Lab 6: Graphic Equalizer

In this lab you will learn and tinker with:

- General behavior and function of counters
- Behavior and functionality of shift registers
- Working with spectrum analyzers and graphic equalizers
- Building an LED display using graphic equalizers

1.1: The Problem to be Solved

Have you ever wondered how to improve the sound equality of a speaker? Graphic equalizers (GEs) are essential audio control devices made for this exact purpose. These devices are mainly used by sound engineers or musicians to improve the clarity of audio signals. The way graphic equalizers achieve this is by boosting or cutting the energy of certain frequency bands. Initially, the graphic equalizer divides the audio signal into a range of about 6 to 30 different bands of frequency. The amplitudes of these bands can then be altered to either make them louder or softer depending on which modifications will improve the quality of the signal. As an example, if the bass of a specific song is too loud, we could lower the amplitude of the lower band frequencies in order to even them out with the other higher frequencies, generating a clearer signal with less bass. In digital electronics, there are various IC chip graphic equalizers that vary depending on how many bands they support. For example, a 5-band graphic equalizer, divides the audio signal into 5 different frequency bands. It can be assumed, therefore, that the higher the number of bands supported by a graphic equalizer, the higher the level of accuracy to which we can achieve good sound quality. A common one is the MSGEQ7, a 7-band graphic equalizer, which we will cover in the next sections of this lab.

Digitally, graphic equalizers such as the MSGEQ7 can be used in a variety of applications that require output control based on audio frequencies. As such, in this lab you will be building an LED control display that turns on the LEDs on your DEB based on certain audio frequencies outputted by the graphic equalizer. With this implementation, you will be able to input your favorite song and generate an entertaining LED animation that follows the frequencies of the signal! Additionally, your design will use two other powerful digital logic circuits known as counters, which you learned about in lab 5, and shift registers, which you will learn about in the following sections.

1.3: Learning About Shift Registers

In order to be able to store multibit data, a single flip-flop does not suffice because it can only store one bit. In digital electronics, a collection of flip-flops is used to store multibit data and such implementation is known as a register. Moreover, this information can be transferred by using shift registers. These registers can either shift bits to the left or right depending on their configuration. Their most important benefit is to expand serial communication into parallel communication or, in other words, transform a single line to several parallel lines, which you will later use to build your graphic equalizer design.

Shift registers have four main classifications depending on the implementation desired:

1. Serial In Serial Out Shift Register (SISO)

This type of shift register has a serial input and a serial output, as shown in figure 4. This means that bits are shifted and outputted one after the other through a single serial data line. The main benefit of this shift register configuration is to delay data by clock cycles.

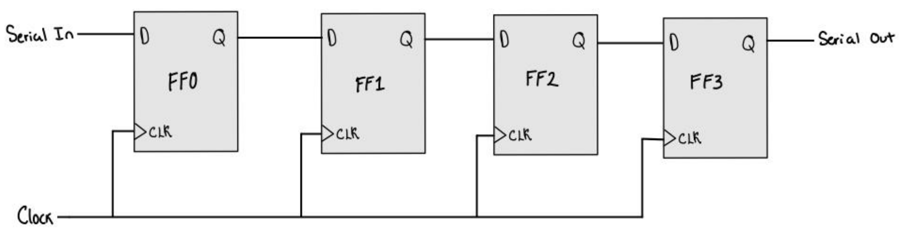

Figure 1: *Serial In Serial Out Shift Register*

2. Serial In Parallel Out Shift Register (SIPO)

This type of shift register has a serial input like the SISO register, but its output is produced in a parallel fashion, as shown in figure 5. This means that the serial data line gets demultiplexed, which is beneficial when it comes to expanding I/O ports and communication lines.

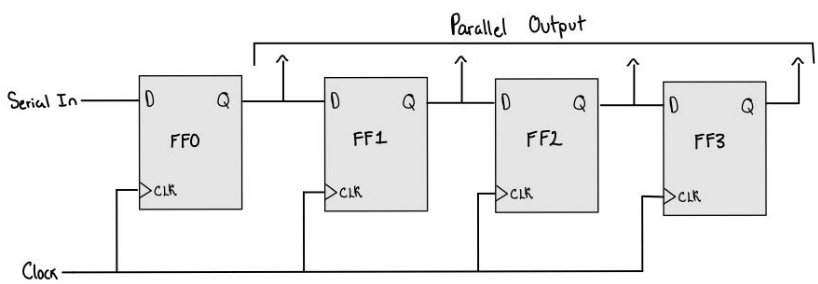

Figure 2: *Serial In Parallel Out Shift Register*

3. Parallel In Serial Out Shift Register (PISO)

This type of shift register has a parallel input and a serial output, as shown in figure 6. This means that data is inputted into each flip-flop separately but simultaneously and the data bits are outputted one at a time. The benefit of this shift register is that it inputs data from several communication lines and transforms the data into serial data.

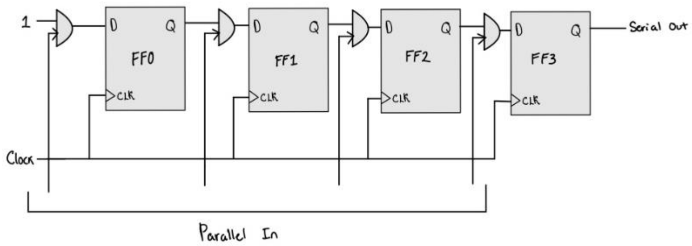

Figure 3: *Parallel In Serial Out Shift Register*

4. Parallel In Parallel Out Shift Register (PIPO)

This type of shift register has a parallel input and a parallel output, as shown in figure 7. This means that data is inputted into each flip-flop separately and simultaneously and the data is outputted from each flip-flop separately. The benefit of the PIPO shift register is that it inputs data from several communication lines and the output does not have to be delayed by clock cycles.

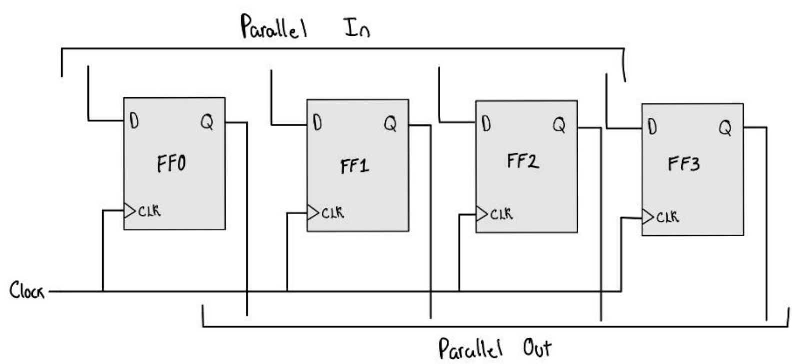

Figure 4: *Parallel In Parallel Out Shift Register*

For your graphic equalizer design, it is recommended that you use a shift register such as the 74HC595 shift register IC chip. This particular 8-bit shift register inputs the data serially and has the option to output it either in a serial or parallel fashion. Additionally, the 74HC595 includes a latch system which either prevents or allows the data outputted from the shift register to be sent to the IC chip outputs. As shown in figure 8, this IC chip has parallel data outputs labeled QA-QH, a serial data output SQH, serial data input A, shift clock and latch clock, a reset signal, and output enable.

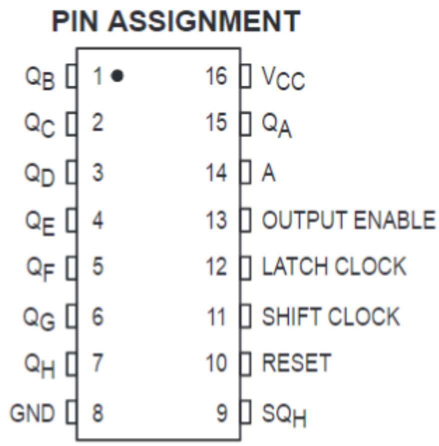

Figure 5: *Pinout for 74HC595 Shift Register IC chip*

a. What are the benefits of each shift register configuration described in section 1.3?

1.4: Learning About the MSGEQ7

For your graphic equalizer design, you will be using the MSGEQ7 7-band graphic equalizer component, which is shown in figure 9. With this device, an audio signal can be inputted using the IN pin, which will then be divided into seven bands: 63 Hz, 160 Hz, 400 Hz, 1 kHz, 2.5 kHz, 6.25 kHz, and 16 kHz. These frequencies are multiplexed by the device, which will then output a DC voltage that represents the amplitude of each band. The multiplexing capabilities of the graphic equalizer is controlled by a reset and a strobe. The reset signal is used for resetting the multiplexer to its initial state and the strobe signal allows the bands to be outputted to the OUT pin of the chip with every leading edge one by one from smallest to highest frequency. Additionally, the MSGEQ7 contains a positive power supply pin (VDDA), a negative power supply pin (VSSA), and a clock oscillator pin for the bandpass filters (CKIN).

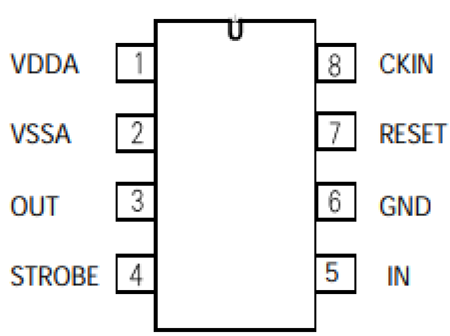

Figure 6: *MSGEQ7 7-band graphic equalizer IC chip*

The MSGEQ7 will be

used through the DEV-13116 Spectrum Shield device (figure 10), which will allow you to input any kind of audio signal into a MSGEQ7 graphic equalizer using a basic audio player. Alternatively, the audio signal can be inputted through the Audio In headers of the DEV-13116 board. The spectrum shield has a second audio jack called Output that allows you to send the signal to a speaker or other device after it goes through the graphic equalizer. The board allows you access to all of the MSGEQ7 pins including reset, strobe, and output pins (A0 for the left MSGEQ7 IC and A1 for the right MSGEQ7 IC).

Figure 7: *DEV-13116 Spectrum Shield board*

1.5: Building a Graphic Equalizer Circuit

In your graphic equalizer design, it is recommended that you use the 74ls393 4-bit up counter IC chip shown in figure 11. This IC chip has 4 outputs labeled Q0-Q3, a master reset input labeled MR, and a clock input labeled CP. The outputs are used to generate the up sequence every time an edge is encountered, MR is used for resetting the sequence to its initial state, and CP is the clock signal that will be controlling when the outputs change.

Your graphic equalizer implementation should include a counter, a shift register, and decoder. In your design, you will use LEDs OUT9-OUT3 to represent each of the seven frequencies outputted by the MSGEQ7 device. In the end, your completed design should be able to take in any audio signal trough the audio jack and output the frequency amplitudes of the audio signal and represent these using the LEDs.

a. Design and construct your graphic equalizer circuit on the DEB using the devices specified above. You can test out your circuit by initially sending an audio signal of a single frequency (e.g. a 65 Hz frequency audio from YouTube). After this has successfully worked, try testing your circuit with any song you would like to make sure that the frequencies are shown as expected.