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Using DeviceNet in the Trailer Industry ©

Abstract

This paper will discuss the effect that the requirement for Antilock Braking Systems (ABS) is having on the trailer electrical system. The trailer's electrical system will require an update and multiplexing is one of the possible solutions being considered by the industry. Vehicle multiplexing and the need for a prototype system will be discussed. Finally, the selection of DeviceNet and the advantages it provided us, along with, a description of the prototype system and how it was demonstrated as a sales and engineering tool will be given

Introduction

With materials such as high strength steel, aluminum extrusions, and even composites -- the Semi-Trailer industry has made considerable strides made from a mechanical standpoint. Until now, however, the electrical side of trailer design has not seen much in the way of advancements.

In March of 1998 the U.S. Federal Government will require that trailers have Anti-lock Brake Systems (ABS) as a standard feature[1]. This, coupled with a growing need of transportation companies to know more information about their customer's cargo while in transit, is stimulating a major advancement in the trailer electrical system. While ABS will be required by the Government, information about the status of the cargo and the vehicle that is transporting it will be a requirement for companies who want to stay competitive in the next century. In this era of "customer service," transportation companies are now realizing that the cargo is the most important part of the equation, not the vehicle. From a vehicle standpoint the semi-tractor is an expensive asset, but the trailer is what actually houses the cargo. Therefore the trailer is quickly becoming equally as important as the tractor. The trailer's electrical system is made up of three major components: a front connector, wire harnesses and lights. The front connector, designated J560 by the Society of Automotive Engineers (SAE), houses seven conductors, a ground wire and six switchable power wires (see Figure 1)[2].

The six power wire functions are:

1. Brake lights
2. Left turn lights
3. Right turn lights
4. Upper marker lights
5. Lower marker lights
6. Auxiliary circuit.

The auxiliary circuit is available for customers who require additional power an accessory, such as interior dome lighting or an electrically controlled air valve, as examples.

Because ABS requires power to function, it will receive full time power from the auxiliary circuit and part time power from the braking circuit. Also, there is a requirement that takes affect in March of 2001 that states that there must be feedback from the ABS unit to the driver in the cab of the tractor in the case of an ABS fault or failure[3]. This requirement of the feedback circuit is what is primarily driving the development of an updated electrical system.

Wiring for ABS

The trailer electrical system is designed satisfactorily for the addition of ABS, until the year 2001 when the fault warning system must go into effect. Simple math will show that the current system has run out of conductors and has no means in which to send a signal back to the driver warning him or her that there is a problem with the trailer ABS. The simple solution would be to add a second 7-conductor connector that would satisfy the needs of the ABS system and allow for future expansion.

This solution, of adding another connector, has already been adopted by the Tractor Trailer Manufactures Association (TTMA) and will go into effect unless a better solution is found[4]. This second connector solution could wind up being a temporary fix however, if it used like the current connector to just switch circuits. Besides the addition of the second connector, the other viable solution being considered is multiplexing.

Multiplexing

A simple way to describe multiplexing is, that it is like the serial port on a computer where data is sent in strings via two wires. While the current and additional connector solution are like the parallel port on a computer, where data is transmitted by multiple lines turning on and off. Multiplexing offers many advantages as a vehicle electrical network but also has a couple disadvantages. Because multiplexing sends data serially, it isn't conductor limited, unlike the two connector solution. Multiplexing allows for communication of control as well as diagnostic signals, forward and backward. It also allows for expansion in steps, because adding a device is just a matter of hooking it up to an open connection on the network and assigning it some basic information. Another advantage to multiplexing is that it supports complex as well as simple devices. The biggest disadvantage in the trailer industry would be the cost of the network. Even with the above advantages it will be difficult to justify the cost. Another disadvantage would be the type of physical media necessary to run the network. This industry does not have much experience with shielded cables and specialized connectors. Even with the obvious disadvantages the potential for multiplexing is very exciting.

Multiplexing in a vehicle isn't something new, there are several protocols that are used by U.S. and European automobile manufacturers. In the 1980's Bosch developed the Controller Area Network (CAN) protocol for the European market[5]. The CAN protocol is the basis for many multiplexing systems including the SAE J1939 specification. CAN based systems are starting to be used in automobiles produced in the United States. They are being considered for the heavy vehicle market as well!

As mentioned before, one of the three major components on the trailer is the lighting system. Lighting alone does not justify the use of a multiplexing system. The addition of ABS on the trailer and the need for feedback helps justify a system. Transportation companies are now becoming interested in as much information necessary to ensure that the cargo gets from point A to point B without any problems. Sensors that can sense presence, pressure, and temperature, are increasingly finding their way into discussions on the trailer of the future. Devices that can prevent breakdowns such as tire monitoring systems and that can increase driving efficiency such as on the move weight monitors are being developed currently. These devices are fairly complex and would be a natural fit for a vehicle network.

As we discussed what the trailer of the future might be with our customers and vendors it became clear that we needed a prototype of a multiplexing system. Because we are an automotive-like industry it seemed natural to try and use products that would incorporate the SAE J1939 specification. This is easier said than done because products with a J1939 interface are limited and mostly used in vehicles that incorporate engines and transmissions. After investigating what it would take to put together a prototype J1939 system, it was decided at the time that it would be too costly and time consuming. Almost every part would be custom built and would have extremely long lead times. We wanted to put together a system quickly so that we could discuss the system and get feedback. And because we were not sure that this technology would be embraced, we didn't want to spend a great deal of money to develop it.

What we needed was a "turn key" type of system that would allow use to use the types of inputs and outputs that would be incorporated into the trailer of the future but still operate similar to the J1939 specification. The obvious benefits to a "turn-key" or off-the-shelf type of system is that it has already been developed and the products are reasonable in cost. With that in mind, we attended a seminar at a local supplier that was presenting a relatively new industrial multiplexing network, DeviceNet. In that seminar and through several meetings with this manufacturer we learned that DeviceNet was based on the CAN protocol. We also got familiarized with the types of products available for DeviceNet from this manufacturer and how they might be used to build a prototype system.

The DeviceNet System

The next step was to design the prototype; what it should look like and what functions should be included. Because this prototype was going to be both an engineering and sales tool, it had to be functional as well as attractive. The prototype had to include the basics, i.e. the lighting system, as well as demonstrate advanced features.

One of the simplest, but most effective, features we wanted to demonstrate was that the entire electrical system of the trailer could be operated with five wires:

1. CAN high
2. Can low
3. +Power
4. -Power
5. Shield

Once the prototype was built there were actually seven wires because the network power conductors were used solely to power network devices not external outputs. Even with the additional two wires we were still able to demonstrate that the system could work within the limits of the current trailer system. Meaning we could run this multiplexing system, theoretically, using a seven conductor connection like that which is currently used. Another important feature that we wanted to demonstrate is the diagnostic feedback that DeviceNet was capable of offering. Therefore, on one of the lights we used an I/O card that had current load sensing that would turn a bit on when an output was on but no current was being drawn, i.e. a bad filament. This was an important feature because it showed that the multiplexing system adds value to the vehicle. Another important feature was the ability to add devices to the network easily. So open connections where designed into the prototype that allowed additional devices to be connected during a demonstration. This is another value-added feature that shows that the system isn't limited once installed. The wide range of devices that could be used with DeviceNet was also an important feature. With DeviceNet we could demonstrate simple I/O as well as complex devices like pneumatic valves, bar code scanners, analog sensors, just to name a few. In our particular application the most advanced device we used was a pneumatic valve.

The DeviceNet system was set up on a 30" x 48" rectangular Lexan panel mounted vertically and framed with Bosch aluminum extrusion. The display has horizontal legs that allows it to stand up on a workbench or a conference room table, and handles so that it can be transported easily. The system runs on 120 volts AC so that it can work anywhere inside a building, it could have been set up to run off of 24 volts DC but we didn't want to use batteries.

On one side of the panel there is the outline of a tractor and trailer in an isometric style view (see Figure 2). An operator display panel and five switches are mounted in the area of the tractor outline. The switches simulate the functions that are normally controlled by the driver, such as turn signals and braking. The alphanumeric operator display panel is an added feature so that we can print out feedback for the driver. Some tractor manufacturers are incorporating alphanumeric display panels into their vehicles already! Also in the area of the tractor, the network's trunkline cable comes out of the front of panel and plugs into a panel mounted connector located inside the trailer's outline. This shows the electrical link between the tractor and the trailer, it is also a place on the prototype where we can disconnect the network's trunkline to show that the system is operating with five conductors. Inside the trailer's outline are eleven lights. The lights are:

1. The front upper clearance light
2. The roadside mid turn light
3. The lower roadside rear lower clearance light
4. The roadside rear turn light
5. The roadside rear brake light
6. The upper rear clearance lights
7. The license plate light
8. The curbside rear brake light
9. The curbside rear turn light (see Figure 3)

There are three more lights located on the curbside of an actual trailer but are not included in the prototype because that side of the trailer isn't shown. The roadside rear turn light (light 4) is hooked up to the I/O block with the built-in diagnostics, that was discussed earlier. The other devices that are demonstrated are a pneumatic valve with built-in DeviceNet interface and a simple limit switch. The pneumatic valve can be used to simulate a valve used for the pneumatic system in the suspension or a valve that might be used for a special function. The limit switch is used to sense whether a door is open or closed. This switch is connected to the network via a special cable that has a built-in DeviceNet interface that acts as its own node. These last two devices, the valve and the switch, are added later to show DeviceNet's ability to be expanded easily and to have devices added to it while the system is running.

The back side of the display has all the hardware and cables mounted to it (see Figure 4). The system utilizes a small logic controller with a DeviceNet scanner and a discrete input card. The switches mounted in the tractor area connect directly to the controller via the input card and the operator display connects to the RS232 port on the controller. Everything else on the prototype runs on the DeviceNet network. Also mounted to the back of the prototype panel are three output blocks and one I/O block, which all the trailer lights are connected to, and all the interconnecting physical media. Also connected to the single I/O block is a switch that simulates a fault in a mock ABS system. For the prototype we used two different styles of trunkline taps, one that connects via terminal strips with compression fittings and the other a sealed connectorized system. This was done to demonstrate the different ways that devices could be connected to the DeviceNet system.

The DeviceNet system is used as educational tool for our customers and a resource for our vendors. We can educate our customers about vehicle multiplexing through a demonstration of the system. It can be used as a resource with our suppliers in that we can try out new products with the system with virtually no lead time for setup.   When demonstrating the system to customers or vendors we first explain why the system was built. Then we power up the system and the operator panel displays “Multiplexing system is normal.” Next we show the electrical link between the tractor and trailer, with the five conductors. Then we demonstrate the basic functions, such as the clearance, turn, and brake lights. Then with the left turn light on we unscrew the cover and remove the bulb. The operator panel then displays that “The roadside rear turn lamp has burned out.” The display goes back to normal once the bulb is put back into position. Then the switch that simulates an ABS fault is actuated and the operator panel displays “Problem with the ABS unit.” The display again will go back to normal once the switch is returned to its original position. The next feature we demonstrate is the door switch device by connecting it to an open port on a tap block while the system is powered up. The switch is actually mounted to a mockup of a trailer door and when the door is open the operator panel displays that “The right rear door is open,” and when it is closed the display goes back to normal. The last thing we demonstrate is the pneumatic valve and we do this by again plugging it into an open port and operating it by actuating two switches simultaneously. Following the demonstration we usually enter into a discussion on the trailer of the future and the various advanced features that are possible.

Summary

In conclusion, the DeviceNet vehicle multiplexing prototype was and continues to be a success. The system has so many features and incredible flexibility because of the use of DeviceNet. Using DeviceNet, the prototype was conceived, constructed, and operating in less than 3 months and at a minimal cost. With the system we can demonstrate simple functions such as lighting as well as advanced features such as diagnostic feedback.   The ability to add new features or reconfigure “on-the-fly” provides us with a powerful demonstration tool for our customers and suppliers. With this system in place we can not only discuss, but demonstrate the differences between the two purposed solutions of upgrading the trailer’s electrical system. More importantly, the system demonstrates that we can meet the government regulation for feedback from the ABS unit to the driver.

Beginning in the spring of 1997 there are plans to build several prototype trailers with two connectors as well as different types of commercially available multiplexing systems. One of those trailers will have DeviceNet as the electrical operating system. The future of DeviceNet for us is not limited to just a demonstration prototype!

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