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Writing Assignment

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Data Acquisition, its History and Usefulness

When googled, Data is defined as: facts and statistics collected together for reference or analysis (Google). To get a thorough understanding of something it is best to know it at its core level or the origin so we'll take Data's philosophical definition which is: things known or assumed as facts, making the basis of reasoning or calculation (Google). To calculate we need some type of units of measurement. Basic units of physical measurement can be found in *Metric_Chart.png*.

Quantity	Unit	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

Metric_Chart.png

Keep in mind that there are many different ways to describe the units and the symbols that represent them. The quantity or type is, by far, the most important factor. Base-Ten systems seem to be the easiest to learn, convert and, overall calculate.

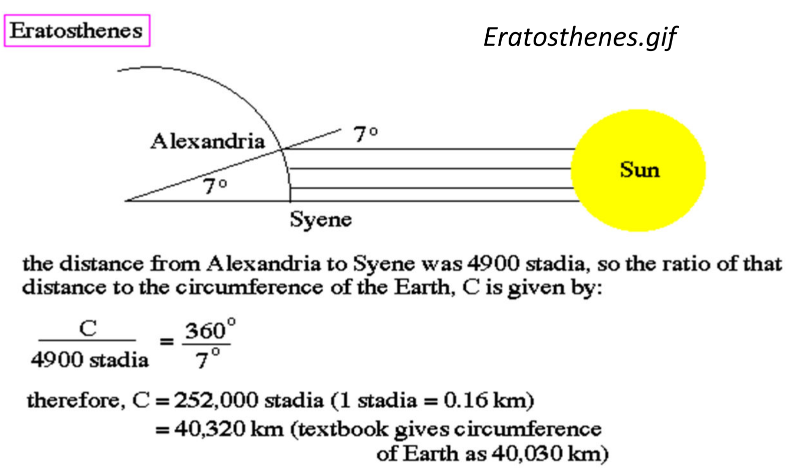
Tera	T	1,000,000,000,000
Giga	G	1,000,000,000
Mega	M	1,000,000
kilo	k	1,000
hecto	h	100
deca	dK -or- da	10
metre, gram, liter, second, celcius		
deci	d	.1
centi	c	.01
milli	m	.001
micro	µ	.000,001
nano	n	.000,000,001
pico	p	.000,000,000,001

LANG_Metric_a3.png

Metric units of measure are commonly referred to as the **International System of Units or SI**. A series of base units define each measurement in an absolute way without directly referring to any other unit. Now that we have a set measuring system we have a consistent way to record our data. These records can then be compared to others and evaluated for predictability through trends. Data may not seem like such a powerful tool at first, but throughout these writings I will prove its worth.

Since Astronomy is the first known science, we will use it to confirm the power of Data Analysis. Hieroglyphics, a very primitive form of data, of early man help us understand that the moon, planets, sun and stars had been around since man's ability to record data (*History of Astronomy*).

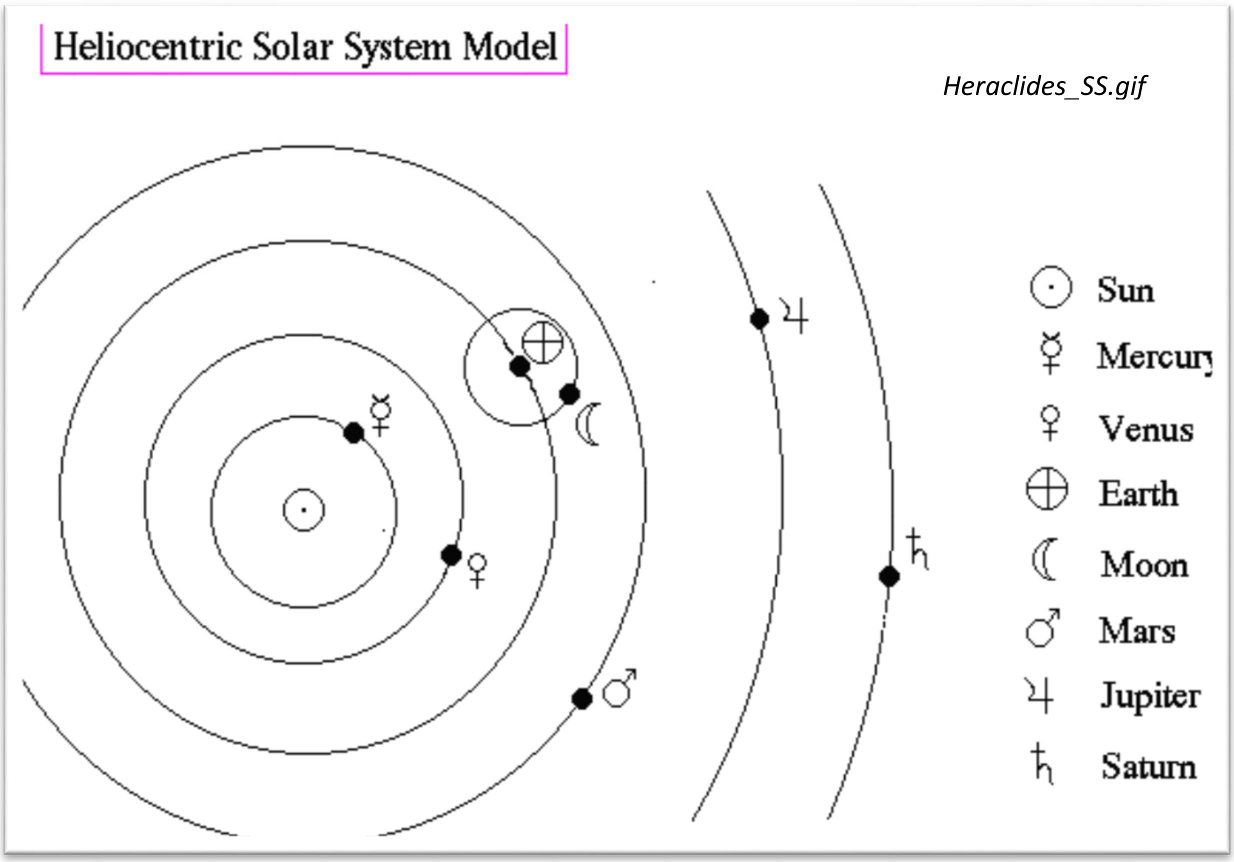
Advancements came when the Babylonians (~1600 B.C.) recorded position of planets, times of eclipses, etc. The ancient Greeks inherited astronomical records from the Babylonians and applied the data to construct a cosmological framework. The early Greeks also had figured out that the Earth was a sphere based on the shadow of Earth on the Moon during lunar eclipses. By



Eratosthenes.gif

220 B.C. Eratosthenes, with this knowledge and - at that time-complicated mathematics, was able to calculate the earth's circumference. Around this same time period Heraclides

developed the first Solar System model, in which all the planets, moon sun and stars revolved around the earth. A couple hundred more years of collecting and analyzing data led Astronomers to the conclusion that the planets - earth included - actually revolved around the sun, though it took



many years for this theory to become widely accepted (*History of Astronomy*). So through the primitive collection and analysis of data, and with the help of some earlier mathematics, the sun and planets - to include our moon - of the entire solar system (as it was known) had been charted and explained.

The first of many powerful tools used to justify the importance of accurate data collection and analysis would be developed sometime within the first millennium. No one person can be credited as the inventor of the experimental method (later to be known as “the scientific method”), as it was really not “invented” but recognized and developed as the natural methodology of obtaining reliable knowledge (*Scientific Method History*). The scientific method that has become widely popular and accepted has four core components; Characterizations, Hypotheses, Predictions and Experiments. By using the four core components as a guideline we can construct a more linear and easily followed procedure such as:

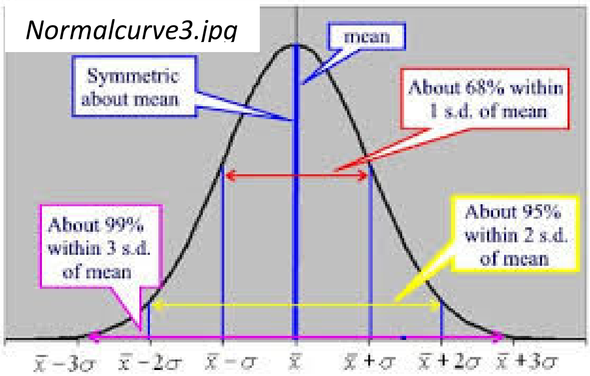
1. Define a question
2. Gather information and resources (observe)
3. Form an explanatory hypothesis
4. Test the hypothesis by performing an experiment and collecting data in a reproducible manner
5. Analyze the data
6. Interpret the data and draw conclusions that serve as a starting point for new hypothesis
7. Publish results
8. Retest (frequently done by other scientists)

(Scientific Method). Using this method, through the steps within the above procedure, we can make better use of the data collected than previously possible.

Calculations can be a bit tricky depending on the numbering system being used to perform the calculations. The Greeks were accustomed to using letters as their numeric system. This made complex calculations very difficult, to say the least. In the early thirteenth century, a scholar going by the name of Leonardo Pisano Bigollo, had traveled to the middle east and learn a numbering system that used symbols instead of letters to represent numbers. His book, Liber Abaci (translated: Book of the Abacus) was a story of these numbers - and their usefulness. It received the endorsement of the Holy Roman Emperor, Frederick II (Bernstein XXVI). This new numbering system would quickly become the choice for mathematicians throughout the Western World.

Jumping ahead five hundred years or so to 1730, Abraham De Moivre introduced the structure of Normal Distribution and with it came the concept of standard deviation (Bernstein 5). We have come to use this powerful tool and other statistical tools, when dealing with data. Statistical mathematics coupled with the scientific method allows us great predictability and reproducibility. Mathematical probability proves that with a greater sample size (population) of data we grow more confident of our result. The same can be said about standard deviation and reproducibility. As you can see from the bell-curve (also known as the normal curve) chart, the more standard deviations (noted by sigma) - within the level of tolerance - the higher our percentage of probability.

Normalcurve3.jpg



standa5.gif

$$\sigma = \sqrt{\frac{\sum (x-\bar{x})^2}{n}}$$

σ = standard deviation

$\sum$ = sum of

x = each value in the data set

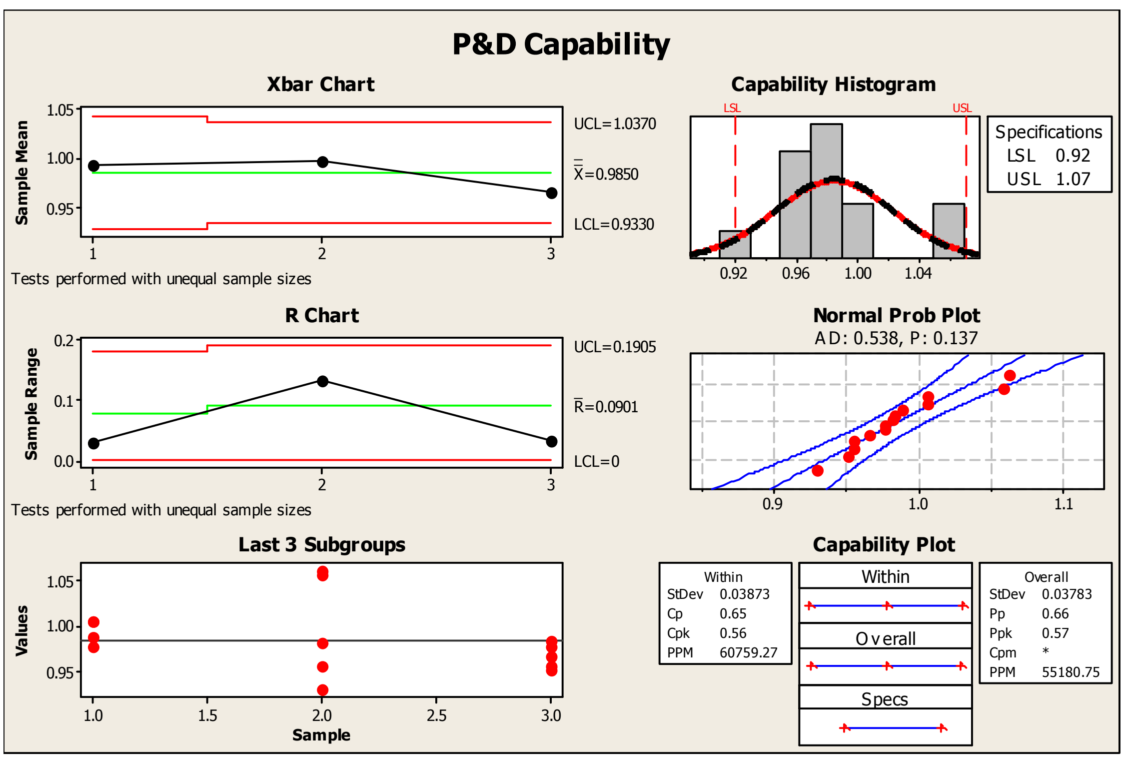
$\bar{x}$ = mean of all values in the data set

n = number of value in the data set

Next we will introduce modern statistical computer software to make these mathematical analyses of the data easier to decipher and help eliminate the human errors made with hand calculations. As an added bonus, the data will be held in an electronic format file making it easier to store or send elsewhere. The use of spreadsheet programs such as Microsoft Excel and Minitab, not only help log and store data in a well-organized fashion but include some very powerful statistical tools to analyze it as well. After the data is entered into the spreadsheet the use of these tools are as easy as a mouse click away. Below are the results from a fuel economy test being performed to evaluate the capability of a pick-up and delivery truck test procedure.

↓	C1-T	C2	C3	C4	C5	C6	C7-T	C8
	Test Type	Fuel Fill A	Fuel Fill B	Mileage	MPG A	MPG B	Calibration	T/C Ratio
1	P&D	7.979	7.888	70	8.773	8.874	Baseline	0.98860
2	P&D	7.931	7.971	70	8.826	8.782	Baseline	1.00504
3	P&D	8.982	8.767	70	7.793	7.984	Baseline	0.97606
4	P&D	6.644	6.684	70	10.536	10.473	Baseline	1.00602
5	P&D	8.169	8.022	70	8.569	8.726	Cal 1	0.98201
6	P&D	8.230	8.736	70	8.505	8.013	Cal 1	1.06148
7	P&D	6.940	7.337	70	10.086	9.541	Cal 1	1.05720
8	P&D	8.152	7.574	70	8.587	9.242	Cal 1	0.92910
9	P&D	8.037	7.672	70	8.710	9.124	Cal 1	0.95459
10	P&D	7.890	7.754	70	8.872	9.028	Cal 2	0.98276
11	P&D	8.065	7.872	70	8.679	8.892	Cal 2	0.97607
12	P&D	7.159	6.910	70	9.778	10.130	Cal 2	0.96522
13	P&D	7.875	7.525	70	8.889	9.302	Cal 2	0.95556
14	P&D	7.614	7.236	70	9.194	9.674	Cal 2	0.95035

This spreadsheet and matching graphical chart samples were completed in MiniTab16 from a Six Sigma Black Belt Chapter that was completed and approved in the Fall of 2011.



The total tolerance for any given run was ±2.0% for this test.

Now that we have a common understanding of the usefulness of collecting data, converting it into numeric form and performing calculations to analyze it we can move on to

modern data acquisition. Though it is sometimes effective to measure and record data by hand, it is not always the most practical way of doing it. Modern technology now allows us to capture several types of measurements in an electronic form. These electronic measurements can be performed and recorded at a much greater rate, thus called sampling rate, then humanly possible.

Just as data may need to be given a numeric value to be calculated, analog (physical) values such as pressure, light intensity, movement, force, temperature and flow must be converted to an electronic value to be captured by today's data acquisition systems. Sensors, also known as transducers, help us make these conversions. Hall-Effect and magnetic pickup sensors are used to record pulses from exciter rings which are mostly used to indicate the speed of rotation. By altering an input voltage, variable resistance or capacitance sensors allow us to convert pressure and force to a lower recordable output voltage. Thermistors and thermocouples transfer temperatures into electrical signals. Photo-sensitive cells can indicate a change in light. All of these types of sensors, and more, can be used to convert physical values into electrical ones.

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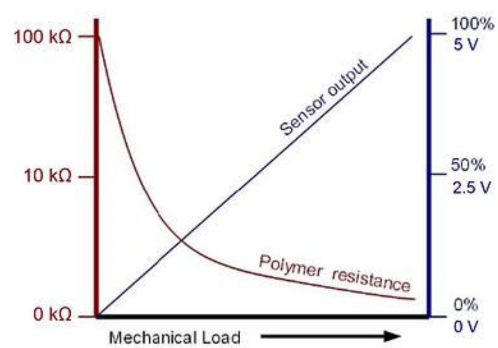
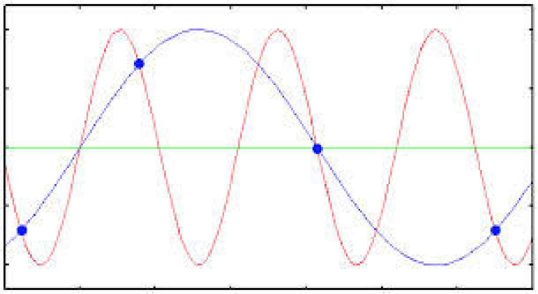
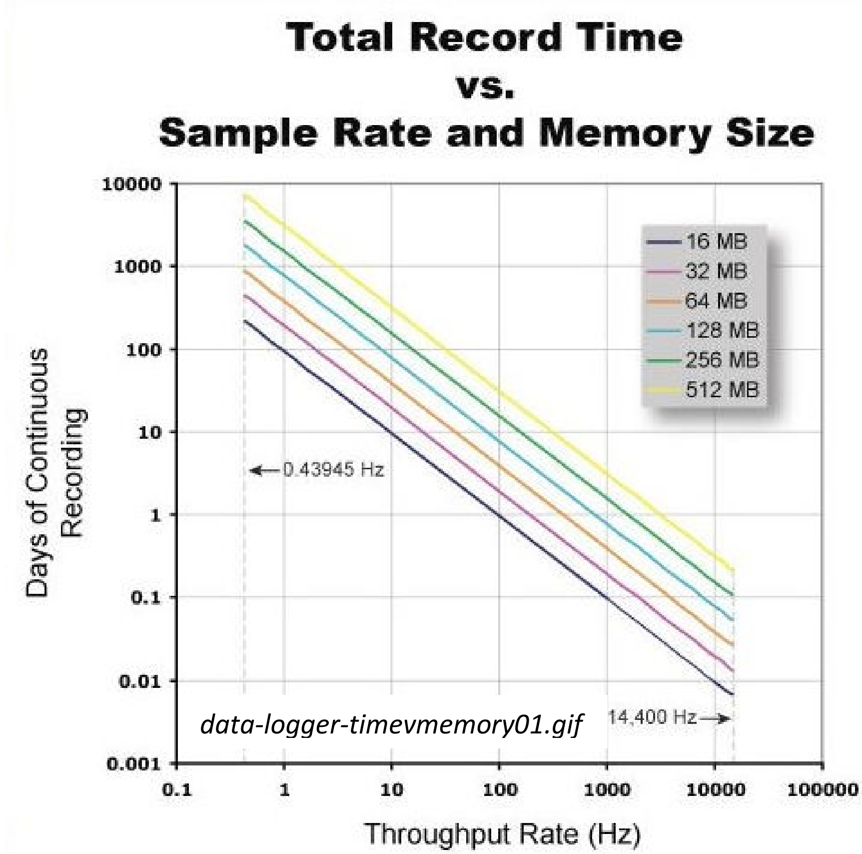


Modern sensors have become linear in their output signals making them much easier to work with and calibrate than their older non-linear counter parts. Once converted they can be recorded and with the help of modern software, uploaded right into a spreadsheet. This allows instant access to calculation tools used to analyze the data collected.

Aliasing-plot.png



The accuracy of the analog to digital conversion is directly related to the sampling rate. The lower the sampling rate the lower the resolution and accuracy of the captured signal, such is the case in the example to the left. The blue points indicate the sampling rate is too slow to accurately record the signal. On the other hand, the faster we sample the signal, the more memory and processing power we will need. This is a trade-off that must be pondered when writing test procedures. The image to the right expresses this frequency verses memory size trade-off. Processing speeds increase and RAM (Random Access Memory) cost decrease over time allowing us to increase our sampling rates, as well as accuracy and resolution, at the same cost we previously captured data at just a few years prior. The number of channels being sample must also be considered (see



data-logger-timevmemory01.gif

hsda1.jpg

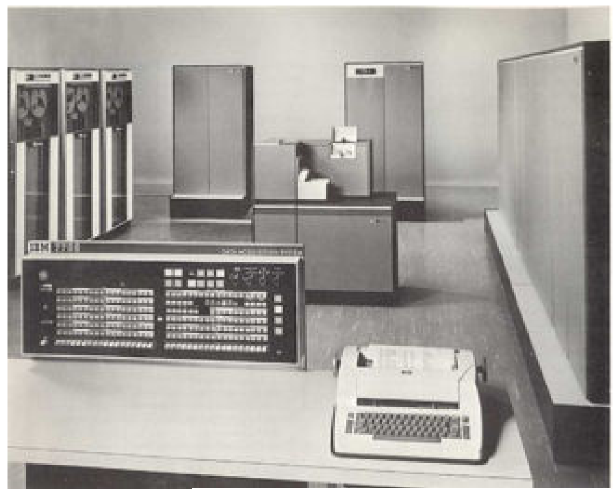
$$\text{Effective throughput} = s\sum_{i=1}^{n}\frac{1}{d_i}$$

S = Sample rate of the fastest channel

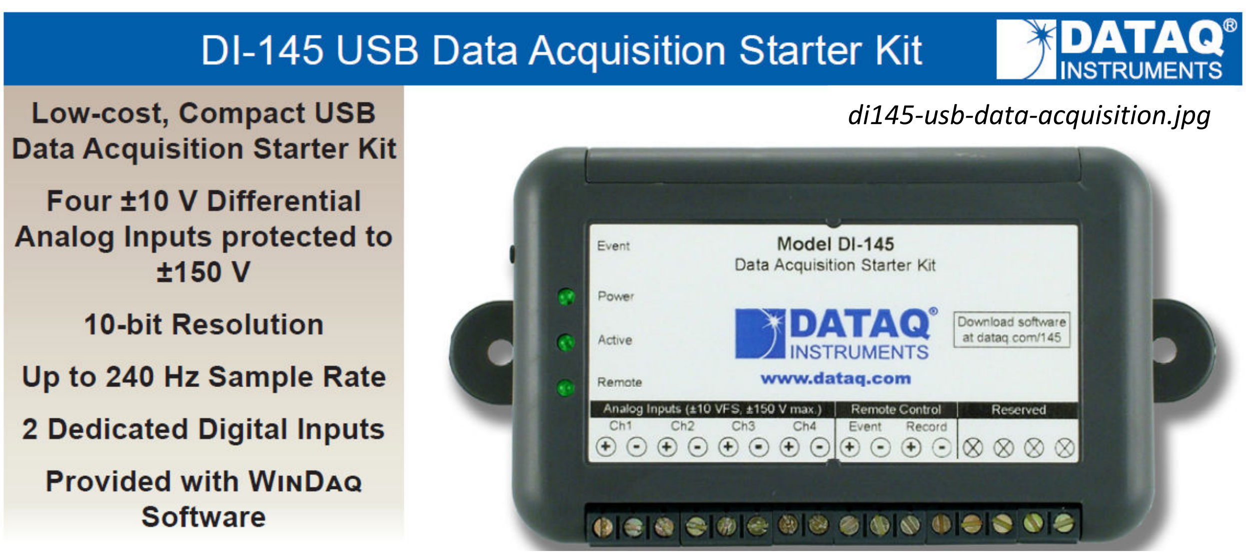
n = The number of enabled channels

d_i = The sample rate divisor of channel i hsda1.jpg). The Effective throughput is the speed at which the data can be recorded to the memory. We conclude that three major considerations must be made when using a data acquisition system to record our physical environment; Number of channels being monitored, the sample rate at which we are capable of monitoring them and the resolution needed to accurately capture the data.

The IBM 7700 Data Acquisition System, released on December 2, 1963, was the first data acquisition system. "It was capable of collecting data from as many as 32 sources simultaneously, process the data and transmit results to up to 16 remote printers, display units or plot boards"(*IBM 7700 Data Acquisition System*). Since the IBM 7700's release, data acquisition systems have both increased in speed and lowered in cost substantially. DATAQ Instruments, Inc. offers a USB (Universal Serial Bus) data acquisition system for the very low cost of $29.95



IBM_7700_System_Photo.png



di145-usb-data-acquisition.jpg

(USD) plus S/H that is capable of handling smaller, lower frequency task (*DI-145 USB Data Acquisition*).

National Instruments, Inc. offers a state-of-the-art high-speed data acquisition capable of monitoring several cards that each boast 32 channels at 24 bit resolution and a 1MS/s sampling rate for thousands of dollars (*cDAQ-9139*).

03201244_9139_m.jpg

- 1.33 GHz dual-core Intel Core i7 processor, 32 GB nonvolatile storage, 2 GB DDR3 800 MHz RAM
- More than 50 hot-swappable I/O modules with integrated signal conditioning
- 4 general-purpose 32-bit counter/timers built into chassis (access through digital module)
- Run up to 7 hardware-timed analog I/O, digital I/O, or counter/timer operations simultaneously
- 4 USB Hi-Speed, 2 Gigabit Ethernet, 2 serial, and 1 MXI-Express port for connectivity
- Measure in minutes with NI-DAQmx software and automatic code generation using the DAQ Assistant

- 32 channels/module, maximum
- 24-bit resolution, maximum
- Multiplexed or simultaneous sampling
- NIST-traceable calibration
- 1 MS/s sampling rate, maximum

040729_crio9215_t.jpg

Task and budget dependent, there seems to be a Data Acquisition system to meet the necessary need. As these systems become more advanced so does modern technology as a result of it, and vice versa. The importance of data collection and analysis is, by far, one of the major causes of technological advancement among the human race and will continue to be the future of advancement for generations to come.

Works Cited

"a29837_99c47370c24b436cbfa0d4044e98470d.jpg." *Buy Sensor Film Kit*. Andrew Clark, n.d. Web. 3 Dec. 2014. <https://grandst.com/marketplace/sensorfilmkit>.

"Aliasing-plot.png." *SVI | NyquistRate*. N.p., n.d. Web. 3 Dec. 2014. <http://www.svi.nl/NyquistRate>.

Bernstein, Peter L. *Against the Gods: The Remarkable Story of Risk*. Paperback ed. N.p.: Wiley, (August 31, 1998). Print.

cDAQ-9139. National Instruments, n.d. Web. 3 Dec. 2014. <http://sine.ni.com/nips/cds/view/p/lang/en/nid/210718#overview>.

DI-145 USB Data Acquisition Starter Kit. DATAQ Instruments, n.d. Web. 3 Dec. 2014. <http://www.dataq.com/products/di-145/>.

Google. Google, n.d. Web. 30 Oct. 2014.

History of Astronomy. University of Oregon, n.d. Web. 12 Nov. 2014. <http://abyss.uoregon.edu/~js/ast121/lectures/lec02.html>.

"hsda1.jpg." *Secrets for Successful High Speed Data Acquisition*. DATAQ Instruments, n.d. Web. 3 Dec. 2014. <http://www.dataq.com/blog/data-acquisition/secrets-successful-high-speed-data-acquisition/>.

"IBM_7700_System_Photo.png." *IBM 7700 Data Acquisition System*. Wikimedia Foundation, n.d. Web. 3 Dec. 2014. <http://en.wikipedia.org/wiki/IBM_7700_Data_Acquisition_System>.

"Metric_Chart.png, LANG_Metric_a3.png." *Metrics*. Next.cc, n.d. Web. 12 Nov. 2014. <http://www.next.cc/journey/language/metrics>.

"Normalcurve3.jpg." *Normal Distribution*. Oswego City School District, n.d. Web. 17 Nov. 2014. <http://www.regentsprep.org/regents/math/algtrig/ats2/normallesson.htm>.

Scientific Method. Wikimedia Foundation, 3 Nov. 2014. Web. 12 Nov. 2014. <http://en.wikipedia.org/wiki/Scientific_method>.

Scientific Method History. Norman W. Edmund, Dec. 2011. Web. 12 Nov. 2014. <http://scientificmethod.com/sm5_smhistory.html>.

"standa5.gif." *Minimum Sample Size Calculation*. Barcelona Field Studies Centre S.L., 5 Nov. 2013. Web. 4 Dec. 2014. <http://geographyfieldwork.com/MinimumSampleSize.htm>.

If at first you don't succeed, that's one **data** point. (Unknown)