EE 4BD4 Lecture 23

Electrical Safety II

Isolated Power for Critical Care Areas to Avoid Ground Pathways

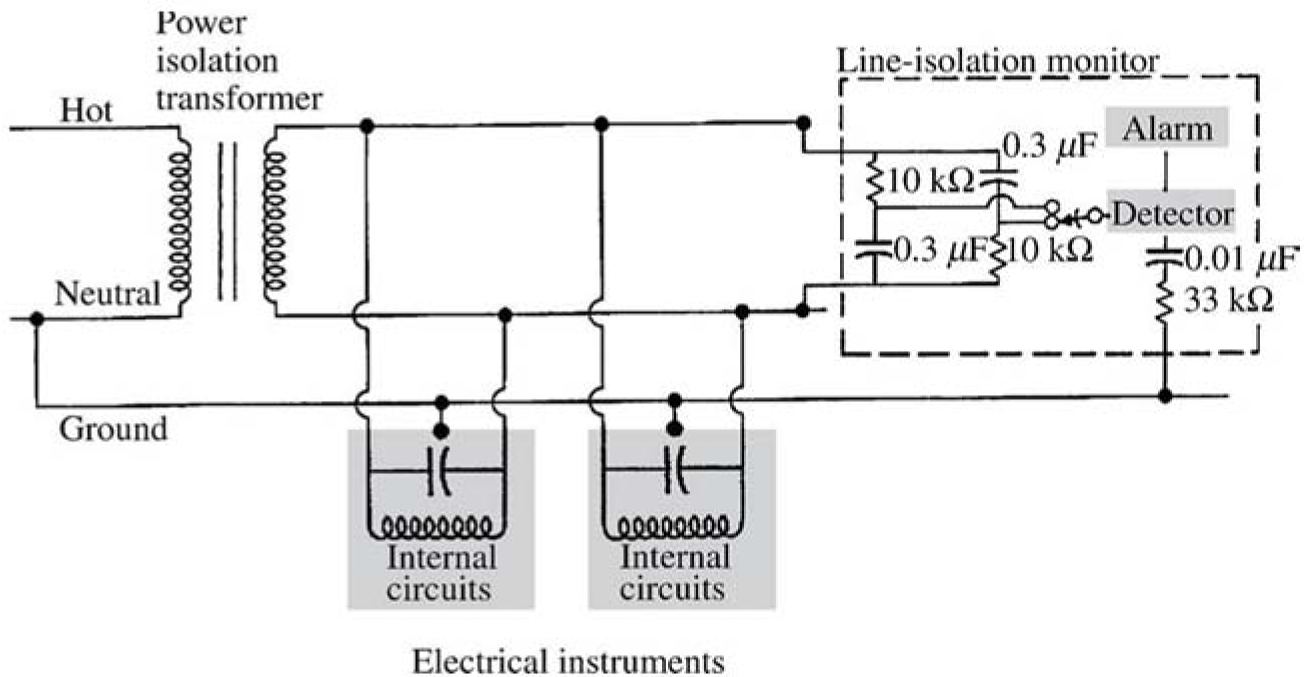


Figure 14.9 Power-isolation-transformer system with a line-isolation monitor to detect ground faults.

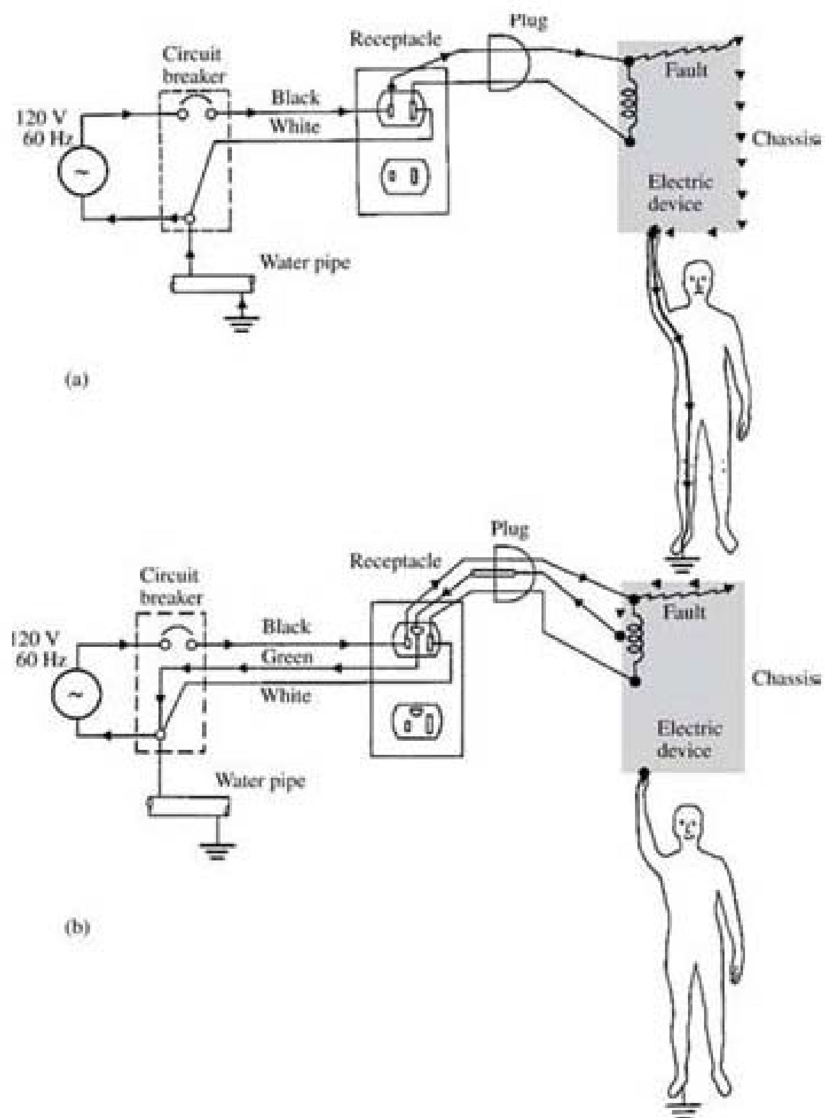
Isolated Power Systems

- First put into place in operating rooms where flammable anesthetics were used (to avoid sparks from powered equipment to ground)
- Alternate was to use non-conductive flooring which had to be periodically tested
- Modern limit on isolation leakage current (from either power line to ground during normal operation) is 3.5 to 5 ma

Macroshock Hazards

- Occur when equipment breaks down and the black (hot wire) touches equipment case or other conductive pathway current flows through subject to ground but not enough to trip circuit breaker or breaker doesn't trip in time
- Grounded circuits (case grounded) provides an almost direct short to ground which will trip breaker but not necessarily in time

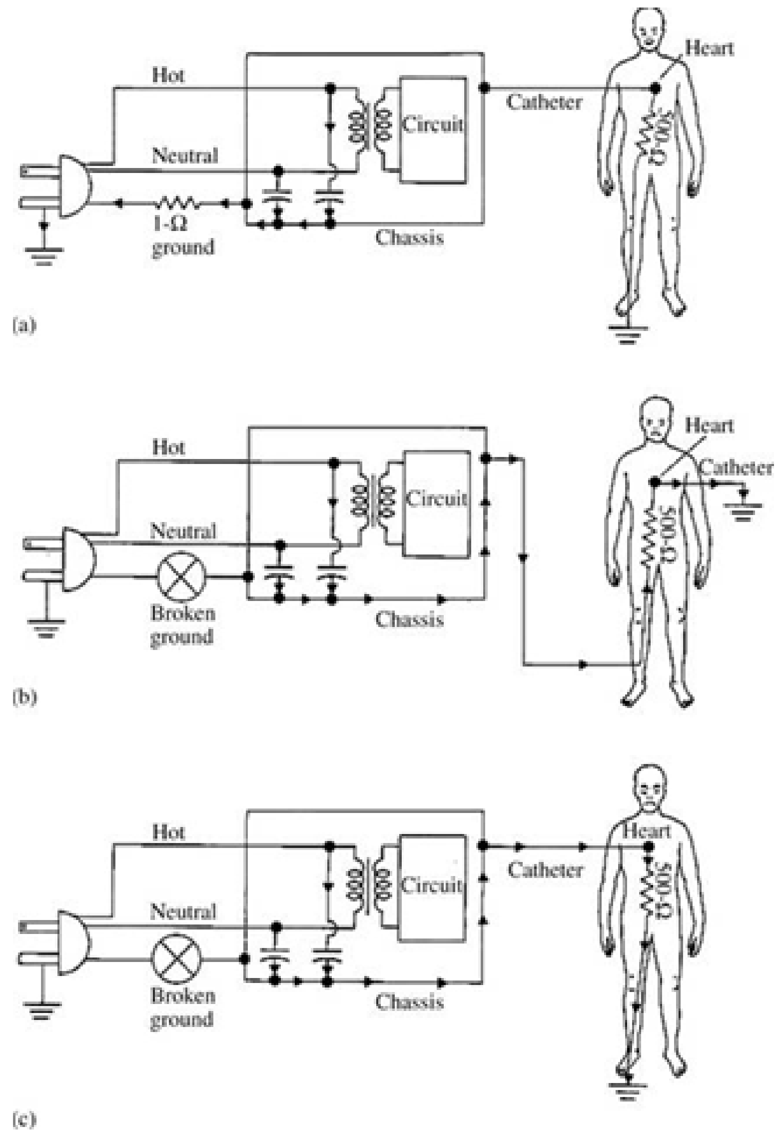
Figure 14.10 Macroshock due to a ground fault from hot line to equipment cases for (a) ungrounded cases and (b) grounded chassis.



Microshock Hazards

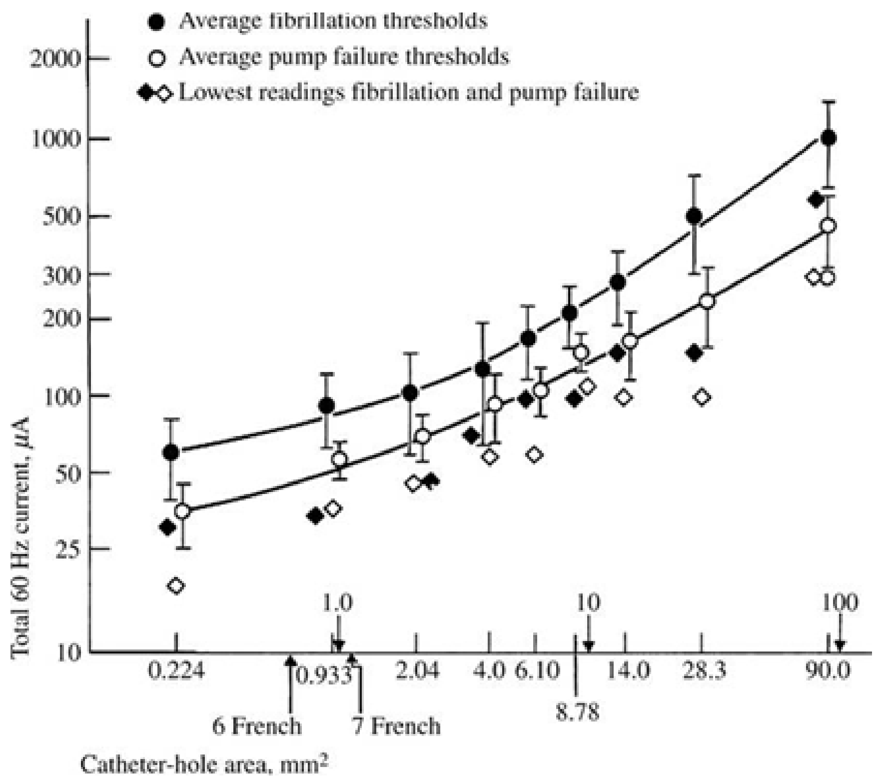
- Leakage currents are small currents (usually μA) that flow between insulated current carrying conductors during normal operation
- Due to virtual or stray capacitance between conductors with AC currents
- Also could be due to resistive pathways established by moisture, dust or insufficient insulation
- Especially dangerous when there are patient applied parts

Figure 14.11 Microshock 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.



Effect of Current Density

- Catheter (or electrode) contact area determines current density J (occurrence of ventricular fibrillation is a function of J not I



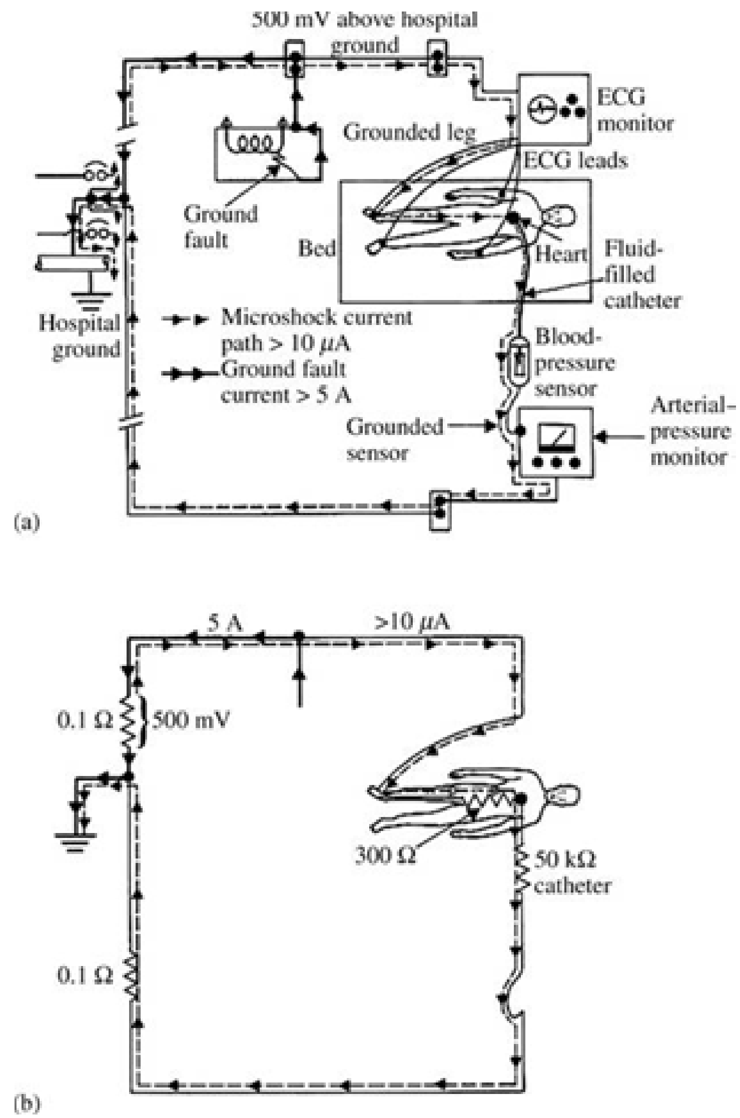
Sources of Patient Leakage Currents

- All electrodes (and sensors with inputs to amplifiers) have leakage currents
- Any indwelling electrodes with pathways to or location close to heart are especially dangerous (epicardial or endocardial electrodes from an external cardiac pacemaker)
- Liquid filled catheters for blood pressure, sampling or delivery of drugs (volumetric pumps which are line powered)
- Danger really only occurs when there is electrical connection to the heart

What if We Didn't have Modern Standards?

- Patient in ICU with right leg electrode grounded to avoid noise and left ventricle pressure conductive diaphragm also grounded (unrealistic scenario)
- A defective floor polisher plugged into the ECG Power supply injects 5 A into the groundwire (in a modern system the circuits would be entirely different)
- With 0.1 Ω resistance in ground wire 500 mV is added to ground on ECG side
- Patient's body, ECG electrode, and catheter are < 50 kΩ causing >10 μA through heart

Figure 14.13 (a) Large ground-fault current raises the potential of *one* ground connection to the patient. The microshock current can then flow out through a catheter connected to a different ground, (b) Equivalent circuit. Only power-system grounds are shown.



Standards and Codes

- A code is a document that contains only mandatory requirements that can be put into law by an authority that has jurisdiction
- A standard also contains mandatory requirements but compliance is voluntary and more detailed notes and explanations are given
- Development of standards was hotly debated in the US but adopted more readily in Canada (e.g. first standards were not practical when trying to limit leakage currents)
- Current US standard is NFPA 99 – Standard for Health Care Facilities 2005 and ANSI/AAMI 1993 Safe Current Limits for Electro-medical Apparatus
- Health Canada Medical Devices Branch recognizes some ANSI/AAMI standards, CSA 22.2 601 (R2006) and 60601 general requirements for basic safety and essential performance
- International Electro-technical Commission set IEC 60601 -1 (latest 2006) general requirements for basic safety and essential performance
- Now accepted by almost all jurisdictions

Current Limits

- A single fault can be the ground lead broken
- Equipment is divided into categories of casual contact, patient applied parts, and cardiac applied parts

Table 14.1 Limits on Leakage Current for Electric Appliances

Electric Appliance	Chassis Leakage, μA	Patient-Lead Leakage, μA
Appliances not intended to contact patients	100	Not applicable
Appliances not intended to contact patients and single fault	500	Not applicable
Appliances with *nonisolated* patient leads	100	10
Appliances with *nonisolated* leads and single fault	300	100
Appliances with *isolated* patient leads	100	10
Appliances with *isolated* leads and single fault	300	50

Use of Electricity in Patient Care Areas

- The entire patient, ER or Operating room is not a patient care area
- Patient care area is an envelope around the patient and equipment so that a staff, visitor or patient cannot touch another conductive surface while in that envelope
- Single point grounding system for each patient area
- Use of isolated power in critical care areas

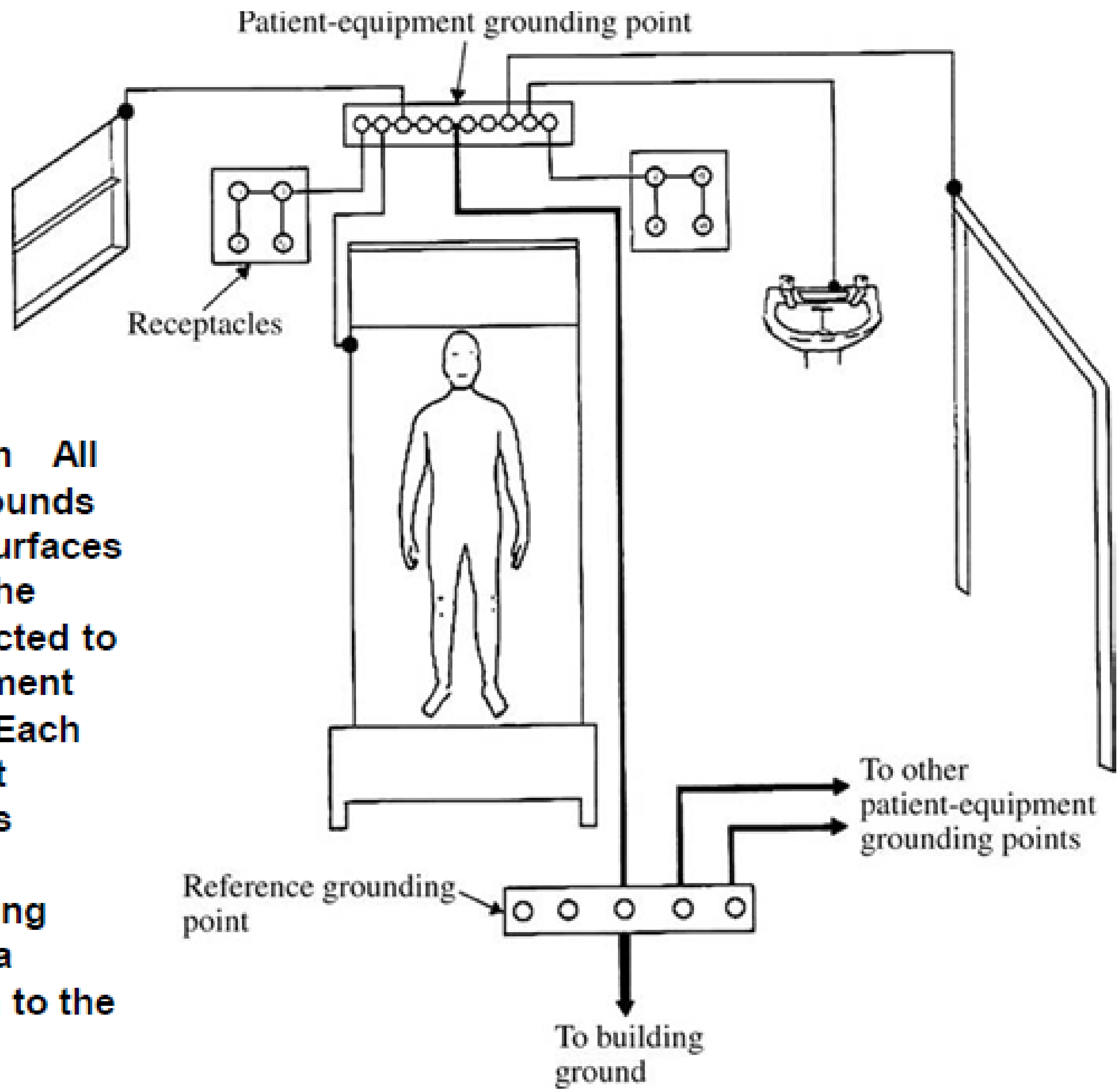


Figure 14.14
Grounding system All the receptacle grounds and conductive surfaces in the vicinity of the patient are connected to the patient-equipment grounding point. Each patient-equipment grounding point is connected to the reference grounding point that makes a single connection to the building ground.

Ground-Fault Circuit Interrupters (GFCI)

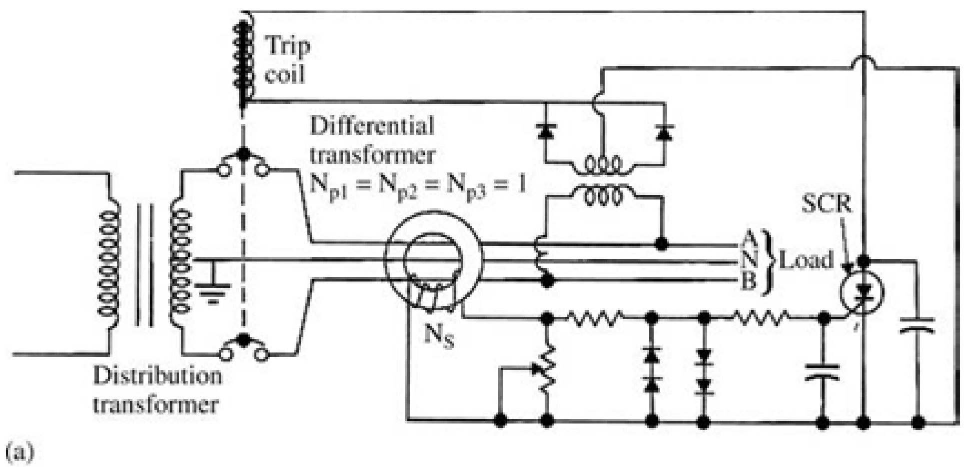
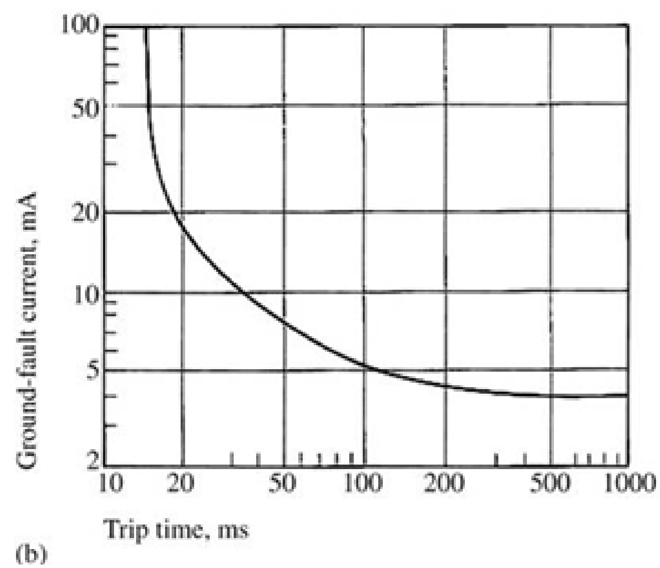


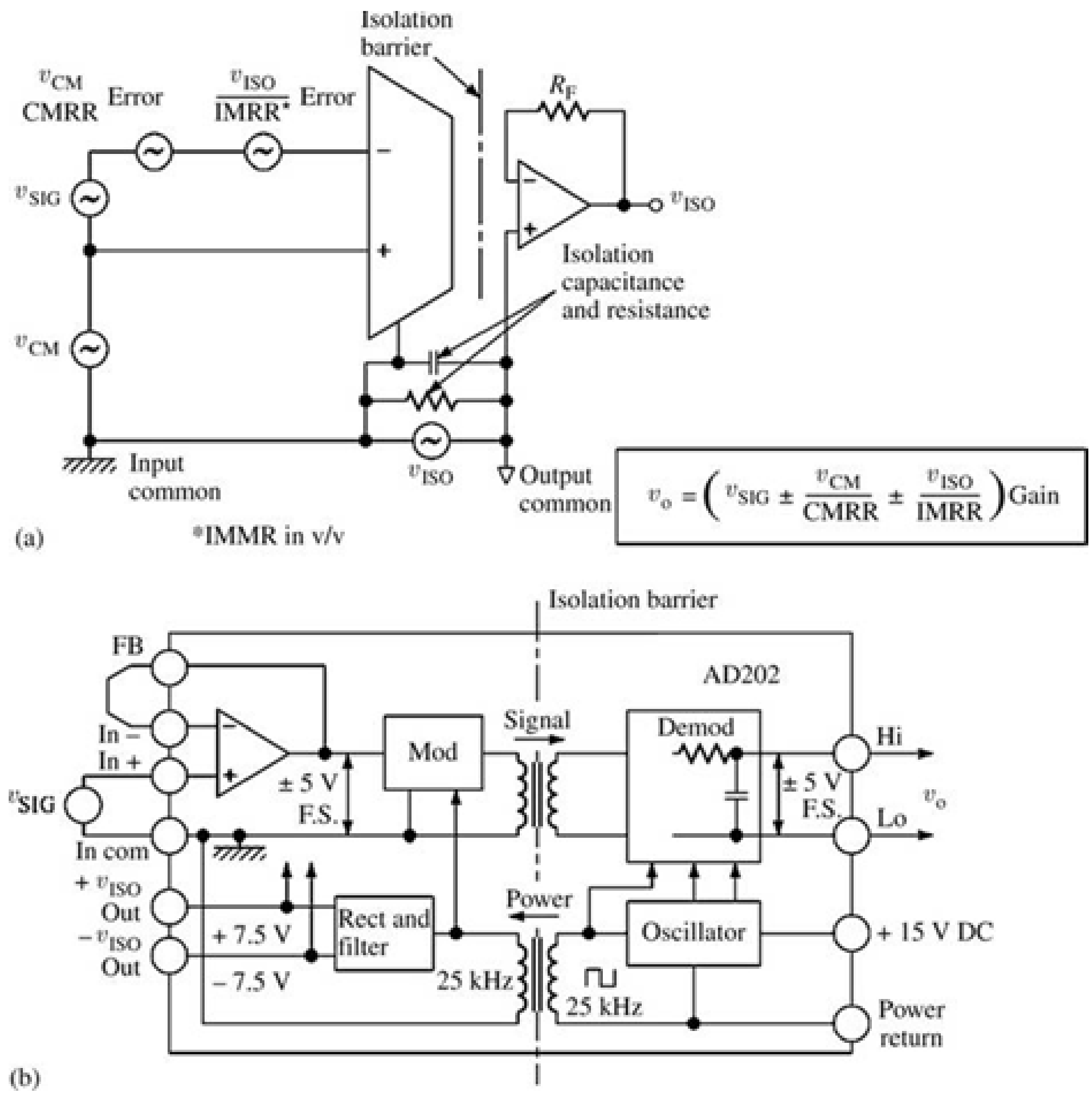
Figure 14.15 Ground-fault circuit interrupters (a) Schematic diagram of a solid-state GFCI (three wire, two pole, 6 mA). (b) Ground-fault current versus trip time for a GFCI. [Part (a) is from C. F. Dalziel, "Electric Shock," in *Advances in Biomedical Engineering*, edited by J. H. U. Brown and J. F. Dickson III, 1973, 3: 223–248.]

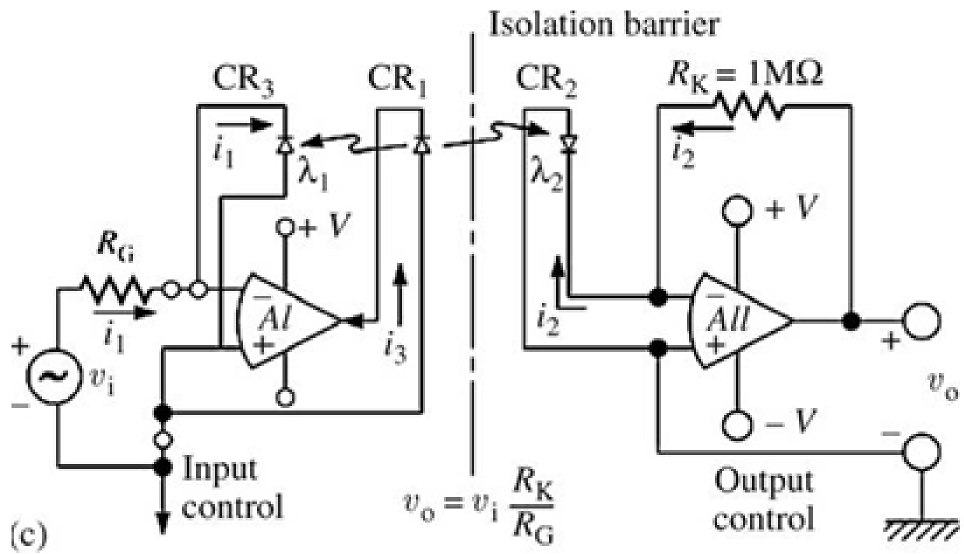


Other Methods of Reducing Leakage

- Double Insulation so no conductive part can be touched by patent or staff
- These are your 2-prong plug devices (electric toothbrushes, hairdryers, domestic and professional equipment)
- Low voltage devices (battery or ac source) have a separate standard
- Isolated equipment or patient applied parts

Figure 14.16 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).





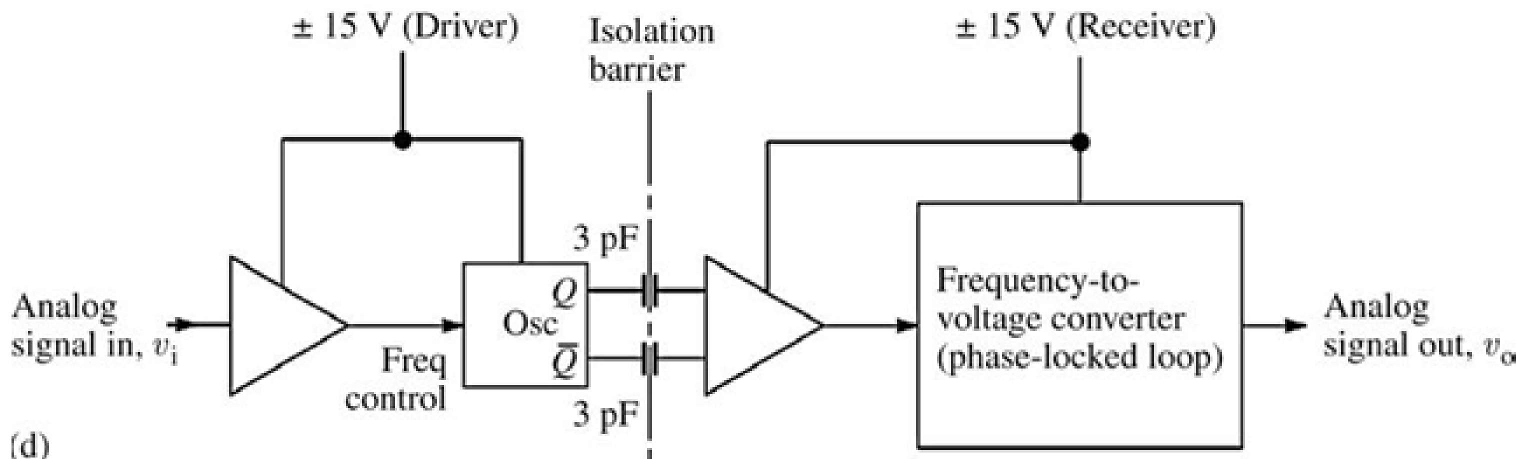


Figure 14.16 ***(Continued)***

Isolation Amplifiers

- In previous slide grounds on input and output are different
- v_{ISO} is the isolation voltage that can exist between input and output grounds (1 to 10 kV without breakdown)
- IMRR is isolation- mode rejection ratio is specified for the amplifier