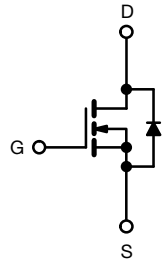
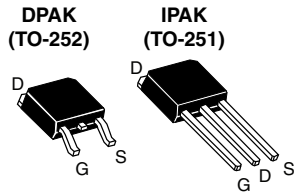




Power MOSFET



N-Channel MOSFET

FEATURES

- Low gate charge Q_g results in simple drive requirement
- Improved gate, avalanche and dynamic dV/dt ruggedness
- Fully characterized capacitance and avalanche voltage and current
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912



RoHS
COMPLIANT
HALOGEN
FREE
Available

APPLICATIONS

- Switch mode power supply (SMPS)
- Uninterruptible power supply
- Power factor correction

TYPICAL SMPS TOPOLOGIES

- Low power single transistor flyback

| PRODUCT SUMMARY | |
|--------------------------------|------------------------------|
| V_{DS} (V) | 600 |
| $R_{DS(on)}$ max. (Ω) | $V_{GS} = 10\text{ V}$ 7.0 |
| Q_g max. (nC) | 14 |
| Q_{gs} (nC) | 2.7 |
| Q_{gd} (nC) | 8.1 |
| Configuration | Single |

| ORDERING INFORMATION | | | | |
|---------------------------------|--------------------------------|----------------------------------|--------------------------------|----------------|
| Package | IPAK (TO-251) | IPAK (TO-251) | IPAK (TO-251) | IPAK (TO-251) |
| Lead (Pb)-free and halogen-free | SiHFR1N60A-GE3 | SiHFR1N60ATRL-GE3 ^a | SiHFR1N60ATR-GE3 ^a | SiHFU1N60A-GE3 |
| | IRFR1N60APbF-BE3 ^{ab} | IRFR1N60ATRPbF-BE3 ^{ab} | SiHFR1N60ATRR-GE3 ^a | - |
| Lead (Pb)-free | IRFR1N60APbF | IRFR1N60ATRLPbF ^a | IRFR1N60ATRPbF ^a | IRFU1N60APbF |

Notes

- See device orientation
- “-BE3” denotes alternate manufacturing location

| ABSOLUTE MAXIMUM RATINGS ($T_C = 25\text{ }^\circ\text{C}$, unless otherwise noted) | | | | | |
|---|----------------------------------|-----------------------------------|-------------|---------------------|---|
| PARAMETER | SYMBOL | | LIMIT | UNIT | |
| Drain-source voltage | V_{DS} | | 600 | V | |
| Gate-source voltage | V_{GS} | | ± 30 | | |
| Continuous drain current | V_{GS} at 10 V | $T_C = 25\text{ }^\circ\text{C}$ | 1.4 | A | |
| | | $T_C = 100\text{ }^\circ\text{C}$ | 0.89 | | |
| Pulsed drain current ^a | I_{DM} | | 5.6 | | |
| Linear derating factor | | | 0.28 | W/ $^\circ\text{C}$ | |
| Single pulse avalanche energy ^b | E_{AS} | | 93 | mJ | |
| Repetitive avalanche current ^a | I_{AR} | | 1.4 | A | |
| Repetitive avalanche energy ^a | E_{AR} | | 3.6 | mJ | |
| Maximum power dissipation | $T_A = 25\text{ }^\circ\text{C}$ | | P_D | 36 | W |
| Peak diode recovery dV/dt ^c | dV/dt | | 3.8 | V/ns | |
| Operating junction and storage temperature range | T_J, T_{stg} | | -55 to +150 | $^\circ\text{C}$ | |
| Soldering recommendations (peak temperature) ^d | for 10 s | | 300 | | |

Notes


- Repetitive rating; pulse width limited by maximum junction temperature (see fig. 11)
- Starting $T_J = 25\text{ }^\circ\text{C}$, $L = 95\text{ mH}$, $R_g = 25\text{ }^\circ\Omega$, $I_{AS} = 1.4\text{ A}$ (see fig. 12)
- $I_{SD} \leq 1.4\text{ A}$, $dI/dt \leq 180\text{ A}/\mu\text{s}$, $V_{DD} \leq V_{DS}$, $T_J \leq 150\text{ }^\circ\text{C}$
- 1.6 mm from case



| THERMAL RESISTANCE RATINGS | | | | |
|--|------------|------|------|------|
| PARAMETER | SYMBOL | TYP. | MAX. | UNIT |
| Maximum junction-to-ambient | R_{thJA} | - | 110 | °C/W |
| Maximum junction-to-ambient (PCB mount) ^a | R_{thJA} | - | 50 | |
| Maximum junction-to-case (drain) | R_{thJC} | - | 3.5 | |

Note

a. When mounted on 1" square PCB (FR-4 or G-10 material)

| SPECIFICATIONS ($T_J = 25\text{ }^\circ\text{C}$, unless otherwise noted) | | | | | | | |
|---|--------------|---|--|---|-----------|---------------|----|
| PARAMETER | SYMBOL | TEST CONDITIONS | MIN. | TYP. | MAX. | UNIT | |
| Static | | | | | | | |
| Drain-source breakdown voltage | V_{DS} | $V_{GS} = 0\text{ V}, I_D = 250\text{ }\mu\text{A}$ | 600 | - | - | V | |
| V_{DS} temperature coefficient | $V_{GS(th)}$ | $V_{DS} = V_{GS}, I_D = 250\text{ }\mu\text{A}$ | 2.0 | - | 4.0 | | |
| Gate-source threshold voltage | I_{GSS} | $V_{GS} = \pm 30\text{ V}$ | - | - | ± 100 | nA | |
| Gate-source leakage | I_{DSS} | $V_{DS} = 600\text{ V}, V_{GS} = 0\text{ V}$ | - | - | 25 | μA | |
| Zero gate voltage drain current | | $V_{DS} = 480\text{ V}, V_{GS} = 0\text{ V}, T_J = 150\text{ }^\circ\text{C}$ | - | - | 250 | | |
| Drain-source on-state resistance | $R_{DS(on)}$ | $V_{GS} = 10\text{ V}, I_D = 0.84\text{ A}^b$ | - | - | 7.0 | Ω | |
| Drain-source on-state resistance | g_{fs} | $V_{DS} = 50\text{ V}, I_D = 0.84\text{ A}$ | 0.88 | - | - | S | |
| Dynamic | | | | | | | |
| Input capacitance | C_{iss} | $V_{GS} = 0\text{ V}, V_{DS} = 25\text{ V}, f = 1.0\text{ MHz}$, see fig. 5 | - | 229 | - | pF | |
| Output capacitance | C_{oss} | | - | 32.6 | - | | |
| Reverse transfer capacitance | C_{rss} | | - | 2.4 | - | | |
| Output capacitance | C_{oss} | $V_{GS} = 0\text{ V}$ | $V_{DS} = 1.0\text{ V}, f = 1.0\text{ MHz}$ | - | 320 | - | |
| Effective output capacitance | | | $C_{oss\text{ eff.}}$ | $V_{DS} = 480\text{ V}, f = 1.0\text{ MHz}$ | - | 11.5 | - |
| Total gate charge | Q_g | $V_{GS} = 10\text{ V}$ | $I_D = 1.4\text{ A}, V_{DS} = 400\text{ V}$, see fig. 6 and 13 ^b | - | - | 14 | nC |
| Gate-source charge | Q_{gs} | | | - | - | 2.7 | |
| Gate-drain charge | Q_{gd} | | | - | - | 8.1 | |
| Turn-on delay time | $t_{d(on)}$ | $V_{DD} = 250\text{ V}, I_D = 1.4\text{ A}, R_g = 2.15\text{ }\Omega, R_D = 178\text{ }\Omega$, see fig. 10 ^b | - | 9.8 | - | ns | |
| Rise time | t_r | | - | 14 | - | | |
| Turn-off delay time | $t_{d(off)}$ | | - | 18 | - | | |
| Fall time | t_f | | - | 20 | - | | |
| Drain-source body diode characteristics | | | | | | | |
| Continuous source-drain diode current | I_S | MOSFET symbol showing the integral reverse p - n junction diode  | - | - | 1.4 | A | |
| Pulsed diode forward current ^a | I_{SM} | | - | - | 5.6 | | |
| Body diode voltage | V_{SD} | $T_J = 25\text{ }^\circ\text{C}, I_S = 1.4\text{ A}, V_{GS} = 0\text{ V}^b$ | - | - | 1.6 | V | |
| Body diode reverse recovery time | t_{rr} | $T_J = 25\text{ }^\circ\text{C}, I_F = 1.4\text{ A}, dI/dt = 100\text{ A}/\mu\text{s}^b$ | - | 290 | 440 | ns | |
| Body diode reverse recovery charge | Q_{rr} | | - | 510 | 760 | μC | |
| Forward turn-on time | t_{on} | Intrinsic turn-on time is negligible (turn-on is dominated by L_S and L_D) | | | | | |

Notes

- a. Repetitive rating; pulse width limited by maximum junction temperature (see fig. 11)
- b. Pulse width $\leq 300\text{ }\mu\text{s}$; duty cycle $\leq 2\%$
- c. $C_{oss\text{ eff.}}$ is a fixed capacitance that gives the same charging time as C_{oss} while V_{DS} is rising from 0 to 80 % V_{DS}



TYPICAL CHARACTERISTICS (25 °C, unless otherwise noted)

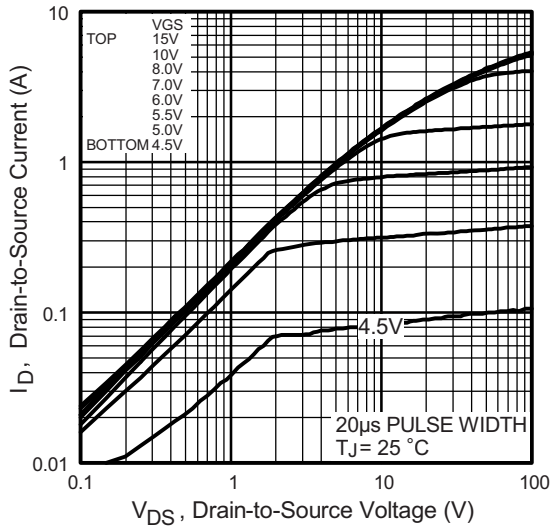


Fig. 1 - Typical Output Characteristics

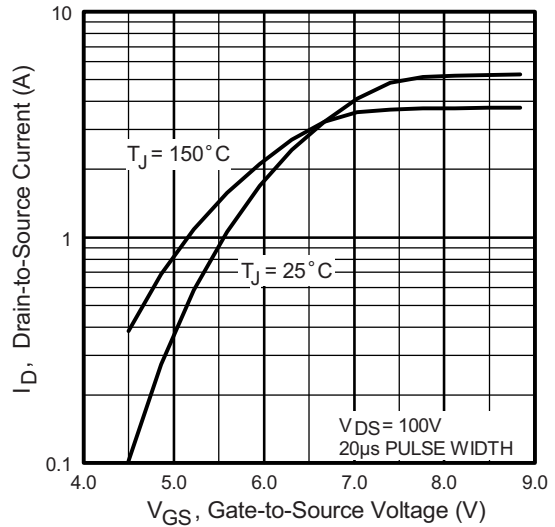


Fig. 2 - Typical Transfer Characteristics

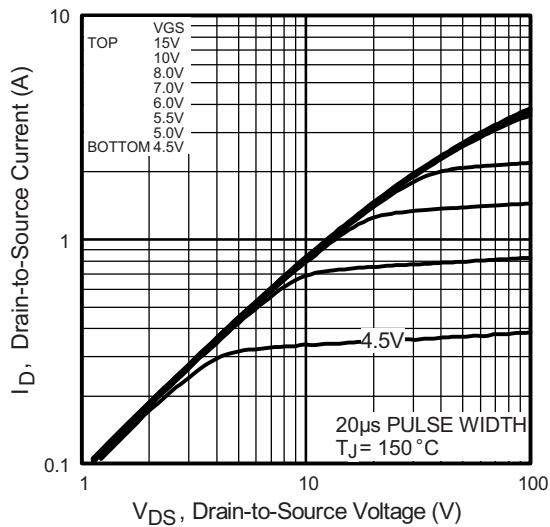


Fig. 1 - Typical Output Characteristics

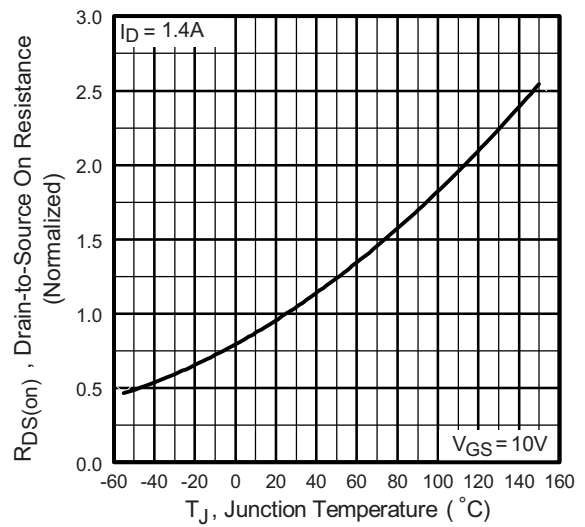


Fig. 3 - Normalized On-Resistance vs. Temperature

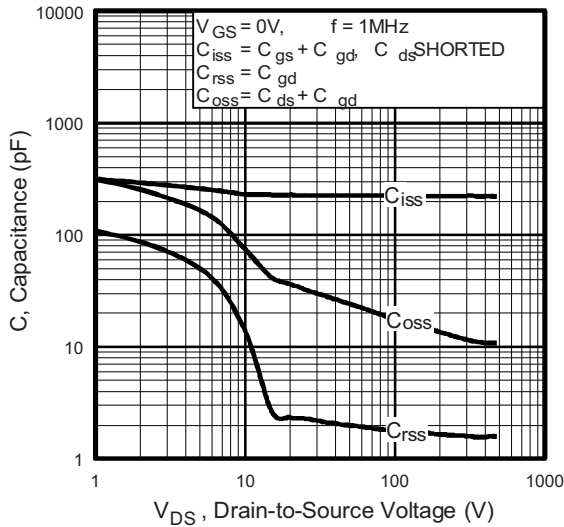


Fig. 4 - Typical Capacitance vs. Drain-to-Source Voltage

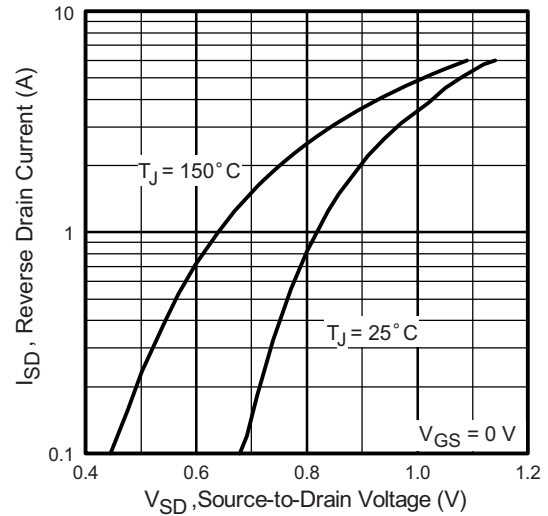


Fig. 6 - Typical Source-Drain Diode Forward Voltage

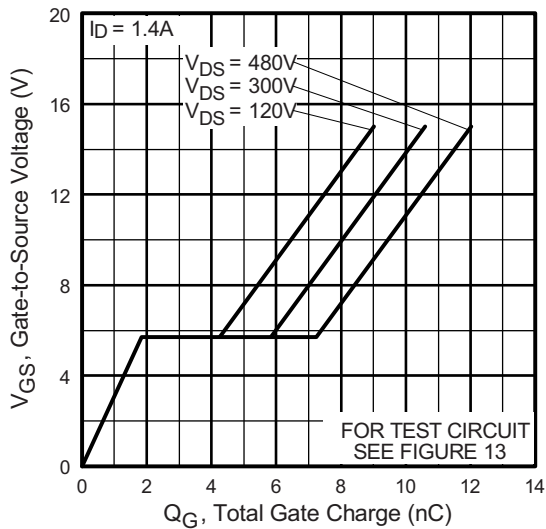


Fig. 5 - Typical Gate Charge vs. Gate-to-Source Voltage

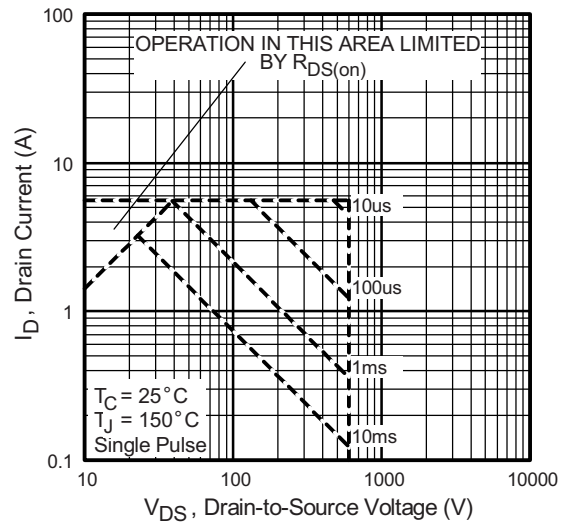


Fig. 7 - Maximum Safe Operating Area

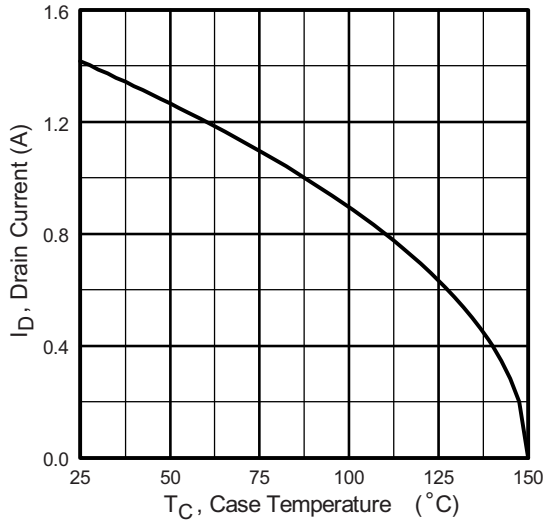


Fig. 8 - Maximum Drain Current vs. Case Temperature

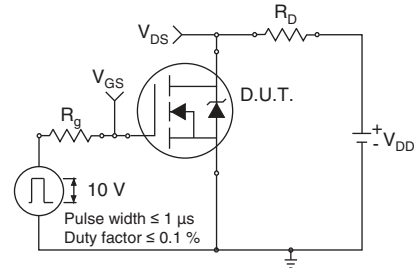


Fig. 10a - Switching Time Test Circuit

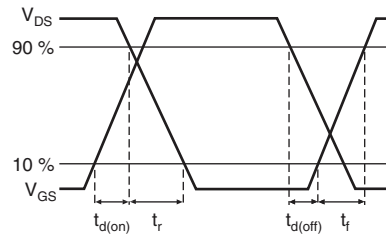


Fig. 10b - Switching Time Waveforms

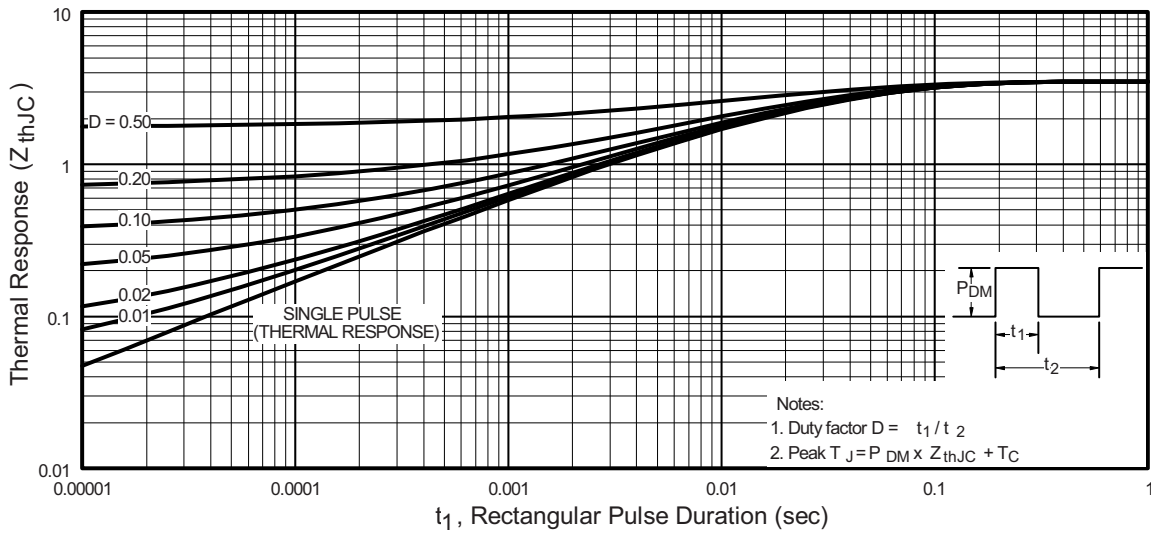


Fig. 9 - Maximum Effective Transient Thermal Impedance, Junction-to-Case

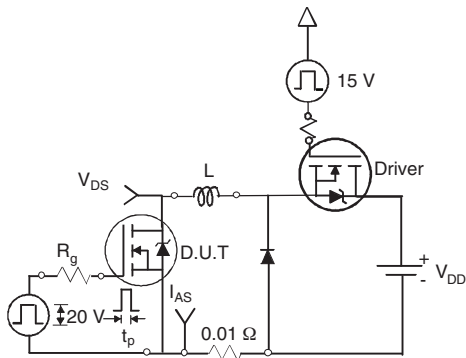


Fig. 12a - Unclamped Inductive Test Circuit

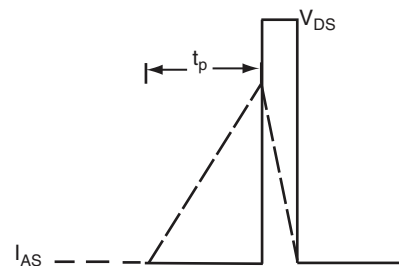


Fig. 12b - Unclamped Inductive Waveforms

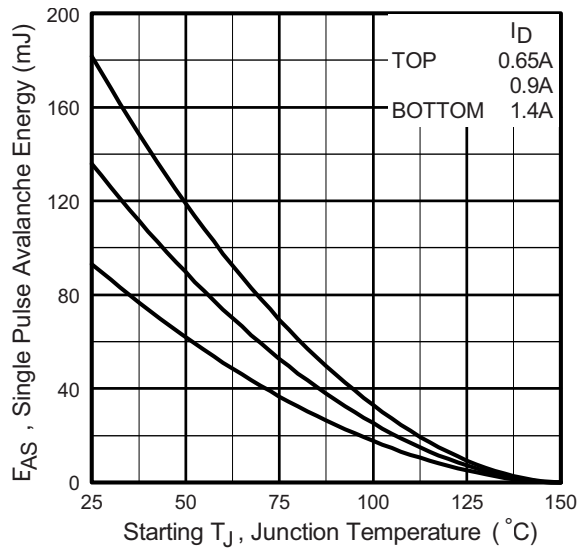


Fig. 12c - Maximum Avalanche Energy vs. Drain Current

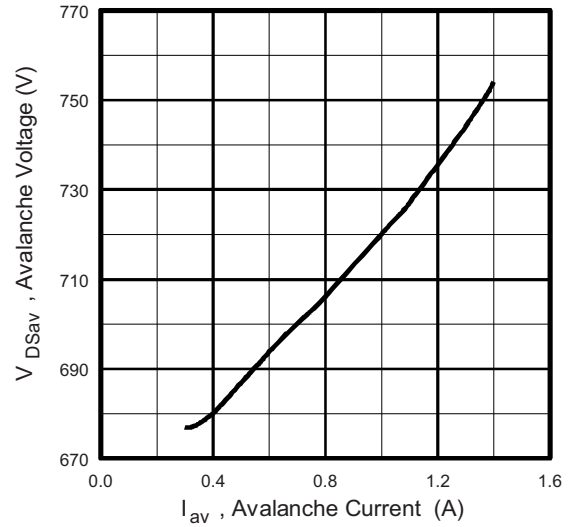


Fig. 12d - Basic Gate Charge Waveform

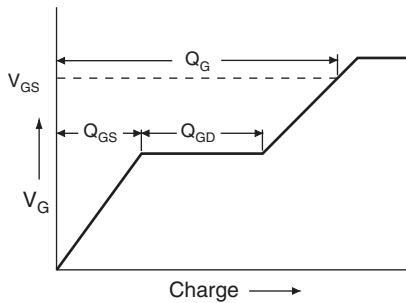


Fig. 13a - Maximum Avalanche Energy vs. Drain Current

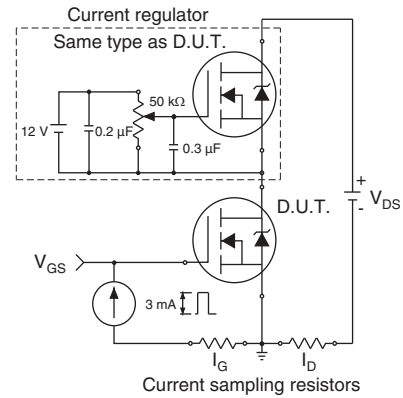
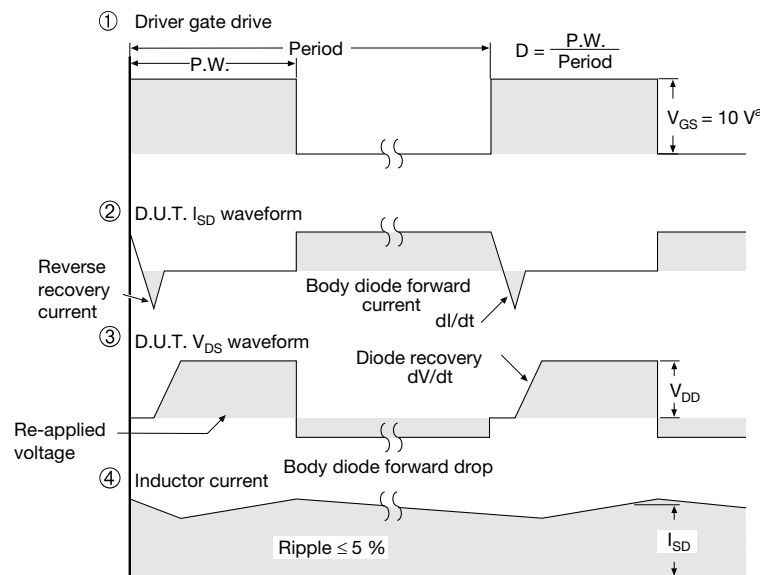
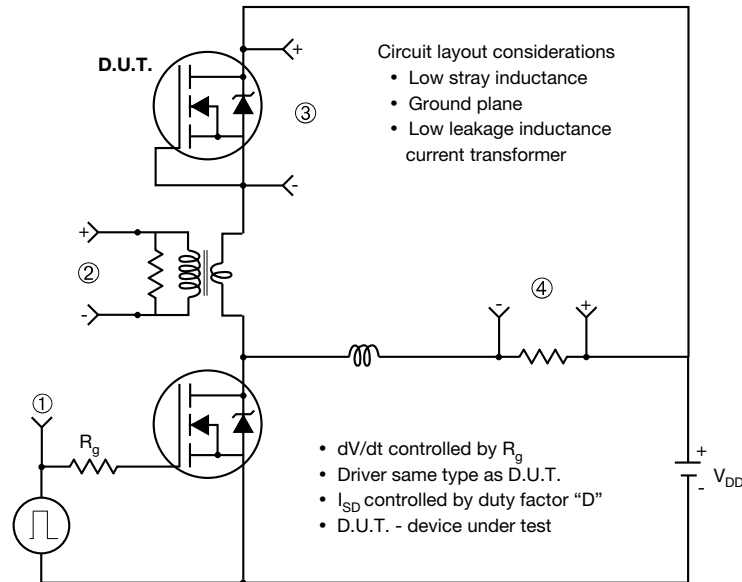


Fig. 13b - Gate Charge Test Circuit

Peak Diode Recovery dV/dt Test Circuit



Note

a. $V_{GS} = 5 V$ for logic level devices

Fig. 10 - For N-Channel

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TO-252AA Case Outline

VERSION 1: FACILITY CODE = Y



| DIM. | MILLIMETERS | |
|------|-------------|-------|
| | MIN. | MAX. |
| A | 2.18 | 2.38 |
| A1 | - | 0.127 |
| b | 0.64 | 0.88 |
| b2 | 0.76 | 1.14 |
| b3 | 4.95 | 5.46 |
| C | 0.46 | 0.61 |
| C2 | 0.46 | 0.89 |
| D | 5.97 | 6.22 |
| D1 | 4.10 | - |
| E | 6.35 | 6.73 |
| E1 | 4.32 | - |
| H | 9.40 | 10.41 |
| e | 2.28 BSC | |
| e1 | 4.56 BSC | |
| L | 1.40 | 1.78 |
| L3 | 0.89 | 1.27 |
| L4 | - | 1.02 |
| L5 | 1.01 | 1.52 |

Note

- Dimension L3 is for reference only



VERSION 2: FACILITY CODE = N



| DIM. | MILLIMETERS | |
|------|-------------|-------|
| | MIN. | MAX. |
| A | 2.18 | 2.39 |
| A1 | - | 0.13 |
| b | 0.65 | 0.89 |
| b1 | 0.64 | 0.79 |
| b2 | 0.76 | 1.13 |
| b3 | 4.95 | 5.46 |
| c | 0.46 | 0.61 |
| c1 | 0.41 | 0.56 |
| c2 | 0.46 | 0.60 |
| D | 5.97 | 6.22 |
| D1 | 5.21 | - |
| E | 6.35 | 6.73 |
| E1 | 4.32 | - |
| e | 2.29 BSC | |
| H | 9.94 | 10.34 |

| DIM. | MILLIMETERS | |
|------|-------------|------|
| | MIN. | MAX. |
| L | 1.50 | 1.78 |
| L1 | 2.74 ref. | |
| L2 | 0.51 BSC | |
| L3 | 0.89 | 1.27 |
| L4 | - | 1.02 |
| L5 | 1.14 | 1.49 |
| L6 | 0.65 | 0.85 |
| θ | 0° | 10° |
| θ1 | 0° | 15° |
| θ2 | 25° | 35° |

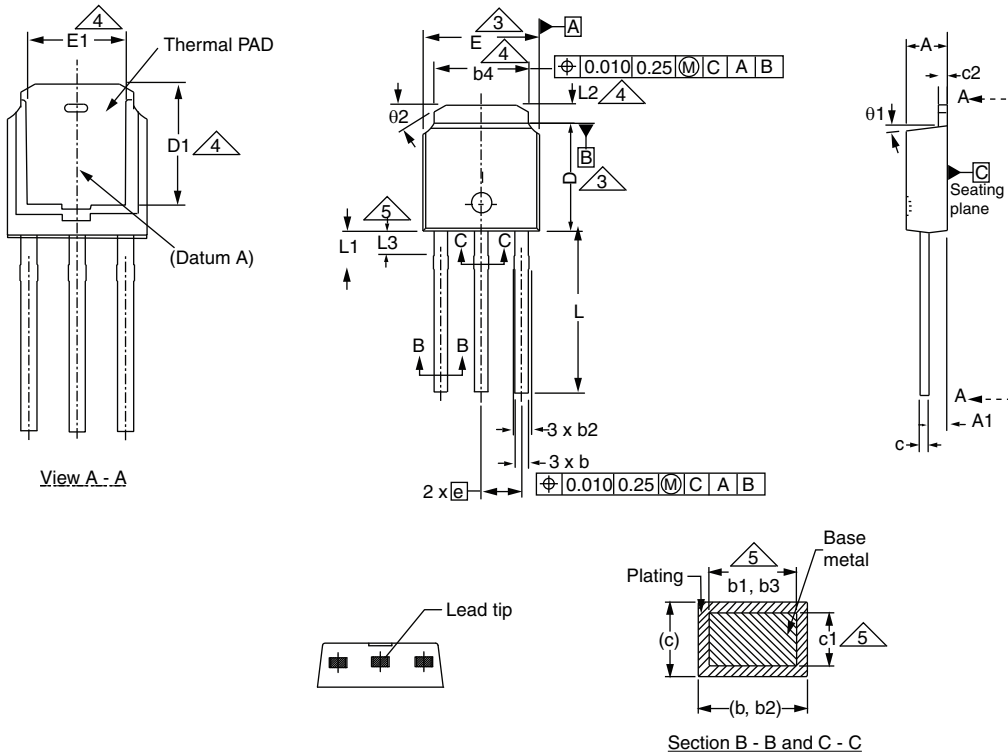
Notes

- Dimensioning and tolerance confirm to ASME Y14.5M-1994
- All dimensions are in millimeters. Angles are in degrees
- Heat sink side flash is max. 0.8 mm
- Radius on terminal is optional

ECN: E22-0399-Rev. R, 03-Oct-2022
 DWG: 5347

Case Outline for TO-251AA (High Voltage)

OPTION 1:



| DIM. | MILLIMETERS | | INCHES | |
|------|-------------|------|--------|-------|
| | MIN. | MAX. | MIN. | MAX. |
| A | 2.18 | 2.39 | 0.086 | 0.094 |
| A1 | 0.89 | 1.14 | 0.035 | 0.045 |
| b | 0.64 | 0.89 | 0.025 | 0.035 |
| b1 | 0.65 | 0.79 | 0.026 | 0.031 |
| b2 | 0.76 | 1.14 | 0.030 | 0.045 |
| b3 | 0.76 | 1.04 | 0.030 | 0.041 |
| b4 | 4.95 | 5.46 | 0.195 | 0.215 |
| c | 0.46 | 0.61 | 0.018 | 0.024 |
| c1 | 0.41 | 0.56 | 0.016 | 0.022 |
| c2 | 0.46 | 0.86 | 0.018 | 0.034 |
| D | 5.97 | 6.22 | 0.235 | 0.245 |

| DIM. | MILLIMETERS | | INCHES | |
|------|-------------|------|----------|-------|
| | MIN. | MAX. | MIN. | MAX. |
| D1 | 5.21 | - | 0.205 | - |
| E | 6.35 | 6.73 | 0.250 | 0.265 |
| E1 | 4.32 | - | 0.170 | - |
| e | 2.29 BSC | | 2.29 BSC | |
| L | 8.89 | 9.65 | 0.350 | 0.380 |
| L1 | 1.91 | 2.29 | 0.075 | 0.090 |
| L2 | 0.89 | 1.27 | 0.035 | 0.050 |
| L3 | 1.14 | 1.52 | 0.045 | 0.060 |
| θ1 | 0° | 15° | 0° | 15° |
| θ2 | 25° | 35° | 25° | 35° |

ECN: E21-0682-Rev. C, 27-Dec-2021
DWG: 5968

Notes

- Dimensioning and tolerancing per ASME Y14.5M-1994
- Dimension are shown in inches and millimeters
- Dimension D and E do not include mold flash. Mold flash shall not exceed 0.13 mm (0.005") per side. These dimensions are measured at the outermost extremes of the plastic body
- Thermal pad contour optional with dimensions b4, L2, E1 and D1
- Lead dimension uncontrolled in L3
- Dimension b1, b3 and c1 apply to base metal only
- Outline conforms to JEDEC® outline TO-251AA



OPTION 2: FACILITY CODE = N



| DIM. | MIN. | NOM. | MAX. |
|------|-------|-------|-------|
| A | 2.180 | 2.285 | 2.390 |
| A1 | 0.890 | 1.015 | 1.140 |
| b | 0.640 | 0.765 | 0.890 |
| b1 | 0.640 | 0.715 | 0.790 |
| b2 | 0.760 | 0.950 | 1.140 |
| b3 | 0.760 | 0.900 | 1.040 |
| b4 | 4.950 | 5.205 | 5.460 |
| c | 0.460 | - | 0.610 |
| c1 | 0.410 | - | 0.560 |
| c2 | 0.460 | - | 0.610 |
| D | 5.970 | 6.095 | 6.220 |
| D1 | 4.300 | - | - |

| DIM. | MIN. | NOM. | MAX. |
|---------|----------|-------|-------|
| D2 | 5.380 | - | - |
| E | 6.350 | 6.540 | 6.730 |
| E1 | 4.32 | - | - |
| e | 2.29 BSC | | |
| L | 8.890 | 9.270 | 9.650 |
| L1 | 1.910 | 2.100 | 2.290 |
| L2 | 0.890 | 1.080 | 1.270 |
| L3 | 1.140 | 1.330 | 1.520 |
| L4 | 1.300 | 1.400 | 1.500 |
| theta 1 | 0° | 7.5° | 15° |
| theta 2 | 4° | - | - |

ECN: E21-0682-Rev. C, 27-Dec-2021
 DWG: 5968

Notes

- Dimensioning and tolerancing per ASME Y14.5M-1994
- All dimension are in millimeters, angles are in degrees
- Heat sink side flash is max. 0.8 mm

RECOMMENDED MINIMUM PADS FOR DPAK (TO-252)



Recommended Minimum Pads
Dimensions in Inches/(mm)

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