LPC2148 BASED KEYBOARD SYNTHESIZER

‘SYRUP’

IN PARTIAL FULFILMENT OF THE COURSE EEE G512 EMBEDDED SYSTEMS DESIGN

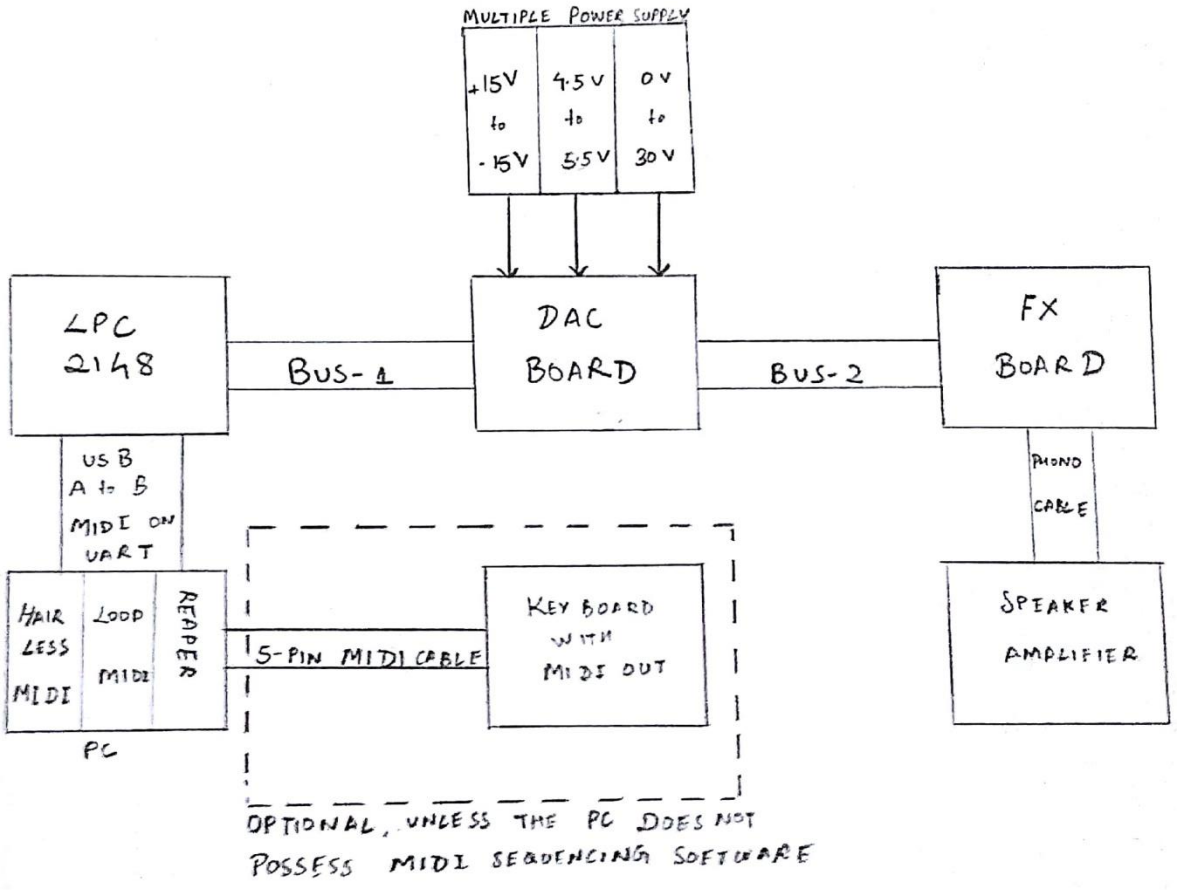
User’s Manual

Table of Contents

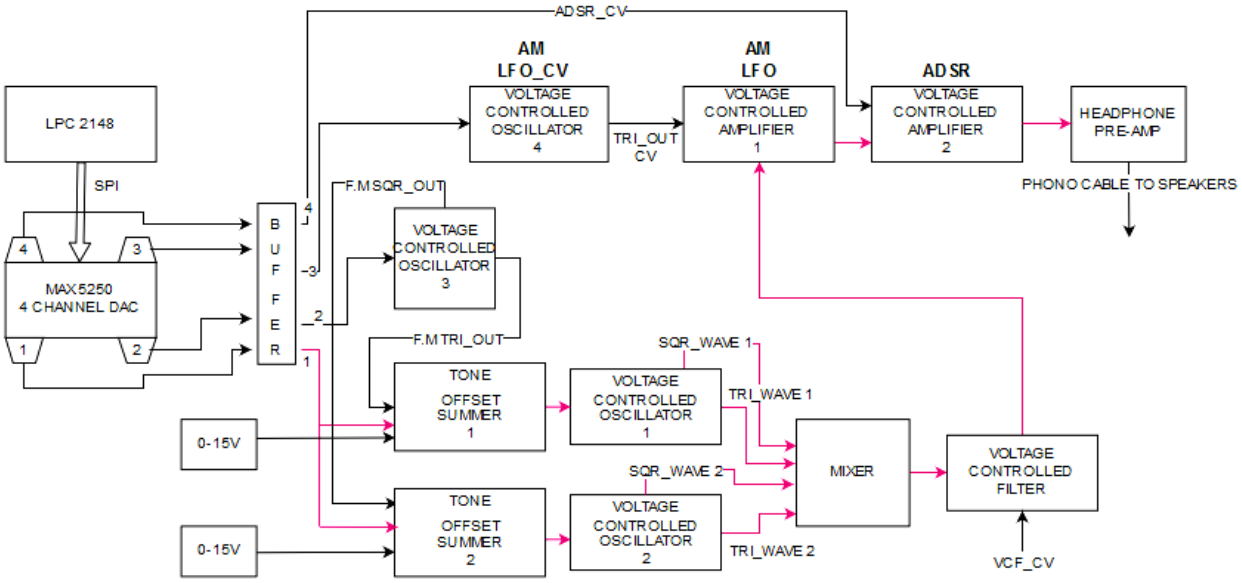
Setup and Connections

In addition to Syrup, you will need:

1. A stand or table sufficient to support Syrup
2. USB type A to 5-pin miniB cable
3. A multiple power supply, capable of supplying 15V to -15V, and an additional 5V and 2.5 V supply.
4. A MIDI controller or a computer with a MIDI interface and MIDI sequencing software.
5. A MIDI cable for connection to the MIDI Out of the MIDI controlling device that will be used.
6. Single core jumpers (Many).
7. Speaker or speaker amplifier.



Signal Flow-



Overview and Features:

'Syrup', as we'd like to call it, is an analog synthesizer. It essentially receives information on the notes that are to be played, in a non-audio format (here MIDI), and *synthesizes* the requisite sound with the help of on board analog blocks such as Voltage controlled oscillators. The sound can further be processed to the desire of the player by use of blocks such as the Voltage controlled filters and amplifiers, all of which have simplified user interfaces. MIDI, being a digital format, needs to first be converted to a usable analog signal, as that's what is understood by the on-board components. Having Digital to Analog converters, which are driven here by the ARM7 Based LPC2148, we can realize this interface. The micro-controller also gives us an excellent control over the sequencing and durations for each of the activities, to keep it in sync with the desires of the player.

Salient Features

- Monophonic
    - Means that this interface is capable of playing only one key at a time

- 4 on-board Voltage controlled oscillators
    - Tone generators (2)
    - Two Low Frequency Oscillators used for Frequency Modulation and Amplitude Modulation

- 2 on-board Voltage controlled amplifiers
    - Amplitude Modulation
    - Attack-Decay-Sustain-Release amplitude envelope generator

- 1 On-board Voltage controlled Filter

- 1 Mixer for four waveforms, two from each tone generator.

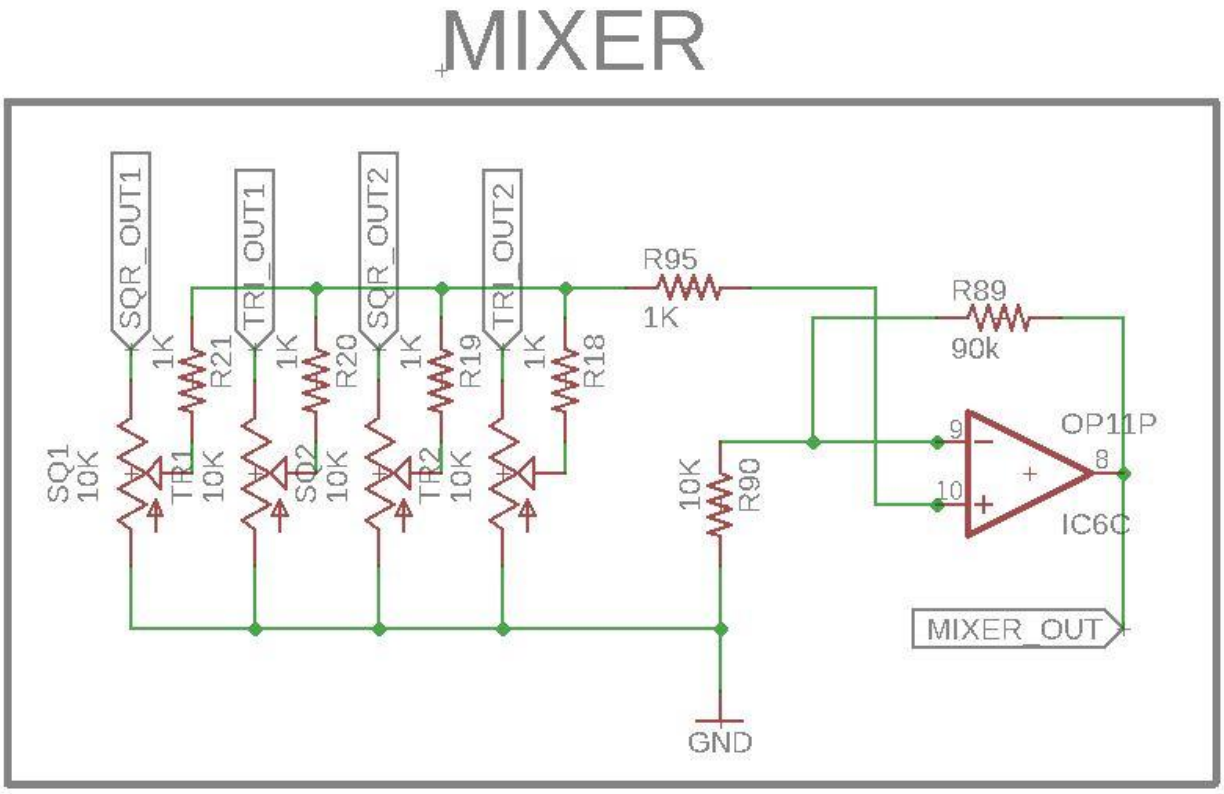
- MAX 5250 10 – bit 4 channel Serial DAC, that works on the SPI Protocol.

- An on-board headphone pre-amp, that helps bring the signal to line-level.

Components and Configuration

Now let's take a look at the individual module components that make up the Syrup Synthesizer, starting with the Mixer section. Then we'll move on to the Oscillators, Filters, Envelopes, and Output Sections, the LFO and Modulation sections.

A. The Mixer Section



The Mixer combines the main sound sources on the Syrup. It's a good place to start when creating a new sound from scratch, or figuring out how a sound is put together. The levels of all four of Syrup's sound sources can be individually adjusted.
The four sound sources are:

1. SQUARE from OSCILLATOR 1
2. TRIANGLE from OSCILLATOR 1
3. SQUARE from OSCILLATOR 2
4. TRIANGLE from OSCILLATOR 2

Each sound source in the Mixer has a dedicated level control.

The audio output of the Mixer is routed to the Filter.

B. The Tone Offset Summer

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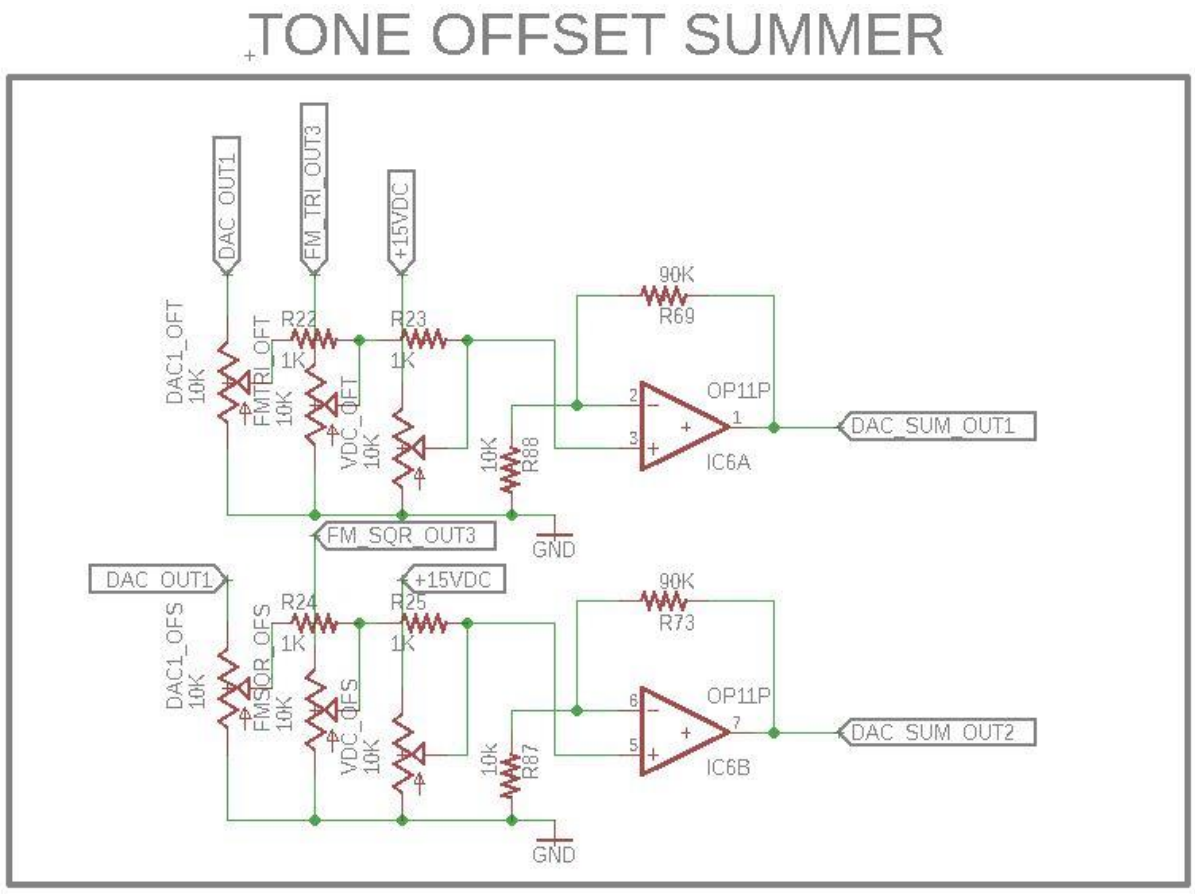
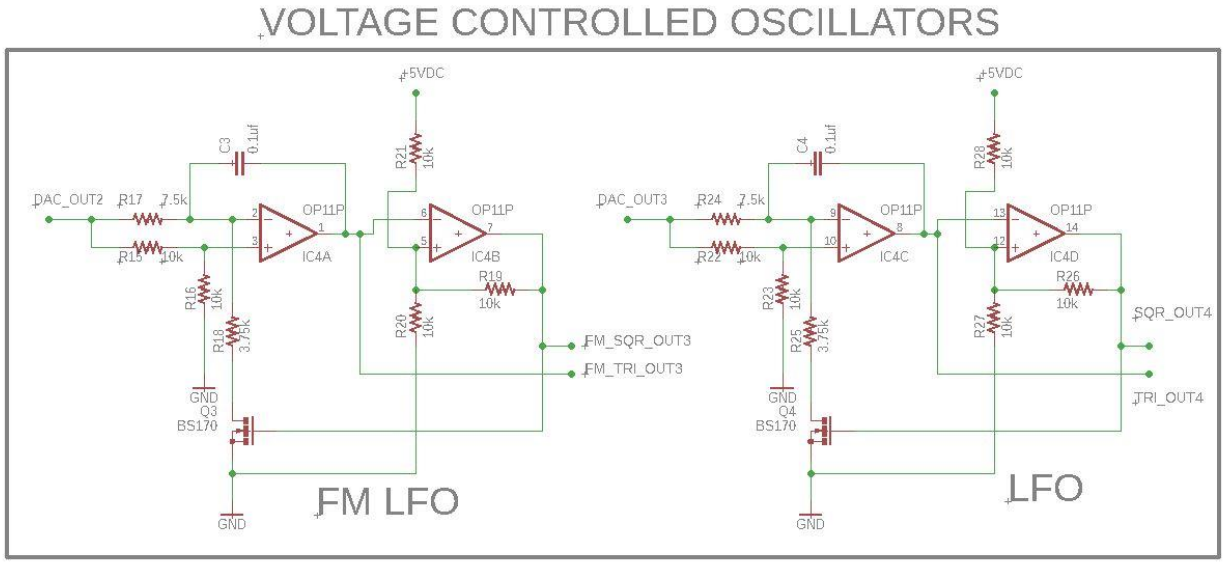


Here the 3 potentiometers allow us to tune the two oscillators independently to any frequency within the range of the oscillators. The DAC1_OFX pots give control over how sensitive the oscillator is to a change in input control voltage. The FM_XXX_OUT3 pots are used to control the amount of FM applied to the signal. Since the FM_XXX_OUT3 signals are oscillating signals, they will cause the output of the summer to have some oscillation which in turn will cause a certain amount of oscillation in the ouput of the tone oscillators in terms of frequency hence giving the user control over frequency modulation. The +15 OFFSET pots are simply used to add offset to change pitch.

C. Voltage Controlled Oscillator [VCO]

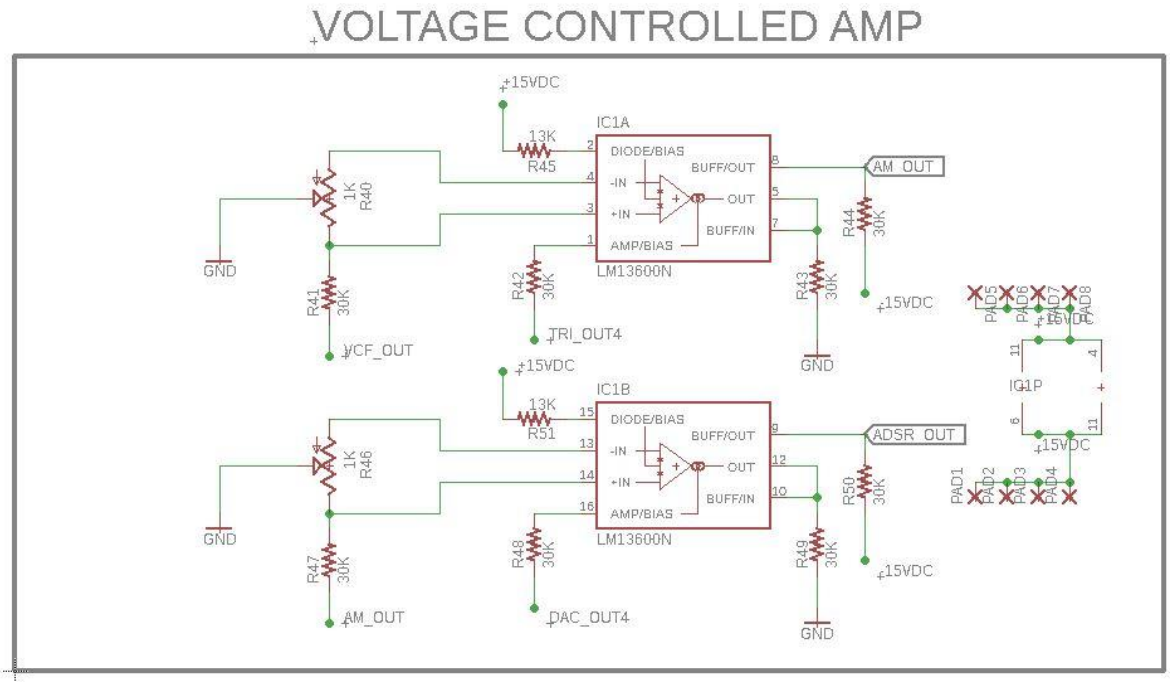
These are the fundamental building blocks of all synths. They use *control voltage* as a parameter to vary their output frequency. Syrup has 4 on board VCOs. Two are dedicated to producing the raw tones, and two are used as low frequency oscillators.



To briefly explain the function of this circuit, for block ‘FM LFO’ the capacitor C3 and resistor R17 essentially control the max/min frequency of the oscillator. On applying a positive input voltage the capacitor starts charging, once the output node of IC4A reaches a set threshold the Schmidt Trigger configured IC4B op amp switches and causes the MOSFET to pull current and effectively discharge the capacitor. This gradual charging and discharging produces a triangle wave at the output of op amp IC4A and a square wave of the same frequency at the output of op amp IC4B.

D. Voltage Controlled Amplifier [VCA]

Amplitude modulation, or Tremolo, is an amazing wave-shaping tool for any musician. Using the LM13700 Trans-conductance Op Amp we devised a circuit to fully control the amplitude of the output of the mixer stage. To add character, we made the oscillating frequency mildly vary with the notes, so as to obtain a distinct unique flavoured sound.



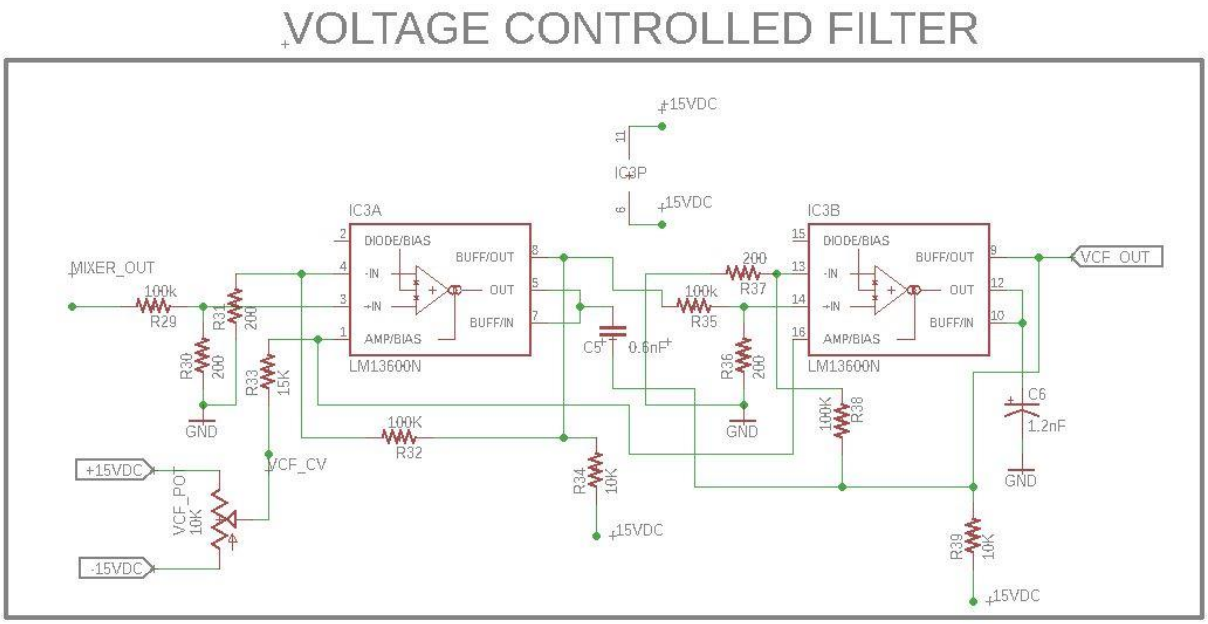
The control voltage affects the output BJTs on the IC and hence upon applying a negative voltage to it, we get a corresponding linear change in output gain. Hence if one applies an oscillating input to the control voltage, one can achieve amplitude modulation. The ADSR VCA is used to control the transient response of a key press.

- Attack:
    - The time taken by the output to go from 0% to 100% output from the time of key press
- Decay:
    - Decay is the time it takes for the signal to fade from 100% to sustain level [SUS%]
- Sustain:
    - The Sustain control sets the corresponding level (SUS%) for the sustained part of the envelope.
- Release:

- The Release controls the time taken to drop from SUS% to 0% output.

E. Voltage Controlled Filter [VCF]

Effects such as the Wah- effect, widely used in instruments such as electric guitars, are made possible by selectively fading in and out the harmonics in a waveform such as a Triangle or a Square. This is made possible by the use of a VCF, behaving as a low-pass filter with a cut-off frequency determined by a control voltage, as it exercises a control on the trans-conductance of the LM13700.
The circuit we chose to implement was a two pole Butterworth filter, using LM13700's.



F. Tuning Syrup

Through testing and calibration we set up a lookup table for the DAC to refer to whenever a note is played. For example if the player plays a note with a MIDI value of 64, the value send to the DAC will be 220. The reason this is important is that since our VCO varies linearly with voltage, hence causing the frequency to depend linearly on control voltage, we need to feed it non linear values because musical notes rise exponentially in frequency. Ergo A4 = 440Hz hence A5 = 880Hz but A3 = 220Hz. So having equal temperaments would make for an unplayable instrument.

1. So first the player is to find A2 on a tuner and tune to that.
2. Tune the DAC_OFFSET pot to match the note, use the 15VDC offset pot if needed.
3. Then play A3 with the same settings, and try to get close using only the DAC_OFFSET pot.
4. Repeat steps 2 and three till playing those two notes on your keyboard produces those two notes exactly.
5. Rest of the notes are set with offsets taking this tuning method into account. Hence you need not tune for any other notes. Fine tuning is subjective.

G. User Parameter Configuration

Syrup has been provided with three push buttons, which can be used to configure parameters, namely

- ADSR Parameters
    - Attack
    - Decay
    - Sustain
    - Release
- Frequency modulated LFO
- Amplitude Modulated LFO

Each of these parameters, can be assigned a value from 0 to 9, corresponding to the amount of effect desired.