1 Low Cost Arbitrary Function Generator

Figure 1: A low cost arbitrary function generator. The accessory device uses the audio output from a DVD player to generate various signals. The oscilloscope is displaying an output signal.

The undergraduate electricity and magnetism classes at CSULB have a lab experiment in which students learn how to use an oscilloscope. This article is about a low cost arbitrary function generator which produces various waveforms for students to measure with an oscilloscope. This low cost function generator consists of a DVD player and an accessory device. The left and right audio outputs from a DVD player are used as the input signals to the accessory device. These signals from the DVD player are altered inside the accessory device to produce a desired output signal that can be measured with an oscilloscope. The DVD player, the accessory device, and an oscilloscope that is displaying a typical waveform are shown in Figure 1.

Students can practice finding the peak to peak voltages, frequencies, and DC offsets of several “unknown” signals that don’t necessarily look like square, triangle, and sine waves that come from most signal generators. Since the information about the characteristics of a signal originate from a DVD player, it is easy to create different signals by making WAV files that describe the signal you want, and then burning these WAV files onto a CD or DVD. The main disadvantage to this strategy is that the signal frequency cannot get above around 15 kHz, since the sampling frequency is only 44100 samples/second. But this is not a big disadvantage for our purposes. This low cost arbitrary function generator has the following features:

1
DVD players (and music players in general) remove any DC offset at the audio output. To get around this obstacle, recall that a stereo audio signal has 2 channels. Therefore, the accessory device uses the LEFT channel from the audio output of a DVD player for information about the characteristics of the AC signal. And the accessory device uses the RIGHT channel from the audio output of a DVD player for information about the DC offset. The signal from the right channel goes to a frequency to voltage converter inside the accessory device. The output voltage from the frequency to voltage converter is added to the AC signal from the left channel. Figure 2 shows how the left and right channels from the audio output of the DVD player connect to the accessory device.

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<td>Frequency</td>
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<td>15 kHz</td>
</tr>
<tr>
<td>DC offset</td>
<td>-6.5 V</td>
<td>+9 V</td>
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</table>

DVD players (and music players in general) remove any DC offset at the audio output. To get around this obstacle, recall that a stereo audio signal has 2 channels. Therefore, the accessory device uses the LEFT channel from the audio output of a DVD player for information about the characteristics of the AC signal. And the accessory device uses the RIGHT channel from the audio output of a DVD player for information about the DC offset. The signal from the right channel goes to a frequency to voltage converter inside the accessory device. The output voltage from the frequency to voltage converter is added to the AC signal from the left channel. Figure 2 shows how the left and right channels from the audio output of the DVD player connect to the accessory device.

![Figure 2](image.png)

Figure 2: The left and right channels from the audio output of the DVD player are used as the input signals to the accessory device.

There is one more small complication about the accessory device. We wanted to have a large range of signal amplitudes, from around 200 mVpp to 18 Vpp. To have such a wide range, the accessory device has two ranges for the gain of the signal that...
comes from the left channel of the DVD player. Normally, the gain is 20. However, there is also an “attenuation” feature that makes the gain only $\frac{1}{2}$. The right channel not only contains information about the DC offset, but also information on whether to attenuate the AC signal on the left channel. If the amplitude of the signal on the right channel is small, then the AC signal on the left channel will be attenuated.

2 Low Frequency signals - a nice feature

For instructional purposes, it’s helpful to have some very low frequency signals, say 0.2 Hz, or one cycle every 5 seconds. This is nice because a handheld multimeter and an oscilloscope can be connected to the unknown signal generator at the same time. And at a low frequency like 0.2 Hz, a student can SEE the meter change AND the trace on the oscilloscope change when the voltages from the accessory device change. This is shown in Figures 3 and 4. Other signals can be made that demonstrate that as the signal frequency increases, a handheld meter becomes less useful, and an oscilloscope is needed to measure the features of a signal. A very low frequency signal can be produced by setting the left channel to zero, and using the information on the right channel to shift the DC offset voltages up and down.

![Image of oscilloscope and multimeter](image.png)

Figure 3: A very low frequency that is near 2.8 Volts. This signal that can be measured with a handheld DMM and with an oscilloscope.
Figure 4: A very low frequency that is near -6 Volts. This signal can be measured with a handheld DMM and with an oscilloscope.
3 Pictures of some signals that can be produced

Here are some pictures of other signals that were produced with the arbitrary function generator.
4 How the Accessory Device Works

The circuit diagram for the accessory device is shown in Figure 5. There are 4 main circuit features in the accessory device. They are a regulated power supply, an amplifier, a frequency to voltage converter, and a window comparator.

The regulated power supply uses an LM317 to produce a regulated positive supply of +15 Volts, and an LM337 to produce a regulated negative supply of -15 Volts.

The right channel from the DVD player is called Ch2:DC offset & gain on the circuit diagram in Figure 5. This signal goes to U3, a frequency to voltage converter, and to U6, a window comparator.

The external resistors and capacitors that are connected to U3 provide a DC offset of -6 volts when the input frequency of Ch2:DC offset & gain is near 80 Hz, and a DC offset of +9.5 Volts when the input frequency is near 550 Hz. The output voltage from U3 is called Voffset. Note that we didn’t want the lowest DC offset to occur when the input frequency was near 0 Hz, because the information about the peak to peak voltage of Ch2:DC offset & gain is also needed by U6, the window comparator.

Ch2:DC offset & gain also goes to U6, a window comparator. When the amplitude of this input signal to U6 is small, i.e. its peak to peak voltages are in between +0.3 to -0.3 Volts, the output of the window comparator, called gain:big or small is -15 Volts. On the other hand, if the amplitude of Ch2:DC offset & gain is large, i.e. its peak to peak voltages are outside of the range of +0.3 to -0.3 Volts, then gain:big or small is +15 Volts. R11 and C5 are needed to keep gain:big or small high during the zero crossings of Ch2:DC offset & gain when this signal is large.

The left channel from the DVD player is called Ch1:AC signal. This signal is amplified by half of U5. The gain is controlled by U4, an analog switch. If gain:big or small is -15 Volts, then pin 5 on U4 is connected to pin 6 on U4. This results in a gain of approximately \(\frac{1}{2}\). If gain:big or small is +15 Volts, then pin 5 on U4 is not connected to pin 6 on U4. This results in a gain of approximately 20. The output of U5 is called Amplified AC.

Amplified AC is coupled to Voffset by C10 and C11. VOUT is the final output signal, which is the signal students measure with an oscilloscope.
Unknown Signal Generator
Mark McLaughlin
Rev 1.0 1/6/2006 Page 1 of 1
5  The Matlab code to produce a signal

An example of a program to produce a signal is shown below.

```matlab
%%Program explanation:
%The left channel contains information for the AC part of the waveform. This includes frequencies like the shape of the waveform.
%The right channel contains information for the DC offset of the signal.
%Note that both channels contain the DC offset of the right channel.
%Note that both channels contain the signal to the AC part of the waveform.
%The right channel contains information for the DC offset of the signal.
%The left channel contains information for the AC part of the waveform.
%The right channel contains information for the DC offset of the signal.
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6 Catwav - A Unix program to make WAV files longer

My computer ran out of memory when I tried to make a WAV file in Matlab longer than a few minutes. To make the track longer, another program called catwav is needed. Catwav is a script that concatenates WAV files. This will allow you to make a WAV file as long as you want. Just concatenate a WAV file that was created in Matlab to itself until the WAV file is the desired length. A more detailed explanation of catwav is shown below. This information came from the website, http://www.boutell.com/scripts/catwav.html

Directions for Use

The correct syntax is:

catwav file1.wav file2.wav outputfile.wav

Bugs

Make sure you put the output file name last! It will be overwritten, with no warning.

The output file will always be 44.1 khz stereo with 16-bit signed samples. (The input files don't have to be.) This is a good thing if your next step is making an MP3. If you want something more compact, you can change the script.

The catwav shell script source code

Directions: copy and paste this script into a file called catwav in /usr/local/bin.
Make it executable with the command chmod 755 /usr/local/bin/catwav. Of course, you don't have to put it in a shared directory if you don't want to, it's just a simple shell script.

See also silence.

License Terms

Public domain. Do as you see fit with this script.

#!/bin/sh
sox $1 -r 44100 -c 2 -a -w /tmp/$$-1.raw
sox $2 -r 44100 -c 2 -a -w /tmp/$$-2.raw
cat /tmp/$$-1.raw /tmp/$$-2.raw > /tmp/$$.raw
sox -r 44100 -c 2 -a -w /tmp/$$.raw $$
rm /tmp/$$*.raw
7 Bill of Materials

The parts to make the accessory device came from Mouser Electronics and Digikey. The prices are as of January 2006.

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**Subtotal:** $98.70

**Handling:** $4.00

**Shipping:** unknown

**Sales Tax:** unknown

**Total:** unknown
8 Printed Circuit Board

The printed circuit board was ordered from ExpressPCB.com, http://www.expresspcb.com. It costs $63 for 3 boards. The printed circuit board layout is shown below in Figure 5.

Figure 5: The printed circuit board layout.

If you have any questions about this device, please feel free to contact me at mmclaugh@csulb.edu