Available online at www.sciencedirect.com
SCIENCE DIRECT®
Computers and Electronics in Agriculture 48 (2005) 245–255
Computers and electronics in agriculture
www.elsevier.com/locate/compag

Use of the "smart transducer" concept and IEEE 1451 standards in system integration for precision agriculture

Jiantao Wei [a], Naiqian Zhang [a,*], Ning Wang [b], Donald Lenhert [c], Mitchell Neilsen [d], Masaaki Mizuno [d]

[a] *Department of Biological and Agricultural Engineering, Kansas State University, Seaton Hall, Room 147, Manhattan, KS 66506, USA*
[b] *Department of Bioresource Engineering, McGill University, Ste-Anne de Bellevue, Que., Canada H9X3V9*
[c] *Department of Electrical and Computing Engineering, Kansas State University, KS 66506, USA*
[d] *Department of Computing and Information Science, Kansas State University, KS 66506, USA*

Received 6 December 2004; received in revised form 18 April 2005; accepted 19 April 2005

Abstract

As an increasing number of electronic control units with various types of sensors and actuators are embedded in agricultural machines and processes, efficient system integration has become a critical issue. A recently developed agricultural bus standard, ISO 11783, provided a platform for mobile equipment communications, enabling a plug-and-play capability for implement microcontrollers made by different manufacturers. This paper further recommends the use of the IEEE 1451 standards to design "smart transducers" to facilitate plug-and-play for sensors and actuators made by

Abbreviations: ADC, analog-to-digital converter; CAN, Controller Area Network; DAC, digital-to-analog converter; ECU, electronic control unit; EEPROM, Electrically Erasable Programmable Read-only Memory; I/O, input/output; IEEE, Institute of Electrical and Electronics Engineers; ISO, International Organization for Standardization; NCAP, Network-Capable Application Processor; NIST, National Institute of Standards and Technology; RAM, Random Access Memory; SPI, Serial Peripheral Interface; STIM, Smart Transducer Interface Module; TEDS, Transducer Electronic Data Sheet; TII, Transducer-Independent Interface; UART, Universal Asynchronous Receiver–Transmitter; USB, Universal Serial Bus

* Corresponding author. Tel.: +1 785 532 2910; fax: +1 785 532 5825.
E-mail address: zhangn@ksu.edu (N. Zhang).

0168-1699/$ – see front matter
doi:10.1016/j.compag.2005.04.006

different manufacturers and thus further simplifying system integration. In this paper, the IEEE 1451 standards are reviewed, compatibility between ISO 11783 and IEEE 1451 is analyzed, an example of a weed sensing system using both the IEEE 1451 and the LBS standard (a predecessor of the ISO 11783 standard) is introduced, and the advantages and disadvantages of this implementation are discussed.

Keywords: Precision agriculture; Embedded systems; System integration; Smart transducer; CAN; Sensors; Actuators

1. Introduction

During recent years, an increasing number of electronic control units (ECU, a complete list of abbreviations is given at the footnote of page 1) with various types of sensors and actuators have been embedded in agricultural machines and processes. For example, a modern John Deere 8000-series tractor with Green Star Ready™ has at least 16 ECUs onboard (Deere & Company, 2001). Based on the Controller Area Network (CAN), a recently developed agricultural bus standard, ISO 11783, provides a platform for mobile equipment communications (ISO, 2001). This standard details the necessary requirements for agricultural electronics communications, such as message types, identifier assignment, and network management, to enable a plug-and-play capability for ECUs made by different manufacturers. However, the standard does not specify how to connect raw sensors and actuators to the ECUs.

Most sensors generate analog (voltage or current), digital, or pulse signals. These signals need to be properly conditioned before further analog signal or digital signal processing can proceed. Typical signal conditioning includes amplification, level translation, linearization, and filtering. The advancement of silicon technology makes it fairly cheap to integrate a microprocessor with physical sensors/actuators and associated signal conditioning/processing circuits to form a single, compact package—a "smart transducer" (Johnson, 1997). The "smart transducer" concept shifts the task of designing signal conditioning and processing from application engineers to transducer manufacturers so that application engineers can concentrate on application-specific tasks. Smart transducers directly output processed digital signals such that, with good electronic system designs, data corruption due to noise pickup should not occur. Furthermore, smart transducers can be easily networked; thus, operations of the sensing elements can be monitored via a network and diagnosis at the system level can be simplified (Wynn, 2000).

For easy sensor/actuator integration, a common interface between transducers and other parts of the system needs to be introduced. Information exchange across such an interface is possible only if the transducer manufacturers and the transducer users follow the same standard. To date, there is no consensus among agricultural equipment manufacturers and transducer manufacturers about how to integrate transducers on agricultural machines (Wei, 2003). In this paper, the IEEE 1451 smart transducer standards are recommended as a tool to be used with the ISO 11783 standard for integration of sensors, actuators, and embedded microprocessors for precision agriculture applications.