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Measurement and Transmission of Process Parameters in GSM and IoT Network

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Abstract: In modern industrial plants, timely and accurate information about process parameters is essential. For those reasons in modern technological and industrial development, the application of electronics in measuring, processing, storing and transferring process data in industrial facilities is increasing. Guided by the need for measurement, visualization and storage of process parameters, modern electronic systems provide the ability to process and store measurement data on-site and transfer it to the GSM and IoT network. On the other hand, the application of sophisticated electronic systems is noticeable not only in power plants, but also in healthy and quality food industries, such as agriculture. We witness daily tribunes and panel discussions sponsored by companies and even governments for the introduction of the terminology of digital agriculture, i.e. the introduction of smart electronic solutions in agriculture. In addition to the commitment to so-called green energy, i.e. obtaining energy from renewable sources, the development of digitization in agriculture is an area in which an enormous application of smart electronic systems is expected in the future. Guided by these reasons, in this paper an electronic system is designed that provides a solution to a problem in hydro melioration system, i.e. the development, design and practical implementation of the Smart electronic system which enables the measurement of the process parameters of an agro-industrial facility and their transfer to the GSM and IoT network. The solution enables the visualization of process parameters locally on LCD displays and remotely on an mobile device in GSM and IoT network. A data log file is also provided for store the value on the process parameters on a local computer.

Keywords: Electronic system, Hydro melioration system, Process parameters, GSM network, IoT network

Introduction

Modern agricultural production, on the one hand, should provide timely management of the parameters necessary for obtaining a quality product, and on the other hand, it should provide the opportunity to collect and process data on control values in the agricultural plant (Fountas et al., 2020; Nareandra et al., 2019). Therefore, the introduction of a system for monitoring and quality control in modern agricultural production is essential knowledge (Rptz et al., 2019; Saiz-Rubio et al, 2020; Benet et al., 1982). In real industrial agricultural processes there are standalone plants that represent a separate whole. Most often these plants are far from intra and internet network of the agricultural production companies. Therefore there is a need to automate and connect these agricultural plants in the intranet of the company and more widely in the Internet (IoT), as and GSM SIM

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network (Bhuiyan et al., 2023; Eduku et al., 2024). Efforts are being made to ensure safer and simpler work, especially for operators who are directly exposed to the correct functioning of the entire industrial process. This approach to work is enabled by smart electronic devices that, among other things, generate data log files of measurement data (Ariel, 2024). On the other hand, a modern controlled system of an industrial process is fully rounded if it is connected to an IoT or GSM SIM network (Stefanov et al., 2021; Stefanov et al., 2023; Memonova et al., 2025). Such a concept enables process data to be transferred to any location, visualized in real-time, and stored on a personal and cloud computer.

Commonly, some standalone industrial agricultural processes might represent a separate entity. Since these plants are far from the Intra and Internet network of manufacturing companies, the data distribution of analog and digital signals from sensors and actuators of some process quantities (eg soil moisture, soil temperature and air temperature and humidity as and voltage, current, pressure, flow and level water, etc.) must be made from these remote entities to the master station via wireless communication, most likely a radio frequency (RF), IoT as and GSM connection (Stefanov et al., 2023; Memonova et al., 2025).

The choice of remote transmission of measurement process data via RF, IoT or GSM connection depends on the location of the specific industrial (agro) facility, the type and quantity of measurement data. Each of these transmission media has advantages and disadvantages. In the case where an RF connection is used, the transfer is limited in scope and is most often used when an standalone industrial (agro) facility needs to be connected to a master station of a complex industrial facility. The connection in the GSM and IoT network requires a reliable and secure GSM and internet medium and a secure and inexpensive cloud platform.

For these reasons, and guided by the need to improve the security of the transmitted data, the paper presents a solution by which the process data is transmitted in both networks. It is actually is designed an electronic system that provides a solution to a problem in hydro melioration system, i.e. the development, design and practical implementation of the Smart electronic system which enables measurement, storage, visualization and transfer of measured process parameters of an agro-industrial facility in the GSM and IoT network.

Design of an Electronic System

The design of the electronic system uses hardware components: microcontroller, sensors, relays, valves, fan. For the implementation of the control logic, an appropriate program code has been developed and is embedded in the microcomputer. The microcontroller MCU ESP8266, according to the control logic, receives the signals from the sensors and sends them to the SIM 900 module in the GSM network, and with the WI-FI module sends them to the IoT network. Figure 1 shows the block diagram of the control logic.

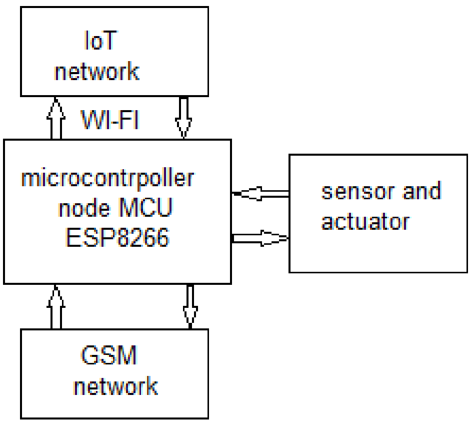


Figure 1. Block diagram on control logic

The design of the prototype electronic system, subject to the paper, includes the design of the system for measurement, monitoring and transfer of the process parameters on mobile device through GSM and IoT network. The detailed block diagram of this electronic system is shown in Figure 2. The task of the electronic system is to manage the agro-industrial facility based on the measured process parameters, temperature, humidity and CO2 on the air, as and soil temperature and humidity. A case is considered when the agro-industrial facility is of a closed type, i.e. built into a room (greenhouse). The central part of the system is Master station where is build the nodeMCU ESP8266 microcontroller (Arduino, 2021).. The agro-industrial facility is equipped with: an air temperature and humidity sensor (DHT22), a soil temperature sensor (DS18B20), a soil moisture sensor (V2.0), as and a CO2 detection sensor (SCD40), (Sensirion SCD40, n.d; Rembor, 2024). These sensors, based on the measured parameter values, send signals to the microcontroller: a digital signal for air temperature and humidity to digital input D8, a digital signal for soil temperature to digital input D7, an analog signal for soil moisture to analog input A0, as well as digital signal for CO2 on crop to the microcontroller's I2C bus.

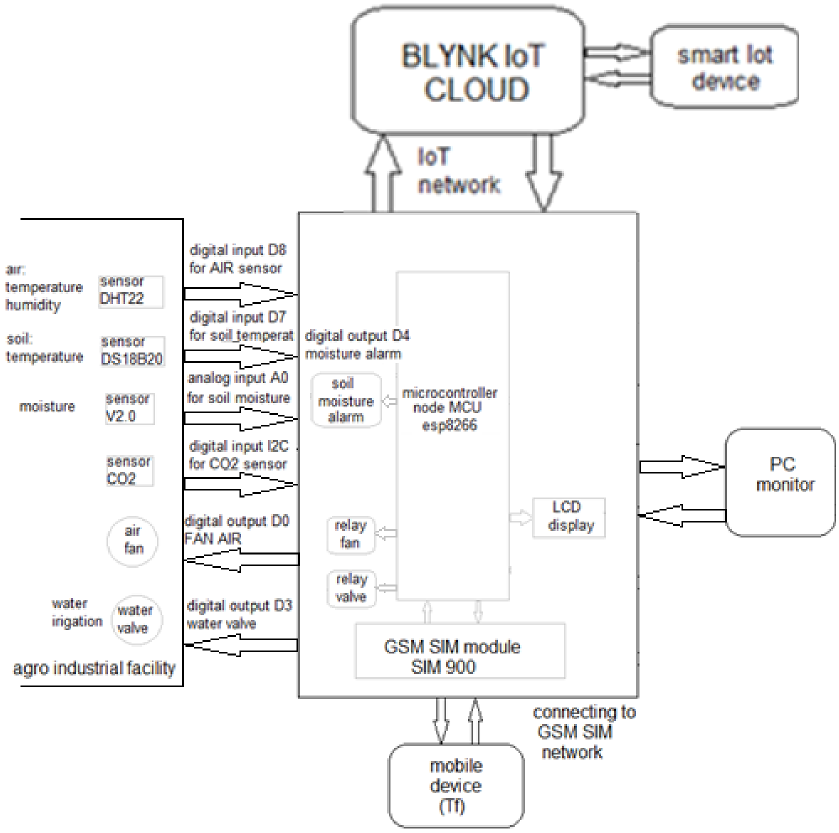


Figure 2. Detailed block diagram on electronic system for measurement, monitoring and transfer of the process parameters in agro industrial facility in mobile device through GSM and IoT network

Based on the measured values of the process parameters, the microcontroller sends control signal (digital output D0) to a fan for supplying fresh air to the agricultural facility and a signal (digital output D3) to turn on a valve for supplying water to the irrigation line of the agricultural crop. The microcontroller on the one hand is connected to the GSM network with the GSM module SIM900, and on the other hand with the WI-FI module built into the microcontroller MCU ESP8266, it is connected to the IoT network (SimCom, 2020). This connection ensures that process parameters are distributed bidirectional in the GSM and IoT network. This concept allows reading the values of process parameters on a mobile device, management of the supply of fresh air and water, as well as an alarm when any of the controlled variables exceeds the critical threshold.

Control Logic

The microcomputer node MCU 8266 via GSM module with the built-in SIM card is a medium (intermediary) for sending instructions from the microcomputer to the mobile phone and receiving them from the mobile device to the microcomputer. Also, microcomputers with build WI-FI module sending and receiving instructions via IoT network to mobile device (tablet, mobile phone). In Figure 3 is shown logical flow diagram on the electronic system.

The GSM module controls the state of the agro-culture by communicating with the microcomputer according to String (text) instructions. These String instructions are received by the SIM900 from the user via a mobile phone. The microcontroller receives the signals for the process parameters of the agro-industrial facility, processes them according to defined logic and sends the them via GSM SIM900 module to mobile phone.

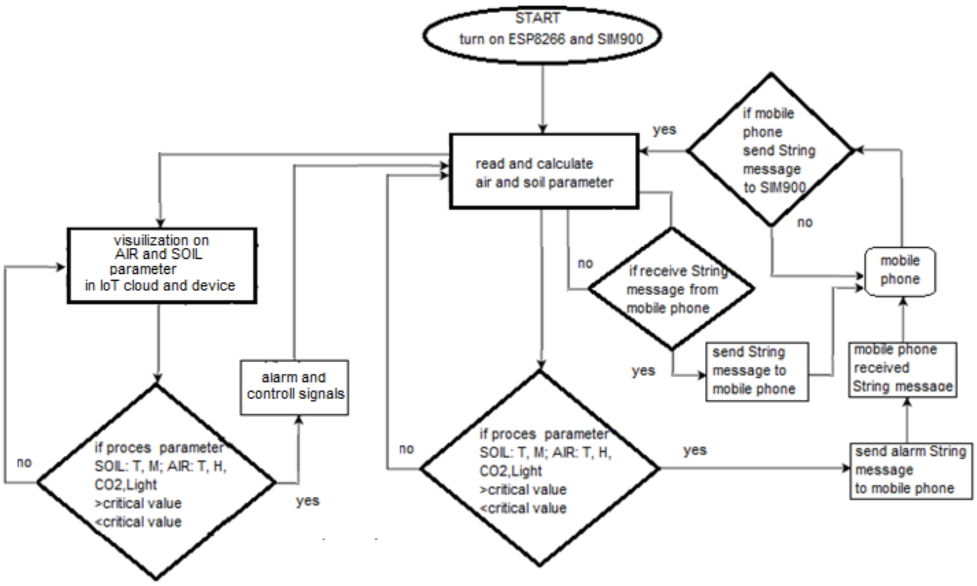


Figure 3. Block diagram on flow diagram on the electronic system

Measurement and Transmission on Process Parameter in GSM Network

These String instructions include:

Instructions on the Condition of Air Parameters

- READ AIR, the SIM900 receive from mobile phone this String message and sends this instruction to the microcontroller for reading air parameters in the agricultural facility; when the microcontroller receives this instruction, he (the microcontroller) reads and calculates the air parameters in the facility and sends a text string SIM message via SIM900 on mobile phone: " AIR: Temperature = " + String(t) + "*C " + "," + " Humidity = " + String(h) + "%" + "," + " CO2 = " + String(CO2) + "ppm". The message contains information about temperature, humidity, light and CO2 in the air as well as the brightness of the agricultural crop. Based on the values of the read data, the user concludes whether any of the process parameters has exceeded the critical value and sends the next string instruction for its correction.
- AIR FAN ON, This instruction is sent by the user when, based on previously read parameter values, he concludes that the humidity, temperature, light or CO2 in the facility has exceeded the critical value; when the microcontroller receives this instruction, he (the microcontroller) reads and calculates the air parameters in the facility, turns on the fan to supply fresh air sends a text string SIM message via SIM900 on mobile phone: "AIR: Temperature = " + String(t) + "*C " + "," + " Humidity = " + String(h) + "%" + "," + " CO2 = " + String(CO2) + "ppm"+ "FAN ON". The message contains information about temperature, humidity and CO2 in the air as well as the brightness of the agricultural crop and confirmation that the user's previous command has been implemented, i.e. the fan is turned on.
- The previous two instructions are for when the user wants to see the air condition in the facility. But the program algorithm has a built-in loop with which the microcontroller automatically monitors the process parameters and when any of them exceeds the critical value, it sends a string alarm message to the user.
- " CO2: " + String(CO2) + "ppm" + "," + " CO2 is HIGH " ; The user of the mobile device receives an alarm that the CO2 level is high.
- " temperature: " + String(t) + "*C" + "," + "temperature is HIGH " ;
- " humidity: " + String(h) + "%" + "," + "humidity is LOW " ;
- " Light: " + String(lux) + "lux" + "," + "light is LOW " ;
- AIR FAN OFF; This instruction is sent by the user when, based on previously read parameter values, he concludes that the humidity, temperature, light or CO2 in the facility have values within the working limits; when the microcontroller receives this instruction, he (the microcontroller) reads and calculates the air parameters in the facility, turns off the fan to supply fresh air sends a text

string SIM message via SIM900 on mobile phone: "AIR: Temperature = " + String(t) + "*C " + "," + " Humidity = " + String(h) + "%" + "," + " CO2 = " + String(CO2) + "ppm"+ "FAN OFF".

Instructions on the Condition of Soil Parameters

- READ SOIL; the SIM900 receive from mobile phone this String message and sends this instruction to the microcontroller for reading soil parameters in the agricultural facility; when the microcontroller receives this instruction, he (the microcontroller) reads and calculates the soil parameters in the facility and sends a text string SIM message via SIM900 on mobile phone: "SOIL: Temperature = " + String(tempSoil) + "*C " + "," + "Moistre = " + String(data1) + "%". The message contains information about temperature and moisture on soil in agricultural facility. Based on the values of the read data, the user concludes whether any of the process parameters on soil has exceeded the critical value and sends the next string instruction for its correction.
- VALVE ON; This instruction is sent by the user when, based on previously read parameter values, he concludes that the temperature and moisture on the soil in facility has exceeded the critical value; when the microcontroller receives this instruction, he (the microcontroller) reads and calculates the soil parameters in the facility, turns on the water valve on irrigation line to supply water and sends a text string SIM message via SIM900 on mobile phone: " SOIL: Temperature = " + String(tempSoil) + "*C " + "," + "Moisture = " + String(data1) + " % " + "," + "Valve ON".
- The previous two instructions are for when the user wants to see the soil condition in the facility. But the program algorithm has a built-in loop with which the microcontroller automatically monitors the process parameters and when any of them exceeds the critical value, it sends a string alarm message to the user.
- " SOIL Moistre: " + String(data1) + "%" + "," + " Moistre is LOW "; The user of the mobile device receives an alarm that the soil moisture level is LOW.
- " SOIL Temperature: " + String(tempSoil) + "*C" + "," + " Temperature is HIGH "; The user of the mobile device receives an alarm that the soil temperature level is HIGH.
- VALVE OFF; This instruction is sent by the user when, based on previously read parameter values, he concludes that the temperature and moisture on the soil in facility have values within the working limits; when the microcontroller receives this instruction, he (the microcontroller) reads and calculates the soil parameters in the facility, turns off the water valve on irrigation line to supply water and sends a text string SIM message via SIM900 on mobile phone: " SOIL: Temperature = " + String(tempSoil) + "*C " + "," + "Moisture = " + String(data1) + " % " + "," + "Valve OFF".

Measurement and Transmission on Process Parameter in IoT Network

The WI-FI module who is built-in ESP8266 card is a medium (intermediary) for sending instructions from the microcomputer to the IoT cloud. The IoT cloud also controls the state of the agro-culture by communicating with the microcomputer according to virtual pin instructions. These instructions are received by the cloud server from the user via a IoT network. The microcontroller receives the signals for the process parameters of the agro-industrial facility, processes them according to defined logic and sends the them via WI-FI module to mobile phone with build cloud platform. On the screen from mobile device in IoT network exist tags with built-in instruments for visualization of measurement parameters.

Figure 4 is shown print screen on IoT cloud screen, which shows the measured values of the process parameters. The measured value is displayed on an analog instrument with a measuring scale and on a digital display. On the screen are shown the following signals:

- AIR TEMP signal for the temperature on air;
- AIR HUM signal for the humidity on air;
- SOIL TEMP signal for temperature on the soil;
- MOISTURE SOIL signal for moisture on the soil.

Also on this screen are shown the button and led diode for management and control of the fan and water valve line:

- BUTTON FAN button for remote on/off of the fan for fresh air supply;
- FAN ON/OFF led diode for visualization of the fan status;

- BUTTON WATER VALVE button for remote on/off of the water valve on irrigation line;
- VALVE OPN/OFF led diode for visualization of water valve status.

The screen also displays alarm blocks when any of the controlled process parameters exceeds a critical value:

- SOIL MOISTURE is LOW a block for indicating when soil moisture is low;
- CO2 is HIGH a block for indicating when CO2 on air is high.

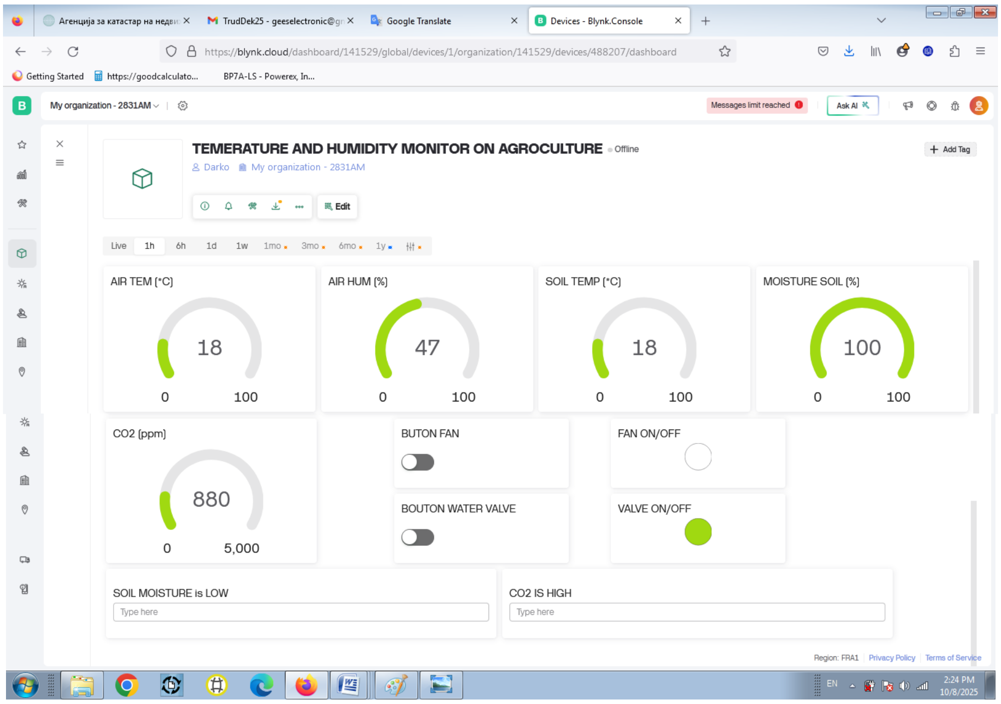


Figure 4. Print screen on IoT cloud screen

Design of Hardware Components on Electronic System

In this part is designed system which accepts the signals from the sensors and after appropriate software processing with nodeMCU8266 visualizes them on the one LCD displays and sends them via SIM900 module to the GSM network, and via WI-FI module in IoT network. Figure Figure 5 shows the electrical connections of the electronic system for managing the process parameters of the agro-industrial facility. The connections between the hardware components are described above, and can also be seen in Figure 5. Now a brief description of the characteristics of the hardware components used will be given here.

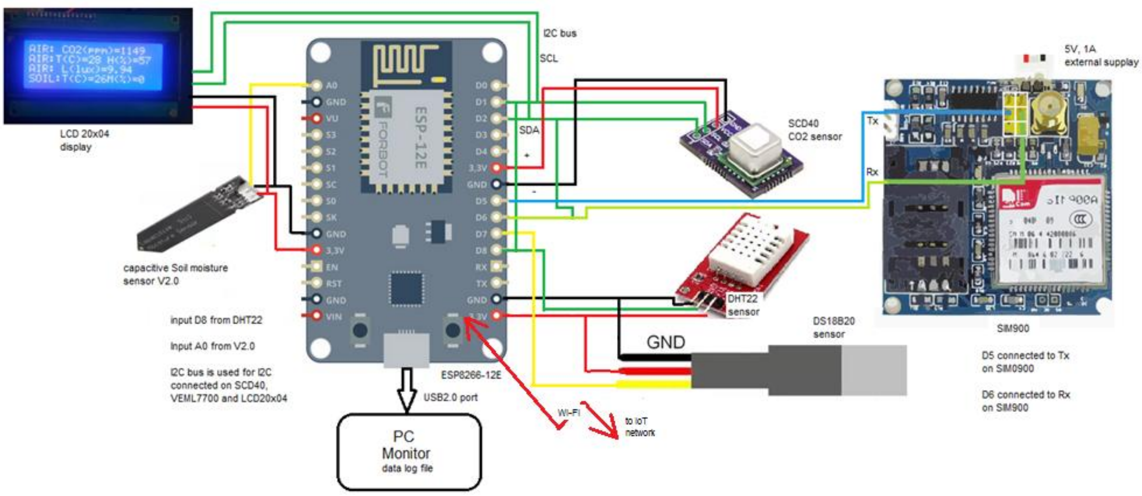
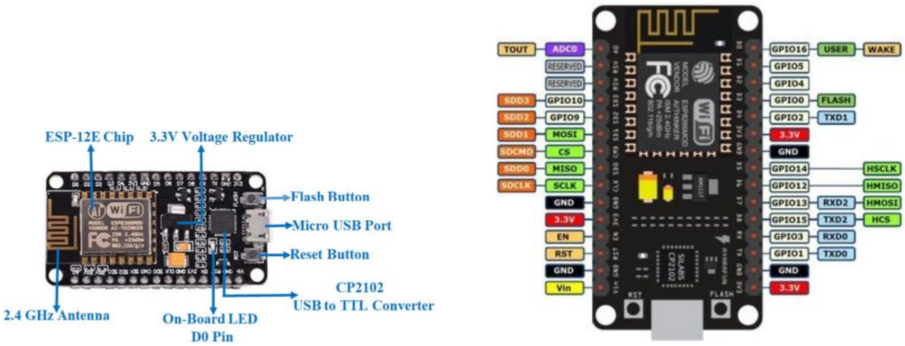


Figure 5. Electrical connections of the electronic system for managing with the process parameters of the agro-industrial facility

Microcomputer NodeMCU ESP8266

The NodeMCU ESP8266 development board comes with the ESP-12E module containing ESP8266 chip having Tensilica Xtensa 32-bit LX106 RISC microprocessor (NodeMCU, n.d). This microprocessor supports RTOS and operates from 80MHz to 160 MHz adjustable clock frequency. NodeMCU has 128 KB RAM and 4MB of Flash memory to store data and programs. Its high processing power with built-in Wi-Fi / Bluetooth and Deep Sleep Operating features makes it ideal for IoT projects. NodeMCU can be powered using Micro USB jack and VIN pin (External Supply Pin). It supports UART, SPI, and I2C interface. In the Figure 4 is shown NodeMCU ESP8266 and his pinout.



a.) b.)

Figure 4. a.) NodeMCU ESP8266 and b.) his pinout

NodeMCU is an open-source based firmware and development board specially targeted for IoT based applications. It includes firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module.

GSM SIM900 Module

GSM is a global system for mobile communication. Hence, to communicate with the computing devices, the GSM SIM needs a module. SIM900 is considered one of the best modules of today's time. It's a quad-band module that works perfectly with four frequencies, which are 850, 900, 1800, and 1900 MHz. The device is so compact and is compatible with Arduino. It easily allows sending SMS, MMS, etc. Moreover, it also supports audio through UART by using AT commands. Besides, it contains microphones and headphone jacks for phone calls. The sensor needs the 5 V power supply and draws 2 A of current. In the Figure 6 is shown the electronic board on SIM900. SIM900 is connected to the microcontroller with only 4 wires, that is power connection (VCC and GND), and serial communication pin (RX-TX). If used arduino UNO which is use 5V operating voltage and has 5V logic level (TTL). So need to connect arduino to RXD 5V and TXD 5V like in pinout picture above. If a nodeMCU8266-12E is used, which is use 3V operating voltage and has 3V logic level, as in our case, pins used are RXD 3.3V and TXD 3.3V. Then plug in SIM card into SIM card cartridge. Then the SIM900 and node MCU wiring connection.

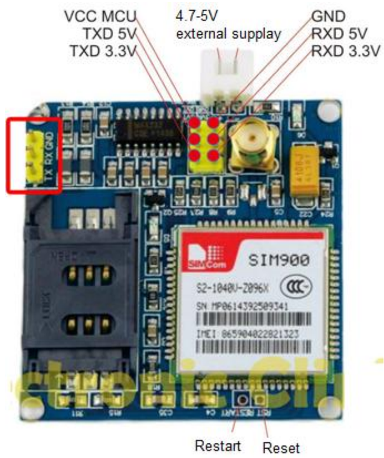


Figure 6. The electronic board on SIM900 module

Wire SIM900A module to node MCU like this:

- node MCU-> SIM900A
- 5V -> VCC
- GND -> GND
- 14 -> TX
- 12 -> RX

Power-on Procedure

First, need to insert your SIM card into the GSM module. Then, connect GSM GPRS Shield with NodeMCUEsp8266-12E. Now, upload the code on an Arduino board. After that, give the external 5V of power supply to the module. Then, press the power key of the GSM Module for 2 seconds. The LED present in the module will start glowing. And, when the sensor finds the networks, it will start blinking every three seconds. Now it is time to send or receive messages and phone calls with Arduino through the code. But, can also receive messages, and send or receive phone calls by using different programming codes.

SCD40 CO2 Sensor

SCD40 is a photoacoustic true CO2 sensor that will tell you the CO2 PPM (parts-per-million) composition of ambient air (Sensirion SCD40, n.d). Perfect for environmental sensing, scientific experiments, air quality and ventilation studies, and more. this sensor has data read over I2C, so it works very nicely with just about any microcontroller or microcomputer. There's both Arduino and Python/Circuit Python code so you can get started in a jiffy. In the Figure 7 is shown CO2 sensor SCD40.

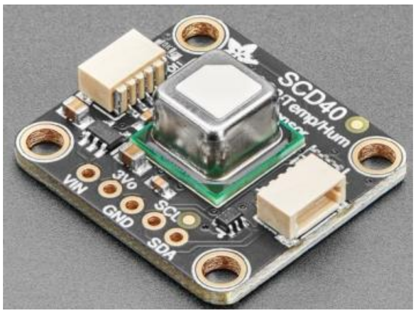


Figure 7. The electronic board on SDC40 CO2 sensor

There are two variants of this sensor - the SCD40 and SCD41

- The SCD40 is lower cost, and is perfect for indoor/outdoor air quality and CO2 measurements. It has a range of 400~2000 ppm with an accuracy of ±(50 ppm + 5% of reading)
- The SCD41 is more expensive, and while it can definitely be used for air quality, it's wide range means its best used for industrial or scientific CO2 measurements where the ppm can get very high. It has a range of 400~5000 ppm with an accuracy of ±(40 ppm + 5% of reading).

This sensor can run from 3.3 to 5V but it's more important for it to have a quiet power supply with low ripple, than any particular voltage. For that reason is added a 3.3V regulator and level shifters: when connecting to a 5V microcontroller like an Arduino UNO the 5V supply is often shared with other electronic components that add noise. The onboard regulator will keep the voltage nice and quiet. For advanced hackers, they can cut/solder the back traces to change whether the regulator is enabled and what I2C logic level is desired. Information about the DHT22, DS18B20 and V2.0 sensors is available in (Blynk, 2025; DHT22, n.d; DS18B20, 2019).

Experimental Results of Testing the Prototype Electronic System

This section presents the results of the experimental work on the prototype system for of the electronic system for managing with the process parameters of the agro-industrial facility. Figure 8 shows Prototype on the design electronic system.

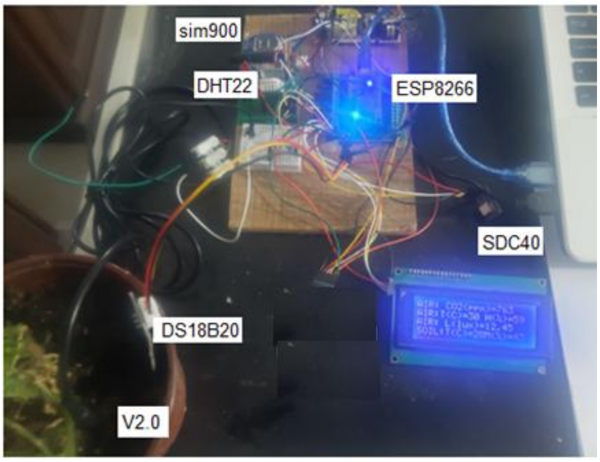


Figure 8. Prototype on the electronic system

Figure 9 shows a print screen of a data log file in Excel for monitoring on the process parameters of the agro-industrial facility obtained with the designed system in the paper.

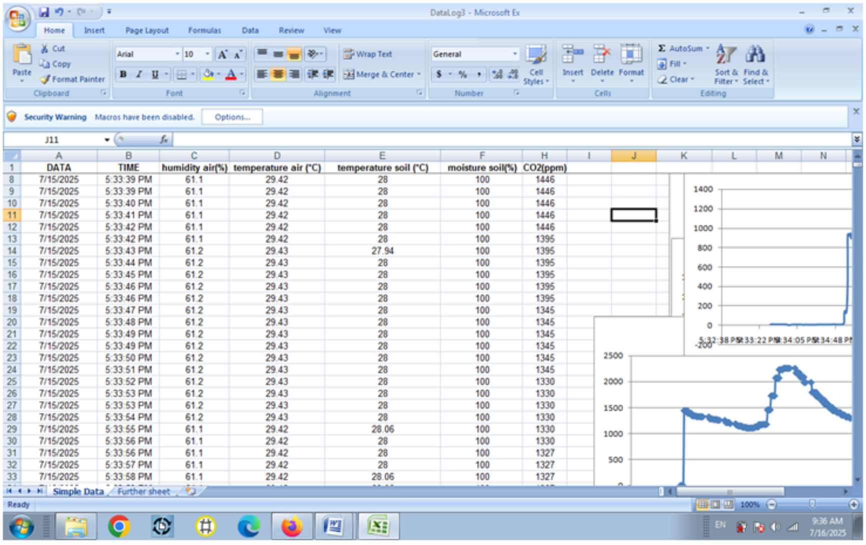
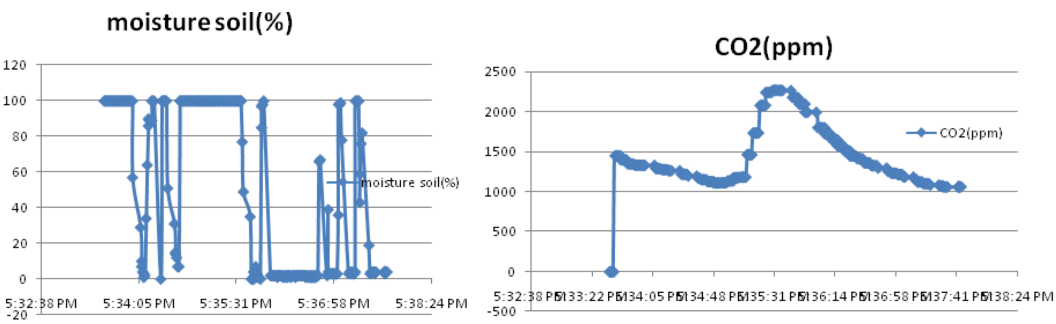


Figure 9. Print screen of a data log file in Excel for monitoring on the process parameters of the agro-industrial facility

Figure 10 shows waveforms of the measured parameters in the agro-industrial facility over a certain time interval. Figure 10a shows the waveform of soil moisture and Figure 10b shows the waveform illustrating the change in CO2.

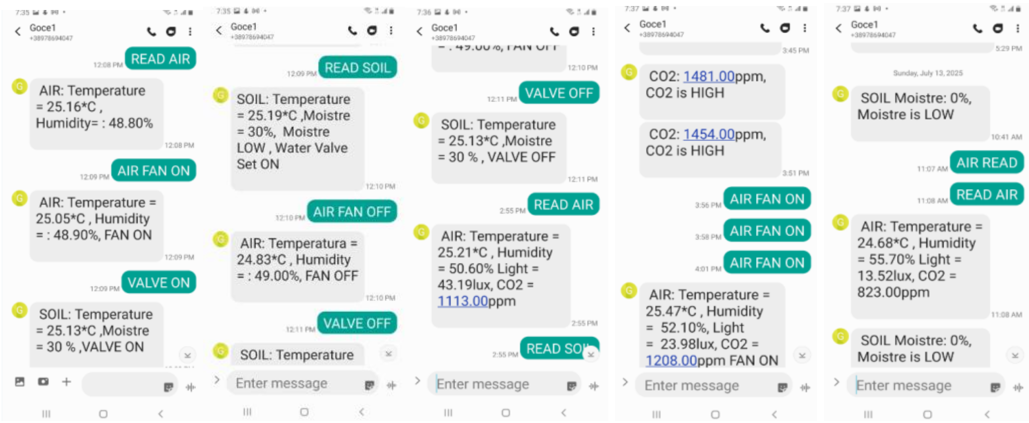


a.) b.)

Figure 10. Waveforms of the measured parameters in the agro-industrial facility over a certain time interval: a) waveform of soil moisture, b) waveform of CO2.

Figure 11 shows a print screen of the mobile phone that illustrates the correct operation of the electronic system.

Figure 11a is print screen on READ AIR, AIR FAN ON, VALVE on instruction; Figure 11b is print screen on READ SOIL and AIR FAN OFF instruction; Figure 11c is print screen on VALVE OFF and READ AIR instruction; Figure 11d is print screen on ALARM from electronic system to mobile phone when level CO2 is HIGH and Figure 11e is print screen on ALARM from electronic system to mobile phone when level soil moisture is LOW



a.) b.) c.) d.) e.)

Figure 11. Print screen from a mobile phone

The print screen on the mobile phone on the Figure 11 shows: a.) print screen on READ AIR, AIR FAN ON, VALVE on instruction; b.) print screen on READ SOIL and AIR FAN OFF instruction; c.) print screen on VALVE OFF and READ AIR instruction; d.) print screen on ALARM from electronic system to mobile phone when level CO2 is HIGH and e.) print screen on ALARM from electronic system to mobile phone when level soil moisture is LOW.

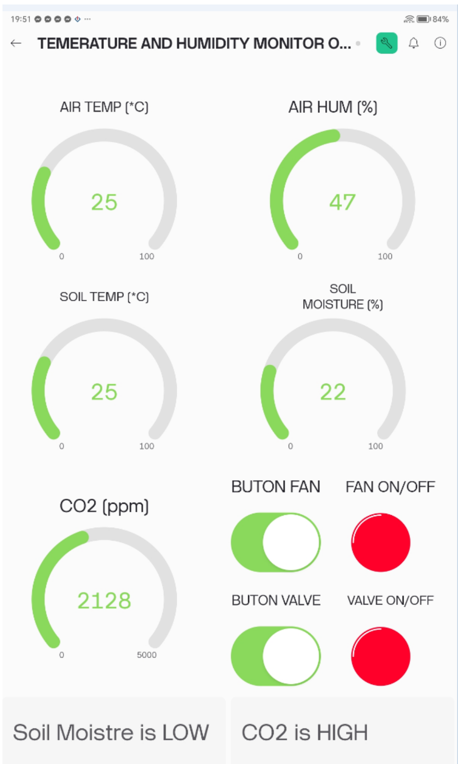


Figure 12. Process parameters screen of mobile device transmission in IoT network

Figure 12 show a data screen on a mobile device showing agriculture process parameters transferred in IoT network.

Analysis of the Results and Discussion

The main task of the paper is to design and implement a prototype electronic system for measuring, monitoring and transferring of the process parameters on agro industrial facility in GSM and IoT network. Verification of the correct operation of the system according to the defined task is illustrated with the Figures 8, 9, 10, 11 and 12.

- In point 2, a prototype of the system for measurement, monitoring and transferring of the process parameters on the agro industrial facility in GSM and IoT network was designed and implemented;
- Section 3 gives the results of the experimental work of the solution in the paper;
- The results show that the system measures, visualizes on LCD screens and stores in a data log file the process parameters of the agro industrial facility and sends them in GSM and IoT network;
- The print screen shown in the Figure 9 is provided to verify that the solution in the paper stores the data in a data log file in Excel;
- Waveforms shows on the Figure 10 illustrating the change of the process parameters in the agro-industrial facility over a certain time interval. They verify that the system measures and monitors the change in process parameters;
- Print screen from a mobile phone given in the Figure 11, verify that the system responds to messages sent from the mobile phone and sends an alarm back to the mobile device as required in point 2.1;
- Print screen from a mobile device given in the Figure 12, verify that the system sending the values of process parameters in IoT network of mobile device and sends an alarm back to the mobile device;
- Figure 12 shows the values of the process parameters during operation of the electronic system. Since the current values of soil moisture and air CO2 have exceeded the critical points (in this case, the critical point of soil moisture is 55%, and of CO2 is 1600ppm), the LEDs light up, indicating that in this state the water supply valve and the fresh air supply fan are turned on.

The paper offers a solution that addresses a problem that is currently relevant in the agro-industry. In (Bhuiyan et al., 2023; Eduku et al., 2024; Ariel, 2024), the subject of analysis is industrial processes from different aspects and in all of them the commitment to connecting measurement data remotely is clear. In some solutions, RF connections are used, in some cloud platforms, (Stefanov, 2023). The way in which this is realized is different and depends on the capabilities and approach of the authors. In the case where an RF connection is used, the transfer is limited in scope and is most often used when an standalone industrial (agro) facility needs to be connected to a master station of a complex industrial facility. Starting from the requirement to provide a reliable system that will provide measurement and transfer of process parameters with increased reliability, the paper provides a solution that distributes measurement data across both networks, GSM and IoT.

Conclusion

In this paper prototype of an electronic system is designed that provides a solution to a problem in agriculture facility, i.e. the development, design and practical implementation of the Smart electronic system which enables the measurement of the process parameters of an agro-industrial facility and their transfer to the GSM and IoT network. The solution enables the visualization of process parameters locally on LCD displays and remotely on an mobile device in GSM and IoT network. The solution also provides two-way communication and management of process parameters in the industrial facility. A data log file is also provided for store on the values on the process parameters on a local computer. There is a possibility of storing the values of the process parameters in the IoT cloud platform.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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