How to design heating and cooling systems for HEV/EVs

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As the world drives toward vehicle electrification, semiconductors enable automakers to optimize performance, accelerate development and make EVs more affordable for more people.

Trends & challenges designing HVAC for HEV/EV

Driving range impact

- Migrating from 400V to 800V
- Heat Pump
- Inclusion of Battery thermal management

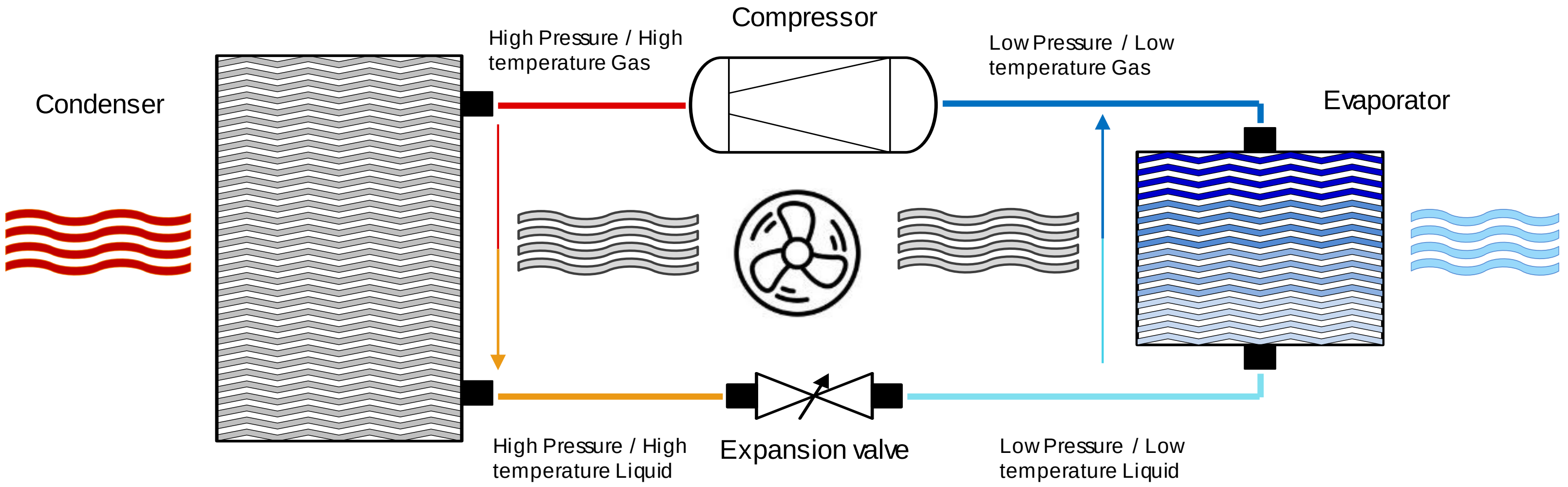
Low Noise and EMI

- MCU design challenges

Affordable solution

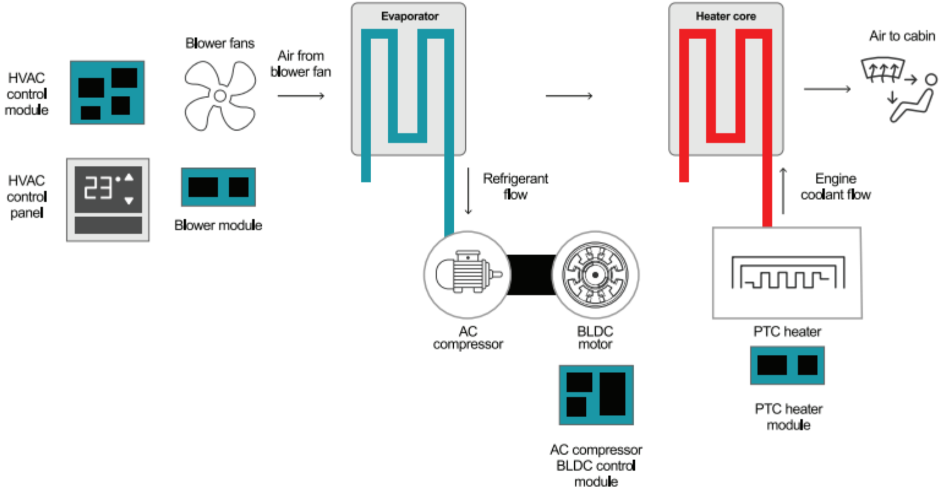
- Needed in every vehicle
- Isolation in High voltage systems
- Isolated power supply topology

Reminding of air conditioning concept

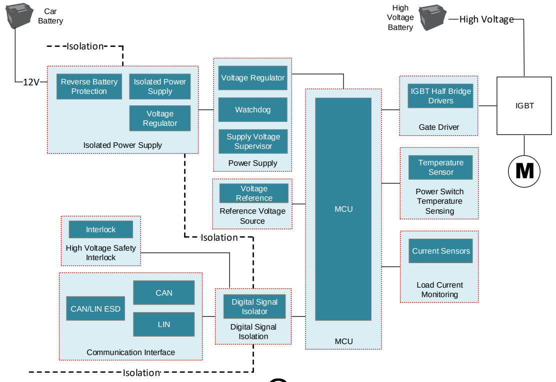


Content of automotive heating and cooling

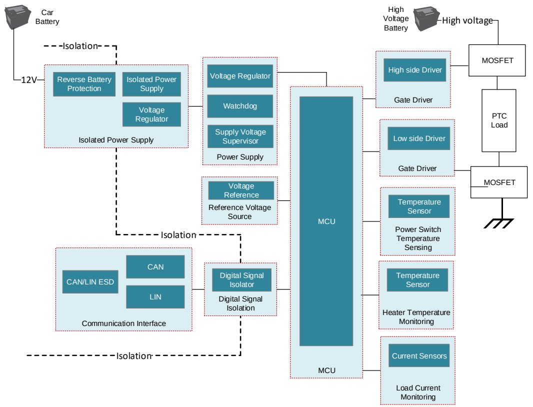
Module	Function
HVAC Control & HMI	Module interfacing with the user as well as controlling the dampers and valves controlling the refrigerant, coolant and air flow
Blower	Blowers are used to move the air through evaporator and heater core to the cabin
Valves	Expansion valve reduces the pressure of the refrigerant fluid upstream of the evaporator. Shut off/direction valves allow the change or direction of the refrigerant and/or coolant.
Compressor	The AC compressor compresses the refrigerant, cooling the air passing through the evaporator
PTC heater	The PTC heater warm the coolant, warming the air passing through the heater core



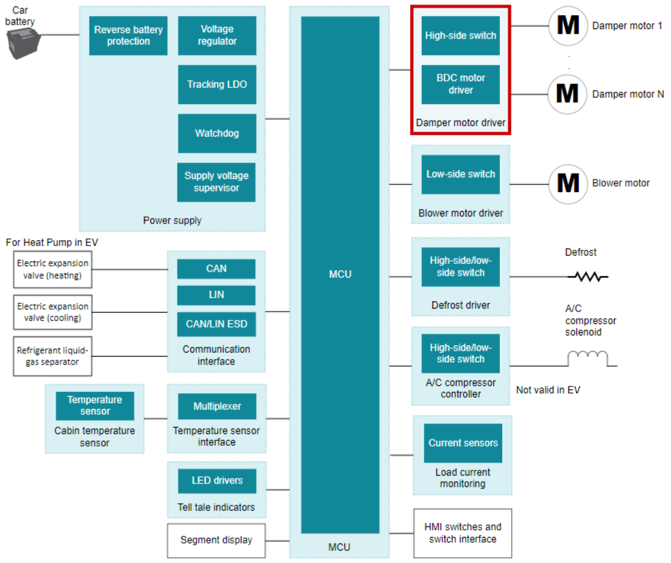
Key subsystems



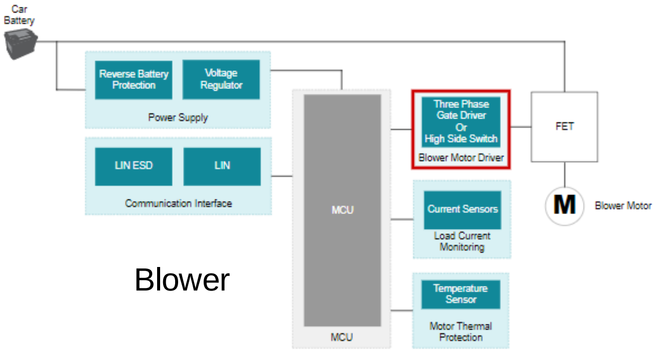
Compressor



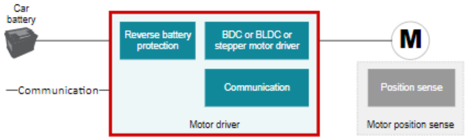
PTC Heater



HVAC Control and HMI



Blower

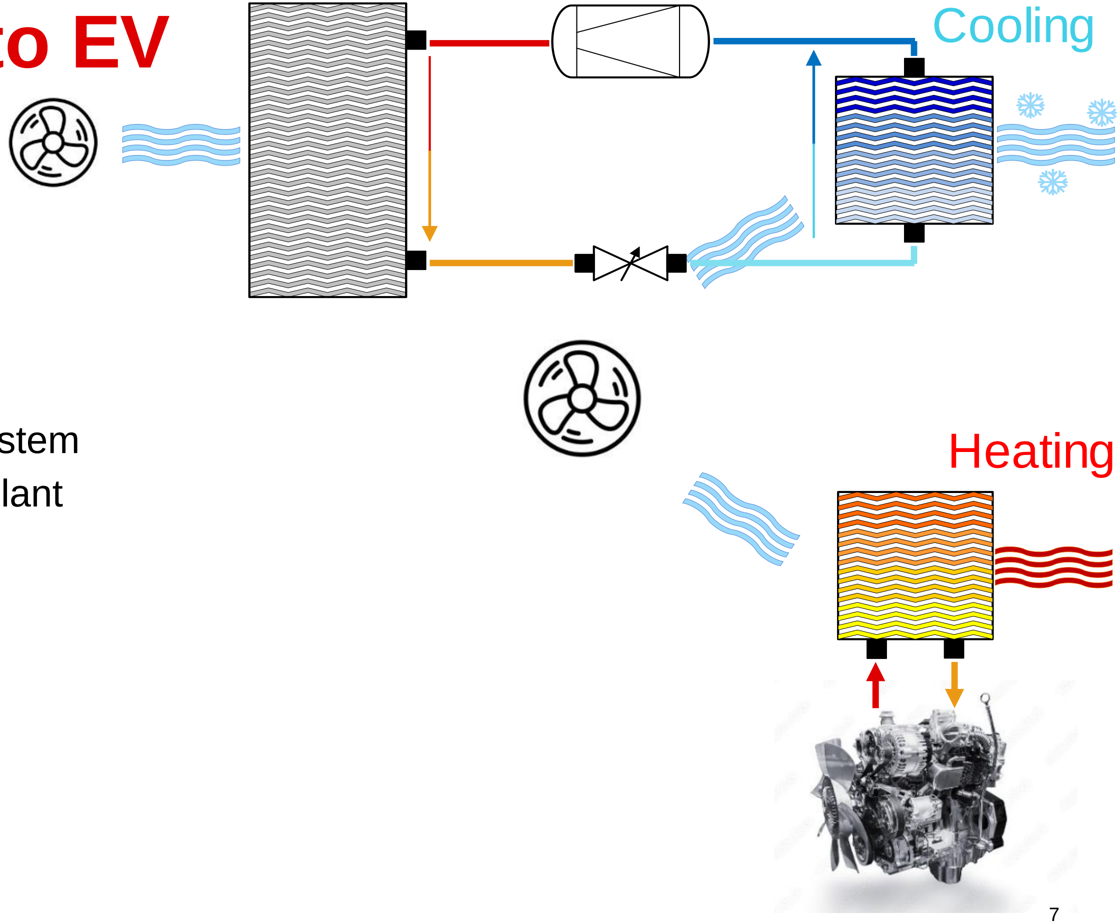


Valve

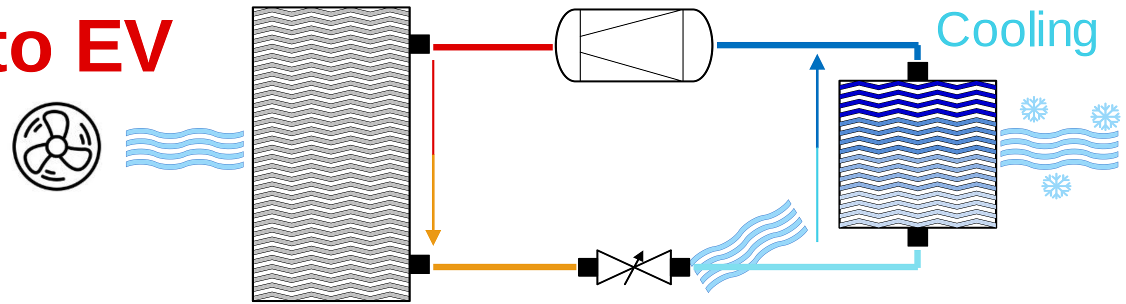
Migrating from ICE to EV

ICE

- Cooling
  - Using the Air Conditioning circuit
- Heating
  - 1/3 power for mechanical motion
  - 1/3 power dissipated by exhaust system
  - 1/3 power dissipated by engine coolant
    - Can be use to heat the cabin

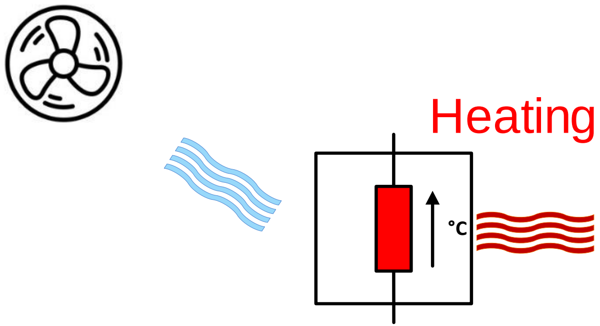


Migrating from ICE to EV

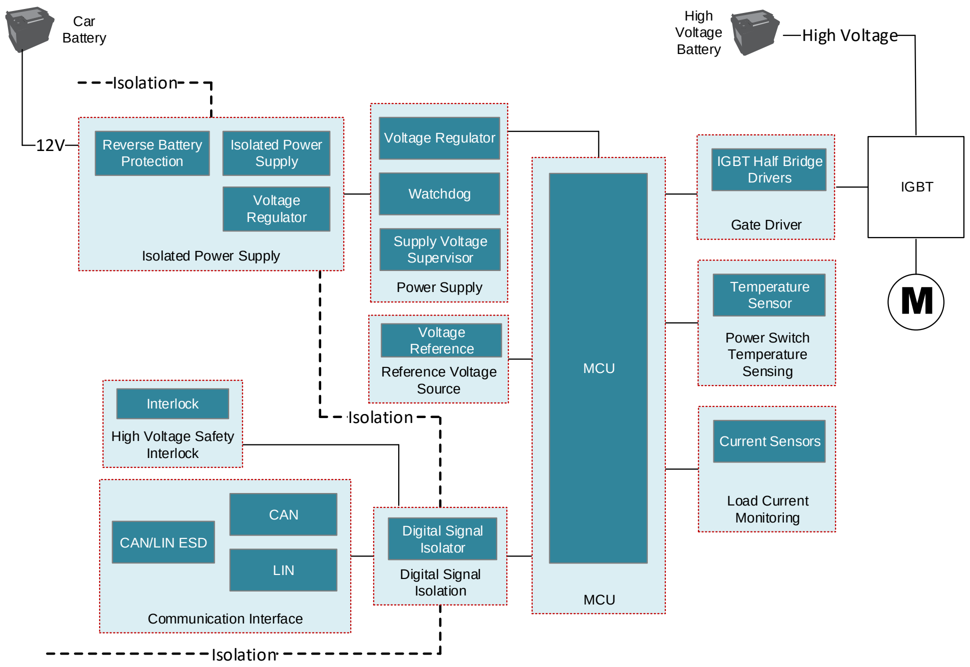


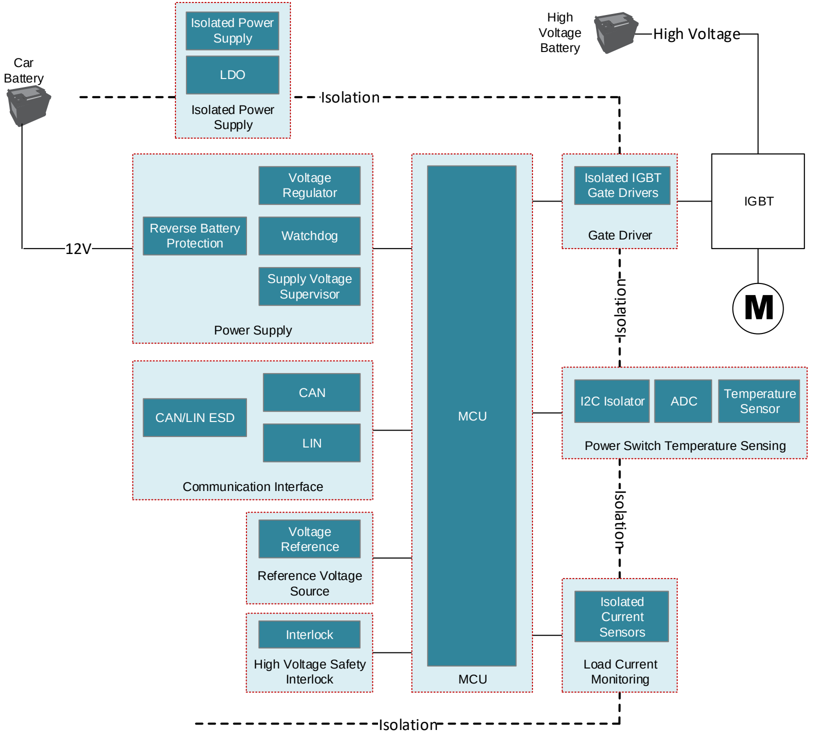
EV

- Cooling is similar than ICE
- Heating
  - Electric motor is significantly more efficient
    - Less heat to dissipate
      - Longer time to heat coolant
      - Less effective as heat source as less temperature difference between coolant temperature and cabin temperature
  - Addition of PTC/resistive heater
    - Around 100% efficiency
    - Instantaneous
    - Impact driving range
  - Heat pump (see later)

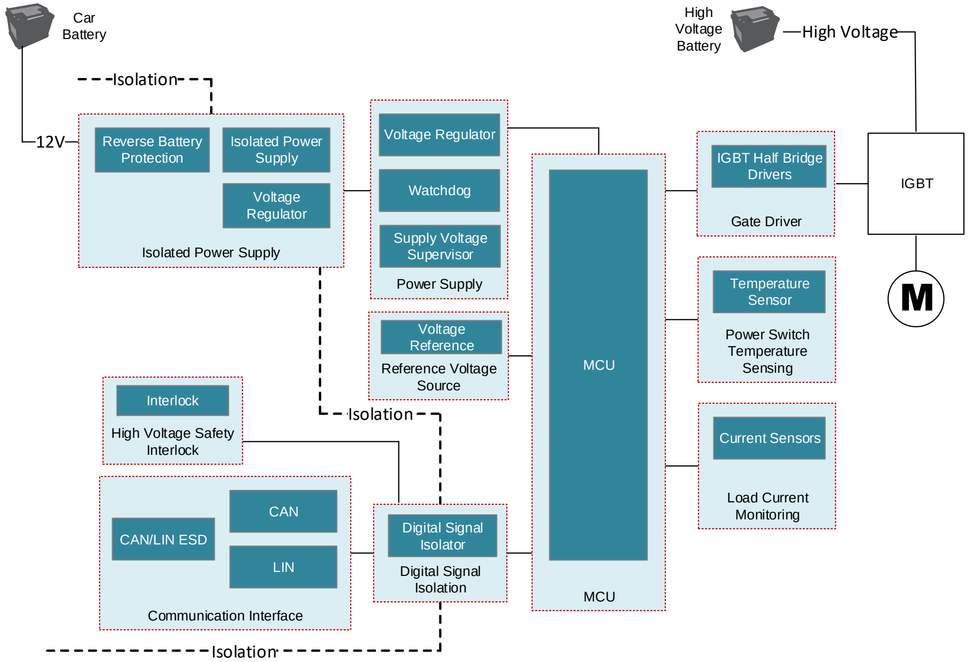


Isolation in high-voltage systems: where to put it?





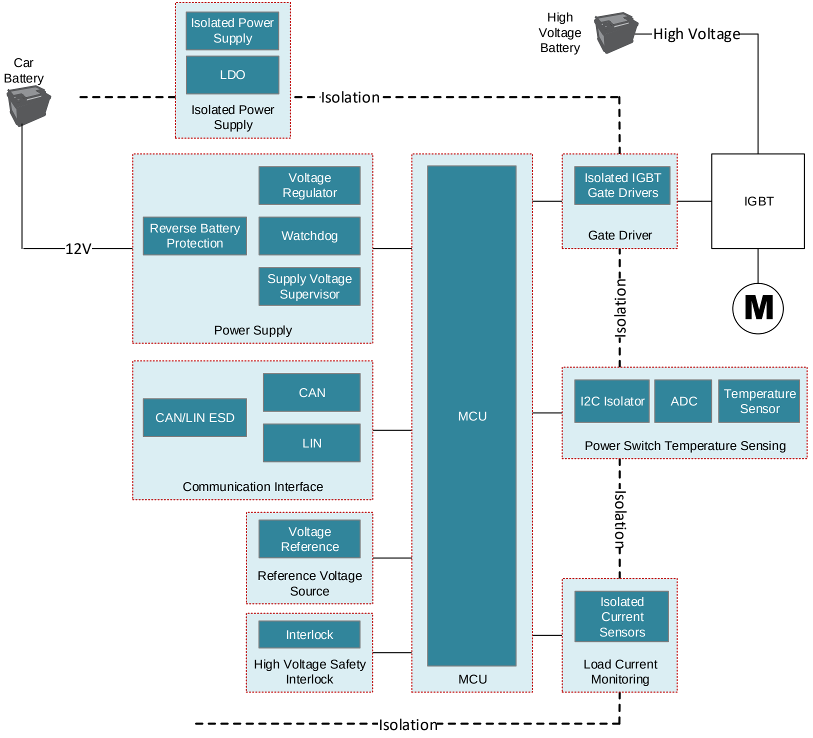
Isolated communication



- Isolation through the power supply and the communication
- Non isolated gate driver
- Non isolated current / voltage / temperature sensing
- Low side current sensing is often preferred (good enough and lower cost)

Isolated driver

- Isolation through the power supply, the gate drivers and the current / voltage / temperature sensing
- As isolated current sensing is present, in-line current sensing is feasible with no additional cost
- Not usually used for Heating and Cooling applications

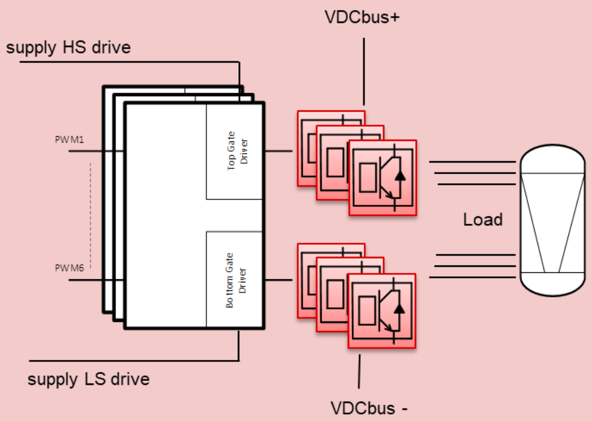


Migrating from 400V to 800V

- Increase in power without increasing current
- Add creepage distance
- Often migrate from IGBT to SIC
- Additional stress on isolation, power supply
- Non isolated drivers limitation (700V abs max)
- Isolated drivers due to voltage rating
- Number of bias rails
- Platform approach for 400V and 800V

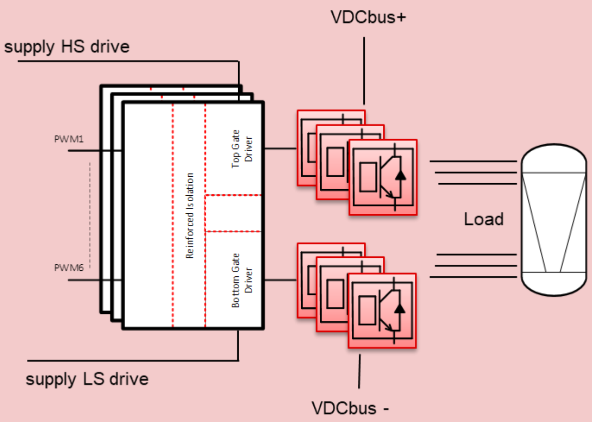
Exploring 48V / 400V / 800 V platform

Non isolated half bridge driver
48V / 400V Compressor



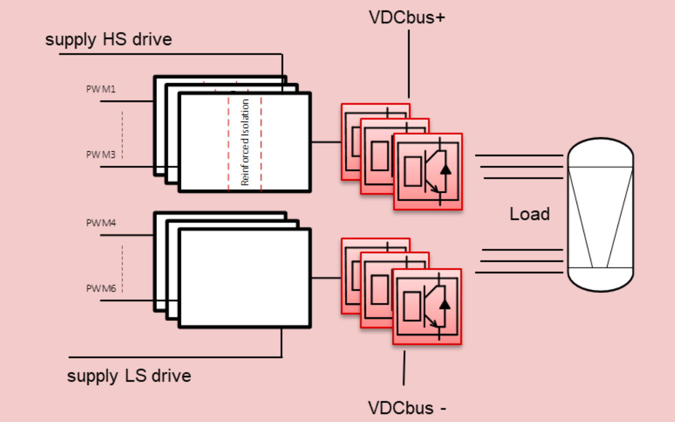
Hero product:
UCC27712: half bridge driver with interlock

Dual-channel isolated gate driver
48V / 400V / 800V Compressor and PTC Heater



Hero product:
UCC21530: dual-channel isolated gate driver for IGBT/SiC

Isolated high side driver / non isolated low side driver
48V / 400V / 800V Compressor and PTC Heater

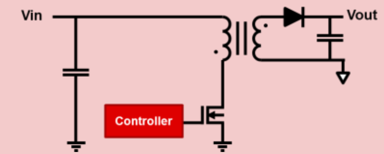
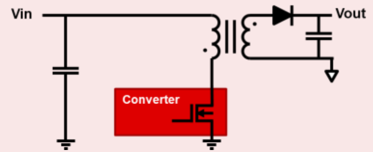
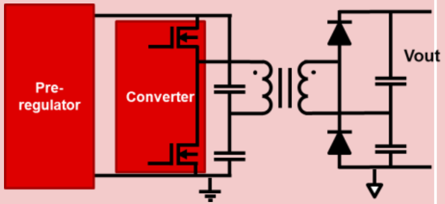
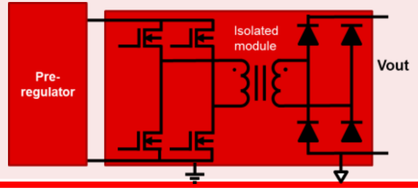


Hero products:
UCC5350-Q1: single-channel isolated gate driver
UCC27524A-Q1: dual channel Low Side driver with improved transient protection

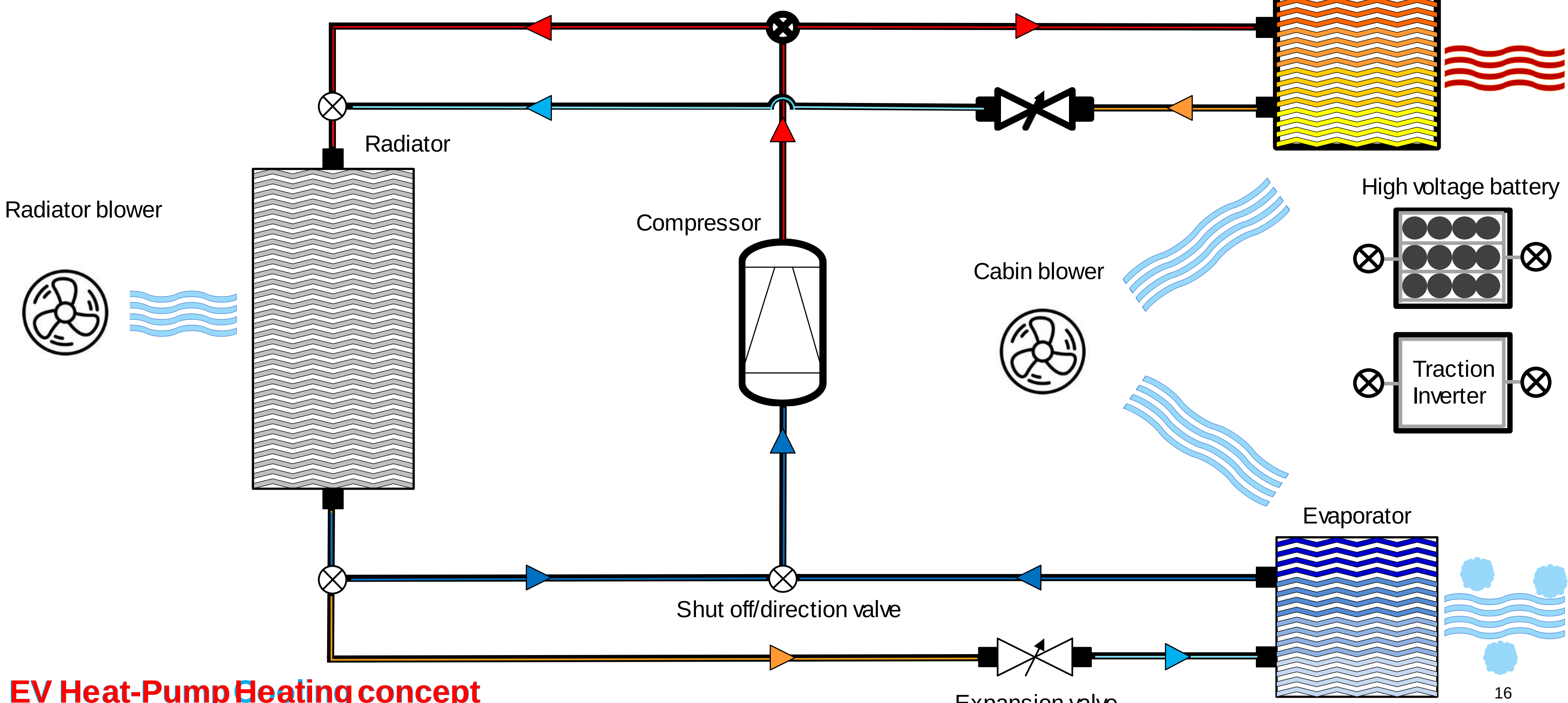
Isolation power supply

- Input voltage ~6 to 16V operating, ~4V to 45V abs
- Usually no redundancy
- 1 Bias rail vs 4/6 rails for isolated drivers
- Single stage versus dual stage

Isolation power supply

Topology		Pro's	Con's	Hero product
Single stage Flyback controller		- Can adjust slew rate for EMI - No pre-regulator needed	- Aux winding required - Needs low leakage inductance to avoid ringing - Larger parasitic capacitance, meaning low CMTI, high EMI	LM34966-Q1
Single stage PSR Flyback converter		- Integrated FETs - No aux winding - No pre-regulator needed	- Cannot adjust slew rate - Needs low leakage inductance to avoid ringing - Larger parasitic capacitance, meaning low CMTI, high EMI	LM(2)518x-Q1
Dual stage LLC		- No aux winding - Leakage inductance is used as resonant inductor - Low parasitic capacitance between windings - Excellent EMI mitigation	- Pre-regulator needed - Open loop	UCC25800-Q1
Dual-stage isolated power module		- Integrated transformer and FETs - Ease of design - Smaller area and height	- Pre-regulator needed - Higher perceived cost	UCC14240-Q1

Understanding heat pump



Understanding heat pump

- Around 100% efficiency for PTC heater
- In several situation, a system with heat pump can have an efficiency between 3 to 4 times higher than with a PTC heater
- Increase complexity (number of valves, refrigerant/coolant circuit, pumps…)
- Limitation at low external temperature

Inclusion of battery

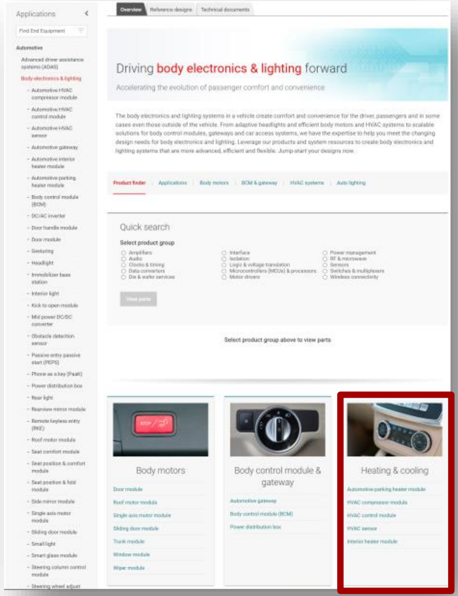
- Addition of battery pack and power train add heat source/system to cool
- Heating and cooling system is now part of the functional safety concept
- Usually ASIL B is required

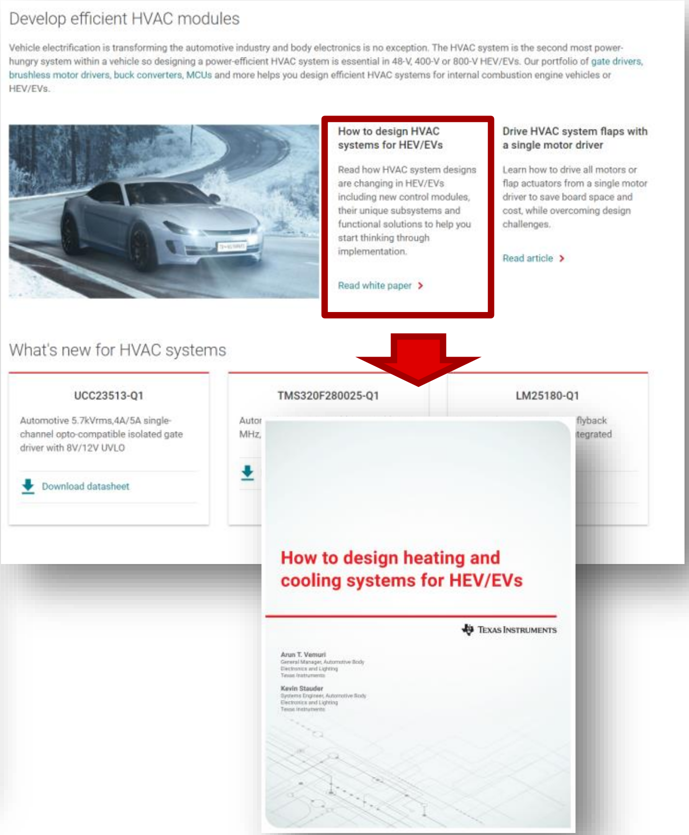
MCU design challenges

- Reliable sensorless control
  - Ease of use InstaSpin-FOC
  - Ease of use SW, example designs and system expertise
- Real-time MCU considerations
  - Scalability (pin count, flash memory, communication interfaces,…)
  - Low audible noise and low EMI
- Functional safety
  - Scalability up to Asil D
  - Comply with ISO26262

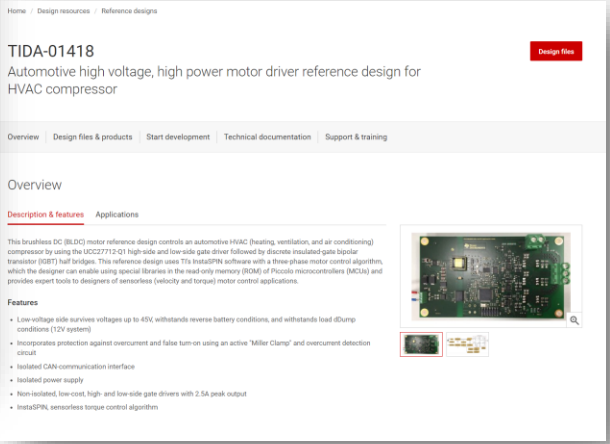
Get help & resources

- TI representatives
- TI.com/body





Reference design



https://www.ti.com/tool/TIDA-01418