

# Noise Immunity for Single Pair Cabling and Applicability to Industrial Applications

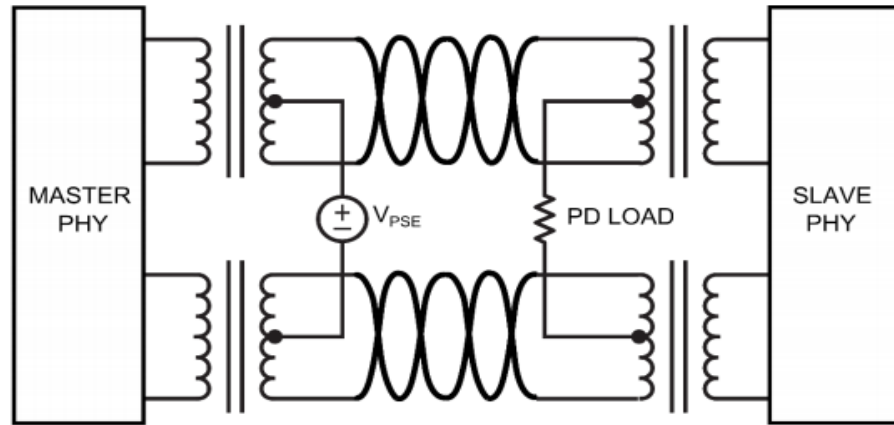
Cameron Jones  
Rockwell Automation  
January 27<sup>th</sup> 2020

# MICE “E” Levels and Acceptance Criteria

	E1	E2	E3
IEC 61000-4-2 (ESD) Criteria B	4kV contact 8kV air	4kV contact 8kV air	4kV contact 8kV air
IEC 61000-4-3 (Radiated Immunity) Criteria A	3V/m 80M-1GHz 3V/m 1.4-2GHz 1V/m 2-2.7GHz	3V/m 80M-1GHz 3V/m 1.4-2GHz 1V/m 2-2.7GHz	10V/m 80M-1GHz 3V/m 1.4-2GHz 1V/m 2-2.7GHz
IEC 61000-4-4 (EFT) Criteria B	500V	500V	1kV
IEC 61000-4-5 (Surge) Criteria B	500V	1kV	1kV
IEC 61000-4-6 (Conducted Immunity) Criteria A	3V	3V	10V
IEC 61000-4-8 (Magnetic Field) Criteria A	1A/m	3A/m	30A/m

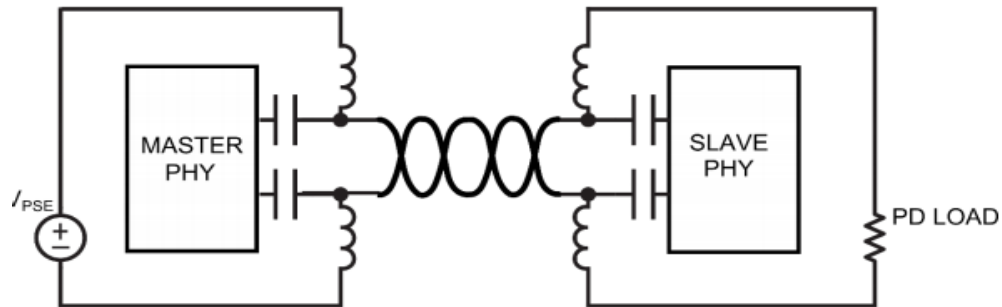
- A – the EUT shall continue to operate as intended during and after the test. No degradation or loss of function is allowed
- B – the EUT shall continue operate as intended after the test. The performance level may be replaced by a permissible loss of performance
- C – Temporary loss of fuction is allowed during the test provided the function is self-recoverable or can be restored by the operation of the controls
- DS-The functions intended for use in safety applications may be affected temporarily or permanently if the EUT reacts to a disturbance in a way that a detectable and defined state of the EUT is achieved in a stated time.
  - In most systems this safe defined state is to stop the application. If enough data is lost, the state is unknown and the application must respond.

# Single Pair Ethernet Application Noise Immunity



Power over Ethernet (PoE)

- Capacitive isolation does not reject common mode voltages like traditional Ethernet systems
- Both communication failure modes apply
- Common mode voltage tolerance is not specified by IEEE and can vary from 5V to 50V



Power over Data Lines (PoDL)

*Comparison of IEEE 4 pair and 1 pair MDI wiring*

# Two Failure Modes

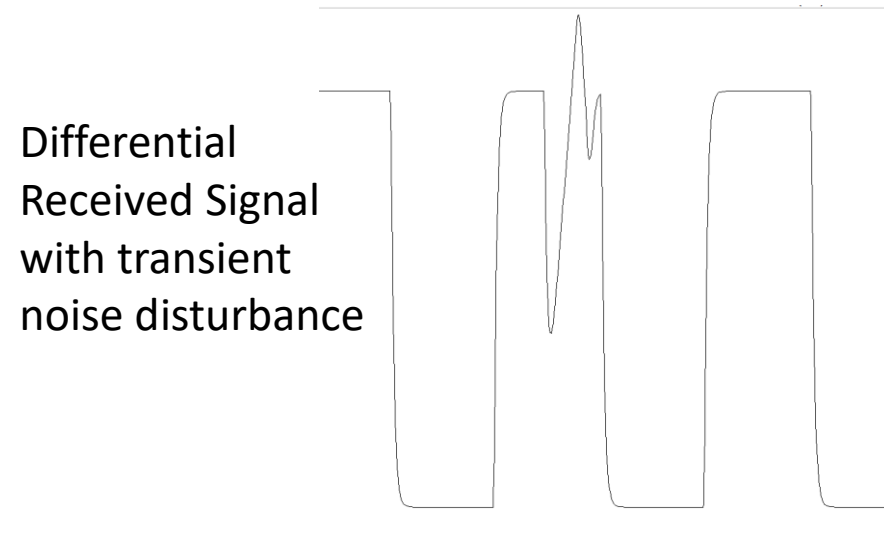
- Common Mode Saturation

- Common mode voltage exceeds tolerable receiver range and protection diodes clamp
- All differential signal is lost



- Differential Signal Corruption

- Noise converted to the differential mode is large enough to cause a transmitted symbol to be misinterpreted



# IEC 61000-4-6 Implications

(Conducted Immunity)

- Functional Levels cap at 10Vrms applied with 80% AM modulation (roughly +/-25V common mode range)
- Acceptance is criteria A
- With these voltage levels Differential signal corruption is typically a more pertinent failure mechanism and drives acceptance rate of TCL and ELTCTL or Coupling Attenuation

# IEC 61000-4-4 Implications

(Electrical Fast Transient Burst)

- Functional Levels climb to +/- 2kV
  - Even at low levels can induce common mode saturation
- Acceptance is only at criteria B which allows some degradation to performance
  - In real time applications this performance can be represented as a bit error rate within a time window such that communications are available upon expected demand
  - *A working definition BER better than  $1e-4$  (1 error in 10000 bits) in a time window of 50ms*

# MICE “E” Levels compared to Industrial Application Levels

	E1	E2	E3
IEC 61000-4-2 (ESD)	4kV contact 8kV air	4kV contact 8kV air	4kV contact 8kV air
IEC 61000-4-3 (Radiated Immunity)	3V/m 80M-1GHz 3V/m 1.4-2GHz 1V/m 2-2.7GHz	3V/m 80M-1GHz 3V/m 1.4-2GHz 1V/m 2-2.7GHz	10V/m 80M-1GHz 3V/m 1.4-2GHz 1V/m 2-2.7GHz
IEC 61000-4-4 (EFT)	500V	500V	1kV
IEC 61000-4-5 (Surge)	500V	1kV	1kV
IEC 61000-4-6 (Conducted Immunity)	3V	3V	10V
IEC 61000-4-8 (Magnetic Field)	1A/m	3A/m	30A/m

*These industrial Application levels come from the application standards used to qualify a product to its respective CE levels and is applied as a signal interface or IO Power interface based on use. A point of distinction, in these applications applying power over the cabling impacts the test levels required for certification and the more severe level will apply.*

Application Description	General Safety Rated	Safety for measurement & control	Safety for measurement & control	measurement & control	General Industrial	adjustable speed motor Drives	Circuit Breakers	electromagnetic control devices	Programmable Logic Controllers	Programmable Logic Controllers
Application Standard	IEC 61000-6-7	IEC 61326-3-1	IEC 61326-3-1 power	IEC 61326 industrial	IEC 61000-6-2	IEC 61800-3	IEC 60947-2	IEC 60947-5-1	IEC 61131-1	IEC 61131-1 Power
IEC 61000-4-2 (ESD) Criteria B	6kV Contact 8kV Air Criteria DS	6kV Contact 8kV Air Criteria DS	6kV Contact 8kV Air Criteria DS	4kV contact 8kV air	4kV contact 8kV air	4kV contact 8kV air	6kV contact 8kV air	4kV contact 8kV air	4kV contact 8kV air	4kV contact 8kV air
IEC 61000-4-3 (Radiated Immunity) Criteria A	20V/m 80M-1GHz 10V/m 1.4-2GHz 3V/m 2-2.7GHz Criteria DS	20V/m 80M-1GHz 10V/m 1.4-2GHz 3V/m 2-2.7GHz Criteria DS	20V/m 80M-1GHz 10V/m 1.4-2GHz 3V/m 2-2.7GHz Criteria DS	10V/m 80M-1GHz 3V/m 1.4-2GHz 1V/m 2-2.7GHz	10V/m 80M-1GHz 3V/m 1.4-2GHz 1V/m 2-2.7GHz	10V/m 80M-1GHz 3V/m 1.4-2GHz 1V/m 2-2.7GHz	10V/m 80M-1GHz 3V/m 1.4-2GHz 1V/m 2-2.7GHz	10V/m 80M-1GHz 3V/m 1.4-2GHz 1V/m 2-2.7GHz	10V/m 80M-1GHz 3V/m 1.4-2GHz 1V/m 2-2.7GHz	10V/m 80M-1GHz 3V/m 1.4-2GHz 1V/m 2-2.7GHz
IEC 61000-4-4 (EFT) Criteria B	2 kV Criteria DS	2 kV Criteria DS	3 kV Criteria DS	1kV	1kV	2kV	2kV	1kV	1kV	2kV
IEC 61000-4-5 (Surge) Criteria B	2 kV Criteria DS	2 kV Criteria DS	2 kV Criteria DS	1kV	1kV	1kV	2kV	2kV	1kV	0.5kV
IEC 61000-4-6 (Conducted Immunity) Criteria A	20V Criteria DS	20V Criteria DS	10V Criteria DS	3V	10V	10V	10V	10V	10V	10V
IEC 61000-4-8 (Magnetic Field) Criteria A	30 A/m Criteria DS	31 A/m Criteria DS	30A/m Criteria DS	30A/m	30A/m			30A/m	30A/m	30A/m

# Conclusion

- Reference only to TCL, ELTCTL, and Coupling Attenuation with respect to MICE level is insufficient for single pair channels
  - Need to add Transfer Impedance or Shielding effectiveness to answer common mode behavior
- Focus only on MICE criteria compatibility according to IEC 61000-4-6 is insufficient
  - IEC 61000-4-4 is also a significant contributor to environmental compatibility
- MICE environment description does not fully answer to industrial application standards certification levels
  - With respect to IEC 61000-4-4 and IEC 61000-4-5 tests
- Recommendations
  - We need to expand noise studies to include IEC 61000-4-4 tests including specifications of the DUT MDI common mode voltage range for data correlation
  - We should send a liaison letter to IEEE requesting further definition of a standardized common mode range of the MDI of SPE applications
  - We should consider how to address extended industrial needs not met by MICE environment description