# ELECTRICAL SAFETY IN THE LABORATORY

Department of Physics and Astronomy

Aarhus University

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## Introduction

Fatal accidents due to electricity occur every year in Denmark and just as many fires can be attributed to electrical installations. Most often the cause is illegal or poorly maintained installations. The aim of this guide is to help avoid accidents.

This guide cannot cover all aspects of electrical safety, therefore:

**If you have any doubts or uncertainties regarding electrical safety, please contact the electronics department. The electronics department is there to help you!**

## Definitions

### Low current (Extra-low voltage)

AC voltages below 25 V and DC voltages below 60 V are characterised as extra-low voltage (low current) and are not covered by the directives for low or high voltage; they are considered as quite harmless for normal skin contact.

AC voltage is typically used in, for example, an AC adaptor used as a charger for a mobile phone.

### Low voltage

AC voltages between 25 and 1000 VAC and DC voltages between 75 and 1500 V are covered by the European low voltage directive, for a wide range of electrical equipment, which applies for both consumer and professional usage, for items such as household appliances, cables, power supply units, laser equipment and other components such as fuses. A number of security measures apply to working in this area.

### High Voltage

High voltage is used, for example, at IFA/ISA for accelerators and as a bias for detectors in the voltage range 500 VDC to 60 kVDC.

High-voltage cables are available and are made as coaxial cables with a grounded sheath.

Free-standing high-voltage installations are surrounded by wire fences with safety cut-off switches at the access points.

## How dangerous is it?

Electric current can directly affect the human body. If a person is healthy, short-term currents must exceed 30 mA in order to be life-threatening (HPFI relays usually switch off if the residual current exceeds 30 mA).

**Electrical currents** can directly affect the human body in several ways:

*A shock can cause muscle spasms* - An alternating current can stimulate muscles and nerves. The effect of the stimulation varies from a weak tingling to violent seizures and can be life threatening if the current passes through the chest. An electric shock can cause a sustained contraction of muscles. The victim may be unable to let go of the source of the current, making the duration of the contact longer and increasing the severity of the shock.

*A shock can cause cardiac arrest* - If a current from outside the body passes through the heart, it can mask natural electrical impulses and disturb the heart's rhythm. This irregular heartbeat is called arrhythmia and can even manifest as a total disorganization of the rhythm, known as ventricular fibrillation. When ventricular fibrillation occurs, the heart stops pumping and the blood stops circulating. The victim rapidly loses consciousness and dies if a healthy heartbeat is not restored with a device called a defibrillator. The arrhythmia can occur at the time of the shock or in the hours following the electric shock.

*A shock can cause burns to tissues and organs* - A direct or alternating current can, depending on the size, frequency and duration of the current, cause burns of varying degrees. When a current above 100 mA passes through the body, it leaves marks at the points of contact with the skin. Electrical burns often affect internal organs. They are caused by the heat generated from the body's resistance to the current passing through it. Internal damage may be much more serious than the external injuries suggest.

## The effect of current

The table below shows the effect on the human body at different current levels (with contact on unbroken skin). These apply for a healthy grown-up weighing over 50 kg and an AC frequency of 50 Hz of the electricity.

| | |
|---|---|
| 100 µA | A tingling sensation on the tongue, (due to the low resistance of the mucous membrane), but not noticeable otherwise. |
| 1 mA | A tingling sensation in the hands |
| 2 - 10 mA | Unpleasant pain with muscle contractions. |
| 16 mA | Muscle contractions at a level where it is not possible to let go of items. |
| 25 - 100 mA | Pain, fainting, respiratory failure |
| 100 mA - 3A | Ventricular fibrillation, heat damage |
| over 3A | Persistent myocardial contractions replaced by normal rhythm (used for defibrillation). Tissue damage due to heating.. |

See also Wikipedia page "Electrical injury" - https://en.wikipedia.org/wiki/Electrical_injury

## Precautions

### Grounding

Electrical equipment that is encapsulated by a conductive material can, in the event of a fault in the appliance, send current from the enclosure (cabinet) and through a person who touches the conductive surface. To divert this leakage current, **the conductive part is grounded**.

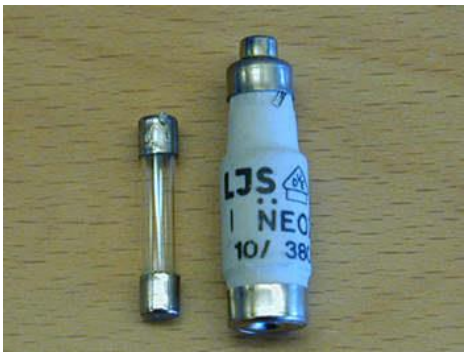
Many appliances use safety capacitors from the mains to the ground connection to protect the appliance from noise from the mains. Since a capacitor conducts alternating voltage, there will be 115 VAC on ground on an appliance where the ground connection is missing.

It is not immediately dangerous as the current is limited to under 10 mA, but can result in unpleasant pain and muscle contractions. This can lead to dangerous situations.

### Fuses

Fuses are installed to protect against excessive heat generation in an installation, or to secure appliances.

**Never change a fuse to one which has a higher current rating than that prescribed.** There is always a reason why a fuse blows.





### HPFI relay

An HPFI relay is usually placed before the standard fuses. Its purpose is to cut off the current if more than 30 mA of the current sent out finds other return paths (e.g. through a human to ground). If the conductive surface of a device is grounded through the ground pin in the wall outlet, any fault current will immediately activate the HPFI circuit breaker.

Remember that an HPFI relay must be tested at least once a year by pressing the test button, which artificially conducts a current of 30 mA around the relay. If it does not switch off, contact the electronics department.

## Electrical equipment

### Plugs

Equipment is often sold with the requirement that it **must be properly grounded**. However, they are often delivered with a 2 pin plug which does not allow connection to the earth connection in the sockets in Denmark. If it is required that a piece of equipment should be grounded, then a **3 pin plug (as pictured) must be used**.

If a plug with only 2 pins is fitted, then **it must be changed** by the electronics department. It can be dangerous to use an appliance without a correct ground connection.

### Distribution boards

In order to have sufficient 230VAC outlets, distribution boards are often used in the laboratories.

Distribution boards without an earth connection through three-pin connectors must not be used.

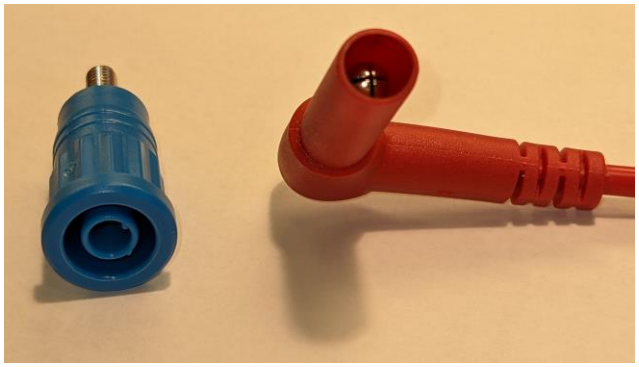
In IFA's laboratories, we prefer this model, which can be obtained by contacting the electronics department.

Distribution board used in laboratories at IFA

### Test leads

***Only use test leads where the pins cannot be touched.***

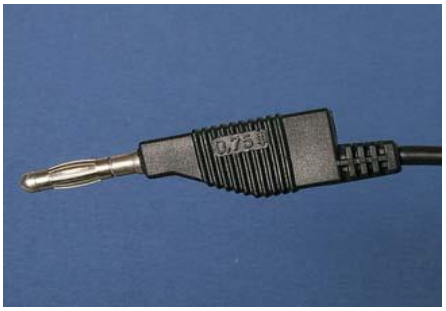
Safety plugs with fixed sheaths should preferably be used. These connectors can only be inserted into a corresponding safety socket.



Safety sleeve/bushing and plug with a fixed shield.

As these bushings are not yet mounted on all equipment, it may be necessary to use safety connectors with sliding cover during a transition phase.

Plug with a sliding cover



Banana plug

***Test leads with uncovered banana plugs must not be used.***

### Coaxial cables

Coaxial cables with a standard BNC connector, or similar, where the pins may be touched can be used with voltages up to 25 V AC or 60 V DC.

BNC plug

SHV plug

Coaxial cables for high voltage use must be fitted with connectors intended for high voltage . Contact the electronics department regarding purchase, installation and use of high voltage connectors

## Working with electrical equipment

### What can I do?

You may only work with or repair anything which comes after the electric socket (e.g. appliances).

As a general rule, anything that has to do with the fixed installation may only be altered, installed or repaired by an authorised electrician.

### Responsibility

Supply and security in delivering to the consumer: Electricity provider.

The wiring and further installations: The consumer (yourself).

***Everything after the socket is your own responsibility.***

## Laws and rules

### Directives:

**2014/35/EU** EU Council directive of the 26th February 2014 on the harmonisation of the laws of the member states relating to electrical equipment designed for use within certain voltage limits.
[https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32014L0035]
The low voltage directive. *The Danish legal basis is defined under executive order number 311 dated the 30th of March 2016*
*[In Danish: https://www.retsinformation.dk/eli/lta/2016/311]*

### Standards:

**EN 61010-1** Safety requirements for electrical equipment for measurement, control and laboratory use.

**IEC 364-4-41** Electrical installations of buildings, Protection for safety, Protection against electrical shock.

**EN 60742** Safety transformers. Contains insulation and distance requirements for low current circuits