Lab 4: Diode Circuits

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Abstract—**DIODES are crucial elements in modern circuitry. They work like one-way gates for current, and have a wide array of electrical applications. This report investigates several circuits which utilize both diodes and zener diodes, which allow one-way current travel until a certain maximum is reached. Several circuits that utilize these diodes are examined, including clipping circuits, clamping circuits, voltage regulator circuits, AC to DC conversion circuits, and circuits that implement digital logic.**

CONTENTS

I. EQUIPMENT LIST

1) Breadboard
2) Measuring Equipment:
   a) Digital Oscilloscope
   b) Digital Multi-Meter [x2]
3) Power Sources:
   a) DC Power Supply
   b) Function Generator
4) Resistors:
   a) 1.0 kΩ (1/4 W) [x1]
   b) 10.0 kΩ (1/2 W) [x1]
   c) Variable Resistor Box
5) Diodes:
   a) 1N4002 Diode [x2]
   b) 1N4737 Zener Diode [x1]
6) Capacitors:
   a) 0.1 μF [x1]
   b) 1.0 μF (Electrolytic) [x1]

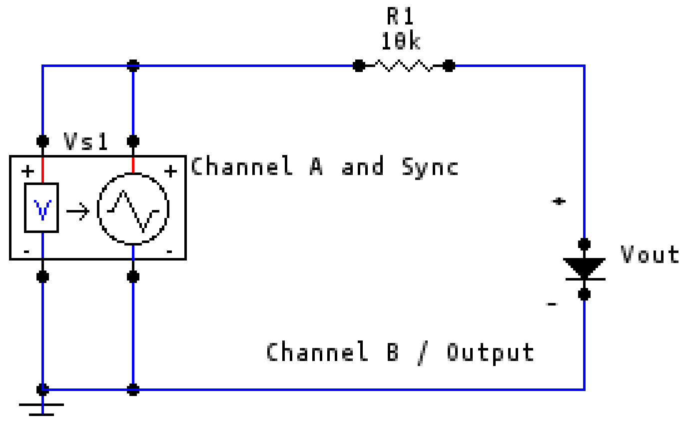

Figure 1. Single Diode Clipping Circuit Diagram

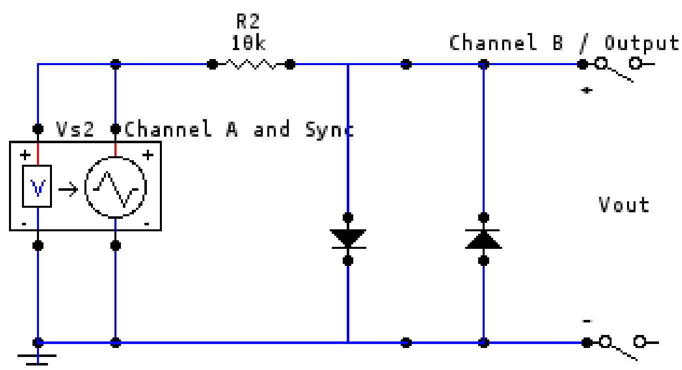

Figure 2. Parallel Diode Clipping Circuit Diagram

II. METHODOLOGY

A. Diodes as Clippers

1) The circuit was built on the protoboard with $R_1 = 10$ kΩ.
2) The oscilloscope was set to DC coupling mode, and Channels 1 and 2 were displayed simultaneously.
3) A **1 kHz triangle wave** was used as the input signal. V_{s1} and $V_{\text{Out 1}}$ were monitored on Channels 1 and 2 respectively.
4) The following parameters of the input signal were varied, and the effects recorded:
   a) DC Offset
   b) Frequency
   c) Peak-to-Peak Voltage

5) Screen captures were generated that indicated the clipping behavior of the circuit.
6) The second diode was wired parallel to the first to observe the resulting clipping effects.
7) The following parameters of the input signal were varied, and the effects recorded:
   a) DC Offset
   b) Amplitude
   c) Waveform Type

B. Diode Clamping

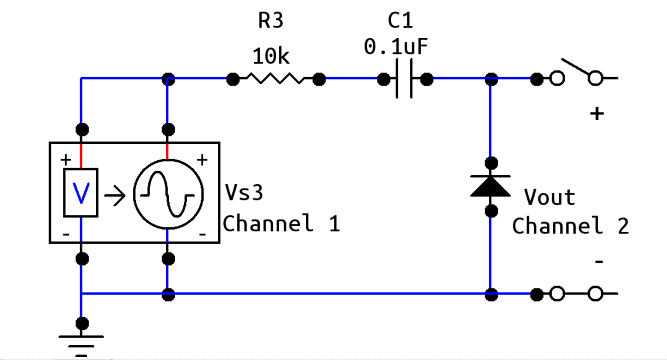

Figure 3. Clamping Circuit Diagram

1) The circuit was built on the protoboard with $R_2 = 10$ kΩ.
2) A **1kHz sine wave** input signal was used, with the **DC Offset** set to **zero**.
3) The oscilloscope was set to DC coupling mode.
4) The oscilloscope was then wired to monitor V_{s2} and $V_{\text{Out }2}$.
5) The input and output signals were measured on Channels 1 and 2 respectively.
6) The DC Offset of the input signal was varied, and the effects on the output signal were measured and recorded.

C. Voltage Regulator

1) The circuit was built on the protoboard.
2) A 20 V DC power generator was used as the source voltage.
3) The oscilloscope was wired to measure the load variables V_L and i_L.
4) The resistance R_L was varied, and data points were collected for both V_L and i_L.
5) A plot was generated of the data points as the experiment was conducted in order to determine where more data points were needed.

D. AC → DC Converter

1) The circuit was built on the protoboard.
2) The function generator was set to produce a **1 kHz sine wave**.

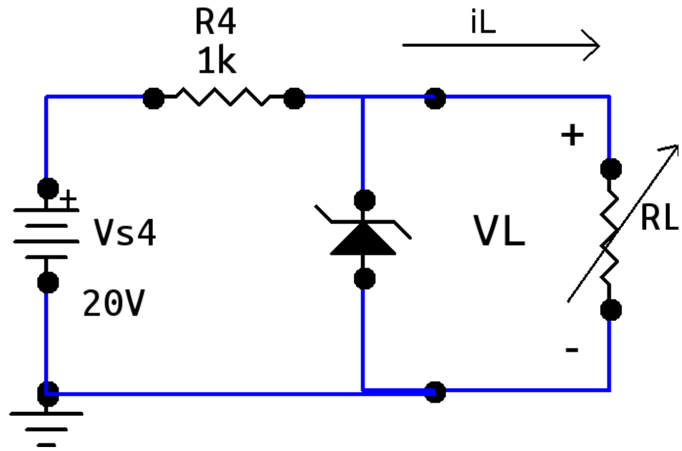

Figure 4. Voltage Regulator Circuit Diagram

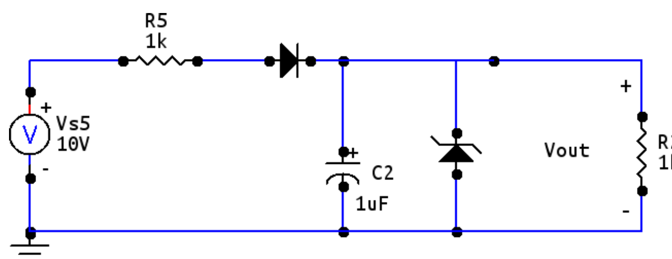

Figure 5. DC Power Supply Circuit Diagram

3) The capacitor was tested for its polarization and connected appropriately.
4) The oscilloscope was wired to measure V_s and V_{Out} on Channels 1 and 2 respectively.
5) The oscilloscope was set to DC coupling on both channels.
6) The oscilloscope was zeroed before capturing data.
7) The resistance R_L was varied, and the results were recorded.
8) The voltages were measured with DVMs and recorded.

E. Diode Logic Circuits

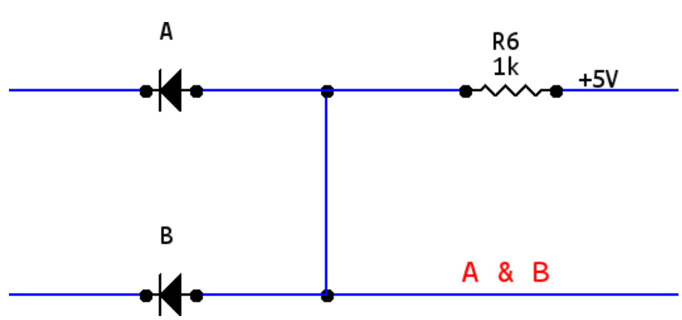

Figure 6. Logical AND Gate Circuit Diagram

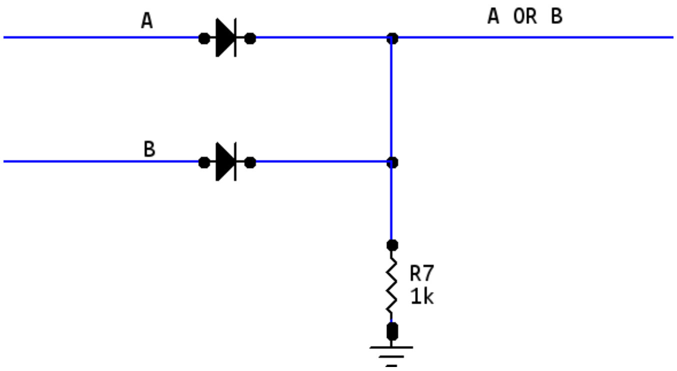

Figure 7. Logical OR Gate Circuit Diagram

1) The circuit for the **AND** gate was built on the protoboard.
2) A **5 V DC** power source was wired into the protoboard.
3) The oscilloscope was wired to measure V_{Out}.
4) Different combinations of voltages were applied to the inputs, and the outputs were recorded.
5) The procedure was repeated for an **OR** gate.

III. Data and Analysis

A. *Clipping Circuit*

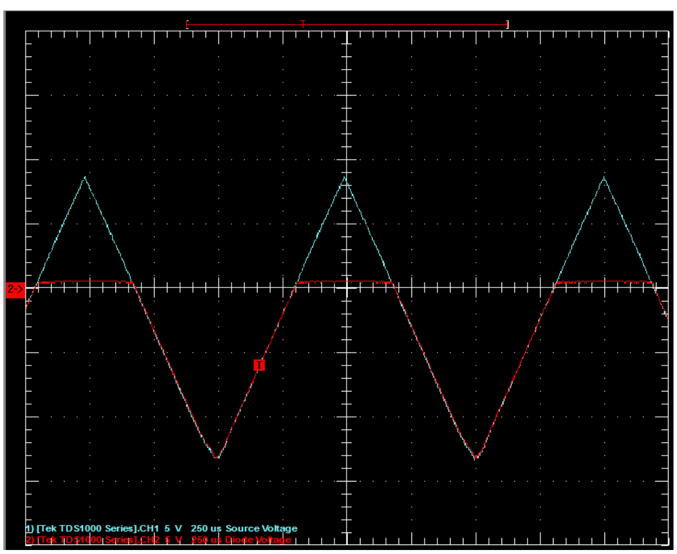

Figure 8. Source and diode voltage overlayed to show clipping behavior. The flat portion waveform just above the x-axis represents the clipped output voltage, while the triangle wave was used as the circuit's source signal.

As the parameters outlined in the Methodology section were varied, the following observations were made, resulting in the waveforms shown in Figure 8.

1) *DC Offset*
Changing the DC Offset of the signal generator changes the magnitude of the voltage supplied, but does not have a discernible effect on the output voltage. The diode effectively cut off the signal at approximately zero volts, regardless of what voltage was supplied by the source.

2) *Frequency*
Changing the frequency of the source signal changes the edge behavior of the output voltage slightly. At low frequencies, the waveform of the output signal will mirror the input signal, with all voltages above zero rounded down to zero, which effectively flattens out the peaks. At higher frequencies, the source and output voltages begin to slip out of phase, and the waveform becomes sinusoidal with a peak at zero volts.

3) *Signal Amplitude*
Increasing the amplitude of the source signal increases the steepness of the waveform of the output voltage, but does not have a large effect on the clipping behavior.

It was found that the circuit deviated slightly from an ideal clipping circuit. While the theoretical maximum output voltage should be clipped to zero volts, the actual maximum output voltage was measured to be **552 mV**, which is shown in Figure 9.

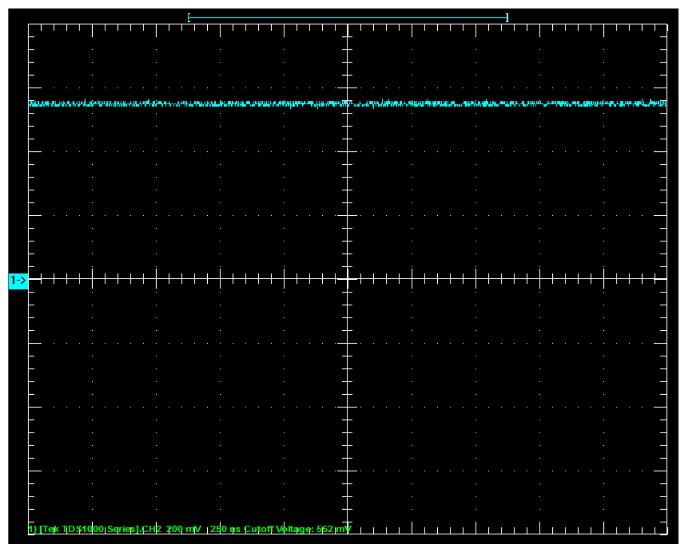

Figure 9. This is a zoomed in portion of the maximum clipped voltage, centered about zero. The deviation from zero volts was measured to be positive 552 mV, showing that the actual circuit behavior differs slightly from its theoretical ideal cutoff voltage.

B. *Clamping Circuit*

C. *Voltage Regulator*

D. *AC $\rightarrow$ DC Converter*

This next circuit uses diodes and capacitors to level out an AC sine wave to approximate a DC source. First the diode connected to the positive terminal of the power supply makes the current only move in one direction, creating times of source

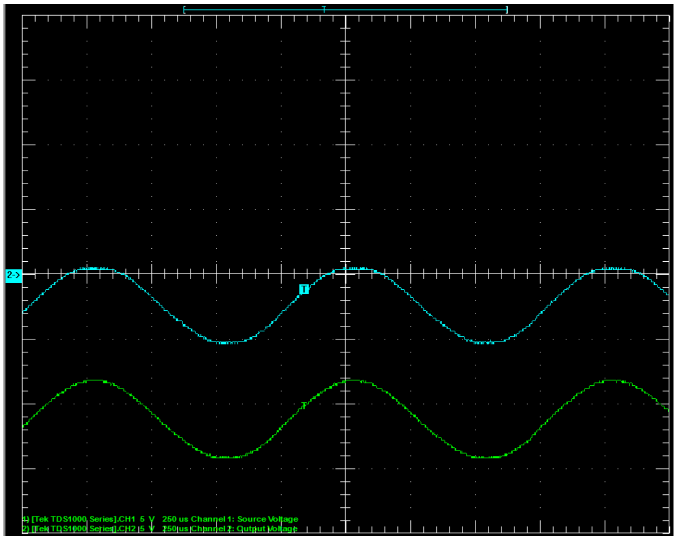

Figure 10. Clamping Circuit

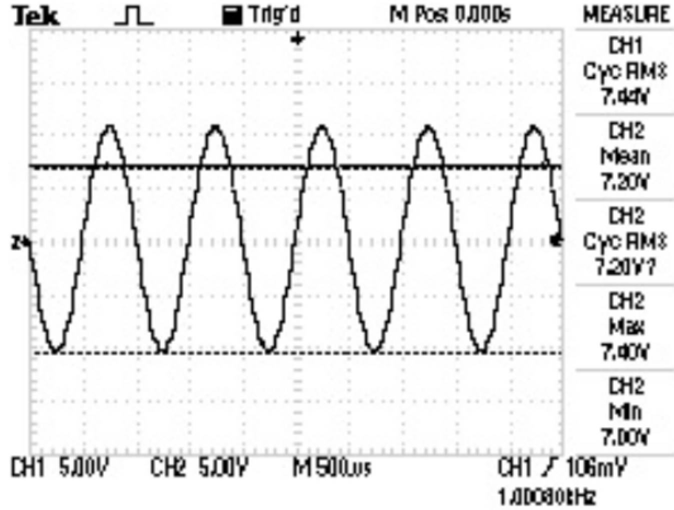

Figure 12. DC Voltage

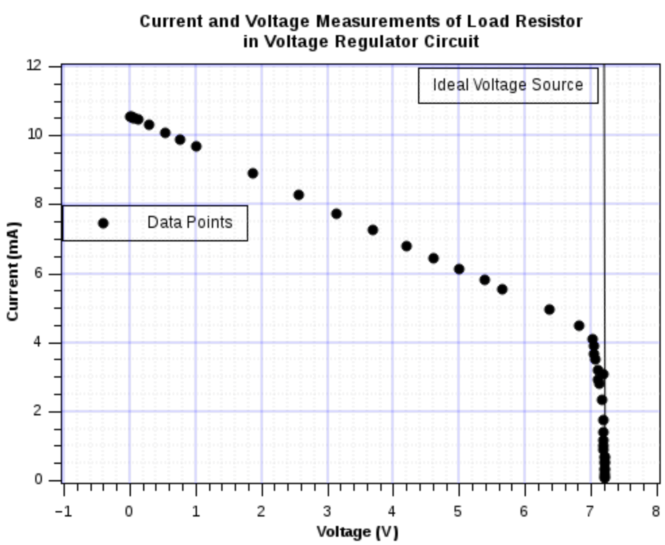

Figure 11. Plots of the load resistor's current and voltage, and its deviation from the behavior of an ideal voltage source.

current and times of no source current. During the time of source current the 1μF capacitor stores voltage. Then during the time of no source current, the capacitor discharges, creating a more level voltage source. The final component to this circuit is the zener diode.

The zener diode is like a pressure valve: if the voltage gets too high, the diode breaks down. This keeps the voltage across the load constant approximately around its breakdown voltage.

When the load resistance is lowered, the voltage across the Load decreases. The voltage across the zener diode connected in parallel with the load also decreases. If this voltage drops below the breakdown voltage, the voltage across the load will not be the breakdown voltage.

When we increase the frequency of the source to 1 kHz, the output voltage levels out to the breakdown voltage of the zener diode. The voltage across the load using an ordinary DC volt meter gives us 7.12 V, while the oscilloscope measures the mean voltage across the load as 7.20 V. The supplied data sheet gives a breakdown voltage of around 7.5 volts.

The value the DC voltmeter gives us is **5%** different then the data sheet and **1%** different then the oscilloscope mean value. This may just be due to the internal resistance of the meter.

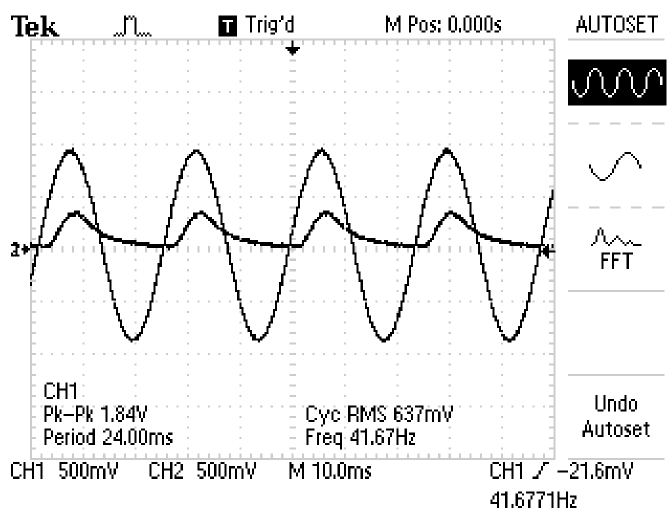

Figure 13. Display of input and output signals. The output voltage is not strictly constant, as it exhibits an exponential voltage decay due to the capacitor.

E. Logic Gates

The final circuits investigated were diode logic circuits. These circuits operate by utilizing diodes to produce an output voltage that is dependent on two input voltages, A and B.

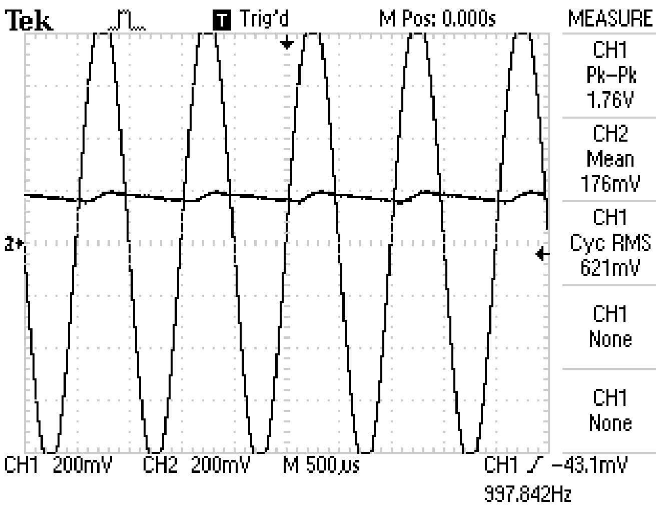

Figure 14. As the frequency increases, the voltage drop between cycles decreases.

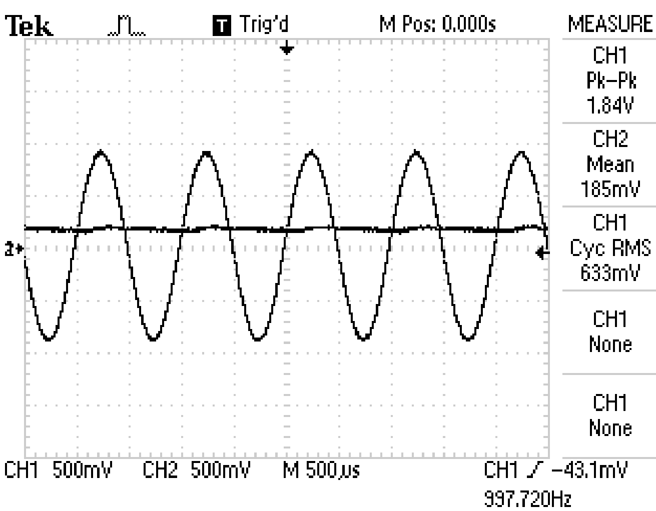

Figure 15. Zooming out at a high frequency shows that the output closely approximates a constant DC voltage.

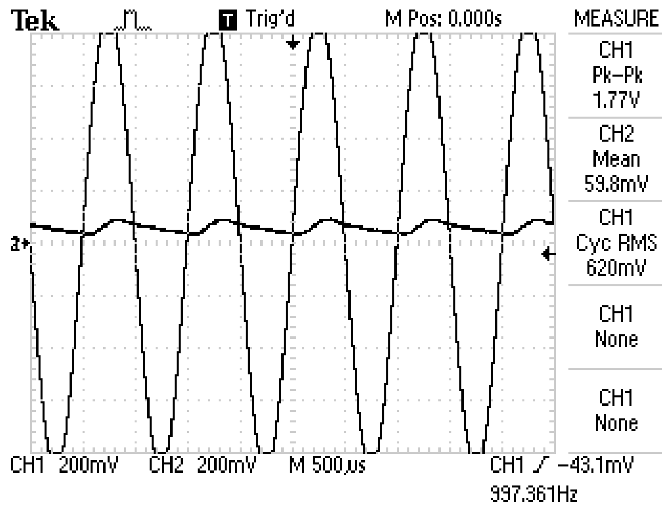

Figure 16. Changing the load resistance directly affects the voltage delivered to it. Decreasing the resistance by a factor of 5 lowered the output voltage by a factor of 3.

Depending how the voltage sources and diodes are oriented, the output voltage can be programmed to hold different voltages for the different voltage combinations of A and B. The input-output patterns of the gates are essential in computer circuitry, since they can be used to mimic the boolean logic functions necessary for computation. In this case, the functions represented were the AND and OR gates:

In order to match the digital quality of the logic functions, the “0” and “1” states for the input voltages were represented by turning a 5 volt DC source either on (“1”) or off (“0”). The output voltage states were slightly different, since the architecture of the circuits prevent the output from always reaching a perfect 0 or 5 volts. Instead, the “0” state was defined as any output voltage lower than 1 volt, and the “1” state as any voltage higher than 4 volts. The two functions represented in this lab were the AND and OR gates.

Table I
AND GATE TRUTH TABLE

Input 1	**Input 2**	**Output**
1	1	1
1	0	0
0	1	0
0	0	0

Table II
OR GATE TRUTH TABLE

Input 1	**Input 2**	**Output**
1	1	1
1	0	1
0	1	1
0	0	0

In both circuits, the behavior of the output voltage matched the output behavior of their corresponding logic functions. Every output voltage larger than 4 volts corresponded to a truth table output of “1“, and every output voltage less than 1 volt corresponded to a truth table value of 0. These results verify the ability of basic circuits to model logic gates using diodes, and gives a glimpse into the kinds of circuitry used in modern computers.

It should be noted that these results only matched when the input voltages were replaced with closed circuits when in the ”0“ (off) state. For example, if voltage A in the AND gate was turned off (disconnected from the circuit), the positive terminal of A had to be shorted with the negative ground, or else the voltage developed in the output would never discharge and remain charged at 1.

This suggests that the power sources used for the input voltages in computers must have some mechanism or structure that allow them to short (or at least keep from remaining open) when in the off state.