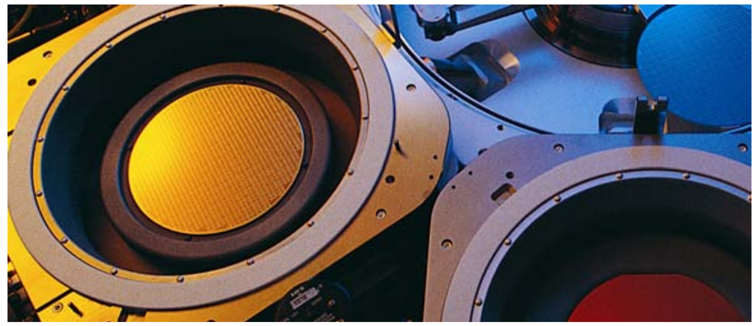
Distributed Control Lessons Learned in the Semiconductor Manufacturing Industry

(by Reg Hunter)



Introduction

In the semiconductor industry, the struggle to exceed yesterday's performance standards is constant – "state-of-the-art" is a fleeting reality. In this environment, suppliers of capital equipment systems must continually improve upon process science and enabling technologies or risk becoming casualties of obsolescence. Seven years ago the 300mm generation of semiconductor processing tools emerged. This provided semiconductor capital equipment manufacturers with the opportunity to re-evaluate their traditional centralized approach to system control. A number of OEMs elected to distribute their control topology based on studies sponsored by SEMATECH. Although highly successful in this endeavor, the introduction process was difficult. For example:

- **Organizational Infrastructure**

  Distributed control technology had a significant impact on many organizational levels and on workflow processes. A comprehensive introduction strategy and subsequent ongoing dedicated support mechanisms were needed to ensure the technology was well understood and used to its best advantage.

- **Complexity**

  Distributed control technologies facilitate communication with multiple devices over just a few wires. Some of these technologies attempt to minimize consumption of network capacity and improve response times by providing special features, such as the ability for devices to communicate directly with each without controller involvement. Other features provide for devices to communicate with the controller on an exception basis. Although special capabilities like these may appear to be desirable at first glance, the benefits are less clear upon closer scrutiny. The dilemma in incorporating such system complexity gives rise to a wide array of trade-offs: relinquishing control authority, accepting less determinism, acknowledging inherent delays during the implementation process, recognizing that future upgrades will be harder and more costly to implement, and conceding the fact that troubleshooting in the field will be significantly more difficult. These sacrifices are often viewed as outweighing the benefits to be derived. As a result, these special capabilities, integral to some distributed control technology protocols, are often not used. Unfortunately, sensor and actuator device suppliers can expend considerable resources in developing products compliant with various special features defined by protocols, which incurs delivery time delay, increases unit costs and can potentially degrade performance.

- **Flexibility and Expandability**

  Both centralized and distributed control systems were developed and optimized for a specific set of tasks using a combination of sensors and actuators. Consequently, it has always been extremely difficult to incorporate additional sensors and/or actuators without extensive performance revalidation. This limitation fostered the emergence of third party sensor networks that surround the cluster tools providing advanced process/equipment control.

Over the years distributed control technologies have continued to evolve and improve. This paper contrasts the distinctions between centralized and distributed control and discusses the rationale behind the use of CC-Link. CC-Link is one of the latest open distributed control technologies. Although CC-Link is the primary distributed control technology in Asia, it has only recently been introduced in North America for initial use in high-speed conveyor and other applications. URS Corporation (a contract engineering services provider), CC-Link Partner Association (CLPA), and Mitsubishi Electric Automation are working closely with a number of semiconductor capital equipment manufacturers upgrading existing systems and developing new systems that capitalize on CC-Link distributed control technology.

Centralized Control

Prior to the advent of 300mm generation toolsets, semiconductor OEMs used a centralized approach to control. In this approach a variety of circuit card assemblies were consolidated into a 19 inch rack. These circuit cards were attached to large distribution backplanes. The backplanes were used to distribute the hundreds of input and output (IO) points from the circuit cards to multiple high density connectors. Custom umbilical cables, often exceeding 50ft in length, were attached to these connectors and routed to multiple distribution boards located at the semiconductor processing cluster tool. The distribution boards located at the cluster tool were used to distribute the IO points to multiple lower density connectors. A large number of smaller custom cables were then attached to these lower density connectors and routed to the devices mounted throughout the semiconductor processing tool.

The 50ft umbilical cables were necessary because many wafer fabrication facilities preferred to position these large controller racks on the floor below the semiconductor processing tool, to minimize tool footprint and the use of costly clean room floor space. The centralized control approach resulted in over 10,000 pin-and-socket contact pairs to provide interconnect of a semiconductor processing system. Interconnect problems have historically been the primary source of delay in final testing, system commissioning and system troubleshooting in the field. Furthermore, the long interconnections serve to degrade the analog signals and compromise performance.

New Generation of Distributed Control Technology

The mechanism for exchanging information in a distributed control system is defined in the protocol. Some protocols are quite complex and difficult to implement. Protocols often require multiple levels of processing to provide capabilities such as peer-to-peer device communication. Other newer protocols, such as CC-Link, emphasize interface simplicity along with speed and determinism. Interface simplicity is brought about through the use of ASICs that provide the protocol communication between the controller(s) and the devices in the system. This approach to device connectivity is straight forward, allowing suppliers and OEMs to refocus scarce resources on their products and core technologies. CC-link is 20X faster than the master-slave distributed control technologies introduced with the first 300mm tools. This speed, along with the ability to define a network configuration that includes "reserve stations", allows the control system to be optimized with provisions already "built-in" to accept enhanced sensors or actuators in the future. "Reserve stations" are, in effect, place holders in the communication stream. Unlike earlier distributed control technologies where performance changes with the addition of new sensors and actuators, CC-Link networks are able to maintain performance by simply reducing the number of "reserve stations" when new sensors and actuators are added to the system.

The benefit of distributed control in semiconductor capital equipment has been established by leaders in the industry for many years. Advances in distributed control technology performance, determinism and implementation have motivated serious consideration by other suppliers to the semiconductor industry.

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