ADTRAN®

BRINGING THE WORLD TOGETHER

PROTECTING POE PSE AND ETHERNET TO THE LATEST INTERNATIONAL OSP STANDARDS

Part 3 of 3

Tim Ardley
Power Fault & Lightning Compliance Engineer

ATIS PEG, April 2016

Introduction

- Part 1 (ATIS-2015) Addressed field failures seen and was presented by Jim Wiese.

- Part 2 (ATIS-2015) covered protecting the PoE and Ethernet semiconductor IC’s to make them more robust to the elements.
- Part 3 will provide an update and review of the latest ITU-T 04/2015 revision standards and address the periphery components not covered in part 2 such as the transformers and RJ-45 socket to make equipment pass the OSP standards.

Standards

- Let's look at what's forcing significant changes in Ethernet design. The most recent changes are coming from:-

International Telecommunication Union (ITU-T)

K.20, K.45 & K.21

Revision 04/2015

ITU-T K.series Standards

- K.20 – Central Office
  - Resistibility of telecommunications equipment installed in a telecom center to over voltages and over currents.
- K.45 – Remote Access
  - Resistibility of telecommunications equipment installed in the access and trunk networks to over voltages and over currents.
- K.21 – Customer Premise
  - Resistibility of telecommunications equipment installed in customer premises to over voltages and over currents.
- K.44 – Test Support Document
  - Resistibility tests for telecommunication equipment exposed to over voltages and over currents – Basic recommendation.

2011 Ethernet Tests

- Testing Ethernet ports for ITU-T was almost non-existent….
  - K.45 Ethernet ports not tested.
  - K.20 internal ports longitudinal test.
    - 500 V basic, 1 kV enhanced.
  - K.21 internal ports longitudinal test.
    - 1000 V basic, 1.5 kV enhanced.
  - No transverse surges.
  - No PoE pair-pair port tests
    - There was an indication in K.44 test document that it was coming.

Rule of thumb was that if the port passed GR-1089-CORE intra-building, it also passed international testing.

Let's take a closer look at ITU-T 04/2015 released last year as lot's of NEW tests have been added!

External Ethernet Deployment

Table 2a – Lightning test conditions for ports connected to external symmetric pair cables

Test no.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	Number of tests	Primary protection [ITU-T K.44], clause 8)	Acceptance criteria [ITU-T K.44], clause 9)	Comments
2.1.7 New	UTP Ethernet transverse	Figure A.6.7-5 (1.2/50-8/20 combination wave generator (CWG)) R=10 Ω	$U_{c(max)}$ = 600 V	$U_{c(max)}$ = 1500 V	alternating ±5 surges (60 seconds between successive surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44]
2.1.8	STP Ethernet simultaneous port to earth test	Figure A.6.7-4 (1.2/50-8/20 CWG) R=10 Ω	$U_{c(max)}$ = 2500 V	$U_{c(max)}$ = 6000 V	alternating ±5 surges (60 seconds between successive surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])
2.1.9	UTP Ethernet port rated impulse voltage test	Figure A.6.7-3a (1.2/50-8/20 CWG) R=5 Ω	$U_{c(max)}$ = 2500 V surge	$U_{c(max)}$ = 6000 V	2 of each polarity for surge/ single applicatio n for dc	None (Note 1)	A	There shall be no insulation breakdown during the test and the post test resistance shall be at least 2 MΩ when measured at 500 V d.c.
2.1.10	PoE Mode A & Mode B transverse testing	Figure A.6.7-2 (1.2/50-8/20 CWG) R= 10 Ω	$U_{c(max)}$ = 600 V	$U_{c(max)}$ = 1500 V	Alternatin g ±5 surges (60 seconds between surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])

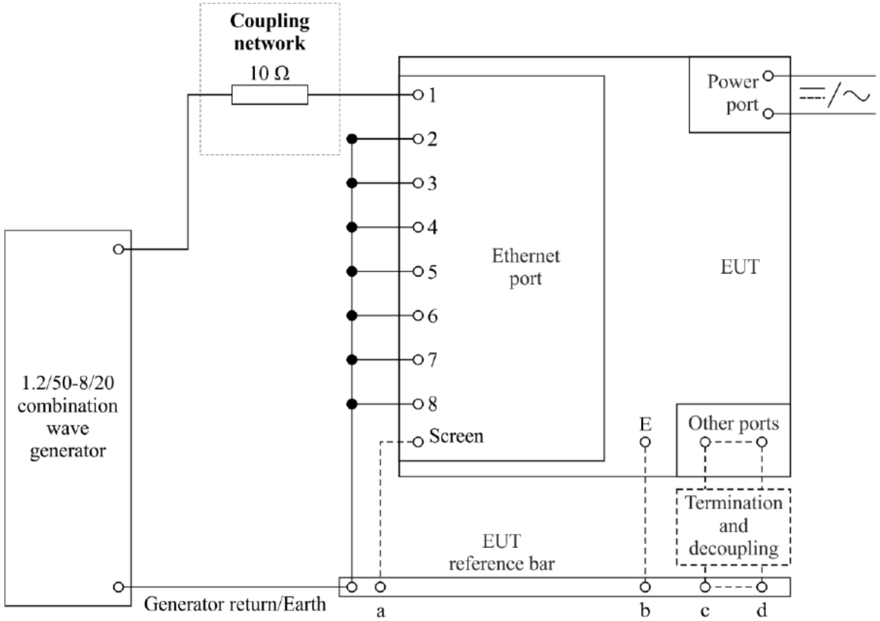
UTP = Unscreened Twisted Pair
STP = Screened Twisted Pair

A.6.7-5 Transverse Test

- Test # 2.1.7 external building
  - ITU-T Basic
    - 600 V 1.2/50 = 50 A.
  - ITU-T Enhanced
    - 1500 V 1.2/50 = 125 A.

GR-1089-CORE internal building tests with 800 V 1.2/50, 6 Ω (100 A).

GR-1089-CORE has been proven to solve field issues in the USA.



1, 2, 3, 4, 5, 6, 7 and 8 are Ethernet RJ45 pin numbers
a = RJ45 screen cable connection for STP connections
b = EUT protective or functional earth connection
c to d = Terminals of all other signal ports

NOTE – This test is conducted to each lead (1-8) separately connected to the generator one at a time, with all of the other leads grounded.

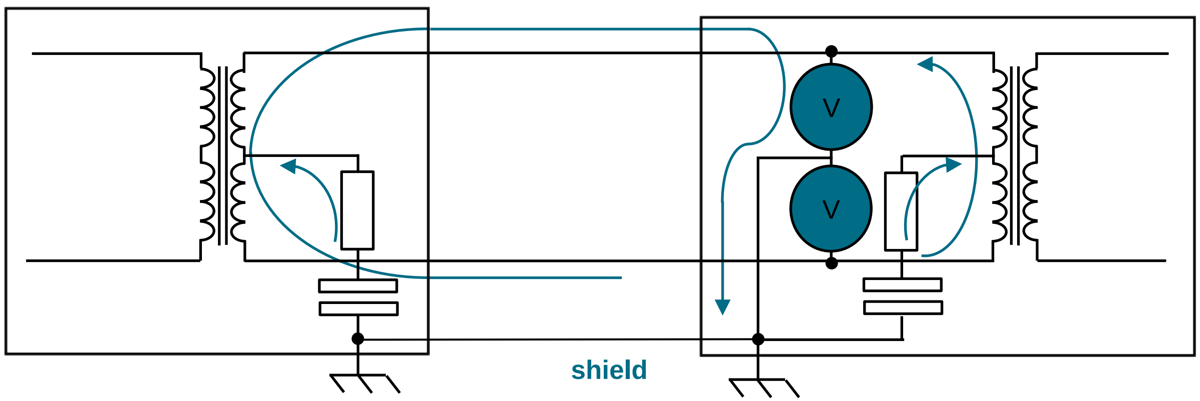
Figure A.6.7-5 – Ethernet port transverse/differential surge test circuit

External Transverse Tests

- There is no transverse test for SHIELDED EXTERNAL CABLES?

  - Shielded cable don't protect against common-mode to differential surge events!
    - Isolation at the Jack to its shield or transformer breakdown?
    - One end using GDT surge protection to Earth?
      - Common to see OSP deployments with GDT primary protectors.

External Transverse Tests

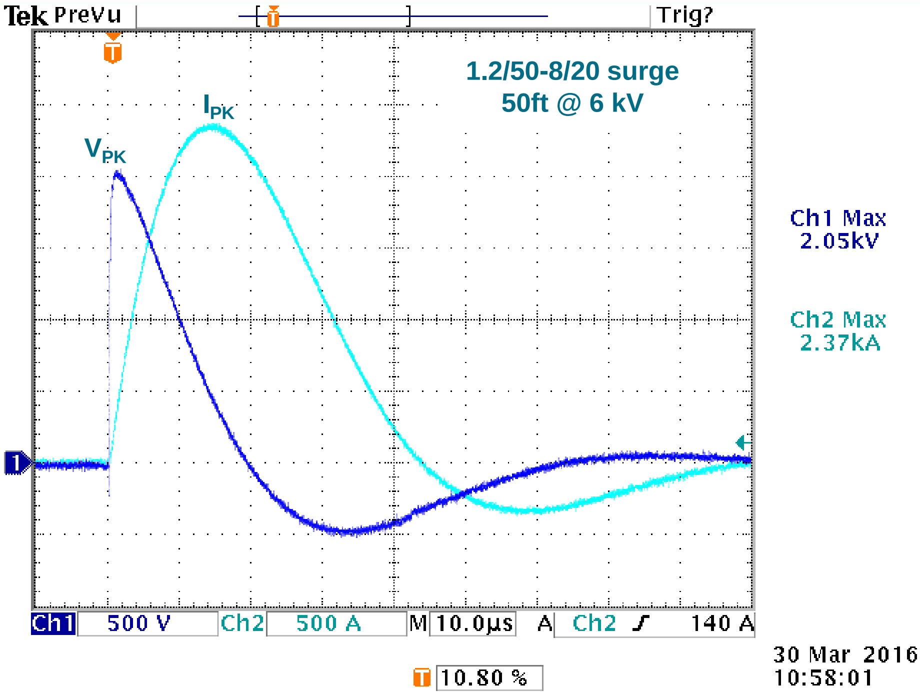


- Arcing from conductor to Earth or an over-voltage protector is used on the interface.
  - Over-voltage protection (GDT's) are common for OSP interfaces.

- The question then comes down to what level of voltage can be seen across the cable shield during surge?

Shielded Cable Length

Shielded Cable Length (ft)								
	10/700 (40Ω)				1.2/50-8/20 (2Ω)			
	25 ft		50 ft		25 ft		50 ft	
V_{GEN}	V_{PK} (V)	I_{PK} (A)	V_{PK} (V)	I_{PK} (A)	V_{PK} (V)	I_{PK} (A)	V_{PK} (V)	I_{PK} (A)
1 kV	60.8	25.2	52.8	25	400	380	332	386
2 kV	124	50	108	50	804	764	666	766
3 kV	183	76.4	159	76.4	1230	1170	1010	1190
4 kV	246	102	215	102	1660	1590	1360	1590
5 kV	304	128	269	130	2090	1970	1700	1970
6 kV	354	155	322	155	**2500**	2370	2040	2380



- Short cable length looks worse when surged across it!
  - 1.2/50-8/20 generator produced a lot higher surge than the 10/700 generator.
    - 6 kV surge is in the 2.5 kV region for 25ft of cable.
    - Inductance of the cable.
  - Found that using RJ-45 sockets at both ends typically increased the voltage by 15%.
  - Coiling the cable in a bundle typically added 25%.

External Ethernet

Table 2a – Lightning test conditions for ports connected to external symmetric pair cables

Test no.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	Number of tests	Primary protection [ITU-T K.44], clause 8)	Acceptance criteria [ITU-T K.44], clause 9)	Comments
2.1.7	UTP Ethernet transverse	Figure A.6.7-5 (1.2/50-8/20 combination wave generator (CWG)) R=10 Ω	$U_{c(max)}$ = 600 V	$U_{c(max)}$ = 1500 V	alternating ±5 surges (60 seconds between successive surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44]
2.1.8 New	STP Ethernet simultaneous port to earth test	Figure A.6.7-4 (1.2/50-8/20 CWG) R=10 Ω	$U_{c(max)}$ = 2500 V	$U_{c(max)}$ = 6000 V	alternating ±5 surges (60 seconds between successive surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])
2.1.9	UTP Ethernet port rated impulse voltage test	Figure A.6.7-3a (1.2/50-8/20 CWG) R=5 Ω	$U_{c(max)}$ = 2500 V surge	$U_{c(max)}$ = 6000 V	2 of each polarity for surge/ single applicatio n for dc	None (Note 1)	A	There shall be no insulation breakdown during the test and the post test resistance shall be at least 2 MΩ when measured at 500 V d.c.
2.1.10	PoE Mode A & Mode B transverse testing	Figure A.6.7-2 (1.2/50-8/20 CWG) R= 10 Ω	$U_{c(max)}$ = 600 V	$U_{c(max)}$ = 1500 V	Alternatin g ±5 surges (60 seconds between surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])

UTP = Unscreened/unshielded twisted pair
STP = Screened/shielded twisted pair

A.6.7-4 Longitudinal Test

- Test # 2.1.8 External Building.
  - ITU-T Basic.
    - 2.5 kV 1.2/50, 208 A.
  - ITU-T Enhanced.
    - 6 kV 1.2/50, 500 A.

Finally a 6 kV surge test for EXTERNAL Ethernet interfaces.

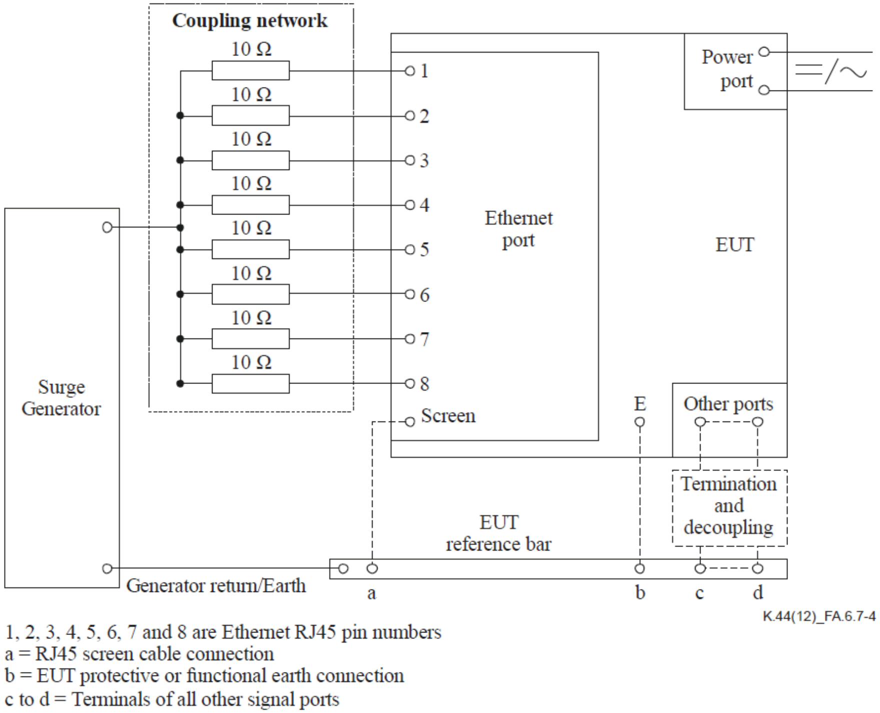


Figure A.6.7-4 – Ethernet port longitudinal/common mode surge test circuit

Great test for an isolated interface, but is the single conductor short circuit current enough if over-voltage protection is used on the interface?

External Ethernet

Table 2a – Lightning test conditions for ports connected to external symmetric pair cables

Test no.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	Number of tests	Primary protection [ITU-T K.44], clause 8)	Acceptance criteria [ITU-T K.44], clause 9)	Comments
2.1.7	UTP Ethernet transverse	Figure A.6.7-5 (1.2/50-8/20 combination wave generator (CWG)) R=10 Ω	$U_{c(max)}$ = 600 V	$U_{c(max)}$ = 1500 V	alternating ±5 surges (60 seconds between successive surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44]
2.1.8	STP Ethernet simultaneous port to earth test	Figure A.6.7-4 (1.2/50-8/20 CWG) R=10 Ω	$U_{c(max)}$ = 2500 V	$U_{c(max)}$ = 6000 V	alternating ±5 surges (60 seconds between successive surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])
2.1.9 New	UTP Ethernet port rated impulse voltage test	Figure A.6.7-3a (1.2/50-8/20 CWG) R=5 Ω	$U_{c(max)}$ = 2500 V surge	$U_{c(max)}$ = 6000 V	2 of each polarity for surge/ single application for dc	None (Note 1)	A	There shall be no insulation breakdown during the test and the post test resistance shall be at least 2 MΩ when measured at 500 V d.c.
2.1.10	PoE Mode A & Mode B transverse testing	Figure A.6.7-2 (1.2/50-8/20 CWG) R= 10 Ω	$U_{c(max)}$ = 600 V	$U_{c(max)}$ = 1500 V	Alternating ±5 surges (60 seconds between surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])

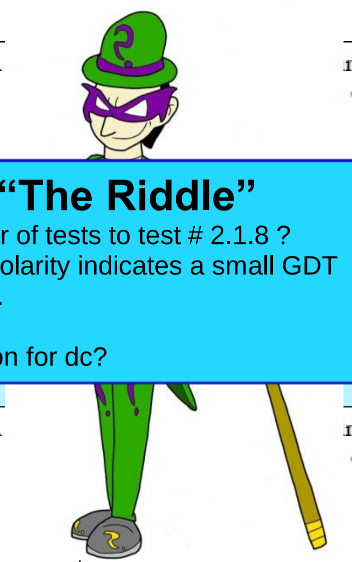
UTP = Unscreened/unshielded twisted pair
STP = Screened/shielded twisted pair

External Ethernet

Table 2a – Lightning test conditions for ports connected to external symmetric pair cables

Test no.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	Number of tests	Primary protection [ITU-T K.44], clause 8)	Acceptance criteria [ITU-T K.44], clause 9)	Comments
2.1.7	UTP Ethernet transverse	Figure A.6.7-5 (1.2/50-8/20 combination wave generator (CWG)) R=10 Ω	$U_{c(max)}$ = 600 V	$U_{c(max)}$ = 1500 V	alternating ±5 surges (60 seconds between successive surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44]
2.1.8	STP Ethernet simultaneous port to earth test	Figure A.6.7-4 (1.2/50-8/20 CWG) R=10 Ω	$U_{c(max)}$ = 2500 V	$U_{c(max)}$ = 6000 V	alternating ±5 surges (60 seconds between successive surges)	None	A	ng also of
2.1.9 New	UTP Ethernet port rated impulse voltage test	Figure A.6.7-3a (1.2/50-8/20 CWG) R=5 Ω	$U_{c(max)}$ = 2500 V surge	$U_{c(max)}$ = 6000 V	2 of each polarity for surge/ single application for dc	N		he east d.c.
2.1.10	PoE Mode A & Mode B transverse testing	Figure A.6.7-2 (1.2/50-8/20 CWG) R= 10 Ω	$U_{c(max)}$ = 600 V	$U_{c(max)}$ = 1500 V	Alternating ±5 surges (60 seconds between surges)	None	A	ng also of

Note that shielded & unshielded tests are done at the same voltage.



? “The Riddle”

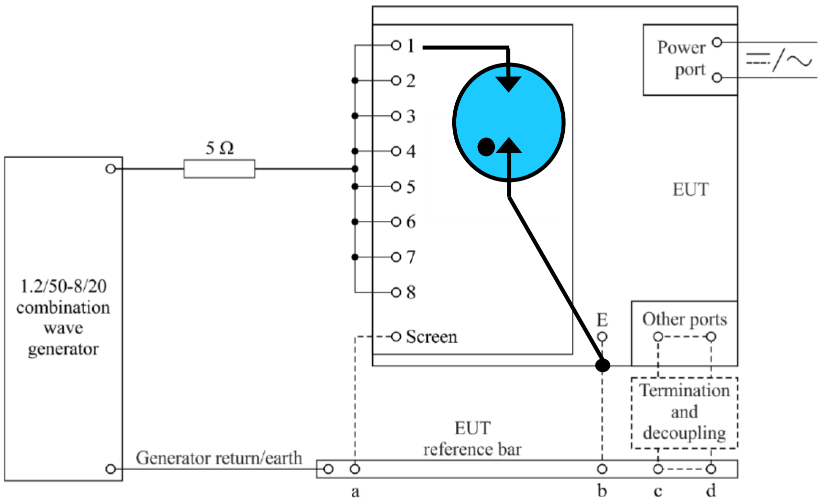
Different number of tests to test # 2.1.8 ?
2 surges each polarity indicates a small GDT surge withstand.

Single application for dc?

UTP = Unscreened/unshielded twisted pair
STP = Screened/shielded twisted pair

A.6.7-3a Isolation Test

- Test # 2.1.9 external building.
  - ITU-T Basic is at 2.5 kV.
  - ITU-T Enhanced is at 6 kV.
- Why is the "longitudinal" test different between unshielded and shielded cables?
- Very easy to protect against with an OV protector.
  - Might explain the 2x surges each polarity rather than 5x.



Would recommend a Hi-POT, 1s test at 80% of the peak surge voltages for ALL Ethernet interfaces instead.

External PoE

Table 2a – Lightning test conditions for ports connected to external symmetric pair cables

Test no.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	Number of tests	Primary protection [ITU-T K.44], clause 8)	Acceptance criteria [ITU-T K.44], clause 9)	Comments
2.1.7	UTP Ethernet transverse	Figure A.6.7-5 (1.2/50-8/20 combination wave generator (CWG)) R=10 Ω	$U_{c(max)}$ = 600 V	$U_{c(max)}$ = 1500 V	alternating ±5 surges (60 seconds between successive surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44]
2.1.10 New	PoE Mode A & Mode B transverse testing	Figure A.6.7-2 (1.2/50-8/20 CWG) R= 10 Ω	$U_{c(max)}$ = 600 V	$U_{c(max)}$ = 1500 V	Alternating ±5 surges (60 seconds between surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])

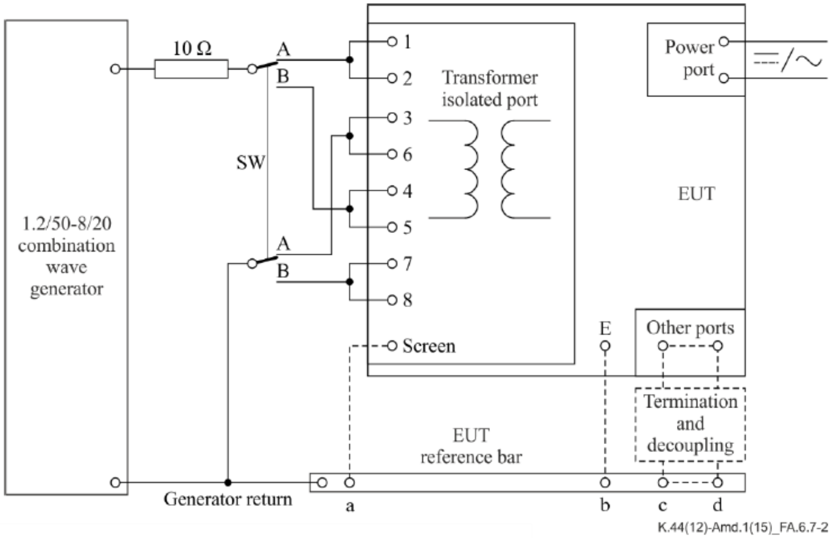
Note that transverse tests are done at the same voltage.

and the same number of surges.

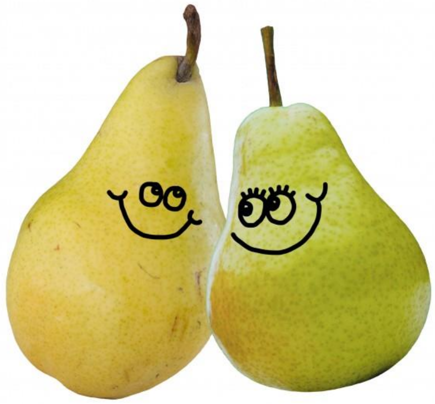
UTP = Unscreened/unshielded twisted pair
STP = Screened/shielded twisted pair

A.6.7-2 PoE Test

- Test # 2.1.10 external building
  - ITU-T Basic
    - 600 V 1.2/50 = 50 A.
  - ITU-T Enhanced
    - 1500 V 1.2/50 = 125 A.
  - GR-1089-CORE intra-building test with 800 V, 100 A (6Ω).



- This is a pair to pair test for the DC interface.
  - There are no pair-pair test for standard Ethernet ports?



External Shield Bond Test

Table 2a – Lightning test conditions for ports connected to external symmetric pair cables

Test no.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	Number of tests	Primary protection [ITU-T K.44], clause 8)	Acceptance criteria [ITU-T K.44], clause 9)	Comments
2.1.11 New	STP Ethernet shield bond test	Figure A.6.7-6 (1.2/50-8/20 CWG) R=10 Ω	$U_{c(max)}$ = 1500 V	$U_{c(max)}$ = 6000 V	alternating ±5 surges (60 seconds between successive surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])
NOTE 1 – When the cabling is fitted with SPDs, the equipment user and manufacturer may use different test conditions upon mutual agreement; this topic is currently under study.								

STP = Screened/shielded twisted pair

A.6.7-6 Shield Bond Test

- Test 2.1.11 external building.
  - ITU-T Basic.
    - 1500 V 1.2/50, 25 A.
  - ITU-T Enhanced.
    - 6 kV 1.2/50, 500 A.
- GR-1089-CORE internal building test.
  - 1500 V, 375 A (2 Ω).

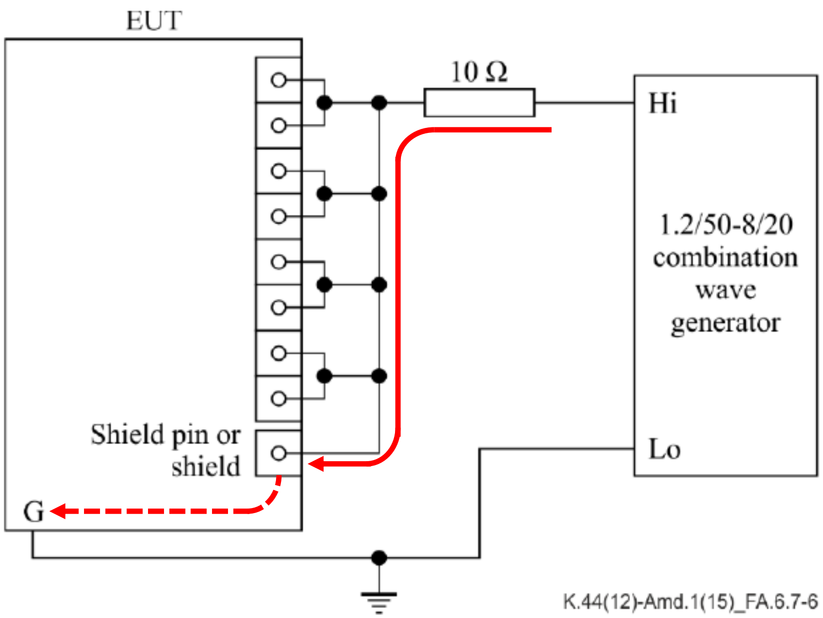
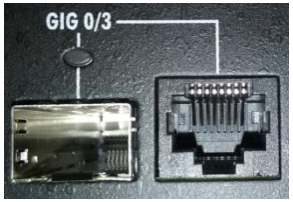


Figure A.6.7-6 – Shielded twisted pair (STP) Ethernet testing

- Would the unshielded isolation test be correct if a shielded cable was used with an unshielded Jack?



Internal Building Changes

- What has changed for Internal building ports?
  - K.45 No tests in 11/2011and nothing has been added in 04/2015.
    - Assumes the cable within the cabinet is very short and therefore no electrical stress?
  - K.21 Some additions.
  - K.20 Some additions but there are issues!

K.21 Intra-building Additions

Table 7 – Lightning test conditions for ports connected to internal cables

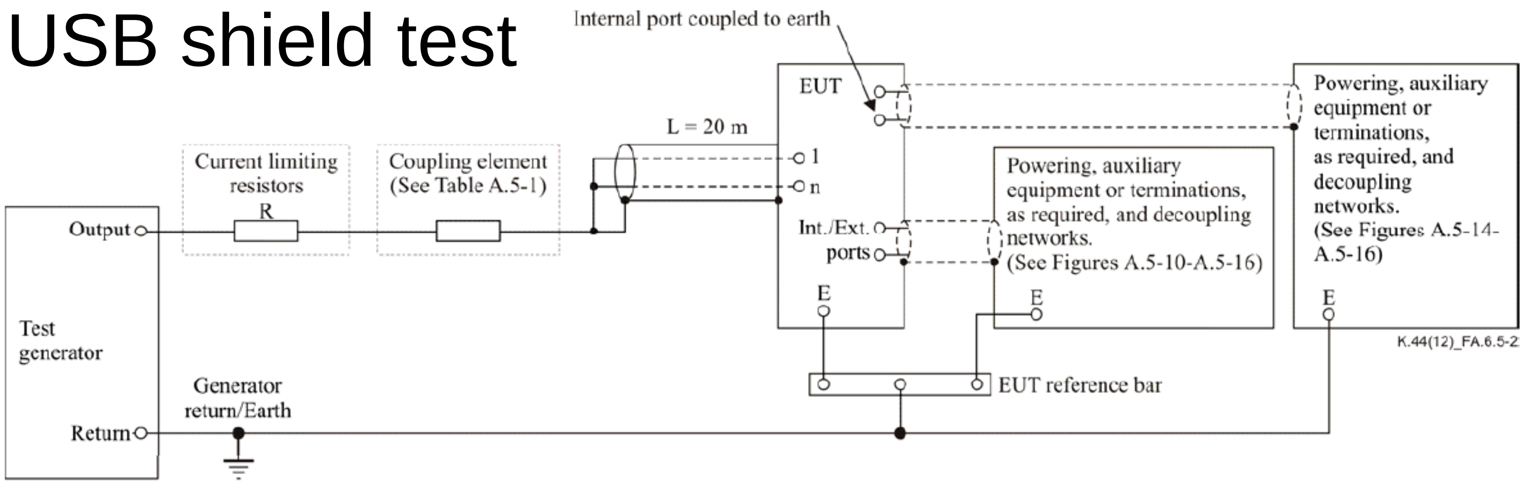
Test no.	Test description	Test circuit and waveform (see Figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	Number of tests	Primary protection [ITU-T K.44], clause 8	Acceptance criteria [ITU-T K.44], clause 9	Comments
7.3 New	USB shielded cable to earth	Figures A.3-5 (1.2/50-8/20 CWG) and A.6.5-2 R = 0 Ω	$U_{c(max)}$ = 100 V	$U_{c(max)}$ = 150 V	alternating ±5 surges	None	A	Test is performed with the supplied cable (not the 20 m cable specified in Figure A.6.5-2). (lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])
7.4 New	STP Ethernet simultaneous port to earth	Figure A.6.7-4 (1.2/50-8/20 CWG) R=0 Ω	$U_{c(max)}$ = 1000 V	$U_{c(max)}$ = 1500 V	alternating ±5 surges (60 seconds between successive surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])
7.5	PoE Mode A & Mode B transverse testing	Figure A.6.7-2 (1.2/50-8/20 CWG) R=10Ω	$U_{c(max)}$ = 600 V	$U_{c(max)}$ = 1000 V	alternating ±5 surges (60 seconds between successive surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])
7.6	UTP Ethernet port rated impulse voltage	Figure A.6.7-3a (1.2/50-8/20 CWG) R = 5 Ω	$U_{c(max)}$ = 2500 V surge	$U_{c(max)}$ = 6000 V surge	2 of each polarity/ single application of dc	(No		no insulation ring the test est resistance shall be at least 2 MΩ when measured at 500 V d.c. Monitor the impulse voltage to detect sparkover or voltage protector operation.

External R value should probably be 10 Ω instead of 0 Ω to match the test set-up schematic.

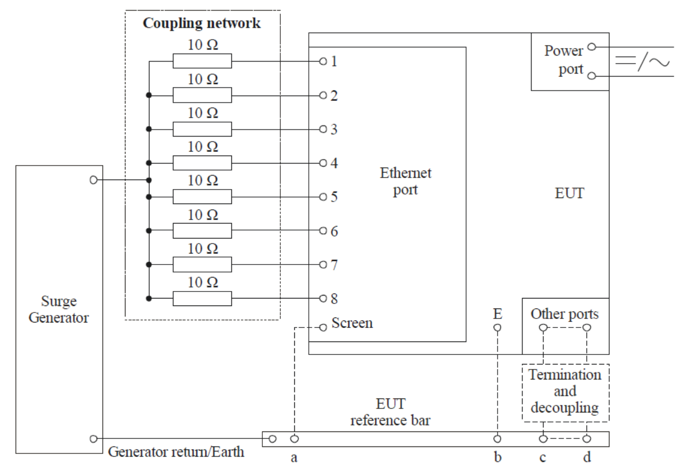
The “?” has popped up again

A.6.5-2 & A.6.7-4 Tests

- A.6.5-2 USB shield test



- A.6.7-4 STP longitudinal Test



K.21 Intra-building Additions

Table 7 – Lightning test conditions for ports connected to internal cables

Test no.	Test description	Test circuit and waveform (see Figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	Number of tests	Primary protection [ITU-T K.44], clause 8	Acceptance criteria [ITU-T K.44], clause 9	Comments
7.3	USB shielded cable to earth	Figures A.3-5 (1.2/50-8/20 CWG) and A.6.5-2 R = 0 Ω	$U_{c(max)}$ = 100 V	$U_{c(max)}$ = 150 V	alternating ±5 surges (60 seconds between successive surges)	None	A	Test is performed with the supplied cable (not the 20 m cable specified in Figure A.6.5-2). (lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])
7.4	STP Ethernet simultaneous port to earth	Figure A.6.7-4 (1.2/50-8/20 CWG) R=0 Ω	$U_{c(max)}$ = 1000 V	$U_{c(max)}$ = 1500 V	alternating ±5 surges (60 seconds between	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])
7.5	PoE Mode A & Mode B transverse testing	Figure A.6.7-2 (1.2/50-8/20 CWG) R=10Ω	$U_{c(max)}$ = 600 V	$U_{c(max)}$ = 1000 V	(60 seconds between successive surges)			testing clause 7.3 of [ITU-T K.44])
7.6 **New**	UTP Ethernet port rated impulse voltage	Figure A.6.7-3a (1.2/50-8/20 CWG) R = 5 Ω	$U_{c(max)}$ = 2500 V surge	$U_{c(max)}$ = 6000 V surge	2 of each polarity/ single application of dc	None (Note 2)	A	There shall be no insulation breakdown during the test and the post test resistance shall be at least 2 MΩ when measured at 500 V d.c. Monitor the impulse voltage to detect sparkover or voltage protector operation.

Adtran uses this specification for some of its **ONT** interfaces for field reliability.

K.20 Internal Cable “Blooper”

Table 7 – Lightning test conditions for ports connected to internal cables

Test no.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	Number of tests	Primary protection [ITU-T K.44], clause 8	Acceptance criteria [ITU-T K.44], clause 9	Comments
7.4	STP Ethernet simultaneous port to earth	Figure A.6.7-4 (1.2/50-8/20 CWG) R = 0 Ω	$U_{c(max)}$ = 1000 V	$U_{c(max)}$ = 1500 V	alternating ±5 surges (60 seconds between successive surges)	None	A	(lower voltage level testing also required – see clause 7.3 of [ITU-T K.44])
								
7.6 New	UTP Ethernet port rated impulse voltage test	Figure A.6.7-3a (1.2/50-8/20-CWG) R = 5 Ω	$U_{c(max)}$ = 2500 V surge	$U_{c(max)}$ = 6000 V surge	2 of each polarity/ single application of dc	None (Note 1)	A	There shall be no insulation breakdown during the test and the post test resistance shall be at least 2 MΩ when measured at 500 V d.c.

Note the discrepancy between shielded and unshielded cables?

6 kV surge for an INTERNAL CABLE for a K.20 telecom center environment?

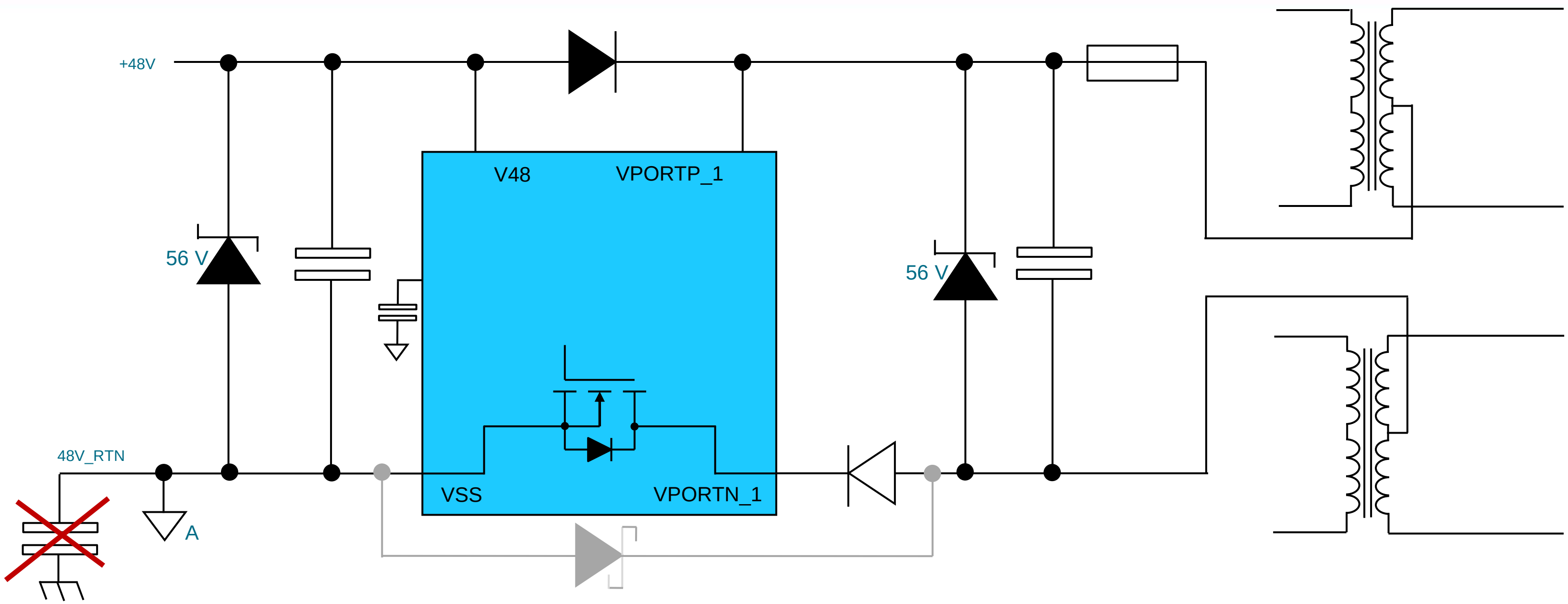
Looks like unshielded cables in the telecom center environment is not liked, but is this the **RIGHT** call?

International Standards Summary

- OSP Ethernet Port tests.
  - At last OSP Ethernet deployments have been recognized but….
    - Shielded twisted pair does not have a transverse test.
    - An Ethernet shielded cable is not a good protector against GPR’s.
    - Shielded Ethernet cables don’t make good earth straps.
    - 6 kV isolation test for K.20 internal Ethernet ports!
    - Isolation testing could be done with a single longitudinal test.
    - Internal building transverse for Ethernet is still missing.
    - Tests for shielded and unshielded ports should be the same.
    - No exclusions for very short (3 meter) outside building cabling.

- With the protection Bar set so high, lets look at the various components of PoE and Ethernet that need to be considered:-

PoE Controller Protection



- From last years presentation:-
- Consider blocking current rather than shunting the current around the FET.
  - Better results with a smaller package and lower cost component.

- Remove the capacitors that are connected between 48V_RTN and chassis GND. Be prepared to compromise with EMC!

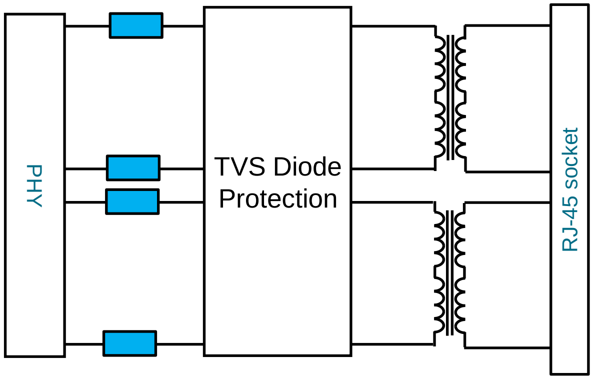
Metallic Ethernet Solution

- Is clamping at the lowest voltage ideal?
  - Found that 2.8 V, 3.3 V options provide small gains if any and under-sized, but often command higher prices.
    - Difficult to do comparable data sheet comparisons between them.
    - The 5 V options are older product and often cheaper.
- 8/20 TVS diode surge current rating of 30 A.
  - Choosing a lower current option increases risk of failure.
    - Ports random failed with TVS diodes shorting with 10-15 A ratings.
    - One Manufacturer rates their TVS diode at 20 A, but their silicon design technique makes for a very robust solution.
    - Some standardization on dynamic electrical specifications would be nice.
- Steering diode Arrays seem to work well.

Metallic Ethernet Solution

- Requiring over-current protection is down to the PHY.
    - Some PHY's can still be protected with just a 5V TVS diode but now a minority.
    - Add over-current protection as a precaution.

– There are a range of options, but two seem to work well.
- ECL (Electronic current limiter).
    – Very good protection but expensive.
    – Watch out for over-voltage stress if TVS diodes are not used.



- Low value Resistor.
    – **NO** (if selected correctly) reduction in performance.
    – Allows 0Ω resistors to also be used.
    – Resistor (if selected correctly) has **NO** impact on line reach.
    – 1/16 Watt resistors are cheap as dirt.

Metallic Ethernet protection

- Ethernet transformers make excellent 1st level protectors.
  - Saturate early to limit secondary current.
    - Current let-through pulse is roughly 100 A 0.5/2 µs (delay to 50% of peak) type surge for intra-building to help set the tertiary protection.
    - TVS diode dynamic voltage clamp performance is important.
  - Act like a fuse with too much impulse current.
  - Good quality transformers usually achieve around 4 kV or more surge isolation between primary to secondary.
    - Not all transformers are made equal.
    - Watch out for multi-port components pin spacing for port-port.
    - Watch out for Engineering modifications to the wiring without a PCN.
    - Don’t get caught out with wide manufacturing isolation tolerances.

Gotcha's

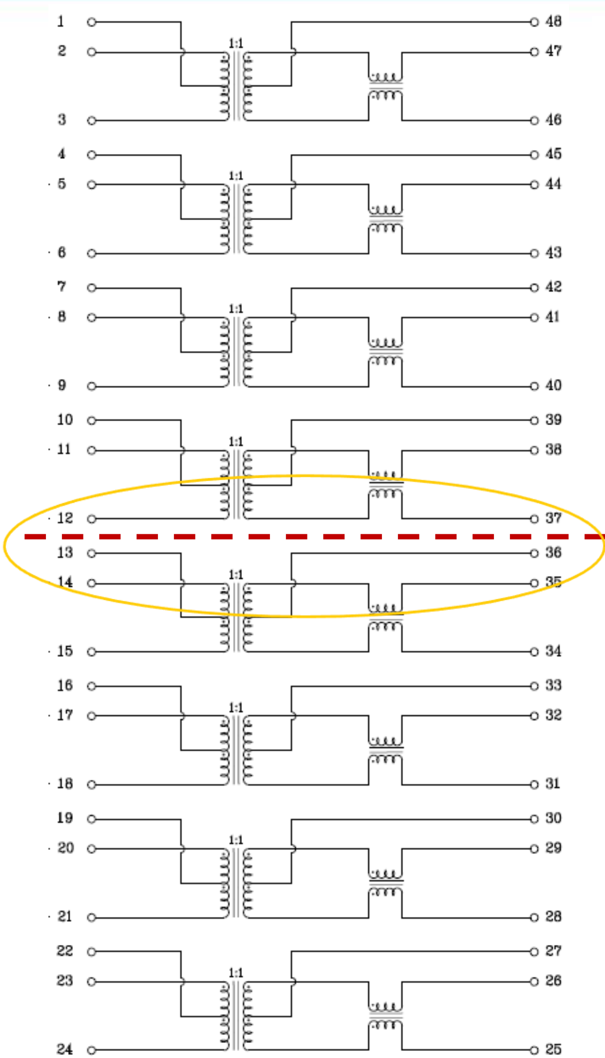
Measured Failure Thresholds of Ethernet Transformers

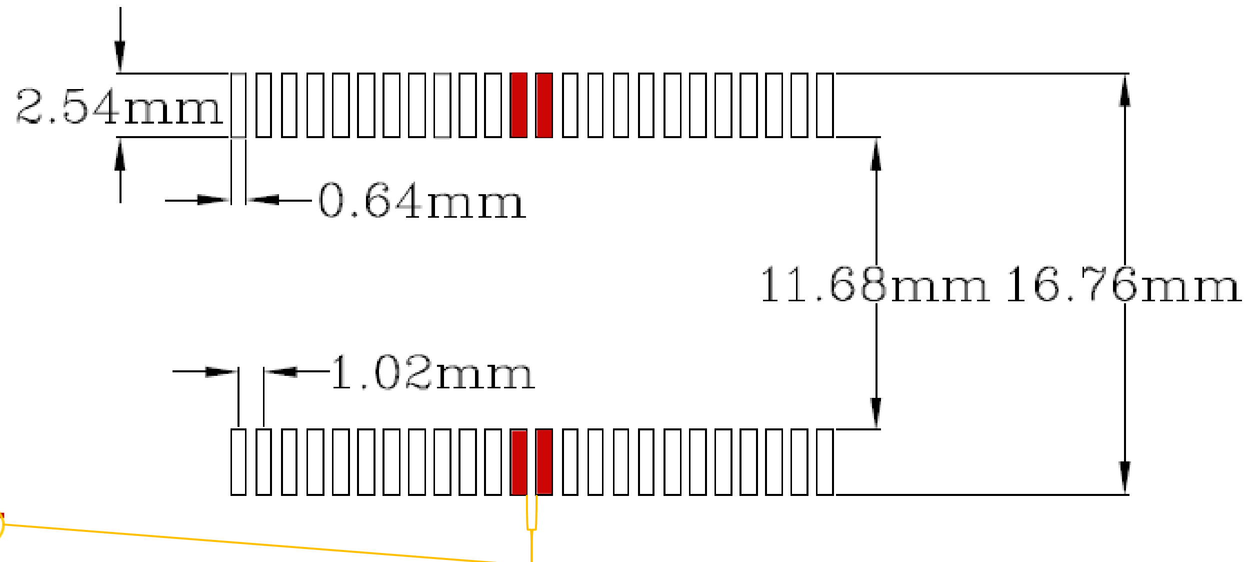
Ethernet Transformer	Breakdown	Notes
Wurth 7090-37	8 kV	
Wurth 7090-37	7 kV	
Falco LV2001	10 kV	
Pulse H1164	Over 10 kV	
Halo TG110-RP26NY	Over 10 kV	
Pulse T1144	9 kV	
Pulse H1102	8 kV	
Pulse H2009	10 kV	
Pulse H5007NL	5 kV	Second sample was 9 kV

ATIS PEG-2015, Randolph Telecom, Inc

- There is a wide tolerance due to micro-fracturing in the wiring enamel when wound on the bobbin and the inconsistency of the enamel thickness between different wire manufacturers.
- All the transformer manufacturers normally have to do is ensure 1500V RMS or 2250V DC Hi-POT.
- Grey area between the relationship between Hi-POT test and surge withstand capability.

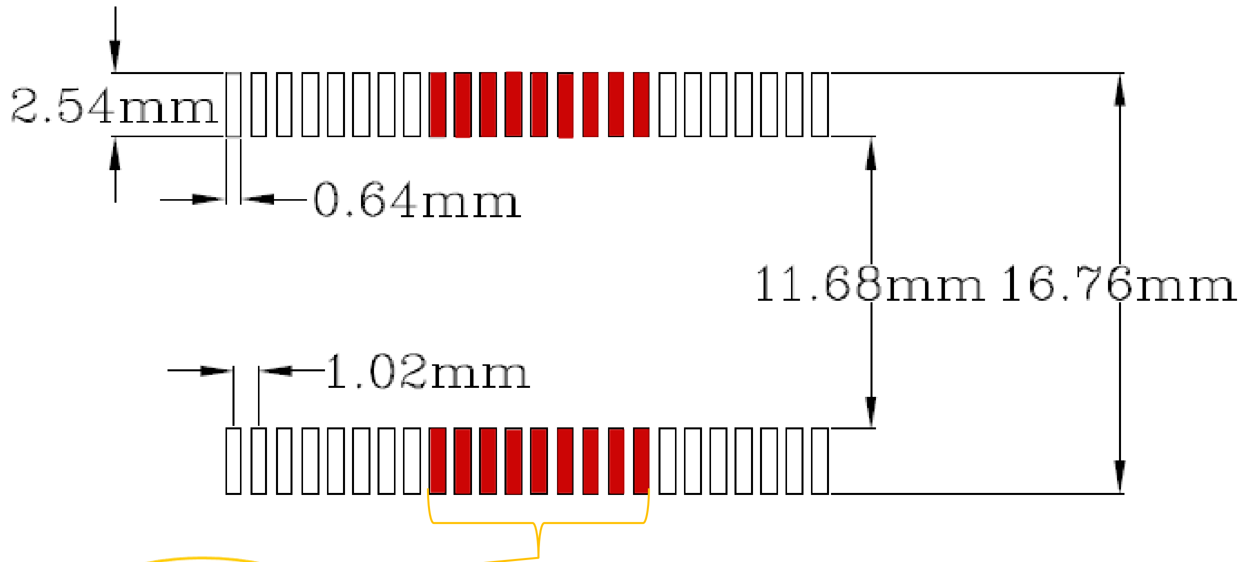
Port to Port Spacing



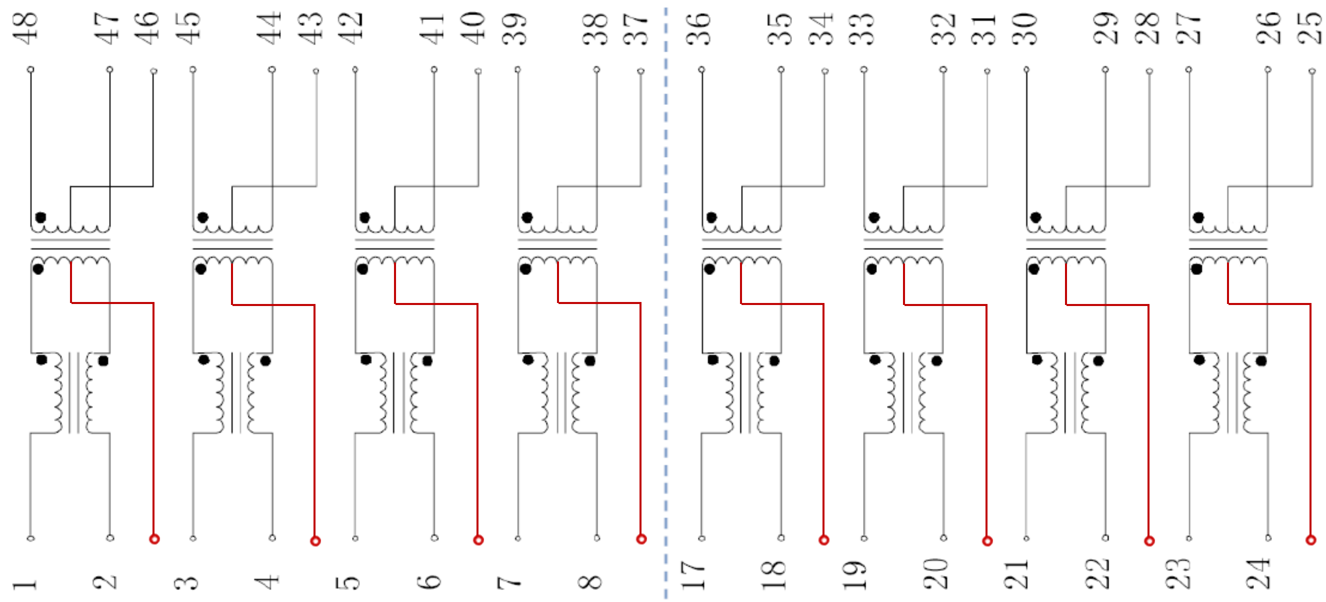


Pad distance is just 0.38mm between the two pairs on this common dual port option. This is around 500 V isolation between port to port!

Port to Port Spacing Fix



- Added 3.8mm between ports with unused pins.
  - Would have liked more spacing, but the package would have to be changed.
    - Would have removed the benefit of footprint & cost.
    - A lead frame modification to remove the pins would help.
- What has been given up?

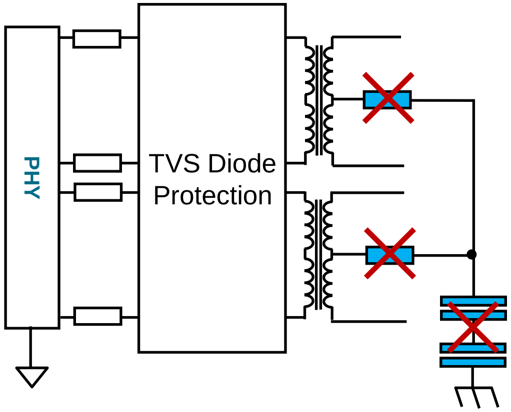


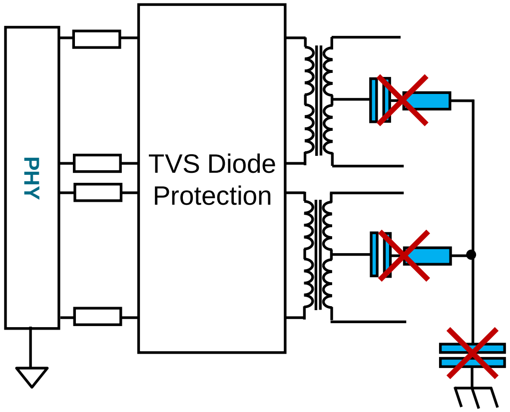
- No Bob Smith termination interfaces.
  - Remove all the problems associated with high voltage capacitors.
  - Design/layout ensures no EMC issues with this topology.
    - Saving on the B.S circuit allows focus in other areas for protection.

Longitudinal Ethernet Protection

- The Bob Smith Circuit is B.S!
  - High voltage rated capacitors are required.
    - Meeting 6 kV surge withstand compounds the problem.
    - Makes the circuit expensive using 2x 3kV capacitors.
  - Found not to impact **EMC** for Ethernet.
    - This is what Bob Smith was suppose to address!
      - Design and layout is important.
  - Testing has not found EMC issues for PoE either.
    - Design and layout is important.

The savings on B.S circuit can be used for making POE interfaces more robust.



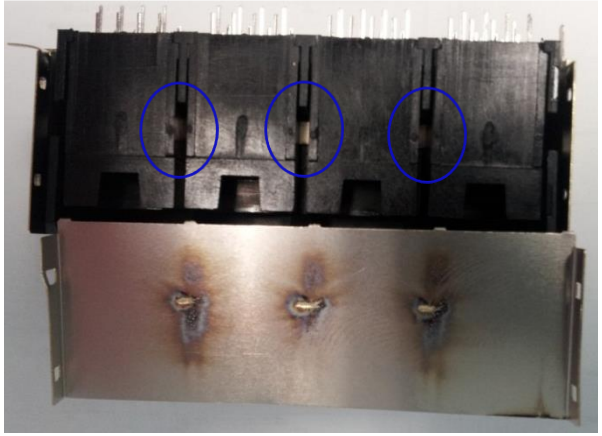


RJ-45 Integrated Jacks

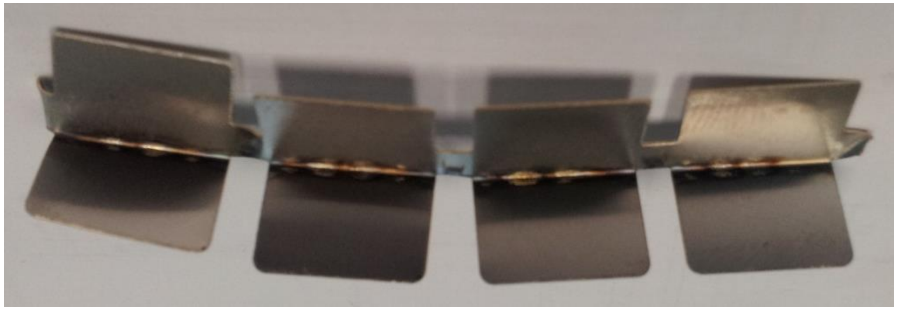
- Be cautious with integrated Jacks for Extended Isolation withstand performance.
  - Lucky if they pass the IEEE-802 isolation withstand of 1500 V RMS or 2250 V DC.
  - Transformers are in very small packages and often poor isolation.
  - Internal spacing's to shield is also often limited.
- Stick with Jack-Only designs outside standard Ethernet interfaces.

RJ-45 Shielded Socket

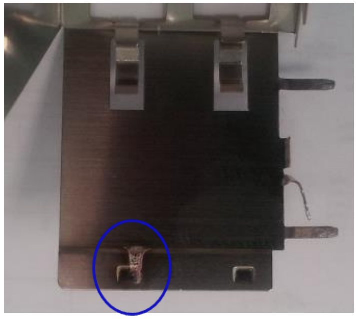
- No exposed pins at the back of the unit, but arcing still occurred to the shield.

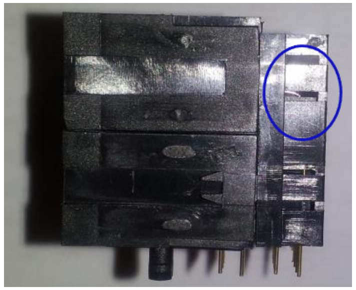


- Shield for EMC between top and bottom jacks.



- Arcing between the shield press fitting.



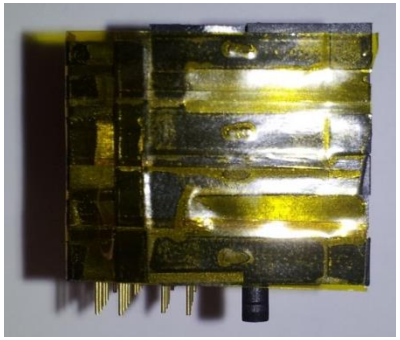


Metallic Ethernet protection

- Solution was to remove the shields.
  - Worked very well for low port count applications.

  ……but EMC got worried as this could cause an increase in eradiated emissions as there were six 4x2 modules (48 port) to create a nice large hole in the metalwork for some applications.
- Wrap the RJ-45 in Kapton tape under the shield!

  ……there are still issues with the pin spacing's on the board but this needs a new module design.
- Good news is that there seems to be experience in the jack manufacturer arena.



Integrated Sockets for Extended Surge Withstand

- Best option is to use just an RJ45 socket and place the magnetics on the board.
  - If there is space issue, anticipate isolation problems.
    - Seen integrated jacks specify that they pass the 1500V rms isolation tests but actually don’t.
      - The sales Engineer’s face was a picture!

  - Seen integrated jacks that have <500 V of isolation
  - Ones that do pass 2250 V DC often just make it!

    - Adtran now tests every Ethernet copper interface.

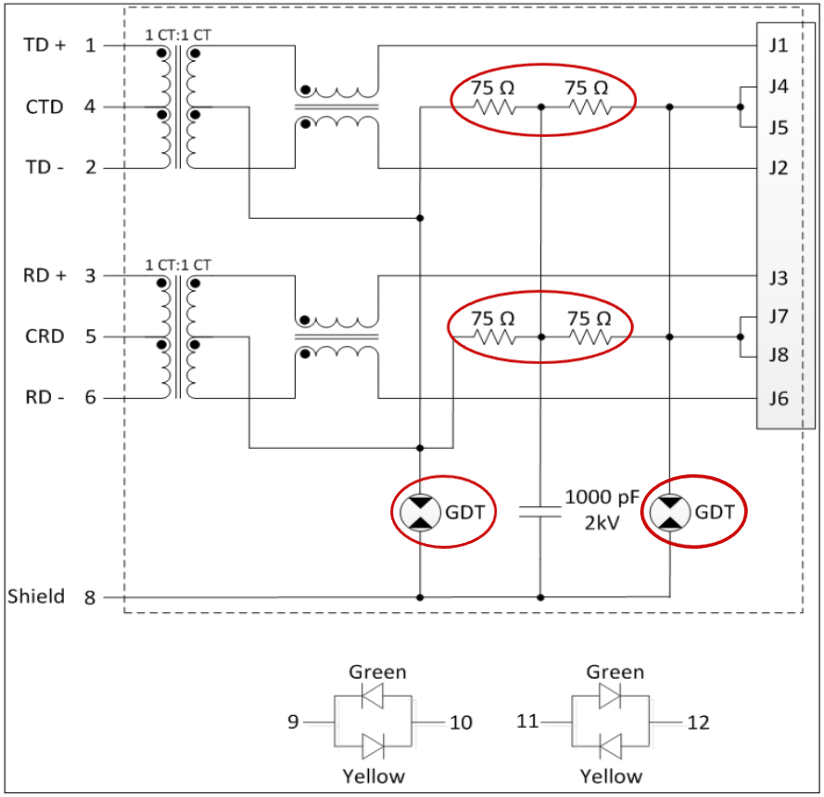
Example of an Integrated Jack

- Don't like showing the bad stuff, but this came across my desk one morning…….

- First GDT only protecting the 75Ω resistors.
  - 75 Ω looks to be done to help coordination.
- Large currents will be seen in the transformer windings when the GDT operates.
- Will fail GR-1089-CORE 120 V RMS, 25 A power fault test as the wire simulator will operate when the first GDT operates.
- If GDT DC breakdown voltage's are above 2250 V DC to pass IEEE Hi-POT, the 2 KV cap or shield spacing is not suitably protected.
- GDT is probably set to pass the 500V dc isolation test for international testing.

- ……Conclusion?

  This stuff CAN be made-up and it's out there!



PCB Layout for IEEE Isolation

- To meet IEEE 802 isolation requirements.
  - 1500 Vrms, 2250 VDC, 1400 V 1.2/50 surge.

  - 1 mm (40 mils) ~1 kV air isolation.
  - Inner layer spacing of 0.5 mm (20 mils) ~1 kV internal isolation.

- – To Everything else
  - Outside layer = 1.5 mm.
    - – Often pushes traces to be on an inner layer.
    - – Can cause layout errors at the connectors & transformers.
  - Inside layer = 0.5 mm.
- – Same port #
  - Outside layer = 0.3 mm
    - – Matches typical pin-pin spacing of transformers.

PCB Layout to Exceed 6 kV

- 6 kV longitudinal surge, using the rule of thumb:-

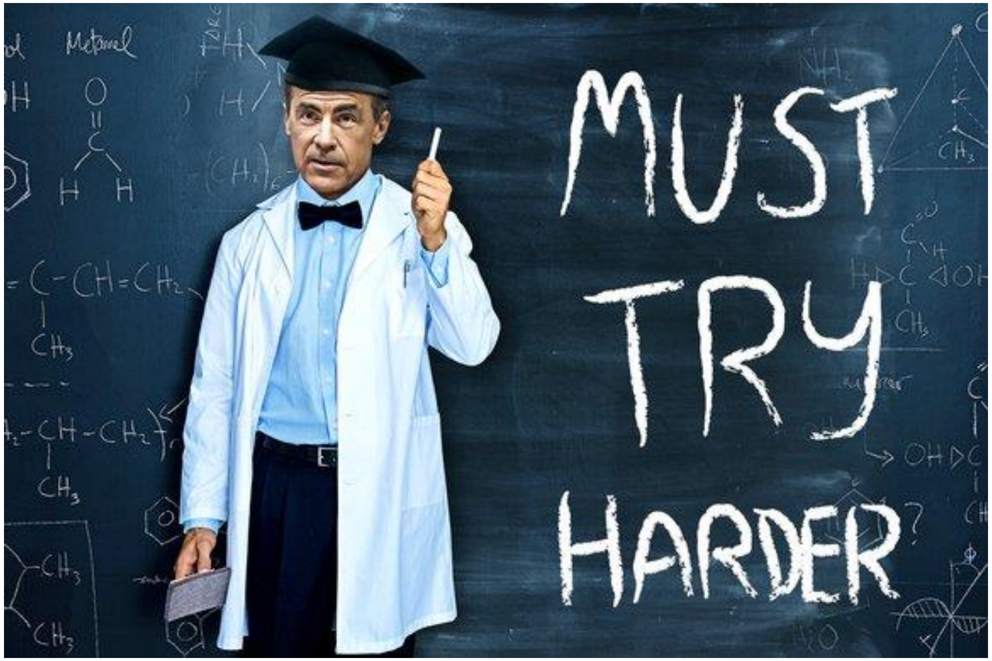
  - Outside layer is increased to 6 mm.
  - Inside layer is increased to 3 mm.

  - Vertical plane between layers also comes into play.
    - Dependent on board thickness but more reliable in isolation.
      - Established 3 kV between layers, so space the conductors with layer separation or off-set the trace layout by 1 mm (40 mils).
  - Trace thickness is dependent on surge currents.
    - 0.3 mm on 1oz copper is a good safety factor for Ethernet & PoE.
      - 0.13 mm traces typically failed GR-1089-CORE Intra-building.

Closing Statement

Ethernet & PoE reminds me of the comments on some of my term school reports……

Making progress, but must try harder!



Questions?