Speaker Resonance

By: Hewlett-Packard Company

This experiment is based on a more elegant one written by Dr. Walter Banzhaf of the University of Hartford.

Purpose:

To show how an FFT can be used to extract information from a time-varying waveform.

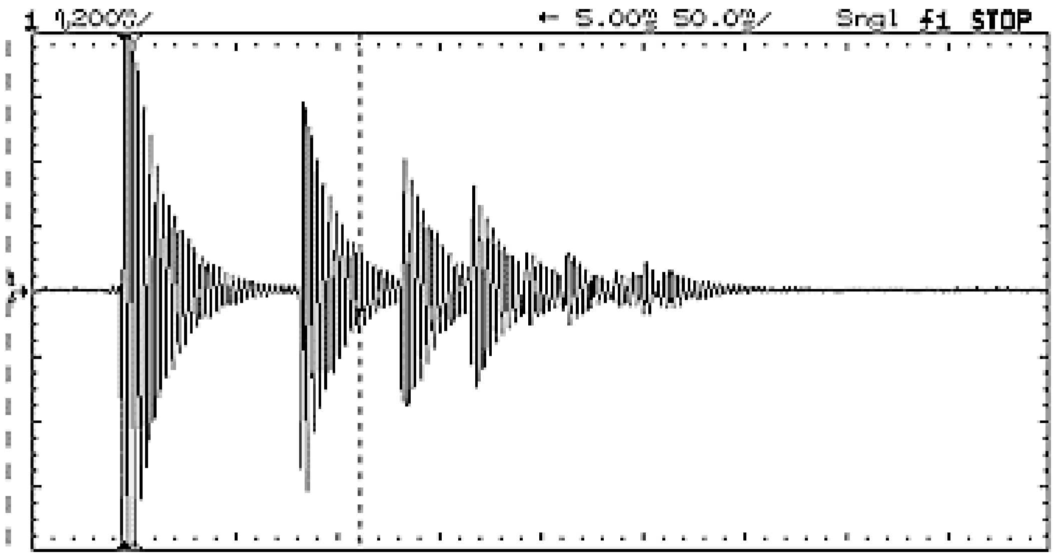
Equipment:

- HP 54645A Oscilloscope
- HP 54657A FFT Module
- 3 inch cheap audio speaker with metal frame

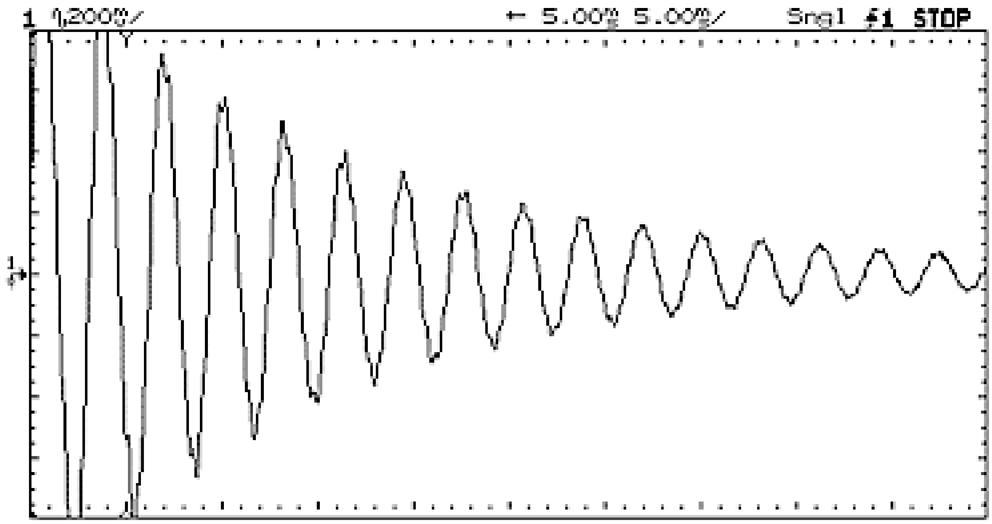
So there I was with a new $2 speaker in my hand, using it as a signal source and playing with my new oscilloscope. I connected the speaker directly to the input of the scope and dropped the speaker on the hard surface of my lab bench (well, after all, it was *my* two dollars). Two things happened: one; each time the speaker bounced, its exponentially decaying cone resonance signal quickly became apparent on the oscilloscope screen; two; the shell of the speaker, which was metal, emanated an audible “klink”.

I wondered to myself, “I know I can see the speaker resonance, but I wonder if the scope can detect the ringing “klink” of the metal shield on the speaker.”

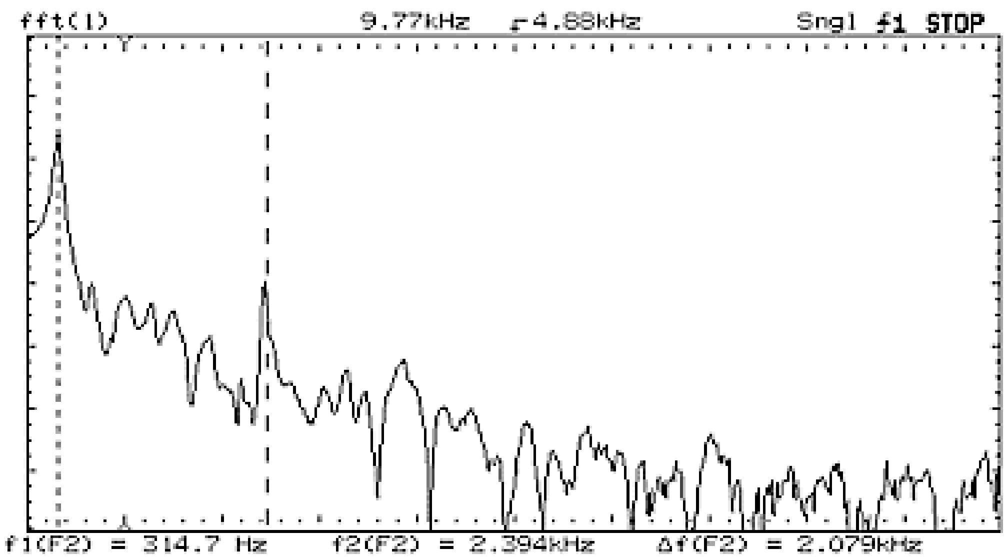
I set the scope for NORMAL TRIGGER, SINGLE, with the TIME BASE at 50ms/div to capture a complete set of waveforms… one for each time the speaker bounced on the table:



Using the scope's pan and zoom features, I spread the first exponentially-decaying waveform to fill the screen:

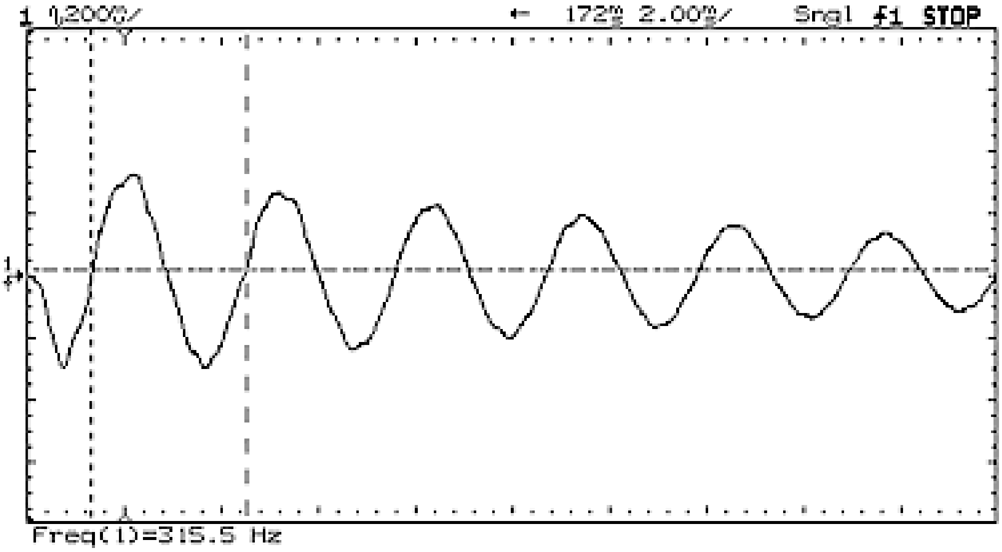


With the time base set at 5ms/div (ten times faster than it was set when I actually acquired the waveform), I could read the cone's resonant frequency. I couldn't see the "klink" frequency in the decaying waveform, so I put the scope in FFT mode:

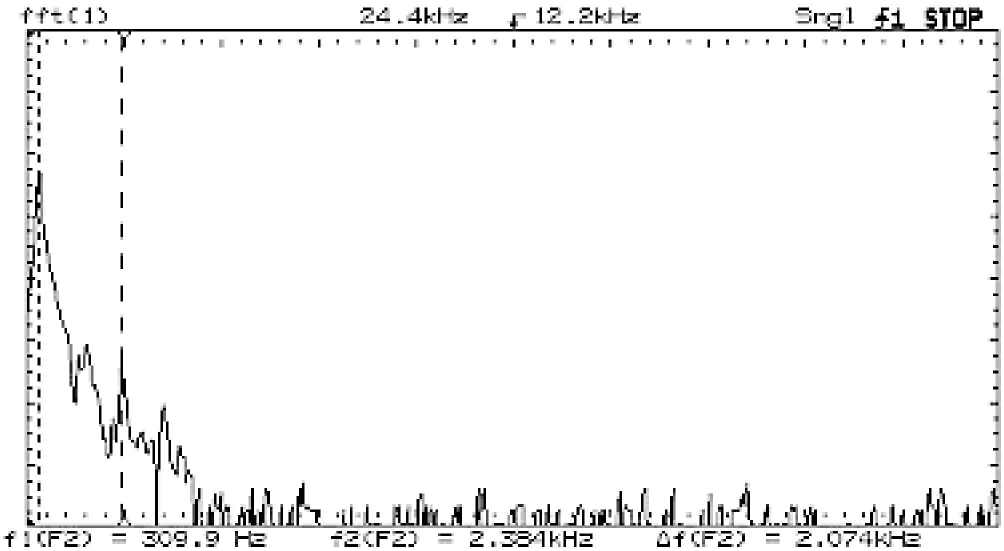


Clearly, the speaker cone resonance was about 315 Hz, and the FFT now allowed me to see the "klink" frequency: about 2.4 kHz.

Now comes the fun part. Since the scope actually captured several repetitions of the same event, I could look at the subsequent events to see just how far the "klink" could be "buried" and still the FFT would have the capability to bring it out. I tuned to the fourth exponential set, and expanded it on the screen:



Now the "klink" resonance was really buried in the time-domain information. I then invoked the FFT function again, and saw:



Even though the signal amplitude was considerably less for the fourth "bounce", the FFT function could extract the resonant frequency of the metal shield, and again identified it to be about 2.4 kHz.

Normally, the above measurements would have made a very difficult triggering problem, but I was using the new HP 54645A MegaZoom Digitizing Oscilloscope with an FFT plug-on module. The HP 54645A has the ability to capture a record of 1,000,000 data points. Once you have captured all those points, you can pan, zoom, use cursors and do FFT operations on the captured data. The result is real-time knowledge for students, with all the frustration filtered out.

This is a simple experiment, but it can be used to teach a multitude of concepts: resonance, FFT's, FFT windowing (we used an exponential window) and the concept of signals buried in noise.

By the way, the "klink" went away when I dropped the speaker on a thin paper pad. The paper pad was enough to dampen the metallic vibration. I verified this by doing the FFT again, and the "klink" frequency component had vanished.