Elec1100 final report

Group 65

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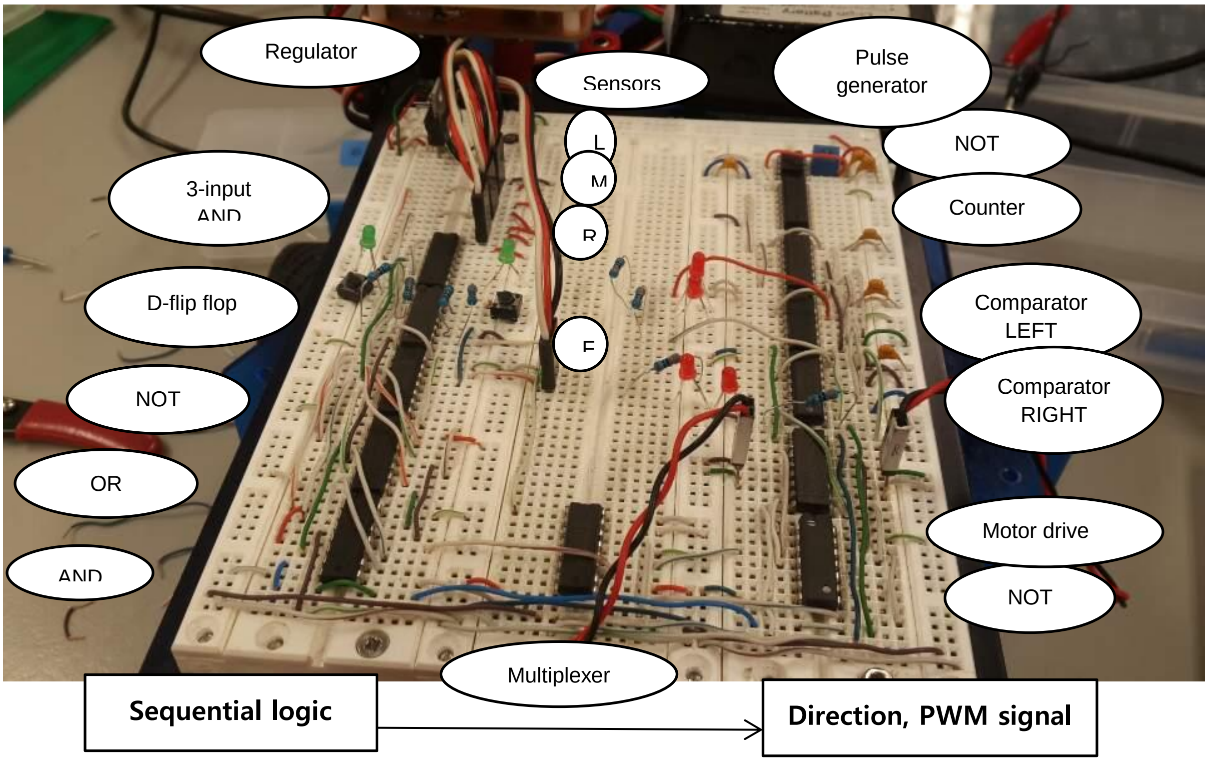
1. Introduction

The main object of the project was to design a robot that follows the track in which the track is painted with white color and green color for its background. As we can see from the picture of the track, there is a split; the robot must be able to memorize how many splits have it went through, and turn right at the last split. In addition, the robot must be able to go back at least 15cm after it reached the end of the track. In order to do this task, the memory must be installed into this robot. Lastly, students were required to demonstrate the use of two different speeds in their robot (excluding the "stop" or "change of direction").

Picture of final circuit design



2. Design

Logic

Truth table for three sensors

State Q0	L	M	R	Action	L Speed	L DIR	R Speed	R DIR
0	0	0	0	X	x	x	x	x
0	0	0	1	left forward	0	1	1	0
0	0	1	0	**LEFT**	1	1	1	0
0	0	1	1	Left	1	1	1	0
0	1	0	0	right forward	1	0	0	1
0	1	0	1	Straight	1	0	1	0
0	1	1	0	Right	1	0	1	1
0	1	1	1	**change state Q0**	x	x	x	x
1	0	0	0	X	x	x	x	x
1	0	0	1	left forward	0	1	1	0
1	0	1	0	**RIGHT**	1	0	1	1
1	0	1	1	Left	1	1	1	0
1	1	0	0	right forward	1	0	0	1
1	1	0	1	Straight	1	0	1	0
1	1	1	0	Right	1	0	1	1
1	1	1	1	X	x	x	x	x

If Q0=0, it goes to left when it encounters split and vice versa.

Truth table for front sensor and state Q1

State Q1	Front sensor	Next state	LDIR	RDIR
0	0	0	LDIR	RDIR
0	1	1	X	X
1	0	1	1	1
1	1	1	1	1

K-maps and logic equation

	Q'L'	Q'L	QL	QL'
M'R'	X(0)	1	1	X(0)
M'R	0	1	1	0
MR	1	X(1)	X(1)	1
MR'	1	1	1	1

$$Left\ Speed = M + R$$

	Q'L'	Q'L	QL	QL'
M'R'	X(1)	0	0	X(0)
M'R	1	0	0	1
MR	1	X(0)	X(0)	1
MR'	1	0	0	0

$$Left\ Direction = \bar{L}(\bar{Q} + R)$$

	Q'L'	Q'L	QL	QL'
M'R'	X(0)	0	0	X(0)
M'R	1	1	1	1
MR	1	X(1)	X(1)	1
MR'	1	1	1	1

$$Right\ Speed = M + L$$

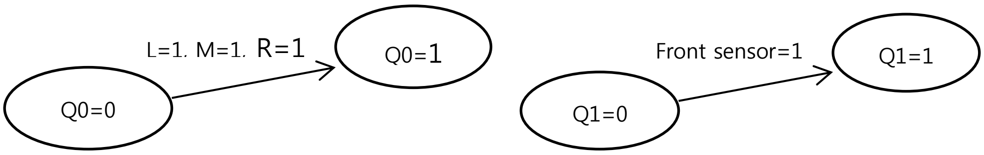
	Q'L'	Q'L	QL	QL'
M'R'	X(0)	1	1	X(1)
M'R	0	0	0	0
MR	0	X(0)	X(0)	0
MR'	0	1	1	1

$$Right\ Direction = \bar{R}(Q + L)$$

	Q'L'	**Q'L**
M'R'	0	0
M'R	0	0
MR	0	**1**
MR'	0	0

Next state, Q0 = LMR

FSM state diagram



Two states, Q0 and Q1 are independent

Mechanical design and justifications

PWM Signals used for two different speeds

PWM signal of **0111** and **0101** was used for two different speeds. Logic for motor speed is responsible for second least significant bit. We used maximum possible speed for which the probability of car falling out of the track is small enough and which the car does not get stuck at one place for a long time.

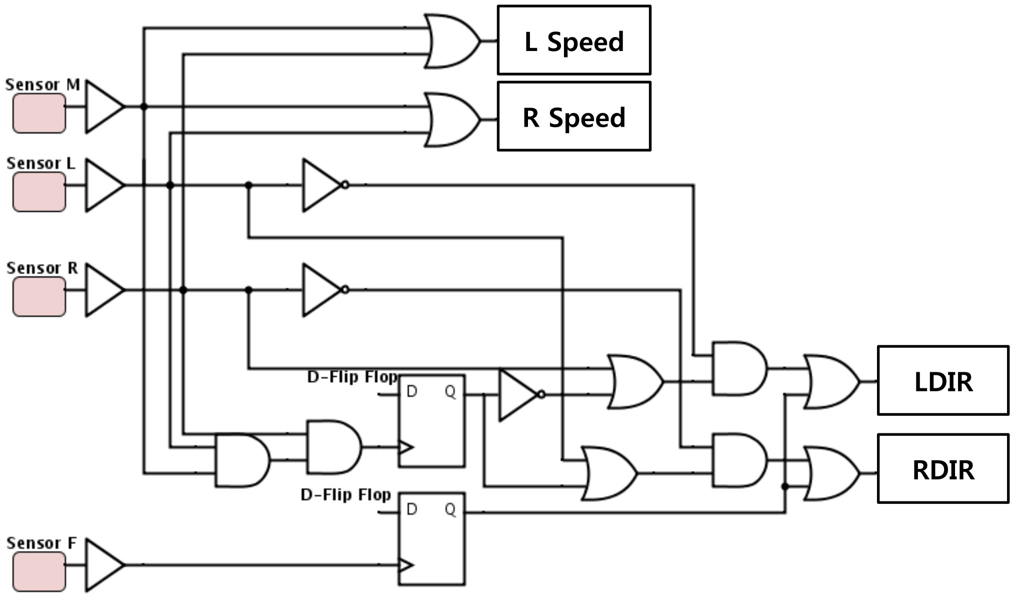
Sensor placement

Sensors were placed in a one dimension, but very tightly close together. Closer the sensors, less the chance for sensors to sense 111 before reaching the black marker, which would change state in undesired way. However, closer sensors meant higher probability of car to fall out of the track at right angle curves. Thus, we put sensors in a maximum tolerable level of distance of which it does not sense 111 before it reaches a black marker.

Further justifications on logic design

Main means of changing direction is by reversing direction of two motors. In the case of turning right for instance, right motor's direction will be 1 and left motor's direction will be 0. In addition, to make the car movement smoother and to stop the car from getting stuck by shaking at one place, we used logic for speed so that motor in reverse direction will have slightly less speed. In the state of sensor 100 for example, left motor will turn in forward direction with PWM signal of 0111 while right motor will turn in reverse direction with PWM signal equivalent to 0101.

Gate-Level schematics



3. Debugging report

LEE, Hyun Seung

When we were working with creating sequential logic for the robot, when we turned on the portable battery, the motor did not work. I thought, we had problem with the sequential logic. However, the motor worked fine by trying out the motor without any logic. Line sensor also did not work. Finally, we found that our fused had broken. This was because we have incorrectly put the line sensor's pin, we gave 5V to its output part and ground to input part. It was lucky that our LED did not break. We solved this problem by reconnecting the Line sensor in correct way and getting a new fuse.

CHOI, Hong Joon

My main debugging strategy was to avoid the trouble in the first place. I kept circuit as tidy and organized and the logic design to be simple as much as possible. I tried to make sure that ICs are placed at proper positions so that I can use less wires of shorter length to connect ICs. I identified and kept an eye on wires and ICs of which bugs can possibly occur and connected LEDs to important pins to identify bugs right away. I used shorter and tighter wires only when that part of design is tested and finalized, such as connections on power and ground, clock signals and motor driver. Process of debugging and adding extra features was significantly simplified since I never had to worry about ruining other parts of circuit when I work on one part.

In spite of my effort to prevent bugs, they are ought to occur. In such cases, General approach that I used for debugging was to track the voltage level by using LED or oscilloscope. Once I notice a bug, I compared expected voltage level and actual voltage level on IC pins at specific situations. If I notice any abnormally, I tracked it down further to identify actual source of the bug. By using that strategy, I could solve bug that's caused by using XOR gate instead of OR gate, and by connecting to output pin instead of input pin.

For example, I connected LEDs on sensors without reading instructions on LMES. After then, I noticed that the car was not following the track anymore. I tried to track outputs on different IC pins and figured out that input of 1 1 on AND gate gave 0 as an output. I realized that either voltage level was below threshold or there was not enough current. Since voltage levels on input pins were closer to 5V, I concluded that there was not enough current flowing to drive IC. So, I changed the way I connect LED on sensors to solve that problem.

There is an error I encountered one day before the mini contest. The state becomes 11 at the wall (Q0 and Q1 respectively) and changes to 00 after it finishes U-turn. For such state change, I used logic $\overline{right\ sensor} = Q_1$ and $\overline{(Q_1\ AND\ \overline{right\ sensor})} = Q_0$. I missed out that Q1 change to zero before Q0 has to change to zero. The logic worked for some reason at the first time, but it didn't work anymore when I tested the car the day before the mini contest. State only changed from 11 to 10. Even after finding source of the problem after struggle, I could not give time delay on signal by using longer wires because signal is just a measure of potential difference across wires. Thus, I tried to find a variable that is always 1 when Q1 = 1. Right after using different approach for solving a problem, I found that I can replace Q1 to Q0 for logic, so that $\overline{(Q_0\ AND\ \overline{right\ sensor})} = Q_0$.

4. Results

Evaluation on design performance

Our effort to simplify every single factor of design worked very well. Compared to other groups, our circuit was much simpler and cleaner. These had great advantage when we were trying to solve the debugging problem. With the organized breadboard, it was easy to construct new sequential logic for the robot when we found certain problem with the previous logic. Also, it took very little effort and time to implement extra features. It just took 30 minutes to make the car to perform U-turn and return to the starting position!

Since we were able to build multiple prototypes effectively, we could pick the best logic design prototype that most fits our aim, which is to ensure that the car never fails during demonstration. We played around with different speeds and sensor positions to make the car to be as stable as possible.

Drawback of our design was the fact that we were using black marker to navigate split. We had to keep sensors very close together so that the car does not see 111 before approaching black marker. However, it made it harder to make 90 degree turn. Therefore, faster the car, higher the risk we had.

Something unexpected happened during the project demo. The speed of our robot was too slow, that it took at least 5 minutes to finish the whole track. Seldomly, the car fell out of the track at 90 degrees turn. Although the problem did not occur very often, we were concerned that this problem could occur during the demo, so we have changed the PWM periods, so that it will go as slow as possible when it is making a turn. We used PWM signal 0101 and 0100 instead of 0111 and 0100 (refer to mechanical design) during demonstration so that odds of failure will be minimized. However but the car got stuck forever at one place during the demo because the track was unexpectedly bright and shiny.

Evaluation on whole process

Overall building process went smoothly. We did not have many conflicts, and arguments went positively. Each time we were building prototypes, we took turns to take charge of the design. We did not really worry about failing because we had lot of possibilities in our mind and we knew that we would be able to come up with working design anyhow. We just needed to succeed once no matter how many times we fail, provided that we have time and energy left to push forward.

If we had more time to work on, I would have made a car to go as fast as it can before third split and make it go steadily at right angle curves by using Most Significant Bit for PWM signal. If we could start over, we would have used counter so that we don’t have to use black marker for navigating splits. If that is properly implemented, we would have been able to split sensors apart so that car can go at higher speed, without much risk.

Most importantly, we wish that we could have tried some crazy designs that no one have ever tried. We kept working on stabilizing performance with one design rather than trying to find innovative way because our course grade lies upon the completion of the task. Since expected gain was very low, we felt unmotivated to further explore crazy possibilities.

Conclusion

We faced lots of challenges during the process, and we were once worried that we would not be able to make it. However, we succeeded somehow and we acquired valuable skill and knowledge from this course. More importantly, we were amazed that we were provided with almost infinitely sufficient amount of resources to play around with. Also, it was just like magic when circuit connections actually worked! It was really exciting experience.