SPARTAN EMBEDDED TECHNOLOGIES

APPLICATION NOTE

Calibrating The ADXL210 Accelerometer

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EXECUTIVE SUMMARY

The purpose of this application note is to explain a simple bench calibration technique applicable the ANALOG DEVICES ADXL202/ADXL210 devices. Without access to expensive and complicated drop test equipment, the ADXL devices can be initially calibrated using the earth's gravitational attraction. The calibration technique will be demonstrated for the ADXL210 accelerometer.

1. INTRODUCTION

The ADXL202/ADXL210 are low cost, low power, complete 2-axis accelerometers with a measurement range of ±2g or ±10g respectively. The ADXL202/ADXL210 can measure both dynamic acceleration (e.g., vibration) and static acceleration (e.g., gravity). The outputs are digital signals whose duty cycles (ratio of pulse width to period) are proportional to the acceleration in each of the 2 sensitive axes.

Since we are only interested in dynamic acceleration for our Self Contained Acceleration Monitor (S.C.A.M.), we will use the static acceleration characteristics to calibrate the dynamic acceleration characteristics.

2. MAIN BODY OF APPLICATION NOTE

2.1 Objective

Use the static acceleration (e.g., gravity) characteristics of the ADXL210 accelerometer to calibrate the dynamic acceleration (e.g., vibration) characteristics.

2.2 Issues

Data and calculations must be made for each of the four orientations of the ADXL210 accelerometer with respect to the Earth. The resulting data will be used for dynamic acceleration calibration as well as overall verification of a functional accelerometer.

2.3 Steps

The following steps are the exact process used for calibrating the ADXL210 accelerometer.

2.3.1 Collect data for each of the four Earth orientations (**Figure 1**) of the ADXL210 accelerometer using the PIC 16C77 Microcontroller to calculate the pulse width. (See application note on Using The PIC 16C77 To Calculate Pulse Width).

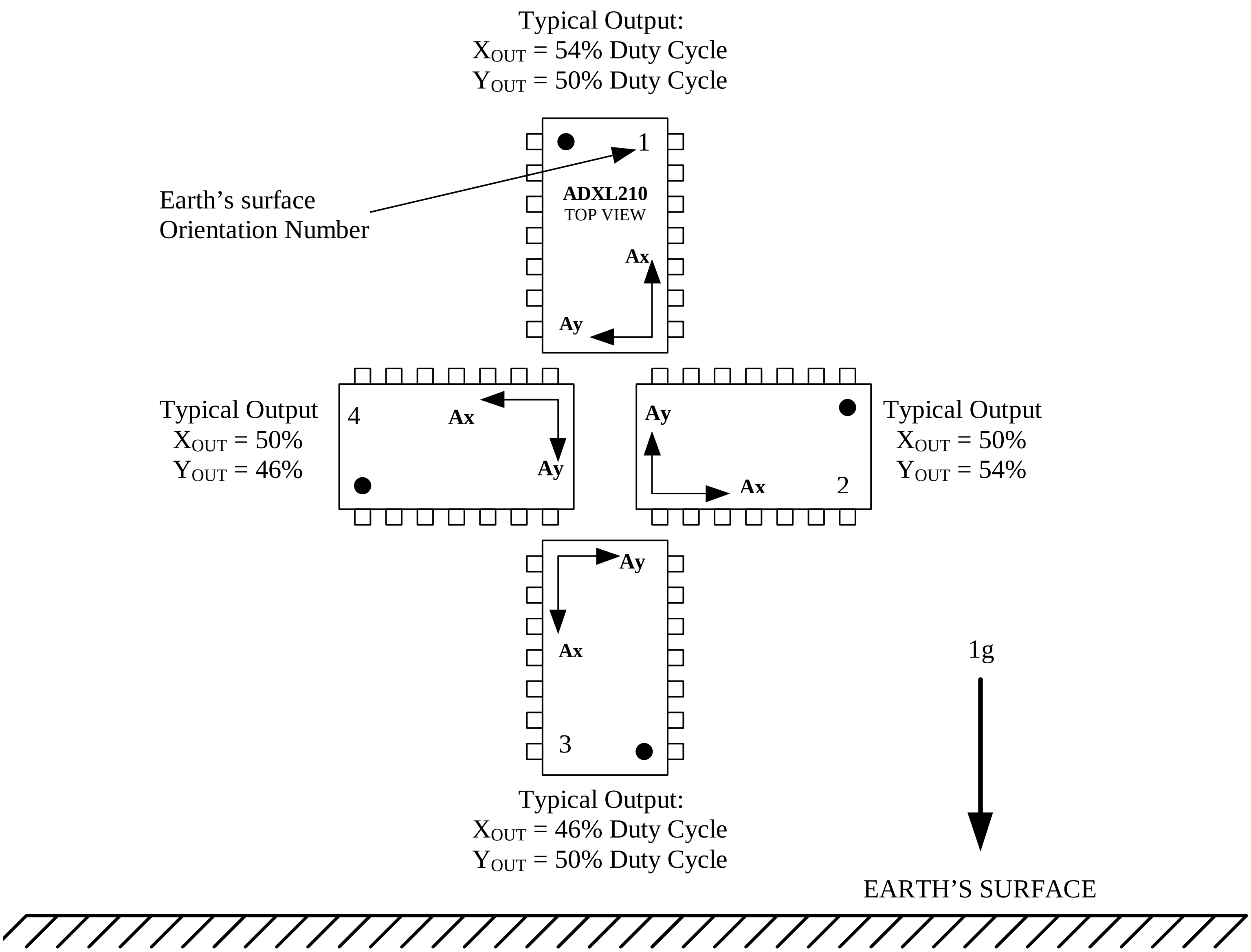

Figure 1 – Earth Orientation

2.3.2 Use the data collected by the PIC 16C77 Microcontroller to calculate an average pulse width value.

2.3.3 Calculate Duty Cycle, (T1/T2) where T1 is the length of the "on" portion of the cycle and T2 is the length of the total cycle. See **Figure 2**.

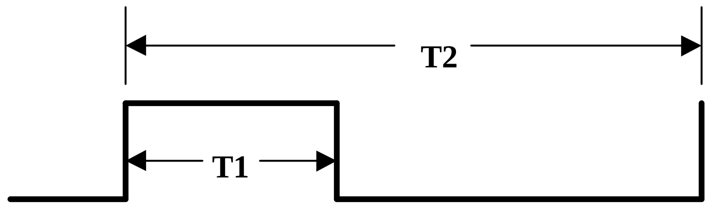

Figure 2 – Output Duty Cycle

2.3.4 Compare resultant data to that of the expected values as expressed in the ADXL202/ADXL210 data sheet.

2.3.5 Program the PIC 16C77 Microcontroller such that a pulse width value indicating a 1g static acceleration is 0g with respect to dynamic acceleration.

2.4 Example

The following example follows the above steps exactly as I used them to calibrate our ADXL210 accelerometer.
The same process can be followed for calibrating the ADXL202 by changing the ADXL210's 4% Duty Cycle Change per g to the ADXL202's 12.5% Duty Cycle scale factor.

2.4.1 Collect data for each of the four Earth orientations of the ADXL210 accelerometer using the PIC 16C77 Microcontroller to calculate the pulse width. Table 1 and Table 2 contain the assimilated accelerometer data.

	Earth's surface Orientation #1			Earth's surface Orientation #2	
	X_{out}	Y_{out}		X_{out}	Y_{out}
	24619	22452		22793	24400
	24601	22421		22820	24369
	24638	22505		22828	24401
	24616	22594		22873	24429
	24594	22463		22806	24478
	24610	22480		22784	24355
	24654	22478		22842	24442
	24681	22392		22822	24443
	24634	22537		22827	24313
	24651	22524		22864	24455
Average	24630	22485		22825.9	24409

Table 1 – Accelerometer Data

	Earth's surface Orientation #3			Earth's surface Orientation #4	
	X_{out}	Y_{out}		X_{out}	Y_{out}
	20885	22737		22682	20774
	20854	22582		22669	20722
	20794	22685		22681	20752
	20846	22706		22681	20729
	20885	22718		22634	20735
	20881	22667		22669	20717
	20879	22706		22700	20766
	20871	22759		22688	20730
	20872	22654		22695	20790
	20879	22684		22675	20747
Average	20865	22690		22677.4	20746

Table 2 – Accelerometer Data

2.4.2 Use the data collected by the PIC 16C77 Microcontroller to calculate an average pulse width value.

See Tables 1 and 2, where labeled "Average".

2.4.3 Calculate Duty Cycle, (T1/T2) where T1 is the length of the "on" portion of the cycle and T2 is the length of the total cycle.

2.4.3-1 T2, the period of the signal, is set by the user choosing a single resistor, R_{SET}, following the equation;

$$T2 = R_{SET}(\Omega)/125M\Omega$$

For our S.C.A.M. application we have chosen R_{SET} to be 1.2MΩ, this gives us a nominal T2 value of;

$$T2 = 9.6ms$$

The actual Multimeter measured period, T2, is;

$$T2 = 9.12ms$$

The Multimeter measured period is the value we will use for the remaining calibration calculations.

2.4.3-2 The four Earth orientation average values from above as acquired from the PIC 16C77 Microcontroller are arbitrary unit-less representation of the pulse width, T1. The following equation is used to convert to a real-time T1 value.

Average value/5000 = real-time T1(milliseconds)

Table 3 displays the calculated real-time T1 values for the four Earth orientations.

Earth's surface		Average			real-time T1 (milliseconds)	
		X_{out}	Y_{out}		X_{out}	Y_{out}
Orientation #1		24630	22485		4.926	4.497
Orientation #2		22825.9	24408.5		4.56518	4.8817
Orientation #3		20865	22690		4.173	4.538
Orientation #4		22677.4	20746.2		4.53548	4.14924

Table 3 – T1 values in real-time

2.4.3-3 Duty Cycle of each signal is calculated using the equation;

Duty Cycle = T1/T2

Table 4 displays the calculated Duty Cycles for our ADXL210.

Earth's surface		Duty Cycle (%)	
		X_{out}	Y_{out}
Orientation #1		54.0132	49.3092
Orientation #2		50.0568	53.5274
Orientation #3		45.7566	49.7588
Orientation #4		49.7311	45.4961

Table 4 – Duty Cycle

2.4.4 Compare resultant data to that of the expected values as expressed in the ADXL202/ADXL210 data sheet.

Table 5 shows the comparison and associated error of the expected and actual Duty Cycle values.

	Actual Duty Cycle (%)		Expected Duty Cycle (%)		Percent Error(%)	
Earth's surface	X_{out}	Y_{out}	X_{out}	Y_{out}	X_{out}	Y_{out}
Orientation #1	54.0132	49.3092	54	50	0.0244	1.40093
Orientation #2	50.0568	53.5274	50	54	0.1135	0.88289
Orientation #3	45.7566	49.7588	46	50	0.532	0.4848
Orientation #4	49.7311	45.4961	50	46	0.5406	1.10767

Table 5 – Expected vs. Actual Comparison

2.4.5 Program the PIC 16C77 Microcontroller such that a pulse width value indicating a 1g static acceleration is 0g with respect to dynamic acceleration.

2.4.5-1 The first step is to determine what pulse width constitutes a change of 1g.

From Table 3, subtracting the average X_{out} value of orientation #2 from the average X_{out} value of orientation #1 represents a 1g decrease, from this I get;

$$24630 - 22825.9 = 1804.1$$

Subtracting the average X_{out} value of orientation #3 from the average X_{out} value of orientation #4 represents a 1g increase, from this I get;

$$22677.4 - 20865 = 1812.4$$

From the two above differences I get the average pulse width value for a 1g change of acceleration, that value is;

$$(1804.1 + 1812.4) / 2 = 1808.25$$

2.4.5-2 For our S.C.A.M. application we are only interested in single axis acceleration. I have chosen to use the X_{out} output since it has the smallest percent error, and thus our ADXL210 will be mounted with Earth's surface orientation #1.

Since I only want to detect and trigger dynamic acceleration, I have programmed/calibrated the PIC to subtract the static 1g value of pulse width, (1808.25), from whatever value calculated from it's most recently received pulse width.

2.4.5-3 The following example demonstrates the above calibration calculation.

Say the PIC determines from a Duty Cycle input a pulse width of 35454. The equation used for determining g-level from pulse width is;

(((((pulse_width/5000)/9.12)*100)-50)/4)

Converting the above pulse width to a static g-level I get;

Static g-level = 6.94g's

All objects at rest are subject to a 1g static acceleration due to the Earth's gravitation attraction. Now since I am only interested in the dynamic acceleration, the above calculation of acceleration is off by 1g due to the aforementioned gravitational attraction of Earth. The actual dynamic acceleration should be the above value minus 1g. The following equation will prove this using my calibrated 1g pulse width calculation.

Pulse width = 35454

35454 – 1808.25 = 33645.75

Calculated dynamic g-level acceleration = 5.95g's

3. CONCLUSION

The purpose of this application note was to explain a simple bench calibration technique for the ANALOG DEVICES ADXL202/ADXL210 accelerometers. The process described above provides a detailed method of data collection and synthesis of a calibration technique easily performed in an average lab setting; that is, one in which access to complicated drop test equipment is not realizable.

4. REFERENCES

Using The PIC 16C77 To Calculate Pulse Width
http://www.egr.msu.edu/classes/ece482/Teams/99fall/design4/web/resources/resources.html

ANALOG DEVICES ADXL202/ADXL210 Data sheet
http://products.analog.com/products/info.asp?product=ADXL202

Listing of various ADXL202/ADXL210 application notes
http://www.analog.com/industry/iMEMS/library/apps.html