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Understanding Risk of Shock & Designing for Compliance

Overview

Product Safety – The Overall Intent

Protecting the User from

6 potential hazards

UL CSA CE UKCA EN IEC

6 Basic Safety Hazards

- Risk of Shock
- Risk of Energy
- Risk of Fire
- Risk of Injury
- Radiation Hazards
- Chemical Hazards

More than 50% of the requirements in most product safety standards are related to Risk of Shock protection

Risk of Shock

- Prevent access to Hazardous Voltages:

  G.T. 30 VRMS, 42.4 Vpk, 60 VDC
- In some standards, higher voltages are permitted with current and capacitance limits

Risk of Shock

- Requires two levels of protection = Protection under a single fault
- Insulation System Dependent

Key Definitions

Installation Categories

(IEC 60664)

- Installation location relates to maximum overvoltages
- Affects creepage and clearance distances

Installation Categories

- Category IV
- Category III
- Category II
- Category I

Category IV

- Overhead power lines
- Equipment at Service Entrance

Category III

- Load side of Service Entrance
- Before Branch Protection

Category II

- Load side of Branch Circuit Protection

Category I

- Load side of isolating power supply
- For example: Class III equipment
- Keyboards, mice

Pollution Degree

- The amount of conductive contaminants in the product's intended environment

Pollution Degree

- Affects creepage and clearance distances
- Microenvironments can exist

Pollution Degrees

- Pollution Degree 1
- Pollution Degree 2
- Pollution Degree 3

Pollution Degree 1

- Product or area within a product sealed to exclude dust and moisture

Pollution Degree 2

- Typical office/lab
- Minimal conductive dust and moisture

Pollution Degree 3

- Product or area within a product subject to conductive contaminants or moisture

Equipment Classes

- Class I
- Class II
- Class III

Class I Equipment

- Grounded
- Provides one level of protection from Risk of Shock (when “reliable”)

Class II Equipment

- Double Insulated
- No grounding conductor
- Polarized plug (US deviation)

Class III Equipment

- Product powered by SELV
- No Hazardous voltages generated
- For example: cell phone, mouse, keyboard

Working Voltage

- Maximum voltage between 2 points
- Under normal operating conditions only
- Designated as “U” in some standards

Hazardous Live

- Electric Shock Hazard
- Operator may not access without tools and warnings

Hazardous Live

Normal Operation

- Working voltage greater than 30 VRMS, 42.4 Vpk, or 60 VDC
- Higher voltages permitted with current and capacitance limits

Hazardous Live

Single Fault Condition

- Voltage greater than 50 VRMS, 70 Vpk, or 120 VDC
- Higher voltages permitted with current and capacitance limits

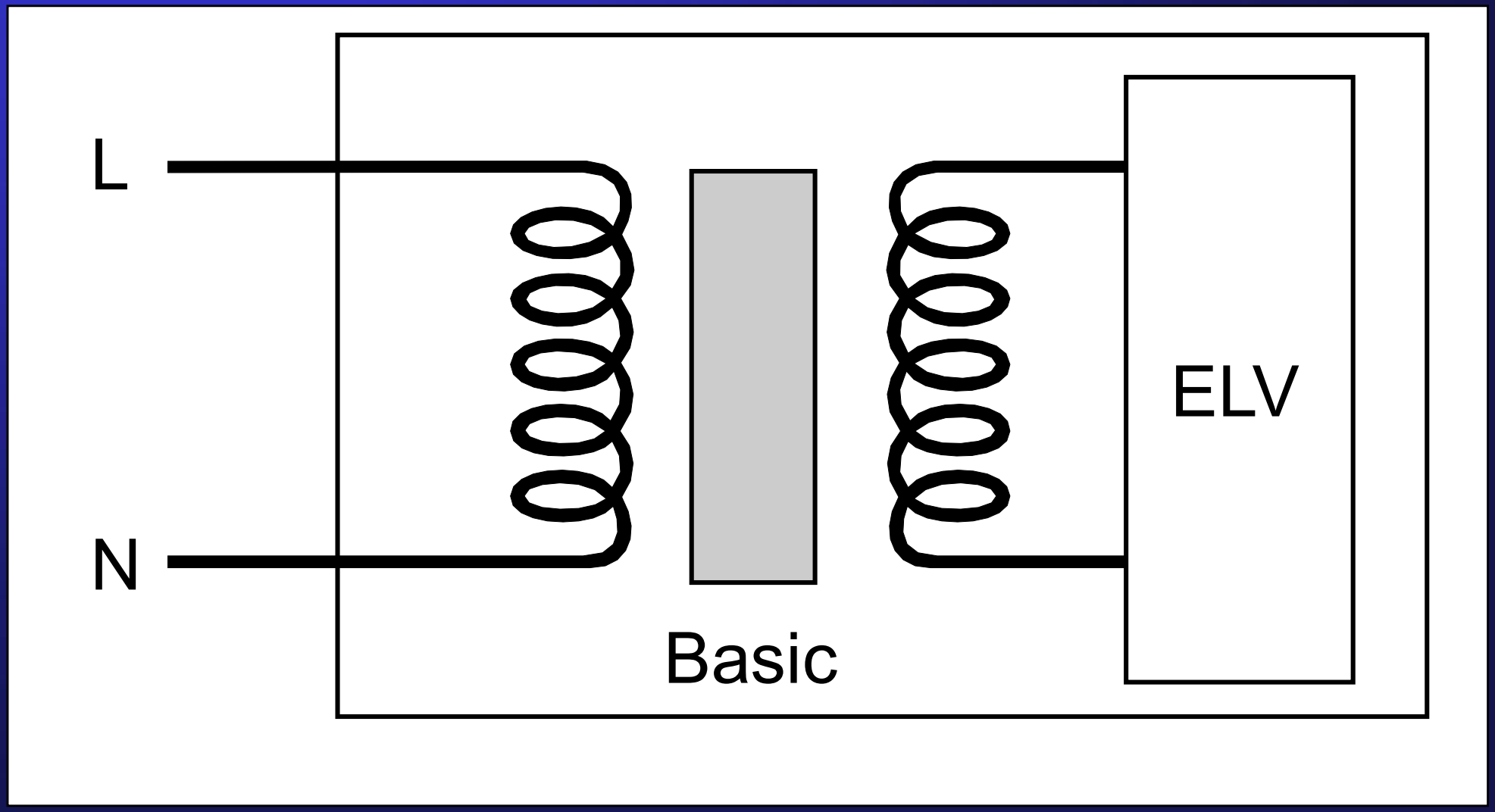
ELV

- “Extra Low Voltage” Circuit
- Isolated Secondary Circuit
- Working Voltage is not “Hazardous”

ELV

- Isolated from Hazardous Voltage by Basic Insulation only (one level of protection)
- Operator **may not** access without tools and warnings

ELV



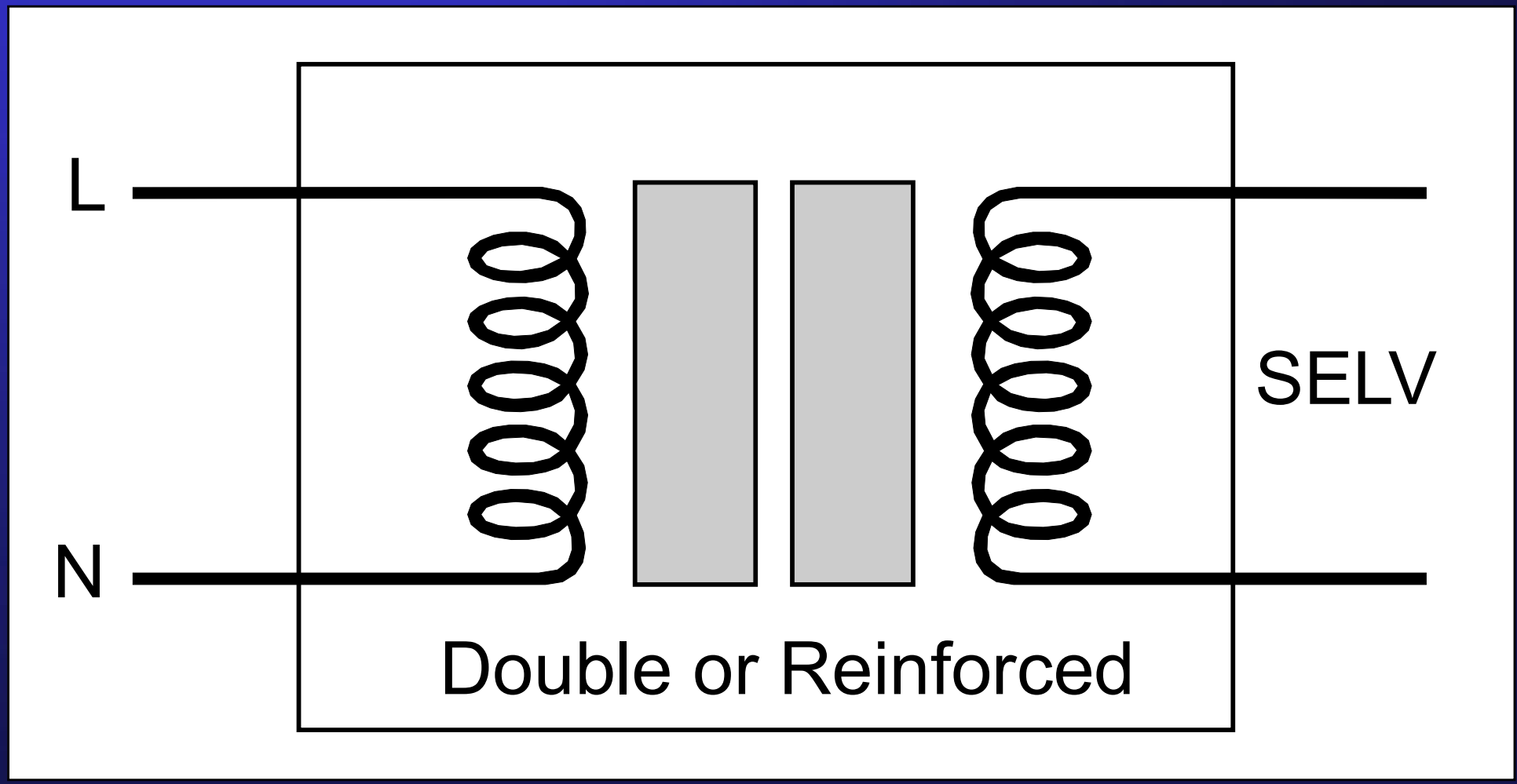
SELV

- “Safety Extra Low Voltage” Circuit
- Isolated Secondary Circuit
- Working Voltage is not “Hazardous”

SELV

- Isolated from Hazardous voltage by Double or Reinforced Insulation (two levels of protection)
- Operator **may** access

SELV



Protective Impedance

- A single *High Integrity* component
- Two or more components such that Non-Hazardous limits are maintained even under a single fault

Impedance Protected Circuit

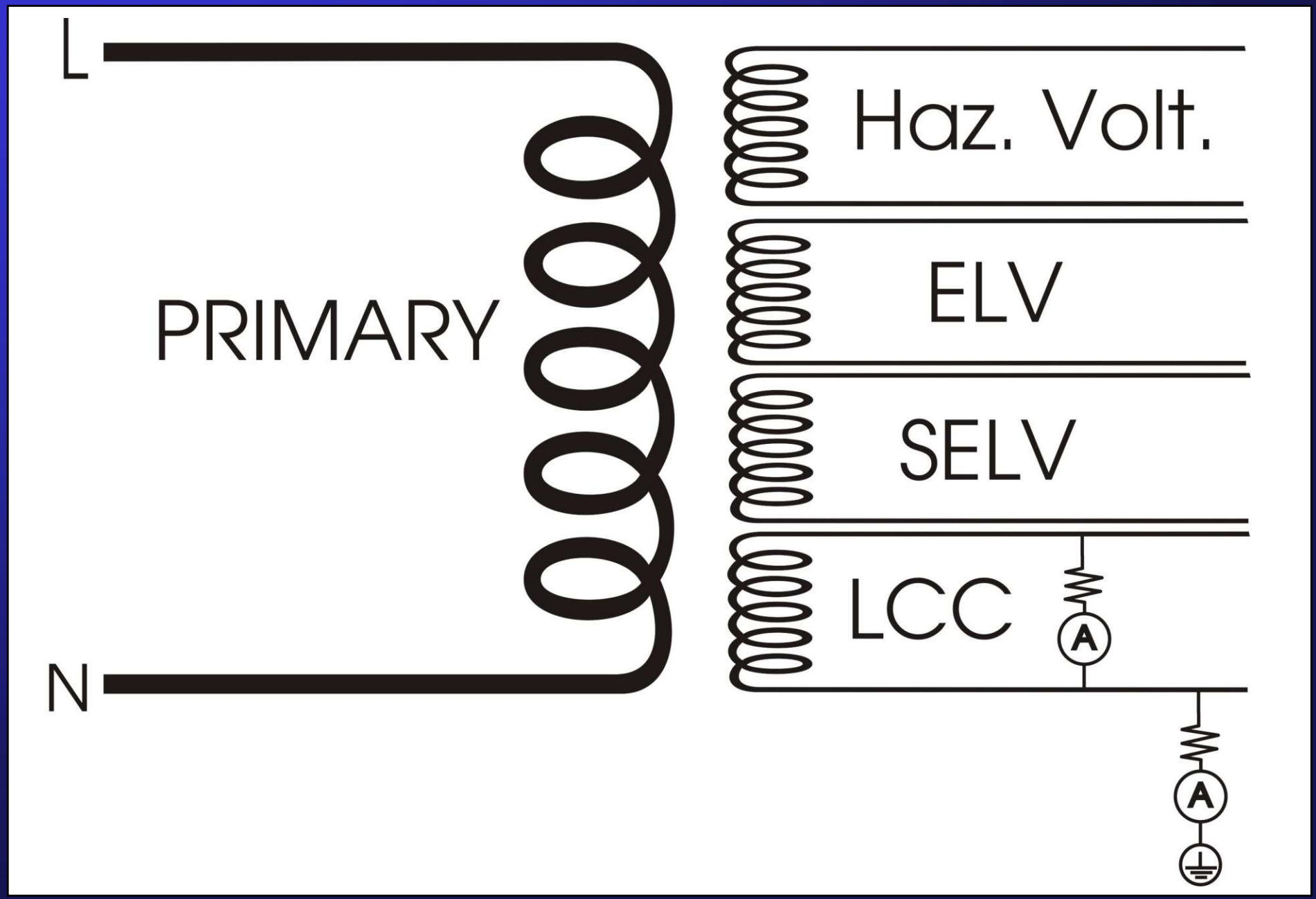
- Included in some standards
- Like SELV, this circuit type is allowed to be operator accessible
- One or more **protective impedance** components limit accessible voltage/current/capacitance to non-hazardous levels

Impedance Protected Circuit

- This type of circuit be directly connected to mains or other Hazardous circuits
- The only alternative to SELV if the circuit must be accessible and it’s not SELV

4 Possible Secondary Circuits

- Hazardous Live
- ELV
- SELV
- Impedance Protected Circuit
  (aka Limited Current Circuit)


L
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PRIMARY
Haz. Volt.
ELV
SELV
LCC
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Insulation Types

- Operational Insulation
- Basic Insulation
- Supplementary Insulation
- Double Insulation
- Reinforced Insulation

Operational Insulation

- Insulation to support operation of product only
- Does not provide a level of protection from Risk of Shock

Basic Insulation

- Single Level of Insulation
- Provides one level of protection from Risk of Shock

Supplementary Insulation

- A second, independent level of insulation
- By definition, it is used as part of double insulation system

Supplementary Insulation

- Provides 1 **additional** level of protection from Risk of Shock

Double Insulation

- Consists of Basic + Supplementary insulation
- Provides 2 levels of protection from Risk of Shock

Reinforced Insulation

- Consists of multiple levels of same insulating system
- Provides 2 levels of protection from Risk of Shock

Reinforced Insulation

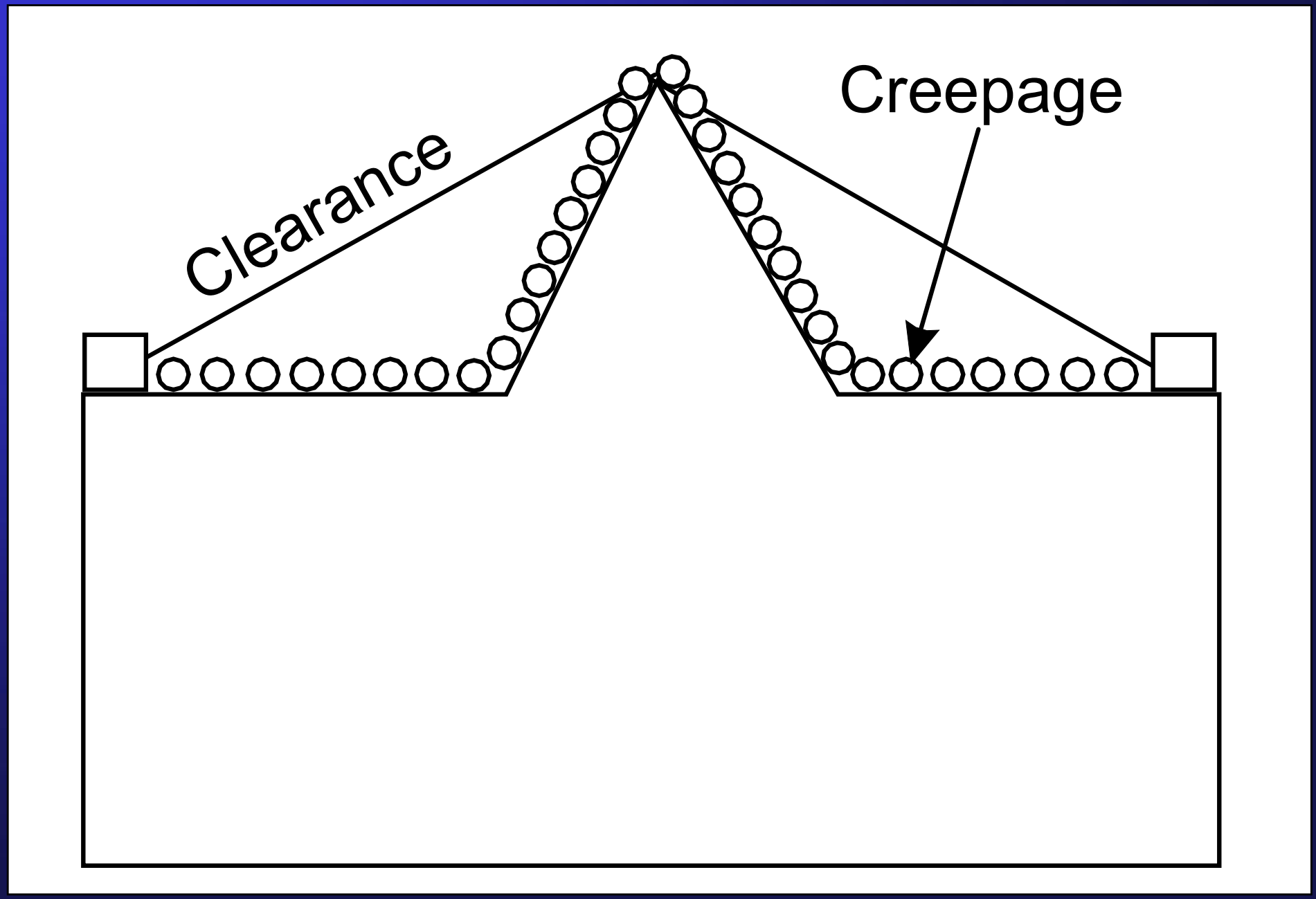
- Provides a level of protection from a Risk of Shock equivalent to Double Insulation

Creepage Distance

- The shortest distance **over surface** between two conductive parts

Clearance Distance

- The shortest distance **through air** between two conductive parts


Clearance
Creepage

IMPORTANT - The *Key Definitions* are much more than just definitions = they are the "knowns" that define the circuit to be evaluated

ALWAYS identify them 1st!

Initial Shock Hazard Design Considerations

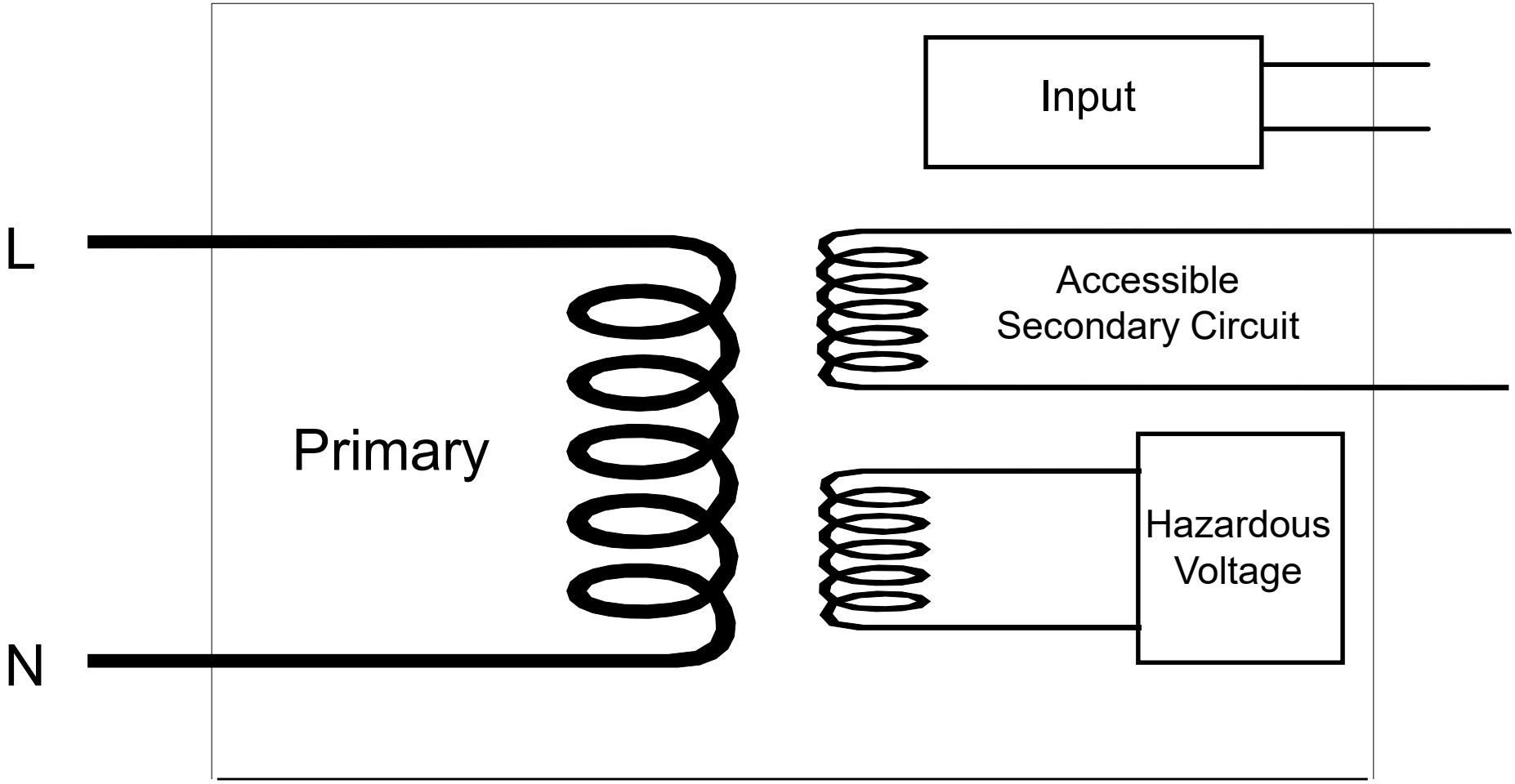
Remember The Intent

- Protect the user from access to Risk of Shock
- Two levels of protection to all accessible circuits

Two Levels of Protection

- Operator to Hazardous Live Mains
- Operator to Hazardous Live Secondary
- Operator through SELV Accessible Secondary to Hazardous Live

Simple Insulation Diagram



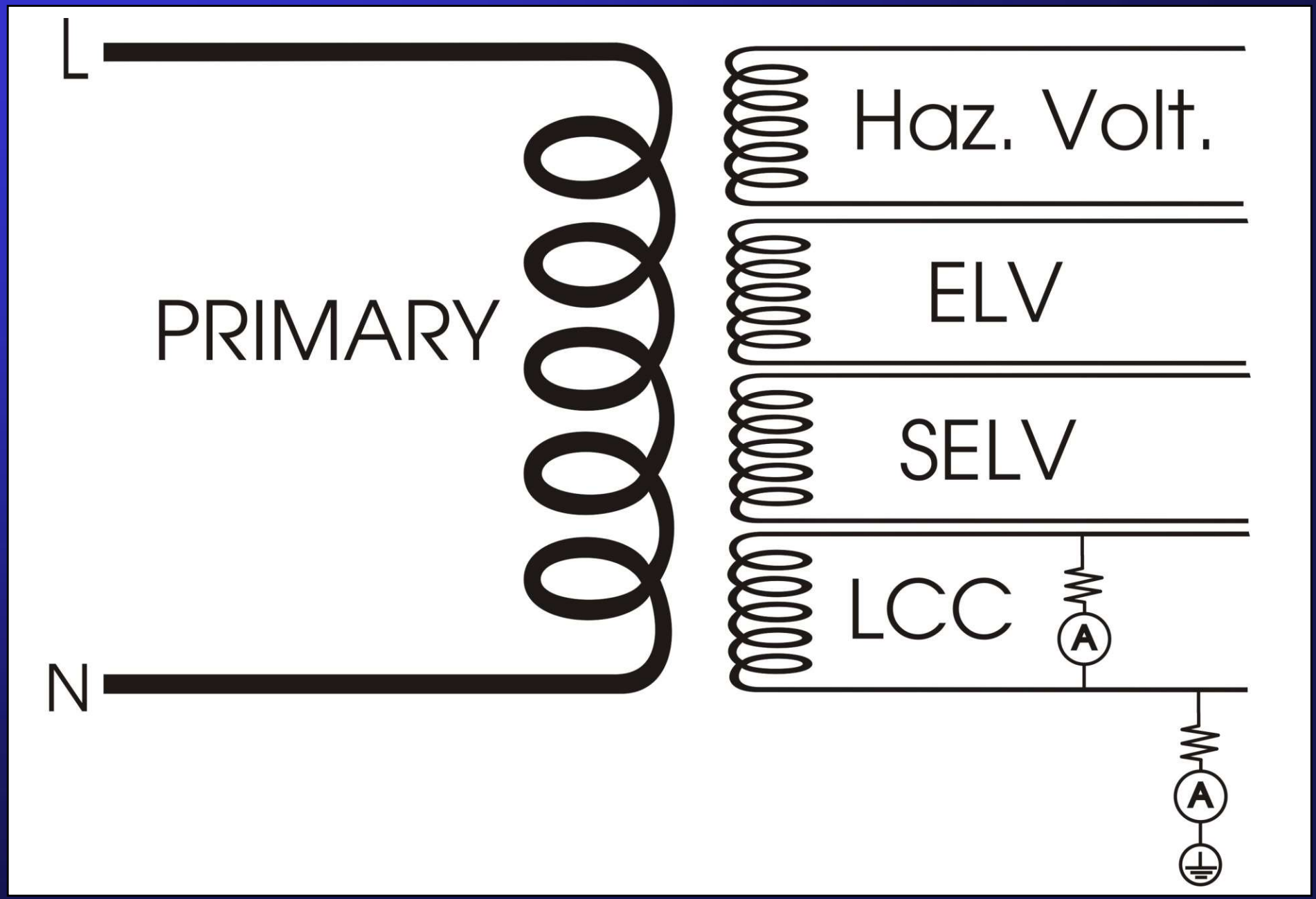
Accessibility Requirements

Operator May Not Access

- “Hazardous Live” Circuits
- ELV Circuits

Operator May Access

- Circuits which **are not** Hazardous Live
  : SELV
  : Impedance protected circuits
- Earthed parts
- Test and measurement terminals
  (T&M standard)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Accessibility Criteria

- Circuits which can be contacted by the accessibility probes
- Parts removable without tools are removed before using probes

Accessibility Criteria

- Examples of accessibility probes:
  - : Finger probe – applied everywhere
  - : Test pin – some exceptions on where the pin is to be applied
  - : Other probes vary by standard and application
    - For example, the recessed controls probe in 61010-1

Accessibility Criteria

- Circuits which the operator is instructed to reach per the operating instructions are considered accessible unless:
  - : Requires use of tools and,
  - : Warning markings and instructions

Secondary Circuit Design Considerations

- Will the operator have access to the circuit?

If you need the operator to access the circuit, the circuit **must not** be considered "Hazardous Live"

Operator May Access

- Circuits which **are not** Hazardous Live
  - : Impedance protected circuits
  - : SELV
- Earthed parts
- Test and measurement terminals

Risk of Shock Protection Methods

Creating a SELV Circuit

- 4 Methods to achieve SELV
- Remember: 2 levels of protection from Hazardous Live required

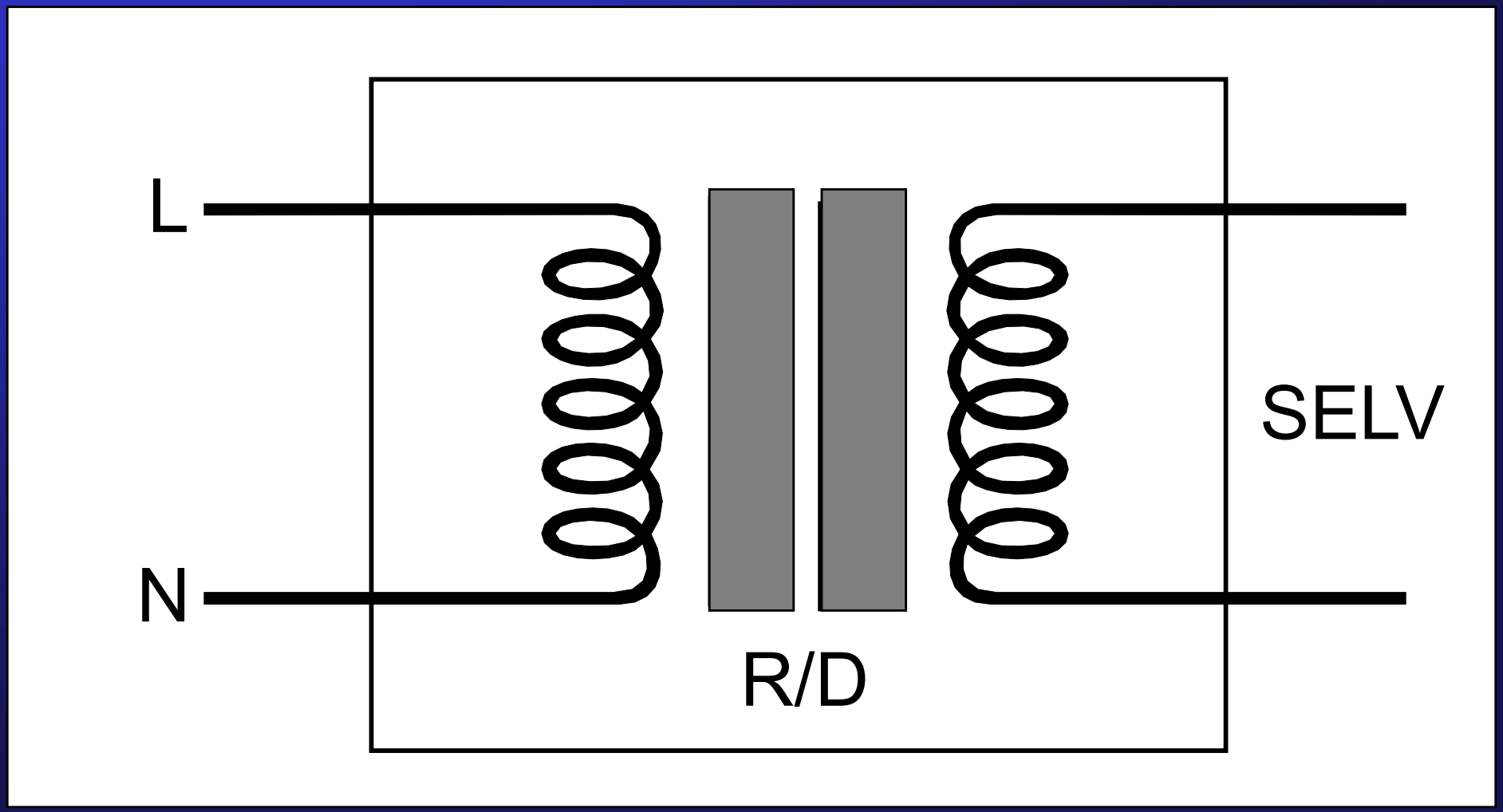
Creating SELV

- In general, limit normal operating voltage in SELV circuit to 30VRMS, 42.4Vpk, or 60VDC
  (Higher voltage may be permitted with current and capacitance limits)
- Single fault voltage limit in SELV circuits is 50VRMS, 70Vpk, 120VDC

SELV Method 1

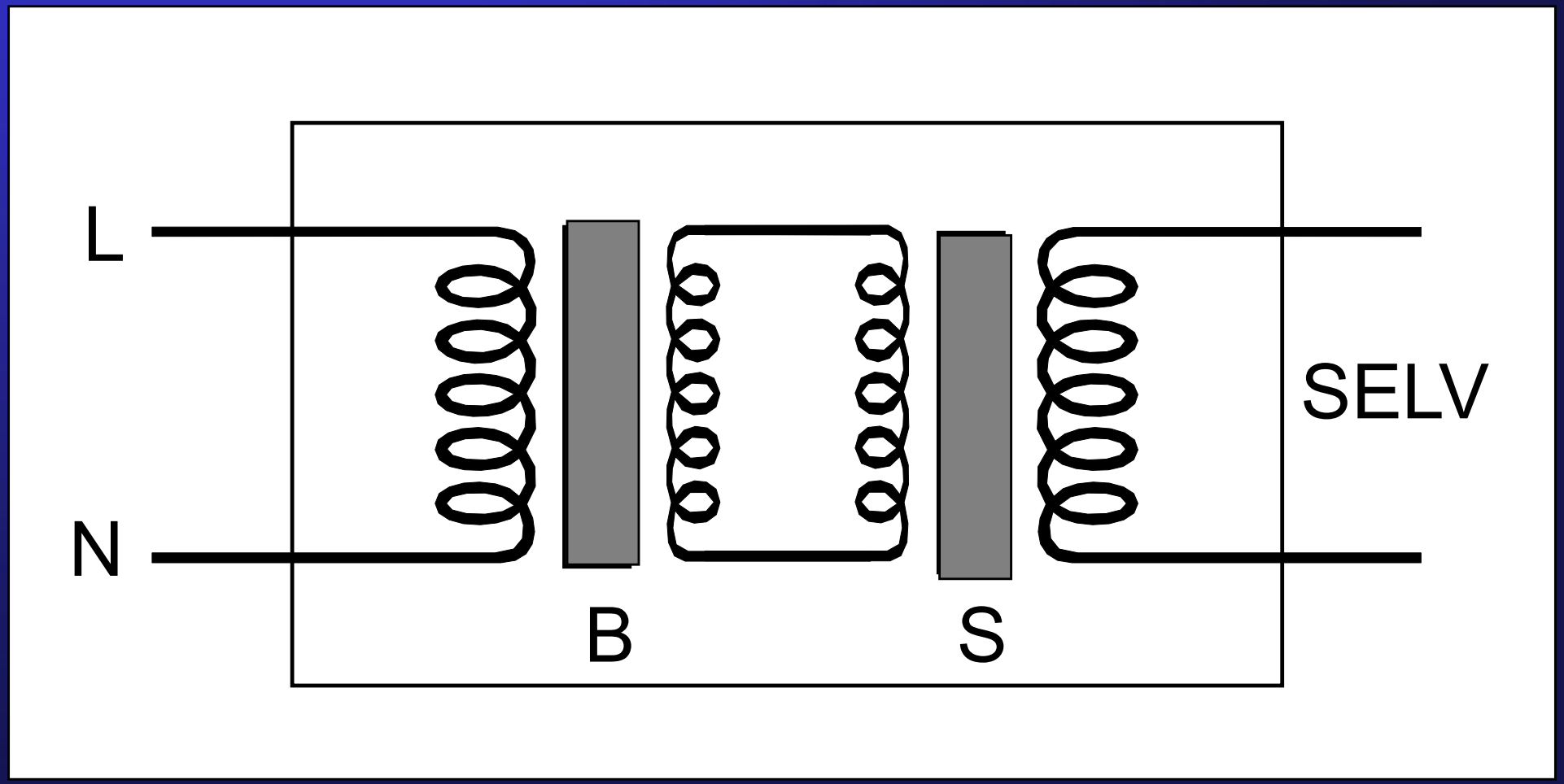
- Separation from Hazardous Live by double or reinforced insulation
- Can use tandem transformers

SELV Method 1



SELV Method 1

Alternate – Tandem Transformers

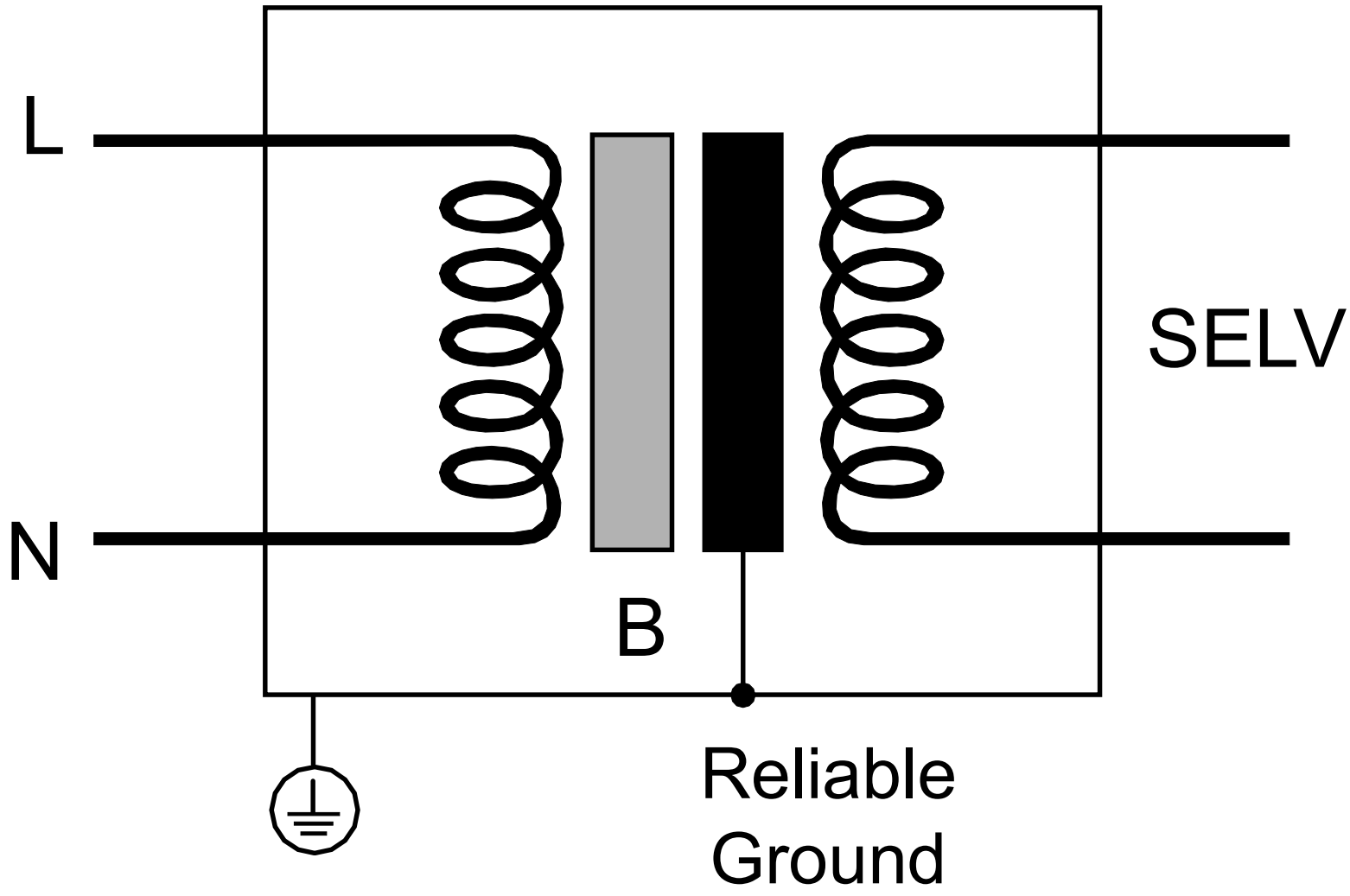


SELV Method 2

- Separation from Hazardous Live by an earthed screen
- Class I Equipment only

SELV Method 2

Ground Screen in Transformer

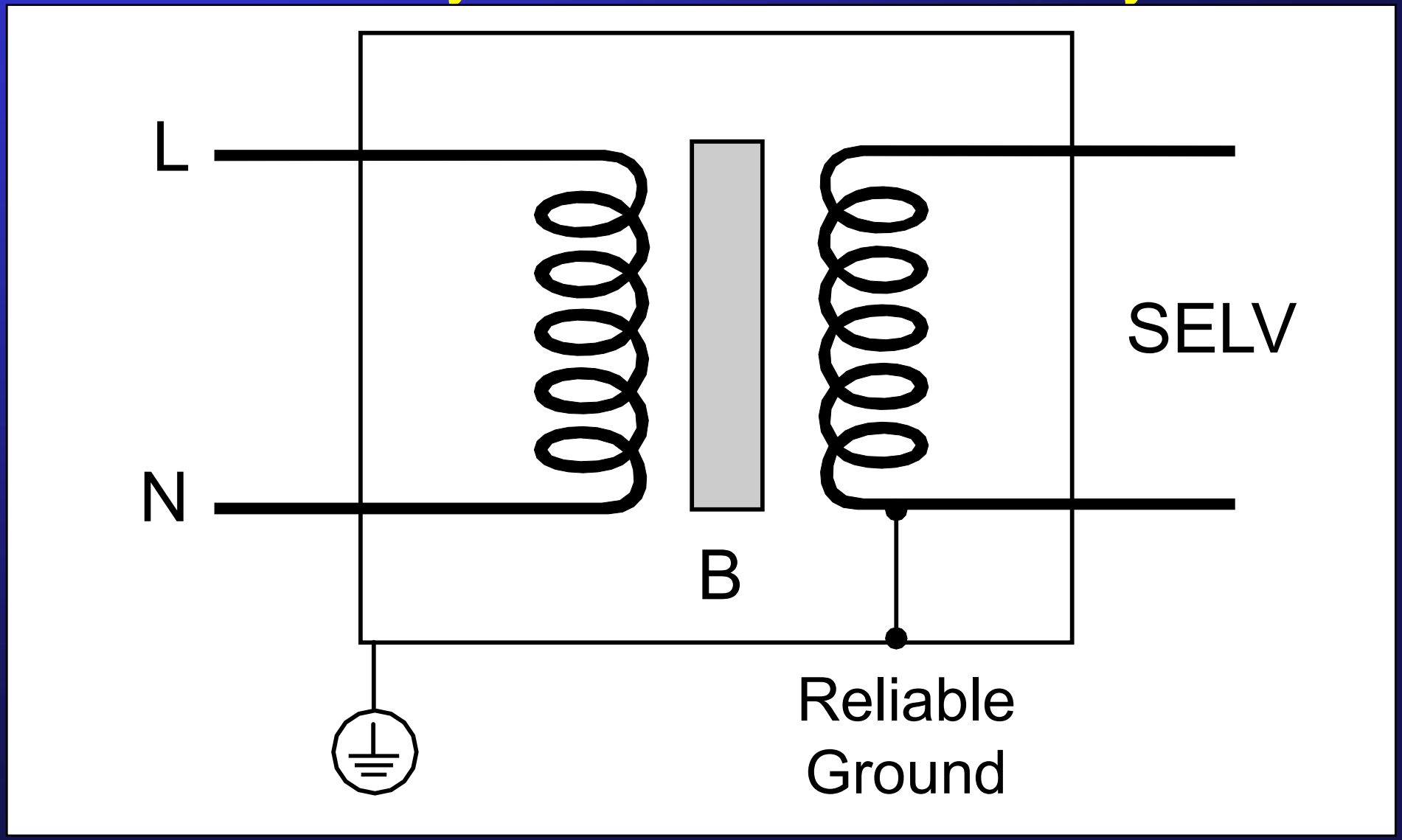


SELV Method 3

- Earthing of the SELV circuit + basic insulation to other circuits
- Class I Equipment only

SELV Method 3

Reliably Grounded Secondary

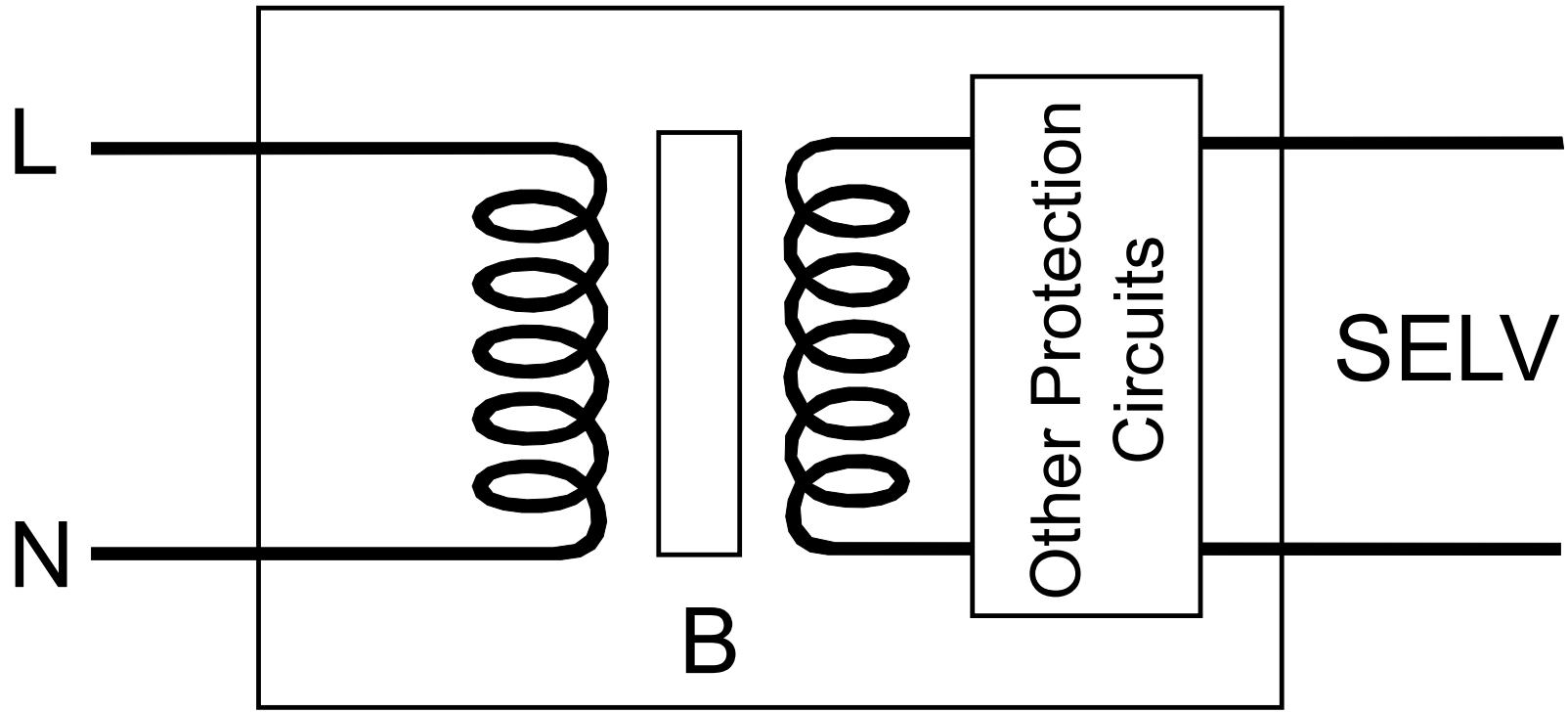


SELV Method 4

- Separation from other circuits by Basic insulation + “other protection circuits”
- “Other protection circuits” protect when Basic fails

SELV Method 4

Basic + “Other Protection Circuits”



Mains Transformers

- Creepage & Clearance and, Hipot testing for $^{B}/_{I}$, $^{D}/_{I}$, or $^{R}/_{I}$
- Overload Test
- Short-Circuit Test

Protective Impedance

- A single *High Integrity* component
- Two or more components such that Non-Hazardous limits are maintained even under a single fault

Impedance Protected Circuit

- Like SELV, this circuit is permitted to be operator accessible
- One or more **protective impedance** components limit accessible voltage/current/capacitance to SELV levels

Impedance Protected Circuit

- Can be directly connected to mains or other Hazardous circuits
  : The only alternative to SELV if the circuit must be operator accessible and mains connected

Insulating Materials
&
Risk of Shock Protection

Insulating Materials

- Solid Material
- Layered Material
- Laminated Material
- Air

Insulating Materials

- Evaluated for electrical, thermal, and mechanical properties

- Based on the working voltage and the environment (temperature, pressure, humidity, and pollution)

Insulating Materials

- Evaluation Criteria:
  1) Electric Strength Test
  2) Creepage Distance
  3) Clearance Distance

Insulating Materials

- Evaluation Criteria:
  4) Distance Through Insulation
  5) Heating Test
  6) Humidity Test

Insulation Types

- Operational Insulation
- Basic Insulation
- Supplementary Insulation
- Double Insulation
- Reinforced Insulation

Operational Insulation

- Insulation to support operation of product only
- Does not provide a level of protection from Risk of Shock
- Maybe be used for Risk of Fire protection

Operational Insulation

- No Creepage/Clearance or Electric Strength Testing
- No minimum thickness

Basic Insulation

- Single Level of Insulation
- Provides one level of protection from Risk of Shock

Basic Insulation

- No minimum thickness - whatever passes the hipot test

Supplementary Insulation

- A second, independent level of insulation
- Used as part of double insulation system

Supplementary Insulation

- Provides 1 **additional** level of protection from Risk of Shock

Supplementary Insulation

- In some standards, no minimum thickness - whatever passes the hipot test
- In other standards, there can be a minimum thickness such as 0.4 mm

Double Insulation

- Consists of Basic + Supplementary insulation
- Provides 2 levels of protection from Risk of Shock

Double Insulation

- Evaluated in pieces = Basic + Supplementary

Reinforced Insulation

- Consists of multiple levels of same insulating system or one solid piece of insulating material
- Provides 2 levels of protection from Risk of Shock

Reinforced Insulation

- Provides a level of protection from a Risk of Shock equivalent to Double Insulation

Reinforced Insulation

- In some standards, no minimum thickness - whatever passes the hipot test
- In other standards, there can be a minimum thickness such as 0.4 mm

Reinforced Insulation
Thin Film Materials

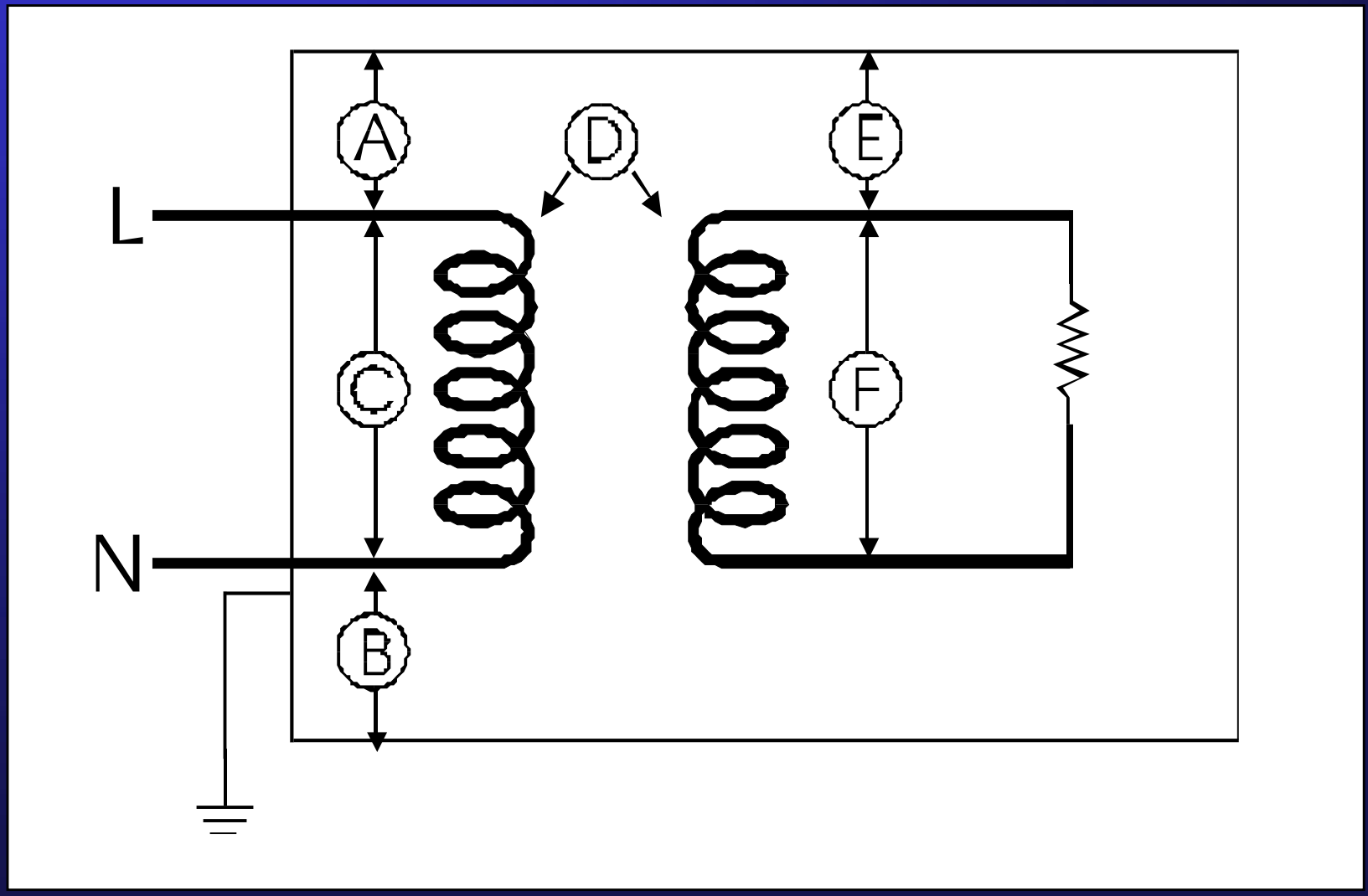
- Layers of thin film materials can be tested as reinforced insulation = minimum 3 layers where any 2 layers will pass the hipot test

Magnet Wire Insulation

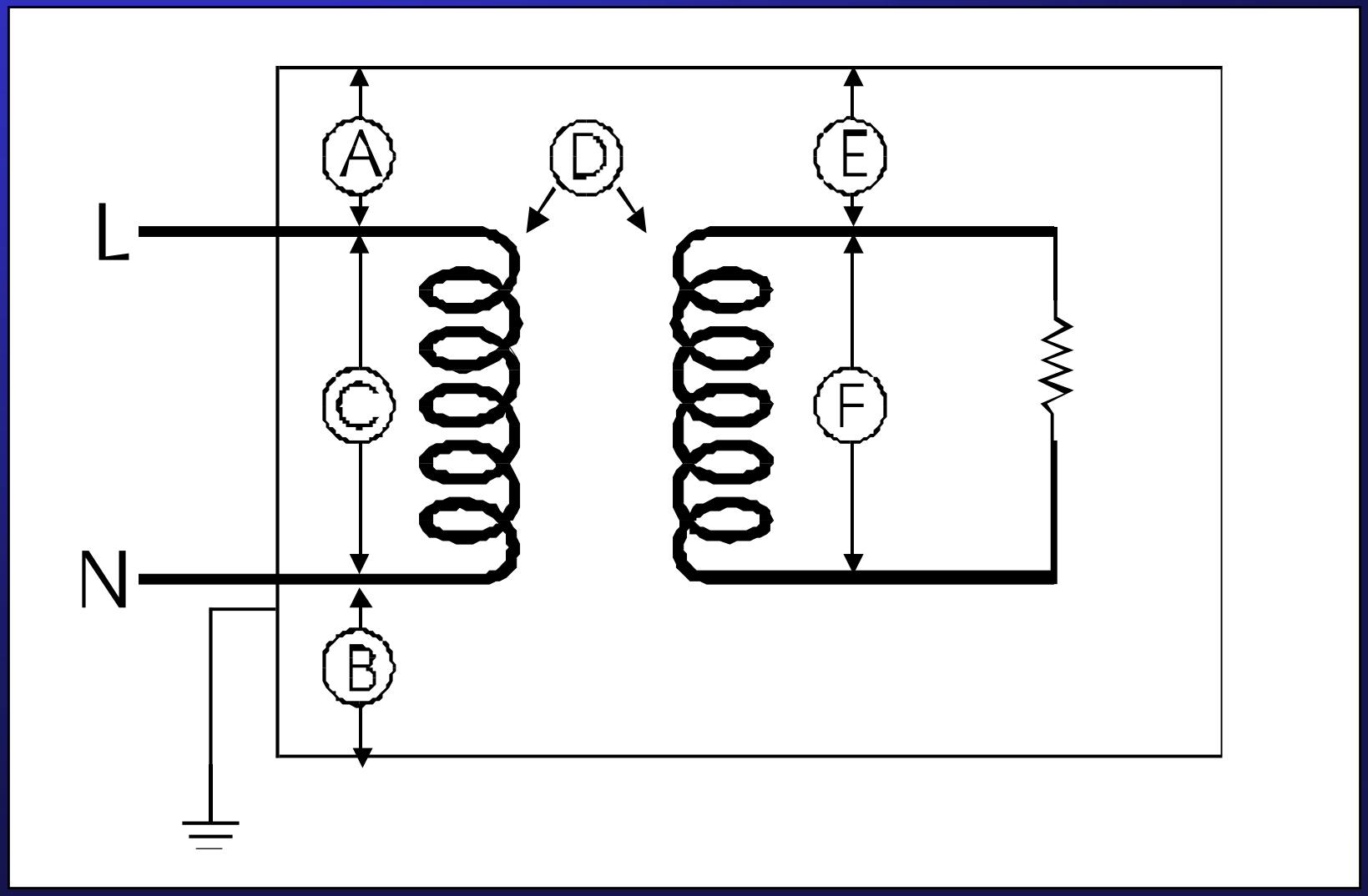
- Not Considered reliable insulation
- Considered bare part

Visualizing Risk of Shock - “Insulation Diagrams”

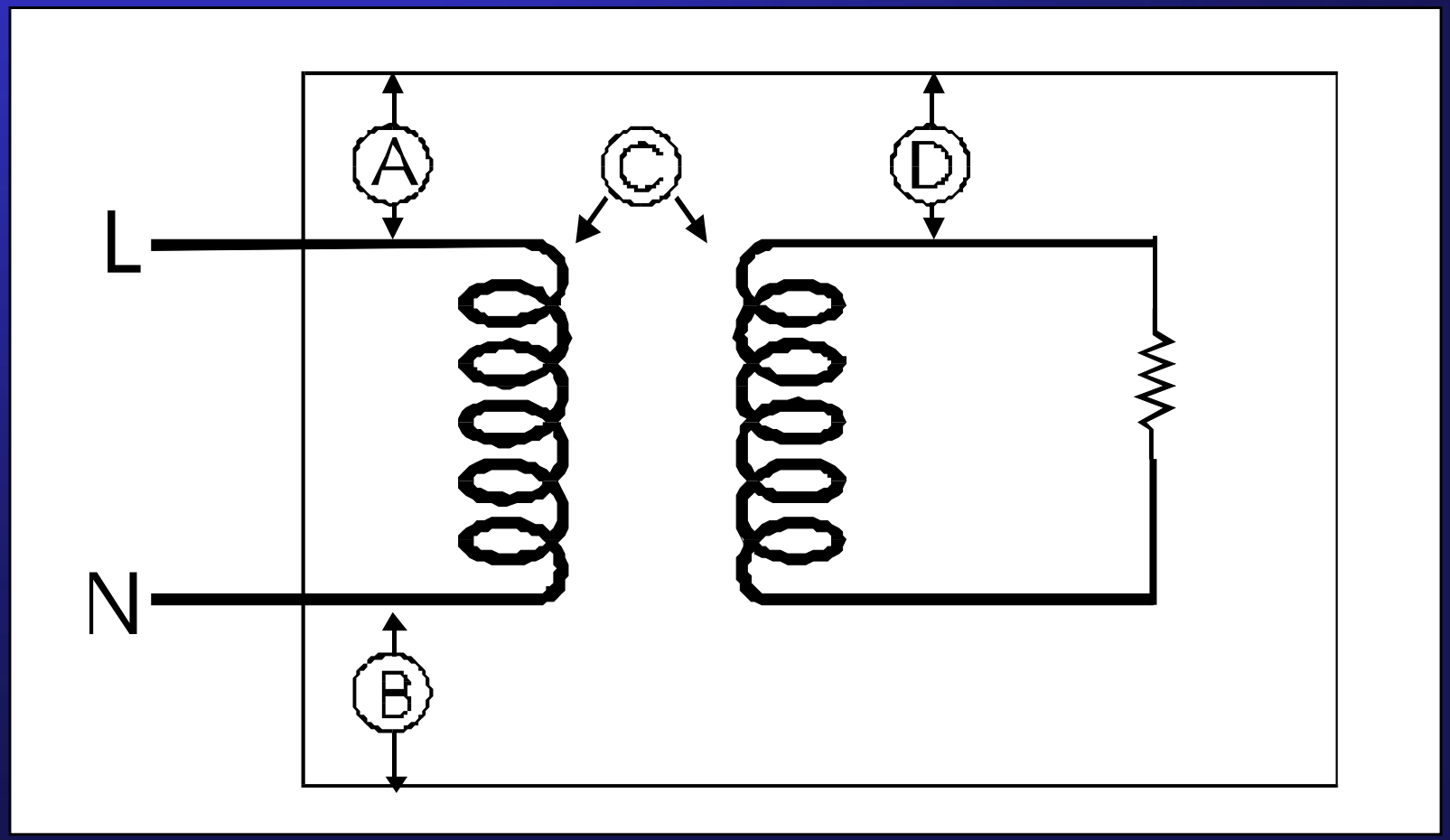
Metal Enclosure
150 V Secondary



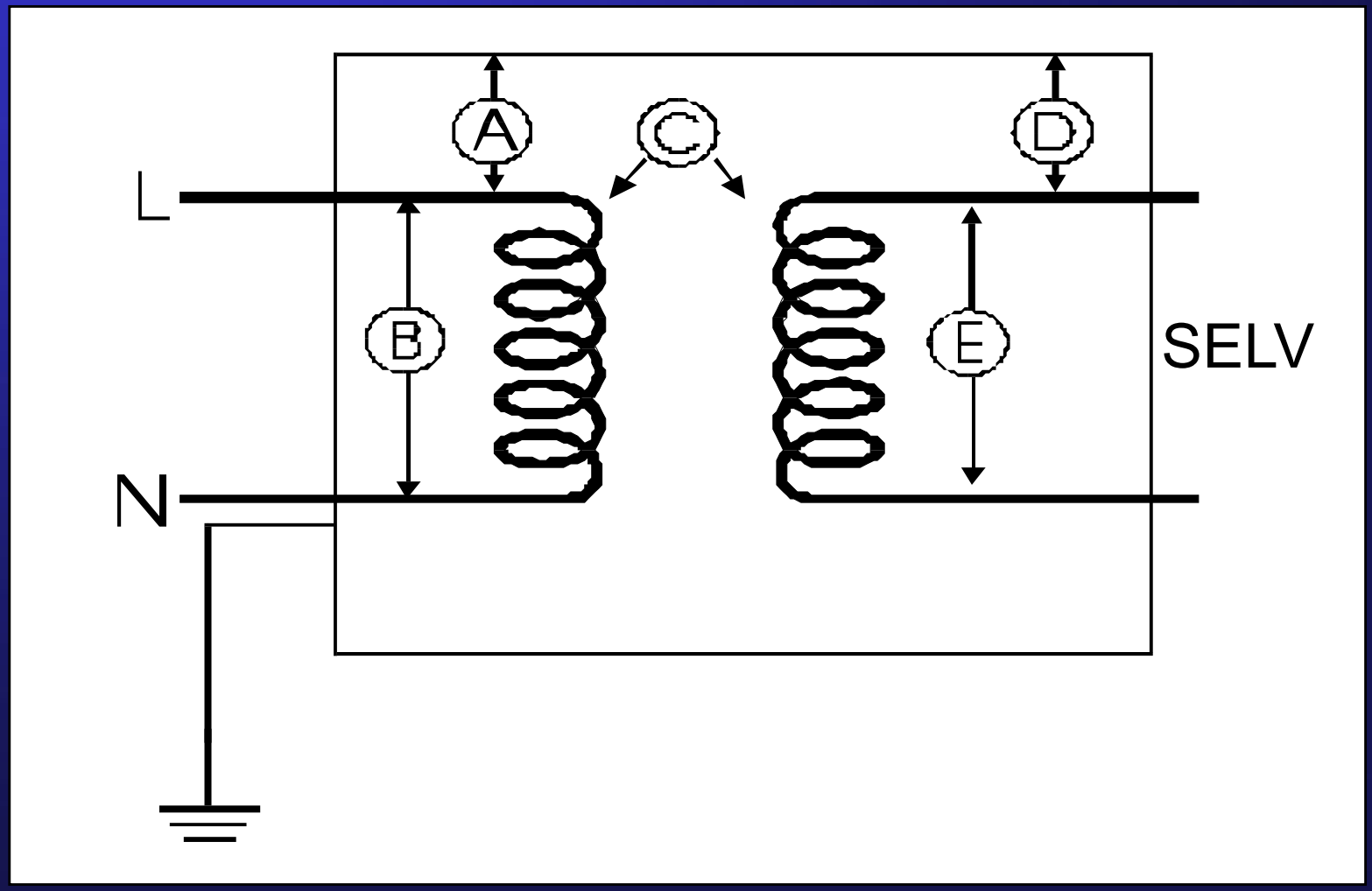
Metal Enclosure
20 V ELV Secondary



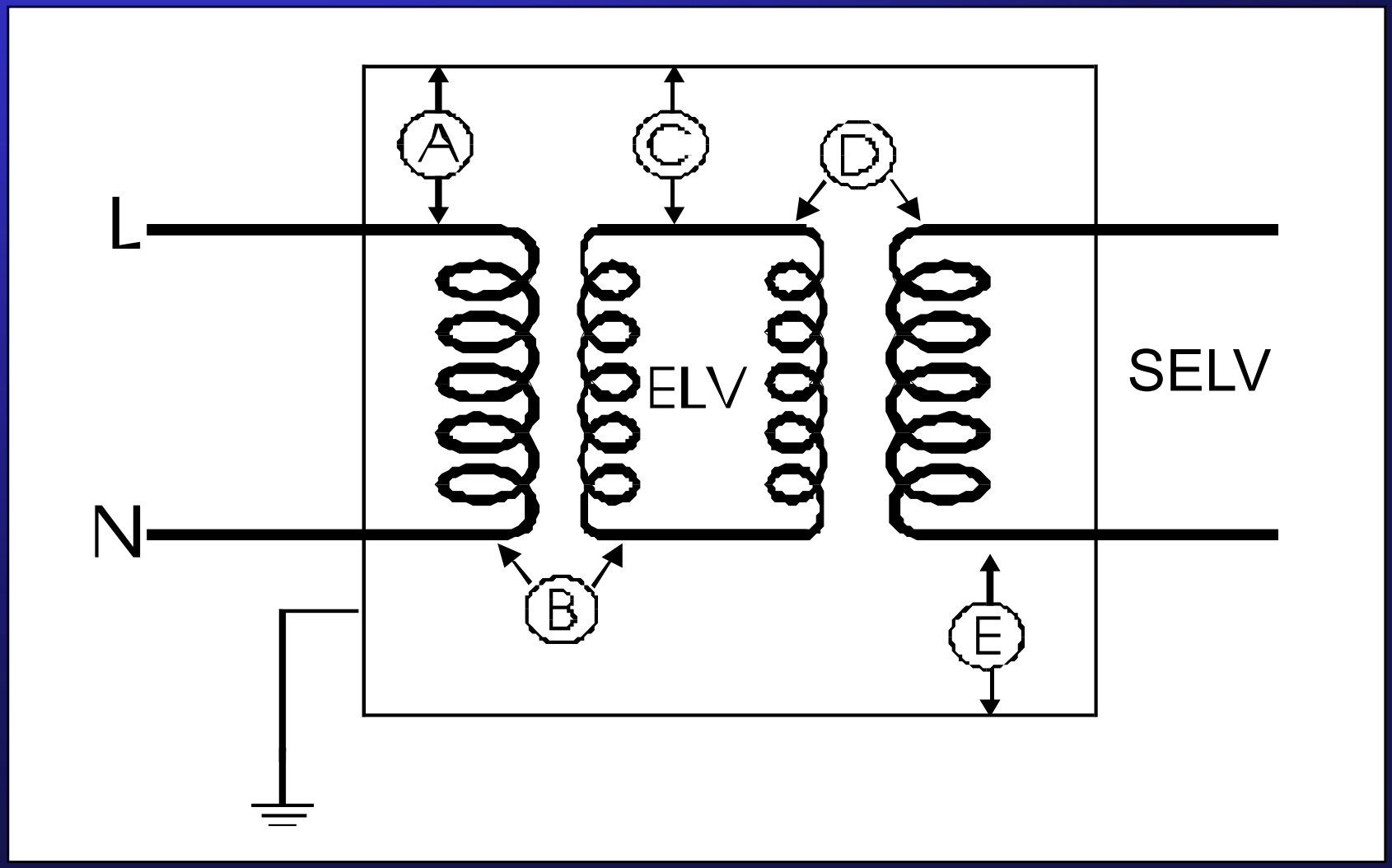
Metal Enclosure
20 V ELV Secondary



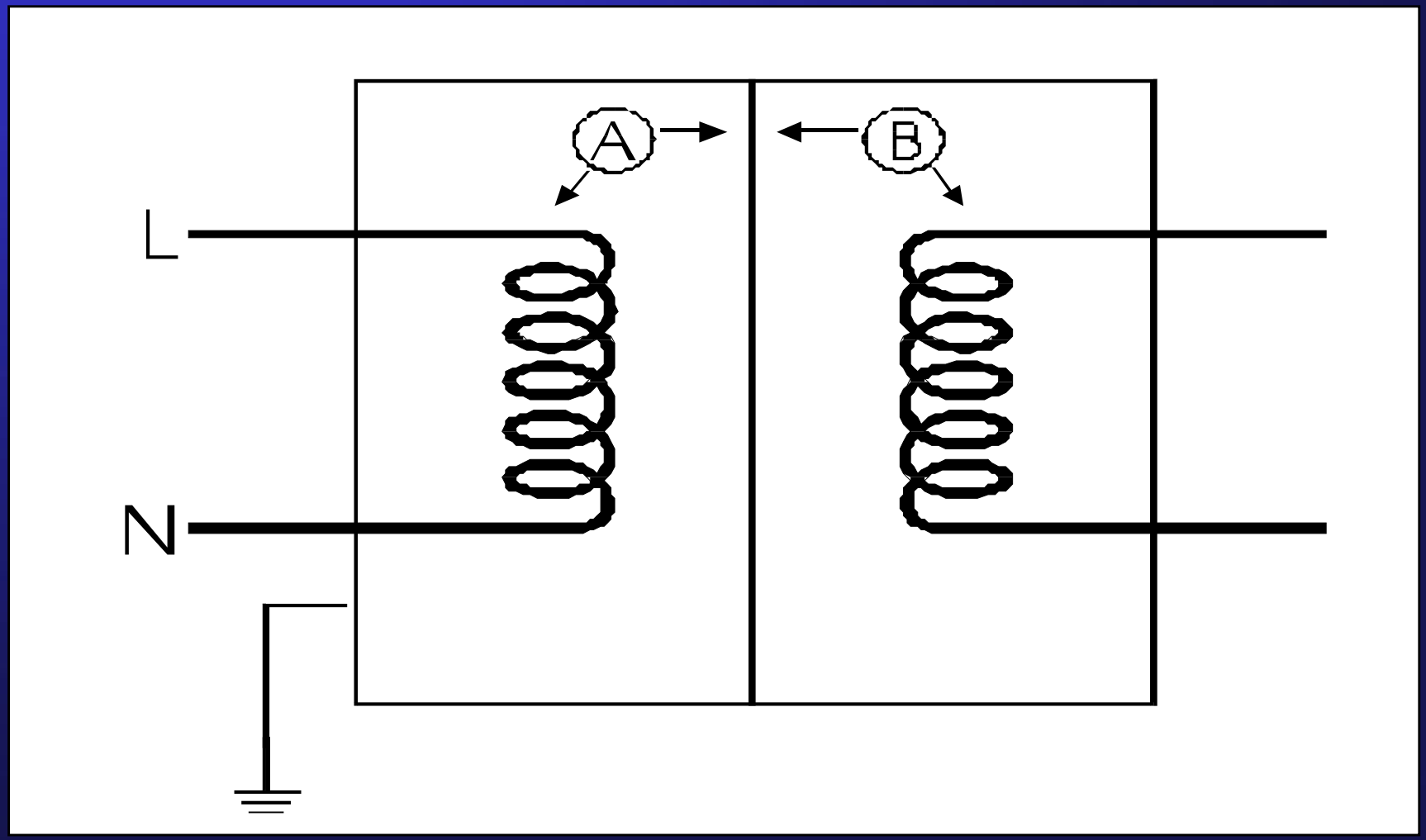
Metal Enclosure
20 V SELV Secondary



Metal Enclosure
20 V ELV to 10 V SELV



Metal Enclosure
20 V SELV Secondary



Designing for Risk of Shock Compliance

Remember The Intent

- Protect the user from access to Risk of Shock
- Two levels of protection

The Key Issue

Risk of Shock = Separation of circuits

Risk of Shock Protection

- Protect the user from shock hazard
- 2 levels of protection

Circuit Inputs/Outputs

- What is Hazardous?
- What is not?
- What is accessible?
- What is not?

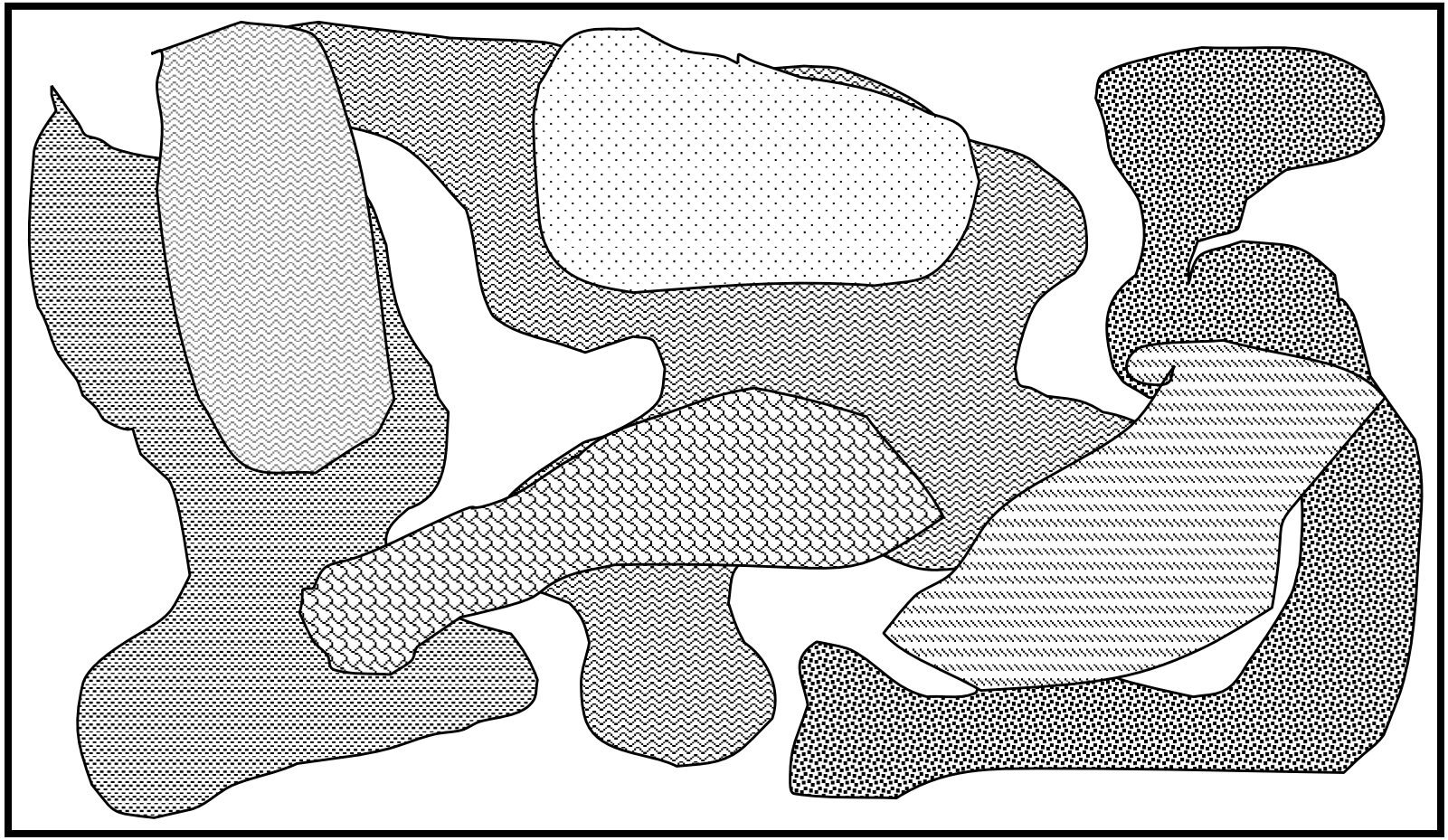
Separate Circuits - Creepage & Clearance

Hazardous Live

SELV Accessible

Hazardous Inputs

Avoid



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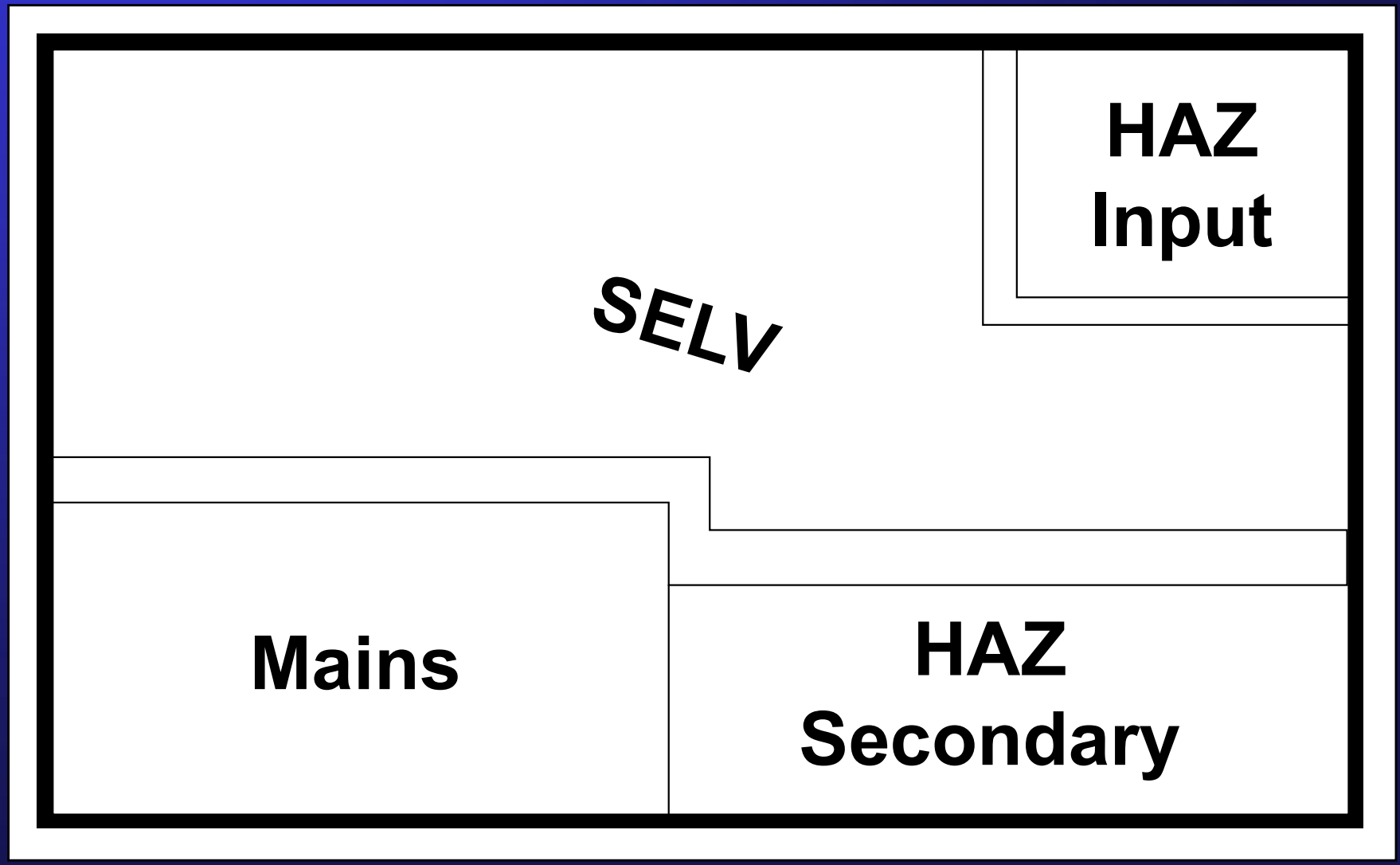

Separate Circuits - Creepage & Clearance

- $^{R}/_{I}$ on PCB between SELV and HAZ
- $^{D}/_{I}$ or $^{R}/_{I}$ air & insulation between SELV and HAZ

Printed Circuit Boards

- $^{R}/_{C}$ min. V-2
- Insulation between SELV & HAZ = creepage distance and hipot test

Options

- Use a coating to increase distance
- Reduce pollution degree (microenvironment)
- Increase CTI
- Reduce Installation Category

Wire Harnesses

- Avoid running hazardous and non-hazardous in the same harness/connector
- Flame retardant (VW-1)
- Suitable for voltage/current including what **can be contacted** by the wire (secured routing & reduce slack)

Wire Harnesses

Hazardous

- Basic insulation to earth
- $^{D}/_{I}$ or $^{R}/_{I}$ from HAZ to NH
- Single Fault protection - SELV to HAZ
  : Use double crimp connectors
  : Wire tie at cable ends if not double crimp

Summary

Product Safety – The Overall Intent

Protecting the User from

6 potential hazards

UL CSA CE UKCA EN IEC

6 Basic Safety Hazards

- Risk of Shock
- Risk of Energy
- Risk of Fire
- Risk of Injury
- Radiation Hazards
- Chemical Hazards

More than 50% of the requirements in most product safety standards are related to Risk of Shock protection

Risk of Shock

- Prevent access to Hazardous Voltages:

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- In some standards, higher voltages are permitted with current and capacitance limits

Risk of Shock

- What can the user touch? Requires two levels of protection = Protection under a single fault
- Accessibility probes to openings
- Insulation System Dependent from accessible circuits to all other circuits

Risk of Shock

Making sure what can't be touched is suitably protected from access

AND

Making sure what can be touched is allowed to be touched = SELV

Conclusion

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Understanding Risk of Shock & Designing for Compliance