

# INTELLIGENT PROGRAMMABLE DRIVES BECOME A CONTROL FOR THE ENTIRE MACHINE

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**Abstract** - Mechatronic solutions and modular machine concepts become more and more important for machine manufacturers. These trends generate advantages for the machine builder in terms of simplifying construction and standardization of the machine, as well as faster assembly and improved operation. Reduction of production costs, faster throughput time from order to shipment and a higher quality of machine are the most positive results. Mechatronics has proven itself for a number of years now to simplify machine construction with servo drives and intelligent Motion Control software. The machines became more flexible and possessed a higher degree of quality. Modular machine building is the next challenge of control systems to make distributed machine control possible. It is the wish of the machine manufacture to standardize machine building by means of standardized machine modules which can be arranged in various combinations.

With the right control architecture, which can be adapted optimally to the machine structure while fulfilling the requirements of mechatronics and modular machine concepts, machine building becomes extremely efficient and allows the development of very flexible machines with a high degree of quality and throughput. Overall, this gives the manufacturer who uses these new concepts a distinct competitive advantage.

## I. INTRODUCTION

Mechatronic solutions and modular machine concepts become more and more important for machine manufacturers. These trends generate advantages for the machine builder in terms of simplifying construction and standardization of the machine, as well as faster assembly and improved operation. Reduction of the production costs, faster throughput time from order to shipment and a higher quality of the machines are the most positive results.

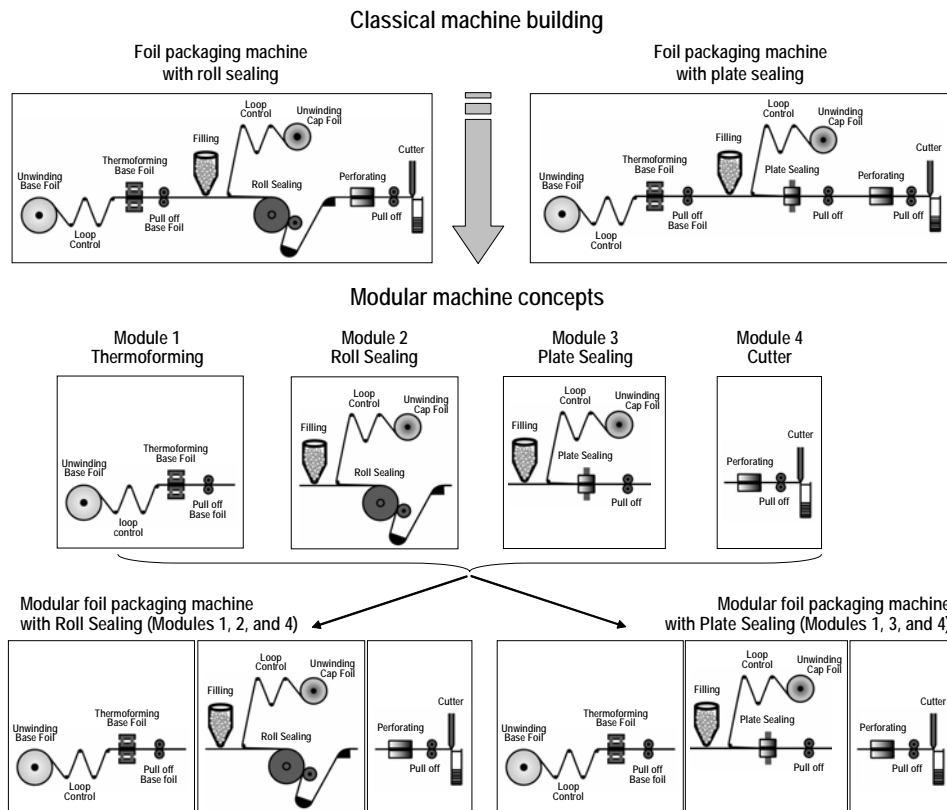
Mechatronics has proven itself for a number of years now to simplify machine construction with servo drives and intelligent Motion Control software. The machines became more flexible and possessed a higher degree of quality. However, with the increase in the electronics of a machine, application developers found themselves challenged. Different controls and tools for drive, motion control and logic control had to be handled which resulted in an increase of the engineering time. To alleviate these new issues an optimized control system is required which supports all functions from Drive and Motion Control to Logic Control all with an easy to use engineering environment. At the same

time new requirements have to be fulfilled like the reduction of cabinet space, distributed hardware architectures and connectivity to the process management level.

Modular machine building is the next challenge of control systems to make distributed machine control possible. It is the wish of the machine manufacture to standardize machine building by means of standardized machine modules which can be arranged in various combinations. This is a much better solution than one big machine which has to be reconfigured with much effort for each individual order. Henceforth, each module needs its own control and the entire machine functionality is the cooperation of all module controls with distributed properties via bus communication.

## II. Modular machine concepts

Modularizing means that the machine is not built as one big mechanical block anymore but consists of numerous standardized modules with defined interfaces. The concept of machine modularization shall be shown exemplary by 2 variants of a foil packaging machine.



**Figure 1: Modular machine concepts**

The first variant of the foil packaging machine accomplishes the process tasks “thermoforming of the base foil”, “Sealing of the cap foil by a roll sealer”, and “Cutting of the final products”. For the second variant of the foil packaging machine a “plate sealer” is used instead of a “roll sealer” because of the cap foil condition.

These 2 examples show very well how the process tasks can be aggregated into the following machine modules:

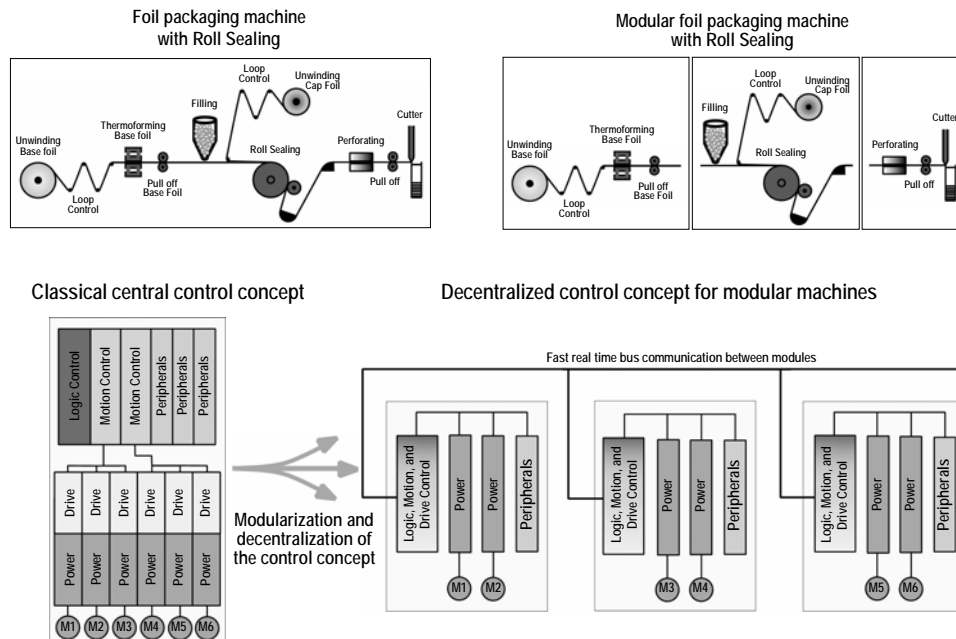
- Module Thermoforming
- Module Plate Sealing
- Module Roll Sealing
- Module Cutter

The manufacturing of an individual foil packaging machine can be accomplished very effectively by assembling the appropriate machine modules. Modularization in this way has the following significant advantages:

- Single machine modules can be projected, manufactured, and commissioned independently from each other.
- Machine modules can be standardized much easier than a complete compact machine.
- Defined and uniform interfaces and cross communication between machine modules using bus systems reduce the wiring complexity tremendously.
- Enhancements or modifications of a machine module can be done almost reaction less to the complete machine.
- Individual customer orders can be arranged very fast by combining the necessary machine modules.

The realization of a modular machine concept requires a controller and drive concept which fits the machine architecture. In other words: the controller and drives architecture does not determine the machine structure; instead, the controller and drives technology has to assimilate to the machine architecture.

### III. Controller concept for modular machines

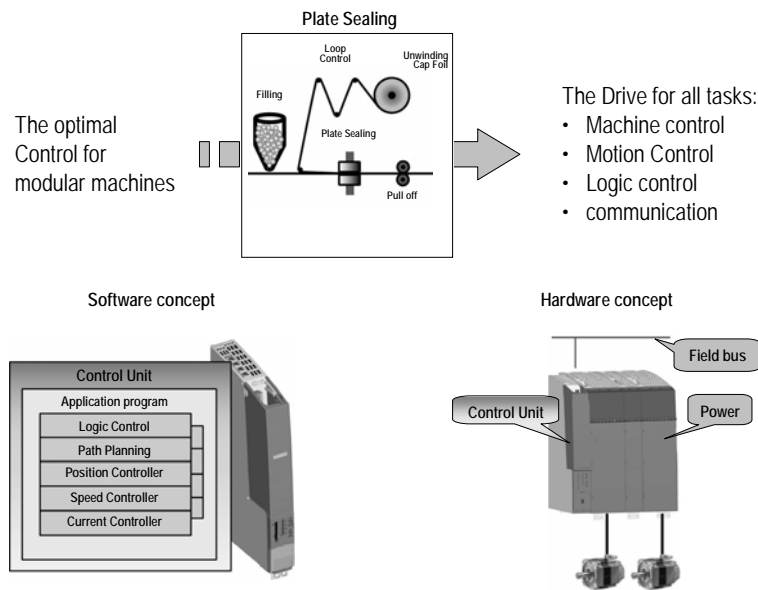


**Figure 2: Decentralized Control concepts**

Modular machine concepts generate the following consequences and requirements to the controller and drives technology:

- A central controller concept is no longer appropriate. Rather, each machine module has its own control unit and inclusively all necessary periphery components.
- The local control unit has to be able to execute drive control, motion control, and logic control with the necessary performance and accuracy.
- The single electrical components (e.g. I/O's, controller, power units, etc.) within a machine module must not be physically related to each other anymore but rather be able to be placed where they are used or fit.
- The wiring of the electrical components within a machine module as well as the coupling between several machine modules has to be as simple as possible. This requires powerful and uniform communication connections.
- All necessary tasks such as projecting, application development, commissioning and test and diagnostics have to absolutely accommodate the expanded demands of a decentralized controller concept.

#### IV. Controller concept for modular machines



**Figure 3: Drive based controller**

Using a machine module out of our modular machine example the appropriate controller concept shall be introduced.

A machine module consists of an individual amount of motion control axes and peripheral components which can be considered as a unit from the view of the application development. This simply means that the application developer has to realize an application program which operates multiple axes with defined motion control capabilities under the consideration of the different machine states.

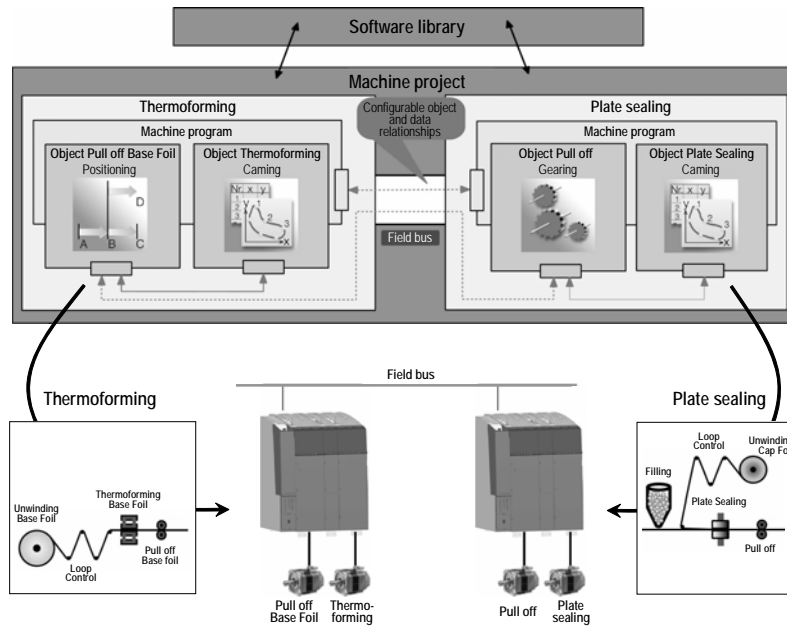
In order to be able to execute this conceptual formulation the control unit has to support drive control, motion control, and logic control. Likewise this control unit has all interfaces to I/O's and drive power components.

This leads to the following advantages for the application developer:

- Only one uniform controller hardware (Control Unit) with onboard capabilities for all machine tasks.
- Only one engineering tool for uniform configuration, parameterization, programming and commissioning.
- Uniform programming of drive, motion control and logic functionality by using standardized programming languages (IEC61131).
- Consistent test, diagnosis, and commissioning functions from drive up to motion control and logic control.
- A consistent data management environment which includes all parts of the application.

- All components (I/O's, encoders, drive rectifier and amplifier) are connected using high speed serial communication which simplifies the wiring tremendously and allows for a distribution of these components if necessary.
- Each machine module can be commissioned independently because of the modular machine concept.

## V. Software concept for a modular machine



**Figure 4: Software concept for modular machines**

The appropriate software concept is the crucial factor to allow modular machine concepts without a high complexity for the application developers.

The main focus of the software concept is supporting a modular way of thinking to simplify the tasks configuration, parameterization, and programming.

The following steps show the optimized approach of the application development based on our machine example:

- **Step 1:** Creation of software objects which offer a definable functionality. Object "Pull off Base Foil" is setup as a positioning axis and contains the current controller, speed and position controller as well as the path planning for positioning. Object "Thermoforming" contains additional cam functionality and has an object relationship to the object "Pull off Base Foil". This relationship describes that the Object "Thermoforming" is coupled to the object "Pull off Base Foil" by using a cam table.

- Step 2: Each object has parameterizeable properties. They are used to define the individual behavior like gain factors for controllers, dynamic parameters for path planning or limitations for monitoring. Graphical wizards should guide one through these setups.
- Step 3: After creation and parameterization of the different objects, the functional quantity structure and its behavior is defined and is now the basis for the development of the individual machine program. The machine program presents the interface between the machine process and the already configured objects. It also must describe the individual behavior of the machine module, supported by graphical and textual languages. The execution system of the control unit needs to supports cyclic, sequential, and event driven programming.

The engineering of each machine module can be done in this way (step 1 to step 3) whereas the management of machine functions can be organized in libraries. Insofar, the modular thinking in terms of software reuse must be optimally supported by the engineering tool.

- Step 4: The last step is software assembly of the necessary machine modules in order to get the complete machine, whereas the communication between the machine modules is handled by fast serial bus communication.

Also, this step is supported by best practices because this communication need not be programmed but only the functional relationship between the objects has to be configured. For instance, the relationship of the electronic gear between the object "Pull off Base Foil" and the object "Pull off Roll" should easily be done by a simple graphical connection of these 2 objects. The necessary communication over the bus cable between the 2 control units is then accomplished automatically.

## **VI. Summary**

In many areas of machine building, modular machine concepts have become more and more accepted. The generated crucial advantages for this type of machine building are easier construction, simpler standardization, better operation and faster manufacturing. These advantages result in reduction of manufacturing costs and a faster through put from order to delivery.

The general feasibility of modular machine concepts are crucially linked to the availability of the appropriate control system which is capable of handling drive control, motion control, logic control, data handling and management, and communication all in one compact unit. Beyond that, the engineering concept has to completely support modular software development in terms of library capabilities and software reuse.