Data Logger For Mechanical Systems

"Bringing Passive Tools to Use"

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Objective

Figure 1: Objective of our project

- Design an accessory for passive mechanical tools that logs their motion data in order to 1) prove that they are working correctly and 2) improve their performance
- Utilizes an accelerometer and a microcontroller to log motion data against a realtime clock and save it in memory
- Plot data using LabVIEW through serial port

Modeling and Analysis

- Block diagram showing the function of our project

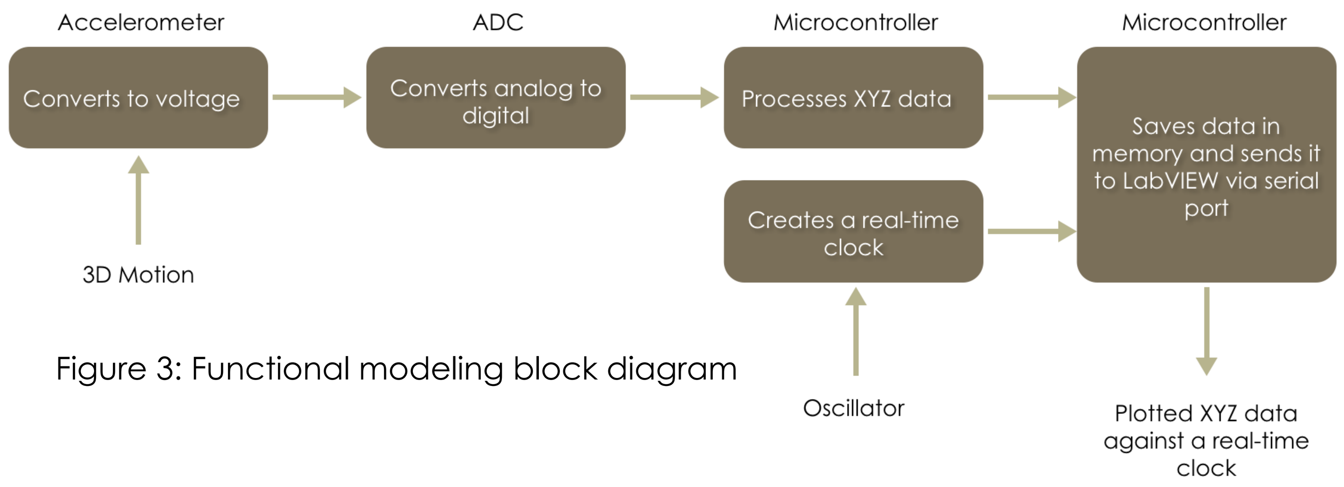


Figure 3: Functional modeling block diagram

- Theoretical calculations for accelerometer values

The accelerometer is supplied with 3.3V. The 12-bit ADC readings will be assigned as follows:

0x000 = (0) for 0V output
0xFFF = (4095) for 3.3V output

The accelerometer used is a ±10g with sensitivity factor of ~ 132mV/g

$$(1)\ \text{Acceleration} = \frac{(\text{ADC} - \text{Offset})}{\text{Sensitivity}}$$

Based on experimental offset calibration we used the following equation to represent the tri-axis acceleration analogue output to readable information to the user:

$$(2)\ \text{AccelerationX} = \frac{(\text{ADCX}-2122)}{152}, \text{AccelerationY} = \frac{(\text{ADCY}-2088)}{158}, \text{AccelerationZ} = \frac{(\text{ADCZ}-2052)}{164}$$

Acceleration to Tilt degrees:

$$(3)\ \text{TiltX} = \frac{180}{\pi}\frac{\text{deg}}{\text{rad}} * \left(\tan^{-1}\left(\frac{\text{Acceleration Y}}{\text{Acceleration Z}}\right) + \pi\right), \text{TiltY} = \frac{180}{\pi}\frac{\text{deg}}{\text{rad}} * \left(\tan^{-1}\left(\frac{\text{Acceleration X}}{\text{Acceleration Z}}\right) + \pi\right), \text{TiltZ} = \frac{180}{\pi}\frac{\text{deg}}{\text{rad}} * \left(\tan^{-1}\left(\frac{\text{Acceleration Y}}{\text{Acceleration X}}\right) + \pi\right)$$

The theoretical accuracy of tilt readings (disregarding Noise and other factors):

$$(4)\ \text{Step Size} = \frac{3.3\text{V}}{(2^{12} - 1)\text{bits}} = \frac{3.3\text{V}}{4095} = 0.8\text{mV/bit}$$

Experimental Results

Can store up to 2500 data points which includes:

- X, Y and Z degrees of tilt of the device.
- Time stamp of each reading (Hours:Minutes:Seconds.Milliseconds)

Logging threshold is a certain amount of change in the acceleration of the device after which it logs continuously for a specified time period.

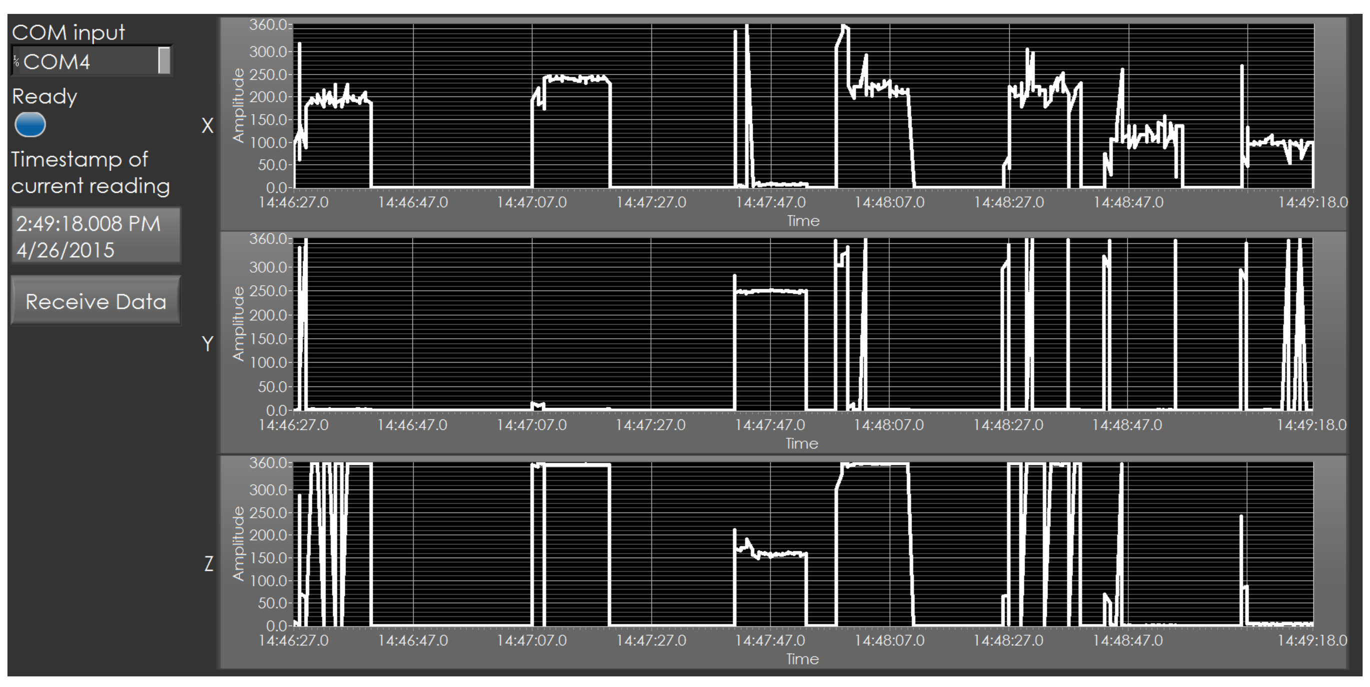


Figure 6: Our retrieving LabVIEW VI that receives the data and plots it in three XYZ graphs against time

References

[1] Downhole Tools Market Analysis, Size, Share, Trends and Forecast 2020 by Sandip Ghate.
[2] Downhole Tools. Logwell. Retrieved from http://www.logwell.com/capabilities/downhole_tools.html.
[3] H.E.A.T. Board. Texas Instruments. Retrieved from http://www.ti.com/tool/HEATEVM.

Market Review

- Customer needs analysis and ethnographic study:
  - Survey showed motion data to be important in the industry
  - Prioritize Accuracy
- Benchmarking with other products

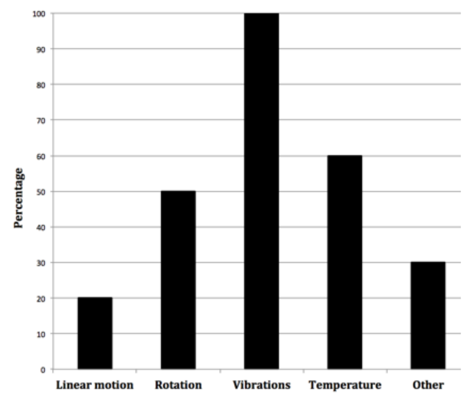


Figure 2: Result of our survey showing the types of data that the industry is interested in logging

Table 1: Benchmarking table comparing our product with similar products currently available

Metric	Our Design Project	TI H.E.A.T Evaluation Module	CompactDAQ (cDAQ-9134)	MSR145 (Standard IP 60)
Power Source	9 V Battery	3.3 V External Supply	24 V 5A External Supply	Lithium-polymer battery (800mAh)
Dimensions (LxWxH)	12x6x1 inches	15.6x1x0.93 inches	8.66x4.6x3.4 inches	2.8x1.5x0.9 inches
Sensors	Rotation	Rotation, pressure, temperature	Holds 4 from 50+ sensor modules	Holds 5 from 8 sensor modules
Memory	Onboard 32 KB	Onboard 32 Mbit	SD Card (Max 16 GB)	Onboard 8 Mbit
Acquisition Frequency	Up to 100 per second	Up to 128k per second	Up to 50k per second	Up to 50 per second
Connectivity	Serial to USB	CAN	CAN/USB	USB

Simulation Results

- PCB Design in Eagle
  - Four PCBs connected with jumpers
  - Plastic housing using SolidWorks with only ports and reset button visible

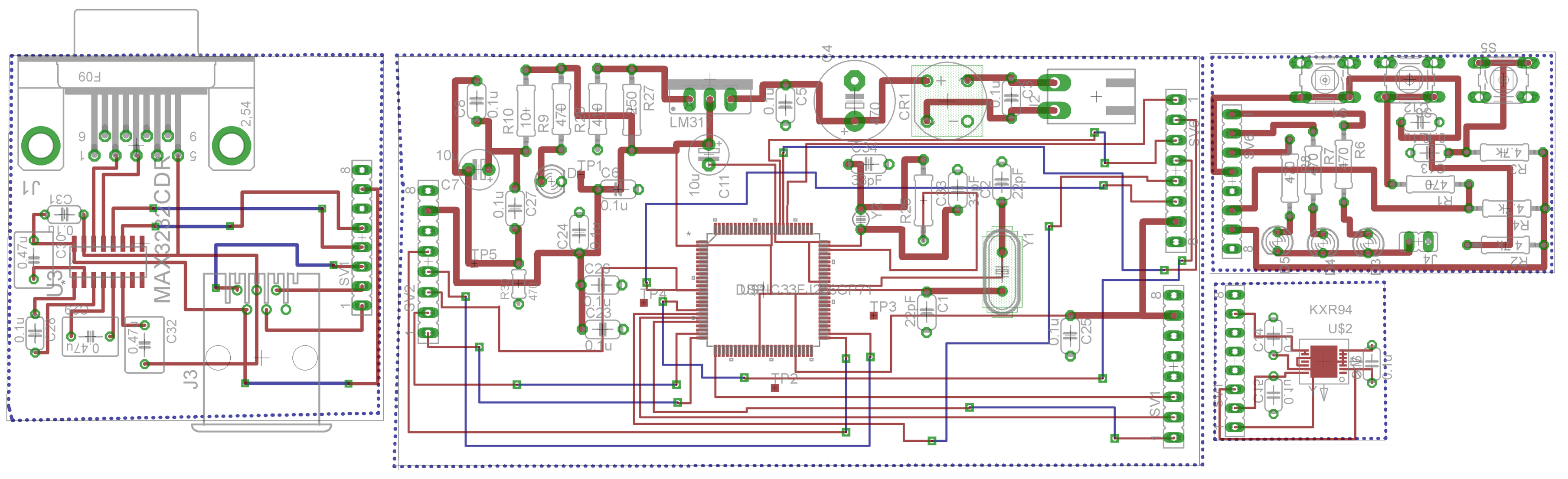
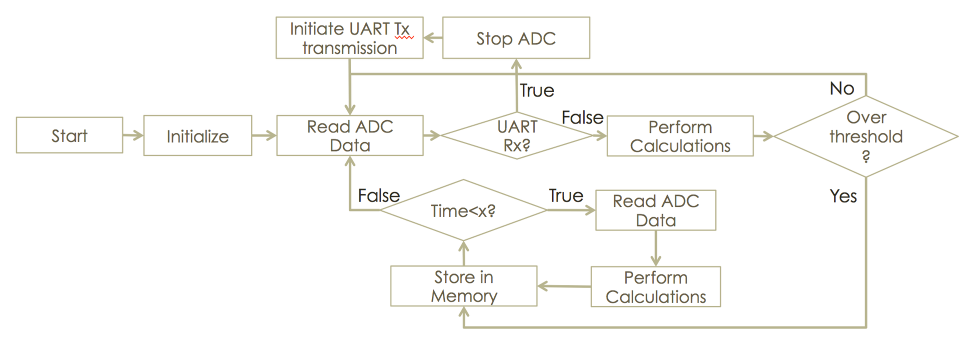


Figure 4: Final PCB design in CadSoft Eagle

- Flowchart showing the logic of our code

Figure 5: Flowchart showing the logic and



Conclusion

As we have achieved our main objective, there are still many improvements and possible additions to the design that can increase its usefulness:

- Add external memory to increase capacity.
- More efficiency optimization like using a buck convertor, sleep/idle mode and less power consuming components.
- Choose durable components to withstand high temperature and shocks of the mechanical tools working environment.

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