

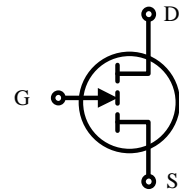
INN650N05

1. General description

650V GaN-on-Silicon Enhancement-mode Power Transistor Bare Die

2. Features

- Enhancement mode transistor-Normally off power switch
- Ultra high switching frequency
- No reverse-recovery charge
- Low gate charge, low output charge
- Qualified for industrial applications according to JEDEC Standards
- ESD safeguard
- RoHS, Pb-free, REACH-compliant



3. Applications

- AC-DC converters
- DC-DC converters
- Totem pole PFC
- Fast battery charging
- High density power conversion
- High efficiency power conversion

4. Key performance parameters

Table 1 Key performance parameters at $T_j = 25\text{ }^\circ\text{C}$

Parameter	Value	Unit
$V_{DS,max}$	650	V
$R_{DS(on),max}$ @ $V_{GS} = 6\text{ V}$	800	m Ω
$Q_{G,typ}$ @ $V_{DS} = 400\text{ V}$	0.6	nC
$I_{D,pulse}$	5	A
Q_{OSS} @ $V_{DS} = 400\text{ V}$	5	nC
Q_{rr} @ $V_{DS} = 400\text{ V}$	0	nC

5. Pin information

Table 2 Pin information

Gate	Drain	Source
G	D	S1~S2

Table 3 Ordering information

Type/Ordering Code	Product Code
INN650N05	INN650N05
To order bare die form please contact sales@diedevices.com	

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6. Maximum ratings

at $T_j = 25\text{ }^\circ\text{C}$ unless otherwise specified

Exceeding the maximum ratings may destroy the device. For further information, contact Innoscence sales office

Table 4 Maximum ratings

Parameter	Symbol	Values	Unit	Note/Test Condition
Drain source voltage	$V_{DS,max}$	650	V	$V_{GS} = 0\text{ V}$; $T_j = -55\text{ }^\circ\text{C}$ to $150\text{ }^\circ\text{C}$
Drain source voltage transient ¹	$V_{DS,transient}$	800	V	$V_{GS} = 0\text{ V}$
Drain source voltage, pulsed ²	$V_{DS,pulse}$	750	V	$T_j = 25\text{ }^\circ\text{C}$; total time < 10 h
				$T_j = 125\text{ }^\circ\text{C}$; total time < 1 h
Continuous current, drain source ³	I_D	2	A	$T_c = 25\text{ }^\circ\text{C}$
Pulsed current, drain source ⁴	$I_{D,pulse}$	5	A	$T_c = 25\text{ }^\circ\text{C}$; $V_G = 6\text{ V}$; $t_{PULSE} = 300\text{ }\mu\text{s}$
Pulsed current, drain source ⁴	$I_{D,pulse}$	4	A	$T_c = 125\text{ }^\circ\text{C}$; $V_G = 6\text{ V}$; $t_{PULSE} = 300\text{ }\mu\text{s}$
Gate source voltage, continuous ⁵	V_{GS}	-1.4 to +7	V	$T_j = -55\text{ }^\circ\text{C}$ to $150\text{ }^\circ\text{C}$
Gate source voltage, pulsed	$V_{GS,pulse}$	-20 to +10	V	$T_j = -55\text{ }^\circ\text{C}$ to $150\text{ }^\circ\text{C}$; $t_{PULSE} = 50\text{ ns}$, $f = 100\text{ kHz}$; open drain
Operating temperature	T_j	-55 to +150	$^\circ\text{C}$	
Storage temperature	T_{stg}	-55 to +150	$^\circ\text{C}$	

1 $V_{DS,transient}$ is intended for non-repetitive events, $t_{PULSE} < 200\text{ }\mu\text{s}$

2 $V_{DS,pulse}$ is intended for repetitive pulse, $t_{PULSE} < 100\text{ ns}$

3 Limited only by maximum temperature allowed

4 Limit was extracted from characterization test, not measured during production

5 The minimum V_{GS} is clamped by ESD protection circuit, as shown in Figure 10

7. Electric characteristics¹

 at $T_j = 25\text{ °C}$, unless specified otherwise

Table 5 Static characteristics

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Gate threshold voltage	$V_{GS(th)}$	1.2	1.7	2.5	V	$I_D = 2.6\text{ mA}$; $V_{DS} = V_{GS}$; $T_j = 25\text{ °C}$
		-	1.8	-		$I_D = 2.6\text{ mA}$; $V_{DS} = V_{GS}$; $T_j = 150\text{ °C}$
Drain-source leakage current	I_{DSS}	-	0.2	3	μA	$V_{DS} = 650\text{ V}$; $V_{GS} = 0\text{ V}$; $T_j = 25\text{ °C}$
		-	3	40		$V_{DS} = 650\text{ V}$; $V_{GS} = 0\text{ V}$; $T_j = 150\text{ °C}$
Gate-source leakage current	I_{GSS}	-	10	-	μA	$V_{GS} = 6\text{ V}$; $V_{DS} = 0\text{ V}$
Drain-source on-state resistance	$R_{DS(on)}$	-	620	800	m Ω	$V_{GS} = 6\text{ V}$; $I_D = 1\text{ A}$; $T_j = 25\text{ °C}$
		-	1300	-		$V_{GS} = 6\text{ V}$; $I_D = 1\text{ A}$; $T_j = 150\text{ °C}$
Gate resistance	R_G	-	11	-	Ω	$f = 5\text{ MHz}$; open drain

Table 6 Dynamic characteristics

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Input capacitance	C_{iss}	-	20	-	pF	$V_{GS} = 0\text{ V}$; $V_{DS} = 400\text{ V}$; $f = 100\text{ kHz}$
Output capacitance	C_{oss}	-	6	-	pF	$V_{GS} = 0\text{ V}$; $V_{DS} = 400\text{ V}$; $f = 100\text{ kHz}$
Reverse transfer capacitance	C_{rss}	-	0.1	-	pF	$V_{GS} = 0\text{ V}$; $V_{DS} = 400\text{ V}$; $f = 100\text{ kHz}$
Effective output capacitance, energy related ¹	$C_{o(er)}$	-	9	-	pF	$V_{GS} = 0\text{ V}$; $V_{DS} = 0\text{ to }400\text{ V}$
Effective output capacitance, time related ²	$C_{o(tr)}$	-	12	-	pF	$V_{GS} = 0\text{ V}$; $V_{DS} = 0\text{ to }400\text{ V}$
Output charge	Q_{oss}	-	5	-	nC	$V_{GS} = 0\text{ V}$; $V_{DS} = 0\text{ to }400\text{ V}$
Turn-on delay time	$t_{d(on)}$	-	2	-	nS	$V_{DS} = 400\text{ V}$; $I_D = 2\text{ A}$; $L = 318\text{ }\mu\text{H}$; $V_{GS} = 6\text{ V}$; $R_{on} = 10\text{ }\Omega$; $R_{off} = 2\text{ }\Omega$; See Figure 22
Turn-off delay time	$t_{d(off)}$	-	3	-	nS	
Rise time	t_r	-	6	-	nS	
Fall time	t_f	-	13	-	nS	
Switching Energy during turn-on	E_{on}	-	10.0	-	μJ	
Switching Energy during turn-off	E_{off}	-	0.2	-	μJ	
Output Capacitance Stored Energy	E_{oss}	-	0.7	-	μJ	

1 The electrical characteristics parameters were tested with the parts assembled in DFN 5X6 package

2 $C_{o(er)}$ is the fixed capacitance that gives the same stored energy as C_{oss} while V_{DS} is rising from 0 to 400 V

3 $C_{o(tr)}$ is the fixed capacitance that gives the same charging time as C_{oss} while V_{DS} is rising from 0 to 400 V

Table 7 Gate charge characteristics

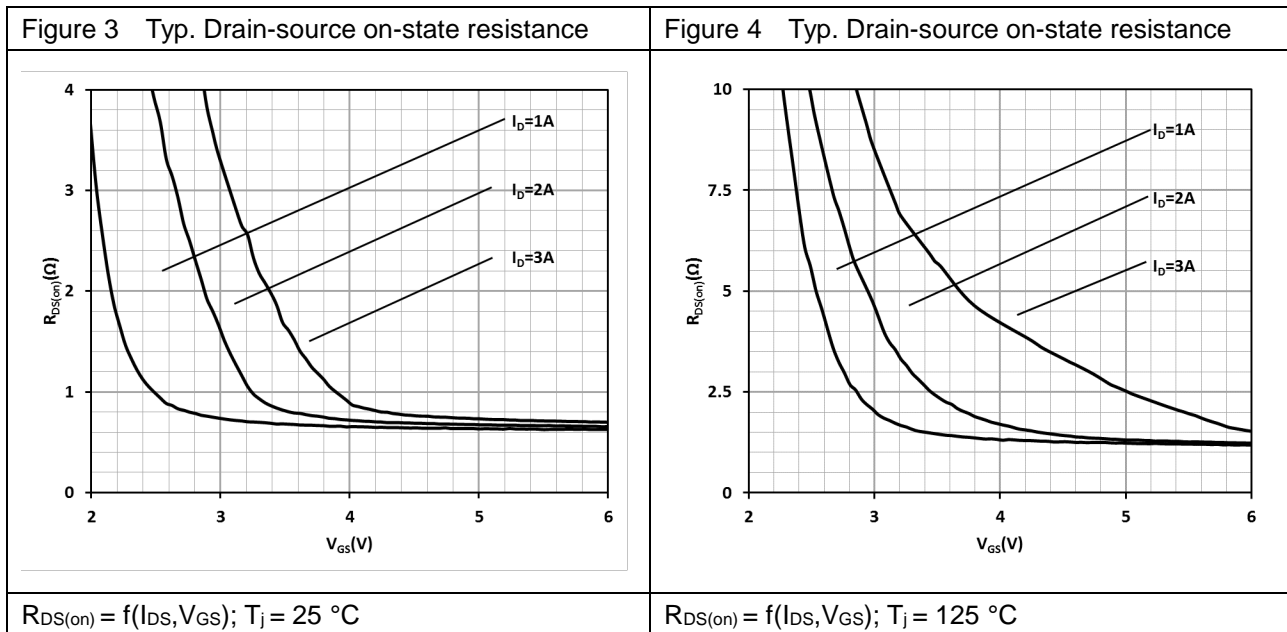
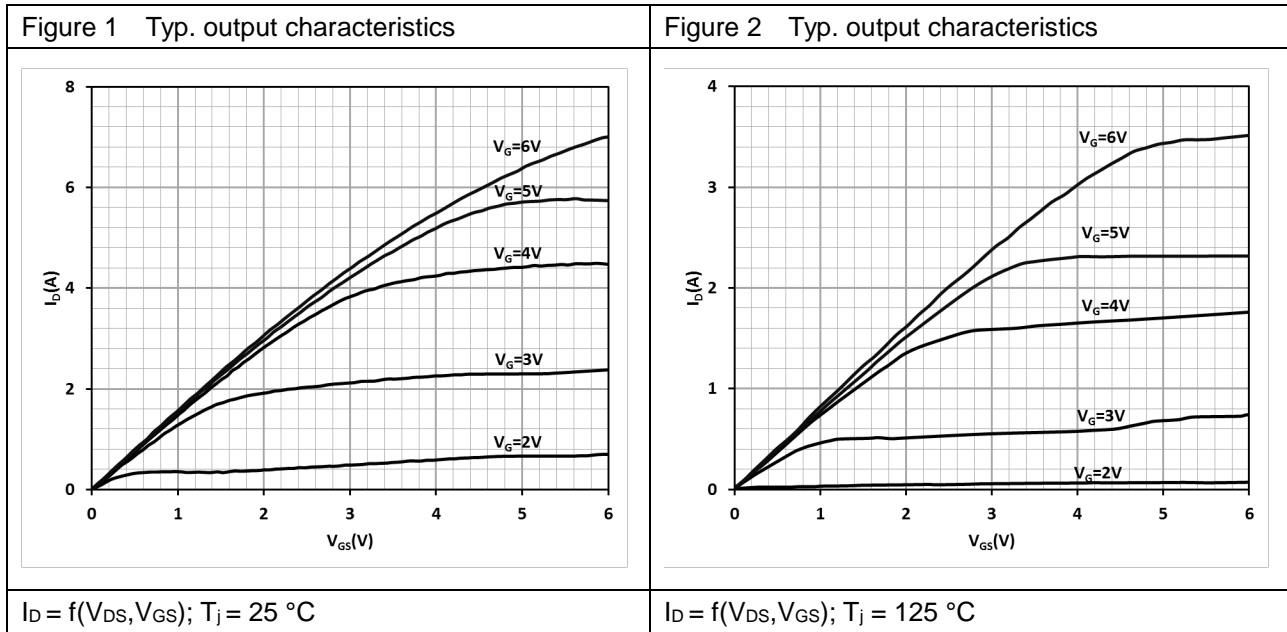
Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Gate charge	Q_G	-	0.7	-	nC	$V_{GS} = 0$ to 6 V; $V_{DS} = 400$ V; $I_D = 1$ A
Gate-source charge	Q_{GS}	-	0.1	-	nC	
Gate-drain charge	Q_{GD}	-	0.4	-	nC	
Gate Plateau Voltage	V_{Plat}	-	2.2	-	V	$V_{DS} = 400$ V; $I_D = 1$ A

Table 8 Reverse conduction characteristics

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Source-Drain reverse voltage	V_{SD}	-	3	-	V	$V_{GS} = 0$ V; $I_{SD} = 1$ A
Pulsed current, reverse	$I_{S,pulse}$	-	-	5	A	$V_G = 6$ V; $t_{PULSE} = 300$ μ s
Reverse recovery charge	Q_{rr}	-	0	-	nC	$I_{SD} = 1$ A; $V_{DS} = 400$ V
Reverse recovery time	t_{rr}	-	0	-	ns	
Peak reverse recovery current	I_{rrm}	-	0	-	A	

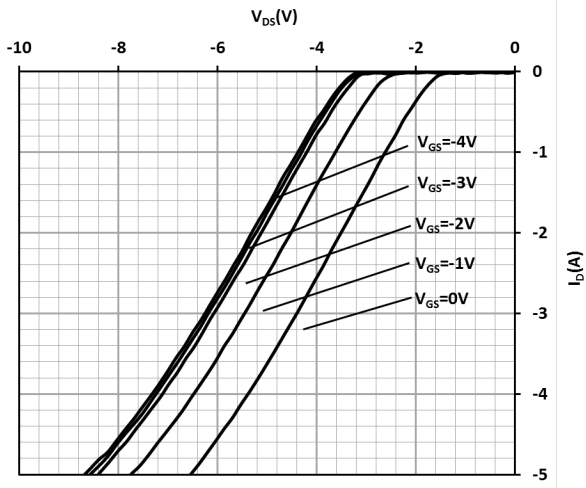
8. Electric characteristics diagrams¹

at $T_j = 25\text{ °C}$, unless specified otherwise



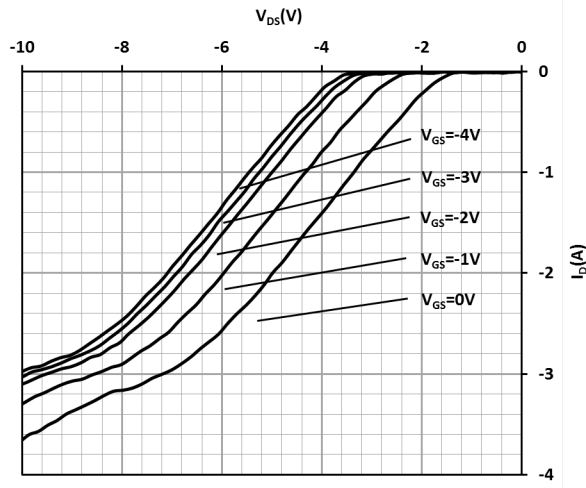
¹ The typical electrical characteristic curves were measured with the parts assembled in DFN 5X6 package

Figure 5 Typ. channel reverse characteristics



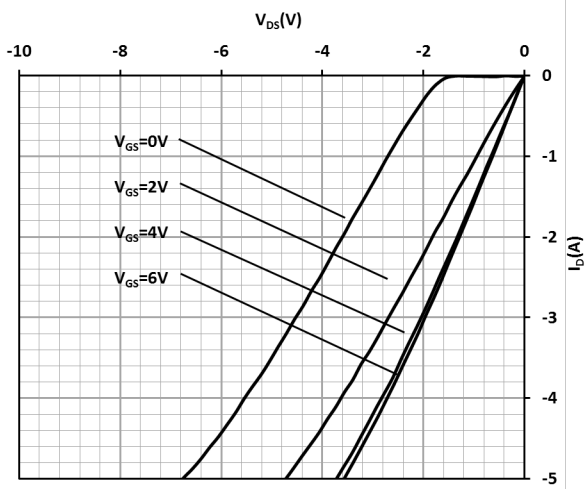
$I_D = f(V_{DS}, V_{GS}); T_j = 25\text{ }^\circ\text{C}$

Figure 6 Typ. channel reverse characteristics



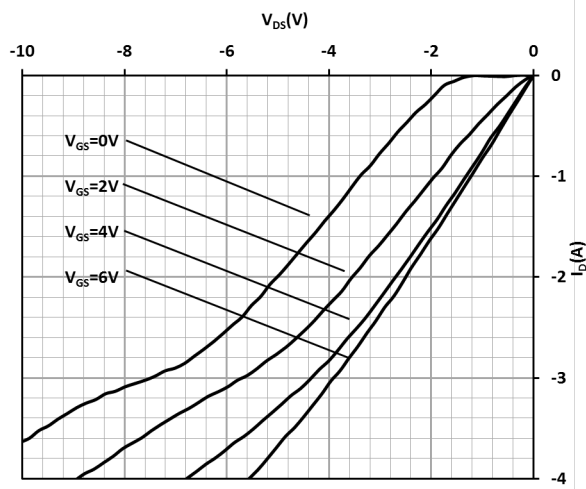
$I_D = f(V_{DS}, V_{GS}); T_j = 125\text{ }^\circ\text{C}$

Figure 7 Typ. channel reverse characteristics



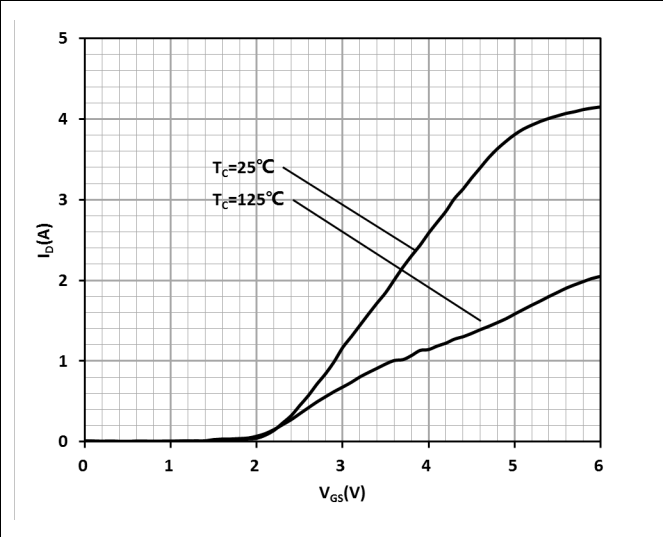
$I_D = f(V_{DS}, V_{GS}); T_j = 25\text{ }^\circ\text{C}$

Figure 8 Typ. channel reverse characteristics



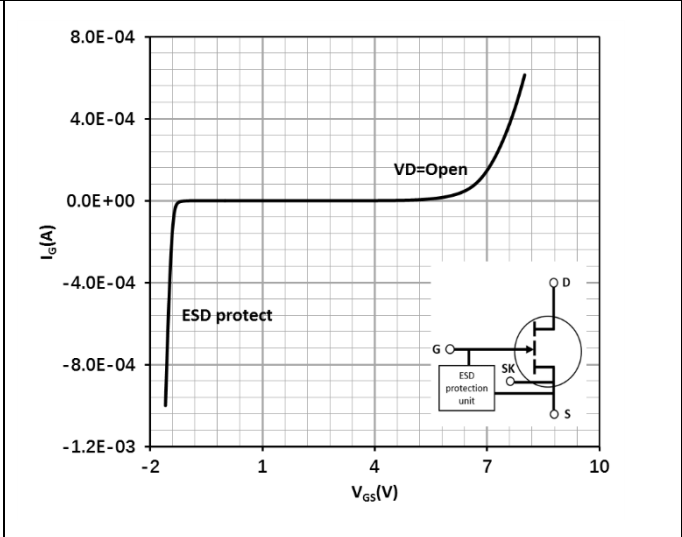
$I_D = f(V_{DS}, V_{GS}); T_j = 125\text{ }^\circ\text{C}$

Figure 9 Typ. transfer characteristics



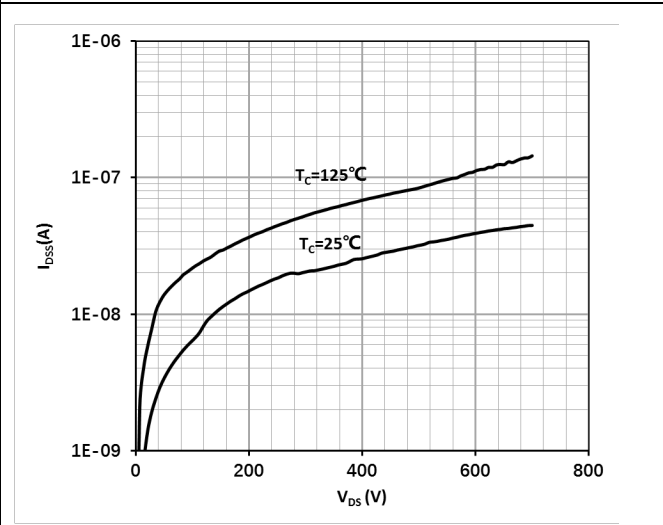
$I_D = f(V_{GS}); V_{DS} = 3 \text{ V}$

Figure 10 Typ. Gate-to-Source leakage



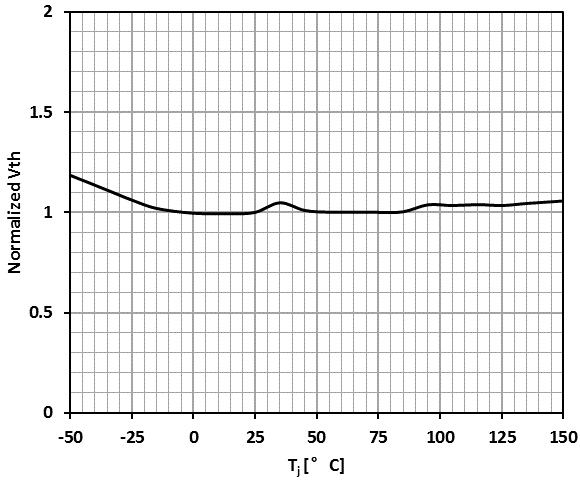
$I_G = f(V_{GS}); I_G$ reverse turn on by ESD unit

Figure 11 Drain-source leakage characteristics



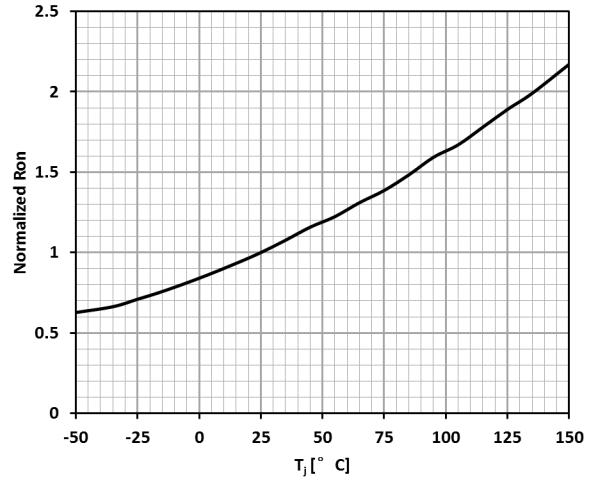
$I_{DSS} = f(V_{DS}); V_{GS} = 0 \text{ V}$

Figure 12 Gate threshold voltage



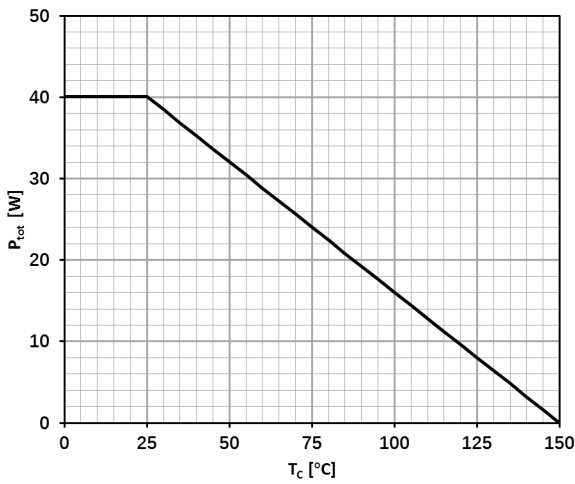
$V_{TH} = f(T_j)$; $V_{GS} = V_{DS}$; $I_D = 2.6 \text{ mA}$

Figure 13 Drain-source on-state resistance



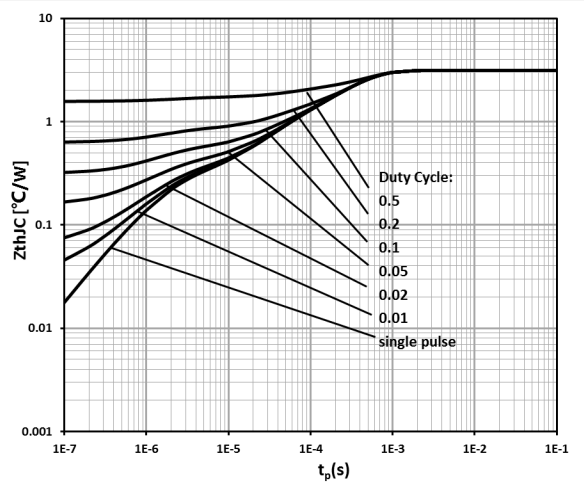
$R_{DS(on)} = f(T_j)$; $I_D = 1 \text{ A}$; $V_G = 6\text{V}$

Figure 14 Power dissipation



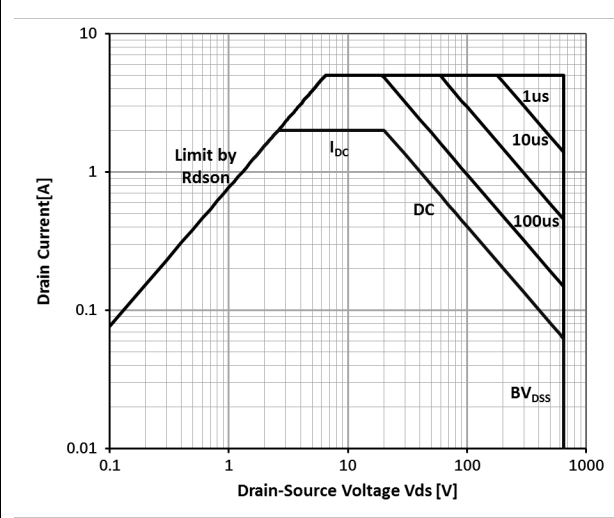
$P_{tot} = f(T_c)$

Figure 15 Max.transient thermal impedance



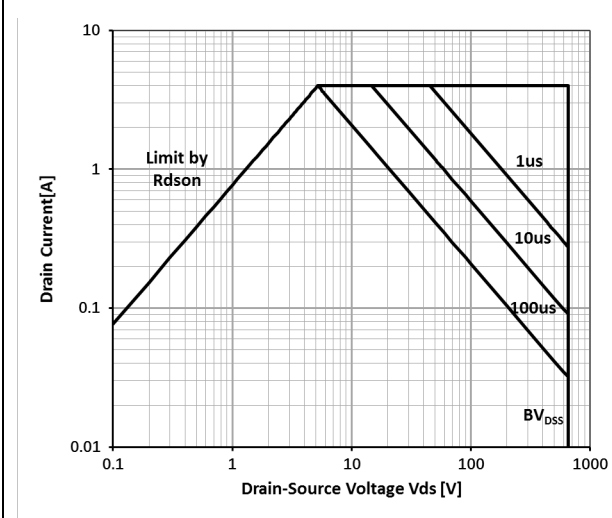
$Z_{thJC} = f(t_p, D)$

Figure 16 Safe operating area



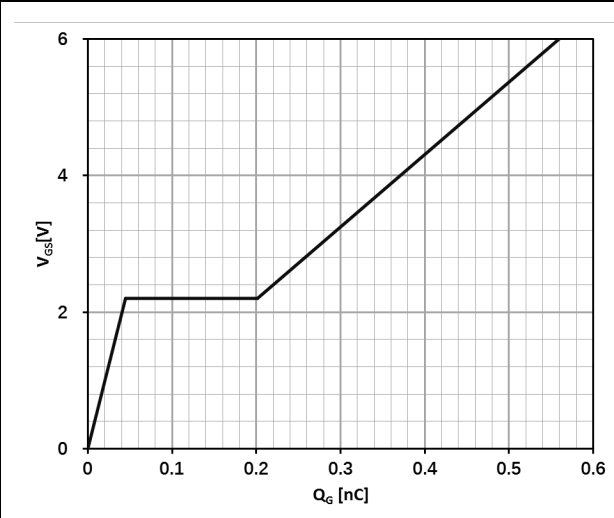
$I_D = f(V_{DS}); T_C = 25\text{ }^\circ\text{C}$

Figure 17 Safe operating area



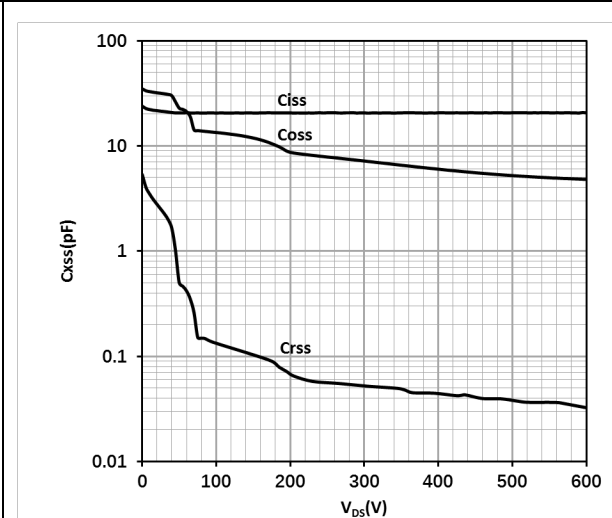
$I_D = f(V_{DS}); T_C = 125\text{ }^\circ\text{C}$

Figure 18 Typ. gate charge



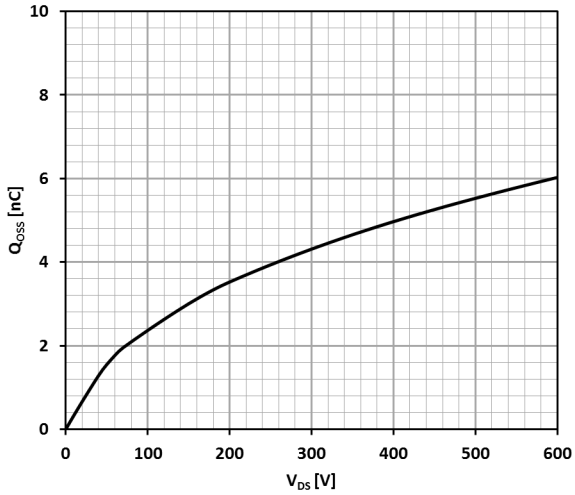
$V_{GS} = f(Q_G); V_{DCLINK} = 400\text{ V}; I_D = 1\text{ A}$

Figure 19 Typ. capacitances



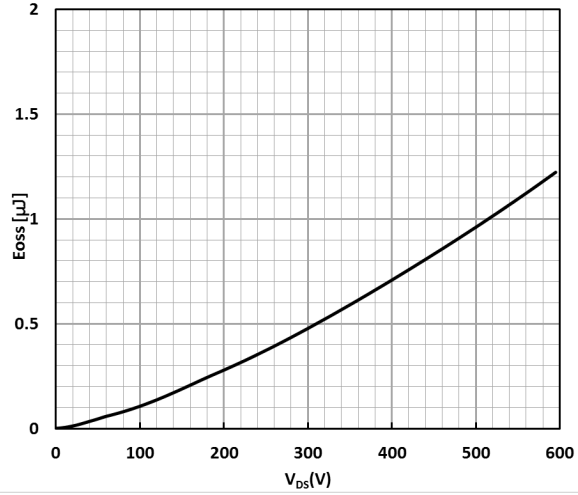
$C_{XSS} = f(V_{DS}); \text{Freq.} = 100\text{ kHz}$

Figure 20 Typ. output charge



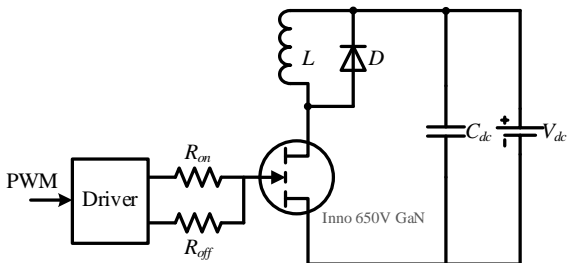
$Q_{oss} = f(V_{DS}); \text{Freq.} = 100 \text{ kHz}$

Figure 21 Typ. Coss stored Energy



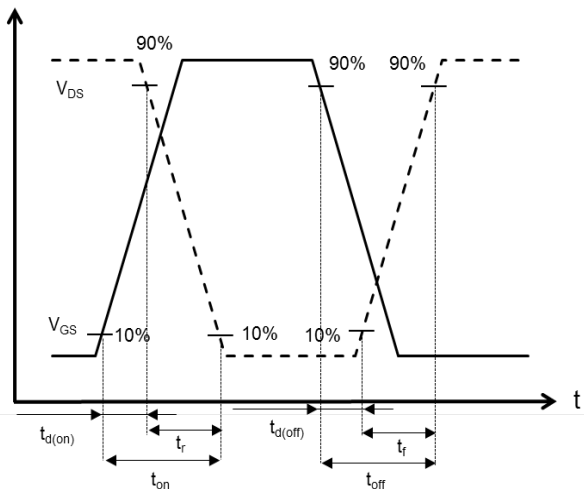
$E_{oss} = f(V_{DS}); \text{Freq.} = 100 \text{ kHz}$

Figure 22 Typ. Switching times with inductive load

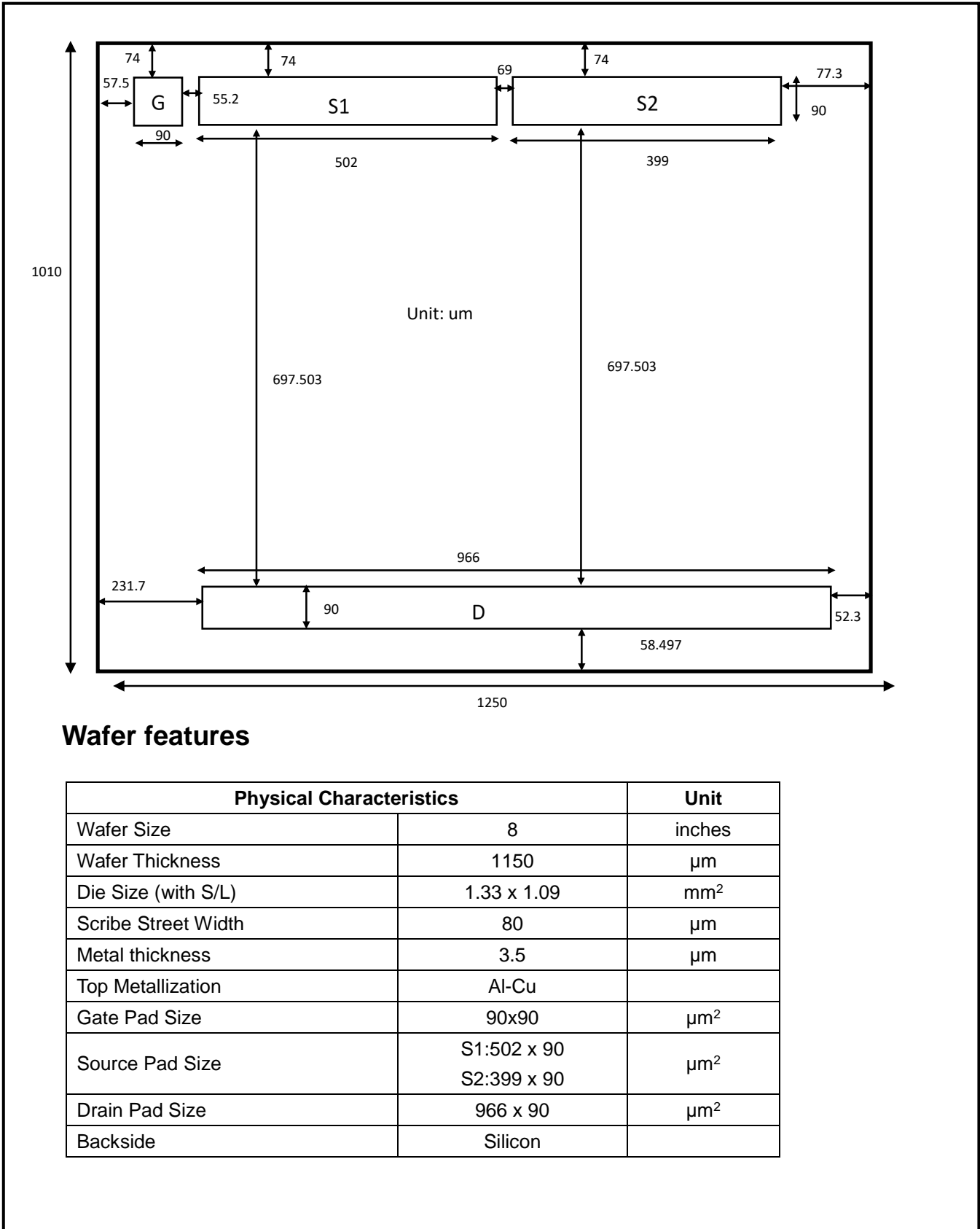


$V_{DS} = 400 \text{ V}, I_D = 2 \text{ A}, L = 318 \mu\text{H}, V_{GS} = 6 \text{ V},$
 $R_{on} = 10 \Omega, R_{off} = 2 \Omega$

Figure 23 Typ. Switching times waveform



9. Chip drawing



Wafer features

Physical Characteristics		Unit
Wafer Size	8	inches
Wafer Thickness	1150	μm
Die Size (with S/L)	1.33 x 1.09	mm^2
Scribe Street Width	80	μm
Metal thickness	3.5	μm
Top Metallization	Al-Cu	
Gate Pad Size	90x90	μm^2
Source Pad Size	S1:502 x 90 S2:399 x 90	μm^2
Drain Pad Size	966 x 90	μm^2
Backside	Silicon	

10. Revision history

Major changes since the last revision

Revision	Date	Description of changes
Preliminary 0.5	2021-07-01	Preliminary 0.5 version setup
Preliminary 0.6	2021-08-19	Fixed product name with new design with ESD protection
1.0	2021-10-26	Update dynamic parameters and typical characteristic curves

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