

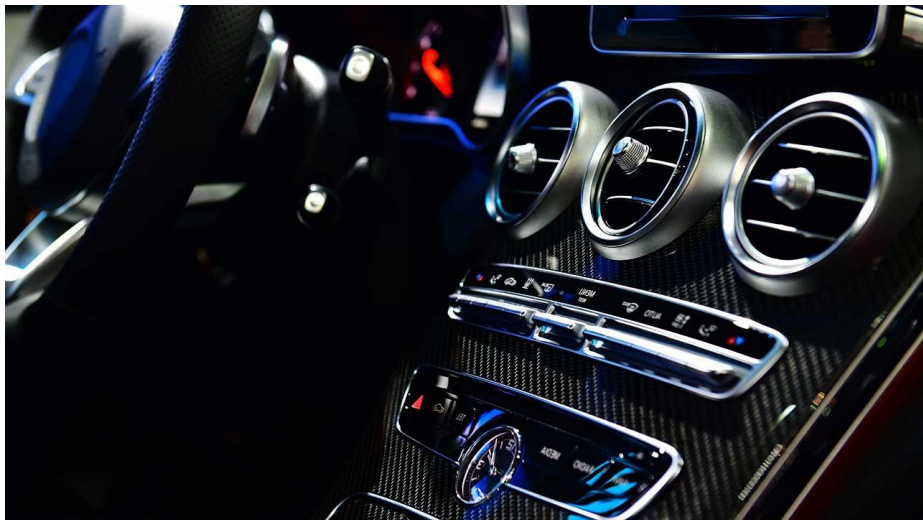
# How to design heating and cooling systems for HEV/EVs

**Kevin Stauder (System Engineer- Automotive Heating and Cooling)**

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

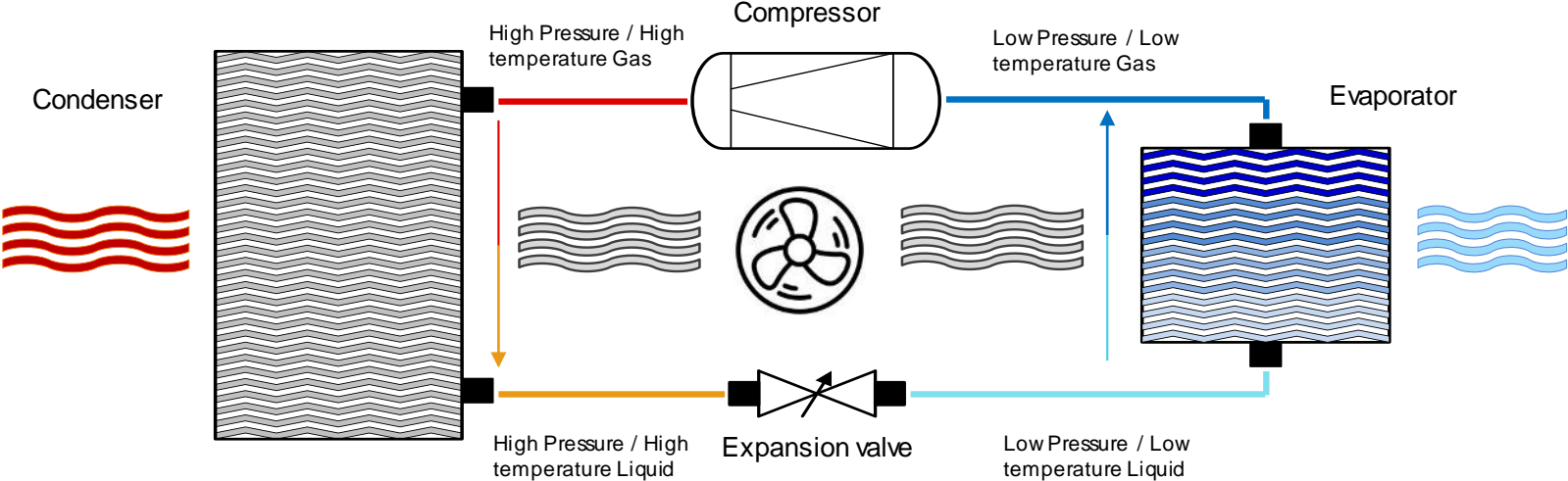
## Low Noise and EMI

- MCU design challenges

## Affordable solution

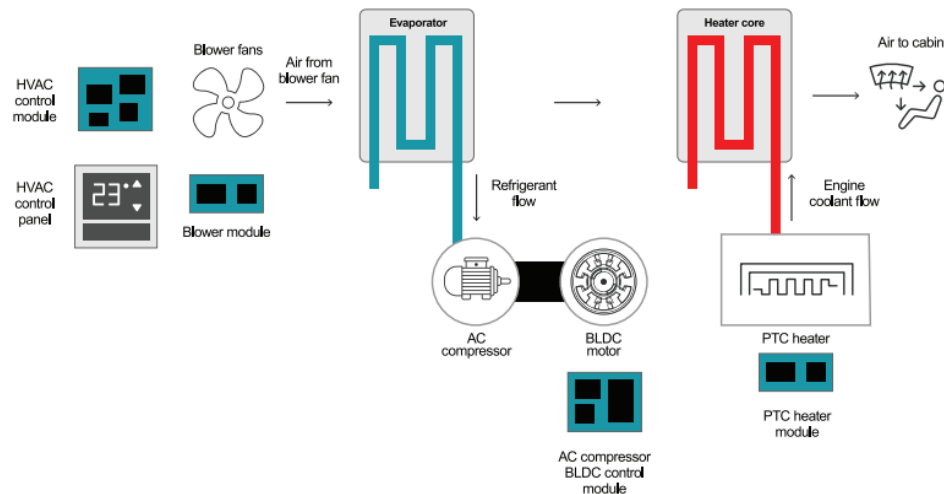
- Needed in every vehicle
- Isolation in High voltage systems
- Isolated power supply topology

# Reminding of air conditioning concept

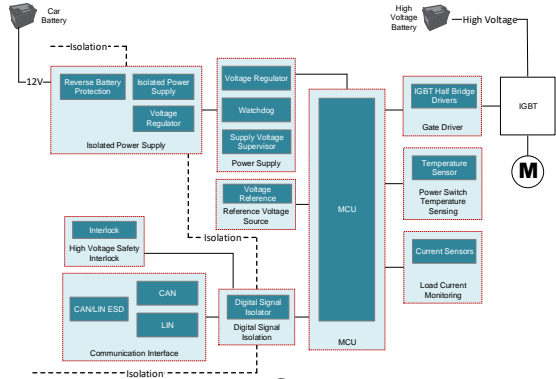


# Content of automotive heating and cooling

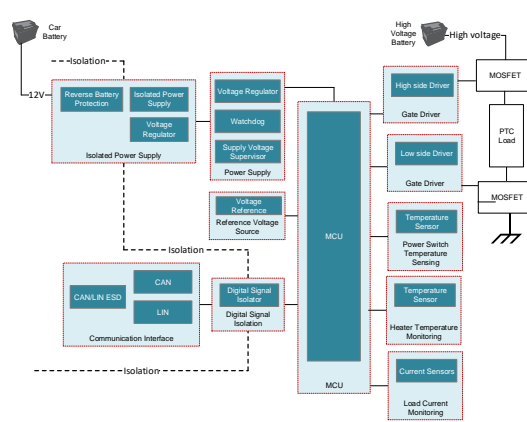
Module	Function
HVAC Control & HMI	Module interfacing with the user as well as controlling the dampers and valves controlling the refrigerant, coolant and air flow
Blower	Blowers are used to move the air through evaporator and heater core to the cabin
Valves	<u>Expansion valve</u> reduces the pressure of the refrigerant fluid upstream of the evaporator. <u>Shut off/direction valves</u> 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



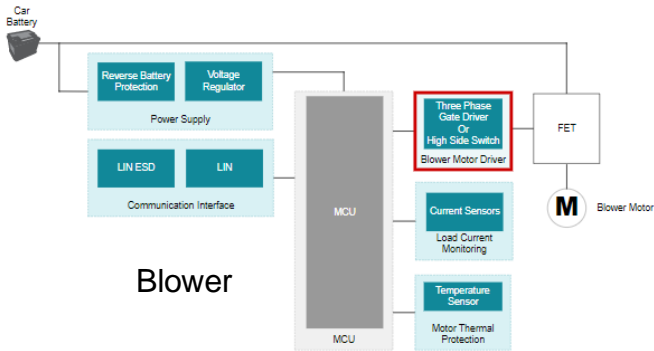
# Key subsystems



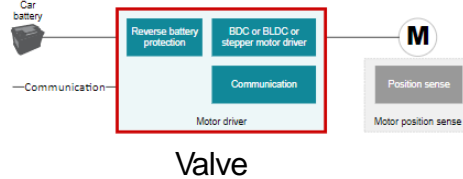
Compressor



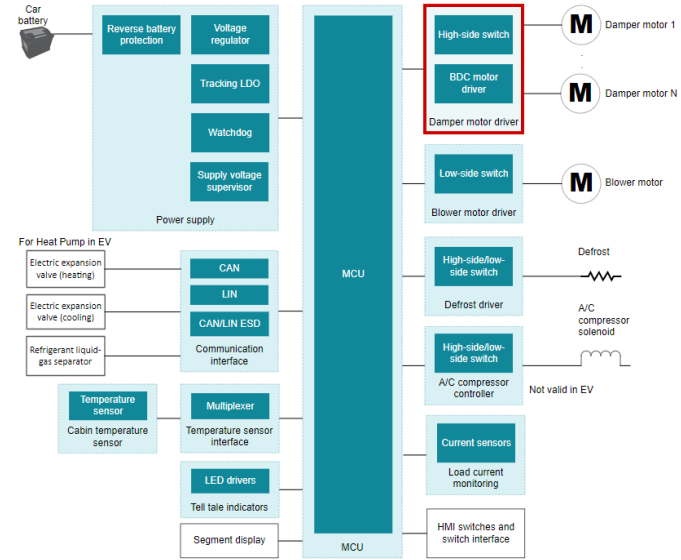
PTC Heater



Blower



Valve

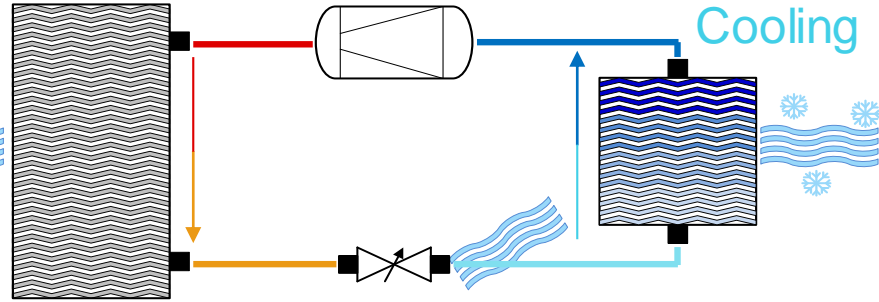


HVAC Control and HMI

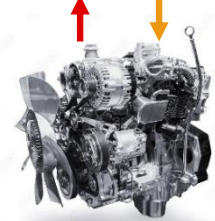
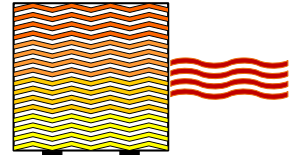
# Migrating from ICE to EV

## 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



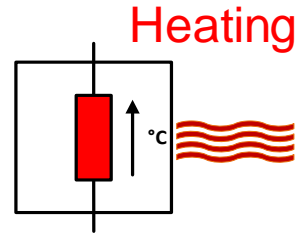
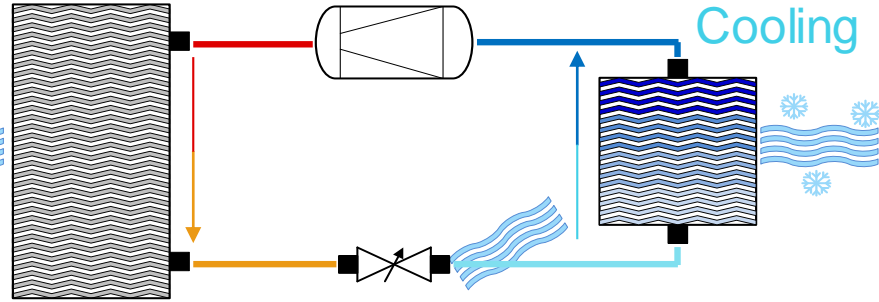
## Heating



# Migrating from ICE to EV

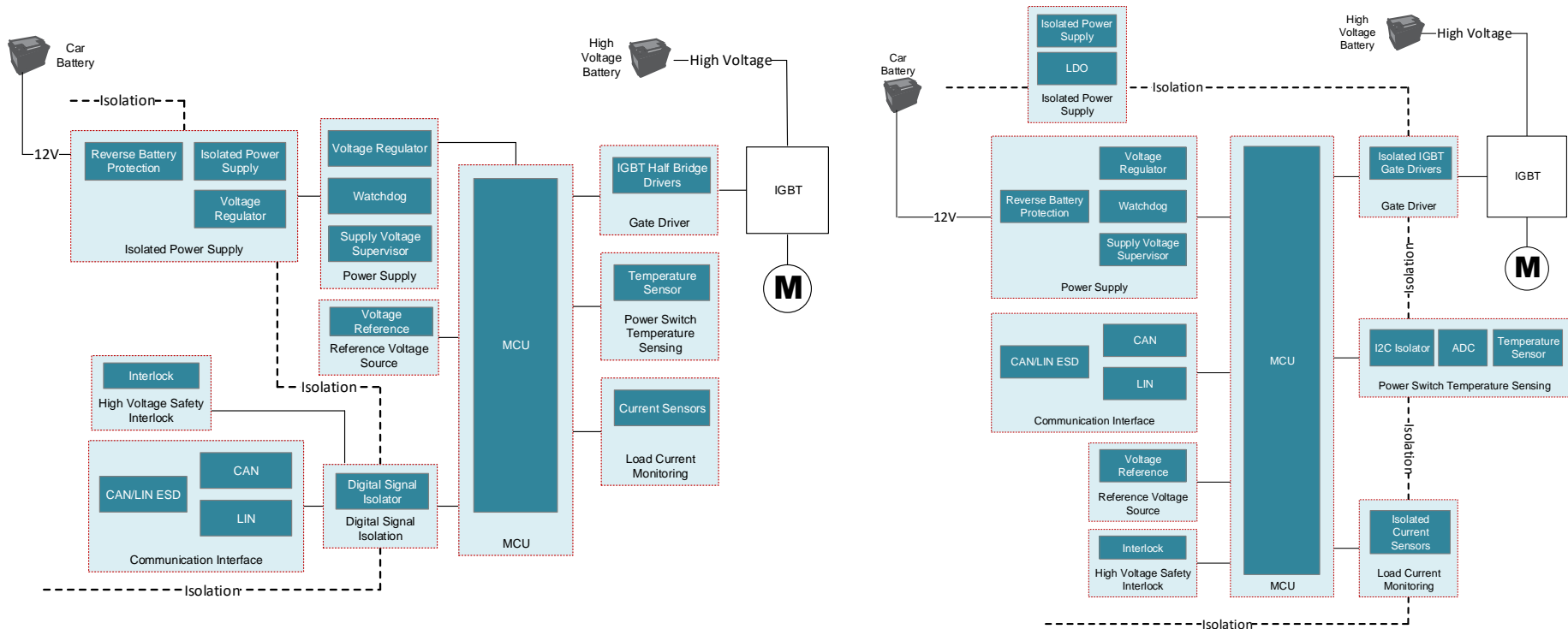
## EV

- 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)

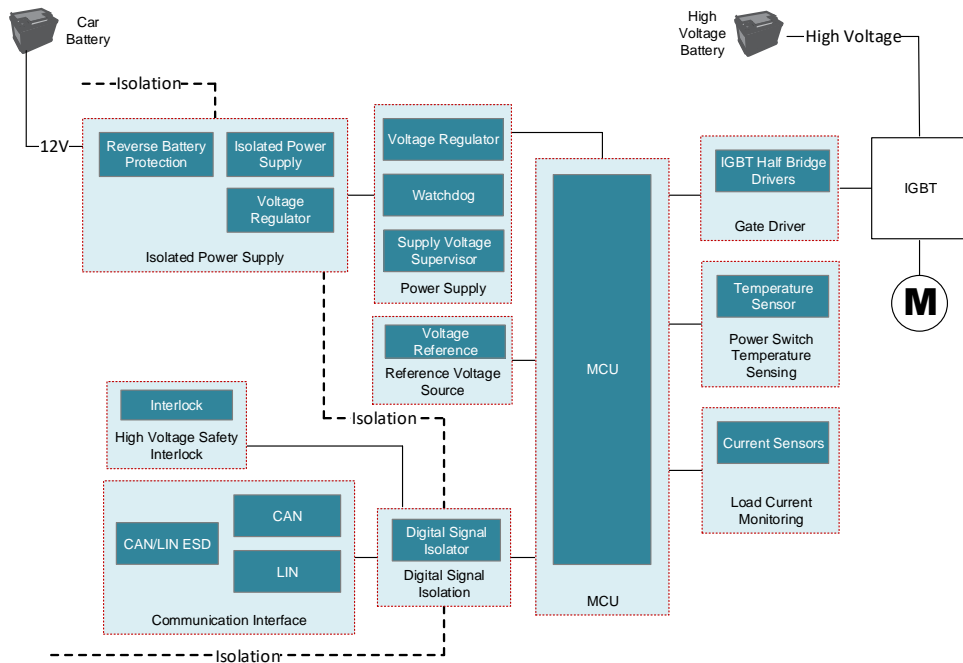




# Isolation in high-voltage systems: where to put it?



# 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)

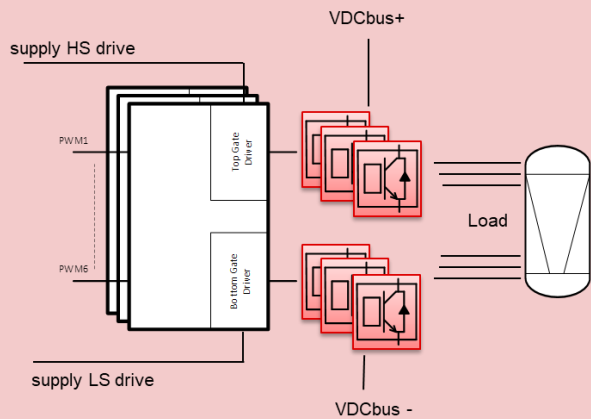


# Migrating from 400V to 800V

- 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

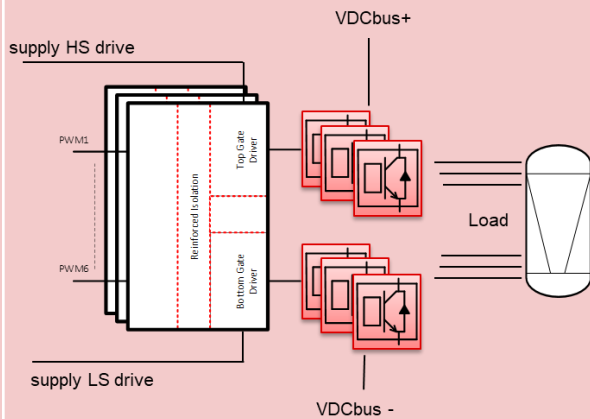
# Exploring 48V / 400V / 800 V platform

**Non isolated half bridge driver**  
48V / 400V Compressor



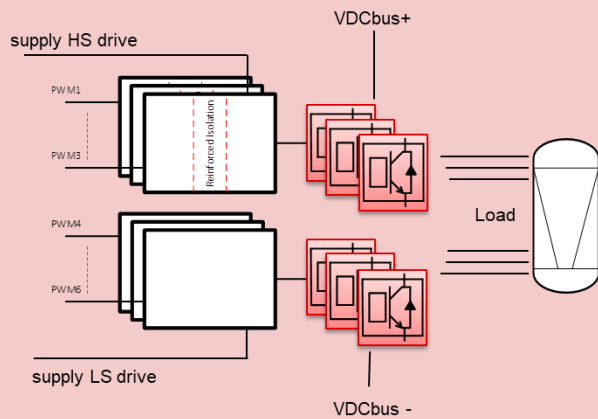
Hero product:  
UCC27712: half bridge driver with interlock

**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

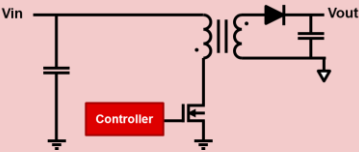
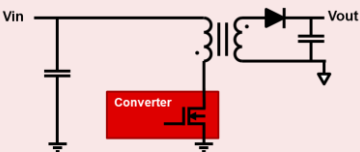
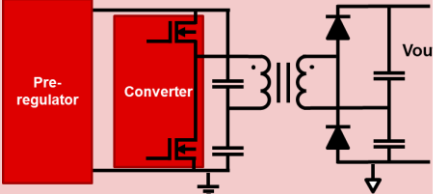
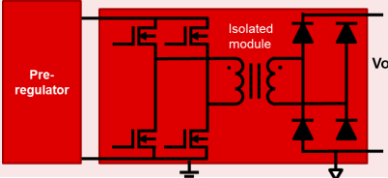


Hero products:  
UCC5350-Q1: single-channel isolated gate driver  
UCC27524A-Q1: dual channel Low Side driver  
with improved transient protection

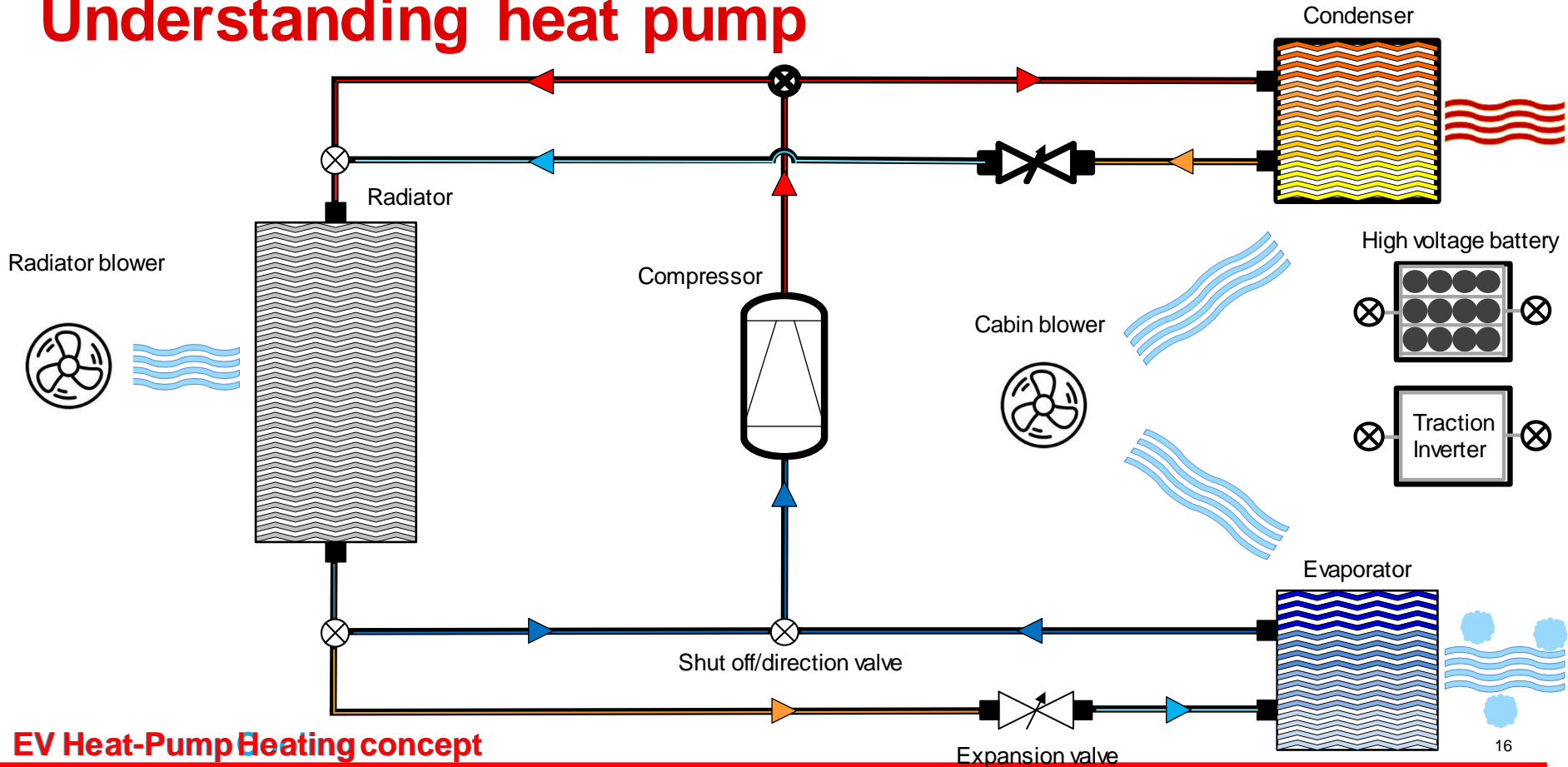
# Isolation power supply

- 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 	<ul style="list-style-type: none"> <li>- Can adjust slew rate for EMI</li> <li>- No pre-regulator needed</li> </ul>	<ul style="list-style-type: none"> <li>- Aux winding required</li> <li>- Needs low leakage inductance to avoid ringing</li> <li>- Larger parasitic capacitance, meaning low CMTI, high EMI</li> </ul>	LM34966-Q1
Single stage PSR Flyback converter 	<ul style="list-style-type: none"> <li>- Integrated FETs</li> <li>- No aux winding</li> <li>- No pre-regulator needed</li> </ul>	<ul style="list-style-type: none"> <li>- Cannot adjust slew rate</li> <li>- Needs low leakage inductance to avoid ringing</li> <li>- Larger parasitic capacitance, meaning low CMTI, high EMI</li> </ul>	LM(2)518x-Q1
Dual stage LLC 	<ul style="list-style-type: none"> <li>- No aux winding</li> <li>- Leakage inductance is used as resonant inductor</li> <li>- Low parasitic capacitance between windings</li> <li>- Excellent EMI mitigation</li> </ul>	<ul style="list-style-type: none"> <li>- Pre-regulator needed</li> <li>- Open loop</li> </ul>	UCC25800-Q1
Dual-stage isolated power module 	<ul style="list-style-type: none"> <li>- Integrated transformer and FETs</li> <li>- Ease of design</li> <li>- Smaller area and height</li> </ul>	<ul style="list-style-type: none"> <li>- Pre-regulator needed</li> <li>- Higher perceived cost</li> </ul>	UCC14240-Q1

# Understanding heat pump



EV Heat-Pump Heating concept



# 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](https://www.ti.com/body)

The screenshot shows the TI.com/body website interface. On the left is a navigation menu with categories like 'Automotive', 'Body electronics & lighting', 'Automotive HVAC compressor module', 'Automotive HVAC control module', 'Automotive HVAC sensor', 'Automotive gateway', 'Automotive motor heater module', 'Automotive parking heater module', 'Body control module (BCM)', 'iBCM heater', 'Door handle module', 'Door module', 'Headlight', 'Headlight beam splitter', 'Interior light', 'Kick-to-open module', 'Mirror power (BCM) sensor', 'Obstacle detection sensor', 'Passive entry passive start (PEPS)', 'Phone on a key (POK)', 'Power distribution box', 'Rear light', 'Rearview mirror module', 'Remote keyless entry (RKE)', 'Roof motor module', 'Seat comfort module', 'Seat position & comfort module', 'Seat position & fold module', 'Side mirror module', 'Single axis motor module', 'Sliding door module', 'Sunlight', 'Sunlight glass module', 'Sunroof motor control module', and 'Thermal relief valve'. The main content area is titled 'Driving body electronics & lighting forward' and includes a 'Quick search' section with filters for 'Select product group' (Body electronics, Body electronics & lighting, Body electronics & lighting - sensors, Body electronics & lighting - actuators, Body electronics & lighting - control) and 'Select product group above to view parts'. Below this are three product category tiles: 'Body motors', 'Body control module & gateway', and 'Heating & cooling'. The 'Heating & cooling' tile is highlighted with a red box and lists sub-categories: 'Door module', 'Roof motor module', 'Single axis motor module', 'Sliding door module', 'Trunk module', 'Wiper module', and 'Wiper module'. The 'Heating & cooling' tile also lists specific components: 'Automotive gateway', 'Body control module (BCM)', 'Power distribution box', 'Automotive parking heater module', 'HVAC compressor module', 'HVAC control module', 'HVAC sensor', and 'Heater heater module'.

## Develop efficient HVAC modules

Vehicle electrification is transforming the automotive industry and body electronics is no exception. The HVAC system is the second most power-hungry system within a vehicle so designing a power-efficient HVAC system is essential in 48-V, 400-V or 800-V HEV/EVs. Our portfolio of gate drivers, brushless motor drivers, buck converters, MCUs and more helps you design efficient HVAC systems for internal combustion engine vehicles or HEV/EVs.



**How to design HVAC systems for HEV/EVs**

Read how HVAC system designs are changing in HEV/EVs including new control modules, their unique subsystems and functional solutions to help you start thinking through implementation.

[Read white paper >](#)

### Drive HVAC system flaps with a single motor driver

Learn how to drive all motors or flap actuators from a single motor driver to save board space and cost, while overcoming design challenges.

[Read article >](#)

## What's new for HVAC systems

The screenshot shows the 'What's new for HVAC systems' section of the TI.com/body website. It features three product highlights: 'UCC32513-Q1 Automotive 5.7kVrms, 4A/5A single-channel opto-compatible isolated gate driver with 8V/12V UVLO', 'TMS320F280025-Q1 AutoMx MHz; flyback integrated', and 'LM25180-Q1'. A large red arrow points from the 'How to design HVAC systems for HEV/EVs' white paper to the 'How to design heating and cooling systems for HEV/EVs' white paper. The latter white paper is highlighted with a red box and lists authors: 'Anas T. Vimal' (Senior Manager, Automotive Body Electronics and Lighting, Texas Instruments) and 'Kevin Riederer' (Systems Engineer, Automotive Body Electronics and Lighting, Texas Instruments). The white paper also features a circuit diagram.

## Reference design

The screenshot shows the TI.com website page for the TIDA-01418 reference design. The page title is 'TIDA-01418 Automotive high voltage, high power motor driver reference design for HVAC compressor'. The page includes a 'Design file' button, navigation links for 'Overview', 'Design files & products', 'Start development', 'Technical documentation', and 'Support & training', and a 'Description & features' section. The 'Description & features' section states: 'This brushless DC (BLDC) motor reference design controls an automotive HVAC (heating, ventilation, and air conditioning) compressor by using the UCC3712-Q1 high-side and low-side gate driver followed by discrete insulated-gate bipolar transistor (IGBT) half-bridges. This reference design uses TI's InstaSPIN software with a three-phase motor control algorithm, which the designer can enable using special features in the read-only memory (ROM) of Piccolo microcontrollers (MPC56xx) and provides expert tools to designers of sensorless (velocity and torque) motor control applications.' The 'Features' section lists: 'Low-voltage side switches voltages up to 45V withstands reverse battery conditions, and withstands load dump conditions (12V system)', 'Incorporates protection against overcurrent and false turn-on using an active "Miller Clamp" and overcurrent detection circuit', 'Isolated CAN communication interface', 'Isolated power supply', and 'Non-isolated, low-cost, high- and low-side gate drivers with 2.5A peak output'. A 'Description & features' section also lists 'InstaSPIN sensorless torque control algorithm'. An image of the reference design PCB is shown on the right.

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