DALF Application Note #001

Current Sensing

Revision 0.02
May 04, 2007

Table of Contents

I

1 Application Note Synopsis

This application note discusses over current detection when using the Dalf Motor Control Board. Two types of off board current sensors are compatible with the current sensing hardware and firmware on the Dalf Board. Both types of sensors generate an analog voltage output in the range of 0V to 5V to indicate current magnitude. The hookup to the Dalf Board for both types of sensors is identical (use the VDD, GND, and IS connectors). The VOUT sensor output is an analog input to the Dalf Board (connected to the IS connector) but it is not routed on the board to the ADC Module on the PIC Microcontroller. Instead IS is handled by special board hardware and firmware using interrupt lines to provide rapid over-current response. The Dalf Board Configuration Setup is used to establish a voltage window [VL,VH] that defines the over current condition. The choice for the VL and VH levels will depend on what type of sensor is employed as well as the sensor sensitivity and the desired protection level for over current.

The "**centered"** type of current sensor generates a quiescent (no current) output of 2.5V. The voltage excursion from 2.5V indicates the current magnitude and direction. A typical example of this type of sensor is the Zap25 Hall Effect Sensor from AMPLOC.

The second type of current sensor, the "**non-centered**" type, generates a quiescent (no current) output of 0V. The voltage excursion from 0V indicates current magnitude only. A typical example of this type of sensor is the integrated current sensor provided on the Simple H-Bridge ESC board sold by Robot Power (http://www.robotpower.com/).

The Dalf Board setup for the centered type is straightforward and explained in some detail in the Dalf Owner's Manual. While this application note discusses both types of sensors, the primary focus is on the non-centered type since the board setup for this type of sensor is a bit non-intuitive.

2 Over Current Detection

The Dalf Board over current detection circuitry makes use of a "voltage window" [VL, VH] determined by the wiper positions of on board digital pots. The four on board pots allow each motor to have its own voltage window. The actual VL and VH levels correspond to current level thresholds which are application dependent and must be set by the user. After setting the VL and VH levels, the user enables over current detection, and selects one of the two provided over current responses provided in the firmware. The details of these configuration steps can be found in the Dalf Owner's Manual.

When over current detection is enabled, and the VOUT voltage level from the sensor moves outside of the [VL, VH] voltage window, the board responds to the over current situation. The user selectable responses to the over current condition are:

FASTOFF: All power immediately removed from the motor(s); interface disabled.
SLOWOFF: Like FASTOFF, but the motor interface remains enabled.

The detection of the over current condition is interrupt driven. The FASTOFF response will typically remove power within a few microseconds after detection. The FASTOFF response is only available in Dalf Firmware Versions >= 1.50. If you are using an earlier version of the firmware and you wish to use the FASTOFF option you must upgrade the firmware first. **The FASTOFF option is the only option available if you are using the non-centered type of sensor.**

The SLOWOFF option allows the application to continue to drive the motor(s) ("keep trying") but at reduced power levels while still providing protection to the motors and drivers.

3 Centered Current Sensors

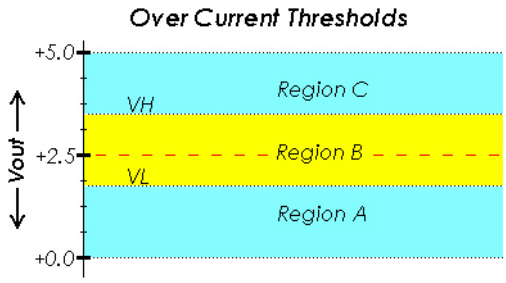
The Dalf over current detection circuitry is designed to best accommodate the use of off board current sensors of the "centered output" variety. This type of sensor generates an analog output voltage VOUT roughly centered at +2.5V. The value of (VOUT-2.5) indicates both current direction and magnitude. An output of +2.8V would indicate a magnitude of 0.3V in the FORWARD current direction while an output of 2.1V would indicate a magnitude of 0.4V in the REVERSE current direction. As an example; If your application can not tolerate a current that corresponds to a voltage excursion in excess of 0.5V, you might set VL=2.0V and VH=3.0V.

4 Non-Centered Current Sensors

This type of sensor produces an output voltage VOUT proportional to current, but the "quiescent" voltage level is zero, and there is no indication of current direction. This type of sensor -CAN- be utilized with the Dalf Board, but there is a limitation that excludes using the SLOWOFF response. That is, if you wish to use this type of current sensor, your only over current response option will be FASTOFF.

The issue:
When your sensor indicates absolutely no current, VOUT will be at, or very near to, +0.0V. This means that VOUT will be "outside" of the [VL, VH] voltage window for normal operation and would appear to the firmware as an over current condition when in fact there is no current! At first, this would seem to exclude the use of this type of sensor. In fact such a sensor can be made to work quite well assuming the FASTOFF response is acceptable. The solution lies in the details of how the over current interrupt handler works and the use of somewhat non-intuitive settings for the VH and VL pot levels to take advantage of this.

5 The Voltage Window



Regions A and C represent over current (INT Hi). Region B is the normal operating region for a "centered" type of current sensor (INT Lo).

The INT Line:
The current sensing interrupt line to the PIC Microcontroller is low when the sensor output is in Region B and high when it is in Regions A and C. **A transition out of Region B is required to recognize the over current condition** (the interrupt handler is initially configured to recognize only a low-to-high transition). This is the key that allows the use of non-centered current sensors with the Dalf Board. After the first transition, all transitions across region boundaries are observed (the interrupt level is toggled on subsequent transitions).

6 Non-centered Sensor Configuration

How does this work with a current sensor of the non-centered type? When the board initially powers up, the VOUT level of the sensor will be small (because the motor control signals from the board will have the motor(s) powered off). The VOUT voltage will be in [REGION A] regardless of the pot settings. Assuming that current levels remain reasonable, [REGION A] operation continues and no interrupt is generated to notify the firmware of an over current condition - just what you want.

Now assume that the current level rises causing VOUT to exceed VL. There is no interrupt here because this is a high-to-low transition which is fine. While the sensor output remains in Region B there is also no interrupt - also fine, but now the interrupt handler is "armed" (because the INT line is low) to detect any transition out of Region B. So how do we make this work for the non-centered type of sensor?

Assume that you are using the non-centered type sensor and you want over current to be handled with the FASTOFF response whenever VOUT > VBAD. You have determined that the VBAD level corresponds to your desired over current threshold. Set:

VH = VBAD
VL = VBAD - 100mV

This leaves a narrow 100 mV range for the usual "operational region" [REGION B]. You power up the board and begin operation in [REGION A]. This state continues until the current level begins to get out of hand because VOUT > VL (VOUT is within 100 mV of your VBAD limit). At this point operation is in [REGION B], and the system is now “armed" to detect all transitions out of [REGION B]. At this point, as far as the board is concerned, there is no over current issue and theoretically, this condition could prevail for some time - still fine. Eventually a transition (into lower current [REGION A] or the higher current [REGION C]) is detected and treated as an over current condition. If the transition was back into [REGION A], you will have triggered the over current condition 100 mV too early - a small penalty to make this scheme work. By the way, the choice of 100 mV for [VL,VH] window extent is somewhat arbitrary and you might want to experiment a bit, but you will want to keep it reasonably small.

I