

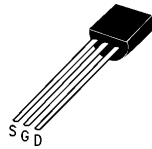
## 2N7000/2N7002/NDF7000A/NDS7002A N-Channel Enhancement Mode Field Effect Transistor

### 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.

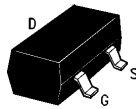
### Features

- 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)



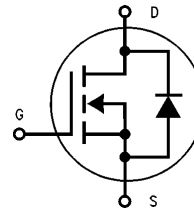
**TO-92**  
7000 Series

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	$V_{DS} = 48V, V_{GS} = 0V$			1	$\mu A$
		$T_C = 125^\circ\text{C}$			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	$V_{GS} = 10V, I_D = 0.5A$		1.2	5	$\Omega$
		$T_C = 125^\circ\text{C}$		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	$V_{DD} = 15V, I_D = 0.5V, V_{GS} = 10V,$ $R_G = 25\Omega, R_L = 25\Omega$			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	$^\circ\text{C}/\text{W}$
$R_{\theta JC}$	Thermal Resistance, Junction to Case				40	$^\circ\text{C}/\text{W}$

\*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	$\Omega$
		$V_{GS} = 5V, I_D = 50 \text{ mA}$		1.7	7.5	$\Omega$
$V_{DS(ON)}$	Drain-Source On-Voltage	$V_{GS} = 10V, I_D = 0.5A$		0.6	3.75	V
		$V_{GS} = 5V, I_D = 50 \text{ mA}$		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	$V_{DS} \geq 2 V_{DS(ON)}, I_D = 200 \text{ mA}$	80	320		ms
<b>DYNAMIC CHARACTERISTICS</b>						
$C_{iss}$	Input Capacitance	$V_{DS} = 25V, V_{GS} = 0V, f = 1.0 \text{ MHz}$		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	$V_{DD} = 30V, I_D = 200 \text{ mA}, V_{GS} = 10V,$ $R_{GEN} = 25\Omega, R_L = 150\Omega$			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	$V_{GS} = 0V, I_S = 115 \text{ mA}$			1.5	V
<b>THERMAL CHARACTERISTICS</b>						
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient				625	$^\circ\text{C/W}$

\*Pulse Test: Pulse Width  $\leq 300 \mu\text{s}$ , 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	$V_{DS} = 48V, V_{GS} = 0V$ $T_C = 125^\circ\text{C}$			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	$V_{GS} = 10V, I_D = 0.5A$ $T_C = 125^\circ\text{C}$		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	$V_{DD} = 15V, I_D = 500 \text{ mA}, V_{GS} = 10V,$ $R_G = 25\Omega, R_L = 25\Omega$			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  $\leq 300 \mu\text{s}$ , 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	$V_{DS} = 60V, V_{GS} = 0V$			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	2	$\Omega$
		$T_C = 125^\circ\text{C}$		2	3.5	$\Omega$
		$V_{GS} = 5V, I_D = 50 \text{ mA}$		1.7	3	$\Omega$
$V_{DS(ON)}$	Drain-Source On-Voltage	$V_{GS} = 10V, I_D = 500 \text{ mA}$		0.6	1	V
		$V_{GS} = 5.0V, I_D = 50 \text{ mA}$		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	$V_{DS} \geq 2 V_{DS(ON)}, I_D = 200 \text{ mA}$	80	320		ms
<b>DYNAMIC CHARACTERISTICS</b>						
$C_{iss}$	Input Capacitance	$V_{DS} = 25V, V_{GS} = 0V, f = 1.0 \text{ MHz}$		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	$V_{DD} = 30V, I_D = 200 \text{ mA}, V_{GS} = 10V,$ $R_G = 25\Omega, R_L = 150\Omega$			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	$V_{GS} = 0V, I_S = 400 \text{ mA}$		0.88	1.2	V
<b>THERMAL CHARACTERISTICS</b>						
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient				417	$^\circ\text{C}/\text{W}$

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

# Typical Electrical Characteristics

## 2N7000/2N7002/NDF7000A/NDS7002A

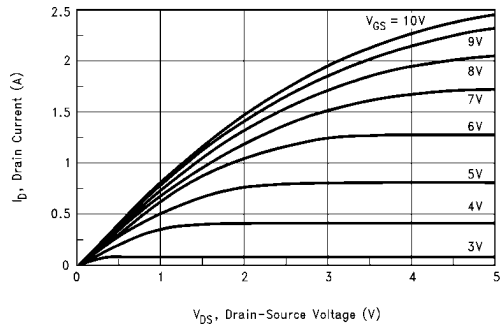


FIGURE 1. On-Region Characteristics  
TL/G/11378-4

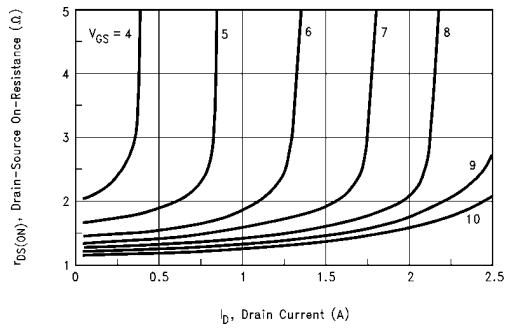


FIGURE 2.  $r_{DS(ON)}$  Variation with Drain Current and Gate Voltage  
TL/G/11378-5

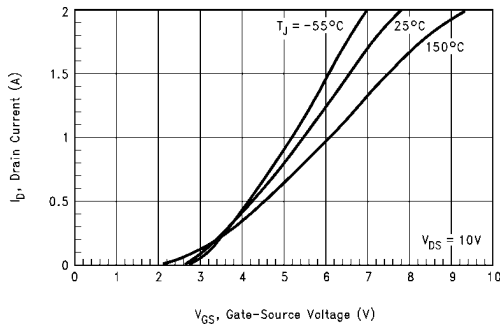


FIGURE 3. Transfer Characteristics  
TL/G/11378-6

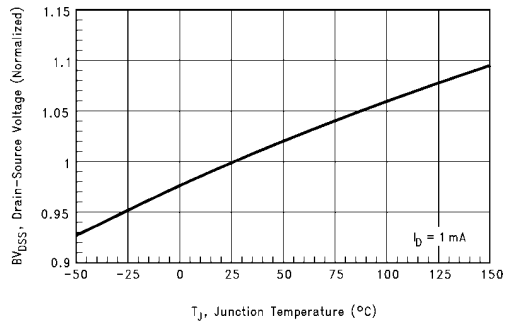


FIGURE 4. Breakdown Voltage Variation with Temperature  
TL/G/11378-7

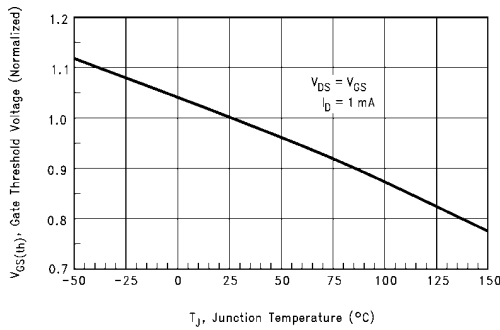


FIGURE 5. Gate Threshold Variation with Temperature  
TL/G/11378-8

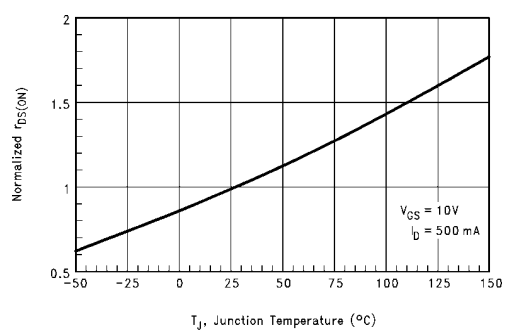
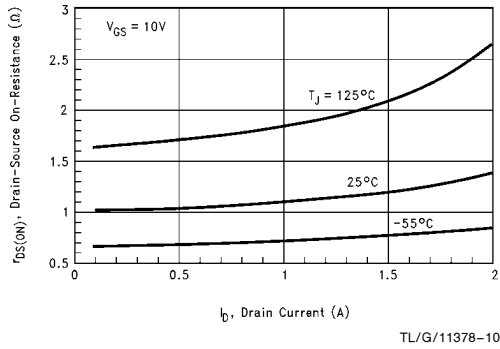


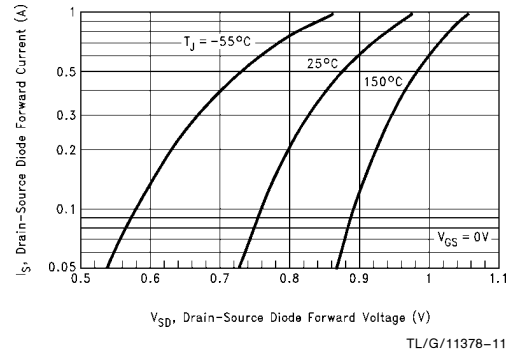
FIGURE 6. On-Resistance Variation with Temperature  
TL/G/11378-9

# Typical Electrical Characteristics (Continued)

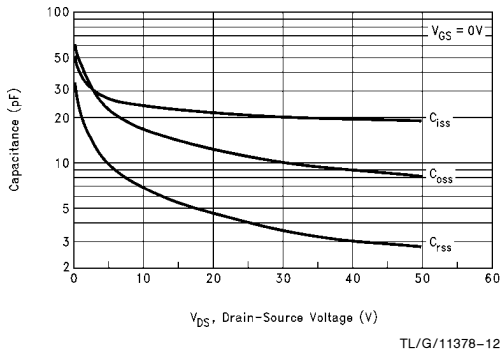
## 2N7000/2N7002/NDF7000A/NDS7002A (Continued)



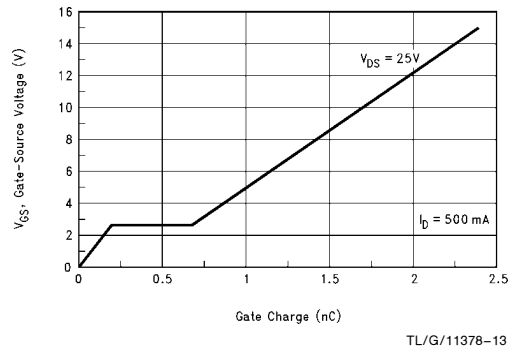
**FIGURE 7. On-Resistance vs Drain Current**



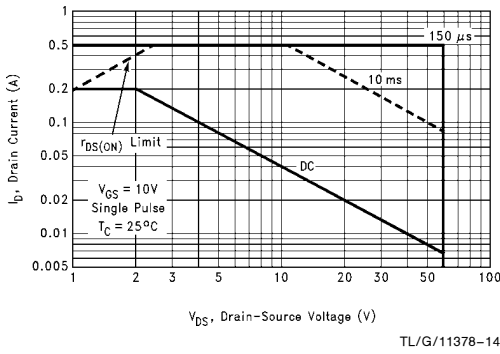
**FIGURE 8. Body Diode Forward Voltage Variation with Current and Temperature**



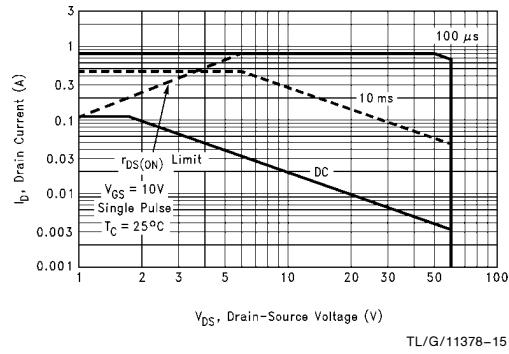
**FIGURE 9. Capacitance vs Drain-Source Voltage**



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



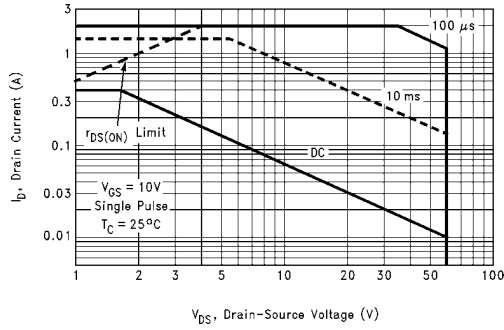
**FIGURE 11. 2N7000 Safe Operating Area**



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

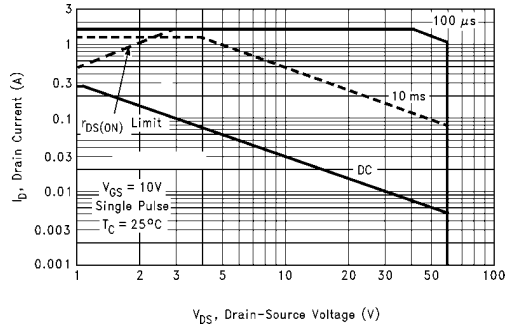
# Typical Electrical Characteristics (Continued)

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



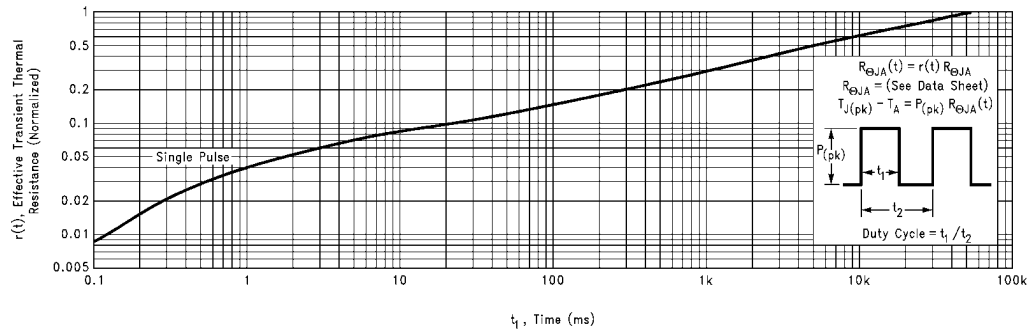
TL/G/11378-16

FIGURE 13. NDF7000A Safe Operating Area



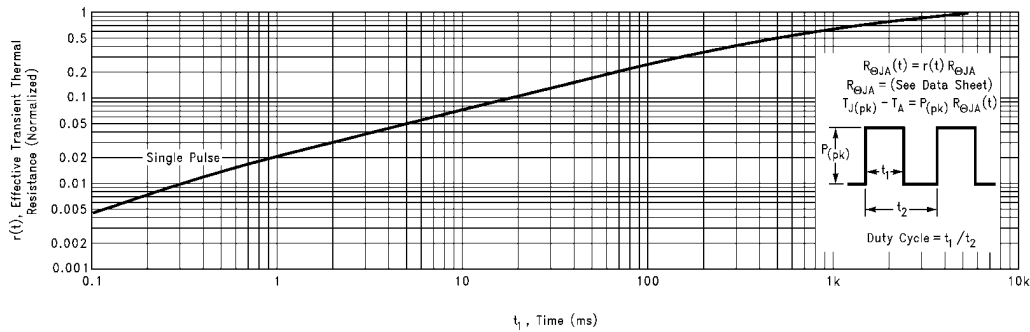
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FIGURE 14. NDS7002A Safe Operating Area



TL/G/11378-18

FIGURE 15. TO-92 Transient Thermal Response

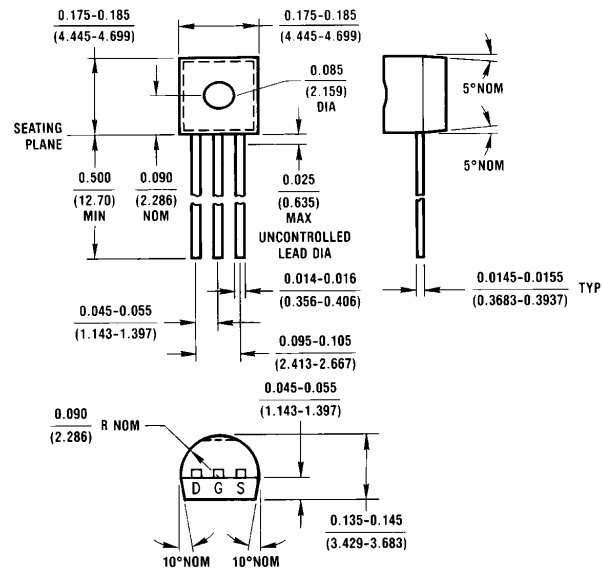


TL/G/11378-19

FIGURE 16. SOT-23 Transient Thermal Response



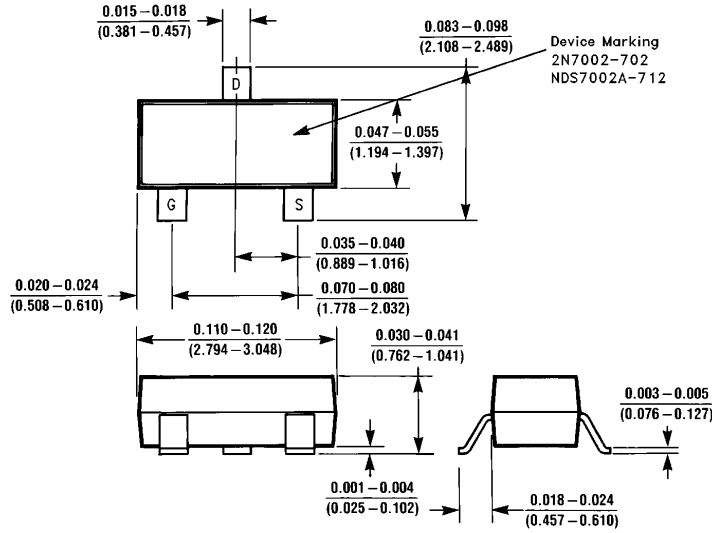
**Physical Dimensions** inches (millimeters)



**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)**

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Datasheets for electronics components.