Introduction

We have been required to design a system to produce an output of various sorts, whether it be audio, video, motion (using a speaker, LED, motor respectively). We have chosen to drive the input to produce outputs that will include LEDs, speakers and a visual display on a computer (collection of data).

Overall system level diagram:

Electronic components:

|  |  |
| --- | --- |
| Component | Quantity |
| Instrumentation Amplifier – LMC660  + buffer stage | 2 |
| TL074 (notch filter) | 1 |
| Push Button – 3CTL9 | 2 |
| Arduino Mega 2560 | 1 |
| Bar LED | 1 |
| ECG electrode | 3 |
| Conductive Gel Ten20 | 1 |
| PP3 Battery | 1 |
| PP3 Battery Clip | 1 |
| Assorted resistors | - |
| Assorted capacitors | - |
| Assorted diodes for half wave rectifier | 2 |

Plan

Franky Saxena – Project Manager/ADC programming

Bruno Calogero – Circuit Diagrams

Theo Velon – PCB Design

Daniel Saul – ADC Programming

Theo

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ADC Programming/microcontroller

Breadboard Test

Circuit design

Collecting input data from sensors – EMG Sensor , electrodes

Problems/Solutions Resume

- Instrumentation amplifier stage

Clipping due to wrong choice of rail voltage. (Solution: use 5V to -5V rail)

- High pass filter stage

Choice of using a second order active High pass filter (add formulae’s used to calculate additional gain and explain the choice-> mainly due to the presence of a steeper cut off high pass curve with efficient segregation of noisy low pass frequencies. -40 dB/decade achieved with segregations up to around 50 Hz). (Solution: design second order high pass filter stage to eliminate low frequencies and offset)

-Rectifier

-Integrator

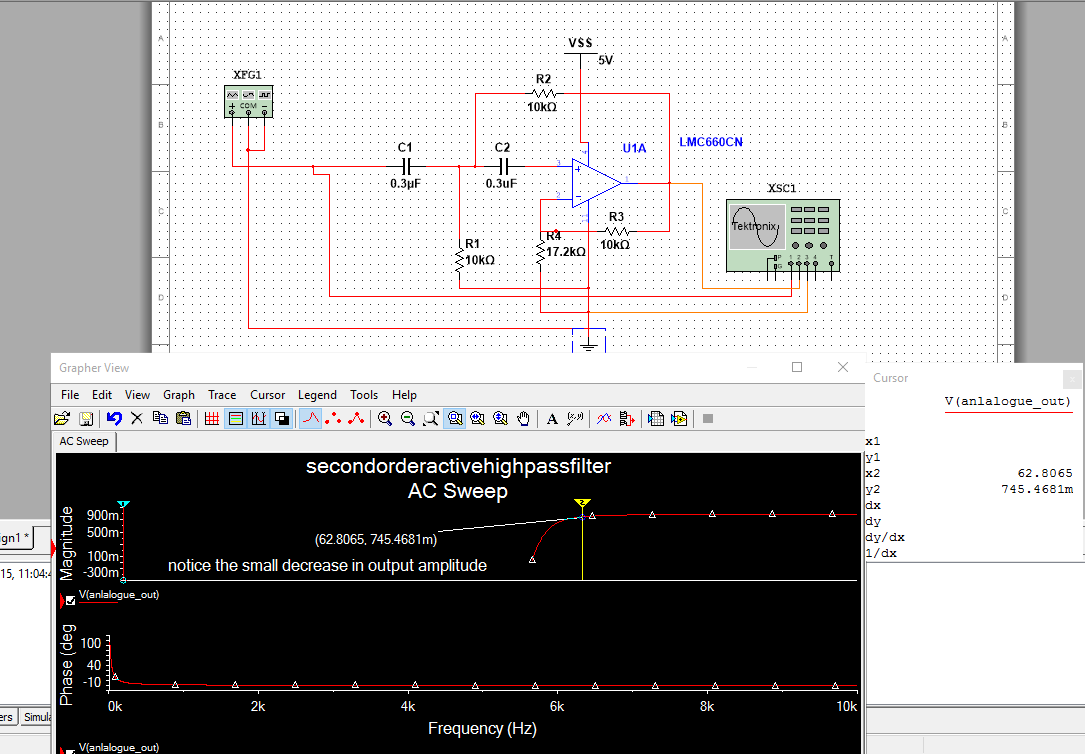
STEPS IN THE REASONING BEHIND THE NEW CIRCUIT

Figure . AC sweep for the Second Order High Pass Filter

Why we chose the LMC660?

All the features are mainly explained in the intro to the datasheet found on the Texas Instrument’s website: <http://www.ti.com/lit/ds/symlink/lmc660.pdf>.

The main feature is its performant rail to rail output swing, the common mode range that includes ground and finally the low noise features. The Integrated circuit provide 4 LMC660CN OP AMPS in a single package which is Ideal and will greatly simplify the circuit design. One of its main application is also one that will be used in our circuit, namely the Instrumentational Amplifier.

Other utilized features:

* Rail-to-Rail Output Swing
* High Voltage Gain: 126 dB
* Ultra-Low Input Bias Current: 2 fA
* Input Common-Mode Range Includes V-

STEP 2 AMPLIFYING OUR EMG SENSOR SIGNAL (TESTING AND BUILDING THE INSTRUMENTATIONAL AMPLIFIER)

Our main goal here is amplification to boost our EMG signal to a useable level. However a very particular type of Amplifier needs to be used; we will examine “the why” by trying to understand the signals involved. Indeed as research suggests, a potential can be sensed on our skin close to 2mV (depending on the individual). To fetch this potential, amplify and use it we use a sensor that consists of 3 different electrodes: One ground or reference EMG attached to a bony part of the body and the two other electrodes to the contours of the wanted muscle (the biceps in our particular case, even though I have to admit that trying to play music from our quadriceps must be pretty fun). The reason behind the use of two electrodes resides in the fact that we dramatically reduce the noise involved (from thermal noise to other disturbances of around 10-20 mV that will just blur out the wanted signal of around 2mv, moreover we don’t want to amplify the noise either so clearly two electrodes is the way to go). The best example to visualize the reasoning behind this is by just considering the two electrodes on the muscle separated by a small distance. With no activity we would have “V1=N, V2=N” with an activity “V1=A+N, V2=B+N”. “Assuming the noise picked up by the two electrodes are equal, we would arrive at a signal that is proportional to muscle activity and has a large reduction of noise V=A-B. Hence a difference amplifier with low common mode gain is wanted for this circuit.” The low input resistance of the standard issue difference amplifier will pose an issue, we thus use an instrumentational amplifier with high input impedance and low output impedance! (Wow that’s great! No buffer stage needed).

*We have decided to set our instrumentational amplifier to provide a gain close to 1000 to 1500. This will not only facilitate coding procedures in the later steps but it will allow our initial signal of approx. 2-5mV to be correctly amplified to V.*

Differential test

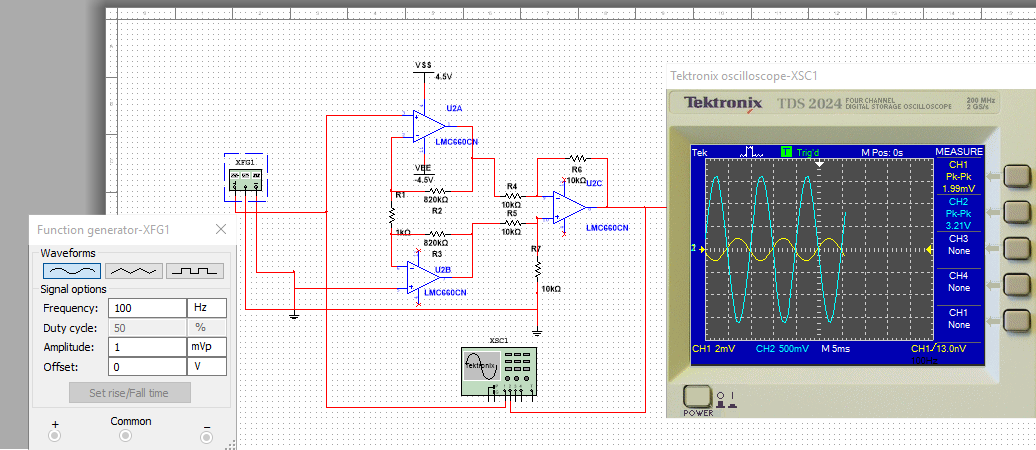
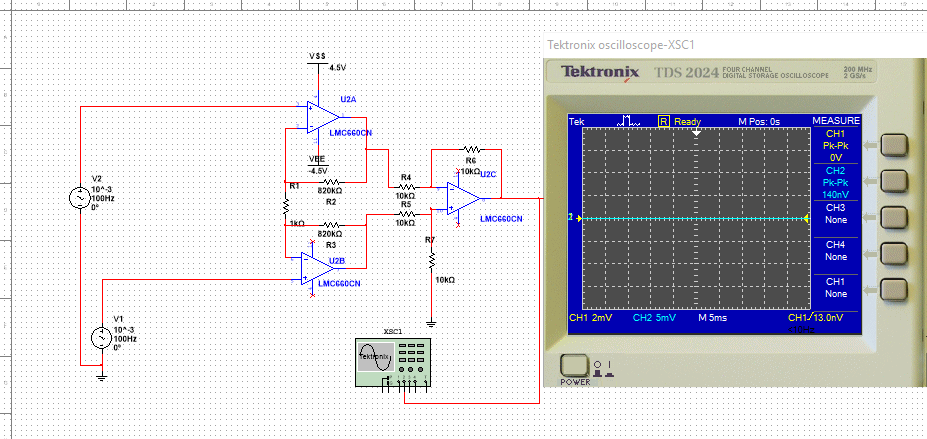


Figure The Instrumentational Amplifier Differential Test

The values can be easily derived following Sedra and Smith’s Microelectronic Circuits. It is clear that we have two buffer stages followed by a differential amp config. With unity gain .

V1 is set to +2mV pk-pk, we reach an output of 3.21V, thus a nice gain of approximately 1605.

Common mode test



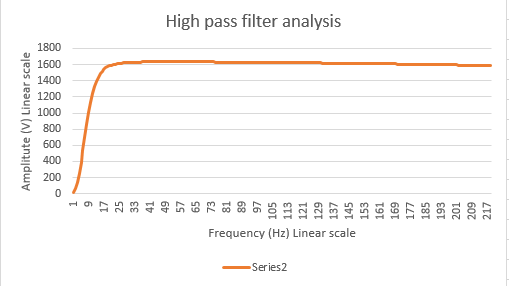
Both input were set to the same 2mV pk-pk and clearly the output is very small (nV).

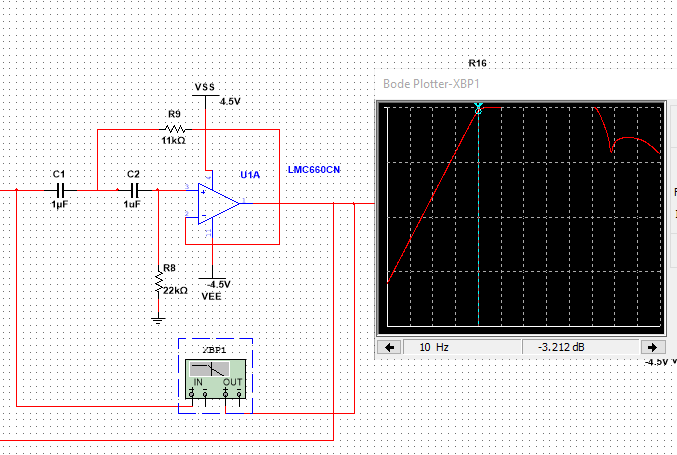
The Amplification is working, we now have to filter all unwanted frequencies and eliminate the DC offset.

STEP 3 FILTERING

“Having extracted the EMG signal and removed the common noise in the signals from the two electrodes, the next stage is to clean the signal further. From research it was found the frequency spectrum of EMG signals emitted from the bicep muscle are in a range of 10Hz to 250Hz with a peak at ~50Hz “. How bizarre… next thing you know the mains introduces loads of noise at 50Hz and we have to use a notch filter…

-Second order Active high pass filter with unity gain and cut off frequency of 10Hz with quality factor Q= 0.707 , this provides optimal db/decade steepness.





We can then add a low pass filter to remove frequencies above 250 hz and effectively create a bandpass. However I’m not fully sure about the 250Hz business, so unless we get a lot of noise at higher frequencies it’ll be fine for now.

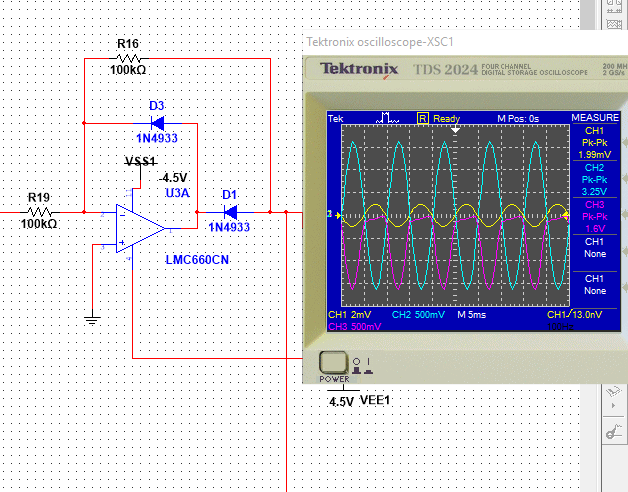
STEP 4 RECTIFYING WITH THE PRECISION RECTIFIER

Signal processing starts here as all the unwanted frequencies are now long gone.

Concept of acquiring the envelope of the signal through the rectified signal.

Why not use a simple diode to rectify our signal? We are dealing with very small signals sometimes even below the voltage threshold of the diode, hence there is a risk of losing the signal on the way and unwanted distortion, hence the use of the super diode rectifier, the latter ignores the 0.7V threshold limit.

Our configuration makes it so that the output of the rectifier will be >0, however if we turn the diodes around we get a rectified signal below 0. This is ideal since our integrator (next stage) will have a gain of -1 and thus make our final output signal to the Arduino positive and between 0-3.33V (input to Arduino).



STEP 5 ACTIVE ENVELOPE DETECTOR (AKA OP AMP INTEGRATOR)

“The integrator acts as a low pass filter, with a cut off frequency given by fc=1/(2\*pi\*R18\*C) and a DC gain of –R18/R17. For our application the cut off frequency was set to approximately 2Hz and the DC gain was set approximately to 2x so the output envelope peak will be between 1V and 2V.”

“ “ has been written by Dan Mannion not me (Bruno)