CAIRO UNIVERSITY

MEDICAL EQUIPMENT II - 2011
ELECTRICAL SAFETY OF MEDICAL DEVICES

Lecture 2

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Physiological Effects of Electricity

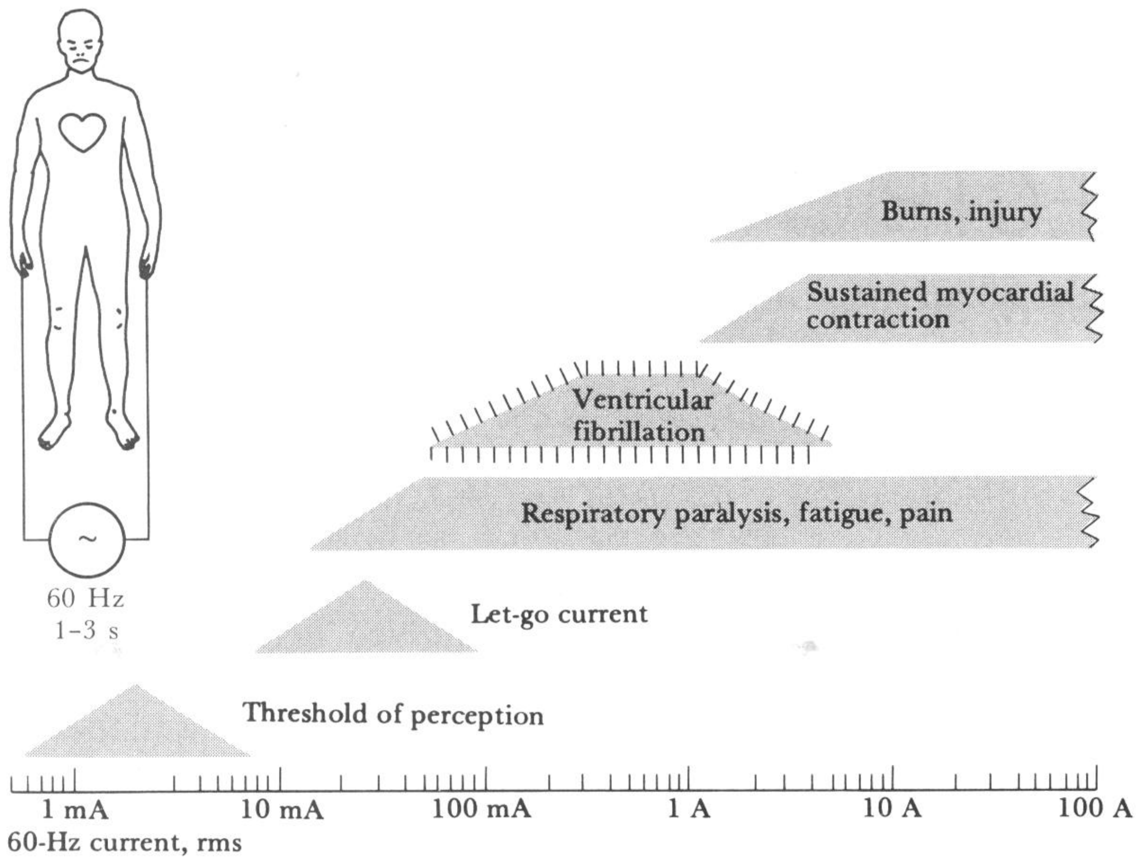


Figure 14.1 **Physiological effects of electricity** Threshold or estimated mean values are given for each effect in a 70-kg human for a 1- to 3-s exposure to 60-Hz current applied via copper wires grasped by the hands.

Variability of Threshold and Let-Go Current

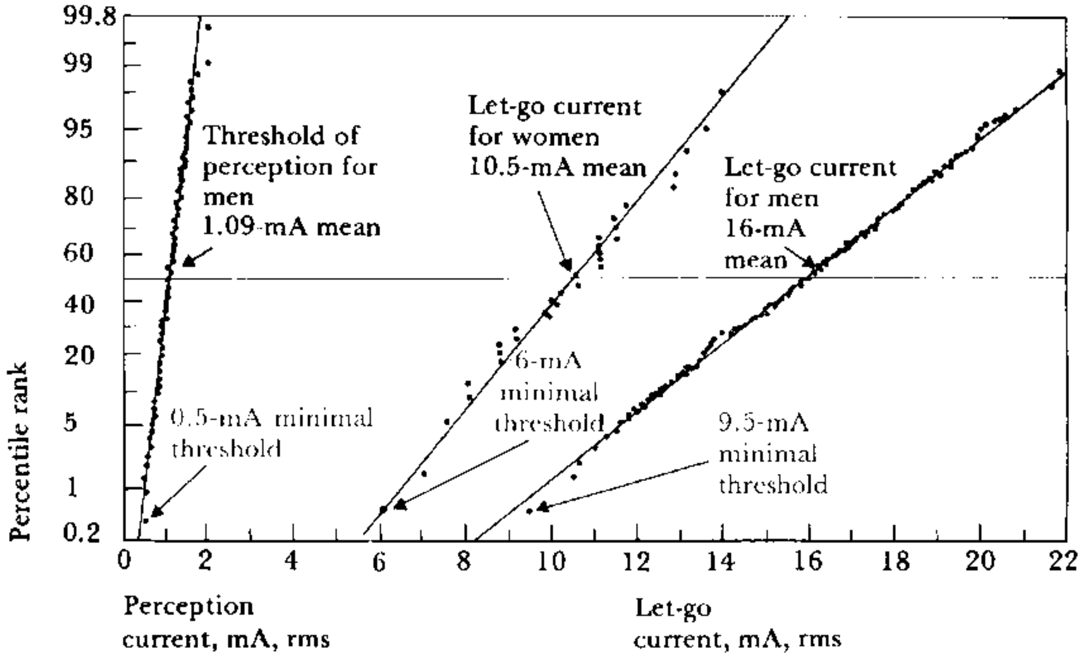


Figure 14.2 **Distributions of perception thresholds and let-go currents** These data depend on surface area of contact (moistened hand grasping AWG No. 8 copper wire). (Replotted from C. F. Dalziel, "Electric Shock," *Advances in Biomedical Engineering*, edited by J. H. U. Brown and J. F. Dickson III, 1973, 3, 223–248.)

Frequency Effect

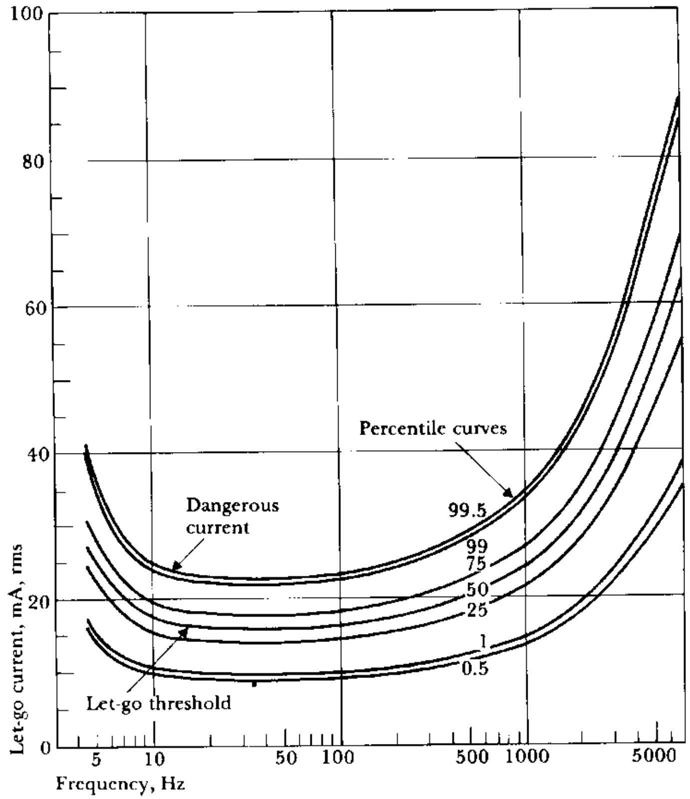


Figure 14.3 Let-go current versus frequency Percentile values indicate variability of let-go current among individuals. Let-go currents for women are about two-thirds the values for men. (Reproduced, with permission, from C. F. Dalziel, "Electric Shock," *Advances in Biomedical Engineering,* edited by J. H. U. Brown and J. F. Dickson III, 1973, 3, 223–248.)

Shock Duration Effect

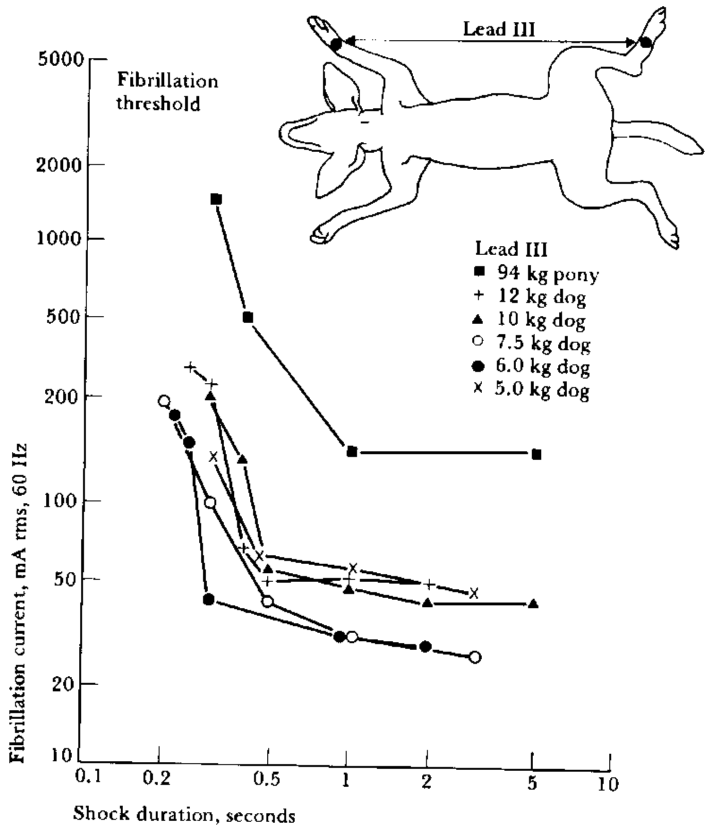


Figure 14.4 Fibrillation current versus shock duration. Thresholds for ventricular fibrillation in animals for 60-Hz ac current. Duration of current (0.2 to 5 s) and weight of animal body were varied. (From L. A. Geddes, *IEEE Trans. Biomed. Eng.*, 1973, 20, 465–468. Copyright 1973 by the Institute of Electrical and Electronics Engineers. Reproduced with permission.)

Point of Contact Effect

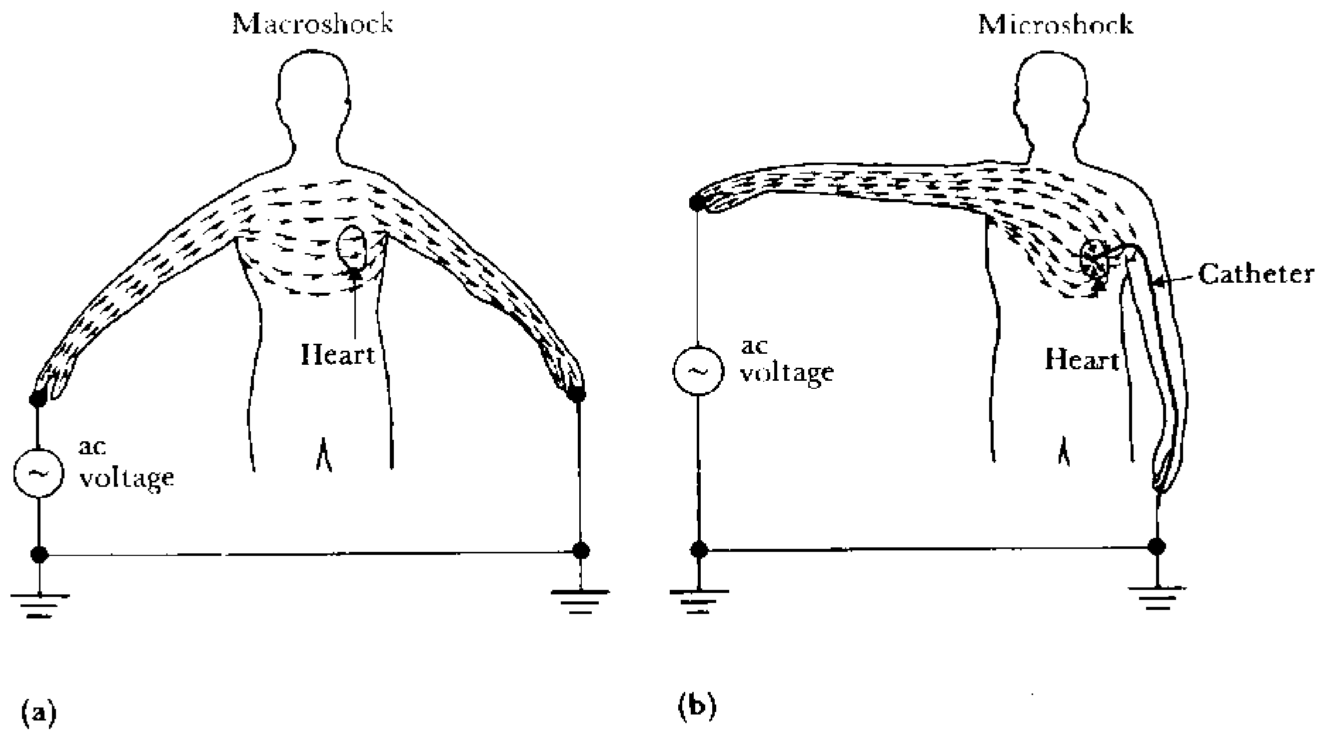
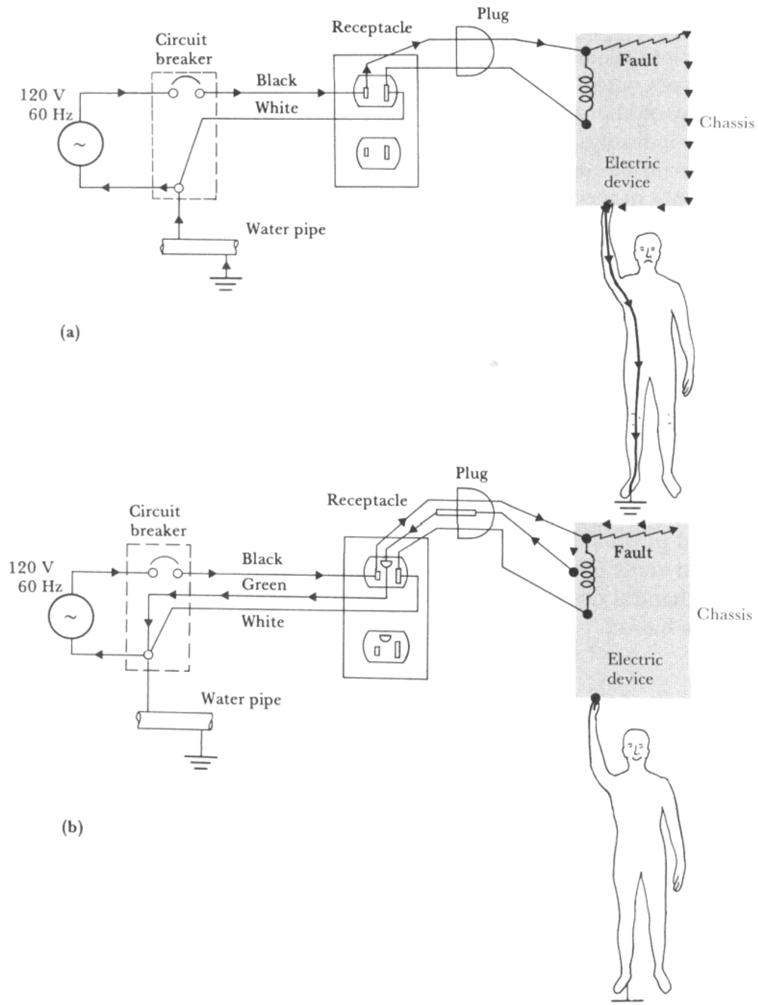


Figure 14.5 Effect of entry points on current distribution (a) *Macroshock*, externally applied current spreads throughout the body. (b) *Microshock*, all the current applied through an intracardiac catheter flows through the heart. (From F. J. Weibell, "Electrical Safety in the Hospital," *Annals of Biomedical Engineering*, 1974, 2, 126–148.)

Macrshock Hazard



gure 14.8 Macroshock due to a ground fault from hot line to equipment
ses for (a) ungrounded cases and (b) grounded chassis.

Microshock Hazard

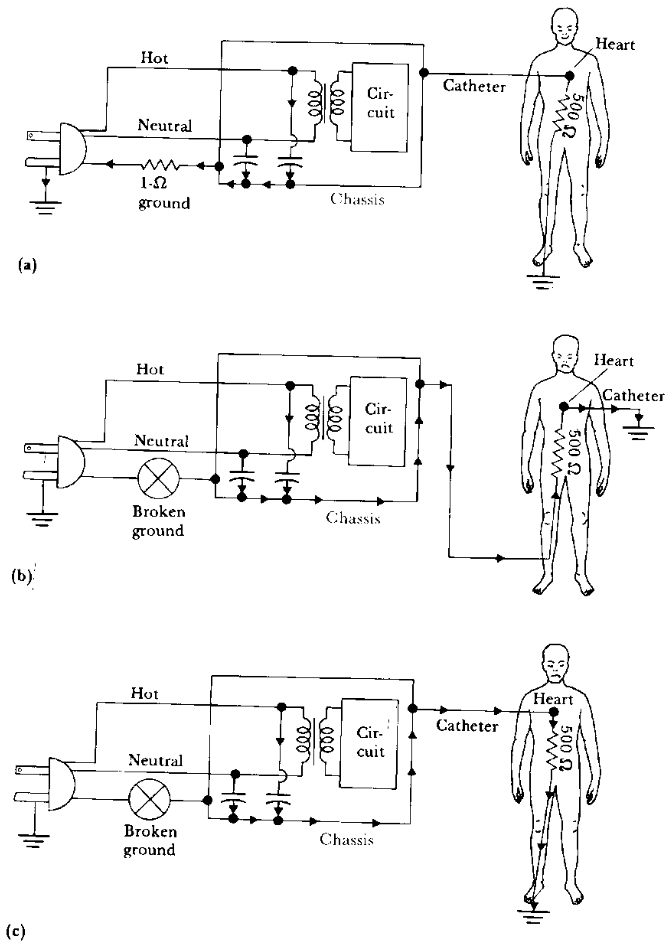


Figure 14.9 Leakage-current pathways Assume 100 μA of leakage current from the power line to the instrument chassis. (a) Intact ground, and 99.8 μA flows through the ground. (b) Broken ground, and 100 μA flows through the heart. (c) Broken ground, and 100 μA flows through the heart in the opposite direction.

Ideal Grounding System

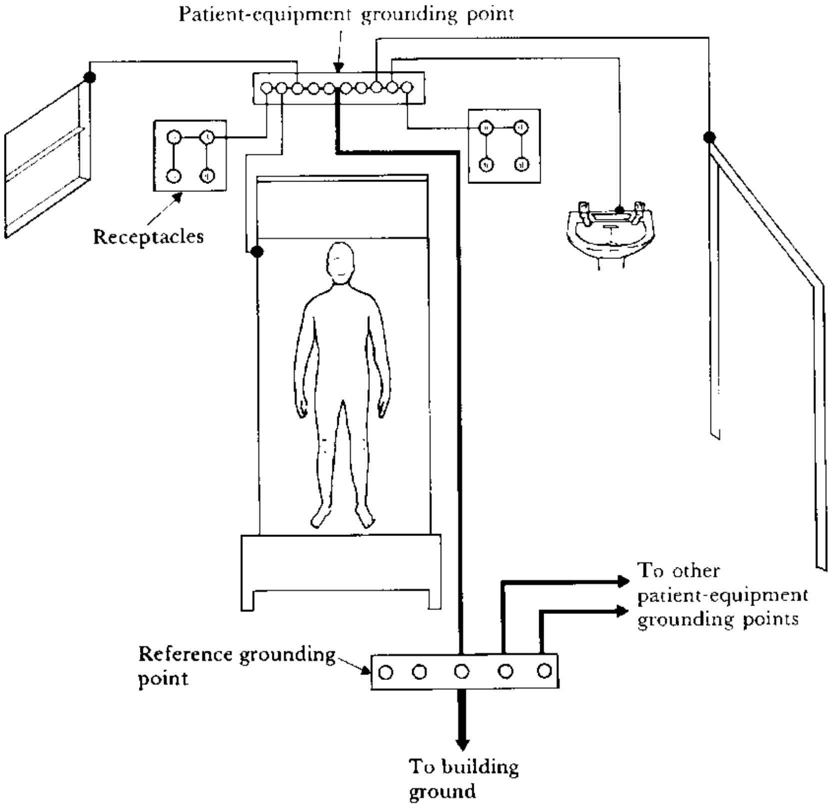


Figure 14.12 **Grounding system** All the receptacle grounds and conductive surfaces in the vicinity of the patient are connected to the patient-equipment grounding point. Each patient-equipment grounding point is connected to the reference grounding point that makes a single connection to the building ground.

Electrical Safety in Design

- Reliable grounding
- Reduction of leakage current
- Double insulated equipment
- Low voltage operation
- Electrical Isolation
  - Break Ohmic continuity of electric signals between input and output

Example Isolation Circuits

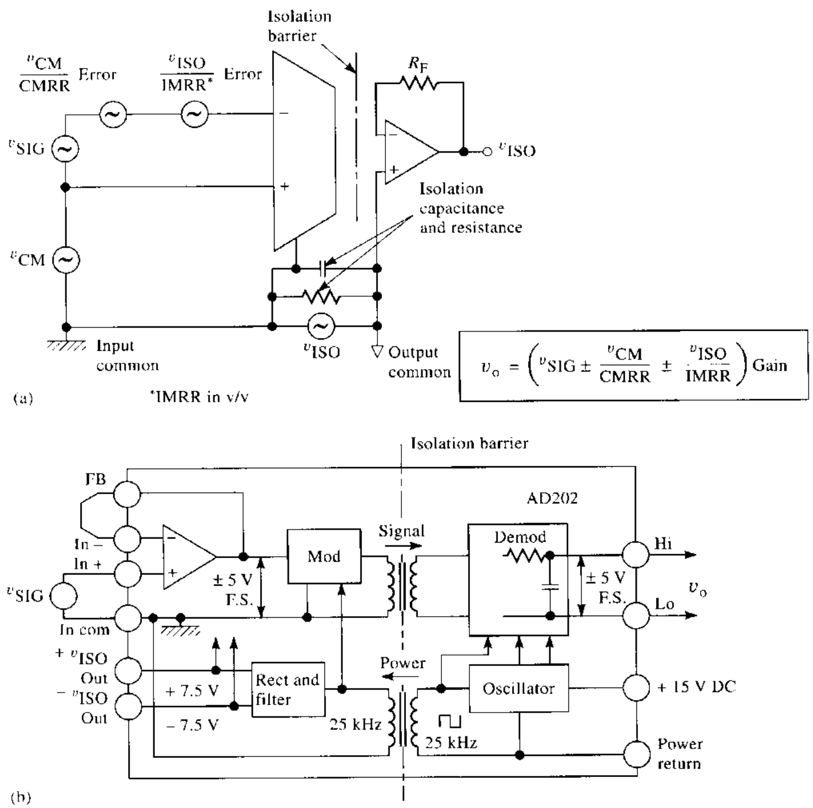


Figure 14.14 Electrical isolation of patient leads to biopotential amplifiers (a) General model for an isolation amplifier. (b) Transformer isolation amplifier (Courtesy of Analog Devices, Inc., AD202). (c) Simplified equivalent circuit for an optical isolator (Copyright © 1989 Burr-Brown Corporation. Reprinted in whole or in part, with the permission of Burr-Brown Corporation. Burr Brown ISO100). (d) Capacitively coupled isolation amplifier (Horowitz and Hill, Art of Electronics, Cambridge Univ. Press, Burr Brown ISO106).

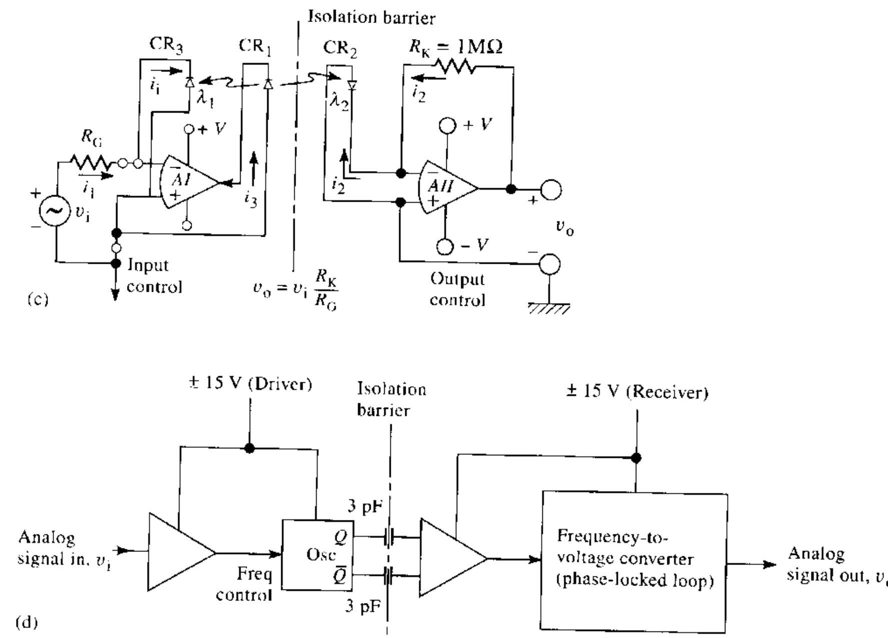


Figure 14.14 *(Continued)*

DC Shock Defibrillator

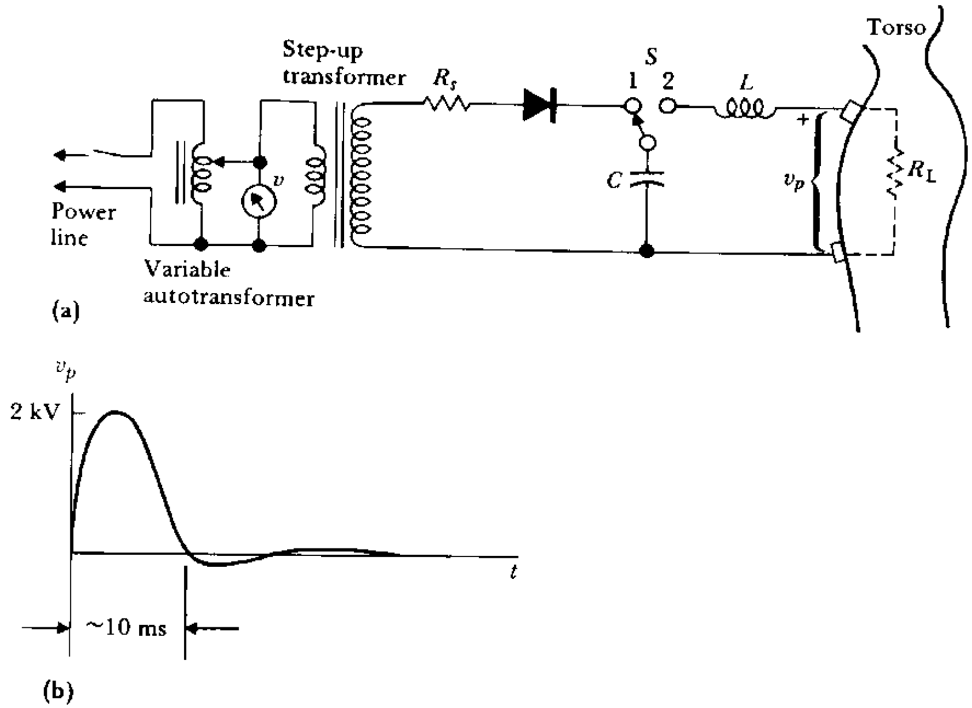


Figure 13.9 (a) Basic circuit diagram for a capacitive-discharge type of cardiac defibrillator. (b) A typical waveform of the discharge pulse. The actual waveshape is strongly dependent on the values of L, C, and the torso resistance R_L.

Cardioverter

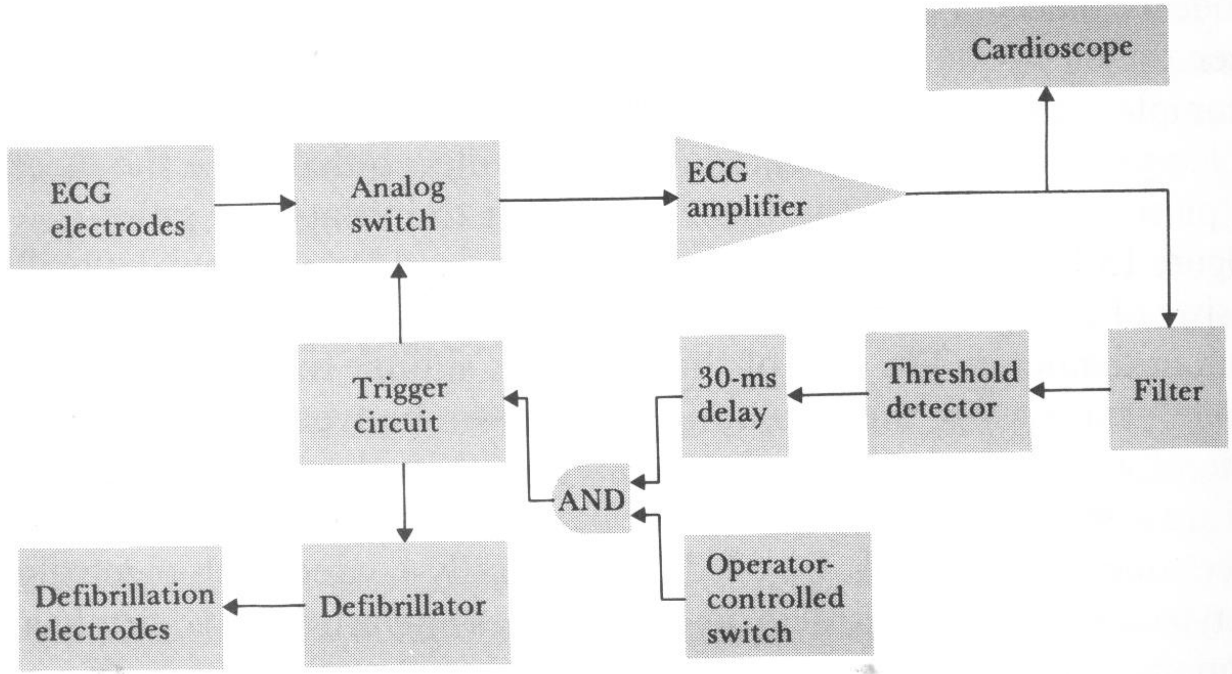
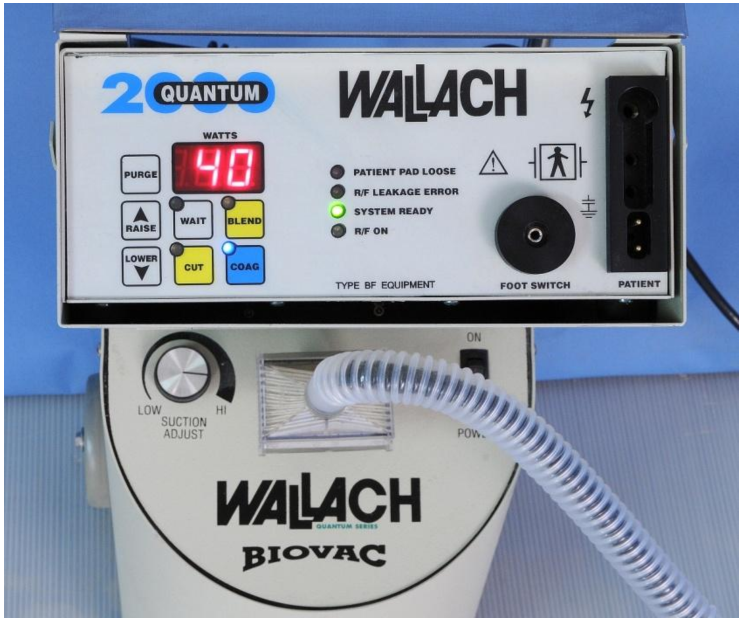


Figure 13.11 A cardioverter The defibrillation pulse in this case must be synchronized with the R wave of the ECG so that it is applied to a patient shortly after the occurrence of the R wave.

Electrosurgical Unit

- In principle, electrosurgery is based on the rapid resistive heating of tissue
  - Monoploar or bipolar modes



Effects of Heat on Tissues

- Up to to 45°C: Reversible cytochemical changes occur
- Above 45°C: Irreversible changes leading to cell death
  - Between 45°C and 60°C: Coagulation
  - Between 60°C and 100°C: Desiccation
  - Beyond 100°C: Carbonization
- Tissue damage depends not only on temperature but also on length of exposure to heat

Term Definitions

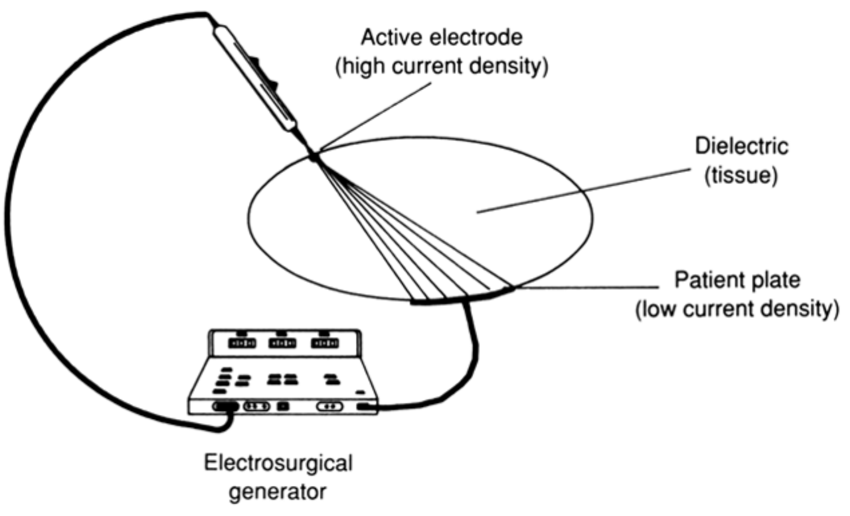
- Active electrode
  - Electrode used for achieving desired surgical effect.
- Coagulation
  - Solidification of proteins accompanied by tissue whitening.
- Desiccation
  - Drying of tissue due to the evaporation of intracellular fluids.
- Dispersive electrode
  - Return electrode at which no electrosurgical effect is intended.
- Fulguration /Spray
  - Random discharge of sparks between active electrode and tissue surface in order to achieve coagulation and/or desiccation.

Monopolar Mode

- In the monopolar mode, electrode either touches tissue or is held a few mm above it
  - Direct current or electric discharge arc
  - Temperature rise from Bioheat equation

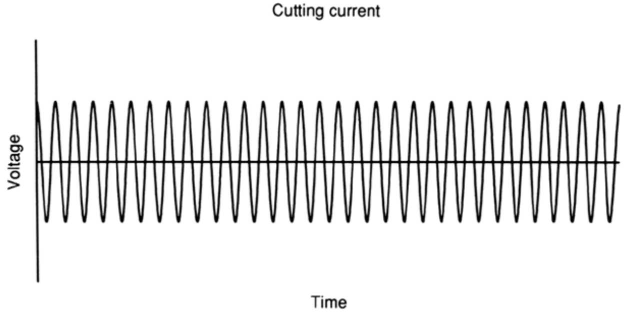
$$T - T_o = \frac{1}{\sigma \rho c} J^2 t$$

  - Control of heating using *J*, *A*, and *t*



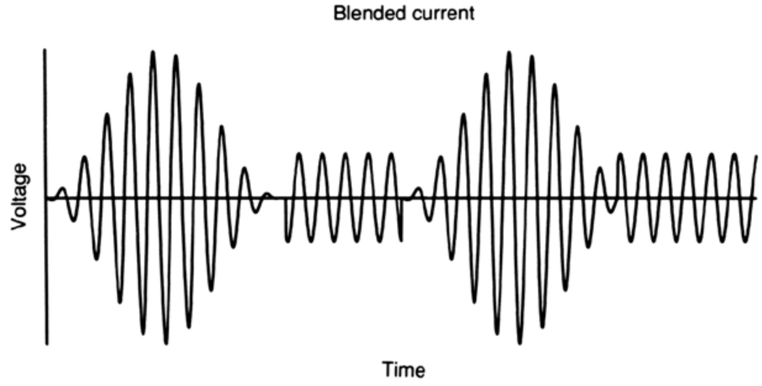
Cutting Mode

- A continuous sinusoidal waveform cuts tissue with very little hemostasis.
  - This waveform is simply called *cut* or *pure cut*.
- Electric current concentrates at one spot
  - Sudden increase in temperature at this location
  - Rapid rise in temperature then vaporizes intracellular fluids, increases cell pressure, and ruptures cell membrane, thereby parting tissue.



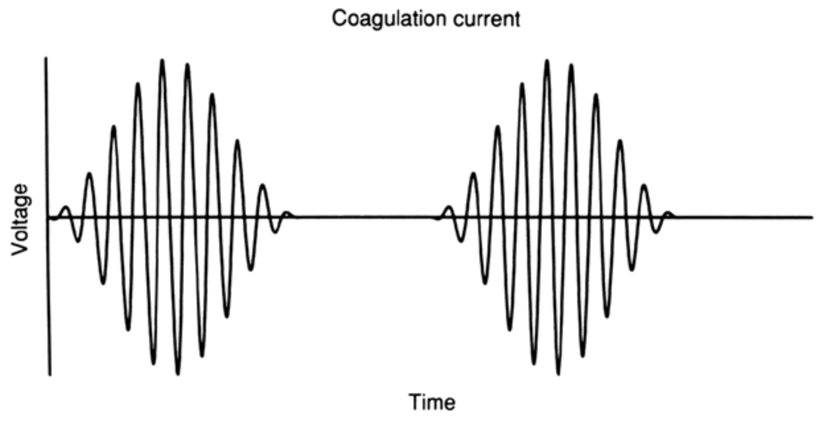
Blended Cutting Mode

- More hemostasis is achieved when cutting with an interrupted sinusoidal waveform or amplitude modulated continuous waveform.
  - Typically called *blend* or *blended cut*.
- Some ESUs offer a choice of blend waveforms to allow the surgeon to select degree of hemostasis desired.



Coagulation Mode

- When a continuous or interrupted waveform is used in contact with the tissue and output voltage current density is too low to sustain arcing, desiccation of the tissue will occur.
  - Distinct mode called *desiccation* or *contact coagulation.*



Spray Mode

- While a continuous waveform reestablishes arc at essentially same tissue location concentrating the heat there, an interrupted waveform causes arc to reestablish itself at different tissue locations.
  - Arc seems to dance from one location to another raising the temperature of the top tissue layer to coagulation levels.
  - Called *fulguration* or *spray* mode

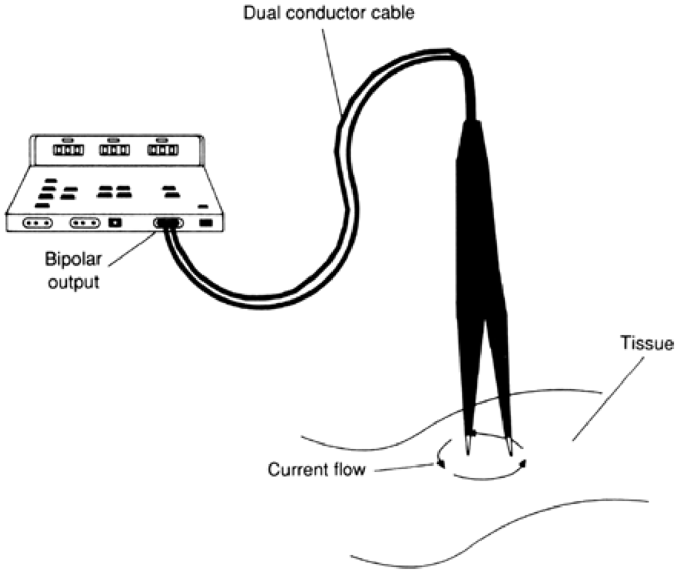
ESU Output Characteristics

TABLE 81.3 Typical Output Characteristics of ESUs

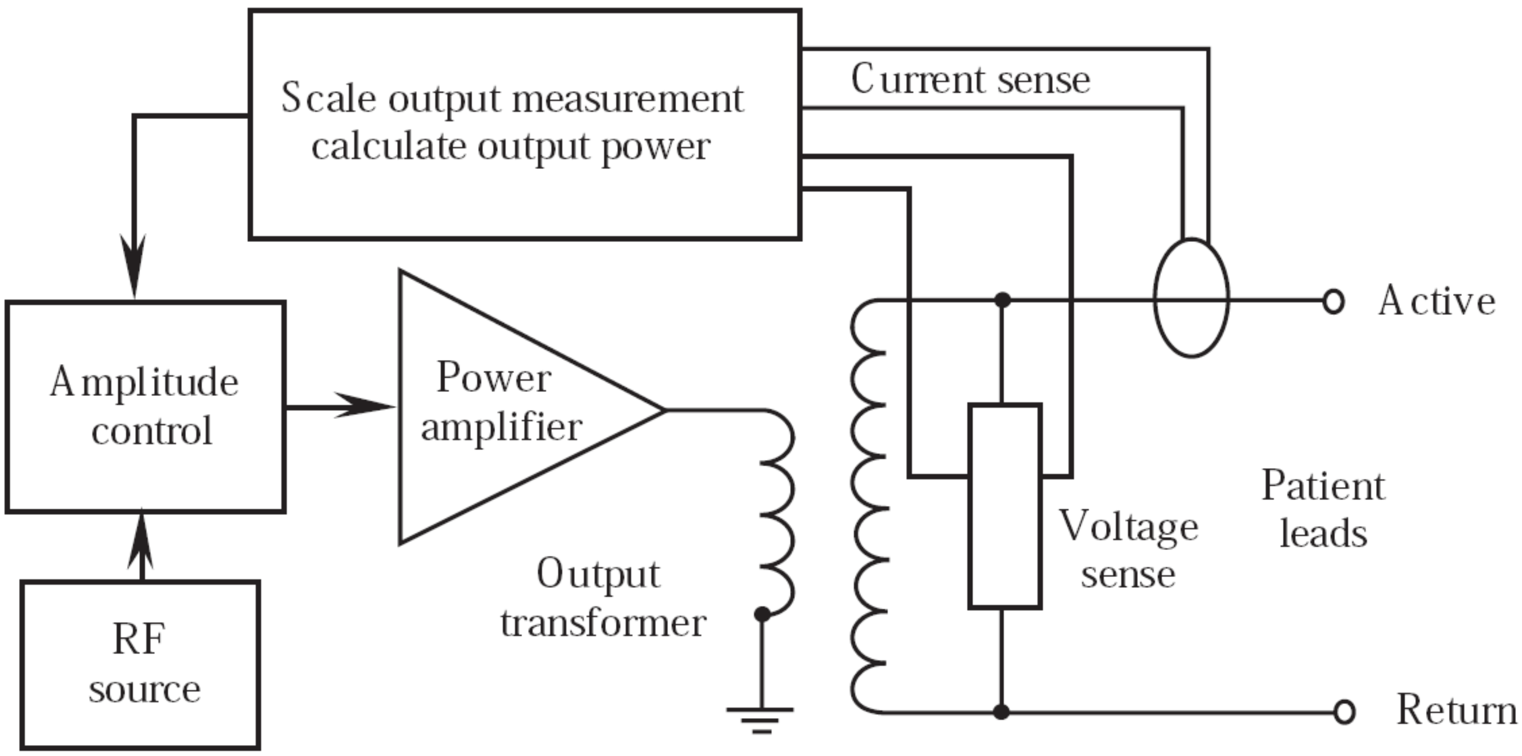
	Output Voltage Range Open Circuit, $V_{peak\text{-}peak}$, V	Output Power Range, W	Frequency, kHz	Crest Factor $\left(\frac{V_{peak}}{V_{rms}}\right)$	Duty Cycle
Monopolar modes					
Cut	200–5000	1–400	300–1750	1.4–2.1	100%
Blend	1500–5800	1–300	300–1750	2.1–6.0	25–80%
Desiccate	400–6500	1–200	240–800	3.5–6.0	50–100%
Fulgurate/spray	6000–12000	1–200	300–800	6.0–20.0	10–70%
Bipolar mode					
Coagulate/desiccate	200–1000	1–70	300–1050	1.6–12.0	25–100%

Bipolar Mode

- Bipolar mode concentrates current flow between the two electrodes
  - Requiring considerably less power for achieving the same coagulation effect than the monopolar mode



ESU Design


Scale output measurement
calculate output power
Current sense
Amplitude
control
Power
amplifier
Active
Patient
leads
Voltage
sense
Output
transformer
RF
source
Return

ESU Hazards

- Electric shock
- Undesired burns
- Undesired neuromuscular stimulation
- Interference with pacemakers or other devices, implant heating

Covered Material

- Parts of chapters 13 & 14 of Webster's Medical Instrumentation textbook.