Analysis and Reverse Engineering of a PASCO Microwave Receiver

Kyle Eckert

Nicholas Krupa

Tessa Lambert

Patrick Joseph

4-22-25

-

5-9-25

Objective

Analyze and reverse engineer a PASCO Microwave Receiver Circuit in order to recreate it for far less cost and with common components. In the process, gaining an understanding of the components used and why certain components are chosen over other options.

Equipment List

- 2x Digital Multimeter
- 1x Microscope
- 1x WA-9800A Microwave Receiver
- 1x WA-9801 Microwave Transmitter
- 2x DC Power Supply
- Breadboard
- Jumper Wires
- 8x Alligator Clip
- 2x LM741 Op-Amp IC
- 18k and 100 Ω resistor

Theory

At the heart of the PASCO WA-9800A microwave receiver Is a Gunn diode, which is used to detect microwave signals in the 10GHz range. The horn attached to the transmitter and receiver creates a standing wave between the two, meaning that the Gunn diode in the receiver circuit is outputting a DC signal as opposed to a high frequency AC signal. Knowing that the diode is outputting DC, makes reverse engineering the PASCO receiving circuit far easier.

By identifying the components used in the PASCO receiver, the function of each, and their usefulness to the final circuit could be determined. This applies especially to the op-amps that are used. Op-amps can be used as either amplifiers or comparators. In the amplifying configuration, one can also use them as a filter. Identifying components connected to the op-amps can clarify how the op amps are configured in the circuit as well as their intention.

Procedure

First, the WA-9800A microwave receiver was taken apart. This was done to achieve a closer look at how the circuit functions. Next, some potential theories as to how the circuit could work were created. Originally, it was assumed that the diode was outputting AC, leading to considerations of component effectiveness at high frequency as well as filtering. Once DC was determined, the PASCO circuit was drawn out in its entirety, using a multimeter in continuity mode to check connections. This process can be seen in *Figure 2*. Once the circuit was drawn out, it was analyzed to determine how each component was contributing. It was determined that some of the components in the original circuit were only used when an antenna was plugged into the receiver. This meant that these components were unnecessary to the core functionality of the receiver, and the circuit could be simplified. Once the circuit was simplified, what was left was 2 Op-Amps acting as a Voltage Follower (or buffer) and a non-inverting amplifier. The voltage follower was used to mitigate the loading effect of the amplifier, and the amplifier was used to transform the small input voltages into much larger output voltages. This circuit could then be recreated using two LM741 op amps, and 2 gain-setting resistors, for which 18k and 100 Ω values were chosen. Once the circuit was built (*Figure 4*) and power was connected properly, the circuit was tested with a DC power supply operating at very low voltage. The results of which can be seen in *Table 1* and *Figure 5.* After testing, the diode from the original circuit was transplanted to be used as the input for the new circuit. The output of the circuit was then measured and compared to the expected outputs of a fully functioning receiver.

Results

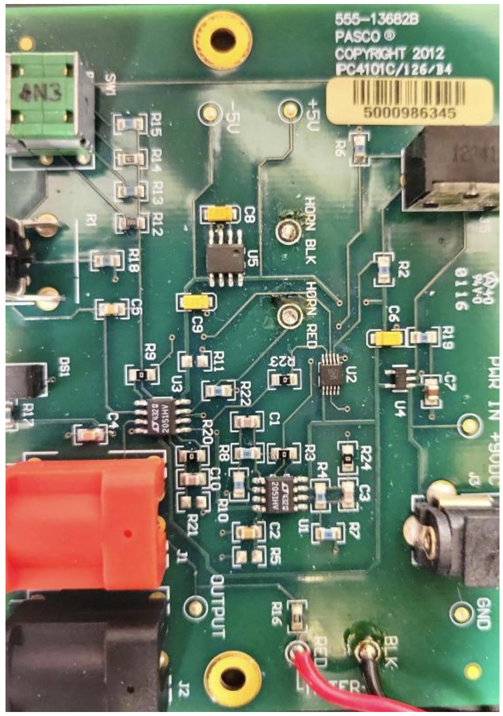

Figure 1: WA-9800A Receiver Circuit

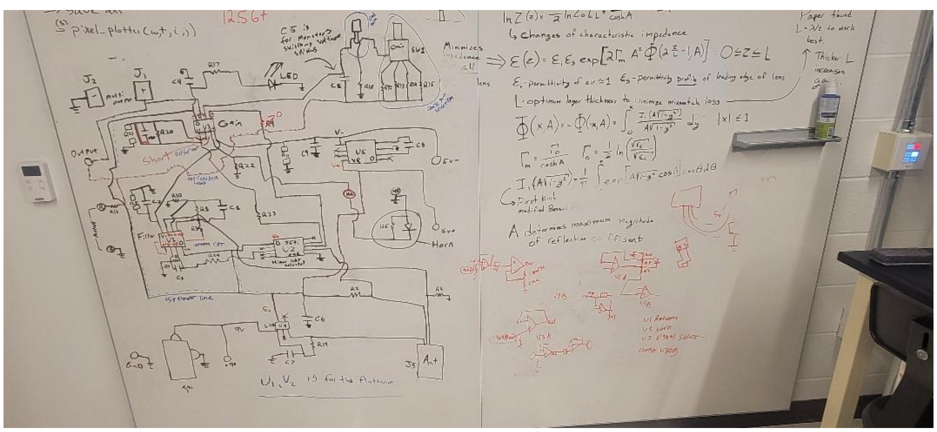

Figure 2: Analysis

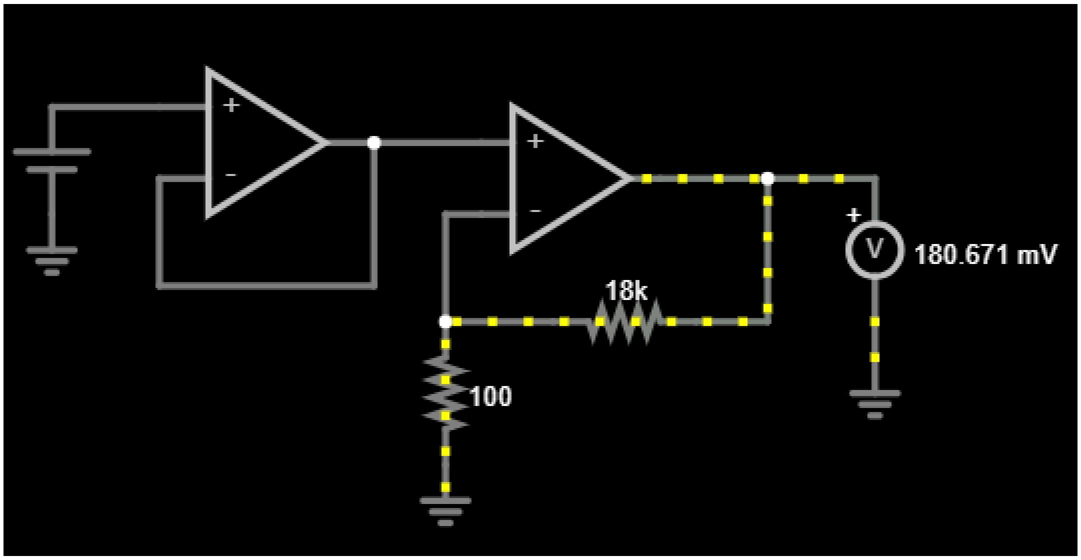

Figure 3: Simulated Circuit

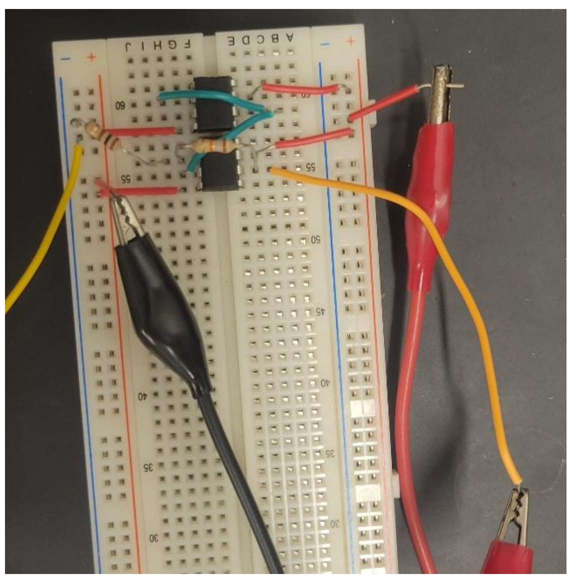

Figure 4: Final Constructed Circuit

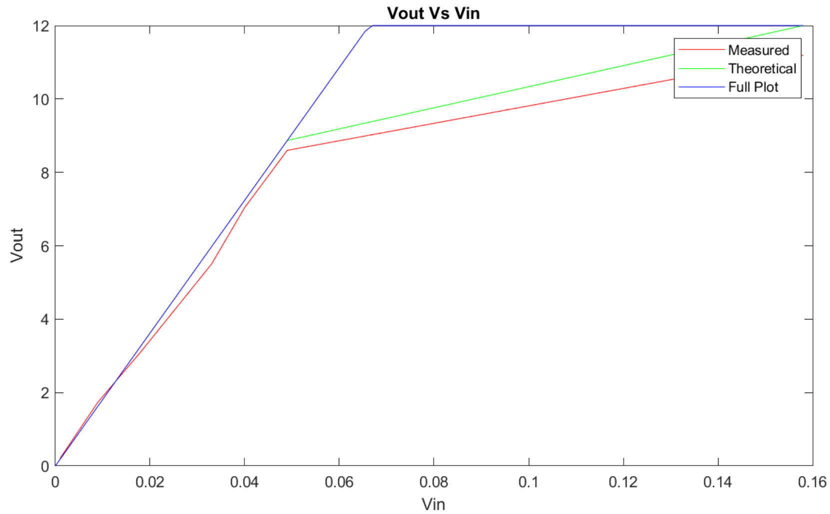

Figure 5: Testing Results

measuredin100and18k	*measuredout100and18k*	*Theoreticalout*	*Error*
0.001	*0.206*	*0.181*	*13.812*
0.009	*1.74*	*1.629*	*6.814*
0.018	*3.1*	*3.258*	*4.8496*
0.033	*5.5*	*5.973*	*7.919*
0.04	*7.04*	*7.24*	*2.7624*
0.049	*8.6*	*8.869*	*3.033*
0.158	*11.19*	*12*	*6.75*

Table 1: Testing Results

[*Demonstration Video*]

Analysis

The results of the final constructed circuit revealed an unexpected offset of approximately -9.8V at the output. This issue is likely due to a known limitation of the LM741 op-amp, which can exhibit significant offset voltage under certain conditions. Additionally, the circuit failed to function effectively at distances where the original PASCO receiver performed reliably. This is likely due to the diode's output current being too low to properly bias the LM741's input stage, resulting in little to no response from the op-amp. Future iterations of this circuit would benefit from using a higher-quality operational amplifier with significantly lower input bias current and offset voltage. Additionally, a dual output voltage regulator would make powering the circuit far simpler and more effective for the situations the circuit will be used in. These are the solutions that PASCO used in the original design as well.

When testing the circuit, the measured output closely matched the expected output, as shown by the percentage errors in *Table 1*. The error in both the testing setup and the final circuit can be accounted for by the poor op-amp quality, and small resistances in all components and breadboards used. When dealing with very small input signals, these minor resistive factors can significantly affect the final output voltage.

Conclusion

This project successfully demonstrated the reverse engineering of the PASCO WA-9800A microwave receiver and the reconstruction of its essential functionality using commonly available components. Through the disassembly, analysis, and testing of the original circuit, it was determined that the original design centered around a buffer and non-inverting amplifier configuration. While the final constructed circuit experienced performance issues, such as a voltage offset at the output and sensitivity limitations, these errors can be attributed to known shortcomings of the LM741 op-amp. Regardless, the simplified test configuration produced results that closely matched theoretical predictions, confirming the core design approach was sound. Future improvements will involve selecting higher-performance op-amps and more stable power supply methods to better replicate the reliability and sensitivity of the original PASCO receiver.