White Paper

Machine-mount automation- cost savings with increased productivity

Machine-mount automation components enable machine and robot modularization, while shortening design, build and commissioning times; increasing machine reliability and improving machine operation.

In the past, machine builders hardwired the equipment they built using multi-conductor cable and point-to-point wiring between sensed and actuated machine elements and a centralized cabinet-mounted controller. As automation and fieldbus communications evolved, intelligence and control began to migrate from rack mounted PLCs and I/O to increasingly distributed architectures. Now, automation devices – controllers, smart I/O, wired and wireless networking hardware, and other components can be mounted on the machine and communicate via networks.

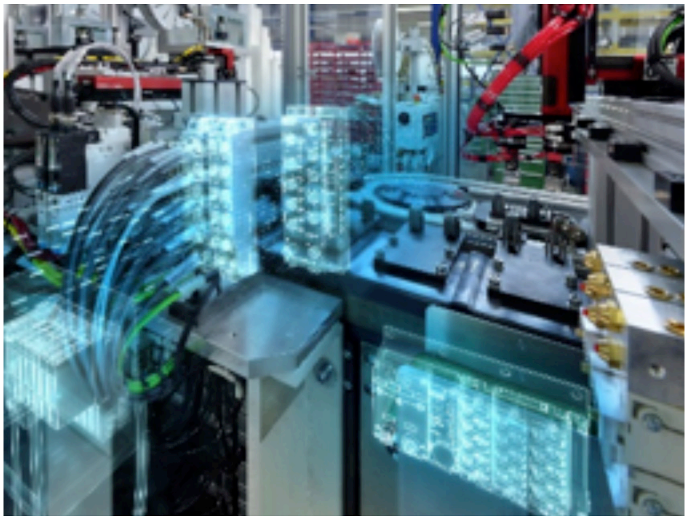
Machine building used to be much more complicated than it is today. Not long ago, nearly every aspect of providing machines to industrial end users was costly, time consuming and plagued by numerous errors in both design and production.

Many of these difficulties were caused by the monolithic nature of machine automation systems. Using one centrally mounted controller and I/O system requiring hard-wired connections to every automation component was and is a process that invites errors.

By their very nature, automation systems are interconnected such that changes in one area ripple through to a host of design drawings and documents. The more monolithic and centralized the automation system, the greater effect of each change on the overall design, and the greater the potential for errors.

A solution in many cases is to break the machine and its automation system down into modules. Each module is much simpler than the overall machine, and this simplification benefits the automation system.

Controlling a module with its own distributed controller and I/O create an automation system that's easier to design, build and commission. In many cases, the module can be effectively controlled with only smart I/O. In either case, changes are greatly simplified because modifications in one area can be self contained without rippling through the entire automation system.



Conventional automation components require enclosures. Machine builders can save the costs of cabinets and their attendant wiring and cabling by using machine-mount automation components.

Implementation of this type of distributed control system used to add considerable cost because every distributed controller and I/O component required its own enclosure. Designing, purchasing and installing multiple and relatively small enclosures is much more expensive than housing one controller and all its I/O in one cabinet. This was a problem when distributed control components were required to be installed in harsh environments – a common occurrence.

However, machine-mount automation components do not require a cabinet housing, which eliminates the expense of multiple enclosure, making distributed control an economically feasible option in many applications. These machine-mount components are industrially hardened for installation in harsh environments and provide a less expensive option than cabinet-mounting.

Machine-mount automation components include but are not limited to controllers, I/O, operator interface, drives, disconnects, motor starters, RFID readers and networking hardware. Machine mount components enable machine modularization with the potential to dramatically improve machine design, construction, installation, commissioning and operation in many applications.

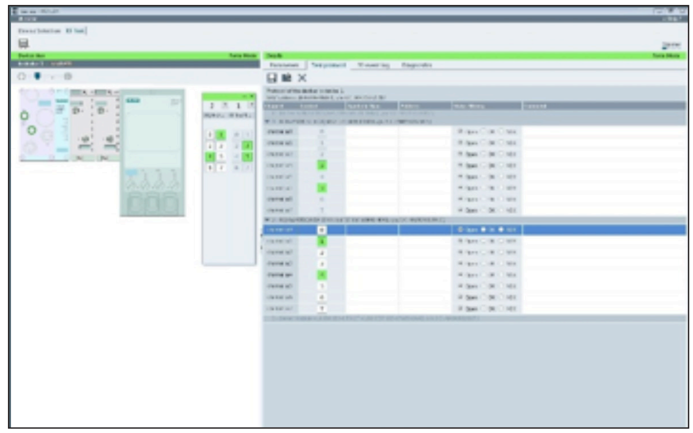
Benefits of machine-mount technology

Conventional rack mounted I/O requires the protection of a cabinet or enclosure, and it only plugs into and communicates through the backplane of the machine controller. Contrast this lack of flexibility with modular I/O, which typically can plug into multiple open industry-standard networks. This gives modular I/O the ability to remotely connect to any controller that supports a common communication standard.

Many functions that were historically only available in rack mounted controllers and I/O such as closed-loop control, counting, measuring and positioning are now available in machine-mount controllers and I/O. In many cases, smart I/O can perform many of these functions on-board, offloading tasks from the controller and making distributed control less expensive to implement and maintain.

Making automation components suitable for machine-mounting can add as much as 30 percent to their price compared to conventional cabinet-bound devices. But overall design, build and commissioning costs will be lower in many applications.

One area where machine-mount components provide substantial savings is wiring and associated labor cost. On machines that use a centralized control system, each sensor or actuator must be wired back to the control cabinet in conduit or cable tray.



Commissioning time is greatly reduced when machine builders use machine-mount automation components.

With machine-mount devices, sensors and actuators can be locally connected to machine-mount I/O. This I/O can either be connected to a local machine-mount controller or connected back to a central controller. If connected to a local controller, that controller can then be connected back to a central controller.

In either case, the connection back to the central controller from the local machine-mount I/O or the local machine-mount controller can be made via a wired or wireless network. If the network is wired, just one cable is required for connection of many I/O points back to the central controller. If the network is wireless, then no wiring is required back to the central controller.

Using this approach saves machine builders the costs to design, purchase, install and commission extensive cable and wiring systems. Of particular note are commissioning costs, which are usually very high when many I/O points are wired back to a central controller and relatively much lower with the reduced wiring of a decentralized control system.

Another area of substantial savings is the reduction in size of the central control cabinet. Although most distributed control designs will still have a central control panel, it will be much smaller as it needs to house much less I/O.

Depending on the application, savings from reduced wiring and a smaller central control cabinet can more than offset the higher cost of machine-mount components. And this does not consider the money and time saved through modularization, an area that will be discussed in detail later in this paper.

Machine-mount benefits

1	Allows machine modularization
2	Enables zone control
3	Reduces wiring cost
4	Reduces labor cost
5	Simplifies machines
6	Shortens design time
7	Shortens build time
8	Shortens commissioning time
9	Increases machine reliability
10	Reduces troubleshooting time

Table 1

Cabinet Free Distributed Intelligence

Designing and building machines that require significant hard-wiring back to controllers and I/O housed in multiple cabinets can create a complex web of wire and cable. Wiring to and from sensors, actuators and motors must be routed through penetrations in cabinet walls, connected to a terminal strip, and finally connected to the rack-mounted PLC and I/O. In many applications, cabinet-free distributed control and I/O intelligence provide a simpler way of building a machine.

Machine-mount automation components shorten machine checkout time, both before the equipment is shipped and during installation at the site

Machine designers and builders are creating control architectures with products specifically designed for on-machine applications. Cabinet-free distributed intelligence simplifies wiring and machine design, reduces the number of cabinets, minimizes design and build time, speeds commissioning and accelerates installation.

Virtually all machine builders check out the products they build thoroughly before shipping them to their customers or installing them in their customers' plants. Machine-mount automation components enable machine builders to make their equipment designs more modular. As machine modularity increases, commissioning is broken down into smaller, discrete steps, becoming simpler.

With monolithic machines and their corresponding centralized control systems, substantial amounts of time and money are often spent on the debug-rework loop. But modular machines and distributed control greatly reduce debug and rework, not only through simplification, but also through reuse of proven modules from one machine design to the next.

The scalability of machine-mount automation components lets machine builders break their machines down into optimal operational modules without regard to size. With cabinet-bound components, the cost to automate modules with small I/O counts can be prohibitive. By using machine-mount automation components and eliminating cabinet costs, even small I/O count modules can be cost effectively controlled.

Machine builder customers also benefit from machine modularity and machine-mount automation. Unlike their enclosure-bound counterparts, machine-mount automation devices do not require forced-air cooling; they are designed to operate at ambient temperatures and sometimes over extended thermal ranges. This increases machine reliability by eliminating the need for forced air cooling, generally a necessity with cabinet-mounted automation components.

Forced-air cooling usually requires moving parts, more susceptible to failure than their fixed alternatives such as heat sinks. Filters to clean inlet cooling air are also often needed. If these filters are not cleaned or replaced when necessary, heat can build up inside the enclosures beyond the reliable thermal limits of the cabinet-bound automation components. Although filters are designed to stop dust and dirt, when they become clogged, they can allow dust and dirt to push through, depending on filter type.

Modular machines are also easier for machine builder customers to maintain. When machine-mount automation components are used, they are visible and accessible, making troubleshooting and maintenance quicker and easier. Cabinet-bound automation components inherently require extra troubleshooting steps, often to gain internal cabinet access while complying with plant safety procedures.

Some machine-mount automation components have built-in diagnostic functions and alarm and other status indicators that are readily visible to plant personnel without requiring cabinet access. These features decrease troubleshooting time and increase machine or plant availability.

With cabinet-bound automation components, external operator interface hardware must often be installed to give plant personnel some idea of automation component status. With machine-mount automation, needed status is often visible on the component itself, eliminating the need for extra operator interface components.

Hot-swappable electronic modules are often available, and they can be replaced during normal operation without the need for special tools and with the equipment live. During module replacement, some machine-mount systems can continue to operate, and the machine may be able to function without interruption to production. Because the automation components are not mounted inside a live enclosure, repairs can often be made without resorting to lock-out/tag-out procedures.

Machine-mount automation devices and components are inherently dead-front in that they are constructed with no exposed live parts. This increases safety for plant maintenance, repair and operations personnel.

Machine modularization requires decentralized system intelligence and control and open networks. Machine-mount automation goes hand-in-hand with distributed intelligence and open network communications; using these components and open networks to distribute intelligence among machine modules is the most efficient and effective way to control and operate machine modules and implement zone control.

Benefits of machine modularization and zone control

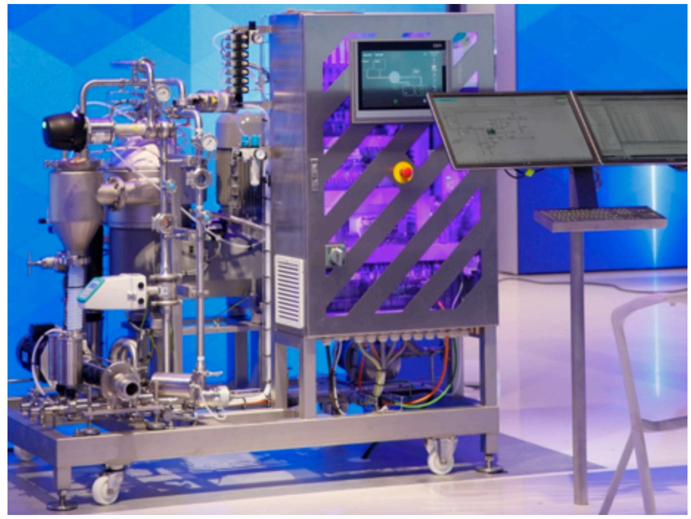
Machine modularization is an effective means of lowering machine builder costs and of increasing the productivity of machines installed in end user manufacturing plants. As a machine design is broken down into smaller modules – the machine becomes simpler to design, build and commission.

Machines with large amounts of I/O are particularly good candidates for modularization as machine complexity increases more than proportionally as I/O counts rise. Each machine module has significantly lower I/O requirements than the overall machine because the total I/O count is divided among the modules. Lower I/O counts at each module add to the relative simplicity of modularized machines.

Machine-mount automation components are designed to work in harsh environments such as those with elevated temperatures and mechanical vibration.

For many modules, smart I/O alone is enough to provide all required control, providing further savings and reducing required footprints. For more complex modules, a local CPU may be required in addition to the I/O. In these cases, CPUs with IP65 and IP67 molded enclosures are available for mounting on the machine and outside of any cabinet (see the "Ingress Protection" sidebar for an explanation of IP categories).

If a monolithic design can be broken into logical or functional zones – each zone or section can be built, programmed and tested as a self-contained sub-system. Each sub-system can then be assembled into the main machine. Much of the check-out and debugging can be done at the module level, making final checkout and commissioning of the overall machine relatively easier.



Machine-mount automation is a primary enabler for machine modularization.

Designing and building complex machines in sections or modules allows machine builders to check out and verify machine sections separately. Some standard machine modules can be built, checked out and inventoried to speed up production of future machines.

Some machine builders can structure their machine designs so that there are several common standard modules for most of the machines they offer. In these cases, custom machines can be created by using different combinations of standard modules. This is generally much less expensive and quicker than designing a custom machine from scratch.

Sometimes gaining access to certain machine sections without shutting down the entire machine becomes necessary. The modularity of distributed zone control allows one part of the machine to be shut down for maintenance or adjustments while the rest of the machine continues to run.

If an entire machine or line stops for too long, critical elements of the process can be adversely affected. Substantial delays can also result when restarting an entire machine and its associated process. Temporary access to machine zones or sections can often obviate the need to shut down the entire machine to fix a problem in one area.

Some machines are divided into safety zones with separate emergency stop interlocking requirements. With modules, each zone is controlled independently. If access is required or if there is an emergency situation in a specific zone, only that zone is shut down while the rest of the machine continues to operate.

Zone-based modularity enables quicker and easier machine troubleshooting and maintenance, and module-based machine mount automation systems are easier to troubleshoot than their cabinet-bound counterparts. If access to only one zone is required, machine-mount automation systems are easier to access. Built-in diagnostic functions with visual indication of status and alarms enable technicians to isolate and repair systems quickly so that production can continue with minimal impact.

Open network advantages

1	Enables distribution of automation components
2	Enables machine-mount automation
3	Allows machine modularizationi
4	Allows rapid and reliable data transfer
5	Increases connection flexibility
6	Allows multi-vendor automation systems
7	Reduces installation costs and time
8	Facilitates easy machine debugging
9	Simplifies equipment monitoring
10	Simplifies module interfacing

Table 2

Modular machine architecture not only provides increased machine availability, but also enables flexibility when making product changes or increasing machine output. Adding modules to a machine is often an effective way to gain flexibility. Adding more automation to a machine is more easily accomplished with distributed control and digital networks than with hard-wired centralized control.

Designing modular machines and systems allows machine manufacturers to flexibly react to customer requirements and to configure and build applications accordingly. The user receives a machine that is optimally tailored to current requirements, but one that can also be readily modified as needed.

Benefits of wireless technology

1	Reduces installation costs and time
2	Simplifies design
3	Eliminates wire and cable wear and tear
4	Cuts downtime by eliminating wiring failure
5	Greatly reduces cost of adding devices

Table 3

Open networks

High-speed deterministic industrial networks make machine mount automation systems and machine modularization a practical alternative for many machine builders. Whether wired or wireless, distributed networks are key elements in the machine automation landscape.

These networks are used in three ways with modular machines and machine-mount automation systems: for communications between a machine-mount CPU and a central control and monitoring system; for communications between machine-mount I/O and a central control and monitoring system; and for communications among machine-mount CPUs and I/O.

Machine-mount automation is based on distributed intelligence and open network communications. Without these two features, the technology is not viable. Modern high-performance controllers with increased processing speeds connect to and communicate with a wide variety of distributed I/O devices through extended open communication networks. These systems ensure rapid data transfer among components as well as consistent response times among distributed automation devices.

The use of digital networks and open communication standards offers flexible connection possibilities. Linking modules over a network instead of hardwiring every signal back to a rack mounted controller in a cabinet cuts installation cost and increases flexibility.

Digital communication facilitates easier machine debugging, more reliable data transfer and easier equipment monitoring. Networks expand distributed system diagnostic capability, which lowers troubleshooting time as well as machine downtime. Features, such as clock synchronization among controllers and system-wide alarm and status information transfer, become possible as well due to the speed of digital networks.

Networking also simplifies module interfacing. Machine builders can design one communication interface to accommodate all modules instead of designing custom hard-wired interfaces for each module. Network loading is reduced with machine-mount automation because individual machine modules can be configured, commissioned, diagnosed and operated independently.

Distributed controllers can often be connected using wireless technology, which further cuts installation costs and time. Machine-mount wireless communication components mean that high-speed wireless networks can be implemented without the need for cabinets and enclosures. Wireless communication can be used for both standard and safety-related machine applications.

The cost of adding controllers and I/O to a wireless network is also very low. By contrast, adding automation components to hard-wired systems increases equipment modification costs, installation time and the likelihood of errors.

Motion-based equipment such as robots, cranes, and packaging and material handling machines experience wire and cable wear and tear more frequently than stationary machines. Temperature and humidity changes and other harsh environmental factors can degrade and break down insulation and corrode wiring and cabling to moving and stationary equipment as well. With wireless technology, users can avoid these costly and time consuming issues.

Ingress protection

Machine-mount automation components do not need cabinets because they are designed to operate in harsh environments. Depending on the industry, some environments can be dusty, dirty, wet, humid or combinations of these. Using controllers and I/O that are designed and certified for these environments reduces costs because machine builders don't have to buy special liquid/dust-proof cabinets, conduit seals and cabling.

Some applications such as those typically found in the food and beverage industries require periodic equipment wash-down, sometimes with chemical sprays. When automation components are mounted on machines in these environments, they are subjected to washdowns along with the machines. Therefore, machines in these and other harsh conditions must have Ingress Protection (IP) that exceeds the expected elements of the environment.

IEC 60529 defines degrees of protection from solids and liquids for IP classifications. A two-digit number represents the defined IP degrees of protection – the higher these numbers, the better the protection (see Table).

Many machine-mount automation components are IP65- and IP67-rated and can therefore withstand the harsh conditions found in many industrial applications such as this food and beverage plant.

The first IP digit represents protection against solids. It distinguishes various particle sizes as small as dust. For example, if the first number is a “1” a device is protected from foreign bodies that are ≥ 50 mm. A “3” used as the first number means that a device is protected from objects that are ≥ 2.5 mm. If “6” is the first number, the device is totally protected from dust. The second IP digit represents protection against water that could drip into equipment from different angles, spray water, water jets and submersion of the equipment in liquid. Each level of exposure must not have a harmful effect on the equipment. For example, a “2” listed as the second IP number represents protection against dripping water, specifically, a vertically falling water drip when the housing is inclined at up to 15° from the vertical to either side. A “5” as the second number represents a water jet directed on the equipment from any direction. A “7” represents temporary submersion in water. Open Ethernet networks between machine mount automation devices and enclosure installed devices.

Significance of the IP protection classes IP65, IP66, IP67

The protection rating indicates how suitable electrical equipment (e.g. devices, lighting, installation material) is for various environmental conditions and also the protection for people against potential dangers when using the equipment. With regard to suitability for various environments, the systems are divided into relevant **IP codes** (Ingress Protection codes). The protection rating is always indicated by the letters IP followed by two digits.

The first digit indicates the degree of protection against contact and solid foreign objects.

The table below explains the meanings of the **first** digits of the IP code.

Digit	Protection against body contact	Protection against solid foreign objects
0	No protection	No protection
1	Protected against large parts of the body	Large solid foreign objects (diameter 50mm) and greater)
2	Finger protection (diameter 12mm)	Medium-size solid foreign objects (diameter 12.5mm and greater, and length up to 80mm)
3	Tools and wires (diameter 2.5mm and greater)	Small solid foreign objects (diameter 2.5mm and greater)
4	Tools, wire, and small wires (diameter 1mm and greater)	Granular solid foreign objects (diameter 1mm and greater)
5 (K)	Wire protection (as IP4), dust-protected	Dust deposit (not harmful)
6 (K)	Wire protection (as IP4), dust-tight	No ingress of dust

The second digit indicates the degree of protection against liquids.

The table below explains the meanings of the **second** digits of the IP code.

Digit	Protection against liquids
0	No protection
1	Protected against vertically falling drops of water
2	Protected against direct sprays of water up to 15° from the vertical
3	Protected against direct sprays of water up to 60° from the vertical
4	Protected against water sprayed from all directions, limited ingress permitted
4k	Protection against water sprayed from all directions under increased pressure, applies only to road vehicles
5	Protection against water sprayed from all directions under increased pressure, applies only to road vehicles
6	Protected against heavy seas or powerful water jets (flooding)
6k	Protected against powerful water jets increased pressure (flooding), applies only to road vehicles
7	Protected against the effects of temporary immersion in water
8	Protected against the effects of continuous immersion in water
9k	Protection against high-pressure/steam-jet cleaning, applies only to road vehicles

IP Ratings Note: Each protection rating is to be considered separately. A high protection rating does not automatically include a **lower** protection rating.

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