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1. EXCELLENT RESEARCH PROVIDING DATA FOR THE SPECIFICATION AND POSSIBLE TECHNOLOGICAL OPTIONS FOR IMPLEMENTATION.
2. ALL 3 CIRCUITS FOR THE PELICAN CROSSING WERE EXPLAINED IN DETAIL.
3. TESTING WAS DETAILED, WITH GOOD USE OF LOGIC ANALYSER. EXPLANATION OF THE RESULTS WAS OVER OVER ELABORATE.
4. MODIFICATION TO A PELICAN CROSSING WAS ACHIEVED AND ANALYSED IN DETAIL.
5. CONCLUSIONS WERE VALID WITH CONSIDERATION OF SUSTAINABLE OPTIONS FOR IMPLEMENTATION.

Table of Contents

1. Executive Summary.....	4
2. Research into advanced digital design techniques (1000)	5
2.1. Pelican Crossing	5
2.1.1. Pelican Crossing Operating Sequence.....	7
2.2. Puffin Crossing	8
2.2.1. Puffin Crossing Operating Sequence.....	9
2.3. FPGAs and ASICs	10
2.4. Sustainability.....	11
3. Design method, choices and calculations (500).....	12
3.1. 5 Second Timer	12
3.1.1. Specification.....	12
3.1.2. State Diagram.....	12
3.1.3. State Table	13
3.1.4. Karnaugh Maps & Boolean Equations	13
3.1.5. Circuits.....	15
3.2. 15 Second Timer	17
3.2.1. Specification.....	17
3.2.2. State Diagram.....	17
3.2.3. State Table	18
3.2.4. Karnaugh Maps & Boolean Equations	19
3.2.5. Circuits.....	21
3.3. Rag Control.....	24
3.3.1. Specification.....	24
3.3.2. State Diagram.....	24
3.3.3. State Table	25
3.3.4. Karnaugh Maps & Boolean Equations	26
3.3.5. Circuits.....	28
3.4. Puffin Crossing	31
3.4.1. Specification.....	31
3.4.2. State Diagram.....	31
3.4.3. State Table	32
3.4.4. Karnaugh Maps & Boolean Equations	33
3.4.5. Circuits.....	34
4. Testing, results and analysis (500)	36
4.1. 5 Second Timer	36

4.2.	15 Second Timer	39
4.3.	RAG Control.....	41
4.4.	Puffin Crossing	42
5.	Conclusions and recommendations (500)	44
6.	References	45
7.	Annexe	47

1. Executive Summary

This report has been an examination of the design of complex electronic circuits – namely digital electronic circuits. The performance of these circuits has been critically analysed and improvements to the circuits have been implemented. The sustainability of these circuits – and their applications – have been investigated, and also any changes that improve their efficiency, reliability, and safety.

A traffic light control system was designed using Finite State Machine principles and then created using NI Multisim. The control system was required to act as a pelican crossing, with a button the pedestrian will press which sets of a sequence of timers that interrupt the flow of traffic and allow the pedestrian to cross before allowing the traffic to resume.

A modification was made to the circuit above, to allow it to act as a puffin crossing, which required a pressure sensor to be added as an input to ensure the sequence was only started if both the button and sensor were engaged.

2. Research into advanced digital design techniques

Research will be undertaken to investigate how the two most common type of Pedestrian crossing are controlled via electronic systems. The two crossings are: Pelican and Puffin. Both are similar in design, but the Puffin crossing can be said to be an improved system – the research below will detail why this is.

2.1. Pelican Crossing

According to the Department for Transport (2005), a Pelican crossing operating cycle can be broken down as follows:

- A) After the push button is pressed, the traffic light remains green for around 7s. This time can be varied by use of below ground sensors, such as inductive loops that can sense a change in magnetic field by a vehicle passing over them, or by above ground detection such as Microwave Vehicle Detectors (MVDs) that sense if a vehicle is nearing the approach – as long as the vehicle is moving above 3mph. If not, another inductive loop is required at the approach to detect slow moving traffic. If a gap is detected in the traffic, the minimum of 7s will be allowed. But if heavy traffic is sensed then the period will be the maximum of 40s.
- B) The amber light will show for 3s to warn approaching vehicles to stop.
- C) Light turns red, but no green man. Time period will be 1s if there is little traffic detected by the inductive loops and MVDs before the red appears – but will be 3s if heavy traffic was sensed, to allow for vehicles to clear crossing.
- D) Green man shows for a set period, dependant on the length of the crossing.
- E) After the above time, the green man begins to flash to notify pedestrians to not start crossing for up to 2s.
- F) The traffic light changes to a flashing amber to notify drivers to proceed if the crossing is clear. The green man remains flashing for the final pedestrians to cross the road.

- G) The red man appears at this point, and the light remains flashing amber for 2s before changing back to green.

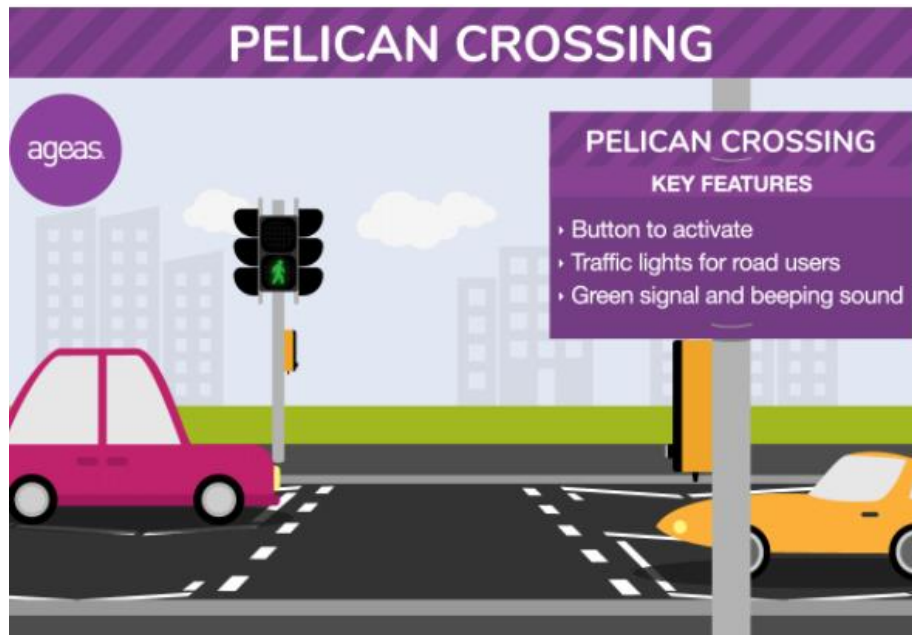


Figure 1 (Ageas, 2021)

2.1.1. Pelican Crossing Operating Sequence

PERIOD	USE	VARIATION FOR
A	Vehicle running time	Traffic volume
B	Standard stop warning to vehicles	None
C	Vehicle clearance period	Vehicle actuation
D	Pedestrian invitation to cross	Road width, disabled pedestrians, crossings with central refuge
E	Warning to pedestrian to clear the crossing and not to cross. Vehicles remain stopped. For use with divided crossing	Site conditions
F	As period E above but with vehicles allowed to proceed provided the crossing is clear of pedestrians ahead of them	Road width
G	Additional pedestrian clearance time before vehicle running period	Road width

Figure 2 (Department for Transport, 2005)

PERIOD	SIGNALS SHOWN		TIMINGS (Seconds)
	TO PEDESTRIANS	TO VEHICLES	
A	Red Standing Figure (wait)	Steady Green (proceed if way is clear)	20-60 (fixed) 6-60 (VA)
B	Red Standing Figure	Steady Amber (stop unless not safe to do so)	3 (Mandatory)
C	Red Standing Figure	Steady Red (stop, wait behind Stop line on carriageway)	1 to 3
D	Green Walking Figure with audible signal if provided (cross with care)	Steady Red	4 to 7 (in some circumstances plus 2)
E	Flashing Green Figure (do not start to cross)	Steady Red	0 or 2
F	Flashing Green Figure	Flashing Amber (give way to pedestrians on the crossing - they have priority)	6 to 18
G	Red Standing Figure	Flashing Amber	1 or 2

Figure 3 (Department for Transport, 2005)

2.2. Puffin Crossing

A Puffin crossing operates in much the same way as a Pelican crossing, but with a few additions to the steps seen above. To start period 'A', a kerbside detector is required to sense a pedestrian as well as the push button. If the detector does not sense anyone then the crossing request will be cancelled, but the sensor has an off-delay of around 2-4s to ensure the pedestrian has left – and not just moved out of the sensing range briefly (Department for Transport, 2019). This additional condition helps with the efficiency of traffic flow, as if there is no one sensed at the crossing then there is no need for the traffic flow to be interrupted.

Another significant improvement is the addition of either above or below ground sensors on the crossing (Start Rescue, 2021). These sensors are used to detect if there are pedestrians on the crossing and increase the time of the red traffic light up to a maximum of 22s. During this time the red man will be shown to stop additional pedestrians beginning to cross. This is an important safety feature which will almost guarantee the crossing will be clear of pedestrians before the lights turn green (Driver and Vehicle Standards Agency, 2021).

These two improvements demonstrate why the Puffin crossing is superior to the Pelican and is the reason why the Department of Transport has advised that no more Pelican crossings are to be installed (Moir, 2019).

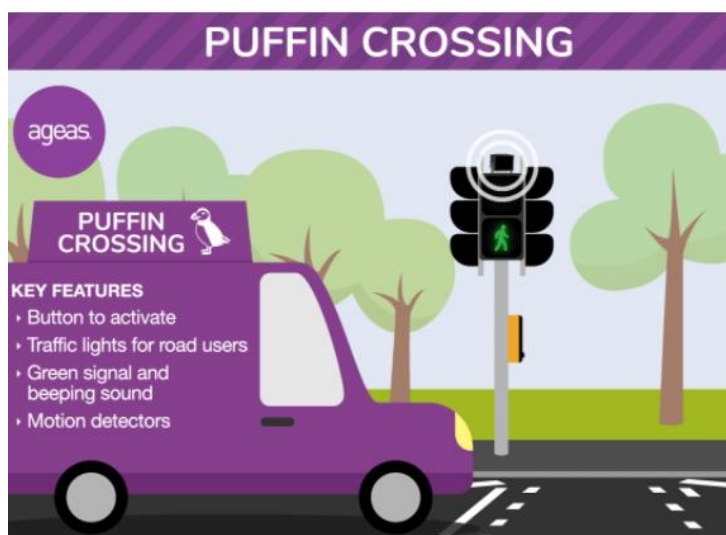


Figure 4 (Ageas, 2021)

2.2.1. Puffin Crossing Operating Sequence

PERIOD	USE	VARIATION FOR
1	Vehicle running time	Traffic volumes
2	Standard amber to vehicles	None
3	Vehicle clearance period	Vehicle actuation
4	Pedestrian invitation to cross	Road width, disabled pedestrians, crossings with central refuge
5	Pedestrians must not start to cross	Type of detector
6	Completion of pedestrian crossing time	Road width
7	Additional pedestrian clearance time	Pedestrian detection
8	Additional pedestrian clearance time	Pedestrian gap change
9	Standard red/amber to vehicles	None

Figure 5 (Department for Transport, 2005)

PERIOD	SIGNALS SHOWN		TIMINGS (Seconds)
	TO PEDESTRIANS	TO VEHICLES	
1	Red Standing Figure (Wait)	Green (proceed if way is clear)	20-60 (fixed) 6-60 (VA)
2	Red Standing Figure	Amber (stop unless not safe to do so)	3
3	Red Standing Figure	Red (stop, wait behind Stop line on carriageway)	1 to 3
4	Green Walking Figure with audible signal if provided (cross with care)	Red	4 to 9
5	Red Standing Figure (do not start to cross)	Red	1-5
6	Red Standing Figure	Red	0-22 (pedestrian extendable period)
7	Red Standing Figure	Red	0-3 (only appears on a maximum change if pedestrians are still being detected)
8	Red Standing Figure	Red	0-3 (only appears at a pedestrian gap change)
9	Red Standing Figure	Red with Amber (stop)	2

Figure 6 (Department for Transport, 2005)

2.3. FPGAs and ASICs

An FPGA is a field programmable gate array. The FPGAs function can be reprogrammed after manufacturing, allowing any changes to be made if required. This feature allows for the continued use of FPGAs, as modifications can be made to the device, instead of purchasing a replacement unit (Boylestad & Nashelsky, 2014). FPGAs can be used in the initial prototyping of a controller for Pedestrian crossings and traffic lights. The various types of situations and events that could arise, as seen in Sections 2.1. and 2.2., could be tested with an FPGA. These prototypes could then be trialled in the field, and data gathered to find out which ones were successful (Horowitz & Hill, 1989).

ASICs – application specific integrated circuit – differ from FPGAs due to them not being reprogrammable as they are a chip that is made to control one specific application (Wakerly, 2019). ASICs are expensive to buy in small amounts but are cheap to buy in bulk, as the design can be mass-produced for the specific application (Storey, 2017). In theory, an ASIC could be utilised for the task of controlling all Pedestrian crossings, as one standard control system could be created for all crossings. The ASICs could then be mass-produced at a cheap rate and installed at all crossings.

A problem with manufacturing one control system is the many variations of roads and crossings seen across the UK. There are varying factors such as road size, traffic flow, pedestrian flow, time of the day, and the demographic of the area. A short time may not suffice for a wide road, a busy pedestrian crossing or a crossing that is mainly used by elderly or disabled people. But in contrast, a longer time may not be the most efficient for narrow roads and sparsely used crossings (Traffic Signal Design, 2020).

2.4. Sustainability

Modern traffic lights have benefitted from the use of LEDs, replacing the incandescent bulbs used previously. This change has improved the sustainability of traffic lights in more ways than one.

Compared with incandescent bulbs, LEDs have an 83% longer lifespan – reducing the need for replacements considerably. This also means the amount of parts and materials needed can be cut down, as the demand for replacements slows down, while energy consumed manufacturing these items will also be reduced (Nicole, 2013). The need for replacements is also lessened as LEDs are more reliable, with bulbs being prone to break due to the high operating temperature.

LEDs are seen as brighter than other lights, and this is due to their light being more directional, which focuses light in the desired direction. This also makes coloured LEDs, like the ones used in traffic lights, brighter (Farnell, 2022). But according to (Osigbemeh, et al., 2017) in their research paper, they state that if the ambient light is similar to the traffic lights, then it is hard to distinguish between whether the light is on or off – causing drivers to make unsafe decisions.

3. Design method, choices and calculations

3.1. 5 Second Timer

3.1.1. Specification

The specification for this task was to create a non-repetitive 5 second timer. This timer will be used as the time interval between a 'Wait' button being pressed at a Pedestrian Crossing, and the traffic lights then changing colour to allow the pedestrian to cross. The count must start when the 'Wait' button is pressed and the input becomes true, the button can then be released and the count will continue until State 5 is reached and the output, 'W', will become true and the traffic lights will change colour after a signal is sent to the RAG Control. A Finite State Machine (FSM) was used to design all the processes, via a state diagram, state table, Karnaugh maps, and Boolean equations before building the circuits.

3.1.2. State Diagram

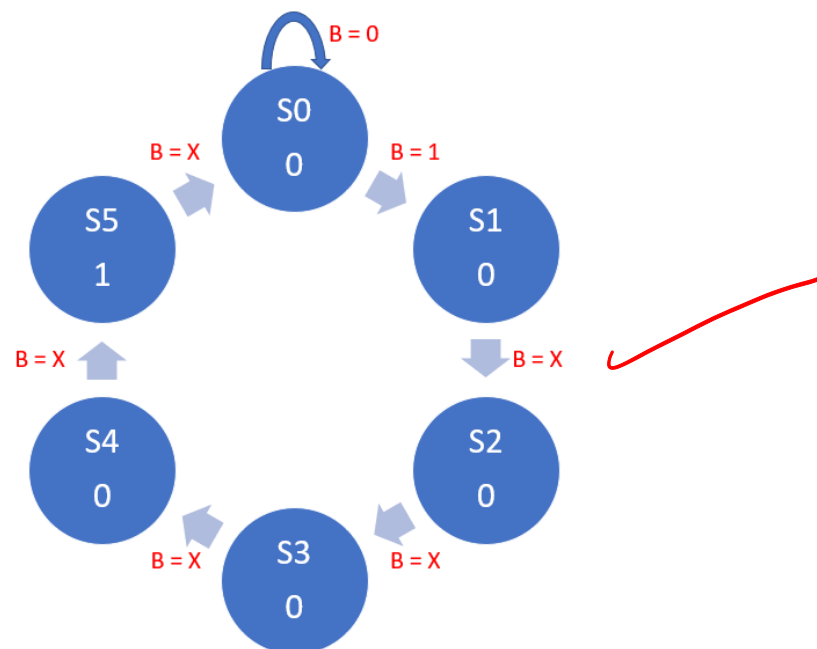


Figure 7

3.1.3. State Table

Current State	Next State		Current Output			Next						Output
						B = 0			B = 1			
	B=0	B=1	QA	QB	QC	QA+	QB+	QC+	QA+	QB+	QC+	
S0	S0	S1	0	0	0	0	0	0	0	0	1	0
S1	S2	S2	0	0	1	0	1	0	0	1	0	0
S2	S3	S3	0	1	0	0	1	1	0	1	1	0
S3	S4	S4	0	1	1	1	0	0	1	0	0	0
S4	S5	S5	1	0	0	1	0	1	1	0	1	0
S5	S0	S0	1	0	1	0	0	0	0	0	0	1
S6	X	X	1	1	0	X	X	X	X	X	X	X
S7	X	X	1	1	1	X	X	X	X	X	X	X

Table 1

3.1.4. Karnaugh Maps & Boolean Equations

QA+

QB QC B QA	00	01	11	10
00	0	0	1	0
01	1	0	X	X
11	1	0	X	X
10	0	0	1	0

Table 2

SUBSCRIPT WOULD BE CLEARER
 $Q_A \overline{Q_C}$

$$QA+ = QA\overline{Q_C} + QBQC$$

QB+

QB QC B QA	00	01	11	10
00	0	1	0	1
01	0	0	X	X
11	0	0	X	X
10	0	1	0	1

Table 3

$$QB+ = QB\overline{Q_C} + \overline{Q_A} \overline{Q_B} Q_C$$

QC+

QB QC B QA	00	01	11	10
00	0	0	0	1
01	1	0	X	X
11	1	0	X	X
10	1	0	0	1

Table 4

$$QC+ = QA\overline{QC} + B\overline{QC} + \cancel{QB\overline{QC}}$$

W

QB QC QA	00	01	11	10
0	0	0	0	0
1	0	1	X	X

Table 5

$$W = QAQC$$

3.1.5. Circuits

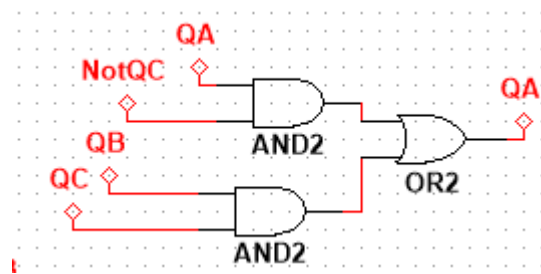


Figure 8

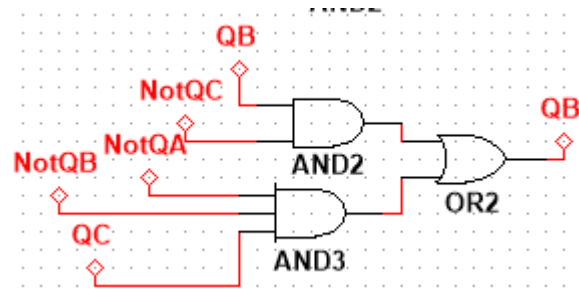


Figure 9

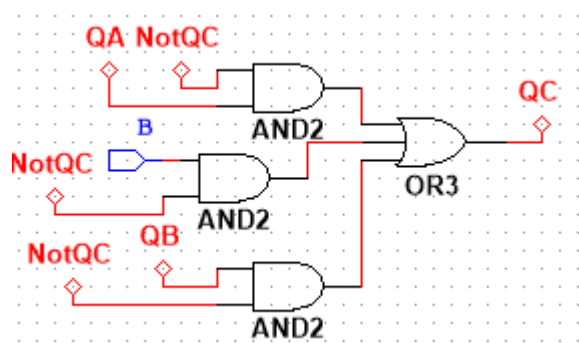


Figure 10

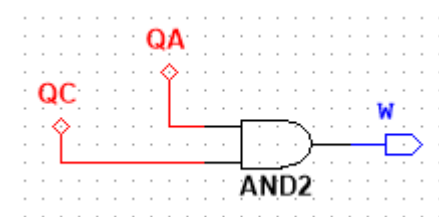


Figure 11

0
IDC

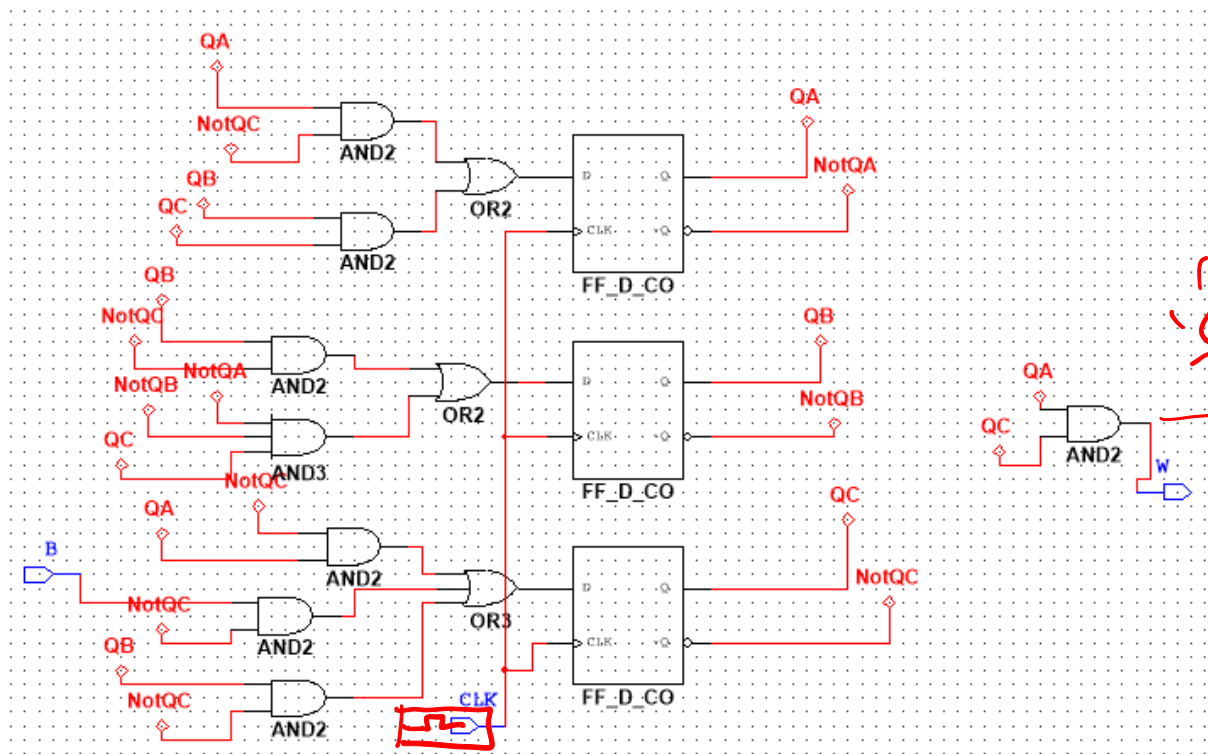


Figure 12

Output Circuit	Figure
QA	8
QB	9
QC	10
W	11
Final Circuit	12

Table 6

A CIRCUIT WITH TEST
OPTIONS IS USED HERE.
ie IDC, CLOCK AND
PROBES.

3.2. 15 Second Timer

3.2.1. Specification

The specification for this task was to create a non-repetitive 15 second timer. This timer will be used as the time interval between the traffic light changing colour to red, and going back to green to allow traffic to pass. This time period allows pedestrians to cross the road, while the vehicles wait at the red light. The count will start when the traffic light becomes red. Once 15 seconds have passed, the output, 'T', will become true send a signal to the RAG Control to change colour.

3.2.2. State Diagram

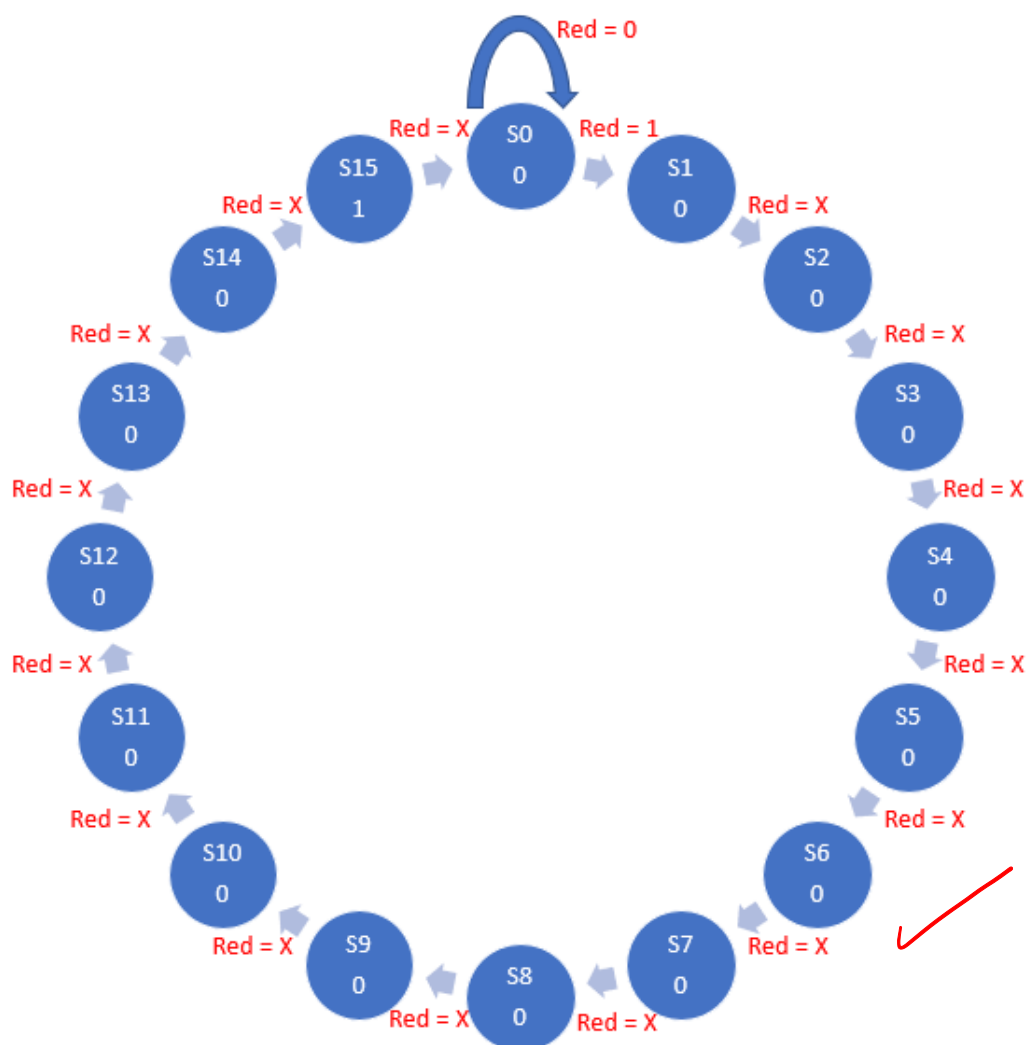


Figure 13

3.2.3. State Table

Current State	Next State		Current				Next								Output	
							R = 0				R = 1					
	R=0	R=1	Q A	Q B	Q C	Q D	QA +	QB +	QC +	QD +	QA +	QB +	QC +	QD +		T
S0	S0	S1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
S1	S2	S2	0	0	0	1	0	0	1	0	0	0	0	1	0	0
S2	S3	S3	0	0	1	0	0	0	1	1	0	0	0	1	1	0
S3	S4	S4	0	0	1	1	0	1	0	0	0	0	1	0	0	0
S4	S5	S5	0	1	0	0	0	1	0	1	0	1	0	0	1	0
S5	S6	S6	0	1	0	1	0	1	1	0	0	1	1	0	0	0
S6	S7	S7	0	1	1	0	0	1	1	1	0	1	1	1	1	0
S7	S8	S8	0	1	1	1	1	0	0	0	1	0	0	0	0	0
S8	S9	S9	1	0	0	0	1	0	0	1	1	0	0	0	1	0
S9	S10	S10	1	0	0	1	1	0	1	0	1	0	0	1	0	0
S10	S11	S11	1	0	1	0	1	0	1	1	1	0	0	1	1	0
S11	S12	S12	1	0	1	1	1	1	0	0	1	1	0	0	0	0
S12	S13	S13	1	1	0	0	1	1	0	1	1	1	0	0	1	0
S13	S14	S14	1	1	0	1	1	1	1	0	1	1	1	0	0	0
S14	S15	S15	1	1	1	0	1	1	1	1	1	1	1	1	1	0
S15	S0	S0	1	1	1	1	0	0	0	0	0	0	0	0	0	1

Table 7

3.2.4. Karnaugh Maps & Boolean Equations

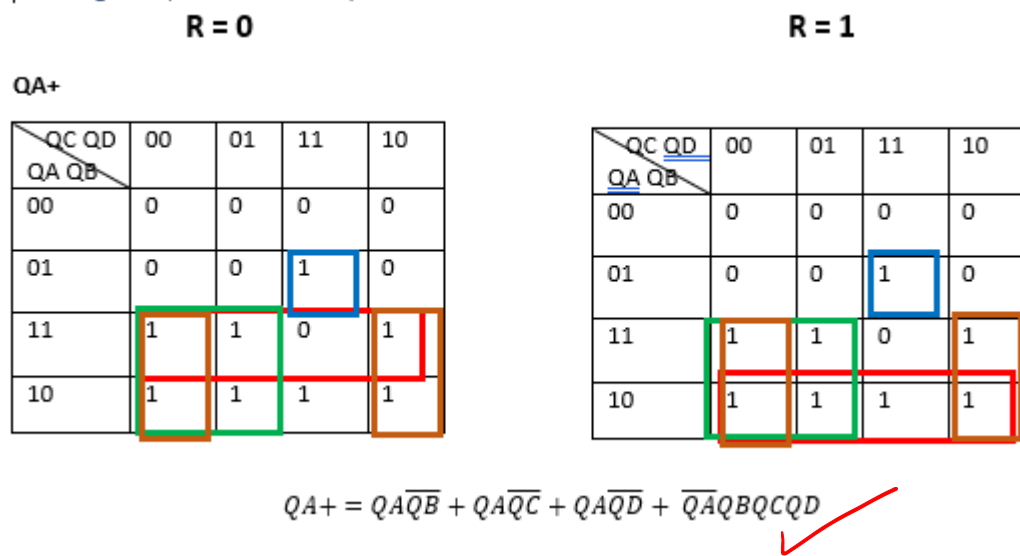


Figure 14

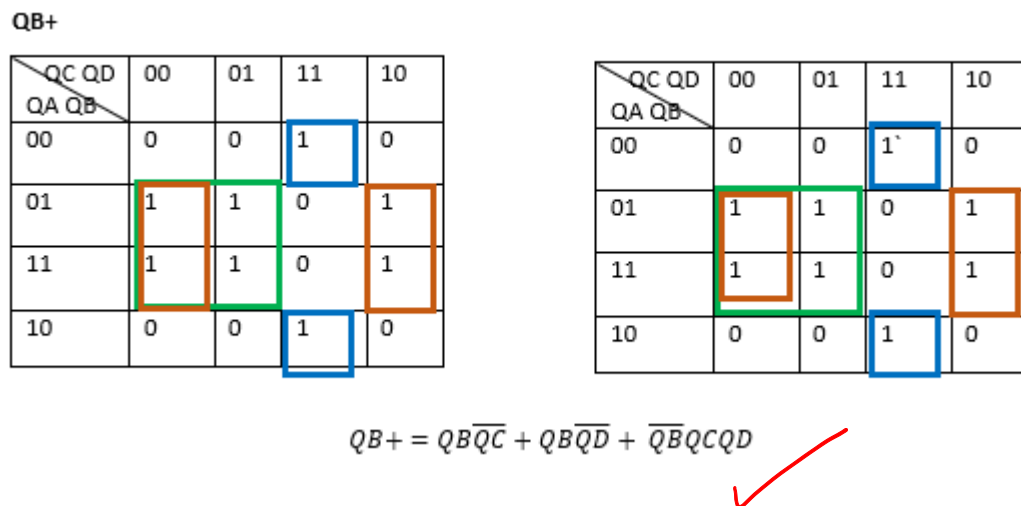


Figure 15

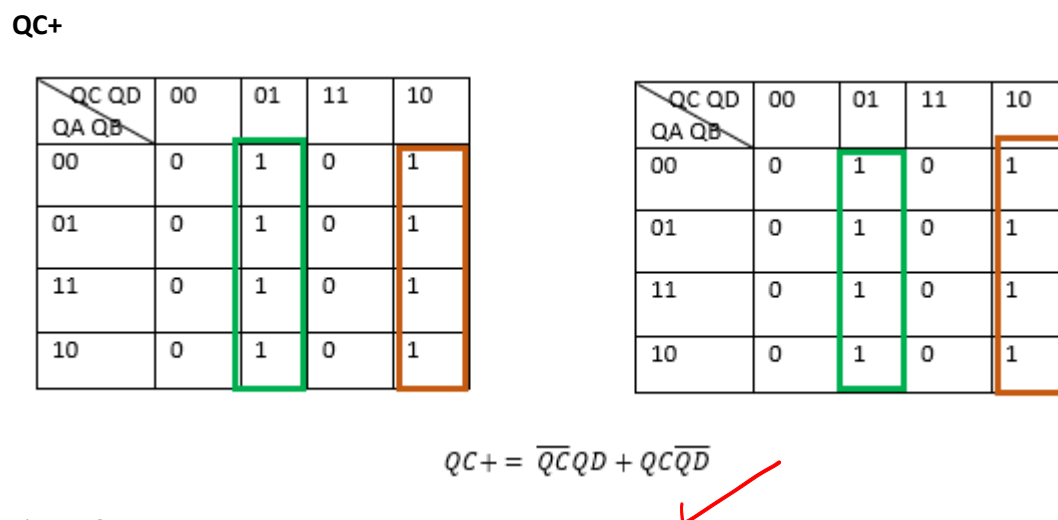


Figure 16

QD+

QC QD QA QB	00	01	11	10
00	0	0	0	1
01	1	0	0	1
11	1	0	0	1
10	1	0	0	1

$$QD+ = QC\overline{QD} + R\overline{QD} + QB\overline{QD} + QA\overline{QD}$$

Figure 17

T

QB QC B QA	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	0	0	1	0
10	0	0	0	0

$$T = QAQBQCQD$$

Figure 18

3.2.5. Circuits

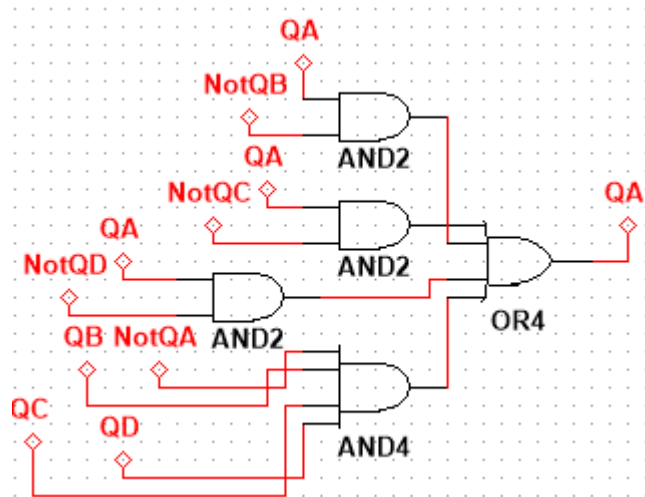


Figure 19

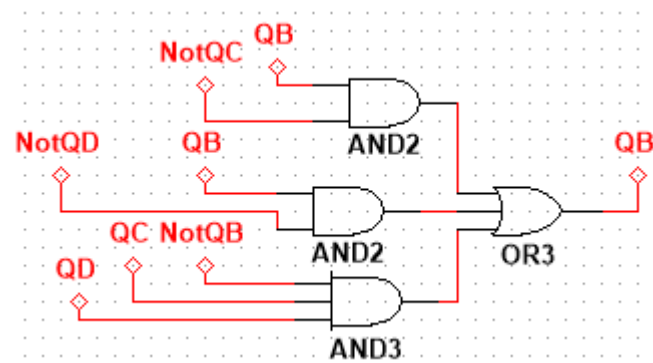


Figure 20

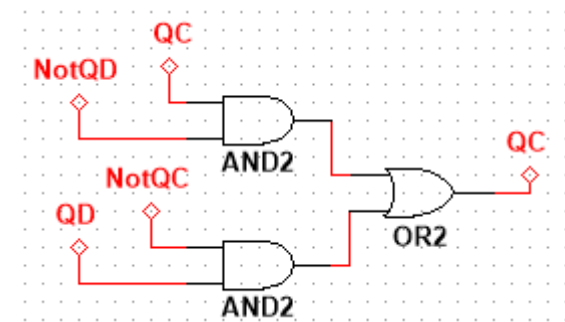


Figure 21

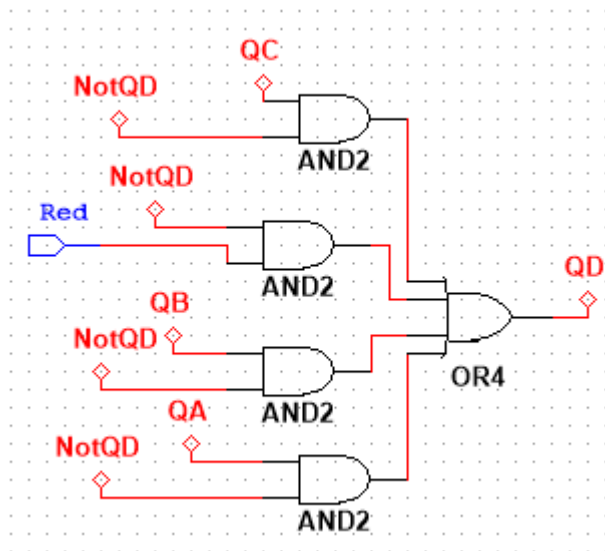


Figure 22

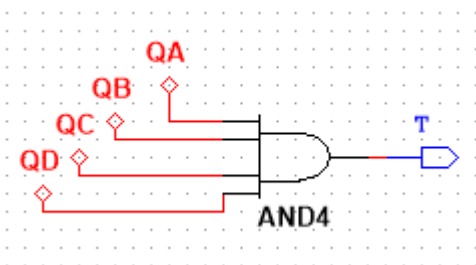


Figure 23

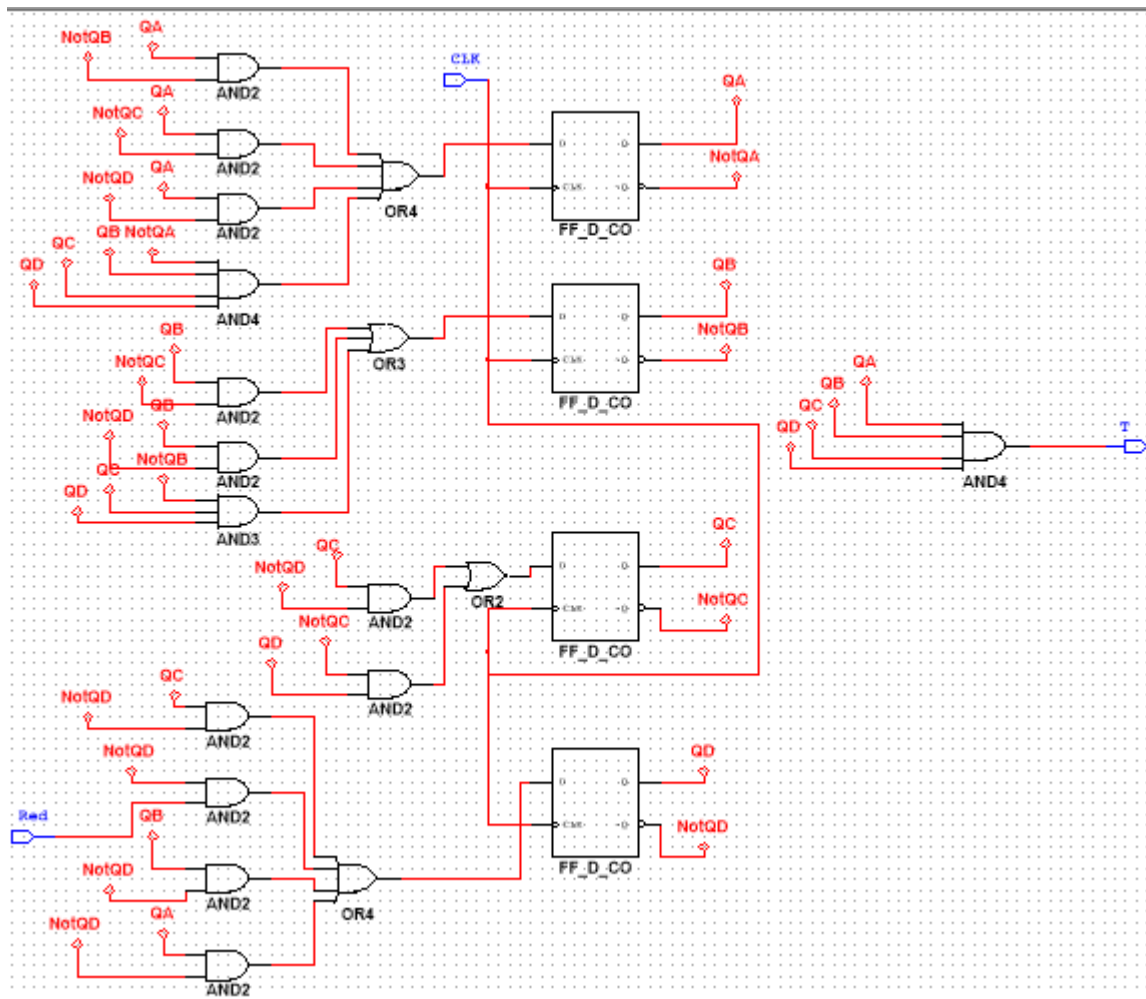


Figure 24

Output Circuit	Figure
QA	19
QB	20
QC	21
QD	22
T	23
Final Circuit	24

Table 8

3.3. Rag Control

3.3.1. Specification

The specification for this task was to create a FSM to control the colour of the traffic lights. Each of the 6 states represent the colour that traffic light will be, depending on the state of the two inputs, 'W' and 'T'. The states and their respective colours can be seen in table below. The first state is the default state of the light being green, until 'W' becomes true. The light will then turn amber for two seconds, until state 3 is reached and the light turns red. The light remains red until 'T' becomes true, which will trigger the light to show red and amber for two seconds and then return to state 0, and the light showing green.

State	Colour
S0	Green
S1	Amber
S2	Amber
S3	Red
S4	Red & Amber
S5	Red & Amber

Table 9

3.3.2. State Diagram

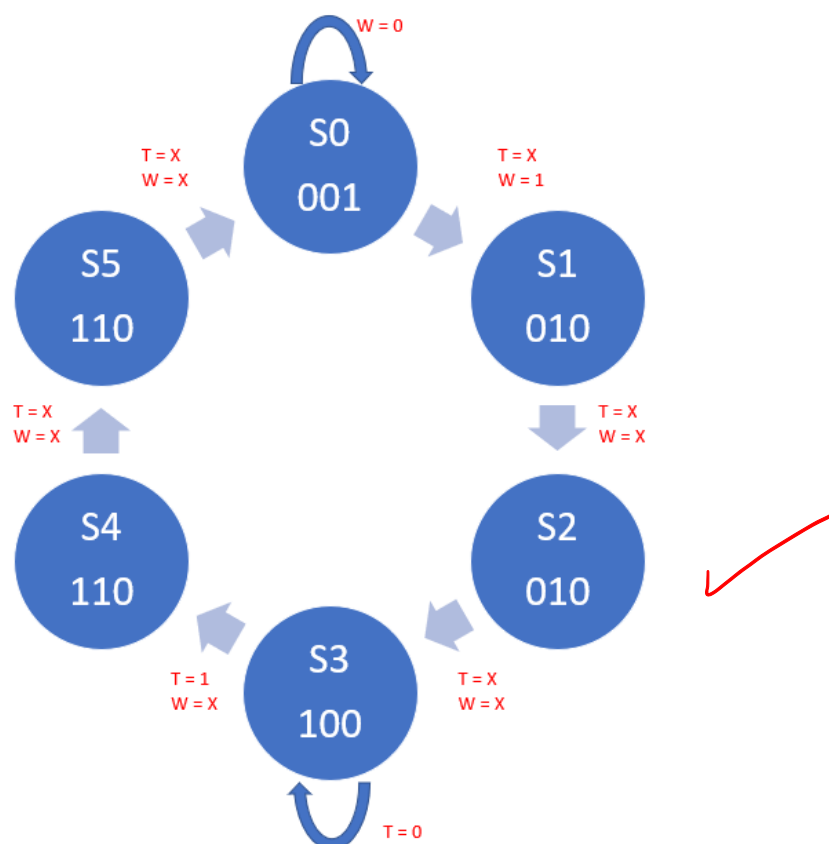


Figure 25

3.3.3. State Table

Present State	Next State																Outputs		
	W = 0		W = 1		W = 0						W = 1								
					T = 0			T = 1			T = 0			T = 1					
	T=0	T=1	T=0	T=1	QA	QB	QC	QA	QB	QC	QA	QB	QC	QA	QB	QC	R	A	G
S0	S0	S0	S1	S1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1
S1	S2	S2	S2	S2	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0
S2	S3	S3	S3	S3	0	1	1	0	1	1	0	1	1	0	1	1	0	1	0
S3	S3	S4	S3	S4	0	1	1	1	0	0	0	1	1	1	0	0	1	0	0
S4	S5	S5	S5	S5	1	0	1	1	0	1	1	0	1	1	0	1	1	1	0
S5	S0	S0	S0	S0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0
S6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 10

3.3.4. Karnaugh Maps & Boolean Equations

W = 0

QA+

QB QC \ T QA	00	01	11	10
00	0	0	0	0
01	1	0	X	X
11	1	0	X	X
10	0	0	1	0

W = 1

QB QC \ T QA	00	01	11	10
00	0	0	0	0
01	1	0	X	X
11	1	0	X	X
10	0	0	1	0

$$QA+ = QA\overline{QC} + TQBQC$$

Figure 26

QB+

QB QC \ T QA	00	01	11	10
00	0	1	1	1
01	0	0	X	X
11	0	0	X	X
10	0	1	0	1

QB QC \ T QA	00	01	11	10
00	0	1	1	1
01	0	0	X	X
11	0	0	X	X
10	0	1	0	1

$$QB+ = \overline{QA}QBQC + \overline{T}QB + QB\overline{QC}$$

Figure 27

QC+

QB QC \ T QA	00	01	11	10
00	0	0	1	1
01	1	0	X	X
11	1	0	X	X
10	0	0	0	1

QB QC \ T QA	00	01	11	10
00	1	0	1	1
01	1	0	X	X
11	1	0	X	X
10	1	0	0	1

$$QC+ = QA\overline{QC} + \overline{T}QB + QB\overline{QC} + W\overline{QC}$$

Figure 28

Red

QB QC \ QA	00	01	11	10
0	0	0	1	0
1	1	1	X	X

$$R = QA + QBQC$$

Figure 29

Amber

QB QC \ QA	00	01	11	10
0	0	1	0	1
1	1	1	X	X

$$A = QA + QB\overline{Q}C + \overline{Q}BQC$$

Figure 30

Green

QB QC \ QA	00	01	11	10
0	1	0	0	0
1	0	0	X	X

$$G = \overline{QA}\overline{QB}\overline{QC}$$

Figure 31

3.3.5. Circuits

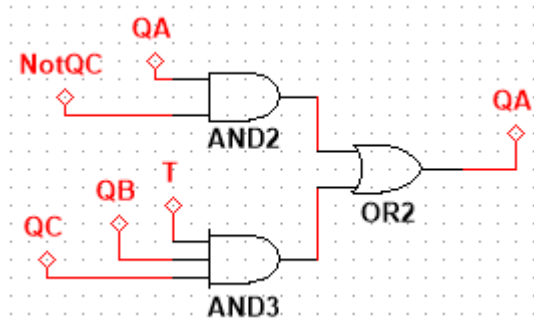


Figure 32

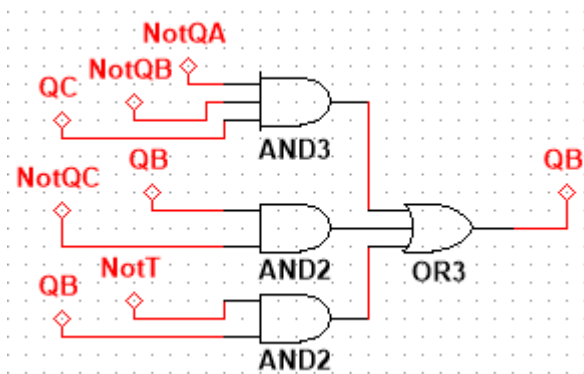


Figure 33

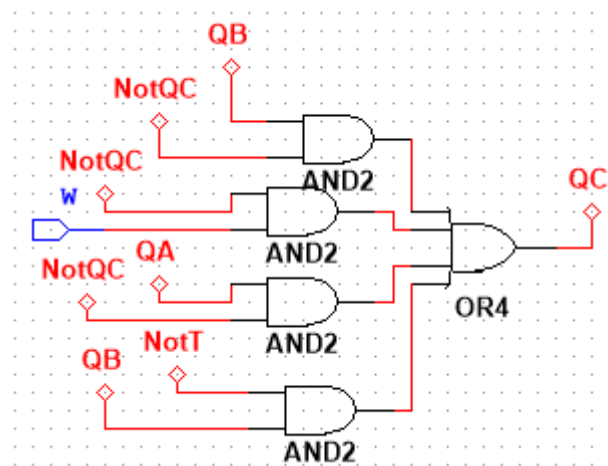


Figure 34

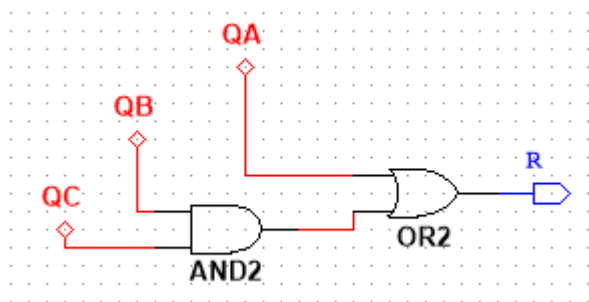


Figure 35

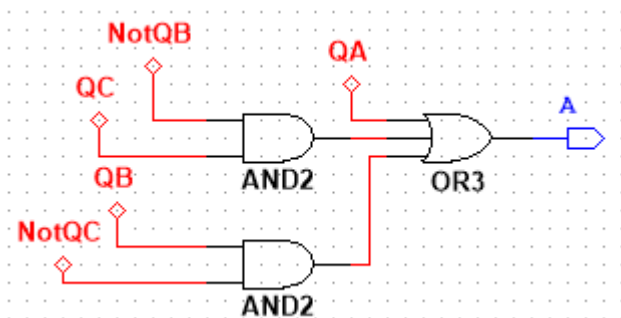


Figure 36

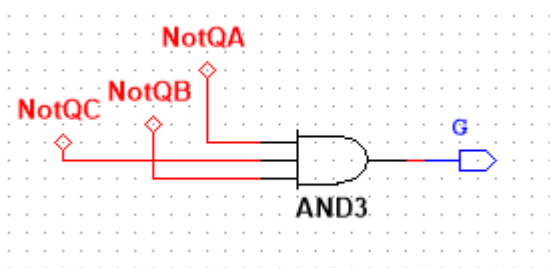


Figure 37

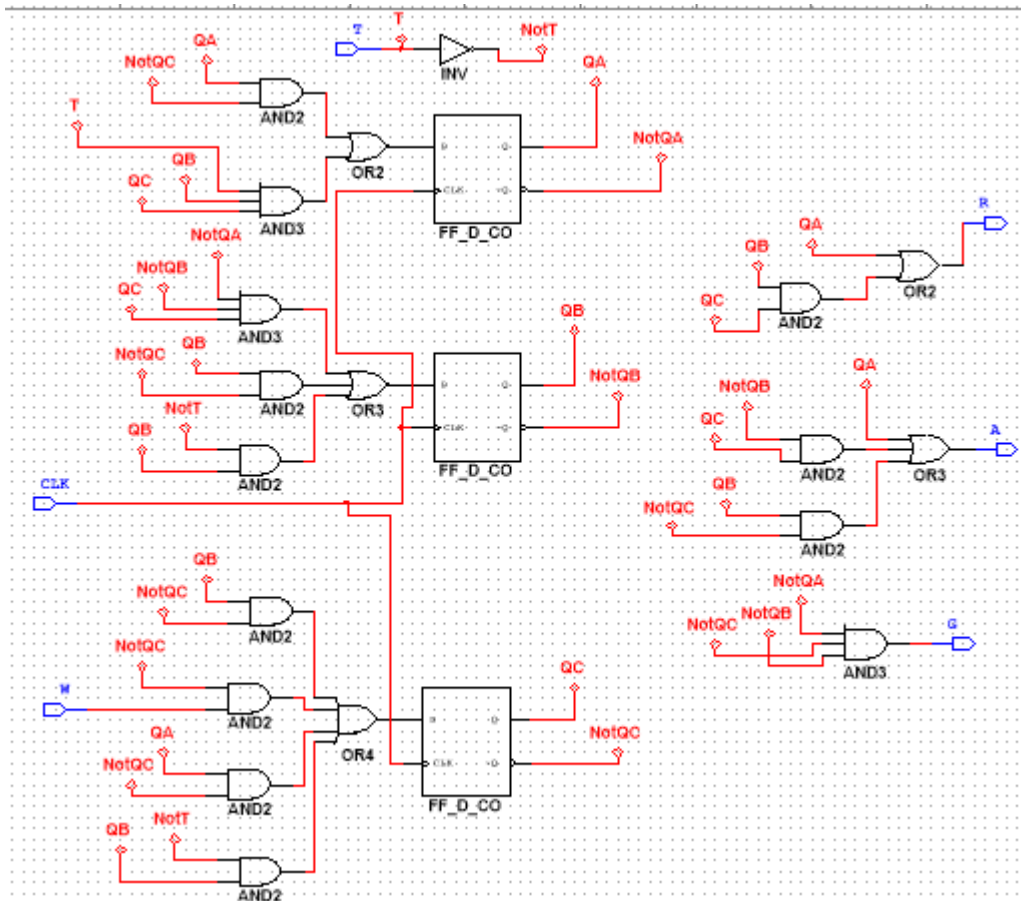


Figure 38

AGAIN, IDC AND PROPER
NEEDED FOR TESTING.

Output Circuit	Figure
QA	32
QB	33
QC	34
Red	35
Amber	36
Green	37
Final Circuit	38

Table 11

3.4. Puffin Crossing

3.4.1. Specification

The specification for this task was to modify the original design to work as a Puffin Crossing. This required a 'pressure sensor' to be added as an additional input, 'P', into the 5 second timer circuit, meaning both inputs, 'P' and 'B', needed to be true before the timer started counting. The 'P' input was required to stay true until state 5 was reached, otherwise the state reverted to state 0. This was to mimic a person pressing the wait button and standing on the pressure sensor until the lights changed colour. This ensures that if someone stands on the pressure sensor and presses the wait button – but then leaves as they don't need to cross the road anymore – then the light will remain green for traffic to flow.

3.4.2. State Diagram

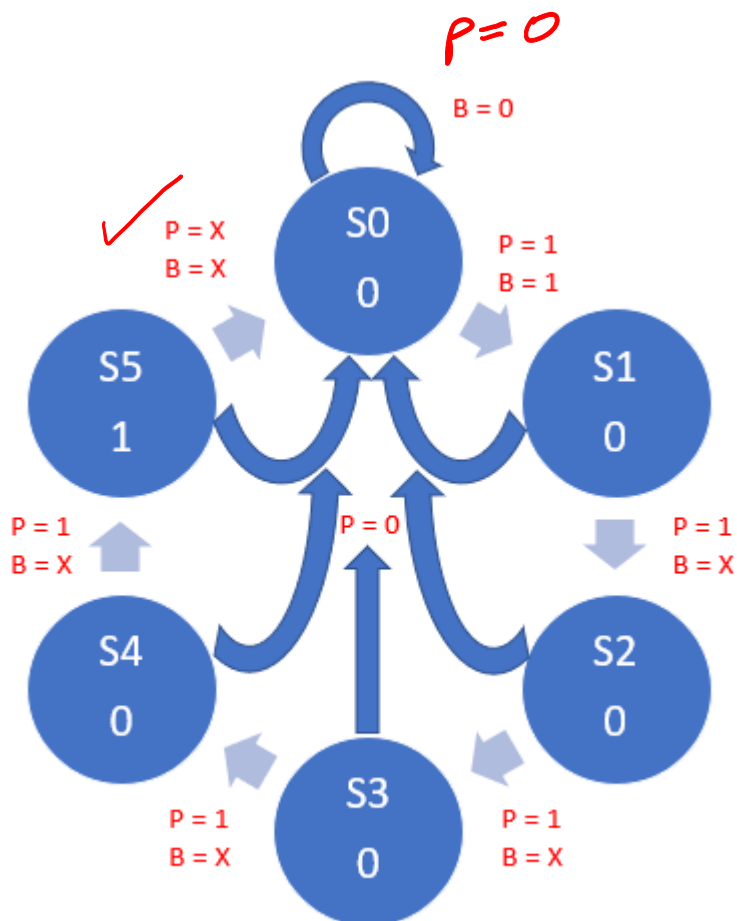


Figure 39

3.4.3. State Table

	Next State							Next												Output
Current State	P = 0		P = 1		Current Output			P = 0						P = 1						
								B = 0			B = 1			B = 0			B = 1			
	B=0	B=1	B=0	B=1	QA	QB	QC	QA+	QB+	QC+	QA+	QB+	QC+	QA+	QB+	QC+	QA+	QB+	QC+	
S0	S0	S0	S0	S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
S1	S0	S0	S2	S2	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0
S2	S0	S0	S3	S3	0	1	0	0	0	0	0	0	0	0	1	1	0	1	1	0
S3	S0	S0	S4	S4	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0
S4	S0	S0	S5	S5	1	0	0	0	0	0	0	0	0	1	0	1	1	0	1	0
S5	S0	S0	S0	S0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
S6	X	X	X	X	1	1	0	X	X	X	X	X	X	X	X	X	X	X	X	X
S7	X	X	X	X	1	1	1	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 12

3.4.4. Karnaugh Maps & Boolean Equations

P = 0

P = 1

QA+

QB QC B QA	00	01	11	10
00	0	0	0	0
01	0	0	X	X
11	0	0	X	X
10	0	0	0	0

QB QC B QA	00	01	11	10
00	0	0	1	0
01	1	0	X	X
11	1	0	X	X
10	0	0	1	0

$$QA+ = PQA\overline{QC} + PQBQC$$

Figure 40

QB+

QB QC B QA	00	01	11	10
00	0	0	0	0
01	0	0	X	X
11	0	0	X	X
10	0	0	0	0

QB QC B QA	00	01	11	10
00	0	1	0	1
01	0	0	X	X
11	0	0	X	X
10	0	1	0	1

$$QB+ = P\overline{QA}\overline{QB}QC + PQB\overline{QC}$$

Figure 41

QC+

QB QC B QA	00	01	11	10
00	0	0	0	0
01	0	0	X	X
11	0	0	X	X
10	0	0	0	0

QB QC B QA	00	01	11	10
00	0	0	0	1
01	1	0	X	X
11	1	0	X	X
10	1	0	0	1

$$QC+ = PQA\overline{QC} + PB\overline{QC} + PQB\overline{QC}$$

Figure 42

3.4.5. Circuits

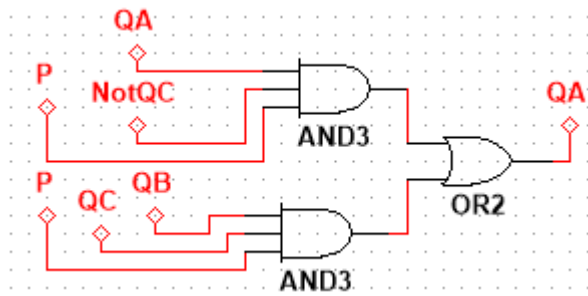


Figure 43

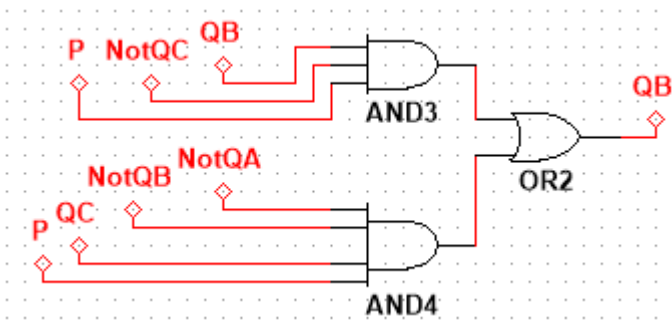


Figure 44

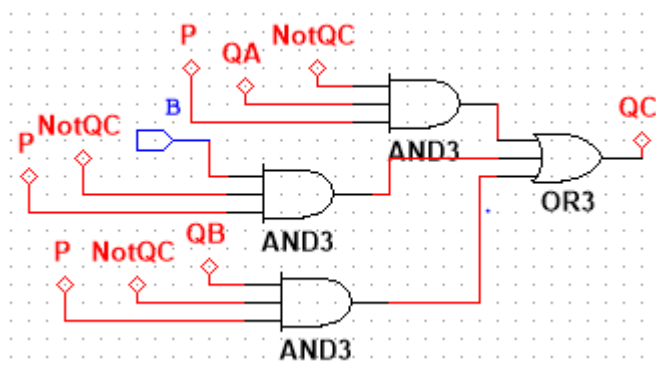


Figure 45

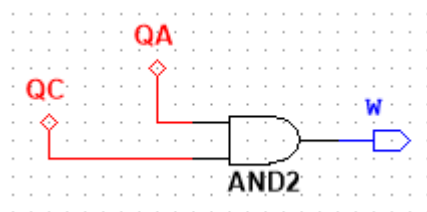


Figure 46

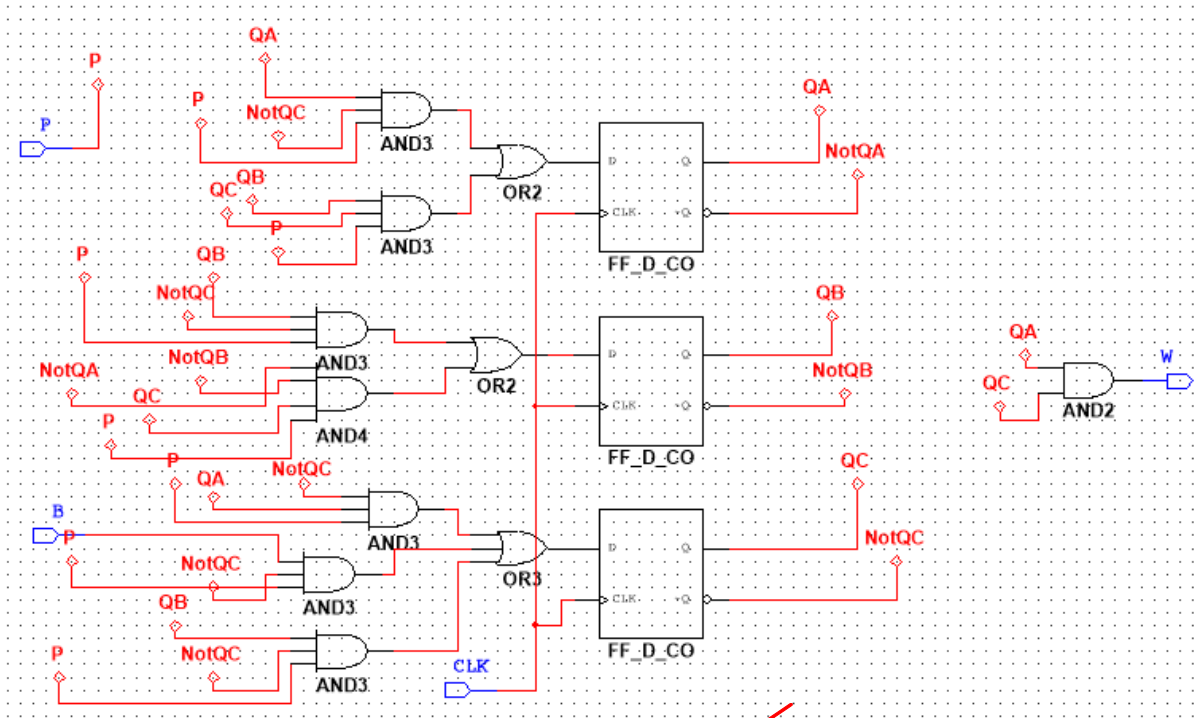
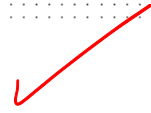


Figure 47



Output Circuit	Figure
QA	43
QB	44
QC	45
W	46
Final Circuit	47

Table 13

4. Testing, results and analysis

4.1. 5 Second Timer

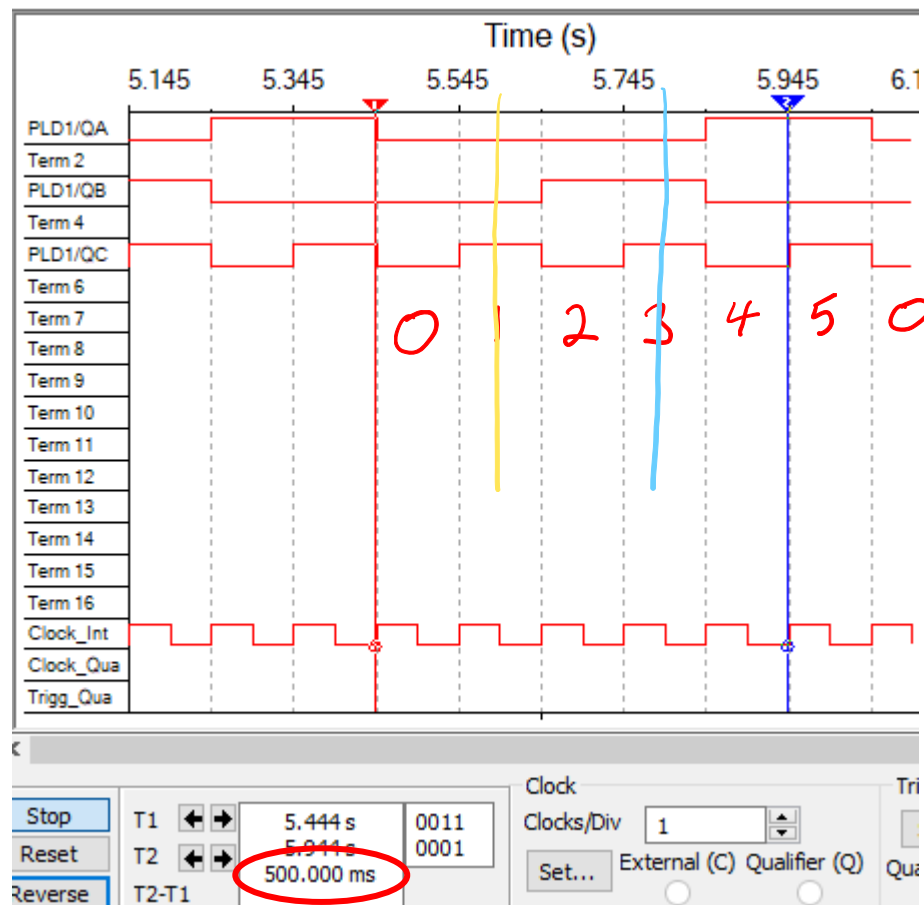


Figure 48

The 5 second timer was completed successfully after first building the circuit from the FSM design and tested using an LED connected to the output. Once this circuit was confirmed to be functioning correctly, it was added as a sub-circuit into the Nexus 4 DDR Board on Multisim. A logic analyser was used to check the sequence of the states changing and an interactive digital constant was used to simulate the WAIT button being pressed. The results of the test can be seen in figure 48, with the timer repeatedly counting from 0 to 5, as the interactive digital constant remained true. Cursors have been placed on the graph to show where state 0 and state 5 begin. The circled box shows the time between the cursor to be 500ms – this is due to the clock settings to be at 10Hz – meaning if we multiply the time by frequency, we will get the correct 5 second time interval. If the clock was set to 1Hz, a 5 second interval would be shown between the cursors but this was unable to be shown in one graph. Each state and the time in seconds are represented by a combination of the outputs – QA, QB and QC – being true or false. Their respective values can be seen in table 14 below.

Output	Binary Value
QA	4
QB	2
QC	1

Table 14

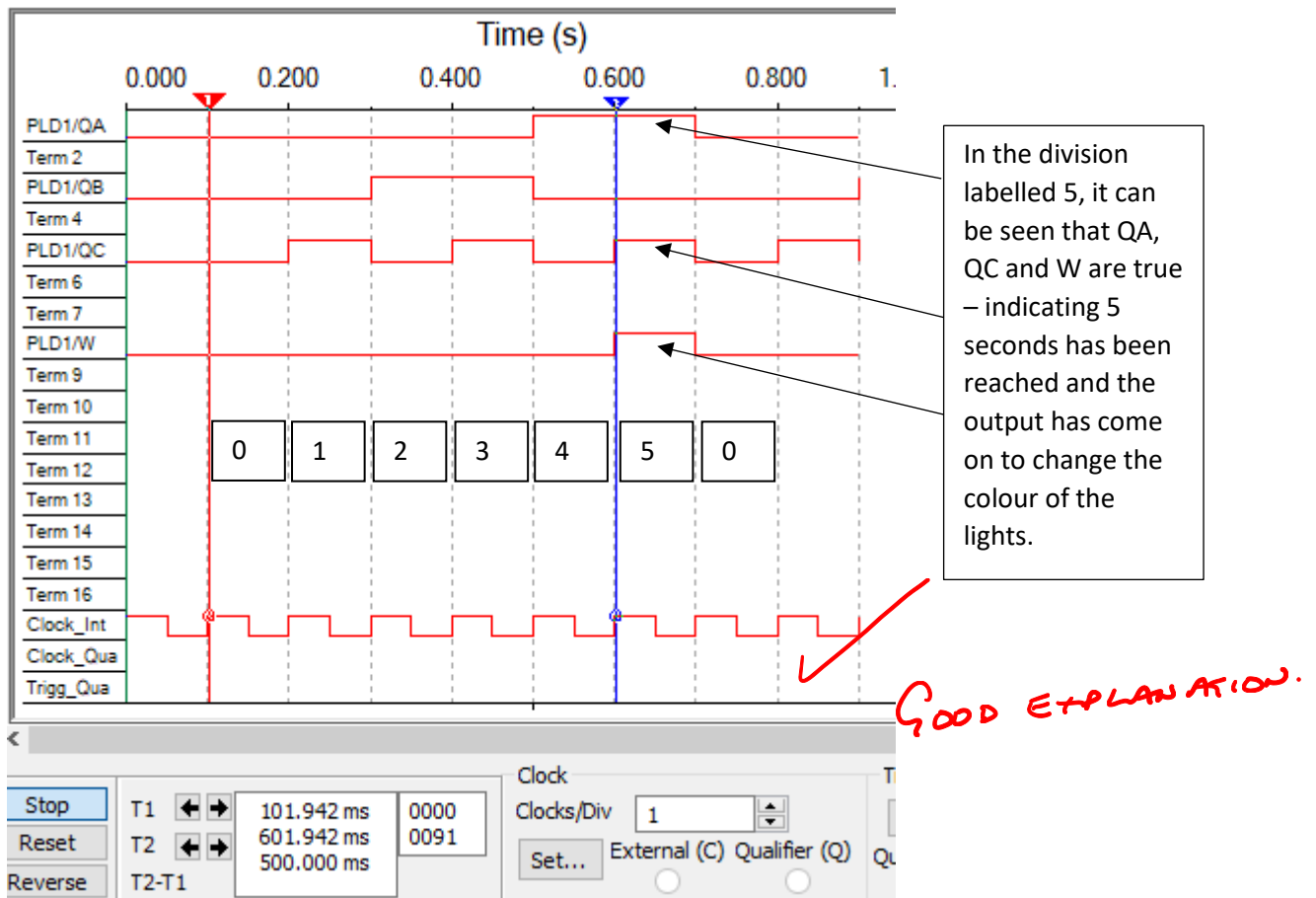


Figure 49

In figure 49 above the output 'W' has been added to the graph, this shows at the same time as state 5 is reached, 'W' becomes true, as expected from the design process. The clocks/div has been set to 1 to show the changing states clearly and have been labelled 0 to 0 to show the complete cycle. An explanation of each state can be seen in table 15 below.

State	Outputs True	Description
0	None	No outputs on. Binary value of 0. 0s of timer.
1	QC	Binary value of 1. 1s of timer.
2	QB	Binary value of 2. 2s of timer.
3	QB & QC	Binary value of 3. 3s of timer.
4	QA	Binary value of 4. 4s of timer.
5	QA, QC & W	Binary value of 5. 5s reached and output W turned on to signal light change.

Table 15

OVER ELABORATED HERE,
LOGIC ANALYSER WAS SUFFICIENT.

4.2. 15 Second Timer

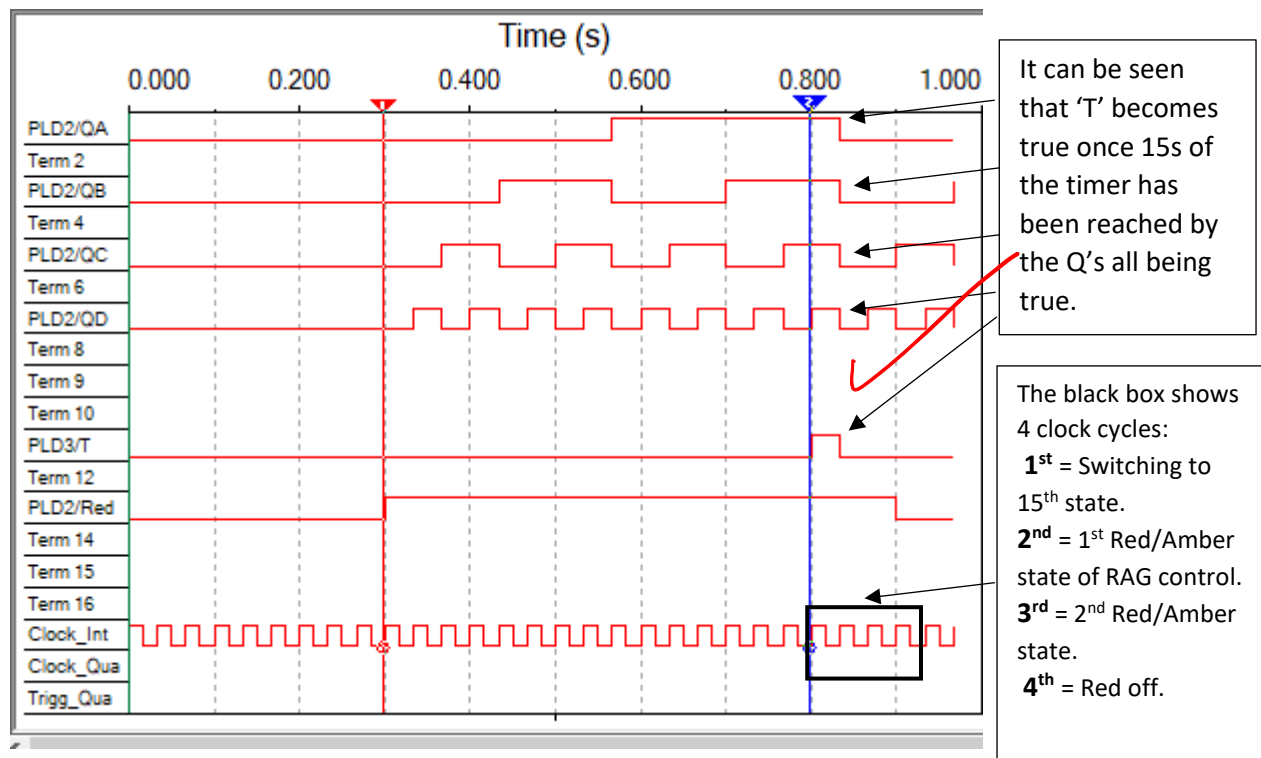


Figure 50

The 15 second timer was completed successfully by carrying out the same design process as the 5 second timer. Once in the complete traffic light control circuit, the 15 second timer was again tested via a logic analyser which was used to check the sequence of the states changing, the output 'T' becoming true after 15 seconds, and the input 'Red' starting off the sequence and remaining true for two additional seconds as part of the sequence of the lights being Red/Amber for two seconds before turning green. The results of the test can be seen in figure 50, with annotated explanations and in table 17 with the timer counting from 0 to 15, as the interactive digital constant remained true. Cursors have been placed on the graph to show where state 0 and state 15 begin. Each state and the time in seconds are represented by a combination of the outputs – QA, QB and QC – being true or false. Their respective values can be seen in table 16 below.

Output	Binary Value
QA	8
QB	4
QC	2
QD	1

Table 16

State	Outputs True	Inputs True	Description
0	None	Red	No outputs on. Binary value of 0. 0s of timer.
1	QD	Red	Binary value of 1. 1s of timer.
2	QC	Red	Binary value of 2. 2s of timer.
3	QD & QC	Red	Binary value of 3. 3s of timer.
4	QB	Red	Binary value of 4. 4s of timer.
5	QB & QD	Red	Binary value of 5. 5s of timer.
6	QB & QC	Red	Binary value of 6. 6s of timer.
7	QB, QC & QD	Red	Binary value of 7. 7s of timer.
8	QA	Red	Binary value of 8. 8s of timer.
9	QA & QD	Red	Binary value of 9. 9s of timer.
10	QA & QC	Red	Binary value of 10. 10s of timer.
11	QA, QC & QD	Red	Binary value of 11. 11s of timer.
12	QA & QB	Red	Binary value of 12. 12s of timer.
13	QA, QB & QD	Red	Binary value of 13. 13s of timer.
14	QA, QB & QC	Red	Binary value of 14. 14s of timer.
15	QA, QB, QC, QD & T	Red	Binary value of 15. 15s reached and output 'T' now true, signalling the lights to change colour.

Table 17

4.3. RAG Control

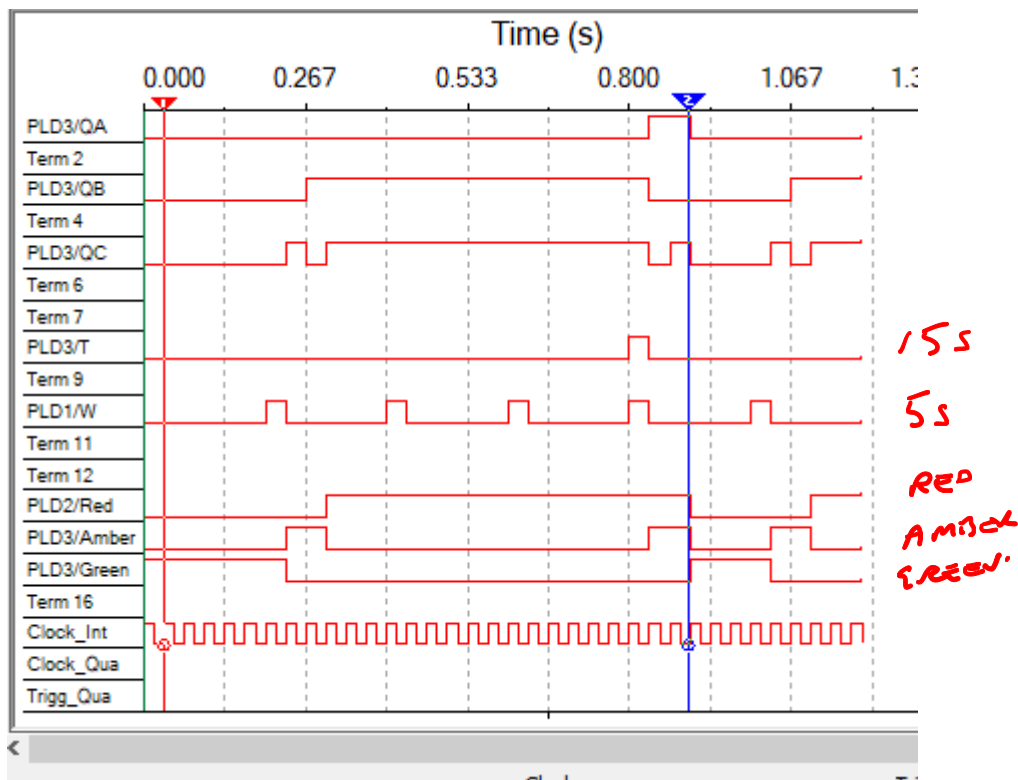


Figure 51

Figure 51 shows the testing of the RAG controller via a logic analyser. The analyser has been set up to monitor the Q outputs, T and W inputs, and the 3 colours of traffic light. The graph shows a complete sequence from start to finish, and is listed below:

- Starting point of light being green.
- The red cursor shows the point where the 'WAIT' button is 'pressed' (Digital constant turns to 1).
- On the rising edge of the 6th clock cycle, W goes true, as state 5 of the 5 second timer has been reached.
- On the next clock cycle, W and green go false, and amber goes true for 2 cycles – meaning the amber light was showing for 2 seconds.
- The rising edge of the next clock is when amber goes false, and red goes true.
- The light remains red for 15 cycles and seconds until T goes true.
- On the falling edge of T signal, amber goes true.
- Both amber and red remain true for 2 more cycles – mimicking the 'get ready' signal the lights give to traffic stopped at the lights.
- The next clock resets the sequence as the light is back green, also indicated by the blue cursor on the graph.
- The period between the red and blue cursors show a full sequence.

4.4. Puffin Crossing

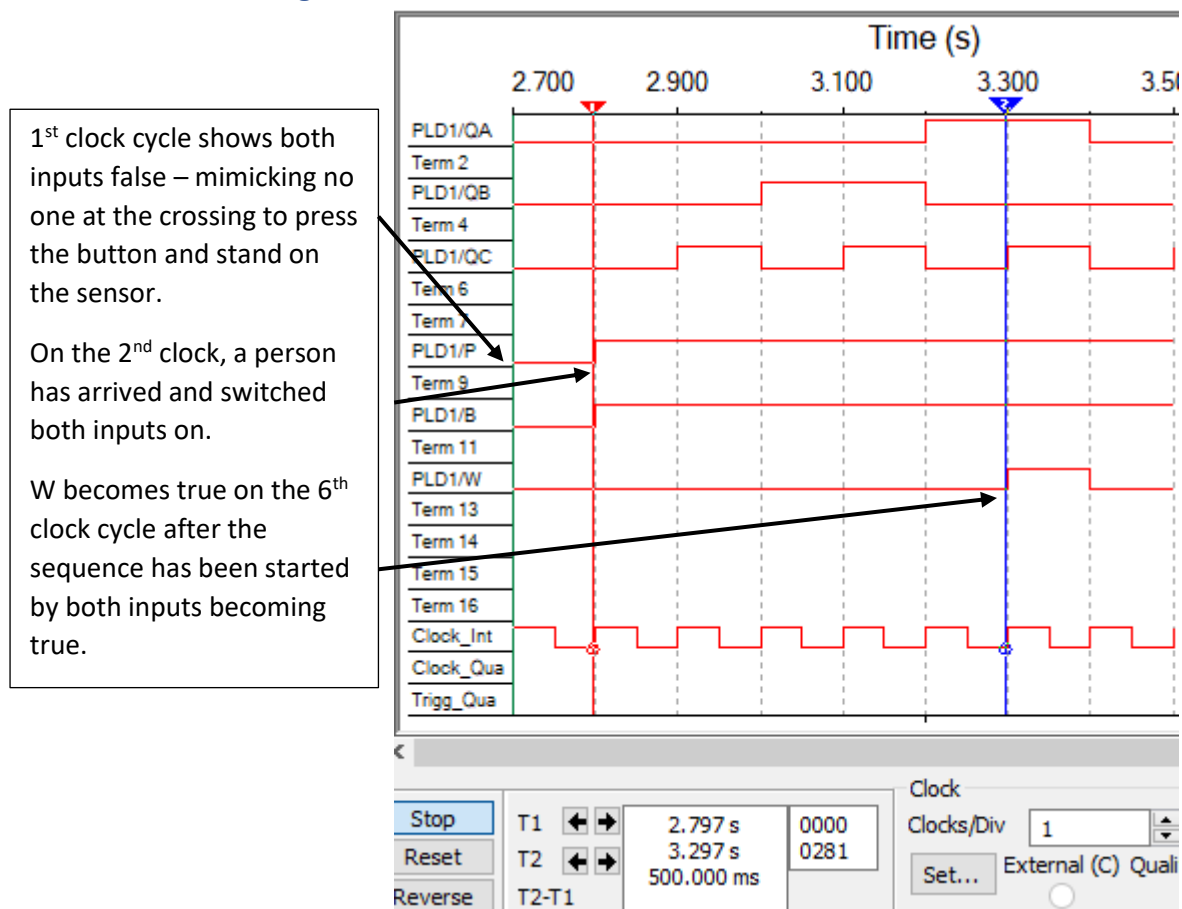


Figure 52

This circuit was a variation of the 5 second timer so the same testing was applied but the addition of the pressure sensor at the Puffin Crossing as an input had to be tested. Figure 52 shows both inputs, P (pressure sensor) and B (button) becoming true and starting the 5 second timer sequence, finishing with output W (wait signal) becoming true at state 5.

In figures 53 and 54, tests were carried out to see if the timer would count if the Wait input was true and Puffin input false, and vice-versa. Both tests revealed that the timer would not begin counting unless both inputs were true.

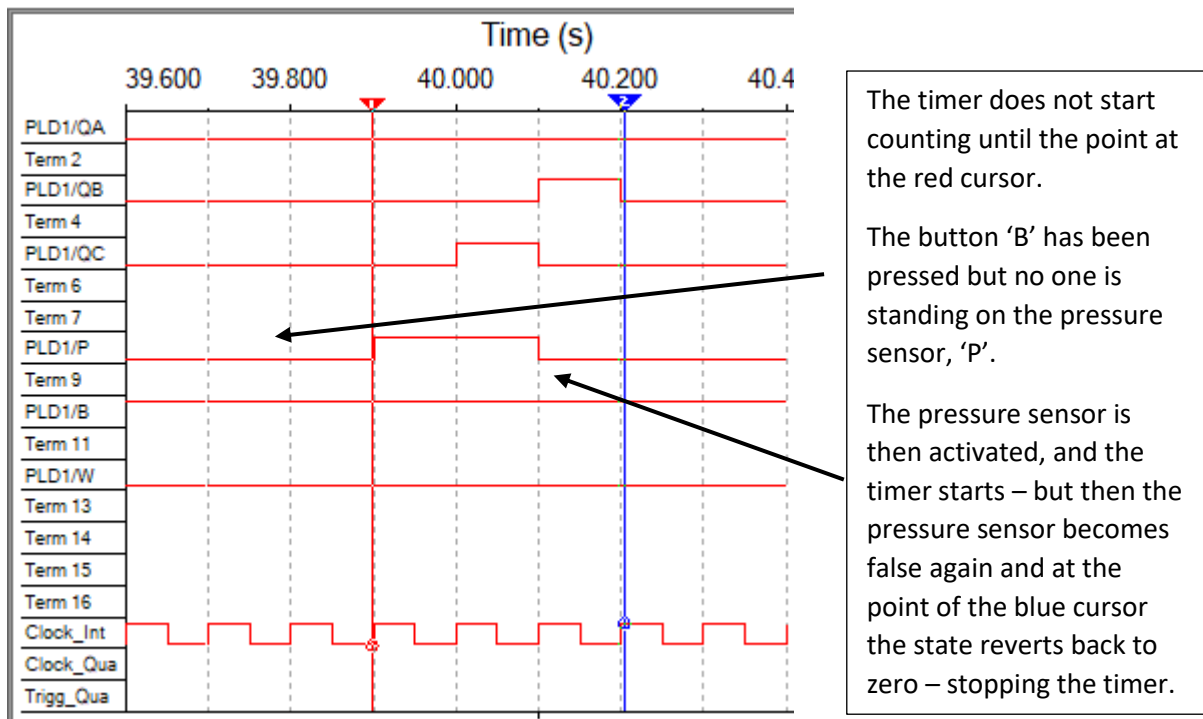


Figure 53

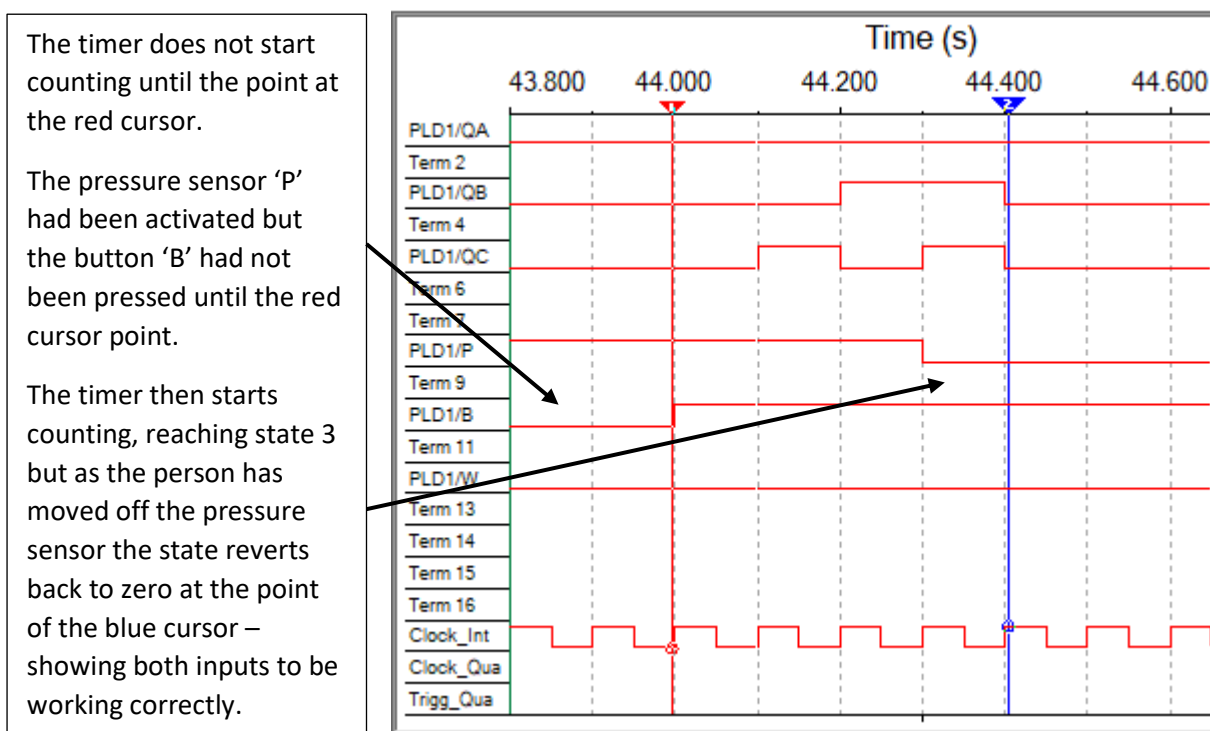


Figure 54

*EXCELLENT ANALYSIS
OF THE PUFFIN MODIFICATION*

5. Conclusions and recommendations

In this report, the results from the testing and analysis met all the required points of the original specification – including the additional task of creating a Puffin Crossing. Each circuit was proven to work independently before being added as a sub-circuit to the NEXYS 4 DDR Board, and then tested again once integrated with the other sub-circuits. As seen in Section 4, the logic analyser was utilised to collect the results from each circuit. Testing was carried out to prove the circuits functioned correctly when they should – and to ensure they did not function when they were required to be off – as seen for example in the testing of the Puffin Crossing.

An issue was encountered when testing the complete circuit, as the light was remaining green, and not changing when the 'Wait' button was pressed. As the logic analyser can monitor a circuit, it was used as a fault-finding aid to help solve the issue above. This process was used on the RAG Control circuit to figure out why the lights were not changing colour – even though the 5 second timer was proven to work before being added as a sub-circuit. The analyser was setup to monitor all inputs and outputs in the circuit and it found that the input 'W' – from the 5 second timer circuit – was constantly false. On inspection of the 5 second timer, it was found the AND gate was not connected to the 'W' on page connector – even though it appeared to be. This issue was resolved, and the RAG Control began to change the colour of the light as intended.

Regarding the research undertaken in Section 2.3., the circuit designed in this report could be manufactured as an ASIC. As stated in the name, these integrated circuits are applications specific, and the control of pedestrian crossings is a specific application that could be mass produced to control each crossing across the country. This generic control of all crossings could allow for cheaper production costs, standardisation of parts and the elimination of waste – as it's a one size fits all situation – rather than there being various ways and parts to do the job. This has some disadvantages as not all crossings are the same; the 15 second red light might be excessive on smaller roads but not long enough for bigger roads. This could be seen as not being as productive as possible, but also dangerous if someone begins to cross a big road with only a small amount of time before the lights turn green. But as seen in Section 2.1. and 2.2., modern crossings are made to suit each individual road, with sensors placed above and below ground to optimise the flow of traffic but also dependant on various other factors such as pedestrian and traffic flow, demographic of area, and speed limit. The cost of research and work to be undertaken to design various ASICs to suit the many different roads outweighs the benefits.

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7. Annexe

FINAL GRADE

GENERAL COMMENTS

Instructor

87 /100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19

PAGE 20

PAGE 21

PAGE 22

PAGE 23

PAGE 24

PAGE 25

PAGE 26

PAGE 27

PAGE 28

PAGE 29

PAGE 30

PAGE 31

PAGE 32

PAGE 33

PAGE 34

PAGE 35

PAGE 36

PAGE 37

PAGE 38

PAGE 39

PAGE 40

PAGE 41

PAGE 42

PAGE 43

GRADING FORM: CSG-RUBIC

AERON SMITHAM**87****RESEARCH-INFORMED LITERATURE**



There was evidence of considerable further reading and research from highly credible and reliable sources. Your interpretation and understanding of the additional research was exceptional and demonstrated a deep underlying appreciation of the subject. Your references were consistently applied to a high level of competency and your reference list was extensive for this assignment.

9**KNOWLEDGE AND UNDERSTANDING**



The knowledge and understanding of the subject demonstrated by this assignment was exceptional. There were no gaps in your knowledge of the basic principles and the higher level concepts were extremely well explained. Your explanation of the design process and calculations was also excellent

26

and you have demonstrated an exceptionally detailed knowledge and critical understanding of the main concepts and expanded your knowledge beyond that contained in the course notes.

ANALYSIS



Your analysis of the task was outstanding, you have demonstrated highly competent analytical skills and your approach to the task was highly logical. You carried out a detailed evaluation of the results and included an excellent conclusion connecting ideas and providing logical and persuasive arguments. You have demonstrated a considerable capacity for independent thought and the ability to see beyond the question and your interpretation of the quantitative and qualitative data was exceptional with sound judgements based on wholly valid arguments.

25

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task was generally exceptional. You used both the basic and advanced features of the resources appropriately when designing the circuit and you used appropriate advanced options for testing and evaluating the circuit performance. You managed to design an effective circuit that functioned well within the specification and achieved this by rarely asking for assistance thus demonstrating some advanced problem solving skills. Your results were comprehensive and allowed for a detailed conclusion to be attempted.

18

SKILLS FOR PROFESSIONAL PRAC.



In this assignment you have demonstrated skills in working individually and also collaboratively. Your written report was exceptionally well structured and written in a highly coherent and logical way. The report was presented in a professional manner using appropriate language and formatting, good diagrams in appropriate places, good sentence/paragraph structure and clear calculations.

9