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SPWD Based IEEE 1451.2 Smart Sensor Self-Recognition Mechanism and Realization

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Abstract

In order to improve the self-recognition capability of the IEEE 1451 smart sensor and enhance the level of sensor's intelligence and application flexibility, this paper presents a SPWD (sorting pulse width difference) based IEEE 1451.2 smart sensor self-recognition mechanism. The mechanism realizes baud rate self-adaption of IEEE 1451.2 serial interface first adopting the SPWD method. It also utilizes TEDS (transducer electronic data sheet) definition and configuration technique and virtual TEDS parsing algorithm to achieve smart sensor self-recognition. Then, an IEEE 1451 smart weighing sensor system is constructed using this mechanism and its self-recognition properties are tested. The experiment results show that, when the baud rate is 28800 bit/s, SPWD based IEEE 1451.2 smart sensor's recognition rate is 99.07% and its average recognition time is 1.20s.

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Keywords: IEEE 1451.2; SPWD; self-recognition; virtual TEDS

1. Introduction

Smart sensor is the development direction of sensor technique, and the IEEE 1451 standards were implemented to solve smart sensors' problems such as self-recognition, interchangeability and standardization. IEEE 1451.2 sub-standard provides general hardware and software connection schemes including IEEE 1451.2 interface and TEDS to achieve smart sensor self-recognition. However, its self-recognition mechanism has different application methods and implementations[1, 2]. The research of smart sensor self-recognition mechanism is signality. Rossi (2009) researched FPGA based programmable TII

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(transducer independent interface) controller to improve the adaptation capacity of NCAP (network capable application processor) and parallel interface. But the TII controller did not cooperate with TEDS to achieve self-recognition[3]. Depari (2007) adopted VHDL to set up TII protocol model and emulated the transmission and triggering procedure of TII protocol data (including TEDS) through finite-state machines. However, only the timing sequence characteristics of different operations were researched and the self-recognition indexes were not researched[4]. Some scholars proposed IEEE 1451.2 sensors system framework to support interface such as RS232, UART, USB, CAN-bus and so on. The researches also achieved smart sensors self-recognition by reading and configurating standard TEDS. But the baud rate of ASI (asynchronous serial interface) does not adapt automatically[5].

This paper proposes a self-recognition mechanism combining SPWD based baud rate self-adaption mechanism with TEDS definition and configuration technique, especially virtual TEDS parsing algorithm, to achieve smart sensor self-recognition. Then an IEEE 1451 smart weighing sensor system is realized adopting this mechanism. Taking recognition rate and recognition time as indexes, the functional testing for SPWD based IEEE 1451.2 smart sensor self-recognition mechanism is implemented.

2. SPWD based IEEE 1451.2 smart sensor self-recognition mechanism

2.1. Architecture of networked smart sensor based on IEEE 1451.2

Fig. 1 illustrates the architecture of networked smart sensor based on IEEE 1451.2, which includes STIM (smart transducer interface module), NCAP and IEEE 1451.2 interface (including TII, UART, RS232/485/422, USB and so on) to achieve the communication between STIM and NCAP. STIM is in charge of sensor data receiving, signal conditioning and A/D conversion. It transmits sensor data and TEDS to NCAP through IEEE 1451.2 interface. TEDS saved in STIM is the key unit. NCAP receives and configurates TEDS, then receives, calibrates and saves sensor data. It also transmits data to the remote through its network interface.

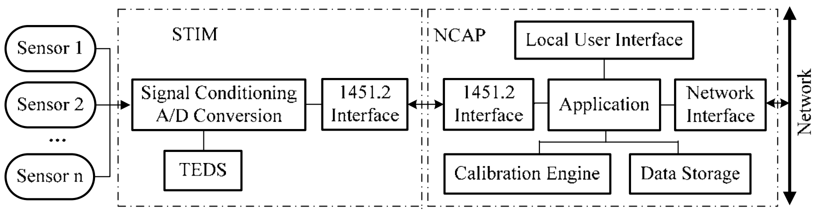

Fig.1. Architecture of networked smart sensor based on IEEE 1451.2

2.2. SPWD based baud rate self-adaption mechanism

The fundamental of SPWD based baud rate self-adaption mechanism includes several steps as follow.

A. STIM samples and measures several pulses, then sorts all unequal pulses width from small to large.

After STIM connects to NCAP and initializes, it samples and measures n (n>1) pulses (positive or negative) in communication between other STIMs and NCAP on the serial bus. Then, it sorts all unequal pulse width from small to large. The first increasing pulse width sequence is obtained as follow.

$$N_1^{(1)}t_{bit}, N_2^{(1)}t_{bit}, N_3^{(1)}t_{bit}, \cdots, N_{m_1}^{(1)}t_{bit}$$

Where t_{bit} is the time of system node sending 1 bit data, $N_{m_1}^{(1)}$ is the integral multiple of t_{bit} (The superscript (1) is the 1st sorting and the subscript from 1 to m_1 is the sequence number of sorting pulses width.)

B. STIM implements difference calculation on sorting pulse width repeatedly until calculating out the minimum pulse width.

The difference calculation is the latter pulse width minus the previous one in contiguous pulses. In the first increasing pulse width sequence, the result of the difference calculation is following.

$$(N_2^{(1)} - N_1^{(1)})t_{bit}, (N_3^{(1)} - N_2^{(1)})t_{bit}, \cdots, (N_{m_1}^{(1)} - N_{m_1-1}^{(1)})t_{bit}$$

Then, STIM renewedly sorts all the unequal pulses in the pulse width sequences before and after subtraction. The second increasing pulse width sequence is obtained as follow.

$$N_1^{(2)}t_{bit}, N_2^{(2)}t_{bit}, N_3^{(2)}t_{bit}, \cdots, N_{m_2}^{(2)}t_{bit} \qquad (m_2 \geq m_1)$$

Similarly, if the p-1 and p increasing pulse width sequences are different ($m_{p-1} \neq m_p$), STIM implements difference calculation on the newest increasing pulse width sequence $N_1^{(p)}t_{bit}, N_2^{(p)}t_{bit}, N_3^{(p)}t_{bit}, \cdots, N_{m_p}^{(p)}t_{bit}$. Then, STIM renewedly sorts all the unequal pulses in the sequence $(N_1^{(p)} - N_2^{(p)})t_{bit}$, $(N_3^{(p)} - N_2^{(p)})t_{bit}$,…, $(N_{m_p}^{(p)} - N_{m_p-1}^{(p)})t_{bit}$ after difference calculation and the p increasing pulse width sequence before difference calculation. The p+1 increasing pulse width sequence is obtained as follow.

$$N_1^{(p+1)}t_{bit}, N_2^{(p+1)}t_{bit}, N_3^{(p+1)}t_{bit}, \cdots, N_{m_{p+1}}^{(p+1)}t_{bit} \qquad (m_{p+1} \geq m_p)$$

STIM repeats the above steps until the q and q+1increasing pulse width sequences are equal (m_q=m_{q+1}) after q times difference calculation. The final increasing pulse width sequence is obtained as follow. $N_1^{(q)}t_{bit}$ is the minimum pulse width.

$$N_1^{(q)}t_{bit}, N_2^{(q)}t_{bit}, N_3^{(q)}t_{bit}, \cdots, N_{m_q}^{(q)}t_{bit} \qquad (m_q > m_{q-1})$$

C. STIM calculates the baud rate using the minimum pulse width.

The baud rate is given by Formula *(1)*. In the formula, i means the i calculation. Then STIM configurates its interface baud rate by BR_i'.

$$BR_i' = \frac{1}{N_1^{(q)}t_{bit}} \qquad (1)$$

$N_1^{(q)}$ has two cases. (a) $N_1^{(q)}$=1. If the greatest common divisor of $N_1^{(1)}$, $N_1^{(2)}$,…, $N_{m_1}^{(1)}$ equals 1, $N_1^{(q)}$=1 and BR_i' and NCAP baud rate BR(Formula *(2)*) are matched. (b) $N_1^{(q)} \neq 1$. If the greatest common divisor of $N_1^{(1)}$, $N_1^{(2)}$,…, $N_{m_1}^{(1)}$ does not equal 1, BR_i' and BR are not matched. In this case, the D step can verify the baud rate unmatched. But the probability of this case is tiny and decreases with n increasing.

$$BR = \frac{1}{t_{bit}} \qquad (2)$$

D. STIM compares its baud rate BR_i' with NCAP baud rate BR.

STIM sends a baud rate confirmation request frame including BR_i' information to NCAP. If NCAP receives the frame within the specified time and the BR_i' information matches with BR, NCAP sends a baud rate confirmation ACK frame to the STIM. If STIM receives the frame within the specified time, BR_i' and BR are matched; otherwise, STIM returns to A, B, C and D steps until the baud rates matching.

2.3. TEDS definition and configuration

TEDS is one of the core technologies of IEEE 1451 standard. In order to achieve sensor self-recognition capability, TEDS completely and systematically describes the STIM's operation mode, attribute and relevant parameters (such as UUID, sensor type, physical unit, data model, calibration model and so on). IEEE 1451.2 defines 8 different kinds of TEDS which detailedly and completely represents the type, property and behavior of STIM and sensors. Meta-TEDS and Channel-TEDS are requisite.

Standard TEDS is saved in the storage device in STIM. After STIM baud rate automatically matches and STIM communicates with NCAP, NCAP reads TEDS from STIM and then parses TEDS and obtains the communication speed, channel number, data format, physical unit and so on. After that, NCAP configurates TEDS and allocates resources. Fig. 2(a) illustrates TEDS configuration procedure.

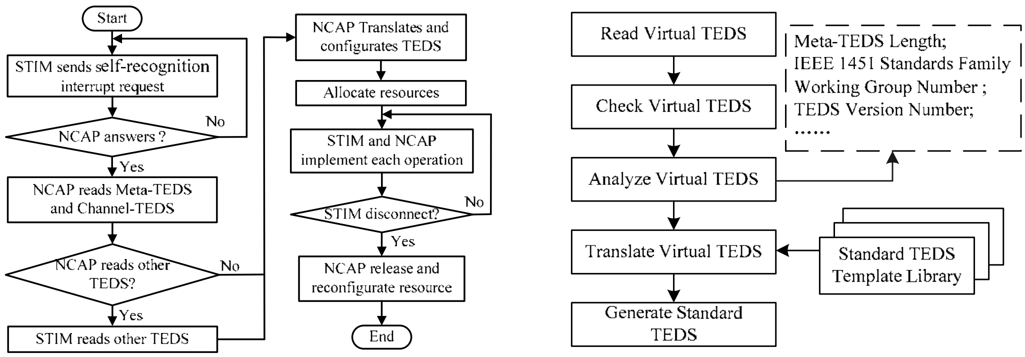

Fig. 2. TEDS process. (a) TEDS configuration procedure; (b) Virtual TEDS parsing algorithm procedure

Electronic storage device is not allowed to use in some measurement environments and some sensors' running status. In these cases, it is necessary to utilize virtual TEDS to achieve sensor self-recognition. Virtual TEDS file may be defined using SGML (such as XML and HTML). It is saved in local computer or networked data base. NCAP downloads the corresponding virtual TEDS from local computer or data base according to sensor's model number and serial number. NCAP utilizes virtual TEDS parsing algorithm to check, analyze and translate virtual TEDS. Finally, virtual TEDS is generated into standard binary TEDS. This virtual TEDS parsing algorithm can ensure the safety, validity and standardization of virtual TEDS configuration. Fig. 2(b) illustrates virtual TEDS parsing algorithm procedure.

3. Application and test

An IEEE 1451 smart weighing sensor system is achieved applying SPWD based IEEE 1451.2 smart sensor self-recognition mechanism (as shown in Fig. 3). STIM employs AD7190 for A/D conversion and C8051F350 for signal conditioning and data processing. Standard TEDS is saved in flash. Virtual TEDS is described by XML and saved in networked data base. TEDS includes Meta-TEDS, Channel-TEDS and Calibration-TEDS. IEEE 1451.2 interface adopts RS422 to achieve one-to-many communication. Taking recognition rate and recognition time as indexes, the functional testing for the self-recognition mechanism is implemented. Table 1 is the functional testing result in different baud rates.

4. Conclusion

(1) SPWD based baud rate self-adaption mechanism fully mines the baud rate information in pulses. In the circumstances without receiving particular frame or sampling 1 bit pulse, the baud rate self-adaption achieves rapidly. The mechanism is strongly adaptable, simple, high-efficiency and high-reliability.

(2) Virtual TEDS expands the scope of application of TEDS in special occasions. The virtual TEDS parsing algorithm achieves checking, analyzing and translating virtual TEDS, then generating standard TEDS. This algorithm can ensure the safety, validity and standardization of virtual TEDS configuration.

(3) SPWD based IEEE 1451.2 smart sensor self-recognition mechanism achieves baud rate self-adaption and sensor self-identification. It greatly enhances sensor's intelligence and application flexibility.

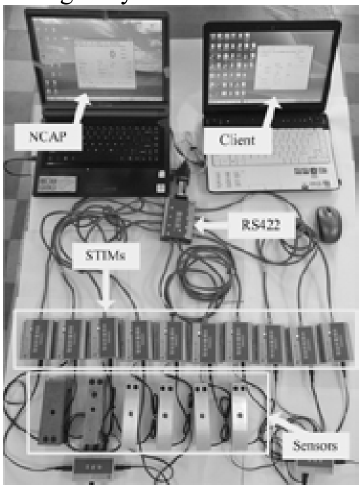

Fig.3 IEEE 1451 smart weighing sensor system

Table 1. Functional testing result in different baud rates

Baud rate (bit/s)	Recognition rate (%)	Recognition time (s)
28800	99.07	1.20
19200	98.94	1.44
9600	98.19	1.61
4800	97.53	1.82

Acknowledgements

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