The Implement of Photonic-EtherCAT for Internal Communication of Mobile Robot

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Abstract—In this paper, we review the network currently in use by intelligent service robot. After derive problems of corresponding network, we review at technical requisite as control network of intelligent service robot.

We proposed a method of implementation of internal communication network of mobile robots based on the photonic EtherCAT, industrial Ethernet.

Index Terms— Mobile Robot, EtherCAT, Photonic.

I. INTRODUCTION

Intelligent service robots provide necessary services to humans by performing mutual response with humans and after recognize circumstance situation, it is moving and operation.

Number of actuators that are used for moving and specific manipulation is lower in number in case of wheel type mobile robot, but in case of humanoid robot, number of actuators increases at the head, arm and leg. Moreover, to achieve modularization of humanoid robot, it is general to use at least 20 or more actuators. Thus, limited space of inside of robot becomes complicated by electronic connection of sensor, actuator, actuator controller and robot controller, and this influences robot as negative element in terms of robot design, production and maintenance [1,2]. Furthermore, though it is necessary to reduce any dangerous movements of robots during malfunction, pre-diagnosis module where error occurred and safely processing. So far, only implementation and movement control of intelligent robot is being performed with lack of enough recognition of safety diagnosis processing.

Therefore, in this paper, we review the network currently in use by intelligent service robot. After derive problems of corresponding network, we also review the technical requisite as control network of intelligent service robot.

We proposed a method of implementation of internal communication network of mobile robots based on the photonic EtherCAT, industrial Ethernet.

II. MOBILE BASED ON SERVICE ROBOT SENSOR/ ACTUATOR NETWORK

Since a lot of services are provided to humans by intelligent service robot, change of control network should become easier. Moreover, due to limitations of platform size of inside of robot, number of sensors and actuators used for modules of robot increases accordingly; therefore, requires synchronization between transmission speed of high control data and each modules and between module and actuator of internal and between actuator. Nevertheless, current control network of intelligent service robot does not fulfill these requirements.

In this section, we review the intelligent service robot developed so far, and by analyzing problems of sensor/actuator network used in each robot, induced of requirement condition that as control network of robot should have and describe the necessary of EtherCAT based sensor/actuator development which satisfies the requirements.

A. CAN Network

Sensor/actuator network of mobile based modular type service robot, HERMES is structured as structure using CAN bus[3] as sensor/actuator network and constructed upper network as multi control processor using DSP like in Fig 1. Sensor/actuator modules are control the sensor and actuator using CAN controller and Microcontroller as a one independent module. However, CAN method has the advantage of allowing high speed processing; however, it still poses certain problems which are an unstable for connected between the processor.

B. RS-232

Developed by Karsruhe University of Germany, sensor/actuator network of module based service robot ARMAR forms network using RS-232 communication between joint control module of each arm and upper level like Fig. 2 and controls sensor and actuator[4] in PIC Controller. Sensor being used is position sensor and force sensor and uses DC actuator for actuator. However, the RS-232 method requires the use of numerous cables, which makes it hard to distribute them over the robot due to their high cost.

C. USB

WAMOeba-2 of Waseda University at Japan uses fast transmission speed Ethernet as upper network between center computer and actuator controller, and actuator and actuator controller forms network for assemble and disassemble using USB[5]. The USB method has the advantage of allowing high speed processing; however, it still poses certain problems which are an unstable for connected between the processor.
Fig. 1 Sensor/actuator Network of HERMES

Fig. 2 Sensor/actuator network of ARMAR
Since intelligent service robot provides various services to humans, change of control network should be easy, and there are some limitations of size of the robot platform. To solve this problem, we introduce the sensor/actuator network based on the photonic EtherCAT.

EtherCAT guarantee 100Mbps or higher communication speed, and because internal modules of control systems are modularized independently focusing on network, expansion of new modules are superior and contains real-time control ability due to formation of synchronization of many modules by providing DC. It provides accurate control for 4 axis driven type actuator, steering actuator of 4 axis and robot arm of 5-6 axis and possible to earn accurate information of local timing of data collection in various sensor modules like GPS and USN. Moreover, EtherCAT network can control network based soft actuator which is the method forming location, speed, torque control of actuator at upper control stage by sending high speed data in actuator control.

Network based soft actuator is unlike previously actuator control methods which actuator control is performed at hardware level forms control of actuator at upper control level centering high speed network. An advantage due to this is, it is possible to reduce the size and weight of actuator driver because of reduction of function by moving of ability of actuator driver to upper level. Moreover, due to the reduction of size of hardware, modularization of sensor/actuator component becomes easier and can increase the reuse of actuator by application to others.

Data transmission of EtherCAT proceeds through not by CSMA/CD method but Broadcast method which after master sends data frame, all slaves connected to master receive and analysis and process. Slave in EtherCAT transmission input data during telegram passes through when there is receive and transmission data by reading transmitted data to related node during data frame passes through slave node by insert into telegram. During this time, delayed time at related node is only about few ns.

The hierarchy structure of EtherCAT follows communication structure of automation system is using OSI(open system interaction), ISO/IEC 7498 standardization as in Fig 4. An OSI 7 layer structure is formed by application layer (AL); 7 layer, data link layer(DL); 2 layer and physical layer(PL); 1 layer.
A. Photonic EtherCAT Physical Layer

Fiber PMD of 100Base-Fx corresponds to optical cable, optical connector, and optical transceiver, and PMD corresponds to media converter changing electrical signal into optical signal.

We design and implement photonic EtherCAT sensor/actuator network module by selecting parts which are optical cable, optical connector and optical transceiver required for implementation of photonic EtherCAT.

Optical cable of Fiber PMD of 100Base-Fx selected optical cable of single mode ST/PC type of LS Industrial System Co., Ltd. The reason for this is because it is possible that single mode optical cable using optical a source of lighting performs more precision data transmission than multi mode laser cable using LED source of light.

Optical connector connecting optical transceiver was selected to be ST type connector of push-pull type. The reason is to get the reliability for data transmission through optical cable since it widely used in industry environment having excellent vibration and mechanical characteristics and low loss ratio when connecting optical cable.

After ST connector of single mode optical cable to make it fit to the condition satisfying duplex ST single mode transceiver. Table 1 shows the specification of it. It is best fit to the 1310nm wave and can have 155Mbs transmission speed up to maximum 3Km, voltage is 3.3V, a source of lighting is laser diode and operating temperature is -40~+80 °C.

B. Photonic EtherCAT Data Link Layer

Data link layer which corresponds to MAC layer of photonic EtherCAT uses EtherCAT slave controller, ET1200. Table 5 shows major features of ET1200. ET1200 supports two PHY ports and one bride port. Two PHY port, according to the hardware chip configuration, selectively uses MII interface of 100BaseTx/Tx and EBUS/LVDS interface. PHY port can be used in three different methods including MII/MII interface, MII/EBUS interface and EBUS/EBUS interface. It is possible to use bridge port when only in case of PHY port of EBUS/EBUS interface allowing additional usage of MII interface.

Table 1 Specification of optical transceiver

<table>
<thead>
<tr>
<th>PNo.</th>
<th>TRS3130G</th>
<th>TRS-3130AG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit Rate(Mbps)</td>
<td>155</td>
<td>155</td>
</tr>
<tr>
<td>SONET/SDH</td>
<td>IR-1/S-1.1</td>
<td>IR-1/S-1.1</td>
</tr>
<tr>
<td>Distance(km)</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Wavelength(nm)</td>
<td>1310</td>
<td>1310</td>
</tr>
<tr>
<td>Voltage(V)</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Package</td>
<td>1X9 SC/ST/FC</td>
<td>1X9 SC/ST/FC</td>
</tr>
<tr>
<td>Temperature(°C)</td>
<td>0 to 70</td>
<td>-40 to 85</td>
</tr>
<tr>
<td>Tx power(dBm)</td>
<td>-8 to -15</td>
<td>-8 to -15</td>
</tr>
<tr>
<td>Rx Sen.(dBm)</td>
<td>-34</td>
<td>-34</td>
</tr>
<tr>
<td>RoH Compliant</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

C. Photonic EtherCAT Application Layer

Application layer of photonic EtherCAT based sensor/actuator network module drive the BLDC actuator through interface of data link layer of photonic EtherCAT using SPI interface of ET1200 as BLDC actuator driver and allows it to perform speed control and torque control of BLDC by receiving sensor data of actuator. Fig.5 shows speed control
block diagram of BLDC actuator. [6,7]

In Fig 5, control block uses PIC microprocessor and PWM block uses IR2131 which is the PWM block driver device. Inverter block is the device of FET which is implemented to. Furthermore, it connects communication with data link layer with SPI interface at PIC microprocessor.

IV. CONCLUSION

In terms of sensor/actuator control network for intelligent service robot, we analyzed problems of sensor/actuator control network of modular service robot and humanoid robot. Then, we implemented physical layer to optical cable of industrial Ethernet protocol EtherCAT which is possible to have standard Ethernet compatibility.

Interface of physical layer, data link layer, and application layer of photonic EtherCAT based sensor/actuator control network has been analyzed. To implement them, after selection of parts used in each layer, design and implementation of module for control network construction was performed.

Table 2. Main characteristic of ET 1200

<table>
<thead>
<tr>
<th>Feature</th>
<th>ET1200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ports</td>
<td>•2 permanent ports, 1 bridge port</td>
</tr>
<tr>
<td>FMMUs</td>
<td>•3</td>
</tr>
<tr>
<td>SyncManagers</td>
<td>•4</td>
</tr>
<tr>
<td>RAM</td>
<td>•1 KB</td>
</tr>
<tr>
<td>Distributed clocks</td>
<td>•64bit</td>
</tr>
<tr>
<td>Process Interfaces</td>
<td>•16bit digital I/O</td>
</tr>
<tr>
<td></td>
<td>•SPI Slave</td>
</tr>
<tr>
<td>Power Supply</td>
<td>Two Integrated voltage regulator(LDO)</td>
</tr>
<tr>
<td></td>
<td>•I/O : 5V to 3.3V</td>
</tr>
<tr>
<td></td>
<td>•Logic core/PLL : 5V/3.3V to 2.5V</td>
</tr>
<tr>
<td>I/O</td>
<td>3.3V or 5V compatible I/O</td>
</tr>
<tr>
<td>Other features</td>
<td>•Internal 1GHz PLL</td>
</tr>
<tr>
<td></td>
<td>•Clock output for external device (10, 20, 25MHz)</td>
</tr>
</tbody>
</table>

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REFERENCES


