

# N

September 1996

## NDS9933A

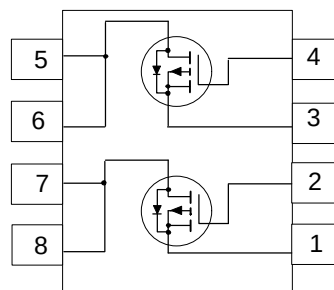
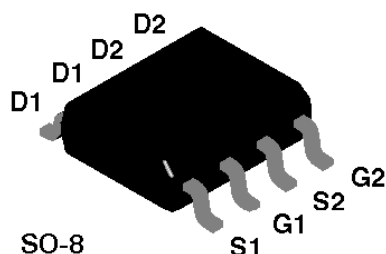
### Dual P-Channel Enhancement Mode Field Effect Transistor

#### General Description

SO-8 P-Channel enhancement mode power field effect transistors are produced using National's proprietary, high cell density, DMOS technology. This very high density process is especially tailored to minimize on-state resistance and provide superior switching performance. These devices are particularly suited for low voltage applications such as DC motor control and DC/DC conversion where fast switching, low in-line power loss, and resistance to transients are needed.

#### Features

- -2.7 A, -20 V.  $R_{DS(ON)} = 0.14 \Omega @ V_{GS} = -4.5 \text{ V}$   
 $R_{DS(ON)} = 0.19 \Omega @ V_{GS} = -2.7 \text{ V}$   
 $R_{DS(ON)} = 0.2 \Omega @ V_{GS} = -2.5 \text{ V}.$
- High density cell design for extremely low  $R_{DS(ON)}$ .
- High power and current handling capability in a widely used surface mount package.
- Dual MOSFET in surface mount package.



#### Absolute Maximum Ratings $T_A = 25^\circ\text{C}$ unless otherwise note

| Symbol         | Parameter                                        | NDS9933A   | Units            |
|----------------|--------------------------------------------------|------------|------------------|
| $V_{DSS}$      | Drain-Source Voltage                             | -20        | V                |
| $V_{GSS}$      | Gate-Source Voltage                              | -8         | V                |
| $I_D$          | Drain Current - Continuous (Note 1a)             | -2.7       | A                |
|                | - Pulsed                                         | -10        |                  |
| $P_D$          | Power Dissipation for Dual Operation             | 2          | W                |
|                | Power Dissipation for Single Operation (Note 1a) | 1.6        |                  |
|                | (Note 1b)                                        | 1          |                  |
|                | (Note 1c)                                        | 0.9        |                  |
| $T_J, T_{STG}$ | Operating and Storage Temperature Range          | -55 to 150 | $^\circ\text{C}$ |

#### THERMAL CHARACTERISTICS

|                 |                                                   |    |                    |
|-----------------|---------------------------------------------------|----|--------------------|
| $R_{\theta JA}$ | Thermal Resistance, Junction-to-Ambient (Note 1a) | 78 | $^\circ\text{C/W}$ |
| $R_{\theta JC}$ | Thermal Resistance, Junction-to-Case (Note 1)     | 40 | $^\circ\text{C/W}$ |

**ELECTRICAL CHARACTERISTICS** ( $T_A = 25^\circ\text{C}$  unless otherwise noted)

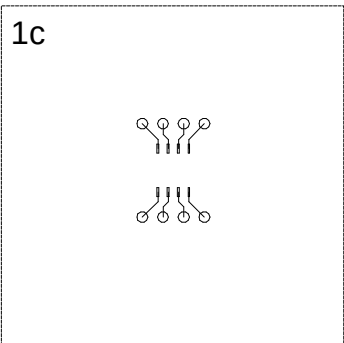
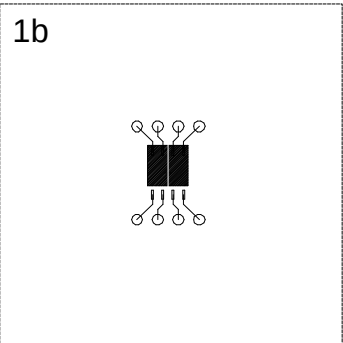
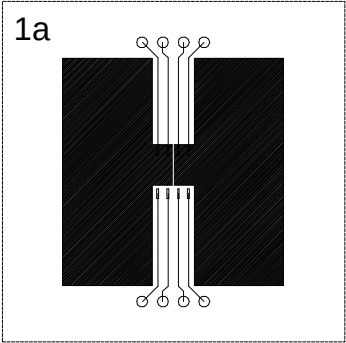
| Symbol                             | Parameter                         | Conditions                                                                                        | Min  | Typ   | Max  | Units         |
|------------------------------------|-----------------------------------|---------------------------------------------------------------------------------------------------|------|-------|------|---------------|
| OFF CHARACTERISTICS                |                                   |                                                                                                   |      |       |      |               |
| $BV_{DSS}$                         | Drain-Source Breakdown Voltage    | $V_{GS} = 0\text{ V}, I_D = -250\text{ }\mu\text{A}$                                              | -20  |       |      | V             |
| $I_{DSS}$                          | Zero Gate Voltage Drain Current   | $V_{DS} = -16\text{ V}, V_{GS} = 0\text{ V}$                                                      |      |       | 1    | $\mu\text{A}$ |
|                                    |                                   | $T_J = 55^\circ\text{C}$                                                                          |      |       | 10   | $\mu\text{A}$ |
| $I_{GSSF}$                         | Gate - Body Leakage, Forward      | $V_{GS} = 8\text{ V}, V_{DS} = 0\text{ V}$                                                        |      |       | 100  | nA            |
| $I_{GSSR}$                         | Gate - Body Leakage, Reverse      | $V_{GS} = -8\text{ V}, V_{DS} = 0\text{ V}$                                                       |      |       | -100 | nA            |
| ON CHARACTERISTICS (Note 2)        |                                   |                                                                                                   |      |       |      |               |
| $V_{GS(th)}$                       | Gate Threshold Voltage            | $V_{DS} = V_{GS}, I_D = -250\text{ }\mu\text{A}$                                                  | -0.4 | -0.65 | -1   | V             |
|                                    |                                   | $T_J = 125^\circ\text{C}$                                                                         | -0.3 | -0.46 | -0.6 |               |
| $R_{DS(on)}$                       | Static Drain-Source On-Resistance | $V_{GS} = -4.5\text{ V}, I_D = -2.7\text{ A}$                                                     |      | 0.122 | 0.14 | $\Omega$      |
|                                    |                                   | $T_J = 125^\circ\text{C}$                                                                         |      | 0.15  | 0.24 |               |
|                                    |                                   | $V_{GS} = -2.7\text{ V}, I_D = -1\text{ A}$                                                       |      | 0.16  | 0.19 |               |
|                                    |                                   | $V_{GS} = -2.5\text{ V}, I_D = -1\text{ A}$                                                       |      | 0.17  | 0.2  |               |
| $I_{D(on)}$                        | On-State Drain Current            | $V_{GS} = -4.5\text{ V}, V_{DS} = -5\text{ V}$                                                    | -10  |       |      | A             |
|                                    |                                   | $V_{GS} = -2.7\text{ V}, V_{DS} = -5\text{ V}$                                                    | -2   |       |      |               |
| $g_{FS}$                           | Forward Transconductance          | $V_{DS} = -5\text{ V}, I_D = -2.7\text{ A}$                                                       |      | 5     |      |               |
| DYNAMIC CHARACTERISTICS            |                                   |                                                                                                   |      |       |      |               |
| $C_{iss}$                          | Input Capacitance                 | $V_{DS} = -10\text{ V}, V_{GS} = 0\text{ V},$<br>$f = 1.0\text{ MHz}$                             |      | 500   |      | pF            |
| $C_{oss}$                          | Output Capacitance                |                                                                                                   |      | 245   |      | pF            |
| $C_{rss}$                          | Reverse Transfer Capacitance      |                                                                                                   |      | 90    |      | pF            |
| SWITCHING CHARACTERISTICS (Note 2) |                                   |                                                                                                   |      |       |      |               |
| $t_{D(on)}$                        | Turn - On Delay Time              | $V_{DD} = -5\text{ V}, I_D = -1\text{ A},$<br>$V_{GS} = -4.5\text{ V}, R_{GEN} = 6\text{ }\Omega$ |      | 10    | 18   | ns            |
| $t_r$                              | Turn - On Rise Time               |                                                                                                   |      | 26    | 50   | ns            |
| $t_{D(off)}$                       | Turn - Off Delay Time             |                                                                                                   |      | 37    | 60   | ns            |
| $t_f$                              | Turn - Off Fall Time              |                                                                                                   |      | 42    | 75   | ns            |
| $Q_g$                              | Total Gate Charge                 | $V_{DS} = -10\text{ V},$<br>$I_D = -2.7\text{ A}, V_{GS} = -4.5\text{ V}$                         |      | 7.8   | 10   | nC            |
| $Q_{gs}$                           | Gate-Source Charge                |                                                                                                   |      | 1     |      | nC            |
| $Q_{gd}$                           | Gate-Drain Charge                 |                                                                                                   |      | 2     |      | nC            |

| ELECTRICAL CHARACTERISTICS (T <sub>A</sub> = 25°C unless otherwise noted) |                                                       |                                                          |     |       |      |       |
|---------------------------------------------------------------------------|-------------------------------------------------------|----------------------------------------------------------|-----|-------|------|-------|
| Symbol                                                                    | Parameter                                             | Conditions                                               | Min | Typ   | Max  | Units |
| DRAIN-SOURCE DIODE CHARACTERISTICS AND MAXIMUM RATINGS                    |                                                       |                                                          |     |       |      |       |
| I <sub>S</sub>                                                            | Maximum Continuous Drain-Source Diode Forward Current |                                                          |     |       | -1.3 | A     |
| V <sub>SD</sub>                                                           | Drain-Source Diode Forward Voltage                    | V <sub>GS</sub> = 0 V, I <sub>S</sub> = - 1.3 A (Note 2) |     | -0.79 | -1.2 | V     |

Notes:

- R<sub>θJA</sub> is the sum of the junction-to-case and case-to-ambient thermal resistance where the case thermal reference is defined as the solder mounting surface of the drain pins. R<sub>θJC</sub> is guaranteed by design while R<sub>θCA</sub> is determined by the user's board design.  

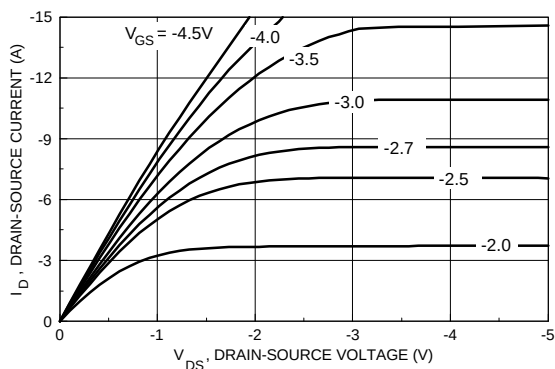
$$P_D(t) = \frac{T_J - T_A}{R_{\theta JA}(t)} = \frac{T_J - T_A}{R_{\theta JC} + R_{\theta CA}(t)} = I_D^2(t) \times R_{DS(ON)@T_J}$$
 Typical R<sub>θJA</sub> for single device operation using the board layouts shown below on 4.5"x5" FR-4 PCB in a still air environment:
  - 78°C/W when mounted on a 0.5 in<sup>2</sup> pad of 2oz copper.
  - 125°C/W when mounted on a 0.02 in<sup>2</sup> pad of 2oz copper.
  - 135°C/W when mounted on a 0.003 in<sup>2</sup> pad of 2oz copper.



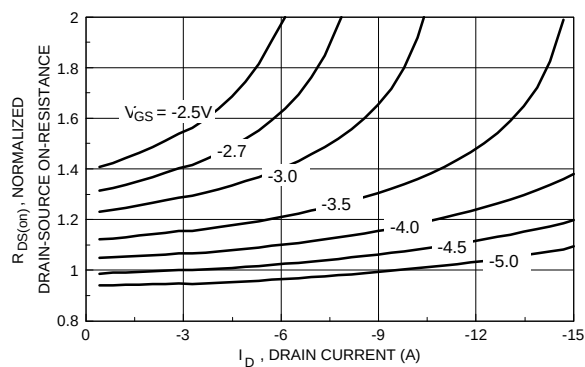
Scale 1 : 1 on letter size paper.

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

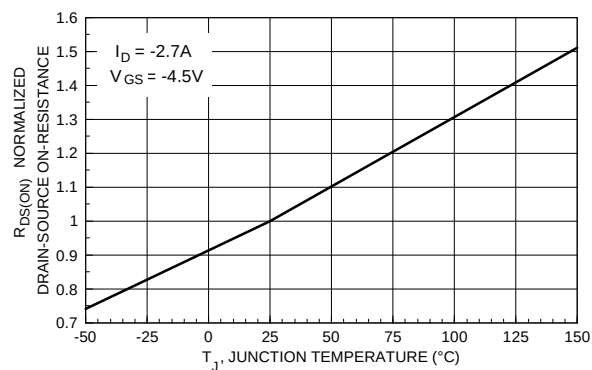
## Typical Electrical Characteristics



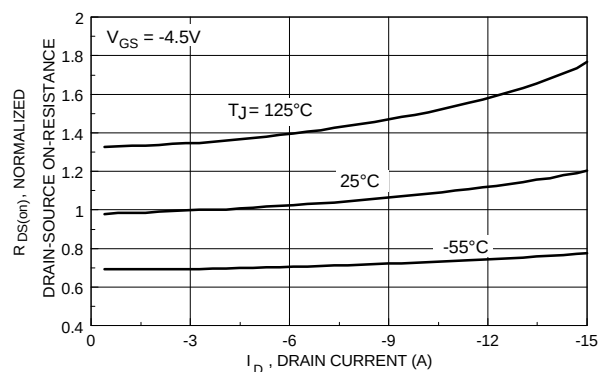
**Figure 1. On-Region Characteristics.**



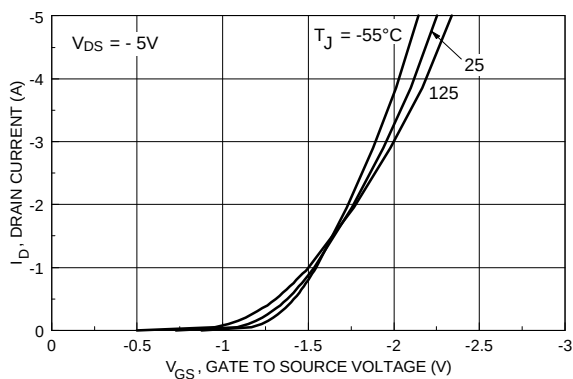
**Figure 2. On-Resistance Variation with Gate Voltage and Drain Current.**



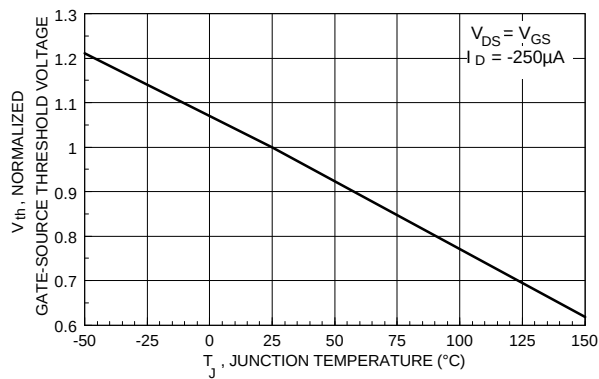
**Figure 3. On-Resistance Variation with Temperature.**



**Figure 4. On-Resistance Variation with Drain Current and Temperature.**

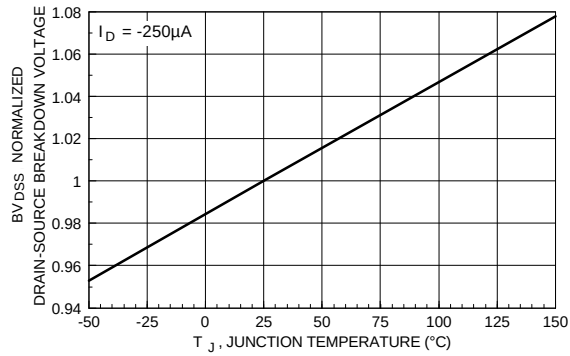


**Figure 5. Transfer Characteristics.**

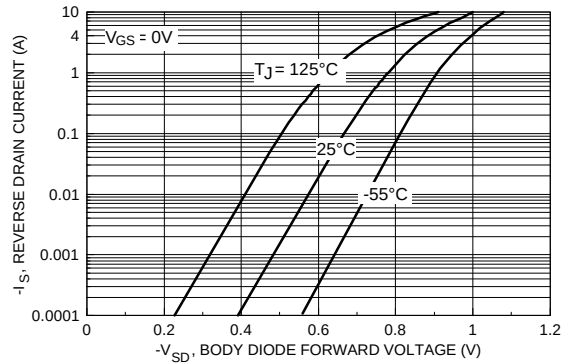


**Figure 6. Gate Threshold Variation with Temperature.**

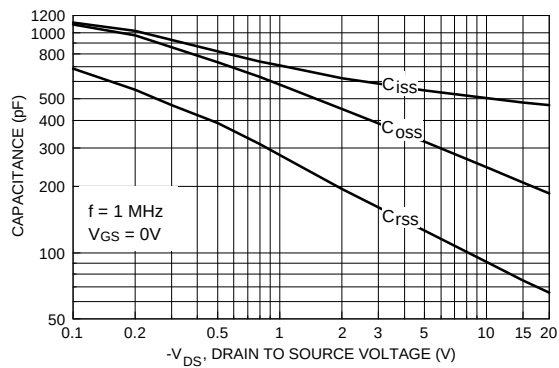
## Typical Electrical Characteristics



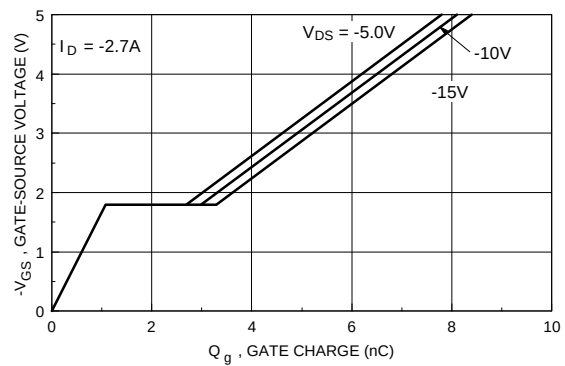
**Figure 7. Breakdown Voltage Variation with Temperature.**



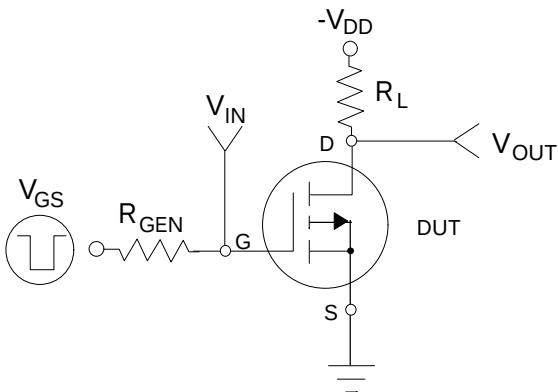
**Figure 8. Body Diode Forward Voltage Variation with Current and Temperature.**



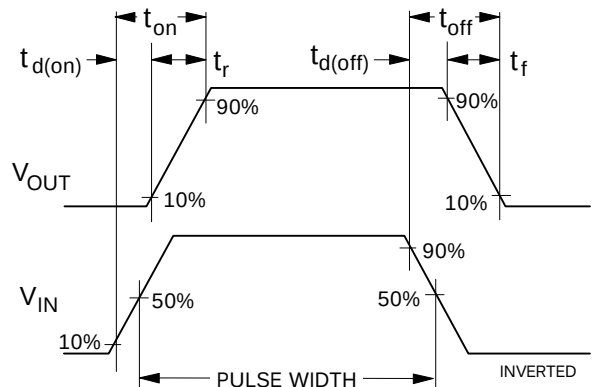
**Figure 9. Capacitance Characteristics.**



**Figure 10. Gate Charge Characteristics.**

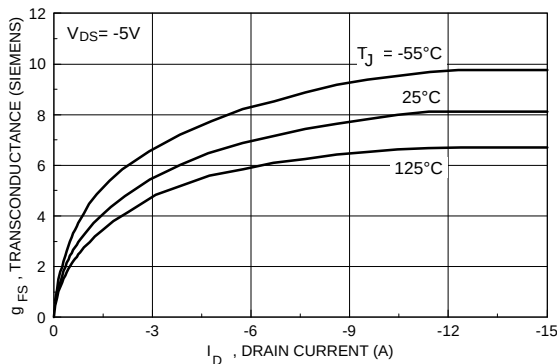


**Figure 11. Switching Test Circuit**

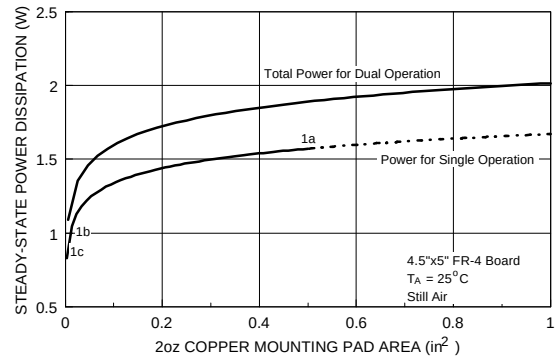


**Figure 12. Switching Waveforms**

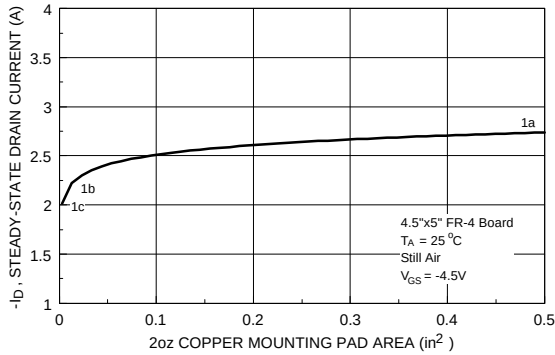
## Typical Electrical and Thermal Characteristics



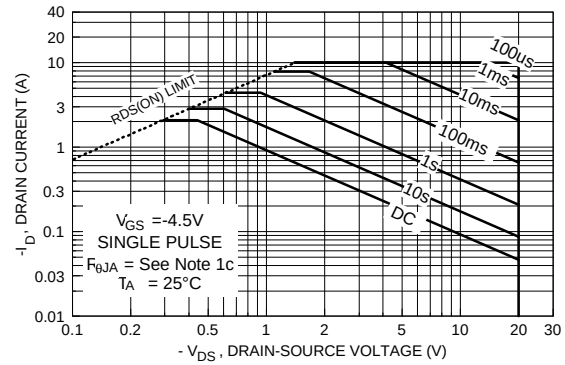
**Figure 13. Transconductance Variation with Drain Current and Temperature.**



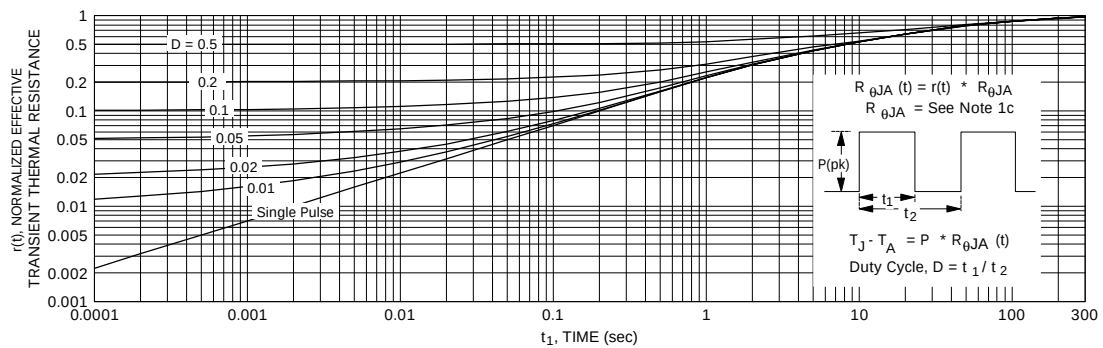
**Figure 14. SO-8 Dual Package Maximum Steady-State Power Dissipation versus Copper Mounting Pad Area.**



**Figure 15. Maximum Steady-State Drain Current versus Copper Mounting Pad Area.**



**Figure 16. Maximum Safe Operating Area.**



**Figure 17. Transient Thermal Response Curve.**

Note: Thermal characterization performed using the conditions described in note 1c. Transient thermal response will change depending on the circuit board design.