

# **Low-Cost Wireless High Water Detection System**

S.Archana, R.Deepalakshmi, S.Ambrin Banu, Mrs. D.Vasanthi,

UG Student, Dept. of ECE, Rajas Engineering College, Vadakkangulam, India

UG Student, Dept. of ECE, Rajas Engineering College, Vadakkangulam, India

UG Student, Dept. of ECE, Rajas Engineering College, Vadakkangulam, India

Associate Professor, Dept. of ECE, Rajas Engineering College, Vadakkangulam, India

**ABSTRACT:** This design project aims to create an inexpensive flood detection system to monitor rising water in remote locations or residential areas. The high water detection system divides into two parts: water sensing unit and data display unit. Both subsystems are based on the ATmega 328P microcontroller and they are communicating wirelessly via radio frequency (RF) transceivers. Additionally, several custom-built modules, including water sensors, charging regulator, and status board, are designed to support moisture detection, power management, and information display.

## **I. INTRODUCTION**

Due to rapid climate change in recent decades, an increase in the severity of flood-related damages is observed. This causes serious destruction to residential properties and it also threatens public safety, particularly residents in the coastal regions or in the areas with heavy rainfalls. The Federal Insurance and Mitigation Administration (FEMA)'s National Flood Insurance Program (NFIP) estimates that total losses due to six-inch flood are approximately \$20,000 per 1,000 square foot home. Although several commercial flood warning systems are currently available, many of them are either expensive or unable to identify multiple water levels. In fact, some water detection devices are triggered by a single event and their alerts are broadcasted via a buzzer. However it is often too late for people to protect their belongings and evacuate to safe ground if their flood warning appliance is solely activated by a certain water level without pre-flood warning.

The goal of this design project is to create a low-cost wireless high water detection system that senses rising water in real time and determines any potential flash floods. The current design includes a solar-powered water recognition system wirelessly transmitting sensor data to a receiver system via radio frequency (RF) transceivers.

## **II. DESIGN ALTERNATIVES**

There are numerous ways to detect water levels and notify flood risk. Callaway, Frechette, and Trapp's winning flood warning station used two sensors to detect specific water levels and triggered a strobe siren when flash flood was identified. National Weather Service (NWS)'s flood warning systems manual offered a range of high water notification solutions which can be implemented at various locations, including reservoirs, streams, and local communities. A wide selection of commercial water detection products were also obtainable online. Despite countless design possibilities, flood systems typically consist two components – identification and communication. This design project aims to provide an inexpensive method to advising possible floods for residents in the remote areas where cellphone signal coverage is usually absent.

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### **III. SYSTEM DESIGN**

The water detection system contains a transmitter subsystem and a receiver subsystem. The transmitter subsystem is consisted of the following modules:

- Low-power microcontroller board
- RF transmission element – 2.4 GHz transceiver relays raw data to the receiver subsystem
- Power management board – Customized MCP73877based board to regulate power supply and charging process
- Water sensors – Basic water sensing components to detect rising water at multiple levels

The self-powered transmitter subsystem can be installed at most outdoor locations.

On the other hand, the receiver subsystem requires external power source. It is comprised of the following modules:

- Stable microcontroller board
- RF transmission element – 2.4 GHz transceiver captures raw data and sends to microcontroller for processing
- Information display board – LED-based notification board provides latest water level update to users
- Siren component – Plain buzzer offers acoustic warning to signal any flood risks

### **IV. HIGH-LEVEL DESIGN**

A portable transmitter system with solar charging feature wirelessly sends water level data to a stationary receiver system. As water rises, the mounted sensors detect appropriate water level, then the transmitter system complies and relays raw data via a RF module, and finally the receiver system interprets incoming data signal and displays real-time information on a dashboard.

In this project, the transmitter system is powered by a solar panel coupled with a high-capacity Lithium polymer (LiPo) battery to reduce touch maintenance. A compact RF package is also employed to enhance wireless transmission distance.

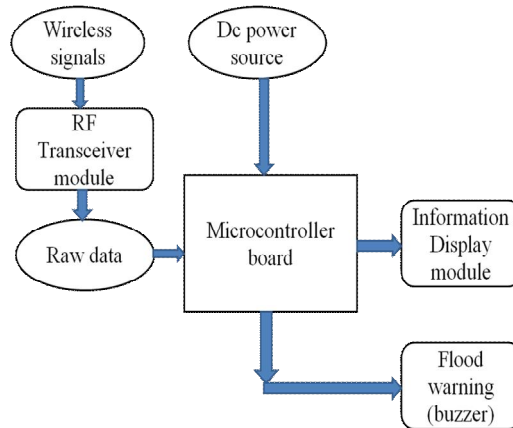
To reduce maintenance requirement, the transmitter system utilizes a low-power microcontroller board, simple water detection circuits, sturdy RF transceiver package, and a power management module to regulate distribution of harnessed solar power. Simplicity and power saving are two key focuses in designing the transmitter system. Therefore, microcontroller is operating at the minimum clock speed and is directly transmitting raw data, gathered from water sensor module, to the receiver system.

Reliable data interpretation and real-time event notification are crucial to the receiver system design. In this part, the receiver microcontroller board processes all incoming data and illuminates corresponding light emitting diodes (LEDs) on the information display board to report current water level and transmitter status. The flood warning module is activated when the system detects persistent high water level. Also, the receiver system automatically resets the display module as soon as water level recedes below the sensor line.

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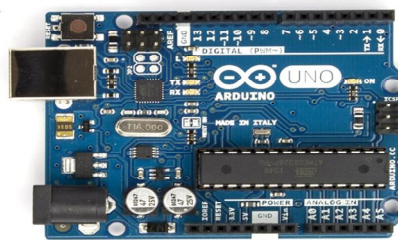
## V. HARDWARE DESIGN

### Low-Power Microcontroller Boards

Microcontroller is the brain of this design project. Microcontroller, a miniature computing chip, enables electronic systems to perform complex logical calculations. Among various microcontroller integrated circuits (ICs), Arduino microcontroller is chosen to be the main processor of both transmitter and receiver components.

Equipped with the ATmega 328P, Arduino microcontroller boards are known for their versatility, wide range of applications, and well-documented software libraries. Many believe there is an Arduino board for any circuit project. All Arduino microcontroller boards are operating at either 5 volts or 3.3 volts

Given its stability and durability, the receiver system uses Arduino Uno as the main computing resource for interpreting constant data inputs and communicating real-time information.



RECEIVER SIDE-ARDUINO UNO (5V)

Unlike the receiver system which has a steady power source, the transmitter system acquires its power source from the solar panel with a backup LiPo battery. Thus, it is important to pick an Arduino model with small footprint and minimum power consumption.

Clearly, Arduino Pro Mini (3.3V) is the best microcontroller candidate for the transmitter system.

### Power Management Module

Keeping constant power supply to the transmitter system is extremely critical. The power management module transfers solar power into electricity and ensures continuous system operation by using an efficient solar panel, a LiPo battery, and a Lithium-ion/LiPo charge management controller.

Since it would be difficult to frequently update the transmitter system's power supply, capacity rating must be considered when selecting a rechargeable battery for the transmitter system. Battery life improves when

using a battery with higher capacity rating.

Also, Lithium Polymer batteries offers enhanced protection against overcharge and lightweight package comparing to traditional Lithium-ion batteries. Therefore, a high capacity LiPo battery (3.7V 2500mAh), is selected to supply electricity when solar power is absent.

A power regulation circuit needs to manage the charging/discharging process once main power source (solar panel) and backup power supply (LiPo battery) are determined. Due to its ease of use and bountiful application examples, the MCP73833 IC package is adopted as the power management controller.

### **Water Sensor Module**

Water sensor module is invented based on the simple fact of water's electrical conductivity. Most types of water contain aquatic ions that expedite electron transfer. In here, water probe is open circuit when water level is below the sensor, but it becomes a closed circuit and signals the transmitter system once water level reaches the probe.

Nevertheless, heavy rainfall tends to dilute ion concentration in fresh water. This reduces or even eliminates electrical conductivity in water (i.e., distilled water does not conduct electricity). To combat ion loss in water during heavy rains, a modified water level sensor includes a small container with salts (e.g., table salt) to increase electrical conductivity.

### **RF Transceiver Module**

As a best seller in the largest online store, nRF24L01+ transceiver module is known for its ease of use, small power usage, and extremely low cost. This Figure shows actual package of the nRF24L01+ 2.4GHz wireless transceiver.



nRF24L01+2.4GHZ WIRELESS TRANSCEIVER

### **Information Display Module**

A monitor display module is created to deliver real-time information of water level and transmitter power status. The following information is available on the status dashboard:

- Transmitter power status-green LED
- Water level 1-yellow LED
- Water level 2-amber LED
- Water level 3-red LED
- Pre-flood warning-white LED

### **High Water Siren Module**

Besides visual status indicator, a high pitch siren is needed to add acoustic warning when the receiver system detects flood risk.

### **Software Design**

Both Arduino microcontroller boards were programmed using the Arduino integrated development environment (IDE).

Based on the C language, the Arduino IDE includes a variety of software libraries such as Ethernet and Wi-Fi. Additional software libraries can be easily imported as well.

In this project, the software design strategy for the transmitter system is minimizing power consumption by

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Lowering the clock speed [8],

Storing individual data into an array for easy transmission, and

□□□□□□□□□□ □ Forwarding raw data to the receiver system without excessive processing .

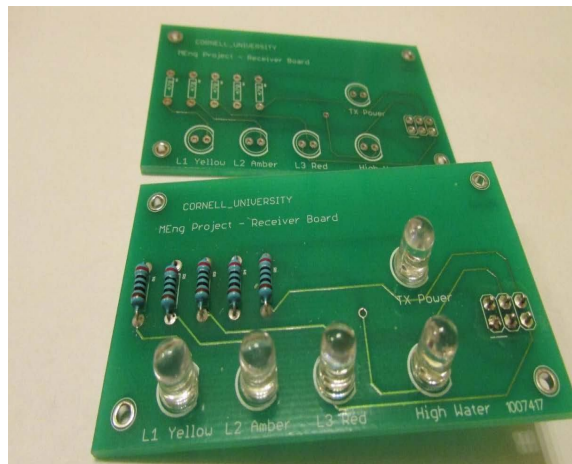
However the receiver system’s software design strategy uses the opposite approach. It implements several logical loops to ensure proper event notifications. The following subsections describes programming for the transmitter system and the receiver system.

**Implementation**

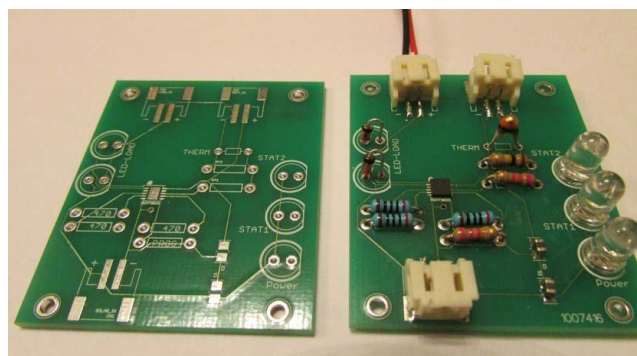
Once the system design and materials selection are complete, the wireless high water detection system can be easily assembled. The following subsections introduce components acquisition and system integration.

**PCB Fabrication**

Two circuit designs, power management module and information display module, must translate into printed circuit board (PCB) layouts prior system implementation. In here, two 1N4148 switching diodes are exerted in place of 5mm load LEDs to reduce forward voltage drop.



**INFORMATION DISPLAY BOARD**



**POWER MANAGEMENT BOARD**

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**Testing and Results**

Transmitter		Receiver	Results
1	Transmitter power off	- Green LED OFF	= Success!
2	Transmitter power on	- Green LED = ON	Success!
3	L1 sensor triggered	Yellow LED ON	= Success!
4	L1,L2 sensors triggered	Amber LED ON	= Success!
5	L1, L2, L3 sensors triggered	RED LED = ON	Success!
6	All sensors triggered for 30+ seconds	White LED, buzzer = ON	Success!
7	All sensors turn off	- All LEDs except Green LED = OFF	Success!

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### Advantages

- Total cost of materials is less than \$70
- Transmitter system needs to be self-powered with low power consumption
- Water sensors need to detect multiple water levels
- Sensor data can be transmitted and displayed via wireless medium A display module is required to show water levels and transmitter status in real time
- A high water warning indicator to inform user any flood risk

### IV. CONCLUSION

The wireless high water detection system is built to identify rising water levels and to warn any potential flood risk. Using solar panel and power management module, the transmitter system is able to serve for a long period of time with minimum maintenance. The receiver system's straightforward dashboard design gives user a fast update of current water level. This flood detection model is suitable for all outdoor and indoor applications, especially for locations without cellphone signal coverage.

### V. FUTURE IMPROVEMENT

The system can be further enhanced by reducing PCB size, lowering overall cost, and measuring water level at multiple sites.

□ Reducing PCB size – The power management board size can easily shrink up to 30% by replacing through-hole components with surface mount device (SMD) elements.

Lowering overall cost – There are several ways to lower costs. For example, Arduino boards can be substituted with equivalent microcontrollers. Another method is to exploit generic electronic parts instead of using branded components.

Measuring water level at multiple sites – It is possible to monitor water levels at more than one location. To achieve this, a sensor network design and extensive transceiver testing are needed. ZigBee module is a good candidate for this application.

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