

## N-Channel 650 V (D-S)MOSFET

### PRODUCT SUMMARY

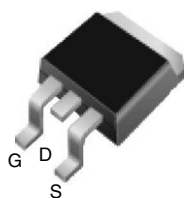
|                           |                        |     |
|---------------------------|------------------------|-----|
| $V_{DS}$ (V)              | 650                    |     |
| $R_{DS(on)}$ ( $\Omega$ ) | $V_{GS} = 10\text{ V}$ | 2.1 |
| $Q_g$ (Max.) (nC)         | 48                     |     |
| $Q_{gs}$ (nC)             | 12                     |     |
| $Q_{gd}$ (nC)             | 19                     |     |
| Configuration             | Single                 |     |

### 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
- Compliant to RoHS directive 2002/95/EC



Available

**RoHS**D<sup>2</sup>PAK (TO-263)

N-Channel MOSFET

### ABSOLUTE MAXIMUM RATINGS $T_C = 25\text{ }^\circ\text{C}$ , unless otherwise noted

| ABSOLUTE MAXIMUM RATINGS T <sub>C</sub> = 25 °C, unless otherwise noted |                         |                         |                                   |               |          |
|-------------------------------------------------------------------------|-------------------------|-------------------------|-----------------------------------|---------------|----------|
| PARAMETER                                                               |                         |                         | SYMBOL                            | LIMIT         | UNIT     |
| Drain-Source Voltage                                                    |                         |                         | V <sub>DS</sub>                   | 650           | V        |
| Gate-Source Voltage                                                     |                         |                         | V <sub>GS</sub>                   | ± 30          |          |
| Continuous Drain Current <sup>e</sup>                                   | V <sub>GS</sub> at 10 V | T <sub>C</sub> = 25 °C  | I <sub>D</sub>                    | 4.5           | A        |
| Continuous Drain Current                                                |                         | T <sub>C</sub> = 100 °C |                                   | 4.2           |          |
| Pulsed Drain Current <sup>a</sup>                                       |                         |                         | I <sub>DM</sub>                   | 18            |          |
| Linear Derating Factor                                                  |                         |                         |                                   | 0.48          | W/°C     |
| Single Pulse Avalanche Energy <sup>b</sup>                              |                         |                         | E <sub>AS</sub>                   | 325           | mJ       |
| Repetitive Avalanche Current <sup>a</sup>                               |                         |                         | I <sub>AR</sub>                   | 4             | A        |
| Repetitive Avalanche Energy <sup>a</sup>                                |                         |                         | E <sub>AR</sub>                   | 6             | mJ       |
| Maximum Power Dissipation                                               | T <sub>C</sub> = 25 °C  |                         | P <sub>D</sub>                    | 60            | W        |
| Peak Diode Recovery dV/dt <sup>c</sup>                                  |                         |                         | dV/dt                             | 2.8           | V/ns     |
| Operating Junction and Storage Temperature Range                        |                         |                         | T <sub>J</sub> , T <sub>stg</sub> | - 55 to + 150 | °C       |
| Soldering Recommendations (Peak Temperature) <sup>d</sup>               | for 10 s                |                         |                                   | 300           |          |
| Mounting Torque                                                         | 6-32 or M3 screw        |                         |                                   | 10            | lbf · in |
|                                                                         |                         |                         |                                   | 1.1           | N · m    |

#### Notes

- Repetitive rating; pulse width limited by maximum junction temperature (see fig. 11).
- Starting  $T_J = 25\text{ }^\circ\text{C}$ ,  $L = 24\text{ mH}$ ,  $R_G = 25\text{ }\Omega$ ,  $I_{AS} = 3.2\text{ A}$  (see fig. 12).
- $I_{SD} \leq 3.2\text{ A}$ ,  $dI/dt \leq 90\text{ A}/\mu\text{s}$ ,  $V_{DD} \leq V_{DS}$ ,  $T_J \leq 150\text{ }^\circ\text{C}$ .
- 1.6 mm from case.
- Drain current limited by maximum junction temperature.

**THERMAL RESISTANCE RATINGS**

| PARAMETER                        | SYMBOL     | TYP. | MAX. | UNIT |
|----------------------------------|------------|------|------|------|
| Maximum Junction-to-Ambient      | $R_{thJA}$ | -    | 65   | °C/W |
| Maximum Junction-to-Case (Drain) | $R_{thJC}$ | -    | 2.1  |      |

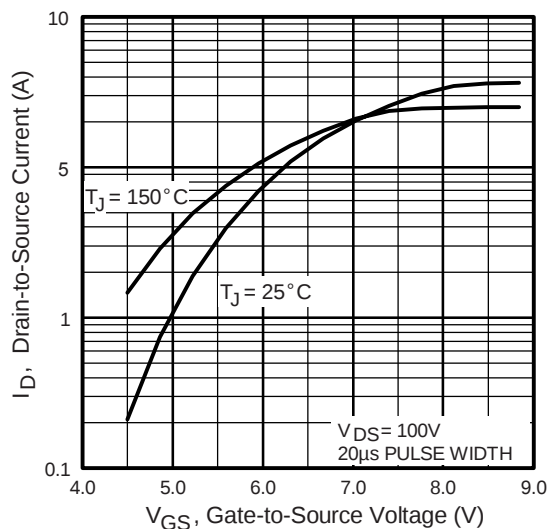
**SPECIFICATIONS**  $T_J = 25\text{ }^{\circ}\text{C}$ , unless otherwise noted

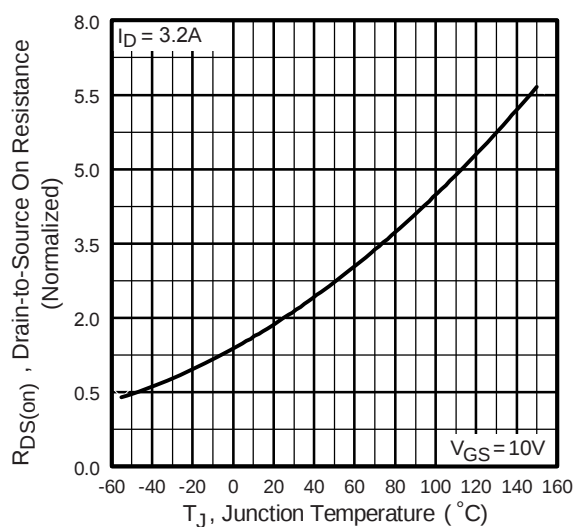
| PARAMETER                                 | SYMBOL                           | TEST CONDITIONS                                                                                                                                         |                                                                                   | MIN. | TYP. | MAX.  | UNIT  |
|-------------------------------------------|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|------|------|-------|-------|
| Static                                    |                                  |                                                                                                                                                         |                                                                                   |      |      |       |       |
| Drain-Source Breakdown Voltage            | V <sub>DS</sub>                  | V <sub>GS</sub> = 0 V, I <sub>D</sub> = 250 μA                                                                                                          |                                                                                   | 650  | -    | -     | V     |
| V <sub>DS</sub> Temperature Coefficient   | ΔV <sub>DS</sub> /T <sub>J</sub> | Reference to 25 °C, I <sub>D</sub> = 1 mA <sup>d</sup>                                                                                                  |                                                                                   | -    | 670  | -     | mV/°C |
| Gate-Source Threshold Voltage             | V <sub>GS(th)</sub>              | V <sub>DS</sub> = V <sub>GS</sub> , I <sub>D</sub> = 250 μA                                                                                             |                                                                                   | 2.0  | -    | 4.0   | V     |
| Gate-Source Leakage                       | I <sub>GSS</sub>                 | V <sub>GS</sub> = ± 30 V                                                                                                                                |                                                                                   | -    | -    | ± 100 | nA    |
| Zero Gate Voltage Drain Current           | I <sub>DSS</sub>                 | V <sub>DS</sub> = 650 V, V <sub>GS</sub> = 0 V                                                                                                          |                                                                                   | -    | -    | 25    | μA    |
|                                           |                                  | V <sub>DS</sub> = 520 V, V <sub>GS</sub> = 0 V, T <sub>J</sub> = 125 °C                                                                                 |                                                                                   | -    | -    | 250   |       |
| Drain-Source On-State Resistance          | R <sub>DS(on)</sub>              | V <sub>GS</sub> = 10 V                                                                                                                                  | I <sub>D</sub> = 3.1 A <sup>b</sup>                                               | -    | 2.1  | -     | Ω     |
| Forward Transconductance                  | g <sub>fs</sub>                  | V <sub>DS</sub> = 50 V, I <sub>D</sub> = 3.1 A                                                                                                          |                                                                                   | 3.9  | -    | -     | S     |
| Dynamic                                   |                                  |                                                                                                                                                         |                                                                                   |      |      |       |       |
| Input Capacitance                         | C <sub>iss</sub>                 | V <sub>GS</sub> = 0 V,<br>V <sub>DS</sub> = 25 V,<br>f = 1.0 MHz, see fig. 5                                                                            |                                                                                   | -    | 1417 | -     | pF    |
| Output Capacitance                        | C <sub>oss</sub>                 |                                                                                                                                                         |                                                                                   | -    | 177  | -     |       |
| Reverse Transfer Capacitance              | C <sub>rss</sub>                 |                                                                                                                                                         |                                                                                   | -    | 7.0  | -     |       |
| Output Capacitance                        | C <sub>oss</sub>                 | V <sub>GS</sub> = 0 V                                                                                                                                   | V <sub>DS</sub> = 1.0 V, f = 1.0 MHz                                              | -    | 1912 | -     |       |
| Effective Output Capacitance              | C <sub>oss eff.</sub>            |                                                                                                                                                         | V <sub>DS</sub> = 520 V, f = 1.0 MHz                                              | -    | 48   | -     |       |
| Total Gate Charge                         | Q <sub>g</sub>                   | V <sub>GS</sub> = 10 V                                                                                                                                  | I <sub>D</sub> = 3.2 A, V <sub>DS</sub> = 400 V<br>see fig. 6 and 13 <sup>b</sup> | -    | -    | 48    | nC    |
| Gate-Source Charge                        | Q <sub>gs</sub>                  |                                                                                                                                                         |                                                                                   | -    | -    | 12    |       |
| Gate-Drain Charge                         | Q <sub>gd</sub>                  |                                                                                                                                                         |                                                                                   | -    | -    | 19    |       |
| Turn-On Delay Time                        | t <sub>d(on)</sub>               | V <sub>DD</sub> = 325 V, I <sub>D</sub> = 3.2 A<br>R <sub>G</sub> = 9.1 Ω, R <sub>D</sub> = 62 Ω,<br>see fig. 10 <sup>b</sup>                           |                                                                                   | -    | 14   | -     | ns    |
| Rise Time                                 | t <sub>r</sub>                   |                                                                                                                                                         |                                                                                   | -    | 20   | -     |       |
| Turn-Off Delay Time                       | t <sub>d(off)</sub>              |                                                                                                                                                         |                                                                                   | -    | 34   | -     |       |
| Fall Time                                 | t <sub>f</sub>                   |                                                                                                                                                         |                                                                                   | -    | 18   | -     |       |
| Drain-Source Body Diode Characteristics   |                                  |                                                                                                                                                         |                                                                                   |      |      |       |       |
| Continuous Source-Drain Diode Current     | I <sub>S</sub>                   | MOSFET symbol showing the integral reverse p - n junction diode<br> |                                                                                   | -    | -    | 4     | A     |
| Pulsed Diode Forward Current <sup>a</sup> | I <sub>SM</sub>                  |                                                                                                                                                         |                                                                                   | -    | -    | 21    |       |
| Body Diode Voltage                        | V <sub>SD</sub>                  | T <sub>J</sub> = 25 °C, I <sub>S</sub> = 3.2 A, V <sub>GS</sub> = 0 V <sup>b</sup>                                                                      |                                                                                   | -    | -    | 1.5   | V     |
| Body Diode Reverse Recovery Time          | t <sub>rr</sub>                  | T <sub>J</sub> = 25 °C, I <sub>F</sub> = 3.2 A, dI/dt = 100 A/μs <sup>b</sup>                                                                           |                                                                                   | -    | 493  | 739   | ns    |
| Body Diode Reverse Recovery Charge        | Q <sub>rr</sub>                  |                                                                                                                                                         |                                                                                   | -    | 2.1  | 3.2   | μC    |
| Forward Turn-On Time                      | t <sub>on</sub>                  | Intrinsic turn-on time is negligible (turn-on is dominated by L <sub>S</sub> and L <sub>D</sub> )                                                       |                                                                                   |      |      |       |       |

**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 %  $V_{DS}$ .  
 d.  $t = 60\text{ s}$ ,  $f = 60\text{ Hz}$ .

**TYPICAL CHARACTERISTICS** 25 °C, unless otherwise noted

**Fig. 1 - Typical Output Characteristics**

**Fig. 3 - Typical Transfer Characteristics**

**Fig. 2 - Typical Output Characteristics**

**Fig. 4 - Normalized On-Resistance vs. Temperature**

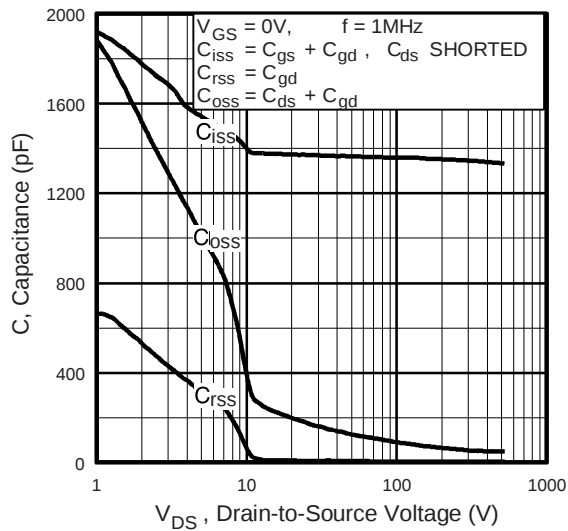


Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage



Fig. 7 - Typical Source-Drain Diode Forward Voltage



Fig. 6 - Typical Gate Charge vs. Gate-to-Source Voltage

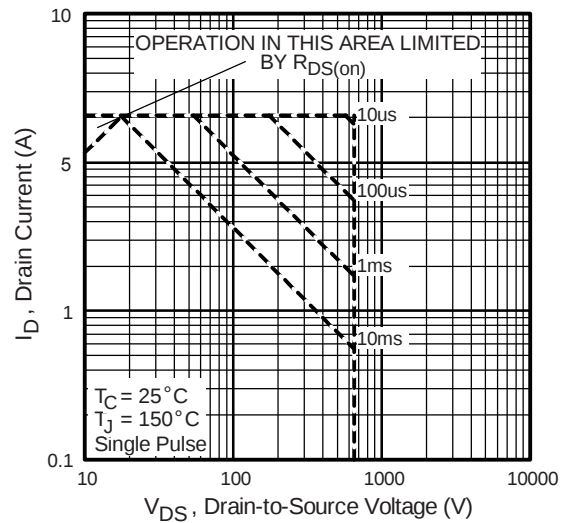


Fig. 8 - Maximum Safe Operating Area



Fig. 9 - Maximum Drain Current vs. Case Temperature



Fig. 10a - Switching Time Test Circuit



Fig. 10b - Switching Time Waveforms

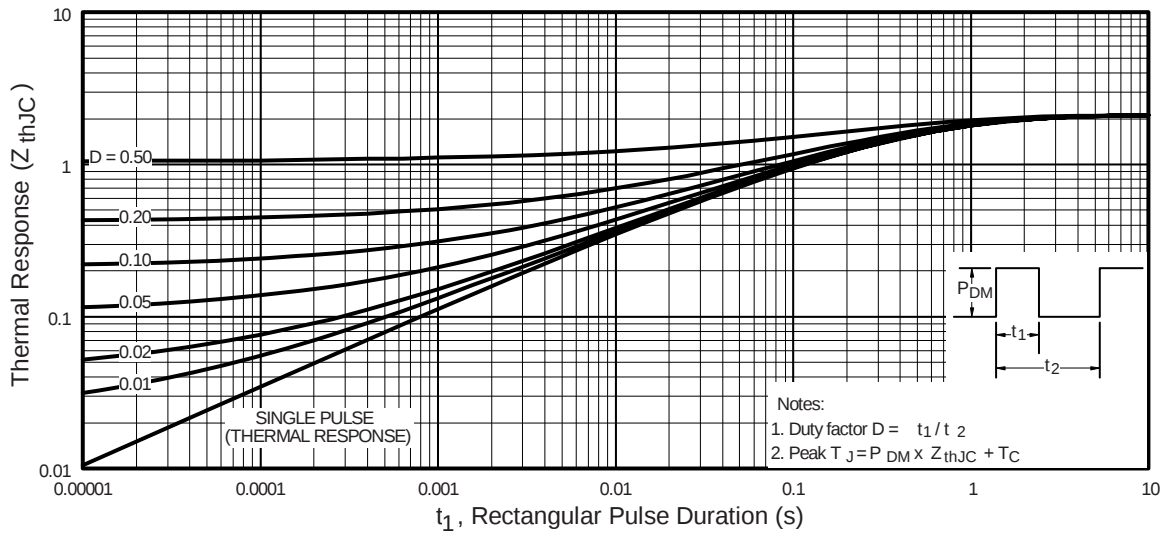


Fig. 11 - Maximum Effective Transient Thermal Impedance, Junction-to-Case



Fig. 12a - Unclamped Inductive Test Circuit



Fig. 12b - Unclamped Inductive Waveforms



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

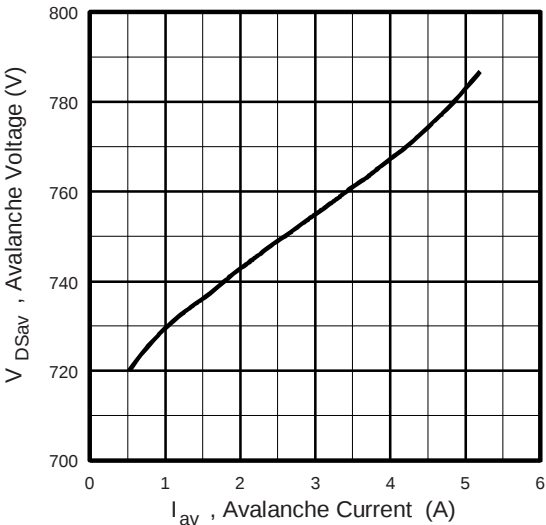


Fig. 12d - Typical Drain-to Source Voltage vs. Avalanche Current



Fig. 13a - Basic Gate Charge Waveform



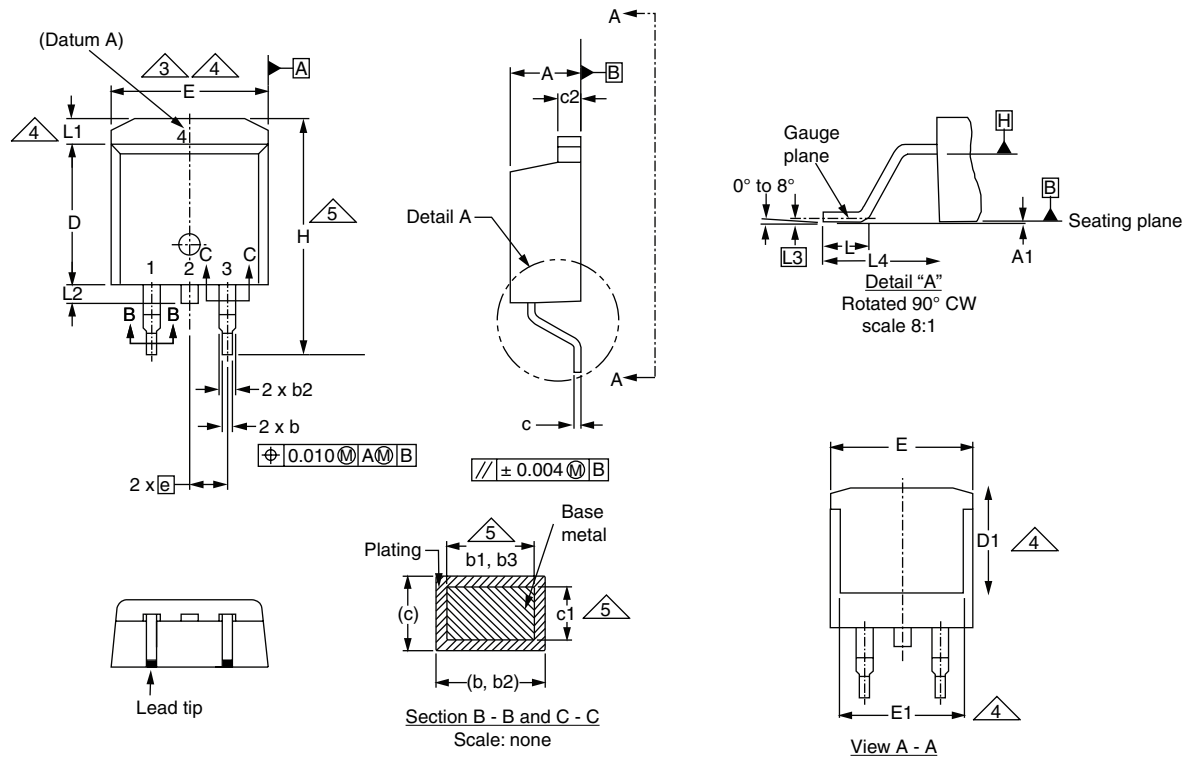
Fig. 13b - Gate Charge Test Circuit

### Peak Diode Recovery $dV/dt$ Test Circuit



\*  $V_{GS} = 5\text{ V}$  for logic level devices

Fig. 14 - For N-Channel

**TO-263AB (HIGH VOLTAGE)**

|      | MILLIMETERS |      | INCHES |       |
|------|-------------|------|--------|-------|
| DIM. | MIN.        | MAX. | MIN.   | MAX.  |
| A    | 4.06        | 4.83 | 0.160  | 0.190 |
| A1   | 0.00        | 0.25 | 0.000  | 0.010 |
| b    | 0.51        | 0.99 | 0.020  | 0.039 |
| b1   | 0.51        | 0.89 | 0.020  | 0.035 |
| b2   | 1.14        | 1.78 | 0.045  | 0.070 |
| b3   | 1.14        | 1.73 | 0.045  | 0.068 |
| c    | 0.38        | 0.74 | 0.015  | 0.029 |
| c1   | 0.38        | 0.58 | 0.015  | 0.023 |
| c2   | 1.14        | 1.65 | 0.045  | 0.065 |
| D    | 8.38        | 9.65 | 0.330  | 0.380 |

|      | MILLIMETERS |       | INCHES    |       |
|------|-------------|-------|-----------|-------|
| DIM. | MIN.        | MAX.  | MIN.      | MAX.  |
| D1   | 6.86        | -     | 0.270     | -     |
| E    | 9.65        | 10.67 | 0.380     | 0.420 |
| E1   | 6.22        | -     | 0.245     | -     |
| e    | 2.54 BSC    |       | 0.100 BSC |       |
| H    | 14.61       | 15.88 | 0.575     | 0.625 |
| L    | 1.78        | 2.79  | 0.070     | 0.110 |
| L1   | -           | 1.65  | -         | 0.066 |
| L2   | -           | 1.78  | -         | 0.070 |
| L3   | 0.25 BSC    |       | 0.010 BSC |       |
| L4   | 4.78        | 5.28  | 0.188     | 0.208 |

ECN: S-82110-Rev. A, 15-Sep-08  
 DWG: 5970

**Notes**

1. Dimensioning and tolerancing per ASME Y14.5M-1994.
2. Dimensions are shown in millimeters (inches).
3. Dimension D and E do not include mold flash. Mold flash shall not exceed 0.127 mm (0.005") per side. These dimensions are measured at the outmost extremes of the plastic body at datum A.
4. Thermal PAD contour optional within dimension E, L1, D1 and E1.
5. Dimension b1 and c1 apply to base metal only.
6. Datum A and B to be determined at datum plane H.
7. Outline conforms to JEDEC outline to TO-263AB.

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