Author: Maximillian Burrell

Team: Smart Park

WSUID: Z749D638

ECE595 SDP2

Smart Park Power Solution(s) Part 2

Here is part two of my research for my team’s product: Smart Park Scanner. It is a system that will allow consumers to find easy parking in organized parking lot’s owned by business’s and organizations. The goal of this part of the research is to find a more permanent (at least long lasting) energy charged solutions to the product device, and it’s components (all the different sensors the rest of the team members are taking care of). In my last document, explain Li Ion batteries as the best solution for the engineering of our device’s power, I briefly discussed miniature solar panels being built in. Sort of like basic electronic calculator’s, but more sophisticated.

In regard with solar energy, using sunshine to generate electricity is becoming more important and attractive because it is clean and inexhaustible. Usually methods of electricity generation based on solar energy are grouped into solar light utilization and solar heat utilization. For solar light utilization, when a PV is irradiated by solar light, the solar energy will be converted into electric energy. There are several types of PV that are being used such as monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide. Among them, though silicon PV has been employed at a commercial level, solar photovoltaic array capacity factors are typically under 25%, which is lower than many other industrial sources of electricity, so the electricity generation efficiency and cost have not yet met the needs demanded by the society. Recently, more attentions have been paid to the study of employing solar heat to generate electricity due to its potentially high efficiency.

Mini solar panels are miniature panels that conduct solar power, receiving energy from the sun and using it to provide power to a product. Mini solar panels typically are portable and usable when larger panels are unnecessary or impractical. Their flexibility is an asset that differentiates them from full-size solar panels. mini solar panels provide a source of renewable energy; as such, they offer an alternative to energy sources that have environmental costs, such as the emission of greenhouse gases. Although mini solar panels might prove expensive to purchase, solar energy saves money on power bills over the long run because there is no cost for the sunlight that they use to generate power.

Mini solar panels are versatile power sources for smaller devices that do not have robust energy needs. Examples include radios, cameras, flashlights, and watches. Some applications, such as in cell phones and laptops, combine mini solar panels with [batteries](https://www.walmart.com/browse/household-essentials/batteries/1115193_1076905). Mini solar panels absorb power from the sun that they distribute to the [batteries](https://www.walmart.com/browse/household-essentials/batteries/1115193_1076905), recharging them so that they can continue to operate the devices. The panels' size offers a simple advantage over larger solar panels. Mini solar panels are easier to handle and to manage, and they have a versatility that larger, bulkier panels cannot offer. Mini solar panels can easily be packed and taken on trips, whether on an airplane or on a camping trip to a remote spot without electricity. Mini solar panels do not generate enough power to operate devices that require a great deal of energy, such as [desktop computers](https://www.walmart.com/search/?query=desktop%20computers). Even for many smaller devices, such as laptop computers, mini solar panels are not yet reliable as a sole energy source but need to work along with a battery. In addition, power interruptions are common in devices with mini solar panels because overcast days can sever access to the solar power source.

The challenge in converting sunlight to electricity via photovoltaic solar cells is dramatically reducing the cost/watt of delivered solar electricity — by approximately a factor of 5–10 to compete with fossil and nuclear electricity and by a factor of 25–50 to compete with primary fossil energy. New materials to efficiently absorb sunlight, new techniques to harness the full spectrum of wavelengths in solar radiation, and new approaches based on nanostructured architectures can revolutionize the technology used to produce solar electricity. The technological development and successful commercialization of single-crystal solar cells demonstrates the promise and practicality of photovoltaics, while novel approaches exploiting x thin films, organic semiconductors, dye sensitization, and quantum dots offer fascinating new opportunities for cheaper, more efficient, longer-lasting systems.

Many of the new approaches outlined by the workshop participants are enabled by (1) remarkable recent advances in the fabrication of nanoscale architectures by novel top-down and bottom-up techniques; (2) advances in nanoscale characterization using electron, neutron, and x-ray scattering and spectroscopy; and (3) sophisticated computer simulations of electronic and molecular behavior in nanoscale semiconductor assemblies using density functional theory. Such advances in the basic science of solar electric conversion, coupled to the new semiconductor materials now available, could drive a revolution in the way that solar cells are conceived, designed, implemented, and manufactured.

* Voltage Regulator

A voltage regulator is a circuit that creates and maintains a fixed output voltage, irrespective of changes to the input voltage or load conditions. Voltage regulators (VRs) keep the voltages from a power supply within a range that is compatible with the other electrical components. While voltage regulators are most used for DC/DC power conversion, some can perform AC/AC or AC/DC power conversion as well. This article will focus on DC/DC voltage regulators. Types of Voltage Regulators: Linear vs. Switching There are two main types of voltage regulators: linear and switching. Both types regulate a system’s voltage, but linear regulators operate with low efficiency and switching regulators operate with high efficiency. In high efficiency switching regulators, most of the input power is transferred to the output without dissipation.

* Linear Regulators

A linear voltage regulator utilizes an active pass device (such as a BJT or MOSFET), which is controlled by a high-gain operational amplifier. To maintain a constant output voltage, the linear regulator adjusts the pass device resistance by comparing the internal voltage reference to the sampled output voltage, and then driving the error to zero. Linear regulators are step-down converters, so the output voltage is always below the input voltage. However, these regulators offer a few advantages: they are generally easy to design, dependable, cost-efficient, and offer low noise as well as a low output voltage ripple. Linear regulators, such as the MP2018, only require an input and output capacitor to operate (see Figure 1). Their simplicity and reliability make them intuitive and simple devices for engineers and are often highly cost-effective.

* Limitations of Voltage Regulators

One of the main disadvantages for linear regulators is that they can be inefficient, as they dissipate large amounts of power in certain use cases. The voltage drop of a linear regulator is comparable to a voltage drop across a resistor. For instance, with a 5V input voltage and a 3V output voltage, there is a 2V drop between the terminals, and the efficiency is limited to 3V/5V (60%). This means linear regulators are best suited for applications with lower VIN / VOUT differentials. It is important to consider the estimated power dissipation of a linear regulator in application, since using larger input voltages results in high power dissipation that can overheat and damage components. Another limitation of linear voltage regulators is that they are only capable of buck (step-down) conversion, in contrast to switching regulators, which also offer boost (step-up) and buck-boost conversion. Switching regulators are highly efficient, but some disadvantages include that they are generally less cost-effective than linear regulators, larger in size, more complex, and can create more noise if their external components are not carefully selected. Noise can be very important for a given application, as noise can affect circuit operation and performance, as well as EMI performance. Switching Regulator Topologies: Step-Down, Step-Up, Linear, LDO, and Adjustable There are various topologies for linear and switching regulators. Linear regulators often rely on low-dropout (LDO) topologies. For switching regulators, there are three common topologies: step-down converters, step-up converters, and buck-boost converters. Each topology is described below:

* LDO Regulators

One popular topology for linear regulators is a low-dropout (LDO) regulator. Linear regulators typically require the input voltage to be at least 2V above the output voltage. However, an LDO regulator is designed to operate with a very small voltage difference between input and output terminals, sometimes as low as 100mV.

* Step-Down and Step-Up Converters

Step-down converters (also called buck converters) take a larger input voltage and produce a lower output voltage. Conversely, step-up converters (also called boost converters) take a lower input voltage and produce a higher output voltage.

* Buck-Boost Converters

A buck-boost converter is a single-stage converter that combines the functions of a buck and a boost converter to regulate the output over a wide range of input voltages that can be greater or less than the output voltage.

* Voltage Regulator Control

The four fundamental components of a linear regulator are a pass transistor, error amplifier, voltage reference, and resistor feedback network. One of the inputs to the error amplifier is set by two resistors (R1 and R2) to monitor a percentage of the output voltage. The other input is a stable voltage reference (VREF). If the sampled output voltage changes relative to VREF, the error amplifier changes the pass transistor’s resistance to maintain a constant output voltage (VOUT). Linear regulators typically only require an external input and output capacitor to operate, making them easy to implement. On the other hand, a switching regulator requires more components to create the circuit. The power stage switches between VIN and ground to create charge packets to deliver to the output. Similar to a linear regulator, there is an operational amplifier that samples the DC output voltage from the feedback network and compares it to an internal voltage reference. Then the error signal is amplified, compensated, and filtered. This signal is used to modulate the PWM duty cycle to pull the output back into regulation. For example, if the load current increases rapidly and causes an output voltage droop, the control loop increases the PWM duty cycle to supply more charge to the load and bring the rail back into regulation.

* Linear and Switching Regulator Applications

Linear regulators are often used in applications that are cost-sensitive, noise-sensitive, low-current, or space constrained. Some examples include consumer electronics such as headphones, wearables, and Internet-of-Things (IoT) devices. For instance, applications such as a hearing aid could use a linear regulator because they don’t have a switching element that could create unwanted noise and interfere with the device’s performance. Moreover, if designers are mainly interested in creating a low-cost application, they need not be as concerned with power dissipation, and can rely on a linear regulator. Switching regulators are beneficial for more general applications and are especially useful in applications that need efficiency and performance, such as consumer, industrial, enterprise, and automotive applications. For example, if the application requires a large step-down solution, a switching regulator is better suited, since a linear regulator could create high power dissipation that would damage other electrical components.

* What are the Basic Parameters for a Voltage Regulator IC?

Some of the basic parameters to consider when using a voltage regulator are the input voltage, output voltage, and output current. These parameters are used to determine which VR topology is compatible with a user’s IC. Other parameters — including quiescent current, switching frequency, thermal resistance, and feedback voltage — may be relevant depending on the application. Quiescent current is important when efficiency during light-load or standby modes is a priority. When considering switching frequency as a parameter, maximizing the switching frequency leads to smaller system solutions. Additionally, thermal resistance is critical to remove heat from the device and dissipate it across the system. If the controller includes an internal MOSFET, then all losses (conductive and dynamic) are dissipated in the package and must be considered when calculating the maximum temperature of the IC. Feedback voltage is another important parameter to examine because it determines the lowest output voltage that the voltage regulator can support. It is standard to look at the voltage reference parameters. This limits the lower output voltage, the accuracy of which impacts the accuracy of the output voltage regulation.

Voltage Regulation Standards In a distribution system, voltage regulation refers to maintaining the steady-state voltage within an acceptable or prescribed range always, with the help of equipment. The voltage variation capacity varies from equipment to equipment, based on the standards for which it is designed. Generally, voltage regulation standards vary from utility to utility and from country to country. American National Standard for Electric Power Systems and Equipment Voltage Ratings ANSI C84.1 [13], is the national standard in USA, which is followed by most of the utilities. There are two categories mentioned in the above standard. Range A corresponds to normal operating conditions and Range B corresponds to short durations or unusual conditions.

Voltage Control with DG In a distribution system, fluctuations in voltages occur mainly due to variations in the load. Change in the load corresponds to change in the current drawn from the substation. As product of impedance and line current constitute voltage drop, variation of line current is directly proportional to the voltage drop. Bus voltage depends on the voltage drop and any changes in the voltage drop affects the bus voltage. Therefore, voltage regulation needs to be done all the time. Voltage regulation is done using substation transformer load tap changers (LTC's) with voltage regulators, line voltage regulators, fixed and switched capacitor banks.

* How to Pick the Right Voltage Regulator

To select the proper voltage regulator, the designer must first understand their key parameters such as VIN, VOUT, IOUT, system priorities (e.g. efficiency, performance, cost), and any additional key features, such as power good (PG) indication or enable control. Once the designer has defined these requirements, use a parametric search table to find the best device to meet the desired requirements. The parametric search table is a valuable tool for designers, as it offers different features and packages available to meet the required parameters for your application. Every MPS device comes with a datasheet that details what external parts are needed, and how to calculate their values to achieve an efficient, stable, and high-performance design. The datasheet can be used to calculate component values such as output capacitance, output inductance, feedback resistance, and other key system components.

References

1. Zhu, N., Matsuura, T., Suzuki, R., & Tsuchiya, T. (2014, August 25). *Development of a small solar power generation system based on Thermoelectric Generator*. Energy Procedia. Retrieved March 10, 2022, from <https://www.sciencedirect.com/science/article/pii/S1876610214009837>

2. *Basic research needs for solar energy utilization*. (n.d.). Retrieved March 10, 2022, from

[https://science.osti.gov/-/media/bes/pdf/reports/files/Basic\_Research\_Needs\_for\_Solar\_Energy\_Utilization\_rpt.pdf](https://science.osti.gov/-/media/bes/pdf/reports/files/Basic_Research_Needs_for_Solar_Energy_Utilization_rpt.pdf 3)

[3](https://science.osti.gov/-/media/bes/pdf/reports/files/Basic_Research_Needs_for_Solar_Energy_Utilization_rpt.pdf 3). Gresham, T. (2020, November 17). *What is a mini solar panel?* Home Guides | SF Gate. Retrieved March 10, 2022, from <https://homeguides.sfgate.com/mini-solar-panel-79615.html>

4. *Feeder voltage control in the presence ... - soar.wichita.edu*. (n.d.). Retrieved March 10, 2022, from <https://soar.wichita.edu/bitstream/handle/10057/14466/t17006_Deshmukh.pdf?sequence=187>

5. *Voltage Regulator types and working principle: Article: Mps*. Voltage Regulator Types and Working Principle | Article | MPS. (n.d.). Retrieved March 10, 2022, from <https://www.monolithicpower.com/en/voltage-regulator-types#:~:text=A%20voltage%20regulator%20is%20a,with%20the%20other%20electrical%20components>.