PCB Design Considerations

Multiple considerations were taken when designing the PCB to ensure that the robot would behave predictably in its environment. Since navigation of the robot would be dependent on the light from a projector, it was deduced that noise would be one of the problems affecting the light sensing circuit. To help reduce it, a high pass filter was introduced with each individual phototransistor in order to help minimise noise without using any software-based solutions. Resistor and capacitor values also had to be considered in order to make sure that the corner frequency would limit as much noise as possible without attenuating the frequency from the projected light, which helped determine whether or not the sensor was on a path or a wall.

Since the voltage values obtained from the light sensor circuits would be quite small, a non-inverting amplifier was added to enlarge the response added, helping to more easily detect the difference between a path or wall on the projected map. It was also decided that two capacitors — one electrolytic and one ceramic — would be placed in parallel of the DC supply used across the whole circuit, to diminish the risk of providing voltage with noise.

In order to be able to use the phototransistors efficiently and easily, the PCB had to be placed and aligned correctly on top of the rest of the robot. This required the use of long header pins in order to be able to superimpose it on top of the robot, which already had a PSoC on top of it. Surface mount technology was used to help reduce the size of each phototransistor circuit, which in turn allowed for them to be placed at specific places without complicating the circuit design.

PCB Design Decisions

Throughout the designing of the PCB, many decisions were taken regarding which values would be more appropriate for components, which component arrangements were more appropriate and what potential problem could arise from certain decisions. One of those decisions was the noise filtering, amplification and offsetting of the signal received from each phototransistor. Although all three of these processes could have been completed on software, it was decided that it would be better to do so with hardware as it would imply more memory would be available to complete other tasks. Even if further signal processing on hardware was possible (such as the implementation of a Schmitt trigger), it was agreed that not doing so would allow further flexibility in the design.

Another decision taken was to not solder the phototransistors directly onto the PCB but rather make them a bit more modular and solder them onto small breakout boards connected to header pins so they could easily be replaced. The main motivation behind this idea was that, since the phototransistors play a crucial role as part of the robot when navigating throughout the map, they should be accessible and easy to replace if need be.

A few components were added to the light sensor circuits in order to ease the understanding and usage. One of these was these was the addition of a voltage follower between the filtering part of the light sensing circuit and the amplifying part. This was done in order to isolate the filtering and amplifying parts of the light sensor circuit from each other. Another component addition were the extra switches added on the board to allow for multiple modes to be programmed on the robot and defined by the arrangement of the switches. Some switches were also added to control the usage of LEDs used to track the robot when evaluated.

In regards to the values selected for resistors and capacitors, they were all chosen to make sure that more sensitive components would not be at risk. One such example would be resistor R? in figure SE (screenshot of LTSpice/Altium light sensor circuit with appropriate R identifier instead of '?') which is the lowest it can be to maximise the size of the signal received without damaging the phototransistor due to excessive current values. At other times, these values were selected to make sure the signal would be preserved as best as possible: the resistor values for the non-inverting amplifier were selected to make sure the signal would be amplified as much as possible without reaching a state where clipping is observed.

Analogue Verification (LTSpice)

A majority of the analogue verification was done on LTSpice, in order to confirm the circuit was designed correctly and behaved as expected. When analysing the light sensor circuit, this allowed us to make sure each individual part of the circuit modified the signal as expected. As seen in Figure ND (ProposedCircuit.jpg) the input signal (green line) is first filtered and has a DC offset of 2.5V added to it, resulting in a signal with a known offset with a lot of noise removed (blue line). In order to help the ADC read the signal more easily, the signal with this new offset is then passed through a non-inverting amplifier to be amplified (red line). With the graphs obtained from LTSpice, it can be quickly noticed that the signal does not go below 0 volts or above 5 volts, which are the limits of the ADC in the PSoC. Similar verifications were conducted for the rest of the circuit as well, which allowed for graphs of voltage, current and gain to be quickly generated, allowing for a simple yet efficient verification process of the analogue section.

Analogue Validation (Breadboard)

After completing the analogue verification, one of the light sensor circuits was breadboarded in order to validate the design's functionality and check the behaviour more fully. The aim of analogue validation is to recreate the behaviour observed during analogue verification but with physical components and make sure a similar behaviour is observed in the desired environment. For the light sensor circuit, this also involved some testing that a difference between the projected path and wall could be detected. As seen in Figure NU (image of oscil. response under black line) and Figure DES (image of oscilloscope response under white line), the output signals from the light sensor circuit's when on a path and on a wall respectively, display a relatively similar behaviour to that of the expected one. Even though the measured responses of the analogue validation are not exactly the same as the ones predicted during the analogue verification, this is quite normal. Many factors such as the imperfection of the signal being projected, the imprecise values (relative to a simulation) for components used and other similar factors all add up and end up distorting the signal. After further tests with different conditions in the environment, the light sensor circuit was deemed as usable and could be implemented onto the PCB.