Electronic Marshalling Robustness and Performance

This document describes the details of how Electronic Marshalling with DeltaV™ delivers improved system availability and robustness compared with traditionally wired systems.

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Introduction

Emerson Process Management recently introduced an innovative way to eliminate unnecessary work and reduce costs associated with wiring field devices to process automation systems. Starting with the version 11 release, the DeltaV™ Process Automation System has Electronic Marshalling capabilities which significantly reduce new installation wiring costs as well as expensive changes to I/O late in a project. Electronic Marshalling is enabled by using CHARacterization Modules (CHARMs) instead of traditional wired cross-marshalling. For details on, and benefits of using Electronic Marshalling and CHARMs, please refer to the Electronic Marshalling Overview Whitepaper.

Network Architecture

Electronic Marshalling delivers many benefits, and at the heart of the technology are two new I/O components developed by Emerson in the version 11 release—CHARMs and the corresponding CHARM I/O Cards (CIOCs). The topology of CHARM I/O Cards in a DeltaV System is a traditional 'star' configuration, where all of the CIOCs and their related controllers are connected to one or more segregated and firewalled switches. The CIOCs are segregated from traffic on the rest of the DeltaV Control Network by this topology.

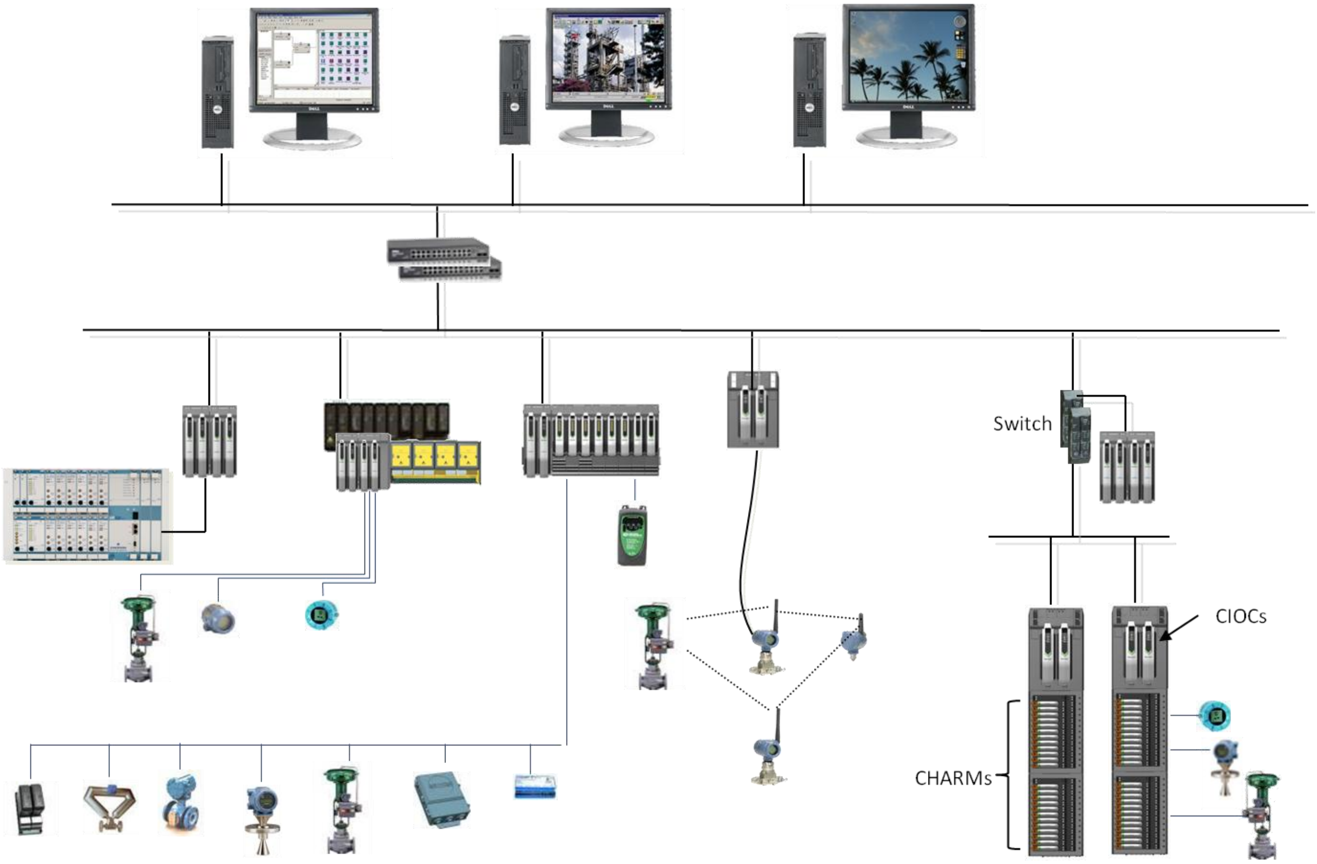

Figure 1 – DeltaV Topology with Electronic Marshalling

This network design provides maximum availability because of the redundant communication network. The primary and secondary networks are completely isolated from each other and do not share any common hardware.

CIOCs can be installed with copper or fiber optic communication modules. Fiber optic modules are end point devices and must be connected to a switch directly. Copper modules have a cascade port that can be enabled to allow a series of CIOCs to be connected together in a cascade manner, utilizing a single switch port. The I/O network can have a combination of the two topologies – star topology, with multiple CIOCs connected in cascade to each switch port. The cascade port on the copper communication modules is a way to connect additional CHARM I/O.

Full duplex communication to each device allows the network to be very efficient. Each device has a dedicated switch port that only allows through data traffic intended for that device. The full duplex connection eliminates collisions of outgoing messages with incoming data. Data packets themselves are optimally sized and packaged, allowing the switch to quickly route data from all CIOCs to the controller with extremely low latencies.

Network Performance

The DeltaV Control Network is built up on a 100 MB redundant Ethernet architecture connecting all components like Operator Workstations, Controllers and Switches. The DeltaV network ''pipe'' is virtually empty and has abundant bandwidth to accommodate additional loading. Testing at Emerson Process Management in Austin, Texas has been done to determine network performance. In a testing environment, a system with a larger node count than any DeltaV system in the world can be created. (See table below for details.)

Table 1 – System used for Node Capacity Testing

120	Controllers
65	Workstations
15	InterZone Servers
300	I/O Nodes (Remote I/O, CIOCs, Wireless I/O Cards)

The strategy was to use 150% of customer specified limits to test things such as unsolicited values sent/received, datalinks in a graphic, dynamic references and network bandwidth. Almost 1,300 test cases were performed around performance alone, and more than 1,500 test cases were performed on system capacity. With all of this testing, the DeltaV network utilization traffic is seen to run between 2-5% normally and during peak communication load, each controller may see the percent utilization of the Ethernet between 2%-10%. Network speed and bandwidth will not be an issue, even as the system expands.

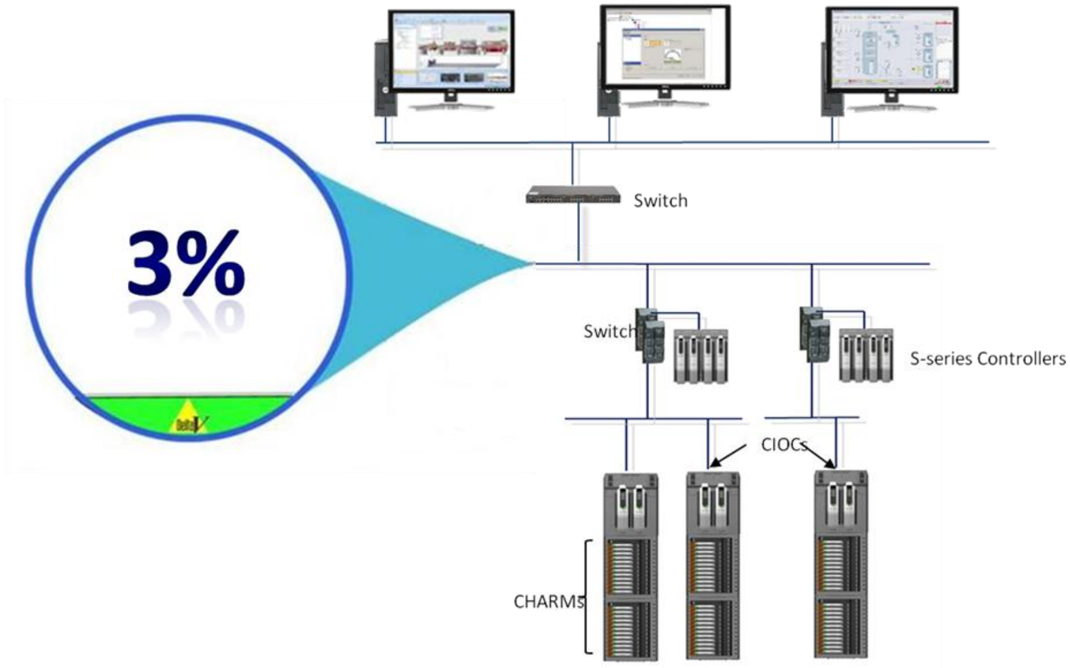

Figure 2 – A Large System Test Shows Maximum Network Load of 3%

Loop Performance

Having I/O which is not physically connected to the controller does not mean that loop performance will be affected. Scan rates and reaction times with CIOCs will be defined in a ‘screw-to-screw’ control reaction time.

Control Reaction Time

Communications between the CHARM I/O Card and the DeltaV S-series controllers have been optimized, and they have independent switching inherent in them to protect against non-control based bursts (e.g. workstation file copies, etc.). With 4 controllers talking to the maximum 16 CIOCs and with testing of 10,000s of samples at Emerson Process Management in Austin, TX, ‘screw-to-screw’ reaction times show much faster than 250ms, even as low as 126ms (with an average well below 225ms). That is, the time it takes the AI value to come into the CHARM, up to CIOC, over to the controller, through the PID, back to the CIOC and out to the AO, will average less than 225ms. The exact control reaction time for each loop will vary because of module and controller configuration, as well as CPU loading. However, almost any configuration will have a screw-to-screw reaction time at or below 250ms.

HART® Signal Performance

Electronic Marshalling supports, and even improves on, the use of HART devices. With traditional DeltaV I/O cards, up to eight HART devices on an AI or AO card must share a 1200 baud HART modem with other enabled HART channels. One of the functions of AI and AO CHARMs is to provide a HART modem. There is only one CHARM per device. Because each channel has its own modem, HART communication is faster with Electronic Marshalling.

Installation and Maintenance

Customer feedback and input was taken into consideration during the design of Electronic Marshalling and associated components, which is evident during initial project installation and during system maintenance. Features were incorporated to provide system robustness, even when the system is undergoing maintenance.

For example, the CIOC and CIOC carrier arrangement reduces the chance of installation errors. The carrier has been designed with alignment features and protected connectors that ensure proper and reliable connection of the card every time. Installation is intuitive, easy and fast. It is impossible for a CIOC to be mounted onto another type of carrier. Similarly, it is impossible for another I/O card type to be mounted onto the CIOC carrier. Furthermore, all connectors are protected from damage, should someone try to mount the CIOC on a different carrier type.

The CHARM Base plates have interlocking connectors. The connectors are designed to ensure proper installation – it is impossible to install them incorrectly. Once the base plates are connected, they will not separate due to vibration or other environmental effects. All hardware specifications and certifications can be found in the DeltaV S-series Product Data Sheet.

Base plate addressing is simple, with numbered Address Plugs. The Address Plugs clearly display the base plate address number, so that finding the correct base plate during initial installation or for maintenance is easy. The terminal block for the Address Plug is uniquely and automatically 'keyed' when the plug is installed. The keying is similar to how the CHARMs are keyed, which is discussed in detail below.

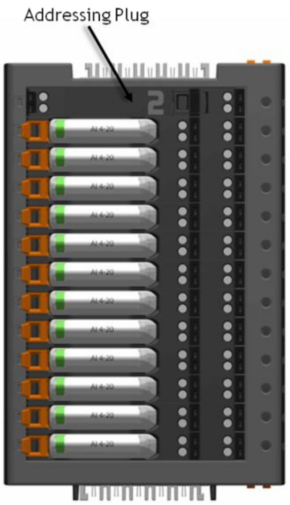

Figure 3 – CHARM Base Plate with Address Plug with Address Number 2

The address of the base plate is read upon power up/initialization of the CHARM. But failure of an Address Plug will not affect a running system. If an Address Plug fails, the system is alerted, and it can be removed online and replaced without impact to any channel.

CHARM terminal blocks ship from the factory "signal neutral", which means they will accept any type of CHARM. However, when a CHARM is first installed in a terminal block, the terminal block is 'keyed' for that signal type. This ensures that if a CHARM needs to be replaced, it will be replaced by the same CHARM type that was removed—no mistakes. On occasion, there may be a need to change the type of CHARM being used; if, for example a pressure switch is changed to a pressure transmitter, a DI CHARM needs to change to an AI CHARM. In that case, the keying posts can be reset to allow a different CHARM type to be installed.

How this works may be visualized by comparing the CHARM terminal block 'keying' to that of a clock being set, shown in Figure 4. Before a CHARM is installed, the terminal block key is in a neutral position, so we can say that the 'clock' is set at 12:00. If we take an example of an AI CHARM being installed, with the expectation of receiving a level transmitter, then the 'clock' is set to 3:00. When a level switch shows up instead of the transmitter, the AI CHARM will need to be replaced with a DI CHARM. The terminal block keying posts are simply reset, which is analogous to setting our 'clock' back to 12:00. The terminal block can now accept any type of CHARM again. Note that with this device change, wiring from the field remains untouched!

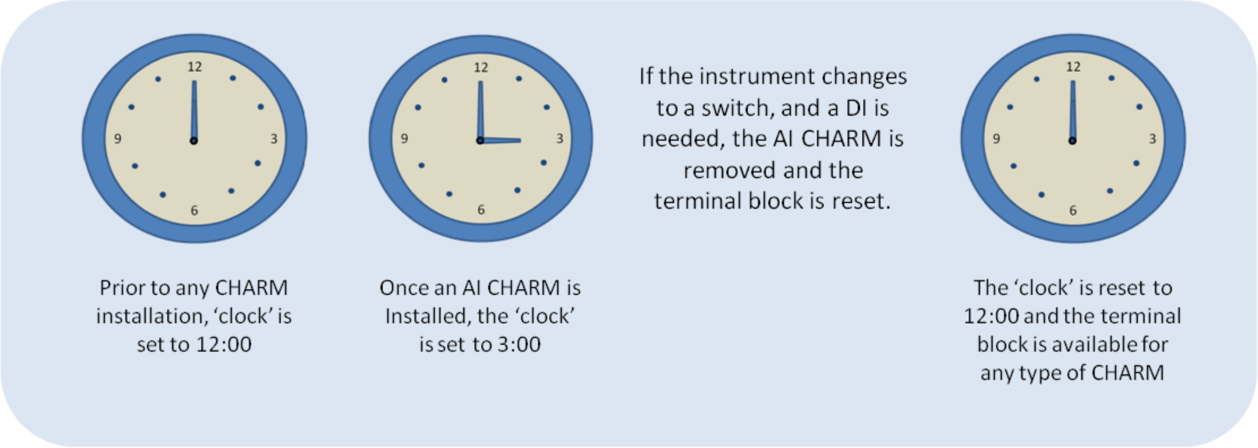

Figure 4 – Illustration of how CHARM Terminal Blocks are Keyed

Each I/O channel can be individually labeled and "tagged" right at the terminal. This eliminates the need for extra wire labeling. The hinged cover with the channel labels rotates to provide both easy access and protection for wire terminations.

Figure 5 – CHARMs with Cover and Labels

Once CHARMs are installed and the system is running, individual CHARM I/O channels can be worked on while the other channels remain fully functional. If a CHARM needs to be removed to perform field maintenance, such as checking wiring insulation, the CHARM can be partially ejected from the terminal block, so that it is disconnected from the field wiring. The CHARM can be fully removed or latched in place so that it is not dropped through grating, into the ocean, or otherwise lost. When the CHARM is latched, there is an air gap between the terminal block and CHARM, which isolates the wiring so work can be completed.

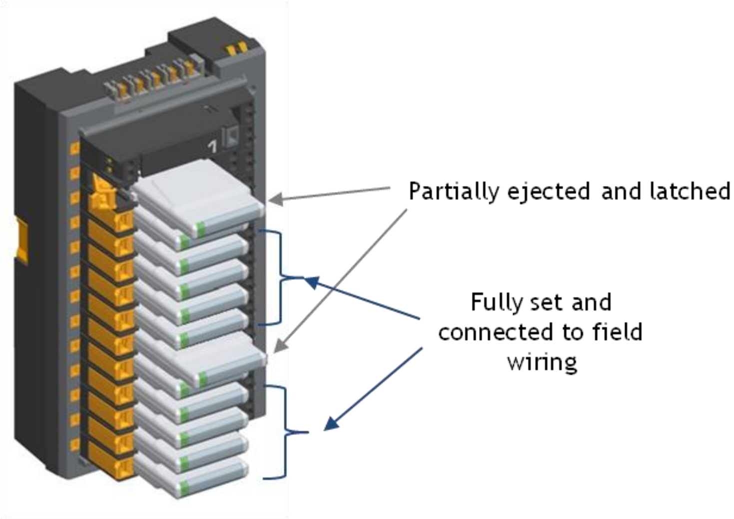

Figure 6 – Both Partially Ejected and Fully Installed CHARMs Remain in Place

Figure 7 – Lock out CHARM While Field Work is Completed

While no one wants to have stripped screws, it is a fairly common issue with field wiring. With classic I/O cards, a field technician could be connecting wires to an 8-channel terminal block. Say the screw for the sixth channel gets damaged; the technician must remove all of the first five wire pairs, get a new terminal block and start over. If a screw is stripped with CHARM I/O, the one terminal block can be replaced without rewiring anything else. This can eliminate rework and wasted time during installation, compared to using classic I/O terminal blocks.

Built for Maximum Availability

Redundancy

Process Automation Engineers require redundancy as a means of attaining high system availability. Primarily, redundancy is used to protect against component failures that could affect production. These are unplanned events that can impact multiple control signals. A secondary use of redundancy is to support online upgrades of control system software. By performing an upgrade online, system availability is maintained. Finally, redundancy offers the ability to repair the system without disruption of functioning control loops.

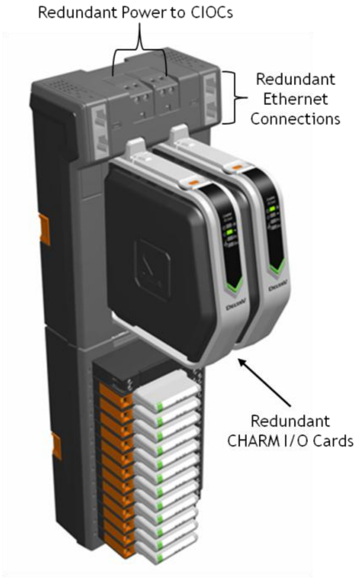

Figure 8 – Visible Indications of Redundancy with Electronic Marshalling

Electronic Marshalling is architected with full redundancy down to the individual channel.

CHARM I/O Cards

- CIOCs are redundant and, therefore, can be upgraded online.
- Each CIOC has redundant Ethernet communication modules that connect to the I/O network.

Power

- Redundant 24VDC power is supplied to the CIOCs.
- Power distribution is provided on redundant busses that connect each channel to the CHARM I/O Card.

CHARMs

- Each CHARM has two separate communication transceivers that connect the signal to the redundant bus.
- A CHARM connects the field signal to the redundant bus and provides loop power from redundant 24VDC power supplies.

CHARMs perform continuous diagnostics to confirm their availability on both power and communication busses. Internal diagnostics provide pro-active hardware alerts to developing conditions. There is no loss of control if one of these redundant transceivers stops working, and the easy replacement mechanism create an extremely low Mean Time to Repair, resulting in an extremely high availability of the field circuit.

The redundancy throughout the architecture provides the highest availability of the system I/O infrastructure while adding individual channel fault isolation of the field signal.

Single Channel Integrity

With Electronic Marshalling installations, any problem with a field loop is limited to just that loop. The CHARM has current limiting circuitry to prevent wiring faults such as short circuits or ground faults from damaging any components. Correcting the wiring restores operation of the channel. In addition, each CHARM is designed to fail open and isolate the field circuit on an excessive voltage fault, such as wiring a DC channel to an AC power source. No fault with one loop can affect any other loop or affect the availability of any other loop.

This provides increased availability for all loops compared with using classic I/O cards. With classic I/O cards, a problem with one loop may affect all other signals/loops that are connected to that card. So, at a minimum, seven other signals/loops can be lost. With higher density cards, more signals are potentially affected. However, with CHARMs, if one signal has a problem, none of the other 95 channels of the CIOC will be affected. Everything from transients and surges to field wiring faults will be contained to the single loop.

In the event of a CHARM failure, replacement of the CHARM is fast, with no engineering or configuration activity required. Replacement of the CHARM or terminal block itself impacts only that single channel. This is different than a traditional terminal block, in that all signals on a traditional terminal block must be disconnected to replace it. The single channel granularity of CHARMs reduces the repair time to a matter of minutes without impact to any other signal. Replacing CHARMs is not an issue for the CIOCs, because they are able to communicate with all versions of CHARMs.

With the single channel integrity design of CHARMs, Electronic Marshalling provides higher availability of all control loops compared to traditional I/O cards and wiring.

CHARMs as Part of the Field Loop

CHARMs provide several basic functions, such as:

- Signal conditioning
- Analog to digital conversion
- Powering the field device
- Protecting against line faults
- Acting as a disconnect mechanism for isolating field wiring
- Provide a HART® modem (AI and AO CHARMs)

The ability of CHARMs to protect against line faults and isolation of field wiring has been previously discussed in the Single Channel Integrity topic. The other CHARM functions demonstrate that CHARMs have been designed to be a part of the field circuit. The redundancy in the Electronic Marshalling architecture is also previously described, and we saw redundancy to the individual channel.

Because of design elements incorporated into Electronic Marshalling around redundancy, single channel integrity and the functions of the CHARMs, the availability of each loop is higher compared with classic I/O cards. Furthermore, the Mean Time to Failure (MTTF) of the CHARM is considerably higher than that of the simplex field instruments. Field instruments, while designed for harsher environments, are far more likely to fail, partly due to these harsher environments.

System Availability

The normal life period and amount of failures for any component can be depicted by a 'bathtub curve'.

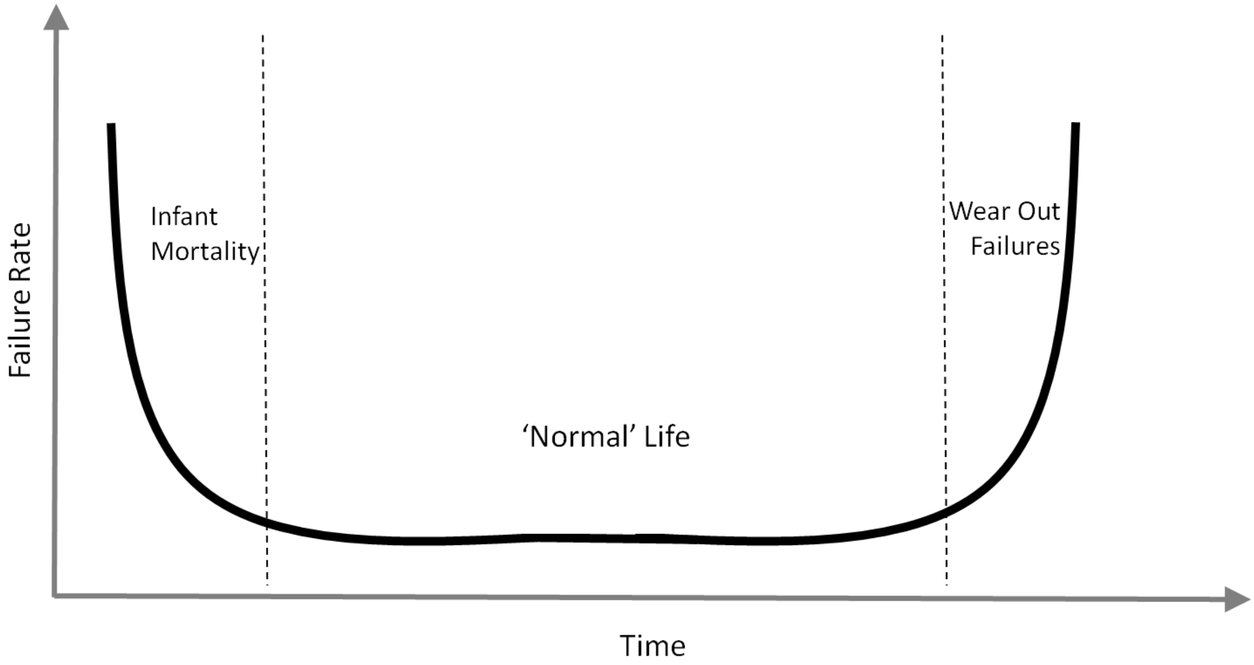

Figure 9 – Bathtub Curve Example

There are typically higher rates of failure early in a component's life span, referred to as infant mortality. These often occur upon power up of the components due to quality issues in manufacturing. During the normal life of the component, the rate of failures is basically constant. And then, as a component nears the end of its life span, failure increase due to wear out.

Emerson has processes in place to prevent high infant mortality failure rates when they are first put into service. For example, CHARMs are power cycled at both -40°C and 70°C to significantly reduce the infant mortality in the field.

Mean Time to Failure

Mean Time to Failure is a statistical indication on the likelihood of a failure of a certain population of components over time. Mean Time to Failure is used for mechanisms that cannot be repaired or resume normal operation. From the bathtub curve, the failure rate during the normal life of the component is Mean Time to Failure (MTTF). As shown in Figure 7, MTTF is essentially the same throughout the normal life of a mechanism.

To further illustrate, a general example can be used. Hard drives are components in a laptop, and have an MTTF. For the example, say the MTTF for a hard drive is 100 years. This doesn't mean that one hard drive will last one hundred years. It means that, given one hundred hard drives, I can expect that one will fail over the course of a year.

If a CHARM fails, it will have to be replaced, not repaired, so MTTF is used to describe its reliability. At the time of writing, only theoretical MTTF values for Electronic Marshalling components are known. Once a significant population of CHARMs is in use, actual MTTF values will be calculated to replace the theoretical values. A comparison can be made between theoretical MTTF values from classic I/O cards and theoretical MTTF values for CHARMs. While actual MTTF numbers cannot be published due to confidentiality, it is found that CHARMs have a much higher theoretical MTTF than their classic I/O counterparts.

Table 2 – Comparison of Theoretical MTTF: Classic I/O and CHARMs

Classic I/O	CHARM Type	Multiplier
AO Card, 4-20 mA w/ Hart, Series 2	AO 4-20mA HART	7.53x
DI Card, 24VDC, Dry Contact, Series 2	DI 24V Dry Contact	3.95x
DO Card, 24VDC, High Side, Series 2	DO 24VDC High Side	4.67x

Worthy of noting is that based on past experience with actual MTTF numbers, compared with theoretical values, it is expected that the Electronic Marshalling MTTF will be shown to be significantly higher than the theoretical values. Of the Classic I/O cards listed above, the actual MTTF values increased typically between 11 and 36 times more than their theoretical values.

Mean Time Between Failure

Mean Time Between Failure (MTBF) is the average amount of time a system will run between failures. The model assumes the failed system will be repaired and restarted. This is in contrast to the Mean Time To Failure (MTTF), where the assumption is that the failure is not repairable. MTBF is used to determine system availability for a DeltaV System, because the component that caused the system failure can be repaired or replaced, and then the system can be started again.

System availability (MTBF) is not a number that can be given for every DeltaV system. The exact hardware components for a system must be known, because the MTTF values of the system components are used in the system availability calculation. In addition to the individual MTTF values, Mean Time To Repair (MTTR) is another factor used in the MTBF calculation. MTTR will vary from site to site and be based variables such as: whether or not the failure is in a hazardous area, are components on site, and does the failure/repair affect other channels in the system.

In order to demonstrate the reliability and robustness of Electronic Marshalling, a comparison was made between a system using DeltaV Classic I/O cards and a system using DeltaV Electronic Marshalling. The following tables show the I/O hardware used for each case. The rest of the system components (controllers, workstations, etc.) were the same for each case. For both systems, a Mean Time to Repair of four hours was assumed.

Table 3 – I/O Hardware, Classic I/O

Number of Redundant Pairs	Description
16	Analog Input Card and Term Block; 4-20mA; HART; 8-Channels
7	Analog Output Card and Term Block; 4-20mA; HART; 8-Channels
29	Discrete Input Card and Term Block; 24VDC; Isolated; 8-Channels
13	Discrete Output Card and Term Block; 24VDC; Isolated; 8-Channels
17	8-wide Carriers

Table 4 – I/O Hardware, Electronic Marshalling

Quantity	Description
128	Analog Input; 4-20mA; HART CHARMs
56	Analog Output; 4-20mA; HART CHARMs
232	Discrete Input; 24 VDC Dry Contact CHARMs
104	Discrete Output; 230 VAC; Isolated CHARMs
65	CHARM Base Plates
6	Redundant CHARM I/O Card Carriers
12	Redundant CHARM I/O Card Pairs

Electronic Marshalling Delivers Higher Availability

For this example and set of assumptions, the system using Electronic Marshalling has a higher availability than a system with redundant classic I/O cards. Looking specifically at the I/O subsystem, there is a dramatic reduction in the estimated downtime per year. While the estimated downtime of both I/O subsystems is only in the seconds per year, the Electronic Marshalling subsystem has seconds of downtime per year that is in thousands of times less than the classic I/O subsystem.

Summary

While creating a system architecture which will greatly reduce costs associated with installing, changing or adding I/O, Emerson Process Management also made improvements to overall system robustness and performance. DeltaV process automation systems provide excellent reliability with Electronic Marshalling. This architecture provides redundancy down to the individual channel. Additionally, single channel integrity protects loop errors from affecting any other loop.

Tests run at Emerson in Austin show that neither network performance nor control loop performance are degraded with Electronic Marshalling. Even as a DeltaV system grows, control network speed and network bandwidth will maintain excellent performance. Control loop performance tests with CHARMs have also shown fast loop performance capabilities.

Electronic Marshalling is one of the options with DeltaV I/O on Demand. I/O on Demand enables users to choose the I/O of any type, anytime, anywhere. Users will find Electronic Marshalling to be a highly reliable and excellent performing option for adding traditional or HART devices.

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