

Leakage and Ground Currents: Measurement Techniques



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Oct 27, 2005

Ground Currents

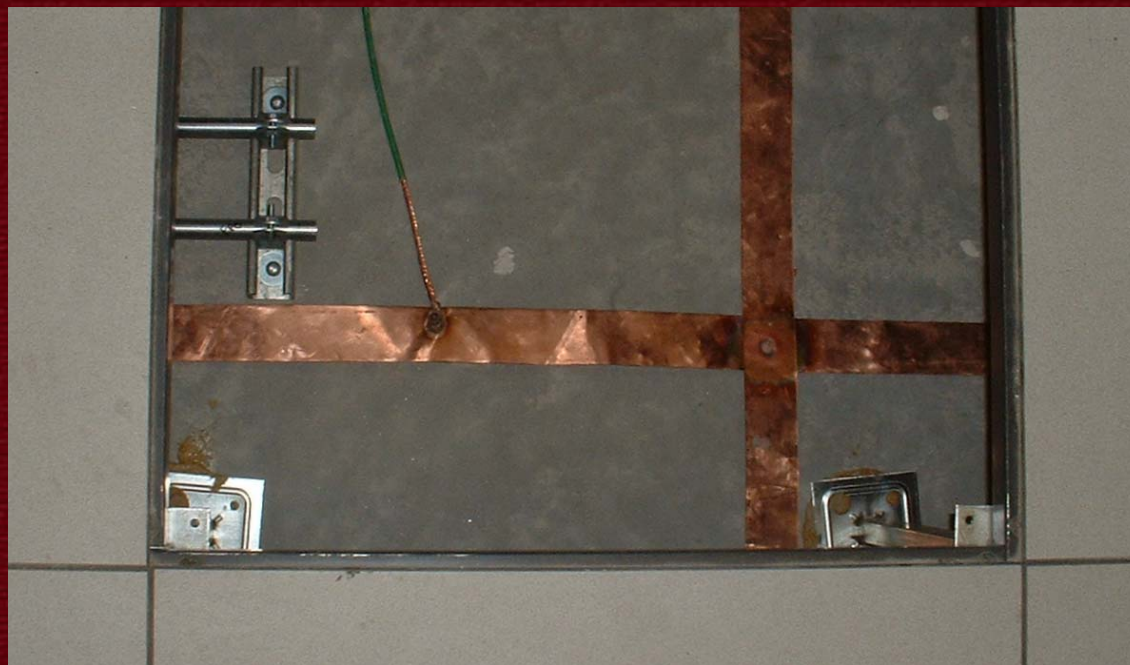
- ❖ Hot Button Issue
- ❖ High Visibility
- ❖ Quantifiable / Measurable
- ❖ Direct Cause of Problems
 - Magnetic Fields
 - Safety / Leakage Currents
- ❖ Symptom / Indicator
 - Ground Loops
 - Wiring Errors
 - Bonding



Scope

I'm **not** talking about Grounding

I **am** talking about Measurement



(We might sneak some Grounding in, however)

Low Level Currents

❖ Ground Currents

- Safety grounds, reference grounds, shields
- Raceways, chassis, conduits, structure
- Wiring errors, leakage currents, signal currents

❖ Leakage Currents

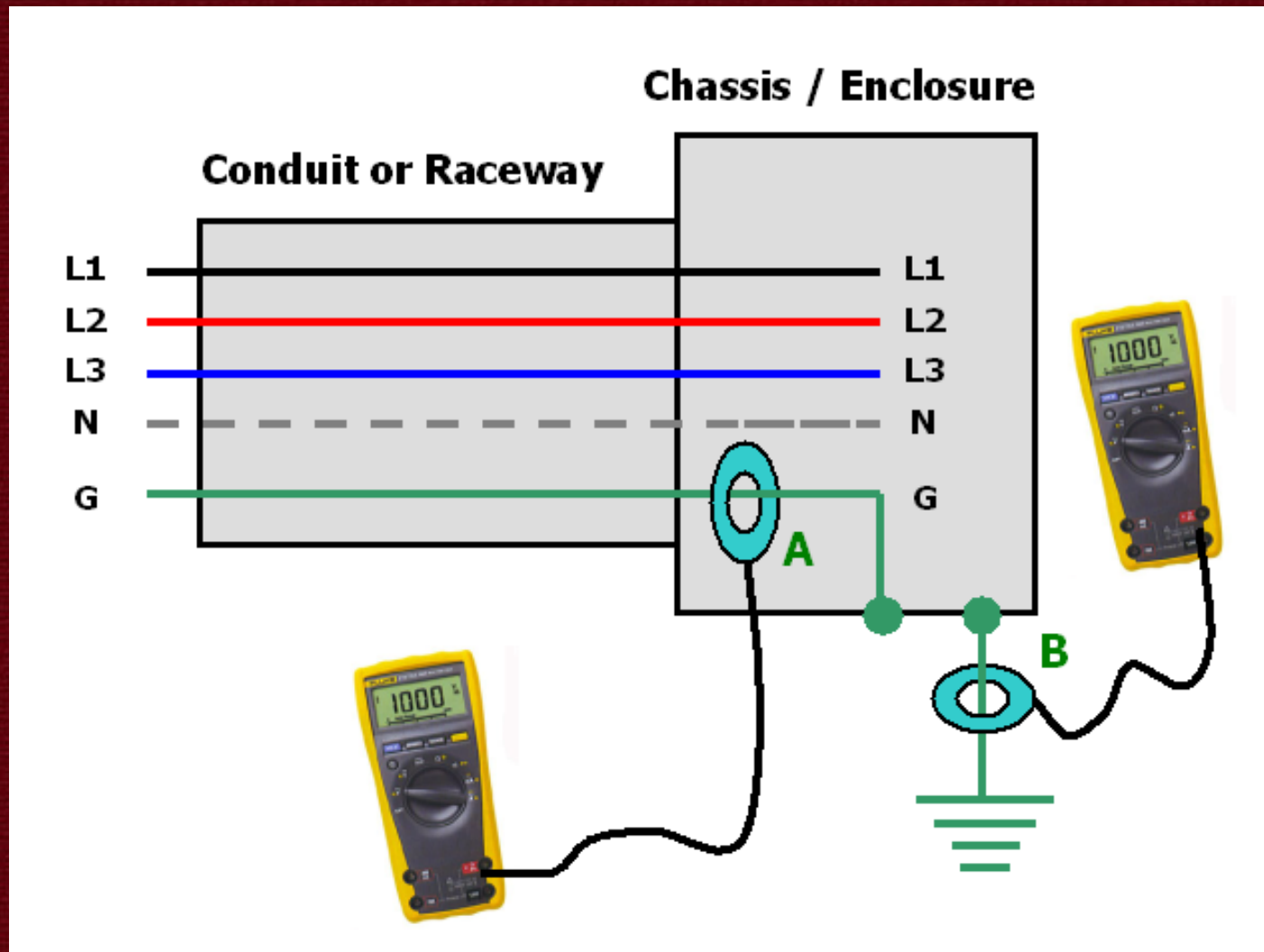
- 3 Phase + Neutral \neq 0 Amps
- Normal: Filters / Capacitance
- Abnormal: Wiring Errors

❖ Net Currents

- Non-Zero Summary Current
- 3 Phase + Neutral + Ground \neq 0 Amps

Ground Currents

Ground Currents



Ground Loops

❖ Deliberate Parallel Ground Paths

- Ground rods
- Redundant grounds

❖ Raceway or Conduit

❖ Mechanical Mounting of Equipment

❖ System Interconnect Wiring

- Shields
- Signal Commons
- Distributed Power

*Ground loops complicate
ground current measurements*

Grounding for Power Quality

- ❖ Insulated fittings (raceway or conduit)
- ❖ Full-sized / Over-sized Ground Conductors
- ❖ Isolated Ground Receptacles
- ❖ Separate, Dedicated Ground Conductor
- ❖ Bonding Jumpers to Signal Reference Grid
- ❖ Interrupting Ground Loops
- ❖ Supplemental Ground Connections to Structure or Electrodes

Show me you did something !

Prove to me that things have been improved !

Wiring Errors

❖ Improper connections of Neutrals & Grounds

- Circuit Breakers
- Surge Suppressors
- UPS Systems

❖ Use of Ground as Return

- Control Systems
- 277 VAC from 480 VAC source
- 240 VAC Delta

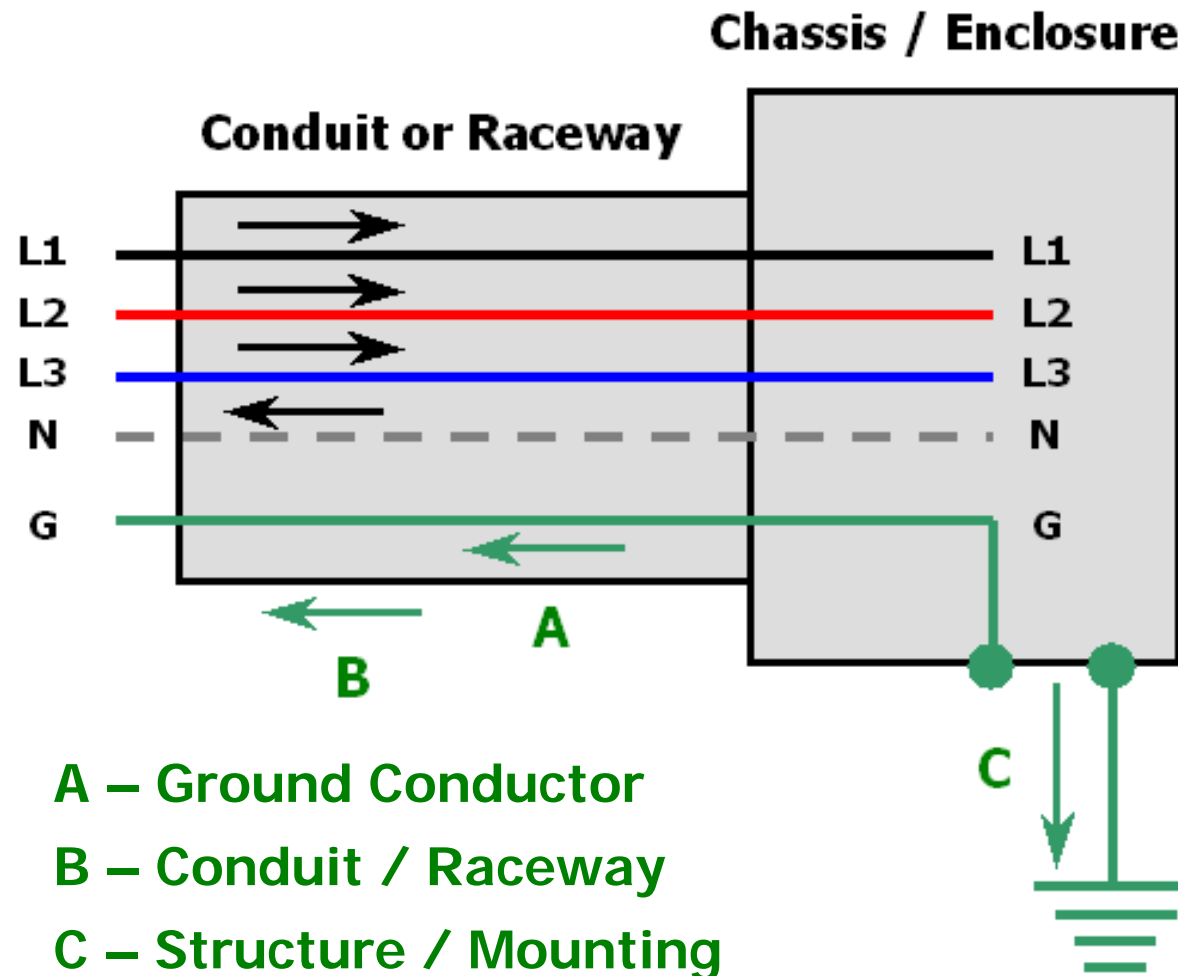


Ground current can be a diagnostic tool

Leakage Currents

Leakage Currents

$$\begin{array}{r}
 L1 \\
 + L2 \\
 + L3 \\
 + N \\
 \hline
 = 0 \\
 \textit{Ideal}
 \end{array}$$



Leakage Currents

❖ GFCI

- 5 mA

❖ Ground Fault Protection

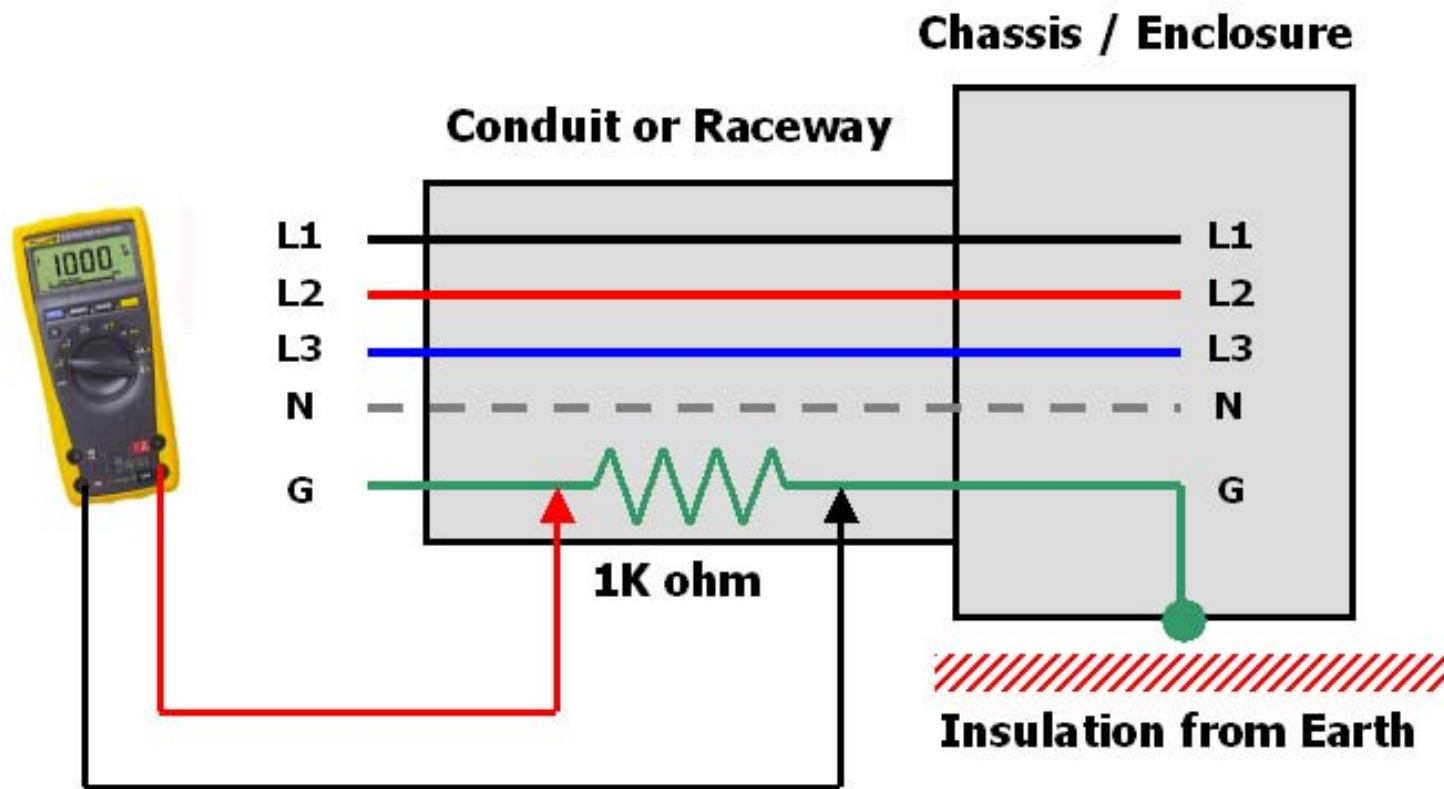
- Large Panels
- Arcing Fault Protection
- 10's or 100's of Amps

❖ Patient Safety (Health Care)

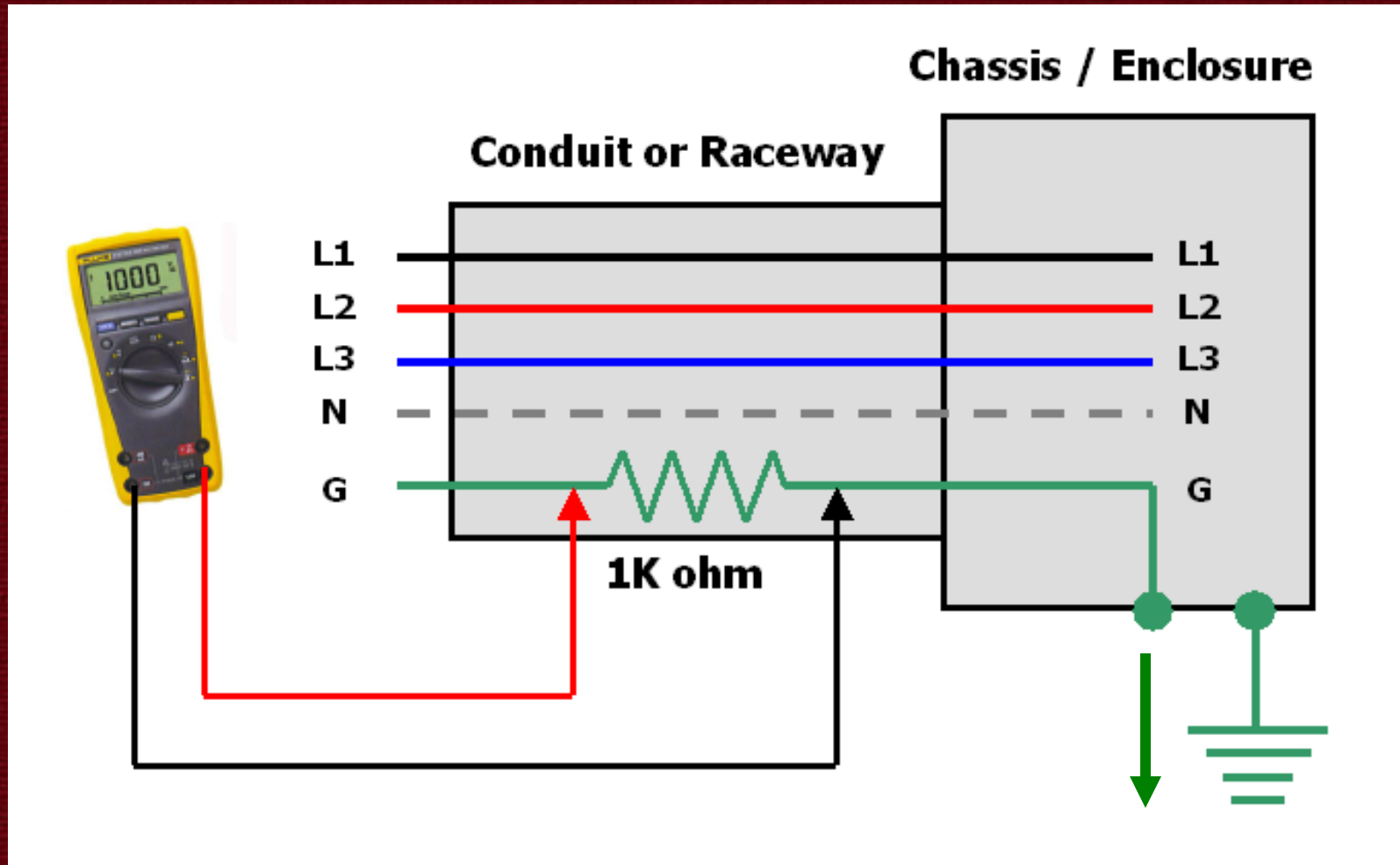
- 5 mA (fixed equipment)
- 300 μ A (cord connected)



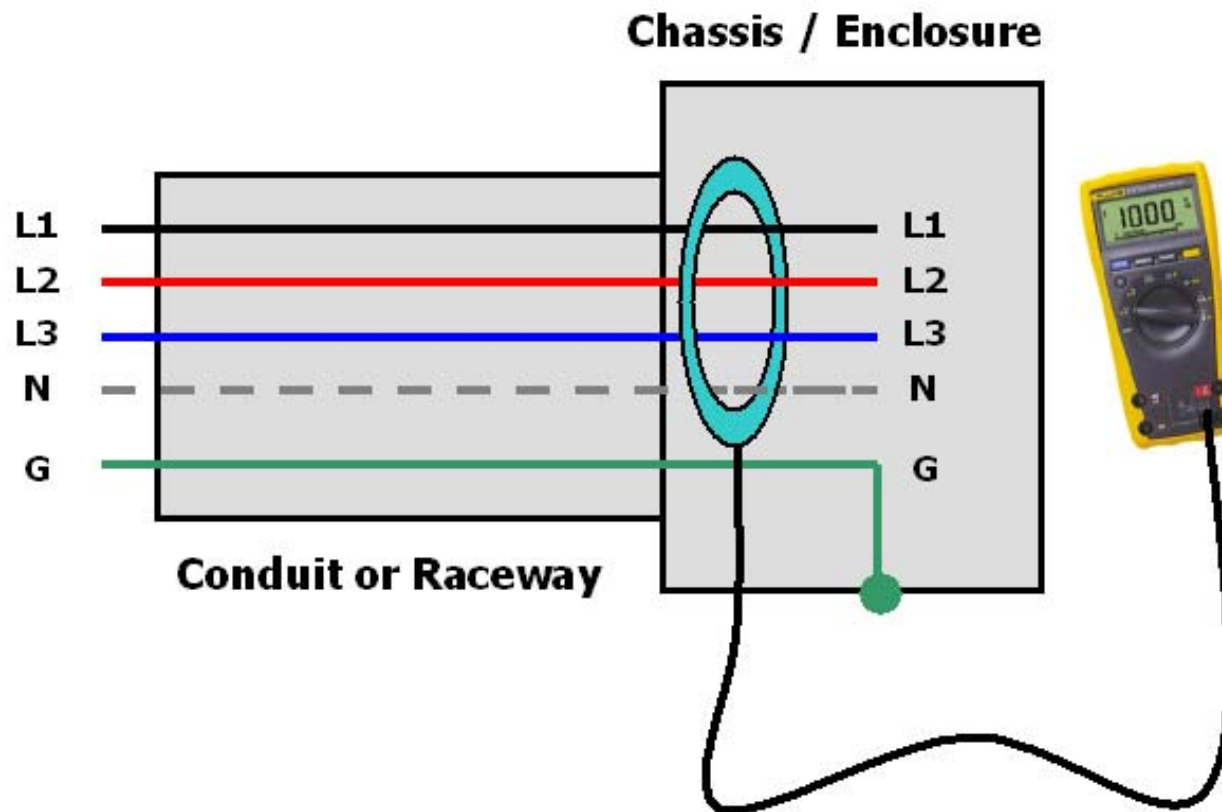
Measuring Leakage Currents: NFPA-99



Measuring Leakage Currents: NFPA-99

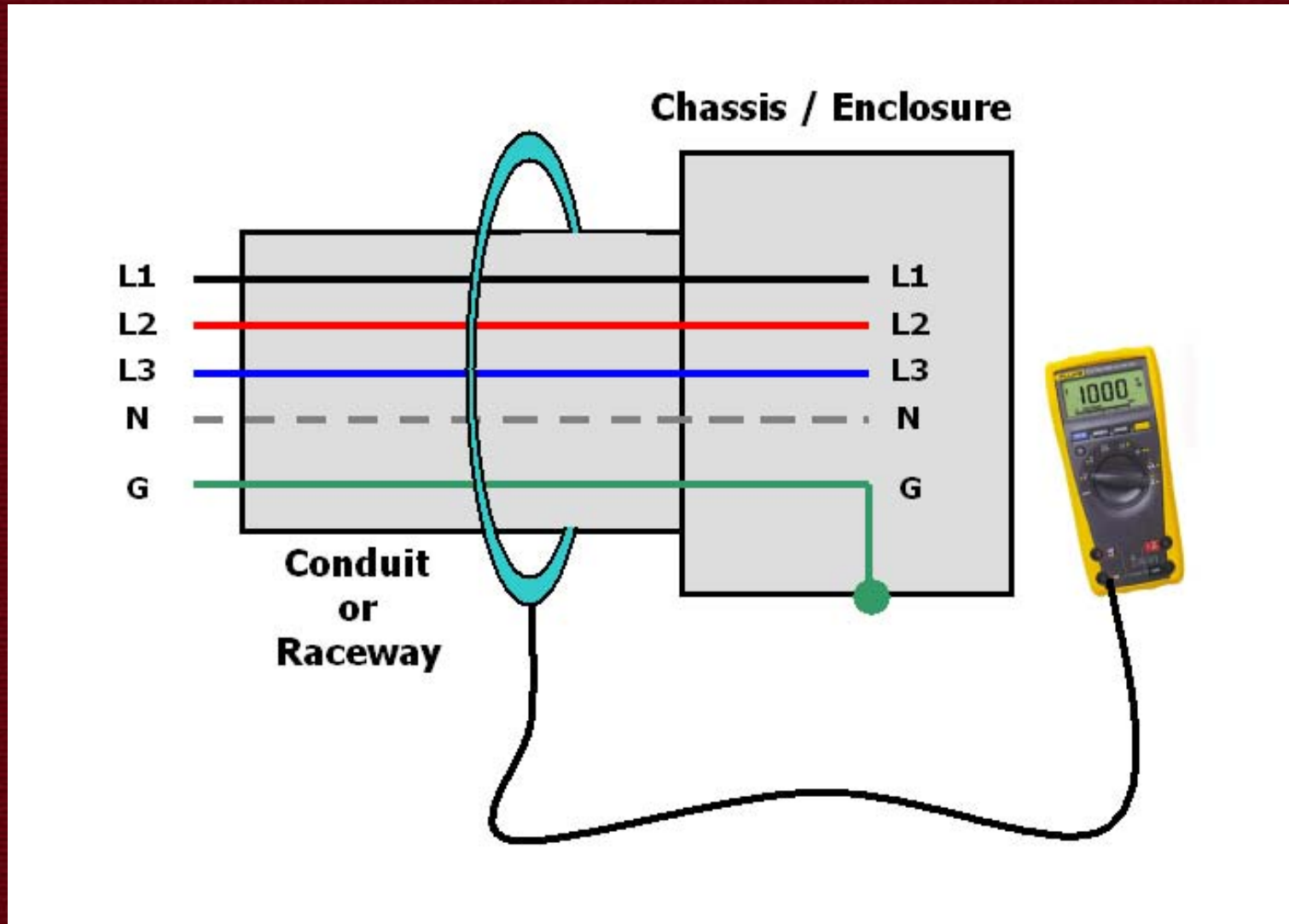


Measuring Leakage Currents: NFPA-99

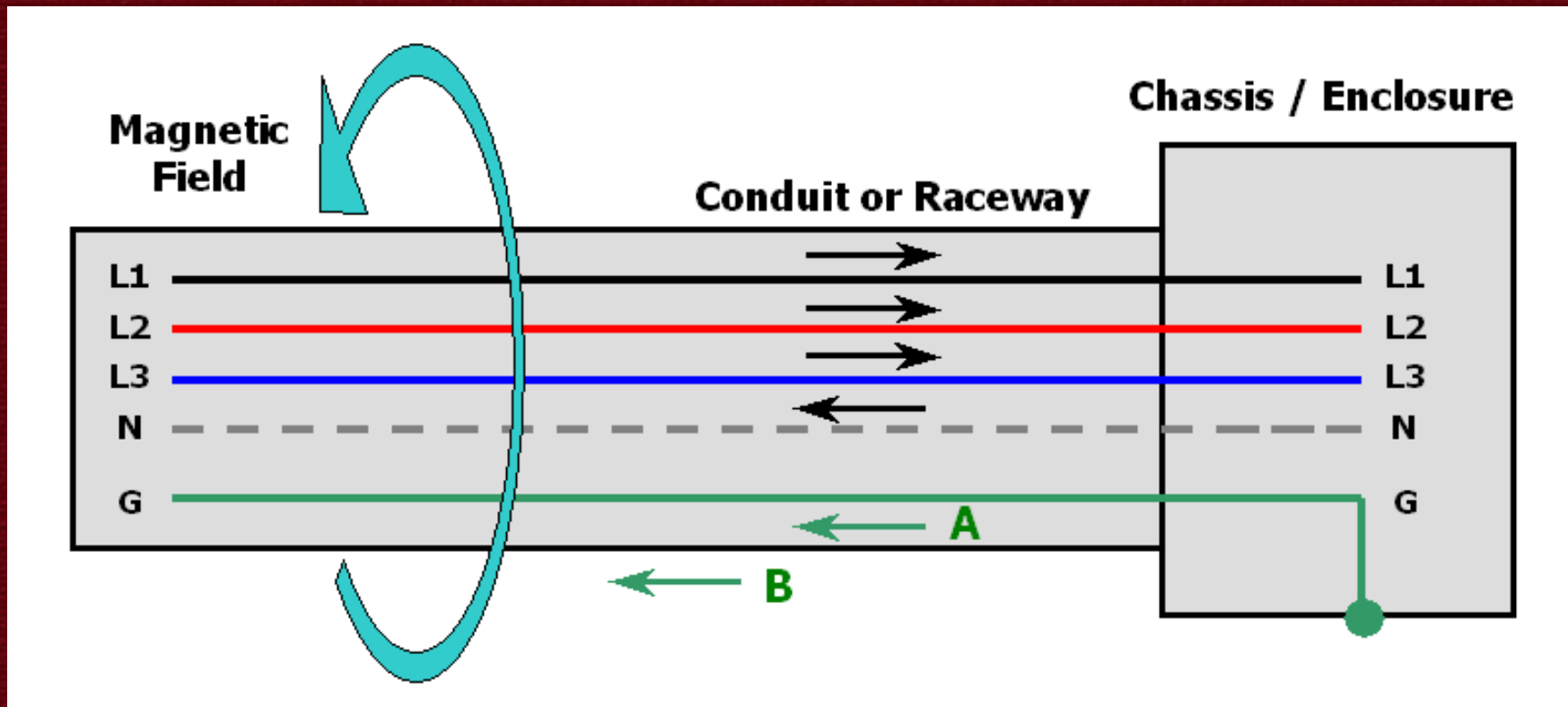


Net Currents

Net Currents

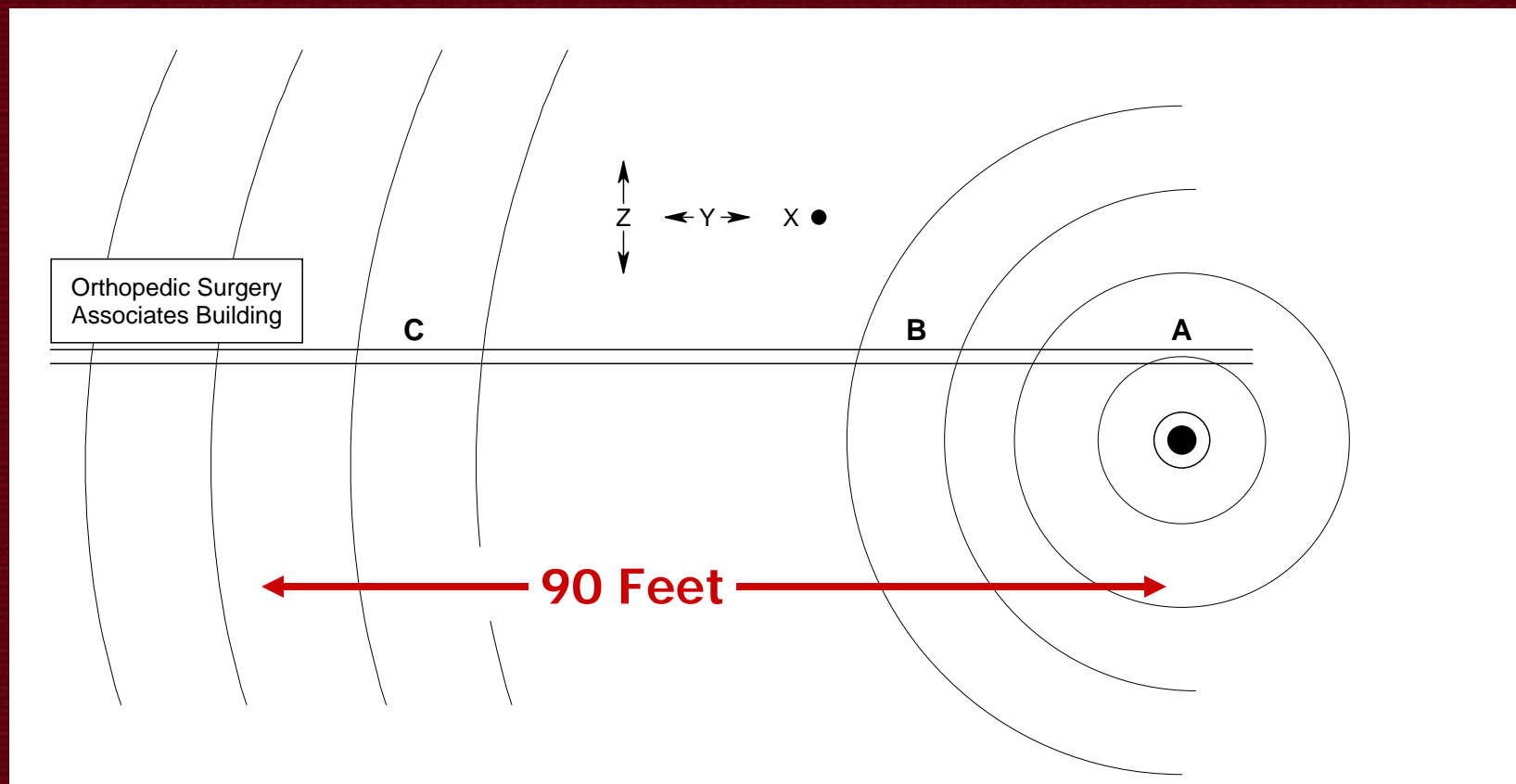


ELF Magnetic Fields Caused by Net Currents



ELF – Extremely Low Frequency (50 / 60 Hz)

ELF Magnetic Fields Caused by Net Currents

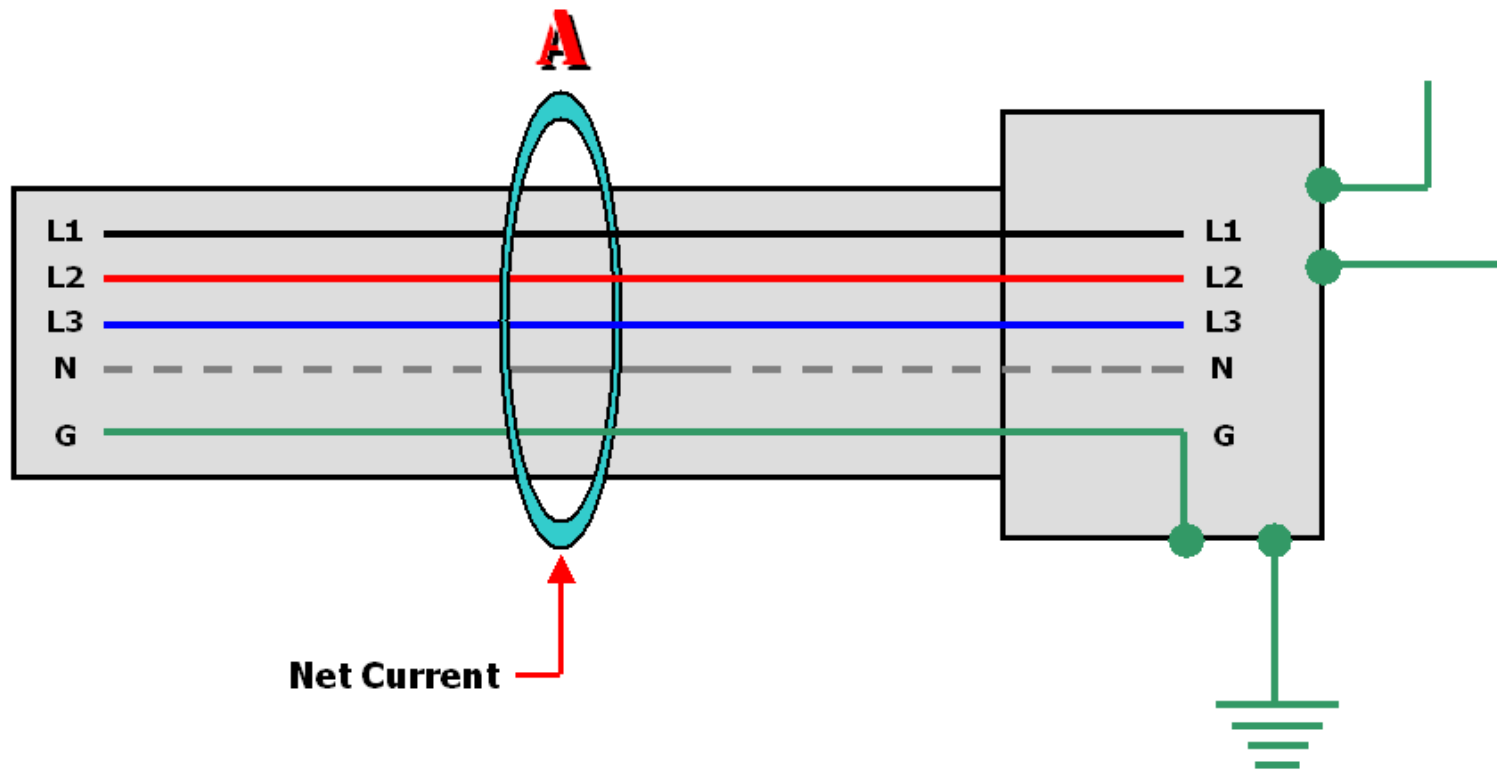


Net Current Fields Do Not Fall Off Quickly

Measurements

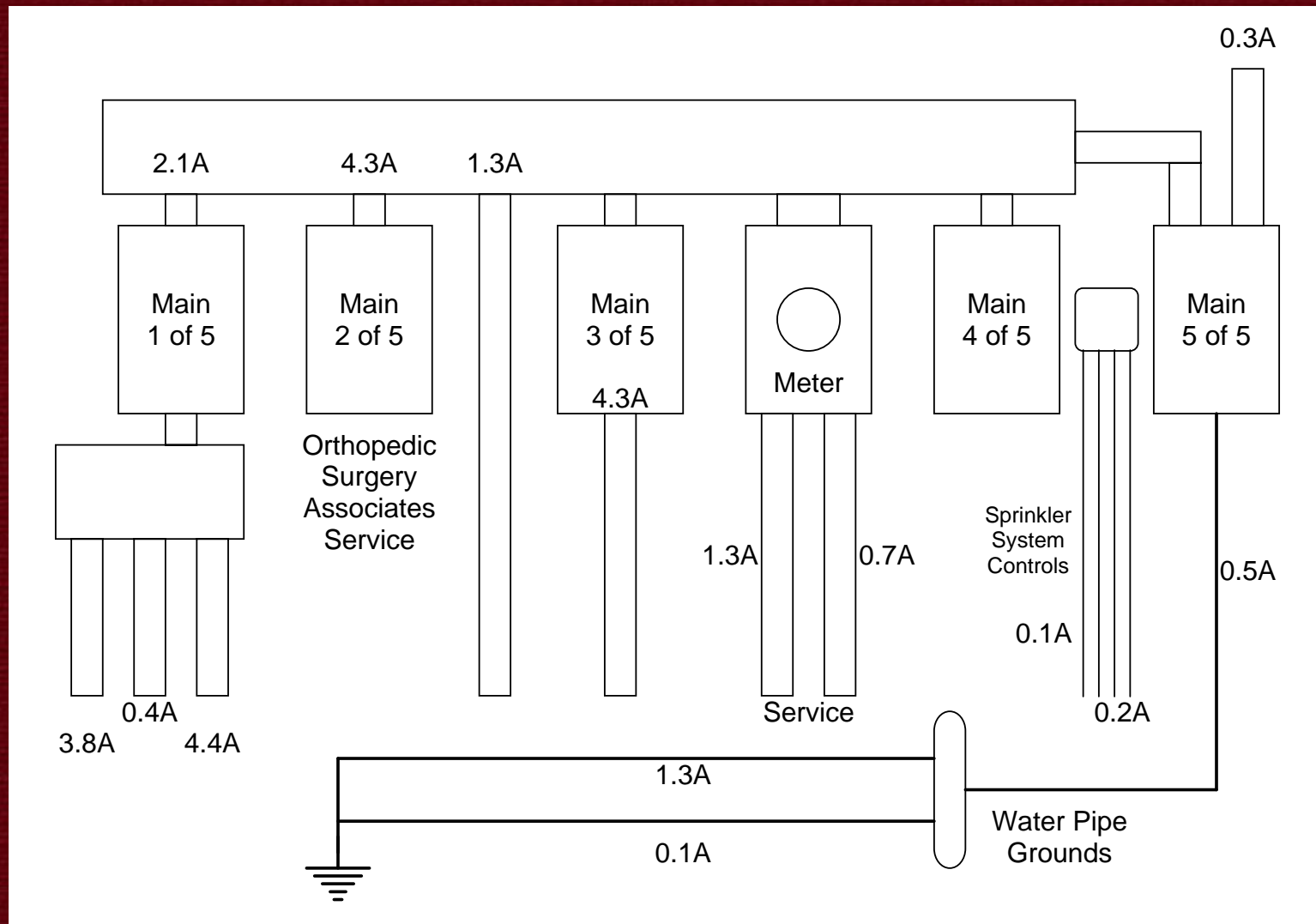
Techniques
and
Instrumentation

Troubleshooting Techniques: Magnetic Fields / Net Currents

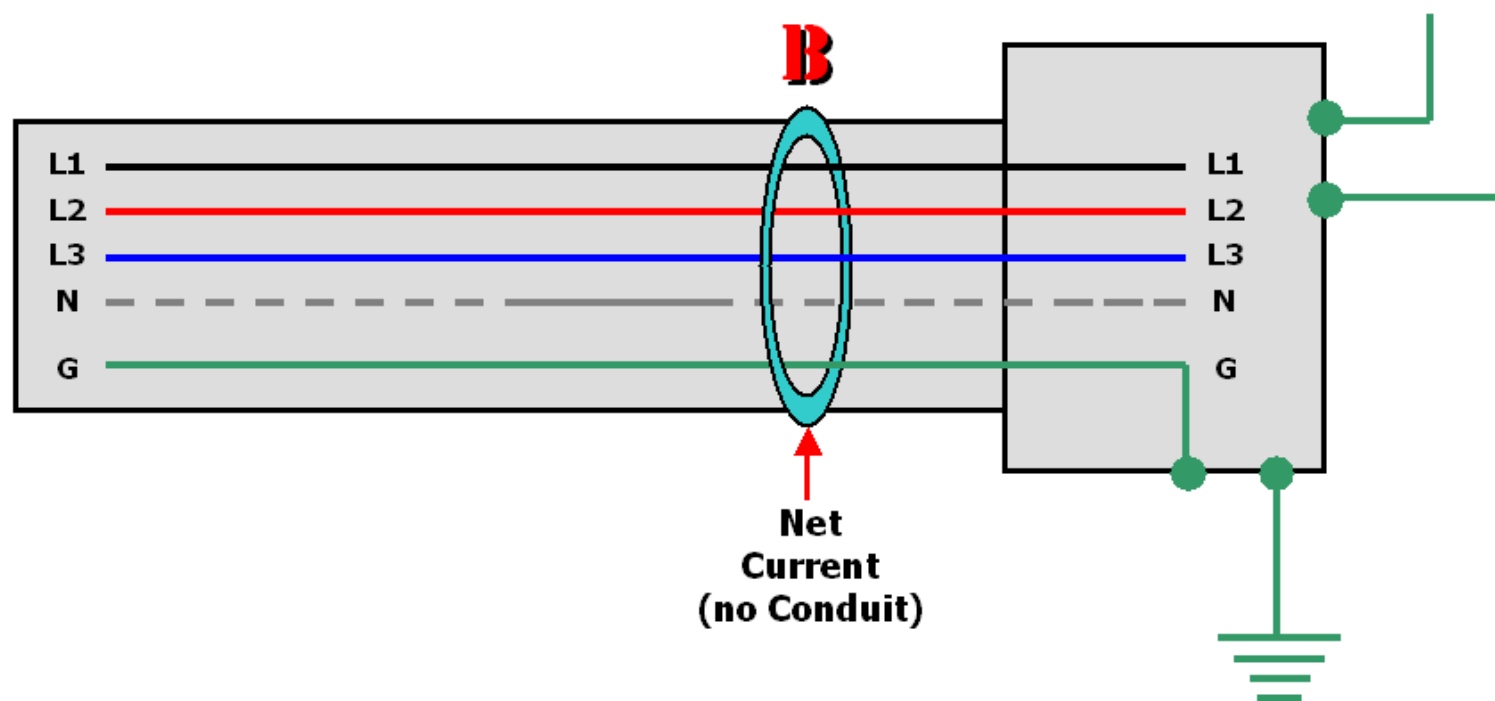


Fast and Easy to Do

Troubleshooting Techniques: Magnetic Fields / Net Currents

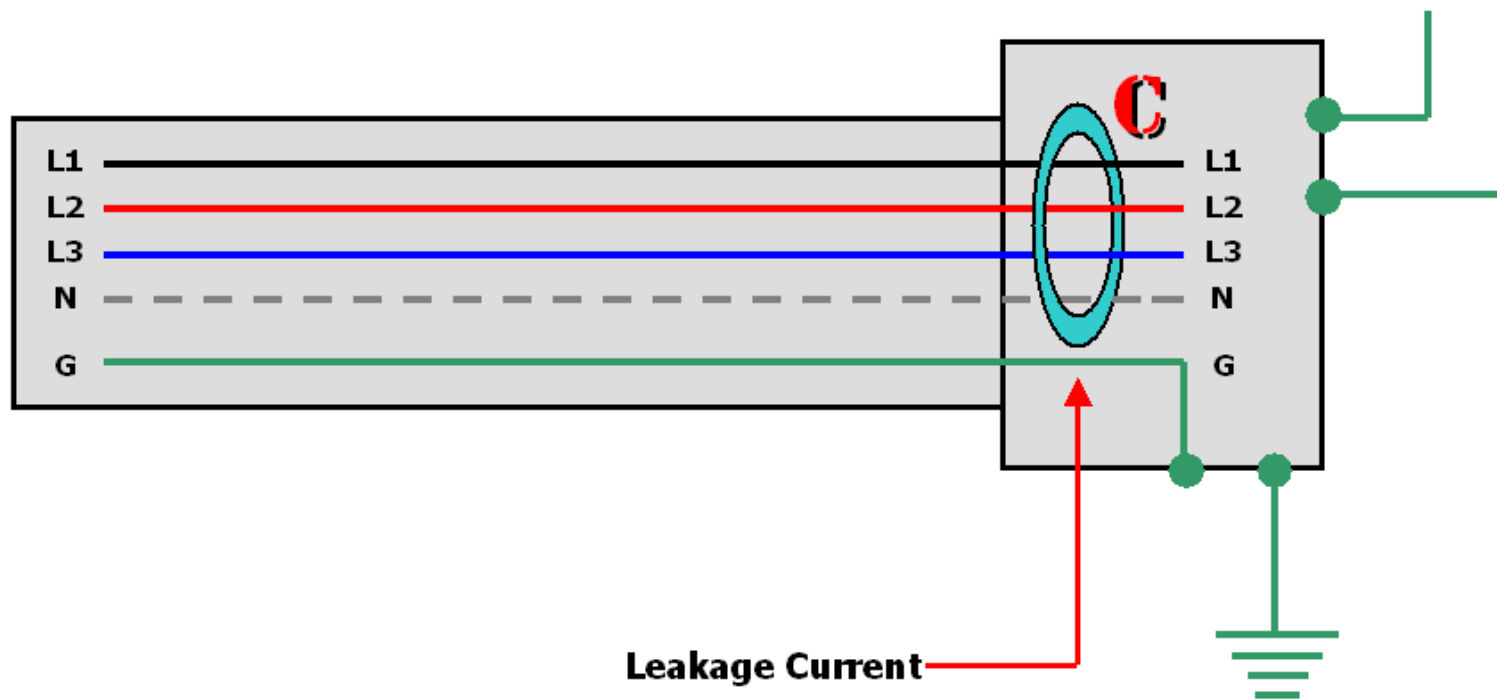


Troubleshooting Techniques: Magnetic Fields / Net Currents



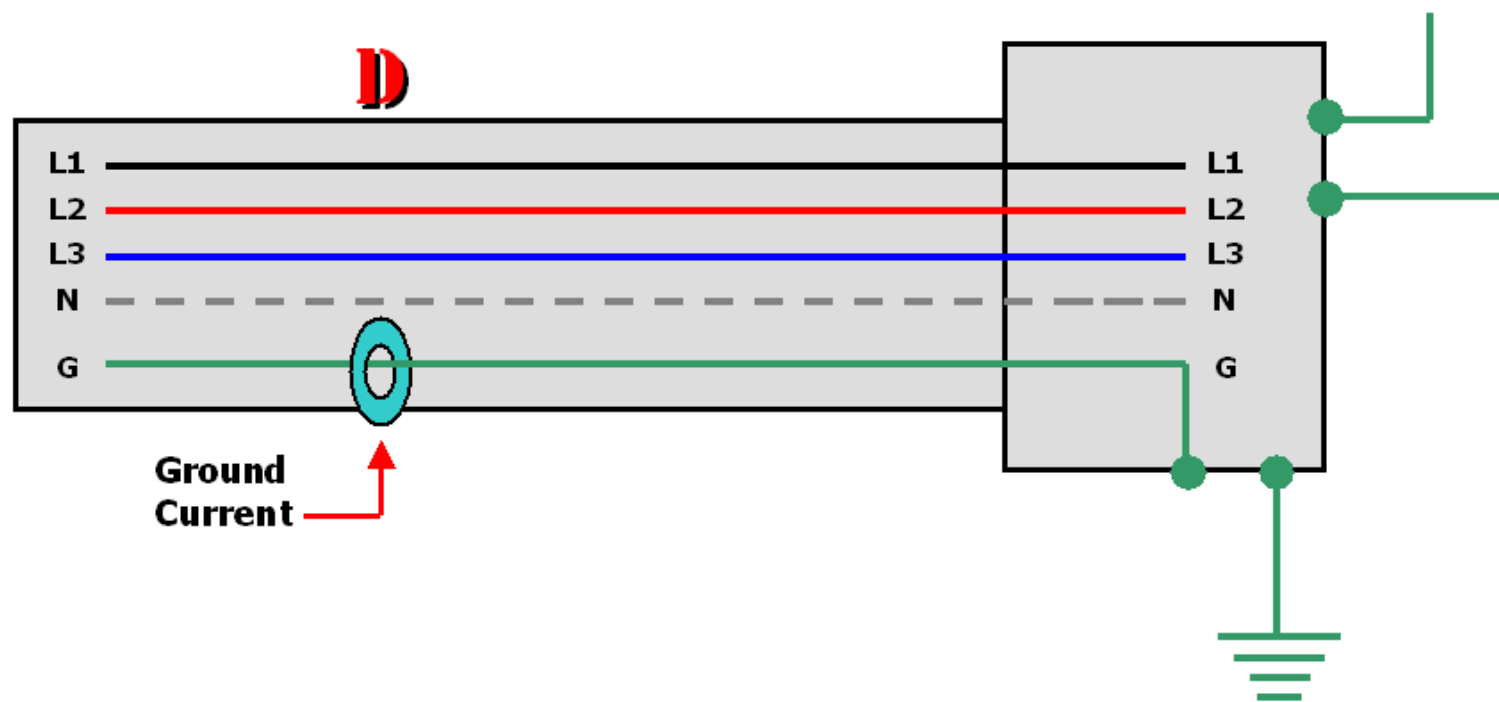
Need to Open Panels

Troubleshooting Techniques: Net Currents / Leakage Currents



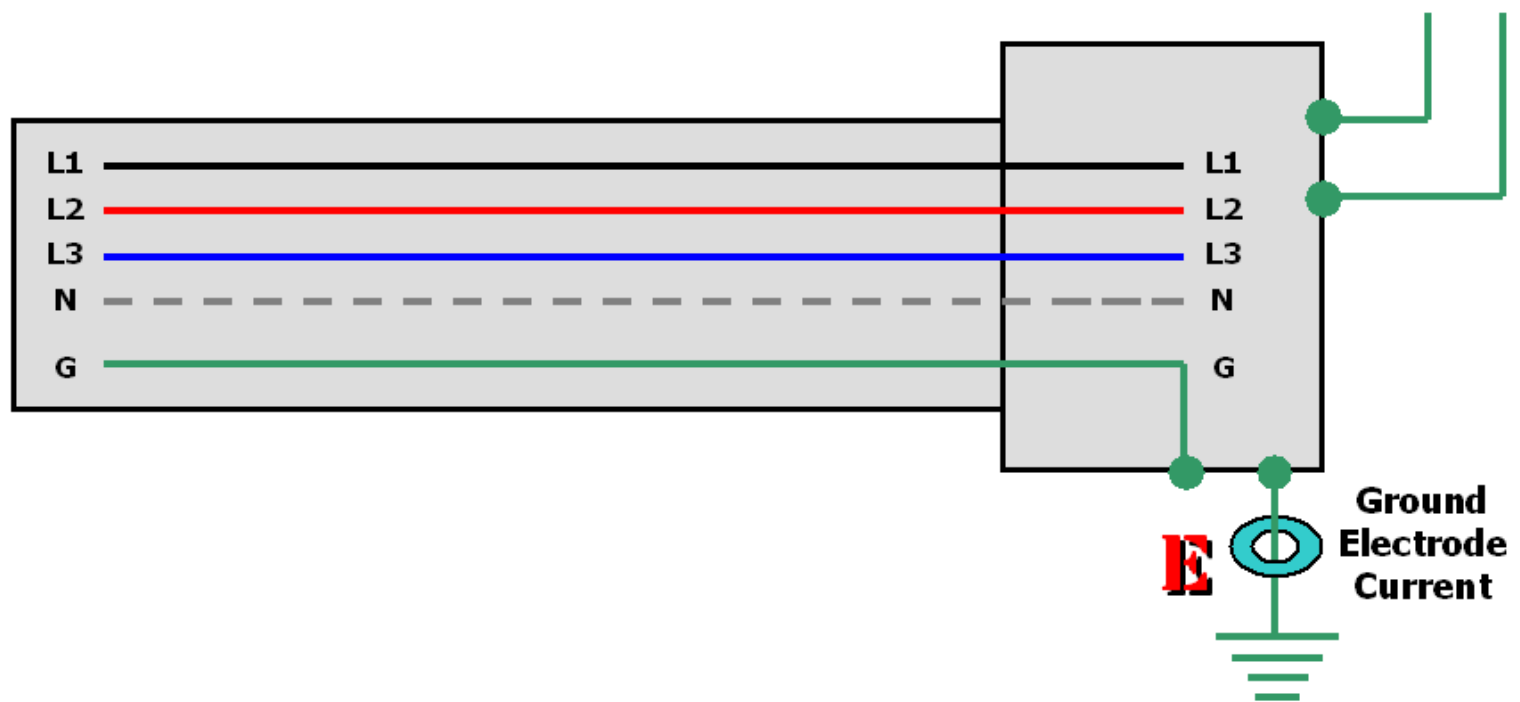
Are Currents Leakage Related?

Troubleshooting Techniques: Ground Currents



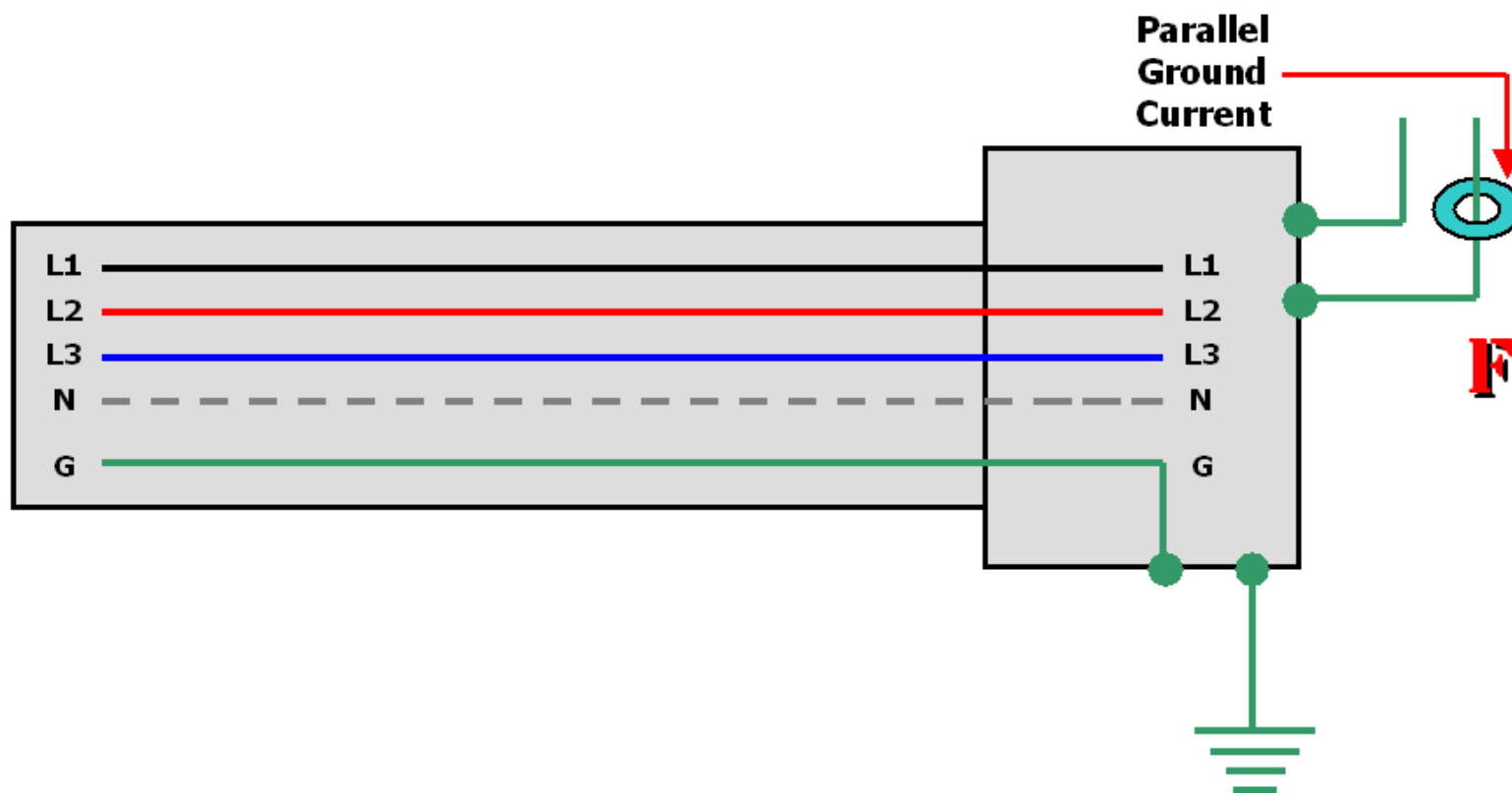
Tried-and-True, Use as Baseline

Troubleshooting Techniques: Ground Loops

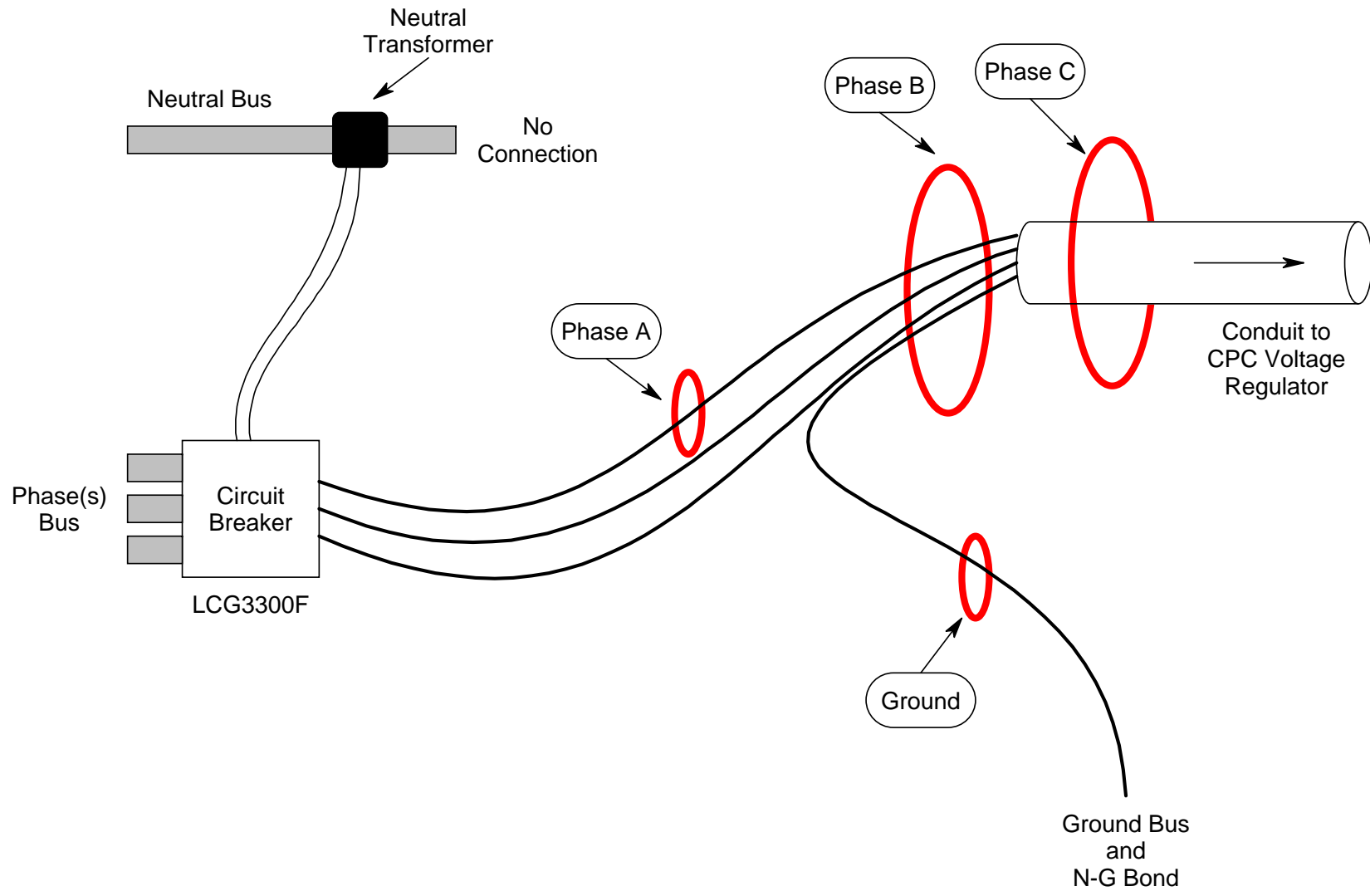


Ground Loops? Power Quality Run Amok?

Troubleshooting Techniques: Ground Loops



Look for Unusual or Unexpected Sneak Paths



Instrumentation: Clamp-on Current Probes / Meters

❖ Conventional Current Probes ?

❖ Electrical Issues

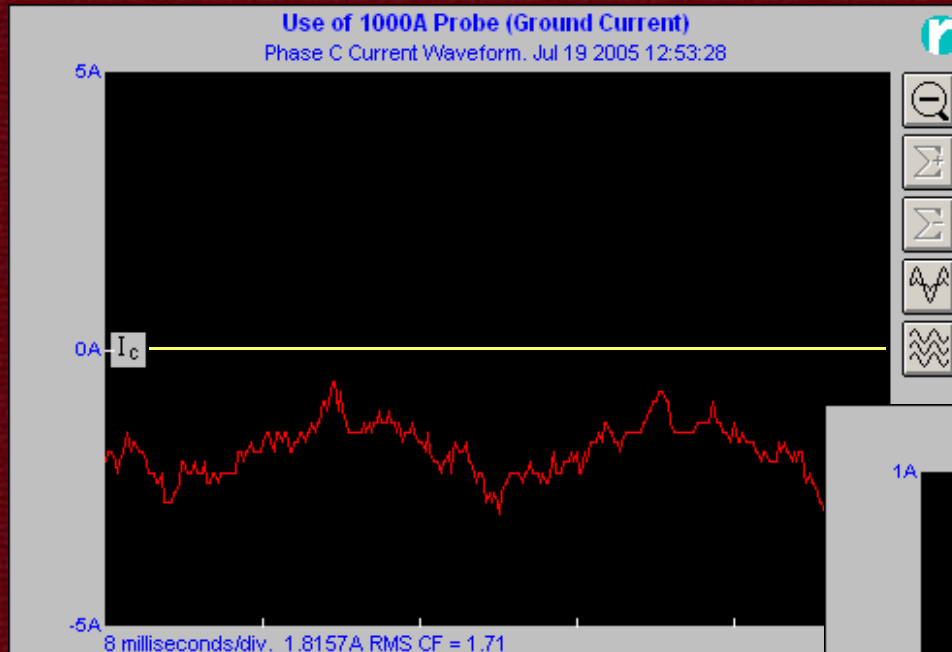
- Resolution
- Accuracy
- Offset

❖ Mechanical Issues

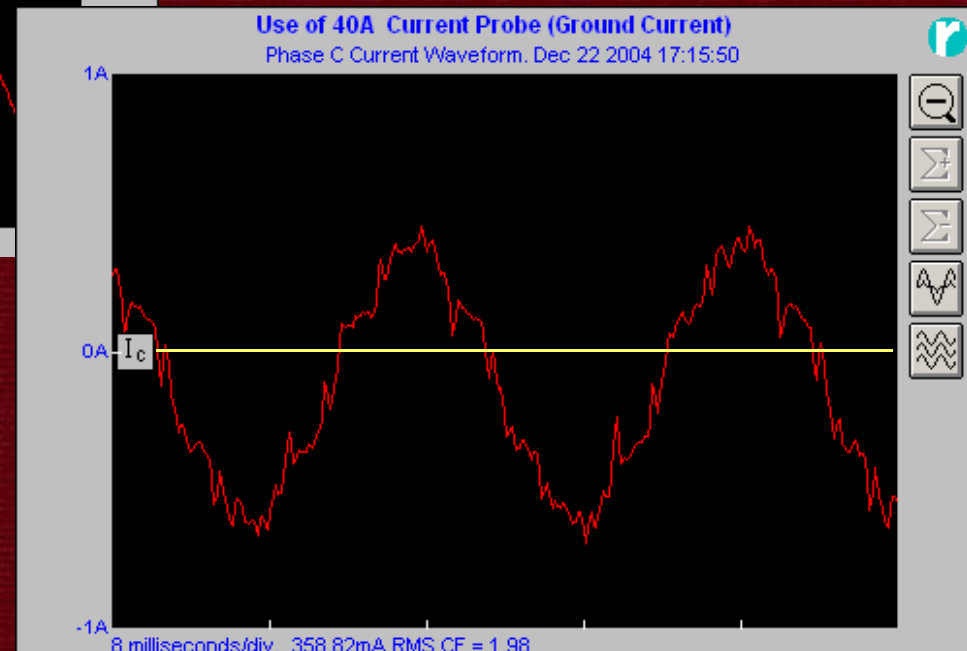
- Measurement Window
- Structural Measurement

Instrumentation: Accuracy and Offset

40 A Probe



1000 A Probe
DC Offset



Instrumentation: Measurement Window



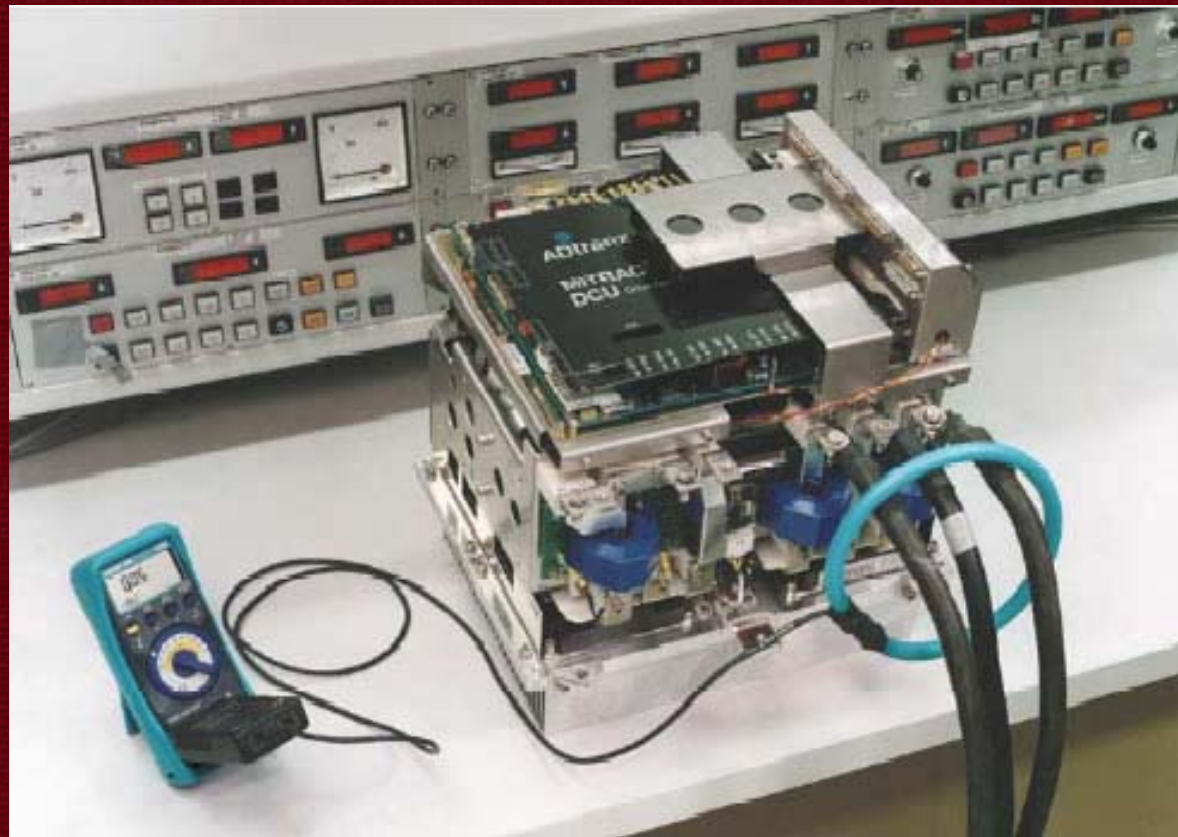
❖ Conventional Current Probes

- Low Amps
= Small Window
- Large Window
= Loss of Resolution
and Accuracy
- No way to measure
conduits, raceway,
structure

Instrumentation: Leakage Current Meters

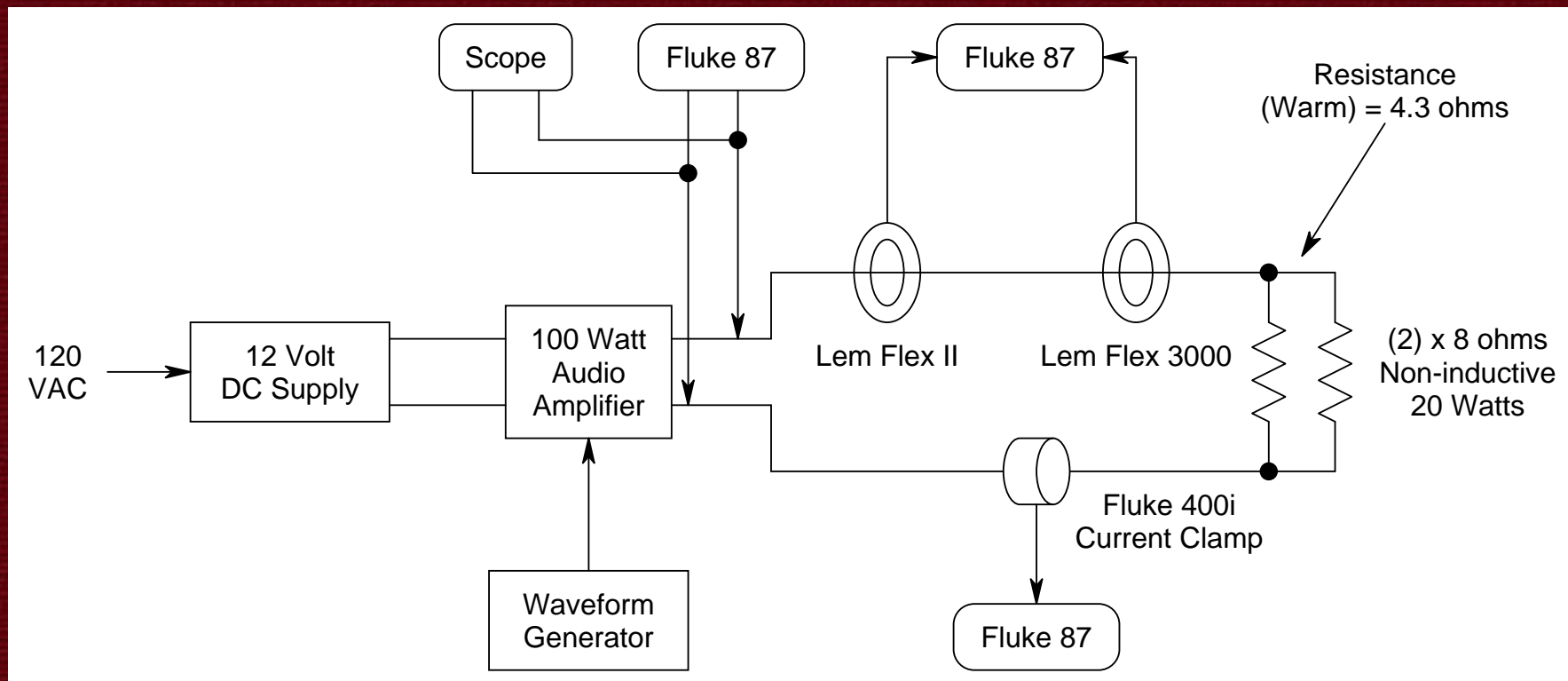


Instrumentation: Flexible Current Probes

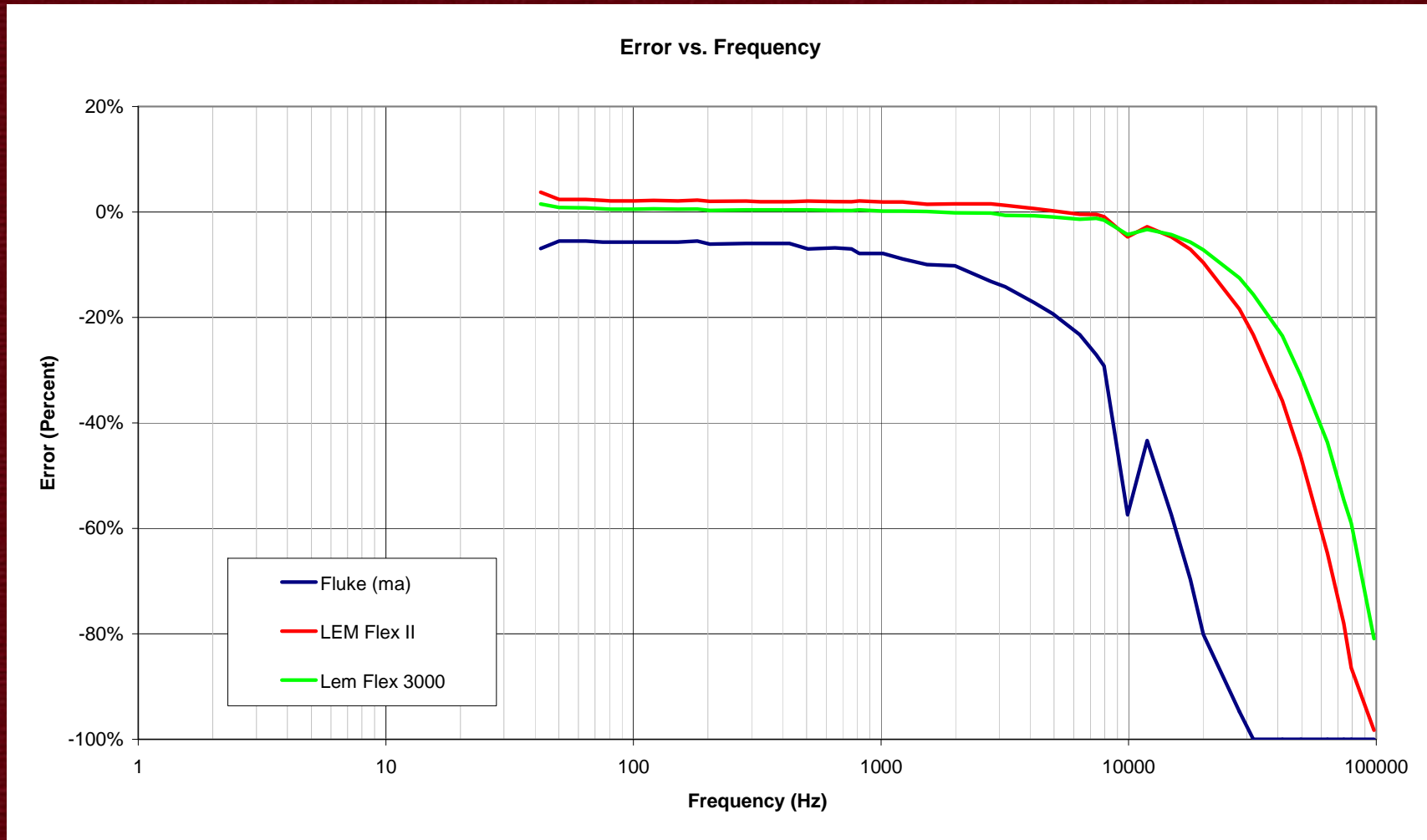


Can We Trust Flexible Current Probes?

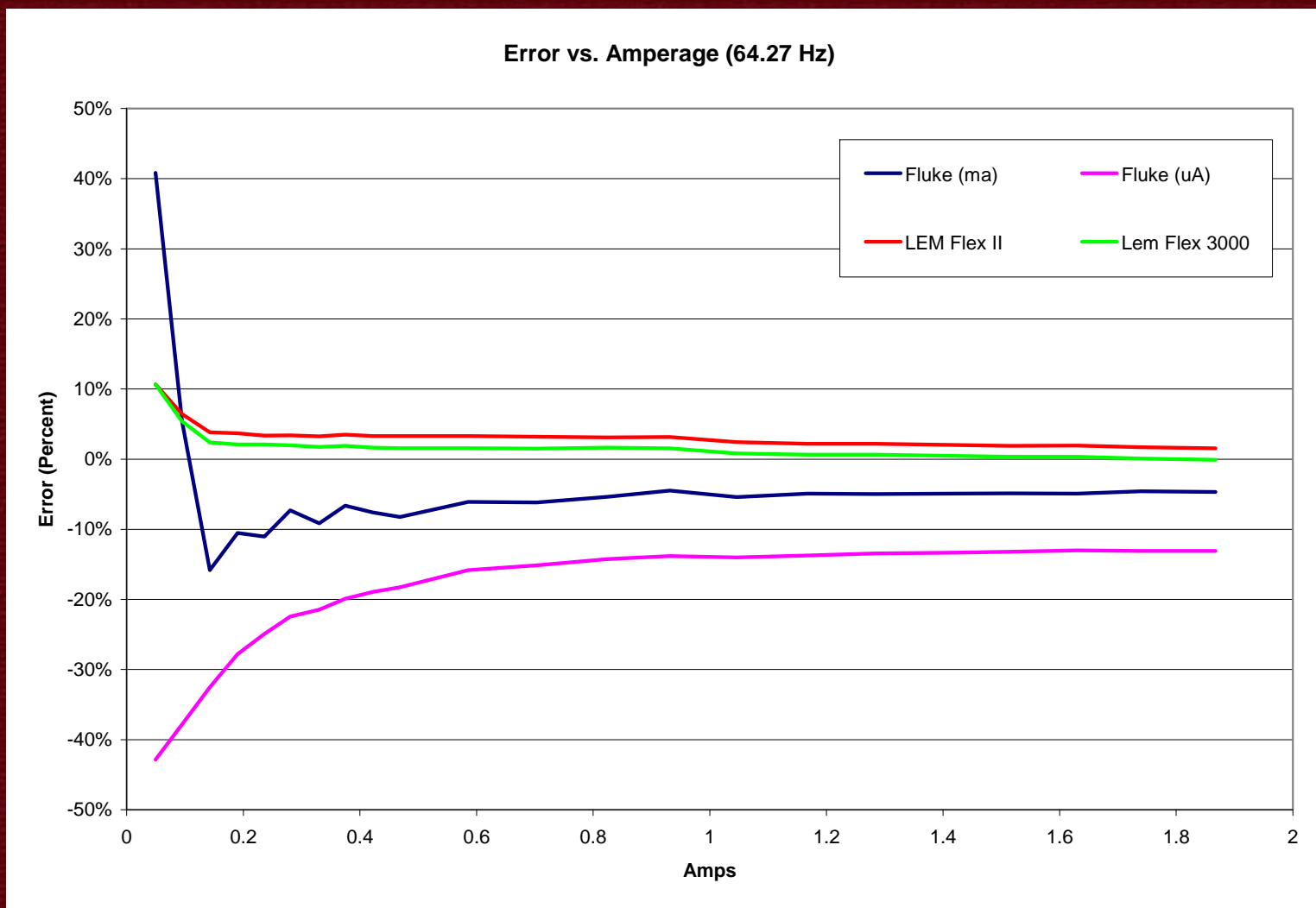
Instrumentation: Flexible Current Probes



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Instrumentation: Flexible Current Probes

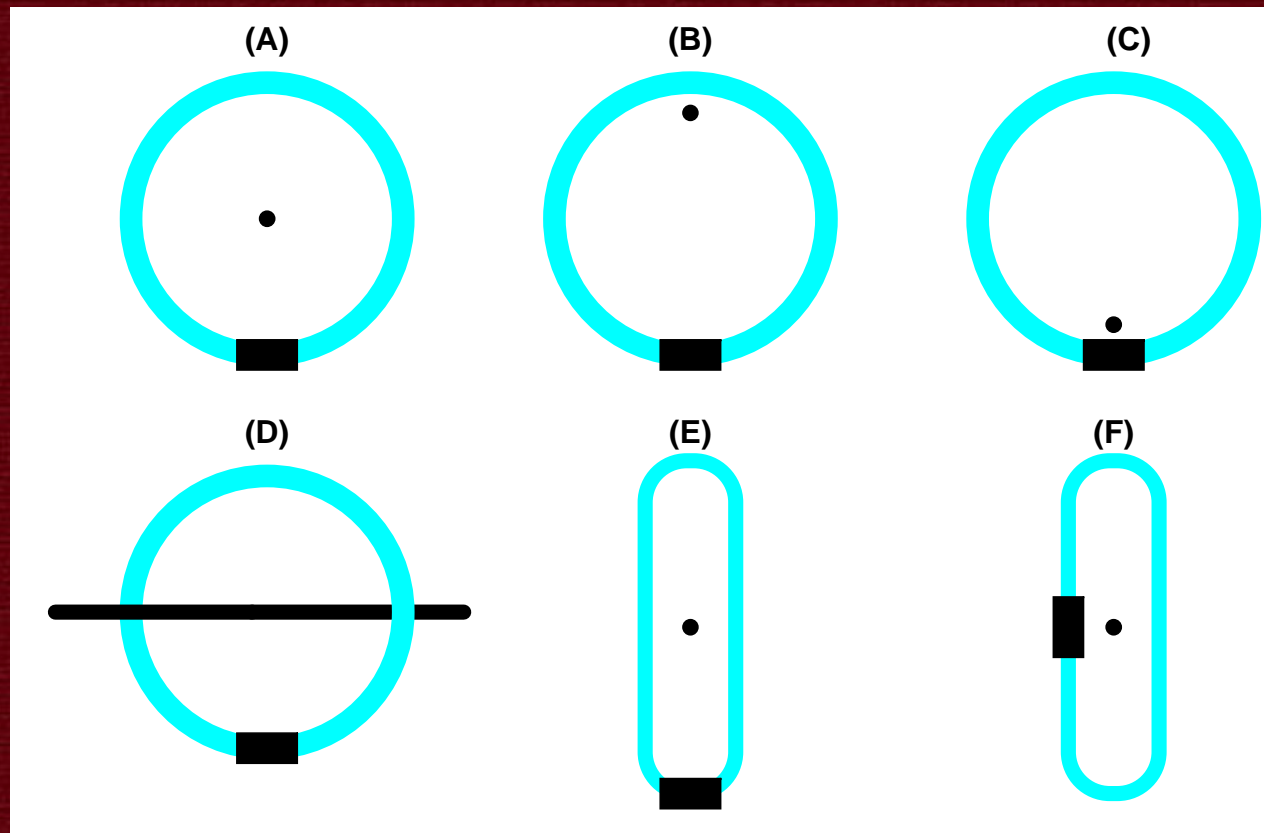


Instrumentation: Flexible Current Probes

Centered

Offset

Offset
(Clasp)



Skewed

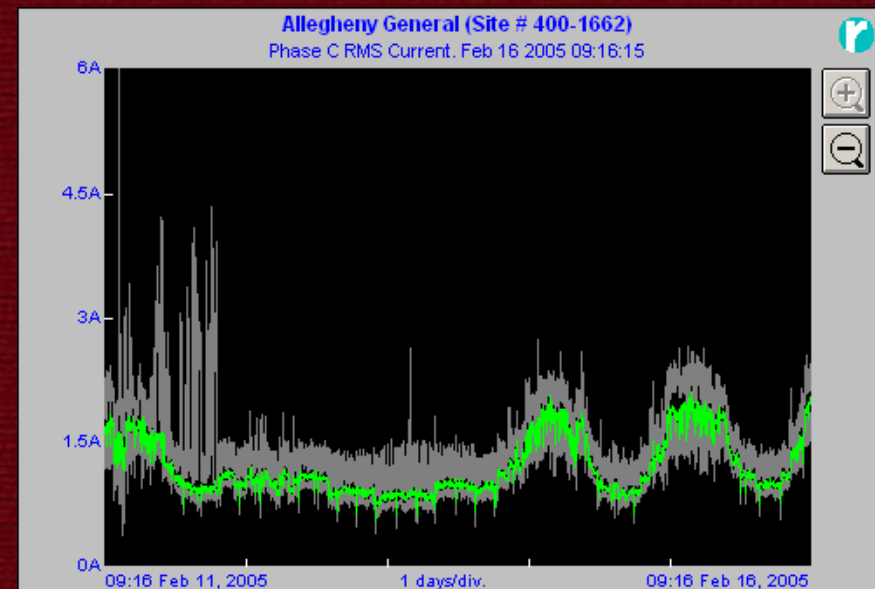
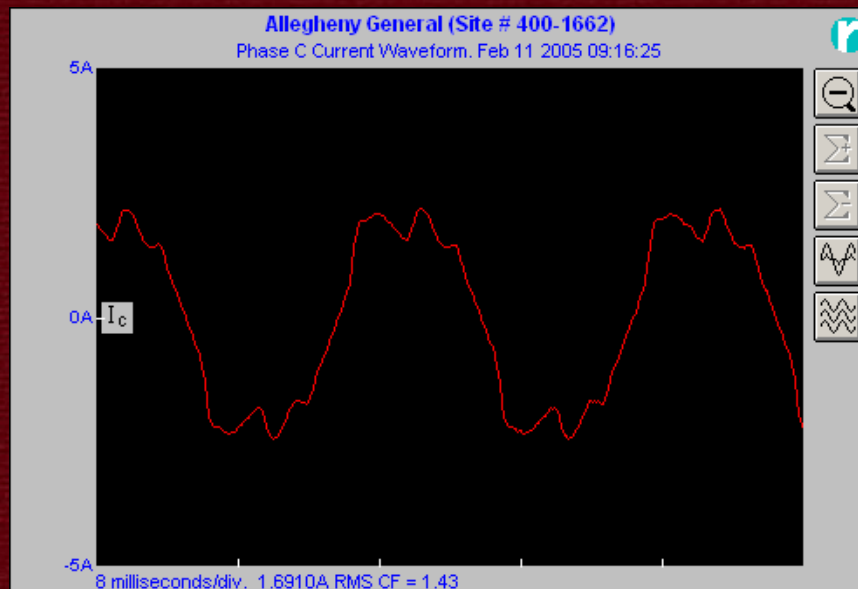
Deformed

Deformed
(Clasp)

Case Studies

Case Study #1: High Ground Currents

- ❖ Medical Imaging Systems
- ❖ 10 Amps of ground current at some sites
- ❖ First Guess: Not real (instrumentation error)
- ❖ On site Investigations: Currents were real



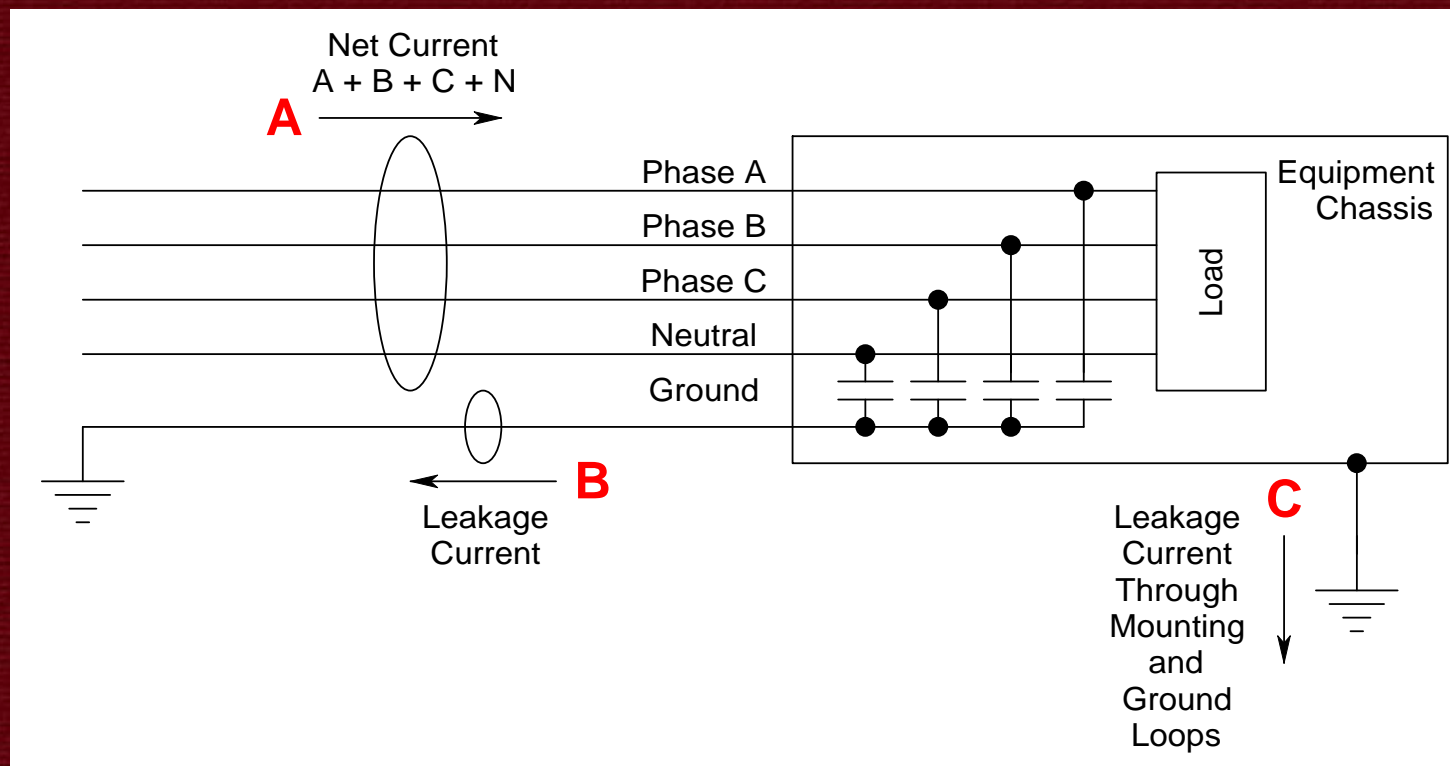
Case Study #1: High Ground Currents



- ❖ Filters for Room Shield
- ❖ 120 VAC Circuits
 - Lighting
 - Outlets
- ❖ Surge Suppressor
 - Delta vs. Wye
- ❖ Power Conditioners
 - Improper NG Bonds
- ❖ Isolated Grounding
 - Making things worse

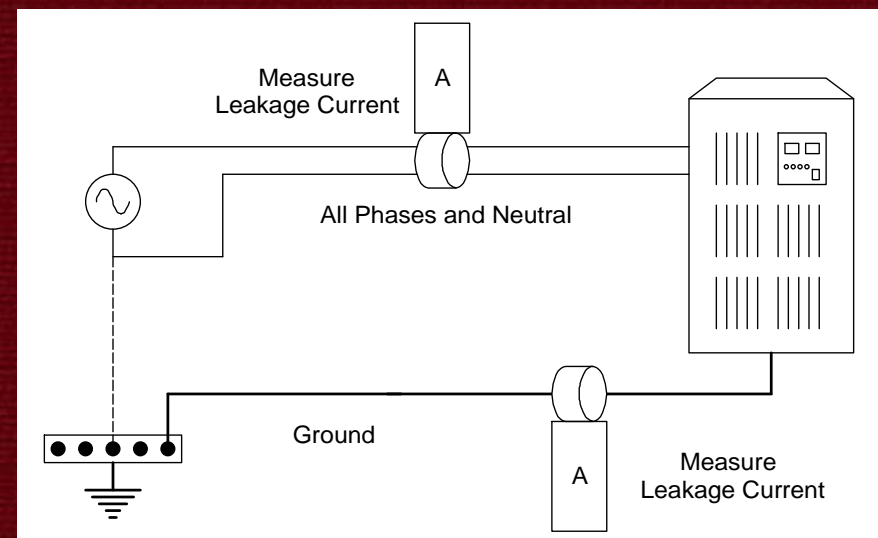
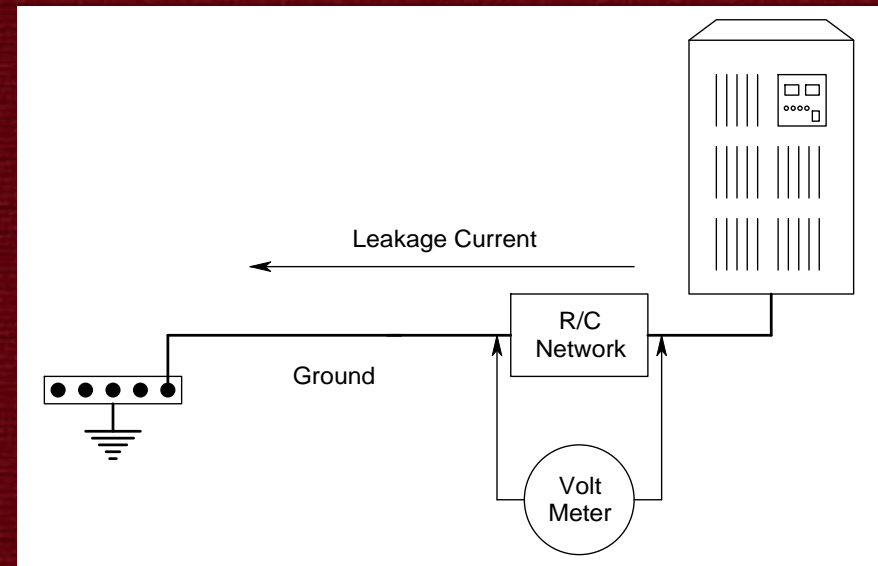
Case Study #2: Leakage Currents

- ❖ Medical Imaging - IEC / UL Testing
- ❖ High Leakage Currents in Some Test-Bays
- ❖ Not System Dependent



Case Study #2: Leakage Currents

- ❖ Using IEC / NFPA Measurement Techniques
- ❖ 1KΩ in Ground
- ❖ Not-insulated
- ❖ Used Clamp-on Leakage Meters
 - Tracked IEC measurement
- ❖ Leakage Current was flowing in mounting
- ❖ Real Situation: *High Leakage Currents!*

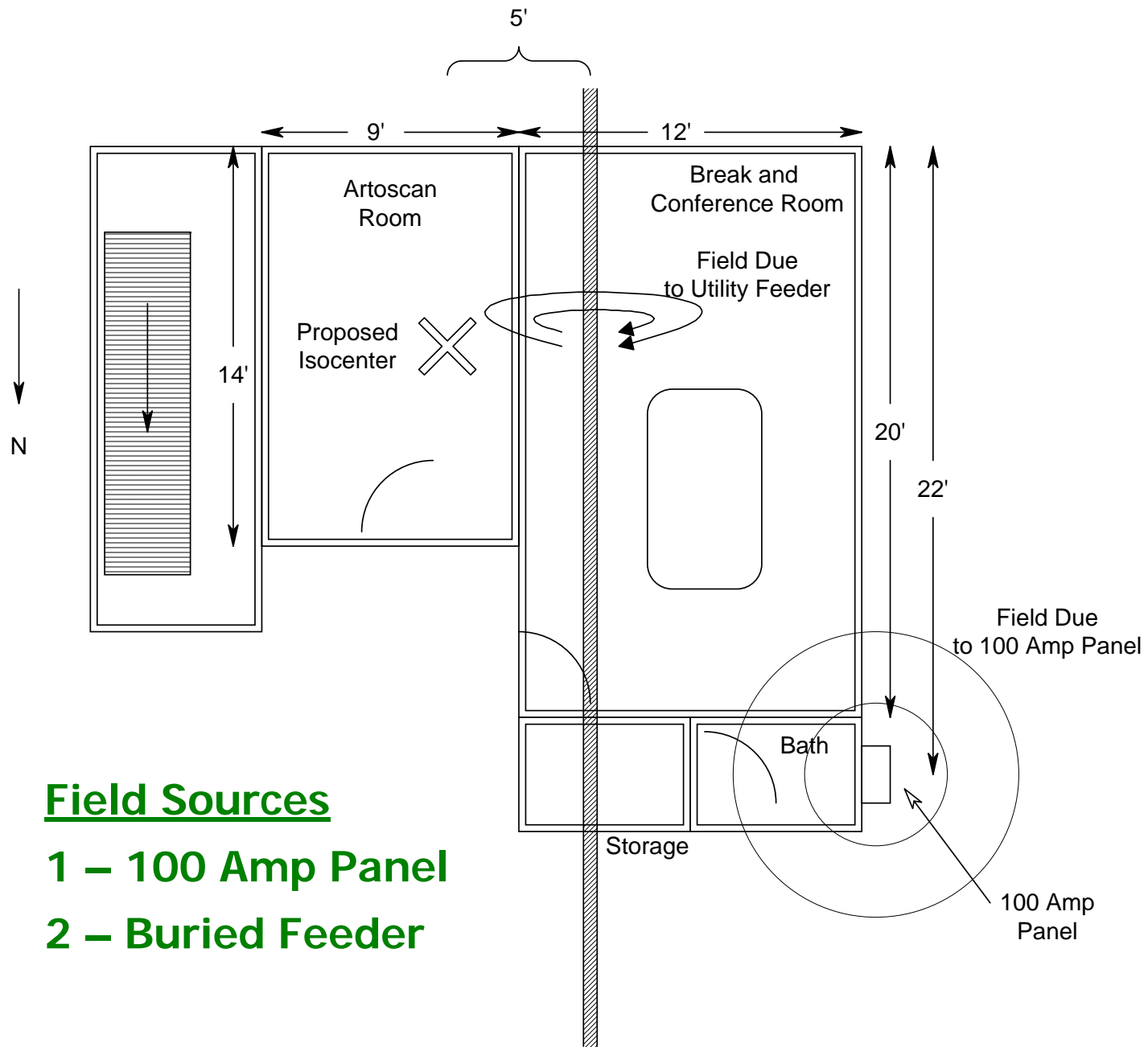


Case Study #3: Magnetic Fields caused by Net Currents

Extremity MRI

- ❖ Ankle, Wrist, Knee Scans
- ❖ 2 mGauss B-Field Limits
- ❖ Small Office
- ❖ Orthopedics





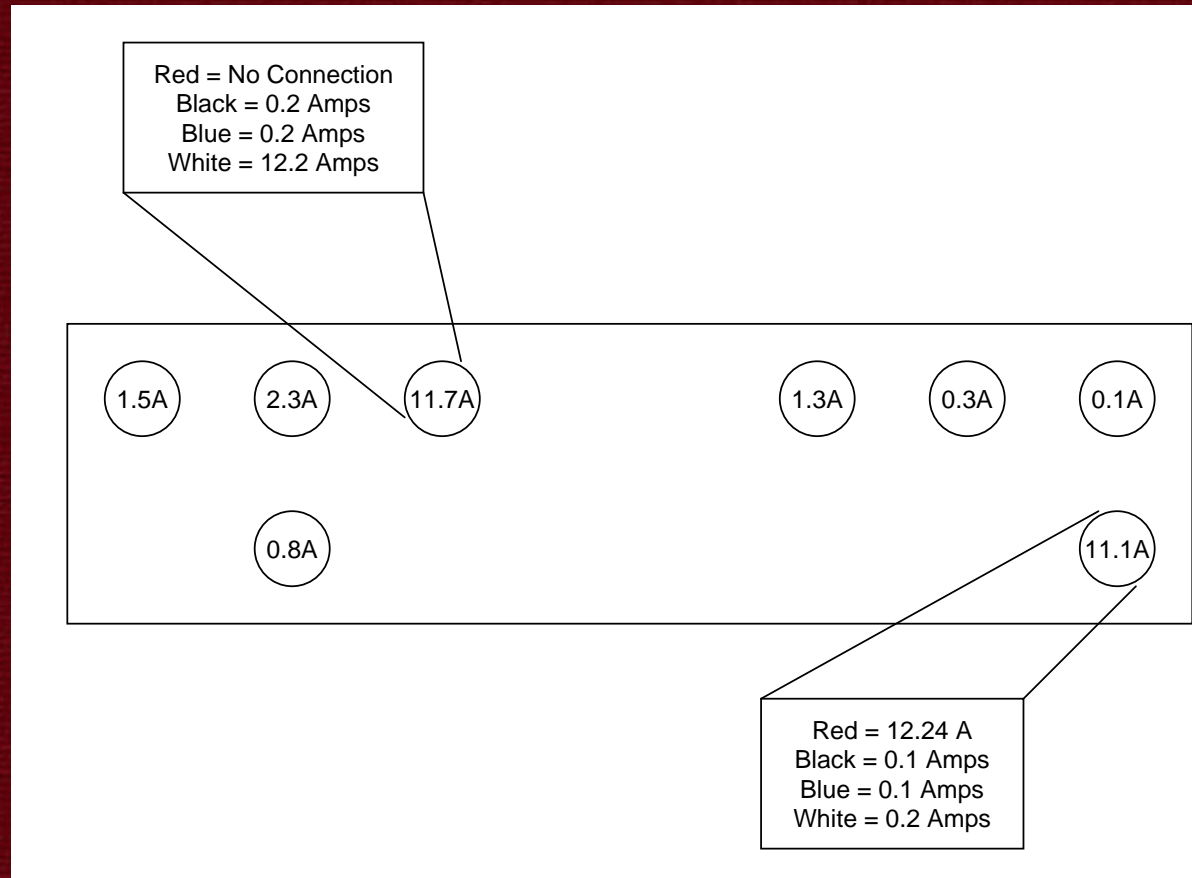
Field Sources

1 – 100 Amp Panel

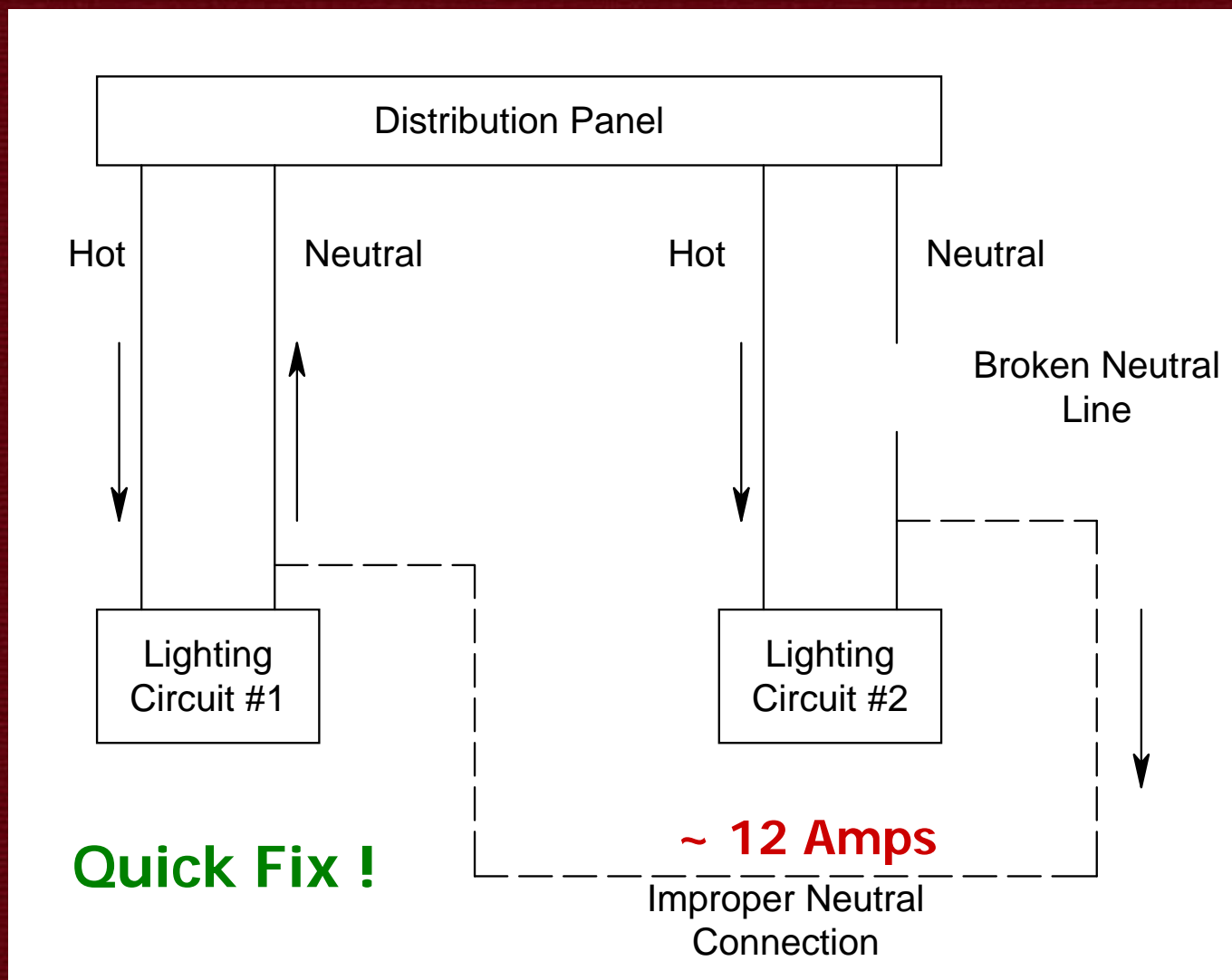
2 – Buried Feeder

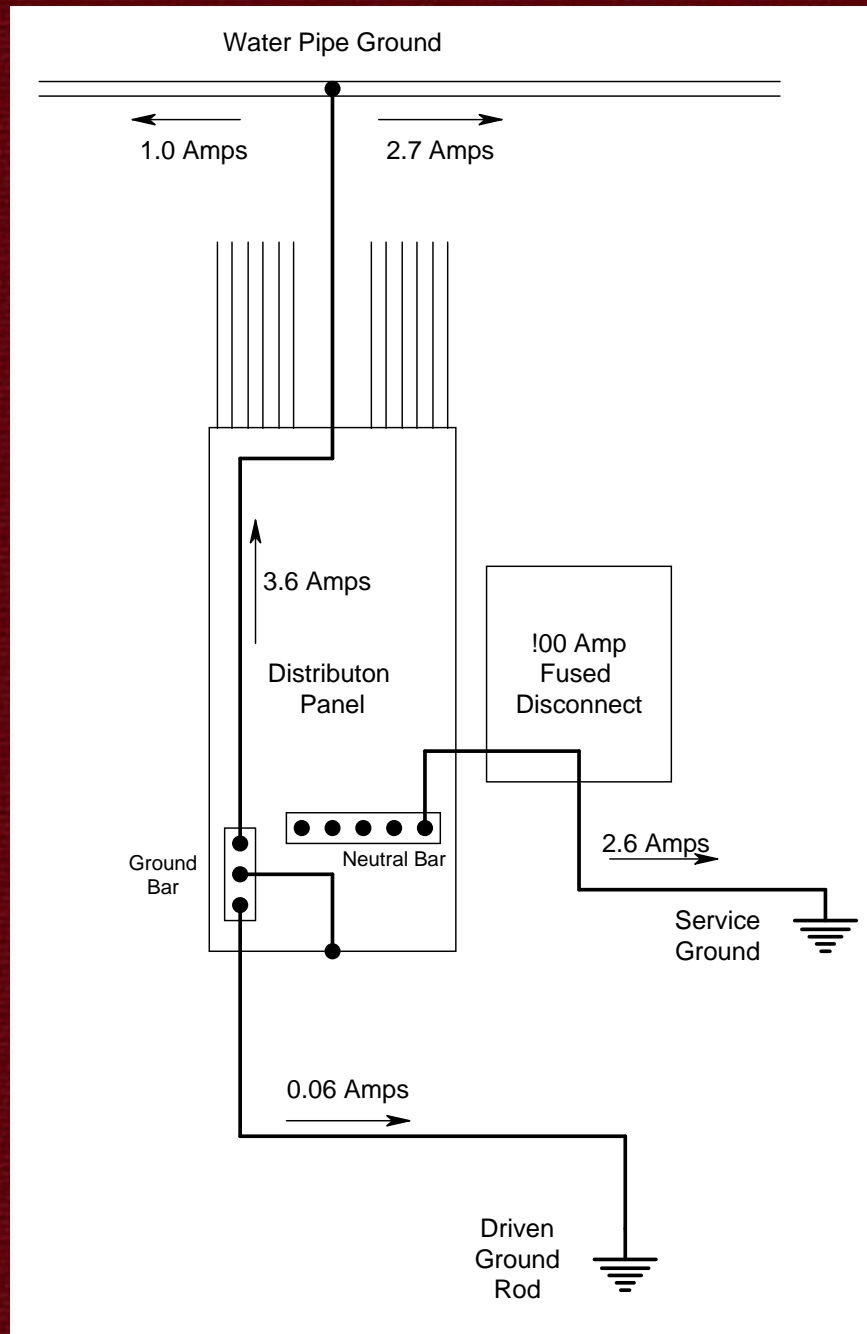
Case Study #3: Magnetic Fields caused by Net Currents

- ❖ Quick Check of Conduits: Net Currents
- ❖ Traced to co-mingled neutrals (fluorescent lights)



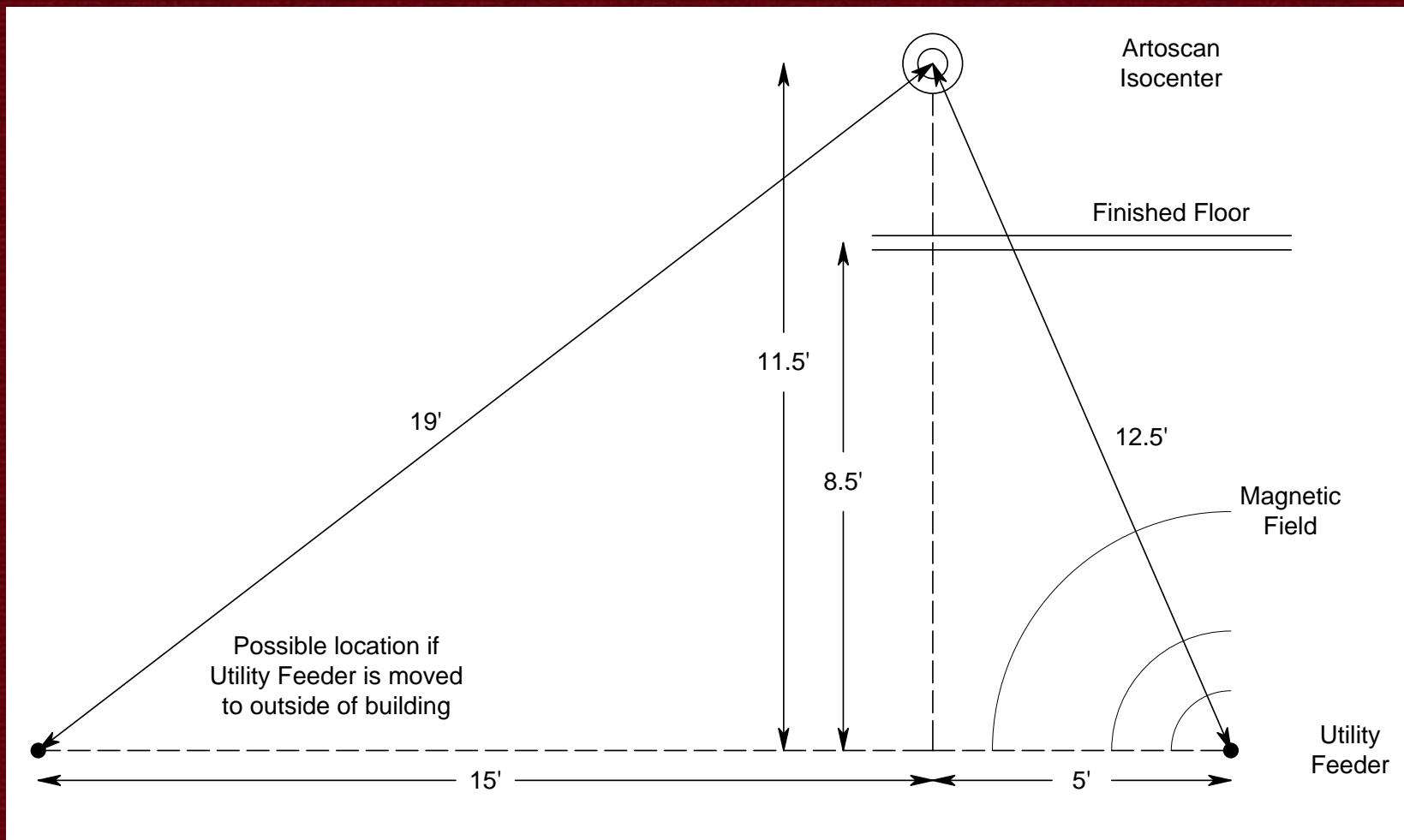
Case Study #3: Magnetic Fields caused by Net Currents





- ❖ **2.6 Amps on Service**
- ❖ **Loop with Water Pipe**
- ❖ **Solution 1:
Reduce Ground Current**
 - Improved Grounding
 - Isolation
 - Utility Involvement
- ❖ **Solution 2:
Mitigation**
 - Shield the Feeder
 - Move the Feeder

Case Study #3: Magnetic Fields caused by Net Currents



Cost-Effective Power Quality Analysis



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Nov 18, 2004