Contents

- Bonding and Grounding
  - Definition of “Ground”
  - Central Office Grounding Architectures
    - North America
    - Europe

- Powering
  - Central Office Powering Architectures
    - North America & Europe
    - AT&T

- Power Fault Scenarios

- Specific NEBS & ILEC requirements

- References

- Acronyms
Bonding and Grounding
What is “Ground”? 

- There’s only one true ground and we are standing on it.
- ITU/CCITT definition of ground or earth (preferred term):
  - Earth: “The conductive mass of the earth, whose electric potential at any point is conventionally taken as equal to zero.”
- All other “grounds” are local:
  - Frame Ground (FG)
  - Chassis Ground (CG)
  - Logic Ground – Analog/Digital ground (LG)
  - Battery Return (BTRN)

Properly **Bonding** different grounds together is the key
Considerations for System Bonding

- Different Central Office earthing architecture requirements
- Personnel Safety
- Lightning & Power Cross
- Radiated & Conducted EMI
- ESD/EFT
- Signal Integrity
- Reliability
## Bonding Network Architectures

<table>
<thead>
<tr>
<th>Equipment configurations</th>
<th>Star configuration</th>
<th>Mesh configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Star configuration</td>
<td>Star Topology</td>
<td>Mesh Topology</td>
</tr>
<tr>
<td>Mesh configuration</td>
<td>Mesh-BN</td>
<td>Mesh-IBN</td>
</tr>
<tr>
<td>Single Point</td>
<td>Star-IBN</td>
<td>Mesh-IBN</td>
</tr>
<tr>
<td>Multiple Point</td>
<td>Not Applicable</td>
<td></td>
</tr>
</tbody>
</table>

**From Figure 1, CCITT K.27**

- **Traditional North America**
  - "Isolated Ground Plane"

- **Evolving North America**
  - Single Point Connection Window (SPCW)

- **Europe**
  - "Integrated Ground Plane"
CO Vertical Equalizer

From GR-1275, Figure 18-4
Ground Bond Connections

- All bonding connectors are listed two-hole irreversible compression copper/tinned-copper connectors.
- All cable-to-cable connections are to be H-Tap or exothermic weld.

From GR-1275, Figure 18-2

From GR-1275, Figure 18-5
H-Tap Connector Example

H-Tap Connector

Hydraulic Crimp Tool

©2003: Thomas & Betts Corp.
Frame Bonding – Integrated Ground Plane

- All frame bonding cables are #6AWG, minimum
- Tags read “CO Ground – Do Not Disconnect”
Isolated Ground Plane

- Much more susceptible to requirements’ violations than Integrated architecture. Violations may occur due to:
  - Communication links – *Design* concern
  - Conduits, light fixtures, cable racks, duct work, anchor bolts, earthquake bracing – *Installation* concern

- Single-Point Connection Window is realized using a “MGB – Main Ground Bar” – a 3’ radius spherical volume
Isolated GP – Frame Bonding

Permitted configurations

Serial Grounding

Radial Grounding

From TR-NWT-000295, Figure 5-1
Isolated GP – Frame Bonding Violations

Examples of loops not permitted on Isolated Ground Planes

From TR-NWT-000295, Figure 5-2
Grounding for Integrated & Isolated GPs

From GR-1275, Figure 19-1

- Battery_Return does not connect to MGB
- Battery_Return connects to MGB
Overall Frame Bonding

From GR-1275, Figure 19-2

Isolated

Integrated
Battery Return Consideration

North America – Isolated GP (Single point connection to CBN)

Integrated GP & Europe (Multiple point connection to CBN)

Equipment design must accommodate both architectures

GR-1275, Chapters 18 & 19

ETSI EN 300 253, Section 6
Communication Links

- What happens when NEs in different ground windows need to communicate?
Communication Links

- **DC-Isolated Links**
  - Fiber including new low-cost VCSEL
  - RS-422
  - T-1
  - Alarms
  - Tip & Ring (POTS)
  - Ethernet
  - Other balanced signals

- **Problematic Links**
  - Shielded cables (T-1, BITS clock)
    - One side of shield must be open
  - RS-232
  - Coax

©2003: Black Box Corp.
Coax DC Isolation

"X" Capacitor

Large overlapping shapes on adjacent layers (<5 thou)

Plastic Isolating Ring

Faceplate or Bulkhead

Shield Transfer Impedance

Interplane capacitance

X-Cap

Frequency

Impedance
AC or DC?

- Telecom Central Offices are designed to use primarily **DC power**.
- AC powered equipment is more prevalent in datacom centers such as large computer rooms or server farms.
- In general, AC-powered telecom equipment is not desired inside a central office.
  - A frame-based DC-AC Inverter is sometimes used as a last resort or for CLEC collocation.

![Diagram of a single frame showing battery, inverter, and AC powered equipment connections](image-url)
Main AC/DC Rectifier Examples

- 50 - 70 kW (1 – 1.4 kA @ -50V) per bay
- Units can be paralleled to increase capacity
BDFB Example

- Main bus bar can handle four 500A feeds.
- Secondary feeds can be breaker at 2 - 150 A.
CO Battery Example

- Flooded VRLA batteries are commonly deployed. 2.2V float x 24 cells = 52.8V float
- Ni-Cad are being increasingly used for new sites.
CO Battery Example – Flooded VRLA

Round Cell Batteries at this central office switching station will be in service for several decades, assuming water is added once every ten years.
Battery Hoist

Batteries weigh up to 85lbs!
# Powering: Voltage Levels

<table>
<thead>
<tr>
<th>Source</th>
<th>Float</th>
<th>Low</th>
<th>High</th>
<th>Turn-off</th>
<th>Turn-on</th>
<th>Max Loop Volt. Drop [V]</th>
<th>Where measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSI T1.315-1994</td>
<td>-53</td>
<td>-42.75</td>
<td>-56.7</td>
<td></td>
<td></td>
<td>1</td>
<td>At power plant</td>
</tr>
<tr>
<td>AT&amp;T 802-010-100</td>
<td>-48</td>
<td>-40</td>
<td>-60</td>
<td>-38.5 +/- 1</td>
<td>-43.0 +/- 0.5</td>
<td>48.0 +/- 0.5</td>
<td>NE input terminals</td>
</tr>
<tr>
<td>AT&amp;T NEDS</td>
<td>-48</td>
<td>-40</td>
<td>-57.5</td>
<td>-38.5 +/- 1</td>
<td>-45.0 +/- 2.0*</td>
<td>47.0 +/- 2.0*</td>
<td>NE input terminals</td>
</tr>
<tr>
<td>Bell South TR73503-10</td>
<td></td>
<td>-42.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NE input terminals</td>
</tr>
<tr>
<td>ETS 300 132-2</td>
<td>-40.5 to -57.0</td>
<td>-40</td>
<td>-60</td>
<td></td>
<td></td>
<td></td>
<td>NE input terminals</td>
</tr>
<tr>
<td></td>
<td>-50.0 to -72.0</td>
<td>-50</td>
<td>-75V</td>
<td></td>
<td></td>
<td></td>
<td>NE input terminals</td>
</tr>
<tr>
<td>GR-513 LSSGR</td>
<td>-47.9 to -56.0</td>
<td>-41.75</td>
<td>-60</td>
<td></td>
<td></td>
<td>1.5</td>
<td>At the BDFB</td>
</tr>
<tr>
<td>SBC TP76200MP</td>
<td>-48</td>
<td>-42</td>
<td>-56.7</td>
<td></td>
<td></td>
<td>2</td>
<td>At the BDFB</td>
</tr>
<tr>
<td>Verizon NEBS Checklist</td>
<td>-48</td>
<td>-40</td>
<td>-57.5</td>
<td>-38.5 +/- 1</td>
<td>-47.0 +/- 0.5**</td>
<td>47.0 +/- 0.5**</td>
<td>NE input terminals</td>
</tr>
<tr>
<td>WorldCom (MCI)</td>
<td>-54</td>
<td>-40</td>
<td>-57.5</td>
<td></td>
<td></td>
<td></td>
<td>At power plant</td>
</tr>
<tr>
<td><strong>Worst Case</strong></td>
<td>Not Applicable</td>
<td>-40</td>
<td>-75</td>
<td>-38.5 +/- 1</td>
<td>Two different requirements</td>
<td>Not Applicable</td>
<td>NE input terminals</td>
</tr>
</tbody>
</table>

* NEDS 4.0 states –45.0 +/- 0.5 Vdc but AT&T is moving to this range in the future.
** Optional
Power Connections to Frame

AT&T Req. 1.1.3-50
- A & B power cables shall have physically diverse routing within the bay.
Typical NE Power Architecture

Network Element
Circuit Board

Power Supply
(Load)

Battery 'OR'ing
Diodes

Fuse and Alarm Panel

-A A Rtn
B Rtn -B

Power Output

Return Output

Battery A

Battery B

Central Office Battery Plant
Powering Fault Scenarios
Power Reversal Fault Scenario - Frame

Frame Power Panel to NE connection reversed

Over-current device will activate

Network Element Circuit Board

Power Supply (Load)

Battery 'OR'ing Diodes

Fuse and Alarm Panel

Power Output

Return Output

Battery A

Battery B

Central Office Battery Plant
Power Reversal Fault Scenario - BDFB

Required Battery Return ‘OR’ing diodes

No over-current device will activate!

Battery Plant to Frame Power Panel connection reversed

Bat_ret OR-ing diodes: AT&T Req. 1.2-40(b)
Powering: Voltage Drop Calculations

- **Worst case power draw**: 256W = 6.4A @ -40V
- **Guaranteed Voltage**: -40V
- **Internal Wiring Loss**: 0.7 V

**Network Element**

- **Fuse**
- **Diode OR Circuit Breaker**

**Bulk EMI filters**

- **0V**
- **12mV**

**Shelf Board**

- **Diode OR**
- **Differential mode chokes**

**Power Supply X**

**Differential mode chokes**

- **Rated to -36V input**

**Total internal loss budget** = 4V
**Total Internal system loss** = 3.6V
**Margin** = 400mV
PCB Voltage Drop Predictions

[Image of PCBTEMP software interface]

1. PCBTEMP: A Temperature Rise Calculator for Printed Circuit Boards

2. Use Data From the Following Source (See Help File):
   - IPC - D - 275
   - Design News, 12/8/68

3. Wire Gauge Calculator
   - Enter any two variables and solve for the third.
   - Trace Resistance:
     - Enter trace temperature and length.
     - Then solve for the resistance of the trace described above.

[Image of Wire Gauge Calculator interface]

http://www.ultracad.com/calc.htm
Wire Voltage Drops

- Voltage drop on a circular copper wire can be estimated using:

\[
\text{Voltage Drop [V]} = 11.1 \times \text{Load Current [A]} \times \text{Wire length [ft]} / \text{circular mils of wire used}
\]

- For example, 100 ft of 8AWG (16510 circular mils) cable carrying 10A will result in a 672mV drop.

<table>
<thead>
<tr>
<th>SIZE</th>
<th>Circular Mils</th>
<th>DC Resistance [mΩ/1000ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 AWG</td>
<td>16,510</td>
<td>672</td>
</tr>
<tr>
<td>6 AWG</td>
<td>26,240</td>
<td>423</td>
</tr>
<tr>
<td>4 AWG</td>
<td>41,740</td>
<td>266</td>
</tr>
<tr>
<td>2 AWG</td>
<td>66,360</td>
<td>167</td>
</tr>
<tr>
<td>1/0 AWG</td>
<td>105,600</td>
<td>105</td>
</tr>
<tr>
<td>2/0 AWG</td>
<td>133,100</td>
<td>83</td>
</tr>
<tr>
<td>3/0 AWG</td>
<td>167,800</td>
<td>66</td>
</tr>
<tr>
<td>4/0 AWG</td>
<td>211,600</td>
<td>52</td>
</tr>
<tr>
<td>250 MCM</td>
<td>250,000</td>
<td>44</td>
</tr>
<tr>
<td>300 MCM</td>
<td>300,000</td>
<td>37</td>
</tr>
<tr>
<td>350 MCM</td>
<td>350,000</td>
<td>32</td>
</tr>
<tr>
<td>400 MCM</td>
<td>400,000</td>
<td>28</td>
</tr>
<tr>
<td>500 MCM</td>
<td>500,000</td>
<td>22</td>
</tr>
<tr>
<td>750 MCM</td>
<td>750,000</td>
<td>15</td>
</tr>
</tbody>
</table>
Power and Ground Safety Issues
Safety Marking and Cable Colour

BS7671 Requirements for electrical installations – Identification by colours, 514-04-02:

“The bi-colour combination Green and Yellow is reserved exclusively for identification of a protective conductor and this combination shall be used for no other purpose.”

“In this combination one of the colours shall cover at least 30% and at most 70% of the surface being coloured, while the other colour covers the remainder of the surface.”

IEC 60417 #5019 Protective Earth Symbol

Needs to be placed on the equipment where the protective earth (ground) cable is to be attached.
# NEC Wire Sizing

## NEC Table 310-17*

<table>
<thead>
<tr>
<th>AWG</th>
<th>0-2000V</th>
<th>51C**</th>
<th>Table 310-15(b)(2)(a)**</th>
<th>Final Cable Ampacity [A]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30C ambient</td>
<td>Temperature Derating</td>
<td>Bundling Derating</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>18</td>
<td>0.76</td>
<td>1</td>
<td>13.7</td>
</tr>
<tr>
<td>16</td>
<td>24</td>
<td>0.76</td>
<td>1</td>
<td>18.2</td>
</tr>
<tr>
<td>14</td>
<td>35</td>
<td>0.76</td>
<td>1</td>
<td>26.6</td>
</tr>
<tr>
<td>12</td>
<td>40</td>
<td>0.76</td>
<td>1</td>
<td>30.4</td>
</tr>
<tr>
<td>10</td>
<td>55</td>
<td>0.76</td>
<td>1</td>
<td>41.8</td>
</tr>
<tr>
<td>8</td>
<td>80</td>
<td>0.76</td>
<td>1</td>
<td>60.8</td>
</tr>
</tbody>
</table>

### Notes

* Allowable ampacities of single-insulated conductors rated 0 through 2000V in **free air** based on ambient air temperature of 30C.

** Temperature derating factor for worst case CO temperature + 1-5C margin. From NEC Table 310-17.

*** No bundling derating assumes that cables will not be run in a raceway. The CO environment does permit raceways although it is uncommon. If bundling is to be considered, NEC Table 310-16 must be used in conjunction.
Voltage Classification

- Battery Voltage is classified as:
  - –48V nominal only: SELV with Hazardous Energy Levels
  - –60V nominal included: TNV-2
- TNV-2 classification requires Basic insulation from SELV circuits and grounded chassis
Power & Ground NEBS Issues
NEBS & ILEC Requirements

- Voltage transients
- Bonding and Grounding
- Short-circuit protection
- EMC
- Power Noise Immunity and Emissions
- Safety (fault current)
Powering: SBC Transients

- **Overvoltage transient**
  - -48V to -75V
  - No damage
  - No service interruption

- **Undervoltage transient**
  - -48V to 5V
  - No damage
  - Self-recovery in <30 minutes

*TP76200MP, Figures 7-2 and 7-4*
Powering: AT&T Transients

- Voltage transients
  - No service interruption

- Undervoltage transient
  - Rise much faster
  - Fall time a little faster
  - No service interruption

<table>
<thead>
<tr>
<th>Transient</th>
<th>Duration</th>
<th>Rise Time/Fall Time</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 Volts</td>
<td>5 microsec.</td>
<td>Not defined</td>
<td></td>
</tr>
<tr>
<td>100 Volts</td>
<td>10 microsec.</td>
<td>Not defined</td>
<td></td>
</tr>
<tr>
<td>75 Volts</td>
<td>10 millisec.</td>
<td>10 volts per millisec. (Rise)</td>
<td>Same as SBC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 volts per millisec. (Fall)</td>
<td></td>
</tr>
<tr>
<td>0.0 Volts</td>
<td>5 millisec.</td>
<td>50 volts per millisec. (Rise)</td>
<td>Less severe than SBC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.5 volts per millisec. (Fall)</td>
<td></td>
</tr>
</tbody>
</table>

©2003: Vishay Semiconductors, Inc.
High Output Voltage Shutdown

AT&T NEDS: 1.2-60

- Each DC-to-DC converter shall have a high output voltage shutdown feature.
- Shutdown shall occur when the output increases past 10% of normal output.
NE Unit Bonding

Verizon Checklist, 3.2.12.3 & 4

- Use either a separate conductor or thread-forming type mounting screws in conjunction with an external-tooth star washer.

Tri-Lobular Thread Forming Screw

External-Tooth Star Washer

©2003: ITW/Shakeproof, inc.
Bonding & Grounding
Conductor and Connection Requirements

GR-1089, Section 9.7:
- Copper is required for all conductors and connections. Aluminum is forbidden.
- Anti-oxidation of all connectors is required. Tinning is a good method to achieve this requirement for the posts and lugs.
- Two-hole compression-type connectors are required. This requirement may be waived on small (1U) boxes.

©2003: Tyco Electronics Power Systems, Inc.
GR-1089 Grounding

- **Embedded Power Sources [GR-1089, Section 9.8.2]**
  - Embedded DC power sources with rated output greater than 20VA shall be grounded, i.e., the Battery_Return (BTRN) is bonded to ‘frame ground’ (FG) or the CO Ground.
  - No grounding required if all the following are true:
    - Rated output <150W
    - Contains output power limiting, e.g., “fold-back” output V-I characteristic
    - Meets the short-circuit requirements in Section 9.10.1

*From GR-1089, Figure 9-1*
P&G Integrity: Short-Circuit Tests

- GR-1089, Sect 9.10: Introduce short at source and farthest sink locations.
  - Applicable to board and centralized power converters
  - Overcurrent protection mechanisms (internal to power-supply or fuse) may operate. No damage to board is permitted.

1. "A" Output Voltage, i.e., 5V, 3.3V, 2.5V, etc.
2. Most distant chip using "B" voltage

Board Short Location

i) ‘+’ve to ‘-’ve lines
ii) ‘+’ve line to FG

Printed Circuit Board
Bonding & Grounding for EMC

- Single Point Logic Ground to Frame Ground connection
Bonding & Grounding for EMC

- Multi-point Logic Ground to Frame Ground connection
Noise Immunity on Power

In addition to the emissions and immunity requirements on power feeds in GR-1089 and EN 300 386, there are customer specific requirements.

- Noise Immunity: SBC TP76200MP, Section 7.04 (a); AT&T NEDS req. 1.2-180 (from ANSI T1.315)

<table>
<thead>
<tr>
<th>Voiceband (0-3kHz)</th>
<th>Wideband Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>C Message dBmC @ 600 ohms</td>
<td>Peak-To-Peak [mV p-p]</td>
</tr>
<tr>
<td>56</td>
<td>400</td>
</tr>
</tbody>
</table>

Diagram:

- RF NOISE GENERATOR
- POWER SUPPLY
- OFFICE BATTERY INPUT
- EQUIPMENT UNDER TEST
- NOTE

NO.10 AWG COPPER WIRE
NUMBER OF TURNS = 10
RADIUS OF TURNS = 5.84cm (2.3 in.)
SPACING OF TURNS = 0.61cm (0.24 in.) ON CENTERS.
Noise Emissions on Power

- **Noise Emission: SBC TP76200MP, Section 7.04 (b)**

<table>
<thead>
<tr>
<th>Maximum Voiceband C Message dBrnC @ 600 ohms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xc [dBrnC] = 9 + 10 log Ic</td>
</tr>
<tr>
<td>Vc [mVrms] = (Ic)^1/2</td>
</tr>
</tbody>
</table>

Where Ic is the rated current or 1A, whichever is greater

**Note 1**
No.10 AWG COPPER WIRE; NUMBER OF TURNS = 4;
RADIUS OF TURNS = 6.84cm (2.75 in.); SPACING OF TURNS = 0.64cm (0.25 in.) ON CENTERS

**Note 2**
No.10 AWG COPPER WIRE; NUMBER OF TURNS = 10;
RADIUS OF TURNS = 5.84cm (2.3 in.); SPACING OF TURNS = 0.61cm (0.24 in.) ON CENTERS
Safety Considerations

Leakage Currents [GR-1089, Section 7.6]
- If exposed area is not bonded to ground:
  - Large Area Contact = 0.3mA through a 1500 Ω resistance
  - Small Area Contact = 0.15mA through a 10 kΩ resistance

Resistance of Earthing Conductors [UL 60950, 2.6.3.3]
- The resistance of the protective bonding conductor shall not exceed 100mΩ if circuit rating <16A.
- If circuit rating > 16A, voltage drop shall not exceed 2.5V.

Do not leave any exposed area unbonded to frame ground
Summary & Conclusions

- Power & Ground design is essential for delivering a dependable carrier-class product.
- Proper understanding of your customers’ Power & Grounding requirements is needed before you start designing a new product.
- Designing-in compliance is straight-forward if done at the early stage – and extremely difficult if left to the end.
References

Telcordia
- GR-1089, Issue 3, October 2002
  - Electromagnetic Compatibility and Electrical Safety
- GR-1275, Issue 4, December 2002
  - Central Office Environment Installation/Removal GR
- TR-295,
  - Isolated Ground Planes: Definition and Application to Telephone Central Offices

Grounding
- CCITT/ITU-T K.27, May 1996
  - Bonding Configurations and Earthing Inside a Telecommunication Building
- ETS 300 253, V2.1.1, 2002-04
  - Earthing and bonding of telecommunication equipment in telecommunication centres
References - Continued

**Powering**

- **ANSI T1.315-1994**
  - Voltage Levels for DC-Powered Equipment Used in the Telecommunications Environment

- **ETS 300 132-2, September 1996**
  - Power supply interface at the input to telecommunications equipment; Part 2: Operated by direct current

- **GR-513-CORE, Issue 1, September 1995**
  - LSSGR: Power, Section 13
References - Continued

Customer-Specific Documents

- AT&T MLID#9069, V4.0, December 2002
  - Network Equipment Development Standards (NEDS)
- AT&T 802-010-100, Issue 4, November 1996
  - In-Bay Power Architecture Requirements for Telecommunication Network Equipment
- BellSouth TR73503, Issue G, December 1997
  - Engineering and Installation Standards – Central Office Equipment
- SBC TP76200MP, Issue 5, October 2003
  - Network Equipment: Power, Grounding, Environmental and Physical Design Requirements
- SBC 802-001-180MP, Issue A, April 1998
  - Grounding and Bonding Requirements; Telecommunications Equipment, Power Systems, Central Offices and Other Structures
References - Continued

Customer-Specific Documents

- VZ 292-100-000, Issue 1, August 2001
  - Material Standards and Engineering Guidelines for DC Distribution Systems
  - NEBS Compliance Checklist
- WorldCom (MCI), Issue 3, November 2000
  - General Requirements for Transmission Equipment Specification
References - Continued

Other
- UL60950, 3rd Edition
  - Safety of Information Technology Equipment
- NFPA 70
  - National Electrical Code, 1999
Acronyms & Definitions

- dBrnC Decibels above reference nose, C-message weighted
- BDCBB Battery Distribution Circuit Breaker Board – See BDFB
- BDFB Battery Distribution Fuse Board
  - Generic term also used to describe frame-based distribution as well as assemblies (BDCBB) utilizing circuit breakers in lieu of fuses
- BN Bonding Network
- CBN Common Bonding Network
- IBN Isolated Bonding Network
- ISG Isolated System Grounding *or* (opposite)
  Integrated System Grounding
- MGB Main Ground Bus
- NE Network Element (Telecom equipment)
- Ni-Cad Nickel Cadmium
- SPCW Single Point Connection Window
- VCSEL Vertical Cavity Surface Emitting Laser
- VRLA Valve Regulated Lead-Acid
Topics not covered

- Material incompatibility
- Compatibility of IBN equipment with CBN currents
- Soil Characteristics
- Battery Charging, Aging, Monitoring, Replacement
- Explosive gases
- Radio Sites, Remote Huts, and Controlled Environmental Vaults (CEVs)
To Learn More

- Telcordia Series of Power and Grounding classes:
  
  http://www.800teachme.com/cgi-bin/teachme/viewcourse.cgi?LIS10005DB
  
  - Telecommunications Grounding
  - Protection Fundamentals
  - Power Engineering for Direct Current
  - Noise-Measurement and Mitigation
  - Introduction to Building Electrical Systems
Special Thanks To...

- Wojtek Antoszkiewicz, Christophe Niglio – (former) Turnstone Systems
- Harmit Singh, Camilo Obana – MET Labs
- Vernon Morris – AT&T
Biography

Marko Radojicic has spent the last fourteen years working in the areas of EMC, Safety, & Reliability design and NEBS compliance. His career at Nortel, which spanned a decade, included involvement in the development of many industry-leading Central Office products such as the DMS-100, AccessNode, and Succession Networks. In addition he contributed to the development of numerous PBX and Wireless products. From 2000 to 2003, he was the hardware design assurance manager for Maple Optical Systems and Turnstone Systems where he established and ran the companies’ compliance, reliability, and hardware validation activities. Currently he is employed by Nokia Internet Communications.

He holds a Bachelor’s and Master’s degree in Electrical Engineering from the University of Ottawa.
Thank you