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E-design 344 Assignment #4

2021

Objectives

- Assemble a light source which is to act as load.
- Design, simulate, implement and test a low-side switch to control the load.
- Design, simulate, implement, and test bidirectional current transducer.
- Commit all the circuits to version control.
- Write and submit a short report using the template and commit the source files to version control.
- Submit your LTSpice circuit.
- Make and submit a 30 second video to demonstrate key features of the design.

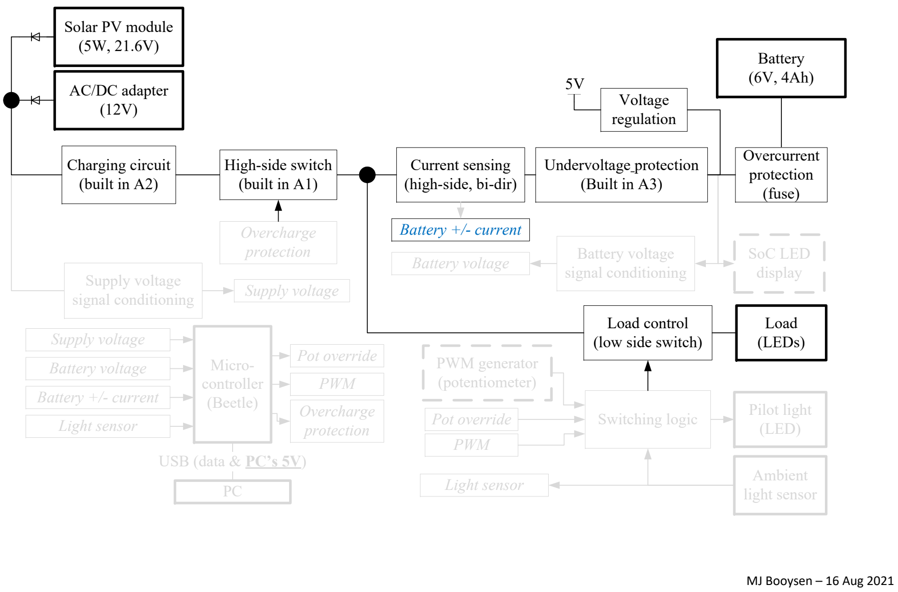

Figure 1: Your progress so far and what you are building for A4.

Deliverables and checklists

1. Submit your schematic as an `ASC` file and `RAW` files to `https://learn.sun.ac.za` for assessment. Ensure that you do/include the following:

   - ☐ Add your name and student number to the schematic (in the schematic).
   - ☐ Make the filenames student number and the assignment number, as follows: `E344_12345678_A4.ASC` and `E344_12345678_A4.RAW`.
   - ☐ Do not change anything in the block, since it is used for the assessment.
   - ☐ Do not use multiple labels for a single net

2. Submit your report as a `PDF` file to `https://learn.sun.ac.za` for assessment.Ensure that you do/include the following:

   - ☐ Add your name and student number to the report, and sign the plagiarism declaration.
   - ☐ Be sure to include literature, design rationale and calculations, simulations, test results and requisite appendices in the report.
   - ☐ Make the filename your Surname, student number and the assignment number as follows: `E344_12345678_A4.PDF`.
   - ☐ Keep the structure and format supplied in the template – only add and remove content.
   - ☐ Strictly keep to the following maximum page limits.
     - Load control design: 1 pages
     - Current sense design: 3 pages
   - ☐ Screen grab of your version control E344 folder on GitHub as an appendix.

3. Submit your thirty-second video to `https://learn.sun.ac.za` for assessment. Be sure to capture the following in an uninterrupted sequence (i.e. continuous flow of video). Note that there may be overlap in the information in the video and the report.

   - ☐ A clear close-up of your student card.
   - ☐ A clear close-up of your PCB with the barcode & number stuck onto your PCB.
   - ☐ A clear close-up of the following setup **(already assembled before the recording)** and sequence **(shown in the recording)**:
     Setup:
     - Connect a multimeter to measure the output from the TSC213 relative to ground.
     - Connect your 12 V DC power supply to the input of your charging circuit, but keep the high-side overcharge switch off.
     - Connect the battery after slowly discharging it to approximately 6.5 V (open-circuit).
     - Connect only three of the LEDs to the load node.
     - Ensure that the load-control low-side switch is off.
     - Add physical labels to the nodes in your circuit that are utilised in this demonstration.

     Then follow the following sequence, and be sure to let the multimeter settle after each step:
     - Show the multimeter reading with a zero current flowing through the current sense resistor.
     - Turn on the the high-side switch to start charging the battery and show the multimeter.
     - Turn on the load-control low-side switch and turn off the high-side switch to power the load from the battery only while showing the multimeter.

- Add the two remaining LEDs (with current-limiting resistors) in parallel with the LEDs already in your circuit and show the impact on the multimeter reading for each LED added.

When capturing these videos, please make sure to show your measurement values clearly - this is what is being assessed. For this assessment, the voltages are being assessed for the following cases: a large positive current (the maximum charging current), a negative current (the load current), and zero current. Using these values, your choice of V_{REF} (on the TSC213) can be assessed (considering the current specifications given).

4. Complete the online test at `https://learn.sun.ac.za`.

1 Instructions

1.1 Load with load-controlling low-side switch

The objective of this section is make the light load and develop a low-side switch to control it.

- Construct a load using five ultra bright LEDs drawing a total of 100 mA (i.e. 20 mA each when the battery voltage is at its maximum of 7.2 V). Note: Each LED should have its own current-limiting resistor; LEDs should also not be connected in series.
- Develop a low-side switch to control the load with a 0 V to 5 V binary signal.
- Use a DIP socket (or something similar) to allow for easy addition and removal of LEDs for variable current measurements.

1.2 Bidirectional current sensing circuit

The objective of this section is to design, simulate, build and test (in that order is NB) a bidirectional current sensing circuit, which outputs an analogue voltage representing the current that flows to and from the battery.
Develop a bidirectional current sensor to measure the battery current:

- The circuit shall measure currents from −150 mA (discharge) to 450 mA (charging). Design your circuit such that the output voltage comes equally close to each supply rail (i.e. given these currents, bias it for optimal output swing).
- The circuit shall suppress noise of frequencies at or above 50 Hz such that:
  - 1 mV_{pk} noise on the sense resistor results in less than 5 mV_{pk} noise on V_{out} (net OUT_TSC213 in LTspice), but preferably less than 2 mV_{pk}.
  - 1 mV_{pk} noise on the 5 V rail results in less than 5 mV_{pk} noise on V_{out} (net OUT_TSC213 in LT-spice), but preferably less than 2 mV_{pk}.
  - the circuit remains sufficiently responsive such that an abrupt change of 150 mA in the current is responded to by a correct and corresponding change in V_{out} (within a tolerance of 5%) within 2 s.
- The output voltage range for the given current range shall be at least 2.5 V, but preferably more than 3 V.
- The output voltage values shall range from a minimum of 0 V to a maximum of 5 V. Do not exceed this range.

Document your design, circuit design, simulation results, physical implementation and actual test results.