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MINIATURIZATION OF THE POWER ELECTRONICS FOR MOTOR DRIVES

By Gerry Limjuco & Dana Wilhelm

INTRODUCTION

The power electronics for a fractional HP AC or BL-DC motor drive can be built in a volume not much larger than a pack of cigarettes. Control IC drivers and co-packaged IGBTs in surface mounted TO-220 (IRGBC30KD2-S) are the key to achieve this level of power density (see Figure 1).

Figure 2 shows the schematic of the power stage. The input is the logic signal from the modulator (standard TTL/CMOS) and the outputs are the three phases to the motor.

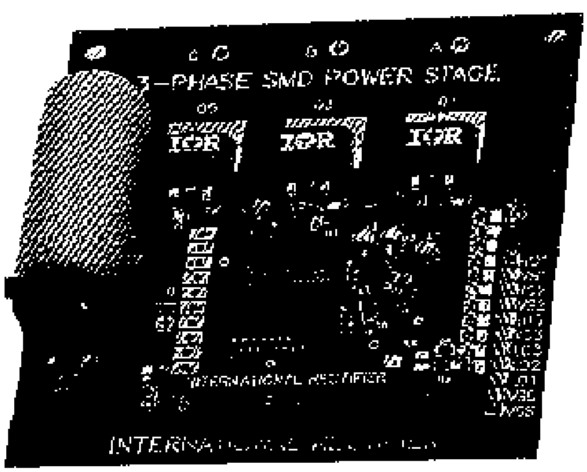


Figure 1
3-Phase SMD Power Stage (Actual Size)

If isolation is required between the modulator and the power stage, it can be provided with inexpensive (low dV/dt) opto-isolators at the input of the IR2130 (see Figure 3).

In addition to the logic inputs, the power stage requires a single 12 - 15V, 20 mA supply. It can operate to bus voltages up to 600V.

The power stage is split into two boards, one with the power devices (see Figures 4 & 4A), the other with the Control IC (gate driver and overcurrent protection and shutdown). Figures 5 and 5A show the control board layout using IR2130S (SOIC), whereas Figures 6 and 6A show the control board layout using IR2130J (PLCC). Either of these control boards can be interconnected with the power board using standard .100" center headers into mating receptacles.

Figure 7 shows how much current can be delivered to an AC motor operated with pulse-width modulation. Larger currents can be obtained from a board with better thermal characteristics than a standard FR4, 4 oz. copper. The thermal resistance between junction and air for this specific designs was measured at 40°C/W per device. The attached sheet shows a breakdown of the different components of losses.

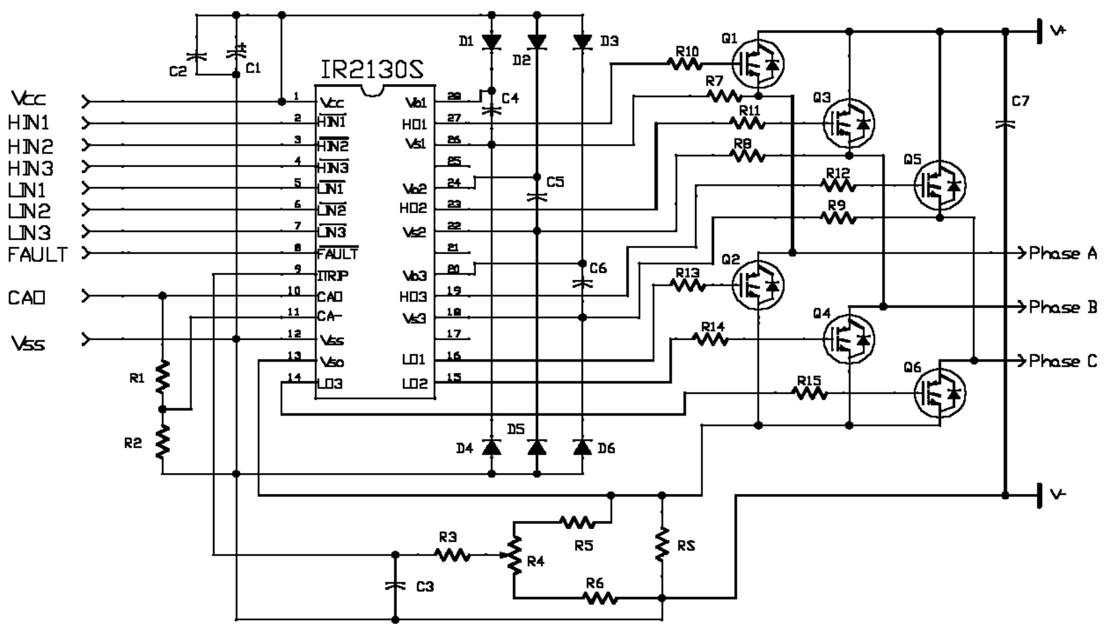


Figure 2

3-Phase SMD Power Stage (Schematic Diagram - IR2130S)

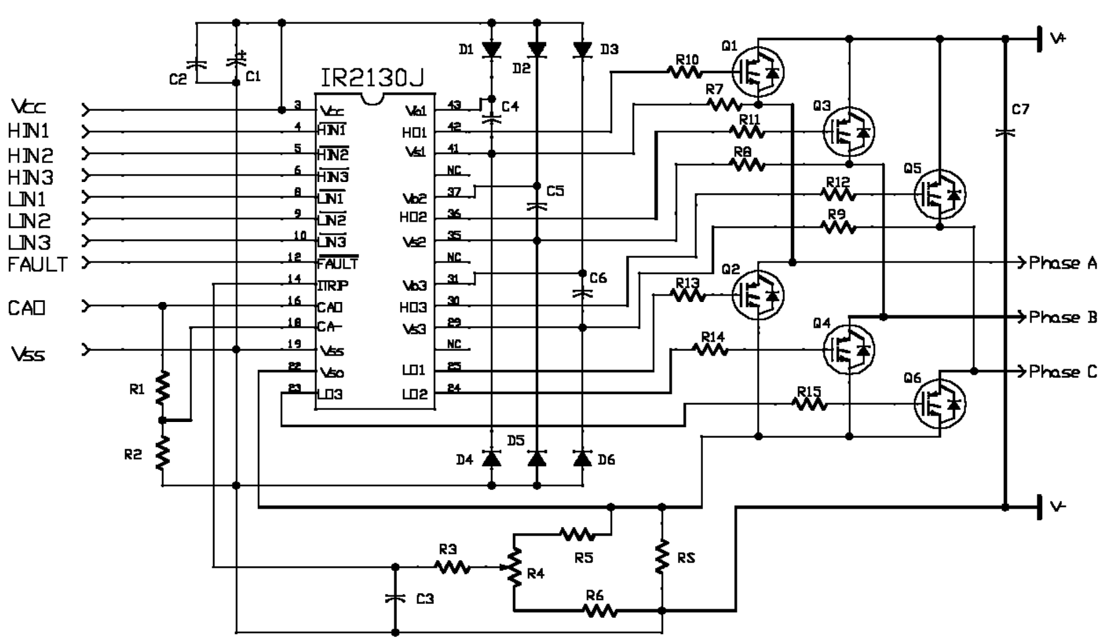


Figure 2A

3-Phase SMD Power Stage (Schematic Diagram - IR2130J)

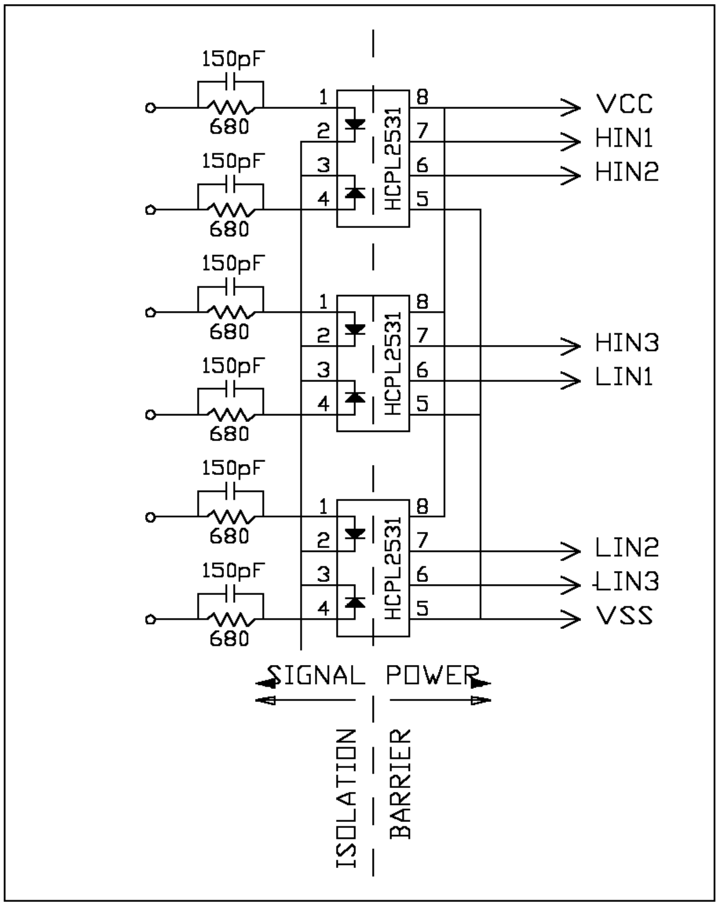


Figure 3
Input Isolation Stage

Power Circuit

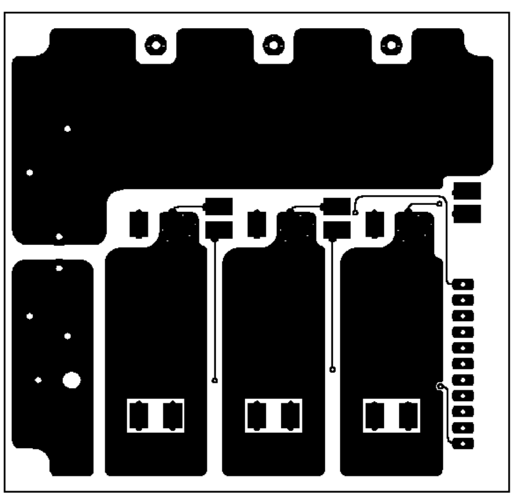


Figure 4
Power Circuit (top view)

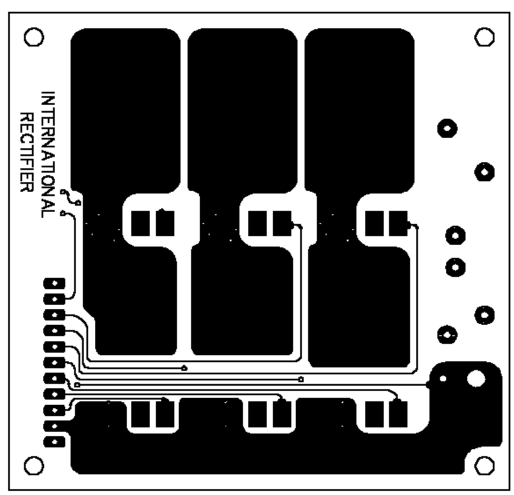
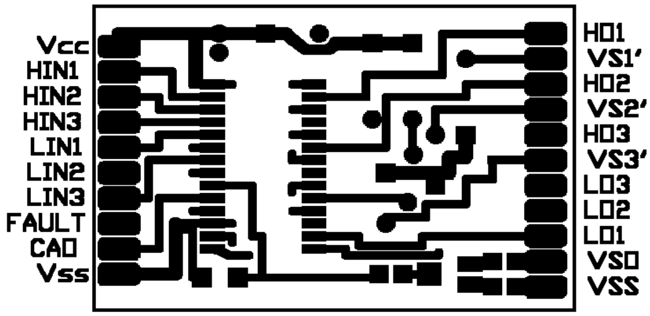


Figure 4A
Power Circuit (bottom view)

IR2130S Control Circuit



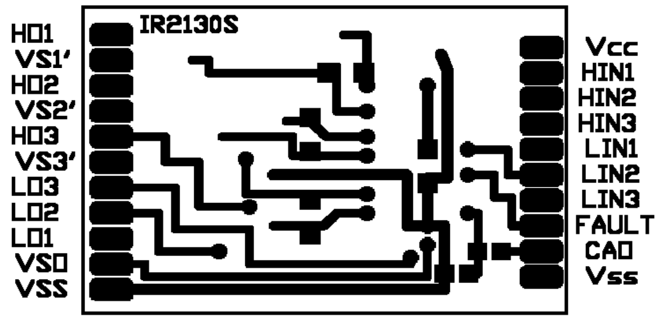
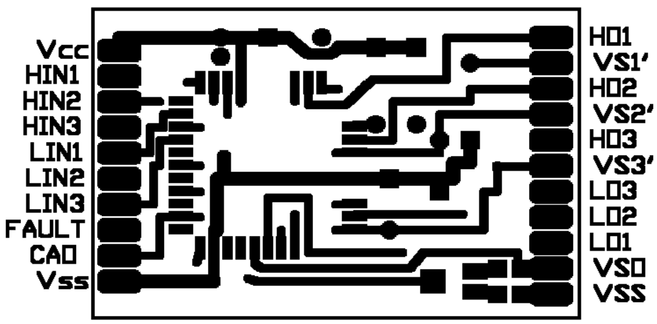


Figure 5
IR2130S Control Circuit (top view)

Figure 5A
IR2130S Control Circuit (bottom view)

IR2130J Control Circuit



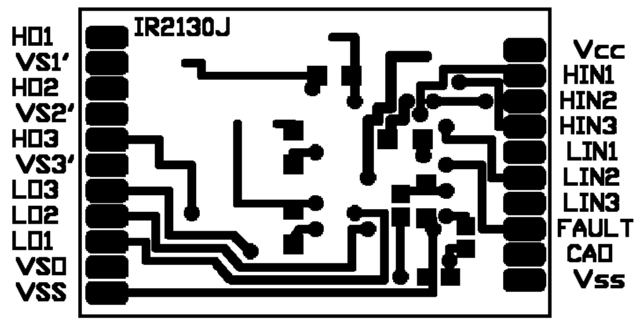


Figure 6
IR2130J Control Circuit (top view)

Figure 6A
IR2130J Control Circuit (bottom view)

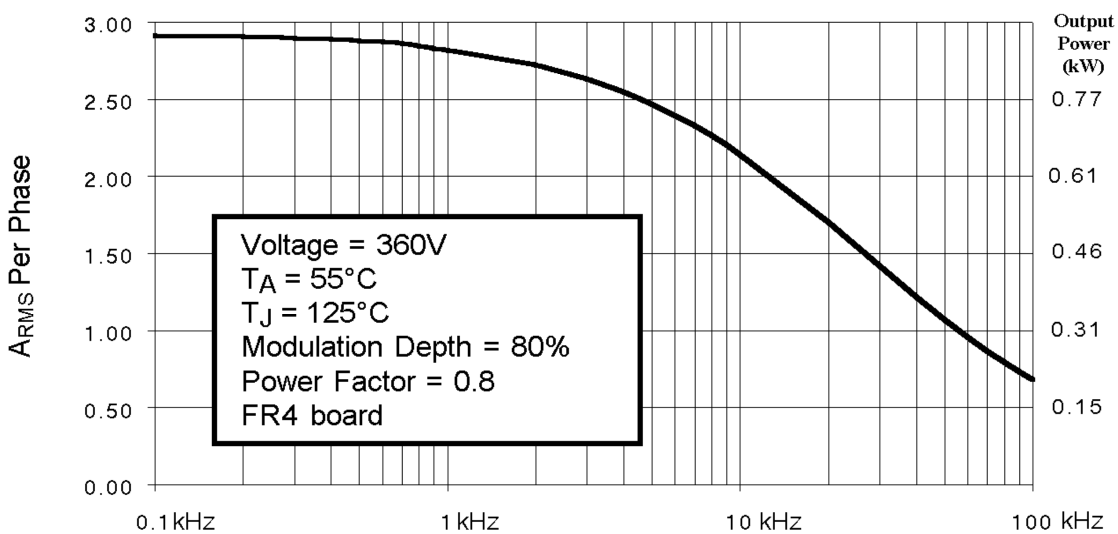
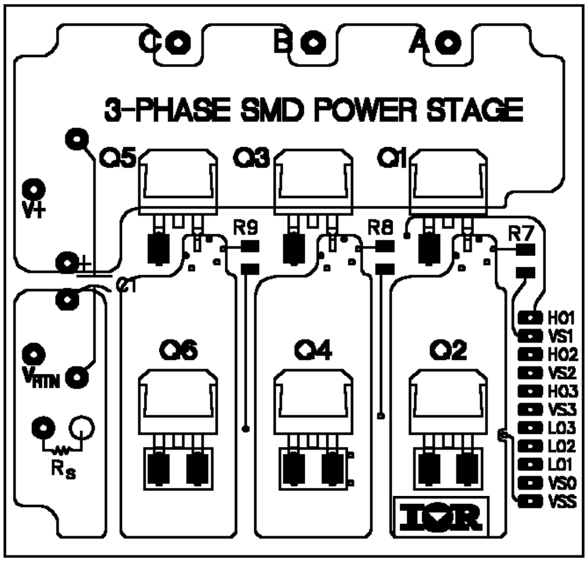


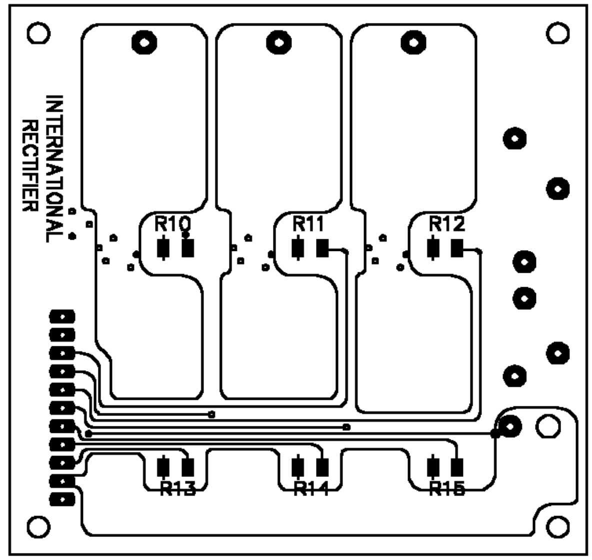
Figure 7
Typical Output vs. Frequency of a 3-Phase Bridge with IRGBC30UD2S

Components Placement Diagrams

Power Circuit



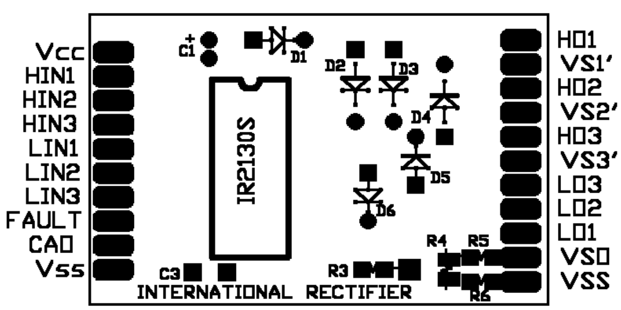
Top View



Bottom View

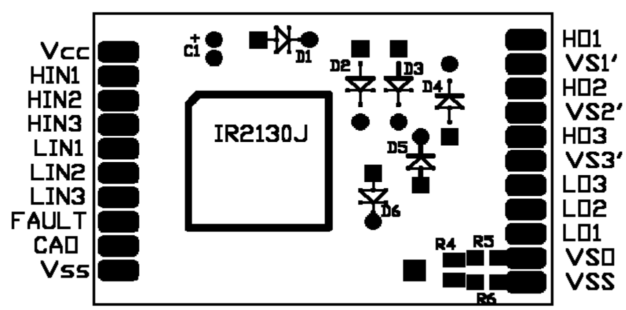
Control Circuit

IR2130S (SOIC)

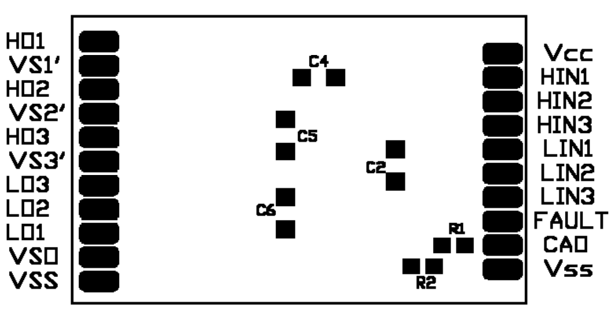


Top View

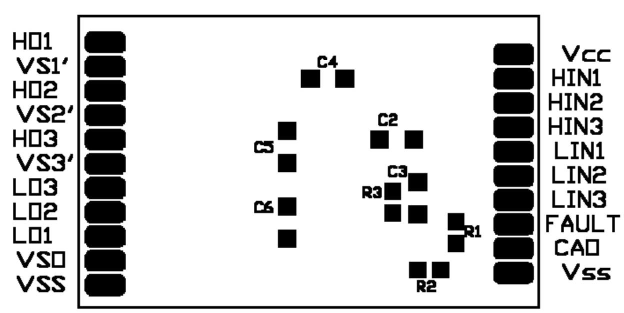
IR2130J (PLCC)



Top View



Bottom View



Bottom View

3-Phase SMD Power Stage Components List

IC	IR2130S or IR2130J Control IC
Q1 - Q6	See Table I
R1	9.1 kΩ, thick film resistor, type 0805
R2, R3	1.0 kΩ, thick film resistor, type 0805
R4	50Ω, Bourns trimmer type 3314G
R5, R6	10Ω, thick film resistor, type 0805
R10, R11, R12, R13, R14, R15	100Ω, thick film resistor, type 1206
R7, R8, R9	47Ω, thick film resistor, type 1206
RS	.100Ω, 16W, (Caddock type MP816)
D1-D6	10DF6 Ultra-fast recovery diode
C2	10 µF, 25V tantalum capacitor
C3	1 nF, 50V Ceramic capacitor, type 1206
C1, C4, C5, C6	0.1 µF, 50V Ceramic capacitor, type 1206
C7	10 µF, 450V Aluminum electrolytic capacitor
C8	(external - use appropriate value for intended application)
Header & Receptacle	0.100" center, square pins

Table I

Frequency	Short Circuit Rating Required
1 to 6 kHz	IRGBC30MD2-S or IRGBC20MD2-S
60 to 25kHz	IRGBC30KD2-S or IRGBC20KD2-S

For more information, please refer to:

AN-983A IGBT Characterstics and Applications.

AN-985 The IR2130: A Six-Output, High Voltage MOS Gate Driver.

AN-978 High Speed, High Voltage IC Drive for HEXFET or IGBT Bridge Circuits.

AN-990 Application Characterization of IGBTs

"An Algorithm for the Section of the Optimum Power Device" (Section 3) by Steve Clemente and Brian Pelly.

"Accurate Junction Temperature Calculations" by Steve Clemente and Don Dapkus II.

APPLICATION PARAMETERS

Switching voltage	V	360		
Displacement angle	rad	0.64	Power factor	0.8
Modulation depth		0.8		

THERMAL OPERATING CONDITIONS

Ambient temperature	°C	55
Thermal resistance j-c	K/W	40.00

IGBT MODEL AND PARAMETERS: IRGBC30UD2-S (typical)

Temperature of ref. parameters	°C	125.00
Vt	V	0.636
a	Ω	0.390
b		0.674
Gamma function, (b+2)/2	1.337	0.892
Gamma function, (b+3)/2	1.837	0.941
h	mJ/A	2.15E-2
k		1.352
Gamma function, (k+1)/2	1.176	0.924
Gamma function, (k+2)/2	1.676	0.904
m	mJ/A	5.27E-2
n		1.102
Gamma function, (n+1)/2	1.051	0.973
Gamma function, (n+2)/2	1.551	0.889
Reference voltage	V	480

DIODE MODEL	**HFRD-2, 600V**		**Tj =125°C**				***Gamma***
Conduction model:	Vt =	0.60	a =	0.120	b =	1.000	0.88623
Switching model:	Pk Irr/If=	1.30	ta (µs)=	0.025	tb (µs)=	0.015	1

ELECTRICAL OPERATING CONDITIONS

Operating frequency	kHz	0.10	0.20	0.50	1.00	2.00	5.00	10.00	20.00	50.00
Peak current	A	4.03	4.02	3.97	3.90	.77	3.41	2.94	1.52	1.06
RMS fund. voltage, line to neutral	V	129.60	129.60	129.60	129.60	129.60	129.60	129.60	129.60	129.60
RMS Current, fundamental	A	2.85	2.84	2.81	2.76	2.66	2.41	2.08	1.45	0.75
Output power, fundamental	kW	0.89	0.88	0.87	0.86	0.83	0.75	0.65	0.45	0.23
Voltage drop at peak current	V	1.63	1.63	1.62	1.61	1.59	1.53	1.44	1.27	1.04
Conduction losses	W	1.44	1.43	1.41	1.37	1.31	1.14	0.93	0.58	0.25
Turn-on losses, ideal diode	W	0.00	0.01	0.02	0.03	0.06	0.12	0.20	0.24	0.25
Correction factor for gate drive	23Ω	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	3.00
Corrected turn-on losses	W	0.00	0.01	0.02	0.03	0.06	0.12	0.20	0.49	0.76
Turn-off losses	W	0.01	0.01	0.03	0.05	0.11	0.24	0.40	0.54	0.65
Total IGBT losses	W	1.45	1.45	1.45	1.46	1.47	1.50	1.53	1.60	1.66
Diode conduction losses	W	0.30	0.30	0.30	0.29	0.28	0.24	0.20	0.13	0.06
Diode, switching losses	W	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.03
Total diode losses	W	0.30	0.30	0.30	0.29	0.28	0.25	0.22	0.15	0.09
Total losses in Co-Pack	W	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
Junction temperature	°C	125.00	125.00	125.00	125.00	125.00	125.00	125.00	125.00	125.00
Semiconductor Efficiency	%	98.82	98.81	98.80	98.78	98.73	98.60	98.38	97.67	95.51