# EXPANDING
# PLC CAPABILITIES

A Network-Based Approach to
Specialty Control

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# SUMMARY

## Executive Summary

Many industrial systems require specialty motion control and position feedback functions that are not supported natively by the installed PLC platform. Resolver inputs, SSI interfaces, and low-axis motion control are common needs, yet many PLC families either do not provide these capabilities or only support them in higher-tier controllers or backplane modules.

When these functions are unavailable, engineers are often forced to upgrade the PLC, add rack expansion hardware, redesign control panels, or integrate third-party devices. These approaches increase cost, engineering effort, and system complexity. In retrofit or validated production environments, controller replacement may not be practical due to downtime and requalification risks.

Physical layout constraints further complicate integration. Sensors and actuators are frequently located far from the control cabinet, requiring long signal runs that are susceptible to electrical noise and grounding issues, particularly for resolver and SSI signals.

A distributed, network-based architecture provides an alternative. By moving specialty motion and feedback functionality off the PLC backplane and onto industrial Ethernet, these capabilities can be added without consuming rack space or swapping the controller. Modules can be mounted near the device, reducing cabinet space and cabling, while maintaining integration through standard industrial protocols.

The AMCI mini-Nexus product family applies this approach through compact, DIN rail-mounted modules that provide motion control, SSI interfaces, and resolver signal conversion over industrial Ethernet. This paper examines the constraints that drive specialty I/O challenges and outlines a practical method for extending PLC capability without redesigning the control system.

# 1. THE CHALLENGE

### 1.1. Gaps in Native PLC Functionality

Many PLC platforms do not natively support one or more of the following:

- Resolver inputs
- SSI (Synchronous Serial Interface) feedback
- Stepper motor control

When these functions are required, the available options are often limited to:

- Upgrading to a higher tier controller within the same platform
- Migrating to a different PLC family
- Adding specialty backplane modules, if available
- Integrating third party standalone motion or signal conversion hardware

Each of these options introduces additional engineering overhead. Controller upgrades may require firmware changes, software migration, and revalidation of the control program. Platform migration can affect spare parts strategy, maintenance training, and long-term support. Specialty modules may only be available in certain rack formats, limiting flexibility. The core issue is structural: the required functionality exists, but not within the constraints of the installed PLC architecture.

### 1.2. Backplane and Rack Constraints

PLC expansion is traditionally tied to physical rack space. Backplane-based architectures impose hard limits:

- Limited rack space
- Power supply capacity limits
- Mechanical enclosure constraints
- Limited expansion provisions in compact controllers

**ARCHITECTURAL INSIGHT**

Moving specialty functionality beyond the PLC rack removes one of the biggest architectural constraints in industrial automation.

In retrofit systems, it is common to encounter fully populated racks or enclosures with no physical space for expansion. Adding a new rack or enclosure introduces additional wiring, mounting requirements, and panel redesign. In OEM equipment with fixed cabinet dimensions, redesign may not be practical. Backplane dependence becomes a limiting factor when specialty functions are required after initial deployment.

### 1.3. Physical Separation and Signal Integrity

In many industrial systems, sensors and actuators are not located near the control cabinet. Conveyors, presses, rotating equipment, and moving assemblies often place feedback devices far from the PLC.

For standard digital I/O, long cable runs are manageable. However, resolver and SSI signals are more sensitive to:

- Electrical noise
- Ground potential differences
- Shielding and termination quality
- Signal degradation over distance

Long signal runs increase installation labor and introduce potential failure points. In electrically noisy environments, maintaining signal integrity becomes more difficult.

The architecture of centralized PLC backplanes often forces sensitive signal wiring to travel longer distances than necessary.

### 1.4. Harsh Environment Feedback Requirements

Certain applications require resolvers instead of encoders due to environmental conditions such as:

- High vibration
- Extreme temperatures
- High electromagnetic interference

Resolvers are mechanically robust and well suited for heavy industrial environments. However, PLC platforms frequently lack native resolver inputs. External resolver to digital converters are commonly used, but these add integration complexity and additional hardware layers. This creates a practical gap: the preferred sensing technology may not align with the PLC’s supported interfaces.

### 1.5. Low Axis Motion Requirements That Do Not Justify Full Motion Systems

Many machines require limited motion capability, such as:

- Single-axis indexing
- Simple positioning
- Basic closed loop stepper control

Full multi-axis motion platforms may exceed the technical requirements of the application. However, without native stepper or servo support in the PLC, engineers must either:

- Integrate a separate motion controller
- Move to a motion-capable PLC family
- Implement custom drive-level control strategies

This results in added cost and architectural complexity for applications that only require modest motion capability.

### 1.6. The Underlying Pattern

Across these scenarios, a common pattern emerges:

- The installed PLC platform defines architectural boundaries.
- Specialty functionality is needed outside those boundaries.
- Traditional expansion methods are tied to the backplane.

When a required function falls outside the controller's native capability set, engineers are forced to modify the control architecture rather than simply extend it. The problem is not the absence of motion or feedback technology. The problem is the structural limitation of backplane centric expansion in modern industrial systems.

# 2. A BETTER ARCHITECTURE

### 2.1. Architectural Alternative: Distributed Specialty Modules

The limitations described in the previous section stem largely from one structural characteristic of traditional control systems: reliance on the PLC backplane as the primary expansion mechanism. When additional functionality is required, the conventional approach is to add a module to the rack. If the rack is full or the module does not exist for that platform, architectural changes become necessary.

An alternative approach is to decouple specialty functionality from the PLC backplane entirely. Instead of expanding through physical slots, specialty motion and feedback capabilities can be implemented as distributed modules connected over industrial Ethernet. In this model, the PLC remains the central controller, but now resolver feedback, SSI feedback, or motion control functions can operate via the industrial Ethernet network.

This shift changes several structural constraints:

- Expansion is no longer limited by rack slots.
- Specialty hardware does not need to match the PLC's backplane format.
- Modules can be mounted near the associated devices.
- Sensitive signal wiring can be shortened.
- Integration occurs over standard industrial protocols rather than proprietary backplane interfaces.

From an architectural standpoint, the PLC becomes a network master unit rather than a chassis that must physically host every capability.

### 2.2. Removing Backplane Dependency

Backplane-based expansion imposes physical and electrical limits. Distributed Ethernet-based modules remove those limits by operating independently of rack slot availability.

In practical terms, this means:

- No need to add a new rack for a single specialty function.
- No dependency on controller family-specific modules.
- No requirement to migrate to a higher tier PLC to access specialty I/O.

The PLC interacts with the distributed module through standard network messaging, treating it as an addressable device rather than a physical slot. This approach preserves the existing controller investment while extending capability.

### 2.3. Network Reliability Considerations

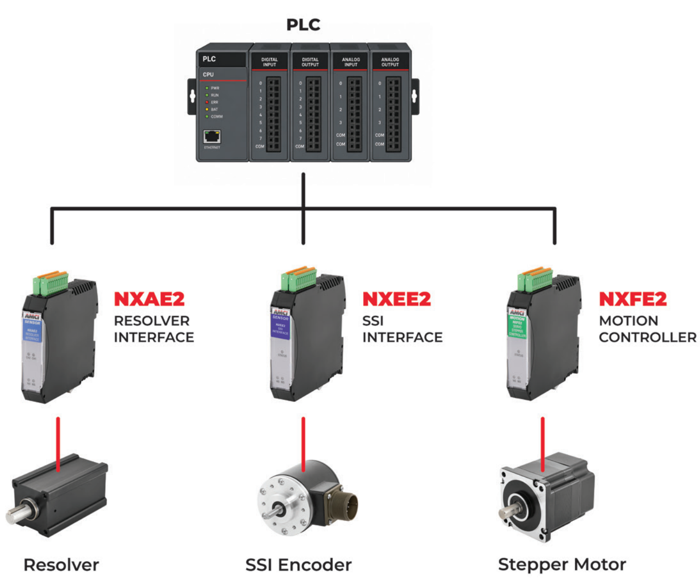
A distributed architecture shifts dependency from the backplane to the network. For this reason, network reliability becomes a critical design factor. Industrial Ethernet technologies such as Device Level Ring (DLR) and Media Redundancy Protocol (MRP) allow networked devices to be configured in ring topologies that maintain communication in the event of a cable break. When distributed specialty modules support dual Ethernet ports and redundancy protocols, they can be integrated into fault-tolerant network designs without introducing single points of failure. In this architecture, reliability is maintained not by physical proximity to the PLC rack, but by resilient network design.

### 2.4. A Structural Shift Rather Than a Feature Addition

The transition from backplane expansion to distributed modules represents a structural change in system design. Rather than asking if the PLC can support this function in a slot. The question becomes, can this function be implemented as a networked device?

This reframing removes several constraints simultaneously:

- Rack limitations
- Controller family limitations
- Panel redesign requirements
- Long sensitive signal runs




**BEYOND THE BACKPLANE**

- No dependence on rack slots
- Specialty modules for resolver, SSI, and motion
- Mount near the device
- Shorter, cleaner wiring
- Integrates over standard Intustrial Ethernet

# 3. THE MINI-NEXUS SOLUTION


### 3.1. Implementation: The mini-Nexus Product Family

The distributed architecture described in the previous section requires specialty modules that operate independently of the PLC backplane while integrating cleanly over industrial Ethernet. The mini-Nexus product family implements this model for three specific functional gaps commonly encountered in industrial systems:

- Stepper motion control
- High resolution SSI feedback
- Resolver signal conversion

The family consists of:

- **NXFE2** – Ethernet-based stepper control
- **NXEE2** – Ethernet-based SSI interface
- **NXAE2** – Ethernet-based resolver interface

Each module is designed as a self-contained DIN rail device with dual Ethernet ports and multi-protocol support, allowing it to operate as a distributed functional node within a PLC controlled system.

### 3.2. Structural Characteristics of the Platform

All mini-Nexus modules share several architectural characteristics that align with the distributed model:

Network Integration

- Dual Ethernet ports for linear or ring topologies
- Support for industrial Ethernet protocols used by major PLC platforms
- Compatibility with DLR and MRP network redundancy schemes

Mechanical and Electrical Form

- Compact DIN-rail mounting
- 24 VDC industrial power
- Designed for placement outside the main PLC cabinet when required

Programming Model

- Configured by the host PLC
- EDS files for device recognition
- Add-On Instructions (AOIs) for structured integration in supported PLC environments
- Integrated web server for simplified setup

These characteristics allow the modules to function as extensions of the PLC without being physically tied to the rack.

### 3.3. NXFE2 – Distributed Stepper Control

The NXFE2 provides stepper motor control over Ethernet, eliminating the need for a dedicated motion slot within the PLC rack.

From an engineering standpoint, this addresses several recurring conditions:

- PLC platforms that do not natively support stepper control
- Applications requiring one or two axes where a full motion controller is excessive
- Retrofit systems where no rack space is available

The NXFE2 handles motion control locally while receiving commands and parameters from the PLC. This reduces scan time dependency for pulse generation and isolates motion control from backplane limitations.

Typical applications include:

- Linear actuators
- Indexing tables
- Feed mechanisms
- Cut-to-length systems

**WHY IT MATTERS**

Instead of generating high-speed motion inside the PLC, the NXFE2 executes motion locally while the PLC simply issues commands.

By distributing stepper control, motion capability can be added without altering the core PLC architecture.

### 3.4. NXEE2 – Distributed SSI Interface

High resolution SSI sensors are commonly used in applications requiring precise position feedback. However, many PLC platforms lack native SSI input capability.


The NXEE2 provides:

- Direct SSI signal acquisition
- High-resolution position data conversion
- Ethernet-based transmission of processed data to the PLC

Mounting the interface close to the sensor reduces SSI cable length and associated noise concerns. The PLC receives digital position data over Ethernet, eliminating the need for specialized backplane modules or external converters.

Typical use cases include:

- Linear position measurement
- Laser displacement systems
- High resolution absolute encoders
- Precision assembly systems

The module effectively converts SSI from a specialty interface into a standard networked data source.

### 3.5. NXAE2 – Distributed Resolver Interface

Resolvers remain preferred in heavy industrial environments due to their durability and noise immunity. However, native resolver support is uncommon in general purpose PLC platforms.


The NXAE2 performs:

- Resolver-to-digital conversion
- Signal conditioning and processing
- Ethernet transmission of position data

Placing the module near the resolver reduces analog signal exposure to long cable runs and electrical interference. The PLC interacts with the device as a position feedback node rather than directly processing resolver signals.

Typical environments include:

- Metal forming and stamping
- Heavy presses
- Mining equipment
- High temperature or high vibration machinery

This allows robust feedback devices to be used without requiring a resolver capable PLC backplane module.

### 3.6. Common Design Intent Across the Family

Although each module addresses a different functional gap, the design intent is consistent:

- Keep the PLC as the system controller
- Move specialty signal processing and motion control out of the rack
- Transmit structured data over Ethernet
- Maintain compatibility with existing industrial network topologies

The mini-Nexus family does not replace the PLC. Instead, it extends the PLC’s practical capability without requiring controller migration, rack expansion, or platform changes.

# 4. INSIDE THE TECHNOLOGY

## 4.1. Internal Design and System Integration

Each of the mini-Nexus modules contains dedicated processing, signal conditioning hardware, and firmware designed to manage time sensitive functions locally while presenting structured data to the host PLC over Ethernet. This division of responsibility is intentional. High speed signal processing and motion control occur inside the module, while supervisory control remains in the PLC.

## 4.2. Processing Architecture

Each module contains:

- A dedicated microcontroller or processor
- High speed input/output circuitry specific to the function
- Non-volatile configuration memory
- Industrial Ethernet communication hardware

The PLC does not generate step pulses, decode SSI bit streams, or demodulate resolver sine/cosine signals directly. Instead:

- The module performs signal acquisition and processing locally.
- The PLC exchanges command and status data cyclically over Ethernet.

This reduces PLC scan time dependency and isolates specialized timing requirements from the controller's ladder logic or structured text execution.

The result is more predictable system performance, particularly in applications where:

- PLC scan time varies under load
- Network traffic fluctuates
- Multiple devices share the same Ethernet segment

## 4.3. NXFE2: Motion Control Model

Stepper motor control requires deterministic pulse generation and accurate motion profiling. Attempting to generate high-frequency pulse trains directly from a PLC can introduce jitter, particularly when controller scan time increases.

The NXFE2 handles:

- Pulse generation
- Direction control
- Acceleration and deceleration profiles
- Position tracking

The PLC provides:

- Target position or velocity
- Motion parameters
- Start/stop commands
- Fault reset control

Internally, the NXFE2 executes motion profiles using its own timing base. The PLC monitors position feedback and status words rather than managing pulse-level output.

This separation provides:

- Stable motion performance independent of PLC scan variation
- Reduced program complexity in the PLC
- Cleaner diagnostics (all status information is located in the PLC)

### 4.4. NXEE2: SSI Signal Acquisition

SSI communication is a synchronous serial protocol requiring precise clocking and bit-level data acquisition. Cable length and noise can affect signal reliability.

The NXEE2 performs:

- Clock generation for the SSI device
- Bitstream capture
- Resolution handling (single-turn or multi-turn)
- Data validation

Once acquired, the module presents position data to the PLC as structured digital values.

From the PLC's perspective, the data appears as:

- Position words
- Status bits
- Error indicators

The PLC does not manage SSI clock timing or bit alignment. That responsibility remains inside the module, reducing programming complexity and improving reliability.

### 4.5. NXAE2: Resolver Signal Conversion

Resolver signals consist of analog sine and cosine waveforms modulated by rotor position. Extracting position data requires:

- Signal excitation
- Analog front end conditioning
- Demodulation
- Angle calculation

The NXAE2 performs these steps internally:

- Provides resolver excitation voltage
- Conditions and filters sine/cosine inputs
- Calculates angular position
- Detects signal faults or loss conditions

Calculated position data and diagnostics are transmitted to the PLC.

By performing conversion locally, the module reduces:

- Sensitivity to long analog cable runs
- Exposure to electrical noise in control cabinets
- The need for PLC based resolver interface hardware

### 4.6. Network and Protocol Handling

Each module supports industrial Ethernet protocols commonly used by major PLC platforms. The communication model typically includes:

- Cyclic I/O data exchange
- Explicit messaging for configuration
- Standard device descriptors (EDS files)
- Structured integration through Add-On Instructions where supported

Dual Ethernet ports allow:

- Linear topology integration
- Ring topologies using DLR or MRP

In ring configurations, a cable break does not necessarily interrupt communication, provided the network is configured for redundancy.

This ensures that distributing functionality away from the PLC rack does not compromise system reliability.

### 4.7. Configuration and Diagnostics

All modules include:

- Web-based configuration interfaces
- Parameter storage in non-volatile memory
- Status and fault reporting over Ethernet

During normal operation, configuration is managed by the PLC, preserving centralized control.

Diagnostics typically include:

- Communication status
- Device specific fault conditions
- Signal integrity indicators
- Motion or feedback error flags

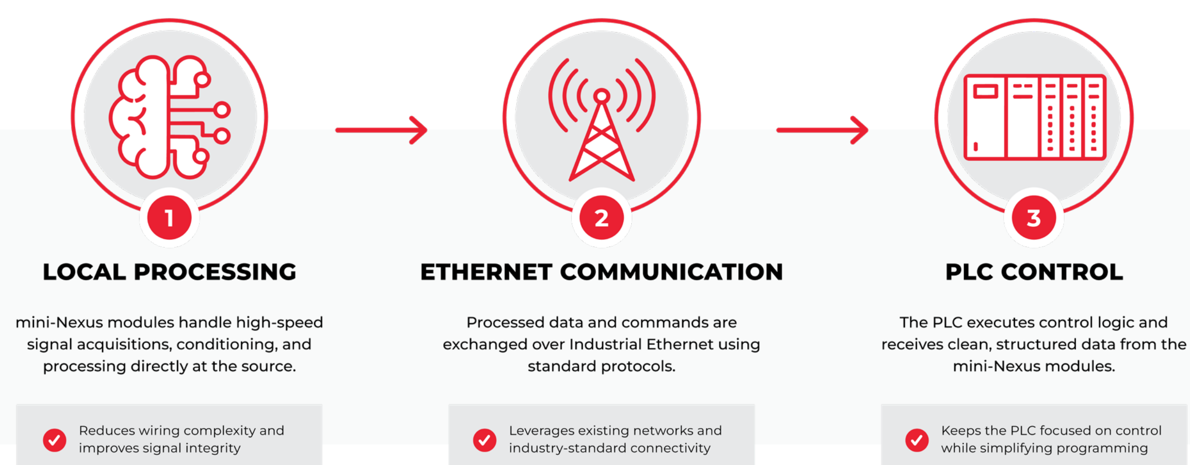
This design keeps troubleshooting localized. A resolver wiring fault, SSI signal error, or motion issue is reported at the module level rather than appearing as an ambiguous PLC failure.

### 4.8. Design Philosophy

Across all three modules, the internal design follows the same engineering principle:

1. Handle time-critical, signal-sensitive tasks locally.
2. Transmit clean, structured data to the PLC.
3. Preserve PLC platform independence.

The modules act as functional extensions of the controller without becoming dependent on its physical architecture.



# 5. REAL-WORLD APPLICATIONS

## 5.1. Application Scenarios and System Level Impact

The distributed specialty module approach becomes most relevant when systems are constrained by physical layout, environmental conditions, or legacy controller architecture. The following scenarios illustrate where this model provides measurable engineering value.

## 5.2. Retrofits with Fixed PLC Infrastructure

In many existing facilities, PLC platforms are standardized and difficult to change. Spare parts inventory, technician training, and validated control programs are all tied to the installed controller family.

When a new requirement arises, such as adding resolver feedback or a precision SSI sensor, the options are limited:

- Upgrade to a higher tier PLC
- Add an expansion rack
- Integrate standalone third-party signal converters

Each option increases integration time and cost.

A distributed module allows the new functionality to be added over Ethernet without modifying the existing rack layout. The PLC program is extended, but the controller hardware remains unchanged.

Typical retrofit examples include:

- Adding a linear positioning system to an existing conveyor
- Replacing a failed encoder with a resolver in a harsh area
- Upgrading to higher-resolution feedback in a forming system

Existing conveyor upgraded with precision positioning while preserving the installed PLC platform.

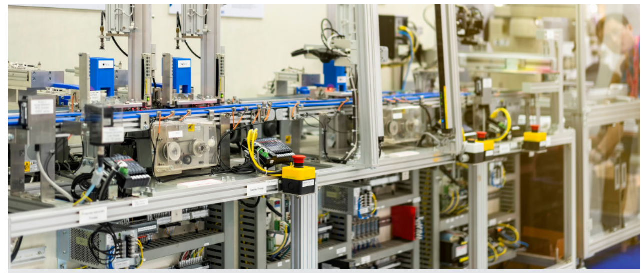
In these cases, the distributed module minimizes architectural disruption.

### 5.3. Machines with Limited Cabinet Space

OEM equipment is often designed around tightly constrained enclosure dimensions. Additional rack-based modules may not fit within the original panel layout.

Installing a distributed DIN-rail module near the motor or sensor can eliminate the need for:

- Cabinet redesign
- Additional enclosures
- Long field wiring runs



Compact automation equipment often leaves little room for additional rack-based expansion. Distributed Ethernet modules can be mounted near the machine, reducing cabinet redesign and simplifying installation.

For example:

- A stepper axis added to a packaging machine
- An SSI linear scale integrated into a compact assembly station

The module can be mounted locally, with only Ethernet and 24 VDC routed back to the control system.

This approach simplifies mechanical design and reduces panel density.

### 5.4. High Noise or Harsh Industrial Environments

Resolvers are commonly selected for environments with:

- High vibration
- Elevated temperatures
- Oil or debris contamination
- Significant electromagnetic interference

However, resolver-to-digital conversion hardware is often placed in the main control cabinet, requiring long analog signal runs.

By mounting a resolver interface module closer to the sensor, analog wiring length is reduced. The conversion to digital position data occurs near the source, and only Ethernet communication extends back to the PLC.

This improves:

- Signal integrity
- Noise immunity
- Diagnostic clarity

Applications that benefit include:

- Metal forming presses
- Mining conveyors
- Heavy stamping equipment
- Industrial processing machinery

Heavy stamping and metal forming equipment often requires resolver-based feedback because of vibration, shock loading, and electrically noisy operating conditions.

**5.5. Low Axis Motion Without Full Motion Platforms**

Not every machine requires multi-axis coordinated motion. Many applications need only:

- Single-axis indexing
- Simple point-to-point positioning
- Feed-to-length control

When a PLC platform does not natively support stepper control, engineers may be forced to integrate a separate motion controller or upgrade to a motion-capable PLC.

A distributed stepper control module allows:

- Motion control independent of PLC scan time
- Command level integration in the PLC
- Simplified motion logic

This is particularly useful in:

- Cut-to-length systems
- Labeling machines
- Small packaging lines
- Secondary positioning axes on larger systems

The system gains motion capability without transitioning to a full motion control architecture.

Labeling systems are a common example of applications requiring simple, single-axis positioning rather than a full multi-axis motion platform.

**5.6. Modular and Distributed Machine Designs**

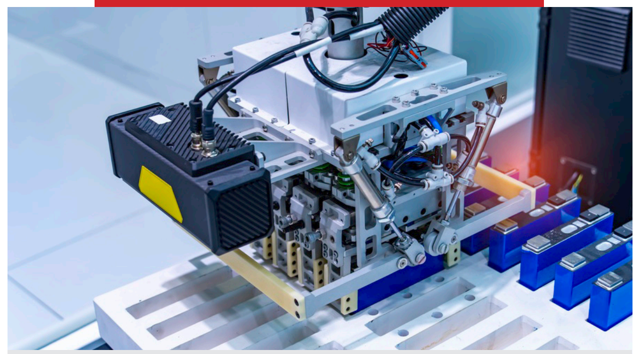
Modern machine designs increasingly favor modular construction. Subassemblies may be built and tested independently before final integration.

Distributed specialty modules align well with this approach:

- Each module can serve a machine subassembly
- Ethernet integration simplifies system interconnection
- Commissioning can occur at the module level

In a modular system, resolver, SSI, or stepper functionality becomes a contained node rather than a centralized rack dependency.

This improves scalability. Additional axes or sensors can be added without restructuring the primary control panel.



Modern automation systems are increasingly built from independent machine modules that can be assembled, tested, and commissioned before final system integration.

### 5.7. System Level Engineering Impact

Across these scenarios, the technical impact is consistent:

- Reduced dependence on PLC rack architecture
- Shorter sensitive signal wiring
- Lower integration complexity for specialty functions
- Preservation of existing PLC platforms

The distributed model does not eliminate the PLC's central role. Instead, it redistributes specialized signal handling and motion control to purpose-built modules while maintaining centralized control logic.

The result is a system that is more adaptable to change without requiring controller replacement or major mechanical redesign.

**SYSTEM IMPACT**

- Preserve existing PLC investments
- Reduce panel redesign
- Simplify commissioning
- Improve scalability

## 6. CONCLUSION

Industrial control systems are typically constrained by the architecture in which they were originally deployed. PLC backplanes define available functionality, physical expansion is limited by rack space, and specialty interfaces are often tied to specific controller families. When new motion or feedback requirements arise, engineers are frequently forced to modify the controller platform rather than simply extend it.

The core issue is architectural dependency.

Stepper control, SSI acquisition, and resolver conversion are not uncommon requirements. However, native support for these functions is inconsistent across PLC platforms. Traditional expansion methods — adding rack modules, upgrading controllers, or integrating standalone converters — increase system complexity and integration effort.

The distributed specialty module model addresses this constraint by separating time-sensitive and signal-sensitive tasks from the PLC backplane. Motion control, SSI bitstream handling, and resolver demodulation are performed locally within purpose-built modules. The PLC retains supervisory control and exchanges structured data over industrial Ethernet.

This approach changes the integration model:

- Expansion is no longer limited by physical rack slots.
- Sensitive analog and serial signals are shortened and localized.
- PLC scan time is isolated from pulse-level motion timing.
- Resolver and SSI interfaces become networked data sources rather than backplane dependencies.

From an engineering perspective, the value is structural rather than cosmetic. The mini-Nexus family allows specialty functionality to be added without redesigning the controller foundation of the system.

For the end user and system integrator, this translates to:

- Preservation of existing PLC investments
- Reduced panel modification and wiring overhead
- Simplified commissioning and diagnostics
- Controlled system scalability

The modules do not replace the PLC. They extend its practical capability beyond the constraints of its physical architecture. By distributing specialty motion and feedback functions over Ethernet, systems can evolve without requiring controller migration or structural redesign.

In environments where uptime, maintainability, and incremental expansion matter, architectural flexibility has measurable value. The distributed model implemented by the mini-Nexus product family provides a method for achieving that flexibility while maintaining centralized control and network-integrated reliability.

## ABOUT AMCI

AMCI is a leading US based manufacturer whose expertise with PLC networked products provides the best PLC integration available on the market today. AMCI offers a wide selection of position sensing and motion control solutions that simplify automation and add reliability to the manufacturing process.

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