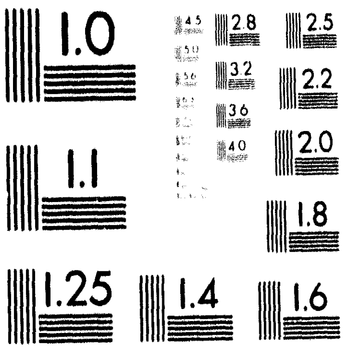
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2.8
2.5
3.2
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1.25
1.4
1.6

1 of 1

OPEN ARCHITECTURE IN CONTROL SYSTEM INTEGRATION

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To be presented at the
Power Conversion and Intelligent Motion Conference
Irvine, CA
October 25, 1993

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Open Architecture in Control System Integration

by
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ABSTRACT

Open architecture offers the manufacturing community a number of advantages in the integration of future machine control systems. Among these advantages is the ability to upgrade and take advantage of innovative new control strategies. A key enabling technology in open architecture control systems is the digital signal processor (DSP). DSPs can be used to provide a complete control system or can enhance the computational capability of larger control systems. The use of DSPs in the integration of open architecture control systems is discussed, including their impact on reliability and control system functionality. In addition, the role of DSPs in control system architecture is addressed.

1. INTRODUCTION

The Oak Ridge Y-12 Plant and Oak Ridge National Laboratory use a large number of standard and special purpose machine tools to meet research, development, and production needs. This has resulted in extensive experience with machine tool control systems from a variety of sources including those which have been developed on site to meet unusual requirements. This experience has led to growing support for an open architecture design approach. Open architecture will increase the useful life of expensive machine tools, simplify system integration, permit rapid technology upgrades, and improve quality control.

Machine tools used in manufacturing are capitalized over a period of ~20 years. It is therefore reasonable to expect the machine and its associated control system to have a useful life at least that long. Equally important is the ability of the manufacturing plant to procure replacement parts for the machine tool and its control system. The vendors of proprietary systems in use today may not remain in business over the lifetime of the machine. Also, past experience has shown that control suppliers routinely abandon support of older systems in favor of newer product lines.

In critical manufacturing operations, a machine tool must be qualified or certified to perform a particular set of functions in the production sequence. This introduces an additional demand on the lifetime of a machine and control system since it delays their entry into production use.

Research and development projects often require the use of machine tools to perform functions beyond their original design capabilities. In some instances the

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machines are modified or fitted with an experimental set of sensors, actuators, or other specialized devices. Usually the control system must be modified or replaced on the basis of the new configuration of the system. For example, precision diamond turning of mirrors originated in Oak Ridge in the late 1970s. For this application, commercially available machine tool control systems were interfaced to laser interferometer feedback devices. This development was responsible for advancing the state of the art in surface finish for precision mirrors. Another example is in the early use of compensation for known errors in slide travel to improve machine tool accuracy and precision.

2. THE APPEAL OF OPEN ARCHITECTURE

From the manufacturing perspective on machine control systems, several issues arise regarding the selection of the systems to control the machines tools of tomorrow. These concerns include the implementation of technology upgrades, the implementation of functional upgrades, acquisition from multiple sources, and the ability to implement innovative new control strategies.

The ability to upgrade a system allows the use of the latest advances in technology. For example, as new microprocessors and digital signal processors (DSPs) become available, it is desirable to upgrade the machine control system to take advantages of increases in processing speed and other features. Experience with machine control systems at Oak Ridge have shown little success in implementing technology upgrades. Frequently, costly replacement of the entire control system is necessary.

Another reason that technology upgrades are important in a manufacturing application is that the control system software often represents a sizeable investment. The investment was made either through the purchase of specialized application software at the time of procurement or through in-house enhancements on systems in which the source code has been made available. Technology upgrades would help enable the reuse of software and would help reduce the machine's lifetime operating cost.

Like technology upgrades, functional upgrades are important in the production environment. Over the life of the machine, different manufacturing processes require the control system to perform operations that were not originally foreseen. Software engineers refer to "hooks" in control system software as access points to implement functional upgrades. Control systems that are flexible in supporting functional upgrades are attractive to the end user.

An example of a functional upgrade is automatic compensation for tool wear which has been demonstrated at the Oak Ridge manufacturing facility. This function required the modification of the part program based on input from an external vision system that analyzes the wear pattern on the cutting tool. With its experience in developing new sensor technologies, Oak Ridge has an interest in applying advancements such as these to production machines through functional upgrades.

As mentioned previously, the long useful lifetime requirement for production machine tools makes the dependence on a single source for control system components undesirable. This is especially true for manufacturing operations that support national defense-related projects. The use of open architecture will increase the number of sources of control system hardware and software. Multiple sources for control system components will reduce cost because of competition in the marketplace.

Another advantage of open architecture machine control systems is the ability to take advantage of innovative new control strategies. Increases in computing speed allow the use of computationally intensive control schemes. Open architecture enables small businesses and research facilities to become more involved in machine control development. These institutions have a potential for introducing unique new approaches in control system design.

3. THE ROLE OF THE DSP

Advances in very large scale integration have resulted in increasingly greater computing power at low cost. The DSP provides a considerable amount of high-speed processing power suitable for machine control systems. This technology has been responsible for allowing small companies to play a significant role in the advancement of the state of the art in the motion control industry. Likewise, it has enabled the use of sophisticated control algorithms that were previously limited because of a lack of computation time.

An example of advanced algorithms made available by DSPs are state feedback methods and techniques such as Kalman filter state estimators. Recursive, real-time system identification algorithms have been implemented to provide optimal, adaptive control for nonlinear, time-varying systems. Applications such as fuzzy logic and neural networks are emerging because of the maturity of the theory and the availability of the required hardware.

An advantage to processing signals digitally in a control system is that intermediate values in the servo loop computation are accessible for collection and subsequent analysis. These data can be used for system analysis or to troubleshoot anomalies in control system behavior. Taken a step further, a DSP can be programmed to excite the system and capture the resulting response. This response is then analyzed to determine the dominant system dynamics using system identification techniques. Servo loop compensation parameters can then be computed to obtain stable machine operation. Techniques such as this are used in self-tuning algorithms of advanced motion control systems on the market today.

For the purpose of this discussion, the DSP refers to the actual semiconductor device, along with the support hardware required to communicate with control system drives and sensors. In other words, DSP can be taken to mean a motion control board or a general-purpose DSP interface board.

From the point of view of the manufacturing facility, what is the best fit for the DSP in an open architecture control system? Two logical possibilities are considered here. One is to implement the entire control system on the DSP. The other is to implement a standard set of function blocks on the DSP (especially those which require a high-speed update rate) and perform higher level functions on another processor.

There are motion control boards on the market today which implement a full control system through the use of the DSP. This has the advantage of not requiring periodic communication with a host. Some currently available systems can operate independent of a host computer after they have been configured and programmed. Only an external power supply is required to support these devices. This offers the advantage of being a compact, self-contained solution.

There are, however, disadvantages to using a DSP as a complete control solution. One disadvantage is that the DSP is burdened with tasks such as trajectory generation, handling user interface requests, interpreting G-codes, and other functions that compete for processing cycles. Normally these tasks do not require the speed that closing a servo loop requires. Thus, they are candidates for offloading to another processor. Most applications permit servo update rates that leave sufficient time for these other tasks. Applications such as off-axis turning, however, require the full processing power of the DSP. With this application, the cutting tool must be continuously positioned during each revolution of the spindle.

Another possible disadvantage of the DSP as the complete control system is that the investment in software development may be lost if a technology upgrade is made to a higher performance DSP. This concern highlights a key challenge of open architecture systems. With falling hardware costs, software accounts for an increasingly larger portion of the control system investment. Moreover, more of the functions performed are being implemented in software rather than hardware. Production users of machine tools would benefit from the opportunity to reuse software developed for older generation control systems.

Another approach to using DSPs in open architecture control systems is to share the processing tasks between the DSP and host computer or other processor. With this approach, a set of commonly used function blocks is defined for execution by the DSP. The other processor performs user interface functions and supervisory tasks and sends requests to the DSP to perform tasks from a standard function set. This allows the DSP to be optimized for these functions without requiring interruptions for overhead tasks.

An advantage of this configuration is that it makes it easier to reuse software with technology upgrades. With clear definitions of standard function blocks, requests made by the supervisory processor remain the same for different DSPs. Only specialized function blocks required by unique applications require updating for new hardware.

A disadvantage of having more than one processor in the control system is that it introduces another level of complexity. Communication between processors is a potential source of problems. Conformance to a standard function set must also be assured for this architecture to be viable.

4. AN INDUSTRY STANDARD FOR OPEN ARCHITECTURE

A significant effort exists in industry today to standardize open architecture in control systems. This effort is sponsored by the National Center for Manufacturing Science to develop the Next Generation Controller (NGC). Originally sponsored by the U.S. Air Force, this initiative is working toward defining the NGC, an open architecture control system.

The NGC working group is made up of machine tool users as well as suppliers of machine tool control systems. This group has the difficult task of combining the various elements of a machine control system into an industry standard for the open architecture control system of the future. Already evident in the group's work to date is the importance of software to the success of the NGC. Much more emphasis is placed on clearly defining the tasks of the control system than on the hardware to perform these tasks. This will help ensure that the NGC will survive as advances in hardware technology are made.

5. CONCLUSIONS

For many reasons, the use of open architecture in the machine control systems of tomorrow is appealing to the manufacturing user. It offers a means to upgrade the control system as new technology and control functions become available. Open architecture also opens the market to more manufacturers and enables the development of innovative new control strategies.

The DSP provides an excellent enabling technology for open architecture machine control systems. Whether it is used as a complete control system or to provide high-speed processing for a supervisory processor, it offers tremendous capabilities for advancing the state of the art in machine control. As important as advanced technology signal processing hardware is, intelligent use of software is even more important in providing viable control solutions for the future.

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