

## Electroporation hardware safety

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*Eva Pirc*

*University of Ljubljana, Faculty of Electrical Engineering*

### Electric shock

Possible consequences of the current flow through the human body are ventricular fibrillation, cardiac asystole, respiratory arrest and burns. Voltages greater than 50 V applied across dry unbroken human skin or pulse energies above 50 J can cause ventricular fibrillation, if they produce electric currents above 30 mA in body tissues through the chest area. Frequently, the individual cannot let go of the power source due to involuntary muscle contraction. Side effects are conditioned by path of electric current, its magnitude, tissue characteristics and exposure time. The most sensitive organs to electric properties in human body are the heart and the brain. Human body is much more sensitive to mains-frequency alternating current (50/60 Hz) than to either direct current or high-frequency currents. Pain perception and muscle contraction at a given current level depend strongly on body weight and frequency. For example, 10 mA current at frequency of 50/60 Hz can result in strong muscle contraction, in a person that weighs approximately 50 kg, but sensitivity decreases with the frequency increase. The amount of voltage needed to produce same effects depends on the contact resistance between the human and the power source. When dealing with high voltages we always have to keep in mind that air breakdown voltage is about 30 kV/cm, so also a non-direct contact can be dangerous.

### GENERAL SAFETY PRECAUTIONS FOR WORKING WITH HIGH VOLTAGES

The following basic safety rules should be observed at all times in the laboratory:

1. Never work alone when dealing with high voltages. Consider having a co-worker with knowledge about equipment and risks.
2. Never leave electrical circuits/devices under high voltages when you are not present.
3. Before working with high voltage devices consider the potential risks. Do not have any contacts with conductive parts of device and keep distance from conductors under high voltage. Keep in mind that air breakdown can occur when dealing with voltages above 30 kV/cm.
4. Before high voltage circuit manipulation, switch OFF the power supply and discharge all high voltage capacitors (preferably through high voltage resistor).
5. Check if all high voltage capacitors are discharge using voltmeter.
6. Use only your right hand to manipulate high voltage electronic circuits, avoid simultaneous touching of two elements and make sure you are not grounded. Wear rubber bottom shoes or sneakers. Set up your work area away from possible grounds that you may accidentally contact.
7. When using electrolytic capacitors:
  - DO NOT put excessive voltage across them,
  - DO NOT put alternating current (AC) across them,
  - DO NOT connect them in reverse polarity.
8. Make sure all high voltage connections, tools and instruments are adequately insulated and rated for the voltage and current used.
9. If someone comes in a contact with a high voltage, immediately shut off the power. Do not attempt to move injured person in contact with a high voltage.
10. In the event of an electrical fire do not use water but special fire extinguishers used for fires caused by electric current.

11. Do not wear any jewellery or other objects that could accidentally come in contact with the conductive parts of electrical circuit.
12. Protect your ears and eyes due to possible discharge sounds and element explosions.