Circuit Description
Wireless Controller for DC-DC Converter

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Summary
This document provides a circuit description of the Wireless Controller for DC-DC Converter. The project is essentially a battery-to-battery charger and is for use on a boat to charge an auxiliary battery with the engine starter battery. To explain how the project circuit works, each of the main components will be described in detail. To see how these components are connected, refer to the separate schematic diagram. The main components are listed below:

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### 3.3V Regulator

**Purpose**
The 3.3V regulator (U1) provides a 3.3V power source for the MCU, Bluetooth device, and temperature sensor.

**Input Connections**
The 3.3V regulator requires two input connections. The +VIN pin is for the regulator input voltage and is connected to the positive terminal of the 12V starter battery labeled START_BATT(+). The GND pin is the ground reference and is connected to the ground reference GND_START. This ground reference is used for all the main components and is connected to the starter battery negative terminal labeled START_BATT(−). The negative terminal of the auxiliary battery labeled AUX_BATT(−) is not directly connected to the starter battery negative terminal. For this reason it is given a separate ground reference label GND_AUX.
Output Connections
The only output connection of the regulator is the 3.3V +VOUT pin that connects to the power input pins of the MCU, Bluetooth device, and temperature sensor.

External Components
The only external component connected to the 3.3V regulator is a 10µF capacitor (C1) connected between the +VOUT and GND pins. The purpose of this capacitor is to smoothen the output voltage of the regulator. The value of the capacitor was taken from the MCU development board schematic, which also includes a 3.3V regulator.

MCU
Purpose
The MCU (U2) performs various functions, including controlling the DC-DC converter, measuring voltages, and sending data to the Bluetooth device to be transmitted to the mobile device.

Input Connections
The MCU requires power and ground connections to pins VDD and VSS respectively. These connections come from the 3.3V regulator +VOUT pin and the reference GND_START. The ADC high and low reference pins VREFH and VREFL are also connected to VDD and VSS respectively. Several input connections go to ADC channels in the MCU for measuring voltage. ADC channel 7 on pin PTA7 measures the starter battery voltage and is connected to its positive terminal. ADC channel 3 on pin PTA8 measures the DC-DC Converter output voltage and is connected to the converter VOUT(+) pin. ADC channel 2 on pin PTA9 measures the auxiliary battery voltage and is connected to its positive terminal. Measuring the DC-DC converter output current is done by measuring the voltage from the DC-DC converter IMON pin with ADC channel 4 on PTB2. ADC channel 1 on PTB5 is the final channel used and measures the voltage from the temperature sensor OUT pin. The last input connection is UART0_RX on pin PTB4, which connects to the UART_TX pin on the Bluetooth device.
Output Connections
Two MCU output connections are used to control the DC-DC converter. The PTB0 pin is used as a GPIO to enable or disable the converter and is connected to the converter active-low ON/OFF. The other output connection is the DAC0_OUT on pin PTB1 to the VTRIM pin on the DC-DC converter. The relation between the VTRIM voltage and the converter output voltage is linear and is defined in the DC-DC converter documentation.

External Components
The MCU is accompanied by a number of external components. First, there is a 0.1µF capacitor (C2) placed directly between the VREFH and VREFL pins. This is a manufacturer recommendation and is used to satisfy the demand of AC current spikes required to charge the SAR ADC capacitor array. The ADC channel pins that measure the starter and auxiliary battery voltages include resistive divider networks to divide battery voltages up to 15V to below 3.3V to satisfy the ADC voltage limit. In case of voltage spikes of divided voltages above 3.3V, Schottky protection diodes (D1,D2,D3) are placed from the ADC pins to 3.3V to provide a safe path for excess current to ground. These diodes are used for their low forward voltage drop and fast turn-on time. The values of the voltage divider resistors are 14k (R1,R3,R5) and 3.92k (R2,R4,R6) with 3.92k connected to ground. The equivalent parallel resistance of these values is about 3.06k, which satisfies the max ADC pin output impedance of 5k. In series with the voltage divider networks are 3.3nF capacitors (C3,C5,C6) that make an anti-aliasing filter with the resistors. The same capacitors (C4,C7) are used on the two other ADC channels that measure temperature sensor voltage and DC-DC converter IMON voltage. Also on these two other channel pins are 3.24k resistors (R7,R8) that complete anti-aliasing RC filters. The cutoff frequency of the RC filters on the ADC channels is set to several kHz below 18.75kHz, which is half of the ADC sampling frequency.

DC-DC Converter
Purpose
The purpose of the DC-DC converter (U5) is to convert the voltage from the starter battery to an appropriate voltage for charging the auxiliary battery.
Input Connections
The DC-DC converter takes as input a voltage source and ground reference. The voltage source pin VIN(+) is connected to the positive voltage terminal of the starter battery START_BATT(+). The ground reference pin VIN(-) connects directly to the battery’s negative terminal START_BATT(-). Two other input connections are for the ON/OFF pin and the VTRIM pin. The ON/OFF pin connects to one of the MCU GPIO pins and the VTRIM pin connects to the DAC0_OUT pin of the MCU. Finally, there is the ITRIM pin, which sets the converter output current limit by a resistor placed between the pin and ground.

Output Connections
The DC-DC converter has three output connections. One of the outputs is the IMON pin, which outputs a voltage that is linearly proportional to the converter output current. It is connected to one of the MCU ADC channels. The other two outputs are the voltage output and ground reference output. The voltage output is from the VOUT(+) pin and connects directly to the positive terminal of the auxiliary battery AUX_BATT(+). The ground reference is from the VOUT(–) pin and connects directly to auxiliary battery negative terminal AUX_BATT(–).

External Components
The only pin that requires an external component is the ITRIM pin. A 68.1k resistor (R9) is placed between that pin and ground. The specific value of 68.1k sets the output current limit to the rated value of 20A. This resistor value is determined by an equation provided in the documentation.

Bluetooth Device
Purpose
The only purpose of the Bluetooth device (U3) is to transmit and receive data between the MCU and the user’s mobile device.
**Input Connections**
The Bluetooth device is powered by 3.3V from the 3.3V regulator on its VDD pin. It has several GND pins that are all connected to the ground reference GND_START. One of the general IO pins PIO7 is connected to 3.3V, which sets the device UART baud rate to 9600bps for communicating with the MCU. The device also has a UART_RX pin that is connected to the UART0_TX pin of the MCU.

**Output Connections**
One of the device’s output connections is the UART_TX pin that sends data to the MCU. The device also has a UART_RTS pin (Request To Send) and a UART_CTS pin (Clear To Send) which are not needed so they are simply shorted together.

**External Components**
The Bluetooth device does not require any external components.

**Temperature Sensor**

**Purpose**
As its name suggests, the purpose of the temperature sensor (U4) is to sense the temperature of the auxiliary battery. The sensor must physically contact the battery for this reason.

**Input Connections**
For input connections, the temperature sensor requires 3.3V from the regulator on its VDD pin. It also requires a ground reference connection on its GND pin to GND_START.

**Output Connections**
The only output connection is from the sensor’s OUT pin to one of the MCU’s ADC channel pins. Again, the voltage on the OUT pin is proportional to the surrounding temperature.

**External Components**
No external components are required by the temperature sensor.