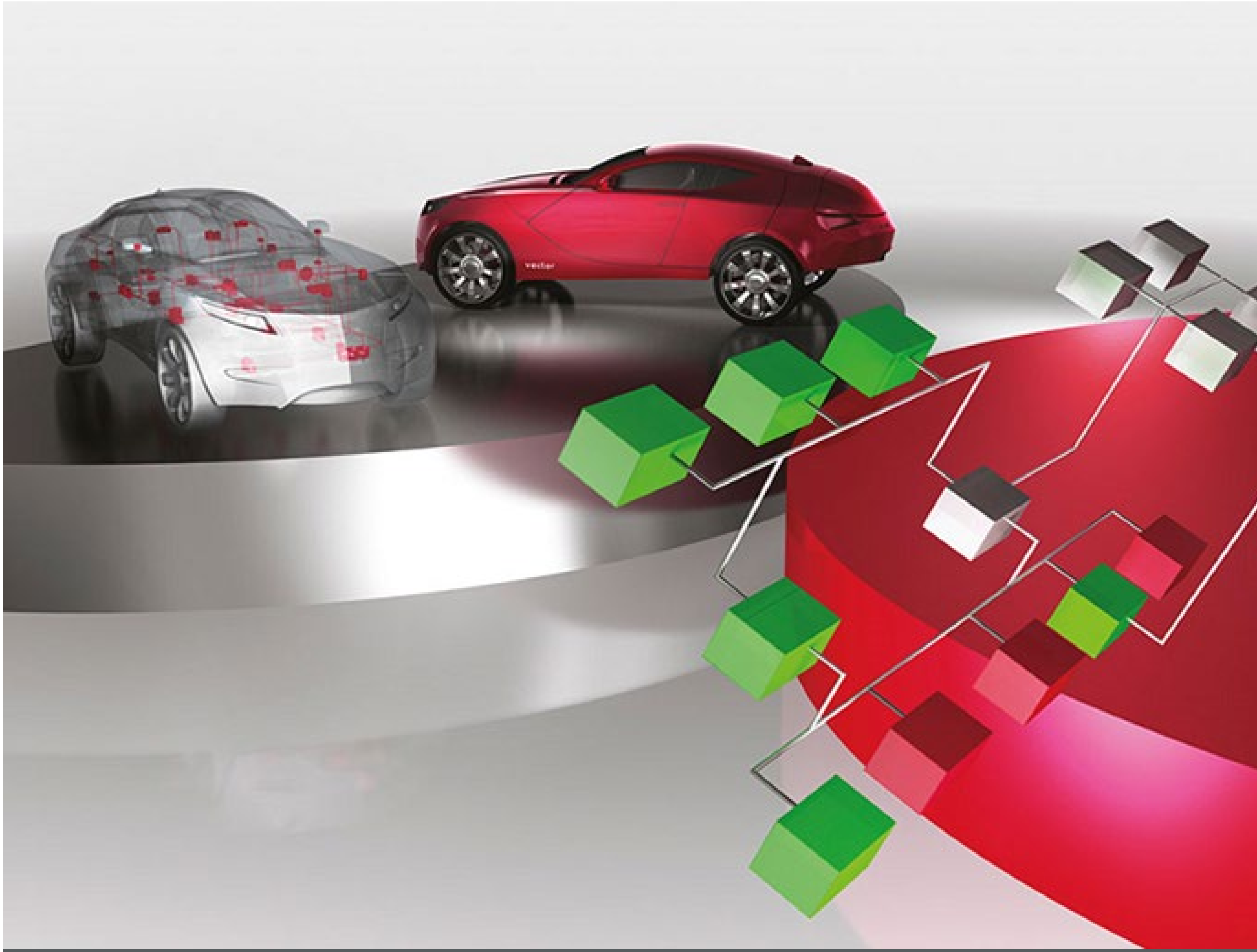


Technical User Manual
VT System

Version 1.2
English

Imprint

Vector Informatik GmbH
Ingersheimer Straße 24
D-70499 Stuttgart

Table of Contents

1 Introduction

This chapter contains the following information:

1.1 About this Technical User Manual

1.1.1 Navigational Aids and Conventions

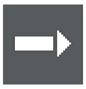
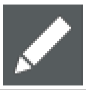
Contents of Technical User Manual

This **technical user manual** can be seen as an additional document to the basic VT System **user manual**. Here topics will be covered which are explained not or only short in the user manual, because they are technically very detailed and complex. This manual is not needed for the basically usage of the VT System but will explain more technical background details, limitations, application tips or connection possibilities of the VT System.

Conventions

The following two charts show the spelling and symbol conventions used in this manual.

Style	Utilization
bold	Fields, interface elements, window and dialog names in the software. Accentuation of warnings and notes. **[OK]** Buttons are denoted by square brackets **File | Save** Notation for menus and menu commands
CANoe	Legally protected proper names and side notes.
`Source code`	File name and source code.
Hyperlink	Hyperlinks and references.
<Ctrl>+<S>	Notation for shortcuts.

Symbol	Utilization
	You can obtain supplemental information here.
	This symbol calls your attention to warnings.
	You can find additional information here.
	Here is an example that has been prepared for you.
	Step-by-step instructions provide assistance at these points.
	Instructions on editing files are found at these points.
	This symbol warns you not to edit the specified file.

1.1.2 Latest Information

Additional technical information

You may find additional technical information about your VT System:

> in the CANoe online help,

> on the Vector website www.vector.com (e.g. application notes), and

> in your CANoe installation.

Reference: You may find the **latest version of this manual** in your CANoe installation (start menu ⇨ CANoe ⇨ Help).

1.1.3 Certification

Certified Quality Management System

Vector Informatik GmbH has ISO 9001:2008 certification.
The ISO standard is a globally recognized quality standard.

CE Compliance

All VT System products comply with CE regulations.

1.1.4 Warranty

Limitation of warranty

We reserve the right to change the contents of the documentation and the software as well as the hardware design without notice. Vector Informatik GmbH assumes no liability for correct contents or damages which are resulted from the usage of the technical user manual. We are always grateful for references to mistakes or for suggestions for improvement, so as to be able to offer you even better-performing products in the future.

1.1.5 Support

Need support?

You can get through to our hotline by calling

+49 (711) 80670-200

or you can send a problem report to CANoe Support.

1.1.6 Registered Trademarks

Registered trademarks

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> Windows, Windows XP, Windows 2000, Windows NT are trademarks of the Microsoft Corporation.

> EtherCAT® is registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

2 Module Specific

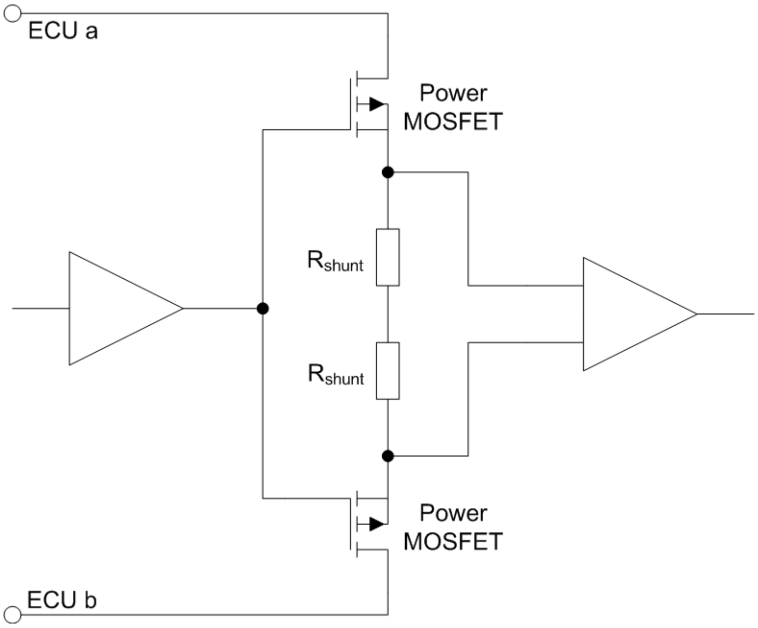
This chapter contains the following information:

2.1 VT1004

2.1.1 Electronic Load

General

The principle design of the electronic load is shown in the following schematic.



Between the two ECU connectors there are two Power MOSFETs and two shunt resistors. The circuit is symmetric to handle positive and negative difference voltages between the ECU connectors. With the Power MOSFETs the current will be controlled. The current will also be monitored by measuring the difference voltage over the shunt resistors. To dissipate the heat the Power MOSFETs and the shunt resistors are mounted on a heat sink.

Load capability

The continuous load carrying capability of the electronic load is limited by the power loss which is changed to thermal energy and dissipated by the heat sink. The heat sink is only able to dissipate a certain amount of power. As the heat sink is common for all 4 channels on the VT1004 the possible theoretical total load capability of the module is independent if the load is distributed to one, two or all four channels. If the heat sink is able to manage for example 30 W of total continuous power then this load can be distributed to two channels with 15 W each or to four channels with 7.5 W each. But in practice if the load is distributed to several channels the distribution of the heat is better and so a higher load can be carried.

The peak load carrying capability is much higher because the thermal distribution on the heat sink is very slow. So the limit for the peak load is only dependent on the capability of the used Power MOSFET.

Temperature protection

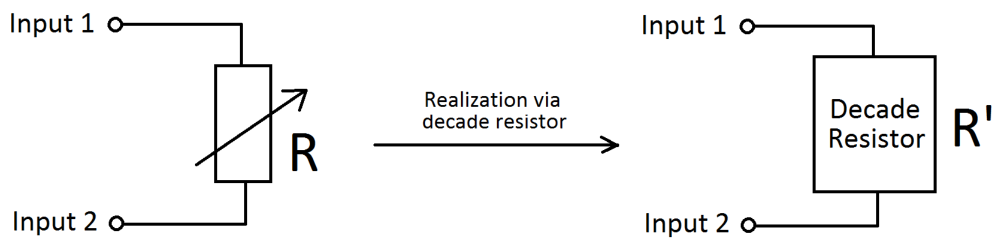
The electronic load has a temperature protection. So if the junction temperature of the used Power MOSFET is too high the electronic load will be switched off. The algorithm to calculate the junction temperature considers the measured temperature at the heat sink, the desired current and the actual voltage. So it might be possible that the electronic load will be deactivated when a high current is tried to set even with a low temperature at the heat sink. Because of the thermal inertia the MOSFETs will be damaged long ago until the temperature sensors at the heat sink will recognize a noticeable temperature increase.

2.2 VT2004

2.2.1 Decade Resistor

Overview

The decade resistor of the VT2004 stimulation module is basically an electronically adjustable resistor. The desired resistance value **R** between the two inputs of each channel can be defined directly in CANoe. The decade resistor then tries to match the desired value resulting in a real resistance value **R'** like shown in the following figure.



A typical use case for this functionality is the simulation of sensors. In order to do so an electronic control unit (ECU) can be connected to the input pins of the VT2004. Usually ECUs read from their sensors by measuring the sensor's resistance values. Because of this different sensor-inputs can be simulated by adjusting the resistance of the decade resistor.

Tolerance values

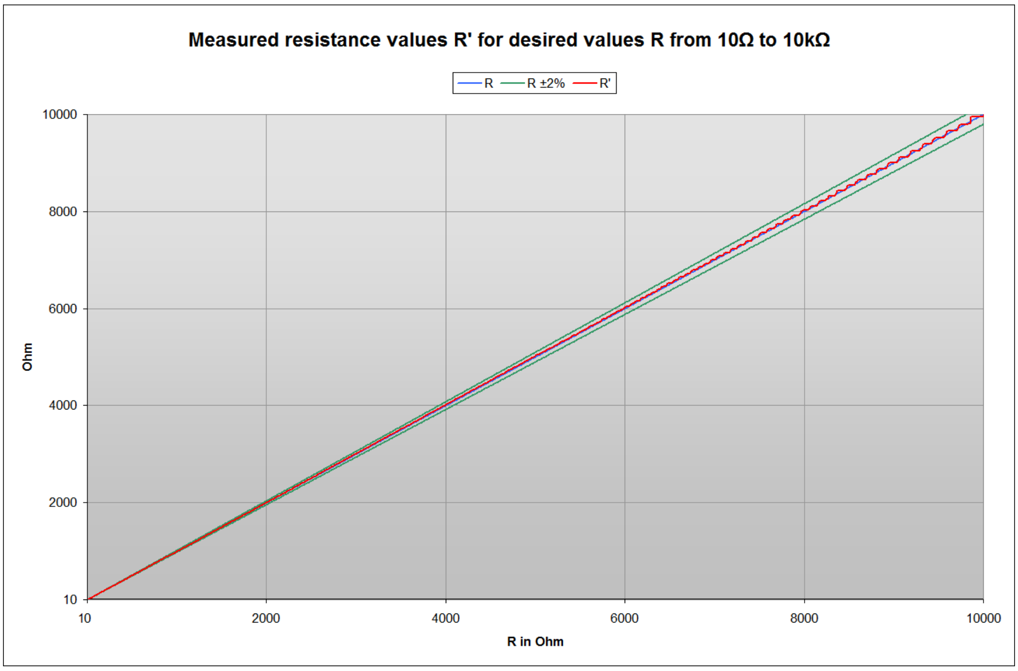
Each of the four channels of the VT2004 is equipped with such a resistor. Channels 1, 2 and 3 allow resistance values of 10 Ω up to 10k Ω. Channel 4 covers an even wider range, i.e. 1 Ω to 250k Ω. Within these ranges the tolerance is the higher value of ± 2% respectively ± 2 Ω.

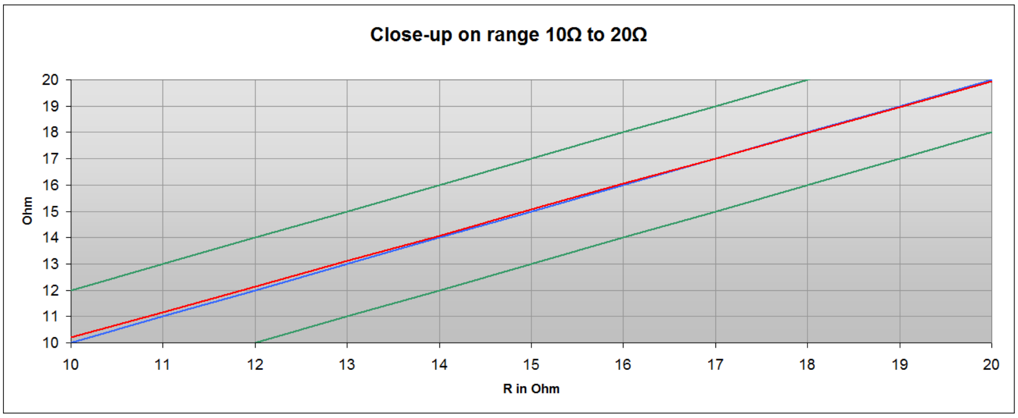
The following table shows some examples of the decade resistor's tolerance values:

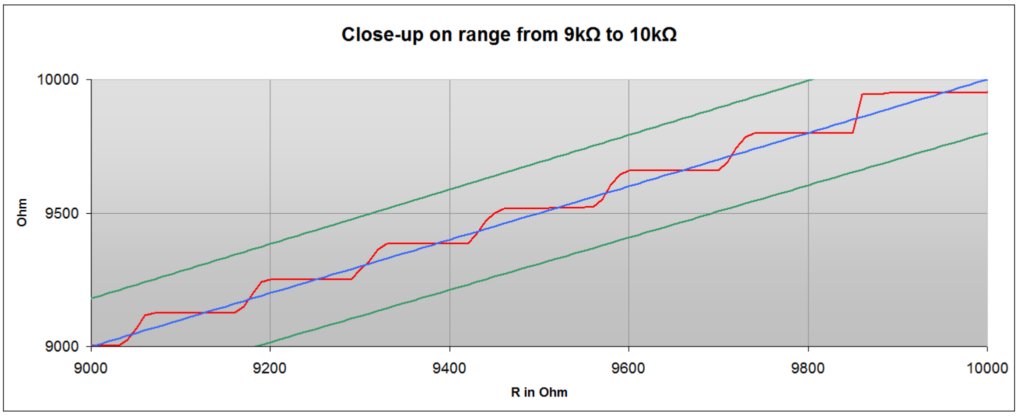
Desired Resistance Value R	Tolerance	Range of R'
10 Ω	± 2 Ω	8 Ω - 12 Ω
100 Ω	± 2 Ω	98 Ω – 102 Ω
1000 Ω	± 20 Ω	980 Ω - 1020 Ω
10000 Ω	± 200 Ω	9800 Ω - 10200 Ω

The results of a measurement of the real resistance value **R'** for every possible resistance value **R** in the range from 10 Ω to 10k Ω are shown in figure 2.2. Here the ideal resistance values are represented by the blue line, while the tolerance of **R** ± 2 Ω resp. **R** ± 2 % is shown in green. The actual measurement of the real resistance values **R'** is represented by the red line.

The following figure shows that the decade resistor's resolution is extremely high for low resistance values, where **R'** only deviates slightly from the ideal resistance value (see close-up on range from 10Ω to 20Ω). Although the size of steps starts to increase for higher resistance values, **R'** still stays very close to the ideal line (see close-up on range from 9kΩ to 10kΩ). So **R'** is within the boundary of **R** ± 2 Ω resp. **R** ± 2 % at all times as guaranteed by the VT2004's specification.

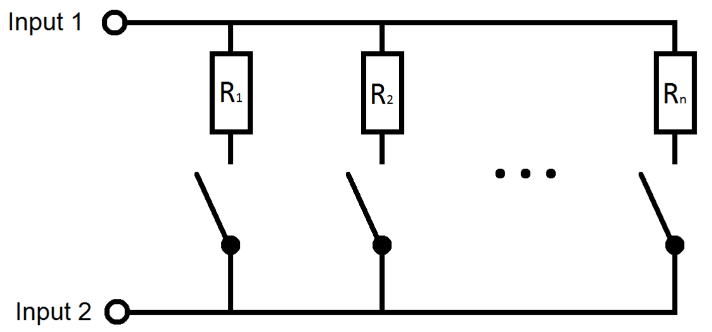






Internal design

The decade resistor used in channel 4 is slightly more complex because of its wider range, but it is designed analogous to the other channel's decades. It will therefore not be addressed here. Each of the decade resistors of channel 1, 2, and 3 consists of 16 single resistors which connect the input pins in parallel. Their resistances ranges from 19 Ω to 655k Ω With FPGA controlled PhotoMOS relays these resistors can be activated independently from each other. The following figure visualizes this concept in form of a schematic.



Using this setup an arbitrary subset of the 16 resistors can be activated at any given time. This way all resistance values in a range from 10 Ω to 10k Ω can be realized with a tolerance of ± 2 Ω resp. ± 2 %. The minimal value of 10 Ω can be reached by activating all resistors in the decade. Although values greater than 10k Ω are possible as well (e.g. by deactivating all resistors except for the 655kΩ resistor) the tolerance of 2% can't be maintained in that range of values.

One benefit of this parallel design over a serial decade resistor is the much higher resolution within the range of small resistance values.

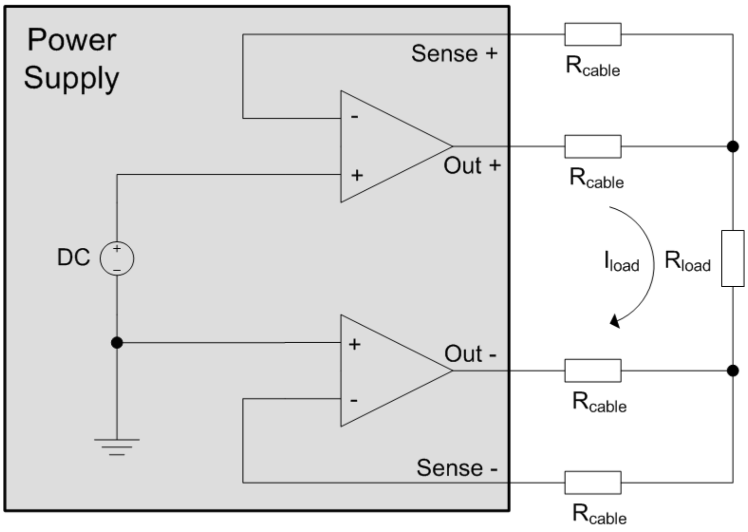
2.3 VT7001

2.3.1 Connection of Sense Lines

General

Normally a regulated power supply tries to keep the voltage at its output constant, independent of the connected load. But the voltage applied at the load may differ from the voltage at the output of the power supply because of a voltage drop on the used cables and connectors especially at higher currents. So with a second pair of sense cables, which are connected between the load and special sense inputs at the power supply, the voltage at the load can be regulated. The sense lines are carrying nearly no current and so there is no appreciable voltage drop.

In the following figure you can see the output circuit of a power supply with sense connectors in principle.

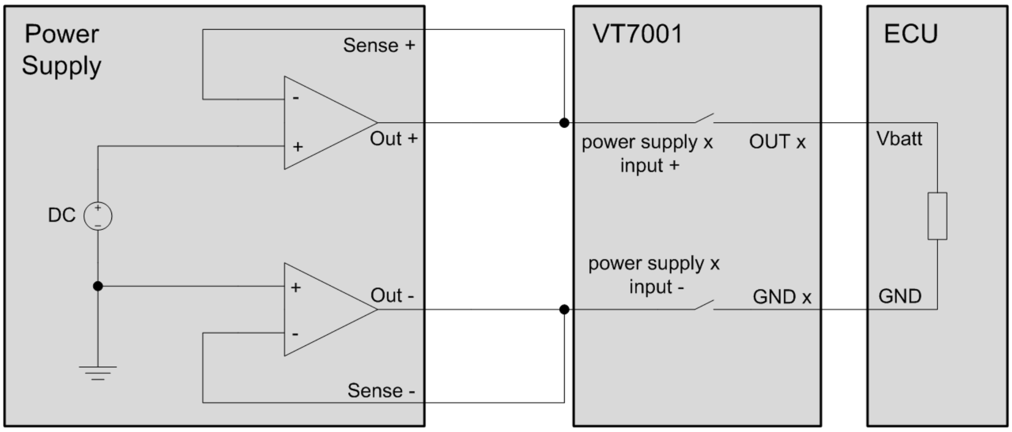


According to this principle schematic you can see what happens if the sense connection or the connection to the load will be removed. The op-amps try to keep the voltage difference between its differential inputs at zero. So if the sense input gets no voltage feedback when the output or the sense cables are removed, the power supply regulates its output to the maximum voltage the output stage can apply.

So if an ECU is connected to the power supply with the VT7001 it might be a problem if the output of the VT7001 is switched off while the sense lines are still connected to the ECU. In this case the output at the power supply will be at its maximum output voltage. If this voltage exceeds the maximum input voltage of the VT7001 the module might be damaged.

Connection

To avoid this behavior the sense lines should not be connected directly at the ECU but at the power supply connector of the VT7001 as shown in the following figure. So the voltage drop from the power supply to the VT7001 will be considered but not the voltage drop from the VT7001 to the ECU. Therefore the cables from the VT7001 to the ECU have to be kept short.



2.3.2 Usage of four-quadrant Power Supply

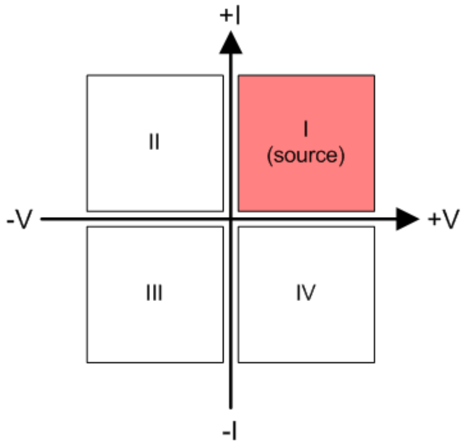
Use cases

Sometimes it is necessary to use a four-quadrant power supply with the VT7001. This might be with the following use cases:

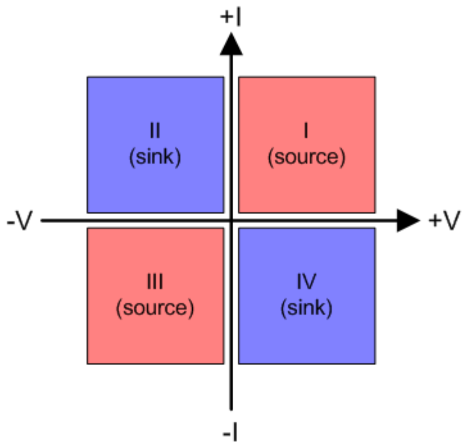
> ECU test with fast changing voltages curves with slew rates up to 10 V/µs
> Simulate ground offset between two components by sinking current with a four-quadrant power supply.

General

Compared to a normal unipolar power supply, a four-quadrant power supply is also able to sink current like an electronic load. It can operate in all four quadrants of the characteristic output curve of a power supply.



Characteristic curve of a unipolar power supply



Characteristic curve of a four quadrant power supply

Limitations

The VT7001 represents a capacity load with a few nanofarad when connected to a power supply. For some four-quadrant power supplies this capacitive load of the VT7001 might be too high. This will lead to instability and the output signal will start to oscillate. The tendency to oscillate depends mainly on the size of the applied load of the four-quadrant power supply and not on the used signal form and speed. The experience shows, that the tendency to oscillate is lower at higher currents. A known power supply with this behavior is Toellner TOE7610.

A recommend four-quadrant power supply which works fine with the VT7001 is the successor Toellner TOE7621. This power supply has a low pass function adjustable to the cutoff frequencies of 100 Hz, 1 kHz, 10 kHz and 100 kHz. If this power supply is operated without any load and without a VT7001, the output signal is stable with every frequency setting. If a VT7001 is connected to the power supply and the load current is only very small or there is no load, the output signal might start to oscillate if a cutoff frequency of 10 kHz or smaller is set. So a known good setup is to use a limit frequency of 100 kHz.

3 Load Capacity

This chapter contains the following information:

3.1 Parallel Usage of Channels

Limitations

Sometimes it might be useful to use two channels in parallel to carry a higher total current. This is especially interesting if using the VT1004 or the VT7001. Although not recommended in general it is possible to use channels in parallel. But a few things have to be considered then.

First it is not guaranteed that the total current will be equally distributed to the participated channels, because of different resistances of connectors and relays contacts and PCB tracks. Also care has to be taken when switching those channels. Relays are mechanical parts. They have no identical switching time and they are bouncing. So when switching channels in parallel it might be that one channel will be switched slightly earlier than the others and so has to carry the whole current on its own for a period of time. Or even worse, relays at one or more channel will not be switched at all because of a mechanical or electrical failure or they have forgotten to switch on or they are switched off accidentally. This can damage the modules, especially the relays and the PCB tracks, as they are designed with a good reliability but not to carry and switch significant more current per channel than specified in the **user manual**. Special attention has dedicated when using a VT7001 module, as this module has no fuses on board and the protection has therefore be done externally.

For the VT1004 another item has to be remembered if using the electronic load. The current sink capability of the electronic load is limited by the total power loss which is turned to thermal energy and dissipated by the heat sink. The usage of several channels in parallel on the same module does provide a better load capability. But a much higher load capability is available if electronic loads on two different VT1004 modules are used. This is because the heat sink is common for all four channels and so the capability of dissipating thermal energy is shared. More details about this topic can be found in the chapter about the electronic load in chapter 2.1.1.

4 VT Safety Concept

This chapter contains the following information:

4.1 Behavior of Fuses

Overview

Most signal paths on the VT modules are protected against short circuits with self-resettable fuses which are not monitored. Only on the VT1004 modules normal lead fuses are used, because the self-resettable fuses are not available for these high currents. But these fuses are monitored then and a tripping is indicated. The signal paths which are protected can be seen in the schematic drawings in the technical user manual. Special care has to be taken when using a VT7001 module. This module can handle very high currents and has therefore no fuse protection on board. The protection has to be ensured by the user by external mechanisms according to the maximum expected current.

Self-resettable fuses

The self-resettable fuses on the VT modules behave not like a lead fuse with a trip threshold. They behave like a nonlinear PTC (positive temperature coefficient) resistance. If a current above the nominal current flows through this fuse, the fuse gets warm and begins to trip by increasing its resistance. If the current decreases when a short circuit is removed, the fuse gets cooled down and after a few minutes it has its initial resistance of a few milliohms again.

These fuses have no really defined trip threshold. Their nominal value is only the value where the fuses have to hold for a certain time. So it is possible to operate the fuses with a current higher than the nominal value for a period of time until they begin to trip. The higher the current the smaller is the time to trip. Hence the fuses are more a protection against really short circuits than a protection against currents above a certain threshold. But one advantage is they don’t have to be replaced after tripping. The other advantage is, they are not that sensitive and will therefore not trip if short current peaks occur for example during switching loads.

Example: Fuses are operated in a range of one to two times their nominal value.

For example if you have a fuse with a nominal value of 6 A. Than it might take minutes, dependent on the environment temperature and heat dissipation, until the fuse trips if a current of 8 A flows through the fuse, because the fuse has to hold a current of 6 A for a certain time and has to trip at 12 A after a certain time at room temperature. So if you have a power supply that is only able to provide 8A or the current limiter at the power supply is set to limit at 8 A than the fuse will not trip immediately although a short circuit occurs.

In worse case a short circuit current of 10 A flows through this 6 A fuse and it will take perhaps still a few seconds until the fuse trips. If a relay is switched during this state the relay might be damaged because of an electric arc at its contacts as the relays are not specified to handle nearly the double current as the current path normally carries.

5 Voltage Measurement

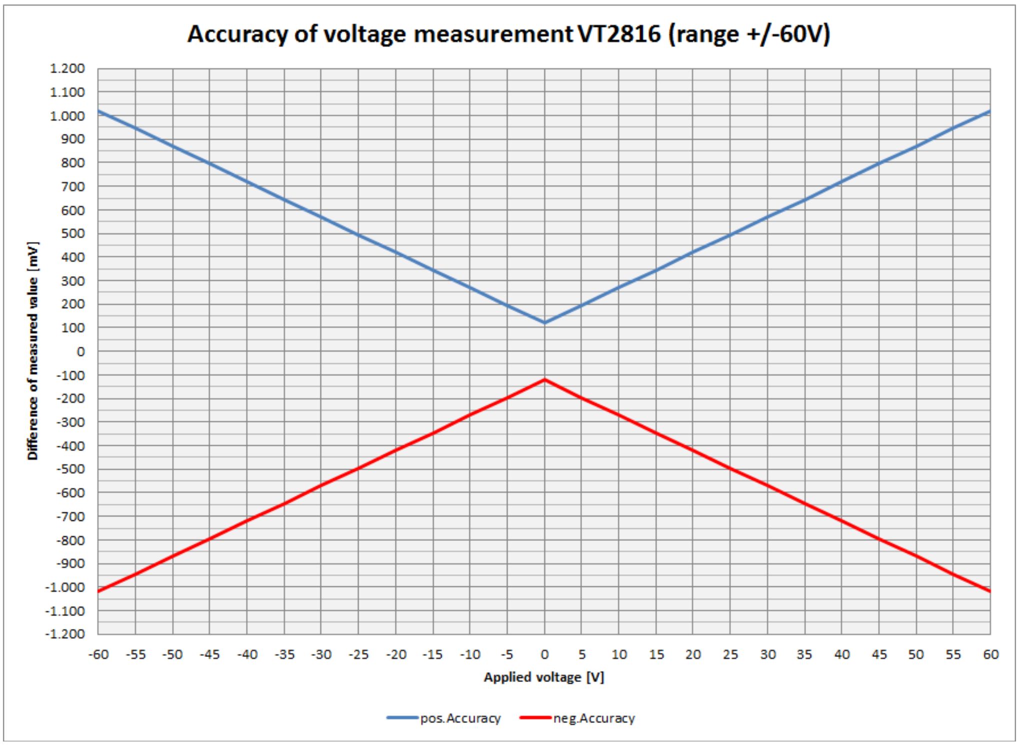
This chapter contains the following information:

5.1 Measurement Accuracy

Overview

The accuracy of the voltage is mainly dependent on the characteristics of the used A/D converter. To get a detailed statement about the accuracy of a measured value the technical data in the technical user manual is specified in a manner to represent the real characteristic of the A/D converter.

As the A/D converter not only has an offset but also a slope in its characteristics, the accuracy curve for the voltage measurement in the 60 V range of the VT2816 looks like the following figure.



Calculation

The calculation of this curve depends on the formula +/- (1.5% of reading + 0.1% of range) and is closer to the behavior of the A/D converter than only specifying the accuracy as % of full scale respectively range. So the accuracy of every measured voltage value will be within this curve. The calculation of this accuracy curve depends on two components:

> The first component is the % of reading, where reading is the measured value. This component is responsible for the slope of the curve.

> The second component is the % of range. This component represents the offset of the curve. This value is independent from the measured value; it only depends on the range. For the +/-60 V range of the VT2816 this component is 120m V (0.1 % of 120 V). This means the accuracy is at least 120 mV, independent of the measured value.

6 Power Supply of ECU

This chapter contains the following information:

6.1 VT7001 Connection Scheme

Overview

The VT7001 is designed to test the power supply of an ECU. For this purpose two external connected power supplies and one internal power supply can be switched directly, in series or parallel to two outputs of the VT7001 to supply one or more ECUs. Thereby the connection of the external power supplies to the VT7001 stays always the same. To cover the various use cases only the interconnection mode in CANoe has to be changed. Also the swapping of the polarity can be done with the VT7001.

PSInt is the internal power supply. It can be used if only small power is needed. PS1 and PS2 are the power supplies which can be connected external to deliver higher currents. At the first VT7001 module DGND and AGND are connected with relays as shown in the following schematic. If more than one VT7001 is used in the test setup, at every further VT7001 module the relay between DGND and AGND is disconnected to avoid ground loops. Then only the AGND is connected, which is needed as reference potential for the voltage measurement. There is only one exception of this rule. If using the internal power supply by choosing the corresponding interconnection mode, the connection to DGND will also be made at further modules because the back current path of the internal power supply is DGND as also shown in the following schematic.

Bus bars

There are two connectors (bus bar V_{batt} and bus bar GND) which are only available at output 1 of the VT7001. At these outputs the battery voltage and ground of output 1 can be connected to the corresponding bus bars connectors of other VT System modules. So signals on other VT System modules can be switched to the battery voltage or ground to simulate a short circuit error.

The current through the bus bar connectors will be considered at the current measurement of output 1. This current path is limited to 4 A with a self-resettable fuse and is active if output 1 is enabled.

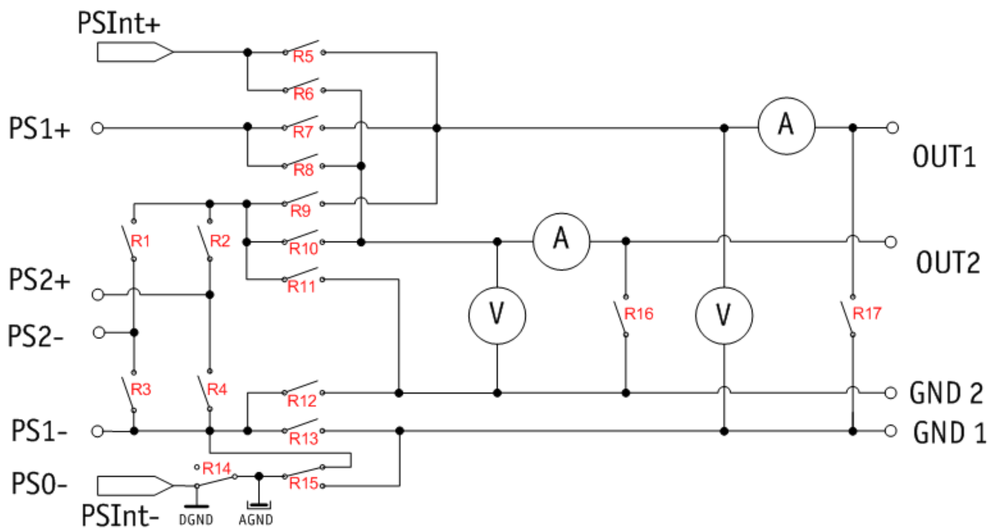
Aux lines

These outputs are available on both output channels of the VT7001 and can be used for example to supply other additional devices in the test setup.

Therefore the current through the aux connectors will be not considered at the current measurement of output 1. This current path is limited to 4 A with a self-resettable fuse and can be switched independent from output 1 or output 2. If output 1 or output 2 will be short to ground, the corresponding aux output is automatically short to ground too.

Relays

The following schematic shows the basic settings of the relays after the module is powered up and no interconnection mode is set. To keep the schematic simple the relays to switch the aux outputs are not shown here.



> **R1**, **R2**, **R3** and **R4** are to swap the polarity of power supply 2.
> **R5** and **R6** are to connect the positive output of the internal power supply to OUT1 and OUT2
> **R7** and **R8** are to connect the positive output of power supply 1 to OUT1 and OUT2
> **R9** and **R10** are to connect the positive output of power supply 2 to OUT1 and OUT2
> **R11** connects GND2 to the positive input of power supply 2. This connection will be used for connecting the two power supplies in series.
> **R12** connects GND2 to AGND/DGND and the negative output of power supply 1. This relay will be opened when **R11** is closed and GND2 is not connected to AGND/DGND.
> **R13** connects GND1 to AGND/DGND and the negative output of power supply 1.
> **R14** connects AGND with DGND. This connection will be set only at the first VT7001 module if used more than one. At all further VT7001 modules only AGND is connected to avoid ground loops.
> **R15** connects GND1 to AGND/DGND. This relay will be used if a ground break is active and R12 and R13 are opened.
> **R16** will short OUT2 to GND2. Before closing this relay the power supplies will be disconnected from OUT2.
> **R17** will short OUT1 to GND1. Before closing this relay the power supplies will be disconnected from OUT1.

6.2 One Power Supply

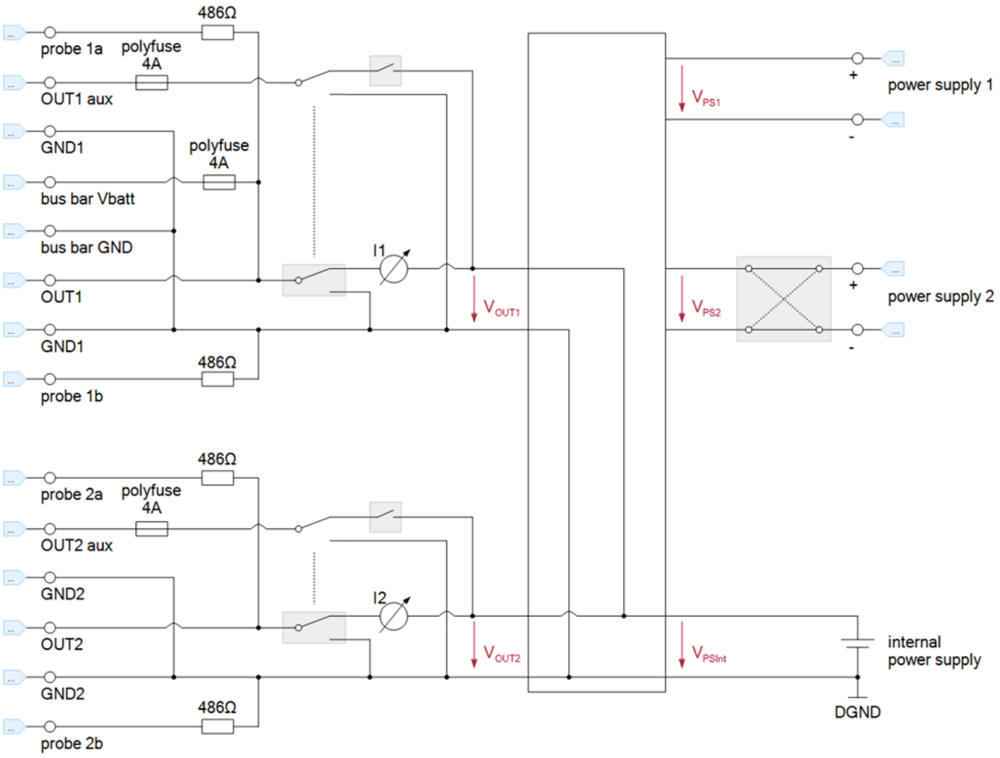
Use cases

> Supply one ECU with two different supply inputs (for example clamp 30 and clamp15) with the same voltage. The current consumption can be measured independent for every supply input.
> Supply two ECUs with one supply input (for example clamp 30) with the same voltage. The current consumption can be measured independent for every ECU.

6.2.1 Internal Power Supply

Interconnection mode

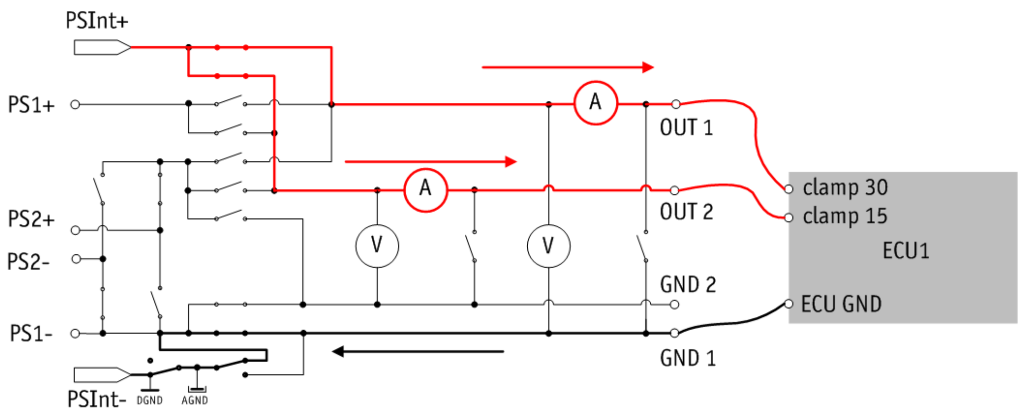
The used interconnection mode is **supint** (internal power supply only).



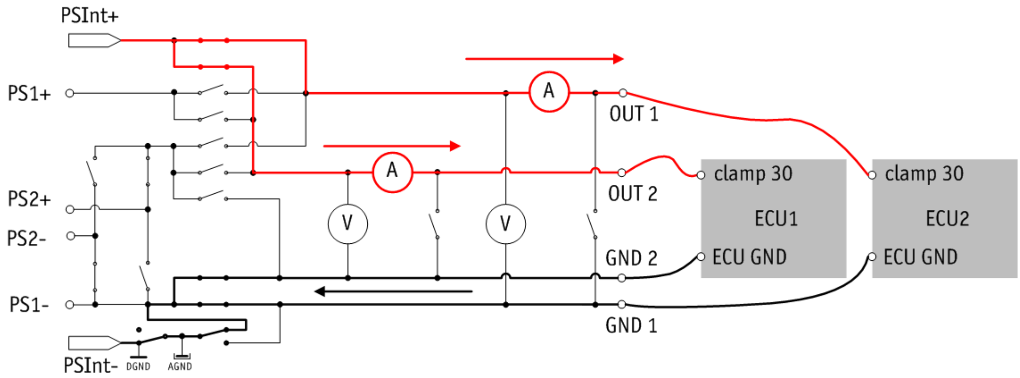
Connection scheme

The following schematics show the relay settings and current flow if the internal power supply is used and both outputs are active. Both outputs can be switched and measured independently. The back current flows from the ECU through GND1 and GND2 to DGND of the VT System because the internal power supply is connected to DGND.

One connected ECU



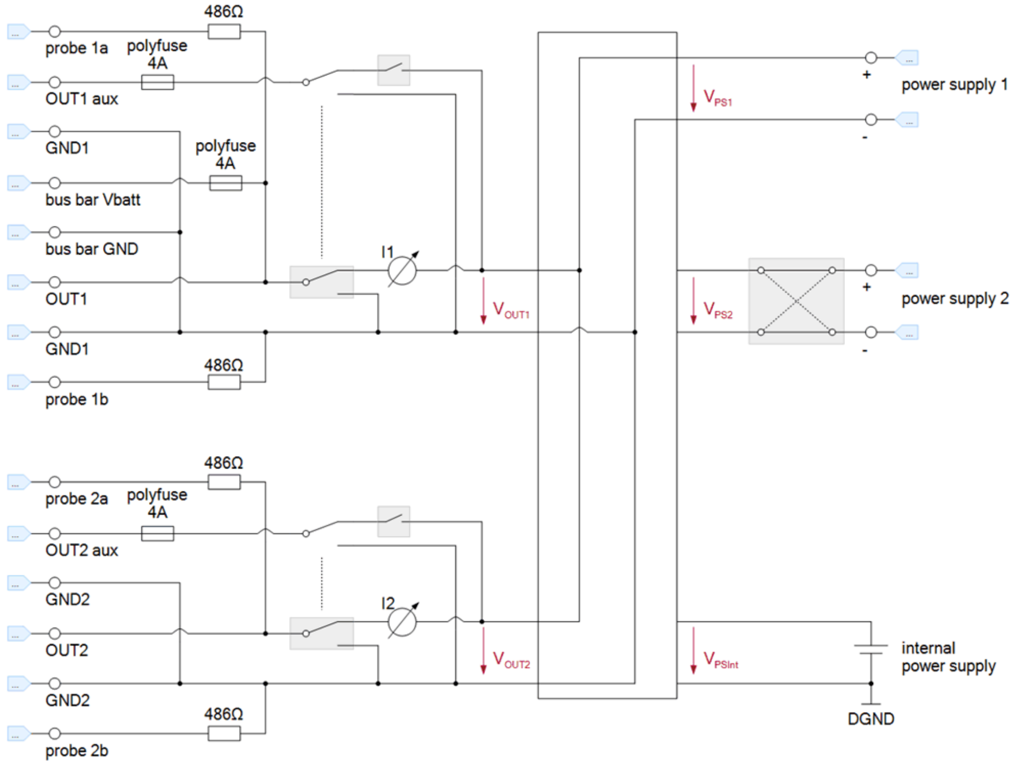
Two connected ECUs



6.2.2 Power Supply 1

Interconnection mode

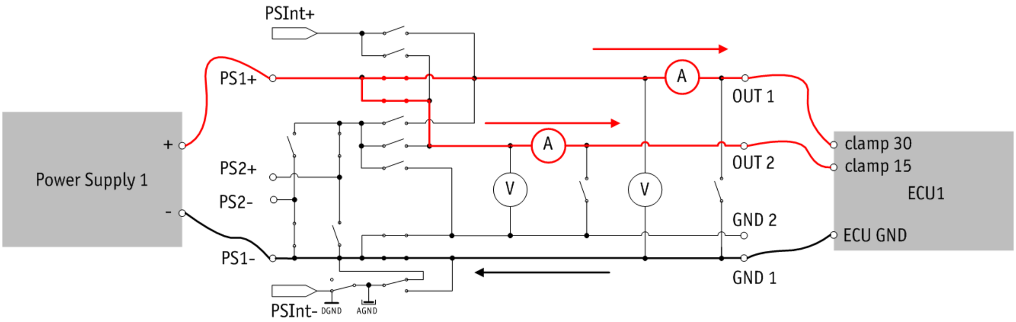
The used interconnection mode is **sup1** (power supply 1 only).



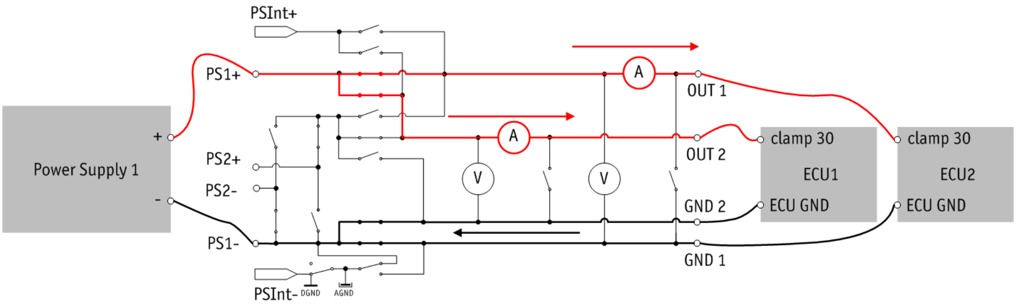
Connection scheme

The following schematics show the relay settings and current flow if power supply 1 is used and both outputs are active. Both outputs can be switched and measured independently. The back current flows from the ECU through GND1 and GND2 to PS1-.

One connected ECU



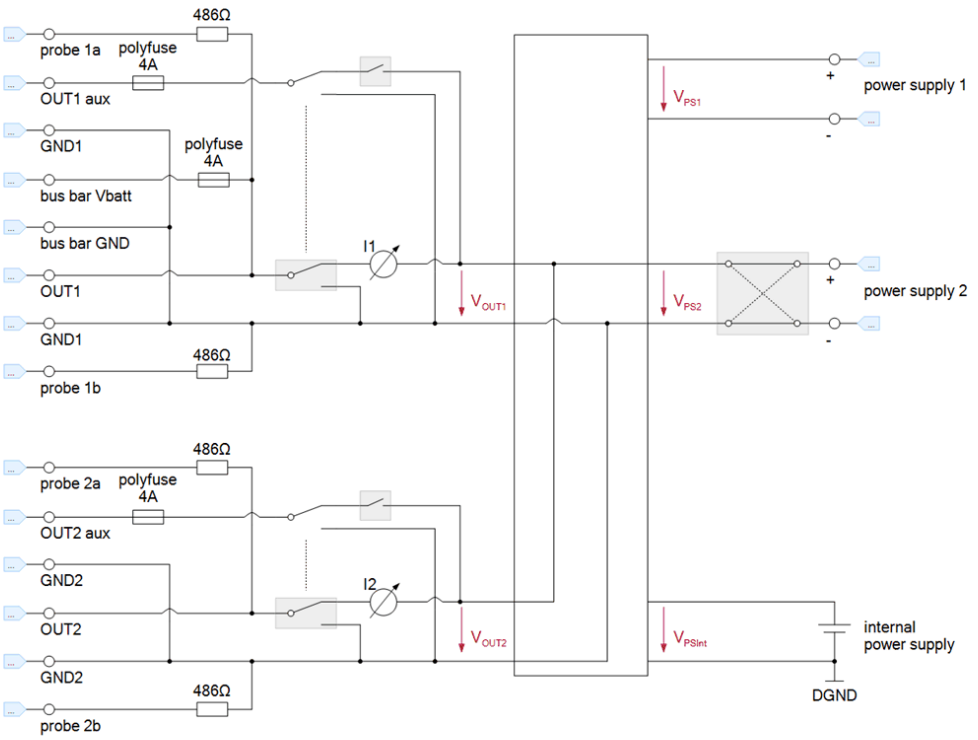
Two connected ECUs



6.2.3 Power Supply 2

Interconnection mode

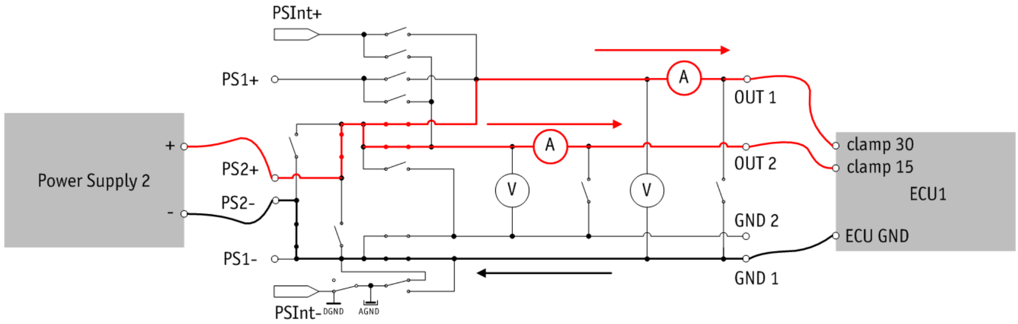
The used interconnection mode is **sup2** (power supply 2 only).



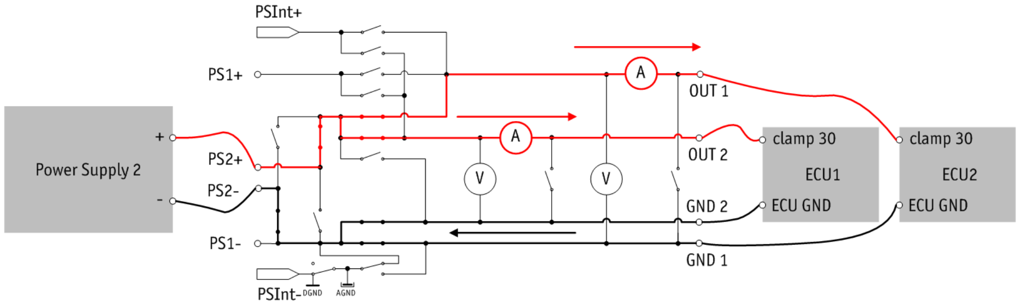
Connection scheme

The following schematics show the relay settings and current flow if power supply 2 is used and both outputs are active. Both outputs can be switched and measured independently. The back current flows from the ECU through GND1 and GND2 to PS2-.

One connected ECU



Two connected ECUs



6.3 Two Power Supplies

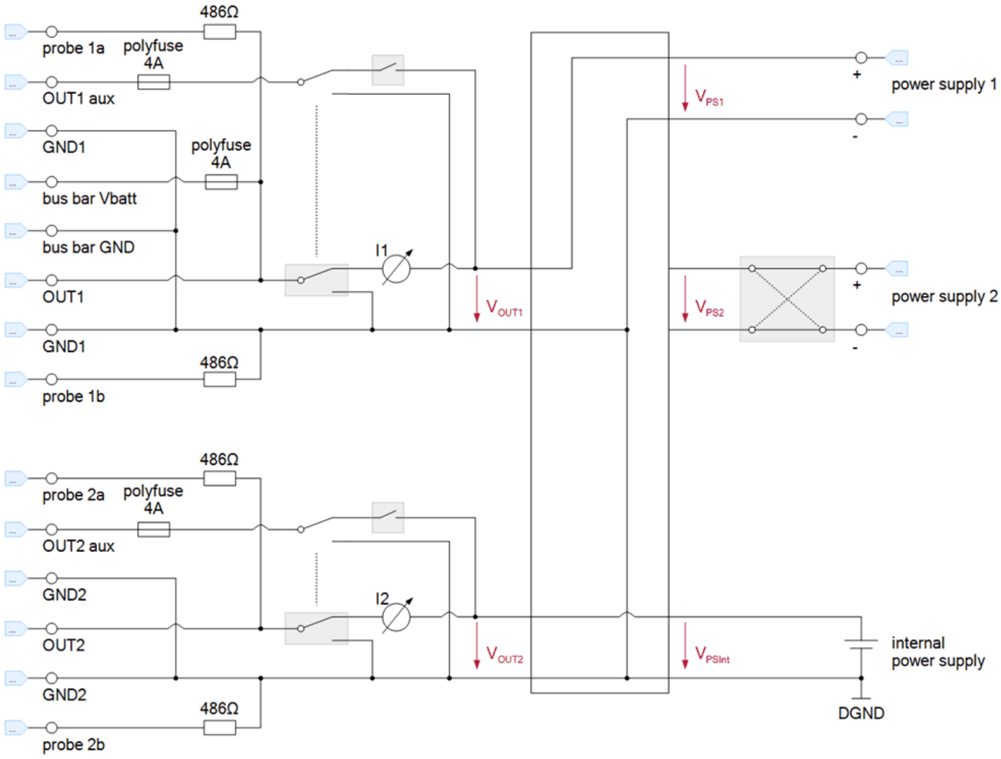
Use cases

- Supply one ECU with two different supply inputs (for example clamp 30 and clamp15) with different voltages. The current consumption can be measured independent for every supply input.
- Supply two ECUs with one supply input (for example clamp 30) with different voltages. The current consumption can be measured independent for every ECU.
- Simulate a voltage offset of the battery voltage between two ECUs.
- Simulate a voltage offset between two different supply inputs (for example clamp 30 and clamp15) of one ECU.

6.3.1 Internal Power Supply and Power Supply 1

Interconnection mode

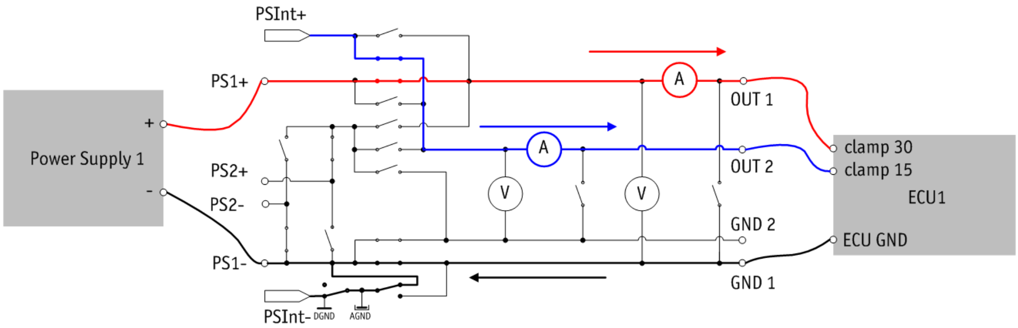
The used interconnection mode is **supint_sup1** (internal power supply and power supply 1) or **sup1_supint** (power supply 1 and internal power supply), dependent on which power supply is connected to which output.



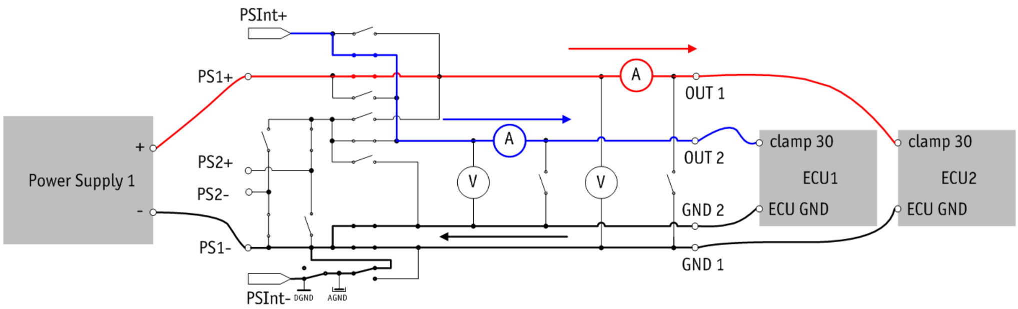
Connection scheme

The following schematics show the relay settings and current flow if the internal power supply is connected to OUT2 and power supply 1 is connected to OUT1. Both outputs are active and can be switched and measured independently. The back current flows from the ECU through GND1 and GND2 to PS1- and DGND of the VT System because the internal power supply is connected to DGND.

One connected ECU



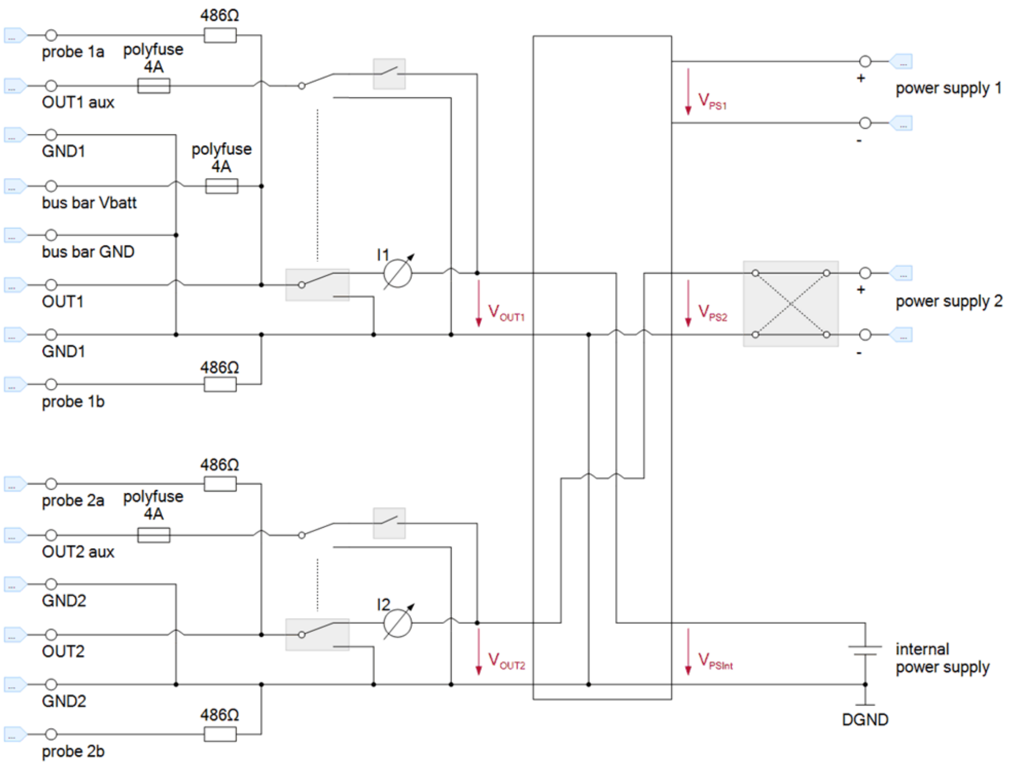
Two connected ECUs



6.3.2 Internal Power Supply and Power Supply 2

Interconnection mode

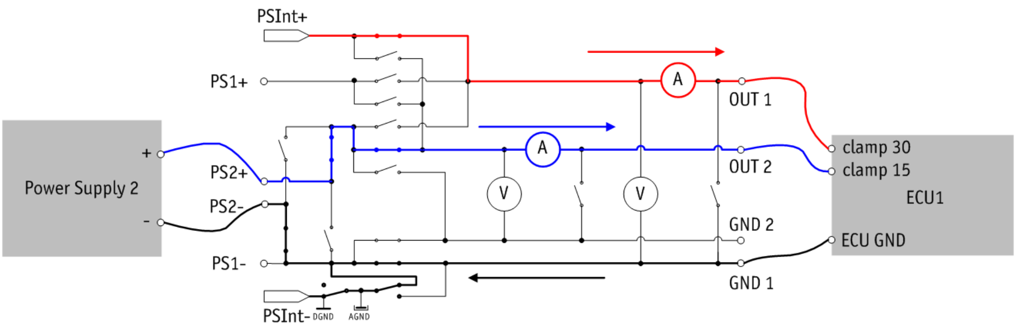
The used interconnection mode is **supint_sup2** (internal power supply and power supply 2) or **sup2_supint** (power supply 2 and internal power supply), dependent on which power supply is connected to which output.



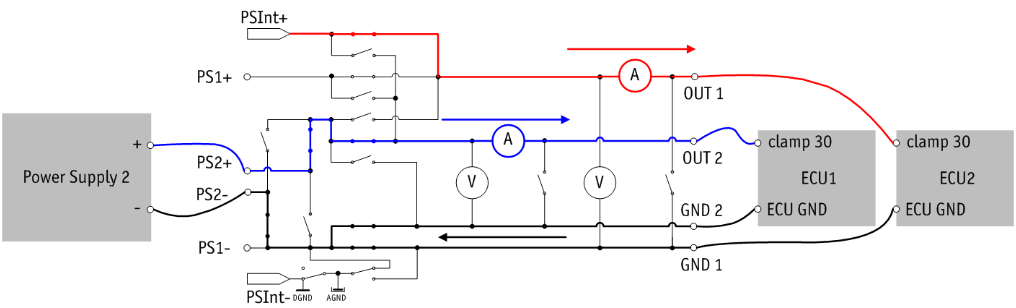
Connection scheme

The following schematics show the relay settings and current flow if the internal power supply is connected to OUT1 and power supply 2 is connected to OUT2. Both outputs are active and can be switched and measured independently. The back current flows from the ECU through GND1 and GND2 to PS2- and DGND of the VT System because the internal power supply is connected to DGND.

One connected ECU



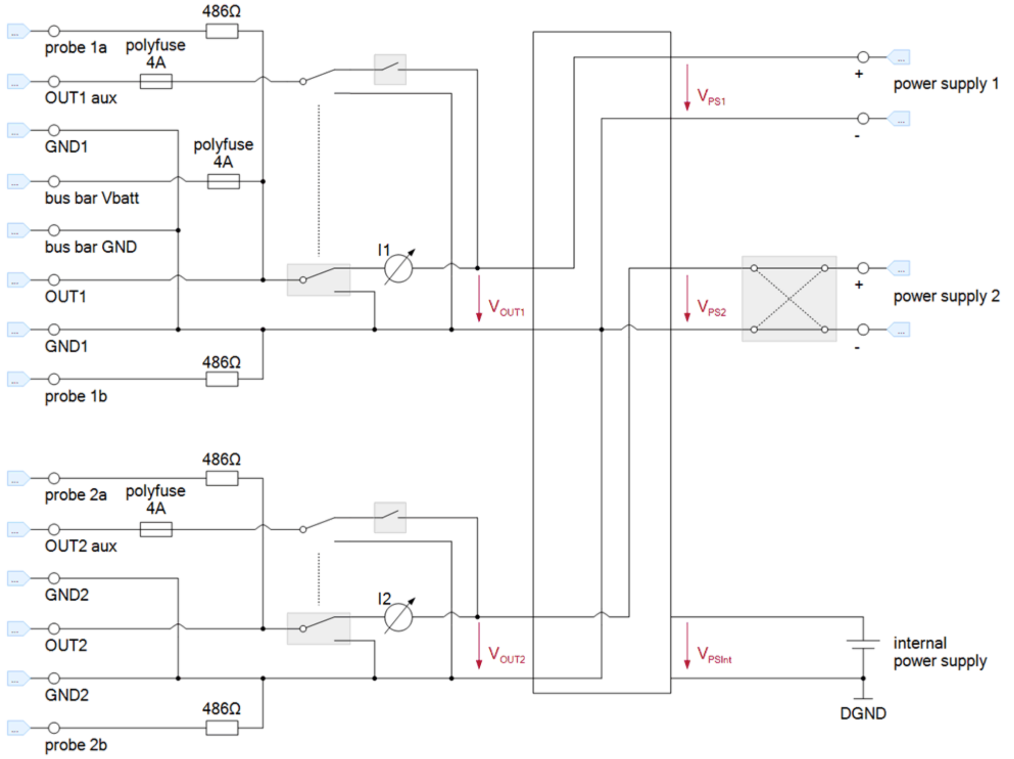
Two connected ECUs



6.3.3 Power Supply 1 and Power Supply 2

Interconnection mode

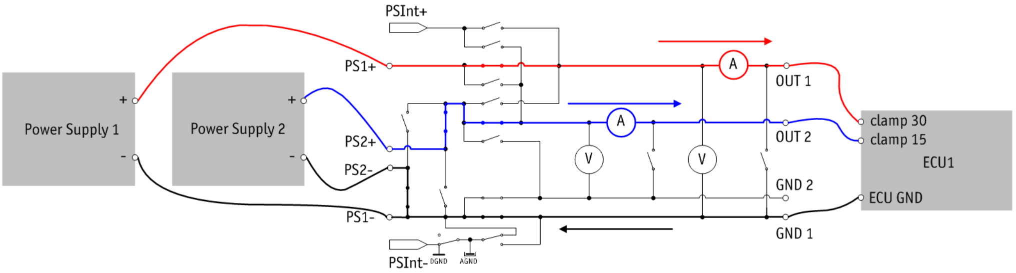
The used interconnection mode is **sup1_sup2** (power supply 1 and power supply 2) or **sup2_sup1** (power supply 2 and power supply 1), dependent on which power supply is connected to which output.



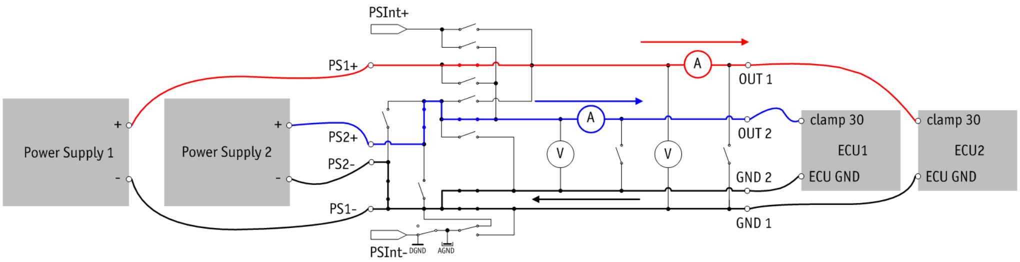
Connection scheme

The following schematics show the relay settings and current flow if power supply 1 is connected to OUT1 and power supply 2 is connected to OUT2. Both outputs are active and can be switched and measured independently. The back current flows from the ECU through GND1 and GND2 to PS1- and PS2-.

One connected ECU



Two connected ECUs



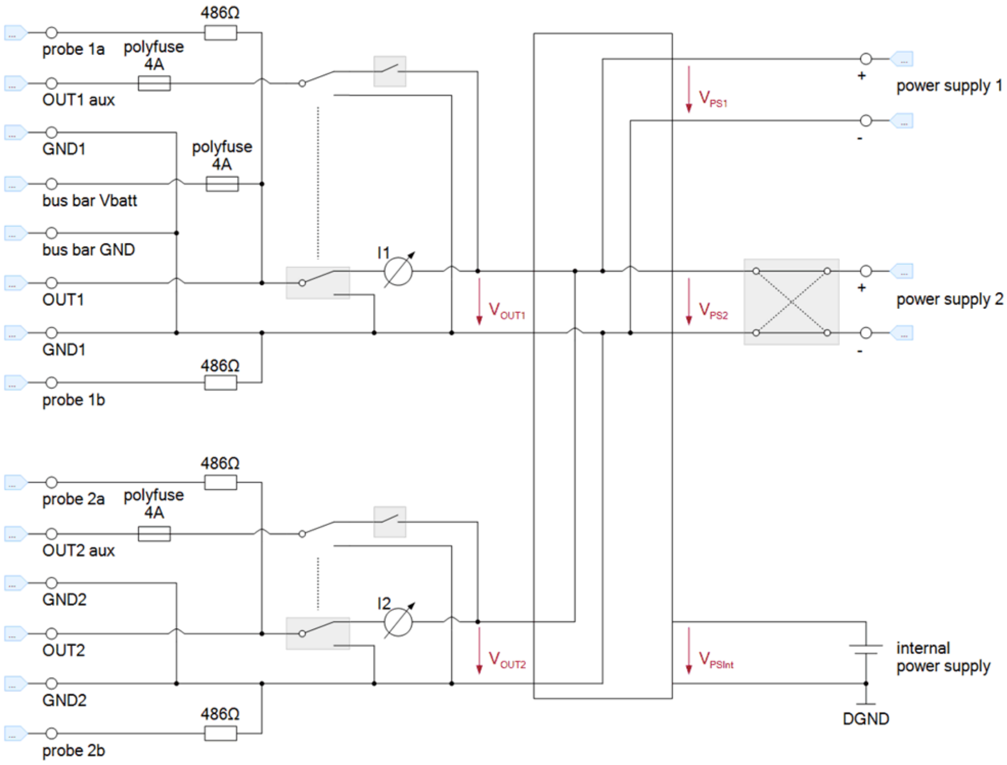
6.4 Two Power Supplies in Parallel

Use cases

- Supply one ECU with two different supply inputs (for example clamp 30 and clamp15) with the same voltage. The current consumption can be measured independent for every supply input.
- Supply two ECUs with one supply input (for example clamp 30) with the same voltage. The current consumption can be measured independent for every ECU.
- Support one power supply with a battery in parallel to deliver short current pulses which the power supply is not able to deliver.
- Support one power supply with battery to allow back-current from the ECU.

Interconnection mode

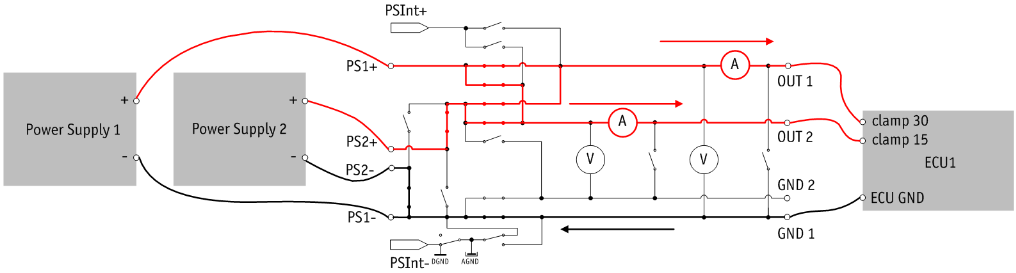
The used interconnection mode is **sup_parallel** (power supply 1 and power supply 2 connected parallel). It is not possible to connect the internal power supply parallel to power supply 1 or power supply 2.



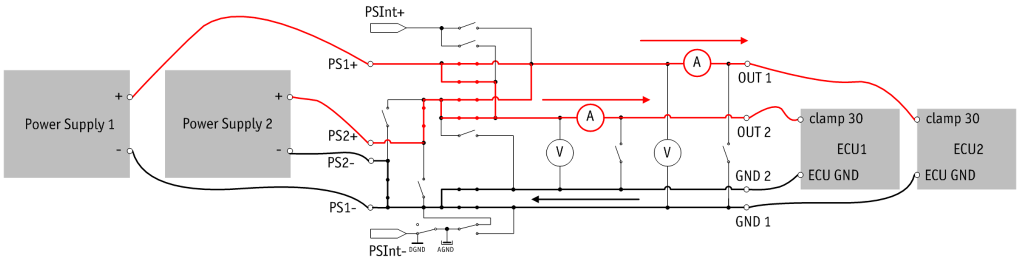
Connection scheme

The following schematics show the relay settings and current flow if power supply 1 is connected to OUT1 and power supply 2 is connected to OUT2. The positive outputs of the two power supplies are connected together. Both outputs are active and can be switched and measured independently. The back current flows from the ECU through GND1 and GND2 to PS1- and PS2-. The polarity of power supply 2 cannot be swapped at this interconnection mode.

One connected ECU



Two connected ECUs



Caution: The voltage difference between the two power supplies will be monitored and must not exceed 1V when connected in parallel.

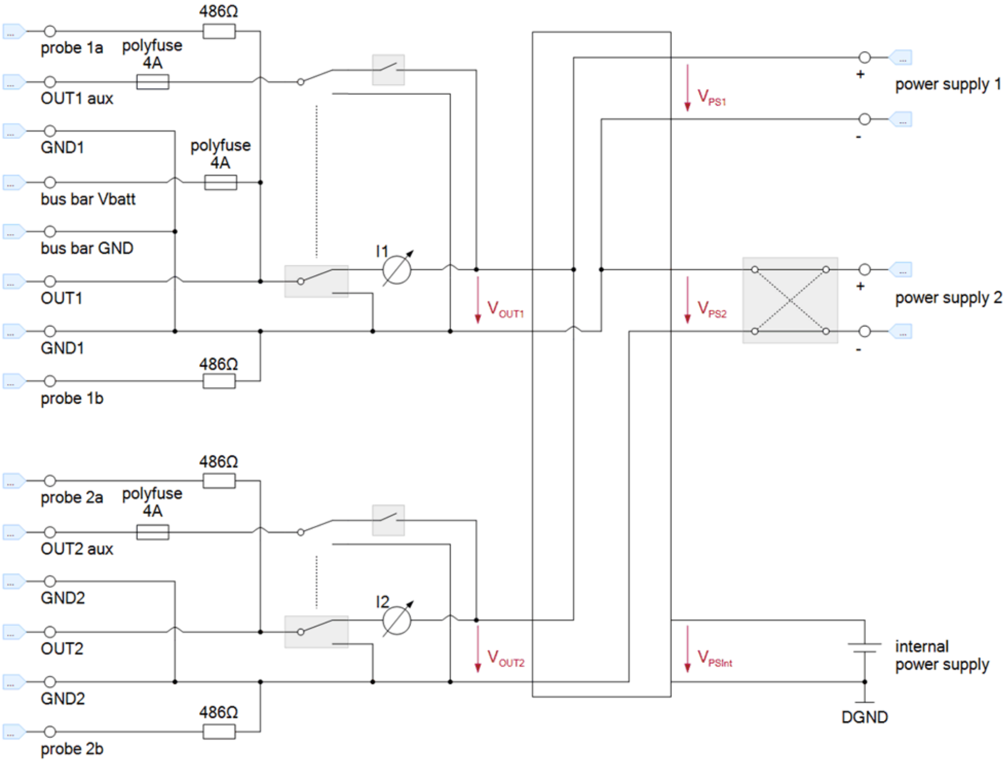
6.5 Two Power Supplies in Series

Use cases

- Simulate ground offset of a single ECU or between two ECUs.
- Overlay a noise voltage to the battery voltage.

Interconnection mode

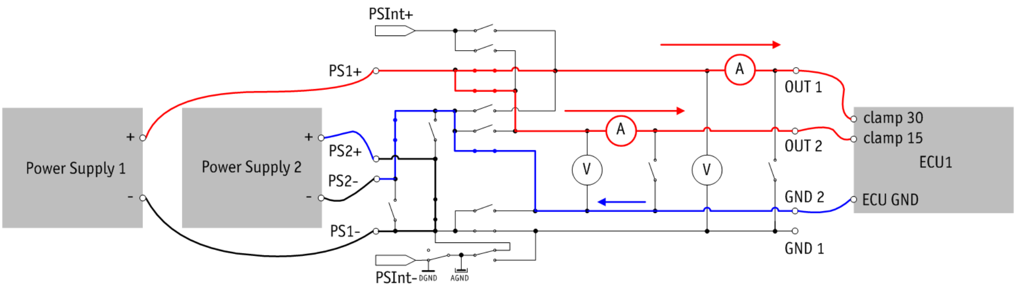
The used interconnection mode is **sup_series** (power supply 1 and power supply 2 connected in series). It is not possible to connect the internal power supply in series to power supply 1 or power supply 2.



Connection scheme

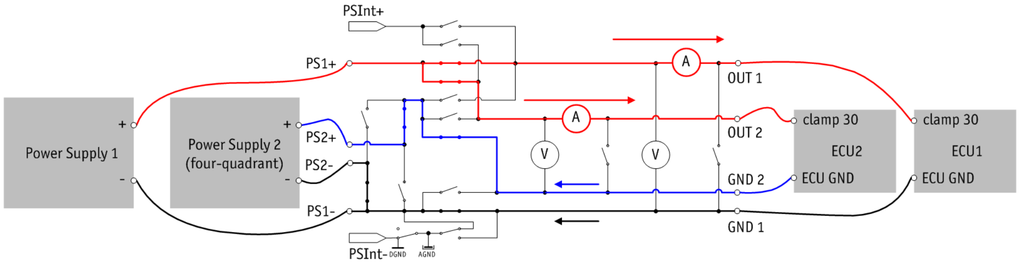
The following schematics show the relay settings and current flow when power supply 1 and power supply 2 are connected in series. The first schematic shows the basic relay setting after the interconnection mode is set. The voltage of power supply 1 and power supply 2 will be added. The positive output of power supply 1 is connected to OUT1 and OUT2. Both outputs are active and can be switched and measured independently. The back current from ECU1 flows through GND2 through power supply 2 to PS1-.

One connected ECU



For the use case ground offset this interconnection mode is used too, but the polarity of power supply 2 will be swapped. The relay settings can be seen in the following schematic. The positive output of power supply 1 is connected to OUT1 and OUT2. Both outputs are active and can be switched and measured independently. The back current from ECU1 flows through GND1 to PS1-. The back current from ECU2 flows through GND2 to PS2+.

Two connected ECUs



Power supply setup

The two power supplies are connected in series, so the voltages of power supply 1 and power supply 2 two will be simply added. The total voltage will be available between OUT1 or OUT2 and GND2.

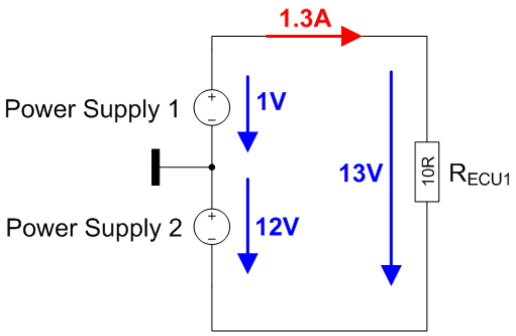
For the use case ground offset power supply 1 has to be set to the voltage which will be applied to both ECUs. With power supply 2 the ground level of the ECU connected between OUT2 and GND2 can be shifted.

Caution: If creating a ground offset, power supply 2 has to sink current. Therefore a suitable power supply like a four-quadrant power supply has to be used. Also the polarity of the power supply 2 has to be swapped.

Power supply 2 has, like an electronic load, to sink current and dissipate the produced thermal power loss. Therefore a four-quadrant power supply has to be used and the polarity of power supply 2 has to be swapped with the system variable **ReversePolarity**. More information about the usage of a four-quadrant power supply can be found in the chapter 2.3.2.

Example: Overlaying a noise voltage

The following equivalent circuit diagram shows the setup of the two power supplies two simulate an overlayed noise voltage.



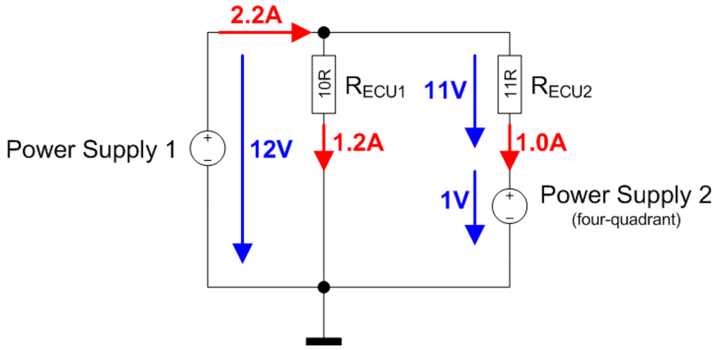
The voltage of power supply 1 and power supply 2 are simply added. The total voltage of 13V is applied to ECU1, which is represented as a resistive load.

For this example the following setup has to made:

> Select interconnection mode 9 (sup_series)
> Set power supply 1 to 1V.
> Set power supply 2 to 12V.
> Activate the output OUT1 and OUT2 (dependent on where the ECU is connected)

Example: Ground offset between two ECUs

The following equivalent circuit diagram shows the setup of the two power supplies two simulate a ground offset between two ECUs.



The two ECUs are represented simplified as resistive load with 10 Ohm and 11 Ohm. Power Supply 1 is set to 12 V and has to deliver the current for both ECUs. ECU1 is connected to power supply 1 as normal. ECU2 is connected in series to power supply 2. The ground offset is set with power supply 2 to 1 V. Therefore the voltage over ECU2 decreases to 11 V.

As distinguished from the first example with a normal series connection of two power supplies, the polarity of power supply 2 is swapped for this use case.

For this example the following setup has to made:

> Select interconnection mode 9 (sup_series).
> Swap the polarity of power supply 2 (system variable **ReversePolarity**).
> Set power supply 1 to 12V (battery voltage).
> Set power supply 2 to 1V (ground offset voltage).
> Activate the outputs OUT1 or OUT2.

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