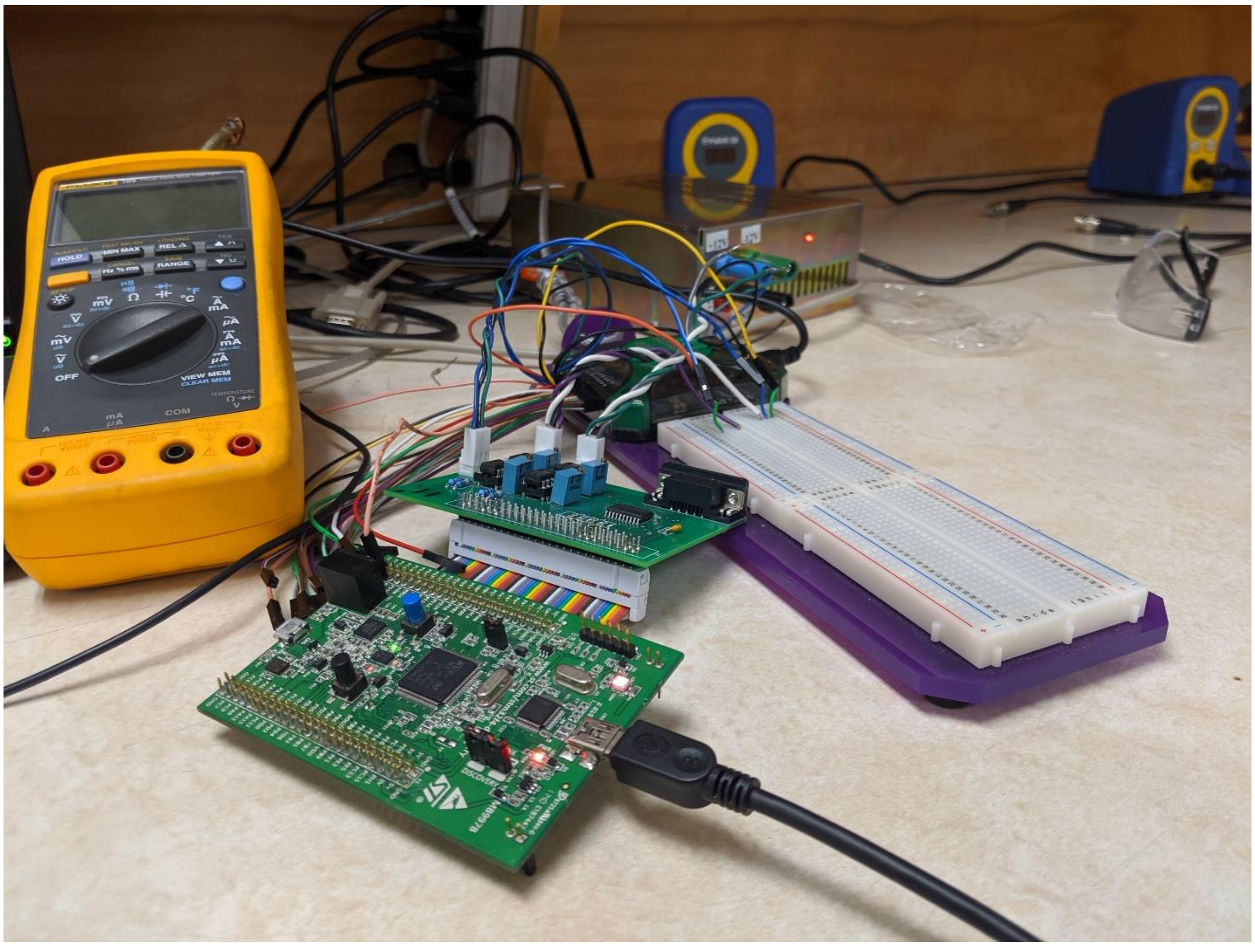
Ben Stonebraker
October 17, 2019
Lab 1.5 – ECE647

Lab 1.5 Sampling Systems

Hardware Setup:

The Hardware used in this lab mainly consisted of an STM32F4 Discovery Board, a V4.1 Serial Analog Interface (SAI) board, and an analog discovery. The STM32F4 board was used to control the SAI board and analyze the interrupt timing with a pin of the analog discovery on the LED pin. The SAI board was used to take the input signal generated by the analog discovery, sample it at a rate of 5Khz, and then reproduce the signal back out with an IIR filter implemented. Both the input and output signals were monitored by the analog channels of the Analog Discovery. A picture of the setup is below.



Software:

The code used consisted of the same code used in Lab 1, but with modifications to the AdcDriver. The code for the AdcDriver.h is located in Appendix A, and the rest of the code can be found online at https://github.com/bstonebraker96/ece647_lab1_5/.

Ben Stonebraker
October 17, 2019
Lab 1.5 – ECE647

Questions:

How well do the frequency response match the response posted to the web page?

Looking at figures 2 and 3 below, the expected result and my result respectively, it's clear that the beginning frequencies (100-900Hz) struggle a bit with matching the wave form, but that could be attributed with the difficulties I was experiencing with using the lab equipment, as for some reason the analog discovery was putting out data was off and the data I collected had to be remeasured at least once. The table of data is located in Appendix B.

Output of direct FIR implementation.

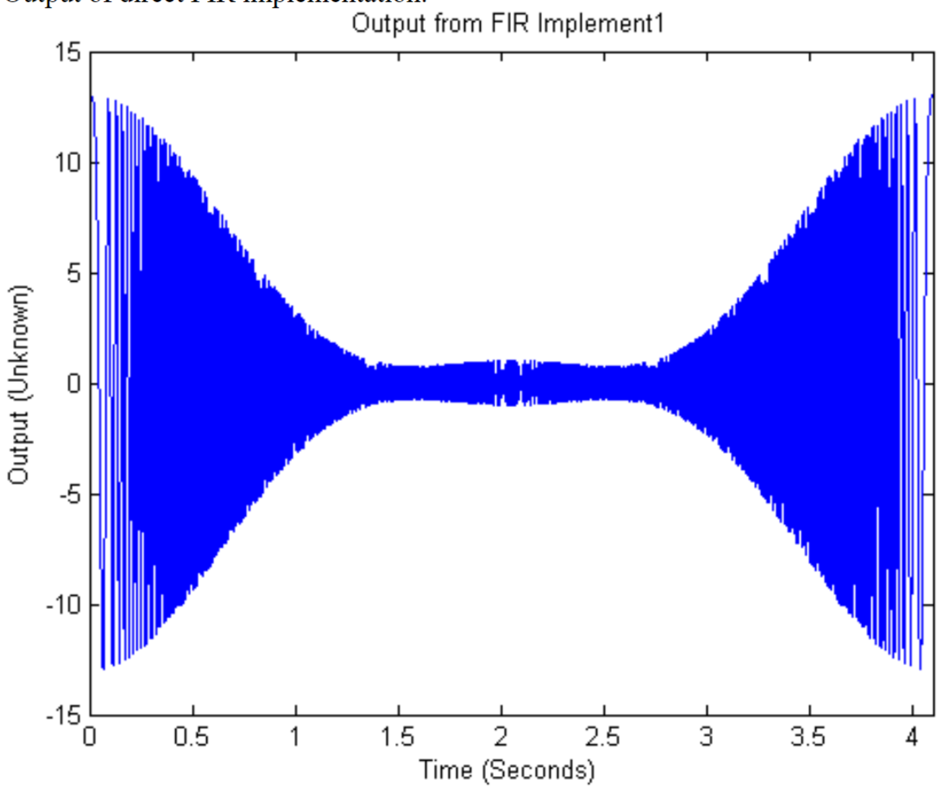


Fig. 2 – Expected response shape of results

Ben Stonebraker
October 17, 2019
Lab 1.5 – ECE647

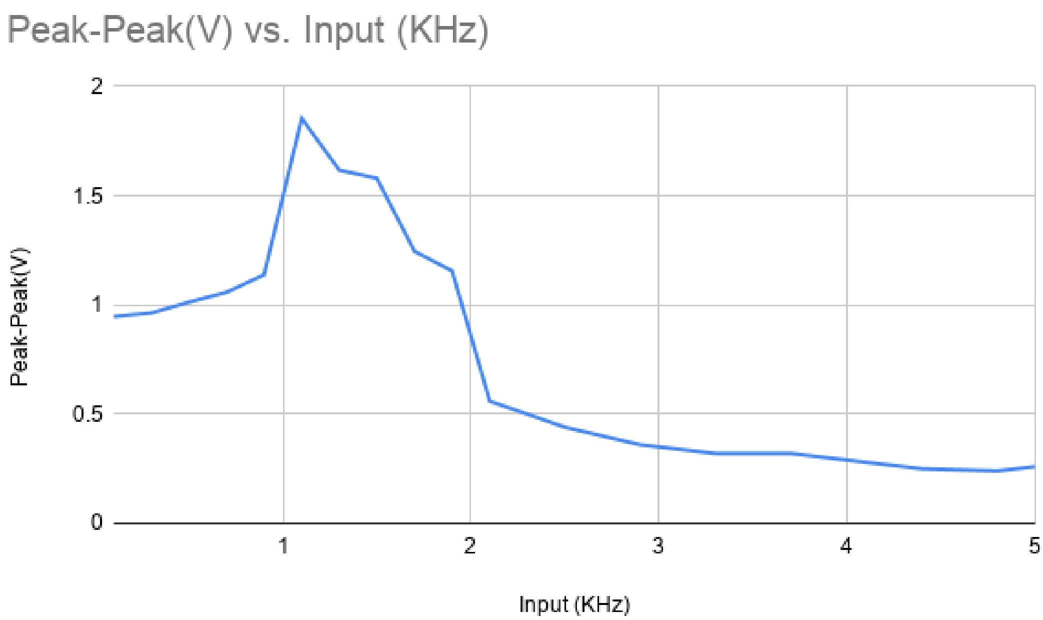


Fig. 3 – Plot of Peak Voltage vs frequency in KHz

Based on the time required to run the filtering code, how large of a filter can be implemented assuming we would want to use 80 of the 100μs for filtering?

$T_{IIR} = 1\mu s \;\; T_{NoIIR} = 658ns$

$\frac{Orders}{Time} = \frac{2}{T_{IIR}-T_{NoIIR}} = \frac{2}{1\mu s-658ns} = 5.84 * 10^6 \frac{Orders}{s}$

$\frac{Orders}{80\mu s} = \frac{Orders}{Time} * 80\mu s = 5.84 * 10^6 \frac{Orders}{s} * 80 * 10^{-6} s \approx 467\ Orders$

The maximum size of the filter can be 467 Orders large.

Ben Stonebraker
October 17, 2019
Lab 1.5 – ECE647

Appendix A

```
// ADC Support.
int Channel2, Channel1;
const float b0 = 0.1, b1 = 0.2, b2 = 0.1,a1 = -1.0, a2 = 0.5;

float IIR2_y[2] = { 0.0 };

float IIR_Implement2(float x){
	float y; // output
	// Implement difference equation
	y = b0 * x + IIR2_y[0];
	IIR2_y[0] = b1 * x - a1 * y + IIR2_y[1];
	IIR2_y[1] = b2 * x - a2 * y;
	return y;
}
// IIR_Implement2
// Compute output using Transposed

const int LED_Indicator = 2;
// DAC service.
void DAC_Data_Send(  int Ch1, int Ch2 )
{
	 DAC->DHR12RD = (Ch2<<16) | Ch1;  // Send data over to DAC

   DAC->SWTRIGR = 3;  // Software trigger DAC

}

// ADC_IRQHandler Function â€“ Only called when conversion is complete.
void ADC_IRQHandler(void){
  LED_On( LED_Indicator );   // Set output pin showing Interrupt.

	Channel1 = ADC1->DR - 2048;  // Pull Data from ADC, channel 1,
  Channel2 = ADC2->DR - 2048;  // channel 2.

	// Filtering could be added here to change Channel1 and Channel2
  //Channel1 = (int) IIR_Implement2((float)Channel1);
// Compute output using Transposed
	DAC_Data_Send(  Channel1 + 2048, Channel2 + 2048 );

	LED_Off( LED_Indicator ); // Turn off Interrupt Flag.

} // End of ADC_IRQHandler

// init_adc Function â€“ Sets up ADC, Dac and Timer.
```

Ben Stonebraker
October 17, 2019
Lab 1.5 – ECE647

```
void Adc_Dac_Init( )
{
  RCC->APB2ENR |= RCC_APB2ENR_ADC1EN | RCC_APB2ENR_ADC2EN;  // Clock
enabled for ADC1.
  RCC->AHB1ENR |= RCC_AHB1ENR_GPIOAEN; // Enable GPIOA clock
                  // Enable DAC and Timer 2, 5 clock

  GPIOA->MODER |= (0x00000ff0);       // PA.2-5 as Analog

        // Set CCR for ADC
        ADC->CCR |= 0x030f02; // Maximum Prescaler and Max delay between samples
                      // Dual simultaneous mode.

        // Set CR1 for ADC 1 and 2
        ADC1->CR1 |= 0x000820; // Enable Discontinuous and EOC interrupt.
  ADC2->CR1 |= 0x000800; // Discontinuous

        // Set CR2 for ADC 1 and 2
        ADC1->CR2 |= 0x16000401; // Set Trigger to Tim2, enable EOCS and turn on ADC1
  ADC2->CR2 |= 0x00000001; // Turn on ADC2

  // Set SMPR2 for ADC 1 and 2
        ADC1->SMPR2 |= 0x000000f8; // Set sampling to maximum
  ADC2->SMPR2 |= 0x000000f8; // Set sampling to maximum

  // Set SQR1 for ADC1
        ADC1->SQR1 = 0x00000000; // Set for 1 Conversions
  ADC2->SQR1 = 0x00000000; // Set for 1 Conversions

  // Set SQR3 for ADC1
        ADC1->SQR3 = 0x00000002; // Set Initial sequence to channels 1 then 2
        ADC2->SQR3 = 0x00000003; // Set Initial sequence to channels 1 then 2

  NVIC_EnableIRQ( ADC_IRQn );  // Enable ADC interrupts.

  // Enable both DAC's and set them to trigger on Tmr4.
  RCC->APB1ENR    |= RCC_APB1ENR_DACEN;
  DAC->CR |=   DAC_CR_EN1
                 | DAC_CR_EN2;

  RCC->APB1RSTR |= RCC_APB1RSTR_TIM2RST;

  RCC->APB1ENR     |= RCC_APB1ENR_TIM2EN;

}
```

Ben Stonebraker
October 17, 2019
Lab 1.5 – ECE647

```
// This macro will start the adc, using the software trigger.
#define Fire_Adc() (ADC1->CR2 |= ADC_CR2_SWSTART)
```

Appendix B

Input (KHz)	Peak-Peak(V)
0.1	0.947
0.3	0.963
0.5	1.013
0.7	1.058
0.9	1.138
1.1	1.854
1.3	1.617
1.5	1.58
1.7	1.245
1.9	1.156
2.1	0.56
2.5	0.44
2.9	0.36
3.3	0.32
3.7	0.32
4.1	0.28
4.4	0.25
4.8	0.24
5	0.26