A VOICE-CONTROLLED AUDIO AMPLIFIER UTILIZING A FIELD EFFECT TRANSISTOR AS A CONTROL ELEMENT

Jonathan A. Enokela[1] & Jonathan U. Agber[2]
Department of Electrical and Electronics Engineering, University of Agriculture, P.M.B. 2373, Makurdi, Nigeria
Email: [1] jonajapeno@gmail.com, [2] jonagber@yahoo.co.uk

ABSTRACT
Many situations arise in the use of public address systems which require the amplification of a signal from one source and the simultaneous attenuation of another signal. A system of this nature which uses a field effect transistor that operates in the voltage variable resistance mode to automatically control the volume of the unwanted signal is described in this work. A significant advantage of the system over the traditional hand operated control method is the fact that the attenuated signal is automatically restored to its original level at the cessation of the control signal. The utilization of the field effect transistor for control in the circuit achieves a 27 dB attenuation of the unwanted signal.

Keywords: *Audio Amplifier, Voice Control, Field Effect Transistor, Electronic Attenuation*

1. INTRODUCTION
In many practical situations when audio signals have to be delivered to an audience the need might arise that will require the mainstream audio signal to be momentarily attenuated while a signal from another source is amplified for the attention of the listeners. In a radio house, for instance, the announcer may want to send an urgent message to his listeners while the amplitude of the music that has been playing at the background should be reduced to a much lower level or even completely attenuated. The traditional method of doing this is for the announcer to use his hands to reduce the volume of the mainstream signal and then to restore it to the former level after the announcement has been made. Difficulties abound with this method because the level of attenuation and the level to which the mainstream signal was restored are highly subjective and in most cases will not be the same as the former level [2].
The present work describes a system that attenuates the mainstream signal significantly at the onset of the announcer's voice and also restores the mainstream signal back to the correct former level automatically at the cessation of the announcer's voice. Most previous systems in existence control the audio signal from only one source [10], [11], [12], [13], [14], and [15]. A system that is close to the one being described but which uses the Bipolar Junction Transistors (BJT) and other elements for the attenuation of the mainstream signal once the voice signal is imposed on the circuit is given in [1]. The system that uses the BJT requires a more complicated arrangement of the attenuator [2]. These difficulties are overcome by designing an attenuator that uses a Field Effect Transistor (FET). The system based on the FET also achieves a 27 dB attenuation of the unwanted signal in comparison to only the 3 dB attenuation achieved by the BJT based system.

2. MATERIALS AND METHODS

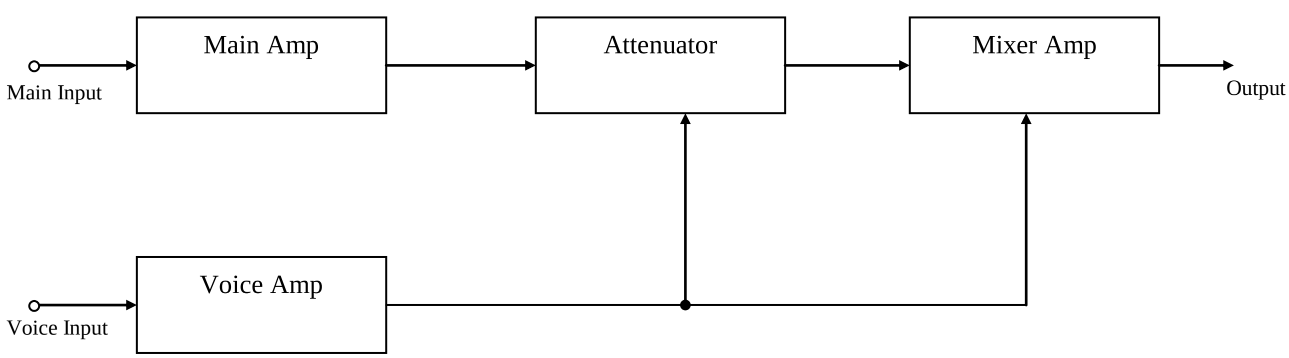

Figure 1, Block Diagram of the Voice Controlled Amplifier

The block diagram of the proposed system is given in figure 1 [1]. The mainstream signal (Main Input) is normally sent to the output through the attenuator and the mixer amplifier. In the absence of the voice input the attenuator has very little effect on the mainstream input signal. The presence of the voice signal causes the mainstream input signal to be attenuated as soon as the magnitude of the voice signal attains a predetermined threshold value. The two inputs are then mixed and sent to the output. The relationship between the two signals is depicted in figure 2. This shows that the signals have an inverse relationship in amplitude.

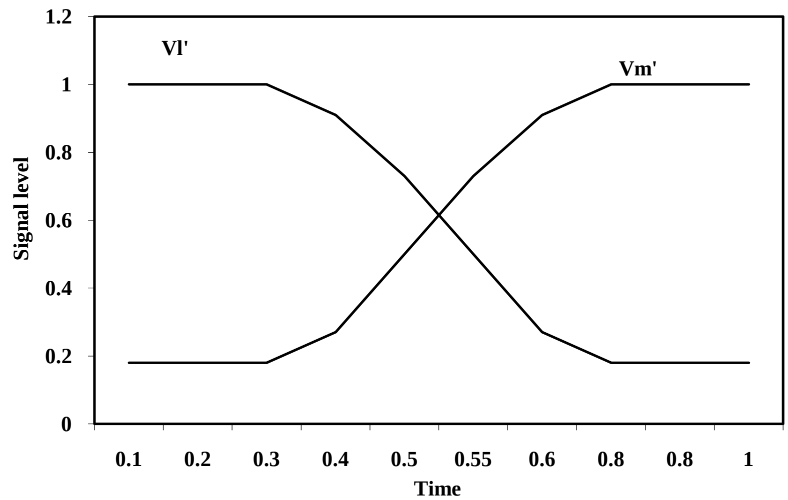

Figure 2: Signal variation of vi' and vm'

2.1 Schematic Diagram

The schematic diagram of the Voice Controlled Audio Amplifier (VCAA) is depicted in figure 3. The mainstream input signal is amplified by the operational amplifier U_2 while the voice input signal is amplified by U_1. The two signals are mixed by U_4. The voice signal is further amplified by U_3 to generate enough amplitude so that it can be rectified by the diode D_1. The dc voltage generated as a result of this rectification is compared with a small reference voltage generated by the Zener diode D_2. The voltage at the output of the comparator (V_{CO}) constitutes the control signal for the Field Effect Transistor Q_1 which functions as the controlled attenuator.

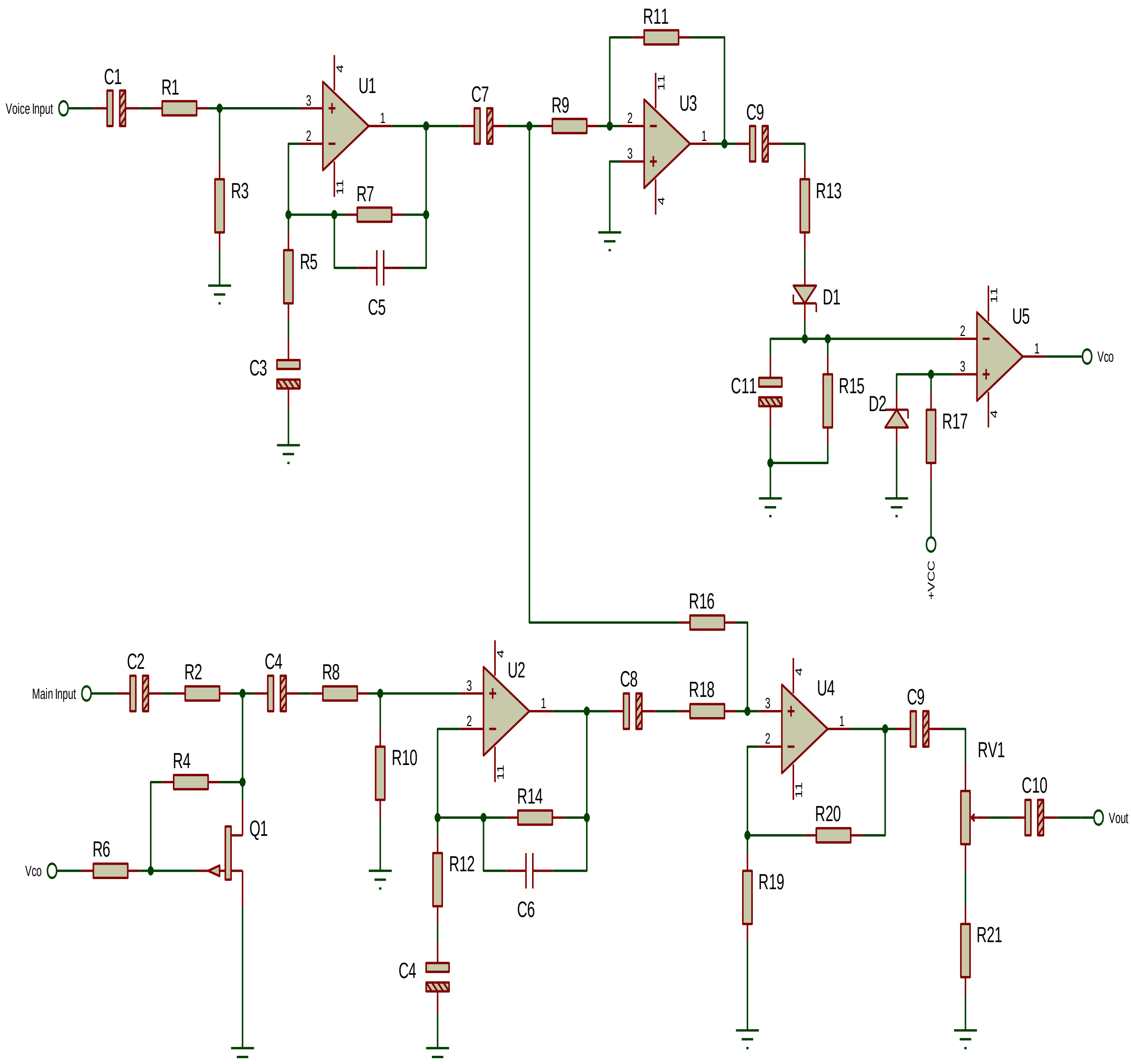

Fig. 3: Schematic Diagram of the Voice Contolled Amplifier

2.2 Specifications

The Voice Controlled Audio Amplifier is expected to be integrated into existing audio systems. The following specifications are thus obtainable [6], [16] and [17]:

Main Input: 300 mV, 10 kΩ
Voice Input: 20 mV, 100 Ω
Output: 1 V, 10 kΩ

Frequency Response: 20 Hz – 20 kHz

2.3 Circuit Analysis and Design

Consider the input stage of the voice input (U_1) shown separately in figure 4. This circuit is a non-inverting amplifier. The low frequency response is controlled by C_1 and C_3 while C_5 controls the high frequency response. The output of the Opamp U_1 is given by equation 1 ([3], [4], [5]).

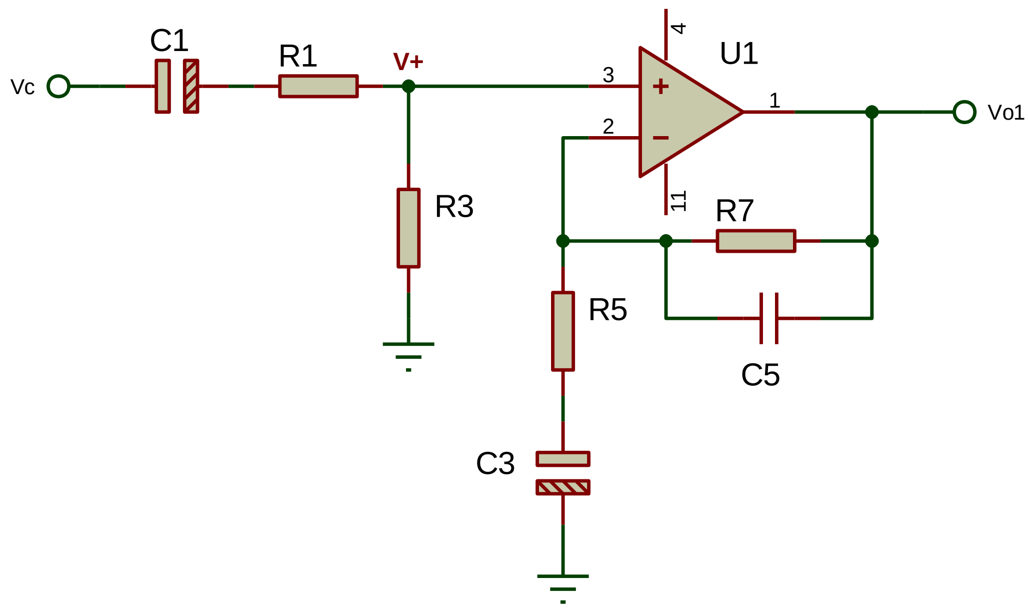

Fig.4: Input Stage of the Voice Input

$$V_{o1} = V_+ \left[\frac{Z_1 + Z_2}{Z_1}\right] \qquad (1)$$

In equation 1

$$Z_1 = R_5 + \frac{1}{sC_3} \qquad (2)$$

$$Z_2 = R_7 || \frac{1}{sC_5} \qquad (3)$$

$$V_+ = \frac{V_c(s) R_3}{R_1 + R_3 + \frac{1}{sC_1}}$$

Or

$$V_+ = \frac{s\left(\frac{R_3}{R_1+R_3}\right) V_c(s)}{s + \frac{1}{C_1(R_1+R_3)}} \qquad (4)$$

Substituting equations (2) – (4) into equation (1) yields an equation of the form

$$A_{v1}(s) = \frac{V_{o1}(s)}{V_c(s)} = \left\{\frac{as}{s+p_1}\right\}\left[\frac{s^2+b_1s+\omega_o^2}{s^2+b_2s+\omega_o^2}\right] \qquad (5)$$

In equation (5)

$$a = \frac{R_3}{R_1+R_3} \qquad (6)$$

$$p_1 = \frac{1}{C_1(R_1+R_3)} \qquad (7)$$

$$b_1 = \frac{1}{C_3R_5} + \frac{1}{C_5R_5} + \frac{1}{C_5R_7} \qquad (8)$$

$$b_2 = \frac{1}{C_5R_7} + \frac{1}{C_3R_5} \qquad (9)$$

$$\omega_o^2 = \frac{1}{C_3C_5R_5R_7} \qquad (10)$$

The pole p_1 is selected to be practically at zero so that equation (5) reduces to a second order expression [7]. The frequency response of the resulting second order equation is controlled by the poles because $|b_2| < |b_1|$. A dominant pole exists at $s_p = -b_2 \; if \; b_2^2 \gg 4\omega_o^2$.

The gain of the amplifier stage in the mid-band region is given by:

$$A_o = \frac{V_{o1}}{V_c} = \left\{\frac{R_3}{R_1+R_3}\right\}\left[1+\frac{R_7}{R_5}\right] \qquad (11)$$

2.4 The Mixer Amplifier

The output of U_1 (V_{o1}) and U_2 (V_{o2}) are summed using the non-inverting summer U_4. The output voltage V_{out} is given by

$$V_{out} = \left\{1+\frac{R_{22}}{R_{20}}\right\}\left[(V_{o1})\left\{\frac{R_{18}}{R_{16}+R_{18}}\right\} + (V_{o2})\left\{\frac{R_{16}}{R_{16}+R_{18}}\right\}\right] \qquad (12)$$

The mixer should be designed so as to have the possibility of simultaneous contributions from the mainstream and voice signals.

2.5 The Field Effect Transistor Attenuator

The FET Q_1 is used in the voltage-variable-resistance or the Ohmic region. In this region the drain characteristic is given by equation (13) [4, 5, 8].

$$I_D = 2k[(V_{GS}-V_T)V_{DS} - V_{DS}^2/2] \qquad (13)$$

In equation (13) k is the scale factor of the FET while V_T is the gate threshold voltage.

In the Ohmic region,

$$V_{DS} < V_{GS} - V_T \qquad (14)$$

In this region the resistance between the drain and the source is obtained from equation (13) to be

$$\frac{1}{R_{DS}} = \frac{I_D}{V_{DS}} = 2k[(V_{GS}-V_T) - V_{DS}/2] \qquad (15)$$

The requirement of expression (14) necessitates the placement of the FET in the path of signal where the amplitude is small (typically less than 1V) [8]. The last term in equation (15) represents a departure from linearity of R_{DS}. R_{DS} is linearized by adding $V_{DS}/2$ to V_{GS}. This is assured in figure 3 by making $R_4 = R_6$. The maximum attenuation of the mainstream signal is obtained when R_{DS} equals the ON drain resistance R_{DS} (ON). This is given by

$$Attenuation(dB) = 20log_{10}\left[\frac{R_{DS}(ON)}{R_2}\right] \qquad (16)$$

3. RESULTS AND DISCUSSIONS

The circuit depicted in the schematic diagram of figure 3 was designed and then simulated using the NI Multisim version 10.0.1 [9]. The frequency response of the main channel amplifier is given in figure 5. The attenuation of the main input signal by the voice signal is depicted in figure 6 which also shows that the circuit attained a maximum attenuation of 27 dB. The threshold of the voice signal at which it begins to cause attenuation of the main input signal was set at 4 mV.

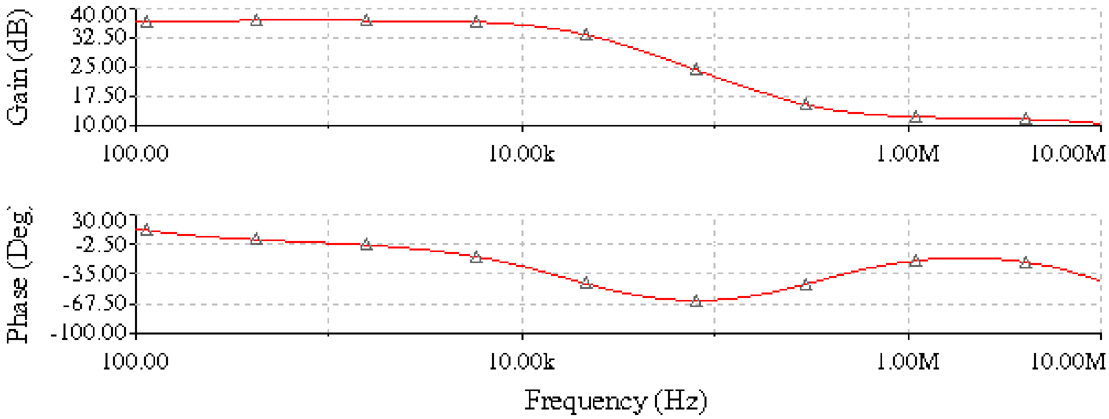

Figure 5, Frequency Response of Main Channel Amplifier

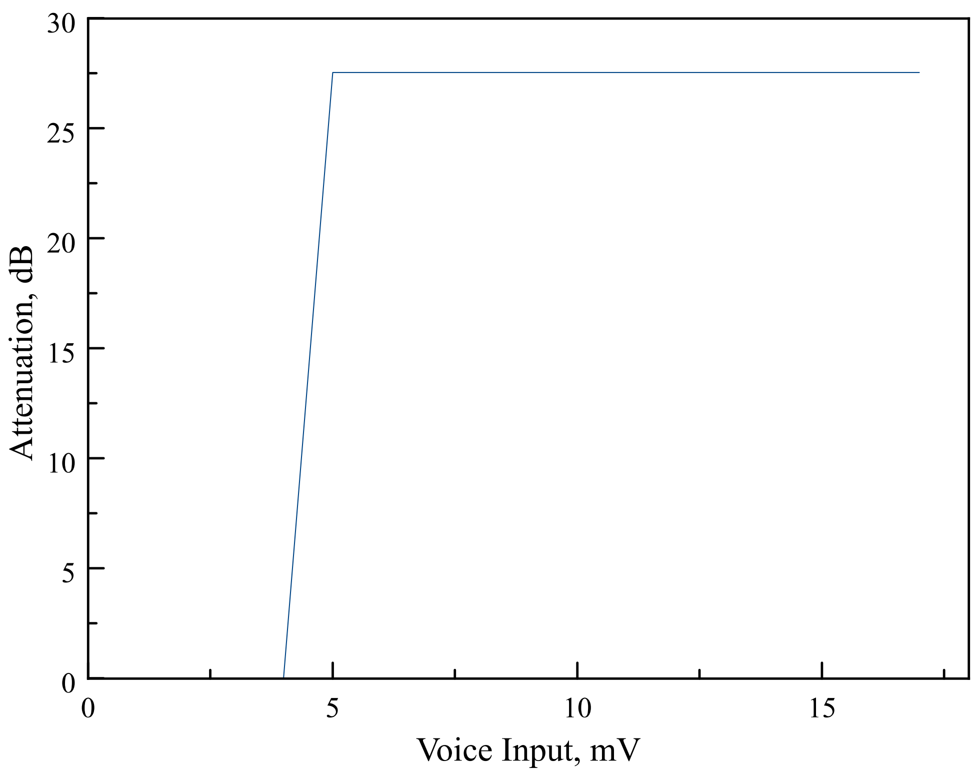

Figure 6, Attenuation of the Main Input by the Voice Input Signal

4. CONCLUSION

The circuit has been designed so that attenuation of the main signal starts as soon as the control circuit senses a certain threshold of the voice input. This threshold was set at 4 mV. The attenuation of the main input achieved was 27 dB. The main input signal was restored to its original level as soon as the voice input was removed. The circuit can be easily incorporated into existing audio systems.

5. REFERENCES

[1]. J. A. Enokela and J. U. Agber, "An Automatic Voice-Controlled Audio Amplifier", *International Journal of Scientific and Engineering Research, Vol.3, Issue 1, January, 2012, pp.1-6.*

[2]. P. M. Echoi, "Design and Construction of a Voice-Controlled Amplifier", *B.ENG Thesis*, **1997,** Department of Electrical/Electronic Engineering, University of Agriculture, Makurdi, Nigeria.

[3]. J. Millman and A. Grabel, "Microelectronics", McGraw- Hill Book Company, New York, **1988**, pp.442-448.

[4]. Donald A. Neamen, "Electronic Circuit Analysis and Design", McGraw- Hill Book Company, New York, **1996**, pp.527-553.

[5]. A.S. Sedra and K.C. Smith "Microelectronic Circuits", 5/e, Oxford University Press Inc., New York, **2004**, pp. 239-241.

[6]. D. Bohn, "Audio Specifications", RaneNote 145, Rane Corporation, http://www.kujancollective.com/

[7]. F.F. Kuo, "Network Analysis and Synthesis", John Wiley and Sons Inc., New York, **1977**, pp. 134-165.

[8]. P. Horowitz and W. Hill, "The Art of Electronics", Cambridge University Press, New York, **1995**, pp. 138-140.

[9]. Multisim (Version 10.0.1) User Guide, National Instruments, 11500 North Mopac Expressway, Austin Texas, January, 2007.

[10]. K. Ikoma, "Voice Control Circuit", US Patent No. 4068092, http://www.freepatentsonline

[11]. W. Osamu, "Speech Circuit Controlling Sidetone Signal by Background Noise Level", US Patent No. 5640450, http://www.wikipatents.com

[12]. K. Kazuhiro, "Automatically Variable Circuit of Sound Level of Received Voice Signal in Telephone", US Patent No.5896450, http://www.wikipatents.com

[13]. K. Fumiyasu, "Audio Reproducing Apparatus", US Patent No.6282296, http://www.wikipatents.com

[14]. J. Hurst, "Telephone Apparatus", US Patent No.6834107, http://www.wikipatents.com

[15]. J.L. Dvorak, "Method for Automatically Assisting Unaided Voice Communication", US Patent No.6353732, http://www.wikipatents.com

[16]. "Reference 3 Line-Stage Preamplifier", Audio Research, http://www.audioresearch.com/REF3.pdf

[17]. "DVD- Audio/Video & Super Audio CD Player with Full 10-bit HD Video Circuit", http://www.usa.denon.com/dvd_2930cilit.pdf