Dual Plug EV Charging Conversion Device

ECE445 Project Proposal

Team 48: Taiyuan Hu, Shuchen Wu, Haochen Zhang

Professor: Jonathon Schuh

TA: Hanyin Shao

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1. Introduction, Objectives, and Background

1.1 Problem

At present, with the increase in the number of electric vehicles, most of the vehicle charging happens at night. In addition, as every families' property accumulates, many families have two or more electric vehicles. The majority of the existing AC charging pile can provide a maximum charging current of 32A, but there is only one plug. When the electric vehicle is charged, the charging object can only be changed manually, which is difficult to meet the charging needs of a larger number of electric vehicles. What's more, in order to protect the battery cells from overheating, the output current of the EV charger decreases and causes a waste of resources.

1.2 Solution

Ideally, in order to solve this problem, we want to design a dual plug EV charging conversion device as figure 1 shows, which includes a power distribution subsystem, control subsystem, power subsystem, and user-interface subsystem. We want to create two charging modes. One is the average charging mode, that is, each output plug allocates the same charging power. When one of the outputs does not need charging any more, the device allocates the excess power to the other output plug; The other one is the limit mode. The user can manually choose to set the output current with the first priority. After the preferential output completes charging, the power will be allocated to the next priority output plug.

Because it is hard to actually test with an EV charger and Electric car. We decided to simplify our device to a level that can be tested based on the lab device as figure 2 shows. We want to directly use a voltage generator as our design input. For electric vehicles, it is hard to manipulate the EV battery's behavior, which is requesting lower power output from the device as the EV battery is filling. We decided to include loads like resistors in our design to control the output current amount, as mentioned previously in the limit mode of our design. In addition, the current's amplitude decreases as the battery charges, so to test the limit mode, we will decrease one of the outputs' current manually through the button module and see if the other output's current increases.

1.3 Visual Aid

Figure 1. Original idea with EV charging station and electril vehicles

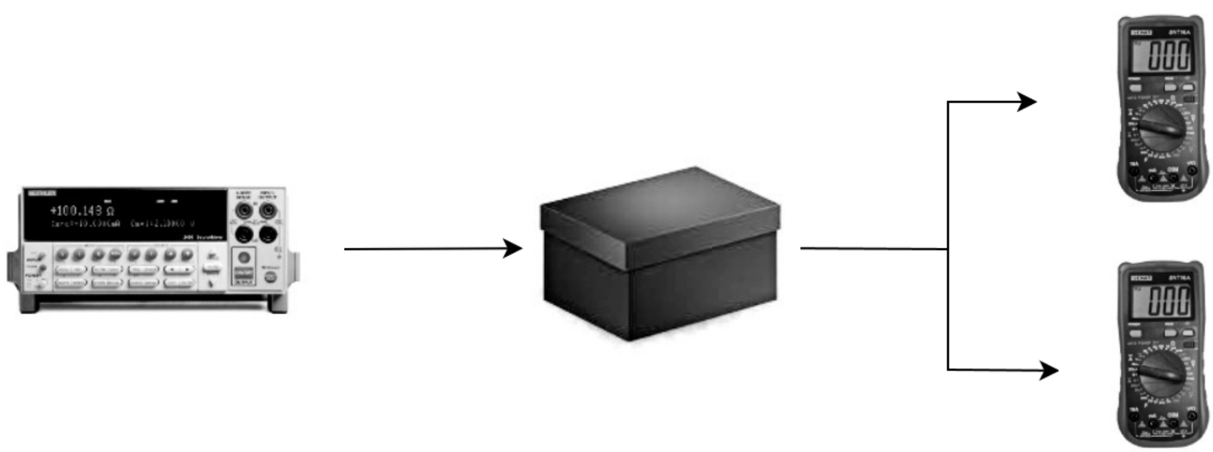

Figure 2. Simplified idea with current generator and Ammeters

1.4 High Level Requirements

- The device can operate two modes successfully. In average charging mode(mode 1), the output currents of two plugs are the same and the amplitude equals one half of the input current. In our design, we will keep input current around 32A. Therefore, in mode 1, both output currents should be around 16A. In limit mode(mode 2), a priority output is set by the user through the button module. The output current of the high priority plug is set to a desired value. The remaining device power will then be allocated to the other low priority plug. In the test case, if one plug's output current is set to 20A, then the other output should be 12A. In addition, in both modes, when one of the output plug completes its charging plug(disconnected), then the other plug will be automatically allocated the highest power output, which is 32A in the test environment.
- In order to manually select two modes, set high priority plug's current value, and display current values and the selected mode, the user-interface subsystem should be able to achieve the goals mentioned above. The LCD module should receive and read data from the MCU module and display information and values correctly. The button module should receive the user input press and send the data to MCU and LCD module would respond to the button press action by displaying certain information either selected mode or set current.
- In order to keep track of the output current, our design includes a current sensor module. This module should be able to measure both output plugs' current through hall effect and send the measured result back to MCU module. Then the MCU module should send the received measured values to the LCD module. The visual outcome of the measuring should be displayed with the help of an LCD module.

2. Design

2.1 Block Diagram

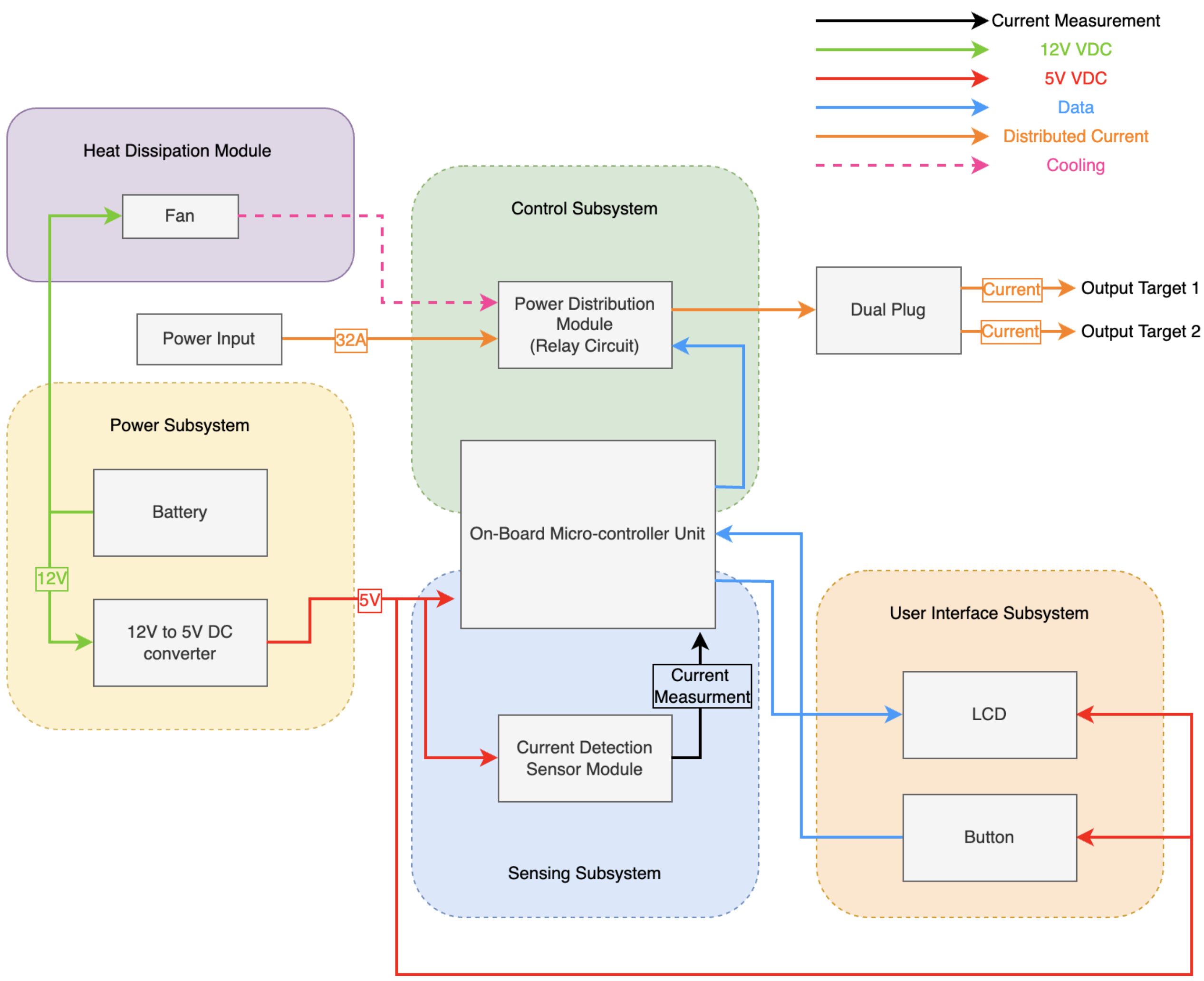

Figure 3. Block diagram of the dual plug EV charging conversion device

2.2 Subsystem Overview & Requirements

- Overview

In our design, the power of sensing subsystem, heat dissipation module, user interface subsystem and on-board micro-controller unit is supplied by the power subsystem with a 12V battery and a 12V to 5V DC converter to supply 12V and 5V VDC power accordingly. Then, the sensing subsystem with current detection sensor module will detect the current and feedback to on-board micro-controller unit, and the micro-controller unit will send the current measurement to the LCD of the user interface subsystem to display. The control subsystem will decide how the power distribution module distributes the power to two loads with the button input from the user interface subsystem which selects the operation mode. The control subsystem also takes current input of 32A to feed into the relay circuit. After power distribution, the current will be transmitted into a dual plug to be splitted into two outlets to feed two different targets with desired current. The heat dissipation module will use a fan to cool the power distribution system to prevent resistor overheating.

Power Distribution Subsystem

- Relay Circuits Module

  The relay circuits should be able to control the amount of current output based on the control signal from the MCU.

  Requirement 1: The relay circuits must successfully read the control signal from MCU.

  Requirement 2: The relay circuits must be able to decode the control signal from MCU to control the relay.

  Requirement 3: The relay circuits must be able to change the current output based on the control signal

  Requirement 4: The contact end of relay must be able to handle a minimum current of 10A

- EV Charger Interface

  The EV charger interface connects our device to the charging dock, the EV charger.

- Control Subsystem:
  - MCU Module:

    The micro controller unit(MCU) would control most of the other components in our device to achieve the goal of user-device interaction, relays' control, and current measurement.

    Requirement 1: The MCU must be able to send data to LCD display

    Requirement 2: The MCU must be able to receive data from buttons

    Requirement 3: The MCU must be able to receive and interpret analog data from Sensor

    Requirement 4: The MCU must be able to perform the basic computation to decide the modes of Operation.

    Requirement 5: The MCU must be able to interact with relay circuits and send control signals to relay circuits to control the current output.

- Current Sensor Module

  The current sensor will provide information regarding the current output of each port. It will check if the current output of each port is what we expected. It will send the feedback signal to MCU. Also, the sensor will be configured to recognize the positive jumps in current which would indicate that the device is plugged in.

  Requirement 1: The sensor must be able to recognize the DC current values up to 32A

  Requirement 2: The sensor must be able to interact with the MCU and send feedback signals to it.

- Power Subsystem:
  - 12V Battery

    The 12V battery should provide the power input for the electronics on the printed circuit board

    Requirement 1: It should be able to provide a steady 12V voltage supply.

  - 12V to 5V DC Converter

    The 12V to 5V DC converter converts the 12V input from battery to a 5V output to match the VDD requirement of MCU.

    Requirement 1: It should successfully convert the 12V input to a steady 5V output

    Requirement 2: The output voltage should successfully power up the MCU and other electronics on the PCB.

- User-Interface Subsystem:
  - LCD Display Module

    The LCD monitor module would display the feedback from the control module which would provide a better user-device interaction.

    Requirements 1: The LCD display should be able to interact with the MCU.

    Requirements 2: The LCD display should be able to display the correct content as MCU directed.

  - Button Module

    The button would allow users to set the working modes manually and control the power distribution as desired. The input signal would be delivered to the Control module which would be processed by the MCU.

    Requirements 1: The buttons should successfully send feedback signals to the MCU when it is pressed.

    Requirements 2: The buttons should be able to interact with the MCU

- Heat Dissipation module

    The heat dissipation module would cool the system down and prevent overheating. It will dissipate the heat generated by the resistors and PCB.

2.3 Tolerance Analysis

The main challenge we might run into is that the relay might have a resistance which would share the voltage and lower the current output. In ideal cases, each branch would generate a current of 8A in our design. With the testing voltage of 16V, we would need to add a 2 ohm resistor to each branch. If the resistance of the relay is also 2 ohms, each branch would only output a current of 16/(2+2) = 4A. However, the contact resistance is usually around 500m ohm and in reality the voltage supply would be around 100V which is much higher than 16V and which means that the resistance of the resistor would be larger than the testing one. If we are using a 80V voltage supply and a resistor with resistance of 10 ohms, assuming that the relay contact resistance is also 500m ohms, the output current would be around 80/(10+0.5) = 7.62 Amps which is not that different from the desired current of 8 Amps.

3. Ethics and Safety

Safety and ethics are two essential aspects in every modern design project. As stated in section 1.1 of the document, "to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment," every team member is going to strictly follow the criteria in IEEE Code of Ethics to operate our design[1]. Because the initial intent of the project is to operate the device in a high voltage and high current environment, team members are exposed to high risk of electrical hazards.Thus, we decide to utilize the generator with lower voltage output. In addition, the potential high power consumption of the loads in the design may cause overheat, which can also lead to accidents. To address overheating, we add a heat dissipation module to cool the device, and, furthermore, numbers of loads would be reduced if heat dissipation module is not enough.

The team will treat other teams and all course staff respectfully and kindly. We will contribute to create an equal, safe, and respectful atmosphere in all ECE 445 working environments with our peers, professors and TAs. All the communication within the team and between our TA and professor will be in an honest and polite manner. More importantly, our team has zero tolerance to any kind of plagiarism and we will report the behavior when we notice it.

References

[1] IEEE Board of Directors. “IEEE Code of Ethics.” IEEE Code of Policies, Section 7 - Professional Activities (Part A - IEEE Policies). [Online]. June 2020. https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed Feb. 10, 2022]