

# 101 BASICS SERIES

## LEARNING MODULE 26: DEVICENET



Cutler-Hammer

**EATON**

## WELCOME

Welcome to Module 26, which is about **DeviceNet™**, a **communication protocol that allows individual devices** (*starters, photoelectric sensors, scanners, etc.*) to **communicate with the network controller**. DeviceNet users may **choose** either an *Industrial Personal Computer (iPC)* or a *Programmable Logic Controller (PLC)* as **their controller**. DeviceNet allows its users to **replace large amounts of wiring with a single cable**. It also **introduces small chips onto each device** to enable communication and allow the devices to gather diagnostic information.

Like the other modules in this series, this one presents small, manageable sections of new material followed by a series of questions about that material. Study the material carefully, then answer the questions without referring back to what you've just read. You are the best judge of how well you grasp the material. Review material as often as you think necessary. The most important thing is establishing a solid foundation to build on as you move from topic to topic and module to module.

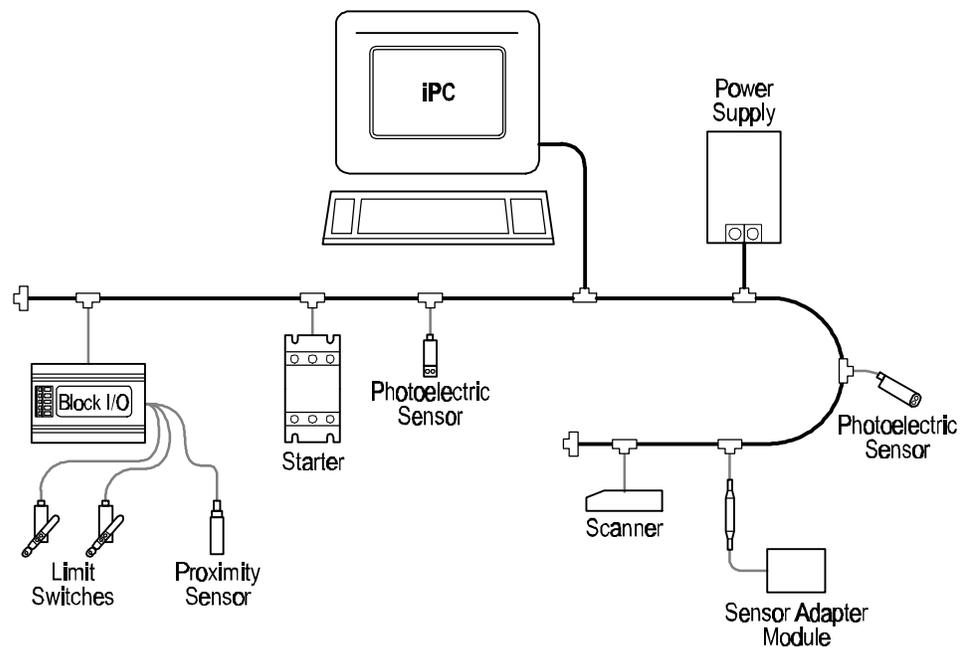


FIGURE 1: A DEVICENET NETWORK

### A Note on Font Styles

Key points are in bold.

*Glossary terms are underlined and italicized the first time they appear.*

### Viewing the Glossary

You may view definitions of glossary items by clicking on terms and words that are underlined and italicized in the text. You may also browse the Glossary by clicking on the Glossary bookmark in the left-hand margin.

## WHAT YOU WILL LEARN

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## INTRO- DUCTION

During the Industrial Revolution of the 18<sup>th</sup>-and 19<sup>th</sup>-centuries, many traditionally manual processes were taken over by machines. These early machines relied on gears and pulleys to work and were, by our standards, extremely primitive. The **first major breakthrough in the development of control systems came with the invention of electrically powered machines**. The first control systems were developed in the early years of the 20<sup>th</sup> century and used **sequential *relay circuits*** for machine control (see the “Relay Control” Module for more information). A major technical breakthrough in its day, and still used in some plants today, **relay technology enabled machines to work faster and more safely**.

Relay circuits performed their job very well, but they **required large amounts of floor space, and huge amounts of energy**. Adding to their drawbacks as the basis for a machine control system, relay circuits also took a **long time to install, troubleshoot, and modify**. Finally, in the early 1970s, a device was developed to replace sequential relay circuits: the Programmable Logic Controller (PLC).

As you will remember from reading about them in Module 24, **PLCs are more reliable, faster, more flexible and more efficient than relay-based systems**. For example, PLCs are cheaper and easier to wire and maintain than relays. Furthermore, when it comes to troubleshooting, PLCs are much quicker than relays at testing and debugging the program.

PLCs are used in all kinds of industries. In fact, almost any industrial process that uses electrical control needs a PLC. For example, let's assume that when a switch turns on we want to turn a solenoid on for 5 seconds and then turn it off regardless of how long the switch is on for. We can do this with a simple external timer. But what if the process included 10 switches and solenoids? We would need 10 external timers. What if the process also needed to count how many times the switches individually turned on? We need a lot of external counters. With a PLC, however, we can dispense with those unwieldy timers and counters, and simply program the PLC to count its inputs and turn the solenoids on for the specified time.

**PLCs, then, offered a significant advance on relay-based control systems**. Now, in the 1990s, **field communications networks** have emerged to offer an advance on PLC based control systems. Field communications networks take advantage of microprocessor technology and help fill industry's need for **smarter devices with more diagnostic capabilities, and further reductions in the cost of installation, wiring, and troubleshooting**. Several major vendors in the control business have developed field communications networks. **DeviceNet** is one of those networks.

**DeviceNet is an open network designed to replace large, complex wiring schemes with a simple trunk and branch structure, while also providing a high-level of diagnostics to each device on the network**. DeviceNet's open network architecture allows products from different vendors to communicate and work together. *Open Architecture* means users can easily add incremental devices to an existing or planned installation. DeviceNet is able to work with either a Programmable Logic Controller (PLC) or an industrial Personal Computer (iPC) as the controller.

**THE  
PURPOSE OF  
DEVICENET**

You get the attention of end users if you **can reduce operating costs, increase profitability and enhance competitive advantage**. The four main areas in which you can achieve these things are: **installation, maintenance, troubleshooting, and downtime**. DeviceNet brings advantages in each of these four areas. For example, DeviceNet **reduces set-up and installation times** because of its **simplified multi-drop wiring scheme** and the elimination of point-to-point wiring. DeviceNet can also **reduce potential wiring errors** and the time it takes to fix them. This may decrease wiring costs by a factor of three or four.

Just as it saves time and money when it comes to installation, DeviceNet also offers significantly lower on-going **maintenance** costs because its smart devices can detect a problem before it causes serious damage, loss of product, or downtime.

**Diagnostics**

By placing micro-processors on each device, we have added a form of intelligence to them. We take advantage of this intelligence by having each device monitor both itself and any associated devices (such as motors, pumps, or drives) for signs of wear, damage, or failure. Having diagnostics in devices reduces downtime by alerting operators immediately when a device fails. We can also use diagnostics to monitor devices for potential problems and correct them before they shut down our system.

**Hot Insertion**

How can having devices all linked on DeviceNet make them that much better if the device is doing the same task as it used to do? Well, DeviceNet was designed with hot insertion and removal of components in mind. For example, a photo-electric sensor can have its focus changed online, so it can adapt to different tasks without shutting down the operations to set a new configuration. If there is a problem, a device is smart enough to tell the engineers that it is no longer reliable, so the problem can be resolved almost immediately. And to correct the problem, the operations no longer have to be shut down for re-wiring. They simply unscrew the faulty device and screw in the new DeviceNet-compatible device. This on-the-fly replacement is called **hot-wire insertion** because power can still be connected and the machine can still be running while repairs are made.

**Input/Output  
(I/O) Devices**

Downsized engineering departments view smart I/O as a time-saver. DeviceNet instruments have **database ability, can be calibrated in the field, and can perform remote diagnostics**. DeviceNet's **plug and play** capability, improved **troubleshooting**, and diagnostics down to the *node* level all contribute to reduce **downtime**. And **increased intelligence in the nodes** doesn't just save users time, along with **distributed logic** it can also eliminate the need for separate controllers for many applications.

Finally, on top of all the time- and cost-efficiencies it offers, DeviceNet will help plants **comply with quality, ISO 9000 regulatory and safety standards**.

### DEVICENET ADVANTAGES OR, WHY BUY DEVICENET?

Before we continue, let's summarize the advantages DeviceNet offers:

- Reduced set-up and **installation** times because of a simplified multi-drop wiring scheme and the elimination of point-to-point wiring. DeviceNet can also reduce potential wiring errors and the time it takes to fix them. This may decrease wiring costs by a factor of three or four.
- Significantly lower on-going **maintenance** costs. Smart devices can detect a problem before it causes serious damage, loss of product, or downtime.
- Reduced **downtime** due to diagnostics down to the node level.
- Downsized engineering departments view **smart I/O as a time-saver**. For example, instruments have database ability, can be calibrated in the field, and can perform remote diagnostics.
- Plug and play capability, as well as improved **troubleshooting** and diagnostics, reduces **downtime**.
- DeviceNet will help plants **comply with quality, ISO 9000 regulatory and safety standards**.
- Ability to **easily add incremental devices** to an existing or planned installation.
- Increased intelligence in the nodes, distributed logic, will **eliminate the need for separate controllers** for many applications.

## WHERE DEVICENET IS USED

To understand where DeviceNet is used, we first need to understand how DeviceNet fits into the overall structure of control systems.

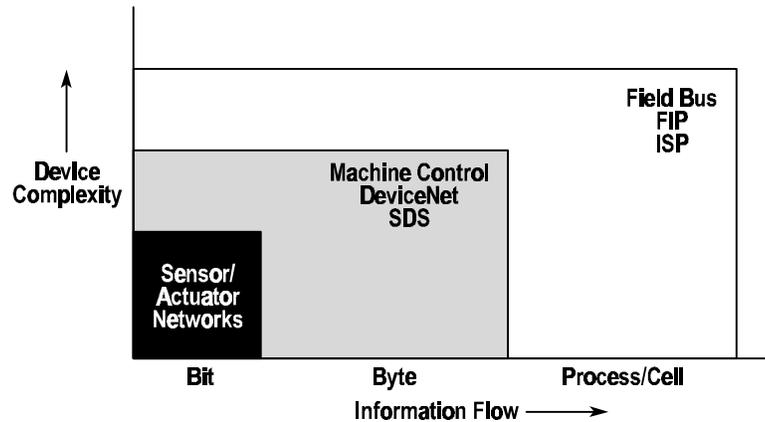


FIGURE 2: WHERE DEVICENET & MACHINE CONTROL POSITION THEMSELVES

As the diagram above shows, **control systems can be divided into three basic levels: *bit*, *byte*, and process.**

**Bit**—Systems where very **small** (1-4 bits per device) **informational packages are passed from the device to the controller.** Examples of this include *limit switches* passing on/off data, photoelectric sensors passing active/inactive signals, and contactors sending open/closed signals. Bit-level control systems are very good at high-speed, low-diagnostics applications. Standard wired PLC systems and *sensor/actuator* networks fall into this level of control.

**Byte**—At this level, **each device is capable of transmitting more information.** While this is typically from 0 to 8 bytes of information, the amount can be much more. This communication size **provides for rapid scan times, quick response, and some diagnostic information.** Examples include devices passing multiple data segments, analog signals, or status messages. Byte-level is ideal for devices such as barcode scanners and electrical current signals.

**Process**—**Large applications**, those that might control the heating and air-conditioning needs of a building, use **the largest package of information** that is delivered over field bus networks, called process level. The process control data can be as long as the design engineers need it to be. The public is generally unaware of the hundreds of valves, thermometers, dampers, fans, and other devices constantly in motion in a large building. Since these systems do not have to respond immediately, and there is so much data, the time it takes for all the data to make the rounds can be quite lengthy for a computer, perhaps 30 seconds or more.

**DeviceNet uses byte-level communications**, or packages of **64 bits**. This size balances network speed and data throughput to best suit manufacturing processes, where more than a hundred individual tasks can be carried out, all very quickly. You've probably seen video segments of "Robotic" assembly lines. This is the type of work carried out by networks like DeviceNet.

## DEVICENET IN THE WORKPLACE

Machine control applications make a modern auto assembly line almost unrecognizable to workers from twenty years ago. Read about this plant in Detroit and learn of how DeviceNet is helping to keep costs down and quality up.

### IN THE WORKPLACE

This engine plant used to run three shifts to compensate for lost production due to downtime. The control boxes alone had a special maintenance staff.

With DeviceNet, downtime was no longer part of the daily plan. The cabling was easy to maintain, and control devices that were operating at marginal spec could be identified on screen and swapped out before a breakdown—and without shutting down the line.

Plus, the space savings from eliminating the bulky control boxes allowed the boxing and labeling station to be placed right on the factory floor, speeding up delivery of product from the factory.

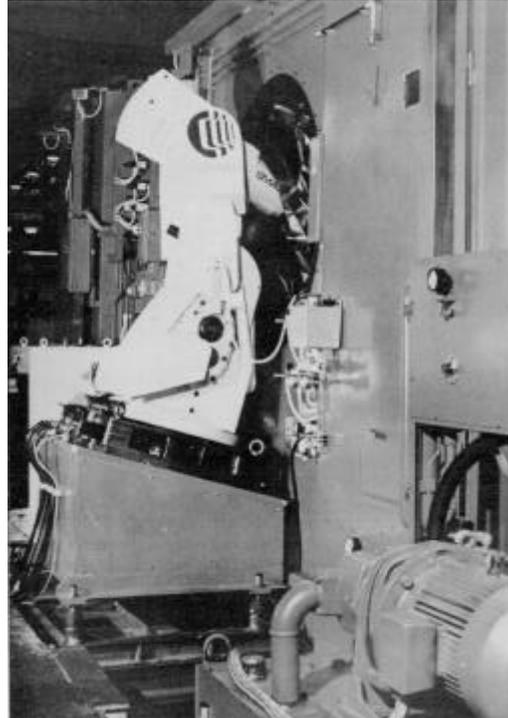


FIGURE 3: ENGINE PLANT USING DEVICENET

Here are a few other common DeviceNet applications:

- **Material Handling**—Conveyor belts and storage systems can eliminate long runs of hard-wired control; plus, the installation time is greatly reduced.
- **Packaging**—Again, significantly reduced installation time lowers start-up costs for new systems. Packaging is an industry with a lot of maintenance and downtime. The diagnostics inherent in intelligent control keep that to a minimum.
- **Food and beverage**—Filling, bottling, baking, and canning machines can be tied into a monitoring program for greater efficiency and safety.
- **Machine tools**—Metal cutting, forming, and drilling operations can not only save wiring and startup costs, but with online adjustments of device parameters, re-configuring for new jobs is a snap.

**OPEN ARCHITECTURE**

One major advantage of DeviceNet is that it is an **Open Architecture Network**. What is 'Open Architecture' and why is it a good thing? Well, as an analogy, let's think about the decisions you have to make in a situation with which many of you will be familiar: buying a stereo system.

When you purchase stereo equipment, you have two basic options: buy a ready made system from one manufacturer or construct your own system by buying each component (speakers, amplifier, receiver, CD player, etc) from different manufacturers. If you buy all of the components from one manufacturer, you know that they will work together and that there's guaranteed service if something goes wrong. Of course, the drawback to buying a pre-packaged system is that it may force you to sacrifice quality for convenience. To overcome this drawback, you could choose to purchase the best component on the market for each piece of the system. Unlike before, you now get the best equipment available; however, you may have to do some additional work to get everything to work together and, if something goes wrong, you will have to call four different vendors for service.

As you can tell, there are advantages and disadvantages to both the above ways of buying a stereo system. But what, you may be asking, do stereo systems have to do with DeviceNet and Open Architecture? Well, simply put, purchasers of control systems have often been in much the same boat as our stereo buyer: they could either buy everything from one company--thus having their choices limited and, potentially, making sacrifices in quality--, or they could spend time and money trying to iron out the incompatibilities of devices bought from competing suppliers. With an Open Architecture network, however, these problems are overcome: **a company can choose the products and components that best fit its needs and be assured of their compatibility.**

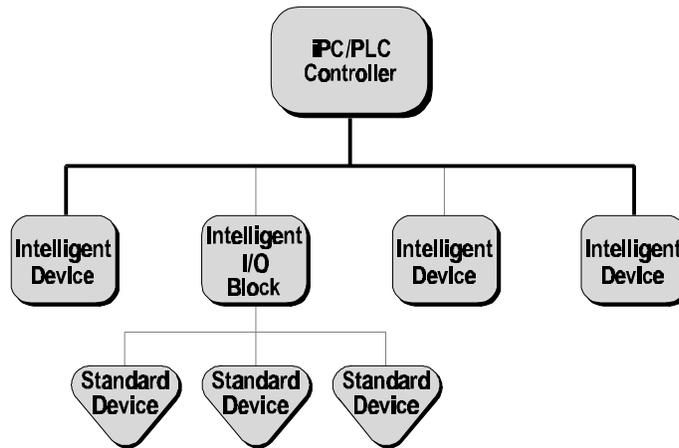


FIGURE 4: ALL DEVICENET PRODUCTS OPERATE IN AN OPEN, PUBLISHED PROTOCOL, SO ANY PRODUCT CAN "PLUG IN" TO ANY NETWORK

## OPEN ARCHITECTURE (CONTINUED)

DeviceNet is an industry-standard network, with published specifications. This means any company can build a product that meets the specifications of the DeviceNet standard, and sell it to any user with the expectation that their product will function correctly in a DeviceNet system. The Open Architecture of DeviceNet not only **allows products from different vendors to communicate and work together**, it also enables **easy addition of incremental devices to an existing or planned installation**. Open Architecture also means that DeviceNet is not controlled by one company able to charge a high price for every new component once you're locked into its system. Since users can go to many companies for products, **prices come down**. Secondly, as more and more companies develop products, the **functionality of the system increases and more parts become inter-operable**—and available—worldwide. Over 240 companies belong to a group that establishes the DeviceNet standards—the *Open DeviceNet Vendor Association (ODVA)*.

## Open DeviceNet Vendor Association (ODVA)

ODVA is an independent group of hardware and software companies—vendors and users—who **develop and foster standards** to perfect the optimal network for machine control.

The Open DeviceNet Vendor Association was founded in 1995 by Cutler-Hammer, Allen-Bradley, Omron, and Hitachi. In less than two years, ODVA increased its membership companies to over 240, including Samsung, Hewlett-Packard, Molex, Sharp, Ingersoll Rand, and Mitsubishi. Membership is open to all interested individuals, groups, and companies.

Two key words for ODVA are **independent** and **standards**. Together, they ensure an open market and Open Architecture for DeviceNet. ODVA activities include:

- Publish the ODVA catalog of products for DeviceNet
- Sponsor various *Special Interest Groups* (SIGs) to address new standards or problems
- Extend and maintain memberships for companies or individuals. Members make recommendations or requests for improvements to existing ideas or products
- Publish specifications and conducts conformance testing
- Advance new standards as technology moves forward

You can find out more information on ODVA on the World Wide Web at:

[www.odva.org](http://www.odva.org)

**Advantages of  
Open  
Architecture**

Let's summarize what we've just learned. With so many companies making parts according to DeviceNet specifications:

- Users can choose the best devices for their system
- Products are more widely available, and less expensive
- A single communication network interfaces plant-floor devices, sensors, and actuators. This network is now an industry standard, with over 240 members producing DeviceNet products
- Devices are interchangeable, although individual companies may exceed industry specifications

REVIEW 1

Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you've just read.

- 1. Identify the four areas in which DeviceNet allows users to save time and money.

\_\_\_\_\_

\_\_\_\_\_

- 2. Which of the following is *not* a general advantage of DeviceNet over conventional systems?

- A. Lower wiring costs
- B. Open standard provides larger pool of inter-operable products
- C. The system can be programmed
- D. Devices may be diagnosed and adjusted online

- 3. Match DeviceNet with the correct definition of byte-level control:

DeviceNet	A. Complex systems using hundreds of devices and allowing response times of several seconds.
	B. Small, very fast systems, having only a few components and using information packages of 8 characters.
	C. Discrete applications using up to a hundred devices while keeping response time below a few seconds. Uses an information package of 64 characters.

- 4. What is the characteristic of ODVA that guarantees DeviceNet does not become a proprietary system?

\_\_\_\_\_

\_\_\_\_\_

- 5. What does ODVA publish to make DeviceNet an Open Architecture?

\_\_\_\_\_

- 6. List three advantages of Open Architecture.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

THE  
ELEMENTS  
OF  
DEVICENET

A CAN-Based  
System

One way to improve your understanding of DeviceNet is to grasp the roles played by its different elements and components. Let's start by looking at what we mean when we say DeviceNet is a Control Area Network (CAN) based system.

Those of you who have worked on cars (or those who have even opened their hoods and looked inside), realize that they have become more and more complex. In the 1970s, you could open up your hood, identify everything inside the engine compartment, and even do some basic maintenance work. By the mid 1980s, however, cars had increased in complexity to the point where it looked like spaghetti under the hood. Most of this increased wiring was due to the addition of electric components such as power windows, locks, seats, defrosters, seat heaters, power mirrors and alarm systems.

Around this time, Mercedes commissioned Bosch to develop a microprocessor chip that could replace this wiring with a **simpler wiring scheme**. The new wiring scheme was so successful—**working reliably under harsh conditions at extremely fast speeds**—that it led the way to CAN being adopted for many other purposes. One of these is the protocol for DeviceNet.

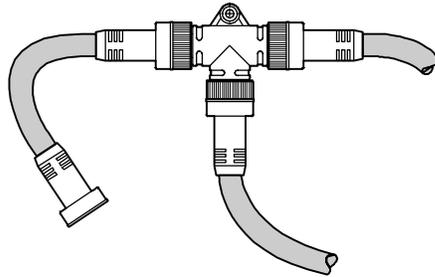


FIGURE 5: DEVICENET CABLE

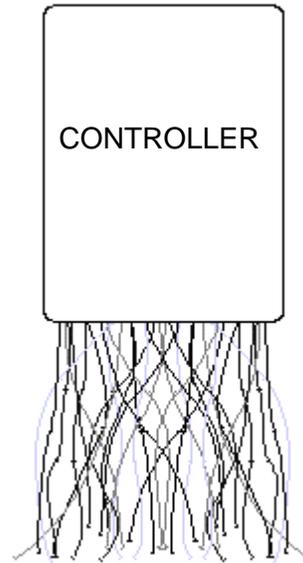


FIGURE 6: CONVENTIONAL WIRING

In a conventionally wired control system, a set of wires goes to each device. Each set of wires carries all of the data for a specific device. Look at the control box above. Go ahead, pick out that faulty wiring for device number 174! **The CAN chip protocol, on the other hand uses a single cable. This single cable carries the communication of all devices and also carries the power for the system. CAN also solves the problem of managing which messages have priority and how to check for—and isolate—errors to protect the system.**

## A CAN-Based System (continued)

Figure 7 below shows how the CAN frame is segmented to determine priorities and isolate errors.

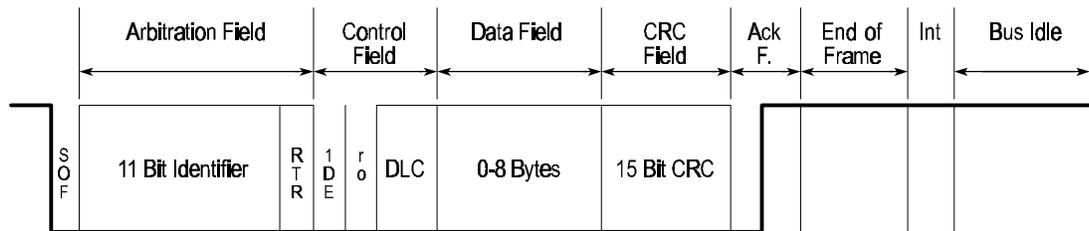


FIGURE 7: CAN FRAME

## The Basics of CAN

Every *intelligent device* on the network contains a CAN chip. This **provides the communication and diagnostic capabilities of the devices**. If you like, you can think of the CAN chip as the brains of the component. It's the CAN chip that makes different devices from different manufacturers speak a common language. In short, it's the CAN chip that makes intelligent devices intelligent.

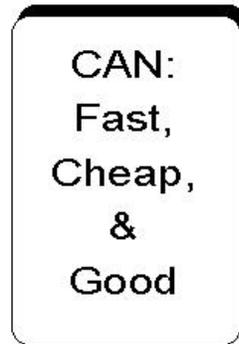


FIGURE 8: THE CAN ADVANTAGE

To identify which CAN chip is on which device, we assign identifiers to each CAN chip on the network. The *Media Access Control Identifier (MAC ID)* is an integer identification value assigned to each node on DeviceNet. This is commonly referred to as either a device **MAC ID** or **Node Address**. No two devices on a network may have the same **MAC ID** assigned to them.

DeviceNet takes advantage of some built in features of the CAN chip. As you just saw, the chips can **prioritize messages and determine which messages have a higher priority and should transmit first**. The CAN chip uses non-destructive bit-wise arbitration to determine who has priority. Once arbitration is determined in the arbitration field (see the diagram above), the losing node stops transmitting and the winning node continues on uninterrupted. The CAN chip also has the ability to monitor and check each message to make sure it issues data in the proper format and with the proper content. These self-diagnostic capabilities spare engineers the task of troubleshooting a few hundred devices when something on the system stops working.

## PLC AND IPC SYSTEMS

Another major feature of DeviceNet is that it gives customers a **choice of controllers**. With DeviceNet, customers can use either an industrial Personal Computer (iPC), or the standard Programmable Logic Controllers (PLC) that have been used in the past.

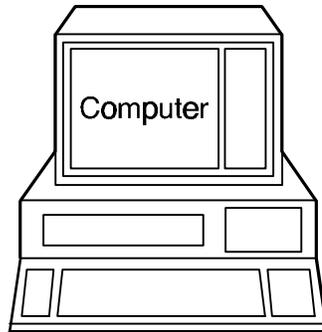


FIGURE 9: IPC

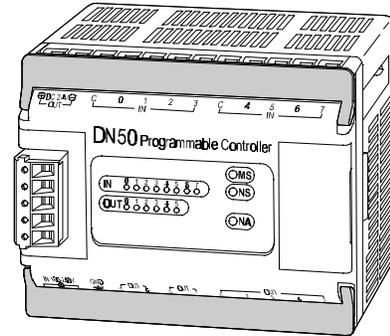


FIGURE 10: PLC

Many factors go into choosing the correct control platform. What follows is a brief comparison of some features and advantages of PLCs and iPCs.

**PLCs** have long been used as small computers specifically geared to a task that is programmed into their code. However, the **PLC code is proprietary** to the company that built it. Therefore, even if the rest of the system is based on Open Architecture, when PLCs are used to store the program that gives direction to the system, that part of the system is not interchangeable with all vendors. Despite this potential disadvantage, PLCs are still useful because of their **reliability, familiarity**, and customer inventory. Furthermore, engineers are comfortable using them. As a result of such factors, DeviceNet has adapted itself to work with these traditional tools of industrial control.

iPCs are very much like an everyday **Windows™ - based PC** that you'd find on a desktop anywhere. **iPCs are built to operate in a manufacturing environment** and can withstand more vibration, heat, *electrical noise*, etc. than your average personal computer. By using iPCs, we can take advantage of Windows functionality and combine several pieces of machinery into one (Operator Interfaces, control software, *Human Machine Interfaces (HMI)*, etc). iPCs also allow the customer a choice of *control editors*, which are easily transportable between different systems and vendors.

## PLC AND IPC SYSTEMS (CONTINUED)

### PLC

- Proven technology
- Existing products in plant
- Plant personnel familiar with product
- Expandable

### IPC

- Greater flexibility
- Wide availability and interchangeability
- Combines control and HMI
- Strength in Dynamic Data Exchange (DDE), communications

## Intelligent Control Devices

These are the devices connected to the network that carry out the normal tasks of prisms, limit switches, photoelectric sensors, proximity sensors, starters, and so on. As you read in the section on CAN, intelligent devices are "intelligent" because they **contain the CAN microprocessor** that enables them to communicate on the DeviceNet system. **Intelligent devices help an engineer to diagnose problems** and make adjustments with the software, instead of "walking the line" to hunt down wire or device errors.



FIGURE 11:  
PHOTOELECTRIC SENSOR



FIGURE 12:  
LIMIT SWITCH



FIGURE 13:  
STARTER

**Software**

The control editor is the software that organizes and controls the network. This may be a Windows™-based program, and can use flowchart code, ladder logic, or any other control language.

You need configuration software to assign each component an address. In addition, software is necessary to display the system on a monitor so people can "look into" the system, see what's happening, and make changes. This software is called the Human Machine Interface, or HMI.

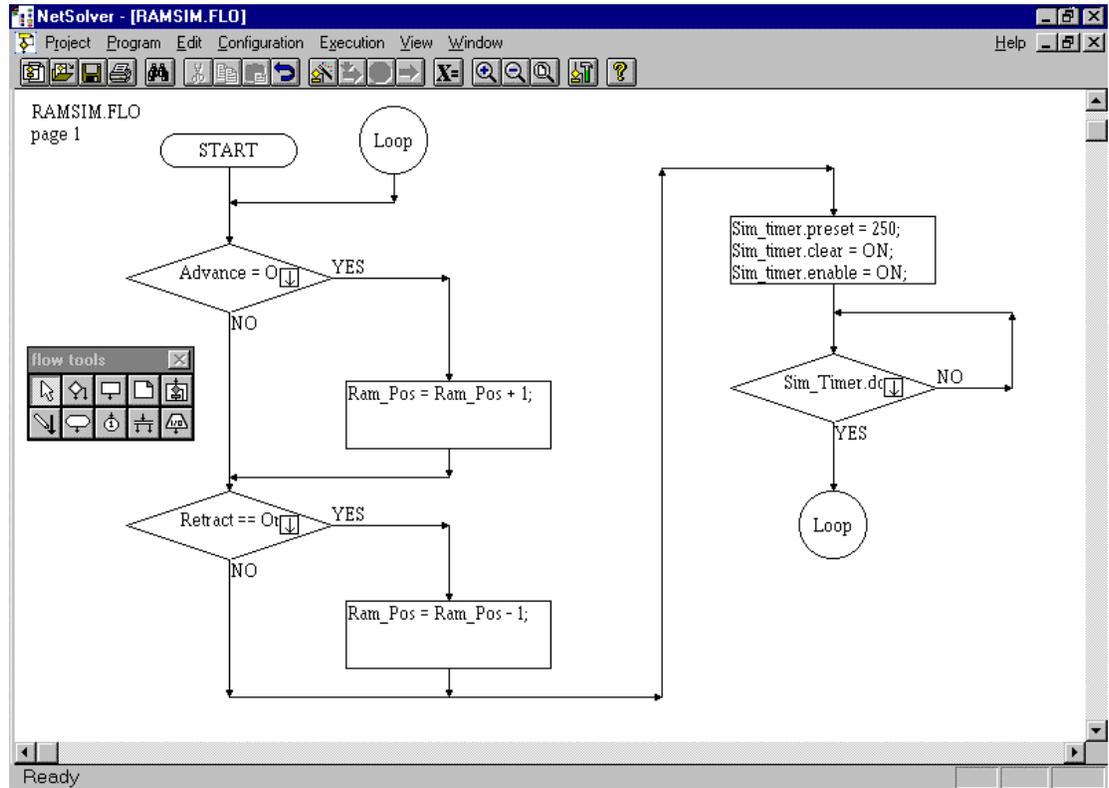


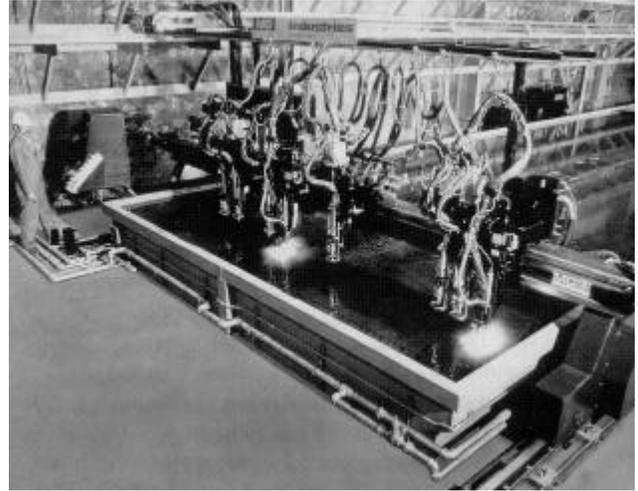
FIGURE 14: A TYPICAL SOFTWARE SCREEN

## DEVICENET IN THE WORKPLACE

Read about this plant for another DeviceNet success story

This thermal machining operation brand-labels components for several companies. Each product run of parts uses a slightly different configuration. On conventional systems, converting the line meant getting out the pliers and screwdriver to change parameters on all the affected devices, or swapping devices altogether. With DeviceNet this engineer simply uses the software to reset devices to accommodate the new parameters.

## IN THE WORKPLACE



**FIGURE 15: THERMAL MACHINING OPERATION  
USING DEVICENET**

REVIEW 2

Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you've just read.

- 1. DeviceNet can be run from two platforms. The first is based on conventional control systems using ladder logic. \_\_\_\_\_ are the core of this form of DeviceNet. Computers similar to desktops PCs everywhere provide the second basic platform. In industrial use, these computers are called \_\_\_\_\_.
- 2. CAN chips can prioritize messages and determine which messages have a higher priority and should transmit first.

TRUE      FALSE

- 3. Name three intelligent control devices.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

- 4. Explain how intelligent devices help reduce time spent troubleshooting problems.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

- 5. What is a Control Editor and what does it do?

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

- 6. Which of the following features are advantages of PLCs and which are advantages of iPCs?

- 1. \_\_\_\_\_ Proven technology
- 2. \_\_\_\_\_ Existing products in plant
- 3. \_\_\_\_\_ Greater flexibility
- 4. \_\_\_\_\_ Combines control and HMI
- 5. \_\_\_\_\_ Plant personnel familiar with product
- 6. \_\_\_\_\_ Strength in Dynamic Data Exchange, communications
- 7. \_\_\_\_\_ Expandable
- 8. \_\_\_\_\_ Wide availability and interchangeability

## THE PHYSICAL MEDIA OF DEVICENET

### Cables

Although a network also consists of its protocol and software, the word "network" often conjures up the image of the snakelike cabling that spreads throughout the system to physically link every device. Let's begin with the cables before showing how products connect to the system.

Information is carried back and forth across the network along a cable. The cable can be strung together in any configuration, but it is typically set up with a **trunk and dropline** layout. This means the main cable can either connect directly to devices along the way, or have a group of devices attach to a secondary cable, which then taps into the main cable.

The two cables that work together to connect a DeviceNet system are called **thick cable**, which is roughly  $\frac{1}{2}$ " in diameter, and **thin cable**, which is roughly  $\frac{1}{4}$ " in diameter. You can use either cable to connect a system; however the thick cable is typically used as the main cable (or *trunk line*), since it carries more amperage and can usefully extend for longer distances. The thin cable usually is a secondary cable, the *drop line*, connecting a group of devices up to the trunk line.

A typical cable configuration looks like this, with the line at the top handled by the thick cable and each drop made of thin cable:

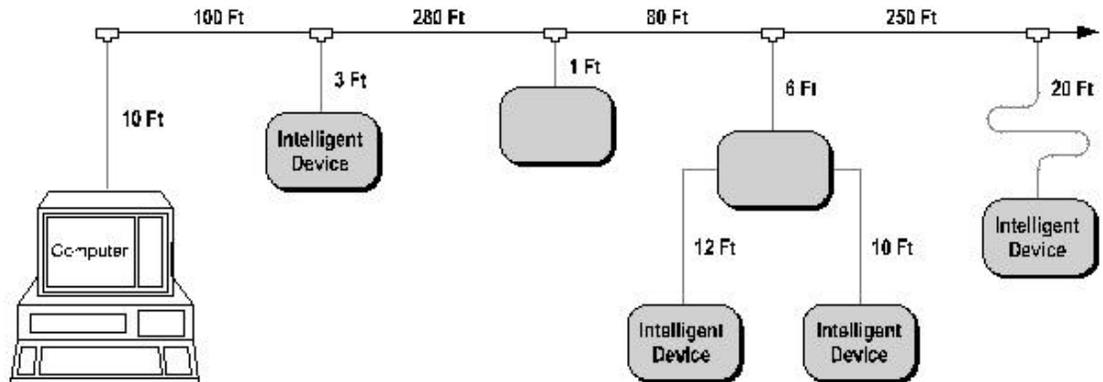


FIGURE 16: TYPICAL CABLE CONFIGURATION

- Thick cable is 0.48" in diameter and carries up to **8 amps**
- Thin cable is 0.26" in diameter and carries up to **3 amps**

## Cables (continued)

Below is a cross-section of the thin DeviceNet cable (the only physical difference between thick and thin cable is their diameter). The outer jacket provides a high degree of **turning flexibility** to wind around equipment corners. The power is a safe **24 Volts**, and you can see from the temperature range that DeviceNet functions under almost any working condition.

- 5 wire design: 1 drain, 2 communication, 2 power cables
- 24 volt wire
- Mylar (AL/MY) insulation on power and communication pairs
- Industrial temperature range = -40°C to +80°C @ 8 Amp
- PVC Jacket

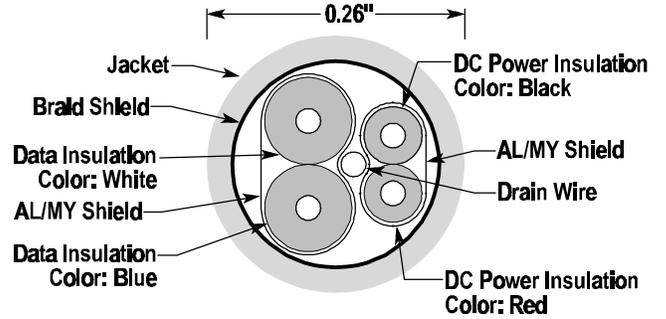


FIGURE 17: CROSS SECTION OF THIN CABLE

## Connecting Devices to the Cable

After laying out the main trunk of the cable, you connect devices and drop lines. **Connectors** typically connect control devices to drop lines or Input/Output ( I/O) blocks. **Device taps** typically connect groups of devices to a cable, or splices one cable into another (i.e., where the dropline meets the trunk). The system also has some built-in protective features. Most vendors also have designed **in-wiring protection** on their devices. This protects a device even if you apply the 24 VDC power to the communication line. Now, if you try applying 120 VAC to the system, it will still have some very undesirable effects!

Below are illustrations of various connectors and taps, along with explanations of when to use them.

### Screw Connectors

A screw connector is the most economical way to connect a device to the line. Control, power, and ground wires from a device insert under the clamps, which are pinned down by the screws on top.

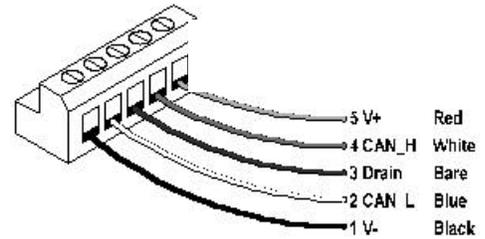


FIGURE 18: SCREW CONNECTORS

This connector is for environments that are dry and free of air-borne contaminants such as sawdust or metal filings.

### Sealed Connectors (Mini style)

A sealed connector installs quickly to save labor costs. It also protects the connection from splashed water, debris, and wind-blown contaminants. A micro style is available for small devices.

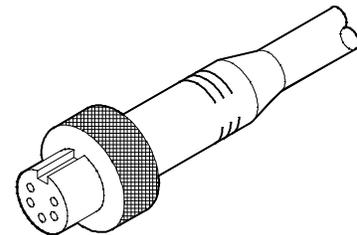
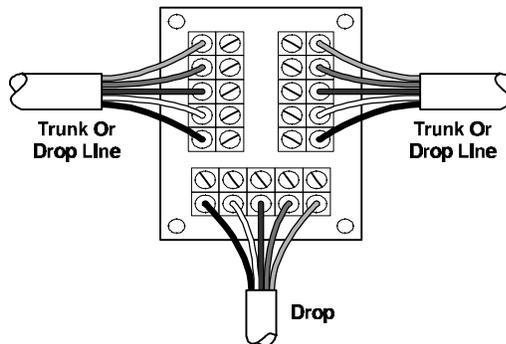


FIGURE 19: SEALED CONNECTORS

### Device Taps

Both open and sealed versions attach branches or devices to the trunk without disrupting network operations.



Open Tap With Drop Line (Up To 6 m/20 ft.)

FIGURE 20: OPEN DEVICE TAP

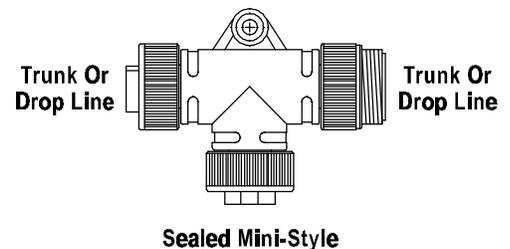


FIGURE 21: SEALED DEVICE TAP

**BUILDING A DEVICENET SYSTEM**

**Computer/PLC**

Now that you have a basic understanding of DeviceNet cabling, here is a walk-through of building a system.

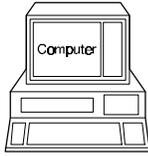


FIGURE 22: COMPUTER/PLC

Either a computer or a PLC can be the controller of DeviceNet. Computers have a monitor for the Human Machine Interface, as well as hard drive capacity for data collection and storage.

PLCs typically are programmed and then left to run unattended. They do not have a monitor or hard drive, although these can be added.

**Network Scanner Card**

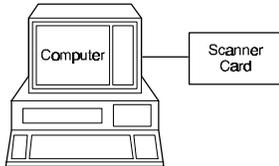


FIGURE 23: NETWORK SCANNER CARD

The scanner card physically connects the DeviceNet cable to the computer or PLC. It transmits and receives messages from the devices and stores the information in memory. Each computer can have as many scanner cards as it has slots available. Each card is a separate DeviceNet network.

**Cabling**

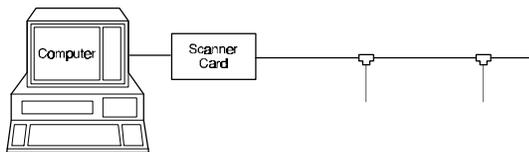


FIGURE 24: CABLING

Cabling comes in two sizes, thick and thin. Both contain two shielded, twisted pairs (power transmission, communication) and a ground wire. Cabling replaces the wiring used by traditional systems and provides both the communication path and the power to devices. It thus reduces install time and allows for easy expansion or additions.

**Connectors**

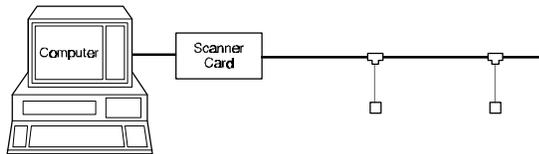


FIGURE 25: CONNECTORS

Connectors come in several varieties, including open and closed versions. The connectors string the main cable together and allow for individual or multi-port node hookups.

**Intelligent Network Devices**

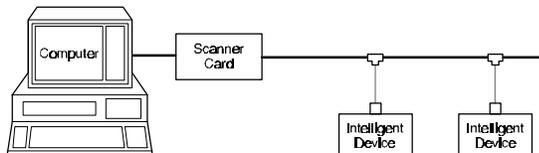


FIGURE 26: INTELLIGENT NETWORK DEVICES

64 intelligent devices can be attached to each DeviceNet system. They can communicate with each other regardless of which vendor produced them.

Intelligent devices allow transmission of diagnostic information on both the devices and equipment they may be running (for example, motors, pumps, etc.).

**Standard Devices**

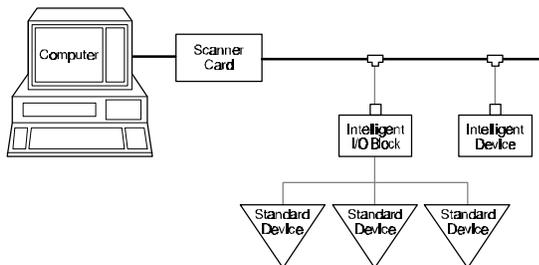


FIGURE 27: STANDARD DEVICES

Using an "intelligent" interface block allows you to add many *standard devices* to the system. These devices are the same as you are currently using. They would be used when no diagnostics are required.

## GENERAL CHARACTERISTICS OF DEVICENET

### Communication Rates and Distances

Now let's look at some general characteristics and properties of DeviceNet. We'll begin by glancing at communication rates and system lengths.

Because the CAN chip was designed to operate at a variety of speed, end users can also choose to use DeviceNet at different speeds. We measure the rate of communication in number of bits (counted in 1000s) per second (KPS or K *baud*). The rate of communication depends on the length of the system cable.

**The shorter the system, the faster DeviceNet can communicate.** DeviceNet has **three rates of speed** corresponding to the different lengths of systems: **125, 250, and 500 kbaud**. In metric terms, the cable lengths are easy to remember: **500 meters, 250 meters, and 100 meters** respectively if you are using thick cable for the entire trunk. The English measurement equivalents are shown in the table on the next page. The graph on the next page shows how speeds vary according to the length of thick and thin cables used in the system.

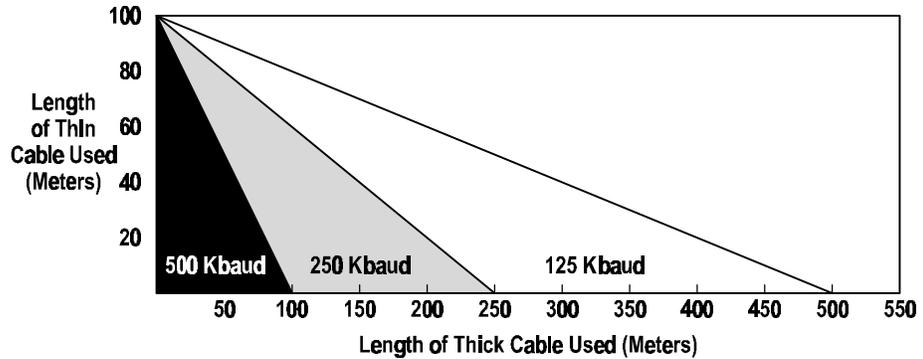


FIGURE 28: THE SHORTER THE SYSTEM, THE FASTER DEVICENET CAN COMMUNICATE

**Maximum Distances**

Maintaining the desired communication speed also involves two additional rules for the trunk and dropline configuration:

- **Maximum individual drop:** the longest length that any one secondary cable can have
- **Cumulative drop:** the total length of all the secondary cables

The following table summarizes the distance versus speed parameters. Notice that all distances and speeds can still have 64 nodes on the line. It's also worth remembering that a system is only as fast as its slowest component.

<b>Data Rates</b>	<b>125 kbaud</b>	<b>250 kbaud</b>	<b>500 kbaud</b>
Number of nodes	64	64	64
Thick cable distance	1640 ft (500 meters)	656 ft (200 meters)	328 ft (100 meters)
Thin cable distance	328 ft (100 meters)	328 ft (100 meters)	328 ft (100 meters)
Maximum individual drop	20 ft (6 meters)	20 ft (6 meters)	20 ft (6 meters)
Cumulative drop	512 ft (156 meters)	256 ft (78 meters)	128 ft (39 meters)

FIGURE 29: DATA RATES AND DISTANCES

**UL Ratings**

The physical media can have a UL rating from 300-600 Volts. The rating that you need will be determined by the demands of the particular application, where you install the cable on the plant floor, what electrical and environmental conditions exist, and what work is being performed.

## Node Count

**A node is a junction, or a collection point, on a network.** It may refer to a single device, i.e., a particular limit switch. A node could also be a group of devices wired to a terminal block of inputs and outputs—a **block I/O**. A block I/O relays the information from the devices connected to it from a single node address. There are some limits to the combinations of block I/O that can be on the network. DeviceNet can support a minimum of 64 nodes, and up to three or four times that number of objects, depending on the configuration.

Here is a node connecting devices to the trunk:

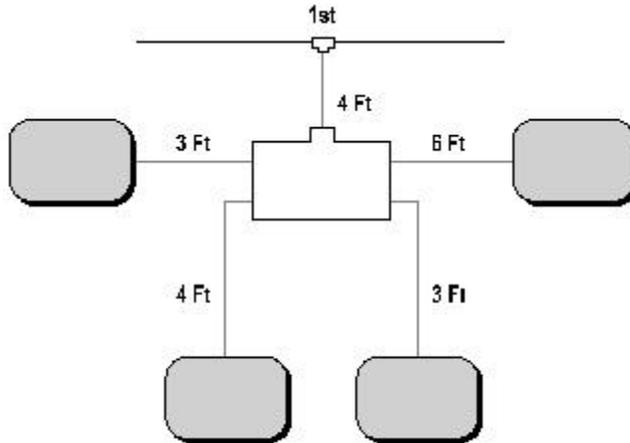


FIGURE 30: NODE CONNECTING DEVICES TO TRUNK

**Terminating Resistors**

Most current communication networks use terminating resistors **for impedance matching along communication lines**. This is true of older systems (such as Data Highway and Data Highway Plus), as well as of newer network communication systems (such as DeviceNet, Interbus-S, and Profibus DP). Without terminating resistors, there would be so much noise and interference on the line that it could shut down the control system.

**DeviceNet requires two terminating resistors on its network**, one on each end of the trunk. The resistors are:

- 121 Ohm
- 1% Metal Film
- 1/4 Watt

The illustrations below show some examples of correctly and incorrectly installed resistors.

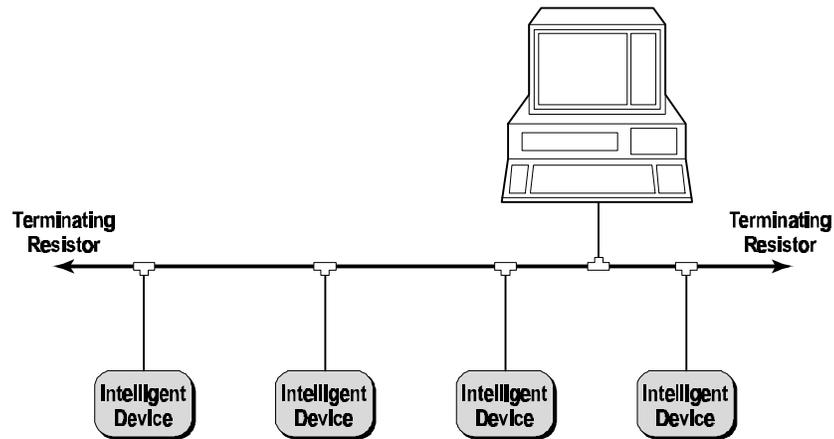


FIGURE 31: TERMINATING RESISTORS ARE REQUIRED AT EACH END OF THE TRUNK

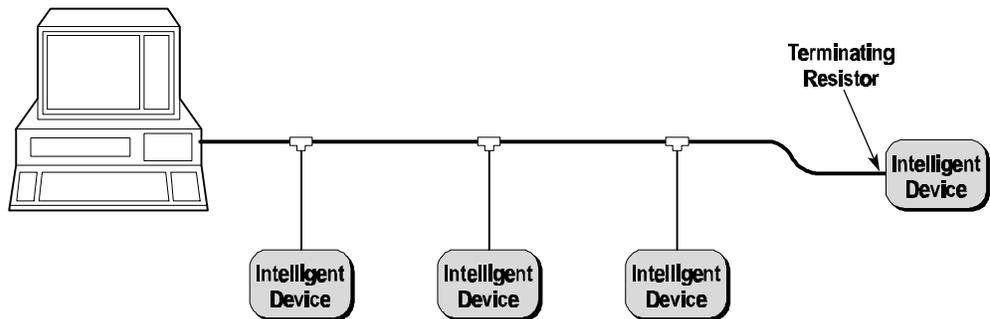


FIGURE 32: THE RESISTORS MUST BE ATTACHED TO THE LONGEST LENGTH OF CABLE

Terminating Resistors  
(continued)

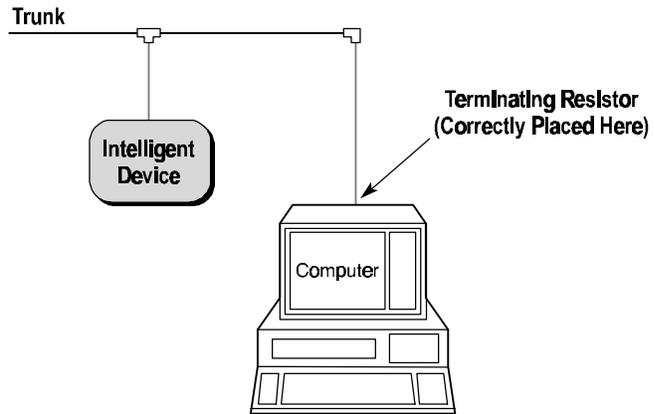
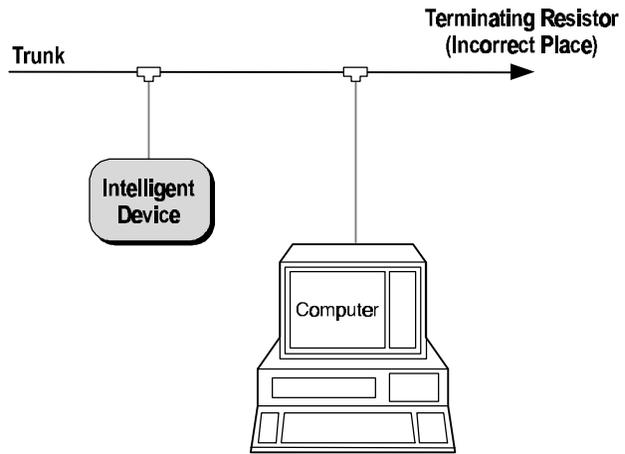


FIGURE 33: IF A DROP COMPLETES THE LONGEST LENGTH OF CABLE, THE RESISTOR IS ATTACHED THERE

**STANDARDS**

As a way of standardizing enclosure performance, groups like National Electrical Manufacturers Association (*NEMA*) and **International Standard (IP)** have created rating systems to identify a product’s ability to withstand outside environmental forces. Here is a list of standards that cables and sealed connectors in DeviceNet should conform to:

NEMA	1, 3, 4, 6, and 13
IP	67

These NEMA enclosure standards are applied to cables and sealed connectors:

Type Designation	NEMA Definition
1	Enclosures are intended for indoor use, primarily to provide a degree of protection against contact with the enclosed equipment or locations where unusual service conditions do not exist.
3	Enclosures are intended for outdoor use, primarily to provide a degree of protection against windblown dust, rain, and sleet; undamaged by the formation of ice on the enclosure.
4	Enclosures are intended for indoor or outdoor use, primarily to provide a degree of protection against windblown dust and rain, splashing water, and hose-directed water; undamaged by the formation of ice on the enclosure.
6	Enclosures are intended for use indoors or outdoors where occasional submersion is encountered.
13	Enclosures are intended for indoor use, primarily to provide a degree of protection against dust, spraying of water, oil, and non-corrosive coolant.

International Standard’s IP Protection Classification:

FIRST NUMERAL		SECOND NUMERAL	
<i>IP</i>	<i>Definition</i>	<i>IP</i>	<i>Definition</i>
6	Totally protected against ingress of dust.	7	Protected against the effects of immersion between 15 cm and 1 m.

## POWER SUPPLIES

DeviceNet allows you to use **both single and multiple power supplies**, and supplies **much greater current to devices** than do comparable networks. By using off-the-shelf power supplies, DeviceNet also guarantees a wide accessibility of parts at a reasonable cost. Here are some details regarding the carrying capacity of the DeviceNet cabling system:

- Single supply current capacity of up to 16 total Amps continuous (thick trunk)
- Up to 8 Amps available to a device located near a power supply

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**Note:** In the United States and Canada, current is limited to a maximum of 4 Amps continuous by NEC and CECODE. If a cable is placed in a conduit, this limit can be increased to 8 Amps.

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- Up to 3 Amps available if a dropline is used
- Continuous power bus (not segmented) when using multiple power supplies. This means all devices can use power from any supply on the line, instead of being limited to a specified power supply.
- DeviceNet system is **optically isolated** from devices. This protection shields the system from the destructive effects of an over-voltage or over-current (short circuit) taking place at a device (okay, who dropped that limit switch into a bucket of water?)

Power supplies can be arranged in a variety of ways. Any arrangement is feasible that meets all current limits on the system and is able to supply sufficient power to all devices.

**PRODUCTS FOR DEVICENET**

We've already mentioned some of the devices that function on DeviceNet: photoelectric sensors, limit switches, and starters. You can add motion control devices, valve manifolds, Resistance Temperature Detectors (RTDs) and hundreds of other products. Essentially, the control products that are used to automate machine control applications are still used, only they have the CAN chip inside to make them "intelligent." DeviceNet is not giving up on standard devices. They can be installed on the network and used to their full capacity utilizing intelligent Block I/O.

A wide variety of intelligent products are available for DeviceNet through ODVA members. These products include, but are not limited to:

- |                                |                        |
|--------------------------------|------------------------|
| Industrial Personal Computers  | Bar Code Readers       |
| Programmable Logic Controllers | Scanner Cards          |
| Operator Interface Stations    | Valve Manifolds        |
| Motor Starters                 | Photoelectric Sensors  |
| Drives (AC and DC)             | Limit Switches         |
| Servos                         | Proximity Switches     |
| Block I/O                      | Motion Control Devices |
| Push Buttons                   | Analog I/O Devices     |
| RTDS                           | Gateways               |

**Enhanced Performance of DeviceNet Products Over Conventional Products**

By examining the benefits offered by individual products, you can begin to estimate the advantages of intelligent control compounded over hundreds or thousands of devices in a plant. In addition to the advantages you'll see outlined in the tables below, the customer also makes large savings on installation and program debugging.

The following tables allow you to see a sampling of the advantages intelligent control by examining the benefits of using individual products on DeviceNet.

**Photoelectric Sensor**

Conventional Use	DeviceNet Use
Change gain: manual	Change gain: via network command
	Monitors for alignment/dirty lens
Light/Dark operating change: manual	Light/Dark operating change: via network command
To replace: requires wiring	To replace: swap device via quick disconnect
To test: manual check	To test: force state via network
	Diagnostics available

## DEVICENET

### Tubular Inductive Proximity Sensor

Conventional Use	DeviceNet Use
Light/Dark operating change: manual	Light/Dark operating change: via network command
Provides latching short-circuit protection	Target too near/too far
No diagnostics available	Stray metal detection
	<i>On-delay, Off-delay</i> , one shot timing functions programmable via network
	To replace: swap device via quick disconnect
To test: manual check	To test: force state via network
	To identify: visual indication of node address

### Limit-Switch Style Photoelectric/ Proximity Sensor

Conventional Use	DeviceNet Use
Wide variety of standard sensing heads available for use	Wide variety of standard sensing heads available for use
Light/Dark operating change: manual	Light/Dark operating change: via network command
No diagnostics available	NOVRAM writes exceeded, power interruption notification
Limited time delay functionality	<i>On-delay, Off-delay</i> , one shot timing functions programmable via network
To replace: requires wiring	To replace: swap device via quick disconnect
To test: manual check	To test: force state via network
	To identify: visual indication of node address

### Limit Switch Sensor

Conventional Use	DeviceNet Use
Wide variety of standard sensing heads available for use	Wide variety of standard sensing heads available for use
No diagnostics available	Diagnostics for end of life prediction, NOVRAM writes exceeded, power interruption notification
Limited time delay functionality	<i>On-delay, Off-delay</i> , one shot timing functions programmable via network
To replace: requires wiring	To replace: swap device via quick disconnect
To test: manual check	To test: force state via network
To identify: manual check	To identify: visual indication of node address

## DEVICENET

### I/O Blocks

Conventional Use	DeviceNet Use
N.A.	Reduced wiring requirements
	Diagnostics available to the node level and limited diagnostics to the device level
	Ability to be used as a power supply
	To identify: visual indication of node address
	Indicates condition of individual I/O points

### Starters

Conventional Use	DeviceNet Use
Wiring includes 2 PLC inputs/outputs	Wiring includes a DeviceNet node
Setup requires install heaters or Dial/DIP switches	Setup uses download set points
20 - 40 starters needed to cover 1 - 50 hp IEC	10 starters cover 1 - 50 hp IEC
Mounting: large control cabinet plus disconnect at motor	Mounting: small enclosed control at motor
Diagnostics limited to on/off and overload trip	Diagnostics include on/off and overload trip, plus ground fault, phase unbalance, phase loss, jam trip, motor current and percent of thermal loading
Motor protection (Bimetal/ Eutectic) limited to overload, phase loss, and trip class 10 or 20	Motor protection (Electronic) includes overload and phase loss, plus phase unbalance, jam, ground fault, and provides a custom trip class of 10 - 60
Configuration with hand-held programmer	Configuration with hand-held programmer or over network

REVIEW 3

Answer the following questions without referring to the material just presented.

- 1. DeviceNet operates on a 24 V system. Thick cable can deliver a maximum of \_\_\_\_\_ amps; thin cable a maximum of \_\_\_\_\_ amps.
- 2. In the trunk and dropline cable configuration, what is the typical role of the dropline?

\_\_\_\_\_

\_\_\_\_\_

- 3. DeviceNet only allows you to use single power supplies.

TRUE    FALSE

- 4. How many rates of speed does DeviceNet have? List the lengths in meters of the systems to which they correspond.

\_\_\_\_\_

\_\_\_\_\_

- 5. Match up these starters with their definitions.

- |                         |  |
|-------------------------|--|
| 1. conventional starter | A. Motor protection: (Electronic) includes overload and phase loss, phase unbalance, jam, ground fault, and provides a trip class of 10 - 60 |
| 2. DeviceNet starter    | B. Motor protection: (Bimetal/ Eutectic) includes overload and phase loss, and provides a trip class 10 or 20                                |

- 6. List four types of products currently available for use on DeviceNet.

- a) \_\_\_\_\_
- b) \_\_\_\_\_
- c) \_\_\_\_\_
- d) \_\_\_\_\_

- 7. Identify a market benefit that is **not** associated with DeviceNet:

- 1. Replaces complex wire harnesses with single cables.
- 2. Uses an inexpensive, widely available communications protocol (CAN)
- 3. Operates reliably in harsh environments
- 4. Allows inter-operable components to install on the system, while its under power ("hot insertion")
- 5. Operates process-level control to link campus-wide fire safety facilities
- 6. Provides self-diagnostics

**GLOSSARY**

<b>Actuator</b>	Mechanism of the switch or switch enclosure which operates the contacts.
<b>Baud</b>	A measure of communication speed. Defined as bit/second.
<b>Bit</b>	A single unit of memory (i.e., 0 or 1). See Byte.
<b>Byte</b>	A unit of memory storing 8 adjacent bits, and defining one alphanumeric character.
<b>Control Editor</b>	The software that organizes and controls the network. This may be a Windows based program, and can use flowchart code, ladder logic, or any other control language.
<b>Controller Area Network (CAN)</b>	A communications protocol specification that defines: (1) A media access control methodology, and (2) Physical signaling. CAN is a broadcast-oriented protocol. CAN frames transmitted on the network are assigned an identifier, and each station decides, based on this identifier, whether or not it receives the frame.
<b>Drop Line</b>	Cable attaching a device to the trunk cable of a DeviceNet system. Must be a thin cable.
<b>Dynamic Data Exchange (DDE)</b>	A communication protocol that allows different software to packages to pass information back and forth.
<b>Electrical Noise</b>	Noise results from the presence of undesirable electrical voltages or current. It causes devices to operate erratically (if the noise is on the supply line to a device), or produces false information or erratic operation (if present on wires carrying signals from the output of a device to the load). Noise can be present in the supply or picked up on lines in many ways. Pick-up from noisy adjacent wires or metal parts is possible. Good wiring practice and/or additional parts can be used to diminish the effects of noise.
<b>Human Machine Interface (HMI)</b>	Software package that uses a graphical interface to allow an operator to control a machine or operation.
<b>Industrial Personal Computer (iPC)</b>	Computer specifically designed to handle harsh environments but still give all the features of a standard PC.
<b>Intelligent Device</b>	Device that is able to transmit a higher level of information about its condition (i.e., diagnostics), and react to received information in an advanced manner (i.e., change via network command).
<b>Limit Switch</b>	Contact sensors used for detecting the presence or position of objects.

<b>Media Access Control Identifier (MAC ID)</b>	An integer identification value assigned to each node on DeviceNet. This is commonly referred to as either a device MAC ID or Node Address. No two devices on a network may have the same MAC ID assigned to them.
<b>NEC</b>	National Electrical Code.
<b>NEMA</b>	National Electrical Manufacturers Association.
<b>Node</b>	A junction, or a collection point, on a network. It may refer to a single device, i.e., a particular limit switch. A node could also be a group of devices wired to a terminal block of inputs and outputs—a block I/O.
<b>ODVA, Open DeviceNet Vendor Association</b>	Open DeviceNet Vendor Association. ODVA is an independent association made up of hardware and software vendors, and customers, whose purpose is to develop and foster standards for devices, software, and a network for byte level (machine control) communications.
<b>Off Delay Logic</b>	Adjustable delay (after input signal stops) before output is de-energized.
<b>On Delay Logic</b>	Adjustable delay (after onset of input signal) before output is energized.
<b>Open Architecture</b>	Refers to the ability of any vendor to produce products that can communicate freely on a published standard.
<b>Photoelectric Sensor</b>	Non-contact sensor used for detecting the presence or absence of objects. It is turned on or off by the presence or absence of received light.
<b>Programmable Logic Controller (PLC)</b>	The PLC is the dominant tool for plant-floor control, monitoring, and sequencing of events involving input devices and output devices. Built around a micro-processor, it is designed specifically for control.
<b>Proximity Sensor</b>	A sensor with the ability to detect the presence of a metal-only target, within a specified range, and without making physical contact.
<b>Relay Circuits</b>	Devices often used in control. Can be opened and closed electronically to complete logic circuits.
<b>Sensor</b>	A sensing element. The basic element that usually changes some physical parameter to an electrical signal.
<b>Special Interest Group</b>	Special Interest Groups (SIGs) are formed by two or more members with a common interest or product line, for the purpose of setting and advancing standards. The Open DeviceNet Vendor Association offers numerous SIGs to join.

<b>Standard Device</b>	Device on a network that does not convey advanced information about its status over the network, or react to a received command in an advanced manner. In general terms, other than On/Off, standard devices must be inspected manually and have their status changed manually.
<b>Starter</b>	A control device usually consisting of a contact and overload. With DeviceNet, it will also contain a communication module used for starting and stopping loads.
<b>Trunk Line</b>	The main line of communication for a DeviceNet system. It can be either thick or thin cable.
<b>UL-Underwriter's Laboratories, Inc.</b>	A non-profit organization that establishes, maintains and operates laboratories for the examination and testing of devices, systems and materials, primarily for safety.

### REVIEW 1 ANSWERS

1. Reduced set-up and installation times  
Lower maintenance costs  
Reduced downtime  
Eliminates need for separate controllers for many applications
2. C
3. C
4. Membership is open and the organization insures that DeviceNet is not controlled by any one company
5. Specifications
6. Any three of the following:  
Users can choose the best devices for their system  
Products are more widely available  
Products are less expensive  
Devices are interchangeable  
A single communication network interfaces plant-floor devices, sensors and actuators

### REVIEW 2 ANSWERS

1. PLCs, iPCs
2. True
3. Any three of the following:  
Photoelectric sensor  
Limit Switch  
Starter  
Proximity sensor  
Prism
4. Answer should basically say “They help engineers diagnose problems and make adjustments to the software without having to “walk the line” to find the problem.”
5. Answer should basically say “The control editor is the software that organizes and controls the network.”
6. PLC – 1, 2, 5, 7  
iPC – 3, 4, 6, 8

**REVIEW 3  
ANSWERS**

1. 8, 3
2. Answer should basically say "The dropline is typically a secondary cable that connects a group of devices up to the trunk line."
3. False
4. Answer should basically say "DeviceNet has three rates of speed. The lengths in meters of the systems to which they correspond are 125, 250, and 500."
5. 1B, 2A
6. Any four of the following:
  - Industrial Personal Computers
  - Programmable Logic Controllers
  - Operator Interface Stations
  - Motor Starters
  - Drives (AC and DC)
  - Servos
  - Block I/O
  - Push Buttons
  - RTDS
  - Bar Code Readers
  - Scanner Cards
  - Valve Manifolds
  - Photoelectric Sensors
  - Limit Switches
  - Proximity Switches
  - Motion Control Devices
  - Analog I/O Devices
  - Gateways

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Note: Instructor should supplement the above list with Cutler Hammer's current list of available DeviceNet products

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7. Item #5

## Cutler-Hammer

Milwaukee, Wisconsin U.S.A.

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