31352-Power Electronics I

— Lecture III: Isolated DC-DC Converters

Lecturer : Ziwei Ouyang

07-Sept.-2016, kl: 9:00-12:00
Location: B325-IT017

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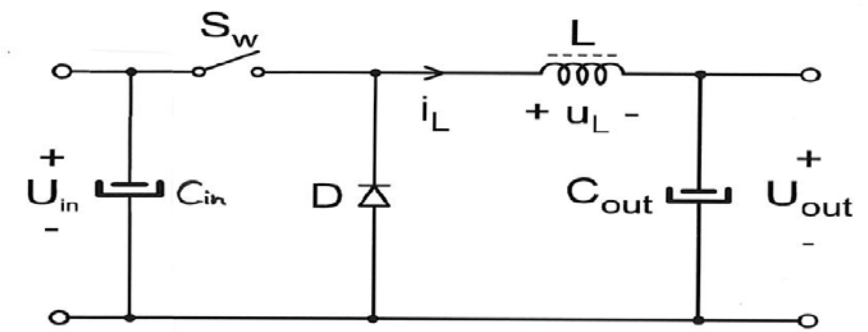
DTU Elektro
Institut for Elektroteknologi

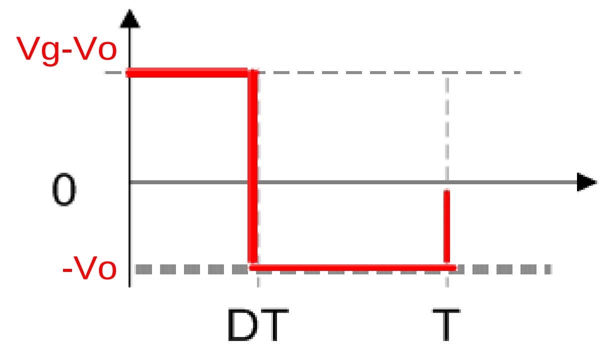
Agenda

- Review nonisolated DC-DC converters
- Foward converter
- Flyback converter
- Push-pull converter
- Half-bridge & Full bridge

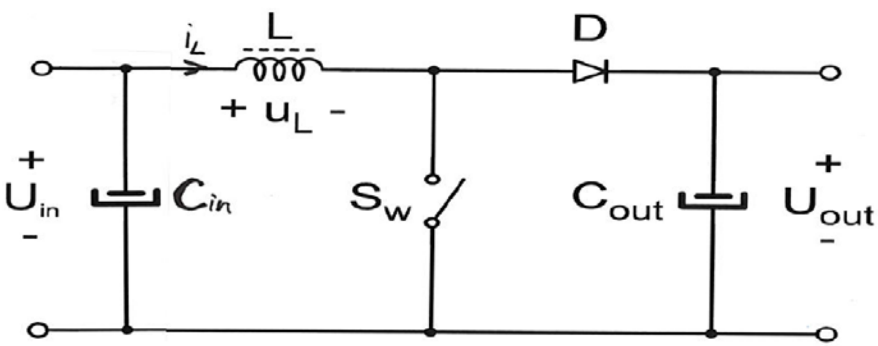
Review nonisolated DC-DC Converters



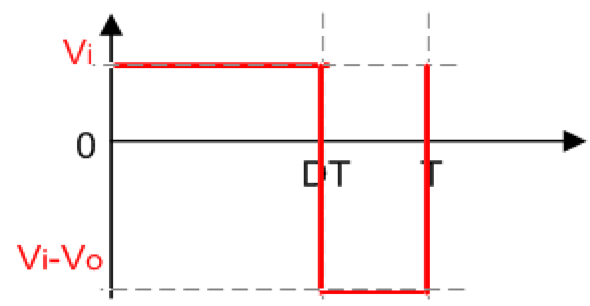
VL1



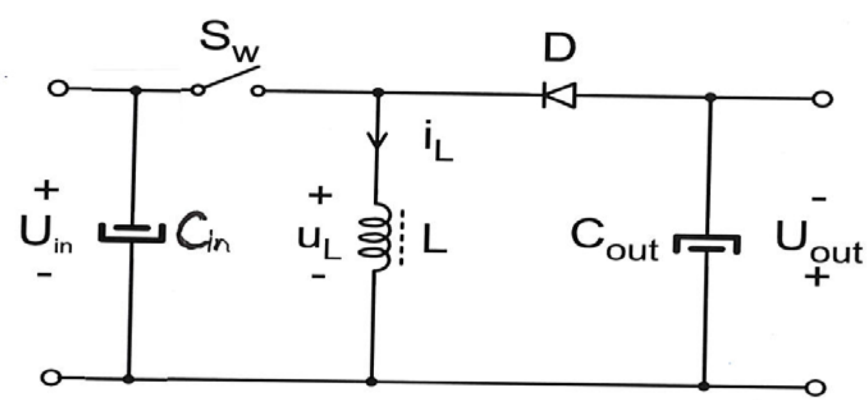
$$\frac{V_o}{V_{in}} = D$$



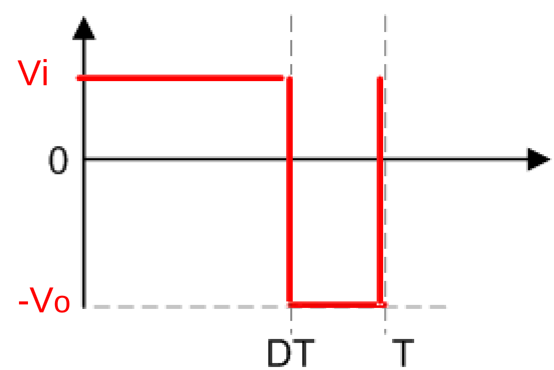
VL



$$\frac{V_o}{V_{in}} = \frac{1}{1-D}$$



VL



$$\frac{V_o}{V_{in}} = \frac{D}{1-D}$$

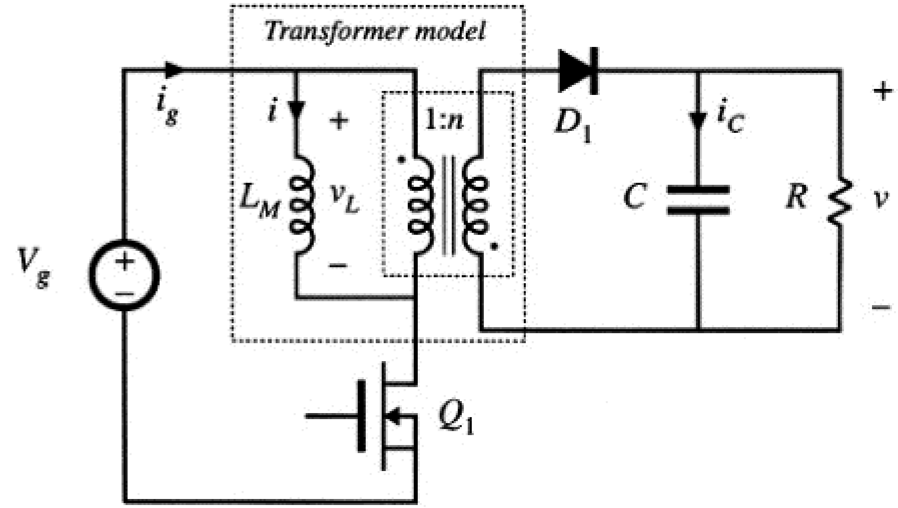
Galvanic Isolation

✓ for safety, preventing accidental current from reaching ground through a person's body

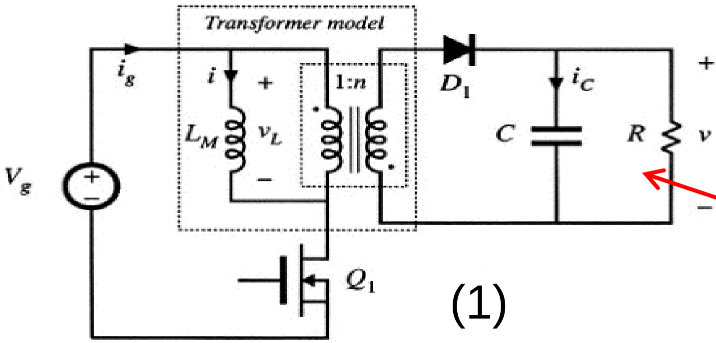
✓ to break groud loops, to suppress electrical noise in sensitive devices

✓ to transfer power between two circuits

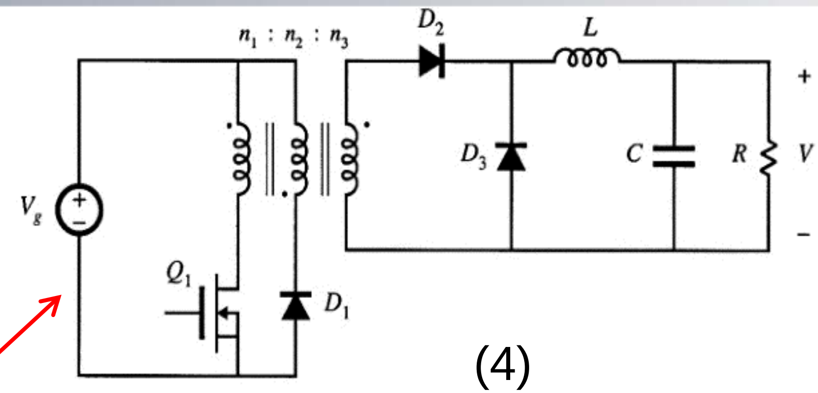
✓ to change the transfer ratio



Topologies



(1)



(4)

Flyback

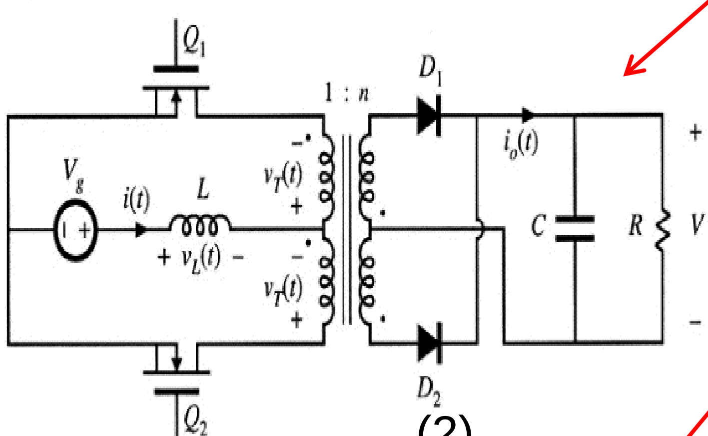
Push-pull

Forward

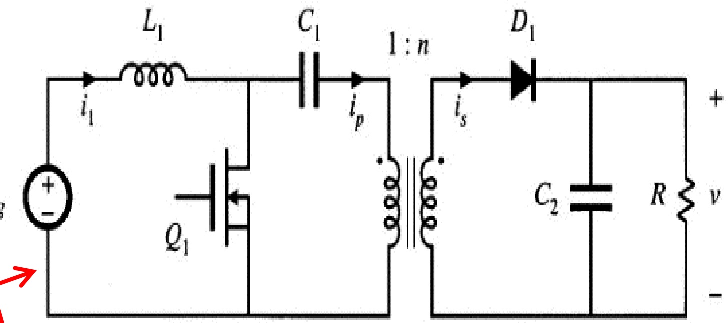
Full-bridge boost

half-bridge buck

SEPIC



(2)



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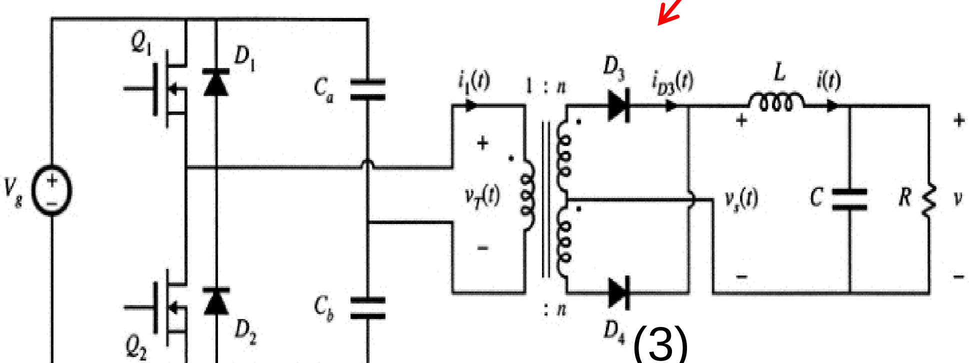

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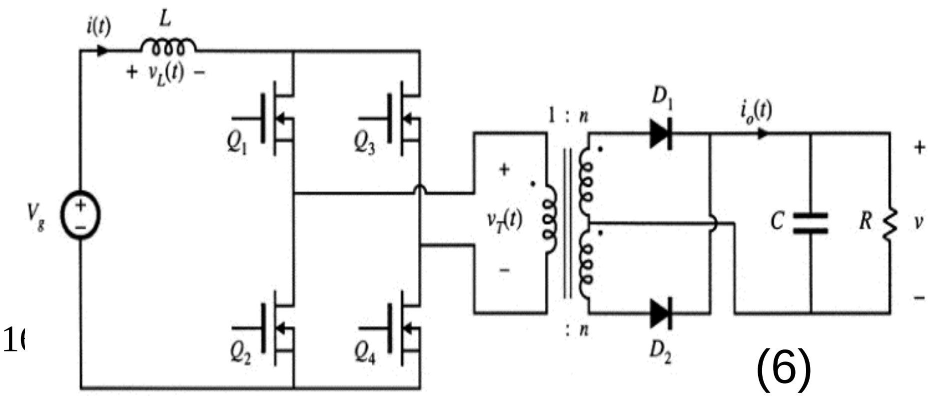
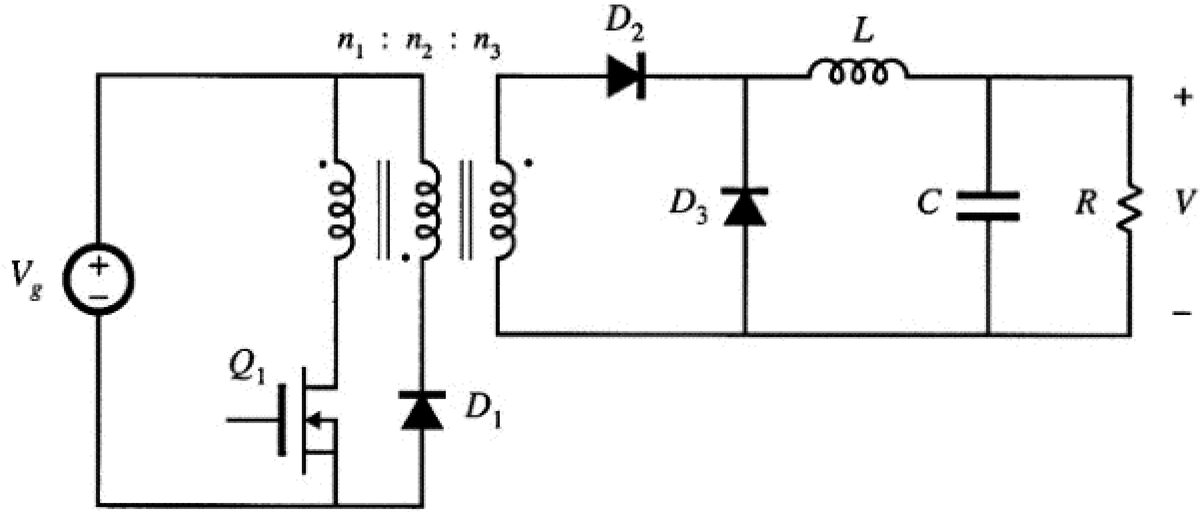
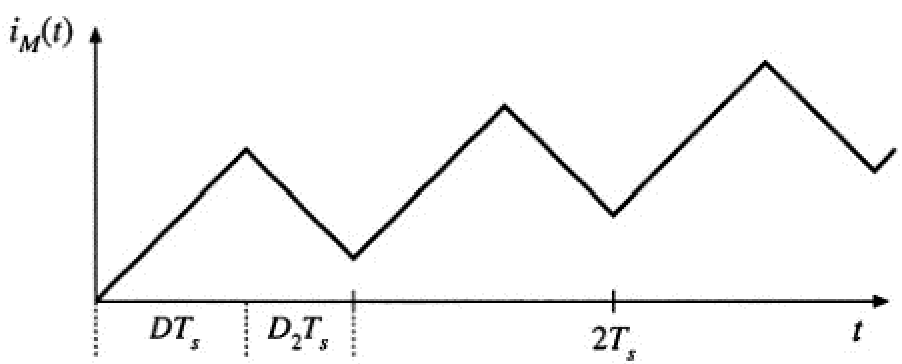


(6)

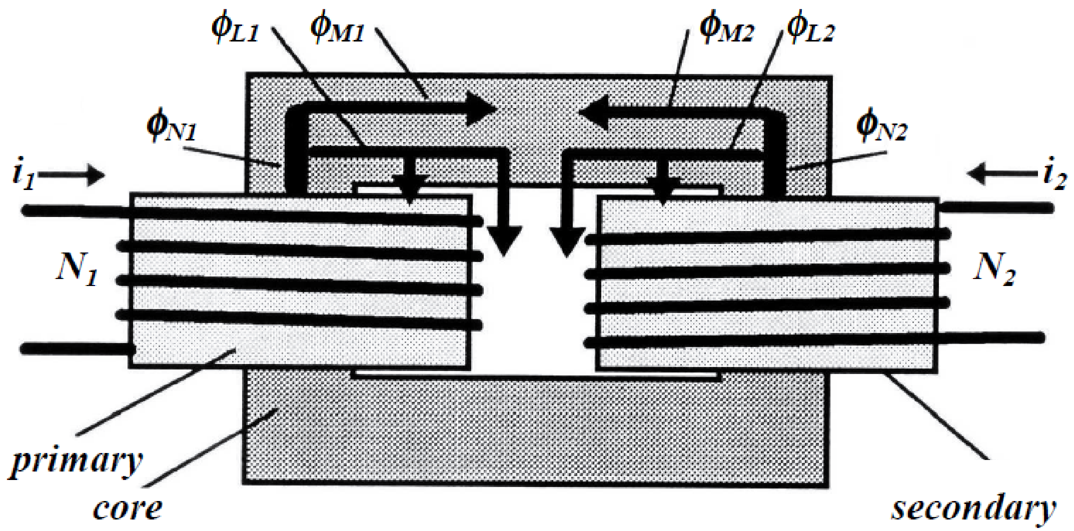
Forward Converter

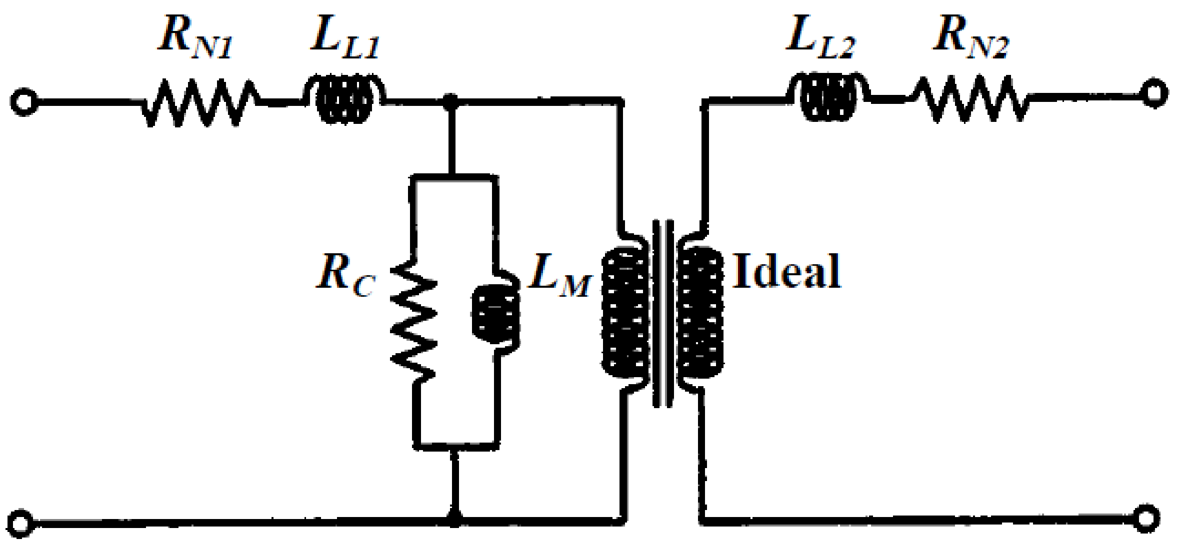


Why is there three windings transformer?

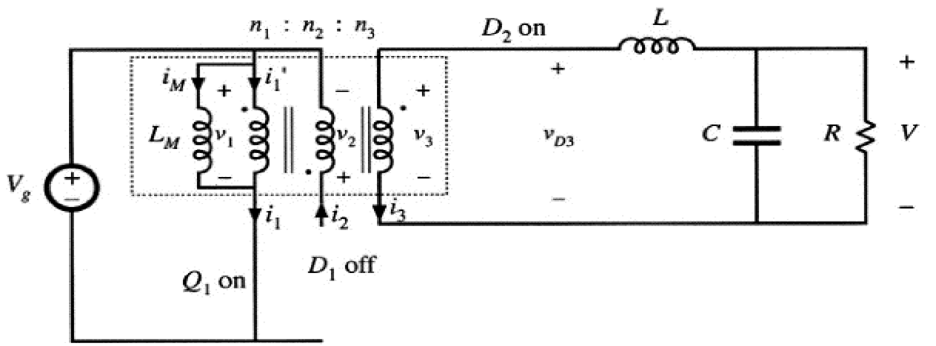


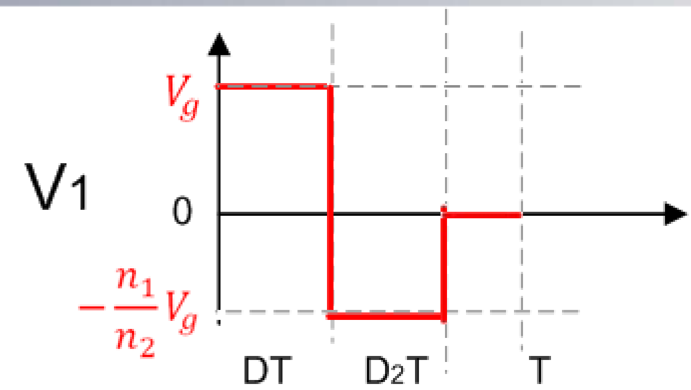
Magnetizing Inductance

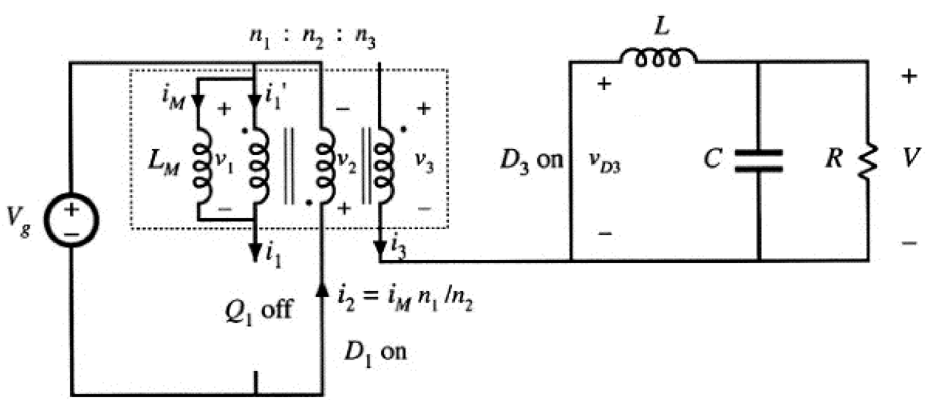


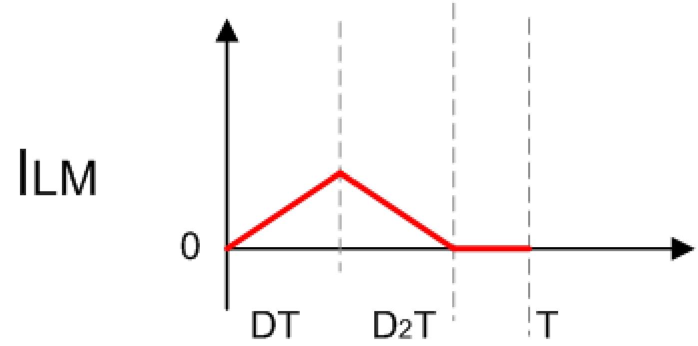


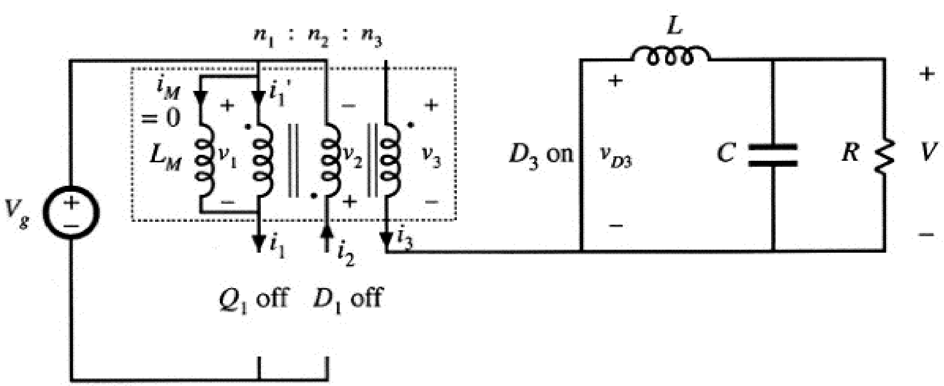
Forward Converter (CCM)

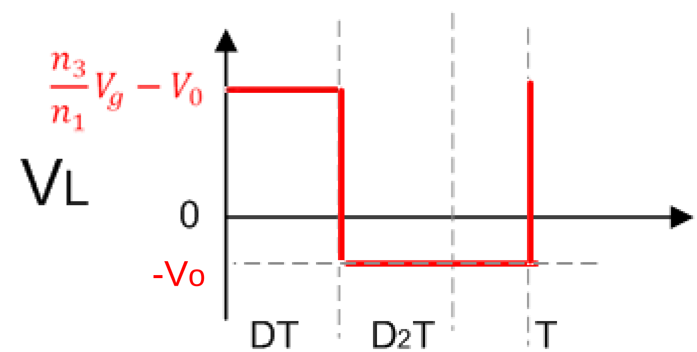






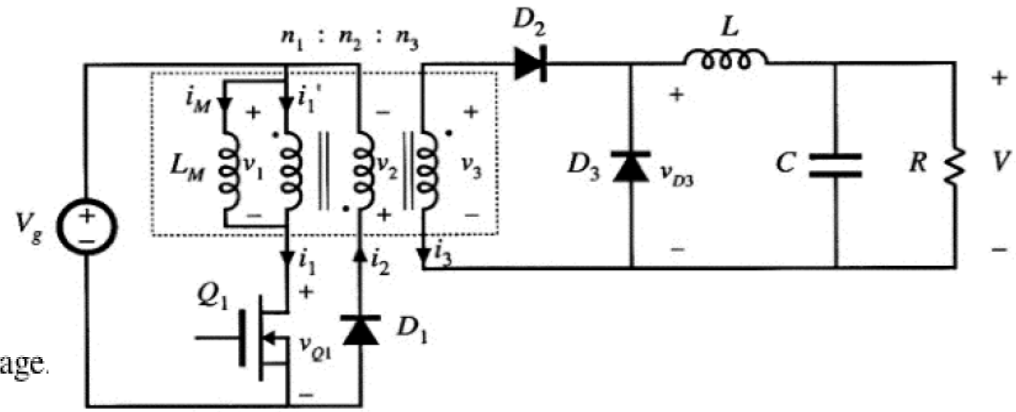






Forward Converter

Duty cycle limitaion:



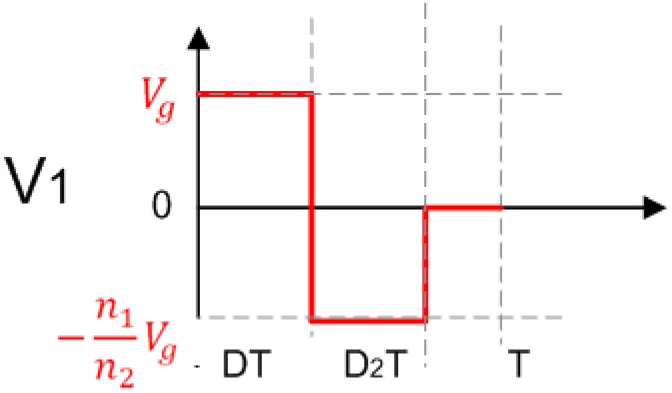
the primary winding voltage $v_1(t)$ must have zero average.

$$\langle v_1 \rangle = D(V_g) + D_2(-V_g n_1/n_2) + D_3(0) = 0$$

$$D_2 = \frac{n_2}{n_1} D$$

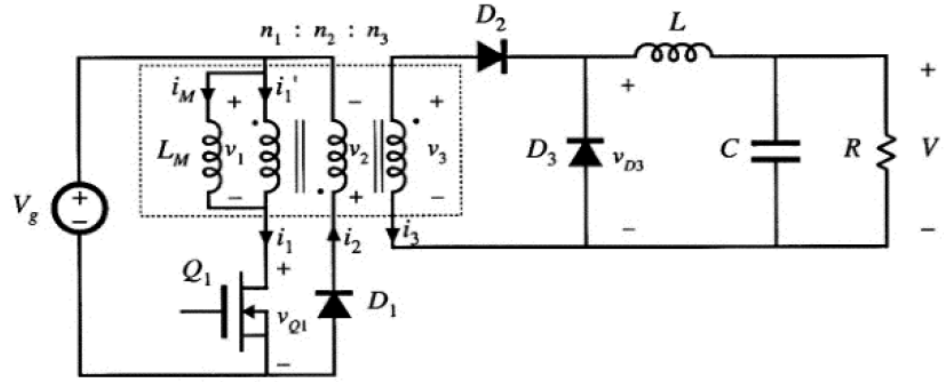
the duty cycle D_3 cannot be negative

$$D \le \frac{1}{1 + \frac{n_2}{n_1}}$$



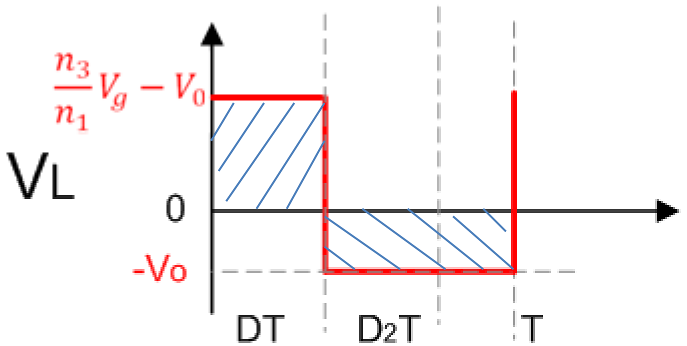
Forward Converter

Transfer function:



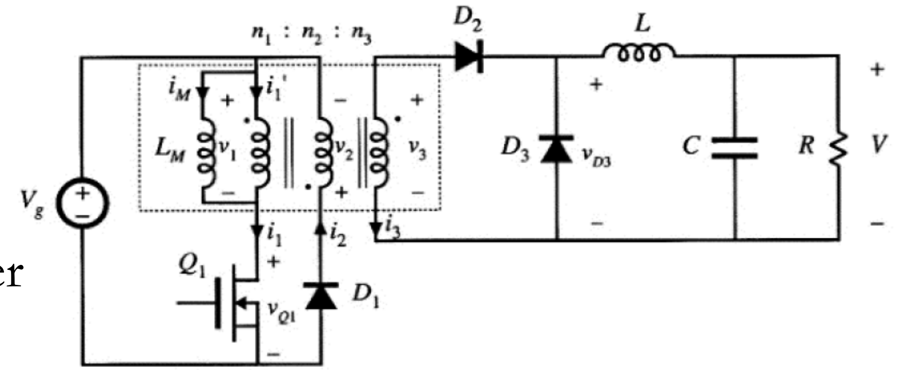
$$\frac{n_3}{n_1} V_g D = V_o(1 - D)$$

$$\frac{V_o}{V_g} = \frac{n_3}{n_1} D$$



Group Discussion

Question 1:

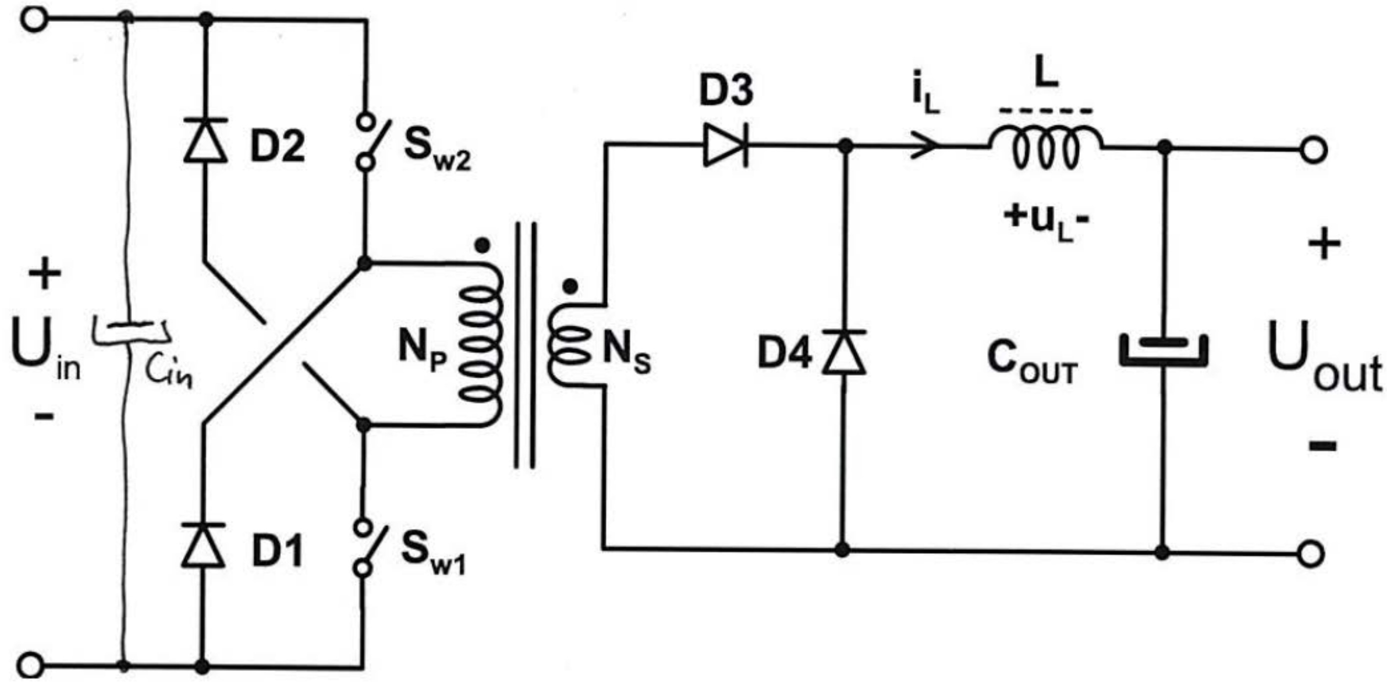


You are going to design a 120W forward converter. The input voltage is 48 V and the output voltage is 12 V. The transformer turns ratio is 1:1:1, and the converter is operated at 100k Hz and in CCM mode. The magnetizing inductance is 12uH. The output inductance is assumed to be infinite. What is the max drain-source voltage of MOSFET, Vds, and what is the peak current of the MOSFET, Ids?

A. 12V
B. 48V
C. 60V
D. 96V

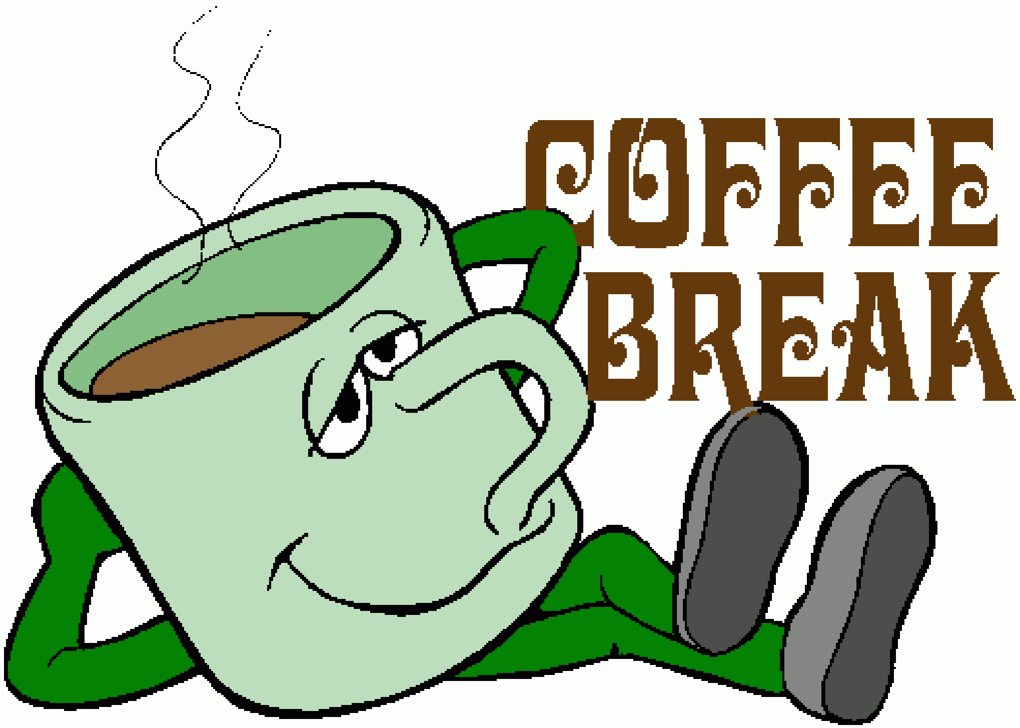
a. 2.5A
b. 5A
c. 10A
d. 20A

Two-switch Forward Converter

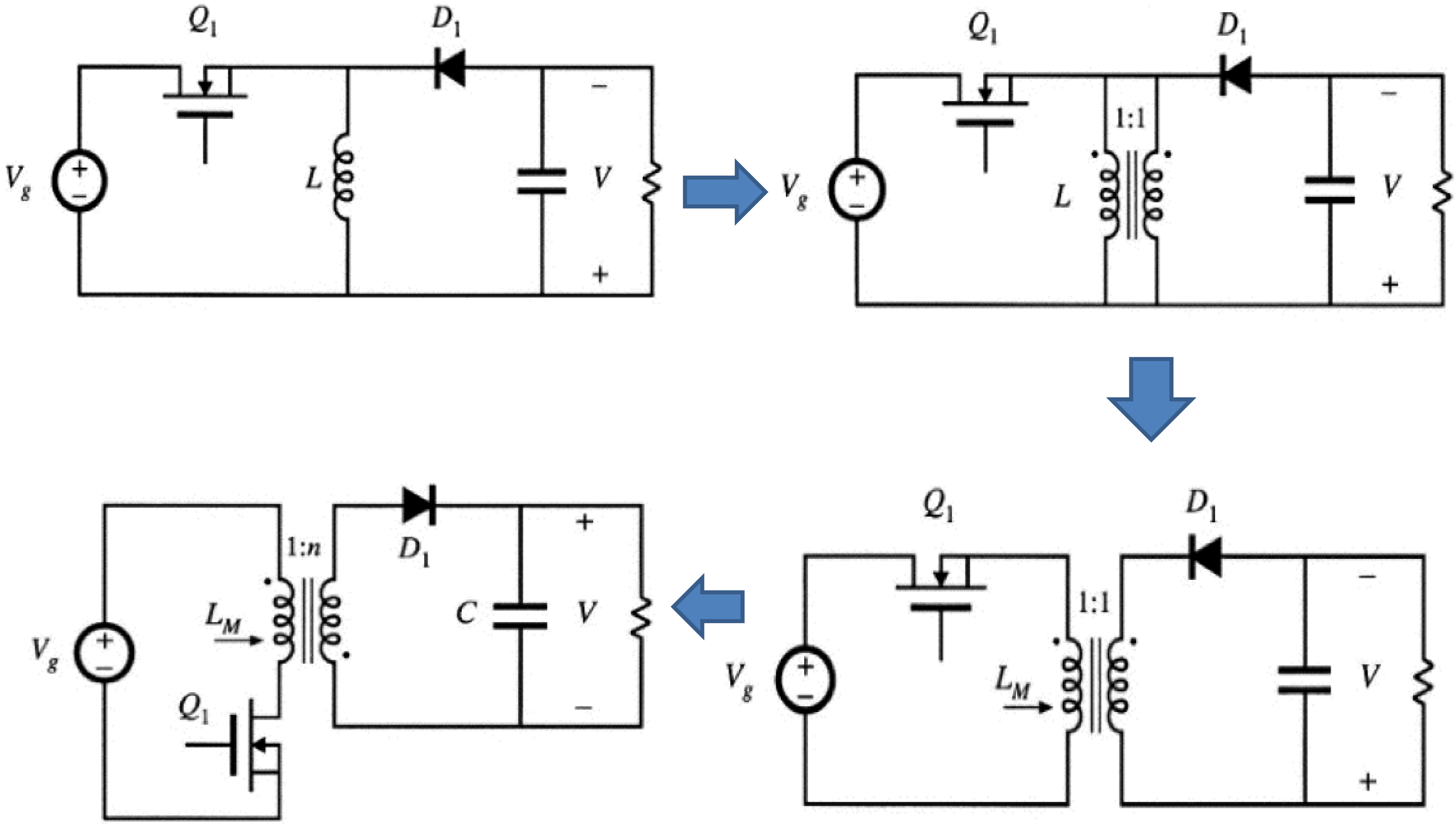


+ The maximum switch blocking voltage is equal to U_{IN} (clamped!)
+ Snubber is regenerative (for the magnetizing current)
+ Very robust (Inherently robust)

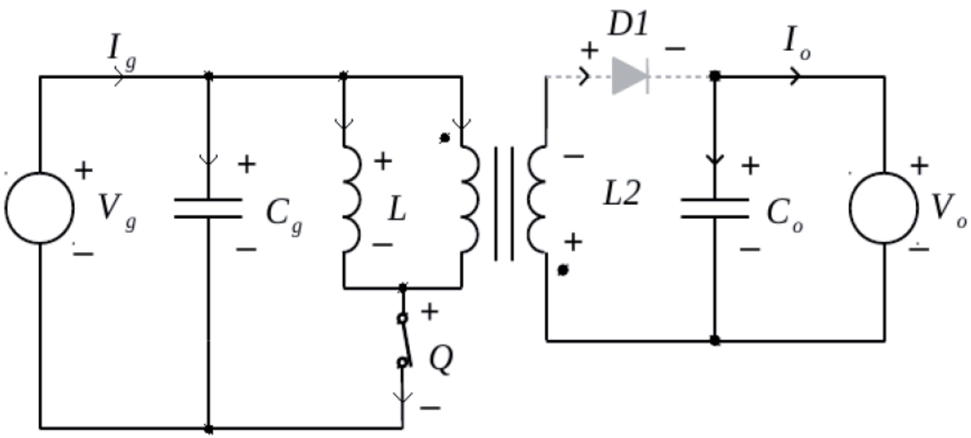
- Requires a high-side driver for switch-2
- Requires two switch elements
- The duty-cycle can never be more than 50%
- Excites only the core in one flux-direction

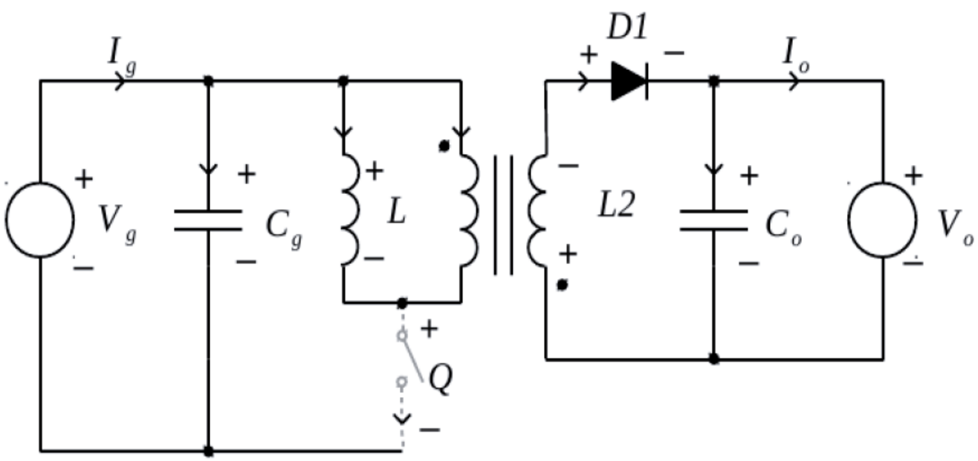

COFFEE
BREAK

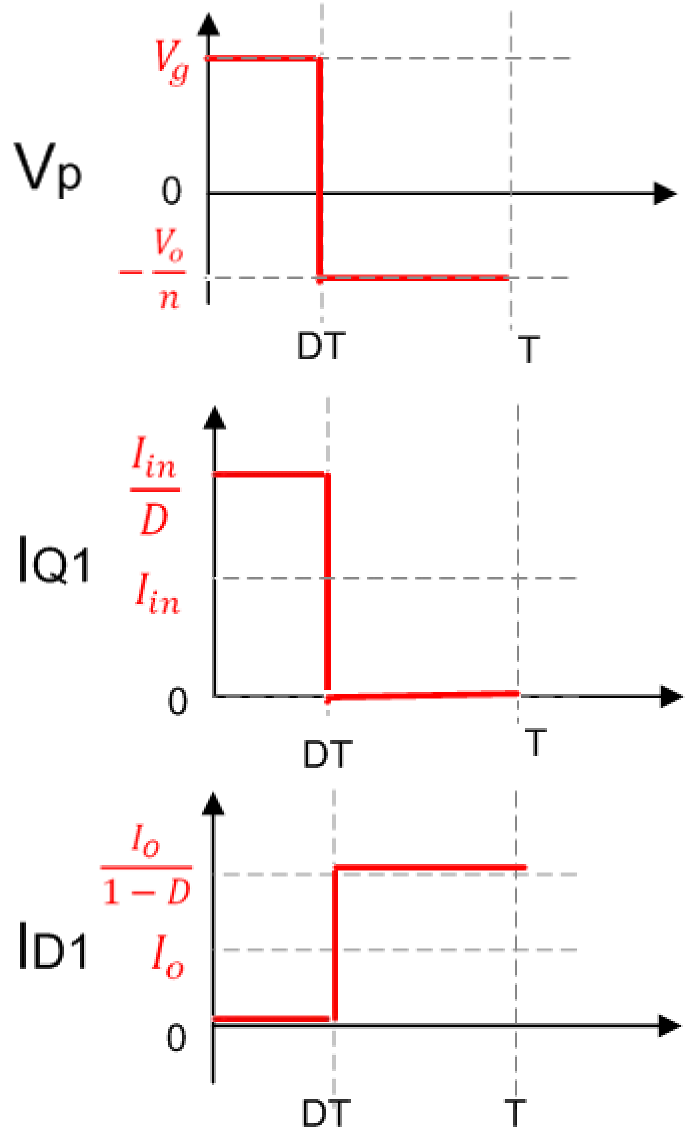
Flyback Converter



Flyback Converter





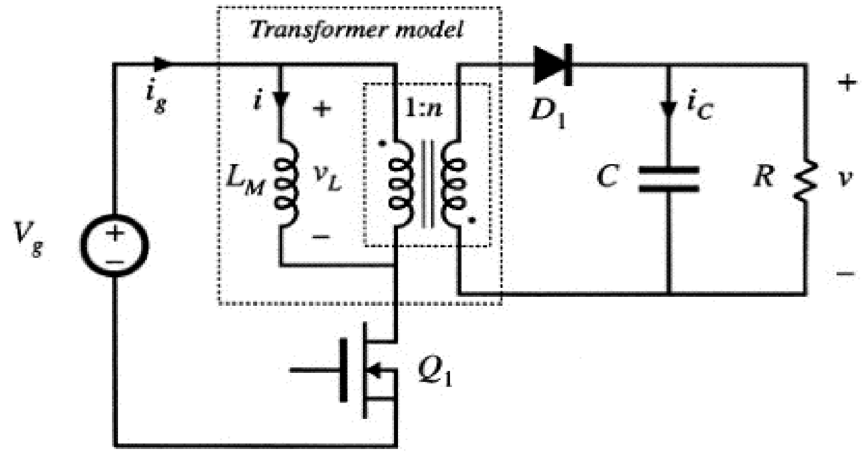


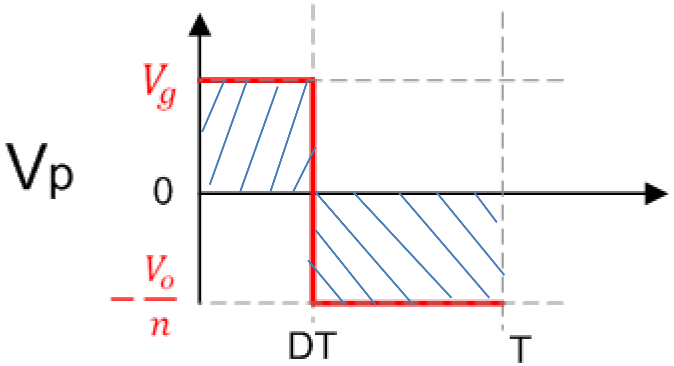
Flyback Converter

Transfer function:

$$V_g DT = \frac{V_o}{n}(1 - D)T$$

$$\frac{V_o}{V_g} = \frac{nD}{1 - D}$$





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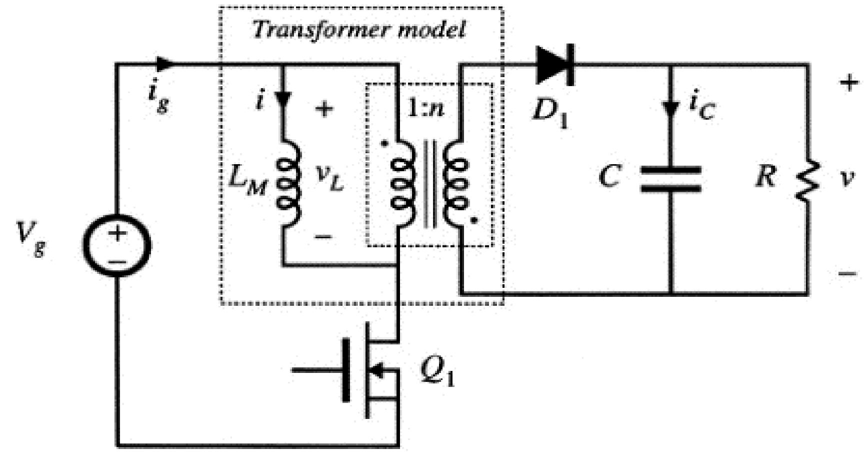
Group Discussion

Question 2:

This is Flyback converter. The input voltage is 48 V and the output voltage is 12 V. The transformer turns ratio is 4:1, and the converter is operated at 100k Hz and in CCM mode. The magnetizing inductance is 100uH. What is the max drain-source voltage stress of MOSFET, Vds, and what is the max voltage stress of the diode D1?



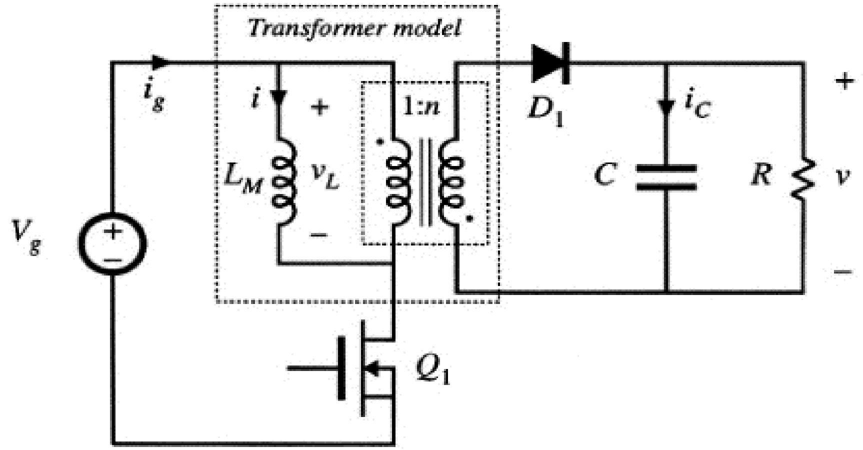
A. 12V
B. 24V
C. 48V
D. 96V

a. 12V
b. 24V
c. 48V
d. 96V

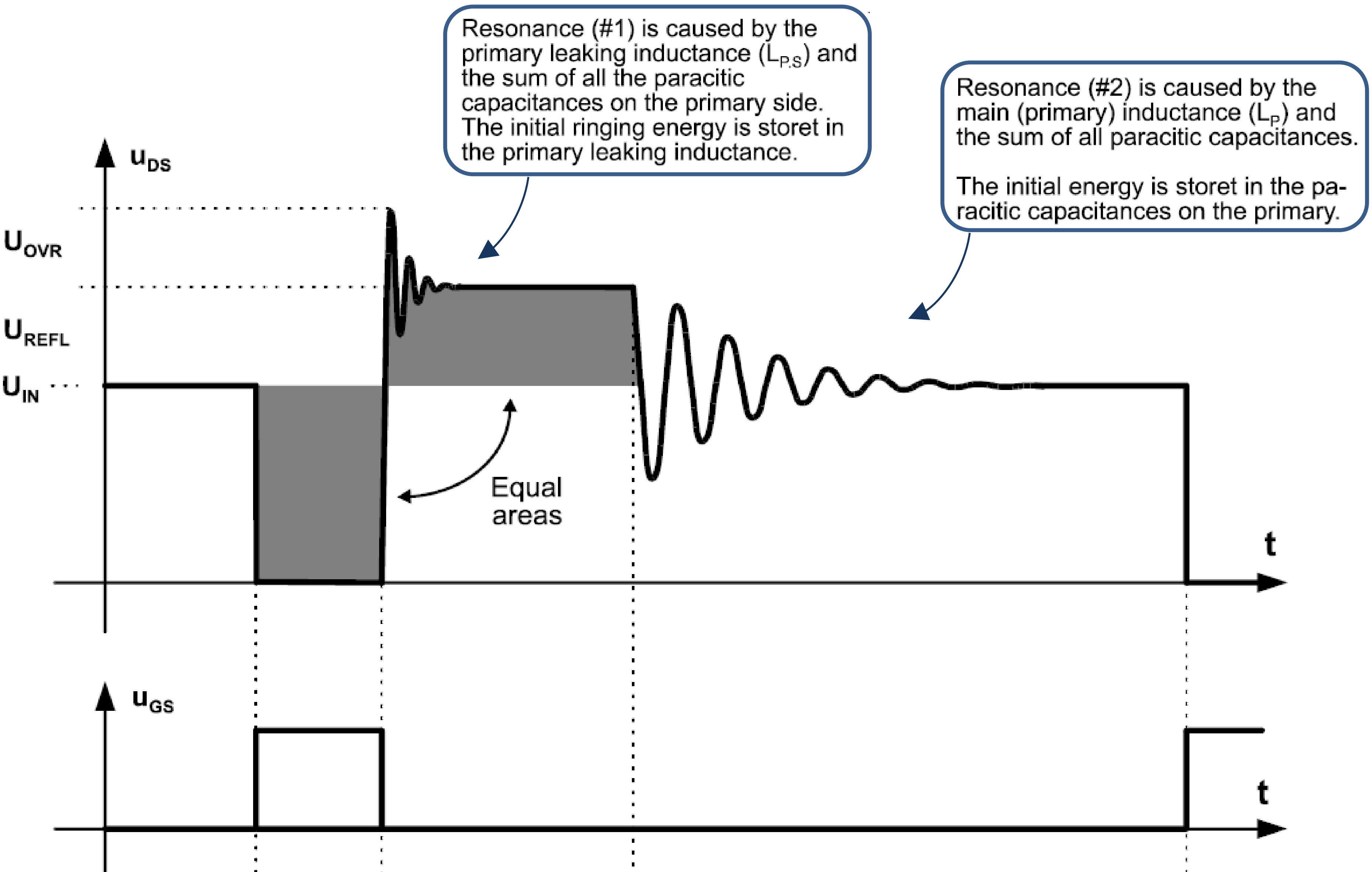
Flyback Converter

Disadvantages:

- ❑ higher component stress
- ❑ spike and ringing due to leakage inductance
- ❑ half of core material B-H loop is utilized

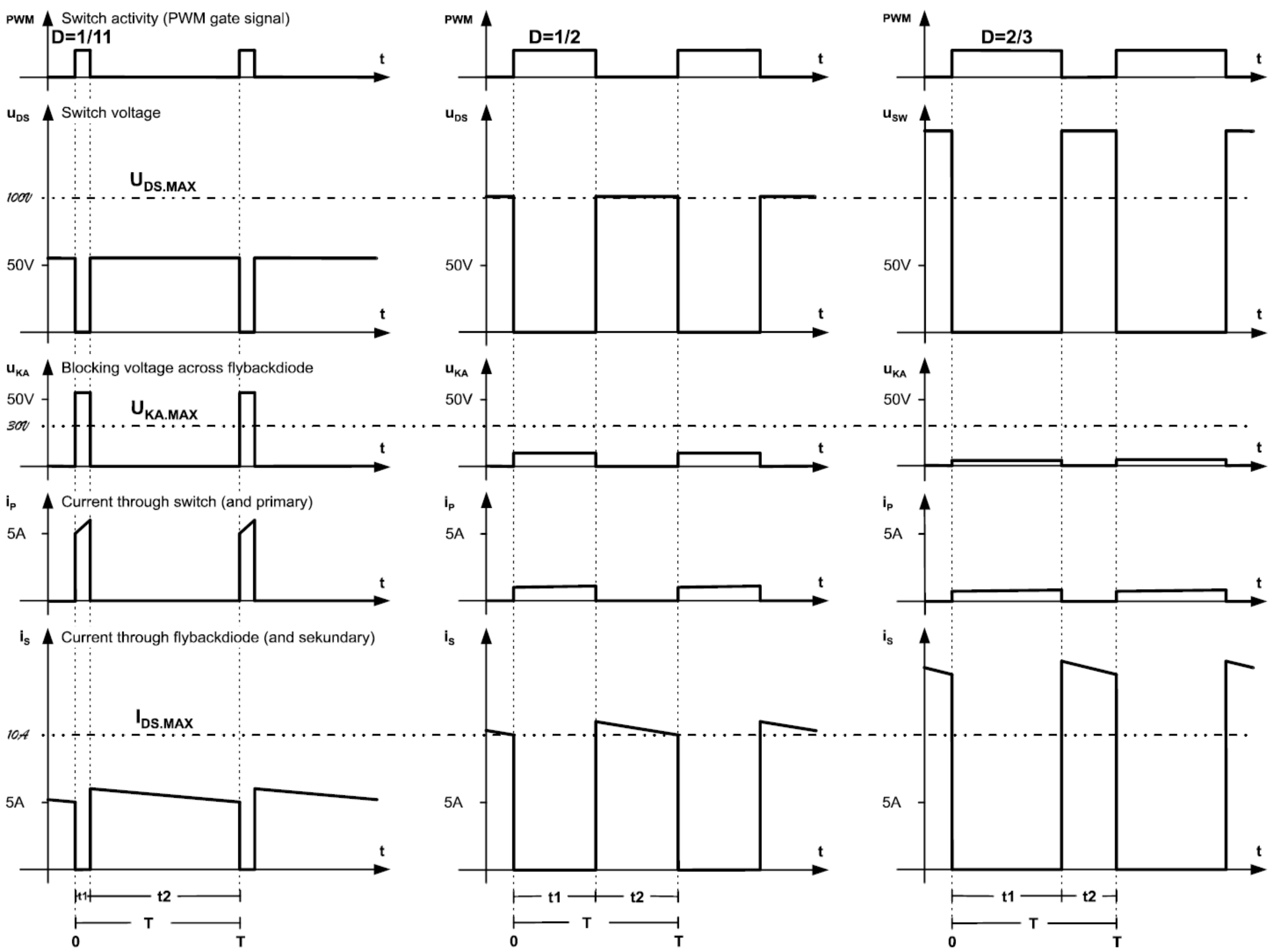


Signals in a “real” flyback converter



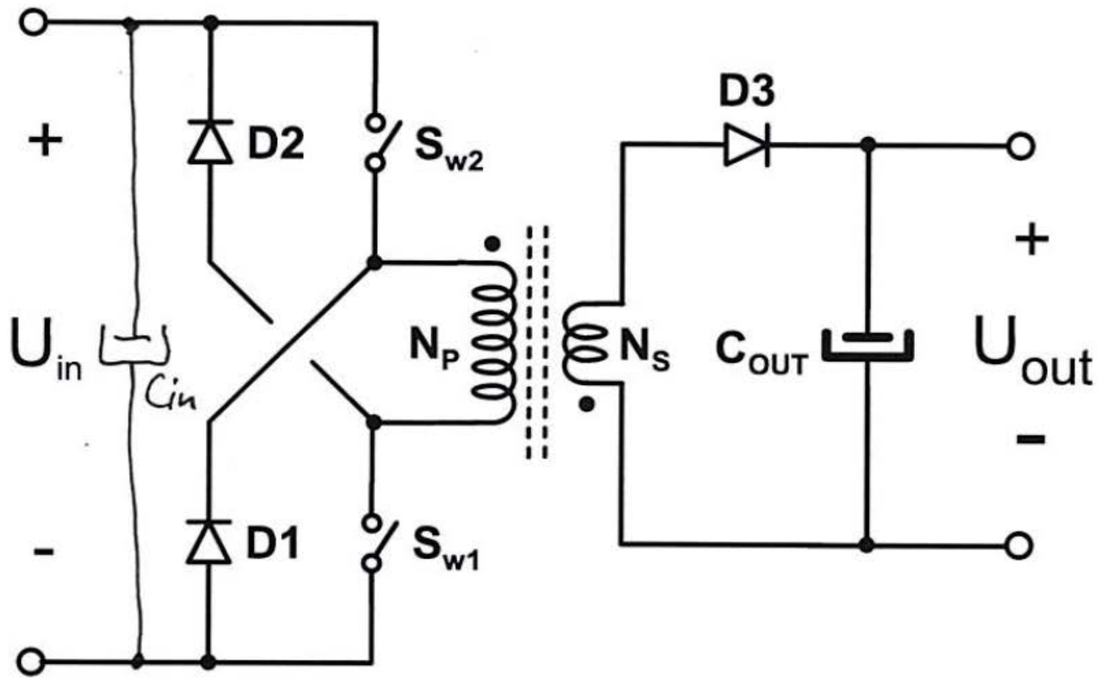
Design Considerations

	U_{IN}=50VDC, U_{OUT}=5VDC, I_{OUT}=5A, ΔI_S=1A, f_{sw}=50kHz	n=Ns/Np=1, D=1/11	n=Ns/Np=0.1, D=1/2	Ns/Np=0.05 D=2/3
Blocking voltage across switch	$U_{DS} = U_{OUT} \cdot \frac{1}{n} + U_{IN}$	55V	100V	150V
Blocking voltage across flyback diode	$U_{KA} = U_{IN} \cdot n + U_{OUT}$	55V	10V	7.5V
Peak current on primary	$I_{PP} = n \cdot I_{SP}$	6A	1.05A	0.775A
Peak current on secondary	$I_{SP} = \frac{I_O - \frac{1}{2} \cdot \Delta I_S (D-1)}{(1-D)}$	6A	10.5A	15.5A
Primary inductance	$L_P = n^2 \cdot L_S$	90.91uH	5mH	13.33mH
Comments:	$\left(L_S = \frac{U_{OUT} \cdot (1-D)T}{\Delta I_S} \right)$	+ smallest output capacitor -High blocking voltage diode --High loss in primary winding	+small input capacitor +low blocking voltage diode - High output capacitor	+ smallest input capacitor +lowest blocking voltage diode -highest output capacitor -high blocking voltage MOSFET



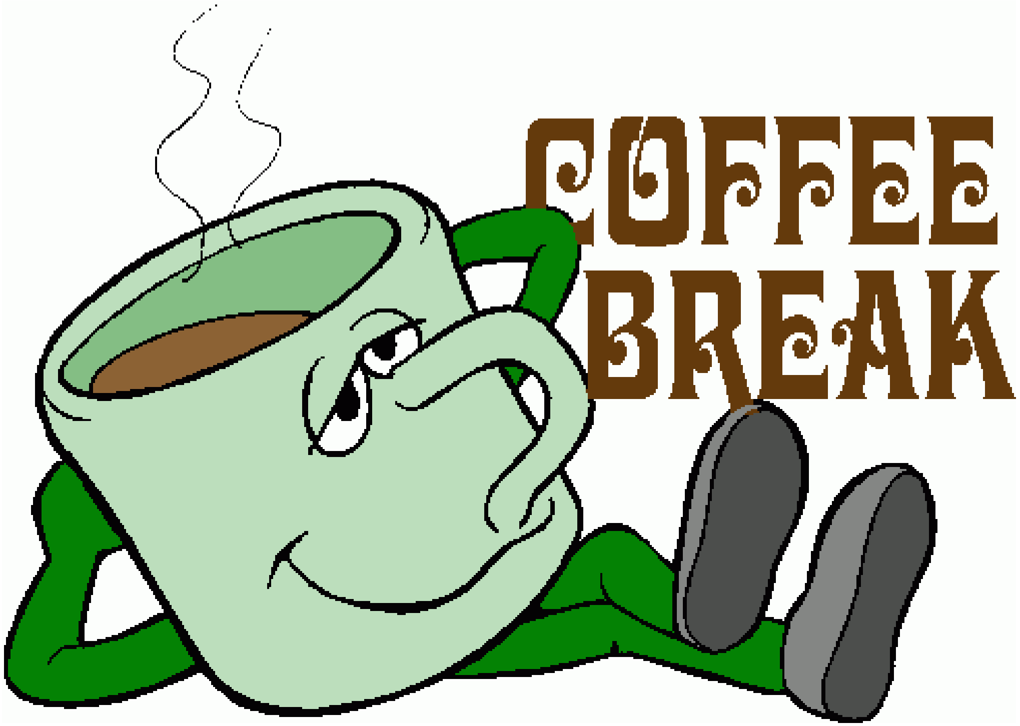
PWM
Switch activity (PWM gate signal)
D=1/11
D=1/2
D=2/3
t
u_DS
Switch voltage
u_SW
U_DS.MAX
100V
50V
u_KA
Blocking voltage across flybackdiode
U_KA.MAX
30V
i_P
Current through switch (and primary)
5A
i_S
Current through flybackdiode (and sekundary)
I_DS.MAX
10A
t1
t2
T
0

Two-Switch Flyback Converter

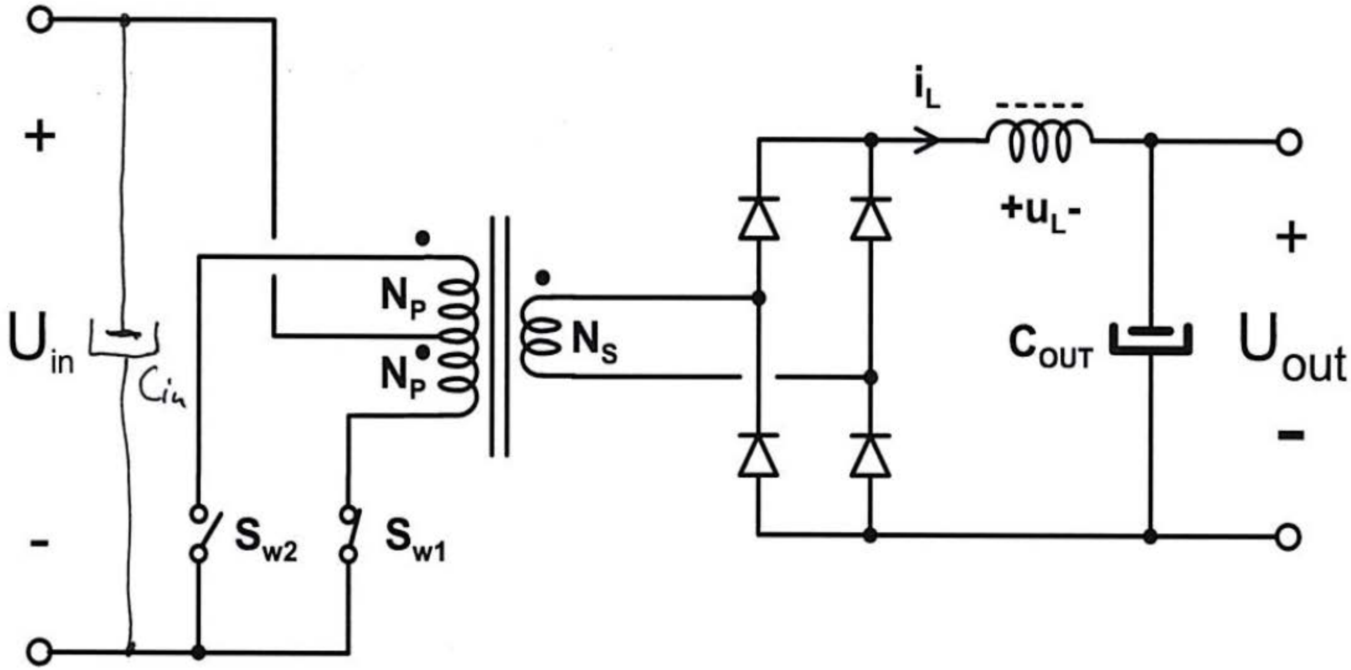


+ The maximum switch blocking voltage is equal to U_{IN} (clamped!)
+ Snubber is regenerative (For the primary leaking inductance)
+ Very robust (Inherently robust)

- Requires a high-side driver for switch-2
- Requires two switch elements
- The duty-cycle can never be more than 50%
- Excites only the core in one flux-direction


COFFEE
BREAK

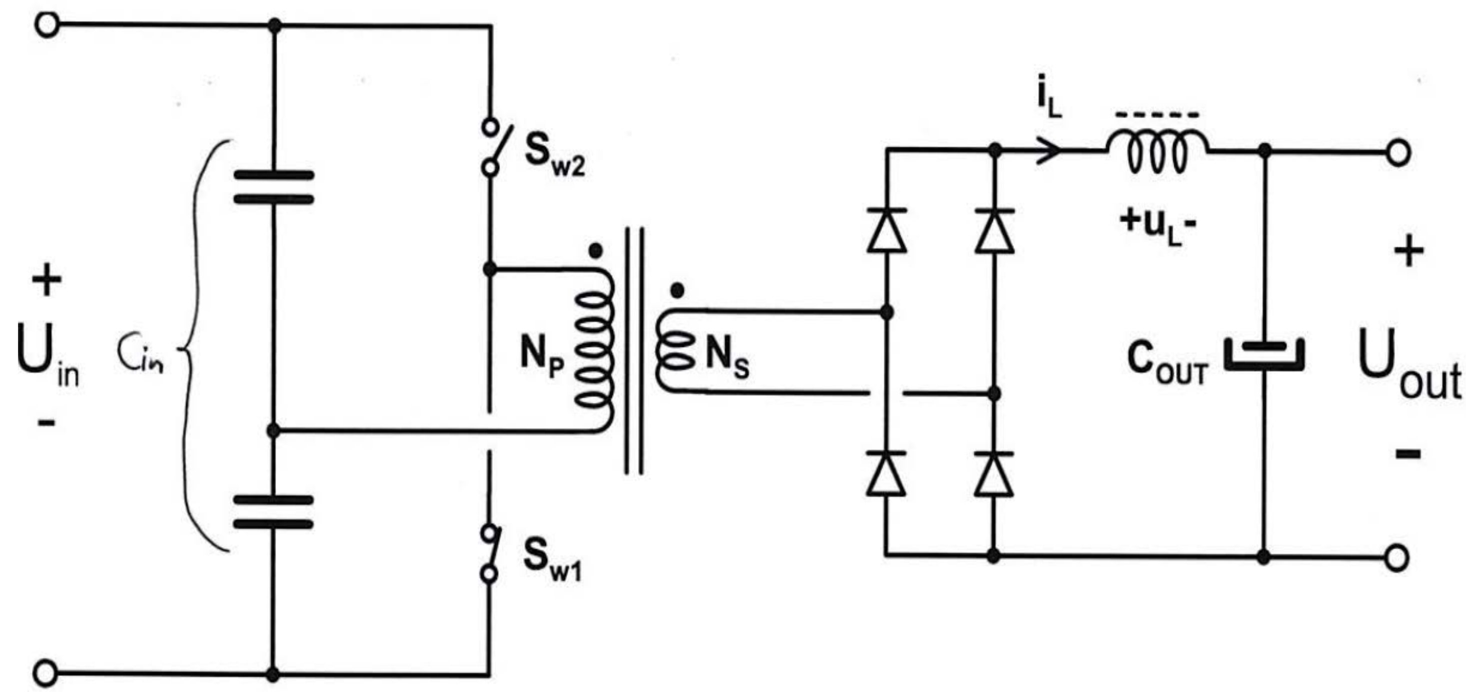
Push-Pull Converter



+ Does not require any high-side driver for switch-2
+ Theoretically the duty-cycle can be 100%
+ Excites the core in both flux-directions

- The switch blocking voltage is at least equal to $2xU_{IN}$, (not well controlled!)
- Requires a split primary (or two equal primary windings)
- Requires two switch elements
- Diode conduction losses is comparatively high at low output voltages

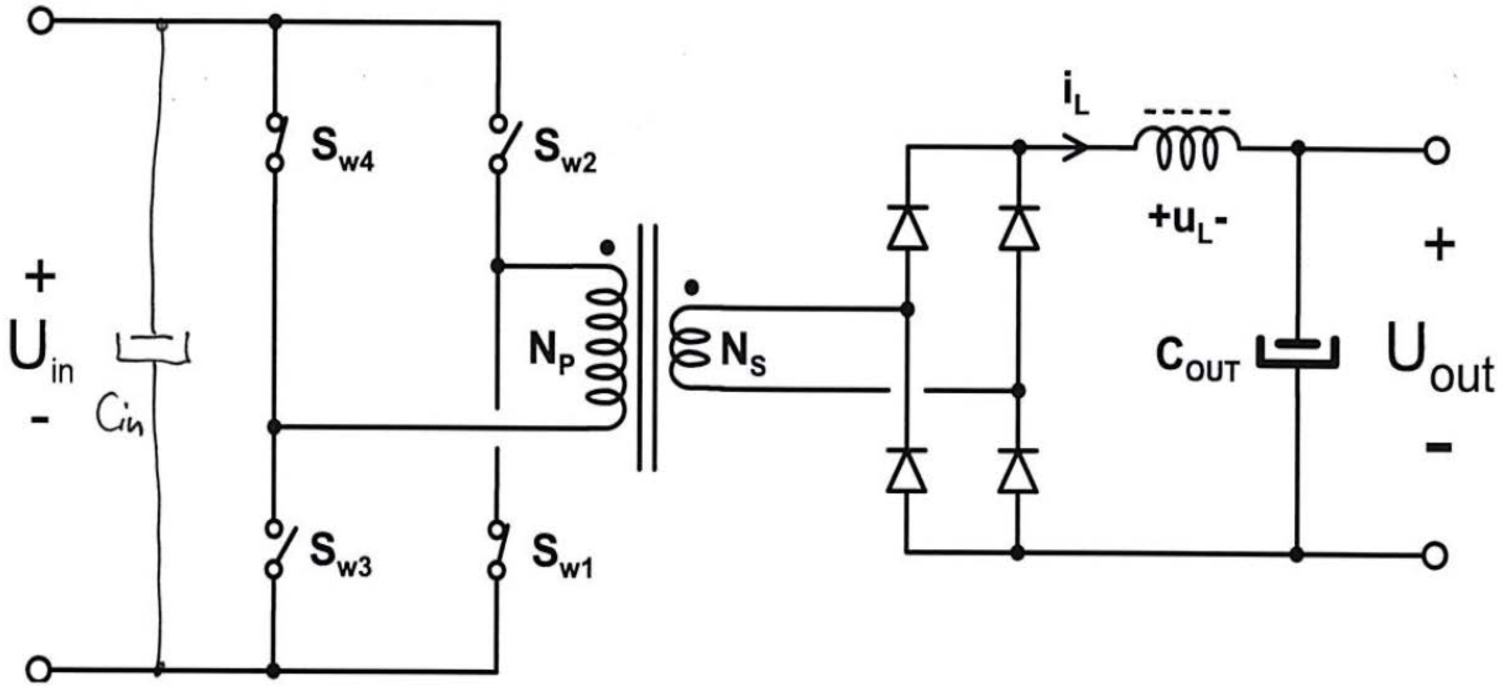
Half-bridge Converter



+ The maximum switch blocking voltage is equal to U_{IN} (clamped by FET BD.)
+ Theoretically the duty-cycle can be 100%
+ Excites the core in both flux-directions
+ Does not require at split primary

- Requires a high-side driver for switch-2
- Requires two switch elements
- Diode conduction losses is comparatively high at low output voltages

Full-bridge Buck Converter

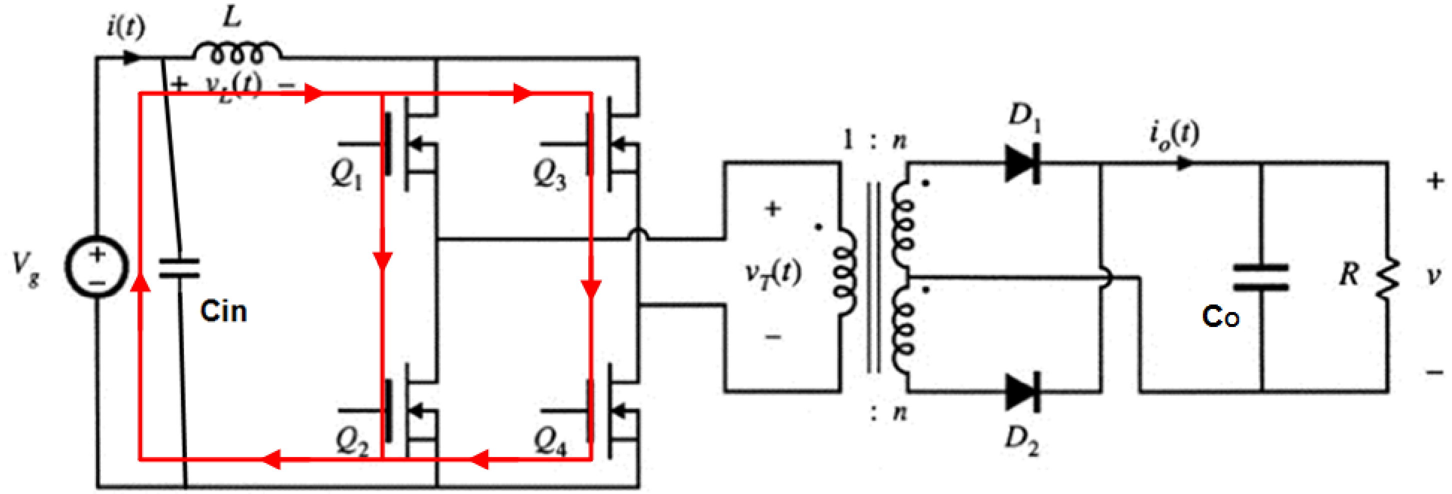


+ The maximum switch blocking voltage is equal to U_{IN} (clamped by FET BD.)
+ Theoretically the duty-cycle can be 100%
+ Excites the core in both flux-directions
+ Does not require a split primary

- Requires a high-side driver for switch-2,4
- Requires four switch elements
- Diode conduction losses is comparatively high at low output voltages

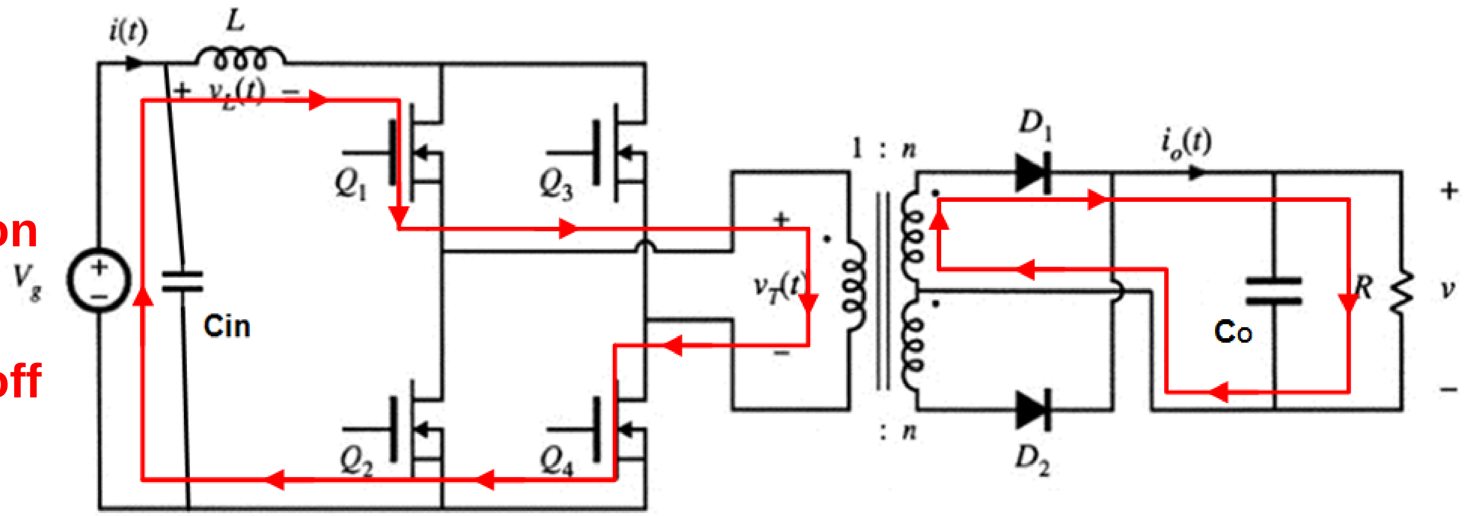
Full-bridge Boost Converter

All turn on



Q1,Q4 turn on

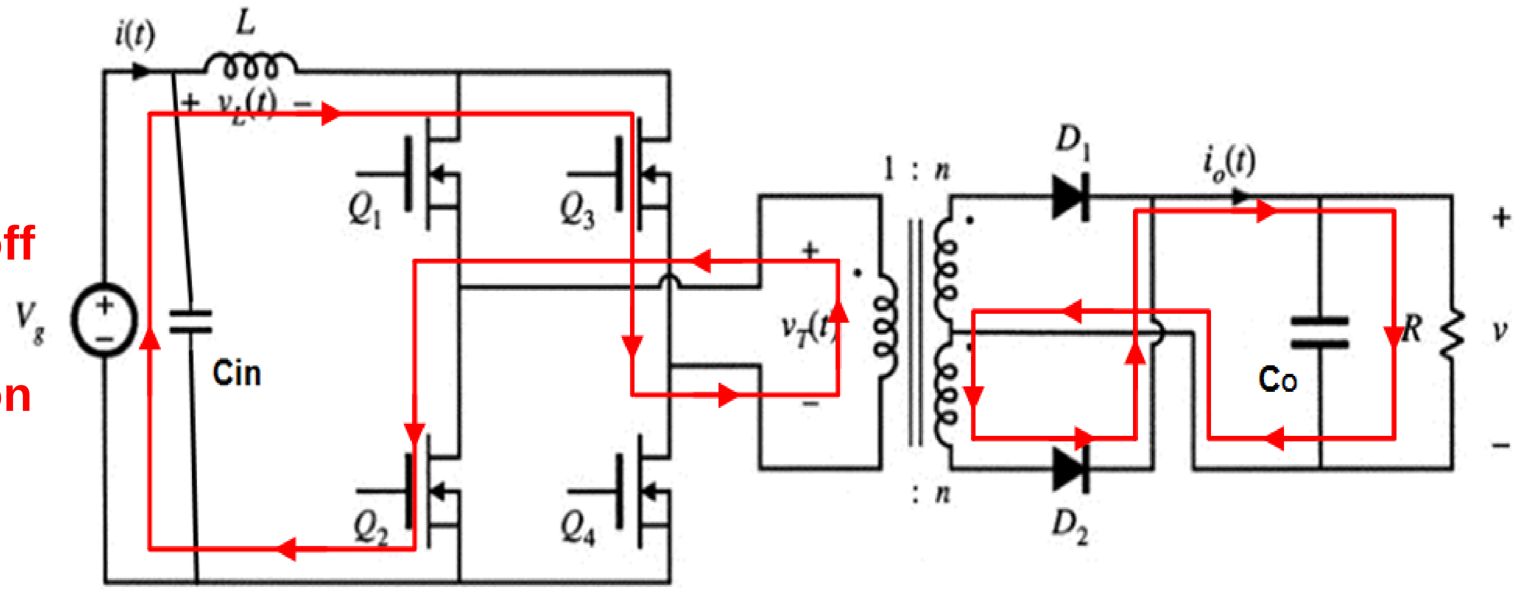
Q2,Q3 turn off



Full-bridge Boost Converter

Q1,Q4 turn off

Q2,Q3 turn on



Please refer to **Chapter 6** in the text book "fundamentals of power electronics"