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Development of the Customized User Interface of Digital Audio System in a Smart Home

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Abstract

Most significantly, user customized control for a sound of digital audio in a smart home must be able to adjust many environmental contexts simultaneously. A sound is affected by a temperature, humidity, and atmospheric pressure. And user must tune the sound of digital audio every time according to environmental contexts. In this paper, we developed a customized user interface for a remote control of digital audio in a smart home according to the environmental contexts. The kinds of input environmental contexts are a temperature, humidity, location, weather, and atmospheric pressure. It creates an experience especially for a user of digital audio sound, allowing the user to interact with the control for digital audio operation in a natural and intuitive way.

***Keywords**: Band Pass Filter**,** Equalization, Digital Audio System, Mobile Application, Remote Control, Graphic Equalizer*

1. Introduction

A smart home is the use and control of home appliances remotely or automatically. Early home automation began with labour-saving machines like washing machines. Some home automation appliances are stand alone and do not communicate, such as a programmable light switch, while others are part of the internet of things and are networked for remote control and data transfer. Hardware devices can include sensors (like cameras and thermometers), controllers, actuators (to do things), and communication systems. Remote control can range from a simple remote control to a smartphone with Bluetooth, to a computer on the other side of the world connected by internet. Owing to the digital audio processing technologies developed, the digital audio systems can provide for higher-quality sounds than their analogue counterparts in terms of signal vs. noise ratio as well as the signal distortions. Furthermore, the audio systems equipped with a digital audio processor can easily process the digital signals via their software [1-8]. However, a sound of digital audio is affected by various environmental contexts. And a user must tune the sound volume every time. In a smart home, the sensors are installed such as a temperature, humidity, and *etc.* As a result, the environmental contexts could be obtained by sensors easily. And a user could tune the best sound of digital audio. In this paper, we developed a customized control of digital audio for a user. That user customized control for the sound of digital audio in a smart home must be able to consider many contexts simultaneously. The input contexts are a temperature, humidity, location, weather, and atmospheric pressure. It creates an experience especially for a user of digital audio sound, allowing the user to interact with the control for digital audio operation in a natural and intuitive way.

The organization of this paper is as follows. Section 2 describes the related works and Section 3 explains the system structure of digital audio system with the equalizer and customized user interface for remote control on android. Finally, conclusions and future research presented in Section 4.

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2. Related Works

2.1. Environmental Contexts

A. Temperature

- A sound is affected by a temperature and the variance of the sound is depended on the following formula (1)
- $V = 331.5 + 0.6t$ (1)

Table 1. Maximum Point of a Sound

Distance	Temperature	Maximum point	500Hz	700Hz	1000Hz	1500Hz
50cm	15.5 ℃	32cm	31.8cm	30.7cm	28.7cm	26.2cm
	24.3 ℃	32cm	31.3cm	28.5cm	25.5cm	21.9cm
75cm	15.5 ℃	48cm	45.2cm	43.5cm	40.5cm	38.8cm
	2.3 ℃	48cm	42.5cm	39.5cm	37cm	31cm

B. Humidity

The high density of humidity makes the loud sound. The Figure 1 and Figure 2 show a ratio of sound according to both the humidity 25% and 40%.

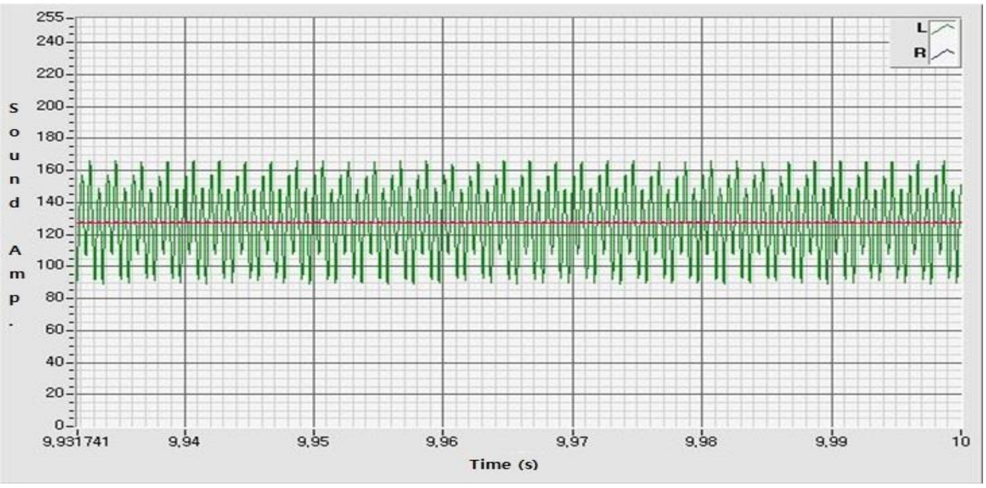

Figure 1. Frequency of a Sound at Humidity 25%

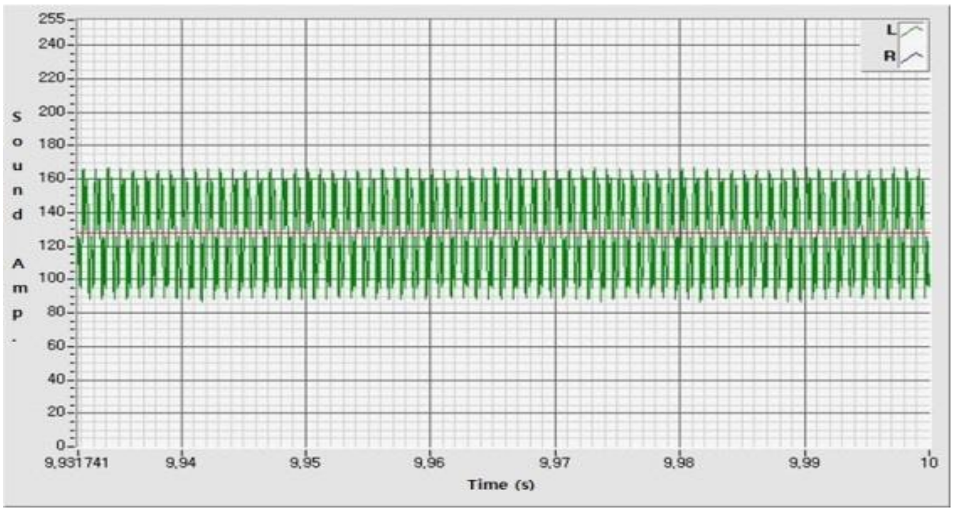

Figure 2. Frequency of a Sound at Humidity 40%

C. Pressure

The increasing of pressure makes the lessened sound due to amplitude decreasing. Figure 4 shows a ratio of sound according to pressure.

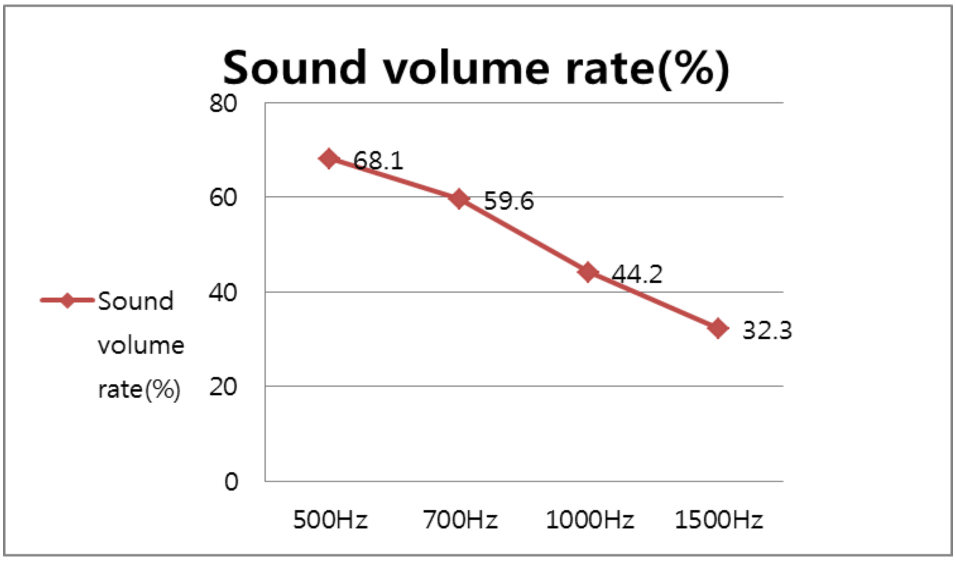

Figure 3. Ratio of Sound

2.2. IoT (Internet of Things)

The Internet of Things (IoT) is the network of physical objects—devices, vehicles, buildings and other items—embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data. The IoT allows objects to be sensed and controlled remotely across existing network infrastructure creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit when IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical systems, which also encompasses technologies such as smart grids, smart homes, intelligent transportation and smart cities. Each thing is uniquely identifiable through its embedded computing system but is able to interoperate within the existing Internet infrastructure. Experts estimate that the IoT will consist of almost 50 billion objects by 2020[9].

3. Development of Customized User Interface for Remote Control

3.1 System Structure

A digital audio system is composed of two parts. The one is hardware and the other is software part. The hardware system has the functions; 1) input: 4 channels which are the analog inputs and 4 channels which are the digital inputs using AES/EBU simultaneous; 2) output: 8 channels according to setting value of a DSP. The software has the functions; 1) sound processing: Cross-over, EQ (Equalizer), Delay, and Limiter; 2) applications for controlling the audio system. The following Figure 4 shows the system structure of the digital audio system.

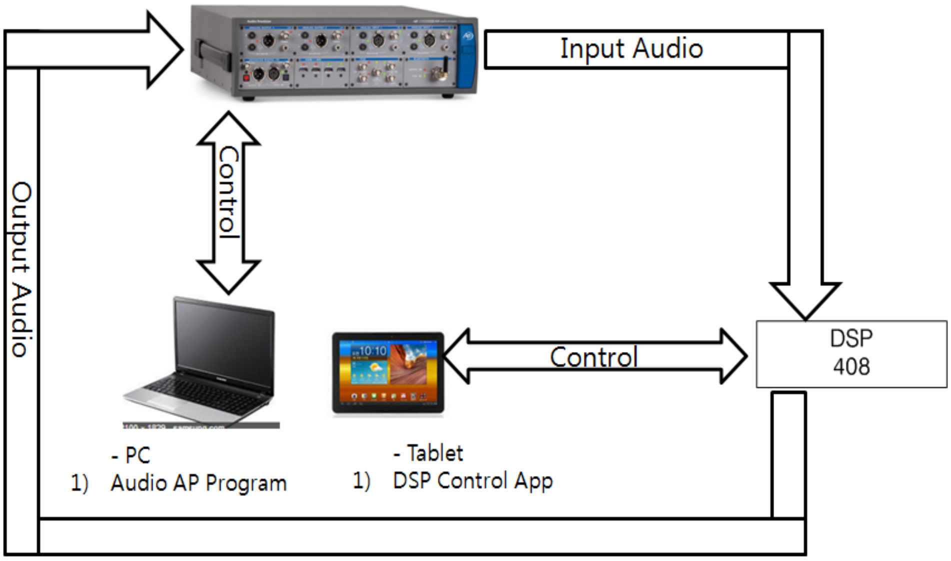

Figure 4. System Structure

The block diagram of the hardware for the DSP-based digital audio system is shown in Figure 4. The inputs are 4 analogue balanced channels and another 4 AES/EBU balanced ones, while the outputs are 8 analogue balanced channels. The analogue signals input from outside will pass through the ADC (Analogue to Digital Converter) to be output as digital ones at 96KHz sample rate, and the digital input part is designed so that it could use the AES/EBU receiver with the SRC (Sample Rate Converter) built-in to process most of the digital signals at the sample rate that are used currently. At FPGA, the input/output signals will be laid out again with the delay function processed, while the rest of the functions will be processed by DSP. A user customized control for the sound of digital audio in a smart home must be able to consider many environmental contexts simultaneously. The environmental contexts are a temperature, humidity, and atmospheric pressure. And user must tune the sound of digital audio every time. Figure 5 shows block diagram of digital audio system.

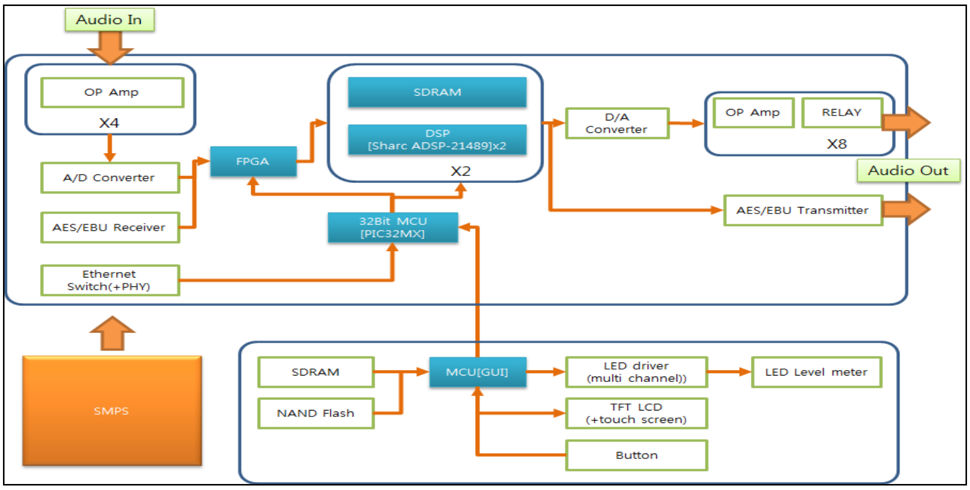

Figure 5. Hardware Structure

3.2. FIR Filter

In the audio processing, the Filter acts to cut out, amplify or attenuate the sounds of certain frequencies. FIR filter does not use the regressed output values to be implemented. Unlike the IIR filter, it has the same typology between its input and output signals. However, if it wants to implement the same attributes as those of IIR filter, it will need more operation time than IIR filter, while it may be delayed in its operation process. We implemented the FIR filter as following:

```
void dsp_filter_calc_fir(float *coef_buf, unsigned short fir_tab, float freq_l, float freq_h, float gain, float att)
{
        //int Np = (fir_tab-1)/2;
        unsigned short Np = (fir_tab-1)/2;
        float Alpha;
        int j;
        float Inoalpha;
        float A[DSP_FIR_COEF_SIZE_MAX];
        //The two band-edge frequencies, Fa and Fb, determine the shape of the sinc function impulse response of the ideal filter.
        //This sinc function may be calculated analytically. The formulae for this impulse response is:
        A[0] = (float)(2*((float)freq_h-(float)freq_l)/(float)SS_SAMPLE_FREQ);

        for(j=1 ; j <= Np ; j++) {
                A[j] = (sinf(2*j*PI*freq_h/SS_SAMPLE_FREQ)-sinf(2*j*PI*freq_l/SS_SAMPLE_FREQ))/(j*PI);
                }
        if (att<21) {
                Alpha = 0;
                }
        else if(att>50) {
                Alpha = 0.1102*(att-8.7);
                }
        else {
                Alpha = 0.5842*powf((att-21),0.4)+0.07886*(att-21);
```

```
                }
        Inoalpha = Ino(Alpha);

        for (j=0 ; j <= Np; j++) {
                coef_buf[Np+j]        =        A[j]*Ino(Alpha*sqrtf((float)1.0-
((float)j*(float)j/((float)Np*(float)Np))))/Inoalpha;
                }
        for (j=0 ; j < Np; j++) {
                coef_buf[j] = coef_buf[fir_tab-1-j];
                }
        for(j = fir_tab ; j < DSP_FIR_COEF_SIZE_MAX ; j++) {
                // fill with 0
                coef_buf[j] = 0;
                }
}
```

The filters using the FIR one are Hanning, Hamming, Blackman, Kaiser-Bessel, and so on. This paper implemented the Kaiser-Bessel filter excellent in view of Ripple and stopband attenuation compared with other filters. Figure 6 shows the result of a frequency response that is generated by above code.

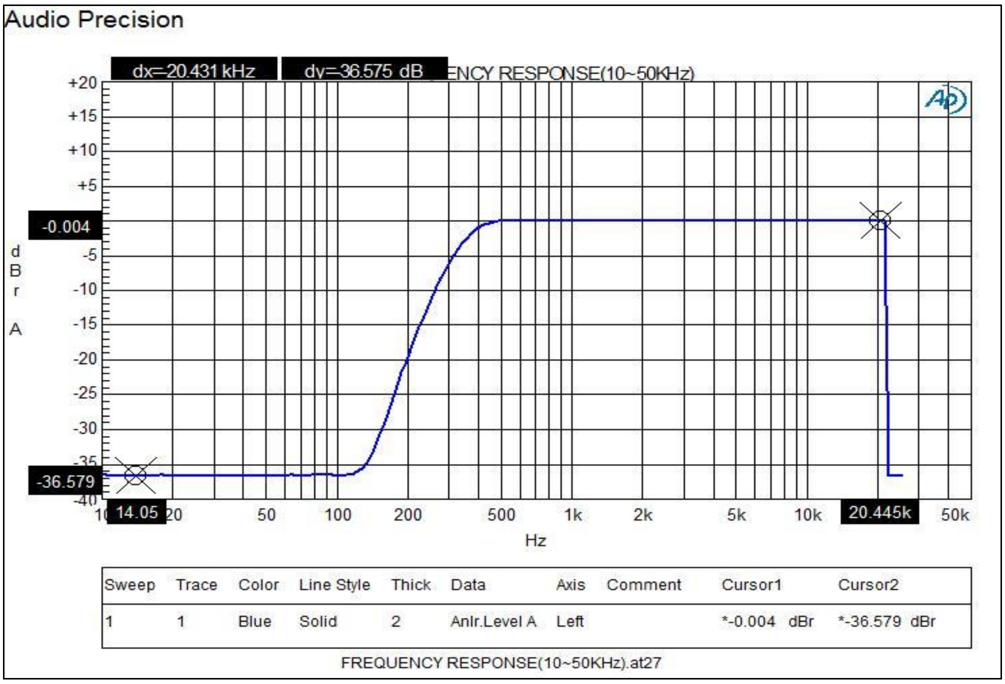

Figure 6. Result of the Frequency Response

3.3. Customized Control

The following Figure 7 shows the result of customized user control according to a temperature, humidity, pressure, weather and *etc.* for the development of the system, JAVA language was used, while the mobile application program could be activated in the Android environment.

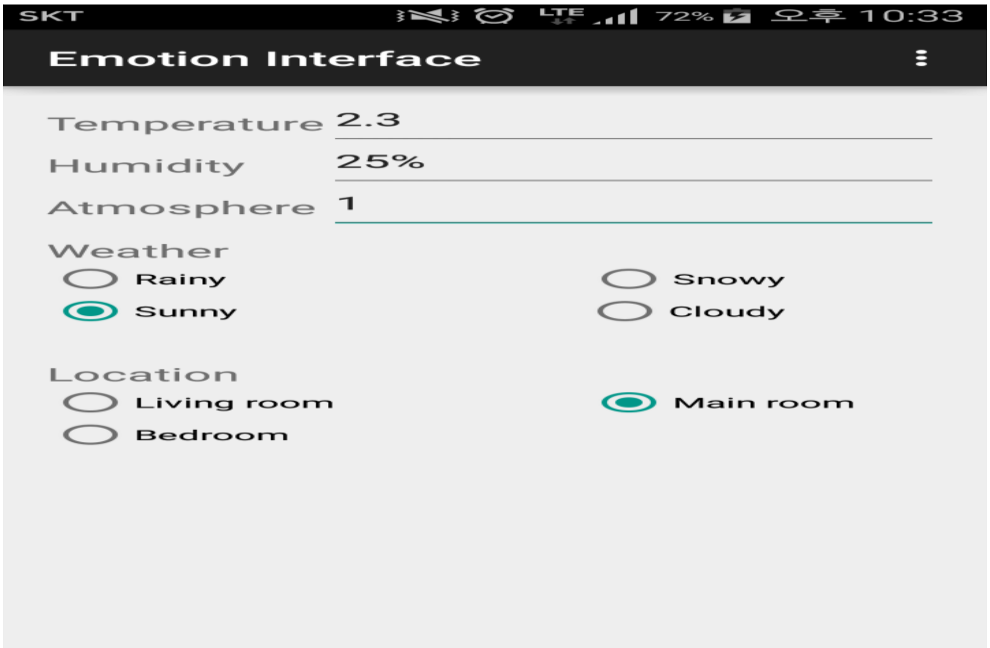

Figure 7. Result of Customized User Interface

4. Conclusions and Future Work

The audio systems equipped with a digital audio processor can easily process the digital signals via their software. However, a sound of digital audio is affected by various environmental contexts. And a user must tune the sound every time. In a smart home, the sensors are installed such as a temperature, humidity, and *etc* As a result, the environmental contexts could be obtained by sensors easily. And the user could tune the best sound of digital audio. In this paper, we developed a customized control of digital audio for a user. That user customized control for the sound of digital audio in a smart home must be able to consider many contexts simultaneously. The environmental contexts are a temperature, humidity, location, weather, and atmospheric pressure. In future study, we will consider more effective various contexts to control a sound of digital audio.

Acknowledgements

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Author

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