Retrofitting a traditional rain detector circuit to reduce water wastage by interfacing it with a cloud computing platform

An experimental project in the Internet of Things domain

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Abstract: This paper focuses on the enhancement of a conventional rain sensor by interfacing it with the cloud. A conventional rain alarm employs a circuit which is shorted by the presence of water to trigger an audio alarm. This sensor highly requires the presence of someone nearby with the audible range of the buzzer and thus, has limited range of operation. The 'IoT based water wastage alarm' is a purposeful experiment aimed to incorporate the concept of mechatronics into a traditional mechanical sensor, to increase the convenience provided along-with added benefits like cloud-based access resulting in long-distance communication with results directly provided on any smart device regardless of the distance between. 'Industry 4.0' highly relies on cloud computing and automation to achieve exceptional accuracy and efficiency. Employing this technology to a conventional sensor enhances the convenience and operability of it thus, making it very appealing to the consumer. This initiative also spreads awareness about the alarming scarcity of water and assists in saving resources when not in use.

Index Terms **- Internet of Things, Mechatronics, Cloud, Industry 4.0.**

I. INTRODUCTION

The 'IoT based water wastage alarm' is a purposeful implementation of the concept of mechatronics into a real-world application. Water or liquid ingestion is one of the fundamental aspects of human life. Water is a crucial element and is needed to be consumed multiple times daily. There have been many instances of water damage to electrical appliances due to careless approach when closing the taps, or shutting the flow of liquid when done using it. This not only hazards the chance of water damage to appliances, but also major or grave injury by slipping, corrosion damage to electrical appliances and even the construction of nearby infrastructure. Unattended water collection aids the growth of algae which can further corrode the environment and leave unpleasant surroundings. Water wastage is also a very concerning aspect to take note of, Household leaks can waste approximately nearly 900 billion gallons of water annually nationwide in the USA [1]. That's equal to the annual domestic water consumption of approximately 11 million households. This device is developed to bring to our attention all the above mentioned and ignored circumstances and avoid wastage of water before it is too late.

Rollyn T. Labuguen [2] et al. researched and developed a method for a rain alarm system that is able to detect and visualize rain patterns. Their work focused on the variation in the radio signal levels from multiple sources and computed to calibrate the amount of rainfall at a particular location. This method provided precise results with confidentiality of the location of the source. J.L.F. Zamora et al. [3] created a rain or liquid-triggered disaster alert system operating on on wireless and acoustic measurements of variations in actual rain events occurring. This acoustic sensor grid was operated by a 5 Ghz hybrid wireless network connected to a central data logger and results were calculated. Several researches [4][5][6][7] have employed the use of Arduino microcontrollers as well as GSM boards [8][9] to interface conventional rain detector sensors to an alarm trigger mechanism thus alerting the occurrence of rain. Arpita Ghosh et al. [10] studied the possibility of integrating the conventional rain alarm with a solar intensity monitoring unit. The device displayed results on an LCD screen in terms of percentage, thus indicating possibility of rainfall.

Water shortage is defined as the lack of availability of sufficient water resources to meet the water consumptions demands of a region. It affects every continent and approximately 2.8 billion people, at least one month out of every year. It is found out that on an average, 1 in 3 people, globally, do not have feasible access to clean drinking water. [11] This device is developed to contribute to water savings in a common household, office, or any place with access to ample water supply.

II. MATERIALS AND METHOD

The bill of materials used to construct the device is shown below in table 2.1.

Table 2.1. Bill of Materials

Item No.	Bill of Materials	
	Component	Quantity
1	4093 Quad NAND Gates	1
2	NPN Transistor pack	1
3	Rectifier Diode	1
4	5mm LED pack	1
5	CFR resistor Kit (100k,4.7k,1k)	1
6	NO switch	1
7	12V DC Relay	1
8	Buzzer	1
9	Battery 9V	1
10	NODEMCU ESP 12-E	1
11	Wires and peripherals	-

2.1 NPN Transistors –

A transistor is a semiconductor electronic component that is usually utilized to amplify or convert electronic signals and electrical power. [12] Two transistors are used in the circuit to create a common collector amplifier (emitter follower mode) In this circuit the base terminal of the transistor serves as the input, the emitter is the output, and the collector is common to both. [13]. The specifications of the NPN transistor used are given in table 2.2. A typical transistor setup in the emitter follower (common collector mode) is shown in figure 1.

Table 2.2. Specifications of NPN transistor [14]

Sr. No.	Parameter	Value
1	Collector-Base Voltage	50V
2	Collector-Emitter Voltage	45V
3	Emitter-Base Voltage	6V

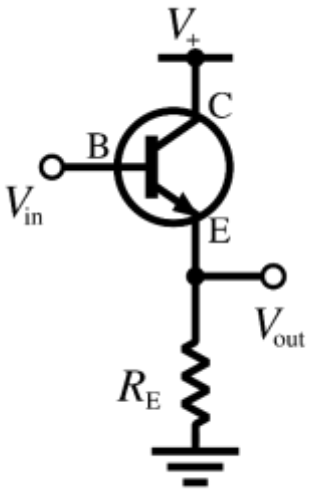

Fig. 1 Transistor in emitter follower mode [15]

2.2 **CFR Resistors –**

A resistor is an electronic device using two-terminals that implements an electrical resistance across a circuit. It is constructed by making use of a thin carbon film which acts as an electrical insulator, over a ceramic substrate which is a thermal insulator. [16]

Table 2.3. Specifications of CFR Resistors

Sr. No.	Parameter	Value
1	Resistance	100K, 4K7, 1K
2	Power	0.25W

2.3 **LED –**

5mm, 3V bright red LED is used as a visual alarm indicator.

2.4 **Rectifier Diode –**

A rectifier diode is a two leaded semiconductor device that allows an electric current to pass unidirectionally. These are a crucial component in any power supply equipment where they are used to convert AC to DC voltage. A IN4007 diode is used in this circuit to achieve the same.

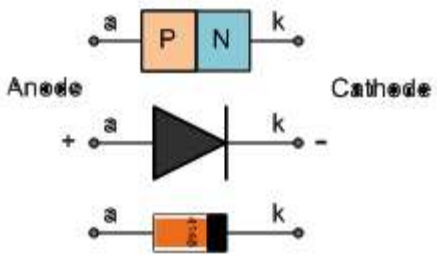

Fig. 2. Diode [16]

2.5 **Push Button –**

A push button is used to hard reset the circuit. It is normally open type, and thus does not participate in the circuit until operated.

2.6 **CD4093 NAND Gates –**

CD4093B consists of four Schmitt-trigger circuits. Each individual circuit functions as a bi input NAND gate with Schmitt-trigger action on both the inputs. The aforementioned gate switches positions at varied points for positive and negative input signals. A Schmitt trigger is a comparator circuit that makes use of positive feedback mechanism to implement hysteresis in the circuit and is used to remove noise from an analog signal while converting it to a digital signal. Pin A-B, C-D, E-F, G-H are input pins to NAND gates 1 2 3 4 respectively. Pin J, K, L, M are output pins to NAND gates 12 3 4 respectively. Pin VSS is ground (0 V) pin. Pin VDD is supply voltage input pin. A schematic diagram of CD4093 is shown in figure 3.

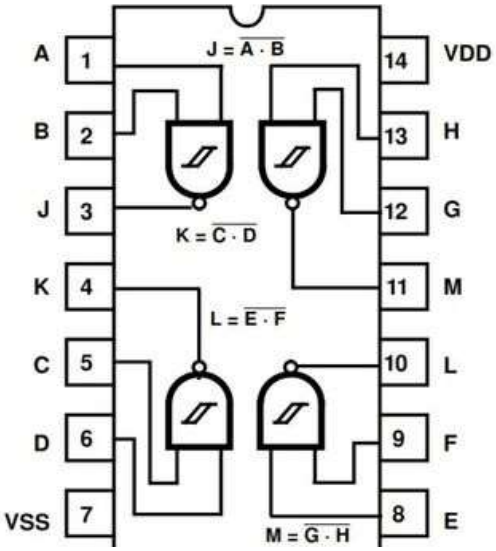

Fig. 3. CD4093 Pins [17]

An image of the CD4093, quad-NAND gates is attached in the figure 4.

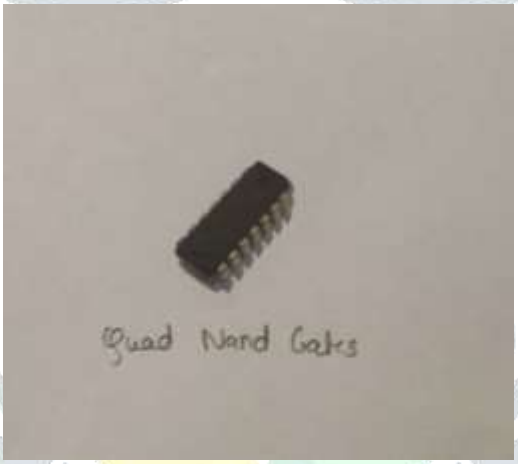

Fig. 4. CD 4093 Quad NAND gates

Table 3. Specifications of CD4093 [18]

Sr. No.	Parameter	Value
1	DC Supply Voltage	-0.5V to +20V
2	Input Voltage	−0.5 to VDD +0.5 VDC
3	Power Dissipation	700 mW

2.7 **ESP 12E (8266) –**

ESP-12E is a mini wireless fidelity interface module utilized for establishing a wireless network connection with a microcontroller. It is a high integration wireless SoC (System on Chip). A Node MCU ESP 12 E is used in the device to make use of its WI-FI capabilities to provide a connection with the host device. The host device injects a program which uses cloud interfacing to trigger a phone notification. [19]

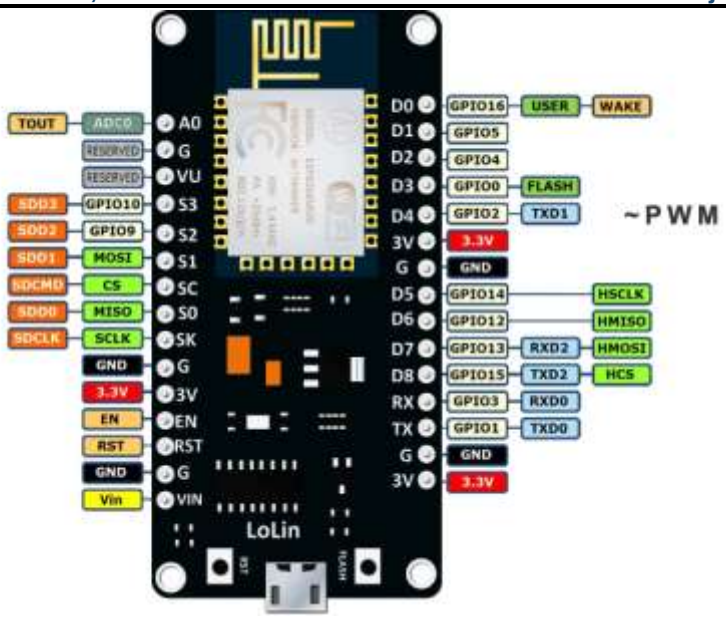

Fig. 5. ESP 12 E (8266) [19]

An image of the ESP 12 E WIFI module is attached in figure 6 below.

Fig. 6. ESP 12 E

Table 4. Specifications of ESP 12E [20]

Sr. No.	Parameter	Value
1	Processor	ESP8266
2	ADC	Integrated 10bit
2	Built in flash	32Mbit
3	Antenna	Onboard
4	Frequency range	2.4GHz~2.5GHz
5	Power supply	5V
6	Operating voltage	3V to 3.6V
7	Operating temperature range	-40 ° C to 125 ° C

2.8 Buzzer –

A small 5V buzzer is used as an audio alert for the device. The resonance frequency of the buzzer is 2048 Hz and the resistance is found out to be 42 Ohms.

Table 6. Specifications of Buzzer

Sr. No.	Parameter	Value
1	Max Supply Voltage	5V
2	Resistance	42Ω
3	Resonance Frequency	2048Hz

III. CIRCUIT DIAGRAM

Figure 7. below shows the circuit diagram of the IoT based water wastage alarm.

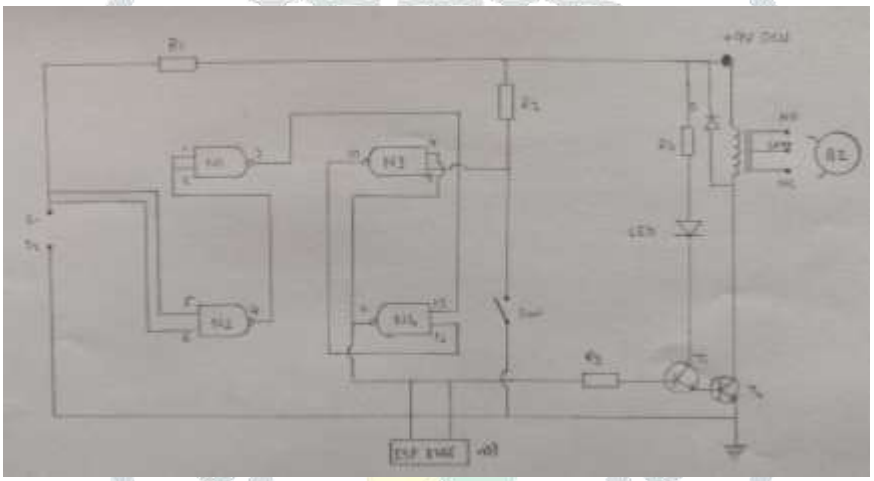

Fig. 7. Circuit Diagram

3.1 Nomenclature of the circuit diagram (fig 7.) –

a. N – NAND Gate
b. R – Resistors
c. S – Sensing element
d. SW – Switch
e. T – Transistors
f. D – Rectifier Diode
g. +9V DCV – Battery
h. Rz – Relay
i. LED – LED
j. ESP 8266 – ESP 12-E (8266)

IV. WORKING

A sensing element is used to detect the presence of water or any liquid, in this application though, 2 wires are used as the sensors so as to increase the sensing range in case the device is mounted on the wall of a bathroom or living space.

This concept works on the phenomenon of short circuit, a pretty common one, in rainy seasons or unshielded appliances near water source. When there is liquid detected, the circuit is closed due to the presence of water and the resistance between the two sensing elements is significantly reduced. This reduction in resistance will reduce the voltage at pin 5 and 6 of NAND 2. Due to the Schmitt trigger, when the voltage drops, the output pin 4 will have a 'NO' or negative output. This happens as the logic of a

NAND gate is, it gives false response only when both input values are true. This Positive output is inverted by NAND 1, the output pin 3 of NAND 1 is connected to input of NAND 4. N4 and N3 are connected in a dependent form as the output of N4 is connected to input of N3. The output of N4 is connected to the relay circuit ahead formed by 2 transistors arranged in the emitter follower mode. This means the input is provided at the base, the output is at the emitter and the collector is common to circuit ahead.

This turns on the relay circuit and the ESP-12E. The ESP- 12E is a Wi-Fi module with an ESP 8266 at its core, it has an inbuilt 10-bit ADC (Analog to Digital Converter) which helps it reads the analog signal received from the traditional circuit and convert it into a digital one for Arduino to understand. The code is written in Arduino IDE with Blynk and NODEMCU libraries included, this allows for smooth compatible interfacing with the phone application. This whole setup is connected to the phone via WIFI and sends a notification to the phone, this notification can be edited by altering the code inside Arduino IDE. After the overfilling is avoided, the contact sensors are to be wiped and the reset switch pressed, this switch hard resets the circuit and the output goes back to the normal output.

V. EXPERIMENTATION AND TESTING

5.1 Sensitivity –

The minimum amount of time the device took to detect the presence of a significant amount of water spill is calculated and plotted on a graph (fig 8.) with an average of 10 tests.

As it is evident from the graph of sensitivity, the sensitivity started decreasing with the increase in number of tests in a single session or a short period of time.

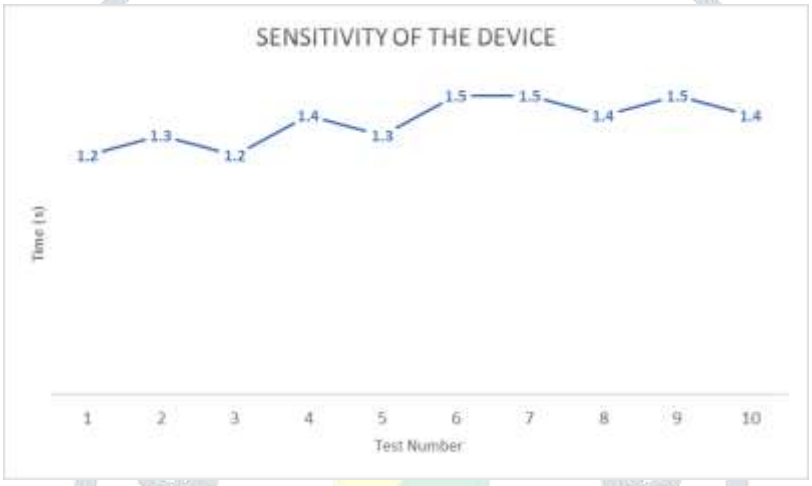

Fig. 8. Sensitivity of the device

5.2 Mounting –

A major advantage of the device is it is constructed to be extremely versatile. Although, primarily made to be mounted on walls near areas of possible liquid spillage, it can be used as a long-distance rain alert as well. The PCB, includes a track of traditional copper wires, (shown in fig 9.) which act as a sensing element altogether. The other pair of wires, also visible in fig 9, act as an extended version of the same copper track, these wires facilitate the sensing of liquid spill without allowing the entire device to come in contact with the liquid itself. This prevents any water damage to the device thus, extending the operational life. Hence, the device can be used to sense spills or rains, in general by using either or both the sensing elements thus allowing multiple mounting options and freedom of location and placement of the device in the best possible location available.

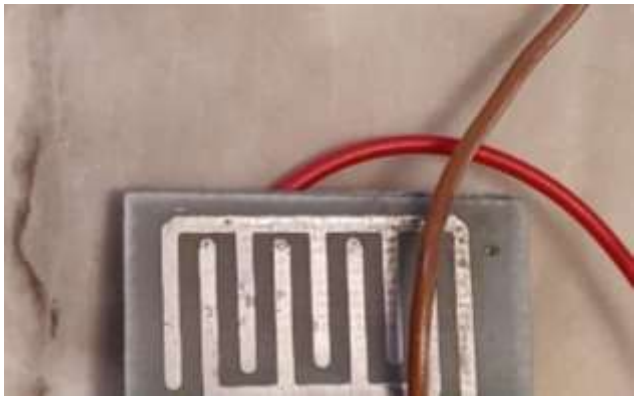

Fig. 9. Copper track as a sensing element

***5.3* Water Protection –**

As discussed earlier in mounting, the mounting of the device significantly above the water level and extending the sensing element down to the liquid level gives the device considerable protection against the possibility of water damage.

Other options include a liquid sealed case, which could also make the device usable in case of submerging, with only the sensing element exposed to the liquid.

VI. RESULTS AND DISCUSSIONS

The above-mentioned Blynk app allows the ESP 8266 to communicate with the smartphone. The output would update every 1 second and provide us a relatively quick response. But not too quick, in case of just a few drops of spillage. The picture (fig 10.) attached below is a screenshot from an android smartphone. The Blynk application is running on the phone. The notification at the bottom shows "Spill Connected" where spill is the device name. The Terminal is an output text box for the device. The notifications in the terminal show real time output given by the device and update every 1 second. Thus, via this interface, the device is able to communicate with the phone and thus the user. This application also allows for push notifications, that is it would give a normal notification just like a new message one, when a spill is detected.

Fig. 10. Output

VII. ADVANTAGES

1. Highly versatile.
2. Instantaneous response.
3. Small size.
4. Adjustable sensitivity.
5. Ease of mounting, fits anywhere.
6. Relatively cheap
7. Has a visual alarm incase the smartphone is switched off.
8. Globally accessible.
9. Changing application is very easy.

10. The sensing element has been extended so water does not come in contact with the device in case of the wall mount.
11. Easily replaceable components.
12. Moisture resistance with cover
13. Water resistance with cover
14. Modular design, can be upgraded/modified.

VIII. LIMITATIONS

1. Battery needs to be replaced after exhaustion.
2. Can be triggered by just a few drops as well when set at high sensitivity.
3. LED light as an alarm can be distracting.

IX. OTHER APPLICATIONS

As mentioned earlier, the device is highly versatile and can be used for multiple applications, the device has been tested as a conventional rain detector and a liquid wastage alarm at the time of writing this paper. Other possible applications of the device include –

1. Rain sensing wipers
2. Shield deployer system during storms.
3. Signal strength booster trigger during rain.
4. Water level indicator
5. Drainage block detector
6. Rain/snow alert
7. Water leak alert.
8. Bucket/tank fill alert

X. CONCLUSIONS

The "IoT based water wastage alarm" was built with the intention to avoid water wastage. It would also aid significantly by reducing accidents due to injury, damage due to short circuits or just water damage to electrical appliances or infrastructure. The primary implementations of this device would be bathrooms, water tanks, water storages, water canister filling stations, sewages, or even in leak detection usage. The significant highlight of this project is the ability to connect to the "IoT" and interface with the traditional circuit which would act as the sensing element. The connection via cloud allows the device to alert your smartphone wherever you are! There is no distance limitation to this device as it is in connection to the cloud and interfaced with the smartphone over the cloud. This is possible due to the Blynk application. Thus, this would prove to be a good alternative to the mainstream smart buckets or smart devices which alert the user by means of audio/visual indication. Those are expensive and usually come integrated into the product. This device is cheap and the efficiency is on-par with the mainstream 'smart' devices if not better. In the future, a case can be designed for the device when it is to be used in adverse conditions, where the entire device could come in contact with the liquid, or other unfavorable circumstances which could lead to physical damage to the device. The case would act as a protecting medium for the device.

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