IEP Design Project. The Level Synthesiser

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Summary

The IEP design challenge focused on developing an electronic level synthesiser that produces frequency outputs through a speaker based on the tilt of a breadboard. The circuit includes key components, as outlined in Figure 1, along with additional elements such as buffers, an ADP3000 voltage regulator, and a breakout board. Using tools like the PicoScope, individual components were analysed and tested to better understand their functions and visualise their responses. Once verified, the full circuit was assembled and tested to ensure accurate frequency outputs. The results were captured through videos and oscilloscope traces, showcasing the synthesiser's performance. This project integrates multiple electronic principles and demonstrates how various components work together to create a functional device with real-world applications.

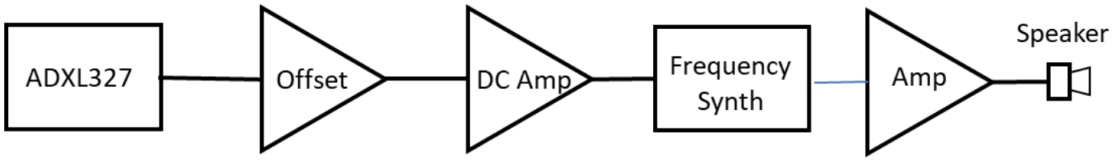

Figure 1 Fundamental Structure of the level synthesiser.

Design

Initially an ADP3000 voltage regulator was used, which decreased V_{usb} to 3.3V, the max limit for the ADXL327 accelerometer. This ensured that a safe supply of voltage was provided to the accelerometer, to avoid any damage to the component.

The accelerometer, once it was supplied with the right voltage, produced varying voltage outputs as it was tilted about its 3 axes. The ADXL327 accelerometer measures acceleration by detecting the deflection of a polysilicon micromachined structure suspended over a silicon wafer. This deflection alters a differential capacitor, producing analogue voltage outputs proportional to both static acceleration (gravity) and dynamic acceleration (motion, shock, or vibration).

To ensure signal integrity, the output from the X-axis was fed into a basic (op-amp) buffer. The buffer served two key functions: minimising noise and preventing loading effects on the accelerometer. By presenting a high input impedance and a low output impedance, the buffer allows the signal to be transferred with minimal current draw while maintaining the original voltage level. This helps stabilise the signal before further processing.

The output voltage from the buffer was supplied to a difference amplifier, to amplify the voltage range to about 2V, and to offset the voltages output by the accelerometer to start from zero. The difference amplifier used can be seen in figure 2, with R_1 = 2.2kΩ and R_2 = 6.8kΩ. A potentiometer was used to set V_1 to the minimum output voltage from the accelerometer (around 1.1V), so theoretically V_{out} should vary from 0V to V_{max}, where V_{max} = $\frac{6.8}{2.2}$(V_{accmax} – offset).

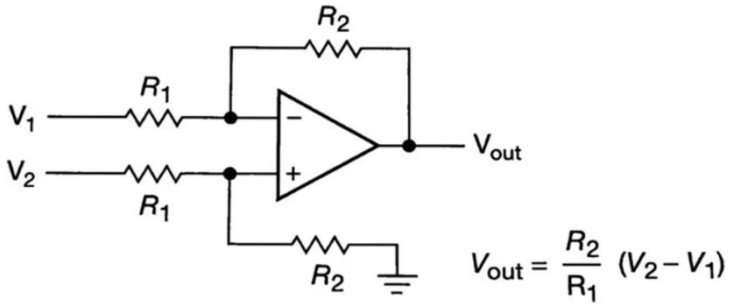

Figure 2 Difference Amplifier Diagram

The AD654 chip is an audio tone generator, and it has 8 pins, as can be seen by figure 3. They combine to produce the frequency output dictated by the function $F_{out} = V_{in}/(10V)(R1 + R2)C_T$. The output produced is a square wave, with frequencies that vary as V_{in} changes. Additionally, R2 is a variable resistor which can be tuned to adjust the frequency range. The values used in the build were: R1+R2 = 9.4kΩ ; C_T = 10nF, which should give a range of around 0 – 2000 Hz, which is a good broad range.

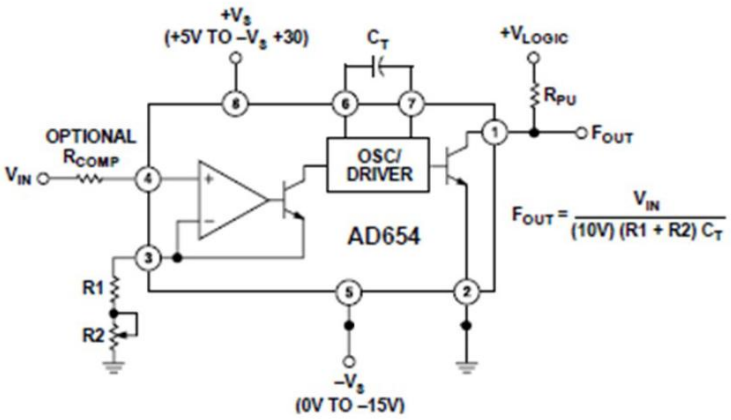

Figure 3 Audio Tone Generator Diagram

Finally, the final circuit included a loudspeaker driver amplifier, which was Class D amplifier based on the ZN3310 MOSFET. It amplified the output signal and connected the output from the audio tone generator to the speaker. As can be seen by the video, the circuit works perfectly, with minimal distortion, due to the buffer used and with a broad range of

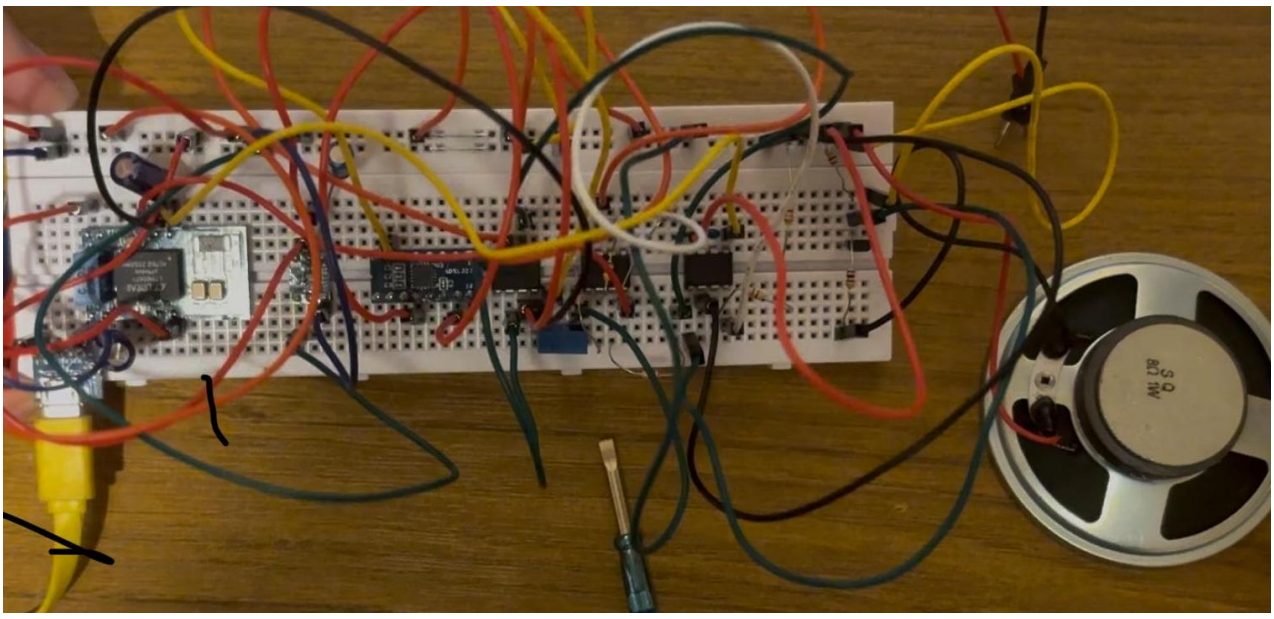

Figure 4 Finished Level Synthesiser Circuit

frequencies.

Build

The completed circuit, shown in Figure 4, was carefully assembled on the breadboard with an emphasis on maintaining an efficient and organised layout. Components were placed as close together as possible to keep wire lengths to a minimum, reducing the risk of noise and signal interference.

One of the key challenges during assembly was ensuring reliable connections while avoiding issues such as shorts or crossed wires. To overcome this, jumper wires and stripped-down

connectors were used to create secure, compact links. Power distribution was managed using rail techniques to ensure consistent voltage delivery across all components without significant drops.

The circuit was constructed incrementally, testing each section individually before incorporating it into the full system. This methodical approach helped to identify and resolve wiring errors or faulty components early in the process. After all components were in place, a thorough review of the breadboard layout was carried out to ensure all connections were correct and the design was stable and functional.

Once the assembly was complete, systematic testing was undertaken to verify the circuit's response to tilt changes and confirm that it produced the expected frequency outputs.

Testing

Testing of ADXL327 and ADP3000:

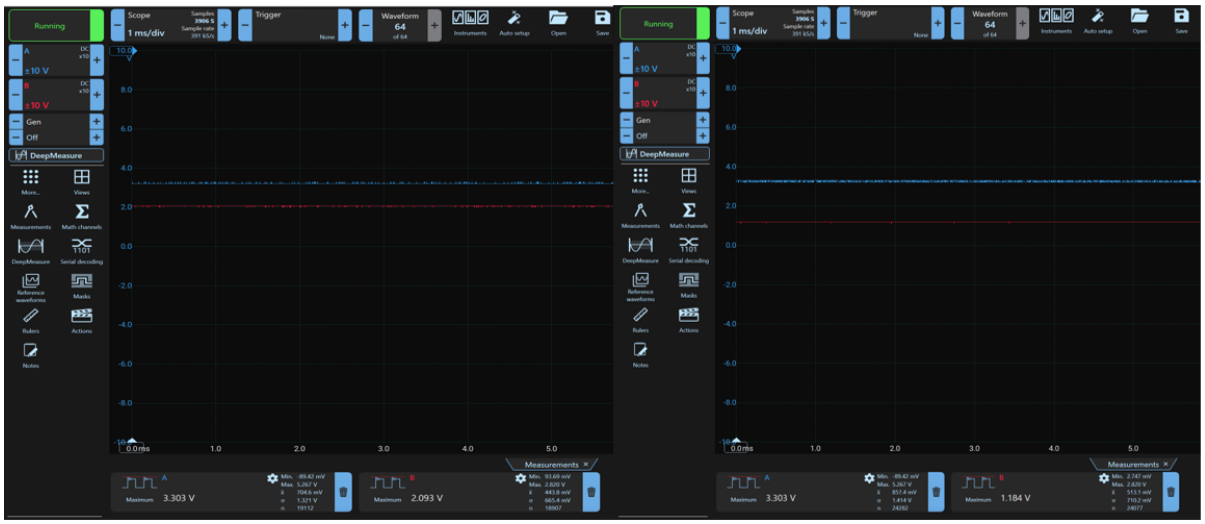

Figure 5 A PicoScope Trace showing the output from the accelerometer and voltage regulator

As seen by Figure 5, it shows that the supply voltage to the accelerometer is 3.3V (in blue), which is the output of the ADP3000 chip. This ensures that the accelerometer receives the correct input and is not damaged. The initial range of the accelerometer varies from a minimum of 1.184V to a maximum of 2.093V. This means that range needs to be offset and amplified

Testing of Difference amplifier:

As seen by figure 6, the difference amplifier outputs an offset and amplified range of voltages compared to the range produced from the accelerometer directly. This is ideal as the range varies from 0V (which can be converted into a very low frequency) to 1.778V (which can be converted into a higher frequency).

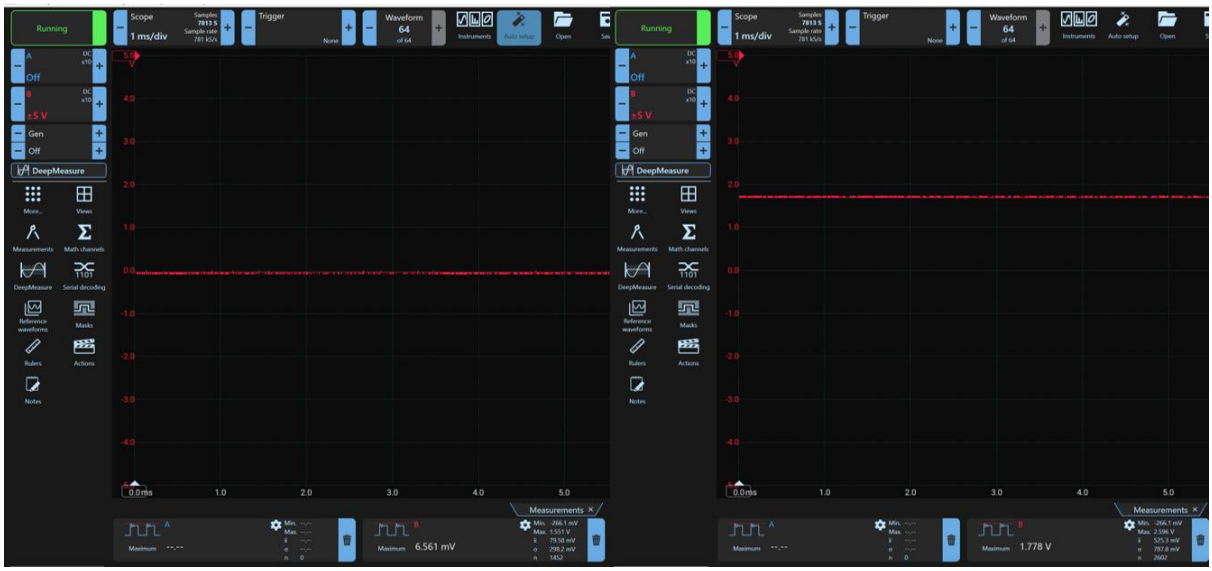

Figure 6 A trace showing the output from the difference amplifier.

Testing of Audio Tone Generator and Loudspeaker Driver Amplifier

The testing of these components was performed practically (as shown in the video), as hearing a frequency is the best way to test it and understand it. In addition to the variation of frequency of square waves produced by the audio tone generator the pitch of the speaker changed from low to high as it was tilted from -90 degrees to +90 degrees. This confirmed the functionality of the components. A difficulty encountered was the amplification of the AWG signal to above 2V, to turn on the MOSFET. This was due to the lack of space on the breadboard, which was overcome by switching the difference amplifier to a normal non-inverting amplifier temporarily to test the frequency output of the audio tone generator.

The video testing the Loudspeaker Amplifier with the AWG uses a sweep function, sweeping from a frequency of 25Hz to around 4600 Hz. This shows good variation in the pitch both on the low and high end, so want a range of frequencies output from the audio tone generator in this range.

The video testing the final circuit works as required, as the frequency of the audio output by the speaker changes from a low frequency to high frequency, as the level synthesiser is tilted from -90 to +90 degrees.

References

Figures 1,3, along with information on components: “IEP Design Project – The Level Synthesiser”, IEP Moodle Page, Prof Wilkinson

Figure 2: “OpAmp basics: balanced to unbalanced signal with difference amplifier”, Jan Cumps, 05/09/2022