James Dyson Undergraduate Bursary 2020/21

Logic Gates Outreach Activity

Robert Hudson

Introduction

Logic gates are a key building block of modern electronics, forming the basis of microcontrollers and computers. This activity introduces the students to the fundamentals of logic gates, and their importance in modern electronics. The curriculum does not introduce logic gates before GCSE level, so this will be the first time the year 9 target audience learns about them. Therefore, the activity is set up to teach logic gates from scratch, starting with simple switch circuits, before introducing truth tables and gate symbols. The main outcome of the activity is for the students to gain an appreciation of the applications of digital electronics, and how smaller components can be combined into more complex systems.

COVID-19 Note

Due to the COVID-19 pandemic, this activity was delivered remotely over Zoom. This meant that the activity could not use any physical electronics equipment. The decision was taken to use an online logic simulator to give an element of interaction and experimentation, but this unfortunately meant that the activity did not link very closely to my project, *"Portable/disposable system to measure liver optical backscatter"*.

Equipment

- Logic Gates presentation slides
- logic.ly online logic gate simulator and PC/laptop
- Scrap paper and pen

Activity

Planned Timetable

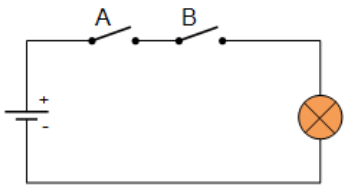
Activity	Time (minutes)
Introduction and basic circuit explanation	5
AND/OR gate from switches	10
Truth tables and logic gates	10
Streetlight controller	7.5
Upstairs lights	7.5
(Extension: SR bistable)	Any remaining time

The activity was designed to run for 40 minutes. Because it was unknown how quickly some of the tasks would be solved by the students, a series of tasks were formulated which could last for as long as the students were interested. An extension was also designed to fill in any remaining time.

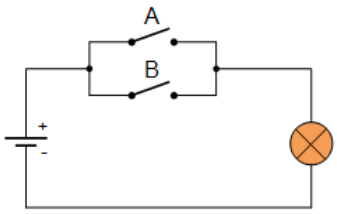
Introduction and Basic Circuits

Since electronics is not a large part of the secondary school curriculum, there was a need to explain circuit fundamentals to the students, to ensure they were not lost from the start. The students were introduced to three basic components (the battery, light bulb, and switch) along with their circuit symbols. A simple circuit was drawn and explained.

AND/OR Gate from Switches



Lawnmower AND Gate



Upstairs light OR Gate

The students were then challenged to combine the three components into circuits which would perform specific functions. These were designed in pairs/groups of three. The problem statements were:

- I have a lawnmower, which can only turn on when both the power button is pressed and the safety button is pressed at the same time
- I have a house with two floors, and I want to be able to turn the landing light on and off with either the upstairs or the downstairs switch

These examples were chosen because they represented an AND gate and OR gate respectively (see above diagrams for solutions).

Truth Tables and Logic Gates

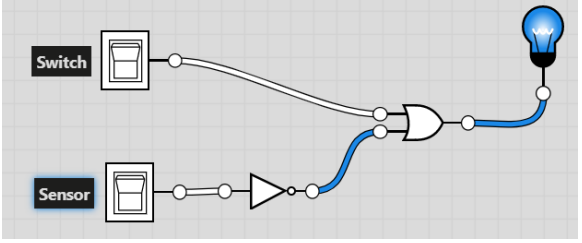
The switch examples above were used to introduce the concept of a truth table. The students were asked to shout out what the light state would be for different combinations of the switch inputs. It was then explained that the circuits could be packaged into the AND and OR gate symbols, which represented circuits which performed the same function as their light bulb circuits. Transistors were briefly introduced as an electronically controlled switch and some RTL/CMOS gates were shown but not explained, to give the students an idea of the actual circuits used inside gates. The NOT gate was also introduced, as the final gate required for useful circuits.

Streetlight Controller

The students were then challenged to combine the logic gates they had been taught to create some useful circuits. The logic.ly online logic simulator was used, as it gave real-time outputs and had a simple drag and drop interface. The first system the students designed was a streetlight controller, and they were given the following brief:

- We want to design the logic controller for an automatic streetlight
- The light should come on either when a person turns a switch on, or when a light sensor indicates that it is dark outside
- The sensor gives a logic ‘0’ when it is dark, and a logic ‘1’ when it is light
- Can you design this circuit? Use logic.ly to test your circuit
- A useful starting point may be to write down what the truth table should be

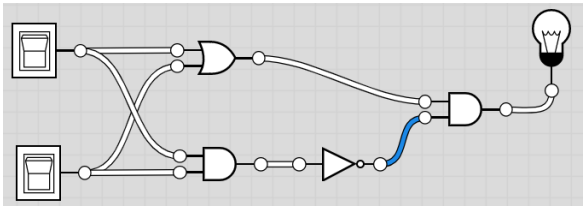
The students were given some time to experiment with the simulator, before being given the truth table as a hint. The solution is given in the image below.



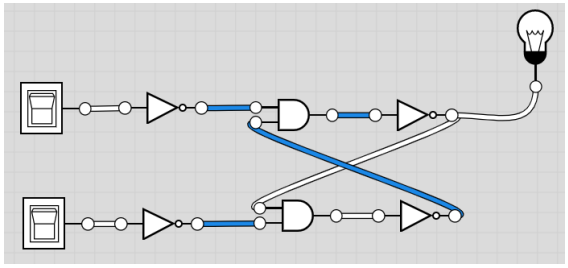
Upstairs Lights

The next example revisited the upstairs light switch example, using the practical implementation which is in effect an XOR gate. The brief given to the students and the solution are detailed below.

- Let's go back to the landing light example we designed before
- In the example before, both switches had to be off for the light to be off
- In reality, the light should toggle between on/off when either switch is toggled
- A simple logic design for this is: turn the light on when one of the switches is on and the other is off, and off if both switches are in the same position
- Can you design this circuit? Use logic.ly to test your circuit



Extension – SR Bistable



An extension was planned to fill any remaining time in case the students were very proficient at the other activities. They were shown the circuit above and asked to work out what it does. This would have been used to explain how feedback could be used to "remember" previous states, and how bistable circuits can form the basis for primitive memory cells and state machines.

Summary

A final slide was included to summarise the different levels of digital electronics, from transistor level, to gate level, to bistable level, and finally to system level. This was intended to show the students that complex systems such as computers and mobile phones are constructed from the same fundamental building blocks, and to demonstrate the power of electronic engineering.

Evaluation

The session went better than expected, with the students being very enthusiastic and trying hard to solve the challenges set. There was lots of discussion, and it was good to see many students finding the correct solutions. The streetlight challenge took longer than expected, mainly due to the students not fully understanding the instruction that the light sensor was logic 0 when it was dark. Nevertheless, once this was explained and the truth table was provided, several groups arrived at a working solution. Another hint was given to detail the two gates which were required, which also helped the students and possibly should have been designed in the plan initially. Due to this challenge taking longer than expected, and because the students arrived in class 5 minutes late, it was decided to not do the second upstairs light activity as this would have been too rushed. Instead, the summary was given, and the students were given an opportunity for questions. One student asked about what bistables did, so a brief summary was given about the SR bistable. All in all, the activity ran well, with good levels of

engagement for an online activity with few practical activities. The timing could possibly be increased to 50 minutes in the future to ensure all planned activities can be run, but this may end up being too long resulting in some students getting bored.