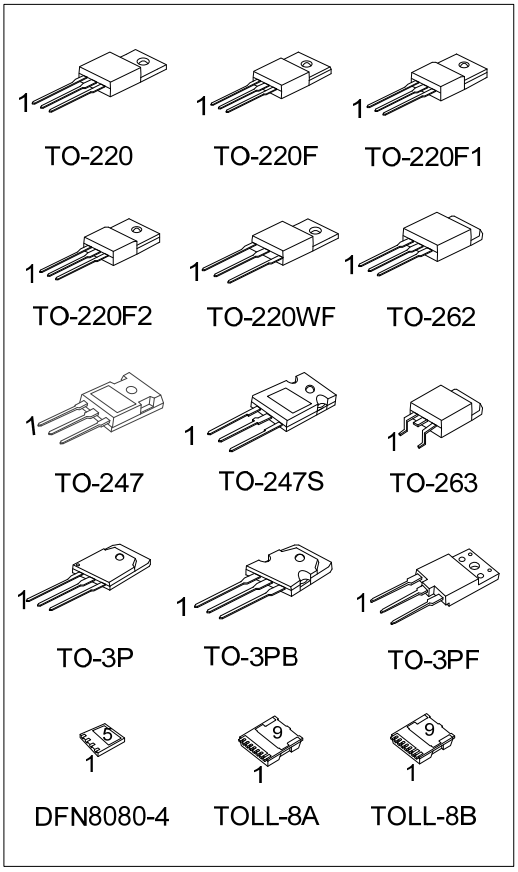
# F24NM60

**Power MOSFET**

## 24A, 600V N-CHANNEL SUPER-JUNCTION MOSFET



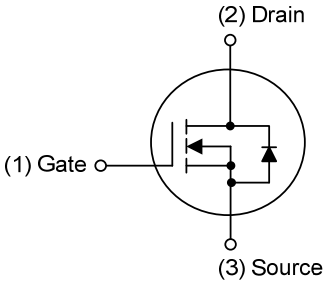

## ■ DESCRIPTION

The **UTC F24NM60** is a N-Channel enhancement mode silicon gate power MOSFET with Fast Body Diode. is designed high voltage, high speed power switching applications such. such as fast switching time, low gate charge, low on-state resistance and high rugged avalanche characteristics.

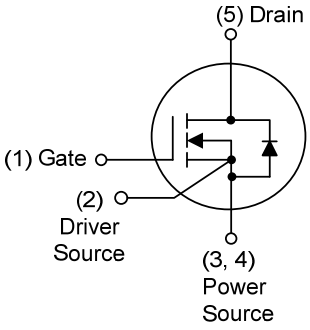
## ■ FEATURES

* $R_{DS(ON)} \leq 0.16\ \Omega$ @ $V_{GS}$=10V, $I_D$=12A
* Fast body diode MOSFET technology
* Low switching losses due to reduced Qrr
* Single Pulse Avalanche Energy Rated
* Fast Switching Speeds
* Linear Transfer Characteristics
* High Input Impedance
* Avalanche energy tested

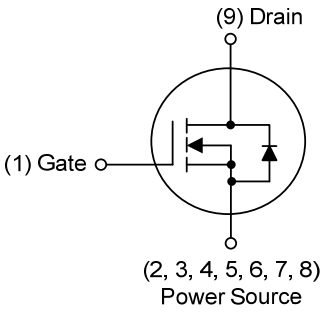
## ■ SYMBOL



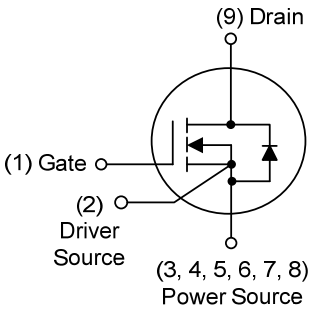

TO-220 / TO-220F / TO-220F1 / TO-220F2
TO-220WF / TO-3P / TO-3PB / TO-3PF
TO-247 /TO-247S / TO-262 / TO-263




DFN8080-4




TOLL-8A




TOLL-8B

## ■ ORDERING INFORMATION

| Ordering Number | | Package | Pin Assignment | | | | | | | | | Packing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lead Free | Halogen Free | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| F24NM60L-TA3-T | F24NM60G-TA3-T | TO-220 | G | D | S | - | - | - | - | - | - | Tube |
| F24NM60L-TF1-T | F24NM60G-TF1-T | TO-220F1 | G | D | S | - | - | - | - | - | - | Tube |
| F24NM60L-TF2-T | F24NM60G-TF2-T | TO-220F2 | G | D | S | - | - | - | - | - | - | Tube |
| F24NM60L-TF3-T | F24NM60G-TF3-T | TO-220F | G | D | S | - | - | - | - | - | - | Tube |
| F24NM60L-TW1-T | F24NM60G-TW1-T | TO-220WF | G | D | S | - | - | - | - | - | - | Tube |
| F24NM60L-T2Q-T | F24NM60G-T2Q-T | TO-262 | G | D | S | - | - | - | - | - | - | Tube |
| F24NM60L-TQ2-T | F24NM60G-TQ2-T | TO-263 | G | D | S | - | - | - | - | - | - | Tube |
| F24NM60L-TQ2-R | F24NM60G-TQ2-R | TO-263 | G | D | S | - | - | - | - | - | - | Tape Reel |
| F24NM60L-T3P-T | F24NM60G-T3P-T | TO-3P | G | D | S | - | - | - | - | - | - | Tube |
| F24NM60L-T3B-T | F24NM60G-T3B-T | TO-3PB | G | D | S | - | - | - | - | - | - | Tube |
| F24NM60L-T3F-T | F24NM60G-T3F-T | TO-3PF | G | D | S | - | - | - | - | - | - | Tube |
| F24NM60L-T47-T | F24NM60G-T47-T | TO-247 | G | D | S | - | - | - | - | - | - | Tube |
| 24NM65L-T47S-T | 24NM65G-T47S-T | TO-247S | G | D | S | - | - | - | - | - | - | Tube |
| F24NM60L-K04-8080-R | F24NM60G-K04-8080-R | DFN8080-4 | G | S | S | S | D | - | - | - | - | Tape Reel |
| F24NM60L-T8A-R | F24NM60G-T8A-R | TOLL-8A | G | S | S | S | S | S | S | S | D | Tape Reel |
| F24NM60L-T8B-R | F24NM60G-T8B-R | TOLL-8B | G | S | S | S | S | S | S | S | D | Tape Reel |

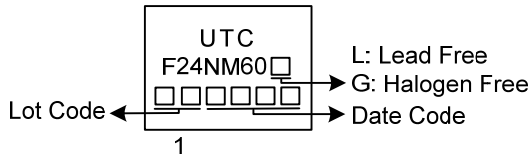
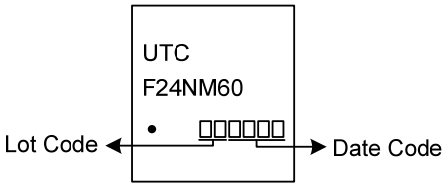
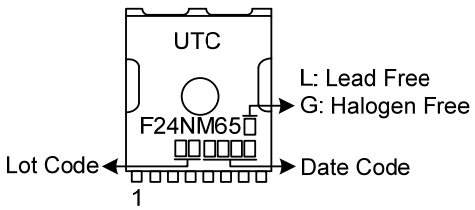
Note: Pin Assignment: G: Gate D: Drain S: Source


(1) T: Tube, R: Tape Reel

(2) TA3: TO-220, TF1: TO-220F1, TF2: TO-220F2, TF3: TO-220F, TW1: TO-220WF, T2Q: TO-262, TQ2: TO-263, T3P: TO-3P, T3B: TO-3PB, T3F: TO-3PF, T47: TO-247, T47S: TO-247S, K04-8080: DFN8080-4, T8A: TOLL-8A, T8B: TOLL-8B

(3) G: Halogen Free and Lead Free L: Lead Free

## ■ MARKING

| TO-220 / TO-220F / TO-220F1 / TO-220F2<br>TO-220WF / TO-3P / TO-3PB / TO-3PF<br>TO-247 / TO-247S / TO-262 / TO-263 | DFN8080-4 |
|---|---|
|  |  |
| TOLL-8A / TOLL-8B | - |
|  | - |

## ■ ABSOLUTE MAXIMUM RATINGS ($T_C$=25°C, unless otherwise specified)

| PARAMETER | | SYMBOL | RATINGS | UNIT |
|---|---|---|---|---|
| Drain-Source Voltage | | $V_{DSS}$ | 600 | V |
| Gate-Source Voltage | | $V_{GSS}$ | ±30 | V |
| Drain Current | Continuous | $I_D$ | 24 | A |
| | Pulsed (Note 2) | $I_{DM}$ | 48 | A |
| Avalanche Energy | Single Pulsed (Note 3) | $E_{AS}$ | 984 | mJ |
| Peak Diode Recovery dv/dt (Note 4) | | dv/dt | 13.4 | V/nS |
| Power Dissipation | TO-220/TO-262<br>TO-263 | $P_D$ | 120 | W |
| | TO-220F/TO-220F1<br>TO-220F2/TO-220WF | | 36 | W |
| | TO-3P/TO-3PB | | 155 | W |
| | TO-3PF | | 58 | W |
| | TO-247/TO-247S | | 140 | W |
| | DFN8080-4 | | 66 | W |
| | TOLL-8A/TOLL-8B | | 205 | W |
| Junction Temperature | | $T_J$ | +150 | °C |
| Storage Temperature | | $T_{STG}$ | -55 ~ +150 | °C |

Notes: 1. Absolute maximum ratings are those values beyond which the device could be permanently damaged. Absolute maximum ratings are stress ratings only and functional device operation is not implied.
2. Repetitive Rating: Pulse width limited by maximum junction temperature.
3. L = 60 mH, $I_{AS}$ = 5.7A, $V_{DD}$ = 50V, $R_G$ = 25Ω, Starting $T_J$ = 25°C
4. $I_{SD}$ ≤ 24A, di/dt ≤ 200A/μs, $V_{DD}$ ≤ $BV_{DSS}$, Starting $T_J$ = 25°C

## ■ THERMAL DATA

| PARAMETER | | SYMBOL | RATINGS | UNIT |
|---|---|---|---|---|
| Junction to Ambient | TO-220/TO-220F<br>TO-220F1/TO-220F2<br>TO-220WF/TO-262<br>TO-263 | $\theta_{JA}$ | 62.5 | °C/W |
| | TO-3P/TO-3PB<br>TO-3PF | | 30 | °C/W |
| | TO-247/TO-247S | | 40 | °C/W |
| | DFN8080-4/TOLL-8A<br>TOLL-8B | | 35 (Note) | °C/W |
| Junction to Case | TO-220/TO-262<br>TO-263 | $\theta_{JC}$ | 1.04 | °C/W |
| | TO-220F/TO-220F1<br>TO-220F2/TO-220WF | | 3.47 | °C/W |
| | TO-3P/TO-3PB | | 0.8 | °C/W |
| | TO-3PF | | 2.155 | °C/W |
| | TO-247/TO-247S | | 0.89 | °C/W |
| | DFN8080-4 | | 1.89 (Note) | °C/W |
| | TOLL-8A/TOLL-8B | | 0.6 (Note) | °C/W |

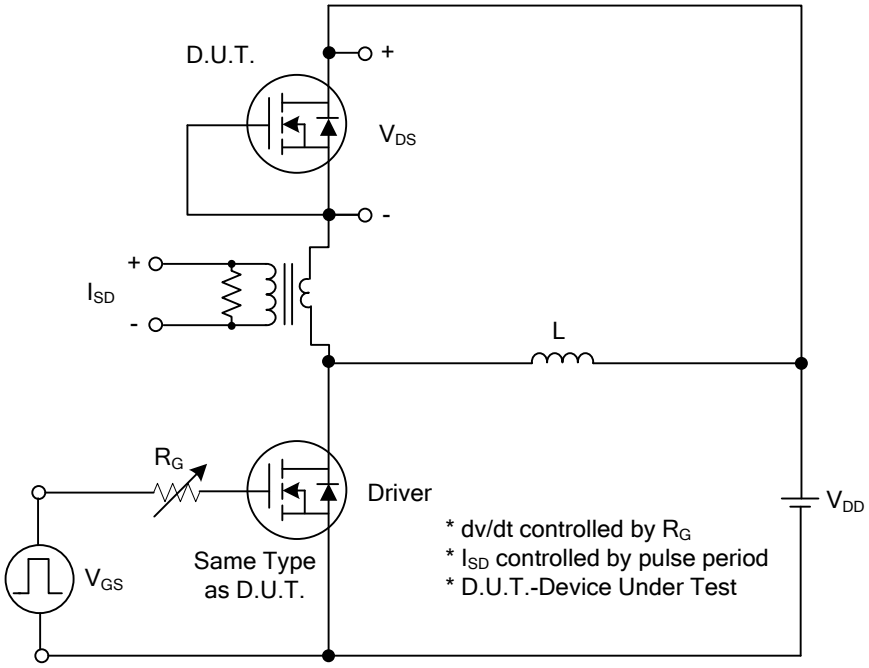
Note: Device mounted on FR-4 substrate $P_C$ board, 2oz copper, with 1inch square copper plate.

## ■ ELECTRICAL CHARACTERISTICS ($T_J$=25°C, unless otherwise specified)

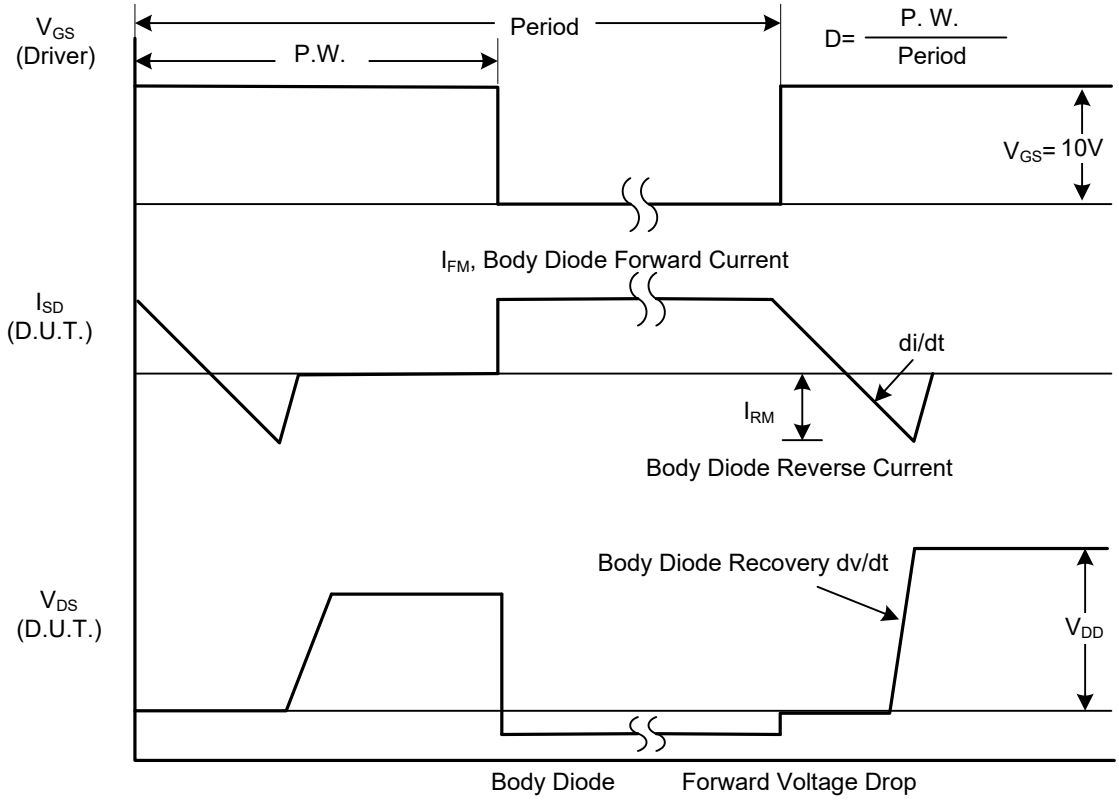
| PARAMETER | | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| **OFF CHARACTERISTICS** | | | | | | | |
| Drain-Source Breakdown Voltage | | $BV_{DSS}$ | $I_D$=250μA, $V_{GS}$=0V | 600 | | | V |
| Drain-Source Leakage Current | | $I_{DSS}$ | $V_{DS}$=600V, $V_{GS}$=0V | | | 10 | μA |
| Gate- Source Leakage Current | Forward | $I_{GSS}$ | $V_{GS}$=+30V, $V_{DS}$=0V | | | +100 | nA |
| | Reverse | | $V_{GS}$=-30V, $V_{DS}$=0V | | | -100 | nA |
| **ON CHARACTERISTICS** | | | | | | | |
| Gate Threshold Voltage | | $V_{GS(TH)}$ | $V_{DS}$=$V_{GS}$, $I_D$=250μA | 2.5 | | 4.5 | V |
| Static Drain-Source On-State Resistance | | $R_{DS(ON)}$ | $V_{GS}$=10V, $I_D$=12A | | | 0.16 | Ω |
| **DYNAMIC PARAMETERS** | | | | | | | |
| Input Capacitance | | $C_{ISS}$ | $V_{GS}$=0V, $V_{DS}$=25V, f=1.0MHz | | 1980 | | pF |
| Output Capacitance | | $C_{OSS}$ | | | 1590 | | pF |
| Reverse Transfer Capacitance | | $C_{RSS}$ | | | 140 | | pF |
| **SWITCHING PARAMETERS** | | | | | | | |
| Total Gate Charge (Note 1) | | $Q_G$ | $V_{DS}$=480V, $V_{GS}$=10V, $I_D$=24A $I_G$=1mA (Note1, 2) | | 77 | | nC |
| Gate to Source Charge | | $Q_{GS}$ | | | 30 | | nC |
| Gate to Drain Charge | | $Q_{GD}$ | | | 33 | | nC |
| Turn-ON Delay Time (Note 1) | | $t_{D(ON)}$ | $V_{DS}$=100V, $V_{GS}$=10V, $I_D$=24A, $R_G$=25Ω (Note1, 2) | | 32 | | ns |
| Rise Time | | $t_R$ | | | 38 | | ns |
| Turn-OFF Delay Time | | $t_{D(OFF)}$ | | | 218 | | ns |
| Fall-Time | | $t_F$ | | | 80 | | ns |
| **SOURCE- DRAIN DIODE RATINGS AND CHARACTERISTICS** | | | | | | | |
| Maximum Body-Diode Continuous Current | | $I_S$ | | | | 24 | A |
| Maximum Body-Diode Pulsed Current | | $I_{SM}$ | | | | 48 | A |
| Drain-Source Diode Forward Voltage (Note 1) | | $V_{SD}$ | $I_S$=24A, $V_{GS}$=0V | | | 1.4 | V |
| Body Diode Reverse Recovery Time (Note 1) | | $t_{rr}$ | $I_S$=24A, $V_{GS}$=0V, $dI_F/dt$=100A/μs | | 290 | | ns |
| Body Diode Reverse Recovery Charge | | $Q_{rr}$ | | | 3.5 | | μC |

Notes: 1. Pulse Test: Pulse width ≤ 300μs, Duty cycle ≤ 2%.
2. Essentially independent of operating ambient temperature.

## ■ TEST CIRCUITS AND WAVEFORMS



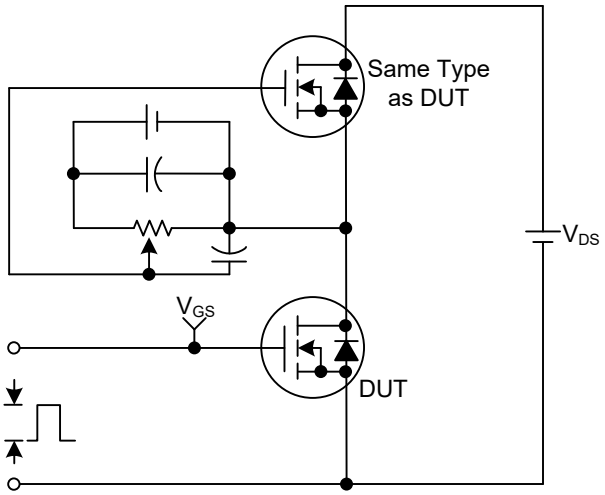

**Peak Diode Recovery dv/dt Test Circuit**



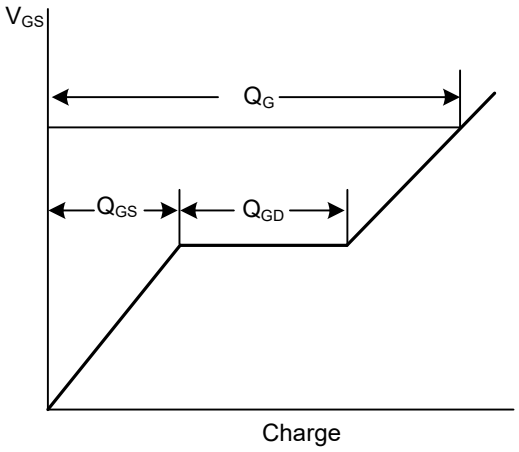

**Peak Diode Recovery dv/dt Waveforms**

## ■ TEST CIRCUITS AND WAVEFORMS

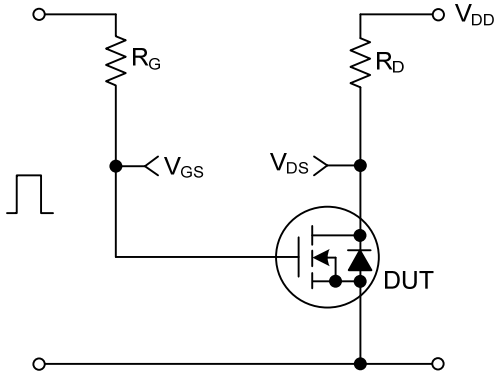
Gate Charge Test Circuit



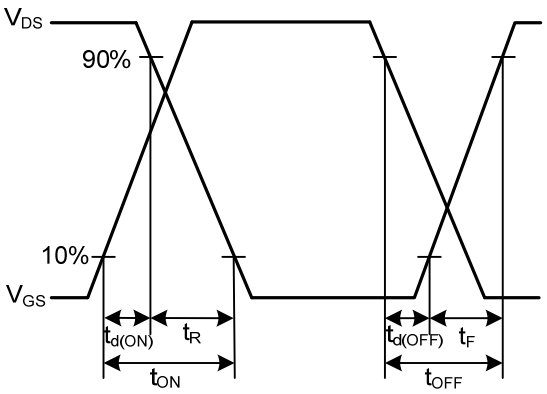

Gate Charge Waveforms



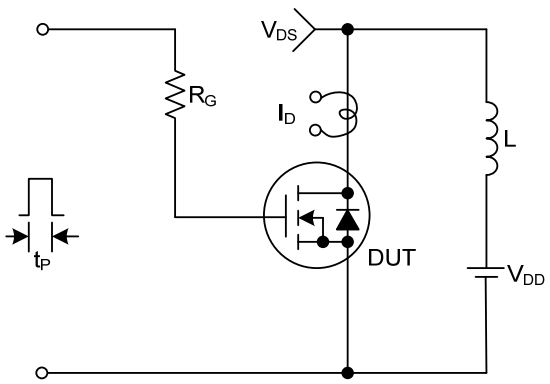

Resistive Switching Test Circuit




Resistive Switching Waveforms

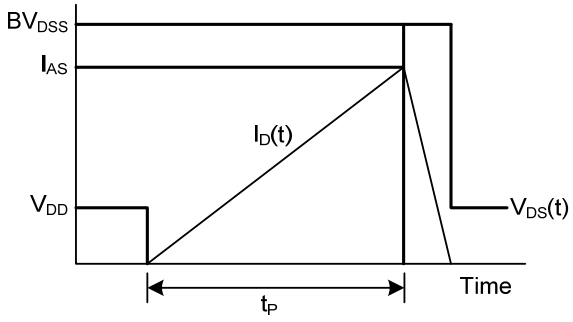



Unclamped Inductive Switching Test Circuit



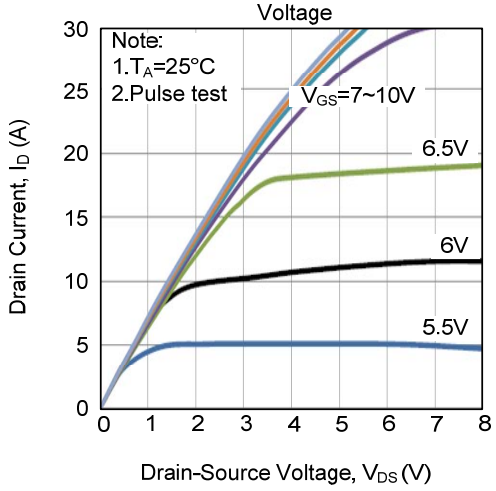

Unclamped Inductive Switching Waveforms

$$E_{AS}=\frac{1}{2}LI_{AS}^{2}\frac{BV_{DSS}}{BV_{DSS}-V_{DD}}$$

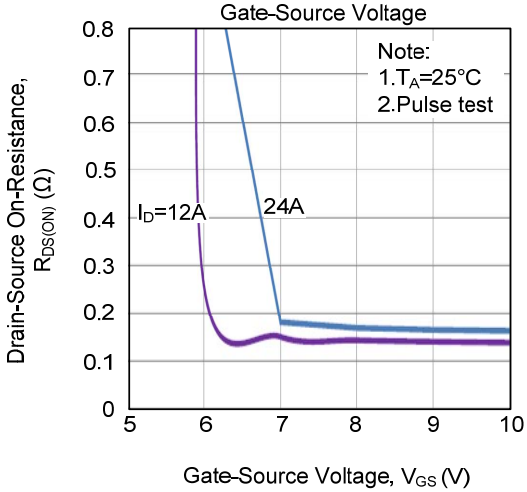


## ■ TYPICAL CHARACTERISTICS

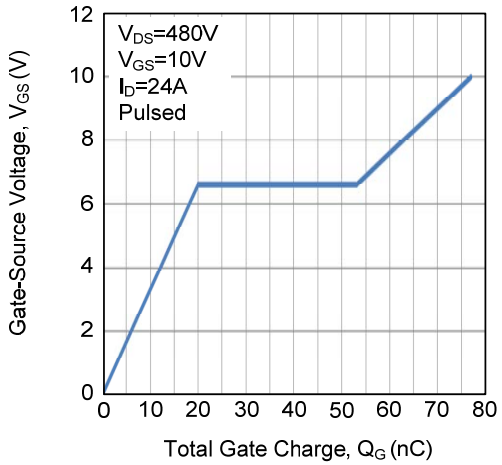
Drain Current vs. Drain-Source Voltage



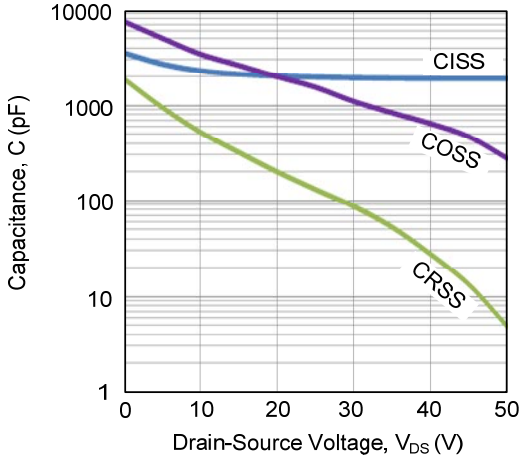

Drain-Source On-Resistance vs. Gate-Source Voltage



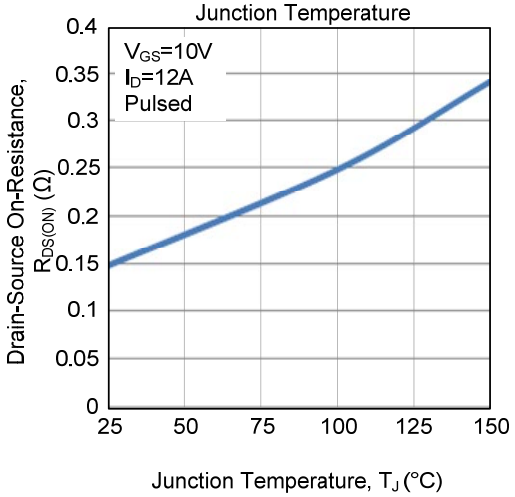

Gate Charge Characteristics



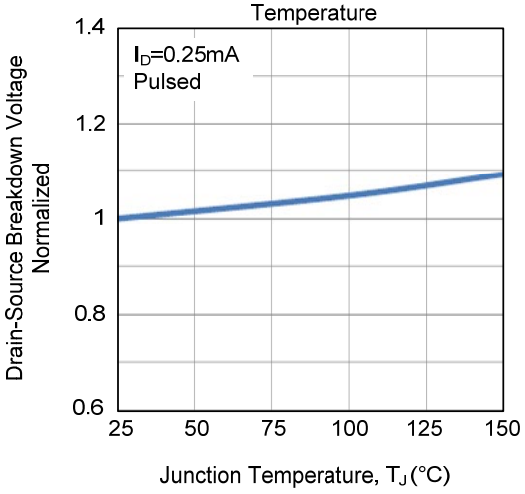

Capacitance Characteristics




Drain-Source On-Resistance vs. Junction Temperature

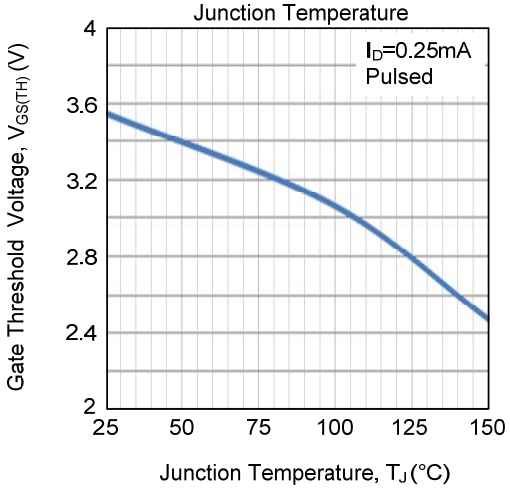



Breakdown Voltage vs. Junction Temperature

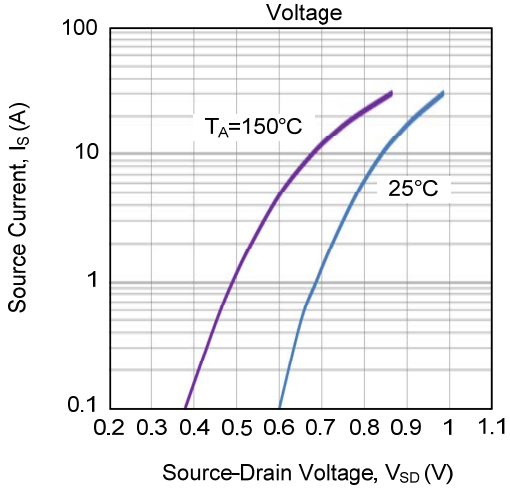


## ■ TYPICAL CHARACTERISTICS (Cont.)

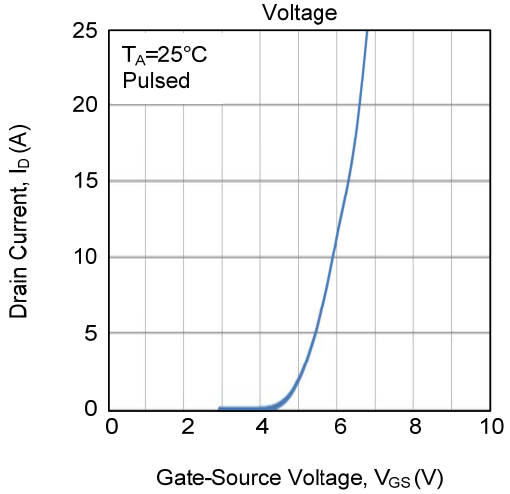
Gate Threshold Voltage vs. Junction Temperature



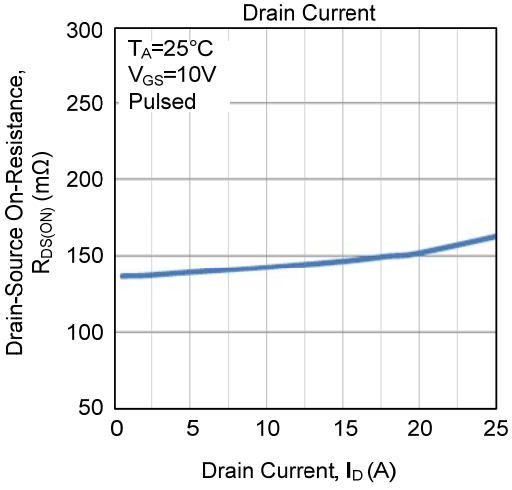

Source Current vs. Source-Drain Voltage



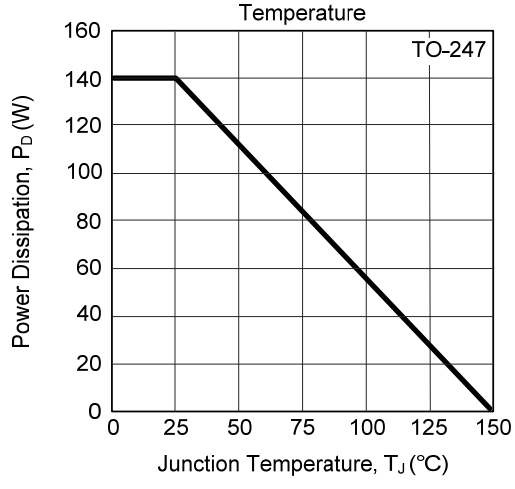

Drain Current vs. Gate-Source Voltage



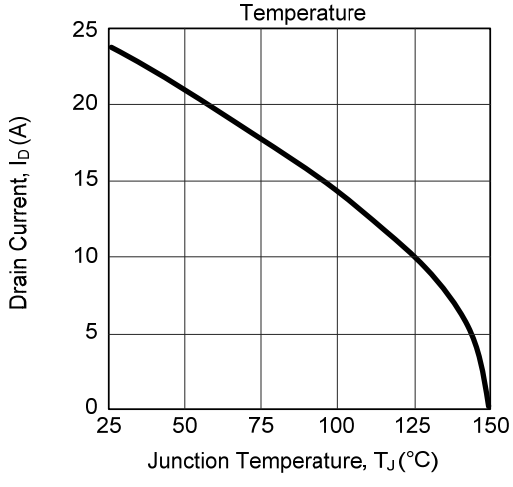

Drain-Source On-Resistance vs. Drain Current




Power Dissipation vs. Junction Temperature




Drain Current vs. Junction Temperature



## ■ TYPICAL CHARACTERISTICS (Cont.)