Understanding the transition

From 12 to 48V in electric vehicles

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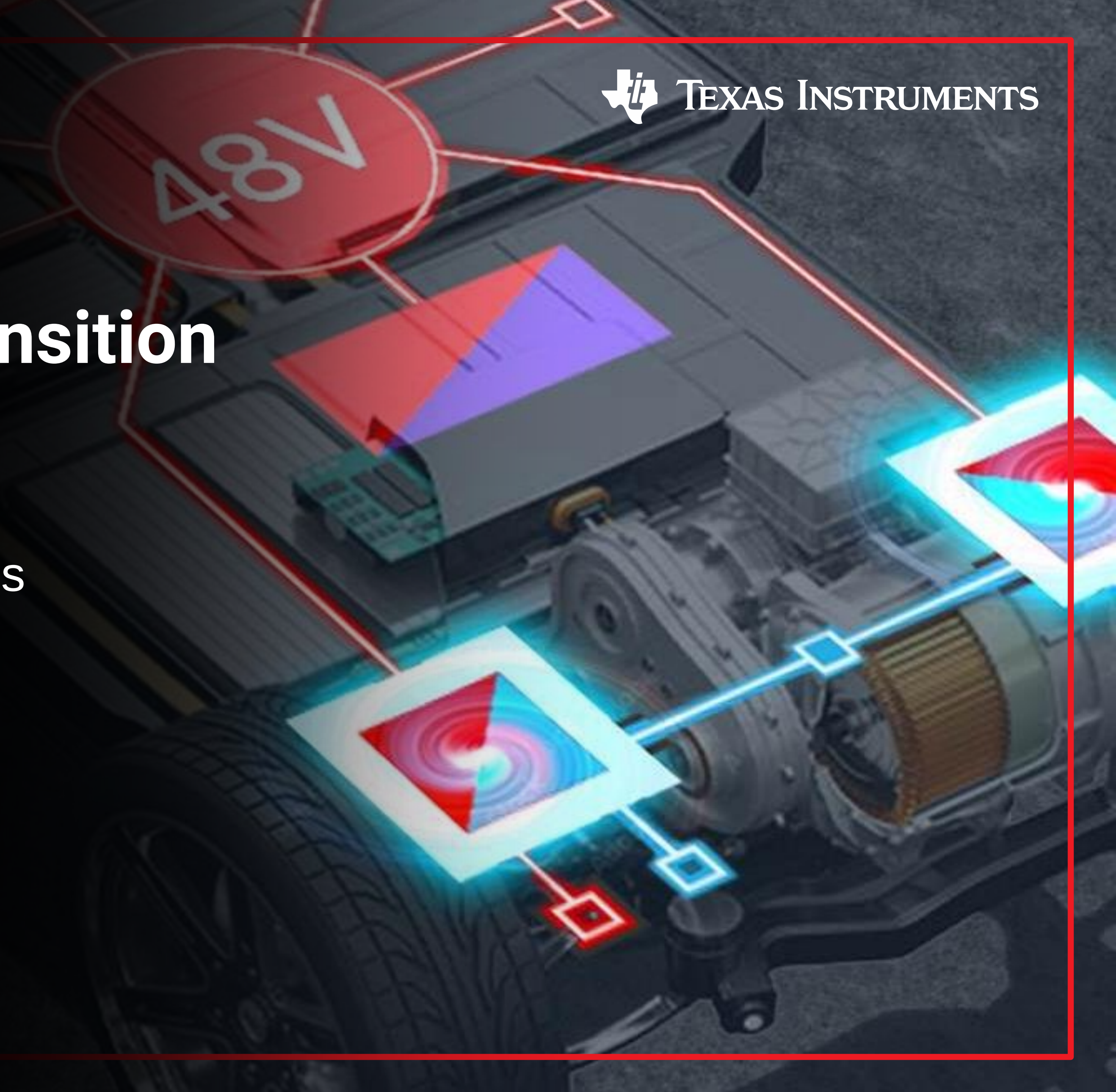


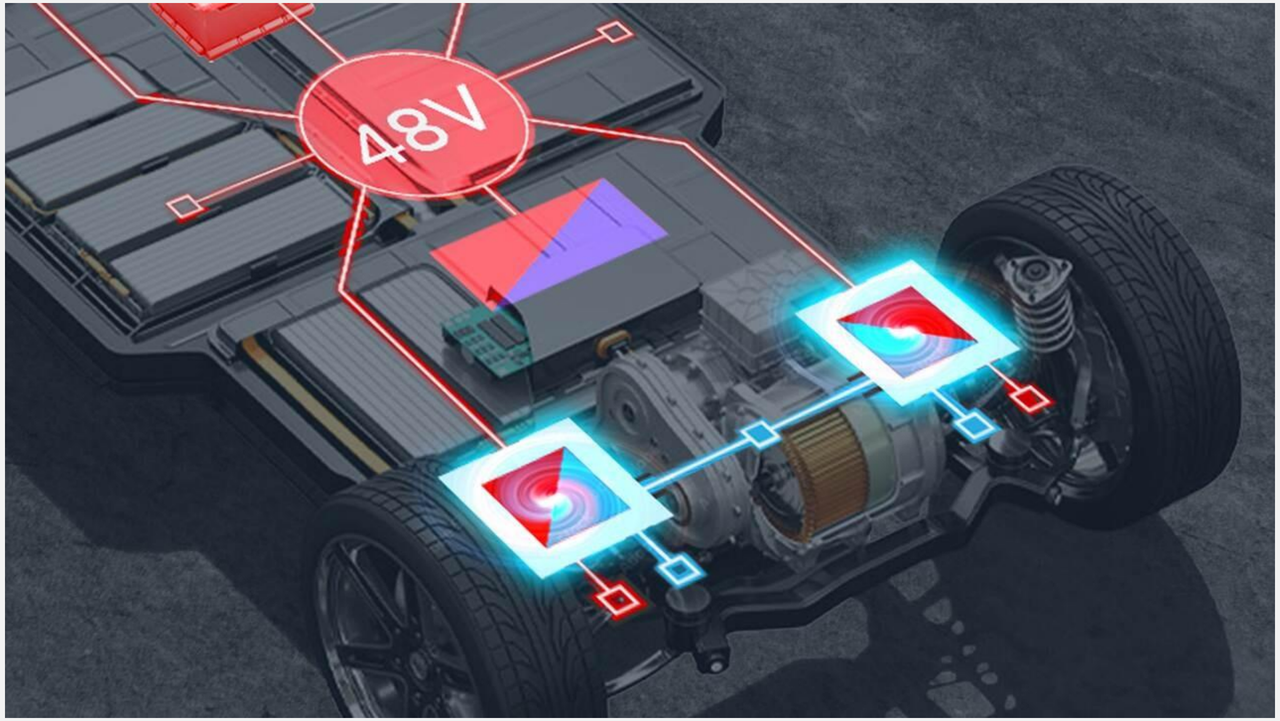
TEXAS INSTRUMENTS

Agenda

- 48V in MHEVs vs BEVs
- Reducing the wire harness
- 48V architectures
- 48V load transition
- 48V design challenges

Transition from 12V to 48V

- Why? Primarily to **reduce wiring harness size, weight, and cost**
  - Voltage ↑, current ↓
- Not a new idea!
  - 42V explored in the 1990's
  - 48V used in mild hybrids
- 48V Sectors
  - **HEV/EV LV rail electrification**
  - Mild Hybrid (MHEV)
  - E-bike, two-wheeler, three-wheeler



48V in MHEV vs HEV/EV

Mild hybrid

Main drive is **ICE**

Vehicle operates on **12V to power the electrical system** and on 48V to power drivetrain, air conditioning, chassis control, and active suspension

48V battery and small electric motor serve to improve efficiency by **recovering braking energy**

Full hybrid and plug-in hybrid

Main drive is **ICE or electric**

Vehicle **operates on HV battery** with additional LV battery

48V low voltage rail would be generated from **HV battery**

Battery electric vehicle (BEV)

Main drive is **electric**

Vehicle **operates on HV battery** with additional LV battery

48V low voltage rail would be generated from **HV battery**

Primary 48V focus from OEMs is on BEVs

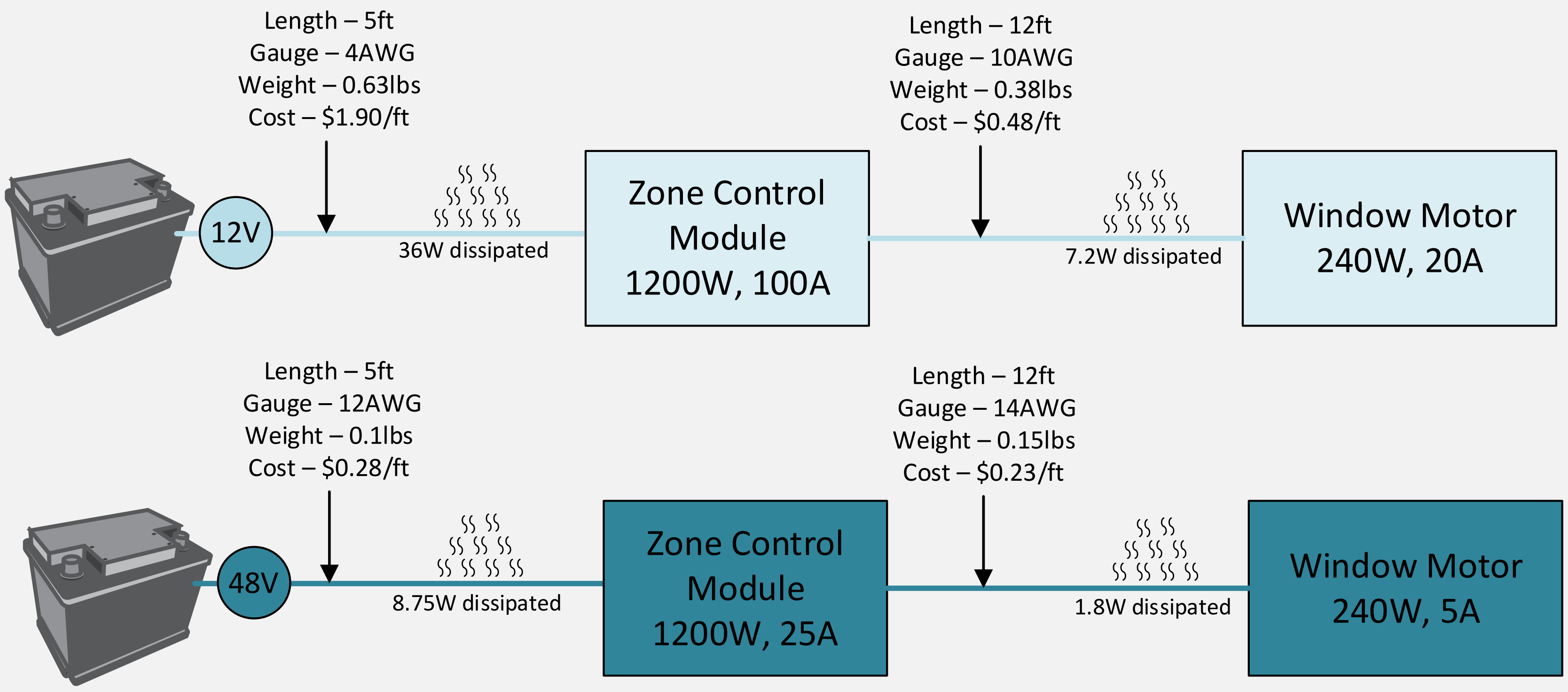
48V benefits & challenges

- **Benefits**
  - Reduced wire gauge (ie. cheaper and lighter)
  - Reduced power loss in wire harness (ie. extended drive range)
  - Reduced PCB and connector size due to current reduction

- **Challenges**
  - 48V accessories (ie. motors)
    - OEMs with vertical integration can develop their own products fast
  - Increased cost of ICs
  - Creepage and clearance requirements of higher voltage
  - Transients and abs max
  - EMI concerns for switching applications

Reducing the wire harness

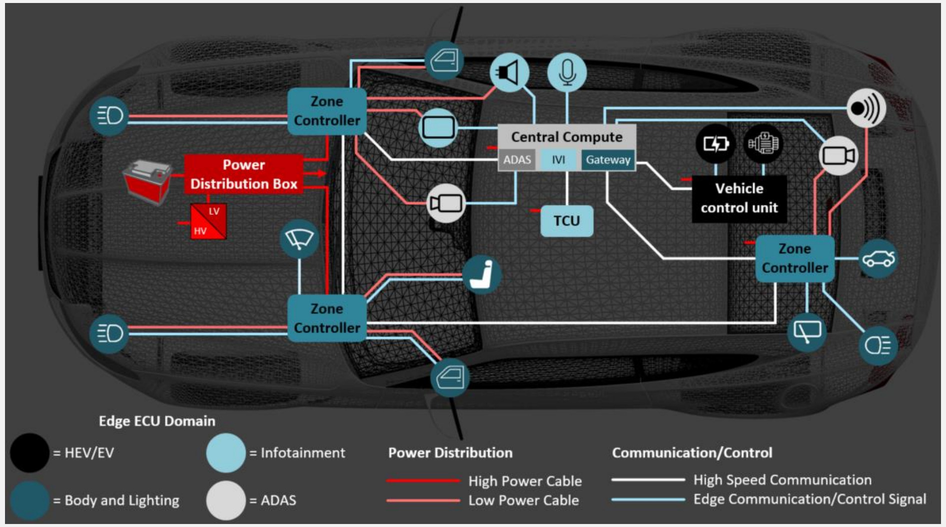
- Smaller wire gauge **reduces cost of wire and manufacturing**
  - 85% weight reduction, 85% cost reduction for ZCM
  - 60% weight reduction, 52% cost reduction for Window Motor



Vehicle power distribution

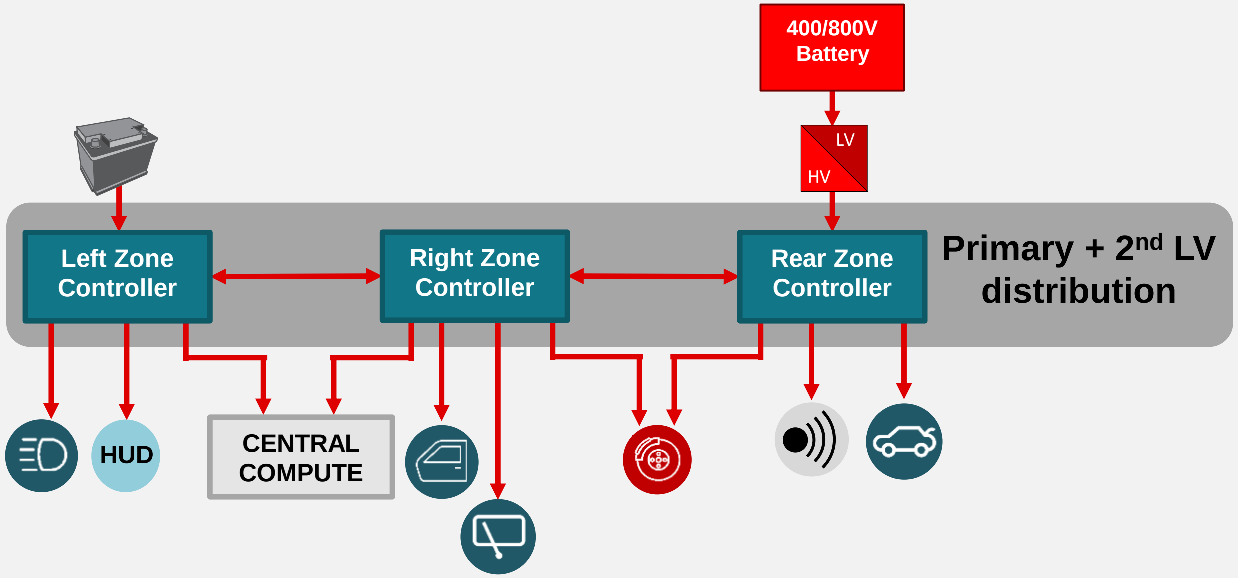
Zone architecture

- Optimize vehicle wiring harness for data and power distribution to improve drive range/efficiency
- Provide increased control of electronic power consumption



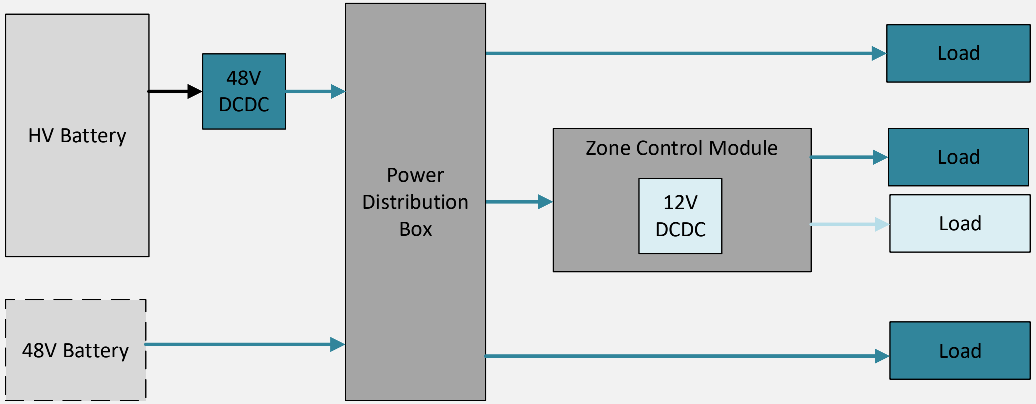
Changes to power distribution

- May remove the central power distribution box or zone
- Reduced thermals in 48V enables more smart eFuse outputs in ZCMs

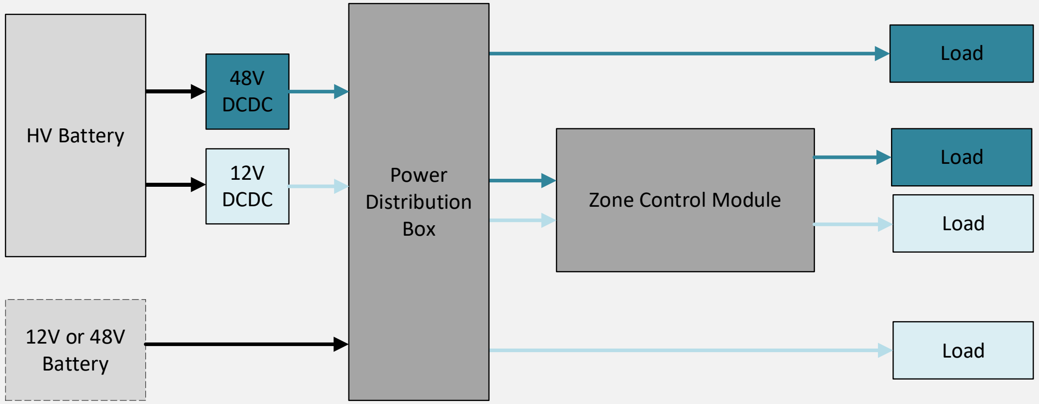


48V architectures

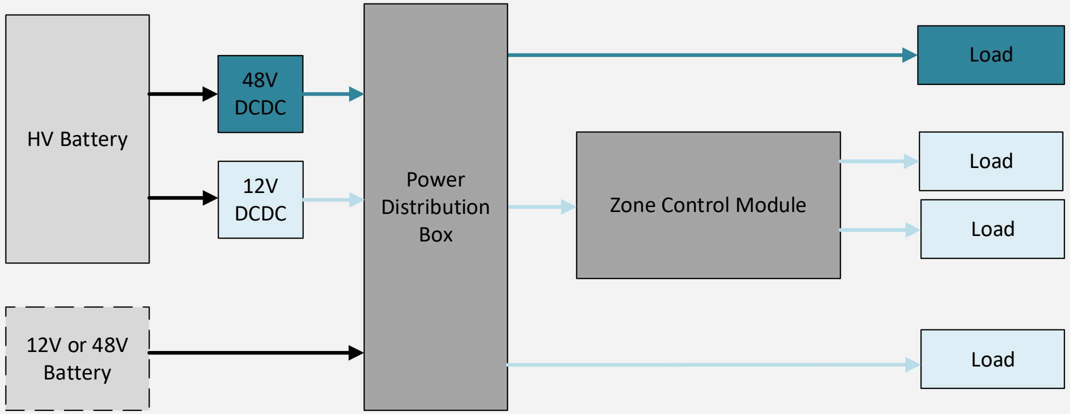
1. 48V primary distribution, 12V secondary



2. 48V and 12V primary distribution – ZCM 48V & 12V



3. 48V and 12V primary distribution – ZCM only 12V



Power requirements in zone control modules

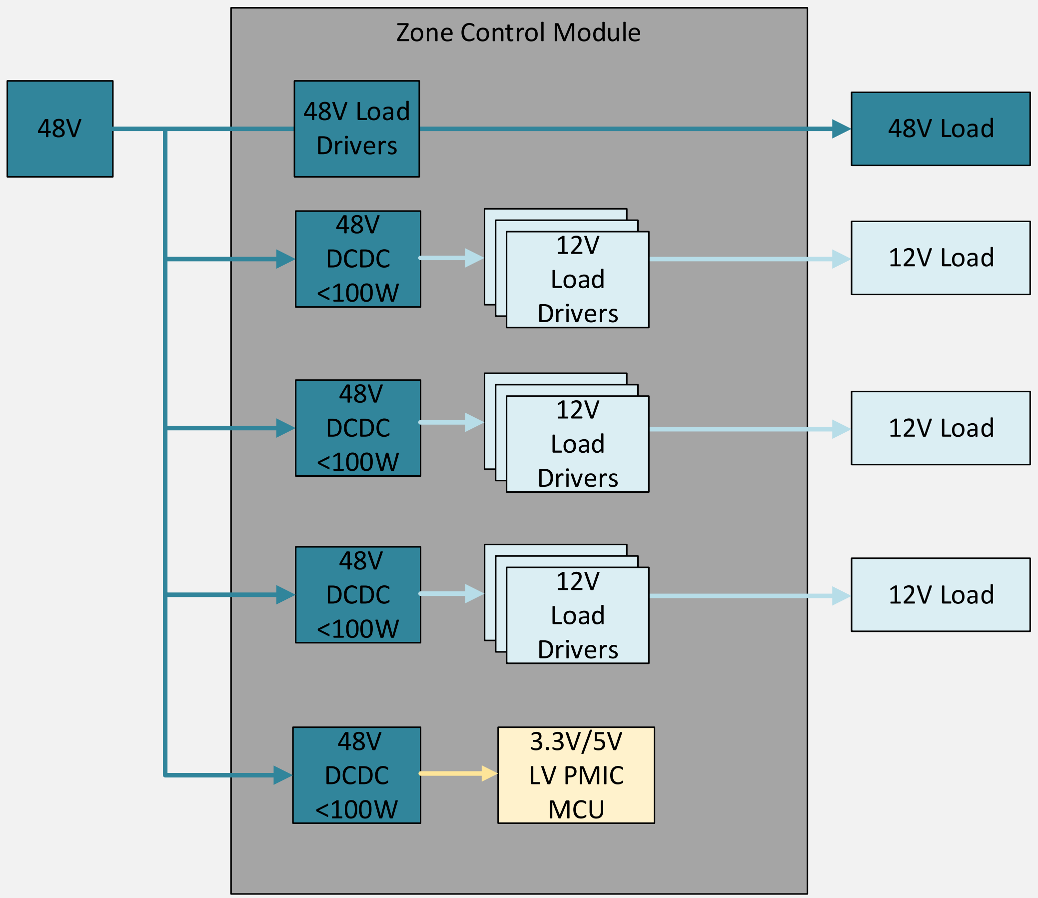
- Zone control modules contain many load drivers (ie. HSS, smart eFuse, motor drivers)
- 22 AWG (0.33mm^2) is the minimum wire gauge used in vehicles to avoid wire breakage concerns
- Loads >5A should transition to 48V, leaving about 500W nominal power on the 12V rail
- Due to high power requirements for the 48V to 12V conversion, different topologies are being considered:
  - Standard Buck or Buck-Boost
  - Switched Capacitor Converter (SCC) or Switched Tank Converter (STC)
  - Inductor Inductor Capacitor (LLC)

	12V	48V	Total
OEM1	200W – 1.3kW	400W – 11.5kW	250W – 12.8kW
OEM2	350W – 1.4kW	3.4kW – 7.6kW	4.6kW – 9kW
OEM3	750W – 1.2kW	2.8kW – 4kW	3.6kW – 5.2kW
OEM4	1.2kW – 1.4kW	3 – 3.1kW	4.2kW – 4.6kW

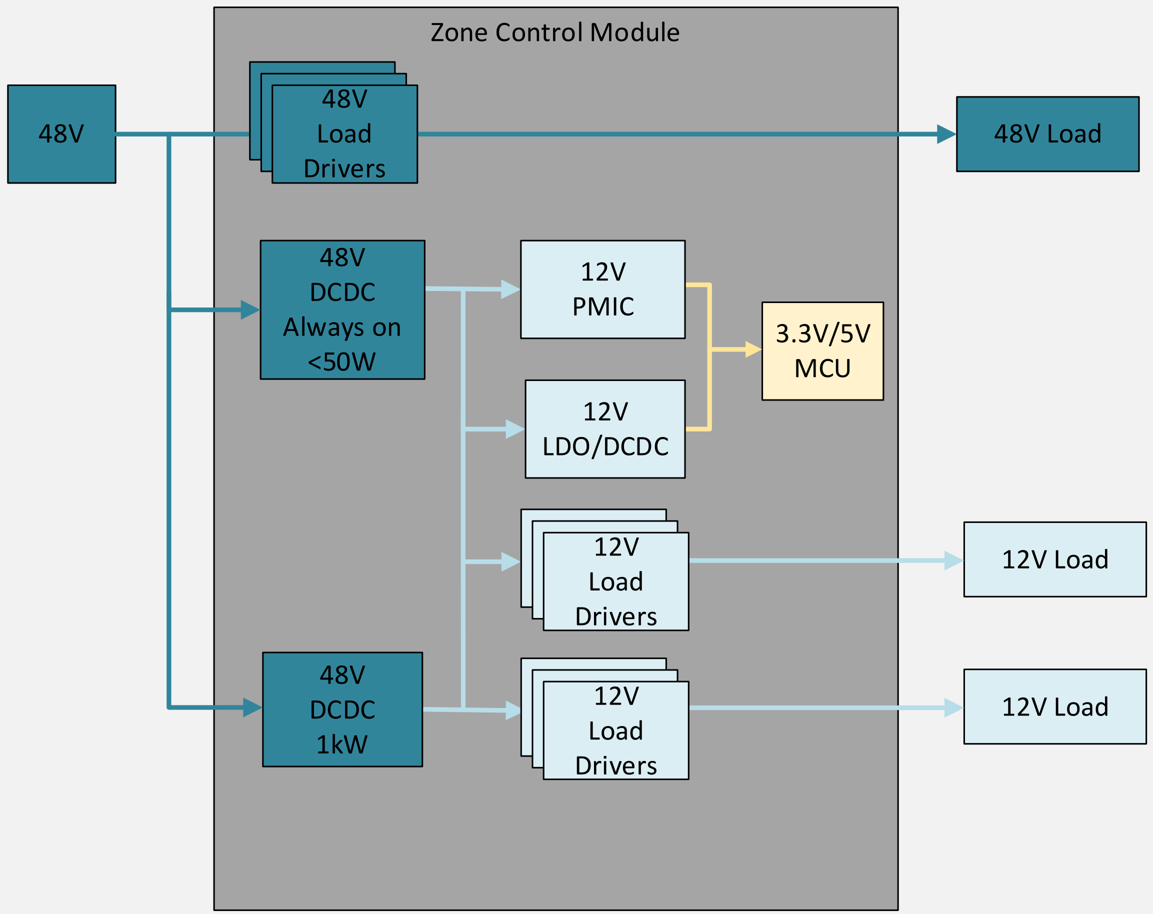
The 48V to 12V power requirements will changed based on the ECU.

48V to 12V conversion

Distributed



Central 12V



48V in zone control modules

Power Supply

Reverse Battery Protection
- LM745xx-Q1
- LM747xx-Q1
- LM74800-Q1
- LM74900-Q1

DC/DC
- LM708x0-Q1
- LM686x5-Q1
- LM5143-Q1
- LM5137-Q1

Supervisor
- TPS376x-Q1
- TPS37100-Q1

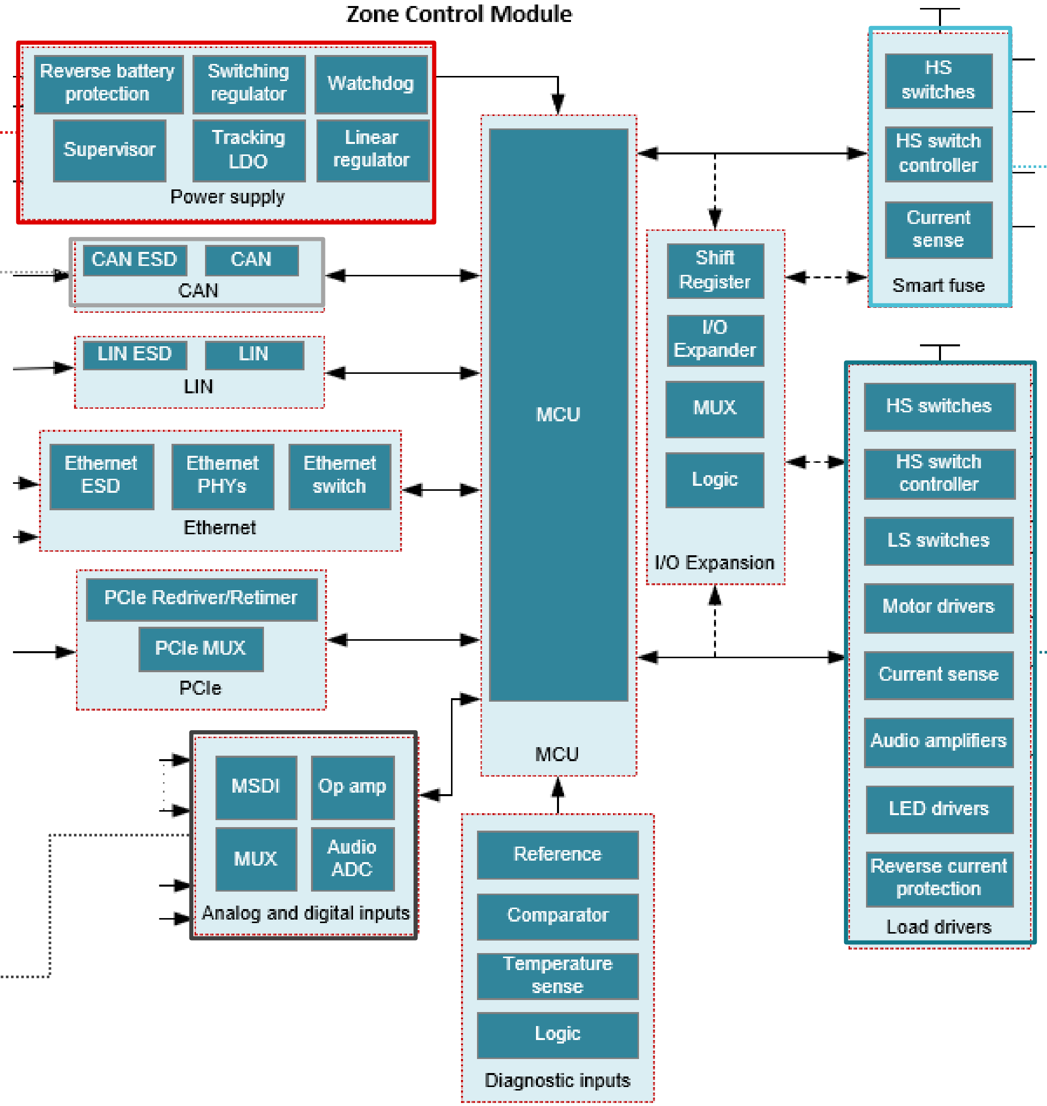
LDO
- TPS7A16A-Q1

Communication

CAN
- TCAN1042H-Q1 70V bus fault
- TCAN1052H-Q1 70V bus fault
- TCAN1043H-Q1

Analog and Digital Inputs

- TMUX1308-Q1, inputs can withstand 48V



Smart Fuse

HS Controllers
- TPS1214-Q1

Load Drivers

HS Controllers
- TPS4811-Q1

HS switches
- TPS1HTC30-Q1
- TPS1HTC100-Q1

Brushed Motor Drivers
- DRV8262-Q1

Current Sense
- INA296B-Q1
- INA281-Q1

LED Drivers
- TPS92520-Q1
- TPS92519-Q1

Loads transitioning to 48V

Low Power – Stay 12V

Damper Controls

Headlight

Mirror

Heat Pump Expansion Valve

Mid Power – In Evaluation

Door / Trunk Locks & Latches

Power Seat

eShifter

Charge Port Lock, Door Handle Presenter

Decision impacted by motor power level, driver topology, # of motors in the ECU, etc.

High Power – Move to 48V

Power Liftgate

Power Sunroof

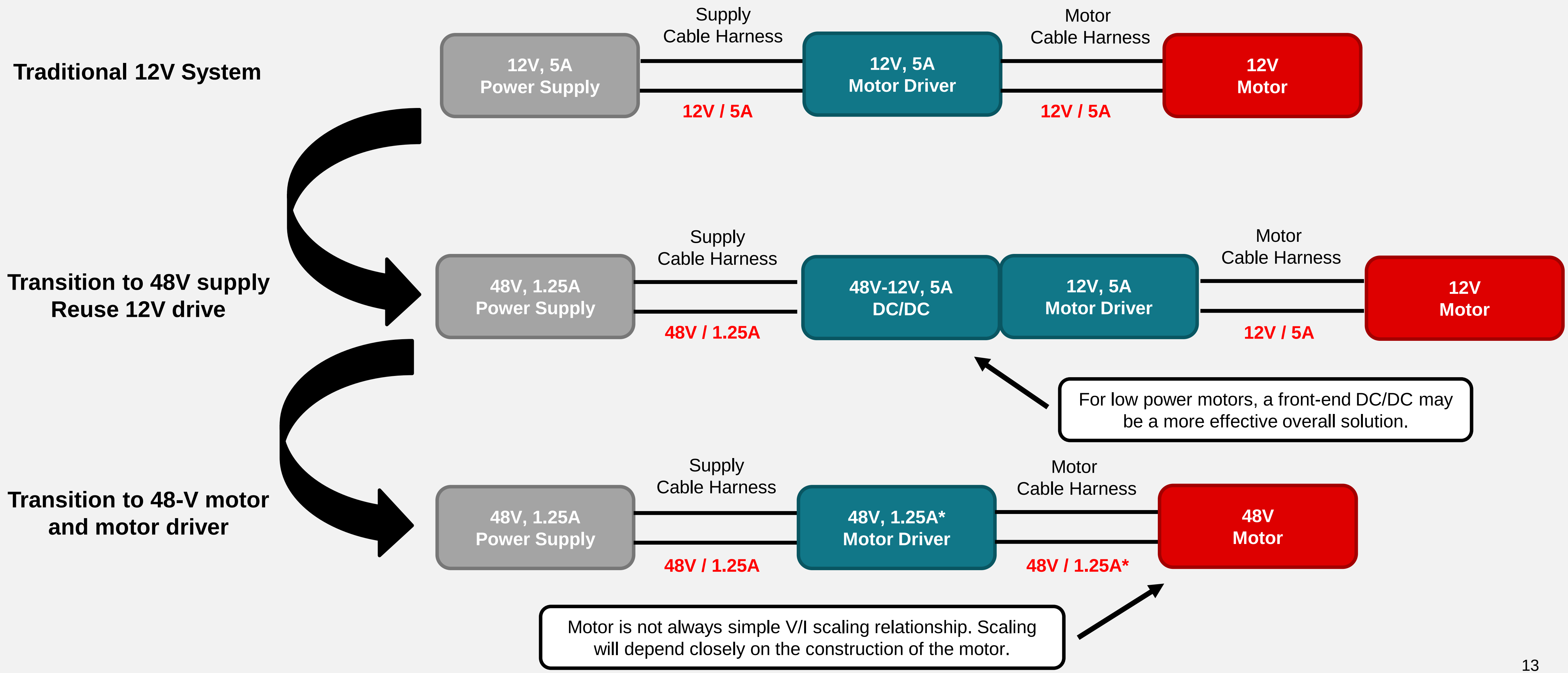
Wipers

Window

HVAC Compressor / Blower

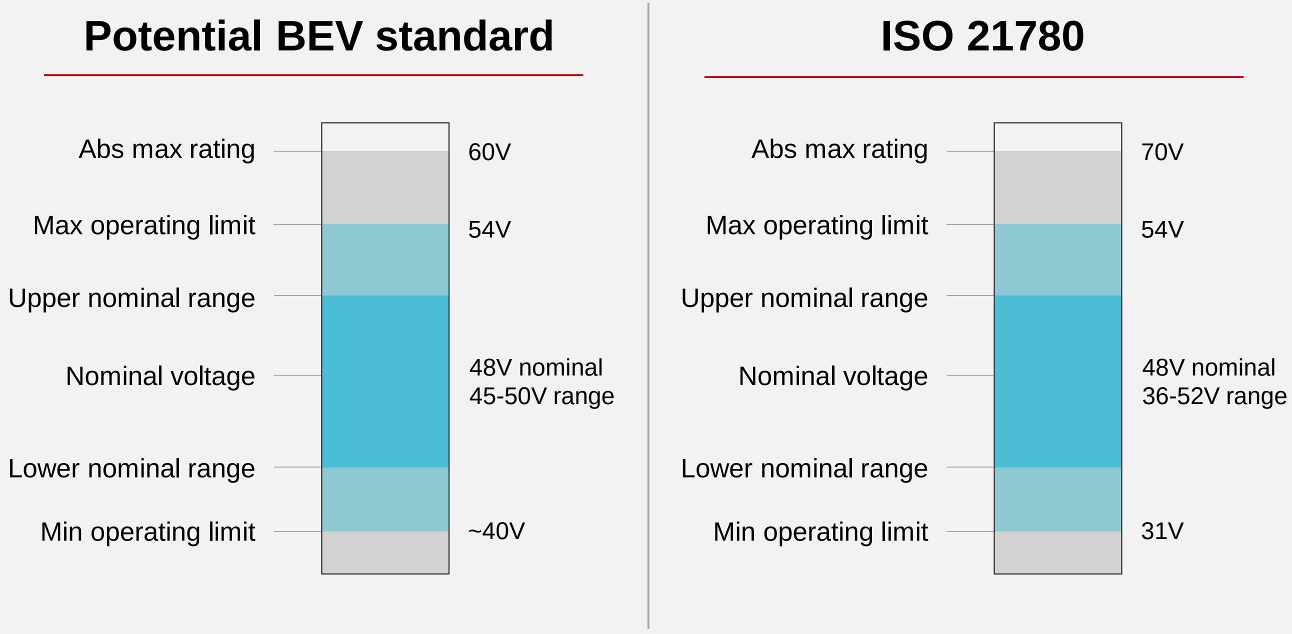
EPS / Braking

Load transition example



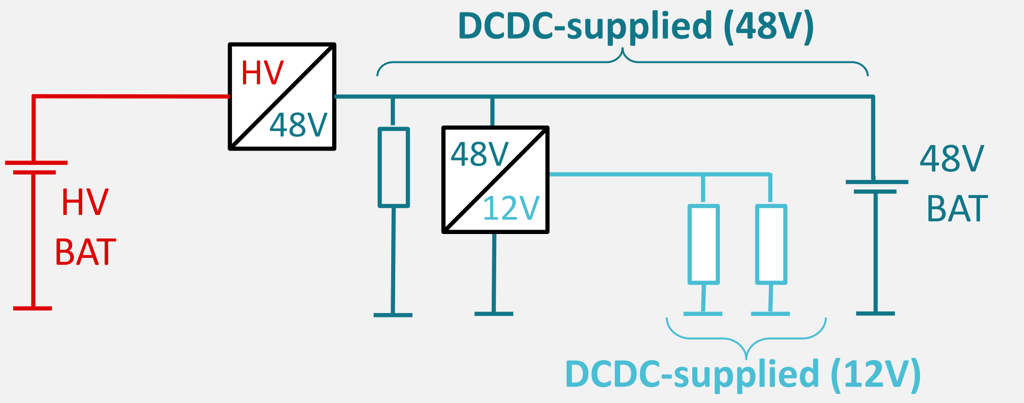
Transient voltage

- Important to understand that traditional 48-V standards for mild-hybrids, while useful as a starting point, are not necessarily valid for an electric or hybrid system generating 48-V off the HV battery and without a high power starter-generator system.
- These systems (mild-hybrid) typically required overvoltage points (ISO21780/LV148) up to 70V and when factoring for switching transients or component margin often dictated component ratings **>>70V.**
- The exact standards around an electric car platform 48V LV net are still in definition, but multiple manufacturers are working to contain line transients **<70V.**
- But even if supply ranges are contained, caution will have to be taken around typical harness failure mode events such as the current ISO7637-2 standard works to address. How these are mitigated will be important decision in 48-V architectures.
  - Pulse 1, **-75V to -150V 2ms**
    - Due to supply disconnection from inductive loads
  - Pulse 2a, **37V to 112V 0.05ms**
    - Due to inductance of wire harness
  - Pulse 3a/3b, **-112V to -220V 150ns**
    - Due to switching processes and influenced by wire harness



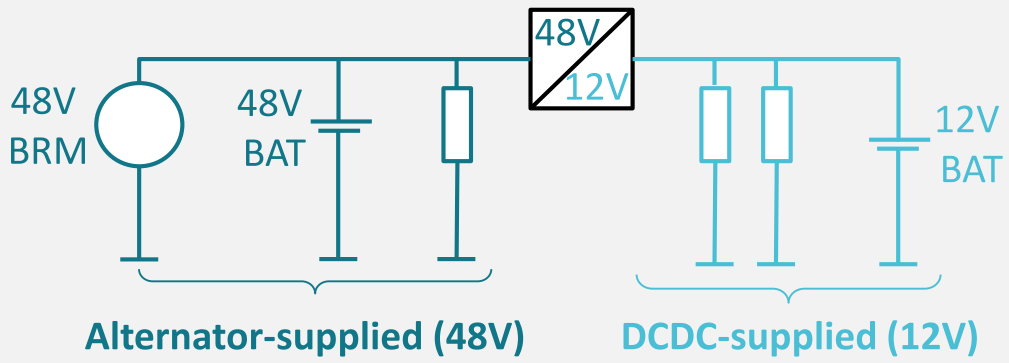
Future standards in development

DCDC supplied



- **New standard** for components supplied by DCDCs for 12V, 24V, and 48V rails
- Vehicles types: BEV, PHEV

Alternator supplied



- Combination of existing standards (ISO21780 and ISO16750) for components supplied by alternators
- Vehicle types: MHEV, ICE

Creepage and clearance

IPC 2221A Standard

Table 6-1 Electrical Conductor Spacing

Voltage Between Conductors (DC or AC Peaks)	Minimum Spacing						
	Bare Board				Assembly		
	B1	B2	B3	B4	A5	A6	A7
0-15	0.05 mm [0.00197 in]	0.1 mm [0.0039 in]	0.1 mm [0.0039 in]	0.05 mm [0.00197 in]	0.13 mm [0.00512 in]	0.13 mm [0.00512 in]	0.13 mm [0.00512 in]
16-30	0.05 mm [0.00197 in]	0.1 mm [0.0039 in]	0.1 mm [0.0039 in]	0.05 mm [0.00197 in]	0.13 mm [0.00512 in]	0.25 mm [0.00984 in]	0.13 mm [0.00512 in]
31-50	0.1 mm [0.0039 in]	0.6 mm [0.024 in]	0.6 mm [0.024 in]	0.13 mm [0.00512 in]	0.13 mm [0.00512 in]	0.4 mm [0.016 in]	0.13 mm [0.00512 in]
51-100	0.1 mm [0.0039 in]	0.6 mm [0.024 in]	1.5 mm [0.0591 in]	0.13 mm [0.00512 in]	0.13 mm [0.00512 in]	0.5 mm [0.020 in]	0.13 mm [0.00512 in]

Many different standards for creepage and clearance with some companies even having their own internal guidance's.

IEC60664-1 Standard

Table F.5 – Creepage distances to avoid failure due to tracking *(1 of 2)*

Voltage RMS [a, e]	Minimum creepage distances								
	Printed wiring material								
	Pollution degree								
	1	2 [f]	1	2			3		
	All material groups	All material groups, except IIIb	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III [b]
V	mm	mm	mm	mm	mm	mm	mm	mm	mm
10	0,025	0,040	0,080	0,400	0,400	0,400	1,000	1,000	1,000
12,5	0,025	0,040	0,090	0,420	0,420	0,420	1,050	1,050	1,050
16	0,025	0,040	0,100	0,450	0,450	0,450	1,100	1,100	1,100
20	0,025	0,040	0,110	0,480	0,480	0,480	1,200	1,200	1,200
25	0,025	0,040	0,125	0,500	0,500	0,500	1,250	1,250	1,250
32	0,025	0,040	0,14	0,53	0,53	0,53	1,30	1,30	1,30
40	0,025	0,040	0,16	0,56	0,80	1,10	1,40	1,60	1,80
50	0,025	0,040	0,18	0,60	0,85	1,20	1,50	1,70	1,90

Key Terms:

- **Conformal Coating:** Lightweight material applied to PCBs that acts as a protective layer. It protects circuit boards and components against various environmental factors, including heat, humidity, moisture, ultraviolet light, chemical contaminants, and abrasive materials
- **Pollution Degree:** Environment of the electronic

Examples:

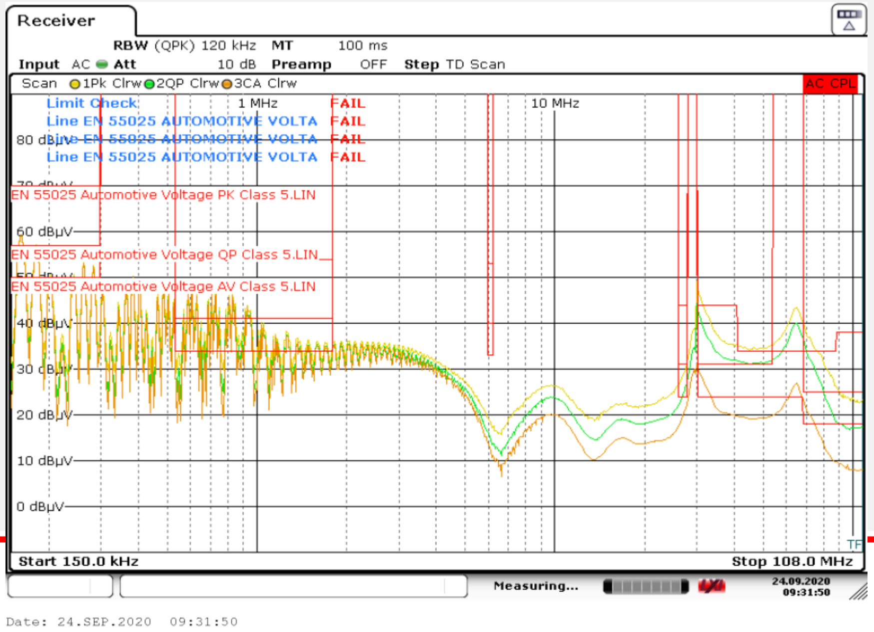
- In a clean environment or enclosed equipment
- Most common environment
- Harsh environments such as factories
- Outdoors where it is mainly exposed to the elements

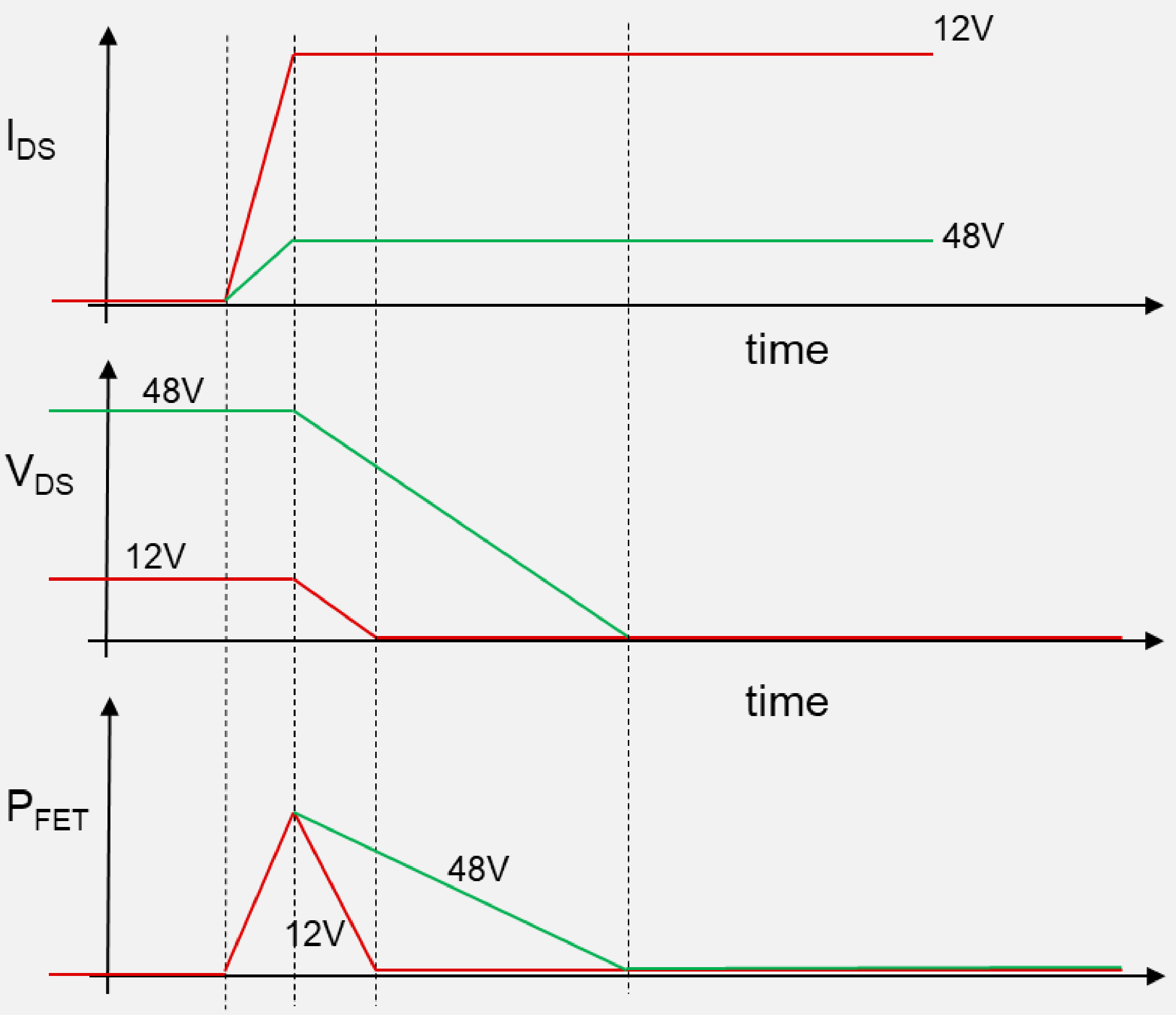
- **Material Group:** Insulative characteristics of the materials used. Classified by their CTI values
- **Comparative Tracking Index (CTI) -** The maximum voltage that an insulating material can operate under in the presence of contamination (whether air, surface or humidity), without resulting in tracking (conductive pathways), specified in volts

Switching losses and EMC

$P_{SW} = 0.5 \times V_{DS} \times I_{DS} \times (t_R + t_F) \times f_{SW}$

- A subtle impact of 48V conversion is that while conduction losses will reduce, switching losses will be negatively impacted
- This will be relevant for switching power converters such as DC/DC and motor drives
- AM band is predominant factor in EMC mitigation techniques. How do we address in a way to allow faster edge rates and take full advantage of higher bus voltage?
  - AM radio removal
  - Different locations of drives/motors
  - Shielding/etc.

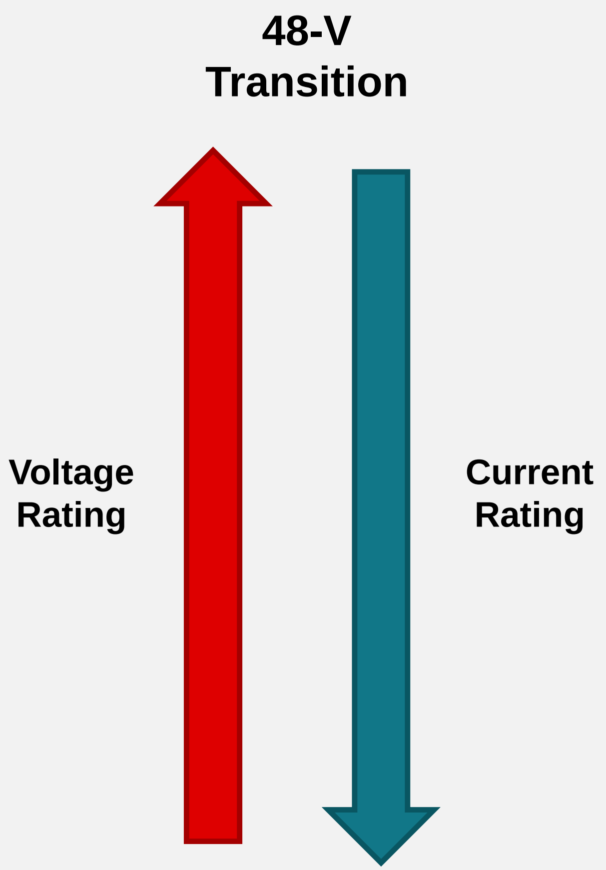




While I_{DS} reduces, if slew rate maintains same as 12V system, then P_{SW} increases 4x.

12V to 48V cost impact

- Semiconductor device cost to manufacture is driven by 3 main factors:
  1. Silicon cost
  2. Package cost
  3. Test cost
- 12V to 48V component transition will impact products differently
- Key factors are power architecture (power switch, DC/DC, motor driver, etc.) and exact specifications (max voltage rating, creepage/clearance, power level)
- Power FET rating will be # 1 factor for determining impact



HSS and Smart eFuse Cost Comparison

	12V (40V) Component	48V (70V) Component
	R_{DSON} = 1 x 2.6mΩ	R_{DSON} = 2 x 16 mΩ
Current	20A	5A
Channel	1	2
Cost/Ch	**100%**	**59%**

If power consumption remains constant in 48V systems, then multi-channel HSS devices can decrease IC cost. RDS on is more impactful than voltage rating.

Questions?