Analog-to-Digital Conversion using Sigma-Delta Modulator on Parallax Propeller P8X32A Quickstart Microcrontroller

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Objective:

The purpose of this tutorial is to construct an analog-to-digital converter using the sigma-delta modulator on the Parallax Propeller P8X32A Quickstart Microcrontroller.

Equipment Used:

Parallax Propeller P8X32A Quickstart Microcrontroller

Mini USB Cable

Computer

Power Supply

Soldering Iron

2-Pin Header

100kΩ and 150kΩ Resistors

Two (2) 1nF Capacitors

Two (2) Banana Jack to Grabber Hook Cables

ADC using S-D Modulator on Parallax Propeller P8X32A Quickstart Microcrontroller
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Background:

The application of the sigma-delta modulator on the Parallax Propeller P8X32A Quickstart Microcrontroller for analog-to-digital conversion entails reading an analog voltage from a power supply, using the Propeller's sigma-delta circuit as well as the corresponding microcontroller code to convert the analog voltage to a digital voltage, and displaying the converted digital voltage to a serial terminal on the computer.

Procedure:

1. Begin reading theory behind the application of sigma-delta modulators in ADC's.

Benefits of Delta-Sigma Analog-to-Digital Conversion.pdf

How delta-sigma ADCs work, Part 1.pdf

How delta-sigma ADCs work, Part 2.pdf

2. Introduce yourself to the Parallax Propeller P8X32A Quickstart Microcrontroller.

Parallax Propeller Manual.pdf

Propeller P8X32A Datasheet.pdf

Parallax Propeller QuickStart Guide v1.0 (RevA).pdf

Parallax Propeller QuickStart Guide v1.1 (RevB).pdf

(Note the differences between RevA & RevB. In this tutorial, we'll be using RevA)

https://www.parallax.com/product/40000

http://learn.parallax.com/KickStart/PropellerObjects

http://www.rayslogic.com/propeller/propeller.htm

http://www.gadgetgangster.com/tutorials/293

http://www.gadgetgangster.com/tutorials/325

3. Begin researching the application of sigma-delta ADC on the Propeller Microcontroller and download the Propeller P8X32A Application Note AN008 containing sigma-delta ADC code and PDF as seen in **Fig. 1** at https://www.parallax.com/downloads/an008-sigma-delta-analog-digital-conversion OR download them from the attachments directly below.

Parallax Propeller Sigma-delta Analog to Digital Conversion.pdf

AN008-SigmaDeltaADC-Code-v1.0\appnote_adc_list1 - Archive [Date 2011.04.19 Time 13.15]\appnote_adc_list1.spin

AN001-P8X32ACounters-v2.0.pdf

Parallax Propeller Communication with a PC Application.pdf

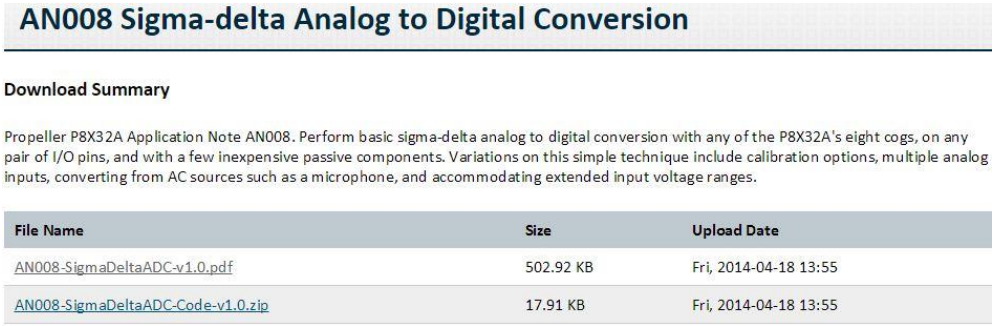
AN018-QuickStartComm-Spin-v1.0\QuickStartCommunicatorV1.0.spin

AN018-QuickStartComm-Spin-v1.0\FullDuplexSerial.spin

AN018-QuickStartComm-Spin-v1.0\Touch Buttons.spin

http://www.rayslogic.com/propeller/Programming/ADC.htm

http://www.gadgetgangster.com/tutorials/382



AN008 Sigma-delta Analog to Digital Conversion

Download Summary

Propeller P8X32A Application Note AN008. Perform basic sigma-delta analog to digital conversion with any of the P8X32A's eight cogs, on any pair of I/O pins, and with a few inexpensive passive components. Variations on this simple technique include calibration options, multiple analog inputs, converting from AC sources such as a microphone, and accommodating extended input voltage ranges.

File Name	Size	Upload Date
AN008-SigmaDeltaADC-v1.0.pdf	502.92 KB	Fri, 2014-04-18 13:55
AN008-SigmaDeltaADC-Code-v1.0.zip	17.91 KB	Fri, 2014-04-18 13:55

Fig. 1: Propeller P8X32A Application Note AN008 (Taken from https://www.parallax.com/downloads/an008-sigma-delta-analog-digital-conversion)

*The sigma-delta ADC circuit in **Fig. 2** below displays the internal circuitry on the Propeller with recommended resistor and capacitor values to be soldered. According to Parallax, "the circuit includes a capacitor to Vdd, in addition to the one to ground. This is done to prevent noise on the power and/or ground rails from affecting the voltage at the summing junction asymmetrically, which could lead to sporadic conversion results."

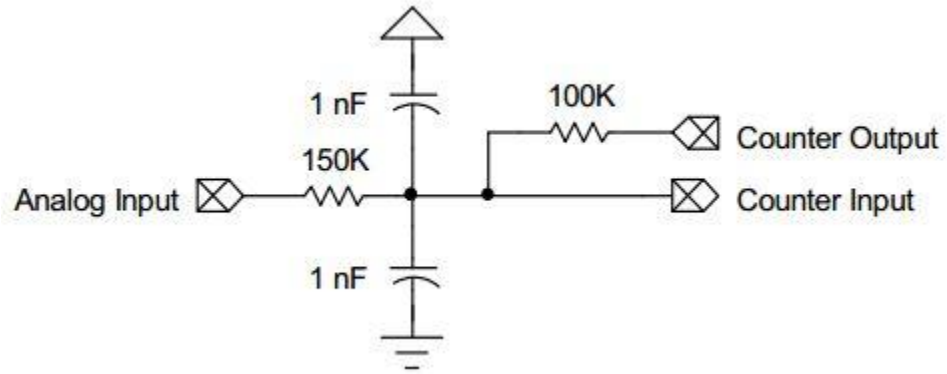


Fig. 2: Sigma-Delta ADC Circuit (Taken from Parallax Propeller Sigma-delta Analog to Digital Conversion.pdf)

*Experiment with various resistor/capacitor values at:

http://www.pulsedpower.net/Applets/Electronics/SigmaDeltaADC/SigmaDelta.html

***Fig. 3** & **Fig. 4** below specify the component names and the locations of the components on the Propeller, respectively, to be used in the sigma-delta ADC circuit of **Fig. 2**.

Delta Sigma (ΔΣ) digital to analog conversion

The unpopulated R14, R15, C16, and C17 pads are available for experimenting with Delta Sigma modulation. R15 is the input resistor, R14 is the feedback resistor, and C16 and C17, in parallel, act as the capacitor. The plated-through just below R15 is the input, and the plated-through just below R14 is ground.

Fig. 3: Component Soldering Locations (Taken from Parallax Propeller QuickStart Guide v1.1 (RevB).pdf)

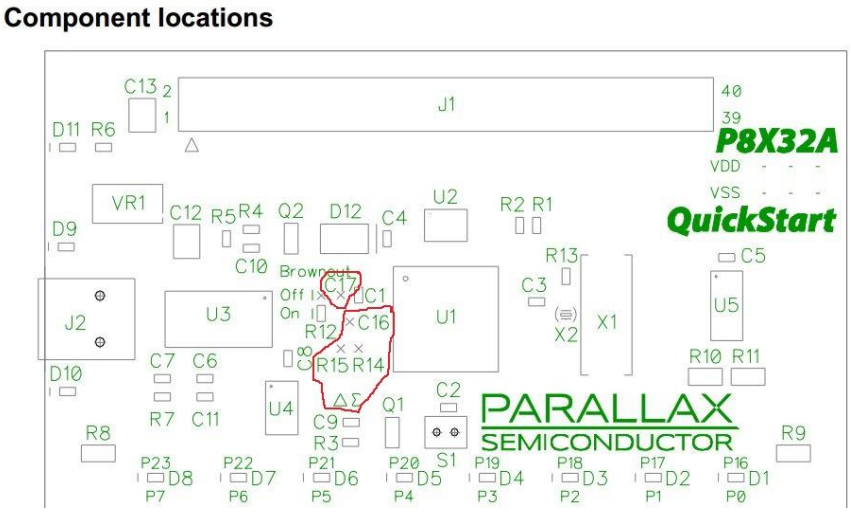


Fig. 4: Component Locations (Taken from [Parallax Propeller QuickStart Guide v1.0 (RevA).pdf])

4. Solder resistors R14 and R15, capacitors C16 and C17, as well as a 2-Pin Header to their corresponding locations as seen in **Fig. 5**. (R14 = 100kΩ; R15 = 150kΩ; C16 = 1nF; C17 = 1nF)

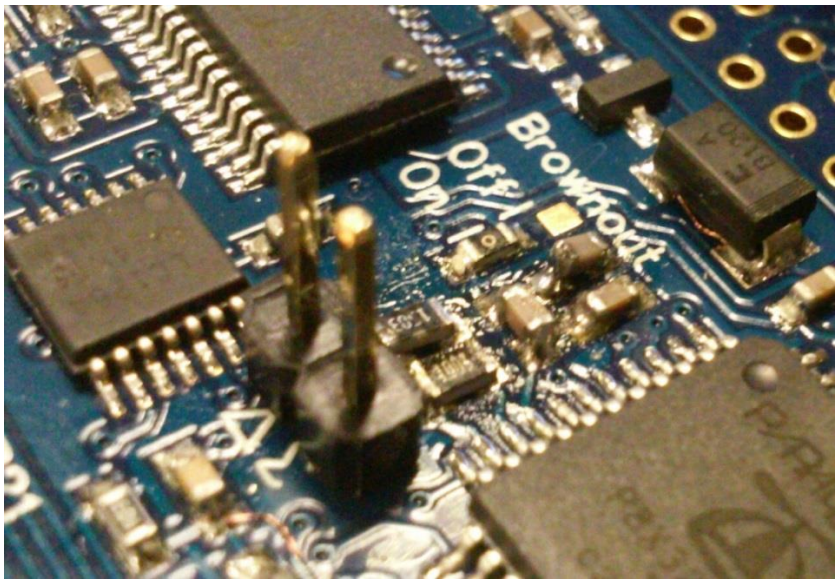


Fig. 5: Soldered Resistors, Capacitors, and 2-Pin Header

5. Download and Install Propeller Tool:

https://www.parallax.com/downloads/propeller-tool-software

6. Download SimpleIDE and become familiar with its Full Duplex Serial Terminal.

http://learn.parallax.com/propeller-c-simple-protocols/full-duplex-serial

http://learn.parallax.com/propeller-c-set-simpleide

http://learn.parallax.com/propeller-c-set-simpleide/windows

http://learn.parallax.com/propeller-c-set-simpleide/update-your-learn-folder

7. Connect the Propeller to the computer via Mini-USB, and open Propeller Tool. In the Propeller Tool toolbar, select Run>Identify Hardware (or press F7) as seen in **Fig. 6** to identify which COM Port the Propeller is connected to.

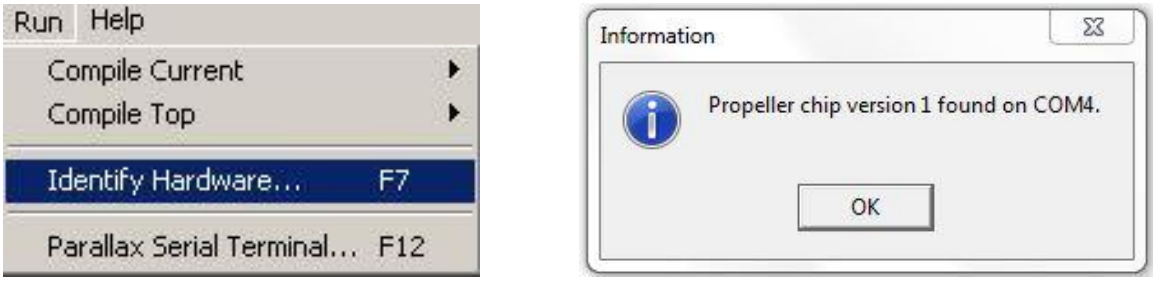


Fig. 6: Identifying Hardware (Propeller connected to COM4 in this tutorial)

8. In Propeller Tool, select File>Open… as in **Fig. 7** to open the downloaded sigma-delta ADC code.

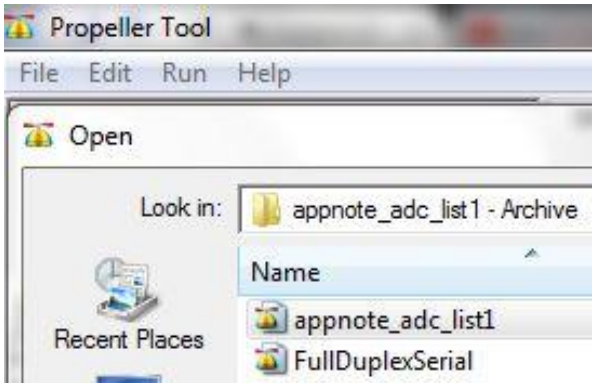


Fig. 7: Opening sigma-delta ADC code in Propeller Tool

9. Open SimpleIDE, and specify the correct COM Port in the upper right hand corner as seen in **Fig. 8**. In the toolbar, select Program>Run with Terminal (or press F8), and verify that the "Hello!" message appears in the SimpleIDE Terminal as shown in **Fig. 8**.

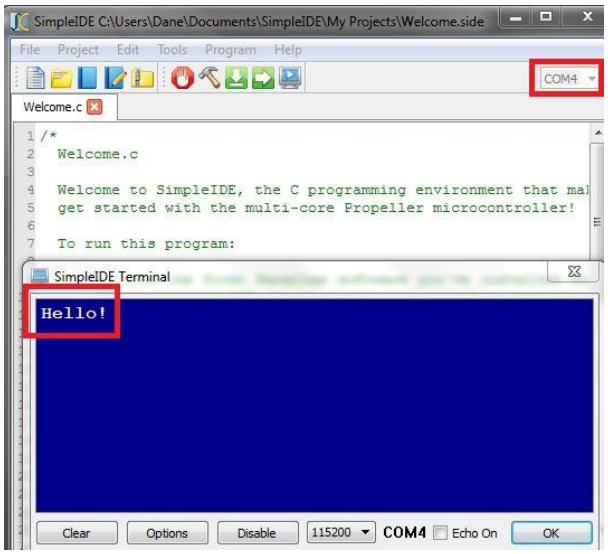


Fig. 8: COM Port (COM4) selected & "Hello!" message displayed in SimpleIDE Terminal

10. Set the terminal to the correct Baud Rate as in **Fig. 9** (Baud Rate = 9,600 as seen in code).

Fig. 9: Baud Rate set to 9,600 in SimpleIDE Terminal

11. Attach two (2) banana jack to grabber hook cables from the power supply to the microcontroller, and set the power supply to a voltage within the range 0 V – 3.3 V (1.5 V is used as an example in this tutorial) as seen in **Fig. 10**.

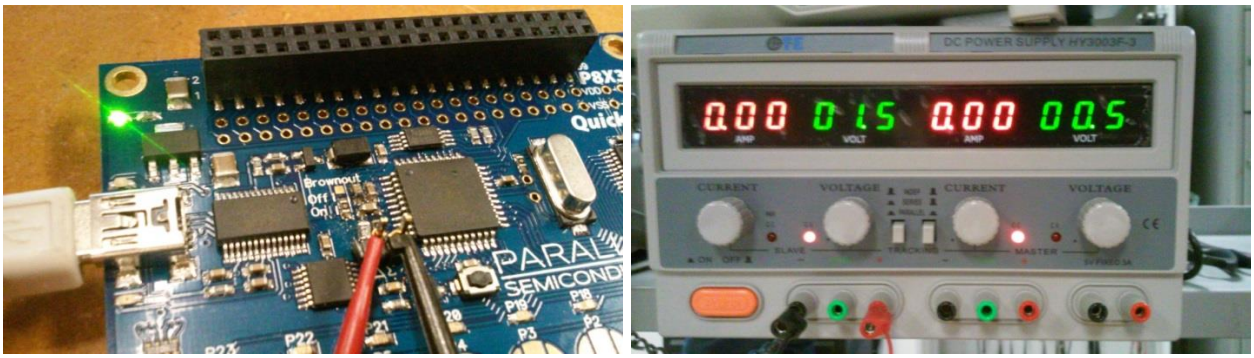


Fig. 10: Propeller Microcontroller attached to power supply (set at 1.5 V) as well as computer

12. In the Propeller Tool toolbar, select Run>Compile Current>Load RAM (F10). After pressing F10, you must quickly click open the SimpleIDE terminal window and click "Enable" WHILE the code is loading in the Propeller Tool. After an appropriate sample time, click "Disable" to stop displaying data.

13. The SimpleIDE Terminal should display various ASCII characters as seen in **Fig. 11**. The up-arrow ASCII character "↑" has a decimal equivalent of 24 but, though it is the most present character, the up-arrow "↑" signifies a break in the input signal and should be neglected as data.

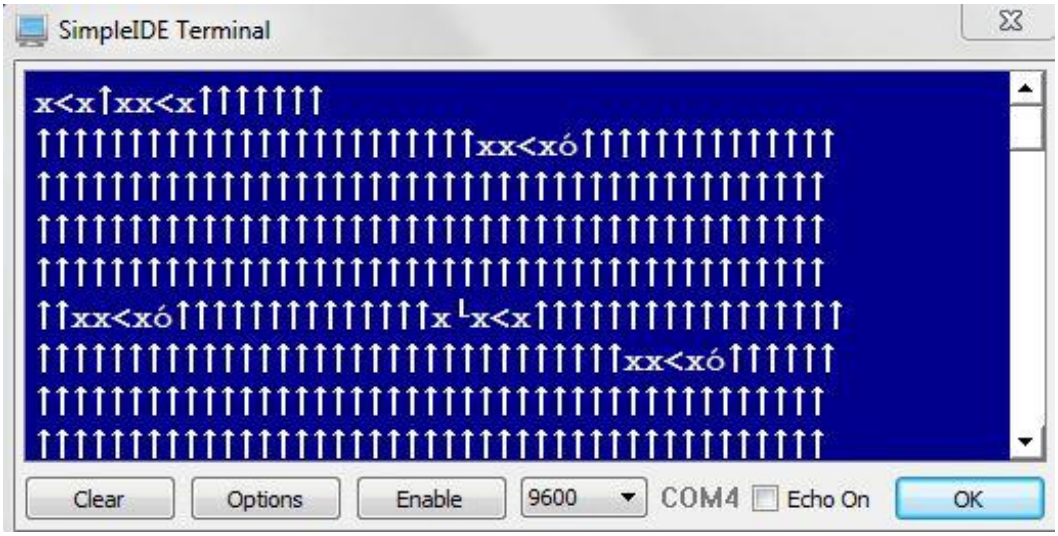


Fig. 11: ASCII characters displayed in SimpleIDE Terminal

14. Paste data (neglecting up-arrows "↑") into the ASCII to decimal converter as seen in **Fig. 12**. Click "Add spaces" and copy corresponding converted decimal values.

https://www.branah.com/ascii-converter

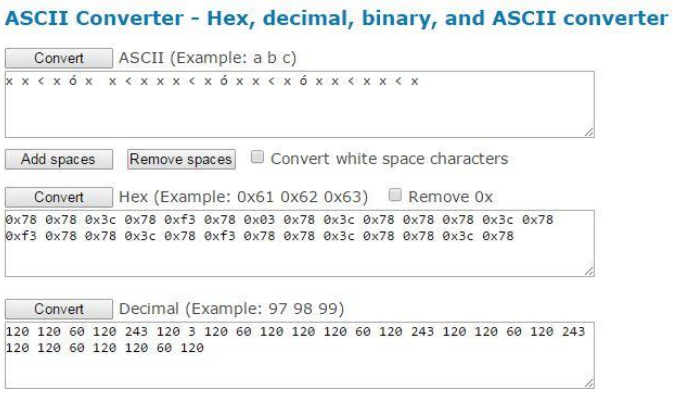


Fig. 12: Data in ASCII to Decimal Converter (Taken from https://www.branah.com/ascii-converter)

15. Paste the copied decimal values into the data set of the average calculator as seen in **Fig. 13** to get an average digital value corresponding to the inputted analog voltage.

http://www.calculatorsoup.com/calculators/statistics/average.php

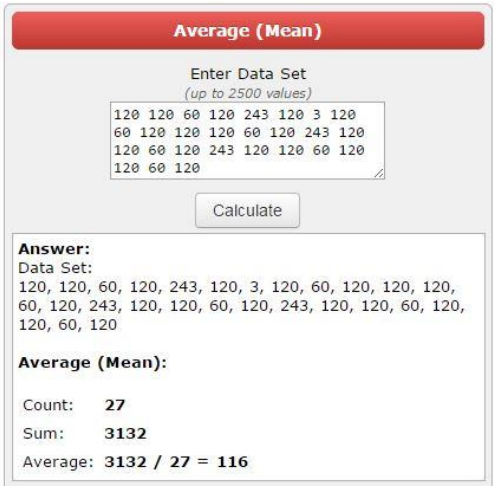


Fig. 13: Decimal values averaged (Taken from http://www.calculatorsoup.com/calculators/statistics/average.php)

Sample Calculations: (Explained in Conclusion)

116/256 = 0.453125 ➔ 0.453125 x 3.3 = 1.495 V

Conclusion:

The average value of 116 shown in **Fig. 13** corresponds to a digital voltage of 1.495 V. This is an accurate converted digital voltage since we had an input voltage of 1.5 V. 5 volts is sent from the computer via USB to power the Propeller Microcontroller and is reduced to VDD = 3.3 V on the Propeller, limiting us to an input voltage range of 0 V – 3.3 V. Having used an 8-bit counter in the Propeller, our input voltage range of 0 V – 3.3 V correlates to a digital range from 1 - 2^8 or 0 to 255.

Further experimentation for improved resolution has been researched in "A Passive 2nd-Order Sigma-Delta Modulator for Low-Power Analog-to-Digital Conversion" by Angsuman Roy and R. Jacob Baker, which explores the addition of a passive second-order RC filter circuit to a sigma-delta modulator used for low-power analog-to-digital conversion.

Resources:

[1] B. Baker. (2011). *How delta-sigma ADCs work, Part 1* [Online]. Available: http://www.ti.com/lit/an/slyt423/slyt423.pdf

[2] B. Baker. (2011). *How delta-sigma ADCs work, Part 2* [Online]. Available: http://www.ti.com/lit/an/slyt438/slyt438.pdf

[3] National Instruments. (2015, April 03). *Benefits of Delta-Sigma Analog-to-Digital Conversion* [Online]. Available: http://www.ni.com/white-paper/11342/en/

[4] Parallax Inc. (2011): *Propeller P8X32A Counters* [Online]. Available: https://www.parallax.com/sites/default/files/downloads/AN001-P8X32ACounters-v2.0.pdf

[5] Parallax Inc. (2011): *Communication with a PC Application* [Online]. Available: https://www.parallax.com/sites/default/files/downloads/AN018-CommPC-v1.0.pdf

[6] Parallax Inc. (2011): *Sigma-delta Analog to Digital Conversion* [Online]. Available: https://www.parallax.com/sites/default/files/downloads/AN008-SigmaDeltaADC-v1.0.pdf

[7] Parallax Inc. (2011): *Propeller Manual* [Online]. Available: https://www.parallax.com/sites/default/files/downloads/P8X32A-Web-PropellerManual-v1.2.pdf

[8] Parallax Inc. (2011): *P8X32A QuickStart (#40000)* [Online]. Available: https://www.parallax.com/sites/default/files/downloads/40000-P8X32A-QuickStart-Doc-v1.0.pdf

[9] Parallax Inc. (2011): *Propeller QuickStart (#40000)* [Online]. Available: https://www.parallax.com/sites/default/files/downloads/40000-Propeller-QuickStart-Guide-v1.1.pdf

[10] Parallax Inc. (2011, June 14): *Propeller P8X32A Datasheet* [Online]. Available: http://www.mantech.co.za/Datasheets/Products/P8X32A_PARALLAX.pdf

[11] Parallax Inc. (2013, May 01): *SimpleIDE User Guide* [Online]. Available: http://learn.parallax.com/sites/default/files/content/propeller-c-reference/landing/SimpleIDE-User-Guide-9-26-2.pdf

[12] R. J. Baker, "Sensing Using ΔΣ Modulation" in *CMOS Circuit Design, Layout, and Simulation,* 3rd ed. Piscataway, NJ: John Wiley and Sons, Inc., 2010, ch. 17. pp 483-520.

[13] R. J. Baker and A. Roy, "A Passive 2nd-Order Sigma-Delta Modulator for Low-Power Analog-to-Digital Conversion," *IEEE 2014.* (2014): 595-598.