## N-CHANNEL 650V - 1 $\Omega$ - 7A TO-220/TO-220FP Zener-Protected SuperMESH ${ }^{\text {TMP }}$ Power MOSFET

TARGET DATA

| TYPE | V $_{\text {DSS }}$ | $\mathbf{R}_{\text {DS(on) }}$ | I $_{\mathbf{D}}$ | Pw |
| :--- | :---: | :---: | :---: | :---: |
| STP9NK65Z | 650 V | $<1.2 \Omega$ | 7 A | 110 W |
| STP9NK65ZFP | 650 V | $<1.2 \Omega$ | 7 A | 30 W |

- TYPICAL RDS(on) $=1.0 \Omega$
- EXTREMELY HIGH dv/dt CAPABILITY
- IMPROVED ESD CAPABILITY
- $100 \%$ AVALANCHE RATED
- GATE CHARGE MINIMIZED
- VERY LOW INTRINSIC CAPACITANCES
- VERY GOOD MANUFACTURING REPEATIBILITY


## DESCRIPTION

The SuperMESH ${ }^{\text {TM }}$ series is obtained through an extreme optimization of ST's well established stripbased PowerMESH ${ }^{\text {TM }}$ layout. In addition to pushing on-resistance significantly down, special care is taken to ensure a very good dv/dt capability for the most demanding applications. Such series complements ST full range of high voltage MOSFETs including revolutionary MDmesh ${ }^{\text {TM }}$ products.

## APPLICATIONS

- HIGH CURRENT, HIGH SPEED SWITCHING
- IDEAL FOR OFF-LINE POWER SUPPLIES, ADAPTORS AND PFC



## INTERNAL SCHEMATIC DIAGRAM



ORDERING INFORMATION

| SALES TYPE | MARKING | PACKAGE | PACKAGING |
| :---: | :---: | :---: | :---: |
| STP9NK65Z | P9NK65Z | TO-220 | TUBE |
| STP9NK65ZFP | P9NK65ZFP | TO-220FP | TUBE |

ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value |  | Unit |
| :---: | :---: | :---: | :---: | :---: |
|  |  | STP9NK65Z | STP9NK65ZFP |  |
| $\mathrm{V}_{\mathrm{DS}}$ | Drain-source Voltage ( $\mathrm{V}_{\mathrm{GS}}=0$ ) | 650 |  | V |
| $V_{\text {DGR }}$ | Drain-gate Voltage ( $\mathrm{RGS}_{\mathrm{GS}}=20 \mathrm{k} \Omega$ ) | 650 |  | V |
| $\mathrm{V}_{\mathrm{GS}}$ | Gate- source Voltage | $\pm 30$ |  | V |
| ID | Drain Current (continuous) at $\mathrm{T}_{\mathrm{C}}=25^{\circ} \mathrm{C}$ | 7 | $7{ }^{*}$ ) | A |
| ID | Drain Current (continuous) at $\mathrm{T}_{\mathrm{C}}=100^{\circ} \mathrm{C}$ | 4.4 | 4.4 (*) | A |
| IDM (•) | Drain Current (pulsed) | 28 | 28 (*) | A |
| Ртот | Total Dissipation at $\mathrm{T}_{\mathrm{C}}=25^{\circ} \mathrm{C}$ | 110 | 30 | W |
|  | Derating Factor | 0.88 | 0.24 | W/ ${ }^{\circ} \mathrm{C}$ |
| $\mathrm{V}_{\text {ESD }}(\mathrm{G}-\mathrm{S})$ | Gate source ESD(HBM-C=100pF, R=1.5K 2 ) | 3500 |  | KV |
| dv/dt (1) | Peak Diode Recovery voltage slope | TBD |  | V/ns |
| VISO | Insulation Withstand Voltage (DC) | - | 2500 | V |
| $\begin{gathered} \hline \mathrm{T}_{\mathrm{j}} \\ \mathrm{~T}_{\mathrm{stg}} \end{gathered}$ | Operating Junction Temperature Storage Temperature | $\begin{aligned} & -55 \text { to } 150 \\ & -55 \text { to } 150 \end{aligned}$ |  | $\begin{aligned} & { }^{\circ} \mathrm{C} \\ & { }^{\circ} \mathrm{C} \end{aligned}$ |

(•) Pulse width limited by safe operating area
(1) I $_{\text {SD }} \leq T B D, ~ d i / d t \leq T B D, V_{D D} \leq V_{(B R) D S S}, T_{j} \leq T_{J M A X}$.
(*) Limited only by maximum temperature allowed
THERMAL DATA

|  |  | TO-220 | TO-220FP |  |
| :---: | :--- | :---: | :---: | :---: |
| Rthj-case | Thermal Resistance Junction-case Max | 1.14 | 4.2 | ${ }^{\circ} \mathrm{C} / \mathrm{W}$ |
| Rthj-amb | Thermal Resistance Junction-ambient Max | 62.5 |  | ${ }^{\circ} \mathrm{C} / \mathrm{W}$ |
| $\mathrm{T}_{1}$ | Maximum Lead Temperature For Soldering Purpose |  | 300 | ${ }^{\circ} \mathrm{C}$ |

## AVALANCHE CHARACTERISTICS

| Symbol | Parameter | Max Value | Unit |
| :---: | :--- | :---: | :---: |
| $I_{\text {AR }}$ | Avalanche Current, Repetitive or Not-Repetitive <br> (pulse width limited by $\mathrm{T}_{\mathrm{j}}$ max) | 7 | A |
| $\mathrm{E}_{\mathrm{AS}}$ | Single Pulse Avalanche Energy <br> (starting $\left.T_{j}=25^{\circ} \mathrm{C}, \mathrm{I}_{\mathrm{D}}=\mathrm{I}_{\mathrm{AR}}, V_{\mathrm{DD}}=50 \mathrm{~V}\right)$ | TBD | mJ |

GATE-SOURCE ZENER DIODE

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
| :---: | :--- | :--- | :---: | :---: | :---: | :---: |
| BV ${ }_{\text {GSO }}$ | Gate-Source Breakdown <br> Voltage | $\operatorname{lgs}= \pm 1 \mathrm{~mA}$ (Open Drain) | 30 |  |  | V |

## PROTECTION FEATURES OF GATE-TO-SOURCE ZENER DIODES

The built-in back-to-back Zener diodes have specifically been designed to enhance not only the device's ESD capability, but also to make them safely absorb possible voltage transients that may occasionally be applied from gate to souce. In this respect the Zener voltage is appropriate to achieve an efficient and costeffective intervention to protect the device's integrity. These integrated Zener diodes thus avoid the usage of external components.

ELECTRICAL CHARACTERISTICS (TCASE $=25^{\circ} \mathrm{C}$ UNLESS OTHERWISE SPECIFIED) ON/OFF

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathrm{V}_{\text {(BR) }{ }^{\text {dss }}}$ | Drain-source Breakdown Voltage | $\mathrm{I}_{\mathrm{D}}=1 \mathrm{~mA}, \mathrm{~V}_{\mathrm{GS}}=0$ | 650 |  |  | V |
| IdSs | Zero Gate Voltage <br> Drain Current (VGS $=0$ ) | $V_{D S}=$ Max Rating <br> $V_{D S}=$ Max Rating, $T_{C}=125^{\circ} \mathrm{C}$ |  |  | $\begin{gathered} 1 \\ 50 \end{gathered}$ | $\begin{aligned} & \mu \mathrm{A} \\ & \mu \mathrm{~A} \end{aligned}$ |
| IGss | Gate-body Leakage Current (VDS $=0$ ) | $\mathrm{V}_{\mathrm{GS}}= \pm 20 \mathrm{~V}$ |  |  | $\pm 10$ | $\mu \mathrm{A}$ |
| $\mathrm{V}_{\mathrm{GS}}(\mathrm{th})$ | Gate Threshold Voltage | $\mathrm{V}_{\mathrm{DS}}=\mathrm{V}_{\mathrm{GS}}, \mathrm{I}_{\mathrm{D}}=100 \mu \mathrm{~A}$ | 3 | 3.75 | 4.5 | V |
| R DS (on) | Static Drain-source On Resistance | $\mathrm{V}_{\mathrm{GS}}=10 \mathrm{~V}, \mathrm{I}_{\mathrm{D}}=3 \mathrm{~A}$ |  | 1.0 | 1.2 | $\Omega$ |

DYNAMIC

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| gfs (1) | Forward Transconductance | $\mathrm{V}_{\mathrm{DS}}=8 \mathrm{~V}, \mathrm{ld}=3 \mathrm{~A}$ |  | TBD |  | S |
| $\begin{aligned} & \hline \mathrm{C}_{\text {iss }} \\ & \mathrm{C}_{\text {oss }} \\ & \mathrm{C}_{\mathrm{rss}} \end{aligned}$ | Input Capacitance Output Capacitance Reverse Transfer Capacitance | $\mathrm{V}_{\mathrm{DS}}=25 \mathrm{~V}, \mathrm{f}=1 \mathrm{MHz}, \mathrm{V}_{\mathrm{GS}}=0$ |  | $\begin{aligned} & \text { TBD } \\ & \text { TBD } \\ & \text { TBD } \end{aligned}$ |  | $\begin{aligned} & \mathrm{pF} \\ & \mathrm{pF} \\ & \mathrm{pF} \end{aligned}$ |
| Coss eq. (3) | Equivalent Output Capacitance | $\mathrm{V}_{\mathrm{GS}}=0 \mathrm{~V}, \mathrm{~V}_{\mathrm{DS}}=0 \mathrm{~V}$ to 480 V |  | TBD |  | pF |

## SWITCHING ON

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $t_{d}(o n)$ $t_{r}$ | Turn-on Delay Time Rise Time | $\begin{array}{\|l\|} \hline \mathrm{V}_{\mathrm{DD}}=325 \mathrm{~V}, \mathrm{I}_{\mathrm{D}}=3 \mathrm{~A} \\ \mathrm{R}_{\mathrm{G}}=4.7 \Omega \mathrm{~V} \mathrm{VS}=10 \mathrm{~V} \\ \text { (Resistive Load see, Figure 3) } \\ \hline \end{array}$ |  | $\begin{aligned} & \text { TBD } \\ & \text { TBD } \end{aligned}$ |  | $\begin{aligned} & \text { ns } \\ & \mathrm{ns} \end{aligned}$ |
| $\begin{aligned} & \hline \mathrm{Q}_{\mathrm{g}} \\ & \mathrm{Q}_{\mathrm{gs}} \\ & \mathrm{Q}_{\mathrm{gd}} \end{aligned}$ | Total Gate Charge Gate-Source Charge Gate-Drain Charge | $\begin{aligned} & \mathrm{V}_{\mathrm{DD}}=520 \mathrm{~V}, \mathrm{I}_{\mathrm{D}}=6 \mathrm{~A}, \\ & \mathrm{~V}_{\mathrm{GS}}=10 \mathrm{~V} \end{aligned}$ |  | $\begin{aligned} & \text { TBD } \\ & \text { TBD } \\ & \text { TBD } \end{aligned}$ |  | $\begin{aligned} & \mathrm{nC} \\ & \mathrm{nC} \\ & \mathrm{nC} \end{aligned}$ |

SWITCHING OFF

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $t_{d(\text { off })}$ | Turn-off Delay Time Fall Time | $\begin{aligned} & \hline \mathrm{V}_{\mathrm{DD}}=325 \mathrm{~V}, \mathrm{I}_{\mathrm{D}}=3 \mathrm{~A} \\ & \mathrm{R}_{\mathrm{G}}=4.7 \Omega \mathrm{~V} \mathrm{GS}_{\mathrm{GS}}=10 \mathrm{~V} \\ & \text { (Resistive Load see, Figure 3) } \end{aligned}$ |  | $\begin{aligned} & \hline \text { TBD } \\ & \text { TBD } \end{aligned}$ |  | $\begin{aligned} & \text { ns } \\ & \text { ns } \end{aligned}$ |
| $\begin{gathered} \hline \mathrm{tr}_{\mathrm{r} \text { (Voff) }} \mathrm{tf}_{\mathrm{t}} \\ \mathrm{t}_{\mathrm{c}} \end{gathered}$ | Off-voltage Rise Time Fall Time Cross-over Time | $\begin{aligned} & \hline \mathrm{V}_{\mathrm{DD}}=520 \mathrm{~V}, \mathrm{I}_{\mathrm{D}}=6 \mathrm{~A}, \\ & \mathrm{R}_{\mathrm{G}}=4.7 \Omega, \mathrm{~V}_{\mathrm{GS}}=10 \mathrm{~V} \\ & \text { (Inductive Load see, Figure 5) } \end{aligned}$ |  | $\begin{aligned} & \hline \text { TBD } \\ & \text { TBD } \\ & \text { TBD } \end{aligned}$ |  | $\begin{aligned} & \text { ns } \\ & \text { ns } \\ & \text { ns } \end{aligned}$ |

## SOURCE DRAIN DIODE

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{gathered} \text { ISD } \\ \text { ISDM }^{(2)} \end{gathered}$ | Source-drain Current Source-drain Current (pulsed) |  |  |  | $\begin{gathered} \hline 7 \\ 28 \end{gathered}$ | $\begin{aligned} & \hline \text { A } \\ & \text { A } \end{aligned}$ |
| $\mathrm{V}_{\text {SD }}$ (1) | Forward On Voltage | $\mathrm{I}_{\mathrm{SD}}=7 \mathrm{~A}, \mathrm{~V}_{\mathrm{GS}}=0$ |  |  | 1.6 | V |
| $\begin{gathered} \mathrm{t}_{\mathrm{trr}} \\ \mathrm{Q}_{\mathrm{rr}} \\ \mathrm{I}_{\mathrm{RRM}} \end{gathered}$ | Reverse Recovery Time Reverse Recovery Charge Reverse Recovery Current | $\begin{aligned} & \hline \mathrm{ISD}=6 \mathrm{~A}, \mathrm{di} / \mathrm{dt}=100 \mathrm{~A} / \mathrm{\mu s} \\ & \mathrm{~V}_{\mathrm{DD}}=35 \mathrm{~V}, \mathrm{~T}_{\mathrm{j}}=150^{\circ} \mathrm{C} \\ & \text { (see test circuit, Figure 5) } \end{aligned}$ |  | $\begin{aligned} & \hline \text { TBD } \\ & \text { TBD } \\ & \text { TBD } \end{aligned}$ |  | $\begin{gathered} \mathrm{ns} \\ \mu \mathrm{C} \\ \mathrm{~A} \end{gathered}$ |

Note: 1. Pulsed: Pulse duration $=300 \mu \mathrm{~s}$, duty cycle $1.5 \%$.
2. Pulse width limited by safe operating area.
3. $\mathrm{C}_{\text {oss eq }}$. is defined as a constant equivalent capacitance giving the same charging time as $\mathrm{C}_{\text {oss }}$ when $\mathrm{V}_{\mathrm{DS}}$ increases from 0 to $80 \%$ $V_{\text {DSS }}$.

Fig. 1: Unclamped Inductive Load Test Circuit


Fig. 3: Switching Times Test Circuit For Resistive Load


Fig. 2: Unclamped Inductive Waveform


Fig. 4: Gate Charge test Circuit


Fig. 5: Test Circuit For Inductive Load Switching And Diode Recovery Times


## TO-220 MECHANICAL DATA

| DIM. | mm |  |  | inch |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | 4.40 |  | 4.60 | 0.173 |  | 0.181 |
| C | 1.23 |  | 1.32 | 0.048 |  | 0.051 |
| D | 2.40 |  | 2.72 | 0.094 |  | 0.107 |
| D1 |  | 1.27 |  |  | 0.050 |  |
| E | 0.49 |  | 0.70 | 0.019 |  | 0.027 |
| F | 0.61 |  | 0.88 | 0.024 |  | 0.034 |
| F1 | 1.14 |  | 1.70 | 0.044 |  | 0.067 |
| F2 | 1.14 |  | 1.70 | 0.044 |  | 0.067 |
| G | 4.95 |  | 5.15 | 0.194 |  | 0.203 |
| G1 | 2.4 |  | 2.7 | 0.094 |  | 0.106 |
| H2 | 10.0 |  | 10.40 | 0.393 |  | 0.509 |
| L2 |  |  | 16.4 | 14.0 | 0.511 |  |
| L4 | 13.0 |  | 2.95 | 0.104 |  | 0.116 |
| L5 | 2.65 |  | 15.75 | 0.600 |  | 0.620 |
| L6 | 15.25 |  | 6.6 | 0.244 |  | 0.260 |
| L7 | 6.2 |  | 3.93 | 0.137 |  | 0.154 |
| L9 | 3.5 |  | 3.85 | 0.147 |  | 0.151 |
| DIA. | 3.75 |  |  |  |  |  |



## TO-220FP MECHANICAL DATA

| DIM. | mm. |  |  | inch |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | 4.4 |  | 4.6 | 0.173 |  | 0.181 |
| B | 2.5 |  | 2.7 | 0.098 |  | 0.106 |
| D | 2.5 |  | 2.75 | 0.098 |  | 0.108 |
| E | 0.45 |  | 0.7 | 0.017 |  | 0.027 |
| F | 0.75 |  | 1 | 0.030 |  | 0.039 |
| F1 | 1.15 |  | 1.5 | 0.045 |  | 0.067 |
| F2 | 1.15 |  | 1.5 | 0.045 |  | 0.067 |
| G | 4.95 |  | 5.2 | 0.195 |  | 0.204 |
| G1 | 2.4 |  | 2.7 | 0.094 |  | 0.106 |
| H | 10 |  | 10.4 | 0.393 |  | 0.409 |
| L2 |  |  |  |  | 0.630 |  |
| L3 | 28.6 |  | 30.6 | 1.126 |  | 1.204 |
| L4 | 9.8 |  | 10.6 | .0385 |  | 0.417 |
| L5 | 2.9 |  | 3.6 | 0.114 |  | 0.141 |
| L6 | 15.9 |  | 16.4 | 0.626 |  | 0.645 |
| L7 | 9 |  | 9.3 | 0.354 |  | 0.366 |
| $\varnothing$ | 3 |  | 3.2 | 0.118 |  | 0.126 |



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