Networking Integration and Monitoring System with CANopen Controller for Intelligent Production Line of Tool Machine

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Abstract

In this paper, the development of CANopen node controller and the integration of intelligent production line is focused and studied by applying the CANopen protocol. While the basic network management and data transmission is followed by the dictionary objects in the CANopen CiA301 protocol, the controller needs to implement with the motor motion control specification subjected to the CiA402 protocol. The SCADA system communicates with each node through CAN Bus to complete the task of constructing and managing the entire network.

Keywords: Production Line, CANopen, Networking Integration, Tool Machine

1. Introduction

In the industrial system, the numbers and categories of electric circuit and controller contained are becoming more and more complicated. The control network becomes the key technology in the industrial system. Controller Area Network(CAN), this communication bus has the advantages of high noise immunity, fast transmission speed and easy installation. CANopen in Automatic(CiA) organization released CANopen communication protocol for CAN application layer. The basic CANopen device and communication profiles are given in the CiA301 specification released by CiA. The Monitor System is mainly responsible for the controlling the nodes states and function in the network and displaying the data posted back from the nodes for the convenience of our testing whole set of network system platform. The tool machine operation control of production line is tested and realized to evaluate and verify the feasibility and performance of CANopen networking system.

2. Production Line Communication System

2.1. *CANopen*

International Organization for Standardization(ISO) series specifies the data link layer and physical of the CAN in Open Systems Interconnection(OSI) model shown in Figure 1. Many manufacturers define CAN frame by themselves for their products. But, when different manufacturers need to integrate the system, it often waste time and costs more. Therefore, the biggest intention of CANopen is to unify the definition CAN application layer.

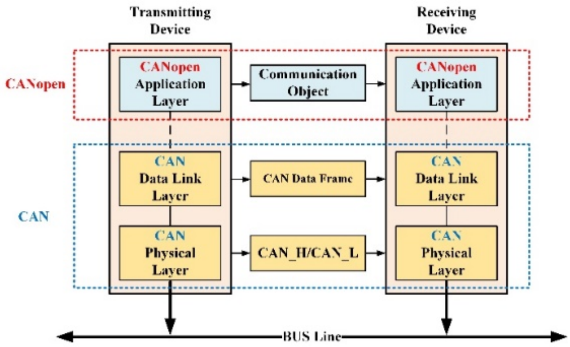

Fig. 1. CANopen Structure

2.1.1. *Communication Object(COB)*

The CANopen standard frame divides the 11-bit CAN-frame id into a 4-bit function code and 7-bit CANopen node ID. In CANopen the 11-bit id of a CAN-frame is known as communication object identifier, or COB-ID. COB-ID is shown in Table 1.

Table 1. Configurations of COB-ID

Object	Function Code	Resulting COB-ID
NMT	0000	0
SYNC	0001	80h
TIME STAMP	0010	100h
EMERGENCY	0001	81h-FFh
TPDO1	0011	181h-1FFh
RPDO1	0100	201h-27Fh
TPDO2	0101	281h-2FFh
RPDO2	0110	301h-37Fh
TPDO3	0111	381h-3FFh
RPDO3	1000	401h-47Fh
TPDO4	1001	481h-4FFh
RPDO4	1010	501h-57Fh
SDO(tx)	1011	581h-5FFh
SDO(rx)	1100	601h-67Fh
NMT Error Control	1110	701h-77Fh

CANopen according to communication feature divides communication feature into four several show below:

(i) Special Function Objects
- Synchronization Objects
- Emergency Objects
- Time Stamp Objects

(ii) Network Management Objects(NMT)
(iii) Process Data Objects(PDO)
(iv) Service Data Objects(SDO)

2.1.2. *Object Dictionary(OD)*

CANopen devices must have an object dictionary, which is used for configure device parameter and communcaiton with the device.The complete OD consists of the six columns shown below:

(i) Index : 16-bits object address
(ii) Object name : Particular index within the OD.
(iii) Name: Simple textual description of the function of that particular object
(iv) Type: Information as to type of the object.
(v) Attribute: Defines the access rights for a particular object
(vi) M/O: Defines whether the object is Mandatory or optional.

2.2. *CANopen Communication Object*

2.2.1. *Network Management Object(NMT)*

In CANopen, the network management objects (NMT) mainly focuses the network states of monitoring nodes as well as the function like the control of node operation. In Figure 2 the network statement of a device is shown.

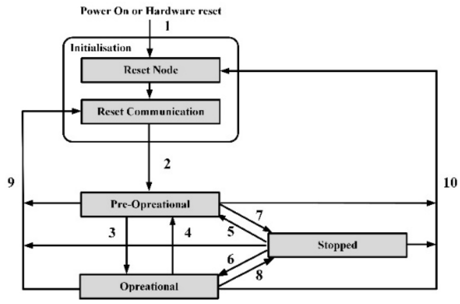

Fig. 2. NMT State Machine

Communication objects may only be executed if the devices involved in the communication are in the appropriate communication states. Table 3 shows the communication objects and states.

Table 3. States and Communication Objects

	Initialization	Pre-Operation	Operation	Stopped
PDO			√	
SDO		√	√	
SYNC		√	√	
Time Stamp		√	√	
EMCY		√	√	
Boot-up	√			
NMT		√	√	√

2.2.2. *Service Data Objects(SDO)*

According to data transfer direction divided into upload and download. Data frame of SDO consists of COB-ID, length and 2 to 8 Bytes data. Within 8 Bytes, Byte0 is Command Specifier(CS) which is data length of the object, Byte 1 and Byte 2 are index of the object within OD, Byte 3 is sub-index of the object, Byte 4 to byte 7 are parameter of the object. SDO frame is shown in Figure 3.

COB-ID	Length	Byte0	Byte1	Byte2	Byte3	Byte4~7
SDO	2~8	CS	Index		Sub-Index	Data

Fig. 3. CANopen Frame

2.2.3. *Process Data Objects(PDO)*

PDO transmission priority is higher than SDO, so PDO is often used to transfer data in real time. PDO divided into Transmit Process Data Object(TPDO) and Receive Process Data Object(RPDO). TPDO is transmitted from the node to the master. In contrast, RPDO is the node to receive messages from the master. Before using PDO, set PDO Communication Parameter and PDO Mapping Parameter through SDO to complete mapping.

2.3. *Device and Motion Control of CANopen*

CiA released CiA-402 protocol, it is the standardized CANopen device profile for digital controlled motion products. Establish device state machine for manage device. The state machine describes the device status and the possible control sequence of the drive shown in Figure 4. Within OD, Controlword(index:6040h) could switch device status. Statusword(index:6041h) could stored device current status.

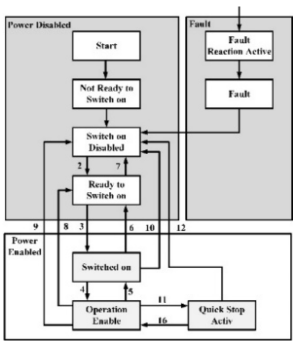

Fig. 4. Device State Machine

3. System Development and Design

3.1. *System Networking Structure*

CANopen network system structure designed is shown in Figure. The network main has one monitoring mode and two tool machine(six motor node). The main function of monitoring node is to monitor the whole CANopen network states. All equipment noodes possesses CANopne protocol to establish the whole set of CANopen network system.

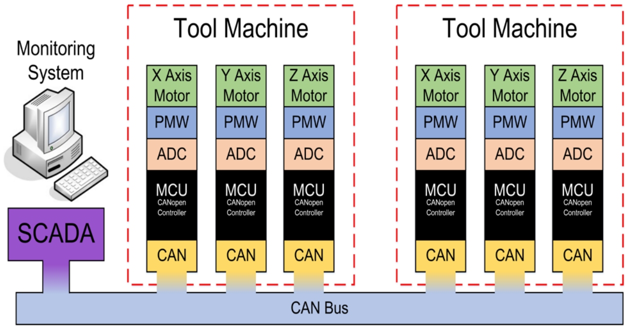

Fig. 5. Network System Structure

3.2. *CANopen Controller Design*

The design of the controller firmware to be written under the CANopen standard agreement, CANopen communication applications are mainly based on CiA-301 specification, which describes NMT, SDO and PDO. This proposed controller needs to implement with the motor motion control specification subjected to the CiA402 protocol. It is also additionally equipped with a motor-specific incremental encoder to receive the motor feedback signal, so as to realize the motor speed control and high-precision positioning control.

3.3. *Monitoring System*

The Supervisory Control and Data Acquisition (SCADA) system is the main monitoring of the Bus, which monitors the entire CANopen and the network status of each node, and displays the real-time CAN data below the SCADA System interface. Its function can be divided into four tabs, Initialize, NMT, Line, Figure 6 for the interface of SCADA System.

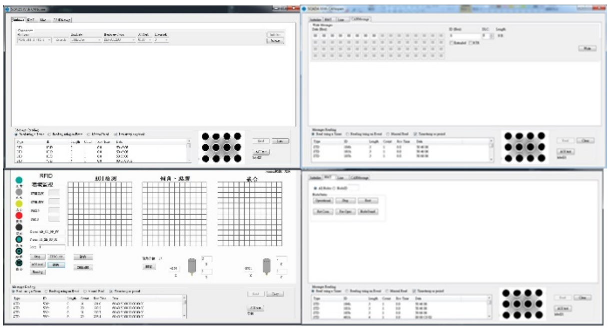

Fig. 6. Monitoring Interface: SCADA System

4. System Integration and Application

4.1. *Application field of production line*

Figure 7 is shown system structure of the production line. Figure 8 is shown the application architecture of this production line system consists of two tool machines and a set of handling robot. The controllers of the two tool machines are operated in accordance with the CiA protocol. The handling robot is controlled by I/O.

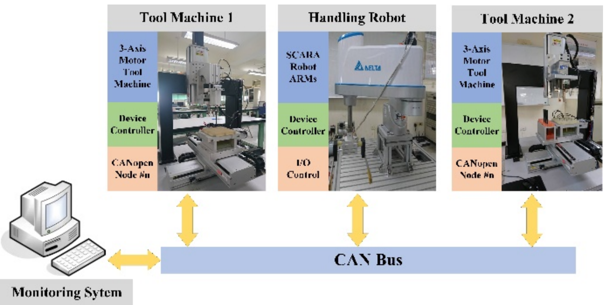

Fig. 7. System structure of production line

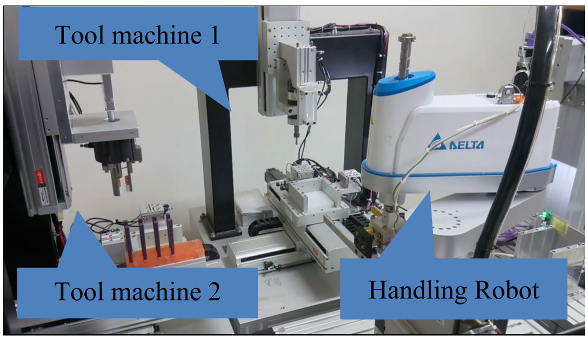

Fig. 8. Application field of production line

4.2. *Networking Integration of System Platform*

Turn on the power of each tool machines and use the SCADA System to initialize the CANopen network. After confirming that the CANopen network is connected, the NMT state will switch from Boot-up to Initialization and then to Pre-Operational. During the NMT state is Pre-Operational, then set the PDO parameter of each node. After setting, switch the NMT state to Operational. When the NMT state enters Operational, it can start to control motion device.

5. Conclusion

This paper is mainly to explore the industrial network. It is hoped that this set of network system platform could be applied in the industrial automation and make use of the CAN and CANopen features to make the industrial network control system to be more completed. The networking communication and motor control is developed for the motor controller node with CANopen. The motor controllers are provided with basic networking management and data transfer functions of CANopen. Additionally, equipped with the incremental encoder to receive the motor feedback, so as to realize the motor speed control and positioning control. Finally, with the actual application of the tool machine, the monitor system issues the commands that follow the protocol. Show the results of the combination of the CANopen local network and industrial automation.

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