

|                     |       |
|---------------------|-------|
| $V_{DSS}$           | 600V  |
| $R_{DS(on)}$ (Max.) | 0.42Ω |
| $I_D$               | 12A   |
| $P_D$               | 50W   |

### ●Features

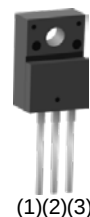
- 1) Low on-resistance.
- 2) Fast switching speed.
- 3) Gate-source voltage ( $V_{GSS}$ ) guaranteed to be  $\pm 30V$ .
- 4) Drive circuits can be simple.
- 5) Parallel use is easy.
- 6) Pb-free lead plating ; RoHS compliant

### ●Application

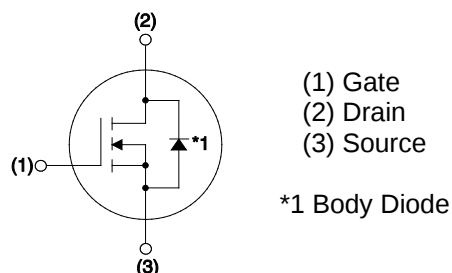
Switching Power Supply

### ●Outline

TO-220FM



### ●Inner circuit



### ●Packaging specifications

|      |                           |          |
|------|---------------------------|----------|
| Type | Packing                   | Bulk     |
|      | Reel size (mm)            | -        |
|      | Tape width (mm)           | -        |
|      | Basic ordering unit (pcs) | 500      |
|      | Taping code               | -        |
|      | Marking                   | R6012ANX |

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

| Parameter                                |                     | Symbol              | Value       | Unit       |
|------------------------------------------|---------------------|---------------------|-------------|------------|
| Drain - Source voltage                   |                     | $V_{DSS}$           | 600         | V          |
| Continuous drain current                 | $T_c = 25^\circ C$  | $I_D^{*1}$          | $\pm 12$    | A          |
|                                          | $T_c = 100^\circ C$ | $I_D^{*1}$          | $\pm 6.1$   | A          |
| Pulsed drain current                     |                     | $I_{D,pulse}^{*2}$  | $\pm 48$    | A          |
| Gate - Source voltage                    |                     | $V_{GSS}$           | $\pm 30$    | V          |
| Avalanche energy, single pulse           |                     | $E_{AS}^{*3}$       | 9.6         | mJ         |
| Avalanche energy, repetitive             |                     | $E_{AR}^{*4}$       | 3.5         | mJ         |
| Avalanche current                        |                     | $I_{AR}^{*3}$       | 6           | A          |
| Power dissipation ( $T_c = 25^\circ C$ ) |                     | $P_D$               | 50          | 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 <sup>*5</sup> | 15          | V/ns       |

### ●Absolute maximum ratings

| Parameter                    | Symbol | Conditions                                           | Values | Unit |
|------------------------------|--------|------------------------------------------------------|--------|------|
| Drain - Source voltage slope | dv/dt  | $V_{DS} = 480V$ , $I_D = 12A$<br>$T_j = 125^\circ C$ | 50     | V/ns |

### ●Thermal resistance

| Parameter                                    | Symbol     | Values |      |      | Unit         |
|----------------------------------------------|------------|--------|------|------|--------------|
|                                              |            | Min.   | Typ. | Max. |              |
| Thermal resistance, junction - case          | $R_{thJC}$ | -      | -    | 2.5  | $^\circ C/W$ |
| 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        |
| Drain - Source avalanche breakdown voltage  | $V_{(BR)DS}$      | $V_{GS} = 0V$ , $I_D = 12A$                           | -      | 700  | -         | V        |
| Zero gate voltage drain current             | $I_{DSS}$         | $V_{DS} = 600V$ , $V_{GS} = 0V$<br>$T_j = 25^\circ C$ | -      | 0.1  | 100       | $\mu A$  |
|                                             |                   | $T_j = 125^\circ C$                                   | -      | -    | 1000      |          |
| Gate - Source leakage current               | $I_{GSS}$         | $V_{GS} = \pm 30V$ , $V_{DS} = 0V$                    | -      | -    | $\pm 100$ | nA       |
| Gate threshold voltage                      | $V_{GS(th)}$      | $V_{DS} = 10V$ , $I_D = 1mA$                          | 2.5    | -    | 4.5       | V        |
| Static drain - source on - state resistance | $R_{DS(on)}^{*6}$ | $V_{GS} = 10V$ , $I_D = 6A$<br>$T_j = 25^\circ C$     | -      | 0.32 | 0.42      | $\Omega$ |
|                                             |                   | $T_j = 125^\circ C$                                   | -      | 0.6  | -         |          |
| Gate input resistance                       | $R_G$             | $f = 1MHz$ , open drain                               | -      | 8.2  | -         | $\Omega$ |

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

| Parameter                                    | Symbol            | Conditions                                                   | Values |      |      | Unit |
|----------------------------------------------|-------------------|--------------------------------------------------------------|--------|------|------|------|
|                                              |                   |                                                              | Min.   | Typ. | Max. |      |
| Transconductance                             | $g_{fs}^{*6}$     | $V_{DS} = 10\text{V}, I_D = 6.0\text{A}$                     | 3.5    | 8.5  | -    | S    |
| Input capacitance                            | $C_{iss}$         | $V_{GS} = 0\text{V}$                                         | -      | 1300 | -    | pF   |
| Output capacitance                           | $C_{oss}$         | $V_{DS} = 25\text{V}$                                        | -      | 890  | -    |      |
| Reverse transfer capacitance                 | $C_{rss}$         | $f = 1\text{MHz}$                                            | -      | 45   | -    |      |
| Effective output capacitance, energy related | $C_{o(er)}$       | $V_{GS} = 0\text{V}$<br>$V_{DS} = 0\text{V to } 480\text{V}$ | -      | 63   | -    | pF   |
| Effective output capacitance, time related   | $C_{o(tr)}$       |                                                              | -      | 63   | -    |      |
| Turn - on delay time                         | $t_{d(on)}^{*6}$  | $V_{DD} \approx 300\text{V}, V_{GS} = 10\text{V}$            | -      | 30   | -    | ns   |
| Rise time                                    | $t_r^{*6}$        | $I_D = 6\text{A}$                                            | -      | 30   | -    |      |
| Turn - off delay time                        | $t_{d(off)}^{*6}$ | $R_L = 50\Omega$                                             | -      | 90   | 180  |      |
| Fall time                                    | $t_f^{*6}$        | $R_G = 10\Omega$                                             | -      | 35   | 70   |      |

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

| Parameter            | Symbol          | Conditions                                     | Values |      |      | Unit |
|----------------------|-----------------|------------------------------------------------|--------|------|------|------|
|                      |                 |                                                | Min.   | Typ. | Max. |      |
| Total gate charge    | $Q_g^{*6}$      | $V_{DD} \approx 300\text{V}$                   | -      | 35   | -    | nC   |
| Gate - Source charge | $Q_{gs}^{*6}$   | $I_D = 12\text{A}$                             | -      | 7    | -    |      |
| Gate - Drain charge  | $Q_{gd}^{*6}$   | $V_{GS} = 10\text{V}$                          | -      | 15   | -    |      |
| Gate plateau voltage | $V_{(plateau)}$ | $V_{DD} \approx 300\text{V}, I_D = 12\text{A}$ | -      | 6.0  | -    | V    |

\*1 Limited only by maximum temperature allowed.

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

\*3  $L \approx 500\mu\text{H}$ ,  $V_{DD} = 50\text{V}$ ,  $R_G = 25\Omega$ , starting  $T_j = 25^\circ\text{C}$

\*4  $L \approx 500\mu\text{H}$ ,  $V_{DD} = 50\text{V}$ ,  $R_G = 25\Omega$ , starting  $T_j = 25^\circ\text{C}$ ,  $f = 10\text{kHz}$

\*5 Reference measurement circuits Fig.5-1.

\*6 Pulsed

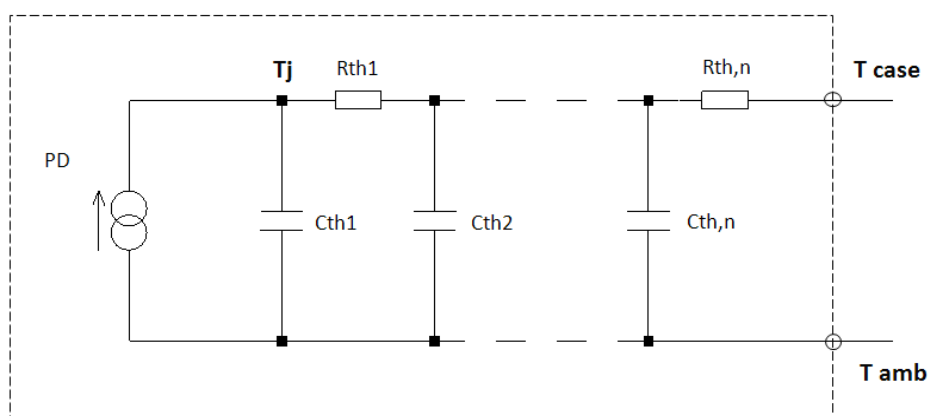
**●Body diode electrical characteristics (Source-Drain) ( $T_a = 25^\circ\text{C}$ )**

| Parameter                                     | Symbol         | Conditions                                              | Values |      |      | Unit                   |
|-----------------------------------------------|----------------|---------------------------------------------------------|--------|------|------|------------------------|
|                                               |                |                                                         | Min.   | Typ. | Max. |                        |
| Inverse diode continuous, forward current     | $I_S^{*1}$     | $T_c = 25^\circ\text{C}$                                | -      | -    | 12   | A                      |
| Inverse diode direct current, pulsed          | $I_{SM}^{*2}$  |                                                         | -      | -    | 48   | A                      |
| Forward voltage                               | $V_{SD}^{*6}$  | $V_{GS} = 0\text{V}, I_S = 12\text{A}$                  | -      | -    | 1.5  | V                      |
| Reverse recovery time                         | $t_{rr}^{*6}$  | $I_S = 12\text{A}$<br>$di/dt = 100\text{A}/\mu\text{s}$ | -      | 396  | -    | ns                     |
| Reverse recovery charge                       | $Q_{rr}^{*6}$  |                                                         | -      | 4.4  | -    | $\mu\text{C}$          |
| Peak reverse recovery current                 | $I_{rrm}^{*6}$ |                                                         | -      | 22   | -    | A                      |
| Peak rate of fall of reverse recovery current | $di_{rr}/dt$   | $T_j = 25^\circ\text{C}$                                | -      | 640  | -    | $\text{A}/\mu\text{s}$ |

**●Typical Transient Thermal Characteristics**

| Symbol    | Value | Unit |
|-----------|-------|------|
| $R_{th1}$ | 0.158 | K/W  |
| $R_{th2}$ | 0.75  |      |
| $R_{th3}$ | 2.15  |      |

| Symbol    | Value   | Unit |
|-----------|---------|------|
| $C_{th1}$ | 0.00247 | Ws/K |
| $C_{th2}$ | 0.0317  |      |
| $C_{th3}$ | 0.485   |      |



●Electrical characteristic curves

Fig.1 Power Dissipation Derating Curve

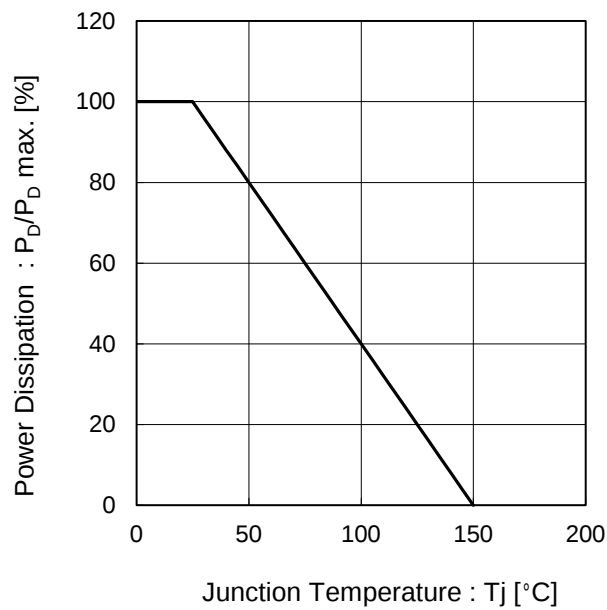


Fig.2 Maximum Safe Operating Area

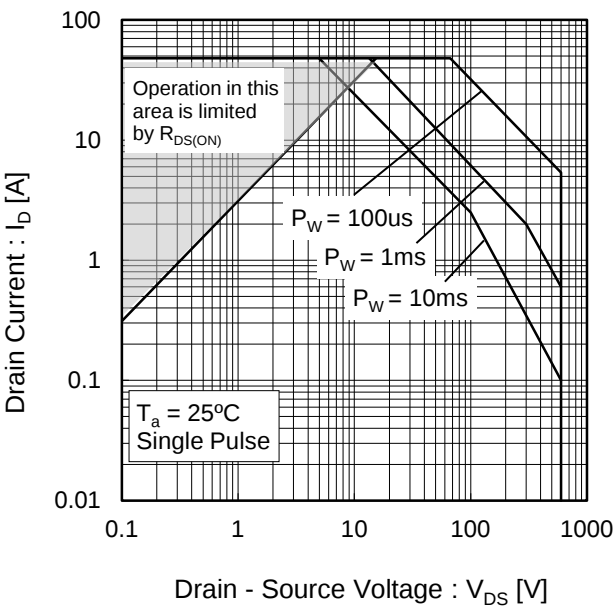
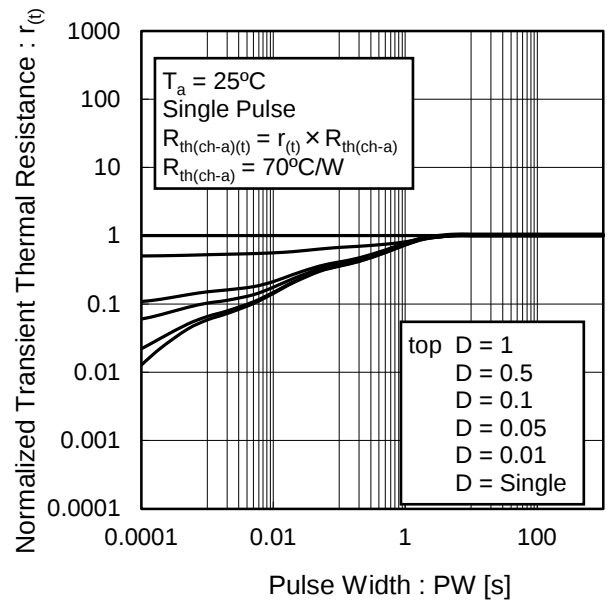


Fig.3 Normalized Transient Thermal Resistance vs. Pulse Width



●Electrical characteristic curves

Fig.4 Avalanche Current vs Inductive Load

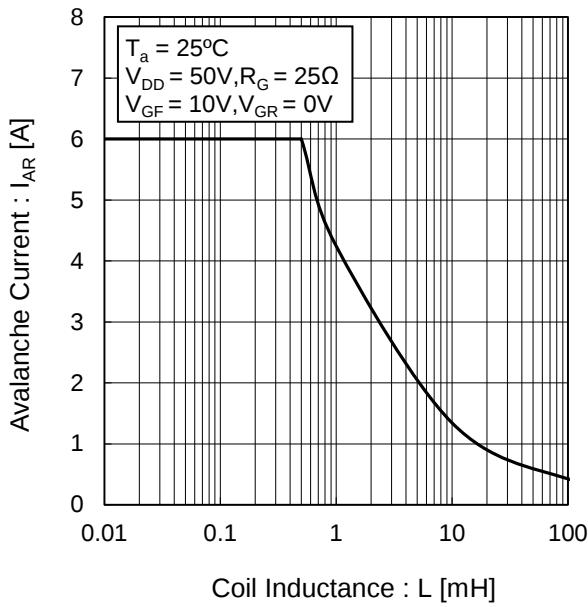


Fig.5 Avalanche Power Losses

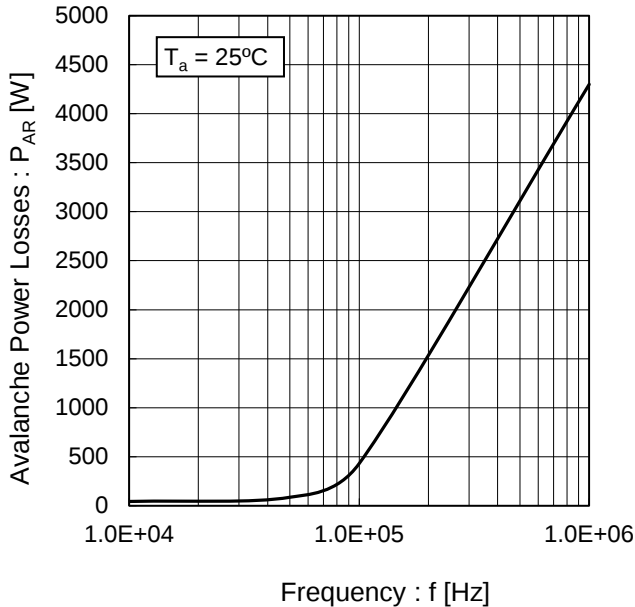
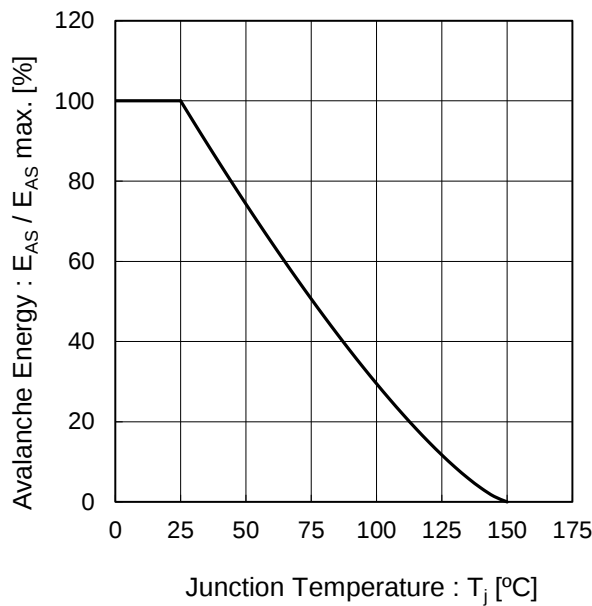


Fig.6 Avalanche Energy Derating Curve vs Junction Temperature



●Electrical characteristic curves

Fig.7 Typical Output Characteristics(I)

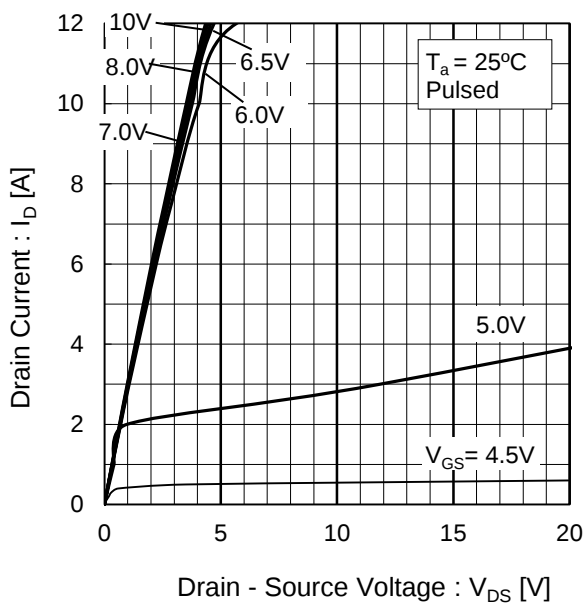


Fig.8 Typical Output Characteristics(II)

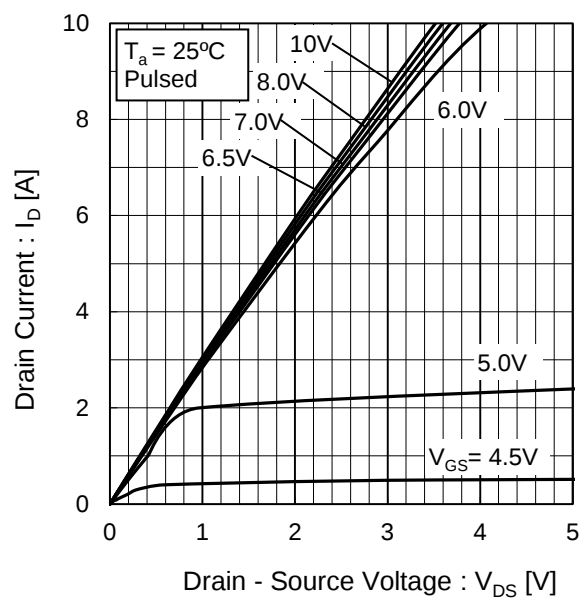


Fig.9  $T_j = 150^\circ\text{C}$  Typical Output Characteristics(I)

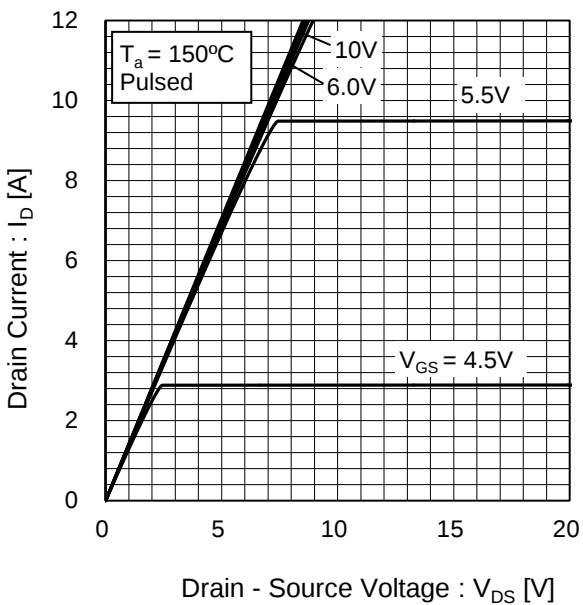
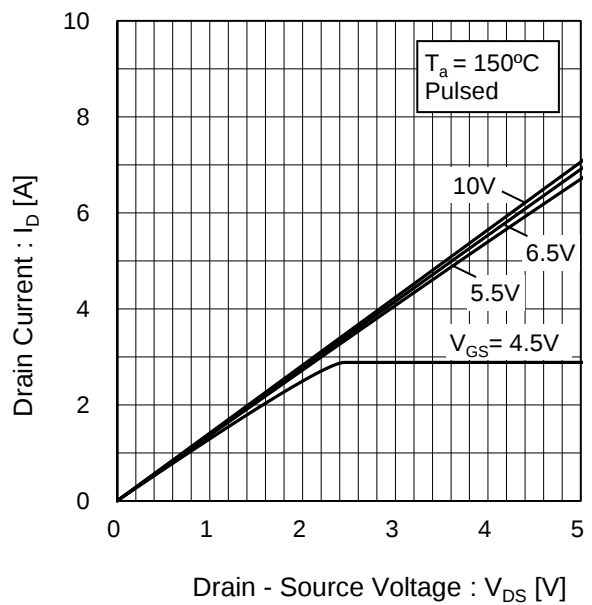


Fig.10  $T_j = 150^\circ\text{C}$  Typical Output Characteristics(II)



●Electrical characteristic curves

Fig.11 Breakdown Voltage vs. Junction Temperature

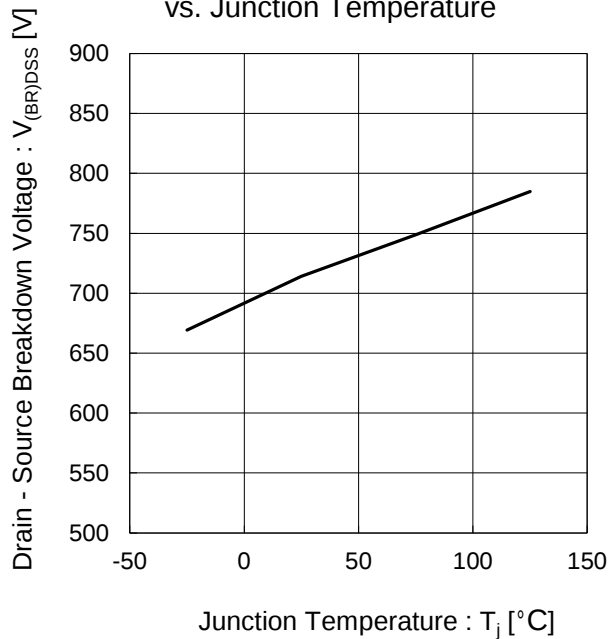


Fig.12 Typical Transfer Characteristics

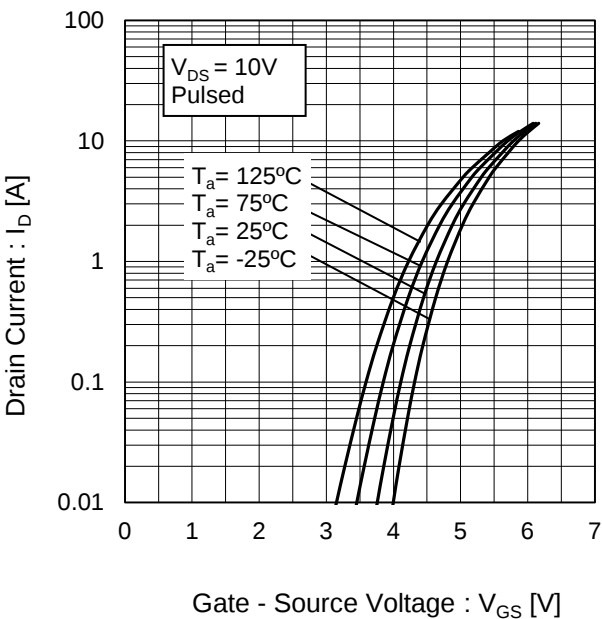


Fig.13 Gate Threshold Voltage vs. Junction Temperature

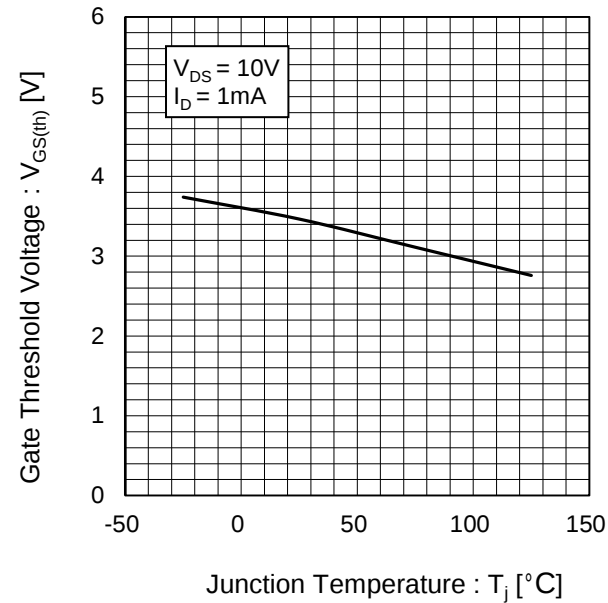
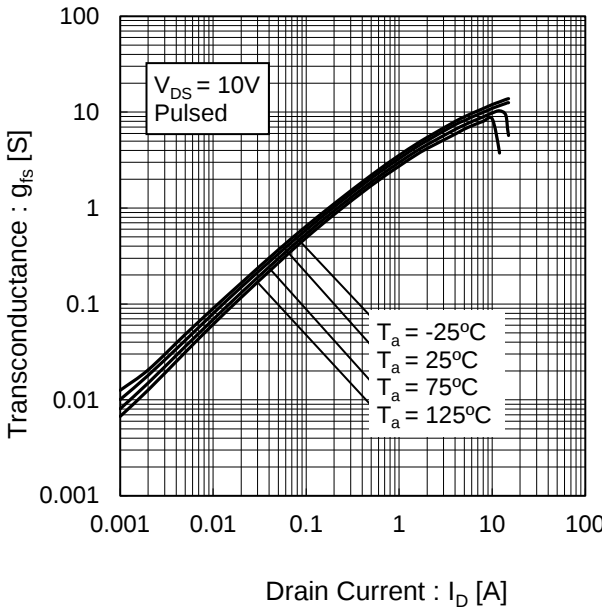


Fig.14 Transconductance vs. Drain Current



●Electrical characteristic curves

Fig.15 Static Drain - Source On - State Resistance vs. Gate Source Voltage

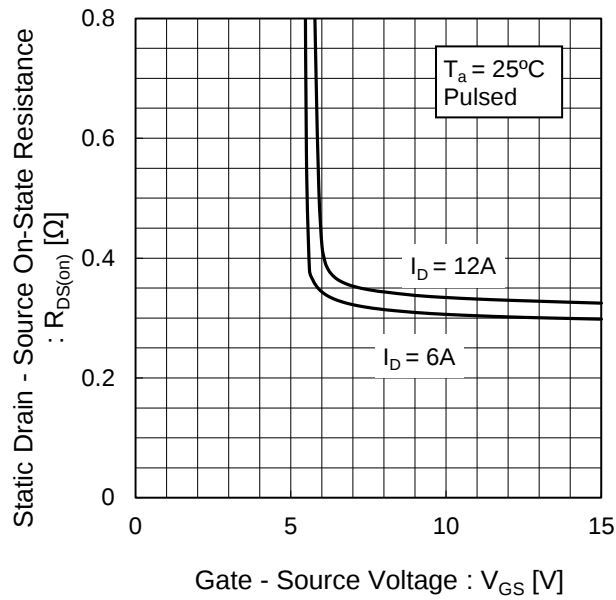


Fig.16 Static Drain - Source On - State Resistance vs. Junction Temperature

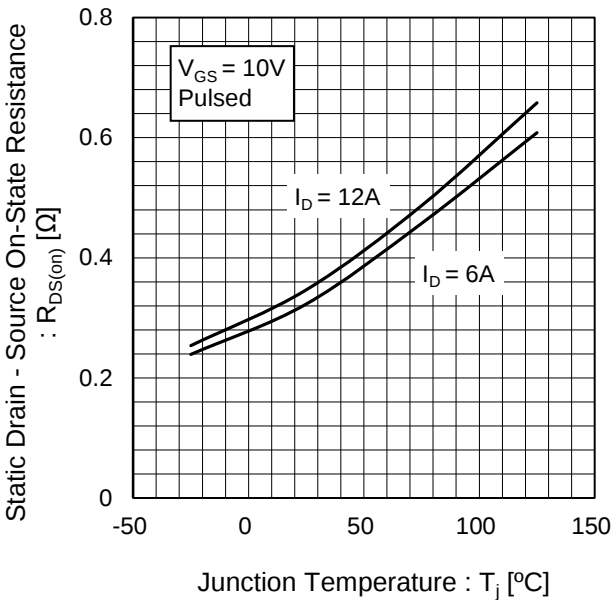
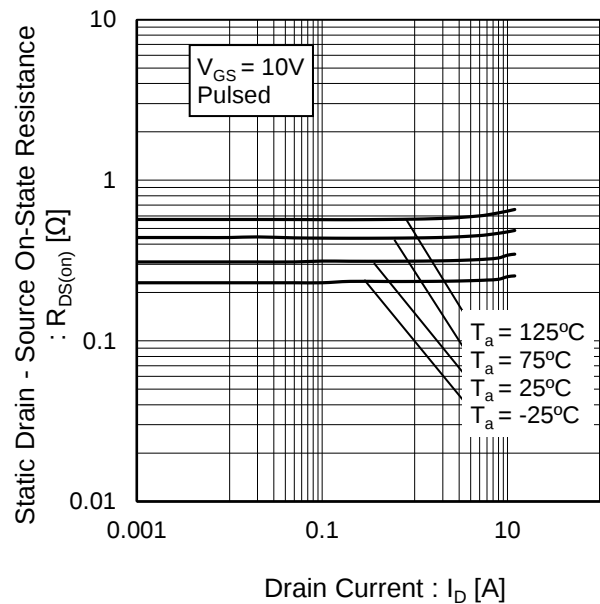


Fig.17 Static Drain - Source On - State Resistance vs. Drain Current



●Electrical characteristic curves

Fig.18 Typical Capacitance vs. Drain - Source Voltage

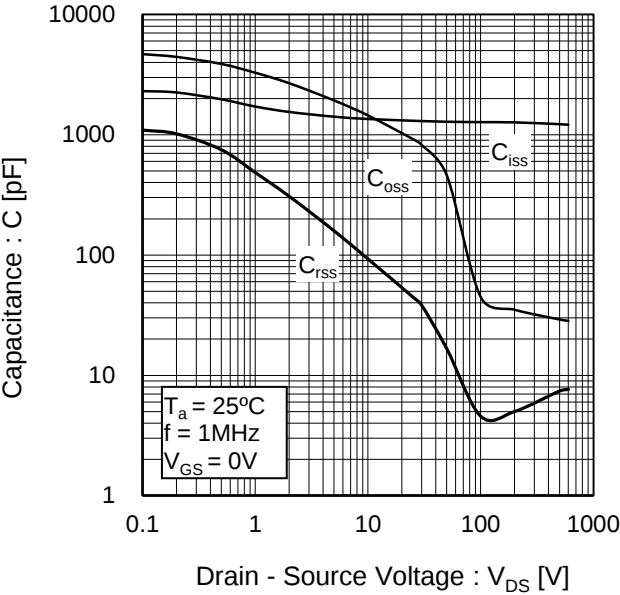


Fig.19 Coss Stored Energy

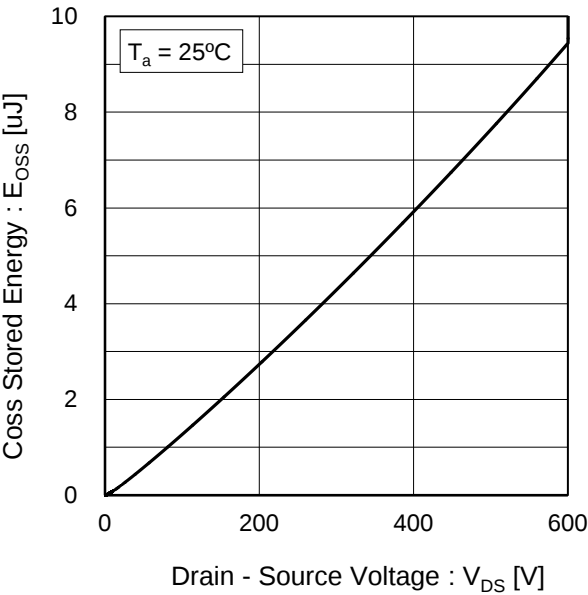


Fig.20 Switching Characteristics

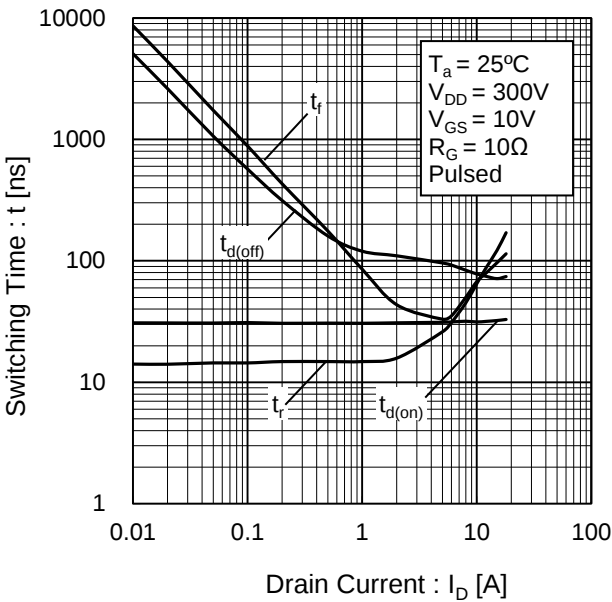
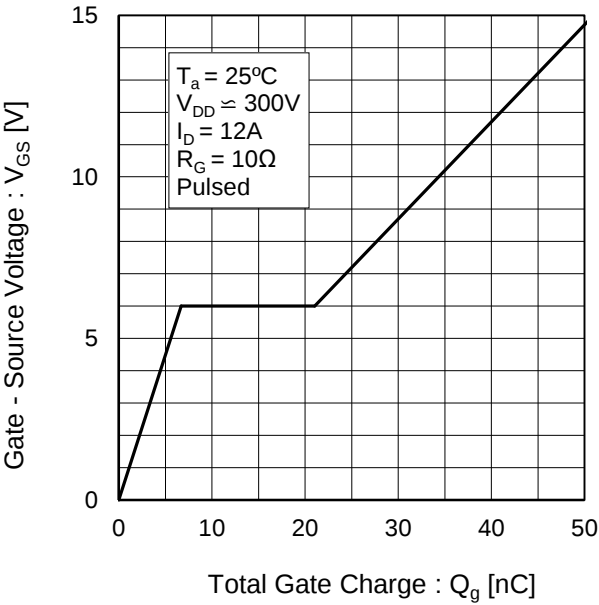


Fig.21 Dynamic Input Characteristics



●Electrical characteristic curves

Fig.22 Inverse Diode Forward Current vs. Source - Drain Voltage

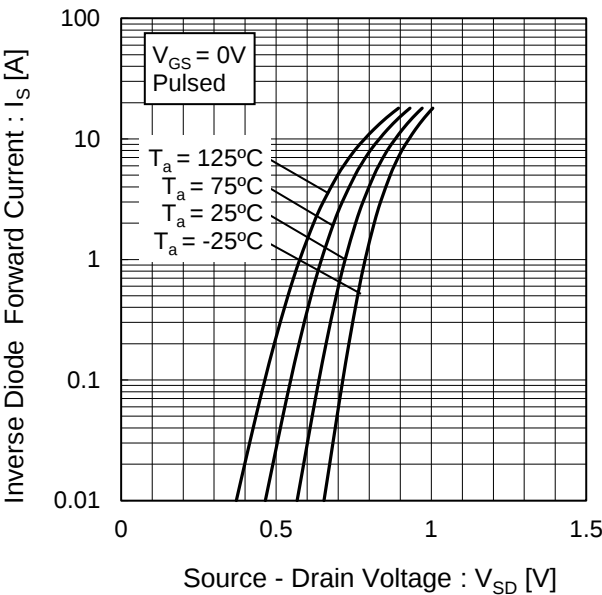
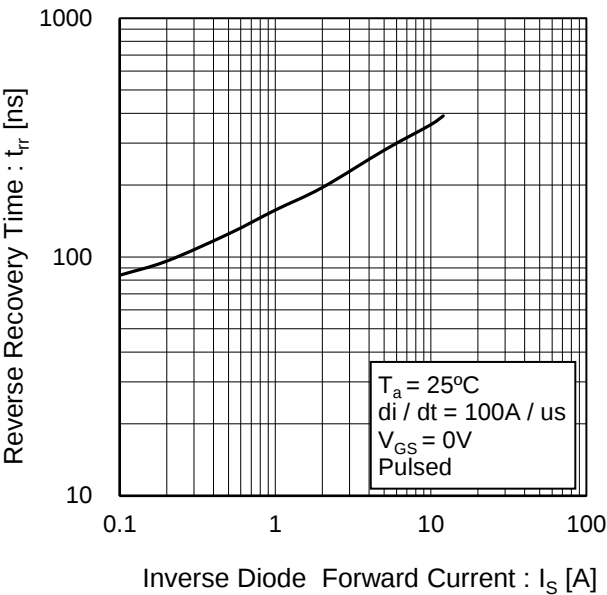


Fig.23 Reverse Recovery Time vs. Inverse Diode Forward Current



●Measurement circuits

Fig.1-1 Switching Time Measurement Circuit

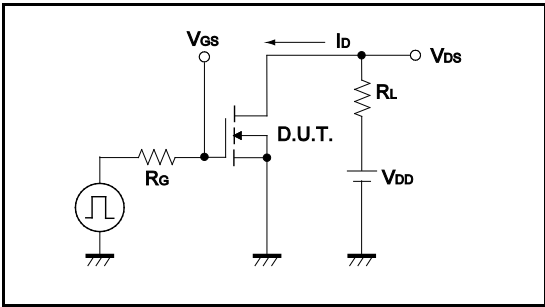


Fig.1-2 Switching Waveforms

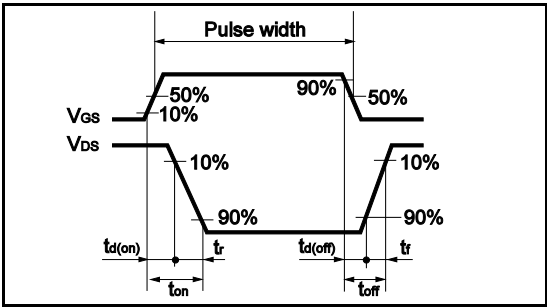


Fig.2-1 Gate Charge Measurement Circuit

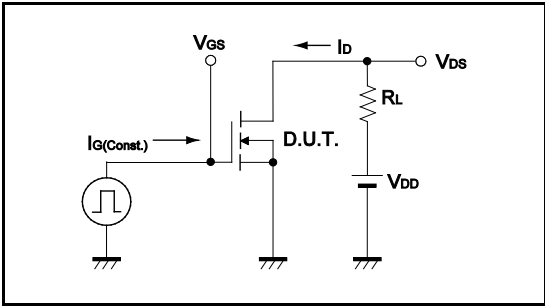


Fig.2-2 Gate Charge Waveform

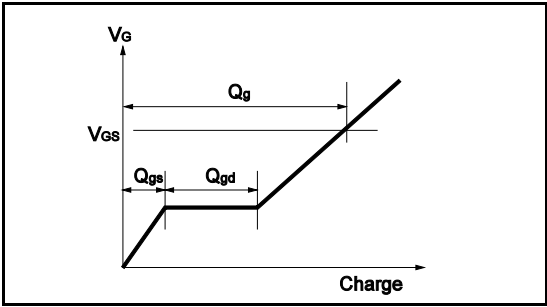


Fig.3-1 Avalanche Measurement Circuit

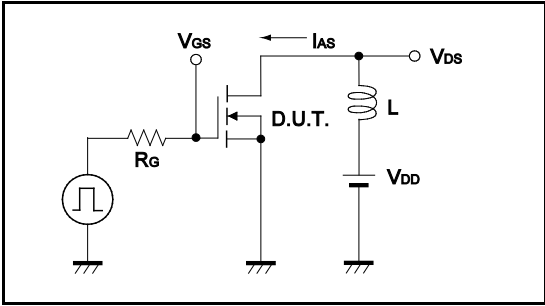


Fig.3-2 Avalanche Waveform

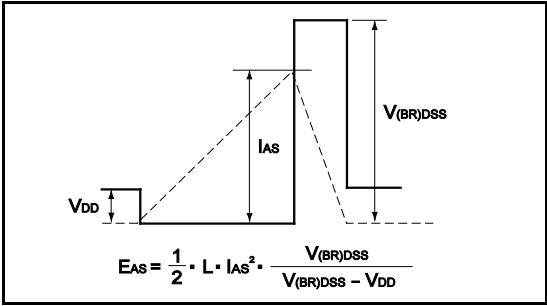


Fig.4-1 dv/dt Measurement Circuit

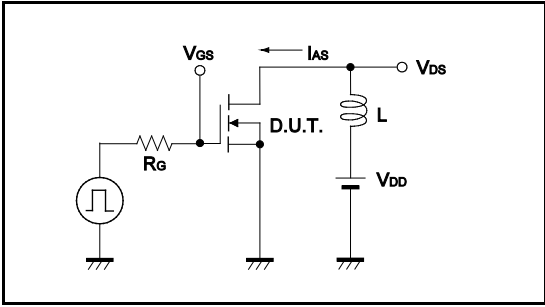


Fig.4-2 dv/dt Waveform

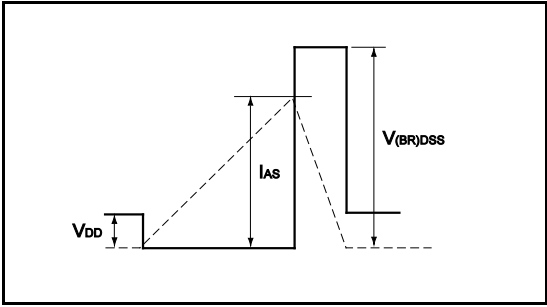


Fig.5-1 di/dt Measurement Circuit

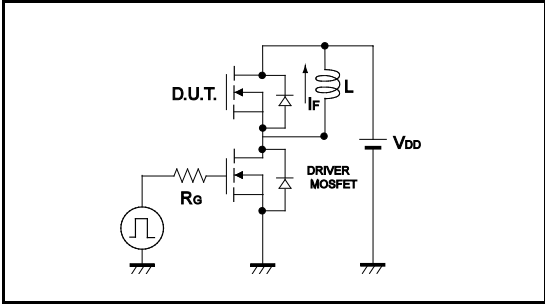
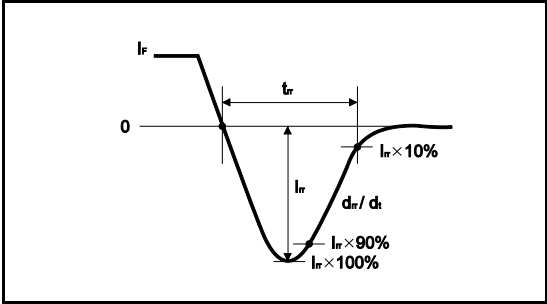
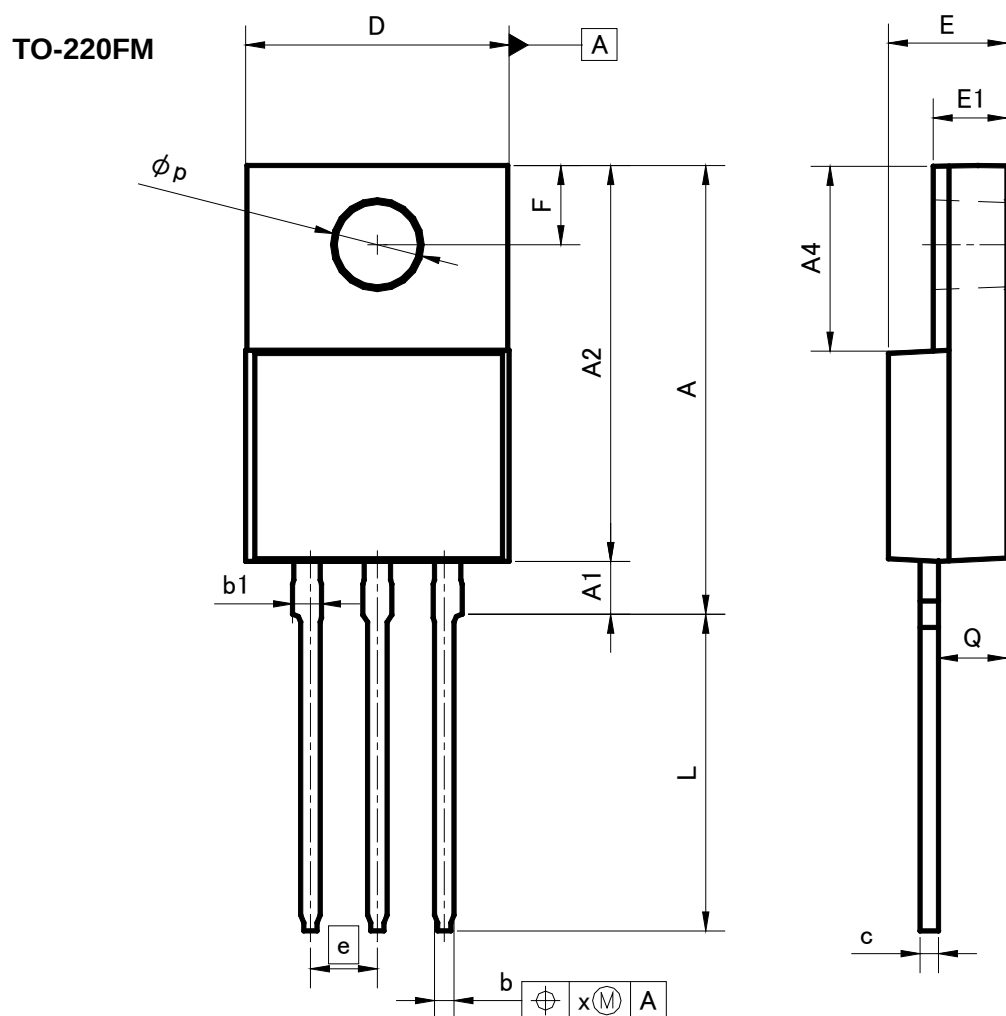


Fig.5-2 di/dt Waveform



●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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