# LAN Based Low Cost Low Power High Speed Industrial Process Monitoring & Control System

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## *Abstract*

*Monitoring and controlling of Industrial processes are more costly in terms of physical area, man power, money, power consumption, and speed. This paper presents a LAN/ Internet based system that can perform monitoring and controlling of Industrial processes remotely in an efficient way by reducing the physical area, man power, money, and power consumption, whereby increasing the speed.*

*The use of ARM based technology reduces the power, cost and increases the speed, while the use of web technology with LANs reduces man power and physical area. In this paper, a system is presented in which web technology is embedded into an ARM7 based Micro controller LPC2148 which acts as a server over web. This server performs continuous monitoring and controls the processes on request. A unique IP address is assigned to the server through which it can be accessed.*



## 1. Introduction

An Industry undergoes through various processes. Each process comprises of various parameters like temperature, pressure, speed, timings and so on. These parameters need to be maintained at a desired level. Missing of these levels may result in heavy loss or severe accidents. So, in order to maintain the desired levels of these parameters, they must be monitored and accordingly controlled. Figure 1. presents the block diagram of a system that is web enabled

The web enabling capability is provided by means of Ethernet standard based device. The system can be accessed over web using a unique IP address that is assigned to it. This enables remote access of the system and hence reduces man power and physical space for monitoring and control operation.

This system uses ARM7 based micro controller "LPC 2148". Use of this controller reduces the power consumption, and increases the speed of operation.

Using this system one can monitor the parameters like temperature and humidity in the Industrial processes. For this, the proposed system uses the humidity sensor SY-HS-220, and the temperature sensor LM35.

The parameter's data sensed by the sensors is being read by the LPC2148 through its one of the ADC pins and stored in its one of the data registers. These readings can be monitored on the web page over the web.

In order to perform control operations, the web page consists of switches through which a device status can be changed. Therefore, by changing the status of the devices we can obtain the desired levels of the required parameters. For an example, if temperature exceeds the maximum level, it can be retained to its normal level by switching ON a fan or an air conditioner. Once the level is achieved, the fan can be switched OFF. Here, turning the fan ON and OFF is a control operation that is being done through the switches available on the web page.

This system can also monitor the status of devices in order to avoid any unwanted situation. For an example, if a fan is switched ON through the web page to retain the

temperature to its normal value. Since a fan is embedded with a on board switch through which it can be turned ON and OFF, some malicious unit may change the status of the fan and may create hazards. So, for the security the device status must be monitored at any time.

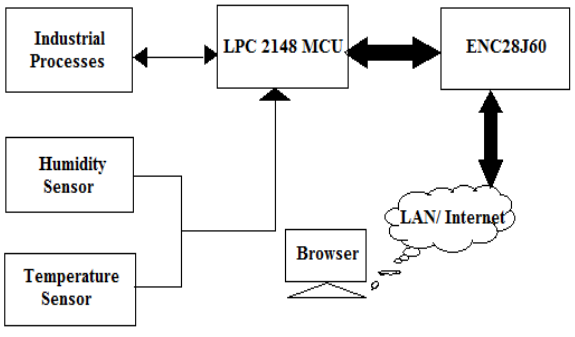


**Figure 1. Block diagram**

## 2. Overview of the System

### 2.1. Schematic Layout of the System

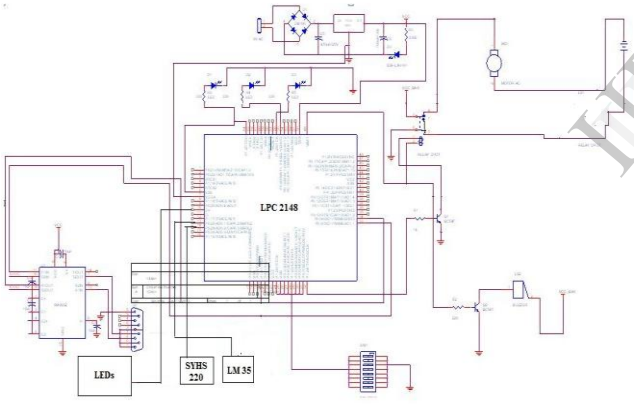


**Figure 2. Schematic diagram**

Figure 2. shows the schematic layout diagram of the proposed system. The sensors SYHS 220, LM35 are interfaced to the ADC pins of the micro controller LPC 2148. The ADC accepts the analog outputs of sensors and converts them into their respective digital format. These data are stored in the ADC registers. Before displaying these data, these are converted into their respective formats. i.e., the temperature is displayed in degree Celsius and the humidity in %RH. The motor is interfaced with the micro controller using a relay in order to expose the control operation. To show the status monitoring of the devices, LEDs are used as devices and are interfaced with the micro controller through DIP switches.

To enable the web access functionality, the micro controller is interfaced with the LAN through Ethernet controller ENC28J60. It provides a 10 Mbps of data communication with full-duplex mode.

## 3. SY-HS-220 Sensor

SYH are series of humidity sensors. SY-HS- 220 belongs to the same series and is a capacitive type sensor. Hence, it requires signal conditioning stages. Its output is DC voltage. This voltage depends on humidity in RH%. The typical current consumption is maximum of 3mA. This sensor can measure the humidity ranging from 30% to 90 % with an accuracy +- 5 % RH at 250 degree Celsius.
It requires a DC voltage of 5 V

**Table 1. Characteristics of SY-HS-220**

| % RH | Spec(mV) |
|---|---|
| 25 | 840 |
| 35 | 1140 |
| 45 | 1490 |
| 55 | 1810 |
| 65 | 2135 |
| 75 | 2450 |
| 85 | 2770 |

### 3.1. Testing of SY-HS-220 Sensor

**Table 2. Observation of humidity sensor**

| S. No | | Voltage(mV) | Relative Humidity in % |
|---|---|---|---|
| 1 | In normal atmosphere | 2130 | 65 |
| 2 | On applying breath | 2292.5 | 70 |
| 3 | After some delay | 2127 | 65 |
| 4 | Again on applying breath | 2291 | 65 |

The humidity sensor is tested by supplying the humidity through breath. The output voltages of the sensor are measured using volt meter in normal atmosphere and on application of breath. The corresponding relative humidity values are calculated using the characteristics of sensor as shown in Table 1.

### 3.2. Advantages of SY-HS-220 Sensor

1. High sensitivity and reliability
2. Miniaturization and light weight.
3. Low hysteresis.
4. Wide operating range.

## 4. LM 35 Sensor

LM 35 is a precision integrated temperature sensor. Its output is linearly proportional to the Celsius (Centigrade) temperature.

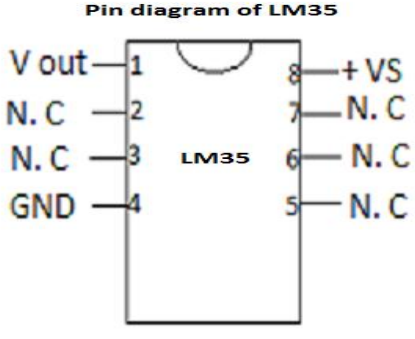


**Figure 2. Pin diagram of temperature sensor**

### 4.1. Testing of LM 35 Temperature Sensor

The temperature sensor is tested with the application of known temperature upon sensor and respective voltages at the output of sensors are measured using multimeter as shown in Table 3. The source of temperature used is bulb whose temperatures are measured using thermometer.

**Table 3. Observation of temperature sensor test**

| Temperature (in ◦C) measured using thermometer | Output Voltage (mV) measured at V out pin of LM35 |
|---|---|
| 20 | 205 |
| 22 | 222 |
| 25 | 251 |
| 28 | 280 |
| 30 | 302 |
| 33 | 333 |
| 35 | 354 |
| 37 | 373 |
| 40 | 401 |
| 45 | 455 |

**4.1.1. Conclusion.** The observations listed in Table 3 represent a linear relationship between the output voltage and input temperature of sensor with a linear increment of 10mV/◦C.

### 4.2. Advantages of LM 35

1. External calibration is not required.
2. Draws very less current. Hence, less self heating.
3. Voltage is linearly related to temperature.

## 5. Interfacing SY-HS-220 and LM35 with LPC 2148

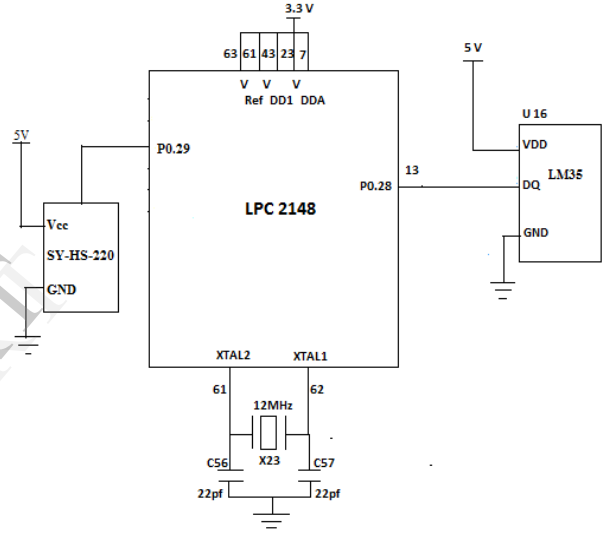


**Figure 3. Interfacing of sensors with LPC2148**

### 5.1. Sample Program to Read the Value of Sensors

```
unsigned long ADC(void)
{
        unsigned char delay=30;
         PINSEL1!= 0x01<<24;
          AD0CR = 0x00250602;
         | CLKDIV = 0x06;
          AD0CR |=0x01000000;
          while(dalay--);
          do
          {
             temp = AD0GDR;
          }
          while ((temp & DONE) == 0);
          temp = ((temp >> 6) & 0x03FF);
          return(temp);
          }
```

## 6. ARM 7 (LPC 2148)

The ARM7 based micro controller LPC 2148 is selected because of the following reasons.
1. It has got two in-built ADCs with 14-channels. So, multiple parameters can be monitored.
2. It has RISC architecture. So throughput is very high and hence it reduces cost and increases speed.
3. It has 512KB of on chip ROM which helps to develop a web based application within memory constraints.
4. It supports SPI communication which is easier to implement than UART.
5. Programmable multi functional I/O pins.
6. Operates at 3.3V. Hence, low power consumption.
7. Uses Thumb instructions.

### 6.1. Features of ADC

1. 10-bit successive approximation analog to digital converter.
2. Measurement range of 0V to Vref.
3. Each converter capable of performing more than 400,000 10-bit samples per second.
4. Every analog input has a dedicated result register to reduce interrupt overhead.
5. Burst conversion mode for single or multiple inputs
6. Optional conversion on transition on input pin or timer match signal.

## 7. Ethernet

Ethernet is a great and different family of frame-based computer networking technologies for local area networks (LANs). The name comes from the physical concept of the ether. It defines a number of wiring and signaling standards for the physical layer, through means of network access at the Media Access Control (MAC)/Data Link Layer, and a common addressing format. On top of the physical layer Ethernet stations communicate to each other by sending each other data packets, small blocks of data that are individually sent and delivered.

Ethernet is standardized as IEEE 802.3. The combination of the twisted pair versions of Ethernet for connecting end systems to the network, along with the fiber optic versions for site backbones, is the most widespread wired LAN technology. It has been in use from around 1980 to the present, largely replacing competing LAN standards such as token ring, FDDI, and ARCNET. In recent years, Wi-Fi, the wireless LAN standardized by IEEE 802.11, is prevalent in home and small office networks and augmenting Ethernet in larger installations.

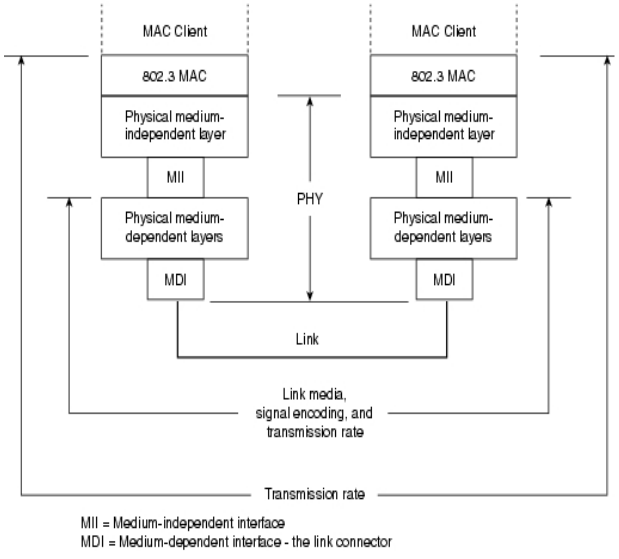


**Figure 4. MAC and PHY layer compatibility for data communication**

### 7.1. Ethernet Controller (ENC28J60)

The ENC28J60 is a stand-alone Ethernet controller with an SPI interface that serves as a communication channel between LPC2148 microcontroller and the ENC28J60. It meets all of the IEEE 802.3 specifications. The ENC28J60 has the MAC (Medium Access Control) module that implements IEEE 802.3 compliant MAC logic and a PHY (Physical Layer) module that encodes and decodes the analog data that is present on the twisted pair interface.

It incorporates a number of packet filtering schemes to limit incoming packets. Communication with LPC2148 microcontroller is implemented via two interrupt pins and the SPI, with data rates of up to 10 Mb/s. The ENC28J60 is selected because it facilitates

1. Easy to interface with SPI port of LPC2148
2. Contains hardware and firmware software installed
3. Wide range of library routines available
4. Generates interrupt for micro controller automatically

### 7.2. ENC8J60 Library Functions Used

1. ENC28J60_Init
2. ENC28J60_doPacket
3. ENC28J60_putByte
4. ENC28J60_putString
5. ENC28J60_getByte
6. ENC28J60_UserTCP
7. ENC28J60_UserUDP

### 7.3. Interfacing ENC28J60 with LPC2148

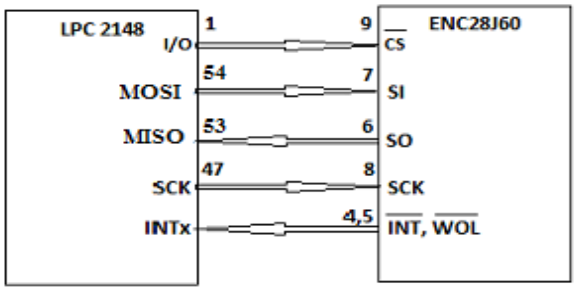


**Figure 5. Interfacing of Ethernet controller with LPC2148**

## 8. Transmission Control Protocol/ Internet Protocol (TCP/IP)

The Transmission Control Protocol (TCP) is one of the center protocols of the Internet protocol suite (IP). TCP provides consistent, prearranged, error-checked deliverance of a stream of octets between programs running on computers connected to a LAN, intranet or the public Internet. Web browsers use TCP when they connect to servers on the World Wide Web, and it is used to deliver email and transfer files from one location to another.

This protocol corresponds to the transport layer of TCP/IP suite. TCP provides a communication service at a transitional level between an application program and the Internet Protocol (IP). That is, when an application program desires to send a large amount of data across the Internet using IP, instead of breaking the data into IP-sized pieces and issuing a series of IP requests, the software can issue a single request to TCP and let TCP handle the IP details.

IP works by exchanging pieces of information called packets. A packet is a series of octets and consists of a header followed by a body. The header describes the packet's source, destination and control information. The body contains the data IP is transmitting.

Therefore, TCP is a reliable stream delivery service that guarantees that all bytes received will be identical with bytes sent and in the accurate order. Since packet transfer over many networks is not reliable, a technique known as positive acknowledgment with retransmission is used to guarantee consistency of packet transfers. This fundamental technique requires the receiver to respond with an acknowledgment message as it receives the data. The sender keeps a record of each packet it sends. The sender also maintains a timer from when the packet was sent, and retransmits a packet if the timer expires before the message has been acknowledged. The timer is needed in case a packet gets lost or corrupted.

TCP protocol operations may be alienated into three phases. Connections must be properly established in a multi-step handclasp process (connection establishment) before entering the data transfer stage. After data transmission is completed, the connection termination closes established virtual circuits and releases all allocated resources. Throughout the lifetime of a TCP connection, the local end-point undergoes a series of state changes.

### 8.1. Two-way Communication

**8.1.1. Connection Establishment.** To establish a connection, TCP uses a three-way handclasp. Before a client attempts to connect with a server, the server must first attach to and listen at a port to open it up for connections. This is called a passive open. Once the passive open is established, a client may initiate an active open. To establish a connection, a 3-step handclasp occurs

1. **SYN**: The active open is performed by the client sending a SYN to the server. The client sets the segment's sequence number to a random value A.

2. **SYN-ACK**: In response, the server replies with a SYN-ACK. The acknowledgment number is set to one more than the received sequence number i.e. A+1, and the sequence number that the server chooses for the packet is another random number, B.

3. **ACK**: Finally, the client sends an ACK back to the server. The sequence number is set to the received acknowledgement value i.e. A+1, and the acknowledgement number is set to one more than the received sequence number i.e. B+1.

At this point, both the client and server have received an acknowledgment of the connection. The steps 1, 2 establish the connection factor for one direction and it is acknowledged. The steps 2, 3 establish the connection factor for the other direction and it is acknowledged. With these, a full-duplex communication is established.

**8.1.2. Connection Termination.** The connection termination uses a four-way handclasp, with each side of the connection terminating separately. When an endpoint desires to stop its half of the connection, it transmits a FIN packet, which the other end acknowledges with an ACK. Therefore, a typical break up requires a pair of FIN and ACK segments from each TCP endpoint. After both FIN/ACK interactions are concluded, the side which sent the first FIN before receiving one waits for a timeout

before finally closing the connection, throughout which time the local port is engaged for new connections; this prevents confusion due to deferred packets being delivered during successive connections.

FIN-WAIT-1 represents waiting for a connection termination request from the isolated TCP, or an acceptance of the connection termination request formerly sent.

FIN-WAIT-2 represents waiting for a connection termination request from the isolated TCP.

CLOSE-WAIT represents waiting for a connection termination request from the confined user.

LAST-ACK represents waiting for an acknowledgment of the connection termination request previously sent to the remote TCP (which includes an acknowledgment of its connection termination request).

TIME-WAIT represents waiting for enough time to pass to be sure the remote TCP received the acknowledgment of its connection termination request.

CLOSED represents no connection state at all.

## 9. IP Address

An IP address is a commercial tag assigned to each machine participating in a computer network that uses the Internet Protocol for communication. It serves two prime functions: host or network interface recognition and position addressing. The designers of the Internet Protocol defined an IP address as a 32- bit number. This system is known as Internet Protocol Version 4(IPv4). IP addresses are binary numbers, but they are usually stored in manuscript files and displayed in human legible notations such as 172.16.4.237.

Whenever with this IP address the system is connected to the LAN, the browser computer must be installed with the following:

1. Subnet Mask: 255.255.224.0
2. Gateway: 172.16.1.1
3. DNS: 172.16.0.1
4. Alternate DNS: 172.16.1.1

In IPv4, an address consists of 32 bits. It confines the address space to 4294967296(2^ 32) possible distinctive addresses. IPv4 assets some addresses for special purposes such as private networks. IPv4 addresses are represented in dot decimal notation, which consists of four decimal numbers, each ranging from 0 to 255, alienated by dots.

## 10. Hyper Text Transfer Protocol (HTTP)

Web technologies are the interface between web servers and their clients. This information includes markup languages, programming interfaces and languages, and standards for document identification and display. Here, HTML and HTTP technology are used. The purpose of a web browser is to read HTML documents and display them as web pages. The browser does not display the HTML tags, but uses the tags to interpret the content of the page. It is a language for describing web pages.

The system uses HTTP 1.1 which is a latest version of HTTP protocol. It provides faster delivery of web pages. Hence, the speed increases. HTTP defines the set of laws by which web browsers, web servers, proxies, and other web systems launch and preserve connections with each other. It uses only four protocol layers within a computer system. The lowest layer is the Network layer. The protocol layer above the Network layer is the Internet Protocol (IP) layer. Next is the TCP. The final protocol layer is HTTP, a TCP/IP application layer. There is a confined and physical communication between each protocol layer.

## 11. Flow Chart

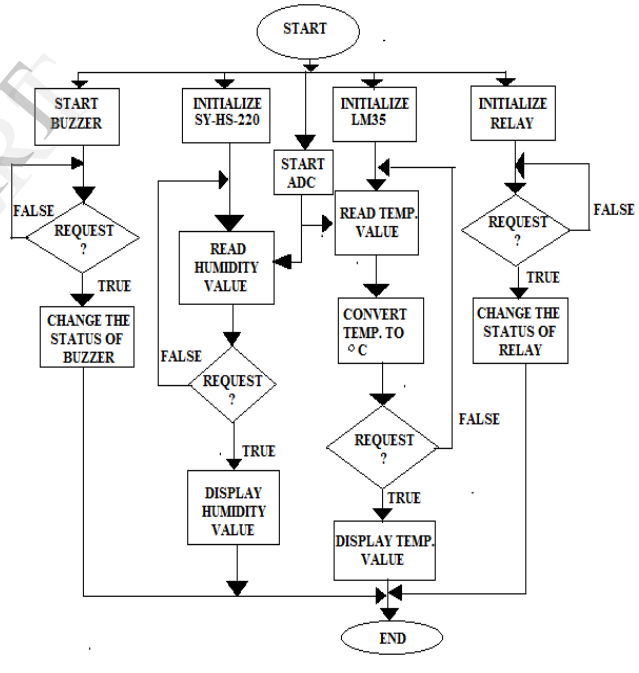


**Figure 6. Flow chart**

## 12. Conclusion

A system enabled with the web technology provides easy and remote access of the industrial processes in an efficient way. If the system is developed using ARM based technology for monitoring and control purposes of Industrial processes, it provides simple, less expensive in terms of cost and physical space with very high speed and accuracy.

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