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IMPROVEMENT OF COMMERCIALIZED ANC SYSTEMS FOR ROAD TRAFFIC NOISE REDUCTION

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ABSTRACT

A growing number of noise problems are emerging, and in South Korea, the road traffic noise problems far exceed the railroad and airport noise problems. To reduce road traffic noise, passive methods such as the installation of noise barriers and soundproof embankments have been employed, but these raise problems such as excessive maintenance cost, obstruction of cityscape, and ecological disturbance. To address these problems, the ANC (active noise cancellation) technology has been significantly researched on. To commercialize the road traffic noise reduction ANC system and to achieve an integrated, inter-operated management thereof, this study presented improvement of the already-developed ANC system and the manufacturing process thereof. It improved control system performance of the ANC system, and a method designed to manufacture commercial cases and a mobile inter-working system was proposed. The methodology consists of methods of manufacturing a signal processing controller and of developing the program.

Keywords: *traffic noise, ANC (active noise cancellation), commercialization, mobile type.*

I. INTRODUCTION

Along with industrial development and economic growth, urbanization is happening all over the world. To address the urban housing shortages caused by such urbanization, South Korea is developing many new towns in the suburbs of cities, which has led to the construction of urban-type expressways. This creates noise in the residential areas adjacent to such expressways, thereby increasing the civil petitions against such noise.

According to South Korea's Anti-Corruption and Civil Rights Commission, 52.7% of the people in the country are exposed to road traffic noise, among the various traffic noises[1]. This figure was obtained by forecasting the noise level per unit area in association with the sound attenuation in the distance measured at several points of the main roads, applying the population distribution rate to the noise level, and thus assessing the percentage of the population exposed to noise. Compared to the 3.8% railroad noise exposure rate and the 2.9% airport noise exposure rate, the road traffic noise exposure rate is very high, affecting the people severely. Also, according to the Ministry of Environment's noise and vibration evaluation results, the highest percentages of the petitions against noise were filed in Seoul (43.6%) and Gyeonggi (21.1%), which constitute the Seoul metropolitan area, suggesting that the noise problems are the most severe in the large cities[2]. To address the country's noise problems, noise barriers, soundproof embankments, and other soundproof facilities are being constructed, but these require excessive construction and maintenance costs and have limited installation heights and spaces. Also, sound absorption noise barriers hurt the urban and surrounding landscapes, and transparent noise barriers are constantly struck by birds, leading to their death and causing ecological disturbance.

To address such weaknesses of the aforementioned noise reduction methods, the ANC technology is being widely researched on. Compared to the ANC technology for automobiles, railroads, and aviation, however, the commercialized ANC technology for roads is minimal. This study was conducted to help improve the already-developed ANC system for its commercialization for roads.

Section II of this paper discusses the domestic and foreign ANC technologies; section III discusses the manufacturing of signal processing controllers; section IV deals with the development of signal processing controller programs; and section V presents the conclusion of this study.

II. OVERVIEW OF THE ANC SYSTEM TECHNOLOGY

Korea Evaluation Institute of Industrial Technology announced that in the 1990s, the ANC technology was actively researched on, leading diverse patents to be filed for application[3]. It was difficult to commercialize and put the technology to use, however, apparently dealing a blow to the R&D efforts for it. Nonetheless, in the 2000s, with the development of high-speed processors, the research on the said technology was activated again, leading the technology to be applied to diverse areas and boosting the growth of the technology.

The portfolio of South Korean patents filed with KIPO entered a period of growth in 1990-1993 and 1994-1997 and declined fast in 1998-2001, but in 2002-2005 and in 2006 to the present time, the patents and patent applications have surged in number, suggesting the rapid development of the technology.

The portfolio of South Korean patents filed with USPTO had a similar pattern as the portfolio of patents filed with KIPO; it underwent growth in 1990-1993 and in 1994-1997 before it stopped growing in 1998-2001, but in 2002-2005 and in 2006 to the present time, the patents and patent applications have surged in number. As for the portfolio of South Korean patents filed with JPO, the patents and patent applications increased in 1990-1993, but in 1994-1997 and in 1994-2005, they declined sharply. They recovered, however,from 2006 to the present time, suggesting that the basic technologies in the early 1990s' research have been shifting of late to practical technologies.

The portfolio of patents filed with EPO has a similar pattern as that of the patents filed in South Korea and the U.S.; it underwent growth in 1990-1993 and in 1994-1997 then declined sharply in 1998-2001, but in 2002-2005 and in 2006 to the present time, the patents and patent applications have increased in number.

Figure:

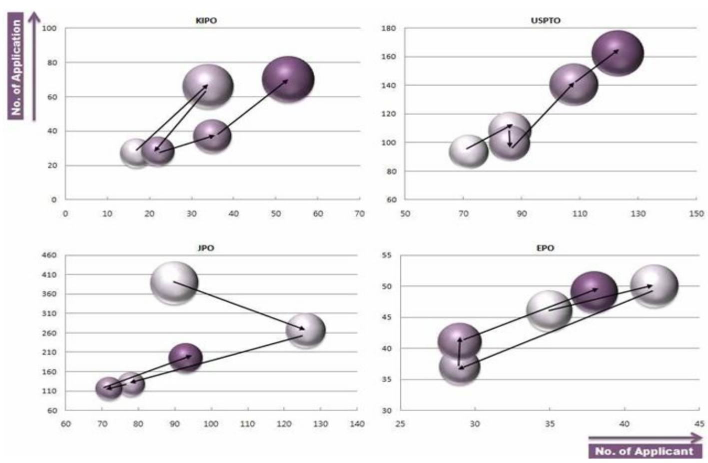

Figure 1: Survey of global patented technologies(KEIT, 2012)

III. MANUFACTURING OF SIGNAL PROCESSING CONTROLLERS

The proposed signal processing controller processes the inputted original noise signals and provides a noise reduction function using a control algorithm. Also, the controller was designed for monitoring the controller control variables and various operation variables' information, and for providing an external network interface that could be applied to noise control using external modules. The controller consists of a noise input device microphone and an output device speaker designed for removing the original noise.

The signal processing controller was designed using the digital-signal-processor-(DSP)-based processor. To process the original noise collected with DSP's main controller signal processing processor, the analogue-inputted audio signals were dispersed. To minimize the errors, a sound removal source was created using a signal processing algorithm for generating a noise removal sound source signal. The controller hardware was configured using a CPU with a DSP-based processor and an ARM-based processor in a parallel core so that it could perform its functions in real time. The DSP-based processor was designed to compute the various applied control filter and noise control algorithms until the operation of the applied algorithm and the creation of a sound removal source against the sampled received original noise. The ARM-based processor was designed to control the inputs and outputs and to interface with the display and external networks.

A microphone and an error microphone were used as the input devices, and for the output devices, analogue or digital non-oriented or oriented speakers were used. The control sound source tuning and gain were set by employing the various parameters influencing the field-inputted original noise using the controller's input devices. In addition, the external interface was used to set the operation environment and various variables. Fig. 2 shows the signal processing controller.

Figure:

(a) The inner structure of ANC system ***(b) ANC system***

Figure 2: Configuration of the road traffic noise reduction ANC system

To boost the algorithm calculation speed, the running speed was secured by applying the fastest device module among the same signal processors. The circuitry was designed by improving the band pass filter for the processing of the road traffic noise source's frequency band with the ANC system algorithm, and for minimizing the impact of the external factors and the high frequency. The input and output devices were configured to be the same as those in the already-developed ANC system, and this controller was mounted with a sensor for collecting the wind direction/speed and temperature/ humidity information and for delivering the information to the controller. Also, to commercialize the controller, its case was manufactured, and a mobile system was developed.

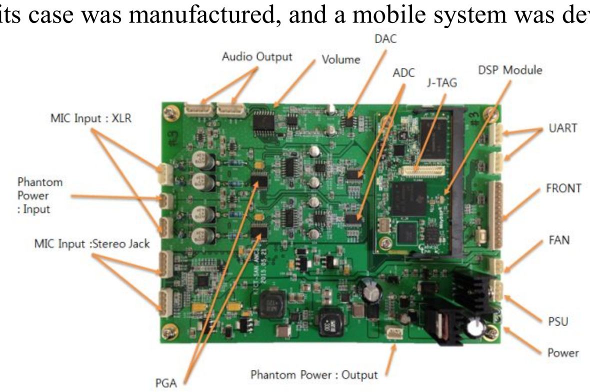

Figure 3: HS DSP board

Fig. 3 shows the proposed HS DSP board. To improve the signal processing speed, the HS OMAP-L138 module was used. To transform the noise collected through the input device into 24-bit digital data and to transmit them to the DSP, the standard protocol I2S bus was used. The audio signals created in the DSP using the algorithm were transformed from 16-bit digital data to analogue signals and were transmitted to the output-free amplifier.
To configure the controller's input device, the microphone input connector was designed as an XLR type, and to supply power to the condenser microphone, 24 and 48V phantom power was designed to be supplied. A stereotype

as a low-precision microphone connector was added to enable the performance of an experiment on an affordable condenser microphone.

The output device was configured to convert the DSP-created control sound (the digital signal) to an analogue signal, and a free amplifier was configured to amplify the outputted signals. Also, a power amplifier was configured to output the free-amplifier-outputted noise signals to the speaker, and for commercialization, a high-efficiency and low-cost class D amplifier was installed.

The switch power installed in the controller was configured with 50 V/10 A to activate the 150W/8Ω output speaker so as to supply sufficient power to the power amplifier. Also, the switching method was configured to supply the controller-required digital power, the phantom power, and the analogue plus power to the auxiliary devices.

Figure:

(a) Front of controller *(b) Rear of controller*

Figure 4: Configuration of the ANC controller

The controller front area consists of a control device power switch, a noise level indicator, an LCD for setting the operation status and menu, a LED for indicating the microphone input operation status, a menu manipulation push button, a noise-outputted sound removal button, a network-connecting jack, a port for connecting the serial communication terminal block, and system reset. The main case has a hole array designed for discharging heat at both sides and at the front. For installing the controller in the 19” rack, four M3 screw holes were drilled on either side. Also, for conducting air-cooling heat discharge, a heatsink wing array and a case manufactured using an extrusion-type mold were used, and the front and rear panels were fastened using screws. The case bottom area was manufactured using an extrusion mold, and it was fastened with the main case, brackets, and front and rear panels using screws. The rear panel consisted of a 220V AC input power jack, the controller’s inside heat discharge fan, a PA speaker connection speak-on terminal, a microphone connection stereo jack, an XLR connector, a phantom power slide switch for selecting the condenser microphone driving voltage, and a terminal block connector port for connecting the external-wind direction/speed and the temperature/humidity sensor.Also, in this study, as shown in Fig. 5, a bag-carried mobile integrated inter-operable system was developed for managing various controllers comprehensively.

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Figure:

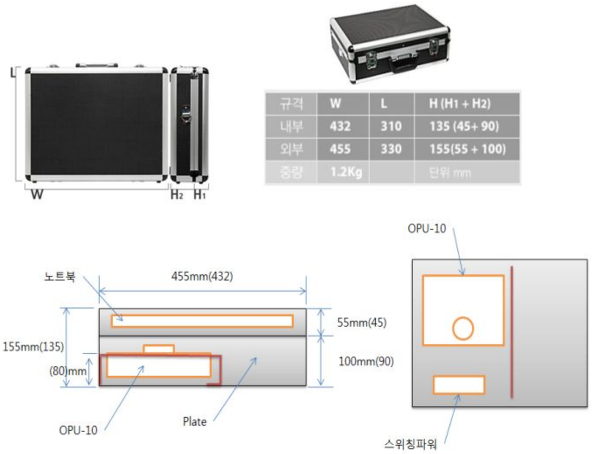

Figure 5: Design of the mobile integrated inter-operable system

IV. DEVELOPMENT OF SIGNAL PROCESSING CONTROLLER

The proposed signal processing controller program consists of a boot loader associated with the DSP signal processing processor operation, an independent DSP operation program, and an algorithm execution function. To drive the input/output devices and to change the set values for adjusting the gain, an interface device drive was developed using an SPI bus, a I2S bus, etc. Also, the proposed controller was made to use an STM32 core to set the controller menu composition parameters through the LCD, keypad, etc. and to enable the integrated inter-operable interface.

The signal processing controller operation programs were developed as shown below, and it consists of the DSP-run embedded operation software and various functions for noise reduction and program support.

• Design of DSP-embedded own operation program
• Design of DSP controller I/O allocation and functions
• Program-enabling free-amplifier I/O device
• Design of device driver
• Design of the environment parameter-input external interface and saving I/O function
• Design of the integrated inter-operable data and serial communication function
• Design of display UI functions such as the controller operation information menu
• Design of operating additional noise removal algorithms

The proposed program's noise reduction algorithm was designed as the applied filter FIR (finite impulse response) model for computing the active noise removal signal processing. The system was designed to be able to operate Fx LMS, Co Fx LMS, and reinforced LMS algorithms.

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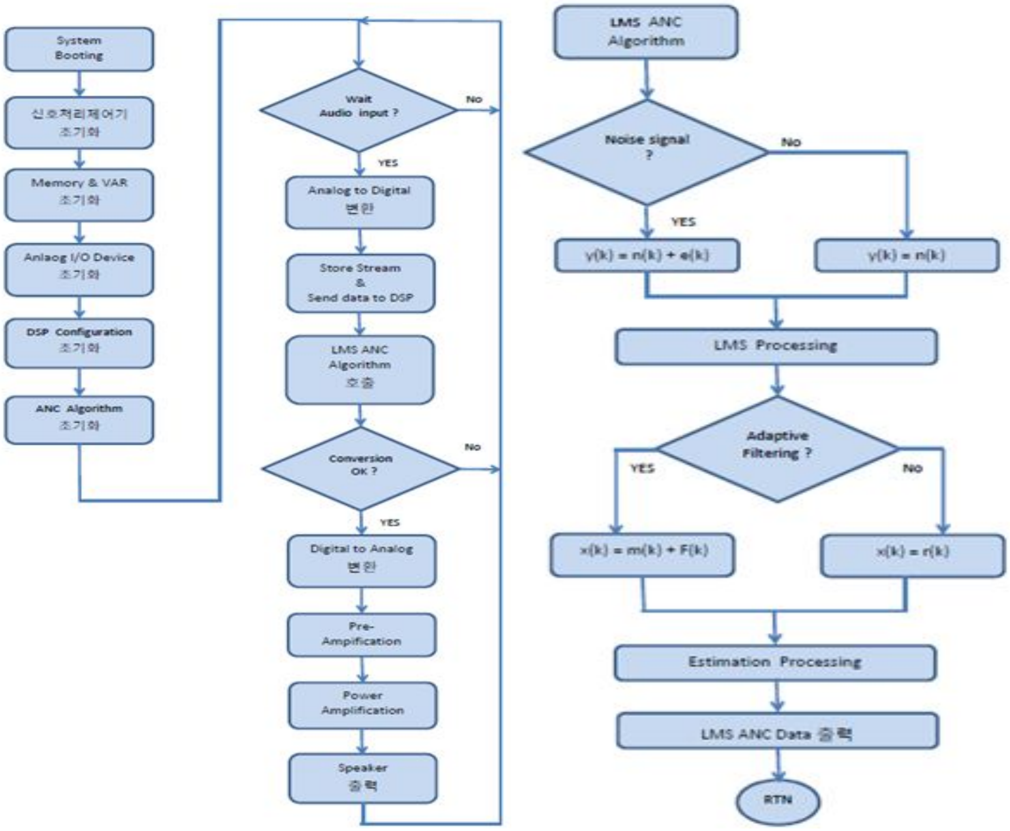

Figure 4: Flowchart of the signal processing controller operation program

V. CONCLUSION

The existing ANC (active noise cancellation) technology is applied only to the interiors of automobiles, headphones, earphones, and other acoustic equipment, and to building interiors. This study improved the ANC system's controller to reduce the road traffic noise and to commercialize the road traffic noise reduction ANC system and ensure the integrated management thereof. ANC system improvement and manufacturing methods were presented according to the development of the signal processing controller and program. The proposed improved equipment will be tested in the field so as to analyze and compare the noise reduction effects by algorithm.

The road traffic noise reduction ANC system, if commercialized, is expected to reduce the noise in the low-frequency band, whose function is weak particularly in the existing noise barriers. Furthermore, if a new noise barrier is developed by combining the noise barrier and the ANC system, it will boost the noise reduction effects. Also, it will reduce the roadside noise and will thus provide a traffic-quieting environment and a pleasant residential-environment condition to the people living alongside roads.

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