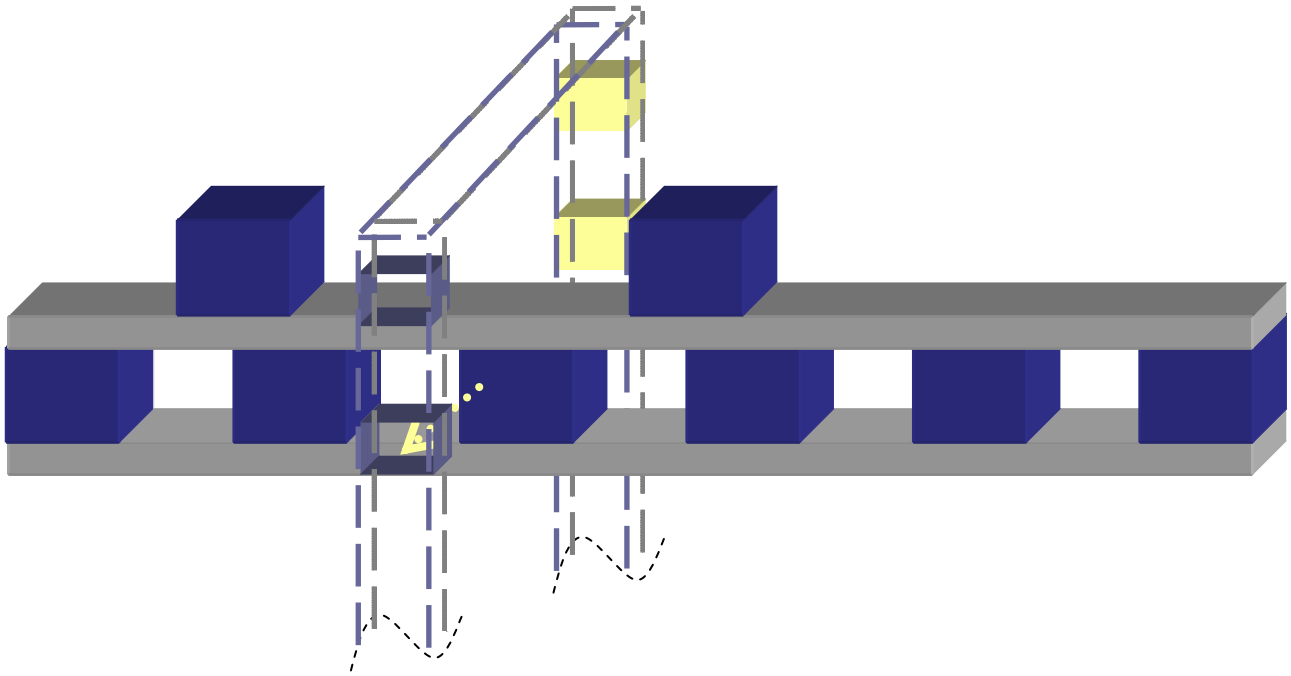
MSAC: The LamBITGhini

ECE298: Project 1



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EXECUTIVE SUMMARY

A request for proposal was presented to MSAC for a communication device capable of transmitting a message from one Ultragizmo station to another receiving station that displays the message. This report presents the design analysis of the unattended communication device developed by the University of Toronto MSAC design team for the ECE298 course. The proposed design is called the LamBITghini and facilitates the transmission of data between stations with the use of a motorized car that drives the signal (in the form of Lego blocks) through the receiving sensors, which detect and decode the message. This design was successful in not only meeting all the required objectives but in surpassing some objectives as well. The design is capable of transmitting data at a rate of 3 message symbols per minute, over a distance of about 1.5 metres. Also, the design can easily be modified to be able to transmit more than one symbol at a time, by simply adding message block layers.

The report is divided into 4 major sections that include the physical description, operational description, design evaluation, and project management. The physical description details the design's physical dimensions and composition with visual examples. The operational description describes the functional aspects and technical information (such as signal flow and functional diagrams) of the design. The design evaluation contains the analysis of the proposal success, and also details the testing stage with all the failed and successful design decisions that were involved throughout the project. Lastly, the project management section consists of the project planning and proposed schedules that were established for the design team to follow.

This report discusses all the factors affecting the design of this communication system and the process through which this design was created.

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INTRODUCTION

The present report is an in-depth design analysis of the unattended communication device built by the University of Toronto MSAC design team as a requisite for the ECE298 course. A request for proposal was presented to MSAC for a communication device capable of transmitting a message from one Ultragizmo station to another receiving station that displays the message. The design objectives are to allow a user to transmit one of 32 distinct message symbols to an unattended receiving Ultragizmo station, which will decode and display the message. Also, the design shall allow the data to be transmitted over a minimum distance of 1m, at a minimum rate of one message symbol per minute.

To meet this request, the MSAC design team proposes a Lego-constructed communication system called the LamBITghini. The 2 major components of the design are a Message Transmitting Device (car) used to transfer messages and a Sensory Device Overpass (bridge) that receives the signals. The car is used to drive the data (composed of Lego blocks) through the receiving sensors that detect and decode the data. Indeed the design meets all the expectations of the project and goes above and beyond. It is capable of transferring unique character symbols at a rate of 3 characters per minute, which is 3 times the required speed. The message carrier is controlled by the user through 2 switches on the transmitting Ultragizmo station, one for forward motion control, and the other for reverse motion control. With no obstructions the message carrier can run for approximately 1.5 meters, which is greater than the expected distance of 1m between stations. Another added feature in the design is that it displays the decoded character on the monitor as well as its hexadecimal value on the Ultragizmo board of the receiving station. Hence the proposed design meets all the requirements as well as other added features.

The report is divided into 4 major sections that include the physical description, operational description, design evaluation, project management, and a user's manual for the design. Various flow diagrams such as electric, signal and FAST diagrams are included as well for easy comprehension.

PHYSICAL DESCRIPTION

The design of this device is discretely separated into two sections; the transmitting portion composed of the Message Transmission Device, and the receiving portion composed of the Sensory Device Overpass.

TRANSMITTING: MESSAGE TRANSMISSION DEVICE *(refer to* **Figure 1***)*

This transmission device is in essence a car, and is built completely of Lego parts. The car is driven with two motors that supply the power to drive forwards and backwards. The total length of the car is 12.5 cm, the width is 15 cm, and the height is 19 cm. It has two motors (one on the front right corner of the car and the second on the rear left corner) to drive both the front and rear wheel axles for more power. The car motors are connected to the Lego-controller and the movement of the car (forward and backward) is controlled through two switches on the transmitting gizmo board.

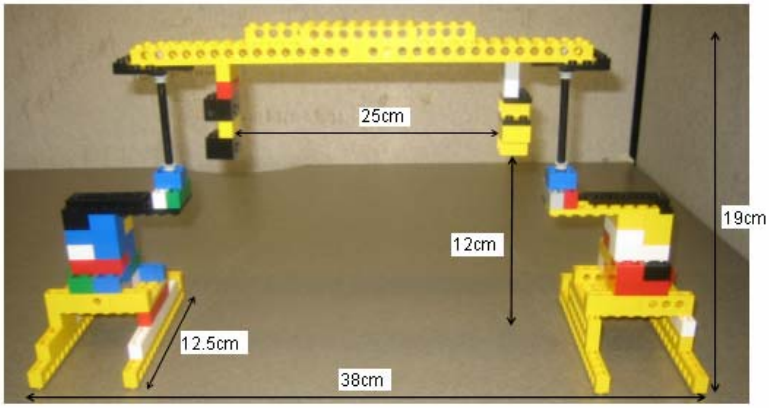


Figure 1: Sensory Device Overpass

The car carries an input block or "signal package" on its top. The input block is 25 cm long and 7 cm tall and is 2 tiered, the upper level is the data signal and the lower level is for the clock signal. The input block runs for 5 clock cycles and hence contains 5 separate sections for

the data. Each Lego block is 1.5 cm in height and each block is placed 3 Lego spaces away from the adjacent one.

RECEIVING: SENSORY DEVICE OVERPASS *(refer to* **Figure 2***)*

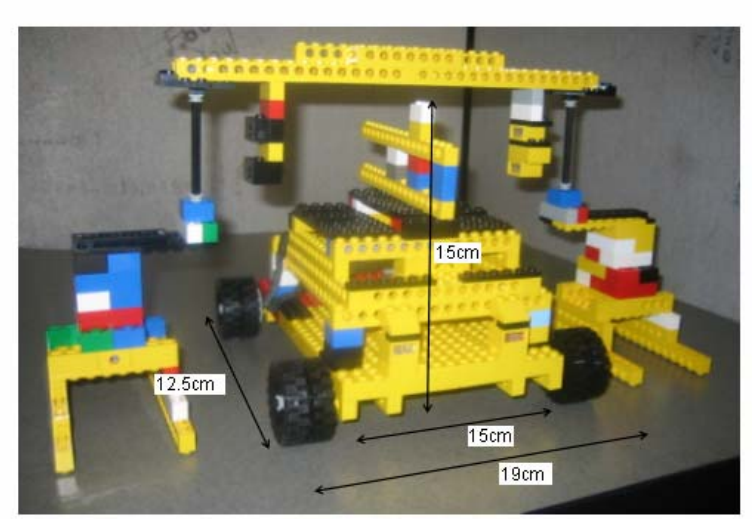


Figure 2: Message Transmission Device going through the Sensory Device Overpass

The sensory device overpass resembles a bridge and is 38 cm long, 12.5 cm wide and 19 cm in height and is also completely composed of Lego blocks. It has two LED's and two light sensors across from the LED's. The lower sensor and LED is 12 cm from the ground. The separation distance between the LED's and their corresponding sensors is 25 cm. The LED's are powered from the receiving station Lego-controller and the sensors are also connected to the same receiving Lego-controller.

PROCESS DESCRIPTION

The transmitting station consists of an Ultragizmo board programmed to control a Lego-controller that operates the motors of the Lego-built Message Transmission device. This message carrier will physically drive to the receiving station and transmit the data. On top of the car is placed a 2-Level Code Block that contains the entire signal data (*refer to* **Figure 3**). The transmission data will be in a binary form represented by Lego blocks placed on top of the car on Level 2. A Lego block will represent a logical 1 state, and the spaces between the blocks will represent a logical 0 state. This is opposite from what the light sensors actually record (since no

block and the presence of light result in a sensor logic 1), and is taken into account by the programming of the receiving station.

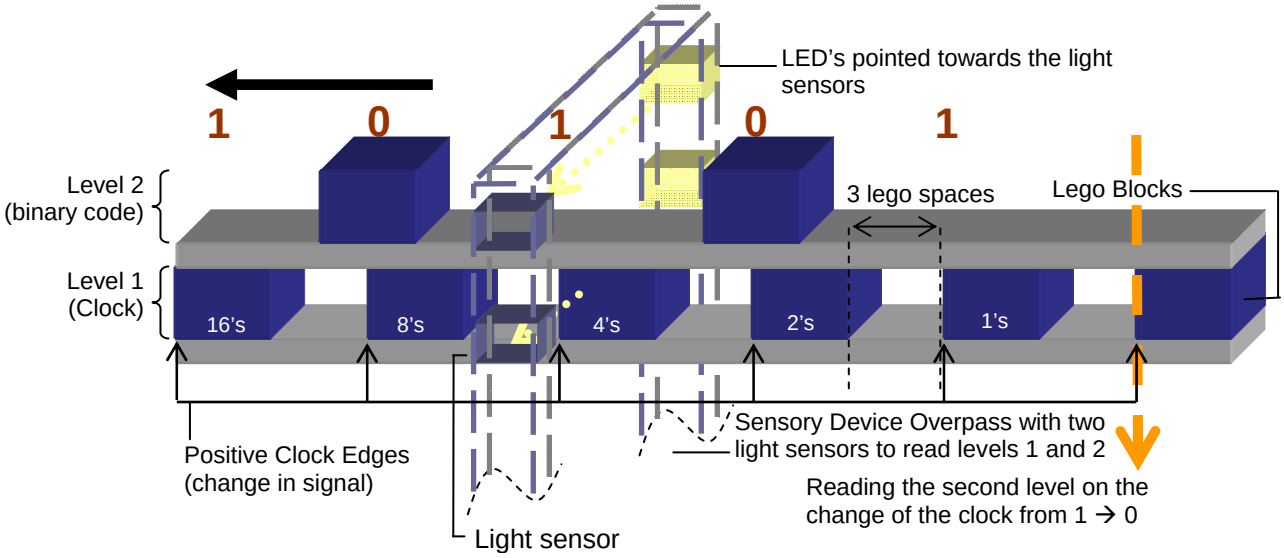


Figure 3: 3D rendering of the 2-Level Code Block moving through the Sensory Device Overpass

Level 1 consists of a steady clock cycle used to instruct the receiving station when to sample the second Lego layer (the transmission data). The transmission data will be sampled each time the Level 1 state changes from logic 0 to 1 (the positive edge of the blocks). The data will be transmitted in packages of 5 binary bits through each run, which will allow for the transmission of 32 unique symbols. The user must first manually place the Lego blocks onto the car in the correct code-order (not right above the clock, but rather slightly before the positive edge) then direct the car through the Sensory Device Overpass using the forward/reverse motor controls of the transmission station.

The receiving station consists of an Ultragizmo board programmed to receive information from a Lego-controller reading the transmitted data. The data will be read using light sensors built on top of a stand, called a Sensory Device Overpass. These sensors will be able to detect different Lego blocks as they pass by (blocking the light to the sensors) and send this data to the Ultragizmo station. The receiving station will be programmed to interpret sensor logic

0 as a data logic 1, and sensor logic 1 as a data logic 0. This is due to the fact that a sensor will have logic 0 when there is no light (when a block is passing by) and logic 1 otherwise, as explained for the transmitting station above. The receiving station will then read the value on the second level at the positive edge of the first level and store it in an array. Once all 5 bits are stored, the program interprets this 5-bit string of data using the 32 predetermined message symbols (one symbol for every 5-bit combination) and display it on the computer screen. The hexadecimal value of this number will be displayed on the Ultragizmo board's 7-Segment display. The receiving station will be unattended and will receive and display these transmitted signals without human direction. The message carrier will then be brought back through the overpass towards the transmitting station to set up the next symbol using the reverse motor function on the Lego controller. The program will ignore any data that is sampled as the message carrier makes way backwards through the overpass. There is also an exiting code for the receiving device, so that transmitting a specific predetermined code to the receiving station may terminate the program.

For a visual understanding of the process description please refer to the Signal Flow Diagram and FAST Diagram in Appendix C.

DESIGN EVALUATION

PROJECT EXPECTATIONS

The main objective of the project is to design an unattended communication device, which can transfer 32 unique characters from 1 Ultragizmo board to another at a minimum distance of 1 meter.

The final design constructed by the design team meets all the requirements of the project. The input block of the message transmitting device has 5 clock cycles which allows for 2^5 (32) combinations and hence the ability to transmit 32 unique characters. The final design

was tested by firstly placing two Ultragizmo boards 1 m apart. The light sensors and light bulbs were connected to the receiving Lego-controller while the Lego-car was connected to the transmitting Lego-controller. Each unique symbol (all 32 symbols) was then tested and transmitted from one gizmo board to the other by sending their corresponding block-coding on top of the car, which was driven through the sensors. Each character was correctly transmitted, received, and interpreted across the 1m gap at an average rate of 3 messages per minute. No operator is required at the receiving station as the sensors automatically receive the signal and transfer the data to the computer, which then decodes and displays the message. Thus the design was found to have met its goals of transmitting data both efficiently and swiftly while at the same time being fairly simple and cost effective. The project was also completed within the time constraints that were imposed.

ENGINEERING DECISIONS

The design implemented by the design team not only meets the requirements of the project but also goes beyond them and hence has added features that make it original and unique. The greatest feature of the design is that it only takes a maximum of 20 seconds to transfer a signal. Testing showed that the speed of transfer of the signal predominantly depended on the user who puts the message block on the car, as well as the separation distance of the two Ultragizmo stations. To ensure no delay the design incorporates the use of two message blocks; the first is transmitted with the car while the second is made ready with the next signal in the meantime. The car takes about 2-3 seconds to pass under the overpass and hence it takes a maximum of 20 seconds for each signal transfer (including the time required to change the message), which is only 1/3rd of the required one message per minute transfer rate.

One of the most important decisions made was to make the signal transfer and reading of the sensors independent of the speed of the car. To ensure the reliability of the data collected by the light sensors and avoid its dependence on the car velocity, a clock signal was attached to the bottom half of the Lego message package as a steady Lego block stream. The transmitted

data is then read at each positive clock edge thus allowing the transmitted data to be read independent of the speed of the car. Hence our design is independent of timing and just depends on the change of signal with the clock.

An added feature of the design is that it displays the decoded transmitted character on the monitor of the receiving station as well as the hexadecimal value of the character on the seven-segment display of the receiving Ultragizmo board.

Thus it can be seen that the proposed design not only meets its required goals but also goes above and beyond and also has added features that make it unique. The simplicity yet efficiency of the design make it a successful design.

PROJECT MANAGEMENT

Initial testing of the car model showed that it lacked the necessary power required to drive a model of the first size (more than 30cm in length). On reducing the car's size and weight, and also powering it by two motors instead of one, the model was then found to function both precisely and reliably. But with the clock signal it was found that the code was not being transmitted correctly at all times when the data was aligned with the clock edges. This problem was solved by aligning the data blocks a bit ahead of the clock edge, instead of at the clock edge itself. In this way the upper sensor would sample the transmitted data only at each positive clock edge.

Testing also showed that the sensors had problems detecting red Lego blocks as they passed by, and the sensors would function abnormally, thus it was decided not to use red colored blocks for inputs.

Refer to the Gantt chart provided in **Appendix D** for further information.

APPENDIX A

M.S.A.C. **TheLamBITghini**

USER MANUAL

System set up:

1. Connect the car motors to the logic switch board.
2. Connect the light sensors and the light emitters to the receiving gizmo board.
3. Place 'the package' on the transporting car.
4. Use the logic switches to drive the car forward / reverse.

> **CAUTION**
> The car should be driven in a straight line.
> The car should be driven completely through the receiving stand before returning.

How to transmit the message?

1. Obtain the binary code for the character to be transmitted from the 'look up' table (*refer to* **Appendix B**)

Decimal	Binary	Hex
1	00000001	1
2	00000010	2
3	00000011	3
4	00000100	4
5	00000101	5
6	00000110	6
7	00000111	7
8	00001000	8
9	00001001	9
10	00001010	A
11	00001011	B
12	00001100	C
13	00001101	D
14	00001110	E
15	00001111	F
16	00010000	10
17	00010001	11

Figure A.1 - Look Up Table *(refer to* **Appendix B***)*

2. Place the Lego blocks on the 'package' (their presence indicating 1 and absence indicating a 0). CAUTION: care should be taken that the Lego blocks are placed just above the positive edge of the lower clock signal as shown below:

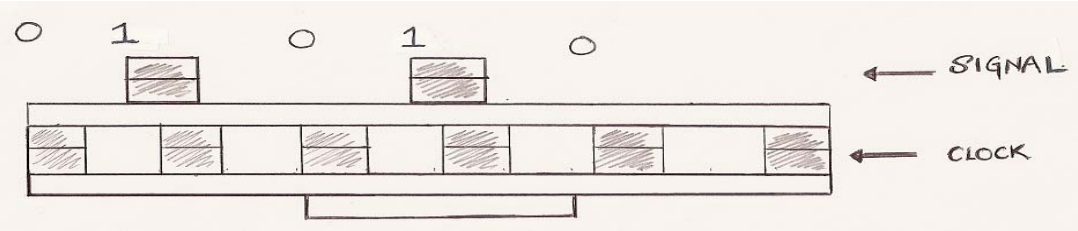


Figure A.2 – The Package *(refer to* **Figure 3***)*

3. Place the finished package on the car top .To drive the car forward use SWITCH1 on the logic board and SWITCH 2 to reverse it back. CAUTION: Make sure the entire package is run through the receiving stand before bringing it back.

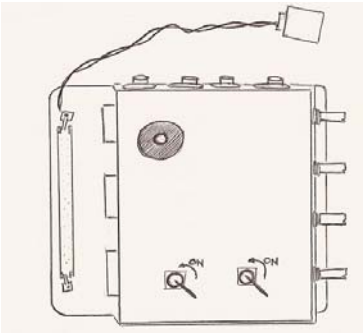


Figure A.3 - Switch Board

4. The transmitted code appears in hexadecimal format on the Ultra Gizmo Board and the corresponding alphabet is displayed on the computer screen.

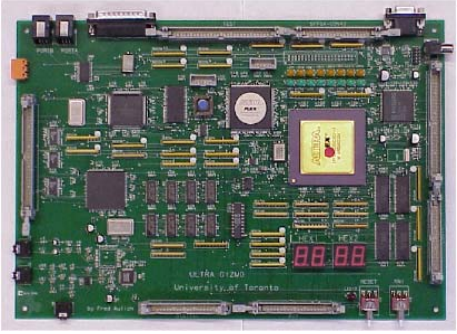


Figure A.4 - Ultra Gizmo Board (Hex Display)

Figure A.5 - Computer Screen

5. To terminate the program a '$' character can be sent just as the others completing the transmitted message.

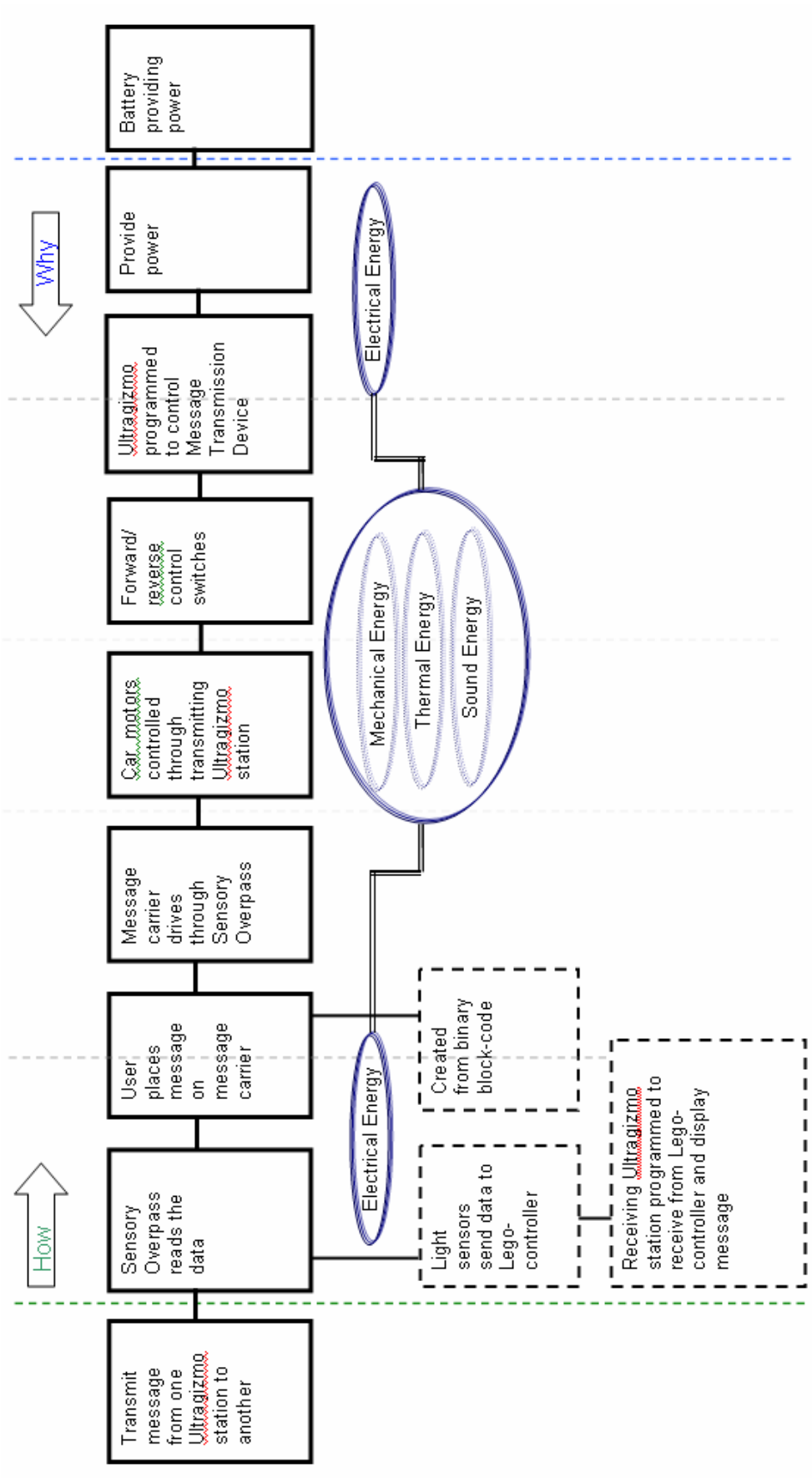
APPENDIX B

BINARY LOOKUP TABLE

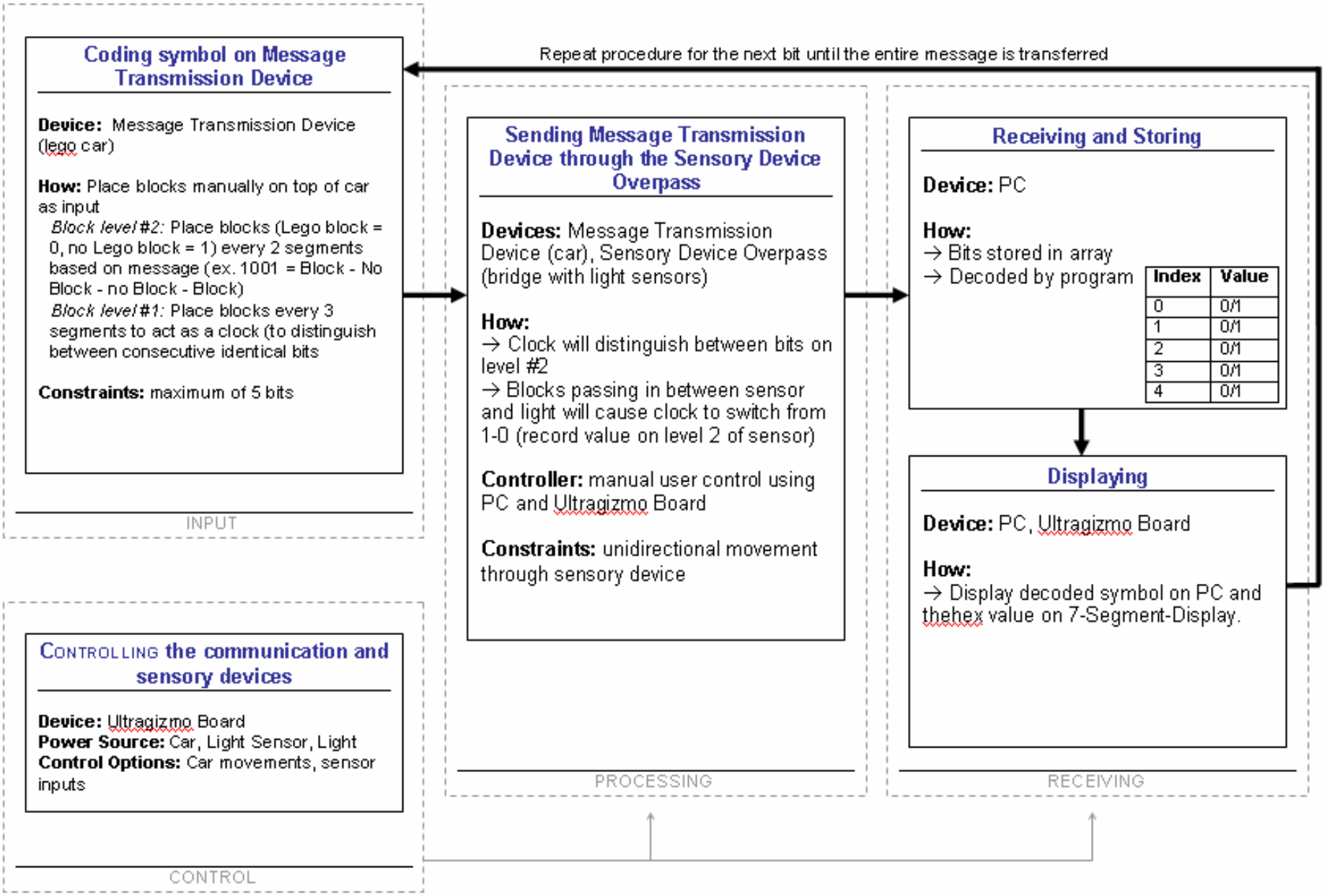
Binary Value	Character	Decimal Value	Hexadecimal Value
00000	A	0	0
00001	B	1	1
00010	C	2	2
00011	D	3	3
00100	E	4	4
00101	F	5	5
00110	G	6	6
00111	H	7	7
01000	I	8	8
01001	J	9	9
01010	K	10	A
01011	L	11	B
01100	M	12	C
01101	N	13	D
01110	O	14	E
01111	P	15	F
10000	Q	16	10
10001	R	17	11
10010	S	18	12
10011	T	19	13
10100	U	20	14
10101	V	21	15
10110	W	22	16
10111	X	23	17
11000	Y	24	18
11001	Z	25	19
11010	!	26	1A
11011	@	27	1B
11100	#	28	1C
11101	$	29	1D
11110	%	30	1E
11111	^	31	1F

APPENDIX C:
DIAGRAMS

FAST DIAGRAM



SIGNAL FLOW DIAGRAM



APPENDIX D:
GANTT CHART

APPENDIX E
PARTS LIST

Message Transmitting Device

Part Name	Function	Dimensions
Car	Carry the input block to transmit signal	12.5cm x 15cm x 15 cm
Motors(2)	For forward and backward movement of car	1.5cm x 2cm
Input Block	Carries the message to be transmitted and the clock	8cm x 3.5cm
Lego controller	Control on motors	15cm x 15cm
Gears	To rotate the axel/wheels	0.5cm diameter
Axel(2)	To align the front and back wheels	4.4cm length
Wires	To connect motors to lego-controller and lego controller to gizmo board	N/A
Wheels	For movement of vehicle (4 wheels)	2cm diameter

Table E.1: Message Transmitting Device Parts List

SENSORY DEVICE OVERPASS

Part Name	Function	Dimensions
Lego bridge	Overpass for car to pass underneath and signal to be intercepted by the sensors	38cm x 12.5cm x 19cm
LED (2)	Message transmission (lego block-light blocked, no lego block-light on)	0.5cm x 0.5cm
Light sensors	Message interception (light on-1, light blocked – 0)	0.5cm x 0.5cm
Lego Controller	Receive signals from sensors	15cm x 15cm
Wires	To connect sensors to lego controller and lego controller to gizmo board and LEDs to gizmo board.	N/A

Table E.2: Sensory Device Overpass Parts List

APPENDIX F
ADDITIONAL PICTURES

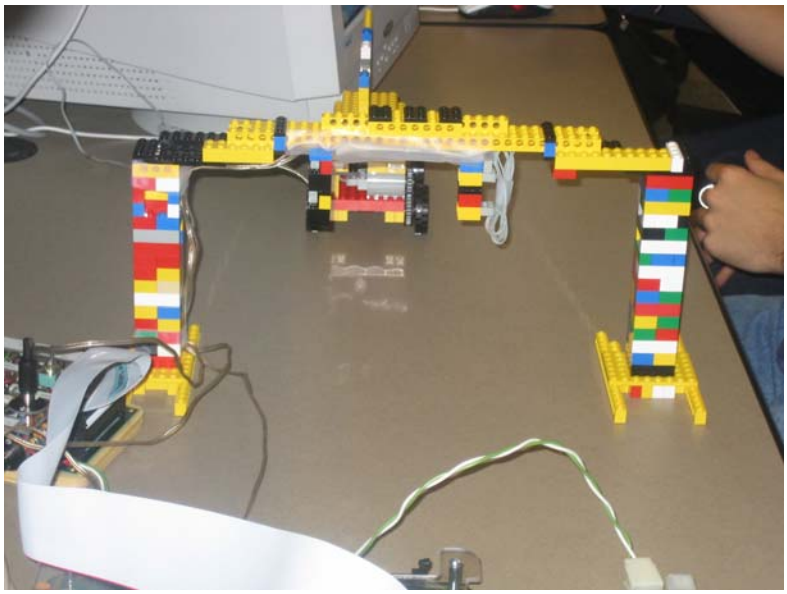


Figure E.1 – Sensory Device Overpass with Lego Controller

Figure E.2 – Message Transmitting Device