# NDF02N60Z, NDP02N60Z, NDD02N60Z

# N-Channel Power MOSFET 600 V, 4.0 Ω

**Features**

- Low ON Resistance
- Low Gate Charge
- 100% Avalanche Tested
- These Devices are Pb−Free and are RoHS Compliant

**ON Semiconductor®**

**http://onsemi.com**

| $V_{DSS}$ | $R_{DS(on)}$ (TYP) @ 1 A |
|---|---|
| 600 V | 4.0 Ω |

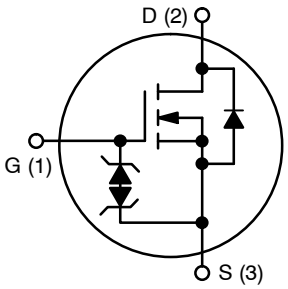
**ABSOLUTE MAXIMUM RATINGS** ($T_C$ = 25°C unless otherwise noted)

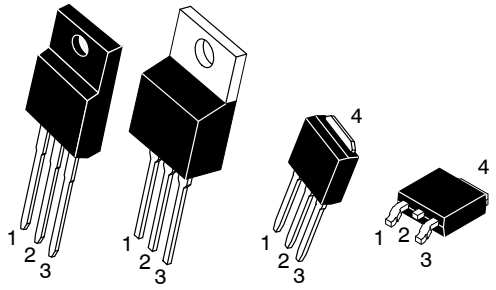
| Rating | Symbol | NDF | NDP | NDD | Unit |
|---|---|---|---|---|---|
| Drain−to−Source Voltage | $V_{DSS}$ | 600 | | | V |
| Continuous Drain Current $R_{\theta JC}$ | $I_D$ | 2.4 (Note 1) | 2.4 | 2.2 | A |
| Continuous Drain Current $R_{\theta JC}$ $T_A$ = 100°C | $I_D$ | 1.6 (Note 1) | 1.6 | 1.4 | A |
| Pulsed Drain Current, $V_{GS}$ @ 10 V | $I_{DM}$ | 10 (Note 1) | 10 | 9 | A |
| Power Dissipation $R_{\theta JC}$ | $P_D$ | 24 | 72 | 57 | W |
| Gate−to−Source Voltage | $V_{GS}$ | 30 | | | V |
| Single Pulse Avalanche Energy, $I_D$ = 2.4 A | $E_{AS}$ | 120 | | | mJ |
| ESD (HBM) (JESD 22−A114) | $V_{esd}$ | 2500 | | | V |
| RMS Isolation Voltage (t = 0.3 sec., R.H. ≤ 30%, $T_A$ = 25°C) (Figure 17) | $V_{ISO}$ | 4500 | | | V |
| Peak Diode Recovery | dv/dt | 4.5 (Note 2) | | | V/ns |
| Continuous Source Current (Body Diode) | $I_S$ | 2.4 | | | A |
| Maximum Temperature for Soldering Leads | $T_L$ | 260 | | | °C |
| Operating Junction and Storage Temperature Range | $T_J$, $T_{stg}$ | −55 to 150 | | | °C |

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

1. Limited by maximum junction temperature
2. $I_{SD}$ = 2.4 A, di/dt ≤ 100 A/μs, $V_{DD}$ ≤ $BV_{DSS}$, $T_J$ = +150°C

**N−Channel**




**TO−220FP CASE 221D STYLE 1** | **TO−220AB CASE 221A STYLE 5** | **IPAK CASE 369D STYLE 2** | **DPAK CASE 369AA STYLE 2**

## MARKING AND ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 7 of this data sheet.

## THERMAL RESISTANCE

| Parameter | | Symbol | Value | Unit |
|---|---|---|---|---|
| Junction−to−Case (Drain) | NDP02N60Z<br>NDF02N60Z<br>NDD02N60Z | $R_{\theta JC}$ | 1.7<br>5.2<br>2.2 | °C/W |
| Junction−to−Ambient Steady State | (Note 3) NDP02N60Z<br>(Note 3) NDF02N60Z<br>(Note 4) NDD02N60Z<br>(Note 3) NDD02N60Z−1 | $R_{\theta JA}$ | 51<br>51<br>41<br>80 | |

3. Insertion mounted
4. Surface mounted on FR4 board using 1″ sq. pad size, (Cu area = 1.127 in sq [2 oz] including traces).

## ELECTRICAL CHARACTERISTICS ($T_J$ = 25°C unless otherwise noted)

| Characteristic | Test Conditions | | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| **OFF CHARACTERISTICS** | | | | | | | |
| Drain−to−Source Breakdown Voltage | $V_{GS}$ = 0 V, $I_D$ = 1 mA | | $BV_{DSS}$ | 600 | | | V |
| Breakdown Voltage Temperature Coefficient | Reference to 25°C, $I_D$ = 1 mA | | $\Delta BV_{DSS}/\Delta T_J$ | | 0.6 | | V/°C |
| Drain−to−Source Leakage Current | $V_{DS}$ = 600 V, $V_{GS}$ = 0 V | 25°C | $I_{DSS}$ | | | 1 | μA |
| | | 150°C | | | | 50 | |
| Gate−to−Source Forward Leakage | $V_{GS}$ = ±20 V | | $I_{GSS}$ | | | ±10 | μA |
| **ON CHARACTERISTICS** (Note 5) | | | | | | | |
| Static Drain−to−Source On−Resistance | $V_{GS}$ = 10 V, $I_D$ = 1.0 A | | $R_{DS(on)}$ | | 4.0 | 4.8 | Ω |
| Gate Threshold Voltage | $V_{DS}$ = $V_{GS}$, $I_D$ = 50 μA | | $V_{GS(th)}$ | 3.0 | | 4.5 | V |
| Forward Transconductance | $V_{DS}$ = 15 V, $I_D$ = 1.2 A | | $g_{FS}$ | | 1.7 | | S |
| **DYNAMIC CHARACTERISTICS** | | | | | | | |
| Input Capacitance | $V_{DS}$ = 25 V, $V_{GS}$ = 0 V, f = 1.0 MHz | | $C_{iss}$ | | 274 | | pF |
| Output Capacitance | | | $C_{oss}$ | | 34 | | |
| Reverse Transfer Capacitance | | | $C_{rss}$ | | 7.0 | | |
| Total Gate Charge | $V_{DD}$ = 300 V, $I_D$ = 2.4 A, $V_{GS}$ = 10 V | | $Q_g$ | | 10.1 | | nC |
| Gate−to−Source Charge | | | $Q_{gs}$ | | 2.4 | | |
| Gate−to−Drain (“Miller”) Charge | | | $Q_{gd}$ | | 5.3 | | |
| Plateau Voltage | $V_{DD}$ = 300 V, $I_D$ = 2.4 A, $V_{OS}$ = 10 V | | $V_{GP}$ | | 6.4 | | V |
| Gate Resistance | | | $R_g$ | | 4.9 | | Ω |
| **RESISTIVE SWITCHING CHARACTERISTICS** | | | | | | | |
| Turn−On Delay Time | $V_{DD}$ = 300 V, $I_D$ = 2.4 A, $V_{GS}$ = 10 V, $R_G$ = 5 Ω | | $t_{d(on)}$ | | 9.0 | | ns |
| Rise Time | | | $t_r$ | | 7.0 | | |
| Turn−Off Delay Time | | | $t_{d(off)}$ | | 15 | | |
| Fall Time | | | $t_f$ | | 7.0 | | |
| **SOURCE−DRAIN DIODE CHARACTERISTICS** ($T_C$ = 25°C unless otherwise noted) | | | | | | | |
| Diode Forward Voltage | $I_S$ = 2.4 A, $V_{GS}$ = 0 V | | $V_{SD}$ | | | 1.6 | V |
| Reverse Recovery Time | $V_{GS}$ = 0 V, $V_{DD}$ = 30 V, $I_S$ = 2.4 A, di/dt = 100 A/μs | | $t_{rr}$ | | 240 | | ns |
| Reverse Recovery Charge | | | $Q_{rr}$ | | 0.7 | | μC |

5. Pulse Width ≤ 380 μs, Duty Cycle ≤ 2%.

## TYPICAL CHARACTERISTICS

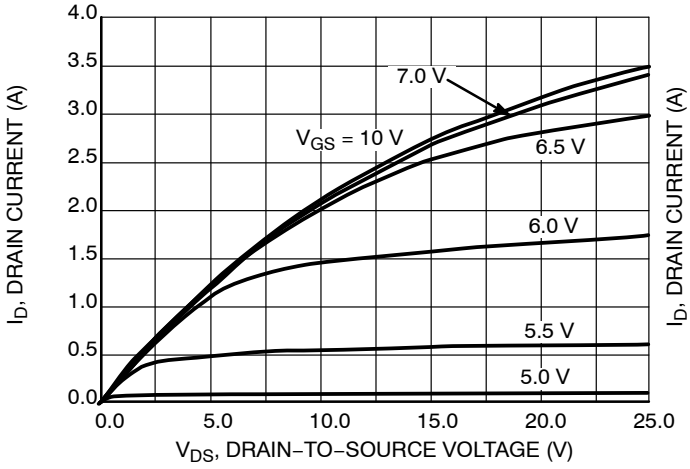



**Figure 1. On−Region Characteristics**

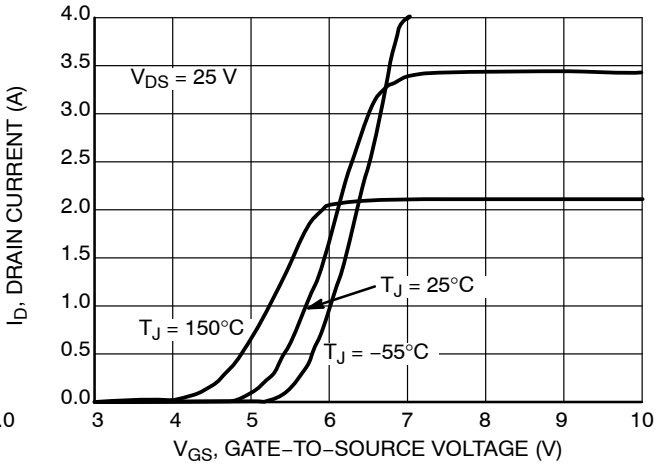



**Figure 2. Transfer Characteristics**

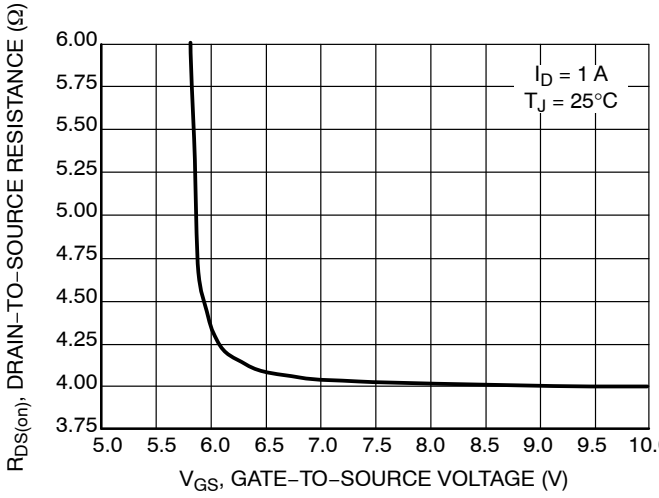



**Figure 3. On−Region versus Gate−to−Source Voltage**

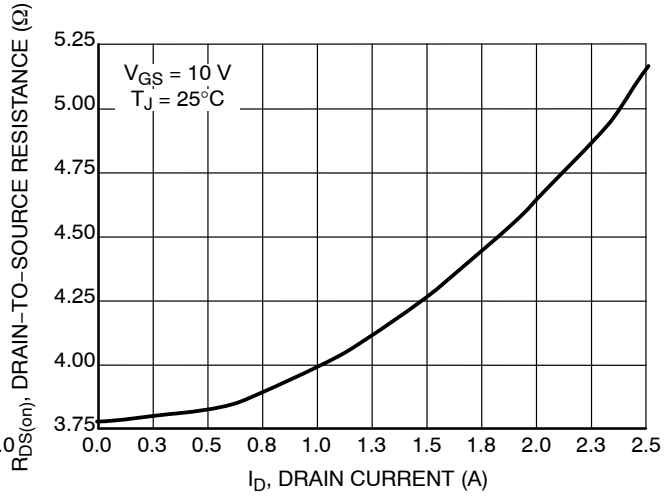



**Figure 4. On−Resistance versus Drain Current and Gate Voltage**

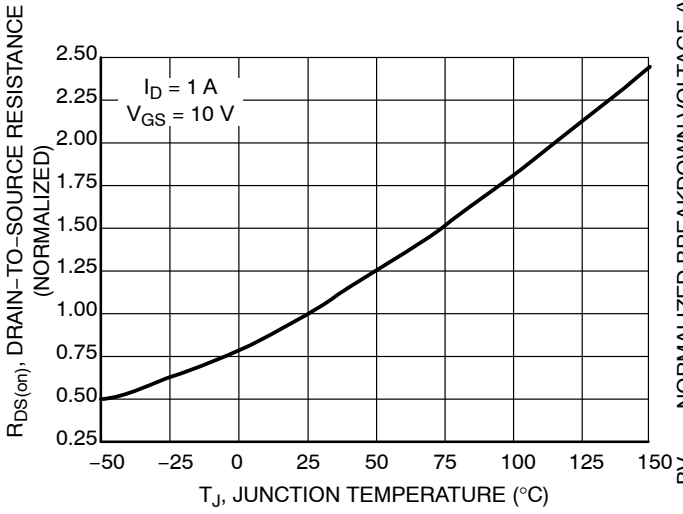



**Figure 5. On−Resistance Variation with Temperature**

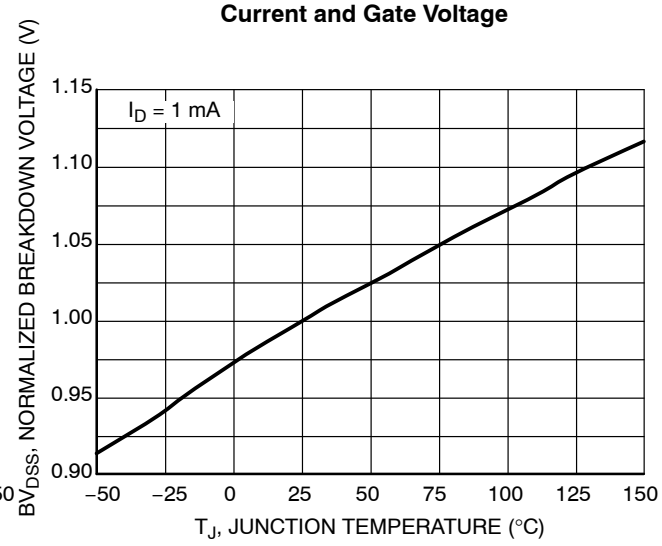



**Figure 6. $BV_{DSS}$ Variation with Temperature**

## TYPICAL CHARACTERISTICS

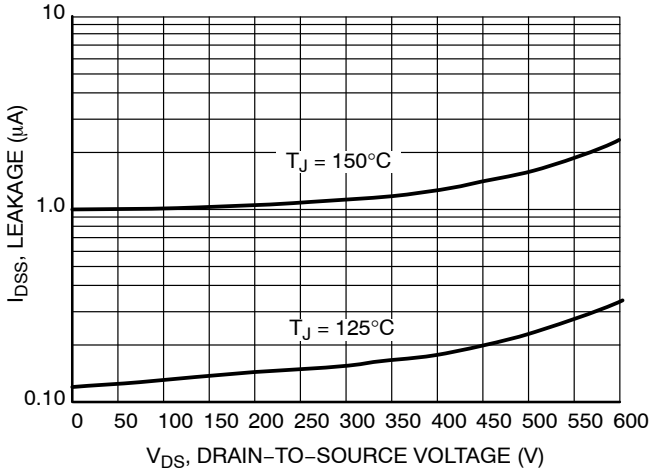



**Figure 7. Drain−to−Source Leakage Current versus Voltage**

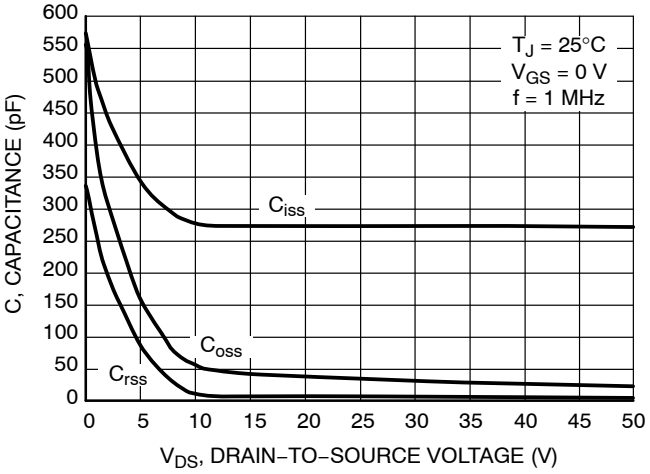



**Figure 8. Capacitance Variation**

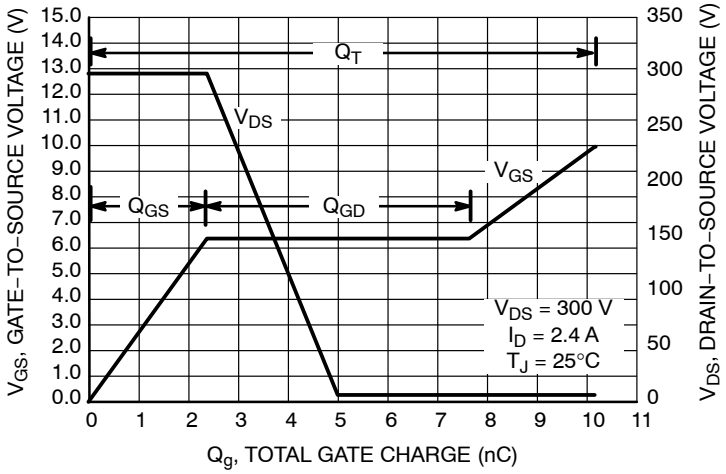



**Figure 9. Gate−to−Source Voltage and Drain−to−Source Voltage versus Total Charge**

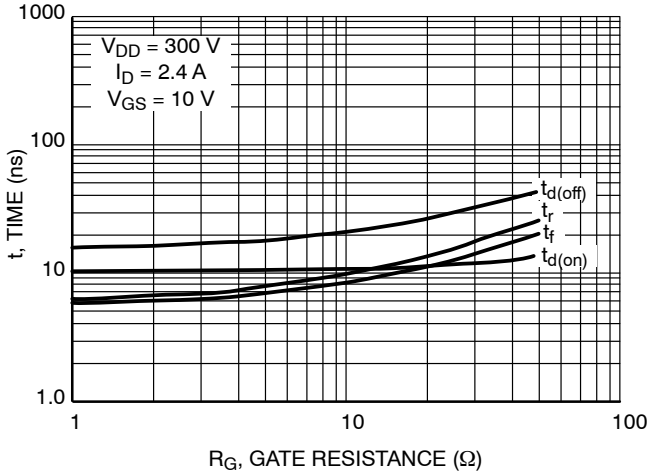



**Figure 10. Resistive Switching Time Variation versus Gate Resistance**

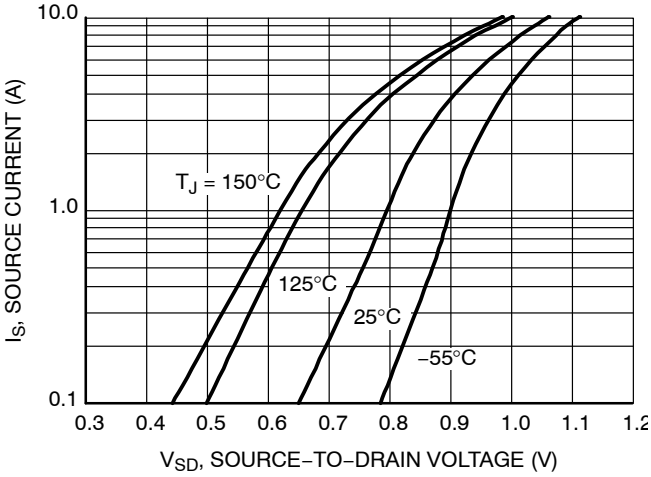



**Figure 11. Diode Forward Voltage versus Current**

## TYPICAL CHARACTERISTICS

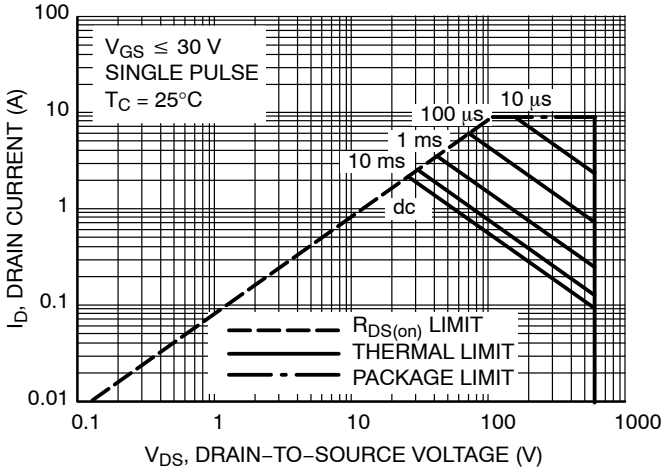



**Figure 12. Maximum Rated Forward Biased Safe Operating Area NDD02N60Z**

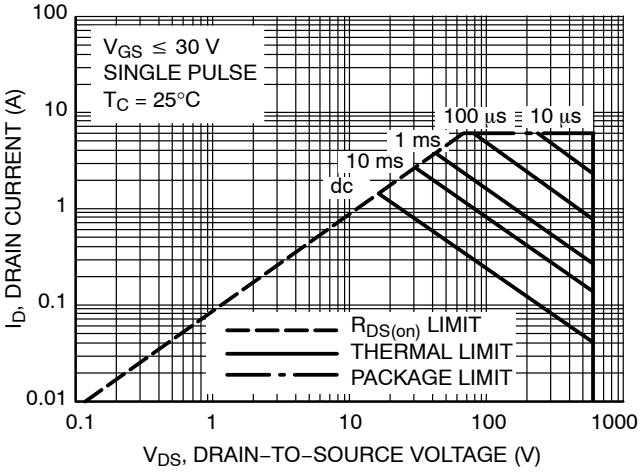



**Figure 13. Maximum Rated Forward Biased Safe Operating Area NDF02N60Z**

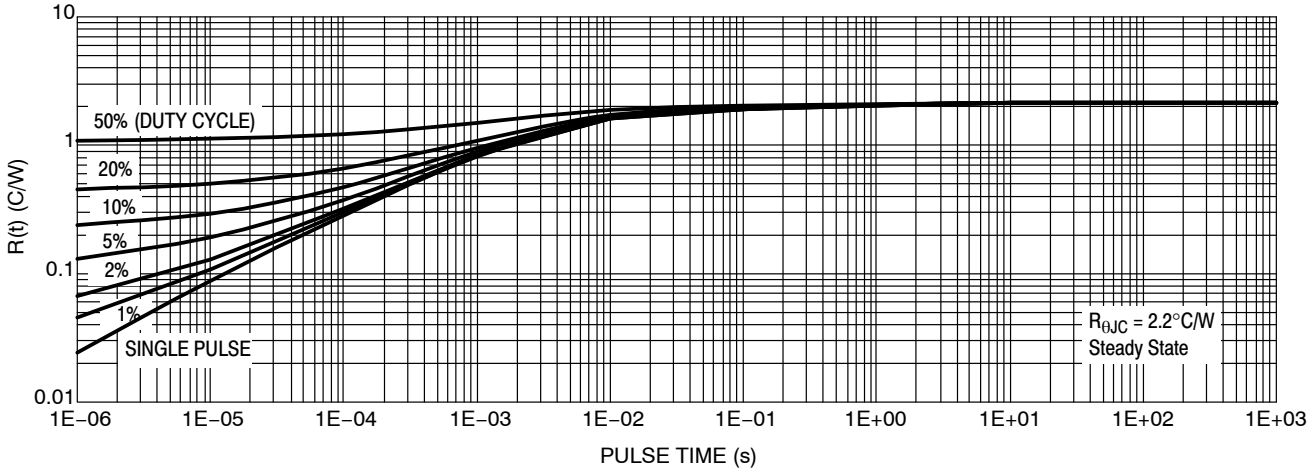



**Figure 14. Thermal Impedance (Junction−to−Case) for NDD02N60Z**

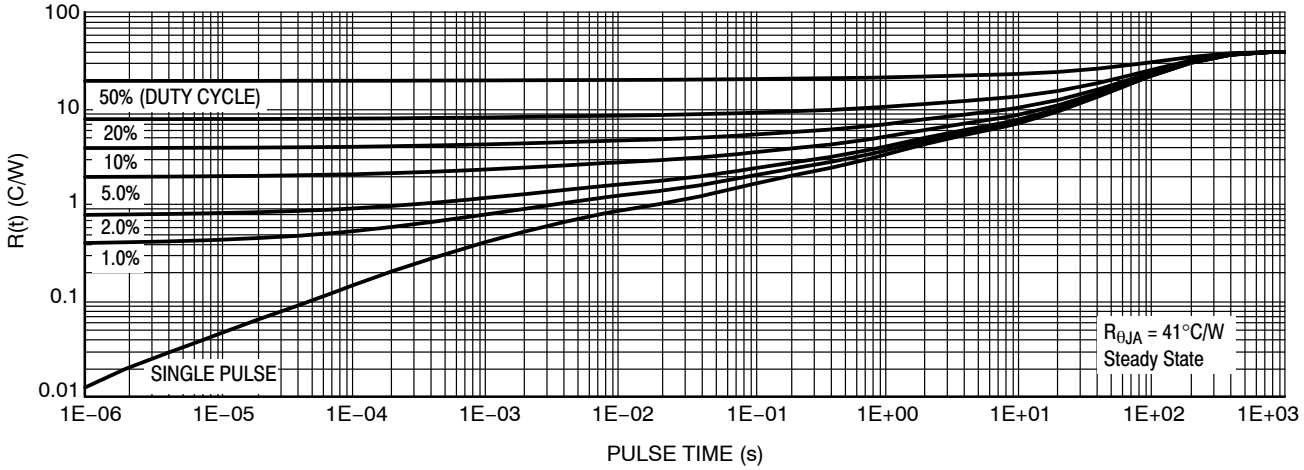



**Figure 15. Thermal Impedance (Junction−to−Ambient) for NDD02N60Z**

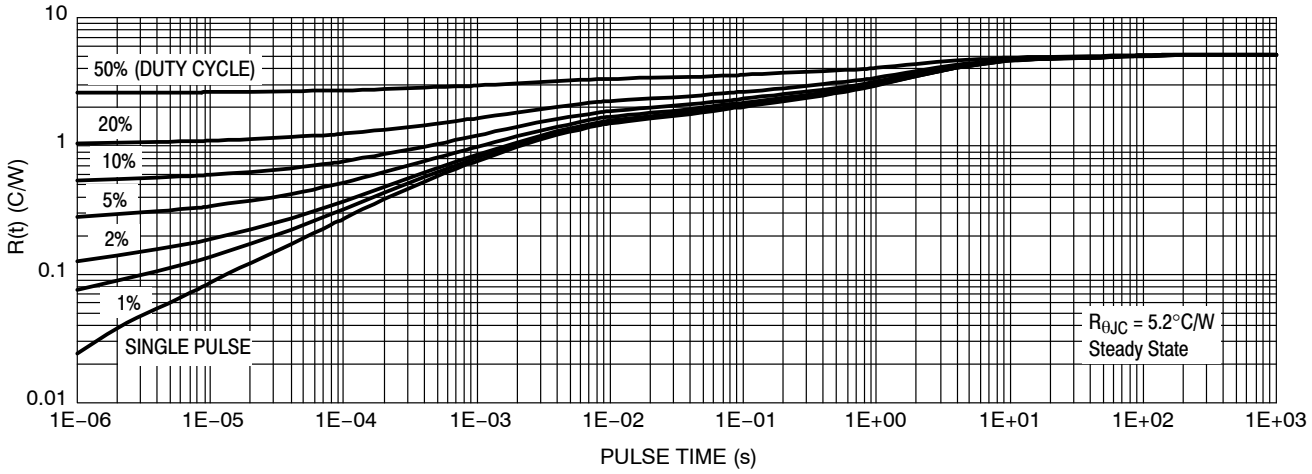



**Figure 16. Thermal Impedance (Junction−to−Case) for NDF02N60Z**

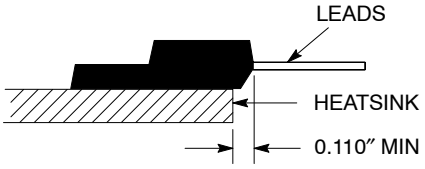



**Figure 17. Isolation Test Diagram**

Measurement made between leads and heatsink with all leads shorted together.

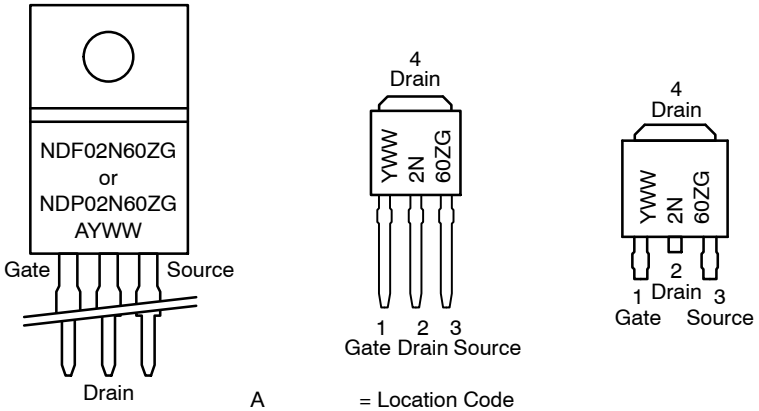
*For additional mounting information, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

## ORDERING INFORMATION

| Order Number | Package | Shipping† |
|---|---|---|
| NDF02N60ZG | TO−220FP<br>(Pb−Free) | 50 Units / Rail |
| NDP02N60ZG | TO−220AB<br>(Pb−Free) | 50 Units / Rail<br>In Development |
| NDD02N60Z−1G | IPAK<br>(Pb−Free) | 75 Units / Rail |
| NDD02N60ZT4G | DPAK<br>(Pb−Free) | 2500 / Tape & Reel |

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

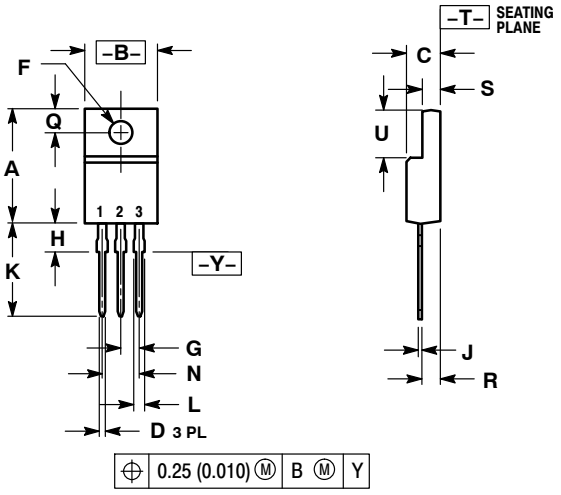
## MARKING DIAGRAMS




A = Location Code
Y = Year
WW = Work Week
G = Pb−Free Package

## PACKAGE DIMENSIONS

### TO−220 FULLPAK
CASE 221D−03
ISSUE J

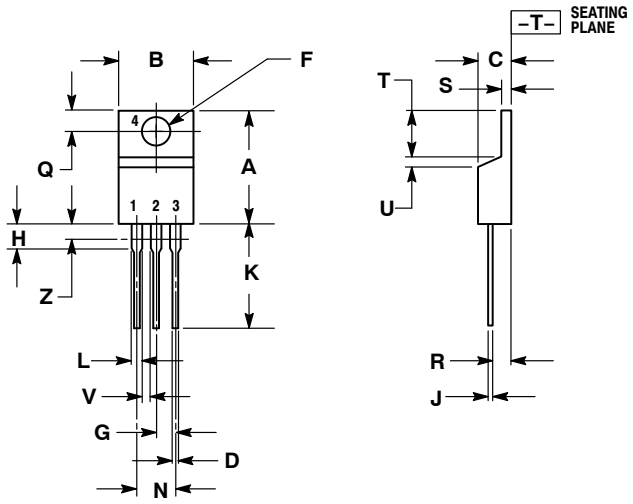



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH
3. 221D−01 THRU 221D−02 OBSOLETE, NEW STANDARD 221D−03.

| | INCHES | | MILLIMETERS | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | 0.617 | 0.635 | 15.67 | 16.12 |
| B | 0.392 | 0.419 | 9.96 | 10.63 |
| C | 0.177 | 0.193 | 4.50 | 4.90 |
| D | 0.024 | 0.039 | 0.60 | 1.00 |
| F | 0.116 | 0.129 | 2.95 | 3.28 |
| G | 0.100 BSC | | 2.54 BSC | |
| H | 0.118 | 0.135 | 3.00 | 3.43 |
| J | 0.018 | 0.025 | 0.45 | 0.63 |
| K | 0.503 | 0.541 | 12.78 | 13.73 |
| L | 0.048 | 0.058 | 1.23 | 1.47 |
| N | 0.200 BSC | | 5.08 BSC | |
| Q | 0.122 | 0.138 | 3.10 | 3.50 |
| R | 0.099 | 0.117 | 2.51 | 2.96 |
| S | 0.092 | 0.113 | 2.34 | 2.87 |
| U | 0.239 | 0.271 | 6.06 | 6.88 |

STYLE 1:
PIN 1. GATE
2. DRAIN
3. SOURCE

### TO−220AB
CASE 221A−09
ISSUE AE



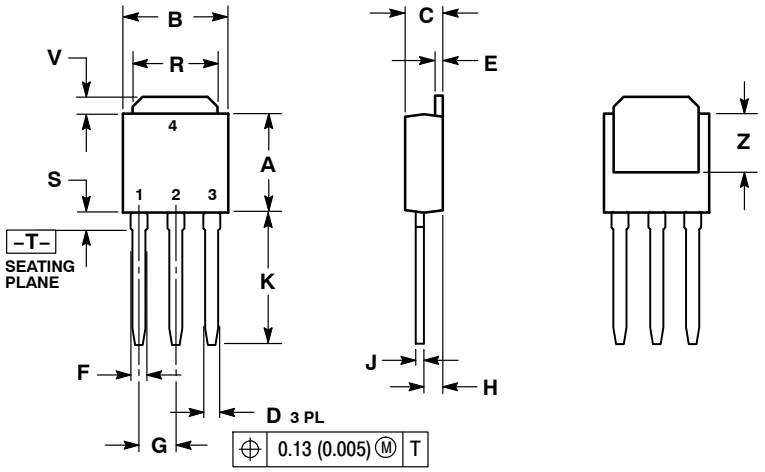

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION Z DEFINES A ZONE WHERE ALL BODY AND LEAD IRREGULARITIES ARE ALLOWED.

| | INCHES | | MILLIMETERS | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | 0.570 | 0.620 | 14.48 | 15.75 |
| B | 0.380 | 0.405 | 9.66 | 10.28 |
| C | 0.160 | 0.190 | 4.07 | 4.82 |
| D | 0.025 | 0.035 | 0.64 | 0.88 |
| F | 0.142 | 0.161 | 3.61 | 4.09 |
| G | 0.095 | 0.105 | 2.42 | 2.66 |
| H | 0.110 | 0.155 | 2.80 | 3.93 |
| J | 0.014 | 0.025 | 0.36 | 0.64 |
| K | 0.500 | 0.562 | 12.70 | 14.27 |
| L | 0.045 | 0.060 | 1.15 | 1.52 |
| N | 0.190 | 0.210 | 4.83 | 5.33 |
| Q | 0.100 | 0.120 | 2.54 | 3.04 |
| R | 0.080 | 0.110 | 2.04 | 2.79 |
| S | 0.045 | 0.055 | 1.15 | 1.39 |
| T | 0.235 | 0.255 | 5.97 | 6.47 |
| U | 0.000 | 0.050 | 0.00 | 1.27 |
| V | 0.045 | --- | 1.15 | --- |
| Z | --- | 0.080 | --- | 2.04 |

STYLE 5:
PIN 1. GATE
2. DRAIN
3. SOURCE
4. DRAIN

## PACKAGE DIMENSIONS

**IPAK**
CASE 369D−01
ISSUE B

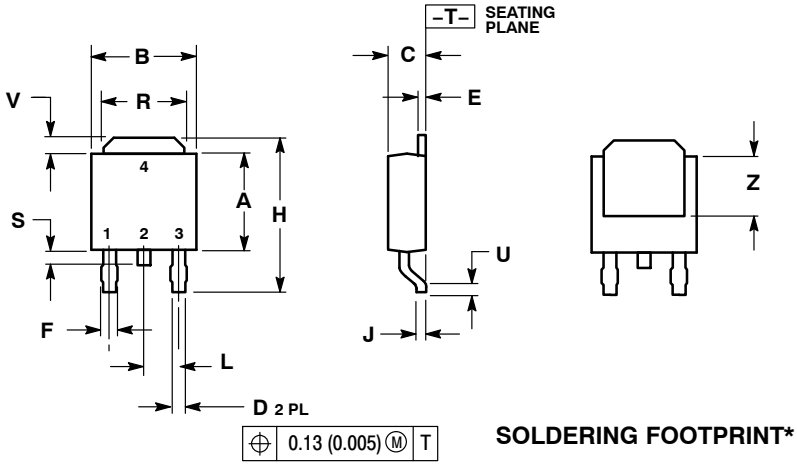



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

| | INCHES | | MILLIMETERS | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | 0.235 | 0.245 | 5.97 | 6.35 |
| B | 0.250 | 0.265 | 6.35 | 6.73 |
| C | 0.086 | 0.094 | 2.19 | 2.38 |
| D | 0.027 | 0.035 | 0.69 | 0.88 |
| E | 0.018 | 0.023 | 0.46 | 0.58 |
| F | 0.037 | 0.045 | 0.94 | 1.14 |
| G | 0.090 BSC | | 2.29 BSC | |
| H | 0.034 | 0.040 | 0.87 | 1.01 |
| J | 0.018 | 0.023 | 0.46 | 0.58 |
| K | 0.350 | 0.380 | 8.89 | 9.65 |
| R | 0.180 | 0.215 | 4.45 | 5.45 |
| S | 0.025 | 0.040 | 0.63 | 1.01 |
| V | 0.035 | 0.050 | 0.89 | 1.27 |
| Z | 0.155 | −−− | 3.93 | −−− |

STYLE 2:
PIN 1. GATE
2. DRAIN
3. SOURCE
4. DRAIN

**DPAK**
CASE 369AA−01
ISSUE A

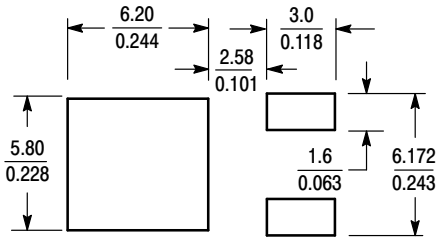



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

| | INCHES | | MILLIMETERS | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | 0.235 | 0.245 | 5.97 | 6.22 |
| B | 0.250 | 0.265 | 6.35 | 6.73 |
| C | 0.086 | 0.094 | 2.19 | 2.38 |
| D | 0.025 | 0.035 | 0.63 | 0.89 |
| E | 0.018 | 0.024 | 0.46 | 0.61 |
| F | 0.030 | 0.045 | 0.77 | 1.14 |
| H | 0.386 | 0.410 | 9.80 | 10.40 |
| J | 0.018 | 0.023 | 0.46 | 0.58 |
| L | 0.090 BSC | | 2.29 BSC | |
| R | 0.180 | 0.215 | 4.57 | 5.45 |
| S | 0.024 | 0.040 | 0.60 | 1.01 |
| U | 0.020 | −−− | 0.51 | −−− |
| V | 0.035 | 0.050 | 0.89 | 1.27 |
| Z | 0.155 | −−− | 3.93 | −−− |

STYLE 2:
PIN 1. GATE
2. DRAIN
3. SOURCE
4. DRAIN

**SOLDERING FOOTPRINT***




SCALE 3:1 (mm / inches)

*For additional information on our Pb−Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

## PUBLICATION ORDERING INFORMATION

**LITERATURE FULFILLMENT**:
Literature Distribution Center for ON Semiconductor
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**Phone**: 303−675−2175 or 800−344−3860 Toll Free USA/Canada
**Fax**: 303−675−2176 or 800−344−3867 Toll Free USA/Canada
**Email**: orderlit@onsemi.com

**N. American Technical Support**: 800−282−9855 Toll Free USA/Canada
**Europe, Middle East and Africa Technical Support:**
Phone: 421 33 790 2910
**Japan Customer Focus Center**
Phone: 81−3−5773−3850

**ON Semiconductor Website**: **www.onsemi.com**

**Order Literature**: http://www.onsemi.com/orderlit

For additional information, please contact your local Sales Representative