Introduction to LabVIEW

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The goal of this experiment was to become familiar with LabVIEW by creating a LabVIEW program to measure the temperature of boiling water with a thermocouple. Three LabVIEW programs were created with two sub-programs performing rudimentary conversions and the main program handling the while loop, data input, and file output. The thermocouple used in this experiment was found to be a first order system. The boiling water was measured with different sampling rates, millisecond multiples, and when the system was at different states to explore the effect that these variables have on the distribution of the data collected. The distribution of a constant value signal should be a normal distribution centered around the signal's true value. The sampling rate and the millisecond multiple can influence the data's distribution if the sampling rate or millisecond multiple cause the program to capture an insufficient number of data points.

Nomenclature

V(t)	=	Analog Signal
V_i	=	Digital Signal

I. Introduction

LabVIEW is a graphical programming language that was built for a lab environment. LabVIEW excels at integrating different hardware and multiple inputs into a single cohesive Virtual Interface (VI). This VI can be customized and the data files that LabVIEW creates are easy to read and import into different programs such as excel [1]. A thermocouple is comprised of two dissimilar metals that when subjected to a temperature creates a voltage. This voltage can be used to precisely determine the temperature that the thermocouple is being subjected to. Since a thermocouple is self-powered and the two metals are relatively cheap the thermocouple is a cheap and precise option to measure temperature, it is widely used [1]. When measuring a steady state system a gaussian distribution (normal distribution) should be apparent in the data with the distribution being centered on the true value of the system [2]. The Nyquist Criterion states that to a5urately measure data the sampling rate needs to be twice the frequency of the data to be collected to avoid aliasing [3].

II. Experimental Setup and Procedure

In this experiment a type J thermocouple is used to measure water that is heated to a steady boil by a Talboys 120 V Mini Hot Plate. The thermocouple is connected to a AD594 Monolithic Thermocouple Amplifier which is in turn connected to a NI USB-6008 Data Acquisition system (DAQ). The DAQ converts the analog signal to a digital signal and sends the data to the LabVIEW Virtual Interface that was programmed in this experiment.

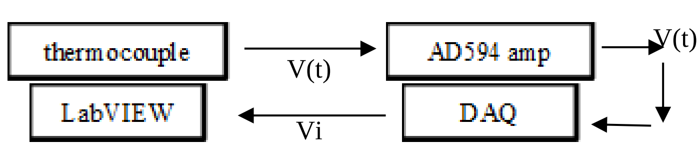


Figure 1 Data flow Diagram

A total of three LabVIEW VIs were created. Two of these VIs are sub VI's that did simple tasks that would of have cluttered the main VI's block diagram. One of the sub-VIs converted Celsius to Fahrenheit and the other sub-VI converted Celsius to Kelvin and Fahrenheit to Rankine. The main VI handled the input from the DAQ, the while loop, a millisecond multiple, the file output, the sampling rate, and displaying all the data including a graph to the VI.

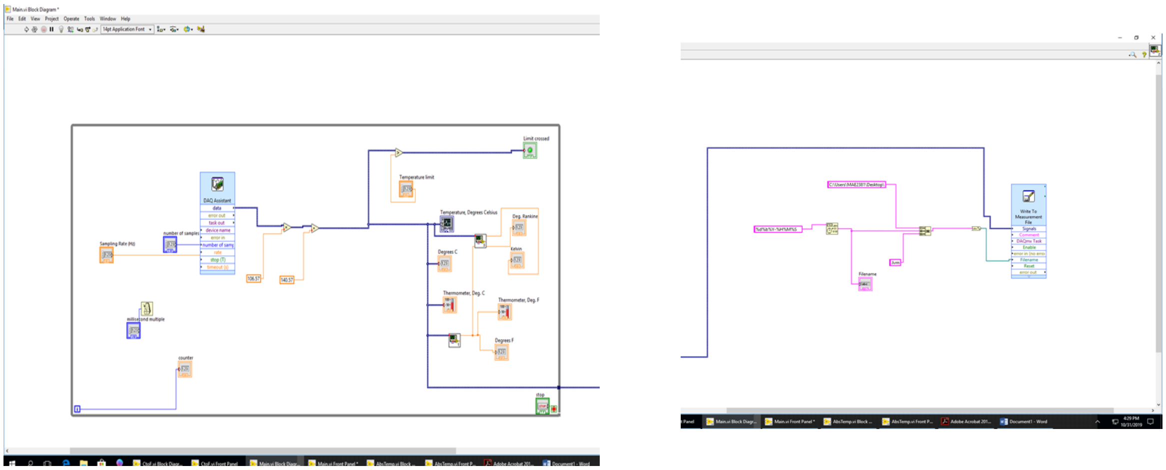


Figure 2 Completed Block Diagram

For the first test set the number of samples and sampling rate to 1000 and the millisecond multiple for 500. Press the start button then quickly immerse the thermocouple in the boiling water. Let the VI run for at least 15 seconds. This test is measuring the response time of the thermocouple. For the second test leave the thermocouple in the boiling water and without changing any of the settings run the test for 15 seconds. This test is testing the thermocouple once it has reached a steady state. For the third test leave the thermocouple immersed in the water and change the millisecond multiple to 1500. Then run the test for 15 seconds. This test explores the effect of the millisecond multiple. For the fourth test set the number of samples, sampling rate, and millisecond multiple to 10 and with the thermocouple immersed in the boiling water run the test for 15 seconds. Record all the file names and transfer them to a USB [1].

III. Experimental Results and Discussion

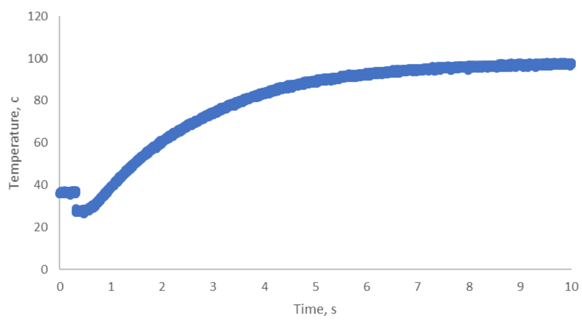


Figure 3 Test 1

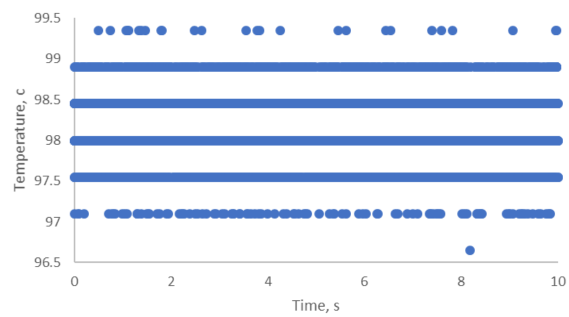


Figure 4 Test 2

In test one the thermocouple starts out at room temp and then when the test is started the thermocouple is at room temperature and then is plunged into the boiling water. The spike at the beginning of the test can be attributed to handling the thermocouple. Looking at the characteristics of fig. 3 the thermocouple can be determined to be a first order system [4]. The time constant of a first order system is defined as time when 63% of the peak amplitude is reached; therefore, looking at fig. 3 the time constant can be estimated to be around 3 seconds. Figure 4 from test 2 is different from test one because the thermocouple system in test two had reached equilibrium.

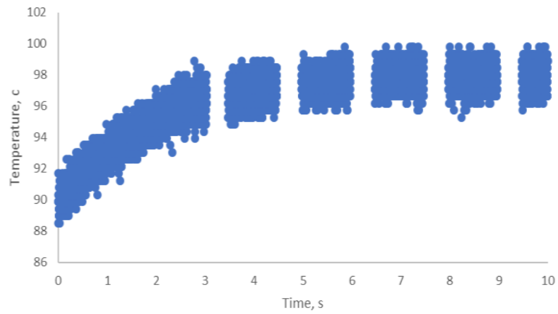


Figure 5 Test 3

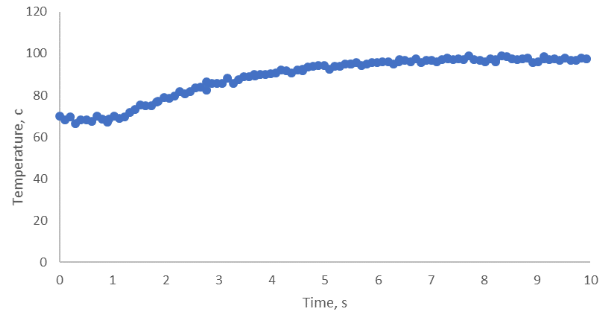


Figure 6 Test 4

In both test three and test four the system appears to not start at a steady state; however, between each test we took the thermocouple out to measure the temperature of the water with the alcohol thermometer to confirm that our system was recording correct data. We believed the thermocouple to be a zero-order system, so we started test three and four before the system could reach a steady state. In tests 4 the test was run with a low sampling rate therefore the data is less a5urate due to having fewer samples and the horizontal bands are not evident also due to not having enough samples. If the resolution of all the figures were to increase there would be horizontal bands present in every figure except fig. 6 due to the lack of samples. This horizontal band of temperature is the easiest to see in fig 4. This horizontal band is due to the DAQ with the distance between each band representing the DAQ's resolution [4]. There are vertical gaps in fig. 5 due to the millisecond multiple on test three being 1500. This meant that once the program recorded 1000 in 1000 milliseconds it had to wait for the remaining 500 milliseconds for the millisecond multiple to let the while loop run again before it could record more data.

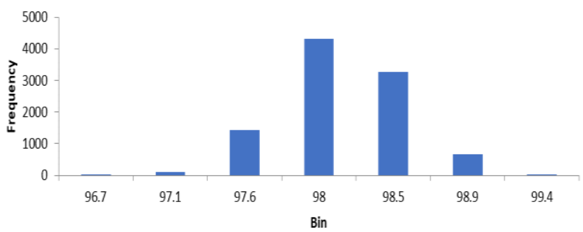


Figure 7 Test 2

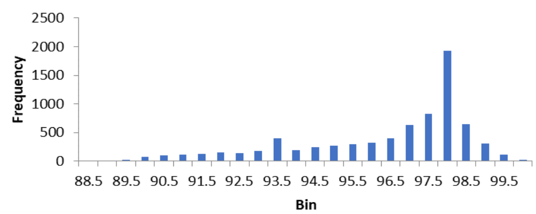


Figure 8 Test 3

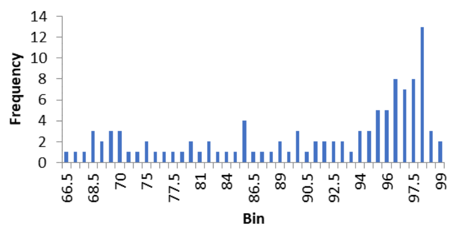


Figure 9 Test 4

The histograms for tests 2 through 4 all appear to be normally distributed even with the extraneous data collected at the beginning of test 3 and 4 [5]. Tests 2 through 4 should have a normal distribution for the data since the tests were run when the system reached a steady state; therefore, the frequency of the temperature recorded should be normally distributed about the mean [5].

Table 1

Test #	Test 2	Test 3	Test 4
Mean	98.13888937	96.13509004	88.91426228
Standard deviation	0.382711625	2.331690513	10.19566181

The standard deviation and mean were calculated using the summary statistics tool [2]. The standard deviation and mean for the first test were as expected given that the first test had a sufficient number of samples with a high sampling rate, no breaks due to the millisecond multiple value, and the system was at a steady state when the test was run[2].

For test three the data at the beginning of the test when the system was not at a steady state dragged the mean down and increased the standard deviation. The millisecond multiple did not affect the mean or standard deviation because even with the gaps in recording data due to the millisecond multiple enough samples were collected. Test 4 suffers from both the system not being at a steady state when the test began and there were not enough samples collected to have an a5urate mean. This leads to a higher standard deviation then any of the other tests. A good sampling rate to record ambient temperatures needs to be able to detect the slow changes of ambient temperatures and be low as to keep the size of the data collected to a manageable. I believe that 1 Hz meets both requirements I defined and therefore would be a good sampling rate to detect the slow changes of ambient temperature. The Nyquist criterion states that to properly sample a signal you need a sampling rate of twice the rate at which the signal changes to avoid aliasing [3]. Taking this into a5ount it is better to oversample a signal then to under-sample a signal and have the data be aliased [3]. With this in mind a good sampling rate for a constant value signal such as boiling water would be somewhere around 1000 Hz since I do not expect the value of the signal to change more then 500 times in a second. My experience with LabVIEW was that while it was intuitive to connect the blocks the interface to find the blocks is clunky and debugging the program was tedious. Overall, I felt that doing simple things such as converting Celsius to Kelvin was easy, but more complicated tasks such as the while loop the interface felt clunky. If LabVIEW was a textual based programming language, then more complicated tasks would be easier and more efficient to program anything that uses more then one loop.

IV. Conclusions

The LabVIEW programming language is intuitive but limiting. The type J Thermocouple is a first order system with a rise time of approximately 3 seconds. The data in tests 2-4 were found to have a normal distribution with sampling rate affecting the distribution, mean, and standard deviation. Horizontal bands in the data was due to digitizing the data with the vertical distance between the bands being the DAQ's resolution. Test three had vertical gaps in the data due to the millisecond multiple value being high and making the program wait before it could continue recording data. These vertical gaps in the data did not adversely affect the distribution, mean, or standard deviation due to the signal being measure being a constant value signal.

References

[1] "Introduction to LabVIEW," Mechanical Methods and Measurements Laboratory Manual, Department of Mechanical and Aerospace Engineering, University of Texas at Arlington, Arlington, Texas, 2019.

[2] American Engineering statistics Handbook, "What do we mean by "Normal" data?," 2019. [Online]. Available: https://www.itl.nist.gov/div898/handbook/pmc/section5/pmc51.htm

[3] Lewins, Jefferey, *Nuclear Reactor Kinetics and Control*, Pergamon 1978.

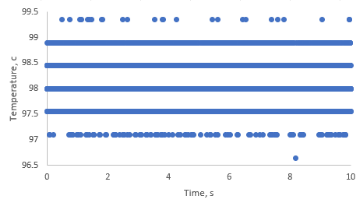
[4] Figolia, R. S. and Beasley, D. E. , *Theory and Design for Mechanical Measurements,* 6th ed, Wiley, 2015.

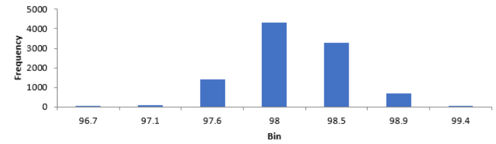
[5] LAERD Statistics, "What is a Histogram," 2019 [Online. Available: https://statistics.laerd.com/statistical-guides/understanding-histograms.php

Appendix

LabVIEW Measurement	
Writer_Version	2
Reader_Version	2
Separator	Tab
Decimal_Separator	.
Multi_Headings	No
X_Columns	One
Time_Pref	Absolute
Operator	mae2381
Date	10/31/2019
Time	17:41.6
End_of_Header	
Channels	1
Samples	1000
Date	10/31/2019
Time	17:41.6
Y_Unit_Label	Volts
X_Dimension	Time

0	97.99835	96.5
0.001	97.548624	96.6
0.002	98.447985	96.7
0.004	97.99835	96.9
0.005	98.447985	97
0.006	98.447985	97.1
0.007	97.99835	97.2
0.008	97.548624	97.3
0.009	97.99835	97.4
0.01	98.447985	97.5
0.011	98.897531	97.6
0.012	98.447985	97.7
0.013	98.447985	97.8
0.014	97.99835	97.9
0.015	98.447985	98
0.016	97.548624	98.1
0.017	98.897531	98.2
0.018	97.99835	98.3
0.019	98.447985	98.4





Bin	Frequency
96.7	1
97.1	105
97.6	1426
98	4317
98.5	3276
98.9	679
99.4	26

Mean	98.13889	
Standard Error	0.00386	
Median	97.99835	
Standard Deviation	0.382712	
Sample Variance	0.146468	
Kurtosis	-0.093	
Skewness	0.02244	
Range	2.698089	
Minimum	96.6489	
Maximum	99.34699	0.027253
Sum	964705.3	
Count	9830	

Figure 10 Page of experimental Data