MAXIMUM POWER POINT TRACKING WITH BOOST CONVERTER FOR SOLAR LAPTOP CHARGER

A PROJECT REPORT

submitted by

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to

the APJ Abdul Kalam Technological University

in partial fulfilment of the requirements for the award of the Degree

of

Master of Technology

in

Power Electronics and Power Systems

विश्वं शास्त्रे प्रतिष्ठितम्।

Department of Electrical and Electronics Engineering

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Ettumanoor, Kottayam

MAY 2023

DECLARATION

I undersigned hereby declare that the project report "Maximum Power Point Tracking with Boost Converter for Solar Laptop Charger" submitted for partial fulfilment of the requirements for the award of degree of Master of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of Assistant Professor Ms. Shoma Mani. This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data, idea, fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can evoke penal action from the sources which have not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

Ettumanoor

22-07-2023 ARCHANA A

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

MANGALAM COLLEGE OF ENGINEERING, KOTTAYAM

विश्वं शास्त्रे प्रतिष्ठितम्।

CERTIFICATE

This is to certify that the report entitle **“Maximum Power Point Tracking with Boost Converter for Solar Laptop Charger”** submitted by **ARCHANA A (Reg. No: MLM21EEPP04)**, to the APJ Abdul Kalam Technological University in partial fulfilment of the requirements for the award of the Degree of Master of Technology in Power Electronics and Power Systems is a bonafide record of project work carried out by her under my guidance and supervision. This report in any form has not been submitted to any other university or institute for any purpose.

Internal Supervisor	Project Coordinator	HEAD OF THE DEPARTMENT

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This endeavour stands incomplete without dedicating my gratitude to everyone who has contributed a lot towards this project.

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Last but not the least I thank my parents, staff of the college and my friends who supported me during the course of this project.

ABSTRACT

Off-grid energy solution is becoming a necessity in our country with the unstable electricity supply from the utility provider. Laptop is an essential electronic appliance for individuals, schools and businesses, which you can't afford to be down on power. Remote areas are often challenged by consistent interrupted power supply, thereby delaying or hindering certain work that needs to be done with laptops. Hence, off-grid solar energy solutions are proposed to charge laptop batteries and various electronics with similar specifications for remote area dwellers. However, solar panels are very inefficient when directly connected to load. Therefore, application of maximum power point tracking (MPPT) and pulse width modulation (PWM) to connect solar panels to laptop charger is presented in this work. This was achieved in this work through simulation and hardware implementation.

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LIST OF ABBREVIATIONS

MPPT	Maximum Power Point Tracking
LS	Load Shedding
PWM	Pulse Width Modulation
SLC	Solar Laptop Charger
SP	Solar Panel

CHAPTER 1

INTRODUCTION

1.1 GENERAL BACKGROUND

Our world has a growing population with an ever-increasing electrical energy demand, but unmatched electricity supply from the state-owned enterprise, Eskom, due to the closure and erratic functioning of its aging power plants. The lack of new power stations and an increase in the number of informal settlements has further increased the pressure on the national power grid leading to many load shedding schedules and blackouts across the country, but more felt in remote areas. These challenges have created a need for alternative, but clean energy sources to meet the growing energy demand in the country. However, renewable energy resources have been proven to be reliable in mitigating lack of access of electricity in the country's unelectrified rural areas. Some of such alternative clean energy sources available in South Africa include solar energy, wind energy, biomass, and hydropower for standalone and grid-connected possibilities. Hence, these fields have attracted research and development over the years.

The continuous power cuts referred to as load shedding in the country have hurt every sector of the economy, as the South African economy is directly proportional to energy consumption. The electricity utility provider in the country has revealed that stage 1 load shedding (i.e., 1 hour power cut out of 24 hours), which is an equivalent of 1000 MW load shed. However, energy experts have reported that load shedding costs the economy one billion rands per stage daily. The utility implements stages 1 – 8 load shedding depending on the state of the grid and demand from time to time, but provides consumers with prior information about the load shedding schedules. However, the backup generators consume a lot of diesels, which is costly and unsustainable to run for a long period of time. Hence, the consistent load shedding being experienced in the country. Power solutions with solar energy assume an enormous job opportunity in the present day and will keep doing so in the future especially in areas with little or no access to electricity. Solar panels can be used for a wide range of applications the same manner as conventional electricity from power stations, due to its scalability. In South Africa with the abundance of solar irradiation, solar panels can be placed and operated almost everywhere in the country. Solar energy is a viable alternative energy source as plenty of rooftop spaces are readily available for this technology in the country, and its massive space advantage needs to be well utilized. Off-the-shelf solar laptop chargers are quite expensive as shown and unaffordable to most of its target customers in remote areas. It is therefore necessary to meet the same need at an affordable cost for the customers, as is carried out in this work. A fully charged laptop is essential for people to be productive in their work, load shedding or lack of access to electricity notwithstanding. The outcome of this work is to demonstrate the ability to charge a laptop in any remote area efficiently using maximum power point tracking principle.

1.2 OBJECTIVE

To study about Maximum Power Point Tracking with Boost Converter for Solar Laptop Charger

1.3 SCHEME OF SEMINAR

Chapter 1gives a brief description of the background and objective of the Project.

Chapter 2 Discusses about literature review

Chapter 3 gives the details of Methodology

Chapter 4 gives details of Simulation

Chapter 5 discuss about the conclusions.

CHAPTER 2

LITERATURE REVIEW

Some beginner level engineers and hobbyists try to connect solar panels directly to the load, but this method is highly inefficient. From general electrical principle, maximum power is extracted from a source (being a solar panel in this work) when the output resistance of the source matches the input load resistance, which is a laptop battery in this work.

In reality, it is very difficult to track and match these characteristic resistances as the solar panels have varying voltages depending on many factors such as time of day, temperature and insulation, and the battery also continuously charges and discharges. These factors affect the characteristic resistance as it is dependent upon Ohm's law. The voltage fluctuations produced by solar panels affect their power output. Hence, an interface is needed between the source and the load to extract the maximum power available per time, thereby improving the efficiency of the solar panels. Various loads can be powered for useful applications. Typically, solar panels are designed with rated output voltage and current, but these specifications are often not supplied by the panels when directly connected to load as shown in Fig. 1, even for smaller loads requiring less power.

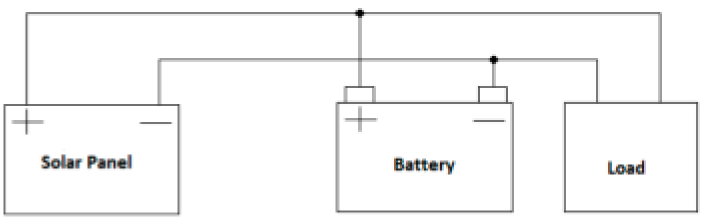

Figure 1. Inefficient Solar Panel - Load Connection.

If required power by the load is directly supplied by the panel, it can be well below rated power of the panel for smaller loads because the current drawn by the smaller load can be lower than rated current of the solar panel or the load operates at a lower voltage than that of the maximum voltage of the solar panel. Hence, not making the solar panel to perform optimally. These challenges can be mitigated by connecting a Maximum Power Point Tracking (MPPT) controller appropriately between the solar panel and the load. The MPPT is an automatic control algorithm that modifies source and load power interfaces in order to ensure maximum power transfer to the load, based on certain parameters such as photovoltaic module characteristics, temperature, solar irradiation, shading, time, etc. In some earlier work as shown in Fig. 2, where traditional Pulse Width Modulation (PWM) charge controllers were directly connected to battery loads, the solar panel voltage automatically gets pulled towards the battery voltage, but with a limited current supply. Therefore, the panel does not supply maximum power even as the PWM controller misses the maximum power operating point.

The improvements in power electronics technology have opened a window for further research and development into making solar panels more efficient. A maximum power point tracking algorithm can be implemented along with microprocessors and Direct Current to Direct Current (DCDC) converters as controllers to extract the maximum power available from solar panels. Conventional PWM controllers are good enough for trivial projects where power inefficiency is not a problem, but in cases where savvy power consumption is needed an MPPT controller can be used.

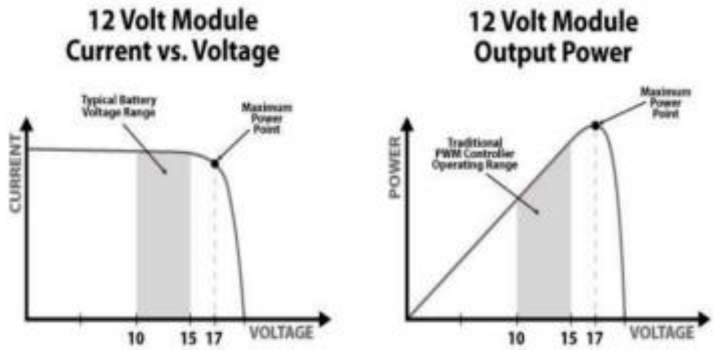

Figure 2. Power profile of PWM controller.

Some common DC-DC converters are hereby discussed. A buck converter steps down the high source voltage to a desired low load voltage, while the boost converter steps up the low source voltage to a high load voltage. The buck-boost converter offers both the voltage stepping down capabilities of the buck converter and voltage stepping up capabilities of the boost converter, but with a negative or inverting output voltage. The flyback converter can basically buck and boost input voltage depending on how the coupled inductor is connected. The forward converter, similar to the flyback converter, possesses the capability to buck or boost an input voltage, but has a third winding on the coupled inductor in order to destabilize unwanted magnetizing currents in the core of the transformer.

The Cuk converter named after the engineer, Slobodan Cuk, performs similarly to the buck-boost, but it directly couples the buck and boost to form a step-up and step-down converter in one. The SEPIC works like both the Cuk converter and buck-boost converter as it can boost or buck the input voltage, however it has a non- inverting output voltage. The full and the half-bridge DC-DC converters uses its transformer to offer electric isolation and the converter can be either buck or boost up the voltage.

Also, MPPT controllers can be designed as MPPT with buck converters, MPPT with boost converters or MPPT with buck-boost converter. The MPPT with buck converters uses voltage and current sensors to incrementally decrease or increase the duty cycle via a microcontroller. The sampled power for different duty cycles is then compared between the previous and a recently sampled point until a maximum power point is found. In a MPPT with boost converter, an interleaved boost converter topology can be used to simultaneously power two boost converters with out of phase signals of the same frequency.

The system aims to improve the efficiency of a single solar panel by connecting converters in parallel so that the input current is be shared. Therefore, a higher voltage is produced with minimal output ripples, which can contribute to losses. Lastly, the MPPT with buck-boost converter uses a fuzzy logic controller to extract maximum power from the solar panel. The power and current deviations are controlled by varying the duty cycle accordingly from the results of the comparison between the converter in boost and buck modes under same atmospheric conditions.

The perturb and observe algorithm is a popular implementation on solar panels with the DC-DC converter for tracking a maximum power point from a solar panel. The algorithm is very easy to implement as it uses a voltage and a current sensor to incrementally decrease or increase the duty cycle via a microcontroller. The sampled power for different duty cycles is then compared between the previous and a recently sampled point until a maximum power point is found.

CHAPTER 3

METHODOLOGY

3.1 TOPOLOGY

The proposed solution for the MPPT solar laptop charger (SLC) is to create a more efficient solution for extracting maximum power from the solar panel as shown in Fig. 3 were the solar panel is connected to the load via a DC-DC converter in a boost topology. The inductor is charged when the electronic switch is ON because the diode is reverse biased and no current flows to the output. However, when the electronic switch is OFF, the charged inductor is forced to dump the energy stored via the diode towards the output.

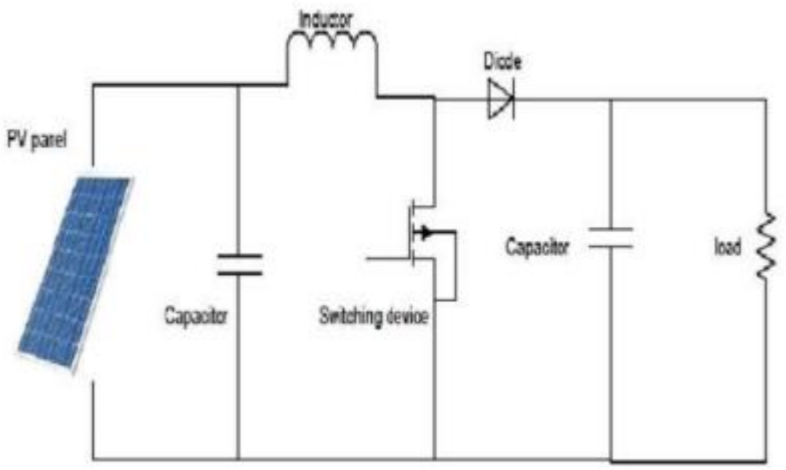

Figure 3. Solar Boost Converter Topology.

The charged inductor and the source voltage add up to produce a higher voltage than the source. The simple DC-DC converter interface is aimed at reducing the inefficiencies of directly connecting the solar panel to the load.

3.2 GATE DRIVER

A Metal Oxide Semi-conductor Field Effect Transistor (MOSFET) require gate driver as shown in Fig. 4 for easy ON and OFF switching because the switching threshold voltage is higher than 5 V, which most microcontrollers don't produce above. The B25 voltage sensor can measure voltages up to 25 V with inputs of 5 V, which is common with microcontrollers like the Arduino, but in this work a PIC18 microcontroller, which operates at 3.3 V was used. The sensor has a resolution of five times the input voltage, which is not desirable for this work. Therefore, the B25 was modified by adding resistors to increase voltage sensing range.

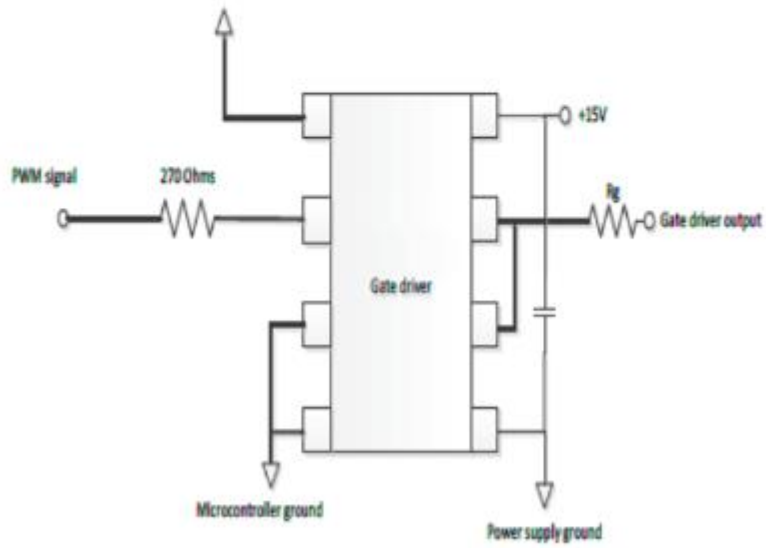

Figure 4. Gate driver circuit.

The gate resistance R g is a function of the supply voltage V cc, digital output voltage Vs and the peak current I peak and it is calculated as shown in (1):

$$R_g = V_{cc} - V_s / I_{peak} \quad (1)$$

3.3 COMPONENT DESIGN

The converter's allowable load resistance is given by (2), while the practical boost converter duty cycle D is expressed in (3) as follows:

$$R_{0,\,min} = V^2_{in}/P \quad (2)$$

$$D = 1 - (V_{in}/ V_{out}) \quad (3)$$

Where V_{in},V_{out},P and are input voltage, output voltage and power respectively. The input current is given by (4):

$$I_{in} = I_l = (V^2_{out}/ R_{o,min}) \times V_{in} \quad (4)$$

Most of the inductors available on the shelf do not meet the required inductance for this design; hence the need to build its inductor. The change in inductor ripple current is modelled as 20% of the input or inductor current given by (5):

$$\Delta i_L = 20\ \% \times I_L \quad (5)$$

The appropriate copper size must have the relevant specification for the input inductor current. Therefore, the inductance L is found using (6):

$$L = V_{in} \times D/\Delta i_L \times F_{sw} \quad (6)$$

where F_{sw} is the switching frequency. For the capacitor design, a 2% output ripple voltage is desired. Hence, change in output voltage is calculated using (7):

$$\Delta V_{out} = 2\ \% \times V_{out} \quad (7)$$

The capacitor must at least handle 25 V maximum voltage. However, for safety reasons, a minimum 50 V capacitor at a designed capacitance must be used such that the capacitance C is found using (8):

$$C = V_{in} \times D/\Delta V_{out} \times (1 – D) \times R_{o,min} \times F_{sw} \quad (8)$$

The internal circuitry of the hardware construction of the MPPT SLC is shown in Fig. 5.

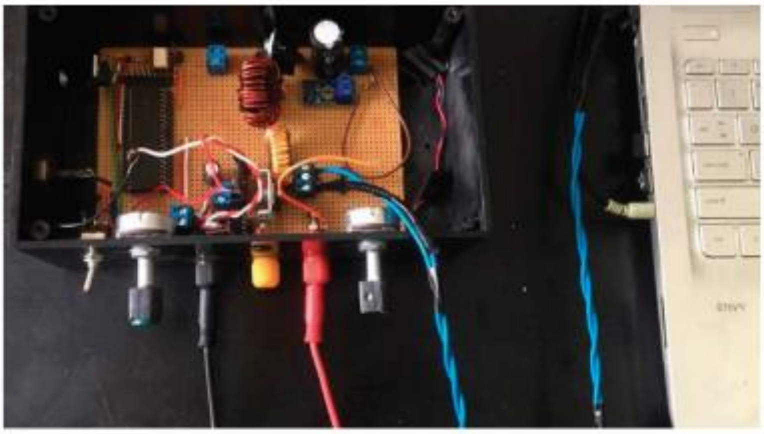

Figure 5. Construction of the MPPT SLC.

CHAPTER 4

SIMULATION

4.1 SIMULATION

The design of the MPPT SLC was also simulated and is presented in this section. The simulation of the MPPT SLC was carried out in MATLAB as shown in Fig. 6. A load resistance of 5.6 Ω was used to simulate the load of the charging laptop battery according to calculations. This simulation was first carried out, the results analysed and understood before the hardware implementation was done.

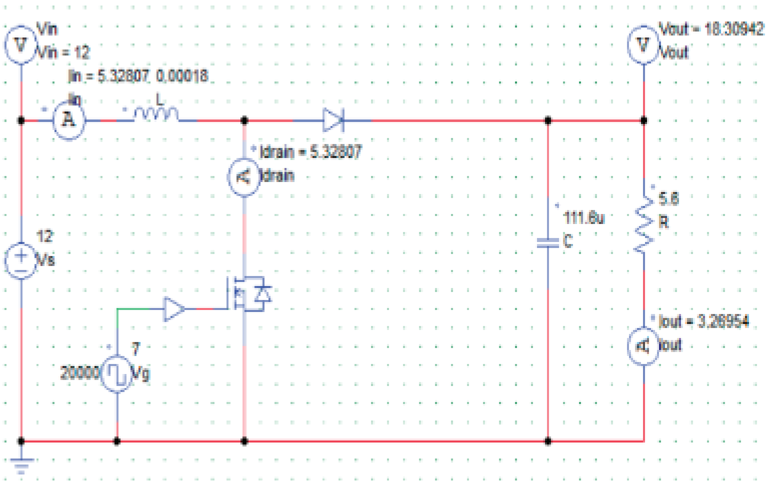

Figure 6. Boost Converter Simulation.

4.2 SIMULATION RESULTS

A simulation of input voltage and output voltage to the boost converter can be seen in Fig. 7. The output voltage has an overshoot initially, but quickly settles down to around 18.5 V for laptop charging as desired from about 0.006 seconds. Furthermore, Fig. 8 shows where the input current initially has a large overshoot before the system stabilizes. Also, it can be seen that the current is delivered at the load in a more efficient way to ensure maximum power at the output.

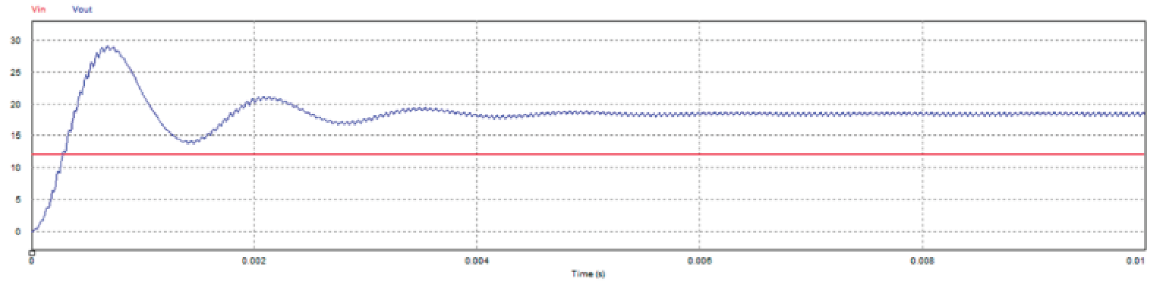

Figure 7. Input and output voltages.

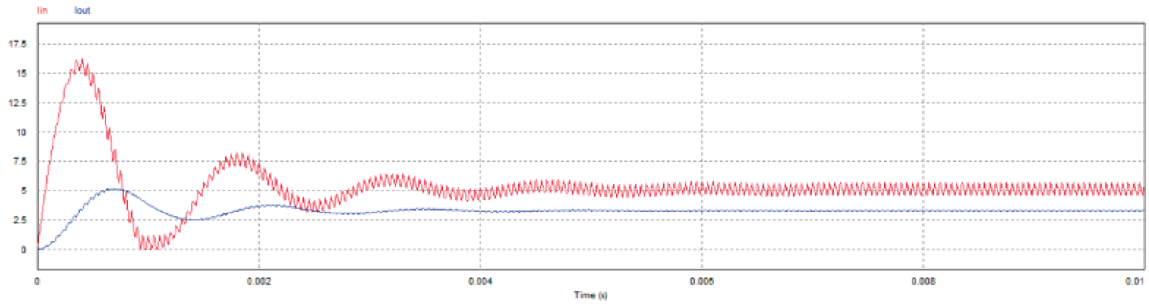

Figure 8. Input current and output current.

4.3 ANALYSIS OF PWM SIGNAL

A raw PWM signal taken from the PIC microcontroller can be seen in Fig. 9 with a root-mean-square (RMS) voltage of 1.09 V at 63.5% duty cycle.

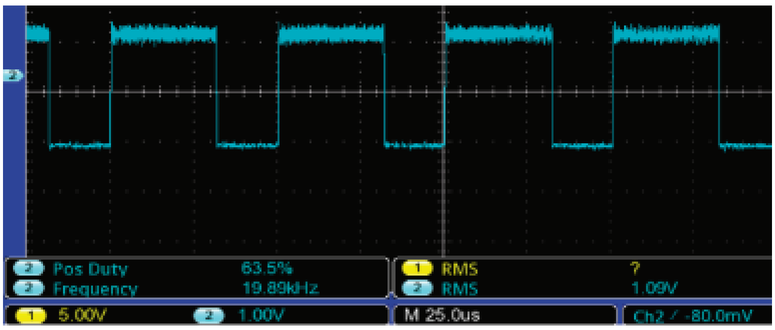

Figure 9. 20 kHz PIC microcontroller PWM.

It is obvious that the microcontroller cannot drive any MOSFET with such a low RMS voltage. To allow for ease of switching ON and OFF the MOSFET, a minimum of 4 V RMS is necessary. Taking the PIC microcontroller PWM and passing it through the TLP251 optically isolated gate driver, it can be seen that the 1.09 V RMS obtained in Fig. 9 is now amplified to 6.76 V RMS as shown in Fig.10.

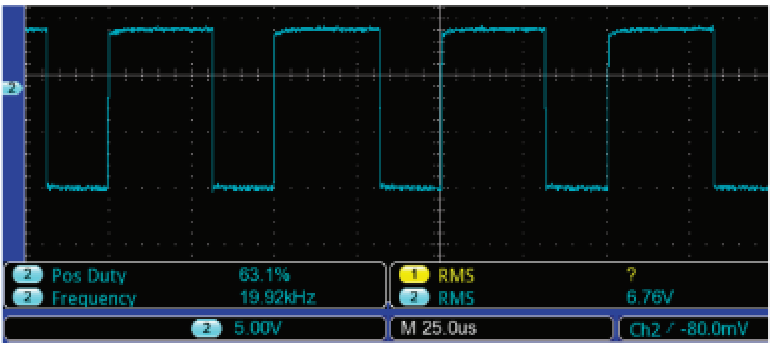

Figure 10. TLP251 Gate driven PIC PWM.

The new PWM signal can now easily switch ON and OFF the MOSFET for the DC-DC converter. An optically isolated gate driver was chosen for safety reasons so as to electrically isolate the fragile microcontroller from heavy voltages of the DC-DC converter. In Fig. 11, the desired output voltage is achieved, which is 19.4 V, and the PWM will automatically bounce around the 65% duty cycle though 63.1% is measured from the oscilloscope. This shows that users of the proposed MPPT SLC can work more profitably with their laptops or other devices that can use similar specifications.

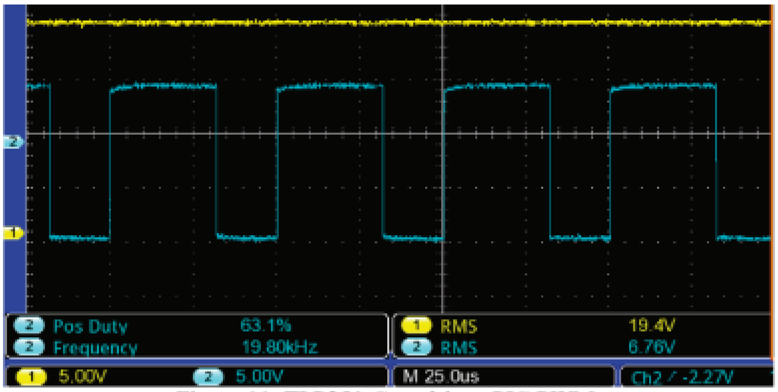

Figure 11. TLP251 Gate driven PIC PWM.

CHAPTER 5

CONCLUSION

The PIC microcontroller was used as the brain of operation in this work to produce a variable PWM and for some sensing applications used for feedback to operate as a closed-loop controller. The low RMS output of the PWM from the PIC meant that a suitable gate driver was to be used to amplify the PWM to overcome the MOSFET gate threshold. The boost converter that was employed to do the maximum power point tracking was well designed and fully functional. When the PWM duty was below 50% the converter was operating below the input voltage, and when the duty cycle was above 50%, a voltage higher than the input voltage was realized. The objectives of the study, which was to design a MPPT solar laptop charger, was carried out, tested and were proven to be successfully achieved. This work finds applications greatly in remote areas where supply of electricity is highly unreliable due to consistent load shedding. Nonetheless, urban laptop users can also benefit from it to charge their laptops in the day. Furthermore, the cost of the hardware implementation of the MPPT SLC in this work is lower than the proprietary ones available in the shops. Hence, its' mass production is encouraged in the country. Apart from individual and business customers, schools can also purchase the MPPT SLC in order to power their computer laboratories (using laptops), so that students can still have their computer practical classes in school even during load shedding. However, there is still room for further research and development on the topic.

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