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Design and Implementation of Visible Light Communication based toys

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ABSTRACT

This paper presents the design and implementation steps of a smart visible light communication based toy system equipped with laser sensors that can send and receive the data message based on the conversion of data from ASCII to binary code. The toy system intends to offer two-ways communication that will be a new medium for educational purposes for kids in their developmental stages in which both players can send and receive the data to and from each other toys equipped with sound indicator module to alert the player. Lastly, functionality and system testing were conducted to verify the functionalities of the system. A thorough implementation methodology details are presented in the paper.

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1. INTRODUCTION

The current main concerns in telecom community now is increased demand for bandwidth to facilitate exchange of data with low latency. Transmitting signals using radio waves is widespread but it lacks security, reliability and scarce bandwidth [1, 2]. It may not be safe to use radios in hospitals, nuclear plant and airplanes [3, 4], and exposure to high doses of RF power for a prolonged period of time may not be healthy [5]. Visible light communication (VLC) technology uses data signals to modulate the light intensity of light emitting diodes (LEDs) [6] and RGB laser diodes (LDs) [7]. In the receiver side, photodiodes detect the fast variations of the emitted light signals [8, 9].

Recently, laser light that is used in the toys have attract the attention of kids since kids easily get attraction to something bright and colorful. Because of that, kids easily get bored when teacher or parents were too exposing them with education books in their early learning process. It is because most of the education books are not colorful and attractive which causing them to be not interested in learning. Hence, parents were trying in finding new medium for education that are bright and colorful to attract the attention of kids in their early learning process.

Apart from that, the implementation of laser light in toys still get strong obstruction from parents since the it can cause hazard to the eyes sight which it can affect the health of their children. Moreover, there are too many new cases involved laser light toys reported in the media social. Other extreme is mostly of the parents strongly believes that new technologies nowadays will only give more harmful than benefit if it is exposed to their children at a very early age. They thought that the kids will prefer to play rather than study if they are allowed to own devices of new technologies that are trending nowadays.

Laser Communication Device was developed in [10] for a smart communicating toy system which transmit text using photo resistors and laser diodes. Array is declared as a library in this system.

After received the user input, the message is simplified into each individual character and total length of it recorded at the transmitter part. Meanwhile at the receiver part, temporary array is created when it received laser input and compared it to the library of the array. The character corresponding to it was displayed. It is impemented using Arduino UNO, 5x5 Volt 6mm diameter laser diodes, acrylic tubing and photo resistor. However, it cannot produce the100% character accuracy because a few letters may get suck during the conversion from laser input to the array of letter.

Khalil Islam and Ibrahim Radwan [11] presented their smart toys system called Laser Fight Toys which based on the concept of a paintball game. Each of the players wore the T-Shirt that is connected to a Raspberry Pi, a light sensor and colour LEDs while the toy gun contained a laser transmitter. Each player has life points, which were marked with LEDs, and each time the player hit, the player will lost one life point by turning off one of the LEDs. If all points are lost the player was considered lost. In this system, Raspberry Pi 2 Model b, laser transmitter, light sensor im120710017, Wi-Fi dongle and mini metal speaker were implemented. With the implementation of Wi-Fi dongle, it enabled the receiver part of the system detect the signal from the laser transmitter even in a long distance between the players. However, this toys system cannot be used without the internet connection to run the program since it use Python Idle 3 that needs internet connection.

In the system proposed by Jr. D [12], Laser Gun Toy was presented by produce a “PeePeePeeuuw’ sound when triggered and a red laser associated with the sounds shot during the game. Laser transmitter and laser receiver were used to send and detect the red laser while mini metal speaker was used to produce “PeePeePeeuuw’ sound. However, this toy system was not equipped with Wi-Fi module. Hence, it cannot detect signal from other player within a long distance. This system also not offered any display unit to display the total number of shoots that have been made.

All the systems previously discussed do not include any display input into their systems. Display unit is important to display the data transmission that occurred between the transmitter and receiver part. Therefore, in the proposed system, a display unit will be added in order to observe and display the transmission of data between the laser modules.

2. RESEARCH METHOD

2.1. Project overview

The proposed system is a smart laser communication toys. It is a medium for educational purposes for kids. The basic idea of the device is kids can use it as a device to send a message to one another. Users will be sending message by switching on the device, which will pop up a on a TFT LCD Touchscreen. Users are free to choose whether they want to send or receive message by only pressing the button on the main screen of the TFT LCD Touchscreen. User can type the message or receive it in type of binary data which will be converted to letters before displayed it on the screen of the touchscreen. The basic design of the system is shown in Figure 1.

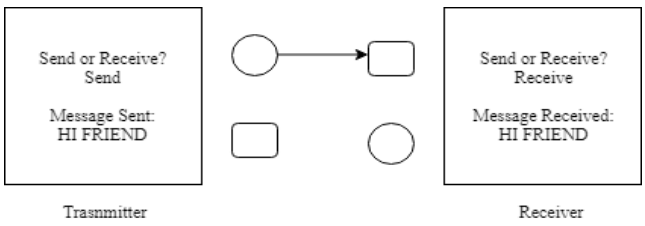

Figure 1. The basic design of the proposed system [13]

In the smart laser communicating toys, Arduino Mega ADK is the brain of the proposed system. The inputs of the system are receiver unit and input module. The receiver will receive the binary input from the transmitter while TFT LCD Touchscreen which acts as an input module enable the user to enter the input to be transmitted. The outputs of the proposed system are transmitter unit, display unit and buzzer. The transmitter send the message in a binary number. Moreover, display unit is used to display the output of the data and buzzer is used to produce the "buzz" sound each time the laser transmitter module of the sender send the data message to the laser receiver module of the receiver according to the binary code of each transmitted letter by producing the “buzz’ sound each time the binary code is 1 and not produce any “buzz” sound when the binary code is 0. Figure 2 shows the block diagram of the system.

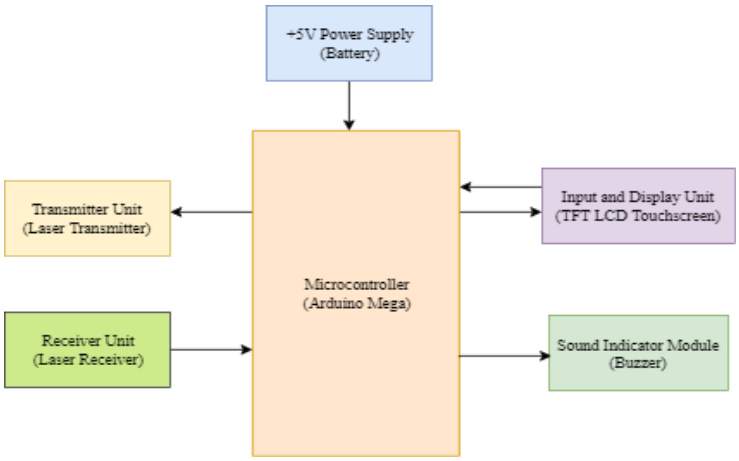

Figure 2. Block diagram of the system

2.2. Flowchart

The proposed flow of the smart laser communicating toys system is shown in Figure 3. The receiver will sense for any light signal detected, interpret the light switching and convert it into a representatve binary code and translate it to the respective ASCII code. Hence, build the alphabetical message character by character and display them on the LCD. Since the encoder and decoder uses asynchronous transmission, words are separated by spaces. Similar reverse pattern happens on the transmitter stream. The ASCII encoder uses a translation table, see figure 20, for the equivalent binary codewords received.

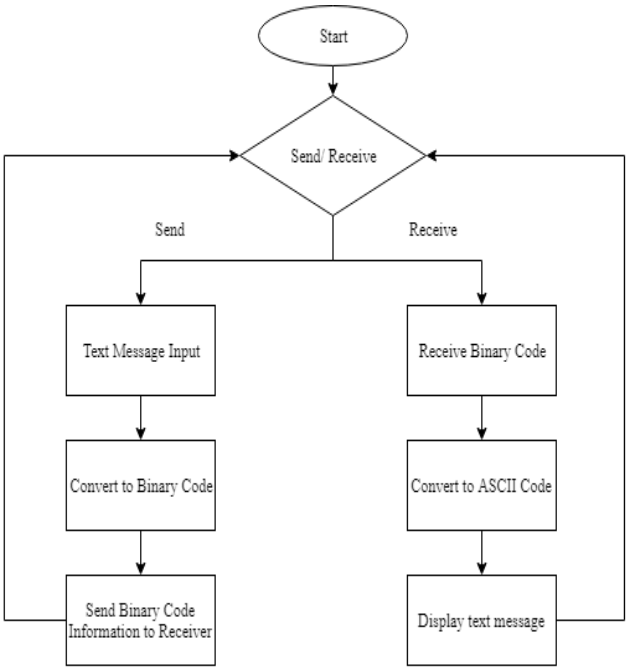

Figure 3. Flowchart of the proposed system [13]

2.3. Mechanical design

Figure 4 through Figure 7 show the isometric, side and back views of the system respectively. To maintain the fun, a beetle shaped casing was selected to encase the LCD, keypad, Arduino board and Transceiver hardware. The wings of the flying beetle opns up to access the LCD and keypad. It opens from the back for a smooth handling by the palm and easy typing on the keypad.

Figure 4. Isometric View 1

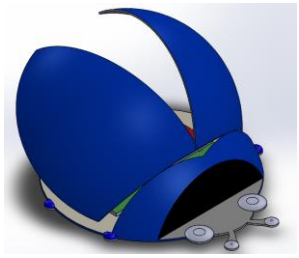

Figure 5. Isometric View 2

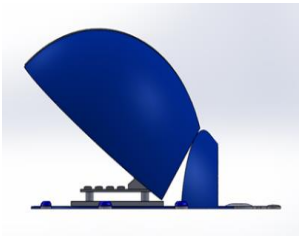

Figure 6. Side View

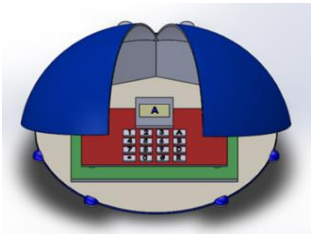

Figure 7. Back View

2.4. Hardware development

2.4.1. Transmitter system

Laser transmitter is used to communicate where it sends signal in terms of voltage. When the voltage is high, it is considered as 1 in binary, where the signal was presented. Vice versa, when the voltage is low, it is considered as 0 in binary so that the laser considers that there is no transmission of data. Hence, this laser transmitter module is programmed to send signal by transmitting a red laser light when binary is 1, and vice versa.

2.4.2. Receiver system

Laser receiver in this proposed system receives only high and low voltage which is 5V and 0V. There is no in between of them. When the receiver receives 5V of laser, the receiver reads it as 1 in binary whereas when the receiver does not detect any 5V in the time setup, it read as 0 in binary.

Hence, it is actually programmed to receive high volts as 1, and no volts as 0 so that the laser receiver in this proposed system was received 1 when there are red light transmitted to it, and reads 0 when it cannot detects any high volts in defined time. It receive the sequence of binary bits and converted it back to ASCII letters which are understandable to the users.

2.4.3. Input and display system

2.8” TFT LCD Touchscreen module is used in this system to enable the user to enter the input data and display the input data in the sender part and display the output data for the player in receiver part. Thus, it acts as both input and display module which makes this proposed system very convenient and flexible.

2.4.4. Sound system

Small Active Buzzer Alarm 5V Sounder Speaker Arduino PIC is programmed to produce the "buzz" sound each time the laser transmitter module of the sender send the binary data 1 to the laser receiver module of the receiver and any "buzz" sound was not being produced when it send binary data 0. This ‘buzz” sound enabled the player became alert to receive the data message during the transmission of data.

2.5. Software development

2.5.1. Arduino IDE

Arduino IDE is used as a platform used to write programs and uploaded them to Arduino expansion board interfaced to it. The board is programmed to read inputs from the transmitter where the library of ASCII is used in the coding to give output in binary number. A letter which consists of 8 bit binary codes was converted into 0s and 1s. Some fonts, variables and the libraries that are needed for the program were also defined.

In developing the program for this proposed system, Graphical User Interface or GUI is used since 2.8" TFT LCD Touchscreen used GUI concept to make it functioned as an input module which is a keyboard and as a display module to display the output data message. The x and y coordinates is setup for each character in the keyboard so that it detect and display the right character each time the user touch the touchscreen. Figure 8 shows x and y coordinates that is used to setup each character in the keyboard on a TFT LCD Touchscreen.

```
X = 539 Y = 679 Pressure = 415
(112, 229)
```

Figure 8. X and Y coordinates for each pressed letter

3. RESULTS AND ANALYSIS

3.1. Distance test

The sensor and transmitter was set within a certain distance defined to see the effectiveness of the module. The module is set within 1 cm distance, and it was worked. Then, the distance is increased by 1 cm until the sensor cannot sense any light transmission anymore. At the end of the testing process of the module, the product is then defined to be effective in the range of 10 Meter during the day 15 Meter during the night. This shows that there are less interference and noise that can interrupt the transmission of the signal during the night compared to during the day. Hence, it can be concluded that the laser receiver module can detect the signal in a longer distance during the night. Figure 9 and Figure 10 show the distance test during the day and night.

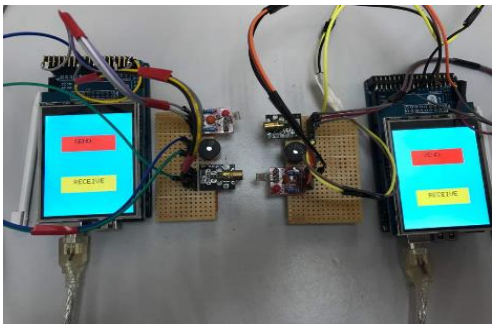

Figure 9. Distance Test during the day

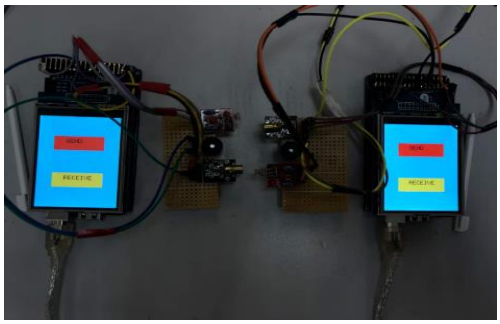

Figure 10. Distance Test during the night

3.2. Angle test

The sensor and transmitter was set within a certain distance angle defined to see the effectiveness of the laser receiver module to detect a red laser signal transmitted by the laser transmitter module. The distance is then increased by 1 cm to observe the limit of the angle between both pf laser modules until it cannot sense any light transmission anymore. At the end of this test, the product is defined to be effective at the angle of 180 degrees only when the distance between the modules is 1 m until 8 m and when the distance between the modules is 9 m until 11 m, it achieves the effectiveness at the angle from 177 degrees to 180 degrees only.

Meanwhile, for the distance between the modules of 12 m until 15 m, the product is then defined to be effective at the angle from 175 degrees to 180 degrees. It can be concluded that the increased of a distance between modules will increase the effective angle for laser receiver module to detect a red laser signal. Figure 11 and Table 1 show the angle test that have been done and the summary result of the angle test.

Table 1. Summary result of the angle test

Distance between modules (m)	Effective angle between modules (degrees)
1 m–8 m	0 degrees
9 m–11 m	0–3 degrees
12 m–15 m	0–5 degrees

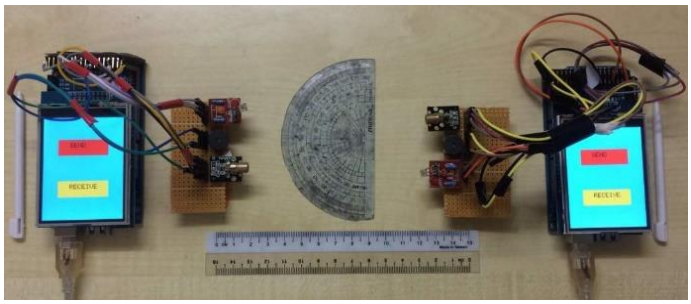

Figure 11. Angle test

3.3. Programme Test

The program test was done by using Arduino compiler where the ASCII codes is converted to the binary codes. The program asked whether the device is used for sending or receiving the data message. When the mode of control is selected, the message intended is send. The message is sent in ASCII format, which is the common language used for users. The message is then converted into 0s and 1s before being transmitted to the laser receiver module of the receiver. Then, the laser receiver module of the receiver was received the data message in 0s and 1s and converted it back into ASCII format.

Thus, when user in device A is send the data message to the second device such as letter 'A', the program converted the letter into binary, where 'A' is 065 in ASCII table making it 01000001 in binary code. The laser blinked one time and then blinked once more after some time. The touchscreen of device B receives 01000001 in binary code and the equivalent character for each binary code and displayed it. The program is tested and validated. Figure 12 to Figure 19 show the result of the programme test while Figure 20 shows the conversion table chart.

Figure 12. Main screen of the proposed system

Figure 13. The Keyboard page appeared when the user choose the SEND button

Figure 14. The blank page appeared when the user choose RECEIVE button

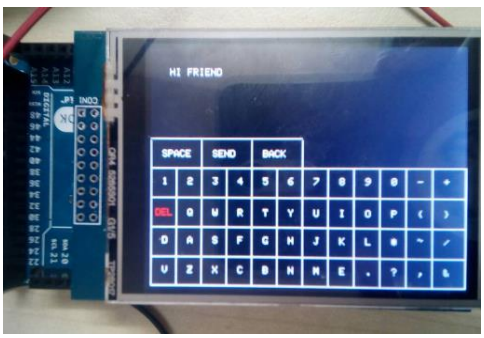

Figure 15. The sender entered the text message to be send to another player

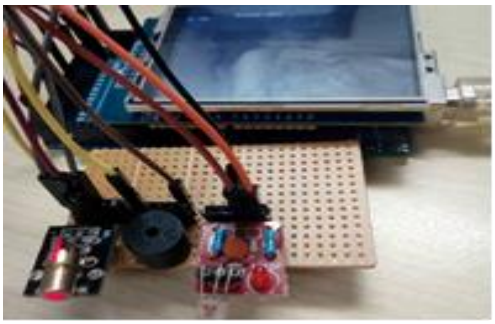

Figure 16. The laser transmitter module blinked

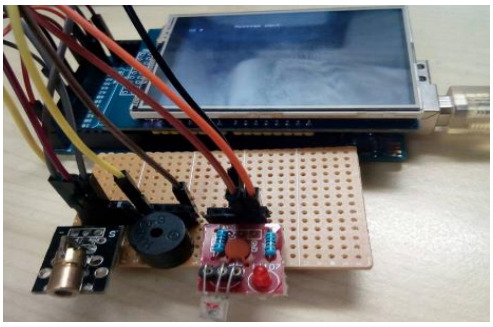

Figure 17. The laser transmitter module not blinked

Figure 18. The output message displayed at the screen of the sender

Figure 19. The output message displayed at the screen of the receiver

Dec	Hex	Oct	Bin	Char	Dec	Hex	Oct	Bin	Char	Dec	Hex	Oct	Bin	Char	Dec	Hex	Oct	Bin	Char
0	0x00	000	0000000	NUL	32	0x20	040	0100000	space	64	0x40	100	1000000	@	96	0x60	140	1100000	`
1	0x01	001	0000001	SOH	33	0x21	041	0100001	!	65	0x41	101	1000001	A	97	0x61	141	1100001	a
2	0x02	002	0000010	STX	34	0x22	042	0100010	"	66	0x42	102	1000010	B	98	0x62	142	1100010	b
3	0x03	003	0000011	ETX	35	0x23	043	0100011	#	67	0x43	103	1000011	C	99	0x63	143	1100011	c
4	0x04	004	0000100	EOT	36	0x24	044	0100100	$	68	0x44	104	1000100	D	100	0x64	144	1100100	d
5	0x05	005	0000101	ENQ	37	0x25	045	0100101	%	69	0x45	105	1000101	E	101	0x65	145	1100101	e
6	0x06	006	0000110	ACK	38	0x26	046	0100110	&	70	0x46	106	1000110	F	102	0x66	146	1100110	f
7	0x07	007	0000111	BEL	39	0x27	047	0100111	'	71	0x47	107	1000111	G	103	0x67	147	1100111	g
8	0x08	010	0001000	BS	40	0x28	050	0101000	(	72	0x48	110	1001000	H	104	0x68	150	1101000	h
9	0x09	011	0001001	TAB	41	0x29	051	0101001	)	73	0x49	111	1001001	I	105	0x69	151	1101001	i
10	0x0A	012	0001010	LF	42	0x2A	052	0101010	*	74	0x4A	112	1001010	J	106	0x6A	152	1101010	j
11	0x0B	013	0001011	VT	43	0x2B	053	0101011	+	75	0x4B	113	1001011	K	107	0x6B	153	1101011	k
12	0x0C	014	0001100	FF	44	0x2C	054	0101100	,	76	0x4C	114	1001100	L	108	0x6C	154	1101100	l
13	0x0D	015	0001101	CR	45	0x2D	055	0101101	-	77	0x4D	115	1001101	M	109	0x6D	155	1101101	m
14	0x0E	016	0001110	SO	46	0x2E	056	0101110	.	78	0x4E	116	1001110	N	110	0x6E	156	1101110	n
15	0x0F	017	0001111	SI	47	0x2F	057	0101111	/	79	0x4F	117	1001111	O	111	0x6F	157	1101111	o
16	0x10	020	0010000	DLE	48	0x30	060	0110000	0	80	0x50	120	1010000	P	112	0x70	160	1110000	p
17	0x11	021	0010001	DC1	49	0x31	061	0110001	1	81	0x51	121	1010001	Q	113	0x71	161	1110001	q
18	0x12	022	0010010	DC2	50	0x32	062	0110010	2	82	0x52	122	1010010	R	114	0x72	162	1110010	r
19	0x13	023	0010011	DC3	51	0x33	063	0110011	3	83	0x53	123	1010011	S	115	0x73	163	1110011	s
20	0x14	024	0010100	DC4	52	0x34	064	0110100	4	84	0x54	124	1010100	T	116	0x74	164	1110100	t
21	0x15	025	0010101	NAK	53	0x35	065	0110101	5	85	0x55	125	1010101	U	117	0x75	165	1110101	u
22	0x16	026	0010110	SYN	54	0x36	066	0110110	6	86	0x56	126	1010110	V	118	0x76	166	1110110	v
23	0x17	027	0010111	ETB	55	0x37	067	0110111	7	87	0x57	127	1010111	W	119	0x77	167	1110111	w
24	0x18	030	0011000	CAN	56	0x38	070	0111000	8	88	0x58	130	1011000	X	120	0x78	170	1111000	x
25	0x19	031	0011001	EM	57	0x39	071	0111001	9	89	0x59	131	1011001	Y	121	0x79	171	1111001	y
26	0x1A	032	0011010	SUB	58	0x3A	072	0111010	:	90	0x5A	132	1011010	Z	122	0x7A	172	1111010	z
27	0x1B	033	0011011	ESC	59	0x3B	073	0111011	;	91	0x5B	133	1011011	[	123	0x7B	173	1111011	{
28	0x1C	034	0011100	FS	60	0x3C	074	0111100	<	92	0x5C	134	1011100	\	124	0x7C	174	1111100	|
29	0x1D	035	0011101	GS	61	0x3D	075	0111101	=	93	0x5D	135	1011101	]	125	0x7D	175	1111101	}
30	0x1E	036	0011110	RS	62	0x3E	076	0111110	>	94	0x5E	136	1011110	^	126	0x7E	176	1111110	~
31	0x1F	037	0011111	US	63	0x3F	077	0111111	?	95	0x5F	137	1011111	_	127	0x7F	177	1111111	DEL

Figure 20. Conversion table chart [14-15]

3.4. Analysis result of the programme test

At the beginning of the system, the users were asked to choose whether to send or receive the data. One player has to send the data while another player has to receive the data. After both players choose the transmission mode, the keyboard page appeared on the screen of the sender while the blank page appeared on the screen of the receiver ready to receive the message. The sender entered the input message which is in ASCII code. Referred to the above test, the sender send message “HI FRIEND”. During this test, the message that have been sent and the number of total bits appeared on the serial monitor of the sender. The total number of bits of message sent were 9 bits. Space in the message sent is also counted as 1 bit. For each letter, the binary code for the corresponding of each letter is appeared. The letter was sent bit by bit.

Reference to the above programme test, 'H' in binary code was 01001000 and 'I' in binary code was 01001001. Hence, the laser transmitter sent the binary code of the letter 'H' first followed by the letter 'I' and others. Each time the binary code is 1, the laser transmitter blinked to show that it was a high voltage which was 1 and vice versa. After the sender pressed the send button on the keyboard, the ASCII code is converted to the binary code and sent to the receiver. The laser receiver module of the receiver receives the binary code for each letter and converted it back to the ASCII code. Then, the output message was displayed on the screen of the receiver.

During this test, the binary code for each letter that has been read by a laser receiver module displayed on the serial monitor of the receiver. When it do not receive any letter, it read it as a 0 which was a low voltage. After the full output message is displayed on the screen of the receiver, the system is looped back to the main page for the both devices which required both players to choose the transmission mode again. Figure 21 and Figure 22 show the serial monttor for both sender and receiver part.

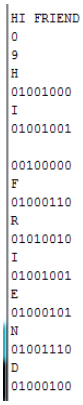

Figure 21. Serial monitor of transmitter

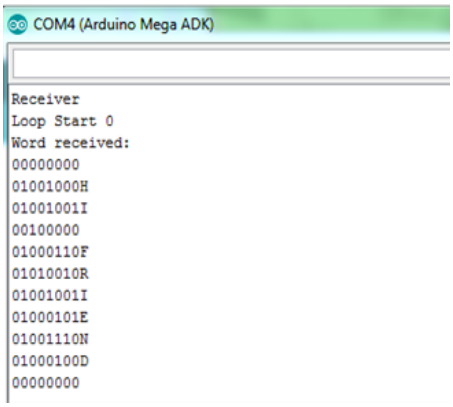

Figure 22. Serial monitor of receiver

3.5. Final product

Figure 23 and Figure 24 illustrates the overall design of the smart laser communicating toys system. The beetle shaped casing hides all the hardware wiring and peripherals inside. We have experimented with several casings. However, the beetle had shaped casing had an attaractive appeal for children. Several colours can be selected.

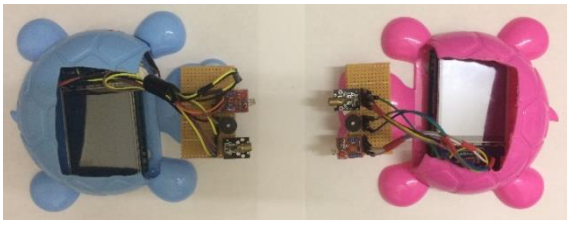

Figure 23. Top view final product of the system

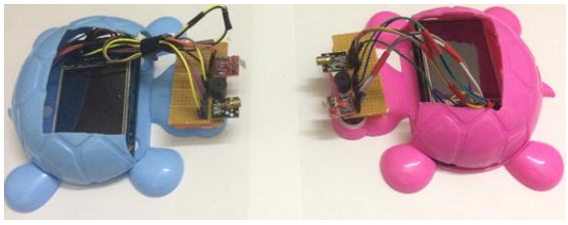

Figure 24. Side view final product of the system

4. CONCLUSION

This project proposed a design of smart laser communicating toys using Arduino Mega ADK and equipped with laser modules that can send and receive the data message to and from each others. Testing of the system to verify the functionality of the system has also been conducted in addition to several system testing. With more enhancements in a future, this smart laser communicating toys can be a very useful system for kids for as a platform for the development of their brain and cognitive skills during their childhood. The future work is to integrate further features into the toy to make it commercially viable and more fun for kids including a remote control module from a smart phone.

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