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Studying Earthquakes With the myQuake NI miniSystem for NI myDAQ (Pioneer Release)

Overview

Devastating earthquakes cause damage to both lives and infrastructure, costing dearly both emotionally and economically. In such cases, it is imperative that engineers understand the dynamics of how an earthquake occurs so that they can design better structures that are resistant to an earthquake and thereby protect and preserve those who are precious.

However, studying earthquakes with traditional techniques in a cost-effective manner is hard given that earthquake simulators are large and often not economically viable. With NI LabVIEW system design software and the [link to model page|myQuake NI miniSystem] for NI myDAQ, it is now possible to educate engineering students on the basics of the seismic waves that occur when an earthquake hits, and how the waves propagate and affect structures.

This tutorial uses the myQuake, NI myDAQ, and LabVIEW to study seismic wave propagation in building structures. By the end of this tutorial, you will be able to perform the following:

- Generate a seismic wave of desired magnitude
- Measure the effect of a seismic wave on two or more points on a structure
- Record and observe the effect of the seismic wave on the structure

Also included are numerous challenge exercises for you to engage in as a means to expand your knowledge of seismic wave effects on structures.

To recreate the experiment in your lab or dorm, download the example program and follow the tutorial.

Table of Contents

Background on Earthquake Waves

Seismic waves occur naturally—they are low-frequency acoustic energy waves and thereby can be caused by multiple mechanisms, even artificially. Most commonly heard of seismic waves are from earthquakes. However, these can also occur in other cases like a volcanic or nuclear explosion. This tutorial explores the seismic waves from an earthquake. Seismic waves can also be measured by different numbers of sensors like accelerometers or hydrophones (underwater). This tutorial uses an accelerometer to measure the effect of the waves.

Earthquake waves can also differ in effect based on the material that they are propagating through. This is important to understand because it affects the choice of building materials used. Generally the more elastic a material is, the better its resistance to seismic waves. However, this has to be balanced by the structural ruggedness of the material so that buildings can be built safely. One of the challenge exercises in this tutorial focuses on this aspect and asks students to build the same structure with different materials.

Two kinds of earthquake waves exist: body waves and surface waves. Body waves travel along the interior of the earth. Surface waves travel along the surface similar to ripples in water. This tutorial focuses on body waves.

Body Waves

There are two kinds of body waves: primary or p-waves and secondary or s-waves. P-waves travel horizontally or longitudinally. They can travel through any medium and are the fastest of all the waves including surface waves. They are called primary waves because they reach the structures or measuring stations first.

Secondary or s-waves displace the earth in a perpendicular fashion—they cause shear and only travel through land because water/fluids cannot support shearing action. These waves also arrive after the p-wave and, therefore, are called secondary waves.

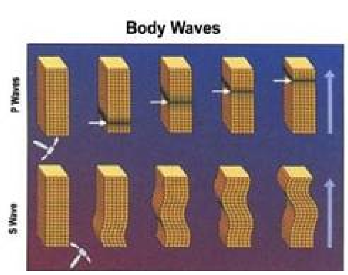


Figure 1. *The difference between a p-wave and s-wave.*

The myQuake

The myQuake is an NI miniSystem that plugs into NI myDAQ. It uses the NI myDAQ analog output to activate and control a motor that is used to generate the p-wave. The motor is connected to a movable platform on which the structure to be observed is placed. The myQuake also has the ability to interface to two sensors—in this case accelerometers. For this experiment we have used a Freescale 3 Axis Low-G accelerometer.

View the Freescale 3 Axis Low-G accelerometer data sheet

The accelerometer can be placed to measure in the X, Y, or Z axes. These instructions are in the tutorial steps below.

Understanding the Connections on the myQuake

Here is a quick snapshot of the connections between the myQuake and NI myDAQ:

myQuake Element	NI myDAQ Connection
Motor	Analog Output 0 (AO 0)
Accel A (accelerometer)	Analog Input 0 (AI 0)
Accel B (accelerometer)	Analog Input 1 (AI 1)
Available as Breakouts	DIO3/CNTR 5V Line Ground

Setting Up the Experiment

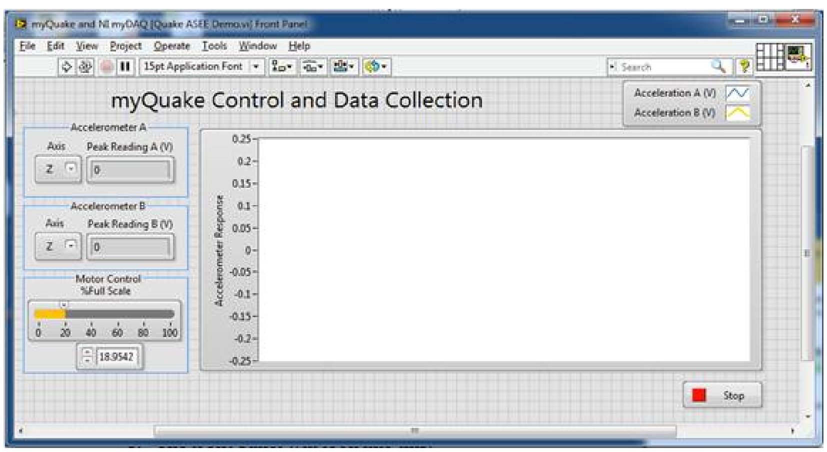
1. Place the myQuake platform on a flat surface and remove any other unwanted items in the area.
2. Connect the green motor output pins (the cable with red and white wire) to the corresponding connector on the myQuake circuit board.
3. Connect the other end of the cable (white connector) to the motor. Note that the pins are keyed, which means that there is only one way that the connector can sit flush with the motor.
4. Place the structure to be tested on the platform. It's helpful to fasten the base of the structure to the platform with some mechanism such as office clips. This ensures that you can take measurements over an extended set of magnitude of waves.
5. Take the two accelerometers and use paper clips to fasten them to the structure at different points where you want to take the measurement. It's best to place one near the base and one near the top to measure the difference between the effect of the waves at the two points.
6. **Important:** Review the accelerometer board and fasten the accelerometers to measure the acceleration in the axis that you want—X, Y, or Z. Make sure that both accelerometers are connected in exactly the same manner so that you can correlate the measurements between one accelerometer and the other. You can check whether you are getting the measurements from the particular axis by selecting the axis from the pull-down menu in the VI and observing the measurement on the graph.
7. Connect the gray accelerometer connectors to the corresponding blue connectors on the myQuake circuit board. Make sure that Accel A corresponds to the lower accelerometer and Accel B is connected to the accelerometer at the top of the structure.
8. Ensure that NI myDAQ is connected to the computer and active.
9. Connect the 12 VDC power.
10. You are now ready to generate and observe seismic waves.

Running the Experiment

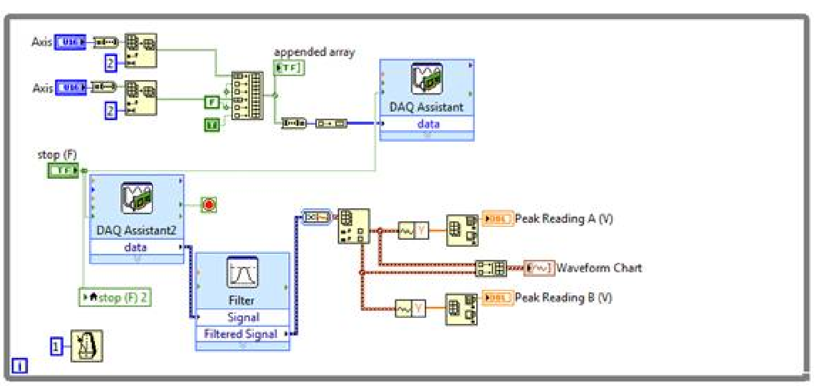
1. Download the myQuake_basic.vi VI.

2. Open the VI in LabVIEW.

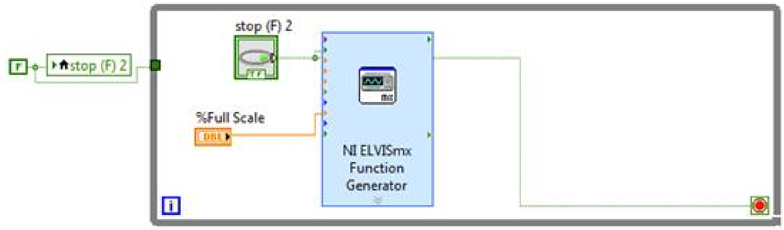
3. The front panel will look like this:



4. Open the block diagram to understand the operation of the VI. There are two loops in the VI: The first loop shown below is used to set the axis to measure from (X, Y, or Z) and the DAQ Assistant VI acquires and displays the data on the chart.



The second loop controls the motor on the myQuake platform:



You could rewrite any of these VIs to use the low-level DAQmx VIs.

Challenge: Rewrite the VI to use low-level DAQmx VIs instead of Express VIs.

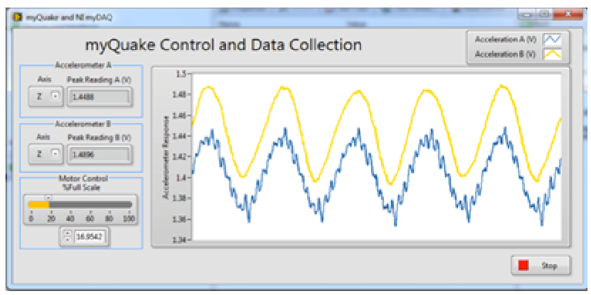
5. Switch back to the front panel (Ctrl-E).

6. Note that you can play with a couple of controls. With the pull-down menus, you can choose which axis of the accelerometer you are measuring from. The control you will be working with the most will be the motor control slider—from 0 to 100 percent. At 100 percent the motor is running at its maximum possible rate. It's best to exercise caution and always start with 0 percent and increase the rate by 5 percent because at higher rates, the structure may collapse and cause injury.

7. In this experiment, mounted accelerometers measure the acceleration in the Z axis. So select Z from the pull-down menu for both Accel A and Accel B inputs.

8. Set the motor control to 0 percent and run the VI by clicking on the Run arrow on the top of the taskbar.

9. Increase the motor control slowly. At around 16 to 18 percent, you will start generating the p-wave and you will observe the structure weaving in response. Your VI will look something like this:



10. To try and understand a bit of what is going on, first note that the readings on the Y axis are in volts and not in Gs.

Challenge: Write a VI to convert the readings from the accelerometer from volts to Gs. Use this data sheet for the right formula.

Next, notice that the blue waveform from Accel A has a lot more harmonics/disturbances than the yellow waveform from Accel B. This is characteristic of the effect of the seismic wave on the bottom of the structure—there is a lot more disturbance here and probably some shear stresses as well. But at the top, the waves generate a smoother pattern when the strength of the wave is less. In fact, this concept is used to design buildings with counter weights that let the building sway within acceptable limits in response to earthquakes but prevent the building from collapsing.

11. Increase the motor control to further observe how the structure responds. If you did not fasten your structure to the platform, the structure may fall off at higher motor strengths, so exercise caution.

Other Challenges

- What is the strongest geometric structure against seismic waves?
- Try to use different damping agents to cushion the impact. Which damping agent works best? Why?
- What type of bridge best withstands stress?
  - How much load can you put on each type of bridge before it collapses?
- What is the relationship of height to earthquake resistance?
  - How tall a structure can you build to withstand an earthquake of a certain magnitude?

Resources

Get the myQuake NI miniSystem for NI myDAQ

What Is an NI miniSystem?

What Is NI myDAQ?

Pioneer Release

NI miniSystems in Pioneer Release allow users in higher education (university/college) to purchase units so they can "ramp up" on integrating NI miniSystems into courses as soon as they are available. National Instruments collects active feedback from users of NI miniSystems in Pioneer Release to acquire sufficient feedback for suppliers and partners before the next release. NI miniSystems in Pioneer Release are stable but not feature complete and will most likely require the use of custom programming to fully meet customer application needs. For this reason, it is recommended that customers self-qualify to participate in the Pioneer Release by obtaining basic LabVIEW training (LabVIEW Core 1 and 2). Participants have access to standard training discounts that can be viewed at ni.com/training.

During the Pioneer Release of an NI miniSystem, support is provided via emails to minisystems@ni.com or by posting to a private NI Discussion Forum. To get access to the Forum for yourself or other customers, please contact National Instruments using the above email address.