EV 48V new E/E structure introduction and MPS power solutions

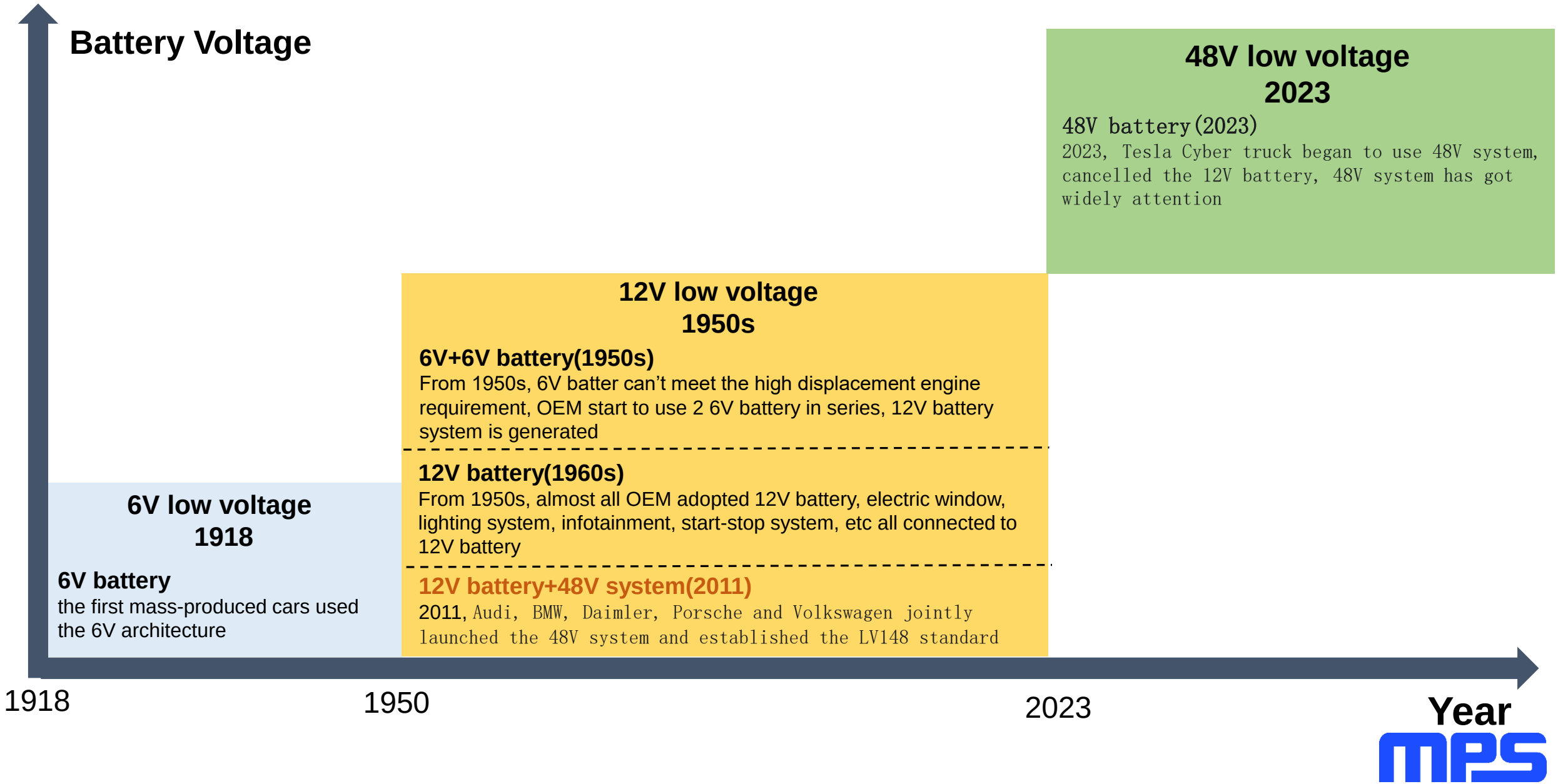
Adley Cheng

2024.05.10

Agenda

1. Background for 48V system
2. 48V EE structure introduction
3. 48V EE test standard
4. MPS solutions for 48V systems

Vehicle low voltage battery develop history

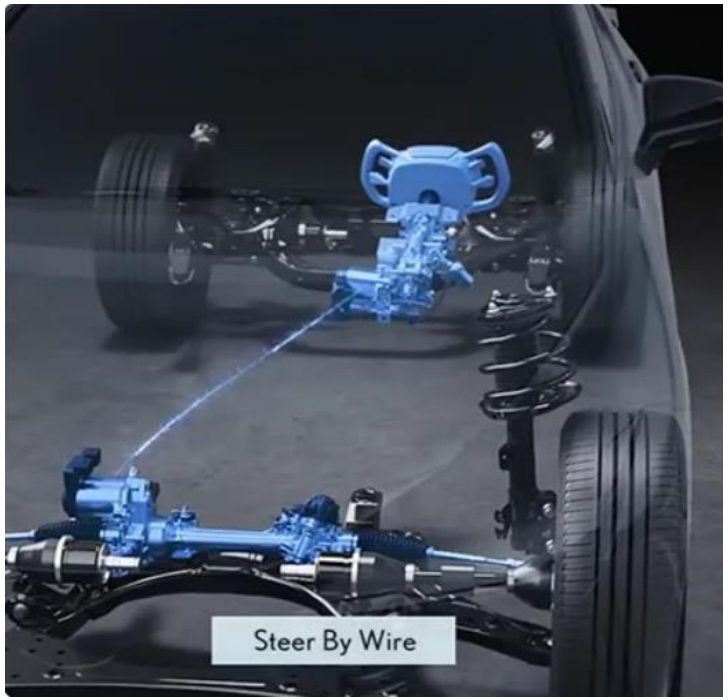


Why need consider 48V system

1. Load power increasing

Why need consider 48V system

2. New comfort function requirement---body



Steer by wire
Power rating is up to 1.75kW

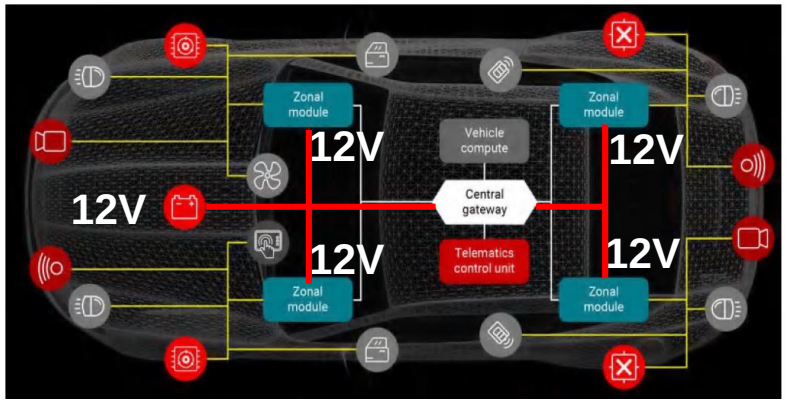
Active air suspension
Power rating is 400~1200W

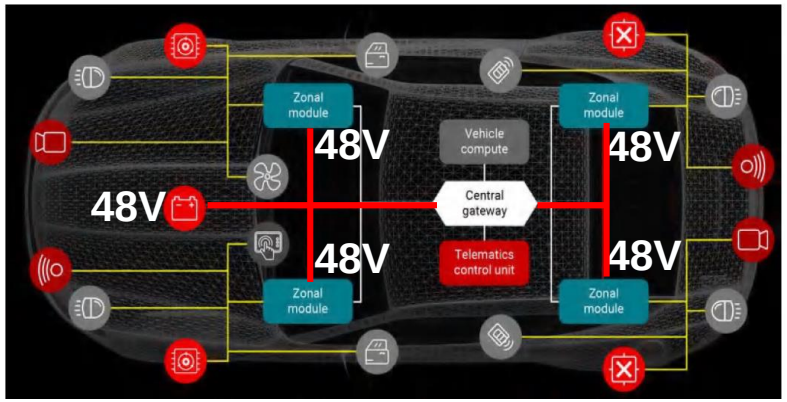
In a summary,

- 12Vbus, the total power is easy to over 3kW, or even over to 6kW
- 12V battery can’t provide more power any more

Why need consider 48V system

3. Saving wire and reduce wire power loss





Wire parameters	600W@12V	600W@48V	
Load current	50 A	12.5 A	
Wire cross-section area	10 mm^2	1.5 mm^2	**80% smaller size**
Weight/length	108 g/meter	17 g/meter	**80% weight reduction**
Power loss/length	4.45 W/meter	1.88 W/meter	**50% loss reduction**

Using 48V system, can save wire weight and reduce power loss

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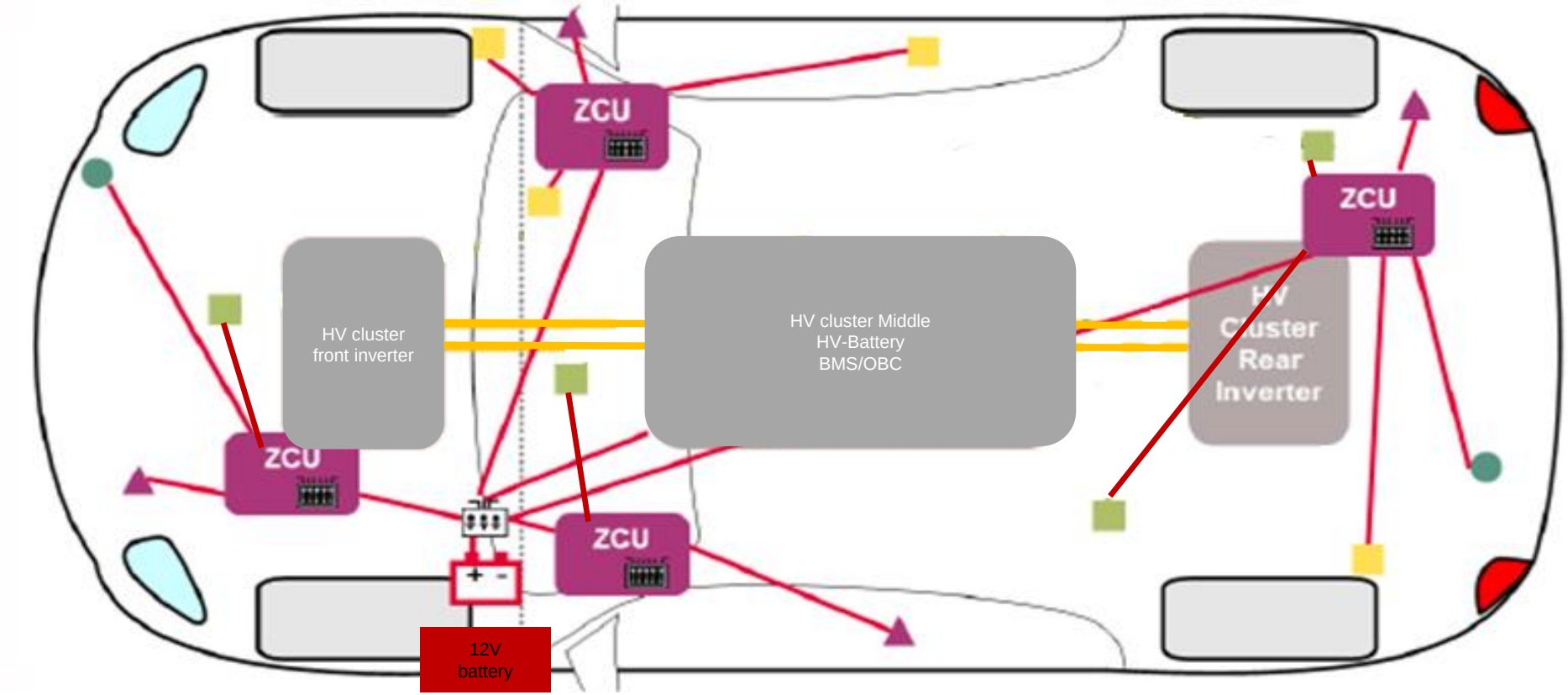
Nowadays 12V Zonal control Unit structure

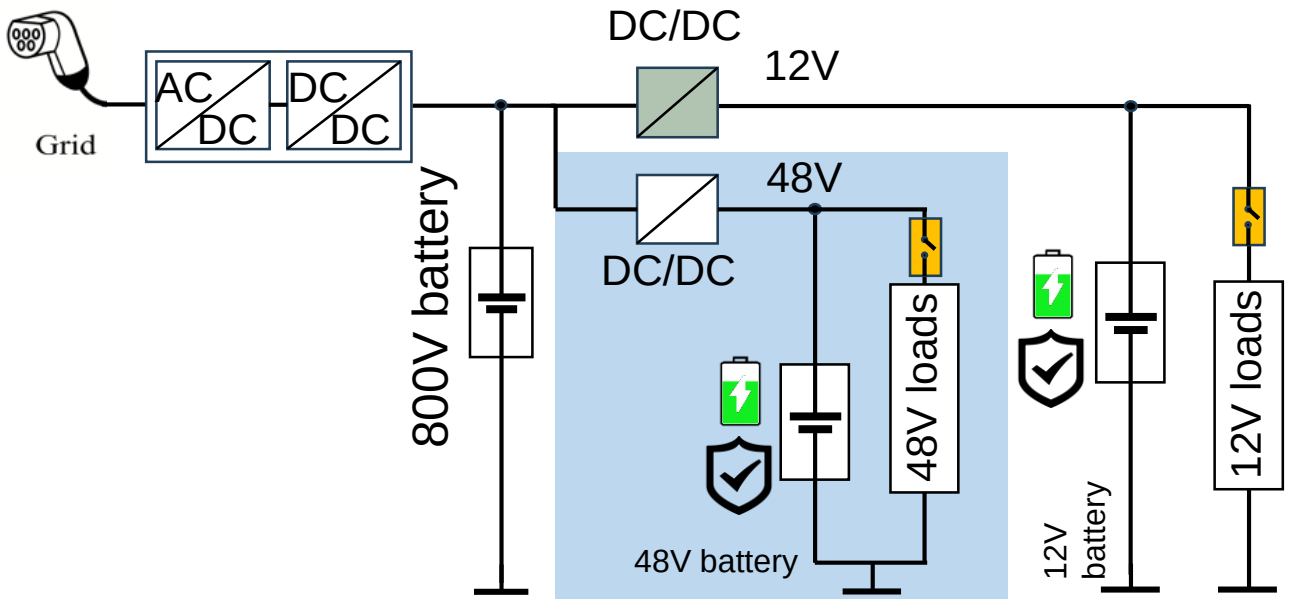


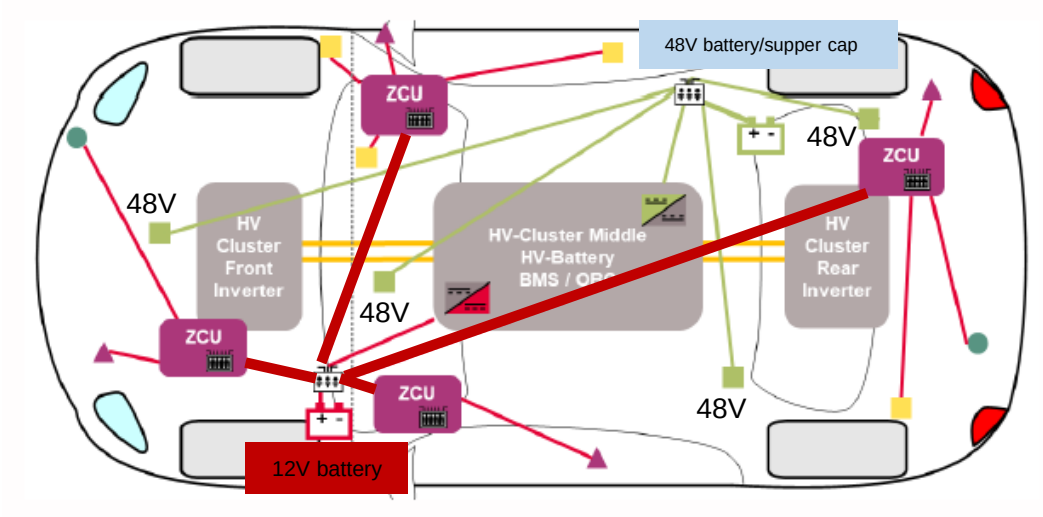
Zonal control Unit :

- Simple and short wiring harness
- Small communication delay
- Distributed power distribution
- Less thermal stress, better redundancy

Power Architecture #1 – 2 batteries, 48V and 12V

- 12V battery+48V battery





Advantage:

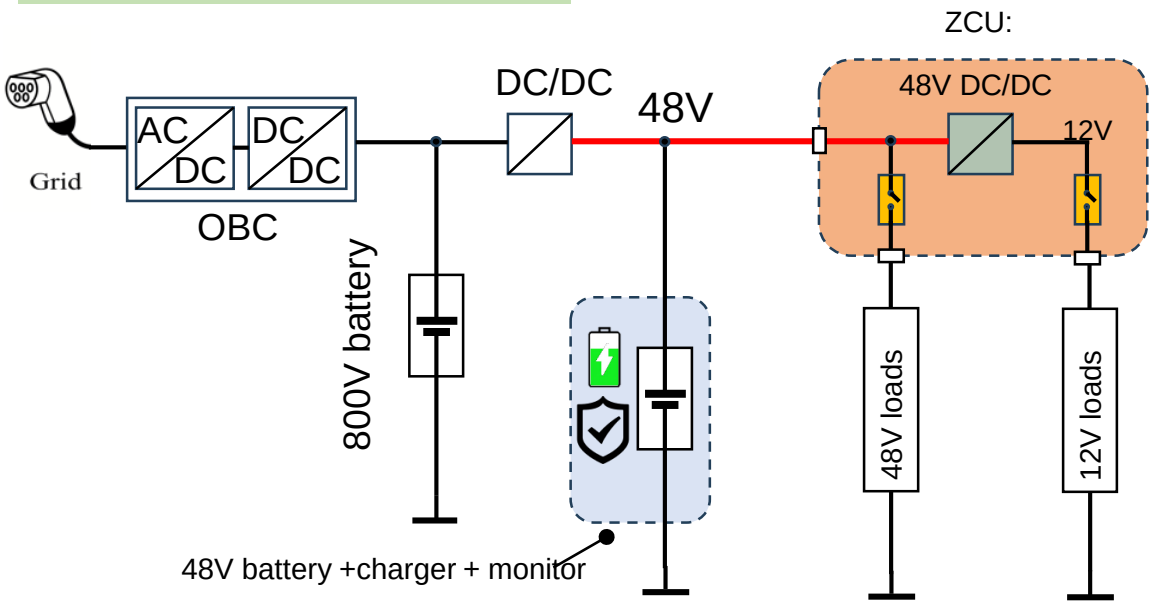
- Easy to implement
- Keep 12V Zonal structure, add a 48V bus to power for high power load

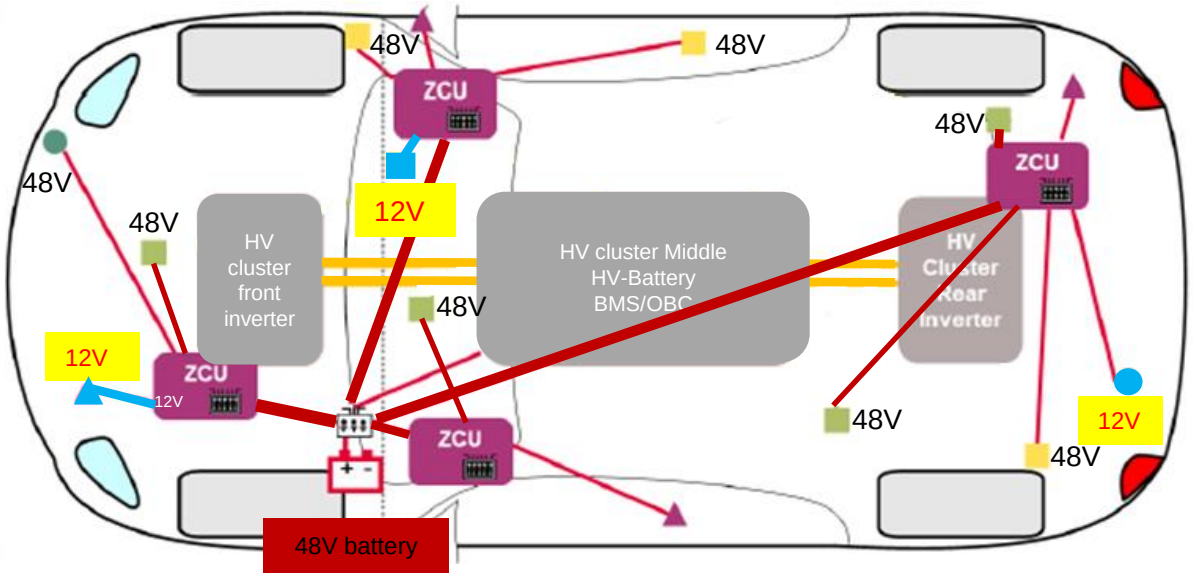
Disadvantage:

- More weight and cost:
  1) 12V/48V battery
  2) 2 high power DCDC system
  3) Less Flexible to upgrade

Power Architecture #2 48V Bus + local 48V->12V

➢ Remove 12 Vbattery



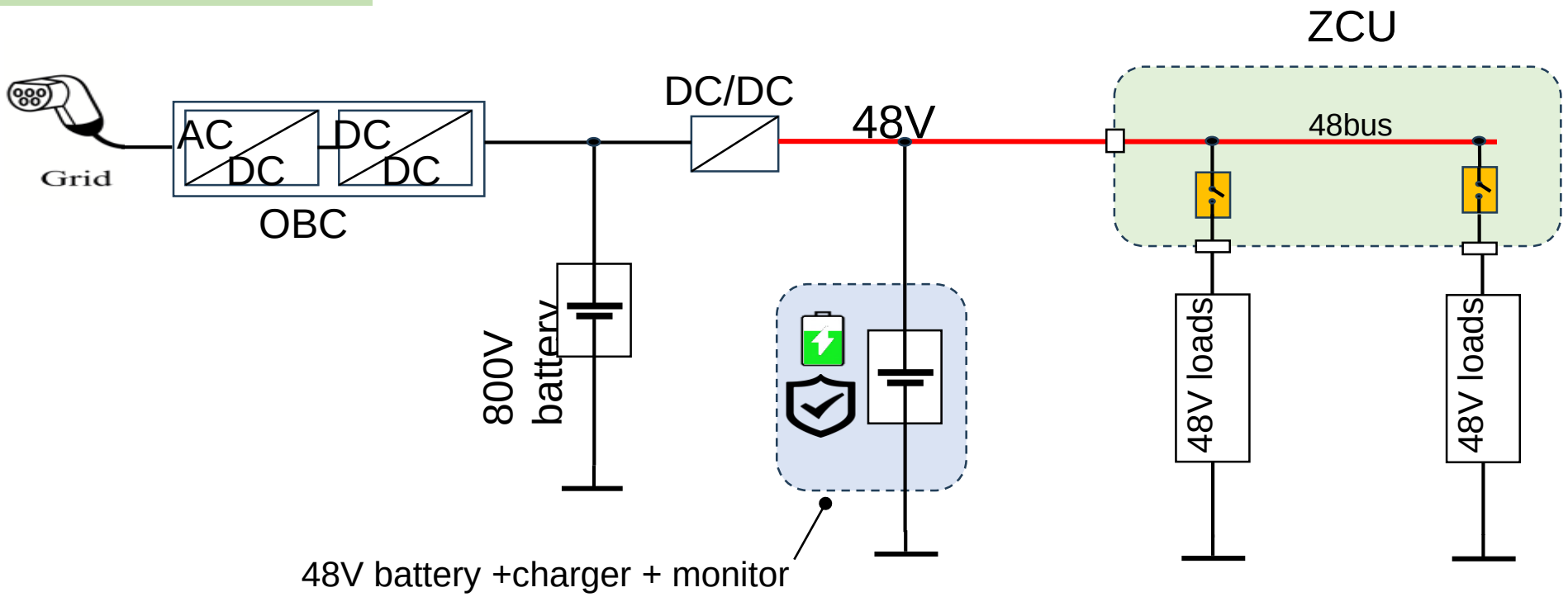


Advantage:

- 48V wire harness has best weight saving, 12V wire is also short
- 12V Battery not required
- Easy to upgrade:
  when more load move to 48V, only need to size the local 48V->12V DCDC w/o touching the architecture
- Good total Efficiency
- Low cost

Power Architecture #3 48V Bus only

- 48V bus Only



Advantage:

- Can save extra 48V->12V DCDC
- 48V battery as a buffer for load
- HV battery charges 48V battery
- Good total Efficiency

Disadvantage:

- 48V supply chain is not mature

Consider functional safety requirement

According to VDA450, for ADS system

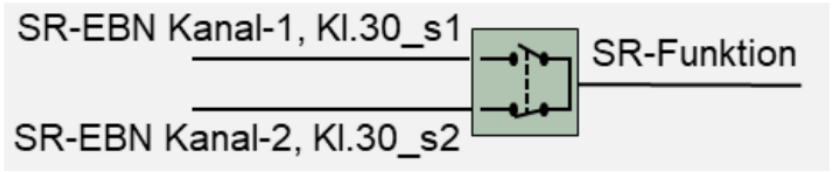
VDA450: Electrical Power Supply System regarding automated driving in the context of ISO 26262

4.2.2.1 Independence between EBN Channels

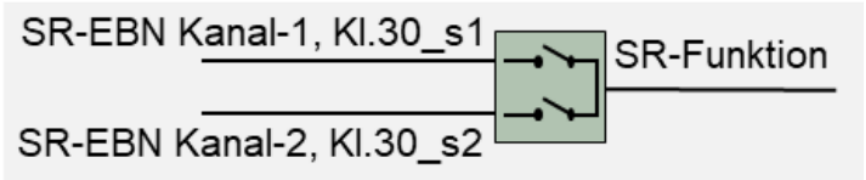
The independent EBN channels (e.g. terminal KI30_s1 and terminal KI30_s2) are used to decompose the ASIL D requirement for the power supply and to achieve the hardware metrics demanded by ISO 26262:2018. The ISO 26262:2018 metric targets relevant to the electrical power supply must be derived in accordance with the procedure as described in Annex E. In doing so, a distinction must be made as to whether the Electrical EBN is treated as an Item or a Subsystem, cf. chapter 5.1. To avoid dependent failures, both the freedom from interference for coexisting Elements and the avoidance of Common Cause Failure must be ensured. One example of a dependent failure is the failure of the HV system or the 12 V generator, which leads to a discharge of both 12 V batteries; cf. case study in Annex D.

Two examples

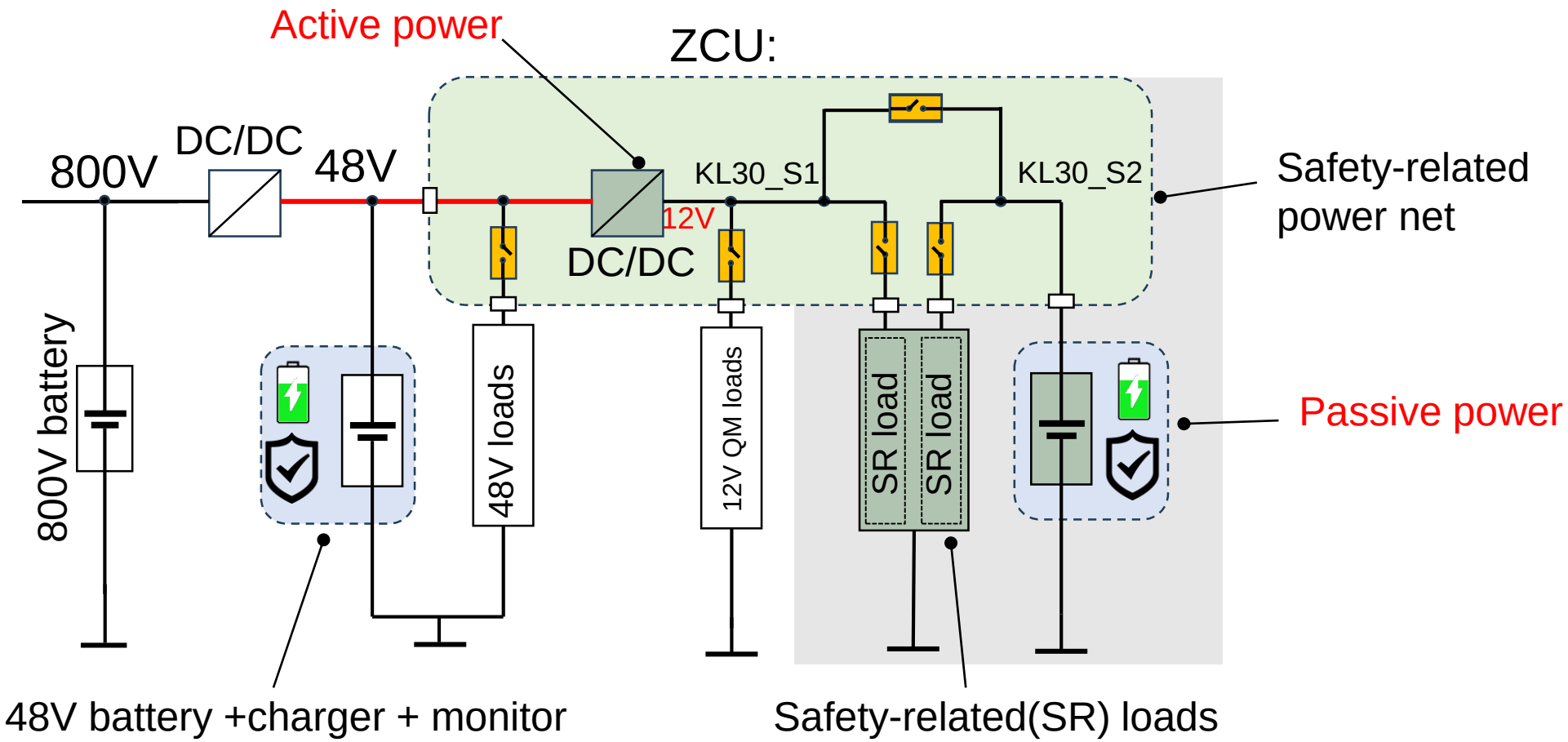
Type 5) Active separating and connecting Element EBN[SR]-L[SR]-EBN[SR]:
Connecting Element designated as Y1 between two safety-relevant EBN channels and a safety-relevant load.
Y1 switch EBN[SR]-L[SR]-EBN[SR]– only one power supply connection active during normal operation.



Type 6) Active separating and connecting Element EBN[SR]-L[SR]-EBN[SR]:
Connecting Element between two safety-relevant EBN channels and a safety-relevant load.
Y2 switch EBN[SR]-L[SR]-EBN[SR] – both power supply connections simultaneously active during normal operation



Power Architecture #2 with Functional Safety Requirement



According to “VDA450, Electrical Power Supply System Regarding Automated Driving in the Context of ISO 26262”

Agenda

1. Background for 48V system
2. 48V EE structure introduction
3. 48V EE test standard
4. MPS solutions for 48V systems

48V vehicle voltage standard

ISO 21780, First edition 2020-08

Road vehicles — Supply voltage of 48 V — Electrical requirements and tests

Supply voltage range

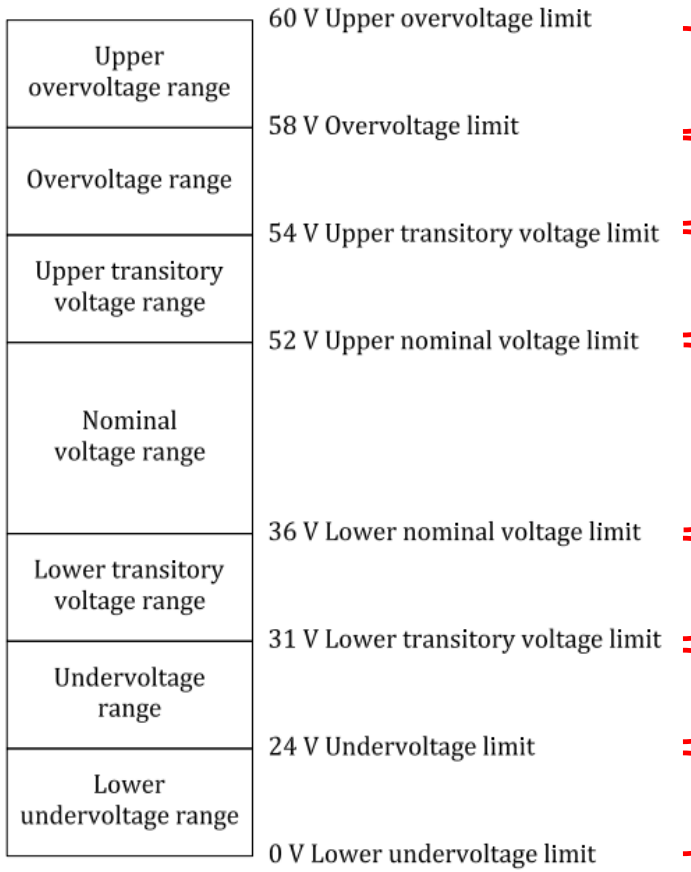


Figure 1 — Supply voltage ranges

Upper overvoltage range (58 V – 60 V):
Reason for being in this voltage range could be a control error

Overvoltage range(54 V – 58 V):
This voltage range may occur due to (short term) return of electrical energy or maybe a control error. The system may operate only temporarily in this range

Upper transitory voltage range (52 V – 54 V):
This range is intended for calibrating the storage media and for uptake of recovered energy. The system may operate only temporarily in this range.

Nominal voltage range (36 V – 52 V):
The system is expected to operate in this range most of the time.

Lower transitory voltage range (31 V – 36 V):
The voltage may for example be in this range during boost or during cold crank. The system may operate only temporarily in this range.

Under voltage range (24 V – 31 V):
The voltage may for example be in this range during cold crank.

Lower under voltage range (0 V – 24 V):
Storage protection. The voltage is not expected to be in this range except for short term discontinuities in the supply voltage or due to long term parking

Functional Status

This will affect power solution voltage rating

Voltage range	Test	Functional category				
		I	II	III	IV	Z
60 V < U_{48} ≤ 70 V	Test-03 Short term overvoltage	FS1	FS2	FS2	FS3	As agreed
58 V < U_{48} ≤ 60 V	Test-06 Long term overvoltage	FS3	FS3	FS3	FS3	As agreed
54 V < U_{48} ≤ 58 V	Test-07 Overvoltage with consumer components which may supply electrical energy	FS1	FS2	FS3	FS3	As agreed
52 V < U_{48} ≤ 54 V	Test-02 Lower and upper transitory voltage ranges	FS1	FS2	FS3	FS2	As agreed
52 V < U_{48} ≤ 54 V	Test-09 Voltage ripples	FS1	FS2	FS3	FS2	As agreed
36 V ≤ U_{48} ≤ 52 V	Test-01 Nominal voltage range	FS1	FS1	FS1	FS1	As agreed
31 V ≤ U_{48} < 36 V	Test-02 Lower and upper transitory voltage ranges	FS1	FS2	FS2	FS3	As agreed
31 V ≤ U_{48} < 36 V	Test-08 Decrease and increase of supply voltage	FS1	FS2	FS2	FS3	As agreed

Voltage range	Test	Functional category				
		I	II	III	IV	Z
31 V ≤ U_{48} < 36 V	Test-09 Voltage ripples	FS1	FS2	FS2	FS3	As agreed
31 V ≤ U_{48} < 36 V	Test-10 Reinitialization	FS1	FS2	FS2	FS3	As agreed
24 V ≤ U_{48} < 31 V	Test-05 Starting profile	FS1	FS2	FS2	FS3	As agreed
24 V ≤ U_{48} < 31 V	Test-08 Decrease and increase of supply voltage	FS1	FS3	FS3	FS3	As agreed
24 V ≤ U_{48} < 31 V	Test-10 Reinitialization	FS1	FS2	FS2	FS3	As agreed
0 V ≤ U_{48} < 24 V	Test-08 Decrease and increase of supply voltage	FS3	FS3	FS3	FS3	As agreed
0 V ≤ U_{48} < 24 V	Test-10 Reinitialization	FS3	FS3	FS3	FS3	As agreed

- **Functional status 1 (FS1):**
  The function shall meet a specified performance without deviation. Derating or switch-off is not allowed.
- **Functional status 2 (FS2)**
  The function shall meet a specified performance with a specified variation below or above the specified performance of FS1. Derating is allowed, switch-off is not allowed.
- **Functional status 3 (FS3)**
  The function may not provide the specified performance. Derating or switch-off is allowed. The function shall automatically recover and return to the specified performance level if the necessary operating conditions are met.
- **Functional status 4 (FS4)**
  The function may not provide the specified performance. Derating or switch-off is allowed. The function shall recover and return to specified performance only after a change in vehicle operational status (e.g. change of ignition status, vehicle restart) has occurred and if the necessary operating conditions are met.
- **Functional status 5 (FS5)**
  The DUT fails to perform one or more functions whilst the test parameters are applied, the DUT does not set itself on fire as defined in 3.2. After application is terminated, the DUT can no longer be used unless it is repaired or replaced

Test requirements which affect power DCDC solutions

Test-03: short term overvoltage

10.3.1 Purpose This test is intended to check the immunity of the component to transient over voltages

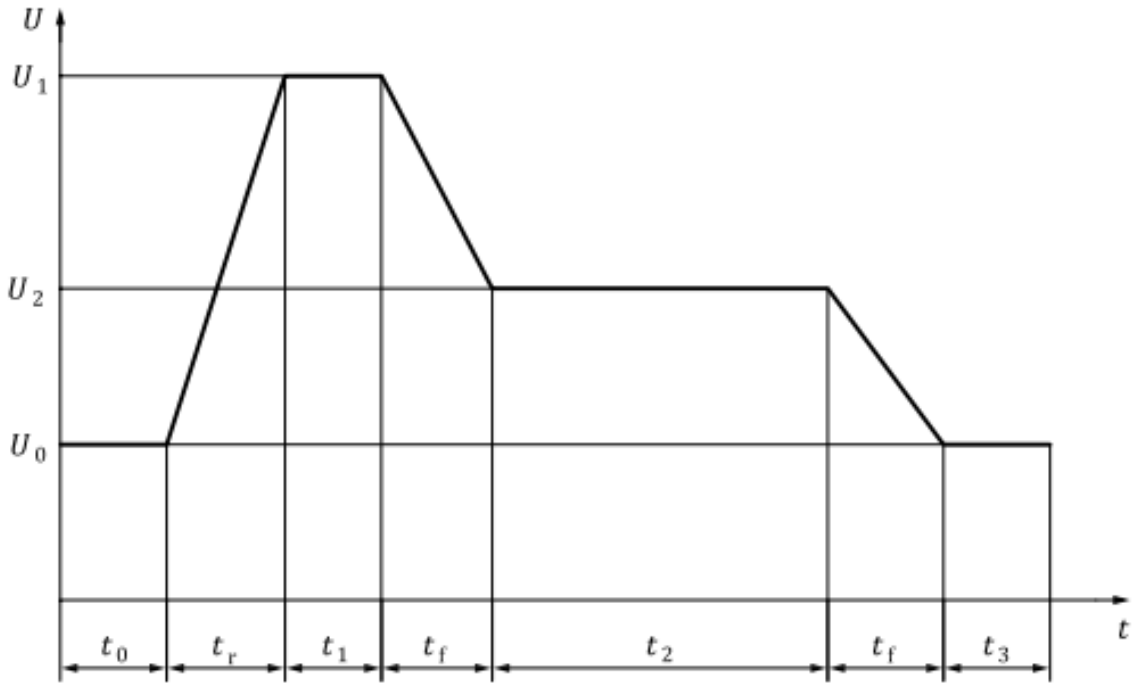


Table 7 — Test parameters for test-03: short term overvoltage

Operating mode	2.4
U_0	52 V
U_1	70 V
U_2	58 V
t_0	≥5 s
t_r	0,7 ms (25,71 V/ms)
t_1	40 ms
t_f	1 ms
t_2	600 ms
t_3	≥5 s
Number of cycles	1 000

Test 03, required 70V short term over voltage with in 40mS
which means for 48V system the DCDC voltage should be over 70V, 80V is better

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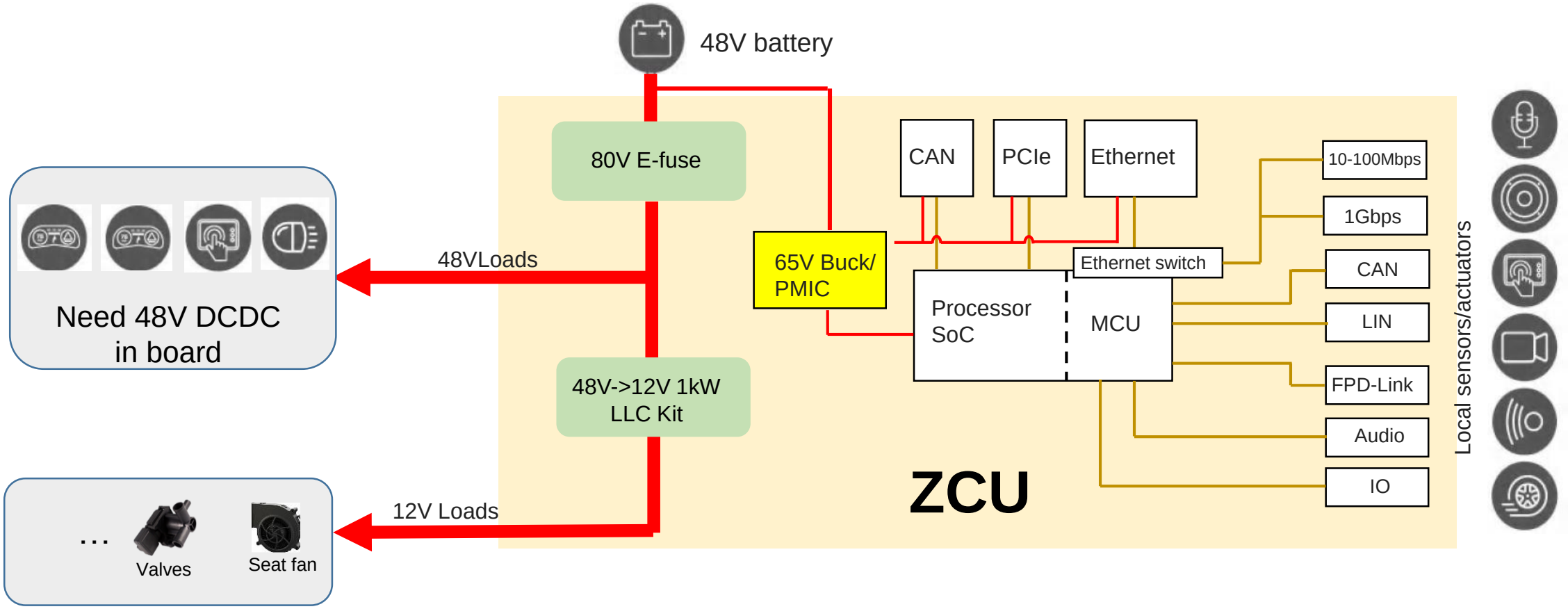
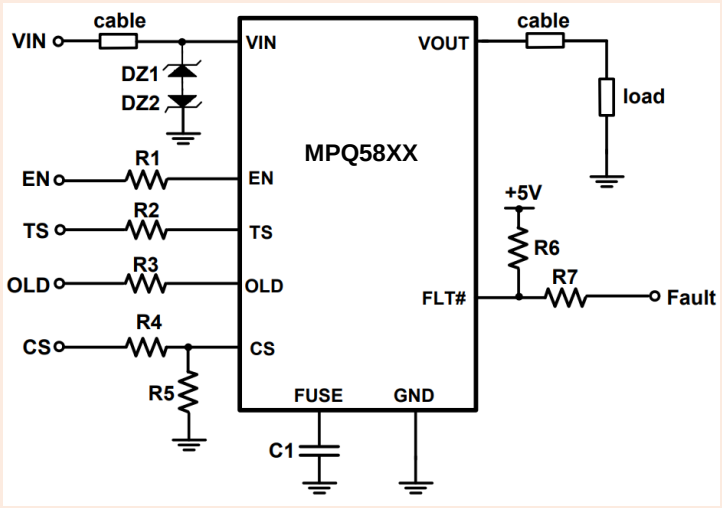
Key Components in the Zonal Module

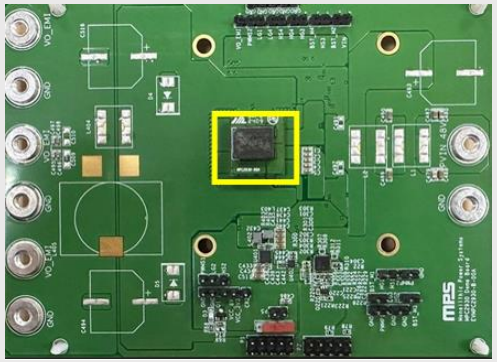


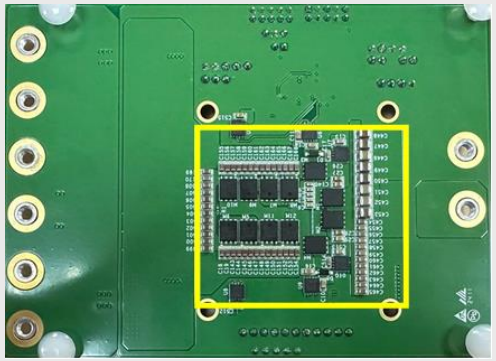
MPS solutions for 48V system

80V E-fuse

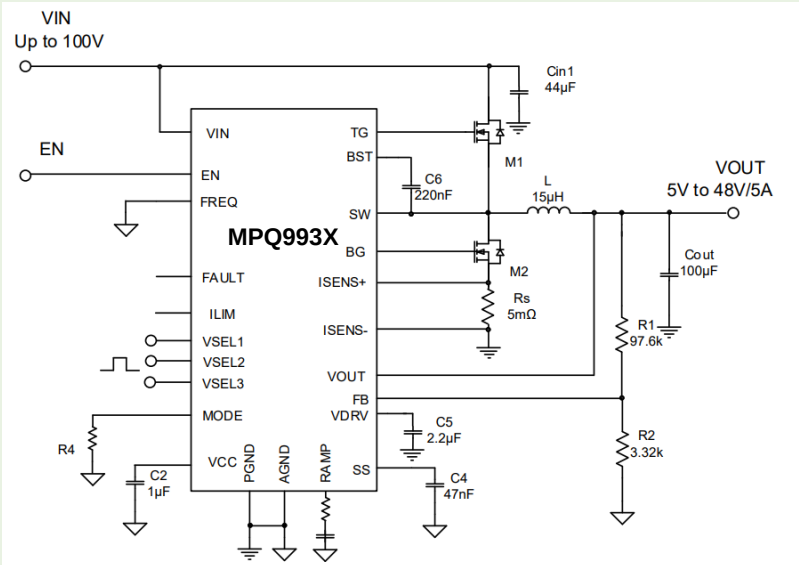


75V 1kW LLC power kit for ZCU





80V general DCDCs



48V E-fuse

MPQ588X-AEC1

80V, 2.5mΩ, E-Fuse & Smart High-Side Power Switch

Features

Built to Handle Tough Automotive Transients

- Load dump up to 80V
- -60V continuous reverse voltage self-protection

Cooler Thermals

- 2.5mΩ $R_{DS,ON}$

Extends Vehicle Battery Life

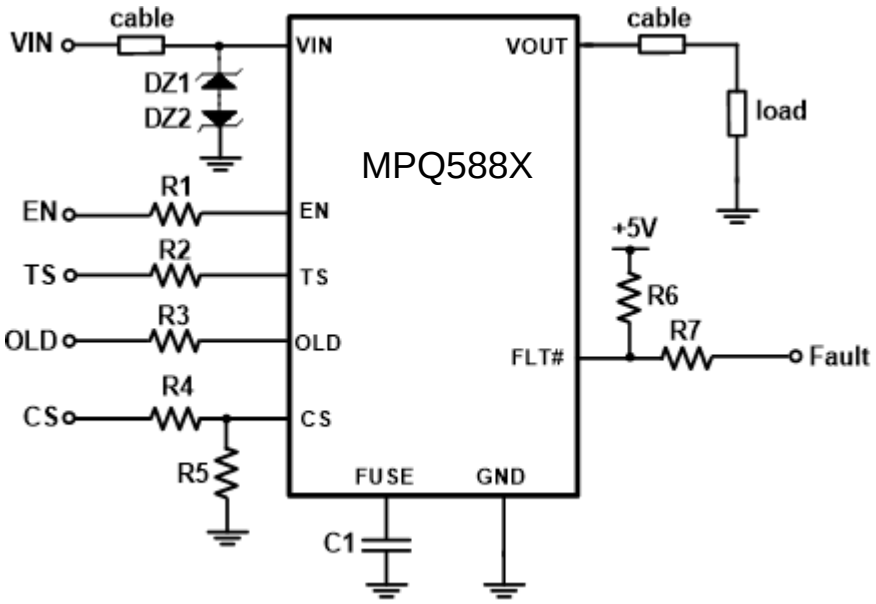
- 24uA Standby current
- Extremely low shutdown IQ

Built-in Various Protection and Monitoring

- Highly accurate current sense and reporting
- Fuse-like over current and short circuit protection
- Self-protection during reverse battery
- Fault reporting
- Thermal monitor
- Thermal shutdown
- Open load detection

Additional Features

- Enable pin support 3.3V or battery connection
- AEC-Q100-012 Test Grade A



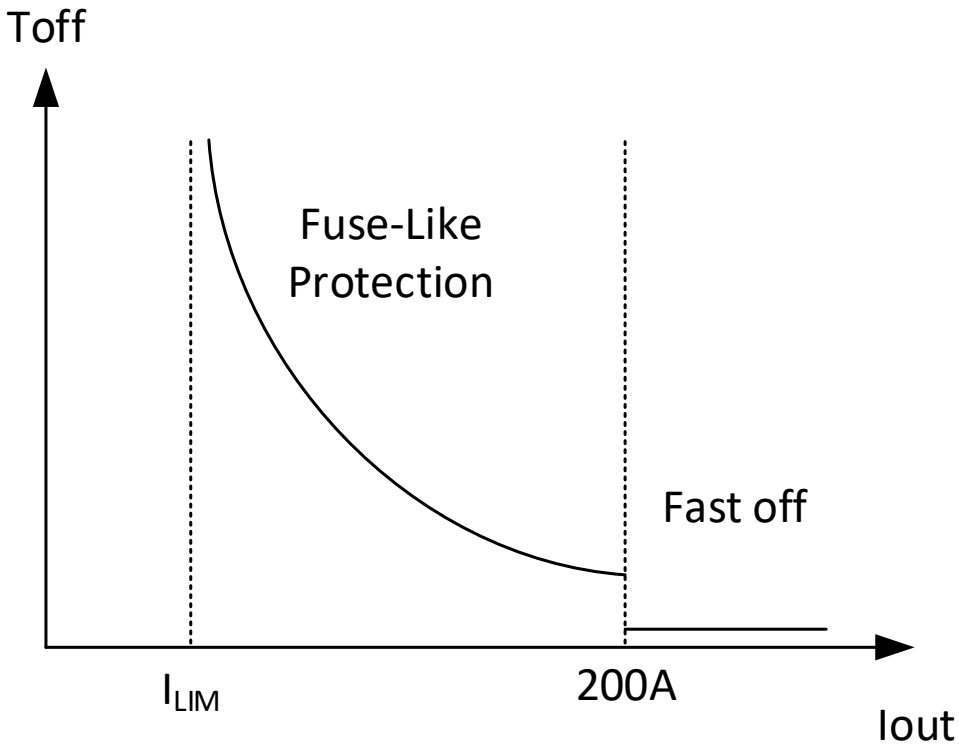
Key Specifications

6V – 80V	**-60V - 80V**	**2.5mΩ**	**25A**	PQFN (6X8 mm)
Recommended Operation Range	**Protected Input Range**	**$R_{DS,ON}$**	**Nominal Current**	**Package**

Applications

48V System E-Fuse and Relay Replacement	Ignition, Heaters, Motors	Inductive, Capacitive and Resistive Loads

I2t Characteristics of MPS E-fuse

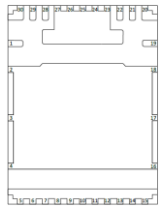


The greater the load current, the shorter the fusing time

48V E-fuse Competition

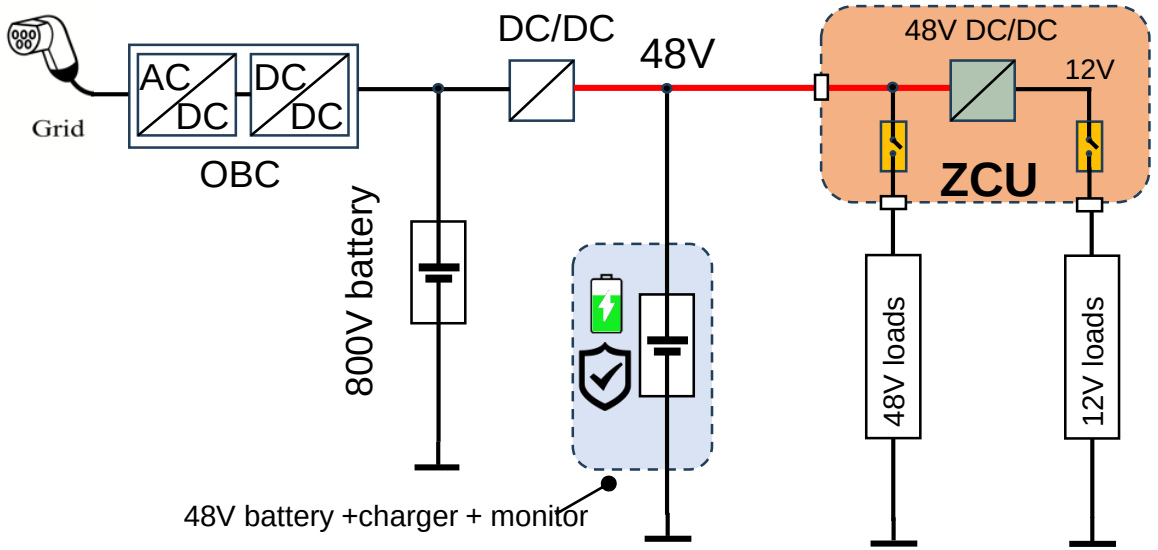
	Competitor	MPS
Parameters	XXXX	MPQ588x
Typ $R_{DS,ON}$	need external FET	2.5mohm, Integrated
Reverse Protection	N/A, need external circuitry	-60V DC
Power Loss	High, loss on both shunt and FET	Low, loss only on FET
Quiescent Current	Support Low Iq Mode	Support Low Iq Mode
	Normal Steady State=12mA	Normal Steady State=1.5mA
Monitoring	External, need additional shunt resistor and NTC	Integrated Current&Temp Sensing
OL Diagnostics		No need for external circuitry
Package	QFN (5*5mm) for controller only	QFN-24 (6*8mm) with integrated FET
BOM	Complicated	Simple

NTC + Shunt resistor + External FET + controller

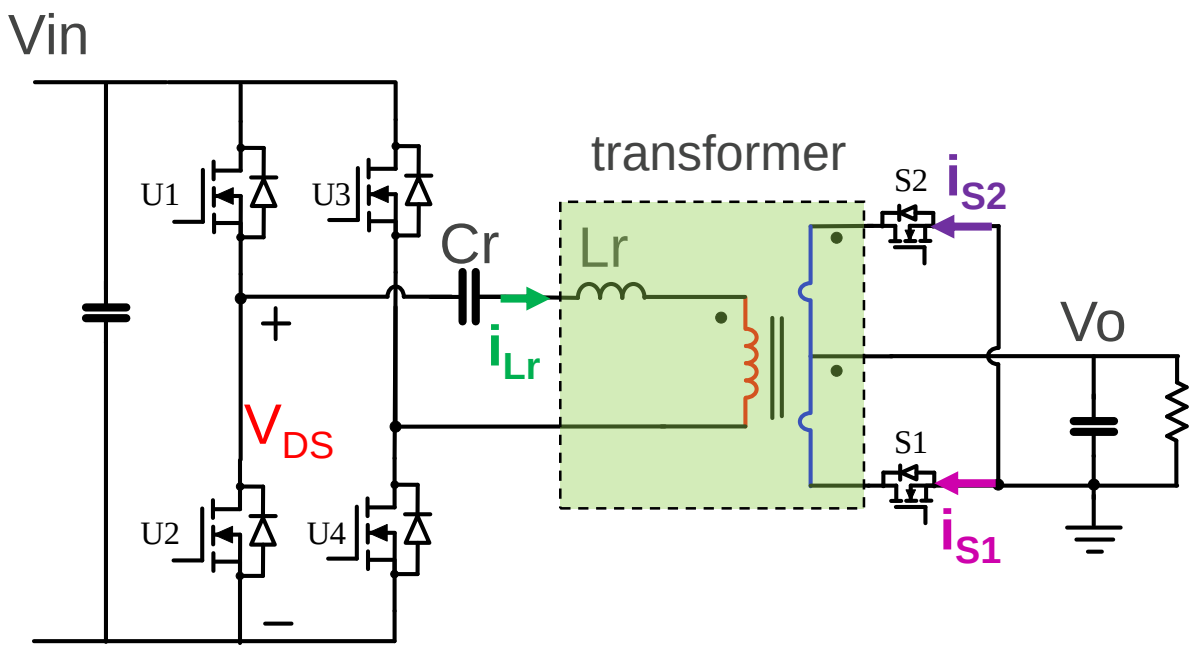


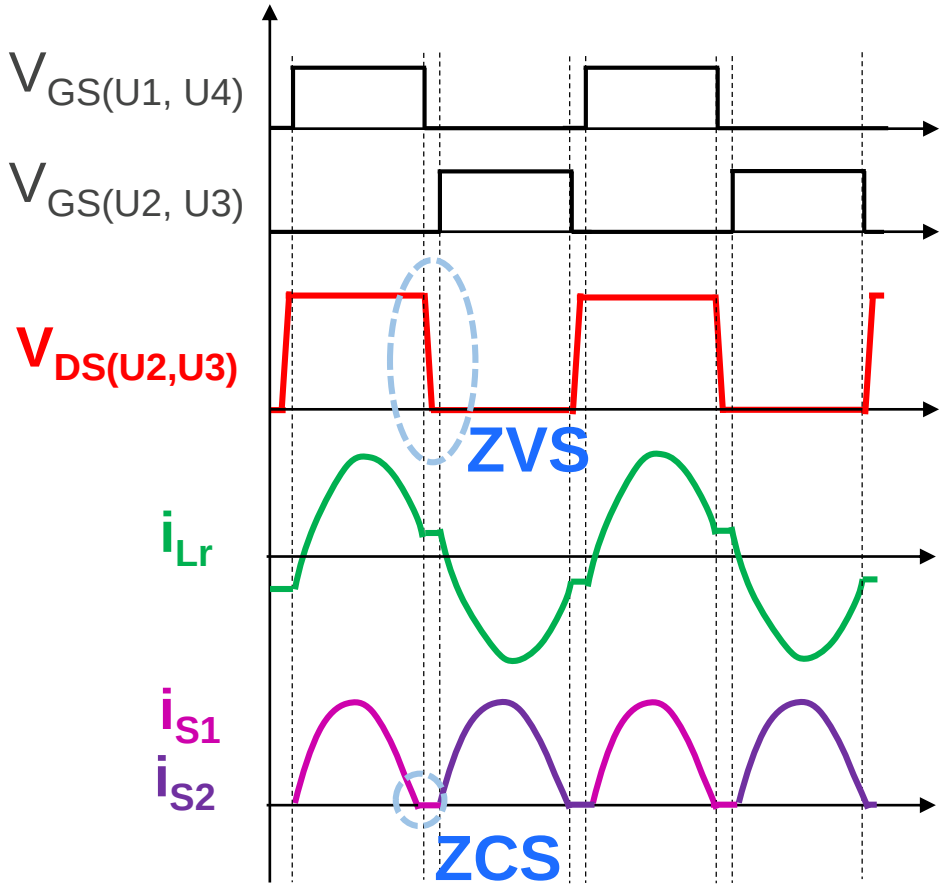
All-in-one solution

MPC12xxx LLC Kit for ZCU



Characteristics of LLC Converter





- **Soft switching: ZVS+ZCS**
  - High efficiency, high power density, low EMI
  - High operation frequency

MPC12xxx

75V Non-Isolated LLC-DCX

Features

- The power converter kit is a high-efficiency non-Isolated converter with a fixed 4:1 ratio,
- operating from a 36-75V DC primary bus to 9-19V output voltage,

- Support up to 400W, 800W, 1,000W continuous power
- Fixed 2MHz or 1MHz switching frequency
- Support parallel connection of 3 kits to 3kW
- Built-in MTP
  - Programmable Soft-start Time
  - Programmable Input OVP/UVLO
  - Programmable Output OVP/UVP
  - Programmable OCP
- Power Good

Comprehensive diagnostic functionality

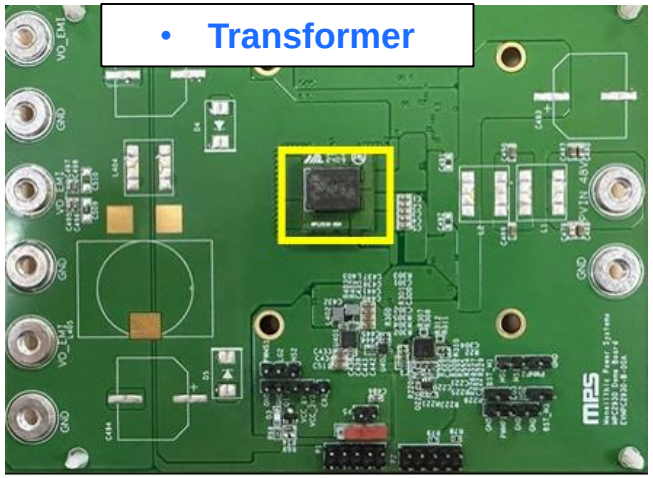
- Input and Output Voltage, Output Current, and Temperature Protection
- Input and Output Voltage, Output Current, and Temperature Monitoring

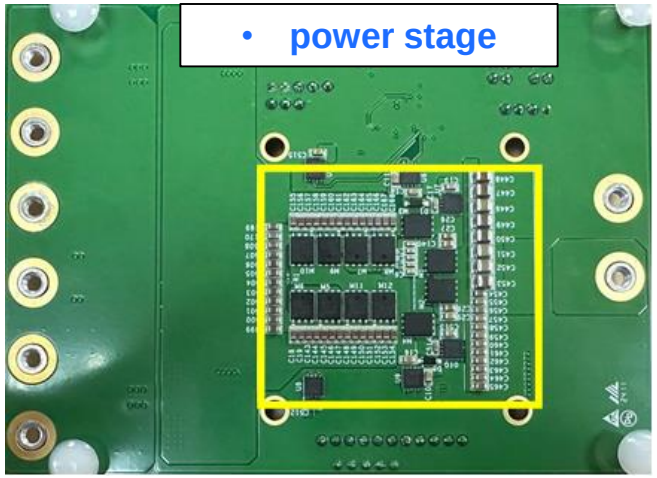
Robust Communication

- Support up to 1MHz frequency of I2C

Benefits of LLC converter kits

- Low EMI
- Highest Efficiency
- Robust reliability with flexible LLC kit option





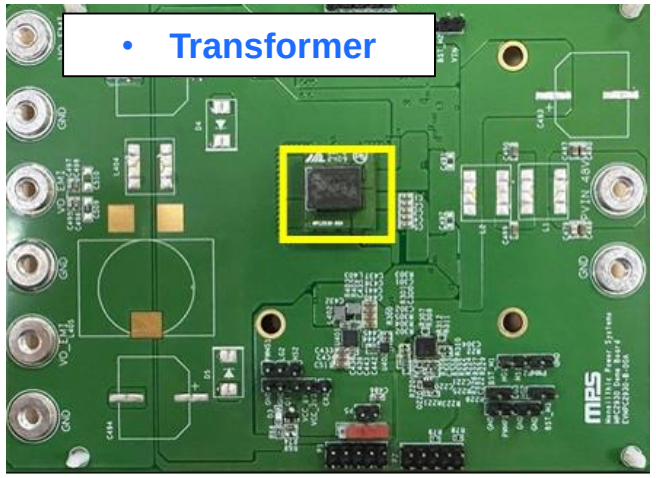
1000W

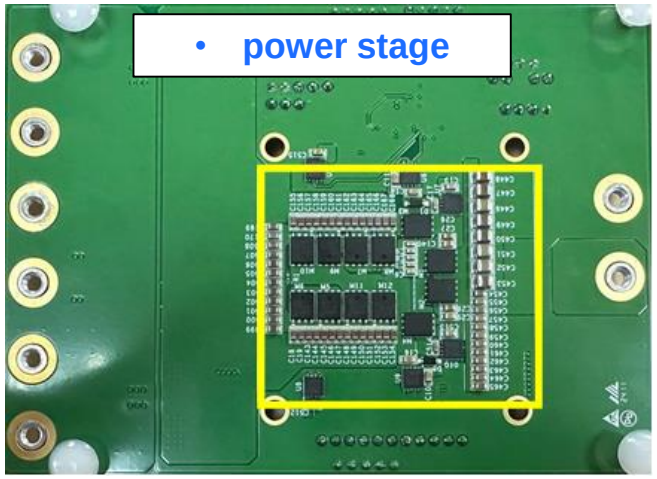
Key Specifications

36V-75V	9V-19V	83A	32x33x8mm
Input Voltage	**Output Voltage**	**Current**	**Kit Size(mm)**

Competitive Analysis: LLC with 4 phase buck

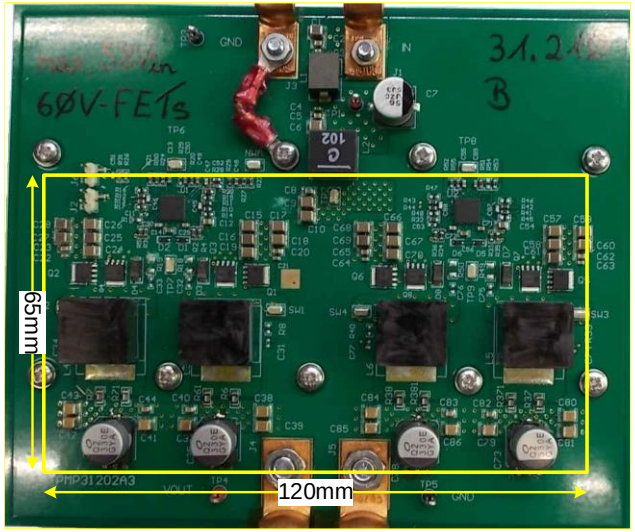
MPS LLC Kit:





- HSFET / LSFET: 5mm × 6mm discrete FETs
- TX : 16mm*14mm

4-phase buck:



- HSFET / LSFET: 5mm × 6mm discrete FETs
- Inductor: 15mm x 16mm

	MPS	Competitor
Topology	LLC	4-phase buck
Switching Frequency	2MHz	200kHz
EMI filter	Small	Large
Size	2250mm2 Height=7mm	7800mm2 Height=11mm
Efficiency	97.7% @400W 98.2%@ 240W	96% @ 400W
Cost	Low	High
Design	Easy design, MPS is the solution supplier	

Save 70% size

less power loss

48V power DCDC

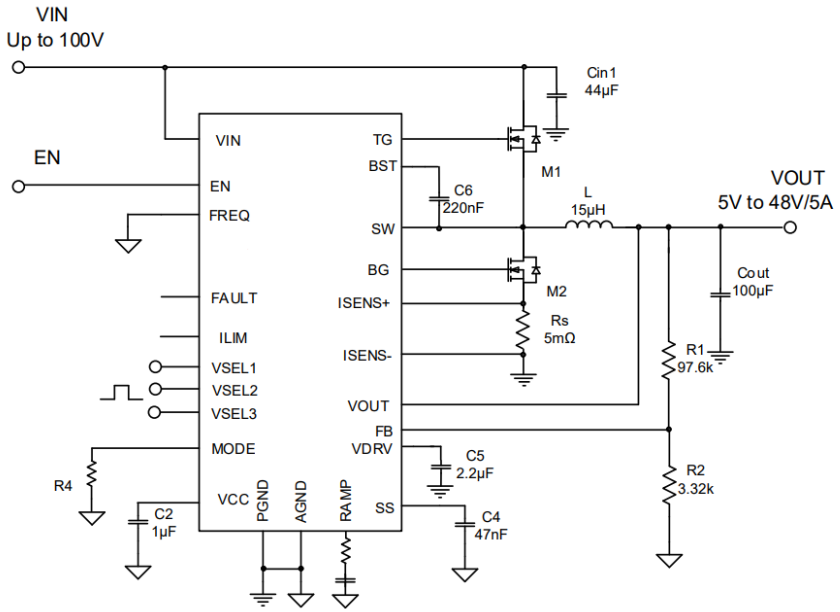
MPQ993X

80V, 30A Buck Controller

Features

- 5.5V-to-80V Input Voltage Range
- Up to 80V Output Voltage Range
- Programmable 0.17V to 1.6V FB Reference Voltage Range
- 30A Output current
- COT control
- Low Dropout Operation: 99% Maximum Operation Duty Cycle
- PSM/FCCM Selectable by Mode Pin
- Programmable 100kHz to 1000kHz Frequency with Spread Spectrum Function
- Bias VDRV by External Power Supply to Improve Efficiency
- 10V Gate Driver Capability for N-MOSFET(GaN gate Driver Option)
  - ✓ TG Source 1.6A Capability, Sink 4.5A Capability
  - ✓ BG Source 1.6A Capability, Sink 4.5A Capability
- Support Line Drop Compensation
- Dynamic Output Transition (VSELx) with Slew Rate Control
- Programmable Valley Current Limit by ILIM
- Output Passive Discharge Function
- Protection for Output OCP/SCP, V_{IN} OVP and V_{OUT} OVP, OTP
- Fault/PG selectable via OTP

Schematic



MPQ4583

90V, Low IQ, 1A/3A, Sync-Buck

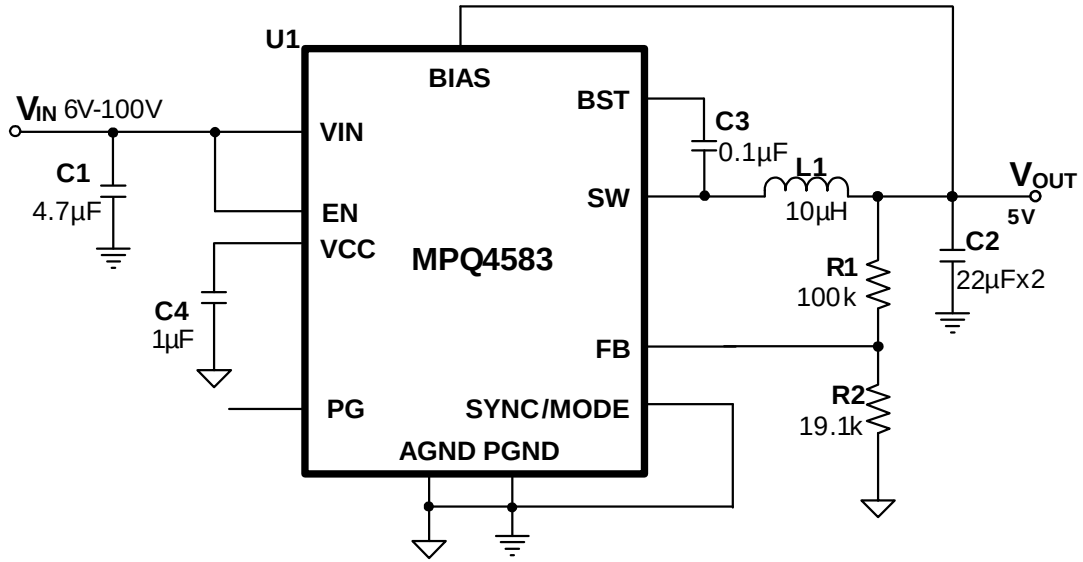
Features

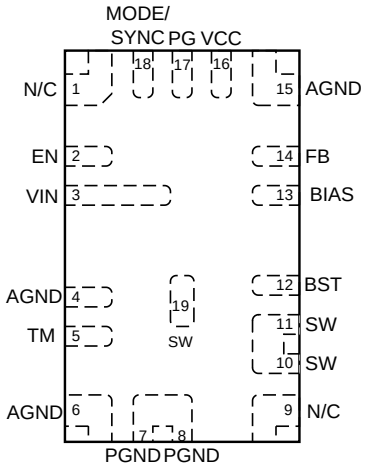
- AECQ and Consumer Options
- 4.5V-to-90V Input Voltage Range
- 9μA Quiescent Current
- Fix 5V/12V output option
- Internal Loop Compensation and Soft-Start
- Integrated Low Ron MOSFETs
- High efficiency in full power range
- Power Good(PG) Indication
- Programmable PSM / FCCM in Light Load
- Available in QFN-19 (3mm×5mm) Package
- Large Space between HV pin and LV pin for automotive
- 5V/12V fixed output option with higher efficiency

Application

- 48V Automotive Power Systems

Schematic





Thanks