CMPE 460 Laboratory Exercise 3
Characterization of OPB745

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Abstract

Optical sensors are devices that detect light and convert it into electrical signals, enabling non-contact measurement of various physical parameters. To demonstrate this, OPB745 Reflective Object Sensor, was assessed for its distance measuring and opto-isolation capabilities. The exercise explored the OPB745 Reflective Object Sensor through the creation and testing of an isolated test environment. The setup involved constructing an enclosure using two opaque PVC pipes with diameters of 1-inch and 1.25 inches, respectively, and lining it with aluminum foil. To regulate the diode current of the OPB745 to 40mA, a current-limiting resistor's value was determined for configurations with and without a SN7604N Inverter in the circuit. The setup excluding the inverters was assembled and evaluated using load resistors of 10kΩ and 20kΩ. The OPB745 performed as anticipated; an increase in the distance between the sensor and the aluminum foil resulted in a corresponding increase in voltage. Subsequently, the circuit incorporating the inverters was built. The maximum frequencies for the setups with 10kΩ and 20kΩ load resistors were established at 1.2kHz and 900Hz, respectively.

Design Methodology

The preliminary exercise was to construct an isolating test environment for the OPB745 Reflective Object Sensor. The environment was constructed with two 1-foot long opaque PVC pipes of 1-inch and 1.25 inches diameter, so that they could fit inside each other snugly. Aluminum foil was attached to one end of the 1-inch diameter pipe as depicted in Figure 1. Cardboard was cut to cover one end of the 1.25 inches diameter pipe with a slit cut out of the center for the OPB745 sensor to be placed facing inside the pipe. Thereafter, the cardboard was attached to the pipe and a printed millimeter ruler was attached to the side of the 1-inch diameter pipe. The ruler was aligned so that 0mm was set to where the foil was touching the sensor and increased as the pipe is pulled out. A current-limiting resistor value, Rf, was found to limit the current to the diode of the OPB745 to 40mA with a source voltage of 5V as seen in Figure 2. This calculation was done again with a SN7406N Inverter placed after the diode of the OPB745 as seen in Figure 3. With a diode voltage drop of 1.7V and inverter voltage drop of 0.8V, the resistor values were found to be 82.5Ω and 62.5Ω respectively.

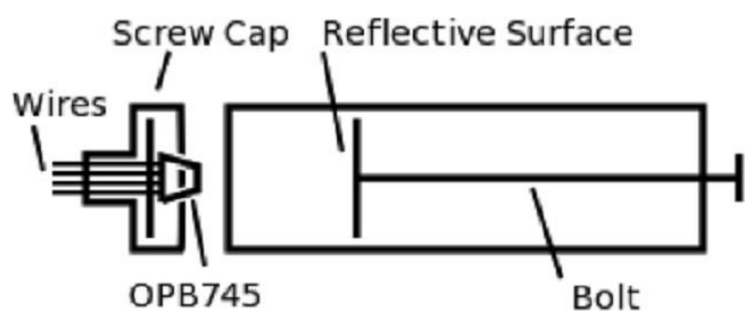

Figure 1. Optoisolator Diagram. Image Source from Lab Manual.

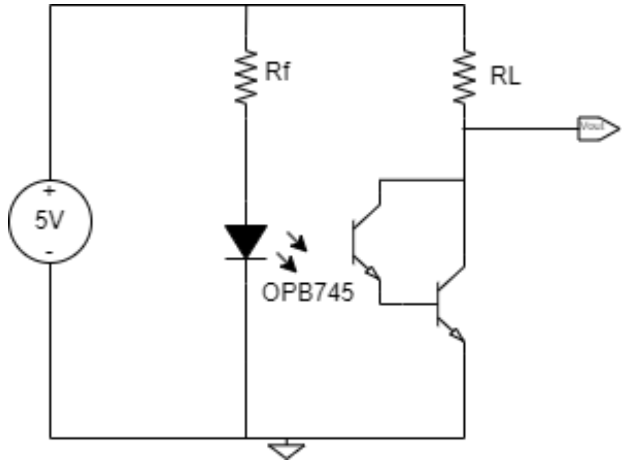

Figure 2: PB745 Circuit Schematic

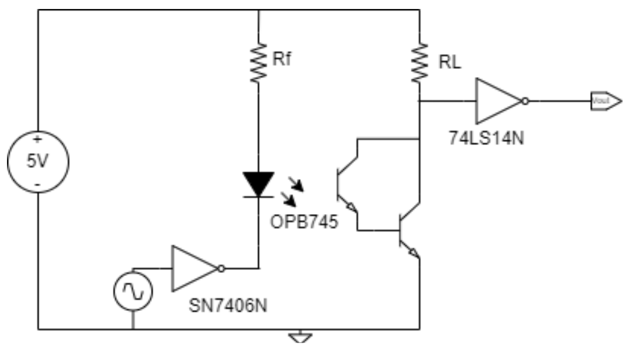

Figure 3: OPB745 Circuit Schematic with inverters

Results and Analysis

The first circuit was constructed with the 82.5Ω resistor approximated to 83Ω. This was done with a load resistor, R_L, of 10kΩ and 20kΩ. A multimeter was attached at V_{out} as seen in Figure 2. The test environment was set to 0mm and was pulled out, measuring voltage and current values between 0-50mm for each load resistor. The voltage and current values measured were recorded as seen in Table 1. It can be seen that initially, the voltage is high as the foil is pressed against the sensor, reflecting light onto the sensor. As soon as the foil is pulled away, the voltage decreases sharply as the light is not reflected onto the sensor. Voltage begins to increase again once as the reflective surface enters the sensors field of view maybe due to ambient light entering the pipe.

Distance(mm)	$V_{out,10k\Omega}$(V)	$I_{RL,10k\Omega}$ (mA)	$V_{out,20k\Omega}$(V)	$I_{RL,\ 20k\Omega}$ (mA)
0	4.72	0.028	4.77	0.012
1	0.67	0.433	0.63	0.219
2	0.69	0.431	0.65	0.218
3	0.72	0.428	0.68	0.216
4	0.74	0.426	0.72	0.214
5	0.77	0.423	0.74	0.213
6	0.79	0.421	0.76	0.212
7	0.83	0.417	0.79	0.211
8	1.91	0.309	0.82	0.209
9	3.25	0.175	1.57	0.172
10	3.89	0.111	3.04	0.098
11	4.23	0.077	3.61	0.070
12	4.39	0.061	4.00	0.050
13	4.51	0.049	4.15	0.043
14	4.57	0.043	4.26	0.037
15	4.60	0.040	4.34	0.033
20	4.61	0.039	4.46	0.027
25	4.55	0.045	4.46	0.027
30	4.53	0.047	4.38	0.031
35	4.48	0.052	4.26	0.037
40	4.43	0.057	4.15	0.043
45	4.38	0.062	4.10	0.045
50	4.37	0.063	4.08	0.046

Table 1: Voltage and Current change as distance increases

The voltage and current values for the 10kΩ load resistor were graphed individually with respect to distance. Figure 4 and 5 are the resulting graphs. It can be seen that the graphs are inverse of each other, as voltage increased, current decreased and vice versa.

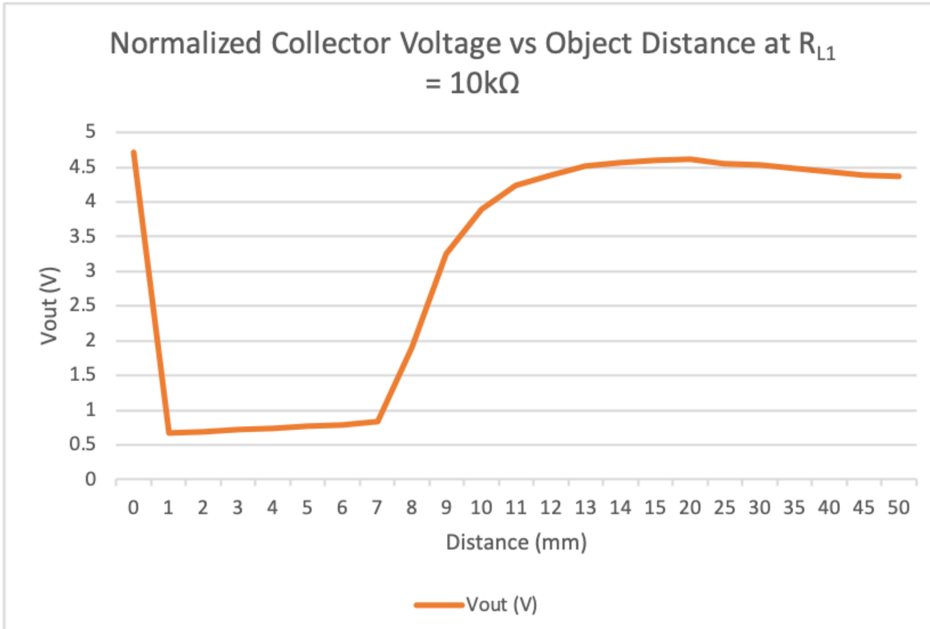

Figure 4: Graph of Voltage(v) vs Distance(mm), RL = 10kΩ

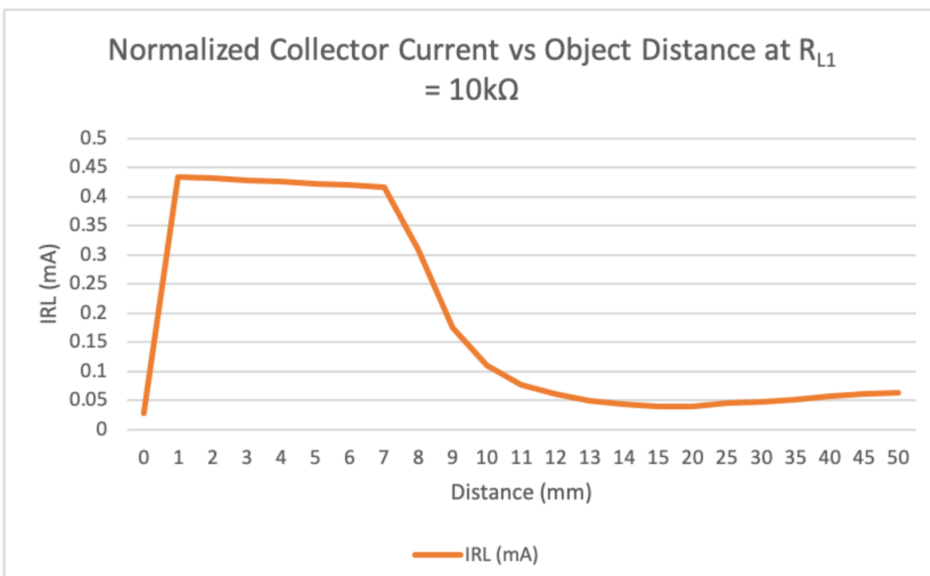

Figure 5: Graph of Current(mA) vs Distance(mm), RL = 10kΩ

The voltage and current values for the 20kΩ load resistor were graphed individually with respect to distance. Figures 6 and 7 are the resulting graphs. It can be seen that once again that the voltage and current act inversely. It can also be seen that despite having a higher voltage at 0mm, increasing the load resistor reduced V_{out} slightly and decreased the load current by a factor of two. Increasing the load resistor also increased the distance before the voltage spiked back up.

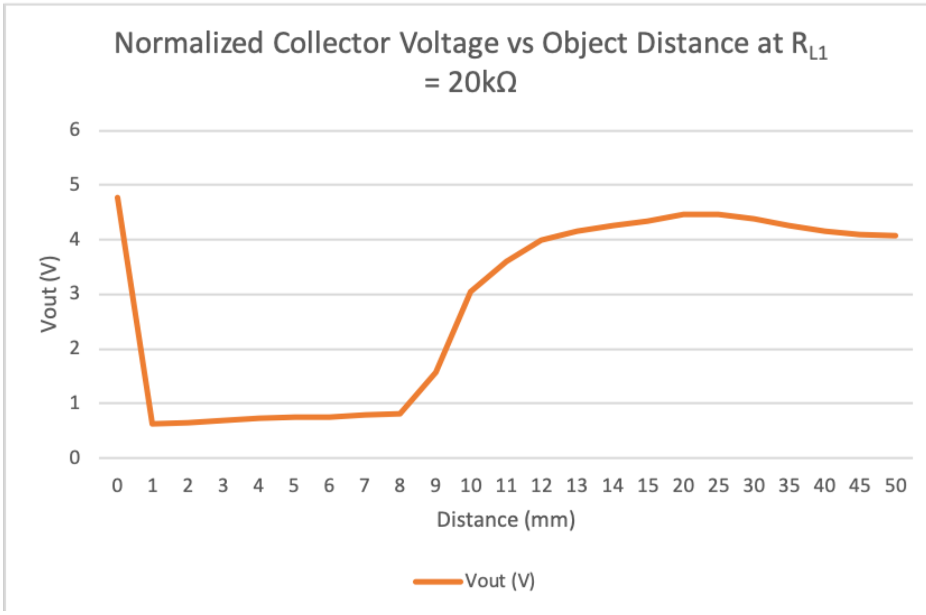

Figure 6: Graph of Voltage(v) vs Distance(mm), RL = 20kΩ

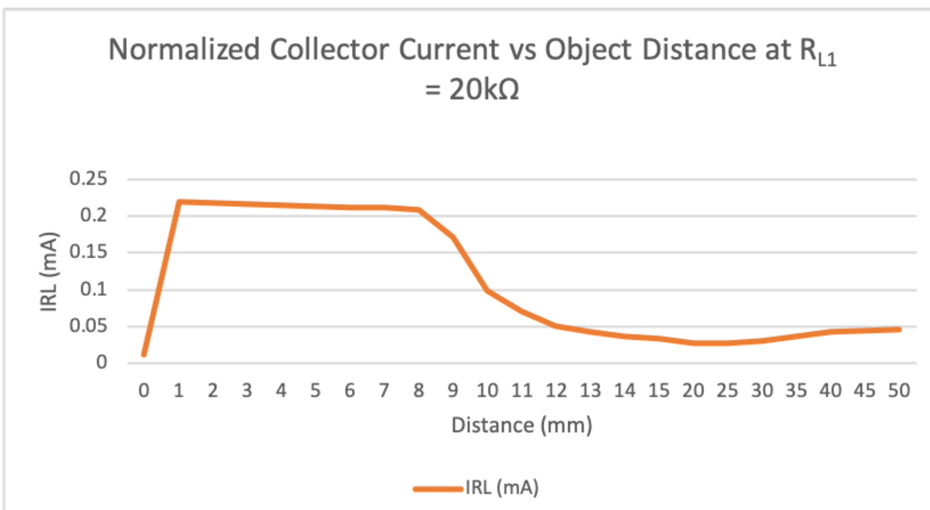

Figure 7: Graph of Current(mA) vs Distance(mm), RL = 20kΩ

The second circuit with an SN7406N and 74LS14N inverter was constructed with an oscilloscope attached after the 74LS14N Inverter, as seen in Figure 3, with a 10kΩ load resistor. The frequency of the function generator was increased to its maximum before the output waveform broke down. The input and output waveform can be seen in Figure 8 before breakdown and in Figure 9 immediately after breakdown. It can be seen that the maximum frequency was 1.2KHz.

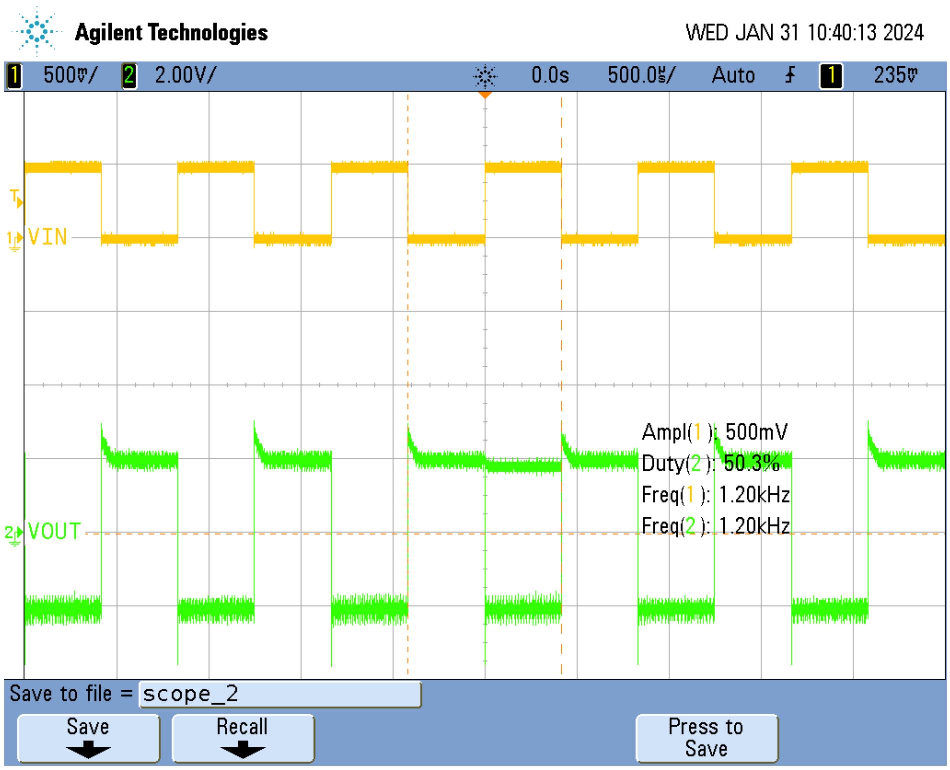

Figure 8: Circuit 2 RL = 10kΩ oscilloscope, Vin(orange) vs Vout(green) before breakdown

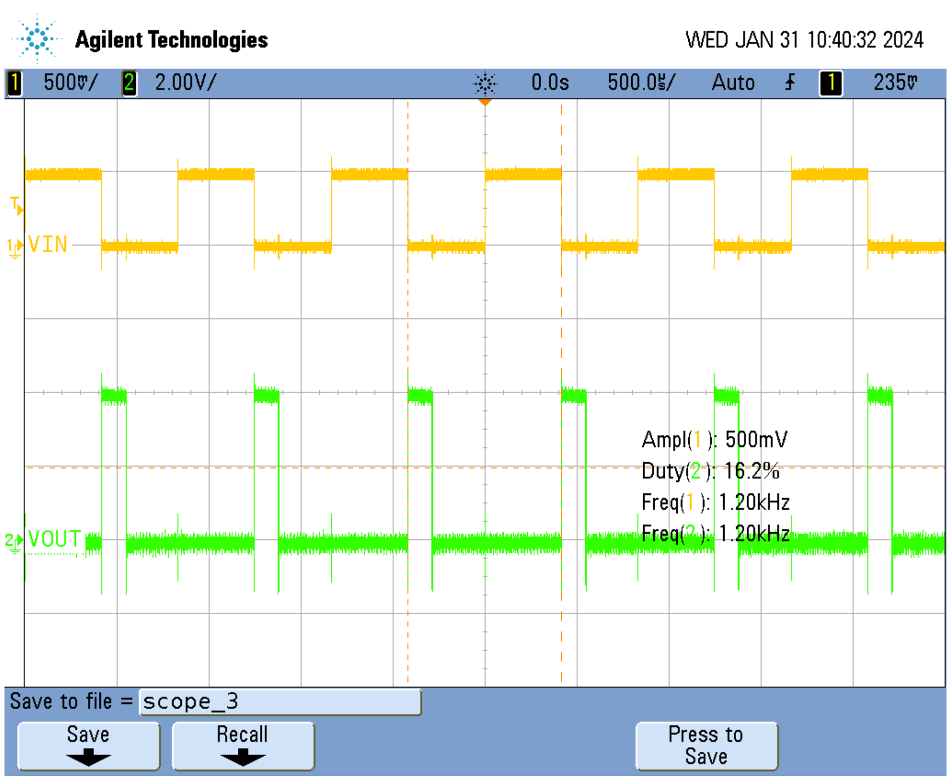

Figure 9: Circuit 2 RL = 10kΩ oscilloscope, Vin(orange) vs Vout(green) after breakdown

The load resistor was increased to 20kΩ. The frequency was reset to 100Hz and increased until breakdown. The input and output waveform can be seen in Figure 10 before breakdown and Figure 11 immediately after breakdown. It can be seen that the maximum frequency decreased to 900Hz.

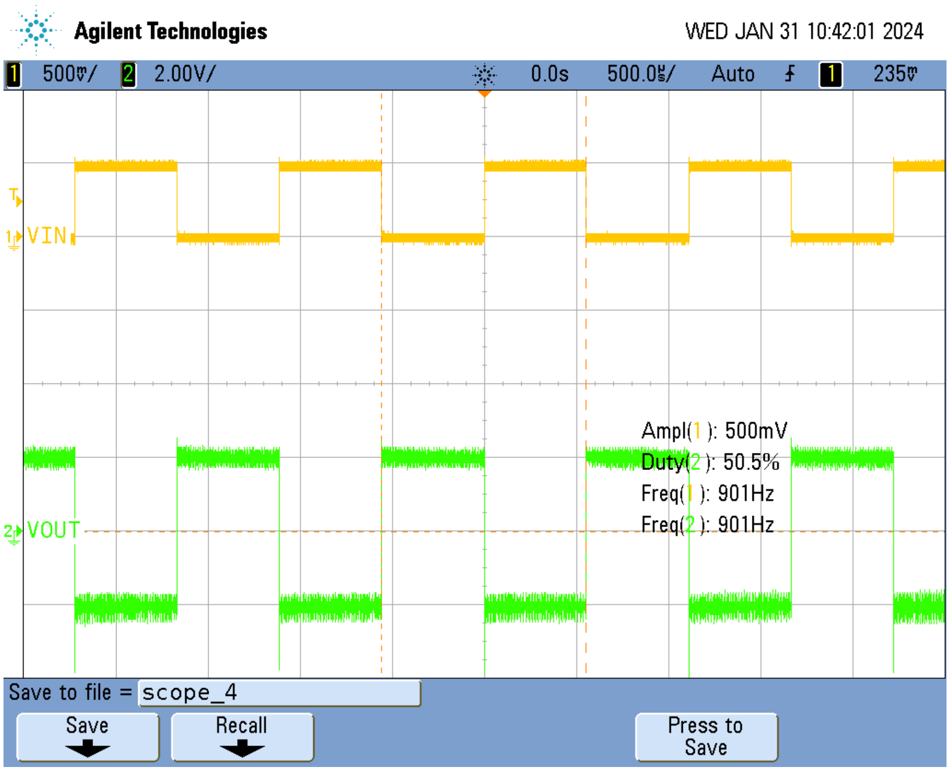

Figure 10: Circuit 2 RL = 20kΩ oscilloscope, Vin(orange) vs Vout(green) before breakdown

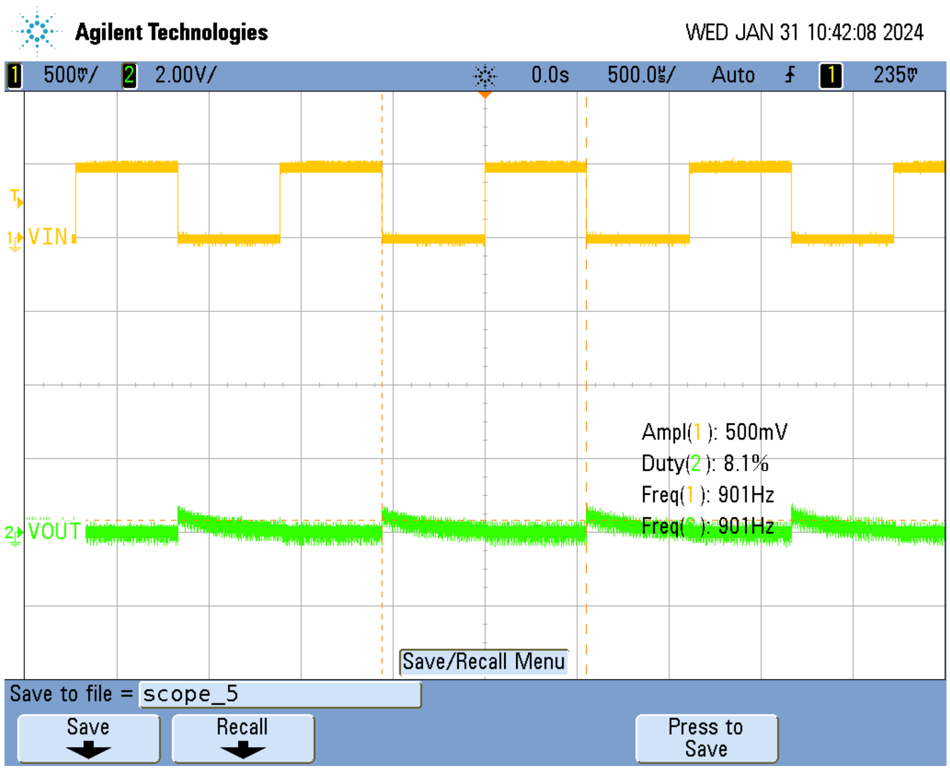

Figure 11: Circuit 2 RL = 20kΩ oscilloscope, Vin(orange) vs Vout(green) after breakdown

Questions

1. The 74LS14 inverter with Schmitt trigger is used instead of a 7406 inverter because the Schmitt trigger provides noise immunity and stable switching. It achieves this by having two threshold voltages for changing states, which helps in cleaning up noisy signals and ensuring sharp transitions, making it ideal for digital circuits where signal integrity is crucial.

2. The initial 5V voltage at 0mm represents the unobstructed output voltage level of the circuit when the reflective surface is very close to the sensor, allowing for maximum reflection and thus maximum sensor output. The voltage then drops quickly as the distance increases because the amount of light reflected back to the sensor decreases, leading to a lower output voltage. Eventually, as the distance continues to increase, the sensor may no longer detect the reflected light, and the circuit reverts to its default state, which restores the voltage back to 5V, indicating no detection. or the increase might be as a result of ambient light or other factors.

3. It would be reasonable to anticipate a decrease in the maximum operational frequency when the load resistance is increased from 10kΩ to 20kΩ. The increased resistance adds to the circuit's total impedance and increases the RC time constant, both of which contribute to a slower response to changing input signals, thereby reducing the maximum frequency at which the output waveform can maintain its square wave characteristics without breakdown. The relationship between the RC time constant and the maximum operational frequency can be expressed as:

$$f_{max} = \frac{1}{2\pi\tau} = \frac{1}{2\pi RC}$$

This equation shows that as the resistance R increases, the RC time constant τ also increases, which leads to a decrease in fmax, the maximum frequency at which the circuit can operate effectively. This supports the anticipation that increasing the load resistance from 10kΩ to 20kΩ would decrease the maximum operational frequency of the circuit, as observed in the experiment.

Conclusion

This exercise explored the OPB745 Reflective Object Sensor through research and development of an isolating test environment. The test environment was constructed using two PVC pipes of 1-inch and 1.25 inches diameter and aluminum foil. Two current limiting resistors were found to limit the current to the diode of the OBP745 to 40mA with and without a SN7406N inverter in series with it. The first circuit without the SN7406N inverter was constructed and tested with load resistance of 10kΩ and 20kΩ. The voltage and current values were measured and graphed. As the distance from the sensor to the foil increased, so did the voltage as the reflective surface entered the field of view, functioning as expected. The second circuit with a SN7406N inverter and a 74LS14N inverter was then constructed varying load resistance of 10kΩ and 20kΩ. Oscilloscope captures of the input and output waveform were then taken before and after breakdown. As the load resistance increased the breakdown frequency decreased, functioning as expected.

Exercise 3: Characterization of OPB745

and Gloria Mbaka

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PreLab		Point Value	Points Earned	Comments
PreLab	Optoisolator	10	10	JrS 1/31
	Resistor Calculations	5	5	

Demo		Point Value	Points Earned	Date
Demo	Part 1	10	10	CU 1/31
	Part 2	15	15	JrS 1/31

To receive any grading credit students must earn points for both the demonstration and the report.

Exercise 3: Characterization of OPB745

Report		Point Value	Points Earned	Comments
Abstract		10		
Design Methodology	Discussion	20		
Results and Analysis	Completed Table	5		
	Distance v Vout Graph	5		
	Distance v Current Graph	5		
	Oscilloscope Captures	5		
Conclusion		5		
Question		5		
Total for prelab, demo, and report		100		