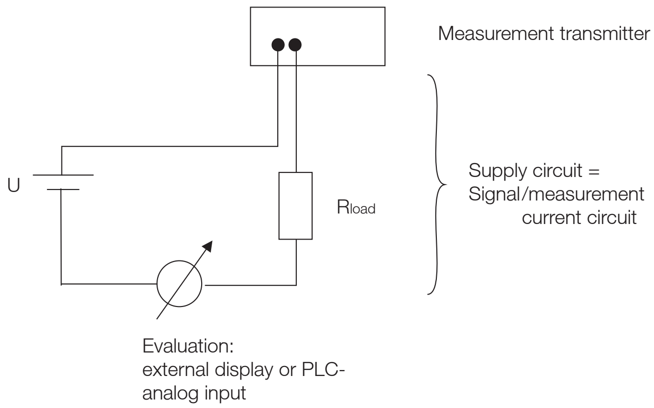
G Information relevant for all measurement transmitters

1 Avoiding errors in wiring

1.1 2-wire technology (4 to 20 mA)

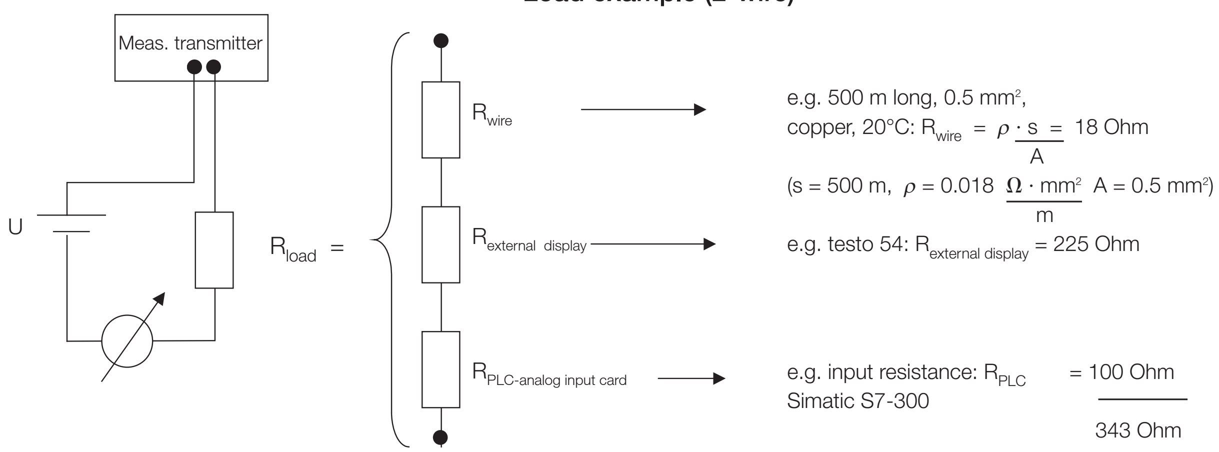
Two-wire measurement transmitters serve to convert non-electrical parameters, e.g. temperature, pressure, relative humidity etc. into a uniform electrical signal of 4 to 20 mA. The measurement transmitters are connected to a DC voltage source via 2 wires. The current consumption of the measurement transmitters changes in the range of 4 to 20 mA, dependent on the parameter to be measured. Supply circuit and signal cicuit are thus identical (see illustration.)

The advantages of two-wire system are for one the extremely small installation costs and the unproblematic connection. The length of the wire has no influence on the measurement signal. A further advantage is the so-called “live-zero” signal, i.e. the scale minimum corresponds to a current of 4 mA. This means that this value is clearly transferred and cannot, for example, be mistaken for a system which is switched off. In many cases, installing a separate network wire to the measurement location is complicated. By carrying the supply and the measurement signal in one wire, the two-wire measurement transmitter can be used to great advantage here.



The maximum load shows how high the permitted total resistance of the instruments connected in the circuit (without the measurement transmitter), and the installed wiring, can be. The sum of the resistances may not be higher than the maximum load.
If the load resistance consists of a wire (500 m, 0.5 mm^2, copper with a specific resistance $\rho = \frac{0.018\ \Omega \cdot mm^2}{m}$ at 20°C), a process display testo 54 and a Simatic-300 analog input card, the resistance is still 157 Ohms below the maximum load limit of 500 Ohms, i.e. a further instrument could be integrated into the measurement circuit, or the wire length could be increased or the cross-section area reduced, provided that an additional maximum of 157 Ohms result (see illustration).

Load example (2-wire)



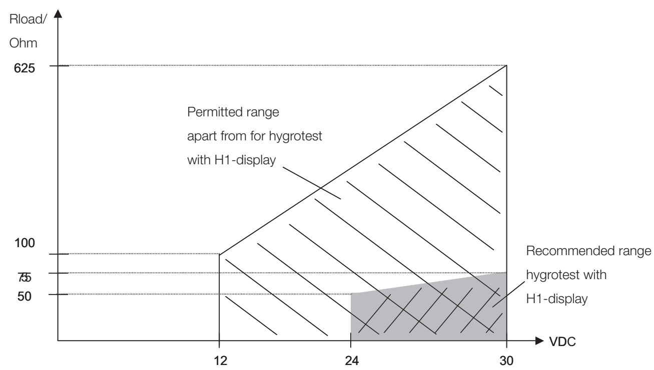
Max. wire length:

- The maximum signal wire length for 4 to 20 mA should be smaller than 1000 m (theoretically max. 3500 m according to the conductivity formula with 99% pure copper, 0.25 mm² cross-section and at 500 Ohms load resistance).
- A greater core cross-section (e.g. 0.5 mm² instead of 0.25 mm²) increases the permitted wire length.
- Screened wires should generally be used.

This means that, with a maximum load resistance of 500 Ohms, a maximum additional load of 157 Ohms (500 Ohms - 343 Ohms) can be placed on the measurement circuit.

Load field 2-wire technology
The maximum permitted load in 2-wire technology is dependent on the connected input voltage i.e. the higher the connected voltage, the higher the permitted maximum load.
In the exemplary load field in the adjacent illustration, this means that with a minimum voltage input of 12 V the maximum load 100 Ohms, and with a maximum voltage input of 30 V the maximum load 625 Ohms may not be exceeded.

Load field 2-wire technology

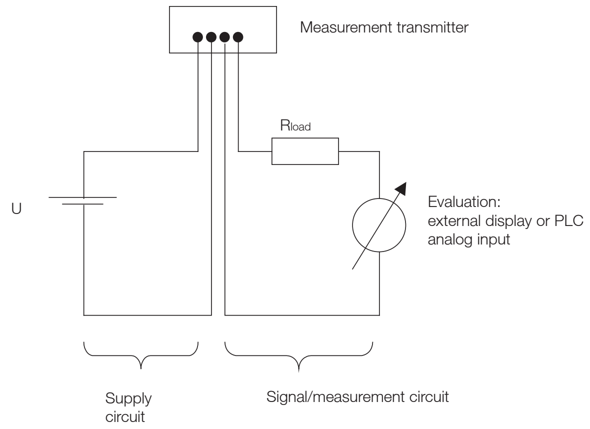


1.2 4-wire technology (0 to 20 mA, 4 to 20 mA, 0 to 1 V, 0 to 10 V)

In 4-wire technology, the measurement transmitter has a supply circuit and a separete (active) measurement circuit

The 4-wire technology is still widely in use, despite the advantages of the 2-wire technology.

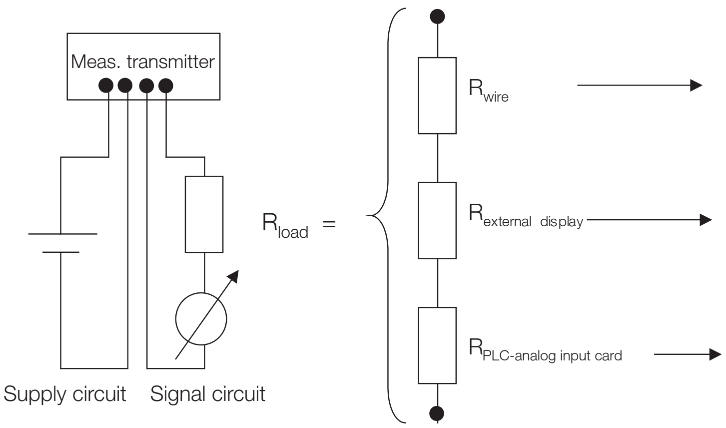
The 4-wire technology furthermore provides a supply of measurement transmitters with a higher current consumption (e.g. for testo 6341/6343 because of the automatic zero point calibration).



The maximum load shows how high the permitted total resistance of the instruments connected in the circuit (without the measurement transmitter), and the installed wiring, can be. The sum of the resistances may not be higher than the maximum load.

If the load resistance consists of a wire (500 m, 0.5 mm^2, copper, 20°C), a process display testo 54 and a Simatic-300 analog input card, the resistance is still 157 Ohms below the maximum load limit of 500 Ohms, i.e. a further instrument could be integrated into the measurement circuit, or the wire length could be increased or the cross-section area reduced, provided that an additional maximum of 157 Ohms result (see illustration).

Load example (4-wire)



e.g. 500 m long, 0.5 mm^2,
copper, 20°C: $R_{wire} = \frac{\rho \cdot s}{A} =$ 18 Ohm

(s = 500 m, $\rho = 0.018\ \frac{\Omega \cdot mm^2}{m}$ A = 0.5 mm^2)

e.g. testo 54: $R_{external\ display}$ = 225 Ohm

e.g. input resistance R_{PLC} = 100 Ohm
Simatic S7-300

343 Ohm

Max. wire length:

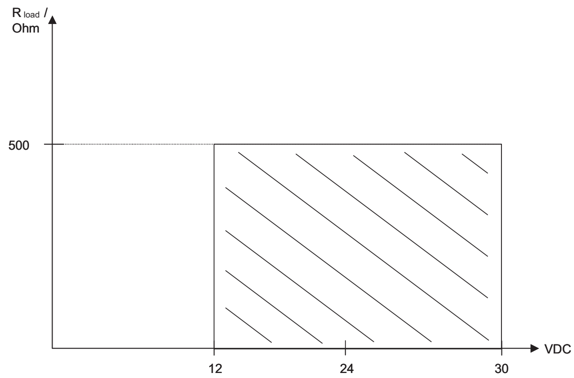
The maximum signal wire length for voltage signals (0 to 1 V and 0 to 10 V) should be smaller than 50 m (note: in the example above, a current signal is being measured), as otherwise the original signal decreases along the length of the wire and is thus falsified. Current outputs (e.g. 0 to 20 mA), however, compensate the load resistances up to a certain length (full utilization of the "max. load", see above), here wire lengths of several 100 m can be achieved.

This means that, with a maximum load resistance of 500 Ohms, a maximum additional load of 157 Ohms (500 Ohms - 343 Ohms) can be placed on the measurement circuit.

Load field 4-wire technology

In contrast to 2-wire technology, in 4-wire technology the load field is constant because of the separate voltage supply, i.e. the permitted load is independent of the connected input voltege (cf. illustration). In the example on the right, the supply voltage may not amount to less than 12 VDC or more than 30 VDC.

Load field 4-wire technology



G Avoiding errors in wiring

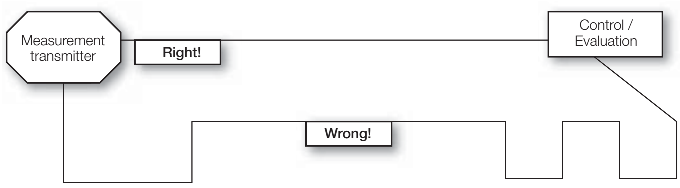
1.3 Wiring guide

Measurement transmitters can be exposed to interference in industrial use. Directly adjacent to the measurement transmitter or its signal wires, for instance, motors can start, which can lead to signal interference. Or metal measurement transmitters are brought into contact with voltage potentials of their mountings. Here are a few tips to help you avoid interference.

Preliminary note:
PE (Protection Earth) wires, insulation colour green-yellow, help to avoid a potential (voltage) difference in equipment assemblies. These potential differences lead to undesired currents and to falsified signals, and in extreme cases to damaged electronic components.

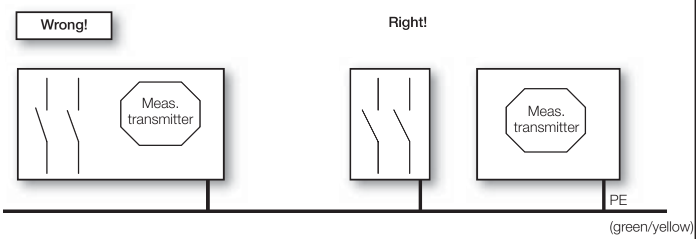
1. Install wires and cables always as short as possible

- This applies primarily to signal wires, but also to supply cables and earthing wires (PE).
- The maximum signal wire length for 0 to 1 V and 0 to10 V should be less than 50 m.
- The maximum signal wire length for 4 to 20 mA should be less than 1000 m (theoretically max. 3500 m according to the conductivity formula with 99% pure copper, 0.25 mm² cross-section and at 500 Ohms load resistance).



2. Measurement transmitters and measurement displays may not be installed directly adjacent to guards, mains switches, motors, frequency converters and similar

- Separating the housings is recommended.
- Separate earth wires (PE) are also recommended.

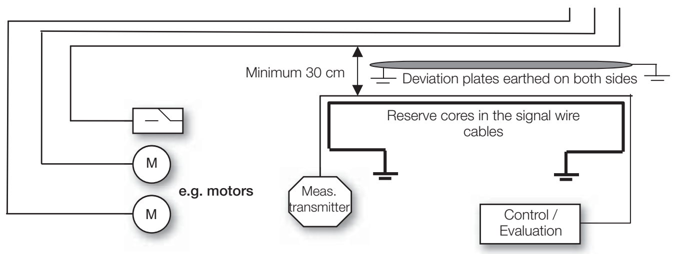


3. Screening units should always be used on guards and other switching equipment

- Switching processes lead to abrupt changes which can cause field effects on neighbouring wires and equipment assemblies.
- Interference effects can often already be prevented with the use of screening units (e.g. toroidal chokes).

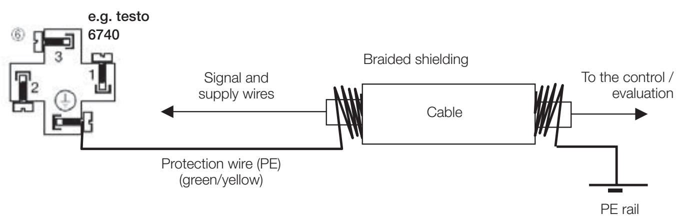
4. Never install measurement transmitter wires parallel to live wires. These should always be located separately.

- The greatest causers of interference are supply cables which are connected to motors, guards, frequency converters and similar.
- A minimum distance of approx. 30 cm should be kept between signal wires and their supply cables.
- Different types of wires should be arranged according to signal groups (current inputs, analog wires, digital wires etc.).
- So-called deviation plates are also to be recommended (applies primarily to supply ≥ 230 VAC). These plates must be earthed on both sides!
- Reserve cores in the signal wire cables can also be earthed on both sides as a screen.



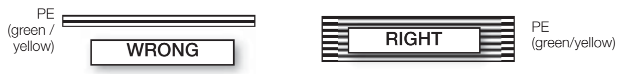
5. Use shielded wires as far as possible

- Shielding reduces external interference effects (e.g. through large switches, frequency converters, motors etc.).
- The use of a cable with braided shielding is recommended, foil shields have a five times worse shielding effect.
- The shield must be connected to a PE on both sides of the cable.



6. Connect PE (protection wire) with low impedance (low resistance)

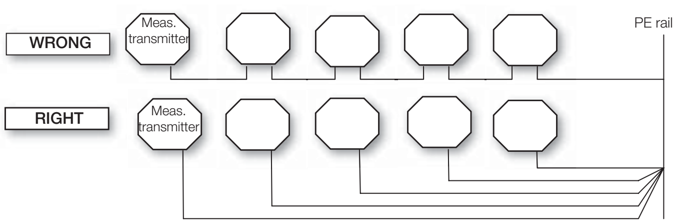
- Use as thick wires as possible, with many individual cores. These should be kept a short as possible (see point 1).



Recommended: min. 0.5 mm² cross-section for PE wires

7. Do not loop the protection wire through from one instrument to the next.

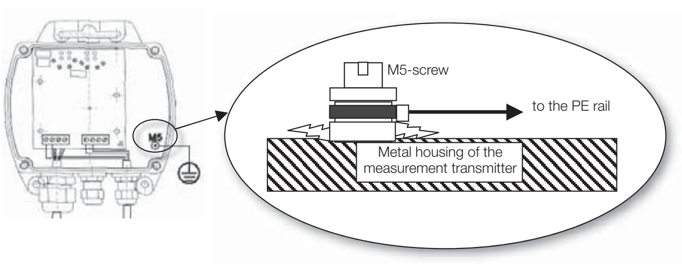
- The protection wire should always be laid in a star-shaped pattern to a fixed point (best is the shortest way to the PE rail)



8. When connecting the protection wire to (metal) measurement transmitters, ensure that the transition resistances are as low as possible

- Remove paint and grease deposits, and any other contamination thoroughly.
- The use of washers and lock washers is recommended!

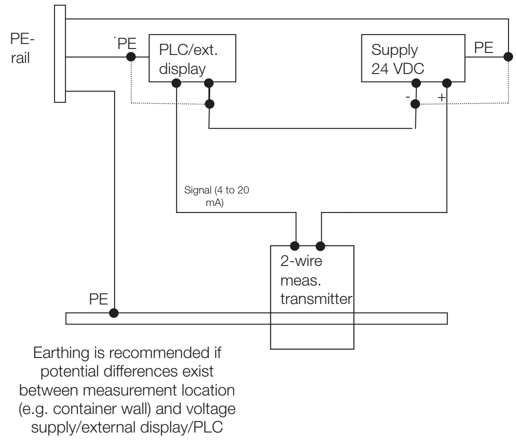
Example hygrotest 650 (metal housing):



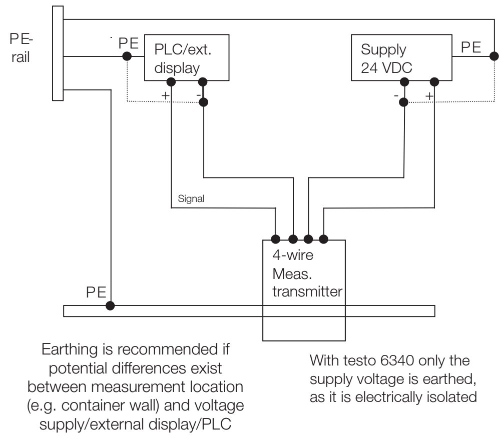
9. Mutual zero potential is recommended if potential differences exist between measurement location (e.g. container wall) and voltage supply/external display/PLC.

The following PE wiring measures are only relevant if metal housings or metal probes are in conductive connection with process partitions

PE connection in 2-wire technology



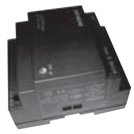
PE connection in 4-wire technology



G Selection assistance for voltage supply

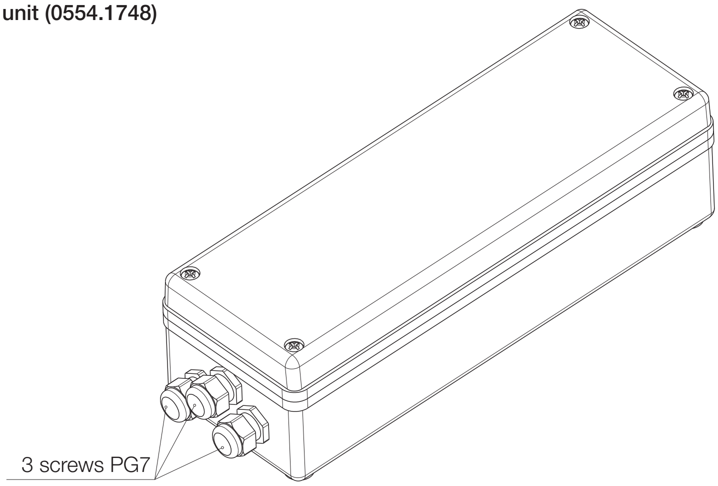
2 Selection assistance for voltage supply

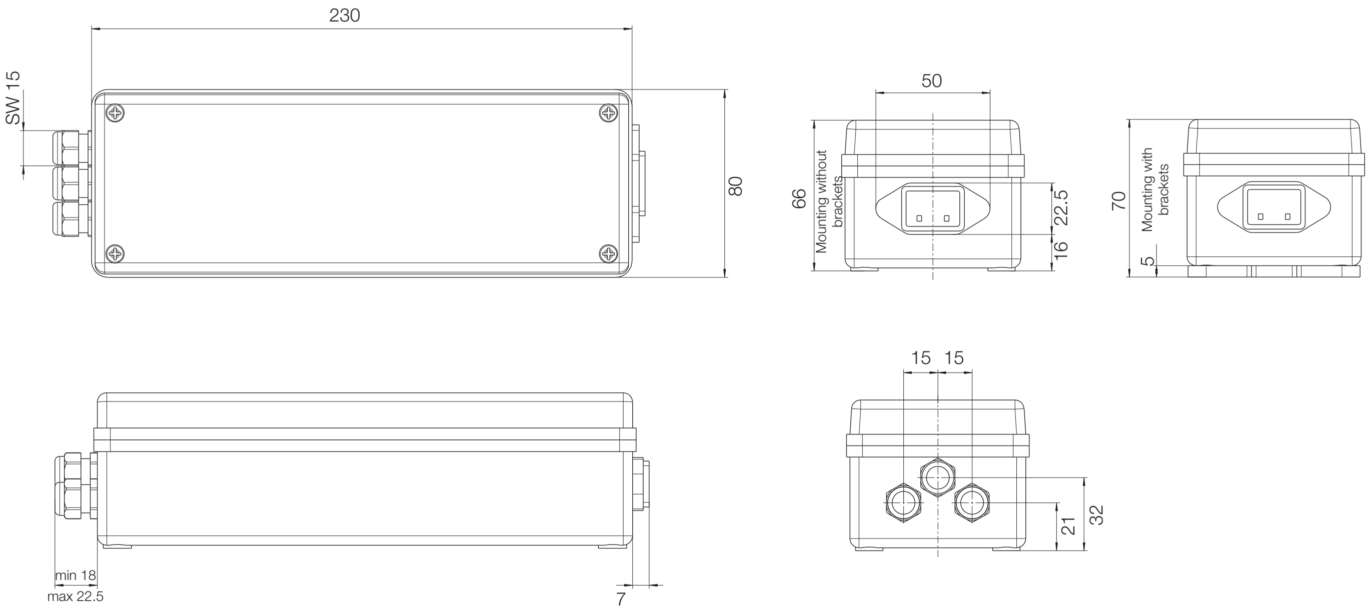
2.1 Description of the voltage supply possibilities

	A Desktop mains unit 0554.1748	B Hat rail mains unit 0554.1749	C Voltage output of the process displays t54-2AC/-7AC	D PLC analog input card. Simatic S7-300
Sketch/dimensions/ drawing/ connection image				
Input voltage	110 to 240 VAC 50/60 Hz	9 to 264 VAC 47 to 63 Hz	90 to 260 VAC 50/60 Hz	230 VAC
Output voltage	24 VDC +/- 5 %	24 VDC adjustment by customer possible (22.2 to 26.4 VDC)	24 VDC +/- 15%	24 VDC
Output current	350 mA, short-circuit-proof, max. 1200 mA	2.5 A, short-circuit-proof, max. 3.4 A	50 mA, max.1 channel	150 mA, max.1 channel

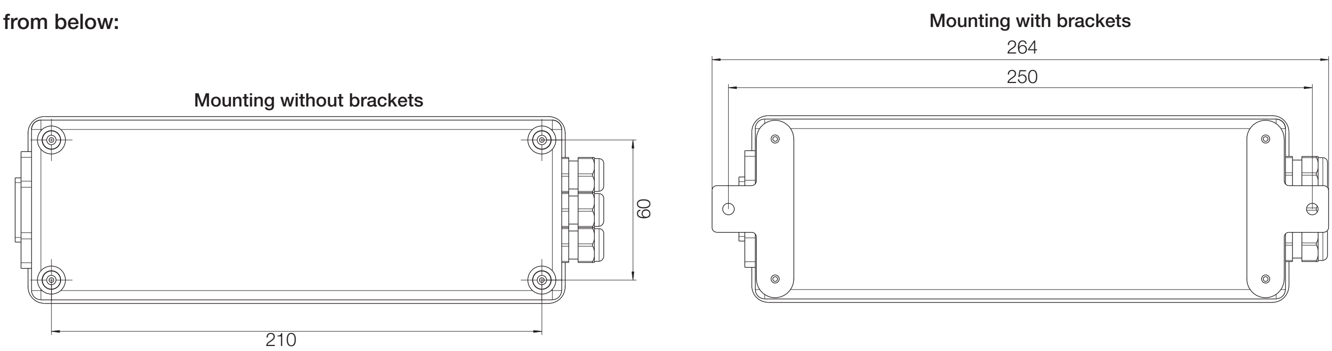
2.2. Dimensional drawings of voltage supplies

2.2.1 Desktop mains unit (0554.1748)



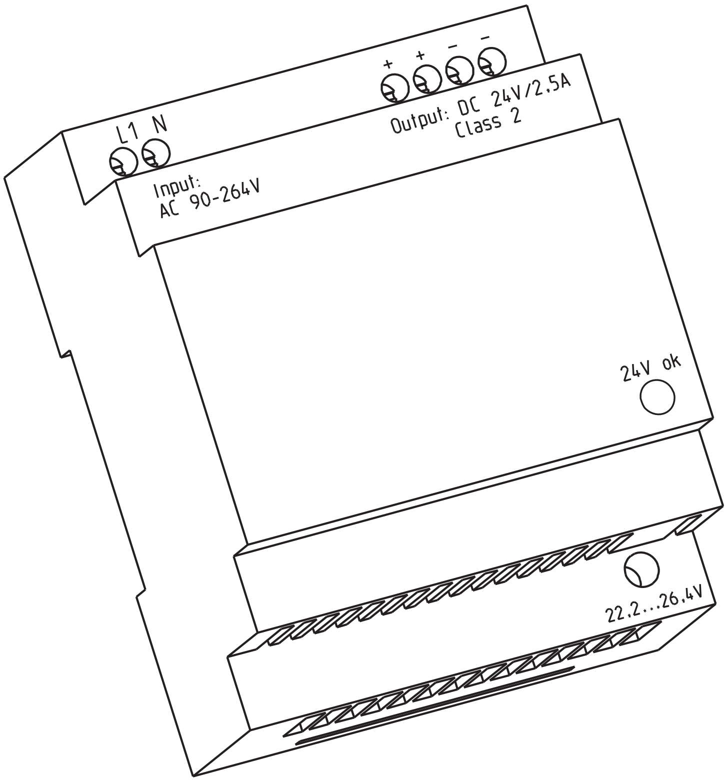


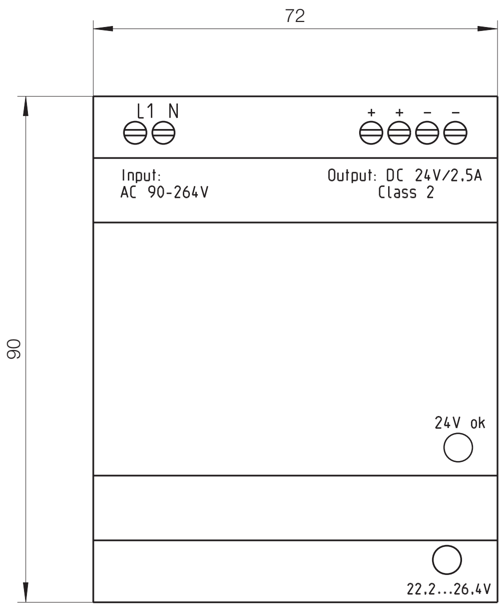
View from below:

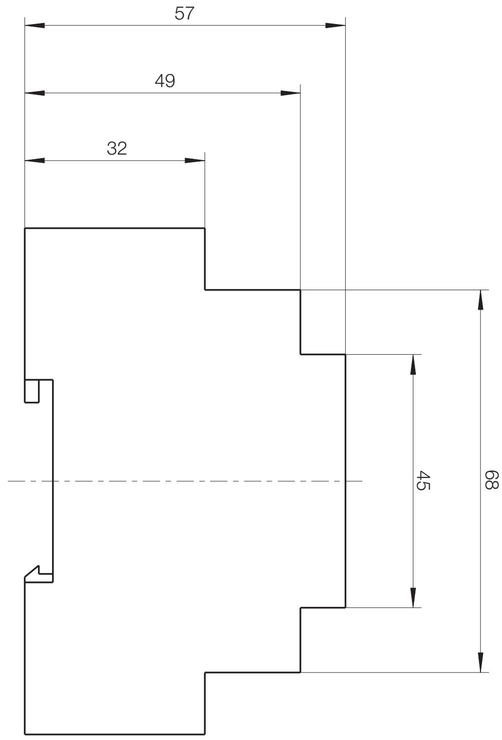


G Selection assistance for voltage supply

2.2.2 Hat rail mains unit (0554.1749)







3 Calibration and adjustment

Testo offers calibration in accredited testo laboratories.

If requirements from the field of quality assurance are in the foreground (ISO 9001, QS9000, GMP, FDA, HACCP,...), ISO calibration (laboratory accredited according to ISO 17025) offers the ideal solution. If highest reliability is required, for instance in production norms, for assessors, official bodies and critical applications, DKD calibration is recommended

If the measuring instrument has a DKD certificate, you are entitled to carry out internal ISO calibrations in the works with this DKD calibrated reference instrument. The hygrotest 650 (with DKD certificate), for example, is thus suitable for an internal works calibration laboratory.

Definition of terms:

A **calibration** is the comparison between the actual value and the nominal value, and its documentation.

An **adjustment** is the alignment of the actual value to the nominal value.

4 Influence of the measurement inaccuracy of the reference instrument

When carrying out an adjustment with the help of a reference instrument, it must be taken into account that not only the measuring instrument has a measurement inaccuracy, but also the refrence instrument.

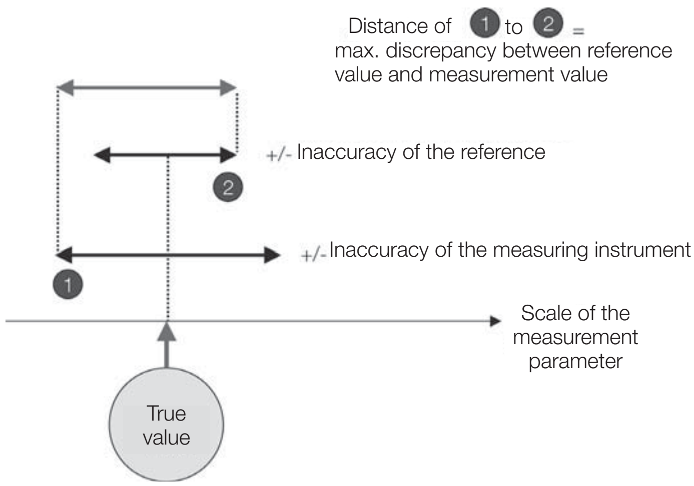
A the illustration shows, the measuring instrument ❶ has a greater measurement inaccuracy than the reference instrument ❷

In the worst case, point 1 and point 2 move as far apart as possible, as shown in the graphic.

It thus follows that the measurement inaccuracy of a measuring instrument is within the tolerance range, if the distance between the measurement value and the true value is not greater than the sum of the two measurement inaccuracies.

Example:
- Measurement inaccuracy measuring instrument: +/- 2 %RH
- Measurement inaccuracy reference instrument: +/- 1 %RH

➙ The measuring instrument is within the tolerance as long as the discrepancy is less than +/- 3 %RH.



G Scaling and resolution

5 Scaling and resolution

Digital measurement transmitters convert the signal coming from the sensor into an analog signal. Digital signals consist only of the two signal stati "0" and "1", to which different current or voltage stati can be allocated. In digital-analog conversion, this creates a step pattern of the signal, i.e. analog signals can only be emitted at a certain grid distance and in a certain voltage or current range.
The grid distance is dependent on the quantisation (Bit resolution) as well as on the absolute value of the measurement range. By scaling the measurement range as tightly as possible, the resulting error of the analog signal can be reduced through the quantisation.

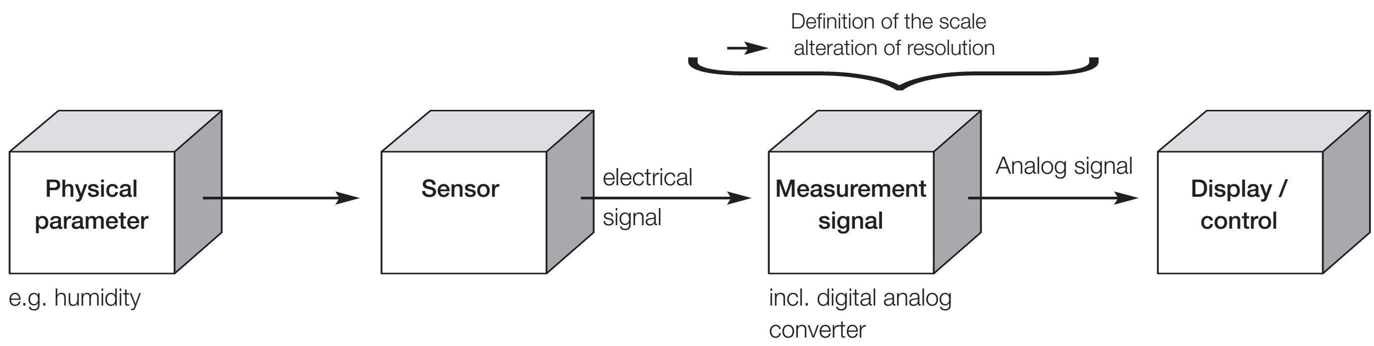
➔ Calculation of the measurement range resolution:

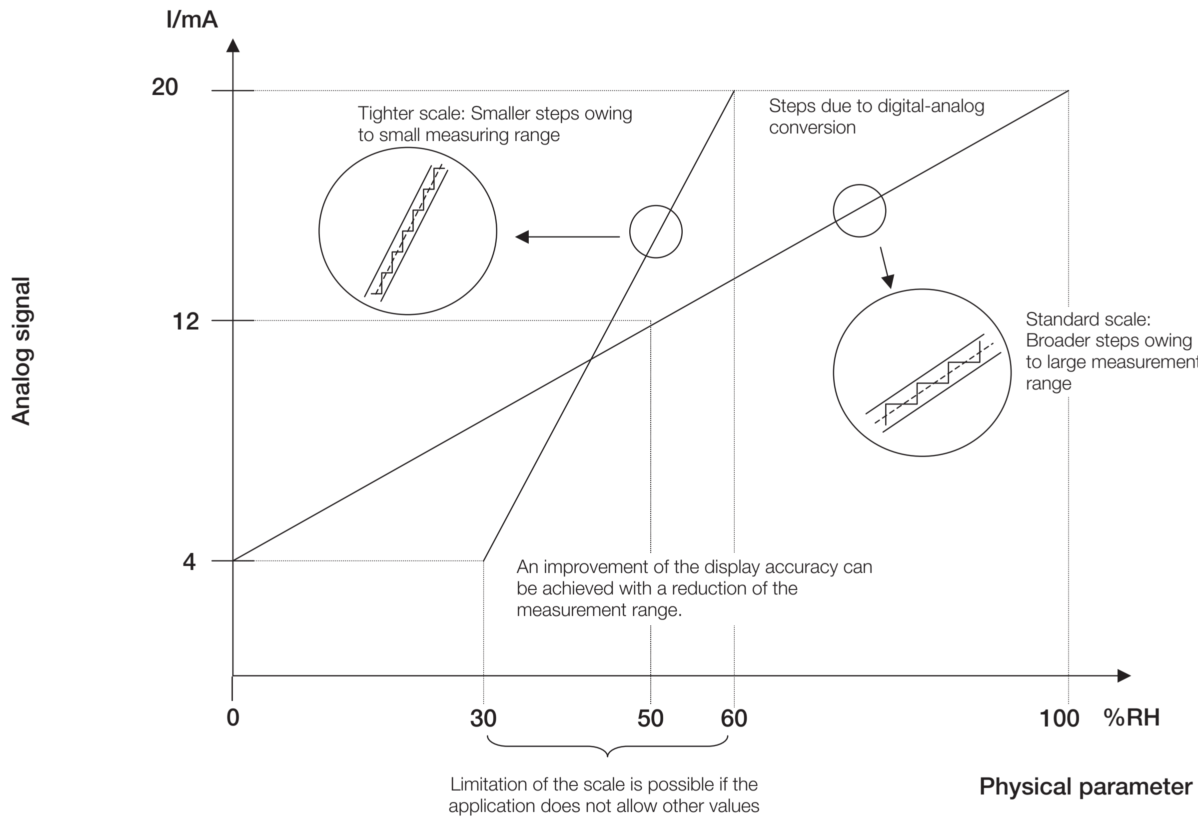
$$\frac{|\text{Meas. range}|}{\text{Bit resolution}} = \frac{|\text{Meas. range}|}{2^x} = \text{Measurement value resolution}$$

Example: Measurement range --> 0.25 to 75 Nm^3/h; 12-Bit resolution

$$\text{Meas. value res.} = \frac{|\text{Meas. value}|}{\text{Bit resolution}} = \frac{|74.75|\ Nm^3/h}{2^{1.}} = 0{,}01825\ Nm^3/h$$

A step pattern of the signal is created (in digital-analog conversion). This so-called "resolution" can be improved by scaling as tightly as possible.

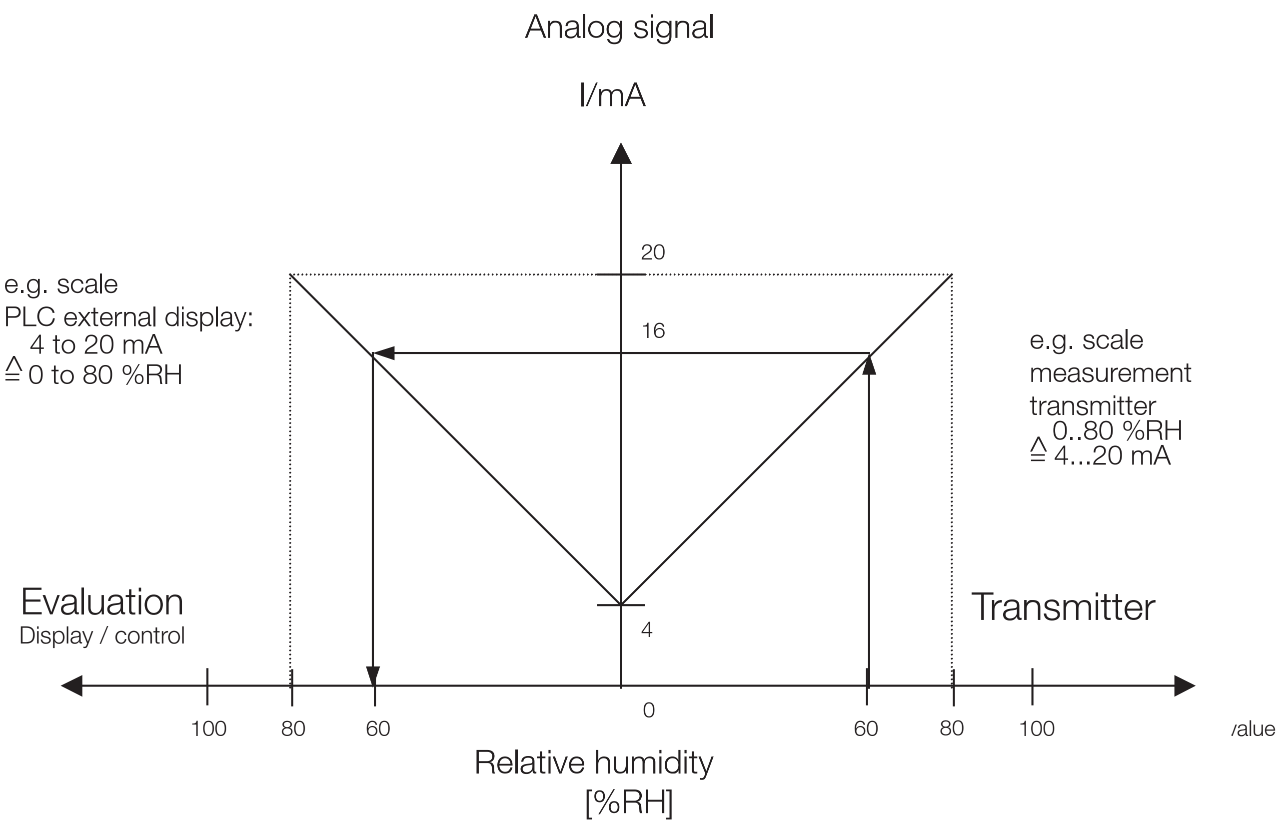




The diagram shows two different measurement transmitter scales, 0 to 100 %RH and 30 to 60 %RH. The resolution of the current signal remains constant (the number of steps), which is why the steps are compressed when the scale is reduced horizontally.

The measurement range should be set as small as possible for this reason (dependent on the process - all expected measurement values must be within the scale!), as this improves the accuracy of the display and the signal through smaller steps.

In scaling, one should generally ensure that the scale of the measurement transmitter and that of the control/external display are laterally reversed/identical (see following illustration).



6 Housing protection according to IP (International Protection)

6.1 Tightness according to IP-norm

The IP regulation VDE 0470-1 (previously: DIN40050) is a system for the classification of the housings of electrical appliances according to the following aspects:

- Protection of persons from dangerous components inside the housing
- Protection of assemblies inside the housing from ingress of solid foreign bodies
- Protection of assemblies inside the housing from ingress of water

G Housing protection according to IP (International Protection)

First digit of the IP-protection class: Protection from solid bodies

The first code number refers to the accessibility of the dangerous component for a person or solid foreign body.

0	No protection
1	Protection from solid bodies to 50 mm, e.g. unintentional hand contact
2	Protection from solid bodies to 12 mm, e.g. fingers
3	Protection from solid bodies over 2.5 mm, e.g. tools and small wires
4	Protection from solid bodies over 1 mm, e.g. small wires
5	Limited protection from dust ingress (no harmful deposits)
6*	Complete protection from dust

* Example IP 65 (testo hygrotest)

First digit of the IP-protection class: Protection from water

The second code number refers to the damage caused by water ingress. The conditions described go from vertically dripping water via water spray and water jets to constant immersion.

0	No protection
1	Protection from vertically dripping water (e.g. condensation)
2	Protection from direct water spray to 15° from vertical direction
3	Protection from direct water spray to 60° from vertical direction
4	Protection from water spray from all directions, limited ingress permitted
5*	Protection from low-pressure water jet from all directions, limited ingress permitted
6	Protection from powerful water jet e.g. for use on ship's decks, limited ingress permitted
7	Protection from immersion in water up to a depth between 15 cm and 1m
8	Protection from immersion in water under pressure for longer periods

6.2 Watertightness test at Testo (based on DIN VDE 0470-1/ EN 60529 / ICE 529)

The Testo measuring instruments are tested under the following conditions (as long as no other instrument specifications are defined):

temperature: 15 to 35°C,

relative humidity: 25 to 75%RH

air pressure: 860 to 1060 mbar

test medium: water (+/- 5 K to test object)

Passing condition:
No damaging quantities of water may have entered the product at the end of the test.

The following table shows the tests for the most common protection classes:

IP 42	Test object is placed under water dripping vertically or at an angle of up to 15°. Protection from dripping water
IP 54	Water is sprayed at the test object from different sides (approx. 60°) at a distance of 200 mm using a hand shower and a water quantity of aprox. 0.07l/min. Protection from water spray.
IP 65	Water is sprayed at the test object from a jet in a quantity of approx. 12l/min. Protection from water jet.
IP 67	Test object is immersed in a tank 0.15 m from top edge up to approx.1m from bottom edge for 30 mins. Protection from temporary immersion.
IP 68	Test object is immersed in a water tank according to its specifications and previously set times. The test must be recorded in a product norm (stricter than IP 67 i.e. deeper than 1 m / longer than 30 min). Protection from immersion.