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FACULTY OF ELECTRICAL ENGINEERING

ETIMA 2021

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19-21 OCTOBER, 2021

TECHNICAL SCIENCES APPLIED IN ECONOMY, EDUCATION AND INDUSTRY

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ЕЛЕКТРОТЕХНИЧКИ ФАКУЛТЕТ

UNIVERSITY „GOCE DELCHEV” - SHTIP
FACULTY OF ELECTRICAL ENGINEERING

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PREFACE

The Faculty of Electrical Engineering at University Goce Delcev (UGD), has organized the International Conference ***Electrical Engineering, Informatics, Machinery and Automation - Technical Sciences applied in Economy, Education and Industry-ETIMA*.**
ETIMA has a goal to gather the scientists, professors, experts and professionals from the field of technical sciences in one place as a forum for exchange of ideas, to strengthen the multidisciplinary research and cooperation and to promote the achievements of technology and its impact on every aspect of living. We hope that this conference will continue to be a venue for presenting the latest research results and developments on the field of technology.
Conference ETIMA was held as online conference where contributed more than sixty colleagues, from six different countries with forty papers.
We would like to express our gratitude to all the colleagues, who contributed to the success of ETIMA'21 by presenting the results of their current research activities and by launching the new ideas through many fruitful discussions.
We invite you and your colleagues also to attend ETIMA Conference in the future. One should believe that next time we will have opportunity to meet each other and exchange ideas, scientific knowledge and useful information in direct contact, as well as to enjoy the social events together.

The Organizing Committee of the Conference

ПРЕДГОВОР

Меѓународната конференција ***Електротехника, Технологија, Информатика, Машинство и Автоматика-технички науки во служба на економија, образование и индустрија-ЕТИМА*** е организирана од страна на Електротехничкиот факултет при Универзитетот Гоце Делчев.
ЕТИМА има за цел да ги собере на едно место научниците, професорите, експертите и професионалците од полето на техничките науки и да представува форум за размена на идеи, да го зајканува мултидисциплинарното истражување и соработка и да ги промовира технолошките достигнувања и нивното влијание врз секој аспект од живеењето. Се надеваме дека оваа конференција ќе продолжи да биде настан на кој ќе се презентираат најновите резултати од истражувањата и развојот на полето на технологијата.
Конференцијата ЕТИМА се одржа online и на неа дадоа свој допринос повеќе од шеесет автори од шест различни земји со четириесет труда.
Сакаме да ја искажеме нашата благодарност до сите колеги кои допринесоа за успехот на ЕТИМА'21 со презентирање на резултати од нивните тековни истражувања и со лансирање на нови идеи преку многу плодни дискусии.

Ве покануваме Вие и Вашите колеги да земете учество на ЕТИМА и во иднина. Веруваме дека следниот пат ќе имаме можност да се сретнеме, да разменime идеи, знаење и корисни информации во директен контакт, но исто така да уживаме заедно и во друштвените настани.

Организационен одбор на конференцијата

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RF SENSOR SMART NETWORK

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Abstract
In the paper are presents the results of a practically realized process RF sensor network. The application is intended for data collection in remote processing plants and their transmission to the main central control panel. The solution is based on the RF interface module NRF24L01 and microcontroller. Two such modules communicate in the RF connection, as transmitter and receiver. On the receiving side, the received process data is displayed on an LCD display and stored in an excel log file.

Key words
NRF24L01module, Microcontroller, RF sensor network.

1. Introduction

In industrial processes, usually there is a need for data transmission in remote areas that are not covered by internet network, [1], [2], [3]. In such cases, a convenient solution is radio transmission and use of interfaces, sensors and controllers that support radio frequency transmission[4].

There are various wireless communication technologies used in building IoT applications and RF (Radio Frequency) is one of them. Usually such radio communications are two-way. In the Fig 1 is shown block diagram of one RF sensors network.

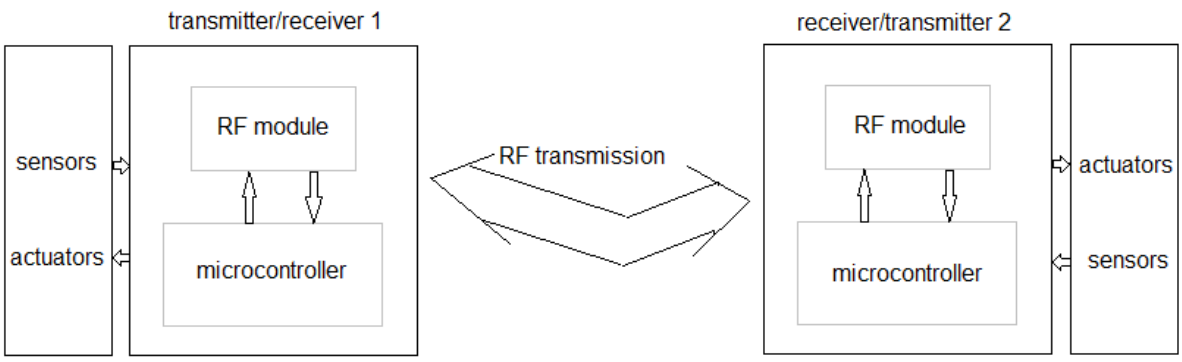


Fig.1. Block diagram of RF sensors network.

Transmitter/receiver 1 and receiver/transmitter 2 on both sides are consist of sensors network and actuators, RF module and microcontroller.

The main goal in this paper is the design of the RF sensor network. For the realization of the goal, the RF module NRF24L01 [5] and a microcontroller Atmega 328P are used on an Arduino uno board platform, [6].

2. Design on RF sensor network based on NRF24L01 and microcontroller

The designed sensor network in thispaper has the task to measure temperature and humidity at the measuring point and send measured values via RF transmission to the receiving point where these values are displayed on LCD screen and stored on PC ina data log file compatible with Microsoft Excel. In the Fig. 2 is shown block diagram of designed RF sensor network[5].

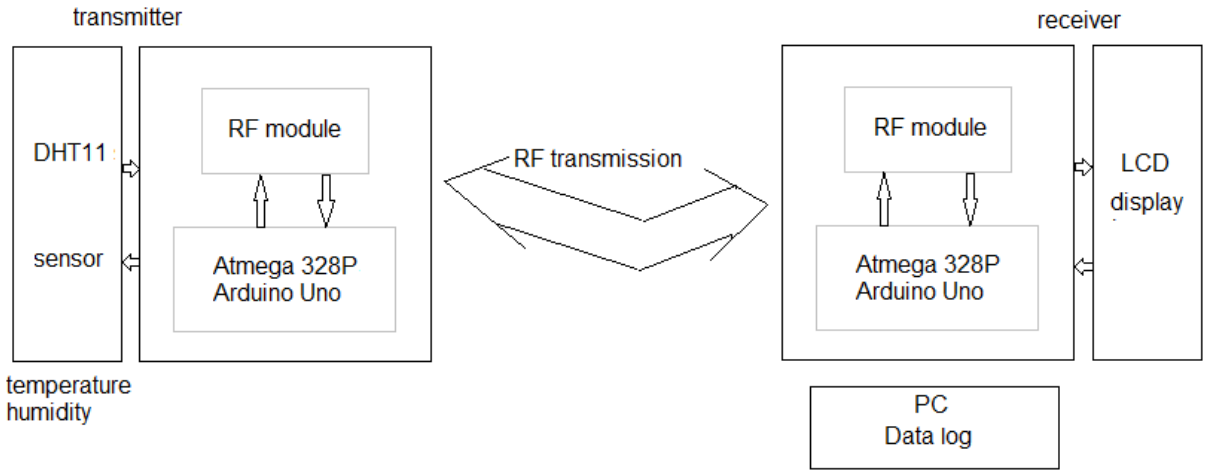


Fig. 2. Block diagram of designed RF sensor network.

The sensor network designed in this paper is consists of a transmitter and a receiver. The transmitter consists a temperature sensor with component DHT11, NRF24L01 module and microcontroller Atmega 328P on Arduino uno board. The receiver consists of NRF24L01 module, Atmega 328P microcontroller on Arduino uno board and LCD display.

Guided by the main goal of the paper, design of RF sensor network, in the next section are given the theoretical foundations of the components used.

2.1 Features of the used hardware

a.) *NRF24L01 module*

NRF24L01 is a single-chip radio transceiver module that operates on 2.4 - 2.5 GHz (ISM band)[5]. This transceiver module consists of a fully integrated frequency synthesizer, a power amplifier, a crystal oscillator, a demodulator, a modulator, and Enhanced ShockBurs protocol engine. Output power, frequency channels, and protocol setup are easily programmable through an SPI interface.Built-in Power Down and Standby modes makes power saving easily realizable. In the Fig. 3 is shown electronic board on NRF24L01 module and his pinout.

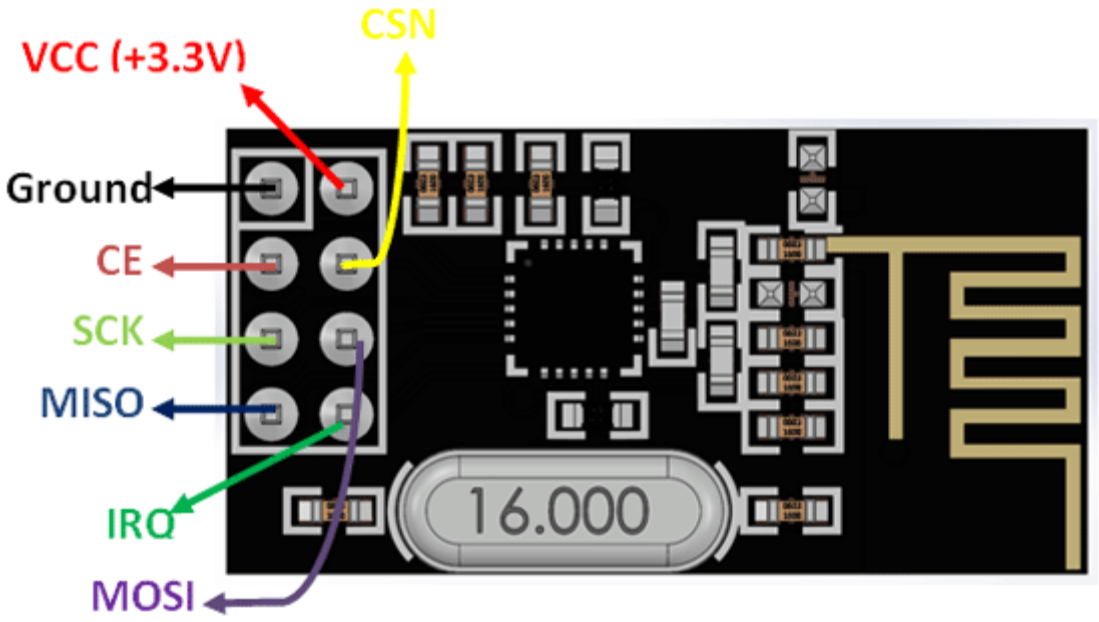


Fig.3. Electronic board on NRF24L01 module and his pinout.

In the Fig. 4 is shown block diagram of electronic components of NRF24L01 module.

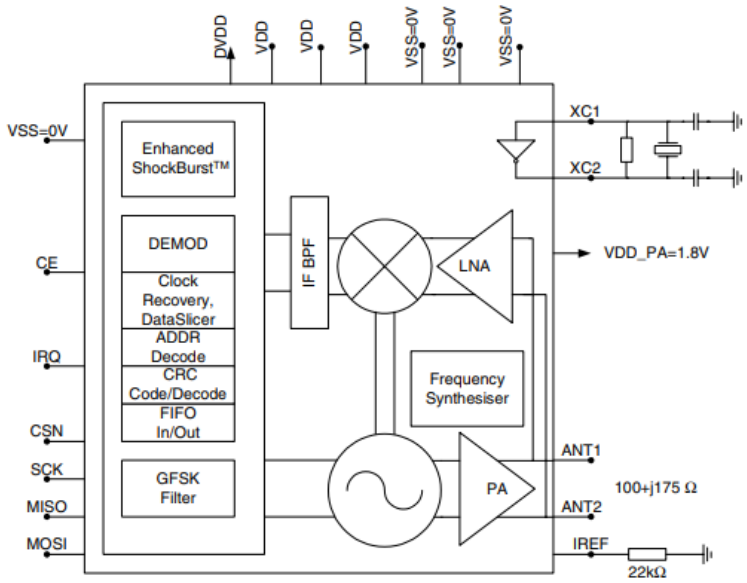


Fig. 4. Block diagram on the electronic components at NRF24L01 module.

In the Table 1 are given pinout configuration on NRF24L01 module.

Table 1: Pinout configuration on NRF24L01 module

Pin Number	Pin Name	Abbreviation	Function
1	Ground	Ground	Connected to the Ground of the system

2	Vcc	Power	Powers the module using 3.3V
3	CE	Chip Enable	Used to enable SPI communication
4	CSN	Ship Select Not	This pin has to be kept high always, else it will disable the SPI
5	SCK	Serial Clock	Provides the clock pulse using which the SPI communication works
6	MOSI	Master Out Slave In	Connected to MOSI pin of MCU, for the module to receive data from the MCU
7	MISO	Master In Slave Out	Connected to MISO pin of MCU, for the module to send data from the MCU
8	IRQ	Interrupt	It is an active low pin and is used only if interrupt is required

NRF24L01 Features:

- 2.4GHz RF transceiver Module
- Operating Voltage: 3.3V
- Nominal current: 50mA
- Range : 50 – 100 m
- Operating current: 250mA (maximum)
- Communication Protocol: SPI
- Baud Rate: 250 kbps - 2 Mbps.
- Channel Range: 125
- Maximum Pipelines/node : 6
- Low cost wireless solution

The NRF24L01 is a wireless transceiver module, meaning each module can both send as well as receive data. The operating frequency is 2.4 GHz, which falls under the ISM band and hence it is legal to use in almost in all countries for engineering applications. When the modules operate efficiently can cover a distance of 100 meters (200 feet) which makes it a great choice for all wireless remote controlled projects.
The module operates at 3.3V hence can be easily used with 3.2V systems or 5V systems. Each module has an address range of 125 and each module can communicate with 6 other modules hence it is possible to have multiple wireless units communicating with each other in a particular area. Hence mesh networks or other types of networks are possible using this module. Therefore, this module is an ideal choice for practical applications.

The NRF24L01 module works by means of SPI communications. These modules can either be used with 3.3V microcontroller or a 5V microcontroller with SPI port. The complete details of usage of this module through SPI is given in the data sheet below. The circuit diagram in the Fig. 5showshow the module should be interfaced with the microcontroller.

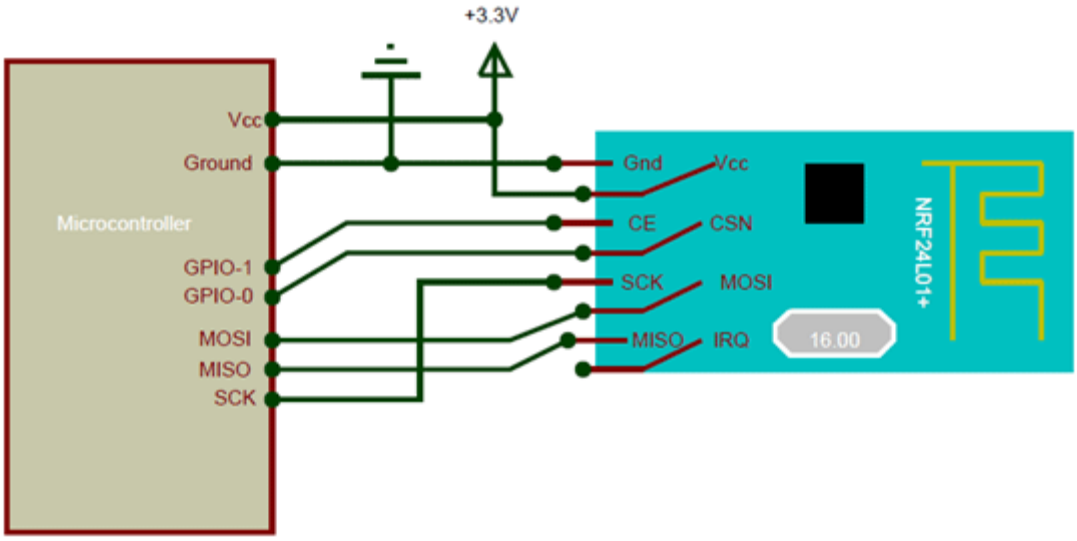


Fig. 5. NRF24L01 module interfaced with a microcontroller.

On Fig.5 is shown the usage of 3.3V microcontroller, but it is applied same for a 5V MCU. The SPI Pins (MISO<MOSI and SCK) are connected to the SPI pins of the Microcontroller and the signal pins (CE and CSN) are connected to the GPIO pins of the MCU.

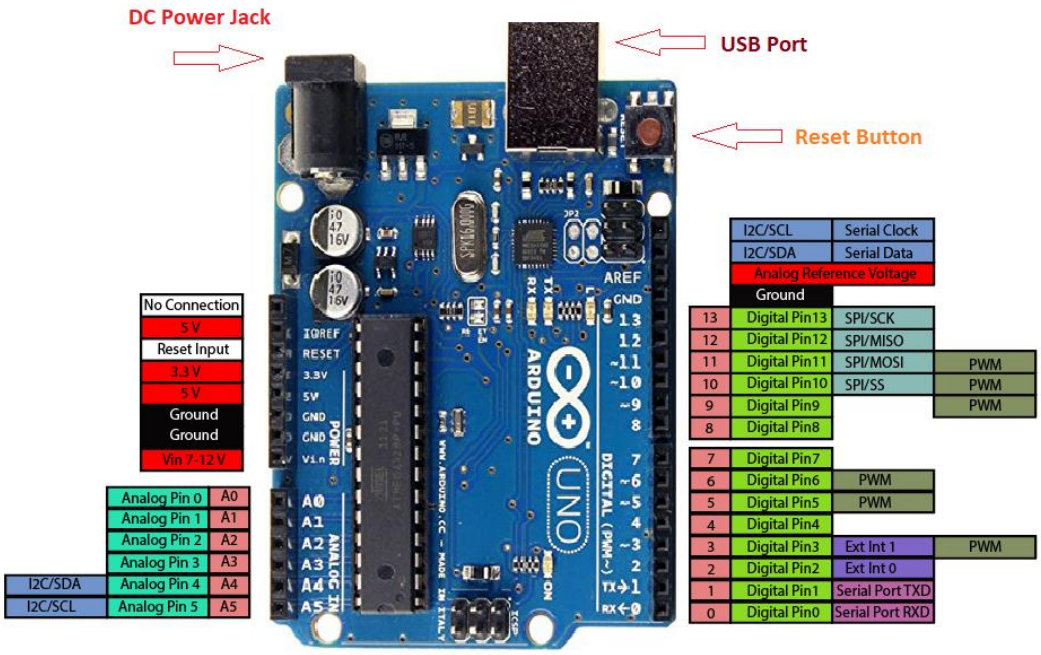
There are ready made available libraries, like R24 Library, for interfacing this module with Arduino. With help of these libraries **N**RF24L01 can be easily interfaced with Arduino with few lines of code.If using some other microcontroller,the datasheet has to be read in order to understand how to establish SPI communication.

The NRF24L01 module is a bit tricky to use especially since there are many cloned versions in the market. In case of troubleshoot, 10µF and 0.1µF capacitors should be added in parallel to source Vcc and Ground pins. Also, the 3.3V supply should be clean and does not have any noise coupled in it.

b.) Microcomputer Atmega 328P

The Arduino Uno is an open-sourcemicrocontroller board based on the MicrochipATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. The word "uno" means "one" in Italian and was chosen to mark the initial release of Arduino Software. The Uno board is the first in a series of USB-based Arduino boards; it and version 1.0 of the Arduino IDE were the reference versions of Arduino, which have now evolved to newer releases. The ATmega328P on the board comes preprogrammed with a bootloader that allows uploading new code to it without the use of an external hardware programmer[6].In the Fig. 6a is shown electronic board on Arduino Uno with build Atmega 328P microcontroller, and in Fig. 6b is shown itspinoout.

a.)



b.)

Fig.6.a.) Arduino Uno and b.) pinout

c.) DHT11 temperature and humidity sensor

The DHT11 is a commonly used temperature and humidity sensors. The sensor comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data.The connection diagram for this sensor is shown in the Fig. 7.

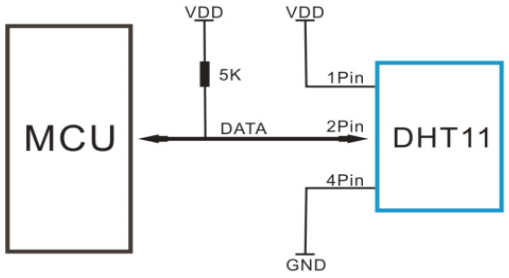


Fig. 7. Connection diagram for DHT11 sensor.

The sensor is also factory calibrated and hence easy to interface with other microcontrollers.The sensor can measure temperature in range from 0°C to 50°C and humidity from 20% to 90% with an accuracy of ±1°C and ±1%. The DHT11sensor is factory calibrated and outputs serial data and hence it is highly easy to set it up. From Fig.7 can be seen that the data pin is connected to an I/O pin of the MCU and a 5K pull-up resistor is used. This data pin outputs the value of both temperature and humidity as serial data. For interface of DHT11 with Arduino there are ready-made libraries for quick start. If it is needed to interface it with some other MCU then the datasheet given below will come in handy. The output given by the data pin is sent in the order of 8 bit humidity integer data + 8bit the Humidity decimal data +8 bit temperature integer data + 8 bit fractional temperature data +8 bit parity bit. To request the DHT11 module to send these data the I/O pin has to be momentarily made low and then held high as shown in the timing diagram in Fig.8.

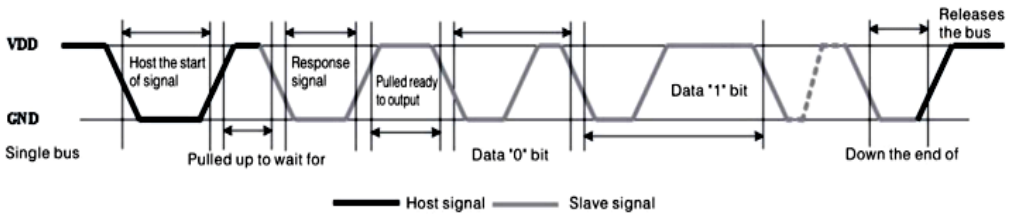


Fig. 8.Timing diagram for DHT11 sensor

The duration of each host signal is explained in the DHT11 datasheet, with neat steps and illustrative timing diagrams.This sensor can be used for temperature and humidity measurement, local weather station, automatic climate control, environment monitoring. In Fig.9 is shown DHT11 sensor in real size with its pinout.

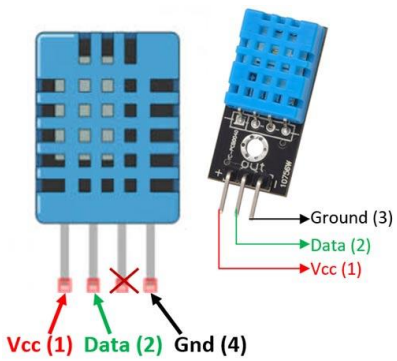


Fig. 9. DHT11 sensor in real size with his pinout.

DHT11 Specifications:

- Operating Voltage: 3.5V to 5.5V
- Operating current: 0.3mA (measuring) 60uA (standby)
- Output: Serial data
- Temperature Range: 0°C to 50°C

- Humidity Range: 20% to 90%
- Resolution: Temperature and Humidity both are 16-bit
- Accuracy: ±1°C and ±1%

The DHT11 sensor can either be purchased as a sensor or as a module. Either way, the performance of the sensor is same. The sensor comes as a 4-pin package out of which only three pins are used whereas the module comes with three pins as shown above.The only difference between the sensor and module is that the module will have a filtering capacitor and pull-up resistor inbuilt, and for the sensor, are externally used if required.

d.) *LCD display*

LCD 16x2 display is used for visualization on date values on the voltage and the current. LCD is connection with expander circuit by parallel date port. In Figure 10 is shown LCD 16x2 display.

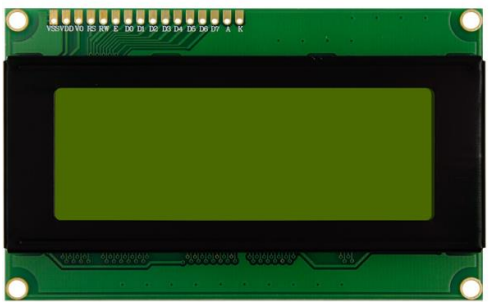


Fig. 10. LCD 20x4 display.

3. Experimental results

a.) *RFTransmitter side*

In Fig. 11 is shown the connection of the components of RF transmitter side. The transmitter side consists of an Arduino UNO, NRF24L01 module and DHT11 sensor. Interfacing of the Arduino UNO with NRF24L01 and DHT11 is shown below. Arduino continuously gets data from the DHT11 sensor and sends it to the NRF24L01 Transmitter. Then the RF transmitter transmits the data into the environment.

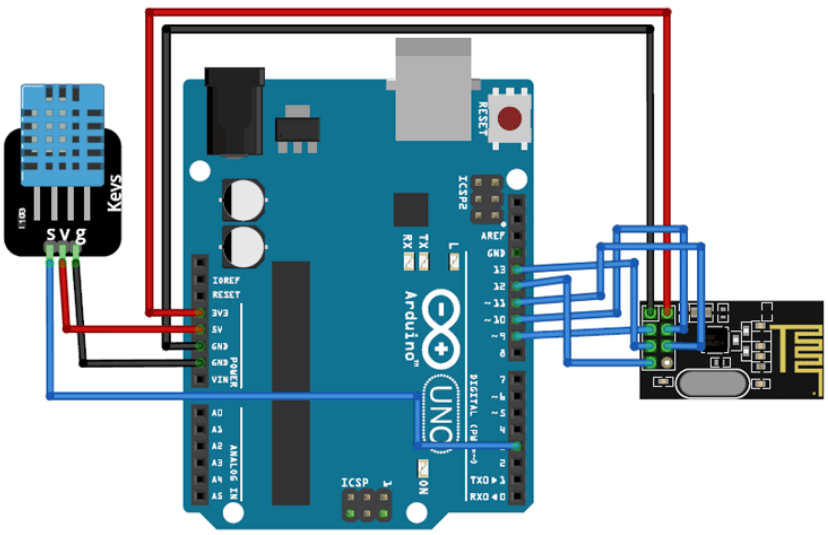


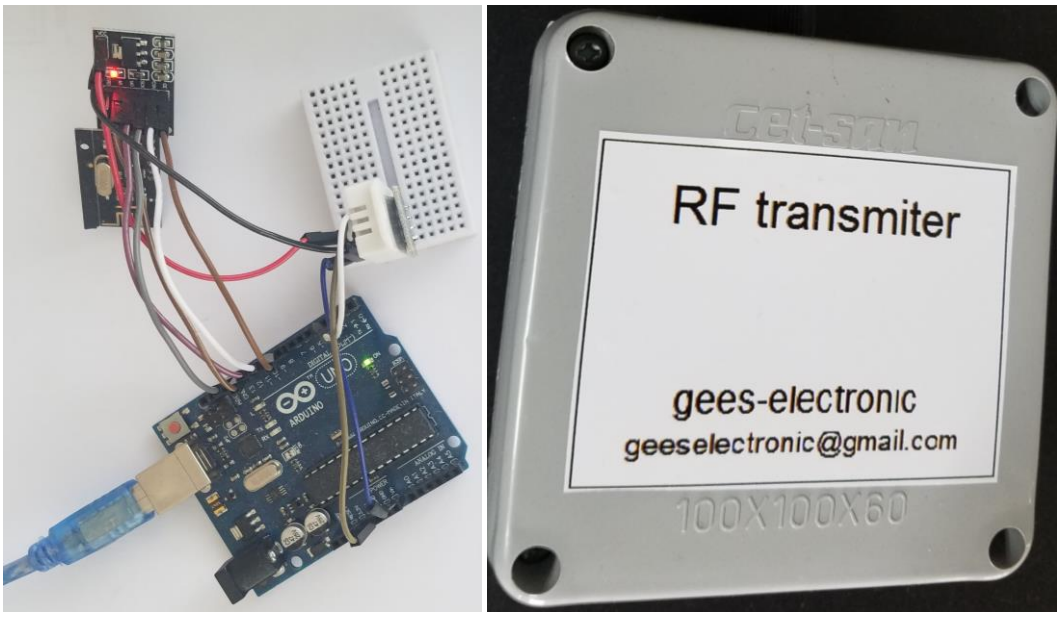
Fig.11. The connection of the components of RF transmitter side

In the Table 2 are given pinouts connection on NRF24L01 module, DHT11 and Arduino uno on transmitter side.

Table 2: Pinouts connection on NRF24L01 module, DHT 11 and Arduino uno on transmitter side

NRF24L01	**Arduino Uno**
VCC	3.3V
GND	GND
CE	Pin 9
CSN	Pin10
SCK	Pin 13
MOSI	11
MISO	12
DHT11	**Arduino Uno**
VCC	5V
GND	GND
DATA	3

In Fig. 12a is shown the practically realized prototype of the RF transmitter, andFig. 12b shows the finished RF transmitter device.



a.) b.)

Fig. 12. RF transmitter device: a.) practically realized prototype of the RF transmitter and b.) finished RF transmitter device.

b.) RF receiver side

In Fig. 13 is shown the connection of the components onreceiver side. The receiver side consists of an Arduino UNO, NRF24L01 module, and 16x2 LCD display. At the receiver side,nRF module receives the data from the transmitter and sends it to Arduino. Interfacing of the Arduino with NRF24L01 and LCD display is shown below.

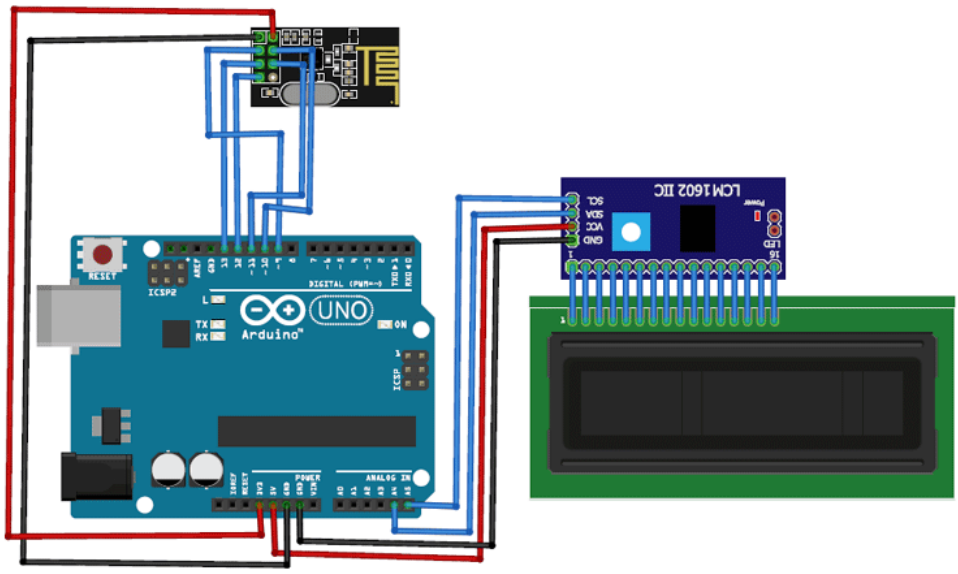


Fig. 13. The connection of the components of RF receiver side.

Table 3: Pinouts connection on NRF24L01 module, LCD display and Arduino uno on receiverr side

NRF24L01	**Arduino Uno**
VCC	3.3V
GND	GND
CE	Pin 9
CSN	Pin10
SCK	Pin 13
MOSI	11
MISO	12
LCD With I2C Module	**Arduino Uno**
VCC	5V
GND	GND
SCL	A5
SDA	A4

In Fig. 14a is shown the practically realized prototype of the RF receiver, and inFig. 14b is shown the finished RF receiver device.

a.) b.)

Fig. 14. RF receiver device: a.) practically realized prototype of the RF receiver and b.) finished RF receiver device.

In Fig. 15 is shown data for the temperature and the humidity measured by the DHT11 sensor, sent by the RF transmitter and received from the RF receiver in a data log file compatible with Microsoft Excel.

	A	B	C	D	E
1	Date	Time	Temperature©	Humidity(%)	
2	6/11/2021	11:41:32	26.5	56.9	
3	6/11/2021	11:42:27	26.5	56.8	
4	6/11/2021	11:42:47	26.7	56.6	
5	6/11/2021	11:42:52	26.7	56.6	
6	6/11/2021	11:42:58	26.7	56.6	
7	6/11/2021	11:43:03	26.7	57.1	
8	6/11/2021	11:43:08	26.7	57.5	
9	6/11/2021	11:43:13	26.7	57.1	
10	6/11/2021	11:43:18	26.8	56.5	
11	6/11/2021	11:43:23	26.8	56.3	
12	6/11/2021	11:43:28	26.8	56.1	
13	6/11/2021	11:43:33	26.8	56.2	
14	6/11/2021	11:43:38	26.8	56	
15	6/11/2021	11:43:43	26.8	56.1	
16	6/11/2021	11:43:48	26.8	56.2	
17	6/11/2021	11:43:53	26.8	56.2	
18	6/11/2021	11:43:58	26.8	56	
19	6/11/2021	11:44:03	26.8	55.9	
20	6/11/2021	11:44:08	26.9	55.8	
21	6/11/2021	11:44:13	26.8	55.7	
22	6/11/2021	11:44:18	26.8	55.7	

Simple Data | Simple Data with Plots | Interactive Bar Graph

Fig.15. Temperature and the humidity data measured by the DHT11 sensor, sent by the RF transmitter, received from the RF receiver in a data log file

Conclusions

In this paper with theoretical analysis is designed and practically realized process RF sensor smart network. Sensor networkmeasurement and collection data for temperature and humidity in measurement point at one remote processing plants and transmission to the main central control panel. The data is displayed on the LCD display and stored in an excel log file. The solution also provides the ability for upgrade to remote transfer on the data over the internet.

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