What is TNV?

How do I know if my interface is TNV-x?

I’ve been hearing a lot about Power over Ethernet. What about PoE?

What’s so hazardous about that?

OK, now what?
- What level of insulation do I need?
- What’s this I hear about Nordic countries?
- What special tests do I need to perform?
What is TNV?

TNV is a colloquialism for a TNV CIRCUIT.

TNV CIRCUITS are:
- inside a piece of equipment considered secondary circuits connected to a:
  - TELECOMMUNICATION NETWORK; or
  - CABLE DISTRIBUTION SYSTEM

TNV CIRCUITS are not:
- any portion outside of the equipment that is a part of a:
  - TELECOMMUNICATION NETWORK; or
  - CABLE DISTRIBUTION SYSTEM

NOTE 2 Conductive parts of an INTERCONNECTING CABLE may be part of a TNV CIRCUIT as stated in 1.2.11.6.
TNV CIRCUITS have:
    specific voltage and current limits under both:
    normal operating conditions; and
    single fault conditions
    found in §2.3, Annex M and 60950-21
limited accessible contact area (§2.1.1)
Subclasses:
    TNV-1 CIRCUIT (§1.2.8.12)
    TNV-2 CIRCUIT (§1.2.8.13)
    TNV-3 CIRCUIT (§1.2.8.14)
Based on:
    voltage limits; and
    whether or not the TELECOMMUNICATION NETWORK they
    connect to is “exposed”
How do I know if my interface is TNV-x?.

§1.2.13.8, Note 2:

A TELECOMMUNICATION NETWORK may be:

- publicly or privately owned;
- subject to transient overvoltages due to atmospheric discharges and faults in power distribution systems;
- subject to longitudinal (common mode) voltages induced from nearby power lines or electric traction lines.

§1.2.13.8, Note 3:

Examples of TELECOMMUNICATION NETWORKS include:

- a PSTN;
- a data network;
- ISDN;
- a proprietary switched telephone network.
For a limited coverage lookup table, refer to IEC TR 62102, Electrical safety – Classification of interfaces for equipment to be connected to information and communications technology networks.

{IEC TC 108 is responsible for IEC TR 62102 and is always looking for input into this technical report to keep it up to date. If you have anything to add, please contact a representative of the ANSI US TAG to TC 108.}

But, if IEC TR 62102 is unavailable, the there’s another way …
What about PoE?

Is it a good fit?
The short answer is: **YES**.

**IEEE 802.3, §33** deals with Data Terminal Equipment (DTE) Power via Media Dependent Interface (MDI)

§33.4.1.1 Electrical isolation environments

**Environment A:** … entirely contained within a single low-voltage power distribution system *and* within a single building.

**Environment B:** … crosses the boundary between separate power distribution systems *or* the boundaries of a single building.
IEEE 802.3, §33.4.1.1, Environment B, also includes crossing over into a part of a building with a separate service entrance, even if within the same building structure, which is not addressed in 60950-1 and is SELV, consistent with the intent of 60950-1.
IEEE 802.3, §33 is also consistent with 60950-1 in that:

§33.1.1 Objectives
“b) Safety—A PSE designed to the standard will not introduce non-SELV (Safety Extra Low Voltage) power into the wiring plant.”

compares well with §2.2 and §2.3 and the interconnection of SELV CIRCUITS and TNV CIRCUITS with other circuits.

§33.1.3 Relationship of Power via MDI to the IEEE 802.3 Architecture
“Complies with TNV limits and §6.5 requirements for protection of overheating of a telecommunication network.”

The reference is to 60950-1, 1st ed. In 60950-1, 2nd ed., the reference is §6.3; the value is 1.3 A.
§33.4.1 Isolation
… electrical isolation shall be in accordance with the isolation requirements between SELV CIRCUITS and TELECOMMUNICATION NETWORK connections in subclause 6.2 of IEC 60950-1:2001.

a) 1500 Vrms steady-state is 500 Vrms higher than 60950-1
b) 1500 V, 10/700 µs impulse test is the same

And the compliance criteria are the same.
What’s so hazardous about that?

Nothing!

Provided the relevant requirements for the type of circuit and the operating environment are applied, namely:

- Limited accessibility (§2.1)
- Voltage and current limitations (§2.3 and Annex M)
- Insulation, separation, earthing or “other constructions” (§2.3.2, §2.3.3, §2.10, §6.2)
- Single fault tests (§2.3.1, §5.3 and Annex M.3.1.4)
- Touch current tests
- Power cross tests or “construction only path”

Let’s look at the unique aspects of TNV CIRCUIT compliance.
What level of insulation do I need?

Summarizing §2.3.2, Table 2H and §6:

<table>
<thead>
<tr>
<th>Parts being separated</th>
<th>Separation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unearthed SELV CIRCUIT</td>
<td>Unearthed TNV-1 CIRCUIT FUNCTIONAL INSULATION</td>
</tr>
<tr>
<td></td>
<td>Testing per §6.2.1</td>
</tr>
<tr>
<td>Earthed TNV-1 CIRCUIT</td>
<td>BASIC INSULATION Testing per §6.2.1</td>
</tr>
<tr>
<td>TNV-2 CIRCUIT</td>
<td>BASIC INSULATION Testing per §6.2.1</td>
</tr>
<tr>
<td>TNV-3 CIRCUIT</td>
<td>BASIC INSULATION Testing per §6.2.1</td>
</tr>
<tr>
<td>Parts being separated</td>
<td>Separation</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Earthed SELV CIRCUIT</td>
<td>TNV-1 CIRCUIT</td>
</tr>
<tr>
<td>or accessible conductive part</td>
<td><strong>FUNCTIONAL INSULATION</strong></td>
</tr>
<tr>
<td></td>
<td>Earthed TNV-1 CIRCUIT</td>
</tr>
<tr>
<td></td>
<td>TNV-2 CIRCUIT</td>
</tr>
<tr>
<td></td>
<td>TNV-3 CIRCUIT</td>
</tr>
<tr>
<td>BASIC INSULATED conductive part</td>
<td>TNV-X CIRCUIT</td>
</tr>
<tr>
<td>ELV CIRCUIT</td>
<td>TNV-X CIRCUIT</td>
</tr>
<tr>
<td>Parts being separated</td>
<td>Separation</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td><strong>TNV-1 CIRCUIT</strong></td>
<td><strong>FUNCTIONAL INSULATION</strong></td>
</tr>
<tr>
<td>TNV-2 CIRCUIT</td>
<td>BASIC INSULATION Testing per §6.2.1</td>
</tr>
<tr>
<td>TNV-3 CIRCUIT</td>
<td>BASIC INSULATION Testing per §6.2.1</td>
</tr>
<tr>
<td><strong>TNV-2 CIRCUIT</strong></td>
<td><strong>FUNCTIONAL INSULATION</strong></td>
</tr>
<tr>
<td>TNV-3 CIRCUIT</td>
<td>BASIC INSULATION&lt;sup&gt;(1)&lt;/sup&gt; Testing per §6.2.1</td>
</tr>
<tr>
<td><strong>TNV-3 CIRCUIT</strong></td>
<td><strong>FUNCTIONAL INSULATION</strong></td>
</tr>
<tr>
<td><strong>TNV-X</strong></td>
<td>Unearthed HAZARDOUS VOLTAGE</td>
</tr>
<tr>
<td></td>
<td>SUPPLEMENTARY INSULATION</td>
</tr>
<tr>
<td></td>
<td>Testing per §6.2.1</td>
</tr>
<tr>
<td><strong>TNV-X</strong></td>
<td>Earthed HAZARDOUS VOLTAGE</td>
</tr>
<tr>
<td></td>
<td>REINFORCED INSULATION</td>
</tr>
<tr>
<td></td>
<td>Testing per §6.2.1</td>
</tr>
</tbody>
</table>

<sup>(1)</sup> – Per Table 2H, Condition f, **BASIC INSULATION** may not be required.
Also per §2.3.2.3, BASIC INSULATION is not needed between if:

- for PLUGGABLE EQUIPMENT in general, a separate “Code type” protective earthing terminal is provided and appropriate installation instructions are provided for it use
- for PLUGGABLE EQUIPMENT TYPE B with only pluggable TELECOMMUNICATIONS NETWORK interconnects, installation instructions are provided stating all TELECOMMUNICATIONS NETWORK connections shall be disconnected before unplugging the equipment
- for PLUGGABLE EQUIPMENT TYPE A the same as above, plus the installation instructions must also state installation is to be made by a SERVICE PERSON and a socket outlet with as PROTECTIVE EARTHING contact
- the product is PERMANENTLY CONNECTED EQUIPMENT

or, per §2.3.2.4, “other constructions.”
In quantifying the insulation, the usual suspects the apply:

- Working voltage
- Anticipated transient overvoltages
- Circuits to insulate from
- Mitigating design features

For clarity:

High voltage bulk sources for ring and other signaling voltages in equipment with multiple TNV CIRCUIT outputs are considered HAZARDOUS VOLTAGE CIRCUITS, unless they also meet the limits for TNV CIRCUITS.
Working Voltages

Normal Operating Voltage

See also Table 1A.
In determining **WORKING VOLTAGES** for **TNV CIRCUITS**, if the normal operating voltages are known, use those voltages. The voltages are known if the sources creating them are internal to the host product (PBX, key system or the like).

If not, per §2.3.1:

- 60 Vdc for **TNV-1 CIRCUITS**
- 120 Vdc for **TNV-2 CIRCUITS** and **TNV-3 CIRCUITS**
- any superimposed ac

\[ \frac{U_{ac}}{71} + \frac{U_{dc}}{120} = 1 \]

- 60 Vdc for Canada and the US, for all **TNV CIRCUITS**.

**NOTE:** Ringing and other telephone signals are ignored, because they are “infrequent.”
Transient Overvoltages

* measured per §2.10.3.9 and Table 2J
Per §2.10.3.4, the transient overvoltage that applies is the highest of either that:

- from the **MAINS SUPPLY**, or
- from the **TELECOMMUNICATIONS NETWORK TRANSIENT VOLTAGE**

For equipment connected to the **AC MAINS SUPPLY**, §2.10.3.6, §2.10.3.8 and Annex G.3 tell us the anticipated transient overvoltages are:

<table>
<thead>
<tr>
<th>Circuit Type</th>
<th>AC MAINS VOLTAGE(^{(1)})</th>
<th>Transient Overvoltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELV CIRCUIT or TNV-2 CIRCUIT</td>
<td>150</td>
<td>800 V(_{pk})</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>1,500 V(_{pk})</td>
</tr>
<tr>
<td>TNV-1 CIRCUIT or TNV-3 CIRCUIT(^{(2)})</td>
<td>150</td>
<td>1,500 V(_{pk})</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>1,500 V(_{pk})</td>
</tr>
</tbody>
</table>

\(^{(1)}\) – the anticipated transient on a secondary circuit from an **AC MAINS SUPPLY** in a installation category II;
(2) – the anticipated transient from the **TELECOMMUNICATION NETWORK**, taken from ITU-T Recommendation K.17, Table 1. (For background, see also ITU-T Recommendations K.11, K.67.)
For equipment connected to a **DC MAINS SUPPLY**, §2.10.3.2, ¶ b) and c) tell us that if:

<table>
<thead>
<tr>
<th>DC MAINS SUPPLY is:</th>
<th>MAINS TRANSIENT OVERVOLTAGE (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>earthed</td>
<td>71</td>
</tr>
<tr>
<td>unearthed</td>
<td>same as the AC MAINS SUPPLY</td>
</tr>
<tr>
<td>batteries only</td>
<td>71</td>
</tr>
</tbody>
</table>

Or as measured by the method in §2.10.3.9.

<table>
<thead>
<tr>
<th>Circuit Type</th>
<th>Transient Overvoltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELV CIRCUIT or TNV-2 CIRCUIT(^{(1)})</td>
<td>71 (V_{pk})</td>
</tr>
<tr>
<td>TNV-1 CIRCUIT or TNV-3 CIRCUIT(^{(2)})</td>
<td>1,500 (V_{pk})</td>
</tr>
</tbody>
</table>
CLEARANCES

From Table 2M, for Pollution Degree 2:

<table>
<thead>
<tr>
<th></th>
<th>for TNV-2 (mm)</th>
<th>for TNV-1 and TNV-3 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEAK WORKING VOLTAGE</td>
<td>60 Vdc or 71 Vac</td>
<td>120 Vdc</td>
</tr>
<tr>
<td>FUNCTIONAL INSULATION</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>BASIC INSULATION</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>SUPPLEMENTARY INSULATION</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>REINFORCED INSULATION</td>
<td>2.6</td>
<td>2.6</td>
</tr>
</tbody>
</table>
CREEPAGE DISTANCES

Transient overvoltages don’t effect CREEPAGE DISTANCES.

Assuming Material Group IIIb and Pollution Degree 2, Table 2N tells us:

<table>
<thead>
<tr>
<th>PEAK WORKING VOLTAGE</th>
<th>60 Vdc</th>
<th>71 Vac</th>
<th>120 Vdc</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUNCTIONAL INSULATION</td>
<td>1.25(1)</td>
<td>1.3(2)</td>
<td>1.5(1)</td>
</tr>
<tr>
<td>BASIC INSULATION</td>
<td>1.25(1)</td>
<td>1.3(2)</td>
<td>1.5(1)</td>
</tr>
<tr>
<td>SUPPLEMENTARY INSULATION</td>
<td>1.25(1)</td>
<td>1.3(2)</td>
<td>1.5(1)</td>
</tr>
<tr>
<td>REINFORCED INSULATION</td>
<td>2.5(1)</td>
<td>2.6(2)</td>
<td>3.0(1)</td>
</tr>
</tbody>
</table>

(1) – The values shown are not interpolated, but are accepted as the next higher value at 63 V
(2) - The values shown are based on the rules for interpolation in the conditions to Table 2N, which require rounding up to the next highest 0.1 mm. Anyone see the inconsistency?
SOLID INSULATION

All the usual aspects of solid insulation apply:

For **FUNCTIONAL INSULATION** and **BASIC INSULATION**, no **SOLID INSULATION** requirements.

For **SUPPLEMENTARY INSULATION** and **REINFORCED INSULATION**, **SOLID INSULATION** requirements *do* apply.

Two significant exceptions exists:

- §2.10.5.13
- ‘Nordic’ National Differences (Finland, Norway and Sweden)
Per §2.10.5.13, solvent-based enameled magnet wire to provide electrical separation that is considered to meet the requirements of 2.3.2.1 is OK, 

*if:*

- Complies with IEC 60317, Class 2, with the EST based on IEC 60950-1
- The finished part meets:
  - EST requirements in §C.2
  - Routine tests with EST at 1 kV
- The assembled equipment still needs to meet §6.1.2.1 (steady-state and impulse testing)

For Canada and the US, Annex P.2 National Differences exist that allow use of magnet wire complying with ANSI/NEMA MW 1000.
In ‘Nordic’ National Differences:

Per EN 60950-1, §2.2.4, §2.3.2, § §2.3.4 and §6.2.1, all of which address interconnection of TNV CIRCUITS to dissimilar circuits, Annex ZB (Special National Conditions) mandates that SOLID INSULATION requirements apply, regardless of the insulation levels otherwise mandated by the standard.

Here, the solid insulation requirements resemble those for SUPPLEMENTARY INSULATION and REINFORCED INSULATION in §2.10.5:

- 0.4 mm thickness of a single insulation layer
- thin sheet insulation in two or more layers
- Y2 capacitors complying with EN 132400:1994
- Y3 capacitors complying with EN 132400:1994 and subjected to additional testing
Except that the EST is 1.5 kV, based on the steady state test in §6.1.2.1, case a, that otherwise applies to hand-held parts.

If the solid insulation is inside an optical isolator of other IC, a routine test at 1.5 kV is also required.
Even though, in many cases, FUNCTIONAL INSULATION or BASIC INSULATION is all that’s required by the 60950-1 standards, there are other standards for circuit boards in products intended to meet NEBS requirements.

Telcordia GR-78-CORE, Issue 1, R-180, has a requirement for minimum of two plies between conductor layers in multilayer boards. There is a testing out, but that might be a tricky one to meet, since it has to be demonstrated as “equivalent” and may be more costly than simply providing two layers.

Also a R6-116, stating, "the dielectric resistance between any two isolated nets shall be greater than 10 megohms," that might be effected by single ply constructions, depending on the prepreg or core thickness used.
What special tests do I need to perform?

**TNV CIRCUIT Limits, Without Ringing**

We’ve already discussed the normal operating voltages for TNV CIRCUITS. Except for telephone signals (ringing, etc.), these tests are performed similarly to those for SELV CIRCUITS, with a few exceptions.

In §2.3.1b, those limits (approximately) follow the below flow chart, which includes the Canadian and US National Differences.

**TNV CIRCUIT** limits under single fault conditions are determined into a 5 kOhm load and the voltages realized are compared to Figure 2F.
TNV CIRCUIT Voltage Limits Under Normal Operating Conditions

Note 1: Implies $Z_{\text{SOURCE}} \geq 10 \text{kOhm} @ U_{\text{ac}} = 70.7 \text{V}_{\text{pk}}$

Note 2: Implies $Z_{\text{SOURCE}} \geq 2 \text{kOhm} @ U_{\text{ac}} = 120 \text{V}$
TNV CIRCUIT Limits, With Ringing And ‘Other’ Signals

‘North American’ ring signals are described in Annex M, Method B.

The values were carried forward from Ma Bell to 47CFR, Part 68, and into TIA 968-A, §4.4.4, and are also given in 60950-1 in §M.3:

- Ring voltage frequency < 70 Hz
- Peak-to peak voltage during ringing must be:
  - < 300 Vpk-pk
  - < 200 Vpk
- Cadenced, so that the quiet periods are:
  - ≥ 1 s long
  - Separated by ≤ 5 s
- In the event a ringing signal becomes continuous, rather than cadenced, it can not deliver more than 56.5 mA_{pk-pk} into a 5 kOhm resistor. In case peak-to-peak is not understood, we’ve graciously been given Fig. M.3. All hail Fig. M.3!
May require ring trip functionality or a monitoring voltage or both
  o Ring currents are limited to 100 mA pk-pk
  o Monitoring voltages are between 19 V and 60 V, so normal line
    wetting conditions comply and is only necessary when ringing is
    not on the line

Ring trip evaluations must be performed:
  ❖ Tip-to-Ring and
  ❖ Ring-to-ground and
  ❖ Tip-to-ground

The following flow chart approximates the written requirements.

In practical terms, using a decade box set at some resistance above
1,500 Ohm, dial down until the maximum peak-to-peak current is
measured. Remove the decade box from the circuit and measure the
resistance at the decade box terminals to see where you fit in the
flowchart.
Ring Trip Evaluation

Ring Trip Evaluation

Ring into $R \geq 500 \text{ Ohm}$

Pass

$I_{p-p} \leq 100 \text{ mA}_{pk,pk}$ ?

No

Ring into $R \geq 1,500 \text{ Ohm}$ (ring trip device in place)

Either a Monitoring Voltage –OR– a Ring Trip Device, per Fig. M.4

$R \geq 1,500 \text{ Ohm}$

Meet Fig. M.4?

Yes

No Monitoring Voltage Required

No

Ring into $500 \text{ Ohm} \leq R > 1,500 \text{ Ohm}$

Ring Trip device required, per Fig. M.4

Yes

No Monitoring Voltage Required

No
**Limits for other signaling voltages in Annex M.4**

These voltages were originally intended to light a neon lamp plunked into a plain old telephone to support a visual message waiting signal on telephones in hospitality environments.

The use expanded to the enterprise, but in new products has been supplanted by LEDs and logic controls and SELV CIRCUIT levels.

Other applications are so-called ‘test voltages’ that send a short blast down a line to ‘clean’ the downstream interconnects. This is not uncommon in certain DSL applications.

These voltages may be ac or dc or have ac and dc components.
For the purposes of these signals, §M.4 identifies:

- **Continuous is any signal with duration > 5 s**
  - 7.1 mA<sub>pk</sub>
  - 30 mA<sub>dc</sub>
  - Fig. M.5, if both ac and dc components

- **Intermittent is any signal with duration < 5 s**
  - Must meet the limits in Fig. M.5, based on the signal’s duration, using the measuring circuit in Fig. D.1
  - During quiet intervals, either meets
    - 0.5 mA current limitation, or
    - Has a line voltage < 56.6 V<sub>dc</sub>
Electrical Separation

§6.1 contains the now infamous electrical separation requirements.

Separation from Earth

§6.1.2.1 wants TNV CIRCUITS separated from earth, even if the earthing occurs in a remote product through any kind of interconnection.

An EST is required at:

- 1.5 kV, where an AC MAINS SUPPLY in the area where the product is installed exceeds 130 V
- 1.0 kV elsewhere, even if no AC MAINS SUPPLY exists in an vicinity where the product is installed
At your discretion, you can remove any components that bridge the insulation, except capacitors, to help you meet the EST.

HOWEVER, if you do, then a pseudoleakage current test is needed to show that current is limited to not greater than 10 mA, using the test circuit in Fig. 6A.

This is a tall order for any product that contains a hybrid circuit or a silicon implemented SLIC. Be careful how you implement this type of circuit element.
The testing can be avoided, if the equipment is:

- **PERMANENTLY CONNECTED EQUIPMENT**
- **PLUGGABLE EQUIPMENT TYPE B**
- has installation instructions that require an earthed socket outlet and is installed by a service person
- has provision for connection of a separate ‘Code’ type protective earthing conductor with appropriate installation instructions

§6.1.2.1 also wants surge suppressors in **TNV CIRCUITS** to operate at not less than 120% of the peak **MAINS SUPPLY VOLTAGE**. The only way around this is to use surge suppressors that have defined characteristics
Separation from Other Circuits and Parts

§6.2 contains requirements for electrical separation of dissimilar circuits, regardless of what level of insulation was applied during the insulation analysis.

Two tests are identified as alternatives to one another:

- Steady state test, is really an EST
- Impulse test uses a 10×700 µs waveshape, taken from IEU-T Recommendation K.17

Test are performed at voltages that are dependent on the accessibility, contact areas and intended use of the dissimilar circuits and parts.

Case a – if you hold the part in normal use (handset, headset, keyboard)
Case b - If you can touch it readily (enclosure)
Case c – all dissimilar circuits
For Case a, the test values are:
EST: 1.5 kV
Impulse: 2.5 kV<sub>pk</sub>

For Cases b and c, the test values are:
EST: 1.0 kV
Impulse: 1.5 kV<sub>pk</sub>

It is sometimes possible to pass one test, but not the other. The only way to know is to test and find out.

The EST is a very simple test, but has a long duration.

The Impulse Test is very short duration, but has a higher peak voltage. Impulse testing also requires collecting and reviewing oscillograms to see if breakdown of the insulation occurred.

NOTE: Australia requires BOTH tests and at higher voltages for Case a.
Due to limitations of the time available, the presentation stopped here. I’d like to thank the audience for their patience and allowing the presentation to run well beyond the allotted 45 minutes,

Supplemental presentations are reserved for the future, to cover the remaining test topics, the 60950-21 standards and case studies.

Be certain to visit the SCV Chapter PSES web site at:


if you’d like to suggest another presentation.

Respectfully,

Peter L. Tarver