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# DeviceNet™: Physical Layer, Media and Power Capabilities

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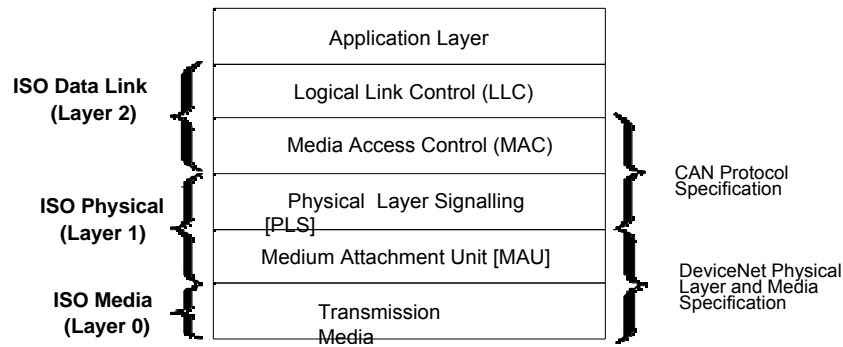
## Abstract:

The DeviceNet Physical Layer and Media include the following features: CAN technology, multiple baud rates, cable distance up to 500 meters, Thick and Thin drop line or trunk line, drop lines as long as 6 meters, isolated and non-isolated physical layers, branching on drop lines and protection from wiring errors. In addition to providing CAN based communications, DeviceNet also provides power. Because power and signal conductors both are contained in the cable, devices can draw power directly from the network without the need for separate device power supplies. DeviceNet provides a flexible approach to supplying power along the bus. Both single and multiple supply configurations are supported allowing high current capability. Power supplies can be placed anywhere along the trunk line resulting in greater flexibility for the system designer. The DeviceNet power bus is supplied by one or more nominal 24 volt power sources and can support up to 8 amps on any section of Thick cable trunk line or up to 3 amps on any section of Thin cable trunk line. This paper describes DeviceNet's physical layer, media and power capabilities.

## Introduction:

The DeviceNet Physical Layer and Media as compared to the ISO/OSI Model is shown in Figure 1. The Physical Layer contains two components, the Medium Attachment Unit (MAU) and the Transmission Media. With respect to the ISO/OSI model, DeviceNet's physical layer is comprised of the MAU section of layer 1 and the Transmission media (layer 0). Within the DeviceNet specification the term Physical Layer is used to represent elements of the MAU and the definition of the electrical and mechanical interfaces to the Transmission Media. DeviceNet's Physical Layer and Media supports the following:

- Use of CAN technology
- Linear bus topology with drop line branching allowed
- Three data rates: 125 kBaud up to 500 m, 250 kBaud up to 200 m, 500 kBaud up to 100 m
- Shielded twisted pair media containing both signal and power conductors
- Support of both Thick and Thin drop line or trunk line
- Drop line lengths up to 6 m
- Up to 64 devices/nodes
- Device removal without severing the network
- Isolated and non-isolated physical layers simultaneously
- Sealed and open media components
- Protection from wiring error (Mis-Wiring Protection, or MWP)
- Devices powered from the network



**Figure 1 DeviceNet Physical Layer vs. ISO/OSI Model**

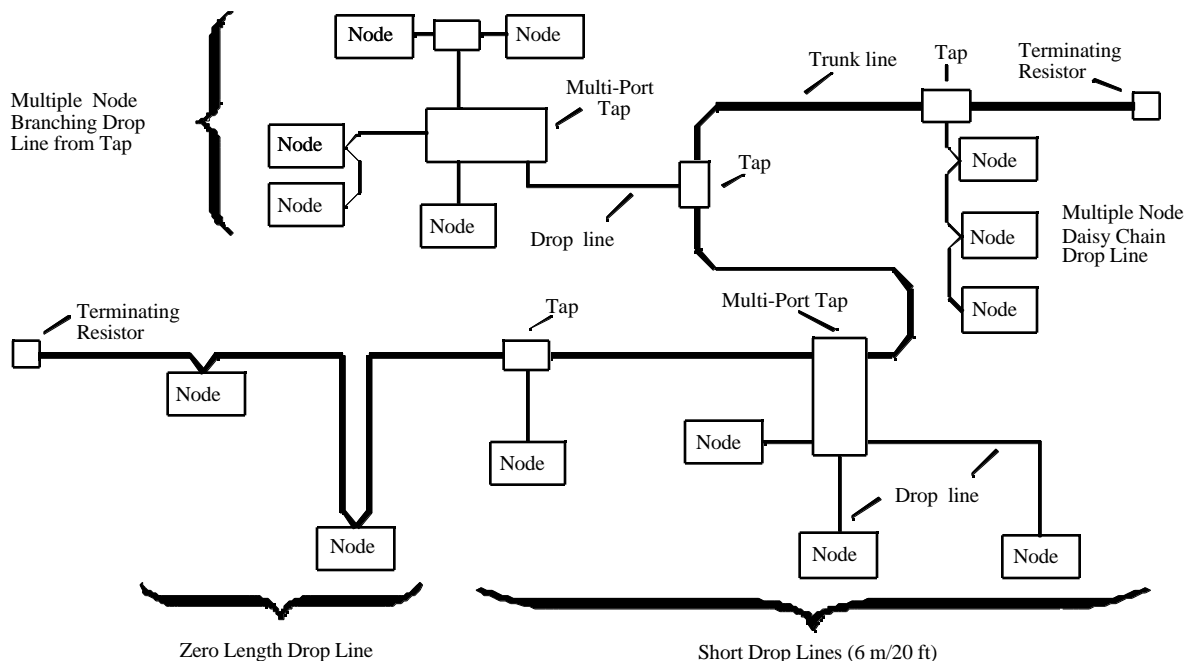
**Transmission Media and Topology:**

DeviceNet's Trunk line - Drop line topology can be constructed of either Thick cable, Thin cable or a combination of both. Thick cable allows longer trunk line distances, greater current and more sturdy trunk and drop lines, while Thin cable provides for easier and more flexible cable routing. The cables consist of two shielded twisted pairs with a drain wire, covered by an overall braid shield. Table 1 lists some of the main cable characteristics.

**Table 1 Thick and Thin Cable Characteristics**

	Thick	Thin
Signal Pair	#18; blue/white	#24; blue/white
Power Pair	#15; black/red	#22; black/red
Drain Wire (Bare)	#18; bare	#22; bare
Current Capability (amperes)	8	3

Figure 2 is an example of the DeviceNet Media topology. The trunk line is a linear bus topology with 121 ohm termination resistors on each end. Drop lines up to 6 meters long are possible with multiple devices per drop line allowed. The topology supports branching on drop lines.

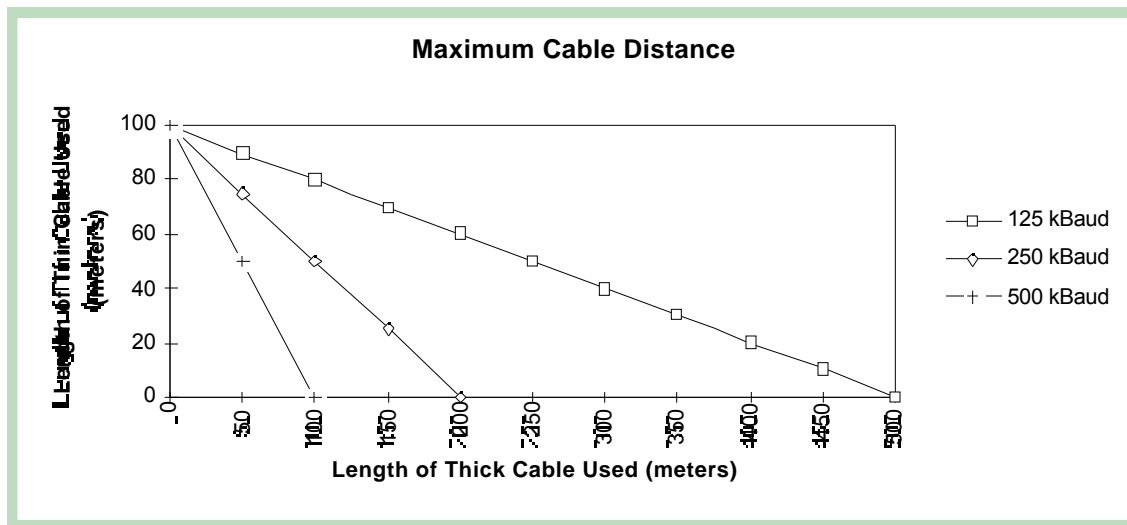


**Figure 2 DeviceNet Media Topology**

The total amount of trunk line allowable depends on the data rate and type of cable used (Thick or Thin). The cable distance between any *two points* in the cable system must not exceed the **Maximum Cable Distance** (see Table 2 and Figure 3) allowed for the data rate. Cable distance between two points includes *both* trunk line cable length and drop line cable length that exists between the two points. Note that the distance between the termination resistors may or may not be the greatest cable distance between two points if there is a long drop line near the end of the trunk line.

**Table 2 Maximum Cable Distance**

Data Rate	Maximum Cable Distance for 100% Thick Cable	Maximum Cable Distance for 100% Thin Cable
125 kBaud	500 meters	100 meters
250 kBaud	200 meters	
500 kBaud	100 meters	



**Figure 3 Maximum Cable Distance**

The equations for the above figure are:

For 125 kBaud:  $L_{\text{Thick}} + 5 \times L_{\text{Thin}} = 500 \text{ meters}$

For 250 kBaud:  $L_{\text{Thick}} + 2 \times L_{\text{Thin}} = 200 \text{ meters}$

For 500 kBaud:  $L_{\text{Thick}} + 1 \times L_{\text{Thin}} = 100 \text{ meters}$

where  $L_{\text{Thick}}$  is the length in meters of Thick cable and  $L_{\text{Thin}}$  is the length in meters of Thin cable.

Any individual drop line must be less than 6 meters. On branching drop lines, the drop line length is the longest cable distance measured from the tap on the trunk line to each device on the drop line. In addition, the allowable cumulative drop line cable length on DeviceNet varies with the data rate (see Table 3).

**Table 3 Drop Line Budget**

Data Rate	Drop Length	
	Maximum	Cumulative
125 kBaud	6 meters	156 meters
250 kBaud		78 meters
500 kBaud		39 meters

There are three primary factors that affect the maximum trunk line cable length in the network:

- Signal Loss/Amplitude
- Delay (CAN Bit timing)
- Power Bus (Common mode voltage)

When using Thick cable at 125 kBaud, the maximum distance is limited by signal loss. At 500 kBaud the maximum distance is limited by delay. For Thin cable at 125 kBaud the maximum distance is limited by signal loss. At 500 kBaud the distance is limited about equally by both delay and signal loss.

**DeviceNet Connections and Media Components:**

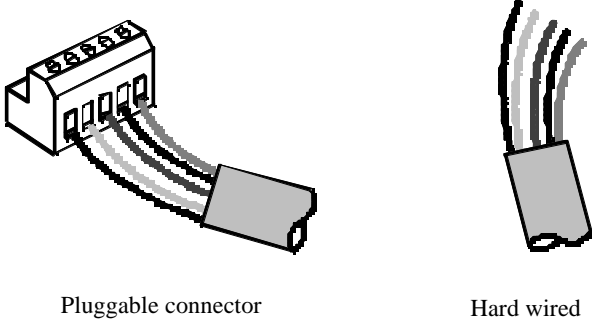
In the spirit of standardization DeviceNet utilizes industry proven 5 pin connectors, which accommodate a signal pair, power pair and a drain wire. This approach makes it easy for the users to obtain “off-the-shelf” connectors which are currently used in industrial applications.

DeviceNet’s trunk line is designed to be continuous with taps and tees which allow for insertion and removal of devices without severing the trunk line as required by the DeviceNet Specification. The following cable connector options are provided by the specification:

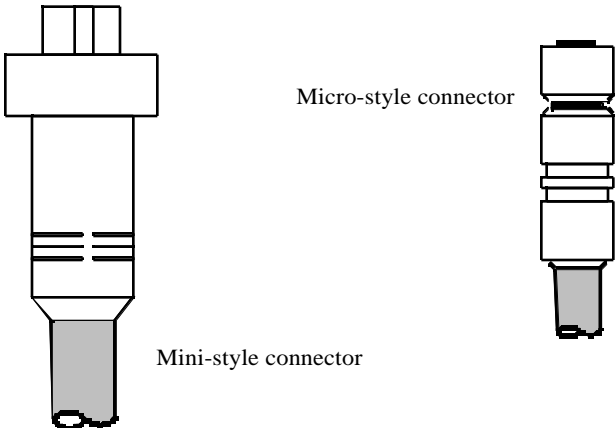
- Open Connectors: Pluggable and Hard wired
- Sealed Connectors: Mini and Micro style connectors

Open connectors are inexpensive and easy to attach to. A pluggable screw connector is recommended. Sealed connectors are typically used in harsh environments. Both mini and micro sealed connectors are allowed. The micro style connectors can only be used with the Thin cable as the wires in the Thick cable are too large.

Figure 4 and Figure 5 depict the cable connector options. DeviceNet requires that connectors on devices have male contacts.

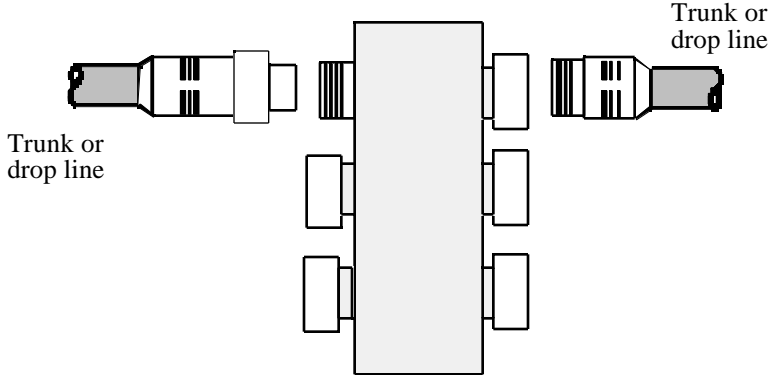


**Figure 4 Open Style Connectors**

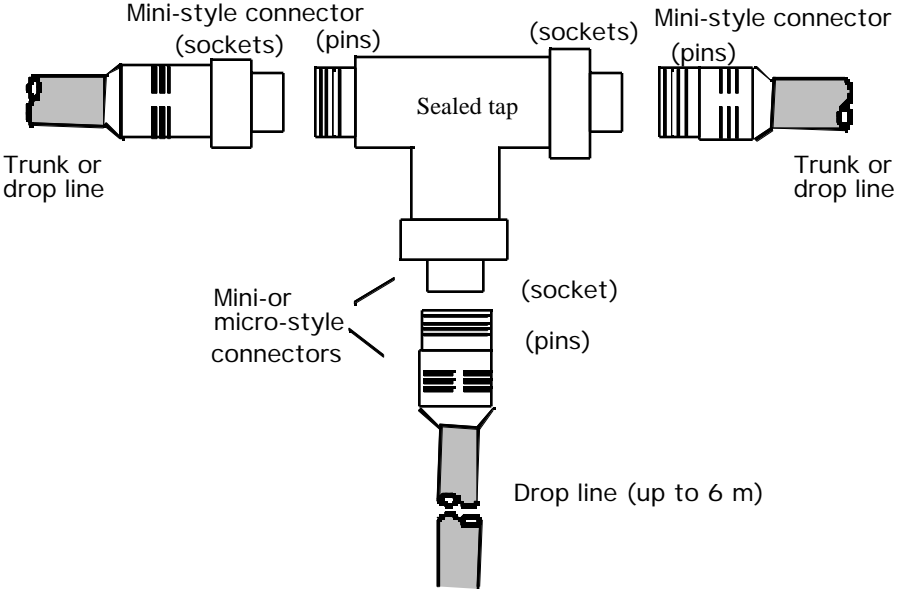


**Figure 5 Sealed Style Connectors**

Figure 6 and Figure 7 show examples of sealed taps. Since DeviceNet supports both sealed and open media pieces, open taps can be used as well.



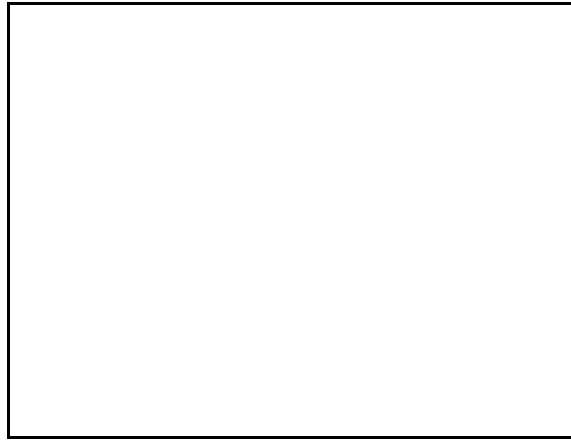
**Figure 6 Sealed Multi-port Tap (4/5 drop lines)**



**Figure 7 Sealed T-Tap with Connectors**

**Physical Layer:**

The Physical Layer is comprised of the transceiver, connector, mis-wiring protection (MWP) circuitry, regulator, and optional optical isolation. The components that make up DeviceNet’s Physical Layer are shown in Figure 8. The transceiver, mis-wiring protection (MWP) circuitry and optional optical isolation will be briefly discussed below.



**Figure 8 Typical DeviceNet Physical Layer**

### **DeviceNet Transceiver:**

The transceiver provides transmission and reception of CAN signals onto and off of the network. The DeviceNet specification provides transceiver specifications to allow device developers to buy or make their own. The DeviceNet specification uses the Philips 82C250 as the basis for the transceiver specifications. This is a standard off-the-shelf part which is ISO 11898 compliant. The current DeviceNet specification requires that the transceiver be powered from the network and that it be powered anytime it is connected to the network. This is because an unpowered 82C250 has a lower input impedance than a powered one, causing network loading and signal attenuation.

To be compatible with DeviceNet's power system design, the transceiver must support a minimum of +/- 5 volts common mode operation, which implies ground differences of +/- 5 volts. One of the limitations that the DeviceNet designers had to overcome was the transceiver's common mode voltage of +/- 5 volts. Here the offset is purely a function of the  $I^2$  losses of the cable and connectors being used in the power system. This limitation required that the power distribution system be carefully designed to minimize the signal to power offset in a typical system.

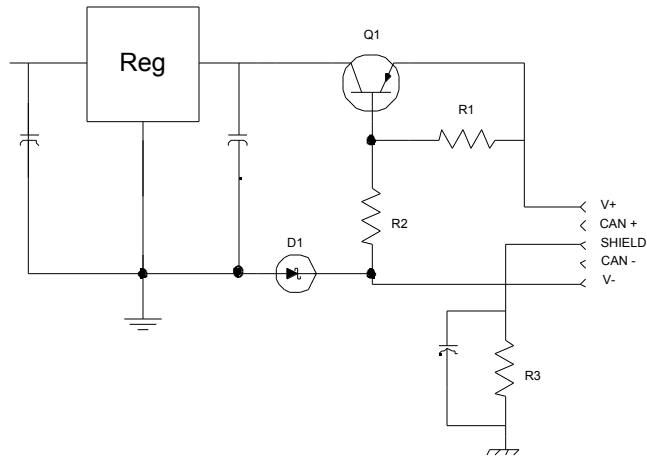
The transceiver's CAN\_H and CAN\_L signals are specified to tolerate maximum voltages of -25 to +18 volts referenced to the transceiver's ground pin.

### **Mis-Wiring Protection:**

A major feature of the DeviceNet physical layer is the addition of a robust Mis-Wiring Protection (MWP) circuit. The circuitry is designed to prevent damage to a device's transceiver in the event that the V-conductor is opened or if the connector is incorrectly wired. The MWP circuit will protect from the following:

- V+ connected to CAN\_H or CAN\_L
- V+ connected to CAN\_H or CAN\_L for V+ less than 18 volts
- V+ and V- reversed
- Missing V-
- V+ connected to V- and V- missing

Figure 9 is an example circuit of the mis-wiring protection circuitry. In the event that the V- conductor is opened, Q1 will have insufficient base current to maintain the required collector current. D1 provides an inexpensive means of reverse voltage protection in the event that V+ and V- are reversed. The selection of diode D1 is based on having a relatively small forward voltage drop ( $V_f$  of 0.6 volts max.) with respect to the other system losses.



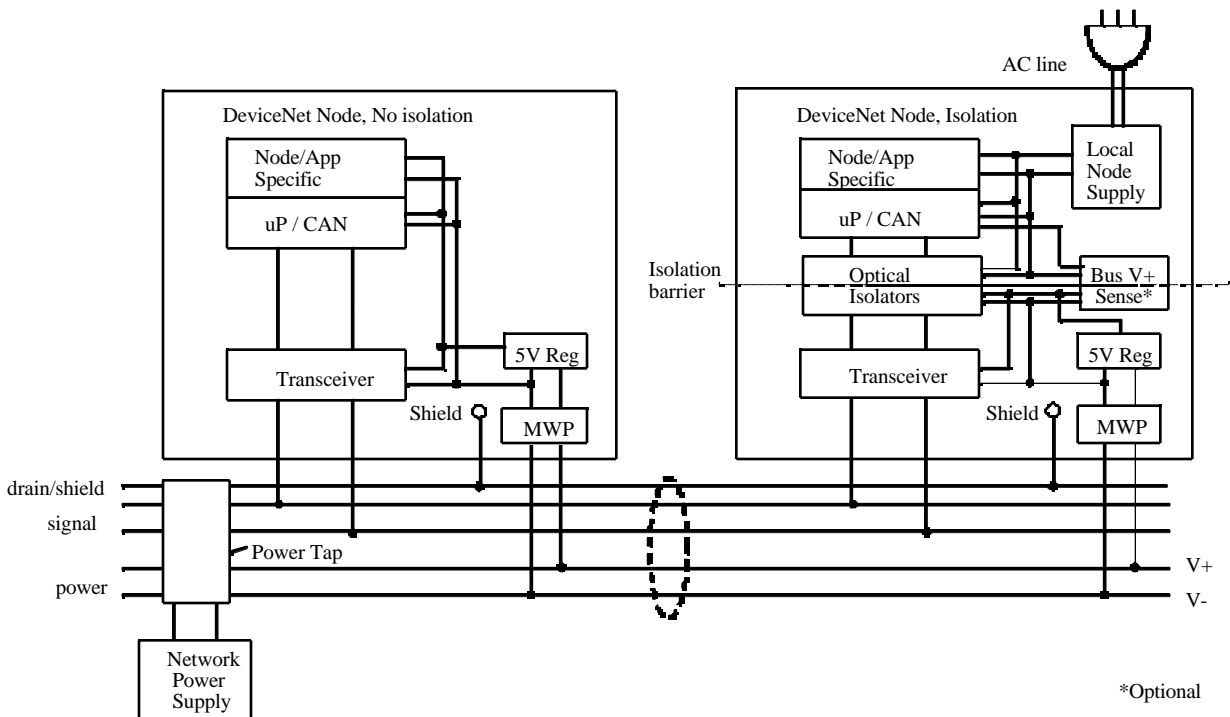
**Figure 9 DeviceNet MWP Example Circuit**

**Non-Isolated and Isolated Physical Layers:**

The network supports both non-isolated and isolated physical layers within devices. Figure 10 shows examples of both physical layers. If a device contains a non-isolated physical layer, all components of that device must be either ground referenced to V- or elsewhere ground isolated. Usually, a device that contains a non-isolated physical layer will obtain all of its power from the network.

Devices that are referenced to other grounds are required to use an isolated physical layer interface to DeviceNet. When isolation is provided in the physical layer, some of the device's components are referenced to a ground other than V-. Devices that contain an isolated physical layer must obtain power from the network for the transceiver and the network side of the optical isolators. The optical isolators must have propagation delays of no greater than 40 ns each.

Devices containing non-isolated and isolated physical layers can exist simultaneously and communicate to each other on the network. The opto-isolator delays are taken into account in the maximum trunk length limits.



**Figure 10 Non-Isolated and Isolated DeviceNet Physical Layer Examples**



## Grounding and Isolation:

One of the decisions that network designers are continually plagued with is where and how to ground the cable system. For DeviceNet, the system is grounded at one and only one place in the system in order to prevent ground loops and minimize shield noise. The grounding location should be at a power tap, see Figure 11. Grounding near the physical center of the network is also desired.

## Power Capabilities:

In addition to providing communications, DeviceNet also provides power. Because power and signal conductors both are contained in the cable, devices can draw power directly from the network without the need for separate device power supplies.

DeviceNet has a single supply current capability of up to 16 amperes using a Thick cable trunk line, and up to 6 amperes using a Thin cable trunk line. However, on any section of cable the current is limited to 8 amperes for Thick cable and 3 amperes for Thin cable. In additions, the mini-style connectors are limited to 8 amperes per pin and the micro-style connectors to 3 amperes per pin. Table 4 summarized these limits.

**Table 4 Load Limits**

<b>Maximum voltage drop on V- and V+</b>	5 volts each
<b>Maximum Thick cable trunk line current</b>	8 amps in any section
<b>Maximum Thin cable trunk line current</b>	3 amps in any section
<b>Maximum drop line current</b>	0.75 to 3.0 amperes
<b>Voltage range at each device</b>	11 - 25 volts
<b>Operating current on each product **</b>	Specified by product manufacturer
* Maximum drop line current depends upon the length of the drop. See Table. ** The operating current represents the average current drawn from the bus. Maximum operating current must be specified if it exceeds the average current by more than 10%.	

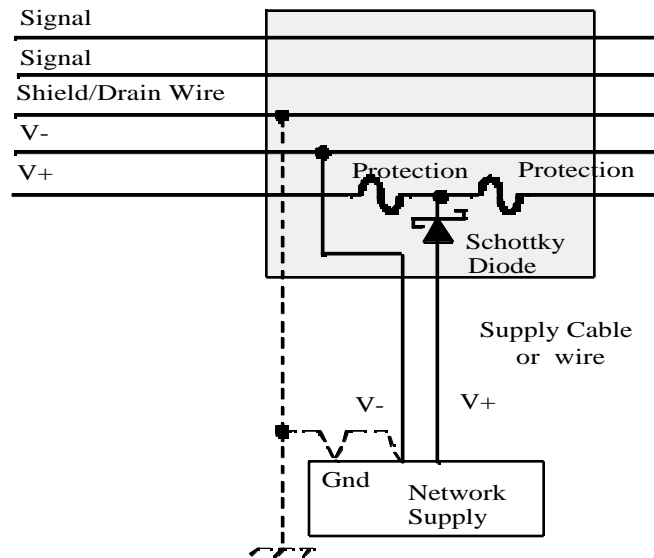
Current limits for drop lines are described by the following equation:

$$I = 4.57 / L \text{ (where I is Maximum 3.0 Amps)}$$

where I is the allowable drop line current in amperes and L is the drop length in meters.

The trunk line can be constructed of either Thick or Thin cable. A combination of the both Thick and Thin cable can be used provided that only one type of cable is used for any section of cable length between two power taps or between a power tap and the end of the trunk line.

DeviceNet supports the use of multiple power supplies, resulting in almost unlimited power. Power supplies connect to the trunk line via power taps. Figure 11 shows an example of a power tap. A power tap contains a schottky diode connected to the power supply conductor and two over-current protection devices to protect the trunk line conductors from excess current.



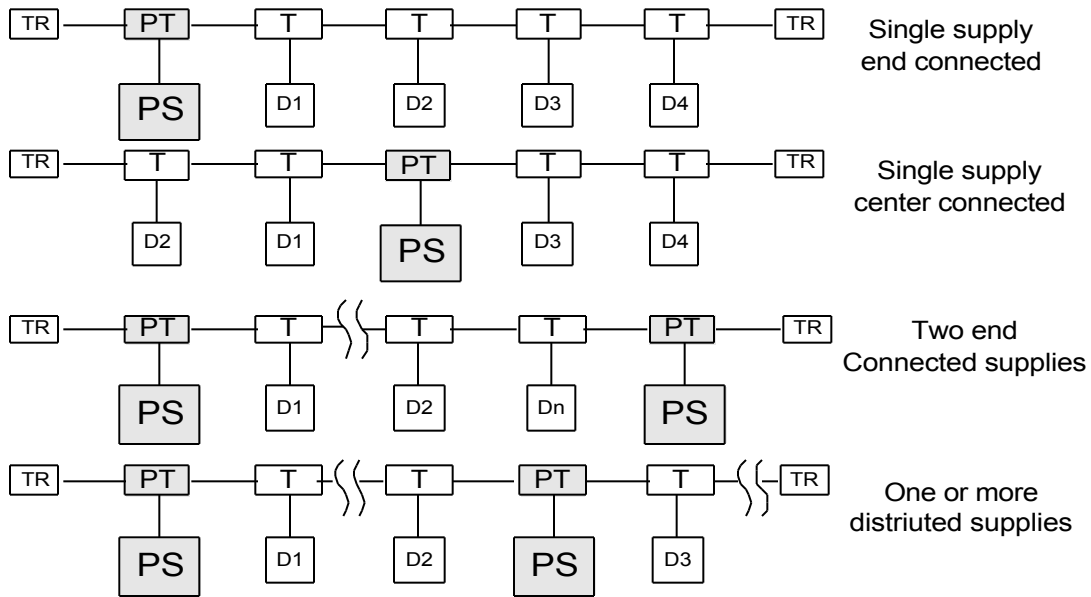
**Figure 11 Example Power Tap**

DeviceNet was designed to make use of standard off-the-shelf nominal 24 Volt power supplies. Devices are required to operate with an input voltage range of 11 - 25 Volts. The current rating of the power supply is dependent on two requirements:

- 1) The current required to power each cable segment.
- 2) The local codes that apply. For the USA the local codes require that the power supply be a class 2 supply with a nameplate rating of not more than 4 Amperes.

### **Power Supply Topologies:**

Power supplies can be located anywhere along the network. To maximize power utilization of the network, power supplies are distributed along the bus as needed to meet load requirements. At a minimum a system must contain one or more power supplies for transceiver power. Figure 12 shows some examples of possible power supply configurations that a system designer may implement.



**Figure 12 DeviceNet Power Supply Configurations**

**Conclusion:**

The DeviceNet physical layer, topology, and power distribution methods provide a flexible system that will meet the needs of product implementers and system designers for some time to come. DeviceNet can support up to 64 devices containing isolated and non-isolated physical layers. The network topology supports Thick and Thin cables, branching on drop lines and both open and sealed media pieces. In addition, the network supports three data rates allowing the system designer to balance speed and cable distance. The physical layer features mis-wiring protection giving the customer unprecedented protection from wiring errors. The power distribution system allows virtually unlimited power to be supplied and for entire devices to be powered from the network. Due to the small size and low cost of the components necessary to implement DeviceNet, it can be embedded into many devices that previously could not justify communication capability.