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| Feature Rundown | | | | | |
| No. | Feature | Owner | FPGA Input Used | Feature Description | Display (Figures) |
| 1 | Basic Voice Visualizer | Team | SW0 | When SW0 = 0, the VGA displays a 50 Hz ramp wave  (Figure 1)  When SW0 = 1, the VGA displays the voice waveform  (Figure 2) | Figure 1. & 2. |
| 2.A, | Volume Indicator | Daniel | N.A. | The peak volume of the voice waveform is represented from 0 to 12, in the 7SEG display (displays 0 to 12 in the default state of the 7SEG)  and from LED11 to LED0 (LEDs light up from the right to left, based on the volume of the voice waveform from 0 to 12).  The volume displayed will slowly falloff which makes it easier to see when the volume level drops. | Figure 3. |
| 2.B. | VGA | Jia Ying | VGA | The VGA port is enabled to output graphics to a display. Backgrounds, axes, ticks, grid lines, various waveforms and on screen elements rely on this module to draw them pixel-by-pixel on to the display. The resolution is 1280 by 1024 pixels. |  |

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| No. | Feature | Owner | FPGA Input Used | Feature Description | Display (Figures) |
| 3 | Mouse | Jia Ying | USB PS/2  C17: Mouse Clock  B17: Mouse Data | A regular USB mouse that is compatible with the PS/2 standard can be plugged into the USB port on the FPGA to control majority of the features of the audio visualiser. Hot plugging of the mouse is supported.  A cursor in the form of a “Plus” sign is drawn on the screen to act as the pointer of the mouse. The cursor will flash Red to indicate that it is held down. The various interactions capable by the mouse will be elaborated further in feature 4. | Figure 4. |
| 4 | On-Screen Display and Interface | Jia Ying | N.A. | Various useful control elements and information is displayed on screen for a more user friendly experience. Options selected are also highlighted for readability, and are synced with the 7-segment menu. The elements are as follows.   1. Volume - apart from displaying current volume levels using the LEDs on the board, they are also displayed on screen in the form of a vertical bar, growing and changing colour as the volume gets louder. 2. Frequency - For sampling constant frequency sounds, their frequencies are displayed on-screen at all times (on top of on the 7-Segment display) 3. Mode changer - There are a total of 11 ways to visualise the audio sample, which could be cumbersome to navigate using the on-board buttons. Hence, they are presented as 11 on-screen buttons that can be easily switched by using the mouse. 4. Colour changer - The 5 colour sets can also be toggled easily by using the on-screen buttons and the mouse. | Figure 4. & Figure 5. & Figure 19. |

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| No. | Feature | Owner | FPGA Input Used | Feature Description | Display (Figures) |
| 5 | 7-Segment Configuration Menu | Daniel | BTNC, BTNU, BTND, BTNL, BTNR | A configuration menu is also added to the BASYS 3 7-segment display. This menu allows the user to customise the settings of the display. The menu is controlled via BTNU, BTND, BTNL and BTNR to navigate through the menu, with BTNC acting as a confirmation button. When in mode 3 and above, the current settings are saved and the user can preview the new options in each mode. Upon exiting a specific mode, the previous setting for that mode is still retained. Options selected are synced with the on-screen display interface.  (For eg. Using color scheme 3, when in mode 3 (color selector), the user can preview other color schemes, and if no new scheme is selected, color scheme 3 will be displayed again after exiting mode 3)  The modes are explained below: | Figure 7. |
| 5.1 | Locking Feature & Oscilloscope Display Settings | Daniel | BTNC, BTNU, BTND, BTNL, BTNR SW15, SW14, SW13, SW12 | Locking feature and oscilloscope display settings are toggled ON or OFF in the 7-segment menu, by accessing mode 0.  BTNL and BTNR are used to navigate through the 4 options, which are LOCK, AXIS, GRID, TICK. By default, LOCK == 0, AXIS / GRID / TICK == 1.  LOCK controls whether the waveform is locked, while AXIS / GRID / TICK controls whether the axis, grid, and ticks respectively in the display or turned ON or OFF.  SW15, SW14, SW13, SW12 also control these 4 options respectively. | Figure 6. & Figure 7. |

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| No. | Feature | Owner | FPGA Input Used | Feature Description | Display (Figures) |
| 5.1 | Locking Feature & Oscilloscope Display Settings (Continued) |  |  | SW15 == 1 or LOCK == 1: waveform is frozen  SW14 == 1 or AXIS == 1: axis is turned on  SW13 == 1 or GRID == 1: grids are turned on  SW12 == 1 or TICK == 1: ticks are turned on  LED15 also shows the status of SW15 or LOCK. It lights up when the waveform is locked / frozen. | Figure 6. & Figure 7. |
| 5.2 | Waveform Parameter Display | Daniel | BTNC, BTNU, BTND, BTNL, BTNR | 7-Segment display shows the current frequency (Hz) and volume (%) of the waveform.  Unlike the original requirement (showing volume from 0 to 12), this mode shows the volume from 0% to 100%, giving more details of how loud the waveform is. | Figure 18. & Figure 19. |
| 5.3 | Color Selector | Daniel | Allows for previewing of the other possible color schemes (5 in total). Pressing BTNC will confirm and set the selected color scheme, and return back to mode 1. | Figure 7. |
| 5.4 | Waveform Mode Selector | Daniel | Allows for previewing of the other possible waveform visualisation (4 in total). Pressing BTNC will confirm and set the selected waveform, and return back to mode 1. |
| 5.5 | Waveform History Selector | Daniel | Allows for previewing of the other possible waveform history visualisation (3 in total). Pressing BTNC will confirm and set the selected waveform history, and return back to mode 1. |

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| No. | Feature | Owner | FPGA Input Used | Feature Description | Display (Figures) |
| 5.6 | Circle Waveform Selector | Daniel | BTNC, BTNU, BTND, BTNL, BTNR | Allows for previewing of the other possible circle waveform visualisation (4 in total). Pressing BTNC will confirm and set the selected circle waveform, and return back to mode 1. | Figure 6. & Figure 7. |
| 6. | Waveforms | Team | N.A | There are 11 waveforms that can be selected. Of which, 1 is a special waveform that will be listed separately. The waveforms are classified into: Waveform / history / circle (6.1 / 6.2 / 6.3) |  |
| 6.1.1 | Volume Waveform | Jia Ying | N.A | Displays the waveform as picked up by the PMOD. | Figure 2. |
| 6.1.2 | Filled Volume Waveform | Jia Ying | N.A | Same as 6.1, but fills the distance between the values on the waveform with the axis. Improves readability. | Figure 8 |
| 6.1.3 | Bar Volume Waveform | Daniel | N.A | Displays the peak volume of the waveform in intervals. | Figure 9. |
| 6.1.4 | Block Volume Waveform | Daniel | N.A | Displays the peak volume in the same way as the bar volume waveform, except it displays in blocks instead (each block corresponds to 10% of the volume). | Figure 10. |
| 6.2.1 | Volume History Waveform | Daniel | N.A | Updates the peak volume of the waveform in real time. Allows for gradual drop-off for readability. | Figure 11. |
| 6.2.2 | Frequency History Waveform | Daniel | N.A | Same as the volume history waveform, except it takes the frequency of the waveform instead. | Figure 12. |

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| No. | Feature | Owner | FPGA Input Used | Feature Description | Display (Figures) |
| 6.3.1 | Volume Waveform (Circle) | Daniel | N.A | Displays the peak volume of the waveform, and visualises it as a circle. The circle is divided into 8 arcs, and are updated clockwise. The entire circle cycle is updated at 2Hz for readability.  A separate circle border is made, and updates at the same speed. An arc of the border circle is highlighted to show which arc is currently being updated in the waveform. | Figure 14. |
| 6.3.2 | Volume Waveform with Slow Drop-off (Circle) | Daniel | N.A | Same as volume waveform (circle) / 6.3.1. Except there is an added slow fall-off should there be a drop in volume. | Figure 15. |
| 6.3.3 | Frequency Waveform (Circle) | Daniel | N.A | Same as volume waveform (circle) / 6.3.1, except it shows the frequency instead. | Figure 16. |
| 6.3.4 | Frequency Waveform with Slow Drop-off (Circle) | Daniel | N.A | Same as volume waveform with slow drop-off (circle) / 6.3.2, except it shows the frequency instead. | Figure 16. |

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| No. | Feature | Owner | FPGA Input Used | Feature Description | Display (Figures) |
| 6 | Music Tuner | Daniel | N.A. | Accessed via the 7-Segment configuration menu. Displays the musical note on the 7-segment that corresponds to the frequency of a sound that is played. Requires the user to play the note at a consistent pace.  Tuner works for notes A3 (220Hz) to G7 (3140 Hz). For a given note, the 7-segment display will show if the note is on the higher or lower end for that note, with a H and L respectively. | Figure 17. |
| 7 | Nyan Cat | Jia Ying | N.A. | By selecting this audio visualisation, the user is greeted by the internet famous “Nyan Cat”, followed by a rainbow which responds to changes in volume of the audio samples captured.  Mapped to mode 5, option 3 (waveform history) | Figure 13. |

References

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Available: <https://reference.digilentinc.com/learn/programmable-logic/tutorials/basys-3-general-io/start> [Accessed on: 2 April 2019]

MParygin, 2014, VGA Font Generator [Online]

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| Figure 1. Ramp wave when SW0 == 0 | Figure 2. Default waveform when SW0 == 1 | Figure 3. LEDs and 7-segment display volume indicators. Showing 9 on the volume indicator |

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| Figure 4. Cursor and Waveform Changing On-Screen interface | Figure 5. On-Screen volume and colour changing interface | Figure 6. 7-Segment menu display (Displaying the locking feature) |

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| Figure 7. 7-segment menu chart | | |

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| Figure 8. Filled Waveform | Figure 9. Bar waveform | Figure 10. Block waveform |
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| Figure 11. Waveform volume history | Figure 12. Waveform frequency history | Figure 13. Nyan Cat waveform |
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| Figure 14. Volume circle Waveform | Figure 15. Volume circle Waveform with slow fall-off | Figure 16. Frequency circle waveform |

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| Figure 17. Tuner (Showing note E5) | Figure 18. Volume indicator (showing 3%) | Figure 19. Frequency Indicators (showing 548 Hz on the 7SEG, and a separate instance, showing 761Hz on the display) |