Function Generator with Laser Waveform Projection

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Project Proposal Draft

The function generator, also commonly referred to as signal generator, is a universal tool used by every electrical engineer at some point in their career. Sine, square, and triangle waves of different periods, duty cycles, and amplitudes are required as input to many digital and analog circuits - a function generator creates these input signals which can then be amplified and used in a variety of applications.

There is currently a wide range of commercial function generators available to choose from, many of them fetching a high price. For our final project, we will construct a function generator using a Nexys 4 FPGA and some digital-to-analog converters (DACs). Using buttons and switches built into the Nexys 4, users will be able to dial in a frequency and have the Nexys 4 generate the waveform on one of two output channels (driven by the DACs). Our device will also produce a VGA signal of the waveforms which will be displayable on any VGA monitor. This way, a user could view the waveform they are generating without having to verify with a scope.

We hope that our function generator will be useful for other fellow electrical engineers, especially students, who would rather purchase a device with a multitude of uses such as an FPGA rather than buying a device that can only work as a function generator.

Implementation Overview

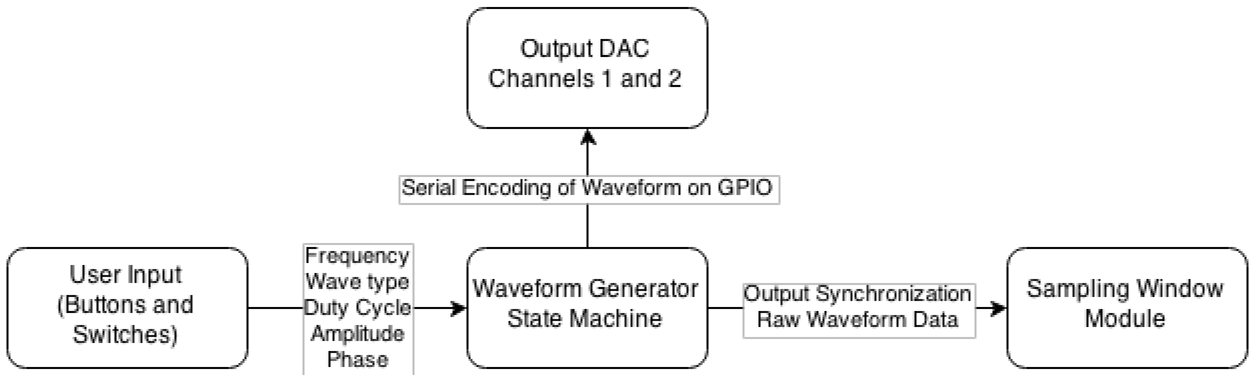
Our project is comprised of three major base modules. The first module, the waveform generator, will be able to generate square waves, triangle waves, and sine waves. Using two 12-bit or 18-bit DACs, we will implement dual-channel outputs which will be able to display independent waveforms simultaneously. The user will be able to control the duty cycle of square and triangle waves as well as the amplitude and frequency for all three types of waves. The two output channels will also have a variable phase shift relative to each other which can be arbitrarily assigned by the user.

The second module, the sampling window, will choose an appropriate scaled sample of the current waveforms to be displayed. The window can be varied to display more or less of the waveform as well as scale it for viewability. This module is tasked with mapping the waveform generated by the waveform module to a format that can be displayed using the third module, the display module.

The third module, the display module, will be used to interface with a VGA display. It will communicate directly with the sampling window module to acquire the information it needs to display. As an extension to the base of the project, this module will also be capable of displaying the waveforms using galvanometers.The display module will take the input of the window and translate it into motion for the galvanometers. This way, with a low-power laser, the waveforms can be viewed on a flat surface like a wall. The square and triangle waves will be drawn continuously from point to point. For sine waves, we will most likely use a pre-computed sine wave table with a reasonable resolution, and draw the signal continuously between discrete points taken from the sine wave table.

The final and experimental extension part of our project will be a fourth module, the trigonometric compensation. The trigonometric compensation will be an additional input to the window module. It will use two sensors, a three-axis accelerometer and a three-axis gyroscope, to determine movement and rotation of the display rig. This sensor input will be used to correct for changes in projection angle to maintain the displayed image in a single spot on the viewing surface. We will implement the movement aspect of the trigonometric compensation before working on the rotation aspect.

Waveform Module

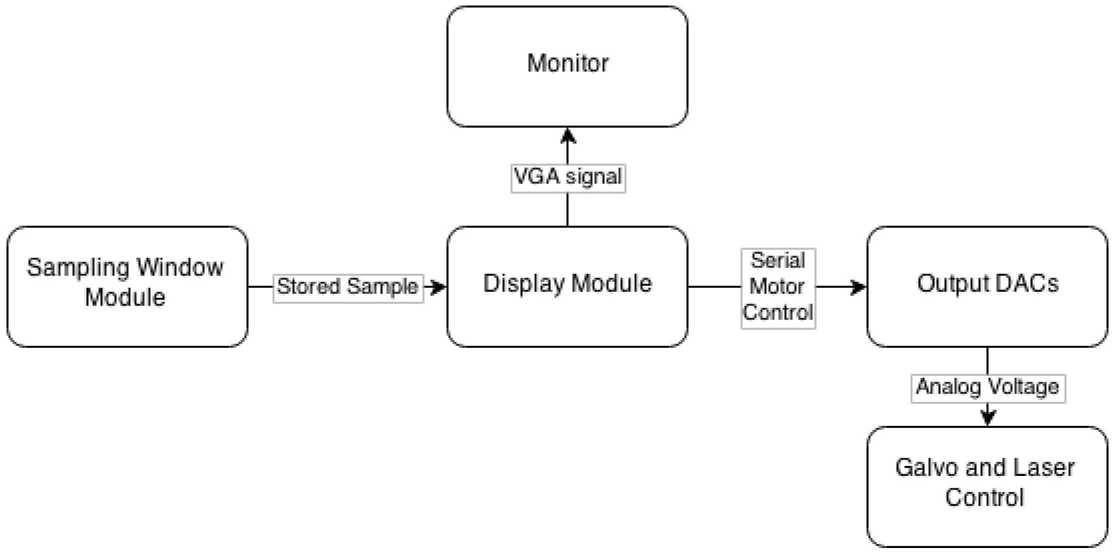


The waveform module will consist of several user inputs in the form of built in button and switches. These can be use to select the type of wave to output on each channel, as well as the frequency, duty cycle, amplitude and phase of these waveforms. Two switches will be responsible for determining the type of waveform that gets output. Three other switches will determine the order of magnitude at which to increase or decrease the frequency which can be accomplished by pressing either the up or down button. That way, if one were to have the frequency switches such that 1kHz was selected, and then were to press the up button, the output frequency would increase by 1kHz. The right and left buttons will be used to increase or decrease either the phase or duty cycle, which can be selected using another switch. The waveform module will take this input and latch onto it, generating a unique wavestate for a given output. This wavestate will be used by the waveform generator state machine to generate the output. For example, if a user were to load in a sine wave with an amplitude of 1 and a frequency of 1kHz, the waveform generator state machine will determine that the best way to make the waveform is to use the sine wave lookup table and scale according to the frequency and amplitude desired. The waveform generator will make this raw output available to the next module base module, the sampling window module.

Sampling Window Module

The sampling window module will be responsible for sampling the waveform and outputting a scaled version which will be viewed. It will need to synchronize with the periods of the waveform to display a steady wave that isn't drifting. With that information, it then needs to scale the period and amplitude accordingly. The user will be able to adjust these settings.

Display Module



The display module is responsible for acquiring the sampled waveform from the sampling window module and displaying it. For the base project, the display module will output a VGA signal, which would be hooked up to a monitor so the waveforms can be viewed on screen. This set up is similar to lab 2 so that is why its part of the base project. The extension would involve outputting to galvanometers in addition to the VGA display. This would involve integrating two 12 or 18-bit DACs to drive each galvo. It would also involve converting the sampled waveform into steps at which to move the motors to accurately draw the image. A mapping will need to be formulated that can convert angular position of both mirrors to cartesian coordinates on the wall to preserve the shape of the waveform.

Bonus Module: Trigonometric Compensation

Given enough time this additional module will be created. This bonus module will be tasked with compensating the image for distortions introduced by rotating and tilting the physical rig. It will interface with two sensors, a three axis gyro and a three axis accelerometer, to determine rotation and tilt. With that information, this module will implement correction factors that are fed back into the display module which will alter the waveform so that it appears normal on the viewing surface.

Testing

We will write tests for our waveform generator which will analyze the response of the output waveforms to different duty cycle, period, and amplitude inputs. We will also test the effect of the phase shift input on the relative phase shift between the two output waveforms. Once we are confident in our simulations, we will hook up DACs and scope the outputs to verify performance. Tests will be created for the window module which will check the scaled output depending on the size and resolution inputs from the user. The VGA output can be tested by hooking up an external monitor.

The galvanometers will first need to be calibrated using built in controls. Once they are calibrated, we will test if the our galvo angle to cartesian mapping and see if we can draw basic geometric shapes. Once that is tested, the sampling window module can be hooked up to the display module and adjustments can be made to enable the displaying of the waveforms with the galvos. We will test the trigonometric compensation module both in software and visually as well, by generating accelerometer and gyroscope sensor inputs and checking if the expected trigonometric compensation is correctly computed. After implementing the trigonometric compensation module, we will write more tests for the display module to make sure that it correctly incorporates the additional input into the display image.

Division of Tasks

Initially, Ciara will work on implementing the function generator and sampling window modules while Brandon will work on implementing the display module and porting over / writing modules for DAC and sensor integration for the Nexys 4. When both parts work, we will combine them and work on implementing the trigonometric compensation (the fourth module) together.

Anticipated challenges

The biggest risk in our project is the galvanometer implementation of the laser display. It might prove to be more difficult that we originally imagined to smoothly draw the function generator outputs on a surface, and we will have to experiment with the resolution and range of the lasers in practice. In order to mitigate this potential risk, we are going to first build and test our function generator with a VGA display output so that even if our galvanometer laser display does not work as we expected, we will still be able to visualize the different waveforms.
If we are successful in implementing the galvanometer laser display for our function generator, the next big challenge will be to build the trigonometric compensation component of the display. Depending on how accurate our gyroscope and accelerometer are in detecting movement, certain limitations may be imposed on the range of movement our function generator is able to compensate for while maintaining a stable image.

Schedule

The time-frame of our project implementation is spread out over a period of six weeks. During the first week, we will be planning and designing our system at a high level. We will also be researching specific parts we will need to get for our project such as galvanometers, gyroscopes, accelerometers, ADCs, and DACs. During the second and third week, we will implement and test our function generator on a VGA display and order the extra parts we will need for the rest of our project. When our function generator is fully implemented on the VGA display, we will begin to work on the galvanometer laser display. Ideally, we will have the galvanometer laser display working by the end of the fourth week; then, we will spend the fifth and sixth weeks working on the movement compensation component of the galvanometer display.