Journal of the Korean Society of Marine Environment & Safety
Research Paper
Vol. 20, No. 3, pp. 318-322, June 30, 2014, ISSN 1229-3431(Print) / ISSN 2287-3341(Online) http://dx.doi.org/10.7837/kosomes.2014.20.3.318

Configuration of Actuator and Sensor Interface Bus Network using PLC

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Abstract : *A kind of field bus called Actuator and Sensor interface bus(AS-i) was designed in this paper. The configuration of AS-i network system used Application Specific Integrated Circuit(ASIC) SAP5S chip and PLC S7-200 station, which included CPU 224 and AS-i master module CP 243-2. We also created an example program for PLC S7-200 to control AS-i network. The fire and smoke detection system was made with AS-i network system that was designed. This system had got more advantages than other system such as number of stations, easy installation, wide working area, etc. And designed system can be used as a partner network for higher level field bus networks.*

Key Words : *Special field bus, Actuator and sensor interface bus, PLC S7-200 station, Module CP 243-2, SAP5S chip*

1. Introduction

Nowadays, replacing simple sensors and actuators with AS-i Actuator/Sensor has become popular in automation, AS-i is already a worldwide standard for simple I/O network. Its potential, to cost effectively replace the rat's nest of wires that permeates most of industrial sites, is tremendously appealing across many industries. Among the available low level sensor/actuator replacement networks, AS-i offers the highest performance at the least cost(Gasser, 1996). In its original form, the network was capable of supporting up to 31 binary I/O components, where each device could exchange 4 bit of input and output data, resulting in a total of 124 inputs and outputs on a single network. Update time of each component is 150 microseconds and for a maximum component, update time is 5msec. With certain specification enhancements, AS-i systems allow the use of analog input/output devices and increase the number of possible binary I/O components to 62 from 2005 to now. The maximum update time of a fully loaded network is 10 msec for inputs and 20 msec for outputs. Diagnostics functionality was also enhanced by the creation of the Peripheral Fault Bit. With these new capabilities, AS-i becomes the ideal partner network for any of the currently available Ethernet based industrial protocols. Besides that, PLCs are used popularly and we can install configuration of AS-i with PLC. Siemens PLC, special PLC S7 stations, is applied vary widely in many fields of industry. So in this paper, we introduced a minimum configuration of AS-i bus using PLC S7 station, which included CPU 224 and AS-i master module CP 243-2. On the other hand, the interface between the actuator/sensor and the bus system should be established. SAP5S chip, a product of ZMD Company, can meet the bus system's demand.

The configuration of this AS-i bus system can be applied to small and medium size industrial systems(approximately 800 digital input/output ports). In addition, AS-i bus can be used in flammable environments such as petrol and gas environment. The drawback of this configuration is that it has no analog parts. So, when the system works with analog signals, the ADC converters are added. This paper will present the application of the AS-i bus to fire, smoke alarm systems.

2. AS-i Protocol Overview

The AS-i communication procedure is a Master/Slave method (Fig. 1), where Master is PC, micro-C or PLC and we have 2 types of Slave, Active Slave(with ASIC), Passive Slave(without ASIC).

AS-interface code is APM(Alternate Pulse Modulation) code which is collected from AFP(Alternate Flanks Pulse) and Manchester code, so AS-i can use single two-conductor cable to supply power to the components and enable data transfer. We can connect components two bus types, Trunk line/Drop line or Daisy chain as shown in Fig. 2.

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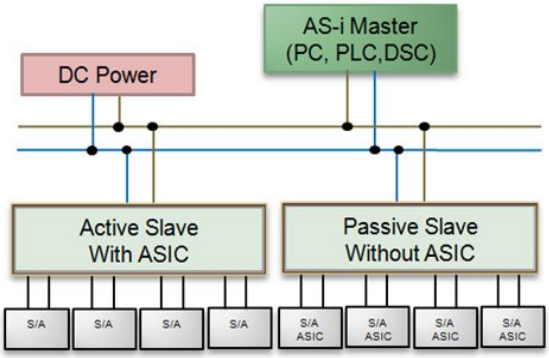


Fig. 1. AS-interface Protocol.

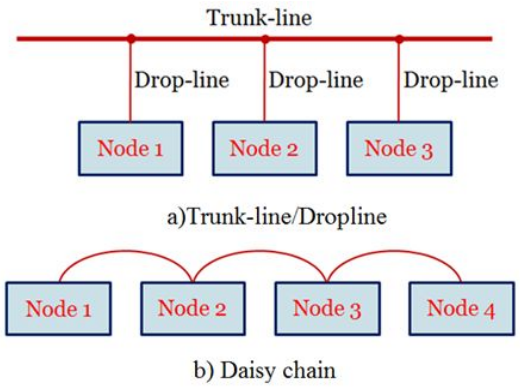


Fig. 2. AS-interface bus.

AS-interface bus processes digital signals of actuators and sensors and it only cares update time as fast as possible. therefore, the AS-interface bus applies the physical layer in OSI(Open System Interconnection reference) model(Reynders et al., 2005).

Characteristics of AS-interface are shown in the table 1.

Fig. 3. shows an example of an AS-i system configuration used PLC S7-200 Station. In this paper, the configuration is researched.

In this configuration, master of configuration is PLC S7-224 and module CP 243-2. Slave is active slave with ASIC SAP5S.

Table 1. AS-i Technical Characteristics

Maximum Number of Nodes	31 in traditional systems, 62 in extended system
Number of I/O Points	248 I/O points (4In, 4Out per node)
Maximum Cable Length	100m without repeaters, 300m with repeaters
Power	24VDC
Medium	Unshielded 2 wire cable for both power and data
Wiring Technology	Insulation displacement for speed and ease of installation.
Topology	Daisy-chain or Trunk line/drop line Structure
Typical Data Rate	5ms for 31 node systems. 10ms for 62 node systems.
Error Detection	The AS-i master automatically detects invalid slave transmissions and schedules repeats
Configuration	Slaves are automatically configured with a Slave Address by the Master or a Programming Tool.
Master-Slave Operation	A Master poll each slave sequentially and awaits a response.
Hot Swap of Slave Devices	Supported
PLC Programming	AS-i data is simply remote IO data to the PLC.
Discrete Device Support	Supported

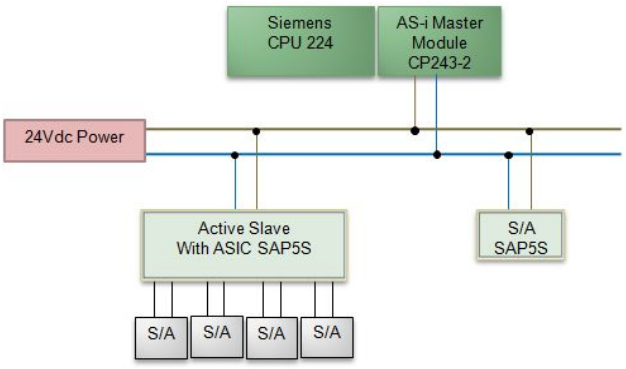


Fig. 3. AS-i system configuration.

3. Module CP 243-2

From the point of view of the S7-22x CPU, the CP 243-2 (Fig. 4) represents two expansion modules(an 8DI/8DO digital module and an 8AI/8AO analog module). The design of the CP 243-2 corresponds to that of a standard expansion module for an S7-200(Siemens, 2000).

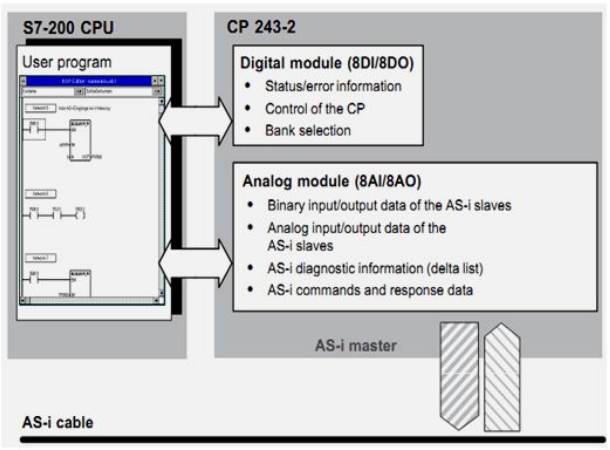


Fig. 4. Structure of CP 243-2.

3.1. Technical specifications of Module CP243-2

The technical specifications of the CP 243-2 module are as follows.

AS-i cycle time : 5 ms with 31 slaves 10 ms with 62 AS-i slaves using the extended addressing mode
Power supply SIMATIC backplane bus : 5 VDC
Current consumption : 220 mA
Power supply from the AS-i cable : According to the AS-i specification
Current consumption : max. 100 mA
Power consumption : 3.7 W

3.2. Interface to the User Program in the S7-200 CPU

The CP 243-2 occupies 2 consecutive expansion module slots in the S7-200: Digital module 8DI/8DO, Analog module 8AI/8AO.

Digital Module : The digital module occupies 8 input and 8 output bits in the address area of the digital inputs and outputs. The S7-200 CPU and the CP 243-2 are coordinated via the digital module. The addressed data in the analog module by the user program is selected using bank select bits. This module consists of 4 registers, but two of them are important. One is status register that shows the status of the CP 243-2 related the AS-i master interface. The other is control register that controls data exchange with the CP 243-2. Their constructions are shown in table 3.

Analog Module : The analog module occupies 16 input and 16 output bytes in the address area of the analog inputs and outputs. Data exchange with the AS-i slaves is handled via the analog module (see Figure 4). The bank select mechanism means that a larger data area in total can be addressed in the analog module than the addressable data area in the S7-200 CPU for the expansion module.

Using a bank-select mechanism, the 8 analog input words and the 8 analog output words can be switched to 64 different analog input areas (banks) and 64 different analog output areas (banks) on the CP 243-2. Each of these banks is 8 words long.

This bank-select mechanism has the advantage that the analog data area of 8 words available for the expansion module is increased according to the number of banks. The switch-over to the various banks is made using bits BS0 - BS5 in the control byte of the CP 243-2.

With Bank 0 (binary I/O data of slaves 1A to 31A) and Bank 31(binary I/O data of slaves 1B to 31B) we can access the binary I/O of the standard slave (slave A) and Slave B (slaves with the extended addressing mode).

In this part, the structure of module CP243-2 and the interface to the user program of the S7-700 CPU were shown. The configuration AS-i bus using PLC S7-224 and CP 243-2 module is used as the master station in the system.

4. Universal AS-i IC

SAP5S is used as a universal AS-i IC. SAP5S is a monolithic CMOS integrated circuit certified for AS-i networks(ZMD, 2005a). AS-i is designed for easy and simple interconnection of binary sensors and actuators. It uses a two-wire unshielded cable to transport power and information. All open drain outputs are NMOS based.

In this application circuit, we can use 4 digital ports in 8 I/O ports(P0～P3, D0～D3) to connect to sensors or actuators. To install addressing of slave with ASIC SAP5S, we use the ZMD AS-i programmer hardware and software(ZMD, 2005b).

Fig. 5 shows a designed slave application circuit using AS-i IC SAP5S.

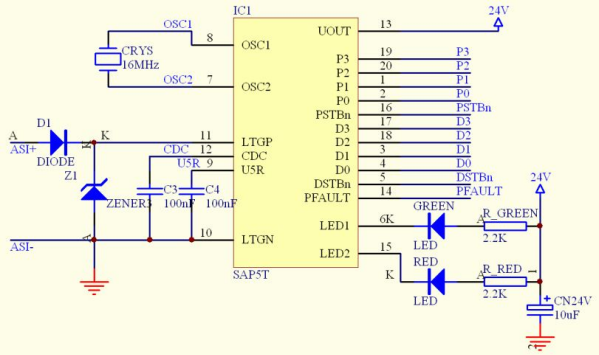
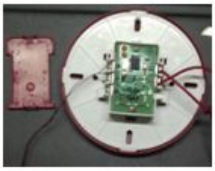


Fig. 5. Designed slave circuit.

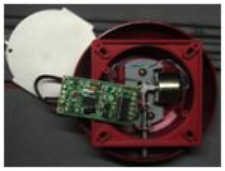
The designed slave circuit is simple and has compact size so it is easy to integrate it into the sensors and actuators. The fig. 6 shows some applications when it is integrated into the smoke detector, the fire detector, the manual call point and the alarm bell. It is used as a slave station in the AS-i bus.

(a) Smoke detector sensor

(b) Fire detector sensor



(c) Manual call point



(d) Alarm bell

Fig. 6. Applications of designed slave PCB.

5. Access to the AS-i user data for AS-i configuration with CP243-2 and ASIC SAP5S

Before you can access the I/O data of the AS-i slaves, the following requirements must be met.

- Deactivate the filtering of the analog inputs for the CP 243 - 2 in the system data block of the S7 - 200 CPU.
- Set the "PLC_RUN" bit(bit 7) in the digital control byte to '1' at the beginning of the cyclic program.
- Access to the I/O data of the slaves is then only allowed when the value of "CP_Ready" bit(bit 1) in the digital status byte is '1'.

To access the binary data of the slaves, we use the analog transfer commands of the STEP 7 Micro/WIN32 programming language. If you want to access individual bits of the slave data, you can use the method shown in the following sample program(Table 2, Fig. 7).

The example created with STEP 7 Micro/WIN32 is valid for a CPU 224 with a CP 243-2 plugged in directly beside CPU(SIMATIC, 2005). The Address of digital and analog Modules of CP 243-2 are shown in Table 3.

Table 2. Sample program

LD SM0.1 // If: bit "First Scan": *SI Q2.7,1 // PLC_RUN = 1* *LD I2.1 // If: CP 243-2_READY*	The steps are required before access I/O data of the CP243-2
LD SM0.0 // Always=1 *RI Q2.0, 6 // Select Bank 0(A Slaves)* *BMW AIW0, VW300, 8* *SI Q2.0, 5 // Select Bank 31(B Slaves)* *BMW AIW0, VW316, 8*	Moving the status of all digital sensors to the CPU's memory from byte no.300 to byte no.330
LD V326.4 // If bit P0 of slave 20B *A V315.1 // And bit P1 of slave 31A* *RI Q2.0, 6 // Select Bank 0 (Slaves A)* *MOVW 16#0400, AQW0 //Turn On bit D2 of slave 1A* *SI Q2.0, 5 // Select Bank 31 (Slaves B)*	If the sensors, which are at slave addresses 31A and 20B, are active then turn on actuators at slave addresses 1A and 11B

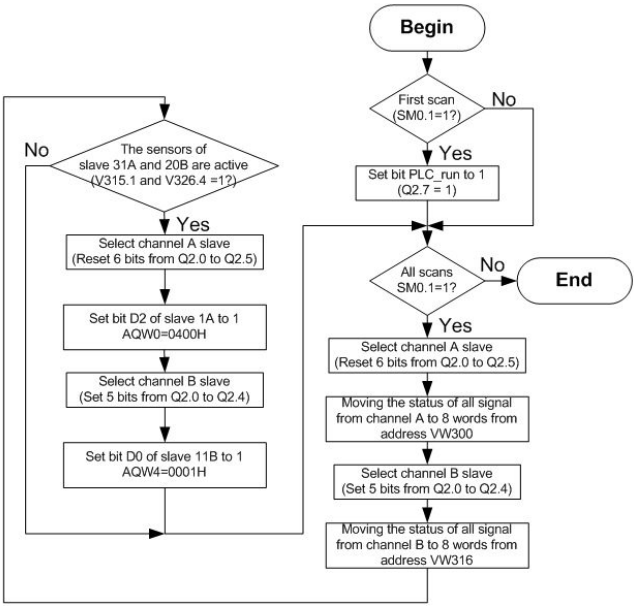


Fig. 7. Flow chart of sample program.

Table 3. CP 243-2 digital and analog modules plugged in directly beside CPU 224

CPU224		AS-i master module CP243-2			
		Digital module		Analog module	
14DI	10DO	Status reg. (8DI)	Control reg. (8DO)	8AI	8AO
I0.0	Q0.0	I2.0(ASI_MODE)	Q2.0(BS0)	AIW0	AQW0
I0.1	Q0.1	I2.1(CP_READY)	Q2.1(BS1)	AIW2	AQW2
I0.2	Q0.2	I2.2(0)	Q2.2(BS2)	AIW4	AQW4
I0.3	Q0.3	I2.3(0)	Q2.3(BS3)	AIW6	AQW6
I0.4	Q0.4	I2.4(0)	Q2.4(BS4)	AIW8	AQW8
I0.5	Q0.5	I2.5(0)	Q2.5(BS5)	AIW10	AQW10
I0.6	Q0.6	I2.6(0)	Q2.6(ASI_COM)	AIW12	AQW12
I0.7	Q0.7	I2.7(ASI_RESP)	Q2.7(PLC_RUN)	AIW14	AQW14
⋮	⋮				

6. Conclusion

The application of AS-i master CP243-2 and universal actuator-sensor interface IC SAP5S create an AS-i system configuration, that is a high-precision, high scalability, compact interface, easy installation, expansion communications system. In addition, AS-i uses Manchester code, the system can eliminate direct current and use only single two-conductor cable to supply power to the components and enable data transfer and also this system can be used in the flammable environments.

The interface circuit with ASIC SAP5S is very small so we can integrate directly to the sensor or actuator devices. The length of system is 100m without repeaters, 300m with repeaters.

In this paper, the fire and smoke alarm system was shown, this system had got more advantages than other system such as number of stations, easy installation, wide working area, etc.

Furthermore this network can be used as a partner network for higher level field bus networks such as Profibus and extended by attaching the number of the CP 243-2 to the CPU S7 200. So its applications are more popular special in complex industrial systems.

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Received : 2014. 02. 05.
Revised : 2014. 04. 19. (1st)
: 2014. 06. 11. (2nd)
Accepted : 2014. 06. 25.