Project Proposal:
Wireless Controller for DC-DC Converter

A Senior Design Project by Isaiah Ryan

Summary

The proposed project will allow the user to wirelessly control and monitor a DC-DC converter between two 12V batteries on a boat. One battery will serve as the donor, providing power to the second, dependent battery via the converter. With an app designed for a smartphone or tablet, the user will be able to remotely enable and disable the converter, adjust the converter output voltage, and also continuously monitor voltage and current.

Background and Benefits

The benefits of the project lie in how it addresses various constraints. A fundamental constraint relates to battery power. Using a 12V engine battery is good for providing a large current for a short time such as when starting a motor, but not necessarily good for providing a small current over a long time. In fact, using an engine battery to power a fish finder, GPS, lights, etc. can drain the battery very easily. This is why a second, longer-lasting battery is recommended for auxiliary equipment. Using a standard charger, however, means that the second battery can only be recharged after returning to shore. That is why a principal benefit of the project is the ability to charge the auxiliary battery at sea with the DC-DC converter through the engine battery, which is usually charged by an alternator. Also, since different battery types have different charging characteristics, multiple battery types can be supported by simply adjusting the charge drawn by the converter. An important constraint to consider is the charge of the donor battery, which must be maintained. The project guarantees this by placing priority on the charge of the donor battery. The voltage of the donor battery will be monitored, and if it drops below some threshold, then the charge drawn by the converter can be automatically reduced.

Environmental constraints are a prime concern in a marine environment. Physically accessing a DC-DC converter can be difficult since it must be embedded to prevent contact with water. Thus, another benefit of the project is wireless capability, providing the user with instant control of the converter and continuous monitoring of converter voltage and current from anywhere on a boat. Of course, range is always a constraint with wireless communication. Since the project is intended for use on small, personal crafts, the range constraint will be satisfied. Limited space is another issue, which is addressed by the small size of the converter and the lack of wires with wireless communication. An economic constraint is the cost of production, which must be low enough to sell the proposed product at a reasonable price for consumers to buy. The project accomplishes this by using low-cost components and by incorporating a smartphone or tablet for the user interface, eliminating the need for a dedicated display. In addition to satisfying economic constraints, the project must meet reliability requirements. Proper protection from water and the selection of rugged, durable project components ensure that the proposed product will be long-lasting. There will be an MCU that controls the converter, and the MCU will be supplied by the donor battery. Thus, the MCU will run as long as the donor battery has charge.

The final but most critical constraint is health and safety. Handling high power electrical components poses an electrical shock hazard. Wireless capability solves this problem since the user will not have to physically handle the converter. Fire is another danger with electrical systems on boats. A benefit of the project that addresses fire danger is an automatic shutoff of the DC-DC converter if excessively high current is detected.

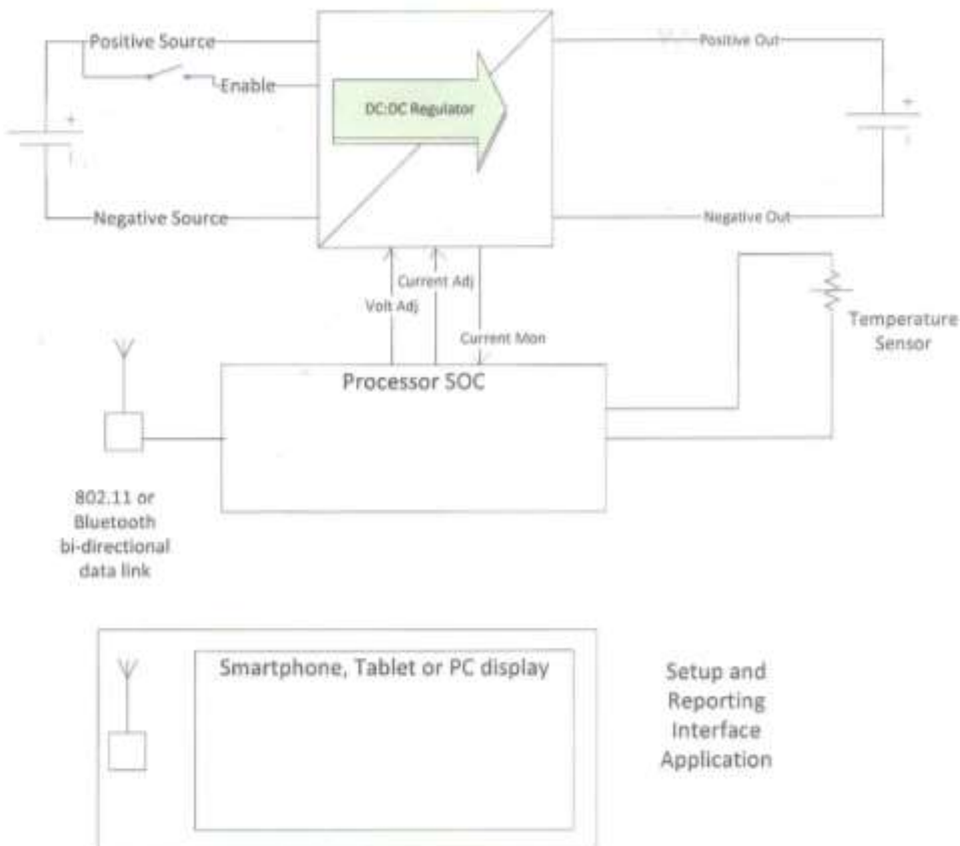
Comparison of Similar Products

A comparison with two existing products will be presented here to highlight the unique features of the proposed project. The first product is the MAGIC DC-DC converter by Mastervolt. The MAGIC product user's manual states: "The DC-DC converter MAGIC converts a DC-voltage into another stabilized DC-voltage with a full galvanic isolation between the input and output." Electrical isolation is used to prevent electrocution when a short circuit occurs between a person and power supply. This specification does not apply to the project since the user will be remotely operating the DC-DC converter and thus not in danger of electrocution. The MAGIC converter specifies an input voltage of 12V and adjustable output voltage range of 10V-15V. The project will share similar voltage specifications, although the converter output will be kept near 12V. In order to adjust the output voltage, the MAGIC converter requires a separate MasterBus serial interface system, MasterView display monitor, and MasterAdjust software. With the project however, as long as users have a smartphone or tablet, they will not have to purchase additional devices. The project's wireless capability provides a great advantage as the MAGIC converter requires properly setting up the MasterBus serial network and connecting multiple serial cables. Another feature of the project that the MAGIC converter lacks is a temperature sensor for the dependent battery. Since temperature affects the functioning of a battery, the project will be able to adjust the converter output accordingly for more efficient charging.

The second product is the Digital Mobile Charge (DMC) by Onboard Solutions. The DMC owner's manual states that the DMC "provides the same utility as an advanced regulator, a zero loss battery isolator, and a 4 step battery charger." This product actually shares many of the same features as the project. Like the project, it continuously monitors the donor battery and gives it top charging priority. It can be configured for charging different types of batteries. It even has a battery temperature sensor. The only major difference in features is the wireless capability. Because of the lack of wireless, the DMC must be controlled with manual switches and monitored by reading LED's. While the DMC provides more features than the MAGIC converter, it must be physically accessed to use. The MAGIC converter does not have to be physically accessed, but it is more expensive and complicated to set up because of necessary cables and extra products. The proposed project will provide many features, and at the same time, will be cheaper and simpler to use because of the wireless capability.

Detailed Description of Project Implementation

Below is a preliminary block diagram of the proposed project:



At the bottom of the diagram is a smartphone, tablet, or PC display that runs the app for interfacing with the DC-DC converter. The device running the app communicates with the MCU via a Bluetooth bi-directional data link. The MCU itself performs two main functions. First, it receives the user's commands sent over the Bluetooth link and uses a DAC to translate the commands into voltage/current signals to drive the DC-DC converter. Second, the MCU uses an ADC to retrieve voltage/current and temperature measurements from the DC-DC converter and send this data wirelessly back to the user to be displayed in the app. The temperature sensor will be implemented with a simple thermistor that returns a voltage proportional to temperature. Not shown in the diagram is the power source for the MCU. The MCU will draw power from the donor battery via a buck converter. The DC-DC converter circuitry is contained in a small sealed package with external leads for voltages and control signals.

Below is a prioritized list of the proposed project features:

1. Functioning DC-DC conversion
2. Working wireless communication link between app device and MCU
3. Option to enable/disable DC-DC conversion
4. Obtaining and displaying current/voltage data from DC-DC converter
5. Ability to adjust DC conversion as desired (step-up or step-down)
6. Addition of temperature sensor to adjust DC-DC conversion for temperature

Applicable Standards

1. IEEE 802.15.1 — Covers methods for communicating in a personal area network
   Will be used as reference for Bluetooth protocol
2. IEEE 45 — Covers recommended practice for electrical installations to shipboard
   Will be used as reference for installing DC-DC converter

Development and Demonstration

In developing the project, the first step will be to acquire the hardware components such as the DC-DC converter, MCU, Bluetooth adapter, and temperature sensor. All of these items are easy to obtain through online vendors. Once obtained, the operation of these parts can be tested with the help of a multimeter or oscilloscope. At first, the DC-DC converter can be tested with a power supply as a voltage source and then later attached to a battery. Once DC-DC conversion is working, the Bluetooth link will have to be established. This will require setting up both the user interface app and programming the MCU. For developing the user interface app, there are numerous free app creator tools available online. The tool used to develop the MCU code will depend on the particular MCU family. Generic code development tools are also available such as Eclipse and Notepad++.

After successful Bluetooth communication, the next step in development will be to control the DC-DC converter with the MCU. This will require further programming of the MCU to send control signals to the converter and read voltage/current from it. Then the MCU can be made to send the voltage/current data back to the user. At this point the last development step will be to set up the temperature sensor, obtain readings with the MCU, and then send that temperature data back to the user. An accurate thermometer will also be needed to provide a reference for testing the project thermometer.

The project will be demonstrated by wiring a 12V donor battery to the converter input and a second 12V battery to the converter output. A smartphone or tablet will be used to run the user interface application. Some kind of resistive element will be attached to the dependent battery to simulate a current-drawing load. Control and monitoring of the converter will be demonstrated with the app interface.

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