



# Ethernet and PoE Operation Over Single Pair Twisted-pair Copper Cabling (SPE)

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# Overview

- SPE is poised to enable a new class of low power devices that will facilitate networking and powering the billions of end point sensors forecasted by the year 2022.
- The SPE standards provide end point sensors with a unifying communication protocol and a common networking infrastructure extending the cost-effectiveness and plug and-play simplicity of Ethernet.
- End point sensor technology and use cases are evolving rapidly in industrial/process, building automation, data centers as well as to support “Intelligent Building” technologies; IoT infrastructure.
- TIA-TR42 – Developing single pair telecommunication standards for single pair infrastructure topologies, cabling, and connectors.

# SPE Standards

- IEEE Std 802.3bw-2015 100BASE-T1 – Automotive Environment
  - 100 Mb/s over a single balanced twisted-pair link segment connection up to 15 m in length.
- IEEE Std 802.3bp-2016 1000BASE-T1 – Automotive and Industrial Environments 1 Gb/s operation in
  - 1 Gb/s over a single balanced twisted-pair.
  - 1000BASE-T1 – Type A - automotive link segment supporting up to four in-line connectors using a single twisted-pair copper cable for up to at least 15 m.
  - 1000BASE-T1 – Type B - Optional link segment supporting up to four in-line connectors using a single twisted-pair copper cable for up to at least 40 m to support applications requiring extended physical reach, such as industrial and automation controls and transportation (aircraft, railway, bus and heavy trucks).

# SPE Draft Standards

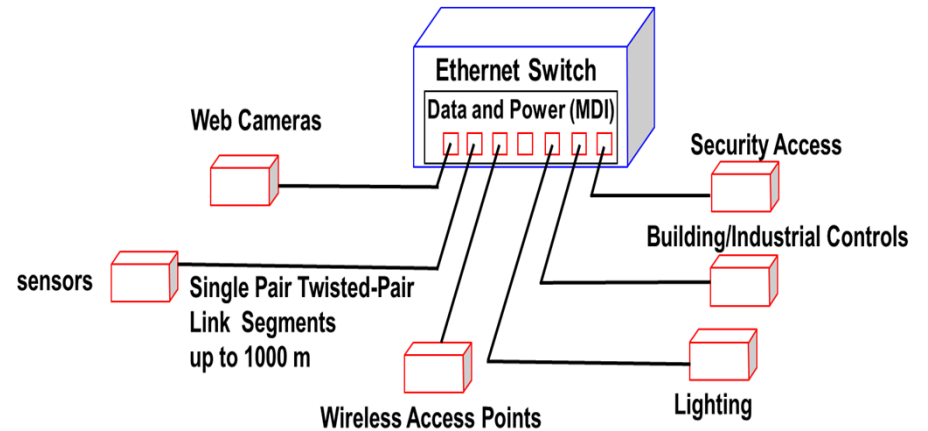
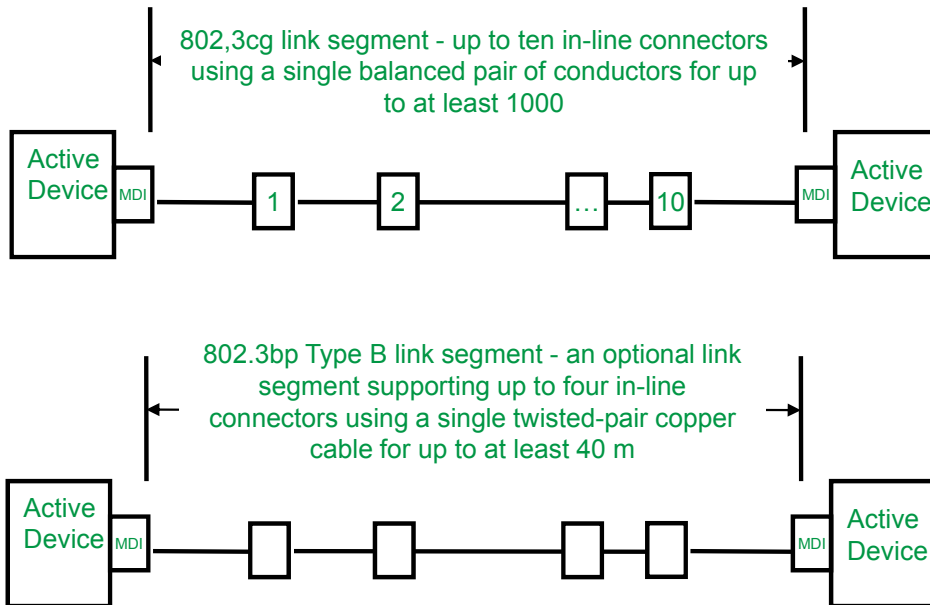
- Draft standard: IEEE P802.3ch Multi-Gig Automotive Ethernet PHY Task Force
  - 2.5GBASE-T1 – 2.5 Gb/s operation over link segment supporting up to four in-line connectors using a single shielded balanced pair of conductors for up to at least 15 m
  - 5GBASE-T1 – 5 Gb/s operation over link segment supporting up to four in-line connectors using a single shielded balanced pair of conductors for up to at least 15 m
  - 10GBASE-T1 – 10 Gb/s operation link over segment supporting up to four in-line connectors using a single shielded balanced pair of conductors for up to at least 15 m
- Draft standard: IEEE P802.3cg 10 Mb/s Single Pair Ethernet Task
  - 10BASE-T1S – 10 Mb/s operation over;
    - a short reach single balanced twisted-pair link segment supporting up to ten in-line connectors for up to at least 15 m.
    - a mixing segment with a single balanced pair of conductors supporting up to at least 8 nodes, for up to at least 25 m reach
  - 10BASE-T1L – 10 Mb/s operation over a long reach single balanced twisted-pair link segment supporting up to ten in-line connectors for up to at least 1000 m

# SPE New Activity

- IEEE 802.3 Automotive Ethernet beyond 10 Gb/s Electrical PHYs study group approved
  - [http://www.ieee802.org/3/cfi/request\\_0319\\_1.html](http://www.ieee802.org/3/cfi/request_0319_1.html)
- IEEE 802.3 Industry Connections New Ethernet Applications Ad Hoc – Presentations
  - Extended 100 Mb/s Automotive reach >15 m for Industrial/Process > 200 m
  - [http://www.ieee802.org/3/ad\\_hoc/ngrates/public/19\\_03/brandt\\_nea\\_01c\\_0319.pdf](http://www.ieee802.org/3/ad_hoc/ngrates/public/19_03/brandt_nea_01c_0319.pdf)

# SPE 10BASE-T1L/1000BASE-T1 Telecommunications Topology

- The SPE switch provides power (PoDL) and data through the medium dependent interface (MDI) over single pair twisted-pair link segments.



# SPE 10BASE-T1L – MDI

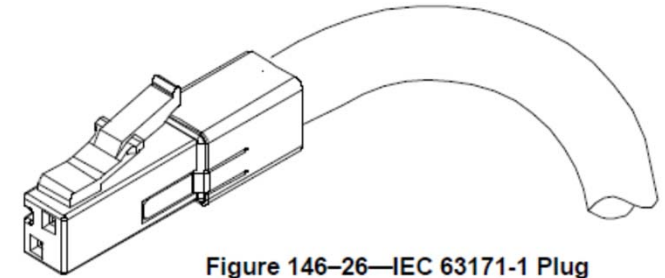


Figure 146-26—IEC 63171-1 Plug

**802.3cg 10BASE-T1L (10 Mb/s)  
– MDI jack connector and plug  
- IEC 63171-1**

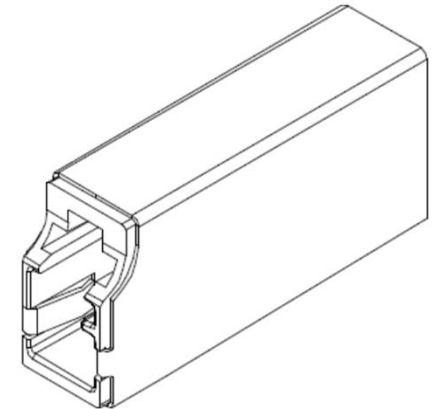
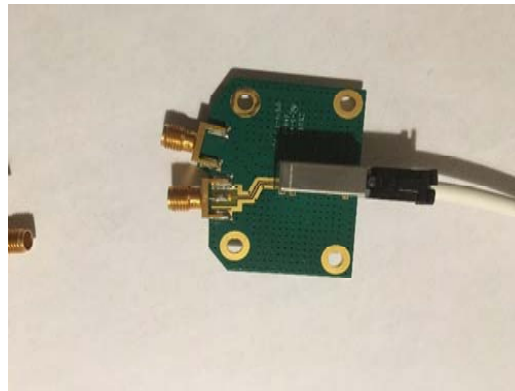
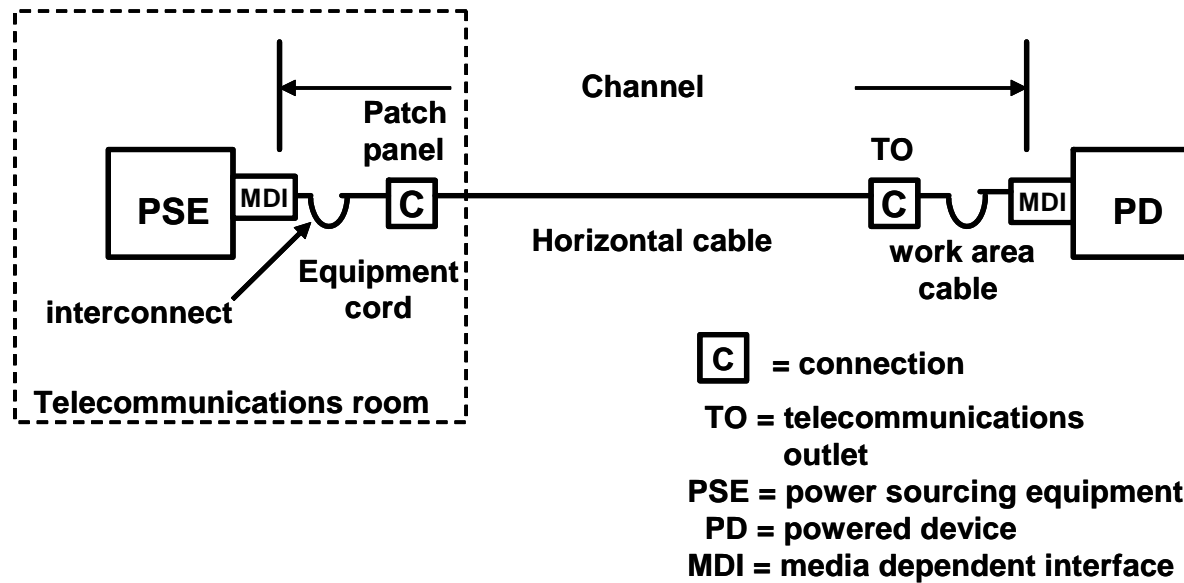


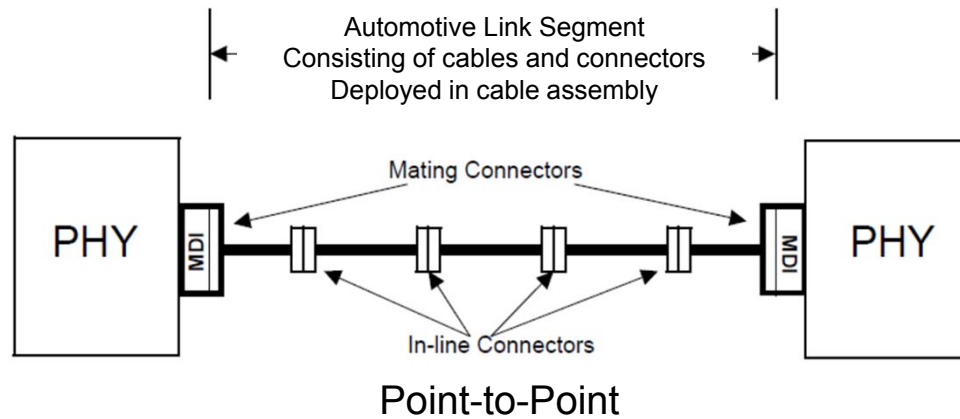
Figure 146-27—IEC 63171-1 Jack

# SPE Power Telecommunications Topology





# SPE Automotive P-to-P Topology



## Automotive Ethernet PHYs

- 10M – 802.3cg
- 100M - 802.3cw
- 1G - 802.3bp
- 2.5G/5G/10G - 802.3ch



Length of automotive wiring system can exceed 3 km with up to 1,500 cables and up to 3,000 contacts.



# SPE Multidrop Topology

IEEE P802.3cg 10 Mb/s Single-Pair 10BASE-T1S

A mixing segment is specified based on cabling that supports up to at least 8 nodes and 25 m in reach.

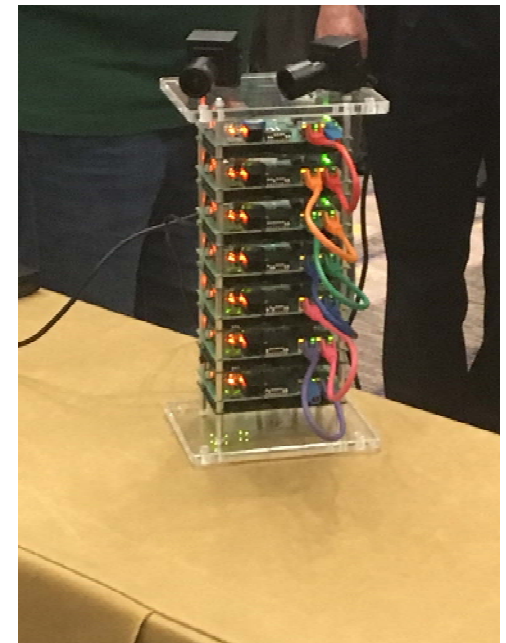
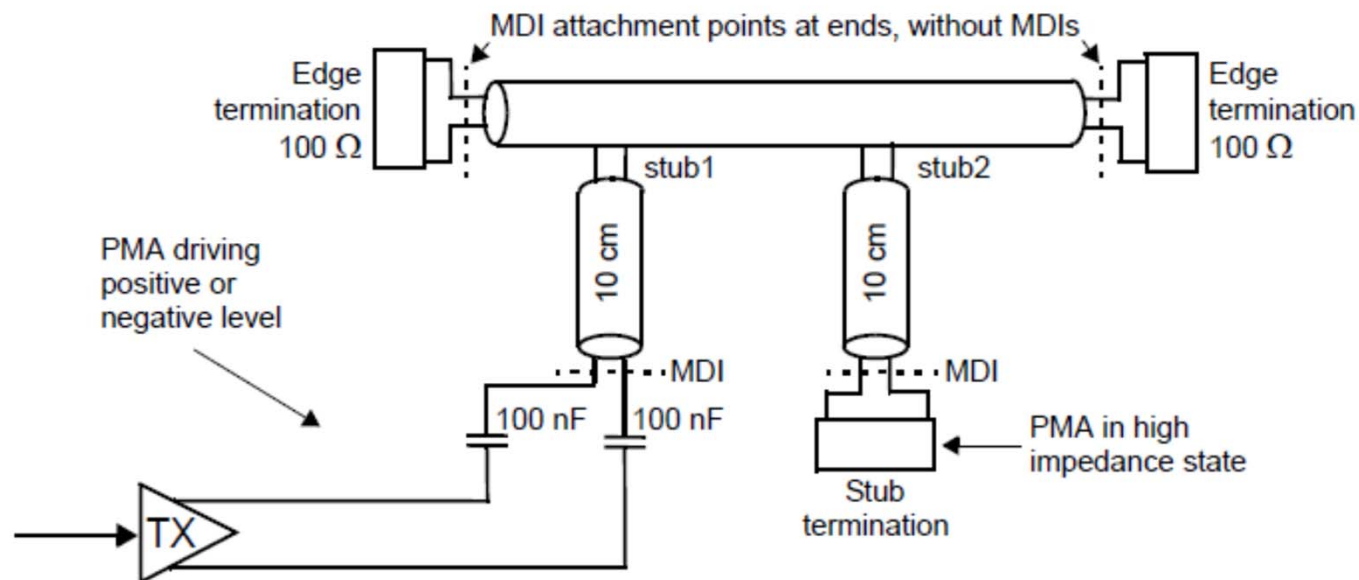


Figure 147–20—Multidrop line termination and PMA

# SPE 1000BASE-T1 Type B – Industrial Automation Applications

- **Enables cable reuse**
  - Installed base of Single Twisted Pair, usually shielded
  - Certain cables are certified
  - Lengthy fieldbus cables are expensive to install (often in filled conduit)
  - End nodes are easier to replace
  - Similar value proposition to 2.5G/5GBASE-T Task Force
- **Enables constrained form factor applications (sensors etc.)**
  - Reduced size and cost

High Cable Reuse Value

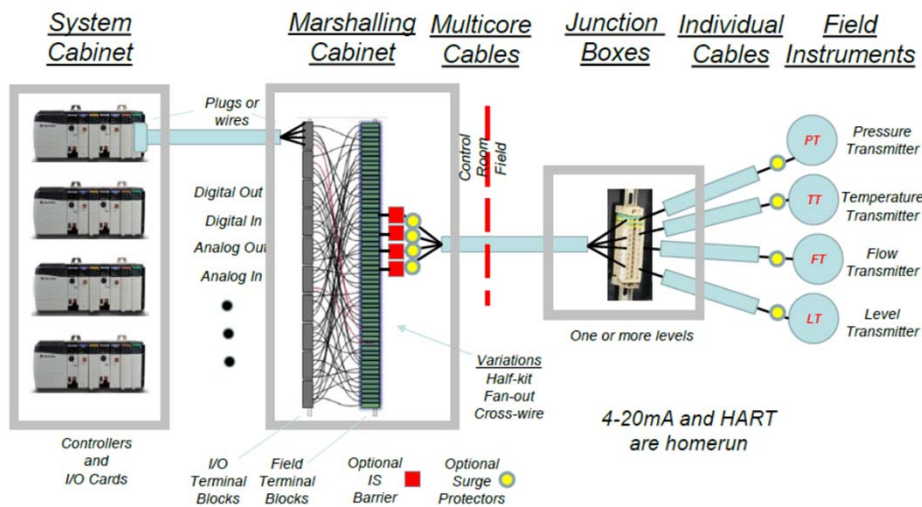
Fieldbus	Cable Type	Cable Power
<b>FOUNDATION H1</b>	FF-844 specified	Yes
<b>HART</b>	Various	Yes
<b>PROFIBUS PA</b>	IEC 61158 Type A	Yes
<b>4-20mA</b>	SP-50 instrumentation cable	Yes
<b>CANopen</b>	EIA-485	Yes
<b>Modbus RTU</b>	EIA-485	No
<b>CC-Link</b>	CC-Link, Ver.1.10 specified Shielded, 3- & 5-core	No
<b>DeviceNet</b>	ODVA DeviceNet specified (5-core, various classes)	Yes
<b>ControlNet</b>	RG-6/U Coaxial	No
<b>INTERBUS</b>	3 / 6 no. twisted pairs, various	Yes
<b>PROFIBUS DP</b>	IEC 61158 Type A (22AWG?)	No

Source: [http://www.ieee802.org/3/10SPE/public/Sept2016\\_Interim/diminico\\_01\\_0916.pdf](http://www.ieee802.org/3/10SPE/public/Sept2016_Interim/diminico_01_0916.pdf)

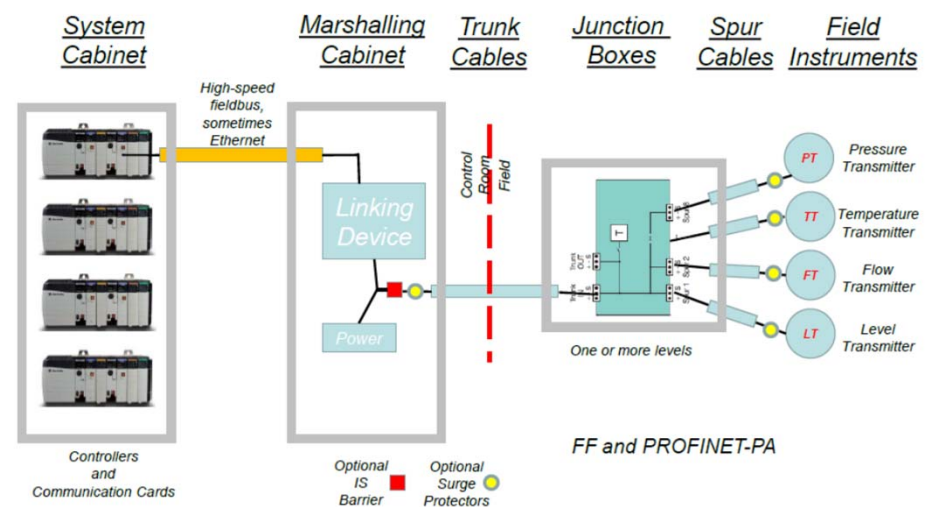
# Process Automation Infrastructure

- Current Infrastructure Practices
  - Homerun wiring
  - Fieldbus wiring
- Infrastructure complexity will be reduced by substitution of Ethernet switches

## Homerun Wiring



## Fieldbus Wiring



Source: [http://www.ieee802.org/3/10SPE/public/Nov2016/diminico\\_01b\\_1116.pdf](http://www.ieee802.org/3/10SPE/public/Nov2016/diminico_01b_1116.pdf)

# SPE 10BASE-T1L – Process Automation Simplifications

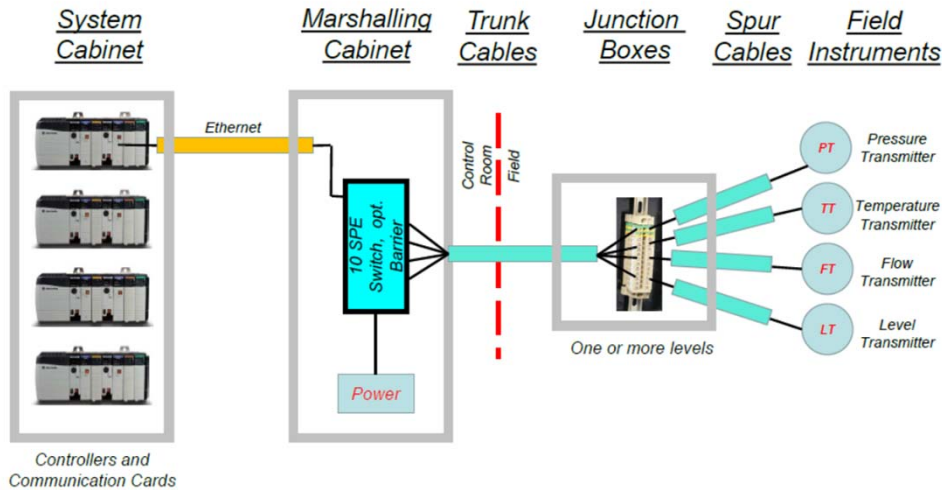
- Surge protection
  - Legacy surge suppression will be removed
    - In-line connections may then be required (2 per link)
  - 10 SPE-compatible surge suppression will be substituted
    - IEC 61000-4-5 (surge immunity) or equivalent
- Barriers
  - Legacy surge suppression will be removed
  - 10 SPE switches (802.1 bridges) will provide intrinsic safety function
- Multi-drop
  - Multi-drop link segments (that form tree structures) will be replaced by multi-port switches that break the multi-drop into multiple shorter point-point link segments
- Marshalling cross-connections
  - 10 SPE will extend the fieldbus trend of replacing marshalling wiring complexity with switches and end node addressing

Source: [http://www.ieee802.org/3/10SPE/public/Nov2016/diminico\\_01b\\_1116.pdf](http://www.ieee802.org/3/10SPE/public/Nov2016/diminico_01b_1116.pdf)

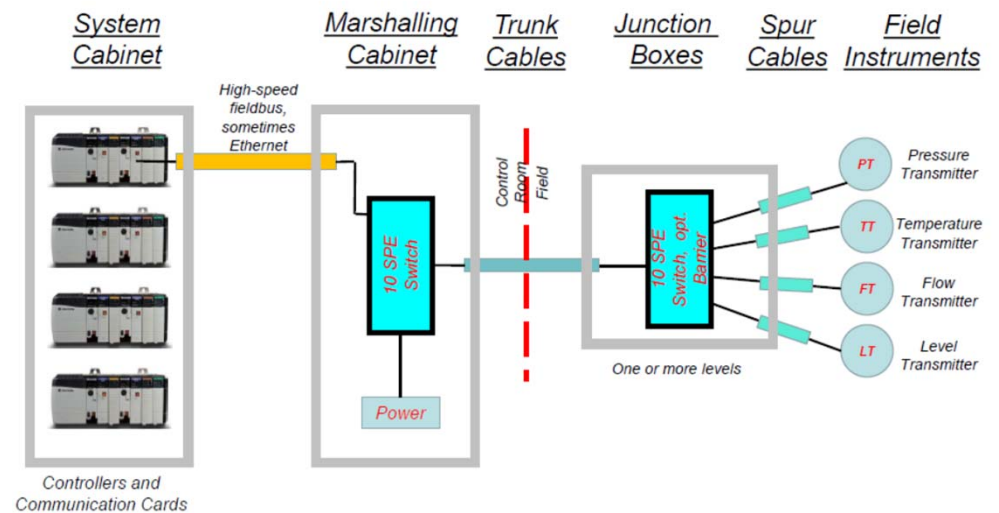
# SPE 10BASE-T1L – Process Automation Simplifications

- Infrastructure complexity will be reduced by substitution of Ethernet switches

## SPE Homerun Wiring



## SPE Fieldbus wiring



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# Automotive SPE Market Drivers

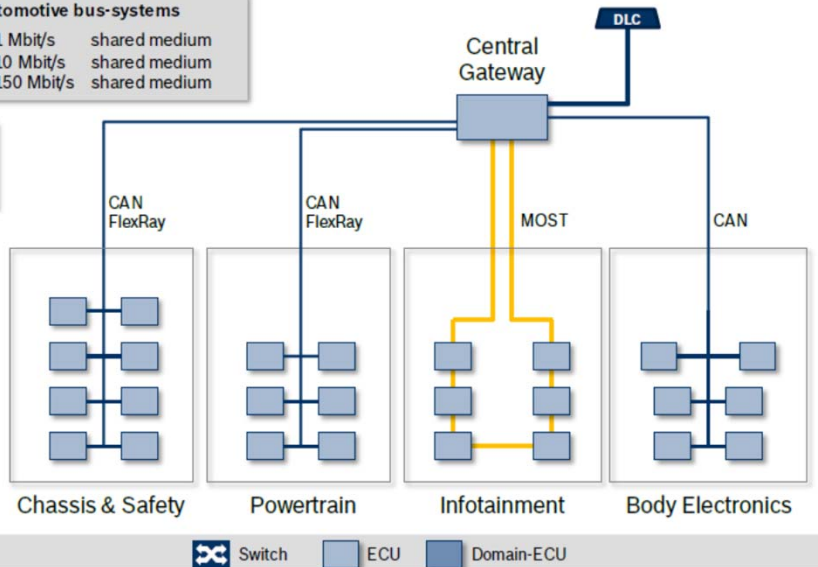
- Starting point of automotive networking is CAN (< 1 Mbit/s) and FlexRay (< 10 Mbit/s) on shared medium

- Replacement of multiple proprietary protocols with Ethernet, furthering consolidation of legacy in-car networks into a homogeneous architecture.

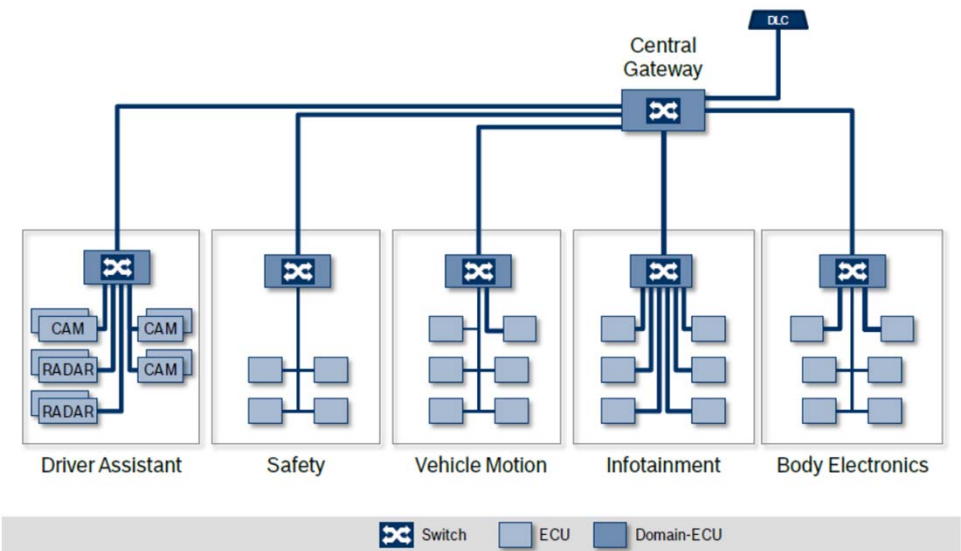
Properties of typical automotive bus-systems

CAN	ISO11898	< 1 Mbit/s	shared medium
FlexRay	ISO 17458	< 10 Mbit/s	shared medium
MOST		< 150 Mbit/s	shared medium

— Ethernet  
— Bus-Systems



## Domain-ECUs & Ethernet-Backbone



Transition to Ethernet

# SPE Field Testing – 1000BASE-T1

- Link segment transmission characteristics based on installed cabling
- Installed cabling reuse expected
- Field testing to validate link transmission parameters
  
- Link transmission parameters for link segment type B
  - Frequency range specified  $1\text{MHz} \leq f \leq 600\text{ MHz}$ 
    - Insertion loss
    - Differential characteristic impedance
    - Return loss
    - Maximum link delay
    - Coupling attenuation
    - Multiple disturber alien near-end crosstalk (MDANEXT) loss
    - Multiple disturber power sum alien near-end crosstalk (PSANEXT) loss
    - Multiple disturber alien far-end crosstalk (MDAFEXT) loss
    - Multiple disturber power sum alien attenuation crosstalk ratio far-end (PSAACRF)



# SPE Field Testing – 10BASE-T1L

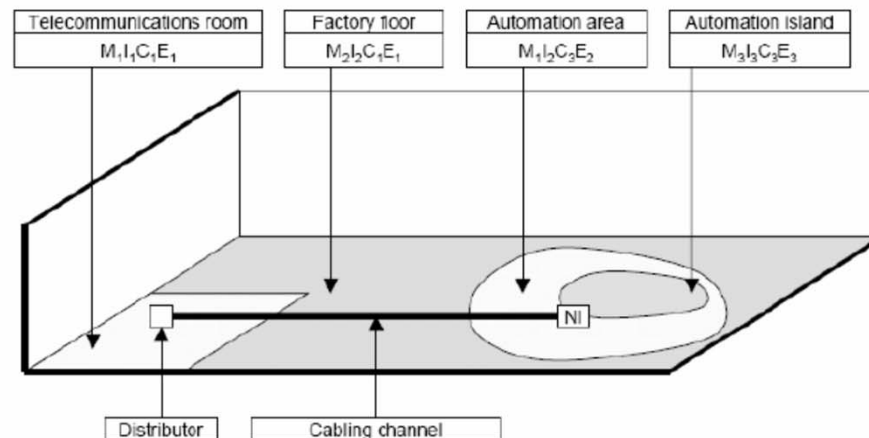
- Link segment transmission characteristics based on installed cabling
- Installed cabling reuse expected
- Field testing to validate link transmission parameters
- Field tester capable of measuring down to 100 KHz
  
- Link transmission parameters
  - Frequency range specified  $100 \text{ KHz} \leq f \leq 20 \text{ MHz}$ 
    - Insertion loss
    - Return loss
    - Maximum link delay
    - Differential to common mode conversion
    - Coupling attenuation
    - Multiple disturber alien near-end crosstalk (MDANEXT) loss
    - Multiple disturber power sum alien near-end crosstalk (PSANEXT) loss
    - Multiple disturber power sum alien far-end crosstalk (PSAFEXT) loss

# TIA-TR42.1 single pair projects

- ANSI/TIA-862-B-2 intelligent buildings
  - Amendment to add single twisted-pair use cases, topology, and architecture to ANSI/TIA-862-B.
    - Guidelines in buildings where 1-pair cabling can be deployed in addition to the 4-pair cabling used for IBS applications.
    - Installation requirements and additional guidelines for transitioning 2 4-pair to 1-pair cabling including sheath sharing.
    - Guidelines for emerging IOT and M2M applications that will require higher density, reduced size, and greater flexibility to serve these IOT devices.
- ANSI/TIA-568.0-D-2 generic cabling
  - The scope of single pair TR42.1 generic cabling is under consideration in TR42.1.
  - Presentations on the scope propose that TIA TR42.1 develop a standard to enable the migration of 100BASE-T1, 1000BASE-T1, 10BASE-T1 and 10GBASE-T1 into buildings by standardizing a generic single pair cabling architecture(s).

# ANSI/TIA-568-C.0 / ISO/IEC TR 29106 -MICE Environmental Classifications

	<b>Class I</b> (commercial)	<b>Class II</b> (light industrial)	<b>Class III</b> (heavy industrial)
<b>M</b> echanical	<b>M<sub>1</sub></b>	<b>M<sub>2</sub></b>	<b>M<sub>3</sub></b>
<b>I</b> ngress	<b>I<sub>1</sub></b>	<b>I<sub>2</sub></b>	<b>I<sub>3</sub></b>
<b>C</b> limatic	<b>C<sub>1</sub></b>	<b>C<sub>2</sub></b>	<b>C<sub>3</sub></b>
<b>E</b> lectromagnetic	<b>E<sub>1</sub></b>	<b>E<sub>2</sub></b>	<b>E<sub>3</sub></b>



# TIA-TR42.7 single pair projects

- ANSI/TIA-568.5 - Single pair balanced twisted-pair telecommunications cabling and Components standard
  - Specifications for cables, connectors, cords, links and channels using 1-pair connectivity in non-industrial premises telecommunications networks (MICE1 environments).
  - Guidelines for adaptations to four pair cabling.
  - The standard will include field tester specifications to verify the performance of installed single pair cabling.
  - The cabling transmission performance requirements apply from 100 KHz up to 600 MHz.
  - 100 meter, 40 meter and 15 meter channel configurations are supported.
  - The 100 m test configuration is consistent with TIA-568 four pair cabling topologies.
  - The 15 meter and 40 meter topologies enables support for 100BASE-T1, 1000BASE-T1, 10BASE-T1 and 2.5/5/10GBASE-T1 technologies.

# TIA-TR42.9 single pair projects

- ANSI/TIA-1005-A - Single pair balanced twisted-pair telecommunications cabling and Components standard
  - Specifications for cables, connectors, cords, links and channels using 1-pair connectivity in industrial premises telecommunications networks (MICE1 and MICE2 environments).
  - Guidelines for adaptations to four pair cabling.

# TR42.7 Single Pair Connector

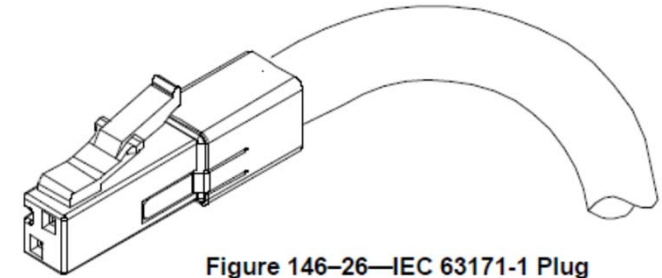


Figure 146-26—IEC 63171-1 Plug

**802.3cg 10BASE-T1L (10 Mb/s)**  
– MDI jack connector and plug  
- IEC 63171-1

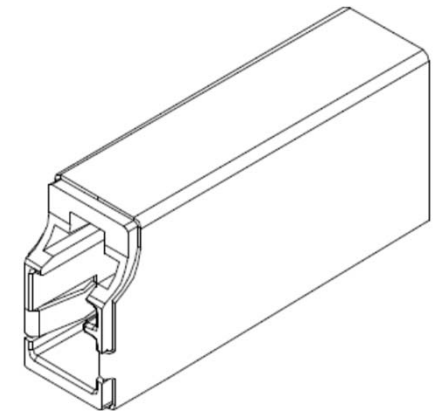
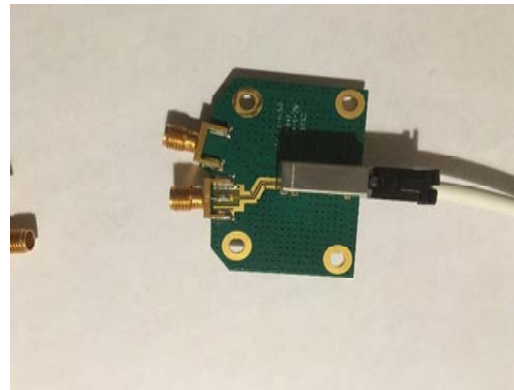
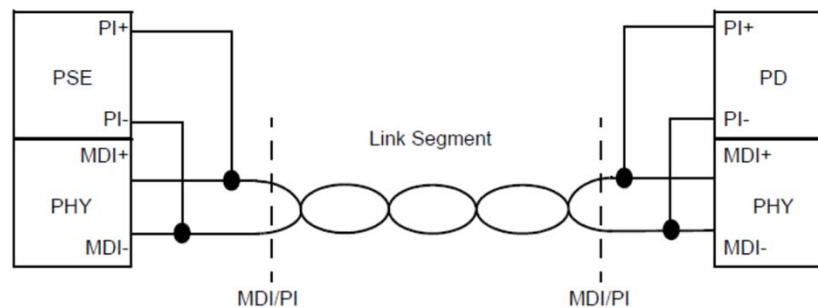


Figure 146-27—IEC 63171-1 Jack

# PoDL SPE Power Standard

- IEEE 802.3 standard: IEEE Std 802.3bu-2016 1-Pair Power over Data Lines (PoDL).  
PoDL specifies a power distribution technique for use over a single twisted pair link segment and allows for power operation even if the data is not present. It supports voltage and current levels for the automotive, transportation, and industrial control industries.



PD is powered device. PSE is power source equipment.  
MDI is the medium dependent interface (equipment connector).

# PoDL Powered Device Classification

Table 104–1a—Class power requirements matrix for PSE, PI, and PD for classes 10 through 15

Class	10	11	12	13	14	15
$V_{PSE(max)}$ (V)	36	36	36	60	60	60
$V_{PSE\_OC(min)}$ (V)	20	20	20	50	50	50
$V_{PSE(min)}$ (V)	20	20	20	50	50	50
$I_{PI(max)}$ (mA)	102	155	169	254	388	400
$P_{class(min)}$ (W)	2.04	3.1	3.38	12.7	19.4	20
$V_{PD(min)}$ (V)	13.98	13.96	13.92	35.01	34.87	35.6
$PPD(max)$ (W)	1.43	2.16	2.35	8.89	13.53	14.24
Cable mm (AWG)	1.02 (18)	1.63 (14)	0.51 (24)	1.02 (18)	1.63 (14)	0.51 (24)
Cable Length (m)	1000	1000	300	1000	1000	300



# Conclusion

- We are in a brave new world of converged data and power.
- The single pair Ethernet and TR42 standards are poised to enable a new class of low power Ethernet devices that will facilitate networking and powering the billions of end point sensors forecasted by the year 2022.



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# Thank You