Fabrication of an electrode sensor and its application to a low-cost rain gauge

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***Abstract* - Landslide is one of the severe natural disasters that cause great losses in lives and property. Therefore, efforts in research, warning, and prevention of landslides have been made at different scales. One of the conditions that triggered landslides is the sudden rise of the rainfall. This paper focuses on building a low-cost rain gauge, which consists of an electrode sensor and a microcontroller board. Alert threshold is determined based on statistical methods in several years to give a timely warning. The system has been successfully built and tested in real experiment.**

Keywords – sensor, rain gauge, low-cost.

I. INTRODUCTION

Landslide is one of the most disasters happening around the world. This disaster has catastrophic impact to the community as well as the economy [1]. Landslide occurs by the fallen movements of rock, soil, and organic materials under the gravity force. There are four groups that lead to this hazard: rainfall induced landslides, earthquake induced landslides, etc. Among of them, it is 90% of landslides is triggered by rainfall. In mountainous areas, the conditions for landslides to occur are met frequently, especially after heavy rains or geological activity, causing harm to the community as well as damaging or destroying much needed infrastructure and key transport routes. We intend to implement a real-time landslide monitoring in Vietnam, where the annual damage due to the landslide is very high [2-7]. In this paper, a low-cost rainfall measuring system is built. It consists of an electrode sensor and a microcontroller board. Alert threshold is determined based on statistical methods in several years to give a timely warning. The system has been successfully built and tested in real experiment.

II. WORKING PRINCIPLES

The block diagram system includes 5 components: power source, sensor probe, microcontroller, alert and battery. In this system, sensor probe measure lever of water in rain gauge and then transfer data to MCU; MCU will process the data and use a threshold detection algorithm to output alert signal. The diagram system is shown in Figure 1:

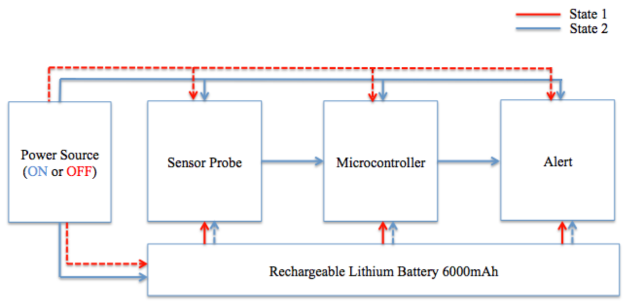

Figure 1. Block diagram of the device

Power Source block: supply power for system, which supplies power for sensor probe, microcontroller, alert and charge for the battery. In this system, module TP4056 and module LM2596 are used for power source. Module TP4056 is used for charging batteries, which will protect the battery. Module LM2596 is used for converting 6-24DC voltage to 5 DC voltage. There are two power states: State 1, when the power source off, the battery will supply power for system running. State 2, when the power source on, power source will supply power for system running and charge battery. Therefore, the system run continuously even power source off.

Electrode sensor: The sensor probe can measure n water levers in the bucket. In this system, n is 16, it is much more the system in [8], which just detect 4 lever of water. The signal from each point measurement is input of comparison amplifier. The output of comparison amplifier is 0 or 1 logic, which is the input of a microcontroller. The microcontroller will process signals and calculate the change of signal following time to show the precipitation. The alert is decided when precipitation over the safe threshold.

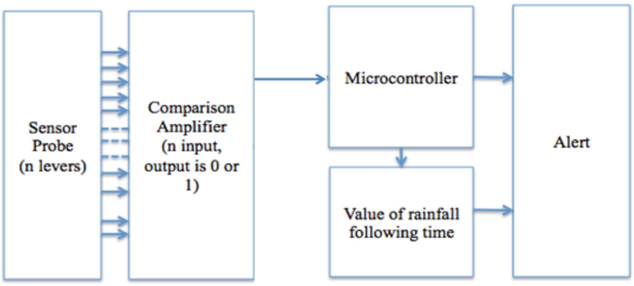

Figure 2. Electrode sensor interface with the MCU

The sensor probe is shown in Figure 3. The sensor probe is designed with 16 measurement points. Each point is a lever of water in the bucket. The distance between two points is 15mm, which is 15mm rainfall respectively.

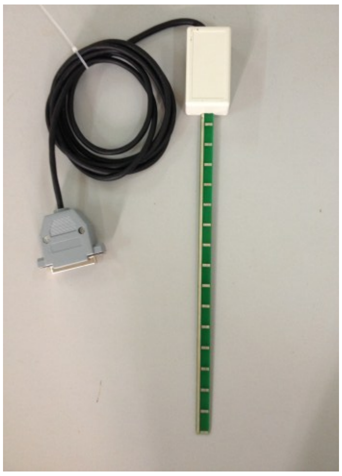

Figure 3. Photo of an electrode sensor

Comparison Amplifier: LM358 amplifier IC is used for comparison function. The comparison function is shown in Fig. 4.

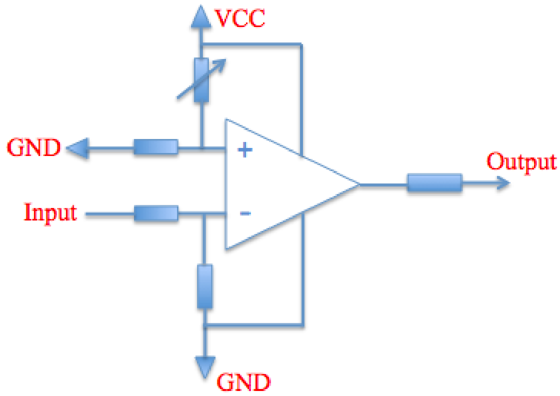

Figure 4. Working principle of the comparison amplifier

Microcontroller: AVR microcontroller is used for processing and calculating data from sensor probe. AVR is a low power microcontroller and high performance, which is useful for power saving when power source is off.

Alert: The high frequency speaker is used for alerting, which can make uncomfortable feeling. Speaker works in the range of 3.7 – 12V.

Figure 5. Speaker for alert

The complete system box is shown in Fig. 6, which includes Arduino board, comparison circuit, battery, module TP4056 and module LM2596.

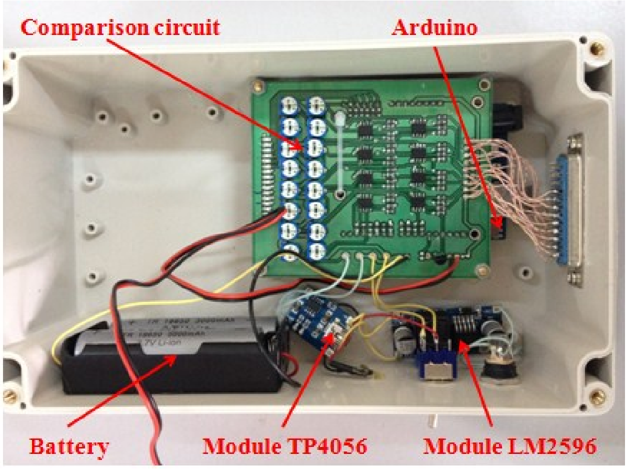

Figure 6. Photo of the MCU box

The rain gauge use to contain rain water which is designed by international standard with 300mm high and 8 inch diameter [9]. In this system, we use net to filter waste from the environment. The rain gauge is shown in Figure 7. The connected wire from rain gauge to system box is 10m.


Figure 7. The tank

III. RESULTS

Lifetime of the device: Calculating power consumption of the device helps detect the lifetime of the device when using batteries. The parameter of battery is 3.7V-6000mAh. Table 1 shows the power consumption of the device. Power is calculated by following equation:

$$P=V\times I \quad (1)$$

Table 2. General parameters of the device

Components	Voltage *(V)*	Current *(mA)*	No. Component	Power *(mW)*
Kit Arduino	3.7	0.2	1	0.74
LM358	3.7	0.5	8	14.8
Total of power consumption				15.54

In this system, battery can supply energy 3.7V×6000mAh = 22200mWh. Therefore, the lifetime of the device is 22200mWh/15.54mW = 1429h = 2 months with battery source.

General parameter is shown in Table 2:

Table 2. General parameters of the device

Parameter	*Value*	*Unit*
High of rain gauge	300	mm
Diameter of rain gauge	8	inch
Lever of detecting	16	
Lifetime with battery	2	month

Define rainfall threshold to alert

1. The equipment have *n* lever to measure the water lever in tank.
2. In this time, the water lever is at lowest lever, which define t_0 and water lever is h_0
3. In this time, the water lever grows up the next lever, which define t_1 and water lever is h_1. The alert algorithm:
    a. Alert function $y = 131e^{-0.013x}$, Where y is the intensity of rainfall (mm/h), x is accumulated rainfall (mm).
    Special case: $y_1 = (h_1-h_0)/(t_1-t_0)$; $x_1 = h_1-h_0$
    b. If $y_1 > 131e^{-0.013x_1}$ then the system alerts, else the system continually monitor.
4. In this time, the water lever grows up lever-n at t_n, water lever is h_n. We have algorithm as follower:

For i=2 to n
For j=1 to i-1
$y = (h_i-h_j)/(t_i-t_j)$
'note: j=1 $h_1=h_0$ and $t_1=t_0$
$x = h_i-h_j$
If $y > 131e^{-0.013x}$ then "Alert"
Next j, i

5. When the tank full or rain stops, the tank is emptied and reset system.

Figure 8 is the device which was tested in real field and Fig.9 show the status of the electrode sensor after five months. It was damaged, but we can replace with a new one with very cheap price (i.e. below 0.2 USD).

Figure 8. The device was tested in real application

Figure 9. The electrode sensor after 5 months

IV. CONCLUSION

In this paper, we have built a low-cost rainfall measuring system, which consists of an electrode sensor, a comparison circuit, a microcontroller board, a speaker, a battery and a tank. Alert threshold is determined based on statistical methods in several years to give a timely warning. The system has been successfully built and tested in real experiment. In future, each rain gauge device can join in a wireless rain gauge network in order to give a timely warning for a larger area.

REFERENCES

[1] Dinh-Chinh Nguyen, Duc-Tan Tran, "Development and implementation of a wireless sensor system for landslide monitoring application in Vietnam", International Journal of Information and Communication Technology, ISSN 1741-8070, Vol.13, No.2, pp. 227 - 242.

[2] Gian Quoc Anh, Duc-Tan Tran, Nguyen Dinh – Chinh, Nhu Viet Ha, Dieu Tien Bui, Design and Implementation of Site-Specific Rainfall-Induced Landslide Early Warning and Monitoring System: A Case study at Nam Dan landslide (Vietnam), Geomatics, Natural Hazards and Risk, ISSN: 1947-5705, Vol. 8, No. 2, pp. 1978-1996, 2017.

[3] Gian Quoc Anh, Duc-Tan Tran, Nguyen Dinh Chinh, Tien Bui Dieu, "Flexible Configuration of Wireless Sensor Network for Monitoring of Rainfall-Induced Landslide", International Conference on Earth Observation & Natural Hazards 2017- ICEO&NH, 2017, Ha noi, Viet nam, ISBN 978-604-913-650-4, pp. 62-65

[4] Gian Quoc Anh, Nguyen Dinh Chinh, Tran Duc Nghia, Tran Duc-Tan, Monitoring of Landslides in Mountainous Regions based on FEM Modelling and Rain Gauge Measurements, International Journal of Electrical and Computer Engineering (IJECE), ISSN: 2088-8708, 2016, Vol. 6, No. 5, pp. 2106-2113

[5] Dinh-Chinh Nguyen, Duc-Nghia Tran, Tran Duc-Tan, Application of Compressed Sensing in Effective Power Consumption of WSN for Landslide Scenario, Asia Pacific Conference on Multimedia and Broadcasting, pp. 111-115, April 2015, doi: 10.1109/APMediaCast.2015.7210276

[6] Chinh D. Nguyen, Tan D. Tran, Nghia D. Tran, Tue Huu Huynh, Duc T. Nguyen, "Flexible and Efficient Wireless Sensor Networks for Detecting Rainfall-Induced Landslides," International Journal of Distributed Sensor Networks, vol. 2015, Article ID 235954, 13 pages, 2015. doi:10.1155/2015/235954.

[7] Tran Duc-Tan, Nguyen Dinh-Chinh, Tran Duc-Nghia, Ta Duc-Tuyen, Development of a Rainfall-Triggered

Landslide System using Wireless Accelerometer Network, IJACT: International Journal of Advancements in Computing Technology, ISSN: 2005-8039, Volume 7, Issue 5, September, 2015, Pages 14-24, [Q4 Scimago].

[8] Hidetomi Oi, "Development of a Simple Rain Gauge Fitted with an Alarm Device", International Sabo Association, http://www.sabo-int.org.

[9] Lanza L. G., Leroy M., Alexadropoulos C., Stagi L., and Wauben W.,"WMO Laboratory Intercomparison of Rainfall Intensity Gauges – Final Report", IOM Report No. 84, WMO/TD No. 1304, 2005.