Implementation of EtherCAT based data acquisition system

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***Abstract*-An EtherCAT based data acquisition system is acquired data from the field sensors through the many slaves. It consists of a master with many slaves. The personal computer on which the controller runs is the EtherCAT Master (SOEM), while the devices that make data of connected I/O devices available for the master are called slaves. The Ethernet network has become the most popular network in data acquisition system to reduce media cost and achieve the higher performance. This paper presents that development of a standard network data acquisition system that is based on the communication protocol called EtherCAT. In particular, we focus on the times necessary to transfer quantity of data among slave stations.**

***Index Terms*-Ethernet, EtherCAT, Data Acquisition System, Real time, sensor**

I. INTRODUCTION

The design of EtherCAT enables any standard PC to be used as an EtherCAT Master and communicate with EtherCAT Slaves, which devices are specialized compliant with the EtherCAT specification. The master and slave EtherCAT device can be used all devices in the network factory-automation controllers, operator interfaces, sensors, actuators, drives and others. Nowadays the embedded system mainly focusing on three aspects: low power, low cost and high speed. The Implementation of EtherCAT based data acquisition system is mainly used in various fields, e.g., industrial automation, printing machines, packaging, injection molding, building automation and power distribution, etc. The increasing demand for high-speed and considerable sensor data acquisition makes more and more control networks being used, especially the industrial Ethernet have also progressed very rapidly.

II. ADVANTAGES OF ETHERCAT BASED DATA ACQUISITION SYSTEM

EtherCAT is a highly flexible and high-performance industrial Ethernet network protocol. Industrial Ethernet was introduced into data acquisition system it is having various advantages; maintenance cost is low, Rapid installation and diagnosis.

III. ETHERNET TELEGRAM PROCESSING

The total EtherCAT network is of master station and slave station in figure 1.One EtherCAT master is connected with several EtherCAT slave stations. All stations are connected together to create in a loop system through the Ethernet cable.

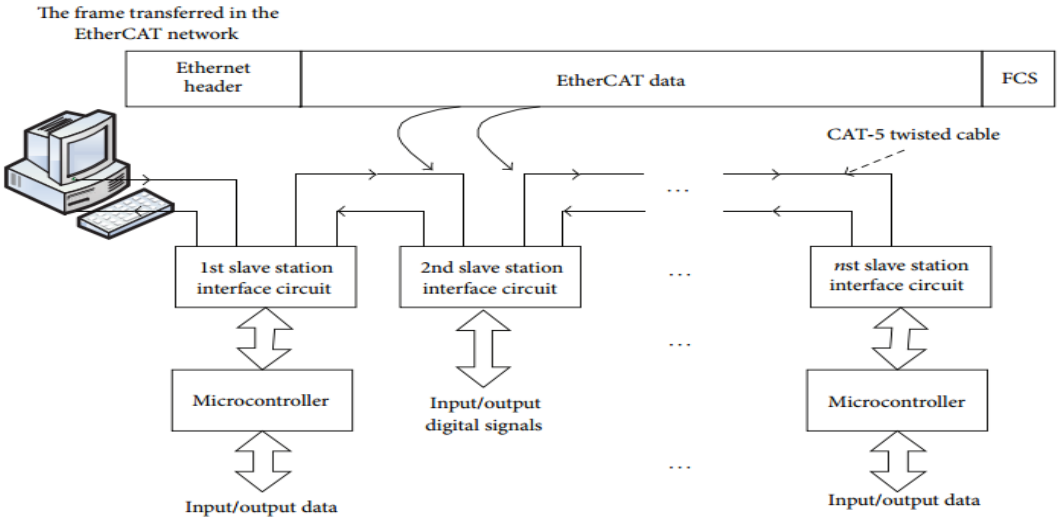

Figure: 1 the frames transfer in the EtherCAT network

Each Ethernet "data pack" called telegrams, is processed directly "on the fly". While the telegram is passed on, the slave recognizes relevant commands and executes them accordingly. Each slave processes the incoming telegram directly and extracts/insert the relevant user data and transfer the telegram to the next EtherCAT slave. The EtherCAT slave sends the whole processed telegram back, so that it is returned by the first slave to the control as a EtherCAT master

Telegram processing is done within the hardware and is therefore independent of the response times of any microprocessors that may be connected. Each device has an addressable memory of 64KB that can be read or written, either consecutively or simultaneously

The telegram processing functional principle of EtherCAT can be explained using the analogy of a fast train expressed in three points

1. With EtherCAT, the "train" (the Ethernet frame) does not need to have the same combination of cars (datagram's) in each cycle.
2. The person (data) in the car (datagram) is identified by the car number (datagram header) and the offset, and then removed or inserted on the fly
3. If more process data are to be communicated more than fit within one train (frame) (1488 bytes), a second train is used within the same communication cycle

IV. ETHERCAT FRAME STRUCTURE

As illustrated figure.2 EtherCAT commands transported in data area of an Ethernet telegram and can either be coded via a special Ether type (0x88a4) or via UDP/IP. It may consist of Ethernet header and several sub-telegrams, each telegram serving a particular memory area of the logical process image that can be upto 1514bytes in size. The periodic data exchange between EtherCAT master and EtherCAT slave is performed by the "EtherCAT telegram" that is stored in the directly within the Ethernet frame. The working counter will be incremented by all EtherCAT devices that were addressed by the EtherCAT command and have exchanged associated data.

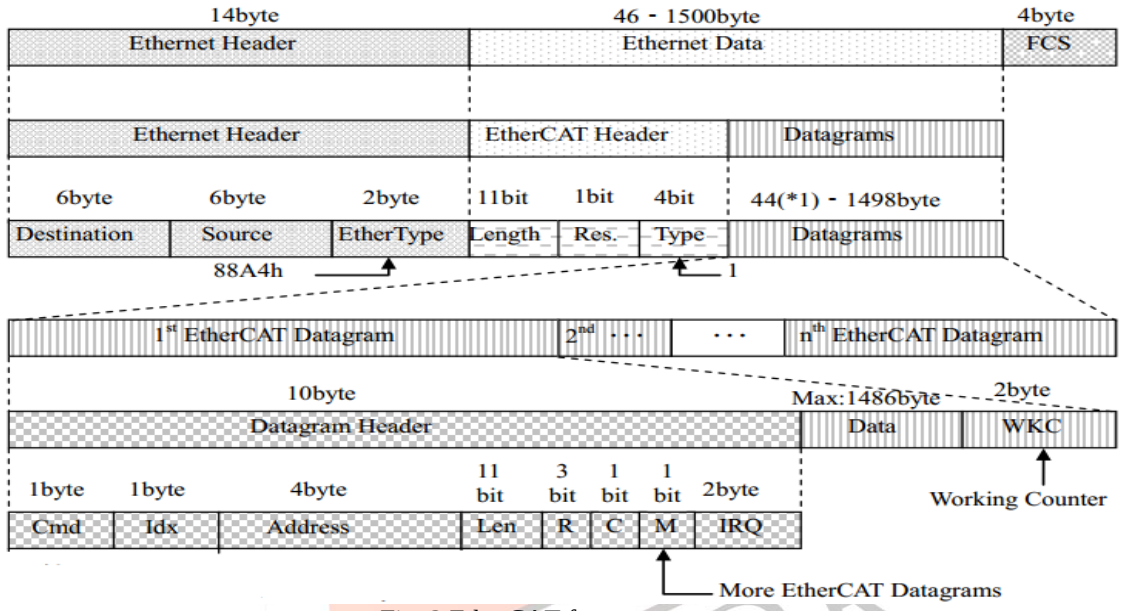

Fig: 2 EtherCAT frame structure

V. THE MAIN CHARACTERISTCS OF ETHERCAT

A. STRUCTURE OF DAQ SYSTEM

In figure.3 In addition the slave station consists of an EtherCAT network interface controller chip and single-chip microcontroller with I/O devices. The I/O devices can receive the analog signals from the field sensors and transmit them into data signals using analog-to-digital of the single-chip microcontroller.

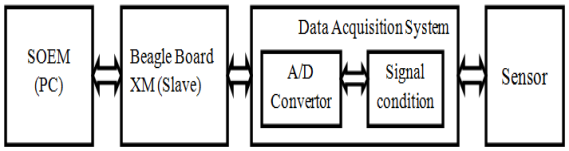

Figure.3 Block diagram of DAQ system

B. ETHERCAT MASTER IMPLEMENTATION

An EtherCAT master is necessary to control the EtherCAT slaves on the network by using the master-slave principle. It is possible to implement an EtherCAT master to every processing unit with a standard Ethernet controller. The EtherCAT master is usually implemented on a pc running a Real-time operating system to provide Real time guarantees. There are many EtherCAT master drives available for different operating system and hardware platforms, e.g. windows, Linux, QNX, PLC's etc. For windows the most known one is maybe TwinCAT by beckhoff, while for Linux there are IgH EtherCAT master and simple open EtherCAT master (SOEM). Finally for this project SOEM is preferred over the Etherlab master because it can be used as a user space application. Instead of implementing it as kernel space application like IgH does, therefore it is more portable and can be implemented without difficulties in any GNU/Linux with Real time extension. Such as RTAI, xenomai or RT-preempt.

Finally I choose SOEM (simple open EtherCAT master) it is EtherCAT master library that is completely written in C and is targeted for any Linux operating system as a user space application. An important advantage of this EtherCAT master library is that it doesn't provide limitations on the applied design architecture.

C.THE PROCEDURE FOR ETHERCAT MASTER PROCESSING

The EtherCAT master station is sending the Ethernet frames which packages the commands and the sensor number of data reading of EtherCAT. And the slave's station it takes directly the commands and sensor from the appropriate location of the Ethernet frame. At the same time the circuit interface is generates the interrupt sign to related microcontroller. Then the microcontroller read out the commands and the number of data channel from the IC's. The selected channels are opened and the Analog-Digital conversion finishes the data conversion

The EtherCAT master station finishes the data transmission under the control of state machines, the state machines are classified into four main stages (see figure.4)

Init

The root of communication relationship is defined between the master and the slave in application layer. The direct communication is impossible between the master and the slave in this state. The master initializes a group of configuration register of the special slave interface IC's including data link layer address register, synchronization manger channel control register for mailbox communication, application control register and application state register.

Pre-operational

Master: initialization of synchronous manager channels for mailbox communication during the transition from init to pre-operational. Salve: validation of synchronous manger configuration during the transition from init to pre-operational. In this state mailbox communication is done but process data will not be exchanged

Safe-operational

In this sate mailbox communication and process data will be exchange but the slaves keep its output in safe state while the input data is updated cyclically

Operational

In this state EtherCAT master and EtherCAT slave fully operational and the mailbox and process data will be exchanged is fully working

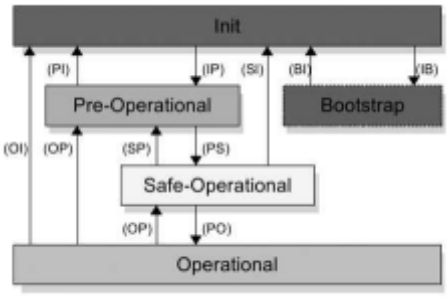

Figure.4 State machines

VI. THE WHOLE STRUCTURE OF DATA ACQUISTION SYSTEM

In figure.3 the proposed system consists of EtherCAT master station and EtherCAT slave station. The EtherCAT master station has the following main functionalities.

1. Parse XML Hardware configuration file
2. (Initialization, state machine, and process data mapping)
3. Initialization of fieldbus
4. Interface to application
5. Run state machines
6. Interface to network drivers
7. Send cyclic process data commands
8. Send mailbox commands

The EtherCAT master is a main controller which is run on computer, for implementation of EtherCAT master either an on-board Ethernet controller or a standard network card is needed, so no special interface card is required. We are connected to perform a closed loop system, the master station send commands to slave station through Ethernet frames and take the collected data from slave station back to analyze and process.

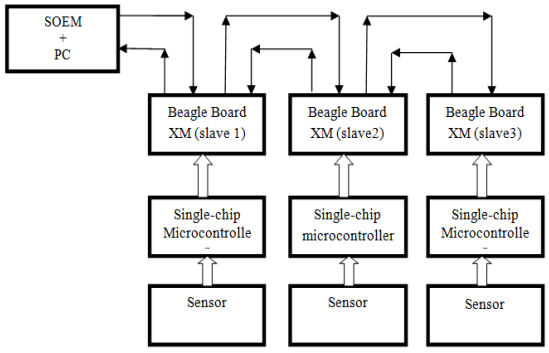

Fig 5.Block diagram of proposed system

Every slave station is having special Hardware interface chip known as beagle board xm can implement the communication between the slave station and master station.

A.EXPERMENTAL ANALYSISOF THE READ OF PROCESS DATA

As shown in figure.6 The process of data is passing in application layer for every node, the corresponding sync manager locks the application memory area unit it will be read from the master, master will send EtherCAT read services with the working counter (WKC=X) the slave node of data link layer sends data of application memory area so that the working counter will be incremented and generates an AL events to the AL controller.

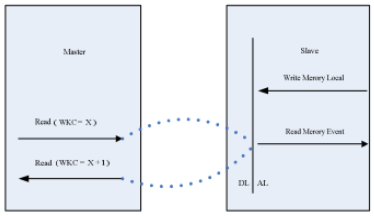

Fig.6 process of data read

B.THE PROCESS OF DATA WRITING

The Following figure.7 shown the processing of data writing from master, the master sends an EtherCAT write services with the working counter (WKC=X), the DL of the slave write the received in application memory area, increment the working counter (WKC=X+1) and generates an application event to the AL controller, the corresponding sync manger channel locks the application memory area until it will read from AL controller

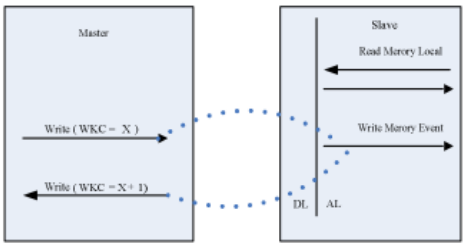

Fig .7 process of data writing

VII. CONCLUSION

In this proposed system, the master of EtherCAT network is SOEM running on PC.SOEM is a simple open EtherCAT master is written in c library function which manages the slave devices with in the EtherCAT network. But in this system it only configure and communication between master and 3 slaves nodes has been done and also when I was passing the data to each slave node, how much time it will taken to receive the Ethernet frames and coming back to main controller of EtherCAT that should be more and more accuracy in the real time system .To send the process data to each slave node and testing the working counter will be incremented or not because of when it will increment the working counter the processing data will be exchanged .

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