ANALYSIS OF ENERGY HARVESTER CIRCUIT FOR A THERMOELECTRIC ENERGY HARVESTING SYSTEM (TEHS) AT ASPHALT PAVEMENT

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This report is submitted in partial fulfillment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DEDICATION

First and foremost, I am very grateful to all the family members for their valuable guidance and support in the completion of this project in its entirety. I would like to express our deepest appreciation to all those who provided us the possibility to complete our Integrated Design Project. A special gratitude we give to our supervisor, Dr. Khairun Nisa Bt Khamil whose contribution in stimulating suggestions and encouragement and help I am lot in this project and with much appreciation too because she gave the knowledge about this project to use all required equipment and the necessary materials to complete the project. Besides, not to forget our coordinator of this PSM Project, Dr. Mas Haslinda who keep reminding us about the important things that must be done before the due date and always give us moral support to complete our project. Next, I also appreciate the guidance given by panels that have improved our project and the knowledge that gives us the idea to complete this project. Finally, gratitude goes to all my friends who directly or indirectly helped me to complete this project

ABSTRACT

The overriding challenge of our time are manifold from climate change, global energy shortages, and even environmental pollution. The search for renewable energy sources that are economical, efficient, and clean is vital. For this purpose, industries have looked at the environmentally friendly usage of renewable energy from many angles including in pavement harvesting. Choosing the right power management circuit for harvesting energy with a thermoelectric generator is an important element. However, most of the energy harvesting (EH) circuits on the market are typically designed to meet solar harvesting applications. Commercial EH circuits typically have an MPPT ratio of 0.7-0.85 for PV cells and 0.5 for TEG. As a result, if it is used with a thermoelectric source, a stable output cannot be obtained. Therefore, this project aims to analyze, an EH circuit that is designed for thermoelectric energy harvesting on asphalt pavement and to analyze the cold-start performance of the power management circuit. To confirm the feasibility of the energy harvesting project with a thermoelectric generator, the project has been tested in the laboratory with asphalt pavement. Based on the result simulation, IC SPV1050 able to fully charge to 4V between 3 to 8s, however LTC3105 able to charge faster than SPV1050 between 0.19s to 0.21s but only able to reach 2.4 V. However, the

results in laboratory experiment show SPV1050, able to charge 4.1 V for about 1 hour, while LTC3105 unable to charge to 44 mV. These results show that ICs with a charge pump type of cold start are able to boost and charge the voltage much faster than transformer's type. In conclusion, the difference in IC energy harvesting in terms of cold start, component use, technical issues from the circuit board and etc can have an effect on the desired voltage reading and make the charging process faster to help increase the performance of the power management circuit

ABSTRAK

Cabaran yang dihadapi manusia hari ini adalah kurangnya tenaga global, berlakunya perubahan iklim, dan juga pencemaran alam sekitar. Dengan adanya pembangunan tenaga baharu, serta pengunaan tenaga yang sedia ada yang menjimatkan, bersih dan cekap ia dapat memberi potensi yang bagus dalam penjanaan kuasa. Industri telah mengkaji pengumpulan perlindungan alam sekitar dan penggunaan tenaga boleh diperbaharui dari pelbagai perspektif termasuk dalam penuaian turapan. Teknologi penuaian tenaga menjadi topik utama kajian antara disiplin dalam penuaian turapan. Memilih litar pengurusan kuasa yang betul untuk menuai tenaga dengan penjana termoelektrik adalah elemen penting. Walau bagaimanapun, kebanyakan litar penuaian tenaga (EH) di pasaran biasanya direka untuk aplikasi penuaian tenaga suria. Litar EH komersial biasanya mempunyai nisbah MPPT 0.7-0.85 untuk sel PV dan 0.5 untuk TEG. Akibatnya, jika ia digunakan dengan sumber termoelektrik, output yang stabil tidak boleh diperolehi. Oleh itu, projek ini bertujuan untuk menganalisis, litar EH yang direka untuk penuaian tenaga termoelektrik pada turapan asfalt dan untuk menganalisis prestasi permulaan sejuk litar pengurusan kuasa. Untuk mengesahkan kebolehlaksanaan projek penuaian tenaga dengan penjana termoelektrik, projek ini telah diuji di makmal dengan turapan asfalt. Berdasarkan hasil simulasi, IC SPV1050 mampu mengecas sepenuhnya kepada 4V antara 3 hingga 8s, namun LTC3105 mampu mengecas lebih pantas daripada SPV1050 antara 0.19s hingga 0.21s tetapi hanya mampu mencapai 2.4 V. Manakala, keputusan dalam eksperimen makmal

menunjukkan SPV1050, boleh mengecas 4.1 V selama kira-kira 1 jam, manakala LTC3105 tidak boleh mengecas hanya mencapai 44 mV. Keputusan ini menunjukkan bahawa IC jenis pam cas mampu meningkatkan dan mengecas voltan lebih cepat daripada transformer. Kesimpulannya, perbezaan penuaian tenaga IC dari segi permulaan sejuk, penggunaan komponen, isu teknikal dari circuit dan sebagainya boleh memberi kesan kepada proses bacaan voltan yang dikehendaki, dan menjadikan proses pengecasan lebih cepat untuk membantu meningkatkan prestasi litar pengurusan kuasa.

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LIST OF SYMBOLS AND ABBREVIATIONS

TEG	:	Thermoelectric generator
DT	:	Temperature difference
Voc	:	Open circuit voltage
VCap	:	Capacitor voltage
Veoc		End of charge voltage
MPPT	:	Maximum power point tracking
T	:	Temperature
C	:	Capacitor
V	:	Voltage

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CHAPTER 1

INTRODUCTION

This chapter will briefly describe project introduction, objective, problem statement, scope of work and Importance/Significant.

1.1 Introduction

The energy harvesting sector is rapidly growing. In Japan, China, Europe, and North America are main market leaders and the components of energy harvesting are expected to be worth more than 4 billion by 2020, which is significant given that the market was only 79.5 million in 2009, indicating a 73 percent annual growth rate. Most companies invest in energy harvesting for various purposes, for example, some companies want to reduce the cost of generating their systems. Although the energy generated is minimal, the upfront expense of using energy harvesting can be paid for in the long run, depending on the lifespan of the system [1]

Harvesting energy from asphalt pavements has shown promise in generating green electrical energy. Asphalt pavements are one of the most prominent components of civil engineering infrastructure. In Malaysia, to do the energy harvesting process is very suitable. According to Ismail & Ahmed (2009) Malaysia is a country endowed with a natural climate, where the average solar radiation of 4500kWh/m2 and sunlight of 12 hours/day process low-grade thermal energy that can benefit all [2]. In addition, according to the Malaysian Meteorological Department (2018) there were few seasonal temperature fluctuations in Peninsular Malaysia and East Malaysia, with the greatest average temperatures in April and May and the lowest average temperatures in December and January. Most of the road developments in Malaysia are paved with flexible and rigid asphalt, which is ideal for Malaysia's climate and influences it positively [3]. The heat absorbed by the asphalt road, which absorbs incident solar radiation, makes it an important source for energy harvesting with a total paved road length of 82,144 kilometers [4].

According to the Sze, (2015) World Economic Forum, Malaysia's roads are among the best in the world, ranked alongside Korea and better than some European countries. Roads in Malaysia that connect districts, villages, and even states have grown rapidly every year for the convenience of Malaysians [5]. With a good road structure in Malaysia, it can benefit the country by using it as a source of energy. Available energy sources can produce energy such as solar radiation, mechanical energy produced by moving vehicles or pedestrians, and geothermal energy. There are two main types of energy harvesting systems used for energy harvesting from roadways thermal and mechanical-based systems. The first type is called solar radiation and thermal gradients convert solar energy from asphalt pavements into electrical energy. A thermoelectric generator (TEG) and an asphalt solar collector (ASC) are used in the thermal gradient system, whereas photovoltaic techniques are used in the solar radiation system to generate electricity [6]. According to Roshani et al,. (2016) piezoelectric harvesters and electromagnetic systems, such as hydraulic, electromechanical, and micro-electromechanical systems, are examples of mechanical-based energy harvesters [7].

1.2 Problem Statement

Power consumption keeps increasing day by day due to high demand from users. According to Twaha et al,. (2017) Energy harvesting is a way to save and minimize electrical energy. Energy harvesters are converters that convert ambient energy into electrical energy, such as thermal energy, wind energy, solar energy, water energy, kinetic energy, vibration energy, and acoustic energy [8].

TEGs (thermoelectric generators) are devices that convert heat into electricity. One of the difficulties with TEG is that the power generated is unstable, necessitating the use of a proper power conditioning mechanism before it is supplied to the load. Furthermore, the maximum power point (MPP) must be tracked to ensure that maximum power is always extracted from TEG devices [8]. And due to this, EH circuits available in the market are normally designed to cater to solar application harvesting applications. Typically, the commercial MPPT circuit ratio was set to 0.7-0.85 for PV cells and 0.5 for TEGs. Hence if it is used to use the thermoelectric source, a stable output cannot be achieved.

In this paper by Khamil et al., (2020a) ,ECT310 was able to step up the voltage by more than 5V but it took long hours to charge. Most of the commercial EH circuit is used to meet the needs of solar energy substances and programmed to meet a 0.7 to 0.85 MPPT ratio, so when the MPPT input is unstable, charging becomes challenging [9].

Another researcher Cabiling & Cristi, (2013) most EH circuits incorporated a cold start process to turn on the power to start the main boost converter, and among the methods used are transformers, mechanical switches, charger pumps, and low power oscillators. Each commercial EH circuit such as LTC3105, ECT310, and BQ25504 used a different cold-start method. For example, LTC3105 uses the step-up transformer to allow it to boost input voltages as low as 250mV. In contrast, BQ25504, cold-starts used a DC-DC boost charger that requires VIN from TEG as low as 600 mV. However, once the cold start operates at the minimum value to boost, it affects the charging capabilities and takes a longer time [10]. Thus, in this project, various cold-start methods are investigated on how they will influence the input from TEG once it operates and starts to charge.

1.3 Objective

1. To analyze the cold-start performance of the energy harvesting (EH) circuit.
2. To investigate the charging capabilities between the commercial EH circuit that is designed for solar and the circuit that is designed for Thermoelectric generator.