

Electrical Safety Information

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1 Electrical Hazards

Your body is somewhat conductive, with resistance varying depending on the points across which you measure and how well electrical contact is made. From arm to arm or arm to leg, R is between about 1 k Ω and 4 M Ω depending on whether your skin is wet or dry, contact area, etc. If your skin is punctured, R can be as low as 100 Ω .

Current thresholds (all are approximate, high frequency is different):

- 1 mA — threshold of perception
- 5 mA — noticeable shock, involuntary movement
- 6–30 mA — GFCI (see below) opens circuit within $< 200 I_t/I$ ms
- 10 mA — pain, loss of muscular control, may not be able to let go
- 30 mA — possible ventricular fibrillation
- 50 mA — probable ventricular fibrillation
- 100 mA — respiratory arrest, fibrillation, death becoming likely
- 1 A — nerve damage, burns, death likely
- 15 A — circuit breaker opens circuit

Example: US Navy 9 V battery death

Types of Electrical Hazard:

- Shock-induced ventricular fibrillation
- Respiratory arrest
- Nerve damage
- Shock-induced mechanical injury
- Burns

- Arc flash
- Arc ignition

Causes of Electrical Hazards:

- Arc conduction: ≈ 1000 V/mm
- Unintended contact (examples: drilling, downed power lines)
- Capacitive discharge
- Inductive current interruption
- Defeated interlock
- Low- V , High- I heating (example: burns from watch band)

2 What comes out of the wall?

- 120 VAC RMS, 170 V amplitude, 340 V p-p
- Most outlets rated for 15 A (14 AWG), some for 20 A (12 AWG)
- 240 VAC RMS split phase
- Much of the rest of the world is on 240 V
- Three phase
- NEMA 5-15 plug/socket — left eye (small) live
- Wire color codes:
 - black: live (think funeral)
 - green: ground
 - white: neutral
 - gray: neutral
 - red: live (split single phase, three phase)
 - blue: live (three phase)
 - brown, orange, yellow: live (alternative three phase)
- European color codes:
 - brown: live

- green/yellow stripe: ground
- blue: neutral

- **Never bet your safety on color codes!**

3 Safety Measures

- Case grounding
- Double insulation (no single-failure shock hazard, usually labeled)
- Residual current devices (GFCI)
- Hand in pocket

4 Demonstration Equipment

- Clamp meter
- Transparent clamp meter cord
- Power supply
- 2.2 Ω , 25 W resistor
- Appliance with polarized plug
- Outlet tester
- Power entry module
- Strain relief

5 Further Reading

- <http://www.cdc.gov/Niosh/injury/traumaelface.html>
- <http://www.cdc.gov/Niosh/face/stateface/ne/03ne022.html>
- <http://www.hanford.gov/rl/?page=508>

Remain conscious of electrical hazards, and never work with dangerous electricity when you are tired!