1171946, 1173481

ELEN30009 Project Group 13 - ASK Modulation

Introduction & Methodology Framework

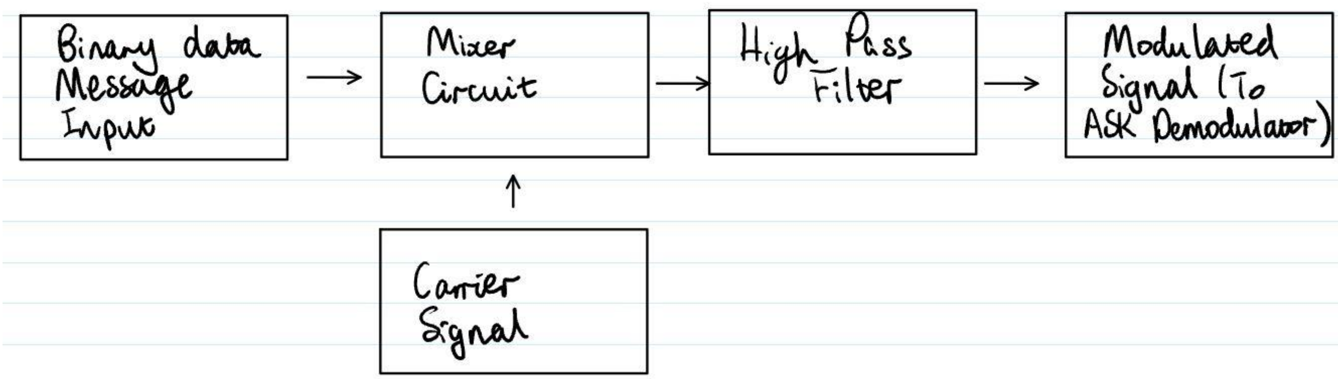
- Overall ASK system design was broken down into two components, an ASK modulator transceiver and demodulator receiver.
- Broad design schematic of the ASK modulator is based on Figure 2 in the ENAD Project - ASK Modulation handout.
  - Input of binary digital data and a carrier signal into the mixer circuit segment is handled using the AD2 Wavegen function.
  - The mixer circuit consists of 5 cascaded operational amplifiers to amplify the magnitude of the carrier signal (Analog Multiplier using Op-amp, 2020).
  - First both the carrier and message signals are converted into a logarithmic signal using a log amplifier, which are then put into a summing amplifier. This is equivalent to multiplying the two signals together due to the logarithmic properties. Then the summed signal is returned to the original scale with an antilog amplifier and inverted again since the summing amplifier is an inverting amplifier.
  - The log amplifier consists of an input resistor and diode through the feedback loop, while the antilog is the reverse of this configuration.
  - Output of the mixer circuit is passed into a high pass filter which is constructed using a series RC circuit to remove the voltage offset and center the signal around 0V. The values R=2k Ohms and C = 100nF to result in a cutoff frequency of $\omega_c = \frac{1}{2\pi*100*10^{-9}*2000} = 796\,Hz$, close to but below the carrier frequency of 1000 Hz so that the mixed signal itself is not filtered out.
  - The high pass filter output signal is then passed on to be the input of the asynchronous ASK demodulator
- Design of the asynchronous ASK demodulator component is based on Figure 4 in the ENAD Project - ASK Modulation handout.
  - The rectifier consists of a diode for half wave rectification with a resistor and capacitor in parallel to the output to smooth the signal. A large resistance value of 10k Ohms was chosen so that the magnitude of the rectified signal was not decreased too much.
  - The lowpass filter will be constructed using an RC circuit with cutoff frequency 1/RC to attenuate higher frequencies than the cutoff. This resulted in a smoothing effect on the signal due to the need to charge and discharge the capacitor. A resistance of 5k Ohms was chosen so that while the modulated signal was on, the capacitor did not fully discharge before the next peak and the overall signal was kept above 0V
  - A non-inverting operational amplifier takes the output signal of the low pass filter and amplifies the magnitude of the signal before passing on the output to the decision device. Amplification of the signal allows for the decision device threshold more margin of error to determine periods of zero signal amplitude, thus resulting in a more accurate demodulated signal output. In this configuration a gain of 2 was achieved.
  - The decision device outputs the final demodulated signal via the input of the non-inverting amplifier. The device consists of an operational amplifier comparator, which outputs 5 volts if the magnitude of the non-inverting amplifier signal is higher than a preset threshold reference voltage of 1.5 volts. If the signal magnitude is less than the reference voltage,

there is an output of 0 volts. This produces a square wave signal representing the demodulated signal.

- The ASK modulator and asynchronous ASK demodulator are combined to form the ASK system via connecting the output of the ASK modulator to the input of the ASK demodulator via a jumper cable.

Block Diagram of ASK System

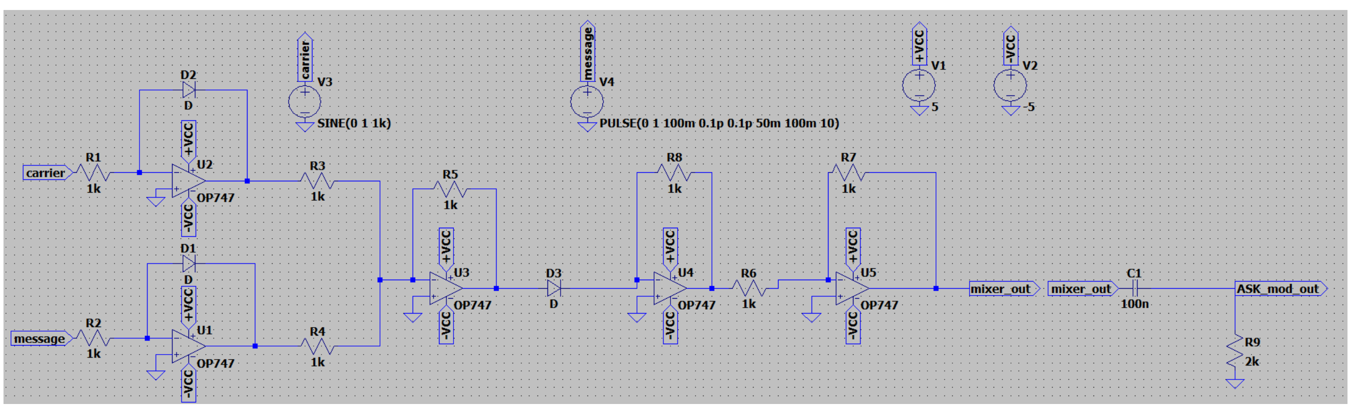
ASK Transmitter



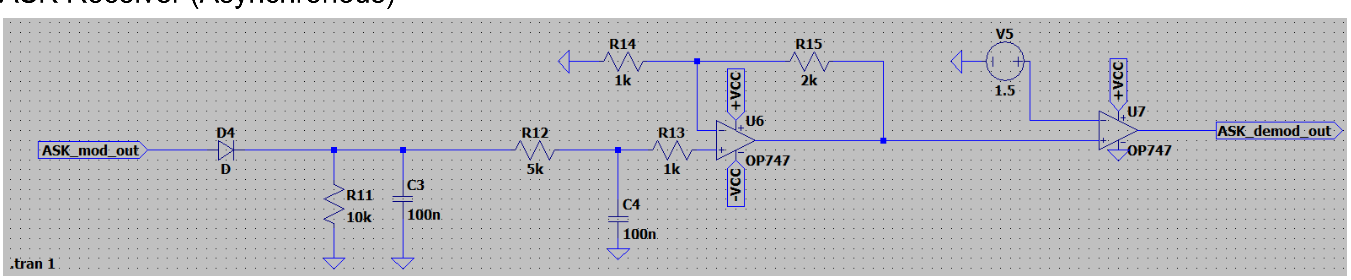
ASK Receiver (Asynchronous)

Theoretical Characterisation

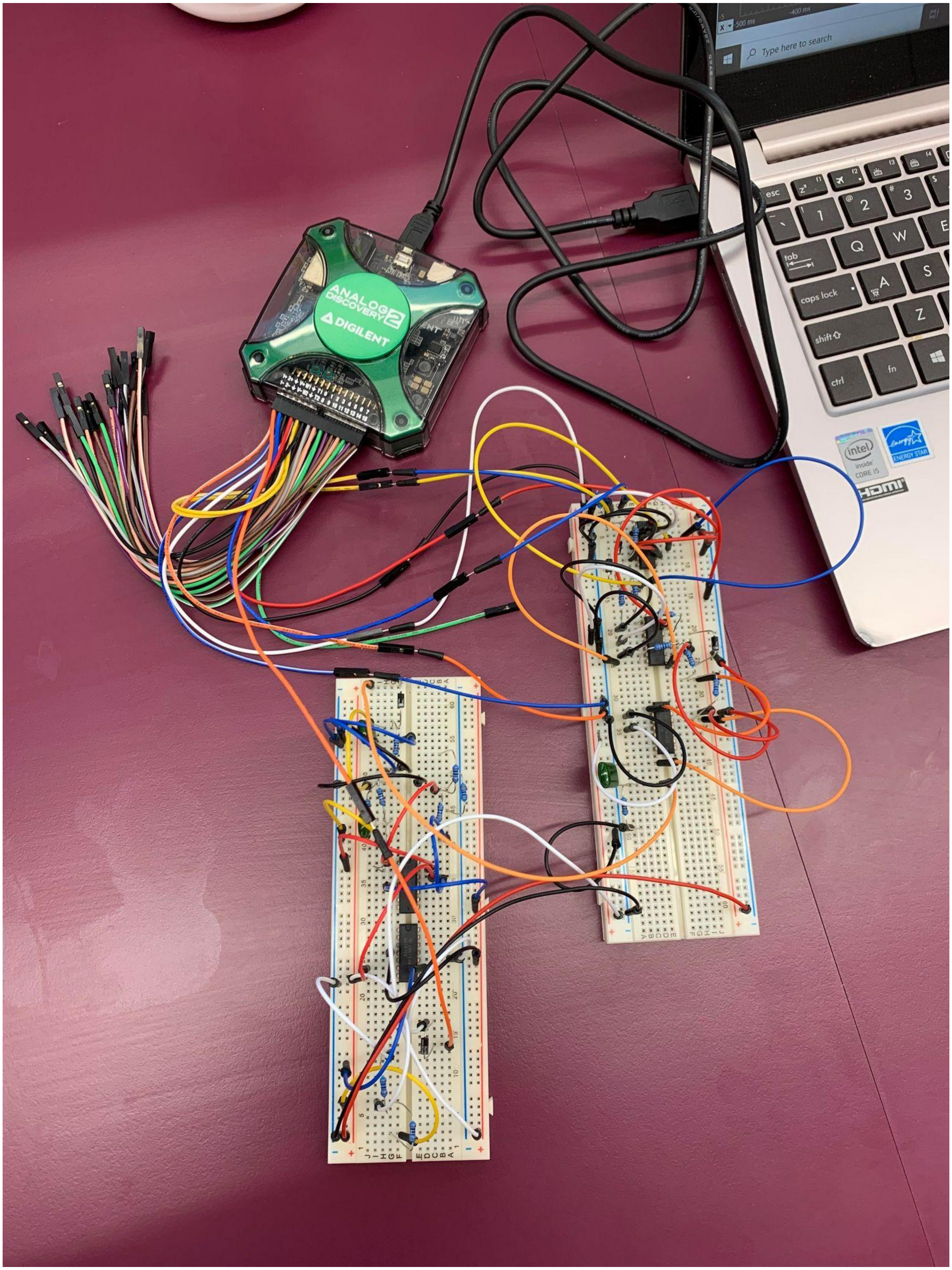
ASK Transmitter



ASK Receiver (Asynchronous)



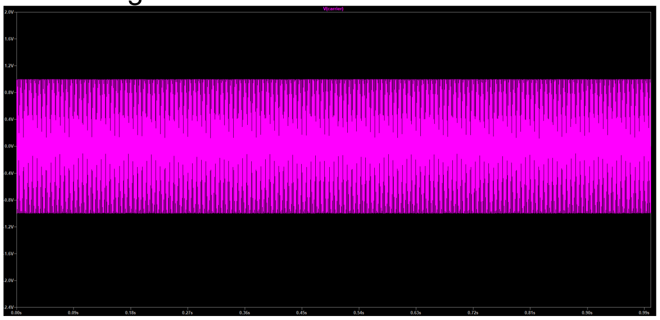
Experimental Setup


ANALOG DISCOVERY 2
DIGILENT
Type here to search

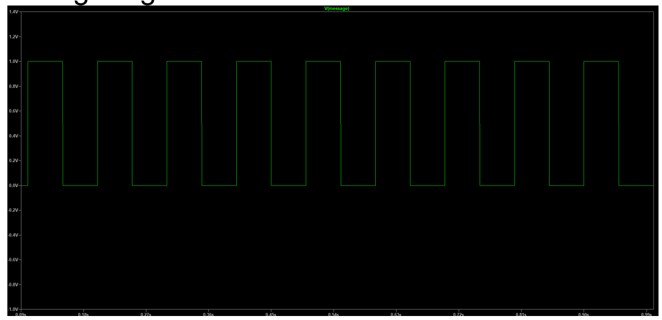
Results

Simulation

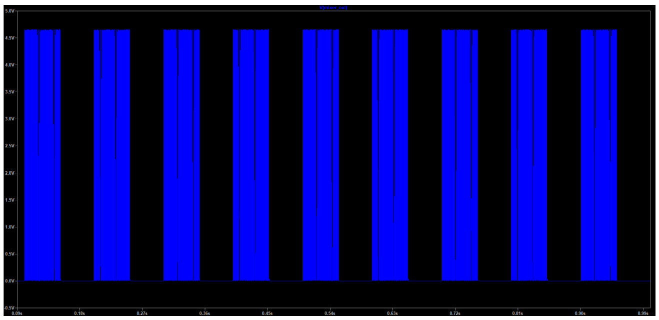
Carrier Signal:



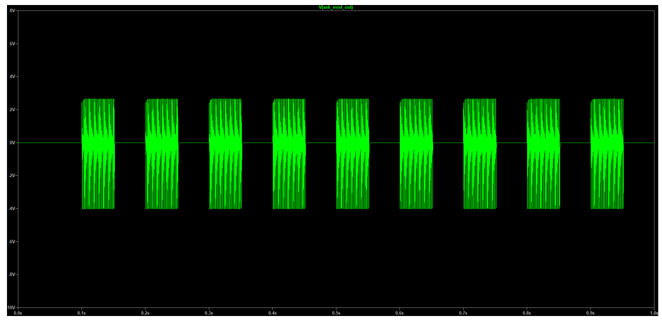
Message Signal:



Mixer Circuit Output:



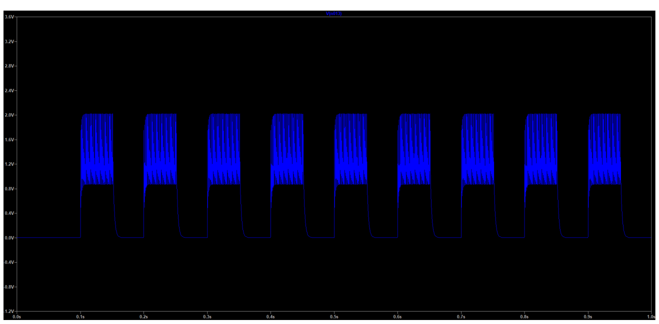
Final Modulated Signal:



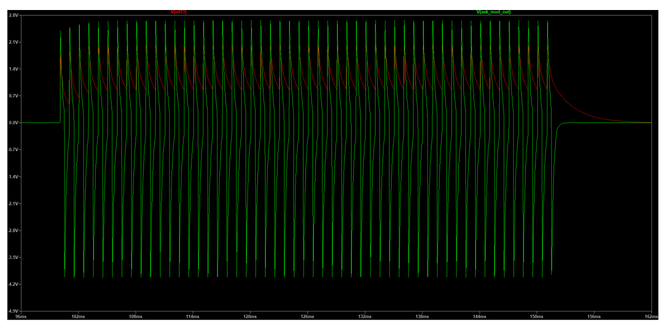
Output of the mixer circuit is a signal that oscillates between 0V and ~4.6V at the carrier frequency of 1000 Hz when the message signal is high and the signal is constant 0V while the message signal is low. It should be noted that the oscillating signal is not perfectly sinusoidal.

The final modulated signal, after the highpass filter, is similar to the mixer circuit output signal but centered on 0V and oscillating between ~-4V to ~3V.

Rectified Modulated Signal:



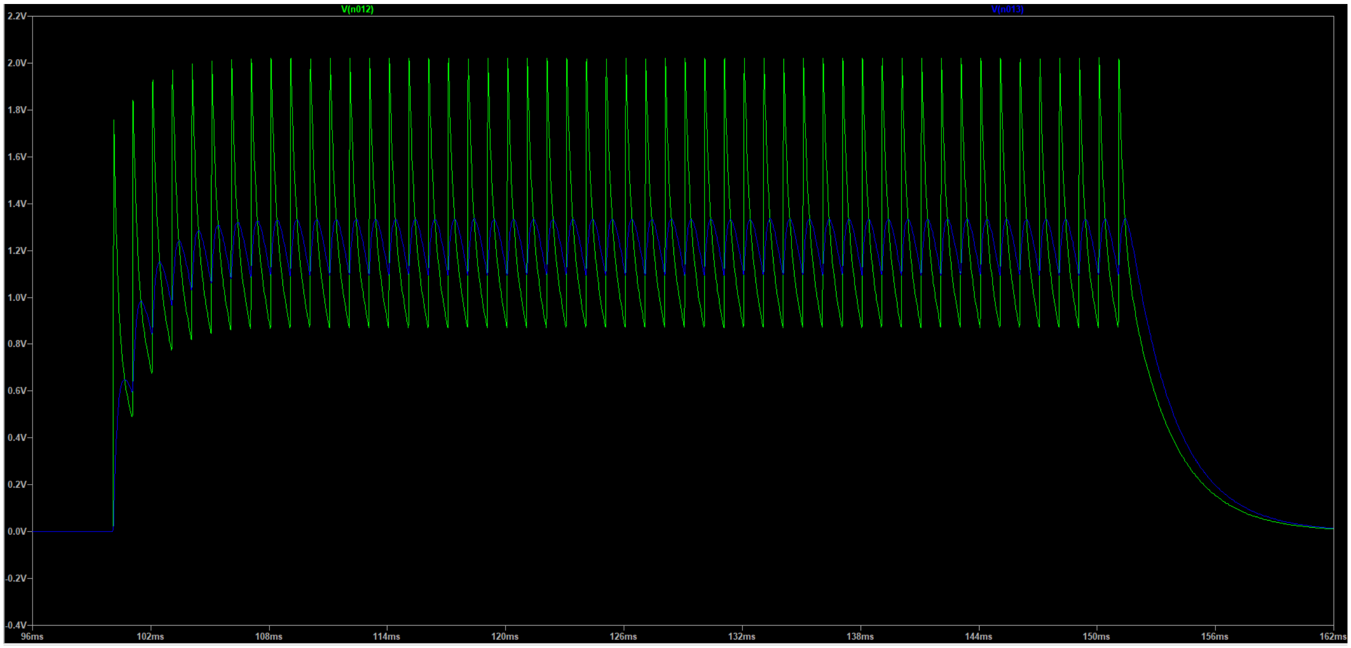
Single Period with Comparison to Modulated Signal:



(Red = Rectified Signal)

The rectified signal peaks at ~2V when the modulated signal reaches its positive peak and afterwards it discharges to ~0.8V until the next positive peak of the modulated signal, at which point it shoots up again. When the modulated signal changes to constant 0V, the rectified signal slowly decreases exponentially to 0V.

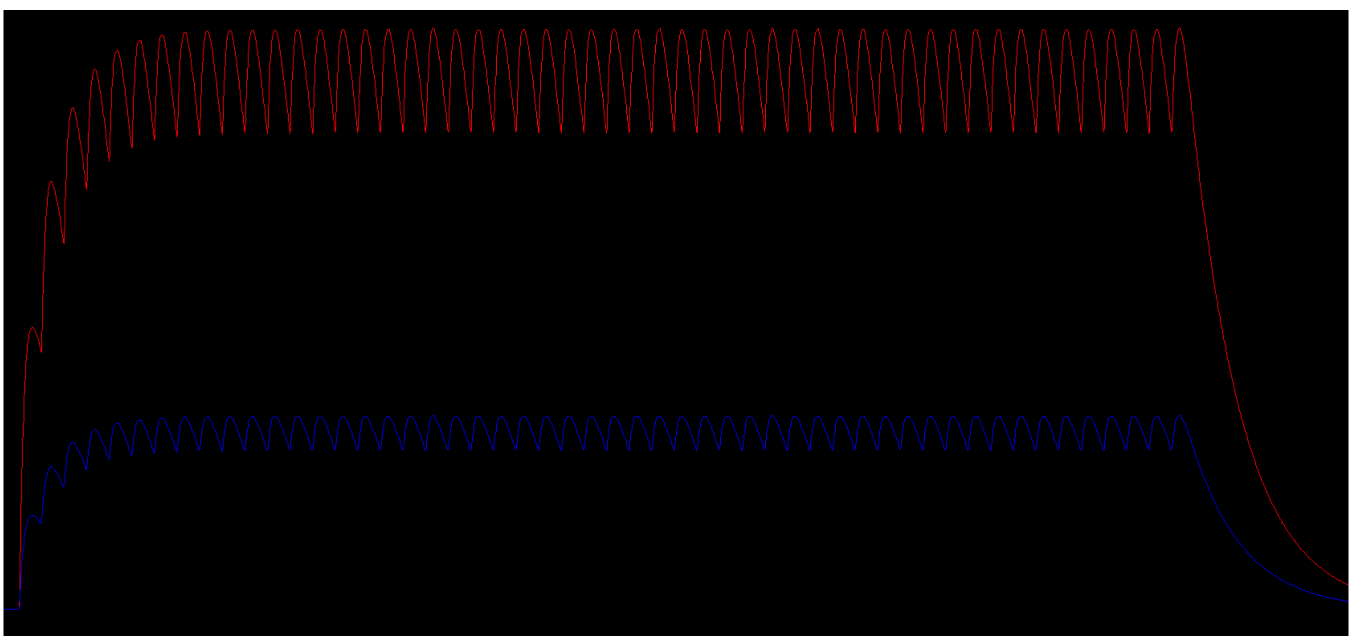
Smoothed Rectified Signal:



(Blue = Smoothed Signal, Green = Original Rectified Signal)

The smoothed rectified signal has the same overall shape as the original signal, however the height of the ripple voltage is smaller and it has a smoother curve when transitioning from charging to discharging. The minimum value of the ripple voltage is also higher than that of the original signal, allowing for a higher threshold voltage in the comparator

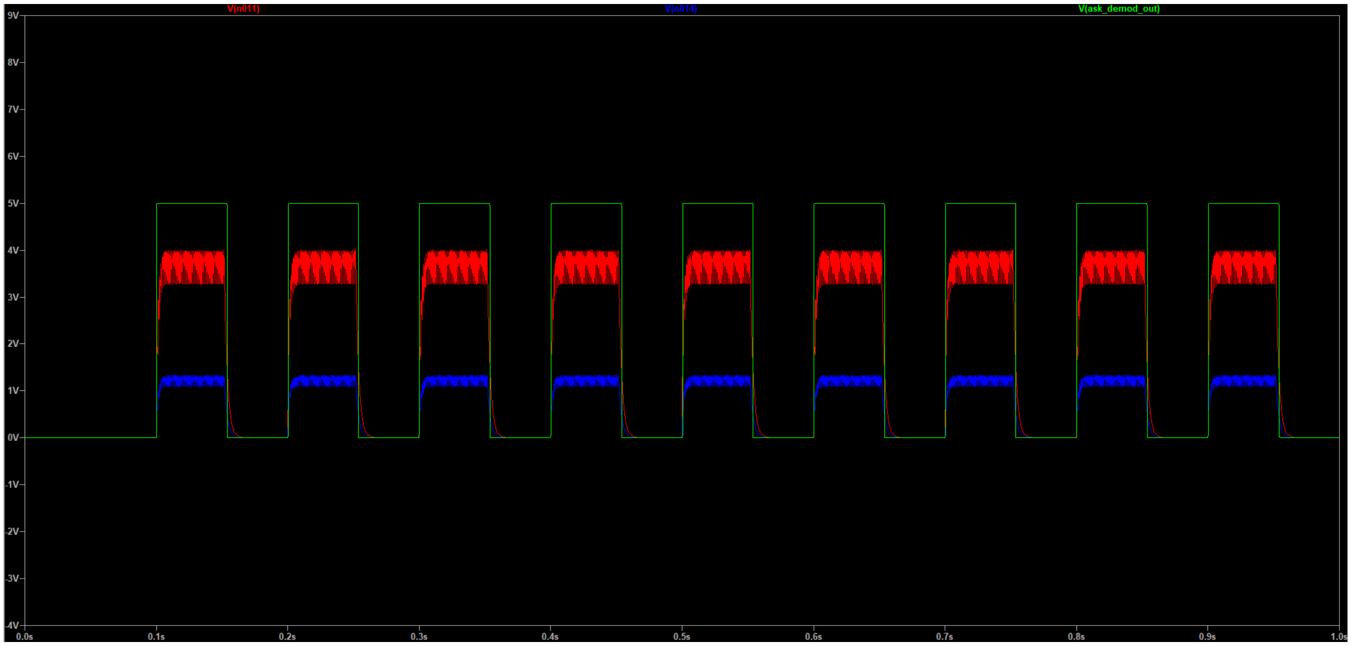
Amplified Smoothed Rectified Signal:



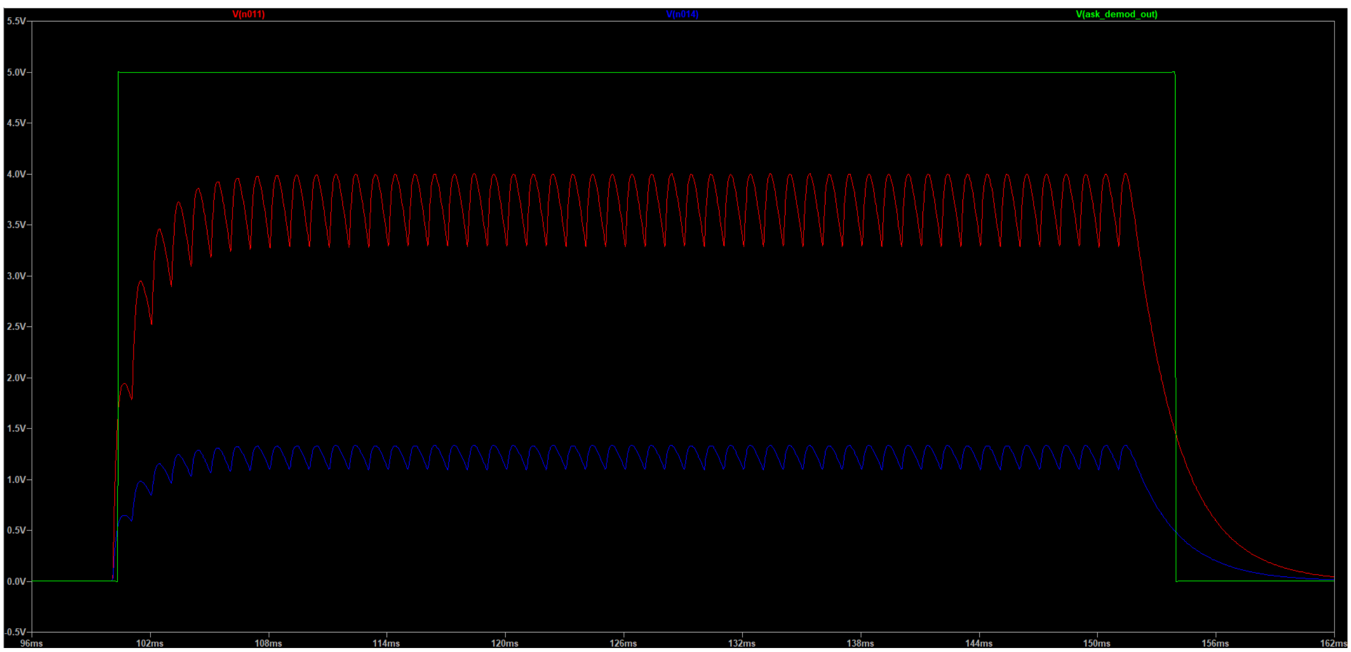
(Red = Amplified Signal, Blue = Original Signal)

The smoothed and rectified signal is amplified by a factor of 2 and thus the ripple voltage is also doubled but still high enough to allow for a comparator threshold voltage of 1.5V

Demodulated Signal with Amplified and Unamplified Smoothed Rectified Signal:



Single Period:5

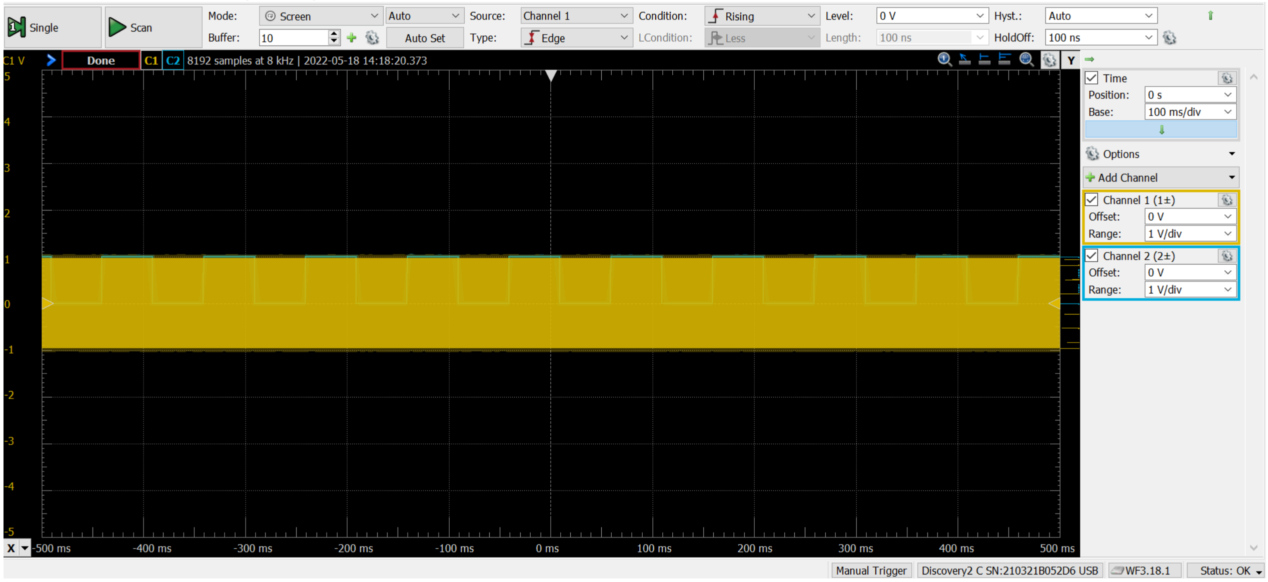


(Green = Demodulated Signal)
(Red = Amplified Rectified Smoothed Modulator Output)
(Blue =Rectified Smoothed Modulator Output)

The demodulated signal outputs a constant signal of 5V when the red signal is above 1.5V. Overall it is slightly delayed compared to the original message signal, due to the time taken for the charging and discharging of capacitors. The threshold is also below the initial dips in voltage, ensuring a constant output voltage.

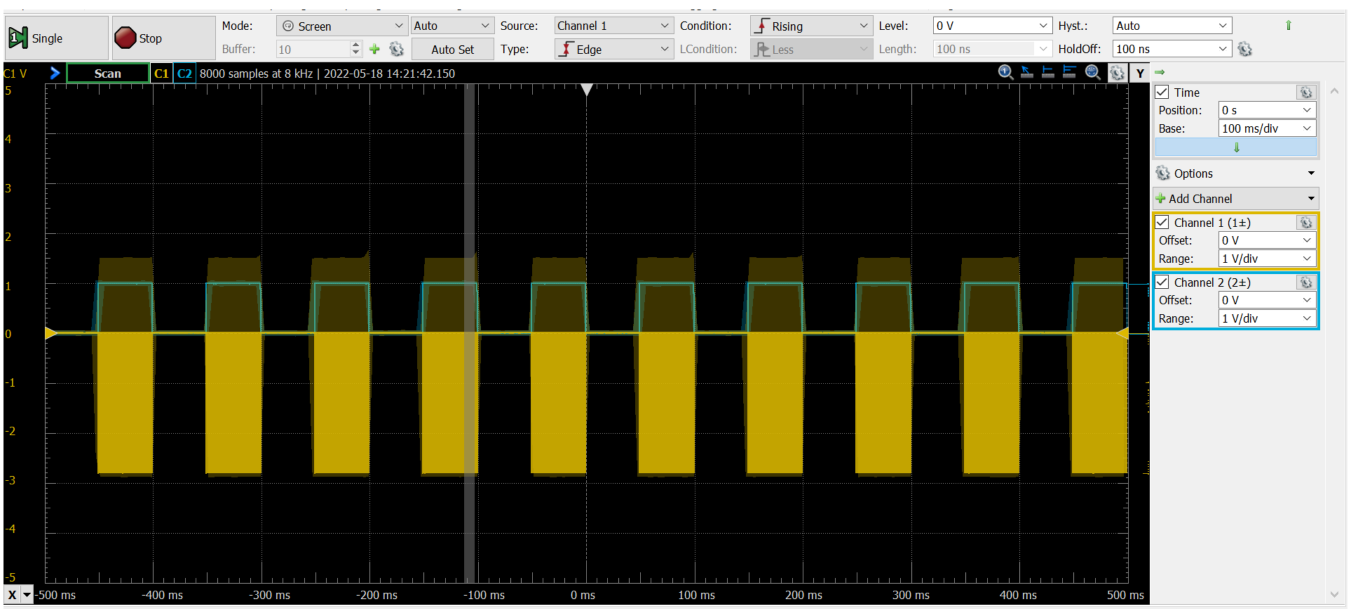
<u>Experimental Circuit</u>

Channel 1: Carrier Signal
Channel 2: Message Signal



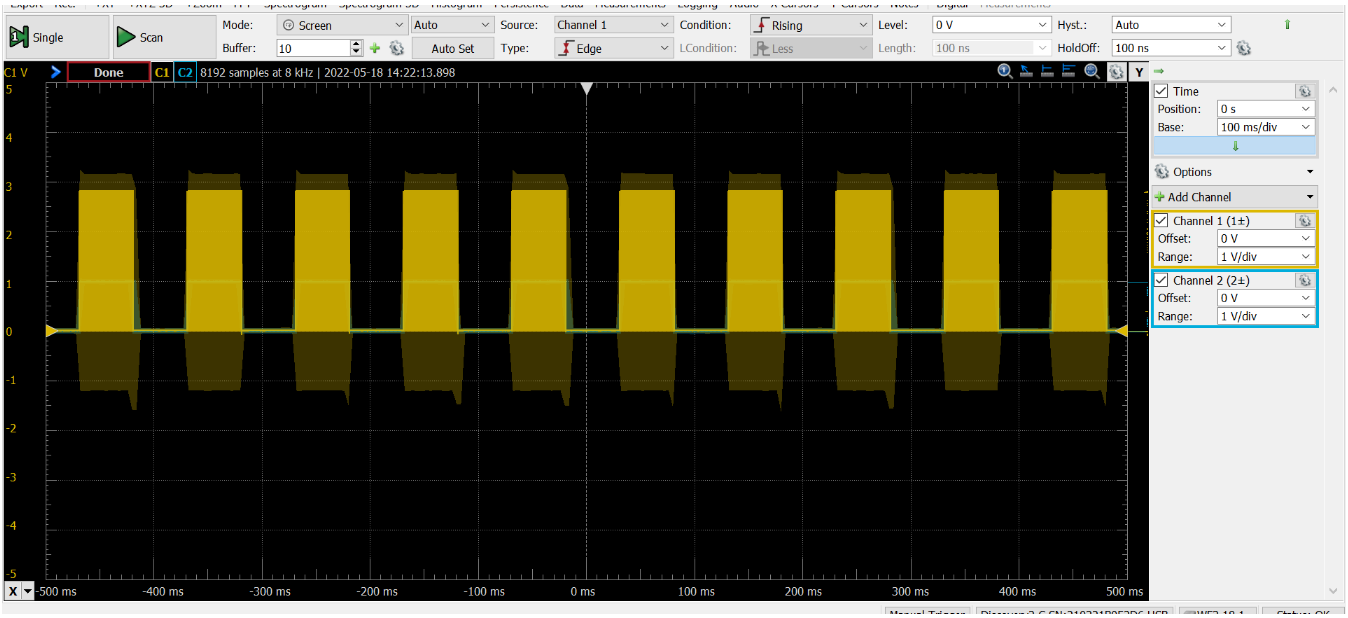
Message signal is a pulse wave with 1V amplitude and 10 Hz frequency
Carrier signal is sinusoidal signal with 1V amplitude and 1000 Hz frequency

Channel 1: Uninverted Mixer Circuit Output Signal
Channel 2: Message Signal



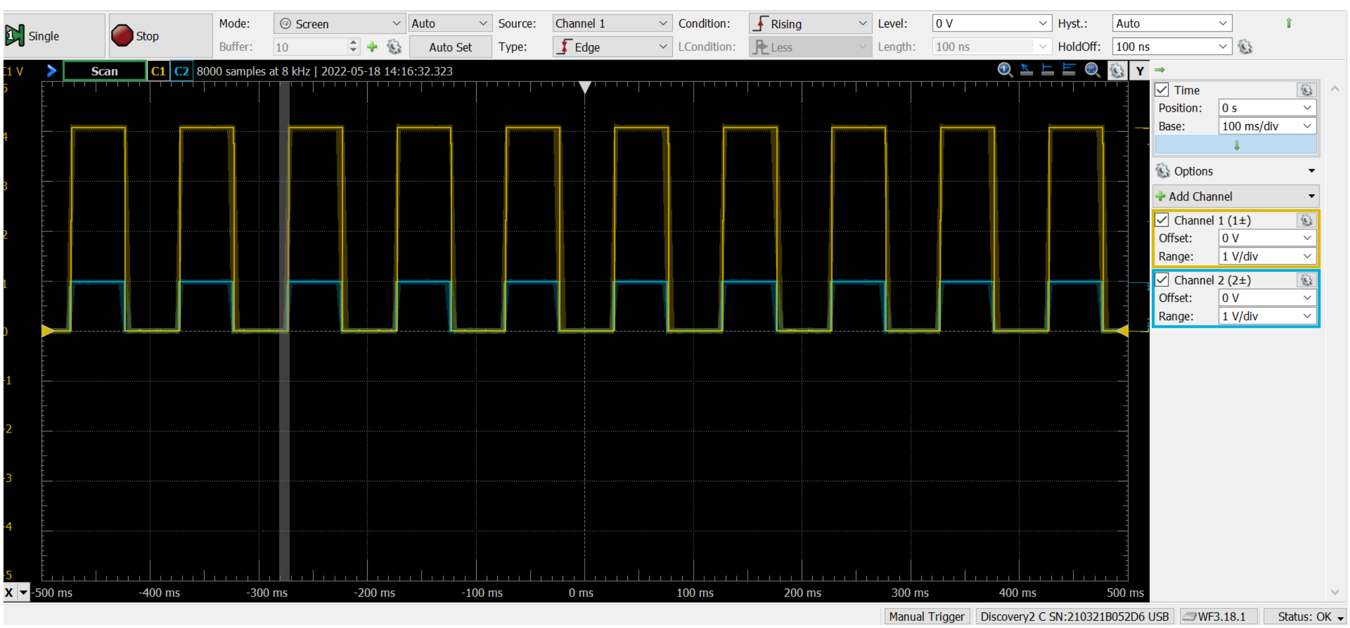
Mixer circuit output signal oscillates between -2.8V and 1.5V at 1000 Hz frequency when the message signal is outputting 1V and a constant 0V when the message signal is 0V.

Channel 1: Modulated Signal
Channel 2: Message Signal



Before the highpass filter, the modulated signal is similar to the mixer output, except oscillating between 0V and 2.9V instead.

Channel 1: Demodulated Signal
Channel 2: Message Signal



The demodulated signal is a slight delayed and amplified copy of the message signal. The amplification is due to the input voltage of 5V into the comparator, however the demodulated signal's amplitude is 4V rather than 5V.

Discussion

- Troubleshooting during the build of the experimental set-up
    - When building the ASK circuit a specific troubleshooting protocol was followed.. If an issue arose with the functionality of the circuit the output of each component would be checked with a multimeter from the start to the end of the circuit. Simulated and results derived by hand would be used as benchmarks. The method proved to be useful as a diode was found to be placed in the wrong orientation during the construction of the ASK modulator.
- Design variances between theoretical and experimental set-ups
    - Reference voltage of comparator in ASK demodulator design
      The theoretical design consisted of a 1.5 V source feeding into the negative input of the 747 comparator op amp. However, a precise voltage of 1.5 V was not able to be obtained when building the experimental setup of the circuit using the AD2. As such, a decision was made to achieve an approximation of the desired 1.5 V result by using the V+ wire of the AD2 to input 5V through a 2kΩ and 1kΩ resistor in series before taking the voltage of the circuit just after the 2kΩ resistor (1.667 V) and connecting it to the negative terminal of the comparator.
    - Negative power supply connection to comparator in ASK demodulator design
      The negative power supply terminal of the comparator is connected to ground in the theoretical design of the circuit. However, when this design was implemented on the breadboard with a 747 op amp, the output of the comparator always ended up flatlining at 0V regardless of the input signal from the non-inverting amplifier. Ultimately, it was found that 747 op amps required a voltage difference of 10V between VCC+ and VCC- to properly function (Dual Operational Amplifier PDIP-14 Type UA747CN LM747CN, Grieder Elektronik Bauteile AG, 2005). As such, an alternative solution for the experimental setup was found by setting VCC- to -5V to achieve the 10V difference required by the 747 op amp. A diode was placed in series after the output of the comparator so that output voltages of less than zero were rectified to zero via reverse bias. Thus, the results obtained now correlate with the simulated outputs.
- Differences between theoretical and experimental results
    - Delay between message and ASK demodulated output signal
      When comparing the message signal and ASK demodulator output signal of the experimental setup in the scope window of Waveforms, a small delay in both the rising and falling edges of the ASK demodulator output signal was observed. The slight deviation from theoretical results can be explained by the threshold voltage used in the op amp comparator in the ASK demodulator section. Since the comparator only outputs voltages with a magnitude of VCC+ when the input voltage is greater than the reference voltage of 1.5V, a slight delay occurs when waiting for the comparator input signal to pass and decay back below the threshold voltage.
    - Modulated signal has sharp peaks, unlike the smooth peaks associated with a sinusoidal signal. This could have been mitigated by implementing a series of lowpass filters to smooth the signal

Conclusion

Overall, the modulator circuit implemented in this assignment had a reasonably accurate output signal compared with the theoretical output, however it could have been improved by passing it through a series of lowpass filters in order to smooth out the peaks. The demodulator circuit was also very successful, outputting a signal that was almost identical to the original message signal, only delayed by a very small amount due to the charging and discharging times of the capacitors, and the circuit had to be modified due to the rail-to-rail properties minimum voltage properties of the op amp used.

References

Analog Multiplier using Op-amp. (2020). Retrieved 19 May 2022, from https://www.youtube.com/watch?v=-2PWkOb1F1Y

ASK Modulation using OPAMP. (2018). Retrieved 10 May 2022, from https://www.electronics-tutorial.net/Mini-Projects/ASK-Modulation-using-OPAMP/

Dual Operational Amplifier PDIP-14 Type UA747CN LM747CN, Grieder Elektronik Bauteile AG. (2005). Retrieved 23 May 2022, from https://shop.griederbauteile.ch/product_info.php?products_id=6903&language=en