**Omarichet School Edusat Project**

**Electrical Power Supply System Design Documentation**

**Introduction**

The school edusat will require a regulated power supply that matches the requirement of the various components within the system. The supply should be well designed to be immune to noise, voltage fluctuations as well as short circuit. The power supplied should be designed in a manner to meet the required demand for a required duration of time enabling the use of the Edusat for a generous amount of time. This documentation documents the thought process in the design and development of the system.

**Design Considerations**

**Size and weight**

The design takes in mind the fact that the system is required to be as portable as possible to allow for ease of use, shipping and storage. It will also improve handling especially by kids who may form the majority of our consumers.

**Cost**

The device is intended to be readily affordable with a total market cap of 500 dollars. This has been considered in coming up with this design.

**Power Budget**

The following is the power budget of the School Edusat.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Component** | **Dimension(mm)** | **Current(A)** | **Voltage(V)** | **Power(W)** |
| ACS712 Current sensor Module | 31 x 13 | 10mA | 5 | 0.05 |
| MPU6050 | 21.2x 16.4 x 3.3 | 3.9m | 3.3 | 0.01287 |
| BME280 | 15.5 x 11.5 | 0.4m | 3.3 | 0.00132 |
| HMC5883L | 18.2 x 13.3 | 0.74m | 3.3 | 0.002442 |
| 5V to 3.3V Logic Level Translator | 16.05 x 13.33 | 16m | 3.3 | 0.0528 |
| Adafruit GPS | 25.5x 35 x 6.5 | 25m | 3.3 | 0.0825 |
| GUVA-S12SD | 28 x 17 x 9 | 4.7u | 3.3 | <1x10^-6 |
| 2x LED | 3 | 18m | 1.8 | 0.0594 |
| PhotoResistor |  | 0.039 | 3.3 | 0.1287 |
| Raspberry PI 4 | 85.6 x 56.5 | 2.5(nom) | 5.1V | 12.5 |
| **Total/Max** |  | **2.7A** | **5.1V** | **13.77W** |

**Note:**

The Raspberry Pi 4 requires 1.8A for its own personal use and 1.2A for the USB peripherals. However, depending on the task at hand the Amperage may rise exponentially. For our use case, a 2.5A current estimation is appropriate as a maximum boundary.

Adding heat sinks in the pi will enhance performance and to some capacity power consumption.

**Requirements**

For this project, the power requirements are as follows:

* Input voltage of the range 5V to 25V. This will be from both the battery and from the Solar panel.
* An output voltage of both 5.1V and 3.3V
* Maximum current of 3 Amps to handle spike and peak demand.
* Highest possible efficiency to ensure the battery lasts long enough.
* A power rating of at least 14 Watts.
* Minimal noise and ripple on the power buses.
* Reverse polarity and short circuit protection.
* Adequate cooling of the components.
* Cost Effective.
* Provide a measurement mechanism for the current consumption and voltage

**Design Details**

The following explores the process of designing the system along with the mathematical models used in deriving the exact parameter values. It will also provide the rationale involved in the coming up with component choices and their impact on the overall system. Trade-offs are also mentioned.

**Block Diagram**

The EPS system will comprise of the following blocks:

* Power Source
* Power Input Terminals
* Regulation
* Sensing
* Protection circuits
* Tracks and routes
* Power Output Terminal
* Recharge System

**Power Source**

The purpose of these will be to provide the power to drive the various circuits. To ease up development, a power bank will be used. This choice is due to the fact that the power bank consists of integrated circuits that support charging. This circuits include the following:

1. Battery State Management

The purpose of this system is to provide manage the battery during operation. The BMS provides charge control by utilizing an algorithm to vary voltage and current during charging.

1. Protection circuitry

The power bank also provides a layer of protection against overcharging and over-current or over-discharge.

1. Regulation

The power bank regulates the voltage from the battery in the power bank ensuring that a steady output is observed.

The power bank selection is important since it will determine how long the Edusat system operates. We selected a power bank rated at 10 AmpereHours with a voltage output of 5.0V. Each USB output port is rated at 2.5A with 3 ports available. This value is however the nominal operating current with the possibility of 3A peak discharge.

**Power Input Terminal**

A USB will be utilized as the Input Terminal. This will allow for e

However, a filter circuit comprising of a shunt capacitor will be required to eliminate noise that may be introduced into the power lines.

**Sensing**

It is important to keep track of power parameters during operation. This parameters include current and voltage. An ACS712 current sensor will be used to keep track of the current while a voltage divider will be used to measure the voltage.

There will be two pairs of this sensors to cater for the recharge system.

**Protection Circuits**

The EPS board requires a protection mechanism to prevent against reverse polarity. A low drop out design is required making a diode with a voltage drop of 0.7V a bad choice. A semiconductor switch using a transistor will suffice where the base will be activated only when the connections are correctly placed. That is, when the VBus pin of the USB is positive and the Ground pin as ground/0V. An NPN transistor rated for 5V and at least 3Amps will suffice.

**Tracks and Routes**

This will provide the paths for power and relevant signals to be transferred to their endpoints. The design of the tracks and routes should be done in a manner such that the tracks provide the least impedance. This can be achieved making the tracks wider up to a certain limit to ensure a well parked board.

More to be discussed in the PCB design section.

**Power Output System**

The power as well as the various signals in the EPS board will need to be transferred and distributed to other boards, systems or components. To achieve this, header pins will be provided at the edges of the PCB board. This will be done in an aim to allow for interconnections by stacking the boards within the a designed structure.

**Recharge system**

To simulate recharge as achieved by orbiting nanosat’s, a solar panel will be utilized. The solar panel will provide an input voltage in the range of 7 - 12V at a maximum of 400mA. This would ideally take along time to charge especially while using the nanosat indoors. It will however be an important part of the experience and will be an important element to learn. The input will need to be regulated and filtered to eliminate ripples. A low drop out regulator will be utilized to ensure minimal losses and higher efficiency. AMS117 has a drop out voltage of 1V at 1A and thus to get an output of 5V to charge the power bank, at least 6V should be passed through the regulator. Another regulator, LM117 has a similar voltage drop of 1.2V and 1.5A

.Using the regulator with the lowest voltage drop is important as a voltage that is lower than the threshold voltage will not be regulated and this may risk damage to the components. To protect against voltage lower than the threshold from passing through the regulator will require the use of a voltage comparator as well as a switch. The comparator will compare the incoming voltage to a fixed incoming voltage, in this case at least 6V, if the incoming voltage is greater, a switched is turned on completing the circuit, otherwise it is turned off. A simple NPN or PNP transistor will suffice as long as it can handle the current from the panel.

Indicator LEDs will also be included to provide a visual feedback for the presence of power. Current and voltage sensors will be included to provide data.

**Schematic Design**

With the design details having been said and done the circuit schematics are as shown below. These should be taken as the complete functional system.

<Add schematics here>

**Hardware Design**

Dimensions of PCB will be a value that is below a 10cm by 10cm by 10cm value. These dimensions are commensurate with the standard outlined cube sat dimensions. The PCB dimensions should provide enough space between its edges and the structural system. Header Pins, connectors and any other peripheral components should be placed on the board in a manner that indicates awareness of the operational experience of the end user. An example is that the USB input should not be hidden from access by a structure or a solar panel which may limit access,instead, it should be placed in the open with a clear line of access. Surface Mount devices will be used in the design as they occupy less space and are cheaper while minimizing the overall system weight. Power consumption and losses are also minimized.

**PCB Design and Layout**

For the printed circuit board, care must be provided to ensure minimal noise and electromagnetic compatibility during operation. A two layer board will suffice with one layer, preferably the lower one, to be the ground layer while the upper layer will have the components and tracks placed. Decoupling capacitors and bypass capacitors are to be placed close to the load to prevent coupling of noise in the lines right after the capacitor. The lines are to be designed in relation to how much current will be conducted through them while keeping in mind the manufacturers capacity. Ideally digital signal lines can be of the width 0.3mm while power supply lines should be at least 0.5mm for power rated at 5v and 2A with a 10 °C temperature rise. A wider track provides low impedance path for power thus improving efficiency during power transfer. It lowers inductance but increases capacitance, a middle ground must be reached. It is important that tracks bee directly above a ground plane to provide a return path. Failure for this may result in coupling of noise into your tracks.

Our Manufacturer was Gearbox with a minimum manufacturing of 0.5mm wide tracks as well as a separation distance of 0.8mm between tracks. This is too wide for typical applications but a good start for a prototype. The placement and assembly of the various components is done there and 0805 components were used for resistors and capacitors on pads designed onto the board. Pin headers, connectors and other terminations were designed as through-hole components.

**Firmware Development**

The EPS board makes use of firmware minimally to only gain access to sensor readings from the current and voltage sensors. This readings are analog in nature and are transferred via header pins to the Sensor Board for processing and reading.

This will be discussed further in the Sensor board documentation.

**Testing**

To be done once the board are received.