National Semiconductor

March 1993

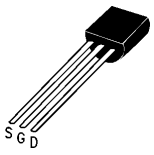
2N7000/2N7002/NDF7000A/NDS7002A
N-Channel Enhancement Mode Field Effect Transistor

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.

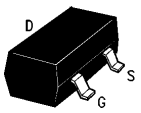
Features

- Efficient high density cell design approaching (3 million/in^2)
- Voltage controlled small signal switch
- Rugged
- High saturation current
- Low R_{DS} (ON)



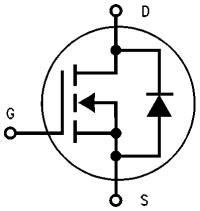
TL/G/11378–1

TO-92
7000 Series



TL/G/11378–2

TO-236 AB
(SOT-23)
7002 Series



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Absolute Maximum Ratings

Symbol	Parameter	2N7000	2N7002	NDF7000A	NDS7002A	Units
V_{DSS}	Drain-Source Voltage	60				V
V_{DGR}	Drain-Gate Voltage ($R_{GS} \leq 1$ MΩ)	60				V
V_{GSS}	Gate-Source Voltage	±40				V
I_D	Drain Current—Continuous	200	115	400	280	mA
	—Pulsed	500	800	2000	1500	mA
P_D	Total Power Dissipation @ $T_A = 25°C$	400	200	625	300	mW
	Derating above 25°C	3.2	1.6	5	2.4	mW/°C
T_J, T_{STG}	Operating and Storage Temperature Range	−55 to 150		−65 to 150		°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/16* from Case for 10 Seconds	300				°C

RRD-B30M115/Printed in U. S. A.

Electrical Characteristics T_C = 25°C unless otherwise noted

Symbol	Parameter	Conditions	Min	Typ	Max	Units
OFF CHARACTERISTICS						
BV_{DSS}	Drain-Source Breakdown Voltage	V_{GS} = 0V, I_D = 10 μA	60			V
I_{DSS}	Zero Gate Voltage Drain Current	V_{DS} = 48V, V_{GS} = 0V			1	μA
		T_C = 125°C			1	mA
I_{GSSF}	Gate-Body Leakage, Forward	V_{GS} = −15V, V_{DS} = 0V			−10	nA
ON CHARACTERISTICS*						
$V_{GS(th)}$	Gate Threshold Voltage	V_{DS} = V_{GS}, I_D = 1 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	Ω
		T_C = 125°C		1.9	9	Ω
$V_{DS(ON)}$	Drain-Source On-Voltage	V_{GS} = 10V, I_D = 0.5A		0.6	2.5	V
		V_{GS} = 4.5V, I_D = 75 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 mA	100	320		ms
DYNAMIC CHARACTERISTICS						
C_{iss}	Input Capacitance	V_{DS} = 25V, V_{GS} = 0V, f = 1.0 MHz		20	60	pF
C_{oss}	Output Capacitance			11	25	pF
C_{rss}	Reverse Transfer Capacitance			4	5	pF
SWITCHING CHARACTERISTICS*						
t_{on}	Turn-On Time	V_{DD} = 15V, I_D = 0.5V, V_{GS} = 10V, R_G = 25Ω, R_L = 25Ω			10	ns
t_{off}	Turn-Off Time				10	ns
BODY-DRAIN DIODE RATINGS						
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 mA			1.5	V
THERMAL CHARACTERISTICS						
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient				312.5	°C/W
$R_{\theta JC}$	Thermal Resistance, Junction to Case				40	°C/W

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

Electrical Characteristics T_C = 25°C unless otherwise noted

Symbol	Parameter	Conditions	Min	Typ	Max	Units
OFF CHARACTERISTICS						
BV_{DSS}	Drain-Source Breakdown Voltage	V_{GS} = 0V, I_D = 10 μA	60			V
I_{DSS}	Zero Gate Voltage Drain Current	V_{DS} = 60V, V_{GS} = 0V			1	μA
		T_C = 125°C			500	μA
I_{GSSF}	Gate-Body Leakage, Forward	V_{GS} = 20V			100	nA
I_{GSSR}	Gate-Body Leakage, Reverse	V_{GS} = −20V			−100	nA
ON CHARACTERISTICS*						
$V_{GS(th)}$	Gate Threshold Voltage	V_{DS} = V_{GS}, I_D = 250 μA	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	Ω
		T_C = 125°C		2	13.5	Ω
		V_{GS} = 5V, I_D = 50 mA		1.7	7.5	Ω
		T_C = 125°C		2.8	13.5	Ω
$V_{DS(ON)}$	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} ≥ 2 $V_{DS(ON)}$	500	2700		mA
g_{FS}	Forward Transconductance	V_{DS} ≥ 2 $V_{DS(ON)}$, I_D = 200 mA	80	320		ms
DYNAMIC CHARACTERISTICS						
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
SWITCHING CHARACTERISTICS*						
t_{ON}	Turn-On Time	V_{DD} = 30V, I_D = 200 mA, V_{GS} = 10V, R_{GEN} = 25Ω, R_L = 150Ω			20	ns
t_{OFF}	Turn-Off Time				20	ns
BODY-DRAIN DIODE RATINGS						
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
THERMAL CHARACTERISTICS						
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient				625	°C/W

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

Electrical Characteristics T_C = 25°C unless otherwise noted

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

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

Electrical Characteristics T_C = 25°C unless otherwise noted

Symbol	Parameter	Conditions		Min	Typ	Max	Units
OFF CHARACTERISTICS							
BV_{DSS}	Drain-Source Breakdown Voltage	V_{GS} = 0V, I_D = 10 μA		60			V
I_{DSS}	Zero Gate Voltage Drain Current	V_{DS} = 60V, V_{GS} = 0V				1	μA
			T_C = 125°C			500	μA
I_{GSSF}	Gate-Body Leakage, Forward	V_{GS} = 20V				100	nA
I_{GSSR}	Gate-Body Leakage, Reverse	V_{GS} = −20V				−100	nA
ON CHARACTERISTICS*							
$V_{GS(th)}$	Gate Threshold Voltage	V_{DS} = V_{GS}, I_D = 250 μA		1	2.1	2.5	V
$r_{DS(ON)}$	Static Drain-Source On-Resistance	V_{GS} = 10V, I_D = 0.5A			1.2	2	Ω
			T_C = 125°C		2	3.5	Ω
		V_{GS} = 5V, I_D = 50 mA			1.7	3	Ω
			T_C = 125°C		2.8	5	Ω
$V_{DS(ON)}$	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} ≥ 2 $V_{DS(ON)}$		500	2700		mA
g_{FS}	Forward Transconductance	V_{DS} ≥ 2 $V_{DS(ON)}$, I_D = 200 mA		80	320		ms
DYNAMIC CHARACTERISTICS							
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
SWITCHING CHARACTERISTICS*							
t_{ON}	Turn-On Time	V_{DD} = 30V, I_D = 200 mA, V_{GS} = 10V, R_G = 25Ω, R_L = 150Ω				20	ns
t_{OFF}	Turn-Off Time					20	ns
BODY-DRAIN DIODE RATINGS							
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
THERMAL CHARACTERISTICS							
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient					417	°C/W

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

Typical Electrical Characteristics

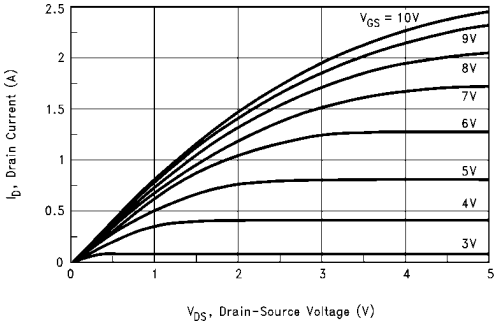

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FIGURE 1. On-Region Characteristics

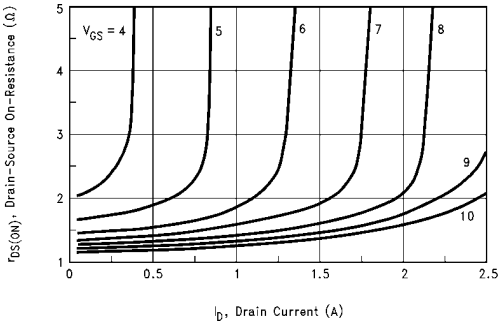

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FIGURE 2. $r_{DS(ON)}$ Variation with Drain Current and Gate Voltage

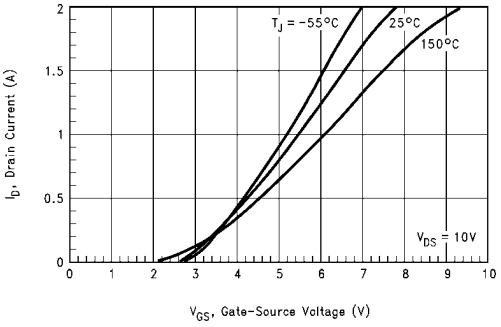

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FIGURE 3. Transfer Characteristics

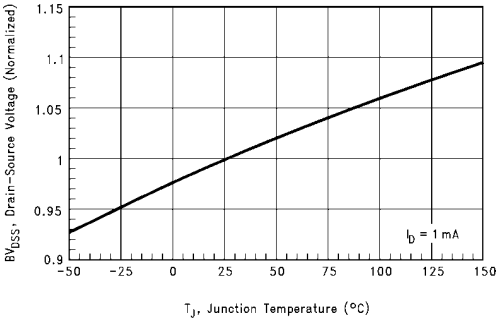

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FIGURE 4. Breakdown Voltage Variation with Temperature

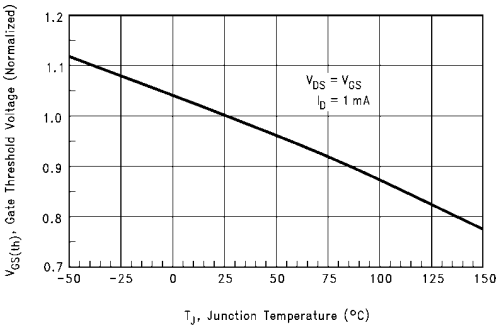

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FIGURE 5. Gate Threshold Variation with Temperature

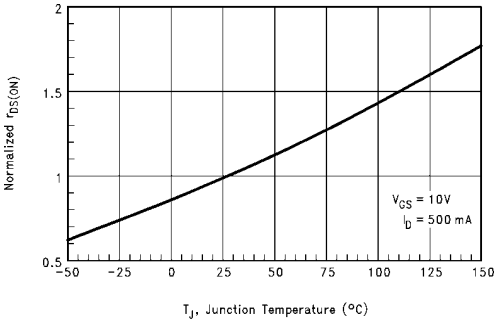

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FIGURE 6. On-Resistance Variation with Temperature

Typical Electrical Characteristics (Continued)

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

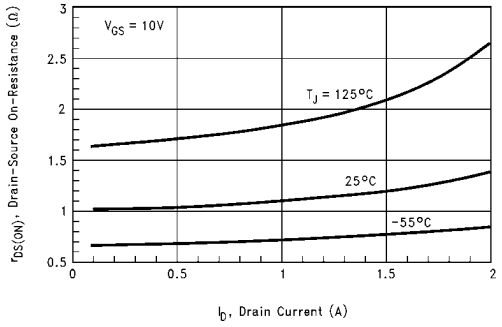

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FIGURE 7. On-Resistance vs Drain Current

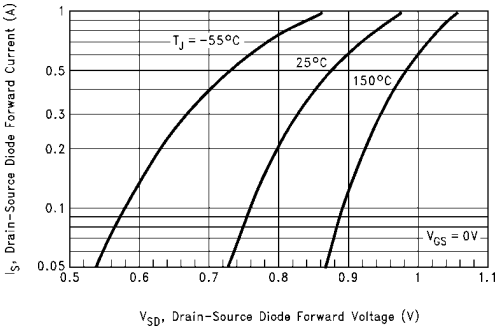

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FIGURE 8. Body Diode Forward Voltage Variation with Current and Temperature

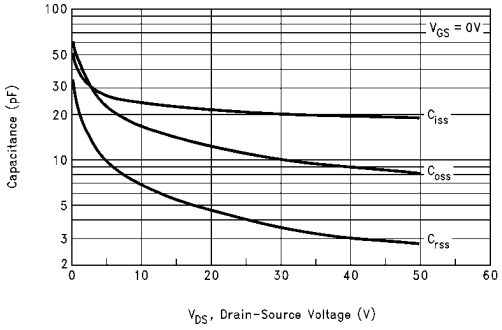

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FIGURE 9. Capacitance vs Drain-Source Voltage

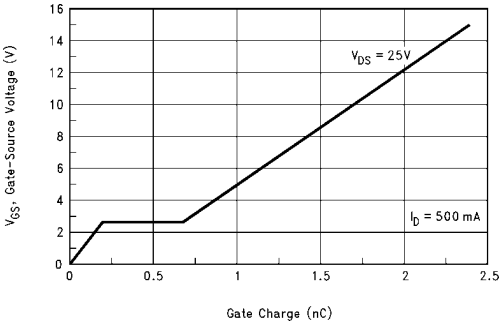

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FIGURE 10. Gate Charge vs Gate-Source Voltage

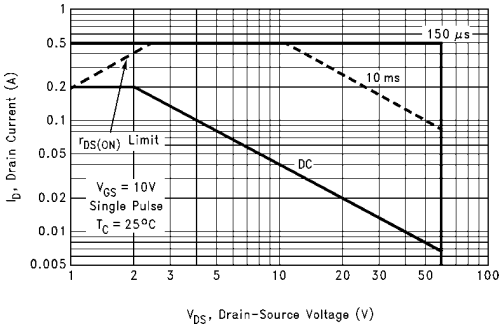

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FIGURE 11. 2N7000 Safe Operating Area

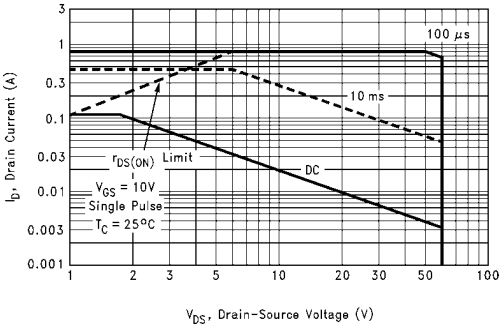

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FIGURE 12. 2N7002 Safe Operating Area

Typical Electrical Characteristics (Continued)

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

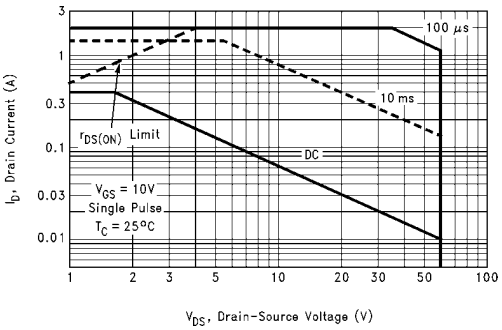

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FIGURE 13. NDF7000A Safe Operating Area

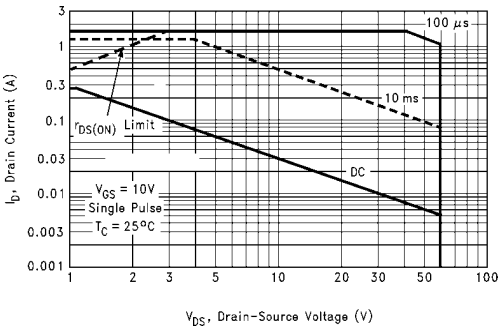

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FIGURE 14. NDS7002A Safe Operating Area

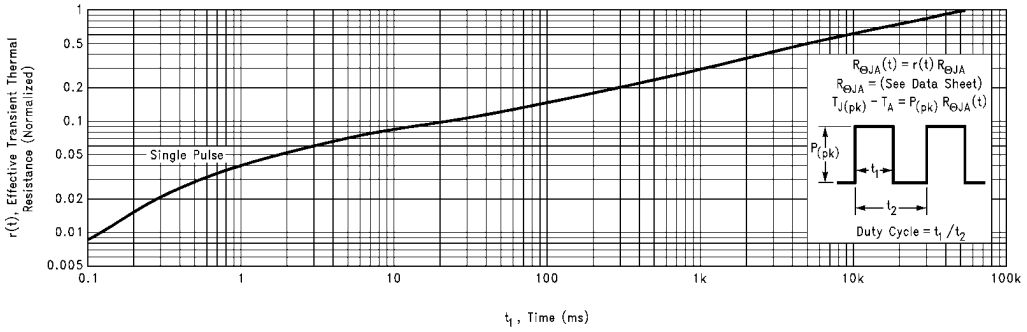

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FIGURE 15. TO-92 Transient Thermal Response

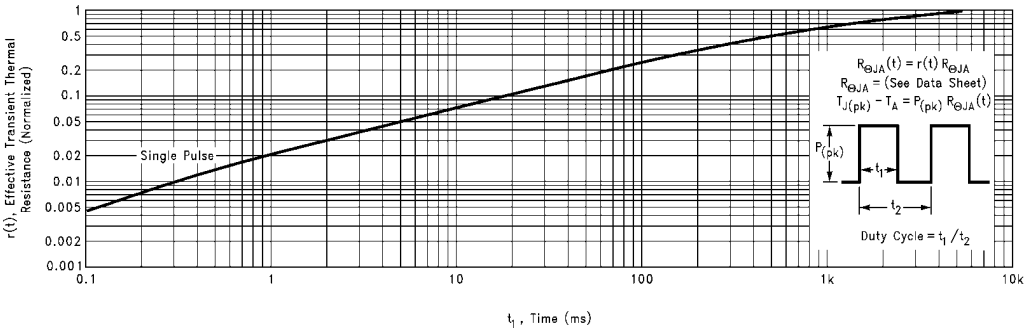

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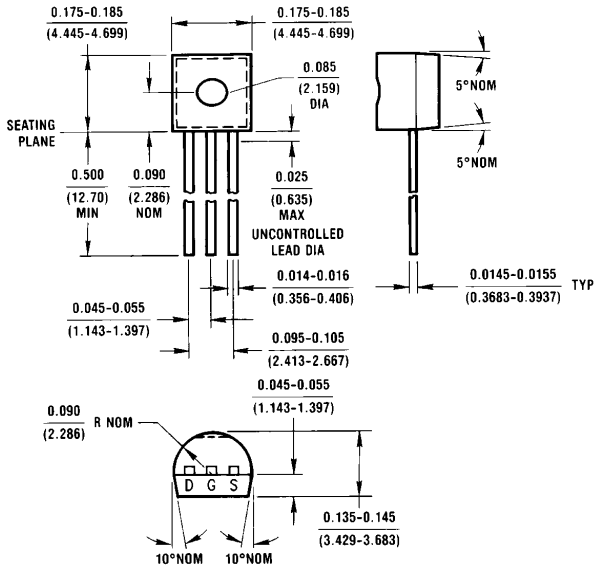
FIGURE 16. SOT-23 Transient Thermal Response

Physical Dimensions inches (millimeters)



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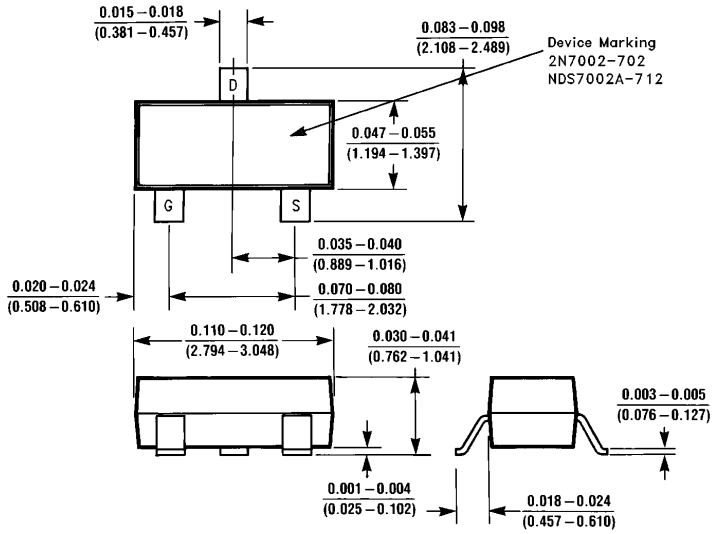
TO-92

Physical Dimensions inches (millimeters) (Continued)



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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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1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
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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