EE-464 STATIC POWER CONVERSION-II

Bridge Converters

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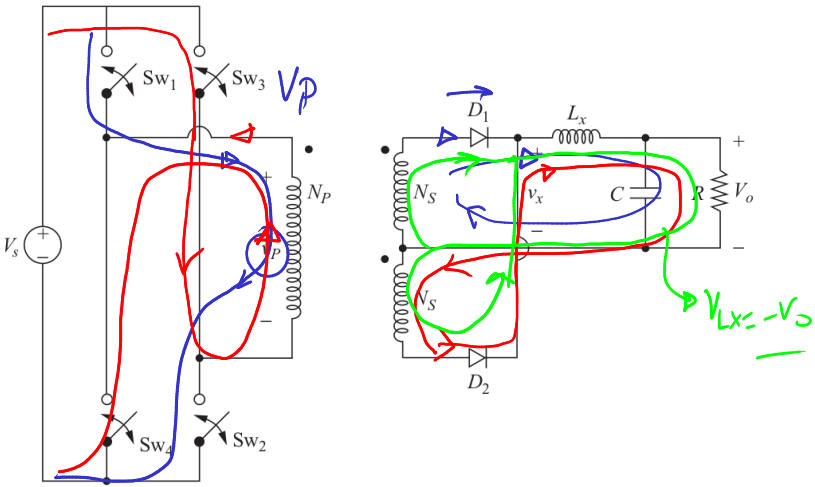
Full Bridge Isolating Converter

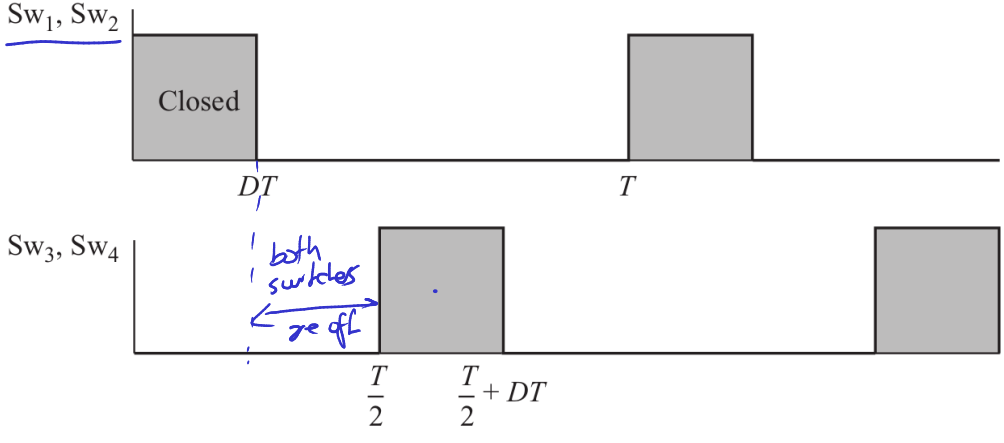


Compact solution for high power levels (>500W)

Similar to push-pull converter

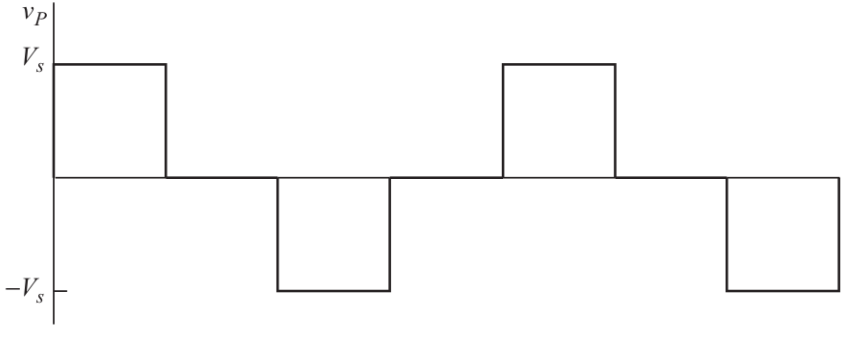
Full Bridge Converter: Operating Modes

Full Bridge Converter: Operating Modes

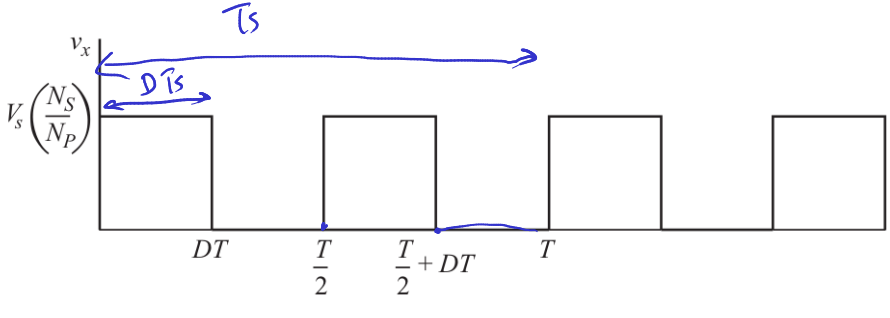


S1 & S2, S3 & S4 operate alternatively

Full Bridge Converter: Operating Modes



(c)



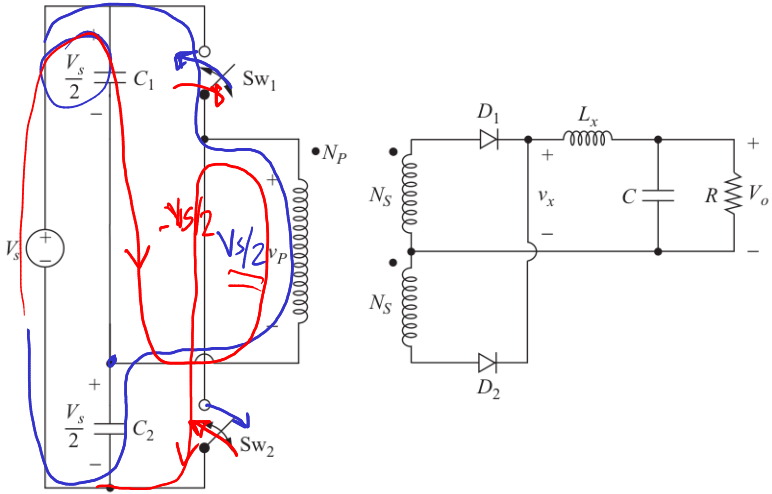
Full Bridge Converter

$$V_o = 2V_s(\frac{N_s}{N_p})D$$

$$D < 0.5$$

Same with the push-pull converter

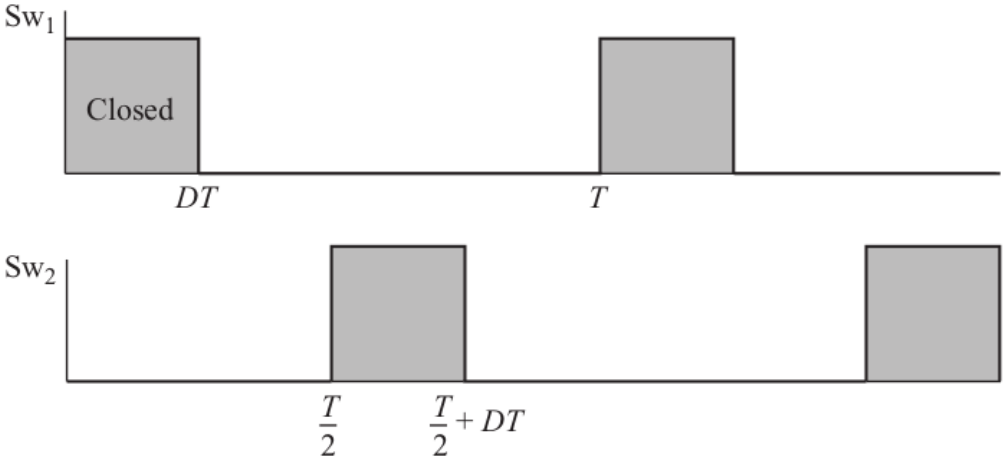
Half Bridge Isolating Converter



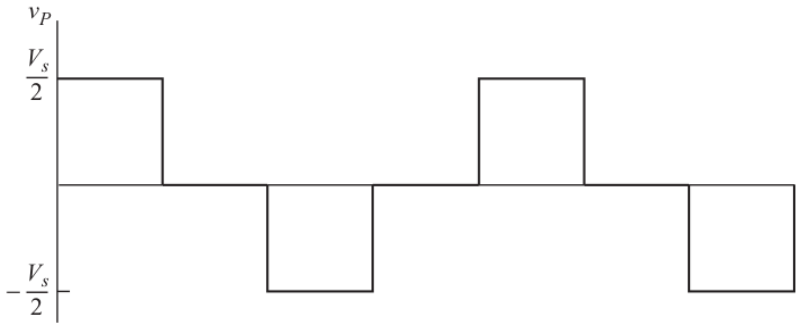
Derived from the Buck Converter

S1, S2 turned on alternatively each for t_{on}, then both off for Δ

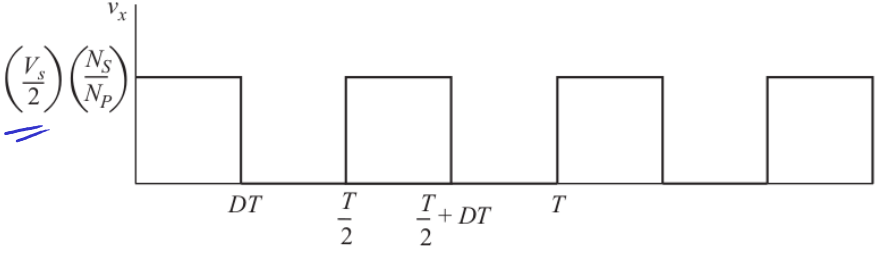
Half Bridge Converter: Operating Modes



Half Bridge Converter: Operating Modes



(c)



Half Bridge Converter

$$V_o = V_s(\frac{N_s}{N_p})D$$

$$D < 0.5$$

Half of the push-pull converter

Current Source Converter

Current Source Converter

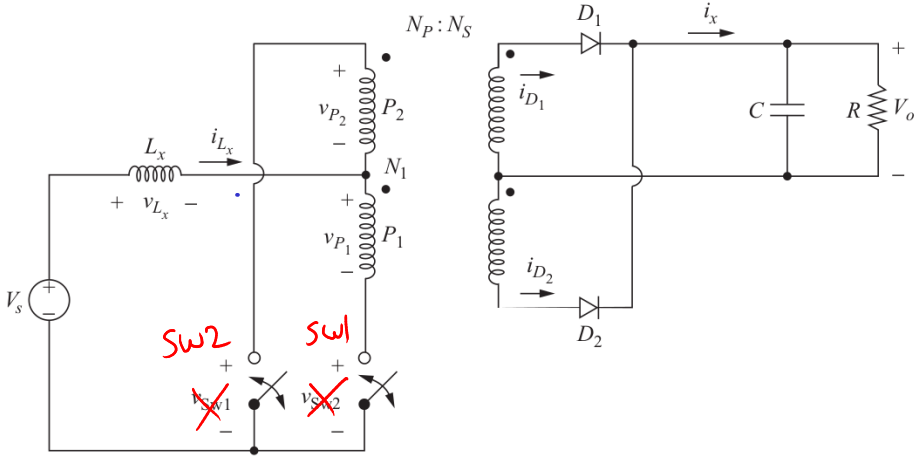
- Voltage Source Inverter (VSI): Fed by a voltage source (i.e. a capacitor large enough)

Current Source Converter

- Voltage Source Inverter (VSI): Fed by a voltage source (i.e. a capacitor large enough)
- Current Source Inverter (VCI): Fed by a current source (i.e. an inductor large enough)

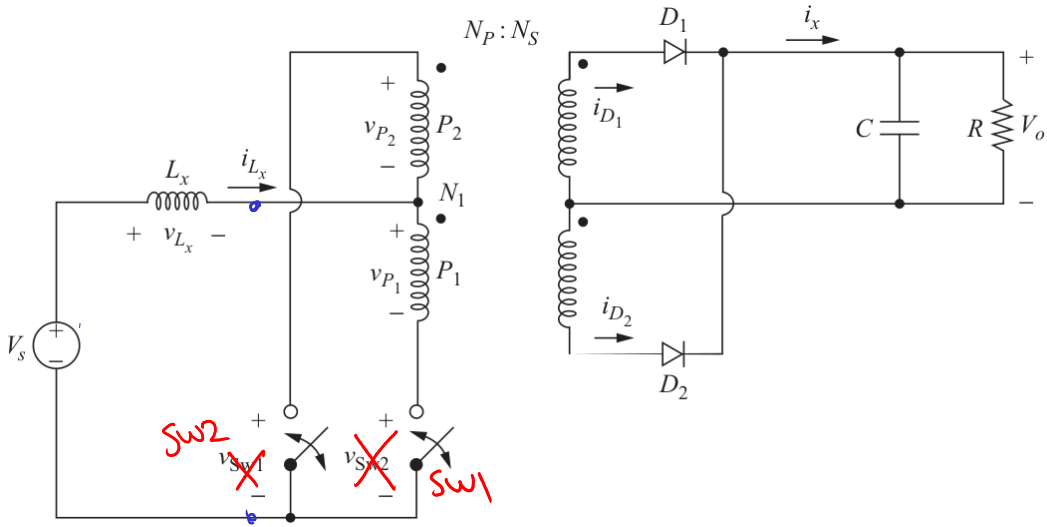
CSI

Current Source Converter



Fed with constant source current (due to large source inductance)

Current Source Converter



Same with push-pull, but the inductance moved to the source side

Voltage Source Converter:

Do not turn both switches ON (to prevent short-circuit)

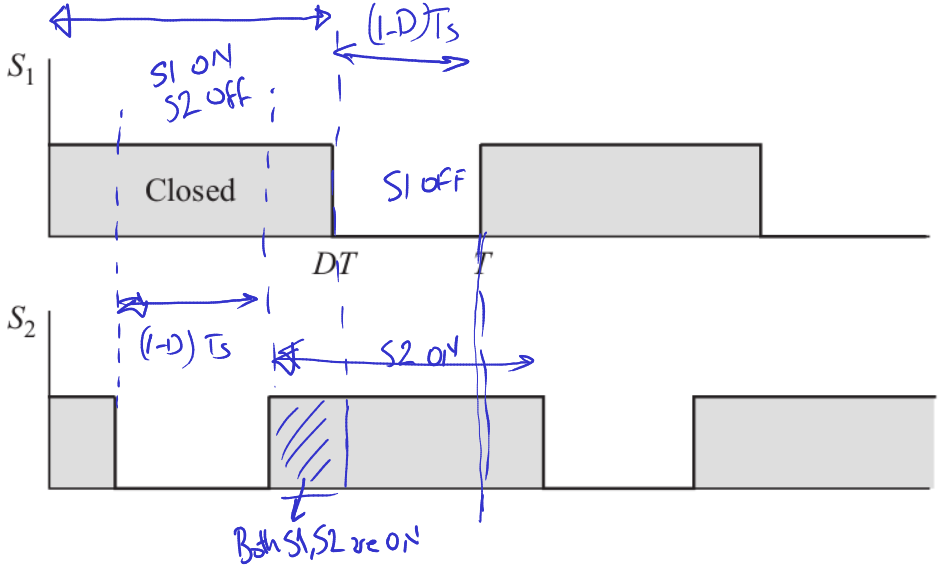
Voltage Source Converter:

Do not turn both switches ON (to prevent short-circuit)

Current Source Converter

Do not turn both switches OFF (to prevent open-circuit)

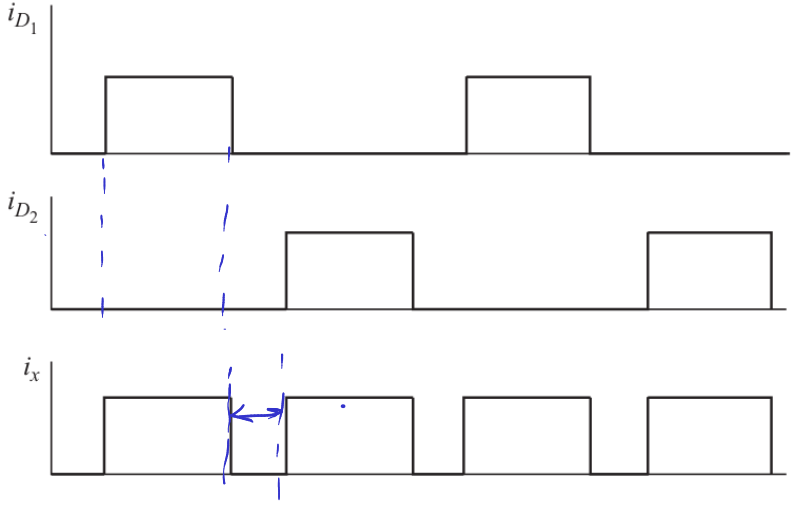
Current Source Converter: Operating Modes



Notice the overlapping periods between switches

D > 0.5

Current Source Converter: Operating Modes



Diode currents are added at the output

Current Source Converter

SW1 ON, SW2 - OFF , D1 is ON

$I_{D1} = I_{Lx}(N_P/N_S)$

$V_{P1} = V_o \frac{N_P}{N_S}$

$V_{Lx} = V_s - V_{P1} = V_s - V_o \frac{N_P}{N_S}$

SW1 OFF, SW2-ON, D2-ON

$I_{D2} = I_{Lx} \cdot (N_P/N_S)$

$V_{P2} = V_o \cdot N_P/N_S$

$V_{Lx} = V_s - V_o(N_P/N_S)$

SW1 ON, SW2 ON , D1, D2 ⇒ off

$V_{P1} = 0 \quad V_{P2} = 0$

$V_{Lx} = V_s$

should be negative.

$V_{Lx} = V_s - V_o \frac{N_P}{N_S}$ } for 2 intervals of $(1-D)T_s$

$V_{Lx} = V_s$ ⇒ for remaining

↳ $T_s - 2(1-D)T_s$

$= (2D-1)T_s$

$V_s \cdot (2D-1)T_s + \left(V_s - V_o \cdot \frac{N_P}{N_S}\right) \cdot 2(1-D)T_s = 0$

$$V_o = \frac{V_s}{2(1-D)} \left(\frac{N_S}{N_P}\right)$$

Current Source Converter

$$V_o = V_s\left(\frac{N_s}{N_p}\right)\left(\frac{1}{2(1-D)}\right)$$

$$D > 0.5$$

Operates as a: Boost Converter

Multi-Quadrant DC Converters

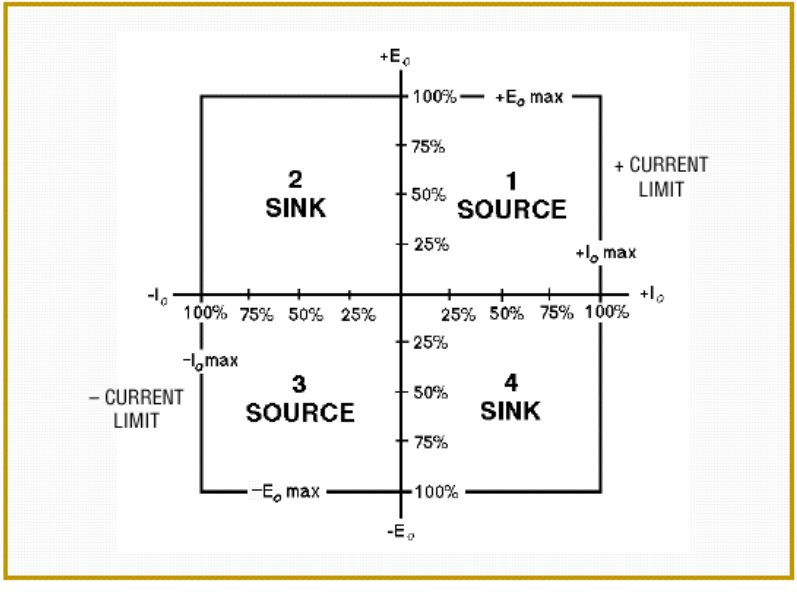
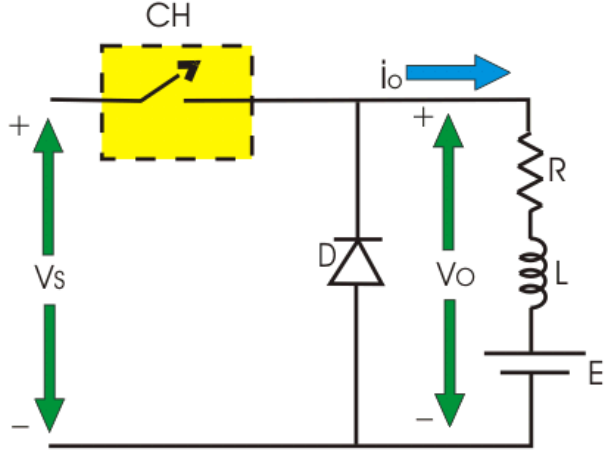


FIGURE 9
Four quadrant operation from a Kepco BOP power supply

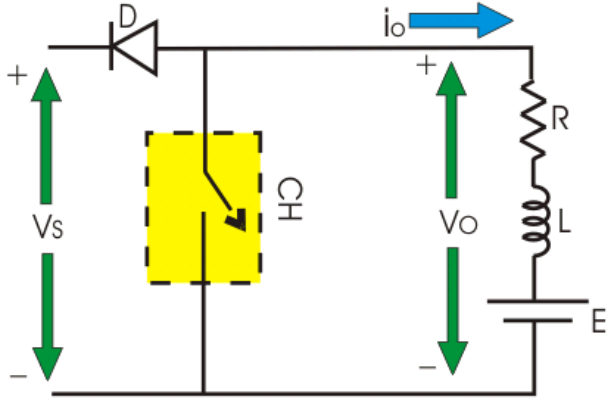
First Quadrant Converter

(Type A Chopper)



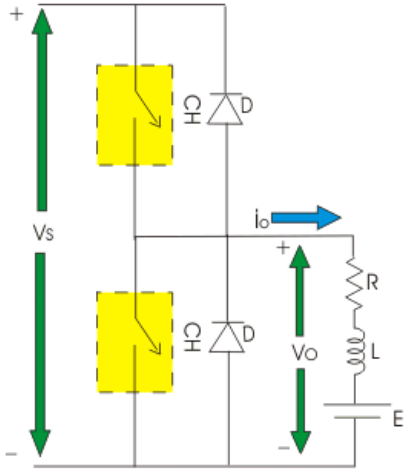
Second Quadrant Converter

(Type B Chopper)

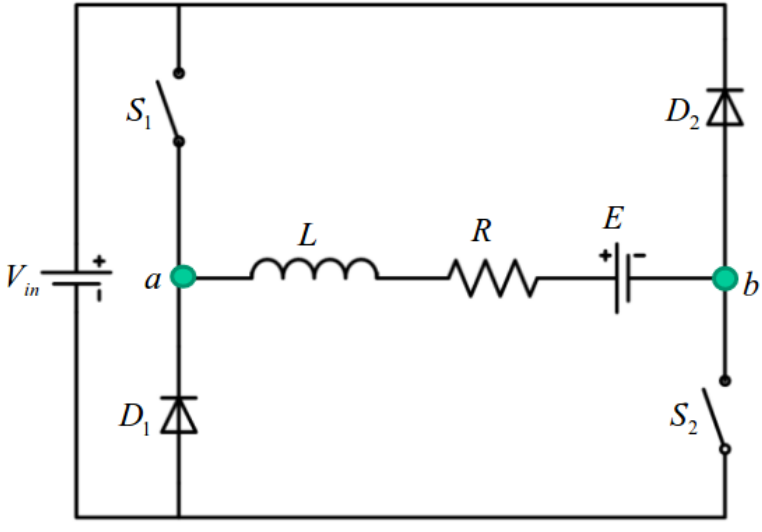


Two Quadrant Converter

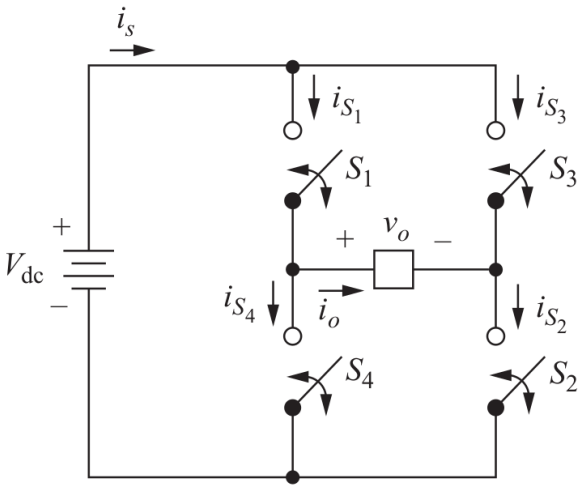
(Type C Chopper)



First and Fourth Quadrant Converter

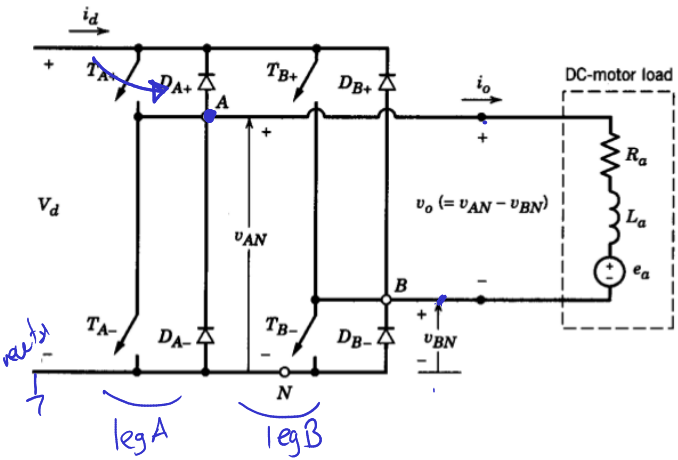


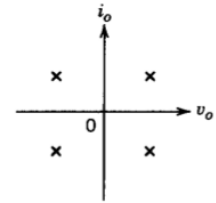
Full-Bridge (Four Quadrant) DC-DC Converter

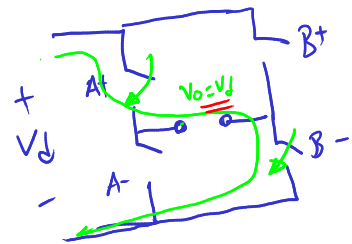


Simplified Circuit

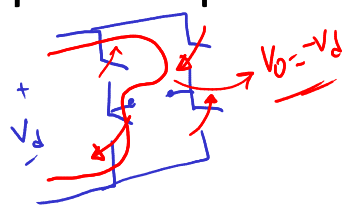
Full-Bridge (Four Quadrant) DC-DC Converter







Suitable for four quadrant operation



Control of Full-Bridge Converter

- Bi-polar Voltage Switching
- Uni-polar Voltage Switching

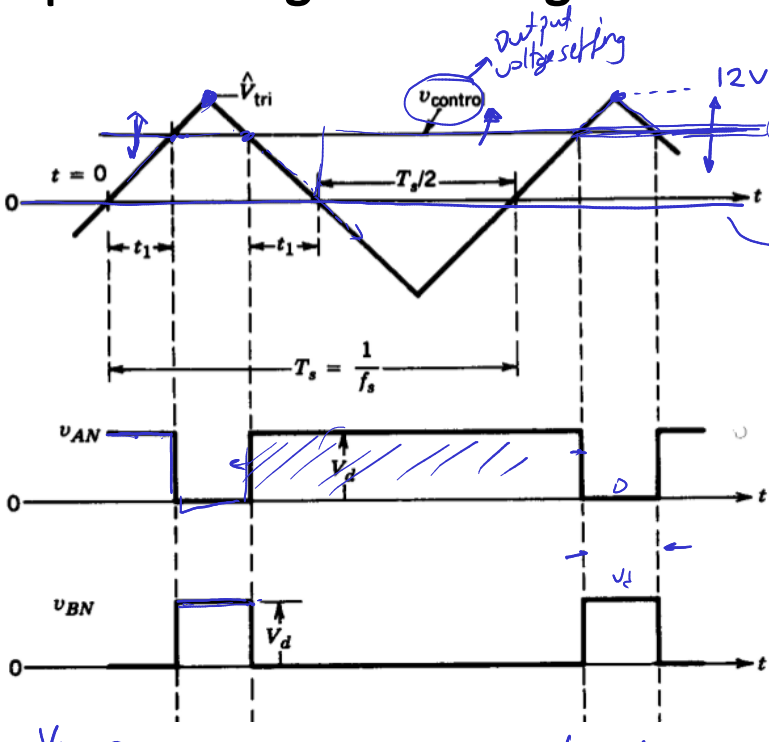
Bi-polar Voltage Switching

T_{A+} and T_{B-} are turn on and off together

T_{A-} and T_{B+} are complimentary of T_{A+} and T_{B-}

Output can be $+V_d$ or $-V_d$

Bi-polar Voltage Switching



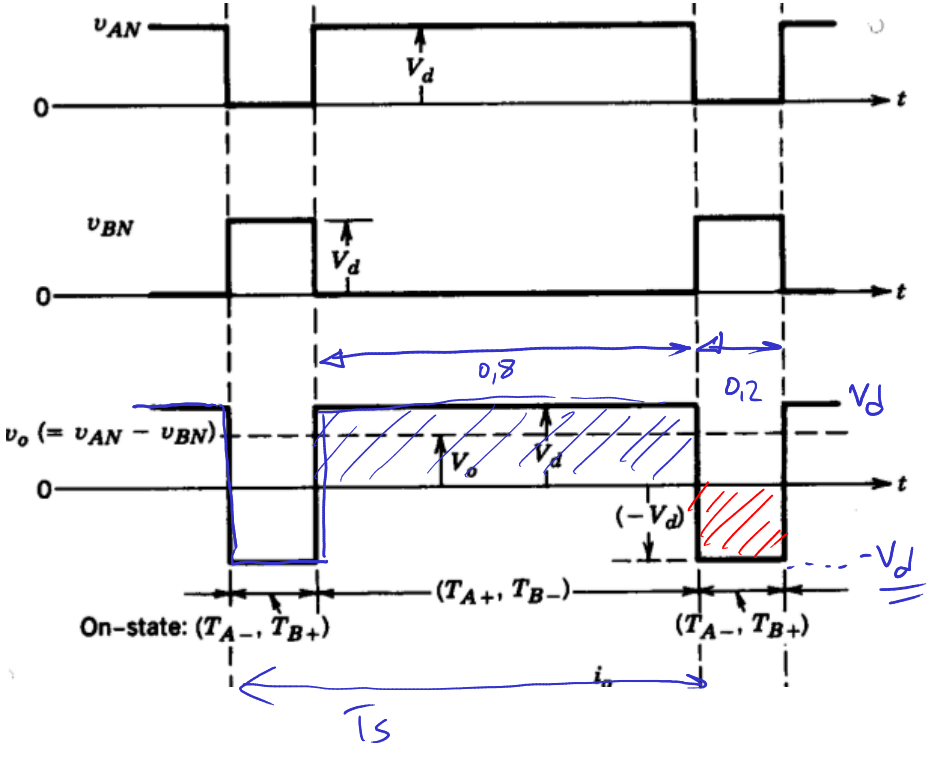
$V_{control} = 0$

$0.5T_s \Rightarrow V_{AB} = V_d$

$0.5T_s \Rightarrow V_{AB} = -V_d$

Average output $\Rightarrow V_o = 0$

Bi-polar Voltage Switching



$V_d = 12V$

$12 \cdot 0.8 + (-12) \cdot 0.2$

$= 9,6 - 2,4$

$= 7,2V$ (average)

Bi-polar Voltage Switching

$$V_o = V_d \frac{v_{control}}{\hat{V}_{tri}}$$

Uni-polar Voltage Switching

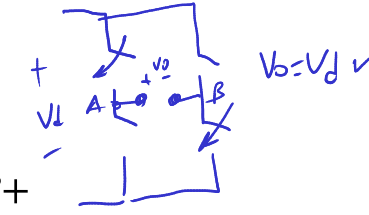
T_{A+} and T_{B+} are controlled seperately

T_{A-} and T_{B-} are complimetary of T_{A+} and T_{B+}

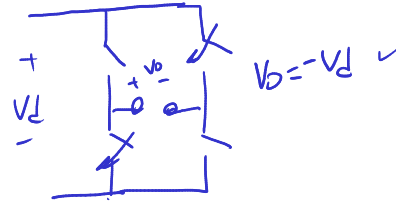
Uni-polar Voltage Switching

T_{A+} and T_{B+} are controlled seperately

T_{A-} and T_{B-} are complimetary of T_{A+} and T_{B+}

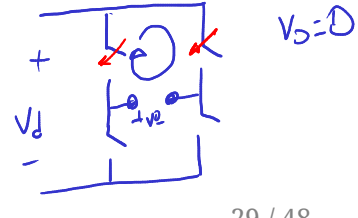


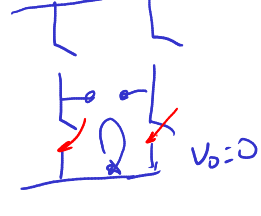
Output can be $+V_d$ or 0 or $-V_d$



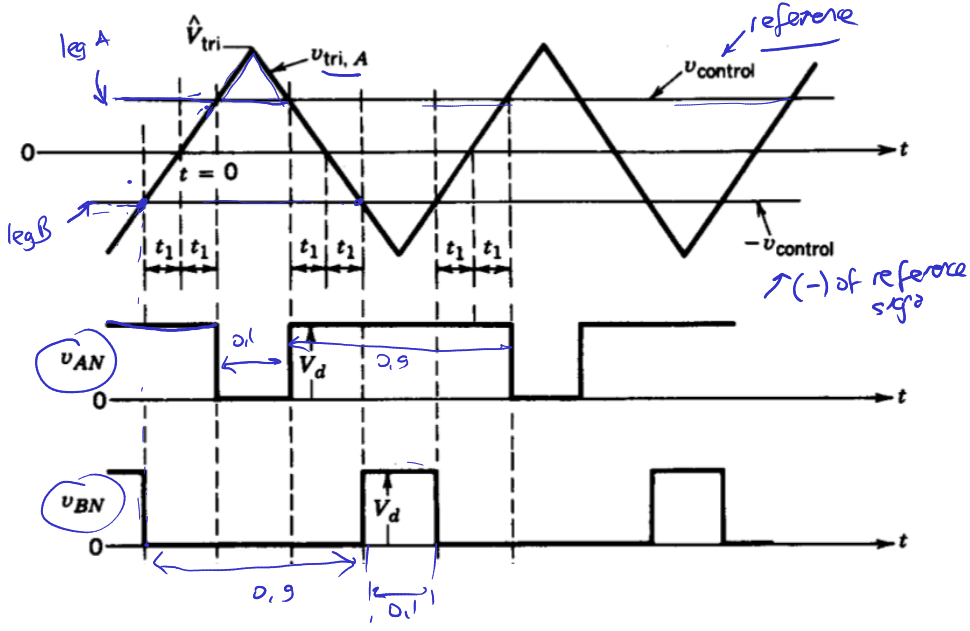
$V_o = 0$ if T_{A+} and T_{B+} are ON

$V_o = 0$ if T_{A-} and T_{B-} are ON



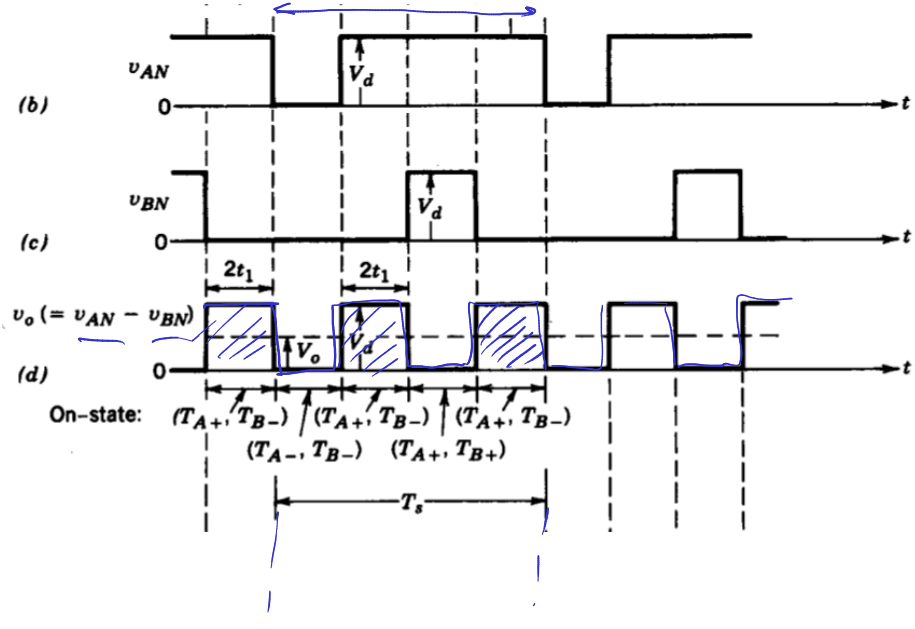


Uni-polar Voltage Switching



$V_{AB} = V_{AN} - V_{BN}$

Uni-polar Voltage Switching



Uni-polar Voltage Switching

$$V_o = V_d \frac{v_{control}}{\hat{V}_{tri}}$$

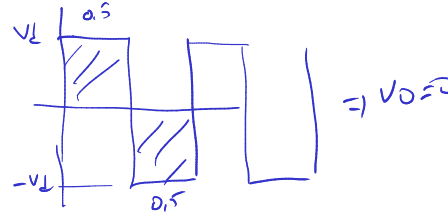
Uni-polar Voltage Switching

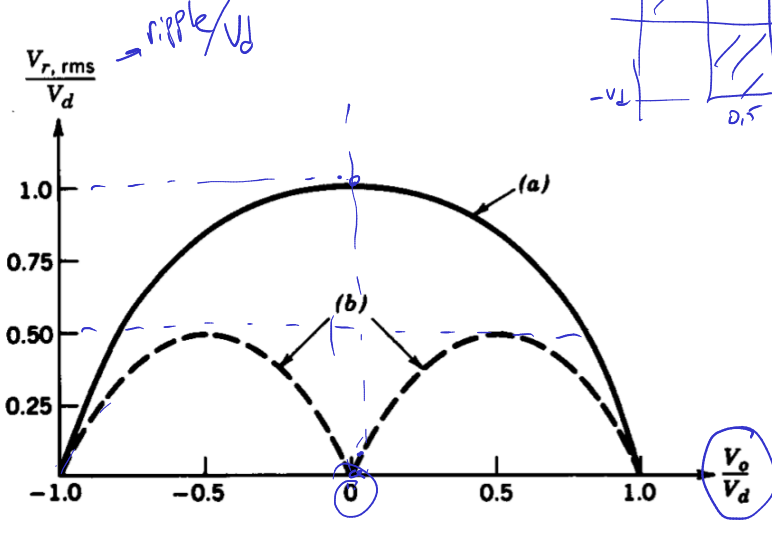
$$V_o = V_d \frac{v_{control}}{\hat{V}_{tri}}$$

So, what's the point?

Ripple Comparison

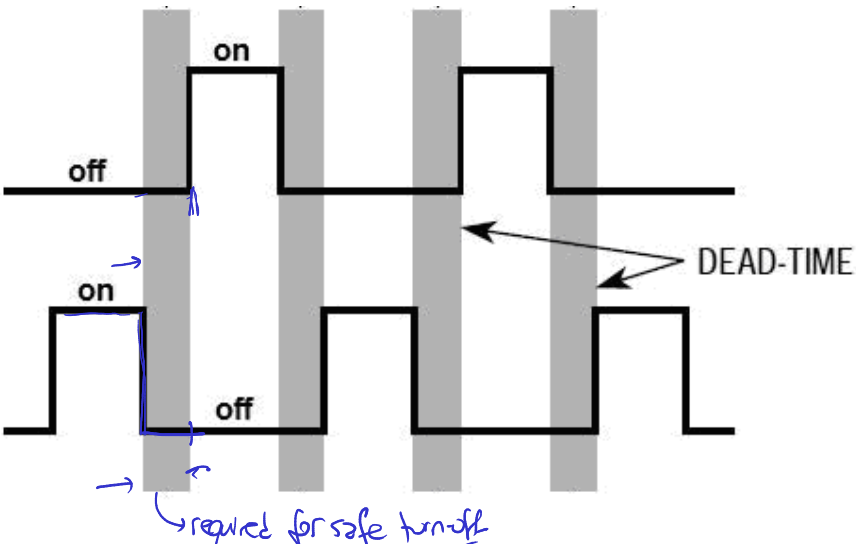
Homework: Mohan Example 7.4 ✓





a) Bipolar PWM, b) Unipolar PWM

Dead Time (Blanking Time)



Off periods are added to compensate with non-zero turn-off time

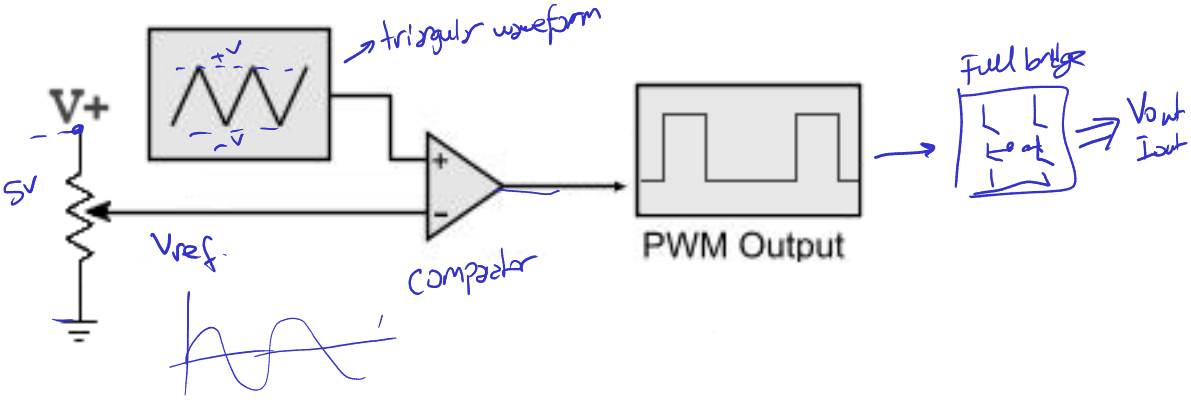
Dead Time

Introduces non-linearity between Vref and Vo.

Pulses shorter than dead-time will be omitted (introduce harmonics)

Vref can be increased to compensate for the off period.

Full Bridge as a DC Converter

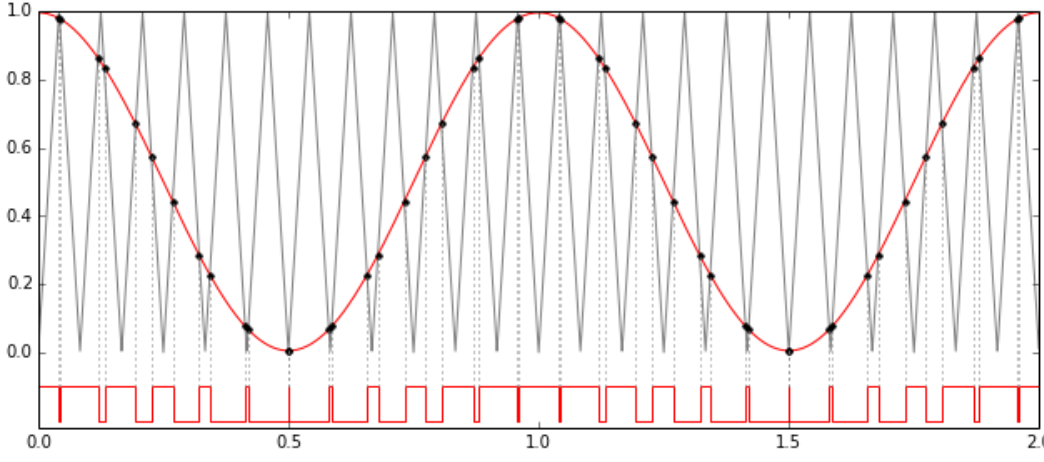


Operate it with Constant Reference Voltage

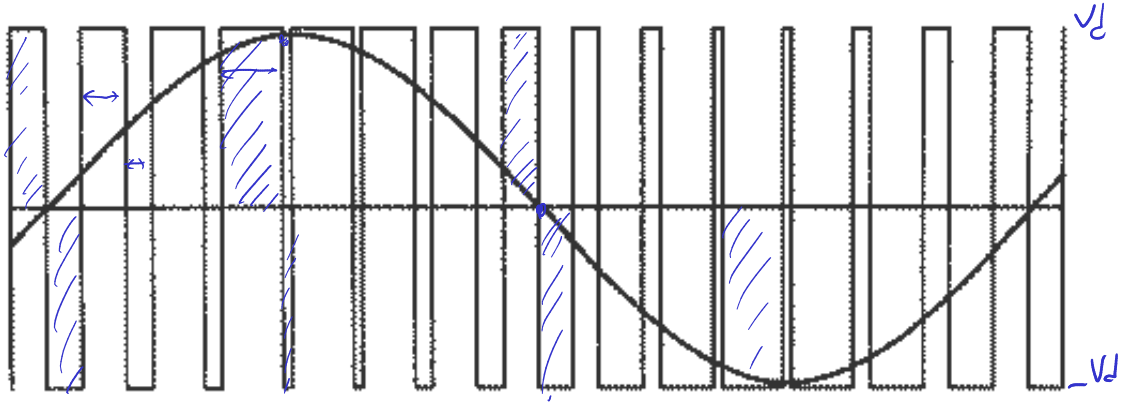
Full Bridge as an Inverter

Full Bridge as an Inverter

Just change the reference voltage with a sinusoid



Full Bridge as an Inverter



Will be covered in detail in the following weeks

PFC?

PFC?

Power Factor Correction

PFC?

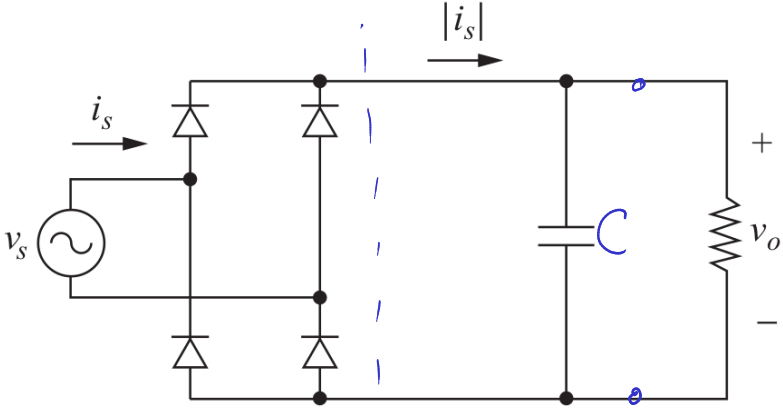
Power Factor Correction

Power Factor of a 1Ph Diode Rectifier?

PFC?

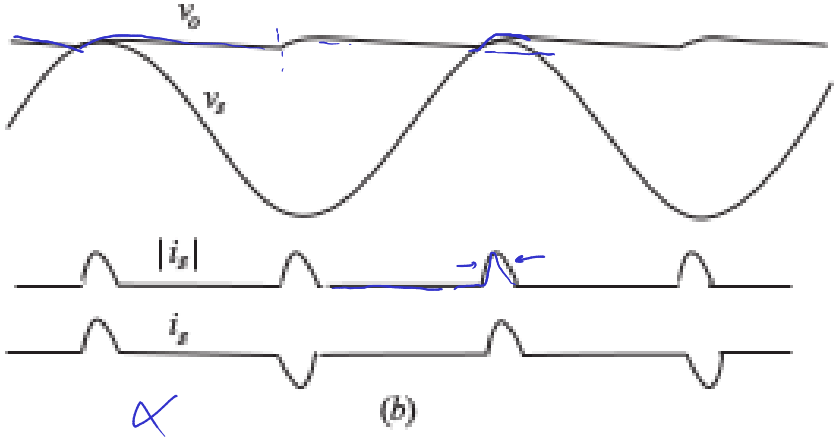
Power Factor Correction

Power Factor of a 1Ph Diode Rectifier?



Diode Rectifier

Source current



PFC required for many applications

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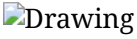
- Computer Power Supplies, LED Drives

PFC required for many applications

- Computer Power Supplies, LED Drives
- Arc Furnaces

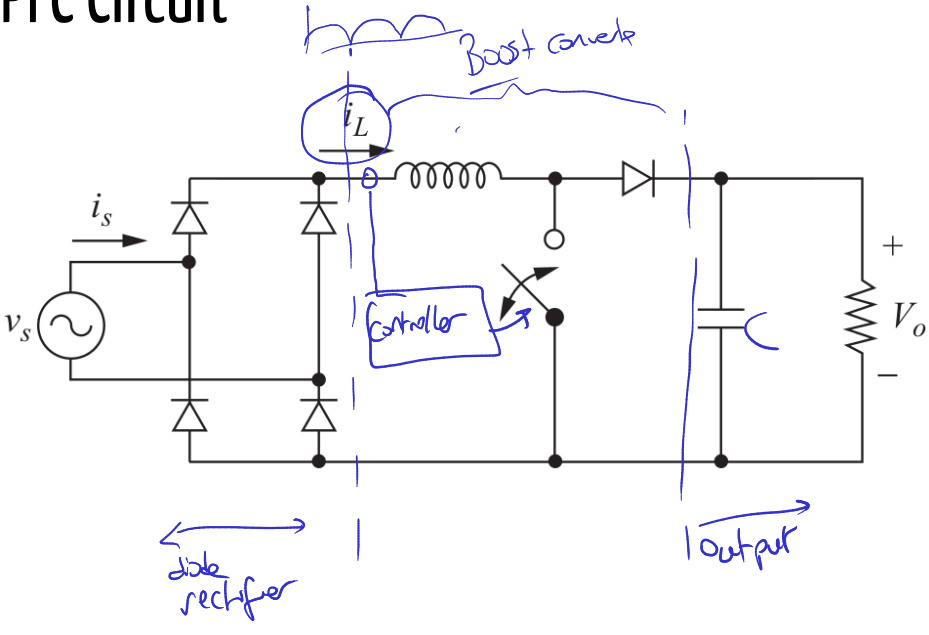
PFC required for many applications

- Computer Power Supplies, LED Drives
- Arc Furnaces
- Welding



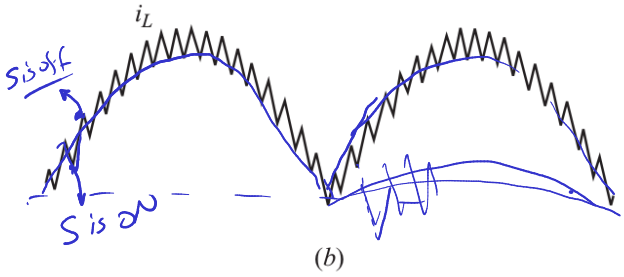
PFC Circuit

PFC Circuit

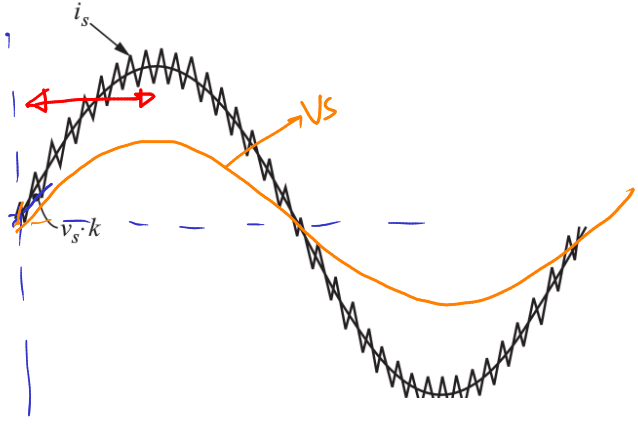

Boost converter
i_L
i_s
v_s
Controller
+
V_o
−
diode rectifier
output

PFC Current

PFC Current



(b)

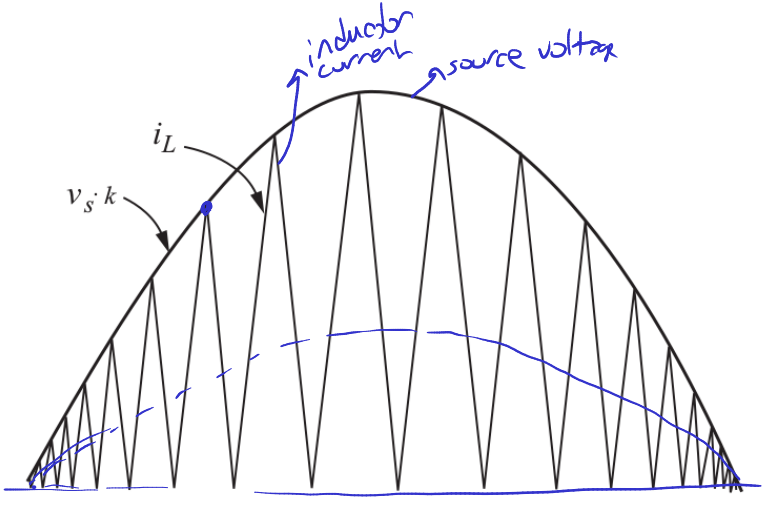


PFC Current

Critical Current Mode (Discontinuous Current Mode)

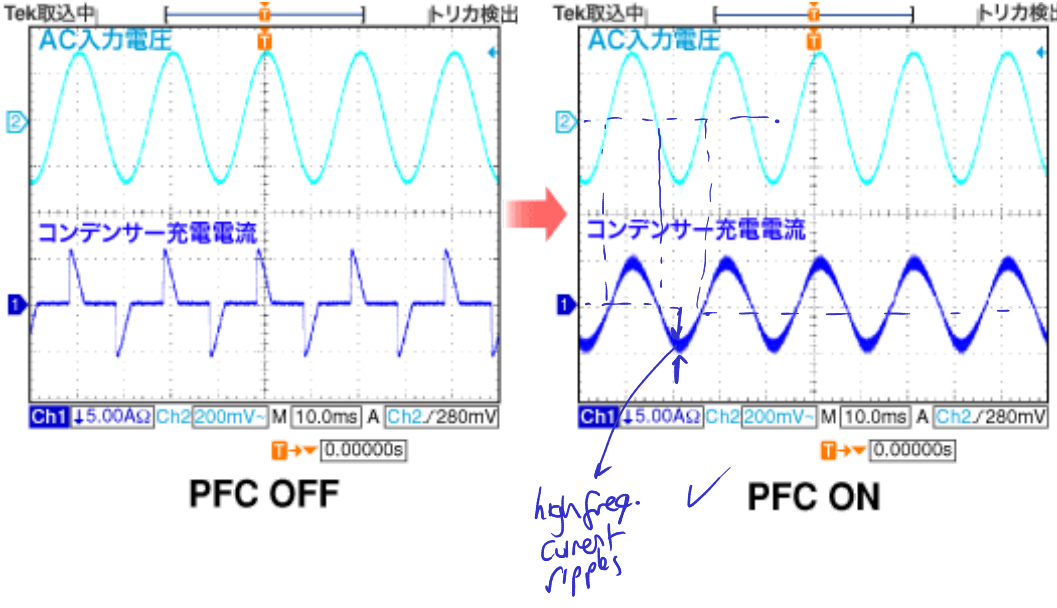
PFC Current

Critical Current Mode (Discontinuous Current Mode)



PFC Effect

PFC Effect


Tek取込中
トリカ検出
AC入力電圧
コンデンサー充電電流
Ch1 ↓5.00AΩ Ch2 200mV~ M 10.0ms A Ch2 ⁄ 280mV
0.00000s
PFC OFF
Tek取込中
トリカ検出
AC入力電圧
コンデンサー充電電流
Ch1 ↓5.00AΩ Ch2 200mV~ M 10.0ms A Ch2 ⁄ 280mV
0.00000s
PFC ON
high freq. current ripples

Commercial PFC Controllers

Commercial PFC Controllers

- Toshiba-TB6819AFG
- OnSemi PFC Controllers
- TI PFC Controllers
- TI UCC28180

PFC Application Study: Welding Circuit

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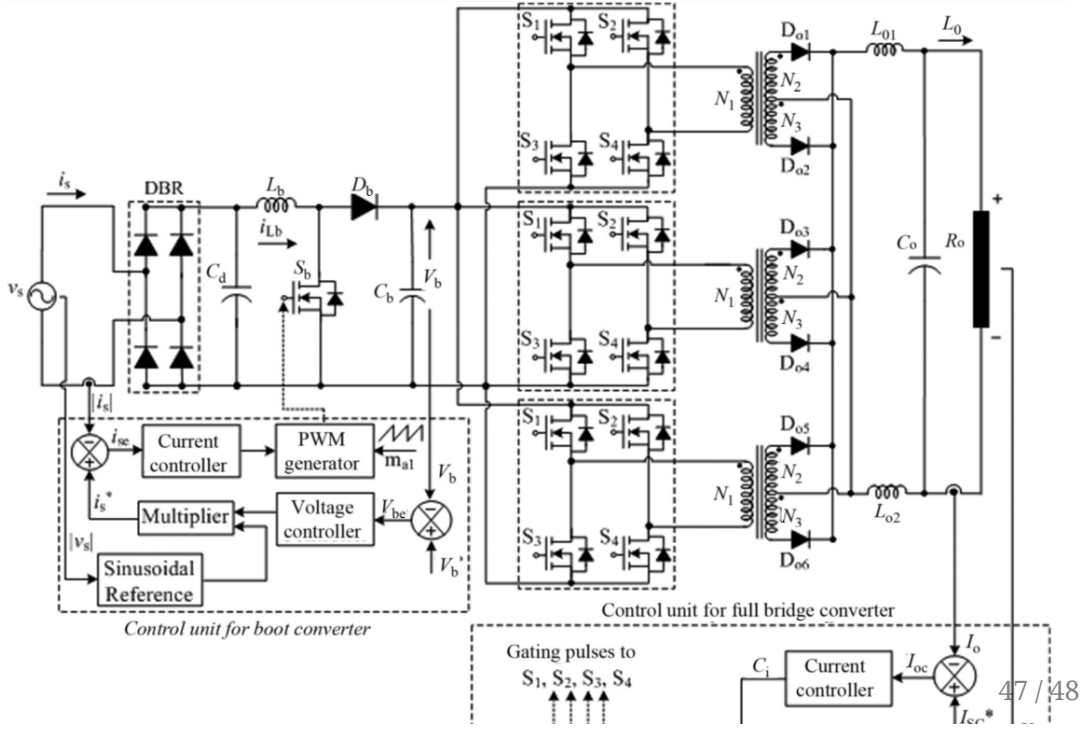

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