

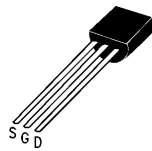
## 2N7000/2N7002/NDF7000A/NDS7002A N-Channel Enhancement Mode Field Effect Transistor

### General Description

These n-channel enhancement mode field effect transistors are produced using National's very high cell density third generation DMOS technology. These products have been designed to minimize on-state resistance provide rugged and reliable performance and fast switching. They can be used, with a minimum of effort, in most applications requiring up to 400 mA DC and can deliver pulsed currents up to 2A. This product is particularly suited to low voltage, low current applications, such as small servo motor controls, power MOSFET gate drivers, and other switching applications.

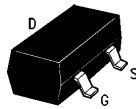
### Features

- Efficient high density cell design approaching (3 million/in<sup>2</sup>)
- Voltage controlled small signal switch
- Rugged
- High saturation current
- Low R<sub>DS</sub> (ON)



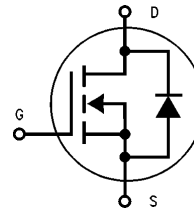
**TO-92**  
7000 Series

TL/G/11378-1



**TO-236 AB**  
(SOT-23)  
7002 Series

TL/G/11378-2



TL/G/11378-3

### Absolute Maximum Ratings

| Symbol                            | Parameter   | 2N7000     | 2N7002 | NDF7000A   | NDS7002A | Units |
|-----------------------------------|---|------------|--------|------------|----------|-------|
| V <sub>DSS</sub>                  | Drain-Source Voltage  | 60         |        |            |          | V     |
| V <sub>DGR</sub>                  | Drain-Gate Voltage (R <sub>GS</sub> ≤ 1 MΩ)                                     | 60         |        |            |          | V     |
| V <sub>GSS</sub>                  | Gate-Source Voltage   | ±40        |        |            |          | V     |
| I <sub>D</sub>                    | Drain Current—Continuous  | 200        | 115    | 400        | 280      | mA    |
|                                   | —Pulsed   | 500        | 800    | 2000       | 1500     | mA    |
| P <sub>D</sub>                    | Total Power Dissipation @ T <sub>A</sub> = 25°C                                 | 400        | 200    | 625        | 300      | mW    |
|                                   | Derating above 25°C   | 3.2        | 1.6    | 5          | 2.4      | mW/°C |
| T <sub>J</sub> , T <sub>STG</sub> | Operating and Storage Temperature Range   | -55 to 150 |        | -65 to 150 |          | °C    |
| T <sub>L</sub>                    | Maximum Lead Temperature for Soldering Purposes, 1/16" from Case for 10 Seconds | 300        |        |            |          | °C    |

## 2N7000

### Electrical Characteristics $T_C = 25^\circ\text{C}$ unless otherwise noted

| Symbol                            | Parameter   | Conditions  | Min | Typ  | Max   | Units              |
|-----------------------------------|---|---|-----|------|-------|--------------------|
| <b>OFF CHARACTERISTICS</b>        |   |   |     |      |       |                    |
| $BV_{DSS}$                        | Drain-Source Breakdown Voltage                        | $V_{GS} = 0V, I_D = 10 \mu A$   | 60  |      |       | V                  |
| $I_{DSS}$                         | Zero Gate Voltage Drain Current                       | $V_{DS} = 48V, V_{GS} = 0V$<br>$T_C = 125^\circ\text{C}$                      |     |      | 1     | $\mu A$            |
|                                   |   |   |     |      | 1     | mA                 |
| $I_{GSSF}$                        | Gate-Body Leakage, Forward                            | $V_{GS} = -15V, V_{DS} = 0V$  |     |      | -10   | nA                 |
| <b>ON CHARACTERISTICS*</b>        |   |   |     |      |       |                    |
| $V_{GS(th)}$                      | Gate Threshold Voltage                                | $V_{DS} = V_{GS}, I_D = 1 \text{ mA}$   | 0.8 | 2.1  | 3     | V                  |
| $r_{DS(ON)}$                      | Static Drain-Source On-Resistance                     | $V_{GS} = 10V, I_D = 0.5A$<br>$T_C = 125^\circ\text{C}$                       |     | 1.2  | 5     | $\Omega$           |
|                                   |   |   |     | 1.9  | 9     | $\Omega$           |
| $V_{DS(ON)}$                      | Drain-Source On-Voltage                               | $V_{GS} = 10V, I_D = 0.5A$  |     | 0.6  | 2.5   | V                  |
|                                   |   | $V_{GS} = 4.5V, I_D = 75 \text{ mA}$  |     | 0.14 | 0.4   | V                  |
| $I_{D(ON)}$                       | On-State Drain Current                                | $V_{GS} = 4.5V, V_{DS} = 10V$   | 75  | 600  |       | mA                 |
| $g_{FS}$                          | Forward Transconductance                              | $V_{DS} = 10V, I_D = 200 \text{ mA}$  | 100 | 320  |       | ms                 |
| <b>DYNAMIC CHARACTERISTICS</b>    |   |   |     |      |       |                    |
| $C_{iss}$                         | Input Capacitance                                     | $V_{DS} = 25V, V_{GS} = 0V, f = 1.0 \text{ MHz}$                              |     | 20   | 60    | pF                 |
| $C_{oss}$                         | Output Capacitance                                    |   |     | 11   | 25    | pF                 |
| $C_{rss}$                         | Reverse Transfer Capacitance                          |   |     | 4    | 5     | pF                 |
| <b>SWITCHING CHARACTERISTICS*</b> |   |   |     |      |       |                    |
| $t_{on}$                          | Turn-On Time  | $V_{DD} = 15V, I_D = 0.5V, V_{GS} = 10V,$<br>$R_G = 25\Omega, R_L = 25\Omega$ |     |      | 10    | ns                 |
| $t_{off}$                         | Turn-Off Time   |   |     |      | 10    | ns                 |
| <b>BODY-DRAIN DIODE RATINGS</b>   |   |   |     |      |       |                    |
| $I_S$                             | Maximum Continuous Drain-Source Diode Forward Current |   |     |      | 200   | mA                 |
| $I_{SM}^*$                        | Maximum Pulsed Drain-Source Diode Forward Current     |   |     |      | 500   | mA                 |
| $V_{SD}^*$                        | Drain-Source Diode Forward Voltage                    | $V_{GS} = 0V, I_S = 200 \text{ mA}$   |     |      | 1.5   | V                  |
| <b>THERMAL CHARACTERISTICS</b>    |   |   |     |      |       |                    |
| $R_{\theta JA}$                   | Thermal Resistance, Junction to Ambient               |   |     |      | 312.5 | $^\circ\text{C/W}$ |
| $R_{\theta JC}$                   | Thermal Resistance, Junction to Case                  |   |     |      | 40    | $^\circ\text{C/W}$ |

\*Pulse Test: Pulse Width  $\leq 300 \mu s$ , Duty Cycle  $\leq 2.0\%$ .

## 2N7002

### Electrical Characteristics $T_C = 25^\circ\text{C}$ unless otherwise noted

| Symbol                            | Parameter   | Conditions   | Min | Typ  | Max  | Units              |
|-----------------------------------|---|--|-----|------|------|--------------------|
| <b>OFF CHARACTERISTICS</b>        |   |  |     |      |      |                    |
| $BV_{DSS}$                        | Drain-Source Breakdown Voltage                        | $V_{GS} = 0V, I_D = 10 \mu A$  | 60  |      |      | V                  |
| $I_{DSS}$                         | Zero Gate Voltage Drain Current                       | $V_{DS} = 60V, V_{GS} = 0V$  |     |      | 1    | $\mu A$            |
|                                   |   | $T_C = 125^\circ\text{C}$  |     |      | 500  | $\mu A$            |
| $I_{GSSF}$                        | Gate-Body Leakage, Forward                            | $V_{GS} = 20V$   |     |      | 100  | nA                 |
| $I_{GSSR}$                        | Gate-Body Leakage, Reverse                            | $V_{GS} = -20V$  |     |      | -100 | nA                 |
| <b>ON CHARACTERISTICS*</b>        |   |  |     |      |      |                    |
| $V_{GS(th)}$                      | Gate Threshold Voltage                                | $V_{DS} = V_{GS}, I_D = 250 \mu A$   | 1   | 2.1  | 2.5  | V                  |
| $r_{DS(ON)}$                      | Static Drain-Source On-Resistance                     | $V_{GS} = 10V, I_D = 0.5A$   |     | 1.2  | 7.5  | $\Omega$           |
|                                   |   | $T_C = 125^\circ\text{C}$  |     | 2    | 13.5 | $\Omega$           |
|                                   |   | $V_{GS} = 5V, I_D = 50 mA$   |     | 1.7  | 7.5  | $\Omega$           |
|                                   |   | $T_C = 125^\circ\text{C}$  |     | 2.8  | 13.5 | $\Omega$           |
| $V_{DS(ON)}$                      | Drain-Source On-Voltage                               | $V_{GS} = 10V, I_D = 0.5A$   |     | 0.6  | 3.75 | V                  |
|                                   |   | $V_{GS} = 5V, I_D = 50 mA$   |     | 0.09 | 1.5  | V                  |
| $I_{D(ON)}$                       | On-State Drain Current                                | $V_{GS} = 10V, V_{DS} \geq 2 V_{DS(ON)}$   | 500 | 2700 |      | mA                 |
| $g_{FS}$                          | Forward Transconductance                              | $V_{DS} \geq 2 V_{DS(ON)}, I_D = 200 mA$   | 80  | 320  |      | ms                 |
| <b>DYNAMIC CHARACTERISTICS</b>    |   |  |     |      |      |                    |
| $C_{iss}$                         | Input Capacitance                                     | $V_{DS} = 25V, V_{GS} = 0V, f = 1.0 MHz$   |     | 20   | 50   | pF                 |
| $C_{oss}$                         | Output Capacitance                                    |  |     | 11   | 25   | pF                 |
| $C_{rss}$                         | Reverse Transfer Capacitance                          |  |     | 4    | 5    | pF                 |
| <b>SWITCHING CHARACTERISTICS*</b> |   |  |     |      |      |                    |
| $t_{ON}$                          | Turn-On Time  | $V_{DD} = 30V, I_D = 200 mA, V_{GS} = 10V,$<br>$R_{GEN} = 25\Omega, R_L = 150\Omega$ |     |      | 20   | ns                 |
| $t_{OFF}$                         | Turn-Off Time   |  |     |      | 20   | ns                 |
| <b>BODY-DRAIN DIODE RATINGS</b>   |   |  |     |      |      |                    |
| $I_S$                             | Maximum Continuous Drain-Source Diode Forward Current |  |     |      | 115  | mA                 |
| $I_{SM}$                          | Maximum Pulsed Drain-Source Diode Forward Current     |  |     |      | 800  | mA                 |
| $V_{SD}^*$                        | Drain-Source Diode Forward Voltage                    | $V_{GS} = 0V, I_S = 115 mA$  |     |      | 1.5  | V                  |
| <b>THERMAL CHARACTERISTICS</b>    |   |  |     |      |      |                    |
| $R_{\theta JA}$                   | Thermal Resistance, Junction to Ambient               |  |     |      | 625  | $^\circ\text{C/W}$ |

\*Pulse Test: Pulse Width  $\leq 300 \mu s$ , Duty Cycle  $\leq 2.0\%$ .

## NDF7000A

### Electrical Characteristics $T_C = 25^\circ\text{C}$ unless otherwise noted

| Symbol                            | Parameter   | Conditions  | Min | Typ  | Max   | Units                     |
|-----------------------------------|---|---|-----|------|-------|---------------------------|
| <b>OFF CHARACTERISTICS</b>        |   |   |     |      |       |                           |
| $BV_{DSS}$                        | Drain-Source Breakdown Voltage                        | $V_{GS} = 0V, I_D = 10 \mu A$   | 60  |      |       | V                         |
| $I_{DSS}$                         | Zero Gate Voltage Drain Current                       | $V_{DS} = 48V, V_{GS} = 0V$<br>$T_C = 125^\circ\text{C}$                                |     |      | 1     | $\mu A$                   |
|                                   |   |   |     |      | 1     | mA                        |
| $I_{GSSF}$                        | Gate-Body Leakage, Forward                            | $V_{GS} = -15V$   |     |      | -10   | nA                        |
| <b>ON CHARACTERISTICS*</b>        |   |   |     |      |       |                           |
| $V_{GS(th)}$                      | Gate Threshold Voltage                                | $V_{DS} = V_{GS}, I_D = 1 \text{ mA}$   | 0.8 | 2.1  | 3     | V                         |
| $r_{DS(ON)}$                      | Static Drain-Source On-Resistance                     | $V_{GS} = 10V, I_D = 0.5A$<br>$T_C = 125^\circ\text{C}$                                 |     | 1.2  | 2     | $\Omega$                  |
|                                   |   |   |     | 2    | 3.5   | $\Omega$                  |
| $V_{DS(ON)}$                      | Drain-Source On-Voltage                               | $V_{GS} = 10V, I_D = 500 \text{ mA}$  |     | 0.6  | 1     | V                         |
|                                   |   | $V_{GS} = 4.5V, I_D = 75 \text{ mA}$  |     | 0.14 | 0.225 | V                         |
| $I_{D(ON)}$                       | On-State Drain Current                                | $V_{GS} = 4.5V, V_{DS} \geq 2 V_{DS(ON)}$   | 400 | 600  |       | mA                        |
| $g_{FS}$                          | Forward Transconductance                              | $V_{DS} \geq 2 V_{DS(ON)}, I_D = 200 \text{ mA}$  | 100 | 320  |       | ms                        |
| <b>DYNAMIC CHARACTERISTICS</b>    |   |   |     |      |       |                           |
| $C_{iss}$                         | Input Capacitance                                     | $V_{DS} = 25V, V_{GS} = 0V, f = 1.0 \text{ MHz}$  |     | 20   | 60    | pF                        |
| $C_{oss}$                         | Output Capacitance                                    |   |     | 11   | 25    | pF                        |
| $C_{rss}$                         | Reverse Transfer Capacitance                          |   |     | 4    | 5     | pF                        |
| <b>SWITCHING CHARACTERISTICS*</b> |   |   |     |      |       |                           |
| $t_{on}$                          | Turn-On Time  | $V_{DD} = 15V, I_D = 500 \text{ mA}, V_{GS} = 10V,$<br>$R_G = 25\Omega, R_L = 25\Omega$ |     |      | 10    | ns                        |
| $t_{off}$                         | Turn-Off Time   |   |     |      | 10    | ns                        |
| <b>BODY-DRAIN DIODE RATINGS</b>   |   |   |     |      |       |                           |
| $I_S$                             | Maximum Continuous Drain-Source Diode Forward Current |   |     |      | 400   | mA                        |
| $I_{SM}$                          | Maximum Pulsed Drain-Source Diode Forward Current     |   |     |      | 2000  | mA                        |
| $V_{SD}^*$                        | Drain-Source Diode Forward Voltage                    | $V_{GS} = 0V, I_S = 400 \text{ mA}$   |     | 0.88 | 1.2   | V                         |
| <b>THERMAL CHARACTERISTICS</b>    |   |   |     |      |       |                           |
| $R_{\theta JA}$                   | Thermal Resistance, Junction to Ambient               |   |     |      | 200   | $^\circ\text{C}/\text{W}$ |

\*Pulse Test: Pulse Width  $\leq 300 \mu s$ , Duty Cycle  $\leq 2.0\%$ .

## NDS7002A

### Electrical Characteristics $T_C = 25^\circ\text{C}$ unless otherwise noted

| Symbol                            | Parameter   | Conditions   | Min | Typ  | Max  | Units              |
|-----------------------------------|---|--|-----|------|------|--------------------|
| <b>OFF CHARACTERISTICS</b>        |   |  |     |      |      |                    |
| $BV_{DSS}$                        | Drain-Source Breakdown Voltage                        | $V_{GS} = 0V, I_D = 10 \mu A$  | 60  |      |      | V                  |
| $I_{DSS}$                         | Zero Gate Voltage Drain Current                       | $V_{DS} = 60V, V_{GS} = 0V$<br>$T_C = 125^\circ\text{C}$                         |     |      | 1    | $\mu A$            |
|                                   |   |  |     |      | 500  | $\mu A$            |
| $I_{GSSF}$                        | Gate-Body Leakage, Forward                            | $V_{GS} = 20V$   |     |      | 100  | nA                 |
| $I_{GSSR}$                        | Gate-Body Leakage, Reverse                            | $V_{GS} = -20V$  |     |      | -100 | nA                 |
| <b>ON CHARACTERISTICS*</b>        |   |  |     |      |      |                    |
| $V_{GS(th)}$                      | Gate Threshold Voltage                                | $V_{DS} = V_{GS}, I_D = 250 \mu A$   | 1   | 2.1  | 2.5  | V                  |
| $r_{DS(ON)}$                      | Static Drain-Source On-Resistance                     | $V_{GS} = 10V, I_D = 0.5A$<br>$T_C = 125^\circ\text{C}$                          |     | 1.2  | 2    | $\Omega$           |
|                                   |   |  |     | 2    | 3.5  | $\Omega$           |
|                                   |   |  |     | 1.7  | 3    | $\Omega$           |
| $V_{DS(ON)}$                      | Drain-Source On-Voltage                               | $V_{GS} = 5V, I_D = 50 mA$<br>$T_C = 125^\circ\text{C}$                          |     | 2.8  | 5    | $\Omega$           |
|                                   |   |  |     |      |      |                    |
| $V_{DS(ON)}$                      | Drain-Source On-Voltage                               | $V_{GS} = 10V, I_D = 500 mA$   |     | 0.6  | 1    | V                  |
|                                   |   | $V_{GS} = 5.0V, I_D = 50 mA$   |     | 0.09 | 0.15 | V                  |
| $I_{D(ON)}$                       | On-State Drain Current                                | $V_{GS} = 10V, V_{DS} \geq 2 V_{DS(ON)}$   | 500 | 2700 |      | mA                 |
| $g_{FS}$                          | Forward Transconductance                              | $V_{DS} \geq 2 V_{DS(ON)}, I_D = 200 mA$   | 80  | 320  |      | ms                 |
| <b>DYNAMIC CHARACTERISTICS</b>    |   |  |     |      |      |                    |
| $C_{iss}$                         | Input Capacitance                                     | $V_{DS} = 25V, V_{GS} = 0V, f = 1.0 MHz$   |     | 20   | 50   | pF                 |
| $C_{oss}$                         | Output Capacitance                                    |  |     | 11   | 25   | pF                 |
| $C_{rss}$                         | Reverse Transfer Capacitance                          |  |     | 4    | 5    | pF                 |
| <b>SWITCHING CHARACTERISTICS*</b> |   |  |     |      |      |                    |
| $t_{ON}$                          | Turn-On Time  | $V_{DD} = 30V, I_D = 200 mA, V_{GS} = 10V,$<br>$R_G = 25\Omega, R_L = 150\Omega$ |     |      | 20   | ns                 |
| $t_{OFF}$                         | Turn-Off Time   |  |     |      | 20   | ns                 |
| <b>BODY-DRAIN DIODE RATINGS</b>   |   |  |     |      |      |                    |
| $I_S$                             | Maximum Continuous Drain-Source Diode Forward Current |  |     |      | 280  | mA                 |
| $I_{SM}$                          | Maximum Pulsed Drain-Source Diode Forward Current     |  |     |      | 1500 | mA                 |
| $V_{SD}^*$                        | Drain-Source Diode Forward Voltage                    | $V_{GS} = 0V, I_S = 400 mA$  |     | 0.88 | 1.2  | V                  |
| <b>THERMAL CHARACTERISTICS</b>    |   |  |     |      |      |                    |
| $R_{\theta JA}$                   | Thermal Resistance, Junction to Ambient               |  |     |      | 417  | $^\circ\text{C/W}$ |

\*Pulse Test: Pulse Width  $\leq 300 \mu s$ , Duty Cycle  $\leq 2.0\%$ .

# Typical Electrical Characteristics

## 2N7000/2N7002/NDF7000A/NDS7002A

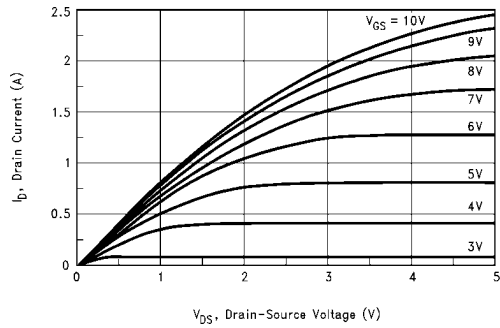


FIGURE 1. On-Region Characteristics

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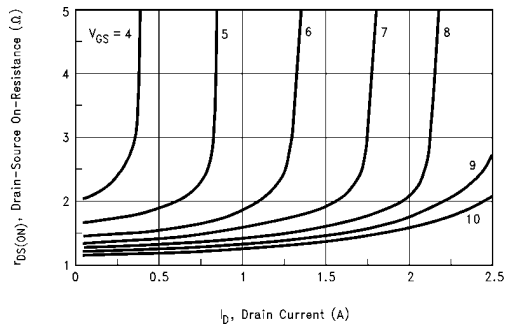


FIGURE 2.  $r_{DS(ON)}$  Variation with Drain Current and Gate Voltage

TL/G/11378-5

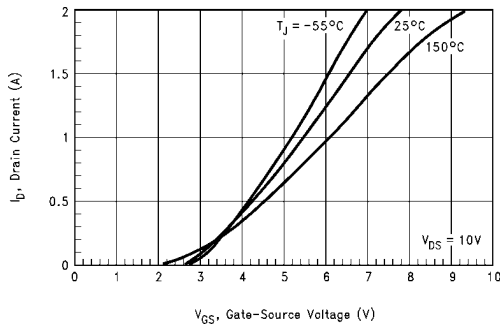


FIGURE 3. Transfer Characteristics

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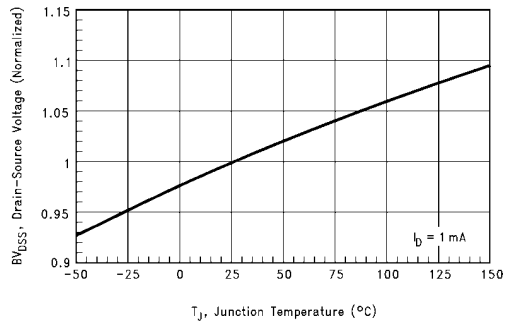


FIGURE 4. Breakdown Voltage Variation with Temperature

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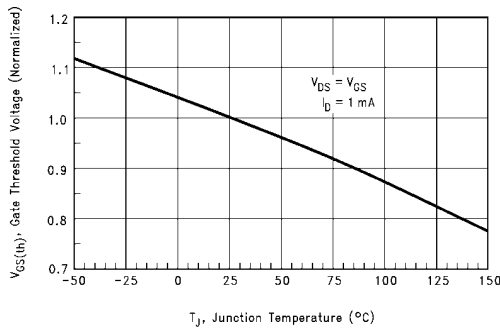


FIGURE 5. Gate Threshold Variation with Temperature

TL/G/11378-8

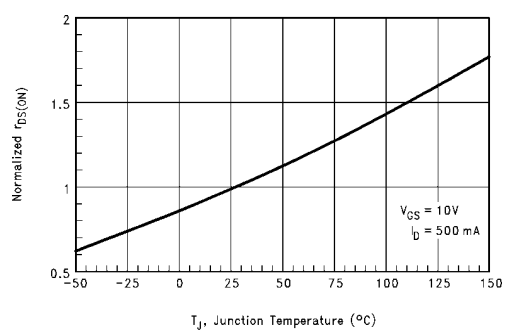
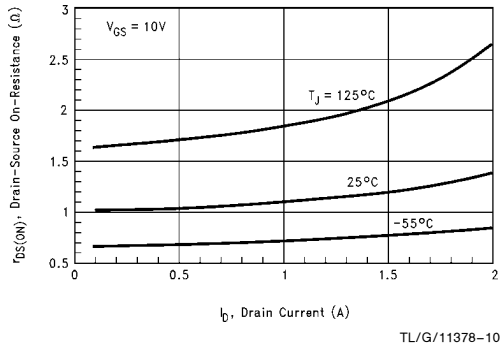


FIGURE 6. On-Resistance Variation with Temperature

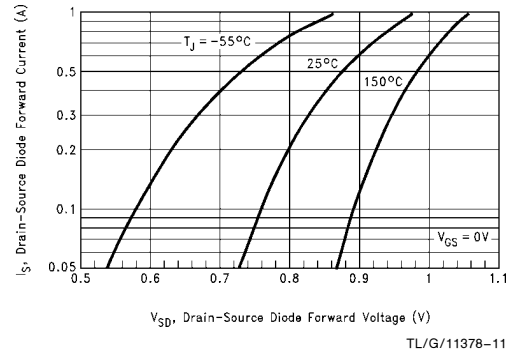
TL/G/11378-9

# Typical Electrical Characteristics (Continued)

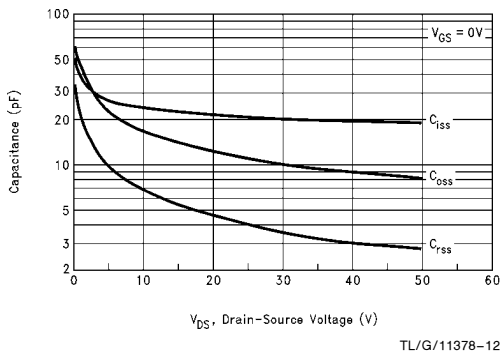
## 2N7000/2N7002/NDF7000A/NDS7002A (Continued)



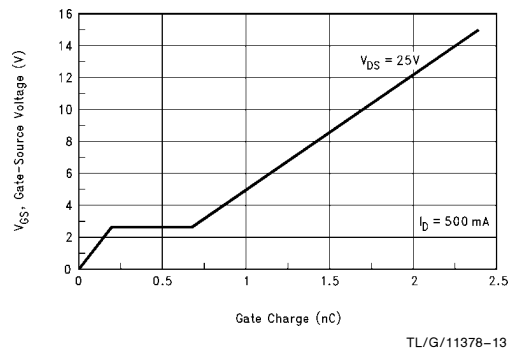
**FIGURE 7. On-Resistance vs Drain Current**



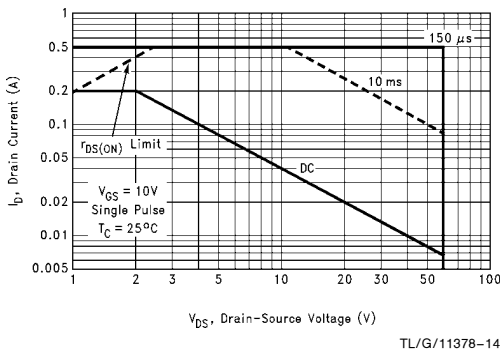
**FIGURE 8. Body Diode Forward Voltage Variation with Current and Temperature**



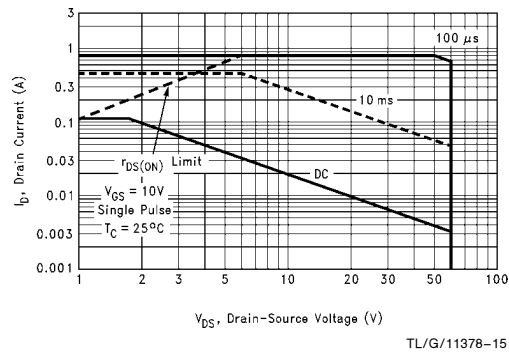
**FIGURE 9. Capacitance vs Drain-Source Voltage**



**FIGURE 10. Gate Charge vs Gate-Source Voltage**



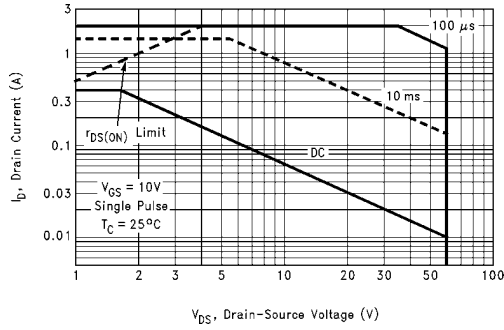
**FIGURE 11. 2N7000 Safe Operating Area**



**FIGURE 12. 2N7002 Safe Operating Area**

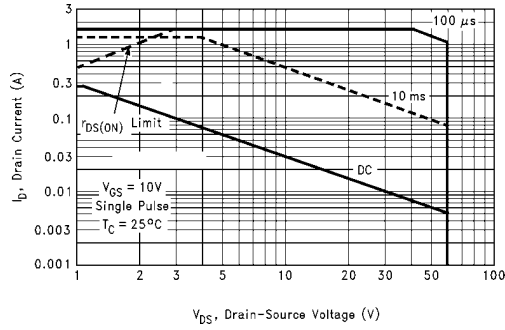
# Typical Electrical Characteristics (Continued)

## 2N7000/2N7002/NDF7000A/NDS7002A (Continued)



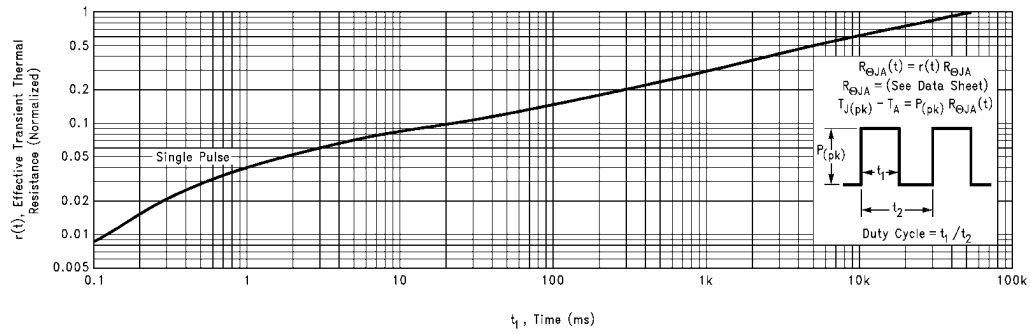
TL/G/11378-16

FIGURE 13. NDF7000A Safe Operating Area



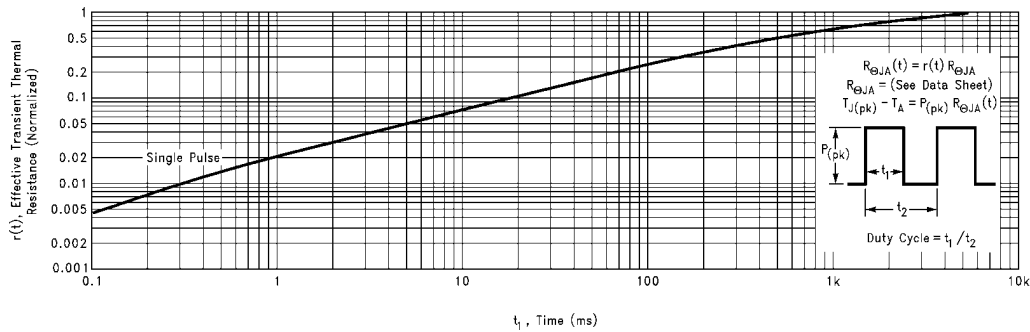
TL/G/11378-17

FIGURE 14. NDS7002A Safe Operating Area



TL/G/11378-18

FIGURE 15. TO-92 Transient Thermal Response

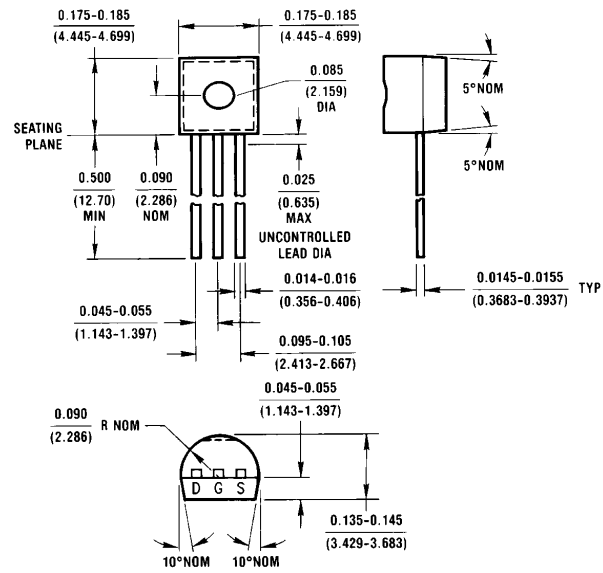


TL/G/11378-19

FIGURE 16. SOT-23 Transient Thermal Response



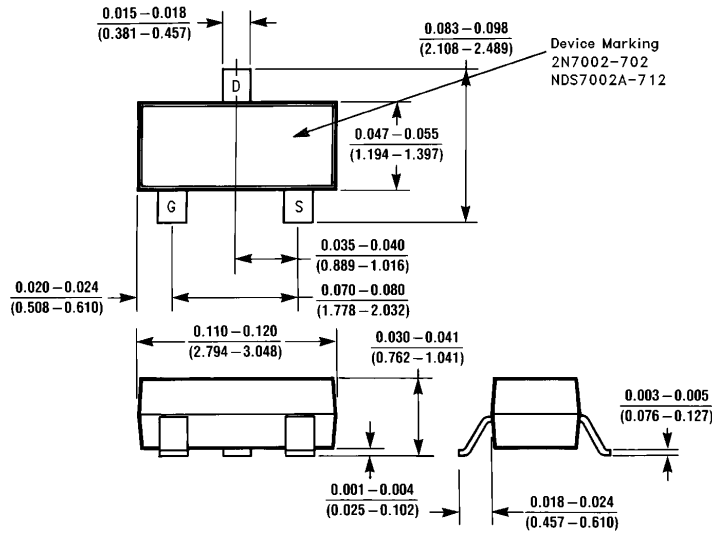
**Physical Dimensions** inches (millimeters)



**TO-92**

TL/G/11378-20

**Physical Dimensions** inches (millimeters) (Continued)



TL/G/11378-21

**Note 1:** Meets all JEDEC dimensional requirements for TO-236AB.

**Note 2:** Controlling dimension: millimeters.

**Note 3:** Available also in TO-236AA. Contact your local National Semiconductor representative for delivery and ordering information.

**Note 4:** Tape and reel is the standard packaging method for TO-236.

**TO-236AB (SOT-23) (Notes 3, 4)**

**LIFE SUPPORT POLICY**

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



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