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NETWORK COMMUNICATIONS FOR WELD CELL INTEGRATION - STATUS OF STANDARDS DEVELOPMENT

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ABSTRACT

Network technology is being used more and more to replace direct-wired links to integrate equipment components of automated and semi-automated welding systems. The standardization of device-level network technology, and the gradual appearance of network capable welding devices, means that users and integrators are facing the challenge of using networks for the first time, or of choosing one among multiple kinds of networks. A survey of network technologies currently being used for welding products is presented. Two formal welding standards efforts, one by the American Welding Society (AWS) A9 Committee and one by the Open DeviceNet Vendor Association (ODVA), are described. An effort by the Robotics Industries Association (RIA) in sponsoring general purpose network standards for robots is described. Examples of non-standard uses of device-level networks in welding products are given.

The AWS A9 committee can gather experts to express the needs of vendors, integrators, and users, and if appropriate develop standards that will reduce the number of diverging choices to be made.

This paper should be useful to users and integrators of weld cells to evaluate the different network technologies available for implementing welding systems. It may also help device developers make decisions about which technology to adopt, or it may suggest new welding areas where networks can be employed. The goal of standards efforts is to make a common communications solution available for new products and new systems, allowing vendors to provide compatible component products to integrate. Standards can also ease the burden of system developers who currently spend significant effort designing custom protocols or point-to-point interfaces.

KEYWORDS

CAN bus, A9.4, Ethernet, networks, high level protocol, weld cell integration, robotic welding, automatic welding, standards

INTRODUCTION

Networks are being used in many industries. Go to any network Web site (Ref. 1-9) and see their "applications." You won't see welding. But there are welding products that use network technology and their numbers will probably increase.

What is network technology? One view is of the physical interfacing connections. To integrate products of different vendors, current methods use the connectors like those in Figure 1. Use of networks would use a single type of connector and cable on all devices. Each networked device has its own input/output circuitry for processing a transducer signal, and embedded software to participate in the network protocol. Instead of using one wire per control signal conveyed, a network uses a digital message with parameters that are configured in software. What is the

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benefit from using networks? The main benefit is easy connection of a wide variety of devices for real-time control. Wouldn't it be efficient to easily cable together a robot, power source, and a laser vision system with a single connector and cable style and then configure some software parameters to have them work together to weld ship joints? And networks make possible the exporting of data from within cells and devices for use by computer controllers and/or human monitors, and even internet processes.

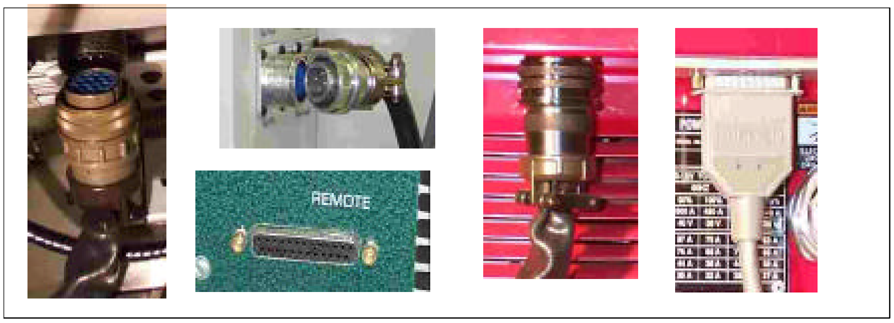
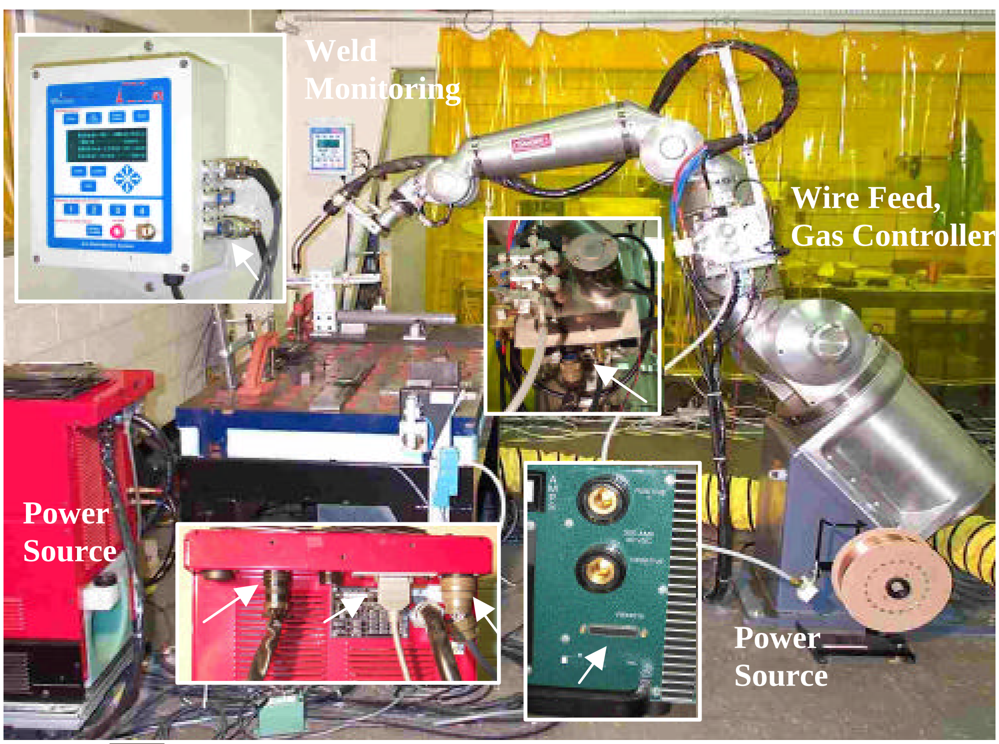


Figure 1. Multiple connector and cable types found in a welding cell.

<u>Weld Cell Integration – the Technology is Changing</u>

Figure 2 shows the point-to-point connections, typical of a non-networked weld cell. The legacy of point-to-point connection can be represented by an AWS standard, *Guide for Components of Robotic and Automatic Welding Installations*, *D16.2-2001*. It describes a 37 pin cable and connector that connects a cell or robot controller to a power source. Each wire conveys binary interlock or 0-10 volt analog signals to and from the power source.



Non-standard interfaces

Figure 2. Opportunities for network connections in a weld cell.

Development of Networks in Other Industries

Several industries are moving forward with comprehensive formal standards for their applications. Table 1 shows a few of them. Their approaches take a broad look at the communications needs for multiple devices that work in integrated units.

INDUSTRY	STANDARD
Semiconductor manufacturing	SEMI E4, E5, 54-0997, IPC 2500
Motor vehicle control	SAE J1939, J1708 (heavy equipment), LIN
Building HVAC and control and monitoring	BACnet, LonTalk (EIA 709.1)
General purpose interface to robots	RIA R15.04 Committee Drafts
Packaging	Leverages device standards of, e.g., CAN, Profibus, Ethernet/IP, DeviceNet
Process Instrumentation	HART

Table 1. Comprehensive Industry Standards

Some standards have narrower scope and define standards for specific devices. Examples are shown in Table 2. These efforts define the characteristics of individual devices within the framework of an established general-purpose network specification.

APPLICATION	NETWORK
Bar code readers	CAN based, Profibus, Ethernet, …
Weaving machines, extruder downstream devices, asphalt paver, diesel locomotives	CANOpen
Lab devices, water treatment	Profibus, Profinet
Coal Mining	Australian project using Ethernet/IP
Components of petrochemical, refining control	Foundation Fieldbus
Pneumatic vales, AC/DC drives	SDS, DeviceNet, Profibus
General purpose devices: Analog IO, binary IO, motion control, valves, photo sensors, proximity sensors, temperature, pressure, limit switches, motor drives	Most field buses

Table 2. Standard Application-Specific Devices

Most industries use generic component-level specifications defined in device-level standards. These specifications define standard interfaces to binary and analog input/output (I/O), proximity switches, limit switches, photo sensors and encoders.

How much is welding control like other applications? Can current networks meet the requirements of welding? Table 3 shows analogies between current standard network devices and welding devices. Many simpler welding devices fit well with models used in other industries. The more complex devices will need welding-specific models but still fit the performance guidelines of existing networks well. The most challenging welding application for networks is the coupling of torch positioners (including robots) with adaptive control processes like thru-arc tracking, or with real-time vision sensors that “see” weld joints and report parameters as the torch is moving. The devices involved are fairly complex, with rich data sets needed for configuration and control. Data rates must meet the needs of torch positioning to produce good welds while adapting to changing sensor parameters.

Welding Component	Standardized Network Device
Clamp, wire snipper	Binary actuator
Part positioner	Motion controller
Switches, optical and proximity sensors	Switches, optical and proximity sensors
Power source	Analogous to position/motion controller
Robot or cell controller	PLC or cell controller
Sensor driven torch positioning system	Coordinated multi-axis motion control

Table 3. Standard general purpose networked devices and similar welding components

WELDING CELL ARCHITECTURE

Opportunities for Networks Inside Welding Cells

The interfaces shown as lines in Figure 3 can be implemented using network technology. Additional devices could include safety sensors, clamps, wire snippers and manual switches. The power source could be a controller for some of the devices, or a robot or programmable logic controller (PLC) could be used. The primary issue for standardization is, are there useful generalizations of each device type that can be used as a standard device profile so that products from different manufacturers will respond the same to network messages, and perform the same functionality. An important vendor concern about standards is that they must also accommodate use of unique device features.

Issues for Welding Component Developers and Integrators

At this time there are very few commercial network-capable products, and no formal welding standards. There is no network technology that dominates in number of available welding devices, and thus no obvious preference expressed by users. Component developers and integrators must risk choosing a network technology with no guarantee of future availability of more devices. In many cases they develop their own network capable devices instead of buying them, and in some cases invent new protocols. Regarding choice of network technology, in some cases where different networks have similar data rate and message properties, gateways can be used to translate messages back and forth. This can ease the integration effort. Some current standard network pairs can by linked by off the shelf gateway products.

There are few off-the-shelf welding devices that come network ready. Some companies develop their own interfaces and protocols because of this. An example is a maker of automated pipeline welding systems that uses basic Controller Area Network (CAN) bus technology with a proprietary high level protocol for their in-house developed components (Ref 11). Standards, and products that conform to them, could have reduced their integration effort. They got their system running with a simplified protocol while the standards situation is not well defined, but will have to develop their own compatible devices. Standards can help pursuade component vendors to implement network interfaces because conformant products are guaranteed to be compatible. Developers within each industry are looking to implement the smallest set of network choices to make their products attractive in the market, where there isn't and probably won't be a single dominant network technology.

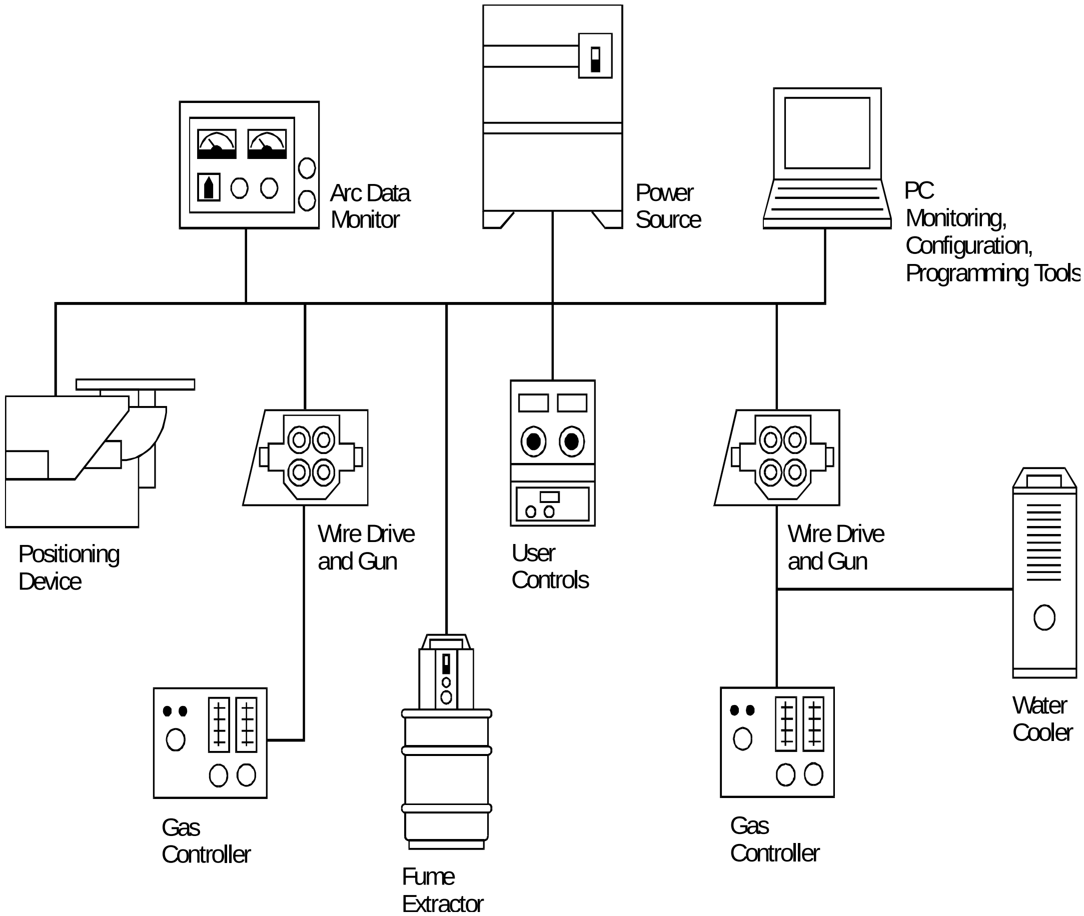


Figure 3. A sampling of welding components interconnected within an automated cell.

CURRENT COMMERCIAL NETWORK TECHNOLOGY FOR WELDING

There are three broad layers of network technology that are targets of standardization. The ***Packet layer*** defines cable, connectors, and electrical signals, and raw packets of data. The ***High Level Protocol*** (HLP) defines the formatting and meaning of packets and how they are routed, and general definitions of device and data types. The ***Device layer*** describes very specific application-dependent devices, their internal information, and their functionality in response to HLP messages.

Non-Standard Network Interfaces

Table 4 shows examples of welding products that implement network technology, but do not implement standard, formal public specifications. The packet layer and HLP used are usually formal standards, but the device layer is defined by vendor specifications.

PRODUCT	NETWORK TECHNOLOGY
Wrist interface, resistance welding controller, resistance weld monitoring, welding robot (for IO), power source	DeviceNet, InterBus
Resistance welding controller	Profibus, ControlNet
Power source	CANOpen, Ethernet with proprietary protocol
Pneumatic valves, AC/DC drives	SDS
Automated pipeline welding system (Ref 11)	CAN bus with proprietary protocol
Wire feed, gas controller, power source	CAN Bus with proprietary protocol

Table 4. Examples of welding products with non-standard interfaces

CURRENT FORMAL WELDING STANDARDS EFFORTS

There is one formal public standard for welding devices that encompasses the device layer. The InterBus-S *Weld-COM-Profile C0 Welding Controllers* [Ref 5] specifies 16 bits of command data and 16 bits of status data. The remainder of the 4 byte interface is allocated to manufacturer data. This narrow scope interface may not support modern power sources. There are two projects underway to develop complete interoperable public specifications, by the American Welding Society (AWS) and the Open DeviceNet Vendor Association (ODVA). Both techniques use the CAN bus and protocol for conveying messages, but they differ in their scope and the details of their application level protocols. Both techniques use 5 wire cables that include 2 wires for DC power. There are also variations in physical cable specifications and the electrical characteristics of signals.

The American Welding Society develops public standards for a wide variety of welding products and processes. The resulting standards are called “American Standards” because the development procedures are proscribed and monitored by American National Standards Institute (ANSI). Participants in AWS standards activities can be any interested and qualified person. The AWS project, *A9.4 Specification for Data Structures and Protocols for the Exchange of Intra-cell Welding Information,* specifies a device-level network for integrating welding components such as power source, wire feeder, gas controller and positioner. Figure 3 comes from the A9.4 document. A9.4 uses the standard CAN specification (ISO 11898) for the bus access arbitration and message encoding. A9.4 defines services implemented using network messages, and ways to define the devices that use the network. It also specifies the descriptions of welding devices in terms of attributes and services that can be accessed. A9.4 is an ongoing project and should be published in 2004. AWS also has a committee on Robotics, called D16, which could sponsor robot-related specifications.

ODVA is a controls and networks industry vendor organization (Ref 5). It sponsors the DeviceNet and Ethernet/IP specifications for networks. Participants must be members of ODVA. The DeviceNet specification contains several general purpose devices, with provision for Special Interest Groups (SIGs) to develop further refinements of device profiles for specific applications. The Arc Welding SIG is working on a DeviceNet profile and IO addressing scheme for an arc welding power source. The network view of the power source includes status of lower level devices but no control of them. The interface would be used by a robot controller or cell PLC to configure welding parameters, command arc on/off, purge gas, and to assess status like voltage and current, arc-started and faults. The scope of this spec is “looking into” the power source from supervisory control. The A9.4 scope covers the interfaces to devices typically "seen" by the embedded real-time controller of a power source or PLC. A network configuration using both specifications would be a DeviceNet interface conveying commands to the integrated power source, possibly from a robot controller, and the internal controller of the power source connected to the wire feeder and gas controller using A9.4.

A standards effort that could affect welding systems is the Robotics Industries Association (RIA) R15.04 Communication and Information Committee (Ref 12). RIA is a North American trade group formed to serve the robotics industry. R15.04 is working on general purpose interfaces to robot controllers, using Ethernet, for functions including controller boot up, configuration, file transfer, status reporting. The committee has begun by choosing among the wide list of current services and defining standard data sets for robots, rather than developing new communications protocols. The effort will eventually address real-time control issues. The specification could eventually apply to welding robotics.

What Organizations Would Sponsor Formal Welding Network Standards?

Specifications for welding devices could remain as informal vendor-developed or corporate versions that could be quite useful to users and integrators of welding systems. However formal standards can produce greater market effect and lead to wider adoption of networks in welding. The most common candidate technologies come from industry associations that represent network technology segments or specific industries. The A9.4 document is an exception to this trend, and AWS, as an American national standards organization, is the sponsor of the standard. AWS standards are eligible for International Organization for Standardization (ISO) consideration, but no plans are yet made for A9.4.

Industry association specifications are often adopted by national, regional (e.g. European), or international organizations. The most likely protocols for welding devices are: DeviceNet, Ethernet/IP, ControlNet, Profibus, CANOpen and ModBus. DeviceNet (EN 50325-2:2000), CANOpen (EN 50325-4:2002) and parts of Profibus have been adopted by the European organization CENELEC (Ref 8), and by International Electrotechnical Commission (IEC). It could be expected that welding device specifications would also follow this route. CENELEC's network committee would be Technical Body CLC/TC 65CX (Fieldbus). From their mission statement: "CENELEC, the European Committee for Electrotechnical Standardization, was created in 1973. CENELEC is a non-profit technical organization set up under Belgian law and composed of the National Electrotechnical Committees of 20 European countries. CENELEC's mission is to prepare voluntary electrotechnical standards that help develop the Single European Market/European Economic Area for electrical and electronic goods and services by removing barriers to trade, creating new markets and cutting compliance costs."

The IEC is an international organization that works with CENELEC and ISO to jointly develop documents. IEC prepares and publishes international standards for all electrical, electronic and related technologies. The IEC group that would develop welding network specs would be TC65 (Industrial Measurement and Control), SC 65C (Digital Communications) or SC 65B (Devices). The ISO branch is TC 184 (Industrial Automation Systems)/SC5 (Communications and Architecture).

SUMMARY

Network capable products are used in manufacturing, process control, and transportation industries extensively. Network implementations for control seem to be yielding the advertised benefits of easier integration, ability to convey data outside of cell limits, more reliable operation than point-to-point, and possible wider marketing opportunities for smaller equipment vendors. A few networked products for welding are available: some use proprietary protocols and some leverage public standard networks, complemented by vendor-defined device profiles. It is likely that the welding industry could benefit from more extensive use of networks for device control, with standards helping to guide component vendors and system integrators in narrowing the choice of network to use among the wide variety available.

There are currently two formal network standards efforts for welding specific devices. There are more non-formal public and proprietary implementations, which may make their way to the formal public standards arenas. AWS supports the "A9.4" effort and can serve as a forum for interested users, vendors and integrators to work together.

REFERENCES

1. ARCnet Trade Association, http://www.arcnet.com.
2. ASHRAE SSPC 135, sponsor of BACnet. http://www.bacnet.org.
3. CANOpen, http://www.canopen.org.
4. Foundation Fieldbus, http://www.fieldbus.org.
5. InterBus, http://www.interbusclub.com/en/doku/index.html.
6. Modbus, http://www.modbus.org.
7. Open DeviceNet Vendor Association (ODVA), sponsor of ControlNet and Ethernet/IP – http://www.odva.org.
8. Profibus, http://www.profibus.org
9. Smart Distributed System (SDS), http://content.honeywell.com/sensing/prodinfo/sds/.
10. European Committee for Electrotechnical Standardization (CENELEC), http://www.cenelec.org.
11. IPC website for semiconductor manufacturing specifications, http://www.ipc.org/html/fsstandards.htm, and http://www.gencam.org.
12. "Men and Machines Set New U.S. Pipeline Productivity, Quality Record". *Welding Design and Fabrication Monthly*, Nov. 2002, Penton Media Publisher. Article available at http://www.appliedwelding.com/arcs_in_action/arc1su02.html.
13. NIST/RIA Open Architecture Workshop, http://www.isd.mel.nist.gov/projects/openarch. RIA R15.04 Chairman Jeff Fryman, (734) 994-6088, jfryman@robotics.org, http//:roboticsonline.com.
14. Sink, Perry, "A Comprehensive Guide to Industrial Networks", June 2001, *Sensors Magazine*, http://www.sensorsmag.com/articles/0601/28/index.htm
15. AWS A9.4, working draft 8. *Specification for Data Structures and Protocols for the Exchange of Intra-cell Welding Information.*
16. Balfour, Chris, Smith, Jeremy, "Controller Area Network (CAN) Applied to Welding Systems", Proceedings of Welding Technology Institute of Australia, 50th Annual Conference, Melbourne, Australia, August 2002.

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