

D11: Instrumentation

Length: 160 minutes

Theory

Learning outcomes

- Know the 5 different protection classes (0, I, 0I, II and III)
- Knowledge of Ingress Protection (IP) ratings
- Understand how to carry out a detailed inspection of an item of portable powered equipment or a system
- Understand the dangers when using test equipment
- Knowledge of the requirements of test probes, clips and leads
- Understand the differences between CAT II, III and IV test instruments
- Know how to select the correct function and range setting
- Be able to carry out pre use checks on a multi meter
- Be able to check for correct calibration
- Be able to check the battery condition and continuity of the leads
- Know the safety requirements of testing for voltage
- Know the requirements of the test leads for measuring for voltage
- Be able to measure voltage
- Be able to measure resistance of a component
- Know how to measure the current (1. with a multi meter and 2. with a clamp meter)
- Know what is meant with insulation resistance
- Understand the reason why to execute insulation resistance test
- Understand the danger related to insulation resistance measuring processes
- Know how to fill in the testing report
- Be able to identify the electrical terminals on a suitable motor (probably a refrigeration / air conditioning compressor)
- Be able to use the multi meter to test the resistance between each pair of terminals
- Be able to work out from the resistance readings which terminal is which

Agenda Module D11 – Protection & Instrumentation

 Electrical protection classes and ratings

Electrical check of appliances and systems

Instrumentation

The multi-meter

Measuring insulation resistance

How to identify single-phase compressor electrical terminals

Electrical protection classes and ratings

The term “Electrical protection class” is often used to describe two different systems.

1. The electrical appliance manufacturing industry has defined four IEC protection classes (IEC 61140: 2016 Protection against electric shock – common aspects. Applies to the protection of persons and livestock against electric shock) to differentiate between protective-earth connection requirements of devices against contact-hazard voltages.
2. Ingress protection (IP) is defined in another IEC standard (IEC 60529 Degrees of protection provided by enclosures) The IP Code, International Protection Marking, IEC standard 60529, sometimes interpreted as Ingress Protection Marking, classifies and rates the degree of protection provided by mechanical casings and electrical enclosures against intrusion, dust, accidental contact, and water.

Electrical protection classes and ratings

Protection classes against electric shock

In electrical engineering, protection classes are used to classify and label electrical equipment such as devices and installation components with regard to the existing safety measures and to prevent electric shock or malfunctions of the refrigerating system, which may lead to generation of sparks.

There are four protection classes for electrical equipment, with protection classes I-III being the most common.

Protection Class	Meaning	Symbol
Protection Class 0	No protective earth. Only a single level of insulation between live parts and exposed metalwork. Often forbidden. <i>If permitted at all, Class 0 items are intended for use in dry areas only.</i>	
Protection Class I	Protective earth	
Protection Class 0I	Electrical installations where the chassis is connected to earth with a separate terminal, instead of via the mains cable.	
Protection Class II	Double or reinforced insulation but no earth connection	
Protection Class III	Extra low safety voltage Often used with flammable refrigerants	

Electrical protection classes and ratings

Protection classes against electric shock

Protection class “0” – no special protection

- Apart from the basic insulation, there is no special protection against electric shock. The connection to the protective earth conductor system is not possible.
- The protection must be ensured by the surrounding area of the equipment.
- If permitted at all, Class 0 items are intended for use in dry areas only.
- For protection class 0, there is no symbol, a marking is not provided.
- It is forbidden in many countries, such as Germany, Austria, UK and New Zealand.
- However, equipment of this class is still common in many countries, whether it is permitted officially or not.

Electrical protection classes and ratings

Protection classes against electric shock

Protection class “I” – protective earth

- In protection class “I”, devices or appliances, conductive housing parts of the equipment are connected to electrical earth (also called electrical ground) by a separate earth conductor.
- Generally, exposed metal and conductive parts in a house are connected to each other to be at ground potential. In case of a fault, a person touching these parts will therefore be protected from an electrical shock.
- In most countries the earth conductor is green/yellow; in the US, Canada and Japan it is green only.
- Movable devices of protection class “I” have a plug connection with protective conductor contact, a plug with protective contact or a three-pole plug. The protective conductor connection is designed in a way, that it is the first contact to be maintained when plugging in the plug and is the last to be disconnected in the event of damage (first-to-make, last-to-break contact).

Electrical protection classes and ratings

Protection classes against electric shock

Protection class “I” – protective earth (continued)

- The insertion of the connecting cable into the device must be mechanically “strain relieved”, when the cable is torn out; the protective conductor must tear off last.
- The earth connection is achieved with a 3-conductor wired mains cable, typically ending with an AC three-pole connector, which plugs into a corresponding AC outlet.
- The basic requirement is that no single failure can result in dangerous voltage becoming exposed so that it might cause an electric shock and that if a fault occurs the power supply will be disconnected automatically (this is sometimes referred to as ADS = Automatic Disconnection of Supply).

Electrical protection classes and ratings

Protection classes against electric shock

Protection class “0I”

- In protection class “0I”, the chassis is connected to earth via a separate terminal and not via the mains cable.
- In class 0I appliances, there is provision for an Earth connection, but it is wired with either twin core cable or only has a 2-pin plug, so an Earth cannot be connected.
- As in class 0 equipment, there is only one level of protection.
- For this reason, class 0I appliances are also prohibited from sale.
- The protection is equivalent to class “I”.

Electrical protection classes and ratings

Protection classes against electric shock

Protection class “II” - Protection by double or reinforced insulation

- Equipment with protection class “II” has reinforced or double insulation in the amount of the rated insulation voltage between active and touchable parts.
- They have no connection to the protective conductor.
- Even if they have electrically conductive surfaces, they are protected by reinforced or double insulation, which ensures complete protection against dangerous contact currents even when the basic insulation is bridged by an insulation fault.
- For the power connection of movable devices of protection class “II”, power cable and plugs are used which have no connection to the protective earth conductor.

Electrical protection classes and ratings

Protection classes against electric shock

Protection class “III” – Extra low safety voltage

Class “III” equipment may only be connected to separated extra-low voltage (SELV) power sources, including:

- Safety transformer according to DIN EN 61558-2-6
- Electrochemical power source (battery, accumulator)
- A separated feeder of the supply network that is effectively independent of the normal feeder

The device is operated with a voltage which corresponds to a maximum of the permissible contact voltage.

Normal	DC: $U \leq 120 \text{ V} =$ AC: $U \leq 50 \text{ V} \sim$
In stables / animal husbandry	DC: $U \leq 60 \text{ V} =$ AC: $U \leq 25 \text{ V} \sim$
For children's toys	$U \leq 25.0 \text{ V}$
In wet rooms	$U \leq 12.0 \text{ V}$
In medical technology	$U \leq 6.0 \text{ V}$

Electrical Protection Classes and Ratings

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Electrical protection classes and ratings

Ingress protection (IP)

In RACHP applications, electrical and electronic equipment must operate safely under harsh environmental conditions for many years. One important point to guarantee this is to prevent the ingress of foreign bodies, such as wires and dust and the mechanical stress caused by impact.

The standard allows an objective comparison of the characteristics, rather than marketing terms such as “waterproof”.

The IP code contains 2 characteristic numerals (for example, IP 67)

Recommended for use with flammable refrigerants:

IP67: total protection against dust ingress and temporary immersion in water.

Electrical protection classes and ratings

Ingress protection (IP)

IP	First digit – Ingress of solid objects	Second digit- Ingress of liquid objects
0	No protection	Not protected
1	Protection against solid foreign objects (≥ 50 mm in diameter)	Protection against vertically falling drops of water or condensation
2	Protection against solid foreign objects (≥ 12.5 mm in diameter)	Protection against sprays of water up to 15° on either side of vertical
3	Protection against solid foreign objects (≥ 2.5 mm in diameter)	Protection against sprays of water up to 60° on either side of vertical
4	Protection against solid foreign objects (≥ 1 mm in diameter)	Protection against splash water from any direction
5	Limited protection against dust ingress	Water protected in low-pressure jets against enclosure from any direction
6	Total protection against dust ingress	Water protected in high-pressure jets against the enclosure from any direction
7	N/A	Temporary immersion in water (1 m of for 30 min)
8	N/A	Protected against continuous immersion under water for short period (2 m for 60 min)
9	N/A	Stream directed at a high pressure against the enclosure from any direction

Agenda Module D11 – Protection & Instrumentation

Electrical protection classes and ratings

☒ Electrical check of appliances and systems

Instrumentation

The multi-meter

Measuring insulation resistance

How to identify single-phase compressor electrical terminals

Electrical check of appliances and systems

- Electrical systems and appliances have to be tested before commissioning, both after installation and modification.
- This has to be carried out by a person with the appropriate qualification and approved equipment and tools.

Electrical inspections generally include the following steps:

- The equipment is looked at, touched, shaken or pulled
- Check firm hold of cables and electrical components
- Check the correct connection
- Check the correct dimensioning, e.g. of cables and fuses
- Check if cable lugs are fixed properly
- Test fault-current circuit breakers, protective measures (such as enclosures) and the correct connection of the protective conductors

Agenda Module D11 – Protection & Instrumentation

Electrical protection classes and ratings

Electrical check of appliances and systems

 Instrumentation

The multi-meter

Measuring insulation resistance

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Instrumentation

- Equipment should be constructed with suitably insulated and shrouded terminals to minimise the risk of short-circuits, which could cause danger.
- Always use suitable test probes, leads, lamps, voltage indicators and multi-meters, as unsuitable equipment can cause electrical arcing due to:
- Inadequately insulated test probes (typically having an excessive length of bare metal at the contact end) accidentally bridging a live conductor and adjacent earthed metalwork; or
- Excessive current drawn through test probes, leads and measuring instruments. This can happen when a multi-meter is set to the wrong function, e.g. set to measure a current or resistance range when measuring voltage.

Instrumentation

Test probes, clips and leads

Modern test probes, clips and leads should:

- conform to the requirements of EN 61010-031 or in the case of a 2-pole voltage detector to EN 61243-3,
- be marked with the rated installation category – CAT II, III, or IV (see below),
- be marked with the manufacturer's name or identifying mark,
- and have probes, and clips, which:
 - have finger barriers or are shaped to guard against inadvertent hand contact with the live conductors under test,
 - are insulated to leave an exposed metal tip not exceeding 4 mm measured across any surface of the tip. Where practicable it is strongly recommended that this is reduced to 2 mm or less, or that spring-loaded retractable, screened probes are used,
 - when used with a multi-meter, should have suitable high-breaking capacity (hbc), sometimes known as hrc, fuse, or fuses, with a suitable current rating (usually not exceeding 500 mA), except when used with a loop impedance or RCD tester where a value of 10 A is typically used or a current-limiting resistor and a fuse.

Instrumentation

Test probes, clips and leads

Leads should:

- be adequately insulated (the choice of insulating material may be influenced by the environment in which the leads are to be used),
- be coloured so that one lead can be easily distinguished from the other (voltage detectors tend not to have different coloured leads),
- be flexible and of sufficient capacity for the duty expected of them,
- be sheathed to protect against mechanical damage,
- be long enough for the purpose, while not too long that they are clumsy or unwieldy,
- not have accessible exposed conductors other than the probe tips,
- or have live conductors accessible to a person's finger if a lead becomes detached from a probe or equipment when in use.

Instrumentation

CAT II, III and IV

EN 61010 defines measurement categories (CAT) as below; these reflect the level of overvoltage that can be expected at the point of measurement:

- measurement category IV is for measurements performed at the source of the low voltage installation (e.g. meters, primary overcurrent protection devices etc.),
- measurement category III is for measurements performed in the building installation (e.g. measurements on distribution boards, socket outlets, permanently connected equipment, etc.),
- measurement category II is for measurements performed on circuits directly connected to the low voltage installation (e.g. appliances, portable tools, etc.).

Instrumentation

Working Live

- Regulations permit few circumstances where it is acceptable for live working activities to be carried out on electrical equipment or systems, this includes electrical testing and fault finding.
- Wherever possible, all work on electrical systems should be carried out with the system dead.
- This includes electrical testing where dead tests are often as effective as live measurements.

NOTE: This information is aimed at people who use electrical test equipment on low voltage electrical systems and equipment.

Instrumentation

Working Live

There must be no live working unless it is unreasonable to work dead and it is reasonable to work live and suitable precautions are taken to prevent injury.

Work must be carried out in a safe manner. Things to consider when developing safe working practices include:

- control of risks while working,
- control of test areas,
- use of suitable tools and clothing,
- use of suitable insulated barriers,
- adequate information,
- adequate accompaniment,
- adequate space, access and lighting,
- precautions to prevent people not carrying out the testing coming into contact with exposed live parts.

Agenda Module D11 – Protection & Instrumentation

Electrical protection classes and ratings

Electrical check of appliances and systems

Instrumentation

 The multimeter

Measuring insulation resistance

How to identify single-phase compressor electrical terminals

The multimeter: Measurement of voltage, current and resistance



Typical Analogue Multimeter

© Pixabay



Typical Digital Multimeter

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The multimeter: Measurement of voltage, current and resistance

- A very widely used measuring instrument is the 'multimeter'.
- This instrument is sometimes referred to as an AVO because it can measure Amps, Volts and Ohms.
- Depending on what the meter is being used for, the multimeter has very different characteristics, and care must be taken whichever function it is being used for.
- There is, therefore, clearly a need for caution when using a multimeter.

The multimeter: Measurement of voltage, current and resistance

The selector switch allows the user to choose the electrical unit and range you wish to measure:

- DC voltage (V)
- DC current (A)
- AC voltage (V)
- AC current (A)
- Resistance (Ω)

The multimeter: Measurement of voltage, current and resistance

Prior to use, check:

- that it is calibrated by reading the calibration label that is attached to the instrument,
- battery condition,
- The instrument test leads, to make sure they are in good order and fit for purpose.

NOTE: Ensure that fused test leads conform to the requirements of BS EN 61010-031 when measuring voltage

The multi-meter: Measurement of voltage, current and resistance

Digital multi-meters are often 'auto ranging'. This means that, for measuring resistance, you would only have to select the ohms (Ω) range and the instrument would then measure from zero up to its maximum value (e.g. 1 mega ohms (1 M Ω)).

NOTE: Always check the resistance of the test leads first, as this will have to be taken away from any resistance readings taken.

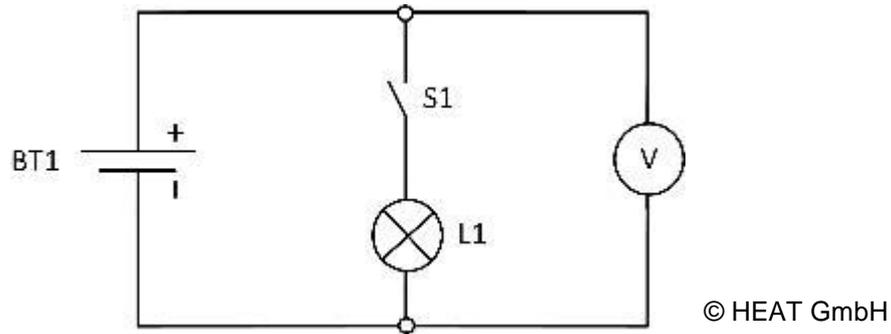
The multi-meter: Measurement of voltage, current and resistance

Prior to the measurement of voltage, resistance and low values of current, always select the correct function and the correct range.

If you are unsure which range to select, then start at the highest range and change progressively to a lower range to achieve a reasonable reading and to prevent overloading.

The multi-meter: Measurement of voltage

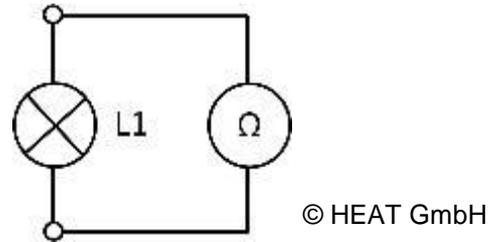
When measuring voltage, the meter leads are placed either side of the component to determine the potential difference across that component



All safety measures must be taken prior to measuring voltage. High risk activity.

The multi-meter: Measurement of resistance

To measure the resistance of a component the leads of the multi-meter are placed either side of the component.

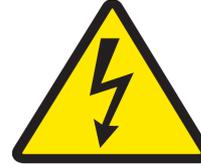
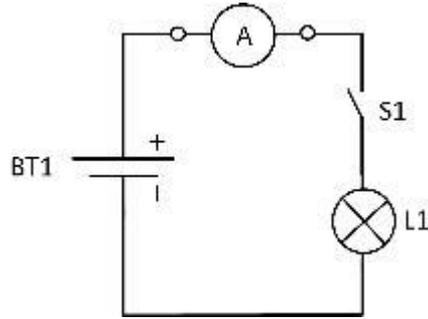


When you are using a multi-meter to measure resistance, remember the following so that you obtain accurate readings and prevent damage to the meter:

- never connect the meter into a circuit with voltage present or current flowing and
- always make sure the component or circuit you are checking is isolated from any other components or circuit.

The multi-meter: Measurement of current

When measuring current, the meter leads have to be placed in circuit to be able to measure the current flowing through the component as below:



© HEAT GmbH

This method is only suitable for measuring small currents, because this method is limited by the current carrying capacity of the meter and its associated test leads. Therefore this method of measuring current is rarely used.

All safety measures must be taken prior to measuring current. The cables and surrounding terminals will be live. High risk activity.

The multi-meter: Measurement of current

- The majority of current measurements will be taken by using a clamp-meter, where the clamp of the meter is placed around the live wire (only) supplying the current to the component.
- When more current flows in the live wire, a stronger magnetic field will be created around that wire.
- The strength of the magnetic field is measured by the clamp part of the meter and converted in to a current reading which is then displayed by the meter.



© Amprobe



All safety measures must be taken prior to measuring current. The cables and surrounding terminals will be live. High risk activity.

The multimeter: Instrument safety

- Always ensure that the instrument is set correctly to the required function and range.
- When measuring voltage, use fused test leads.
- Exercise great care when measuring voltages greater than 50 V.
- For measuring resistance or, if using a buzzer/diode test function, the circuit or equipment under test must be de-energised.
- Do not use the instrument on voltages or currents in excess of the instrument's capability
- Instrument test leads must be in good order and fit for the purpose, as in BS EN 61010-031

Agenda Module D11 – Protection & Instrumentation

Electrical protection classes and ratings

Electrical check of appliances and systems

Instrumentation

The multi-meter

 Measuring insulation resistance

How to identify single-phase compressor electrical terminals

Measuring insulation resistance

- Insulation deteriorates over time, caused by thermal, chemical and mechanical stress.
- Deteriorating insulation is one of the main causes for faults in electrical systems.
- The insulation resistance should therefore be measured regularly.
- This is done by measuring the insulation between the active conductors and the protective conductor.
- Insulation resistance measurements can be done for specific refrigerated appliances and components such as compressors, fans, and heaters.



- Ensure no flammable refrigerants or other flammable substances are within the measuring environment.
- Inert the equipment if necessary and make sure there are no residues.
- In spaces where explosive atmospheres might occur, all conductors are measured against each other.

Measuring insulation resistance



Typical insulation resistance test meter

© Fluke

Measuring insulation resistance

- 1) Connect two leads across the insulation barrier you want to test
- 2) Apply a voltage higher than the operating voltage
- 3) Use a regulated and stabilised DC as AC could produce capacitive or inductive reactance, falsifying the measurement result
- 4) Disconnect devices that can be damaged by the measuring voltage or falsify the measurement (e.g. transformers)
- 5) Keep the whole system voltage free
- 6) If possible/necessary, switch on fuses and switches to measure the whole system in the voltage free system
- 7) Measure the flow of leakage current and calculate a resistance measurement (in mega-ohms)

Measuring insulation resistance

- By carrying out an insulation resistance test the meter pushes a higher than normal voltage in to the component under test to check if any of the voltage leaks out to earth.
- This is similar to carrying out a strength pressure test on an air conditioning system, where the system is pressurised to a higher pressure than it would normally work at, using OFDN.
- The insulation resistance shall be measured between live conductors and the protective conductor connected to the earthing arrangement.
- Where appropriate during this measurement, line and neutral conductors may be connected together.
- The insulation resistance measured with the test voltages indicated in following Table shall be considered satisfactory if the component (in refrigeration and air conditioning, this is usually the compressor) has an insulation resistance not less than the appropriate value given in the Table

Measuring insulation resistance

Circuit nominal voltage (V)	Test voltage DC (V)	Minimum insulation resistance (MΩ)
SELV (Separated extra low voltage)	250	0.5
Up to and including 500 V with the exception of the above systems	500	1.0
Above 500 V	1000	1.0

NOTE: Additional precautions, such as disconnection, may be necessary to avoid damage to electronic devices.

Agenda Module D11 - Instrumentation

Electrical protection classes and ratings

Electrical check of appliances and systems

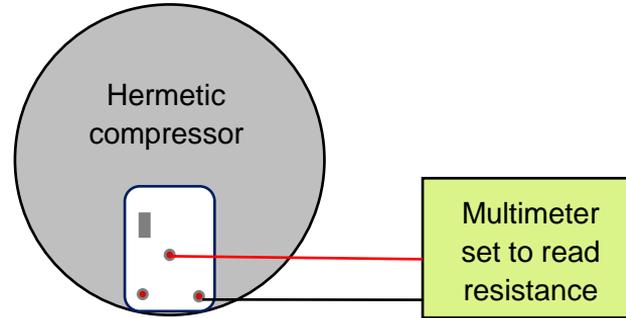
Instrumentation

The multimeter

Measuring insulation resistance

 How to identify single-phase compressor electrical terminals

How to identify single phase compressor electrical terminals



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- 1) Set the multi-meter to read resistance on the lowest ohms range,
- 2) turn the multi-meter on,
- 3) Ignoring the earth terminal, select any two of the remaining terminals and measure the resistance between them,
- 4) select a different pair of the remaining terminals and measure the resistance between them,
- 5) select the last pair of the remaining terminals and measure the resistance between them,
- 6) using the three resistance readings taken you can determine which terminal is which (see below).

How to identify single phase compressor electrical terminals

- If your first reading was between the top terminal and the bottom right terminal and the resistance reading was 5Ω .
- Then your second reading was between the top terminal and the bottom left terminal and the resistance reading was 3Ω .
- Finally your third reading was between the two bottom terminals and the resistance reading was 8Ω .
- What these results tell you is that because the first and second readings add up to give the third reading, the top terminal is the common.
- Also because the first reading was higher than the second, then the bottom right terminal is connected to the start winding.
- The reason for the start winding to produce a higher reading is that the start winding is manufactured from thinner copper wire, hence producing a higher resistance.
- Therefore the bottom left terminal is connected to the run windings.
- So the three terminals are referred to as C (common), S (start) and R (run) and normally compressor terminals are marked as such, either on the compressor or on the electrical connection cover.

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Published by:

Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn

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