EXTENDABUS®

Tutorial

INTRODUCTION

Device level networks such as DeviceNet and Smart Distributed System are low-level networks that provide connections between simple industrial devices such as sensors and actuators and higher-level devices such as controllers. Benefits of device level networks include reduced wiring costs, the ability to exploit the intelligence present in some low-level devices and improved diagnostic capabilities from that of hard-wired systems.

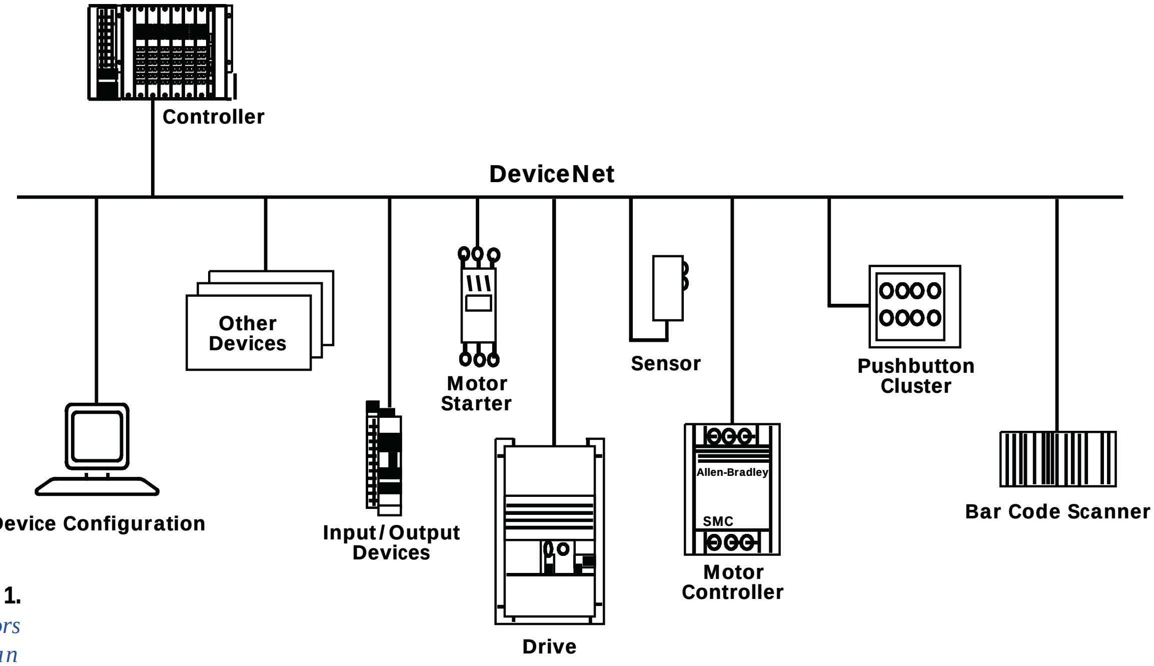


Figure 1.
Sensors, actuators and controllers can reside on a common DeviceNet network.

Device level networks, in general, generate two types of messages. I/O messages provide all the work by conveying actual real-time data between controllers and sensors or actuators. This is called implicit messaging since a connection is already established between these devices with an agreed-upon messaging protocol. So there is no need to send protocol information with the data—just the data. This speeds up data transfers.

All other messages can be lumped into a class called explicit messaging. These messages are your traditional source/destination messages when protocol information must also be provided in order to understand what requests or commands are being made. These types of messages are for establishing connections, configuring ports or obtaining diagnostic information. Both DeviceNet and Smart Distributed System utilize the same concepts but at the application layer they are incompatible.

Although DeviceNet and Smart Distributed System have incompatible messaging, they do share some commonalties. Both systems utilize Controller Area Network (CAN) controller technology at the data link layer and their physical layers are quite similar. CAN technology, originally developed for vehicular communications, provides low cost and compact controller chips and companion transceivers that can fit within a 12mm proximity switch.

The distance limitations of DeviceNet and Smart Distributed System are about the same. At the 500 kbps data rate, the network cannot exceed 100 meters in length. For vehicular communication this generally is not a consequence; however, for industrial networks this could be a severe limitation.

The EXTEND-A-BUS series breaks the distance barrier at the cost of increased data latency. Even though DeviceNet and Smart Distributed System are incompatible, the EXTEND-A-BUS can operate with either network. This is because the EXTEND-A-BUS understands the CAN data link protocol but does not understand the various application layers that sit on top of CAN.

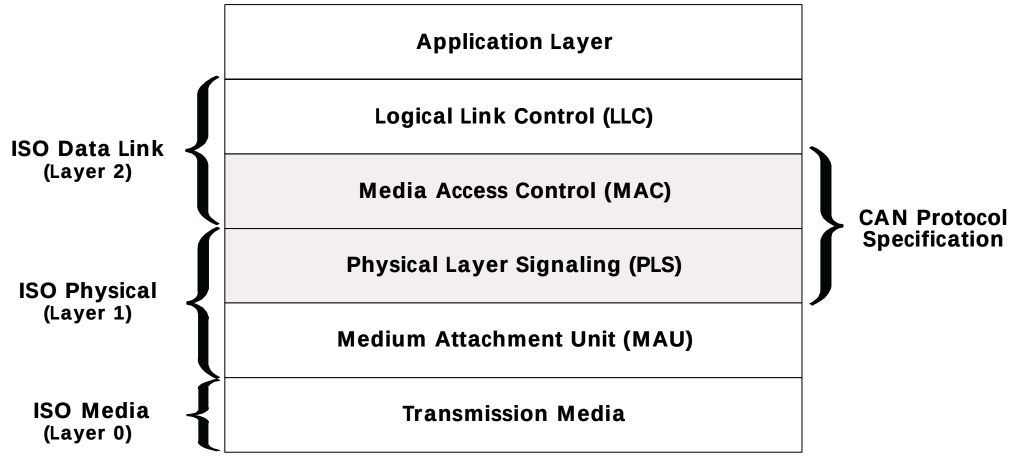


Figure 2. *Although DeviceNet and Smart Distributed System incorporate different application layers, they both incorporate CAN.*

The EXTEND-A-BUS series of fieldbus extenders enable the geographic expansion of CAN-based device networks such as DeviceNet and Smart Distributed System by linking individual CAN subnets together into a single larger network. EXTEND-A-BUS interconnects two physically separated but similar networks using a different interconnecting medium. Thus, a pair is required to interconnect two networks (or subnets) the way two modems are used on leased phone lines.

Utilizing ARCNET as the high-speed deterministic interconnecting medium, the EXTEND-A-BUS captures CAN traffic and replicates it to the receiving device. The receiving device removes CAN data and rebroadcasts the data to its attached CAN subnet.

EXTEND-A-BUS does not filter our CAN identifiers, so CAN messages are rebroadcast unmodified.

CONTROLLER AREA NETWORK

CAN was designed by Bosch and is currently described by ISO 11898[1]. In terms of the Open Systems Interconnection model (OSI), CAN partially defines the services for layer 1 (physical) and layer 2 (data link). Other standards such as DeviceNet, Smart Distributed System, CAL, CAN Kingdom and CANopen (collectively called higher layer protocols) build upon the basic CAN specification and define additional services of the seven layer OSI model. Since all of these protocols utilize CAN integrated circuits, they all comply with the data link layer defined by CAN.

CAN specifies the medium access control (MAC) and physical layer signaling (PLS) as it applies to layers 1 and 2 of the OSI model. Medium access control is accomplished using a technique called non-destructive bit-wise arbitration. As stations apply their unique identifier to the network, they observe if their data are being faithfully produced. If it is not, the station assumes that a higher priority message is being sent and, therefore, halts transmission and reverts to receiving mode. The highest priority message gets through and the lower priority messages are resent at another time. The advantage of this approach is that collisions on the network do not destroy data and eventually all stations gain access to the network. The problem with this approach is that the arbitration is done on a bit by bit basis requiring all stations to hear one another within a bit-time (actually less than a bit-time). At a 500 kbps bit-rate, a bit-time is 2000 ns which does not allow much time for transceiver and cable delays. The result is that CAN networks are usually quite short and frequently less than 100 meters at higher speeds. To increase this distance either the data rate is decreased or additional equipment is required.

Standard Format

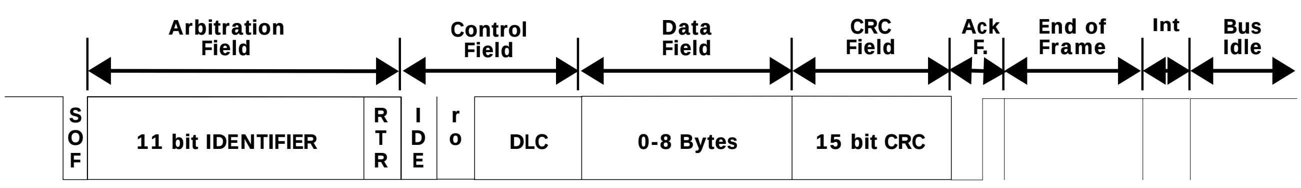


Figure 3.
An 11-bit identifier is used in standard format.

CAN DATA LINK LAYER

CAN transmissions operate using the producer/consumer model. When data are transmitted by a CAN device, no other devices are addressed. Instead, the content of the message is designated by an identifier field. This identifier field, which must be unique within the network, not only provides content but the priority of the message as well. All other CAN devices listen to the sender and accept only those messages of interest. This filtering of the data is accomplished using an acceptance filter which is an integral component of the CAN controller chip. Data which fail the acceptance criteria are rejected. Therefore, receiving devices consume only that data of interest from the producer.

A CAN frame consists mainly of an identifier field, a control field and a data field (figure 3). The control field is six bits long, the data field is zero to eight bytes long and the identifier field is 11 bits long for standard frames (CAN specification 2.0A) or 29 bits long for extended frames (CAN specification 2.0B). Source and destination node addresses have no meaning using the CAN data link layer protocol.

Bus arbitration is accomplished using a non-destructive bit-wise arbitration scheme. It is possible that more than one device may begin transmitting a message at the same time. Using a “wired AND” mechanism, a dominant state (logic 0) overwrites the recessive state (logic 1). As the various transmitters send their data out on the bus, they simultaneously listen for the faithful transmission of their data on a bit by bit basis until it is discovered that someone’s dominant bit overwrote their recessive bit. This indicates that a device with a higher priority message, one with an identifier of lower binary value, is present and the loser of the arbitration immediately reverts to receiving mode and completes the reception of the message. With this approach no data are destroyed and, therefore, throughput is enhanced. The losers simply try again during their next opportunity. The problem with this scheme is that all devices must assert their data within the same bit-time and before the sampling point otherwise data will be falsely received or even destroyed. Therefore, a timing constraint has been introduced that impacts cabling distance.

PROPAGATION DELAY

In a Philips’ application note[2], the author does an in-depth study on the maximum allowable propagation delay as a function of various controller chip parameters. The propagation delay (figure 4) is due to the input/output delays of the CAN controller chip (tsd), transmission delay of the transceiver (ttx), reception delay of the transceiver (trx) and the signal delay due to the cable (tcbl). The total propagation delay (tp) experienced is basically the round trip delay from a CAN node located at the end of a cable segment communicating to the furthest node and is expressed as follows:

tp = 2(tsd+ttx+trx+tcbl)

All delays are constant except the cable delay (tcbl) which depends upon the length of the cable and the propagation delay factor of the cable (Pc). The author provides a chart of maximum allowable propagation delays (tpm) for various data rates and CAN chip timing parameters. The actual propagation delay must not exceed the maximum allowable propagation delay. By making the appropriate substitutions, we can determine the maximum allowable cable length (L).

$$L < \frac{\frac{1}{2}tpm - tsd - trx - ttx}{Pc}$$

Using appendix A.1 of the application note and the most favorable parameters for long distance, at 500 kbps, tpm equals 1626 ns. Assuming transceiver delays of 100 ns each, chip delay of 62.5 ns and a cable propagation factor of 5.5 ns/m, the maximum cable length is 100 meters which is the value used in the DeviceNet specification. Doing the same calculation at 250 kbps yields 248 meters and at 100 kbps, 680 meters. These values can be improved with better cable and faster transceivers.

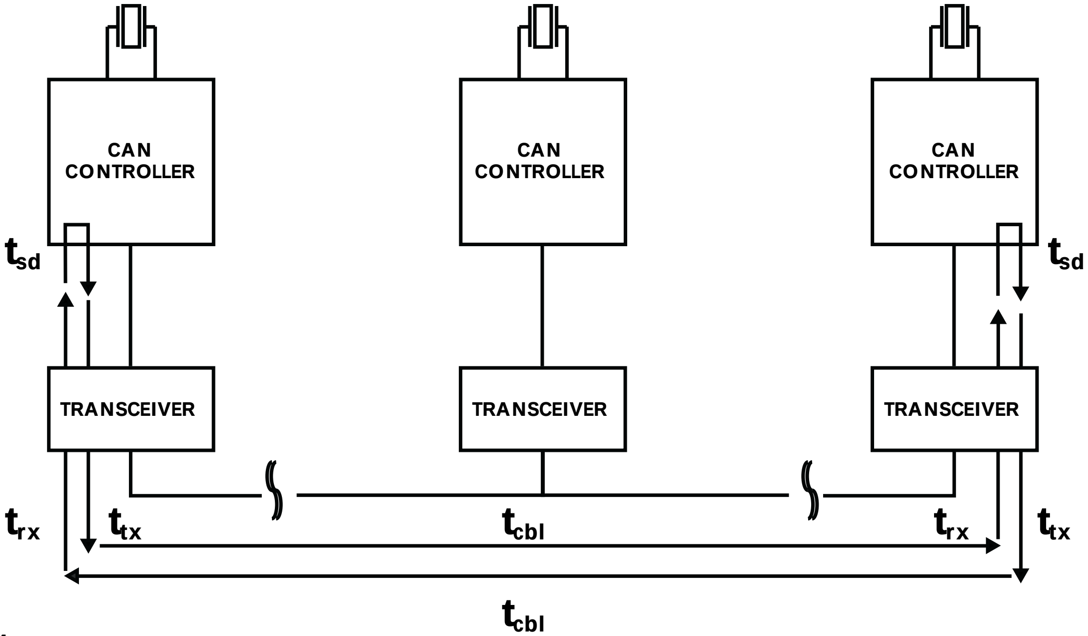


Figure 4.
Use the longest path when calculating propagation delay.

The point here is that CAN's bit-wise arbitration scheme inherently limits the maximum length of a CAN segment. Increasing the distance requires a reduction in data rate; however, there might be some benefit to incorporating repeaters or bridges.

REPEATERS

The usual approach to increasing network distance is to use repeaters. Repeaters provide signal boost to make up the loss of signal strength on a long segment. However, the problem with many CAN segments is not lack of signal strength but excessive signal latency. This latency is due to the propagation delay introduced by the transceivers and twisted-pair wiring. If this latency approaches one bit-time, the non-destructive bit-wise arbitration mechanism fails. Repeaters actually introduce more delay due to the additional electronics and are not effective in increasing the overall length of high speed CAN networks. Repeaters can be used to increase the effective length of drop cables from CAN trunk lines. Repeaters operate on the physical layer and are ignorant of the data link layer.

BRIDGES

Bridges are defined as devices that link two similar networks[3]. A local bridge stands by itself connecting adjacent wiring segments together as in the case of a repeater. Therefore, a local CAN bridge would have two CAN chips, one for one segment and one for the other. A microprocessor would pass messages between the two CAN chips. Using this approach, the effective length of the complete network is doubled while requiring only one bridge. Remote bridging interconnects two physically separated but similar networks together using a different interconnecting medium. Therefore, a pair of bridges are required to interconnect two networks the way two modems are used on leased phone lines. Sometimes bridges block network traffic by restricting data only to stations specified in the transmission that resided on the network controlled by the bridge. This blocking is difficult to implement in broadcast networks such as CAN and, therefore, is not recommended. Bridges operate at the data link layer and, therefore, are ignorant of the higher level protocols sent over CAN. As with the local bridge, two ports are required. However, instead of two CAN ports, one CAN port is replaced with a port compatible with the technology of the bridging connection. The technology chosen should be fast, deterministic, robust and capable of extending CAN networks without introducing excessive delay that would jeopardize the operation of the CAN system. The technology used by the EXTEND-A-BUS is ARCNET.

ARCNET

ARCNET is a local area network technology which is described in ANSI/ATA 878.1[4]. Like CAN, ARCNET only defines the data link and physical layers (figure 5). ARCNET is attractive for use in bridging CAN segments because it is faster than CAN (2.5 Mbps), it supports many nodes (255), it can send large packets (507 bytes), it can communicate over long distances (4 miles) and it provides deterministic performance due to its token-passing medium access control. All these elements are important if CAN messages are to be transferred with the lowest possible delay.

APPLICATION
PRESENTATION
SESSION
TRANSPORT
NETWORK
DATA LINK
PHYSICAL

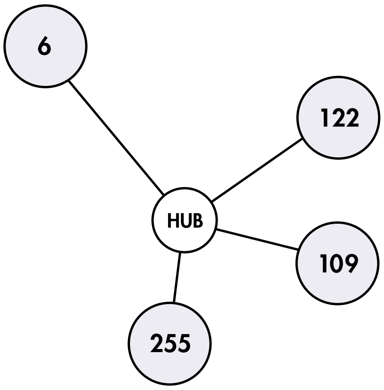
Figure 5.
Like CAN, ARCNET defines the lower two layers of the OSI Reference Model.

Deterministic Performance

The key to ARCNET's performance and its attractiveness as a control network is its token-passing protocol. In a token-passing network, a node can only send a message when it receives the "token." When a node receives the token it becomes the momentary master of the network; however, its mastery is short lived. The length of the message that can be sent is limited and, therefore, no one node can dominate the network since it must relinquish control of the token. Once the message is sent, the token is passed to another node allowing it to become the momentary master. By using token passing as the mechanism for mediating access of the network by any one node, the time performance of the network becomes predictable or deterministic. In fact, the worst case time that a node takes to deliver a message to another node can be calculated. Industrial networks require predictable performance to ensure that controlled events occur when they must. ARCNET provides this predictability.

Logical Ring

A token (ITT—Invitation to Transmit) is a unique signaling sequence that is passed in an orderly fashion among all the active nodes in the network[5]. When a particular node receives the token, it has the sole right to initiate a transmission sequence or it must pass the token to its logical neighbor. This neighbor, which can be physically located anywhere on the network, has the next highest address to the node with the token. Once the token is passed, the recipient (likewise) has the right to initiate a transmission. This



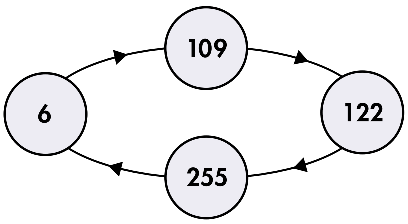


Figure 6.
ARCNET passes tokens in a logical ring fashion independent of the physical location of the nodes.

token-passing sequence continues in a logical ring fashion serving all nodes equally. Node addresses must be unique and can range from 0 to 255 with 0 reserved for broadcast messages.

For example, assume a network consisting of four nodes addressed 6, 109, 122 and 255. Node assignments are independent upon the physical location of the nodes on the network. Once the network is configured, the token is passed from one node to the node with the next highest node address even though another node is physically closer. All nodes have a logical neighbor and will continue to pass the token to their neighbor in a logical ring fashion regardless of the physical topology of the network.

Directed Messages

In a transmission sequence, the node with the token becomes the source node and any other node selected by the source node for communication becomes the destination node. First the source node inquires if the destination node is in a position to accept a transmission by sending out a Free Buffer Enquiry (FBE). The destination node responds by returning an Acknowledgement (ACK) meaning that a buffer is available or by returning a Negative Acknowledgement (NAK) meaning that no buffer is available. Upon an ACK, the source node sends out a data transmission (PAC) with either 0 to 507 bytes of data (PAC). If the data was properly received by the destination node as evidenced by a successful CRC test, the destination node sends another ACK. If the transmission was unsuccessful, the destination node does nothing, causing the source node to timeout. The source node will, therefore, infer that the transmission failed and will retry after it receives the token on the next token pass. The transmission sequence terminates and the token is passed to the next node. If the desired message exceeds 507 bytes, the message is sent as a series of packets—one packet every token pass. This is called a fragmented message. The packets are recombined at the destination end to form the entire message.

Broadcast Messages

ARCNET supports a broadcast message, which is an unacknowledged message to all nodes. Instead of sending the same message to individual nodes one message at a time, this message can be sent to all nodes with one transmission. Nodes that have been enabled to receive broadcast messages will receive a message that specifies node 0 as the destination address. Node 0 does not exist on the network and is reserved for this broadcast function. No ACKs or NAKs are sent during a broadcast message making broadcast messaging fast.

Automatic Reconfigurations

Another feature of ARCNET is its ability to reconfigure the network automatically if a node is either added or deleted from the network. If a node joins the network, it does not automatically participate in the token-passing sequence. Once a node notices that it is never granted the token, it will jam the network with a reconfiguration burst that destroys the token-passing sequence. Once the token is lost, all nodes will cease transmitting and begin a timeout sequence based upon their own node address. The node with the highest address will timeout first and begin a token pass sequence to the node with the next highest address. If that node does not respond, it is assumed not to exist. The destination node address is incremented and the token resent. This sequence is repeated until a node responds. At that time, the token is released to the responding node and the address of the responding node is noted as the logical neighbor of the originating node. The sequence is repeated by all nodes until each node learns its logical neighbor. At that time the token passes from neighbor to neighbor without wasting time on absent addresses.

THEORY OF OPERATION

The EXTEND-A-BUS is classified as a remote bridge that is used to extend CAN-based device networks. On the device side of the bridge, a CAN segment is connected complying to the distance limitation for the bit-rate used. On the other side is ARCNET that captures the CAN traffic and replicates it to another bridge. The receiving bridge converts the data to its attached CAN segment. A minimum of two bridges is required but in the general case, many bridges can be used since ARCNET supports star and distributed star topologies. The bridges are protocol neutral. They do not understand higher layer protocols. The bridges simply capture the data transmitted on its CAN segment and encapsulate the data into ARCNET frames for retransmission to the other bridges on the network. The receiving bridges remove the CAN data from ARCNET packets and rebroadcast the data to its CAN segment. The bridges do not filter out CAN identifies. CAN messages originating on a particular CAN segment are rebroadcast to all other CAN segments without modification. Therefore, it is important that all CAN compliant devices on the complete network incorporate a unique CAN identifier which would be the case for a CAN network without bridges.

CAN Port

One electrically isolated CAN port has been provided capable of operating to either Smart Distributed System or DeviceNet physical layer specification. This was done to minimize ground loop problems while providing isolation to the ARCNET backbone.

When a CAN port is receiving data from the CAN segment, its acceptance filter is wide open since all messages must be received. When a CAN port is transmitting to the CAN segment, the port replicates the CAN message originating from a remote CAN segment as if that CAN chip was present locally.

ARCNET Backbone Port

The ARCNET backbone port operates at 2.5 Mbps and is available with either a coaxial or fiber optic transceiver. Each EXTEND-A-BUS requires a unique ARCNET node ID which has no meaning to the CAN segments. Node IDs are automatically assigned by the EXTEND-A-BUSes themselves using an arbitration scheme upon power up eliminating the need to make switch assignments in the field.

CAN Frames

CAN transmissions exist as either standard frames or extended frames. The standard frame includes an eleven-bit identifier while newer CAN controller chips are also capable of producing an extended frame with a 29-bit identifier. Both DeviceNet and Smart Distributed System support only standard frames; however, the EXTEND-A-BUS is capable of supporting extended frames.

The EXTEND-A-BUS listens to all CAN frames on its CAN port and if a successful acknowledgment is noted, stores the identifier, control and data fields into a buffer. The bridge continues to listen for additional transmissions while the buffer is flushed by sending the data over the ARCNET backbone.

If the EXTEND-A-BUS receives a message from the ARCNET backbone, it must transmit the message to its CAN port. The EXTEND-A-BUS will have the identifier, control and data fields for the transmission it needs to produce and conditions the CAN port accordingly. This time, however, the CAN port on the EXTEND-A-BUS must transmit an identifier which might have a low priority and could experience difficulty gaining bus access in order to transmit this message. During this time the EXTEND-A-BUS continues to receive CAN port data while attempting to transmit onto the CAN segment. Data is not lost during this time but queued in the EXTEND-A-BUS. Once the CAN transmission is initiated, the acknowledgment is monitored for success. If unsuccessful, the transmission sequence is repeated until successful. CAN messages are queued on a first come-first serve basis so that fragmented CAN messages are not missequenced.

ARCNET Frames

ARCNET frames are longer than CAN frames. Instead of eight data bytes for CAN, ARCNET can accommodate up to 252 bytes in short packet mode, 507 in long packet mode. Short packet handling is more efficient and, therefore, was chosen for the EXTEND-A-BUS. The CAN frames are encapsulated into ARCNET frames, and it is possible that more than one CAN frame could be stored within one ARCNET frame. For each CAN message, space must be reserved in the ARCNET frame for identifier, control and data fields.

ARCNET frames are sent as broadcast messages and not as directed messages for the purposes of speed. Using this approach a transmitting EXTEND-A-BUS can send CAN data to multiple CAN segments in the same time it can send to one. To ensure reliable delivery of data, the data is resent several times as time permits. A sequence number is appended to the data and duplicate transmissions of the data are automatically discarded by the receivers after viewing the sequence number. If the sequence number has not incremented since the last transmission, the data is not new and must be discarded. This sending of broadcast messages continues in a round-robin fashion due to ARCNET's built-in token-passing protocol.

INSTALLATION

Mounting the EXTEND-A-BUS

The EXTEND-A-BUS is intended for mounting onto a vertical panel within an industrial control enclosure. The device level network cable attaches to one port on the EXTEND-A-BUS while the backbone cable attaches to the other port. Power can be provided by either a low voltage AC or DC source.

Powering the EXTEND-A-BUS

The EXTEND-A-BUS requires either low voltage AC or DC power in order to operate. Consult the specifications for power requirements. Power is provided to a four pin removable keyed connector. There are several methods for providing power. These methods are DC powered, redundant DC powered, AC powered and AC powered with battery backup.

DC Powered

The EXTEND-A-BUS incorporates a DC-DC converter that accepts a wide voltage range (10-36VDC) and converts the voltage for internal use. Input current varies with input voltage so it is important to size the power conductors accordingly. Input power to the EXTEND-A-BUS maximizes at 4 watts; therefore, at 10VDC, the input current is approximately 400 ma. The ground connection to the EXTEND-A-BUS is connected to chassis within the EXTEND-A-BUS. The input connections are reverse voltage protected.

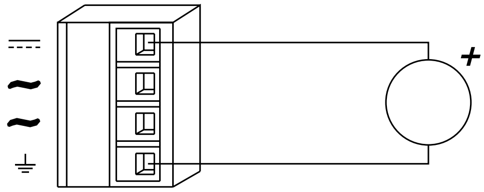


Figure 7.
DC Powered

Redundant DC Powered

Redundant diode isolated DC power inputs are provided on the EXTEND-A-BUS for those applications in which there is a concern that the EXTEND-A-BUS remain operational in the event of a primary power failure. Each power supply source must be sized for the full 4-watt load of the EXTEND-A-BUS since input currents may not be balanced from the two supplies.

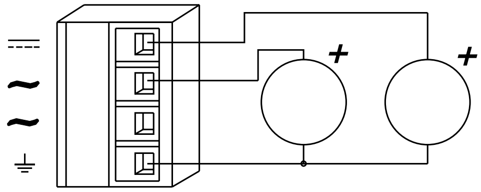


Figure 8.
Redundant DC Powered

AC Powered

If only AC power is available, the EXTEND-A-BUS can be powered by the secondary of a low voltage transformer whose primary is connected to the AC mains. The secondary voltage must be in the range of 8 to 24VAC, 47-63 Hz with the capability of delivering up to 4VA of apparent power. The secondary of the transformer can be floated or grounded. The connections are different for the two configurations.

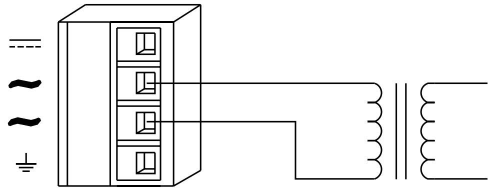


Figure 9.
AC Powered—Floating Secondary

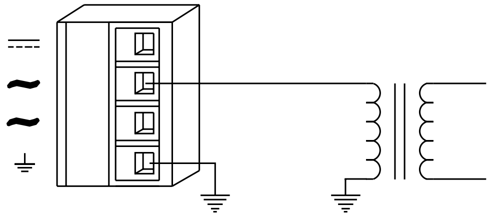


Figure 10.
AC Powered—Grounded Secondary

AC Powered with Battery Backup

The EXTEND-A-BUS can also be powered from both an AC and DC power source. Usually, the DC source is from a battery supply which is connected as the DC powered option. In this application, the EXTEND-A-BUS does not charge the battery so separate provisions are required for charging. If the AC source fails, the EXTEND-A-BUS will operate from the battery source.

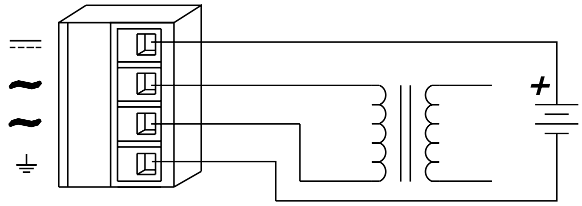


Figure 11.
AC Powered with Battery Backup

Connecting to the CAN Port

Depending upon the model, the CAN port complies with either the DeviceNet or Smart Distributed System physical layer specification for an isolated port. Since the port is isolated, bus power (V+, V-) must be present in order for the port to function. A bus power sensor has been provided in the EXTEND-A-BUS to ensure that in the absence of bus power, the port will not enter the "bus off" state.

CAN Port Assignments

A five-position open style male connector exists on the EXTEND-A-BUS CAN port. A mating female connector has been provided in order to make field connections.

Terminators are required at the ends of trunk cables. If the EXTEND-A-BUS is located at the end of a trunk and no terminator is present, a discrete resistor terminator (121 ohms) can be connected under the screw terminals for CAN_H and CAN_L.

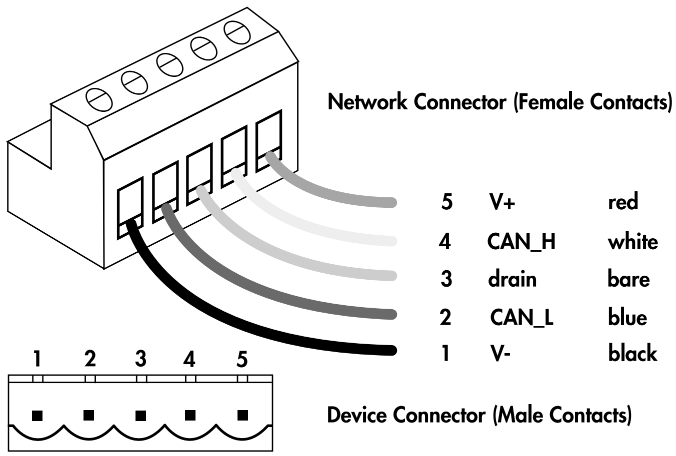


Figure 12.
CAN Port Connector Assignments for DeviceNet[6]

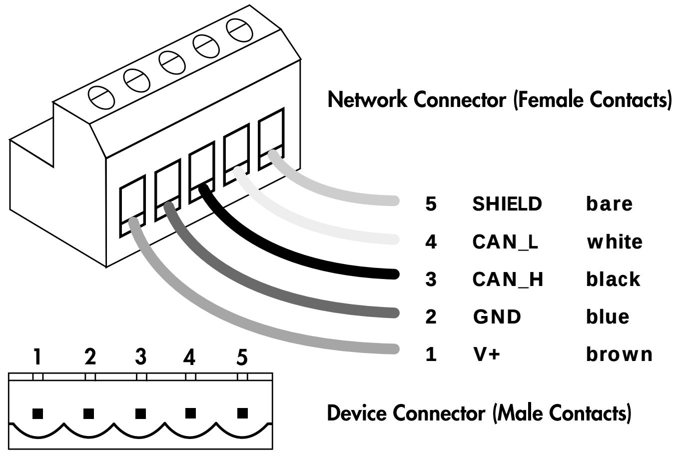


Figure 13.
CAN Port Connector Assignments for Smart Distributed System[7]

When cabling CAN ports, follow the cabling rules for the type of network being used—DeviceNet or Smart Distributed System.

CAN Port Data Rates

Several data rates can be selected by a rotary switch as shown in figure 14. Switch positions are labeled A, S, 125, 250, 500. A and S are used to implement autobauding which will be discussed later. The remaining positions determine a fixed data rate in units of kbps. Therefore, the lowest rate is 125 kbps and the highest is 500 kbps. The data rate switch is only read upon power up; so to change settings, the switch position should be changed and the power cycled to the EXTEND-A-BUS. A clockwise rotation increases the data rate setting.

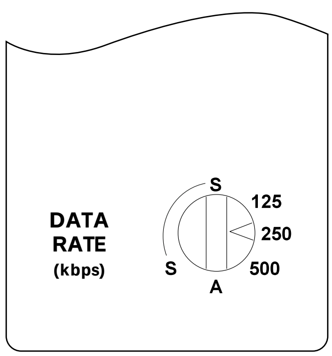


Figure 14.
Data Rate Switch

Although CAN controller chips will operate at 1 Mbps, there is a question if there is sufficient time at that speed to reliably implement the station arbitration scheme using isolated ports. Although Smart Distributed System lists 1 Mbps as an option, it is rarely used. DeviceNet does not support it.

Autobauding

Autobauding is the action of automatically matching the data rate of the EXTEND-A-BUS to the data rate of a master controller or scanner in a device-level network. By moving the Data Rate switch to the A position and powering up the EXTEND-A-BUS, the EXTEND-A-BUS will attempt to determine the data rate by observing the traffic on the CAN port. Therefore, it is important that the CAN port be connected to the subnet connecting the master controller. All other EXTEND-A-BUSes should have their Data Rate switch set to S (slave) position since their data rate will be set by the master EXTEND-A-BUS (the one connected to the master) which will broadcast the required data rate to all slaves once the data rate is determined. Autobauding functions for the three data rates: 125, 250 and 500 kbps.

Autobauding can be tricky when using bridges, especially for Smart Distributed System because there is a risk that not all devices will be recognized in the time allowed for detection. If it is at all possible, the recommendation is to use fixed data rates for the EXTEND-A-BUS and not use autobauding.

Connecting to the Backbone Port

The backbone (link) port is ARCNET compliant and, therefore, complies with the cabling rules for ARCNET networks. For more information on designing an ARCNET cabling system, refer to Contemporary Controls' (CC) publication, "ARCNET Tutorial & Product Guide."[5] However, by simply following a few cabling rules, it is unnecessary to know how ARCNET works. It can simply be referred to as the backbone port.

The EXTEND-A-BUS series is available in either of two backbone ports. The less expensive port is the coaxial port requiring RG-62/u coaxial cable and BNC connectors. Although similar in look to Ethernet 10BASE2 "thin" cable, the cables are not the same although the connectors are. Only use RG-62/u which is 93 ohm cable and easy to source. This port is a bus port meaning that multiple devices can be attached to the same cable. With the (-CXB) coaxial port up to eight EXTEND-A-BUS devices can be attached to the same coaxial cable utilizing BNC-T connectors.

The second style port is the fiber optic port. This port utilizes ST connectors and requires a pair of fibers for each port connection. Up to two (-FOG) fiber optic EXTEND-A-BUS devices can be connected together. If star or distributed star topologies are desired or if the cabling distances must exceed the basic specifications, ARCNET compliant active hubs are required. Contemporary Controls provides two series of active hubs—the MOD HUB series of modular hubs and the AI series of fix port hubs. Their use will be discussed later.

Connecting Coaxial Bus Networks (-CXB)

Coaxial bus backbone ports must be interconnected with RG-62/u 93 ohm coaxial cable. In a simple two EXTEND-A-BUS arrangement, a BNC-Tee (BNC-T) is twisted onto each BNC backbone port. A length of RG-62/u cable, no shorter than 6 feet (2 m) nor longer than 1000 feet (305 m) is connected between the BNC-Tee connectors. At the open end of each BNC-Tee is connected a 93 ohm terminator (BNC-TER). This completes the basic connection.

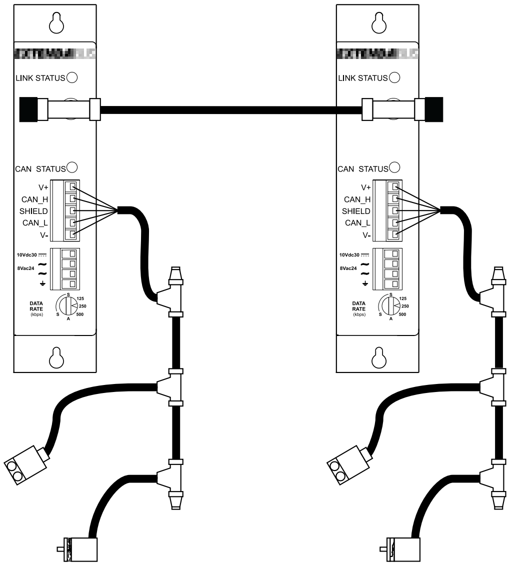


Figure 15.
Appropriate terminators are required at the ends of both the coaxial cable backbone and DeviceNet subnets.

More than two EXTEND-A-BUSes (but no more than eight) can be connected to one wiring segment. Insert the desired number of EXTEND-A-BUSes using BNC-Tee connectors to the backbone wiring. Make sure that any two EXTEND-A-BUSes are separated by at least 6 foot (2 m) of cable and that the complete cabling segment does not exceed 1000 feet (305 m).

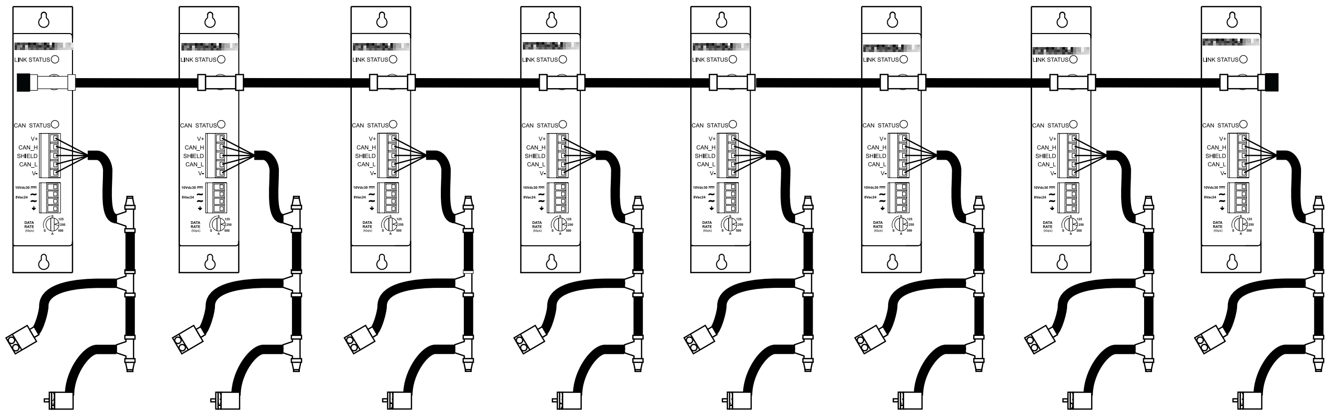


Figure 16.
A maximum of eight EXTEND-A-BUSes can occupy one coaxial backbone segment before an active hub is required. Use BNC "Tees"and terminators when making connections. One of each is included in the -CXB model.

Connecting Fiber Optic Cable (-FOG)

Multimode fiber optic cable is typically available in three sizes, 50/125, 62.5/125, and 100/140. The larger the size, the more energy that can be launched and, therefore, the greater the distance. Bayonet style ST connectors, similar in operation to BNC coaxial cable connectors, are provided for making the fiber connections.

Fiber optic connections require a duplex cable arrangement. Two unidirectional cable paths provide the duplex link. There are two devices on the EXTEND-A-BUS fiber port. One device, colored light gray, is the transmitter and the other, dark gray, is the receiver. Remember that "light goes out of the light (gray)." To establish a working link between an EXTEND-A-BUS and another EXTEND-A-BUS or an EXTEND-A-BUS to a hub, the transmitter of point A must be connected to a receiver at point B.

Correspondingly the receiver at point A must be connected to a transmitter at point B. This establishes the duplex link which is actually two simplex links. Fiber optic cable is available paired for this purpose. Usually the manufacturers' labeling is only on one cable of the pair which is handy for identifying which of the two cables is which. Establish your own protocol for connecting cable between hubs and EXTEND-A-BUSes in the field using the manufacturers' labeling as a guide. However, remember that to connect point A to point B requires a paired fiber optic cable and that the light gray connector at one point must connect to a dark gray connector at the other point.

Optical Power Budget

When specifying a fiber optic installation, attention must be paid to the available optical power budget. The power budget is the ratio of the light source strength divided by the light receiver sensitivity expressed in dB. This value must be compared to the link loss budget which is based upon the optical cable and optical connectors. The link loss budget must be less than the power budget. The difference is called the power margin which provides an indication of system robustness.

Transmitter power is typically measured at one meter of cable and, therefore, includes the loss due to at least one connector. The outputs vary so CC tests each device to ensure that a minimum output power is achieved. The output power also varies with core sizes. In general, larger cores launch more energy; however, CC specifies the use of 62.5/125 fiber.

Receiver sensitivity also varies so again CC tests for the least sensitive receiver. The difference between the weakest transmitter and least sensitive receiver is the worst case power budget which

CC specifies. Realized power budgets will exceed this value since the probability of the worst case transmitter being matched with the worst case receiver is remote. However, CC recommends using the stated power budget.

OPTICAL POWER BUDGET			
Fiber Size (Microns)	**Transmit PWR (dBm)**	**Receiver PWR (dBm)**	**Power Budget (dB)**
62.5/125	-15.0	-25.4	10.4

Link Loss Budget

Fiber optic cable attenuation is usually specified by the cable manufacturer. Use this figure to determine the maximum distance of the fiber link. It is necessary to include losses due to cable terminations. Connectors usually create a loss of from 0.5 to 1 dB. For example, assume a 1500 meter run of 62.5 cable which the cable manufacturer specifies as having a cable attenuation of 3.5 dB per 1000 meters. The cable loss will be 5.25 dB. Assuming one additional connector loss of 0.5 dB, the link loss budget would

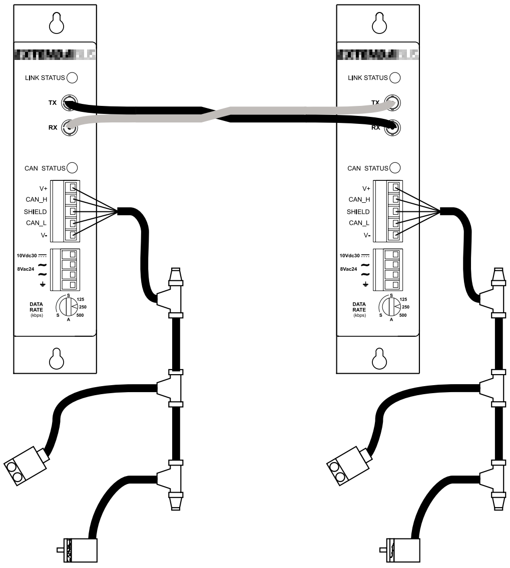


Figure 17.
A 62.5/125mm duplex fiber optic cable is used on the -FOG model up to a maximum of 1830 meters.

be 5.75 dB which is within the 10.4 dB power budget specified by CC. The 4.65 dB difference represents a high degree of margin. A 3 dB margin is what is typically recommended. With this same cable, CC recommends a maximum segment length of 1830 m for 62.5/125 fiber optic cable.

Extending the Backbone

The backbone side of the EXTEND-A-BUS must comply with standard ARCNET cabling rules. Companion AI ARCNET active hubs are available for extending the backbone cabling up to 6 km using coaxial cabling and ten active hubs. When using a fiber optic backbone, a maximum of 4.8 km can be achieved requiring two active hubs. Hubs can be cascaded to reach the required distance.

By using active hubs, star and distributed star topologies are possible. There is, however, a limit to the overall length of the backbone network. The delay experienced when an EXTEND-A-BUS communicates to another EXTEND-A-BUS with each located at the extreme ends of a network cannot exceed 31ms. This delay is due to cable and hub delays. This delay translates to a maximum of 6 km of coaxial cable or 4.8 km of fiber optic cable. When making this calculation, only consider the distance between the two furthest EXTEND-A-BUSes. Also verify the distance limitations of active hubs being used. Active hubs that incorporate coaxial star ports (-CXS) allow for 2000 foot (610m) connections between compatible ports but no bussing. When making a connection to a -CXS port from the EXTEND-A-BUS' -CXB port, make sure that the -CXS port is located at one end of the segment and that no terminator is used. The length of a segment connecting a -CXB port cannot exceed 1000 feet (305m).

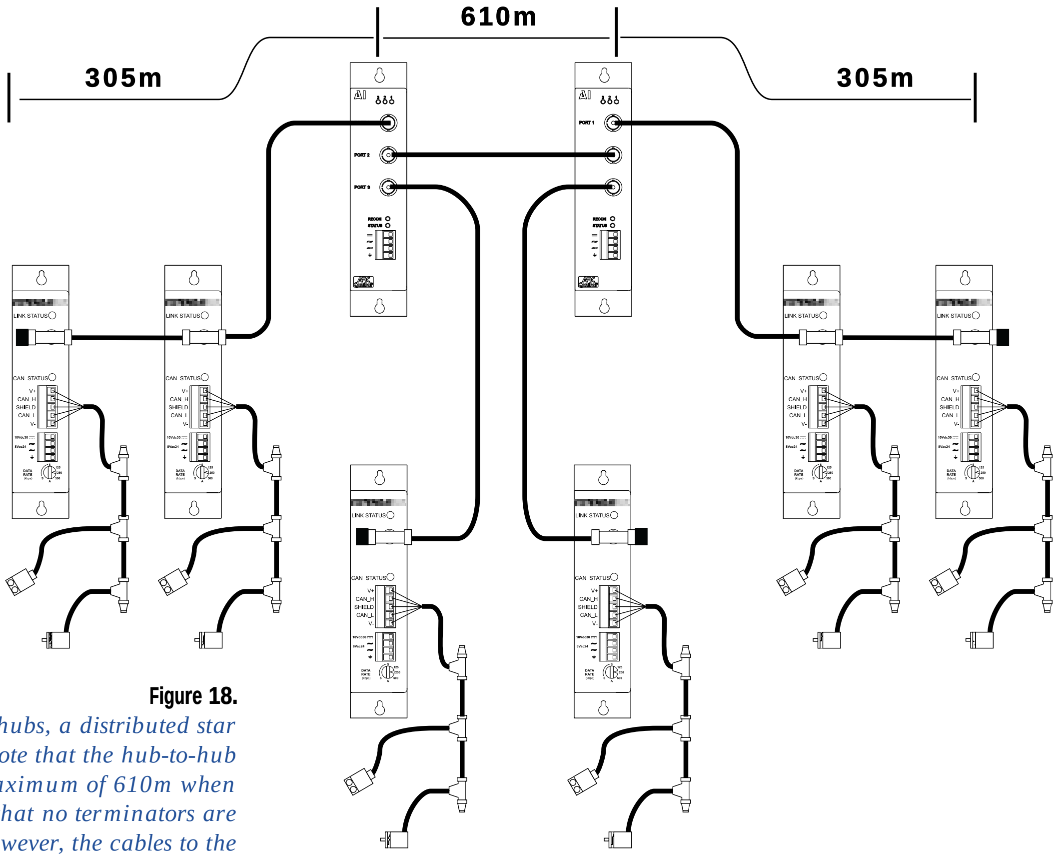


Figure 18.

By using two AI3-CXS hubs, a distributed star topology is achieved. Note that the hub-to-hub distance can be a maximum of 610m when using coaxial cable and that no terminators are used at the AI3 ports. However, the cables to the EXTEND-A-BUSes still cannot exceed 305m.

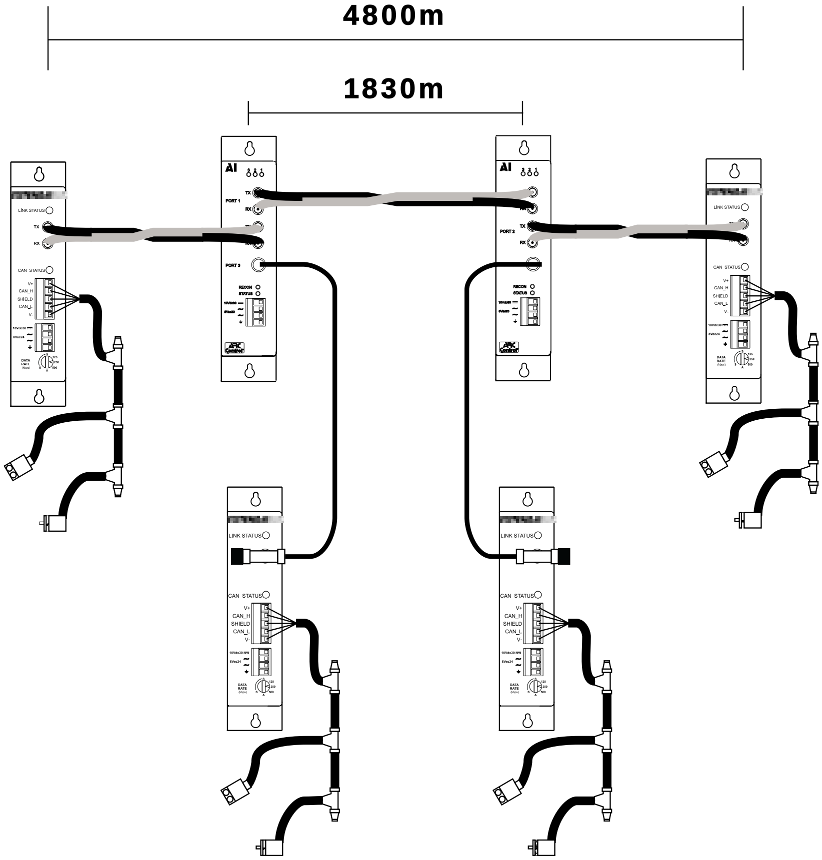


Figure 19.
By using two AI3-FOG-ST/CXB hubs, a fiber backbone can be achieved. Notice that no fiber segment can be greater than 1830m and that the total length of fiber cannot exceed 4800m. The two coaxial segments at the bottom cannot exceed 305m each.

For complete flexibility and cabling choices, the MOD HUB series can be used. The MOD HUB is an ARCNET modular active hub requiring the installation of companion expansion modules (EXP series). Expansion modules exist for coaxial cable, twisted-pair cabling and single or multimode fiber optics. The MODHUB-16 can handle up to 16 ports while the MODHUB-48 can handle up to 48 ports. The MOD HUB can be used in applications that exceed the capability of the AI series. Examples are large fiber optic systems or installations where star topology is more conducive to wiring.

System Considerations

There are some design considerations when implementing a remote bridging system.

By its very nature of storing and forwarding messages, the EXTEND-A-BUS system introduces additional signal latency which may disturb DeviceNet and Smart Distributed System with tight timing constraints. With these protocols, there has been little evidence of any timing problems. However, the potential exists for a system to erroneously signal a failed response to an action when short cabling delays are assumed. On systems with very fast scanners while operating at low data rates and lightly loaded systems, the possibility exists for the master to issue a command to a slave and fail to wait for the slave's response before issuing another command assuming a failed response. This is especially true for devices that support long fragmented messages. The solution is to increase the interscan time to either 5 to 10 ms in order to allow sufficient time for response. Another solution is to increase the data rate on all devices to 500 kbps. Still another solution is to move problem devices to the local segment (the same segment as the scanner) in order to eliminate delays due to the EXTEND-A-BUSes.

The DeviceNet and Smart Distributed System protocols support autobauding which is possible for the EXTEND-A-BUS to implement. One EXTEND-A-BUS acts as a master for all other bridges on the network functioning as slaves. The master EXTEND-A-BUS must be connected to the CAN segment connected to the master controller. As the master controller transmits data, the master EXTEND-A-BUS determines the data rate and informs all other EXTEND-A-BUSes the required data rate over the ARCNET connection. Once the data rates are determined, traffic is sent between the bridges functioning as one long extension cord. The EXTEND-A-BUS data rates can be manually set by way of a switch and there is no inherent reason why individual CAN segments cannot be set to different data rates.

Using the same extension cord analogy, it would appear that a remote bridging system must be powered before or at the same time as the slave devices or master controller in order that all devices can execute initialization routines such as duplicate MAC ID tests as in the case of DeviceNet or Smart Distributed System. However, if a remote bridge loses power while all other devices remain powered, the failure mode should be no different than cutting the cable in the middle of a CAN segment. When power is restored to the remote bridges, the restart sequence should be the same as if the maintenance person reconnected a disconnected cable.

CAN networks are usually configured in a bus or multidrop topology while ARCNET can be configured as a bus, star or distributed star topology. Therefore CAN implementations can take advantage of the more flexible ARCNET cabling options. Do not cascade EXTEND-A-BUSes beyond two since the delay stackup could be excessive. Instead, connect all EXTEND-A-BUSes in a star topology using a hub thereby reducing data latency to that of two EXTEND-A-BUSes.

Implementing fiber optics over any reasonable distance with CAN is difficult due to the increased delays caused by the additional circuitry. However, fiber optic ARCNET solutions are readily available. Therefore, the benefits of fiber optics can be gained simply by adding remote bridges. Note that the propagation delay of fiber optic cable (5ns/m) is 25% more than that of coaxial cable. This is important when calculating ARCNET delay margin and was considered when setting the 4.8 km fiber optic limit.

Rp ***Segment Repeater*** **between segments**

- Segments participate in the same media arbitration

B B ***Subnet Bridge*** **between subnets**

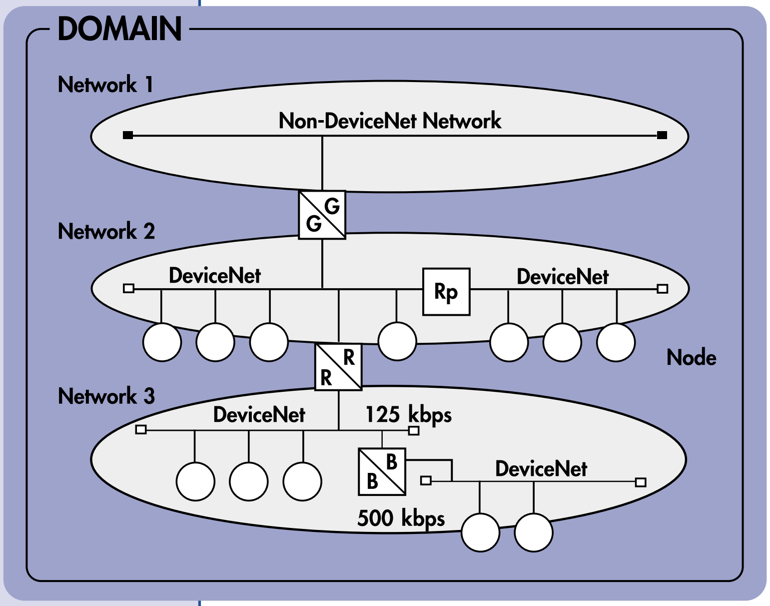
- Duplicate MAC ID check passes through
- MAC IDs on one subnet may not be duplicated on the other subnet
- Subnets may operate at different baud rates

R R ***Network Router*** **between similar networks**

- Both networks are DeviceNet

G G ***Gateway*** **between dissimilar networks**

- One network is DeviceNet, the other is not



The DeviceNet specification defines the various devices that can be used to expand a DeviceNet network. DeviceNet networks simply consist of one segment. A segment repeater must allow attached segments to participate in the same media arbitration. This requirement limits their use. The EXTEND-A-BUS is properly defined as a subnet bridge; however, the device shown is a local bridge with two CAN ports per device. Such a device would double the network length. The EXTEND-A-BUS is actually a remote bridge with one CAN port and one backbone port per device. Separate devices are required on each CAN segment; however, much greater distances can be achieved with remote bridging.

Tutorial

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