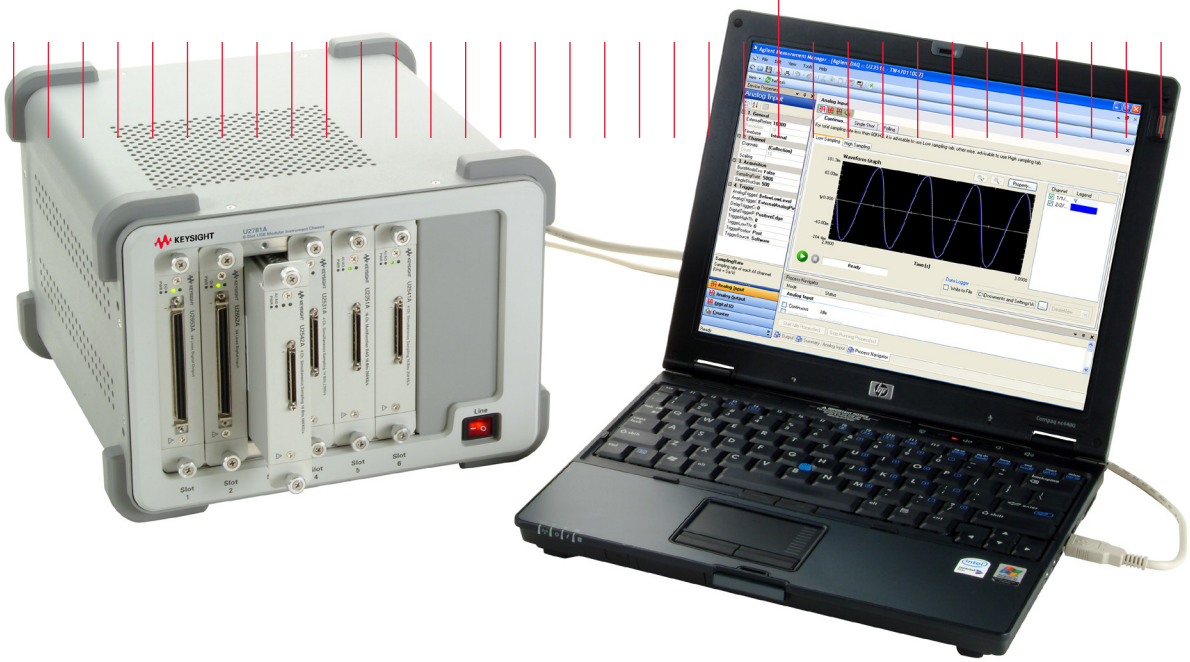
Keysight Technologies
DAQ with Matlab for Medical Science

Case Study



KEYSIGHT TECHNOLOGIES

Introduction

Keysight Technologies, Inc. data acquisition (DAQ) units can now work with MATLAB, thanks to a MATLAB adaptor that acts as a plug-in, allowing the users to control the DAQ product family with the MATLAB DAQ Toolbox.

MATLAB is a suitable programming platform to be used in conjunction with the DAQ because of its
versatility in:

a) Mathematics and computation
b) Algorithm development
c) Data acquisition
d) Modeling, simulation, and prototyping
e) Data analysis, exploration, and visualization
f) Scientific and engineering graphics
g) Application development including Graphical user interface (GUI) building

It is recommended that the users
understand the basics of MATLAB programming before you start with any application that involved the Keysight DAQ.

Operating Principle

The following prerequisites are required before the users use the Keysight DAQ with MATLAB:

- Keysight IO Libraries Suite 14.2
- Keysight U23XX or Keysight U25XX IVI-COM driver
- MATLAB DAQ toolbox
- Keysight U2300A or U2500A MATLAB DAQ toolbox adaptor

Correct installation depends on which DAQ family is being used. Therefore, it is recommended that the users install the U2300A or U2500A MATLAB DAQ Toolbox Adaptor and also the IVI-COM driver.

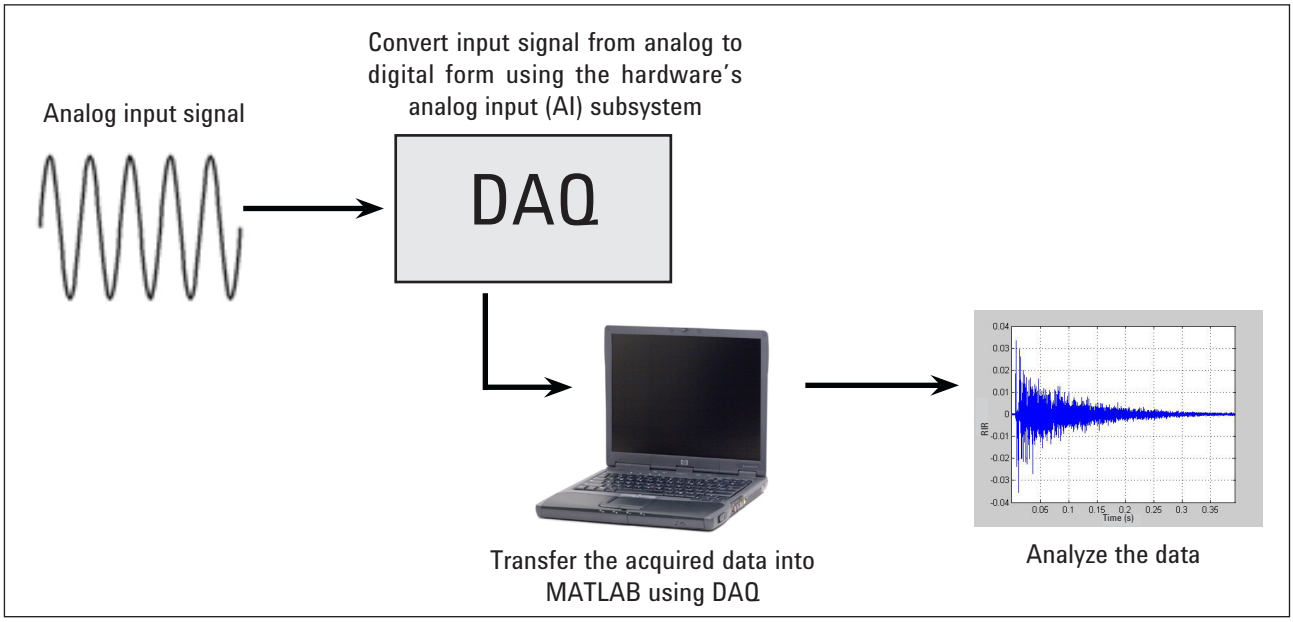


Figure 1. DAQ with MATLAB flow system

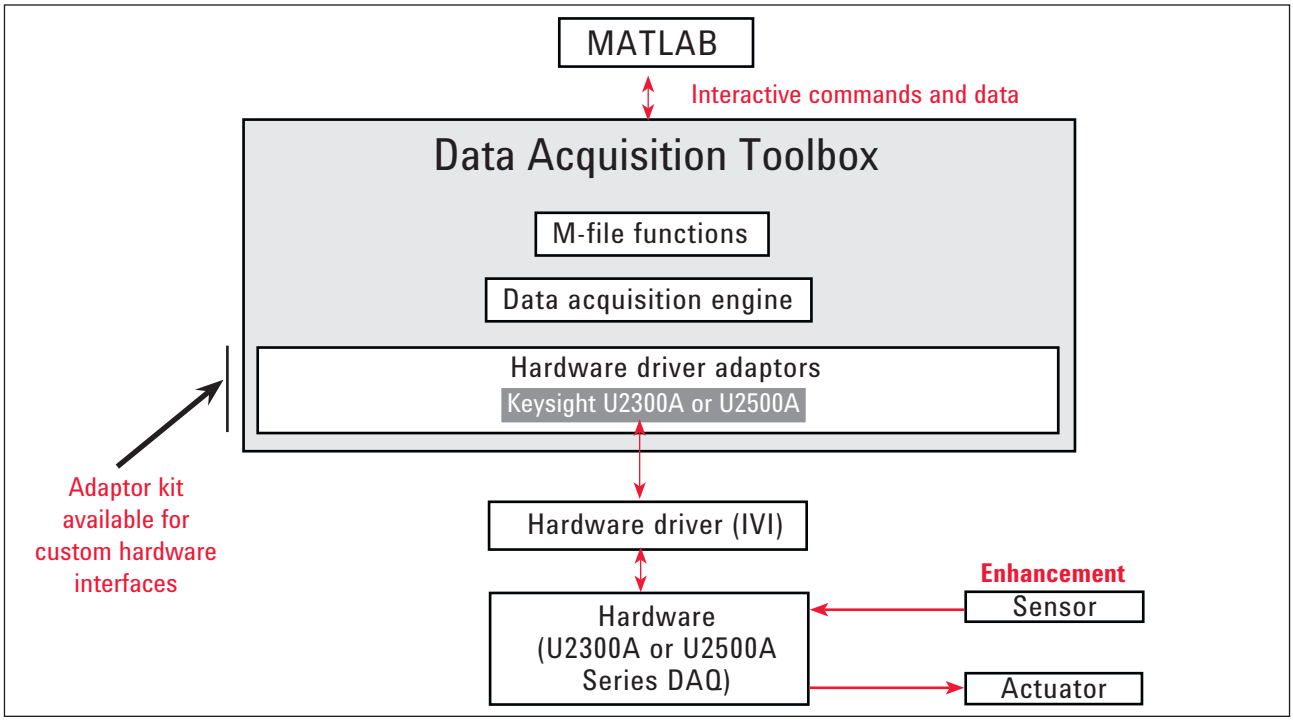


Figure 2. DAQ architecture

System Configuration

MATLAB can be used with a Keysight data acquisition unit in medical research, as illustrated by the following example. Human and animal brains are constantly making decisions that cause neurons to fire, creating neural voltage spikes. The spike information can be gathered by implanted circuitry and an extremely low power transmitter that reads these neural spikes from the brain and transmits the information back to be processed by a nearby receiver link.

Although the receiver can be set to the proper frequency and modulation type in order to receive the transmitted signal, a good deal of computation and digital processing is required to recover and analyze the incoming data. MATLAB can be used with the DAQ unit to digitize the analog receiver data for further analysis.

– For the transmitter portion:

  A voltage is encoded as an 8-bit word (eg.: 0 being 0 V and 255 being 1 mV). There is a known packet structure in the transmission: 11XXXXXXXX0.

– For the receiver portion:

  This receiver will receive the wireless data from the transmitter and digitize it using DAQ. MATLAB will control the acquisition and data analysis. Then, MATLAB will perform the Fast Fourier Transform (FFT), apply the clock-recovery algorithm, resample data, align words, and graph live data.

The above configuration enables the users to plot live neural spikes as voltage versus time. Refer below for an example on how the data acquisition process is done using MATLAB and DAQ.

An example of MATLAB code is shown below:

1) MATLAB control of data acquisition

```
% set acquisition variables
sampleRate = 2000000                                  % samples/s
acquisitionTime = inf                                 % seconds

% setup acquisition
ai = analoginput ('keysightu2500', 0)                 % create analoginput object ai
chan = addchannel (ai, 0)                             % create analoginput channel chan
set (ai, 'samplerate', sampleRate)                    % setup ai acquisition
set (ai, 'samplespertrigger', acquisitionTime*sampleRate)  % inf to continuously acquire data
```

System Configuration (continued)

2) FFT to recover clock

% We take an FFT of the data and plot the power spectral density as a function of frequency

```
N = length (SampledSignal)*2
```

According to Nyquist theory, it would be good to have 2x points for FFT but recommendation is 10x points.

```
f = fft (Edges, N);
Pyy = f. *conj (f) / (N)
freq = sampleRate / (N) * (N/2-1) ;
subplot (2,1,2) ;
semilogx (freq,Pyy(1:N/2));
title ('Power spectral density');
xlabel ('Frequency (Hz)');
```

% We take an FFT of the data and plot the power spectral density as a function of frequency

```
N = length (SampledSignal)*2;
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According to Nyquist theory, it would be good to have 2x points for FFT but recommendation is 10x points.

```
f = fft (Edges, N);
Pyy = f.*conj(f)/(N);
freq = sampleRate/(N)*(0:(N/2-1));
subplot (2,1,2);
semilogx (freq,Pyy(1:N/2));
title ('Power spectral density');
xlabel ('Frequency (Hz)');
```

Power Spectral Density and Clock Recovery

MATLAB enables the users to utilize its mathematical capability and perform functions such as power spectral density plot shown below:

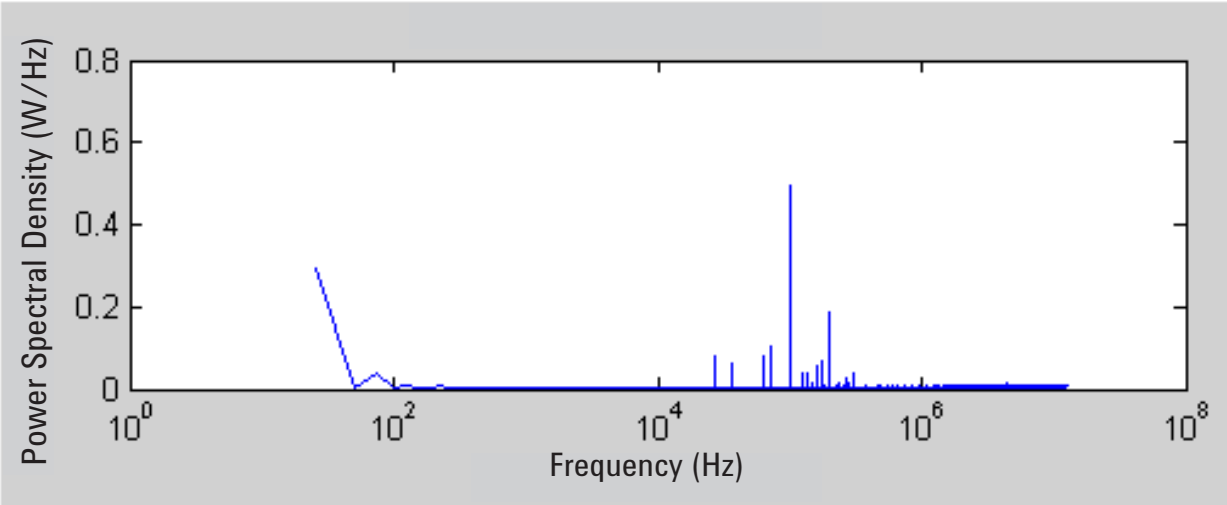

Figure 3. Sample of power spectral density graph

The data is resampled before it converts all the samples into bits based on clock recovery. This will convert a large MATLAB vector of samples into a vector of 1's and 0's. The basic idea is highlighted on the graph below:

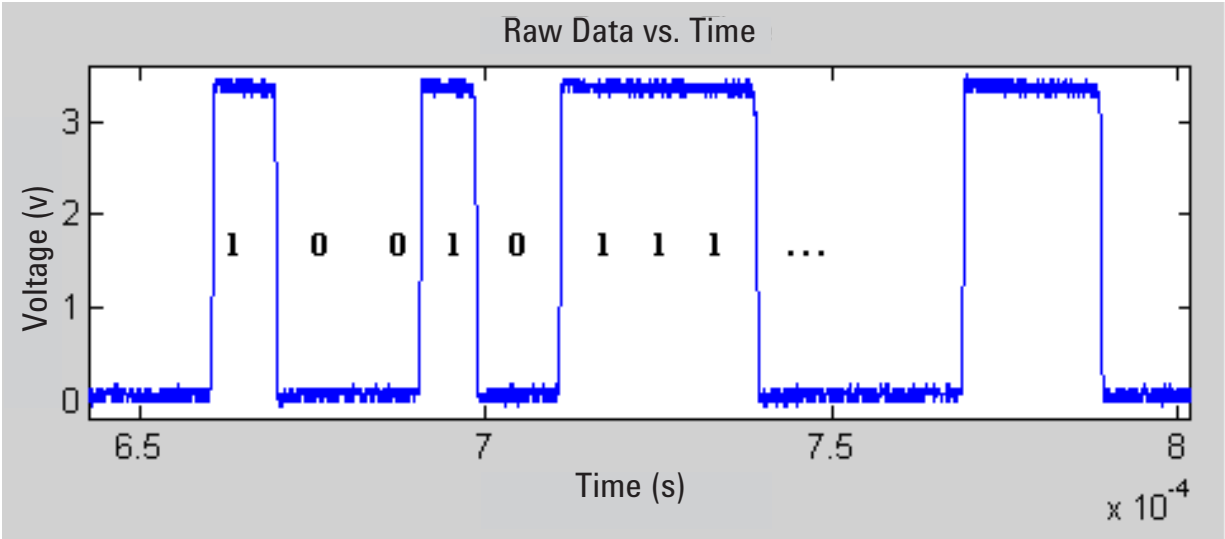

Figure 4. Deciphering the graph into binary data

Transmission Packet Structure

The transmission packet structure is of the pattern 11XXXXXXXX0. This means there are two 1s, 8 data bits, and a 0 in every word. The users need to align the captured data properly in order to find the first valid data. Figure 5 is a plot that demonstrates how the data is captured. The upper portion shows the misaligned data whereas the lower portion shows the aligned data. The red pixels in the graph represent 1s, and the blue pixels represent 0s. The top graph is created before the data alignment, while the bottom graph is created after the data alignment. The leading 1s and trailing 0s are eliminated, leaving with a lot of 8-bit data words.

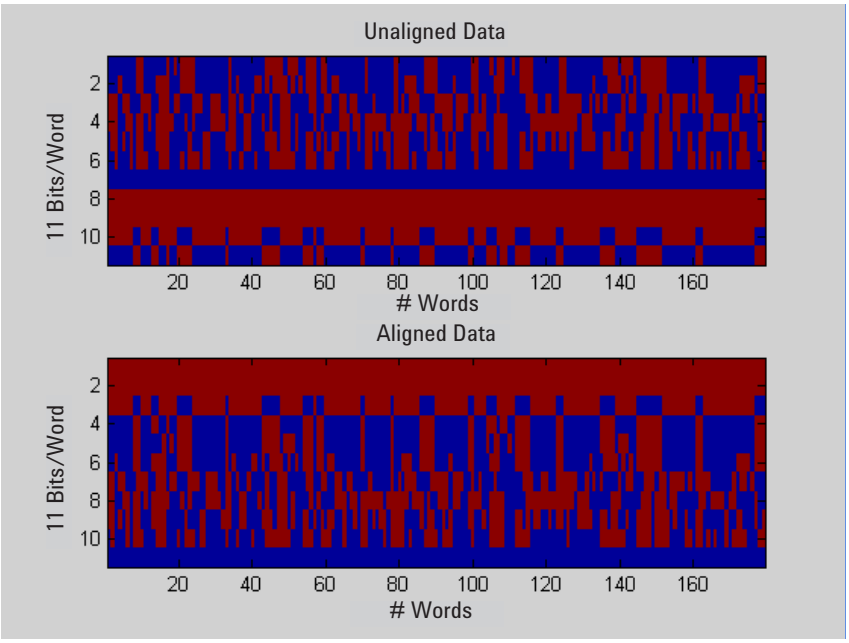

Figure 5. The difference between unaligned data and aligned data

Now the users can grab each voltage value as a function of time and can plot the data to view the neural spike data.

The users need to be aware that an off-the-shelf wireless receiver will have a "data out" channel to be connected to the DAQ for sampling, processing, and analysis using the MATLAB program. However, the receiver usually does not come with clock recovery, and thus it is important for MATLAB to perform FFT to determine the sampling rate of the received data.

The sample rate must be determined in order for the users to align the data properly.

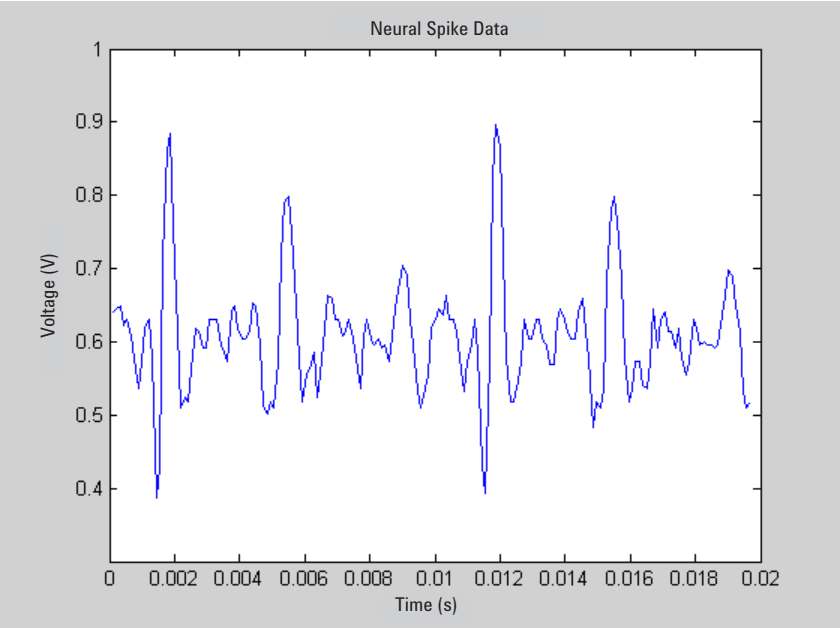

Figure 6. Neural spike readings as voltage versus time

Summary

This case study illustrates how a DAQ such as Keysight's U2531A could be used in medical research, among many industries. The ability to take advantage of Data Acquisition Toolbox software, in conjunction with the MATLAB technical computing environment, such as data exploration and visualization in MATLAB's programming platform will allow the users to engage in medical research and medical science breakthroughs.

Reference

[1] R.R. Harrison, P.T. Watkins, R.J.Kier, R.O.Lovejoy, D.J.Black, B.Greger, F.Solzbacher, "A Low-Power Integrated Circuit for a Wireless 100-Electrode Neural Recording System," IEEE Journal of Solid-State Circuits, vol.42, pp. 123-133, January 2007.

[2] J. Holleman and B. Otis, "A Sub-Microwatt Low-Noise Amplifier for Neural Recording," in Proc. IEEE Engineering in Medicine and Biology Society Conference, pp. 3930-3933, August 2007.

[3] Woradorn Wattanapanitch, Michale Fee, Rahul Sarpeshkar, "An Energy-Efficient Micropower Neural Recording Amplifier," IEEE Transactions on Biomedical Circuits and Systems, vol. 1, pp.136-147, June 2007.

[4] J. L. Bohorquez, J. L. Dawson, A. P. Chandrakasan, "A 350μW CMOS MSK transmitter and 400μW OOK super-regenerative receiver for Medical Implant Communications," IEEE Symposium on VLSI Circuits, pp. 32-33, 2008.

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