

Designing traction inverters with the UCC5870-Q1

Presented by: Audrey Dearien

Texas Instruments



Enabling the
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HVP



TEXAS INSTRUMENTS

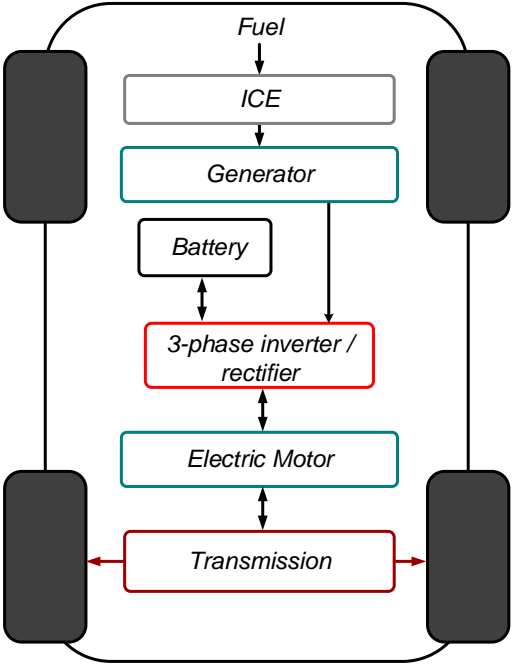
Agenda

- HEV/EV system architectures
- Traction inverter overview and failure modes
- UCC5870-Q1 integrated features and protection mechanisms
- Summary

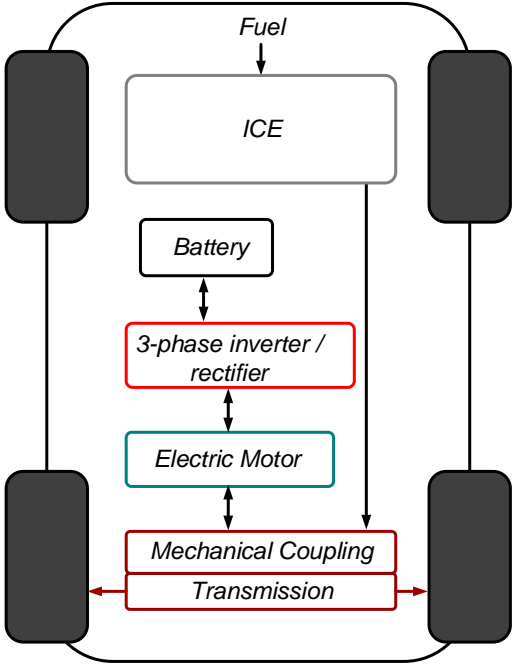
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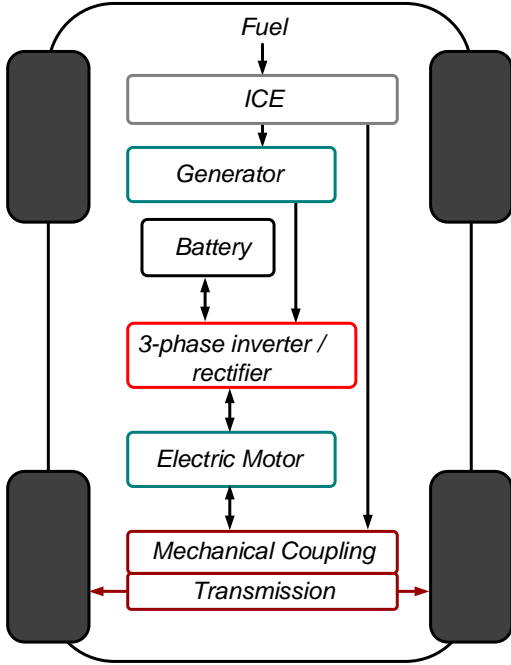
HEV/EV systems | hybrid vehicles



(a)

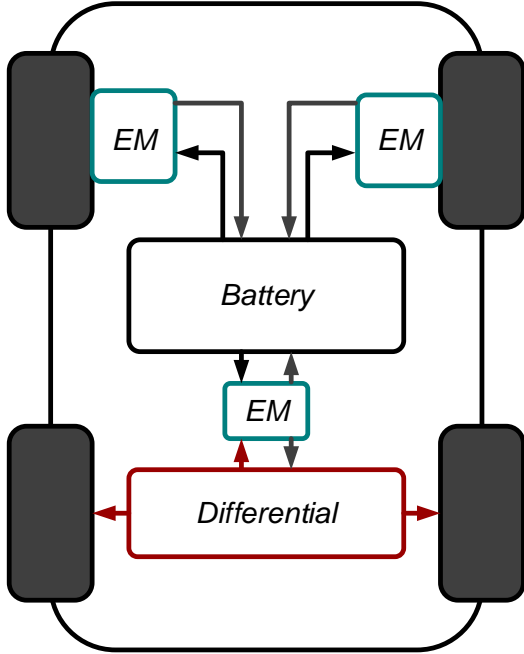


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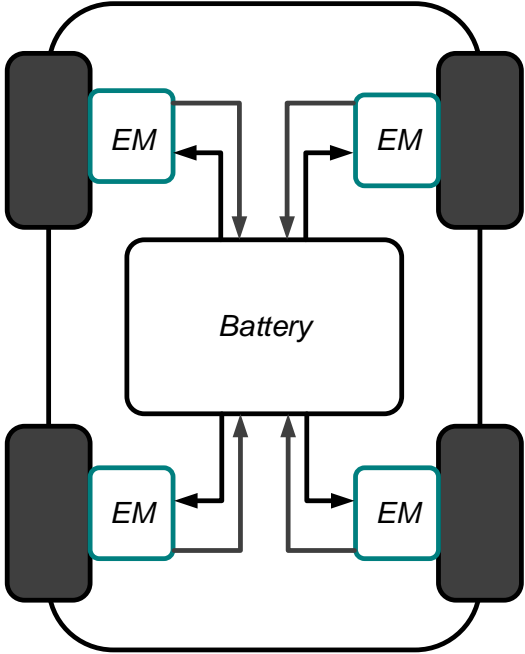


(c)

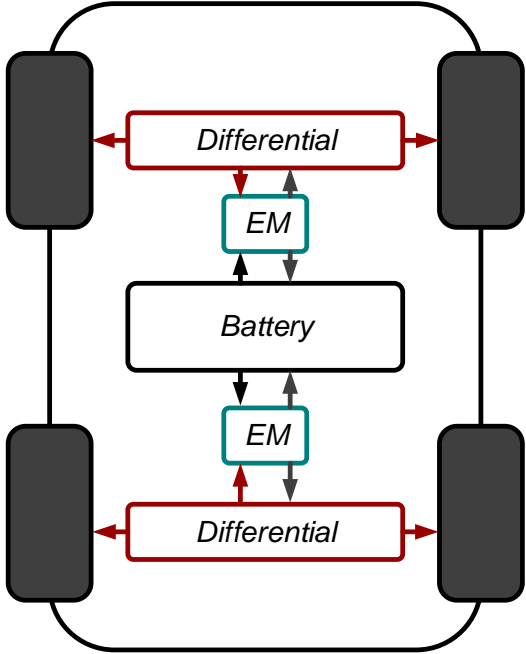
HEV/EV systems | electric vehicles



(a)

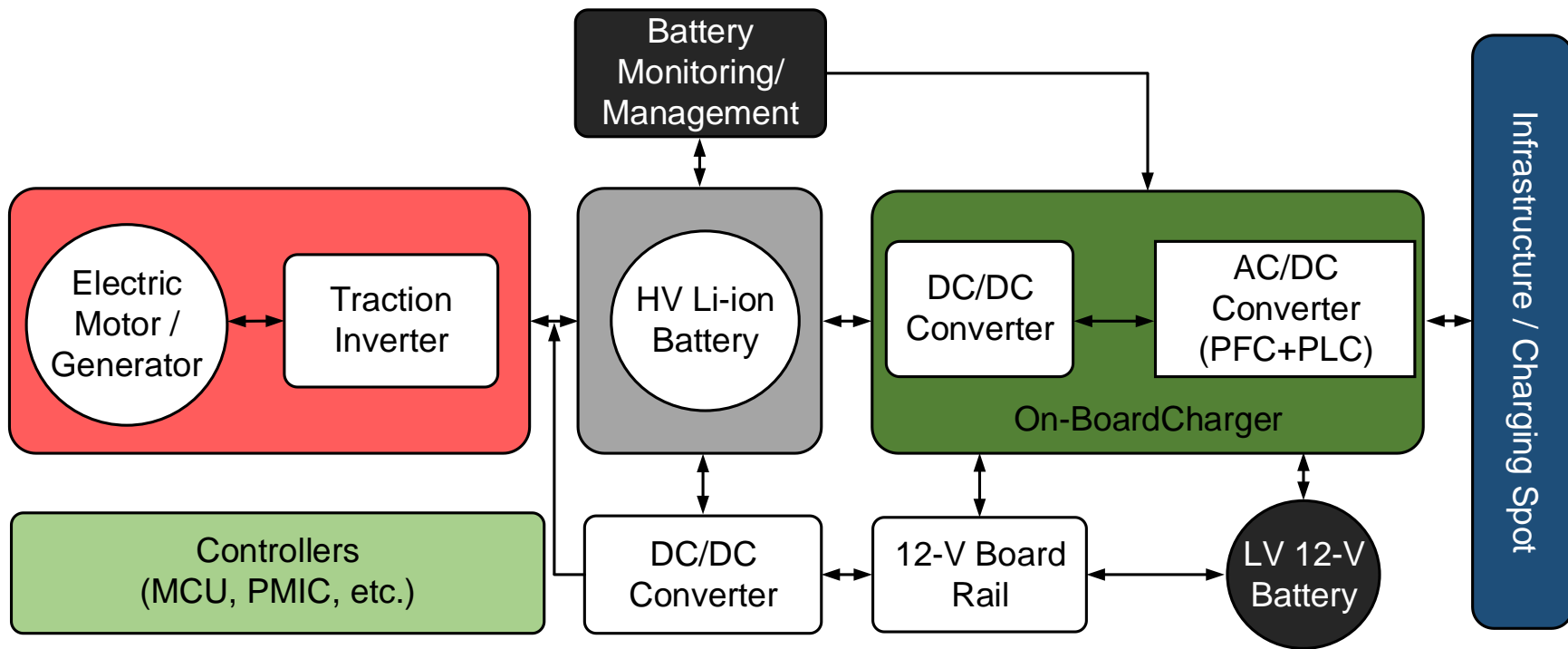


(b)



(c)

HEV/EV systems | EV block diagram

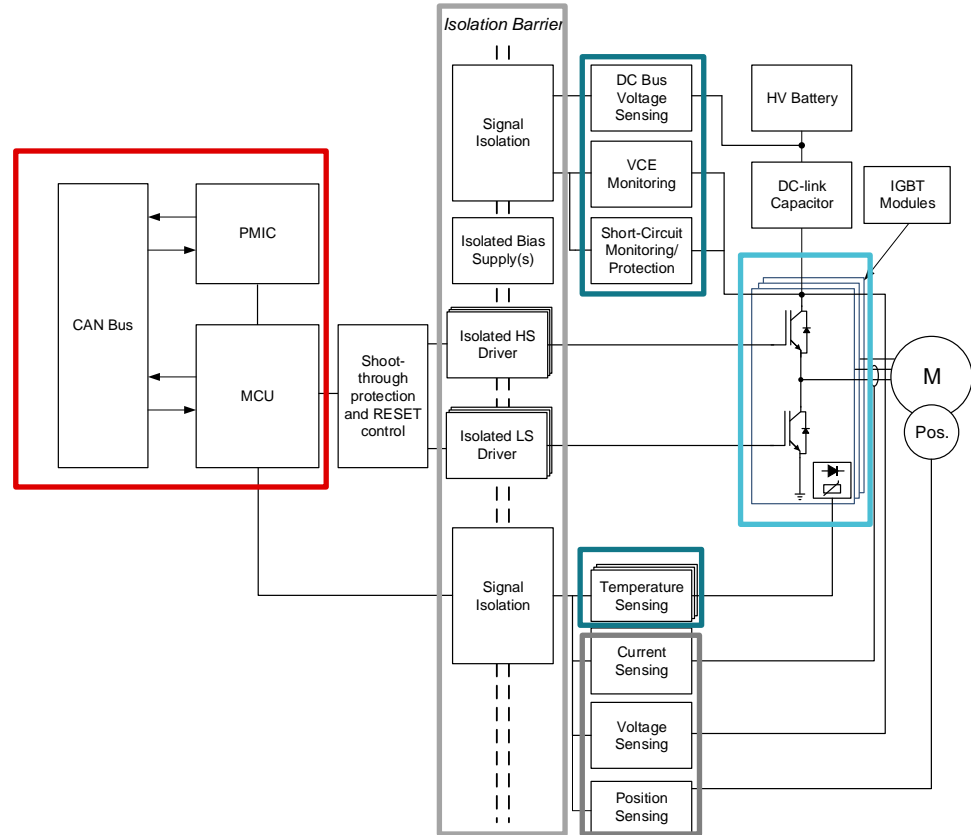


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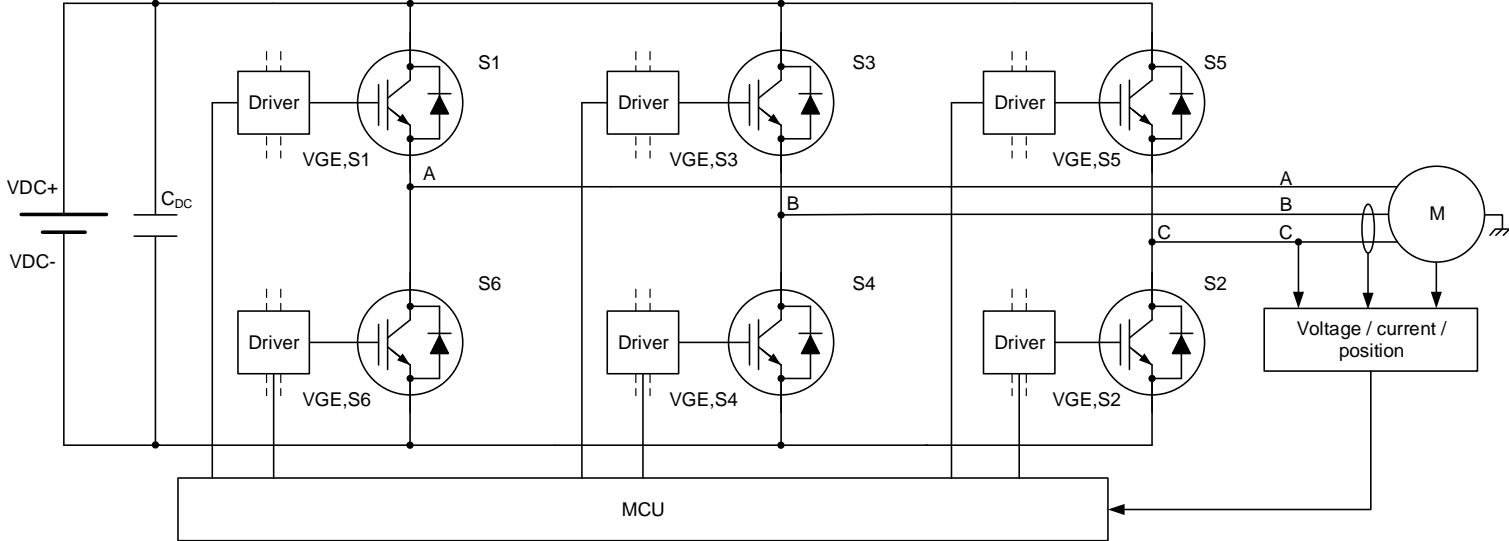
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EV powertrain | traction inverter block diagram

- Controllers
- Isolation
- Power conversion transistors
- Protection and monitoring
- Critical control feedback and motor monitoring



Powertrain | three-phase traction inverter



Vector	S1	S2	S3	S4	S5	S6	VAB	VBC	VCA	Vector Mode
{000}	OFF	ON	OFF	ON	OFF	ON	0	0	0	Zero
{100}	ON	ON	OFF	ON	OFF	OFF	+VDC	0	-VDC	Active
{100}	ON	ON	ON	OFF	OFF	OFF	0	+VDC	-VDC	Active
{010}	OFF	ON	ON	OFF	OFF	ON	-VDC	+VDC	0	Active
{011}	OFF	OFF	ON	OFF	ON	ON	-VDC	0	+VDC	Active
{001}	OFF	OFF	OFF	ON	ON	ON	0	-VDC	+VDC	Active
{101}	ON	OFF	OFF	ON	ON	OFF	+VDC	-VDC	0	Active
{111}	ON	OFF	ON	OFF	ON	OFF	0	0	0	Zero

Traction inverter | failure modes and prevention

TRACTION INVERTER SYSTEM IMPACT	MECHANICAL CAUSE	ELECTRONICS CAUSE	PREVENTION MECHANISM
Under torque	Coil short or open	IGBT short or open	IGBT protection
		Gate driver damaged	Self-test and diagnostics
		Gate driver output latched	
		Gate driver incorrect logic	
		Isolation Failure	
		MCU failure	MCU watchdog
		PMIC failure	PMIC monitor
		Sensor failure	Redundant sensing
Over torque	N/A	MCU failure	MCU watchdog
		Sensor failure	Redundant sensing
Unintended motor commutation	N/A	MCU failure	MCU watchdog
Unintended motor shutdown / no output	Coil short or open	IGBT short or open	IGBT protection
		DC bus failure	Voltage monitor
		MCU failure	MCU watchdog
		PMIC failure	PMIC monitor

Agenda

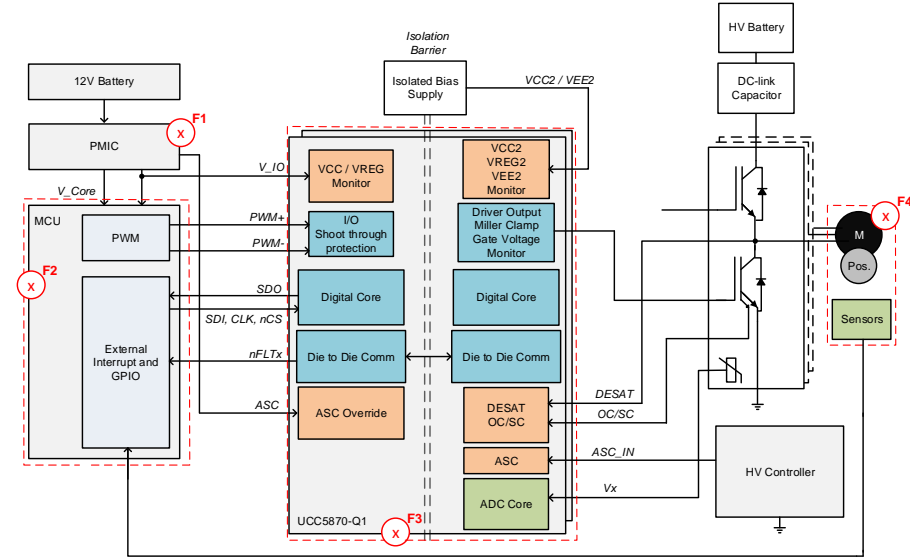
- HEV/EV System Architectures
- Traction Inverter Overview and Failure Modes
- UCC5870-Q1 Integrated Features and Protection Mechanisms
- Summary

UCC5870-Q1 | protection and diagnostic features

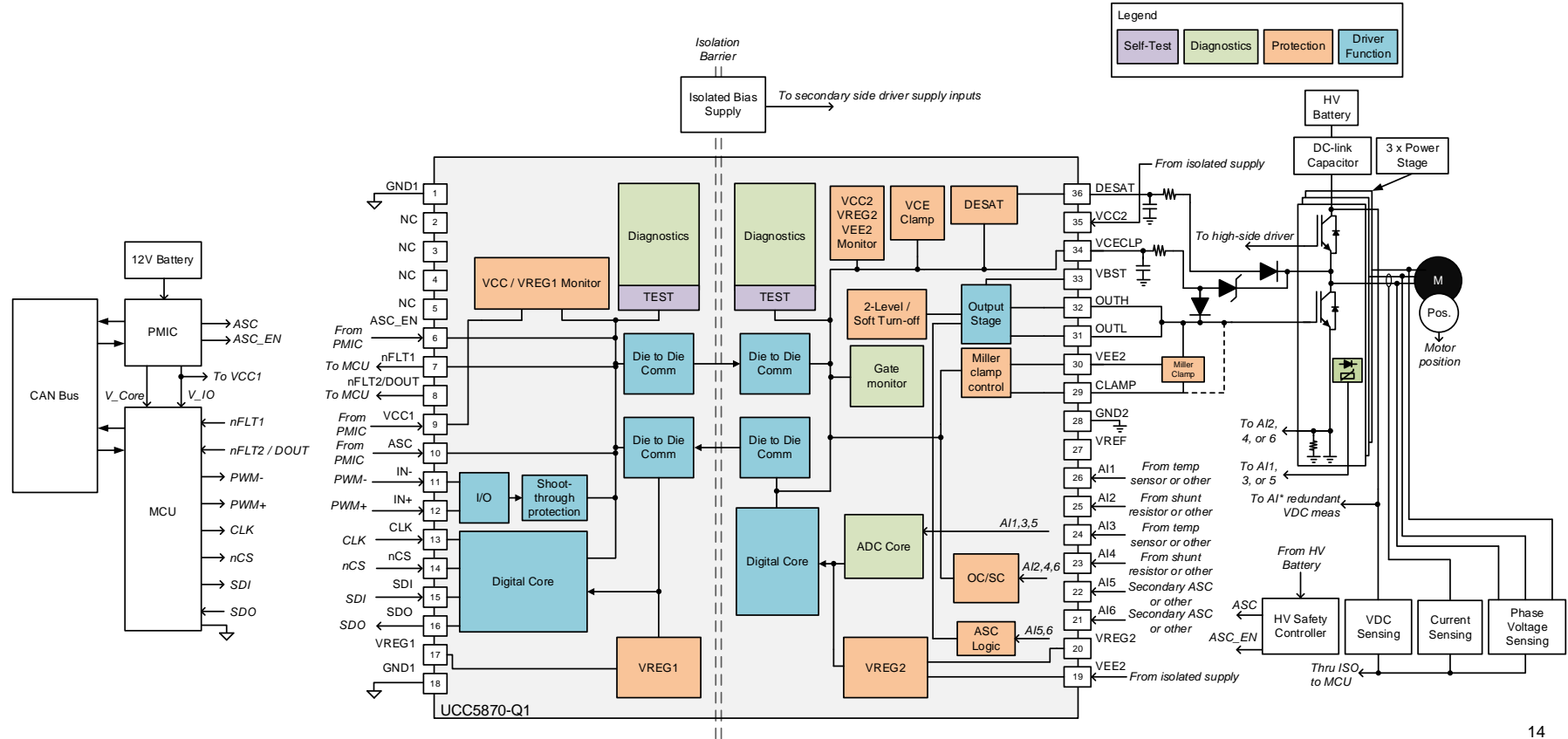
System Impact	Associated driver and/or inverter failures	Potential failure location(s)	UCC5870-Q1 integrated features
Torque disturbance	Over or under voltage of driver power supply	F1	UVLO, OLVO and interrupt
Unintended commutation	Gate driver pulse width skew	F2 or F3	Low-delay capacitive isolation barrier, clock data transmission monitoring
Unintended motor shutdown / Torque disturbance	Power switch short circuit	F2 or F4	DESAT/OC detection and interrupt, DESAT/OC self-test
	Gate shorted to ground or VDD	F2 or F3	VGE monitoring and compare to PWM with interrupt
Unintended motor shutdown	Power switch shoot-through due to false gate signal or dv/dt-induced current	F2	Anti-shoot-through logic and Miller clamp (internal or external)
Torque disturbance	Power switch over-voltage	F4	Two-level turn-off and/or soft turn-off, VCE/VDS monitoring using ADC, VCE clamp
	Power switch over-temperature	F1, F2, or F4	Integrated ADC with biasing current
	Power switch gate oxide breakdown	F2 or F4	Short circuit clamp
	Power switch false turn-on when input power is floating	F1 or F2	Active pulldown
Torque disturbance / Unintended motor shutdown	Power system DC bus over/under voltage	F1 or F4	Integrated ADC

UCC5870-Q1 | protection and diagnostic features

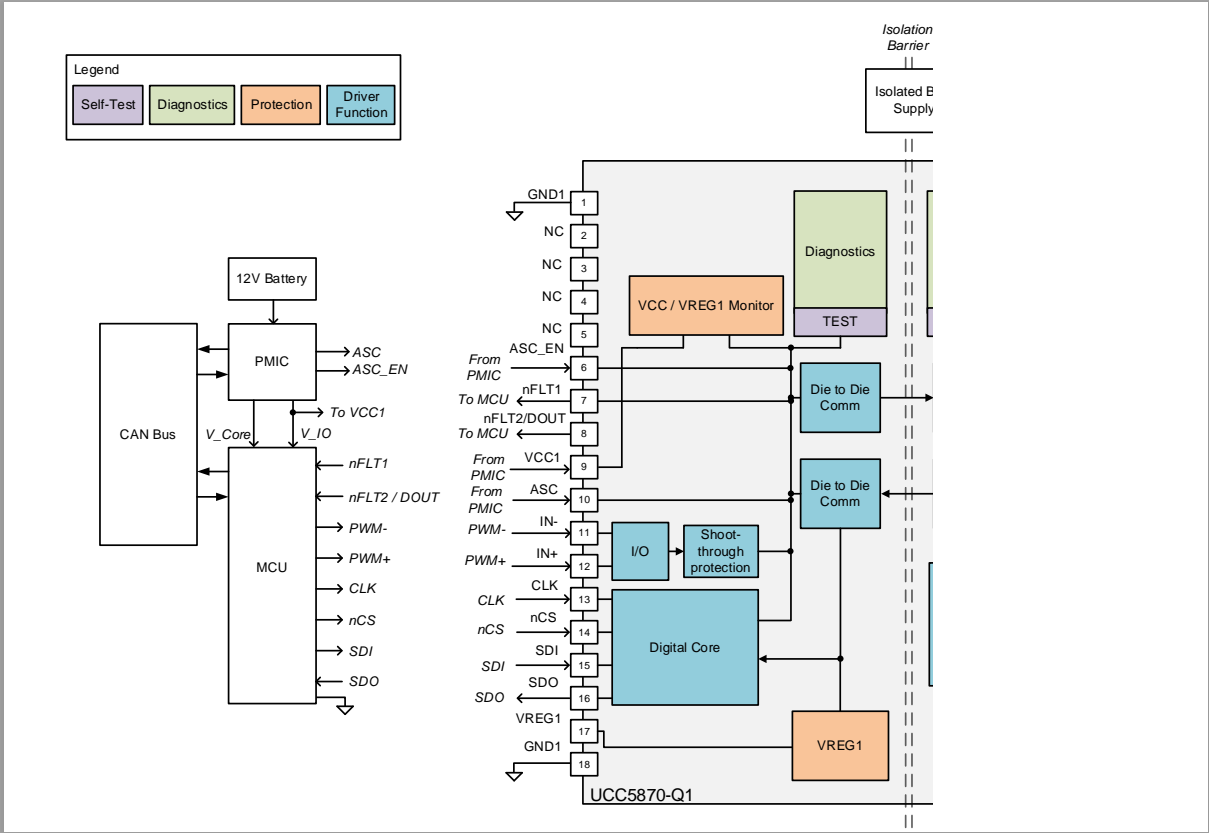
System Impact	Associated driver and/or inverter failures	Potential failure location(s)
Torque disturbance	Over or under voltage of driver power supply	F1
Unintended commutation	Gate driver pulse width skew	F2 or F3
Unintended motor shutdown / Torque disturbance	Power switch short circuit	F2 or F4
	Gate shorted to ground or VDD	F2 or F3
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Torque disturbance	Power switch over-voltage	F4
	Power switch over-temperature	F1, F2, or F4
	Power switch gate oxide breakdown	F2 or F4
	Power switch false turn-on when input power is floating	F1 or F2
Torque disturbance / Unintended motor shutdown	Power system DC bus over/under voltage	F1 or F4



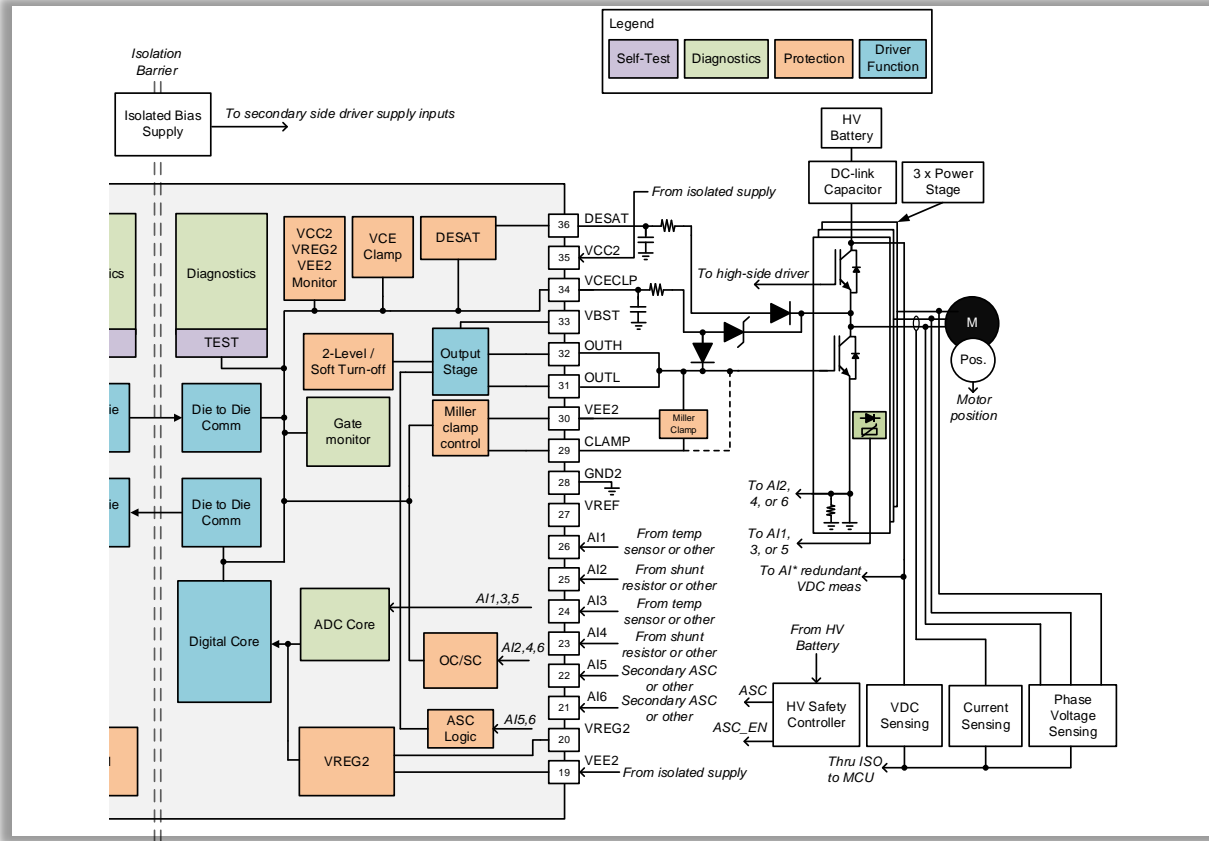
UCC5870-Q1 | inverter block diagram



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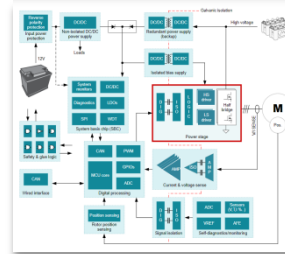
Summary

Key Points

- There are various mechanisms for failures in a HEV/EV traction inverter
- These can be a result of incorrect control or other mechanical failures
- The UCC5870-Q1 can help to detect and protect against common inverter failure modes and provides flexibility by way of SPI configurable parameters

Additional Resources

- [Full Traction Inverter Design Guide](#)
- [TI Solutions for Inverter & motor control](#)



- [UCC5870-Q1 Product Folder on ti.com](#)