Evolution of Hybrid Vehicle Electric System and its Support Technologies

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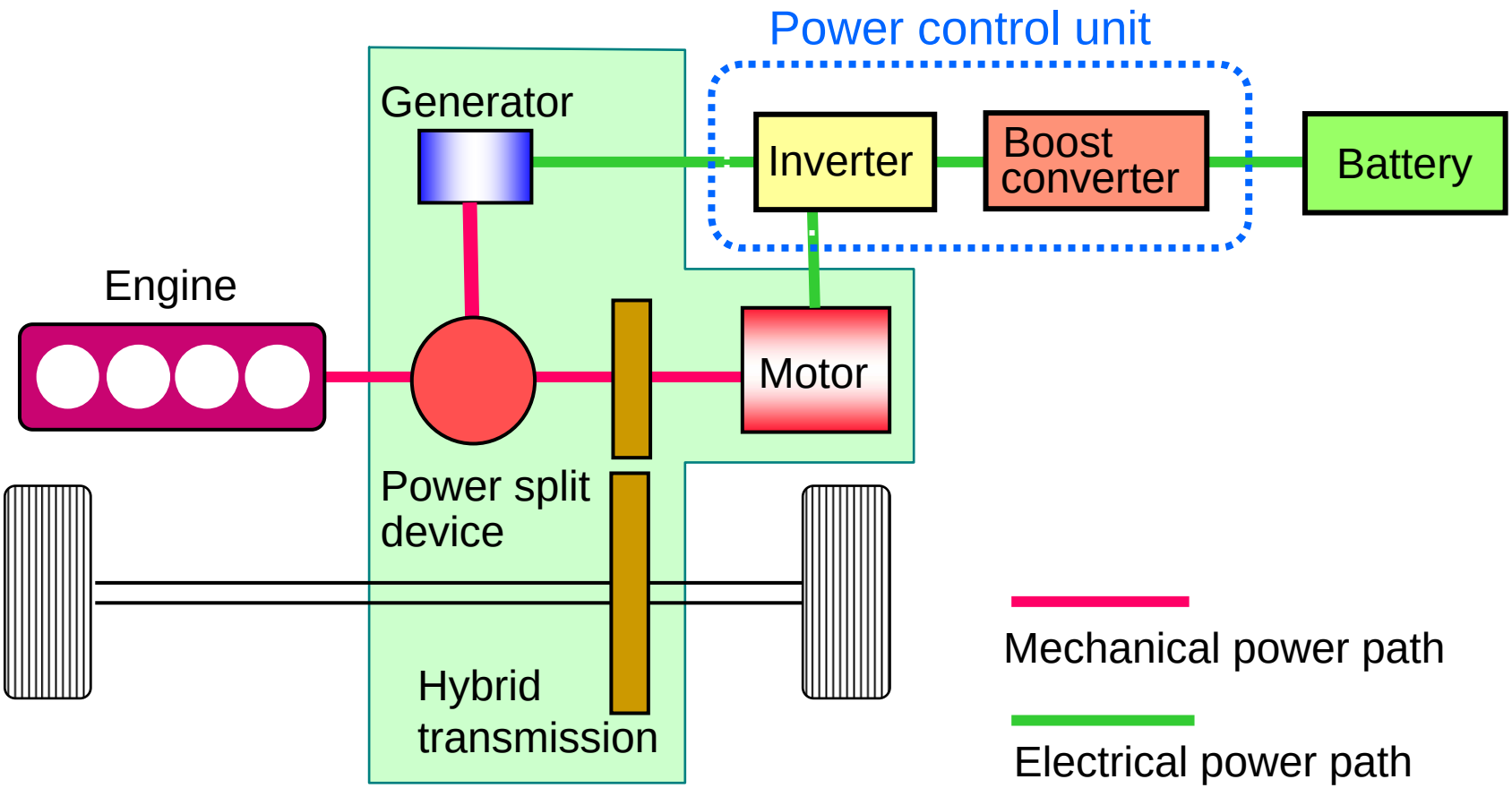
TOYOTA MOTOR CORPORATION

Contents

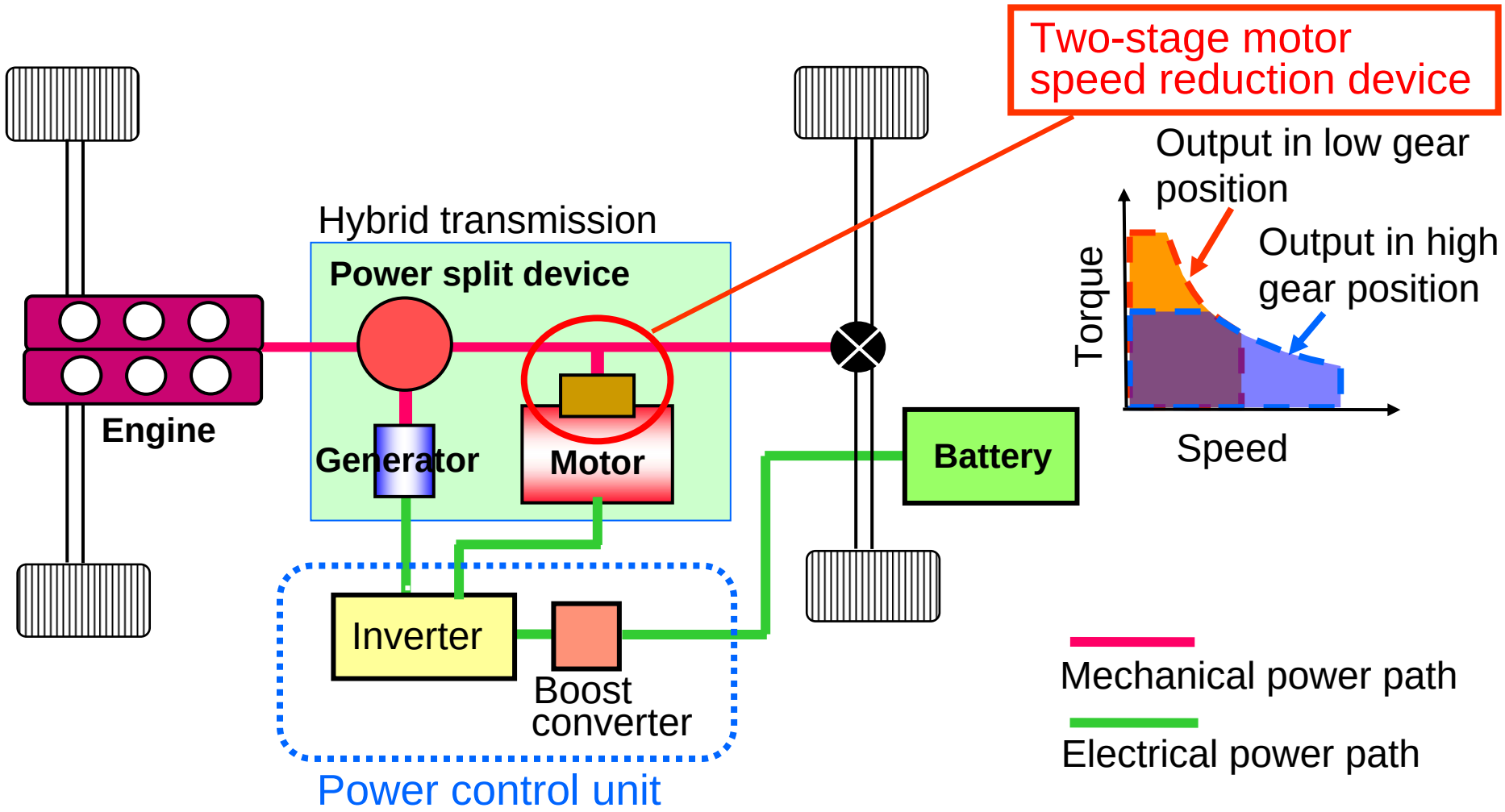
1. Toyota Hybrid System-II (THS-II)

Toyota Hybrid System II

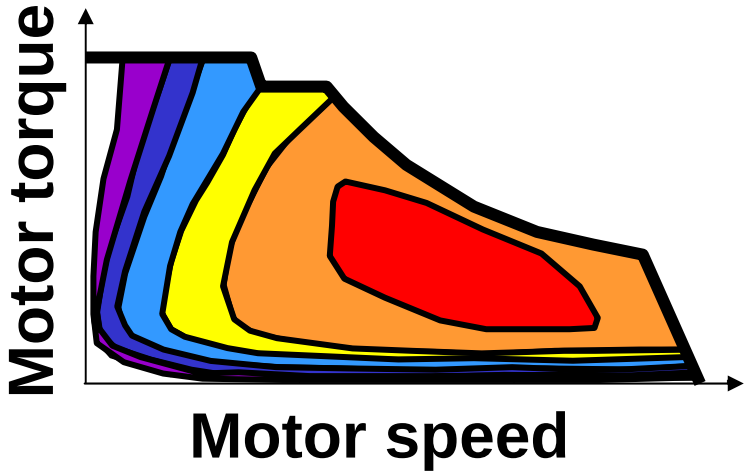


Toyota Hybrid System II

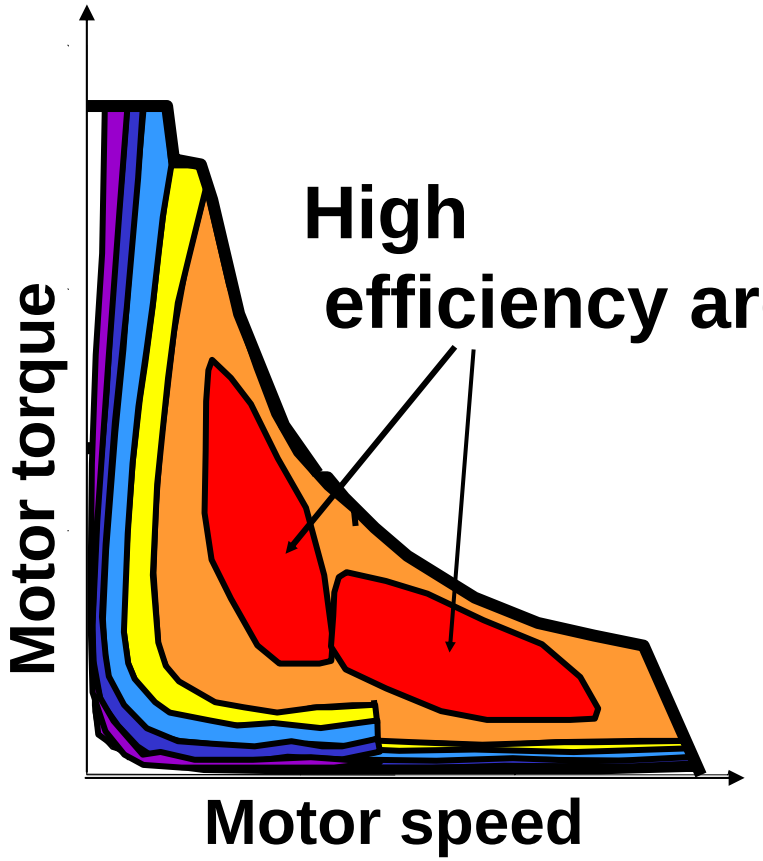
With two-stage motor speed reduction device



Motor Efficiency

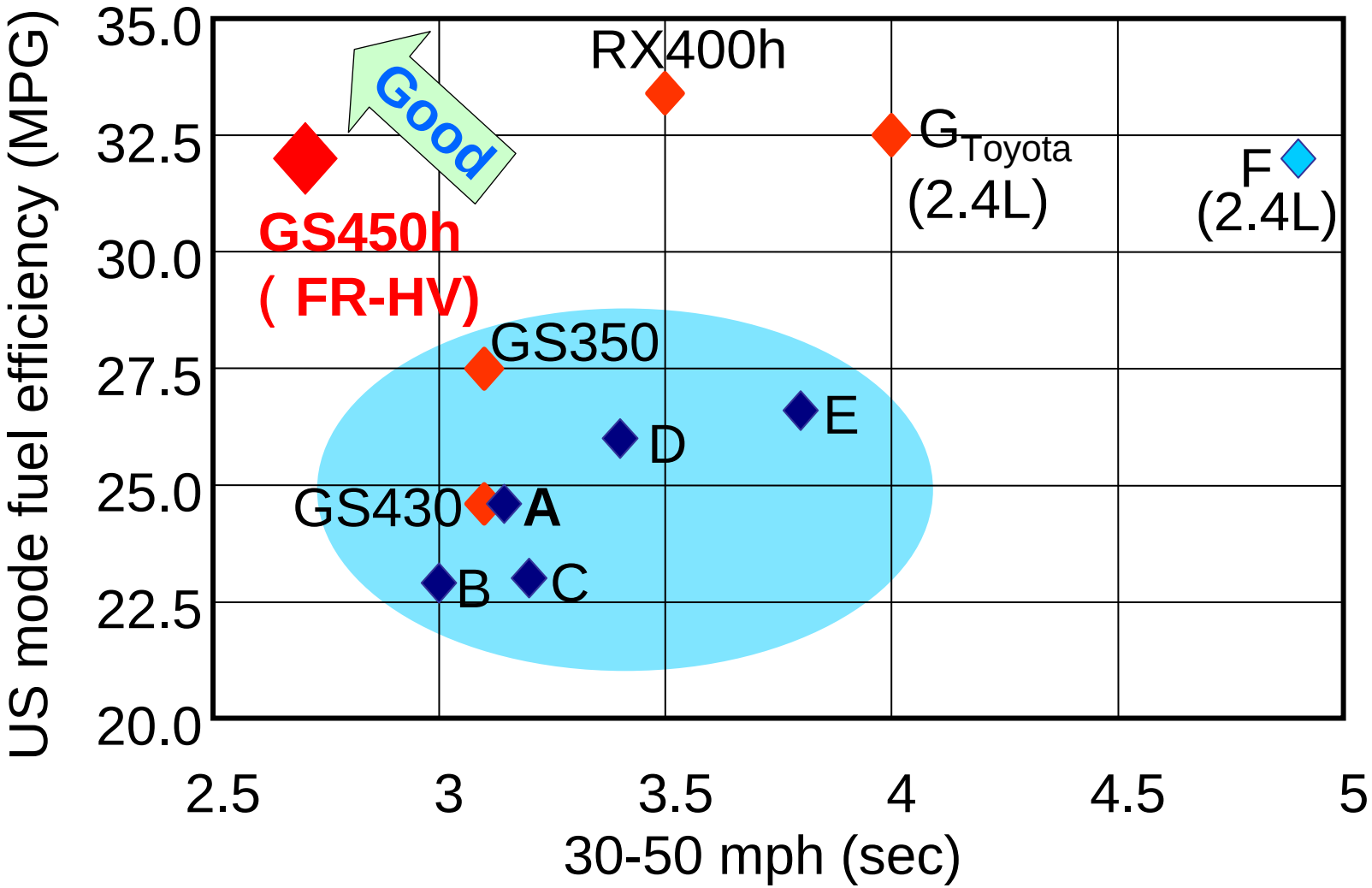


Fixed motor speed reduction device



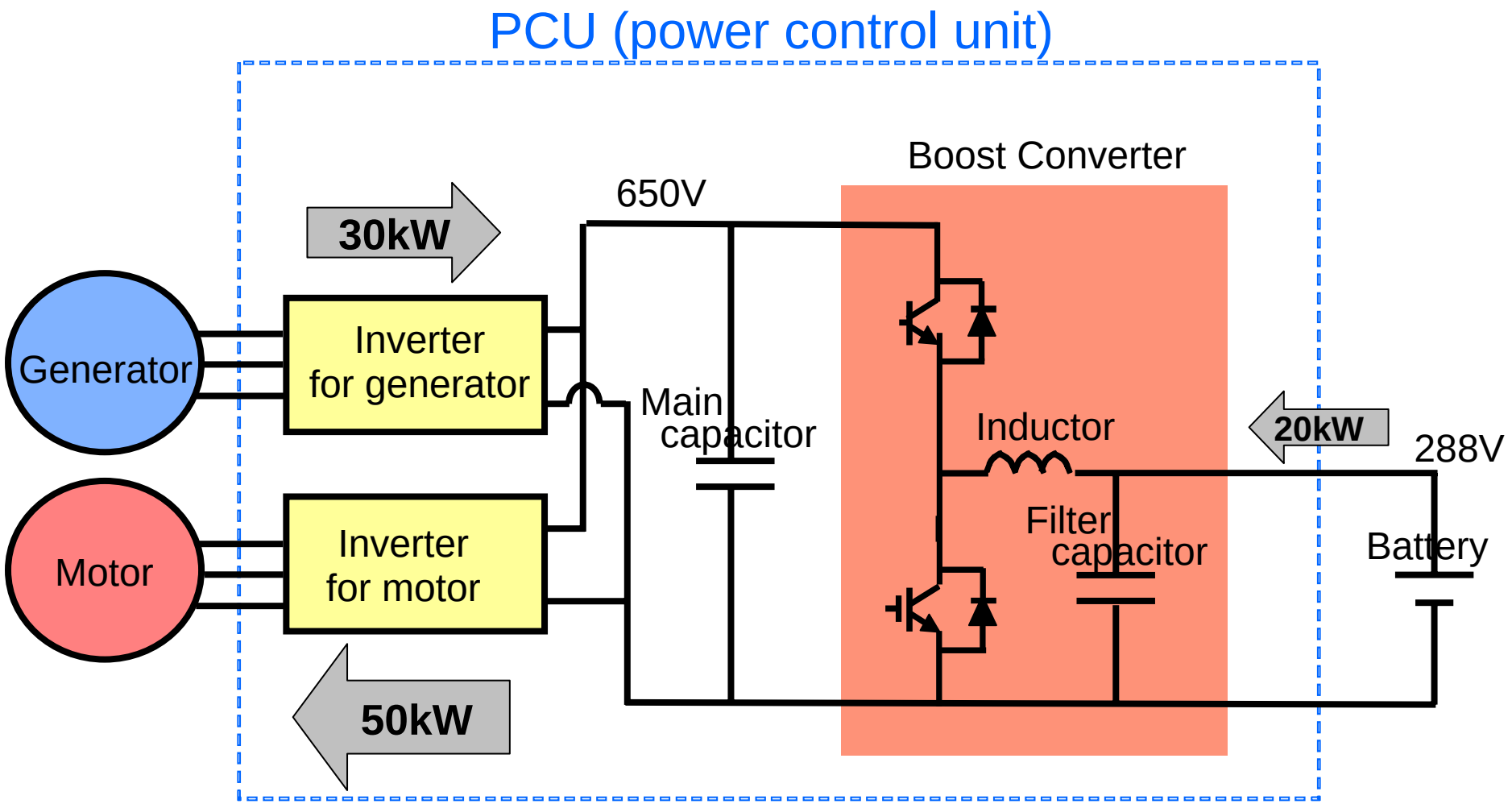
Two-stage motor speed reduction device

Fuel Efficiency & Acceleration Performance



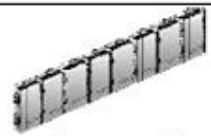
2. Electric Components in Hybrid System

Electric Circuits and Energy Flow in THS-II

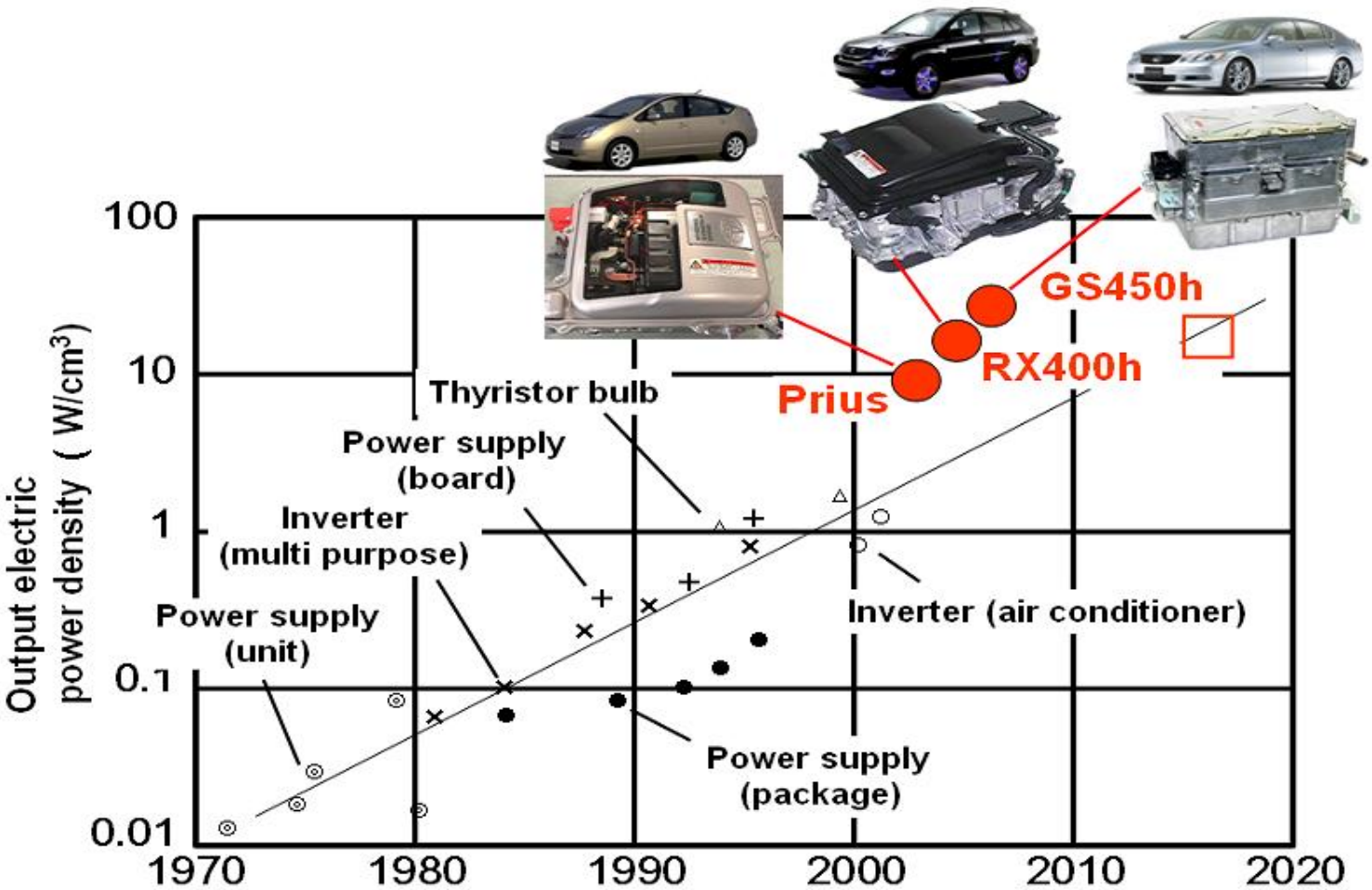


Evolution of Electric Components in Hybrid System

Compact & Lightweight / Higher Power Density

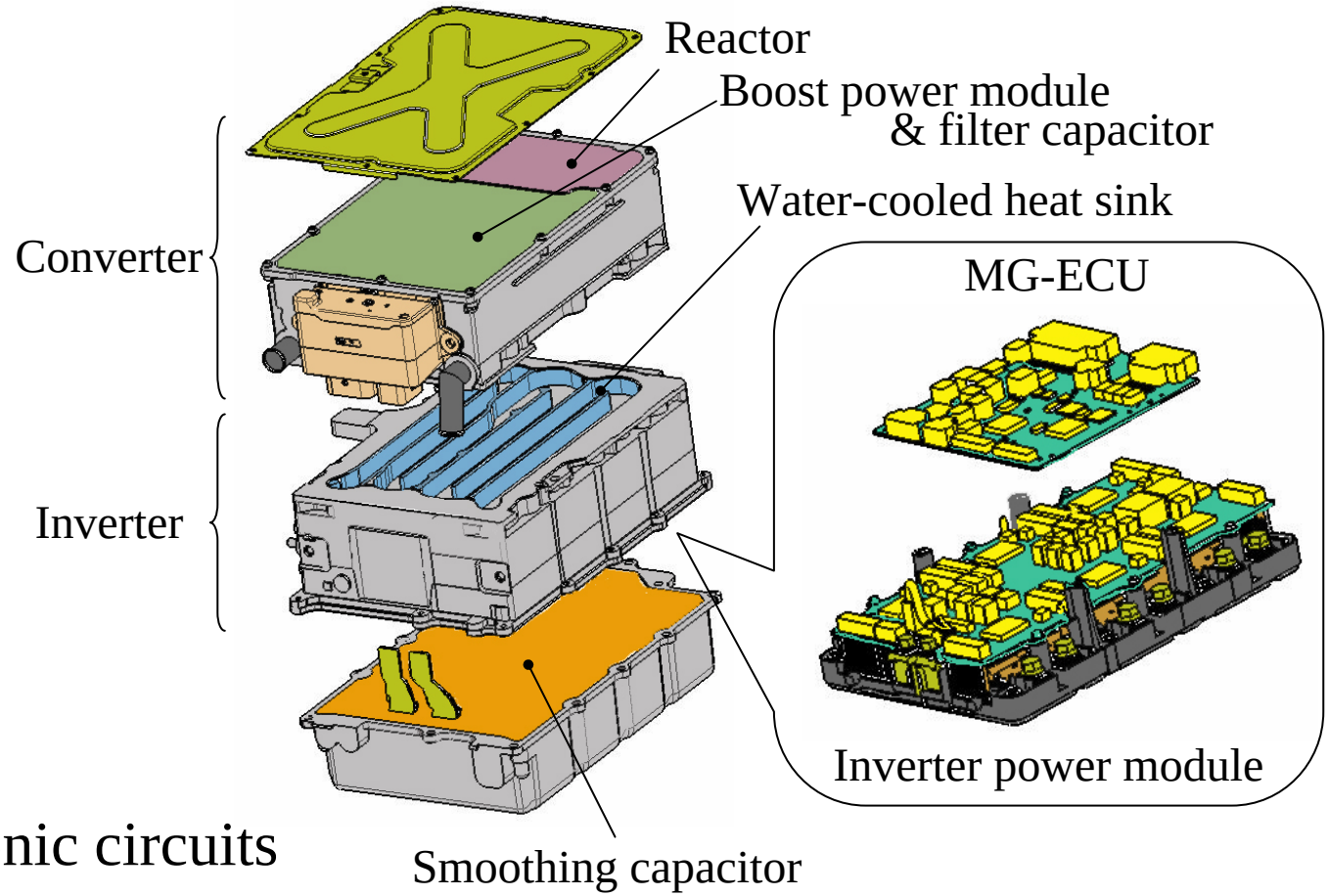
	THS	THSII		
	'97 Prius	'03 Prius	'05 RX400h	'06 GS450h
Motor	 permanent magnet motor 33kW	 • Higher voltage • Structure optimization 50kW	 • Reduction gear 123kW	 • 2-stage motor speed reduction device 147kW
Power control unit	 Highly-reliable motor controller	 Max. 500V / IPM integrated	 Max. 650V / rear motor inverter integrated	 Max. 650V / improved cooling and switching freq.
Battery	 Sealed Ni-MH battery	 Lower internal resistance Higher power density	 Improving cooling Compact Higher power density	 '03 Prius battery

Progress of Power Density of PCU



by H. Ohashi in the Journal of the Institute of Electrical Engineers of Japan No.122 (3).

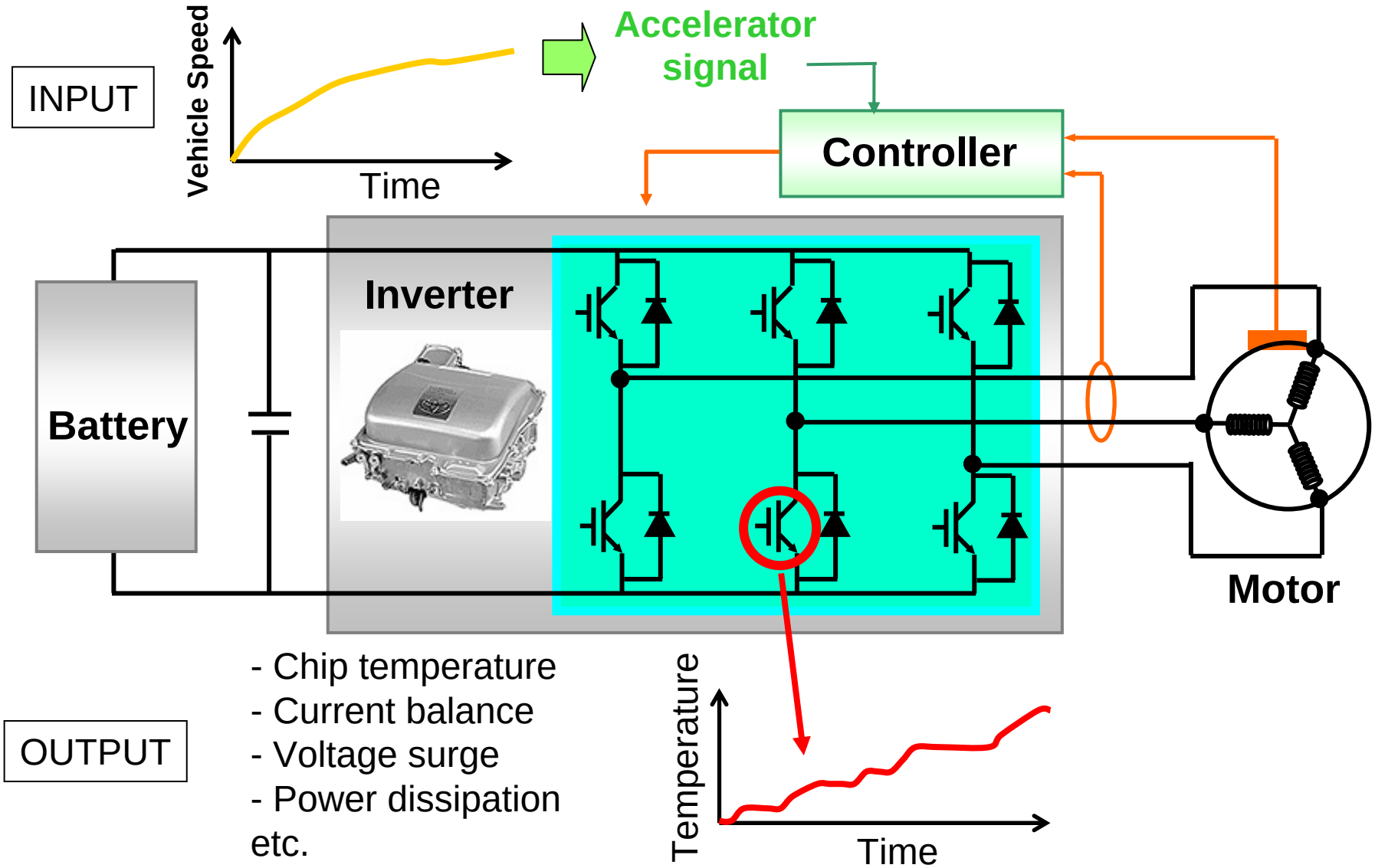
Internal Structure of PCU for GS450h



- Cooling units
- Electric/electronic circuits
- **Power semiconductors**
- **Simulation**

3. HV Inverter Simulation

Aims of Simulation Technology



Overall Structure of HV Inverter Simulation

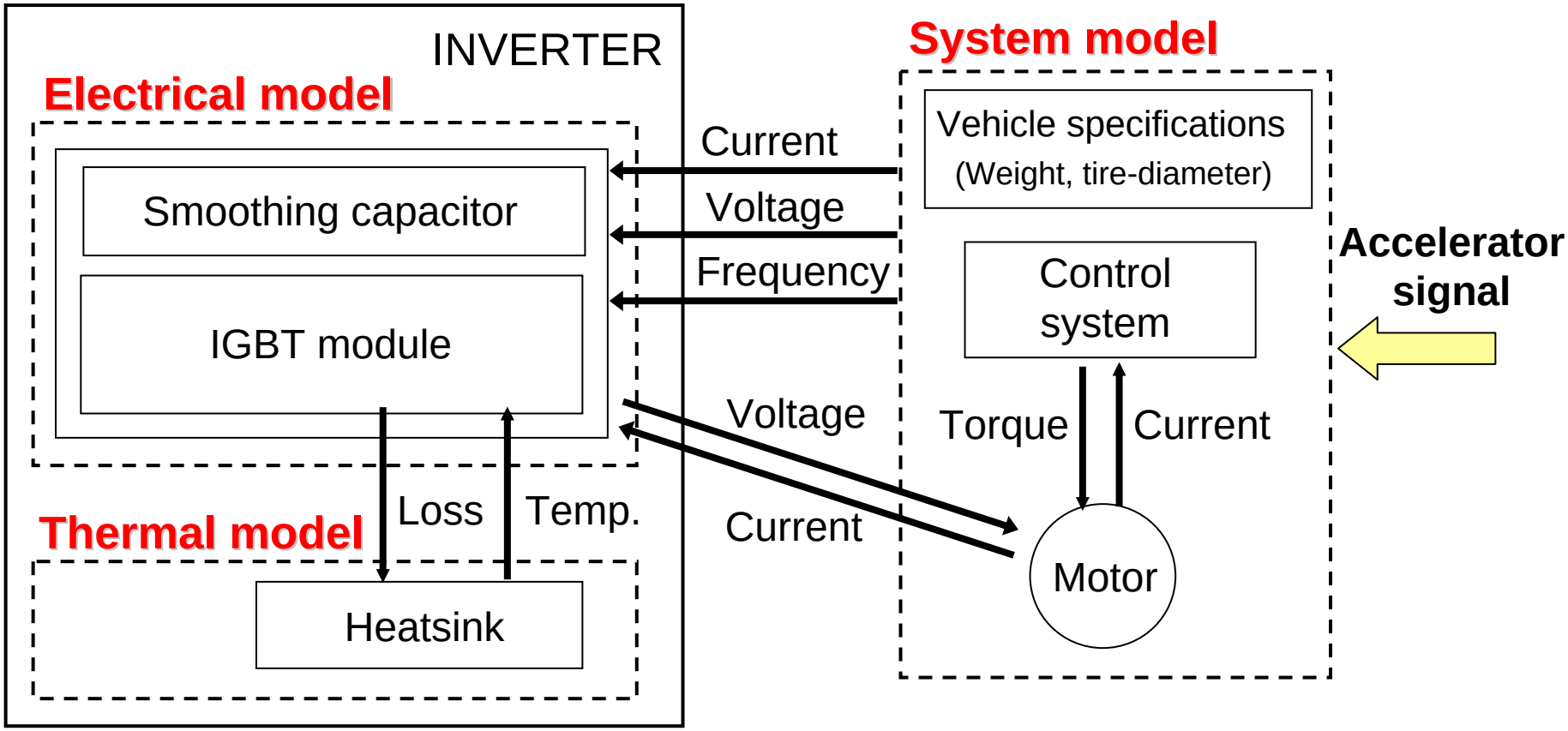
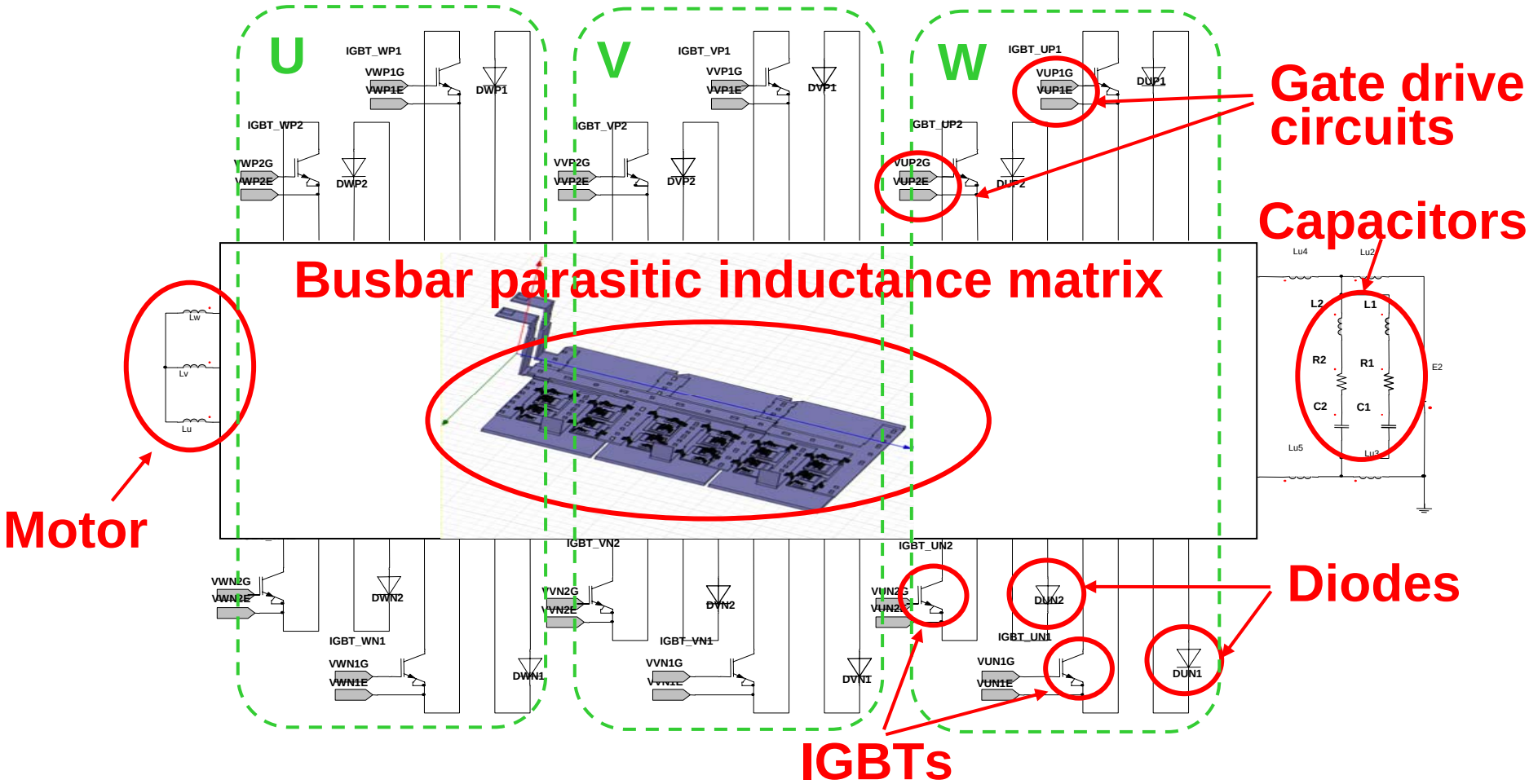


Diagram of electro-thermal-mechanical simulation for HV inverter system

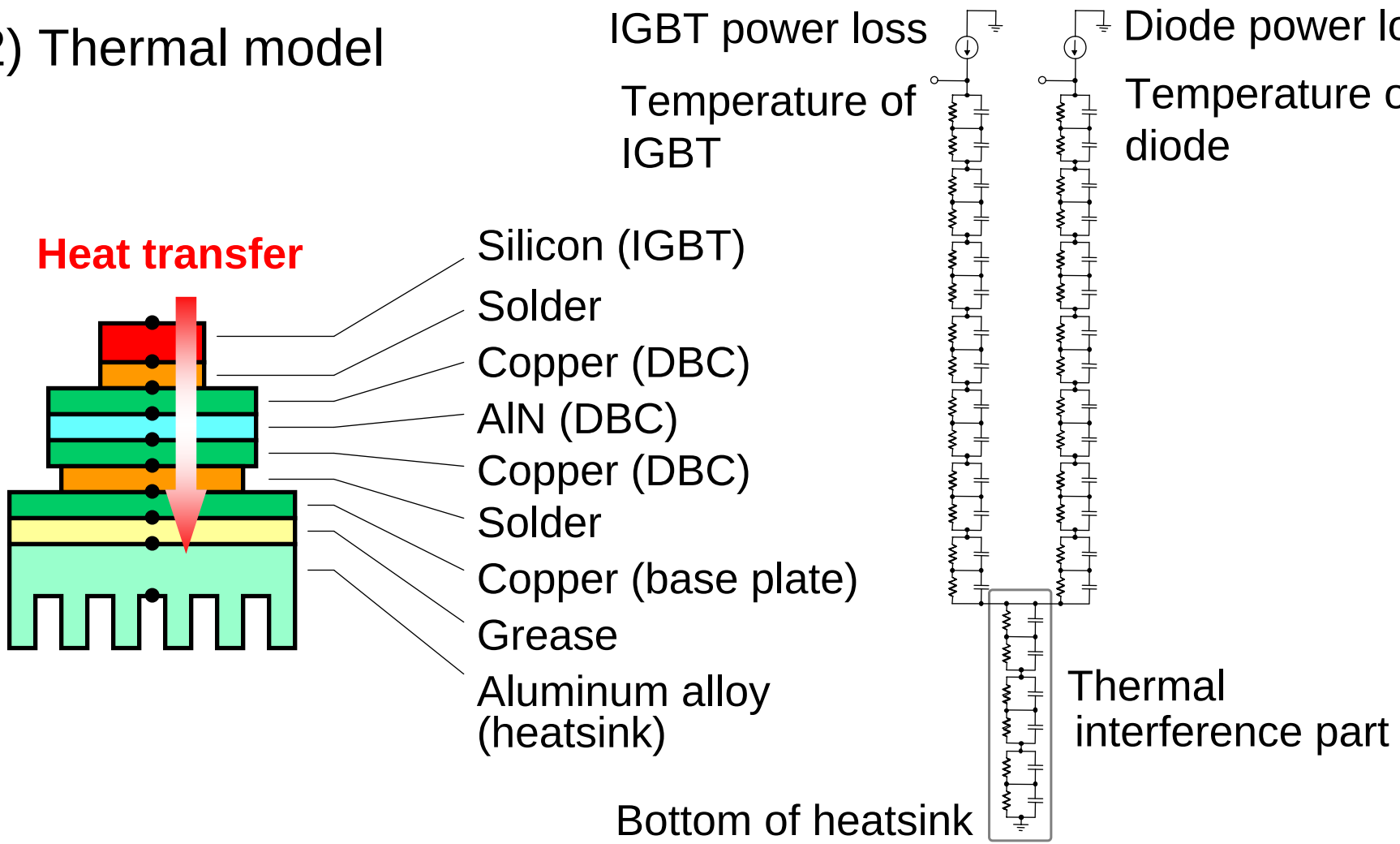
Major Parts of Inverter Simulation

(1) Electrical model



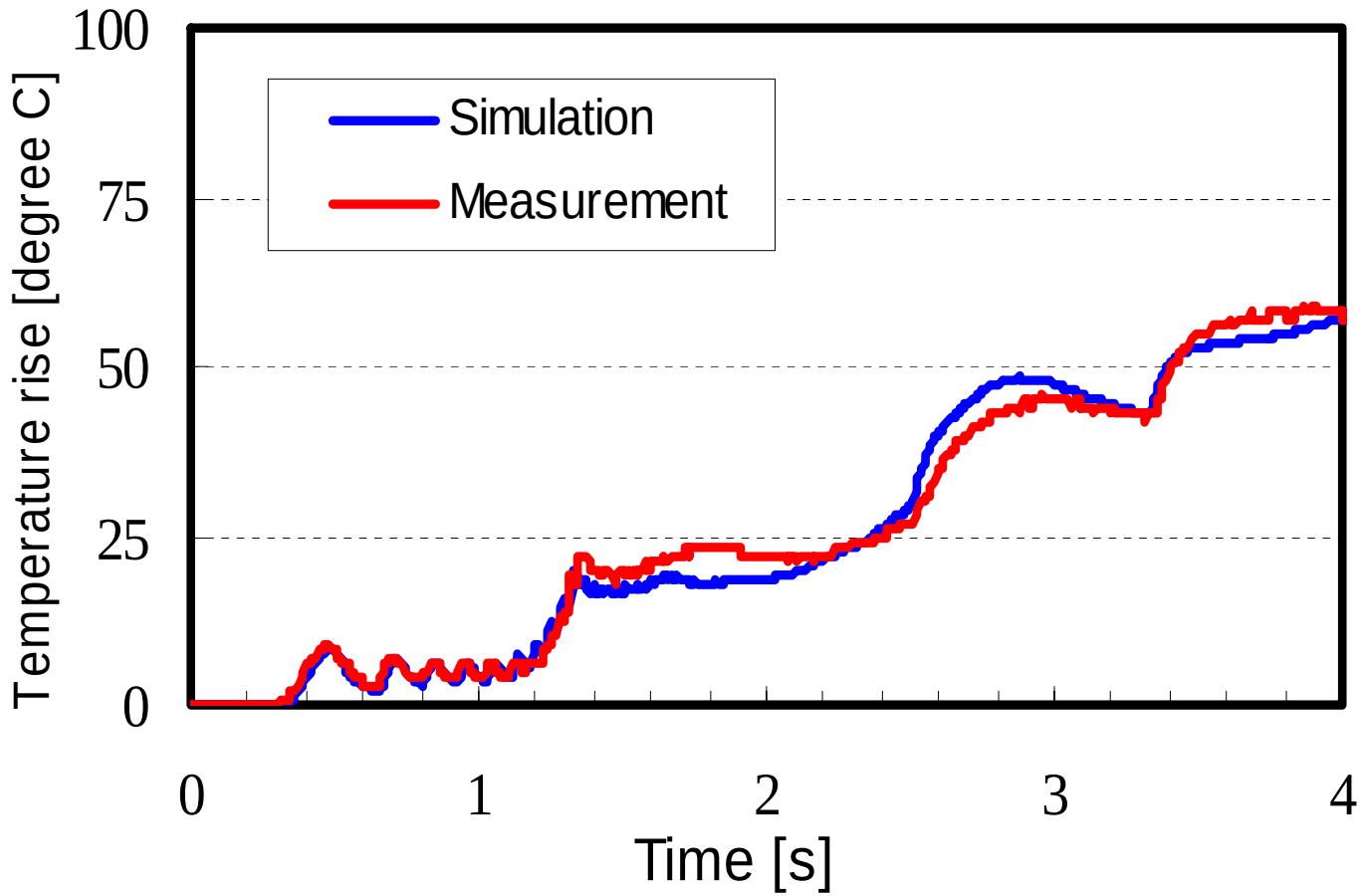
Electrical model in HV inverter system

(2) Thermal model



Compact thermal model (CTM) for IGBT module including water-cooling system

Verification of HV Inverter Simulation

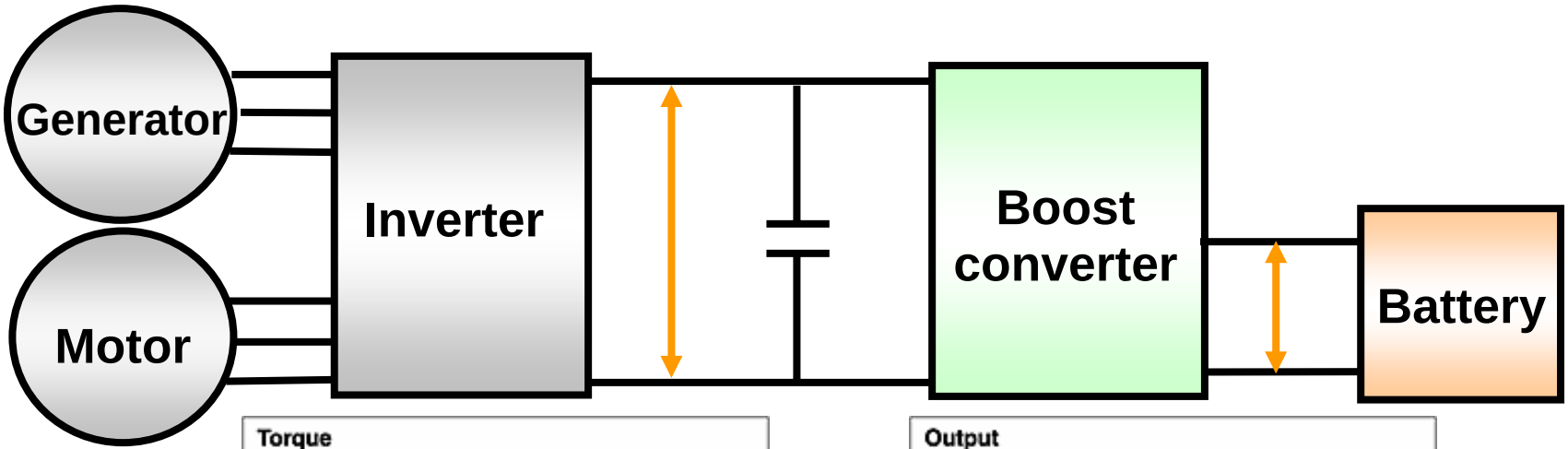


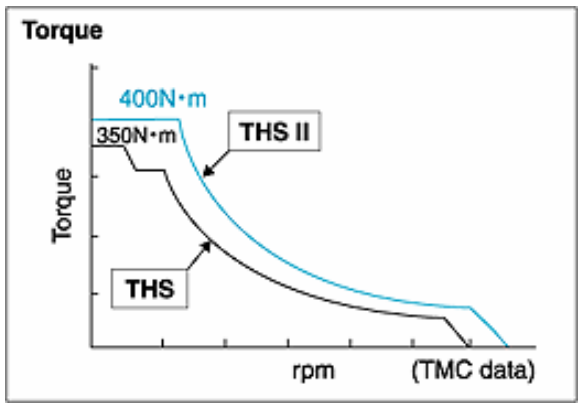
Prediction of IGBT temperature at full-throttle acceleration

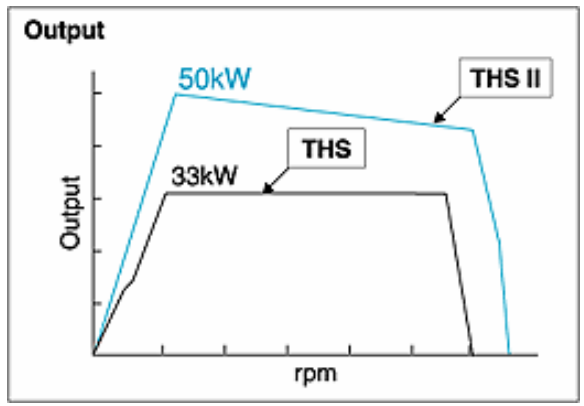
4. IGBT Development

High-Voltage Electrical System

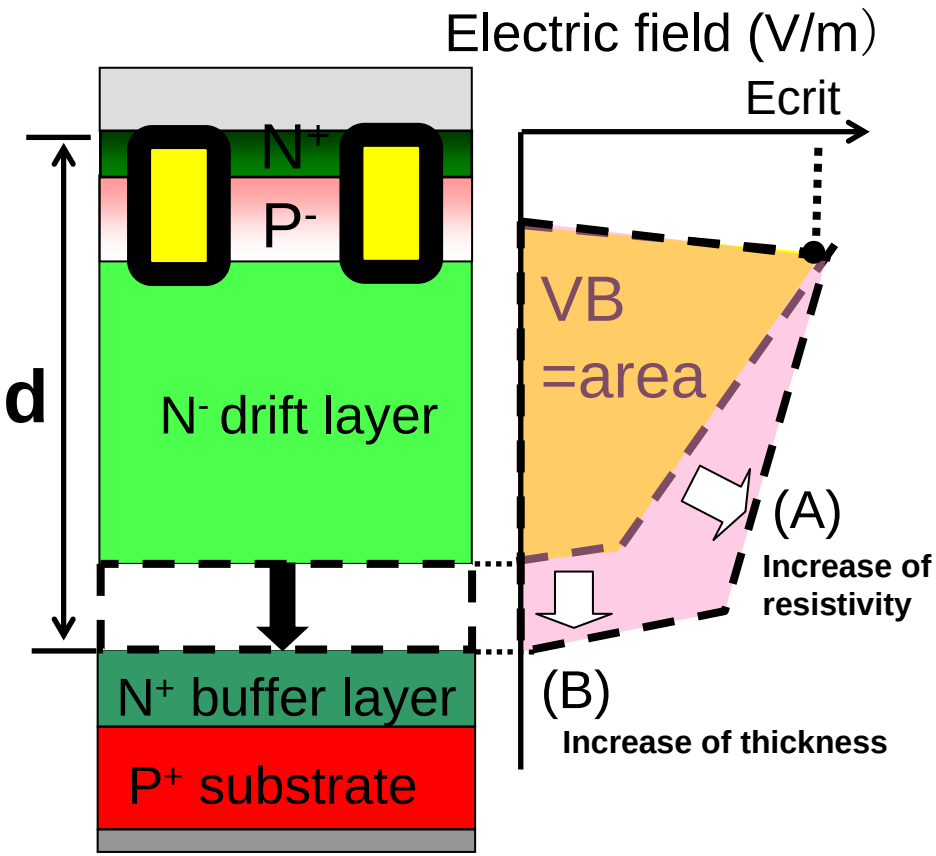
	IGBT V_{BD}	Bus line voltage	Battery voltage
Prius	970V	500VDC	200VDC
RX400h	1200V	650VDC	288VDC



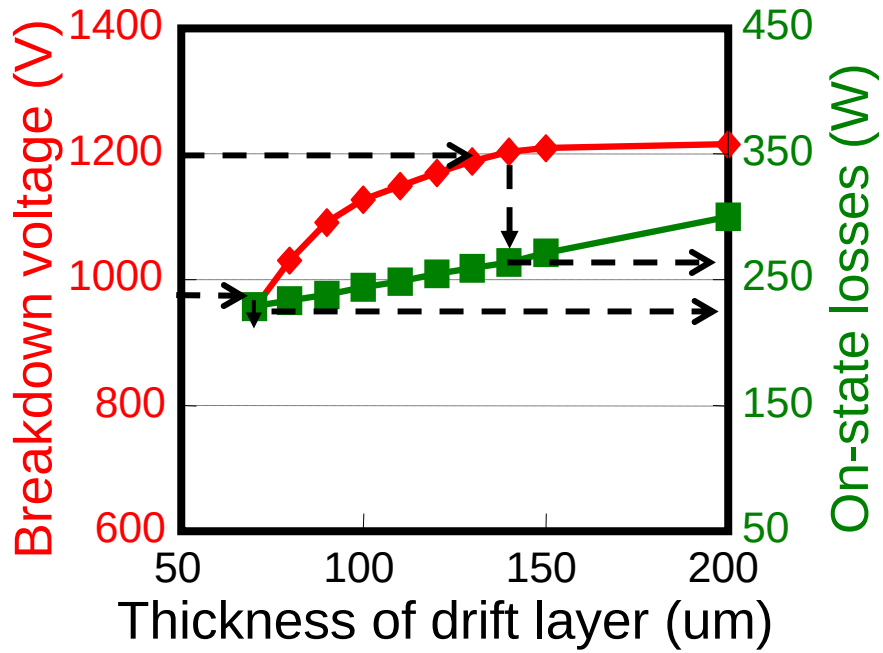




Improvement of IGBT Breakdown Voltage

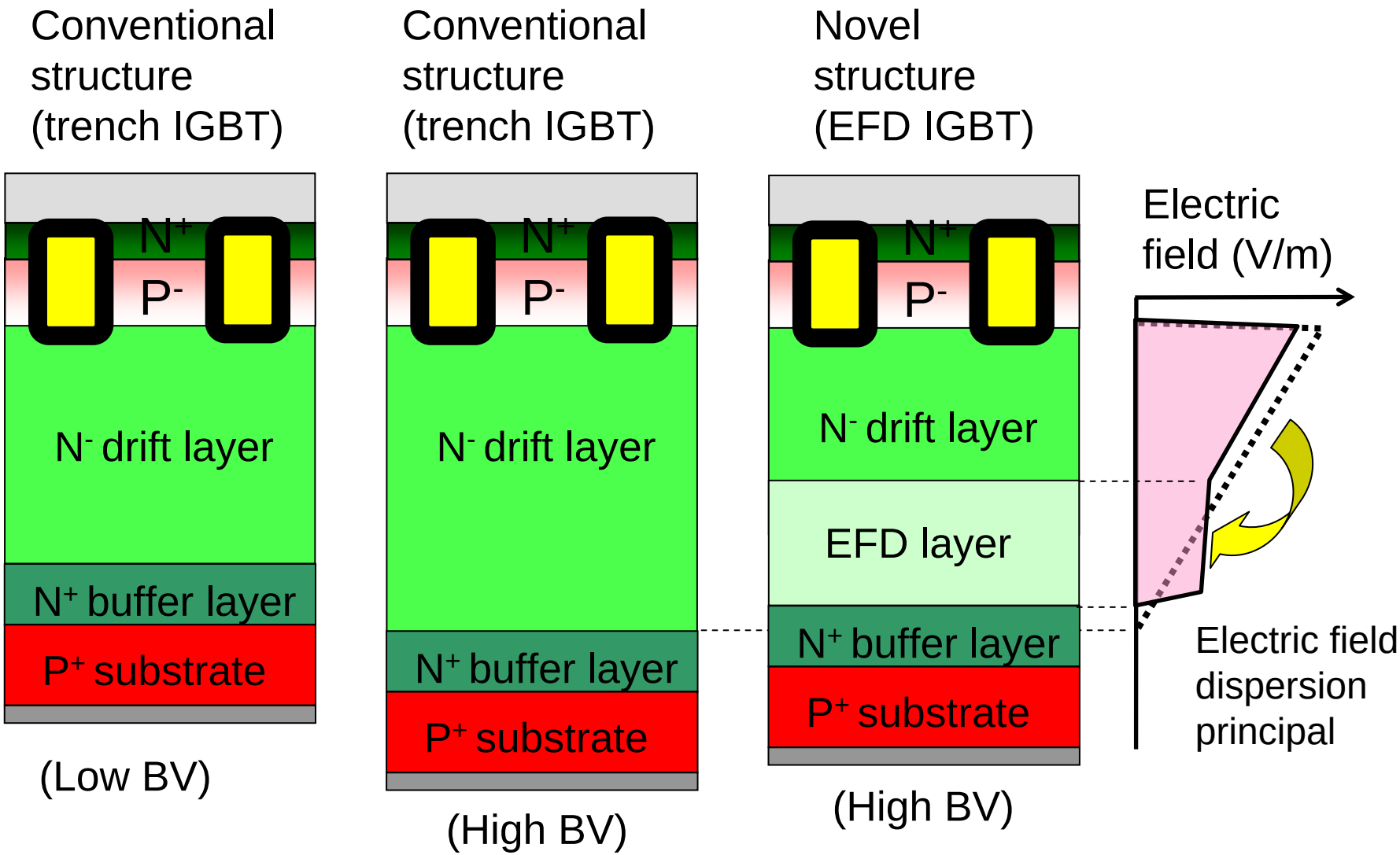


General ways to improve breakdown voltage of IGBT

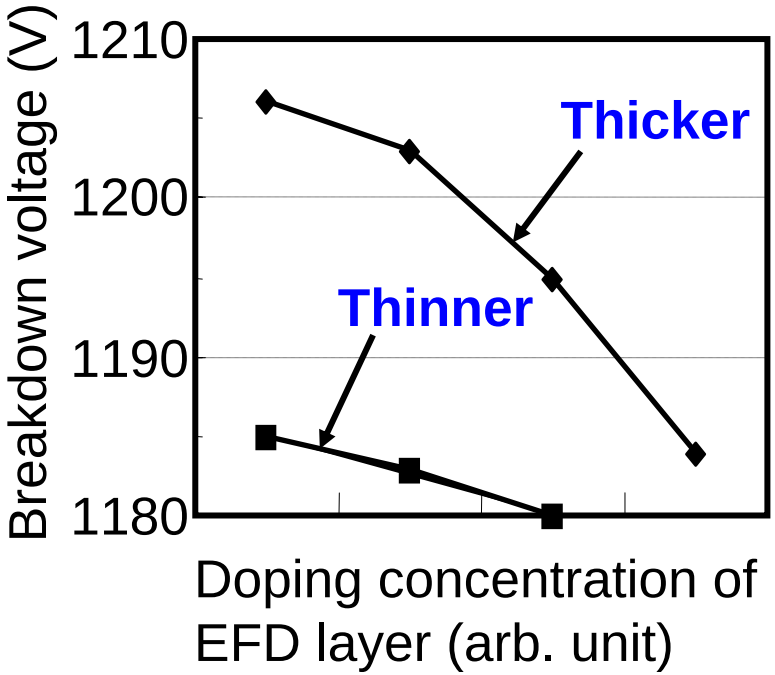


Increase of on-state losses accompanied with improvement in breakdown voltage

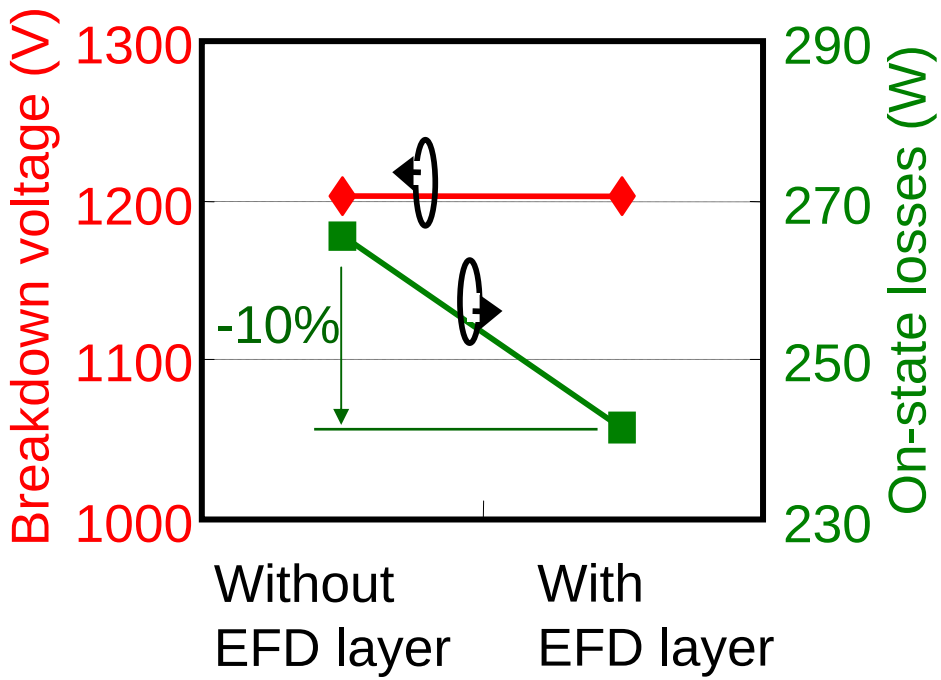
Introduction of Electric Field Dispersion (EFD) Layer



Design and Effect of EFD Layer

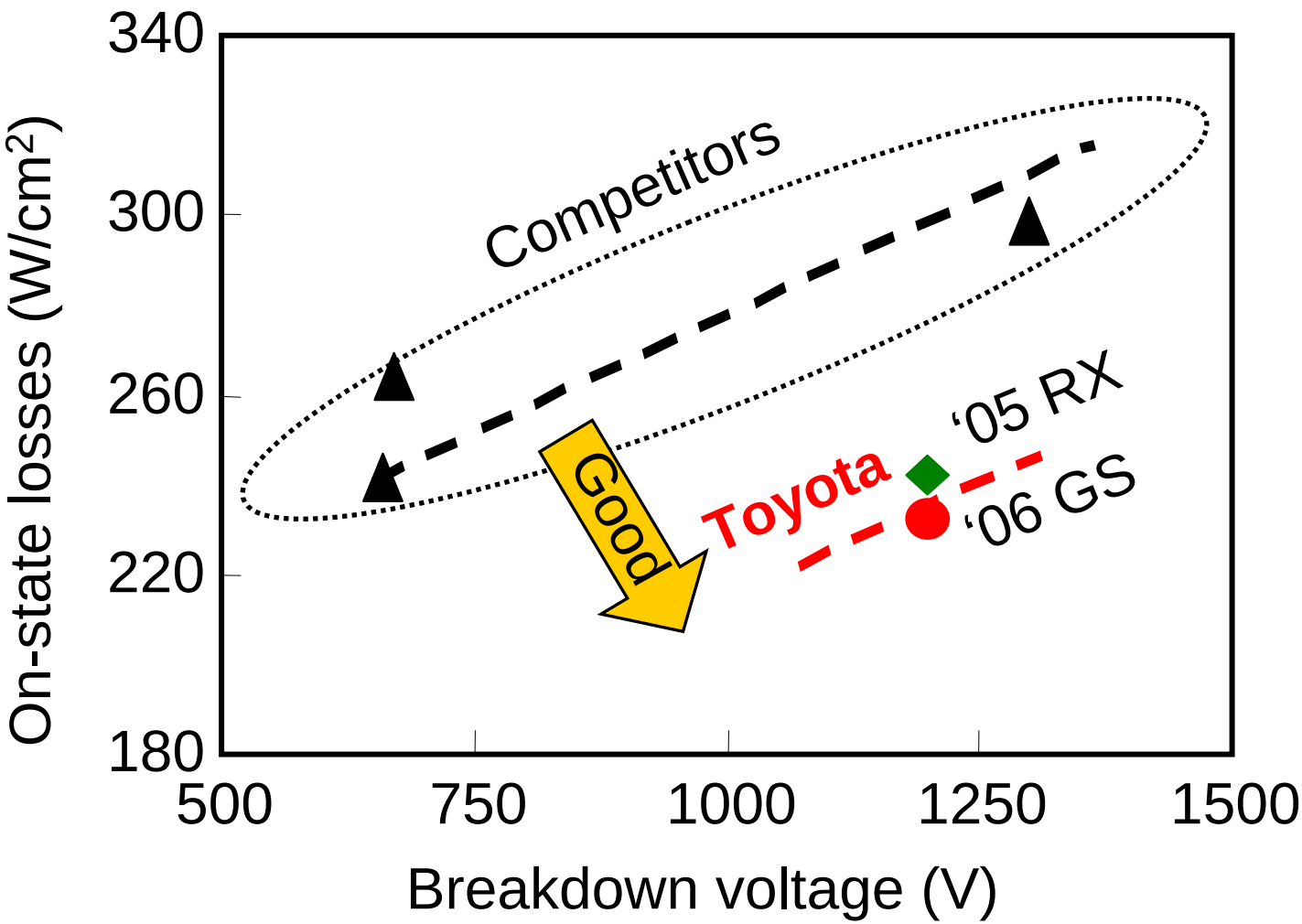


Breakdown voltage dependence on EFD layer conditions

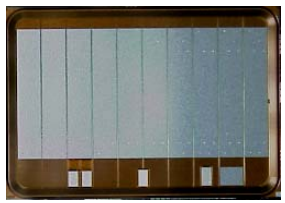
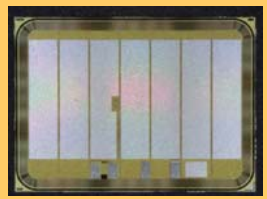


Effect of EFD layer

Benchmark of Toyota In-House IGBTs



Evolution of In-House IGBTs

Item	'03 Prius	'05 RX	'06 GS
Chip appearance			
Device structure	Planar IGBT	EFD IGBT	EFD IGBT
Chip size (mm^2)	13.7×9.7	12.75×9.39	12.75×9.39
Chip thickness (um)	380	375	**300**
Breakdown voltage (V)	970	**1200**	**1200**
On-state losses (W/cm^2)	265	**242**	**232**

5. Conclusion

- **THS-II realizes dual requirements of fuel efficiency and acceleration performance by employing boost converter and two-stage motor speed reduction device.**
- **The electrical components of the THS-II are contributing to making the system more compact, and lightweight, and to increasing its power density.**
- **An HV inverter simulation has been developed as a powerful tool for HV system development.**
- **Low loss high-breakdown voltage novel IGBTs ,named EFD IGBTs, have been successfully developed for the THS-II.**

Thank you!