DEVELOPMENT OF IOT SYSTEM WITH RASPBERRY PI FOR SWITCHGEAR CONDITION MONITORING

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DEVELOPMENT OF IOT SYSTEM WITH RASPBERRY PI FOR SWITCHGEAR CONDITION MONITORING

BY

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The thesis is dedicated to everyone in the field of electrical and electronic engineering who wants to find the knowledge about partial discharge and use of raspberry pi.

First and foremost, I am truly thankful to Allah for give me a chance and healthy life during period of project implementation. I would like to express my gratitude to Associate Professor Dr. Asrulnizam bin Abd Manaf as my project supervisor. He always give his support for this project even though busy with his life. This gives me a strength and motivation for me to do this project.

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LIST OF ABBREVIATION

IOT	Internet of Things
PD	Partial Discharge
LED	Light emit diode
ADC	Analog to digital converter.

PEMBANGUNAN SISTEM IOT DENGAN RASPBERRY PI UNTUK SUIS PEMANTAUAN KEADAAN

ABSTRAK

Pelepasan separa adalah fenomena yang biasa berlaku akibat pecahan separa di dalam atau di seluruh penebat, terhad kepada retak kecil atau tidak sah (di dalam penebat) atau di atas permukaan yang tidak boleh dilihat secara kasar dengan mata. Untuk mengelakkan ini berlaku, perlu melakukan pemeriksaan dan pemantauan bagi keselamatan kakitangan dan juga untuk menjaga peralatan voltan tinggi dalam keadaan yang elok. Untuk projek ini, gabungan raspberry pi dan beberapa pengesan telah digunakan untuk melakukan pemantauan secara atas talian supaya maklumat tentang apa-apa kelengkapan voltan tinggi akan dihantar melalui e-mel pengguna. Pengesan bunyi akan mengambil bahagian untuk mengesan bunyi yang mencetuskan percikan dalam suis manakala termistor akan mengambil bahagian untuk mengesan peningkatan suhu apabila pelepasan separa berlaku. Kaedah ini akan digunakan dan diuji.

DEVELOPMENT OF IOT SYSTEM WITH RASPBERRY PI FOR SWITCHGEAR CONDITION MONITORING

ABSTRACT

Partial discharge is common phenomenon of partial breakdown inside or across the insulation, confined to a small crack or void (inside the insulation) or over the surface that cannot be seen roughly with eyes. In order to prevent that happens, needs to do inspection and monitoring for safety of the personnel and also to keep the high voltage equipment in well care. For this project, the combination of raspberry pi and several sensors was using to do monitoring via online so that the information about any high voltage equipment will be send through a user email. The sound sensor will take part for detecting sound of sparking inside the switchgear while thermistor will take part for sensing the temperature increase when the partial discharge occur. This method will be apply and tested.

CHAPTER 1

INTRODUCTION

1.1 : Background

Nowadays, electrics become one of the most used in our daily life in this modern civilisation. Electric supply is very importance for people such as domestic appliances, industrial machineries and so on. So, in order to save electric supply from to do any harm or damaging the power system, it must have something that needs to protect it from to do so. For this purpose, we need the switchgear because the switchgear are able to do switching, controlling and protecting devices and electrical circuits for instance switches, fuses, relays, circuit breakers and so on [1].

One of the most basic function of the switchgear is overloading load current and interrupts any short circuit happens meanwhile the switchgear also gives isolation of circuits and improve power system which is allow more than one power supply to supply to the load [1]. Normal operation of the switchgear is switch on or off generators, transmission lines, distributors and many other electrical devices or equipment [1]. Besides that, if failure or short circuit happens on any part of the power system, big currents will flow through the electrical equipment and it may do some damaged to the electrical equipment. This is also become an interruption to the customer due to the failure. Thus, to prevent the failure or to be specific a partial discharge occur, needs detection tools that can be detect early stages of partial discharge.

1.2 : Problem Statements

Switchgear was discovered early around year 1910 and act as one of the most important electrical equipment in the power system [1]. Without it, may cause many electrical equipment or devices damaged. However, there is fault in the devices in the switchgear. For instance, inside the switchgear such as coaxial cable may have leakage which is very tiny that cannot be seen with eyes and have sparks or sounds that cannot be heard [2]. Thus, to avoid the switchgear become more damaged due to the leakage, there must be various ways to save the switchgear. One of the ways is by using raspberry pi to monitor switchgear just in case sparks of light or sounds produced then it can send precaution alert to the maintenance department or user.

1.3 : Objective

- To develop raspberry pi software sensor to continuous monitoring the switchgear.
- To validate the sensor in monitor switchgear and send data to the raspberry pi.

1.4 : Project Scope

In this project is basically about to test sparks or sounds occur due to partial discharge in the switchgear and its be able to send data to the user email. Raspberry pi 3 is the main device that will be use in this project in order to send the data obtained from the result of detecting the partial discharge. Raspberry pi 3 Model B figures as shown below:

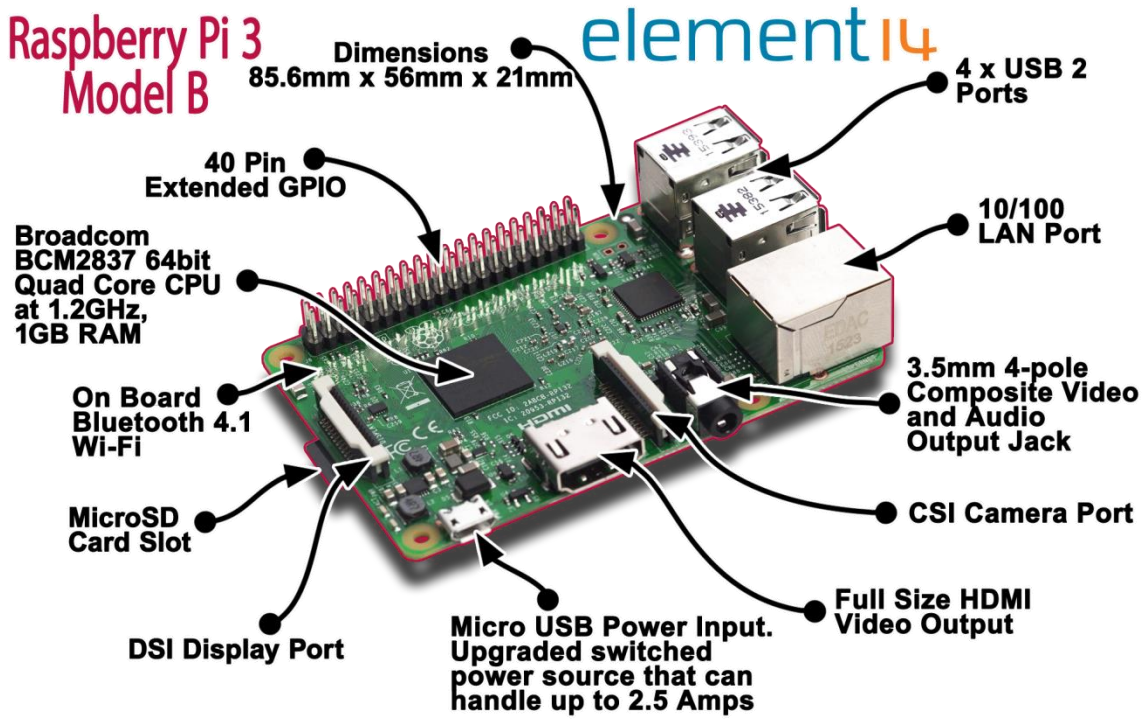

Figure 1 : Raspberry pi 3 Model B [3].

Besides using raspberry pi 3, on late 2015 there is new software that pre-installed in the SD card of the raspberry pi called Node Red. Node Red is an open source for wiring internet of things (IOT) virtually in the website called iceweasel. Each node of the Node Red allows it to read and write the raspberry pi nodes.

1.5 : Thesis organisation

This thesis consist of five chapters includes introduction, literature reviews, methodology, result and discussion and finally the conclusion.

In the Chapter 1, it gives an introduction which includes background, problem statement, objectives, scope of the project and the thesis organisation on development of Internet Of Things (IOT) with raspberry pi for switchgear condition monitoring.

Besides, in the Chapter 2 emphasizes literature review regarding exploration on background and recent progress about switchgear condition monitoring. Furthermore, in the Chapter 3 focuses on the methodology of the project. This chapter gives specific details about the method and flow used in this project. First and foremost, it explains about the project implementation flow. Then , it describes project requirement for detecting an early partial discharge occur in the switchgear. Its have two implementation which hardware and software that need to be done in this project.

In addition, Chapter 4 presents and discusses the results obtained from experiments on the both sound and thermistor sensors. Finally, this thesis ends with conclusion and recommendation for the future work in the Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1: Overview

On this literature review will be covered application of partial discharge (PD) measurement for insulate breakdown in the switchgear. In order to prevent the breakdown due to partial discharge, high voltage equipment such as switchgear and transformer must be in continuous monitoring. There are advantages of doing the continuous monitoring of partial discharge. One of the advantages is to find any problem occur in any high voltage equipment quickly. Then, the monitor will identify the problems and user will take precaution action for detecting an early defect[4]. This will provide one with sufficient information as to the growth rate and the severity of the defect [4]. Furthermore , its also increased safety of personnel and reducing unnecessary maintenance because the monitor will be constantly testing and will have accurate data on which to base decisions [4].

2.2 : Partial Discharge (PD)

Partial Discharge (PD) is a phenomenon of partial breakdown inside or across the insulation, confined to a small crack or void (inside the insulation) or over the surface that cannot be seen roughly with eyes [5]. In addition, partial discharge also can occur at any point in the insulation system, where the electric field strength exceeds the breakdown strength of that portion of the insulating material [6]. Partial discharge may not happens regularly but it could happen if the equipment operating for long time and fail to do maintenance on it [5]. So, how to early detect the partial discharge occur?. There are several ways that can be detect partial discharge which is electromagnetic emission, acoustic emission and oxide of oxygen of nitrogen gases [7]. Furthermore, for an accurate detection, ultra high frequency (UHF) sensor and ultrasonic sensors [7].

2.2.1 : Partial Discharge mechanism

Partial discharge is very unique phenomenon that confined to small crack or form a void that manage to do harm to the any equipment. However, how its partial discharge can form a small crack or void. In the Figure 2.1 will show the illustrated of the partial discharge forming void. Voids are defined as gaps in a more dense dielectric material [8].

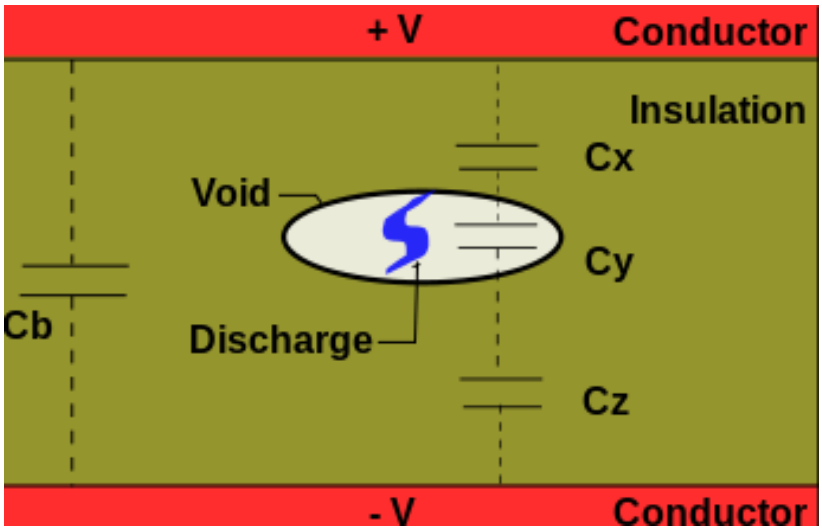

Figure 2.1 : Partial discharge forming void [9].

Partial discharge can occur on any insulating medium such as gaseous, liquid or solid. Regularly partial discharge occur on gas insulator because the bubble of the oil in high voltage equipment will block the electrical discharge that does not completely bridge the gap between two electrodes due to the bubble of the oil [10].

2.3 : Types of sensors

There are many types measurement that can measure partial discharge. For example, ultra high frequency (UHF) sensors and ultrasonic sensors.

2.3.1 : Ultra high frequency (UHF) sensors

Ultra high frequency sensors cannot use it far from the equipment but need to inspect and do the measuring internal of the partial discharge activity in order to detect it in effective way [7].

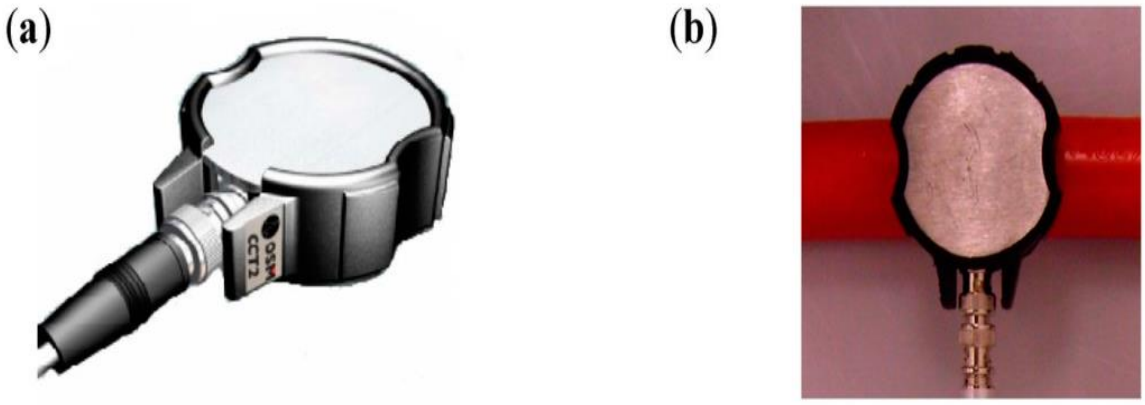

Figure 2.2 : (a) UHF non-invasive patch coupler; (b) Sensor installed on the surface of a power cable [11].

2.3.2 : Ultrasonic sensors

Ultrasonic sensors device is that can measure the distance to an object by using sound waves. It measures distance by sending out a sound wave at a specific frequency and listening for that sound wave to bounce back. By recording the elapsed time between the sound wave being generated and the sound wave bouncing back, it is possible to calculate the distance between the sonar sensor and the object [12]. Ultrasonic sensors can be done in effective way by doing the inspection on the surface of the partial discharge activity [7]. For a simple concept diagram of ultrasonic sensors is shown below :

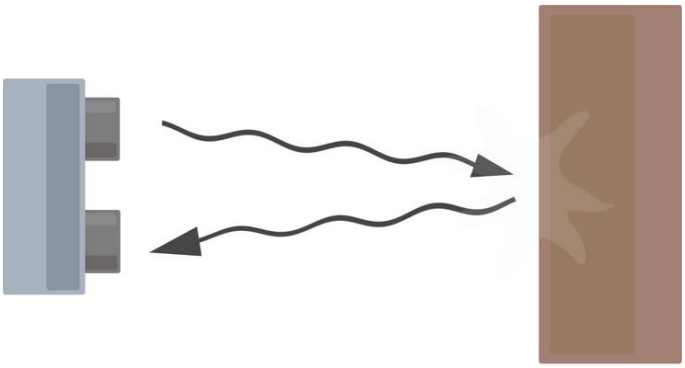

Figure 2.3 : Simple ultrasonic sensors concept diagram [12].

By using formula of distance = $\frac{speed\ of\ sound\ x\ time\ taken}{2}$, any object can be determine the distance of the object between the sensors and the object itself. However, there might be some object that cannot be detected due to temperature and humidity of the air that being used [12].

2.3.3 : Sound sensors

There are several ways to detect partial discharge in any high voltage equipment. For example, chemical, electrical, acoustic and optical. On this review will be focus on the sound. The basic understanding of sound sensor is it have microphone built in. The microphone will detect any upcoming signal enters it and convert a sound signal into a voltage or current that proportional to the detected signal. Furthermore, typically all sound sensor have diaphragm that made up of magnets surrounded by coil metal wire. Once, the sound wave enters the microphone it cause the diaphragm to vibrate which vibrates the magnet and will induces a current in the coil.

Besides that, when the partial discharge occur, the sound sensor will be recording of the signal. The signal here is created when the current streamer is formed within the void, the material around the hot streamer is vaporized [8]. The advantage of using sound detection is that position information is readily available from sound systems using sensors at multiple and specific locations [8]. Meanwhile, sound detection also have its limit which is complex sound wave propagation [13].

2.3.4 : Thermistor sensor

By using thermistor sensor also one of the ways to detect partial discharge. The basic understanding about thermistor sensor are resistors whose resistance changes with the temperature. While for most of the metals the resistance increases with temperature, the thermistors respond negatively to the temperature and their resistance decreases with the increase in temperature. Since the resistance of thermistors is dependent on the temperature, they can be connected in the electrical circuit to measure the temperature of the body [14]. The resistance of thermistor is given by [14]:

$R = R_o e^k$ where k is :

$$K = \beta(1/T - 1/T_o) \quad (1)$$

R is the resistance of the thermistor at any temperature T in ^oK (degree Kelvin).

R_o is the resistance of the thermistors at particular reference temperature.

β is a constant whose value ranges from 3400 to 3900 depending on the material used for the thermistors and its composition [14]. In the Figure 2.4 shows the graph of the thermistor sensor based on the formula.

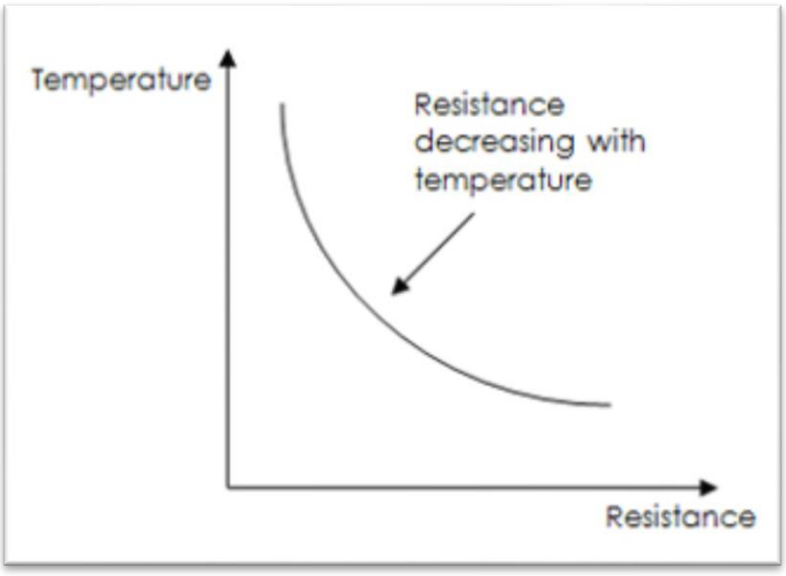

Figure 2.4 : Graph of thermistor sensor [14].

Besides that, the advantages of using thermistor sensor are when the resistors are connected in the electrical circuit, heat is dissipated in the circuit due to flow of current. This heat tends to increase the temperature of the resistor due to which their resistance changes. For the thermistor the definite value of the resistance is reached at the given ambient conditions due to which the effect of this heat is reduced. In addition, the size of the thermistors is very small and they are very low in cost. However, since their size is small they have to be operated at lower current levels.

2.4 : Internet Of Things (IOT)

Internet of Things (IoT) is a major focus in development scope in this era. Explosion of data and connection is occurring in this era of digital economy Internet of things is internet of physical devices that embedded with electronics, sensors, software, sensors and network connectivity of internet. Its enable all items mention to be able to collect and exchange data to the user depend on how its programmed. However, in this era, the definition of IoT has been changed in parallel with the evolution of technology.

The definition of IoT is implied as the use of computers to detect information without the use of human beings, not only focusing on sensing information from the environment but also using the internet as standard service for transferring information, analysing information, application and communications .Development of IoT leads to advancement of cloud computing, robotics and increasing the capabilities of the internet.

2.5 : Summary

The measurement for partial discharge can provide an early warning of insulation breakdown before a surge test. It is a great tool to track the condition of high voltage equipment over time and can provide an opportunity to lengthen the remaining life span of a high voltage equipment.

CHAPTER 3

METHODOLOGY

3.1 : Overview

On this chapter will highlight about the methodology of this project. The main objective of this project is to test and monitor the limit of the switchgear by using combination various types of sensors and raspberry pi in order to detect any sparking or sounds produce in the switchgear. In order to detect the partial discharge in the switchgear, the sound sensor and thermistor must be sensitive enough. Otherwise, the information about the partial discharge will not be send to the user and it can cause serious damage to the high voltage equipment.

3.2 : Project Implementation Flow

Project implementation flow must be well planned and organized in order to ensure that the steps to implement the project are carried out symmetrically. However, the flowchart consist of steps to implement the project is made to fulfil this purpose. The flowchart in Figure 3.1 shows that the development flow of the project. The objective to do this project is based on problem statement which is it have been stated in the Chapter 1. The project implementation begin with the understanding of partial discharge occur in the high voltage equipment such switchgear. Several research papers have been reviewed in order to solve the problems. Thus, the flowchart shown in the Figure 3.1 is the flow of the project that will be followed.

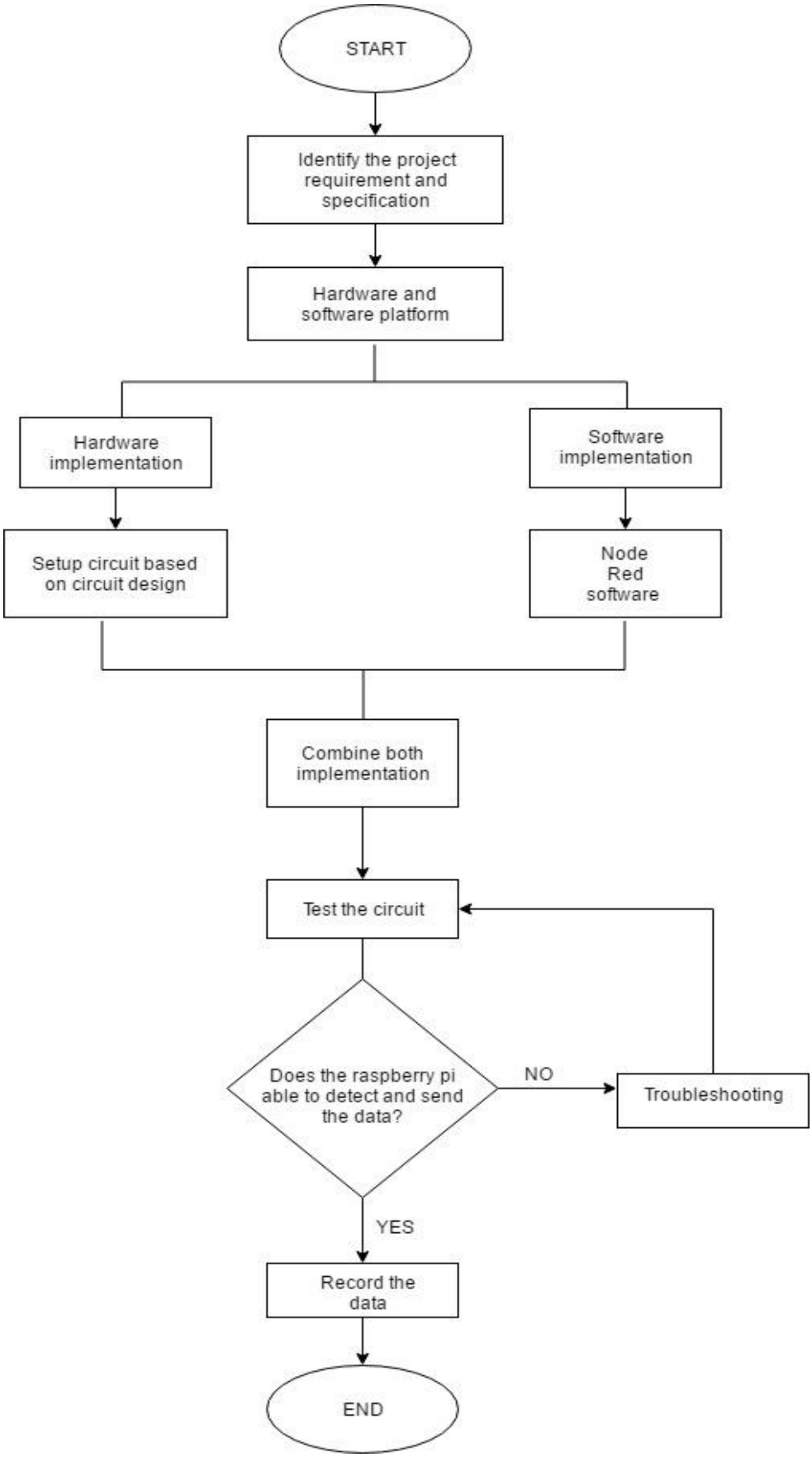

Figure 3.1 : Project implementation flow for this project.

3.3 : Project Requirement

3.3.1 : Hardware

- Sound sensor

Sound sensor can detect the sound strength of the environment. The main component of the module is a simple microphone, which is based on the LM358 amplifier and an electret microphone. The specification of the sound sensor shown below.

Table 1 : Specification of the sound sensor [13].

Operation voltage range	Vs = 1Vdc ~ 10 Vdc
Frequency range	100 ~ 10000 Hz
Sensitivity	- 46 ± 2.0, (0 dB = 1V / Pa) at 1K Hz.
Sensitivity reduction	3.0 V to 2.0 V -3 dB
Operating temperature	-20ºC to + 60ºC
Loading resistance	External, 680 Ω at Vs = 1.5 V, Max. 2,200 Ω
Power supply (Vs)	1.5 V
Maximum current	0.5 mA
Minimum Sensitivity to Noise Ratio	58 dB
Maximum input Sound Pressure Level (SPL)	110 dB at 1.0 KHz, THD <1%
Built in capacitor	None

- Thermistor temperature sensor

Thermistor is one of the type of resistor which is depend on the temperature to be able detect any temperature within its range. The figure and specification of thermistor sensor shown below :

Table 2 : Specification of thermistor sensor [15].

Parameter	**Thermistor**
Temp Range	Within ˜50°C of a given center temperature
Stability	Very stable, ˜0.0009°C
Sensitivity	High

- Raspberry pi 3 Model B

Raspberry pi 3 Model B is an evolution of raspberry pi 2 by adding more functions such as 1.2GHz 64-bit quad-core ARMv8 CPU, 802.11n Wireless LAN, Bluetooth 4.1 and Bluetooth Low Energy (BLE). In this project raspberry pi act as medium for the internet of things (IOT).[16]

3.3.2 : Software

- Node Red

Node red is a tool that can wiring together hardware devices via online services by using iceweasel browser. Manually connected all the function nodes that related to the circuit design. Java script also included for the coding in the text editor. All test and measurements will be send through an email of the user and display the data [17].

3.3.3 : Printed Circuit Board (PCB)

A printed circuit board (PCB) is electrically connect any electronic components by using conductive material from copper sheets laminated on the non-conductive material in order to make the circuit design fully connected to each other [18]. In this project, I will be using an EAGLE software which is its stands for Easily Applicable Graphical Layout Editor. Printed circuit board schematic diagram and its layout of the sound and thermistor sensors shown in the figure below.

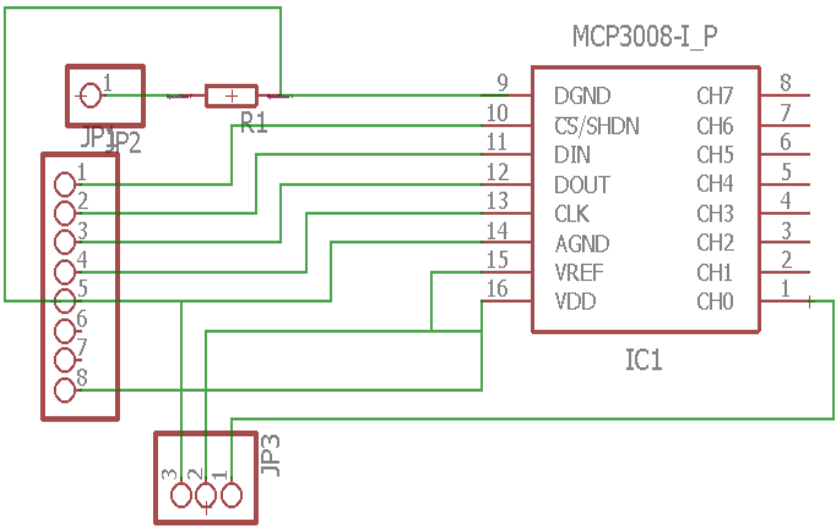

Figure 3.2 : Schematic diagram of the sound and thermistor sensors.

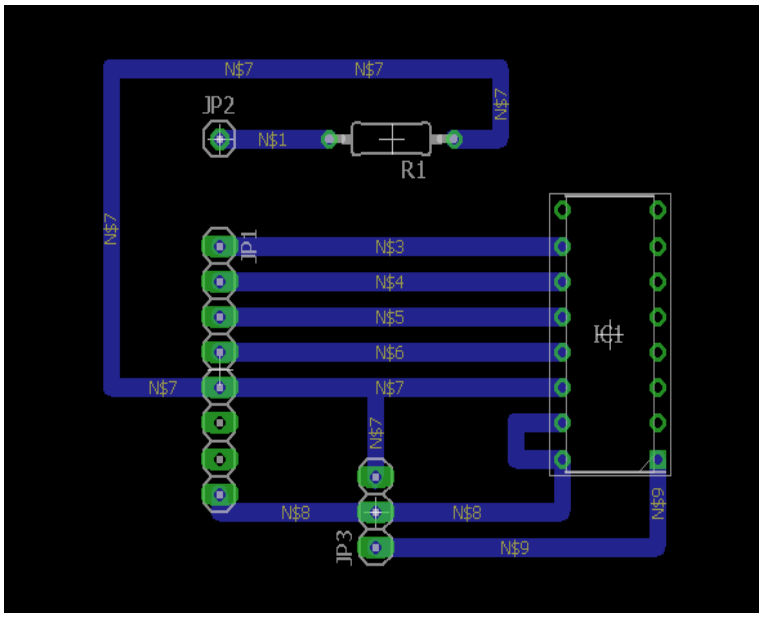

Figure 3.3 : Printed circuit board layout of sound and thermistor sensors.

3.3.3.1 : EAGLE program

EAGLE software is an application that can be use to do schematic capture , printed circuit board layout, auto router and computer –aided manufacturing features. The parts in this program can be found in its library or manually search parts on the website [19]. This is because not all parts are included in the library of the program. So,in this project only the layout of printed circuit board will be the main features. For example of the schematic diagram and layout of printed circuit board can be seen in the Figure 3.2 and Figure 3.3.

3.4 : Project designs

In this section, project designs have two main parts which is hardware and software. Hardware and software both have the same parts which involve sound and thermistor sensors.

3.4.1 : Hardware

In this project, there are two main parts of hardware which are sound sensor and thermistor sensor. The parts have its own role in this project. In a simple terms, sound sensor is to detect any frequency signal within its range frequency in the Table 1 meanwhile thermistor sensor is to detect any different changes of heat in the surrounding near it.

3.4.1.1 : Sound sensor

The specification of the sound sensor have been described meanwhile the circuit design of the sound sensor will be explain in this section. The circuit design consist of analog digital converter (ADC) and raspberry pi 3. Analog to digital converter is a electronic device that can converts an analog signal to the digital signal. In this case, the microphone of the sound sensor will picked up any sound in analog forms and converts to the digital forms due to the analog digital converter. Fully circuit design of the sound sensor shown in the Figure 3.4.

3.4.1.2 : Thermistor sensor

The specification of the thermistor sensor have been described meanwhile the circuit design of the sound sensor will be explain in this section. The function of analog digital converter in this circuit design is when heats exist around the surrounding of the thermistor sensor, it will convert the analog signal to digital signal.The circuit design is same as sound sensor but the only difference here is using thermistor sensor. The circuit design is in the Figure 3.4 as well.

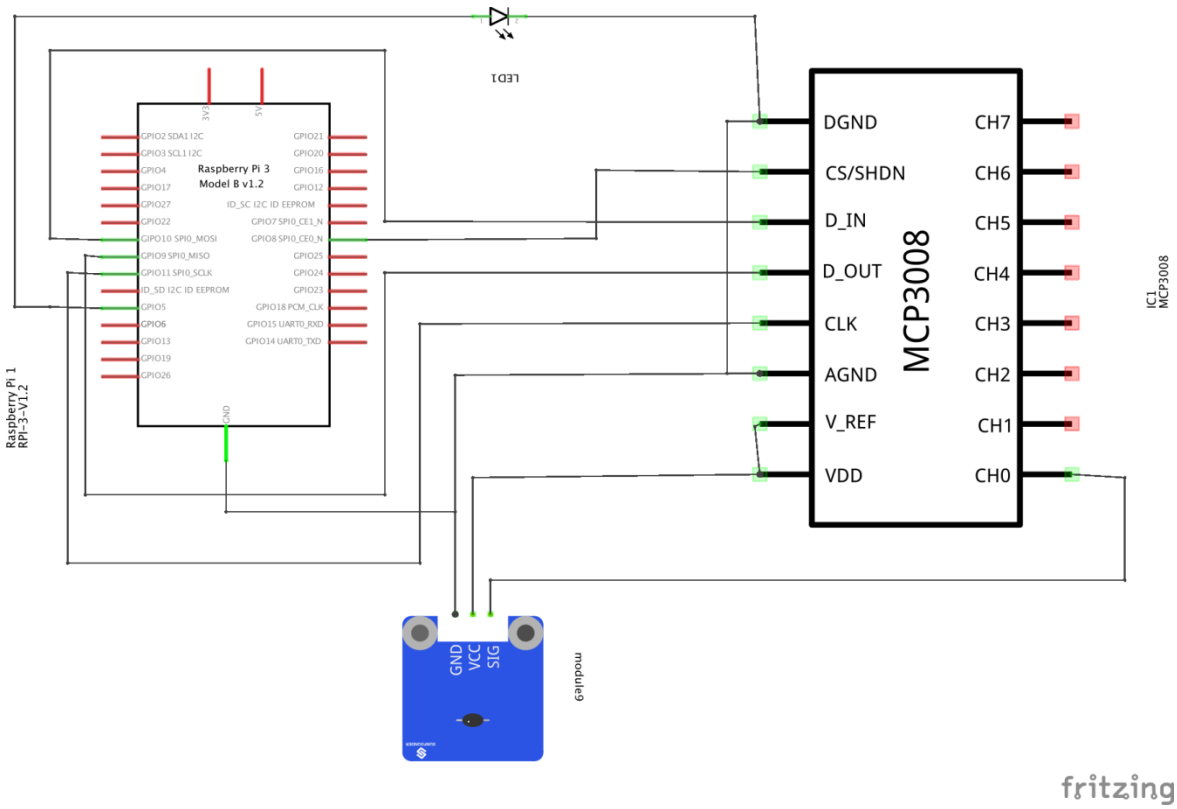

Figure 3.4 : Circuit designs for sound and thermistor sensors

3.4.2 : Software

In this section, will show the flow of the project by using Node Red software. Node Red have many features including basic and advanced functions. It is up to the user to customize the circuit design. Besides that, in order to use the Node Red must be via ice-weasel browser which is need to install and update manually in the raspberry pi 3. The Node Red circuit design is in the figure below. Each functions node shown in the Figure 3.5 were different functions.

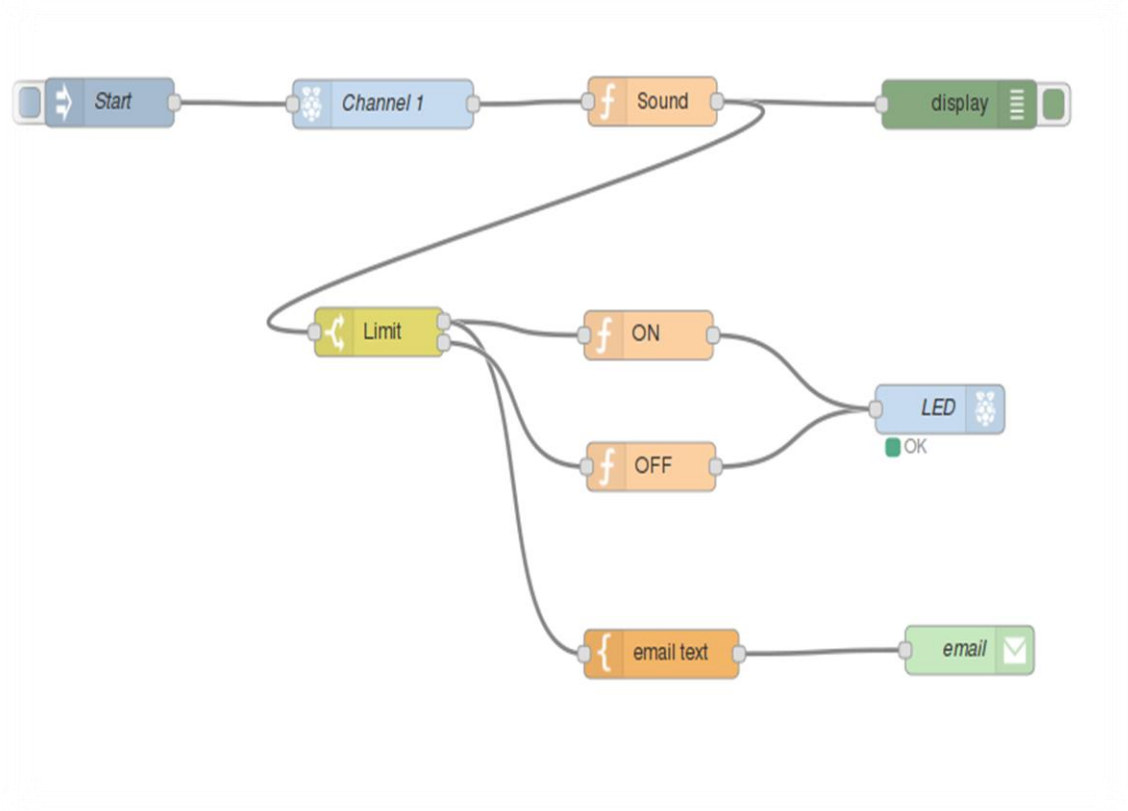

Figure 3.5 : Node Red circuit design.

Based on Figure 3.5, the “start” function node is an inject node which is it allows user to inject messages into a flow when the signal received either by clicking on the button on the node or user can setting a time interval between injects.

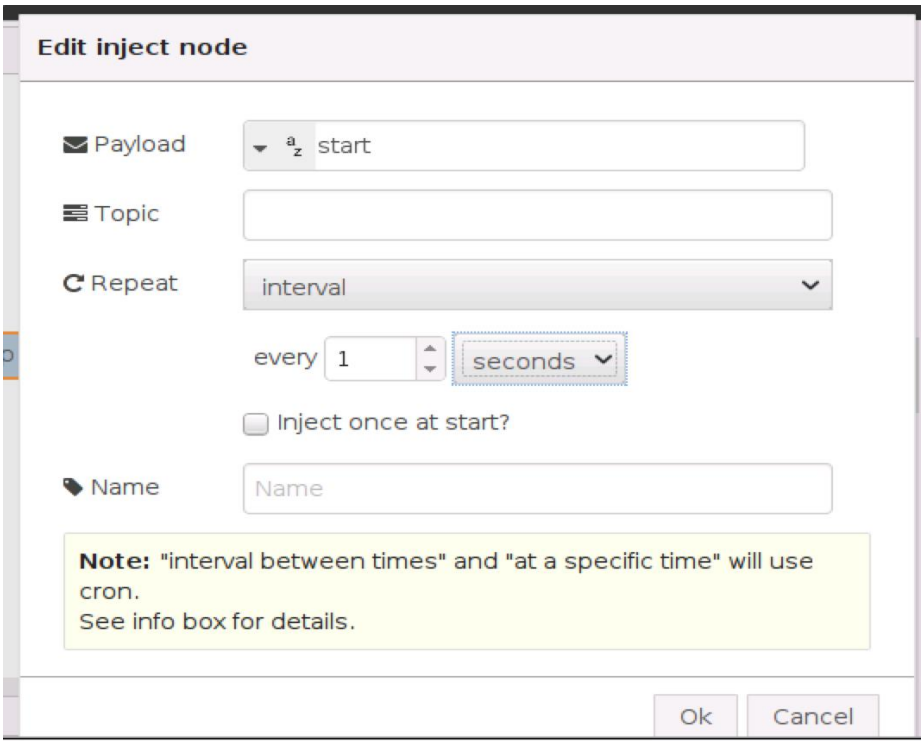

Figure 3.6 : Inject node in Node Red

In the Figure 3.6, user can setting its own interval time on how many seconds, minutes, hours or years. The data will be displayed on the display after the complete circuit fully activated. Besides that, whenever the early partial discharge occurred, the sensor will detect it and the “start” node will keep injecting based on how many interval time the user set in order to see the data.

Next is the channel 1 which that is the node for the analog to digital converter or pi mcp3008 node. There are many types of analog to digital converter but for this project will be use MCP 3008 type. Thus, for the Node Red node of the analog to digital converter use the pimcp3008 node because the node is suitable for it. The setting for the pimcp3008 shown in the Figure 3.7.

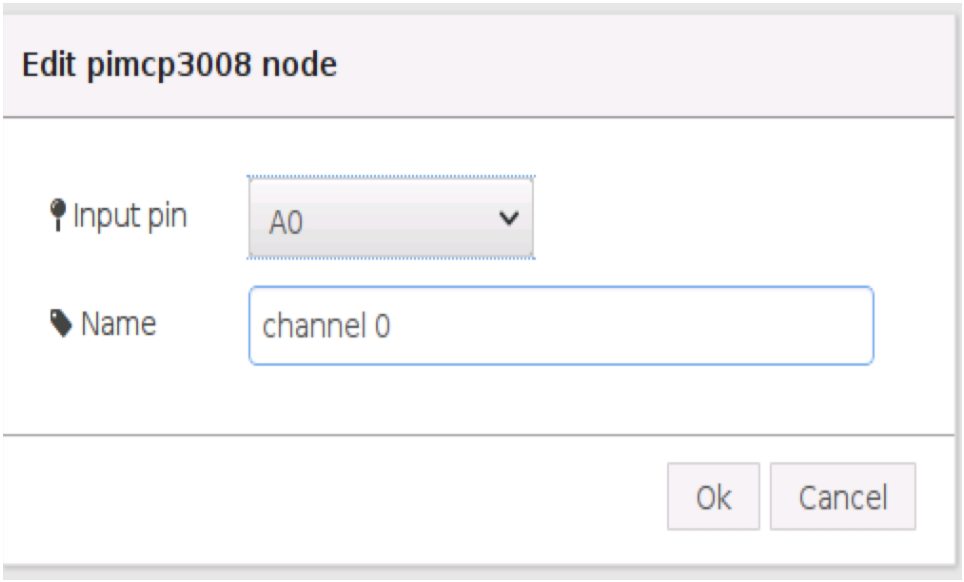

Figure 3.7 : pimcp3008 node for analog to digital converter node.

The input pin of pimcp3008 node can be determined by depending on the datasheet of raspberry pi 3 in order to connect which input pin is suitable for analog to digital converter.

Besides that, in the Figure 3.5 can be seen the function node named sound. In this project, the circuit design for the sound and temperature almost alike. The function node of sound can be changed into temperature due to different coding of each component. Sound have its coding so do the temperature. Both sound and temperature codings was shown in the Figure 3.8 and Figure 3.9 respectively.

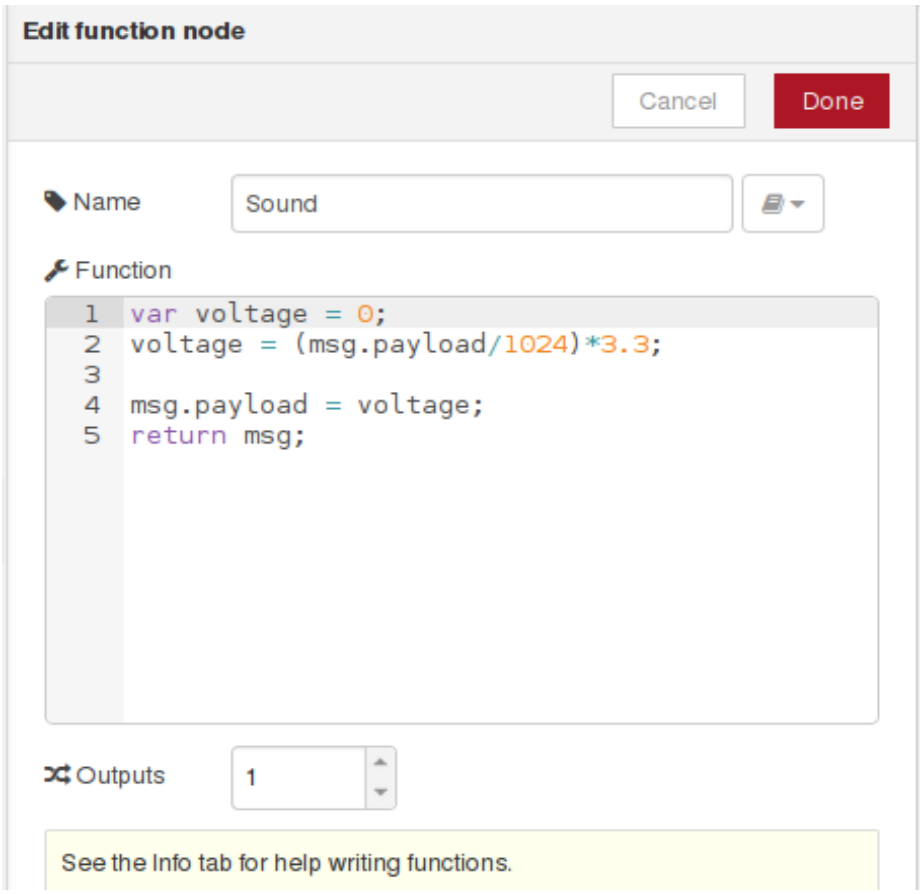

Figure 3.8 : Coding of sound sensor in the function node.

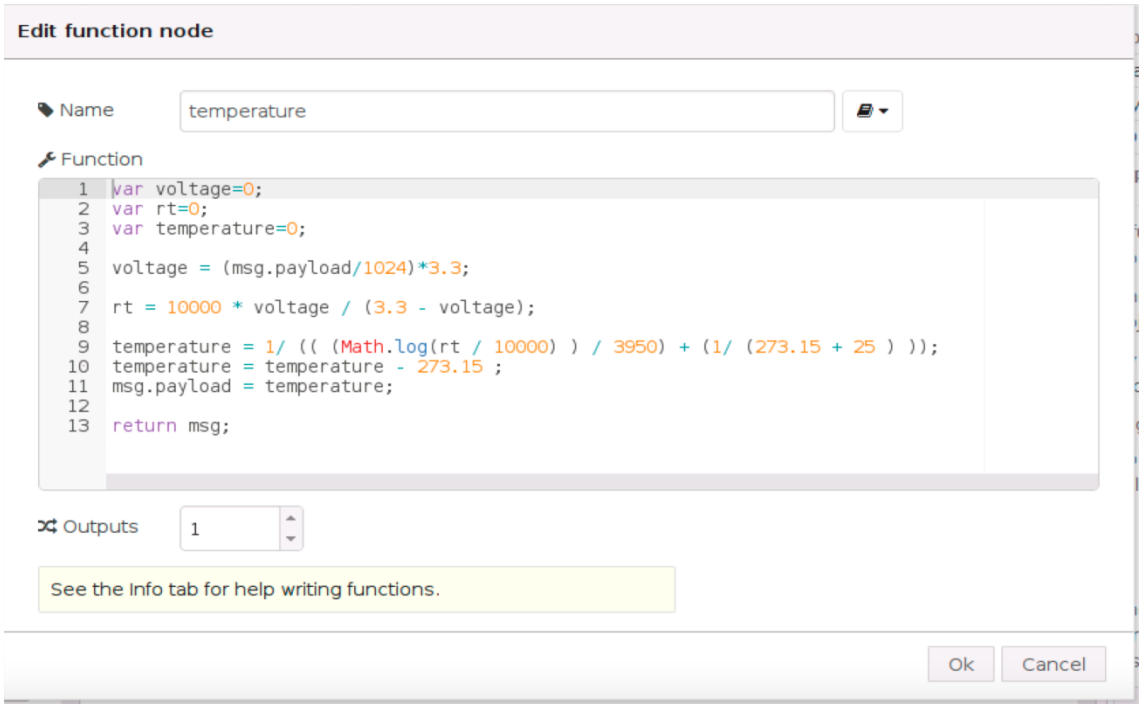

Figure 3.9 : Coding of temperature in the function node.