**Choosing the light sensor**

1. **Types of light sensors**
   1. **Photoresistors**

Photoresistors are also knows as light dependent resistors. When light hits an object, the object absorbs the radiation from the light, and electrons move from the valence band of the semiconductor to the conduction band. If there are tons of electrons in the conduction band, the resistance will be incredibly low. Essentially, as the light increases, the resistance decreases. This means that if a photoresistor was in a completely dark room, its resistance would be at 100%. These devices are used usually in streetlamps or some photography equipment, such as a light meter. These light measurements sensors help photographers capture more accurate pictures because they help professionals understand how the light will impact the scene of the photo they’re trying to take.

* 1. **Photodiodes**

Photodiodes are a type of light sensor that converts light in electric current. Basically, when light hits a photodiode, an electron-hole pair is formed. Yet is vital to note that the light must have at least 1.1 electron volts for this pair to form. The electrons will have a negative charge, and the hole will have a negative charge. This creates depletion regions in a photodiode. The electron-hole pair can’t stay in depleted zone, so they move towards the positive charge where the hole was first created. Photodiodes use this electron-hole pair to convert light into an electric current. Photodiodes are used in various devices, including smoke detectors and televisions.

* 1. **Phototransistors**

Phototransistors are similar to photodiodes in that they both convert energy into an electric current. Yet, phototransistors are more accurate than photodiodes because they can adjust their settings based on the amount of light received. Phototransistors can view different intensities of light because these devices can alter the electrical current they create. Since phototransistors are relatively easy to use and because they’re adjustable, there are various applications for them. Phototransistors are used in security systems and light control.

* 1. **Photomultiplier tubes**

Photomultiplier tubes, members of the class of vacuum tubes, and more specifically vacuum phototubes, are extremely sensitive detectors of light in the ultraviolet, visible, and near-infrared ranges of the electromagnetic spectrum. These detectors multiply the current produced by incident light by as much as 100 million times, in multiple dynode stages, enabling (for example) individual photons to be detected when the incident flux of light is low.

The combination of high gain, low noise, high frequency response and large area of collection has maintained photomultipliers an essential place in low light level spectroscopy, confocal microscopy, Raman spectroscopy, fluorescence spectroscopy, nuclear and particle physics and many other domains.

1. **Choosing a method to measure light intensity**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Photoresistor** | **Photodiode** | **Phototransistor** | **Photomultiplier tubes** |
| **Accuracy** | Even if the light intensity is constant, the resistance can vary due to the temperature change. They are temperature sensitive too. Not suitable for high accuracy needed applications. | accurate | the most accurate | amplify the light signal but also amplifies the background electric noise |
| **Available wavelength** | 500 nm (green) to 700 nm (red) | 200 nm to 1100nm (out of the visible spectrum which is 400 nm to 800 nm) | up to 840 nm, and allows a small current to flow when is not exposed to light | 200 nm to 900 nm |
| **Linearity** | not linear | excellent | good | good |
| **Cost** | the cheapest | low | low | high |
| **Stability** | not very stable, the dark resistance decreases over time | very good | very good | very good |
| **Physical size** | small | small | small | large |
| **Response time** | relatively big | the fastest | relatively fast | fast |

Now that I presented some of the methods which are used to measure light, it is time to choose the method that best fits my project.

The first parameter that I am going to discuss is accuracy. Here the phototransistors are clearly the best, but the photodiodes present satisfying values too. Photoresistors are also heat sensitive, which is not a good thing taking in account that the thermostat can be exposed to heat too. Photomultiplier tubes are not a really good choice either.

All the methods cover the visible spectrum of light (400 nm to 800 nm) except the photoresistors (but are pretty close too). The best are clearly the photodiodes, but all methods present satisfying parameters. So here, there is not necessary a better method than the other taking into account the project that I intend to do.

Photodiodes are the most linear of all. They definitely win this one. Phototransistors and photomultiplier tubes present good values too. I consider that they suit my requirements too.

Even though the photoresistors have the higher ground here, they have lost the battle so far, not being really suitable from the other points of view. At this point the fight is between the phototransistors and photodiodes. I think that photomultiplier tubes are not really the best for my project because of their seize.

Considering the stability, which is pretty important in applications that involve long term use, both methods which remained to be consider (phototransistors and photodiodes) are quite good, with photodiodes being a little bit faster.

Considering all the parameters that I discussed about, I consider that a photodiode would be the best method for my application. It is linear, accurate, cheap and present good stability, which for a thermostat (my project), is very important.

1. **Some sensors regarding the method that I have chosen**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **ISL29001** | **ISL76683** | **VEMD5510C** |
| **Accuracy** | 15-bit resolution | 16-bit resolution | +-3% |
| **Range** | 0.3-10,000 lux | range can be selected via I2C interface, range 4 varying from 0 to 64,000 lux | - |
| **Response time** | 100 ms | 100 ms | 40 ns (rise time) |
| **Interface method** | I2C | I2C | - |
| **Output type** | digital | digital | analog |
| **Linearity** | 3 counts to 15 counts per lux | up to 65 counts per lux | - |
| **Price** | ≈17 RON | ≈7 RON | ≈9 RON |
| **Ambient temperature range** | -40˚C to 85˚C | -40˚C to 105˚C | -40˚C to 100˚C |
| **Supply voltage** | 2.5V to 3.3V | 2.5V to 3.3V | 1.3V (forward voltage) |
| **Supply current** | less than 0.33 mA | less than 85 uA | 50 mA (forward current) |
| **Peak wavelength** | 550 nm | 540 nm | 550 nm |

Taking into consideration that the temperature sensor that I have chosen had an analog output, the third sensor in the table can be considered out of the equation.

The other two sensors remain to be consider. Even though the second one (ISL76683) seems to have better parameters, the first one (ISL29001) I consider to be easier to find on the market. I found it on digikey with 17 RON. It also present good parameters, which are satisfying for the project that I intend to do.

1. **About ISL29001**

The ISL29001 is an integrated ambient light sensor withADC and I2C interface. With a spectral sensitivity curvematched to that of the human eye, the ISL29001 provides15-bit effective resolution while rejecting 50Hz and 60Hzflicker caused by artificial light sources.

The ISL29001 contains two photodiodes. One of thephotodiodes is sensitive to visible and infrared light (Diode 1)while the other diode (Diode 2) is used for temperaturecompensation (leakage current cancellation) and IRrejection. The ISL29001 also contains an on-chip integratinganalog-to-digital converter (ADC) to convert photodiodecurrents into digital data.

The ADC has three operating modes with two timing controls. In the first operating mode, the ADC only integrates Diode 1's current, and the digital output format is 16-bit unsigned-magnitude. In second operating mode, the ADC's operation is the same, except Diode 2's current is integrated. In the third operating mode, the ADC integrates Diode 2's current first, then Diode 1's current. The total integration time is doubled, and the digital output is the difference of the two photodiode currents (Diode 1’s current - Diode 2’s current). In this mode, the digital output format is 16-bit 2's-complement. Any of the three operating modes can be used with either of the two timing controls (either internally or externally controlled integration timing).

The interface to the ADC is implemented using the standard I2C interface.