Development of Remote Control Dongle Connecting to Smartphone

Sang-Bong Byun, Young-Hyung Kim, and Yong-Hwan Lee

***Abstract*—Recently various consumer electronic devices can be controlled by remote controls. Usually home appliances such as TV, radio, Blu-ray players, home theater, air conditioner, and room lighting come with remote controls that are used to select items and change status. As a result, users need to get familiar with the different features and the operations of many remote controls. For some manufacturers, they want to build these remote controls into one dongle with smartphone. In this paper, we develop remote control dongle to connect smartphones. Signals generated by the application are converted to the PCM signals through the earphone jack of smartphone. In addition we develop user-friendly mobile apps as an interface to users.**

***Index Terms*—Smartphone, earphone jack, remote control, ir.**

I. Introduction

Usually home appliances such as TV, radio, video/audio players, home theater, air conditioner, and room lighting come with remote controls that are used to select items and change status. As a result, people keep many remote controls to interact with their home devices. In addition, each control has different look and feel and functions assigned to buttons. This configuration gives the user difficulty in browsing information and finding a correct button. Sometimes the user needs to press a button repeatedly to set the volume and TV channel[1]. Various remote controls are shown in Fig. 1.

Fig. 1. Various remote controls.

Nowadays, the number of appliances that provide multi services or complex functions increases more and more. As a result, users need to get familiar with the different features and the operations of many remote controls. For some manufacturers, they have built these remote controls into one controller, which is called universal remote control. Sometimes, such universal remote control comes up with numerous buttons, but one button corresponds into one function [2].

In this paper, we develop an infrared transmitter to control various devices via the earphone jack of smartphones. According to the status of the button of smartphone app, smartphone transmits the data via the earphone jack to remote control dongle and the dongle emits suitable IR signals to control appliances. Smartphone with dongle is shown in Fig. 2.

Fig. 2. Smartphones with dongle.

II. Architecture of Hardware

A. H/W Requirements

Smart remote control should be equipped with a battery because high current is needed for compatibility, output distance, output directional and repeat key. This device also should be compatible with all models of iPhone and Android smartphone and should support Bluetooth 4.0 [3] using external key. That needs over 20 byte data for air conditioning

B. H/W Design

Smart remote control requires a chip for analyzing earphone jack signal and supporting Bluetooth 4.0. This chip should consume low power so that coin battery can be used. Coin battery specifications are shown in Fig. 3.

CR2016 or CR1616 batteries were selected in considerations of the size and design.

C. Dongle

The CC2540 is a cost-effective, low-power, true

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system-on-chip (SoC) for Bluetooth low energy applications. It enables robust BLE master or slave nodes to be built with very low total bill-of-material costs. The CC2540 combines an excellent RF transceiver with an industry-standard enhanced 8051 MCU, in-system programmable flash memory, 8-KB RAM, and many other powerful supporting features and peripherals. The CC2540 is suitable for systems where very low power consumption is required. Very low-power sleep modes are available. Short transition times between operating modes further enable low power consumption [4]. Block diagram of CC2540 is shown in Fig. 4.

(Model)	(No minal Voltage)	(Nominal capacity)	Dimensions (mm)		Load Standard	Discharge Time	High-drain	ContinuousLow	(Weight)
			Diameter	Height			PuIse (mA)	Drain (uA)	
CR816	3.0	8	8	1.6	15	38	3	1	0.25
CR927	3.0	30	9.5	2.7	15	135	3	1	0.6
CR1025	3.0	30	10	2.5	15	142	3	1	0.6
CR1130	3.0	48	11.6	3.0	6.8	105	3	1	0.6
CR1212	3.0	18	12.5	1.2	15	92	3	1	0.25
CR1216	3.0	25	12.5	1.6	30	200	3	1	0.7
CR1220	3.0	40	12.5	2.0	3	7.5	3	1	0.85
CR1225	3.0	48	12.5	2.5	15	310	5	1	1.3
CR1616	3.0	50	16.0	1.6	3	46	5	1	1.2
CR1620	3.0	70	16.0	2.0	330	68	5	1	1.2
CR1625	3.0	90	16.0	2.5	22	780	5	1	1.4
CR1632	3.0	120	16.0	3.2	22	950	5	1	1.6
CR2016	3.0	75	20.0	1.6	3	75	5	1	1.8
CR2025	3.0	140	20.0	2.5	2	95	5	1	2.1
CR2032	3.0	210	20.0	3.2	3	215	5	1	2.4
CR2320	3.0	175	23.0	2.0	15	875	5	1	3
CR2330	3.0	250	23.0	3.0	3	310	5	1	4
CR2354	3.0	490	23.0	5.54	350	485	5	1	6
CR2430	3.0	275	24.5	3.0	3	270	5	1	4.5
CR3032	3.0	520	30.0	3.2	350	510	5	1	8
CR2450	3.0	540	24.5	5.0	3	530	5	1	6.5
CR2477	3.0	1050	24.5	7.7	3				

Fig. 3. Coin battery specifications.

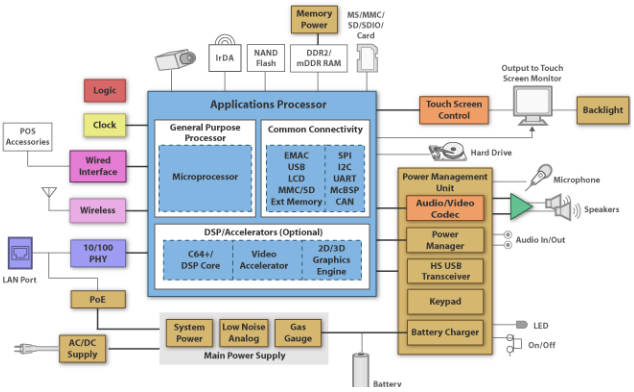

Fig. 4. Block diagram of CC2540.

Comparator needs low-power and low-voltage operation for earphone jack compatibility. That uses quiescent current below 1uA and operating voltage below 1.8V ~ 3.3V. Comparator that meets the above conditions is AS1977. Block diagram of AS1977 is shown in Fig. 5.

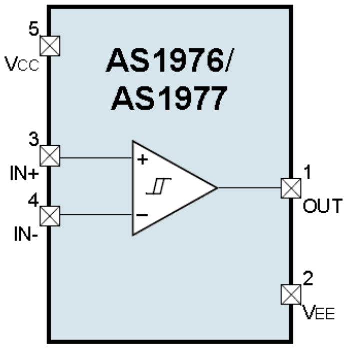

Fig. 5. Block diagram of AS1977.

D. Earphone Jack

Data transfer is set up via the earphone jack. Then the data is transmitted via the microphone jack on the earphone jack. Depth map that is transmitted via the earphone jack is displayed to the screen of the smartphone. Fig. 6 shows the earphone jack jacks which can be used to transmit and receive the data [5]. Earphone jack jacks which can be used to transmit and receive the data are shown in Fig. 6.

Fig. 6. Earphone jack connectors.

III. Analysis of the Signal Characteristics of Each Models

A. Samsung Galaxy S4

The signal of Samsung Galaxy S4 is shown in Fig. 7.

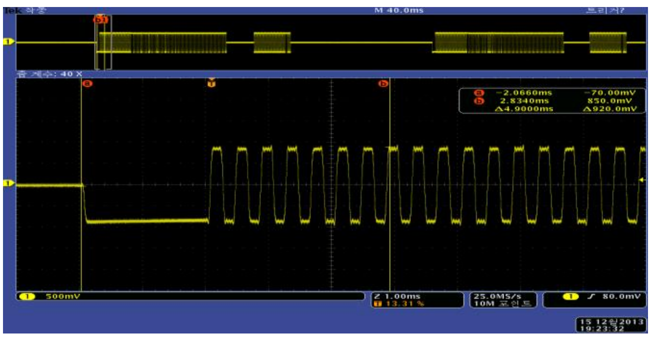

Fig. 7. Signal of Samsung Galaxy S4

The signal characteristic of Samsung Galaxy S4 is shown in Table I.

TABLE I: THE SIGNAL CHARACTERISTIC OF SAMSUNG GALAXY S4

Ingredients	Result
Output Voltage	±0.9V(With fiducially to ground)
Initial low value	0.2ms
Rising time	100us
Falling time	100us

B. LG Optimus

The signal of LG Optimus is shown in Fig. 8.

The signal characteristic of LG Optimus is shown in Table II.

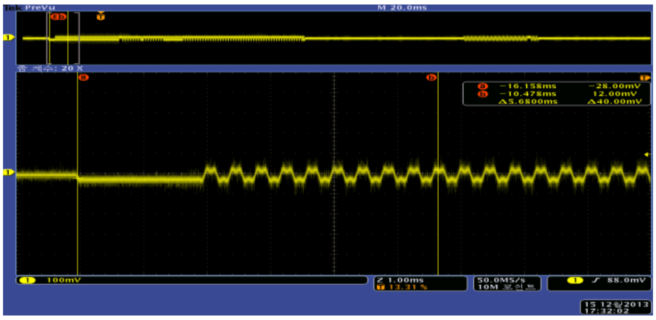

Fig. 8. Signal of LG Optimus.

TABLE II: THE SIGNAL CHARACTERISTIC OF LG OPTIMUS

Ingredients	Result
Output Voltage	±0.04V(With fiducially to ground)
Initial low value	0.2ms
Rising time	100us
Falling time	100us

C. *Pantech Vega Racer*

The signal of Pantech Vega Racer is shown in Fig. 9.

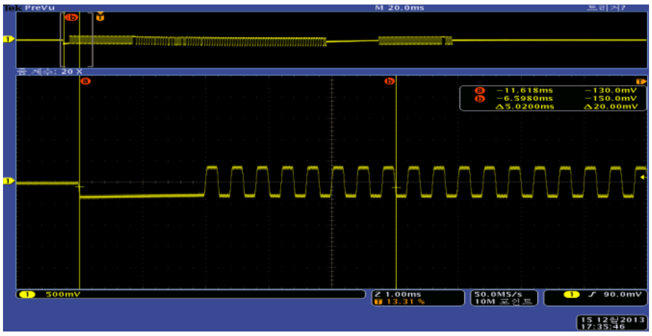

Fig. 9. Signal of Pantech Vega Racer.

The signal characteristic of Pantech Vega Racer is shown in Table III.

TABLE III: THE SIGNAL CHARACTERISTIC OF PANTECH VEGA RACER

Ingredients	Result
Output Voltage	±0.7V ~ ±1.4V (With fiducially to ground)
Initial low value	7.6ms
Output Delay	20ms
Rising time	150us
Falling time	150us

D. *Apple iPhone 5*

The signal of Apple iPhone 5 is shown in Fig. 10.

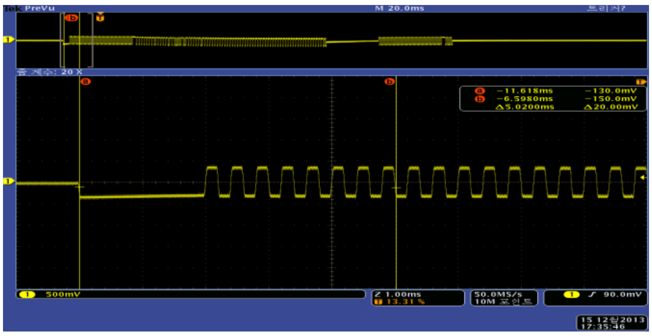

Fig. 10. Signal of Apple iPhone 5.

The signal characteristic of Apple iPhone 5 is shown in Table IV.

TABLE IV: THE SIGNAL CHARACTERISTIC OF APPLE IPHONE 5

Ingredients	Result
Output Voltage	±0.7V ~ ±1.4V (With fiducially to ground)
Initial low value	7.6ms
Output Delay	20ms
Rising time	100us
Falling time	100us

E. *Dell*

The signal of Dell is shown in Fig. 11.

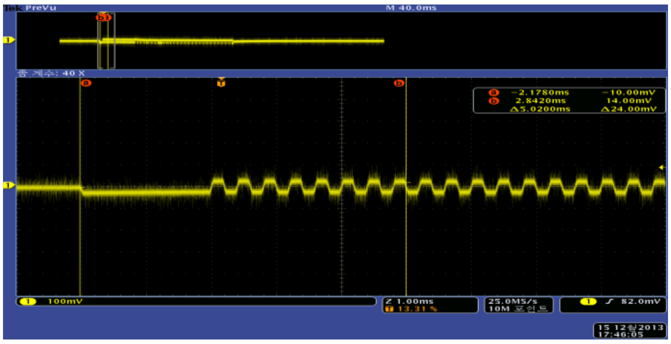

Fig. 11. Signal of Dell.

The signal characteristic of Dell is shown in Table V.

TABLE V: THE SIGNAL CHARACTERISTIC OF DELL

Ingredients	Result
Output Voltage	±0.04V (With fiducially to ground)
Initial low value	2ms
Rising time	150us
Falling time	150us

F. *HTC*

The signal of HTC is shown in Fig. 12.

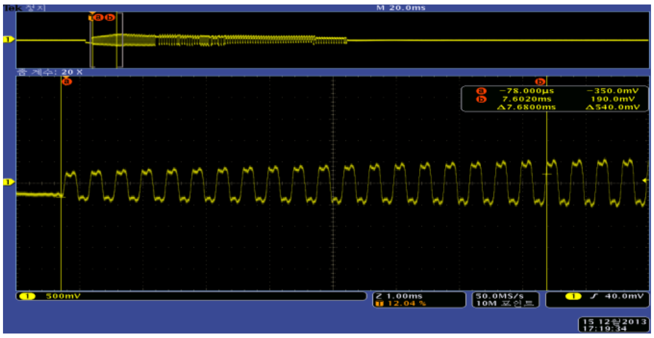

Fig. 12. Signal of HTC.

The signal characteristic of HTC is shown in Table VI.

TABLE VI: THE SIGNAL CHARACTERISTIC OF HTC

Ingredients	Result
Output Voltage	±0.25V ~ ±0.5V (With fiducially to ground)
Initial low value	8.4ms
Rising time	50us
Falling time	50us

G. *Motorola*

The signal of Motorola is shown in Fig. 13.

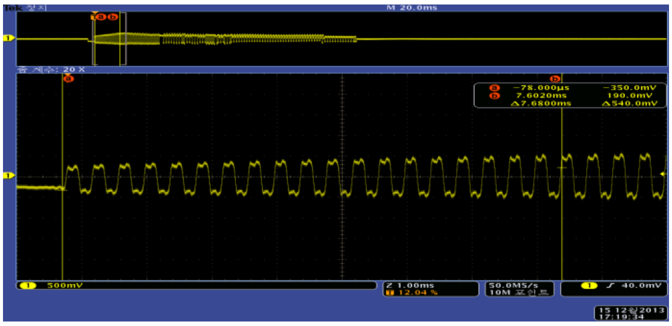

Fig. 13. Signal of Motorola.

The signal characteristic of Motorola is shown in Table VII.

TABLE VII: THE SIGNAL CHARACTERISTIC OF DELL

Ingredients	Result
Output Voltage	-1V ~ 1.2V (With fiducially to ground)
Initial low value	8ms
Rising time	20us
Falling time	20us

H. *Result Analysis*

The results were analyzed on the basis of signal measurements. The results analysis of each models is shown in Table VIII.

TABLE VIII: RESULTS ANALYSIS OF EACH MODELS

Ingredients	Result
Frequency	Input frequency : 20kHz Output deviation : ±5% Output delay : 8.4ms ~ 20ms(iPhone, HTC, Motorola) **Required at least 20ms for output stabilization time.**
Voltage	P-P(peak-peak) voltage : 0.04V~1.2V **Required amplifier or comparator for using communication signal.**
Rising, falling time	Rising, Falling time : 20us ~ 150us **The time constant required to satisfy all conditions.**

IV. PROTOCOL DESIGN

Signal generated by the application are converted to the PCM signal through the earphone jack of smartphone. That defines the minimum and maximum values that can be output to the earphone. The PCM data specification is shown in Table IX.

TABLE IX: PCM DATA SPECIFICATION

Sampling rate	16kHz
PCM properties	8bit mono(1byte/sample)
Sampling rate/sec	16,000(16/1ms)
Sec/Sampling	1/16,000 = 0.0000625 = 62.5us

The minimum unit of the signal waveform is 500us. It means that the 500us required to transmit 1 bit. The signal of sampling data is shown in Fig. 14.

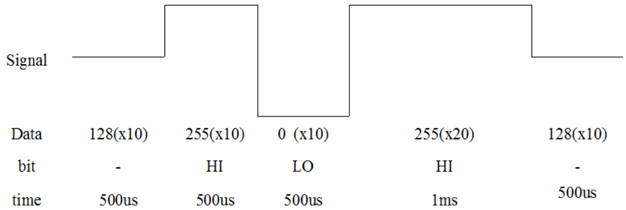

Fig. 14. Signal of sampling data.

The types of the basic waveform are three. After pressing the remote control button, the data signal starts. The end signal is output when you release the button. The hardware should assume that the user is holding down the button until the end signal is transmitted. The basic signal of PCM is shown in Fig. 15.

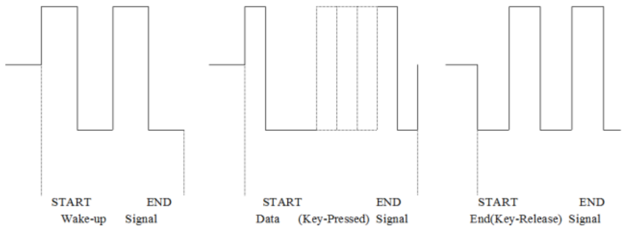

Fig. 15. Basic signal of PCM.

V. USER INTERFACE FOR SMARTPHONE APP

User interface was designed to simplify the buttons for easy use of the user. It is possible to control nine device. The user interface of smartphone app is shown in Fig. 16.

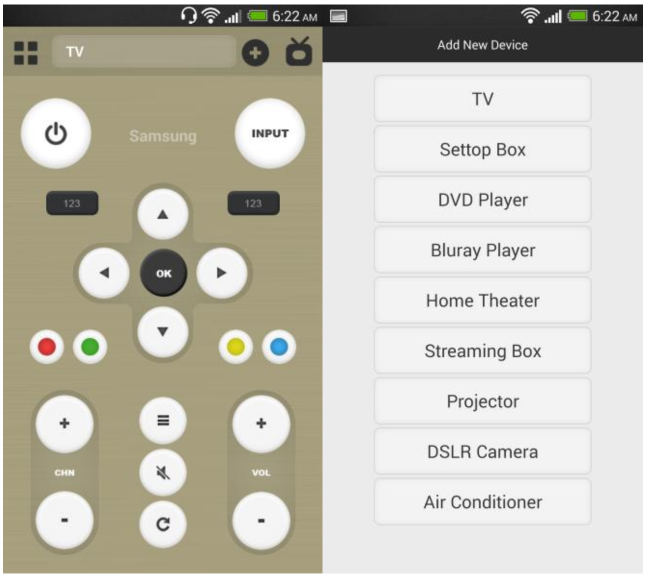

Fig. 16. User interface of smartphone App.

It was developed for both Android and iOS apps. The UIs of both apps are the same.

VI. HARDWARE DESIGN

Case is made from plastic material. The front case was equipped with eight keys. The back case was equipped with hole and cap for coin battery. In the top of the case an infrared transmitter was built. In the bottom of the case an earphone jack was equipped. The case is shown in Fig. 17.

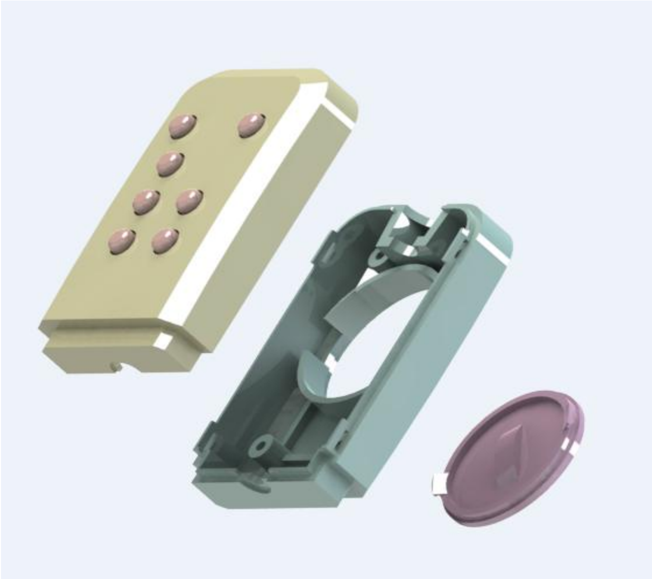

Fig. 17. Case design.

Development board was designed for the functional verification. Development board and prototype board are shown in Fig. 18 and Fig. 19.

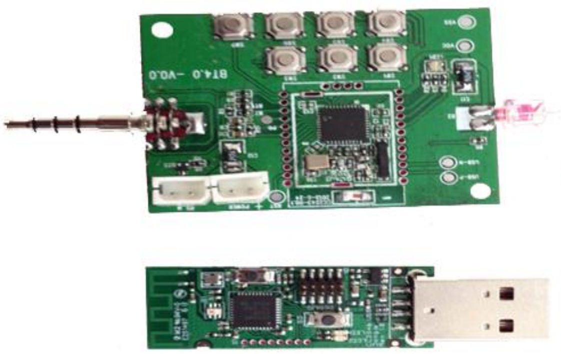

Fig. 18. Development board.

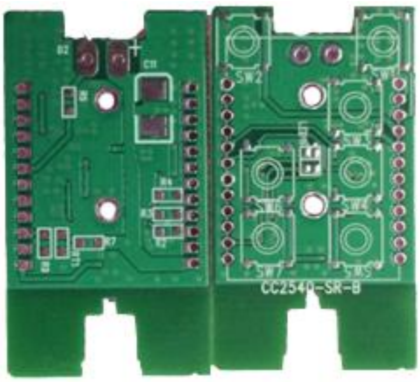

Fig. 19. Prototype board.

VII. Conclusion

We designed an infrared transmitter for various devices controlling via smartphone earphone jack. The analysis of the PCM signal from various manufacturers of smartphones was performed. We have designed a protocol to meet the PCM signals of different specification. We also designed the PCB board and the case for functional verification. The smartphone app is developed to control the board. It is possible to control up to eight devices in a single app. Therefore this smart remote control dongle can control various devices by using the smartphone without use of multiple remote control.

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