CAN Bus for Elevators

Details of this important data-conveyance system are given, from the ground up.

by David Herres

Controller Area Network (CAN) bus is one of several serial-bus electronic communication methods that has found favor in recent years in elevator technology. Its outstanding success in this and similar applications is due to its reliability and low cost, with reduced wire count in the traveling cable(s) and throughout the installation. There are fewer terminations and greater immunity to electronic noise.

By way of background, this article will review some definitions and trace how CAN bus was first developed as an automotive innovation. But, first, what is a bus? Like the name of a large vehicle used in public transportation, the word is derived from Latin "omnibus," which means "for all."

To an electrician, "bus" denotes a metal bar or strip, frequently rectangular in cross-section, that conducts electricity in electrical power distribution. Usually, a lot of electricity is conducted across relatively short distances, often inside a switchgear enclosure. In computing and communication systems (which is what we are dealing with here), "bus" has a different, though related, meaning. Rather than a single conductor, it is the complete system that conveys data. It is the pathway between integrated circuits or other devices on a printed circuit board, between devices on adjacent boards, among computers in a local area network or between pieces of electrical equipment in different locations. A bus includes the cable with one or more (sometimes many) conductors and the hardware at either end, plus software and written documentation and protocols. Thus, a data bus is not just a metal conductor as in electrical work, but a complete subsystem, including its theoretical underpinning.

In early data transmission, the dominant medium was the parallel bus, but that has been largely supplanted by the serial bus, a

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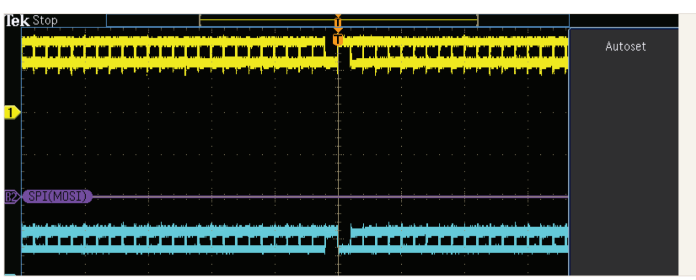
Learning Objectives

After reading this article, you should have learned:

- Reasons for the outstanding success of CAN bus
- Differences between serial and parallel buses
- Why CAN bus works well in elevator installations
- Differences between LLC and MAC sublayers
- Why data reflections are harmful



A Tektronix Series 3000 oscilloscope displays the CAN bus protocol traffic for a serial, differential pair running at 1 MHz. Messages consist of one or more 16-bit words, each of which is preceded by a 3-µs synchronized pulse and followed by an odd parity bit. The signals are acquired from a Tektronix Demo 1 board.

Value: 1 contact hour (0.1 CEU)

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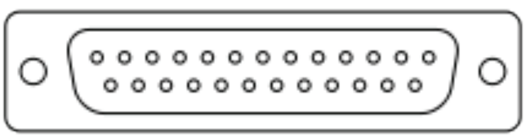
broad category that includes I2C, SPI, RS232, LIN, FlexRay, audio, USB and MIL-STD-1553.

The parallel bus predated serial-bus technologies. The former is easier to understand and simpler to troubleshoot and repair, but far less efficient, and since much more wiring and many more terminations are required, the initial installation is costlier. Serial data transmission makes use of some complex multiplexing concepts, but since it resolves into two-wire circuitry (for the most part), a lot of the work is simple plug-and-play.

A parallel bus has multiple separate conductors that transmit data simultaneously, whereas in a serial bus, data bits are conveyed sequentially, one at a time, albeit very rapidly. This would seem to suggest a parallel bus could transmit data faster than a serial bus, but such is not the case due to certain inefficiencies in parallel data transmission. For one thing, it is not feasible for a parallel bus to sustain the high clock speeds present in a serial bus. A parallel bus typically has separate conductors for the clock signal, data transmission, data reception, handshaking signals and others. Overall transmission speed is limited by the slowest of these channels. Moreover, due to the multiple conductors, there is a greater potential for crosstalk and series inductive and parallel capacitive loss, in addition to characteristic impedance mismatch resulting in signal reflections and data errors. Parallel cabling is also more subject to physical damage, and there are more terminations to worry about.

Parallel communication is still used inside integrated circuits, industrial production, scientific instrumentation and random-access-memory devices. However, the move to serial communication has continued apace and will undoubtedly be the wave of the future.

Computer networks have migrated to serial communication, which is, of necessity, used for any type of long-haul data transmission, because the cost and inherent losses in long distance multiconductor parallel cabling are prohibitive.



The term "serial" is sometimes taken to refer exclusively to the RS232 port on the back of an older PC, with its distinctive serial connector (pictured).

Contrary to this impression, since serial technology has proliferated, numerous variants have emerged, each with a distinctive topology, physical layer and operating protocol. Some transmit data in streams with frames, an arbitration mechanism to prevent data collisions and a master/slave architecture. A system of addresses may be used for selective reception, or data may be conveyed for all (nodes) to hear. Transmission can be one-way or full duplex.

As may be expected, elevator manufacturers have recognized the benefits of serial transmission and the unique suitability of CAN bus. Robert Bosch GmbH, the large manufacturer of automotive electronic equipment and related products located near Stuttgart, Germany, began work on CAN bus in 1983. The idea was to replace the old-world automotive wiring harness with serial-bus communication that would link the many subsystems being introduced into new cars and trucks. This new technology, of course, would require microchips. In 1987, Intel and Philips semiconductors began to fill the need, then, in 1988, BMW came out with its 8 Series, which incorporated a CAN bus multiplex electrical system.

Bosch continued to specify CAN bus details, the latest in CAN 2.0 (1991). Part A specifies an 11-bit identifier and is considered the standard format, while Part B, the extended format, employs a 29-bit identifier. These two parts are labeled "CAN 2.0A" and "CAN 2.0B." Bosch distributes the standards free, in addition to related specifications and white papers.

A key player in this arena has been the Organization for Standardization (ISO), which published ISO 11898 in 1993. Part 1 of this standard describes the data link layer, and Part 2 covers the physical layer for high-speed CAN. Subsequently, ISO released ISO 11898-3, which pertains to the physical layer of what became known as low-speed, fault-tolerant CAN bus.

CAN bus use spread far beyond its initial application in automobiles to industrial and agricultural machinery, medical systems, nautical navigation and the control of elevator systems. There are several types of the technology, all using low-cost integrated controllers:

- High-speed CAN bus incorporates differential signaling, making it relatively immune to noise. It typically runs at 0.5-1.0 Mbps. Two wires, both isolated from ground, are required.
- Low-speed CAN bus is less expensive to implement and is used in less-critical applications, such as automotive radio and door control. Due to the lower frequency, differential signaling is not required, because immunity to noise is less of an issue. Only one wire is used, with the vehicle chassis serving as ground return.
- Fault-tolerant CAN bus is a hybrid implementation. It is essentially high-speed CAN bus in which one of the wires is eliminated. It is widely used in automobiles to control the airbags.
- CAN FD (with "FD" standing for "flexible data-rate") is an emergent technology expected to permit longer messages with less delay.

Despite its development being exclusively for automotive harnesses, within a decade, CAN bus' use had expanded into numerous areas — avionics, plant and factory control, medical devices and many others.

Regarding elevator technology, CAN bus is an excellent fit. A group installation (as in a large high rise) consists of several cars traveling vertically in separate shafts. Through the miracle of traveling cables, a modest amount of electrical power, plus an adequate number of serial data buses, can be brought to the moving cars.

Looking at the electrical system that is so basic to an elevator group installation, the most prominent and fundamental is the power, which originates at the electrical utility. Actually, this is a power grid made up of numerous networked generators, whether connected to individual turbines or, increasingly, solar panels. This complex distribution system injects trillions of electrons through

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In an elevator group installation, electricity is used in two ways. First, it powers the motors that do the heavy lifting and often provide regenerative braking, as well as powering lights, resistive heat, evaporative air-conditioning, door functions and the like. All of this may be considered the analog domain. The other way in which electricity is used, the digital domain, has to do with the creation, processing and display of information. These two operational modes are equally important and, in fact, essential in elevator functionality.

Elevator professionals, including design and installation workers and maintenance personnel, work in these two modes, often in combination. To create a good elevator installation, it is necessary for these individuals to have a thorough understanding of both worlds. The power flow through a variable-frequency drive (VFD) to the motor is straightforward and easy to understand, even if, due to high current and voltage levels, there are challenges and potential hazards that have to be confronted.

In contrast, the digital domain involves a steeper learning curve. When an elevator installation performs intermittently or not at all, and when power supply, VFD, power transmission, motor and loading problems have been eliminated, the next step is to look at the digital end, which consists of data transmission and reception. As previously indicated, CAN bus plays a significant role where digital transmission is involved, and this will remain true for the foreseeable future.

CAN bus connectivity, like other serial bus types, consists of a physical layer (including bit encoding, timing, synchronization, and types of connectors and cables) and a data-link layer, which consists of logical link control (LLC) and medium access control (MAC) sublayers. The LLC sublayer enables transmission of information from beginning to destination. This includes data transfer and requests for remote data, message filtering as a part of received message acceptance and management of recovery (i.e., overload notification).

A principle focus of CAN protocol specification is the MAC sublayer, which is for a very large category: message framing, communication medium arbitration, management of acknowledgement, error detection and signaling. If some conceivable permanent fault is detected, error states must be monitored, and operations of the affected node limited, and this task is performed by a controller. The original Bosch standard did not cover all aspects of the physical layer. Excluded elements included types of cables and connectors, and acceptable voltage and current ranges. Instead, the original standard focused on bit encoding, timing and synchronization.

The signal type that is a dominant feature in CAN bus is known as non-return-to-zero (NRZ) bit encoding. This is important, because it involves a minimum number of transitions. The medium states that are established are dominant, which is arbitrarily equated to zero, and recessive, which is one. This may sound backward, but as the standard and implementation are consistent, it is not a problem.

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All nodes are synchronized on bit edges, and, accordingly, all nodes are in agreement in regard to the value of the currently transmitted bit. For this to occur continuously, each node has to maintain a form of synchronization that aligns the bitrate at the receiver with that of the transmitted bits. To do this, nodes are synchronized in agreement with transition edges. Synchronization would be jeopardized by a long sequence, which would result in node bit clock drifting. To avoid this outcome, bit stuffing (also known as bit padding) is employed. The idea here is that a bit is inserted in the stream after any run of five identical bits (00000 or 11111). Bit stuffing is initiated at the transmitter and removed at the receiver prior to frame contents processing, which maintains accurate synchronization.

Bit synchronization, which is necessary for the arbitration protocol and efficient management of data, is performed initially at reception of the start bit accompanying each asynchronous transmission. Then, if messages are to be correctly received, resynchronization on an ongoing basis is needed. Bit timing is further conditioned by other requirements as specified in the protocol. For example, to enhance bus arbitration and message acknowledgement and error signaling, nodes are capable of changing bit status from recessive to dominant. When this happens, a further requirement is that all other nodes in the network are informed of the change during bit transmission. Bit time must be sufficient for bit transit to make the round trip from sender to receiver and back.

A data bus is not just a metal conductor as in electrical work, but a complete subsystem, including its theoretical underpinning.

A propagation delay must be sufficient for signal transmission, in addition to any signal delay occurring in transmitters and receivers. The total delay depends upon the distance between whichever nodes are farthest apart.

Device designers program the CAN controllers using registers. It is necessary to ascertain the amount of propagation delay, and this determines maximum bus length at a given data rate or the data rate at a given bus length. The physical layer is subject to constraints that result from the requirement that all nodes remain synchronized at the bit level at the time of transmission.

CAN bus designers absolutely must avoid data reflections. They have two major causes: impedance mismatch between input or output and cable, and long low-impedance stub lengths. These are usually design issues, so once a system is up and running, there shouldn't be a problem, unless a cable becomes pinched or damaged, or a termination becomes loose or oxidized. High-speed CAN is the more critical in this regard.

Termination resistors are used to accomplish impedance matching. ISO 11898 specifies 120-ohm cable, so 120-ohm resistors are used at terminations. When multiple devices are located along the cable, only those at the ends of the line require termination resistors. In low-speed CAN, all network devices require termination resistors for each data line. These are built into the hardware by some manufacturers, so it is important to consult the installation documentation.

In the CAN protocol, there are four possible frames. The data frame contains data that is sent to one or more receivers. The frame contains a request for information in connection with a data frame that has the same identifier. An error frame is sent when one of the network nodes detects an error. An overload frame is used to request additional time, if needed, before resumption of data-frame or remote-frame transmission.

Data frames send information to receivers, which, unlike in other types of serial buses, are not identified by discrete addresses. Instead, the receiving nodes specify messages they will receive in accord with the information they contain as encoded in the frame's identifier. CAN messages may have either of two alternate types of identifiers. Standard frames have 11-bit identifier fields. Extended frames have 29-bit identifier fields. They can both be transmitted on a single bus by either the same or different nodes. Arbitrators can differentiate between these frame types.

The recessive state of an idle bus is interrupted by the starting of a frame with a single dominant bit. Then, the identifier field defines the arbitration priority for the message and the data content that comprises the message stream. There are other fields, as well: the control field contains information pertaining to the type of message. The data content is in the data field. The checksum verifies the veracity of the message bits. Reception is acknowledged. This is followed by the ending delimiter and idle space or interframe bits that denote separation between frames.

The purpose of a remote frame is to request information that has a specific identifier from a remote node. A remote frame is structured in the manner of a data frame. The identifier of the requested message is indicated in the identifier field. The data length of the requested message is stated in the DLC field. In the arbitration field, the RTR bit is recessive.

In the extremely critical area of elevator operation, where human safety is always the greatest concern, errors cannot be tolerated. CAN bus is designed for reliable data transmission, and so this can take place, the protocol has been designed for error detection, signaling and self-diagnostics and measures for fault confinement, the purpose of which are to prevent faulty nodes from contaminating the entire network.

CAN standards do not take note of optical fiber as media in the network, but it has been used with great success. In this configuration, by definition, light denotes dominant, and dark is recessive. Since the optical signals are directly coupled into the media, two lines must be provided: one for transmission and the other for reception. Additionally, to permit bit monitoring, the two lines must be coupled externally.

Optical fiber has the usual advantages of electromotive force immunity, and its nonincendiary properties is an asset in areas where explosive gases or flammable liquids or dusts may be present. Nevertheless, Article 770 of the *National Electrical Code* contains mandates for an optical-fiber installation, and compliance is essential to get the greenlight from site inspectors and ensure a long-term safe installation.

Whether electrical or optical fiber, CAN arbitration is at once priority based and non-preemptive. This means that a message being conveyed cannot be overridden by a higher-priority message as in some other bus protocols. In the CAN bus, channels are wired in accordance with "AND logic" that connects all nodes. Contention and transmission phases alternate to acquire media access. If a shared medium is not being used, a node may initiate transmission. Nodes that have messages to be transmitted will transmit the identifier in the arbitration slots. AND logic resolves collisions, and whichever node reads its bits as unchanged is the winner and proceeds to transmit the balance of its message, while the other nodes listen and await an opening.

In the elevator business, safety as it pertains to electrical and data transmission is gaining prominence as a focus in discussions among industry professionals. Recognizing the importance of the trend, CANopen Lift, the standardized network for lifts and elevators, is working toward creation of a worldwide community of elevator and subassembly manufacturers with a goal of sharing information in this rapidly changing field. In this diverse area, transmission of knowledge and expertise is a high-priority undertaking, and in this still-evolving arena, communications among participants is more important than at any time in the past.

David Herres holds a New Hampshire Master Electrician's license and has worked as an electrician in the northern part of that state for many years. He has focused on writing since 2006, having written for such magazines as ELEVATOR WORLD, *Electrical Construction and Maintenance, Cabling Business, Electrical Business, Nuts and Volts, PV Magazine, Electrical Connection, Solar Connection, Solar Industry Magazine, Fine Homebuilding Magazine* and *Engineering News Record*. He has also written four books published by McGraw-Hill: *2011 National Electrical Code Chapter by Chapter, Troubleshooting and Repairing Commercial Electrical Equipment, The Electrician's Trade Demystified* and *The Homeowner's DIY Guide to Electrical Wiring*, the latter published in December 2014. He holds a BA in English Literature and Composition from Hobart College of Geneva, New York.

Learning-Reinforcement Questions

Use the below learning-reinforcement questions to study for the Continuing Education Assessment Exam available online at www.elevatorbooks.com or on p. 145 of this issue.

- Why was CAN bus needed in the automotive industry?
- What is a serial bus?
- Why are termination resistors used in CAN bus installations?
- How are recessive and dominant states denoted in CAN bus?
- What are the advantages of optical fiber in a CAN bus installation?

ELEVATOR WORLD Continuing Education Assessment Examination Questions

Read the article "**CAN Bus for Elevators**" (p. 69) and study the learning-reinforcement questions at the end of the article.

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1. In data processing, a bus is a complete system, including cabling, devices and software.
   a. True
   b. False

2. Serial buses include:
   a. I2C bus.
   b. SPI bus.
   c. CAN bus.
   d. All of the above.

3. In NRZ bit encoding, a minimum number of transitions is involved.
   a. True
   b. False

4. A propagation delay, ____, must be sufficient for signal transmission.
   a. in addition to signal delay in transmitters
   b. in addition to signal delay in receivers
   c. Both A and B.
   d. Neither A nor B.

5. Data reflections:
   a. Are always harmful.
   b. Are never harmful.
   c. Are caused by slow data speed.
   d. Are caused by poor voltage regulation.

6. ISO 11898 calls for:
   a. 90-ohm cable.
   b. 110-ohm cable.
   c. 120-ohm cable.
   d. 150-ohm cable.

7. In CAN bus, receivers are identified by their addresses.
   a. True
   b. False

8. All CAN bus messages have:
   a. Six-bit identifier fields.
   b. 11- or 29-bit identifier fields.
   c. 40-bit identifier fields.
   d. 45-bit identifier fields.

9. In optical fiber as used for CAN bus in elevator installations:
   a. Light is dominant, and dark is recessive.
   b. Light is recessive, and dark is dominant.
   c. Optical fiber is not used as a network media.
   d. Optical signals are not conveyed by media.

10. In CAN bus:
    a. Channels are wired in accordance with AND logic, and contention and transmission phases alternate to acquire media access.
    b. Channels are wired in accordance with AND logic, and contention and transmission phases simultaneously acquire media access.
    c. Channels are wired in accordance with OR logic, and contention and transmission phases alternate to acquire media access.
    d. Channels are wired in accordance with OR logic, and contention and transmission phases simultaneously acquire media access.

ELEVATOR WORLD Continuing Education Reporting Form

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