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FusionPlus

Novel Hybridswitch to improve efficiency and reduce system cost in 800V battery vehicles inverter

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Content

Content

YiTong is a start up company with experts around the world

*China Speed + China innovation + German knowledge = **YiTong***

Our ambition is to take power modules to the next level

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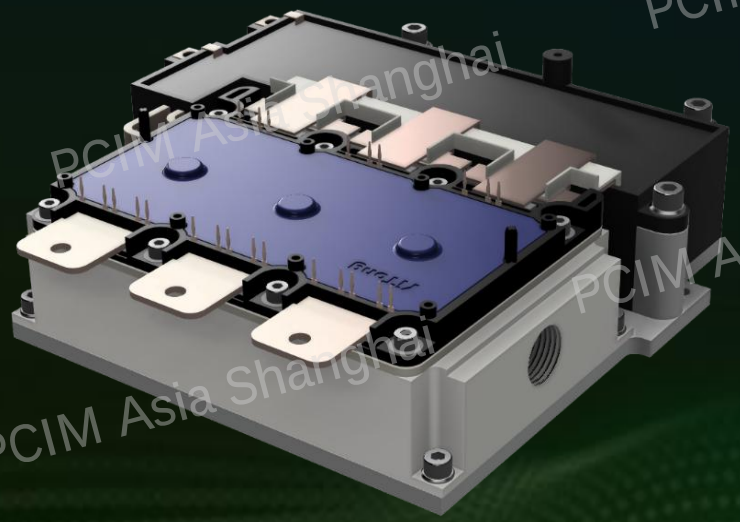
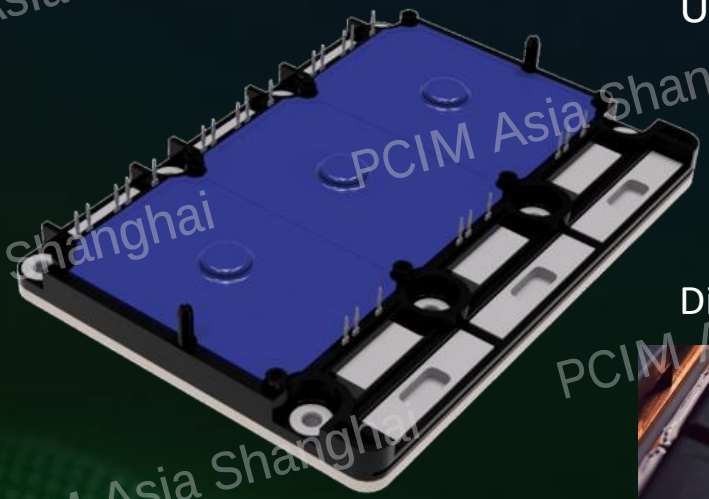
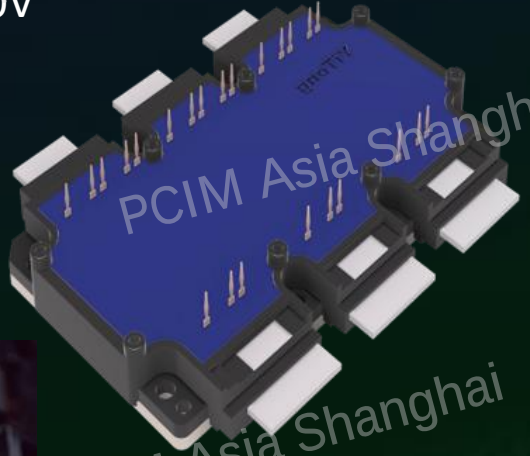


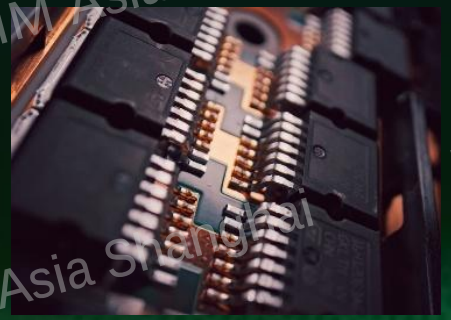


Up to 1200A/1200V

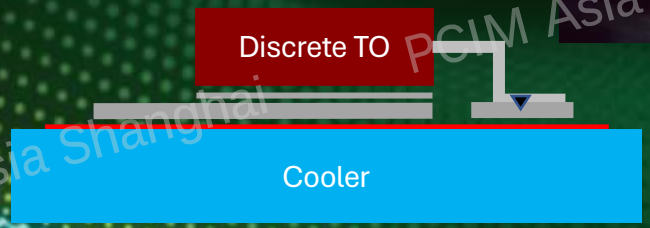
D2M

Discrete to module





Power brick in D2M technology
for low and high voltage (46 – 860V)
(350A to 800A)



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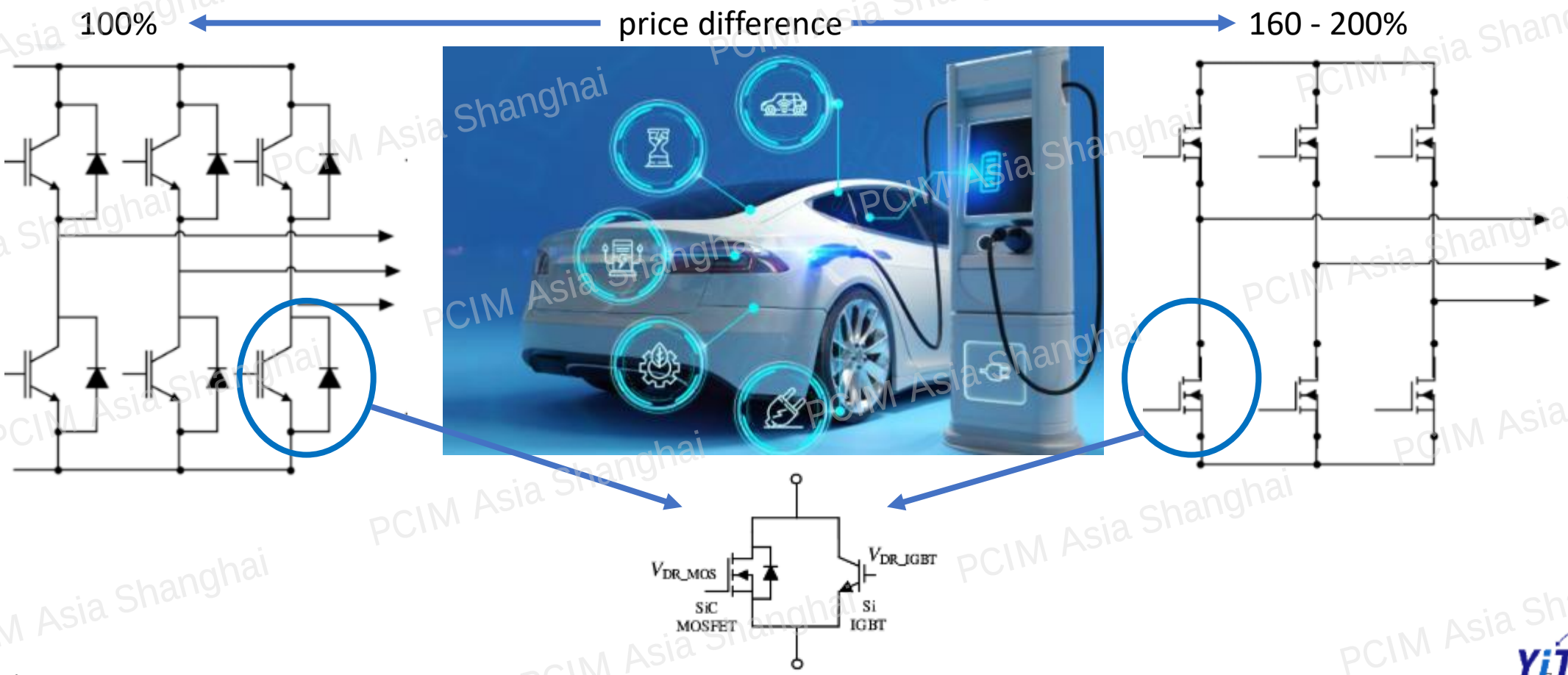
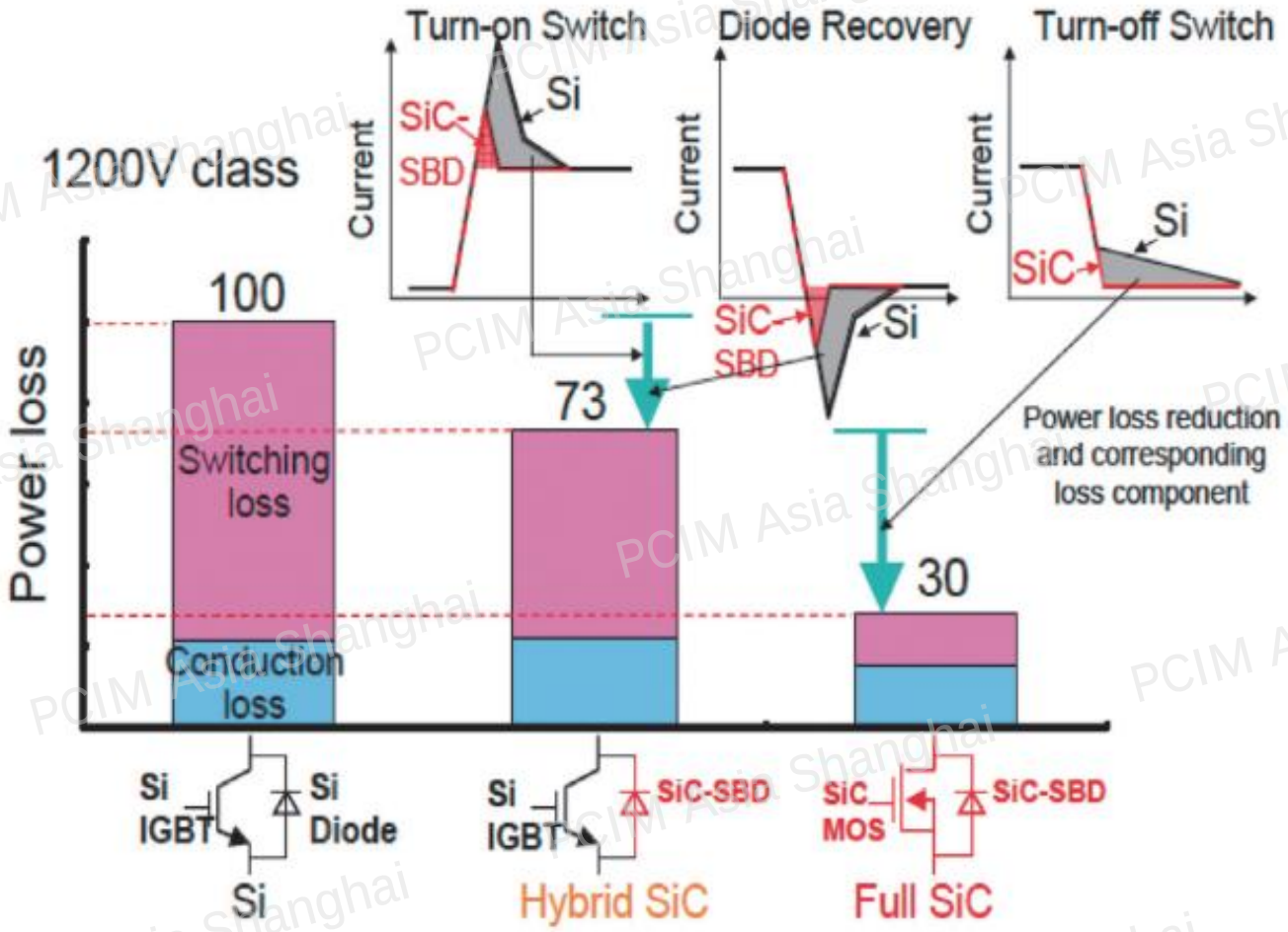
Common power module – EV inverter design for 800V Battery voltage

EV – inverter market is a “price driven market”



Well known knowledge of losses with IGBT, Hybrid-SiC and Full SiC



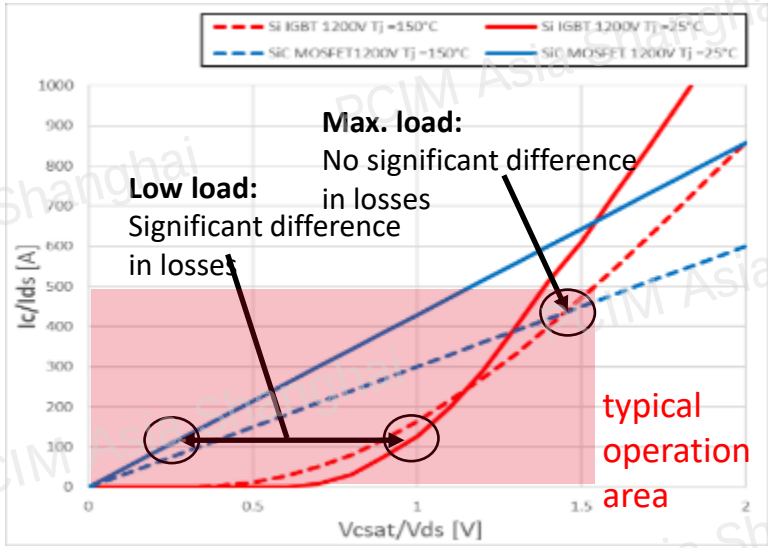
Source “internet”

We should use the benefits of:

- IGBT
- Full SiC

in a new “switch”

Many papers show below picture, this is only partially correct if we compare same current in IGBT and SiC



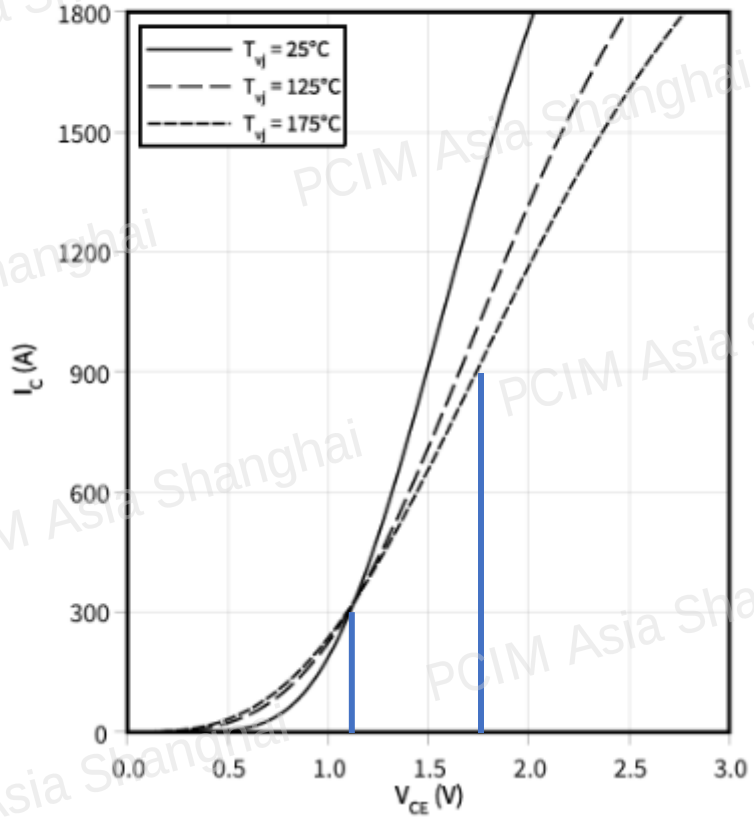
Source “internet”

Comparison between SiC module Icn-900A and IGBT Icn-900A

Output characteristic (typical), IGBT, Inverter

$I_C = f(V_{CE})$

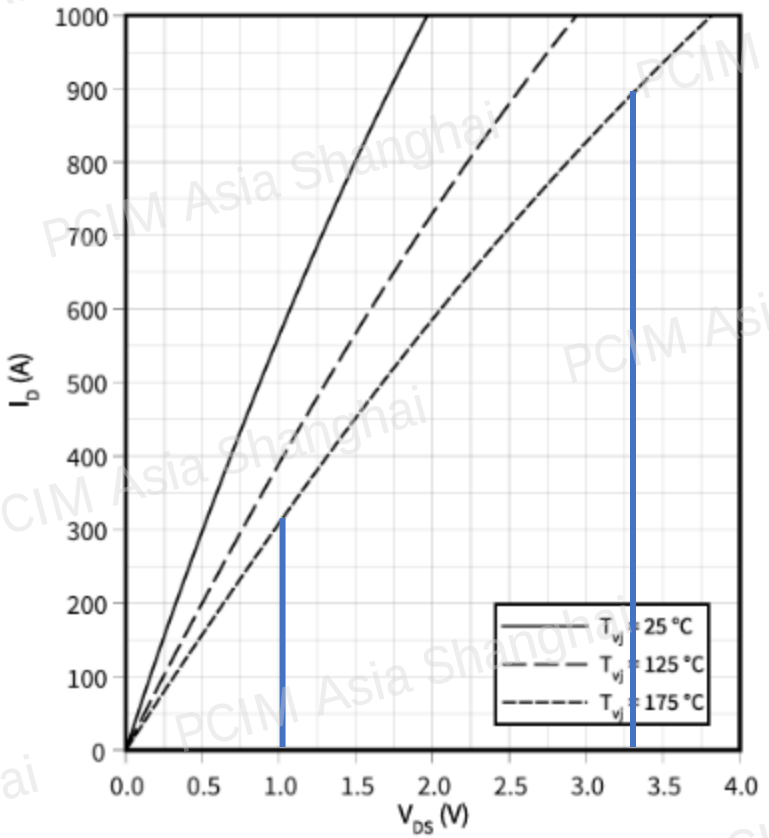
$V_{GE} = 15\ V$



Output characteristic (typical), MOSFET, T1 / T2

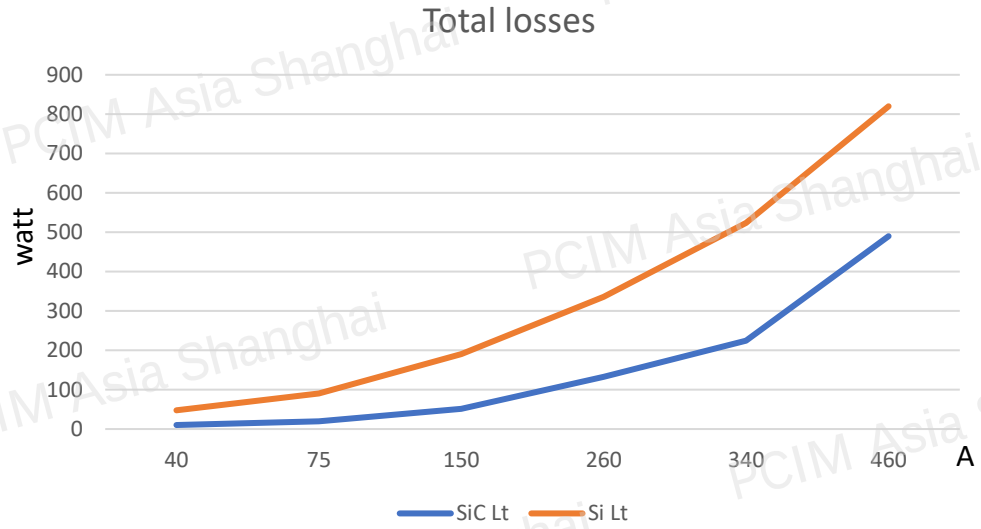
$I_D = f(V_{DS})$

$V_{GS} = 15\ V$

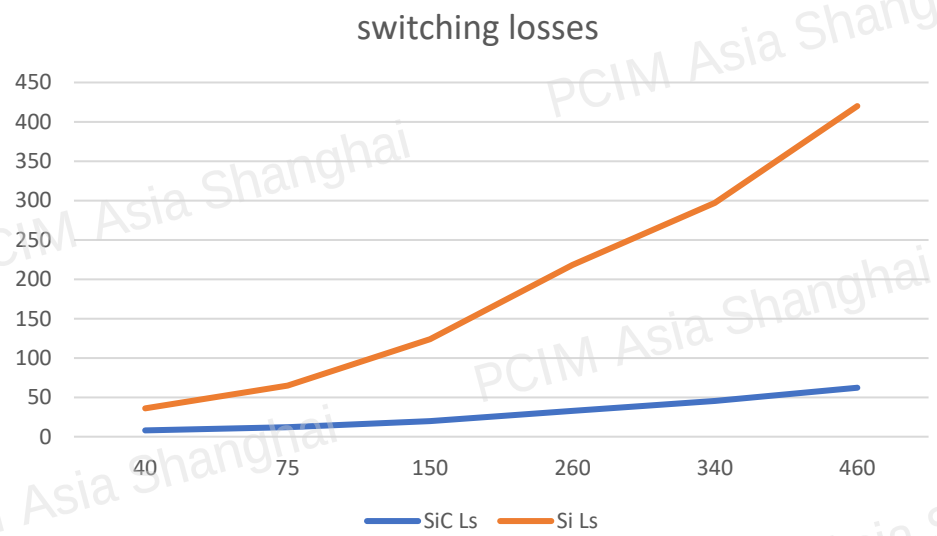


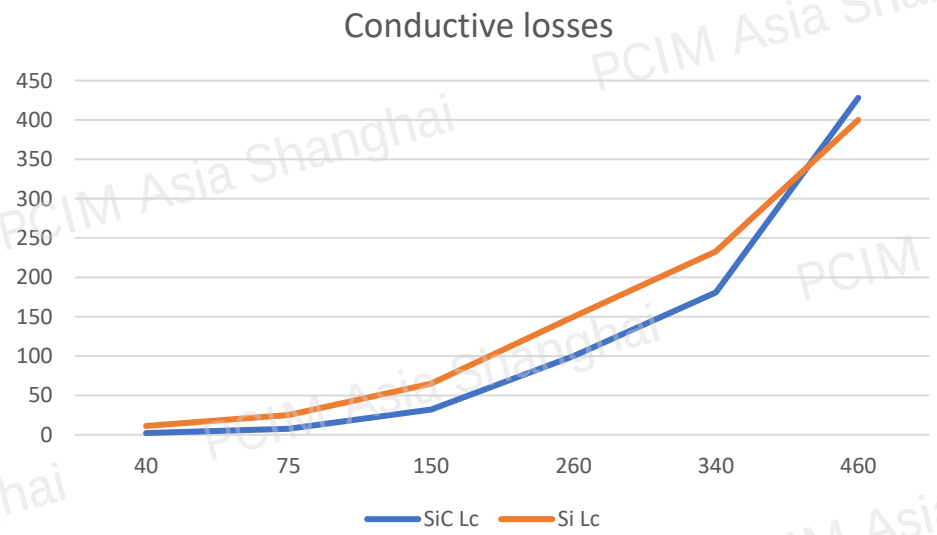
Source: Infineon

Loss comparison between Si-IGBT (2 x 200A) and SiC (4 x 128A)



Test conditions/losses per switch
3-phase inverter
Vdc = 800V
Fs = 8kHz
Fout = 100Hz
Pf = 0.86
Tf = 65 degree
Tj < 150 degree





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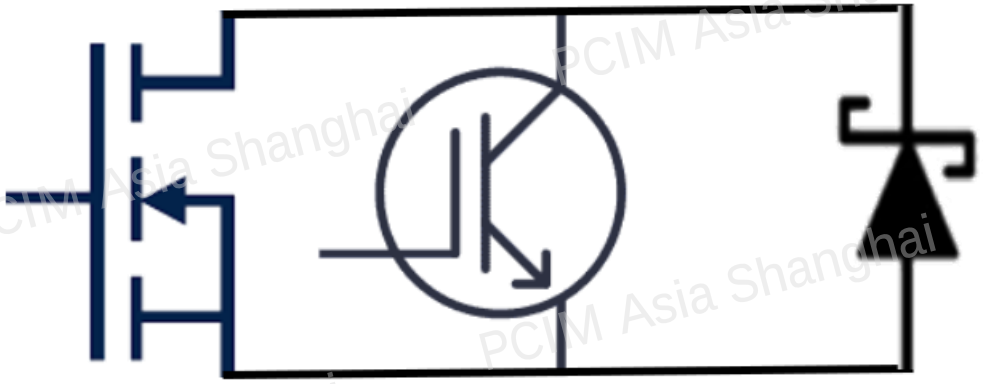
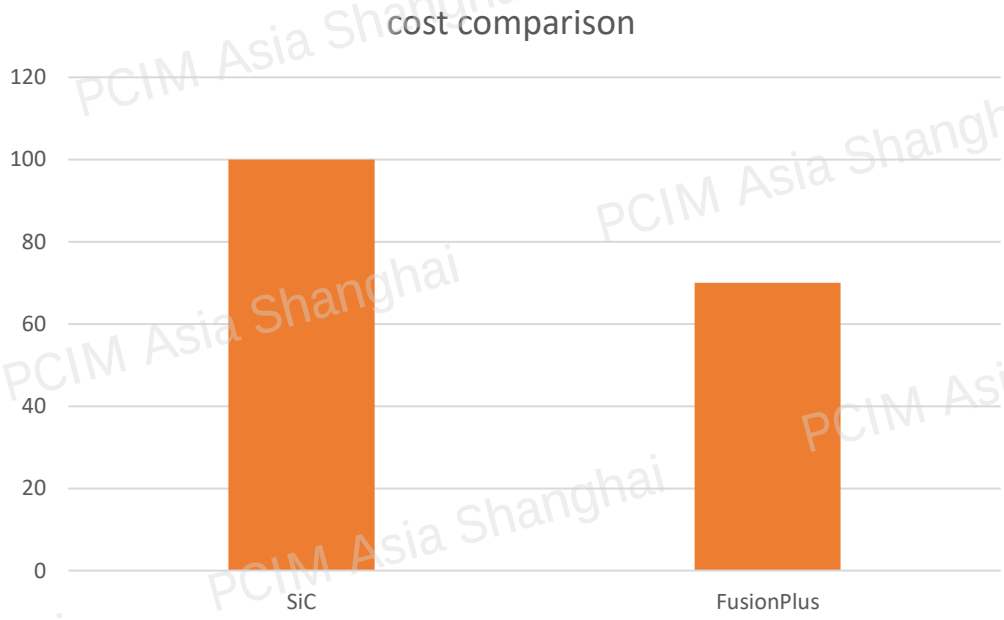
Cost comparison between Full SiC and FusionPlus

FusionPlus

performance and cost alternative





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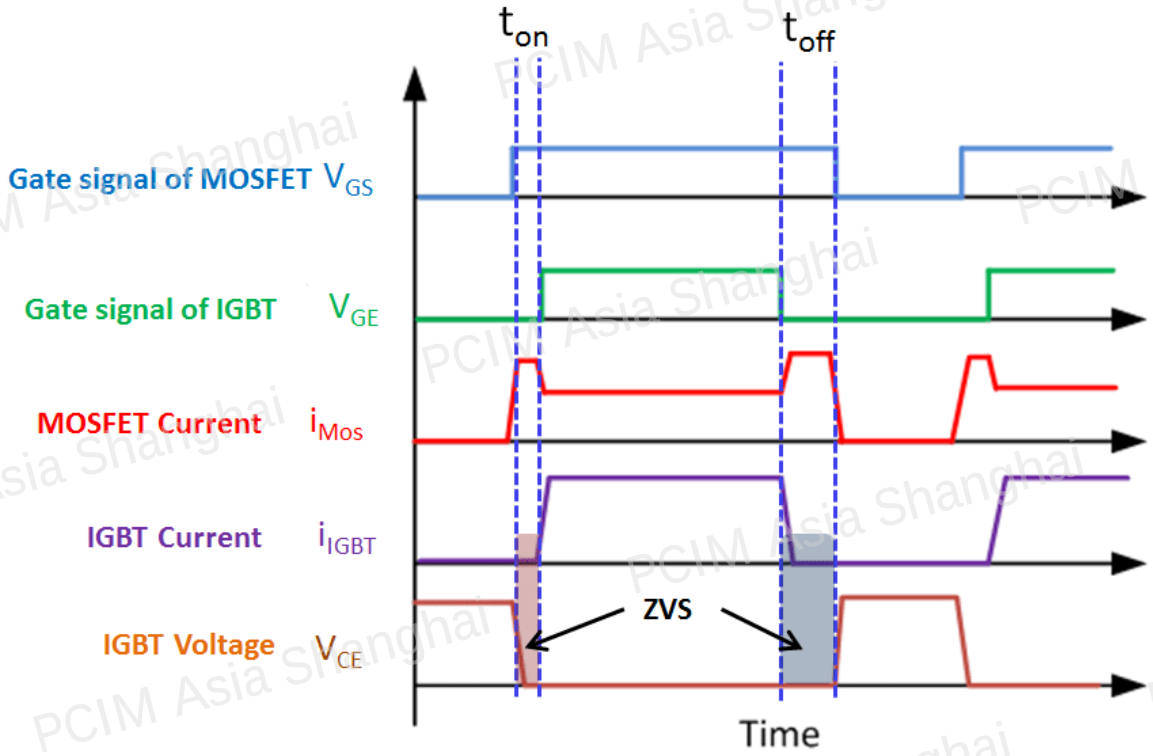
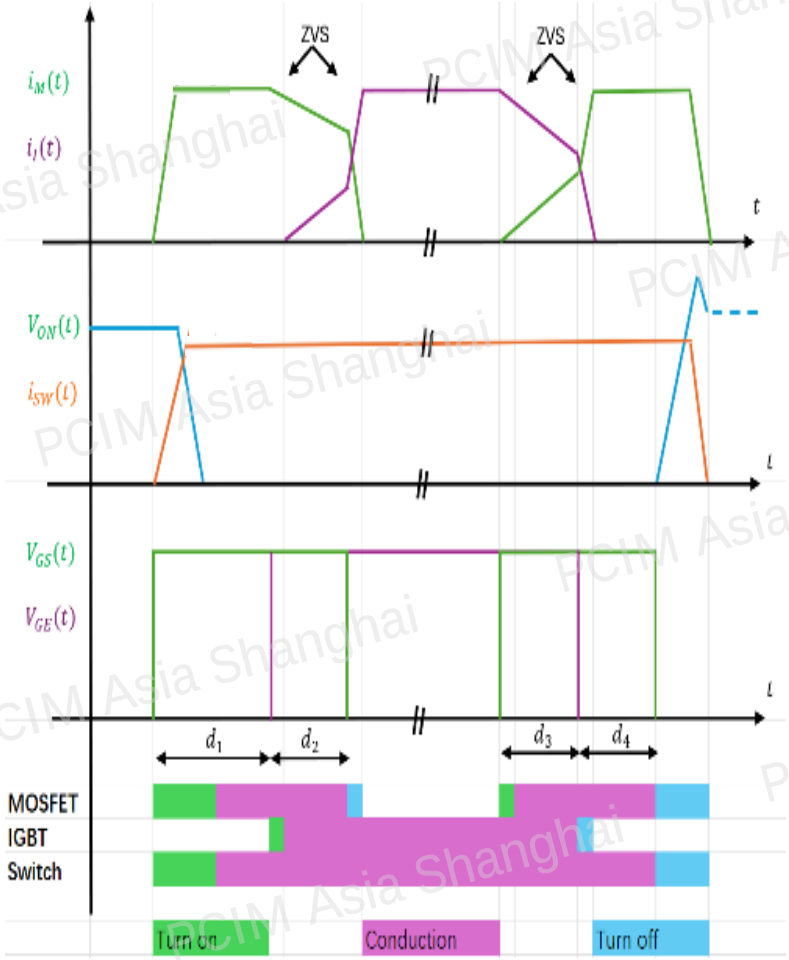
Common control strategies for Hybrid - switches





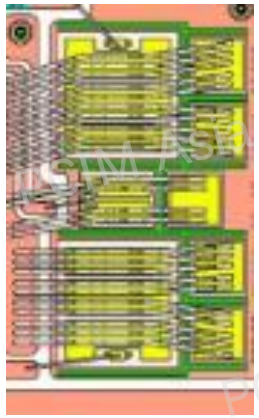
SiC turns on first, keep turned on and carry current in low load conditions, IGBT turn on after SiC and carry high load current, IGBT turn off first and SiC takes over load current, IGBT and SiC operation in parallel in conductive mode

SiC takes over only turn on/turn off job, IGBT takes over conductive job

FusionPlus in standard power module housing

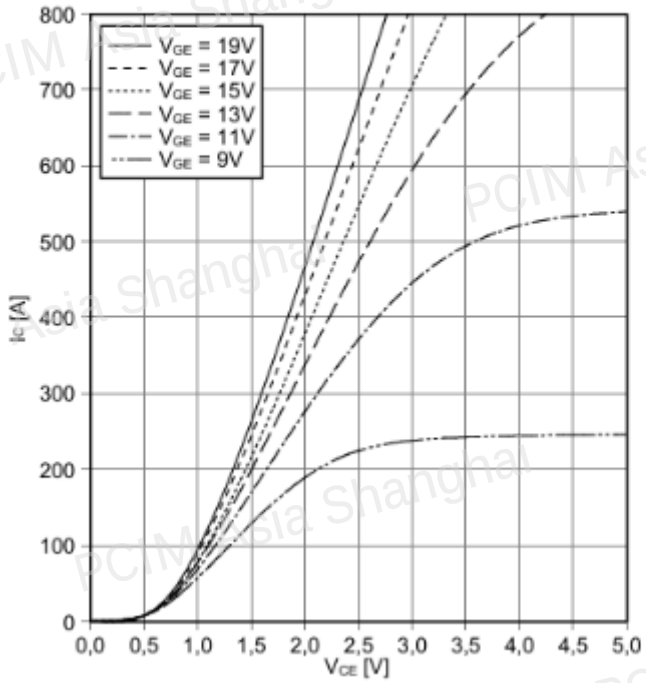
3-phase power module
1200V blocking voltage
460A Irms (8kHz) – up to 750A Irms

Changes in housing/layout design:
- low stray inductance layout
- Low stray inductance terminal design



Vds and Vce comparison between IGBT & SiC in Hybrid-switch (Ratio 1:4)

(400A-IGBT compared to 128A-SiC)



Ration 1:4 100A = 1V

Ration 1:10 40A = 0.65V

SiC – 25 degree

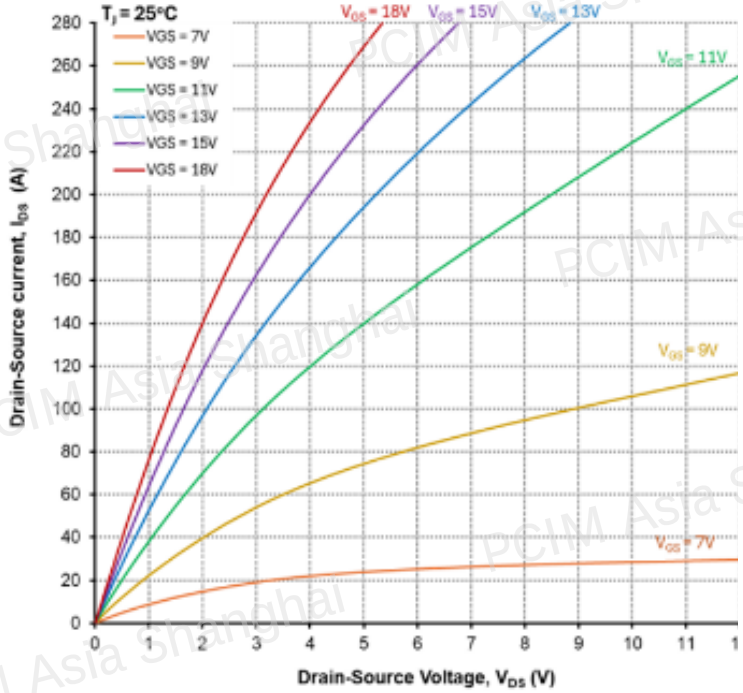


Figure 2. Output Characteristics, T_J = 25°C

100A = 1.25V

40A = 0.55V

70 degree 40A = 0.7V

SiC – 175 degree

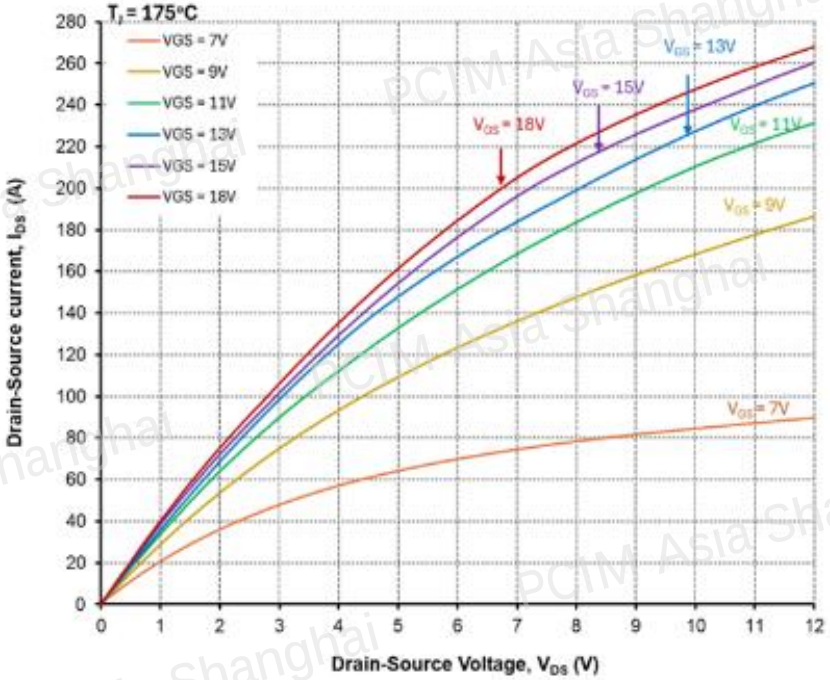


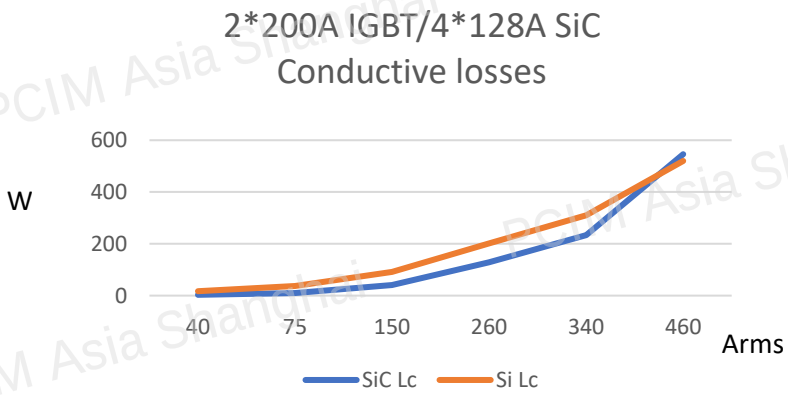
Figure 3. Output Characteristics, T_J = 175°C

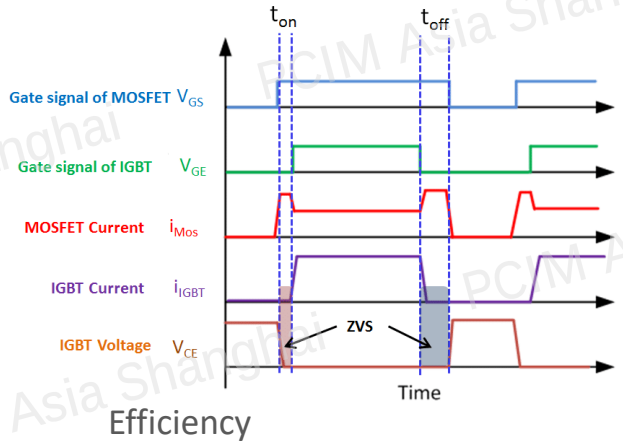
100A = 2.8V

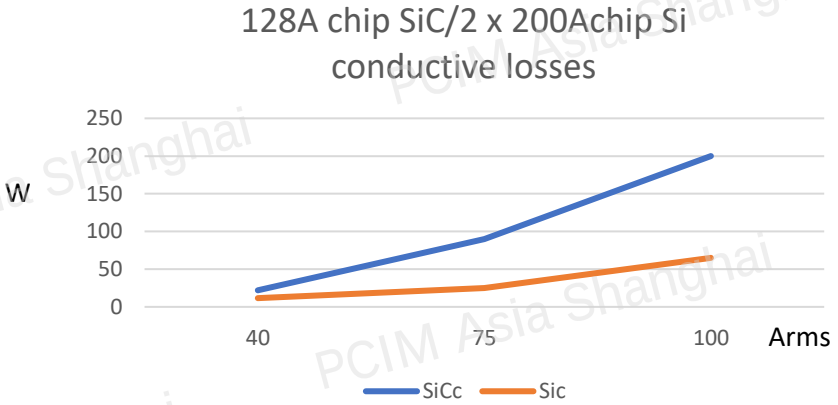
40A = 1V

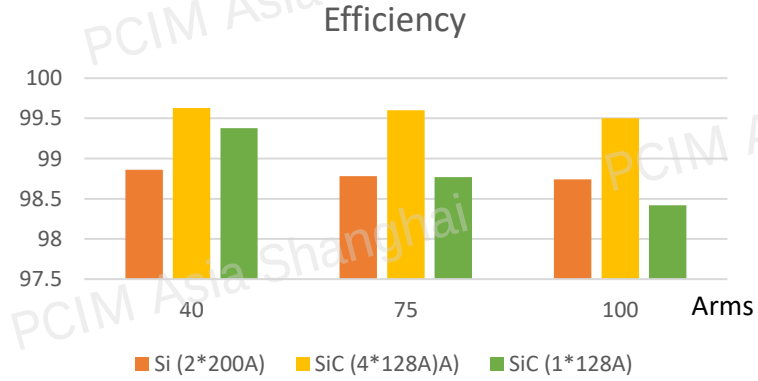
100 degree 40A = 0.73V

128A - SiC chip losses compared to 2 * 200A Si chip





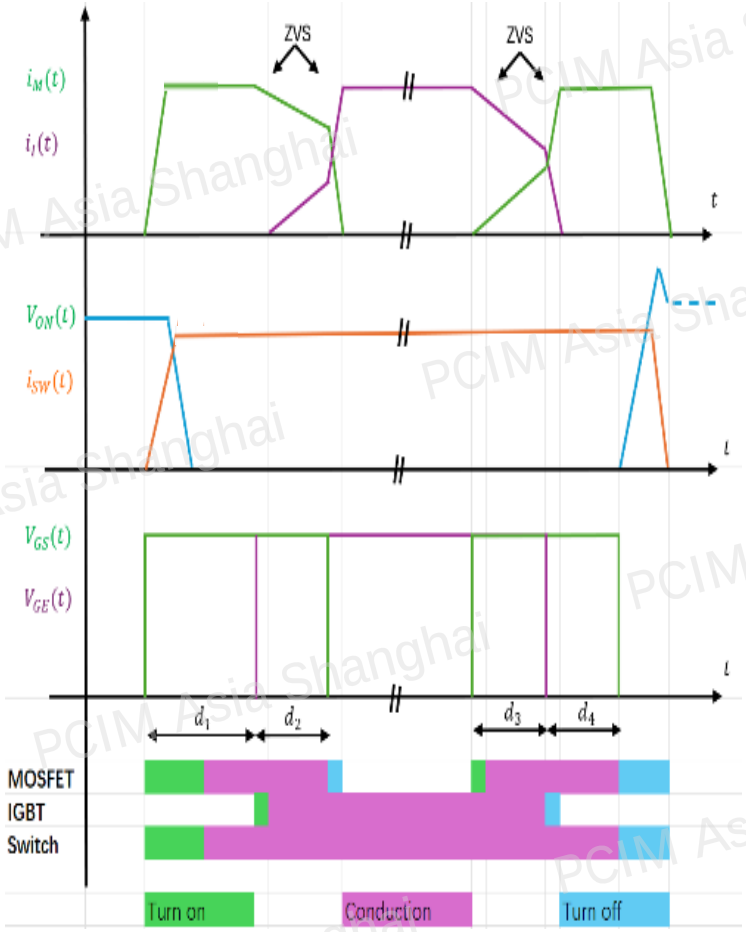




3-phase inverter operation
Vdc = 800V
Fs = 8kHz
Fout = 100Hz
Pf = 0.86
Tf = 65 degree
Tj > 150 degree

In hybrid-switch (Si/SiC) configuration, it is not efficiency if SiC chip carry the current in low load conditions
But - - - -- it depends on the size of the used SiC chip in a hybrid switch

FusionPlus-Control strategy and peak Tj simulation

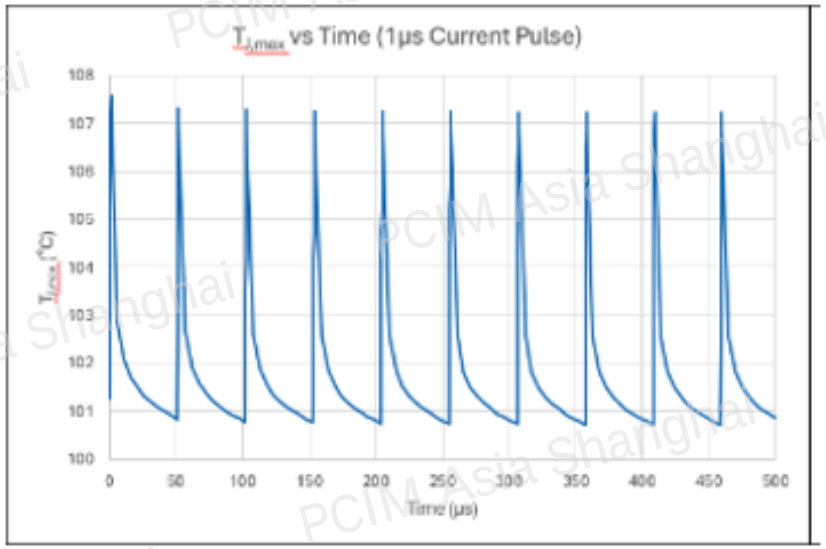


FusionPlus control strategy

- Small SiC (28% of rated current) will takes over switching job of rated current for 0.7-1.0us
- Si IGBT (100% rated current) takes over conductive job

Thermal simulation

- SiC chip junction temperature and 4 times nominal current



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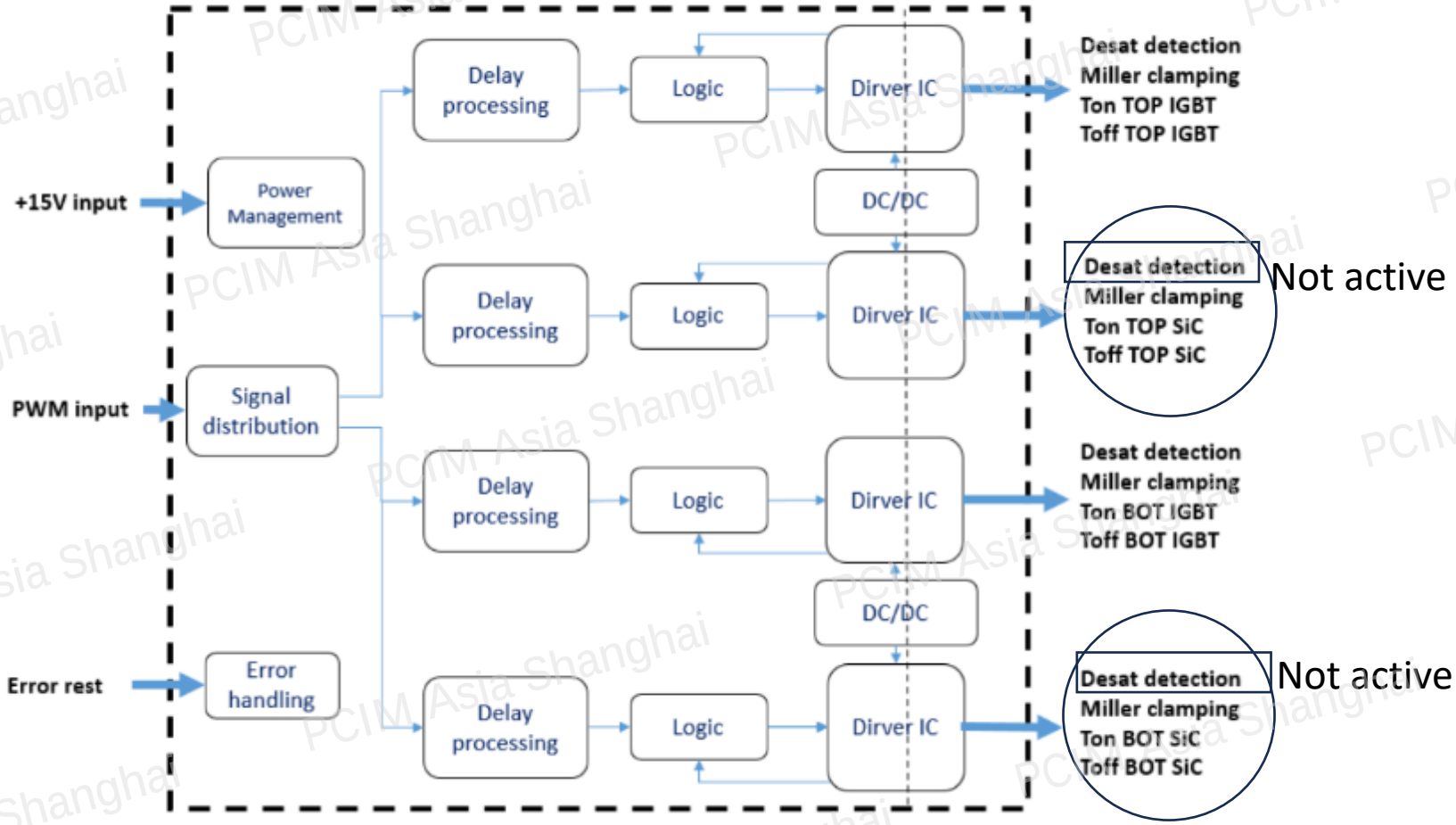
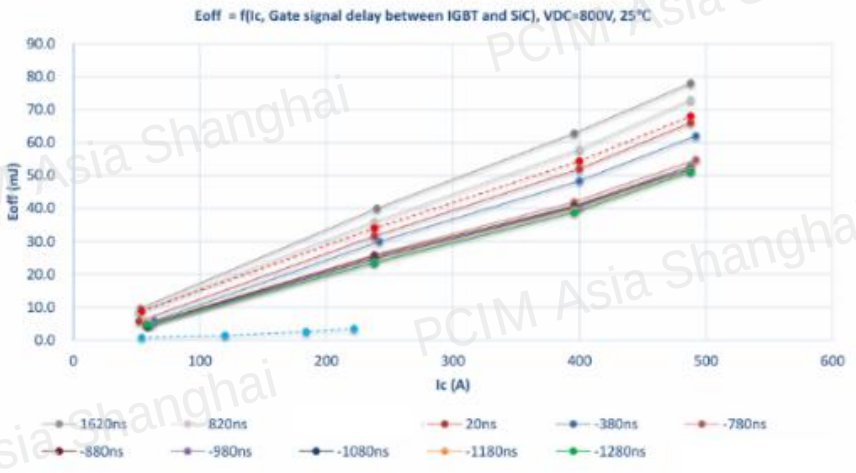
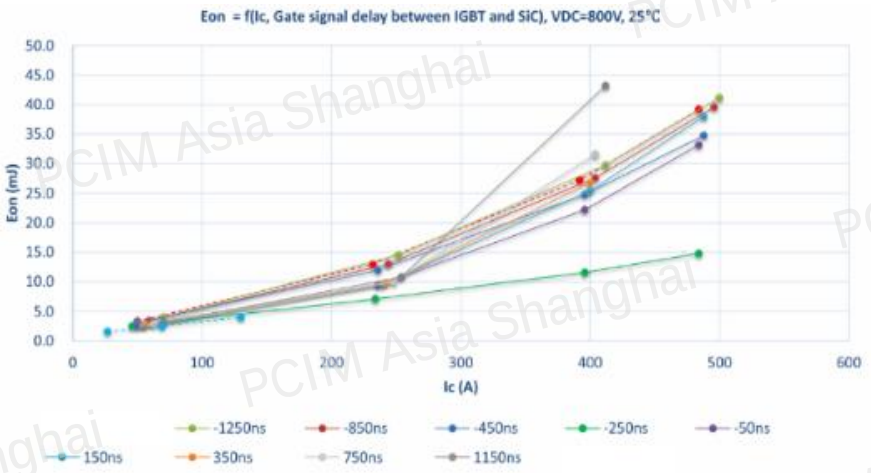
Test set up to measure all data

FusionPlus test driver



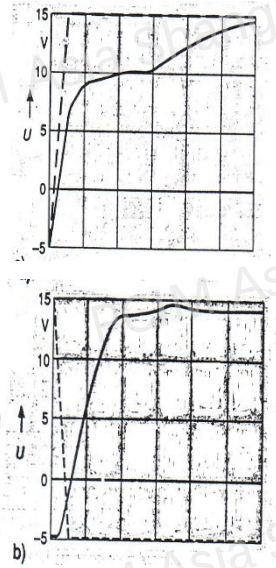
FusionPlus – optimized delay in turn off and turn on



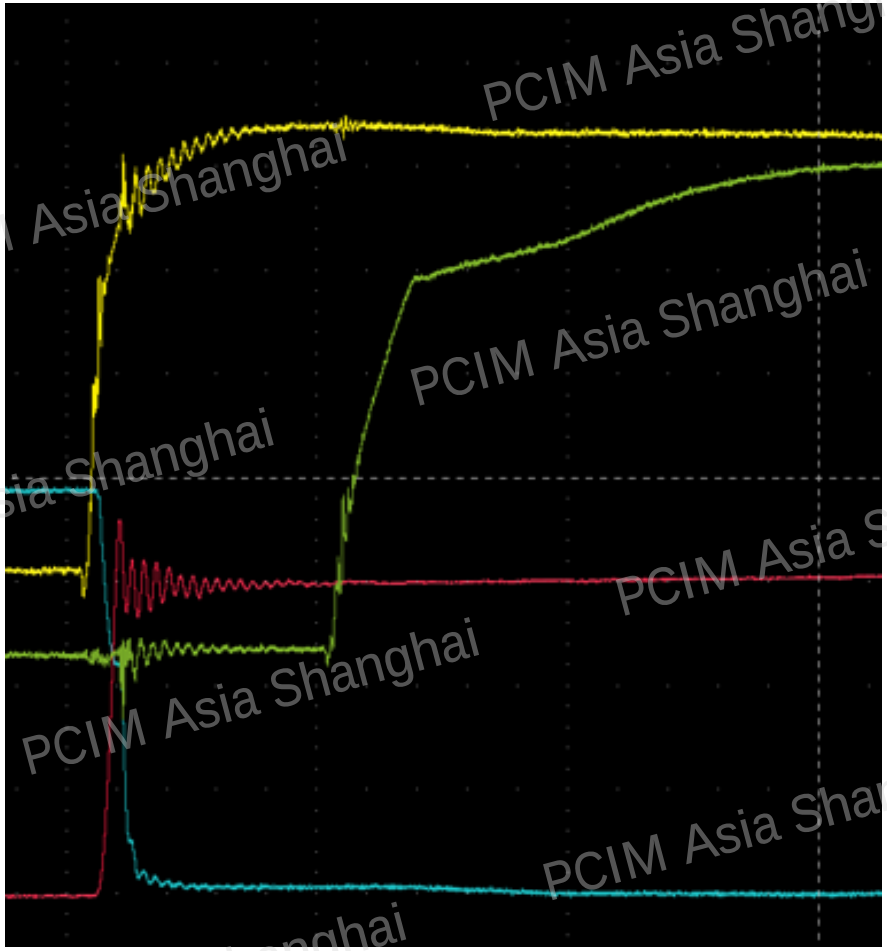


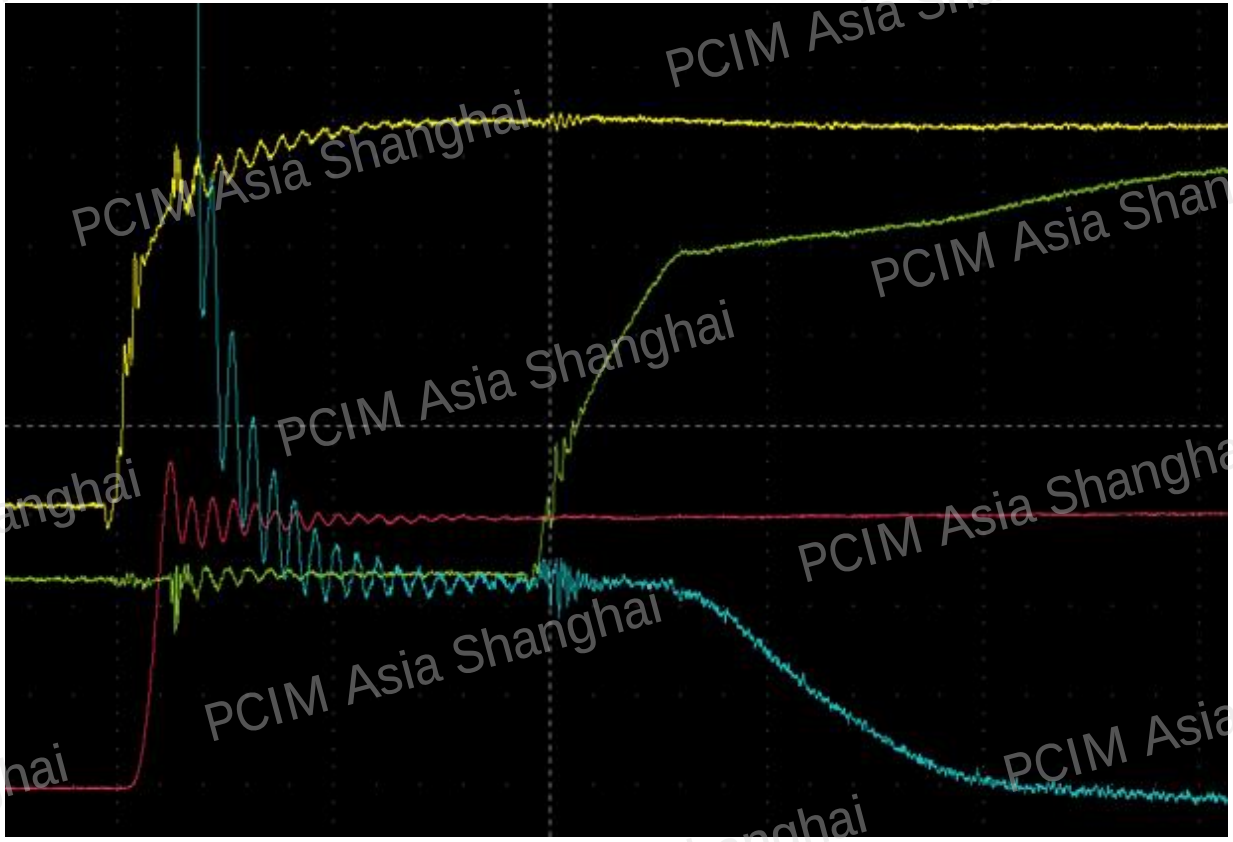
In test:
current source IGBT driver
- control turn on delay of IGBT
- control turn off delay of IGBT

Advantage
- optimization of SiC chip, less cost
- controlled Vge



Turn on procedure of FusionPlus



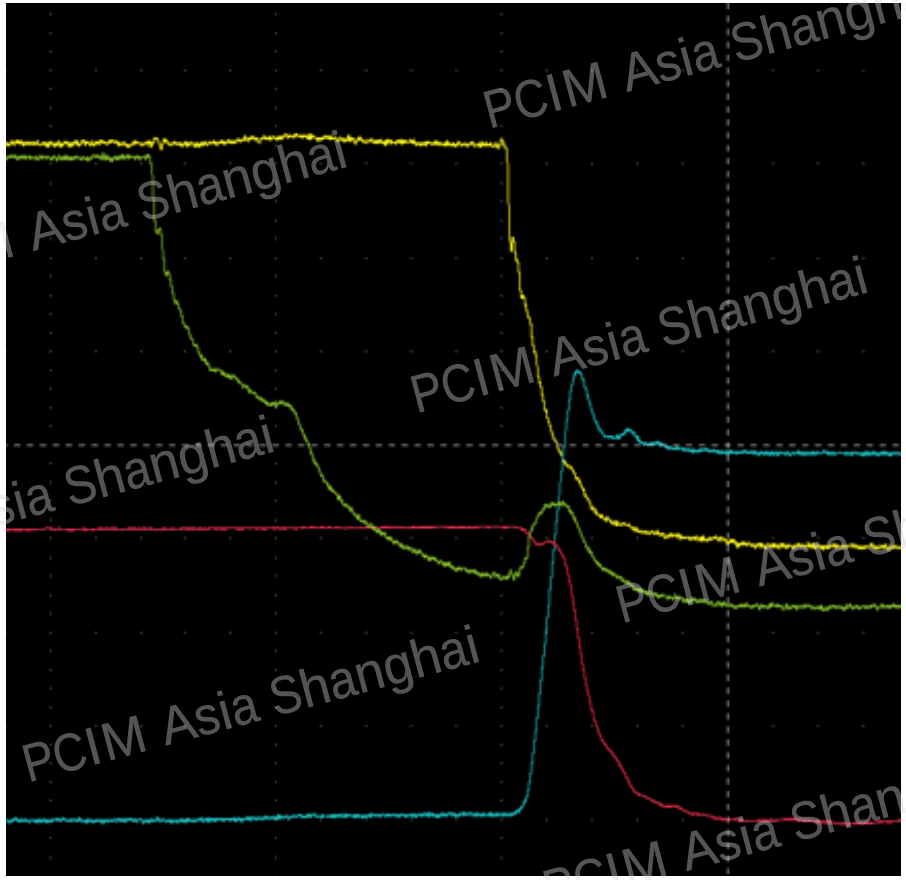


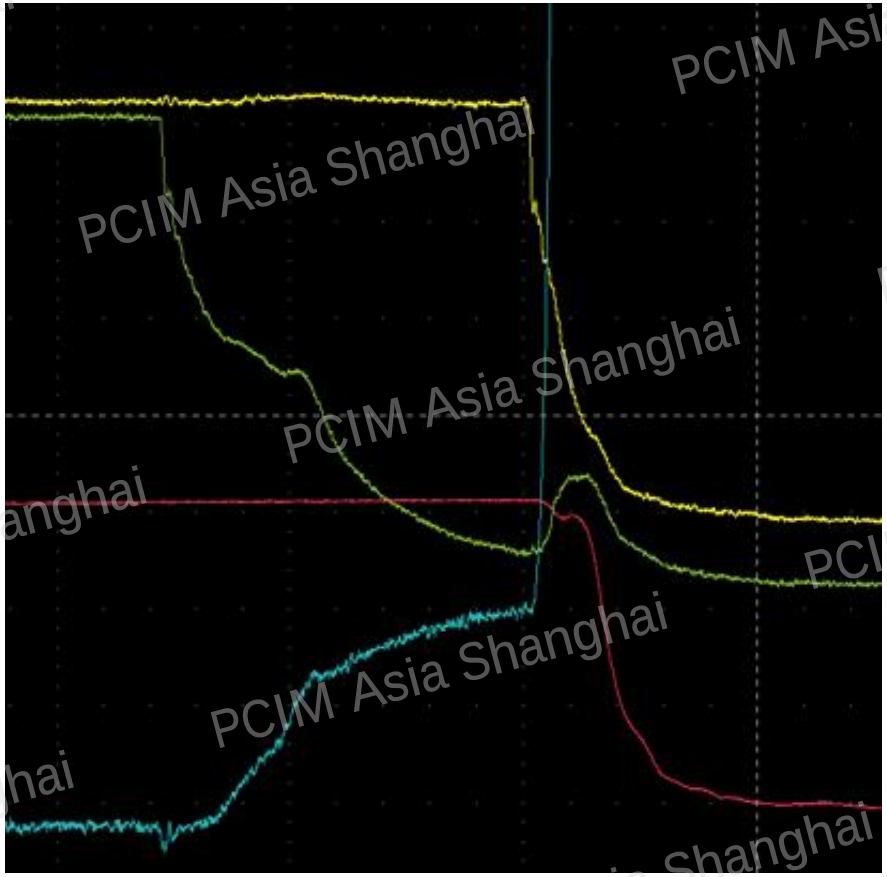
Red – load current (420A)
Yellow – Vgs
Blue – Vce
Green - Vge

SiC turn on first, IGBT turns on with delay
load current is carried by SiC first

SiC carry high current (high Vds) and current is commutating to IGBT (low Vce sat)

Turn off procedure of FusionPlus



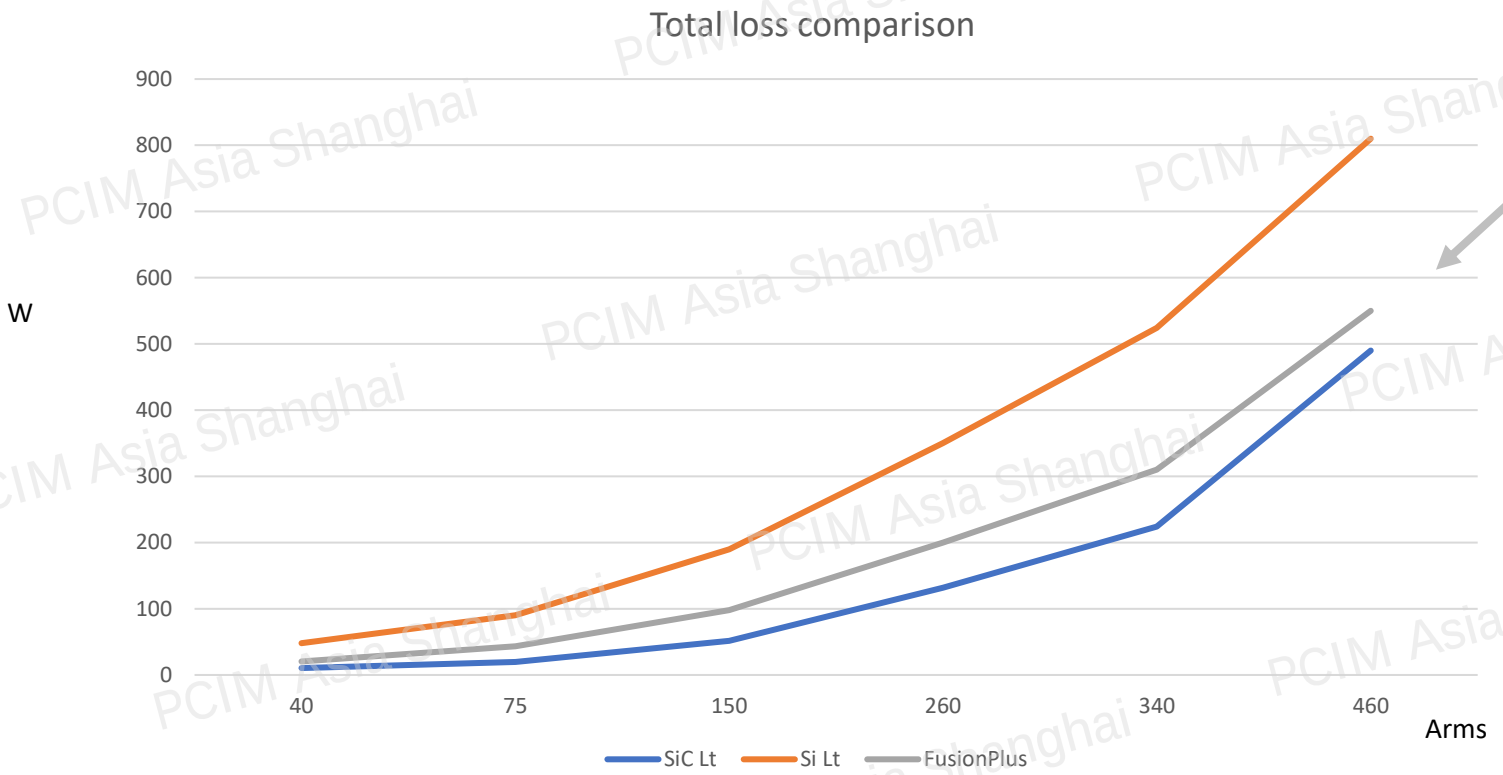


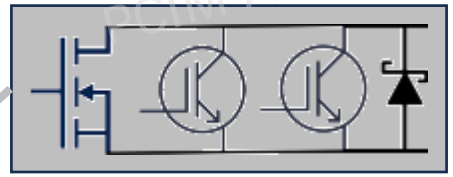
Red – load current (420A)
Yellow – Vgs
Blue – Vce
Green - Vge

IGBT turns off first, load current constant
Low overvoltage in turn off process

IGBT turns off first and SiC takes over load current and turn off

FusionPlus loss comparison with FusionPlus, Full-SiC and IGBT





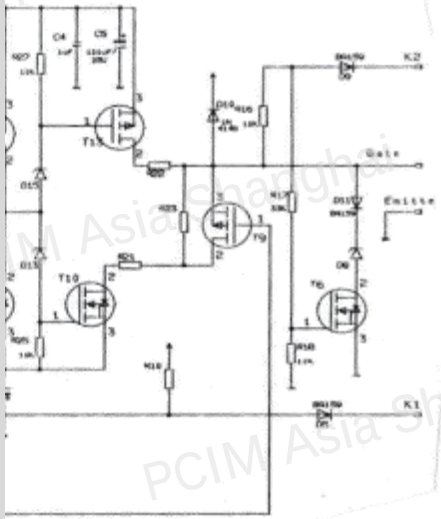
Test conditions/losses per switch
3-phase inverter
Vdc = 800V
Fs = 8kHz
Fout = 100Hz
Pf = 0.86
Tf = 65 degree
Tj = max 150 degree

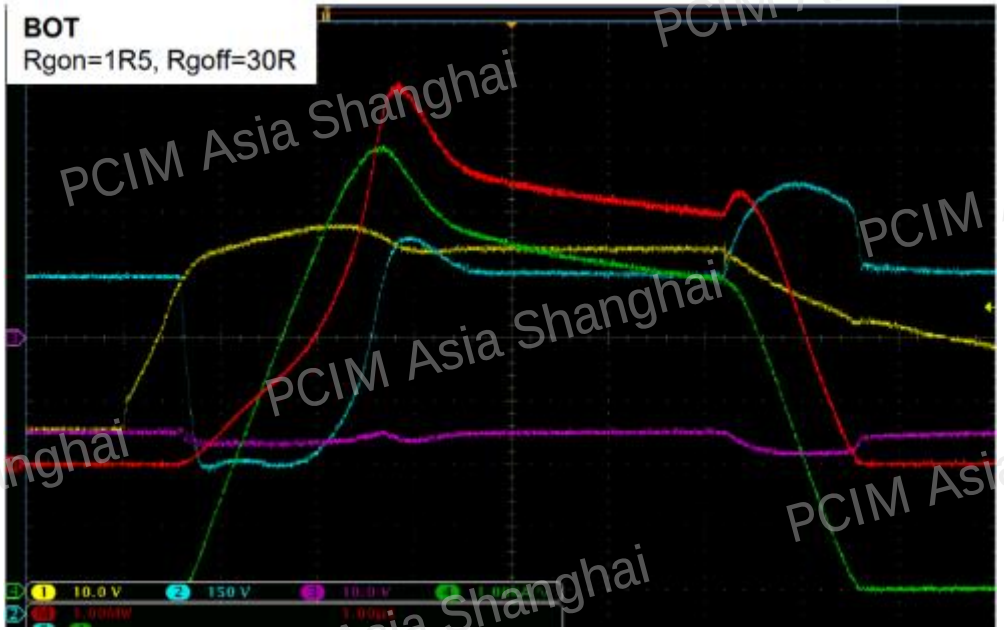
FusionPlus is an attractive alternative to pure SiC – cost advantage in the rage of 30-34% to pure SiC

Content

FusionPlus Short circuit protection strategy

Simple concept





Green – load current (1350A)
Yellow – Vge
Blue – Vce-max 1020V-800V DC
red – power
Soft turn off procedure

Short circuit protection is only focusing on the IGBT current because the SiC device will turn off after around 1us
Vce monitoring identify SC and start “2-level-turn off” , keep Vge constant and block SiC signal

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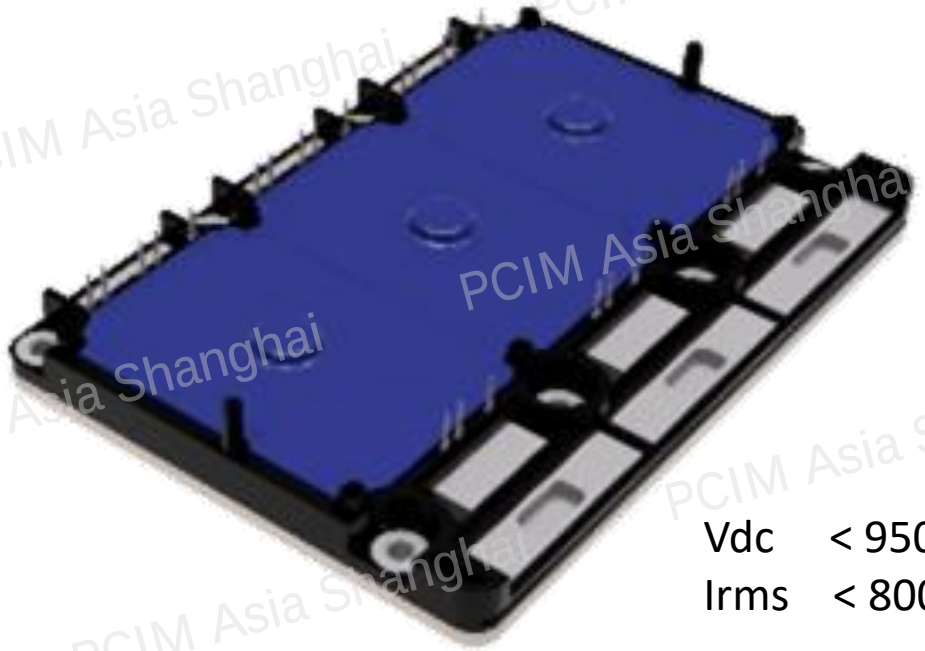
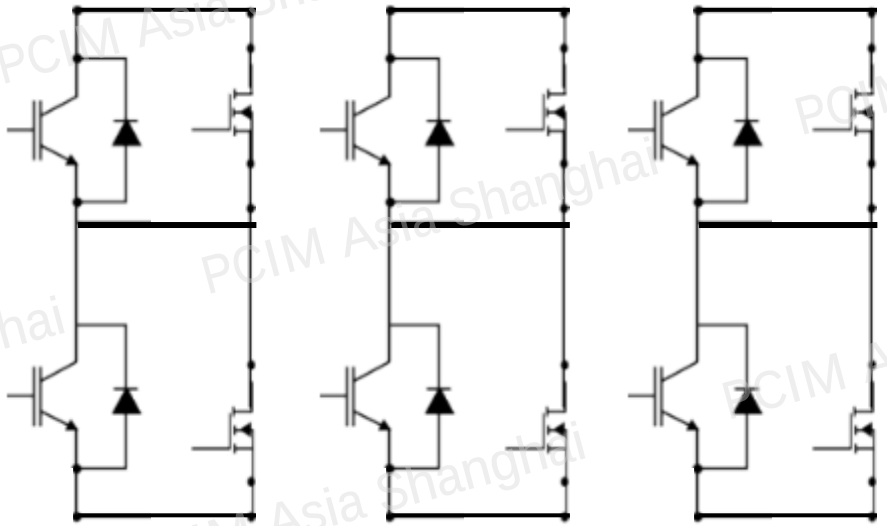
New **FusionPlus** with overlapping terminals/reduced stray inductance



Vdc < 950V
Irms < 800A



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Thanks for your attention

Any questions, please do not hesitate to ask in our “presenter booth”