2.1 Introduction

There is always the need of a dedicated hardware with reasonably good accuracy for the measurement of temperature, humidity, and gases like CO₂ etc. This can be done by using discrete electronic components. But to overcome certain inherent disadvantages of this method we develop microprocessor or microcontroller based systems. These systems use sophisticated sensors to measure the various physical parameters intended in the design. In addition to the special features of the microcontroller chosen in the design, the various features of the sensors and other components used in the design also influence the performance of the developed system. So, it is always important to choose meticulously the hardware details of the design under consideration. The use of microcontrollers in embedded design is not only increased but brought revolutionary changes in the entire field of embedded design. Monitoring and controlling environmental parameters by embedded systems using microcontrollers is very much effective in meteorological and industrial requirements. Especially due to the RISC architectural features and low-cost design advantages, now a days ARM microcontrollers are very widely used in embedded system designs. Once we design a system with microcontroller and sensors, it is always important to interface the sensors suitably to the controller, i.e. one should use suitable filters and amplifier elements for proper signal conditioning. Because the outputs of most of the sensors may not be compatible with the control systems i.e., with the microcontroller. Sometimes the sensor may not even produce a suitable electrical output. The signal level could be low that the electrical output may be dominated by the electrical noise in the system itself, before it reaches the next stage. The sensors like thermistors may produce nonlinear outputs. So signal conditioning is very much required. These signal conditioning circuits amplify, linearize and scale the output of sensors to match the requirements of the device in the control system [29,30].
2.2 Hardware details of the system

The detailed hardware description of the present work is shown in the photograph given below in Fig.2.1. The internal connections of the system and the details of the arrangements are shown in the block diagram Fig 2.2. This design is build around LPC2129 based ARM 7 Controller along with temperature sensor, Humidity sensor, CO$_2$ sensor, 2x16 LCD module and the GSM modem. All these components are suitably interfaced to the ARM controller using the necessary signal conditioning circuits. The following sections explains each component of the system.

Fig.2.1. Photograph showing the experimental design
2.2.1 ARM 7 PROCESSOR - LPC 2129

The ARM7TDMI-S processor is a member of the ARM family of general-purpose 32-bit microprocessors. The ARM family offers high performance for very low-power consumption and gate count.

The ARM architecture is based on Reduced Instruction Set Computer (RISC) principles. The RISC instruction set, and related decode mechanism are much simpler than those of Complex Instruction Set Computer (CISC) designs. The ARM7TDMI-S processor uses a pipeline to increase the speed of the flow of instructions to the processor. This enables several operations to take place simultaneously, and the processing, and memory systems to operate continuously. A three-stage pipeline is used, so instructions are executed in three stages, Fetch, Decode, Execute.
The ARM7TDMI-S processor has a Von Neumann architecture, with a single 32-bit data bus carrying both instructions and data. Only load, store, and swap instructions can access data from memory. Data can be 8-bit bytes, 16-bit half words, or 32-bit words. Words must be aligned to 4-byte boundaries. Half words must be aligned to 2-byte boundaries.

The LPC 2129 is based on a 16/32 bit ARM7TDMI-S™ CPU with real-time emulation and embedded trace support, together with 128/256 kilobytes (kB) of embedded high speed flash memory. A 128-bit wide memory interface and unique accelerator architecture enable 32-bit code execution at maximum clock rate. For critical code size applications, the alternative 16-bit Thumb® Mode reduces code by more than 30% with minimal performance penalty[31].

2.2.2 Key features of LPC 2129

- 16/32-bit ARM7TDMI-S microcontroller in a tiny LQFP64 package.
- 16 kB on-chip Static RAM.
- 128/256 kB on-chip Flash Program Memory. 128-bit wide interface/accelerator enables high speed 60 MHz operation.
- In-System Programming (ISP) and In-Application Programming (IAP) via on-chip boot-loader software. Flash programming takes 1 ms per 512 byte line. Single sector or full chip erase takes 400 ms.
- Embedded ICE-RT interface enables breakpoints and watch points. Interrupt service routines can continue to execute while the foreground task is debugged with the on-chip RealMonitor™ software.
- Embedded Trace Macro cell enables non-intrusive high speed real-time tracing of instruction execution.
- Two interconnected CAN interfaces with advanced acceptance filters.
- Four channel 10-bit A/D converter with conversion time as low as 2.44 ms.
- Multiple serial interfaces including two UARTs (16C550), Fast I2C (400 k bits/s) and two SPIs
• 60 MHz maximum CPU clock available from programmable on-chip Phase-Locked Loop with settling time of 100 ms.
• Vectored Interrupt Controller with configurable priorities and vector addresses.
• Two 32-bit timers (with four capture and four compare channels), PWM unit (six outputs), Real Time Clock and Watchdog.
• Up to forty-six 5 V tolerant general purpose I/O pins. Up to nine edge or level sensitive external interrupt pins available.
• On-chip crystal oscillator with an operating range of 1 MHz to 30 MHz.
• Two low power modes Idle and Power-down.
• Processor wake-up from Power-down mode via external interrupt.
• Individual enable/disable of peripheral functions for power optimization.
• Dual power supply: CPU operating voltage range of 1.65 V to 1.95 V (1.8 V ±0.15 V).
• I/O power supply range of 3.0 V to 3.6 V (3.3 V ± 10%) with 5 V tolerant I/O pads. The block diagram of LPC2129 is shown below in Fig.2.3
Fig. 2.3. Block diagram of LPC2129
2.2.3 On-Chip Flash program memory

The LPC2129 incorporate a 128 kB and 256 kB Flash memory system respectively. This memory may be used for both code and data storage. Programming of the Flash memory may be accomplished in several ways. It may be programmed In System via the serial port. The application program may also erase and/or program the Flash while the application is running, allowing a great degree of flexibility for data storage field firmware upgrades, etc. When on-chip boot loader is used, 120/248 kB of Flash memory is available for user code. The PC2119/LPC2129 Flash memory provides a minimum of 100,000 erase/write cycles and 20 years of data retention. On-chip boot loader (as of revision 1.60) provides Code Read Protection (CRP) for the LPC 2129 on-chip Flash memory. When the CRP is enabled, the JTAG debug port and ISP commands accessing either the on-chip RAM or Flash memory are disabled. However, the ISP Flash Erase command can be executed at any time (no matter whether the CRP is on or off). Removal of CRP is achieved by erasure of full on-chip user Flash. With the CRP off, full access to the chip via the JTAG and/or ISP is restored. On-Chip static RAM may be used for code and/or data storage. The SRAM may be accessed as 8-bits, 16-bits, and 32-bits. The LPC2129 provide 16 kB of static RAM[32].

The LPC2119/LPC2129 each contain single 10-bit successive approximation analog to digital converter with four multiplexed channels. The important features of this on chip ADC are

- Measurement range of 0 V to 3 V.
- Capable of performing more than 400,000 10-bit samples per second.
- Burst conversion mode for single or multiple inputs.
- Optional conversion on transition on input pin or Timer Match signal.

The LPC 2129 each contain two CAN controllers. The Controller Area network (CAN) is a serial communications protocol which efficiently supports distributed real-time control with a very high level of security. Its domain of application ranges from high speed networks to low cost multiplex wiring. The important features of the CAN port are

- Data rates up to 1 Mbit/s on each bus.
• 32-bit register and RAM access.

• Compatible with CAN specification 2.0B, ISO 11898-1.

• Global Acceptance Filter recognizes 11 and 29-bit Rx identifiers for all CAN buses.

• Acceptance Filter can provide Full CAN-style automatic reception for selected Standard identifiers.

The LPC2129 each contains two UARTs. One UART provides a full modem control handshake interface, the other provides only transmit and receive data lines. The salient features of this UART are

• 16 byte Receive and Transmit FIFOs.

• Register locations conform to '550 industry standard.

• Receiver FIFO triggers points at 1, 4, 8, and 14 bytes

• Built-in baud rate generator.

• Standard modem interface signals included on UART1.

I2C is a bi-directional bus for inter-IC control using only two wires: a serial clock line (SCL), and a serial data line (SDA). Each device is recognized by a unique address and can operate as either a receiver-only device (e.g. an LCD driver) or a transmitter with the capability to both receive and send information (such as memory). Transmitters and/or receivers can operate in either master or slave mode, depending on whether the chip has to initiate a data transfer or is only addressed. I2C is a multi-master bus, it can be controlled by more than one bus master connected to it. I2C implemented in LPC2129 supports bit rate up to 400 k.bit/s (Fast I2C). The features of this I2C interface are

• Standard I2C compliant bus interface.

• Easy to configure as Master, Slave, or Master/Slave.

• Programmable clocks allow versatile rate control.
• Bidirectional data transfer between masters and slaves.

• Multi-master bus (no central master).

• Serial clock synchronization allows devices with different bit rates to communicate via one serial bus.

• Serial clock synchronization can be used as a handshake mechanism to suspend and resume serial transfer.

• The I²C bus may be used for test and diagnostic purposes.

The LPC2129 contain two SPIs. The SPI is a full duplex serial interface, designed to be able to handle multiple masters and slaves connected to a given bus. Only a single master and a single slave can communicate on the interface during a given data transfer. During a data transfer the master always sends a byte of data to the slave, and the slave always sends a byte of data to the master. The basic features of the SPI interface are

• Compliant with Serial Peripheral Interface (SPI) specification.

• Synchronous, Serial, Full Duplex, Communication.

• Combined SPI master and slave.

• Maximum data bit rate of one eighth of the input clock rate.

The schematic of LPC2129 is shown below.
2.3 GSM MODEM: Global System for Mobile communication is a digital mobile telephone system that is widely used in Europe and other parts of the world [33]. GSM uses a variation of Time Division Multiple Access (TDMA) and is the most widely used of the three digital wireless telephone technologies (TDMA, GSM, and CDMA). GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its own time slot. It operates at either the 900 MHz or 1,800 MHz frequency band. The photograph of GSM Modem is shown in Fig. 2.5.
Mobile phones with SIM cards use GSM technology to help you communicate with your family, friends and business associates. GSM systems have following advantages over basic landline telephony systems:

1. Mobility
2. Easy availability
3. High uptime

The GSM Modem supports popular "AT" command set so that users can develop applications quickly. The product has SIM card holder to which activated SIM card is inserted for normal use. The power to this unit can be given from UPS to provide uninterrupted operation. This product provides great feasibility for devices in remote location to stay connected which otherwise would not have been possible where telephone line do not exist.
"AT" COMMANDS:

AT commands, also called Hayes AT commands, are based on the Hayes Modem de facto standard, ATTENTION Commands for modems. They are used to communicate with your modem. These commands modify your modem's behavior or instruct the modem to do something specific, such as dialing a telephone number. The "AT" refers to getting the Attention of your modem. To send a command to modem, we need to start a terminal program such as Windows Hyper Terminal. No matter which terminal program you use, it should be configured to communicate with the COM port that your modem is attached to. You then type commands in the Terminal window. The modem executes the command and responds appropriately. One set of AT commands will identify your modem and version information.

Eg: -ATD [<dial_string>][;]

Dials the phone number specified in the <dial_string> parameter.

2.3.1. INTERFACING OF GSM UNIT: Interfacing of GSM modem is done through a serial communication link between the modem and microcontroller. Whatever data is to be sent to GSM modem is done through this RS 232 link. The different initializing signals and commands are sent as data packets. The interfacing of MAX232 with the microcontroller through UARTs is shown in figure 2.6.

![Interfacing of MAX232 with ARM Microcontroller through UARTs](image-url)
2.4 Temperature Sensor

In the present work the measurement of temperature is done using the temperature sensor LM35. The LM 35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1/4°C at room temperature and ±34°C over a full -55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35’s low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 μA from its supply, it has very low self-heating, less than 0.1°C in still air [34]. The typical circuit diagram for temperature sensor is shown below in Fig.2.7

![Fig.2.7. LM 35 Pin Diagram](image_url)

The interfacing of LM35 temperature sensor to LPC2129 processor at the pin P0.29 is shown in the below figure 2.8. This pin is the input pin of the on-chip ADC.
2.5 Humidity Sensor (SY-HS-220)

A humidity sensor measures the relative humidity in the air. The humidity sensors are widely used in domestic, industrial, and meteorological applications, and the relative humidity is expressed as a percent (RH %). It is the ratio of actual moisture in the air to the highest amount of moisture the air can hold at that temperature. The warmer the air is, the more moisture it can hold, so relative humidity changes with fluctuation of temperature. The most common type of humidity sensor used is the "capacitive sensor." This system relies on electrical capacitance, or the ability of two nearby electrical conductors to create an electrical field between them. The sensor itself is composed of two metal plates with a non-conductive polymer film between them. The film collects moisture from the air, and the moisture causes minute changes in the voltage between the two plates. The changes in voltage are used to know the amount of moisture in the air [35].
Three types of sensor technologies are in use. Resistive, Capacitive, and Thermal Conductivity sensing. Resistive sensors are useful in remote locations. Capacitive sensors are useful for wide RH range and condensation tolerance. Thermal conductivity sensors are beneficial in corrosive environments that have high temperatures. The type of sensor used depend on the type of environment. Commercial and office buildings often have humidity sensors in their HVAC systems, (Heating, Ventilating, and Air Conditioning) which assists in keeping the air safe and healthy to breathe. Humidity sensors also have industrial uses for the manufacturing of materials that are sensitive to moisture. As well, humidity sensors are used for collecting data for weather stations and ocean research where humidity has to be measured and recorded for a period of time to evaluate patterns and forecast weather. A simple humidity sensor is shown in figure 2.9 below.

![Humidity Sensor Diagram](image)

**Fig.2.9.Humidity Sensor**

The SY-HS-220 series Humidity sensor is used in the present work. This module converts relative humidity to output voltage. Its operating voltage is 5V DC. Its operating temperature is 0 - 60° C and its operating humidity is 30- 90% RH. Its standard output at 25°C and 60% RH is 1980mV DC[36].The specifications of this humidity sensor are given in Table2.1. The typical output characteristics of this humidity sensor are given in Table 2.2 and the calibration graph is shown in Fig.2.10.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Voltage</td>
<td>DC 5.0 V</td>
</tr>
<tr>
<td>Rated Power</td>
<td>≤ 3.0 mA</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>0~60°C</td>
</tr>
<tr>
<td>Operating Humidity</td>
<td>30-90 %RH</td>
</tr>
<tr>
<td>Storage Humidity</td>
<td>Within 95 %RH</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>-30~85 °C</td>
</tr>
<tr>
<td>Standard Output</td>
<td>DC 1980mV (at 25°C, 60 %RH)</td>
</tr>
<tr>
<td>Accuracy</td>
<td>±5 %RH (at 25°C, 60 %RH)</td>
</tr>
</tbody>
</table>

Table 2.1. Specifications of the humidity sensor

<table>
<thead>
<tr>
<th>Humidity (%RH)</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>95</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output voltage(mV)</td>
<td>660</td>
<td>990</td>
<td>1320</td>
<td>1650</td>
<td>1980</td>
<td>2310</td>
<td>2640</td>
<td>2970</td>
<td>3140</td>
</tr>
</tbody>
</table>

Table 2.2. Typical output characteristics of the humidity sensor

![Calibration curve of Humidity sensor](image)

Fig.2.10. Calibration curve of Humidity sensor
The pin details of the humidity sensor are given in figure 2.11 below. Among the three pins first one is (B) connected to ground, the other (R) is to +5 volts and the third one (W) gives the analog output voltage.

![Humidity Sensor Module](SY-HS-220)

**Fig 2.11. Pin details of Humidity Sensor**

The interfacing of the humidity sensor SY-HS-220 to the on chip ADC port pin P0.28 is shown in the figure 2.12.

**Fig 2.12. Interfacing of Humidity sensor**

The interfacing of the humidity sensor SY-HS-220 to the on chip ADC port pin P0.28 is shown in the figure 2.12.
2.6 Carbon Dioxide (CO2) Sensor (MG811)

In the present work MG 811 CO2 Sensor is used to detect the CO2 present in the atmosphere. This sensor features good sensitivity and selectivity to CO2. It has low humidity and temperature dependency and long stability and reproducibility. When the internal heating element is activated, this gas sensor responds to CO2 gas by generating a small voltage in proportion to the amount of CO2 gas present in the air exposed to the internal element. The sensor is a high impedance device and requires a buffer/amplifier[37].

This Sensor adopt solid electrolyte cell Principle. When the sensor is exposed to CO2, the following electrodes reaction occurs:

**Cathodic reaction**: \[ 2\text{Li}^+ + \text{CO}_2 + \frac{1}{2}\text{O}_2 + 2\text{e}^- = \text{Li}_2\text{CO}_3 \]

**Anodic reaction**: \[ 2\text{Na}^+ + \frac{1}{2}\text{O}_2 + 2\text{e}^- = \text{Na}_2\text{O} \]

**Overall chemical reaction**: \[ \text{Li}_2\text{CO}_3 + 2\text{Na}^+ = \text{Na}_2\text{O} + 2\text{Li}^+ + \text{CO}_2 \]

So, the EMF is developed when this sensor is exposed to the reducing gas. The developed voltage is in accordance with the concentration of the gas present in the medium. The relation between the output voltage and gas concentration in ppm is given by
\[ C = \left( \frac{(V_C R_L/V_o) - R_L}{R_o} - 1 \right) \frac{1}{K} \]  

Here \( V_C \) is the input voltage 
\( V_o \) is the output voltage 
\( R_L \) is the load resistance and \( R_S \) is the sensor resistance normally between 5 k\( \Omega \) - 15k\( \Omega \)

When the internal heating element is activated, this gas sensor responds to CO\(_2\) gas by generating a small voltage in proportion to the amount of CO\(_2\) gas present in the air exposed to the internal element. The signal conditioning circuit is shown in figure 2.13.

The sensor is a high impedance device and requires a buffer/amplifier to measure the output. The output from the buffer/amplifier (op-amp) is then sent to the inverting input of another op-amp which is configured as a comparator. A voltage divider formed by \( R_3 \) is used to provide a reference voltage. The output of this voltage divider is fed into the non-inverting inputs of the second op-amp on the LMC6035 dual op-amp IC. The buffered output of the sensor can be measured for the signal voltage at TP1 (+) and TP2 (-). The reference voltage is available at TP3 (+) and TP4 (-). The output of op-amp B goes out to the ALR pin through a 1 k\( \Omega \) resistor providing a TTL-compatible signal to a microcontroller. This output also connects to a red LED on the gas sensor module. The trip level adjustment is set via potentiometer \( R_3 \). This is just a simple voltage divider that lets you set the voltage from 0V to 3.3V. This voltage is compared to the voltage coming from the gas sensor buffer/op-amp. When the voltage from the gas sensor is lower than the voltage set by potentiometer \( R_3 \) the red LED will light and the ALR output will be high (3.3 V). The voltage from the sensor actually drops as CO\(_2\) increases [38].
Fig. 2.13. Signal conditioning circuit for the CO2 Gas sensor

Calibration of the sensor

The following steps are involved in the calibration of the gas sensor:

- Keep the Gas Sensor Module in a clean air environment and supply power to the module. The heater should be active during this time. Allow at least 5 minutes before making adjustments.
- Measure the voltage at TP1 (+) and TP2 (-). It should be between 1.5 – 2V, but could be from 1V – 3.3V.
- Adjust potentiometer R3 (Trip Level) until the voltage across TP3 (+) and TP4 (-) reads approximately just below the reading from TP1/TP2. The LED should go out.
- Apply your gas source to the gas sensor. The LED should light up.
- Remove the gas source and allow the sensor to settle. The LED should go back out.
- If the LED does not go out within 60 seconds, adjust R3 until the LED goes out and repeat the two previous steps.
- The gas sensor module's ALR pin should only be checked when the heater is on and the readings have stabilized.

Fig 2.14 CO2 Sensor circuit

The CO2 gas sensor circuit is shown in figure 2.14 and the detailed interfacing circuit of CO2 interfacing with ARM controller at the input of on-chip ADC P0.27 is shown in figure 2.15 below.

Fig 2.15. Interfacing of CO2 Sensor
The dependency of CO2 on Temperature and Humidity are shown in figures 2.16 and 2.17 below.

Fig.2.16. Variation of CO2 sensor output with Temperature.

Fig.2.17. Variation of CO2 sensor output with Humidity.
2.7. 2X16 LCD MODULE

In recent years the LCD is finding widespread use replacing Seven segment LEDs or other multi segment LEDs. The striking reasons are mentioned below

- The ability to display numbers, characters, and graphics. This is in contrast to LEDs, which are limited to numbers and a few characters.
- Incorporation of a refreshing controller into the LCD, thereby relieving the CPU of the task of refreshing the LCD. In contrast, the LED must be refreshed by the CPU to keep displaying the data.
- Ease of programming for characters and graphics.
- The declining prices of LCDs

In the present work a HD44780 2X16 Hitachi LCD module is used to display the measured data. It is a 16 pin Module. The Pin diagram of LCD is shown in Fig. 2.18.

![Pin diagram of 2X16 LCD Module](image)

Fig.2.18 Pin diagram of 2X16 LCD Module

The pin description of each pin of the LCD module is given below:

**RS (Register select)**

There are two very important registers inside the LCD. The RS pin is used for their selection as follows. If RS=0, the instruction command code register is selected, allowing the user to send a
command such as clear display, cursor at home, etc. If RS=1 the data register is selected, allowing the user to send data to be displayed on the LCD.

**R/W (Read/Write)**

R/W input allows the user to write information to the LCD or read information from it. R/W=1 when reading; R/W=0 when writing.

**E (Enable)**

The enable pin is used by the LCD to latch information presented to its data pins. When data is supplied to data pins, a high to low pulse must be applied to this pin in order for the LCD to latch in the data present at the data pins. This pulse must be a minimum of 450ns wide.

**D0-D7**

The 8 bit data pins, D0-D7 are used to send information to the LCD or read the contents of the LCD's internal registers.

To display letters and numbers, we send ASCII codes for the letters A-Z, a-z, and numbers 0-9 to these pins while making RS=1. There are also instruction command codes to clear the display or force the cursor to the home position or blink the cursor etc.

HD 44780 LCD module is a specialized device to be used with the microcontrollers, which means that it cannot be activated by standard IC circuits. It is used for displaying different messages on a miniature liquid crystal display. It is based on the HD 44780 microcontroller (Hitachi) and can display messages in two lines with 16 characters each[39]. It displays all letters of alphabet, greek letters, punctuation marks, mathematical symbols etc. In addition, it is possible to display symbols made up by the user. Other useful features include automatic message shift (left and right), cursor appearance, LED backlight etc.

Display contrast depends on power supply voltage and whether messages are displayed in one or two lines. For that reason, varying voltage 0-Vdd is applied on the pin marked as Vee. Trimmer potentiometer is usually used for that purpose. Some LCD displays have built in backlight (blue or green diodes). When used during operation, a current limiting resistor should be serially connected to one of the pins for backlight (similar to LED diodes)[40]. If there are no characters displayed or if all of them are dimmed upon the display is switched on, the first thing
that should be done is to check the potentiometer for contrast adjustment. The interfacing of a LCD module with the ARM processor is shown in Fig.2.19.

2.8 Serial communication

Serial communication is an important way which enables the device modules to communicate with the outside world. It is called serial because the data bits will be sent in a serial way over a single line. A personal computer has a serial port known as communication port or COM Port, used to connect a modem or any other device. There could be more than one COM Port in a PC. Serial ports are controlled by a special chip called UART (Universal Asynchronous Receiver Transmitter). Different applications use different pins on the serial port and this basically depend on the functions required [41].

Devices that use serial cables for their communication are split into two categories.

1. DTE (Data Terminal Equipment). Examples of DTE are computers, printers & terminals.
2. DCE (Data Communication Equipment). Example of DCE is modems.

**Communication methods**

There are two methods for serial communication, Synchronous & Asynchronous.

(i) **Synchronous serial communication**

In Synchronous serial communication the receiver must know when to "read" the next bit coming from the sender, this can be achieved by sharing a clock between sender and receiver. In most forms of serial Synchronous communication, if there is no data available at a given time to transmit, a fill character will be sent instead so that data is always being transmitted. Synchronous communication is usually more efficient because only data bits are transmitted between sender and receiver, however it will be more costly because extra wiring and control circuits are required to share a clock signal between the sender and receiver.

(ii) **Asynchronous serial communication**

Asynchronous transmission allows data to be transmitted without the sender having to send a clock signal to the receiver. Instead, special bits will be added to each word in order to synchronize the sending and receiving of the data. When a word is given to the UART for Asynchronous transmissions, a bit called the "Start Bit" is added to the beginning of each word that is to be transmitted. The Start Bit is used to alert the receiver that a word of data is about to be sent, and to force the clock in the receiver into synchronization with the clock in the transmitter.

![Diagram of Synchronous and Asynchronous communications](image)

After the Start Bit, the individual bits of the word of data are sent, each bit in the word is transmitted for exactly the same amount of time as all of the other bits. When the entire data word has been sent, the transmitter may add a Parity Bit that the transmitter generates. The Parity Bit may be used by the receiver to perform simple error checking. Then at least one Stop Bit is sent by the transmitter.

**Baud rate**
Baud rate is a measurement of transmission speed in asynchronous communication; it represents the number of bits that are actually being sent over the serial link. The Baud count includes the overhead bits Start, Stop and Parity that are generated by the sending UART and removed by the receiving UART.

RS232

RS-232 (Recommended standard-232) is a standard interface approved by the Electronic Industries Association (EIA) for connecting serial devices. In other words, RS-232 is a long established standard that describes the physical interface and protocol for relatively low-speed serial data communication between computers and related devices.

An industry trade group, the Electronic Industries Association (EIA), defined it originally for teletypewriter devices. In 1987, the EIA released a new version of the standard and changed the name to EIA-232-D. Many people, however, still refer to the standard as RS-232C, or just RS-232.\[42\]

RS-232 is the interface that your computer uses to talk to and exchange data with your modem and other serial devices. The serial ports on most computers use a subset of the RS-232C standard.

Advantages of serial communication

Serial communication has certain advantages over the parallel communication. One of the advantages is transmission distance, serial link can send data to a remote device more far then parallel link. Also the cable connection of serial link is simpler then parallel link and uses less number of wires. Serial link is used also for Infrared communication, now many devices such as laptops & printers can communicate via infrared link.

2.8.1 MAX232

The MAX232 is an integrated circuit that converts signals from an RS-232 serial port to signals suitable for use in TTL compatible digital logic circuits. The MAX232 is a dual driver/receiver and typically converts the RX, TX, CTS and RTS signals [43].

The drivers provide RS-232 voltage level outputs (approx. ± 7.5 V) from a single + 5 V supply via on-chip charge pumps and external capacitors. The receivers reduce RS-232 inputs (which may be as high as ± 25 V), to standard 5 V TTL levels.
When a MAX232 IC receives a TTL level to convert, it changes a TTL Logic 0 to between +3 and +15 V, and changes TTL Logic 1 to between -3 to -15 V, and vice versa for converting from RS232 to TTL. Its pin diagram is shown in Fig. 2.20.

![Pin diagram of MAX232](image)

Fig. 2.20. Pin diagram of MAX232

The circuit diagram of MAX232 to PC Serial port is shown in Fig. 2.21.
2.9 Buzzer

Here the buzzer circuit is used when the temperature exceeds beyond 40°C, and the humidity is less than 20% and the CO2 concentration is higher than 370 ppm. The buzzer will alarm the user as a caution. The working of the buzzer circuit is discussed below.

The output of the controller decides buzzer operation. The buzzer works only if the Positive and the Ground is connected to the appropriate terminals. We control the buzzer by controlling the ground signal given to the buzzer using a transistor.

When the output of the controller is High, then the transistor conducts, allowing the low potential to reach one end of the buzzer, which results in sounding of the buzzer [44].

When the output is Low, the transistor will not conduct. So ground is not applied to the buzzer. So the buzzer is not sounded.

Fig. 2.21. Circuit diagram of MAX232 to PC Serial port
The buzzer connection to the ARM Processor is shown in Fig. 2.22.

This buzzer will send an alert signal to the user, if the concentration level of CO\textsubscript{2} increases beyond the set values. For example if the concentration of CO\textsubscript{2} is higher than 370 ppm, the buzzer will generate an alert.