Mobile Studio Measurements of Audio Signals

Although it is not necessary this time, before we begin working with the Mobile Studio, we should generally check to be sure that we have the latest version of the software, which is called the Mobile Studio Desktop. (This was just downloaded a few days ago on the computers you are using, so you have the latest version.) On your computer desktop, you should see an icon that looks like

Connect your board and click on the icon to start running the program. You will see an image like the one shown below. Where is says 'version 2.3.3006.3131' you should see the version you have. This image goes by rather quickly, so only look for the last 3 digits to check your version.
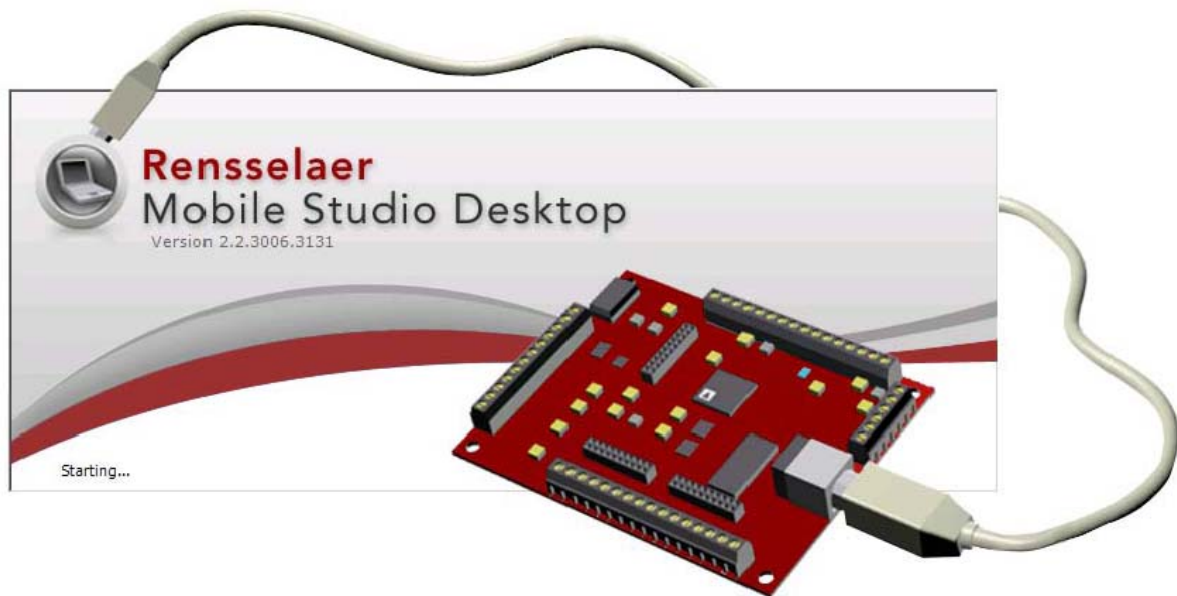
If you miss the version number, you can also read it by clicking on the Help menu and then select About. This will give you another window, which you need to click on to close when you are done checking the version. Once you know the version you are running, you should go to the Mobile Studio Website to determine the latest version number. This process is simple. Go to

http://www.mobilestudioproject.com

then select either of the two links on that page. Click on the Download Software link which will take you to http://mobilestudio.rpi.edu/Downloads.aspx where you will find the version number and the date of the latest revision in a green box. If your version is not up-to-date, download the installation manual and follow the instructions. You will be asked to download the Mobile Studio Desktop software. The link for this is also on this page in the green box.

Using the Mobile Studio

The Mobile Studio consists of the Desktop software, a RED2 board and a USB cable.
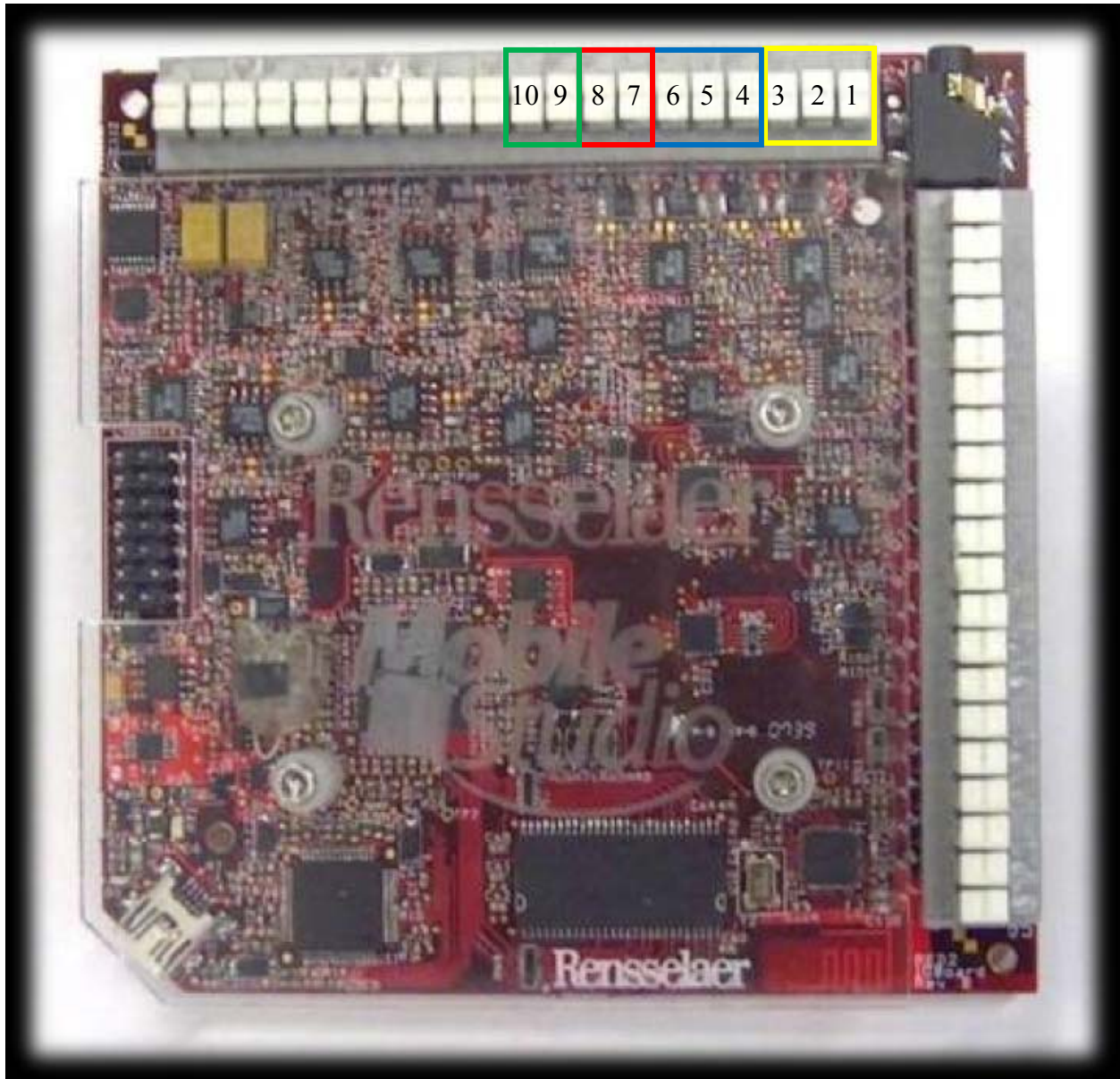

Shown above is the RED2 board (each version of the board has a name). The USB cable is connected to the board at the lower left. The other end of the cable connects to the computer. On the top and right side of the board are the connectors we use to produce and measure electrical signals. All of the connections have names, but we will refer to them by the numbers listed above. The green and red areas are for signal generators also called function generators. The blue and yellow areas are for measurements. We can produce two signals and measure two signals at the same time. When the software asks you if you want to calibrate, select no.

When the Mobile Studio is on and the board is connected, you will see the screen below.
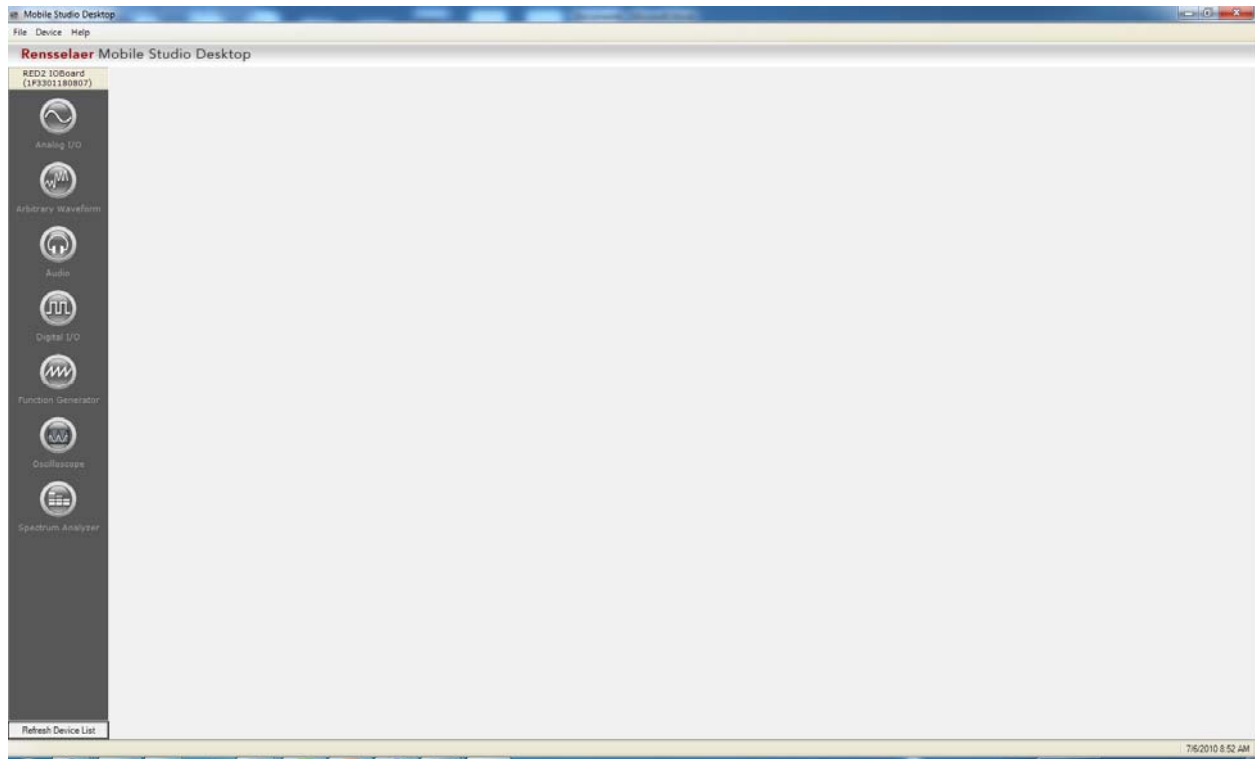

Select the Oscilloscope and the Function Generator (in that order).
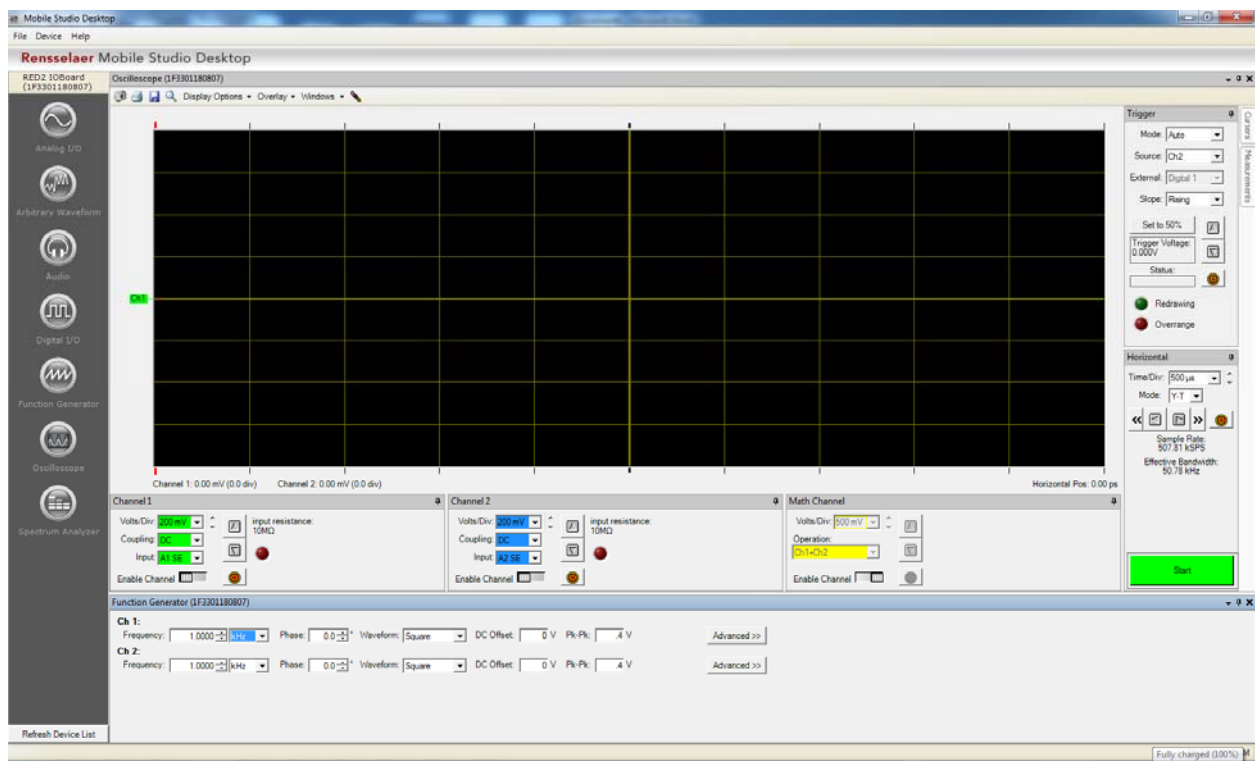
We will now use the function generator to produce a signal to be measured. Before we can do that, we have to connect the function generator output to the oscilloscope. The output for Function Generator One is on pin 7 and the output for Function Generator 2 is on pin 9. These are called AWG1 and AWG2 on the board. (The pinouts for the board are shown below and are also available on the Mobile Studio Website. The input for the oscilloscope channel one is pin 1 and the input for channel 2 is pin 4. Using one of the jumper wires, connect pin 7 to pin 1 and connect pin 9 to pin 4. Usually we also have to connect the grounds but that is taken care of inside the board. The grounds on the board (labeled GND) and all circuits are the reference points for voltage measurements.
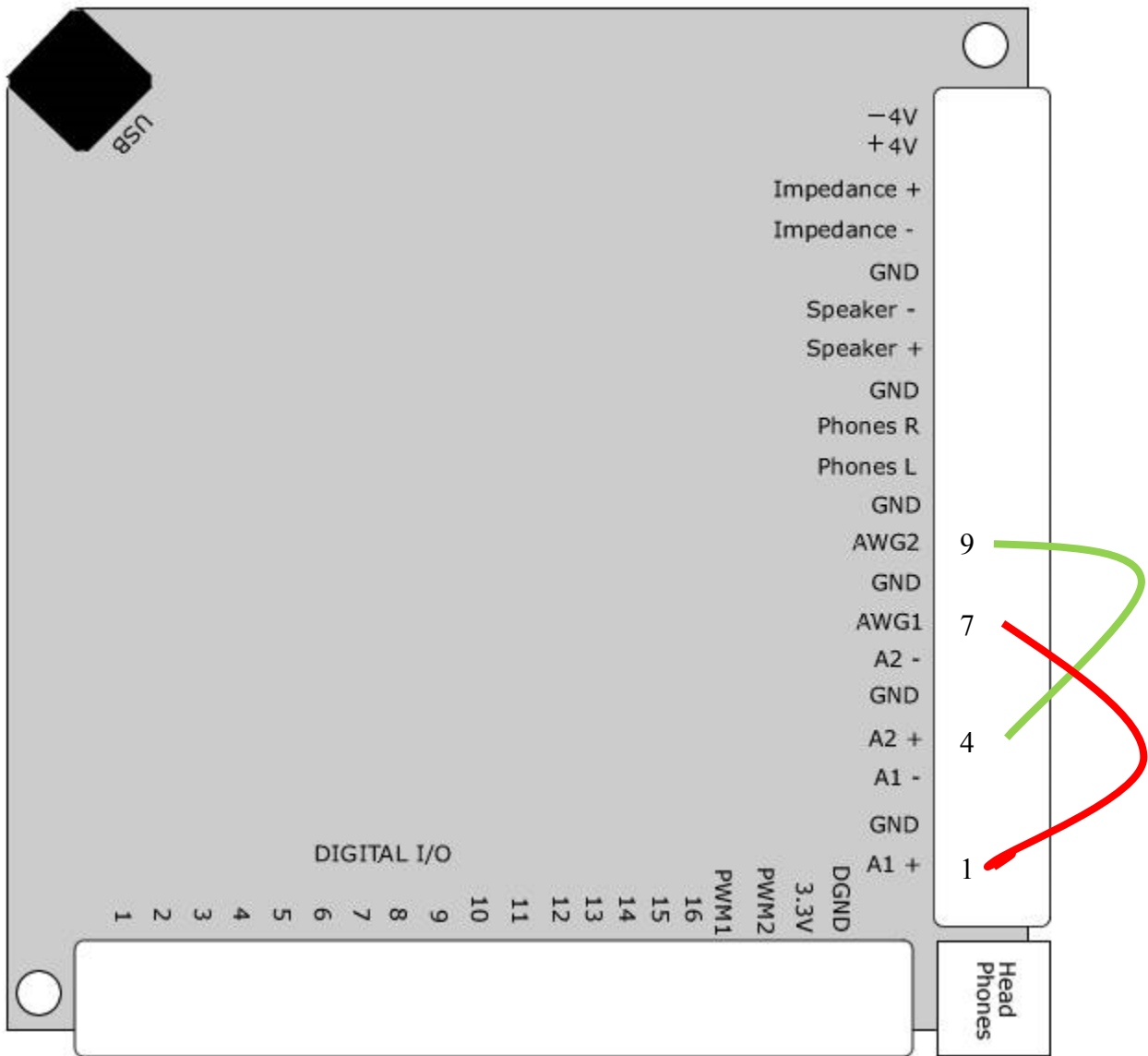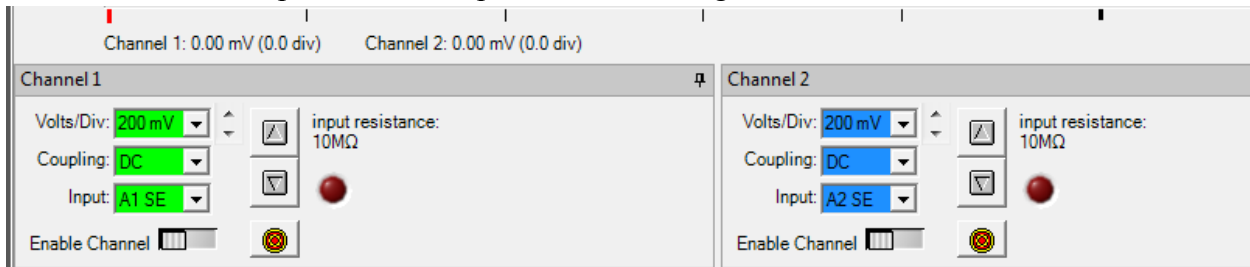
Set up the two function generators to be the same.
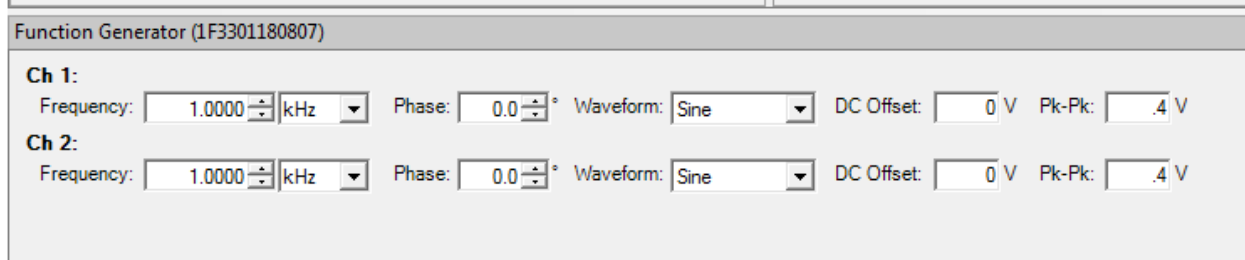
We will see what these all mean by displaying what they look like.

Now we need to set up the oscilloscope to view these signals.

Again, we will see what these all mean by changing things to see what happens. However, we can notice one thing at this point. The input for channel one is A1+ (pin 1) and for channel 2 is A2+ (pin 4). A1 SE means the measurement is being made between A1+ and ground (GND) and A2 SE means the measurement is being made between A2+ and GND.

There are two more things we have to set up to be sure we are looking at things the same way.
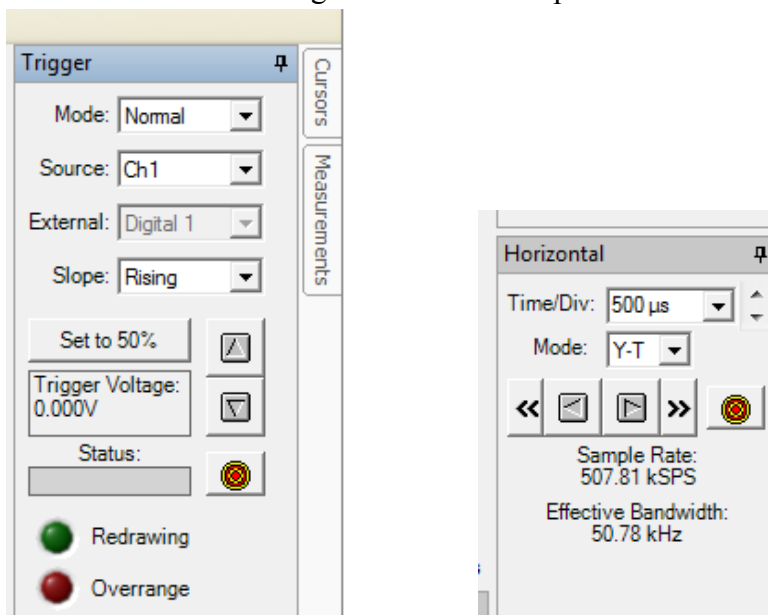
The trigger tells the oscilloscope when to start making the measurement. The horizontal sets the time during which the measurement is to be made.

Now for some measurements.

1. Everything is set up for measuring a 1kHz sine wave on both channels. Click the Start button and you should see the image below.
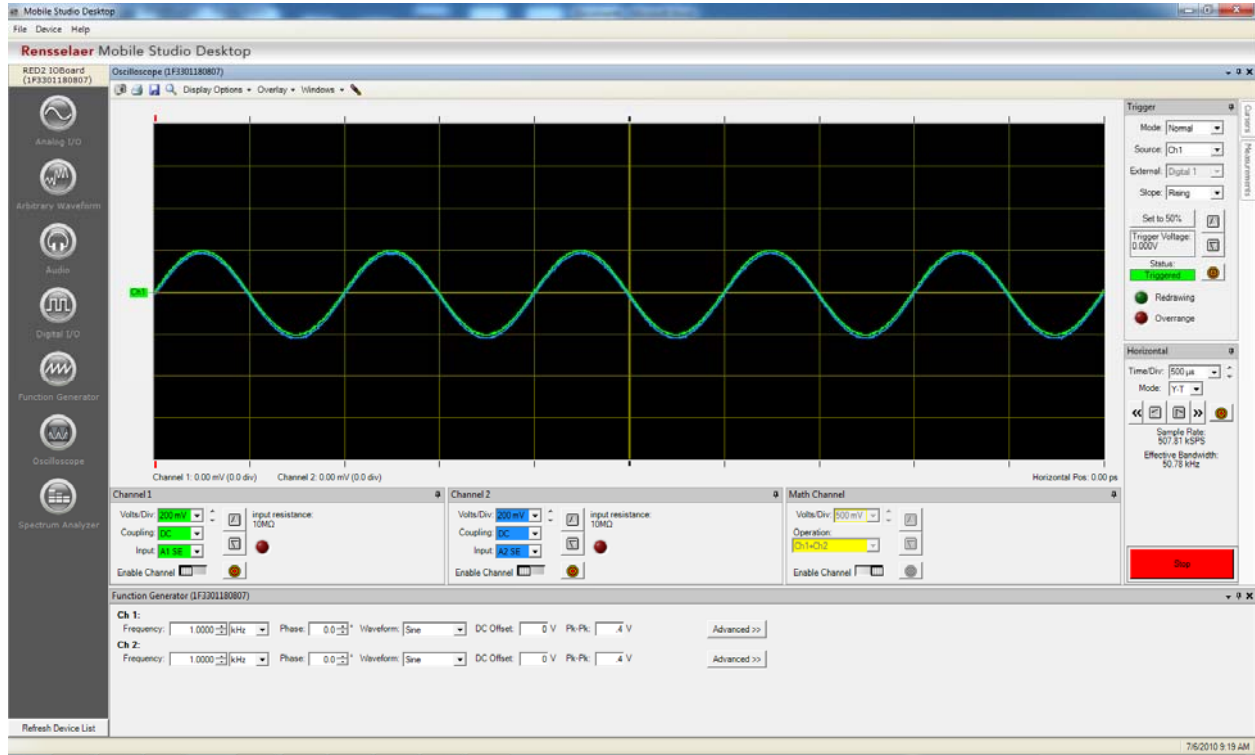
Because of calibration differences between boards, your two sine waves may be somewhat separated in the vertical direction. We will not worry about this phenomenon. For simplicity at this point, we will turn off channel 2 and only look at channel 1. Click on the 'Enable Channel' button under Channel 2 and the blue curve should disappear.

We will leave the signal alone and only change the display to see what that does.

2. Change the Volts/Div to 100mV. What do you observe?
   The Volts/Div controls the vertical scale. That is, there are 8 divisions in the vertical direction and each division is the number of volts selected. 100mV is 0.1V (m means divide by 1000). We set up the function generator to produce a sine wave for which the peak-to-peak voltage is 0.4V so the sine should cover 4 divisions vertically. You should see that it does this approximately but probably not perfectly since we have not calibrated the board. Set the Volts/Div back to 200mV. What do you observe?
3. Find the Horizontal window and change the Time/Div to 200µs. What do you observe?
   The Time/Div controls the horizontal scale. There are 10 divisions in the horizontal direction and each division is the number of seconds selected. 200µs is 0.0002 seconds (µ means divide by 1000000). We set up the function generator to produce a sine wave with

a frequency of 1kHz or 1000Hz. That means is completes 1000 cycles every second or each cycle takes 1/1000 seconds or 1ms to complete. Note that the signal completes one cycle in 5 divisions at this setting. 5 divisions is 5 times 0.0002s or 0.001=1ms as should be the case. Set the Time/Div back to 500μs. What do you observe?

4. Try making other changes in the Volts and Time per division and see if they make sense to you.

Now set the oscilloscope back to the original settings so we can adjust the function generator and see what changes occur.

5. Change the frequency, phase, waveform, offset and pk-pk amplitude. Describe what you observe and then explain what is being controlled. Explain your results to one of your peers and one of your mentors if they are available.

To get a better idea of what is being done with the board, we will now listen to the signals being produced by the function generators, since they are all in the audio range (which means we can hear them). ***Be sure your offset is set to zero before doing the next part.*** Click on the Audio button at the left of the Mobile Studio Desktop. If you have a set of headphones, connect them to the headphone jack. This will be better than using a speaker but be careful with the volume so you do not make it too loud. If you prefer to use a speaker, connect one of the speakers across the speaker connections on the board. (These are pins 14 and 15). This will connect across both channels so you will be able to hear them with one speaker. We do not plan to use the speakers for this since we end up with a lot of annoying sounds throughout the room.

6. Again, change the parameters (except for the offset, which you leave at 0.0) of the function generators and describe what differences you hear, if any. Also, keep the amplitude small, only making it large enough to hear.

Now we will return to resistors in series and see that they produce a division of voltage.

7. Rebuild the circuit with 4 1kΩ resistors in series. Disconnect the wire from pin 9 (we will not be using the second function generator). Disconnect the wire from pin 1 and connect it to one end of the series combination of 4 1kΩ resistors. You will need some additional wires. Connect one wire from pin 1 (channel 1) to the same end of the series combination of 4 1kΩ resistors that you have just connected to pin 7. Connect one from the ground connection next to the first function generator (pin 8) to the other end of the series combination of 4 1kΩ resistors. Connect the wire from pin 4 (channel 2) to the point between the first and second 1kΩ resistor in the series combination. A circuit diagram is provided below.

Pin 7

Pin 1

R1
1k

VAMPL = 0.2   V1

R2
1k

FREQ = 1kHz

R3
1k

Pin 4

R4
1k

Pin 8

0
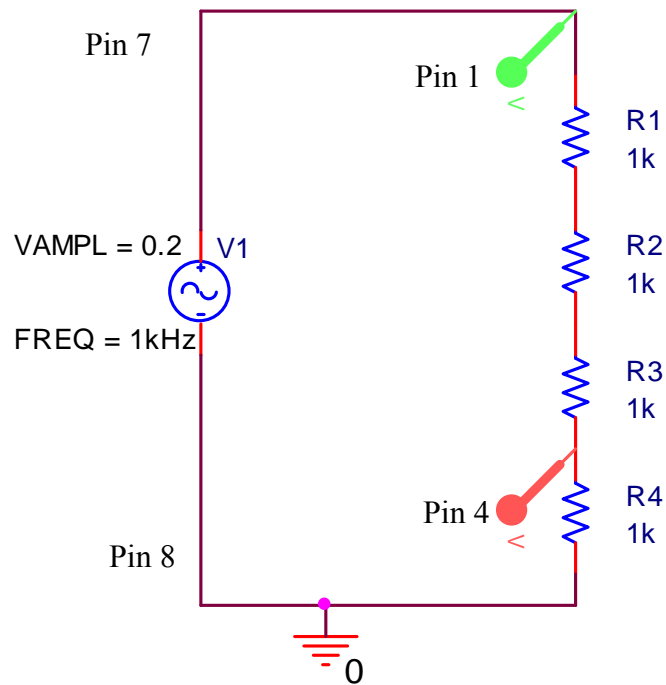
Describe what you observe. Does it make sense to you? Move the connection to pin 4 (channel 2) so that there are two resistors above and below it in the series combination. Again describe what you observe. Finally, move it up one more resistor so that there is only one resistor above it and three below (between it and ground). Describe what you observe.

Note: Before moving on to the next part of this activity, remove all of the wires from the Mobile Studio board. You will not require any wires for #8 and you will use a new wire for #9.

We can also observe the individual audio frequencies using the spectrum analyzer display of the Mobile Studio. Turn off both the function generator and the oscilloscope. Select the spectrum analyzer and then the function generator. (This keeps the screen real estate distributed well.)
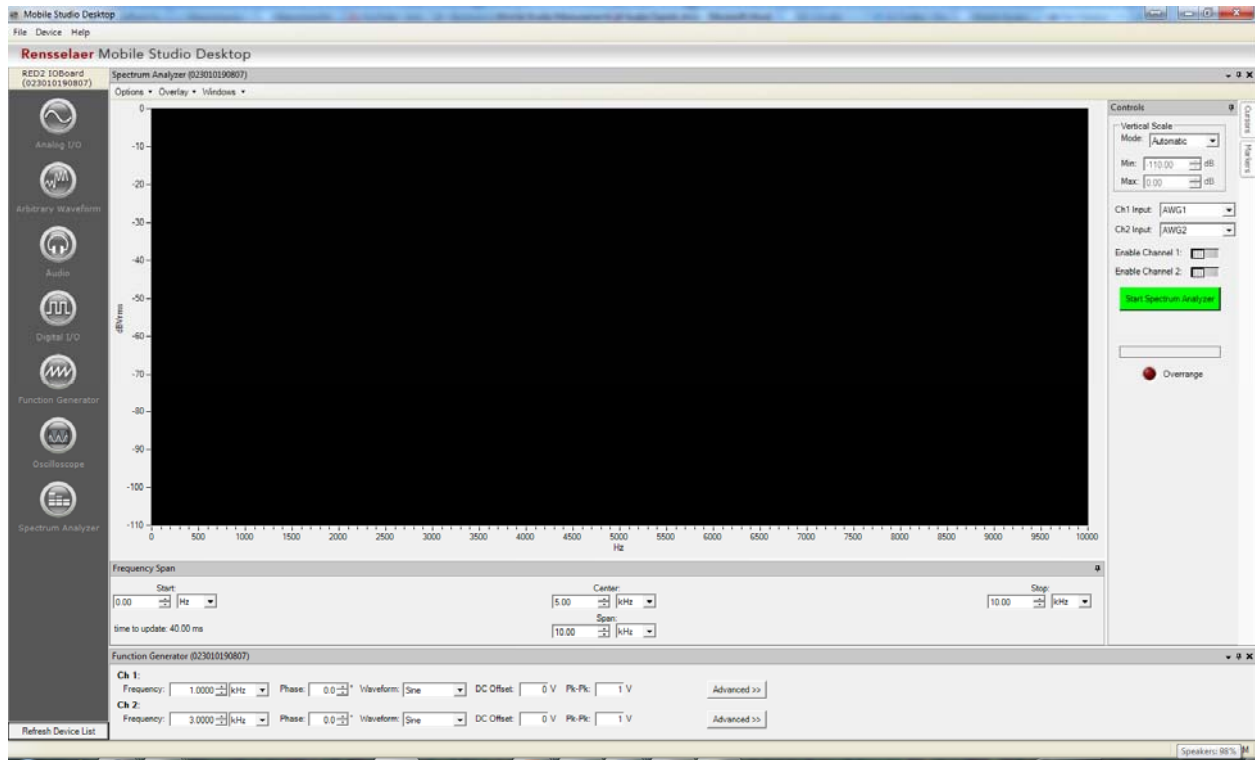
8. To display the frequencies in the signal, we must set the center frequency and the span. The definition of the center frequency is obvious. The span is the range of frequencies we will display. To see all frequencies from 0Hz to 10,000Hz, select 5kHz as the center and 10kHz as the span. You may recall that sound levels are usually given in dB (decibels). That is because the human ear can sense very quiet and very loud sounds so we display the log of the sound level. Your spectrum analyzer probably is not showing the vertical scale in dBVrms but you change this by selecting Options, Vertical Scale and then dBVrms. Note also that the input to the spectrum analyzer is AWG1 for channel 1 and AWG2 for channel 2. This allows us to connect directly to the arbitrary waveform generators without using wires. We will find this useful most of the time and be glad it is an option (it saves hooking up wires). Start the spectrum analyzer. You should see a signal like the one on the next page. Note that there is a big peak at 1kHz for channel 1 (the source is a 1kHz sine wave) and at 3kHz for channel 2. There is also a lot of other background structure shown but all other peaks are many dB below the main sine waves. The peaks are about 60dB above the background. How big is this difference?

$$VdB = 10\log_{10}\left(\frac{V_{main}}{V_{background}}\right) = 60$$. See if you can figure out how big the ratio is.
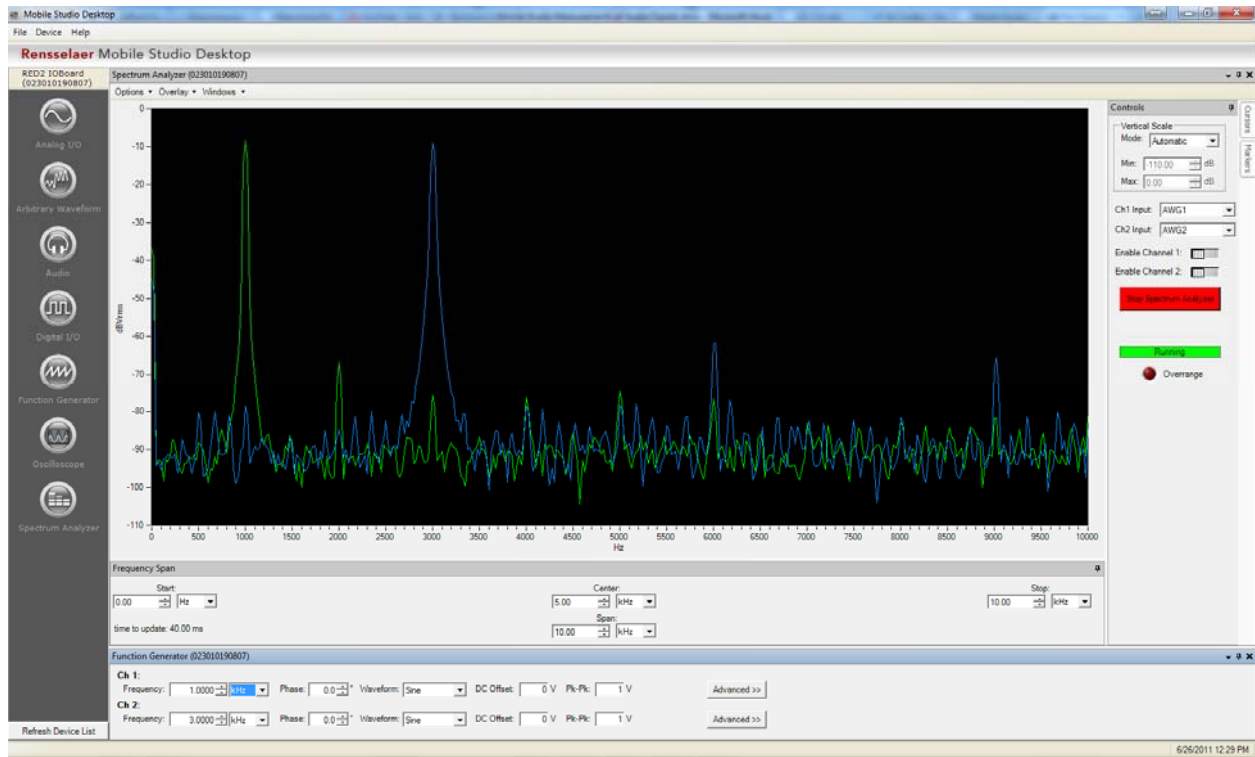
You should try some different frequencies, listen to the sounds and watch how the display changes on the spectrum analyzer. Do the changes you observe in the spectra make sense in terms of what you can hear and what you have set the function generators up to do?

In addition to trying sine waves of different frequencies, you should try the other functions that can be generated by the AWG, the square and triangle waves. Those of you who play musical instruments may know that the reason a clarinet sounds different than a trumpet (even though they both play in the key of B ♭ is that their sounds are not made just from a simple sine wave but are a mixture of harmonics. When you try a 2kHz square wave, you should see significant signals at 6kHz, 10kHz, etc. These are the harmonics of the square wave and make it sound much different than a pure 2kHz sine wave. You should definitely notice this.

You can also show how a square wave is made up by the sum of many sine waves. From a branch of math you will learn more about as a university student (Fourier Analysis), a square wave consists of the following: sin(x)+sin(3x)/3+sin(5x)/5+sin(7x)/7+… or, in other words, each of the odd harmonics divided by the number of the harmonic. Rather than writing this out here, there is a video added to the list of videos on our webpage that shows how we can use the AWG of the Mobile Studio to configure a square wave. As you will see from the video, even 25 harmonics will not produce a perfect square wave, but it will get close. The video was made without access to a good microphone, so the

sound is a little bad. It is at found at
http://hibp.ecse.rpi.edu/~connor/SmartPowerandLight/2011/200Hz_Square_Wave_from_25_Harmonics.mp4

The last part of this activity is to use this capability to observe the properties of speech and music. If you have an MP3 player with you, you can use it as the source. If not, you can use the computer.

9. Obtain an audio cable. It should have a plug on one end that fits in the audio output from the MP3 player or computer or phone. Using the Mobile Studio with audio signals is addressed in another document that is available on the program page. There is also a video that goes with it. You just read the document, but the video is only 5 minutes long. The video can be watched at home to review what you do today. Either way is fine. The video is useful because it includes some sounds that help understand things. The document explains how to connect the cable. If you do things correctly, you will be able to listen to your music and watch the signal on the oscilloscope or the spectrum analyzer. The simplified directions for audio are at http://hibp.ecse.rpi.edu/~connor/SmartPowerandLight/2011/Simplified%20Directions%20for%20Audio.pdf
Be sure to read them carefully to get the maximum benefit from this experience.

A good choice for an audio file to listen to is the NPR story about the Theremin, which is found at: http://www.npr.org/templates/story/story.php?storyId=1147257 We will play with a Theremin this week of the type discussed in this clip. Set up the oscilloscope to measure the signal from the audio clip. Write down your impressions of what you observe. Repeat with the spectrum analyzer.

Note: For both the oscilloscope and the spectrum analyzer, you can save what you see on the screen. There are a couple of options. One is to take a snapshot (the camera icon) while the other is to save the data to an excel file. If you do either one and would like a copy of what you generate, you can either save it on a memory stick or you can email it to yourself (we assume you have a gmail account or something similar).