High Efficiency SiC (Silicon Carbide) Motor Controller for Electric Vehicles

HKPC TechDive: Smart City – EV Technology

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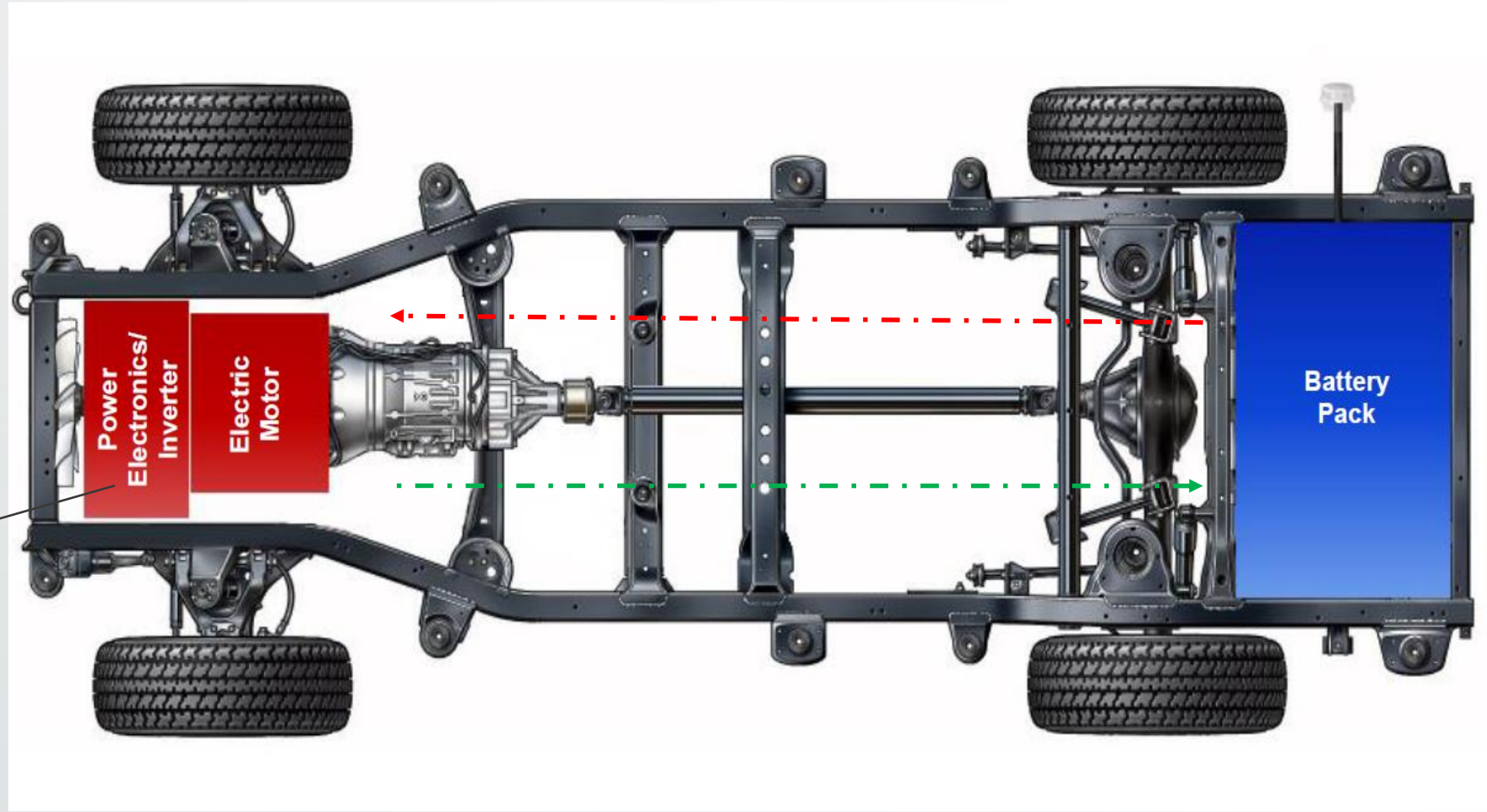
EV Powertrain Overview

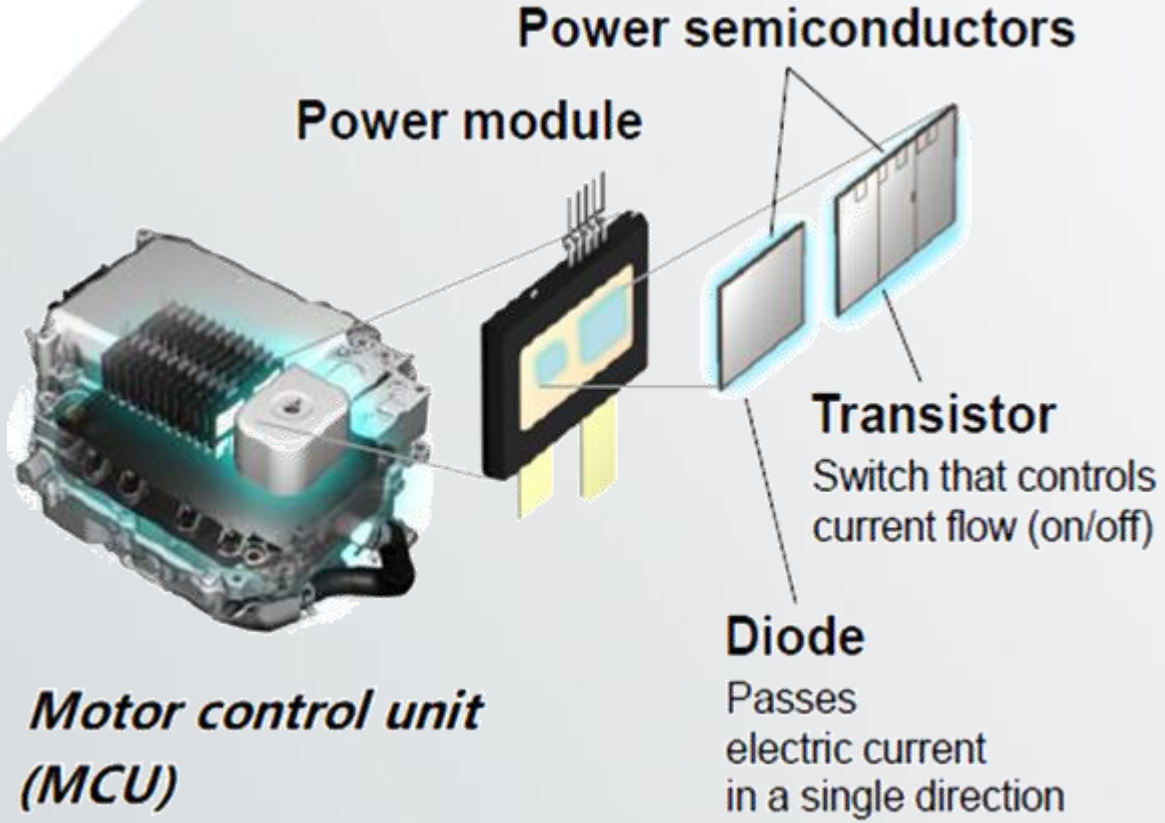


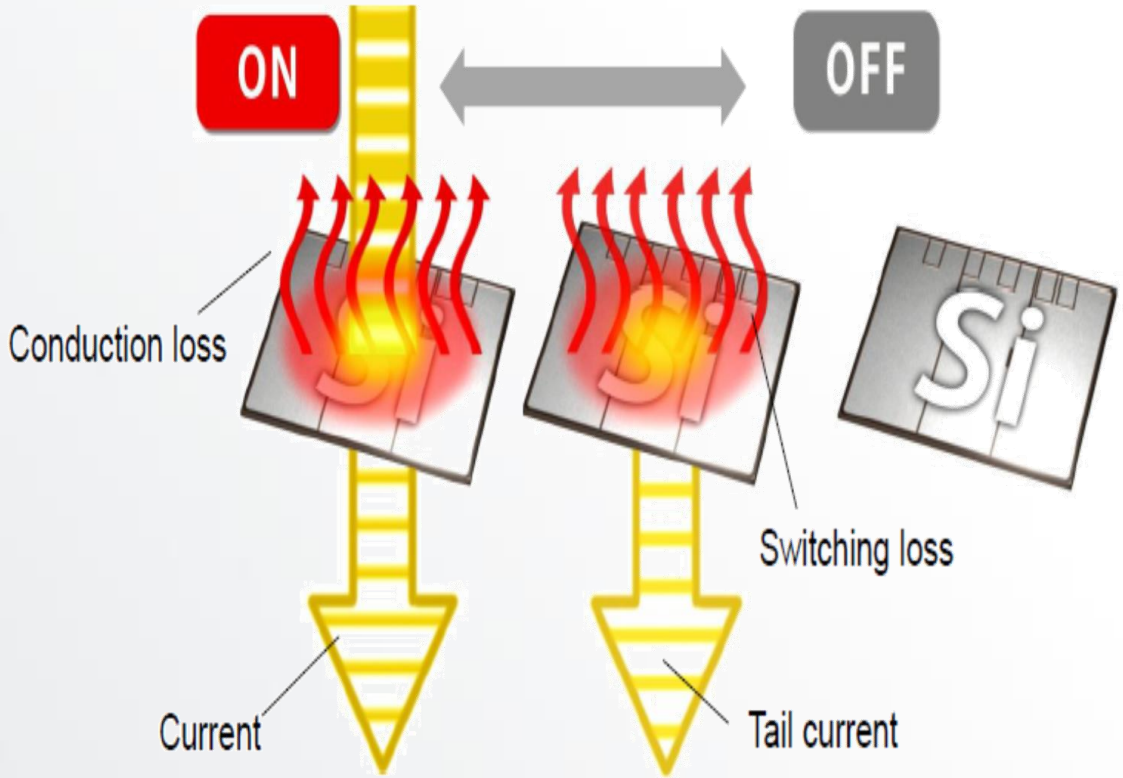
Motor Control Unit (MCU)

Power drive

Energy regeneration

Role of Power Semiconductors in MCU





- MCUs contain multiple power semiconductors, which are usually made of silicon.
- Large power loss in silicon power semiconductors during conduction and switching.
- One key to boost EV range is to ***improve efficiency of power semiconductors***.

Electric Drive Technology Trend

2012 Electric Drive System

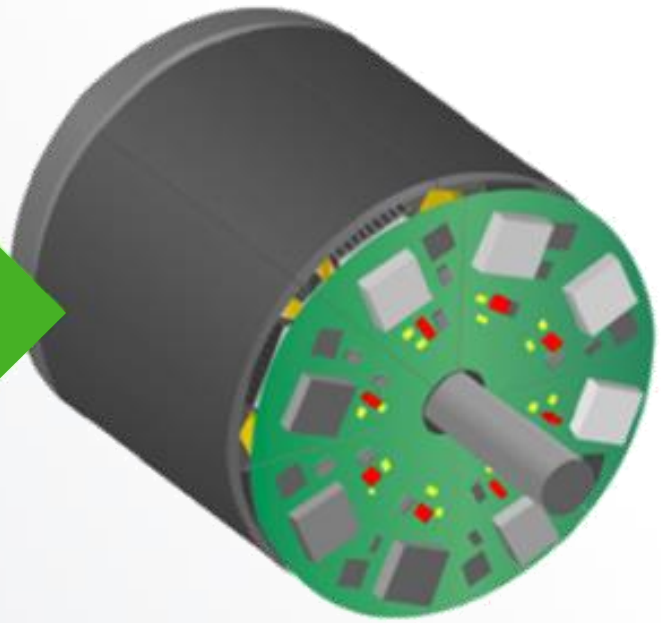
$30/kW, 1.1kW/kg, 2.6kW/L

90% system efficiency

(on-road status)

- Discrete Components
- Silicon Semiconductors
- Rare Earth Motor Magnets

4X Cost Reduction
35% Size Reduction
40% Weight Reduction
40% Loss Reduction



**** From U.S. DOE***

Power Electronics Targets			
Year	2020	2025	Change
Cost ($/kW)	3.3	2.7	18% cost reduction
Power Density (kW/L)	13.4	100	87% volume reduction

2020 Electric Drive System

$8/kW, 1.4kW/kg, 4kW/L

94% system efficiency

(R&D target)

- Fully Integrated Components
- Wide Bandgap Semiconductors
- Non-rare Earth Motors

MCUs with next generation **Wide Bandgap semiconductors** will dominate the market in **next 5 years**.

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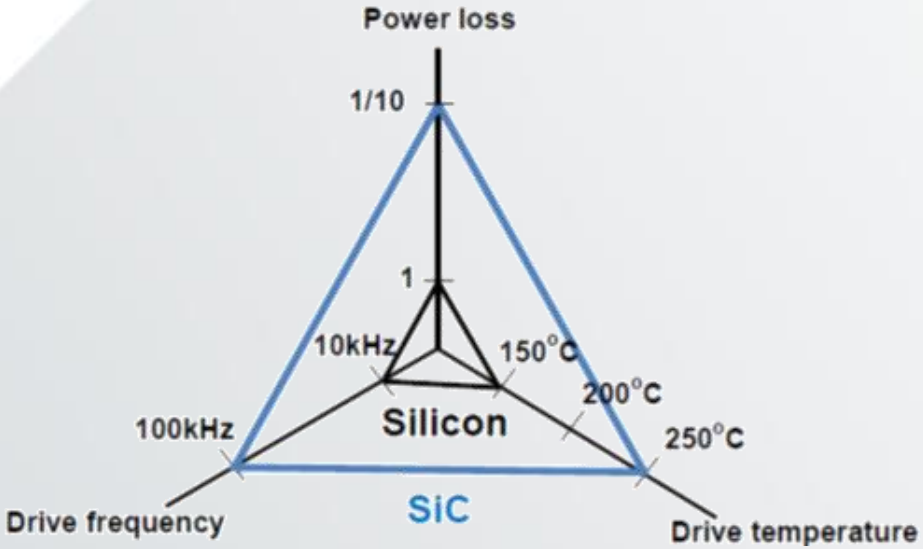
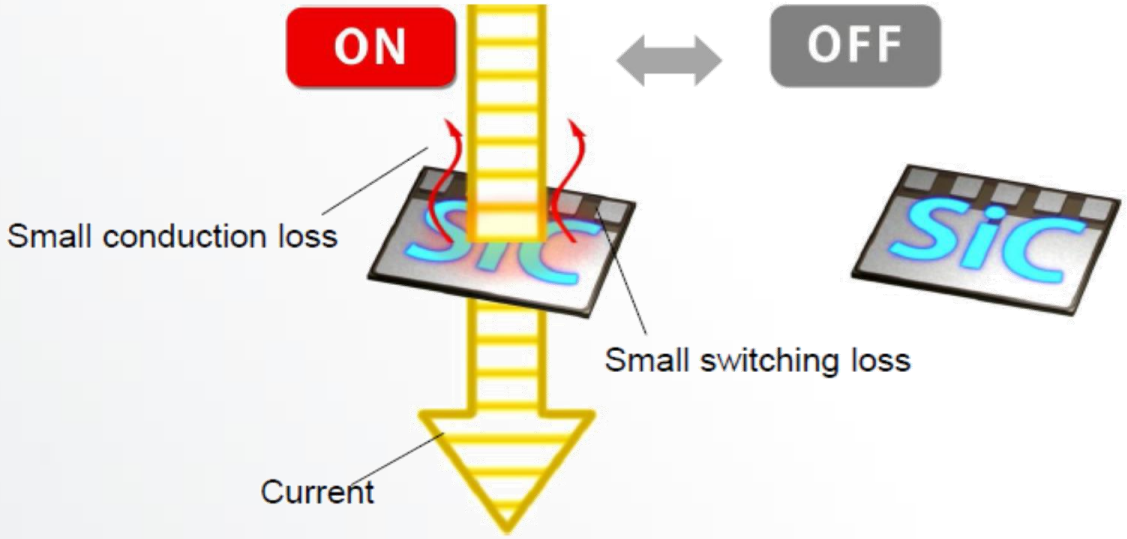
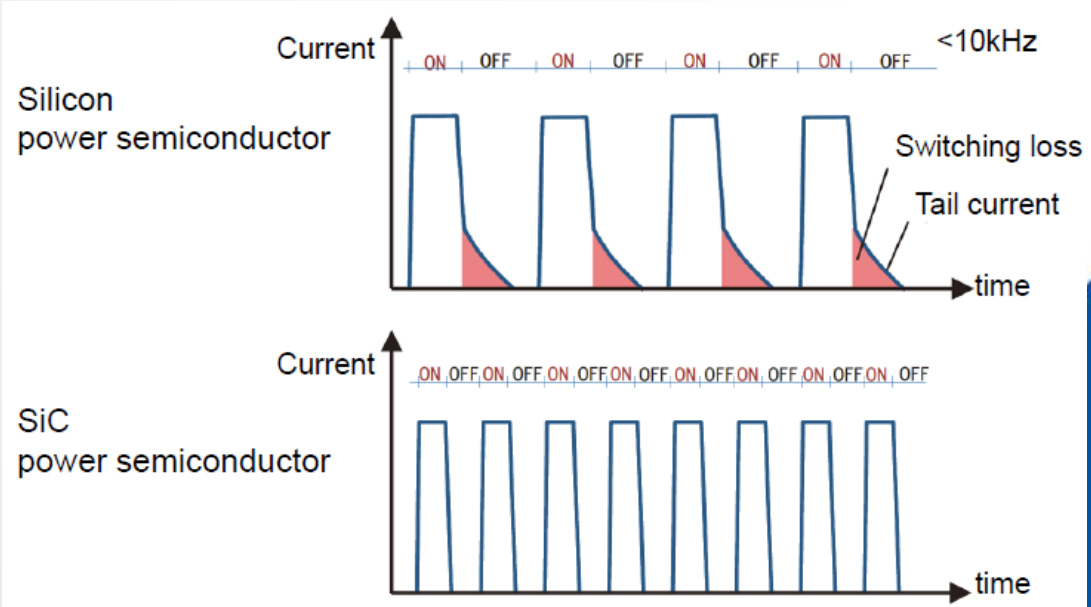
What's SiC Power Semiconductor





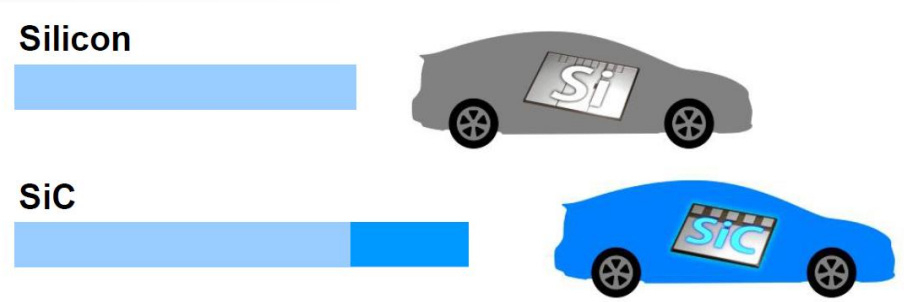
SiC = A Compound of silicon and carbon

	Traditional design	Future design
Main Power Device	Si-IGBT	SiC-MOSFET
Switching Loss	High	Reduced by 90%
Switching Frequency	10kHz max	>100kHz
Operation Temperature	150℃	250℃
Efficiency	95%	Over 98%
Overall Volume	Large	Reduced by 80% or above

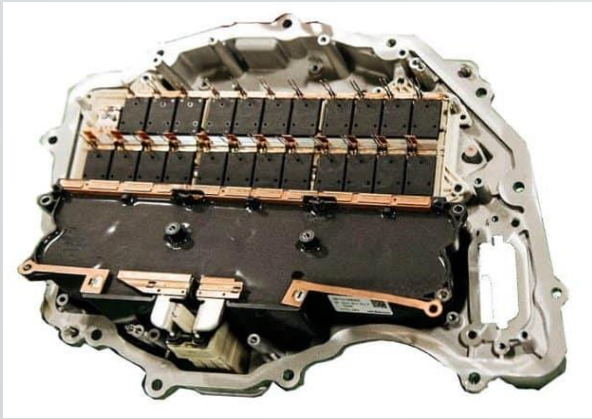


SiC Application in EV

Camry prototype and fuel cell bus featuring SiC power semiconductors



Over 5% range extension confirmed



SiC MOSFET modules in Tesla Model 3

Karma Automotive

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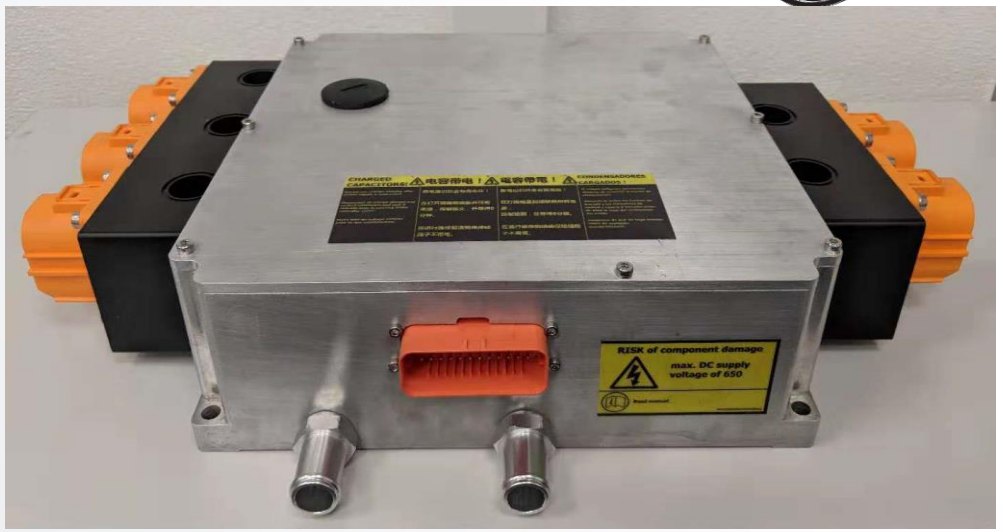
Main Specification

Prototype Version 2



Prototype Version 1

DC link voltage	50~650VDC
DC bus rated current	200Arms max
Nominal output apparent power	140kVA @600VDC
Switching Frequency	5kHz~50kHz (10kHz normally)
Phase current (Peak)	300A (15s)
Phase current (Rated)	200Arms
Efficiency @rated status	>98.5%

Test Result

Speed (rpm)	Torque (Nm)	Power _M_out (KW)	Udc (V)	Idc (A)	Power_dc (KW)	Iphase (A)	Power _Inv-out (KW)	η_Inv (%)	η_M (%)	η_Sys (%)
600	231.3	14.5	500	34.68	17.29	199.98	15.964	92.3575	91.05	84.0935
1200	231.6	29.1	500	65.19	32.48	201.25	31.111	95.7939	93.59	89.6522
1800	232.0	43.7	500	95.82	47.78	202.19	46.381	97.07	94.3	91.5386
2400	232.2	58.3	500	126.58	63.14	203.14	61.704	97.7257	94.57	92.4161
3000	232.0	72.8	500	157.35	78.47	203.79	77.009	98.1444	94.65	92.8977
4000	229.2	96	500	206.48	102.88	200.83	101.405	98.5692	94.67	93.3153

*Without test cables power loss compensation

- Higher efficiency
- Less current ripple
- Higher power density

Future Plan

- Trials for **HKPolyU Racing Team's electric car** to verify and improve performance.
- Through technology transfer, we can help traditional automotive component manufacturers step into next-generation EV's powertrain business.

Thank you!

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