CORNELL MARS ROVER

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Controls Electrical

Power Distribution PCB, End Effector PCB

I. Overview

A) Power Distribution PCB

The purpose of the Power Distribution Board (PDB) is to act as a buffer between the battery and the components on the rover that require a battery voltage. As such, the PDB has 13 power ports that other boards in the Ecore can plug into and receive the battery voltage, but not directly from the battery. There are 7 low-side ports (for lower voltage/current applications) and 6 high-side ports (which include the proper circuitry to support high voltage/current applications). If any of the motors/boards were to fail in any way, the PDB will allow for *just that board* to be shut off while keeping the other components running, all the while avoiding damage to the battery.

This semester's project included completing the current-sensing firmware upgrade as well as debugging the board to get it running correctly. Current-sensing is new functionality that has been added to the board. This allows the current that is running through any given port to be read out by the microcontroller, and sent out over CAN to the Central Communication Board (CCB). *SEE DESIGN - iii FOR HIGH LEVEL SCHEMATIC*

B) End Effector PCB

The purpose of the end effector board is to drive the two motors that make up the end effector. The end effector, in general, must be dextrous enough to be able to complete such tasks as equipment repair. The end effector contains one servo motor and one DC brushed motor.

The board will take commands from the CCB and use them to drive the two motors as desired. As such, the board will use one external motor driver for the DC brushed motor and will use the microcontroller to drive the servo motor.

Note: This project was given later in the semester, so the board will be in a conceptual/high level state as of writing this report. **ADD PICTURE**

II. 2020-21 Design Progress

A) Power Distribution PCB

Throughout the last year, the PDB design process included upgrading firmware and soldering the board. Upgrading the firmware included adding new functionality as well as updating the code to support the new design of the PDB. Current sensing is the new functionality, which allows for the current draw out of any of the ports to be read out over CAN. This is important not just to read current, but also to calculate power draw. Other updates were routine, such as changing GPIO port numbers. At the end of last year, the firmware was mostly completed and the board was soldered. What remained was to debug both the firmware and the board.

B) End Effector Board

The End Effector Board was not yet conceptualized last semester. All of the work that has been done on the board was done as of late November 2021.

III. 2021-22 Design

This section should focus on only work done this year, and is going to be the bulk of your report. This task is similar to the "Supporting Documentation" from last year's end of semester assignment. There are some very helpful guidelines from that page; I suggest you read it just to reference the technical examples given. For every report, the following items should be addressed:

i. Design Requirements

A) Power Distribution PCB

- The PDB must be able to deliver the battery voltage to all ports on the board in a stable manner. In addition to that, the board should be able to read current from each of the ports via the microcontroller.
- Each port is required to deliver the battery voltage because all the boards that are plugged into the PDB are expecting the battery voltage. This voltage must be correct and stable in order to avoid damage to the other boards. The current sensing functionality is motivated by a general need for debugging, for which current draw values can be important. Additionally, current values can help calculate power consumption which can help gauge how much time the battery will last.

B) End Effector Board

- The End Effector Board must be able to provide logic and power to the two motors on the end effector. For the logic, the board must provide two PWM signals from the microcontroller. For power, the board will regulate voltages down from the battery voltage to feed into the respective motors. This board is not a direct result of URC rules, but rather a supporting board for the end effector, which is necessary for specific tasks at competition.

ii. Design Cycle/Validation Testing

A) Power Distribution PCB

- The work for this semester for the PDB mostly involved debugging. Because of the size of the board and all of the circuitry, the process took a long time, especially considering some “errors” including soldering errors which are often microscopic. Nevertheless, there was a testing cycle that I went through with the board.

  - 1 - Test each port with the multimeter and identify functional vs. non-functional ports. Label them somehow.
  - 2 - For each non-functional port, identify the points on the circuit where a failure is most likely to cause non-functionality of the port. These failure points are different for the low vs high side ports.
  - 3 - For each non-functional port, identify the necessary signals that make the port work, and test each one with the multimeter. These typically involve connections between resistors and IGBTs, signals from the microcontroller, etc.
    - Failure points on the High-side circuitry are as follows:
      - Connection between V_{bat} and the IGBT
      - Connection between the PIC32 and the gate driver
      - Any ground connection
    - Failure points on the Low-side circuitry are as follows:
      - Connection between the driver and the PIC32
      - Shorts on the driver itself
      - Firmware ports not specified correctly
      - Any ground connection
  - 4 - Fix any signals/failure points accordingly. This may be a firmware issue, solder joint, schematic error, etc. Finally, re-test the port.
- Most of the issues on the PDB were firmware issues or solder joint issues. These were difficult to identify but easy to fix.

B) End Effector Board

- The End Effector Board (EEB) must drive a servo motor and a DC brushed motor, providing both power and logic.
- For power, the EEB will use a series of voltage regulators to step down the battery voltage. The servo motor takes 6V power while the DC brushed motor takes 12V. The board additionally requires 5V and 3.3V lines for the CAN transceiver and the PIC32, respectively. So, the EEB has a total of 4 voltage regulators.
- For logic, the EEB uses one external motor driver for the DC brushed motor, and the PIC32 for the servo motor. The servo motor requires only a PWM signal, 6V power, and a ground connection. So, I simply connect the appropriate lines to a connector.
- The DC brushed motor is more involved, since it requires a separate motor driver which can support up to 4.9A. This is because the stall

current of the motor is 4.9A. I chose to use the *TB67H400AFNG*. This is a motor driver which can support two DC motors at a max current of 4.0A, and one DC motor at 8.0A. The motor driver is configured to be in *Large Mode*, which means it will support the one motor at a maximum of 8A. However, for heat dissipation purposes, it is recommended to set the driver up to have a max current of around 5.6A (which is still larger than the required 4.9A) while in *Large Mode*. We set this up by using a specific resistor value connected to the *VM* pin. In this case, it would be about 0.12 ohms. Finally, we can connect a PWM signal and 12V power to the driver.

- Because the board is still in development, testing has not been done. The board is currently in the schematic stage.

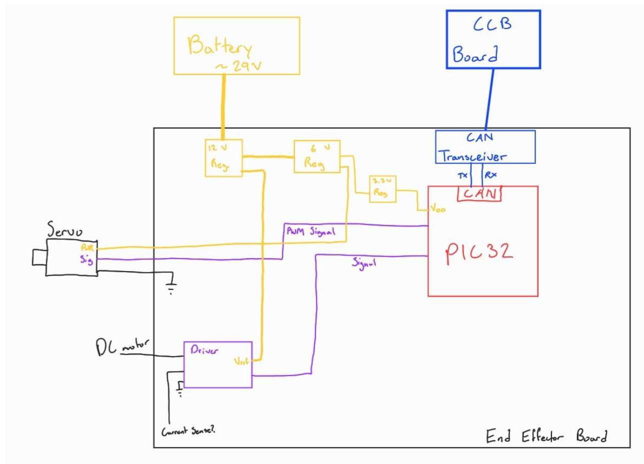
iii. Final Design

A) Power Distribution PCB

- The final design for the PDB is no different than the design for the 2020-2021 PDB. In summary, 7 low side ports provide the battery voltage for low power devices, while 6 high side ports provide the battery voltage for high power devices. However, after testing the board, it was found that 1 low side port is dysfunctional, possibly due to electromagnetic interference with the battery voltage line. Additionally, 1 high side port is dysfunctional due to a layout flaw. For this reason, the rover will need 2 PDBs in the Ecore to provide the necessary number of ports.
- In terms of firmware, the code simply turns on each of the ports and keeps them on. As stated before, the code also enables the reading of the current draw from each of the ports. This information is then sent out in a CAN message.

B) End Effector Board

- Due to the fact that the end effector board was not started until late november, the design is not yet completed. There are some parts however, that are chosen.
- The motors that the board will support are as follows:
    - **HS-225MG-Clockwise** servo motor
    - **280 RPM Premium Planetary Gear Motor** DC Brushed motor
- The board will use the *TB67H400AFNG* motor driver to drive the DC Brushed motor, as discussed before. This driver can support more than the stall current of the motor, which is a design requirement.
- The board will feed a PWM signal into the servo using the PIC32.

- For power, 4 voltage regulators will be used to support the 12V DC motor, 6V servo motor, 5V CAN transceiver, and 3.3V microcontroller.
- A high level schematic:
    - 

iv. Risk

A) Power Distribution PCB

- The board has already been manufactured, soldered, and tested. There is no risk during manufacturing.
- The PDB has an important connection to the battery, so any complications with the battery could break the board. This is a low risk. The PDB also supports 13 devices. If any of these devices pull too much power, the corresponding port on the PDB will burn out, causing the device to shut off. The rest of the board, and the rest of the devices, will still be operational. This is a medium risk.

B) End Effector Board

- The EEB board is manufactured by PCBWay, and so there is very little risk that the manufacturing will go wrong. The only thing that could delay the completion of the EEB would be errors in the layout/schematic itself.
- Since the EEB has a battery voltage line, complications with the battery could damage the board. This is a low risk.

v. Schedule

A) Power Distribution PCB

- The PDB firmware/soldering was started in March of 2021. This task took until the end of the semester. The PDB was put together and tested from the beginning of the semester to November.
- I would recommend soldering the board sooner rather than later, working on it in small increments. It’s back breaking work!

B) End Effector Board

- The EEB project was introduced in late november, well after PDR. The schematic was also started then.
- At the end of the semester, the design and schematic will be complete.
- I would recommend trying to get specifics about motor choices ASAP since this may change the design of the board. I would also recommend immediately buying high importance components like motor drivers.

IV. Testing

A) Power Distribution PCB

- The PDB was tested completely this semester. As I noted above, the functionality of each port can be confirmed by feeding the battery voltage into the board, and then using a multimeter to probe each port. The battery voltage should be read out.
- The second PDB will still need to be soldered and tested in a similar way during JanMan.

B) End Effector Board

- The EEB can be tested in a similar way to the PDB. The EEB will have two ports connecting to each of the motors. We can probe these ports on the oscilloscope (or on piscope using a raspberry pi) to confirm a correct PWM signal. We can also just plug in the motors and see if they work correctly. This will ultimately only be possible after the firmware has been written.
- We can also perform preliminary testing on each of the 4 voltage lines from the regulators to ensure that proper voltages are being read out. This will enable us to catch shorts quickly before they become more frustrating to find.

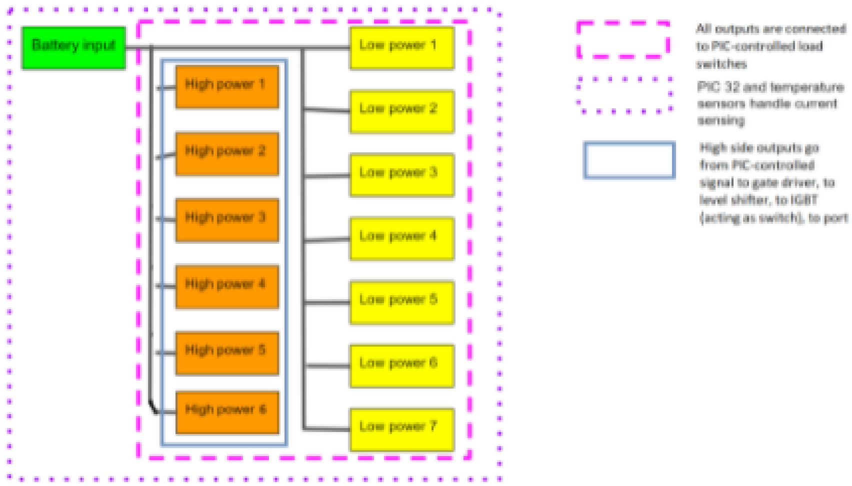
V. Integration

- Tasks for successful Integration
    - PDB
        - Plug in all components that expect a connection to the PDB.
        - Provide a connection to the CAN bus
        - Solder the second PDB (will take at least one week)
            - Test the second PDB and ensure 5 operational high side ports and 6 operational low side ports (will take at least one week)
    - EEB
        - ALL TASKS TO BE DONE IN SERIES
        - Finish the layout - at least 1.5 weeks
        - Get the board manufactured - at least 1 month
        - Solder the board - at least 3 days
        - Write the firmware - at least 3 weeks
        - Test the board as referenced above - at least 1 week

VI. Appendix

Appendix A: Power Distribution Board Information

- https://confluence.cornell.edu/pages/viewpage.action?spaceKey=CMR&title=Power+Distribution+Board+2%3A+Electric+Boogaloo



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