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Second Year Design Project

ELEC50003/ELEC50008

The MARS Rover

Group 1

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Word Count: XXXX Words
June 8, 2021

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Abstract

The purpose of the Vision module is threefold: 1. Capture data from camera module; 2. Detect objects of interest within the current view and send their location to the Control module; and 3. Send image data to Control for streaming to Command.

2.3.1 Hardware Organisation

The Vision module comprises of two main hardware elements: the Terasic DE10-Lite, a cost-effective Intel MAX 10 based FPGA board [1] and the Terasic D8M-GPIO camera package [2] that interfaces with the FPGA through the onboard GPIO connectors.

These hardware choices were made by the project organisers, but are also sufficient and capable of carrying out the tasks at hand. As the FPGA's hardware is configurable, it is more flexible than other embedded systems that are limited to a general purpose processor,and is also able to handle both streaming and processing of high resolution images without significant compromises on framerate or data speed through the use of concurrent operations and dedicated blocks for signal processing applications like multiplication. This particular FPGA is also equipped with a 4-bit VGA output which is useful for debugging object detection live, and also has a connector for an Arduino Uno R3 shield, [1] which can be used to interface with the ESP32 used for control.

In order to perform general purpose operations like to configure camera settings and to provide a debugging interface, a Nios II soft core was instantiated on the FPGA. Alternatively, to implement a more advanced image processing algorithm or to reduce other hardware components in the system like the multiple Arduinos, a FPGA with a hard core, known as a FPGA System-On-Chip (FPGA SoC) [3] could be used, which would provide both the advantages of having reconfigurable hardware and a more capable general purpose processor.

2.3.2 Image Capture Processing Stream

The image capture and buffering is based on a starter project provided by Terasic Inc for the D8M Camera module that was modified by Ed Stott [4].

2.4 Drive

2.5 Energy

Abstract

The main goal of the energy sub-module is to design a battery pack for the rover and charge it using solar power. With this goal in mind, the energy sub-module must develop a battery management system which allows the tracking of battery SOC and SOH, and if necessary perform SOH maintenance.

2.5.1 Characterising Components

When designing a system it is necessary to know the behaviour and limitations of its constituent components. There are three main components that make up the energy subsystem: the battery cells, the PV panels and the SMPS.

Battery Cells

To determine the behaviour of the battery cells they were all tracked through a full charge/discharge cycle using the provided "Battery_Charge_Cycle_Logged_V1.1.ino" code[5]. Every cell behaved similarly in terms of the cell voltage compared to time. The cell voltage of cell 1 over a full discharge/charge cycle is shown in figure 1:

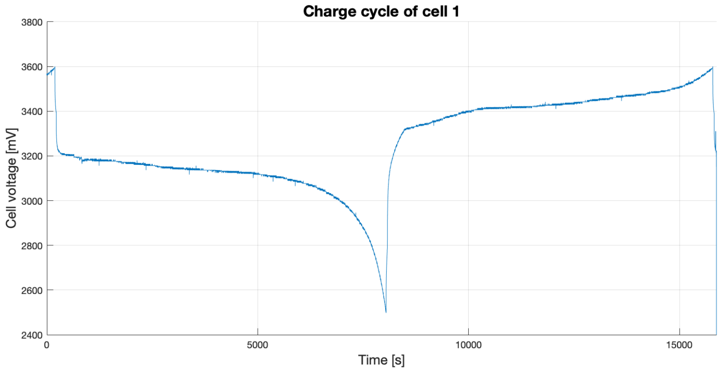


Figure 1: The voltage evolution of cell 1 through a full discharge/charge cycle.

Note the following important points on the graph. At 200 s the cell is done charging and enters an idle state for 30 s after which it starts discharging. At 8000 s the cell is fully discharges and enters an idle state for 30s after which it starts charging. Finally, at 18800 s the cell is once again fully charged and the charge cycle is completed.

The provided charging algorithm also logs the current into the cell. By integrating said current for a full charge or discharge section we can determine the cell capacity in mAh. The results of this analysis is presented in the table below:

Cell Number	1	2	3	4	5
Capacity (mAh)	542.7	526.1	519.5	530.1	543.7

As expected all cells have a capacity somewhere around 500 mAh. However, some cells are have a higher capacity than others which may have implications for the performance of certain battery cell configurations.

PV panels

The provided PV panels are rated for a maximum power of 1.15 W at a voltage of 5.0 V and current 230 mA. Away from the maximum power point the performance of the panels can be determined from their I-V curves. To find the I-V curves each panel was connected to the B-inputs of the SMPS operating in non-synchronous boost. They were then lit by the lamp and the duty cycle of the SMPS was varied while measurements of panel current and voltage were taken. After processing the resulting data is plotted in figure 2.

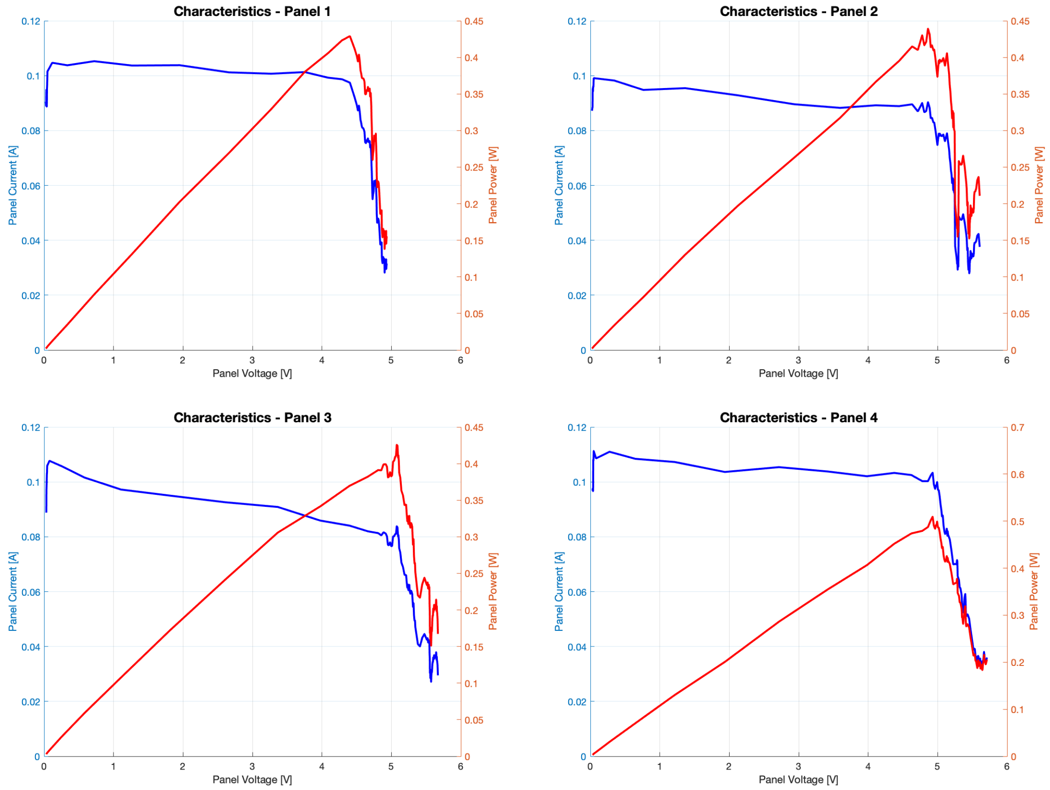


Figure 2: I-V curves for the PV panels.

Though the data is noisy, it is clear that all panels exhibit the standard I-V characteristics of a PV cell. That is, they behave as non-ideal current sources with a nearly constant current at low voltages and a rapid current reduction at high voltages[6]. Moreover, we see that the provided lamp activates the panels poorly as the peak power for each of the panels is only 0.5 W.

SMPS

The provided SMPS is rated for 10 W throughput with a maximum boost output voltage of 35 V and maximum output current of 10 A[7]. All these ratings are far higher than needed and neither is expected to impose limitations on the design of the energy module.

The many characteristics of the SMPS have been thoroughly examined in 2nd year labs. However, for the energy submodule the most important characteristics will be the SMPS efficiency during non-synchronous boost operation. A graph of efficiency versus output current is shown in figure 3.

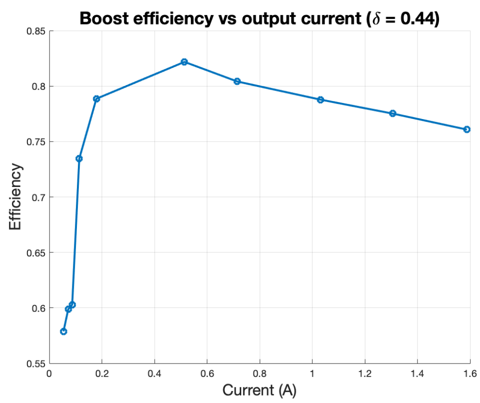
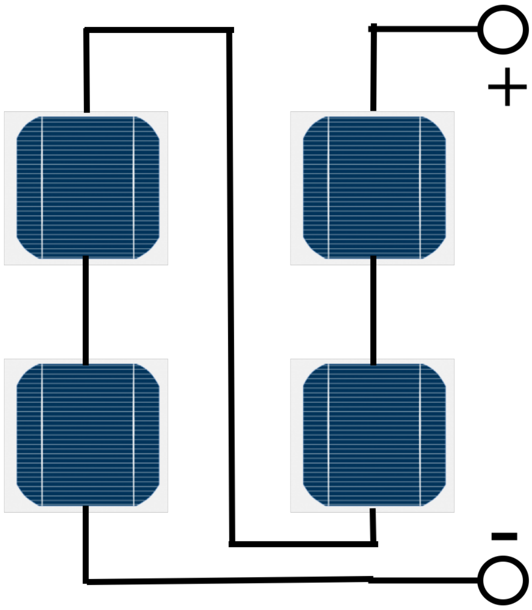


Figure 3: SMPS efficiency versus output current with input voltage 5V

2.5.2 Battery Configuration

2.5.3 PV Array Configuration



2.5.4 SMPS Configuration

2.5.5 Maximum Power Point Tracking

2.5.6 Charging Algorithm

2.5.7 Discharging Algorithm

2.5.8 Safety Mechanisms

2.5.9 State of Charge

2.5.10 State of Health

maintenance

2.5.11 Communicating with Other Modules

Though it is not necessary to fully integrate the energy module with the rest of the rover, other submodules, specifically command, needs access data such as the battery SOH and SOC. For communicating with other modules the Arduino shield has a set of UART ports. However, as group members were not in the same location it was not possible to physically connect the energy module to the rover, which is necessary to use UART. As such, an alternative approach was employed. First the Arduino was connected to a computer via USB. On the computer a Python script was run [8]. At the start the Python script establishes a connection to a server created by running a similar script on the command module [9]. After a connection has been established the Python script starts reading the serial data coming from the Arduino and transmits it using TCP to the command module. Each message coming from the Arduino is in CSV form where the first entry is the message ID, which allows the command script to decode what type of data is being sent.

2.5.12 Physical Integration of the Energy Module

2.6 Integration

3 Evaluation and Conclusion

4 Project Management and Organisation

As this project was carried out remotely with contributors located in different countries, it was important to have a good framework for communication and management.

The main tool used for communications and management was Git + GitHub. As the codebase was incredibly complex, involving many different libraries and with each submodule being capable as a standalone project, it was vital to have a version control system in place. Being able to keep a history of commits and changes made to a project was useful, especially when trying to track down the origin of a bug and what caused it.

The team also made use of GitHub Issues to track progress and accountability in the initial design phase. A thread was opened for each submodule to show what the lead for that submodule had been doing and potential avenues of achieving their goals. This was beneficial both for the leads to keep track of their research, but also allowed other members to contribute to other submodules by adding comments and voicing their thoughts. GitHub Issues were also linked directly to commits in the codebase to allow for a more in-depth explanation and reasoning with context for a commit than what is allowed in the commit message area.

Simultaneously, a Gantt chart was maintained to keep track of progress and is available for viewing under the maintained GitHub repository linked in the Appendix.

5 Intellectual Property

References

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[5] Phil Clemow.

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[7] P. Clemow.

[8] A. Einstein, “Zur Elektrodynamik bewegter Körper. (German) [On the electrodynamics of moving bodies],” *Annalen der Physik*, vol. 322, no. 10, pp. 891–921, 1905. DOI: http://dx.doi.org/10.1002/andp.19053221004.

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Figure 4: Sample Figure

Sample Reference[8]

Appendices

Some Appendix The contents...