DESIGN AND DEVELOPMENT OF SMART WATER METER POWERED BY ELECTROMAGNETIC GENERATOR



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND DEVELOPMENT OF SMART WATER METER POWERED BY ELECTROMAGNETIC GENERATOR

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2023

DECLARATION

I declare that this report entitled "DESIGN AND DEVELOPMENT OF SMART WATER METER POWERED BY ELECTROMAGNETIC GENERATOR" is the result of my own work except for quotes as cited in the references.



Author : RENGANATHAN A/L VIJAYAN

Date : 13 JAN 2023

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.



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Date: 13 JAN 2023

DEDICATION

I dedicate this research work to my beloved and cherished father and mother who have always support and gave encouragement to me throughout my education journey, my beloved lecturers who have not felt tired giving guidance and knowledge throughout my education and my precious sibling who have always been supportive and helped through the hardships which I went through. Of course, not to forget my fellow friend who I cherished helped me throughout

my studies and research.

اونيۈم سيتي تيڪنيڪل مليسيا ملاك UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ABSTRACT

The smart water meter powered by an electromagnetic generator is a device that uses the energy generated by the flow of water to power a wireless sensor and a wireless communication module, it is designed to provide real-time information on water usage, while also generating electricity. The smart water meter can be integrated with a smart grid infrastructure, to improve the overall efficiency and sustainability of the energy system.

The design and development of the smart water meter is a multi-stage process that involves conceptual design, simulation design and detailed design, Additionally, simulations and analyses such as AC analysis, DC analysis, turbine analysis, open circuit resistor analysis, and capacitor charging and discharging analysis are performed to understand the performance of the converter and turbine under different conditions and optimize their performance.

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The smart water meter has the potential to reduce the reliance on external power sources, decrease the carbon footprint, promote water conservation and reduce water waste, and integrate with smart city infrastructure.

ABSTRAK

Meter air pintar yang dikuasakan oleh penjana elektromagnet ialah peranti yang menggunakan tenaga yang dijana oleh aliran air untuk menggerakkan penderia wayarles dan modul komunikasi wayarles, bertujuan untuk memberikan maklumat masa nyata tentang penggunaan air sambil turut menjana elektrik. Meter air pintar boleh disepadukan dengan infrastruktur grid pintar bersepadu untuk meningkatkan kecekapan dan kemampanan keseluruhan sistem tenaga.

Reka bentuk dan pembangunan meter air pintar ialah proses pelbagai peringkat yang melibatkan reka bentuk konsep, reka bentuk simulasi, dan reka bentuk terperinci, di samping simulasi dan analisis seperti analisis AC, analisis DC, analisis turbin, analisis rintangan litar terbuka, dan pengecasan kapasitor. Dan lakukan analisis nyahcas untuk memahami dan mengoptimumkan prestasi penukar dan turbin di bawah keadaan yang berbeza.

Meter air pintar mempunyai potensi untuk mengurangkan pergantungan kepada sumber kuasa luaran, mengurangkan jejak karbon, menggalakkan pemuliharaan air dan mengurangkan sisa air, dan menyepadukan dengan infrastruktur bandar pintar.

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LIST OF SYMBOLS AND ABBREVIATIONS

- IoT: Internet of Things
- °C: Degree Celsius
- Kg: Kilogram
- S: Second
- Wi-Fi: Wireless Fidelity
- ESP: Espressif
- L/Min: Litres per Minutes
- V:
 Voltage

 P:
 Power

 I:
 Current

 Vin:
 Input Voltage

 Vout:
 Output Voltage

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CHAPTER 1



1.0 Introduction

The chapter mainly emphasises the background and problem statement of the project, including the objective and scope that have been recognized. Which are also not limited with the discussion of the solution which has been proposed.

1.1 Background of the project

Water is an essential resource for human life and is used for many purposes, including drinking, bathing, cooking, irrigation, and industrial processes. It is necessary to accurately measure and manage water use to ensure it is used efficiently and sustainably.

Traditional water meters are mechanical devices that measure water flow through a pipe and display the total volume of water consumed. These meters must be manually read and recorded by a meter reader, who visits each location to record the reading on the meter. This process can be time-consuming and prone to errors, and it also requires regular visits by a meter reader to each location. In addition, traditional water meters may not provide real-time data on water consumption, making it difficult to detect and address leaks or other issues on time.

Smart water meters offer a solution to these problems by automating the measuring and recording of water consumption. These devices use electronic sensors and communication technology to measure water flow and transmit the data to a central location for analysis and billing purposes. Smart water meters can provide real-time data on water usage and enable early detection of leaks and other issues, improving the efficiency and sustainability of water management.

However, many smart water meters require an external power source, such as a battery or electrical connection, which can be a limiting factor in terms of installation location and maintenance. In particular, this can make it challenging to install smart water meters in remote locations or areas without access to electrical power.

The development of a smart water meter powered by an electromagnetic generator offers a solution to these issues by providing a self-powered device for an automatic meter reading. Electromagnetic generators use electromagnetic fields to generate electricity, which can be used to power the device without the need for external power sources. Electromagnetic generators use magnetism to convert mechanical energy into electrical energy. They have been used for many years to generate electricity and have several advantages over traditional generators, including high efficiency and the ability to generate power in various settings. Furthermore, water flow in the pipe, on the other hand, offers a constant supply of energy. Given the density of water, the amount of energy that can be captured should be sufficient to power all of the essential sensors and data transmission equipment.

1.2 Statement of purpose

This project aims to design and develop a smart water meter powered by an electromagnetic generator. The device will measure and record water consumption in a home or building and transmit that data to a central location for analysis and billing purposes. Using an electromagnetic generator to power the device will allow it to be installed in remote locations or areas without access to electrical energy, making it a more flexible and versatile solution for an automatic meter reading. The project aims to create a device that is accurate, reliable, and easy to install and maintain, with a long lifespan and low cost of ownership.

1.3 Problem Statement

One of the main problems with traditional water meters is that they require manual reading and recording of water consumption. It can be time-consuming and prone to errors, and it also requires regular visits by a meter reader to each location. In addition, traditional water meters may not provide real-time data on water consumption, making it difficult to detect and promptly address leaks or other issues. Smart water meters offer a solution to these problems by automating the measuring and recording of water consumption. However, many smart water meters require an external power source, such as a battery or electrical connection, which can be a limiting factor in terms of installation location and maintenance. The development of a smart water meter powered by an electromagnetic generator addresses these issues by providing a self-powered solution for an automatic meter reading. The use of an electromagnetic generator allows the meter to be installed in remote locations or areas without access to electrical power. It eliminates the need for regular battery replacements or maintenance. It makes the device more flexible and cost-effective to install and maintain.

Moreover, the electromagnetic generator only works with a high volume of water. Therefore, the water turbine generator must be characterized to know more about the working principle of the water turbine. Furthermore, the power produced by the generator won't be enough to power up all sensors. So before assembling all sensors, take note of power usage for each sensor and ensure the generator produces more than enough.

One problem with using energy harvesting technologies, such as electromagnetic generators, for smart water meters is that these technologies may not consistently generate sufficient electricity to power the device. It can be due to factors such as variations in the strength of the electromagnetic field, changes in ambient conditions, or the degradation of the energy harvesting components over time. To overcome this problem, optimizing the design of the electromagnetic generator and the overall system for energy harvesting and storage system in the smart water meter. It could involve techniques such as selecting appropriate materials and components, optimizing the layout and form factor of the device, and implementing effective maintenance and repair processes. Another potential problem is that energy harvesting technologies may be less efficient at generating electricity than other power sources, such as batteries or electrical connections. It could result in a longer payback period for the initial investment in the smart water meter and may make the device less attractive to potential users. To address this issue, optimizing the energy harvesting system to maximize efficiency and minimize the cost of ownership may be necessary. In summary, the main problem with using energy harvesting technologies, such as electromagnetic generators, for smart water meters is the potential for reliability and efficiency issues that may impact the performance and cost-effectiveness of the device.

1.4 Objective

- a) To develop a new energy harvesting system that converts the hydrokinetic energy of natural water flow into usable energy.
- b) To investigate the relationship between fluid flow and the proposed harvester.
- c) To analyze the integration proposed harvester with a Node MCU module.

1.5 Research Question

- a) What materials and components are suitable for the smart water meter, including the electromagnetic generator, flow meter, and communication module?
- b) What are the most effective ways to store and use the electricity generated by the electromagnetic generator in a smart water meter, considering factors such as power demand, battery life, and efficiency?
- c) How does the performance of electromagnetic generators compare to other energy harvestings technologies, such as solar panels or kinetic generators, for use in smart water meters?

UNIVERSITI TEKNIKAL MALAYSIA MELAKA 1.6 Scope of Work

The scope of work for integrating ThingSpeak, a cloud-based platform for the Internet of Things (IoT) data analysis and visualization, with energy harvesting technologies for a smart water meter could include the following activities:

- Research and selection of appropriate materials and components for the smart water meter, including the electromagnetic generator, flow meter, and communication module.
- Research and selection of an appropriate Power management circuit and energy storage system.

- 3. Research and characterize the specific of the electromagnetic generator with water flowrate sensor.
- 4. Research and characterize the specific power management circuit with the electromagnetic generator.
- 5. Design and development of a prototype of the smart water meter incorporating energy harvesting and storage technologies, as well as a communication module for transmitting data to ThingSpeak.



CHAPTER 2



2.0

This chapter corresponds to the reading materials which are purposed for the literature review that will be used to discuss the history, different systems, and the methods functioning of the Smart Water Meter Powered by Itself. Furthermore, this chapter discusses the components used and operation of each previous Smart Water Meter Powered by Itself, conventional water meter and power management circuit. The gathered information from this literature review will be utilized to aid in the application of the following procedure.

2.1 Conventional water measurement meter

According to the United Nations, water usage worldwide has been increasing by about 1% per year since the 1980s and is expected to rise, at a similar rate, up to 30% above the current level by 2050[1]. Predictions suggest that the demand in industrial and domestic sectors will be the primary drivers for demand increase. In Malaysia, most household and factory water uses conventional methods, which use mechanical meters to read the water volume[2]. Water is an essential resource for human life, and it is important to accurately measure and manage water use to ensure it is used efficiently and sustainably[1]. Traditional water meters are mechanical devices that measure water flow through a pipe and display the total volume of water consumed[3].

Conventional water meters consist of a measurement chamber, a dial or display, and a rotating impeller or turbine[3]. As water flows through the meter, the impeller or turbine rotates, registered by the dial or display. The reading indicates the total water consumed on the dial or display. One of the main drawbacks of conventional water meters is that they require manual reading and recording of water consumption. This can be time-consuming and prone to errors, and it also requires regular visits by a meter reader to each location. In addition, conventional water meters may not provide real-time data on water consumption, making it difficult to detect and address leaks or other issues on time. Traditionally, water management companies used fully mechanical water meters with low cost and reliability.

Despite their long history, mechanical meters have significant accuracy and reliability limitations. The issue of accuracy is particularly problematic at low flow rates. Because a sufficient measurement capability is not affordable, mechanical meters typically under measure or do not register any flow at low flow rates. The impact of low-flow accuracy and degrading performance over time is significant. The low-flow performance makes leak detection difficult or impossible despite these limitations. Conventional water meters are still widely used due to their relatively low cost and simplicity of operation.

2.1.1 The principal operation of a conventional water meter

In recent years, water demand has increased in households. Consumer awareness regarding daily water consumption is very low. Traditional water meters cannot get daily consumption efficiently, and water consumption has been calculated monthly[4]. It has been calculated manually. With the advancement of information technology over the past years, some have attempted to enhance manual meter reading to automate within Malaysia.

The working principle of a mechanical meter is based on the measurement of the flow of a fluid through a pipe. These meters typically consist of a measurement chamber, a rotating impeller or turbine, and a dial or display. As the fluid flows through the meter, it causes the impeller or turbine to rot at a rate proportional to the flow rate. This rotation is registered by the dial or display, which indicates the total volume of the fluid that has passed through the meter. Mechanical meters are typically calibrated to a specific unit of measurement, such as cubic feet or liters. The accuracy of the measurement depends on the quality and precision of the measurement chamber and the impeller or turbine, as well as the regularity of the flow. Mechanical meters are generally considered accurate within a few percent of the actual flow. However, the actual accuracy may vary depending on the specific model and the conditions of use.

2.1.2 The disadvantage of the conventional water meter

Even with many pros, conventional water meter has their cons. The disadvantage of conventional water meters is their accuracy. While they are generally considered accurate to within a few percent of the actual water consumption, the accuracy may vary depending on the specific model and the conditions of use. Factors such as wear and tear on the measurement chamber and impeller or turbine, as well as changes in the flow rate, can affect the accuracy of the measurement.

Another disadvantage of conventional water meter is their reliance on manual reading and recording of water consumption. This can be time-consuming and prone to errors, requiring regular visits by a meter reader to each location. In addition, conventional water meters may not provide real-time data on water consumption, making it difficult to detect and address leaks or other issues on time. One of the main issues with mechanical meters is that they can become less reliable over time. Due to factors such as friction and wear-and-tear, the performance of these meters can deteriorate, resulting in the under-measurement of water flow. This leads to a loss of accuracy in the readings, as the meter becomes less effective at measuring water usage.

Finally, conventional water meters may not suit some environments or applications. For example, they may not be able to withstand extreme temperatures, high pressure, or other harsh conditions, which can affect their accuracy and lifespan. In addition, they may not be compatible with certain water treatment systems or other equipment.

Overall, while conventional water meters have some advantages, their limitations make them less suitable for some applications compared to other types of water meters, such as smart water meters, which use electronic sensors and communication technology to automate the process of measuring and recording water consumption.

2.2 Electronics based water measurement meter

The current method of utility billing used by providers often results in inefficient workforce deployment, leading to situations where customers cannot have their meters read. In these cases, bills are calculated using an average monthly reading, which may not accurately reflect the customer's actual consumption. This can result in higher customer charges in certain tariff categories when their actual consumption exceeds the estimated monthly amount[5]. These

customers have been instructed to read their meters themselves and inform a substation after receiving the monthly bill for alteration. This will be an extra cost to the billing as an officer has to be appointed to solve these matters. In many parts of the world, analog water meters have been installed by water companies to measure the consumer's water consumption. These water meters are read monthly by an authorized employee, and the consumer's bill is computed based on the approval rates according to the amount of water consumed. Sometimes the customer premises are not easily accessible, and consumption estimates must be used to compute the water bill. This approach is error-prone as accuracy cannot be guaranteed. The manual data collection method is also expensive, labour-intensive, and inefficient.

Electronic water meters typically consist of a flow meter, a microprocessor, a communication module, and a power source. The flow meter measures the flow of water through the meter using a variety of technologies, such as ultrasonic sensors, magnetic field sensors, or pressure sensors[6]. The microprocessor processes the data from the flow meter and calculates the total volume of water consumed. The communication module transmits the data wirelessly to a central database or cloud-based platform, where it can be analyzed and visualized. The power source, which may be a battery or an energy harvesting technology, provides the necessary power for the electronic components of the meter.

New Zealand families have been using this system on electricity meters. Power distribution companies do not need staff to come to read the meter, and the meter reading will be automatically transferred back to the server[7], improving the efficiency of transcribing. Watercare, the water conservancy company in New Zealand, is still using the traditional mechanical water meter, which needs transcribing by human beings, with low efficiency and huge salary expenses. Applying AMR technology to the water meter, one of the important problems needing to be solved is to realize smart water meters. This provides a good opportunity for research on intelligent water meters.

2.2.1 The principal operation of an electronic-based water meter

The principle of operation for an electronic water meter, also known as a smart water meter, is based on measuring and recording water flow through a pipe using electronic sensors and communication technology[1]. These meters typically consist of a flow meter, a microprocessor, a communication module, and a power source. The data from the flow meter is then processed by the microprocessor, which calculates the total volume of water consumed based on the flow rate and the time elapsed. The communication module transmits the data wirelessly to a central database or cloud-based platform[5], where it can be analyzed and visualized. The power source, which may be a battery or an energy harvesting technology, provides the necessary power for the electronic components of the meter.

One of the main advantages of electronic water meters is their accuracy and reliability. They use advanced sensors and processing technology to provide highly accurate water consumption measurements[3], and they can operate continuously without needing manual reading or recording. In addition, electronic water meters provide real-time data on water consumption, which can be used to detect and address leaks or other issues on time. Overall, the principle of operation for an electronic water meter is based on the continuous measurement and recording of the flow of water using advanced sensors and processing technology, which enables the meter to provide accurate and reliable data on water consumption in real-time.

Recently developed fully electronic water meters use advanced measurement techniques such as electromagnetic, fluidic, and ultrasonic methods. The electromagnetic method utilizes the induced electromotive force produced by the fluid passing through a magnetic field to measure velocity, while the fluidic method uses the Coanda effect to establish an oscillation frequency proportional to fluid velocity. An ultrasonic water meter uses ultrasonic sound waves to detect fluid velocity. These fully electronic water meters offer improved measurement accuracy compared to mechanical ones, making them a promising solution for enhancing water supply management in smart cities. As shown in Figure 2.1, electromagnetic meters, and in Figure 2.2, fluidic effect meters require a specially designed chamber to create a fluctuating pressure sequence that causes the water flow to oscillate[2]. During this process, electrodes are placed to detect magnetic force and estimate the water flow rate. Ultrasonic meters, including transmit time meters and Doppler effect meters, adopt ultrasonic sensors to measure water flow.



2.3 Types of Water Flow Meters EKNIKAL MALAYSIA MELAKA

Water flow meters are devices used to measure water flow through a pipe or channel. Several water flow meters are available, each with unique features and benefits. Overall, the choice of water flow meter depends on the specific needs and requirements of the application and should be carefully considered based on factors such as accuracy, cost, convenience, and compatibility with other systems and equipment.

2.3.1 Mechanical Flow Meters



Figure 2.3 Mechanical water meter

They are the most common and economical type of water flow meters, which perform flow measurement through turbine rotation with a shunt, propeller, or paddle wheel design. The mechanical types of water flow meters, as shown in Figure 2.3, work by measuring the speed of water flowing through the pipe that causes a piston or turbine to rotate. The volumetric flow rate of the water is proportional to the rotational speed of the blades[1]. The disadvantage of mechanical water flow meters for water measurement is that they may clog up when the water is dirty or contain larger particles, which leads to increased maintenance costs. Mechanical water meters also do not work well when there is low water flow. Mechanical meters are positive displacement flow meters[1]. They isolate and count known fluid volumes while feeding them through the meter. Flow measurement is obtained by counting the number of passed isolated volumes. These meters are suited for measuring clear water with little turbidity and are generally less expensive than non-mechanical types. Hence these are commonly used in urban water supply systems. However, they have a higher maintenance requirement.

2. 3.2 Vortex Flow Meters



Figure 2.4 Vortex water flow meter

A vortex meter is a volumetric flow meter that uses a natural phenomenon that occurs when a liquid flows around a bluff object. Vortex flow meters operate under the shedding principle, where vortices (or eddies) are shed alternately downstream of the object[8]. The vortex shedding frequency is directly proportional to the velocity of the liquid flowing through the meter. Vortex flow meters are best suited for flow measurements where the introduction of moving parts presents problems. They are available in industrial grade, brass, or all-plastic construction. Sensitivity to variations in the process conditions is low and, with no moving parts, relatively low wear compared to other flow meters. Vortex, as shown above in Figure 2.3.2.1, uses vortices shed from a sensor immersed in the flow. Vortices are forces of nature, "swirls" produced when a fluid moves past an obstruction, like the wind past a flagpole or water flowing around a rock in a stream[8]. In a vortex meter, a sensor tab flexes from side to side when each vortex flows past, creating a frequency output directly proportional to the volumetric flow rate. Multivariable vortex flow meters can measure up to five process variables with one process connection: temperature, pressure, density, mass flow, and volumetric flow

rate. Insertion vortex meters work well on very large pipes as they can be inserted into the flow by hot tapping with a retractor[8].

Flow Rate (vol/sec) =
$$\frac{Vortex Frequency(p/sec)}{K-Factor(p/vol)}$$
 2.1

2. 3.3 Ultrasonic Flow Meter

Ultrasonic water flow meters, as shown below in Figure 2.5, measure the speed of fluid passing through the pipe using ultrasound to measure the volumetric flow. In a transit-time ultrasonic liquid flow meter, an ultrasonic signal is transmitted in the direction of the flowing fluid downstream. Then another signal is transmitted against the flowing fluid upstream[9]. In its most basic form, the time for the sonic pulse to travel downstream is compared to the time for the pulse to travel upstream. Using this differential time, the velocity of the following fluid is calculated. Then the meter calculates the volumetric flow rate in the pipe using this fluid velocity. In addition, BTU energy measurement can be derived from the volumetric flow rate and the temperature difference between the hot and cold legs[9]. Clamp-on ultrasonic meters can measure water from outside of the pipe by shooting pulses of sound through the pipe walls, thus having application flexibility and making them suitable for water flow measurements in large pipes. An ultrasonic water meter uses an ultrasonic transducer to send ultrasonic sound waves through the fluid to determine the velocity and translate the velocity into the water volume measurement[9]. The ultrasonic meter has a sensor that can be inserted inside or attached outside the pipe. The sensor measures the pipe's water velocity and converts this into flow rate.



Figure 2.5 Ultrasonic Flow Meter

2. 3.4 Magnetic Flow Meter

Magnetic flow meters, as shown below in Figure 2.6, measure the speed of a fluid passing through a pipe using a magnetic field to measure the volumetric flow. They are based on the principle of Faraday's Law of Electromagnetic Induction, according to which liquid generates a voltage when it flows through a magnetic field[9]. The more rapid the fluid flow, the more the voltage generated. The voltage produced is directly proportional to the water movement; the voltage signal is processed into the volumetric flow rate by the electronics. Since the magnetic flow meters show an intermediate accuracy, they are unsuitable for custody transfer applications. They cannot be used to measure pure water as there are no ions to measure. An electromagnetic meter is a non-mechanical meter mainly used in urban, wastewater, and industrial systems. This is also known as a mag flow meter. Technologically, these are velocitytype water meters, except that they use an electromagnetic system to determine the water flow velocity. Mag meter uses the principle of Faraday's law of induction for measurement and requires AC or DC electricity from a power line or battery to operate the electromagnets[9]. Since Mag meters have no mechanical measuring element, they can normally measure flow in both directions and use electronics to measure and totalize the flow. Mag meters can also be useful for measuring raw (untreated/unfiltered) water and wastewater since there is no mechanical measuring element to get clogged or damaged by debris flowing through the meter.



Figure 2.6 Magnetic flow meters

2.4 Energy generate in relation to water flow

The output voltage of a smart water meter powered by an electromagnetic generator is directly related to the water flow rate. The electromagnetic generator in the water meter converts the kinetic energy of the flowing water into electrical energy, and the output voltage is proportional to the water flow rate.

An equation that relates the output voltage to the water flow rate can be derived from the laws of physics. The basic principle is that the power generated by the generator is equal to the water flow rate multiplied by the head (difference in water pressure) and the turbine's efficiency. The formula for power can be written as follows [15]:

$$P = Fw x L x E$$
 2.2
e of the generator can be represented as the power generator

The output voltage of the generator can be represented as the power generated divided by the current, which can be represented as:

Therefore, the output voltage of the smart water meter is directly proportional to the water flow UNIVERSITI TEKNIKAL MALAYSIA MELAKA rate, head, and turbine efficiency and inversely proportional to the current[16].

Where P is the power, L is the dimension of the head, E is the turbine efficiency.

2.5 Energy Harvesting

In the environment around us, we can "harvest" tiny amounts of dissipating energy and use it as available electric energy[14]. This technology is known as energy harvesting. It is also attracting attention as a technology for achieving Goal 7 ("Ensure access to affordable, reliable, sustainable and modern energy for all") of the Sustainable Development Goals (SDGs) and strengthening the resilience of our society[13]. Energy harvesting, also known as power harvesting or energy scavenging, captures and stores small amounts of energy from the environment that would otherwise be wasted[11]. This energy can then be used to power small electronic devices or to recharge batteries. Energy harvesting can revolutionize how we power our devices and systems, as it offers a way to generate electricity without needing external power sources or batteries.

There are many ways to harvest energy, including solar panels, wind turbines, kinetic energy, and thermoelectric generators[17]. Solar panels use photovoltaic cells to convert sunlight into electricity, while wind turbines use the kinetic energy of moving air to generate electricity. Kinetic energy generators capture the energy of movement, such as the movement of a person's body or the flow of water. In contrast, thermoelectric generators convert the difference in temperature between two materials into electricity. One of the main benefits of energy harvesting is that it allows us to generate electricity in a sustainable and renewable way. Instead of relying on finite fossil fuels that produce greenhouse gases when burned, energy harvesting captures energy from constantly replenished sources, such as the sun and wind. This makes it an attractive alternative to traditional power sources, particularly in remote or hard-to-reach areas where it is difficult to access electricity from the grid. Another benefit of energy harvesting is that it can power small electronic devices and systems requiring batteries. This can save money, reduce the environmental impact of disposing of used batteries, and make it possible to power devices in areas where it is not practical to replace batteries.

In conclusion, energy harvesting is a promising technology that has the potential to revolutionize the way we generate and use electricity. By capturing and storing small amounts of energy from the environment, we can power our devices and systems in a sustainable and renewable way while also reducing our reliance on batteries and fossil fuels[18].


Figure 2.7 Survey of energy harvesting technologies

2.5.1 ENERGY HARVESTING TECHNOLOGIES



Figure 2.8 Scale of Energy Harvesting

Many types of energy sources can be used as energy harvesting sources. There are two ways for their categorization, considering who or what provides the energy for conversion and what type of energy is converted. Table 2.1 relates the two categorization schemes

Energy Source	Type of Energy

Living body	Kinetic, thermal, piezo, metabolic energy		
	blood sugar energy		
Environment	Kinetic, thermal, vibration, radiation		

The literature inspection shows that any single energy scavenging source is not adequate for all applications and should be application specific. Before going into details, we presented and summarized the resources according to their characteristics. Table 2.2 shows a general overview of ambient energy sources with their power generation capability.

Energy source	Types	Energy harvesting	Power density	
and the	ALAYSIA ME	method		
Radiant	Solar	Solar cells (indoors)	< 10 µW/cm2	
E.		Solar cells (outdoors,	15 mW/cm2	
(AEB)	Nn .	sunny day)		
الاك	بکل ملیسی ^R F	Electromagnetic	0.1 μW/cm2 (GSM)	
UNIV	ERSITI TEKNIKA	conversion "	LAKA	
Mechanical	Wind flow and hydro	Electromagnetic	16.2 µW/cm3	
		conversion		
	Acoustic noise	Piezoelectric	960 nW/cm3	
	Motion	Piezoelectric	330 µW/cm3	
Thermal	Body heat	Thermoelectric	40 µW/cm2	

Table 2.2 Energy scavenging Sources[18]

2.5.2 Electromagnetic Energy Harvesting

There is a large amount of electromagnetic energy transmitted by communication devices; we need to tap into it. Some scavenging devices can capture this energy, convert it from AC to DC, and then store it in capacitors and batteries or be used as a power source. An ultra-

wideband antenna can exploit various signals in different frequency ranges, providing greatly increased power-gathering capability. The maximum output voltage and power are up to 3.2 mV and 3.2 μ W, respectively, for 14 μ m exciting vibration amplitude and a 0.4 mm gap between the magnet and coils[13].

Electromagnetic energy harvesting, as shown in Figure 2.9, captures and stores small amounts of energy generated by electromagnetic fields in the environment. It works by using an electromagnetic generator, which is a device that converts electromagnetic energy into electricity, to capture and store the energy[14]. Electromagnetic energy harvesting systems typically consist of an electromagnetic generator, a power management circuit, and a storage device such as a battery or capacitor. The electromagnetic generator captures the electromagnetic energy and converts it into electricity, which is then managed by the power management circuit. The power management circuit regulates the flow of electricity and ensures it is at the storage device's correct voltage and current level. The electricity is then stored in the storage device. One of the main challenges of electromagnetic energy harvesting is that the amount of energy that can be captured is typically small and may not be sufficient to power larger electronic devices. However, advances in electromagnetic generator technology and energy storage technologies are helping to improve the efficiency and effectiveness of electromagnetic energy harvesting systems.

In conclusion, electromagnetic energy harvesting is a technology that allows for the capture and storage of energy generated by electromagnetic fields in the environment. It has several potential applications and can help to reduce reliance on external power sources or batteries. While there are challenges to overcome, advances in electromagnetic



Figure 2.9 Working Principle of Electromagnetic Energy Harvesting 2.6 Self-powered water meter

In more recent times, many researchers have developed smart meters. A smart meter can be used for irrigation systems and residential and industrial water consumption[6]. A self-powered water meter is a device that measures the flow of water and calculates the amount of water being used. It is designed to operate without needing an external power source, instead relying on an onboard energy harvesting system to generate electricity to power the meter.

One of the key components of a self-powered water meter is the DC-DC converter, as mentioned in Power Management controls in Figure 2.10, which is used to regulate the flow of electricity from the energy harvesting system to the other components of the meter. The DC-DC converter adjusts the voltage and current of the electricity to ensure that it is at the correct level for the other components. Several types of DC-DC converters can be used in a selfpowered water meter, including buck converters, boost converters, and flyback converters[6], [13]. Each type of converter has its own unique set of characteristics and is well-suited for different types of energy harvesting systems and loads.

DC-DC circuits are typically implemented using integrated circuits (ICs) that contain the necessary circuitry and control logic to perform the voltage conversion. These ICs are readily available from various manufacturers and are widely used in various applications, including energy harvesting systems. Overall, the DC-DC converter is a critical component of a self-powered water meter, as it helps to regulate and manage the flow of electricity from the energy harvesting system to the other components of the meter. It ensures that the meter receives a stable power supply and can operate continuously without interruption.



Figure 2.10 Power Management Circuit

2.6.1 Boost Converter

As shown below in Figure 2.11, a boost converter is a DC-to-DC converter commonly used in energy harvesting systems to convert a lower-voltage DC source to a higher-voltage DC output. This is useful for powering electronic devices that require a higher voltage power supply, such as LED lights or motors.

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The basic principle of a boost converter is similar to that of a buck converter. It uses a switch, typically a MOSFET, to periodically short the input voltage and store the energy in an inductor. The switch is then opened, and the energy stored in the inductor is transferred to the output load through a diode. The converter's output voltage can be regulated by carefully controlling the switch's duty cycle 20]. However, unlike a buck converter which reduces the input voltage, a boost converter increases the input voltage to produce a higher output voltage. This is achieved by reversing the direction of the current through the inductor during the switch-on period, causing the output voltage to be boosted.

One of the main advantages of using a boost converter in an energy harvesting system is its ability to increase the output voltage beyond the input voltage[20], [21]. This can be useful when the energy source, such as a solar panel or vibration energy harvester, has a low voltage output that is insufficient to power the load. One of the main benefits of a boost converter is that it can step up the input DC voltage by a large factor, making it well-suited for energy harvesting systems where the available input voltage is low. It can also operate over various input and output voltages, making it flexible and adaptable to various applications.

A boost converter typically consists of an inductor, a switch, and a diode, as well as control circuitry to regulate the switching of the inductor. It may also include other components, such as a capacitor to smooth out the output voltage or a voltage feedback loop to maintain a constant output voltage[21].

The basic equation for calculating the output voltage of a boost converter is[13]:

$$Vo = Vin * (1 + (D / (1 - D)))$$

Where Vin is the input voltage, D is the duty cycle (ratio of on-time to total period), and Vo is the output voltage. **VERSITI TEKNIKAL MALAYSIA MELAKA**

2.4

The input current can be calculated using the following equation:

$$Iin = (Vo * Io) / Vin \qquad 2.5$$

Where Iin is the input current, Io is the output current, and Vin and Vo are as defined above.

Another advantage of the boost converter is its high efficiency, particularly at low input voltages. By carefully selecting the components and optimizing the control strategy, it is possible to achieve conversion efficiencies of over 90%. Overall, the boost converter is a valuable tool for energy harvesting systems. It allows them to efficiently and effectively convert and deliver power to electronic devices requiring a higher voltage power supply.



Figure 2.11 Boost Circuit

2.6.2 Buck Converter

As shown in Figure 2.12, a buck converter is a power electronic circuit commonly used for energy harvesting. It is a DC-to-DC converter designed to efficiently convert a higher DC voltage to a lower DC voltage. Energy harvesting is collecting and storing energy from various sources, such as solar panels or kinetic energy generators, to power electronic devices. One of the challenges of using energy harvesting systems is that the energy collected may vary greatly depending on the source and the environment. For example, the amount of energy collected by a solar panel may vary depending on the time of day, weather conditions, and the panel's angle.

A buck converter is well-suited for energy harvesting applications because it can

efficiently convert a wide range of input voltages to a stable, regulated output voltage. It uses a switching element, such as a transistor, to rapidly switch the input voltage on and off. The switching frequency is typically much higher than the input voltage frequency, allowing the converter to average the input voltage and produce a smooth, stable output voltage[11], [13].

One of the main advantages of a buck converter is its high efficiency. It can achieve efficiency levels of up to 95%, making it an ideal choice for energy harvesting applications where maximizing energy efficiency is critical[18]. Another advantage is its ability to handle high power levels, making it suitable for powering larger electronic devices. Overall, the buck

converter is a valuable tool for energy harvesting systems, allowing them to efficiently and effectively convert and deliver power to low-power electronic devices.

The basic equation for calculating the output voltage of a buck converter is:

Where Vin is the input voltage, D is the duty cycle (ratio of on-time to total period), and Vo is the output voltage.

The output current can be calculated using the following equation:

$$Iout = (Vin * Iin) / Vout 2.7$$

Where Io is the output current, and Iin is the input current

The input current can be calculated using the following equation:

Where Iin is the input current, and Io is the output current

In conclusion, a buck converter is an important tool for energy harvesting applications, as it efficiently converts a wide range of input voltages to a stable, regulated output voltage. Its high efficiency and ability to handle high power levels make it a practical choice for powering electronic devices using energy harvested from various sources.



Figure 2.12 Buck Converter

2.6.3 Smart Integrated Circuits (ICs)

Smart Integrated Circuits (ICs) for Energy Harvesting is a revolutionary technology that allows for the efficient collection and conversion of energy from various sources, such as solar, wind, and kinetic energy. These ICs are designed to optimize the performance of energy harvesting systems and provide a reliable source of power for a wide range of applications.

One key advantage of smart ICs for energy harvesting is their ability to optimize energy collection and conversion. Using advanced algorithms and sensors, these ICs can detect and track the most efficient energy sources, ensuring that the maximum amount of energy is collected and converted[18]. This is particularly important in environments where energy sources may be intermittent or unstable, as the smart ICs can adjust to changing conditions in real time.

Another benefit of smart ICs is their ability to store and manage collected energy. These ICs often include advanced storage systems, such as batteries or supercapacitors, which allow for the efficient storage of collected energy. This stored energy can power many devices and systems, even when the primary energy source is unavailable. Smart ICs also have the potential to improve the reliability and durability of energy harvesting systems significantly. By constantly monitoring and optimizing the energy flow, smart ICs can help to prevent the system from overloading or malfunctioning[12], [23]. This can help reduce maintenance costs and extend the system's lifespan.

Smart ICs for energy harvesting is also highly efficient, with many designs achieving conversion efficiencies of over 90%. This means that a large portion of the collected energy can be used rather than lost during the conversion process. This high efficiency is particularly important in applications where energy is at a premium, such as in remote or off-grid locations. Overall, smart ICs for energy harvesting is a powerful technology that allows for the efficient

collection and conversion of energy from various sources. These ICs can optimize energy collection and conversion, store and manage collected energy, and achieve high levels of efficiency, making them an essential component of many energy harvesting systems.

In conclusion, the use of smart ICs in energy harvesting systems has the potential to greatly improve the efficiency, versatility, and reliability of these systems

2.7 Capacitor



UNIVERS Figure 2.13 Type of Capacitors A MELAKA

In energy harvesting systems, capacitors can store energy from renewable sources such as solar, wind, or kinetic energy. These systems typically use small, low-power energy sources to charge the capacitor. Capacitors are widely used in energy harvesting systems because they store and release electrical energy as needed. They are made up of two conductive plates separated by an insulating material called a dielectric, as shown below in Figure 2.13 When a voltage is applied to the capacitor, it stores energy in the form of an electric field between the plates. The amount of energy a capacitor can store is directly proportional to the metal plates' surface area and the dielectric's thickness[7], [24]. This stored energy can be released back into an electrical circuit when needed.

Several types of capacitors are commonly used in energy harvesting systems, including ceramic, polyester, and tantalum. Each type has its unique characteristics and is suitable for different applications.

Ceramic capacitors are made from layers of ceramic material and are known for their high dielectric strength and stability. They are often used in energy harvesting systems due to their high capacitance, which allows them to store a large amount of energy in a small package. They are also relatively inexpensive and have a long lifespan, making them a cost-effective choice for many energy harvesting applications. Polyester capacitors, also known as film capacitors, are made from layers of thin plastic film and are known for their high stability and low dissipation factor[10]. They are often used in energy harvesting systems that require a high level of precision, such as those that use piezoelectric generators to capture kinetic energy. Tantalum capacitors are made from a porous tantalum material and are known for their high capacitance and low leakage current[17]. They are often used in energy harvesting systems that require a high level of reliability, such as those used in critical infrastructure or military applications.

One of the benefits of using a capacitor for energy storage is its ability to charge and

discharge very quickly. This makes it well-suited for applications where rapid changes in power demand are expected[11]. Capacitors also have a relatively long lifespan, making them a durable and reliable choice for energy storage. This makes them particularly useful in applications where the energy source is intermittent or variable, such as water turbines which only generate electricity when the water is flowing.

This makes them well-suited for use in applications that require rapid bursts of energy, such as powering IoT or other devices that only need a small amount of power for short periods. Another advantage of using capacitors for energy storage is their low cost compared to other energy storage devices such as batteries. While batteries have a higher energy density[11], they are also more expensive and have a limited number of charge/discharge cycles before they need to be replaced. Another benefit of capacitors in energy harvesting systems is their durability and long lifespan. Many types of capacitors can withstand harsh environments and have a lifespan of several decades, making them a reliable choice for long-term energy storage.

In a turbine generator, a capacitor can be used as a storage device for excess electrical energy that is generated. For example, when a wind turbine generates more electricity than is used, the excess energy can be stored in a capacitor for later use. There are several advantages to using a capacitor as a storage device for a turbine generator[1]In addition, capacitors have a relatively high energy density, meaning they can store a large amount of energy in a small space. This is especially useful when space is at a premium, such as in a wind turbine.

Another advantage of using a capacitor as a storage device is that it does not suffer from degradation over time, as with other energy storage devices[13], [17]. This means it can be used for long periods without needing maintenance or replacement.

Overall, capacitors are a vital component of energy harvesting systems, providing a means of storing and releasing energy as needed. Their versatility and reliability make them popular for various applications, from small-scale solar panels to large-scale kinetic energy generators.

2.7.1 Capacitor Charging&Discharging

A capacitor is a passive electronic component that stores electrical energy in an electric field. When a voltage is applied across the terminals of a capacitor, it begins to charge. The rate at which the resistance determines a capacitor charges in the circuit and the capacitance of the capacitor.The formula for charging a capacitor is :

$$Q(t) = Q_0 * (1 - e^{(-t / (R * C))})$$
 2.9

$(\tau = \mathbf{R}^*\mathbf{C}) \tag{2.10}$

where Q(t) is the charge on the capacitor at time t, Q_0 is the initial charge on the capacitor, R is the resistance in the circuit, and C is the capacitance of the capacitor.

The exponential term $(e^{(-t / (R * C))})$ represents the rate of charge on the capacitor, with the time constant representing the time it takes for the capacitor to charge 63.2% of the difference between its initial charge and its final charge. The time constant is the product of resistance and capacitance. The larger the time constant, the slower the capacitor charges.

When the voltage is removed from the capacitor, it begins to discharge. The rate at which the resistance also determines a capacitor discharges in the circuit and the capacitance of the capacitor. The formula for discharging a capacitor is

$$Q(t) = Q_0 * e^{(-t/(R * C))}$$
 2.1

where Q(t) is the charge on the capacitor at time t, Q_0 is the initial charge on the capacitor, R is the resistance in the circuit, and C is the capacitance of the capacitor.

The exponential term ($e^{(-t/(R * C))}$) represents the rate of discharge on the capacitor, UNIVERSITI TEKNIKAL MALAYSIA MELAKA with the time constant representing the time it takes for the capacitor to discharge 63.2% of its initial charge. The time constant is the product of resistance and capacitance. The larger the time constant, the slower the capacitor discharges.

2.8 Internet of Things (IoT) and similar transmissions

The Internet of things is the revolution of the Internet, which will make the world smarter. A wide range of physical objects is connected over the Internet, allowing them to think and communicate without requiring human-to-human or human-to-machine interaction. IoT is an emerging global technology in which things can be connected and controlled remotely[5]. Many industrial and domestic IoT applications, such as automated monitoring, control,

management, and maintenance, have been developed and deployed in recent years. Actuators and Sensors are becoming more and more powerful, cheaper, and smaller, which makes their use pervasive. The information gathered by sensors is transformed into intelligent information, thus engrafting intelligence into our environment. In addition, the IoT will involve billions of devices that can report their location, identity, and history over wireless connections. With installed sensors, cities can optimize revenue, parking space availability, electricity, and water[3]. IoT will Optimize operations, boost productivity and save industry resources and costs. People can remotely monitor and manage their homes and reduce monthly bills and resource usage. Below is Figure 2.14 show the Power consumption of the Internet of Thing



Figure 2.14 Power consumption of the Internet of Things (IoT) and similar transmissions

CHAPTER 3



3.0 Introduction

This chapter will concentrate and expand on how the flow of experiments and procedural steps required to achieve the specified objective of the study can be carried out. The primary feature of the technique was included in the approach to complete and complete the overall analysis. The key subject of the chapter on methodology will also be discussion of raw materials, characterization, for sample preparation, and sample analysis.

3.1 Flow Chart of the process



Figure 3.1 Flow Chart of the Project

A smart water meter powered by an electromagnetic generator is a device that combines a water meter with an electromagnetic generator to generate electricity from the flow of water. The generated electricity is used to power the electronic systems and communications module of the meter, allowing it to transmit data on water usage to a remote monitoring system. The flow chart of this project can be described as follows:

The first step in the flow chart is the water flow through the meter. Water flows through the meter and spins the turbine or other power generation mechanism, which generates electricity. This is the starting point of the flow chart, as the water flow is the driving force behind the entire system.

The second step is the Dc-Dc converter. It can convert the voltage produced to a regulated voltage to power up other electronic devices. The third step is to store the voltage or filter it with a capacitor from Dc-Dc circuits. The Dc-Dc circuit can be Boost, Buck, or smart ICs, so these steps depend on the ICs used.

The fourth to sixth step is powering up the microcontroller and connecting it with local Wi-Fi to transmit the data to IoT Cloud. Powering up the NodeMCU chip is easy compared to connecting it to Wi-Fi. So, step three is to burst the current from the capacitor, so each time a burst happens in the capacitor, data is transmitted to the IoT cloud.

Additionally, simulations and analyses such as AC analysis for a DC-DC converter, DC analysis for a DC-DC converter, turbine analysis, open circuit resistor analysis, and capacitor charging and discharging analysis are performed to understand the performance of the converter and turbine under different conditions and optimize their performance.

3.2 Block Diagram



Figure 3.2 Block Diagram for the proposed system

The electromagnetic generator generates electricity, which is then managed by the power management circuit. The microcontroller is a central processing unit responsible for connecting with Wi-Fi. The power management circuit is responsible for regulating the flow of electricity from the generator and ensuring that it is at the correct voltage and current level for the other components of the smart water meter—the power management circuit powers up the microcontroller to send an IoT signal.

3.3 Hardware

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Below are the components used and methods to make the parts work accurately and properly based on the proposed project and to ensure the system functions based on the idea which has been confirmed. Each component has its procedure to ensure it functions and how the system's requirement is accomplished with the elements.

3.3.1 Water Flow Sensor (YF S201)

The Flow Sensor is a device that detects and measures water flow through pipes. The water flow meter works with the flow sensor to calculate water flow[3]. The water flows through the rotor blade; Rotor will start to rotate. Thus, pulses produce an output frequency directly proportional to the volumetric flow rate/total flow rate through the meter. Figure 3.3.1 shows

the Water Flow sensor diagram. The water flow sensor consists of a pinwheel sensor that measures the quantity of liquid passed through it. The Working of the YF-S201 water flow sensor is simple to understand. The water flow sensor works on the principle of the hall effect. Hall effects are the production of the potential difference across an electric conductor when a magnetic field is applied in a direction perpendicular to that of the flow of current[21]. The water flow sensor is integrated with a magnetic hall-effect sensor, which generates an electric pulse with every revolution. Its design is such a way that the hall effect sensor is sealed off from the water, allowing it to stay safe and dry. Figure 3.3.1.2 show the block diagram of the water flow sensor.



UNIVERSITY Figure 3.3 Water Flow Sensor



Figure 3.4 Water Flow Sensor Block Diagram

3.3.1.1 Arithmetic

Flow rate can be determined by relating it to different techniques like change in velocity. The flow rate can vary according to the velocity of the water. Velocity will be dependent on the pressure through the pipelines. The pipe's cross-sectional area is known and remains constant. The average velocity is an indication of the flow rate. The basic relationship for determining the liquid flow rate in such a case is $Q = V \times A$...equation 2.11[2]

where Q = flow rate/total flow rate of water through the pipe.

V = average velocity of the flow

A = cross-sectional area of the pipe. (viscosity, density, and friction of the liquid in contact with the tube also influence the flow rate of water)

Pulse frequency (Hz) = $7.5 \times Q$, Q is the flow rate in Litres/minute

Flow Rate (Litres /Hour) = $\frac{Pulse Frequency \times 60 \text{ minutes}}{7.50}$

3.3.2 Electromagnetic Generator



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Figure 3.5 Electromagnetic Generator

Micro hydro is a hydroelectric power that typically produces electricity using the natural water flow. Installations below 5 kW are called pico hydro. Figure 3.5 shows the micro hydro turbine, called an electromagnetic generator. These installations can provide power to an isolated home or small community, or are sometimes connected to electric power networks, particularly

2.11

where net metering is offered. A hydro turbine is a rotating machine that transforms the energy of the water flow into the energy of the rotating shaft[12]. When water flows through a waterwheel, the water between the blades is almost stationary. Hence the force exerted on a blade is essentially due to the difference in pressure across the blade. In a water turbine, however, the water is fast-moving, and the turbine extracts kinetic energy from the water. Micro hydro systems complement solar PV power systems because, in many areas, water flow, and thus available hydro power, is highest in the winter when solar energy is at a minimum. Micro hydro is frequently accomplished with a Pelton wheel for high head, low flow water supply. However, this electromagnetic generator has a rectifier circuit to convert created ac voltage to dc voltage. Below figure 3.6 and figure 3.7 show the circuit that is responsible for converting AC to DC Voltage. The Dc conversion circuit is shown below and consists of 6 pieces 1N4007 diode,2 Zener diode 1N5349B, and an SMD capacitor.



Figure 3.6 Structure of Electromagnetic generator



Figure 3.7 Conversion of AC to DC voltage

3.3.3 NodeMcu ESP8266



Figure 3.8 NodeMCU ESP 8266

There are open-source prototype board designs for NodeMCU, an open-source firmware. The phrase "NodeMCU" is derived from the term's "node" and "microcontroller" (micro-controller unit). "NodeMCU" refers to the firmware rather than the accompanying development kits. The firmware and the prototype board designs are open-source [25]. The firmware uses the Lua programming language. The firmware is based on the eLua project and was produced using the Espressif Non-OS SDK for ESP8266. It incorporates Lua JSON and SPIFFS, among other open-source projects. Due to resource constraints, users must pick the components crucial to their project and build firmware tailored to their requirements. Also included is support for the 32-bit ESP32. Prototype hardware typically consists of a dual in-line package (DIP) that combines a USB controller with a smaller surface-mounted board that houses the MCU and antenna. Prototyping on breadboards is a snap, thanks to the DIP format. The design is based on the ESP-12 module from the ESP8266, a Wi-Fi SoC with a Tensilica Xtensa LX106 core often used in IoT applications.



FIGURE 3.9 CHIP FUNCTION BLOCK DIAGRAM NODEMCU ESP 8266

3.3.4 XL6009 Buck-Boost Converter Module

The buck-boost regulator uses two different topologies; as the name suggests, it consists of buck and boosts topologies. The complete buck-boost converter circuit diagram and the function of the ic pins is shown in Appendix B There are 14 components used in this module, and the details or parameters of the components are shown in Table 3.1. The components value is different from provided in appendix because the value is chose upon required for the system to power up microcontroller. Figure 3.10 identify the components parameters.



Figure 3.10 Identification of the component

D1	Rectifier Diode 1A, 400V
D2	Schottky rectifying 60V 3A
L1	33uH 4A
L2	2.2uH 1A

Table 3.1	Parameters	of the co	mponents
-----------	-------------------	-----------	----------

L3	33uH 4A
R1	330 ohms
R2	10K ohms adjustable
C1	220u 35V
C2	22uF 50V
C3	22uF 50V
C4	1uF 63V
C5	1uF 63V
C6	220u 35V

3.3.5 MP 1584 Nonadjustable Module

MP 1584 Module consists of all necessary buck converter components. The complete MP 1584 Module circuit diagram is shown Appendix C. There are 14 components used in this module, and the details or parameters of the components are shown in Figure 3.11. Each component has its purpose for the module the components value is same as shown in Appendix C.



Figure 3.11 Identification of the component

3.3.6 CJMCU-LTC3108 Module

The LTC3108 datasheet is shown in Appendix D.The 2.2V LDO powers an external microprocessor, while the main output is programmed to one of four fixed voltages to power a

wireless transmitter or sensors[18]. The good power indicator signals that the main output voltage is within regulation.

But in the datasheet, the manufacturers mention using this module for energy harvesting, which has more than 5V as input voltage as shown in Figure 3.12. So, changes in the components value is required to make the system more suitable and efficiency. Table 3.2 shows the parameter for the circuit.



Table 3.2	Components	Value
-----------	------------	-------

C1	Removed
C2	Removed
C3	Removed
C4	1uF
C5	150uF
C6	2.2uF
R1	1250hm

3.4 Software

This part shows the software which will be used to make the programming—harvesting energy using an electromagnetic generator and power management and the IoT application of the system. An experimental setup has been shown below to conduct this experiment.

3.4.1 Arduino IDE framework

The Arduino framework is a software used to do the programming for the Arduino Board and the components listed in the hardware. This desktop application can write, compile and load code for Arduino boards and boards compatible with the Arduino framework. The Arduino framework also has plenty of code examples, configuration for other boards, and documentation qualities, making user friendly[11]. There are also constant updates for the Arduino Framework, which ensures the framework can be constantly used for upcoming works. The Arduino Framework also allows for integration with the IoT application, making it very suitable for the Smart Water Meter System. Below is figure 3.13 for the Arduino Framework.



Figure 3.13 Arduino Framework

3.4.2 ThingSpeak IoT Platform



Figure 3.14 ThingSpeak IoT application

ThingSpeak is an IoT analytics platform that allows you to aggregate, visualize and analyze live data streams in the cloud. ThingSpeak provides instant visualizations of data posted by your devices to ThingSpeak. With the ability to execute MATLAB code in ThingSpeak, it can perform online analysis and processing of the data as it comes in[25]. ThingSpeak is often used for prototyping and proof of concept IoT systems that require analytics.

3.4.3 LtSpice

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LTSpice is a free circuit simulator from Analogue Devices manufacturer that uses a mixture of Spice commands and circuit diagrams with a sizable library of passive and active components. The software also allows sub-circuits and Hierarchical circuits of any size, even from thirdparty sources, to add components not currently available in the library. There is already a lot of support for the program, and it always helps to have more if questions are answered vaguely online. Also, this tool is useful for testing out ideas that often use high current, which requires plenty of safety factors when testing. This first post about this software will cover installation and getting started with drafting.

3.5 Developing Process

In this part it will be shown and explain all the process which has been done to achieve the objective and to obtain the results which will been shown at Chapter 4. Here were a few methods done by using the sensors to obtain these results. Below the experiment step is explained briefly.

3.5.1 Electromagnetic Generator Analysis

In this part, analysis or characterization of the turbine will be done as 2. To start this experiment water flow sensor which is YF-S201, Nodemcu, electromagnetic Generator, and Arduino IDE will be required. Code for the water flow sensor uploaded in nodemcu, the flow rate, and total volume can view or measured from the serial monitor. The code is shown in Appendix A. A digital multimeter is used to measure the generated output voltage to calculate the power and voltage obtained from this generator. A protector was used or tied together to a pipe, as shown in Figure 3.15, to open the valve to the necessary angle.



Figure 3.15 Protector with valve

The first experiment opened the pipe for seven types of angles, 0,15,30,45,60,75,90 degrees, and took the voltage reading from an electromagnetic generator and L/min reading

from the serial monitor for each angle. Repeat this experiment 5 times and record the data in excel.

For the second part of the electromagnetic generator analysis, the Decade Resistance box was connected in series with the output of the electromagnetic generator in open circuit form. Then various resistor value was tested with a range of 6.68 L/min. Figure 3.16 show the experiment setup for electromagnetic generator analysis. The data was then used to sketch the graph.



Figure 3.16 Experiment set-up of the water flow measurement and electricity generation.

3.5.2 LTspice Analysis

After the electromagnetic generator analysis, a suitable DC-DC circuit is required for the next step. LTspice can be used to analyze the converter's performance under different input voltage and load conditions, and to optimize the converter's performance in terms of efficiency, output voltage accuracy, and other parameters. The circuit for LTC3108 and buck converter was built

and simulated using LTspice and managed to observe the system's performance. Figure 3.17 shows LTC 3108 in LTspice.



3.5.3 DC Analysis & AC Analysis for Dc-Dc Circuit

LTC3108, XL6009 Buck-Boost and MP1584 circuit are chosen to proceed with this part. The Dc analysis is started with a power supply connected to the input and a digital multimeter connected to the output of the Dc-Dc circuit, as shown in Figure 3.18. Various input voltage from the power supply has been tested and recorded.



Figure 3.18 DC Analysis

The AC Analysis is conducted by the function generator connected to the input of the Dc-Dc circuit, and the digital multimeter is connected to the output of the Dc-Dc circuit. The oscilloscope is connected to the input of the Dc circuit to view the waveform. Figure 3.19 show the experimental setup for this analysis.



3.5.4 Open Circuit Dc-Dc Circuit Analysis

To start this electromagnetic experiment Generator, a Decade Resistance box, a Dc-Dc circuit, and a multimeter is required. The generated voltage from the electromagnetic Generator is connected to the input of the dc circuit, and the output of the circuit is connected with the Decade Resistance box to adjust various resistor values, as shown below in Figure 3.20. The digital multimeter is connected to the Decade Resistance box to the measured output voltage, and the calculated current depends on the load.



Figure 3.20 Open circuit Analysis

To understand more about capacitor role for this circuit a 2-piece 1000u 16V capacitor was connected to a series, and a 12K resistor, as shown in Figure 3.21, was used to calculate and observe the capacitor's charging and discharging time. A capacitor charging and discharging analysis is done to understand the performance of the converter's output voltage and current during the charging and discharging process of the capacitor. The experiment setup was an electromagnetic Generator connected to the input of the dc circuit, and the circuit's output is connected to the capacitor circuit shown in Figure 3.21. The experiment setup is shown below in Figure 3.22. The valve was opened at a 90 angle, and the charging process started; the data was recorded. For discharging, turn off the valve and short the capacitor leg, and record the data in excel.



Figure 3.21 Capacitor Series Connection



Figure 3.22 Charging&Discharging of series capacitors

3.5.5 Microcontroller Analysis

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For the final part, this circuit was built, and connect DC converter output to this circuit. The input of the DC converter was connected to the electromagnetic generator, as shown in Figure 3.23. AT R2 Decade resistor box was used with three different R2 values. The charging and discharging time of the capacitor depends on the load. When the load increases, the charging time increases. By discharging the capacitor after being charged, the microcontroller turns ON. Still, it can't connect with Wi-Fi because XL6009 is not a smart ICs.5.2V rating Zener voltage was used to give constant voltage to the load or microcontroller. This code shows whether the DC circuit can supply enough voltage to power up the microcontroller, as shown in Figure 3.5.9.



Figure 3.23 LOAD Connection

CHAPTER 4



4.0 Introduction

The chapter is on the result and analysis which has been obtained through the various methods which are used based on the methodology. This part also discusses on what the result which has been obtained and difficulties which were found when the process of the result to be obtained.

4.1 Analysis and interpretation of results

1. Electromagnetic Generator Analysis:

The Electromagnetic Generator produces an insane Dc voltage level, which experiment data took for five attempts. The experiment was repeated five times, as shown below in Table 4.1, to see any voltage decrease. There is a difference in the data taken by increasing the valve angle and recording the liters per minute of water and voltage produced by the flow or pressure of water. When the flow of water is 3 L/Min, the generator roughly produces 3 V. When the flow of water is 6.66 L/Min, and 8.21 L/Min, the voltage produced by the generator is almost the same. The difference in voltage produced between the flow of water is 0.2V. This means the maximum voltage produced by the generator is 12V. The reading was taken five times, and Figure 4.1 shows the graph. The specific weight of the water, the flow rate, and the pressure difference between the intake and the exit all affect the produced power, which is a function of the shaft's rotating speed.

L/Min VE	Degree	1ST(V)	2ND(V)	3RD(V)	4TH(V)	5TH(V)
0	0	0.33	0.32	0.34	0.33	0.35
1.2	15	0.5	0.51	048	0.52	0.5
3	30	3.1	3.1	3.12	3.07	3.08
4.88	45	8.2	8.21	8.19	8.23	8.2
6.66	60	11.6	11.65	11.58	11.62	11.6
8.21	75	11.8	11.83	11.78	11.81	11.77
9.32	90	12	12	12	12	12

Table 4.1 Voltage generated from Electromagnetic Generator





2. Electromagnetic Generator With open-circuit Voltage Analysis

For the next part of the experiment, the flow of water at 6.66 L/Min was chosen to proceed to this part. The data recorded is shown in Figure 4.2, adjusting the Decade Resistor box to various resistor values. Figure 4.2 displays the generator's voltage with various load resistances between 10 and 100K ohms. The findings indicate that as load resistance rises, the voltage rises, reaching a more-or-less constant value as load resistance approaches ten k Ω . Figure 4.3 shows the generated output power concerning the load resistance at a flow rate of 6.7 liter/min. The findings demonstrate that the generated output power rises until it reaches its maximum value at around 100 mW when the resistive load is about 400 Ω . The experiment results show that the maximum power generated by the electromagnetic energy harvester is around 100 mW for a water flow rate of 6.7 liter/min, sufficient to power a wireless sensor node. This research proves the feasibility of using electromagnetic energy harvester to power an automated electronic flow meter for an uninterrupted water usage monitoring and billing system.


Figure 4.2 Variations of the calculated mean power from the measurements with



the load resistance.

Figure 4.3 Variations of the measured mean voltage with the load resistance

3. XI6009 BUCK BOOST

From Figure 4.4, when the flow of water is at 1.55 L/Min, the boost converter produces 30 V at maximum adjusted voltage.



Figure 4.4 Variations of the measured mean voltage with the Dc-Dc circuit.

These changes happened when the adjustable voltage was adjusted from boost to buck mode. Figure 4.5 show the graph of the boost buck mode of XL6009. At 3V Vin, the power supply cannot increase the voltage because the power supply is capped at that value. Figure 4.6 shows the graph of the boost mode of XL6009.



Figure 4.5 Boost Buck mode of XL6009



Figure 4.6 Boost mode of XL6009

For this experiment, the experimental setup was as shown in Figure 3.5.6. Figure 4.7 displays the generator's voltage with various load resistances between 10 and 100K ohms. The findings indicate that as load resistance rises, the voltage rises, reaching a more-or-less constant value as load resistance approaches ten k Ω . Figure 4.8 shows the generated output power about the load resistance at a flow rate of 9.32 liter/min. The findings demonstrate that the generated output power rises until it reaches its maximum value at around 72 mW when the resistive load is about 100 Ω . From the experiment results, the maximum power that is generated by the XL6009 at BUCK mode is around 72 mW for a water flow rate of 9.32 liter/min. Figure 4.7 below shows the measured mean voltage and power Variations with the Buck mode load resistance.



Figure 4.7 Variations of the measured mean voltage with the load resistance



Figure 4.8 Variations of the calculated mean power from the measurements with the load resistance.

4. MP1584

Below, Figure 4. 9 show the reading of MP1584 of buck mode. Figure 4.9 show the graph of the buck mode of MP1584. It started to buck voltage when the Vin was more than 3.4 V, and the output of the Dc converter was going constant when the Vin was more than 4.5.



Figure 4.9 Buck MP1584

For this experiment, the experimental setup was as shown in Figure 3.5.6. Figure 4. 11 displays the generator's voltage with various load resistances between 10 and 100K ohms. The findings indicate that as load resistance rises, the voltage rises, reaching a more-or-less constant value as load resistance approaches one k Ω . Figure 4.1.10 shows the generated output power about the load resistance at a flow rate of 9.32 liter/min. The findings demonstrate that the generated

output power rises until it reaches its maximum value at around 150 mW when the resistive load is about 100 Ω . The experiment results show that the maximum power generated by the BUCK mode is around 150 mW for a water flow rate of 9.32 liter/min. Table 4.8 shows the measured mean voltage and power Variations with the load resistance for MP1584.



Figure 4.10 Variations of the calculated mean power from the measurements with the



Figure 4.11 Variations of the measured mean voltage with the load resistance

MP1584 Ac analysis was conducted, and the data was collected, as shown in Figure 4.12. The experiment setup was like shown above in Figure 3.5.5. The graph of ac analysis for the Dc converter is shown in Figure 4.12.



Figure 4.12 AC graph for DC converter

5. LTC3108

For this part, the reading was taken with the experiment setup, as shown in Figure 3.17. The expected output for this part is 3.3v at the VOUT pin. The reading value is shown in Figure 4.13, and the graph is plotted for VOUT, VLDO, and VSTORE pins. When the vin is more than 3.3v, the vout value will be constant, and the balance voltage will be sent to the Vstore pin. The graph is plotted as shown below in Figure 4.13.



Figure 4.13 LTC3108 FOR 3.3VOUT

For this part, the reading was taken with the experiment setup, as shown in Figure 3.5.5. The expected output for this part is 4.1v at the VOUT pin. The reading value is shown in Figure 4.1.14, and the graph is plotted for VOUT, VLDO, and VSTORE pins. When the vin is more than 4.1v, the vout value will be constant, and the balance voltage will be sent to the Vstore pin. The graph is plotted as shown below in Figure 4.1.14. The VLDO remains constant when the input voltage is more than 2.4V.



Figure 4.14 LTC3108 FOR 4.1VOUT

6. Capacitor

This part was conducted with an experiment setup, as shown in Figure 3.18. Figure 4.15 shows the Capacitor Charging for the first 13 seconds, even though the full process of charging the capacitor took 3 hours 15 minutes. Figure 4.1.16 shows the first-time constant; the charging complete is 63.8%. Figure 4.1.15 shows the full capacitor charging reading until the supply voltage is the same as the capacitor voltage.



Figure 4.15 Capacitor charging for 3hours 15 minutes



Figure 4.16 Capacitor charging for first 6 second

This part was conducted with an experiment setup, as shown in Figure 3.18. Figure 4. 17 shows the Capacitor Charging for the first 13 seconds even though the full process of charging the capacitor took 1 hour and 24 minutes. Figure 4.18 shows the first time constant: the discharging complete is 63.8%. Figure 4.17 shows the full capacitor discharging reading until the supply voltage is the same as the capacitor voltage, which the supply voltage is 0V for discharging.



Figure 4.17 Capacitor Discharging for 1hour 24 minutes



Figure 4.18 Capacitor Discharging for first 6 second

7. MICROCONTROLLER

Figure 4.19 shown below the experiment results was conducted by charging for 6 seconds and discharging for 6 seconds. The charging and discharging were recorded for two cycles. This experiment was conducted to determine if the charging and discharging process depended on a load similar to the microcontroller.



Figure 4.19 CHARGING&DISCHARGING

4.2 Analysis Explanation

1) Electromagnetic Generator Analysis:

A turbine analysis is done to understand the performance of the turbine or other power generation mechanism used in a smart water meter powered by an electromagnetic generator. Turbines are mechanical devices that convert the energy of a fluid (such as water) into mechanical energy, which can then be converted into electricity. The turbine analysis is important because it provides information on the turbine's efficiency, power output, and other performance characteristics.

The turbine analysis can help identify potential issues, such as mechanical stresses, vibration, and wear, which may occur during operation. This can help ensure that the turbine can withstand the expected operating conditions and provide a reliable source of electricity.

The turbine analysis can also be used to optimize the turbine's performance. The analysis can be used to evaluate different turbine designs, materials, and manufacturing techniques to find the best design that meets the project's specific requirements.

Overall, a turbine analysis is an important step in the design process of a smart water meter powered by an electromagnetic generator. It helps to ensure that the turbine can provide a reliable source of electricity and withstand the expected operating conditions. This is essential for the accurate and reliable operation of the meter.

2) DC Analysis

A DC analysis for a DC-DC converter is done to understand the converter's performance under steady-state DC conditions. DC analysis is important because it allows the designer to observe the converter's performance at a specific point of operation and provide information such as the voltage and current levels at the input and output, efficiency, and power dissipation. DC analysis is used to verify that the converter operates within its specified limits, such as input voltage range, output voltage range, and maximum current. It also helps to ensure that the converter meets the desired specifications for output voltage and current and that the converter can provide the required power to the load. DC analysis is done for DC-DC converters to determine the steady-state operating conditions of the converter, such as the output voltage and current, and the efficiency of the converter under specific input conditions. This information is useful for designing and optimizing the converter for a particular application.

Additionally, DC analysis can optimize the converter's performance by evaluating different circuit configurations, component values, and control strategies. It can also identify potential issues, such as stability and thermal issues, which may occur under steady-state DC conditions.

Overall, a DC analysis for a DC-DC converter is an important step in the design process of a smart water meter powered by an electromagnetic generator. It helps to ensure that the converter will function correctly and efficiently under steady-state DC conditions, which is essential for the accurate and reliable operation of the meter.

3) AC Analysis

AC analysis of a DC-DC converter is done to determine the converter's performance under varying input voltage and load conditions. It helps to identify potential issues such as ripple voltage, power loss, and efficiency and to verify that the converter meets the design specifications. Additionally, it can be used to optimize the converter's performance and identify potential areas for improvement.

An AC analysis can provide information about the performance of a DC-DC converter under varying input voltage and load conditions, such as ripple voltage, power loss, and efficiency. However, the output of the analysis is typically presented in the form of waveforms or graphs that describe the converter's behavior over time rather than providing a specific DC output value.

Additionally, it's worth noting that the input and output of a DC-DC converter are both DC, so the term "AC analysis" may be a bit of a misnomer in this context. It's more accurate to say that the converter is being analyzed under varying input and output conditions rather than specifically analyzing an AC input or output.

4) Open Circuit resistor Analysis

Open circuit resistor analysis is a technique used to analyze the behavior of a circuit when there is no load connected to it. In the context of a smart water meter powered by an electromagnetic generator, open circuit resistor analysis can be used to study the performance of the DC-DC converter when there is no load connected to it.

The open circuit resistor analysis is done by measuring the voltage across the output terminals of the DC-DC converter when no load is connected. This measurement is then compared to the expected voltage level to determine if the converter operates within its specified parameters. This can help to identify any issues with the converter, such as a malfunctioning component or a problem with the control circuit. The open circuit resistor analysis can also be used to study the converter's power loss due to its internal resistance when it operates under open circuit conditions.

In summary, open circuit resistor analysis is a technique used to analyze the behavior of a DC-DC converter when there is no load connected to it. It can be used to study the converter's performance, identify any issues, and study the power loss in the converter. This can help to improve the overall performance of the smart water meter powered by an electromagnetic generator.

4.3 Environment and sustainability



The smart water meter powered by an electromagnetic generator can have a positive impact on the environment and sustainability in several ways:

- Energy efficiency: The smart water meter powered by an electromagnetic generator can generate electricity from the flow of water, which reduces the need for external power sources. This can help to decrease the reliance on fossil fuels and decrease the carbon footprint of the device.
- Water conservation: By providing real-time information on water usage, the smart water meter can help to promote water conservation. This can help to reduce water waste and decrease the demand for water resources.
- Durability: The smart water meter powered by an electromagnetic generator is designed to be durable and long-lasting. This can help reduce the need for frequent replacements, which can decrease the device's environmental impact.
- Renewable energy: The smart water meter powered by an electromagnetic generator is a form of renewable energy, and it is not dependent on fossil fuels, which are non-renewable sources. It can help to decrease the reliance on fossil fuels and decrease the carbon footprint of the device.
- Smart grid integration: By connecting the smart water meter to a smart grid, it can help to improve the overall efficiency and sustainability of the energy system by allowing

for the integration of renewable energy sources, demand response, and other advanced features.

Overall, the smart water meter powered by an electromagnetic generator can positively impact the environment and sustainability by reducing reliance on external power sources, promoting water conservation, being durable, utilizing renewable energy, and integrating with a smart grid. However, it's important to note that this project's environmental and sustainability impact will also depend on the specific design and implementation of the device.



CHAPTER 5

CONCLUSION AND FUTURE WORK



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thesis and the Performance analysis of DESIGN AND DEVELOPMENT OF SMART WATER METER POWERED BY ELECTROMAGNETIC GENERATOR. Other than that, this chapter is also on the Future works and upgrades that can be further done to the system to make it better in terms of functionality or sensitivity.

5.1 Conclusion

In conclusion, the design and development of a smart water meter powered by an electromagnetic generator is a significant advancement in water management. The ability to harness the energy generated by the flow of water allows for a cost-effective and energy-efficient method of measuring water consumption. Furthermore, integrating advanced technologies such as wireless communication and data analytics provide valuable insights into water usage patterns, aiding conservation efforts.

The design and development of the smart water meter powered by an electromagnetic generator is a multi-stage process that involves conceptual design, detailed design, prototyping, production, deployment, and maintenance. The project requires a thorough understanding of the turbine, DC-DC converter, electronic systems, and communication protocols. Additionally, simulations and analyses such as AC analysis, DC analysis, turbine analysis, open circuit resistor analysis, and capacitor charging and discharging analysis are performed to understand the performance of the converter and turbine under different conditions and optimize their performance.

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By experimenting with XL6009, MP1584, and LTC 3108 as DC-DC circuits converter, the electromagnetic generator output voltage is more stable and regulated to power up the microcontroller. However, XL6009 and MP1584 are not smart ICs like LTC3108. This is because using XL6009, MP1584 can power up the microcontroller, but difficult to connect to Wi-Fi. For ESP8266 to connect to wifi, it needs 250mA, whereas to power up ESP8266, 1uA is enough. LTC3108 is a smart ICs compared to both other ICs because this system got its Vstore pin where the supercapacitor can be connected. This type of ICs uses its Vstore pin to store energy and burst the voltage to transmit data to the IoT cloud. However, it's important to note that this technology is still in its early stages of development. Further research and testing are needed to optimize the design and ensure its reliability in real-world applications. In addition, the effectiveness of this technology will also depend on the infrastructure of the area where it is to be implemented.

In summary, the design and development of a smart water meter powered by an electromagnetic generator present a promising solution for measuring water consumption in a cost-effective and energy-efficient manner. Integrating advanced technologies such as wireless communication and data analytics can provide valuable insights into water usage patterns and aid conservation efforts. However, further research and testing are needed to optimize the design and ensure its reliability in real-world applications.

5.2 Future Work

One possible area of future work for this project is to increase the power density of the turbine energy harvesters. Power density measures how much power can be generated per unit volume of the turbine. Increasing the power density of the turbine energy harvester can improve the overall performance of the device. Increasing the power density allows the turbine energy harvester to generate more power per unit volume, making the device more efficient and costeffective. Implementing these methods will require further research, testing, and development, but it could significantly improve the performance of the device.

Improving the accuracy of the water flow measurement accuracy: The water flow measurement can be improved by using advanced sensors and signal processing techniques. For example, using ultrasonic sensors or electromagnetic flow meters can improve the accuracy of the water flow measurement.

Improving wireless communication: The wireless communication between the device and the remote monitoring system can be improved by using advanced wireless protocols such as Zigbee or Z-Wave, providing a more secure and reliable connection.

Developing a user-friendly interface: A user-friendly interface can be developed to make it easy for users to monitor and control the device. For example, a mobile app or web interface can be developed to allow users to view real-time data and control the device remotely.

Improving energy efficiency: The device's energy efficiency can be improved by optimizing the power management system and implementing advanced power management techniques. For example, using a sleep mode or hibernation mode can reduce the device's power consumption when it is not in use.

Developing a more robust and durable design: A more robust and durable design can be developed to make the device more resistant to environmental factors such as extreme temperatures, humidity, and corrosion. This can be achieved using high-performance materials and developing a more robust mechanical design.

Overall, these future works can help to make the smart water meter more accurate, portable, easy to use, energy-efficient, durable and reliable, which can help to make it more convenient for users and more successful in its intended application.

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APPENDIX A



long currentMillis = 0;

long previousMillis = 0;

int interval = 1000;

boolean ledState = LOW;

float calibrationFactor = 4.5;

volatile byte pulseCount;

byte pulse1Sec = 0;

float flowRate;

```
unsigned long flowMilliLitres;
```

unsigned int totalMilliLitres;

float flowLitres;

float totalLitres;

```
void IRAM_ATTR pulseCounter()
{
    pulseCount++;
}

void setup()
{
    Serial.begin(115200);
    delay(10);
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```

pinMode(LED_BUILTIN, OUTPUT);

pinMode(SENSOR, INPUT_PULLUP);

pulseCount = 0;

flowRate = 0.0;

flowMilliLitres = 0;

totalMilliLitres = 0;

previousMillis = 0;

attachInterrupt(digitalPinToInterrupt(SENSOR), pulseCounter, FALLING);

}

```
void loop()
```

{

```
currentMillis = millis();
```

if (currentMillis - previousMillis > interval)

{

```
pulse1Sec = pulseCount;
pulseCount = 0;
```

// Because this loop may not complete in exactly 1 second intervals we calculate
// the number of milliseconds that have passed since the last execution and use
// that to scale the output. We also apply the calibrationFactor to scale the output
// based on the number of pulses per second per units of measure (litres/minute in
// this case) coming from the sensor.

flowRate = ((1000.0 / (millis() - previousMillis)) * pulse1Sec) / calibrationFactor;
previousMillis = millis();

// Divide the flow rate in litres/minute by 60 to determine how many litres have
// passed through the sensor in this 1 second interval, then multiply by 1000 to
// convert to millilitres.

flowMilliLitres = (flowRate / 60) * 1000;

flowLitres = (flowRate / 60);

// Add the millilitres passed in this second to the cumulative total

totalMilliLitres += flowMilliLitres;

totalLitres += flowLitres;

// Print the flow rate for this second in litres / minute

Serial.print("Flow rate: ");

Serial.print(float(flowRate)); // Print the integer part of the variable

Serial.print("L/min");

Serial.print("\t"); // Print tab space

// Print the cumulative total of litres flowed since starting UNIVERSITI TEKNIKAL MALAYSIA MELAKA Serial.print("Output Liquid Quantity: ");

Serial.print(totalMilliLitres);

Serial.print("mL / ");

Serial.print(totalLitres);

Serial.println("L");

APPENDIX B

Pin Configurations



Table 1 Pin Description

ch 1		
Pin Number	Pin Name	Description units when a low
1	GND	Ground Pin.
2UNI	VERENITI	Enable Pin. Drive EN pin low to turn off the device, drive it high to turn it on. Floating is default high.
3	SW	Power Switch Output Pin (SW).
4	VIN	Supply Voltage Input Pin. XL6009 operates from a 5V to 32V DC voltage. Bypass Vin to GND with a suitably large capacitor to eliminate noise on the input.
5	FB	Feedback Pin (FB). Through an external resistor divider network, FB senses the output voltage and regulates it. The feedback threshold voltage is 1.25V.





PIN FUNCTIONS

SOIC Pin #	Name	Description
1	SW	Switch Node. This is the output from the high-side switch. A low forward drop Schottky diode to ground is required. The diode must be close to the SW pins to reduce switching spikes.
2	EN	Enable Input. Pulling this pin below the specified threshold shuts the chip down. Pulling it up above the specified threshold or leaving it floating enables the chip.
3	COMP	Compensation. This node is the output of the error amplifier. Control loop frequency compensation is applied to this pin.
4	FB	Feedback. This is the input to the error amplifier. The output voltage is set by a resistive divider connected between the output and GND which scales down V_{OUT} equal to the internal +0.8V reference.
5	GND Exposed Pad	Ground. It should be connected as close as possible to the output capacitor to shorten the high current switch paths. Connect exposed pad to GND plane for optimal thermal performance.
6	FREQ	Switching Frequency Program Input. Connect a resistor from this pin to ground to set the switching frequency.
7	VIN	Input Supply. This supplies power to all the internal control circuitry, both BS regulators and the high-side switch. A decoupling capacitor to ground must be placed close to this pin to minimize switching spikes.
8	BST	Bootstrap. This is the positive power supply for the internal floating high-side MOSFET driver. Connect a bypass capacitor between this pin and SW pin.



Figure 4—5V Output Typical Application Schematic



PIN FUNCTIONS (DFN/SSOP)

VAUX (Pin 1/Pin 2): Output of the Internal Rectifier Circuit and V_{CC} for the IC. Bypass VAUX with at least 1µF of capacitance. An active shunt regulator clamps VAUX to 5.25V (typical).

VSTORE (Pin 2/Pin 3): Output for the Storage Capacitor or Battery. A large capacitor may be connected from this pin to GND for powering the system in the event the input voltage is lost. It will be charged up to the maximum VAUX clamp voltage. If not used, this pin should be left open or tied to VAUX.

V_{OUT} (Pin 3/Pin 4): Main Output of the Converter. The voltage at this pin is regulated to the voltage selected by VS1 and VS2 (see Table 1). Connect this pin to an energy storage capacitor or to a rechargeable battery.

V_{OUT2} (Pin 4/Pin 5): Switched Output of the Converter. Connect this pin to a switched load. This output is open until V_{OUT2_EN} is driven high, then it is connected to V_{OUT} through a 1.3Ω P-channel switch. If not used, this pin should be left open or tied to V_{OUT}. The peak current in this output is limited to 0.3A typical.

VLD0 (Pin 5/Pin 6): Output of the 2.2V LD0. Connect a 2.2µF or larger ceramic capacitor from this pin to GND. If not used, this pin should be tied to VAUX.

PGD (Pin 6/Pin 7): Power Good Output. When V_{OUT} is within 7.5% of its programmed value, PGD will be pulled up to VLDO through a 1M Ω resistor. If V_{OUT} drops 9% below its programmed value PGD will go low. This pin can sink up to 100µA.

VS2 (Pin 7/Pin 10): V_{OUT} Select Pin 2. Connect this pin to ground or VAUX to program the output voltage (see Table 1). VS1 (Pin 8/Pin 11): V_{OUT} Select Pin 1. Connect this pin to ground or VAUX to program the output voltage (see Table 1).

 V_{OUT2_EN} (Pin 9/Pin 12): Enable Input for V_{OUT2} . V_{OUT2} will be enabled when this pin is driven high. There is an internal 5M pull-down resistor on this pin. If not used, this pin can be left open or grounded.

C1 (Pin 10/Pin 13): Input to the Charge Pump and Rectifier Circuit. Connect a capacitor from this pin to the secondary winding of the step-up transformer.

C2 (Pin 11/Pin 14): Input to the N-Channel Gate Drive Circuit. Connect a capacitor from this pin to the secondary winding of the step-up transformer.

SW (Pin 12/Pin 15): Drain of the Internal N-Channel Switch. Connect this pin to the primary winding of the transformer.

GND (Pins 1, 8, 9, 16) SSOP Only: Ground

GND (Exposed Pad Pin 13) DFN Only: Ground. The DFN exposed pad must be soldered to the PCB ground plane. It serves as the ground connection, and as a means of conducting heat away from the die.

Table 1. Regulated Voltage Using Pins VS1 and VS2

	VS2	17		V\$1	1	VOUT	
	GND			GND		2.35V	
	GND			VAUX		3.3V	
~	VAUX		-	GND		4.1V	
	VAUX			VAUX		5V	

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