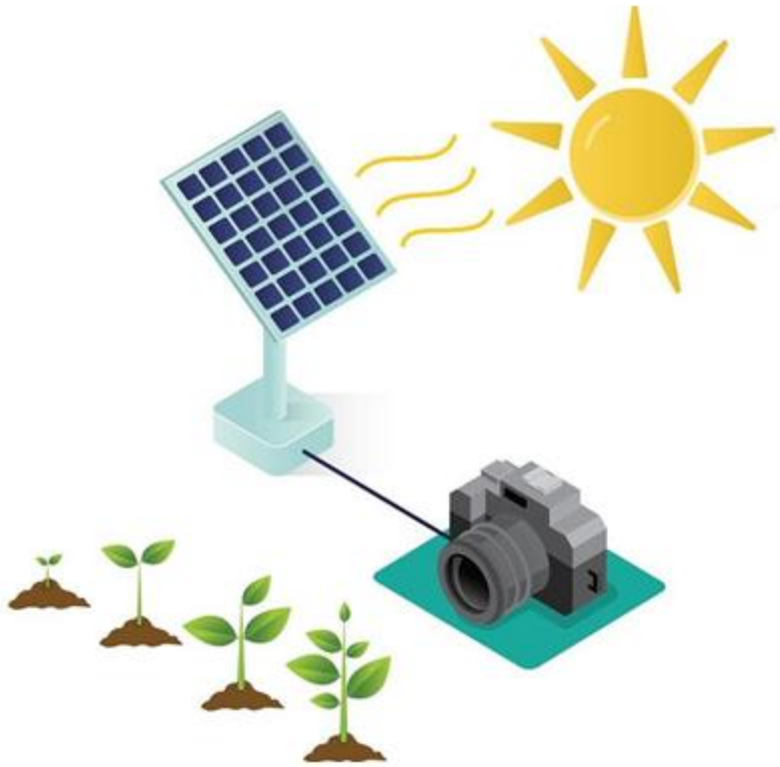
האוניברסיטה העברית בירושלים
THE HEBREW UNIVERSITY OF JERUSALEM | The Rachel and Selim Benin School of Computer Science and Engineering
Electrical and Computer Engineering

Solar Powered Time Lapse Camera



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Abstract

In recent years, cameras are found everywhere, especially as part of the cell phone that most of us carry. They allow us to document almost everything we want, taking pictures in different techniques to receive diversified results.

Most of the cameras today are battery-based cameras and are limited by their battery capacity. For Dedicated time lapse cameras, the working period is usually around three to four months and then they require battery charging or replacement. To overcome these limitations an outer power source is needed.

In recent times, Environmental concerns are on the rise, and efforts are being made to reduce waste and pollution, and to find clean alternatives to fossil fuels as a power source. These sources are renewable energy resources, that are naturally replenishing, such as solar power, hydropower and more.

Using such resources is referenced to as Energy harvesting. It is a process where electrical circuits generate small amounts of energy from natural processes such as movement, pressure, light radiation etc. By using these natural resources, it is possible to generate clean energy without creating waste or environmental pollution.

The goal of this project is to create a power efficient time lapse camera that can sustain itself by harvesting solar energy and will be able to document slow processes in nature for years.

We developed a low power time lapse camera that uses low-cost components. We added solar charging capability by adapting a solar panel for charging the battery. We wrote the code that operates the SOC, so that the camera would take a picture for a predefined time-interval, save it on a memory card, and send a picture through email. To take pictures when it's dark, we designed a light sensor from electronic circuits, which determines when to turn on the flashlight, only when needed and for a minimal amount of time.

The main challenges we faced during the project were reducing the system's power consumption as much as possible as well as keeping the components cost to a minimum. We also needed to ensure that the system remains operational during its entire work period.

Introduction

<u>The problem</u>

Time lapse photography is a photographing technique in which a series of photos is taken at the same frame rate at regular intervals over a period, and then the entire photo series is played in a faster frame rate, creating the illusion of high-speed movement, and make subtle and small changes in slow processes more visible and noticeable to the human eye. (Also applicable to fast processes).

Any camera that can take still photos can produce a time lapse video. Most of the cameras today, either integrated into a device or as a dedicated camera ,rely on batteries as their power source.

Documenting long-term processes requires a camera that can work for a long period of time, and if the camera can't keep working during the entire process period, data loss will occur, and the documentation will be partial. As a result, there is a need to elongate the camera's battery life as much as possible.

<u>Existing solutions</u>

Dedicated time lapse cameras are designed solely for this purpose from the factory. Their work period ranges from 11 days to 120 days[1] for a common off the shelf time lapse camera. There are cameras with longer work periods, but they usually have bigger battery capacity and cost more accordingly, and they usually rely on batteries only.

Cellphones, one can create a time-lapse video with his own smartphone. just put it on a mount and make sure to take a picture or use a time-lapse app. The disadvantages of smartphone use are that a cell phone comes with many other features and components that consume more power and aren’t necessary, not suitable for outside use (weather conditions can damage them).

Our project aims to overcome the battery capacity and power consumption limitations by charging the battery using solar energy harvesting and reducing the power consumption as much as possible. Doing so will allow us to overcome the battery capacity limit and allow the camera to work constantly for years.

[1] Based on existing cameras made by brinno

SOC – system on chip

A system on a chip[2] is an integrated circuit that integrates all or most components of a computer or other electronic system. they almost always include a central processing unit, memory, input/output ports.

System on chip has many advantages over past technologies: instead of having multiple specific use chips and components, system on chip integrates them on a single circuit and creates a multiple use chip. The SOC also offers a small footprint, great processing power with a small power consumption in comparison to a traditional computer with similar hardware extensions. They are also fully or almost fully compatible with a lot of different hardware modules and offer great flexibility. such modules could be cameras, sensors, memory card slots, wireless connectivity, and more.

SOC usually includes:

- Processor
- On chip interconnections
- Analog circuits
- ASCI logic
- Read Only Memory
- Software (OS, application)

To power mobile SOC applications, battery is the most common solution. As a result, the SOC needs to be as power efficient as possible, allowing a maximal working period for the intended use. The power consumption depends on the components that are used and their power efficiency, work procedure and duration for each component.

SOC are used in a variety of applications (cell phones, tv and so much more), becoming more and more efficient and powerful as the technology progresses onwards, while retaining a small size and inexpensive cost per unit.

Using a SOC for our project allows us to program it with our custom code, using the SOC computing capability and connecting peripherals to it while maintaining low power consumption. In our project we use an ESP32 SOC embedded into a commercial module with several peripheral's, such as an external antenna for communications, GPIO connectors, camera connector, SD-card and more which are essential for our project.

[2]'What is a system on chip(SoC)?'- anysillicon

Energy harvesting methods

Energy harvesting[3] is the gathering of energy from renewable resources by capturing and storing power from natural energy sources such as solar power, thermal energy, wind energy and more. It allows us to gather and store energy in a clean way, without producing pollutants in the process. As our project is destined to be set outside, the most suitable source of energy harvesting for our project is solar power harvesting.

Solar Cells

Solar cells are one of the most common energy harvesting solutions available today. From calculators to space stations, Solar cells harvest energy by converting solar radiation into direct current electricity, using semiconductors which are based on the photovoltaic effect[4]. Each solar cell energy output depends on the panel's characteristics, such as size and efficiency. Typical solar panels efficiency is about fifteen percent and energy output vary between few watts and several kilowatts for domestic applications. For our project we will use a small commercial solar panel to recharge our battery.

Project goals

The main goal of the project is to create an affordable and power efficient time-lapse camera that can work for years. The required project achievements are:

- Device maintains overall low power consumption
- Supporting solar charging.
- keeping the cost of the entire system as low as possible.
- Maintaining and monitoring the camera's operation.
- Being able to take photos in dark conditions – night, fog etc.
- Creating a time-lapse video from the photos that were taken.

[3] 'Material and techniques for energy harvesting' - M.E.KiziroglouE.M.Yeatman - Imperial College London, UK March 2014.

[4] 'Solar Energy and Photovoltaic Technology' - KakkanRamalingam, ChandrasenIndulkar - Airports Authority of India, Delhi, India, Indian Institute of Technology, Delhi, India ,may 2017

Methods and Materials

In our project we created a system which is composed from electrical components with low-power consumption, which has the capability of being powered by solar power. By integrating a solar panel to our system, we will be able to recharge the battery and allow the system to work for a prolonged period. In this section we will describe in detail the system parts, the electric circuit, the code workflow, and the different functions that operate the system.

During the project, we designed the system along with a couple of guiding principles:

- Power Consumption – The system is designated to work for a long period of time (months to years; depending on the user's needs), which dictates power consumption data as the main characteristic for selecting different electronic components.

- Solar Charging – The system must support solar charging.

- Cost – We intended our system to be affordable, thus the different components we chose to use in our system are relatively cheap.

<u>Implementation method</u>

To achieve maximum operating time (up to years) we chose to use a solar panel for energy harvesting, as a power source, to charge the system's power supply. During the day, the sunlight hits the solar panel and generates an electric current which charges the rechargeable battery. That way the battery can be charged many times and therefore enable the system to operate for a long period of time. In addition to renewing energy as mentioned, we also considered the power consumption of the components we used to get minimal energy usage.

To prove that the solar panel can charge the system during its entire operating time, we calculated the daily average current that will be produced by the solar panel according to the IMS archive[5] of the solar irradiance measured at Givat Ram.

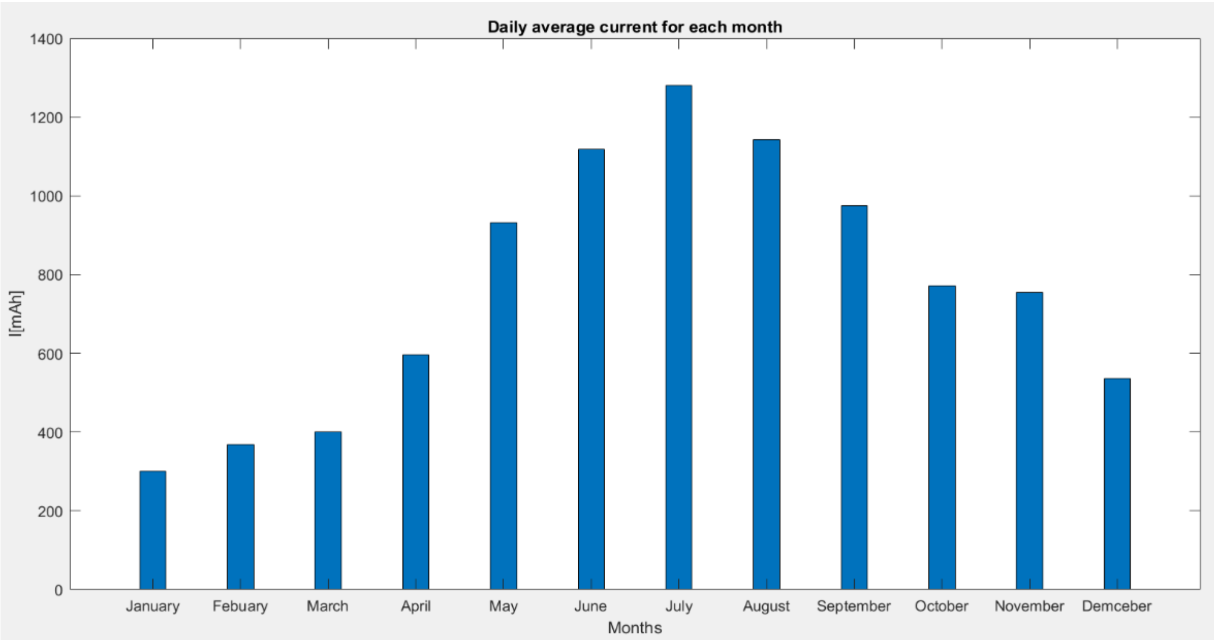

Figure 1: Daily average current for each month of the year of 2019

To calculate these values, we used the following formula[6] :

$$daily\_current = \frac{daily\_average\_solar\_irradiance \cdot solar\_panel\_size \cdot solar\_panel\_efficieny}{solar\_panel\_voltage} \; [mAh]$$

We can see from Figure 1 that even in January, which has the least sunlight hours, the solar panel produces[7] up to 360 mAh at average every day of the month while the system consumption is 55.2 mAh per day.

To improve the power consumption even more, we programmed the SOC to use any power consuming function only when it needs to work and for the minimum time-period necessary to complete it work.

[5] Measurements taken by the ims through the entire year of 2019
[6] The explanation to the formula is described at photovoltaic-software.com
[7] Calculating according to the specs of the solar panel we used, which is described in the next section

Methods Verification

To verify proper functioning of the system, software, and hardware wise, we performed several tests to ensure every function works as it should.
Also, making sure all of them are working together and allowing the camera to work and take enough pictures to create a time lapse video.

These are the main domains of the system to be tested:

- Power consumption: measuring the power consumption of the system in different operating modes with different parameters will allow us to verify our theoretical calculations.

- Photography – making sure the camera can take a picture and save it to a memory card and deciding what camera sensor parameters will suit our needs (exposure, lens corrections, brightness, contrast, etc.).

- Battery charging : verifying the solar panel's capability to charge a battery and therefore allowing the system to operate.

- Communication: checking the system working status remotely by having it send an email with a text or a photo once in a pre-defined interval, proving it is still working and producing photos as expected.

- Low light photography: making sure the camera knows how to identify low light conditions and that the LED offers sufficient illumination for taking pictures.

To test all those features together, we will set the system to take pictures in an hour intervals and position it out-doors for a whole week, documenting a growing plant, while the solar panel charges the battery. Every day we will make sure we get an email as expected and at the end of the week make a time-lapse video from all the pictures that will be taken.

System’s Structure Review

ESP-32 CAM

The main component of the system is the ESP-32 CAM, which is a low cost and low power system on a module, with several input and output peripherals. The ESP-32 SOC on the module can be programmed with various languages and development environments. We chose to program it with CPP using the Arduino IDE. The ESP-32 CAM module has several integrated hardware modules in it, including internal memory, Wi-Fi module, a camera port, and a SD card slot which we used for our project. Using different serial pins on the microcontroller, we can connect different hardware components and circuits to it and operate them using our software.

Solar Panel

For Charging the battery and powering the system we used a $11\ X\ 6$ cm, 6V output, solar panel.

Solar Charger

To collect the power generated by the solar panel to charge the rechargeable battery, we used a SparkFun Sunny Buddy solar charger. the sunny includes a battery charging circuit to charge and protect the battery and a potentiometer to set the output current, up to a maximal current of 450 mA.

Camera

The image sensor we use in our project is the OmniVision OV2640. The OV2640 is a 2MP image sensor with an auto-exposure feature and which meets our image requirements for the project with pictures with resolution up to 1600X1200.

Battery

The system's power supply is a rechargeable 3.7V lithium battery with a capacity of 1800 mAh. Its capacity enables the system to work enough time on days with not low sun light.

Flash

For taking pictures in low-light conditions we chose the rebel star CW100 led light, for its lumen amount of 180 lumens and relatively low forward current of 700 mA.

Light sensor

To control the flash, we used a phototransistor to determine whether it's dark, measuring the voltage drop on it and if the voltage is below a certain threshold, meaning the transistor is closed because not enough light is getting to it, the LED will be enabled. The phototransistor we are using in our project is the LPT035.

Micro-SD card

To save the pictures that are taken the system uses a micro-SD card to store them. the needed capacity for our usage is 4GB.

Case

To weatherproof the system we created a 3D printed case to contain the system. It's a 95X62X60 mm box, made from PTEG[8] for its durability and its chemical resistance. The case is divided into cells: one for the ESP itself, one for the battery and one for the solar charger. rubber seals are also added in connection points to prevent water and dust intrusion. In front of the case there are three openings, The One shaded by a visor is for the camera, two smaller ones for the light sensor and the LED light accordingly.

The top cover of the case has a hole in it to connect the solar panel to the system. The solar panel seats on top of two fins sloped in a forty-five-degree angle for optimal energy harvesting.

Figure 2 : The planned sketch of the case for the 3D printer from different perspectives

Figure 3: The printed case

[8] Polyethylene terephthalate glycol

Pictures resolution and memory capacity

The resolution of the OV-2640 camera is 1600X1200 with 2MP and the format is JPG. An average image size is 67.5KB and the micro-SD card has 4GB of storage which means it can hold up to 59,258 pictures. With an hour picture interval, the system can document the object for six years and eight months.

Block Diagram and System's Flow

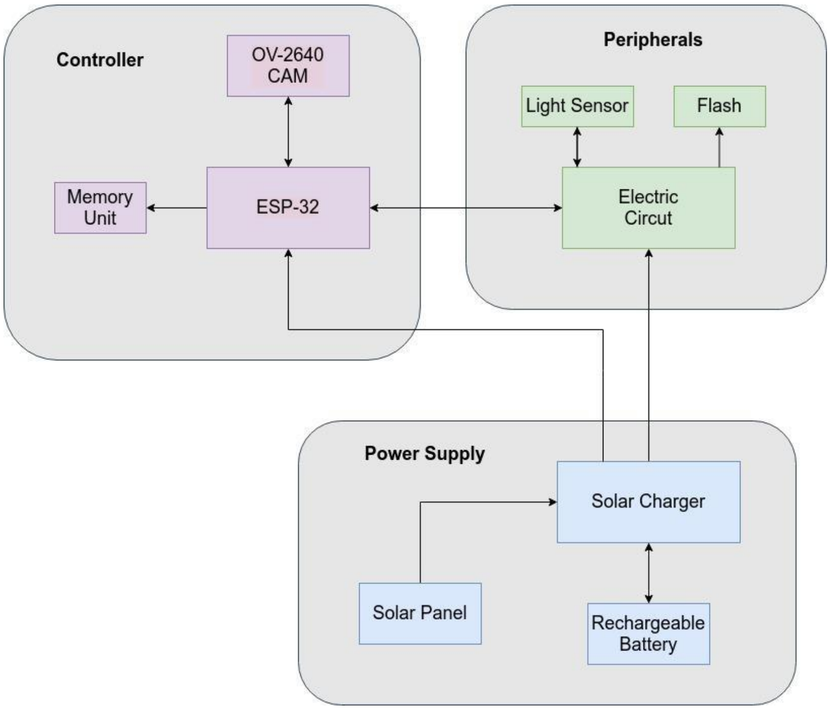

Figure 4: System blog diagram

The system is divided into three main blocks:

- The Controller block:
  This block oversees correlating between the software and the hardware. This block contains the ESP-32 module, the OV-2640 camera and the memory unit which is the micro-SD card. The ESP-32 is connected directly both to the camera and the memory unit. All the photos that are captured by the camera are saved in the SD-card and the controller itself is powered by the battery in the Power Supply block. The ESP-32 is also connected to the Peripherals block to operate its peripherals as needed, such as turning on the led bulb and indicating when it's dark by sampling the light sensor.

- Power Supply Block:
  This block contains a solar panel, a rechargeable battery, and a solar charger. The solar panel is connected to the solar charger, which converts the input voltage from the 6V panel and produces 450 mA current for charging the battery. The battery powers the entire system.

- <u>Peripherals Block:</u>

This block is built on a perfboard and is composed of two circuits:

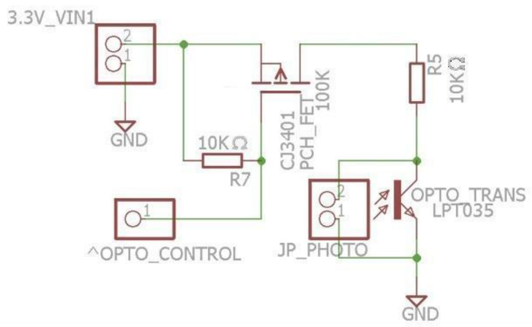

Figure 5: light-sensor circuit

This circuit is responsible for measuring light conditions, by measuring the voltage drop on the phototransistor which open. A P-mos transistor controls the phototransistor and opens when it gets a low control signal (digital '0') from the ESP32-GPIO 0 output. Then the phototransistor gets voltage and can now be opened. by reading the voltage drop on it and setting a threshold value of certain measurements, it can indicate its dark enough so the LED light should turn on.

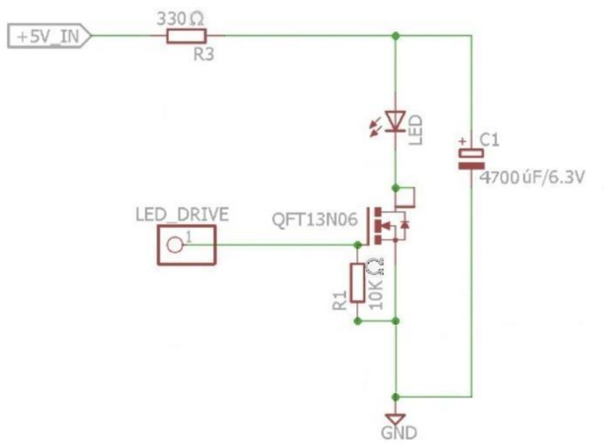

Figure 6: led circuit

This circuit is responsible to turn supply enough current to the led so it will turn on. a N-mos transistor opens by received a high control signal (digital '1') from the ESP32-GPIO 16 output and opens. It then discharges the capacitor which was loaded before into the led and turns it on, feeding the led in 700 mA current until the photo process has finished (600 ms) and it's being turned off.

Software

The code we wrote runs on the SOC processor and controls the hardware of the ESP module and its peripherals, including the camera sensor, the SD card, the Wi-Fi module. Using the module's GPIO outputs, the ESP32 controls the light sensor and the LED light circuits. The program's workflow and logic are described in figure 7.

The program is divided to three parts, camera, logger, and smtp server:

- camera: responsible for board definitions such as GPIO assignments, camera sensor configuration, initialize the SD card, taking a picture and saving it on the SD card, initiate WI-FI connection, measuring light function and deep sleep function.
    - Light measurement function: responsible to measure the light conditions using the phototransistor. It reads the voltage drop on it and if the voltage is below the threshold, the function turns on the LED light. After a photo is taken, if the LED was turned on, it is turned off.
    - Deep sleep function: A function that orders the module to get into deep sleep mode, either if the entire procedure was finished or the battery voltage is lower than the minimum required working threshold. The time for each deep interval is set there.
    - WI-FI function sets up a wireless connection to a specified network.
- logger: responsible for logging every picture that is being taken in the log file. has functions to create a directory, create, read, and write to the end of a text file. include text messages to be sent and the email sending interval.
    - logger – writes picture numbers in the log file.
- SMTP server: responsible for setting up a smtp server and facilitating an email client on the ESP to send emails from it.

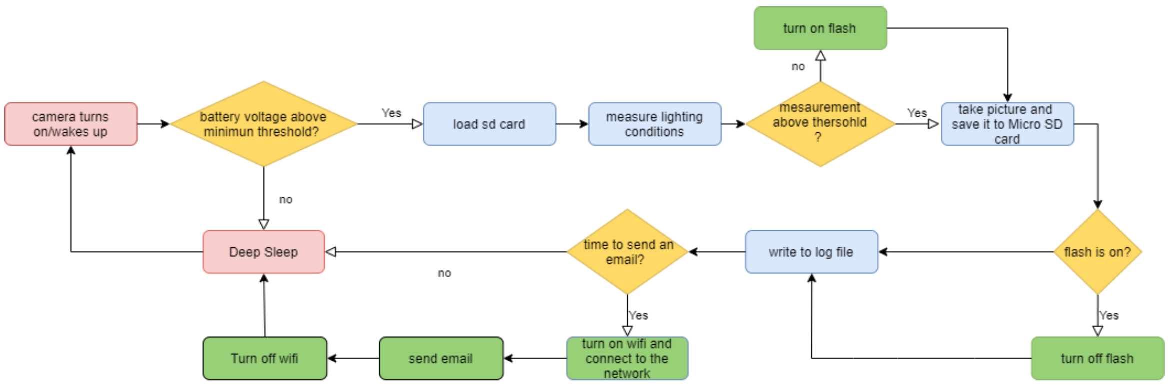

Figure 7: code workflow

Results

Power consumption:

We would like to measure the camera's power consumption to make sure it is according to our specifications, so we took several power and current measurement, in several working conditions and with different parameters.

Current stabilizers comparison and measurements:

During the work on the project, we found that the original LDO[9] that comes with the ESP32 cam is a major power consumer, and it raised the current consumption, even when the system is in sleep mode.

After comparing several linear dropout regulators, we chose the HT7333 LDO, because it has significantly lower Quiescent Current consumption.

Current stabilizer	AMS1117	HT7333
Voltage Range [V]	12	12
Input voltage [V]	5	5
Output Voltage [V]	3.3	3.23
Quiescent Current [mA]	5	$4 \cdot 10^{-3}$
Current output [A]	1	0.25

Table 8: comparison between the two LDO's electrical characteristics

Stabilizers practical test:

To see the difference between the LDO in real time, we tested two ESP modules, one with the AMS1117 and one with the HT7333 at the same conditions, meaning they both ran the entire system code and for the same time operation time.

Stabilizer	AMS1117	HT7333
Power Consumption [mAh]	4864	3358
Time [h]	63	63
Current Consumption [mA]	77.2	53.3
ESP Deep Sleep Current [mA]	76	2.13

Table 9: Results of current measuring of same code on ESP32's, one with the original AMS1117 and the other with the HT7333

[9] Linear drop out regulator, the original that comes with the ESP, the AMS1117

System's power consumption by function

we needed to know how much power its draws and how much time it takes to send an email:

Communication current consumption – Connecting to WI-FI and sending email:

Action	Communication	Photographing	LED	Deep sleep[10]
Average Power consumption [mAh]	220	165	700	2.13
Average time per function [s]	19	8	0.6	3600
Average current consumption [mA]	1.16	0.36	0.11	2.13

Table 10: Power and Current consumption and time measurements

Working Voltage Analysis

To prevent the system from resetting or shutting down completely, when the voltage drops below a certain level, a battery monitoring capability is required. If the power drops below a certain threshold, the camera enters sleep mode, until the battery is charged enough by the solar panel and the camera can continue working properly. we measured the output voltage of the ESP as a function of the input voltage, to find the threshold working voltage value for the system

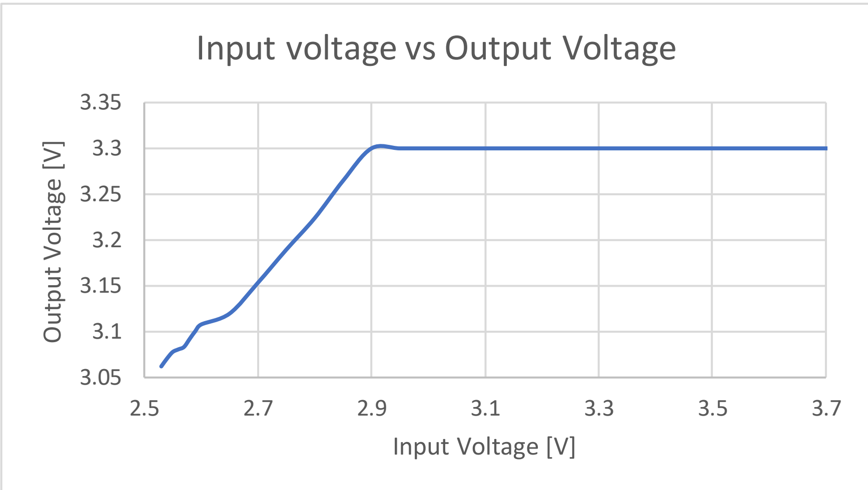

Figure 11: input battery voltage vs. Output voltage

by testing the ESP with a power supply, we found that:

The Wi-Fi's voltage threshold is 3.79 [V]

The system's voltage threshold is 3.06 [V]

[10] Can be set by the user

Power saving – Choosing micro-SD card

Another way to save power in our project was choosing a power-efficient micro-SD card.

Without a micro-SD card and without a camera sensor, that base power consumption is to 0.22 mA (with 2640 sensor it goes to 2.13) and that there exists a significant difference between different micro-SD cards. After comparing several of different micro-SD-card we got the following result, measured when the system ran its code and entered sleep mode:

Manufacturer	Misatp	Lexar	Transcend	OV	Sandisk-ultra	Sandisk-edge
Capacity [B]	128M	8G	16G	16G	16G	16G
Consumption [mA] (with sensor)	2.9	3.21	3.15	3.7	3.87	4.09
Consumption [mA] (without sensor)	0.85	1.11	1.17	1.27	1.35	1.44

Table 12: Micro-SD current consumption table

- **Solar Charging**

This measurement is to determine the time that it takes the solar panel to charge the battery.

Battery capacity [mAh]	Solar panel output current[mA]	Full Charging time [hours]
700	450	1.66

Table 13: solar panel current measuring

- **System costs**

In this project we aimed to keep the system cost as low as possible by using low-cost components. The total cost of our prototype is about 80$.

Discussion and conclusions

Discussion

Power Consumption

Current stabilizers comparison and measurements:

When we researched different ways to lower the system's power consumption, we noticed that the ams1117 LDO draws a lot of current and can be replaced by a more efficient LDO. after comparing some alternatives, we chose the HT7333, mainly because of its lower quiescent current consumption, which is 0.008 times lower in comparison to original LDO, as seen in table 8.

Stabilizers practical test:

As seen in table 9, In the practical test results, we noticed a significant improvement in the power consumption in the real world, of almost 1500 mAh less in favor of the ESP equipped with the HT7333 LDO.

System's power consumption by function

For most of its operating time, the system will be in sleep mode, which has the lowest power consumption between the different work modes (photographing and communication). From the results at tables 9, 10 we can determine the battery capacity necessary to keep the camera working during several days without any solar charging. Using a battery with a capacity of 1800 mAh allows the system to work twenty-five days of continuously without need of charging.

Working Voltage Analysis

By measuring the output voltage as a function of the input voltage on the ESP, we determined that the WIFI can work until the battery drops below 3.79 volts, and the camera stops working when the input voltage drops below 3.06 volts. that gave us the voltage thresholds for the code and which battery voltage we need.

Power saving -micro-SD card

From table 12 see the difference in current consumption between different micro-SD cards. Choosing a power economical SD-card can save us up to one milliamp in sleep mode, and therefore is very critical to our project. The differences come from different manufacturing technologies and methods, and application designations[11].

[11] Based on essay 'Optimising SD Saving Events to Maximise Battery Lifetime for ArduinoTM/Atmega328P Data Loggers' -Luke j. Bradley, Nick g. wright

Solar Charging

As we can see from table 13, the required charging time to fill the entire battery capacity by the solar panel is short enough to make sure that even on the month with the lowest sun hours per day, the battery will still be fully charged We measured a full charging time of 1.66 hours (700 mAh) and the daily system’s consumption is only the fourth of it, 55.2 mAh. This means the system won’t be short of energy.

System's cost

The cost of the system is lower than any name-brand off the shelf time lapse camera. The ESP32-cam itself its very cheap and so are the electronic components such as capacitors, transistors wires, etc. The most expensive parts are the sunny buddy and the case.

Future Work

Create a printed circuit that will replace the perfboard we made.

For the project we created the circuit by soldering components (resistors, brackets, capacitors, wires, transistors etc.) to a preboard, which was fine for our uses, but takes a lot of physical space and is very delicate and fragile.
Ordering a printed board will save us space and make the system more durable and flexible in comparison.
A printed board will also allow us to add additional connectors and make the system more modular.

Implement a lens clearing method or device

The camera is going to be set outside on the ground for very long periods. in Such conditions it's safe to assume that the lens of the case of the camera will get dirty, either by rain or from dust carried by the wind, compromising the pictures taken.
To deal this problem, there is a need to clear the lens from time to time. using optic chemical coats to lens can make less dirt stick to it and water slip off it.
Adding vibration motors to the case can shake the dirt off the lens, but at a cost of power consumption.

Improve the existing case.

The existing case we created is relatively a simple one and only supports the solar panel connector. To make the case more modular, it is possible to add external connector sockets, allowing to adapt the camera to other power sources and needs.

Creating a better user interface

The current interface with the camera is quite cumbersome. It's required to remove the SOC from the case and connect it directly to the computer with an adapter or by taking out the micro-SD card and entering it to a computer socket. We would like to improve that by creating an app that lets us access the camera remotely, change parameters of photo taking and viewing taken pictures without needing to move the camera from its position.

Further cost reduction.

Costs can be reduced even more by replacing the sunny buddy with custom-designed PCB performing the only relevant functions that the sunny buddy offers.

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Appendix

Low-light Photography

After Making sure the system can detect low-light conditions and illuminate, we checked the LED illumination effective range. After several tests and errors, we found that the LED is illuminating plants effectively to range up to 50 cm, when it draws current of about 700 mA.

Results

Phototransistor light measurements:

To prove the light sensor can measure the lighting conditions we took several measurements in different illumination conditions:

1. Low Light simulation: phototransistor is completely covered; it takes the phototransistor 1.2 milli-seconds to open completely and the voltage drop is 1.62 Volt.

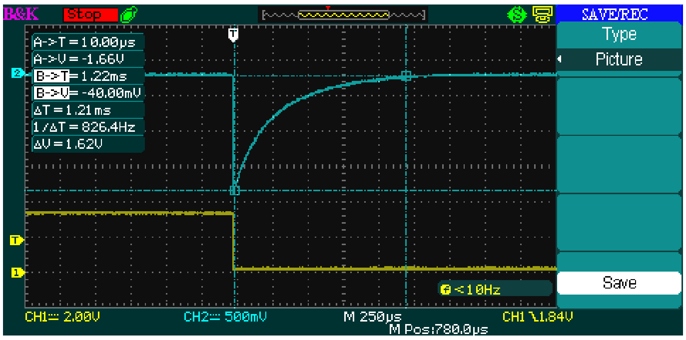

Figure 14: voltage drop on photo resistor in dark conditions

2. Medium lighting simulation, pr is lightened by the room lighting, it takes the phototransistor 350 microseconds to open completely and the voltage drop is 1.54 Volt.

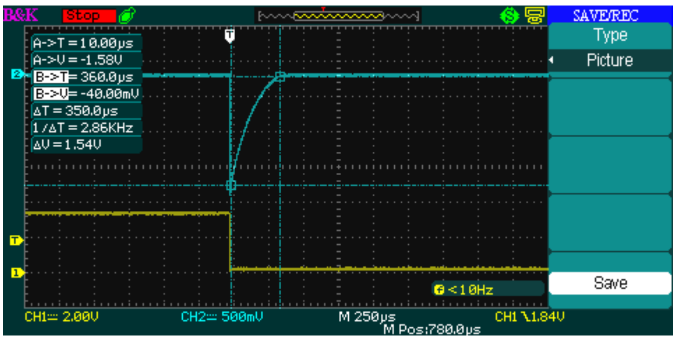

Figure 15: voltage drop on photo resistor in room lighting conditions

3. High lighting simulation, the phototransistor is illuminated directly by a flashlight pointed to it, it takes the phototransistor 300 microseconds to open completely and the voltage drop is 1.5 Volt.

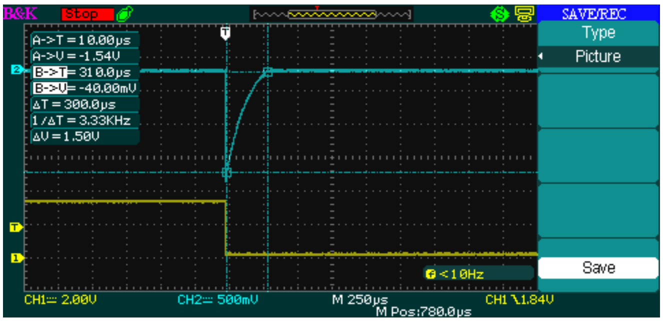

Figure 16: voltage drop on photo resistor in direct illumination conditions

<u>Led Light Measurements:</u>

To guarantee the ability to take pictures at night, we chose a led with a specific power consumption. On the one hand we needed to make sure it's powerful enough and on the other hand, that it doesn't draw too much power and causes the system to crash. First, we measured the voltage that drops on the capacitor to evaluate its charging current:

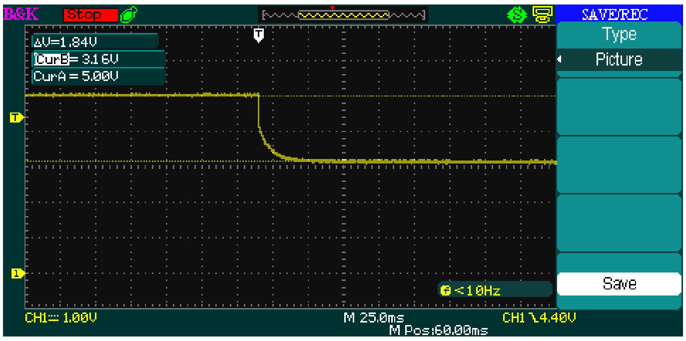

Figure 17: voltage drop on capacitor

We got a voltage measure of 1.84 [V] and by dividing it by the entry resistor resistance value we got that capacitor charging current is 5 [mA].

At the Second measurement , we measured the voltage that drops on the led against the voltage that drops on the capacitor, to see if it's able to supply 700 mA of current to the led to light it. When a picture is supposed to be taken a signal is sent to a transistor which opens and lets the capacitor discharge its current into the led and turn it on.

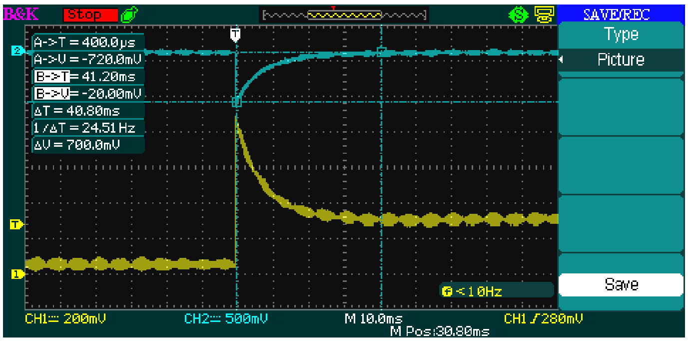

Figure 18: voltage drop when led is activated

<u>Light threshold value</u>

To determine the threshold voltage that signify low-light conditions, we positioned the system outside and took several measurements in the late afternoon. After several measurements we concluded that the threshold value for low light conditions is at 3.1 Volt.

Discussion

<u>Phototransistor light measurements:</u>

As it can be seen from figures 14, 15 and 16, the phototransistor circuit reacts to different lighting conditions an so we can use it as a light sensor.

<u>Led Light Measurements:</u>

From figures 17 and 18 we verify the LED circuit functionality, the capacitor gets a sufficient charging current and when the LED is supposed to turn on, or the transistor that allows it is opening, the capacitor discharges its current into the LED and turns it on.

Summary

As the low light conditions photography was a secondary goal in our project, we included our work in an appendix to the project. The functionality tests of the light sensor and the LED light circuits prove that they will allow us to take pictures in dark conditions.