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# Gas Discharge Tube (GDT) Operation in Ethernet Protection

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Bourns



## Objective – to find out how various GDT types interact with Ethernet ports under surge conditions

- There have been many reports of instances where surge protective devices (SPDs) using GDTs have caused equipment failures. Possible failure causes are described in “Voltages and currents in Ethernet cables due to lightning strokes” (given in references)
- GDTs are frequently used for protection in Ethernet devices and equipment, which often interfaces with unknown cable routing and other equipment
- The original GDT investigation produced an ITU-T Study Group 5 contribution on GDT common-mode to differential-mode surge conversion for various GDT configurations
- Recently, concerns about using SPDs have resulted in standardization activities of different standard committees



## Topics

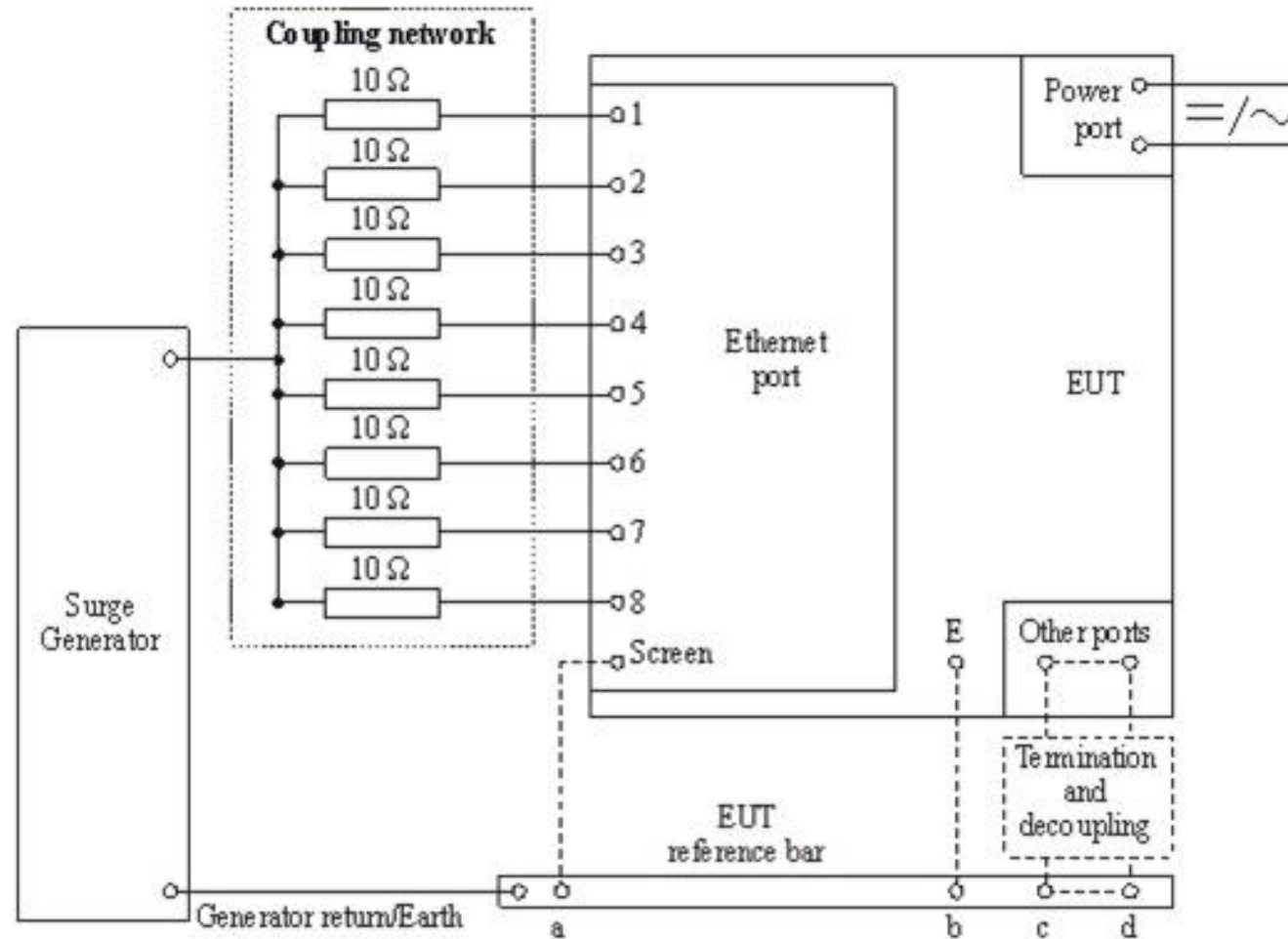
- Latest standardization activities
- Ethernet ports configuration and surge
- GDT as protection component
- Common Mode surge to Differential Mode surge conversion
- Test setup and what we are aiming for
- Compliance to the IEEE 802.3
- Test results and discussion
- Best approach for protection of Ethernet ports

## Ethernet port Common Mode (CM) surge test arrangement

CM surge of Ethernet ports based on the latest ITU-T Ethernet port tests e.g. ITU-T K.21 (7/2017) Test # 2.1.8 on transformer twisted-pair

- basic 2.5 kV / enhanced 6 kV 1.2/50-8/20 Combination Wave Generator (CWG) as given in Figure A.3-5 of ITU-T K.44 (5/2017)

Test setup given in the A.6.7-4 with coupling  $R = 10 \Omega$



## Differential Mode (DM) surge of inter pair PoE

DM surge of PoE powering pairs  
based on the latest ITU-T tests  
e.g. ITU-T K.21 (7/2017)

Test # 2.1.11

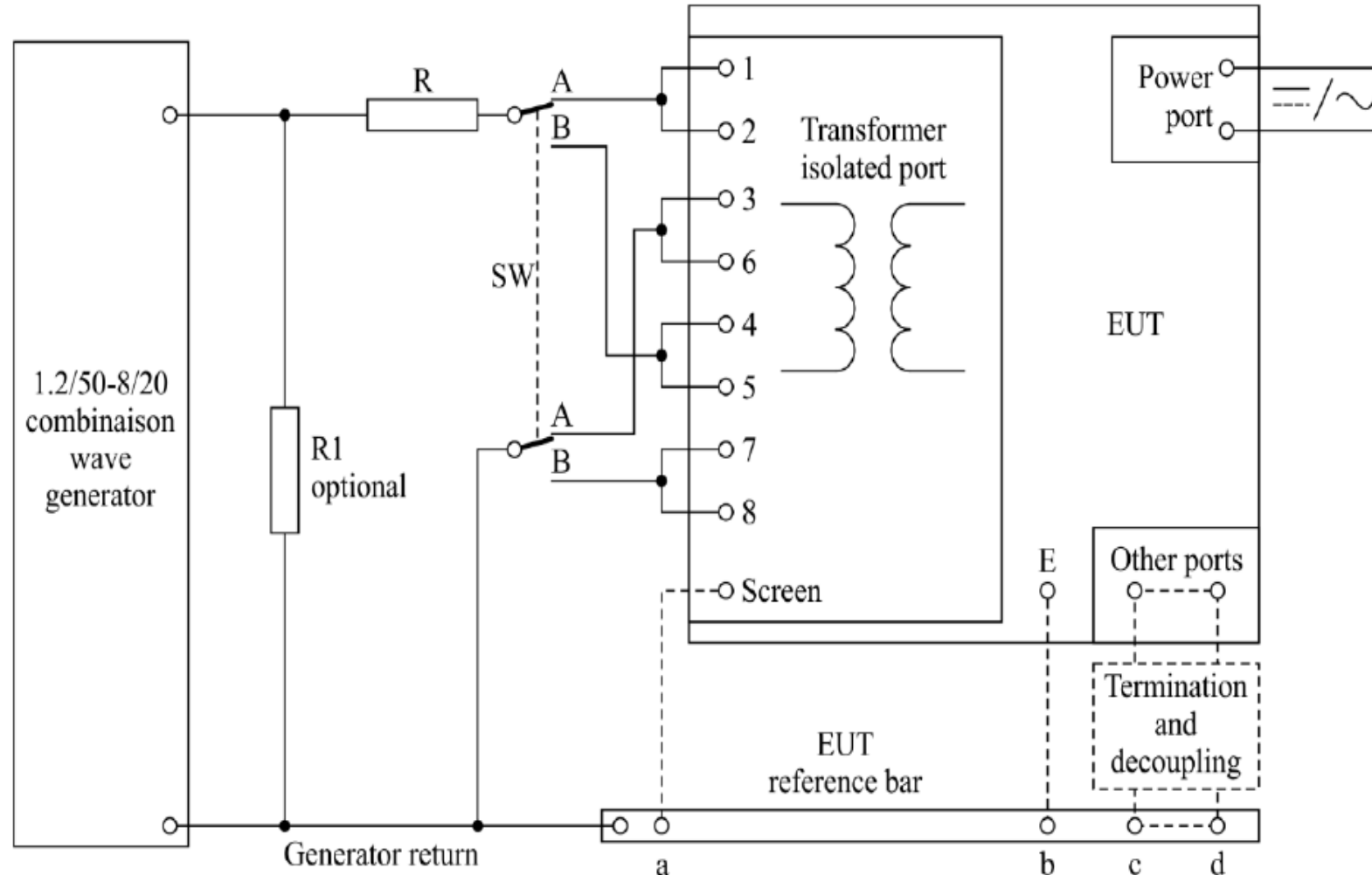
on PoE port powering pair

- 2.5 kV / 6 kV (0.6 kV / 1.5 kV )

1.2/50-8/20 CWG as given in  
Figure A.3-5 of ITU-T K.44 (5/2017)

Test setup given in the A.6.7-2

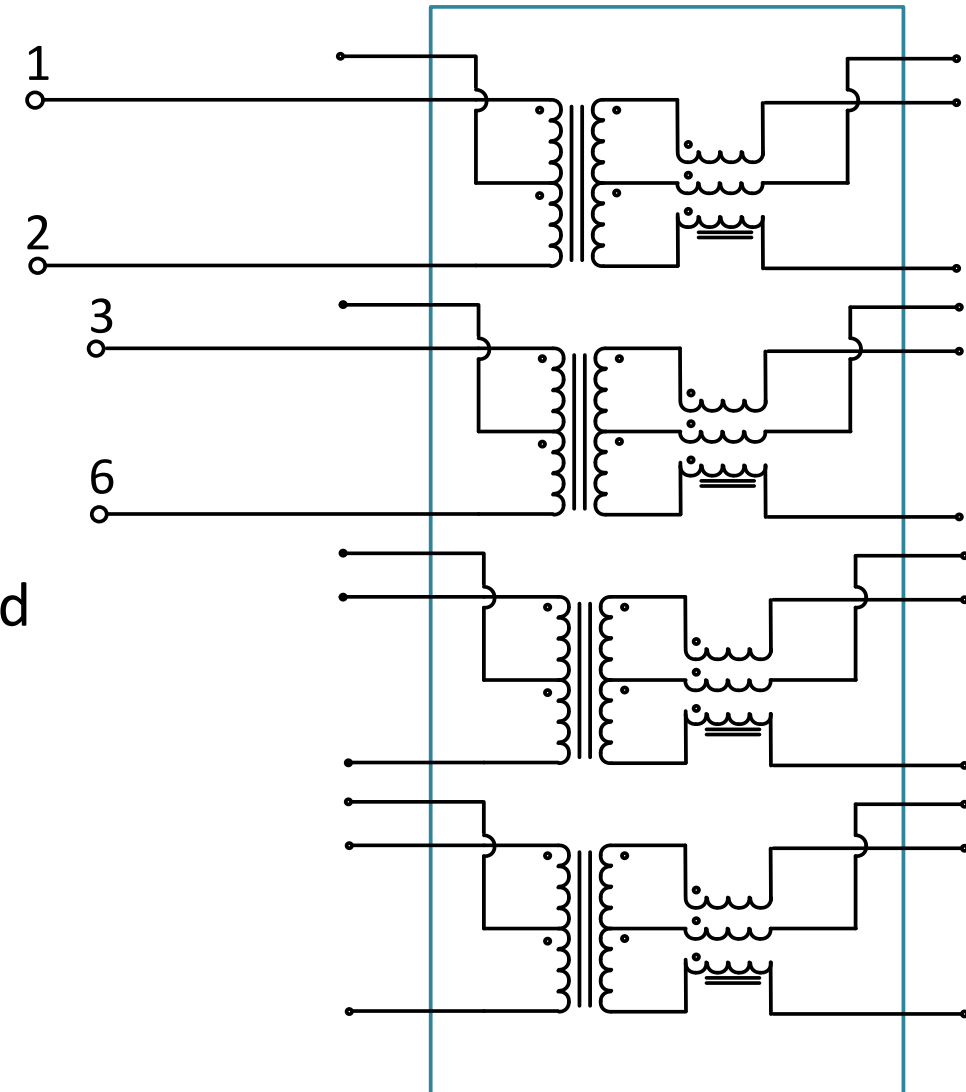
$$R = R1 = 10 \Omega$$



## Ethernet ports

Looking inside the RJ45 port and magnetics

- 1 and 2 twisted pair to consider (second pair 3 and 4)
- CM surge will raise the voltage of a pair  
=> pair is floating
- If the insulation between the transformer primary and its secondary is sufficient – no current will flow
- 6 kV surge will require a robust insulation and thoroughly dimensioned clearance and creepage distances
- Primary protection consideration



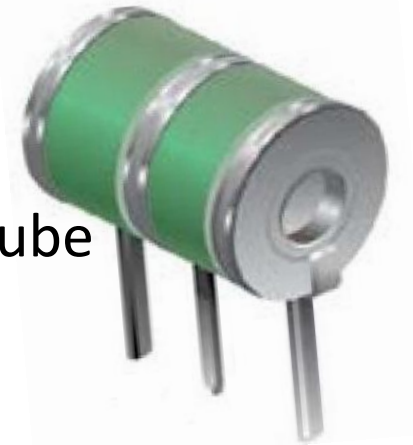


## GDT operation as primary protection of Ethernet twisted pair

Ethernet signals require low capacitance protection component

Gas Discharge Tube

- robust primary protector
- typ.  $C < 1 \text{ pF}$

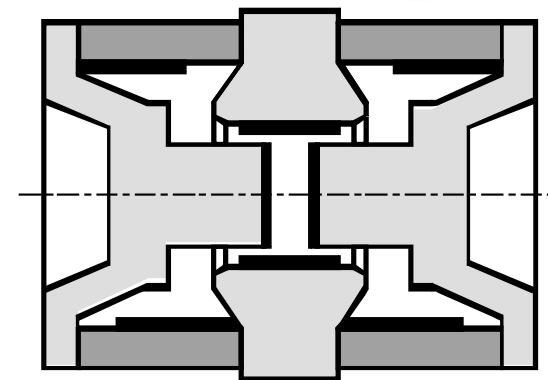
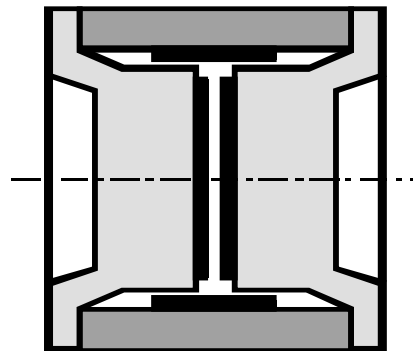


3-electrode tube



2-electrode tube

cross-section of a 2-electrode tube



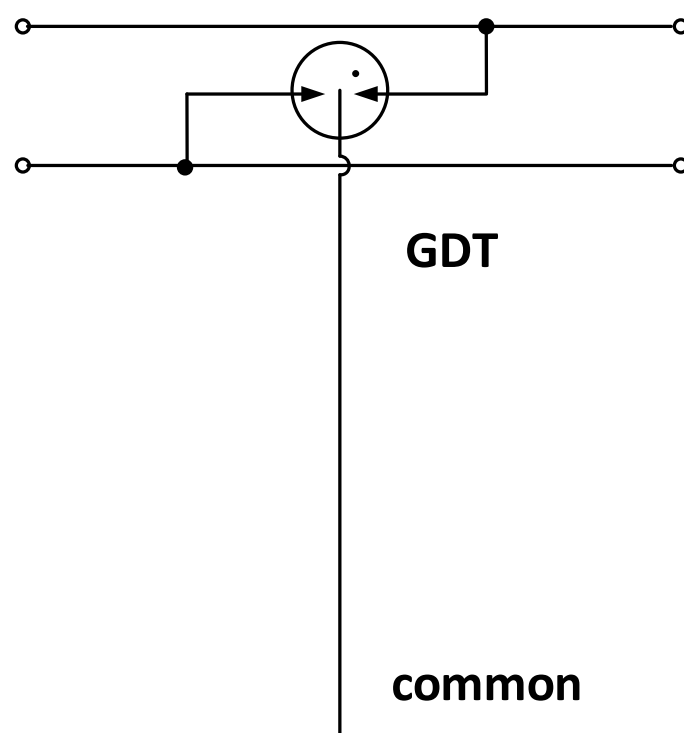
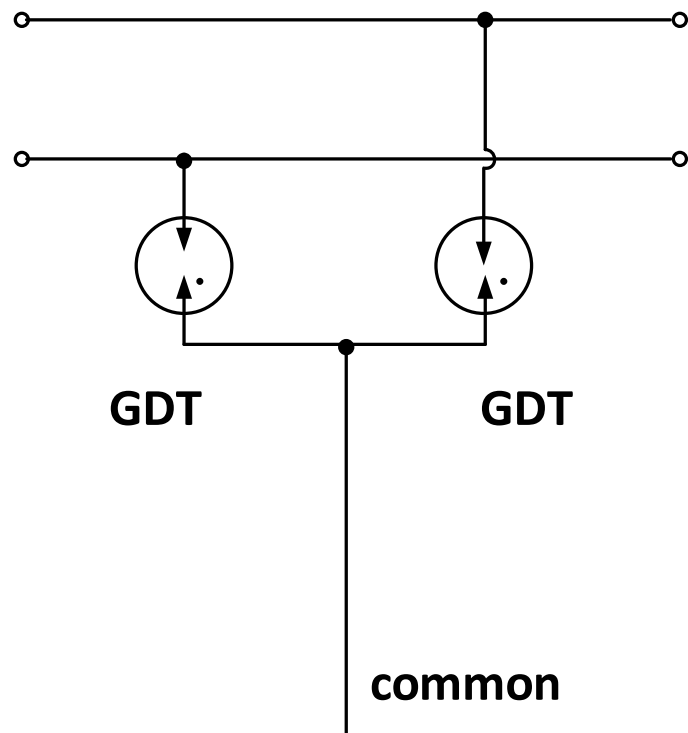
cross-section of a symmetrically designed 3-electrode tube

# Common Mode (CM) surge to Differential Mode (DM) surge conversion

two 2-electrode GDTs

vs.

one 3-electrode GDT



GDTs do not trigger at the same time

even the 3-electrode GDT will not conduct concurrently



## Test setup:

I) Surge (CM) only  
pair 1-2

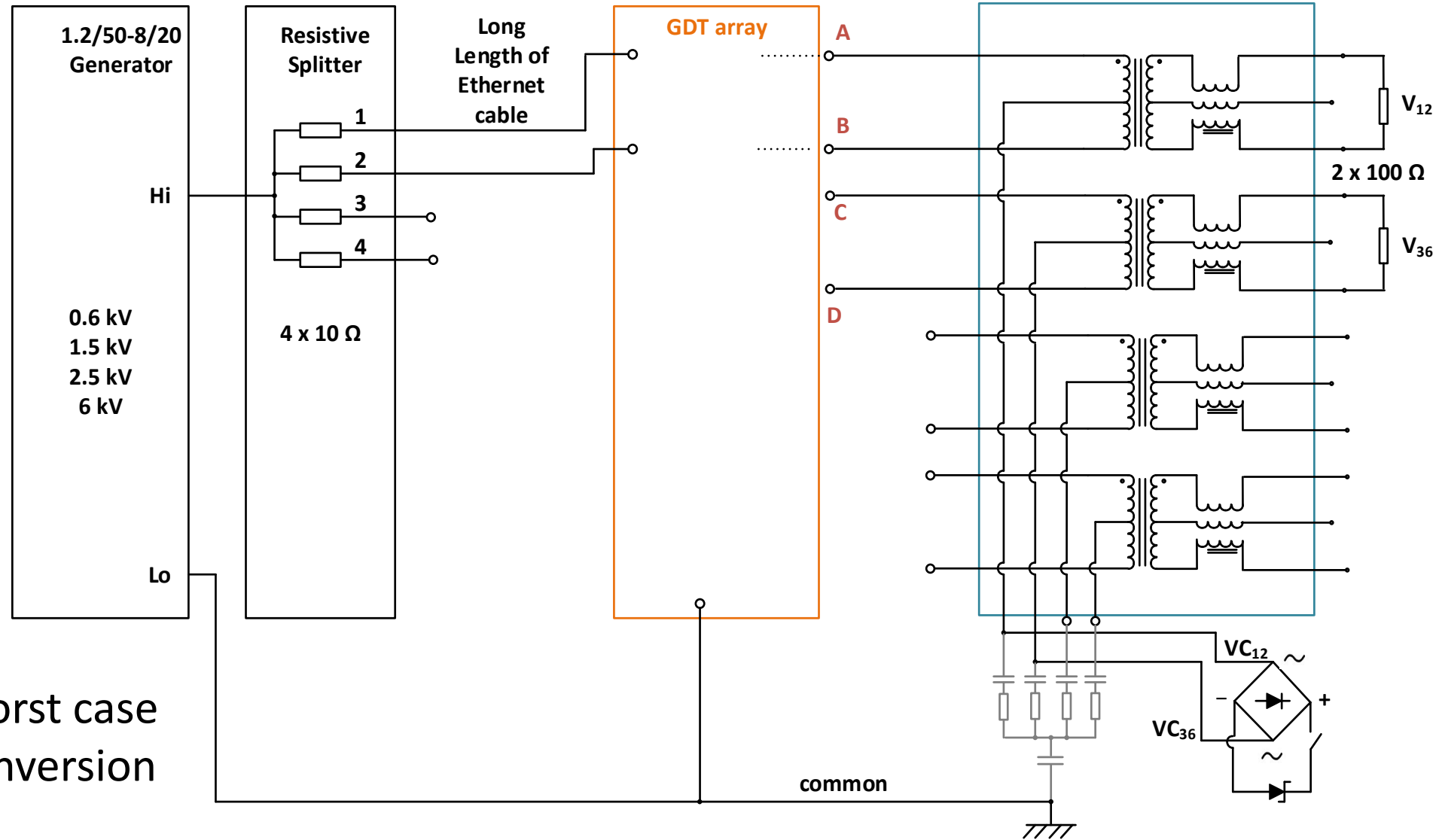
⇒ Record the A to B  
voltage difference

⇒ Record the  $V_{12}$

II) Surge (CM) all 4,  
i.e. pairs 1-2 & 3-4

⇒ Record the A to C  
voltage difference

... looking for the worst case  
of CM to DM surge conversion



## Test setup – cont'd

using two GDT arrays / with two arrangements

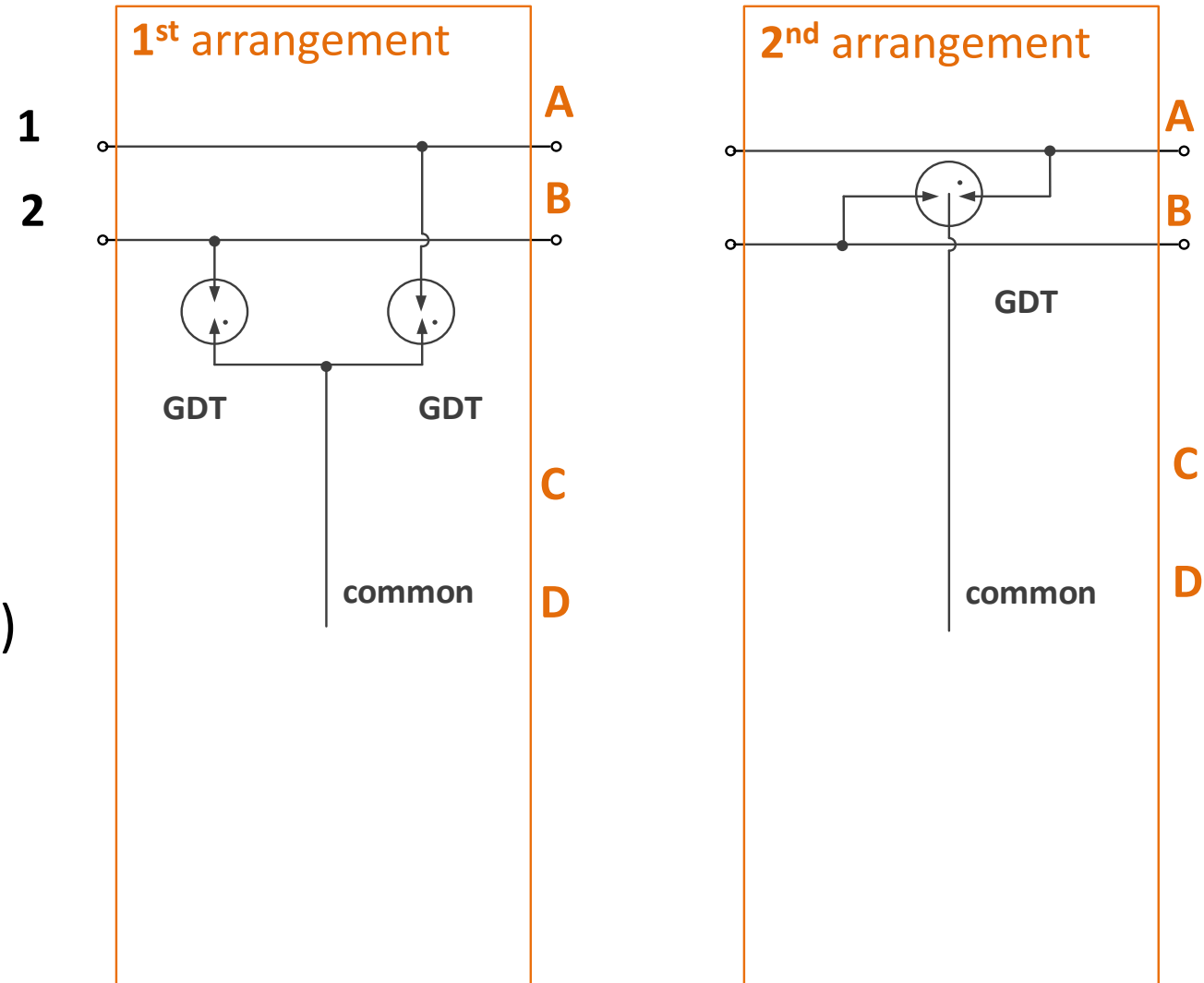
- 2 x 2-electrode GDTs (1<sup>st</sup> arrangement)
- 1 x 3-electrode GDTs (2<sup>nd</sup> arrangement)

per each pair

Surge (CM) at specified generator voltage levels (0.6 kV, 1.5 kV, 2.5 kV and 6 kV)

⇒ Record the  $V_{12}$  secondary voltage which is of our main interest

⇒ Record the A to C voltage difference for measuring points – see previous slide



## Compliance to the IEEE 802.3 (2012) – consolidated version

The resistance after the test shall be at least 2 MΩ, measured at 500 V dc.

- Medium Dependent Interface (MDI) shall be tested with 500 V d.c.
- The resistance after the test insulation voltage withstand test shall be at least 2 MΩ, measured at 500 V d.c.
- “MDI” interpretation: not only transformer, but all in between
- It means the GDT primary protectors together with the transformers!
- ... otherwise the system is not IEEE 802.3 compliant
- Implies using of GDTs with **DC spark-over voltage > 800 V** (including ± tolerance ±25% and ±30% )

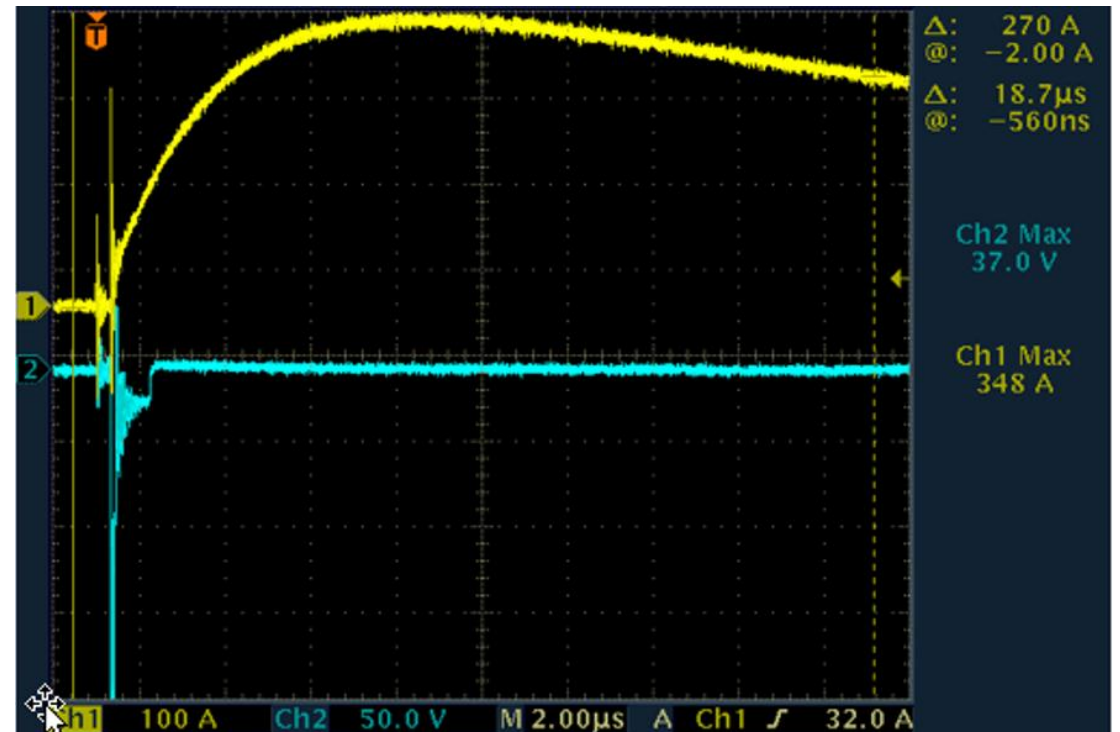
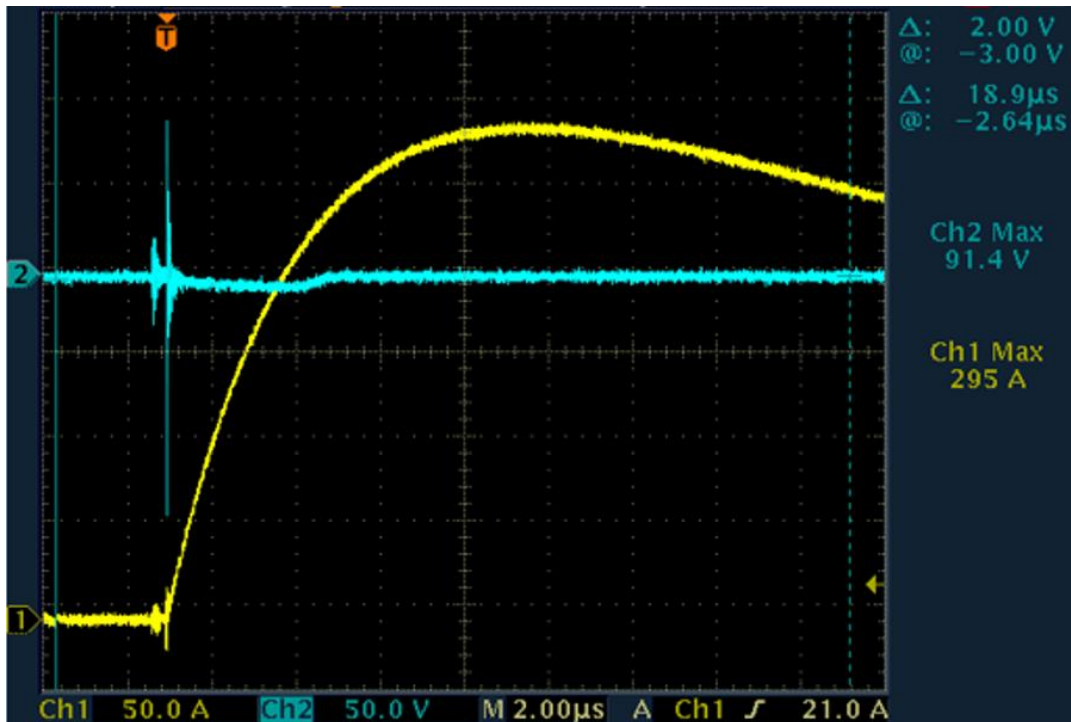
## Secondary winding surge voltage from 2 x 2-elect. and 1 x 3-elect. GDT

Primary CM surge, pair 1-2, 2.5 kV CWG — Yellow trace total SG current

Secondary DM surge voltage — Blue trace  $V_{12}$  voltage, core saturation truncated

2 x 2-el. GDTs → 8 V peak, 3.5  $\mu$ s ramp

1 x 3-el. GDT → 20 V, 0.8  $\mu$ s pulse





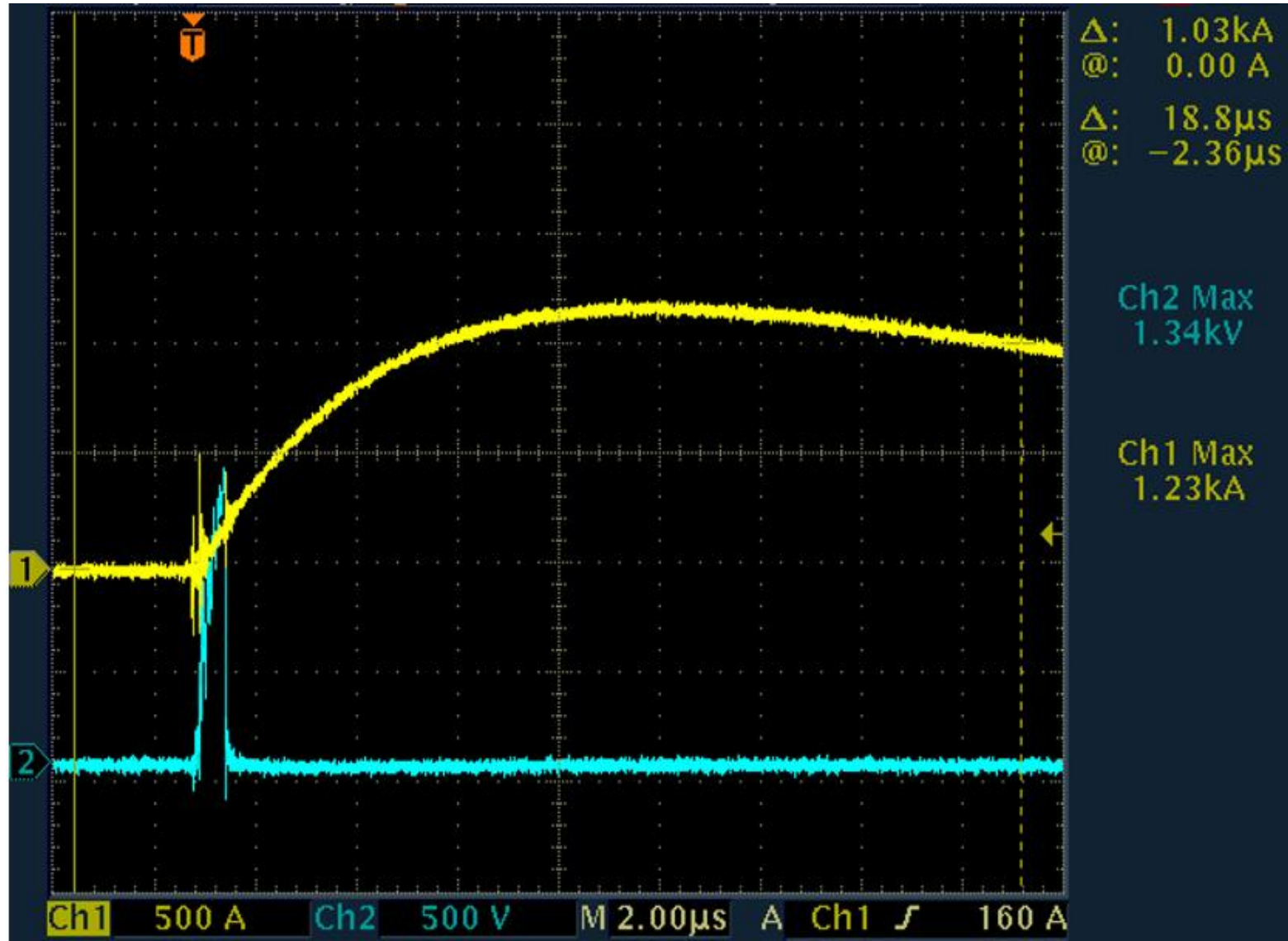
## CM surge with two 3-elect. GDTs, each per twisted pair

If two pairs, i.e. the inter-pair surged (CM), much higher differential voltages are measured after the GDT array reaches 1500 V peak

- CM pair 1-2 and 3-6 at 6000 V  
=> measured A and C (GDT array third output in test setup)

Blue – measured voltage A to C

Yellow – current of the SurgGen



# How is 3-electrode Impulse Transverse Delay measured traditionally?

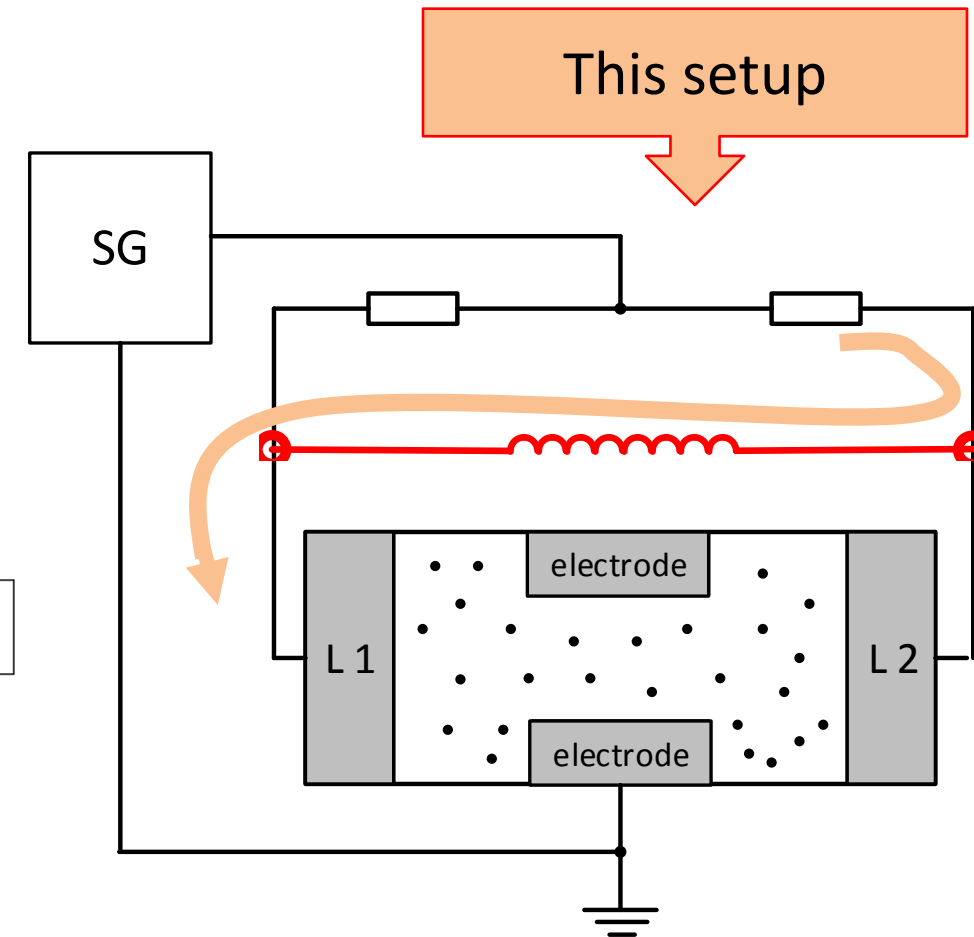
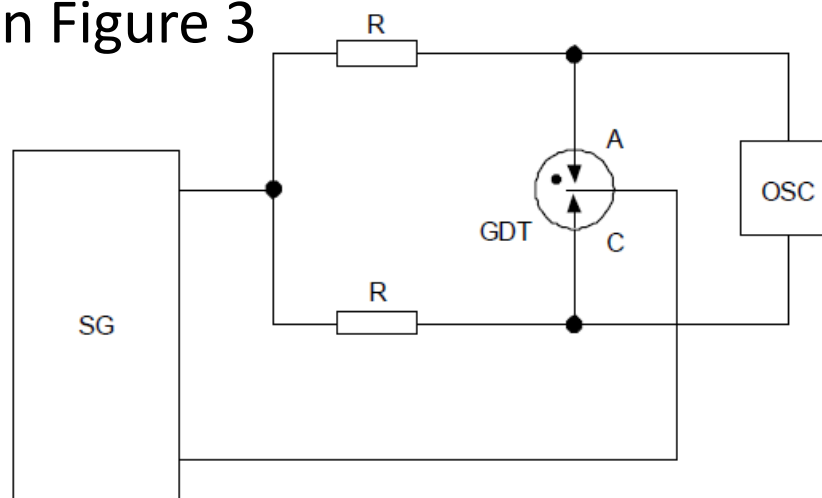
Impulse Transverse Delay is measured per ITU-T Recommendation K.12 (5/2010) :  
Characteristics of gas discharge tubes for the protection of telecommunications installations

- Clause 6.4 and
- Chapter 7.4, as given in Figure 3

Circuit for impulse transverse voltage test



SG – Surge Generator

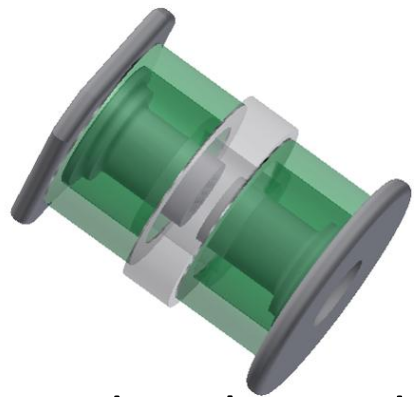




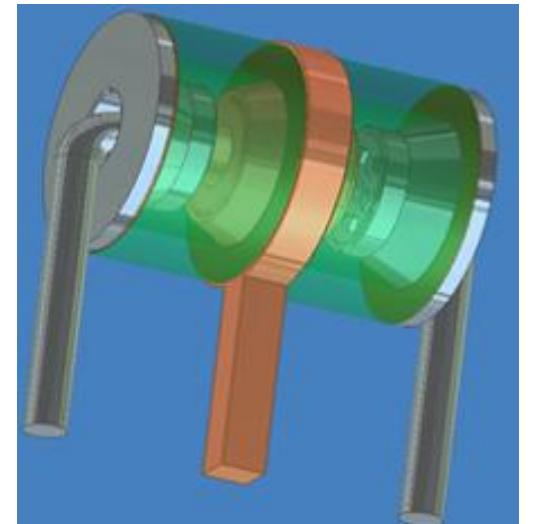
## How to reduce CM into DM surge conversion

Voltage measured after the GDT array, assuming the earthed GDTs, with only one pair surged is considerable smaller and the GDT itself appears to act as a protector

- CM surged voltage of up to 6000 V converts into differential
- Being a twisted-pair system a natural protection choice is the three-electrode, single chamber GDT to protect both conductors of the twisted pair.



Common chamber  
symmetrically designed 3-electrode GDT



Conventional design  
of a common chamber 3-electrode GDT

## Test results – discussion & observations

The path the surge current follows is not always the shortest one, looking at the schematics:

- One has to consider the physics of the plasma generation in GDTs as well.  
Example of an unexpected conduction path is to an unsurged GDT via the PoE d.c. powering extraction circuit – this is what has been observed.
- Example of the shunt transformer effect on a three-electrode GDT's simultaneous conduction is shown when the non-conducting side takes microseconds to enter conduction, because the transformer has pulled the voltage down below the glow voltage region.
- One observation: The residual voltage on the GDT array when using 2 x 2-electrode GDTs is in range of 100 V to 200 V, while the use of one symmetrically designed 3-electrode GDT with a common chamber left significantly less residual voltage, thus lessen this effect of CM to DM conversion.

## Ethernet ports SPD

Isolating Surge Transformer (IST)

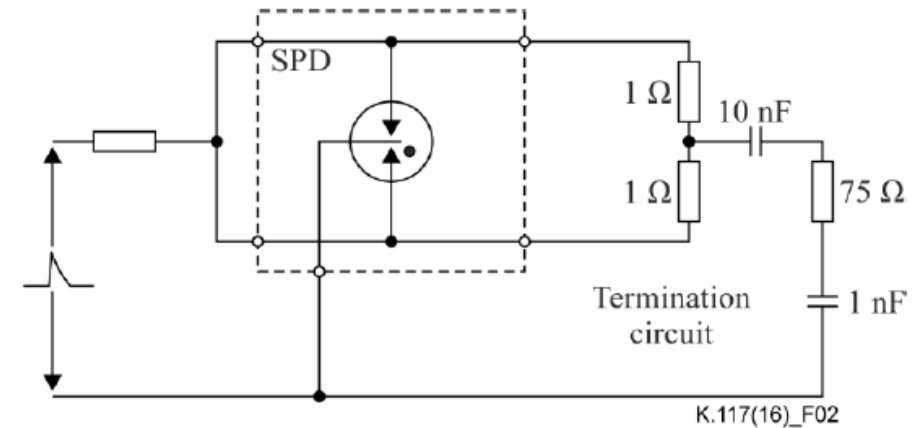
“two in one” approach for protection

- Recommendation ITU-T K.95 (6/2016) : Surge parameters of isolating transformers used in telecommunication devices and equipment

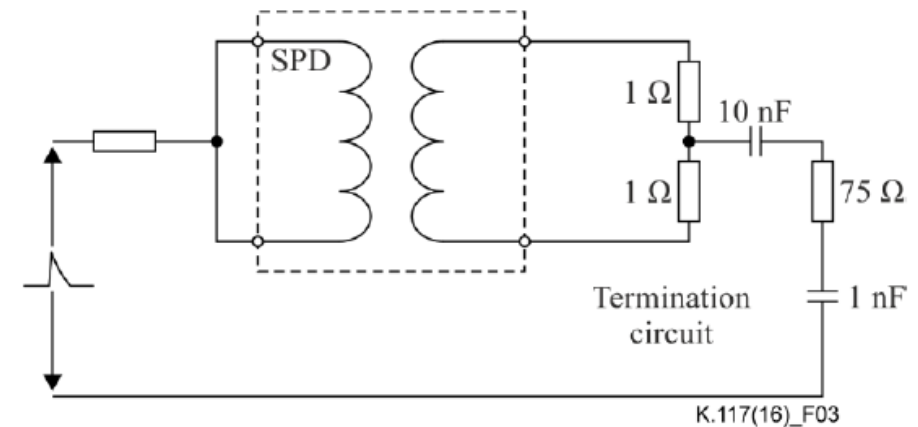
and

- Recommendation ITU-T K.117 (12/2016): Primary protector parameters for the surge protection of equipment Ethernet ports

showing examples of a voltage limiting GDT and IST in a CM surge test with the termination connected



**Figure 2 – GDT common-mode voltage limiting (partial circuit for only one twisted pair)**



**Figure 3 – Isolating transformer common-mode voltage blocking**



## Summary

- Ethernet ports are introducing new challenges for realization of protection schemes
- There are a few approaches like: voltage limiting gas discharge tube (GDT) and Surge isolating transformer
- Common Mode surge to Differential Mode surge conversion is the effect tested with GDTs
- Measured phenomenon – could get differential surges that can last into the microsecond region
- Guideline for achieving best results: 3-electrode GDTs with common chamber introduce less Impulse Transfer Delay than 2-electrode GDTs
- Keeping it compliant to the IEEE 802.3 and its 500 V d.c. insulation resistance requirement means that the differential surge is not generated for common-mode surges below about 600 V peak.

## References

- IEEE 802.3-2012 : IEEE Standard for Ethernet
- [Recommendation ITU-T K.12 \(5/2010\) : Characteristics of gas discharge tubes for the protection of telecommunications installations](#)
- [Recommendation ITU-T K.21 \(7/2017\) : Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents](#)
- [Recommendation ITU-T K.44 \(5/2017\) : Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents - Basic Recommendation](#)
- [Recommendation ITU-T K.95 \(6/2016\) : Surge parameters of isolating transformers used in telecommunication devices and equipment](#)
- [Recommendation ITU-T K.117 \(12/2016\): Primary protector parameters for the surge protection of equipment Ethernet ports](#)
- [Voltages and currents in Ethernet cables due to lightning strokes](#) – essay by M. J. Maytum





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Questions ?