CMPE-460 Laboratory Exercise 3
Characterization of OPB745

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Abstract

The purpose of this exercise was to develop an understanding behind the functionality and various functional parameters of the OPB745 opto-isolator. In order to test its ability to perform as an opto-isolator, a tube with an adjustable reflective surface was created, and the OPB745 was placed inside in order to isolate it from any external light source. The sensor was tested in two distinct ways. The first was the voltage and current characteristics versus distance from the reflective surface. This was observed by measuring the voltage output across the sensor while loaded while the reflective surface was moved relative to the sensor. The second was the frequency capabilities of the sensor. This was performed using a waveform generator to generate waveforms of various frequencies and measuring the output using an oscilloscope. With the following implemented, the Opto-Isolator functioned accordingly yielding the expected results.

Design Methodology

The first step in this lab exercise was to build the enclosure for the opto-isolator. Figure 1 shows the logical diagram for the enclosure.

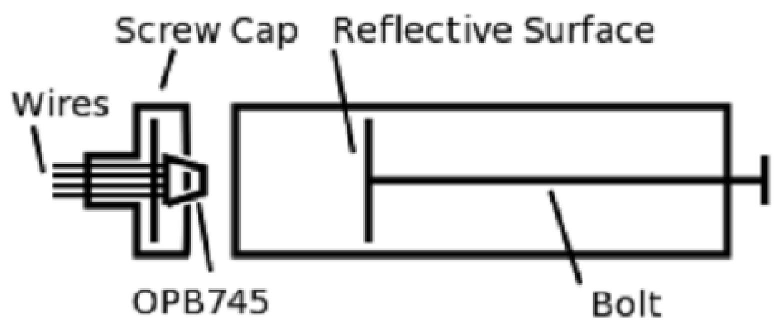

Figure 1: Opto-Isolotor enclosure diagram

Two black ABS plastic tubes were used to create this enclosure. One with roughly a one inch outer diameter with an end cap to hold the OPB754 sensor. The second tube, with a slightly smaller diameter, was used to hold the reflective surface at a variable distance from the sensor as well as block out any interfering light from outside the tube. A metric ruler was also attached to the inner tube to allow the distance from the sensor to the reflective surface to be measured.

Once the enclosure was assembled the next step was to calculate the necessary resistors for the two different circuits used to analyze the voltage vs. distance and frequency characteristics of the OPB745 sensor. Figures 2 and 3 show the two circuits.

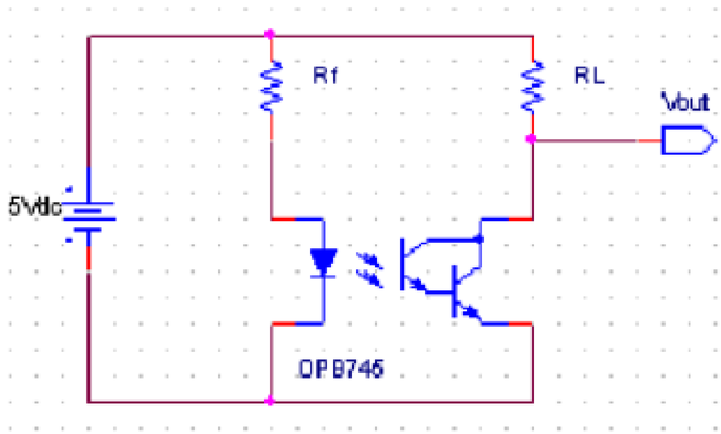

Figure 2: Voltage vs. Distance circuit

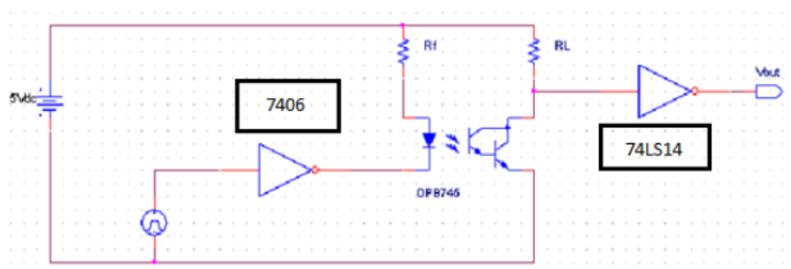

Figure 3: Frequency response circuit

Equations 1 - 4 show the derivation for the R_f resistor for the circuit in Figure 2. The values for V_f were obtained from the respective datasheets.

$$I_f = \frac{V_{dc} - V_f}{R_f} \tag{1}$$

$$R_f = \frac{V_{dc} - V_f}{I_f} \tag{2}$$

$$R_f = \frac{5\text{V} - 1.7\text{V}}{40\text{mA}} \tag{3}$$

$$R_f = 82.5\Omega \tag{4}$$

The same process was used for deteminging the R_f resistor for the circuit in Figure 3 and is shown in Equations 5 - 7. Again, the values for V_f were obtained from the appropriate data sheets.

$$R_f = \frac{V_{dc} - (V_{f,inverter} - V_{f,diode})}{I_f} \tag{5}$$

$$R_f = \frac{5 - (1.7\text{V} - 0.8\text{V})}{40\text{mA}} \tag{6}$$

$$R_f = 65\Omega \tag{7}$$

These circuits were then built using a breadboard, jumper wires and various resistors to get as close as possible to the calculated values above. Each circuit was analyzed twice with two different load resistor values of 10kΩ and 20kΩ.

The circuit in Figure 2 was analyzed by using a multimeter to measure the voltage at V_{out} while the distance between the reflective surface and the sensor is varied. This gives the voltage vs. distance characteristics of the OPB745 sensor.

The circuit in Figure 3 was analyzed by using an oscilloscope at V_{out} and a waveform generator at the input of the diode. The output was then measured while the frequency of the input waveform was varied starting at 100Hz and increasing by 100Hz steps until the output of the OPB745 sensor no longer resembled the input waveform. A square wave with a duty cycle of 50% was used for this lab exercise. This shows the frequency limitations of the OPB745, specifically the frequency limitations of the photo-transistor.

Results & Analysis

Table 1 shows the measurements taken from the multimeter as the distance from the OPB745 sensor and the reflective surface was varied. Measurments were taken using the circuit in Figure 2.

Table 1: Voltage/Current vs. Distance measurements

	$R_{l,1}$ - 10kΩ		$R_{l,2}$ - 20kΩ	
Distance (mm)	V_{out} (V)	I_{R_l} (mA)	V_{out} (V)	I_{R_l} (mA)
0	4.934	0.4934	4.859	0.24295
1	0.866	0.0866	0.781	0.03905
2	0.723	0.0723	0.679	0.03395
3	0.701	0.0701	0.653	0.03265
4	0.703	0.0703	0.651	0.03255
5	0.717	0.0717	0.662	0.0331
6	0.736	0.0736	0.681	0.03405
7	0.757	0.0757	0.707	0.03535
8	0.782	0.0782	0.729	0.03645
9	0.808	0.0808	0.729	0.03645
10	0.844	0.0844	0.772	0.0386
11	0.985	0.0985	0.791	0.03955
12	2.107	0.2107	0.809	0.04045
13	2.800	0.2800	0.838	0.0419

14	3.097	0.3097	0.885	0.04425
15	3.300	0.3300	1.137	0.05685
20	3.582	0.3582	1.613	0.08065
25	3.627	0.3627	1.985	0.09925
30	3.848	0.3848	2.246	0.1123
35	4.243	0.4243	3.255	0.16275
40	4.508	0.4508	3.971	0.19855
45	4.637	0.4637	4.287	0.2139
50	4.695	0.4695	4.421	0.22105

The data in Table 1 was graphed using Excel and produced Figures 4 and 5. These figures show data produced by the circuit with both the 10kΩ and 20kΩ load resistors. From inspection the voltage at the 0mm mark reads close to that of the source, 5V. As the distance initially increases, the voltage drops close to 0 and as the distance continues to grow, the voltage begins to return to the source value of 5V. This is due to the operating range of the device.

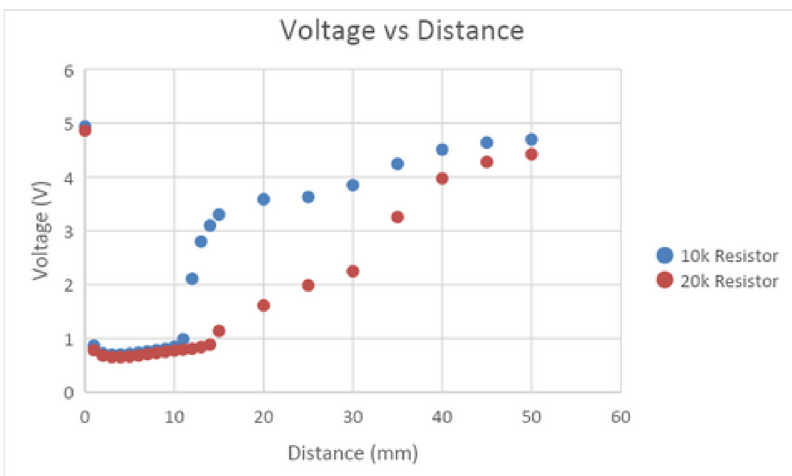

Figure 4: Voltage vs. Distance of OPB745

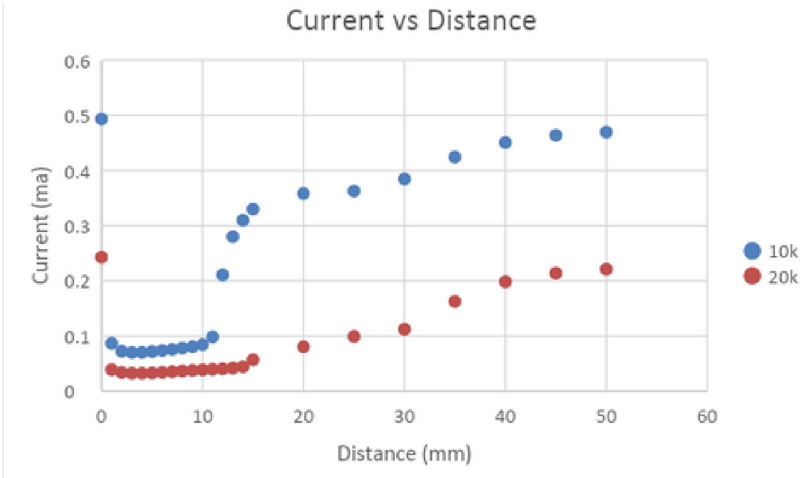

Figure 5: Current vs. Distance of OPB745

The next part of the lab exercise focused on the frequency limitations of the OPB745 sensor. This was done using the circuit in Figure 3, along with a waveform generator to generate input waveforms for the IR LED embedded in the OPB745 and an oscilloscope to measure the output of the photo-transistor.

Figures 6 and 7 show the oscilloscope captures for the circuit in Figure 3 for both the 10kΩ and 20kΩ load resistors with an input waveform of a 100Hz and a 50% duty cycle. The top waveform shows the input waveform and the bottom waveform is the output waveform.

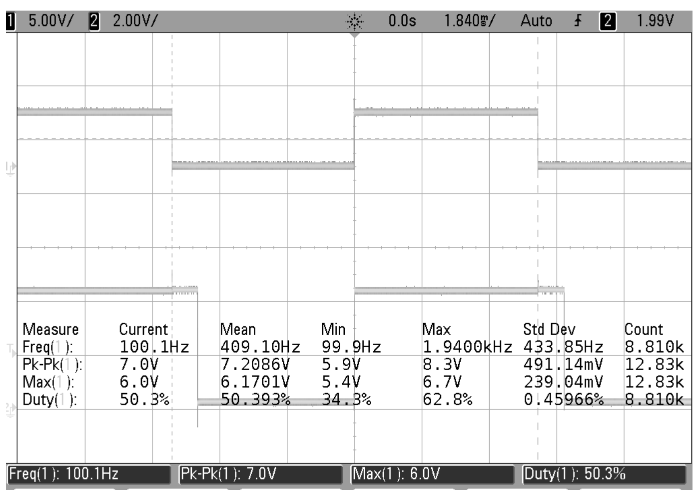

Figure 6: Oscilloscope capture with 10kΩ load at 100Hz

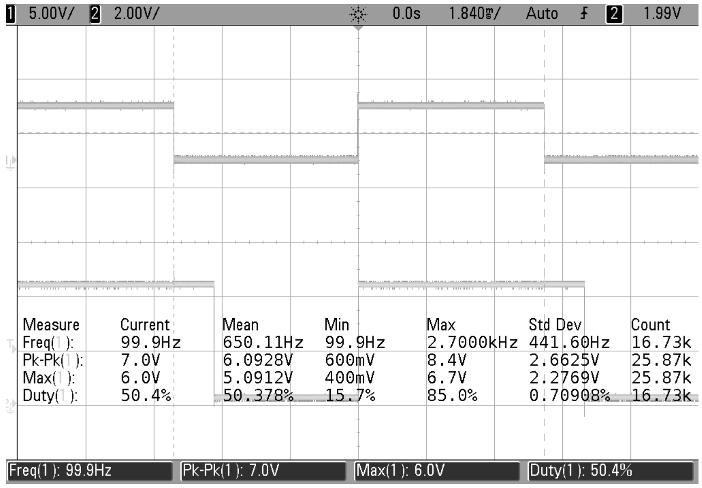

Figure 7: Oscilloscope capture with 20kΩ load at 100Hz

Figures 8 and 9 show the oscilloscope captures where the OPB745 is no longer able to handle the input waveform frequency. Instead of seeing a nice square wave output, all that is seen is a steady signal. The point at which this happens is different depending on the load resistor. For the 10kΩ resistor the OPB745 sensor stopped working at around 1kHz while for the 20kΩ resistor, the breakdown point was only around 600Hz. Again, the top signal is the input waveform and the bottom signal is the output waveform.

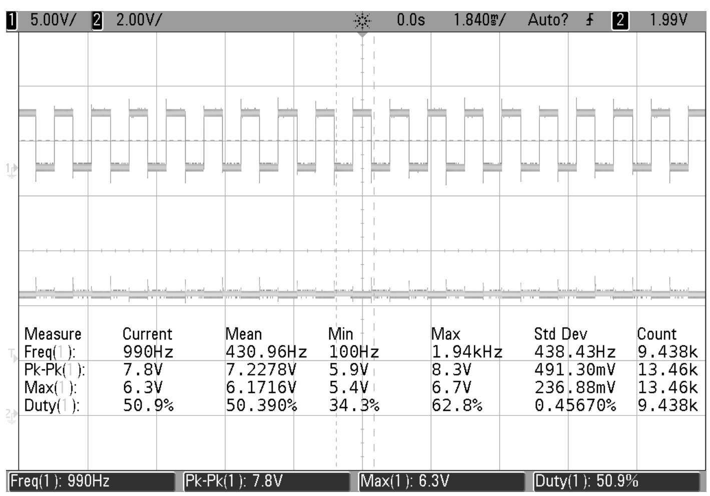

Figure 8: Oscilloscope capture with 10kΩ load at 1kHz

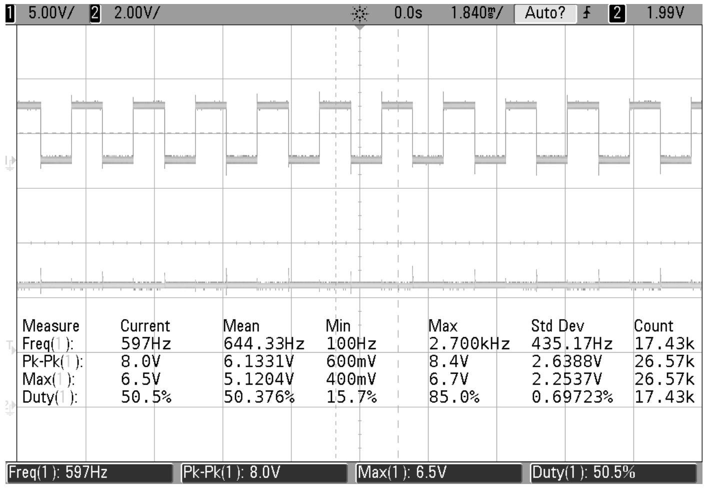

Figure 9: Oscilloscope capture with 20kΩ load at 600Hz

Questions

1. Schmitt inverter reduces noise and produces a more defined square wave when taking an analog signal (opto-isolator) and converting it to a digital signal (oscope). The difference between the two devices are that the 74LS14 with Schmitt trigger will sustain the output value until the input has an adequate amount of change to trigger a change in the output.

2. The voltage initially starts off at 5V at 0mm because there is no change in the opto-isolators positioning. As the distance is increased, the voltage drops to close to 0V, the reasoning behind this is due to the operating range of the OPB745. Based on the data sheet, the operating range is from 0 inches to 0.5 inches which is the distance to the reflective surface. At 0mm, the device is out of its range and no IR light from the LED can reach the photo-transistor, meaning no current is flowing through the transistor and therefore, $V_{out} = 5V$.

3. The frequency changes when replacing the 10k load resistor with the 20k resistor due to the rise and fall times of the OPB745. The OPB745 rise and fall times increase until it reaches a 1k load resistance, any increase in load resistance from this point on will cause the frequency to drop, therefore the decrease was anticipated.

Conclusions

Opto-isolators are very common devices found in many fields of interest. There are applications where physical measurements are not feasible. Opto-isolators are the solution to these issues as they provide a means of measurement that is isolated from the actual unit. Understanding the fundamentals of how one operates is imperative to being able to create well-designed systems. The exercise proved to be an overall success.