

V_{DSS}	600V
$R_{DS(on)}$ (Max.)	980mΩ
I_D	4A
P_D	40W

●Features

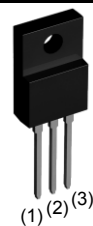
- 1) Low on-resistance.
- 2) Fast switching speed.
- 3) Gate-source voltage (V_{GSS}) guaranteed to be $\pm 30V$.
- 4) Drive circuits can be simple.
- 5) Parallel use is easy.
- 6) Pb-free lead plating ; RoHS compliant

●Application

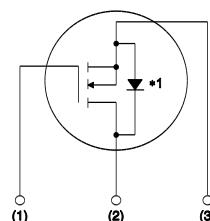
Switching Power Supply

●Outline

TO-220FM



●Inner circuit



(1) Gate
(2) Drain
(3) Source

*1 BODY DIODE

●Packaging specifications

Type	Packaging	Bulk
	Reel size (mm)	-
	Tape width (mm)	-
	Basic ordering unit (pcs)	500
	Taping code	-
	Marking	R6004ENX

●Absolute maximum ratings ($T_a = 25^\circ C$)

Parameter		Symbol	Value	Unit
Drain - Source voltage		V_{DSS}	600	V
Continuous drain current	$T_c = 25^\circ C$	I_D^{*1}	± 4.0	A
	$T_c = 100^\circ C$	I_D^{*1}	± 2.2	A
Pulsed drain current		$I_{D,pulse}^{*2}$	± 8.0	A
Gate - Source voltage		V_{GSS}	± 20	V
Avalanche energy, single pulse		E_{AS}^{*3}	46	mJ
Avalanche energy, repetitive		E_{AR}^{*3}	0.13	mJ
Avalanche current, repetitive		I_{AR}	0.8	A
Power dissipation ($T_c = 25^\circ C$)		P_D	40	W
Junction temperature		T_j	150	$^\circ C$
Range of storage temperature		T_{stg}	-55 to +150	$^\circ C$
Reverse diode dv/dt		dv/dt^{*4}	15	V/ns

●Absolute maximum ratings

Parameter	Symbol	Conditions	Values	Unit
Drain - Source voltage slope	dv/dt	$V_{DS} = 480V$ $T_j = 25^\circ C$	50	V/ns

●Thermal resistance

Parameter	Symbol	Values			Unit
		Min.	Typ.	Max.	
Thermal resistance, junction - case	R_{thJC}	-	-	3.13	$^\circ C/W$
Thermal resistance, junction - ambient	R_{thJA}	-	-	70	$^\circ C/W$
Soldering temperature, wavesoldering for 10s	T_{sold}	-	-	265	$^\circ C$

●Electrical characteristics ($T_a = 25^\circ C$)

Parameter	Symbol	Conditions	Values			Unit
			Min.	Typ.	Max.	
Drain - Source breakdown voltage	$V_{(BR)DSS}$	$V_{GS} = 0V, I_D = 1mA$	600	-	-	V
Zero gate voltage drain current	I_{DSS}	$V_{DS} = 600V, V_{GS} = 0V$ $T_j = 25^\circ C$	-	0.1	100	μA
		$T_j = 125^\circ C$	-	-	1000	
Gate - Source leakage current	I_{GSS}	$V_{GS} = \pm 20V, V_{DS} = 0V$	-	-	± 100	nA
Gate threshold voltage	$V_{GS(th)}$	$V_{DS} = 10V, I_D = 1mA$	2	-	4	V
Static drain - source on - state resistance	$R_{DS(on)}^{*5}$	$V_{GS} = 10V, I_D = 1.5A$ $T_j = 25^\circ C$	-	0.90	0.98	Ω
		$T_j = 125^\circ C$	-	1.36	-	
Gate input resistance	R_G	$f = 1MHz, \text{open drain}$	-	16.7	-	Ω

●Electrical characteristics ($T_a = 25^\circ\text{C}$)

Parameter	Symbol	Conditions	Values			Unit
			Min.	Typ.	Max.	
Transconductance	g_{fs}^{*5}	$V_{DS} = 10\text{V}, I_D = 2\text{A}$	1.5	3.0	-	S
Input capacitance	C_{iss}	$V_{GS} = 0\text{V}$	-	250	-	pF
Output capacitance	C_{oss}	$V_{DS} = 25\text{V}$	-	250	-	
Reverse transfer capacitance	C_{rss}	$f = 1\text{MHz}$	-	30	-	
Effective output capacitance, energy related	$C_{o(er)}$	$V_{GS} = 0\text{V}$ $V_{DS} = 0\text{V to } 480\text{V}$	-	14	-	pF
Effective output capacitance, time related	$C_{o(tr)}$		-	57	-	
Turn - on delay time	$t_{d(on)}^{*5}$	$V_{DD} \approx 300\text{V}, V_{GS} = 10\text{V}$	-	22	-	ns
Rise time	t_r^{*5}	$I_D = 2\text{A}$	-	22	-	
Turn - off delay time	$t_{d(off)}^{*5}$	$R_L = 150\Omega$	-	55	-	
Fall time	t_f^{*5}	$R_G = 10\Omega$	-	40	-	

●Gate Charge characteristics ($T_a = 25^\circ\text{C}$)

Parameter	Symbol	Conditions	Values			Unit
			Min.	Typ.	Max.	
Total gate charge	Q_g^{*5}	$V_{DD} \approx 300\text{V}$	-	15	-	nC
Gate - Source charge	Q_{gs}^{*5}	$I_D = 4\text{A}$	-	2.5	-	
Gate - Drain charge	Q_{gd}^{*5}	$V_{GS} = 10\text{V}$	-	10	-	
Gate plateau voltage	$V_{(plateau)}$	$V_{DD} \approx 300\text{V}, I_D = 4\text{A}$	-	6.5	-	V

*1 Limited only by maximum temperature allowed.

*2 $P_W \leq 10\mu\text{s}$, Duty cycle $\leq 1\%$

*3 $I_D = 0.8\text{A}$, $V_{DD} = 50\text{V}$

*4 Reference measurement circuits Fig.5-1.

*5 Pulsed

●Body diode electrical characteristics (Source-Drain) ($T_a = 25^\circ\text{C}$)

Parameter	Symbol	Conditions	Values			Unit
			Min.	Typ.	Max.	
Inverse diode continuous, forward current	I_S^{*1}	$T_c = 25^\circ\text{C}$	-	-	4.0	A
Inverse diode direct current, pulsed	I_{SM}^{*2}		-	-	8.0	A
Forward voltage	V_{SD}^{*5}	$V_{GS} = 0\text{V}, I_S = 4\text{A}$	-	-	1.5	V
Reverse recovery time	t_{rr}^{*5}	$I_S = 4\text{A}$ $di/dt = 100\text{A}/\mu\text{s}$	-	320	-	ns
Reverse recovery charge	Q_{rr}^{*5}		-	2.4	-	μC
Peak reverse recovery current	I_{rrm}^{*5}		-	15	-	A

●Typical Transient Thermal Characteristics

Symbol	Value	Unit
R_{th1}	0.557	K/W
R_{th2}	1.61	
R_{th3}	2.24	

Symbol	Value	Unit
C_{th1}	0.00102	Ws/K
C_{th2}	0.00898	
C_{th3}	0.440	



●Electrical characteristic curves

Fig.1 Power Dissipation Derating Curve

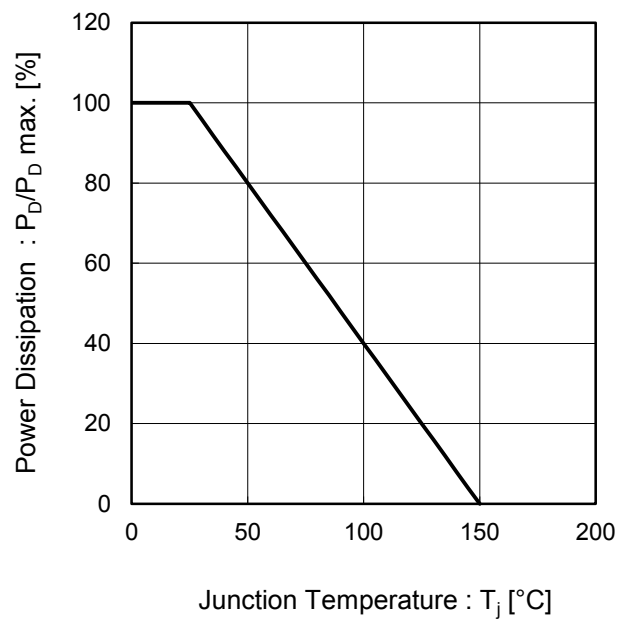


Fig.2 Normalized Transient Thermal Resistance vs. Pulse Width

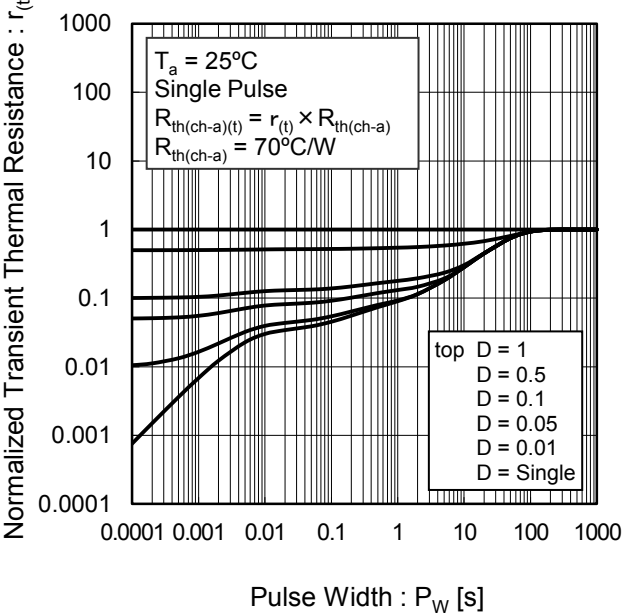
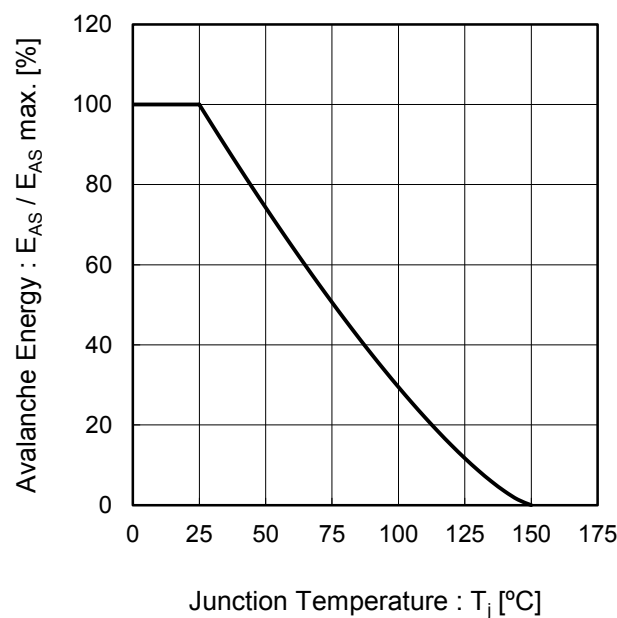


Fig.3 Avalanche Energy Derating Curve vs Junction Temperature



●Electrical characteristic curves

Fig.4 Typical Output Characteristics(I)

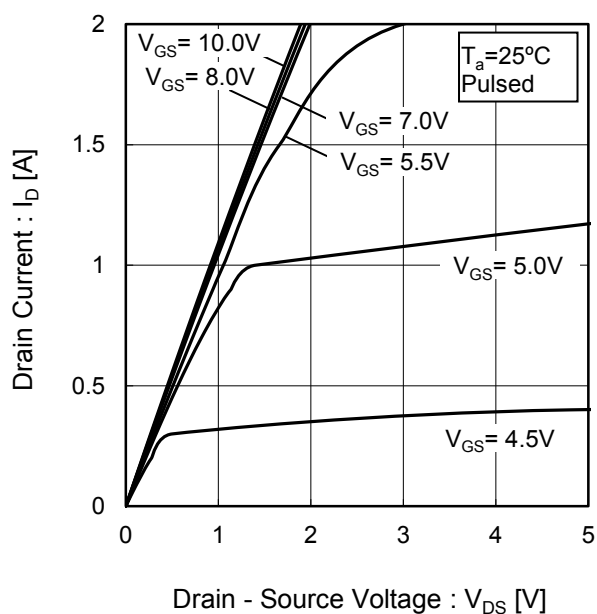


Fig.5 Typical Output Characteristics(II)

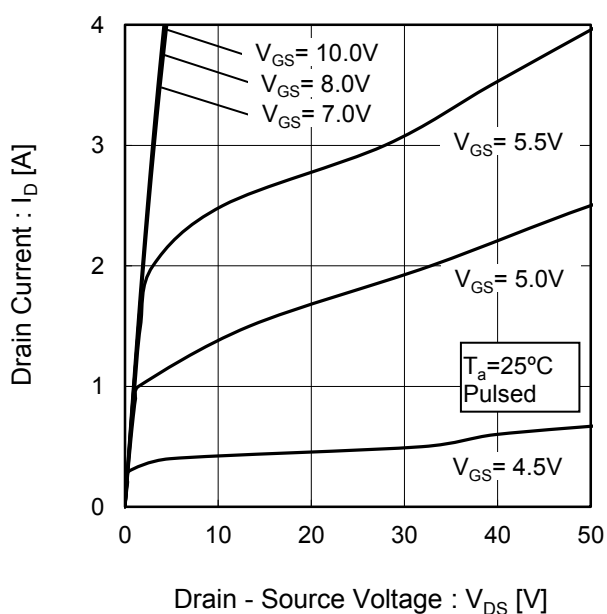


Fig.6 T_j = 150°C Typical Output Characteristics(I)

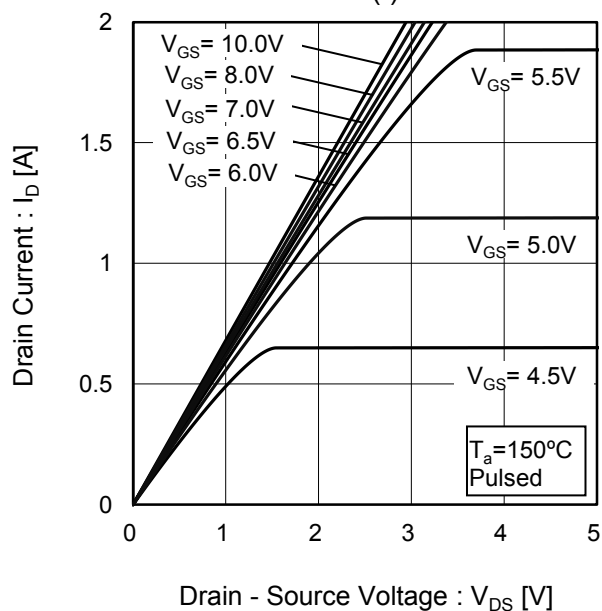
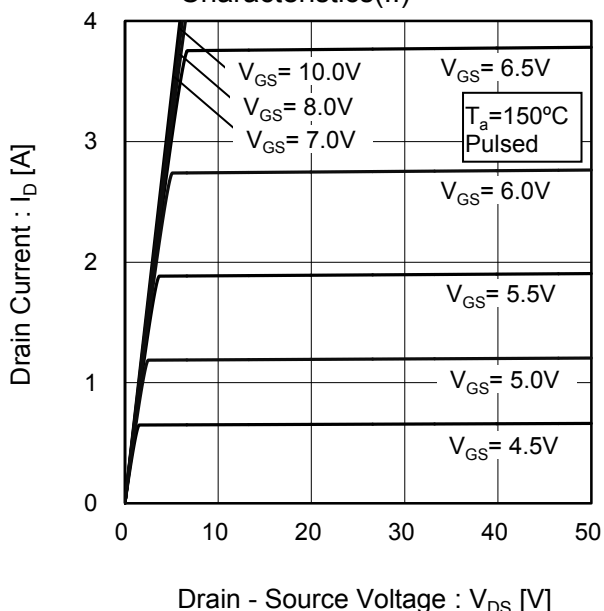


Fig.7 $T_j = 150^{\circ}\text{C}$ Typical Output Characteristics(II)



●Electrical characteristic curves

Fig.8 Breakdown Voltage
vs. Junction Temperature

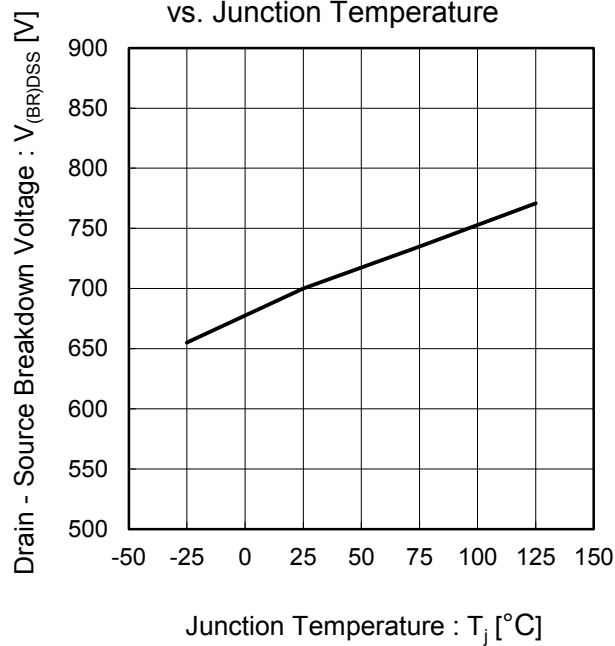


Fig.9 Typical Transfer Characteristics

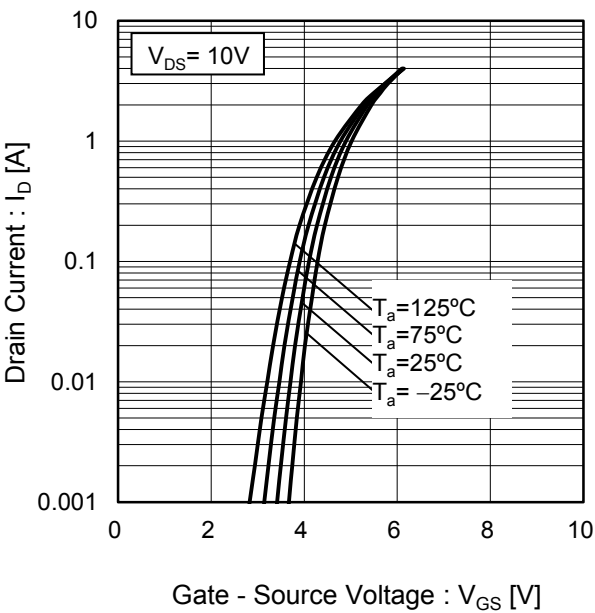


Fig.10 Gate Threshold Voltage
vs. Junction Temperature

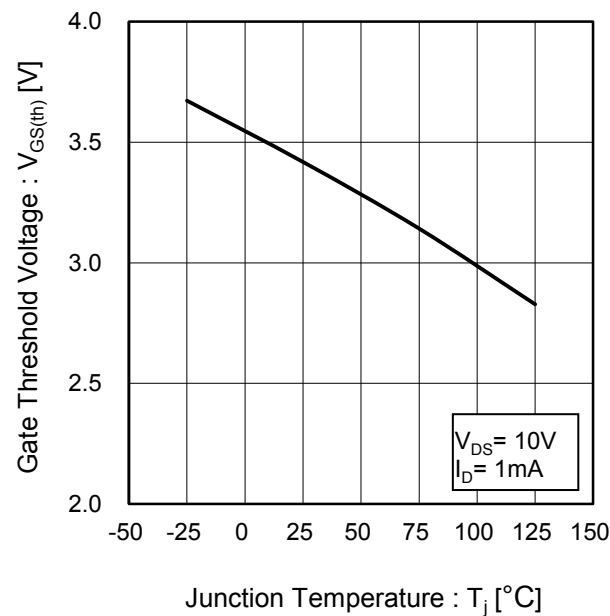
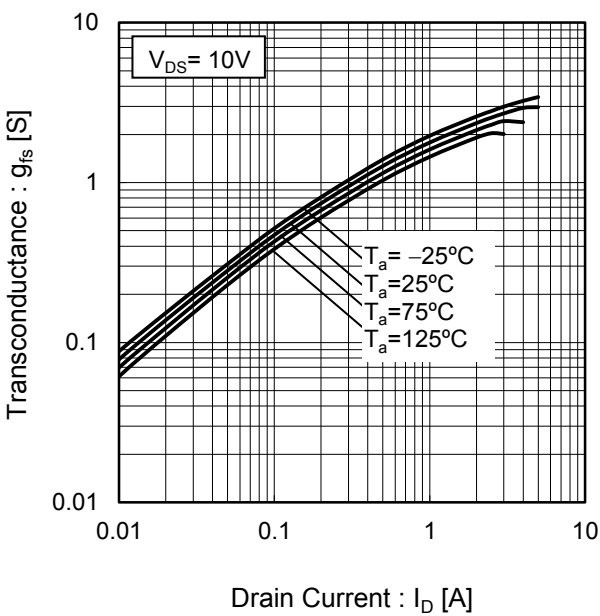


Fig.11 Transconductance vs. Drain Current



●Electrical characteristic curves

Fig.12 Static Drain - Source On - State Resistance vs. Gate Source Voltage

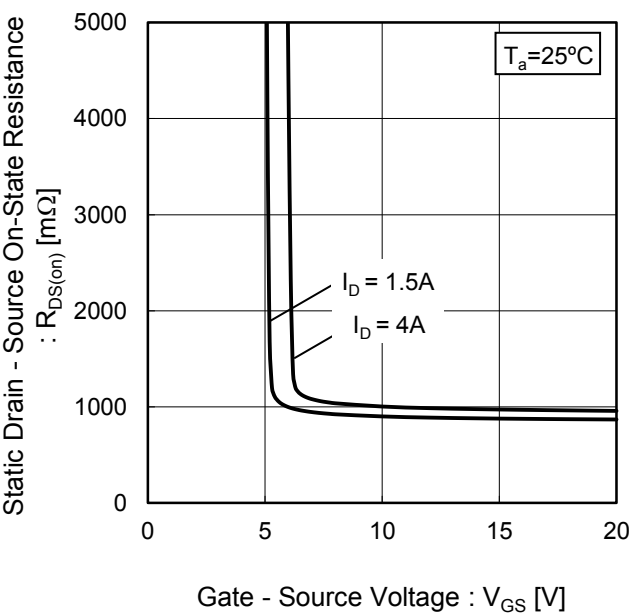


Fig.13 Static Drain - Source On - State Resistance vs. Junction Temperature

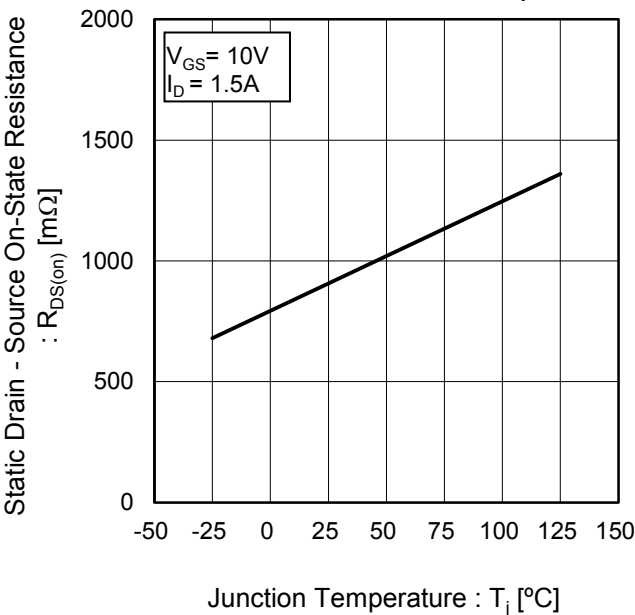


Fig.14 Static Drain - Source On - State Resistance vs. Drain Current

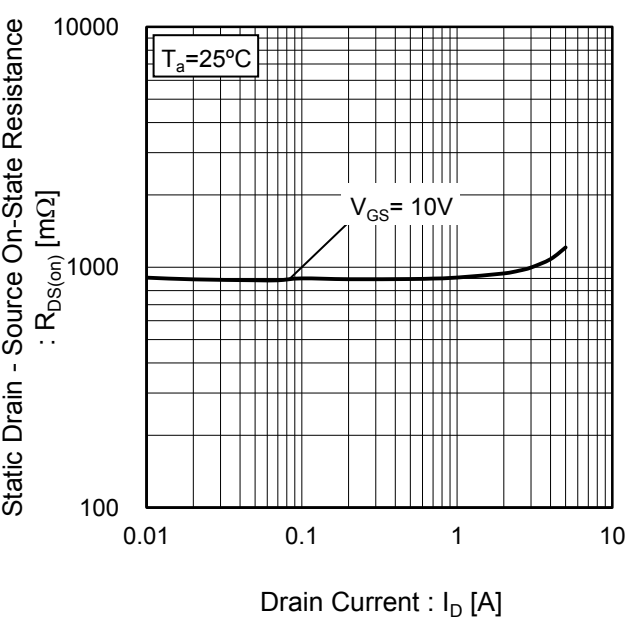
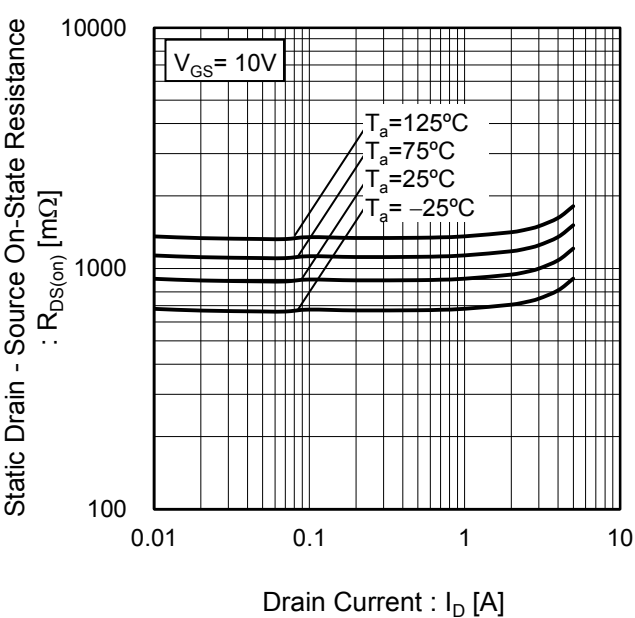


Fig.15 Static Drain - Source On - State Resistance vs. Drain Current



●Electrical characteristic curves

Fig.16 Typical Capacitance vs. Drain - Source Voltage

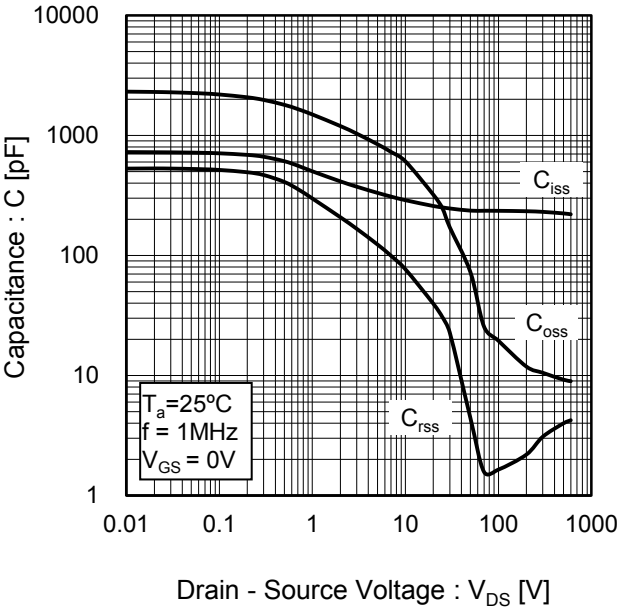


Fig.17 Coss Stored Energy

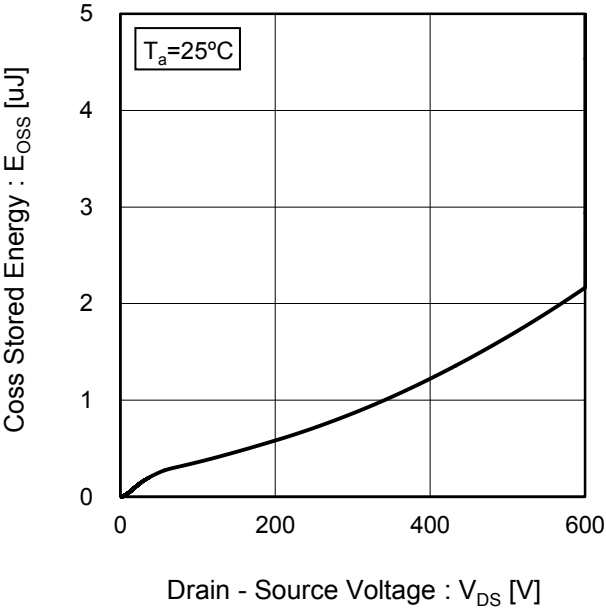


Fig.18 Switching Characteristics

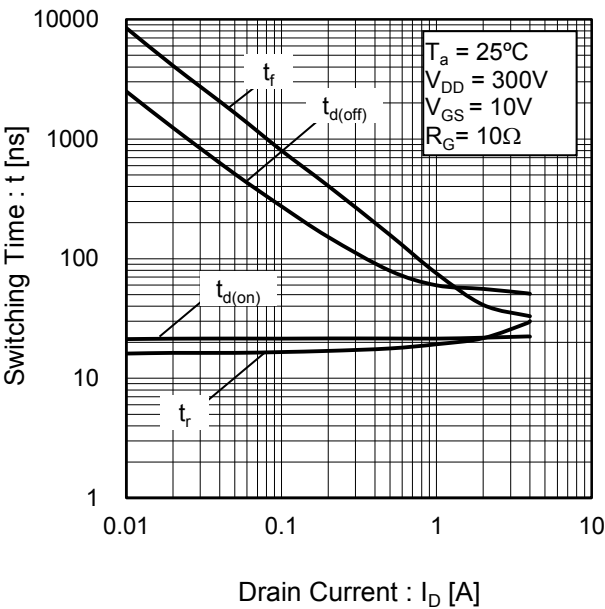
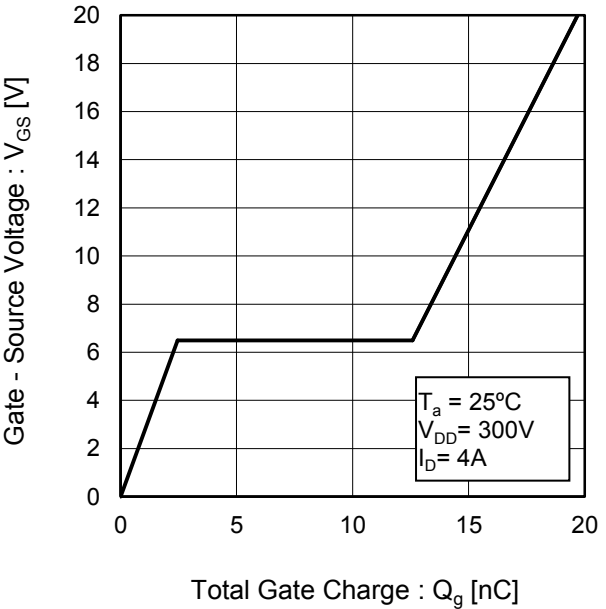


Fig.19 Dynamic Input Characteristics



●Electrical characteristic curves

Fig.20 Inverse Diode Forward Current
vs. Source - Drain Voltage

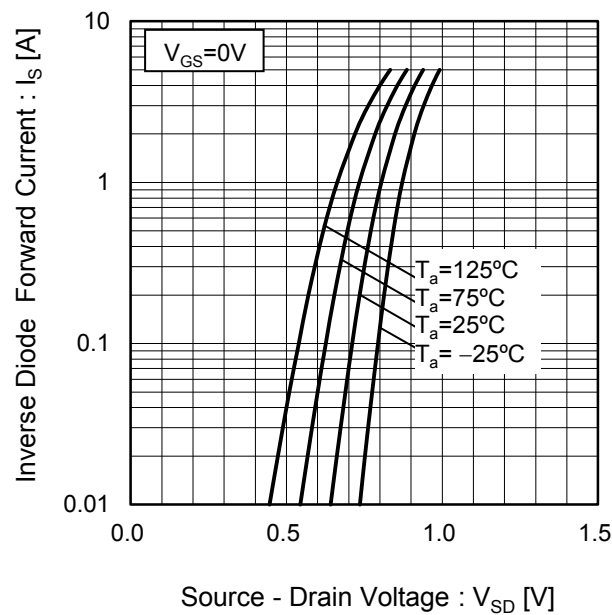
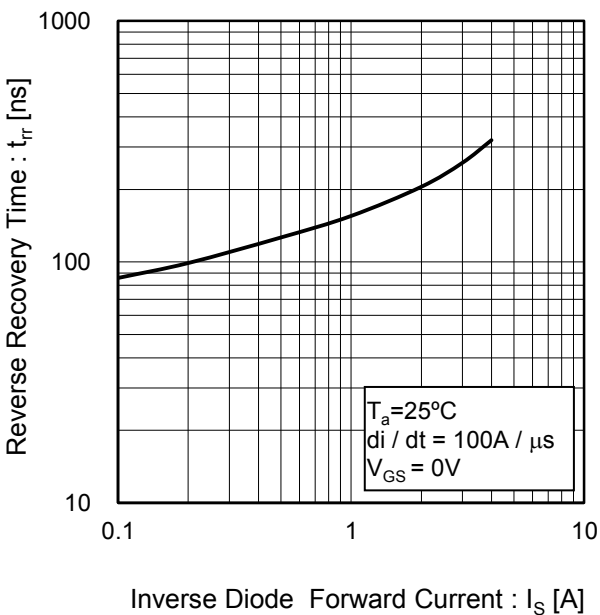


Fig.21 Reverse Recovery Time
vs. Inverse Diode Forward Current



●Measurement circuits

Fig.1-1 Switching Time Measurement Circuit

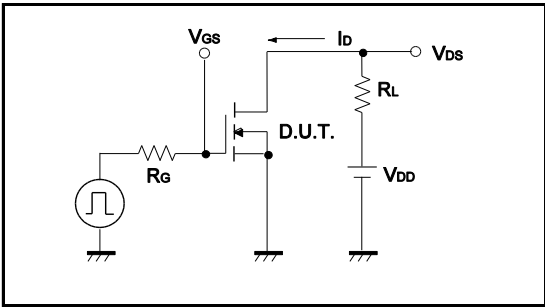


Fig.1-2 Switching Waveforms

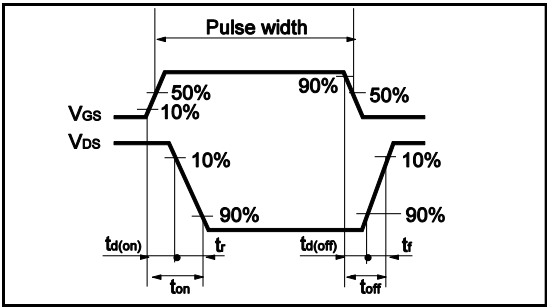


Fig.2-1 Gate Charge Measurement Circuit

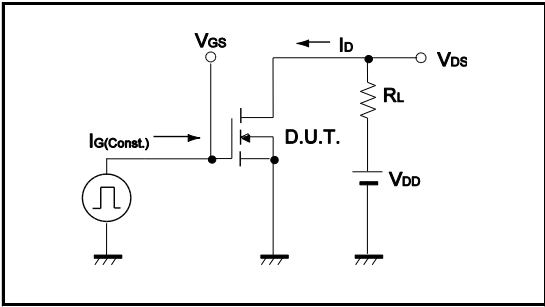


Fig.2-2 Gate Charge Waveform

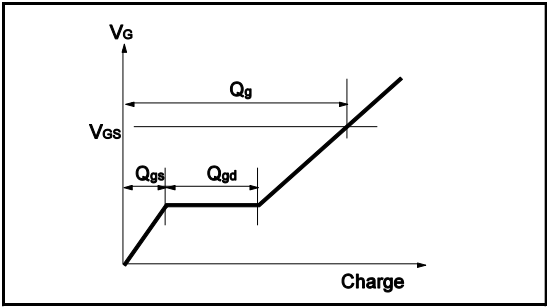


Fig.3-1 Avalanche Measurement Circuit

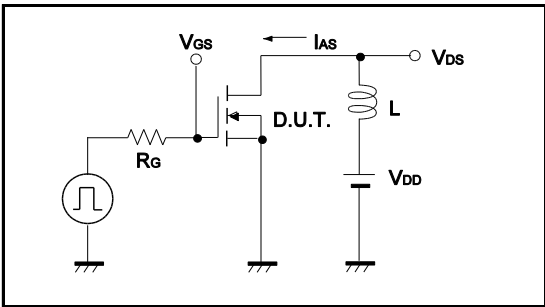


Fig.3-2 Avalanche Waveform

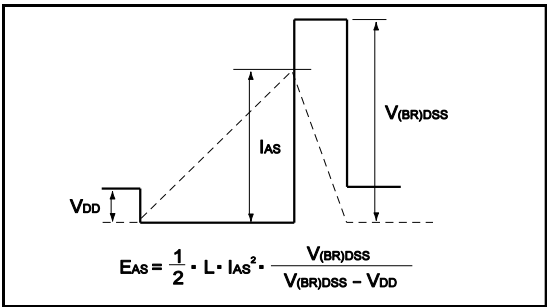


Fig.4-1 dv/dt Measurement Circuit

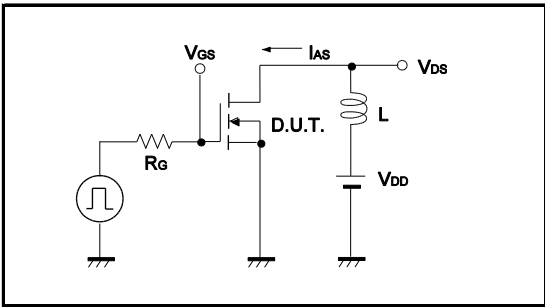


Fig.4-2 dv/dt Waveform

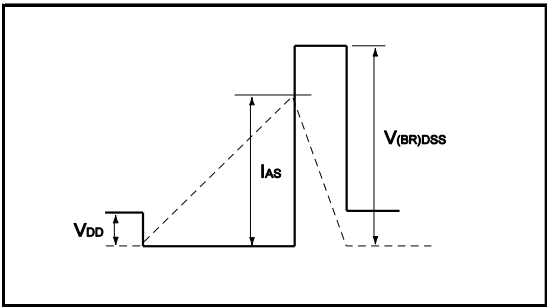


Fig.5-1 di/dt Measurement Circuit

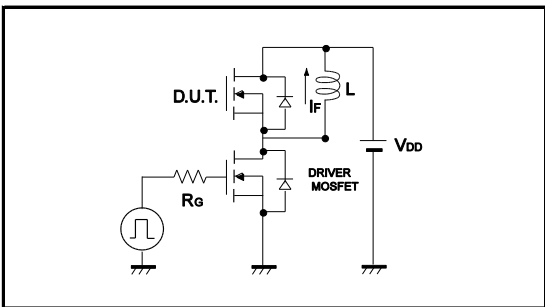
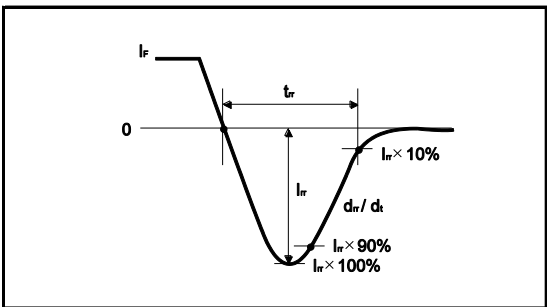
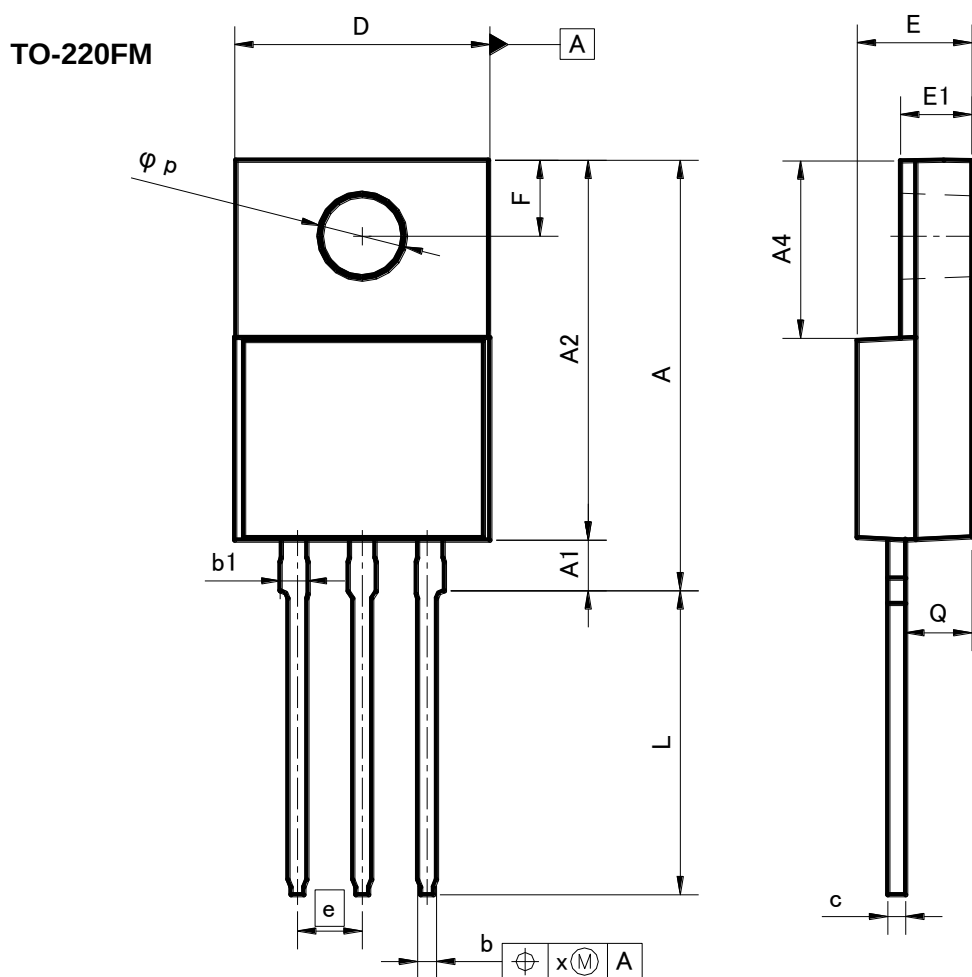


Fig.5-2 di/dt Waveform



●Dimensions (Unit : mm)



DIM	MILIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	16.60	17.60	0.654	0.693
A1	1.80	2.20	0.071	0.087
A2	14.80	15.40	0.583	0.606
A4	6.80	7.20	0.268	0.283
b	0.70	0.85	0.028	0.033
b1	1.10	1.50	0.043	0.059
c	0.70	0.85	0.028	0.033
D	9.90	10.30	0.39	0.406
E	4.40	4.80	0.173	0.189
e	2.54		0.10	
E1	2.70	3.00	0.106	0.118
F	2.80	3.20	0.11	0.126
L	11.50	12.50	0.453	0.492
p	3.00	3.40	0.118	0.134
Q	2.10	3.10	0.083	0.122
x	—	0.381	—	0.015

Dimension in mm/inches

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