

AT-NPC Module Switching Pattern (M404 Single Phase)

Fuji Electric Co., Ltd.

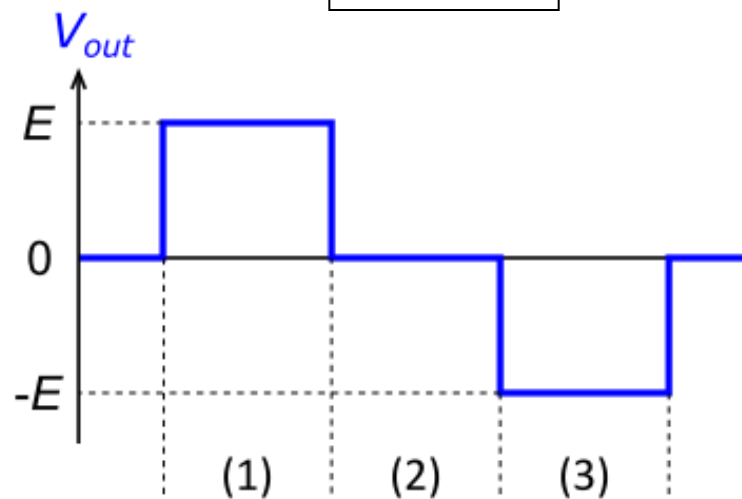
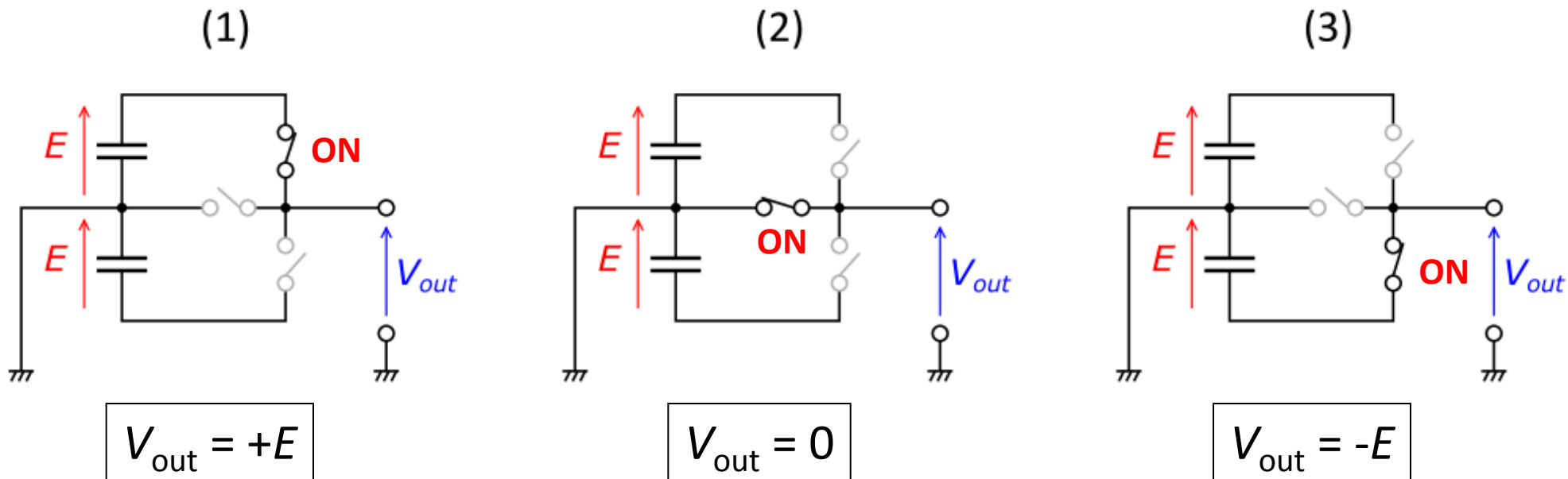
Device Application Technology Dept.

Semiconductor Sales Div.

Sales Group

Nov, 2014

What is the “three level” ?

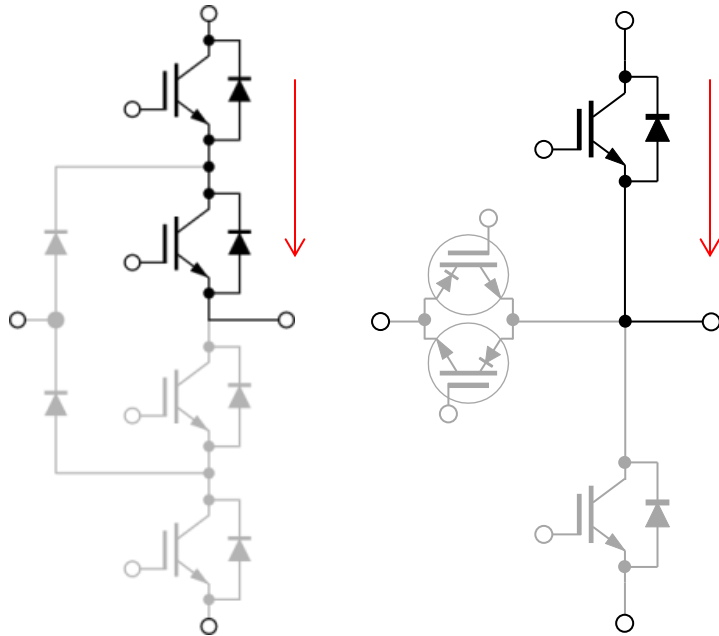
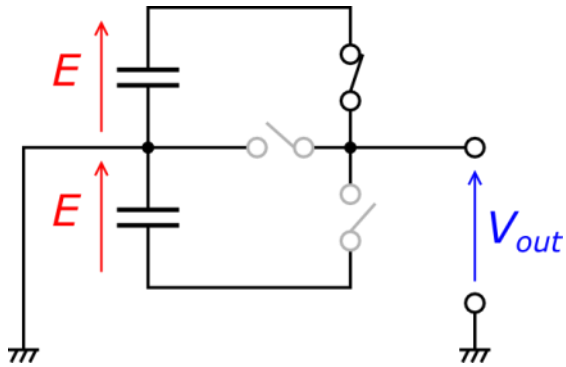


Three level outputs!
(+E, 0, -E)

NPC & T-type 3-level Configuration

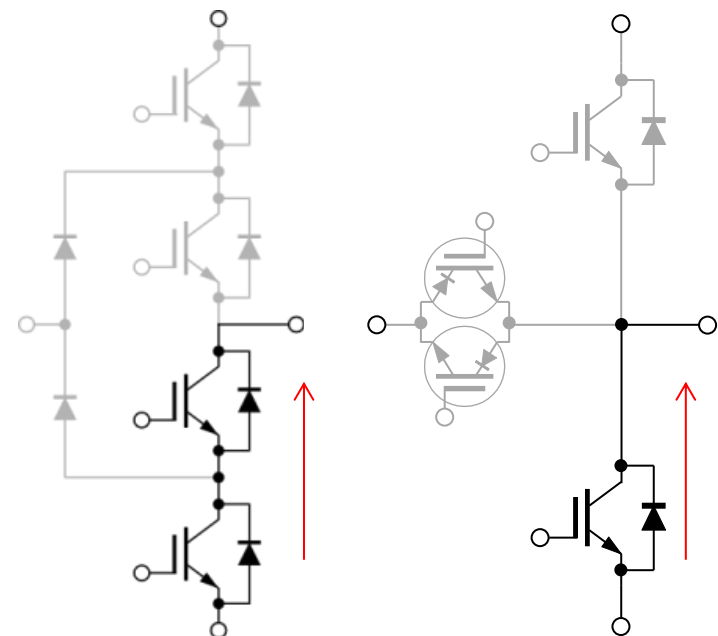
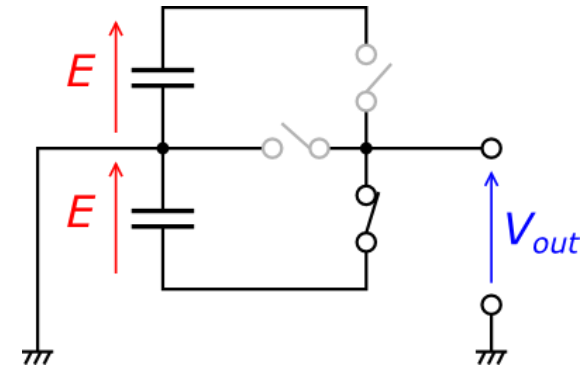
(1)

$$V_{out} = +E$$



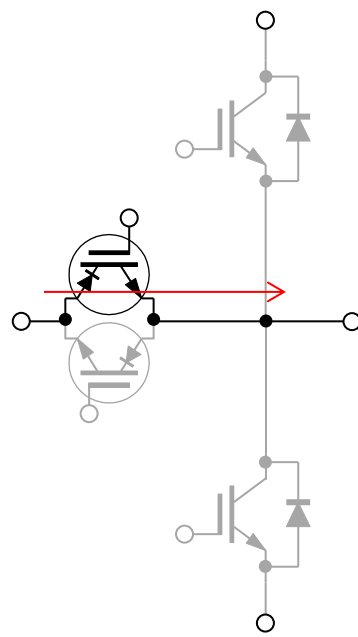
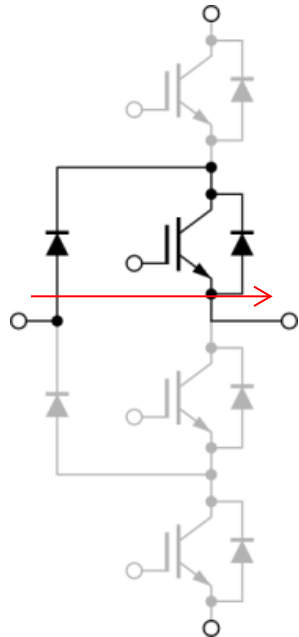
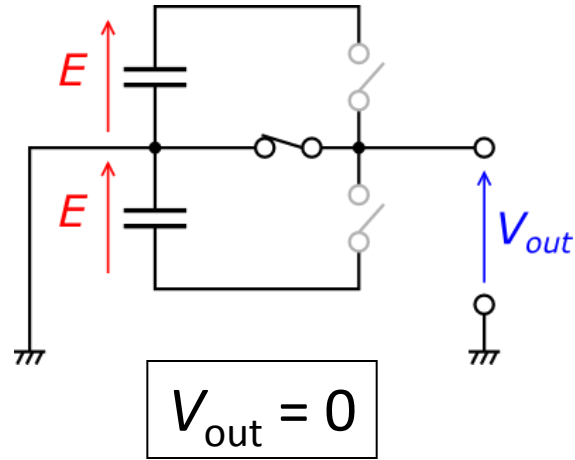
(3)

$$V_{out} = -E$$

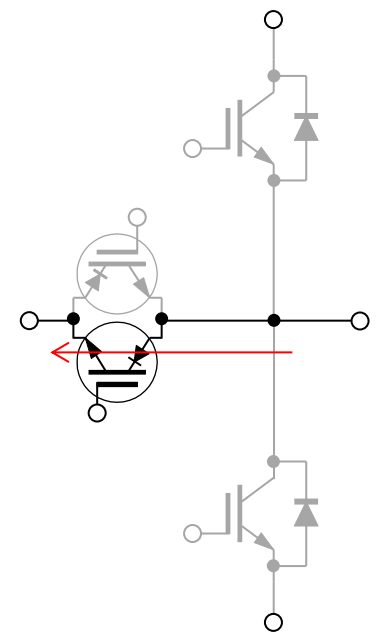
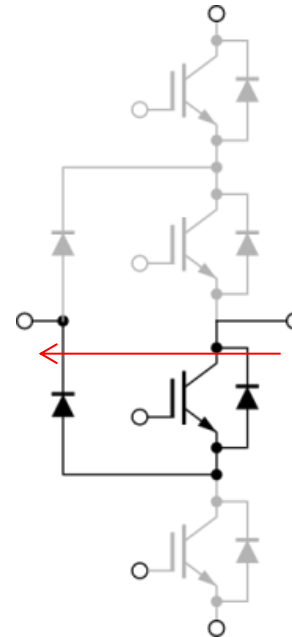


Switching Pattern

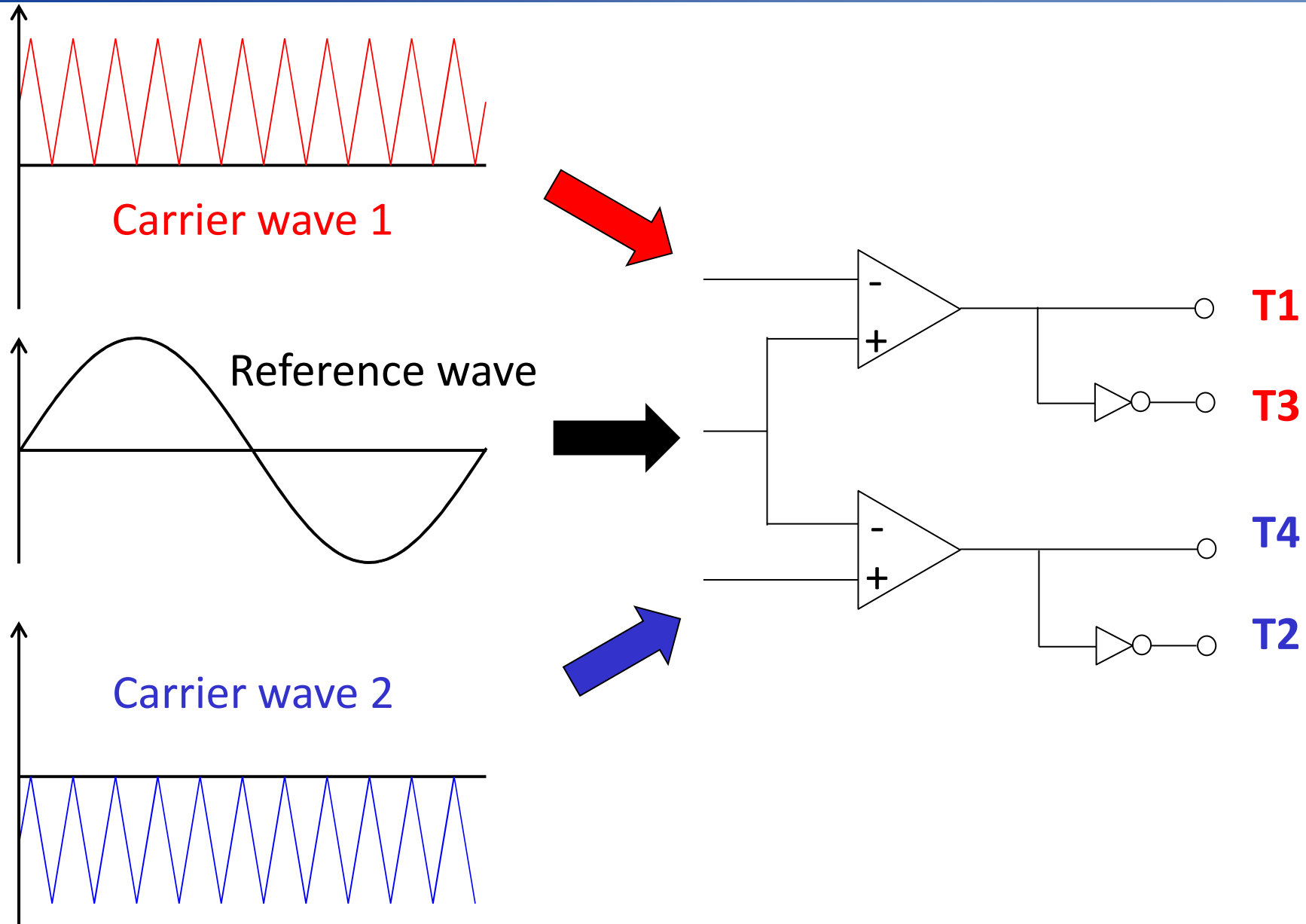
(2)



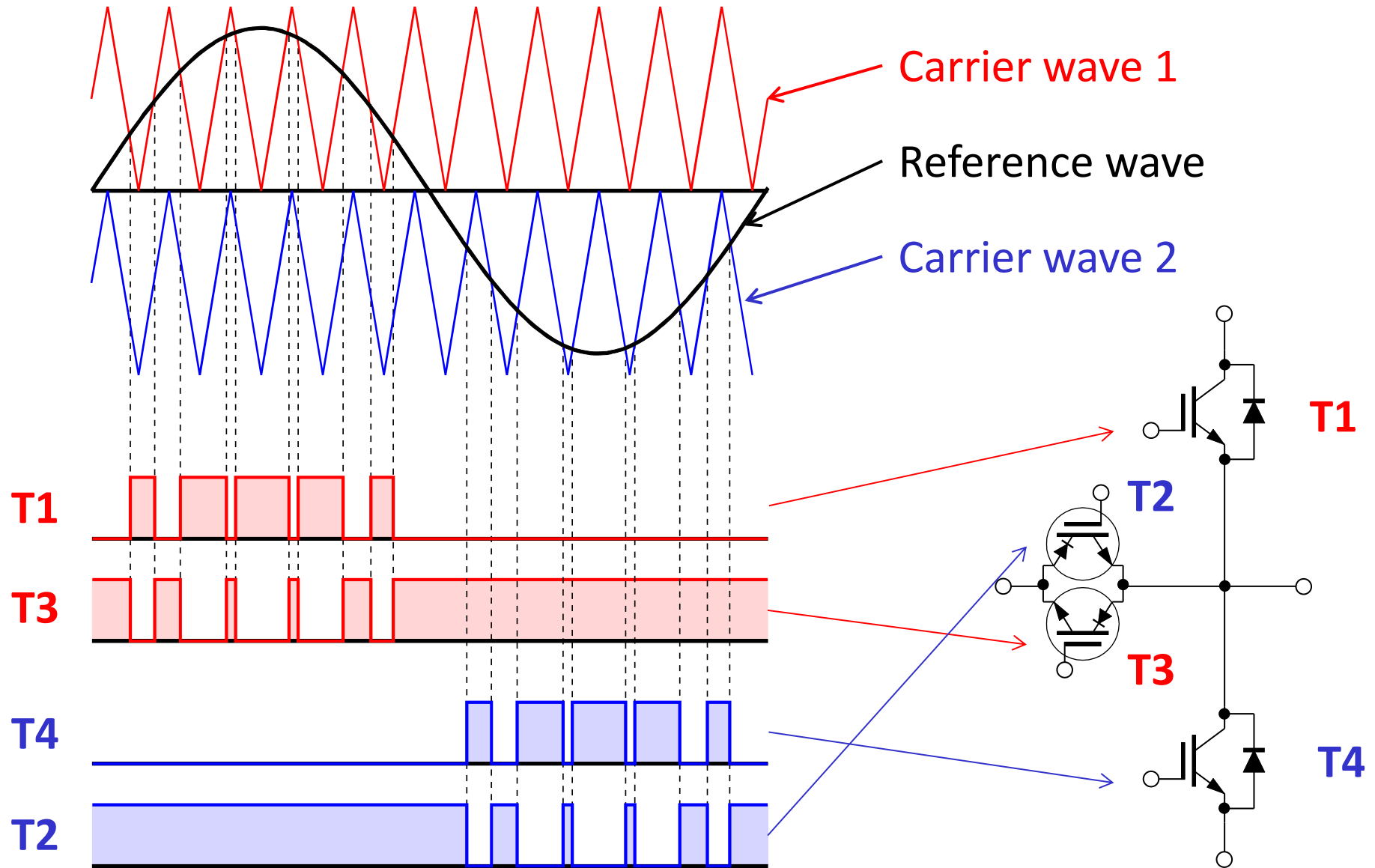
or



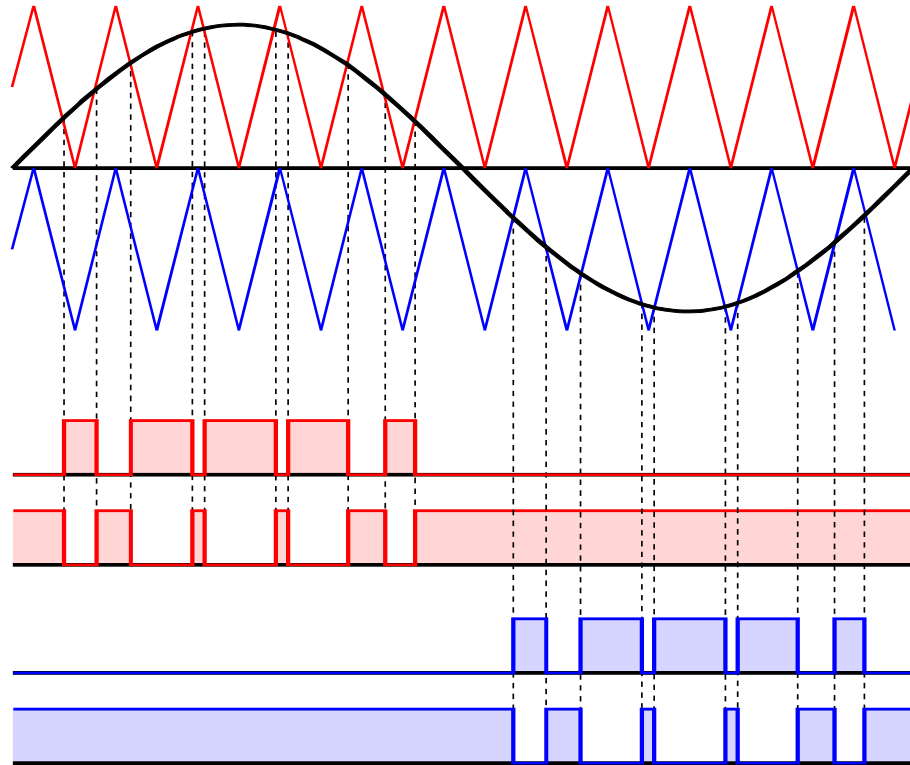
Generate PWM Pulse



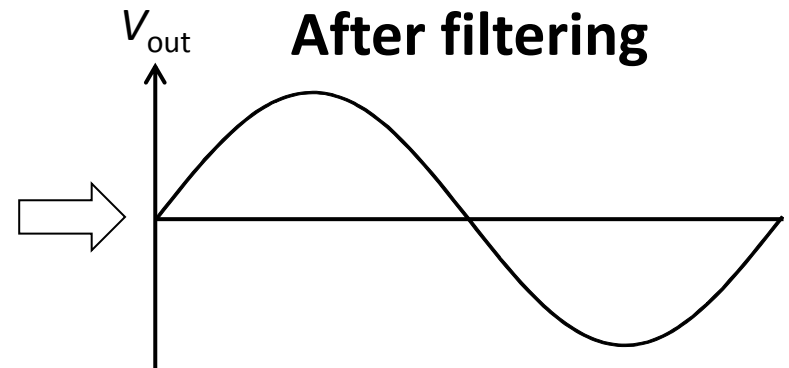
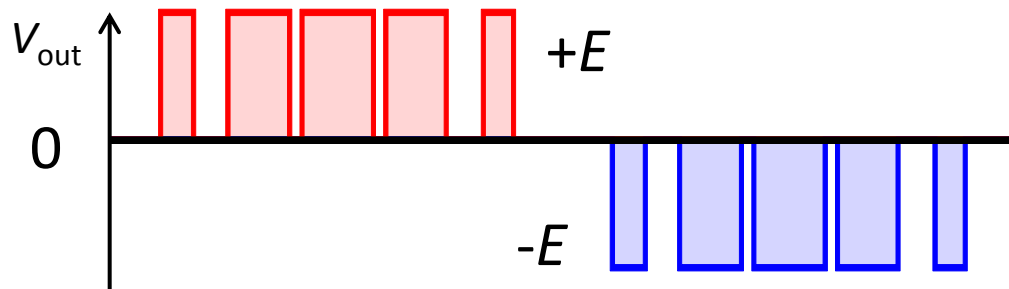
Switching Pattern (Phase Voltage)



Switching Pattern (Phase Voltage)

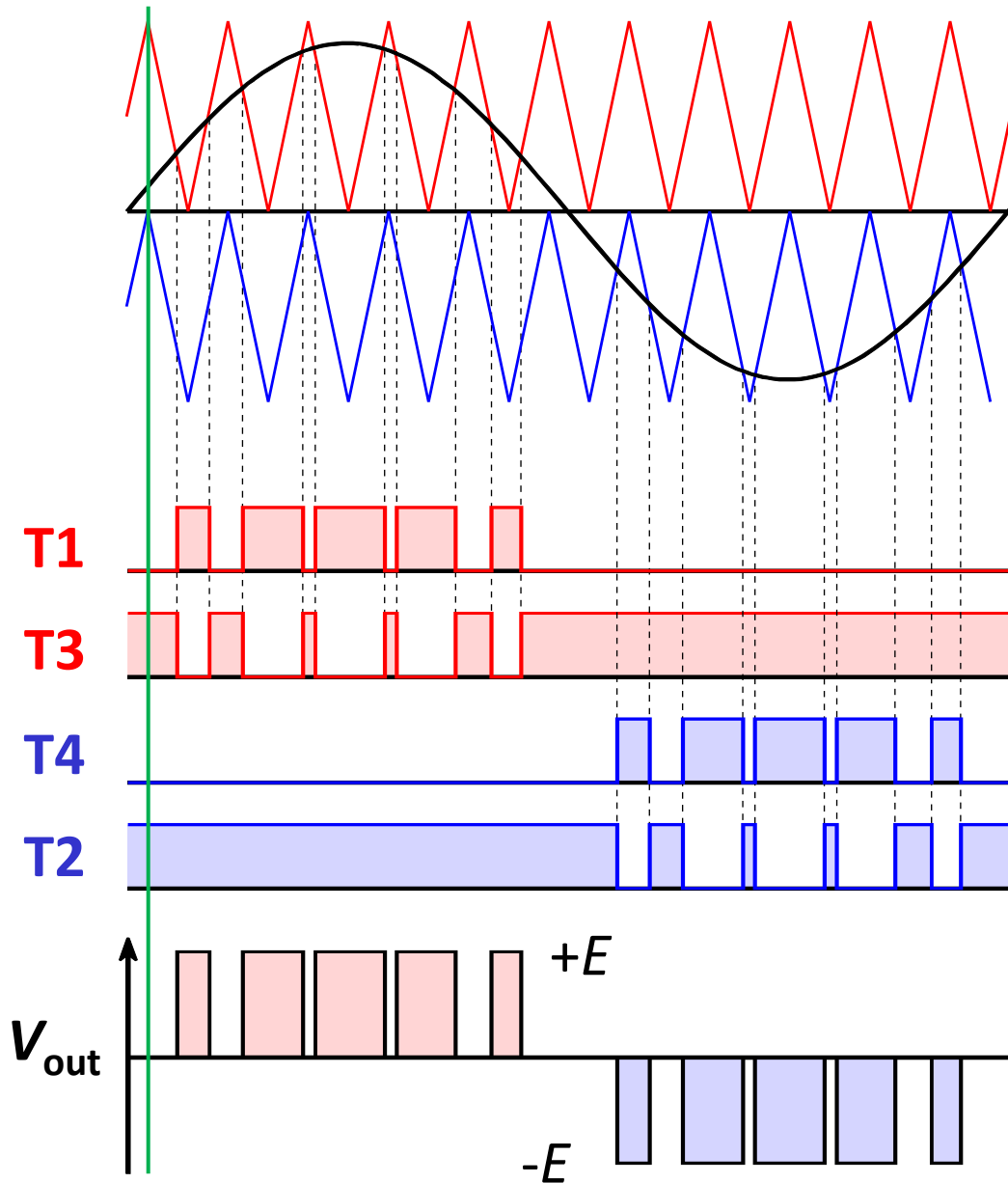


Output voltage (Phase voltage)

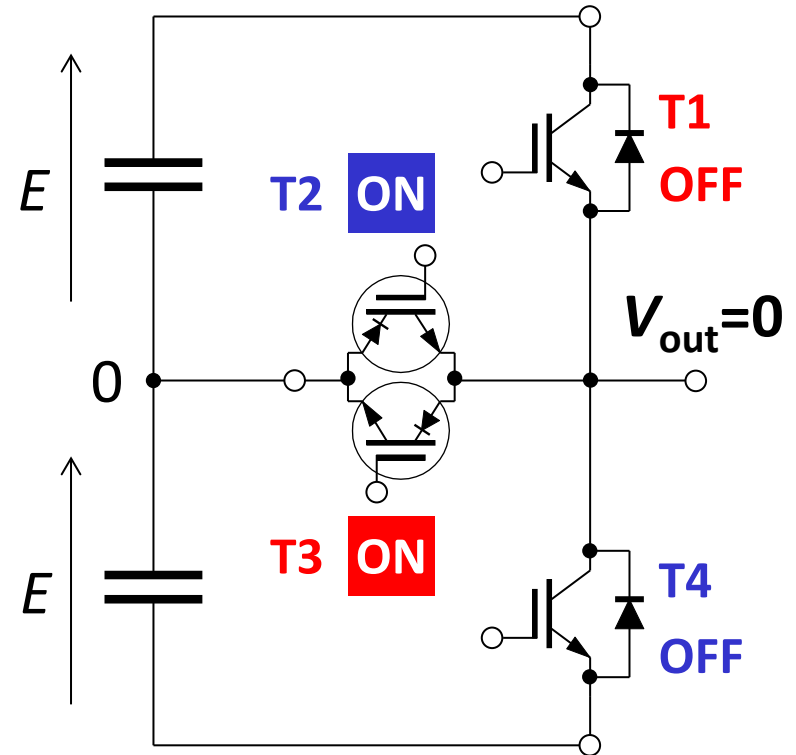


Phase Voltage Output Pattern (No current delay)

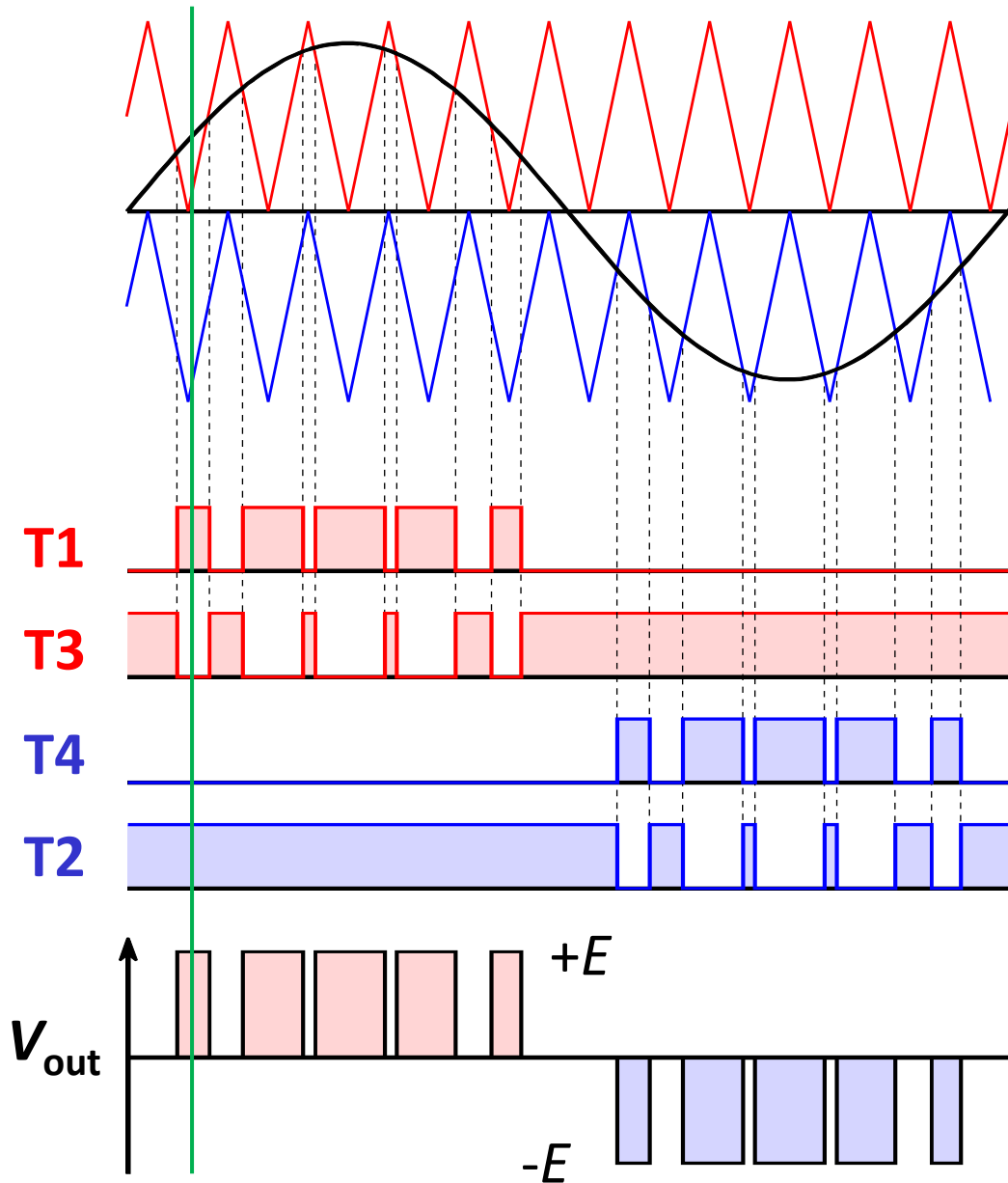
Switching Pattern (Phase Voltage)



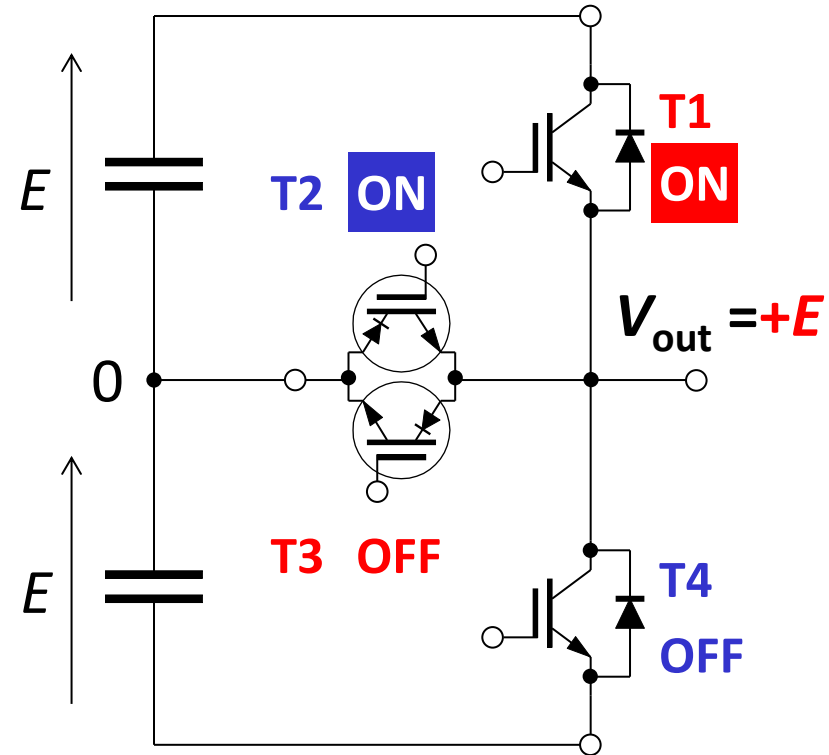
MT5F28645c



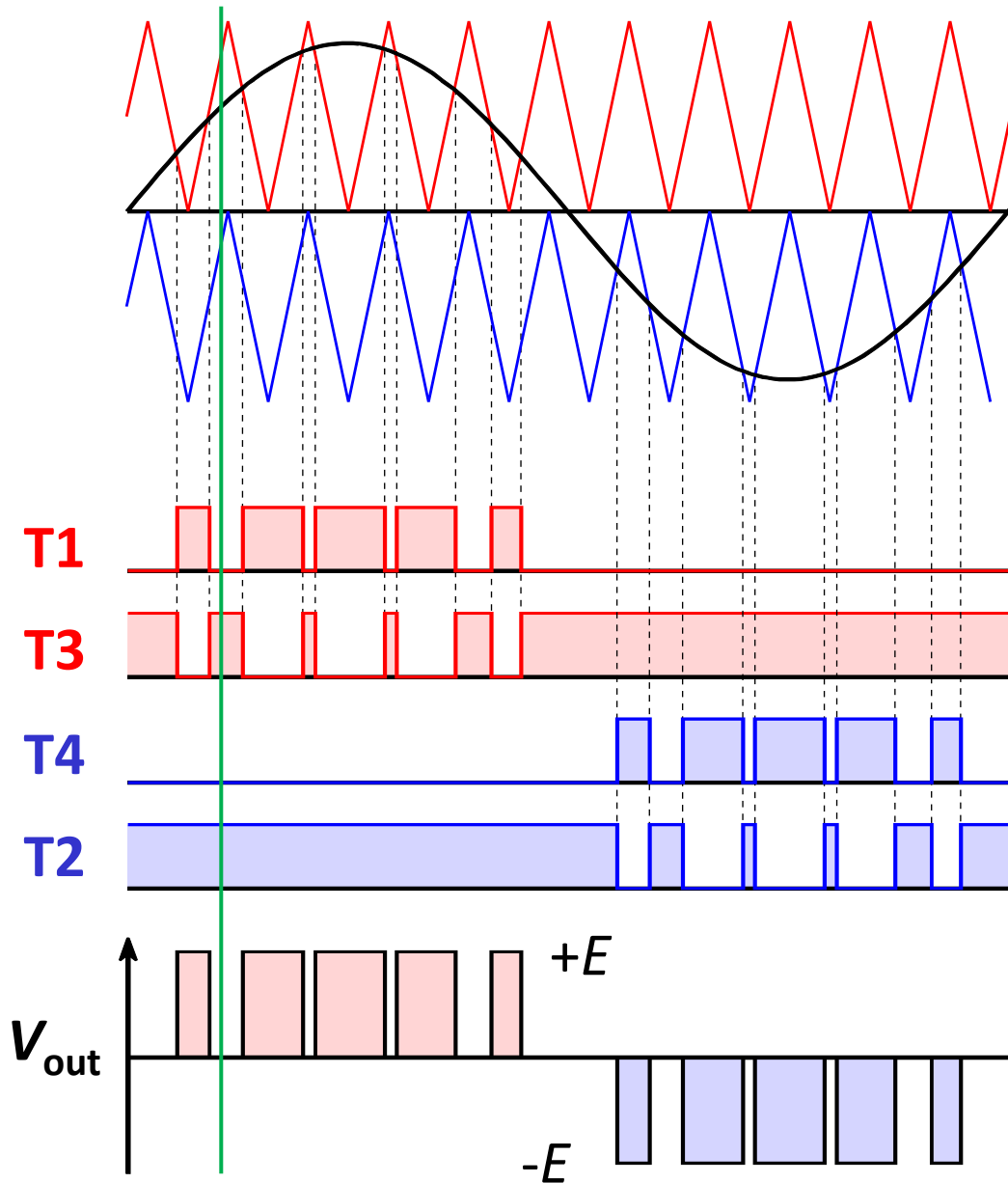
Switching Pattern (Phase Voltage)



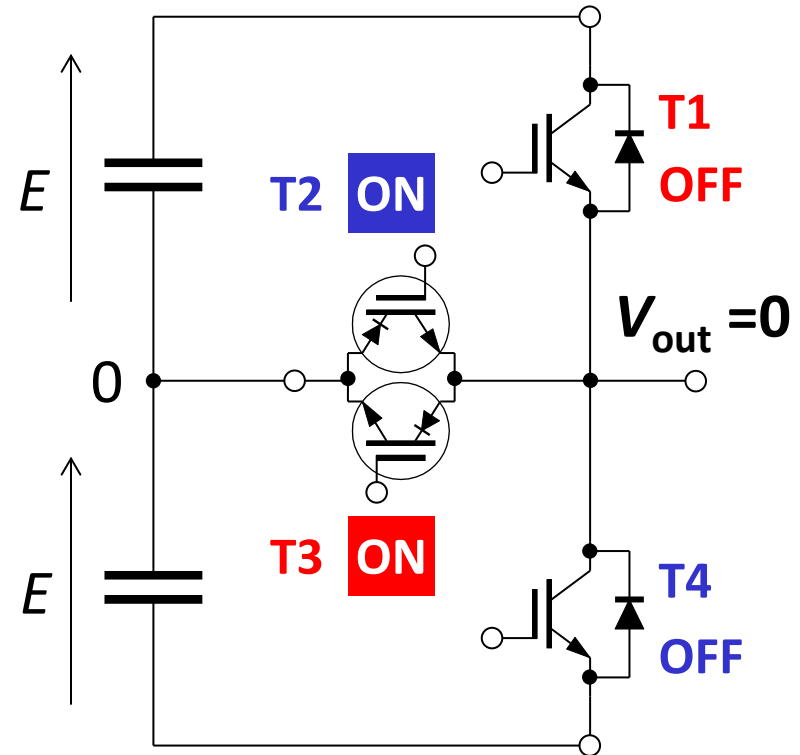
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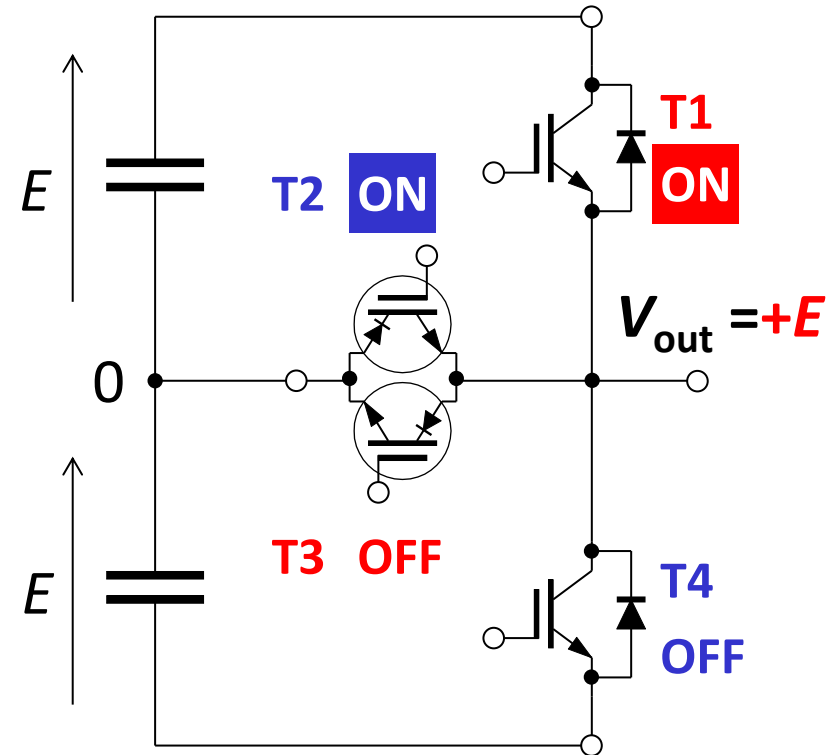
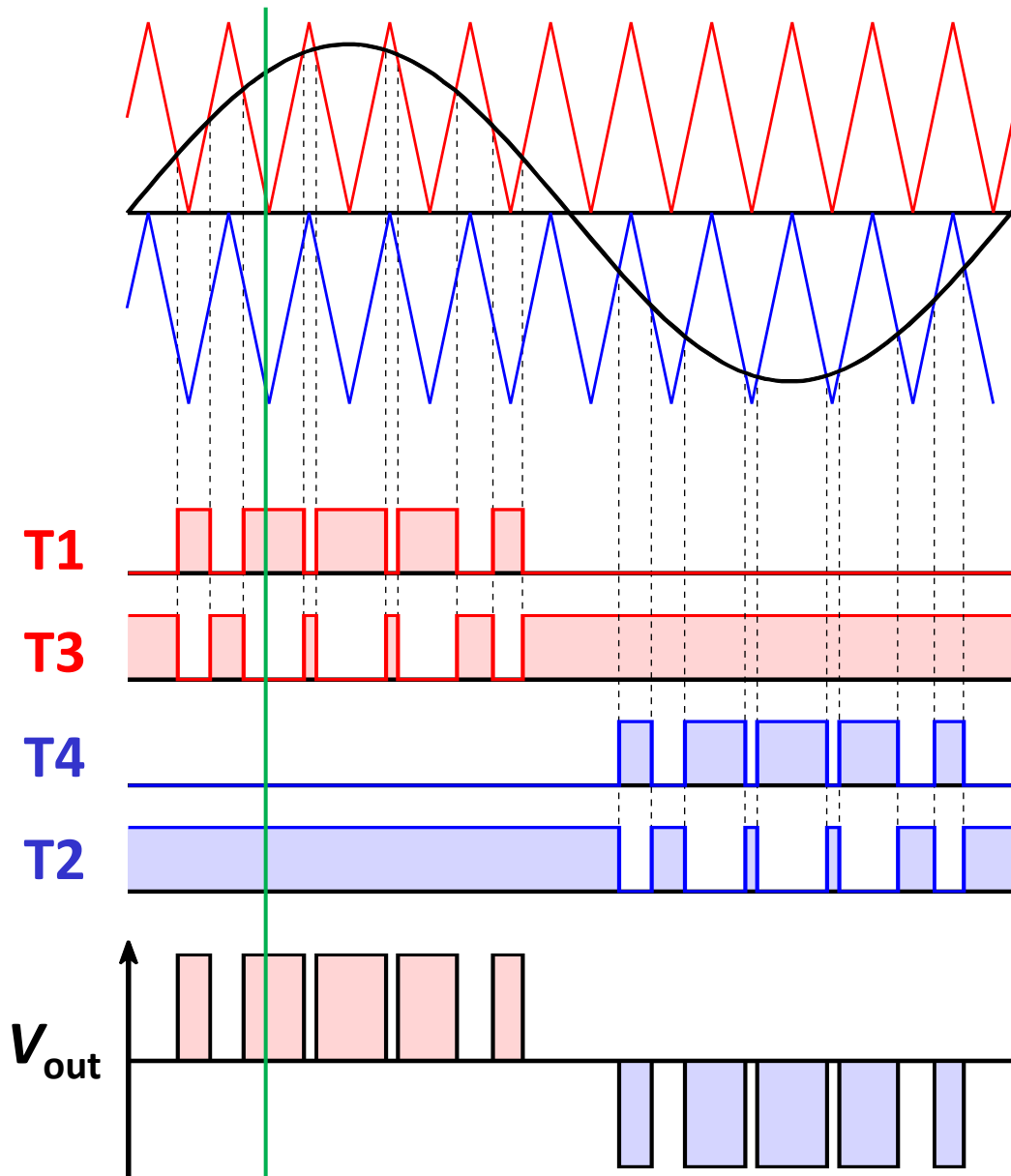
Switching Pattern (Phase Voltage)



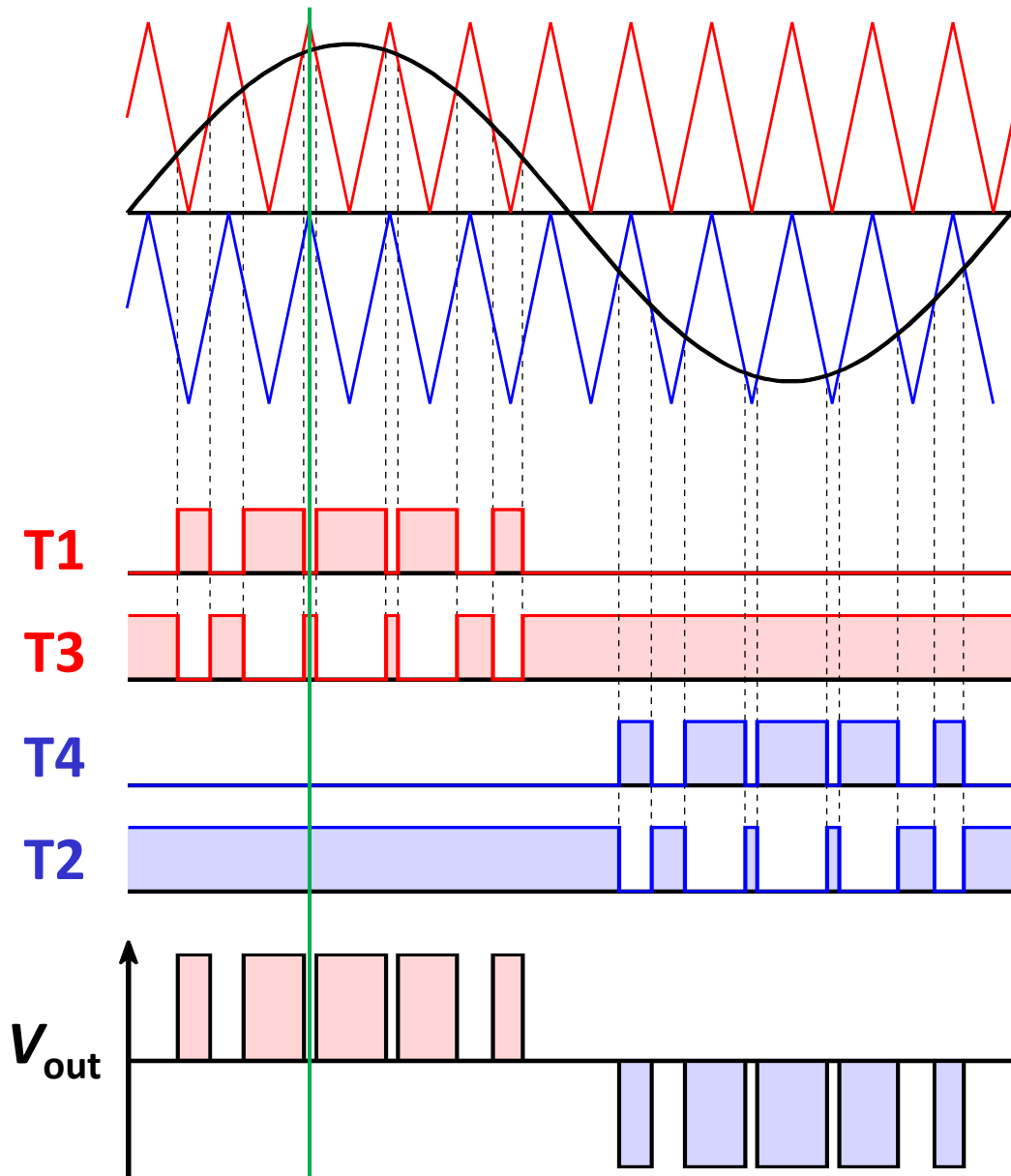
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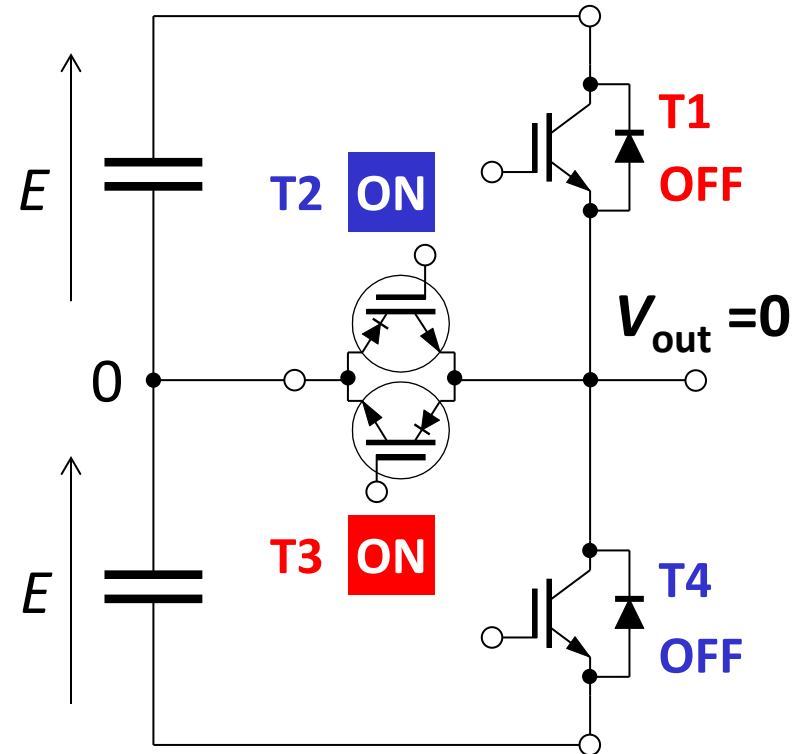
Switching Pattern (Phase Voltage)



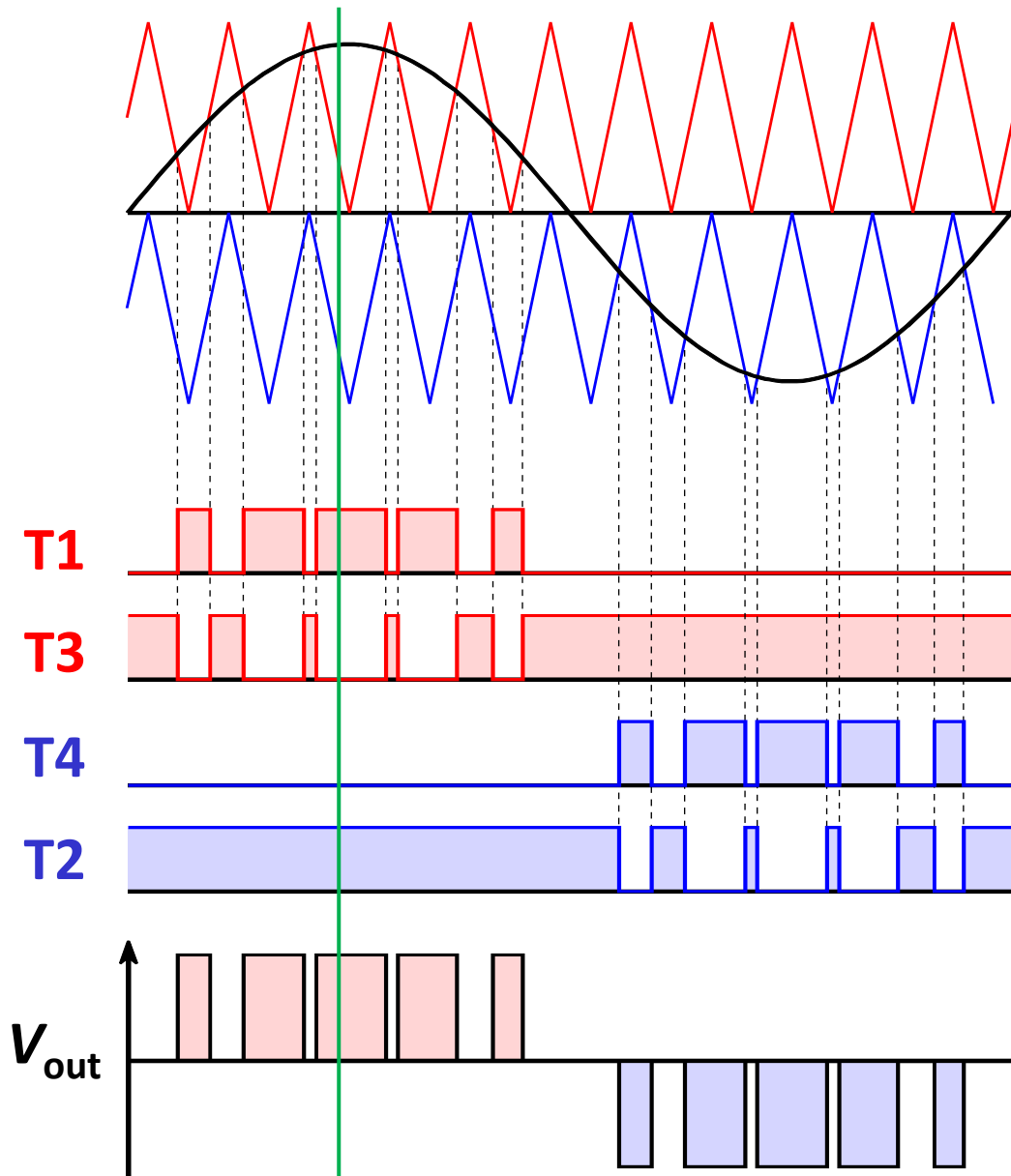
Switching Pattern (Phase Voltage)



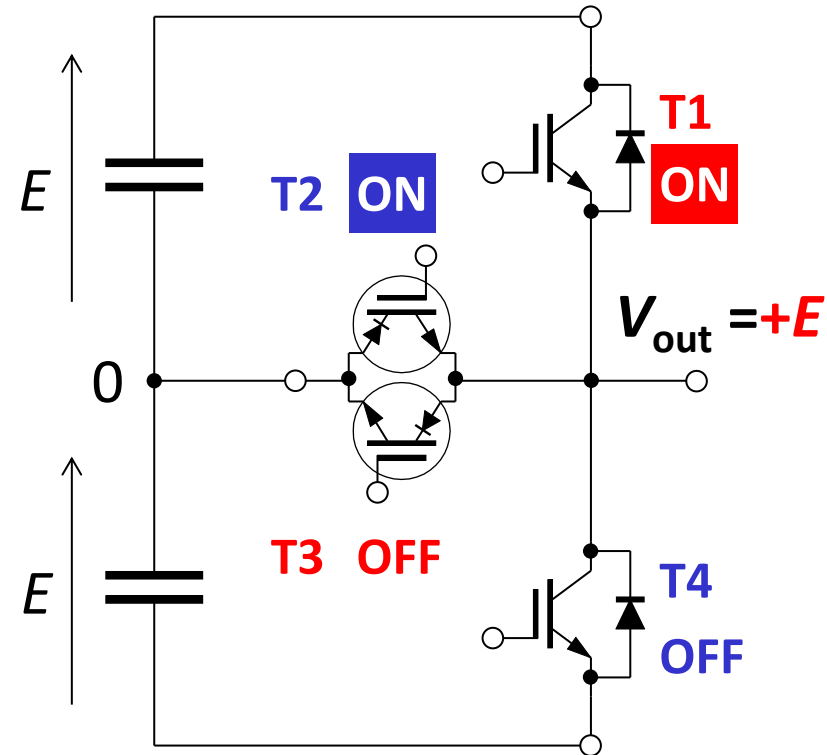
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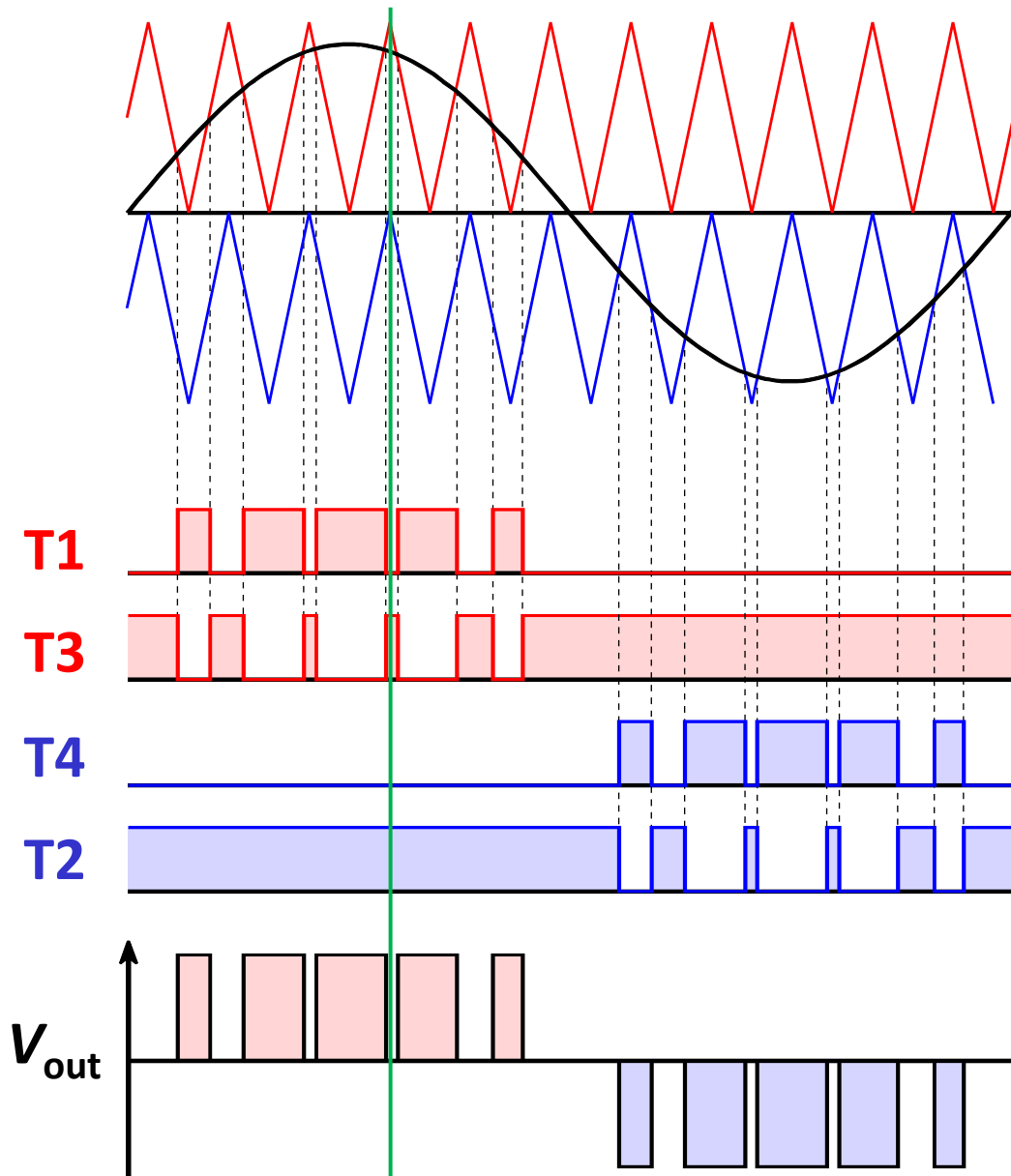
Switching Pattern (Phase Voltage)



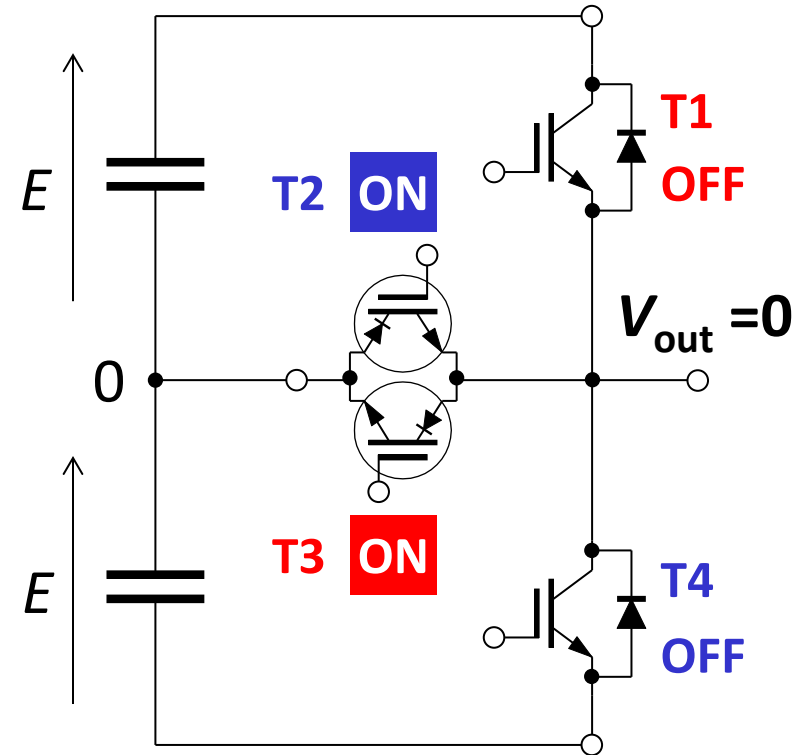
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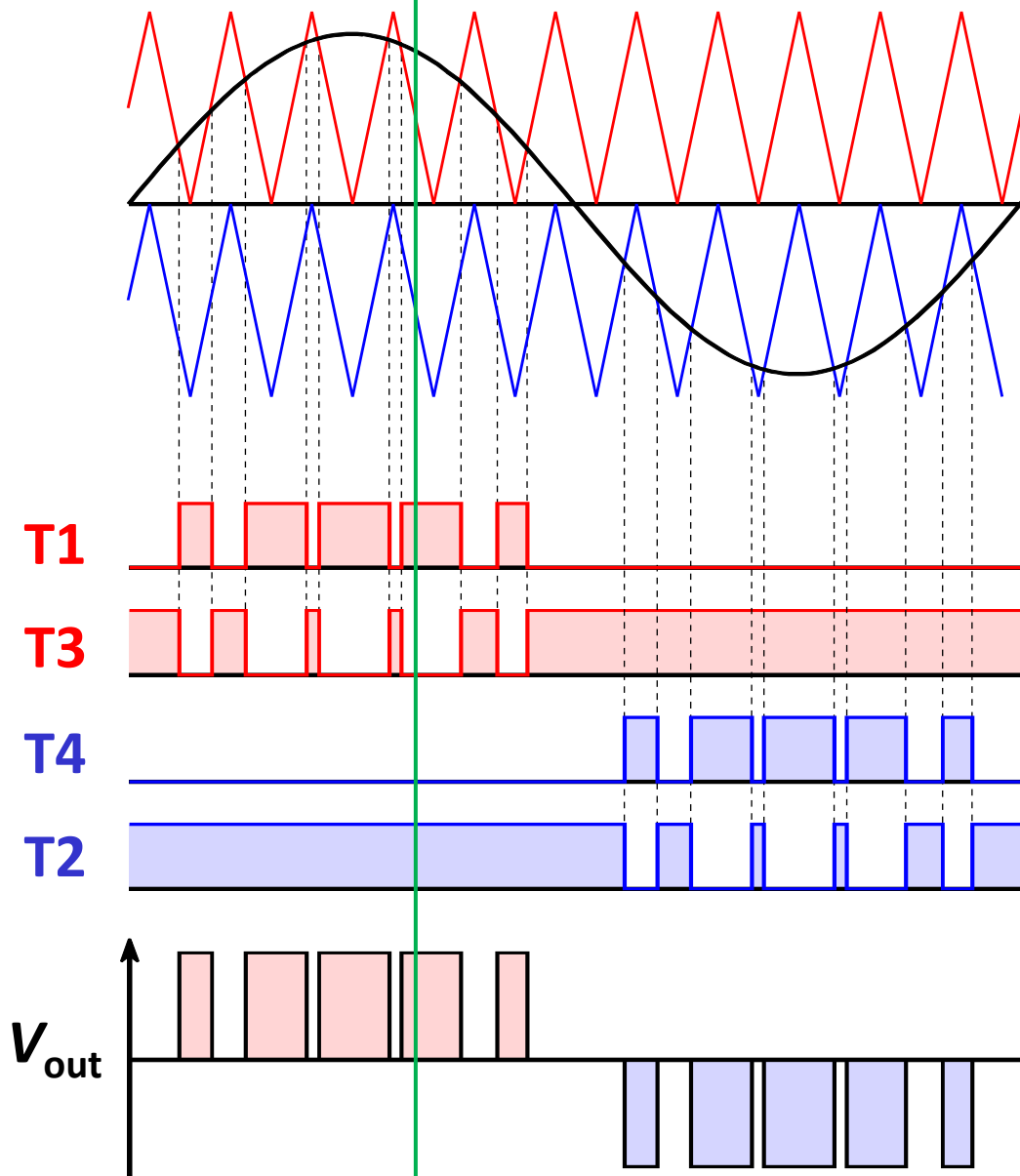
Switching Pattern (Phase Voltage)



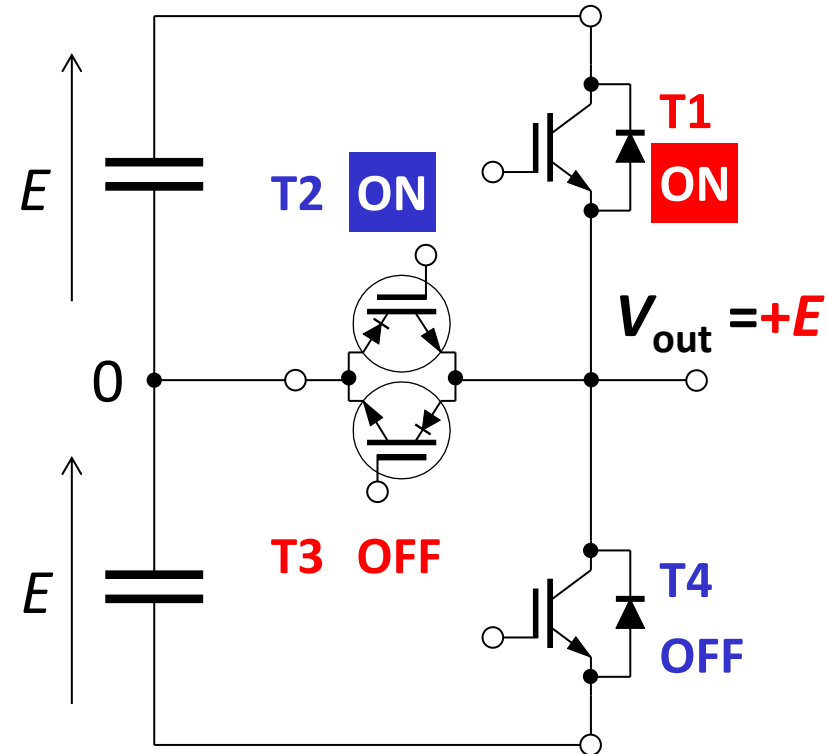
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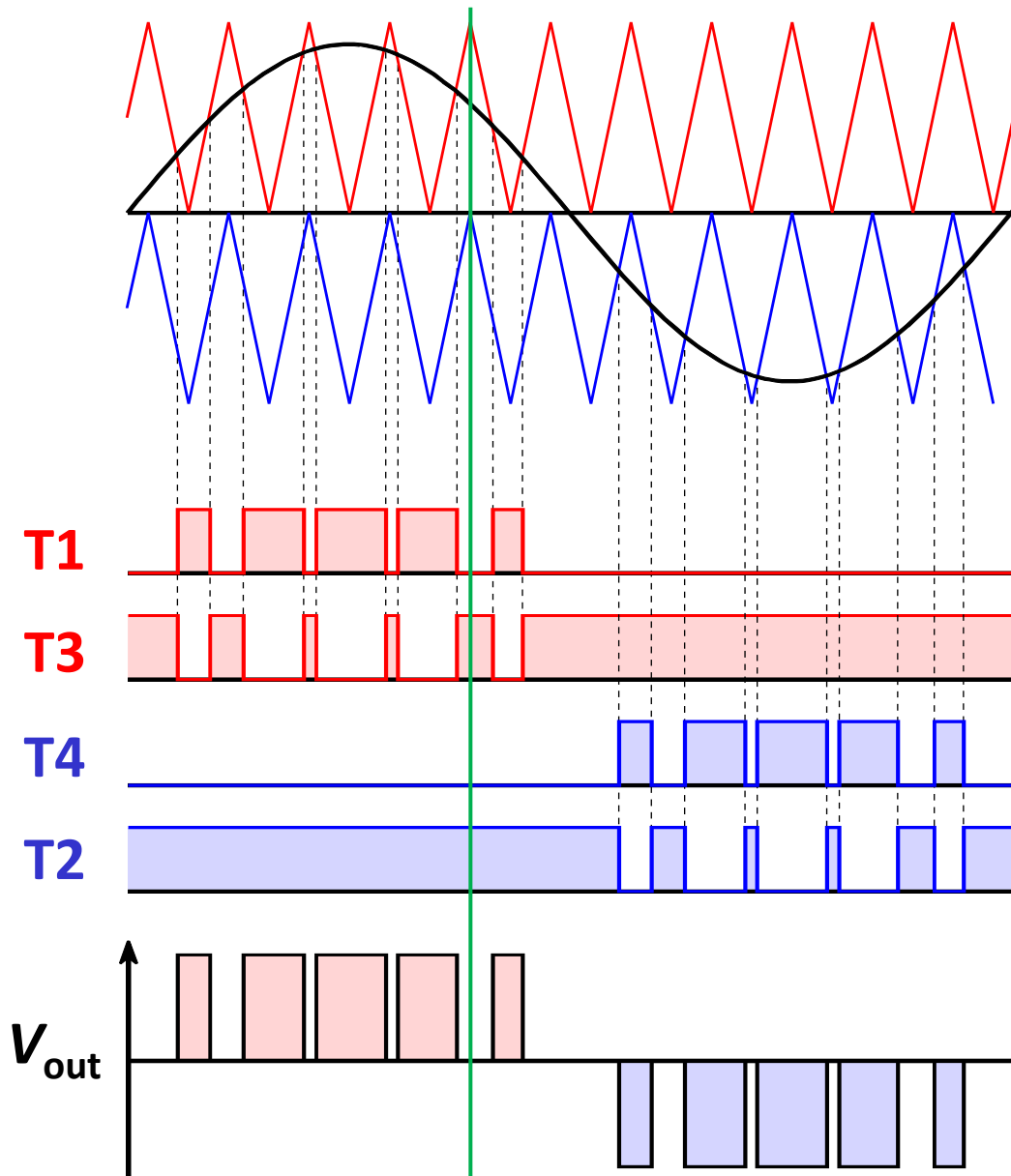
Switching Pattern (Phase Voltage)



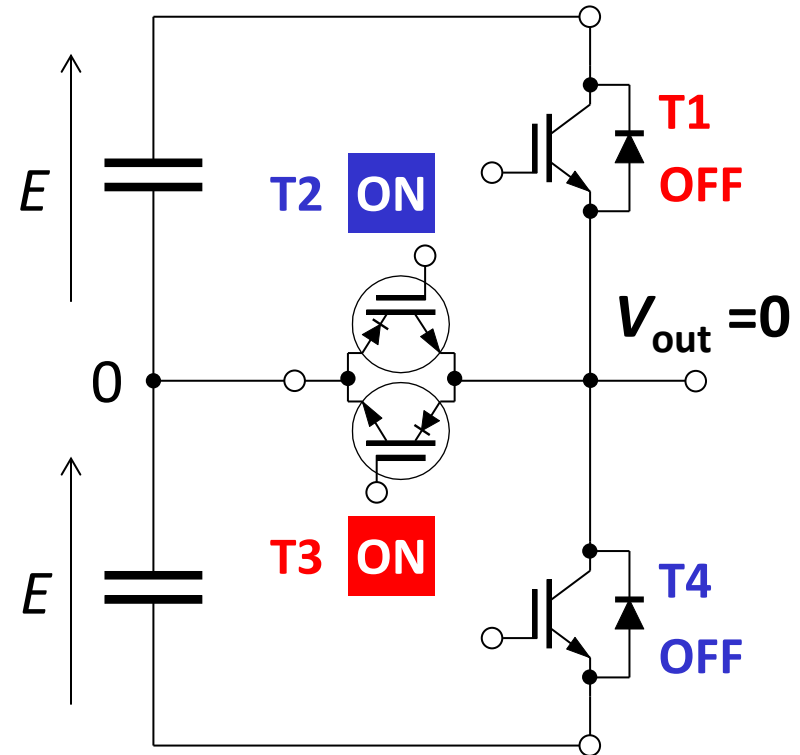
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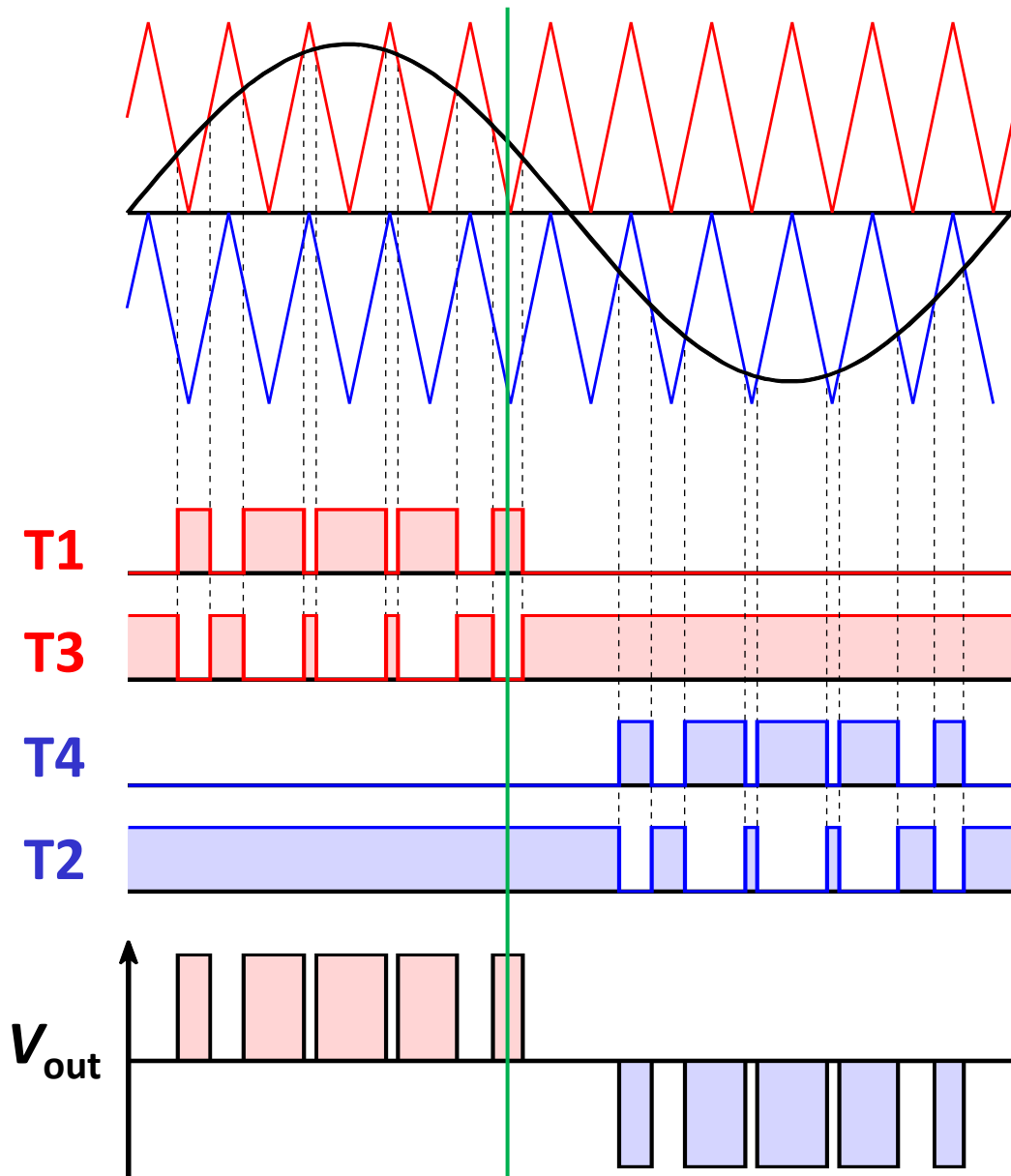
Switching Pattern (Phase Voltage)



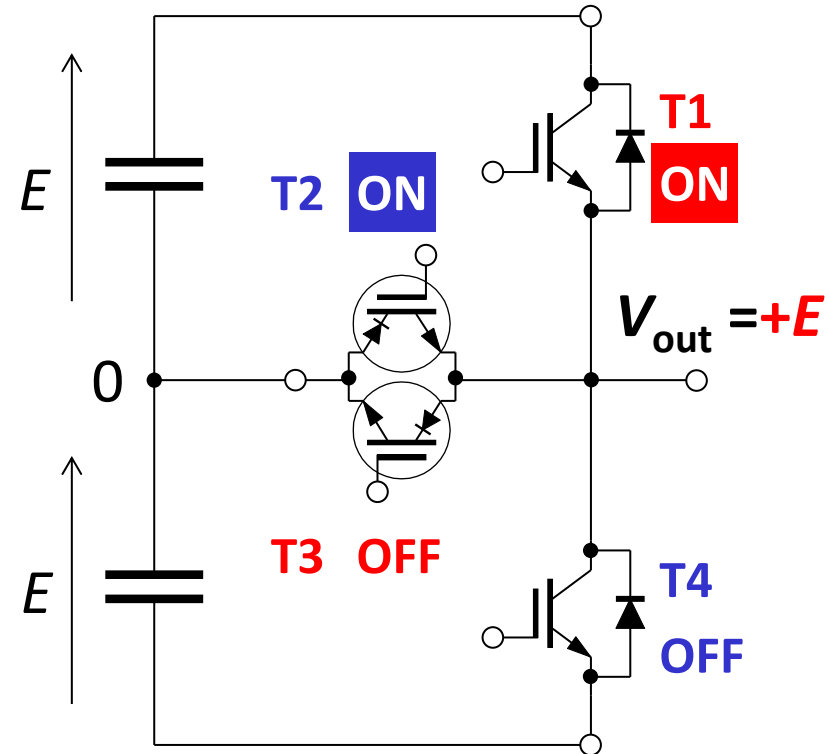
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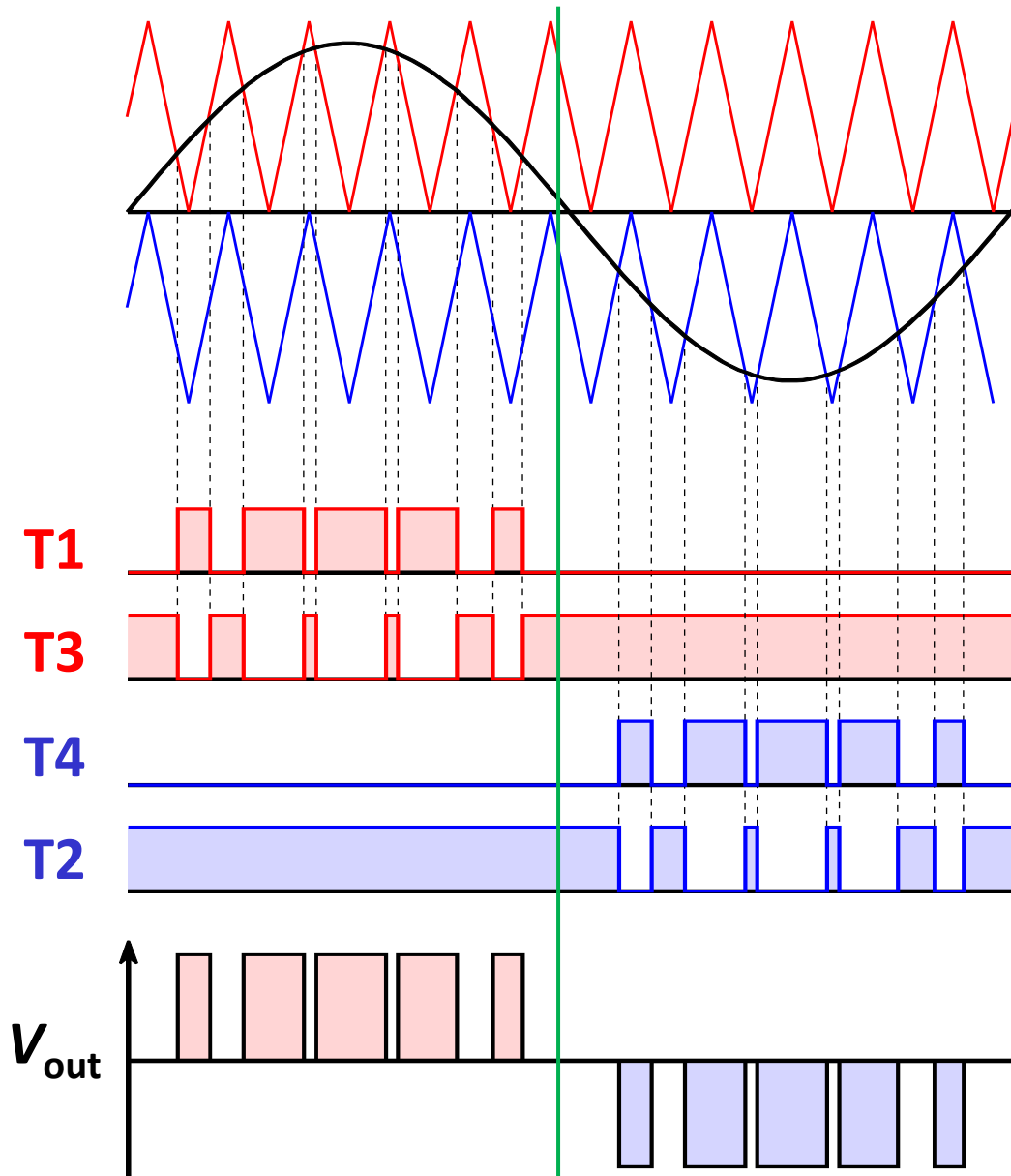
Switching Pattern (Phase Voltage)



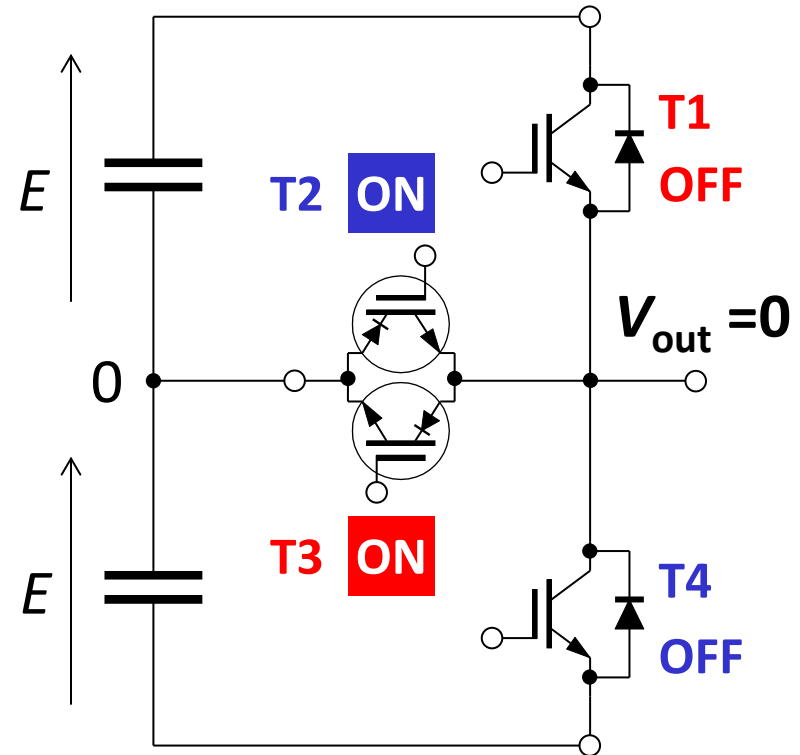
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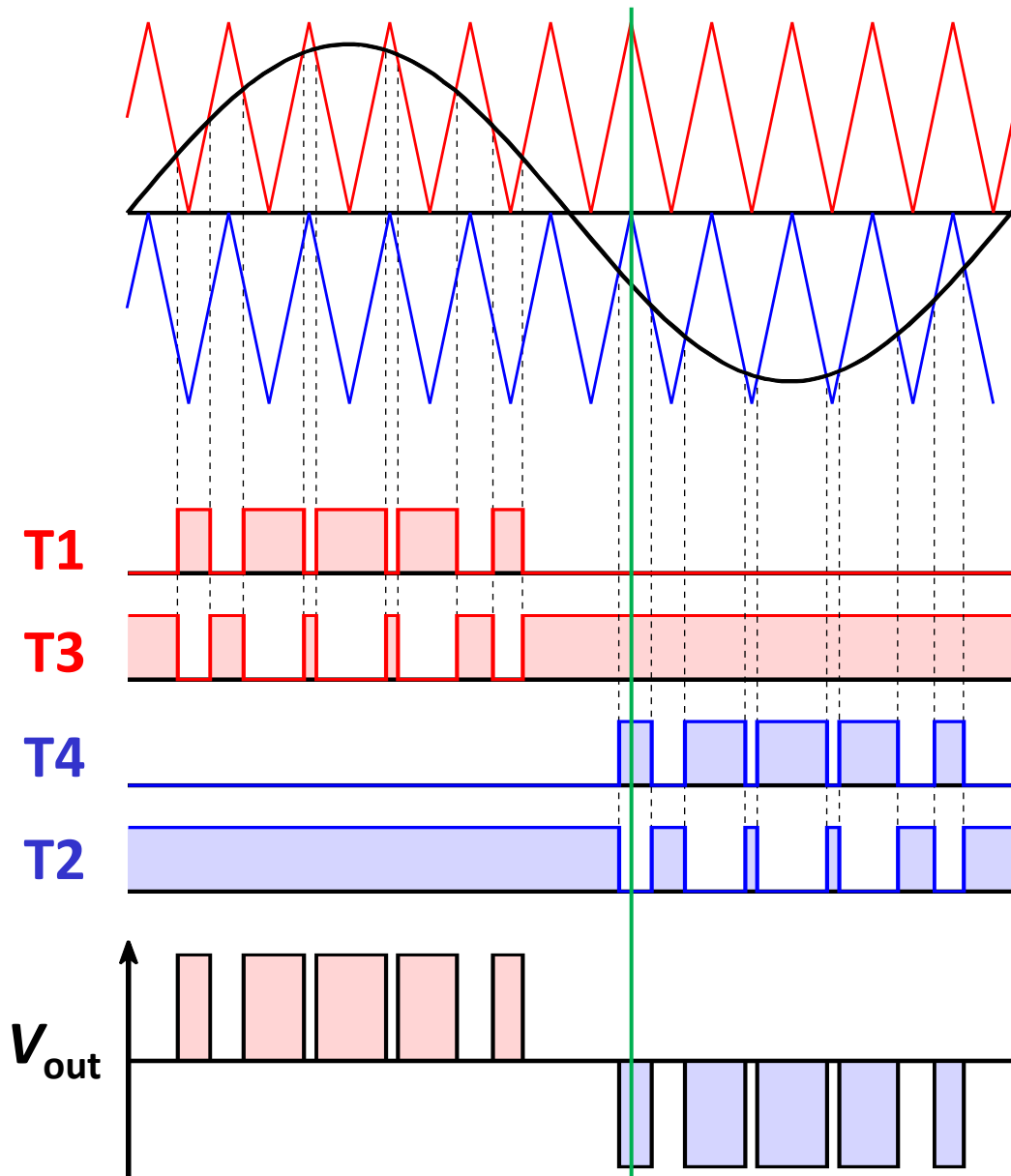
Switching Pattern (Phase Voltage)



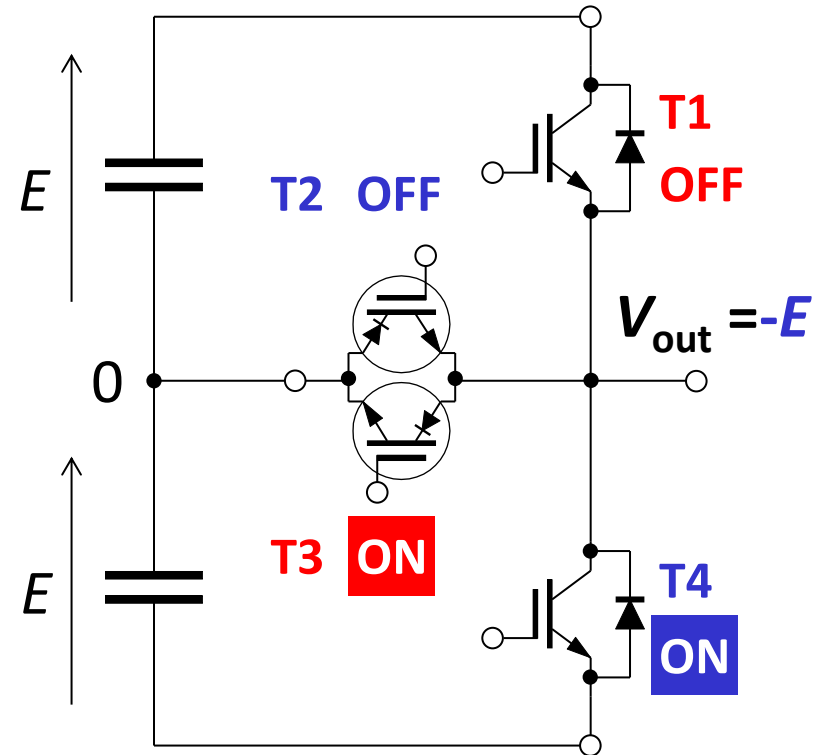
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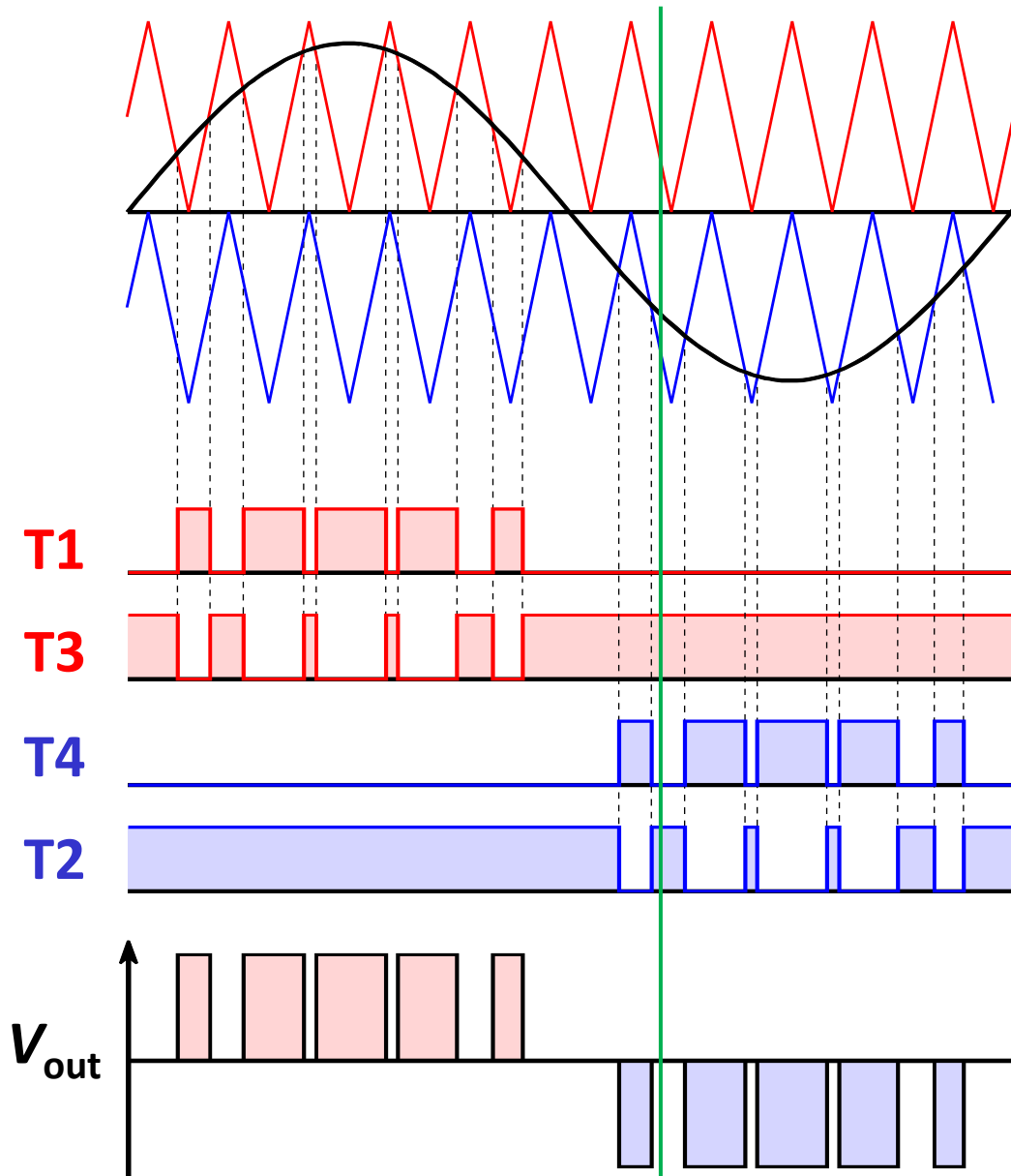
Switching Pattern (Phase Voltage)



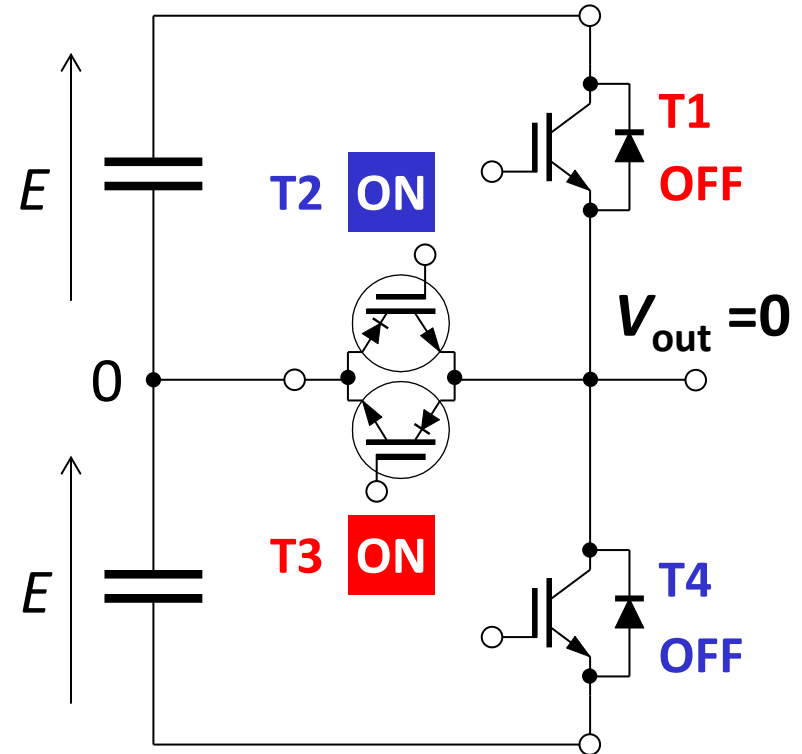
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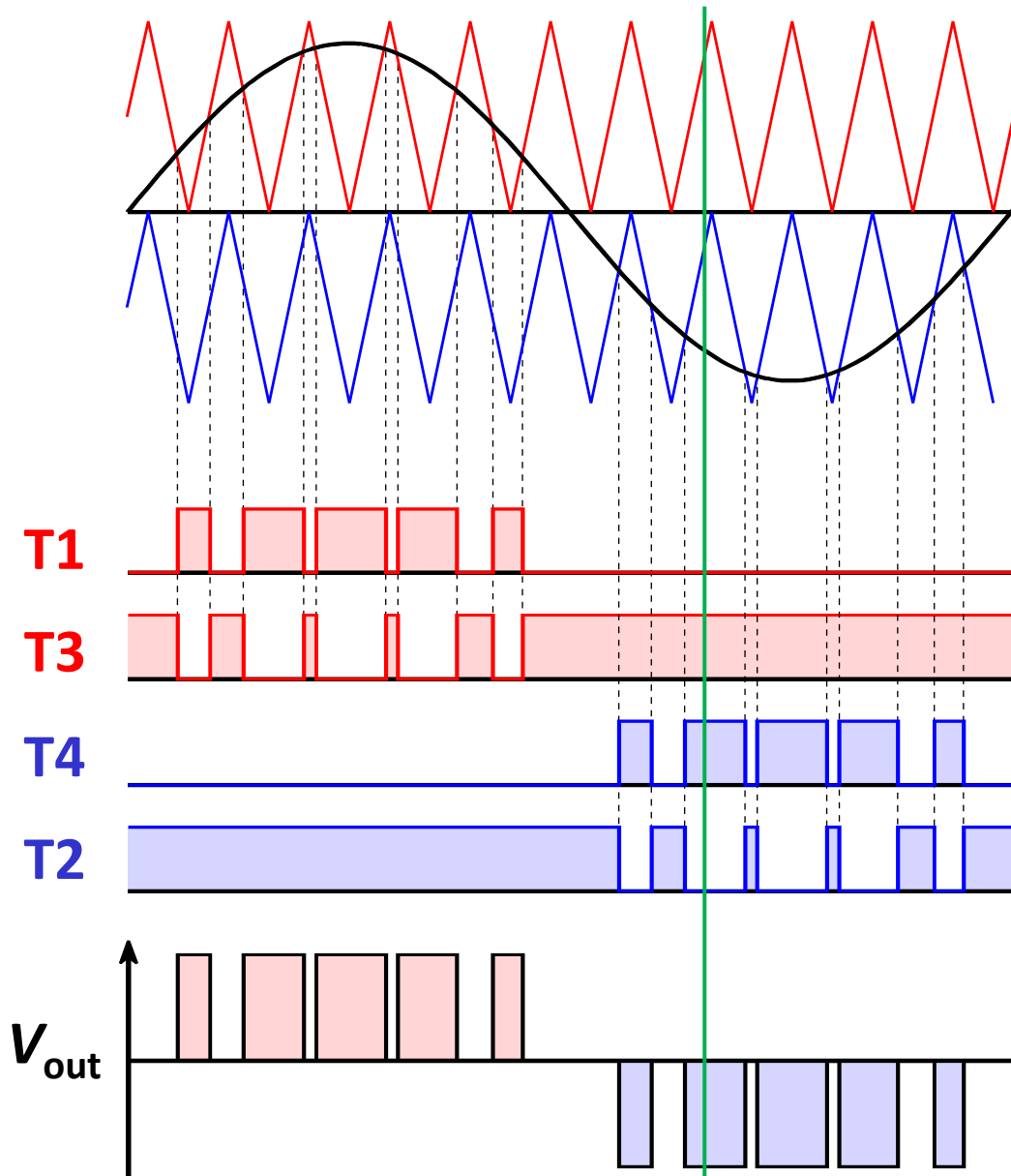
Switching Pattern (Phase Voltage)



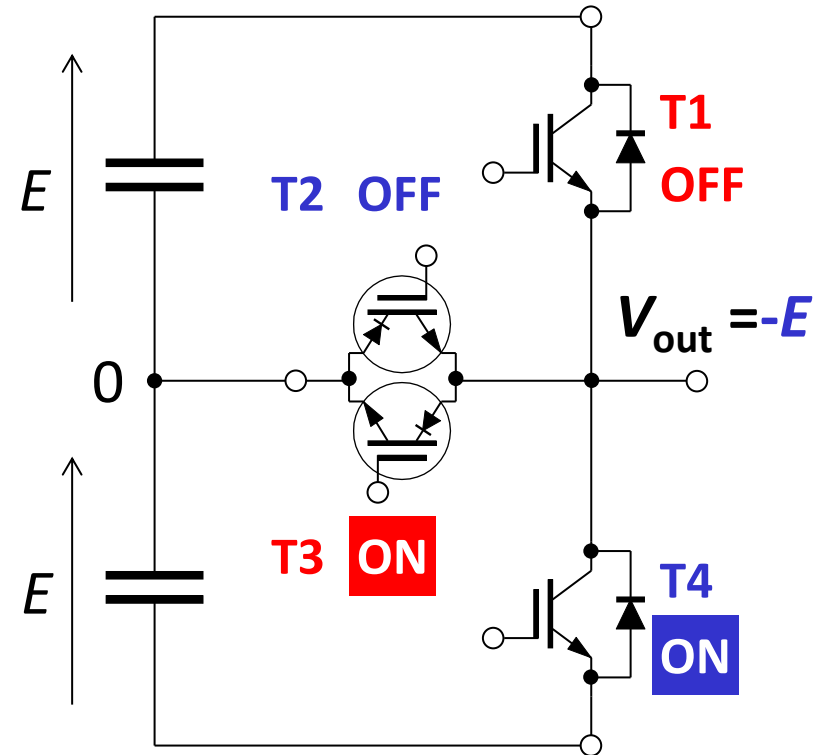
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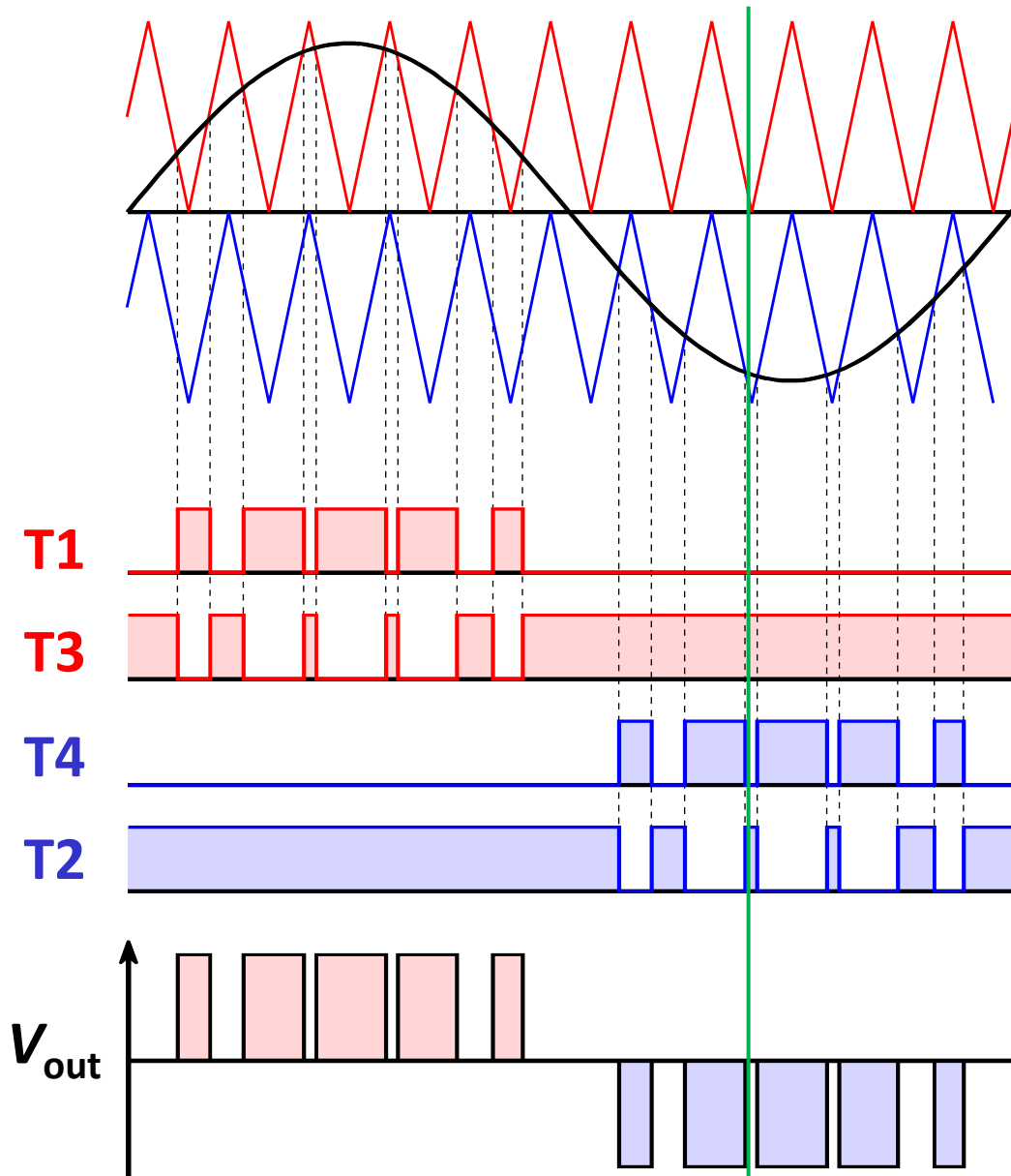
Switching Pattern (Phase Voltage)



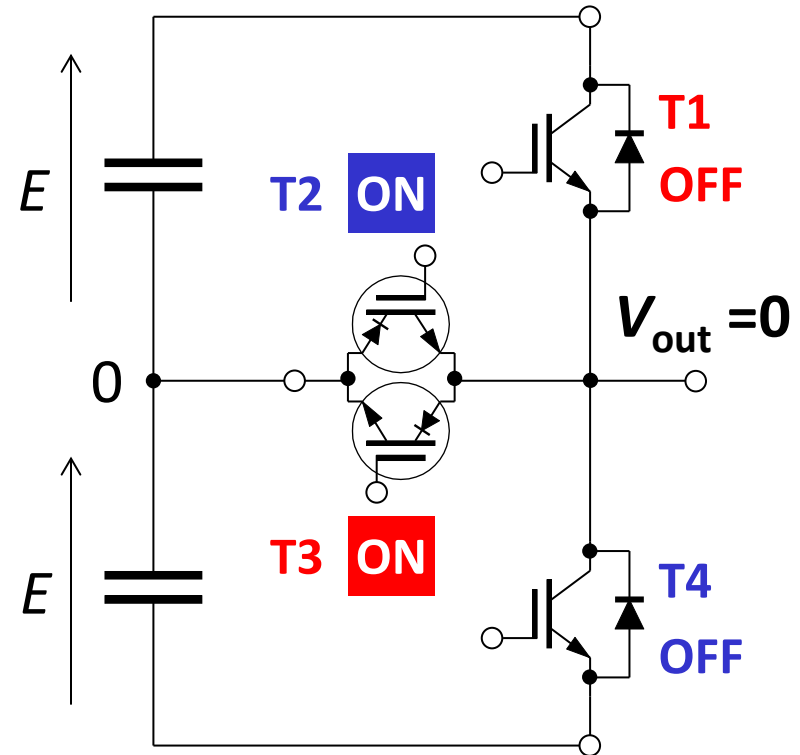
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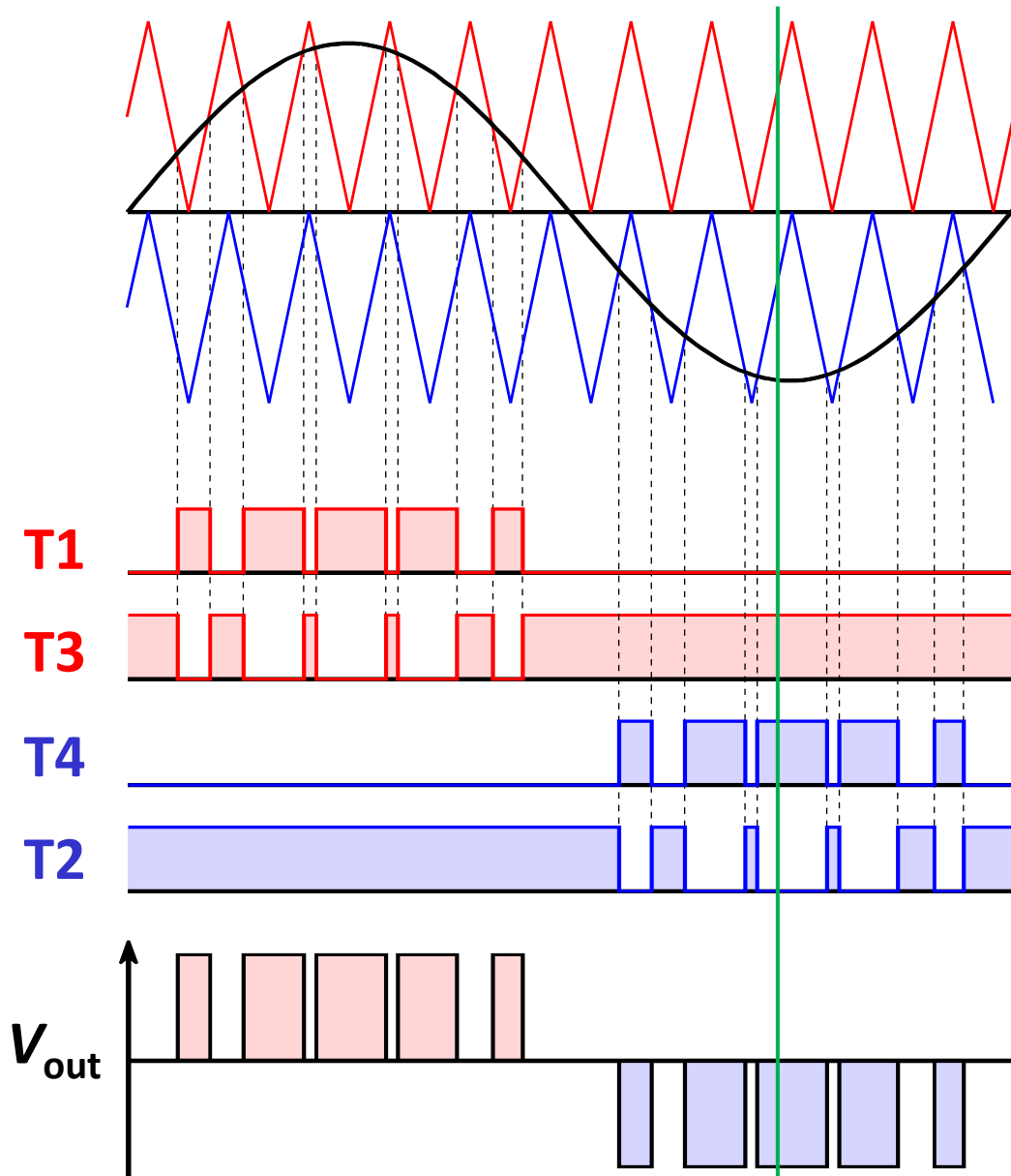
Switching Pattern (Phase Voltage)



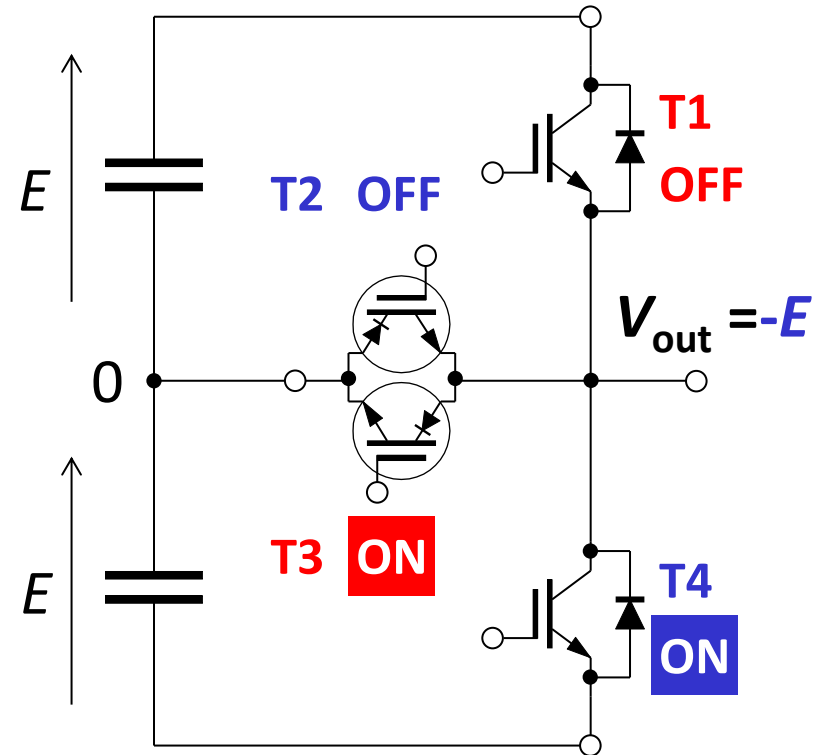
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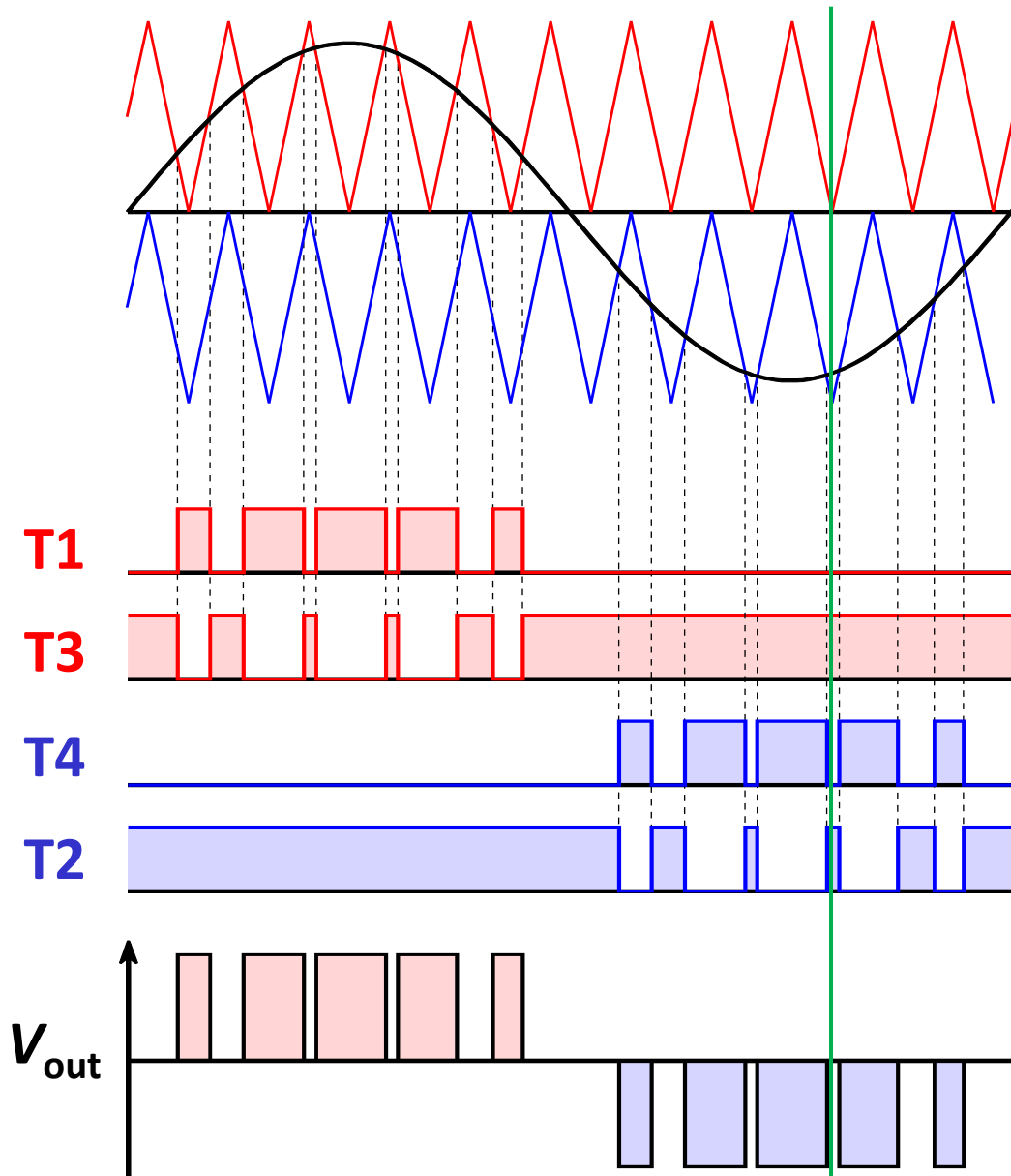
Switching Pattern (Phase Voltage)



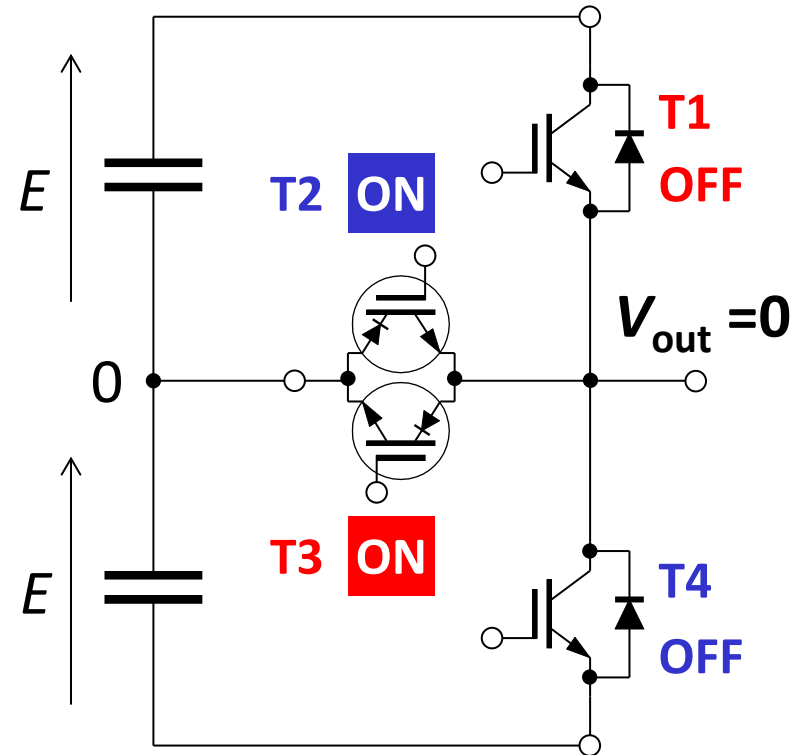
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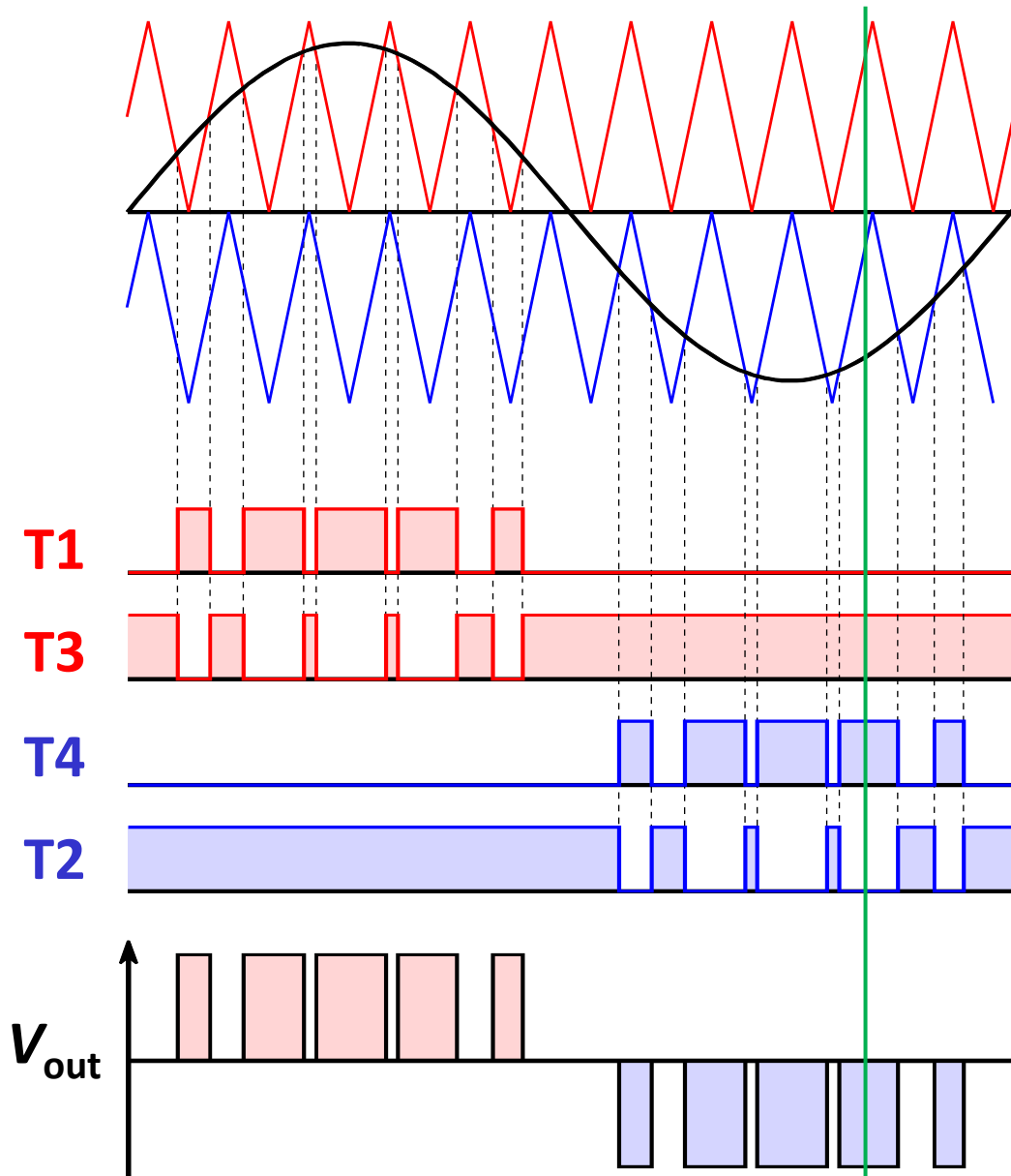
Switching Pattern (Phase Voltage)



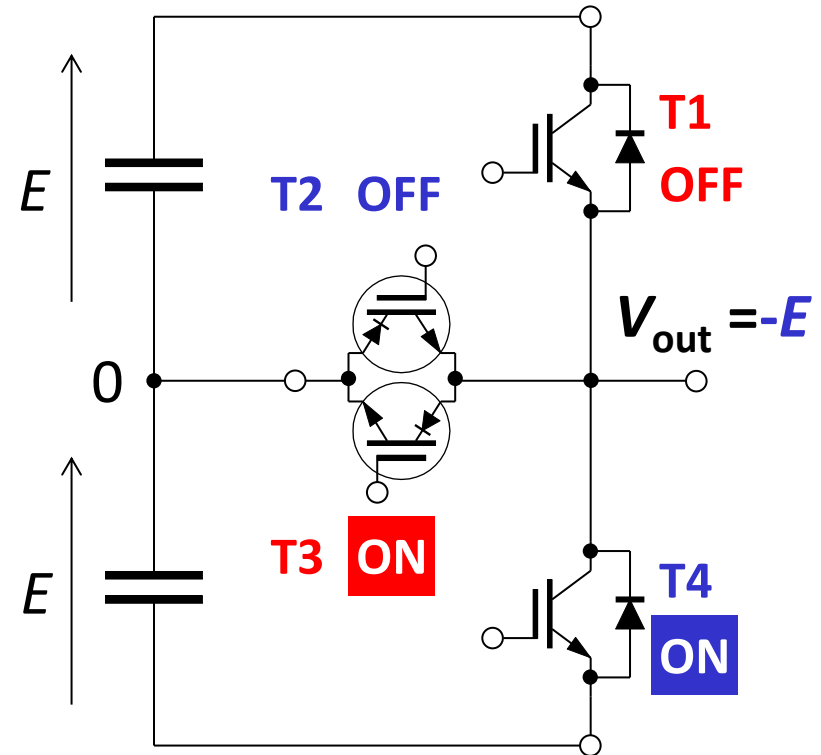
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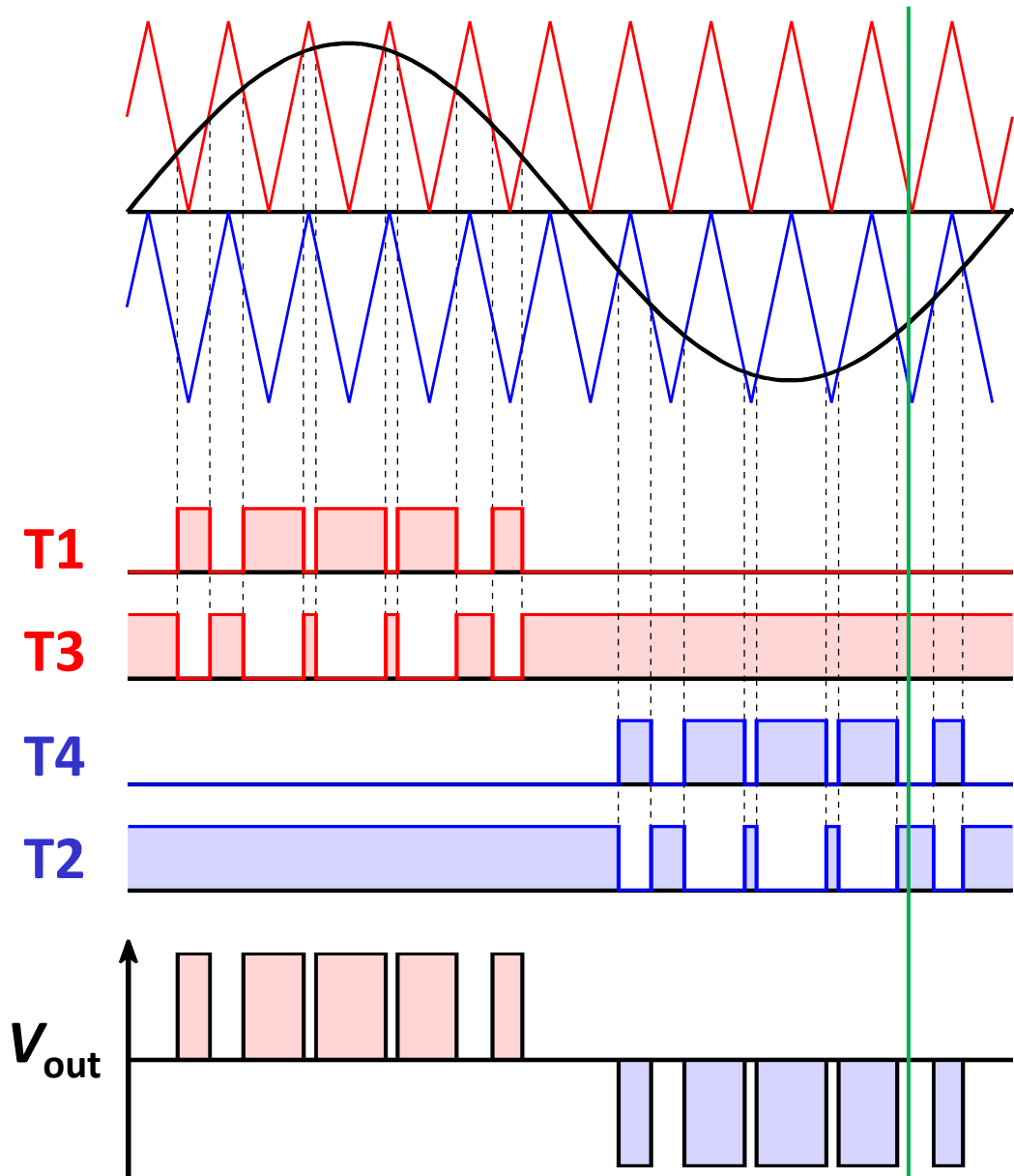
Switching Pattern (Phase Voltage)



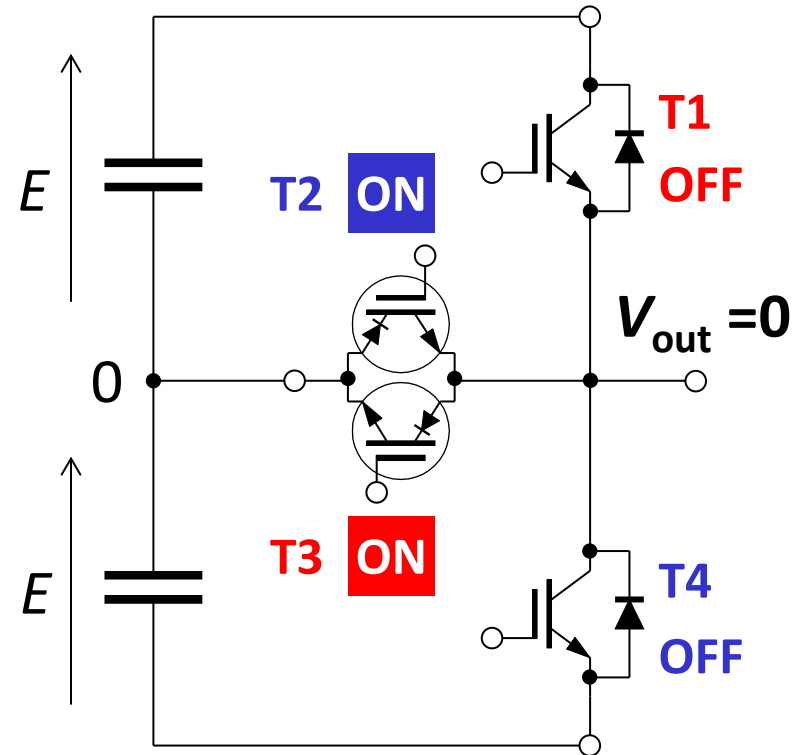
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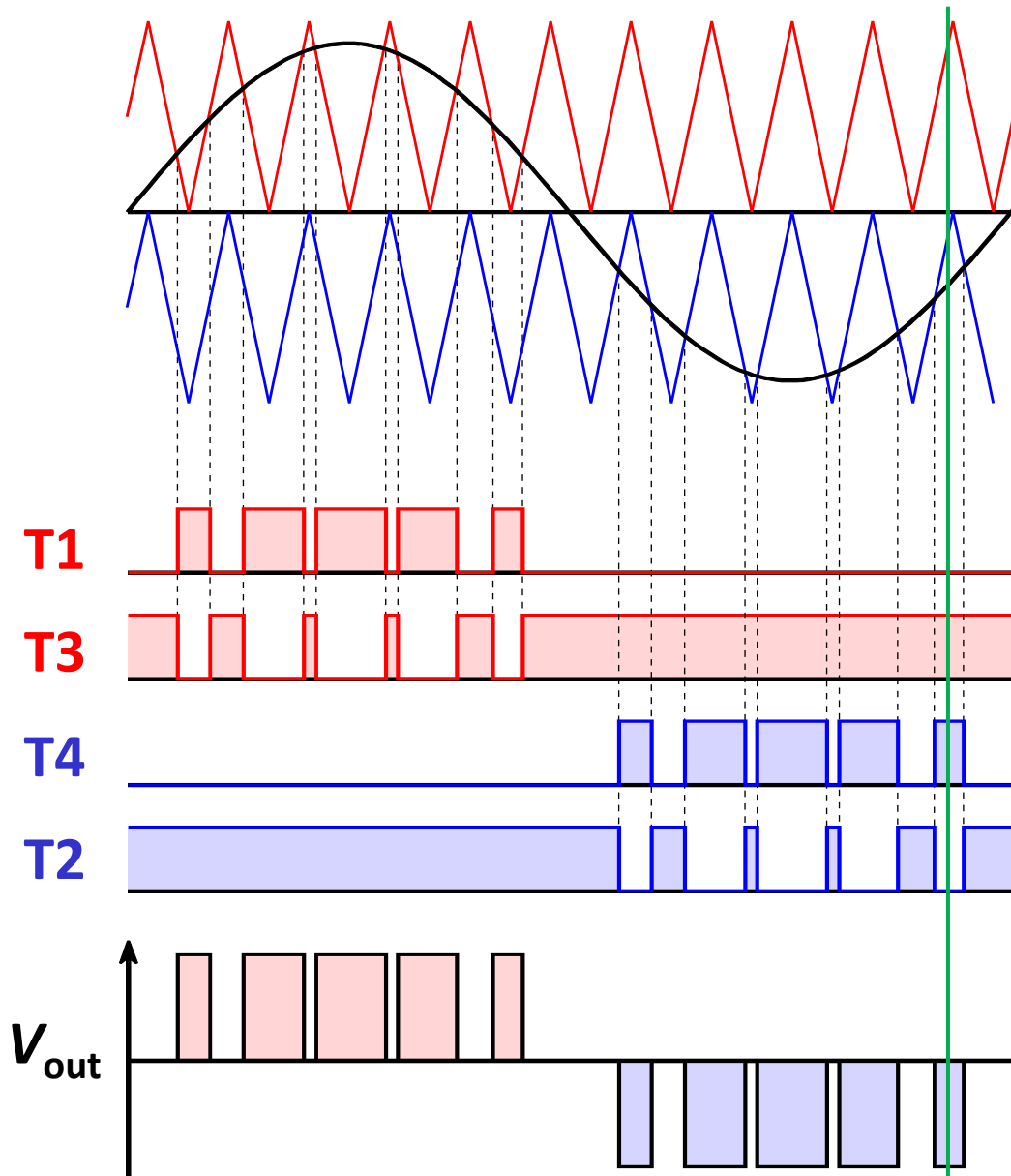
Switching Pattern (Phase Voltage)



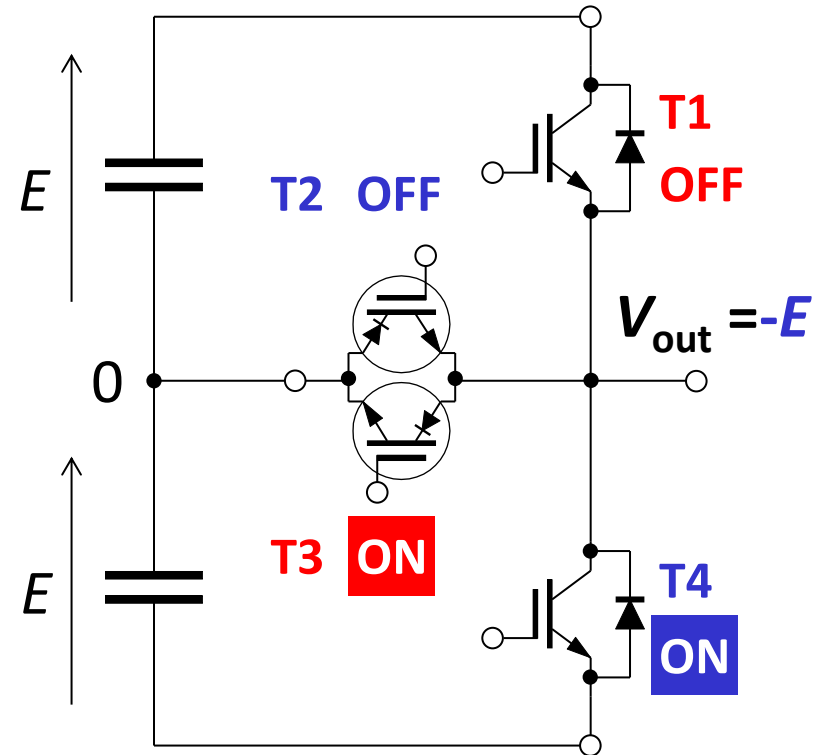
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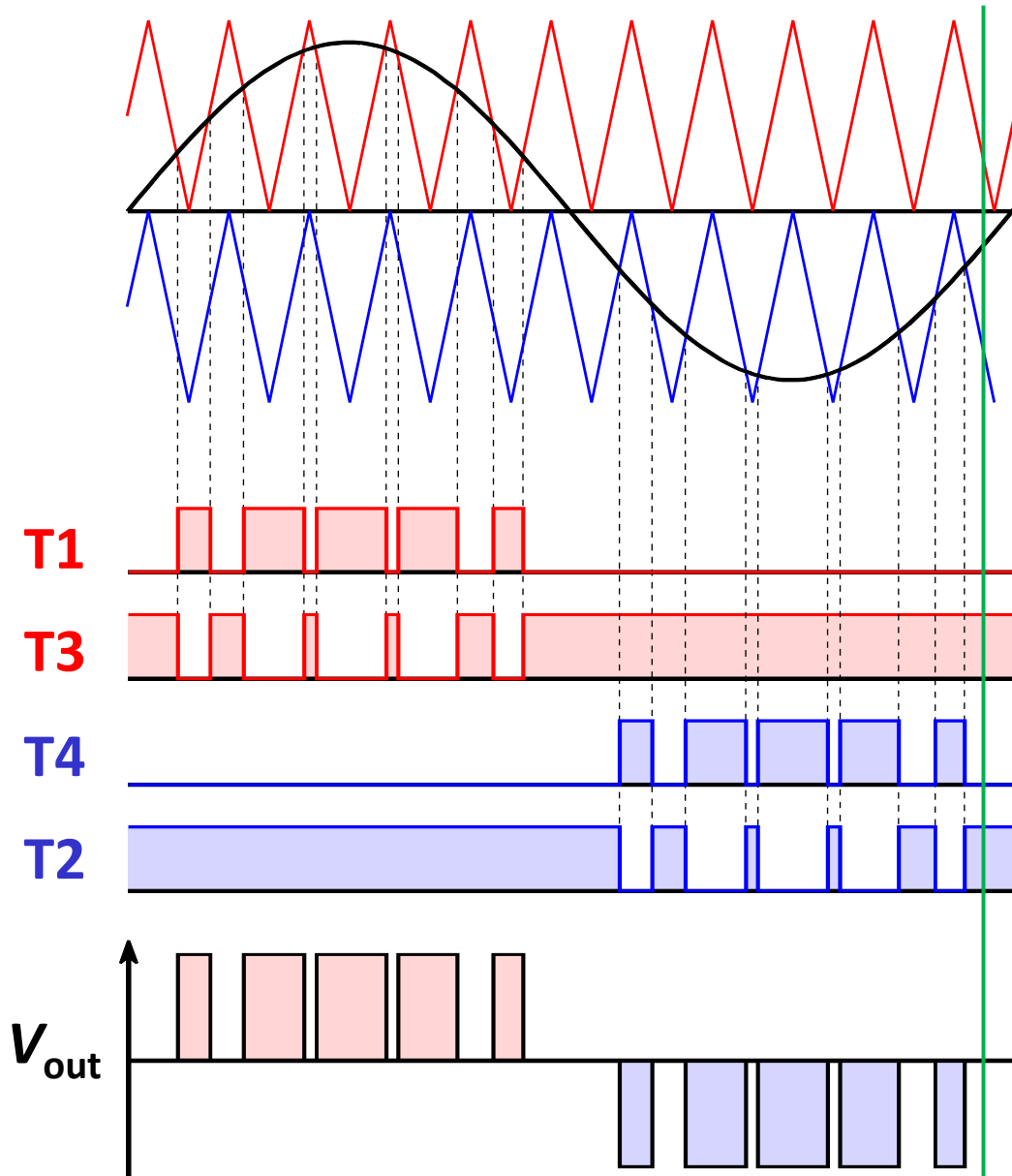
Switching Pattern (Phase Voltage)



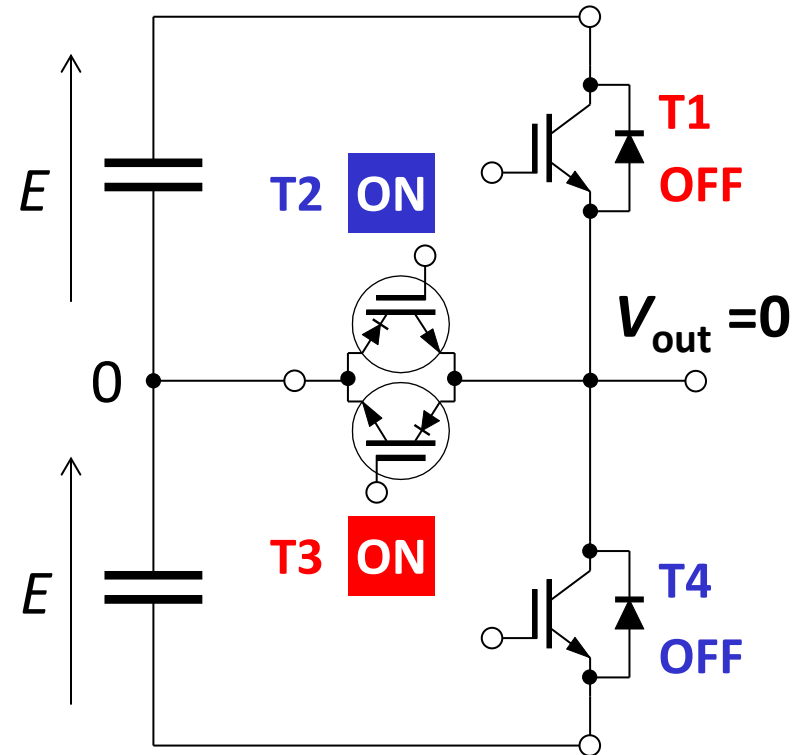
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Switching Pattern (Phase Voltage)

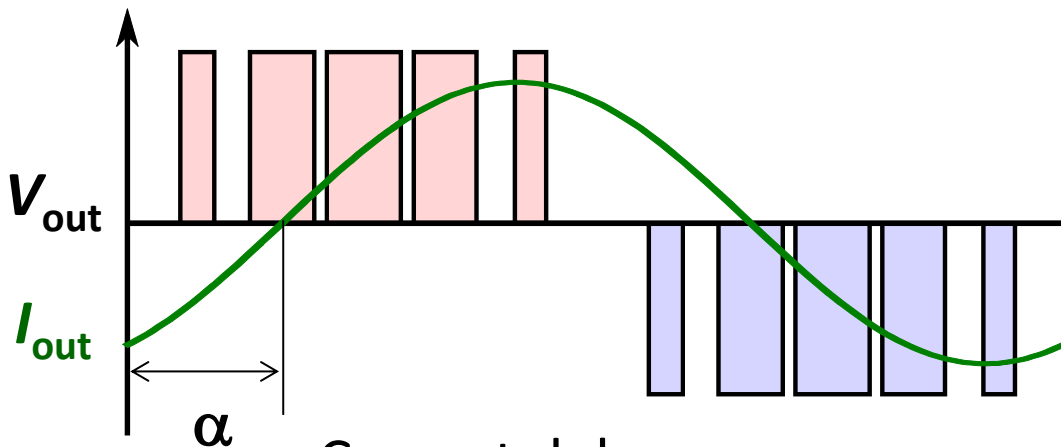
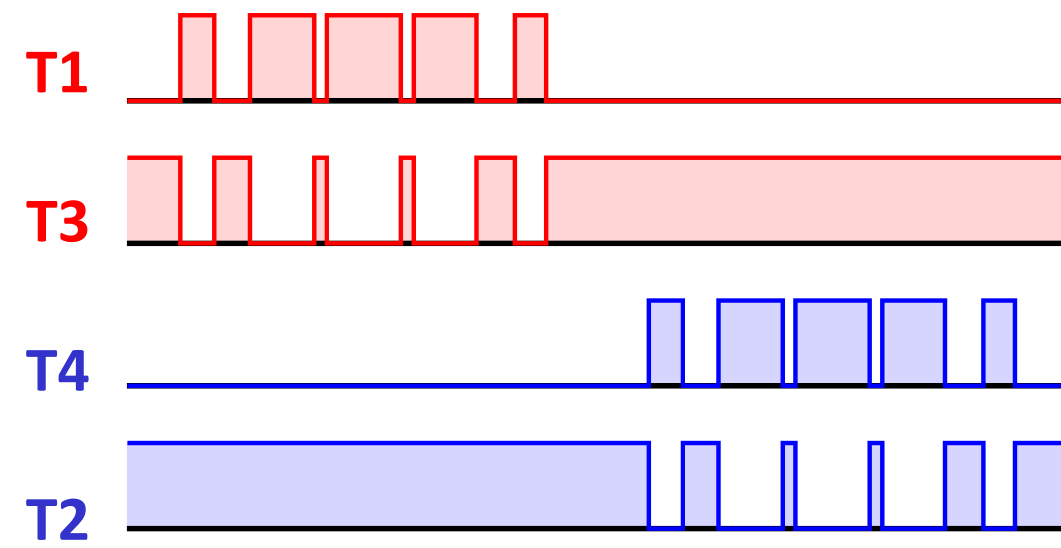


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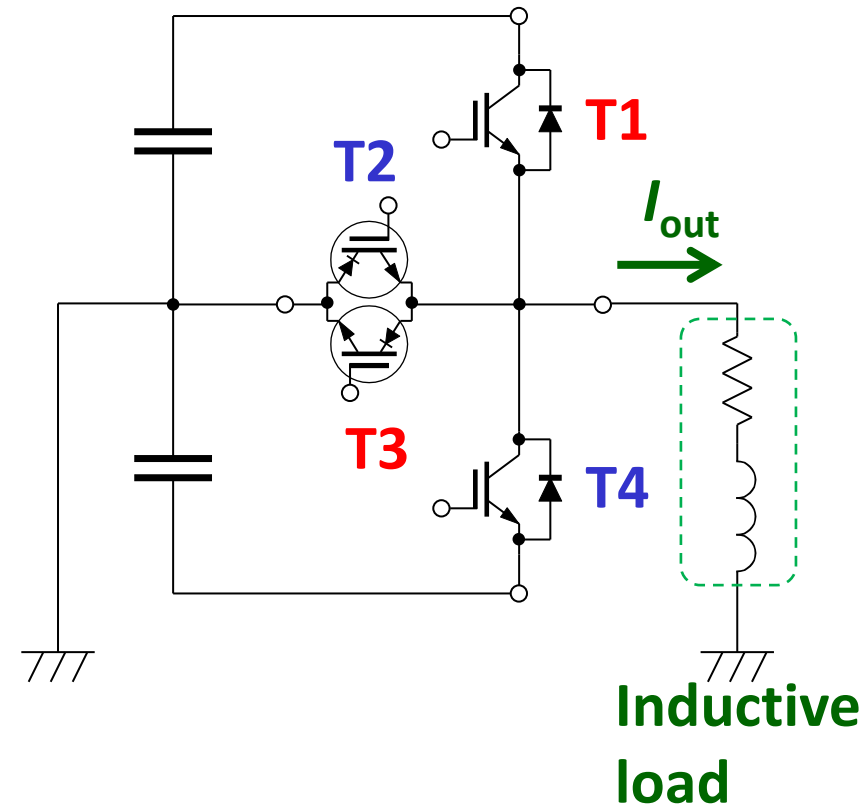


Inductive load - Delayed current

Inductive Load – Lagging Current

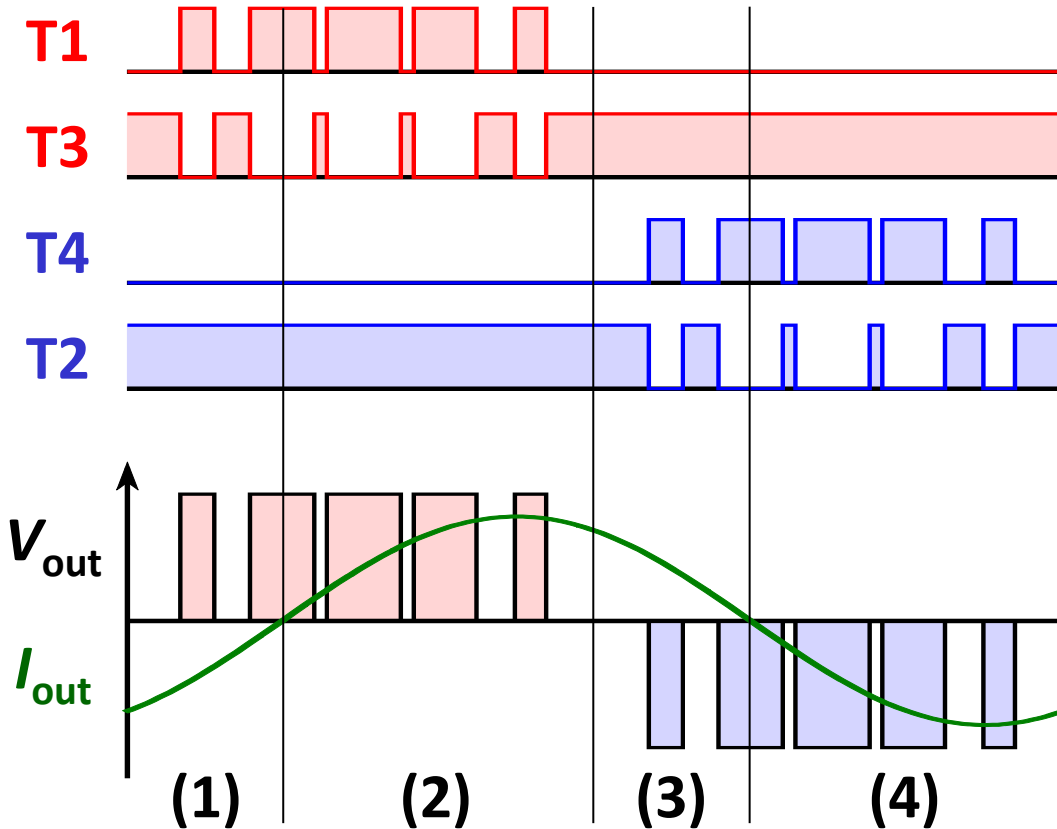


Current delay: α
Power factor: $\cos \alpha$



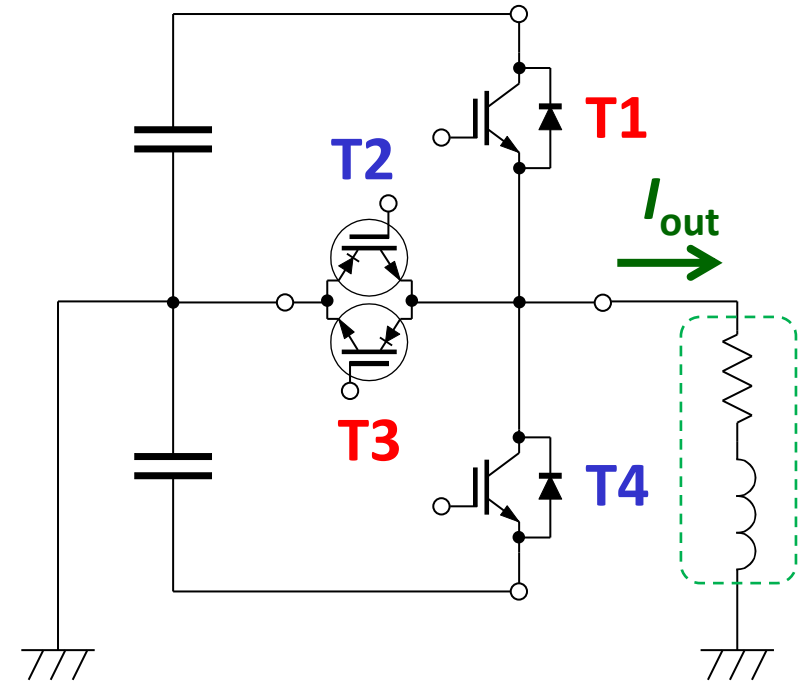
If an inductive load is connected, the current waveform is lagging behind the voltage waveform.

Switching Mode



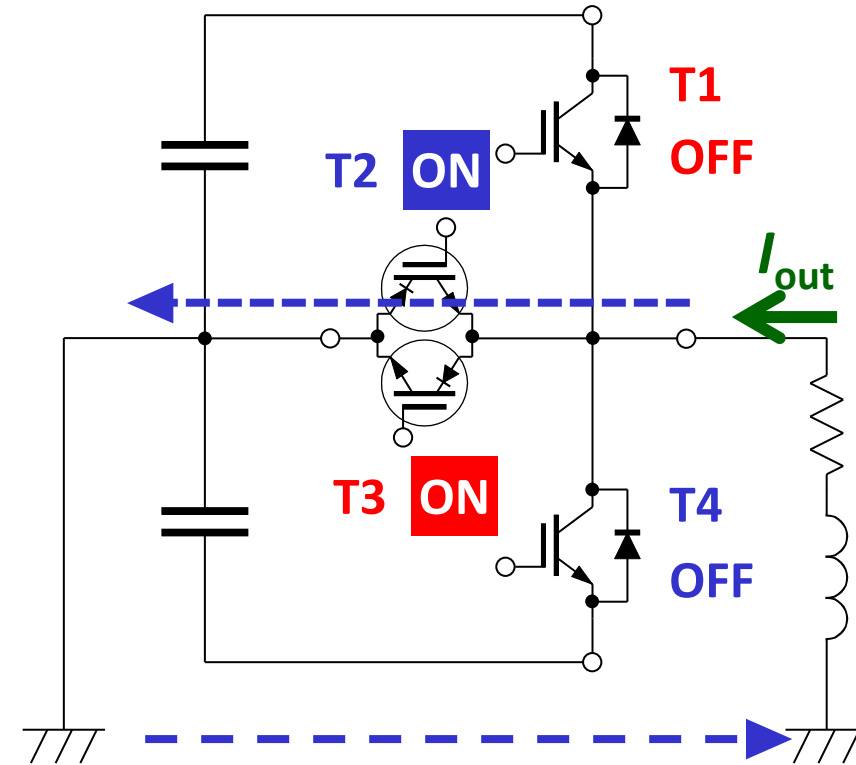
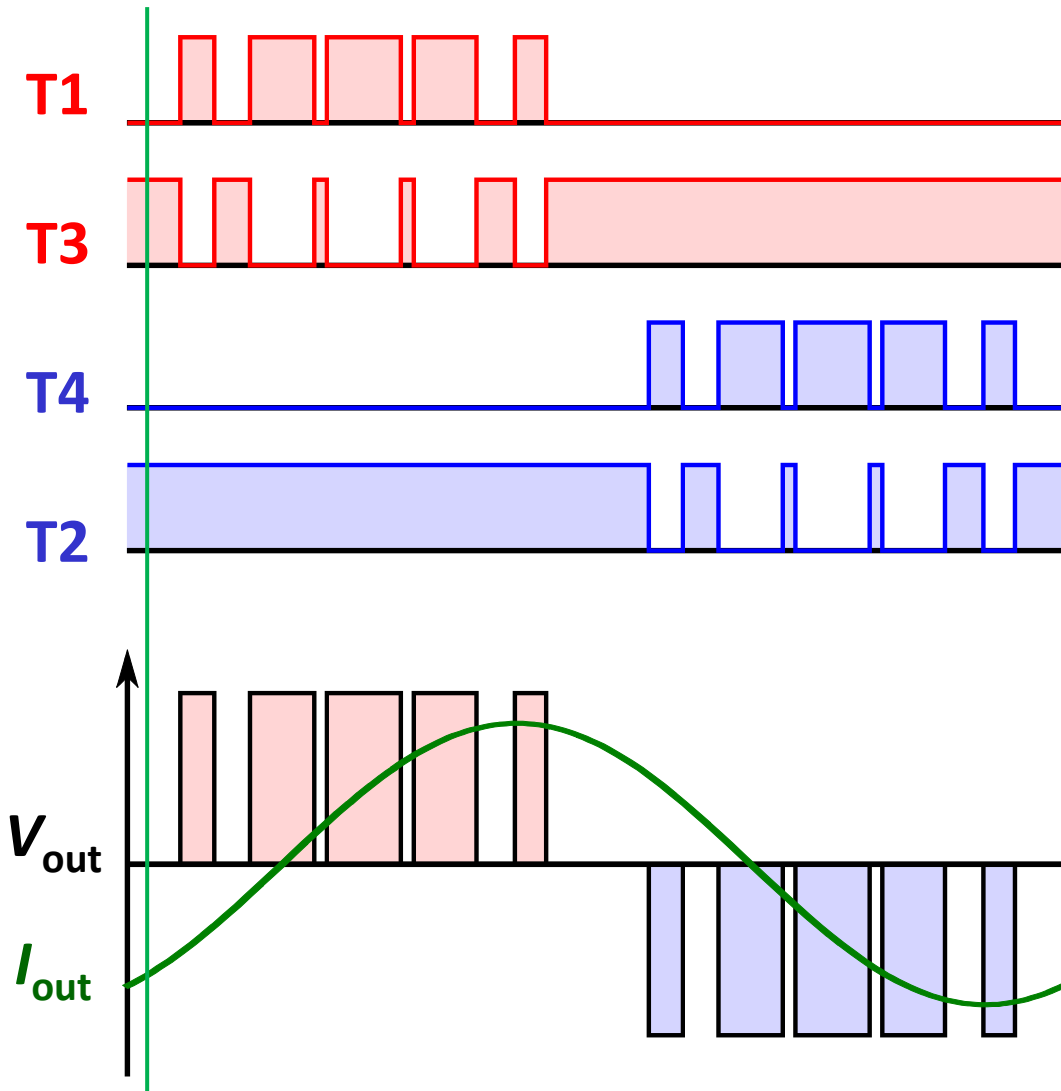
- (1) SW mode B
- (2) SW mode A
- (3) SW mode B'
- (4) SW mode A'

- T1: Free wheeling
- T1: Switching
- T4: Free wheeling
- T2: Switching



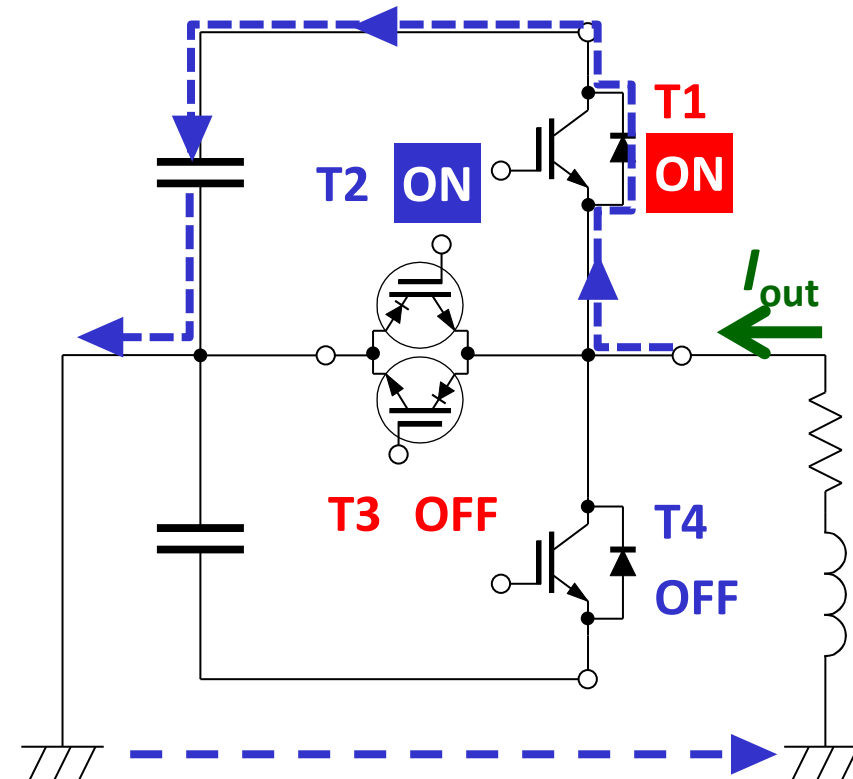
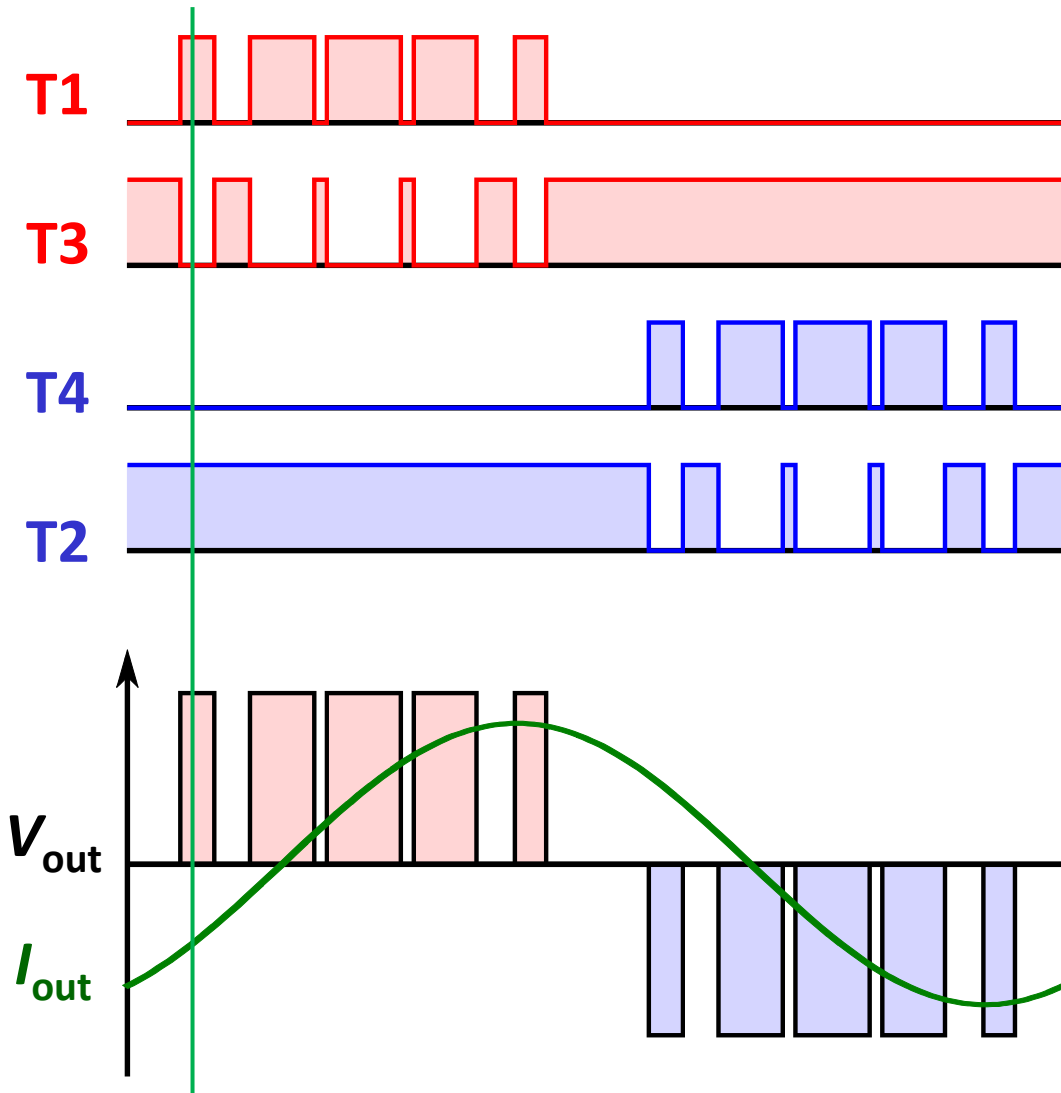
- T3: Switching
- Tc: Free wheeling
- T4: Switching
- T3: Free wheeling

Switching Pattern (1) SW mode B



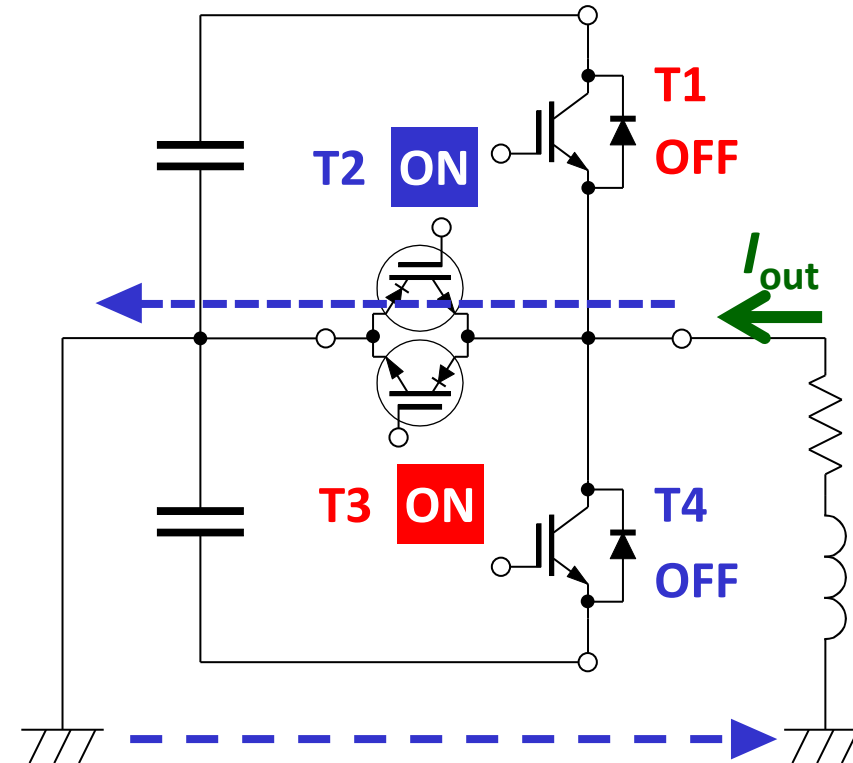
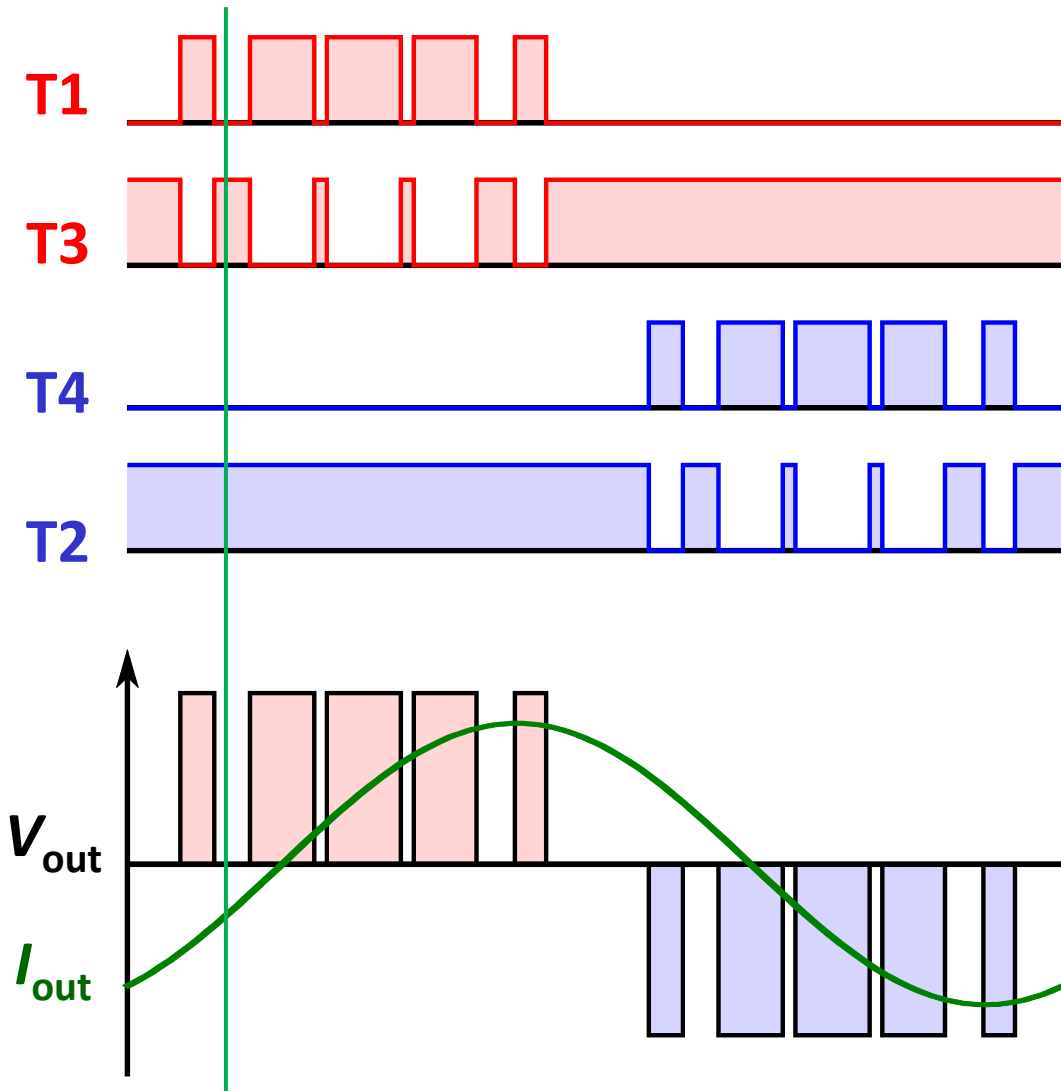
T1: OFF
T2: ON
T3: Turn on (Free wheeling)
T4: OFF

Switching Pattern (1) SW mode B



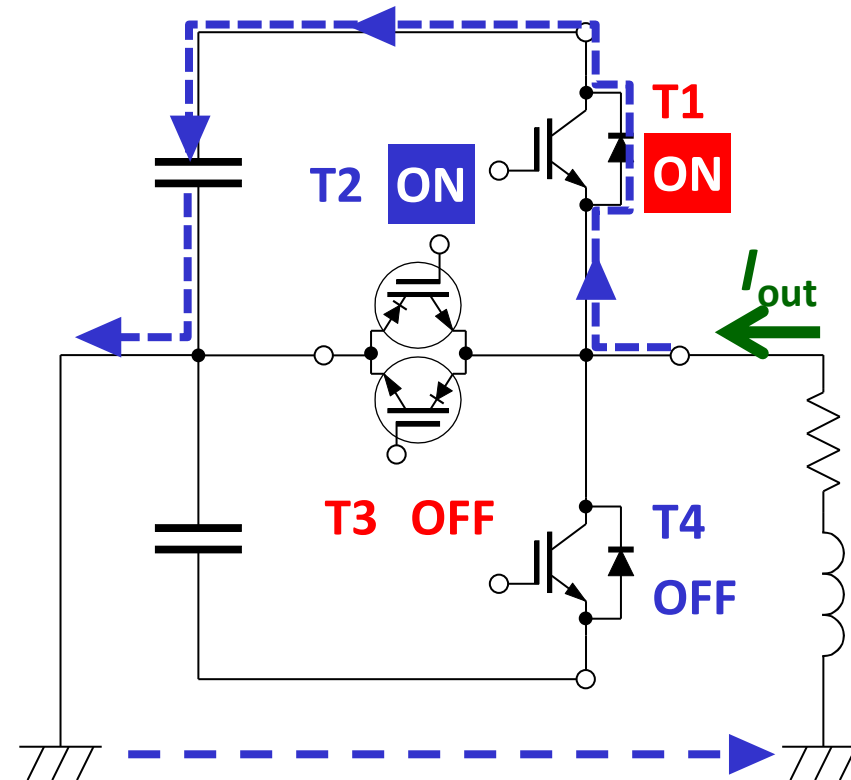
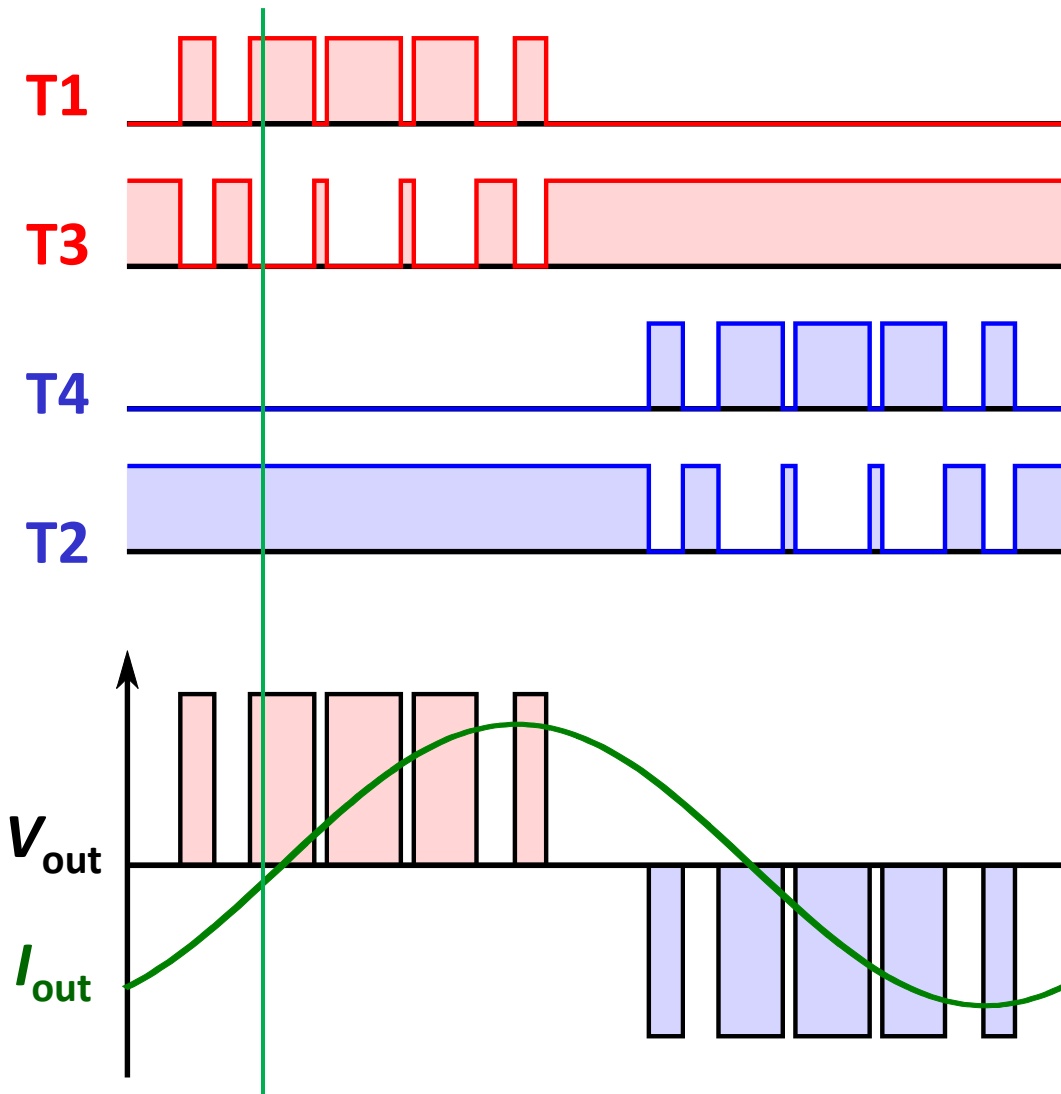
- T1:** Free wheeling
- T2:** ON
- T3:** Turn off
- T4:** OFF

Switching Pattern (1) SW mode B



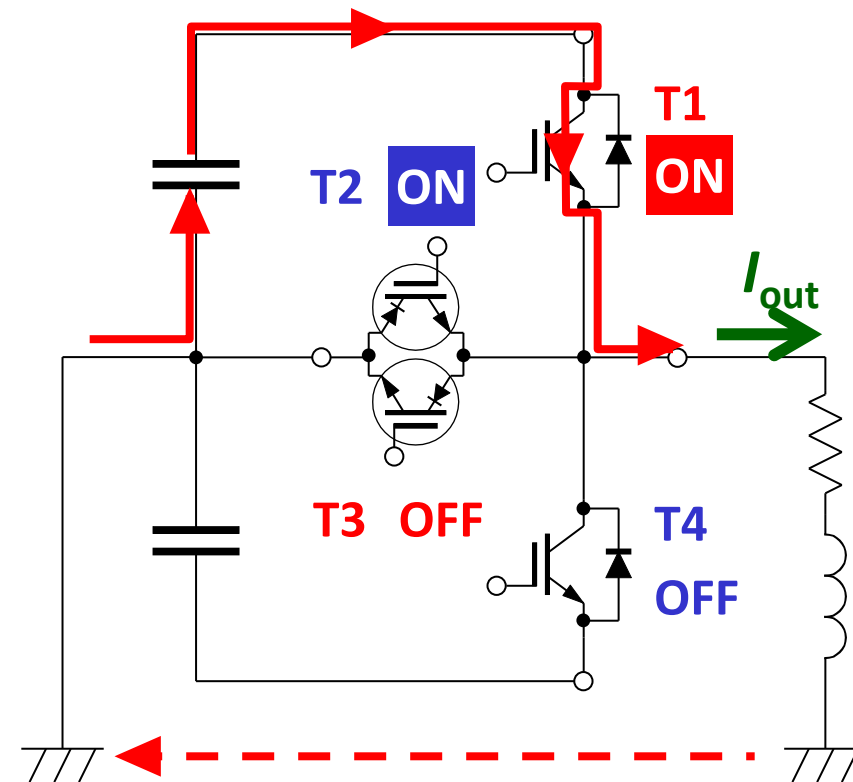
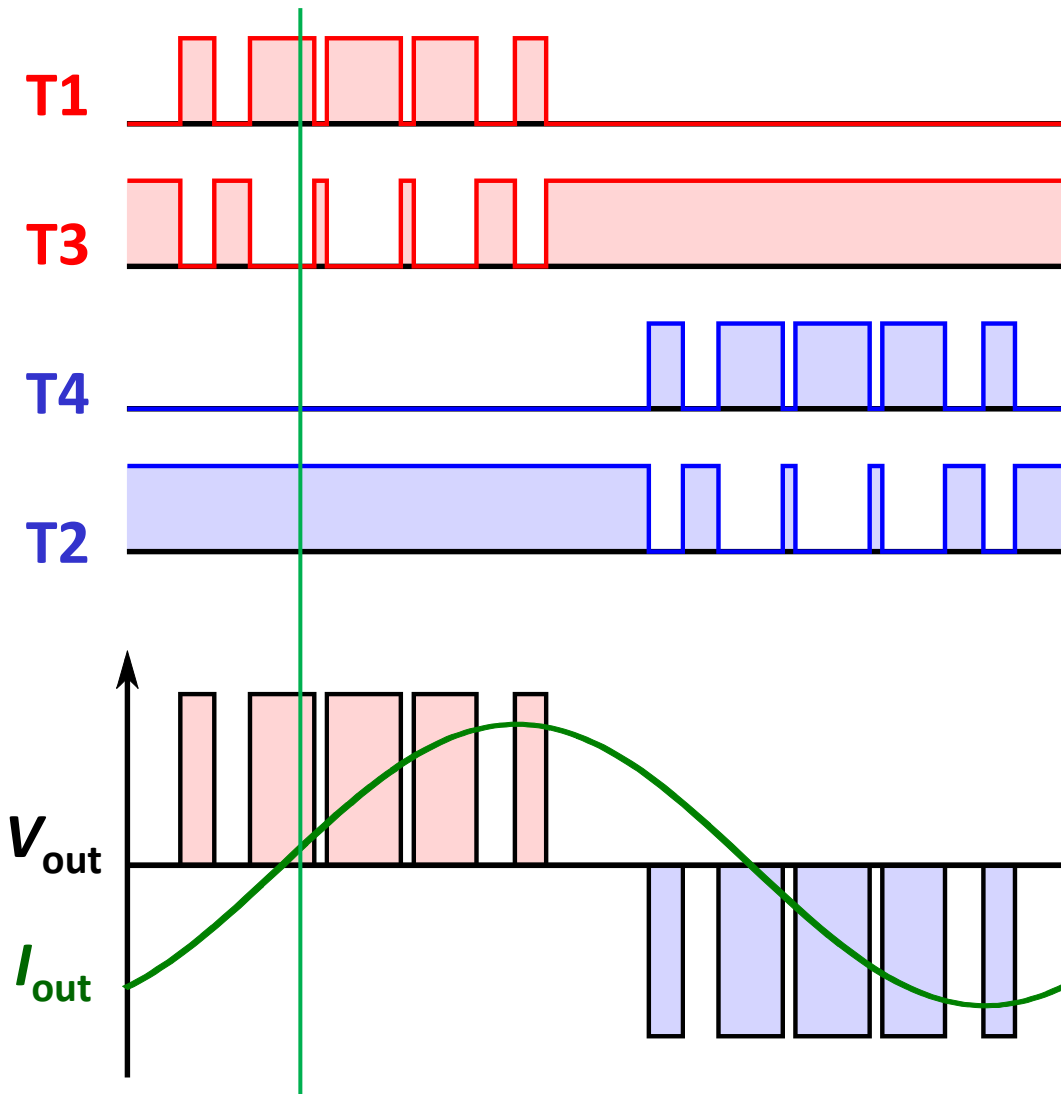
- T1: Reverse recovery**
- T2: ON**
- T3: Turn on (Free wheeling)**
- T4: OFF**

Switching Pattern (1) SW mode B



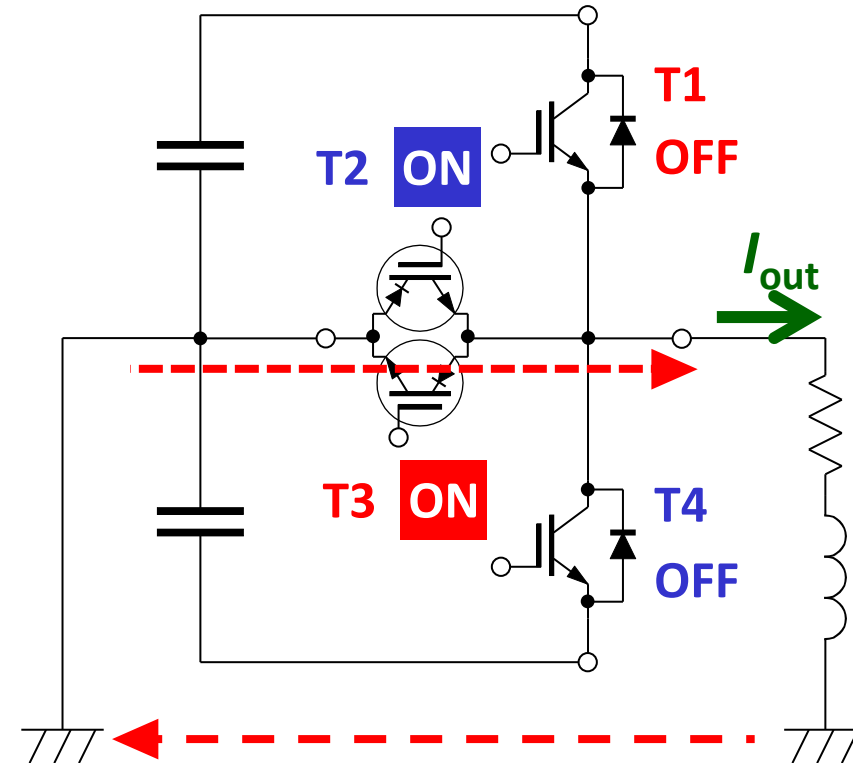
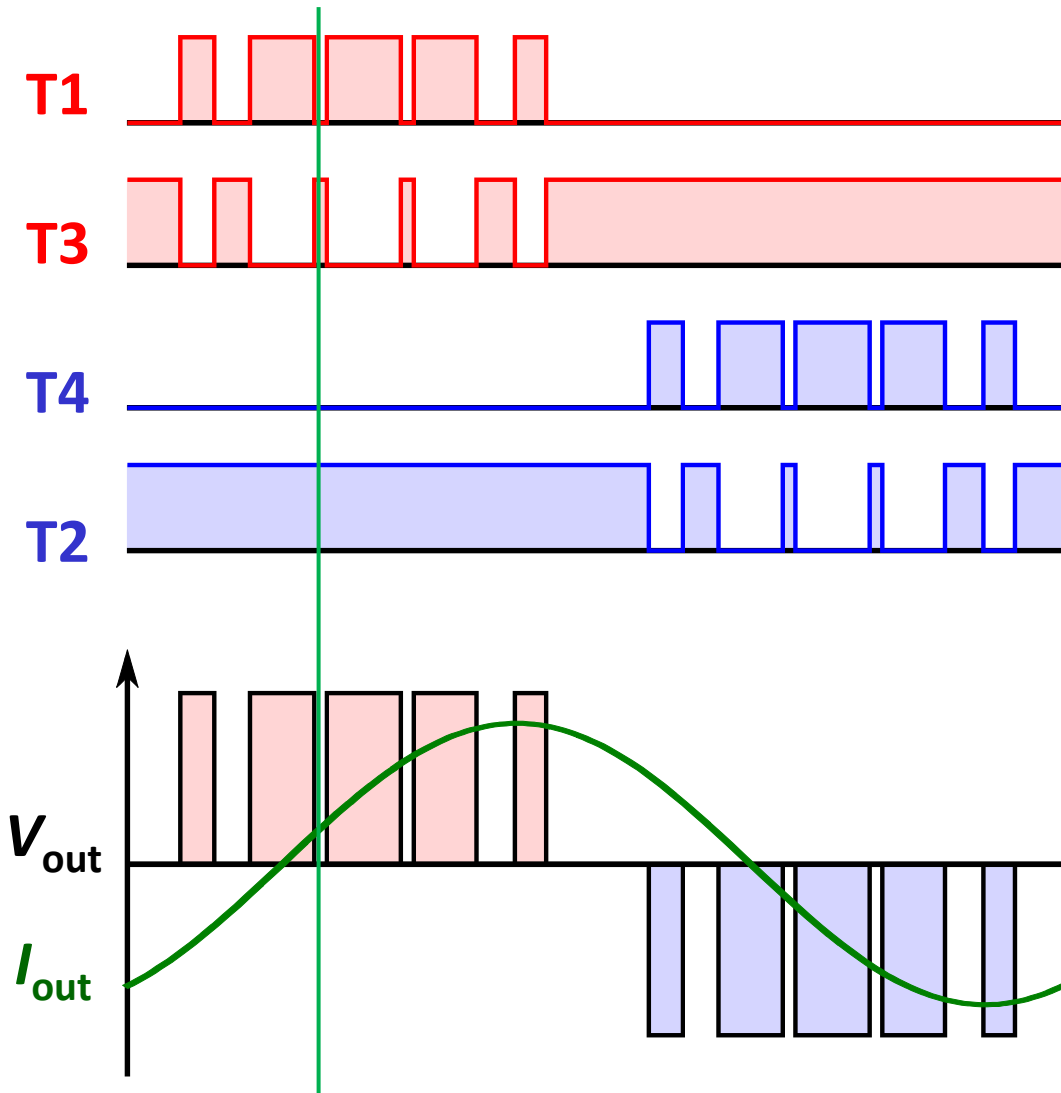
- T1:** Free wheeling
- T2:** ON
- T3:** Turn off
- T4:** OFF

Switching Pattern (2) SW mode A



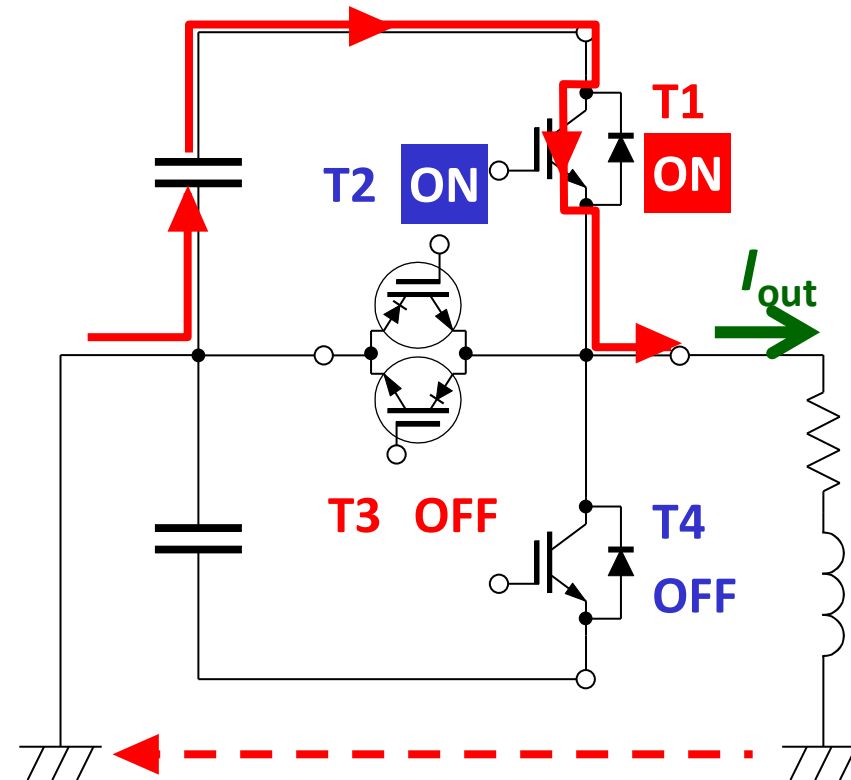
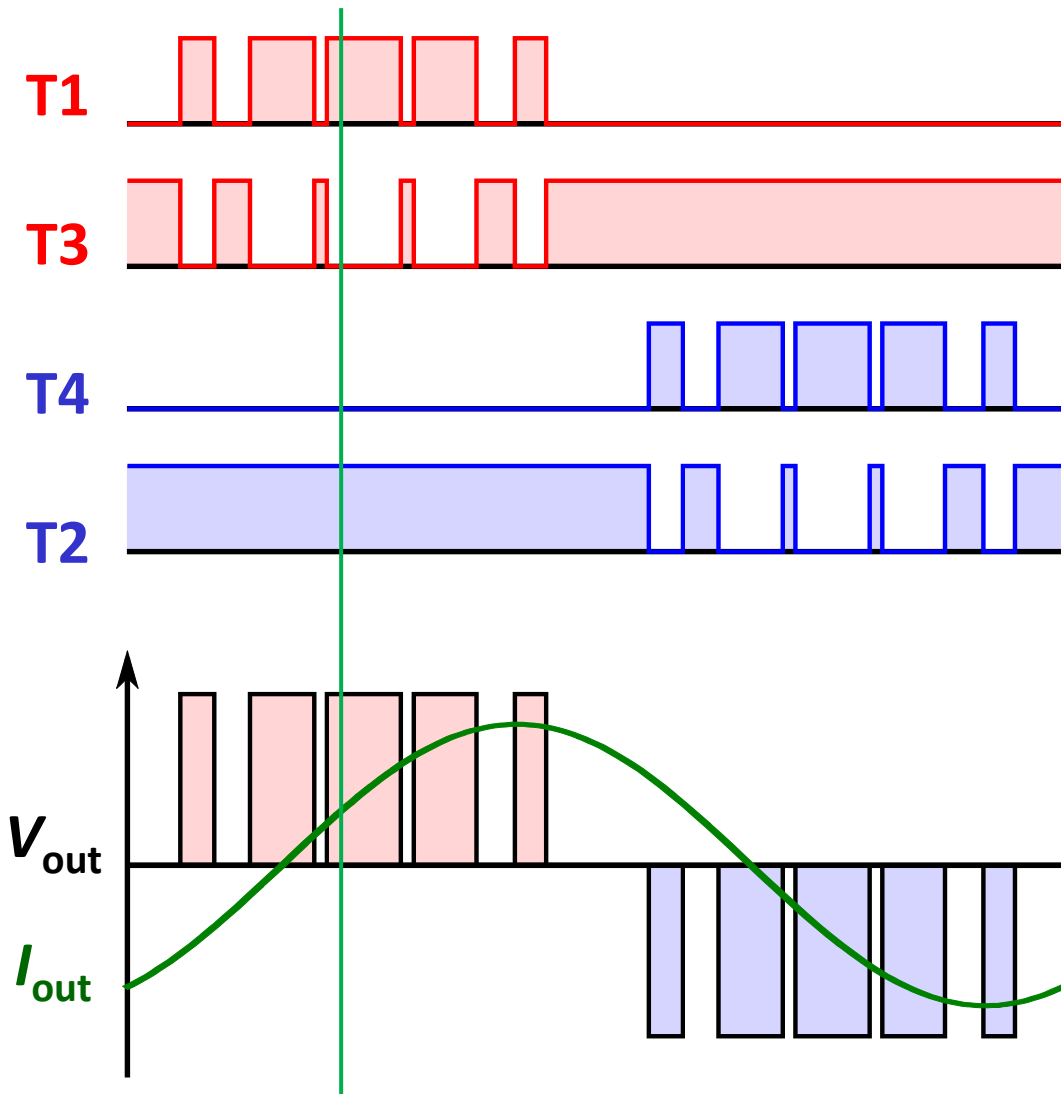
T1: Turn on (No switching loss)
Tc: ON
T3: OFF
T4: OFF

Switching Pattern (2) SW mode A



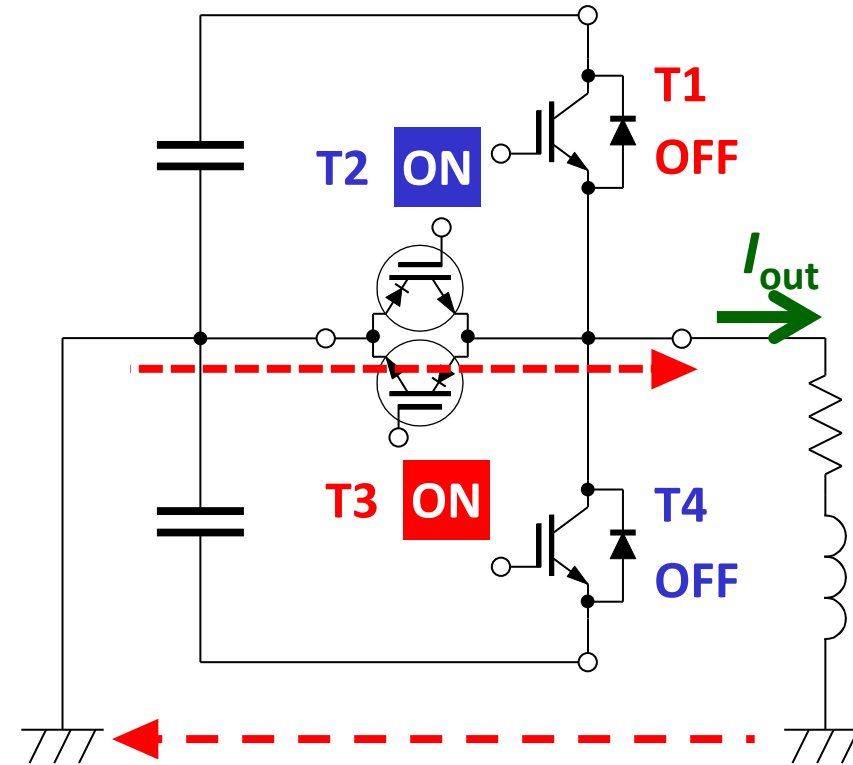
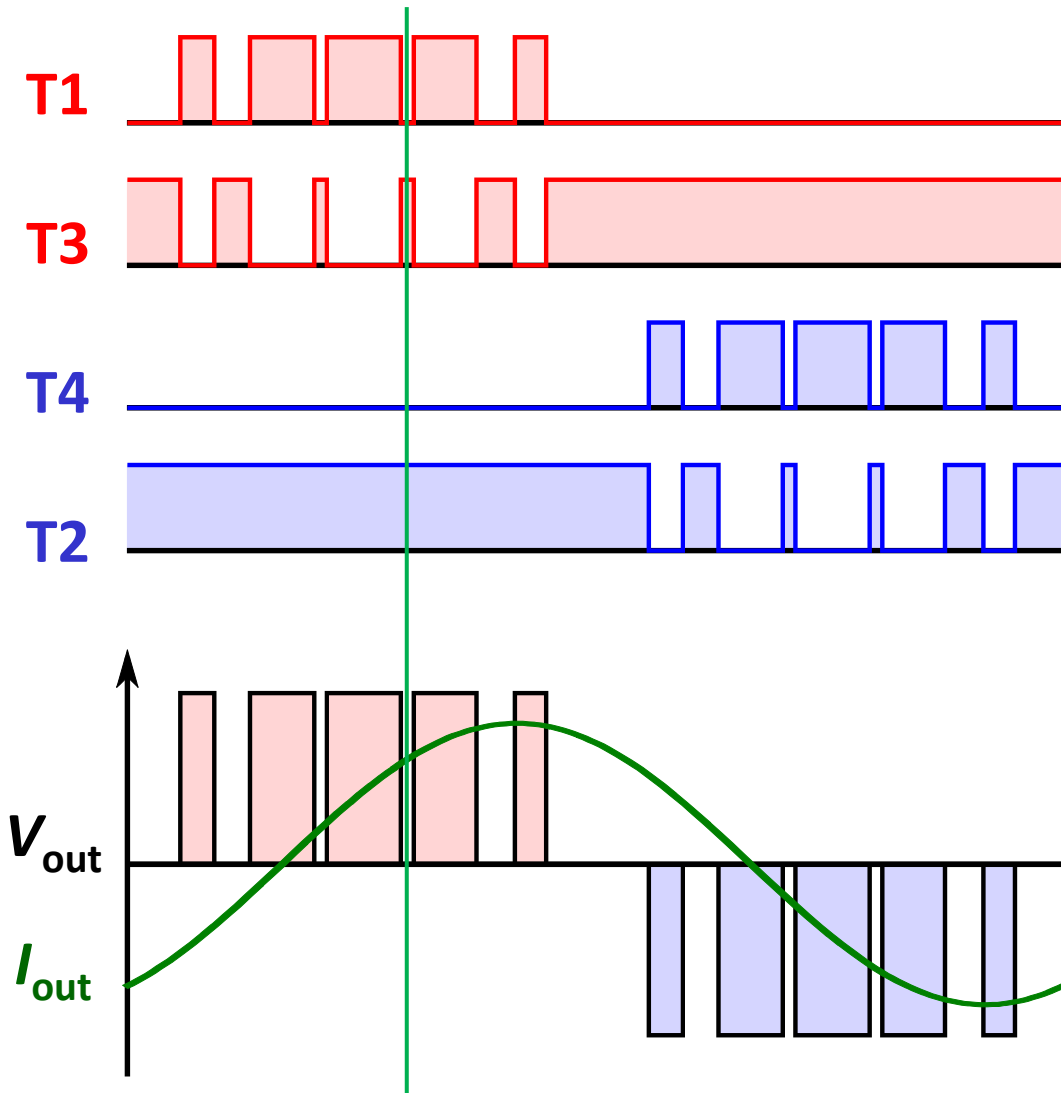
- T1: Turn off**
- T2: Free wheeling**
- T3: ON**
- T4: OFF**

Switching Pattern (2) SW mode A



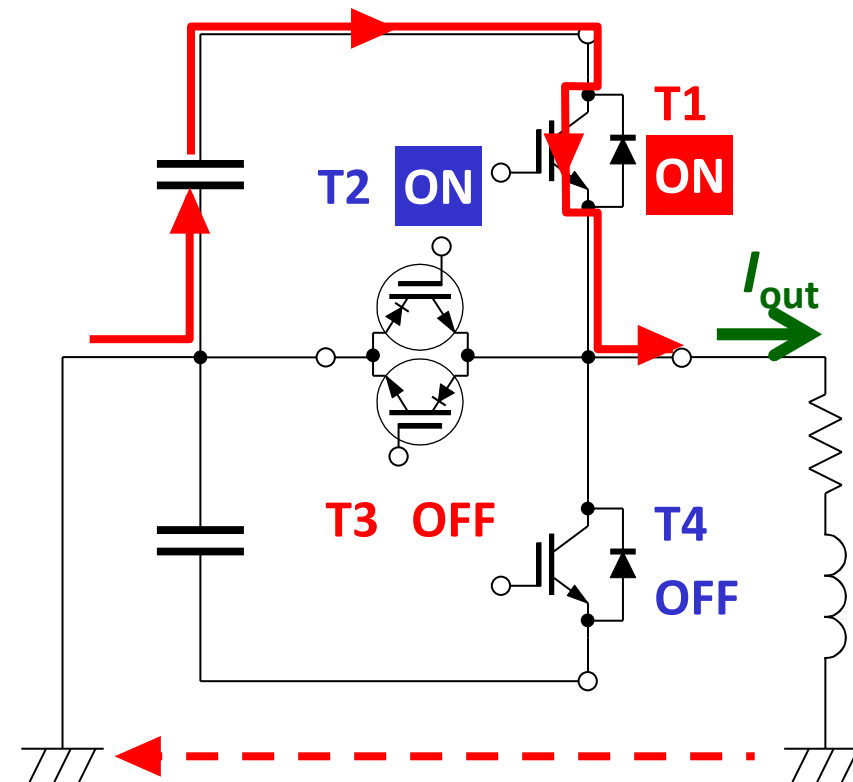
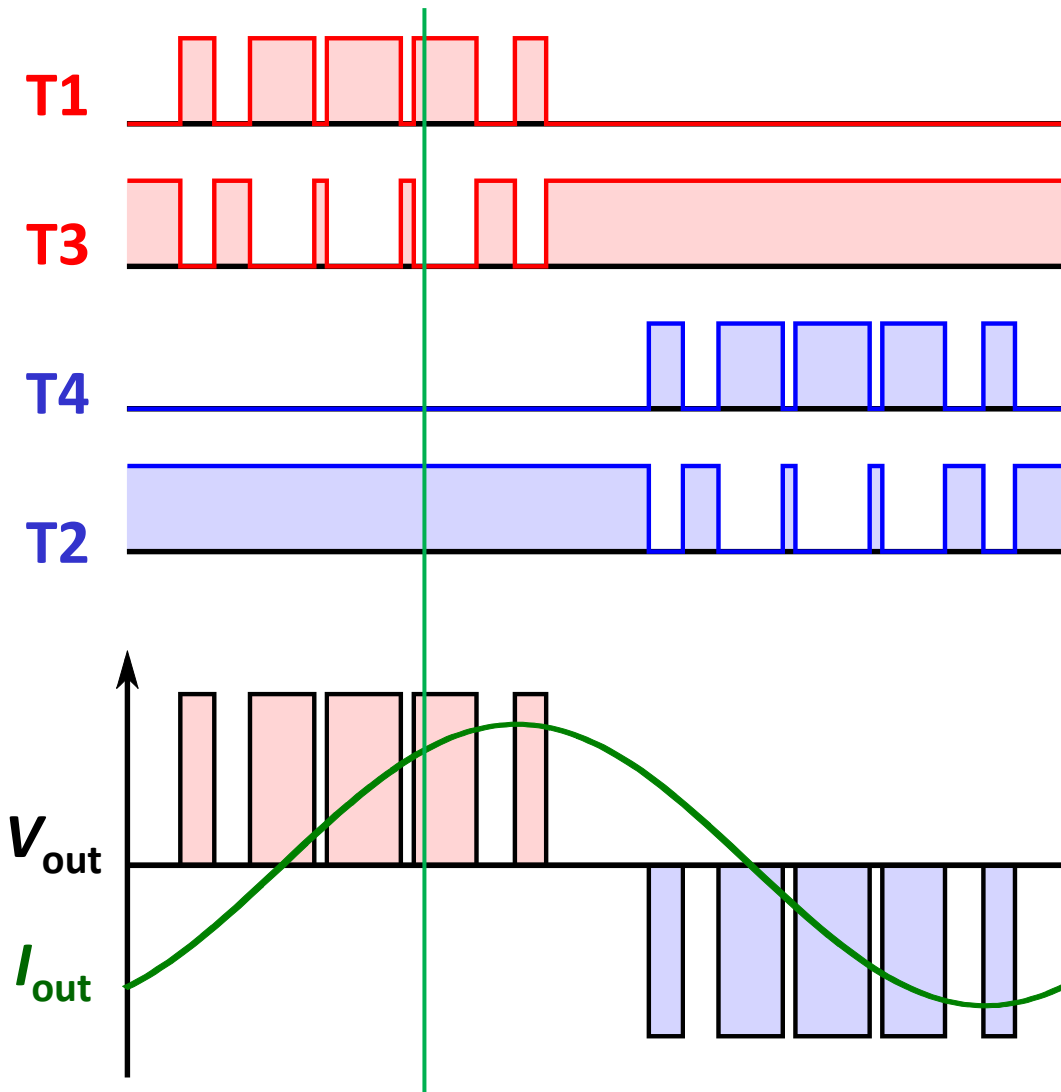
- T1: Turn on**
- T2: Reverse recovery**
- T3: OFF**
- T4: OFF**

Switching Pattern (2) SW mode A



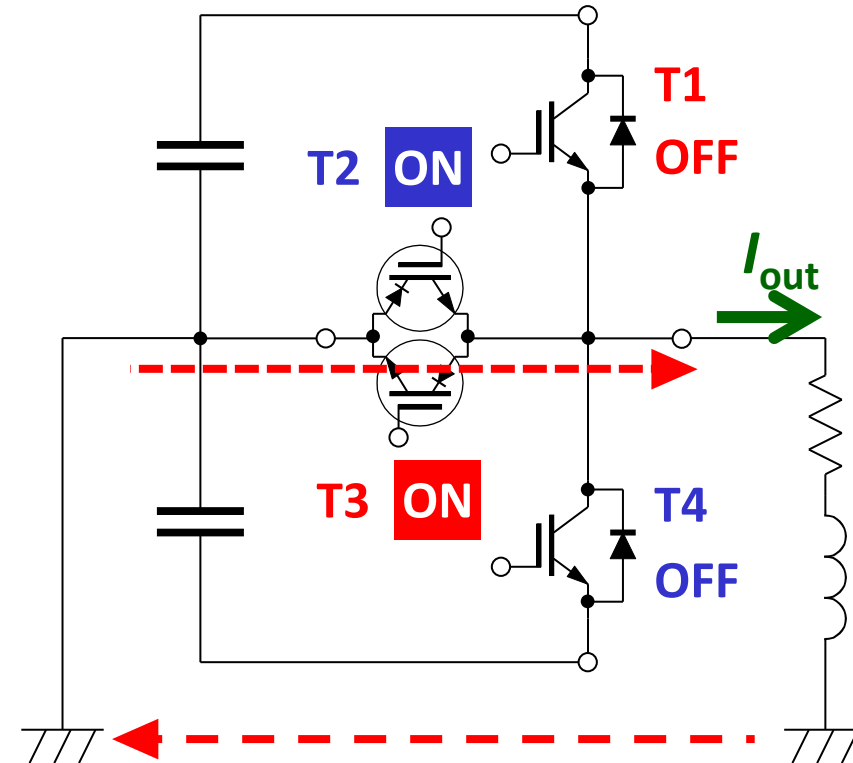
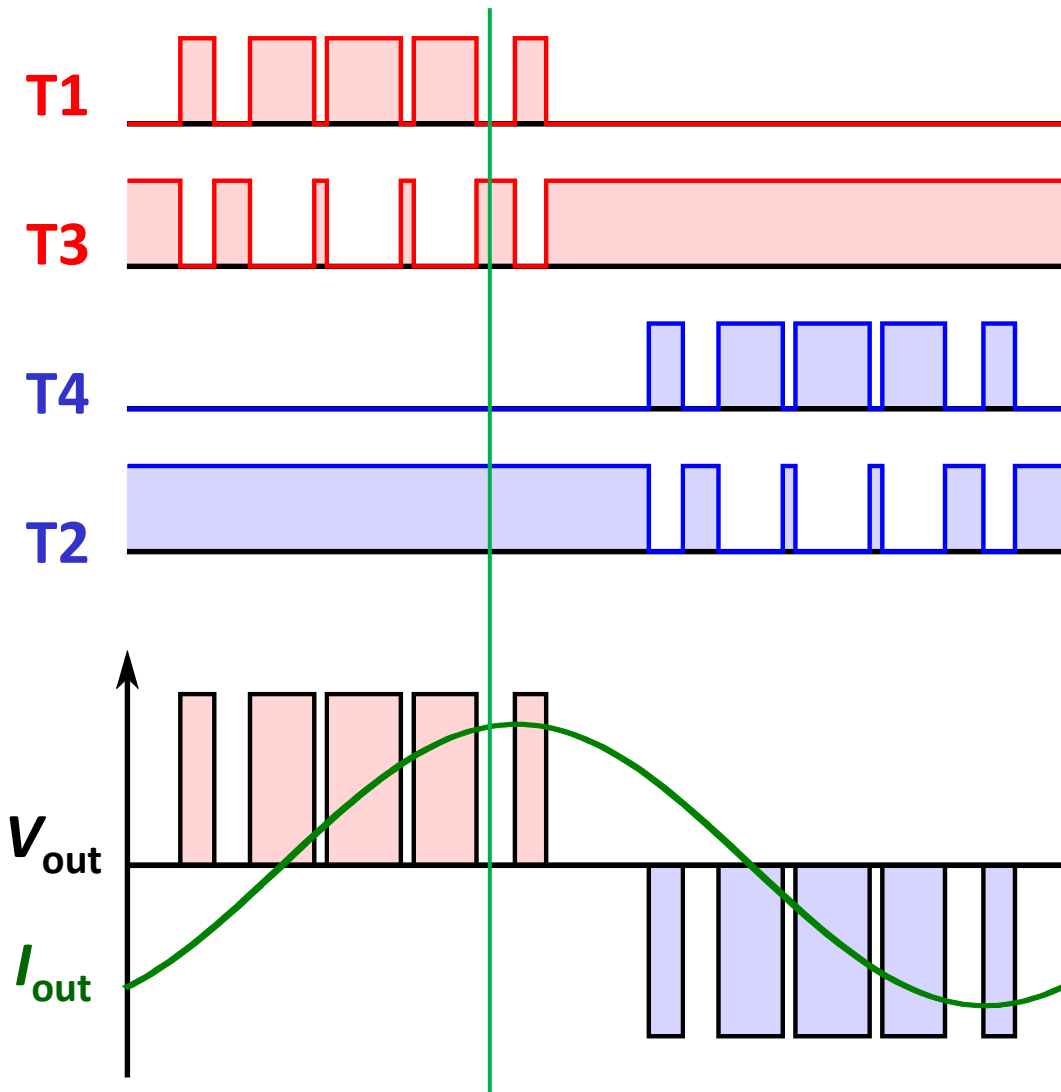
- T1: Turn off**
- T2: Free wheeling**
- T3: ON**
- T4: OFF**

Switching Pattern (2) SW mode A



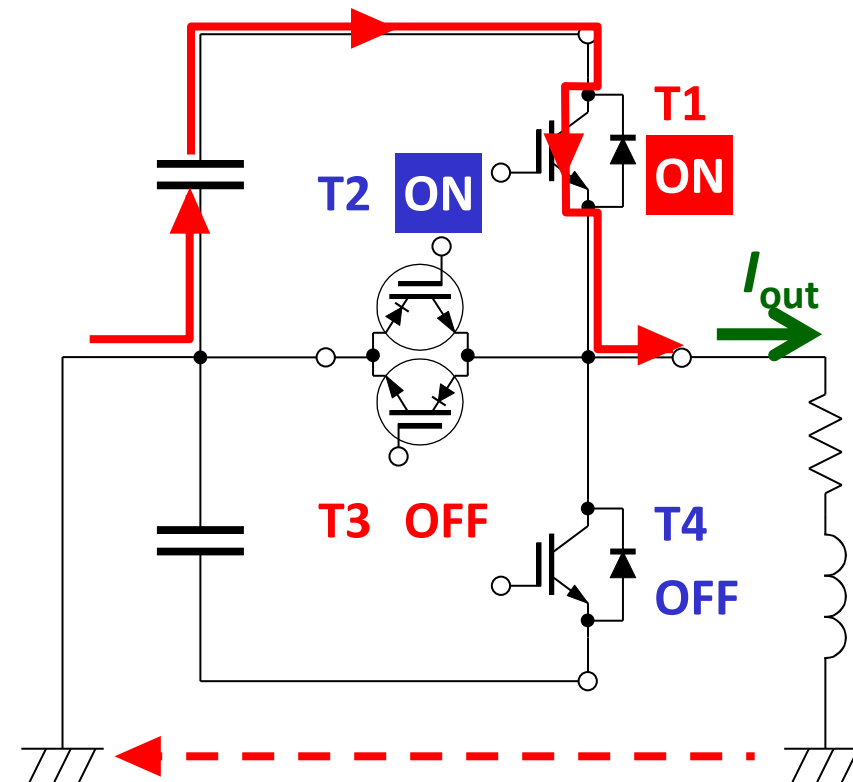
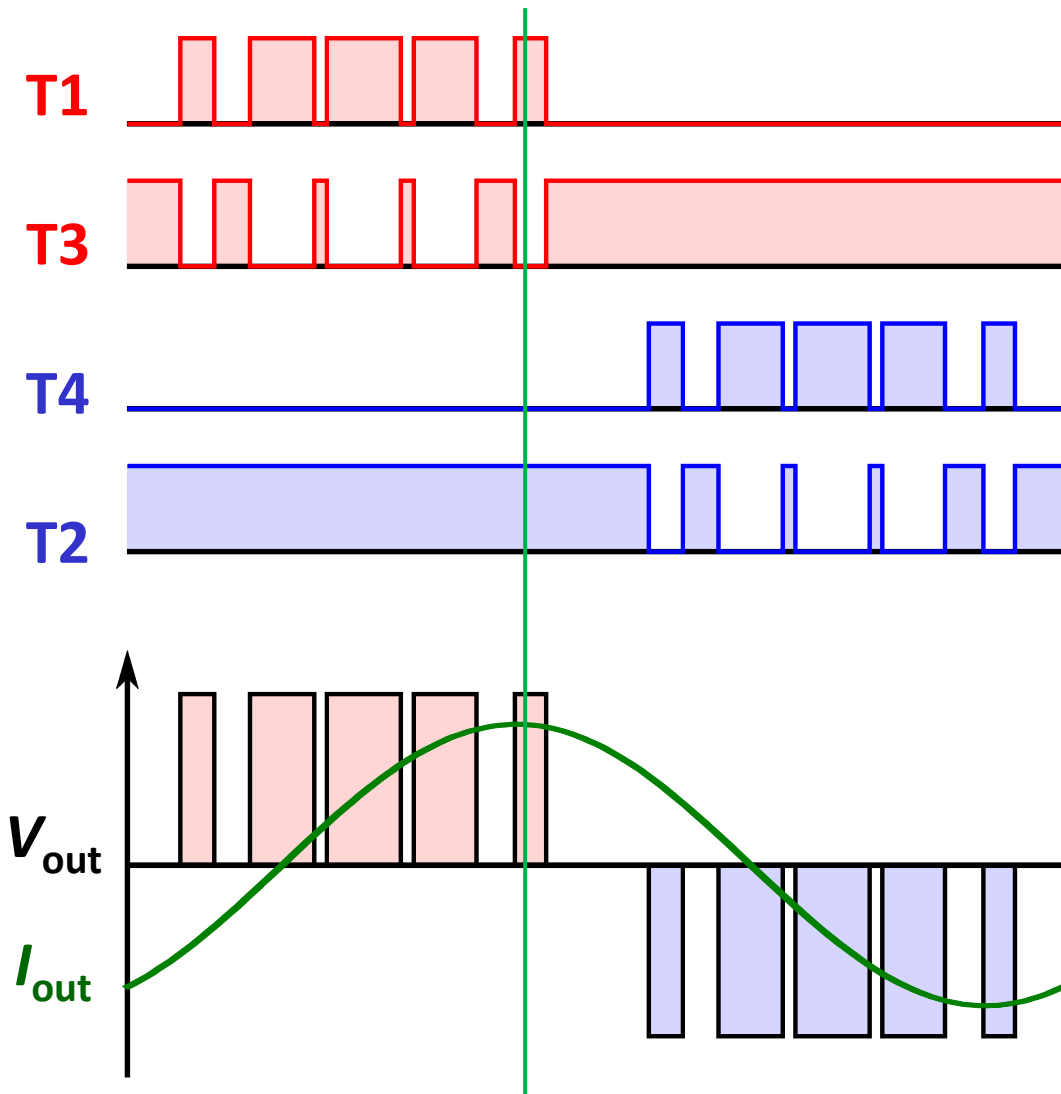
- T1: Turn on**
- T2: Reverse recovery**
- T3: OFF**
- T4: OFF**

Switching Pattern (2) SW mode A



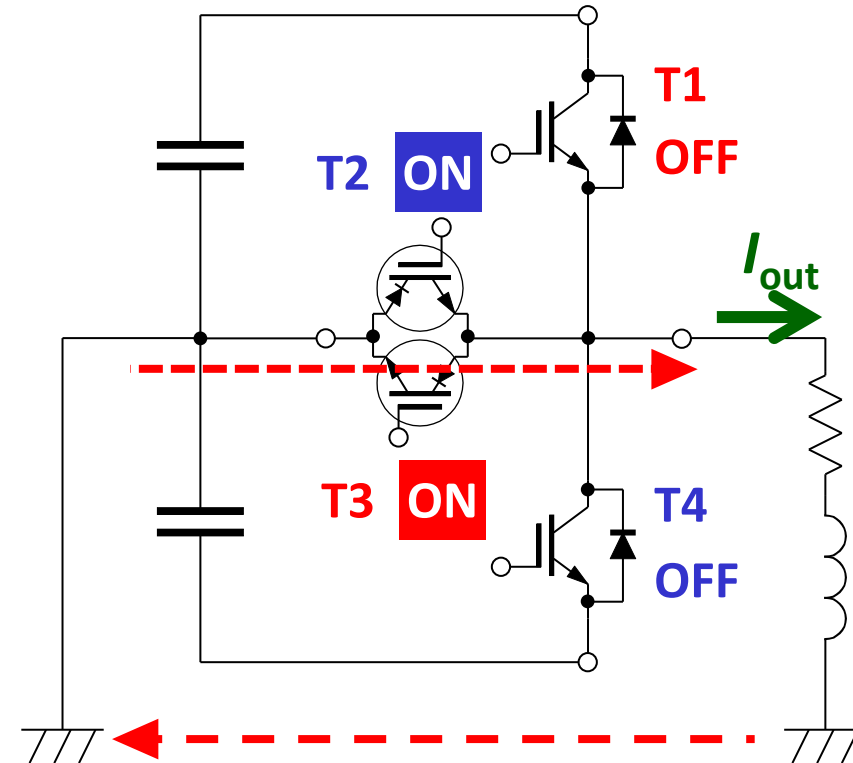
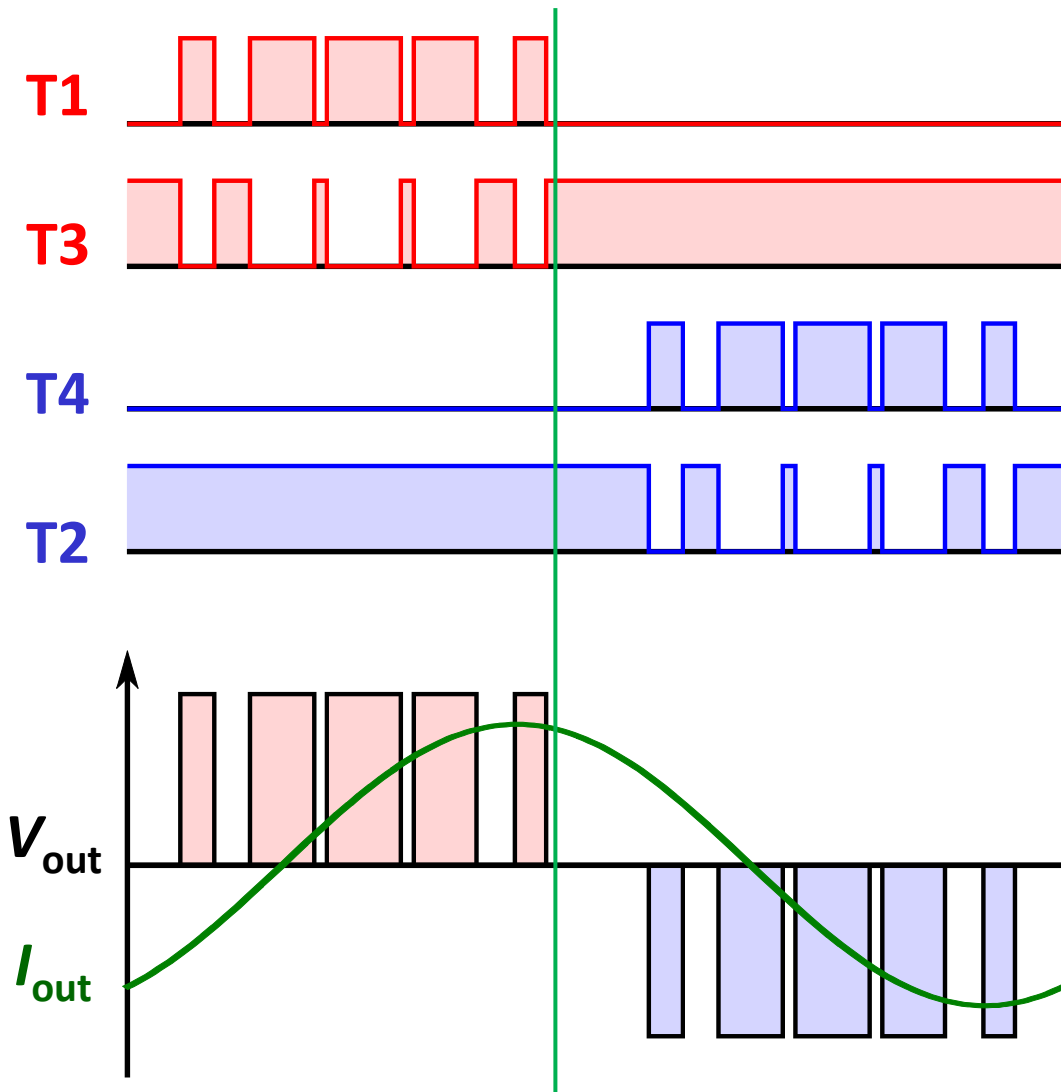
T1: Turn off
T2: Free wheeling
T3: ON
T4: OFF

Switching Pattern (2) SW mode A



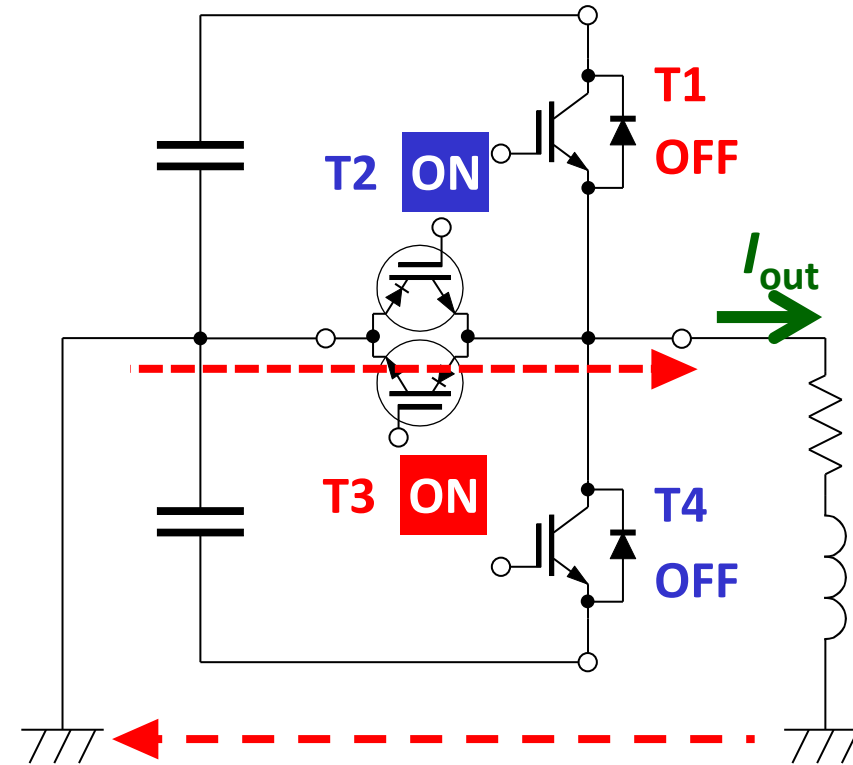
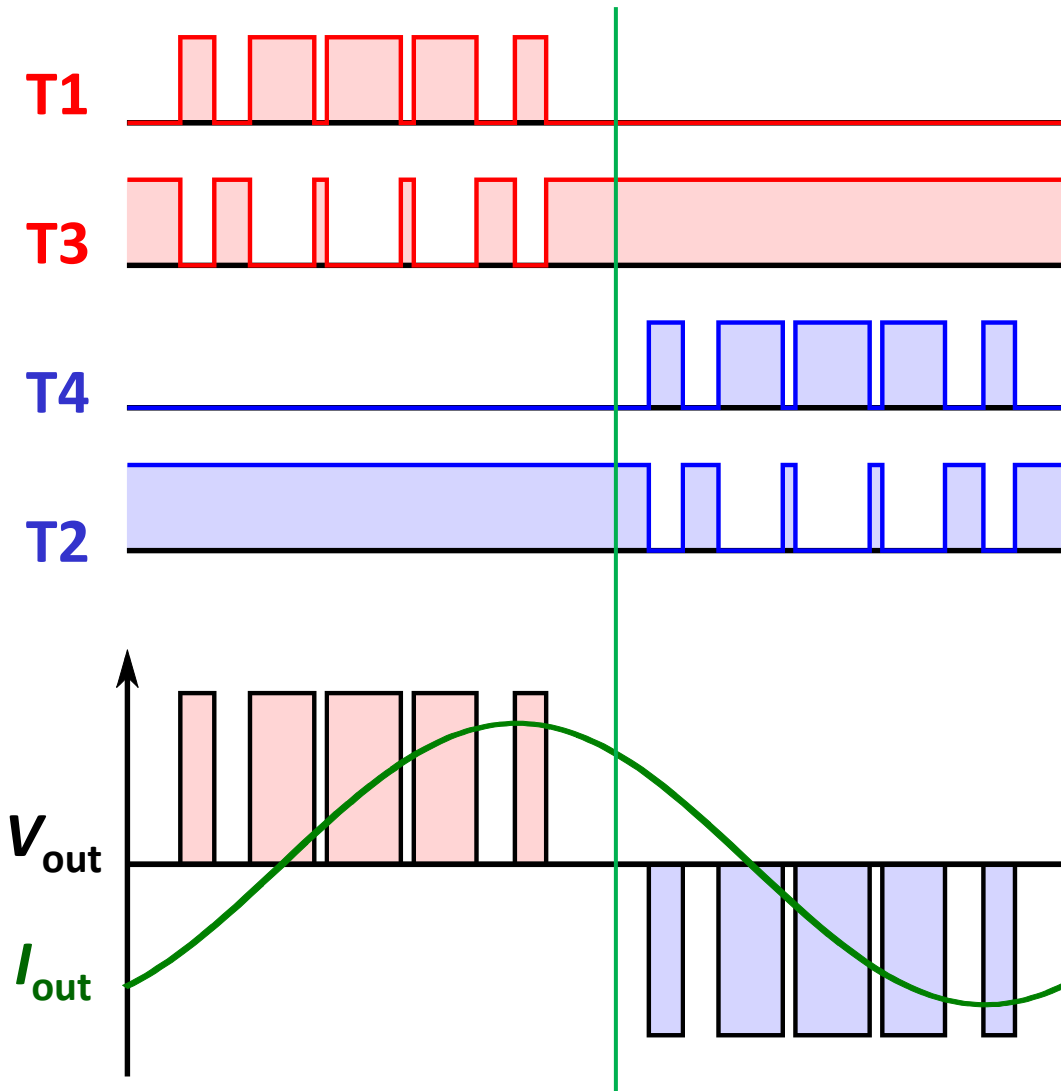
- T1: Turn on**
- T2: Reverse recovery**
- T3: OFF**
- T4: OFF**

Switching Pattern (2) SW mode A



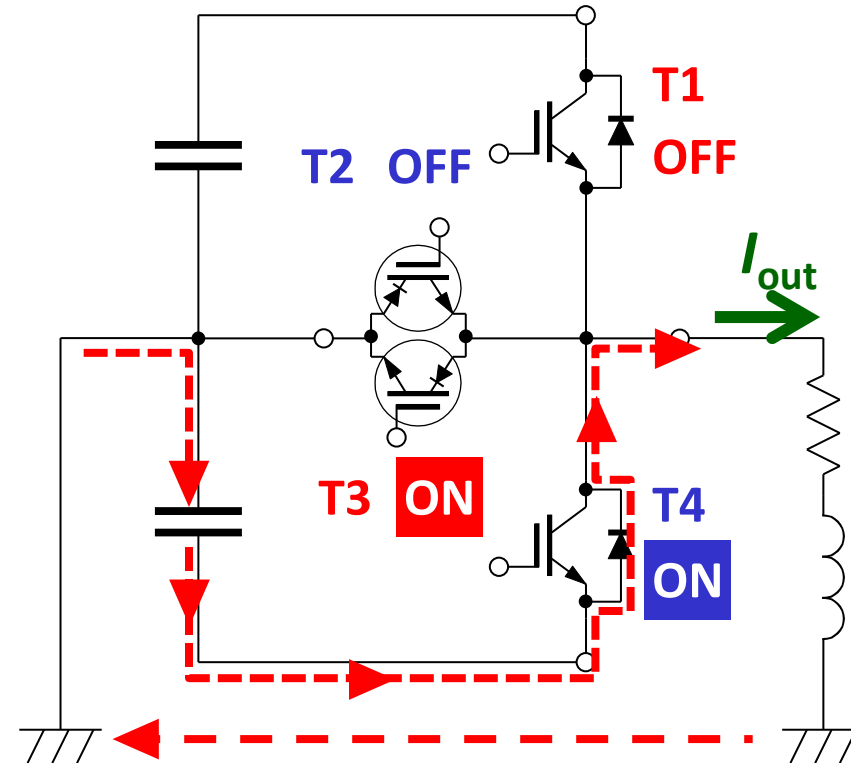
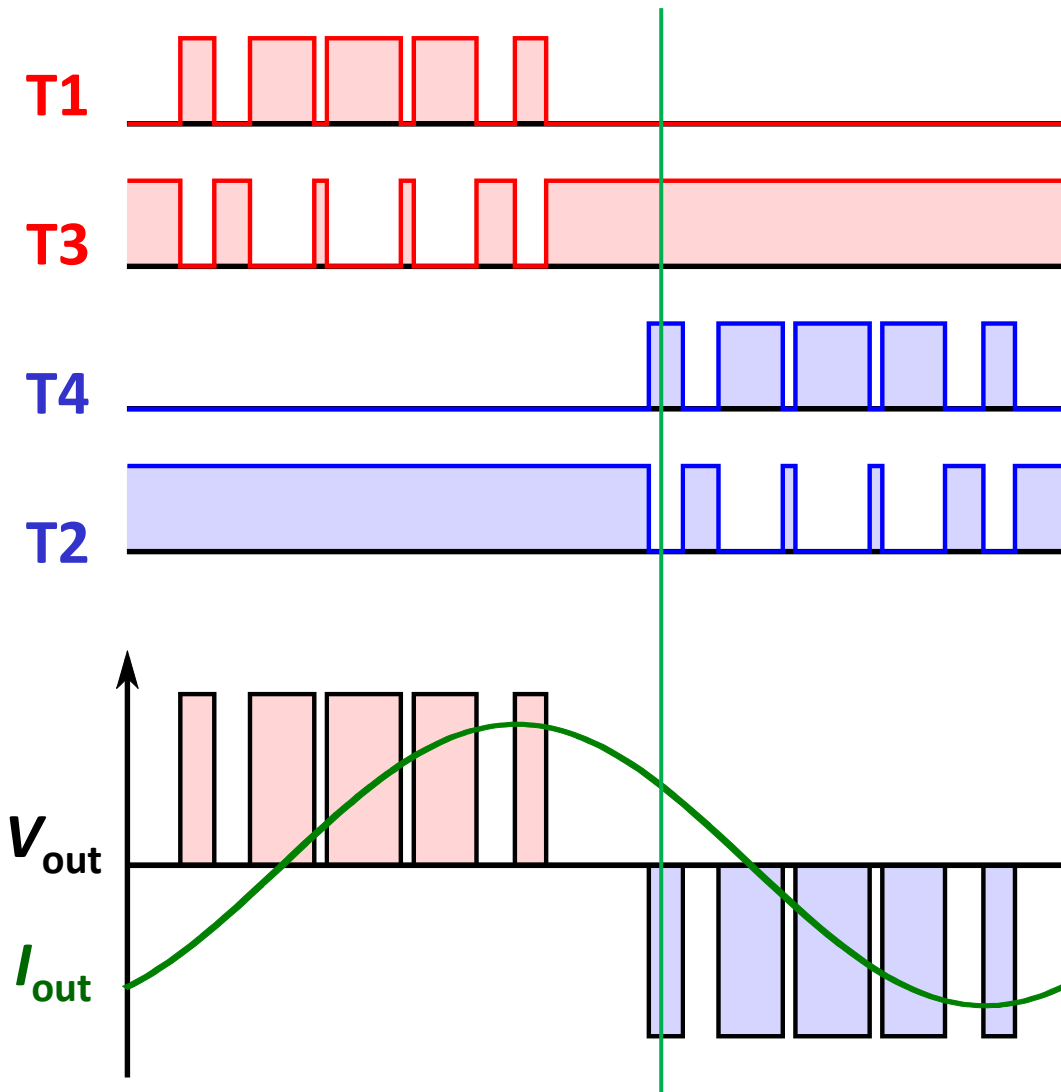
T1: Turn off
T2: Free wheeling
T3: ON
T4: OFF

Switching Pattern (3) SW mode B'



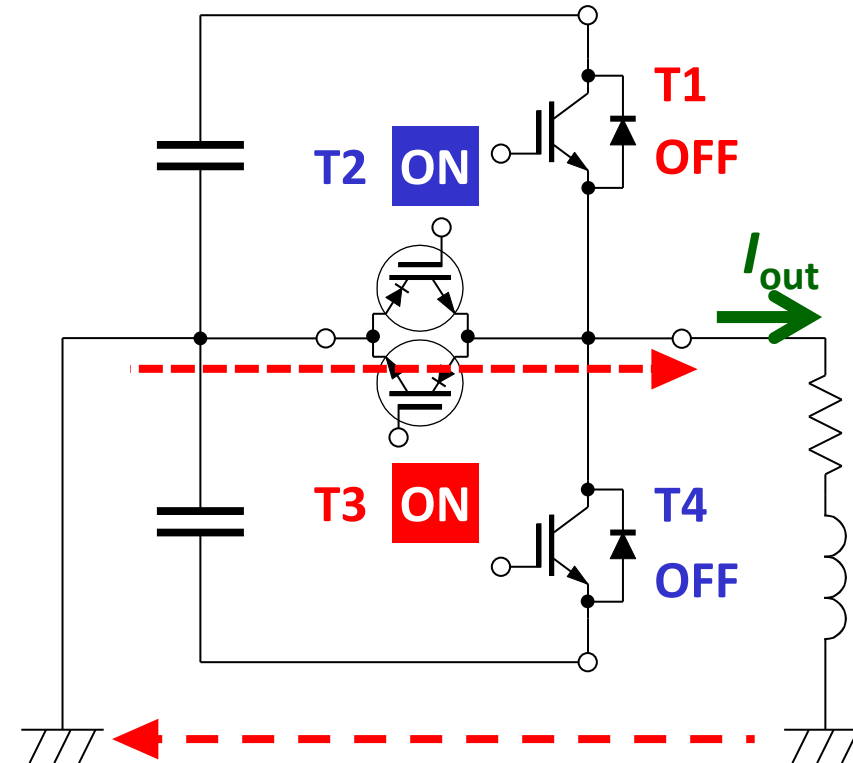
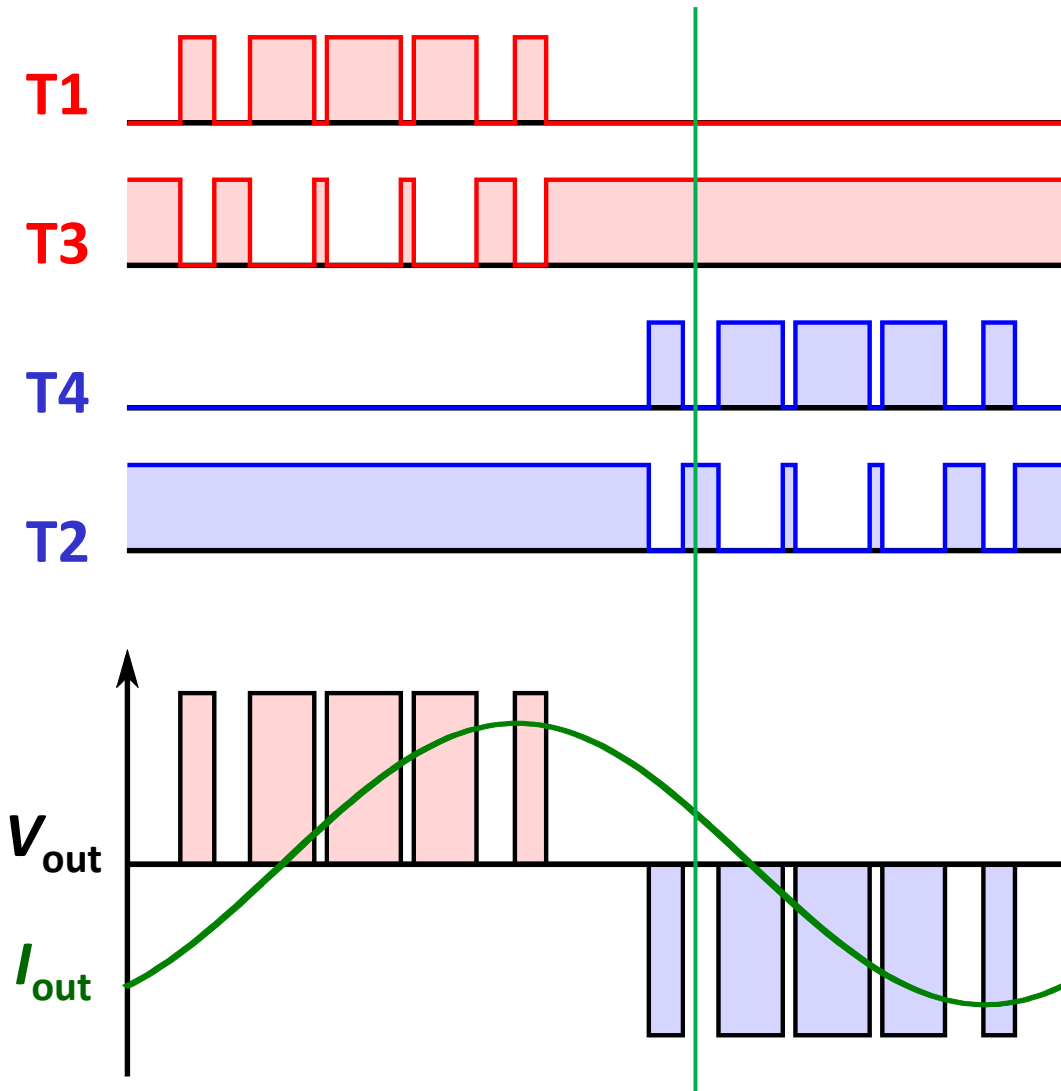
T1: OFF
T2: Free wheeling
T3: ON
T4: OFF

Switching Pattern (3) SW mode B'



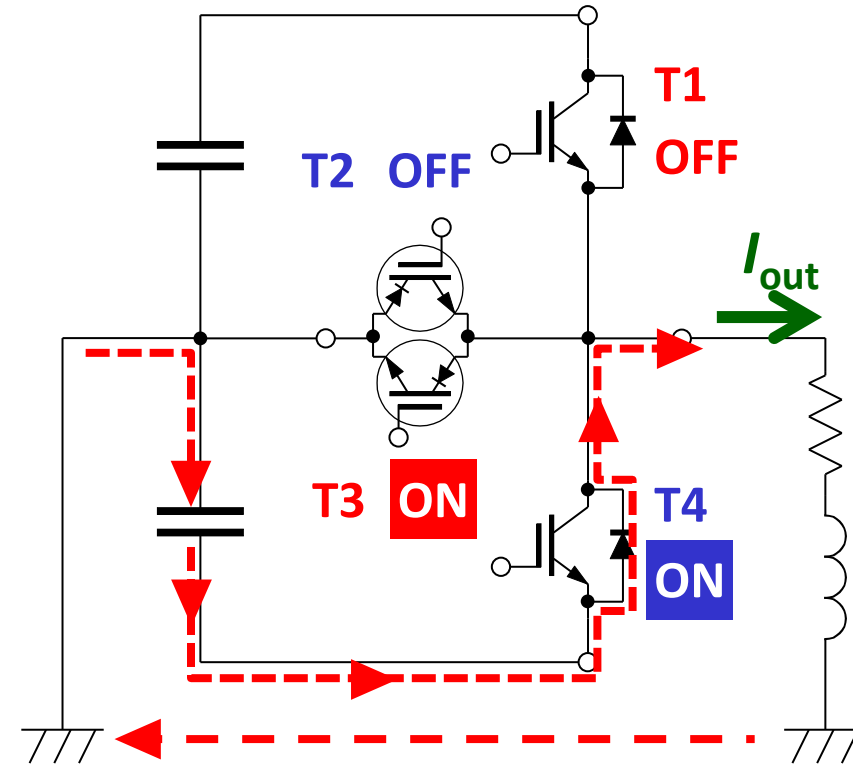
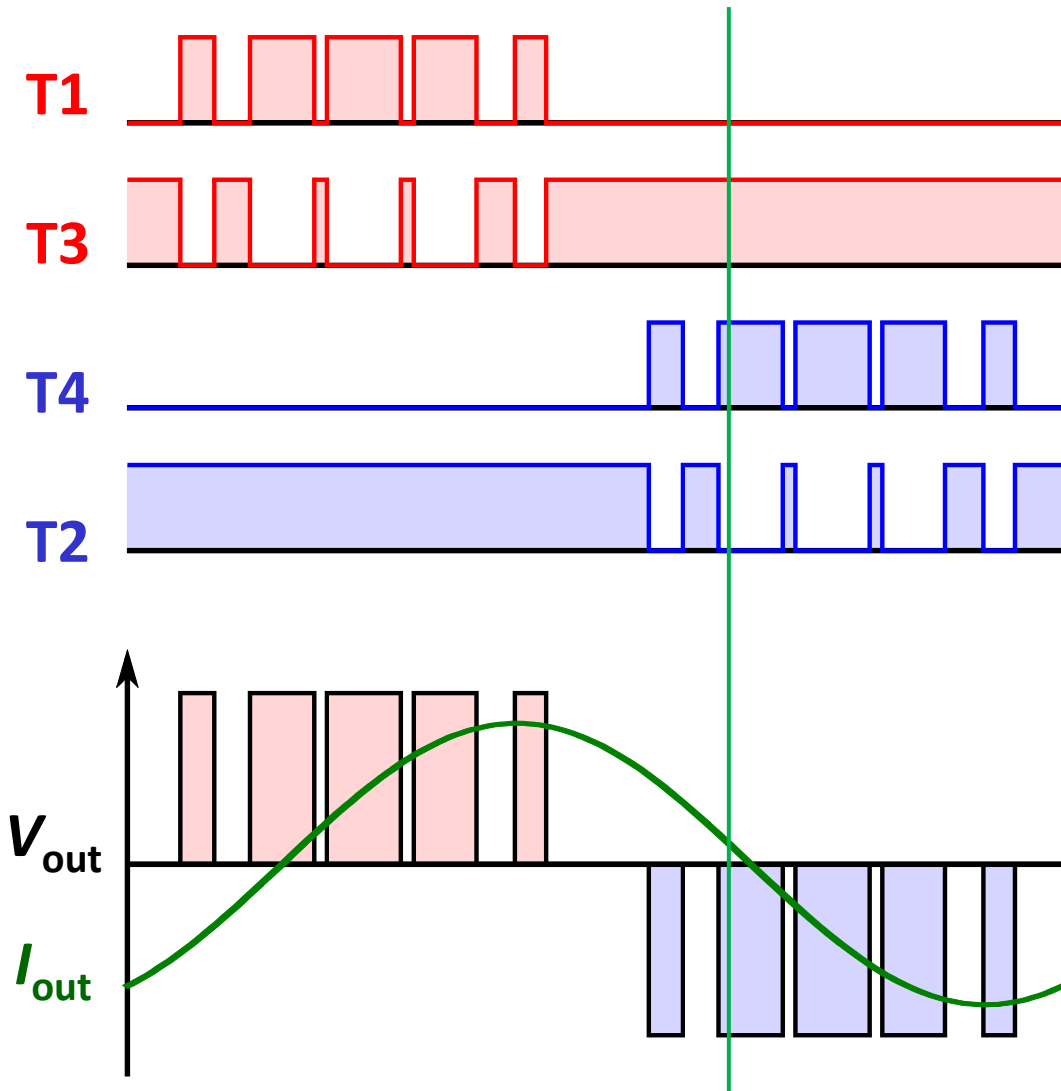
- T1: OFF**
- T2: Turn off**
- T3: ON**
- T4: Free wheeling**

Switching Pattern (3) SW mode B'



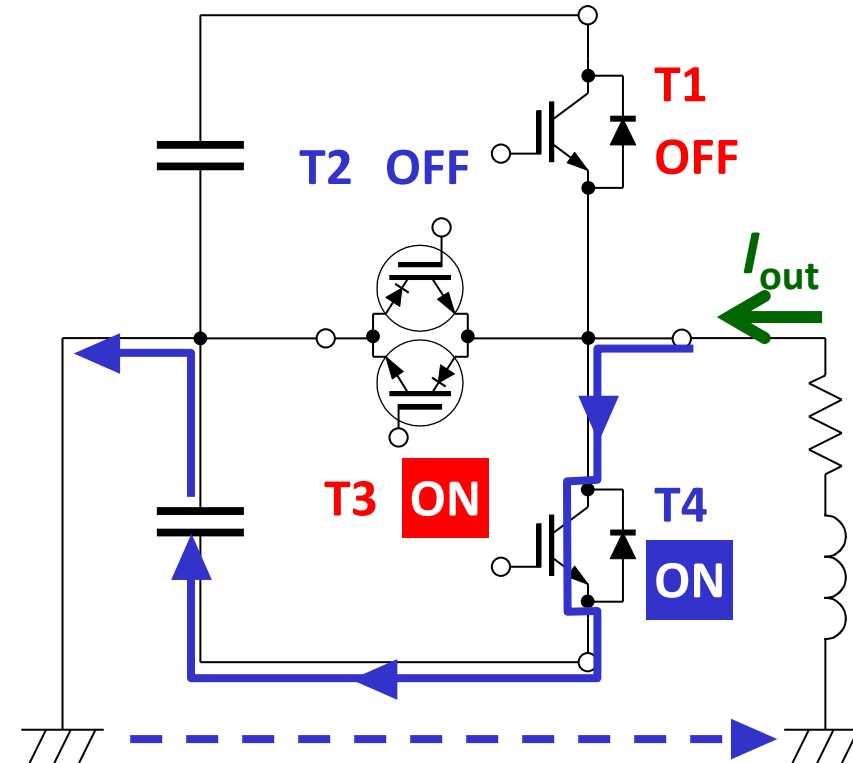
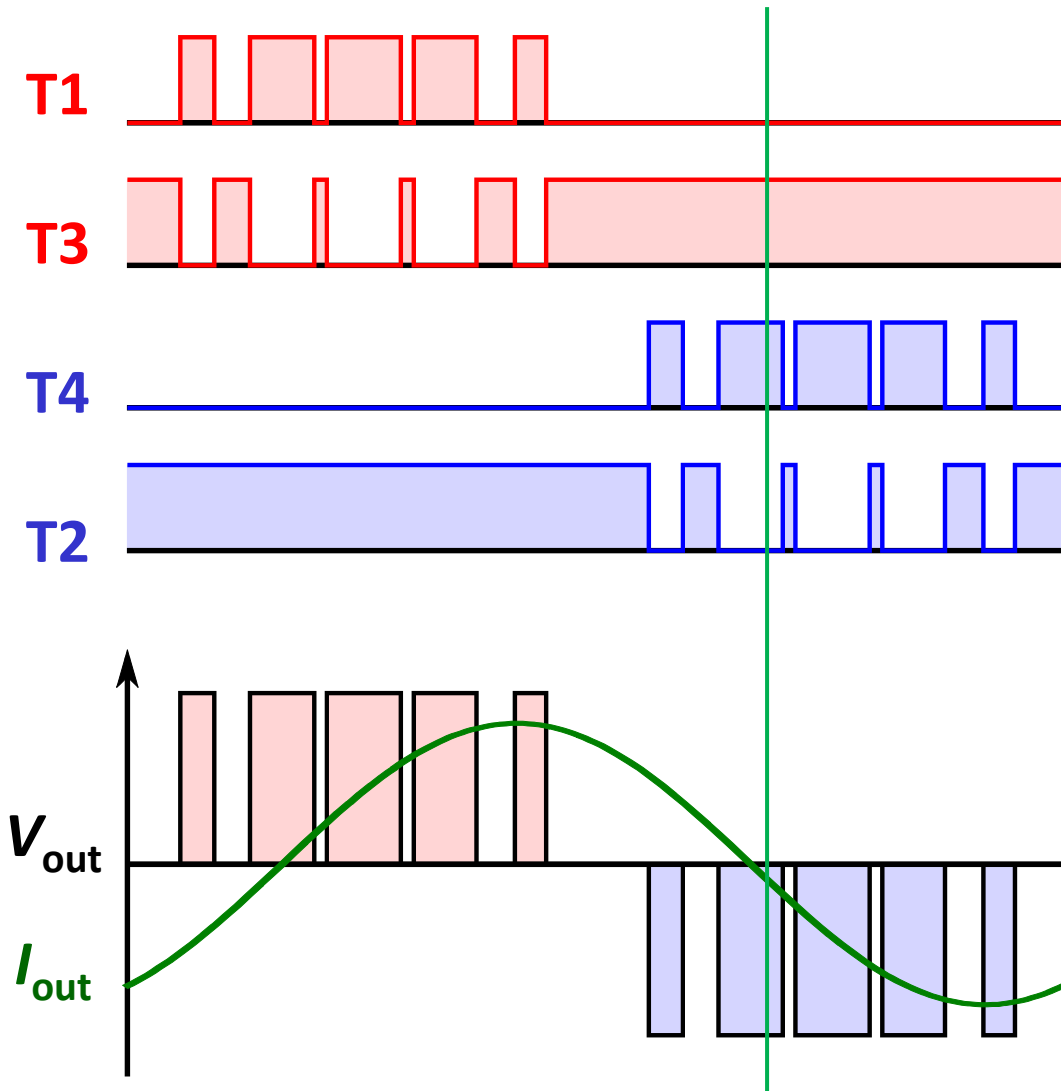
- T1: OFF**
- T2: Turn on (Free Wheeling)**
- T3: ON**
- T4: Reverse recovery**

Switching Pattern (3) SW mode B'



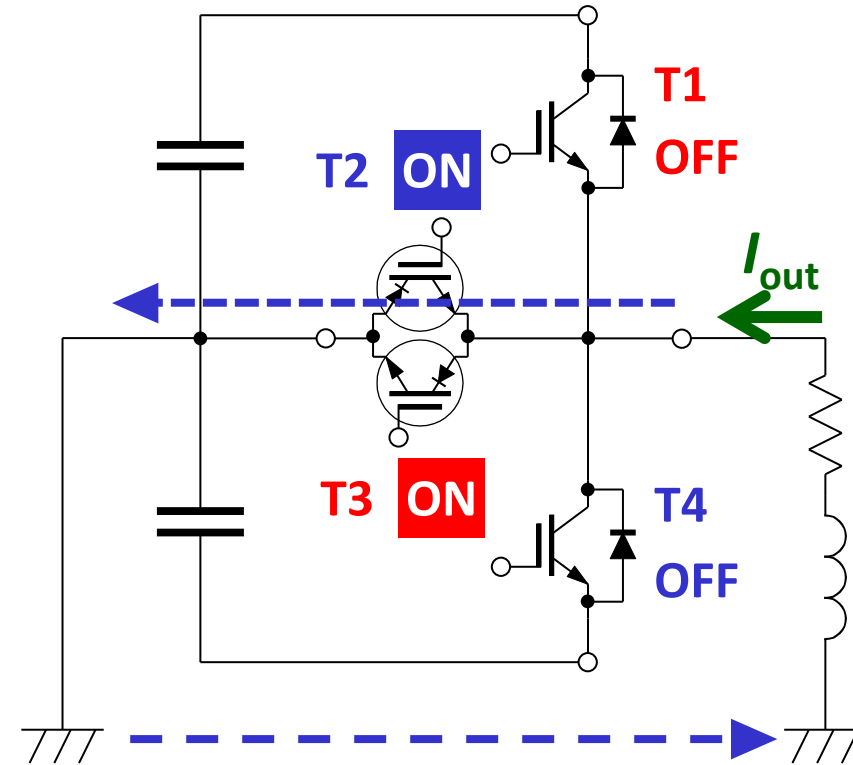
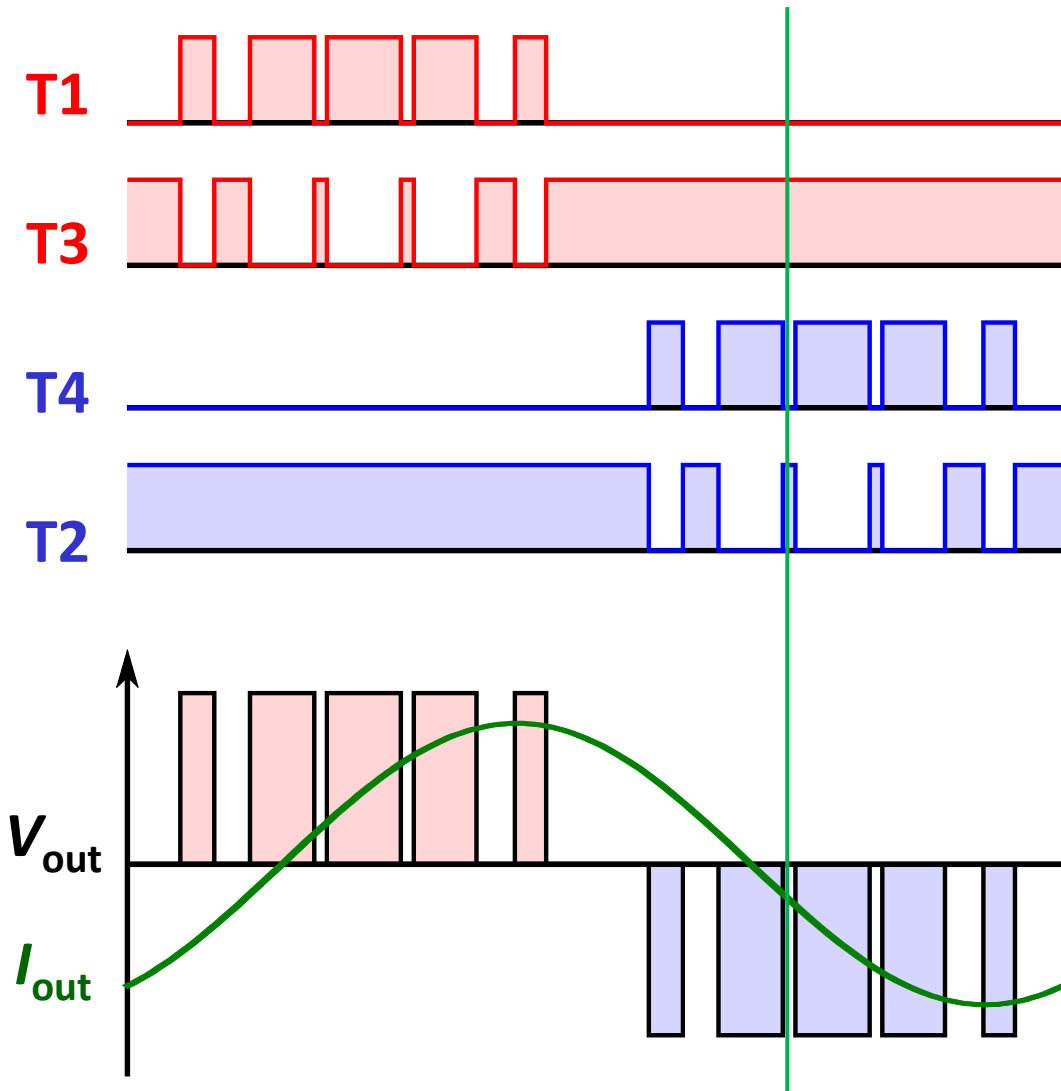
- T1: OFF**
- T2: Turn off**
- T3: ON**
- T4: Free wheeling**

Switching Pattern (4) SW mode A'



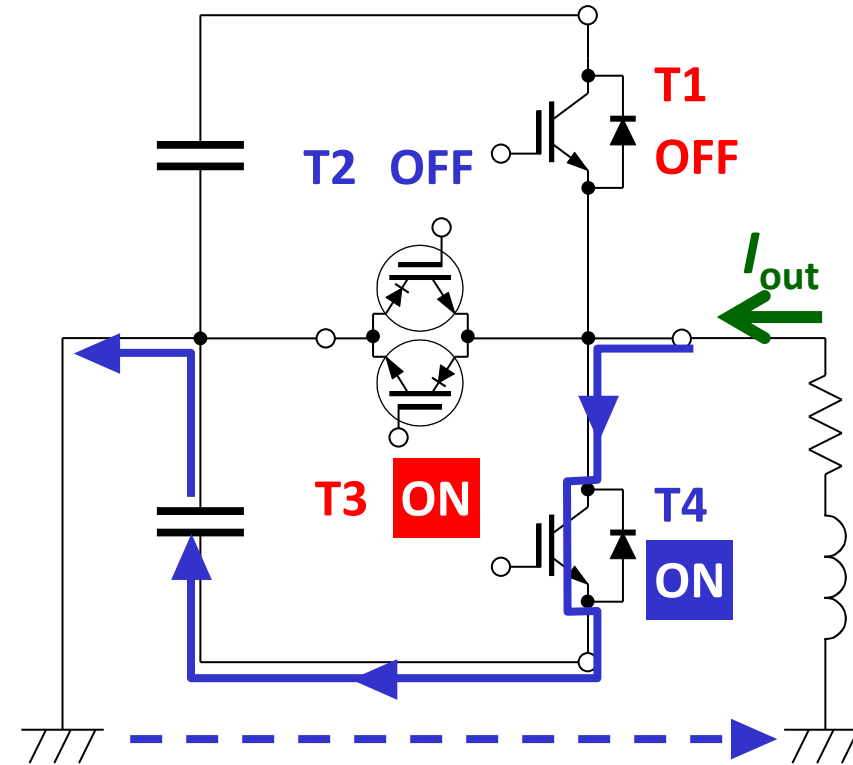
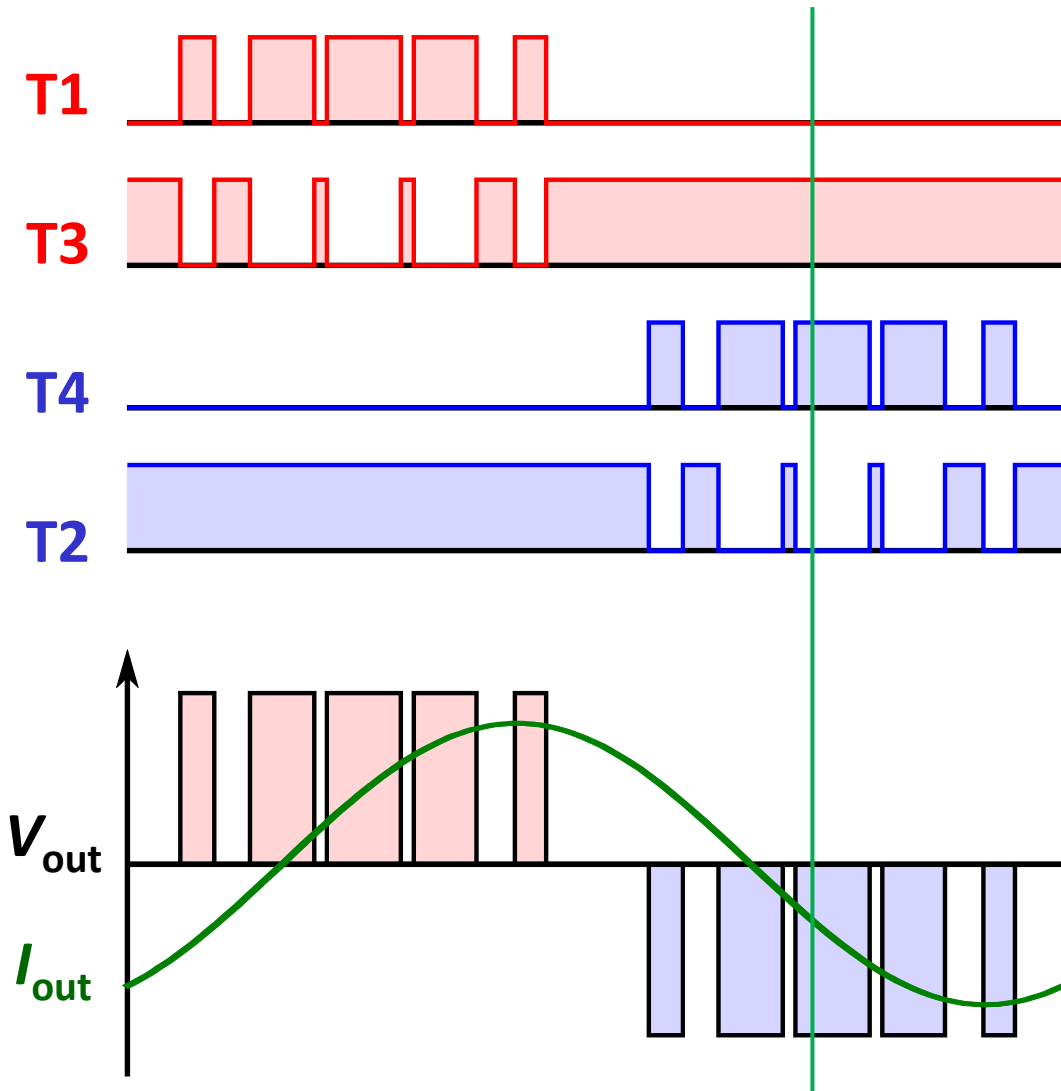
- T1:** OFF
- T2:** OFF
- T3:** ON
- T4:** Turn on (No switching loss)

Switching Pattern (4) SW mode A'



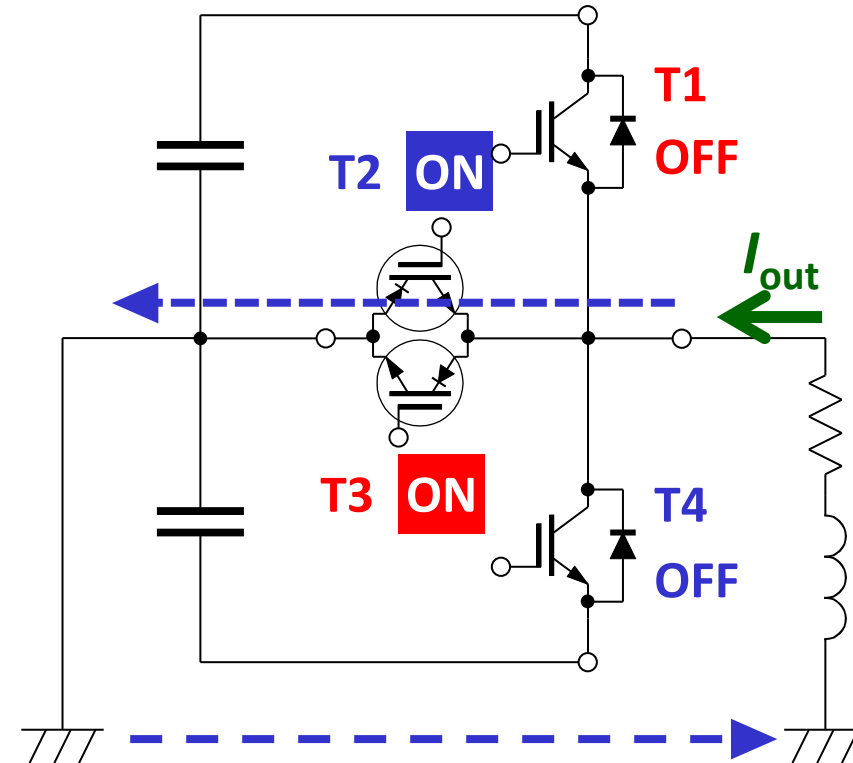
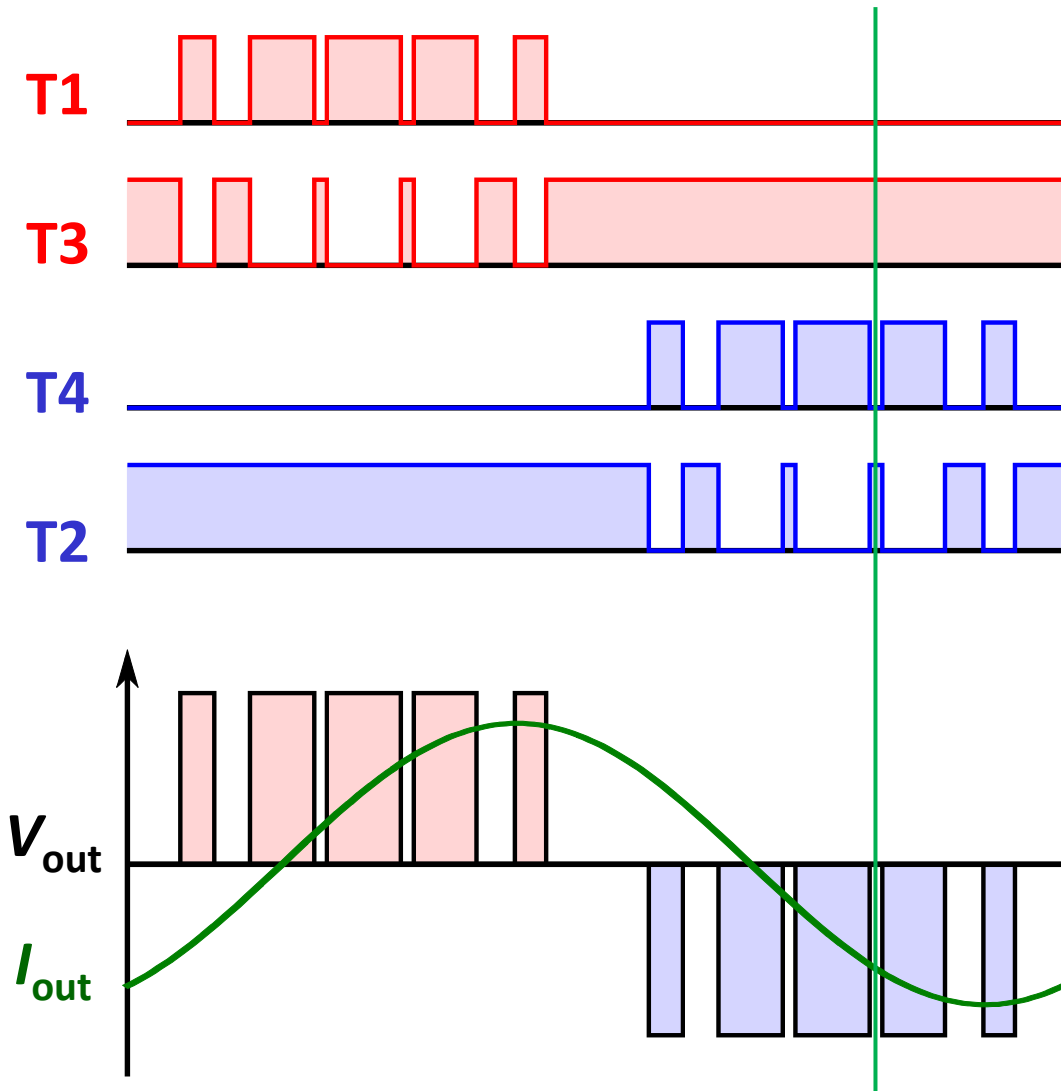
T1: OFF
T2: ON
T3: Free wheeling
T4: Turn off

Switching Pattern (4) SW mode A'



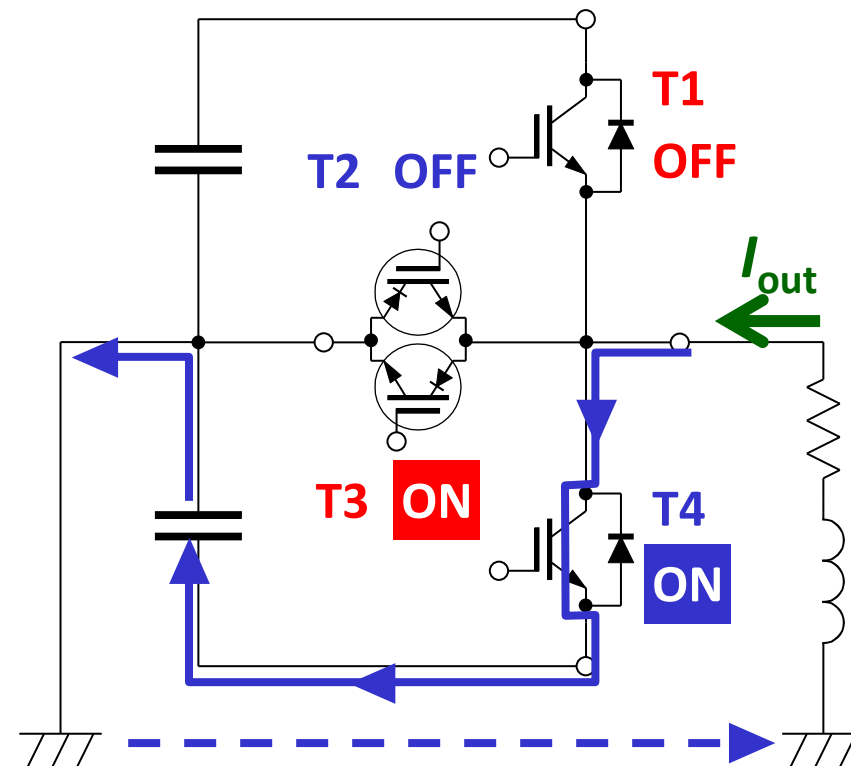
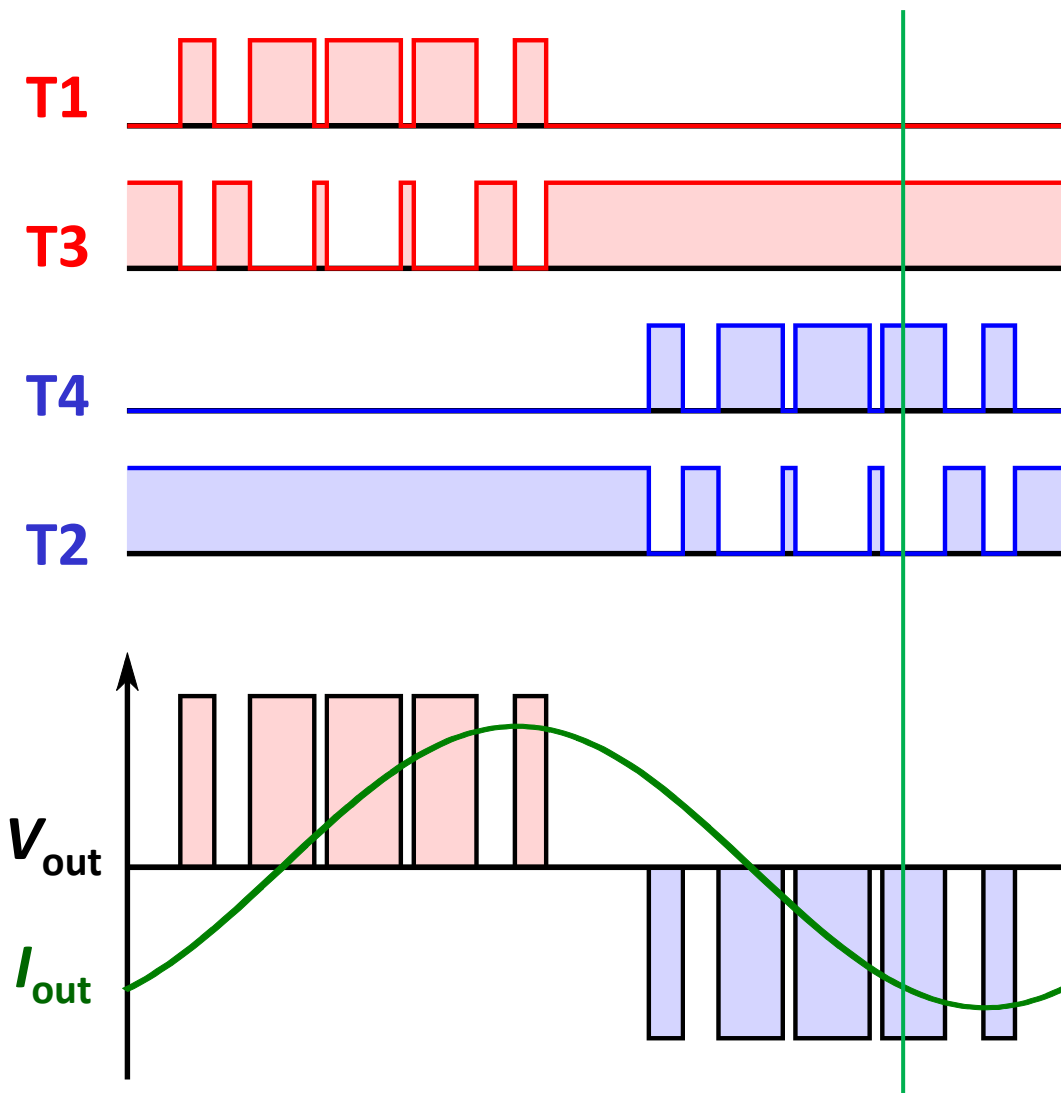
- T1:** OFF
- T2:** OFF
- T3:** Reverse recovery
- T4:** Turn on

Switching Pattern (4) SW mode A'



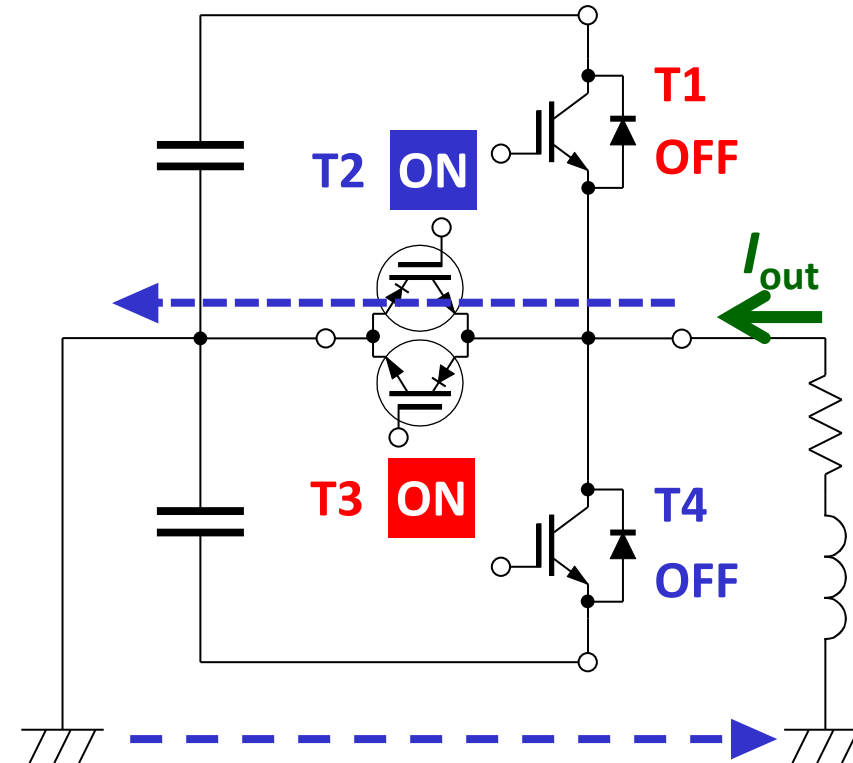
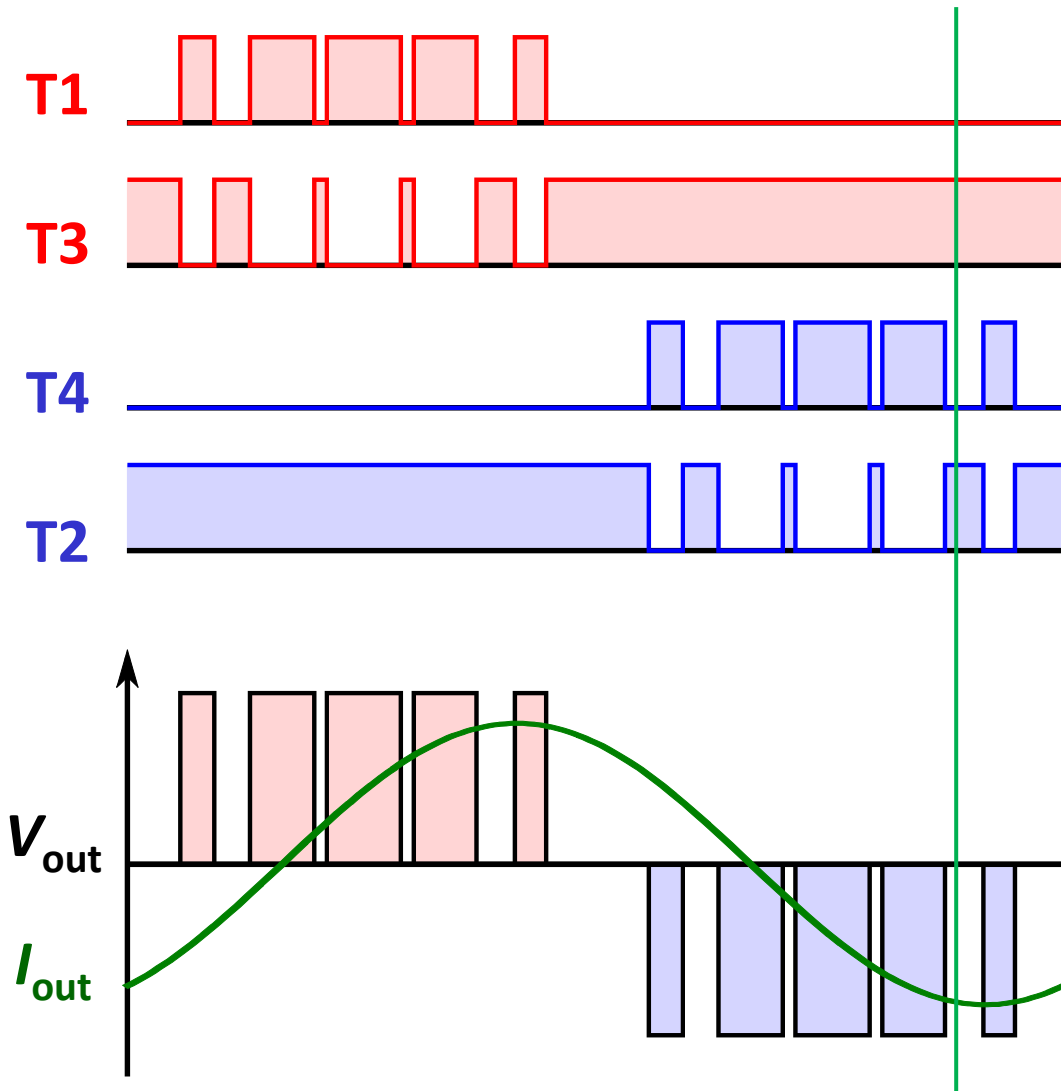
T1: OFF
T2: ON
T3: Free wheeling
T4: Turn off

Switching Pattern (4) SW mode A'



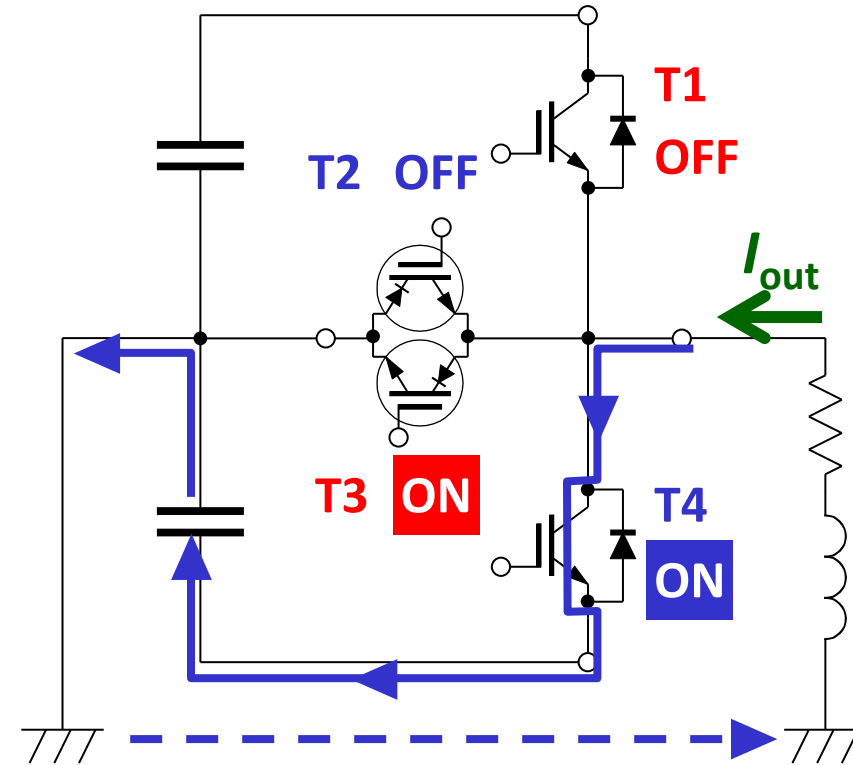
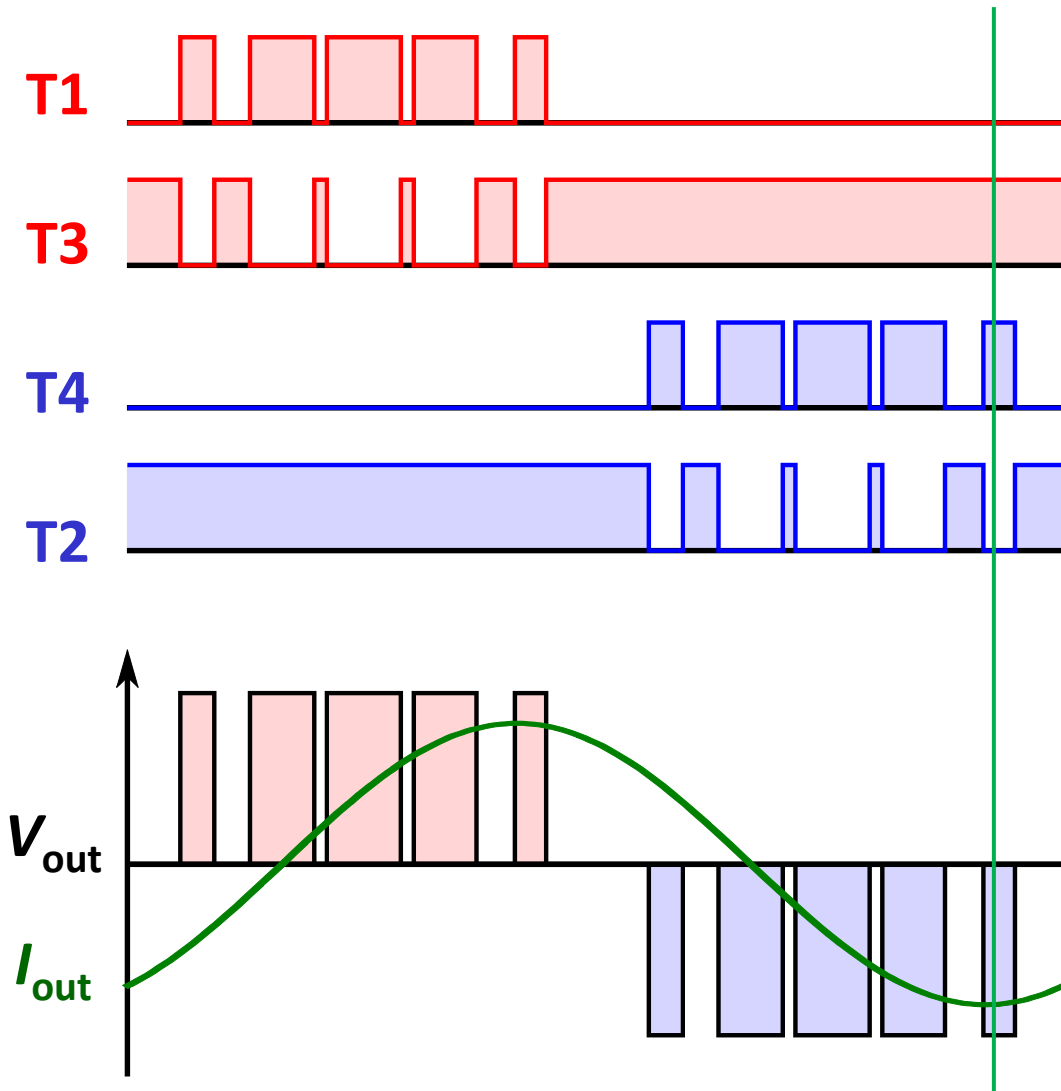
T1: OFF
T2: OFF
T3: Reverse recovery
T4: Turn on

Switching Pattern (4) SW mode A'



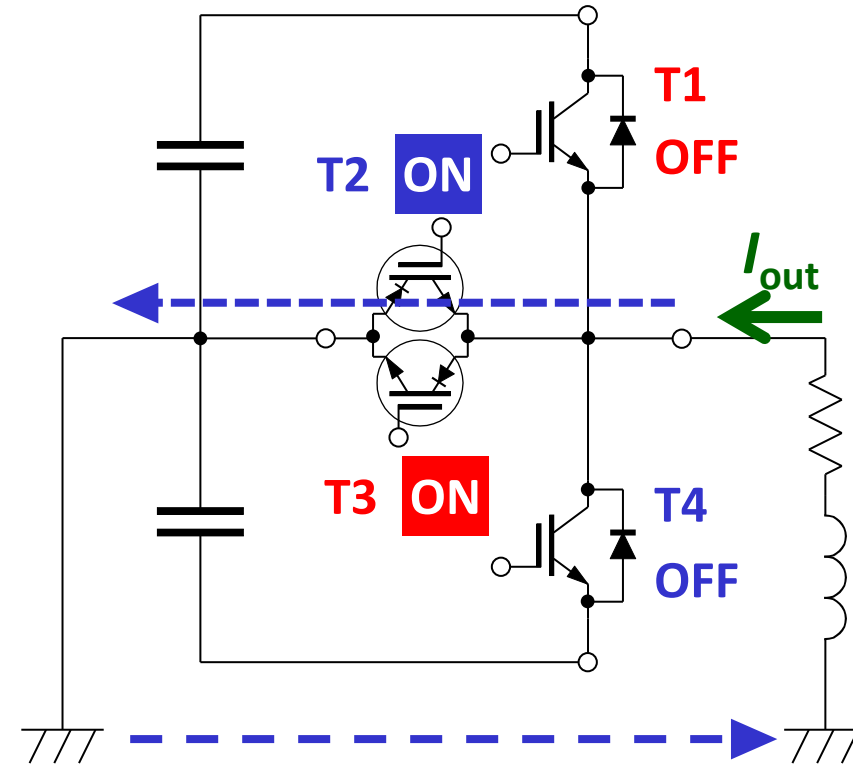
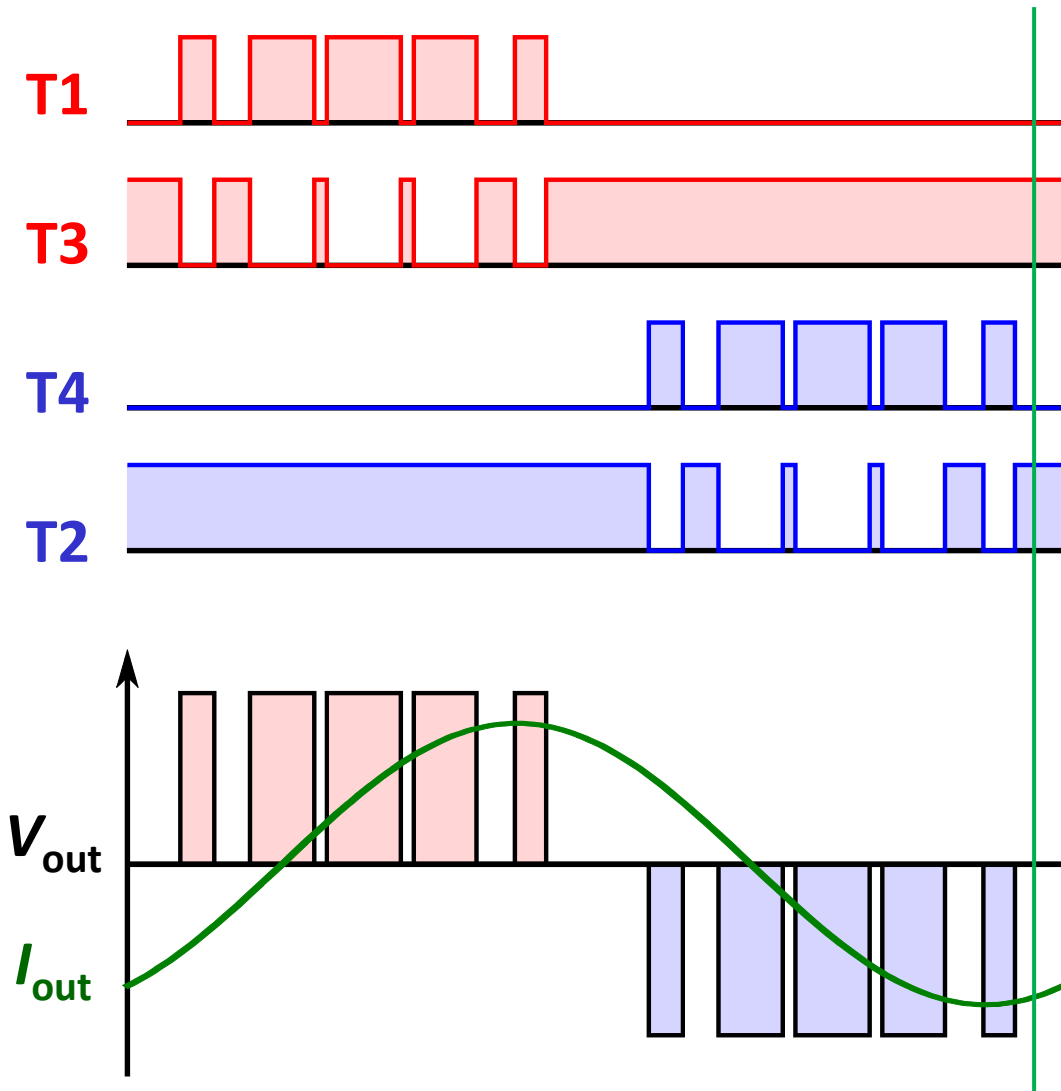
T1: OFF
T2: ON
T3: Free wheeling
T4: Turn off

Switching Pattern (4) SW mode A'



T1: OFF
T2: OFF
T3: Reverse recovery
T4: Turn on

Switching Pattern (4) SW mode A'



T1: OFF
T2: ON
T3: Free wheeling
T4: Turn off