PHYS 5061 Lab 7
Timing and the Speed of Sound

Introduction

The goal of this lab is to measure the contact time of a metal rod bouncing on a metal plate and to understand the bouncing process well enough to estimate the speed of sound in the rod. You should keep a good notebook of all your efforts in carrying out the tasks associated with this experiment. You will write a brief technical report on the experiment later. (Details to follow.)

Counting is a simple operation for digital systems. Timing the duration of an event is then a simple application of this idea to count regularly repeating clock pulses. As a result of the simplicity of timing, it's often desirable to convert the physical quantity you want to measure into an interval of time and use counters and a reliable clock to measure that time interval. Hence any quantity easily converted into either a frequency or a time interval can be measured almost trivially by some counting technique.

Contact time

If you allow a piece of material to be dropped onto another, the falling piece will usually bounce one or more times. Upon first contact, both it and the piece underneath are momentarily compressed before the falling piece returns to the air. The situation for this lab is a long thin metal rod dropped onto a heavy steel plate. The objective is to measure how long the rod remains in contact with the plate during the first bounce. Designing this is a two-step process: (1) Figuring out how you might detect that the rod and plate are in contact; (2) Figuring out how to measure this time. To do the necessary counting/timing make use of tools in LabVIEW and our DAQ device's digital inputs and its timing/counting capabilities.

LabVIEW and the USB-6211 have counting and timing abilities readily available. First, learn how to make use of the USB-6211 timer/counter subsystem. You can make some initial explorations of the timing/counting features on the USB-6211 through NI-MAX before building your own VI in LabVIEW for the experiment. You want to explore the options to make a measurement of the length or duration, T, of a logic level pulse in the high state, or perhaps the low state. (For TTL logic high $\approx 5\,\mathrm{V}$, low $\approx 0\,\mathrm{V}$.) The USB-6211 has internal clocks and counters that make this pretty easy. And there are DAQ Assistant VI's available in LabVIEW that allow you to make use of these timing and counting features.

Once you have played a bit with the timing/counting features in LabVIEW, develop a strategy using those tools to measure the contact time for the bouncing rod. You will need to invent an appropriate switch circuit including the rod and plate as parts of your circuit to help carry out this measurement. The switch is 'closed' when the rod and plate are in contact and will produce the TTL pulse whose duration you want to measure. Then figure out how to use this and LabVIEW to measure the contact time.

Caution!!

It is important to design a "switch" mechanism that produces TTL compatible levels *and* is designed to limit the current that can flow through your switch mechanism. Allowing a +5 V supply to be shorted directly to ground is wrong and dangerous to the power supply and perhaps other components. Think carefully about how your mechanism to detect when the rod is in contact with the block works: more than just thinking about voltages, be able to explain what currents are flowing where under the various states of your switch. Include appropriate pull-up or pull-down resistors that limit the currents that can flow.

How/why does the rod bounce?

In thinking about the physics of the bouncing process, you'll need to be able to explain exactly how it is that the rod is made to move upwards after contact with the plate, and when the bottom end of the rod is made to leave the plate. Constructing a mental model of the rod to think about what's really happening to the rod may be useful. Since this experiment is supposed to yield a speed of sound, the fact that the rods are stiff but not perfectly rigid must in some way be relevant.

After thinking about the physics of the bounce, measure the bounce contact times and determine the speed of sound in the metal rod. You should carry out lots of trials, since the measurements themselves will take very little time. And keep careful and complete written records of lab work and all measurements.

Investigate at least two different rod materials, and for at least one of those rods or materials look for any systematic dependencies on one other parameter that might influence the contact time or velocity of sound: the length of the rod, the diameter of the rod, the initial height the rod is dropped from.

For each rod tested report a best estimate of the speed of sound deduced from your measurements, an uncertainty in that best-estimate value, and report any trends you see in other tested parameters. Use some statistical analysis tools from class. If you omit any measurements during your data analysis, suggest reasons or mechanisms why they can be discarded in analyzing your data.

Compare your measured value to values reported in handbooks (e.g. CRC Handbook of Chemistry and Physics or reliable WWW sources - cite them!).