# CMPE 460 Laboratory Exercise 3

# Characterization of OPB745

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Lab Section: 2
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Lecture Section: 1
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## Abstract

In this laboratory exercise, the electrical properties of the OPB745 optoisolator sensor was investigated. An isolation chamber with varying length was constructed to measure the resistivity properties of the sensor. The sensors characteristics were charted and compared to the device characteristic on the corresponding data sheet. A square wave power signal was also tested with this circuit to determine the frequency at which the output would degrade.

## Design Methodology

When designing an environment to isolate the optoisolator sensor, the most important design consideration is to avoid leakage of as much light as possible. To accomplish this, two PVC pipes were used. One pipe has the same outer diameter as the others inner diameter. This allows as much light to be blocked from entering in the space between the two pipes.

The OPB745 sensor is a set of two different diodes, a light source and its corresponding light detector. The basic idea is that the light source would emit outward and reflect off of some surface. When the light travels back to the receiver, the receiver diode will draw more current which allows us to measure the voltage drop across a series resistor. This measured voltage will give us information about the distance between the emitter and the reflective surface and can therefore be used as a distance measurement sensor.

### Part 1

In the first portion of this exercise the OPB745 was used to measure certain distances inside the isolation chamber. The voltage drop across a specific resistor was used to determine the current draw through the receiver which could later be used to chart the characteristics of the sensor output.

The schematic diagram below was made to better illustrate the functionality of the optoisolator circuit.

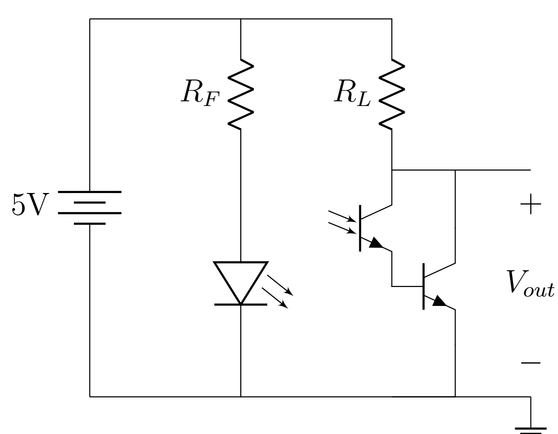



Figure 1: Part 1 schematic of optoisolator circuit

Figure 1 shows the circuit that was constructed in the first portion of the lab. Here we can see two resistors, $R_F$ and $R_L$. The load resistor $R_L$ has known values. For the purposes of this lab, $10\,\mathrm{k\Omega}$ and $20\,\mathrm{k\Omega}$ were used for $R_L$. $R_F$ has an unknown resistance value dependent on the value of the load resistor. When determining which resistance to use for $R_F$, we must consider that we want the maximum allowed current to pass through the diode in series with $R_F$. This current is listed on the diode's data sheet at $40\,\mathrm{mA}$. Using this information, the resistance of $R_F$ was determined to be $82.5\,\Omega$ and $65\,\Omega$ when the $R_L$ values are $10\,\mathrm{k\Omega}$ and $20\,\mathrm{k\Omega}$ respectively.

Measurements of the sensor can be made by placing a multimeter on the $V_{out}$ node to measure the voltage drop on $R_L$. This information will tell us the current that the receiver NPN transistor was able to pass due to the amount of light it was exposed to.

**Part 2**

During the second portion of this exercise, a square wave generator was used to pulse the current across the emitter diode and generate a square wave output signal. A schematic showing how the part 2 circuit differs from the part 1 circuit is shown below.

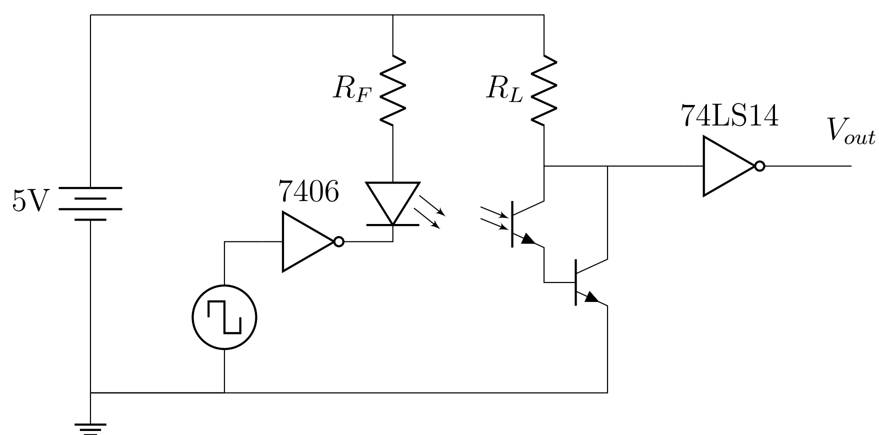



Figure 2: Part 2 schematic of optoisolator circuit with wave generator

Figure 1 and 2 are both quite similar in their basic design. There are some new components added in series with the emission diode. The wave generator's purpose is to feed a period square with to the 7406 inverter. This inverter is not simply a logical inverter. On input level low, instead of the inverter outputting a logic level high, it actually provides high impedance on the output line. This is important because the emission diode can be damaged if a reverse voltage is applied to it. The result of feeding the square wave and inverter signal into the output of the diode is to pulse the emitter at the frequency of the square wave.

The final 74LS14 inverter has the purpose of re-inverting the generated wave from the input square wave. The needs to be done because a current will only pass $R_L$ when the emission diode is not at high impedance. This state will only occur when the input from the square wave is high. When current passes through the $R_L$ resistor, the voltage at $V_{out}$ will be low and therefore needs to be inverted. The other purpose this inverter serves is to convert an analog voltage to a digital one. The value of the output will be floored to logic levels low and high.

## Results & Analysis

To graph the characteristics of the optoisolator circuit, a table of volage readings is created by reading the voltage at $V_{out}$ after altering the length of the space between the inner and outer tubes. The same process was applied for both $10\,\mathrm{k\Omega}$ and $20\,\mathrm{k\Omega}$ values for the load resistor $R_L$. The current through the load resistor was also calculated using the voltage drop across the load resistor. A table of voltage measurements at $V_{out}$ was created for varying distances from 0 mm-50 mm within the isolation chamber.

Table 1: Part 1 voltage readings for 0 mm-50 mm for $R_L$ at $10\,\mathrm{k\Omega}$ and $20\,\mathrm{k\Omega}$

| $R_L$ | $10\,\mathrm{k\Omega}$ | | $20\,\mathrm{k\Omega}$ | |
|---|---|---|---|---|
| Distance (mm) | $V_{out}$ | $I_{R_L}$ (mA) | $V_{out}$ | $I_{R_L}$ (mA) |
| 0 | 4.25 | 0.075 | 4.945 | 0.00275 |
| 1 | 0.683 | 0.4317 | 0.652 | 0.2174 |
| 2 | 0.677 | 0.4323 | 0.653 | 0.21735 |
| 3 | 0.685 | 0.4315 | 0.668 | 0.2166 |
| 4 | 0.688 | 0.4312 | 0.689 | 0.21555 |
| 5 | 0.707 | 0.4293 | 0.704 | 0.2148 |
| 6 | 0.723 | 0.4277 | 0.721 | 0.21395 |
| 7 | 0.736 | 0.4264 | 0.737 | 0.21315 |
| 8 | 0.75 | 0.425 | 0.75 | 0.2125 |
| 9 | 0.766 | 0.4234 | 0.761 | 0.21195 |
| 10 | 0.801 | 0.4199 | 0.773 | 0.21135 |
| 11 | 0.82 | 0.418 | 0.784 | 0.2108 |
| 12 | 0.839 | 0.4161 | 0.789 | 0.21055 |
| 13 | 0.878 | 0.4122 | 0.799 | 0.21005 |
| 14 | 1.345 | 0.3655 | 0.809 | 0.20955 |
| 15 | 1.671 | 0.3329 | 0.819 | 0.20905 |
| 20 | 2.777 | 0.2223 | 1.248 | 0.1876 |
| 25 | 3.366 | 0.1634 | 2.534 | 0.1233 |
| 30 | 3.835 | 0.1165 | 3.321 | 0.08395 |
| 40 | 4.447 | 0.0553 | 3.813 | 0.05935 |
| 45 | 4.575 | 0.0425 | 4.086 | 0.0457 |
| 50 | 4.614 | 0.0386 | 4.169 | 0.04155 |

Using the values from Table 1, voltage and current graph were generated to show the effect of distance in the inner tube on the sensor. Both graphs for $R_L$ at $10\,\mathrm{k}\Omega$ and $20\,\mathrm{k}\Omega$ were charted alongside each other to compare varying load resistances.

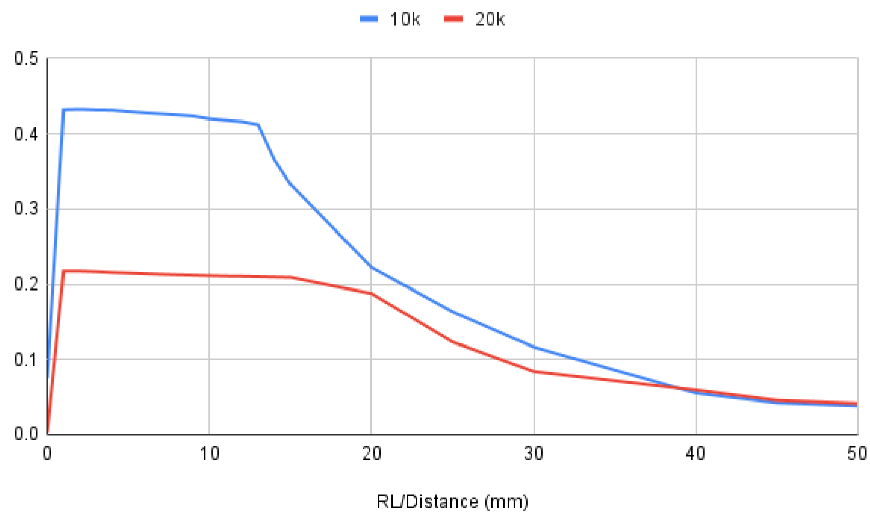



Figure 3: $I_{R_L}$ (mA) vs distance inside isolation chamber.

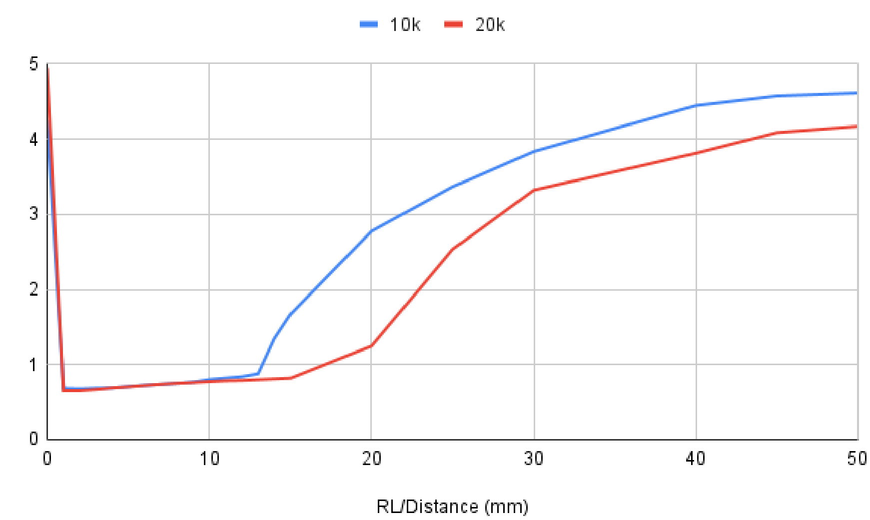
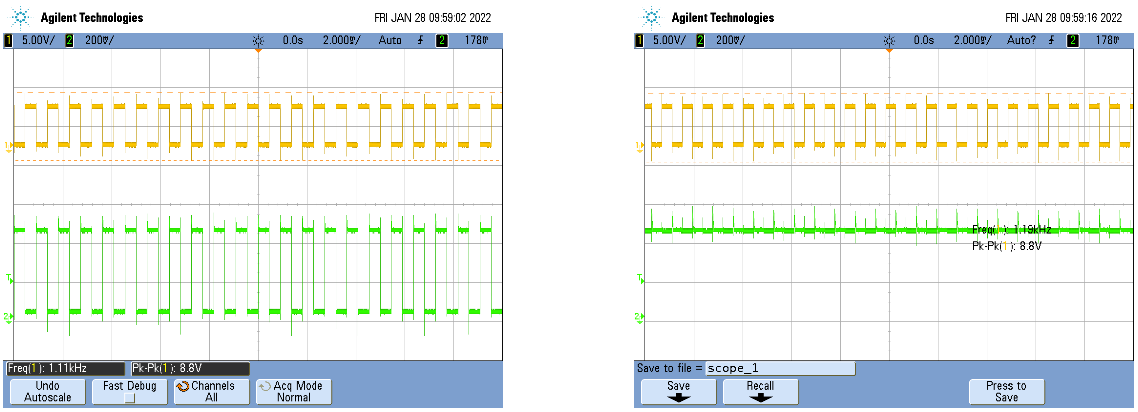



Figure 4: Voltage at $V_{out}$ vs distance inside isolation chamber.

Looking at figures 3 and 4 we can see the expected characteristic curves of the OPB745. The current draw should be zero when the distance from the sensor is zero because most of the light emitting from the diode does not reach the transducer on the receiving end.

### Part 2

Part 2 of the exercise involved running the second circuit at both values of $R_L$. The frequency input on the square wave generator was varied until the signal degraded.




(a) Signal at 700 Hz (b) Degraded signal at 800 Hz

Figure 5: Screen captures of oscilloscope with $R_L = 10\,\mathrm{k}\Omega$


(a) Signal at 1100 Hz (b) Degraded signal at 1200 Hz

Figure 6: Screen captures of oscilloscope with $R_L = 20\,\mathrm{k}\Omega$

Figures 5 and 6 show the signal degradation experienced by both of the different $R_L$ values. Before signal degradation, the output waveform closely matched the input waveform in frequency. When the frequency of the input reached a critical point, the sensor seemed to output a constant voltage. This is due to the fact that the light being emitted by the diode is integrated. As the pulse reaches a critical frequency, the light integrate to a constant current draw from the transducer.

## Conclusion

This laboratory exercise constructed an optoisolator circuit which could be used to chart the eletrical characteristics of the OPB745 sensor. The expected behaviour was seen both of the tests performed. The current response of the sensor at varying distances could be observed and matched the expected results on the datasheet. The square wave input caused signal degredation at the expected frequencies noted in Part 2 of this exercise. Overall, this exercise was a success as the proper electrical characteristics of the designed circuit could be seen when tested experimentally.

## Questions

1. A 7406 inverter will provide high impedance instead of a high logic signal. On the output node this would cause the low logic level to stay at zero but cause the high output signal to be disconnected from the circuit. This half of the output waveform would simply be as if the probe was not connected to a node.

2. The voltage on the output starts at 5 V at 0 mm because the reflector is blocking the light from the emitter. This causes none of the light to reach the transducer on the other end of the sensor. When no light enters the transducer, it will not pass any current and therefore not apply a voltage drop across $R_L$ and therefore leaving it at 5 V. The reason the voltage will eventually reach 5 V again is because less and less light will reach the transducer as the distance to the reflector increases.

3. The degredation frequency increases when the load resistor is increases from 10 kΩ to 20 kΩ because the transducer will integrate the current it sinks. When the load resistance increases, less current is drawn through the load branch of the circuit and therefore shorter pulses will not be integrated together into a single constant output signal. I'd therefore anticipate the frequency to increase as the resistance increases.

Exercise 3: Characterization of OPB745

Student's Name: Andrei Tumbar Section: 2

| PreLab | | Point Value | Points Earned | Comments |
|---|---|---|---|---|
| PreLab | Optoisolator | 10 | 10 | CJB 1/28/22 |
| | Resistor Calculations | 5 | 5 | CJB 1/28/22 |

| Demo | | Point Value | Points Earned | Date |
|---|---|---|---|---|
| Demo | Part 1 | 10 | 10 | 1/28/ [illegible] |
| | Part 2 | 15 | 15 | XB 1/28 |

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