Isolation in Industrial Motor Drives

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Agenda

- **Brief introduction to isolation concepts and terminologies**
- **Isolation in motor drive systems**
  - System architectures
  - Isolated gate drivers
  - Isolated delta-sigma modulators and amplifiers
  - Digital isolators
  - Isolated interfaces
- **Isolation requirement per end equipment standard IEC 61800-5-1**
  - Standard stipulations
  - Steps to pick the right isolators per IEC 61800-5-1
- **Q&A**

Introduction to ISOLATION

What is Isolation?

A means of transporting data & power between circuits with different ground references (functional isolation) or hazardous voltage levels (user safety) while preventing uncontrolled transient current from flowing in between the two.

When to isolate?

- To protect from and safely withstand high voltage surges that would damage equipment or harm humans
- To tolerate large ground potential differences and disruptive ground loops in circuits that have high energy or are separated by large distance
- To communicate reliably with high side components in high-voltage motor/inverter drive systems, switches, and metrology applications

Industrial

Automotive & HEV

Server

Communications

Why Now?

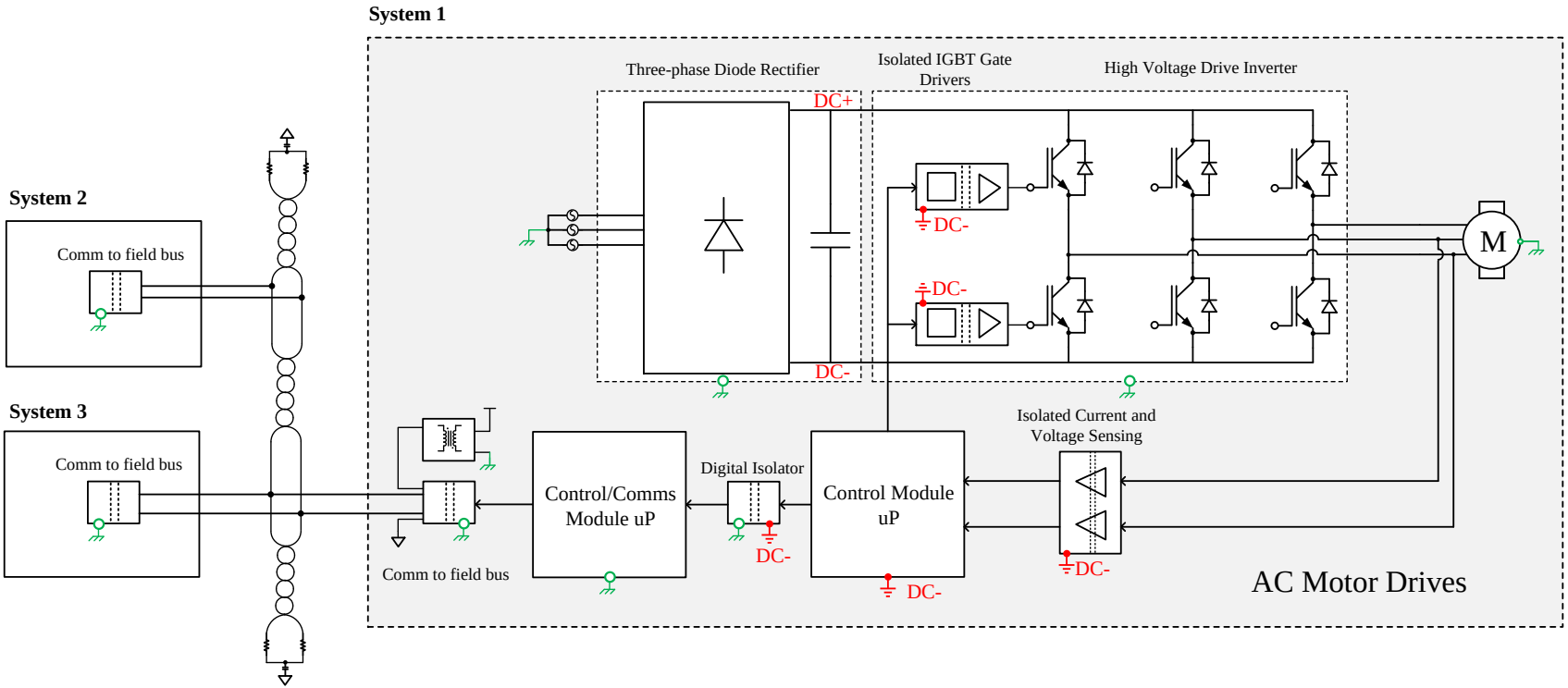
- Industry's move to the **next gen in Industrial Automation** and Control (Reliable links between Controllers/Sensors/Actuators)
- Need for step function **increase in Working Voltage and Energy Efficiency** in Motor Drives and Energy Storage/Delivery Systems

Isolation Terminology

Parameter	Definition	Relevance
Basic Isolation	Isolation that can provide protection against high voltage as long as the barrier is intact.	Basic isolation must be coupled with another insulation barrier for safety isolation.
Reinforced Isolation	Isolation that is equivalent to two basic isolation barriers in series.	Reinforced isolation by itself is sufficient as a safety barrier against high voltage.
V_{IOTM}	The sinusoidal voltage isolator can tolerate for 60s (defined in pk)	Temporary overvoltage on supplies due to load changes, arcing etc.
V_{ISO}	The sinusoidal voltage isolator can tolerate for 60s (defined in rms)	
V_{IORM}	Maximum periodic voltage that the isolator has to handle on a continuous basis throughout its operating life (defined in pk)	The continuous voltage across the isolator over lifetime.
V_{IOWM}	Maximum continuous working voltage that the isolator has to on a continuous basis throughout its operating life (defined in rms)	
V_{SURGE}	Maximum peak voltage of the 1.2us/50us IEC-standard surge waveform that the isolator can handle.	Represents direct and indirect lightening strikes.
Creepage	Minimum distance from pins on side 1 to side 2 along the surface of the package	Limits working voltage due to degradation along package surface
Clearance	Minimum distance from pins on side 1 to side 2 through the air	Limits peak voltages and surge voltages due to air breakdown
CMTI	The maximum rate of change of ground potential difference (GND1-GND2) that the isolator can withstand without bit errors	Indicates robustness of isolator to ground noise.

For details refer: http://www.ti.com/lit/pdf/slyy063

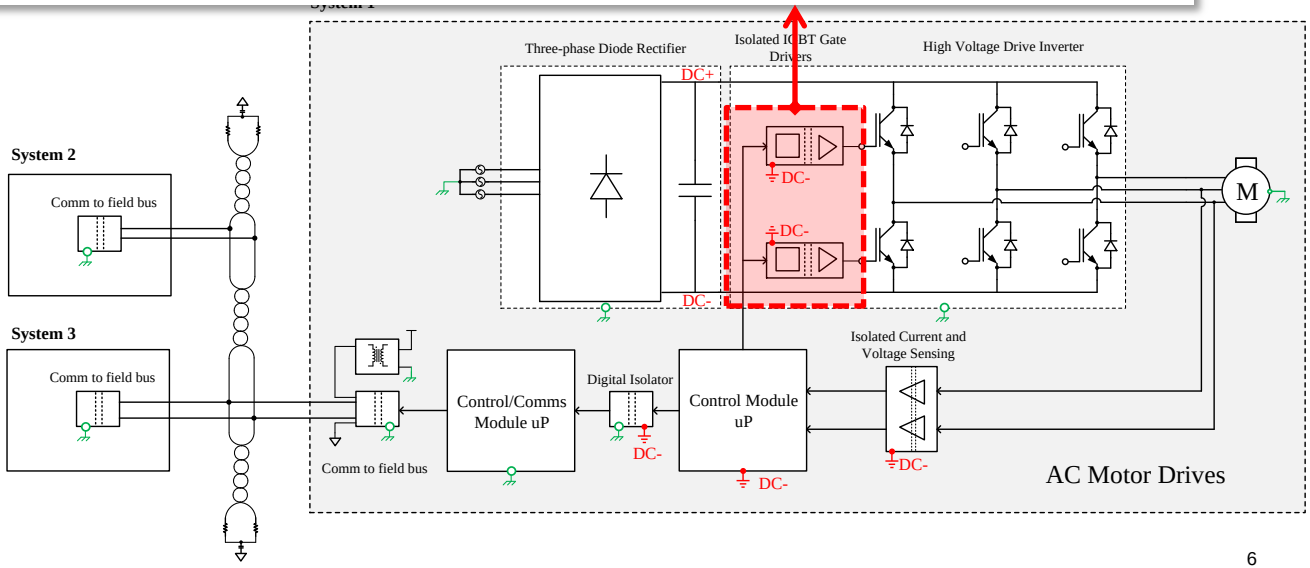
System Block Diagram of Industrial Drive System



System Block Diagram of Industrial Drive System

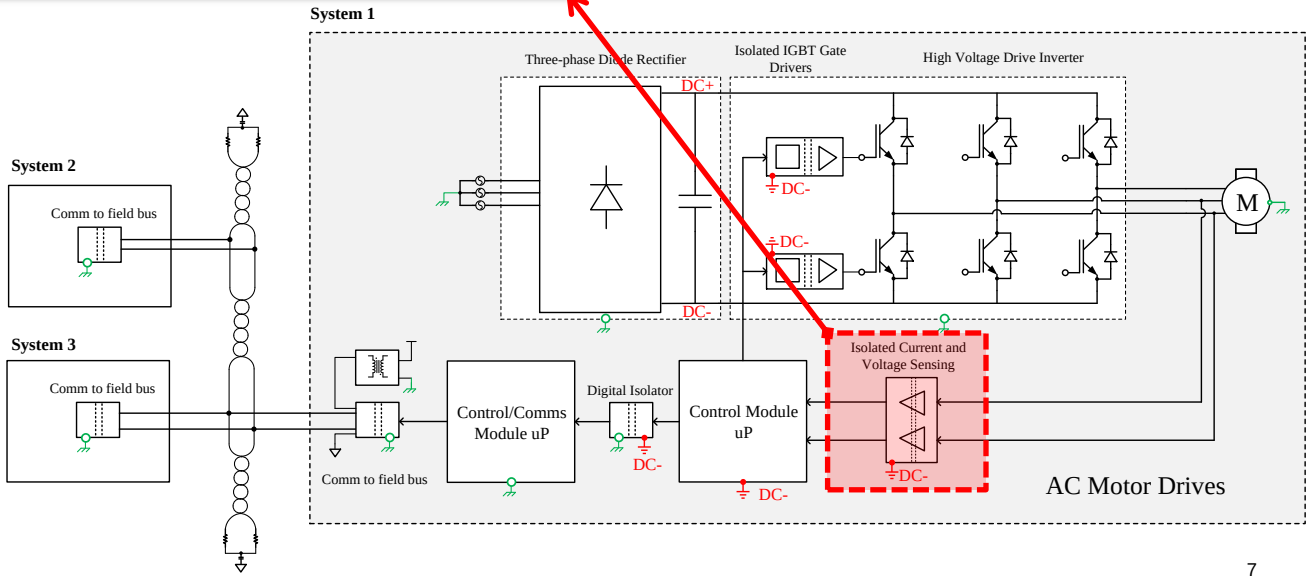
Isolated Gate Driver

- Combo solution of discrete digital isolator + gate driver. This solution is more popular for **low power drive applications** where IPMs are used.
- Isolated simple gate drivers with integrated isolation. This solution is more popular for **low to medium power drive applications**. In these applications, protections are implemented with dedicated current sensing.
- Isolated smart gate drivers with integrated isolation and protection features. This type of drivers are more for **high power applications**. The integrated protection features can protect both system and power devices in case of short circuit and over current conditions.



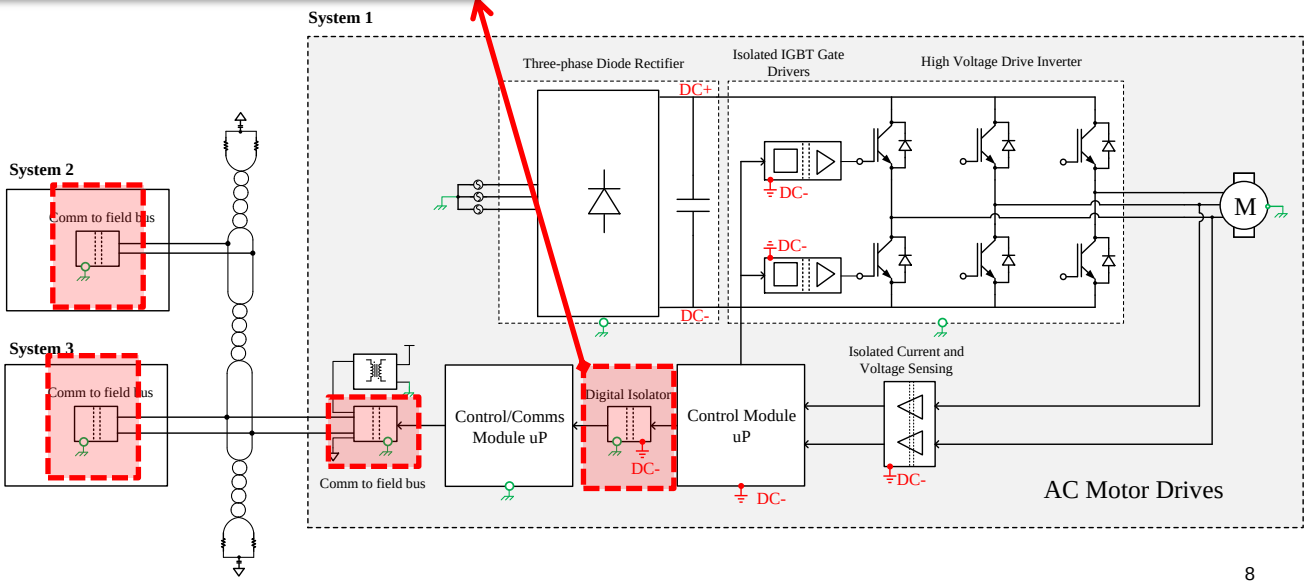
System Block Diagram of Industrial Drive System

- **Isolated current and voltage sensing**
  - LEM sensor + signal processing circuits.
  - Isolated amplifier + signal processing circuits.
  - Isolated delta-sigma modulator, which features best AC & DC performance at flexible data rate (depending on digital filter settings).



System Block Diagram of Industrial Drive System

- **Isolated Interface**
  - Combo solution of discrete digital isolator + interface protocol
  - Isolated CAN transceivers
  - Isolated RS485 transceivers
  - Isolated LVDS
  - …



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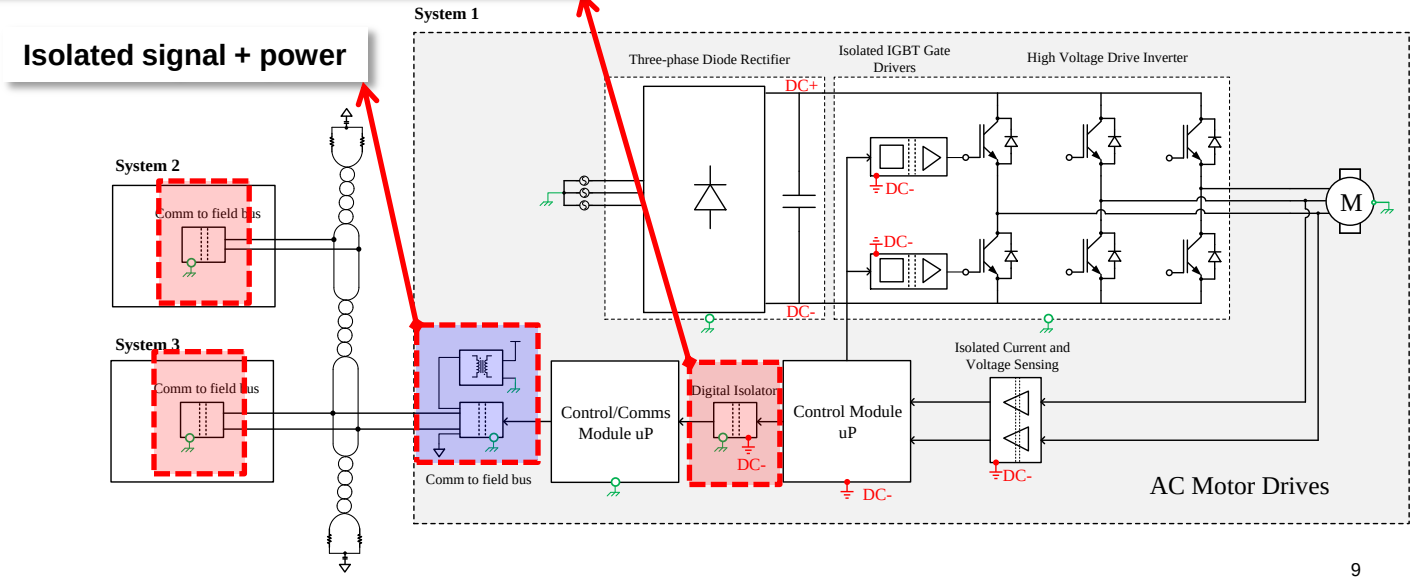
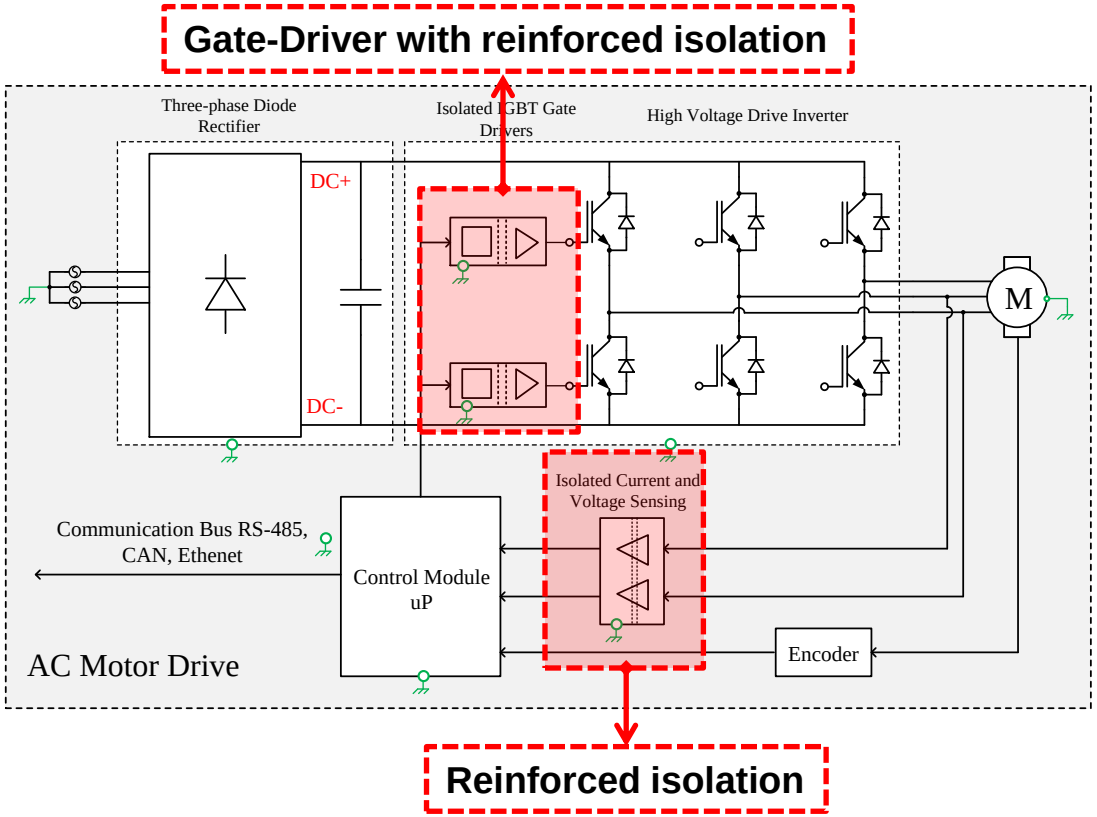
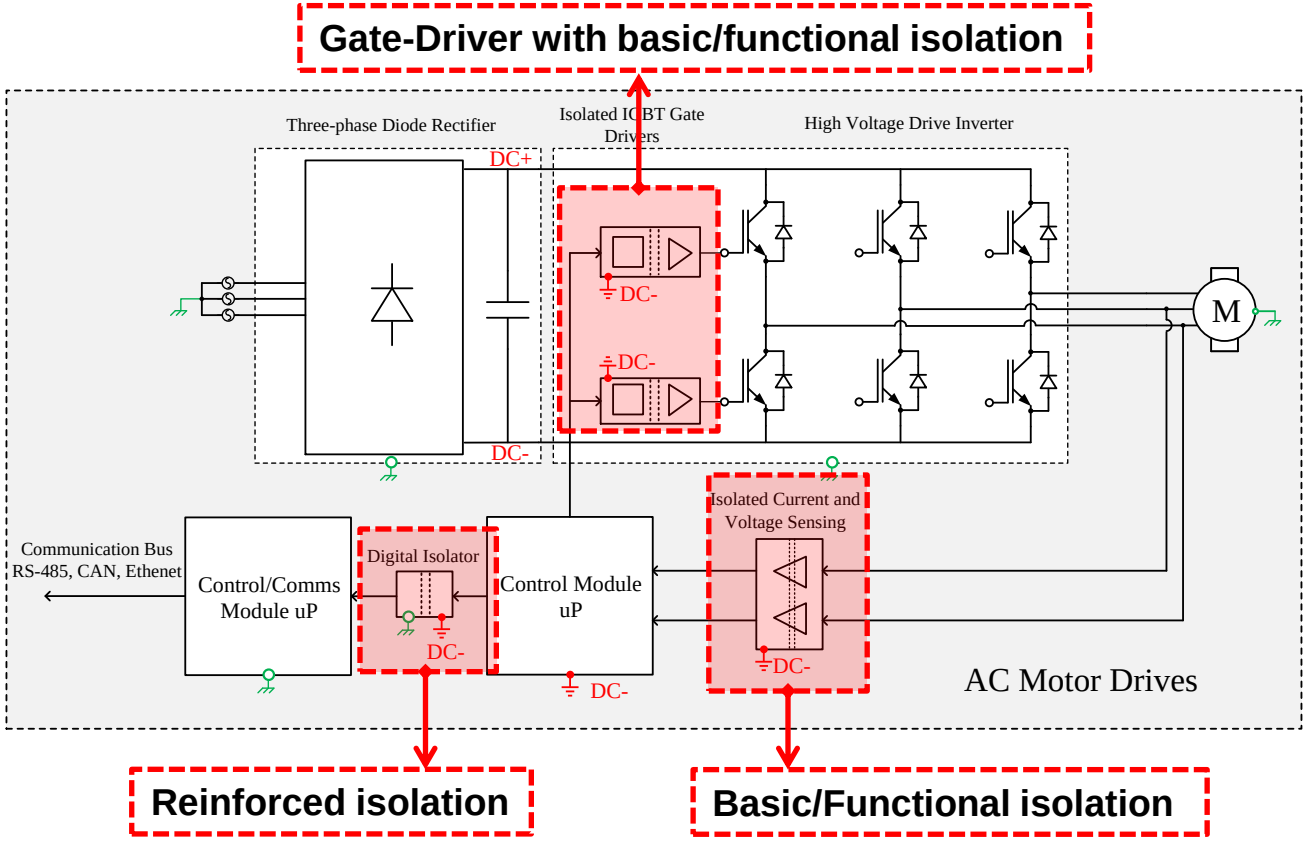


Isolation in Motor Drive System – Case I



Isolation in Motor Drive System – Case II



The Isolation Standards Landscape

Semiconductor Component Safety Standards

All isolators **MUST** pass.

Isolator type	International	Europe	U.S.	Canada	Germany
Organization	*IEC*	*CENELEC (EN)*	*UL*	*CSA*	*DIN/VDE*
Magnetic/Capacitive Isolator Standards	60747-17 (DRAFT)				VDE-0884-10/11
Optoisolator Standards	60747-5-5	60747-5-5	1577	Component Acceptance Notice 5A	DIN-EN-60747-5-5

End Equipment Safety Standards

Customer systems **MUST** pass. TI Isolators must enable.

Application	International	Europe	U.S.	Canada	Germany
Organization	*IEC*	*CENELEC (EN)*	*UL*	*CSA*	*DIN/VDE*
Reference Equipment standard for Low-Voltage Systems	60664-1	–	–	–	–
Industrial	60204	50178	508	14-M91	–
Medical	60601	60601	2601-1	601	750
Telecom	6095	0 60950/41003	1459	225	804
IT Equipment	60950	60950	60950	60950	60950
Household	60065	60065	8730-1	–	860
Motor Drives	61800-5-1	–	–	–	–
Photo Voltaic Systems (Solar)	62109-1	–	–	–	–
Measurement and Control	61010-1	61010-1	1262	1010	0410/0411
EM Immunity	61000-4-x				
EM Emission	CISPR22B				

IEC 61800-5-1: What it specifies

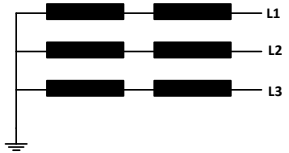
- IEC 61800-5-1 specifies the level of *insulation* required between high voltage and conductive parts/equipment surface, in terms of:
  - Working Voltage
  - Transient Overvoltage (corresponds to V_{IOTM})
  - Surge Voltage (corresponds to V_{SURGE})
  - Creepage
  - Clearance

- …. Depending On/Proportional to:
  - Basic, Double or Reinforced Isolation.
  - System Voltage (depends on supply voltage)
  - Working Voltage (corresponds to V_{IOTM})
  - Overvoltage Category
  - Pollution degree
  - Material Group

- …. Tables to establish the above relationship.

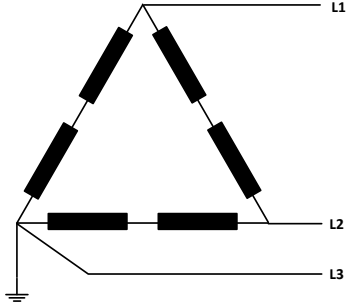
IEC 61800-5-1: Definitions

- **System Voltage**
  - For **mains circuit**, the RMS value of the rated phase voltage
    - $V_{ph\text{-}ph}/\sqrt{3}$ for 3-phase system with neutral connected to earth.
    - $V_{ph\text{-}ph}$ for 3-phase system with one phase connected to earth.



Neutral to earth

- **Overvoltage Category** is:
  - IV for equipment connected permanently at origin of an installation (downstream of main distribution board).
  - III for equipment connected to supply in fixed installations (downstream of main distribution board)
  - II for equipment not permanently connected to supply, but connected through a plug.



One phase to earth

Steps to choosing Isolators per IEC 61800-5-1

- **Step 1**: Identify Isolators, determine if basic or reinforced.
- **Step 2**: Determine System Voltage based on supply line voltage and earthing scheme.
  - Interpolation not allowed. Next defined System Voltage must be chosen.
- **Step 3**: Determine V_{ISO} and V_{SURGE} requirements from System Voltage.
  - For reinforced use 2x V_{ISO}, and next level of V_{SURGE}.
- **Step 4:** Determine Clearance based on V_{ISO}/V_{SURGE} levels determined in step 3.
  - For reinforced use 1.6x the V_{ISO}, and next level of V_{SURGE}.
  - Scaling factor required for altitudes > 2000m
- **Step 5:** Determine working voltage (both pk and rms) based on actual operating condition of isolator.
  - Depends on architecture, earthing, ringing, braking, regen etc.
- **Step 6:** Determine Creepage based on RMS values of working voltage expected.
  - Depends on material group (CTI) and pollution degree.
- **Step 7:** Choose isolator that meets V_{ISO}, V_{SURGE} , working voltage, creepage and clearance requirements obtained above.

IEC 61800-5-1: Examples of isolation requirements

AC phase-phase Voltage (V_{RMS}) and Earthing Scheme	System Voltage (V_{RMS})	System Voltage (V_{RMS}) Per IEC 62109-1	Basic/ Reinforced	Temporary Overvoltage (V_{RMS} /V_{PK})	Impulse/ Surge Voltage (V_{PK})	Minimum Clearance (mm)	Working Voltage (V_{RMS}/ V_{PK})	Minimum Creepage (mm)		
								CTI I	CTI II	CTI III
480 Neutral Earthed	277	300	Functional	NA	NA	0.1/0.2/0.8	480/ 678	2.5	3.6	5.0
480 Neutral Earthed	277	300	Basic	1500 / 2120	4000	3	480/ 678	2.5	3.6	5.0
480 Neutral Earthed	277	300	Reinforced	3000 / 4240	6000	5.5	480/ 678	5.0	7.2	10.0
690 Corner Earthed	690	1000	Functional	NA	NA	0.5/0.5/0.8	690/ 975	3.5	4.9	6.9
690 Corner Earthed	690	1000	Basic	2200 / 3110	8000	8.0	690/ 975	3.5	4.9	6.9
690 Corner Earthed	690	1000	Reinforced	4400 / 6220	12000	14	690/ 975	7.0	9.8	13.8
1000 Corner Earthed	1000	1000	Reinforced	4400 / 6220	12000	14	1000/ 1414	10.0	14.2	20.0

- Summary of requirements per IEC 61800-5-1 for a few example systems (Category III, pollution degree 2, altitude <2000 m)
- Isolators with more than **14.2mm** creepage and clearance are required to support systems with system voltage up to **1000Vrms**.

Trends of Industrial Motor Drives and Isolation Demanding

- **More efficient and compact drives**
  - Higher working voltage to reduce I2R loss
    - **Isolators with higher working voltage and creepage and clearance.**
  - SiC MOSFET to enable lower conduction and switching losses
    - **Isolators with higher CMTI to support faster switching.**
    - **Isolators with lower prop delay to help reduce dead time.**
- **Smarter drives**
  - More communication links to enable connected network
    - **Higher data rate communication links including ISOLVDS.**
- **Reliable drives**
  - More protection, fault diagnostic, and prognostic features
    - **Isolated gate drivers with more protection features to help reduce system cost and reduce solution size.**


Q&A