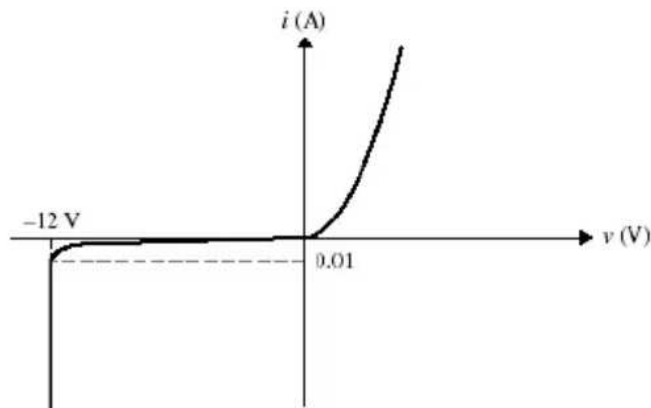
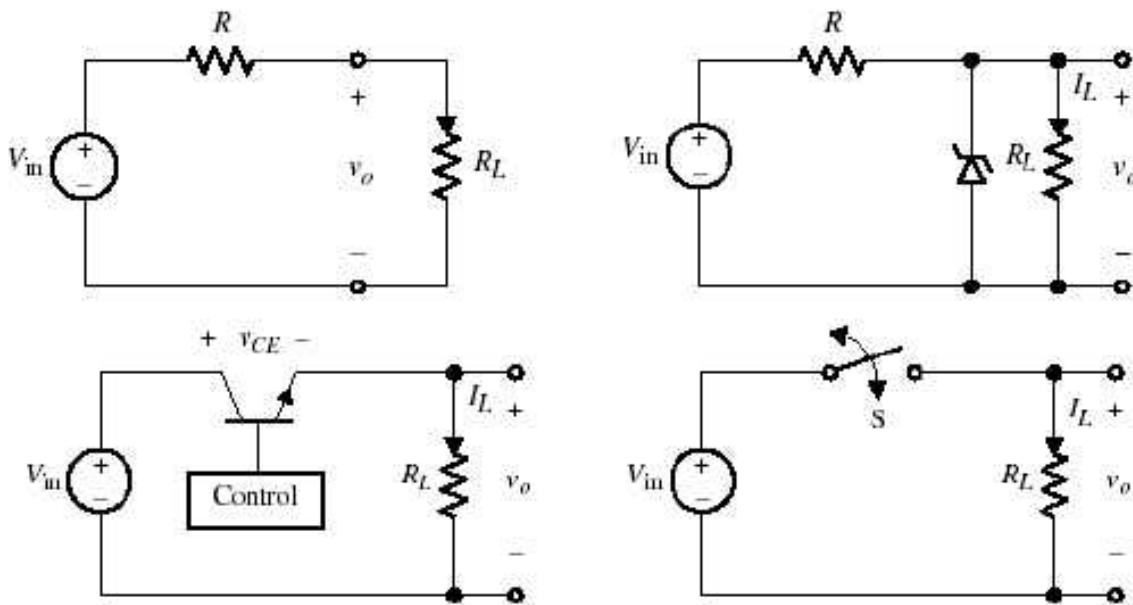


Series 2

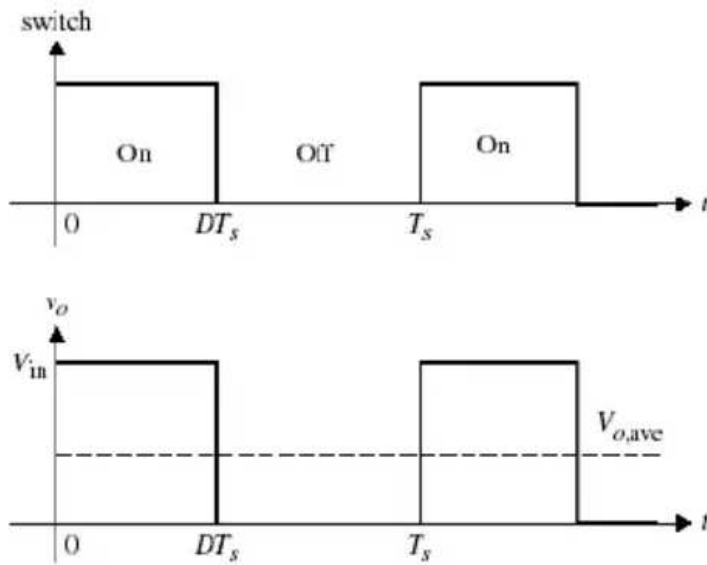
Switching mechanism in static converters

Exercise 1

The purpose of this exercise is to investigate the efficiency of four different power electronic circuits whose function is to take power from a 24 V dc source and deliver a 12 V dc output to a 6 Ω resistive load. In other words, the task of these circuits is to serve as dc transformers with a ratio of 2:1. The four circuits are shown in Fig. 2.1(a), (b), (c), and (d), representing a voltage divider circuit, zener regulator, transistor linear regulator, and switching circuit, respectively. The objective is to calculate the efficiency of these four power electronic circuits.



(e)



(f)

Exercise 2

A rectifier diode whose technical characteristics (Datasheet) are given in the figure below. Determine the value of the maximum losses linked to this diode?

FORWARD CONDUCTION					
PARAMETER	SYMBOL	TEST CONDITIONS		VALUES	UNITS
Maximum average forward current at case temperature	$I_{F(AV)}$	180° conduction, half sine wave		25	A
				120	°C
Maximum RMS forward current	$I_{F(RMS)}$			40	A
Maximum peak, one-cycle forward, non-repetitive surge current	I_{FSM}	t = 10 ms	No voltage reappplied	Sinusoidal half wave, initial $T_J = T_J$ maximum	A
		t = 8.3 ms			
		t = 10 ms	100 % V_{RRM} reappplied		
		t = 8.3 ms			
Maximum I^2t for fusing	I^2t	t = 10 ms	No voltage reappplied	636	A^2s
		t = 8.3 ms			
		t = 10 ms	100 % V_{RRM} reappplied	450	
		t = 8.3 ms		410	
Maximum $I^2\sqrt{t}$ for fusing	$I^2\sqrt{t}$	t = 0.1 to 10 ms, no voltage reappplied		6360	$A^2\sqrt{s}$
Low level value of threshold voltage	$V_{F(TO)1}$	$(16.7 \% \times \pi \times I_{F(AV)} < I < \pi \times I_{F(AV)})$, $T_J = T_J$ maximum		0.80	V
High level value of threshold voltage	$V_{F(TO)2}$	$(I > \pi \times I_{F(AV)})$, $T_J = T_J$ maximum		0.90	
Low level value of forward slope resistance	r_{f1}	$(16.7 \% \times \pi \times I_{F(AV)} < I < \pi \times I_{F(AV)})$, $T_J = T_J$ maximum		6.80	mΩ
High level value of forward slope resistance	r_{f2}	$(I > \pi \times I_{F(AV)})$, $T_J = T_J$ maximum		5.70	
Maximum forward voltage drop	V_{FM}	$I_{pk} = 78$ A, $T_J = 25$ °C, $t_p = 400$ μs rectangular wave		1.30	V

Exercise 3

The two figures below present the datasheets of an IGBT and a MOSFET.

- Locate the IGBT and MOSFET parameters?
- Calculate the conduction losses associated with these two transistors?

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$g_{fs}^{(1)}$	Forward transconductance	$V_{DS} = 15\text{ V}, I_D = 2.6\text{ A}$	-	5	-	S
C_{iss}	Input capacitance	$V_{DS} = 25\text{ V}, f = 1\text{ MHz}, V_{GS} = 0$	-	1138	-	pF
C_{oss}	Output capacitance		122	-	pF	
C_{rss}	Reverse transfer capacitance		25	-	pF	
$C_{oss\text{eq}}$	Equivalent output capacitance	$V_{DS} = 0, V_{GS} = 0\text{ to }640\text{ V}$	-	50	-	pF
$t_{d(on)}$	Turn-on delay time	$V_{DD} = 400\text{ V}, I_D = 2.6\text{ A}, R_G = 4.7\ \Omega, V_{GS} = 10\text{ V}$ (see Figure 17)	-	20	-	ns
t_r	Rise time		12	-	ns	
$t_{f(off)}$	Turn-off delay time		45	-	ns	
t_f	Fall time		20	-	ns	
Q_g	Total gate charge	$V_{DD} = 640\text{ V}, I_D = 5.2\text{ A}, V_{GS} = 10\text{ V}$ (see Figure 18)	-	40	56	nC
Q_{gs}	Gate-source charge		7	-	nC	
Q_{gd}	Gate-drain charge		21	-	nC	
$t_{r(volt)}$	Off-voltage rise time	$V_{DD} = 640\text{ V}, I_D = 5.2\text{ A}, R_G = 4.7\ \Omega, V_{GS} = 10\text{ V}$ (see Figure 17)	-	12	-	ns
t_f	Fall time		10	-	ns	
t_c	Cross-over time		20	-	ns	

Type	V_{DSS} (@Tjmax)	$R_{DS(on)}$	I_D
STP7NK80Z	800V	< 1.8Ω	5.2A
STP7NK80ZFP	800V	< 1.8Ω	5.2A
STB7NK80Z	800V	< 1.8Ω	5.2A
STB7NK80Z-1	800V	< 1.8Ω	5.2A

1

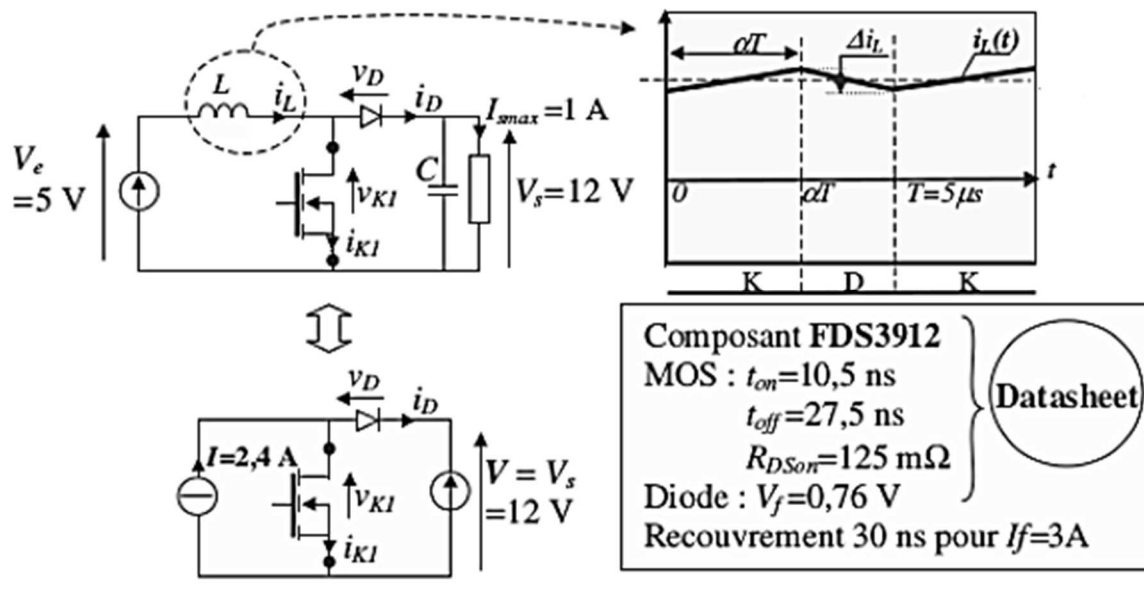
$t_{d(on)}$	Turn-On Delay Time	-	25	-	ns	Tj = 25°C Ic = 12A, Vcc = 480V VGE = 15V, RG = 23Ω Energy losses include "tail" See Fig. 9, 10, 13, 14
t_r	Rise Time	-	16	-		
$t_{d(off)}$	Turn-Off Delay Time	-	99	150		
t_f	Fall Time	-	67	100		
E_{on}	Turn-On Switching Loss	-	0.13	-	mJ	
E_{off}	Turn-Off Switching Loss	-	0.13	-		
E_{ts}	Total Switching Loss	-	0.26	0.35		

$V_{CES} = 600\text{V}$
 $V_{CE(on)\text{max}} = 2.70\text{V}$
@VGE = 15V, Ic = 12A

2

Exercise 4

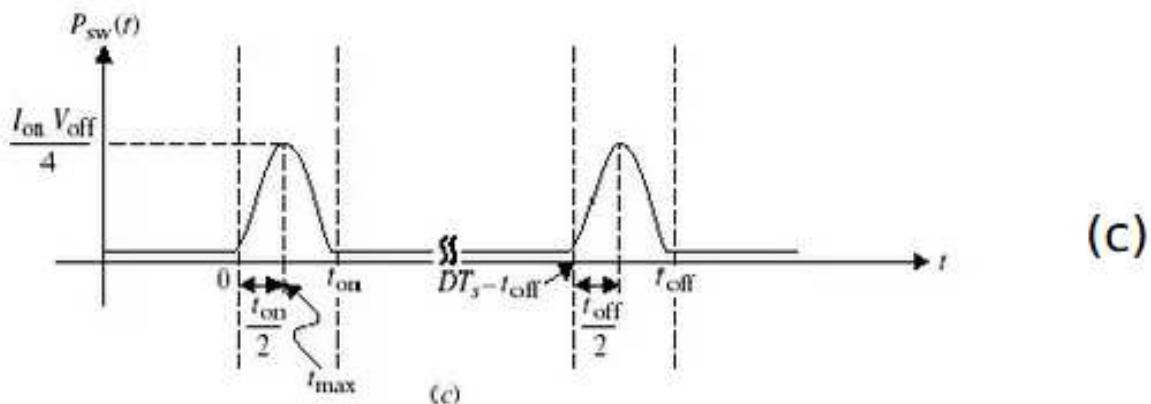
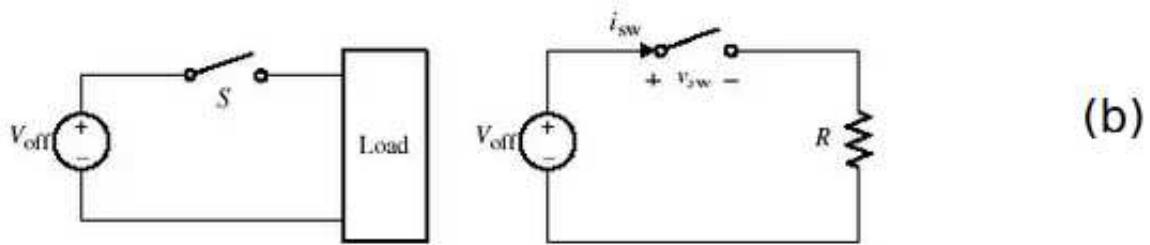
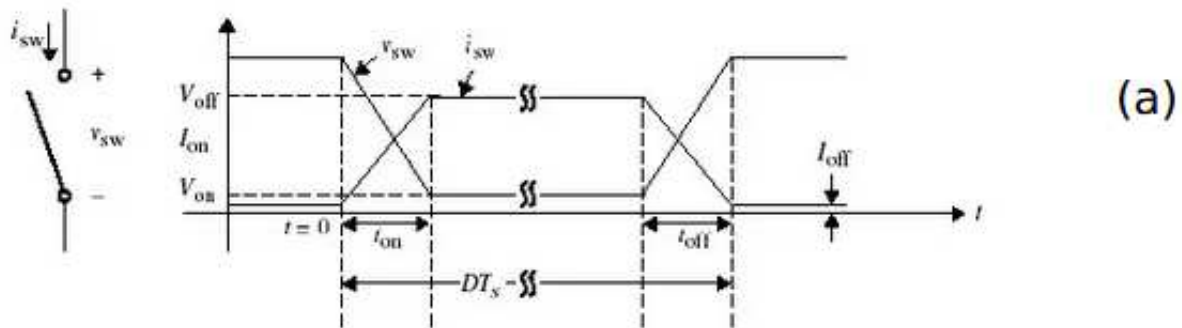
Calculate the losses of the switching cell of a small step-up chopper (BOOST) used within a power supply integrated into a portable electrical appliance. This small converter works at a switching frequency of 200 kHz and at a power of 12 W since it converts the input voltage of 5 V into a higher voltage of 12 V providing a maximum of 1 A. The figure below represents the simplified electrical diagram of the device as well as the shape of the current passing through the inductor. The figure also lists the documentation elements associated with the components.



Exercise 5

Consider a linear approximation of Fig (a) as shown in Fig (b) with $D=1$ (this assumes that T_s is on the time).

- Give a possible circuit implementation using a power switch whose switching wave forms are as shown in Fig (b).
- Drive the expressions for the instantaneous switching and conduction power losses and sketch them.
- Determine the total average power dissipated in the circuit during one switching period.
- Find the maximum power.



Exercise 6

Given that $v_s(t)$ is a triangular waveform, assume the switch is ideal and initially off. Control works in such a way that it toggles every time $v_s(t)$ crosses zero. Use $V_p = 12\text{ V}$, $R = 10\Omega$ and $T = 1\text{ ms}$.

- Sketch the waveforms for i_s and V_o .
- Calculate the average and rms values for the output voltage.
- Calculate the average input power, average output power and efficiency.
- Repeat parts (a)-(c) by assuming $T=1\mu s$.
- Repeat parts (a)-(c) by assuming the switch has 1 V voltage drop when closed.

