

DIGITAL WE DAYS

2024



DIAGNOSTICS ON PCB

Arnaud Wendling | Würth Elektronik ICS

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

Diagnostics on PCB
INTRODUCTION

YOUR SPEAKER ON TODAY'S TOPIC



Arnaud Wendling
Product Manager – Electronics
at Würth Elektronik ICS GmbH & Co. KG



Ittenheim / FRANCE

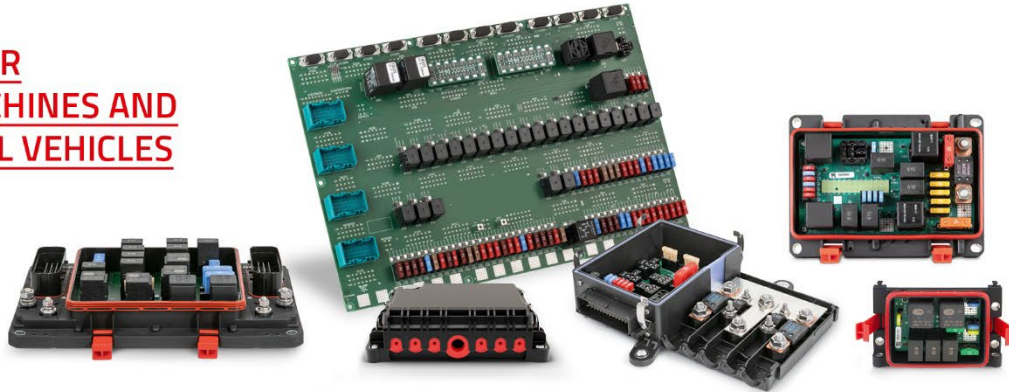
DIAGNOSTICS ON PCB

- What is a system diagnostic?
- Focus on PCB integrated solutions – examples
- Our service offer
- Questions and answers

Diagnostics on PCB

WÜRTH ELEKTRONIK ICS

SYSTEMS FOR MOBILE MACHINES AND COMMERCIAL VEHICLES



POWER DISTRIBUTION



HIGH VOLTAGE SOLUTIONS

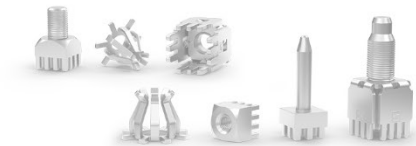
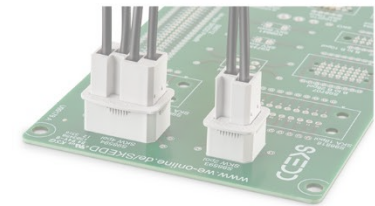


HMI SOLUTIONS



ELECTRONIC CONTROLLERS

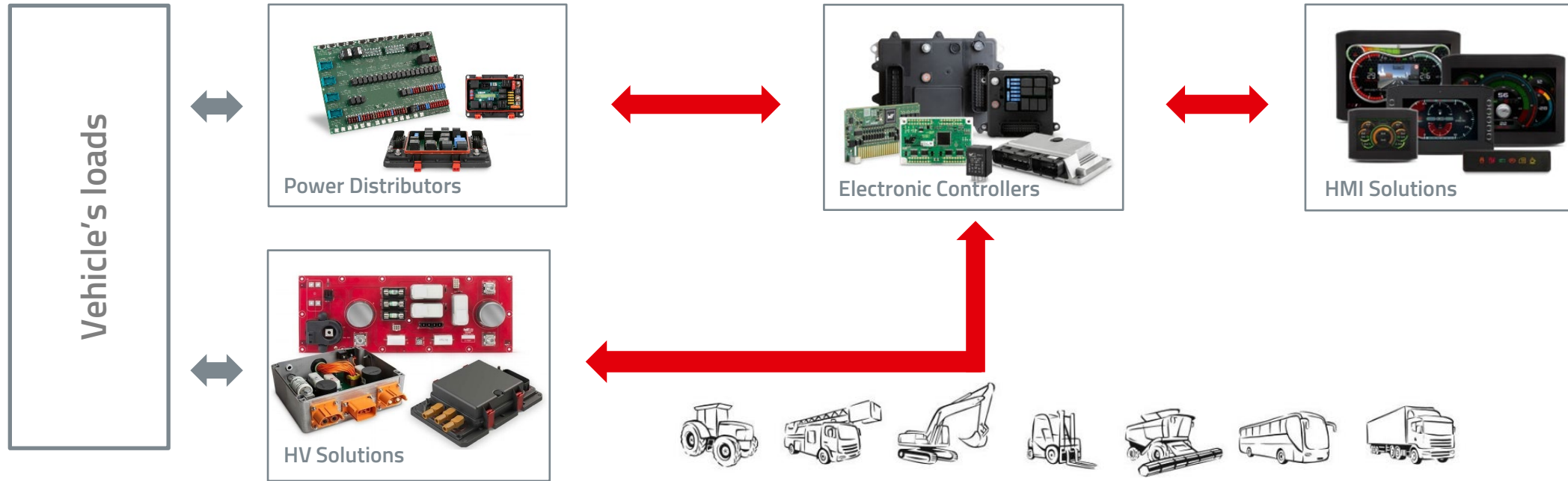
POWERFUL COMPONENTS FOR A WIDE RANGE OF APPLICATIONS



PCB COMPONENTS



SYSTEM DIAGNOSTIC: 3 LEVELS



1

PCB design (HW)

- Physical interface for diagnostic

2

Embedded software design

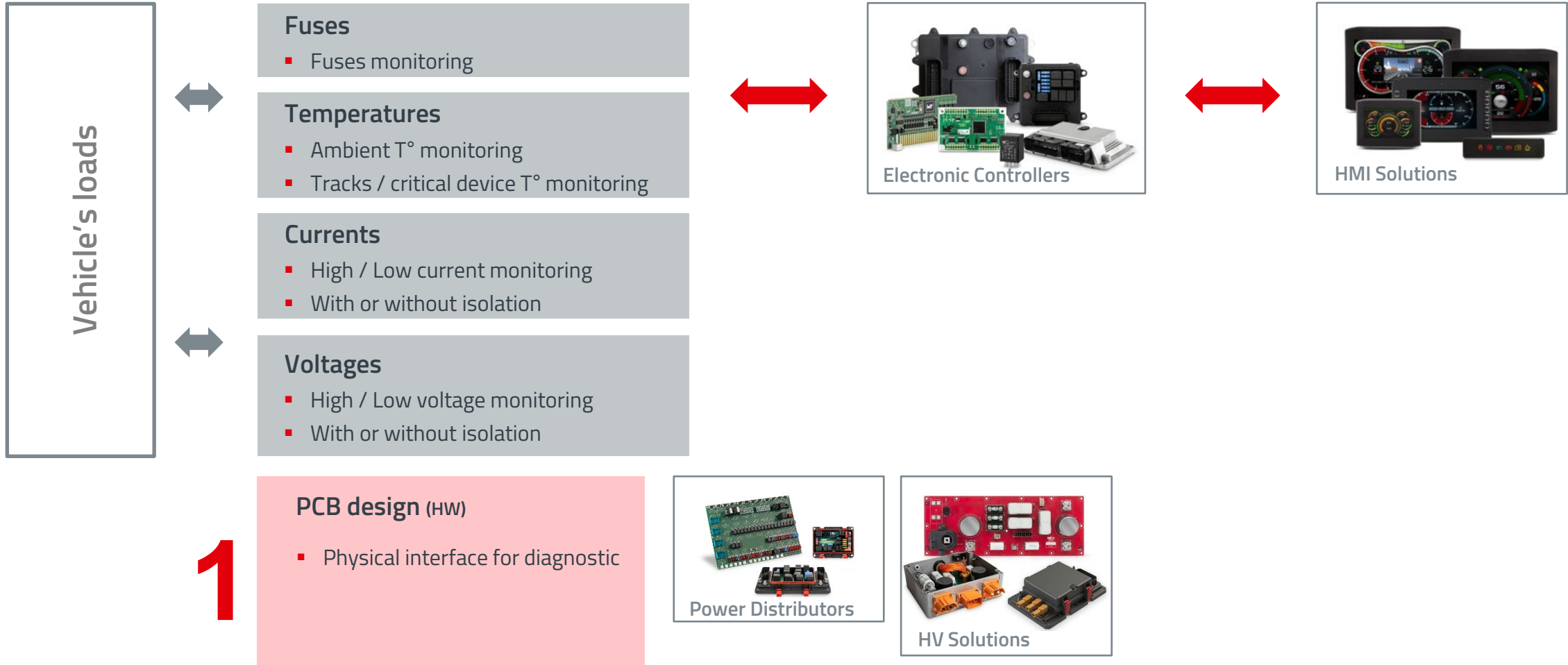
- Diagnostic logic implementation
- Diagnostic on vehicle networks

3

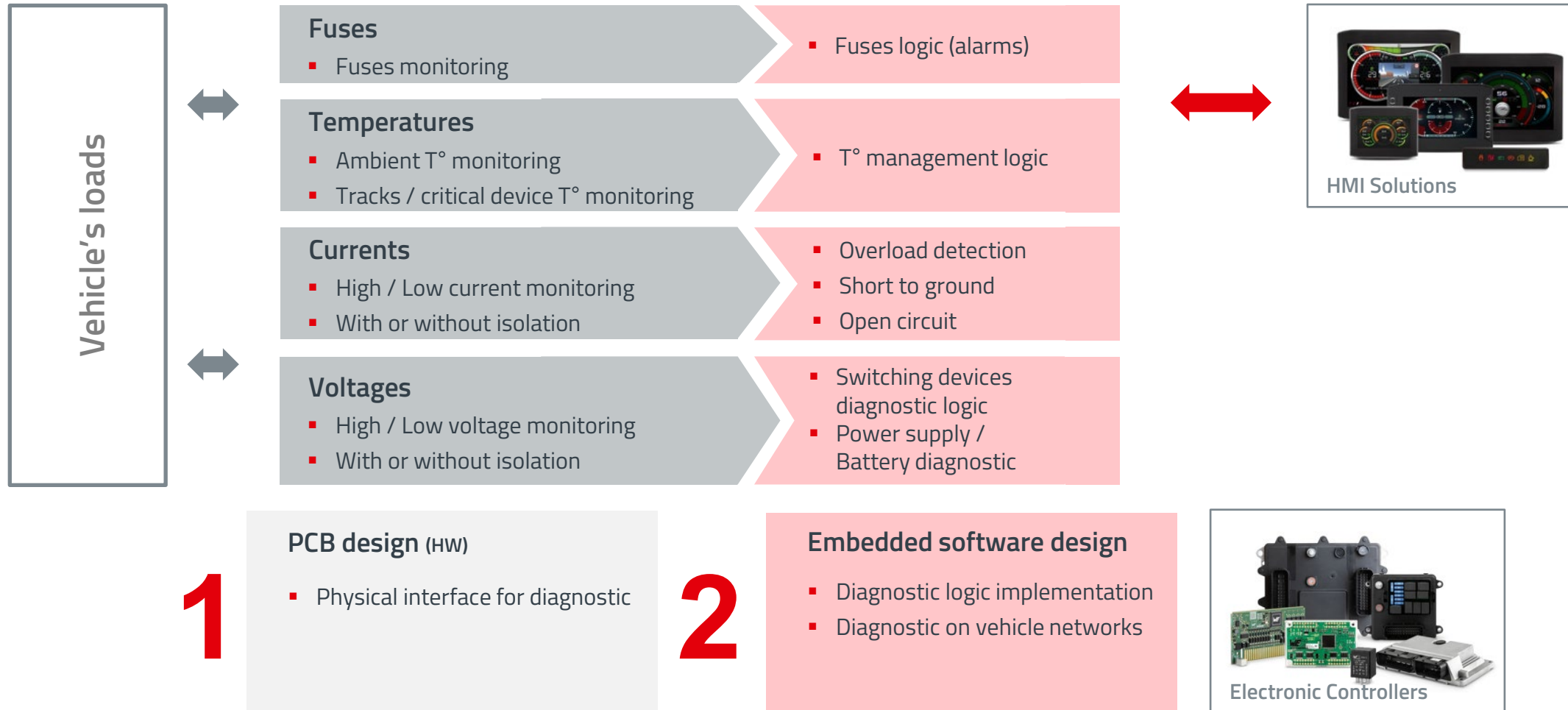
HMI design

- Report issues
- Record issues
- Provide dashboards

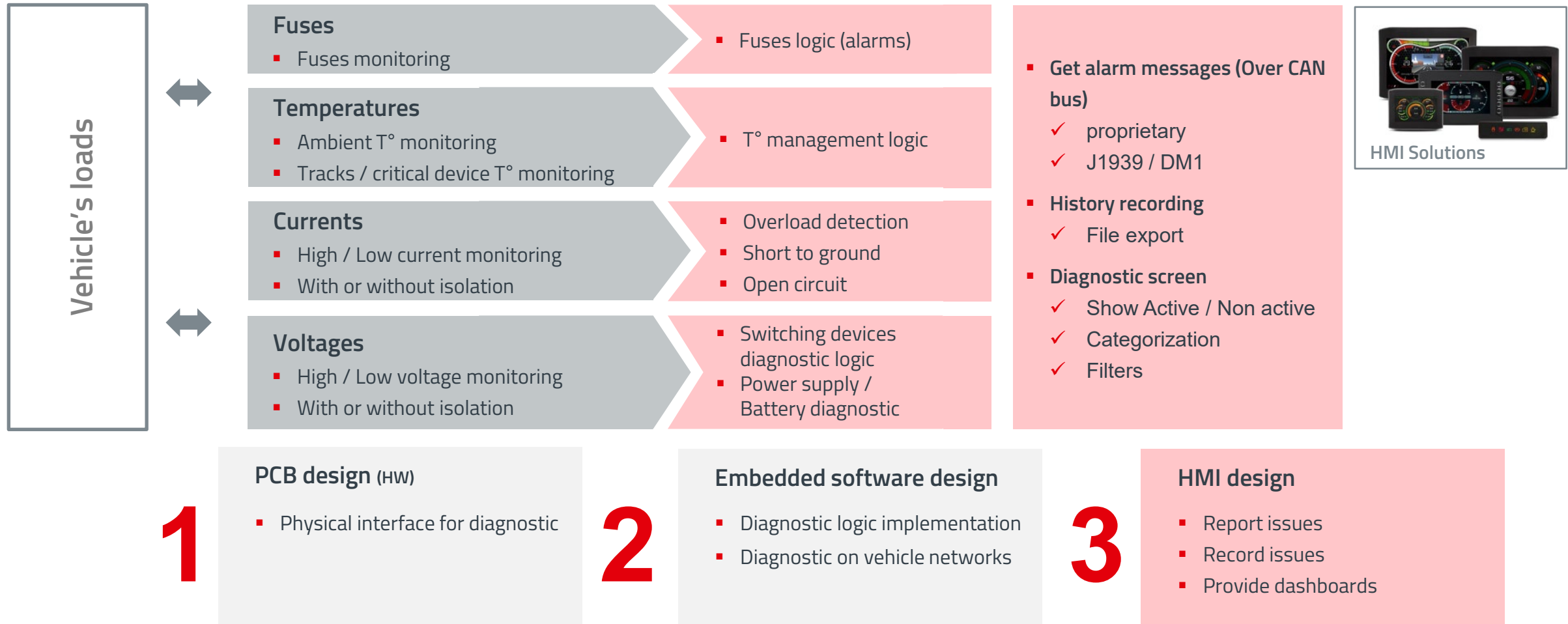
SYSTEM DIAGNOSTIC: HARDWARE



SYSTEM DIAGNOSTIC: SOFTWARE



SYSTEM DIAGNOSTIC: HMI



DIAGNOSTICS ON PCB

- What is a system diagnostic?
- Focus on PCB integrated solutions – examples
- Our service offer
- Questions and answers

Diagnostics on PCB

INTEGRATED SOLUTIONS - EXAMPLES

Fuse

Temperature

Current

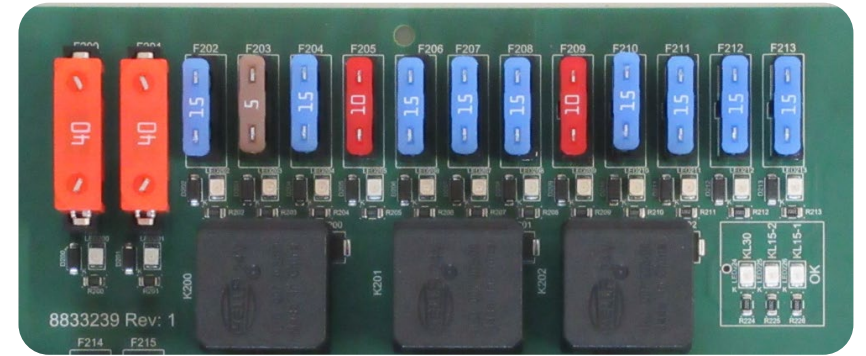
Voltage



Diagnostics on PCB

INTEGRATED SOLUTIONS - EXAMPLES

Fuse



INTEGRATED SOLUTIONS - EXAMPLES

Fuse

Context:

- ✓ A load on a LV electrical system has an overcurrent fault.
- ✓ A harness is faulty.

A fuse is blown on the PCB.

Problem:



How to find the blown fuse?

Goal:

See different integrated solutions to identify the blown fuse.

Show how PCB design can help to spare time and avoid mistakes during troubleshooting.

Diagnostics on PCB

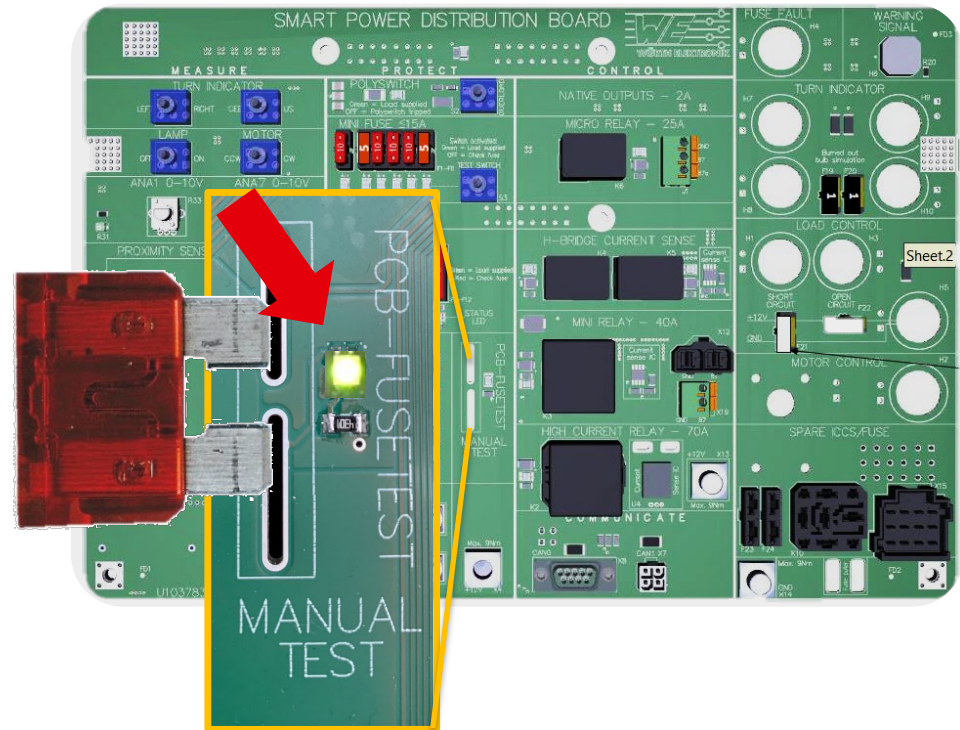
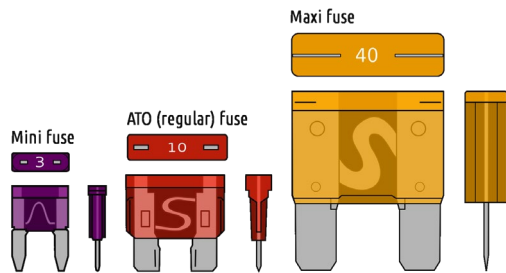
INTEGRATED SOLUTIONS - EXAMPLES

Fuse

Manual fuse test

Simplest solution

- Embedded on PCB
- Hold the lever switch to test the fuses!



Diagnostics on PCB

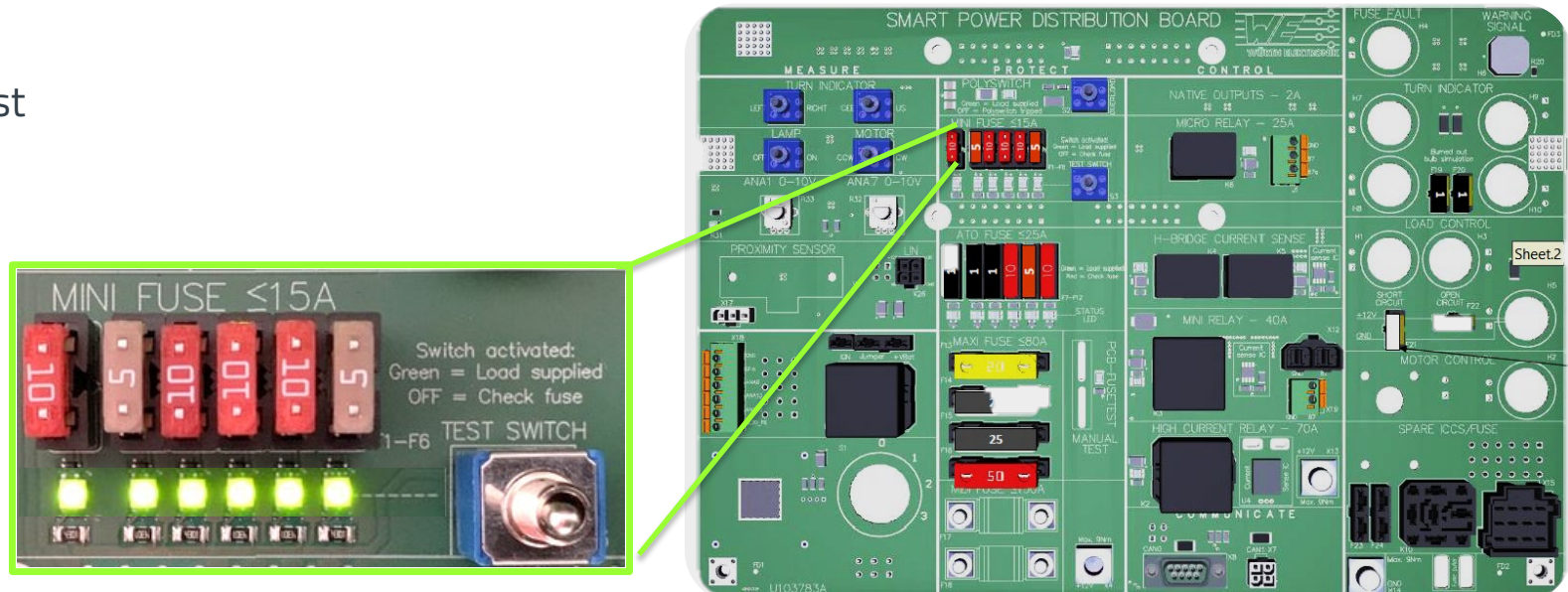
INTEGRATED SOLUTIONS - EXAMPLES

Fuse

Manual fuse test

Fast & Easy troubleshooting

- Embedded on PCB, low cost
- Mini, ATO, Maxi fuse

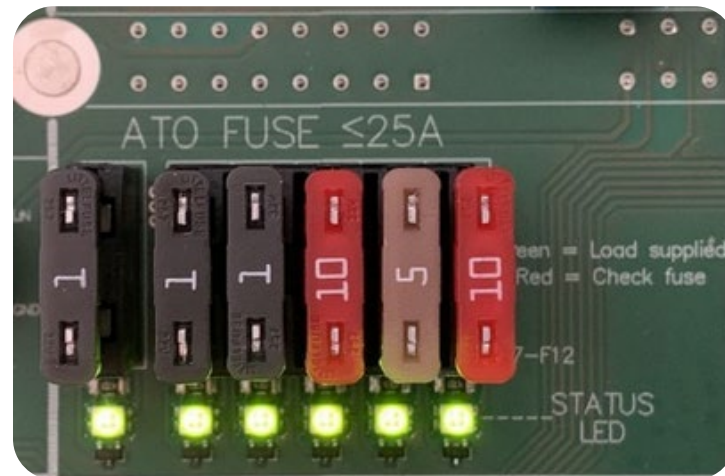


Diagnostics on PCB

INTEGRATED SOLUTIONS - EXAMPLES

Fuse

Permanent display fuse test



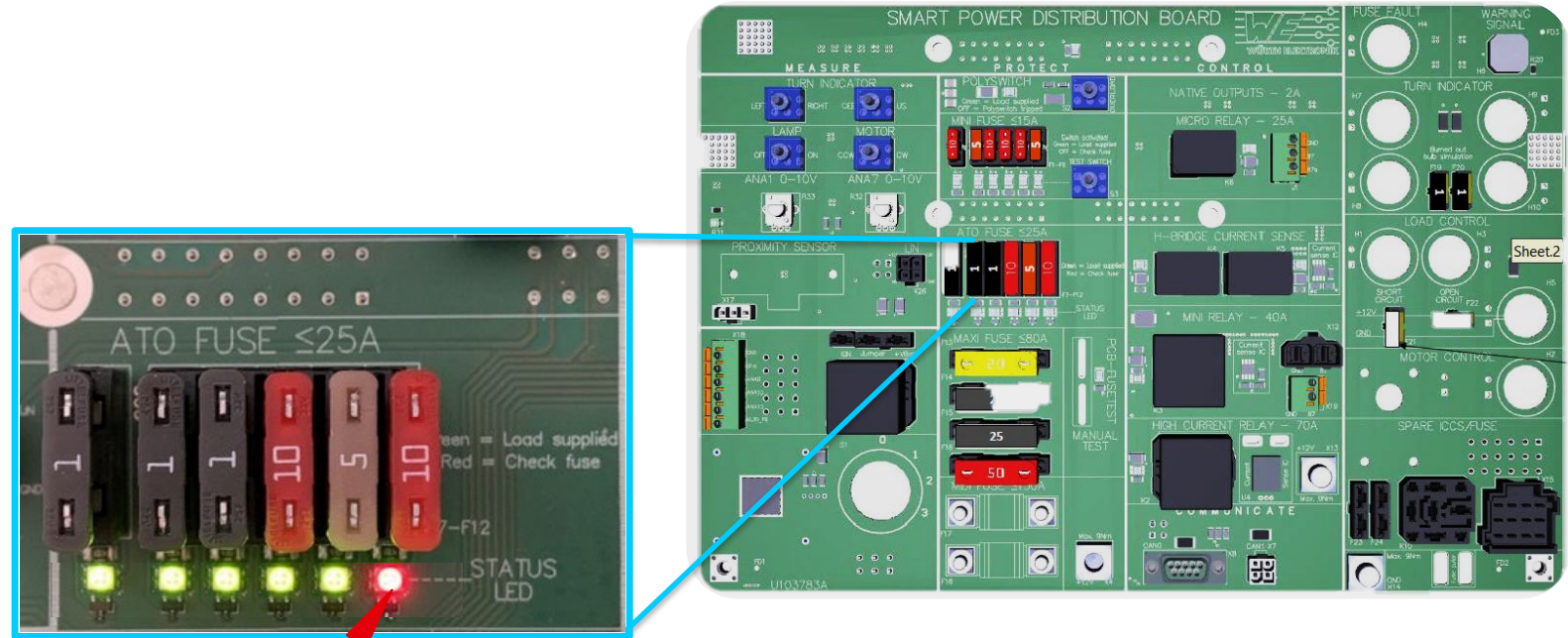
INTEGRATED SOLUTIONS - EXAMPLES

Fuse

Permanent display fuse test

Direct display

- Embedded on PCB
- Fuse status view



For lower current consumption, permanent green LED option can be removed. And show only blown fuses (in red).

INTEGRATED SOLUTIONS - EXAMPLES

Fuse

Controller based monitoring

- ICCS CAN Controllers
- ICCS SDK Plus
- C / function block



- CAN Controller 8FR-6, ePDM 70-150, CDM-A16
- WEcontrol Designer
- IEC 61131-3 based



INTEGRATED SOLUTIONS - EXAMPLES

Fuse

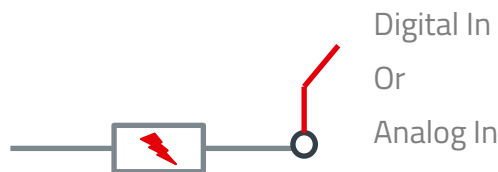
Controller based monitoring

Example on 12/24 Volts systems

- ICCS CAN Controller 64P V2

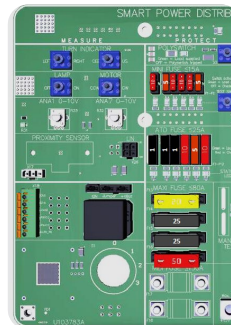
Measure fuse voltage using:

- Analog input
- Digital input



CAN bus

PCB + ICCS
Controller



WEcabin Solutions

- Live monitoring
- Alarms
- History
- Dashboards



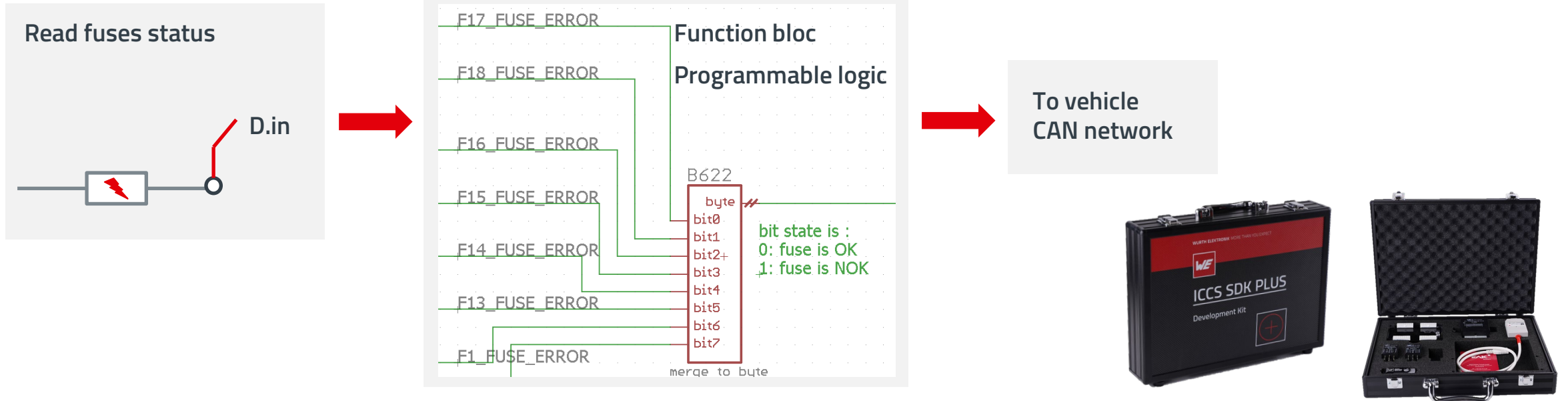
Measuring with analog input allows to monitor the power supply voltage for voltage drop, battery state, ...

Diagnostics on PCB

INTEGRATED SOLUTIONS - EXAMPLES

Fuse

Controller based monitoring



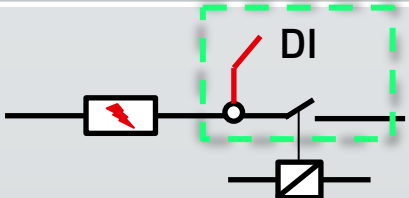
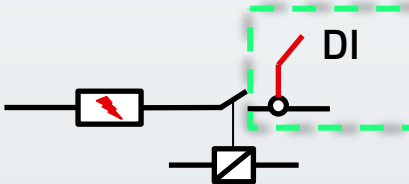
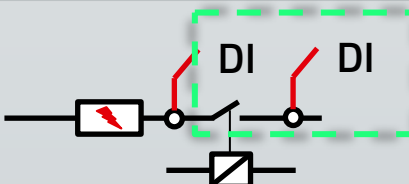
ICCS SDK Plus supports C programming language.

INTEGRATED SOLUTIONS - EXAMPLES

Fuse

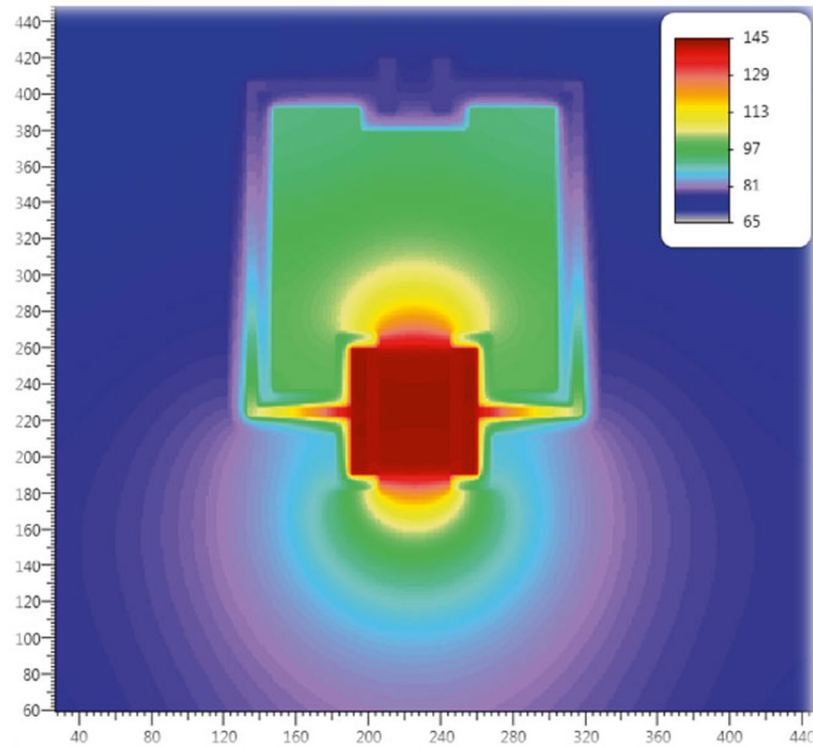
Controller based monitoring

Advanced solutions

Schematic	Use case
	Simple fuse check → Information about fuse only
	Load voltage check → Information about load supply only
	Both → allows to check power supply availability, and switching relay

INTEGRATED SOLUTIONS - EXAMPLES

Temperature



INTEGRATED SOLUTIONS - EXAMPLES

Temperature

Context:

- ✓ Ambient T° has to be monitored inside an electrical enclosure.
- ✓ Surface T° has to be monitored on a PCB.

IC device dimensions shrink, heat management become tougher-than-ever challenge.

Problem:



How to monitor a T° ?

Goal:

See different integrated solutions to measure a T° on PCB / inside a PCB enclosure.

Diagnostics on PCB

INTEGRATED SOLUTIONS - EXAMPLES

Temperature

Thermistors



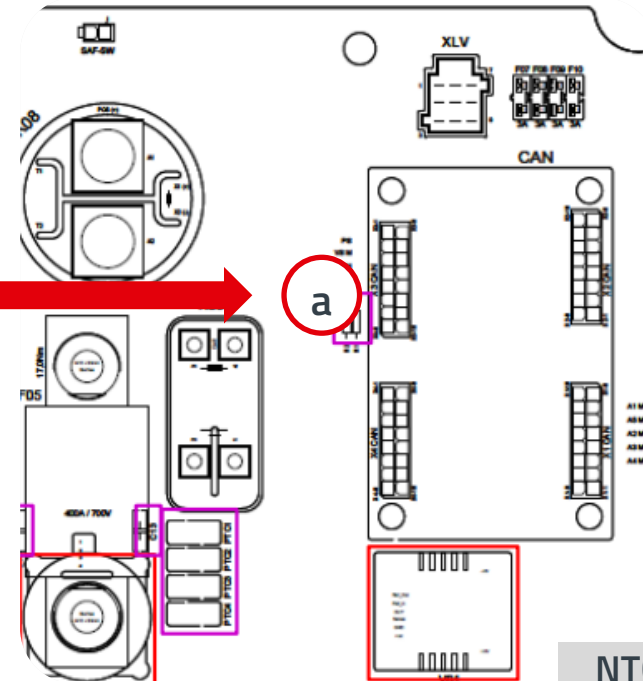
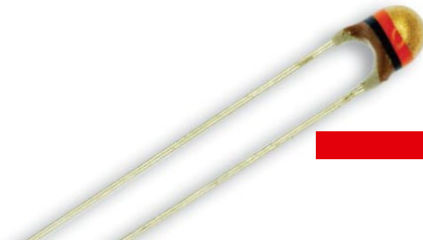
INTEGRATED SOLUTIONS - EXAMPLES

Temperature

Thermistors

Monitor ambient temperature in HV enclosure

- NTC thermistor
- NTCLE100E3 ... series



Typical values

- Medium temperature range (-40°C to 125°C)
- Good accuracy (+/- 0.05°C to 3°C)
- Stability (+/- 0.2°C per year)
- Medium response time (1.2 s)

Notes

- Low price
- Regulated power supply required
- Self heating
- Non linear

NTC

- Mounted close to controller **a** for ambient T° sensing

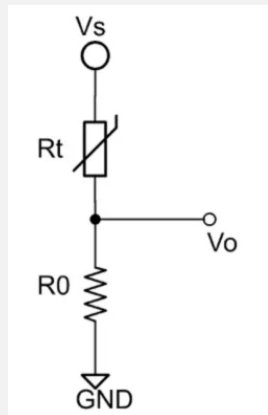
INTEGRATED SOLUTIONS - EXAMPLES

Temperature

Thermistors

Implementation example of ICCS CAN Controller 64P V2

Analog voltage acquisition



ICCS CAN Controller 64P V2



- ✓ $R_t = R_0 \cdot (V_s / V_{meas} - 1)$
- ✓ use Look-up table $R_t = (T^\circ)$



To CAN network



Telematics



WEcabin Solutions



Keep current under 1mA or less to avoid self heating

INTEGRATED SOLUTIONS - EXAMPLES

Temperature

Thermistors

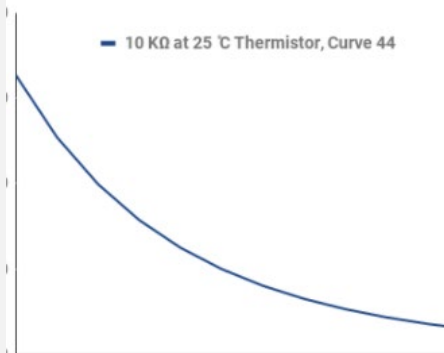
Easy ICCS SDK Plus programming

Read voltage

- ✓ Calculate R_t NTC resistor Value
- ✓ Use Look-up table



Resistance (Ω) vs. Temperature ($^{\circ}\text{C}$)



Use in graphical code

```
..... See usercode.c .....  
VARIABLE_IN xxxx .....  
..... USERVAR_Tntc_DEGC .....
```



ICCS SDK Plus has built-in functions for look-up-table

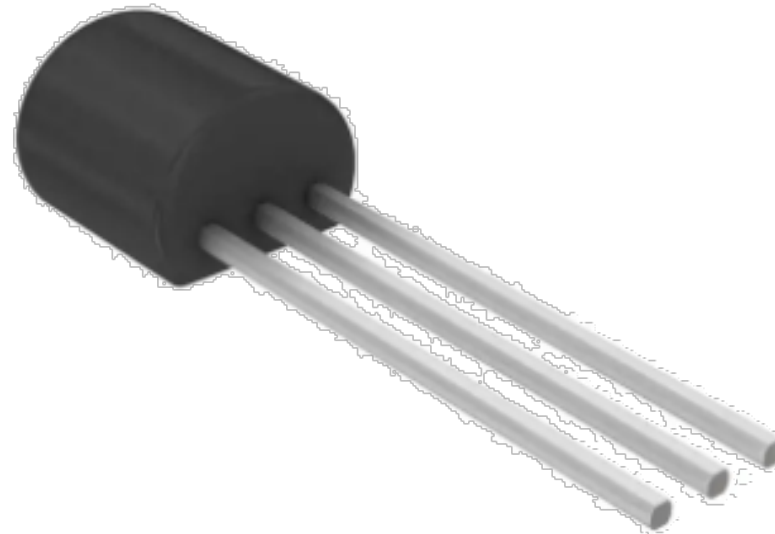
```
ret = os_util_lookup1D(arr_x, arr_y, 5, 250, LUT_MODE_EXTRAPOLATION);
```

Diagnostics on PCB

INTEGRATED SOLUTIONS - EXAMPLES

Temperature

IC based measurement



Diagnostics on PCB

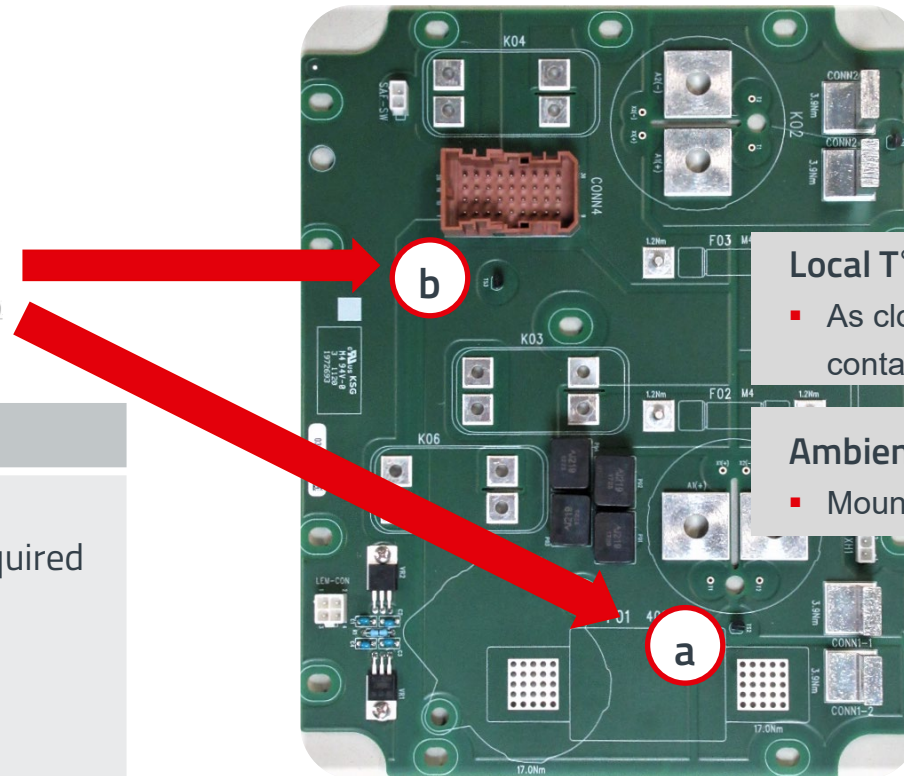
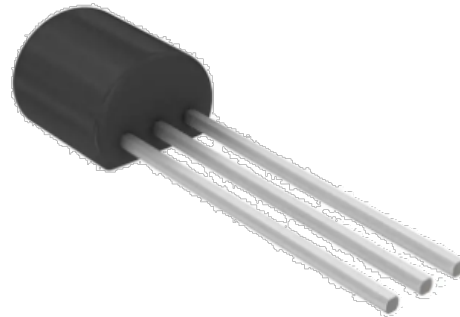
INTEGRATED SOLUTIONS - EXAMPLES

Temperature

IC based measurement

Monitor hotspots on PCB

- Mounted on PCB
- Through holes or SMT
- TMPXX series



Local T° Measurement

- As close as possible with power contactor

a

Ambient T° Measurement

- Mounted in clear area

b

Typical values

- Low-medium temperature range (-55°C – 150°C)
- Accuracy(+/- 0.05 to 1.5°C)
- Stability (+/- 0.4°C per 10 years)
- Linearity (+/- 0.5°C)
- Slow response time (80 % @ 40 s)

Notes

- Inexpensive
- Voltage supply required (active)
- Low self heating

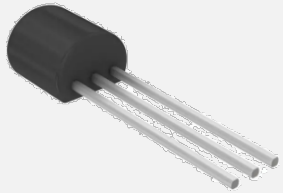
INTEGRATED SOLUTIONS - EXAMPLES

Temperature

IC based measurement

Implementation example of ICCS CAN Controller 64P V2

Analog voltage acquisition



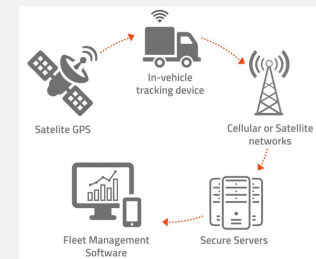
ICCS CAN Controller 64P V2



To CAN network



Telematics



WEcabin Solutions



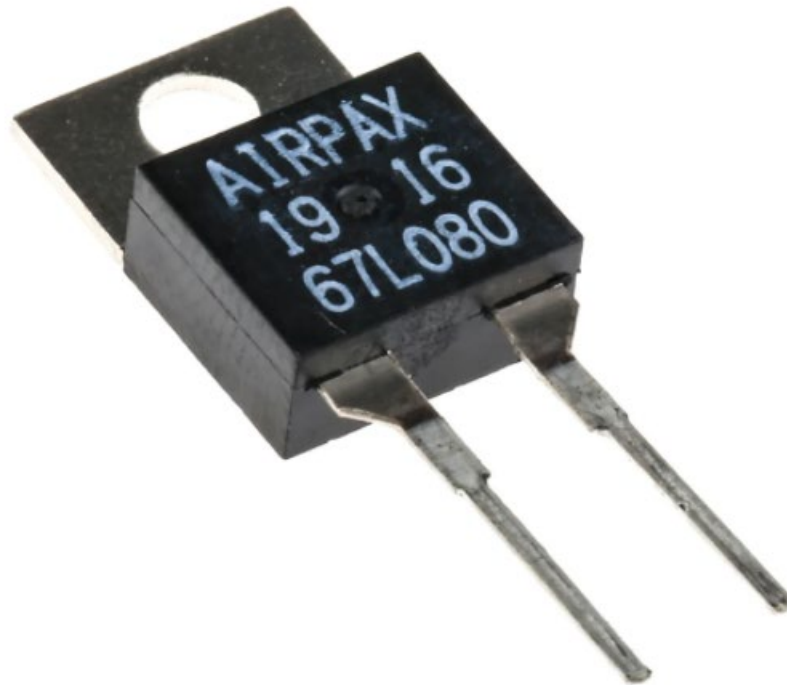
Useful for precise live monitoring or recording temperature history

Diagnostics on PCB

INTEGRATED SOLUTIONS - EXAMPLES

Temperature

Thermo-contacts



INTEGRATED SOLUTIONS - EXAMPLES

Temperature

Thermo-contacts

Safety switch

- Surface mount & ambient air sensing
- Switches a bi-metal contact when $T^\circ > \text{threshold}$
- AIRPAX 6700 SERIES

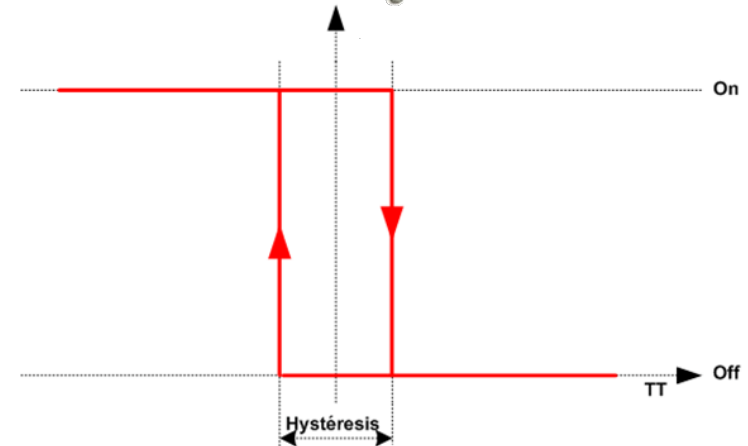
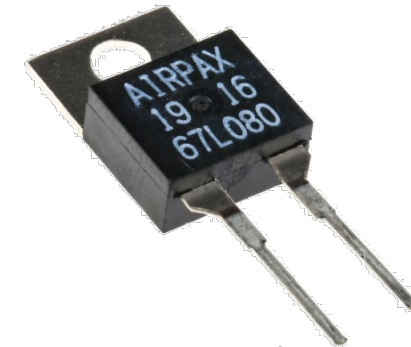


Typical values

- Low temperature range (40°C to 130°C)
- Low accuracy (+/- 5°C)
- Stability (30000 to 100000 cycles)
- Slow response time

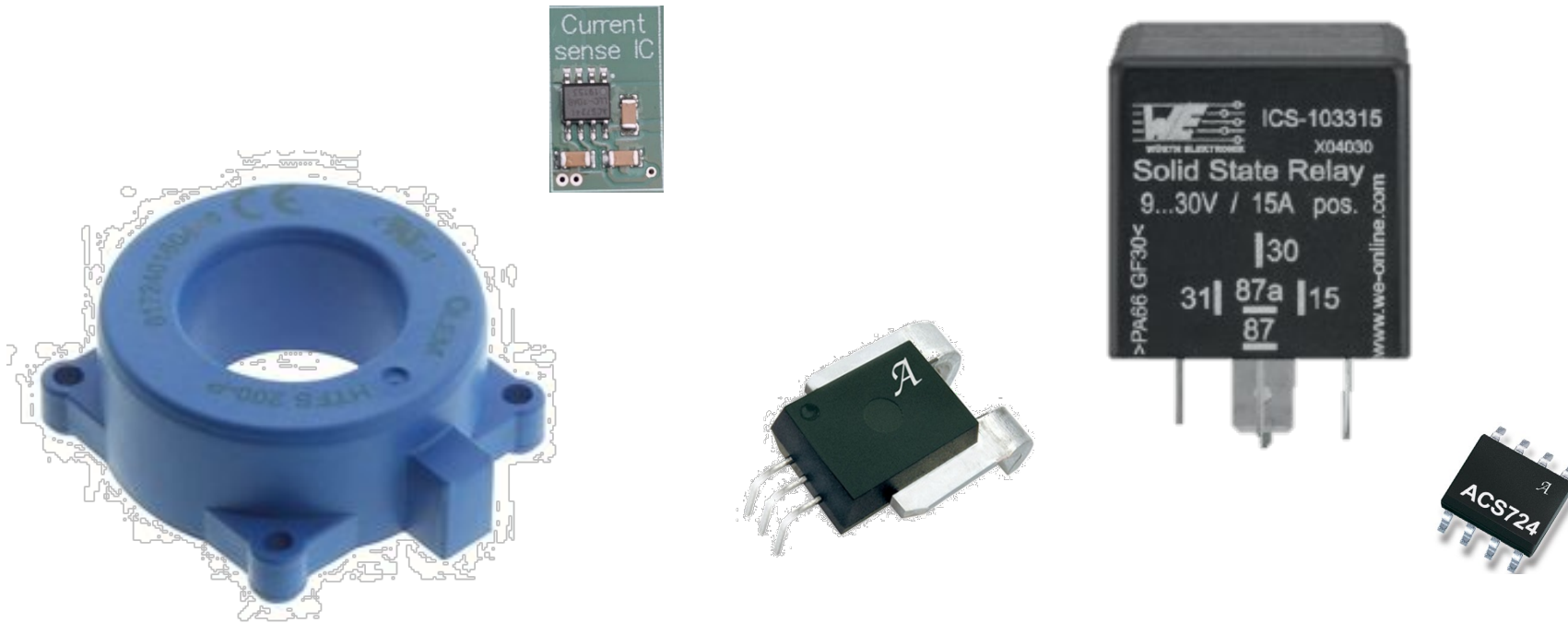
Notes

- Inexpensive
- Auto-rearm
- Low current (max 1 A)



INTEGRATED SOLUTIONS - EXAMPLES

Current



INTEGRATED SOLUTIONS - EXAMPLES

Current

Context:

A system needs current survey:

- ✓ sourcing current from battery or power supply
- ✓ sinking currents from loads (i.e. auxiliaries, motor, ..)

Problem:



How to monitor a current?

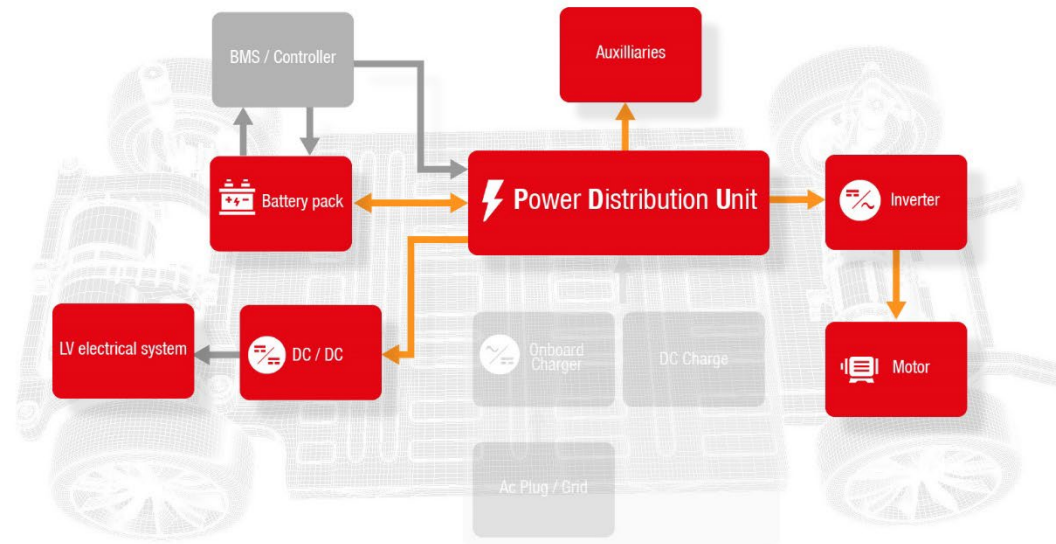
Goal:

See different techniques to integrate a current measurement on PCB.

INTEGRATED SOLUTIONS - EXAMPLES

Current

Application example

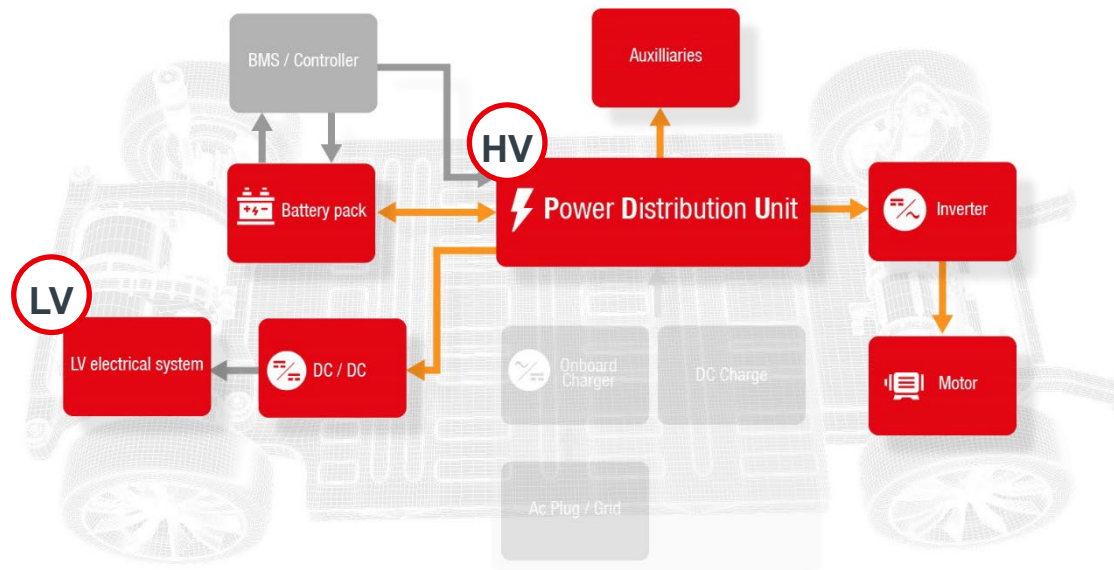


INTEGRATED SOLUTIONS - EXAMPLES

Current

Application example

Measurement solutions split between **HV** and **LV** systems.



PDU

- High voltage
- High current

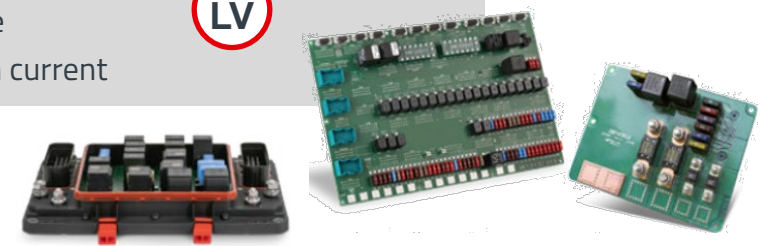
HV



LV electrical system

- Low voltage
- Low or High current

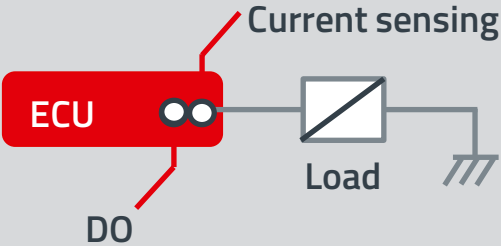
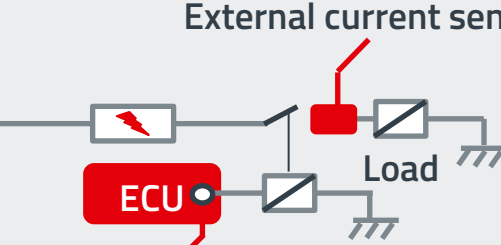
LV



INTEGRATED SOLUTIONS - EXAMPLES

Current

Application example

Schematic	Use case
 <p>Current sensing</p> <p>ECU</p> <p>DO</p> <p>Load</p>	<p>Built-in the controller Low voltage systems (9–30 V) < 2 A (typical for ICCS CAN Controllers) No galvanic isolation</p> <p>HV LV</p>
 <p>External current sensing</p> <p>ECU</p> <p>DO</p> <p>Load</p>	<p>External sensor High or low voltage systems with high current loads or galvanic isolation required</p> <p>HV LV</p>

INTEGRATED SOLUTIONS - EXAMPLES

Current

Built-in sensors (ICCS CAN & Power Distribution Controllers)



Implementation example of CAN Box 8FR-6

- ✓ high side outputs measurement (low range, up to 2 A).
- ✓ relay outputs measurement (medium range, up to 15 A)



CAN Box 8FR-6

Built-in current diagnostic



To CAN network



Telematics



WEcabin Solutions



- ✓ *Display*
- ✓ *Record*
- ✓ *Alarm*

Diagnostics on PCB

INTEGRATED SOLUTIONS - EXAMPLES

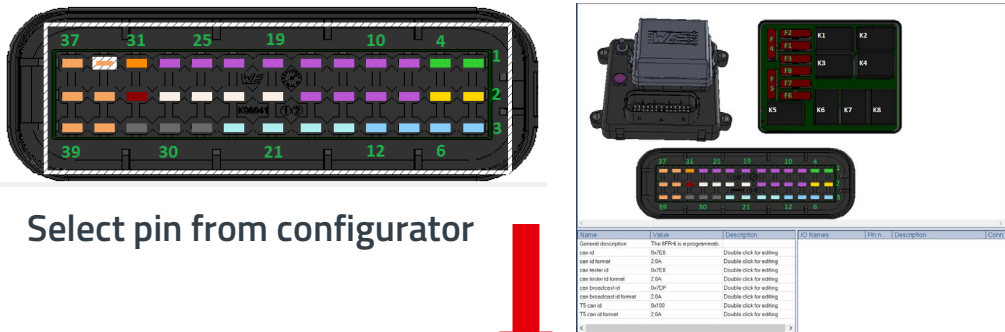
Current

Built-in sensors (ICCS CAN & Power Distribution Controllers)



Implementation example of CAN Box 8FR-6

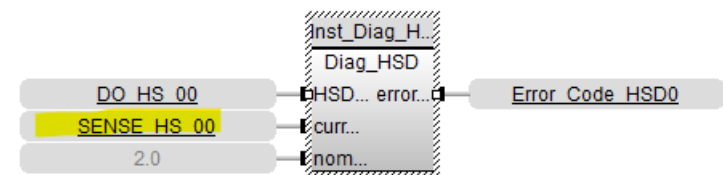
High side output monitoring in WEcontrol Designer software



Select pin from configurator

Use signal name in graphical programming

- 1 Open load
- 2 Overcurrent
- 3 Short to bat



Custom IEC 61131-3 function bloc

INTEGRATED SOLUTIONS - EXAMPLES

Current

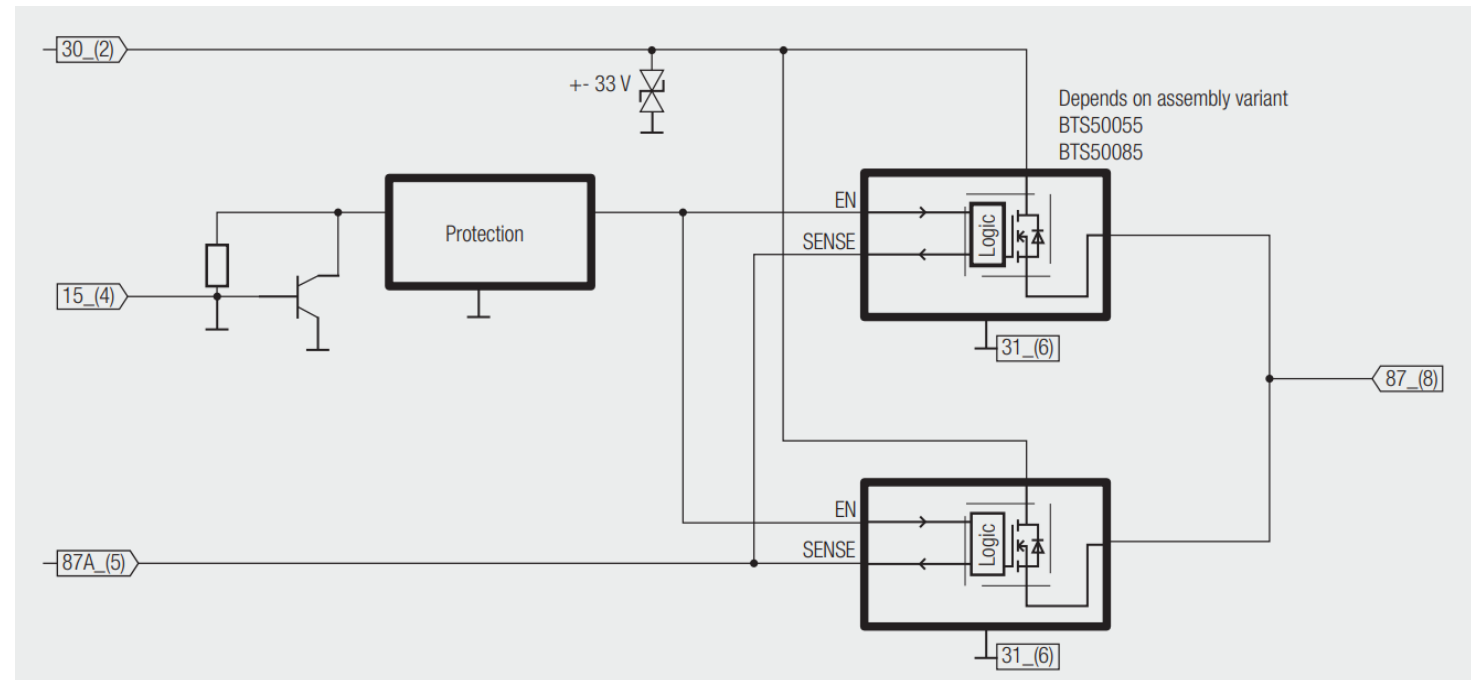
Solid State Relay

Solid State Relays (with integrated current sensing)

2 in 1 relay + sensor Low / Medium range, up to 25 A

Monitor current with low precision ($\pm 0,2$ A)

Voltage output, proportional to current

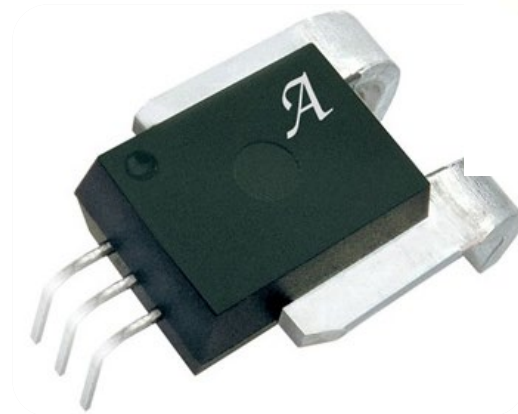


Diagnostics on PCB

INTEGRATED SOLUTIONS - EXAMPLES

Current

Hall sensors



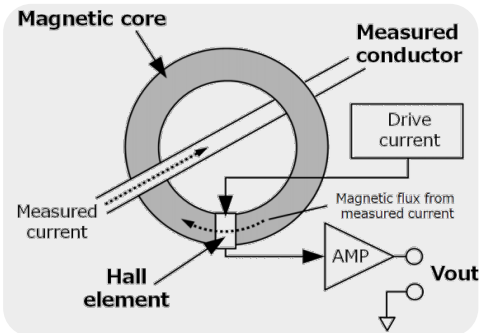
INTEGRATED SOLUTIONS - EXAMPLES

Current

Hall sensors



Open Loop



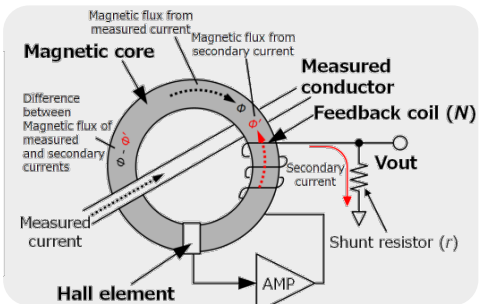
Typical values

- Up to 10kHz
- Lack of precision (+/- 1.5%) (due to magnetic chore characteristics)

Notes

- Sensing large currents
- Low power consumption
- Isolated / non intrusive
- Low cost

Closed Loop



Typical values

- Higher bandwidth (Up to 200kHz)
- Better precision (+/- 0.5%) (unaffected by magnetic chore characteristics)

Notes

- Higher consumption current
- Expensive

Diagnostics on PCB

INTEGRATED SOLUTIONS - EXAMPLES

Current

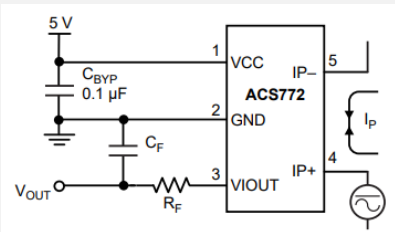
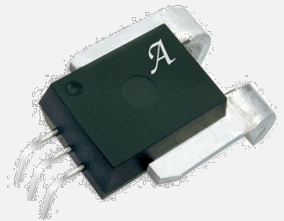
Hall sensors

HV

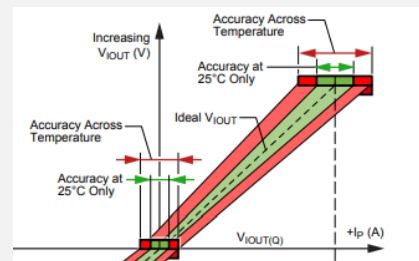
LV

Implementation example of ICCS CAN Controller 64P V2

Analog voltage acquisition



ICCS CAN Controller 64P V2



- ✓ Monitor open load
- ✓ Monitor overcurrent
- ✓ Monitor short to ground



To CAN network



Telematics



WEcabin Solutions



- ✓ Display
- ✓ Record
- ✓ Alarm

INTEGRATED SOLUTIONS - EXAMPLES

Current

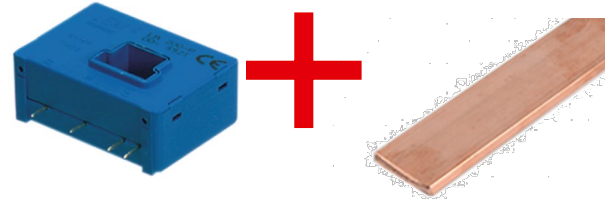
Hall sensors



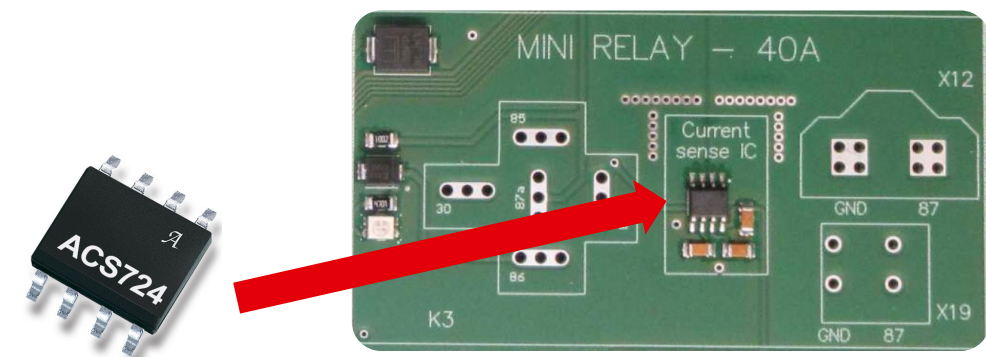
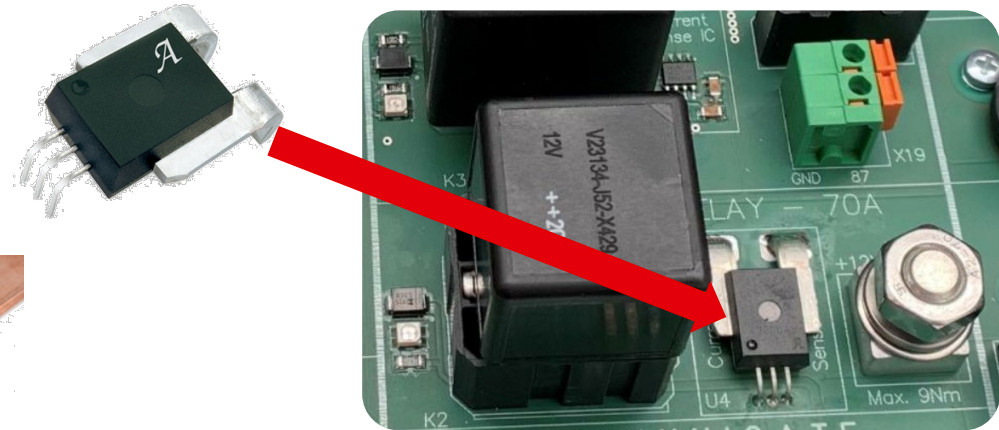
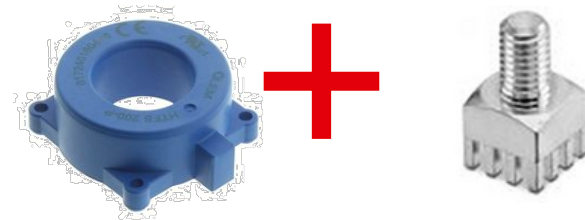
Different mechanical implementation

- ✓ Soldered on PCB on tracks

1 Bus bars



2 Power studs



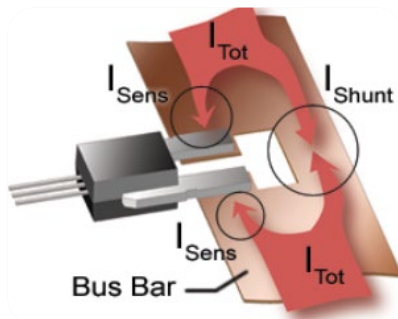
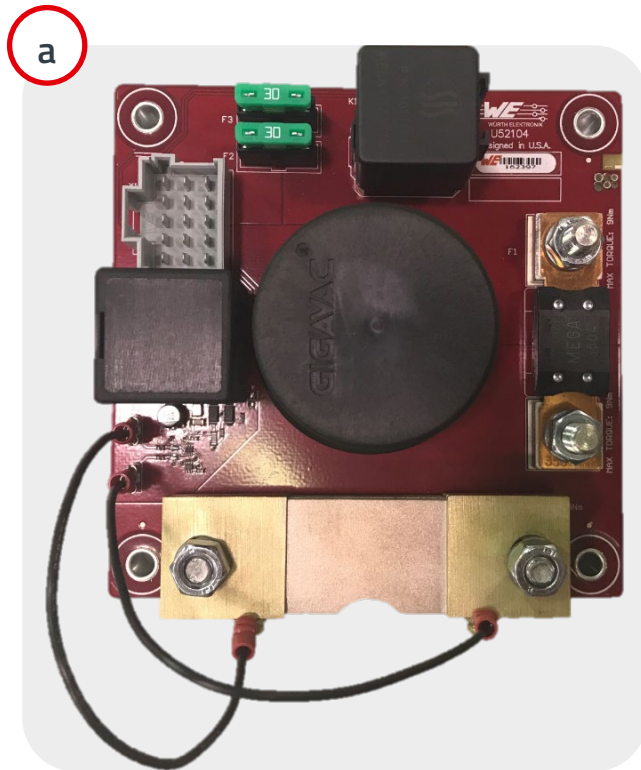
INTEGRATED SOLUTIONS - EXAMPLES

Current

Hall sensors

HV

LV



Shunt

a

Busbar (current divider)

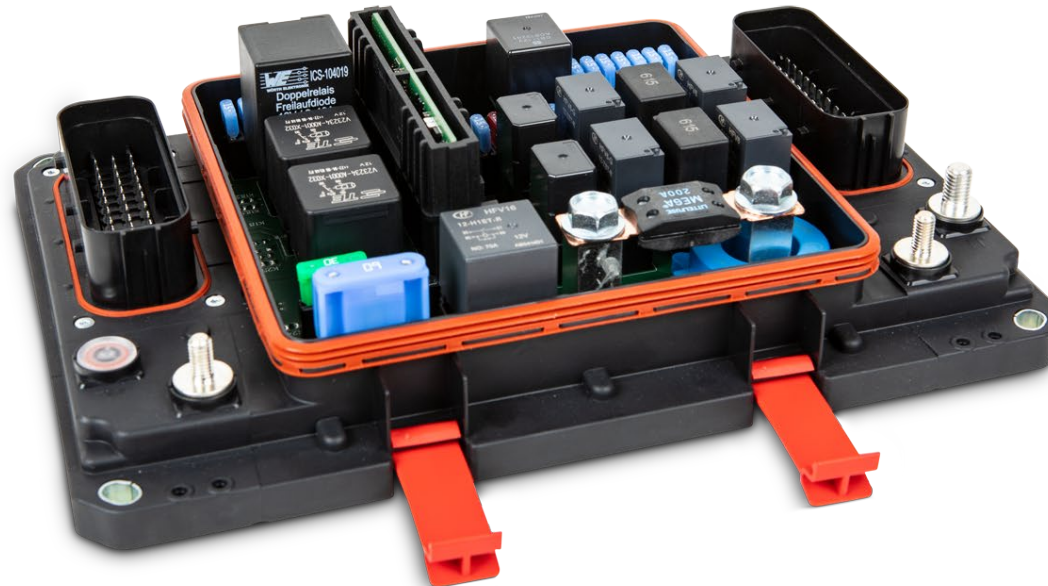
b

Diagnostics on PCB

INTEGRATED SOLUTIONS - EXAMPLES

Current

Central Electrical Unit – with current monitoring



INTEGRATED SOLUTIONS - EXAMPLES

Current

Central Electrical Unit – with current monitoring

With global sensors

- Average precision on low current
- Total overview of vehicle status



With dedicated sensors

- More expensive solution
- Only partial system overview



Global
current
 $T=x$

Load
activation

Global
current
 $T=x+y$

Expected current
increase of defined
value (min/max)

Diagnostics on PCB

INTEGRATED SOLUTIONS - EXAMPLES

Voltage



INTEGRATED SOLUTIONS - EXAMPLES

Voltage

Context:

A PCB needs voltage survey.

Problem:

How to monitor voltage on 12/24 V systems?

On high voltages systems (HV)?

Goal:

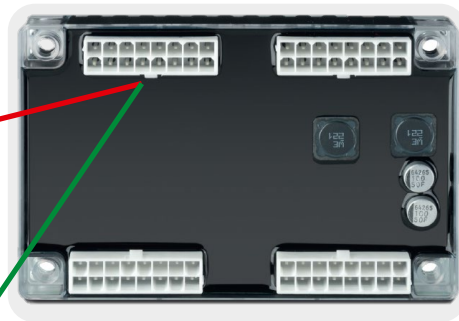
See different integrated solutions to measure a voltage on PCB.

INTEGRATED SOLUTIONS - EXAMPLES

Voltage **Built-in sensors** ~~HV~~ LV

Digital to Analog Controller (DAC)

X3 CONNECTOR		
Pin	Description	Function
1	ANA_UI_12	Analogue input 0-10 V or 0-20 mA
2	AGND	Ground
3	ANA_UI_10	Analogue input 0-10 V or 0-20 mA
4	ANA8	Analogue input 0-30 V
5	ANA6	Analogue input 0-5 V
6	DIGIN_RPM_A0	Digital / Frequency input
7	DIGIN_RPM_A1	Digital / Frequency input
8	DIGIN_DI17	Digital input (X03259) or LIN BUS
9	ANA_UI_13	Analogue input 0-10 V or 0-20 mA
10	ANA_UI_11	Analogue input 0-10 V or 0-20 mA
11	ANA9	Analogue input 0-30 V
12	ANA7	Analogue input 0-30 V
13	ANA5	Analogue input 0-5 V
14	DIGIN_RPM_B0	Digital / Frequency input
15	DIGIN_RPM_B1	Digital / Frequency input
16	DIGIN_DI16	Digital input



General purpose input
Measure 12 Volts voltage systems

Typical values	Notes
<ul style="list-style-type: none"> 22.6k impedance input. Scale 0-11.4 V – 12 bits ADC 	<ul style="list-style-type: none"> No isolation

INTEGRATED SOLUTIONS - EXAMPLES

Voltage

Built-in sensors



Digital to Analog Controller (DAC)

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13	ANA5	Analogue input 0-5 V
14	DIGIN_RPM_B0	Digital / Frequency input
15	DIGIN_RPM_B1	Digital / Frequency input
16	DIGIN_DI16	Digital input



General purpose input
Measure up to 30 Volts

Typical values	Notes
<ul style="list-style-type: none"> 66.6k impedance input. Scale 0-33.68 V – 12 bits ADC 	<ul style="list-style-type: none"> No isolation

INTEGRATED SOLUTIONS - EXAMPLES

Voltage

Built-in sensors



Digital to Analog Controller (DAC)

X3 CONNECTOR		
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1	ANA_UI_12	Analogue input 0-10 V or 0-20 mA
2	AGND	Ground
3	ANA_UI_10	Analogue input 0-10 V or 0-20 mA
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14	DIGIN_RPM_B0	Digital / Frequency input
15	DIGIN_RPM_B1	Digital / Frequency input
16	DIGIN_DI16	Digital input



High impedance input 5 Volts

Not suitable for voltage measurement

Typical values	Notes
<ul style="list-style-type: none"> High impedance input. Scale 0 – 5 V – 12 bits ADC 	<ul style="list-style-type: none"> No isolation



Dedicated to 0-5 V signals from sensors

INTEGRATED SOLUTIONS - EXAMPLES

Voltage

LEM Sensors



1000 V UPN Bipolar and insulated measurement

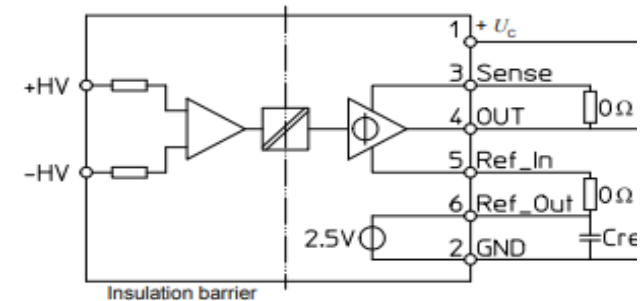
- Voltage transducer
- DVC 1000-P



Produces a secondary voltage proportional to primary voltage



Typical values	Notes
<ul style="list-style-type: none">▪ High range up to +/- 1500 V▪ High bandwidth (up to 20kHz)▪ Accuracy (+/- 1 to 2 %)	<ul style="list-style-type: none">▪ Needs 5 V stable voltage supply▪ Expensive▪ Isolation barrier



Diagnostics on PCB

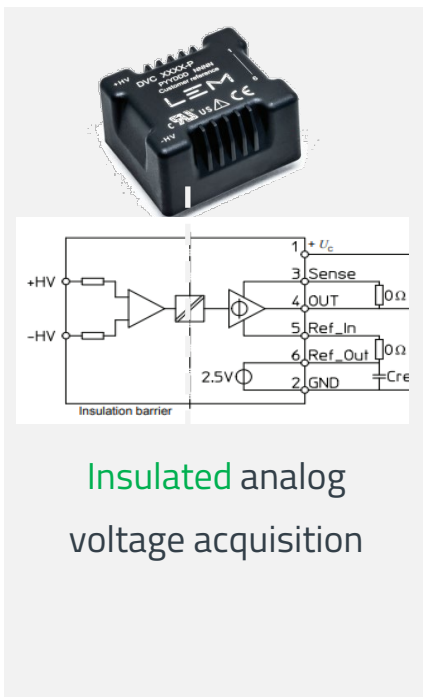
INTEGRATED SOLUTIONS - EXAMPLES

Voltage

LEM Sensors

HV

Implementation example of ICCS CAN Controller 64P V2



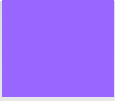
To CAN network



Useful for precise live monitoring or recording temperature history



Voltage



Other solutions

Voltage / current intelligent sensors



a



b



Voltage – shunt based (and current)

- With CAN bus interface

a

Intelligent battery sensor

- With CAN bus interface

b

DIAGNOSTICS ON PCB

- What is a system diagnostic?
- Focus on PCB integrated solutions – examples
- Our service offer
- Questions and answers

Diagnostics on PCB

OUR SERVICE OFFER

Project management

- Integration of system diagnostic solutions on PCB
- Assistance in sensors selection
- Knowledge of proven solutions

Field application engineer

- Software assistance - sample projects & code
- Hardware selection assistance
- Software development - Controller / HMI

Research & Development

- Customised solution, tailored to your needs
- Custom firmware for specific functions
- Concept evaluation and advertisement

Diagnostics on PCB

SUMMARY

Highlights & Takeaway!

System diagnostic can be offered on PCB.

We are experienced in providing PCB diagnostic solutions for HV and LV applications.

WE are offering services to help you integrating diagnostics in a complete system.

The right diagnostic is the one that fits your needs.
Get in touch with us.

DIAGNOSTICS ON PCB

- What is a system diagnostic?
- Focus on PCB integrated solutions – examples
- Our service offer
- Questions and answers

Questions

& Answers



We are here for you now!
Ask us directly via our chat or via E-Mail.

digital-we-days@we-online.com
Arnaud.Wending@we-online.de