**ARC BRIEF**

By ARC Advisory Group

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# Best Practices for Selection of Performance Driven Motion Control Solutions

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ARC Advisory Group

**MEI's ZMP Architecture Forms the Nucleus of an Integrated Solution**

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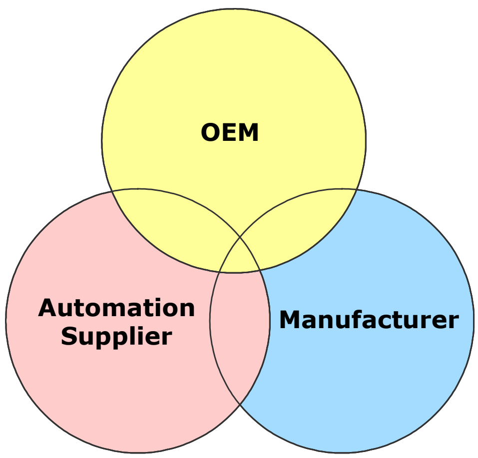
|---|
| Open modular architectures based on PC model |
| Single programming environment |
| Object oriented programming |
| Increasing number of axes |
| Ethernet-based networks |
| Distributed and centralized architectures |
| Productivity though higher speeds |
| Parallel design of machine and motion |
| Enhanced diagnostics |
| Greater flexibility |
| Modular functional sections |
| Web based support infrastructure |

**Overall Trends in Machine Design**

# Executive Overview

In the face of the current economic pressures, manufacturers are making processes leaner, increasing asset utilization, and seeking higher returns on capital investments. Paying closer attention to the real returns from capital investments means setting stricter approval criteria, raising the minimum return hurdle, and demanding a shorter payback period. The result is that manufacturers are spending limited capital with greater discretion. Manufacturing in a variety of industries has become more challenging due to increased product variations, higher production speeds, demanding regulatory requirements, and increasing quality goals at every stage of production.




Optimum Machine Design Is a Partnership

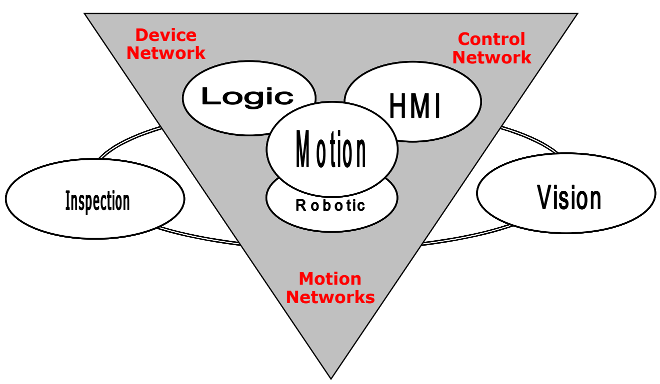
One of the primary elements of a machine control solution that is capable of enabling both the OEM machine builder and manufacturer to face up to these business challenges is electronic motion control. Many organizations, however, have a limited number of engineering resources to invest in the expertise required to stay at the leading edge in this area. The innovation cycle in motion control is simply too rapid, leaving machine builders at risk when trying to develop a machine control architecture that provides the adaptability to meet each customer's current and future requirements and achieve the performance goals under each of these circumstances. OEMs need a partner with a core competency in automation integration along with the willingness to respond to individual design requirements.

### Machine Design Demands Partnerships

Optimal machine control requires a partnership to achieve affordable solutions and meet performance goals required by the manufacturing community. A partnership between OEM, automation supplier, and manufacturing customer is critical to achieve performance and price targets. An equally important issue facing the OEM machine building market is the recognition that the internal expertise needed to develop modern day machinery has radically shifted from mechanical to mechatronic skills, from box level integration to system level integration. Software and network knowledge also play a key role in integration of these systems.

# Component Architectures Optimize Machine Performance

The trend in the automation market is toward integrated solutions that unify motion control, I/O control, Operator Interface, and information connectivity in a single environment. The days of the multi-vendor black box solutions are over. To achieve a unified solution, machine builders seek automation suppliers with proven expertise and a well defined platform or component offering that facilitates the integration problem, but leaves enough flexibility to choose individual components selectively. The market is seeking improved system designs that leave sufficient room to integrate component solutions with both software and networked machine architectures that are easily modified to incorporate custom specifications as well as increase diagnostic capability of machinery.




**Machine Architectures Require Domain Expertise**

As machine builders push the performance envelope in speed, accuracy, and reliability, they seek automation suppliers that offer technology that enables achievement of these goals. The optimal design of highly automated machinery employed in material handling, light component assembly or automated fabrication is simply demanding expertise in a variety of disciplines.

Software is providing the integration glue to improve the overall operation of the machine while networking and actuator selection is the underlying fabric or infrastructure that facilitates integration, as well as providing the capability to implement without barriers. As a consequence, there is an influx of innovations in control platforms, networking architectures, and "intelligent" actuator designs that are flooding the market. The challenge for machine builders that make the decision to develop a component based solution is to identify a platform that provides the greatest flexibility thereby allowing for opportunity to identify the optimal solution set for their application

## Integration of Motion Control Moves to the Forefront

In highly automated machinery, integration of electronic motion components with control systems is moving to the forefront. Machine builders are offering their customers expanded capabilities in production equipment to increase both the flexibility of the machinery, automate setup & reconfiguration, improve the cycle rates required to balance production lines, and increase performance. In many instances, the manufacturing process is simply not possible without using a totally automated system. However, as more manufacturers seek to incorporate lean and agile concepts in their operations, the use of motion control technology in automated machinery continues to expand. Specifically, industries that are moving to a make-to-order model such as metal fabrication, semiconductor, wood working, plastics, and packaging, there is a greater impetus to incorporate machinery that radically reduces set and configuration time. As a result, considerably more motion control components are being integrated into machinery than ever before along with a wider range of requirements. To meet the requirements of this greater range of applications, traditional hardwired integration solutions are rapidly giving way to network architectures that are easing the cost and associated complexity of integration. However, highly optimized designs face the issue of integrating multi-vendor components into a single solution, where many networking standards are not positioned to offer a wide range of options in motors, drives, and sensors.

## Common Networks for Motion and Sensors

Selection of a device or motion control network forms the basis of many machine control architectural decisions. Convergence of motion and I/O networks has become an increasingly important evolution in machine control, as the market witnesses device networks incorporating motion control capabilities and motion control networks incorporating I/O capabilities. Although device networks were not originally designed for motion control applications, the combination of servo drive intelligence and network enhancements have enabled these networks to provide a solution in a range of applications that are seeking performance levels expected in the general machinery market. However, high performance machinery design depends upon a network solution that does not force architectural compromises on machine designers. In the final analysis, network selection in the motion control domain is founded principally on performance, while a wide range of available actuators & sensors will drive down the cost of integration.

# Evolutionary Trend of Interoperable Motion Networks

Over the last decade, there have been numerous networking solutions that have been deployed, some of which have been opened to the public domain. However, no single solution has been able to dominate any industry or application segment. This period is clearly marked by the first generation of networked motion control systems that demonstrated the benefits of networking, but a compelling value proposition was insufficient on a broad market basis to lower the cost of machine deployment and life cycle support. Machine builders seeking to gain a competitive advantage with solutions from this period realized that performance and a broad range in actuator selection for their market segment were limited when designing around a specific motion control network.

| Motion Network | Features |
|---|---|
| **CANOpen** | CAN Bus that has standardized on the high level messaging layer. This has been extended to motion control. Very popular in the electronics and semiconductor industry. |
| **DeviceNet** | Based on CAN physical layer. There have been protocol extensions built to support motion control applications. |
| **Profibus DP V2.0** | Developed by Siemens. Profibus is extended to support applications requiring precise synchronization. |
| **Sercos** | Open standard, Fiber optic, Synchronous network<br>Used in Packaging, Machine tools, and Printing. |
| **SynqNet** | Motion Engineering developed. Now owned & supported by Danaher Motion. Supported by multiple drive and device vendors. Physical Ethernet. IEEE 802.3 standards for 100Base-TX, Non-standard protocol. High performance. Primarily in high volume semiconductor, electronics, and medical OEM machinery. |
| **PowerLink** | B&R Automation developed. Physical Ethernet. Non standard protocol. Wide range of applications, Injection molding, metal cutting, wood, etc. |

**General Characteristics of the Leading Motion Control Networks**

Machine builders sought the benefits that were becoming well entrenched in PC-based platforms and web based architectures, which in essence are a distributed network of intelligent systems. The PC introduced network centric architectures that are driving the use of commercially available Ethernet networking components. Performance of Ethernet as a viable motion control network has been widely accepted in the market Once

Ethernet based technology was validated for applications in the industrial market, the real benefit to machine builders was that automation suppliers could leverage commercial components and technologies that will continue to ride down the cost curve. Soon, Ethernet based solutions will be cost effective enough to be integrated on servo drive systems down to the sub kilowatt power range.

Similarly, use of FireWire (IEEE 1394), as a motion control network is another example of where a commercial, non-industrial network is adopted for motion control solutions. FireWire, initially pioneered by smaller automation suppliers, has benefited users in a variety of applications, especially where motion and vision domains are used together. However, market fragmentation and lack of open standards is shifting the market to offer solutions based on Ethernet technologies. This is clearly evident by the number of suppliers active in developing Ethernet-based motion control networks.

Initially several entrepreneurial firms, including, B&R Automation and Motion Engineering Incorporated (MEI), developed Ethernet-based motion control solutions that were well ahead of the market trends. This has forced well-established open network groups for Profibus and SERCOS to develop competitive alternatives. Profinet (IRT) and Third Generation SERCOS (Sercos III) are leveraging Ethernet technology to bring improved performance to the market while lowering the cost of integration. In general, manufacturers on a global basis are employing Ethernet for business systems applications, and welcome the adoption of Ethernet on the factory floor with open arms for easier integration of shop floor-to-top floor applications, as well as web connectivity.

## Motion Engineering Deploys SynqNet as an Interoperable Integration Strategy

MEI's development and subsequent release of SynqNet® as an open, interoperable Ethernet based motion control network is proving to be a development that has brought this division of the Danaher Motion Group to the forefront of the market. While MEI's core competency remains motion control, they are clearly focused on easing the integration problem with the overall machine control system. Thus, the focus is on interoperability of the motion software that can be targeted to virtually every widely available operating system and the wide availability of servo drives that can be integrated on SynqNet. The focus on interoperability has enabled OEMs to overcome many of the integration barriers on component based machine controls commonly found in the industry.

| Business Objective | Key Drivers and Metrics |
|---|---|
| Customer Focus | Satisfying and anticipating customers' needs.<br>Remote configuration, version control, and diagnostics. |
| Time to Market | Reducing the overall design, manufacturing and installation risks of a new machine.<br>Simplifying the integration of a wide choice of components.<br>Making machines easier to integrate and support in the customers' plant. |
| Machine Capabilities | Optimum price to performance ratio.<br>Maximum flexibility to broaden machine capabilities and maximize utilization.<br>Reduced downtime through use of high reliability fault tolerant network features. |
| Return on Assets | Improving machine reliability.<br>Lower service and support costs.<br>After market revenue enhancements. |

**Balancing Business Objectives Optimizes Performance**

Networking solutions and their level of interoperability are very important criteria for machine control architectures where they provide the basic infrastructure for integration of automation components in either a distributed or centralized architecture. Machine control solutions that employ digital networks are benefiting from more than just a cost reduction in wiring. Although this certainly should not be discounted, the primary driver behind motion control networking combines the benefits of reduced cabling with device intelligence.

## Device Intelligence Improves Machine Robustness

Device intelligence at the drive level makes a machine control solution increasingly robust by adding another dimension that simplifies the overall control problem, while improving the operational safety. Distributed devices also play an important role in modern machine control solutions that require other degrees of freedom to accommodate the specific requirements of a diverse customer base. With the emergence of higher performance dedicated motion networks such as SynqNet, the benefits of distributed devices is combined with those of the centralized controller to deliver higher performance and reliability. So, the primary factor in machine design is to determine at what stage the machine builder needs to define component interoperability and flexibility. This is absolutely critical in machinery sectors that thrive on innovation as a competitive edge. However the innovation will not be accepted at any price in the market.

> The unbiased litmus for SynqNet's success is demonstrated by the rate of adoption where over 60,000 SynqNet axes have been shipped at this writing.

Although SynqNet is a relatively late comer into the market, the developers of SynqNet have effectively eliminated the hurdles that faced many of the available motion control networking solutions. The development of the SynqNet networking solution is representative of MEI's willingness to take a leadership in Ethernet based motion control networking solutions. This was at a time when Ethernet was still being debated as a viable alternative for motion control applications. This debate has clearly subsided as the major market players have all announced a next generation of motion networking solutions that rely upon Ethernet-based physical and protocol layers. There have been numerous barriers to adoption by many of the existing open networking solutions. Barriers include overall cost, performance, and availability of servo products in the right power range. Virtually every hurdle faced by other networks is addressed with SynqNet. The market has recognized this and as a consequence SynqNet has set a new precedent for the adoption rate of for drive networking solutions. The unbiased litmus for SynqNet's success is demonstrated by the rate of adoption where over 60,000 SynqNet axes are being controlled in machinery at this writing. At this junction, SynqNet has surpassed the rate of adoption for any motion control network that has been available on the market to this date.

## SynqNet Complements the Capability of the ZMP Board Level Motion Controller

MEI's motion control solution, centered on their board level products allows machine builders to acquire domain expertise in precision motion control. A primary advantage is that the solution is simply an open core building block for the OEM not a closed integrated solution. Thus, machine builders seeking to pick sensors and actuators individually that maximize the performance of the machinery does not have to compromise the performance integrity by using a highly integrated automation solution.

Highly integrated solutions are available on the market, but the challenge is to identify a solution that optimizes the performance of your application. The issue is that a machine builder is compromising performance for the benefit of a turnkey solution that is difficult to adapt to specific requirements.

A benefit of basing the core architecture on the ZMP motion controller is that much of the engineering effort is reusable. This is the big benefit of basing your architecture on the controller. If you need to deviate incrementally this provides much more flexibility. Highly integrated solutions simply have too much overhead needed to serve a broad range of applications whereas component solutions can be streamlined by the machine builder in both cost and capability to meet the specific requirements of an application. In the overall machine control solution the most dominant part of the costs are concentrated in the motors and drives part side of the solution when the number of axes is greater than two. In general, buying at the highest level of the food chain (i.e. totally integrated solutions), the bundled cost is much too high for many organizations. Conversely, component solutions allow many more degrees of freedom in the design process.

**An Entirely Digital Solution that Enables Adaptive Motion Control Implementations**

MEI's board level solution, ZMP, provides the machine builder a core building block in a highly flexible machine control system. ZMP, however, was designed with performance in mind in an all digital solution. This is the motivation behind SynqNet. MEI has developed SynqNet to provide an entirely digital communication solution that allows ZMP to process motion control applications that are adaptive and capable of reacting to highly dynamic environments. Equivalently, SynqNet has also brought a tremendous number of benefits to the overall motion control solution by precisely addressing the issues that machine builders are most concerned: (1) Machine deployment, (2) Reliability and (3) Field Diagnostics.

SynqNet complements the performance capability of ZMP. At the time of ZMP development there was not a networking solution on the market that would provide the performance required to complement the ZMP. The capabilities of the ZMP would have been compromised with existing networking alternatives on the market. Thus, SynqNet provides the machine builder with a highly integrated platform solution that also offers a

**Component Selection Optimizes Machine Performance**

tremendous amount of flexibility in choosing motors and drives from multiple vendors.

SynqNet is just one of the components to an integrated solution, but it is a critical enabler to reducing system costs. The overall systems costs are allocated differently allowing for a lower cost of deployment. The cost reduction is in a variety of places, but first and foremost there is significantly less wiring. This is a very strong point to this solution as a machine builder can replacing complex cabling with a single CAT 5 cable. The ZMP motion controller has also benefited from this type of network solution. The ZMP itself is much less expensive than the comparable analog controller as a lot of the duplicative cost is being removed. Partners are adding I/O to the drive and from a reliability and flexibility standpoint this is a vastly improved solution. It is clear that the ZMP has sought to address the costs associated with the design and build cycle; however as OEMs become increasingly responsible for the machinery throughout the entire life cycle a control architecture based on the ZMP combined with SynqNet is easier to deploy and easier to diagnose when service calls are addressed either in the field or remotely.

## Streamlining the Design Process

Perhaps the most compelling issue facing machine builders today is to improve performance, minimize initial investment in design & development, and ensure that the machine performs according to the original design goals. Designing and building a new line of machinery always encompasses a certain amount of risk to the machine building OEM. Many OEMs would prefer to stay in their comfort zone with new machinery designs as actuator selection, mechanical configurations, and final integration rarely come together flawlessly. However, it is becoming increasingly apparent that a competitive edge in several machine verticals are centered around performance.

In most instances the design challenge is to replace existing mechanical solutions and introduce electronic motion control to gain a performance advantage. The market is demanding mechatronic solutions – an integrated solution of mechanics, electrical actuation, and motion control software. As more machinery builders seek the benefits of electronic motion control to enhance flexibility, productivity, and performance, the engineering issues they confront overlap multiple disciplines. Many machine builders now venture into domains that demand collaboration between electrical and mechanical engineers, as both of these areas of expertise are required to optimize solutions.

> As increasingly more machinery builders seek the benefits of electronic motion control to enhance flexibility, productivity, and performance, the engineering issues they confront with overlap multiple disciplines.

Once the initial machine design phase is complete, an engineer typically simulates the machine dynamics based on a mathematical model to avoid returning to the design board once a prototype is built, which can result in a potential project delay or increased machine cost. Although the machine design is based on a selection of various electrical and mechanical components with well defined characteristics, the exact performance of a machine is still difficult to predict. The final integration of components can introduce unpredictable results. An accurate model of motion behavior is difficult to simulate when complex components are integrated into a complete system. Therefore, the modeling accuracy breaks down in the real world of machine design.

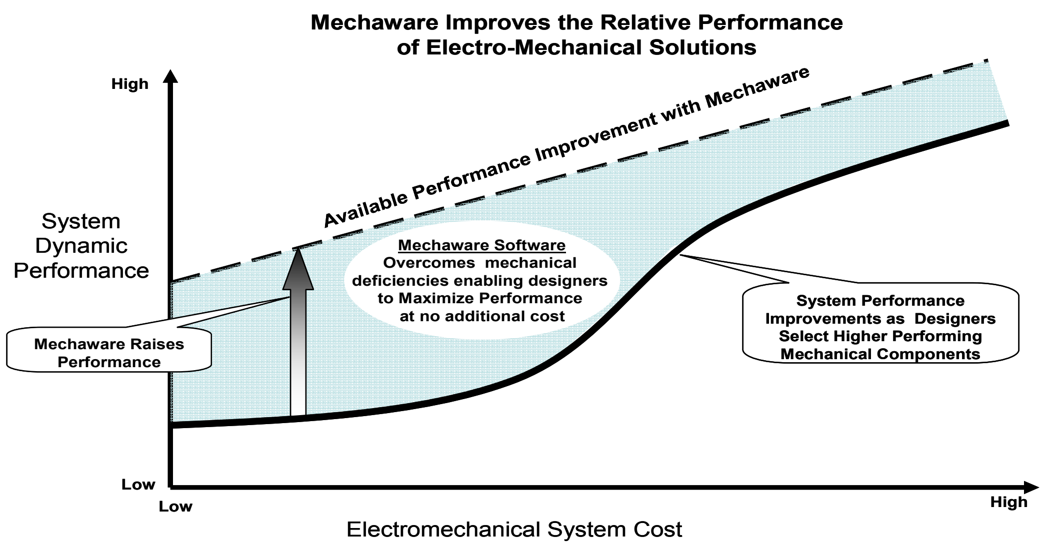
### Bridging CAE and Implementation

It becomes extremely valuable to form a bridge between the machine design process and the prototype or implementation phase of the development. It might be best to think of this as the bridging the Computer Aided Engineering (CAE) tools and laboratory tools needed to diagnose design issues. The initial simulation and modeling phase of the design process needs to be augmented with empirical analysis on the actual machine, though a real benefit can be achieved when the data in the two worlds can be exchanged using a common database. It is only through the empirical testing that machine designers can accurately identify any dynamics not envisioned or incorporated in the original simulation.

Motion control suppliers are continuously improving the software that is used to select, configure, and commission an application. Some early introductions of software from automation suppliers were servo sizing programs that assisted users and the associated sales force to select the correct motor and drive combination for an application. As digital drives emerged on the market, the introduction of digital oscilloscopes were added to the graphical configuration tools to set tuning parameters.

## A New Generation of Analytical Tools Builds a Bridge

A new generation of analytical tools is on the market enabling machine builders to improve machine performance by using software algorithms that compensate for mechanical resonances and nonlinear perturbations that could not be modeled accurately on the design board. In many instances, the location of a feedback device, the effect of a coupling, stiction force to decouple masses, or the effects of temperature variation on the mechanics cannot be accurately predicted. These unanticipated effects commonly result in system resonances, causing inaccuracies and underperforming movements. The ability to cancel out unanticipated ringing in a system without redesigning the mechanical system is not a new concept, but these new analytical tools provide a unique ability to do this with integrated software solutions that provide analysis and automatic software generation capabilities. The end result is a much faster machine design cycle that delivers optimum performance.




MEI is setting the pace in this arena. MEI has developed a set of "plug in" components that work seamlessly with the The Mathworks' Simulink analytical tools. To streamline the overall design cycle in machine design, MEI's Controls Toolkit provides the analytical tools that work closely with their board level motion controllers to allow a system engineer to identify the actual dynamic characteristics of the physical machine. Analytical tools are not uncommon for integrated motion control solutions, but MEI has gone one step further with their MechaWare™ toolkit, which is a set of predefined control blocks for the The Mathworks Simulink environment. Thus, once the control blocks are in the Simulink environment an engineer can evaluate numerous control strategies and then automatically generate the application code for the target motion controller.

The Mathworks model-based design software, Simulink, enables system engineers to work in an environment that doesn't require them to translate from engineering design to software implementation. Effectively, simulation, test, and analysis of the control system with the actual machine model is very powerful, while the ability to automatically generate application code that can make system calls to MEI's motion control software library enables a tremendous amount of time saving. Automatic production code generation enables OEM machine builders to accurately and efficiently create embedded control loop software for these MEI controllers, resulting in significant reductions in both development time and deployment costs.

The technology these companies have brought to the market does not represent a revolution when looked at independently, but the combination of the Controls Toolkit, Mechaware, and Simulink is a comprehensive design tool that facilitates an iterative documentation and design process during the machine deployment cycle. This is the beginning of a trend in machine control deployment that is expected to provide numerous benefits.

**Analyst:** Sal Spada

**Acronym Reference:** For a complete list of industry acronyms, refer to our web page at www.arcweb.com/Community/terms/terms.htm

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|---|---|---|---|
| **AI** | Artificial Intelligence | **ERP** | Enterprise Resource Planning |
| **API** | Application Program Interface | **HMI** | Human Machine Interface |
| **APS** | Advanced Planning & Scheduling | **IT** | Information Technology |
| **B2B** | Business-to-Business | **LAN** | Local Area Network |
| **BPM** | Business Process Management | **MIS** | Management Information System |
| **CAGR** | Compound Annual Growth Rate | **MRP** | Materials Resource Planning |
| **CAS** | Collaborative Automation System | **OpX** | Operational Excellence |
| **CMM** | Collaborative Manufacturing Management | **OLE** | Object Linking & Embedding |
| **CNC** | Computer Numeric Control | **OPC** | OLE for Process Control |
| **CPG** | Consumer Packaged Goods | **PAS** | Process Automation System |
| **CPAS** | Collaborative Process Automation System | **PLC** | Programmable Logic Controller |
| **CPM** | Collaborative Production Management | **PLM** | Product Lifecycle Management |
| **CRM** | Customer Relationship Management | **ROA** | Return on Assets |
| **EAI** | Enterprise Application Integration | **ROI** | Return on Investment |
| **EAM** | Enterprise Asset Management | **RPM** | Real-time Performance Management |
| | | **SCE** | Supply Chain Execution |
| | | **WAH** | Web Application Hosting |
| | | **WMS** | Warehouse Management System |

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