Three Phase Power Monitor

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April 2022

1 Introduction

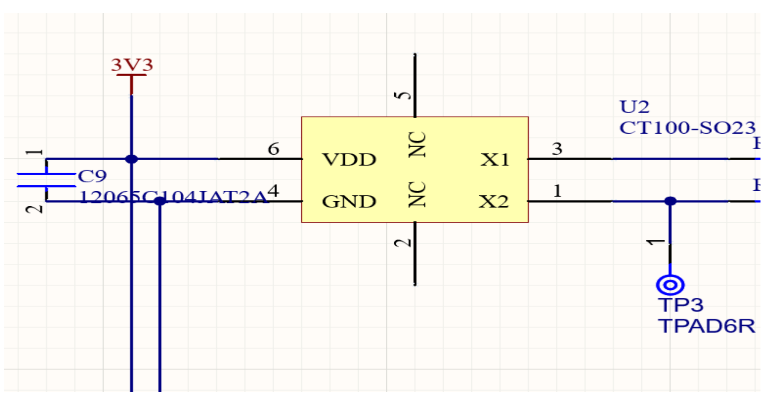
2 Circuit

The circuit will be discussed in this chapter. A PDF of the complete circuit can be found in the appendix.

2.1 Sensors

The sensors used for this project are the CT100 contactless TMR Field Sensors. These sensors are able to measure the magnetic field without coming in physical contact with the conductor[1]. This is crucial for this project, as the aim of the project is to develop a device that can sense current in a non-invasive manner.

An alternative sensor that was considered for a short time is the RR111 TMR sensor developed by RedRock[2]. However, this sensor has become obsolete and is therefore not recommended for new designs. The replacement for the RR111, RR112, features a sampling rate of 100Hz. Considering that the product has a requirement to sample at a rate of 5000Hz, this new sensor is not suitable for this project.



The CT100 features a differential output. The output of the sensor, the value of the magnetic field, is the difference between the X2 and X1 pins. As the potential is measured between the two output pins and not from a single output pin to ground, less noise shall be present on the output.

The sensors also feature a 100nF decoupling capacitor across the supply pins, as per the recommended application mentioned in the datasheet.

2.1.1 Amplifiers

The output of the CT100 sensor shall be passed through a differential amplifier. The amplifier will calculate the difference between the two signals and shall then proceed to amplify the signal.

The op-amp (operational amplifier) that has been chosen for this project is the OPA342 series. This op-amp has been chosen for its rail-to-rail in- and output capabilities, it's low input offset of ± 1 mV and because of the power supply specifications. The op-amp can function with a (single) supply voltage of as low as 2.5V.

The amplifier circuit can be seen in this figure. The formula for calculating the gain can be seen in equation 1.

$\mathrm{I}_{x1} = \frac{U_{x1} - U_-}{R_1 1}, I_{x2} = \frac{U_x 2 - U_+}{R13}, I_f = \frac{U_- - U_{out}}{R7}$

$\mathrm{U}_- = U_+$

$U_+ = U_{x2} * \frac{R17}{R13+R17}$

$If U_{x2} = 0, then U_{out(x1)} = -U_{x1} * \frac{R7}{R11}$ (1)

2.1.2 Multiplexers

The output of the amplifier will be connected to either a multiplexer, directly to the analog input of the nRF52840 MCU. The connection depends on the amount of sensors present on the board. The connection and choice will be made using a 0 ohm resistor.

[Figure]

The multiplexer that has been selected for this project is the TMUX1208RSVR by Texas Instruments.

This multiplexer supports a supply voltage range of 1.08 to 5.5V. This means that we will be able to supply the multiplexer with 3.3V. With a supply current of only 10nA it's also very efficient.

The multiplexer offers 8:1 single ended channels. Meaning, eight sensors will be connected to the multiplexer. The multiplexer will let one of those sensors through to the analog input pin at a time.

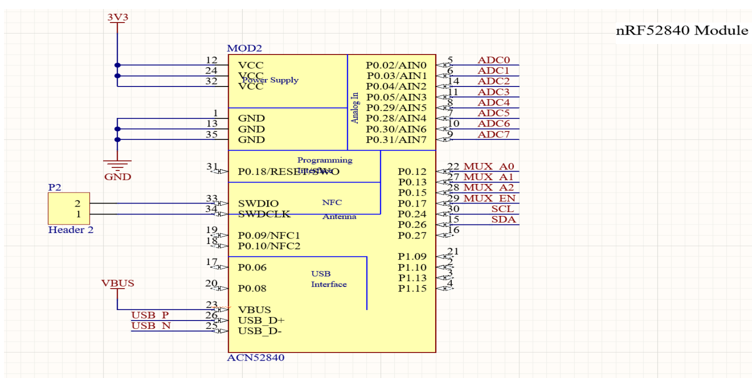
The multiplexers turn on by pulling the EN (enable) pin high. This pin features a 10k ohm pull-down resistor, per the recommendation found in the datasheet. Another recommendation from the datasheet is the 100nF decoupling capacitor on the VDD pin.

Pins S1 through S8 are used as inputs from the TMR sensors. The A0,A1 and A2 pins are used to select which input gets through the multiplexer. Pin D is the output of the multiplexer, which will be connected to the analog input of the nRF52840.

2.1.3 nRF52840 module

The nRF52840 module that will be used is the ACN52840 module by Aconno. It features all the necessary pins for this project and connections so it can be easily soldered to a PCB.

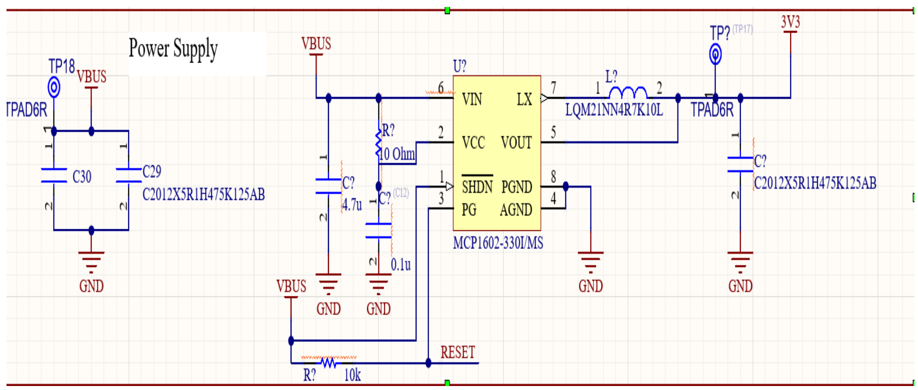
The design also features a 2-pin header for the SWDIO and SWDCLK pins. This is to ensure that the microcontroller can be programmed by the user. The VBUS and D+/D- pins are connected so that the device may exchange data with a computer.



2.1.4 Power Supply

The unit will be powered by a USB-C port. However, most components will require 3.3V, while the USB standard delivers 5V. To convert the 5V to a suitable 3.3V, a buck converter shall be utilized.

The chosen buck converter is the MCP1602-3301. This buck converter has a fixed output voltage of 3.3V.



The only required external components for this chip are the 4.7uF input and output capacitors, followed by the small RC network on the VIN and VCC pins. A 10k pull-up resistor is also used on the PG (power good) pin. This pin indicates if the output voltage is within 94% of regulation. The NOT SHDN (shutdown control) pin (1) is a pin used to enable or disable the converter. A logic high (¿45% of VIN) will enable the device. While an a logic low (¡15% of VIN) will disable the device. This device features two different ground pins, AGND (analog ground) and PGN (power ground). LX is connected directly to the buck inductor. VOUT is the output pin.

2.1.5 USB

The product will feature a USB-C connection. This connection is used to supply the product with power, but also to enable data communication between this device and another (desktop pc, laptop etc.). The USB-C port will be wired according to USB 2.0 specifications, meaning the USB connection will supply the device with a voltage of 5V and a maximum current of 500mA.

The USB-C port requires two 5.1k resisot