Feature Application: Telecom & Computing - Wi-Fi Router

Application Guide
High Voltage
Superjunction MOSFET

www.icemostech.com

Applications Guide Rev.7 24. 09.2024

Contents

1. Scope:

This Application Note supplies information about IceMOS Technology's high voltage Superjunction MOSFET products containing electrical characteristics and proposed application circuits. The Application Note is intended for Engineers involved in the design of circuits for power module products.

2. Electrical Characteristics

2.1 Maximum ratings

Example of ICE20N170 (Tj=25℃)

Maximum ratings, at T_j=25°C, unless otherwise specified

Parameter	***Symbol***	***Condition***	***Value***	***Unit***
Continuous drain current	I_D	T_c=25°C T_c=100°C	20 11	A
Pulsed drain current	$I_{D,\ pulse}$	T_c=25°C	62	A
Avalanche Energy, single pulse E_{AS}=1/2*L*I^2(V_{BR}DSS/(V_{BR}DSS-V_{DSS}))	E_{AS}	I_D=10A	520	mJ
MOSFET d*v*/d*t* ruggedness	d*v*/d*t*	V_{DS}=480V, I_D=5A, T_j=125°C	50.0	V/ns
Avalanche current, repetitive	I_{AR}	limited by *T*jmax	10	A
Gate source voltage	V_{GS}	Static	±20	V
		AC (*f*>1Hz),	±30	
Power dissipation	P_{tot}	T_c=25°C	236	W
Operating and storage temperature	T_j, T_{stg}		-55 to +150	°C
Mounting torque [a]		M 3 & 3.5 screws	60	Ncm

a When mounted on 1inch square 2oz copper clad FR-4

2.1.1 E_{AS} Avalanche Energy

E_{AS} Avalanche Energy is the energy surge when the MOSFET is switched off due to Induced Current flow from Inductance(L) it is illustrated below as a simple equation

E=L*di/dt

In the test circuit, ON time was adjusted to create Inductance(L) and keep a certain level of current energy. The current was then forced through the Test device at switch off. This test is called a UIS Test (Unclamped Inductive Switching) providing the amount of energy the device can survive by test giving an indication of the device robustness.

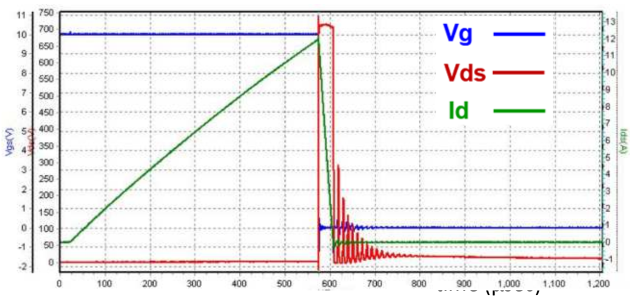


Fig. 1 output wave example of UIS test.

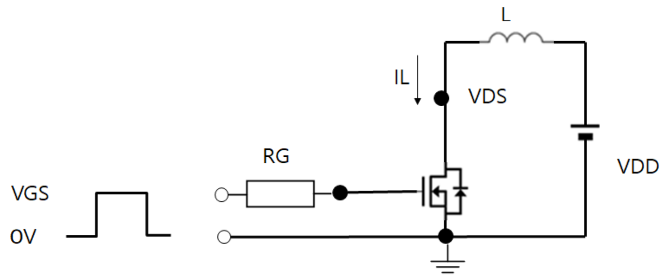


Fig.2 Example of UIS circuit

2.1.2 MOSFET dv/dt ruggedness

The Parasitic npn bipolar transistor in the SJMOSFET is shown in Fig4.
When the voltage is changed with dv/dt at Turn off, Current flows through Capacitor C and Resistor R. Since this current creates a Voltage due to the resistance the gate of the parasitic npn bipolar transistor may turn ON and further current may flow which may lead to MOSFET destruction by this phenomenon.

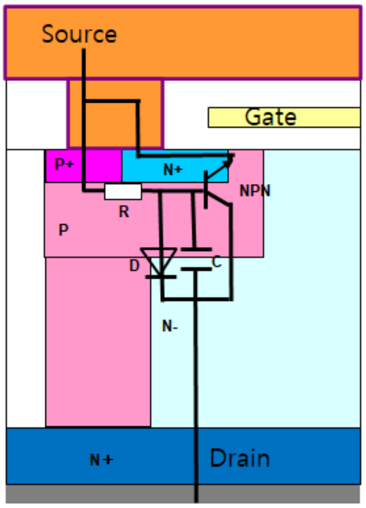


Fig.3 Parasitic npn Transistor

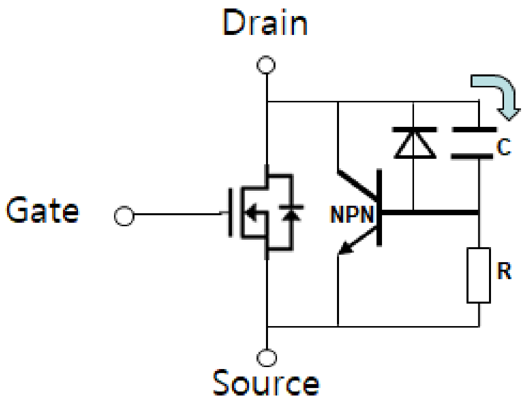


Fig.4 Equivalent Circuit

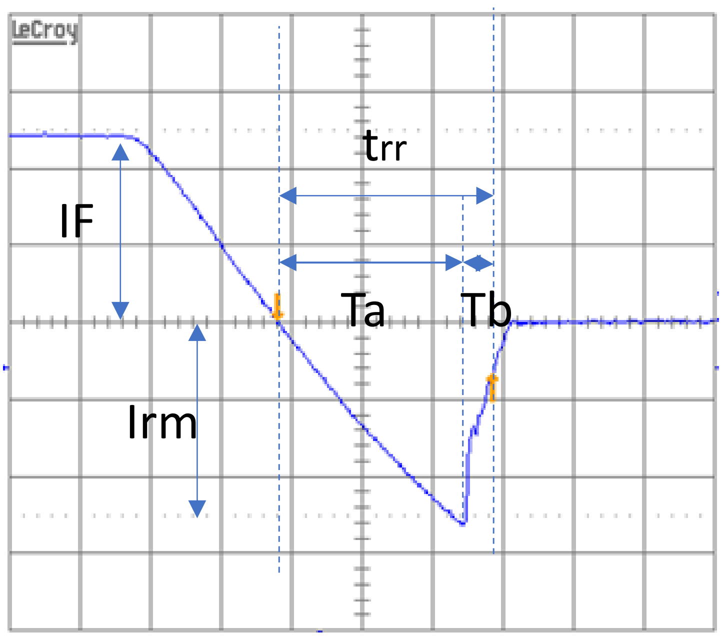


Fig.5 Trr waveform at Reverse recovery

Time Ratio Tb/Ta could be soft recovery index.

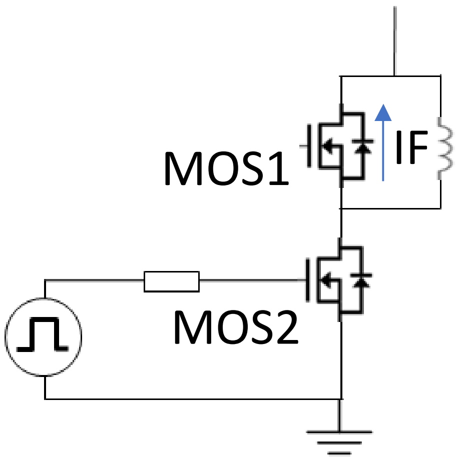
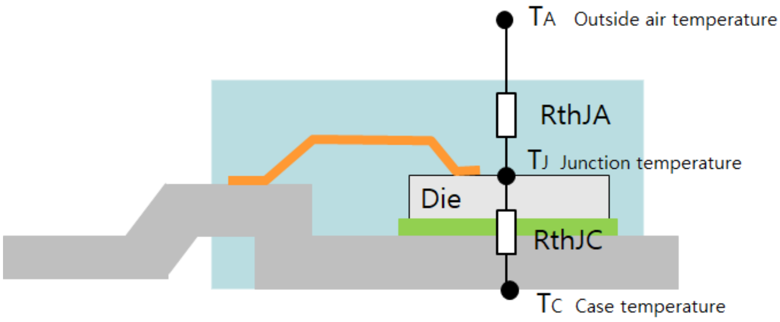


Fig.6 Switching circuit example. When the Current flows through MOS2 and is then turned off, IF current flows through MOS1. When MOS2 is turned on again, this current flows through MOS2, the voltage of the body diode of MOS1 rises showing reverse recovery operation, and current waveform is shown by this change of dv/dt in Fig5.

2.2 Thermal Characteristics

Parameter	***Symbol***	***Conditions***	***Values***			***Unit***
			Min	***Typ***	***Max***	
Thermal characteristics						
Thermal resistance, junction-case [a]	R_{thJC}		-	-	0.53	°C/W
Thermal resistance, junction-ambient [a]	R_{thJA}	leaded	-	-	62	°C/W
Soldering temperature, wave soldering only allowed at leads	T_{sold}	1.6mm (0.063in.) from case for 10 s	-	-	260	°C



Ptot =I*I*Rmax*Tc=(TJ-Tc)/RthJC
=(150-25)/0.53
235.8491

Fig.7 Definition of each temperature point and how to calculate Power dissipation P_{TOT}. P_{TOT} can be calculated based on R_{thJC}.

2.2.1 Guidelines for soldering

(Refer to Lead free process by JSTD020/JSTD-020)

Method	Solder Temperature	Duration time	Times
Flow/ Reflow	260°C MAX	10 sec MAX	2 times
Soldering iron	380°C MAX	3 sec MAX	1 time

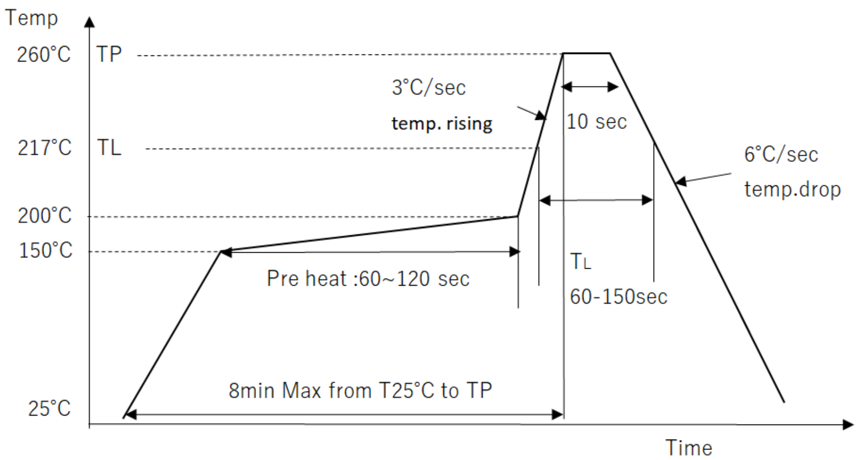
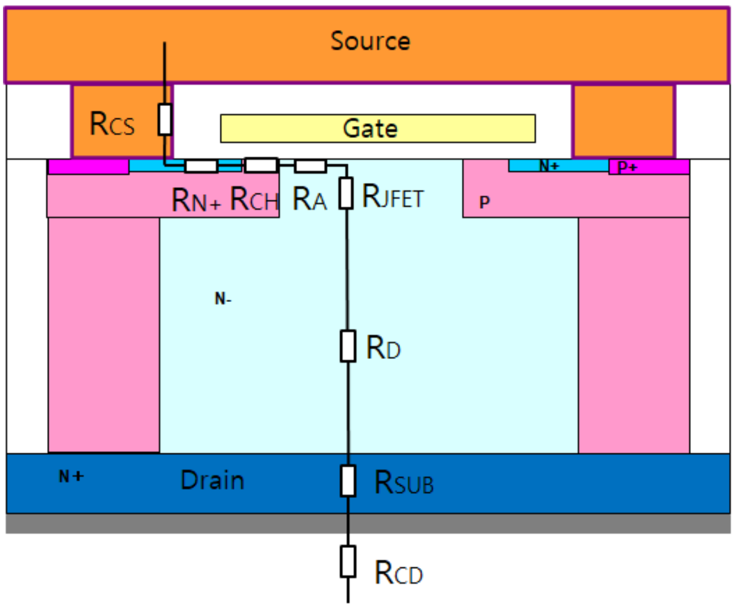


Fig.8 An Example of a Flow Temperature Profile.

2.3 Static Characteristics（DC characteristics)（Tj=25℃） 🌡 :Temperature dependent

Parameter	Symbol	Conditions	Value Min	Value Typ	Value Max	unit
Electrical characteristics , at T_j=25°C, unless otherwise specified						
Static characteristics						
Drain-source breakdown voltage 🌡 Relationship with P and N Charge balance , R_{DS}ON	$V_{(BR)DSS}$	V_{GS}=0 V, I_D=250uA	600	650	-	V
Gate threshold voltage 🌡 Affect switching performance	$V_{GS(th)}$	V_{DS}=V_{GS}, I_D=250μA	2.1	3	3.9	V
Zero gate voltage drain current 🌡	I_{DSS}	V_{DS}=600V, V_{GS}=0V, T_j=25°C	-	0.1	1	μA
		V_{DS}=600V, V_{GS}=0V, T_j=150°C	-	100	-	μA
Gate source leakage current	I_{GSS}	V_{GS}=±20 V, V_{DS}=0V	-	-	100	nA
Drain-source on-state resistance 🌡 Important parameter for **on**-state power loss	$R_{DS(on)}$	V_{GS}=10V, I_D=10A, T_j=25°C	-	0.17	0.199	Ω
		V_{GS}=10V, I_D=10A, T_j=150°C	-	0.49	-	Ω
Gate resistance	R_G	f=1 MHZ, open drain	-	3.8	-	Ω



RdsON is total summary of Below Resistance：
RCS: Source contact Resistance
RN+: Source N+ Resistance
RCH: Channel Resistance
RD: Drift Resistance(Main resistance)
RJFET: JFET Resistance
RA: Accumulation Resistance
RSUB: Substrate resistance
RCD: Drain Contact Resistance

Fig. 9　The Components of ON Resistance

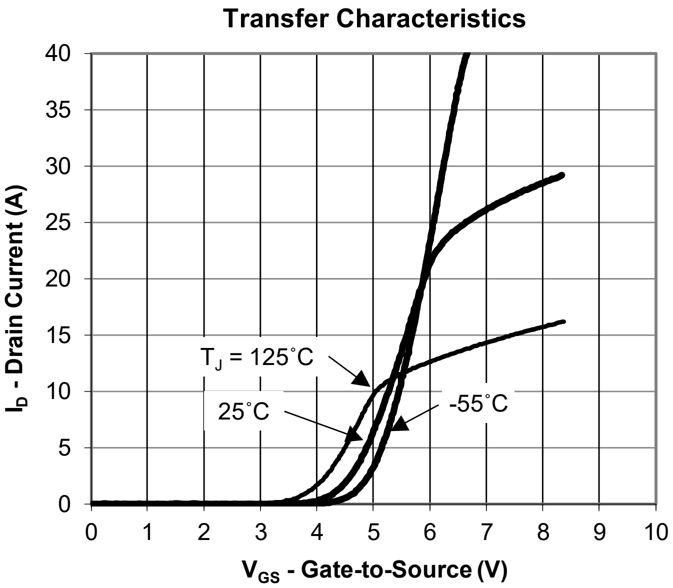


Fig 10 V_{GS}-I_{DS} Characteristic
Voltage beyond $V_{GS(th)}$ can flow a Drain- Source current. Current can be different depending on the Temperature.

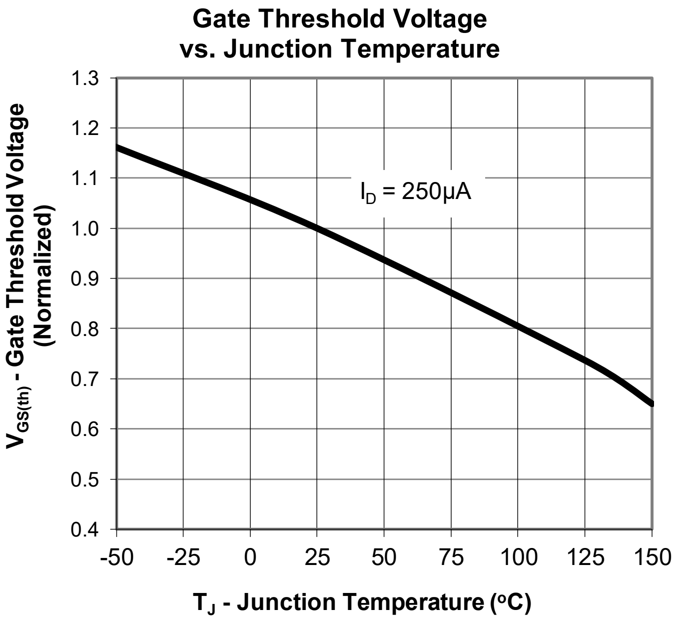


Fig.11 $V_{GS(th)}$ *Vs* T_J Junction temperature.

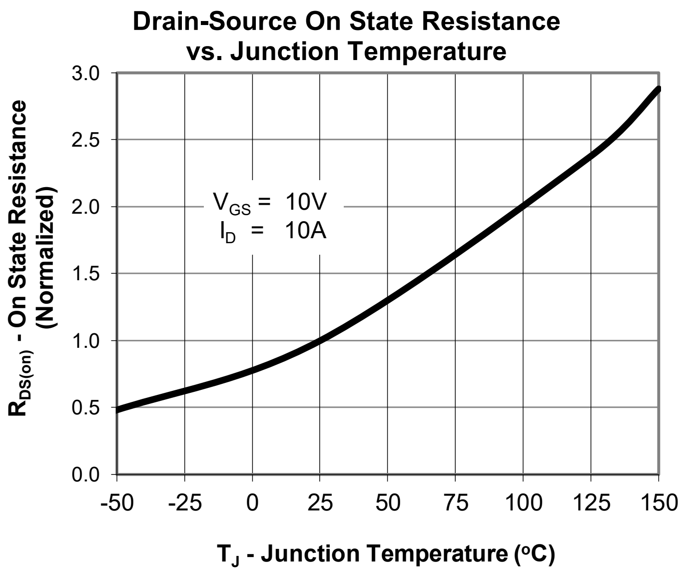


Fig.12 $R_{DS(ON)}$ Vs T_J Junction temperature.

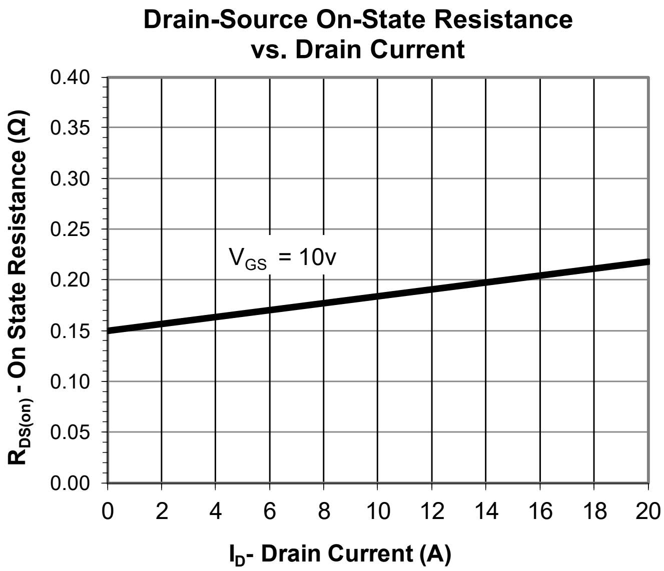


Fig.13 I_D — $R_{DS(ON)}$

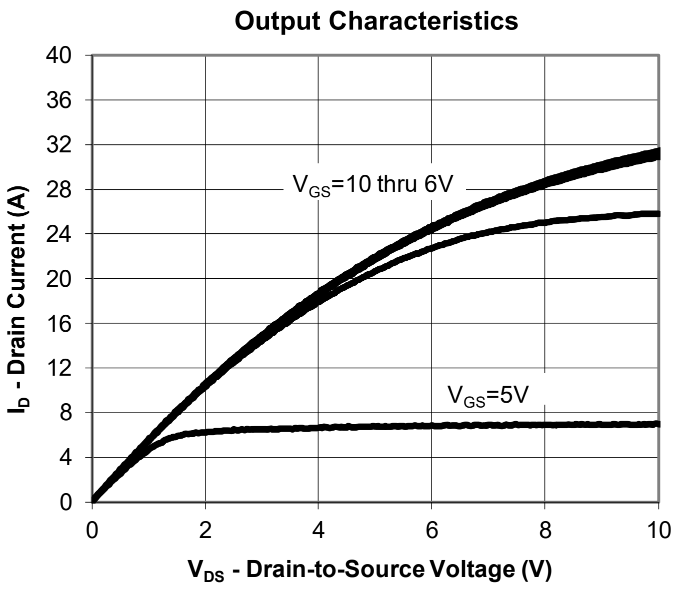


Fig.14: V_{DS}-I_D

By raising Gate Voltage over $V_{GS(th)}$, the drain current flows depending on the Drain Voltage.

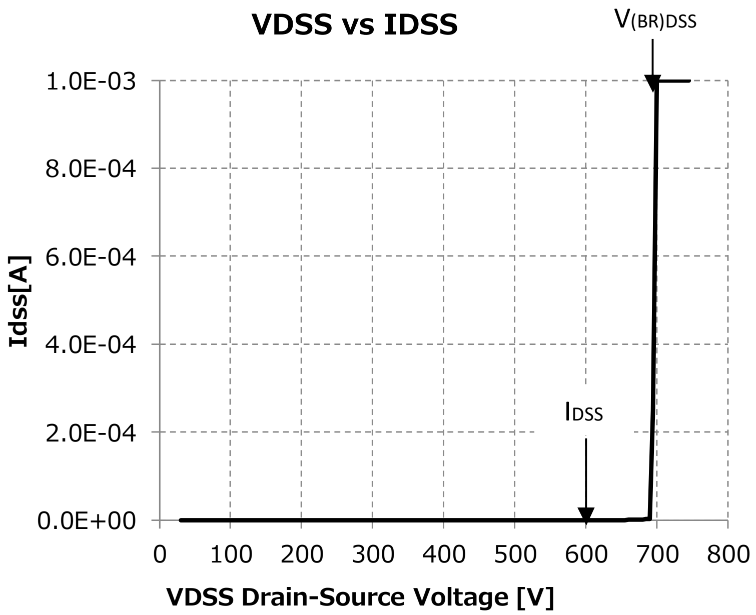


Fig.15: V_{DSS}-I_{DSS}

When a voltage is applied between the drain and source when Gate voltage =0V, an Avalanche current begins to flow, and the voltage that reaches the specified current at that time is the breakdown voltage ($V_{(BR)DSS}$)

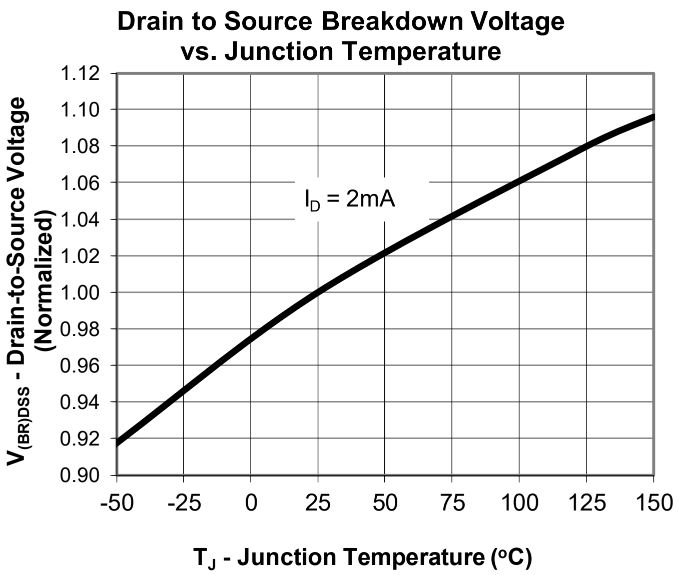


Fig.16 $V_{(BR)DSS}$ Vs T_J Junction temperature.

At 25°C the normalized ratio for $V_{(BR)DSS}$ as V_{DSS} is 1 this subsequently increases with increasing temperature.

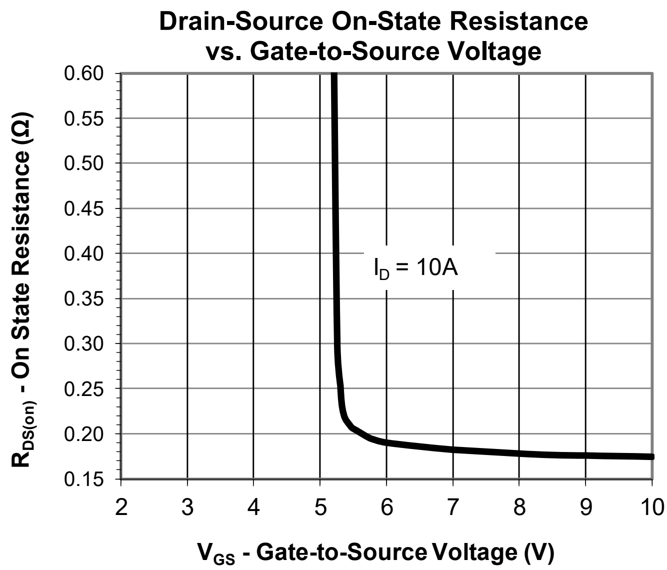


Fig.17 V_{GS}- R_{DSON}

The graph shows the required V_{GS} voltage for I_D=10A and the corresponding $R_{DS(ON)}$ value.

2.4 Dynamic characteristics （AC characteristics）（Tj=25℃）🌡 :temperature dependability

Parameter	Symbol	Condition		Value Min	Value Typ	Value Max	Unit
Dynamic characteristics							
Input capacitance	C_{iss}	V_{GS}=0 V, f=1 MHz	V_{DS}=25 V	-	2064	-	pF
Output capacitance	C_{oss}		V_{DS}=100 V	-	87	-	
Reverse transfer capacitance	C_{rss}		V_{DS}=25 V	-	18	-	
Transconductance	g_{fs}	$V_{DS}>2*I_D*R_{DS}$, I_D=10A		-	17	-	S
Turn-on delay time	$t_{d(on)}$	V_{DS}=380V, V_{GS}=10V, I_D=10A, R_G=4Ω (External)		-	23.2	-	ns
Rise time	t_r			-	11.8	-	
Turn-off delay time	$t_{d(off)}$			-	92.5	-	
Fall time	t_f			-	3.9	-	

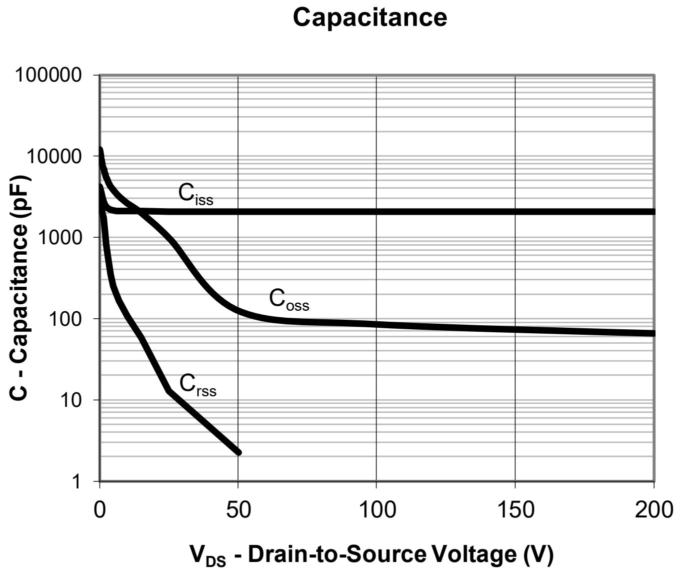


Fig. 18 C_{iss},C_{oss},C_{rss} vs V_{DS}

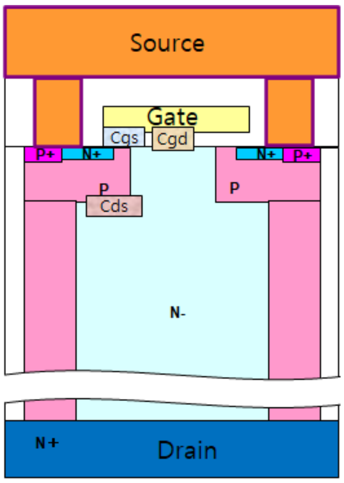


Fig19. Capacitance of the SJMOSFET structure

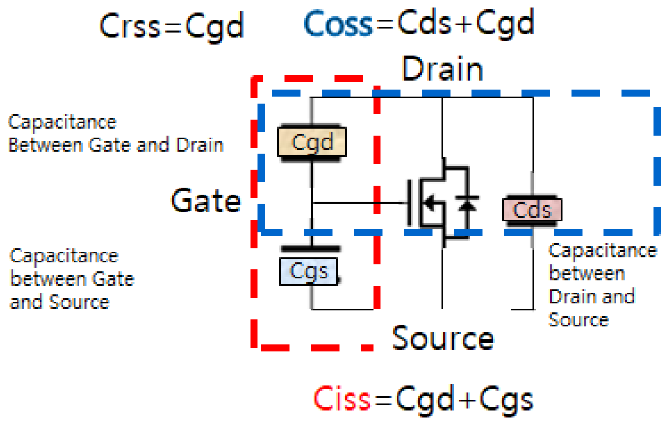
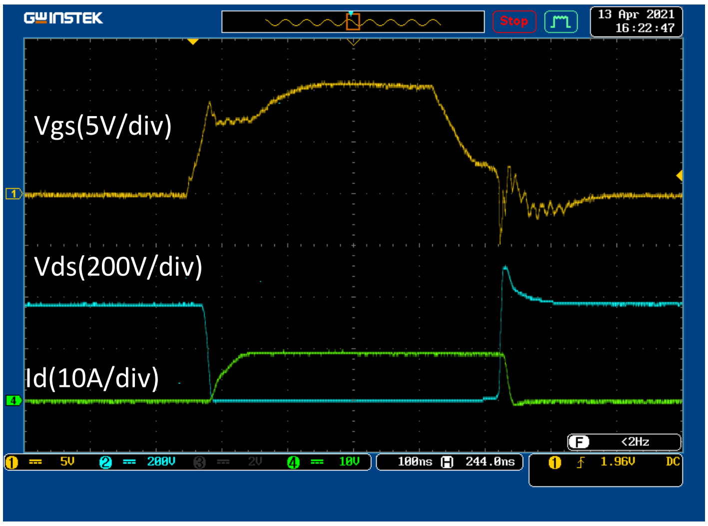


Fig20. Equivalent circuit for capacitance with labelled parameters: C_{iss},C_{oss},C_{rss}

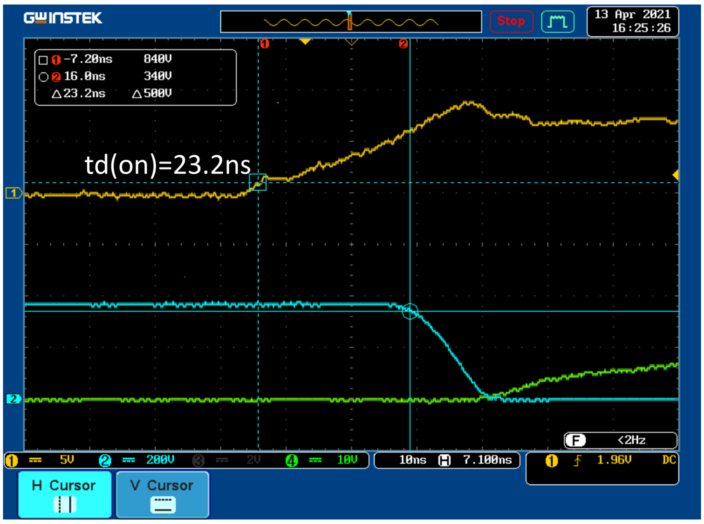
Fig21. Switching waveform for the case of ICE20N170 at Id 10A.

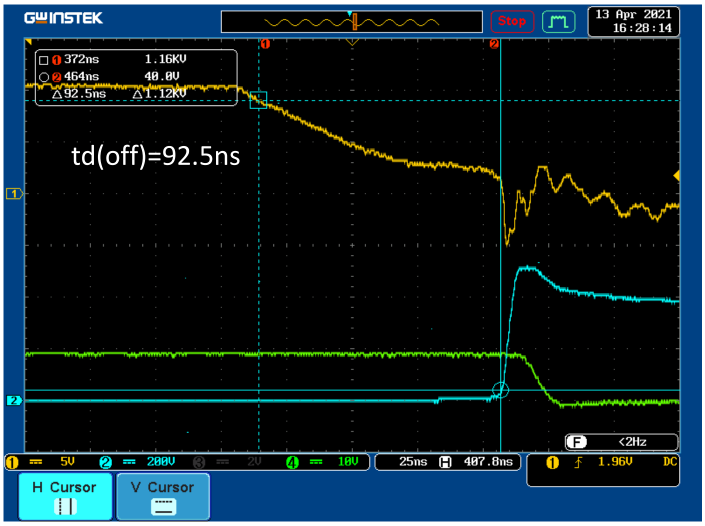


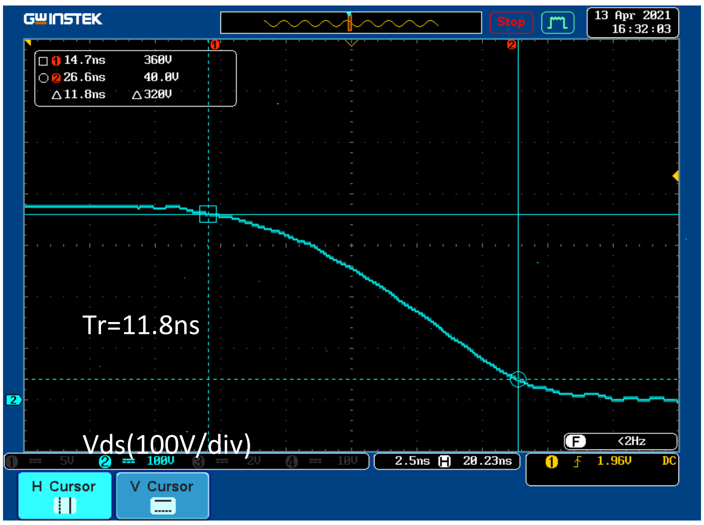
Td (on) (ns)	tr (ns)	Td (off) (ns)	Tf (ns)	Condition
23.0	11.5	82.2	5.5	VDS=380V VGS=10V ID=20A Rg=4ohm (external)
23.2	11.8	92.5	3.9	VDS=380V VGS=10V ID=10A Rg=4ohm (external)

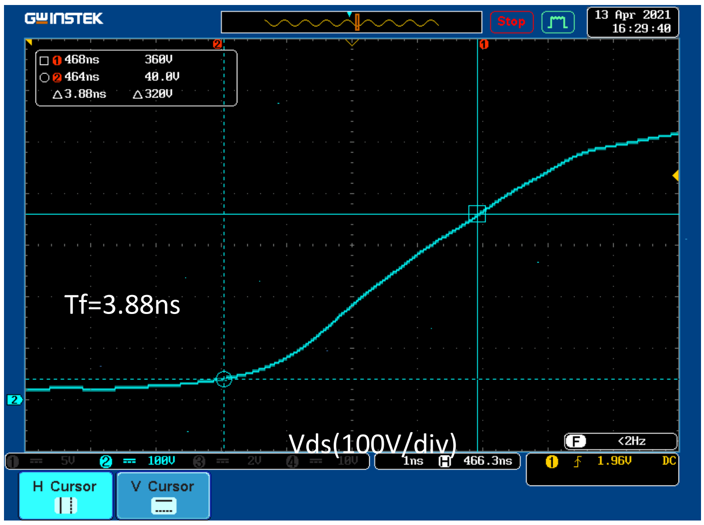
There is no significant difference in the measured Id current at max 20A or 10A
For switching.

Maximum frequency is 380kHz at 50% duty cycle.
(Safety Ratio is not applied in this case)









2.5 Gate Charge Characteristics and Body Diode Characteristics

(T_j=25℃)   🌡 :temperature dependent

Parameter	***Symbol***	***Conditions***	***Value***			***Unit***
			Min	***Typ***	***Max***	

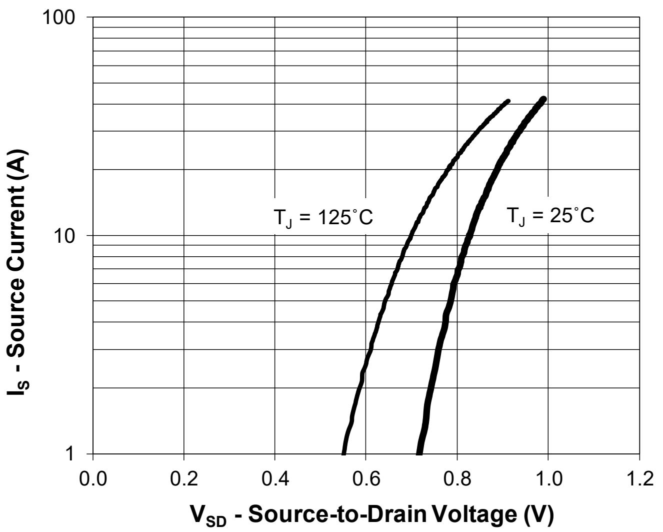
Gate charge characteristics

Gate to source charge	Q_{gs}	V_{DS}=480V, I_D=20A, V_{GS}=10V	-	8	-	nC
Gate to drain charge Affect to switching characteristic	Q_{gd}		-	19	-	
Gate charge total Affect to drive loss by Gate voltage	Q_g		-	59	-	
Gate plateau voltage	$V_{plateau}$		-	4.2	-	V

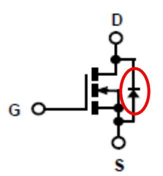
Reverse Diode（Body diode between source and Drain)

Continuous forward current as source current This is Body diode Forward current as Max.	I_S	V_{GS}=0V	-	-	20	A
Diode forward voltage 🌡 Voltage when forward current flow in body diode.	V_{SD}	V_{GS}=0V, I_S=I_F	-	0.9	1.2	V
Reverse recovery time 🌡 Time to disappear reverse recovery current.	t_{rr}	V_{RR}=480V, I_S=I_F, d_{iF}/d_t=100 A/μS	-	358	-	ns
Reverse recovery charge Charge to disappear reverse recovery current	Q_{rr}		-	6.8	-	μC
Peak reverse recovery current	I_{rm}		-	43.1	-	A

Source-Drain Diode Forward Voltage



Body Diode



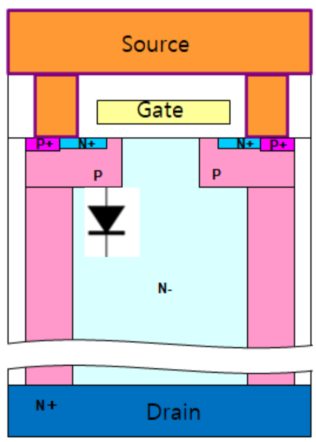


Fig.22 V_{SD} vs I_S as IF of Body Diode

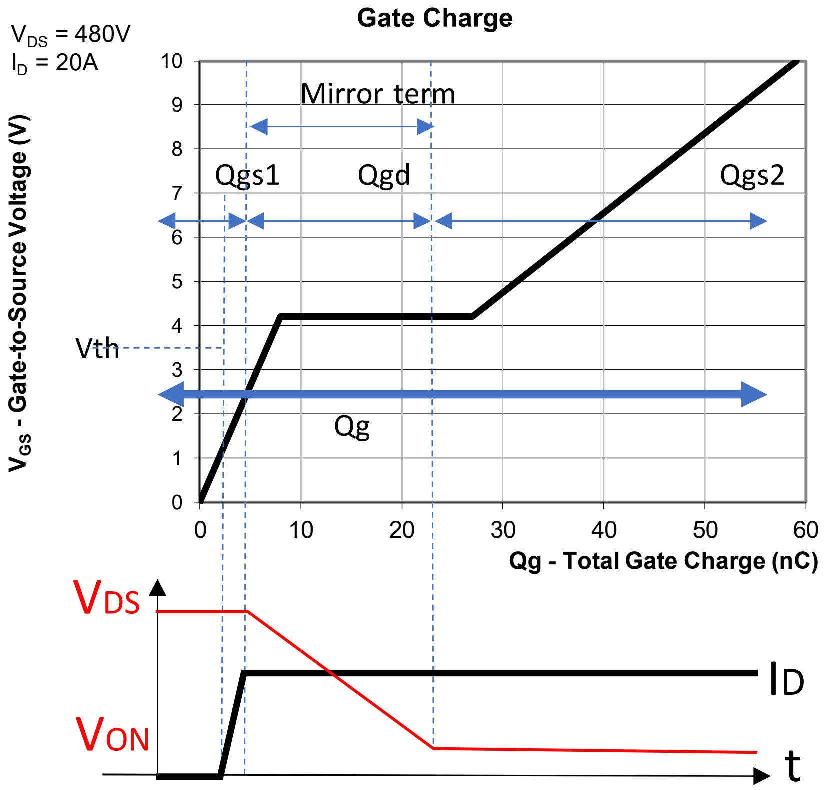


Fig.23 Gate Charge

Qgs=Qg-Qgd

Qgs=Qgs1+Qgs2

When a constant current is applied to the Gate, the Gate Voltage rises and the MOSFET turns ON. Charges are charged between Gate and source, and Gate and Drain during the mirror term. Total Gate Charge Qg is give by Total Gate Current x Time.

Lower Qg correlates to less Gate drive losses.

FOM :Figure Of Merit is used as a performance index for Power MOSFETs.

FOM=$R_{DS\,(on)}$ x Qg（Ω.nC)

A Lower FOM is superior.

2.6 Safe Operating Area (SOA)

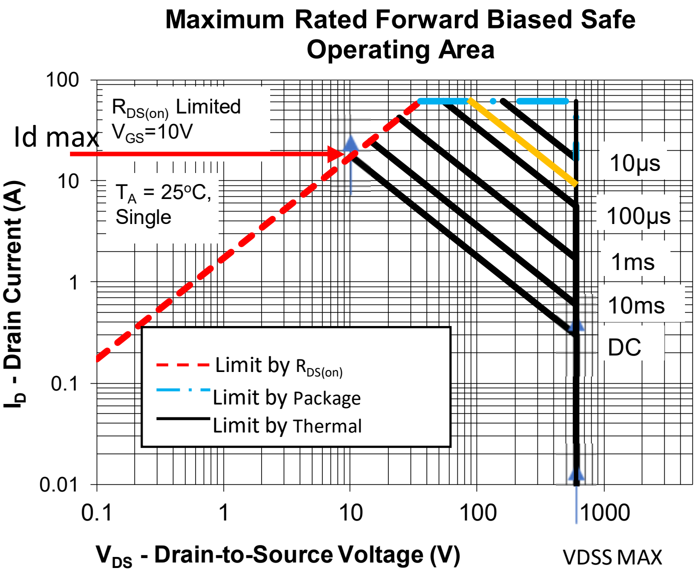


Fig.24 Safe Operating Area

Product shall be used within Idmax ,$R_{DS(ON)}$,

Package and BVDSS

This figure is based on a temp=25℃

Illustrating that the SOA range narrows as the case temperature T_c rises.

Example: Pulse=10µsec, Tc=75degC to estimate SOA

Derating Rate D=（150－Tc）/125*100

For the point, 16A*600V = 9600W,

D=0.6 Pd(75) = P(25)xD

= 9600 x 0.6

= 5580W

Therefore, the Yellow line could be SOA area for 10µsec,Tc=75degC

2.7 Transient Thermal Response

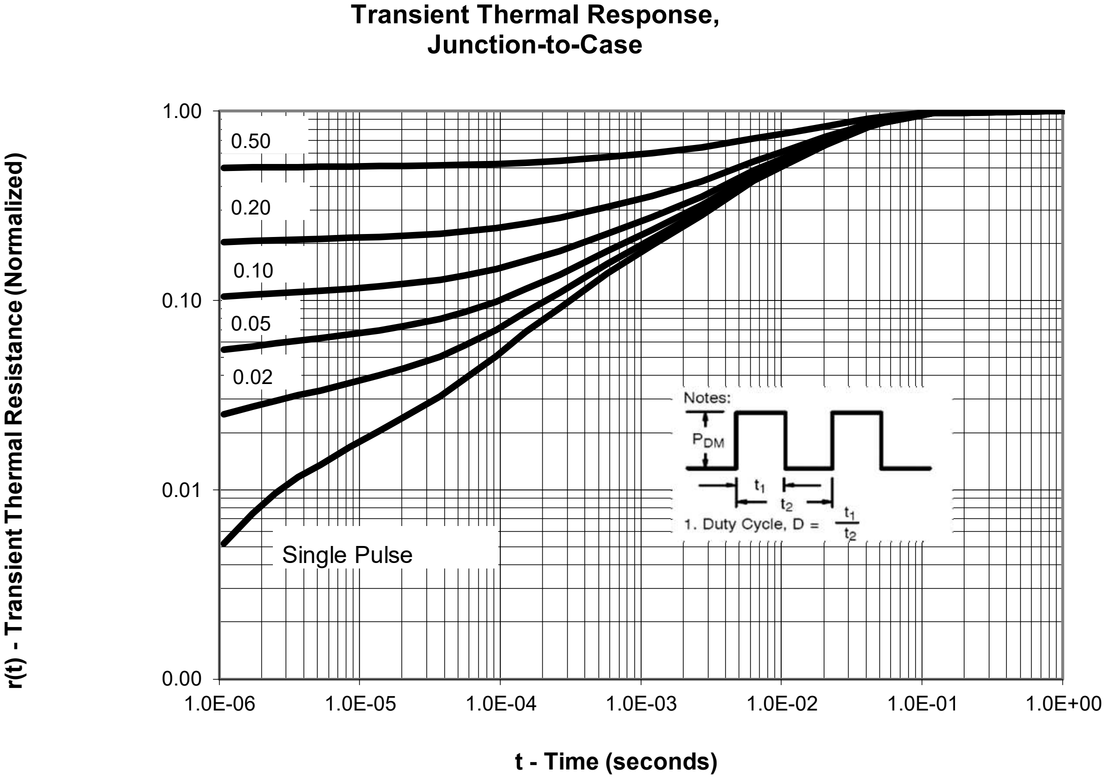


Fig.25 Transient Thermal Resistance r (t)-pulse width time
t1=Pulse Width=PW
t2=Total Time
Duty=t1/t2
To calculate Channel temperature increasing ΔTch, refer to Fig24 for value of r(t). ΔTch=P*r(t)

Example 1 Pulse width t1 PW=10ms, D=0.2 (Duty Cycle=20%)
How much temperature is increased when Power consumption=60W?

From the graph, 10ms with D=0.2 is for r(t)=0.6 、 Rthjc=0.69degC/W
ΔTch=P*r(t)=60x0.6x0.69=24.84℃

Example 2 Condition: Tc=85℃, Power=40W, Pulse Time=10ms, Single Pulse
How much temperature of Tj?

Tc=85degC,Rthjc=0.69degC/W, P=40W,Duty=0, r(t)=0.5
ΔTch=P*r(t)=40x0.5x0.69=13.8℃
Tj=Tc+P*r(t)=85+(40x0.5x0.69) =98.8℃

Example 3 Condition: Tc=85℃,Frequency=2kHz,Duty Cycle=20%,
Peak Power=50W, How much temperature of Tj?
Tc=85degC,Rthjc=0.69degC/W,P=50W,Duty=0.2,f=2kHz
r(t)=0.24 Pulse width=Duty*1/f=0.2/2000=1E-4sec
Tj=Tc+P*r(t)=85+(50x0.24x0.69) =93.28℃

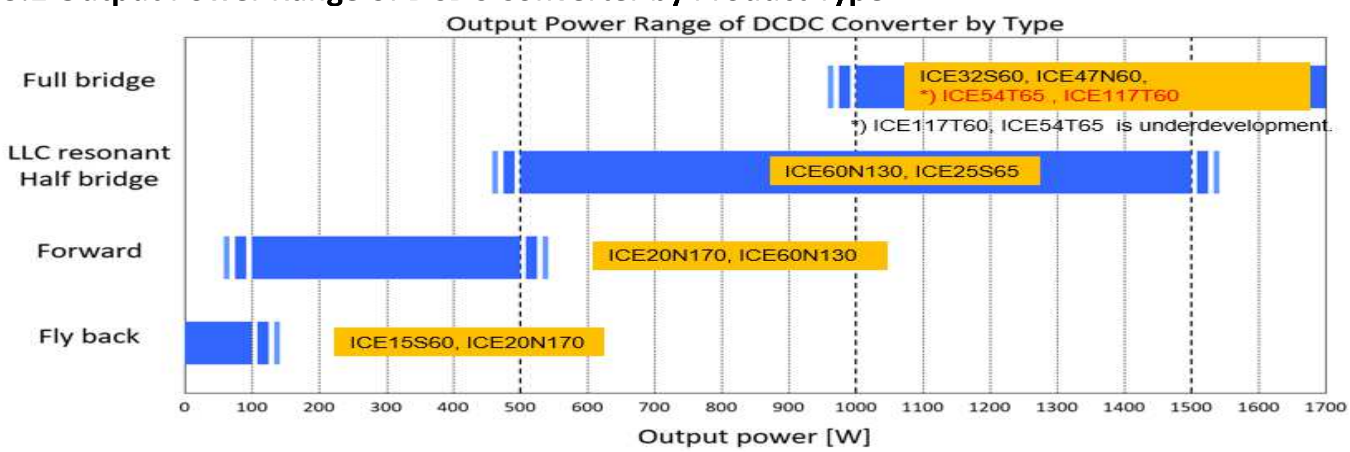
3. Product Family

3.1 Product List

GEN	Product	BVDSS Min. (V)	ID Max. (A)	RDSON Max. (Ω)	Qg Typ. (nC)	FOM (Ω・nC)	IAR (A) Avalanche Current	Package *Pbfree TO=TO220* FP=Full Pak* W=TO247* D=TO252 L=DFN88 ,LK=DFN56 B=TO263 T=TOLL C=Wafer*
1	ICE47N60	600	47	0.068	189	12.85	20	W,C
	ICE60N130	600	25	0.15	84	12.60	11.5	TO,FP,W,C,B
	ICE22N60	600	22	0.16	84	13.44	11	TO, B ,W, T
	ICE20N170	600	20	0.199	59	11.74	10	TO,FP,W,C,B,T
	ICE20N60	600	20	0.19	59	11.21	10	TO,FP,W,B,C,T
	ICE19N60	600	19	0.22	59	12.98	9.5	L8x8
	ICE15N73	730	15	0.35	75	26.25	7.5	TO,FP,W ,T
	ICE13N60＊	600	13	0.27	48	12.96	6.5	TO,FP,W,L8x8,B,T
	ICE11N70	700	11	0.25	84	21.00	7.5	TO,FP,W,B,C ,T
	ICE10N60	600	10	0.33	43	14.19	5	TO,FP,W,B,L8x8,T
	ICE8N60＊	600	8	0.52	32	16.64	4	TO,FP,W,B,L8x8, T,D,LK
2	ICE32S60	600	32	0.078	47	3.67	10	TO,FP,W,C,T
	ICE25S65	650	25	0.133	34	4.52	8	TO,FP,W,C,B, T
	ICE24S65	650	24	0.141	34	4.79	8	L8x8
	ICE15S60	600	15	0.175	30	5.25	5	TO,FP,W,C,B ,T
	ICE14S65	650	14	0.195	24	4.68	5	TO,FP,W,C,B ,T
	ICE8S65	650	7.8	0.4	11.5	4.60	2.7	TO,FP,W,B,C,D,LK56, T
3	ICE117T60＊	600	117	0.0134	304	4.07	13	Wplus
	ICE54T65	650	54	0.038	136	5.17	7	T
	ICE54T60	600	54	0.037	136	5.03	7	W
	ICE18T60＊	600	18	0.15	31	4.65	5	TO,FP,W,B,D,C,L5x6 T
	ICE15T65＊	650	15	0.22	23	5.06	2	TO,FP,W,,B,D,C,L5x6 T

＊New as under development

3.2 Output Power Range of DCDC Converter by Product Type



Circuit choice may be different depending on the output power. Full bridge may have over 1700W Power therefore please select the appropriate product depend on the power range. For example, the case of 100W Fly back , we offer ICE20N170 for Max Id=20A or ICE15S60 for Max Id=15A.

4. Applications

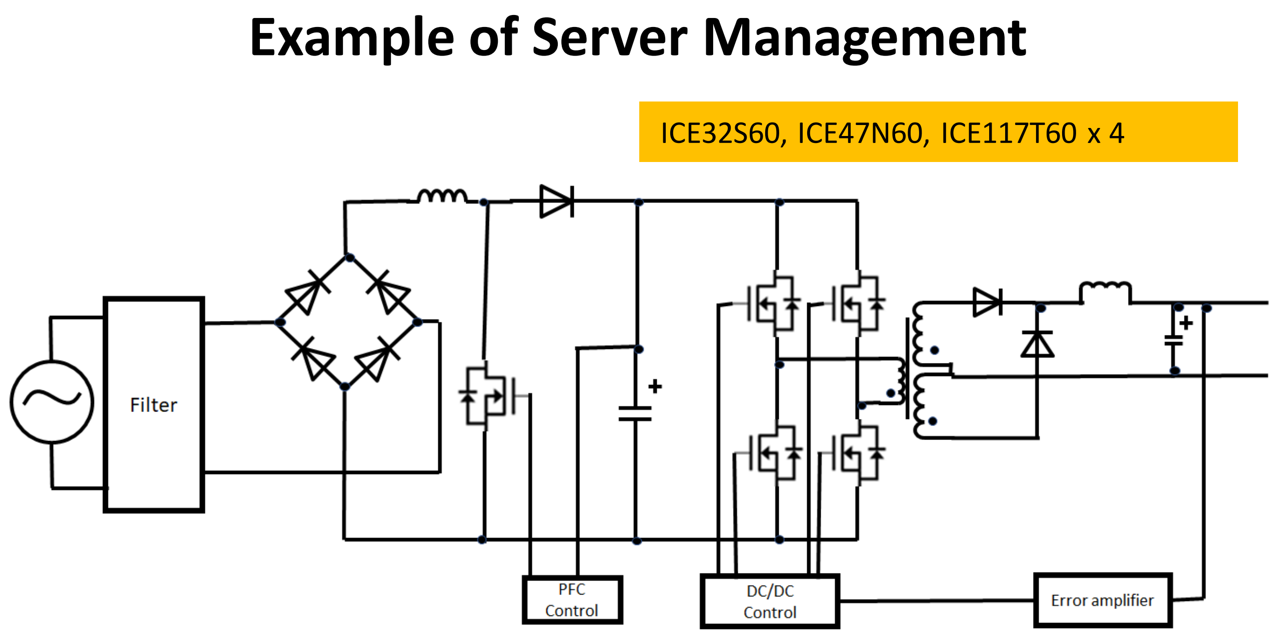
4.1 “Where used” Application Matrix

★: Displays the circuit used for each application

#	Application	Output Power (W)		Circuit								ICEMOS PART #
				AC-DC			DC-DC				DC-AC	
		Min	Max	Half Wave	Full Wave1	Full Wave2	Flyback	Forward	LLC Half Bridge	Full Bridge	Inverter	
a1	SMPS Power Factor Correction	500							★	★		ICE25S65 ICE60N130
a2	LLC Half Bridge	1000								★		ICE47N60 ICE32S60
b	Low Power SMPS Quasi- Resonant Flyback		100				★					ICE15S60 ICE20N60 ICE22N60W
c	High Power SMPS LLC Half- Bridge	500	1500						★			ICE47N60 ICE32S60
d	ATX Power Supplies	200	1600	★	★	★	★	★	★			ICE47N60 ICE32S60
e1	LED TV (140 Inch)	5k				★				★		ICE117T60 ICE47N60
e2	LED Lighting	20	500	★	★	★	★	★				ICE25S65 ICE60N130
f	Data Center AC/DC (Severs & Telecom)	500k-1k node				★				★		ICE117T60 ICE47N60
g	Fast Chargers	3k	400k			★				★		ICE117T60 ICE47N60
h	Chargers PC Adapters	36	90	★	★		★					ICE15S60 ICE10N60 ICE19N60L
i	TV Power Application	24	410		★	★	★	★				ICE25S65 ICE60N130
j	UPS	500	10k			★			★	★	★	ICE117T60 ICE47N60
k	Solar Inverters	300	6k					★	★	★	★	ICE117T60 ICE47N60
l	HID Street Lights	22	500			★		★	★			ICE25S65 ICE60N130
m	Gaming Consoles	100	200		★	★		★				ICE60N130 ICE19N60L
n	LED Signage	10	250	★	★			★				ICE60N130 ICE20N170
o	E-Bikes/E-Mobility	600	40k			★			★	★		ICE117T60 ICE47N60
p	Printers	10	1500	★	★	★	★	★	★	★		ICE10N60FP ICE20N60FP ICE47N60
q1	White Goods Fridge	200	300			★			★	★	★	ICE60N130 ICE20N170
q2	Washing Machine	800	1500			★			★	★	★	ICE117T60 ICE47N60
r1	Audio Amp	200 x n	5k x n			★			★	★		ICE117T60 ICE47N60
r2	Projector	300	2k			★		★	★	★		ICE47N60 ICE8S65FP
s1	Car audio	10 x n	100xn				★	★				ICE47N60 ICE32S60
s2	Navigation	10	20				★					ICE15S60 ICE19N60L
u	3D printer	180	1500	★	★	★	★	★	★	★		ICE117T60 ICE47N60
v	Smart Phone Adaptors	20	90	★	★		★					ICE15S60 ICE20N170
w	Industrial Power Supply	320	1300			★			★	★		ICE117T60 ICE47N60
x	Tablet/Laptop	200	1500	★	★		★					ICE15S60 ICE20N170
y	Micro Inverters	200	1500						★	★	★	ICE117T60 ICE47N60

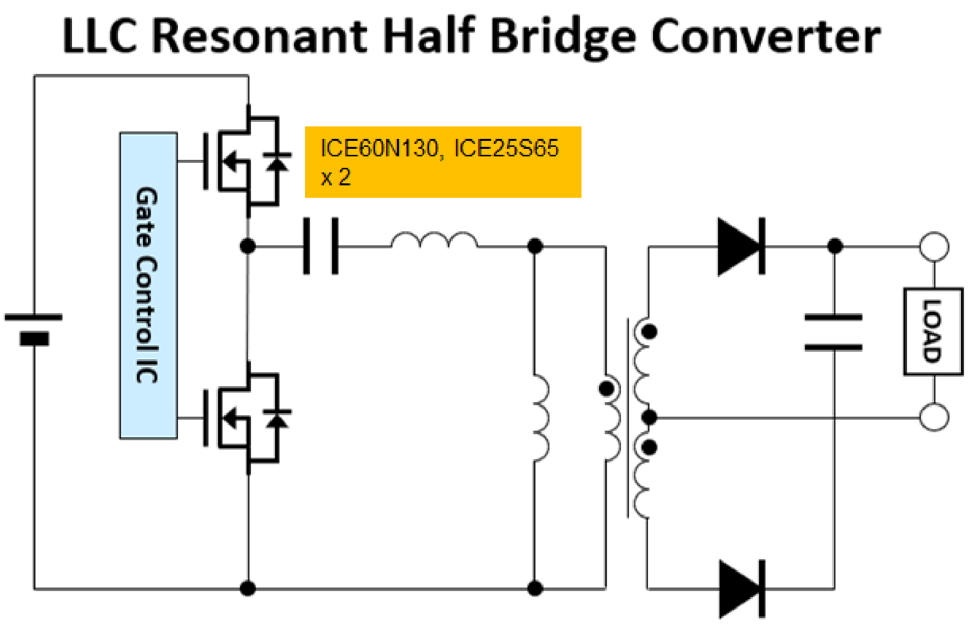
4.2 Circuits

4.2.1 Full Bridge Converter (Isolated)



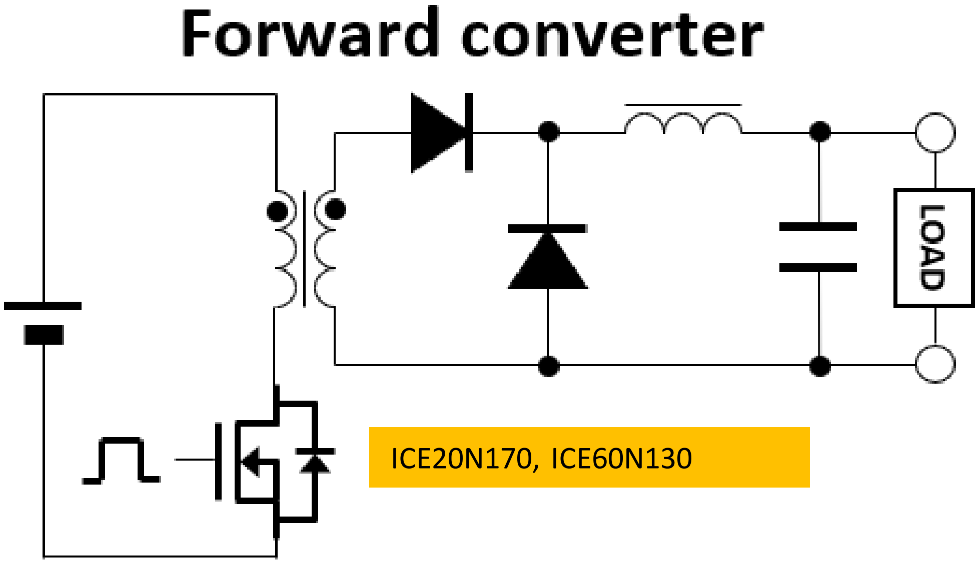
4 pieces used of ICE47N60 or ICE32S60

4.2.2 LLC　Resonant Half Bridge Converter（Isolated）



2 pieces used of ICE60N130 or ICE25S65

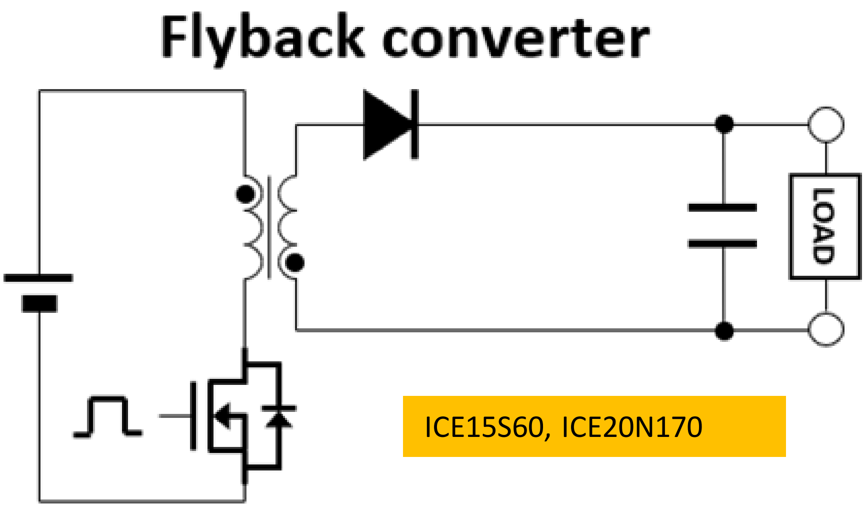
4.2.3 Forward Converter （Isolated）



1 piece used of ICE20N170 or ICE60N130

This system can supply a wide range of power. Compared to the flyback converter an additional diode and choke coil are required but the ripple voltage is lower. The output voltage is determined by the ratio of the number of turns on the primary and secondary sides.

4.2.4 Flyback converter （isolated）



2 pieces used ICE15S60 and ICE20N170

Since the ripple voltage is larger compared to the other converters, a larger capacitor is required. The output voltage is determined by the ratio of the number of turns on the primary and secondary sides.

4.3 Feature Application: Telecom & Computing
LTE Wi-Fi Router Power Supply

Key Device Technology: ICE8S65FP (8A,650V, TO220FP) and ICE11N70FP (11A,700V,TO220FP)

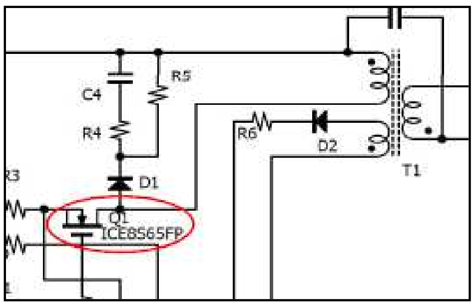
Long Term Evolution (LTE) routers, also known as “4G routers”, are a specific type of network router that can provide mobile broadband internet connectivity to devices via a Wi-Fi, Ethernet, or USB connection. They are categorized by their use of fourth-generation long-term evolution (4G LTE) and LTE-Advanced wireless modems, modules, or PCI Mini Cards to drive high-speed data transfer over cellular networks. These routers are very popular for machine-to-machine (M2M) and the Internet of Things (IoT) communications environments because they offer full-duplex communications links using frequency-division duplexing (FDD) or time-division duplexing (TDD) depending on the frequency band used. LTE router mobility can support devices moving at speeds of up to 350 kilometers per hour, with coverage of 5 to 100 km, along with individual channel bandwidths between 1.4 and 20 MHz. Antenna diversity and spatial multiplexing with MIMO features enhance the performance and speed. Using MIMO increases downlink speeds of up to 300 Mbps with low latency (10 mS).

The designers of these routers are placing greater emphasis on more reliable efficient power MOSFET devices in their circuits. The ICE11N70FP (Gen1 technology) and the ICE8S65FP (Gen2 technology) are both idea for the LTE Wi-Fi Router application.

LTE Wi-Fi Router Case Study:
Customer “A” evaluated the ICE8S65FP as a replacement for the device from our competitor because of delivery problems. The table below shows the actual side-by-side comparison test results assessing the ICE8S65FP performance versus the device from “SUPPLIER-1”. The conclusion was that the ICE8S65FP had no issue for thermal characteristic and was a viable replace for the new Wi-Fi Router design in development. IceMOS got the design win!

			AC90V			AC100V			AC230V			AC264V		
CH. No.	REF.No.	SUPPLIER	Tc	△T	Tc (50°C)	Tc	△T	Tc (50°C)	Tc	△T	Tc (50°C)	Tc	△T	Tc (50°C)
7	Q1	SUPPLIER-1	68.55	38.70	88.70	65.50	36.15	86.15	65.20	36.80	86.80	66.80	38.50	88.50
	Q1	ICE8S65FP	64.30	34.95	84.95	62.60	33.50	83.50	60.70	32.80	82.80	63.10	34.55	84.55
		Δ	-	-	-3.75	-	-	-2.65	-	-	-4.00	-	-	-3.95
14	Q21	SUPPLIER-1	59.45	29.60	79.60	57.75	28.40	78.40	65.40	37.00	87.00	68.25	39.95	89.95
	Q21	ICE8S65FP	56.20	26.85	76.85	55.00	25.90	75.90	60.30	32.40	82.40	64.30	35.75	85.75
		Δ	-	-	-2.75	-	-	-2.50	-	-	-4.60	-	-	-4.20
Power Consumption (W)		SUPPLIER-1	59.6	-	-	58.5	-	-	57.6	-	-	57.8	-	-
		ICEMOS	59.1	-	-	58.4	-	-	57.5	-	-	57.7	-	-
		Δ	-0.50	-	-	-0.10	-	-	-0.10	-	-	-0.10	-	-

Power Module Load Conditions: 5V/4A and 54V/0.55A
Temperature Requirement: < 142°C @ 1.75W



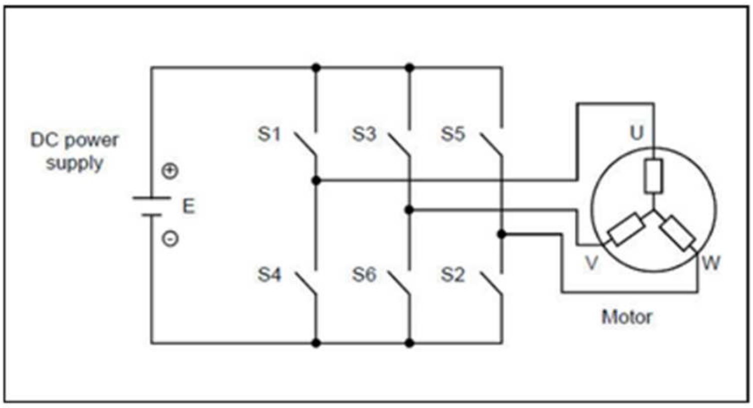
- **Two MOSFETs used for LTE Router AC-DC**
- **AC in 90-100V**
- **Two lines DC out for DC 5V and 54V POE**

4.4 Home Appliances
Motor drive application and hard switching commutation

The motor drive market continues to push for increased efficiency, more compact size, and enhanced system robustness. This is especially true in appliance field as white goods become "smarter". The power switch technologies selected for different operating conditions to meet these market requirements is important, and Superjunction Power MOSFETs are a practical option as a solution to meet those requirements.

As a result of rising energy cost, a top priority of major household appliance manufacturers is to increase energy saving. Their attention is focused on the reduction of power loss during the steady state operation. That must be the case at low load conditions in several applications, in addition to the full load ones. Selecting efficient switches, at low current conditions is a crucial element to achieving this goal.

Motor control applications are made up of variable voltage and frequency inverters. The purpose of a power converter is to produce a controllable voltage and frequency and produce an AC output waveform from a DC link circuit with the help of a pulse-width modulation. This can be done by employing several modulation techniques. This illustration shows one of the most common topologies used in motor control application. It is a basic circuit of a voltage source inverter, based on three half bridges or phase legs to generate three-phase AC for the motor.



The topology is based on six power switches to supply voltage to a motor to control its speed, position or electromagnetic torque. Each half bridge operates in hard switching commutation on an ohmic-inductive load (motor) with a continuous load current and every commutation requires the freewheeling phase done by six diodes coupled with the power switches, to conduct reverse current.

When the lower side freewheeling diode is in reverse recovery, the direction of its current flow is the same as the upper side switch and vice versa, thus an overshoot occurs on the turn-on commutation, which produces added power loss. This means that in the half bridge topology, running in hard switching commutation, the freewheeling diode must be optimized with low forward voltage characteristic and fast reverse recovery behavior (low trr and Qrr).

Many motor drive applications operate at switching frequencies from 4 kHz to 20 kHz, to reduce the audible noise for human hearing. This suggests perfecting the power switch, primarily with low conduction loss and secondarily with low switching loss. Devices used in motor drive applications must also be robust and capable of withstanding faults long enough for a protection scheme to be activated.

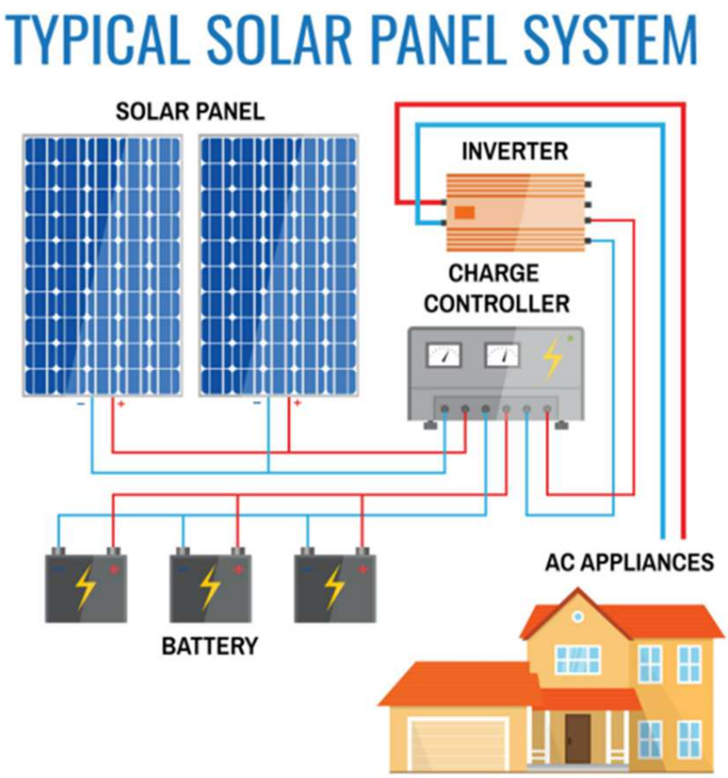
4.5 Renewable Energy - Solar Application
Solar Inverter Technology

Typical inverter topology designs can be characterized by one of two features, topology and power switch control. The topology can be single or double ended, while the control may be self-oscillating or driven by a separate circuit. The preferred approach depends on performance required versus cost objective.

Single ended topologies have fewer power switches and associated circuits than double ended topologies. They are therefore less expensive. However, the transistor used as a power switch in a single ended topology must carry the entire load, in terms of current and voltage. Hence, single ended designs require transistors with greater current capacity and higher breakdown voltage rating than the double ended designs. These requirements suggest using a bipolar transistor. However, this limits the topology to low frequency operation. The Superjunction MOSFET is an excellent solution to this problem. The low $R_{DS\,(on)}$ of the Superjunction devices allow the current carrying capability to compete with the Bipolar Transistor. The fast-switching speed of the MOSFET and the simple drive circuit makes the Superjunction Transistor the device of choice for single ended ballast topologies.

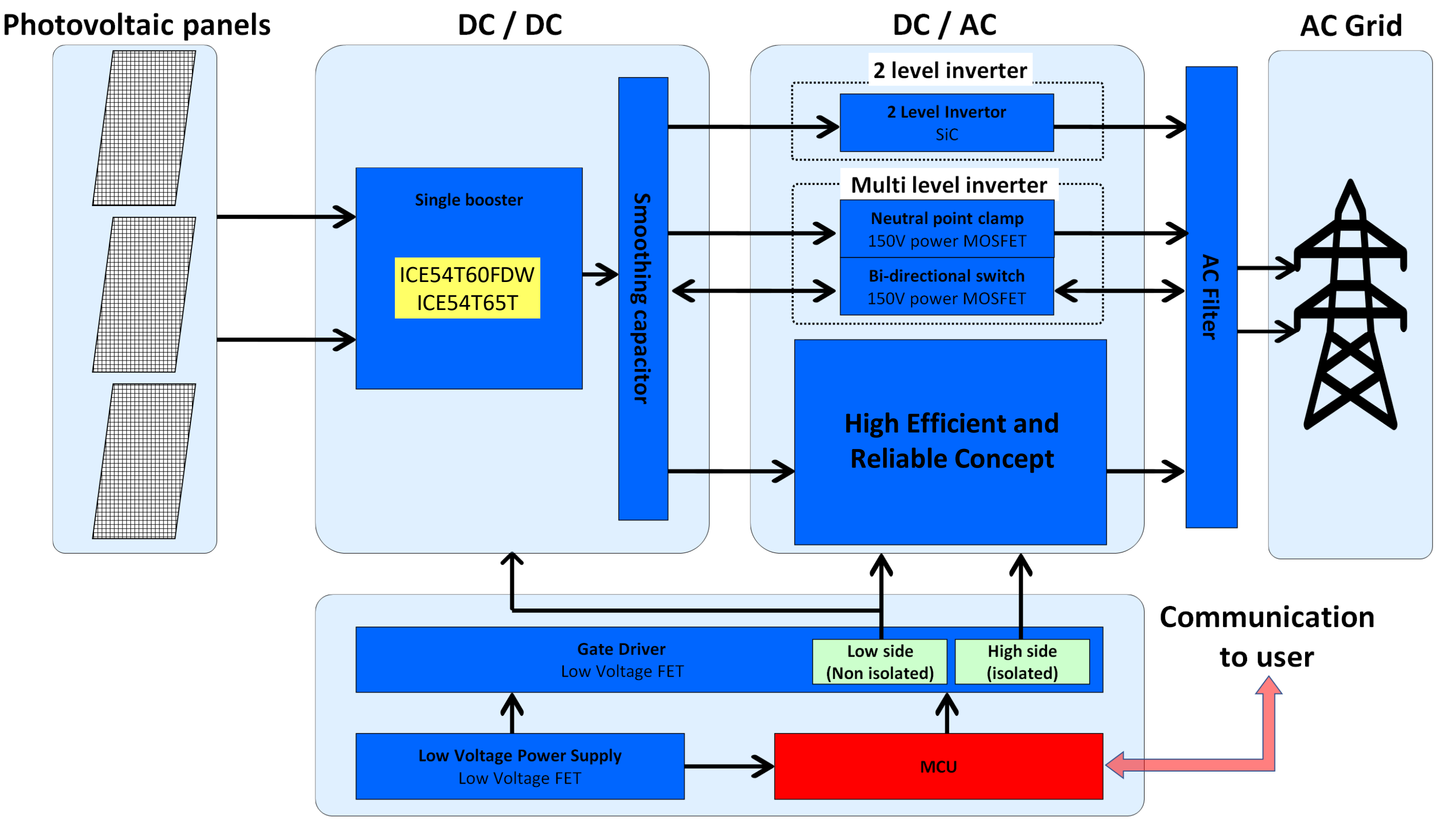
Double ended inverters use at least two power switches. As a result, each power transistor carries all of the load current, but only half the voltage. In other topologies the transistor carries half the load current, but all the voltage. Again, MOSFETs are the transistor of choice for this topology and because of the superior $R_{DS\,(on)}$, simple drive circuit the Superjunction Power MOSFET ideal for this application.

The inverters work by taking in power from a Direct Current (DC) Source, in this case the solar panels. The power is generated in the range of 250 Volts to 600 Volts. DC power is converted into AC power by the inversion process taking place in the inverter. This process of DC to AC Conversion is achieved by using a set of solid-state devices like Insulated Gate Bipolar Transistors (IGBT's) or Power Superjunction MOSFETs. These devices when connected in a typical H-Bridge arrangement oscillate the DC power thereby creating AC power.



Solar Inverter System Illustration (Source: Herholdt's Group (Pty) Ltd.)

System diagram for Solar designs up to 6kW

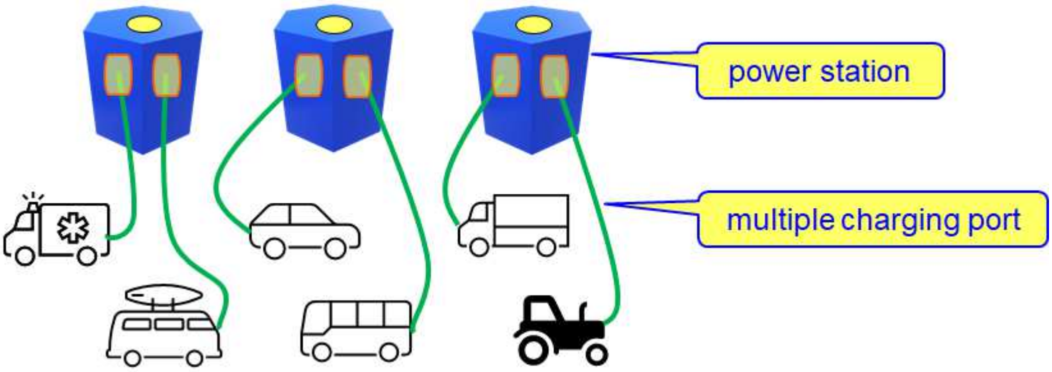


For DCDC, a single booster is usually used. and for DCAC, there are three methods for DCAC block.

GEN	Product	BVDSS Min. (V)	ID Max. (A)	RDSON Max. (Ω)	Qg Typ. (nC)	FOM (Ω・nC)	IAR (A) Avalanche Current	Package *Pbfree TO=TO220* FP=Full Pak* W=TO247* D=TO252 L=DFN88 ,LK=DFN56 B=TO263 T=TOLL C=Wafer*
3	ICE117T60	600	117	0.0134	304	4.07	13	Wplus
	ICE54T65	650	54	0.038	136	5.17	7	T
	ICE54T60FDW	600	54	0.037	136	5.03	7	W

4.6 Electric Vehicle
Charging Infrastructure

Quick chargers for EV have several connector shapes, communication methods (e.g. CAN and PLC) and maximum power outputs (1000Vx400A=400kW, 950Vx250A=237.5kW, 410Vx330A=135kW respectively). In the case of Slow chargers, there are two main types 3kW and 7kW used primarily for home charge with some public use. The 3kW slow charger takes 12-13 hours to reach full charge with the 7kW taking 6 hours. For a 50kW (125A) Quick DC charge , it can take as little as 20 minutes to 1hour for an 80% Power charge. As recent trends indicate that battery capacity shall increase, new electric vehicles will need ultra-rapid chargers that exceed 100kW for Fast Charge.



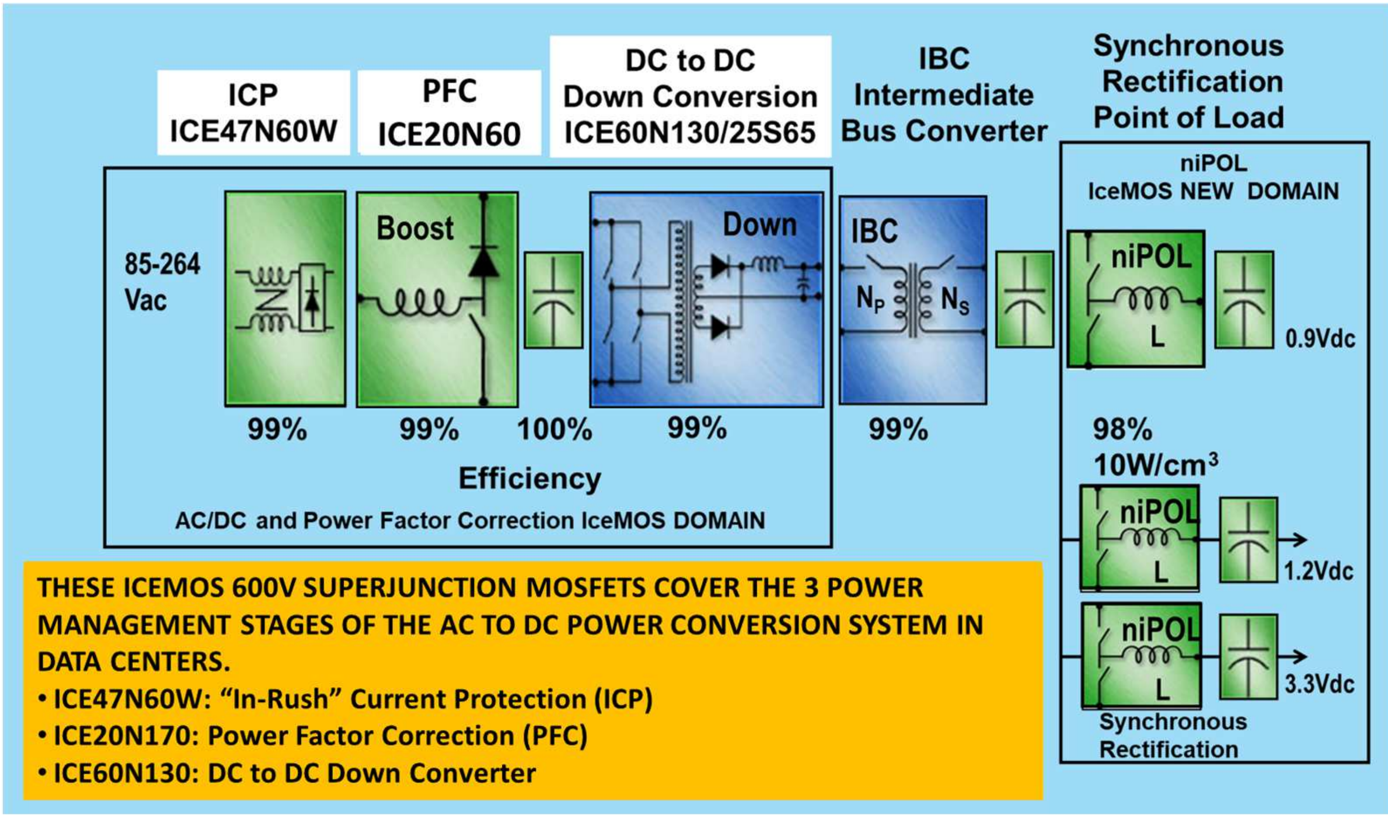
In stations that charge several electric vehicles simultaneously, it is necessary to connect 15kW~30kW charger units in parallel to output 100kW or more.

Our GEN3 product currently under development ICE117T60 has a BVDSS of 600V in a TO247 package enabling a 15~30kW system. For a 100kW ultra-rapid charger the important parameters shall be low $R_{ds(on)}$ and Pd(W).

GEN	Product	BVDSS Min. (V)	ID Max. (A)	RDSON Max. (Ω)	Qg Typ. (nC)	FOM (Ω・nC)	IAR (A) Avalanche Current	Package *Pbfree TO=TO220* FP=Full Pak* W=TO247* D=TO252 L=DFN88 ,LK=DFN56 B=TO263 T=TOLL C=Wafer*
3	ICE117T60	600	117	0.0134	304	4.07	13	Wplus
	ICE54T65	650	54	0.038	136	5.17	7	T
	ICE54T60FDW	600	54	0.037	136	5.03	7	W

IceMOS can offer both wafer and die level sales so you can freely design your package or module type by combining several devices for 1 package.

4.7 Data Center
Power Management Stages



Device Specifications For Power Management In Data Center Servers

Product	ICE47N60W	ICE20N60	ICE60N130
Stage	ICP	PFC	DC/DC
Id (MAX)	47A	20A	25A
V(BR)DSS (MIN)	600V	600V	600V
RDS(on) (TYP)	0.06Ω	0.17Ω	0.14Ω
Qg (TYP)	189nC	59nC	72nC

The IceMOS GEN-1 Superjunction MOSFET technology is a high performance, reliable, cost-effective solutions for data center power supplier designers.

- ✓ Superior Avalanche Energy (EAS) performance – IceMOS GEN-1 devices are designed to be a more robust power MOSFET.
- ✓ Device Versatility – The ICE47N60W N-channel device is one of the most popular devices selected by circuit designers because of its versatility. This device is used in high performance power system and in AC-DC, DC-DC and DC-AC circuits.

5. Failure Modes of Power MOSFETs.

There are 3 main failure modes as below:

5.1 Avalanche Failure （UIS failure）

The device will be destroyed by a voltage / current load that exceeds the E_{AS} capacity to withstand when switching off, such as in an L load circuit. Phenomenon such as VG(th) deterioration and short circuit between drain and source are confirmed. It is also necessary that the channel temperature Tj in the avalanche state is 150ºC or less.

5.2 EOS Failure (Electrical Over Stress outside SOA or beyond Voltage or Current)

When devices experience stresses beyond their safe operating range such as voltage surge, excess current or thermal stress resulting in a damaged device. In this mode metal burn marks can be visible over die surface and the silicon might be melted. The three 3 pin terminals(Gate-Drain-Source) could short circuit. Our product has been tested to failure by a Class 2 1000V Voltage Surge from a IEC61000-4-5 Surge Generator resulting in burn marks around the Gate and Source pads.

5.3 ESD Failure(Electro-static Discharge)

Our SJMOSFET ESD capacity is classified by MIL-STD-1686 as below:
Human Body Model Class 3 (4000-15999V)
Machine Model Class M5＞+-800V

ESD can cause problems such as gate leaks due to polysilicon or gate oxide film destruction, and resistance shorts between drain and source. When handling, ESD such as 1MΩ grounding and applying Anti static Discharge action to the Equipment.

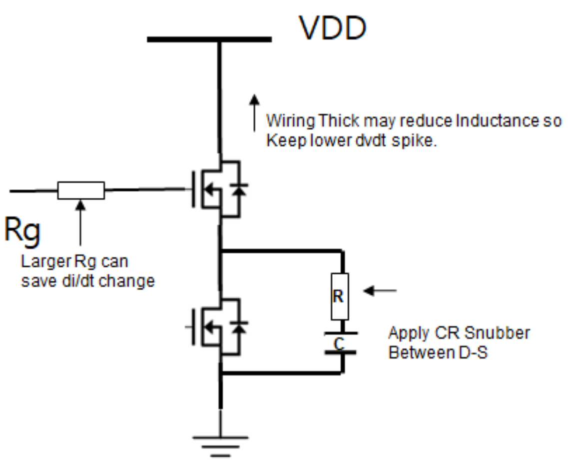


Fig.26 Measure to prevent Body Diode breakage

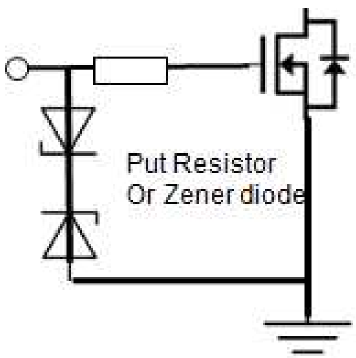


Fig.27 Measure to prevent ESD failure

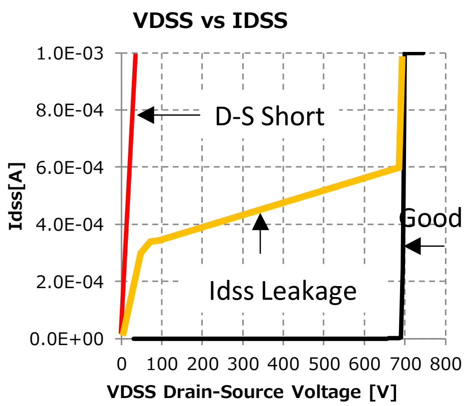
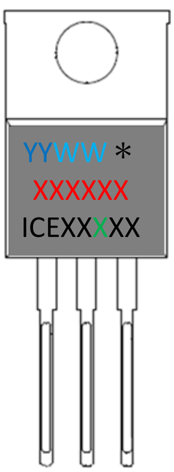


Fig.28 Example of characteristic DC failure

6. Reliability Test Results

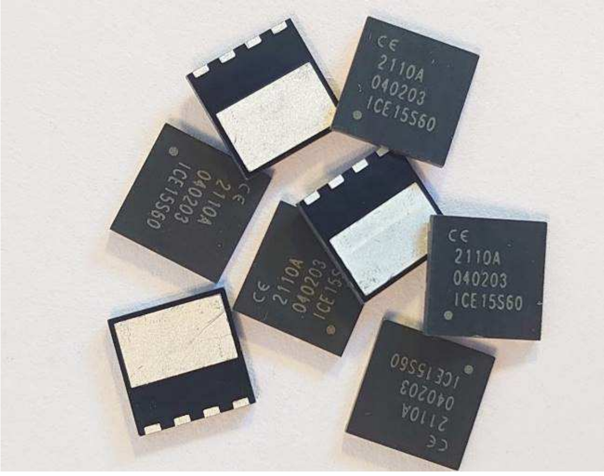
Items	Test Description(Abbr.)	Test method.	Stress Condition	Result
1	Temperature Cycle(TCT)	JESD22-A104	1000 cycles, Δ Tj -55 to 150˚C	PASS
2	High Temp storage(HTS)	Mil-Std. 750 Method 1032	500 hrs, Tj = 150˚C	PASS
3	Steady State Gate Bias positive (HTGB)	Mil-Std. 750 Method 1042-B	1000 hrs, VGS = +24V Tj = 150˚C	PASS
4	Steady State Gate Bias negative (HTGB)	Mil-Std. 750 Method 1042-B	1000 hrs, VGS = -24V Tj = 150˚C	PASS
5	Steady State Reverse bias (HTRB)	Mil-Std. 750 Method 1042-A	1000 hrs, VDS = 80% BVDSS Tj = 150˚C	PASS
6	High Temp High Humidity Reverse Bias (H3TRB)	Mil-Std. 750 Method 1042-A	1000 hrs, VDS = 480V Tj = 85˚C, RH = 85%	PASS
7	Pressure Cooker Test (PCT)	Method JESD22-A102	121C 100% RH, 205Kpa,96 hours	PASS
8	Highly Accelerated stress test (HAST)	JESD22-A110D	130°C 85% RH, 230Kpa, 96 hours	PASS
9	Resistance to Solder Heat Test (RSH)	JESD22-B106(PTH)	265°C 10-12secss 3 cycles	PASS
10	Solderability	JESD22-B102E	260°C 10 secs	PASS

7. Device Marking Format

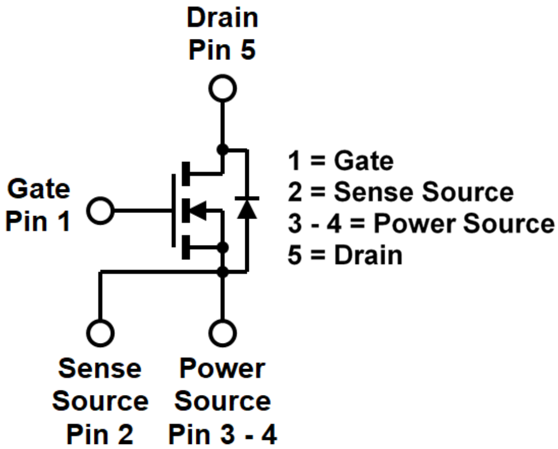


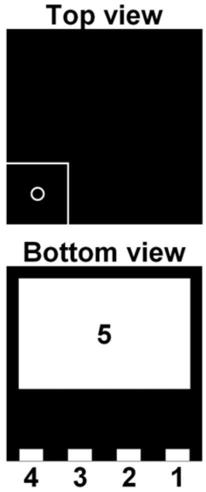
YY=Last two digit in Year
WW=Work Week
∗ Manufacturing site ID
XXXXXX =Production lot ID
ICEXX X XX =ICEMOS Product name
X=N : GEN1 , S : GEN2, T :GEN3

8. DFN 8X8 information



DFN 8x8 Leadless Package





DFN8x8

Features:

- Low On-resistance
- Ultra Low Gate Charge
- High peak current capability
- High dv/dt capability
- Tape & Reel packaging (13-inch reel)
- 3,000 units per reel size
- Eco-Friendly, MSL-1

Part Number	GEN1	GEN2	GEN2
	ICE19N60L	ICE15S60L	ICE25S65L
Polarity	N	N	N
Id(Max)	19A	15A	25A
V(BR)DSS(Min)	600V	600V	650V
Rds(on)(Typical)	0.20Ω	0.155Ω	0.120Ω
Qg(Typical)	59nC	30nC	34nC
FOM(ΩxnC)	11.8	4.65	4.08

Applications:

✦ Servers ✦ Adapters ✦ HID Lighting

✦ UPS ✦ Renewable Energy

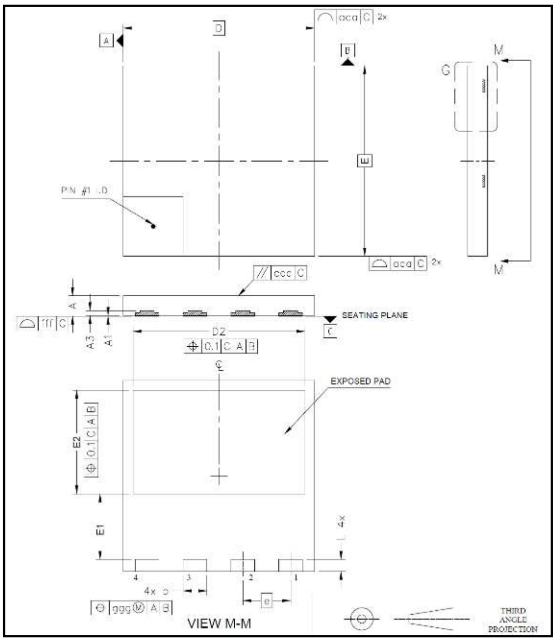
Release plan is early Q3 on GEN1, Q4 on GEN2

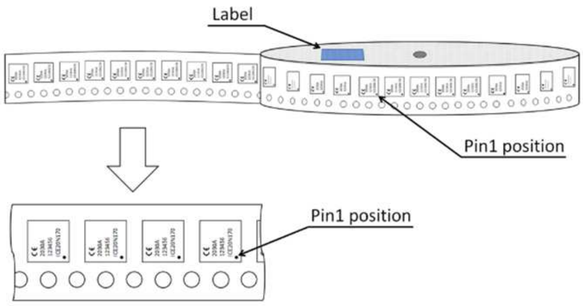
Benefits:

✓Ideal For High Density Applications

✓Ideal For High-Speed Automated Production

✓Low Profile Leadless Package





SYMBOL	MIN		MAX
A	0.75		0.95
A1	0.00		0.05
A3	0.10		0.30
b	0.90		1.10
D	7.90		8.10
E	7.90		8.10
D2	7.10		7.30
E1	2.65		2.85
E2	4.25		4.45
e		2.00 BSC	
L	0.40		0.60
aaa		0.10	
ggg		0.05	
ccc		0.05	
fff		0.05	

NOTES

1.0 DIMENSIONING & TOLERANCEING CONFIRM TO ASME Y14.5M-1994.

2.0 ALL DIMENSIONS ARE IN MILLIMETERS. ANGLES ARE IN DEGREES.

3.0 DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.90mm AND 1.10mm FROM TERMINAL TIP.

4.0 DIMENSIONS DO NOT INCLUDE BURRS OR MOLD FLASH.

5.0 COPLANARITY APPLIES TO THE EXPOSED HEAT SLUG AS WELL AS THE TERMINAL.

6.0 RADIUS ON TERMINAL IS OPTIONAL.

RoHS COMPLIANT RoHS (EU) 2015/863

HALOGEN FREE

9. PACKAGE information

TO220 Lead Free

TO220FP
Full Pak Lead Free

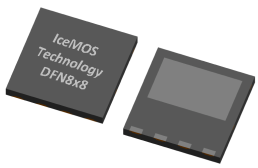
TO247 Lead Free

IPAK
TO251 Lead Free

I2PAK
TO262 Lead Free

D2PAK
TO263-2L
(MSL3)

DPAK
TO252
(MSL3)



DFN8x8
(MSL3)

DFN5x6
(MSL3)

TOLL
(MSL3)

Leadless Package Shipping Information

Package Type	Packing	MOQ
DFN 5x6	Tape & Reel	3,000 pcs
DFN 8x8	Tape & Reel	3,000 pcs
TOLL 8	Tape & Reel	2,000 cps

Leaded Package Shipping Information

Package Type	Packing	MOQ
TO-220	Tubes	50pcs
TO-220 Fullpak	Tubes	50pcs
TO-247	Tubes	30pcs
TO-263 (D2pak)	Tape & Reel	800pcs

Package:

- ☑ RoHS Directive (EU)2015/863
- ☑ Lead Free(Pb free) product.(except some of surface mount)
- ☑ Halogen Free
- ☑ Eco-Friendly Mold Compound

RoHS COMPLIANT RoHS (EU) 2015/863

HALOGEN FREE

CE

Our Pb free definition is no use of Pb for any device inside and outside.

～Guidelines for Handling our SJ MOSFET～

1． Soldering Temperature
   Flow /Reflow : 260℃Max 10 sec 2 times
   iron soldering ：380℃Max 3 sec 1 time

2． Shelf Life Guideline:
   Packaged product 5 years Wafer form 3 years

3． Avoid sudden temperature changes and store at a Temp 5～35℃ and a humidity of 20～75％RH The moisture Sensitive Level of TO220,TO220FP and TO247 is MSL1. DPAK,D2PAK,DFN8x8 and DFN5x6 is MSL3.

4． Please keep away from ccorrosive, chloride, excessive weight and direct sunlight as the product quality may degrade so please avoid these conditions for your storage.

5． To prevent damage from static electricity (ESD) store the product in an ESD-resistant package. When handling the device ground the jig, device, bench etc.

6． Our products comply with RoHS and REACH. We do not use any minerals from conflict zones

Contact:
IceMOS Sales: sales@icemostech.com