Extremely Rough Draft: Soil Power Sensing Board Manual

v. 0.1 - Board Rev. A

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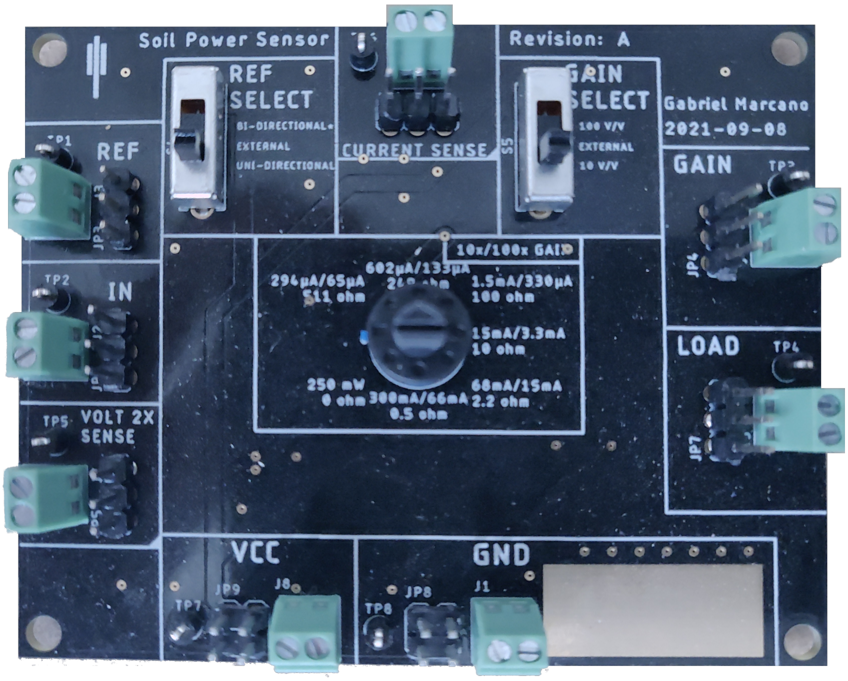

Introduction

The soil power sensor board was developed to facilitate low voltage/current sensing from soil MFC circuits, but it should work well to any application operating at low voltages and currents. The current sense resistor is selectable with values from 0.5 Ohm to 511 Ohm, with a 0 Ohm option for testing purposes (limit power dissipated to 250mW). Voltage sensing is buffered, to ensure that the sampling circuit doesn't impact the voltages being sensed.

Contents

1 Overview

The sensor board is shown in fig. 1. It has 8 sets of pins/headers, encompassing VCC and GND, IN or input, LOAD, control signals REF and GAIN, and sensing outputs VOLT 2X SENSE and CURRENT SENSE. Additionally, the board has three switches that change the behavior of the current sensingl, namely REF SELECT, GAIN SELECT, and the sense resistor rotary switch.

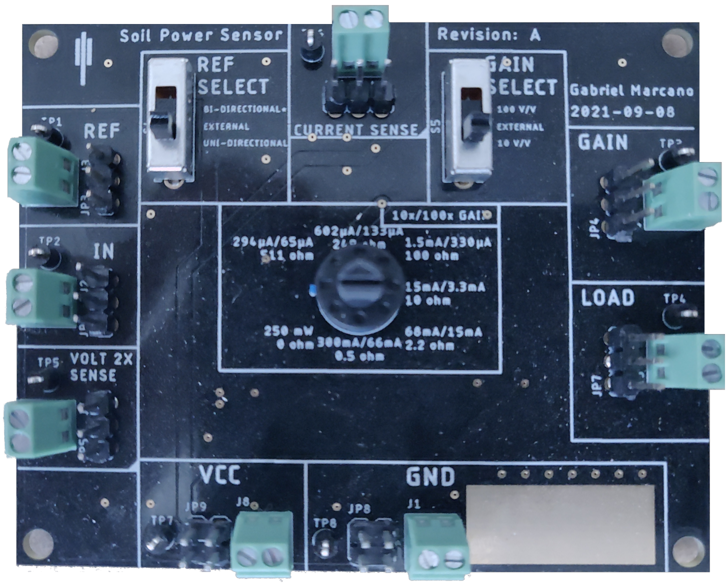

Figure 1: Soil Power Sensor board.

VCC input voltage should be between GND and 5 volts. Most of the initial testing has been done using 3.3 volts. The op-amp voltage buffer is configured to report double the voltage sensed, limiting the range of sense-able voltages to half of VCC.

2 Setup

Connect ground to the GND block on the board, and power to the VCC block on the board. Voltage must be less than 5 volts.

Connect the line to be tested to the IN block on the board. If doing current sensing, connect the load to the LOAD block on the board.

3 Current Sensing

3.1 Directionality

REF SELECT is used to control the directionality of the current sensing. The upper most position enables bi-directional sensing, meaning the current sensor can report values that map to negative and positive current. The lower position enables uni-directional sensing, which only allows sensing of current travelling from the IN terminal to the LOAD. The middle position is EXTERNAL, which allows an external microcontroller, by plugging into the REF block, determine the directionality. Refer to the MAX40204 datasheet [1] for more information about directionality.

3.2 Gain

GAIN SELECT is used to control the level of gain used by the current sensing chip. The upper position sets the gain to 100x gain, the lower position sets the gain to 10x, and the middle position enables a microcontroller to control the gain based on a signal provided via the GAIN block. Refer to the MAX40204 datasheet [1] for more information about directionality.

3.3 Interpreting Current Measurements

The voltage output from the sensor chip is as follows:

$$V_{out} = G * V_{sense}$$

Where G is the Gain setting (10 or 100), and V_{sense} is the voltage at the sense resistor. Per Ohm's law, the current through the sense resistor is:

$$I = V_{sense}/R$$

So the current sensed should be[1]:

$$I = \frac{V_{out}}{GR}$$

Now, this is only true for uni-directional sensing. For bi-directional sensing, V_{out} is offset by the voltage at REF, which normally should be half of VCC (plus or minus error due to resistor tolerances, where each resistor is rated at 1% error each and both are nominally the same value). In other words, for bi-directional sensing:

$$I = \frac{V_{out} - V_{ref}}{GR}$$

For an exact reading of V_{ref}, it should be possible to read the voltage from the REF block on the board when set to BI-DIRECTIONAL mode.

4 Voltage Sensing

An op-amp is used to buffer the sensed voltage on the IN block, and multiplies the input voltage by two. This means the maximum positive voltage that can be sensed is half of VCC. On the negative rail, the limit is somewhat closer to 0 than half of -VCC (the exact limit depends on the charge pump's ability to provide a consistent reference negative voltage).

Voltage sensing likely needs some calibration to be done in software, as quick experiments with the boards indicate an error between 2 and 3% in the reported voltage.

[1] Gabe had some problems figuring out the right math the first time, as the datasheet was not very clear. Once he is able to confirm this is correct, he'll remove this comment.

5 Suggested configuration

Set GAIN SELECT to either 10V/V or 100V/V (this only impacts the range of currents that can be sensed). Set REF SELECT to UNI-DIRECTIONAL. Set the sense resistance as low as possible while still being able to reliably detect changes in current. The board has numbers around the rotary switch explaining the maximum current that can be detected by the sensor per setting and gain in UNI-DIRECTIONAL mode. For BI-DIRECTIONAL mode, divide the mA numbers on the board by 2. For instance, a marking of 300mA/66mA indicates that at that resistor (0.5 Ohm) the maximum current that can be sensed in 10x GAIN mode is 300mA, and in 100x GAIN mode is 66mA. If the resistance is set too low, an ADC might not be able to detect subtle changes, or the reading might be below the noise floor.

6 TODO

This section is partially a reminder to Gabriel to finish the manual, but also to illustrate some of the more obscure details about the board that need to be tested and documented.

It should be possible to configure the op-amp on the board to be a unity-follower, or a simple buffer, for the input voltage, by bypassing the resistors on the feedback line of the op-amp.

There needs to be a better section describing the maximum currents that can be sensed in UNI-DIRECTIONAL mode and another for BI-DIRECTIONAL mode. Additionally, it would be really great to identify, either empirically or by reading datasheets, what is the expected minimum detectable currents per resistor. This depends on the ADC being used, but it should be possible to come up with some example numbers for, say, an Arduino Uno.

In reality, the actual maximum currents depend also on the input VCC. The exact details are specified in the MAX40204 datasheet[1]. The numbers on the board were computed using a 3.3 voltage VCC source. A wider range is possible if VCC is 5 volts.

It might be nice to provide a repository or something with example code on how to sample the ADC on an Arduino or some common platform.

References

[1] `https://datasheets.maximintegrated.com/en/ds/MAX40204.pdf`