

# MMSFA60R360E6Z

## 600V 0.360Ω N-channel MOSFET

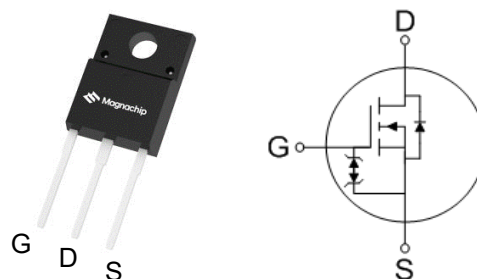
### ■ Description

Superior 6<sup>th</sup> generation SJ MOSFETs (E6-series) are cutting-edge high voltage power MOSFETs, based on Magnachip's extensive design expertise and years of experience. The main strengths of E6-series are low on-resistance, low gate charge and reduced tendency for ringing. As a result, its switching loss is very low, making it optimized for switching applications. Moreover, these user friendly devices offer the advantages of improved ruggedness and remarkable ESD capability by integrated zener diode, making it an ideal choice for designers.

### ■ Key Parameters

| Parameter            | Value | Unit |
|----------------------|-------|------|
| $V_{DS} @ T_{j,max}$ | 650   | V    |
| $R_{DS(on),max}$     | 0.360 | Ω    |
| $V_{TH,typ}$         | 3.5   | V    |
| $I_D$                | 9     | A    |
| $Q_{g,typ}$          | 13.6  | nC   |

### ■ Package & Internal circuit



**RoHS Compliant**  
HALOGEN-FREE

### ■ Features

- Low power loss by high speed switching and low on-resistance
- 100% avalanche tested
- Green package – Pb free plating, halogen free
- Zener-integrated

### ■ Applications

- PFC power supply stages
- Switching applications
- DC-DC converters

### ■ Ordering Information

| Order Code       | Marking     | Temp. Range | Package   | Packing | RoHS Status |
|------------------|-------------|-------------|-----------|---------|-------------|
| MMSFA60R360E6ZTH | A60R360E6ZS | -55 ~ 150°C | TO-220SFA | Tube    | Compliant   |

**■ Absolute Maximum Rating ( $T_c=25^{\circ}\text{C}$  unless otherwise specified)**

| Parameter                                   | Symbol           | Rating   | Unit               | Note                      |
|---------------------------------------------|------------------|----------|--------------------|---------------------------|
| Drain-source voltage                        | $V_{\text{DSS}}$ | 600      | V                  |                           |
| Gate-source voltage                         | $V_{\text{GSS}}$ | $\pm 25$ | V                  |                           |
| Continuous drain current <sup>1)</sup>      | $I_{\text{D}}$   | 9.0      | A                  | $T_c=25^{\circ}\text{C}$  |
|                                             |                  | 5.7      | A                  | $T_c=100^{\circ}\text{C}$ |
| Pulsed drain current <sup>2)</sup>          | $I_{\text{DM}}$  | 27       | A                  |                           |
| Power dissipation                           | $P_{\text{D}}$   | 22       | W                  |                           |
| Single-pulse avalanche energy <sup>3)</sup> | $E_{\text{AS}}$  | 27       | mJ                 |                           |
| MOSFET $dv/dt$ ruggedness                   | $dv/dt$          | 80       | V/ns               |                           |
| Continuous diode forward current            | $I_{\text{SD}}$  | 9.0      | A                  |                           |
| Diode $dv/dt$ ruggedness <sup>4)</sup>      | $dv/dt$          | 50       | V/ns               |                           |
| Storage temperature                         | $T_{\text{stg}}$ | -55 ~150 | $^{\circ}\text{C}$ |                           |
| Maximum operating junction temperature      | $T_{\text{j}}$   | 150      | $^{\circ}\text{C}$ |                           |

1)  $I_{\text{D}}$  limited by maximum junction temperature, Duty cycle  $D=0.5$

2) Pulse width  $t_{\text{p}}$  limited by  $T_{\text{j,max}}$

3)  $I_{\text{AS}}$  : 3.3 A

4)  $I_{\text{SD}} \leq I_{\text{D}}$ ,  $V_{\text{DS peak}} \leq 400\text{V}$ ,  $di/dt \leq 900\text{A}/\mu\text{s}$

**■ Thermal Characteristics**

| Parameter                                | Symbol            | Value | Unit                        |
|------------------------------------------|-------------------|-------|-----------------------------|
| Thermal resistance, junction-case max    | $R_{\text{thJC}}$ | 5.58  | $^{\circ}\text{C}/\text{W}$ |
| Thermal resistance, junction-ambient max | $R_{\text{thJA}}$ | 65.3  | $^{\circ}\text{C}/\text{W}$ |

**■ Static Characteristics ( $T_c=25^\circ\text{C}$  unless otherwise specified)**

| Parameter                        | Symbol        | Min. | Typ.  | Max.  | Unit     | Test Condition                    |
|----------------------------------|---------------|------|-------|-------|----------|-----------------------------------|
| Drain-source breakdown voltage   | $V_{(BR)DSS}$ | 600  | -     | -     | V        | $V_{GS} = 0V, I_D = 1mA$          |
| Gate threshold voltage           | $V_{GS(th)}$  | 2.5  | 3.5   | 4.5   | V        | $V_{DS} = V_{GS}, I_D = 250\mu A$ |
| Zero gate voltage drain current  | $I_{DSS}$     | -    | -     | 1     | $\mu A$  | $V_{DS} = 600V, V_{GS} = 0V$      |
| Gate leakage current             | $I_{GSS}$     | -    | -     | 10    | $\mu A$  | $V_{GS} = \pm 25V, V_{DS} = 0V$   |
| Drain-source on-state resistance | $R_{DS(ON)}$  | -    | 0.317 | 0.360 | $\Omega$ | $V_{GS} = 10V, I_D = 2.7A$        |

**■ Dynamic Characteristics ( $T_c=25^\circ\text{C}$  unless otherwise specified)**

| Parameter                                                 | Symbol       | Min. | Typ. | Max. | Unit     | Test Condition                                          |
|-----------------------------------------------------------|--------------|------|------|------|----------|---------------------------------------------------------|
| Input capacitance                                         | $C_{iss}$    | -    | 608  | -    | pF       | $V_{DS} = 400V, V_{GS} = 0V, f = 250kHz$                |
| Output capacitance                                        | $C_{oss}$    | -    | 15   | -    |          |                                                         |
| Reverse transfer capacitance                              | $C_{rss}$    | -    | 1.8  | -    |          |                                                         |
| Effective output capacitance energy related <sup>5)</sup> | $C_{o(er)}$  | -    | 25.3 | -    |          | $V_{DS} = 0V \text{ to } 400V, V_{GS} = 0V, f = 250kHz$ |
| Effective output capacitance time related <sup>6)</sup>   | $C_{o(tr)}$  | -    | 173  | -    |          | $V_{DS} = 0V \text{ to } 400V, V_{GS} = 0V, f = 250kHz$ |
| Turn-on delay time                                        | $t_{d(on)}$  | -    | 14.2 | -    | ns       | $V_{GS} = 10V, R_G = 25\Omega, V_{DD} = 300V, I_D = 9A$ |
| Rise time                                                 | $t_r$        | -    | 20.4 | -    |          |                                                         |
| Turn-off delay time                                       | $t_{d(off)}$ | -    | 48.6 | -    |          |                                                         |
| Fall time                                                 | $t_f$        | -    | 21.0 | -    |          |                                                         |
| Total gate charge                                         | $Q_g$        | -    | 13.6 | -    | nC       | $V_{GS} = 10V, V_{DD} = 400V, I_D = 2.7A$               |
| Gate-source charge                                        | $Q_{gs}$     | -    | 3.0  | -    |          |                                                         |
| Gate-drain charge                                         | $Q_{gd}$     | -    | 6.0  | -    |          |                                                         |
| Gate resistance                                           | $R_G$        | -    | 15.0 | -    | $\Omega$ | $V_{GS} = 0V, f = 1MHz$                                 |

5)  $C_{o(er)}$  is a capacitance that gives the same stored energy as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 400V

6)  $C_{o(tr)}$  is a capacitance that gives the same charging time as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 400V

**■ Reverse Diode Characteristics ( $T_c=25^{\circ}\text{C}$  unless otherwise specified)**

| Parameter                | Symbol    | Min. | Typ. | Max. | Unit          | Test Condition                                                                        |
|--------------------------|-----------|------|------|------|---------------|---------------------------------------------------------------------------------------|
| Diode forward voltage    | $V_{SD}$  | -    | -    | 1.4  | V             | $I_{SD} = 2.7\text{A}$ , $V_{GS} = 0\text{V}$                                         |
| Reverse recovery time    | $t_{rr}$  | -    | 156  | -    | ns            | $I_{SD} = 2.7\text{A}$<br>$di/dt = 100\text{A}/\mu\text{s}$<br>$V_{DD} = 400\text{V}$ |
| Reverse recovery charge  | $Q_{rr}$  | -    | 0.9  | -    | $\mu\text{C}$ |                                                                                       |
| Reverse recovery current | $I_{rrm}$ | -    | 11.7 | -    | A             |                                                                                       |

## ■ Characteristic graph

Fig.1 On-region characteristics.

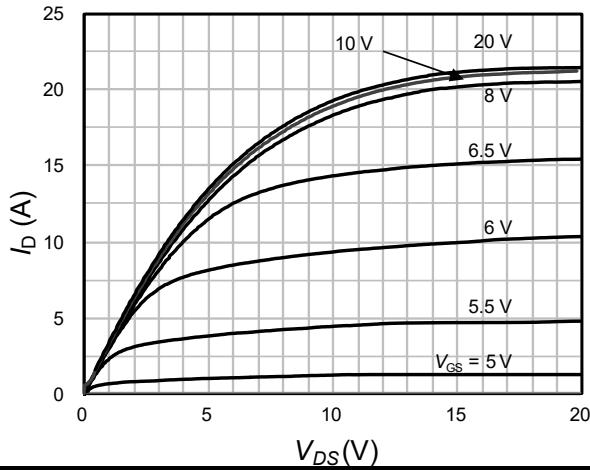


Fig.2 On-resistance variation with drain current

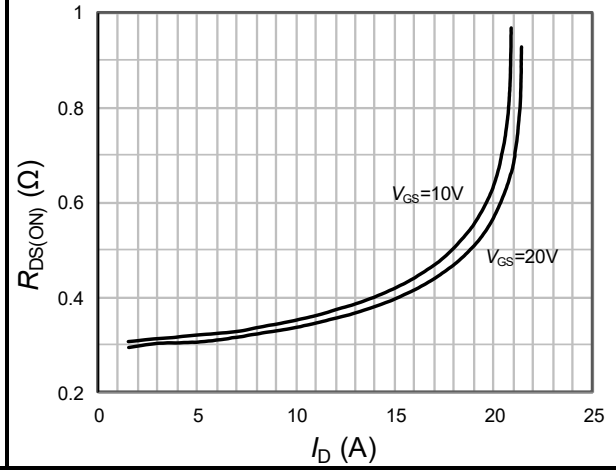


Fig.3 On-resistance variation with junction temperature (normalized)

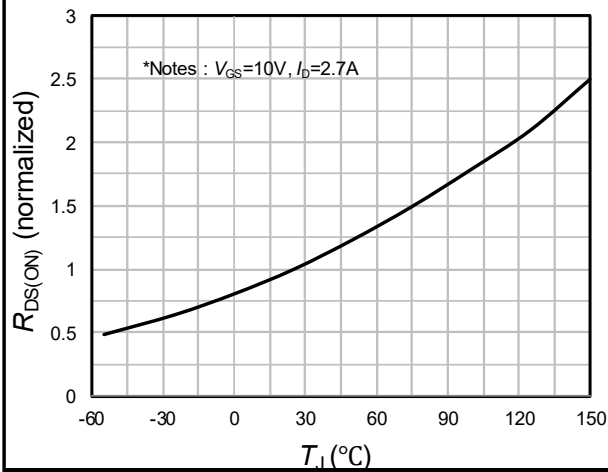


Fig.4 Breakdown voltage variation with temperature (normalized)

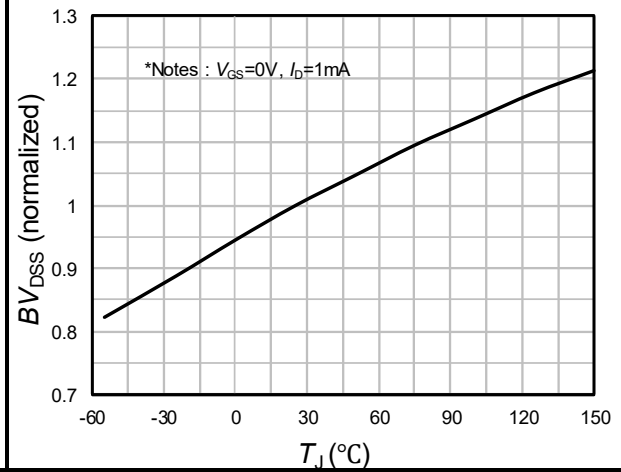


Fig.5 Transfer characteristics

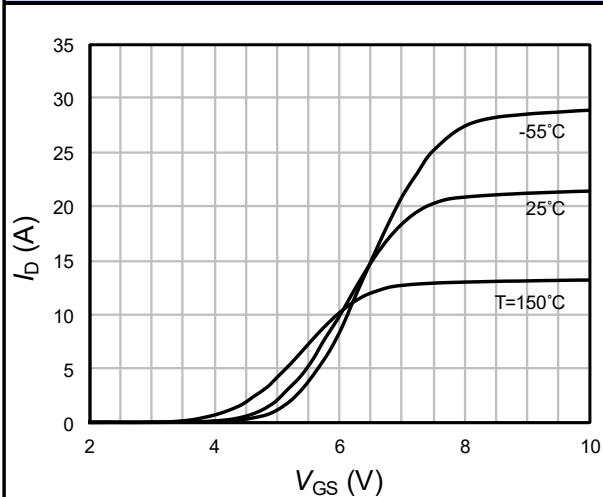
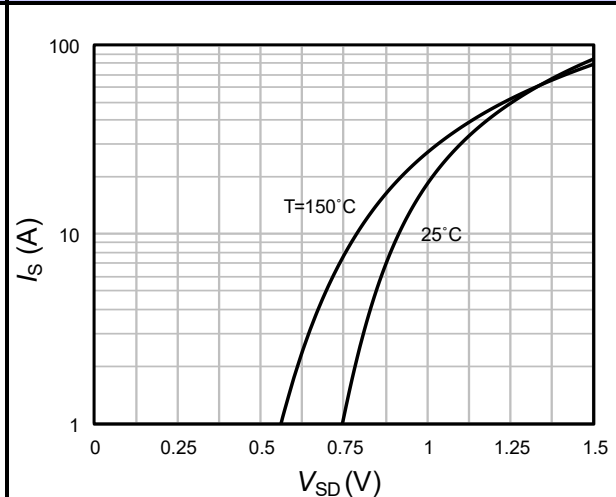
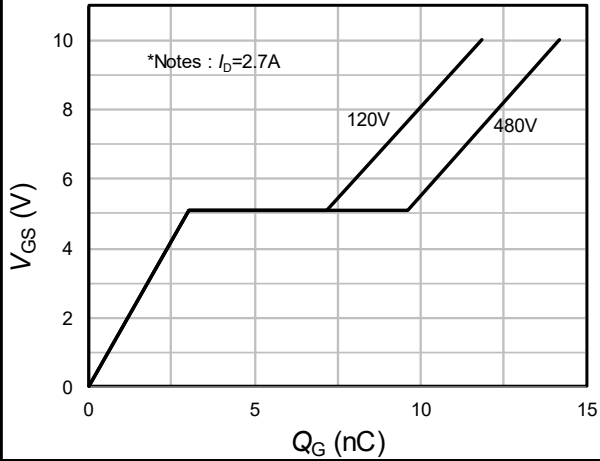
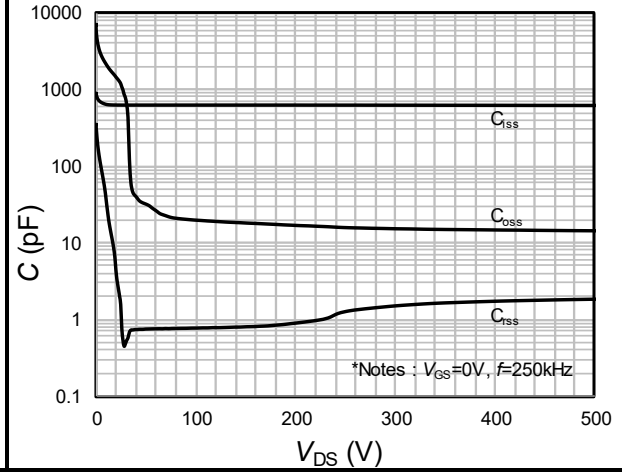
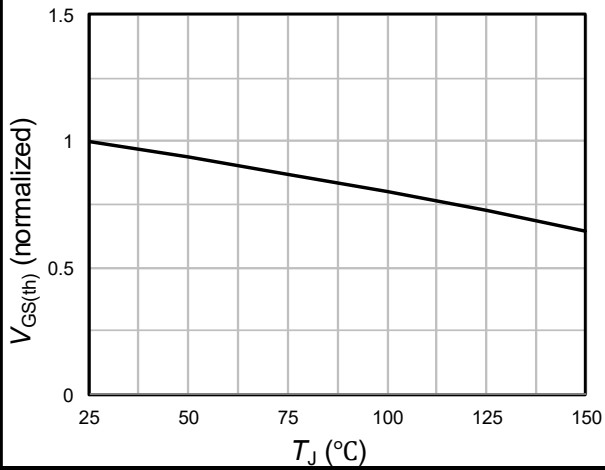
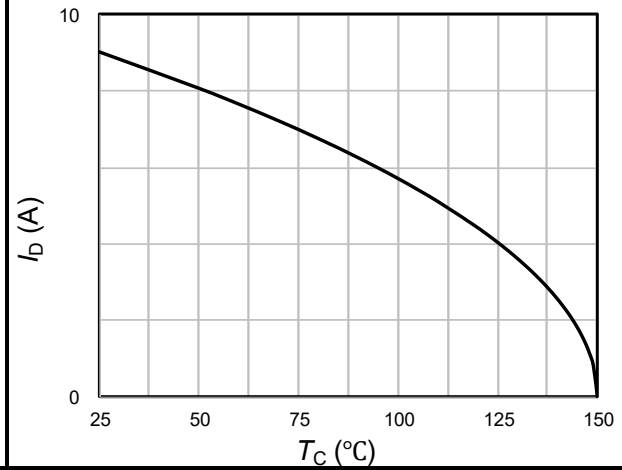
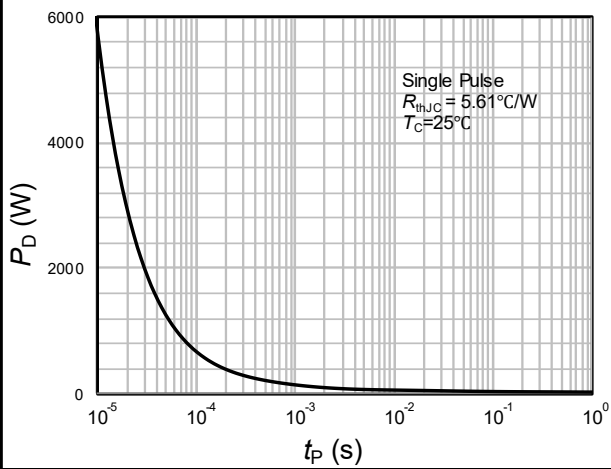
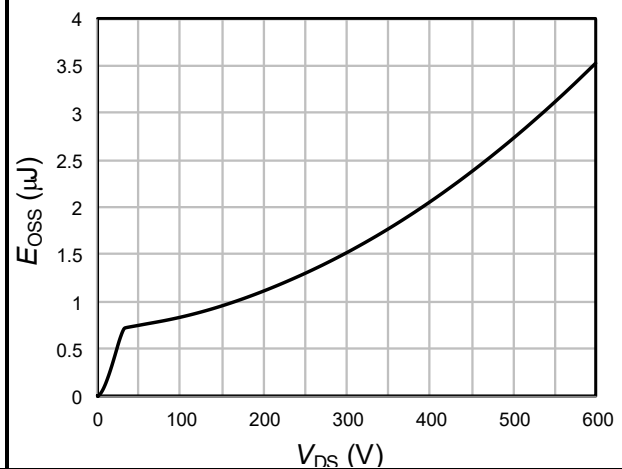
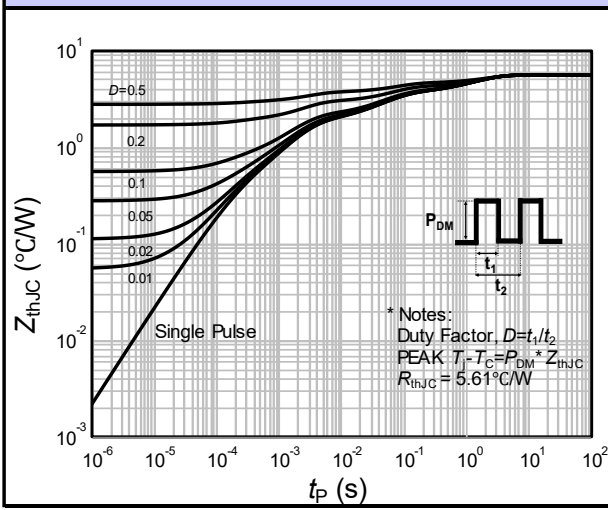
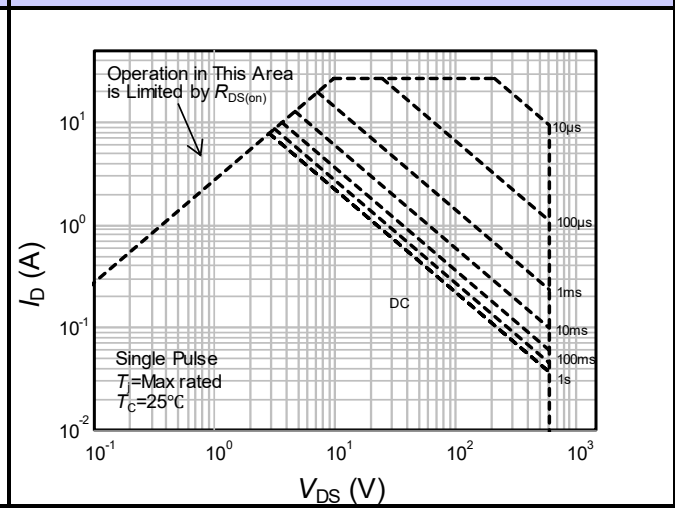


Fig.6 Diode forward characteristics



**Fig.7 Gate charge characteristics**

**Fig.8 Capacitance characteristics**

**Fig.9 Threshold voltage variation with junction temperature**

**Fig.10 Drain current**

**Fig.11 Power dissipation variation with pulse time**

**Fig.12 Output capacitance stored energy**


**Fig.13 Transient thermal response**

**Fig.14 Safe operating area**


## ■ Test Circuit

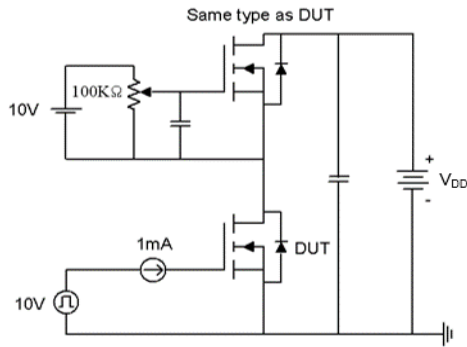


Fig15-1. Gate charge measurement circuit

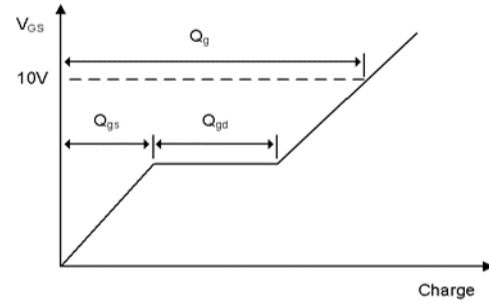


Fig15-2. Gate charge waveform

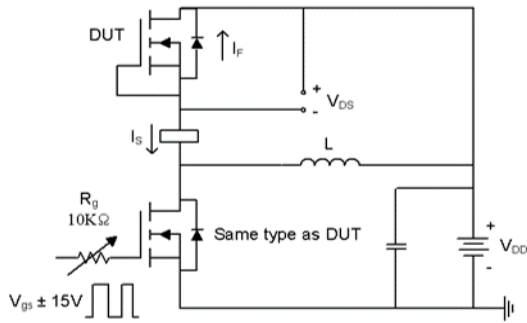


Fig16-1. Diode reverse recovery test circuit

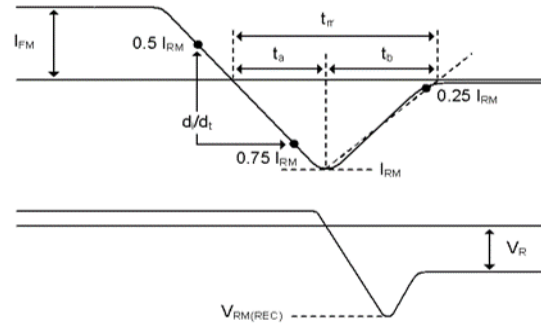


Fig16-2. Diode reverse recovery test waveform

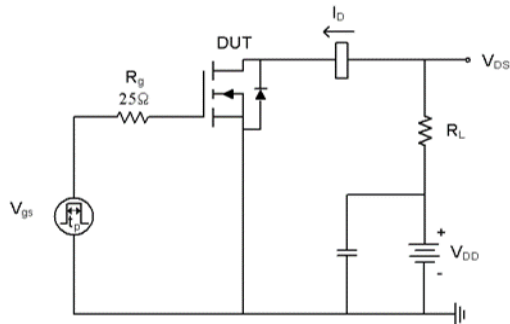


Fig17-1. Switching time test circuit for resistive load

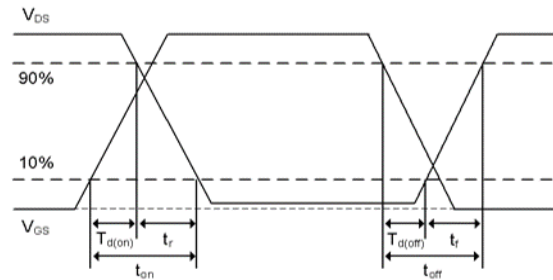


Fig17-2. Switching time waveform

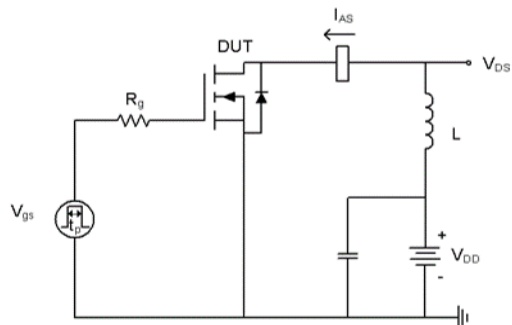


Fig18-1. Unclamped inductive load test circuit

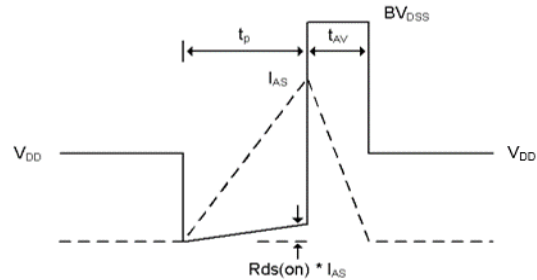
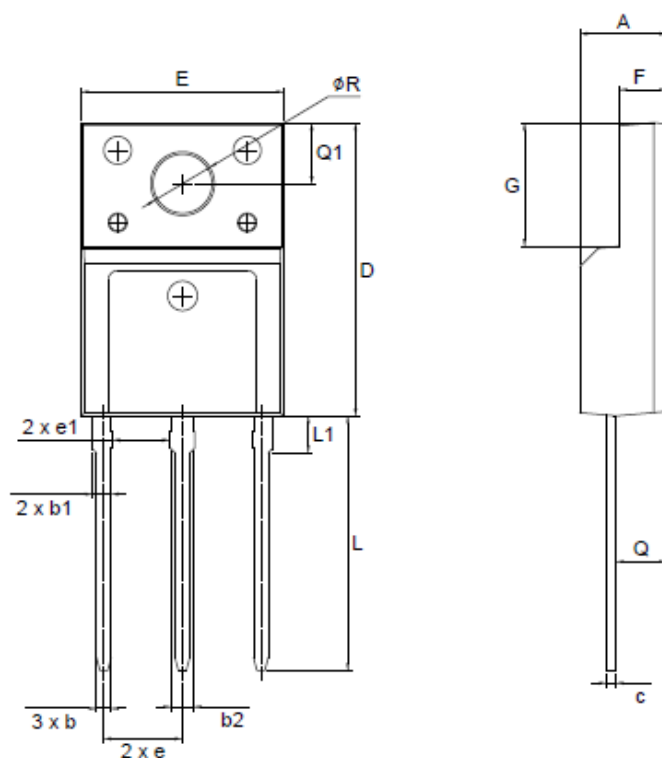


Fig18-2. Unclamped inductive waveform

## ■ Physical Dimension

### TO-220SFA (3L)



**Note :** Package body size, length and width do not include mold flash, protrusions and gate burrs.

| Symbol | Dimension [mm] |     |       |
|--------|----------------|-----|-------|
|        | Min            | Nom | Max   |
| A      | 4.5            | -   | 4.9   |
| b      | 0.7            | -   | 0.9   |
| b1     | 0.9            | -   | 1.3   |
| b2     | 1.0            | -   | 1.4   |
| c      | 0.45           | -   | 0.60  |
| D      | 15.67          | -   | 16.07 |
| E      | 10.8           |     | 11.2  |
| e      | 4.25 BSC       |     |       |
| e1     | 3.0            | -   | -     |
| F      | 2.34           | -   | 2.74  |
| G      | 6.48           | -   | 6.88  |
| L      | 13.58          | -   | 13.98 |
| L1     | 1.8            | -   | 2.20  |
| Q      | 2.65           | -   | -     |
| Q1     | 3.20           | -   | 3.40  |
| ΦR     | 3.08           | -   | 3.28  |
| θ      | 3° Ref         |     |       |

**DISCLAIMER:**

The Products are not designed for use in hostile environments, including, without limitation, aircraft, nuclear power generation, medical appliances, and devices or systems in which malfunction of any Product can reasonably be expected to result in a personal injury. Seller's customers using or selling Seller's products for use in such applications do so at their own risk and agree to fully defend and indemnify Seller.

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