# PCB V5 ADC Problems

Matthew Collins

July 3, 2014

# Contents

# 1 Overview

On the V5 PCB, there is an issue with the ADC current sense module. The chip being used is the ACS716KLATR-6BB-T. This chip is bi-directional and outputs an analog voltage proportional to the current through its sensing path. This ouput is center at 1.65V for zero current with a slope of 100 mV/A. Additionally, based upon the configuration of the chip upon the V5 PCB, an increase in current corresponds to a decrease in voltage. Also, for the purposes of the project, the current is unidirectional.

# 2 Problem

The issue at hand is that there is a floating offset present in the measured current value from the chip. At zero current, the measured current should be zero; however, this is not the case. When the ADC is read using the read ADC function (found in ADC.c) and the CurrentSensorPlotter.py python function that plots and average the current vaues, at zero current a value of about .05 to .08A is obtained. This can be seen in Figure 1. Additionally, it can also be seen that there is a wide variability for the ADC readings.

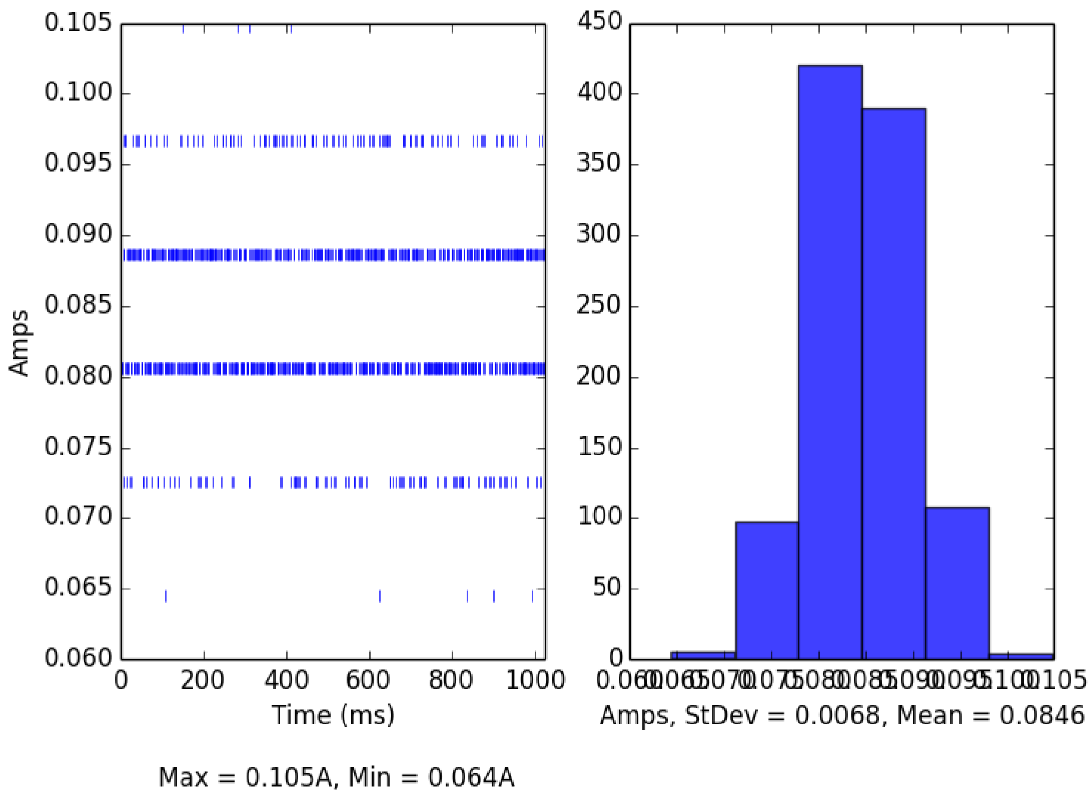


Figure 1: ADC Reading at Zero Current

It should be noted that for a while the measured current falls within an 8mA range, i.e. if the first reading gives a value of .085A, the next measurements for a while will have a minimum and maximum value that falls within 8mA. This is not an issue for the resolution of the current sensor is 8mA/ADC count, thus this falls within the expected range.

## 3 Testing

To test the problem, a power resistor was used in place of the motor with a multimeter in series to measure the actual current running through the resistor. A new motor state (commutate(7)) was created that sets line 1 low and line 2 high. The multimeter was indeed reading 0mA when the all floating motor state (commutate(0)) was in place. The offset described in Section 2 was present, however, in the value given by the ADC reading.

The motor state was then switched to commutate(7) using USER button. When the ADC reading was obtained, the value decreased compared to the floating state, which is as expected based upon the board setup. This test was done with two different power resistor values (500 and 1K ohms), with varying duty cycles, and with only the primary board, with the secondary board connected, and with one of the magnets on to see if these values affected the offset and it was due to the current running through the whole board and not just the motor. The latter test on the amount of components powered did not appear to affect the offset during testing.

If the difference between the floating state value and the commutate(7) state was taken, the value was very close to the measured current value from the multimeter. For example, the 500 ohm power resistor at a 50 percent duty gave a current reading of .02345A on the multimeter. The difference between the floating and commutate(7) ADC readings resulted in a current of .0241A, or a 2.77 percent error. This shows that the current sensor is accurately measuring the current, but there is that offset that is present.

## 4 Possible Solutions

To fix the problem, the source of the offset must be discovered. Somehow the problem must be isolated to determine the exact source of the problem, whether that be board design or some other issue, to allow for a solution to be implemented in code or in the V6 PCB design.

One possible solution would be to add some number of readings to the intialize ADC function and take the average of those readings to set as the zero current value and essentially negate the offset. One issue with this would be that if the offset is floating and changes over the time of running, the average value calculated at intialization would no longer serve as a good representation of the offst and would lead to error in the measured current reading and would therefore affect any code utilizing the current sensor readings.

## 5 Solution: Chip Characteristics

The error seen on the ADC was not due to any board or code issue. The problem lays within the chip itself. The chip being used has a typical offset voltage of plus or minus 11mV, as seen in Figure 2.

| Characteristic | Symbol | Test Conditions | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| ***X*6BB CHARACTERISTICS** | | | | | | |
| Noise[2] | $V_{NOISE(rms)}$ | $T_A$ = 25°C, Sens = 100 mV/A, $C_f$ = 0, $C_{LOAD}$ = 4.7 nF, $R_{LOAD}$ open | – | 3.0 | – | mV |
| Electrical Offset Voltage Variation Relative to $V_{OUT(QBI)}$[4] | $V_{OE}$ | $I_P$ = 0 A, $T_A$ = 25°C | – | ±11 | – | mV |
| | | $I_P$ = 0 A, $T_A$ = 25°C to 125°C | – | ±11 | – | mV |
| | | $I_P$ = 0 A, $T_A$ = –40°C to 25°C | – | ±35 | – | mV |

Figure 2: Performance Characteristics for the X6BB Current Sensor

This voltage offset for the chip when it is at zero current explains the values that have been experimentally found. With the .8mV/ADC resolution of the dsPIC, a voltage of 11mV corresponds to 13.75 ADC counts. When the calculation is taken further with the 100mV/A current slope of the chip, the typical offset range of the chip will fall between -.11A to .11A. This new found discovery provides evidence that although the reading in Figure 1 is not around 0A as anticipated, it proves that the readings are in fact correct as all the readings fall within the voltage offset range.

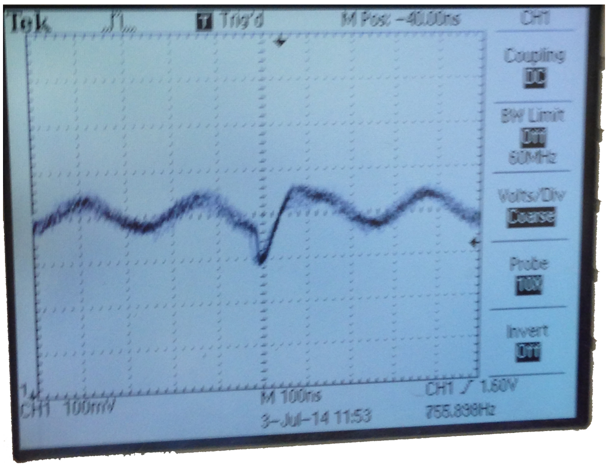


Figure 3: Oscilloscope Reading of Current Sensor Voltage Ouput at Zero Current

A reading from the oscilloscope of the output voltage from the current sensor at zero current can be seen in Figure 3. The voltage seems to oscillate within in a range of 100mV or so. This value falls within the current limts due to the quiescent voltage offset.

# 6 Dealing With Offset in Code

One solution is to have the ADC do some number of reads upon initialization within zero current to set the average offset which will be used as a baseline to compare the current values. Due to the wide range that the offset can have, this solution will not entirely eliminate the error, but it will reduce it.

Since the current can also "float" within that range, it may change and alter the current readings as the average value calculated at initialization no longer fits. To combat this, after prolonger inactivity, the current average can be recalculated to make sure it represents the values being read at that time and provides a more reliable and accurate current measurement with which to use for the internal calculations.