High Level Design

The final version of the circuit is composed of five different functional blocks: *time enabling system, sensor's amplification*, *spiral enabling system*, *motors' state assessment* and *motors' control system*. Each stage is discussed and analysed separately from a high level prospective in terms of inputs and outputs below.

# Time enabling system

This initial function controls the entire circuit acting as an enabling and resetting stage. In other words, this function dictates the state of the circuit (*ON* or *OFF*) either activating or deactivating the other blocks. In particular, this stage is time controlled since the circuit is required to begin its operation with a delay of 8 seconds. As a result, this function processes a single input from the user to produce a single output (E). The input to output relationship is summarised in the table below (Table 1):

|  |  |  |
| --- | --- | --- |
| **USER's INPUT** | **8s from INPUT** | **OUTPUT (E)** |
| LOW | LOW | LOW |
| LOW | HIGH | LOW |
| HIGH | LOW | LOW |
| HIGH | HIGH | HIGH |

Table 1 : Time enabling system input to output relationship

Consequently, if a LOW input is selected by the user, then the output is required to stay LOW. Instead, if a HIGH input is selected, then the output needs to stay LOW for 8 seconds and then switch to HIGH if the input has not changed meanwhile.

# Sensor's amplification

The purpose of this function is simply to receive a certain input from a sensor and amplify it in order to allow successive stages to effectively process it. In fact, the sensor is used to detect a black line over a white background and therefore produce two discrete states (ON-line or OFF-line). However, this output needs to be compatible with the following digital stages. As a result, this function effectively processes the output of the sensor to produce two compatible discrete states (LOW and HIGH). The following table summarises the operation of the function (Table 2) :

|  |  |
| --- | --- |
| **SENSOR's INPUT** | **OUTPUT (L)** |
| ON-line | HIGH |
| OFF-line | LOW |

Table 2 : Sensor's amplification input to output relationship

In particular, this amplification stage is not conclusive???. Consequently, this function is not required to provide strong and exact LOW and HIGH states. However, the output needs to tend as much as possible to them . Moreover, the output's swing is at least required to lie midway between these LOW and HIGH states of reference.

# Spiral enabling system

This function determines whether or not the device reaches the end of the line and therefore if the spiral process needs to be enabled. Now, while following the line, the sensor constantly changes state from ON-line to OFF-line with a certain average frequency or period (TA). However, if during this period the change of state does not occur and the sensor's output is OFF-line, then the device has certainly reached the end of the line. Consequently, this stage is required to be time controlled, processing the amplified sensor's output (L) to produce a time varying output (S) lying between the LOW and HIGH states of reference???. The following table summarises the input to output relationship (Table 3):

|  |  |  |
| --- | --- | --- |
| **INPUT**  **(L)** | **TA from INPUT** | **OUTPUT (S)** |
| LOW | LOW? | LOW |
| LOW | HIGH | HIGH |
| HIGH | LOW | LOW |
| HIGH | HIGH | LOW |

Table 3 : Spiral enabling system input to output relationship

Again, since this is not the last amplification stage, the output is not required to be exactly close to either LOW or HIGH states. However, a threshold value should be at least defined above which the time delay TA is reached and below which the same delay is not reached.

# Motors' state assessment

The following stage simply processes and amplifies the different outputs of the previous functions to determine the state of both motors (either ON or OFF). Consequently, this function is required to accept three inputs (E, L and S) and to produce two amplified and outputs (ML and MR) each accepting only two possible states (LOW or HIGH). The input to output relationship is summarised in the table below (Table 4) :

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **INPUT**  **(E)** | **INPUT**  **(S)** | **INPUT**  **(L)** | **OUTPUT**  **(ML)** | **OUTPUT**  **(MR)** |
| LOW | LOW | LOW | LOW | LOW |
| LOW | LOW | HIGH | LOW | LOW |
| LOW | HIGH | LOW | LOW | LOW |
| LOW | HIGH | HIGH | LOW | LOW |
| HIGH | LOW | LOW | LOW | HIGH |
| HIGH | LOW | HIGH | HIGH | LOW |
| HIGH | HIGH | LOW | HIGH | HIGH |
| HIGH | HIGH | HIGH | HIGH | LOW |

Table 4: Motors' state assessment input to output relationship switch L and S

Therefore, if the circuit is not enabled (E, LOW), both motors are turned off (*MR LOW and ML LOW)*. However, if the circuit is enabled (E, HIGH), then the state of both motors is exclusively determined by the states (L) and (S). On the one hand, if the end of the line is not reached (*S, LOW*), then if the sensor is on the line (*L, HIGH*), the device turns right (*MR LOW and ML HIGH*). Instead, if the sensor is off the line (*L, LOW*), the device turns left (*MR HIGH and ML LOW*). As a result, the device is designed to follow the right edge of the line.

On the other hand, if the end of the line is reached (*S, HIGH*), then if the sensor is on the line (*L, HIGH*), the device still turns right (*MR LOW and ML HIGH*). However, if the sensor is off the line (*L,LOW*), then both motors are turned on (*MR HIGH and ML HIGH*). In the last case, by appropriately controlling the speed of both motors, a spiral is obtained (see *motors' control system* function).

# Motors' control system

The purpose of this last stage is to control both motors in terms of speed based on the previously assessed states (*MR* and *ML*). Now, while the device follows the line, the motors are expected to constantly change state with a quite high frequency. Instead, as seen previously, when the end of the line is reached, both motors stably turn on resulting in no appreciable switching frequency. Therefore, by reducing the speed of both motors over a certain time TM which is reset each time switching occurs, at high switching frequencies a constant speed is obtained while at low frequencies a decreasing speed is obtained. In particular, if appropriately controlled, this decreasing speed in each motor is able to generate a spiral as requested.

Low Level Design

Now, each module previously described from a high level prospective is analysed in details and the circuits behind them as well as their connections are unveiled.