# The Notator

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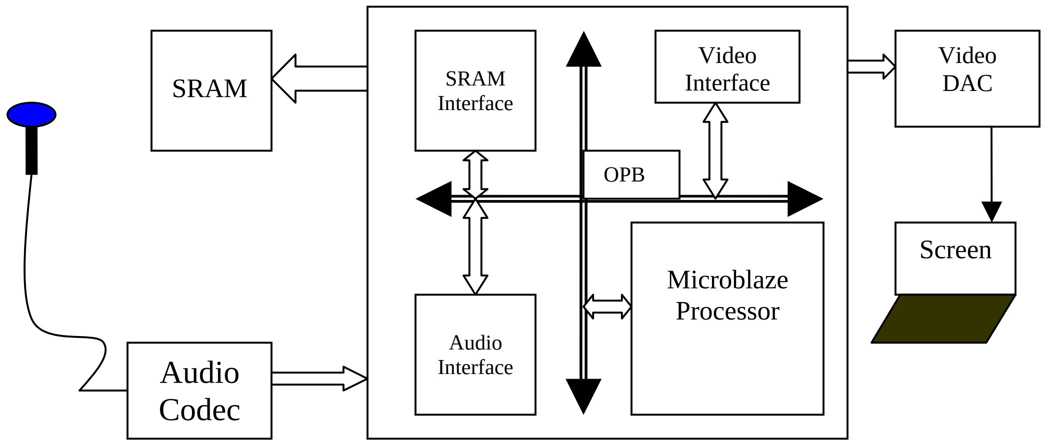
We intend to create a system that is designed to convert a human-produced musical symbol into musical notes and intervals that could be displayed on a computer screen, or conceivably in some sort of memory. The intent would be to receive an audio signal of a single voice or musical instrument. After converting the analog signal into a digital signal, we would perform a fast Fourier transform (FFT) on the signal to find its spectral elements, we would find which frequency has the highest amplitude above a certain threshold (this would presumably be $F_0$, the fundamental frequency.) Every few milliseconds we would check the signal again for any change. A transition from silence to a note, note to note, or note to silence, would indicate the beginning or end of a note, or both. The FFT and note analysis would most likely take place within a C program that interacts with memory, the audio input, and the display through the OPB bus.

The applicability of this design would be in some kind of portable device that would allow musicians to sing into it as they are going from place to place so that they can make a note of some tune that they have devised in their head so that they can transfer it to music paper or some other form of notation at a later time. Even as a non-portable device, there is plenty of value in being able to directly produce notes and musical intervals from an audio signal.

The overall layout of our design is shown in the following figure:




As shown, the audio signal enters through the microphone and the audio codec converts the analog signal into a digital signal. The audio interface (which we will create) will interact with the codec to receive the signals and will do some initial processing on them. At that point, it will probably make the relevant data available so that a C program on the Microblaze can read it from the audio interface. The Microblaze will have access to the on-board SRAM for various kinds of storage.

A C program on the Microblaze will perform a FFT on the incoming signal to find the strengths of the various notes in the signal, and then attempt to find the strongest note in the signal ($F_0$). We will draw upon the findings of the group that produced a spectrum analyzer as their project last year. The program would then keep track of the note it was receiving, and its duration, until the note stopped sounding or a different $F_0$ were detected. This pseudocode outlines the basic operation of the main program:

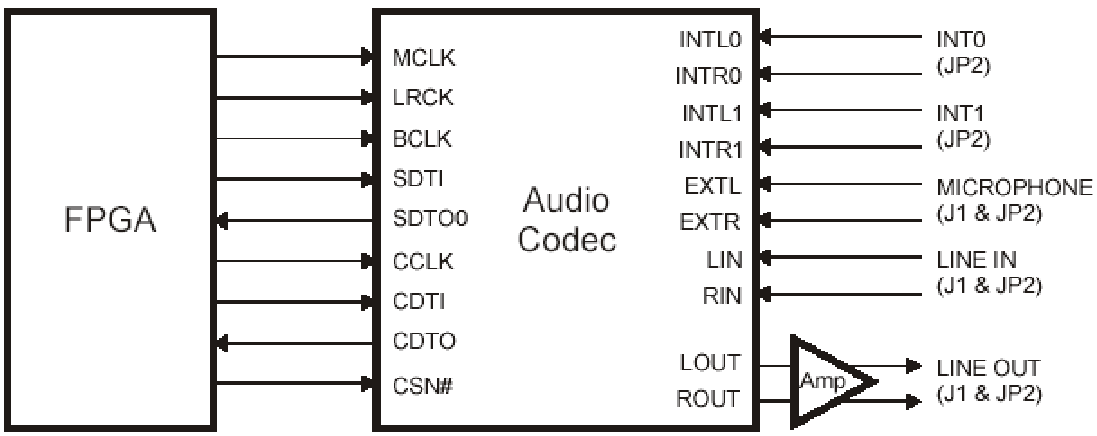
```
while(1){
      analysis = FFT(signal)
      current_note = findf0(analysis)
      if(current_note != last_note){
            display(currtime - start_time)
            start_time = currtime
            display(current_note)
            last_note = current_note
      }
      sleep(10ms)
}
```

If we find that we are able to achieve this part of the project without too much trouble, we may attempt a more attractive display through some complicated interaction with the VGA DAC, but at least initially, we will display the output of the program in text, using an interaction with the display similar to lab 2.

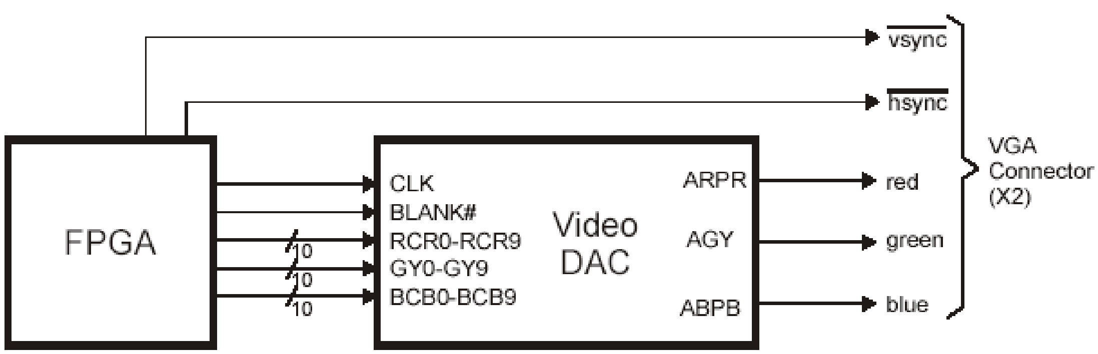
# Appendix 1:

Peripherals on the board and communication protocols.

We intend to use the Xilinx board's audio codec to decode incoming sound, and the VGA DAC to display the output of our program. The following diagrams show how these two devices are connected to the FPGA:

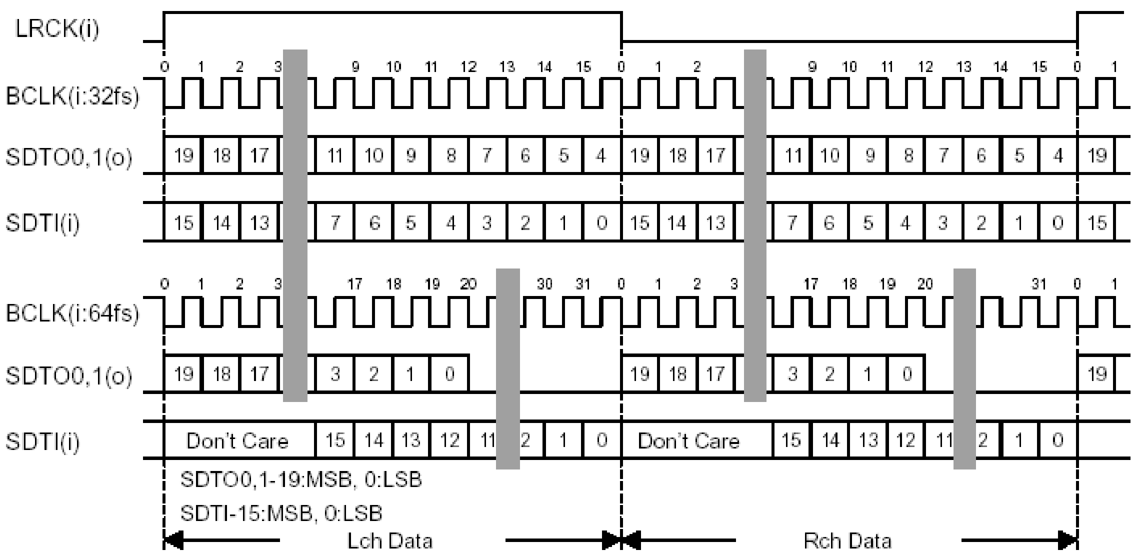



Interaction between the FPGA and the Audio Codec




Interaction between the FPGA and the Video DAC

The following is a timing diagram of the audio serial interface that the audio codec uses:



# Appendix 2:

## Musical quantities

The following is a table of the frequencies of musical notes $C_0$ through $C_8$. We will attempt to recognize about four octaves somewhere within this range.

| Note | Frequency(Hz) | Note | Frequency (Hz) | Note | Frequency(Hz) |
|---|---|---|---|---|---|
| $C_0$ | 16.35159783 | $G^{\#}_2/A^b_2$ | 103.8261744 | $E_5$ | 659.2551138 |
| $C^{\#}_0/D^b_0$ | 17.32391444 | $A_2$ | 110 | $F_5$ | 698.4564629 |
| $D_0$ | 18.35404799 | $A^{\#}_2/B^b_2$ | 116.5409404 | $F^{\#}_5/G^b_5$ | 739.9888454 |
| $D^{\#}_0/E^b_0$ | 19.44543648 | $B_2$ | 123.4708253 | $G_5$ | 783.990872 |
| $E_0$ | 20.60172231 | $C_3$ | 130.8127827 | $G^{\#}_5/A^b_5$ | 830.6093952 |
| $F_0$ | 21.82676446 | $C^{\#}_3/D^b_3$ | 138.5913155 | $A_5$ | 880 |
| $F^{\#}_0/G^b_0$ | 23.12465142 | $D_3$ | 146.832384 | $A^{\#}_5/B^b_5$ | 932.327523 |
| $G_0$ | 24.49971475 | $D^{\#}_3/E^b_3$ | 155.5634919 | $B_5$ | 987.7666025 |
| $G^{\#}_0/A^b_0$ | 25.9565436 | $E_3$ | 164.8137785 | $C_6$ | 1046.502261 |
| $A_0$ | 27.5 | $F_3$ | 174.6141157 | $C^{\#}_6/D^b_6$ | 1108.730524 |
| $A^{\#}_0/B^b_0$ | 29.13523509 | $F^{\#}_3/G^b_3$ | 184.9972114 | $D_6$ | 1174.659072 |
| $B_0$ | 30.86770633 | $G_3$ | 195.997718 | $D^{\#}_6/E^b_6$ | 1244.507935 |
| $C_1$ | 32.70319566 | $G^{\#}_3/A^b_3$ | 207.6523488 | $E_6$ | 1318.510228 |
| $C^{\#}_1/D^b_1$ | 34.64782887 | $A_3$ | 220 | $F_6$ | 1396.912926 |
| $D_1$ | 36.70809599 | $A^{\#}_3/B^b_3$ | 233.0818808 | $F^{\#}_6/G^b_6$ | 1479.977691 |
| $D^{\#}_1/E^b_1$ | 38.89087297 | $B_3$ | 246.9416506 | $G_6$ | 1567.981744 |
| $E_1$ | 41.20344461 | $C_4$ | 261.6255653 | $G^{\#}_6/A^b_6$ | 1661.21879 |
| $F_1$ | 43.65352893 | $C^{\#}_4/D^b_4$ | 277.182631 | $A_6$ | 1760 |
| $F^{\#}_1/G^b_1$ | 46.24930284 | $D_4$ | 293.6647679 | $A^{\#}_6/B^b_6$ | 1864.655046 |
| $G_1$ | 48.9994295 | $D^{\#}_4/E^b_4$ | 311.1269837 | $B_6$ | 1975.533205 |
| $G^{\#}_1/A^b_1$ | 51.9130872 | $E_4$ | 329.6275569 | $C_7$ | 2093.004522 |
| $A_1$ | 55 | $F_4$ | 349.2282314 | $C^{\#}_7/D^b_7$ | 2217.461048 |
| $A^{\#}_1/B^b_1$ | 58.27047019 | $F^{\#}_4/G^b_4$ | 369.9944227 | $D_7$ | 2349.318143 |
| $B_1$ | 61.73541266 | $G_4$ | 391.995436 | $D^{\#}_7/E^b_7$ | 2489.01587 |
| $C_2$ | 65.40639133 | $G^{\#}_4/A^b_4$ | 415.3046976 | $E_7$ | 2637.020455 |
| $C^{\#}_2/D^b_2$ | 69.29565774 | $A_4$ | 440 | $F_7$ | 2793.825851 |
| $D_2$ | 73.41619198 | $A^{\#}_4/B^b_4$ | 466.1637615 | $F^{\#}_7/G^b_7$ | 2959.955382 |
| $D^{\#}_2/E^b_2$ | 77.78174593 | $B_4$ | 493.8833013 | $G_7$ | 3135.963488 |
| $E_2$ | 82.40688923 | $C_5$ | 523.2511306 | $G^{\#}_7/A^b_7$ | 3322.437581 |
| $F_2$ | 87.30705786 | $C^{\#}_5/D^b_5$ | 554.365262 | $A_7$ | 3520 |
| $F^{\#}_2/G^b_2$ | 92.49860568 | $D_5$ | 587.3295358 | $A^{\#}_7/B^b_7$ | 3729.310092 |
| $G_2$ | 97.998859 | $D^{\#}_5/E^b_5$ | 622.2539674 | $B_7$ | 3951.06641 |
| | | | | $C_8$ | 4186.009045 |

Next is a table of the ratio and logarithmic relationships of musical intervals (example: if the ratio between a note and the one after it is 1.2599 or 0.7937, then they are a major third apart. 1.2599 would indicate a descending major third and 0.7937 would indicate an ascending major third.)

| Interval | upper/lower | lower/upper | log base e | log base 2 |
|---|---|---|---|---|
| P1 | 1 | 1 | 0 | 0 |
| m2 | 1.059463094 | 0.943874313 | 0.057762266 | 0.083333333 |
| M2 | 1.122462048 | 0.890898718 | 0.115524531 | 0.166666667 |
| m3 | 1.189207115 | 0.840896415 | 0.173286797 | 0.25 |
| M3 | 1.25992105 | 0.793700526 | 0.231049063 | 0.333333333 |
| P4 | 1.334839854 | 0.749153538 | 0.288811328 | 0.416666667 |
| A4/D5 | 1.414213562 | 0.707106781 | 0.346573594 | 0.5 |
| P5 | 1.498307077 | 0.667419927 | 0.40433586 | 0.583333333 |
| m6 | 1.587401052 | 0.629960525 | 0.462098125 | 0.666666667 |
| M6 | 1.681792831 | 0.594603557 | 0.519860391 | 0.75 |
| m7 | 1.781797436 | 0.561231024 | 0.577622657 | 0.833333333 |
| M7 | 1.887748626 | 0.529731547 | 0.635384922 | 0.916666667 |
| P8 | 2 | 0.5 | 0.693147188 | 1 |