Line Sensor Characterisation

Experimental Methods

To be able to effectively characterise individual emitter and receiver components, multiple key tests must be performed on every possible sensor combination. These tests allow the group to apply the technical information on datasheets to real world situations; such as monitoring output across different heights and the behaviour of the sensor when moving from black to a white path. The initial test, dark current, measures the current flowing across the transistor/diode/LDR at complete darkness when the emitter is switched off. While the TCRT5000 phototransistor shares its traits to an NPN bipolar junction transistor, the group noticed that even under zero illuminance conditions, there was a small current flow, this may be due to the depletion region still allowing the flow of electrons as it is impossible to achieve complete darkness.

|  |  |  |
| --- | --- | --- |
|  | Dark Current (mA) | Background Illumination (mA) |
| TCRTR5000 Receiver | 0.0072 | 0.0084 |
| SFH203 | 0.0000000739 | 0.0000794 |
| VT90N2 | 0.0045 | 1.639 |
| BPW17N | 0.0000000212 | 0.00104 |

Table 3.1 Comparing current flow across receivers

Similarly, with background illumination, in order to create a standardised lighting condition, a phone torch was used by placing it a metre above the sensor[??]. While this had very little effect on infrared photodiodes and transistors, the potential difference across the LDR showed a considerable difference.

The experimental methods of the line-spread and height variation measurements involved using a test rig with slots separated every 5mm. The sensors were attached to an 8 pin DIL socket in a circuit mounted to a stripboard. This stripboard could be slid into individual slots. This ensured the test sensors would be measured across the same heights and horizontal positions on the test platform (white tape on a black plastic).

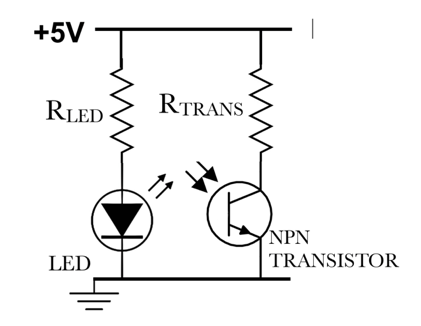


Figure 3.1 A snapshot of a schematic diagram showing how both emitter and receiver and connected.

The results are reproducible as the measurements can be taken using the testing rig and mounting the sensors onto the stripboard[??]. Ensuring that using a power supply with sufficient current and electromotive force output is important as individual sensors draw on specific amounts of current. To keep the data consistent, the same power supply was used across all sensors with calculations to confirm that the current would not be exceeding 100mA on the MyDAQ[??].

The following current flow across different sensors were measured by reading the voltage across the resistor connected in series to the sensors. As the resistance of the photodiodes/phototransistor/LDR is unknown and dependent on the conditions, measuring the potential difference across the resistor, followed by dividing by the resistor value, finds the current flow across the branch.

Sensor Characteristics

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Type | Wave-length range | Peak λ (nm) | Affected by Sunlight | Resistor in Series (ohm) | Capacitance |
| TCRT5000 | Photo-transistor | NA | NA | No | 10000 | NA |
| SFH203 | Photodiode | 550-1050 | 840 | No | 470,000 | 11 pF |
| VT90N2 | LDR | 500-650 | 550 | Yes | 8170 | 2.49 uF |
| BPW17N | Photo-transistor | 450-1040 | 825 | No | 100,000 | 8 pF |
| TCRT5000 | LED IR | 940-960 | 950 | - | 100 | 17 pF |
| OVL5521 | LED Visible | “White” | - | - | 62 | - |
| OPE5685 | LED IR | 825-875 | 850 | - | 33 | 20 pF |

Table 3.2 Showing characteristics of a range of emitters and receivers.

By reviewing the technical datasheet, a decision was made to test 5 different combination of sensors. Starting with infrared emitters and sensors, the OPE5685 and BPW17N showed characteristics that would be similar to TCRT5000 as both combinations use a phototransistor[??]. These phototransistors work effectively in the infrared region of wavelengths and the background illumination tests confirmed that the effect of sunlight would produce a negligible amount of noise that could affect the effectiveness of the sensors.

Emitter and Detector Pairing

Similarly, the OPE5685 was paired with the SFH203 photodiode. As the photodiode consists of a PN junction[??], one of the quirks of the photodiode was to place it in reverse polarity to the current flow. The SFH203 also is effective towards infrared wavelengths which would make it a sensible pairing with the OPE5685.

Other than infrared sensors, a visible light emitting sensor involved the OVL5521 and VT90N2. As the datasheets define both components to be effective in visible light[??]. An immediate disadvantage of this combination would involve the ambient brightness of the room changing the effectiveness of the sensor. The background illumination tests suggest that even applying a source of light a meter away from the LDR seemed to increase the noise in value of the potential difference across the resistor connected in series to the LDR. Despite analysing the lack of effectiveness of testing OPE5685 with VT90N2, this combination was chosen to confirm the hypothesis that infrared emitters would not perform as well with visible light detectors.

Figure 3.2 A graph showing the effective voltage drop across the receiver components.

Comparing the line-spread characteristics of multiple sensors, where -9 and +9mm are the edges of the white tape, the OVL5521-VT90N2 and OPE5685-VT90N2 clearly suggest a very limited dynamic range of voltage outputs. While both sets of data had taken background illumination voltage into consideration and negated ambient noise, the voltage drop across the LDR is still 3.88 V, comparing this to TCRT5000’s voltage drop of 4.85 V at -28 mm from the centre of the line suggested that the TCRT5000 has a greater dynamic range of comparing white to black. While OPE5685-SFH203 and OPE5685-BPW17N showed very similar behaviour, there is a shallower gradient due to a greater variation. This could perhaps be due to OPE5685’s greater angular displacement[??]. As the infrared light waves will be dispersed to a greater area, the precision of the OPE5685 would be limited as it would illuminate a larger surface area than the OVL5521. The TCRT5000 performs consistently with measurements and seems to reject noise signals fairly well. While the TCRT5000 only displays 3% of noise at the point where its furthest away from the centre of the line, the other sensor combinations have over 11.7% of noise that skew the measurements vertically. While the VT90N2 is not designed to be detect infrared wavelengths, it does produce a weakly distinguishable reading that is comparable to the visible light emitter.

Figure 3.3 A graph comparing the effective voltage difference of sensors at varying heights.

The use of term ‘effective’ compares the potential difference across sensors between the white and black surfaces. To find the effective voltage difference, every data point in the graph reads the value of the resistor when the sensor is on white and negates the dark voltage and voltage when the sensor is on white.

From figure 3.3, the OPE5685 and VTN90N2 combination outputs the least effective voltage differences compared to other combinations. While the sensor combination does show a weak correlation of distance to effective voltage, the effect of ambient light and electrical noise renders the sensor useless after 14mm. Similarly, the OVL5521 and VT90N2 performs slightly better but has the same shortcomings. This is a clear indication that using an analogue device like an LDR does not provide a stark enough contrast in measurements to be used in this situation. While the SFH203 receiver produces a correlation that is comparable to the TCRT5000 and BPW17N, there was an extended period of time for the measurement to stabilise. This may be due to the high value of the resistor connected to the receiver. With a capacitance of 11 pF and resistance of 470,000 ohms, it has a time constant that is 5 times longer than BPW17N at 100,000 ohms. The SFH203 is therefore 5 times slow at reading true values making it difficult to implement on a fast-moving buggy.

Choosing Preferred Sensor

The group chose the TCRT5000 as the preferred sensor due to its smaller footprint, accurately spaced emitter and detector and its consistent results. Comparing the two sets of measurements, the 10,000 ohm resistor performs better as it is able to discern the line over a greater distance than the 4,700 ohm combination.

Reviewing the measurements of the TCRT5000 with another TCRT5000 approximately 10mm away from the receiver, there is a negative skew that causes the effective voltage difference to decline with a higher gradient. This could be explained due to negating the higher background illumination that is a result of both LEDs being turned on. This would suggest

specifying that no adjacent emitters must be switched on at the same time to avoid crosstalk in measurements.

Figure 3.4 A graph comparing line-spread of TCRT5000 at 10,000 ohms across different heights.

Error Bars

As the measurements of the TCRT5000 were repeated 5 times, the average of all measurements was taken and plotted. The error bars are plotted by finding the difference between the highest value of the reading and average. The same is calculated for the minimum value and average. Figure 3.4 suggests a greater variation in measurements as the voltage drop increases. Figure 3.3 shows the variation being so small that the error bars not visible.

Upper bound : = (MAX(TEST1:TEST5) – AVERAGE(TEST1:TEST5))

Lower bound : = ((AVERAGE(TEST1:TEST5) – MIN(TEST1:TEST5))

References

<https://www.mouser.com/ds/2/311/SFH%20203,%20SFH%20203%20FA,%20Lead%20(Pb)%20Free%20Product%20-%20RoHS-319015.pdf>

<http://www.farnell.com/datasheets/1818035.pdf?_ga=2.64058409.783467778.1543460102-164713630.1539548520>

<https://www.vishay.com/docs/83760/tcrt5000.pdf>

<http://www.farnell.com/datasheets/1662254.pdf?_ga=2.103249798.783467778.1543460102-164713630.1539548520>

<http://www.farnell.com/datasheets/612931.pdf>

<https://www.vishay.com/docs/81516/bpw17n.pdf>