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# PID Controller Implementation For Temperature Control In 20kV Insulator Leakage Current Test Chamber

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***Abstract****: Insulator is an important device to separate between conductors of the electric power systems transmission. Generally, insulator is affected by environmental conditions such as temperature, humidity and other pollutants. Therefore, it is necessary to test the insulator in a simulated environment using a controlled chamber to determine the characteristics of the insulator leakage current. In this paper, a PID controller was implemented to control the chamber temperature. The PID controller is embedded in the Arduino R3 microcontroller which is connected to a DHT22 sensor and a thermoelectric cooling actuator (TEC12706.) Experimental results show that the PID controller can maintain the chamber temperature at the desired setpoint with Kp = 200, Ki = 10, Kd = 5. The system can reduce the temperature up to 23.6 °C with a rise time of 198 seconds with a peak time of 218 seconds at a temperature of 24.8 °C. The system can reach a preset temperature value with a response time of 32 seconds.*

**Keywords—**Test Chamber; Leakage Current; PID Controller

## 1. INTRODUCTION

Electrical insulators are an important component to support the safety of electricity operations. Insulators must consider a specified standard in order to work properly. The insulators must be tested in such a way to determine their performance. One of the methods used to test the insulator is to determine the leakage current using a chamber with temperature and humidity settings in order to get a suitable condition environment. Therefore a test chamber that is controlled with a precise controller is proposed. PID control is implemented in the test chamber where PID control is a popular feedback controller. This controller consists of three combined methods, namely proportional, integral, and derivative [1]. The controller uses an Arduino Uno microcontroller with a DHT22 sensor and an actuator in the form of a TEC12706 Peltier. The DHT 22 sensor was chosen because it has high accuracy at-40 – 80$^{o}$C and humidity measurement of 0-100% RH [2].

In previous research, an on-off control method was applied by Wibowo et al [3]. It was designed to a 20 kV insulator leakage test chamber with temperature and humidity controls. The research work applied an on-off control method using Arduino Uno Rev.3. The control systems could manipulate the test room to resemble a certain environment conditions to get accurate test results. In the paper, the temperature setting was carried out at three set points, i.e. a maximum temperature at 33°C with a minimum humidity at 58%, an average temperature at 27°C with an average humidity at 82% and a minimum temperature at 21°C with a maximum humidity at 91%. The experimental results showed that the maximum temperature setting with the minimum humidity, the highest temperature was 33.30°C and the lowest humidity was 58.25%. In the average temperature with an average humidity, the measurement results were close to the set point. In this condition, the temperature was 27.25°C with humidity of 81.60%. Moreover, a minimum temperature with maximum humidity, the measurement results were the closest to the set point and the temperature and humidity were 25.35°C and 91.50%, respectively.

A Proportional Integral (PI) controller has been carried out by Rudianto et al [4] to adjust an automatic expansion valve control of an evaporator. In this study, the performance of the PI control system got a good response at parameter values of $Kp$=20 and $Ki$=10. In this parameter configuration, it took 251 s to reach the preset temperature with a lower maximum overshoot value of -2.4˚C. The experimental work using an automatic expansion valve control system showed a faster cooling process. The energy required was more efficient which equals to 0.265 kWh.

In this study, we propose a PID controller as temperature control for a 20kv insulator test chamber using microcontroller Arduino Uno R.3. A Peltier 12706 is implemented to the cooling process.

## 2. RELATED WORKS

### 2.1 20Kv Leakage Current Test Chamber

An insulator must have good insulation properties at high voltage and low voltage applications. Also, it must have a good performance and high resistance, which is indicated by the amount of leakage current in the insulator. Generally, polymer materials have better dielectric properties compared to ceramic, glass, and porcelain materials. Factors that greatly affect the performance of the insulator are temperature, rain, humidity, ultraviolet light, condensation, and contaminants [5], therefore the leakage current is tested on the insulator. Several records showed that the flashover voltage in wet conditions is smaller than in dry conditions

[6] [7]. Research conducted for the characteristics of the leakage current in a single suspension insulator with variations in contaminants and humidity mentioned that the limit of leakage current is less than 50mA [7]. To carry out the leakage current test, a controlled chamber must be set up as shown in Figure 1. It was recorded in [3] that the leakage current test chamber was designed using the on-off control method. The test chamber used an Arduino R3 microcontroller controller and actuators in the form of a cooler, heater, humidifier, and fan. The highest temperature point was set at 33.80°C with the lowest RH set point of 58%. The highest temperature achieved in the 22nd minute at 33.30° C with a humidity of 58.65%, while the results of achieving the lowest humidity occurred at 23 minutes with a humidity measurement of 58.25% and temperature of 33.25°C. At the highest temperature setting with the lowest humidity, it was carried out in a duration of 53 minutes.

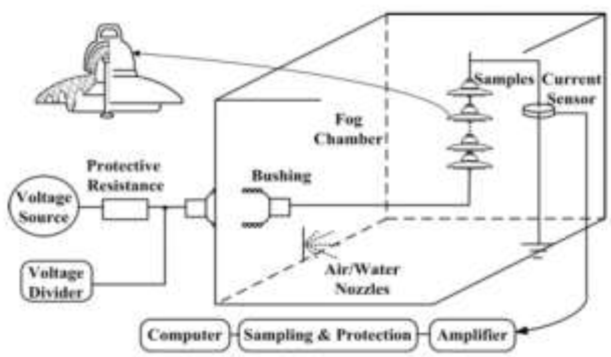


Fig.1 Schematic diagram of the fog chamber system and sketch of single suspension insulator[7]

### 2.2 Effect of temperature on leakage current

It is known that the insulator design should have a breakdown voltage higher than its flashover voltage. The dielectric strength and voltage value can be estimated from three basic characteristics of the insulator, i.e. alternating flashover voltage in dry conditions, alternating flashover voltage in wet conditions, and time-voltage characteristics obtained from standard surge voltage [3]. The testing condition for the insulator must follow standard requirement mentioned in Table 1. Table 1 shows the standard conditions of barometric pressure, ambient temperature, and absolute humidity based on the Japanese Industrial Standard (JIS) C3801 and the Japanese Electrotechnical Committee (JEC) Standard 106.

Table.1 Japan Industrial Standard

| | **Amount** | **Unit** |
|---|---|---|
| Barometer Pressure | 760 | mmHg |
| Environment Temperature | 20 | °C |
| Absolute Humidity | 11 | gram/$m^3$ |

### 2.3 PID Controller

PID control is one type of controller that is widely used in industrial systems and other general applications [8]. Since the controller has a good performance, this system can be combined with other systems [1]. PID control consists of three combined methods, namely Proportional, Integral, and Derivative with their respective parameter constants so that they can work properly as shown in Figure 2.

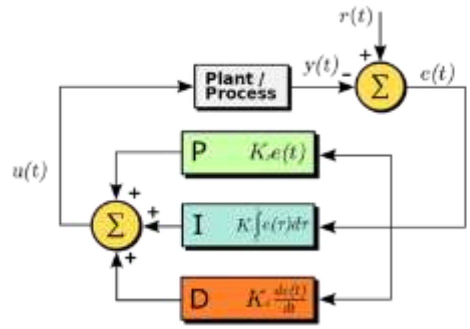


Fig.2 PID controller Block Diagram

The PID controller in Figure 2 can be written as follows [8]:

$$u(t) = K_p(e)t + K_i \int_0^t e(t)dt + K_d \frac{d}{dt} e(t) \quad (1)$$

where $u(t)$ is system output, $K_p$is a proportional constant, $K_i$ is an Integrator constant and $K_d$is a proportional constant [8]. The parameter characteristics are shown in Table 2.

Table.2 PID Controller characteristic

| **Close Loop Respons e** | **Rise Time** | **Over shoot** | **Settling Time** | **SS Error** |
|---|---|---|---|---|
| **Kp** | Increase | Increase | Small Change | Decrease |
| **Ki** | Decrease | Increase | Increase | Eliminat e |
| **Kd** | Minor Change | Decrease | Decrease | No Effect |

### 2.4 Arduino Rev.3 Microcontroller

Arduino Uno R3 is a microcontroller board based on ATmega328. It has 14 digital input/output pins (6 pins can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header and a reset button. The features are contained in one chip to support the microcontroller [9]. Arduino can be programmed easily because the programming language has been simplified and uses opensource systems[10]. Pins for analog

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input are addressed in A0 - A5. Digital pins are located in pin 2 to pin 13, with a special Pulse Width Modulation (PWM) on pins 3,5,6,9,10,11. Arduino can be supplied by 9v to 30v DC using an external power supply as shown in Figure 3 and Figure 4.

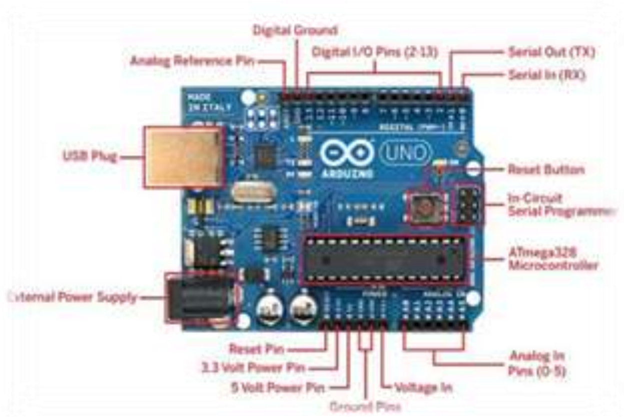


Fig. 3 Ardiuino Rev.3

Fig. 4. Ardiuino Rev.3 Pin Mapping[10]

### 2.5 *Thermo Electric Cooler* (TEC)

Thermoelectric cooler (TEC) or Peltier module is composed of ceramics. Peltier has two different sides, namely a hot side and a cold side. It can be used for cooling and heating. The principle of Thermo-Electric cooling was first discovered in 1834 by Jean Peltier, so that it is often called "Peltier Cooler". When two conductors are connected in electrical contact, electrons will flow from the conductor that has less electrons to the conductor with the more bonded electrons. The most commonly used Thermo-Electric semiconductor material today is Bismuth Telluride (Bi2Te3) [12] as shown in Figure 5 and 6. Thermo-Electric is built by two different semiconductors, one type N and the other type P. A Thermo-Electric will produce a maximum temperature difference of 70°C between its hot and cold sides. The efficiency is reduce when the Thermo-Electric become hotter. Thermo-Electric has an efficiency of about 10% - 15%, while the efficiency of conventional models is between 40% - 60%[11].


Fig.5 Peltier TEC 12706

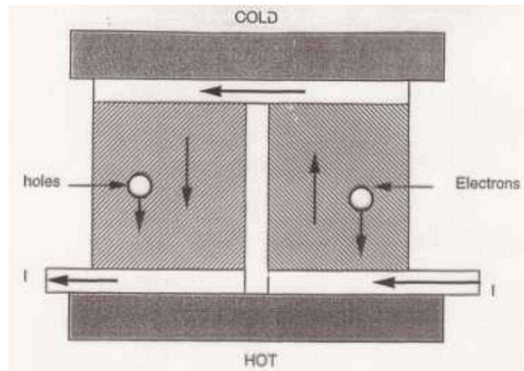


Fig.6 Thermoelectric schematic diagram

### 2.6 DHT 22 Sensor

DHT 22 is a temperature and humidity sensor with 8 bit single chip calibrated output as depicted in Figure 7. DHT22 consists of a polymer capacitor with a temperature sensing range of -40 - 80°C and a humidity of 0 - 100% RH [2]. The output of the DHT22 is digitally calibrated. It employs a proprietary digital signal-gathering technique and moisture sensing technology, with high reliability and stability. This sensor is small in size with low consumption [13]. The technical data of DHT22 is elaborated in Table 3.

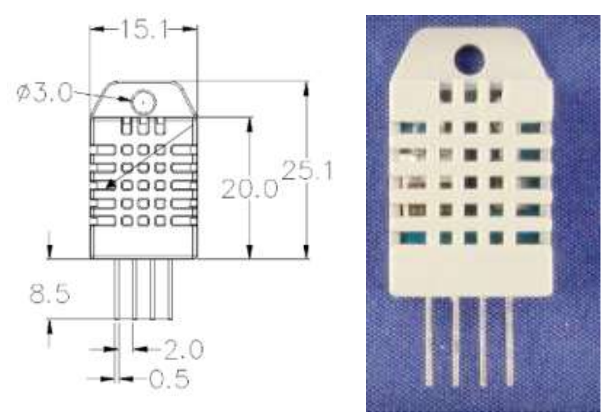


Fig 7. DHT22 Sensor Dimension [2]

Table 3 : DHT22 Sensor Technical Data [2]

| DHT 22 Technical Data | |
|---|---|
| Power Supply | 3.3-6V DC |
| Output Signal | digital signal via single-bus |
| Sensing Element | Polymer capacitor |
| Operating Range | humidity 0-100%RH; temperature -40~80Celsius |
| Accuracy | humidity +-2%RH(Max +-5%RH); temperature <+-0.5Celsius |
| Resolution | humidity 0.1%RH; temperature 0.1Celsius |
| Repeatibility | humidity +-1%RH; temperature +-0.2Celsius |
| Humidity Hysteresis | +-0.3% RH |
| Long Term Stability | +-0.5% RH/year |
| Sensing Period | Average: 2s |
| Interchangebility | fully interchangeable |
| Dimensions | small size 14*18*5.5mm; big size 22*28*5mm |

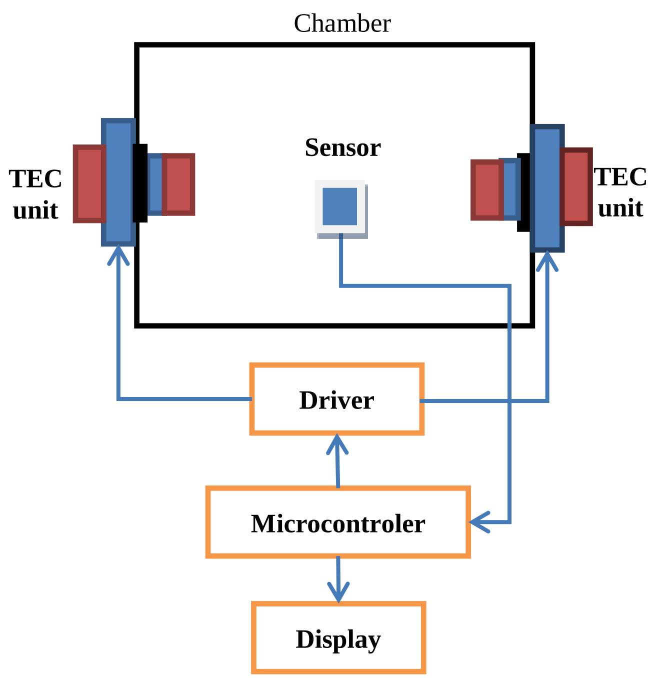


Fig 8. Block Diagram

### 3. METHODS

### 3.1 Hardware Design

Test chamber is developed by using a plastic box which has size of 510 x 360 x 290 mm. Block diagram of the implemented control temperature system for test chamber can be seen in Figure 8. In this work, the PID controller was programmed in an Arduino Rev.3 microcontroller. Two TEC units were installed in the test chamber room for cooling step. The cooling components are connected to driver. This driver amplifies the PWM signal coming from Arduino microcontroller to the TEC. PWM signal is provided by microcontroller as an output of PID controller. The width or duration depend on the deviation between feedback signal and preset value or setpoint.

Setpoint value is set at 20°C. Firstly, the controller will take a temperature reading on the test chamber room and send it to pin 8 Arduino. PID method then control based on the differences between this value to the setpoint or preset value.

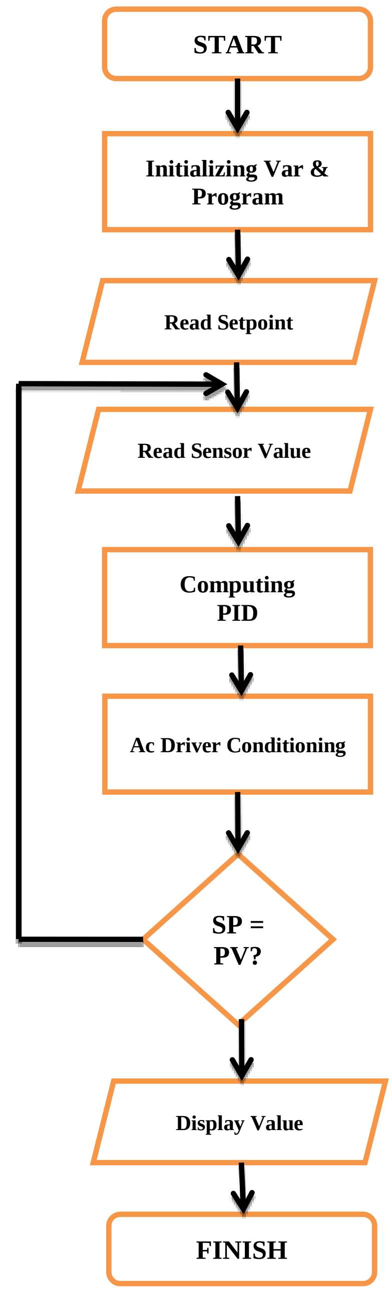


Fig 9. Flow Chart Systems

The PID algorithm was programmed using C language. In order to realize the PID controller, a flow chart is created to determine each process for controlling the temperature as shown in Figure 9.

Initially, some variables or constant must be given a value. Then a controlling process will be started at reading a setting point or preset value. The process will be continued by reading the actual temperature value. This value can be taken from a sensor used in this temperature control systems and this value is called feedback signal. As mentioned above, this temperature value is taken from DHT sensor through a dedicated protocol communication. The deviation between setting value and feedback signal value will be used by PID controller to determine the width of PWM signal. This algorithm is applied during controlling process until the temperature is reach to the setting value. The actual temperature value will be displayed on the LCD screen. It can be seen the actual temperature value by looking at the LCD display text. The flow chart which is programmed in Arduino can be seen as shown in Figure 9.

### 3.2 Open loop Test

Before the control process is carried out, an open loop thermoelectric test is carried out, testing by giving a 100% PWM duty cycle to the peltier driver, then the data is recorded in second intervals as shown in Figure 10.

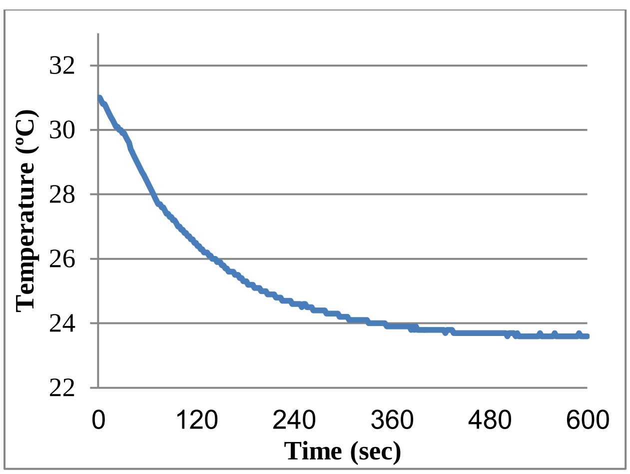


Fig 10. Open Loop Responses

From the open loop test data, it is found that the system can reduce the temperature from 31 ° C to stable at 24.6 ° C at 500 seconds.

### 3.3 PID Controller Test

The PID control process is carried out using a setpoint of 25° C, then determining the constants by trial and error methods with Kp = 200, Ki = 10, Kd = 5.

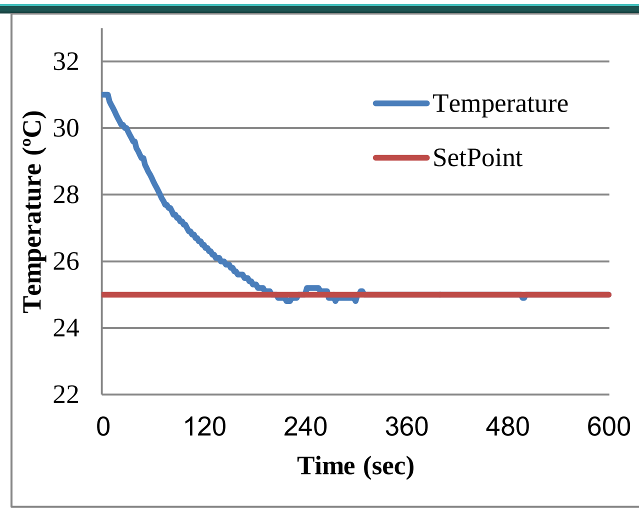


Fig 11. System response

In Figure 12, the set point has changed from temperature 25 to 26, it can be seen that the system response follows the setpoint with a change in response time of 32 seconds

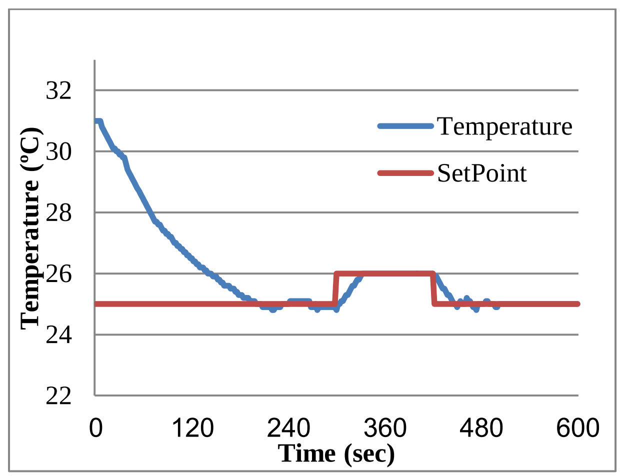


Fig 12.the system response if the setpoint is changed

## 4. CONCLUSION

We have successfully implemented PID control in the 20 kv insulator leakage test chamber. Based on the experimental results, the temperature can be reduced by up to 23.6 ° C, a rising time of 198 seconds with a peak time of 218 seconds at a temperature of 24.8 ° C, when the setpoint is changed the system follows the setpoint with the response time is 32 seconds until it reaches steady state.

## 5. .REFERENCES

[1] M. A. Johnson *et al.*, *PID control: New identification and design methods*. 2005.

[2] T. Liu, "Digital-Output relative humidity & temperature sensor/module DHT22," *New York*

*Aosong Electron.*, vol. 22, pp. 1–10, 2015, [Online]. Available: https://www.sparkfun.com/datasheets/Sensors/Temperature/DHT22.pdf%0Ahttps://cdn-shop.adafruit.com/datasheets/Digital+humidity+and+temperature+sensor+AM2302.pdf.

[3] L. Wibowo, A. Syakur, and T. Andromeda, "Design of temperature and humidity control devices in the leakage current test chamber of 20 kV insulator," 2019, doi: 10.1109/ICITACEE.2019.8904318.

[4] B. Rudiyanto, A. Susanto, and Y. Susmiati, "Aplikasi Kontrol PI (Proportional Integral) pada Katup Ekspansi Mesin Pendingin," *Rona Tek. Pertan.*, 2016, doi: 10.17969/rtp.v9i2.5647.

[5] A. Syakur, H. Berahim, and T. Rochmadi, "Leakage current monitoring for silane epoxy resin insulator under tropical climate conditions," 2012, doi: 10.1109/CMD.2012.6416291.

[6] A. Syakur and Hermawan, "Leakage current characteristics at different shed of epoxy resin insulator under rain contaminants," 2015, doi: 10.1109/ICITACEE.2014.7065782.

[7] J. Y. Li, C. X. Sun, and S. A. Sebo, "Humidity and contamination severity impact on the leakage currents of porcelain insulators," *IET Gener. Transm. Distrib.*, 2011, doi: 10.1049/iet-gtd.2009.0559.

[8] K. Ogata and J. W. Brewer, "Modern Control Engineering," *J. Dyn. Syst. Meas. Control*, 1971, doi: 10.1115/1.3426465.

[9] Arduino, "Arduino Uno Rev3," *Store.Arduino.Cc*, 2018. .

[10] R. H. Sudhan, M. G. Kumar, A. U. Prakash, S. A. R. Devi, and S. P., "ARDUINO ATMEGA-328 MICROCONTROLLER," *IJIREEICE*, 2015, doi: 10.17148/ijireeice.2015.3406.

[11] G. D. Mahan, "Introduction to thermoelectrics," *APL Mater.*, 2016, doi: 10.1063/1.4954055.

[12] I. Terasaki, "Introduction to thermoelectricity," in *Materials for Energy Conversion Devices: A Volume in Woodhead Publishing Series in Electronic and Optical Materials*, 2005.

[13] T. Liu, "Digital Humidity and Temperature sensor," *Adfruit*, 2016.