ECE 404-TD / 504-TD

ST: T&D APPLICATIONS OF VOLTAGE SOURCE CONVERTERS

SESSION no. 8

ECE 404 / 504
T&D Applications of VSC
HW2 Solution

$m\Omega := 10^{-3}\cdot\Omega$

Problem 2

$V_i := 12\cdot V \quad V_o := 5\cdot V \quad P_o := 100\cdot W \quad d_A := 0.50 \quad f_s := 100\cdot kHz \quad t_r := 100\cdot ns \quad t_f := 100\cdot ns$

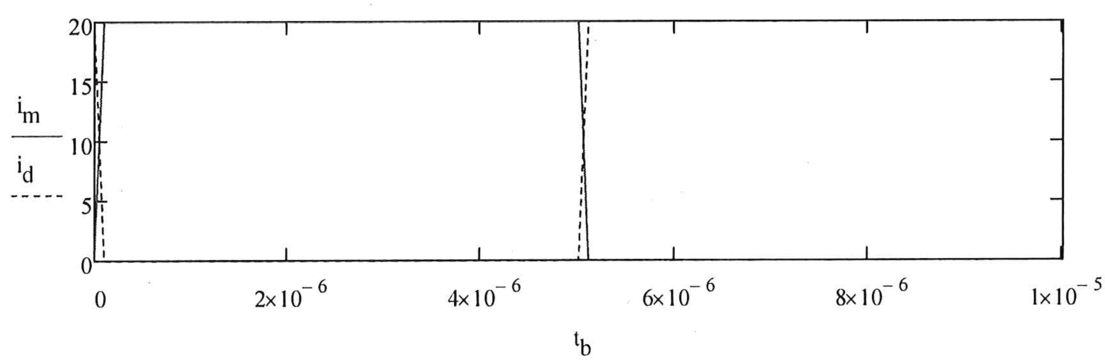
$I_o := \frac{P_o}{V_o} = 20\,A \quad T_s := \frac{1}{f_s} = 10\,\mu s \quad V_d := 1.00\cdot V \quad R_{ds\_on} := 50\cdot m\Omega \quad t_{vf} := 0\cdot s \quad t_{vr} := 0\cdot s$

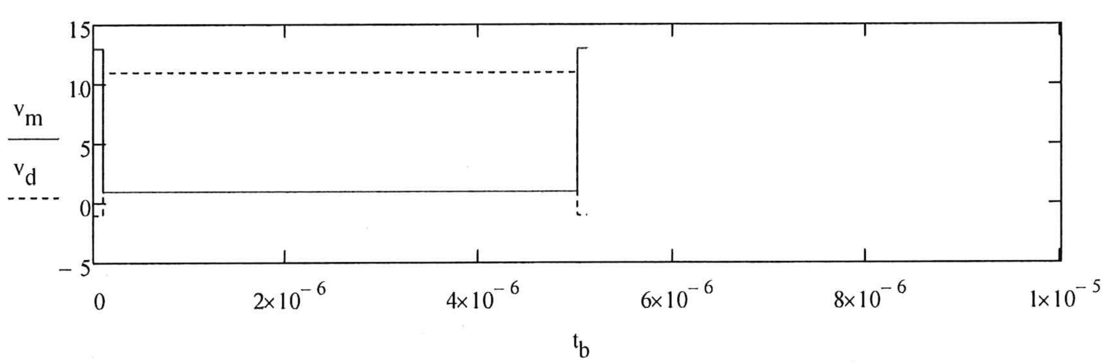
The problem is overspecified. The duty cycle is correct, but can be calculated from the other information.

$$V_a := d_A\cdot\left(V_i - I_o\cdot R_{ds\_on}\right) + \left(1 - d_A\right)\cdot\left(-V_d\right) = 5\,V$$

Draw the waveforms.

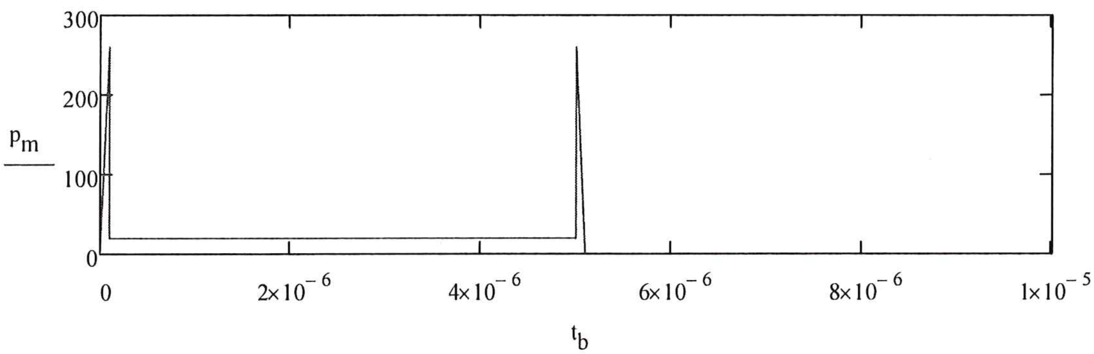
$$i_m := \begin{pmatrix} 0\cdot A \\ I_o \\ I_o \\ I_o \\ I_o \\ 0\cdot A \end{pmatrix} \quad i_d := \begin{pmatrix} I_o \\ 0\cdot A \\ 0\cdot A \\ 0\cdot A \\ 0\cdot A \\ I_o \end{pmatrix} \quad v_m := \begin{pmatrix} V_i + V_d \\ V_i + V_d \\ I_o\cdot R_{ds\_on} \\ I_o\cdot R_{ds\_on} \\ V_i + V_d \\ V_i + V_d \end{pmatrix} \quad v_d := \begin{pmatrix} -V_d \\ -V_d \\ V_i - I_o\cdot R_{ds\_on} \\ V_i - I_o\cdot R_{ds\_on} \\ -V_d \\ -V_d \end{pmatrix} \quad t_b := \begin{pmatrix} 0\cdot s \\ t_r \\ t_r + t_{vf} \\ d_A\cdot T_s \\ d_A\cdot T_s + t_{vr} \\ d_A\cdot T_s + t_f + t_{vr} \end{pmatrix}$$





$$p_m := \begin{pmatrix} v_{m_0} \cdot i_{m_0} \\ v_{m_1} \cdot i_{m_1} \\ v_{m_2} \cdot i_{m_2} \\ v_{m_3} \cdot i_{m_3} \\ v_{m_4} \cdot i_{m_4} \\ v_{m_5} \cdot i_{m_5} \end{pmatrix} = \begin{pmatrix} 0 \\ 260 \\ 20 \\ 20 \\ 260 \\ 0 \end{pmatrix} W$$

$$p_d := \begin{pmatrix} v_{d_0} \cdot i_{d_0} \\ v_{d_1} \cdot i_{d_1} \\ v_{d_2} \cdot i_{d_2} \\ v_{d_3} \cdot i_{d_3} \\ v_{d_4} \cdot i_{d_4} \\ v_{d_5} \cdot i_{d_5} \end{pmatrix} = \begin{pmatrix} -20 \\ 0 \\ 0 \\ 0 \\ 0 \\ -20 \end{pmatrix} W$$



$$P_d := (1 - d_A) \cdot V_d \cdot I_o = 10\ W$$

$$P_m := d_A \cdot I_o^{\,2} \cdot R_{ds\_on} + \frac{V_i \cdot I_o}{2} \cdot (t_r + t_f) \cdot f_s = 12.4\ W$$

Reference

$$d_A \cdot I_o^{\,2} \cdot R_{ds\_on} = 10\ W$$

$$\frac{V_i \cdot I_o}{2} \cdot (t_r + t_f) \cdot f_s = 2.4\ W$$

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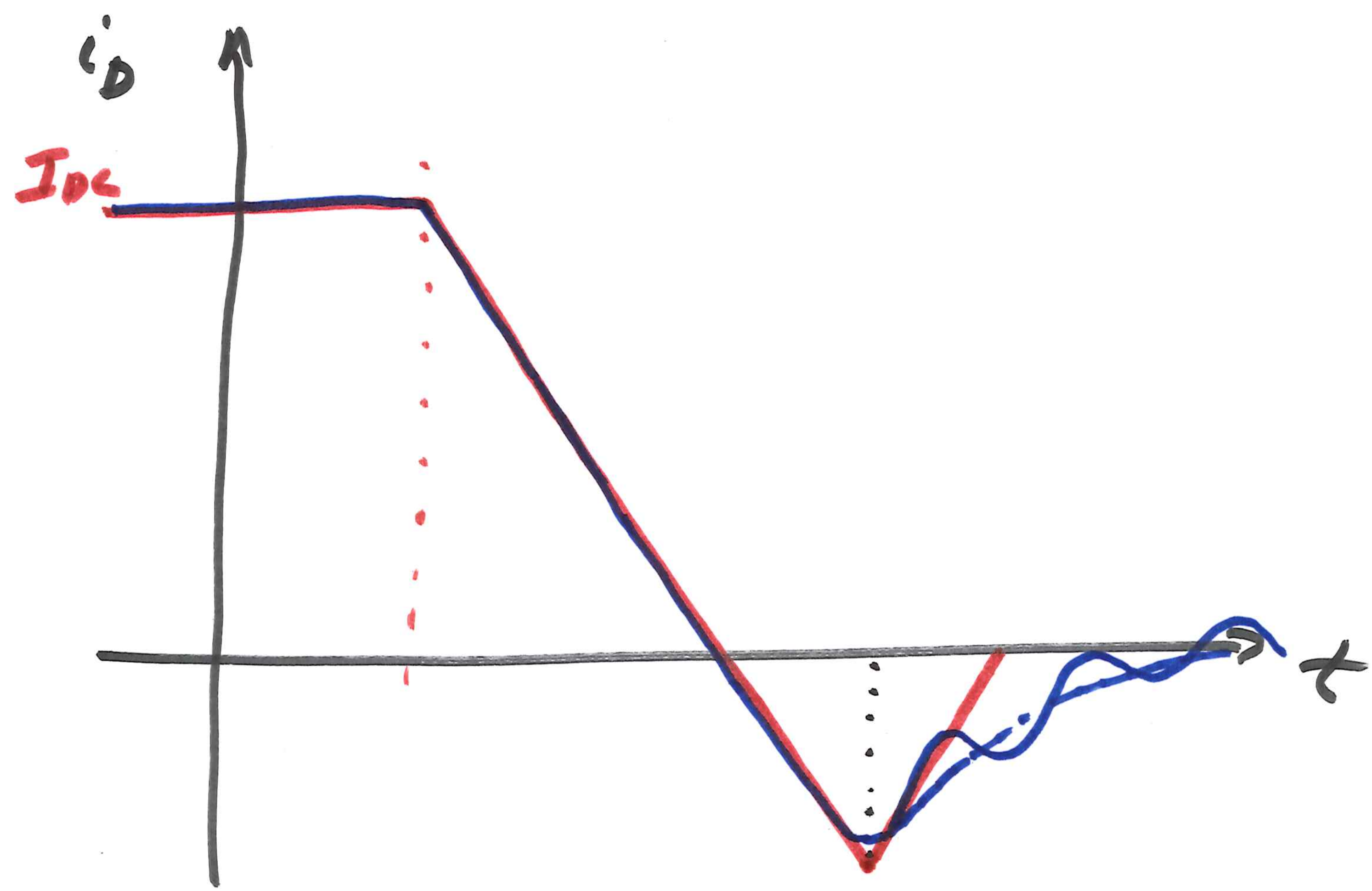

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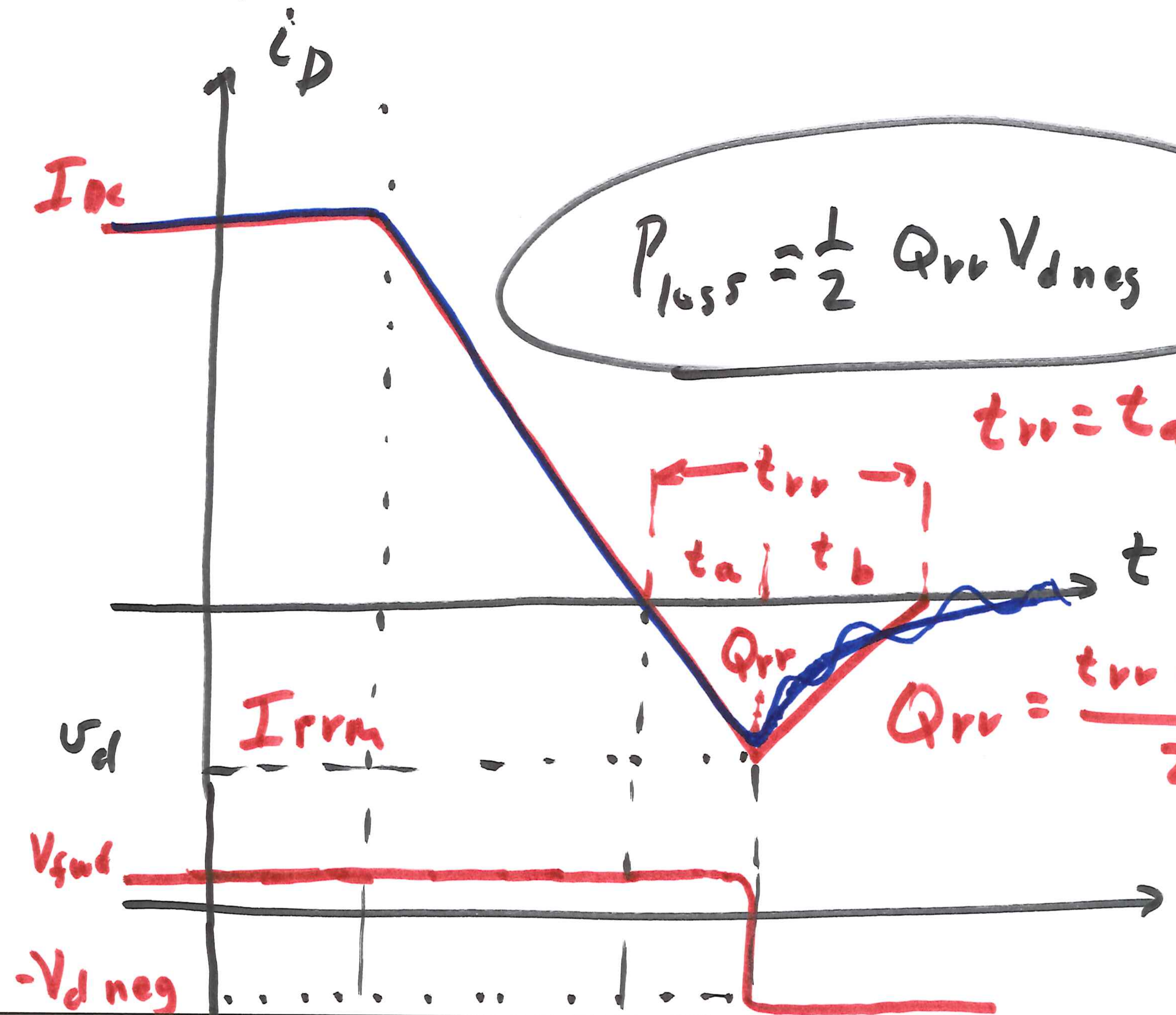
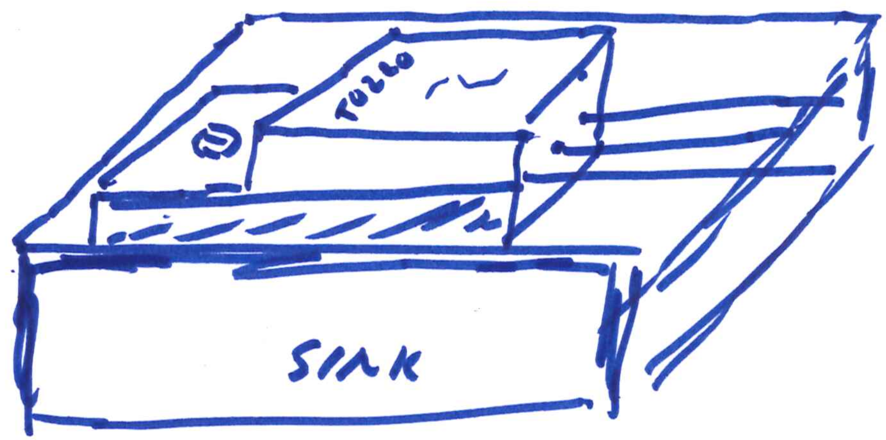


$$P_{loss} = \frac{1}{2} Q_{rr} V_{d\,neg} f_s$$

$$t_{rr} = t_a + t_b$$

$$Q_{rr} = \frac{t_{rr} I_{rrm}}{2}$$


SINK

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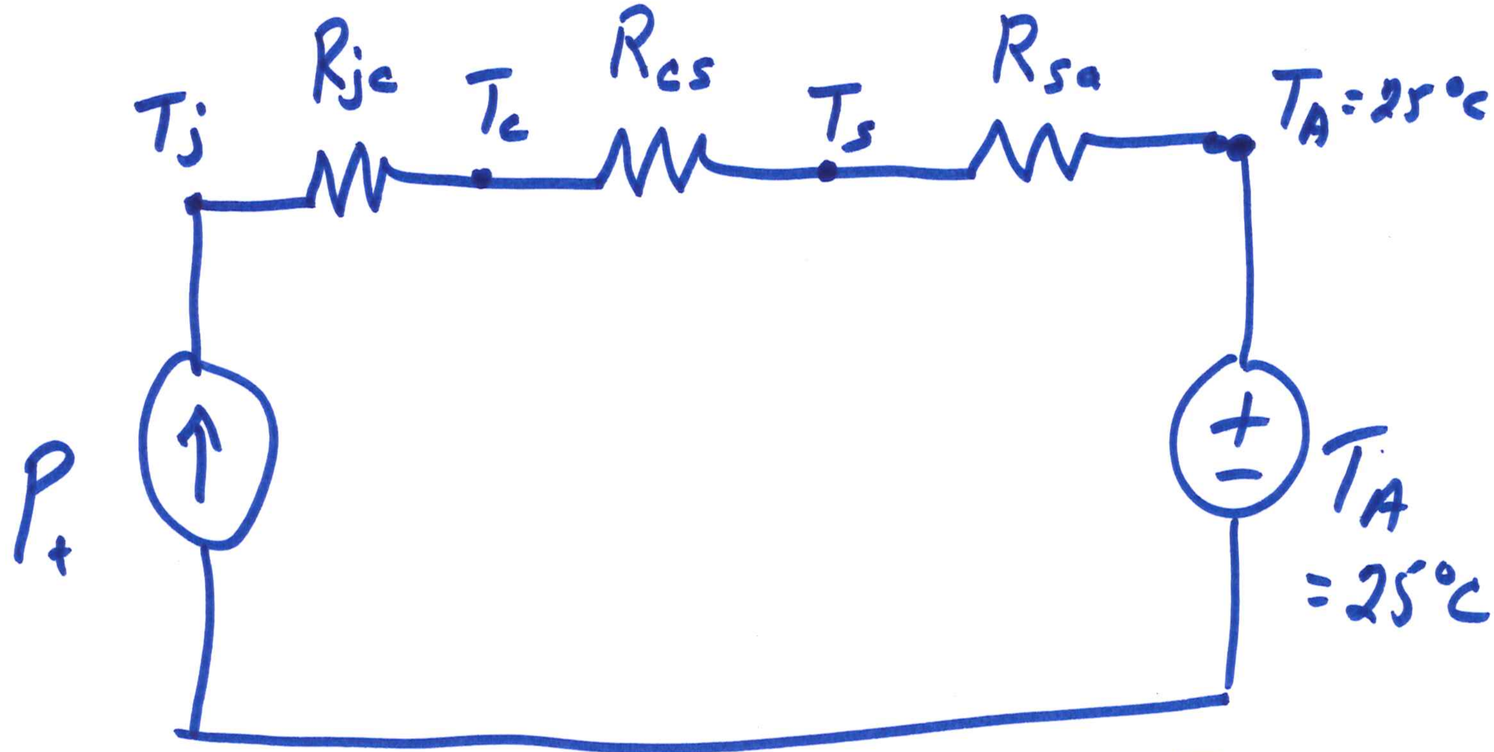
$$P_t \cdot R_t = T$$

$$IR = V$$



$$T_j = P_t\left(R_{jc} + R_{cs} + R_{sa}\right) + T_A$$

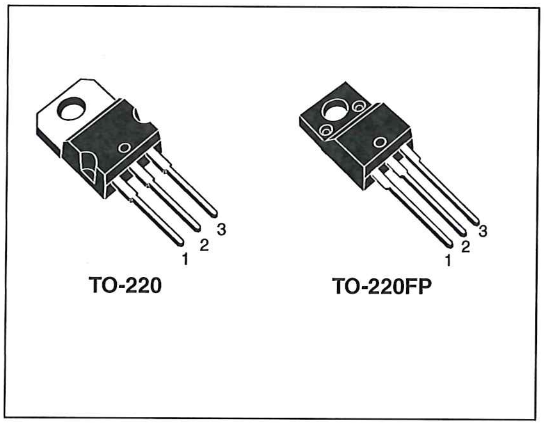
IRF630
IRF630FP

N-channel 200V - 0.35Ω - 9A TO-220/TO-220FP Mesh overlay™ II Power MOSFET

General features

Type	V_{DSS}	$R_{DS(on)}$	I_D
IRF630	200V	<0.40Ω	9A
IRF630FP	200V	<0.40Ω	9A

- Extremely high dv/dt capability
- Very low intrinsic capacitances
- Gate charge minimized



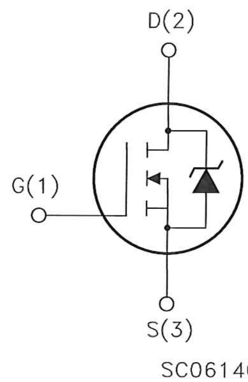
Description

This power MOSFET is designed using the company's consolidated strip layout-based MESH OVERLAY™ process. This technology matches and improves the performances compared with standard parts from various sources.

Applications

- Switching application

Internal schematic diagram



Order codes

Part number	Marking	Package	Packaging
IRF630	IRF630	TO-220	Tube
IRF630FP	IRF630FP	TO-220FP	Tube

Contents

1 Electrical ratings

Table 1. Absolute maximum ratings

Symbol	Parameter	Value		Unit
		TO-220	TO-220FP	
V_{DS}	Drain-source voltage (V_{GS} = 0)	200		V
V_{DGR}	Drain-gate voltage (R_{GS} = 20 kΩ)	200		V
V_{GS}	Gate-source voltage	± 20		V
I_D	Drain current (continuous) at T_C = 25°C	9	9(1)	A
I_D	Drain current (continuous) at T_C=100°C	5.7	5.7(1)	A
I_{DM}(2)	Drain current (pulsed)	36	36(1)	A
P_{TOT}	Total dissipation at T_C = 25°C	75	30	W
	Derating factor	0.6	0.24	W/°C
dv/dt (3)	Peak diode recovery voltage slope	5		V/ns
V_{ISO}	Insulation winthstand voltage (DC)	--	2000	V
T_J T_{stg}	Operating junction temperature Storage temperature	-65 to 150 150		°C

1. Limited only by maximum temperature allowed
2. Pulse width limited by safe operating area
3. ISD ≤9A, di/dt ≤300A/µs, VDD ≤V(BR)DSS, Tj ≤TJMAX

Table 2. Thermal data

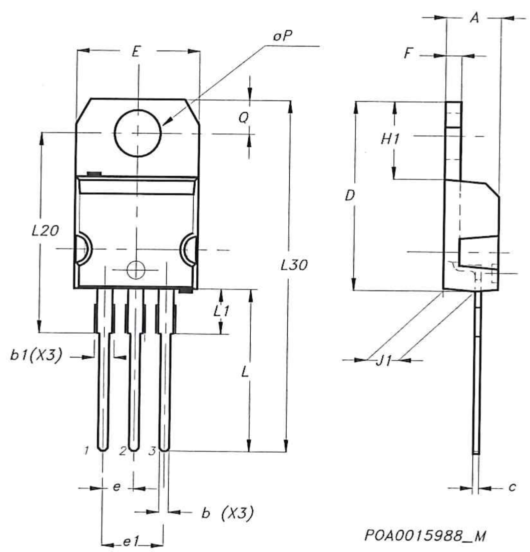
Symbol	Parameter	Value		Unit
		TO-220	TO-220FP	
$R_{thj-case}$	Thermal resistance junction-case Max	1.67	4.17	°C/W
R_{thj-a}	Thermal resistance junction-ambient Max	62.5		°C/W
Rthc-sink	Thermal resistance case-sink typ	0.5		°C/W
T_l	Maximum lead temperature for soldering purpose	300		°C

Table 3. Avalanche characteristics

Symbol	Parameter	Value	Unit
I_{AR}	Avalanche current, repetitive or not-repetitive (pulse width limited by Tj Max)	9	A
E_{AS}	Single pulse avalanche energy (starting Tj=25°C, Id=Iar, Vdd=50V)	160	mJ

TO-220 MECHANICAL DATA

DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A	4.40		4.60	0.173		0.181
b	0.61		0.88	0.024		0.034
b1	1.15		1.70	0.045		0.066
c	0.49		0.70	0.019		0.027
D	15.25		15.75	0.60		0.620
E	10		10.40	0.393		0.409
e	2.40		2.70	0.094		0.106
e1	4.95		5.15	0.194		0.202
F	1.23		1.32	0.048		0.052
H1	6.20		6.60	0.244		0.256
J1	2.40		2.72	0.094		0.107
L	13		14	0.511		0.551
L1	3.50		3.93	0.137		0.154
L20		16.40			0.645	
L30		28.90			1.137	
øP	3.75		3.85	0.147		0.151
Q	2.65		2.95	0.104		0.116



ECE 404 / 504

T & D Applications of Voltage Sourced Converters

Lesson 8

The course materials will be on the course website, as given in the syllabus. Outreach will no longer post the same thing on their website. Your videos will still be on the Outreach website.

Diode Reverse Recovery

Heat sinking

Electromechanical analogs:
use circuit concepts to solve problems that have little to do with circuits.

Energy...charge

Power...current

Thermal resistance...resistance

Temperature...voltage

We generate thermal power from our switches...MOSFETs and diodes, for example. The heat so generated must go somewhere. We want to choose that somewhere.

*Heat is generated in a semiconductor junction. (pn junction).

*It flows from junction through the silicon to the device's case.

*From the case, the heat flows into the heat sink, should we choose to use one.

*From the heat sink, the heat flows out into the ambient.