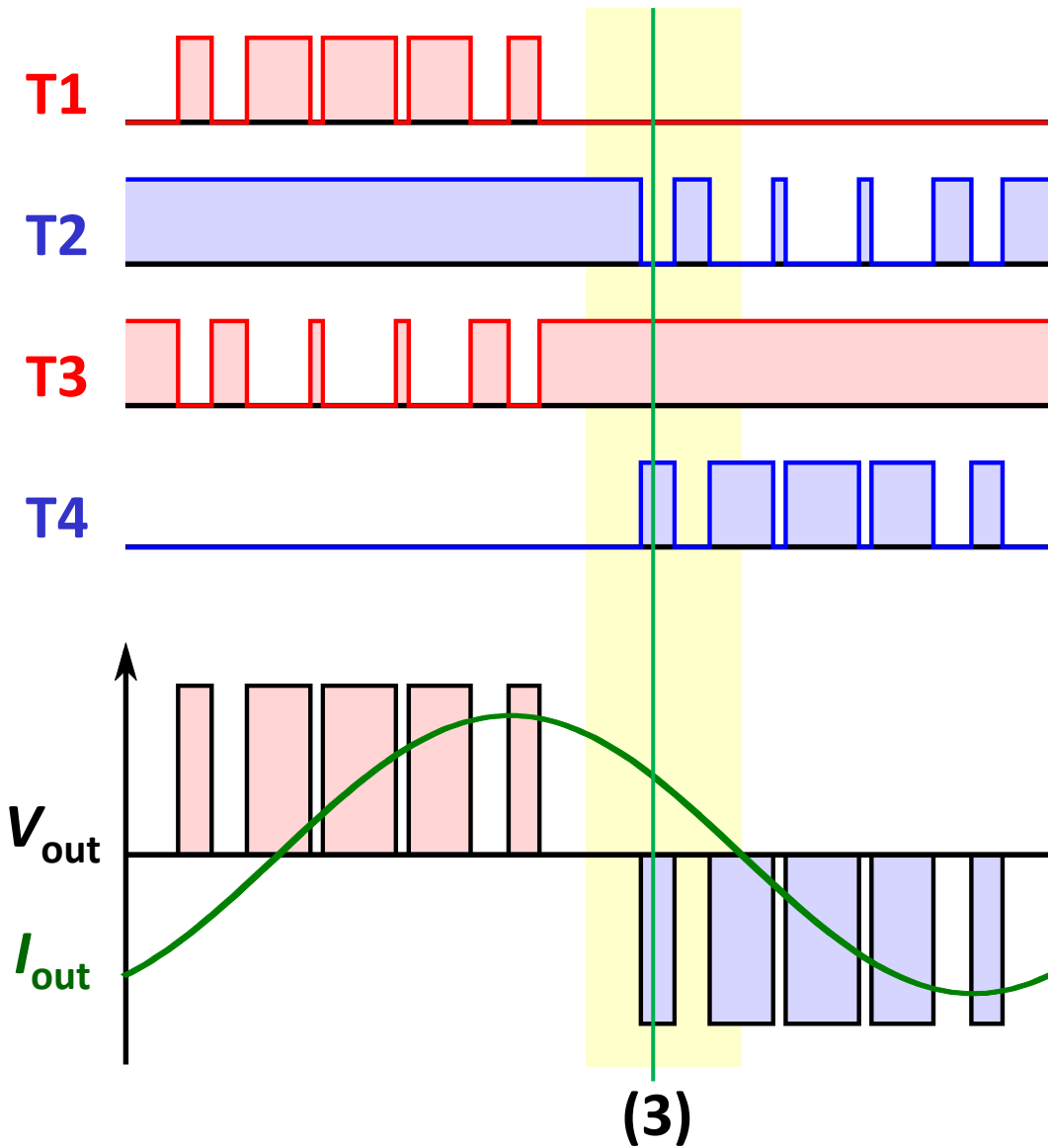


(3)



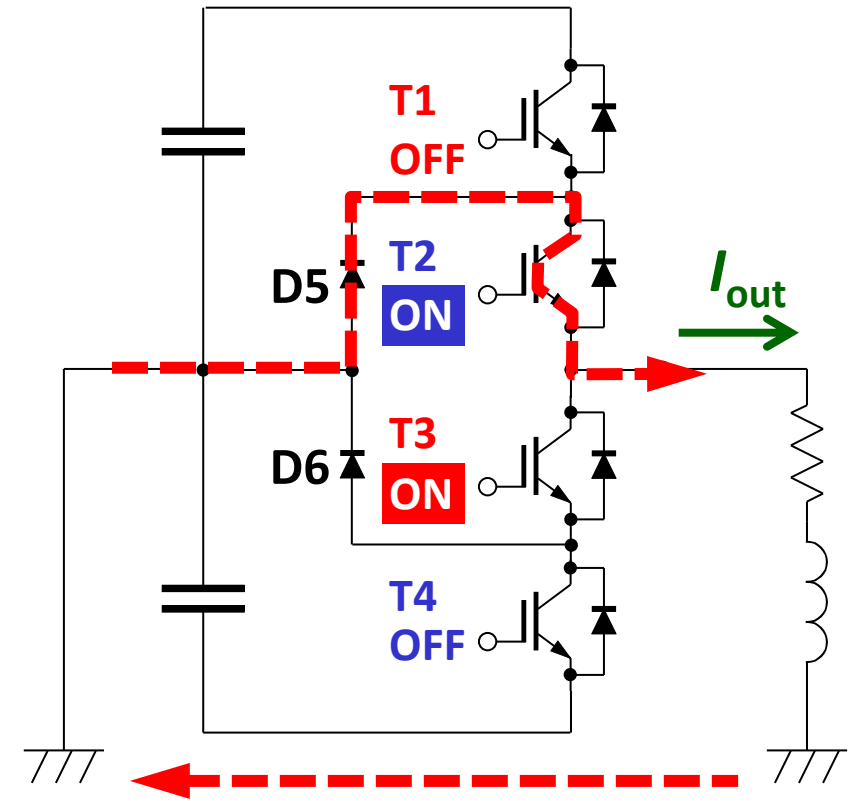
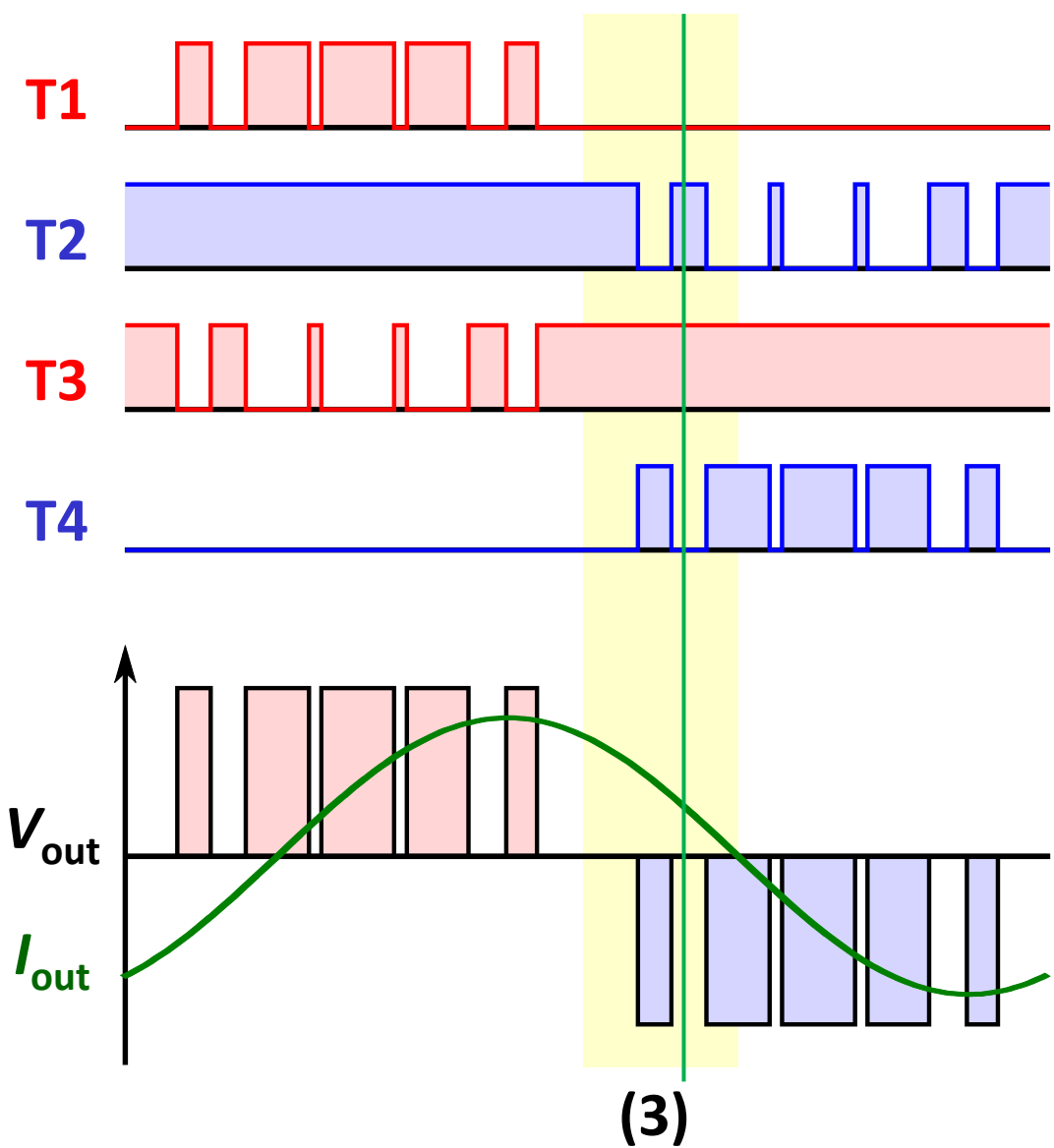
T2: ON
D5: Free wheeling

Switching Pattern (3) SW mode B'



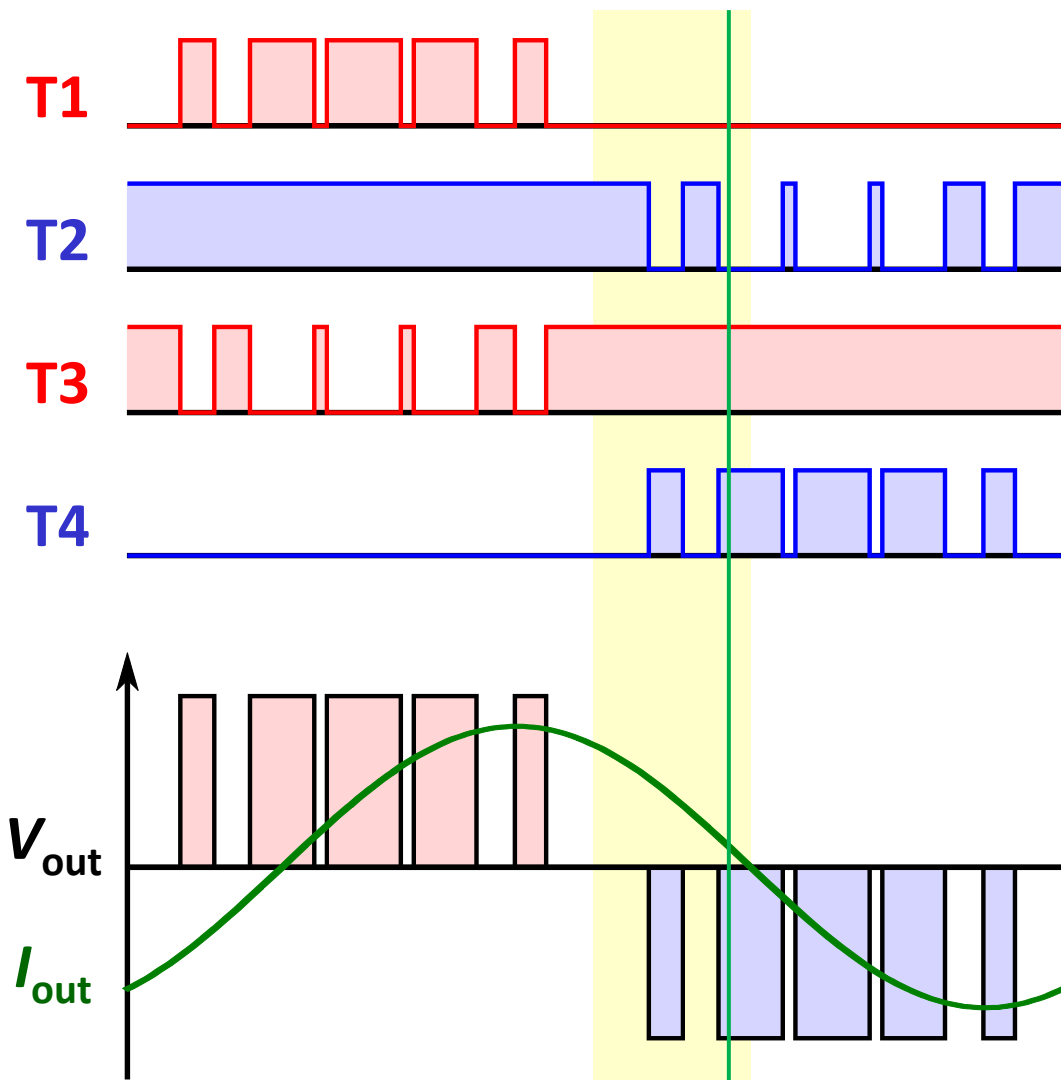
T2: Turn OFF
D3: Free wheeling
D4: Free wheeling

Switching Pattern (3) SW mode B'

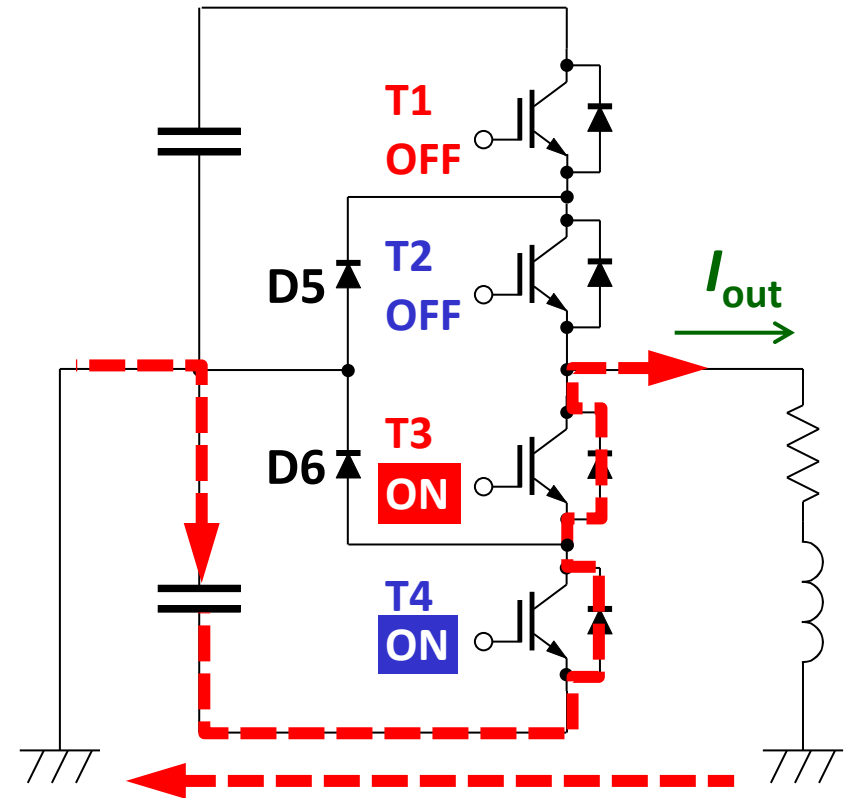


T2: Turn ON
D4: Reverse recovery
D5: Free wheeling

Switching Pattern (3) SW mode B'



(3)

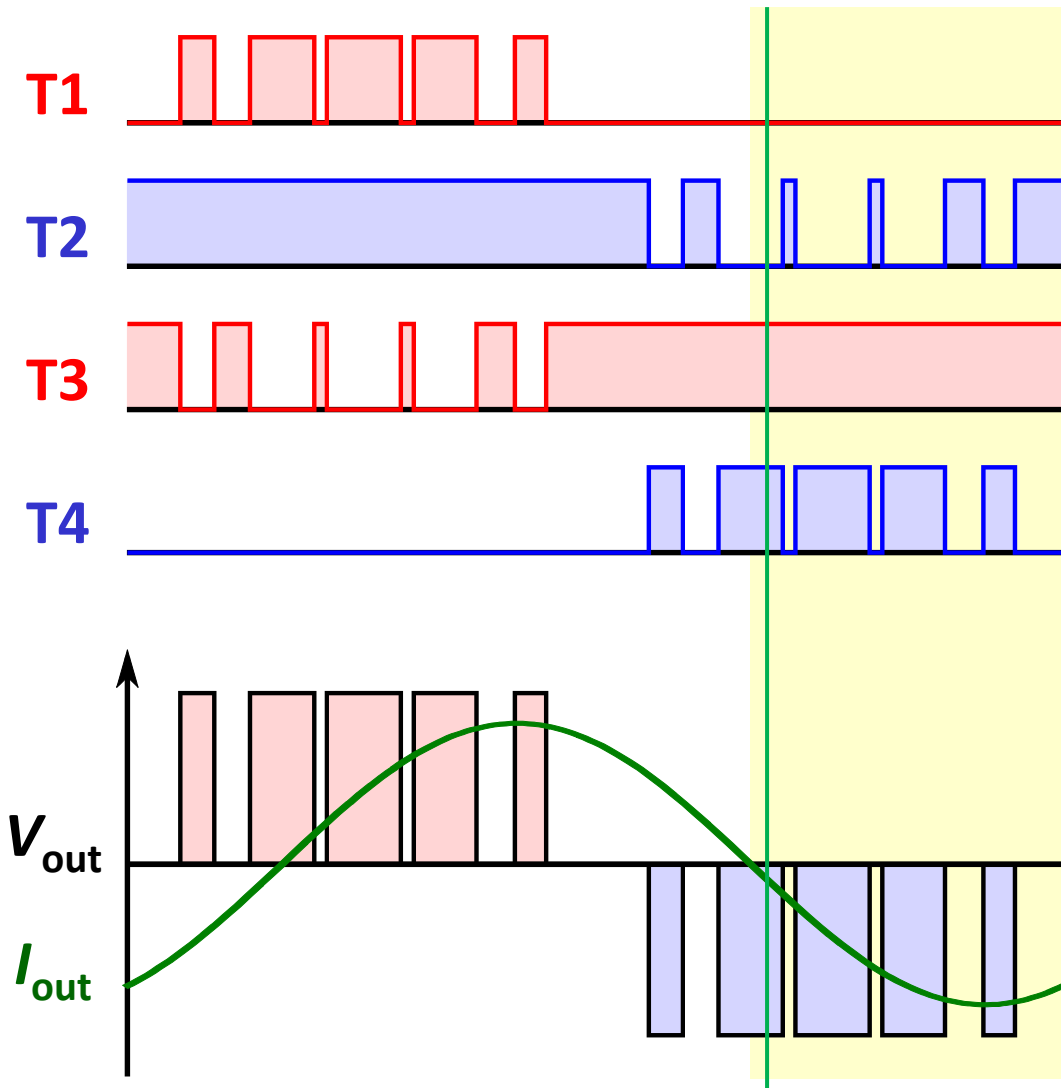


T2: Turn OFF

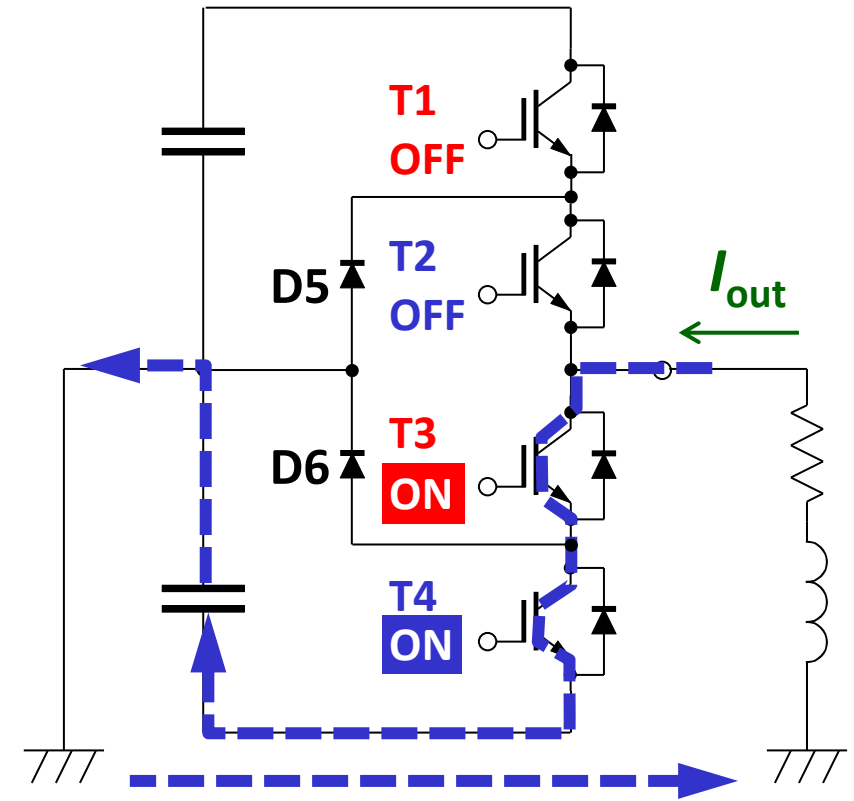
D3: Free wheeling

D4: Free wheeling

Switching Pattern (4) SW mode A'

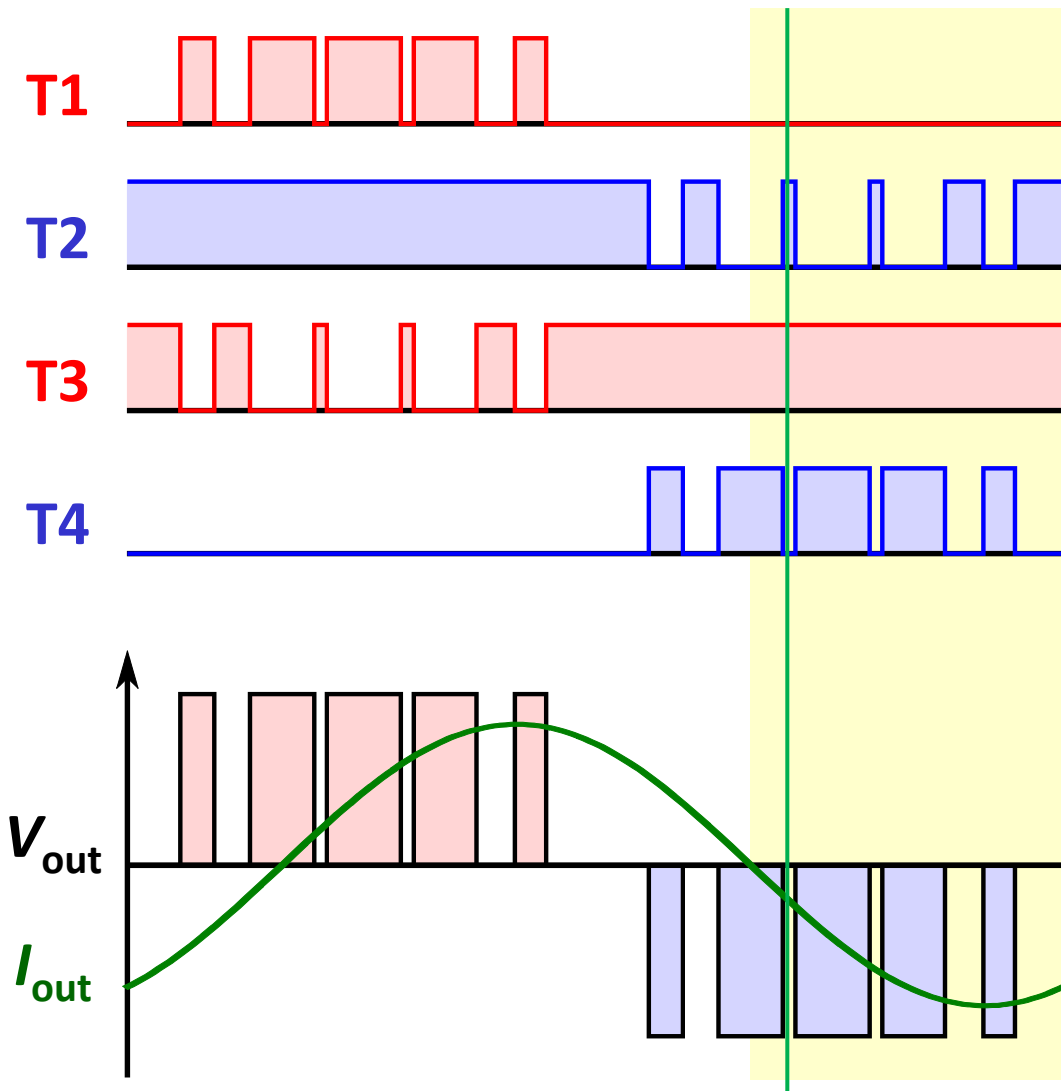


(4)

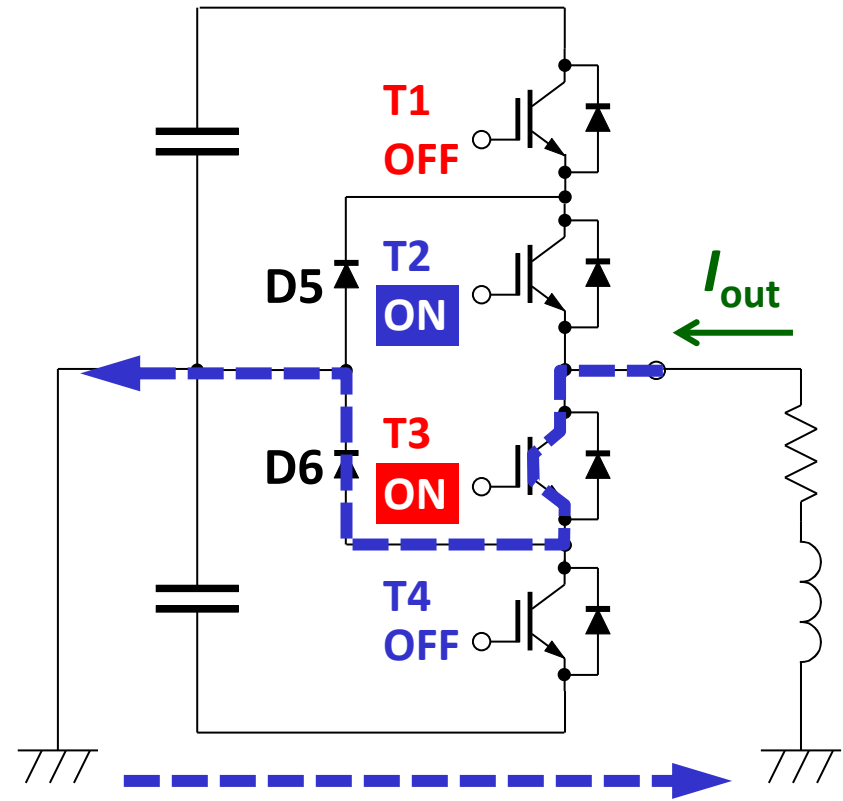


T3: ON
T4: ON

Switching Pattern (4) SW mode A'



(4)

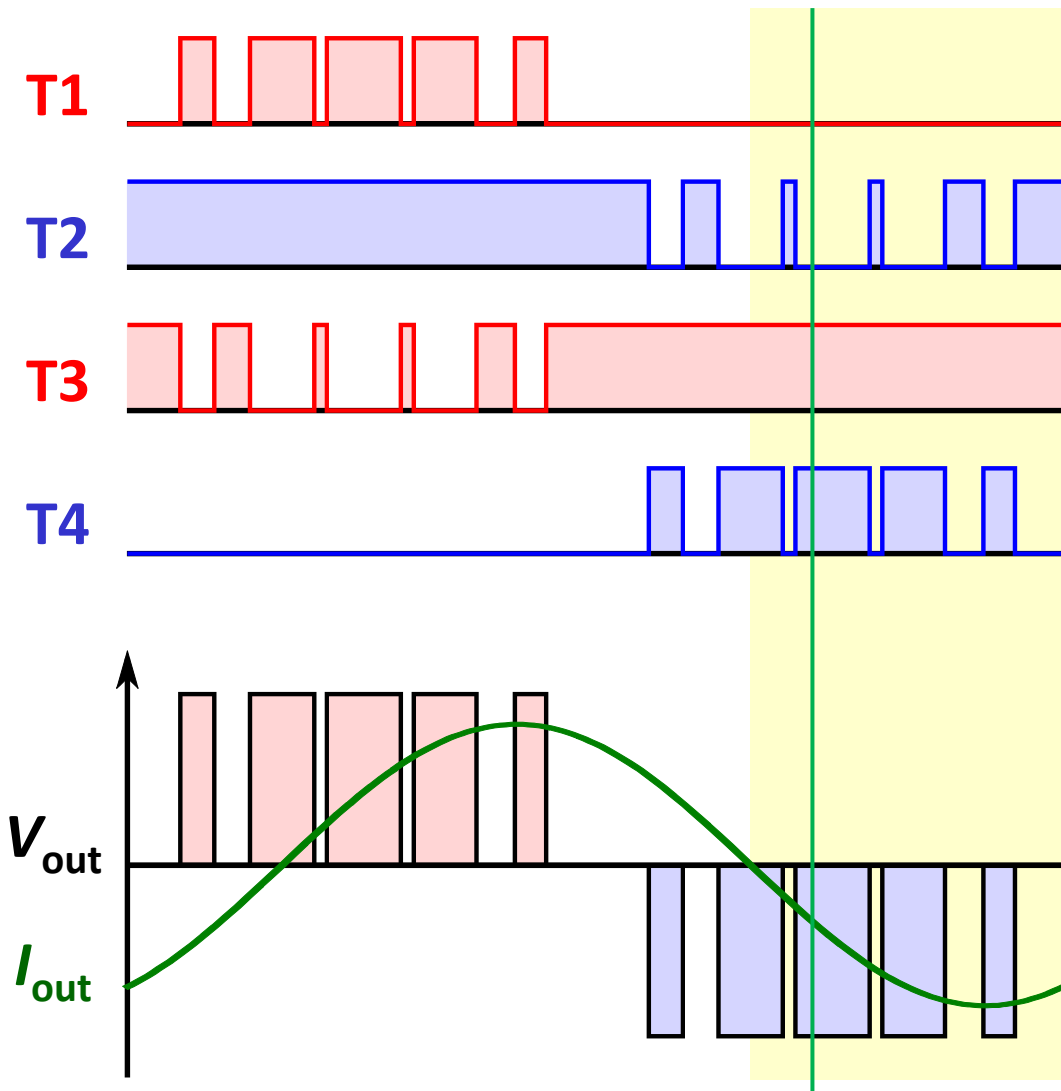


T3: ON

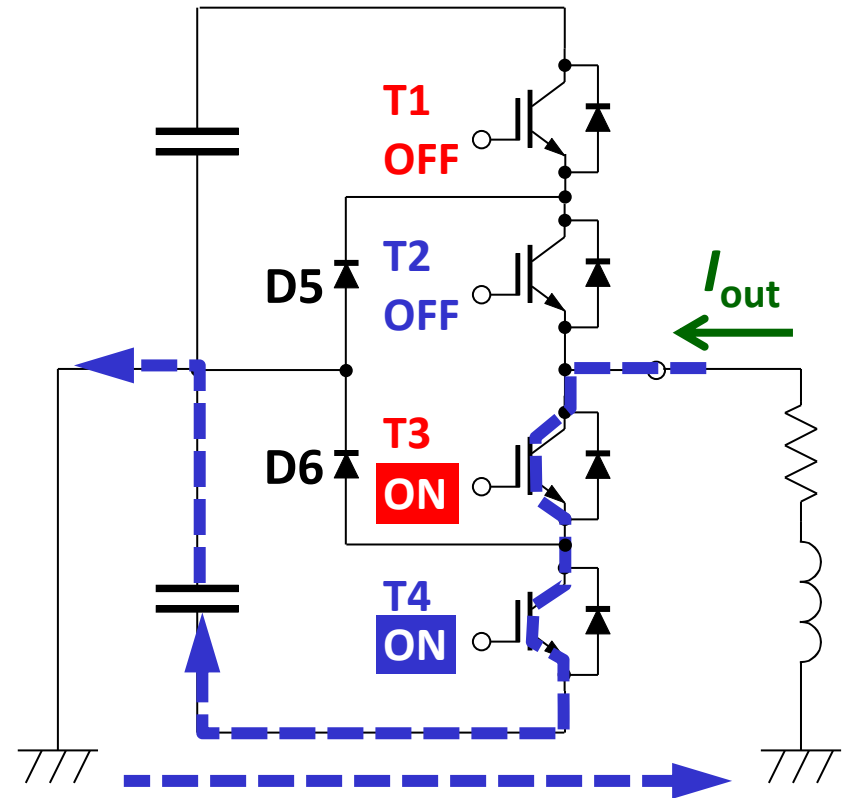
T4: Turn OFF

T6: Free wheeling

Switching Pattern (4) SW mode A'



(4)

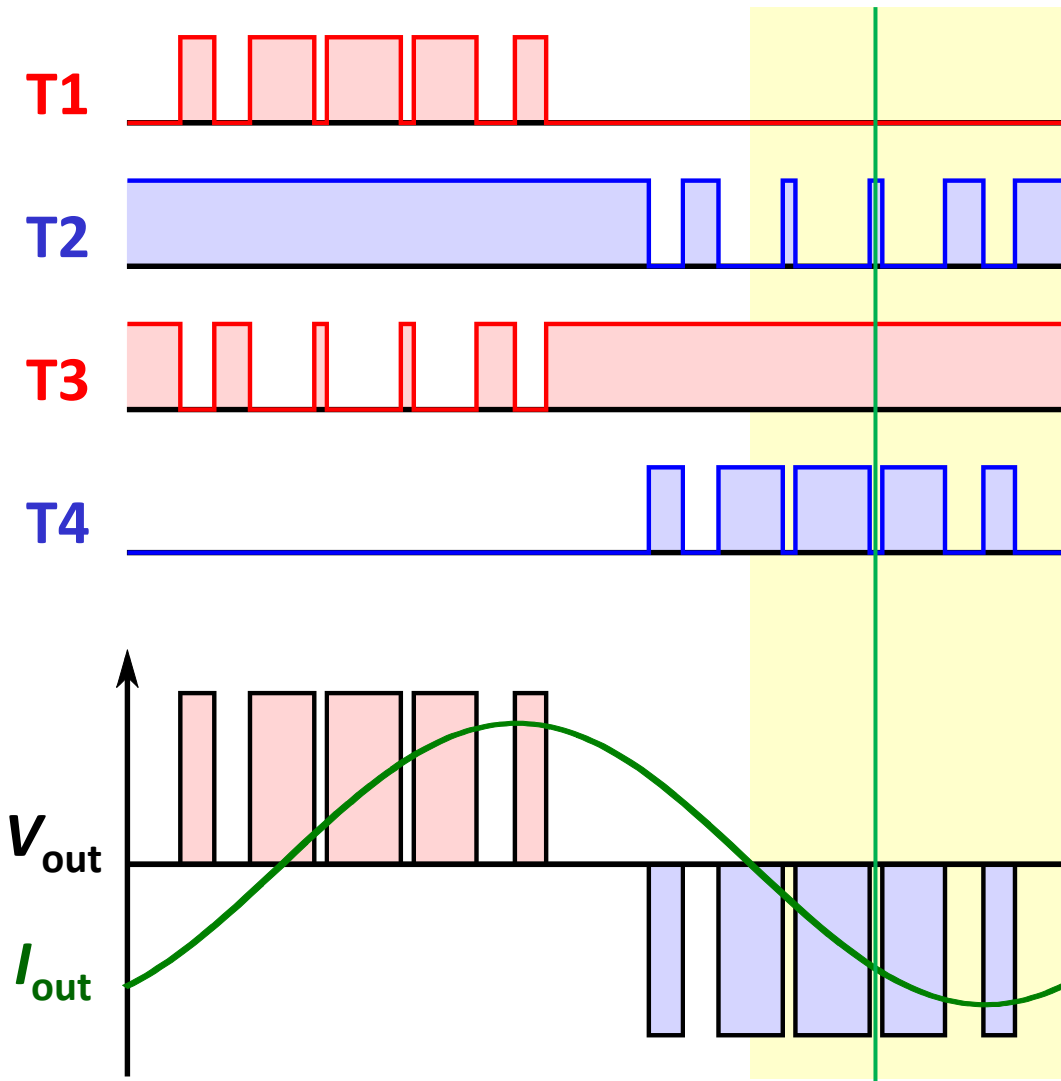


T3: ON

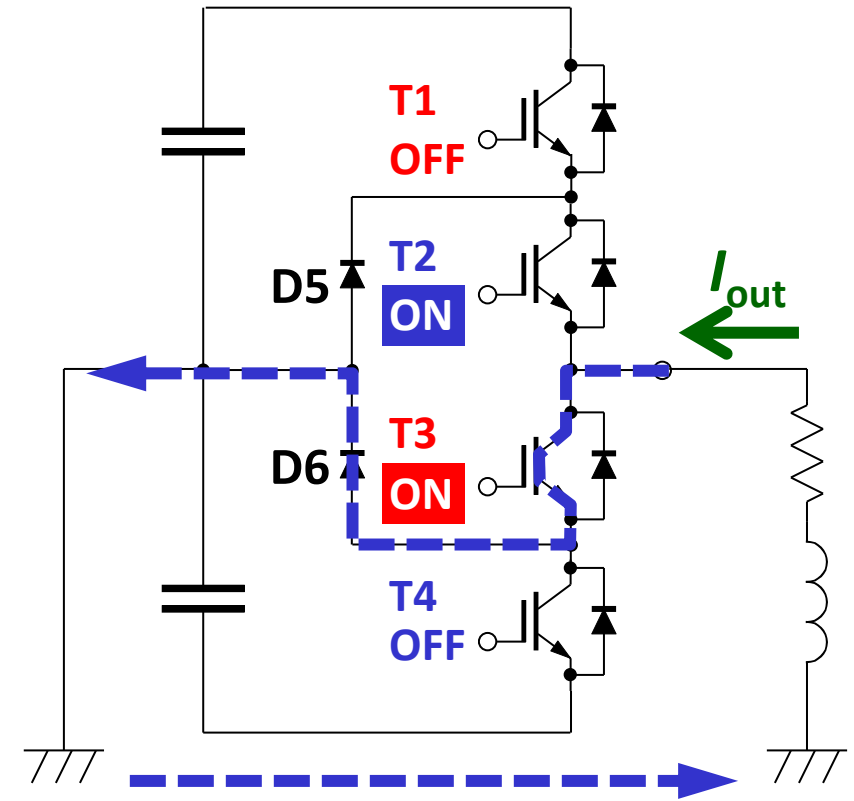
T4: Turn ON

D6: Reverse recovery

Switching Pattern (4) SW mode A'

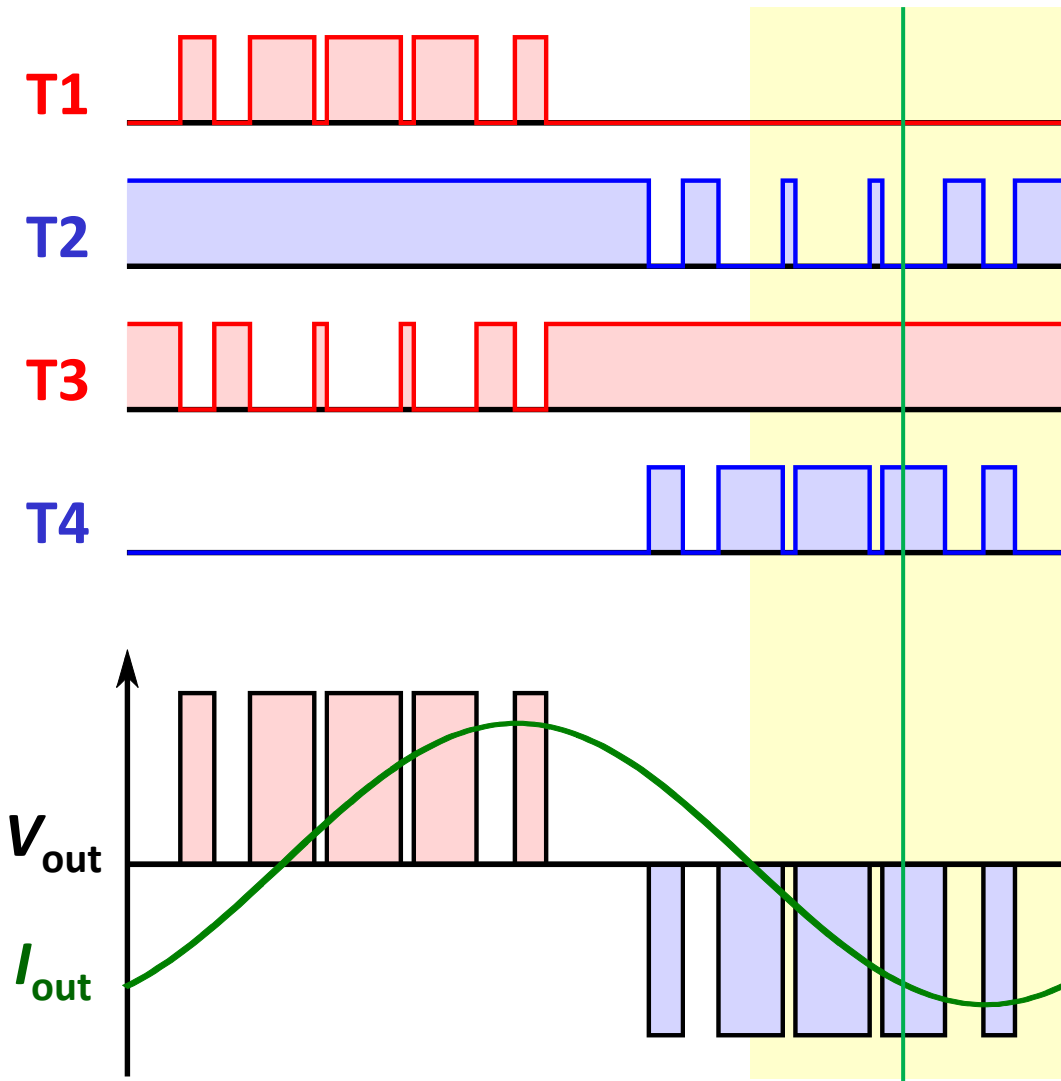


(4)

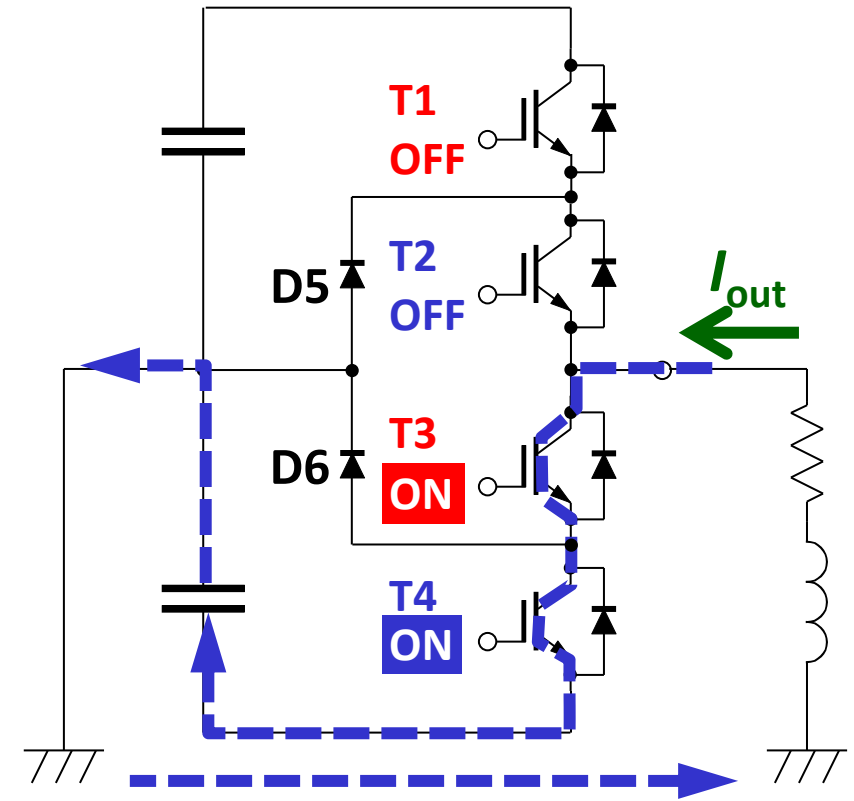


T3: ON
T4: Turn OFF
T6: Free wheeling

Switching Pattern (4) SW mode A'

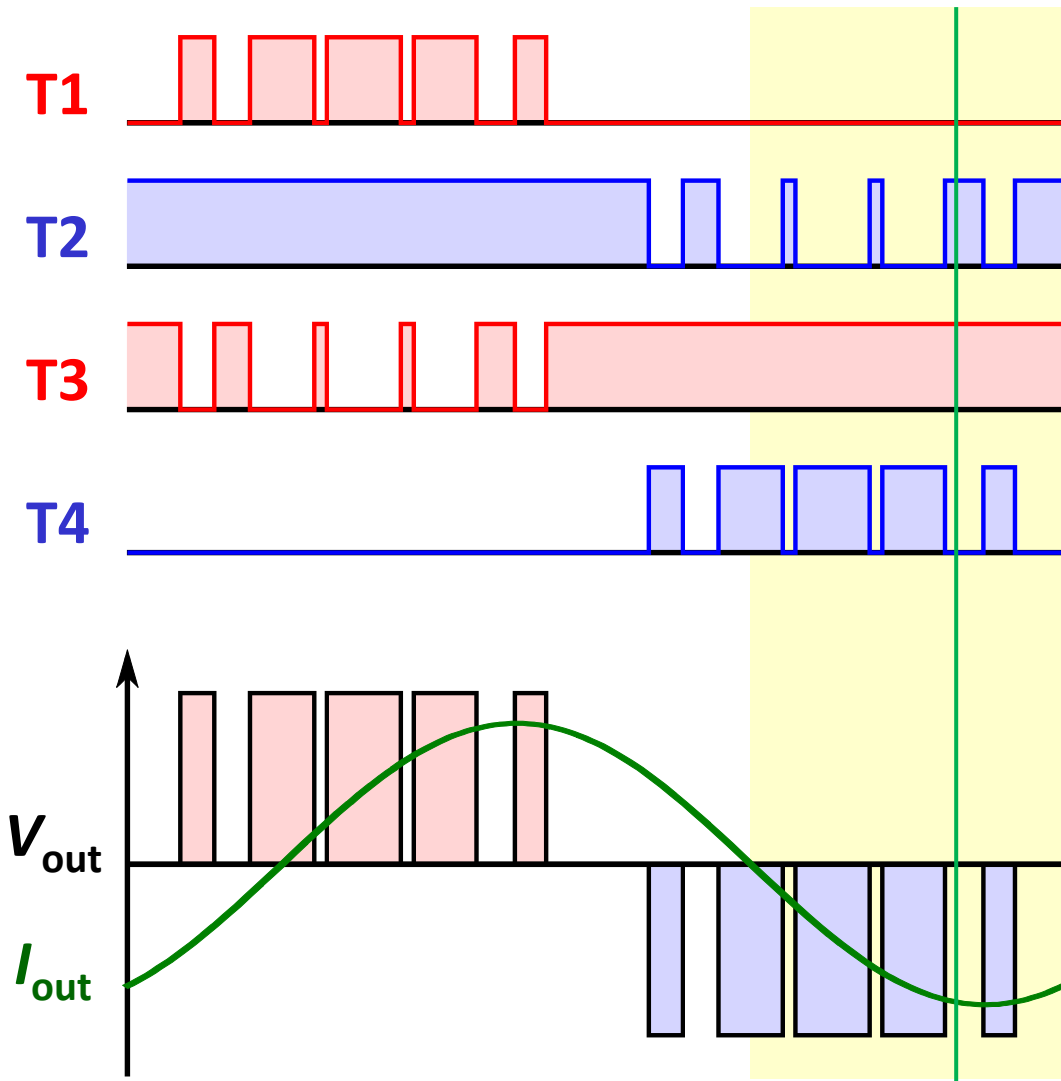


(4)

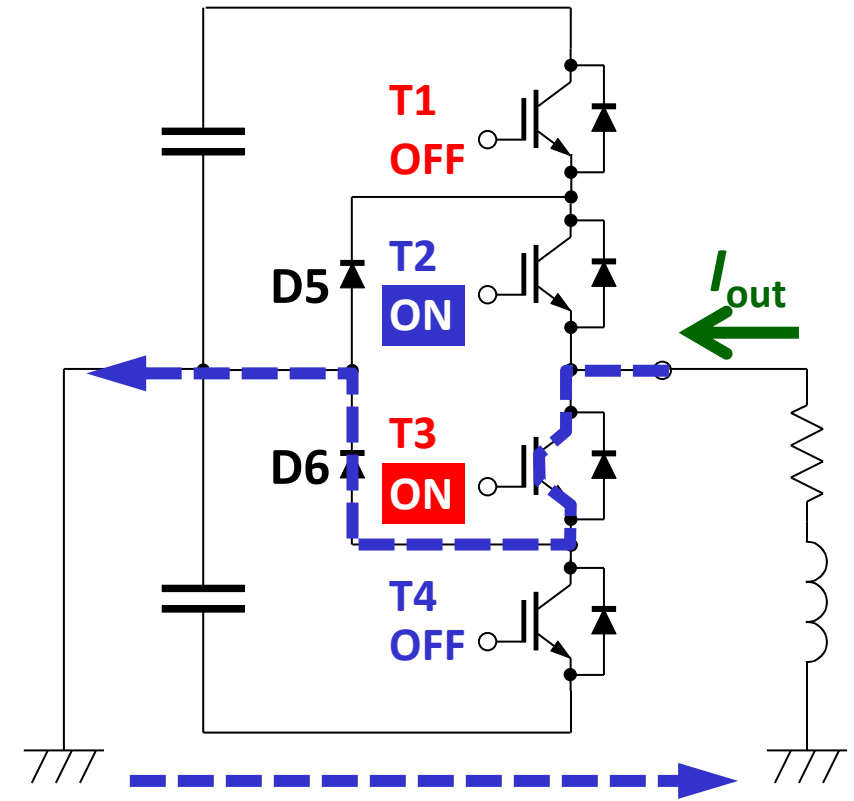


T3: ON
T4: Turn ON
D6: Reverse recovery

Switching Pattern (4) SW mode A'

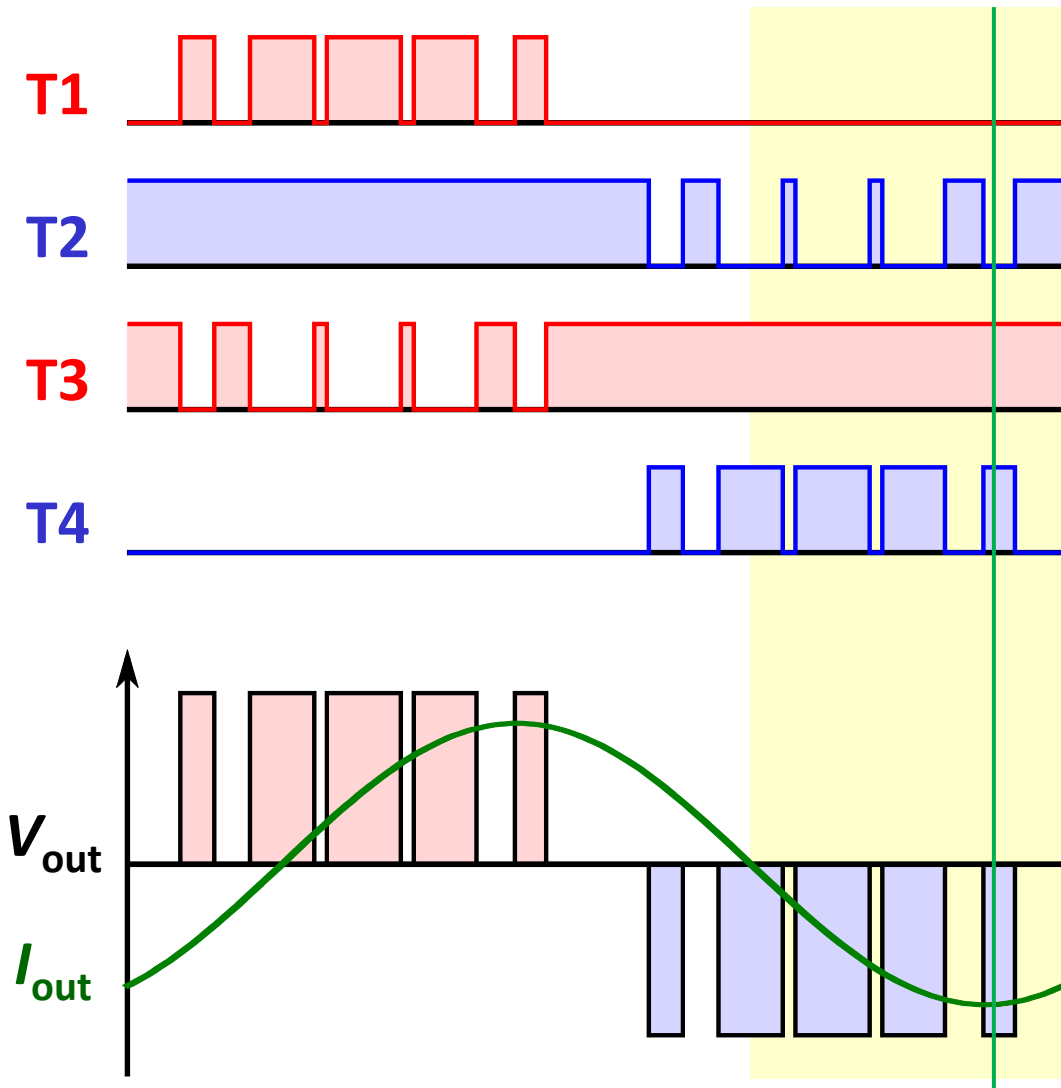


(4)

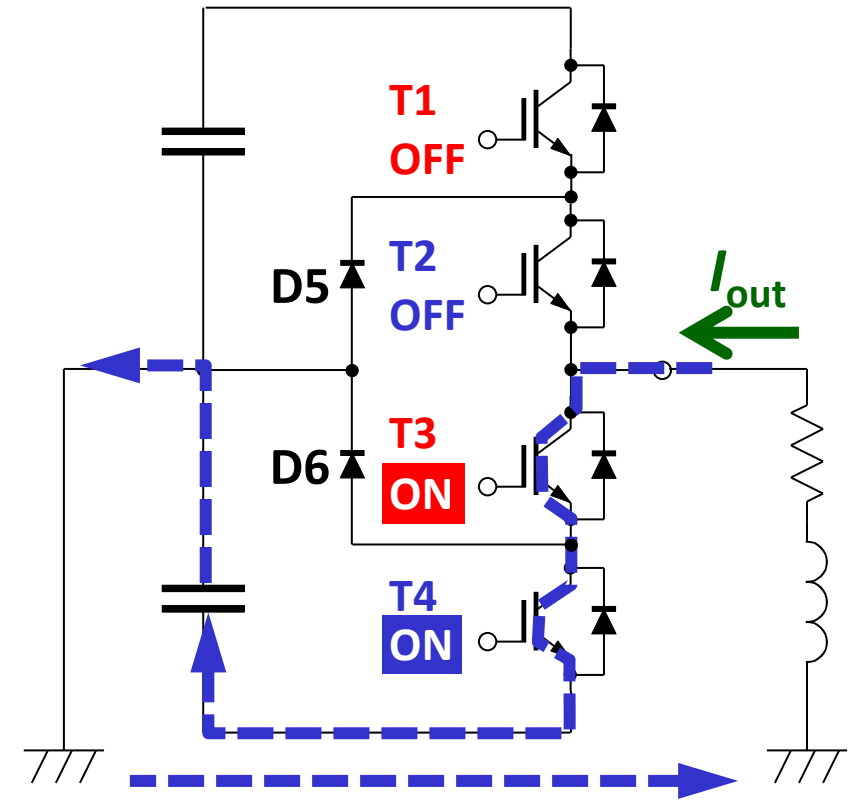


T3: ON
T4: Turn OFF
T6: Free wheeling

Switching Pattern (4) SW mode A'

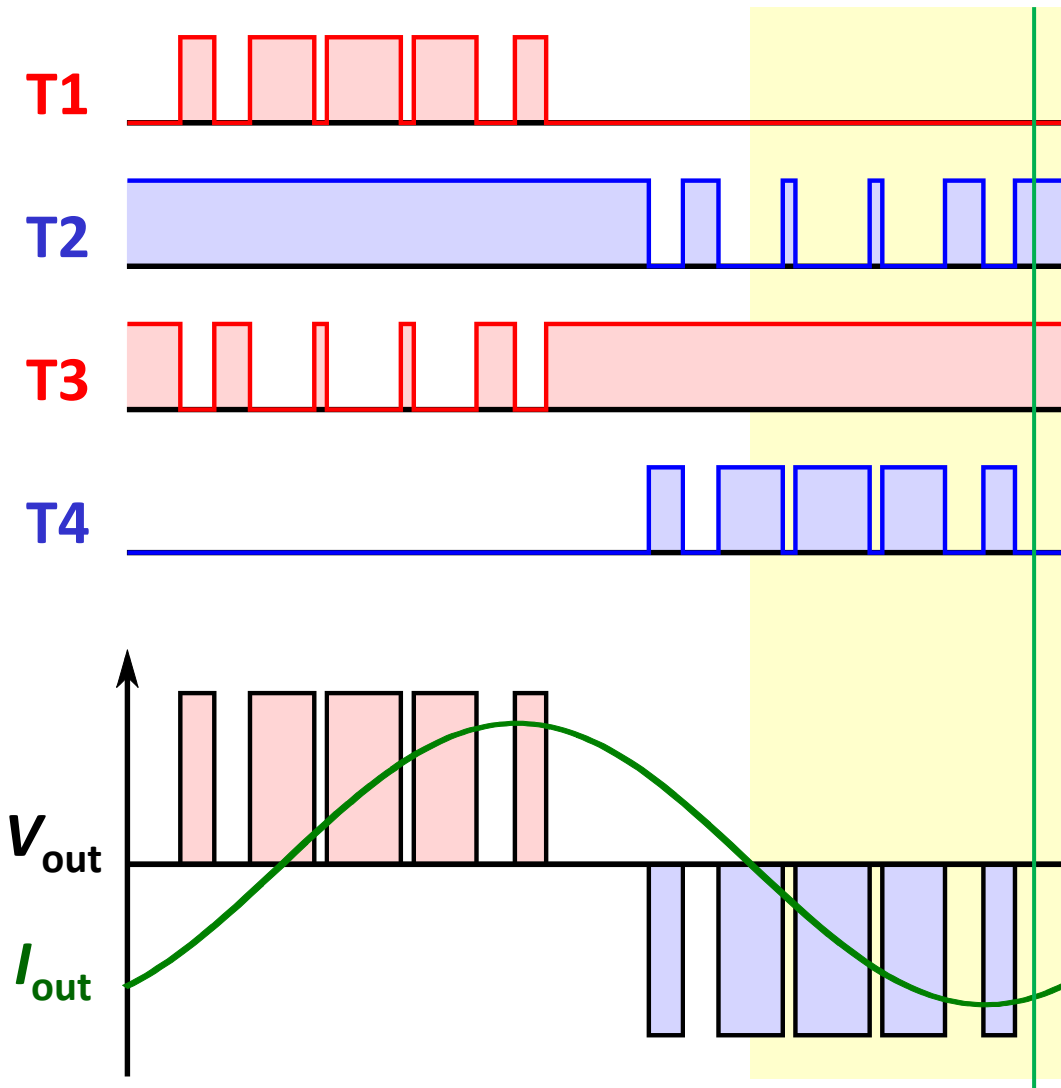


(4)

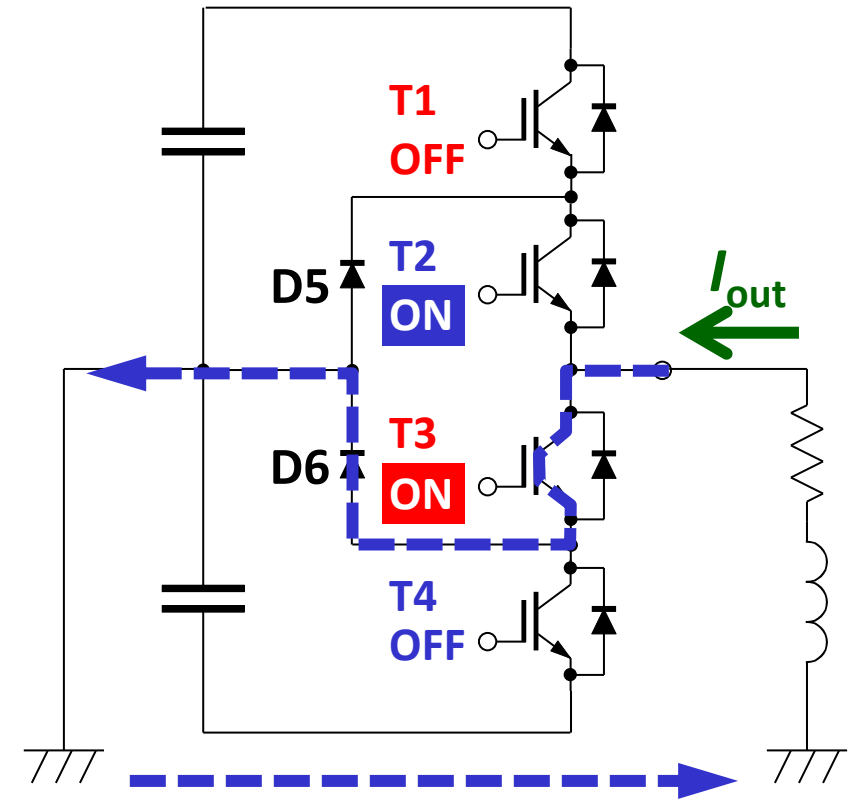


T3: ON
T4: Turn ON
D6: Reverse recovery

Switching Pattern (4) SW mode A'



(4)



T3: ON
T4: Turn OFF
T6: Free wheeling