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Performance of Noise Canceller of LC823450

ON Semiconductor®

APPLICATION NOTE

INTRODUCTION

This application note describes the performance of Noise Canceller of LC823450 Series (called LC823450 hearafter).

The customer can improve of audio characteristics by using this canceller. Its function can be used for various products such as Wireless headset, Earbads, Wireless speaker or IC−recoder.

Intended audience is customers who are building audio application using LC823450.

OVERVIEW OF NOISE CANCELLER

Table 1 shows types of noise canceller which are adopted to LC823450.

Table 1. TYPES OF NOISE CANCELLER FOR LC823450

Target APP	NC type	Algorithm category	note	
For HF	Small mic distance	Beam forming + 1mic NC	Unidirectional characteristics	
	Large mic distance	2mic NC using power information	Pick up sound near main mic	
For REC	Far Talk	2mic NC using phase information	Pick up sound which comes from front direction.	
	Close Talk	2mic NC using power information	Pick up sound near main mic	

*"Large mic distance for HF" is same as "Close talk for REC" at the point of the internal processing.

1mic noise canceller (small mic distance for HF) assumes that the distance of 2mic is very small like Earbuds. It is realized by combining 1mic noise canceller and spatial techniques like beam forming. Target noise of 1mic noise canceller is stationary noise. Therefore, non−stationary noise like babble noise cannot be reduced by 1mic noise canceller.

2mic noise canceller (Close talk for REC) assumes that the distance between 2mics is large and main mic is near the mouth like smart phone. 2mic noise canceller can reduce stationary and non−stationary noise. To get effective performance, power difference between microphones must be more than 12 dB.

2mic noise canceller (Far talk for REC) is used in the scene which the far voice is recorded with noise canceller. This type of 2mic noise canceller can enhance voice signal which comes from center direction. (Target signal must be captured by each microphone with same phase). Furthermore, 2mic noise canceller (Far talk for REC) can be used with 1mic noise canceller to reduce stationary noise which comes from center direction.

In these noise cancellers, "Large mic distance for HF" is same as "Close talk for REC" at the point of the internal processing.

EVALUATION ENVIRONMENT AND CONDITION

Because we have no anechonic room which is suitable for evaluation environment, the reflection of the wall surface makes some influences to the evaluation result data when we use the microphones implemented on the evaluation board: LC823450XGEVK (called EVK hearafter). Therefore, in this report, we carry out the performance evaluation by using the simulation on PC. However, as for 2mic noise canceller (Close talk for REC), we introduce the result of real evaluation also because the sound pressure difference between two microphones on EVK was observed enough.

Please note that the performance of noise canceller is influenced strongly by the characteristics of microphone, shape of set and the position of microphones.

1mic Noise Canceller (Small Mic Distance for HF)

Evaluation condition for 1 mic noise canceller (small mic distance for HF) is as follows;

Table 2. EVALUATION CONDITION FOR 1MIC NOISE CANCELLER (SMALL MIC DISTANCE FOR HF)

Items	Contents

Parameters of 1mic Noise Canceller	Sampling rate : 16 kHz
	FFT size : 256
	Noise cancel level (parameter is H_min) :
	   0.25 (H_min is 0x20000000)
	   0.125 (H_min is 0x10000000)
	   0.0625 (H_min is 0x08000000)
	   0.0 (H_min is 0x00000000)

Beam Forming	Off
Test Data	Male data (male.wav) or female data (female.wav) which was added white noise, babble noise and pink noise to adjust 6dB, 12dB and 18dB of segmental SNR. To calculate PESQ score correctly, male.wav or female.wav was already reduced ambient noise by using sound tool (Goldwave).

Further, we did not conduct evaluation of beam forming, because suitable data could not be collected. Beam forming is a function that creates uni−directional characteristics by using 2 microphone inputs. Please refer 1 mic noise canceller performance for the sound which comes from front direction.

2mic noise canceller (Close talk for REC)

Evaluation condition for 2mic noise canceller (Close talk for REC) is as follows:

Table 3. EVALUATION CONDITION FOR 2MIC NOISE CANCELLER (CLOSE TALK FOR REC)

Items	Contents
Parameters of 2mic Noise Canceller	Sampling rate: 16 kHz FFT size: 256 Noise cancel level "Weak" or "Strong" of default setting
Test Data	Male data (male.wav) or female data (female.wav) which was adjusted +18 dB to Rch (main) compared with Lch (sub), and added white noise, babble noise and pink noise to adjust 6 dB, 12 dB and 18 dB of segmental SNR To calculate PESQ score correctly, male.wav or female.wav was already reduced ambient noise by using sound tool (Goldwave)

2 Mic Noise Canceller (Far Talk for REC)

Evaluation condition for 2mic noise canceller (Far talk for REC) is as follows:

Table 4. EVALUATION CONDITION FOR 2MIC NOISE CANCELLER (FAR TALK FOR REC)

Items	Contents

Parameters of 2mic Noise Canceller	Sampling rate: 16 kHz
	FFT size: 256
	HPF: Off
	Stereo Emphasis:
	   mic distance: 2 samples.
	   Emphasis gain: 0.5
	Noise cancel level
	   (2mic noise canceller)
	      CF = Weak, NC = Off
	      CF = Strong, NC = Off
	   (2mic noise canceller with 1mic noise canceller)
	      CF = Weak, NC = Weak
	      CF = Strong, NC = Strong

Test Data	Male data (male.wav) and female data (female.wav) To create condition that target signal is arrived from front direction, R ch signal is same as L ch These signals are added white_noise_0_degree.wav, babble_noise_0_degree.wav and pink_noise_0_degree.wav to adjust to target segmental SNR. (These noise data is arrived from 90 degree of left side) To calculate PESQ score correctly, male.wav or female.wav was already reduced ambient noise by using sound tool (Goldwave)

Measurement of evaluation

We evaluated performance of noise canceller by using following measurement.

Table 5. MEASUREMENT OF EVALUATION

Improvement of SNR	This evaluation uses SNR which is calculated between 8000 samples of silence area of before−cancel data and after−cancel data. To reduce an influence of direct current, we use high pass filter (Fc = 100 Hz) before calculating of SNR
Improvement of PESQ Score	This evaluation uses improvement of PESQ score between before−cancel and after−cancel

1. Each results are mean value of improvement of male data and female data. However, amount of data are not enough in this evaluation.
2. PESQ（ITU−T P.862 : Perceptual Evaluation of Speech Quality）

EVALUATION RESULTS

1mic noise canceller (small mic distance for HF)

Table 6. SNR IMPROVEMENT OF 1MIC NOISE CANCELLER (SMALL MIC DISTANCE FOR HF)

| Item | Test Data | | Improvement of SNR (dB) | | | |
| | type | Segmental SNR | Noise Cancel Level | | | |
			0.0	0.0625	0.125	0.25
SNR Improvement	White Noise	6 dB	21.0	19.9	16.9	11.8
		12 dB	19.0	18.2	16.1	11.6
		18 dB	13.6	13.4	12.5	10.0
	Babble Noise	6 dB	14.3	14.0	13.1	10.4
		12 dB	13.7	13.5	12.7	10.2
		18 dB	10.4	10.3	10.0	8.6
	Pink Noise	6 dB	16.8	16.4	15.0	11.3
		12 dB	16.2	15.8	14.6	11.2
		18 dB	11.6	11.5	11.0	9.3

Table 7. PESQ SCORE IMPROVEMENT OF 1MIC NOISE CANCELLER (SMALL MIC DISTANCE FOR HF)

| Item | Test Data | | Improvement of PESQ Score | | | |
| | Type | Segmental SNR | Noise Cancel Level | | | |
			0.0	0.0625	0.125	0.25
PESQ Score Improvement	White Noise	6 dB	0.41	0.41	0.40	0.35
		12 dB	0.21	0.27	0.26	0.23
		18 dB	−0.15	−0.03	0.06	0.09
	Babble Noise	6 dB	0.01	0.06	0.10	0.14
		12 dB	−0.05	0.01	0.07	0.11
		18 dB	−0.25	−0.16	−0.07	0.00
	Pink Noise	6 dB	0.28	0.31	0.30	0.28
		12 dB	0.11	0.18	0.19	0.16
		18 dB	−0.26	−0.15	−0.05	0.00

2mic Noise Canceller (Close Talk for REC)

Table 8. SNR IMPROVEMENT OF 2MIC NOISE CANCELLER (CLOSE TALK FOR REC)

| Item | Test Data | | Improvement of SNR (dB) | |
| | Type | Segmental SNR | Noise Cancel Level | |
			Weak	Strong
SNR Improvement	White Noise	6 dB	11.9	12.7
		12 dB	12.2	13.1
		18 dB	14.5	16.8
	Babble Noise	6 dB	15.6	17.8
		12 dB	15.7	18.1
		18 dB	18.1	20.3
	Pink Noise	6 dB	18.1	23.5
		12 dB	17.6	22.3
		18 dB	16.9	20.6

Table 9. PESQ SCORE IMPROVEMENT OF 2MIC NOISE CANCELLER (CLOSE TALK FOR REC)

| Item | Test data | | Improvement of PESQ score | |
| | type | Segmental SNR | Noise cancel level | |
			Weak	Strong
PESQ score Improvement	White Noise	6dB	0.52	0.55
		12dB	0.48	0.52
		18dB	0.56	0.59
	Babble Poise	6dB	0.47	0.49
		12dB	0.45	0.49
		18dB	0.45	0.50
	Pink noise	6dB	0.62	0.72
		12dB	0.63	0.80
		18dB	0.74	0.72

2mic Noise Canceller (Far Talk for REC)

Table 10. SNR IMPROVEMENT OF 2MIC NOISE CANCELLER EVALUATION (FAR TALK FOR REC)

| Item | Test Data | | Improvement of SNR (dB) | |
| | Type | Segmental SNR | Noise Cancel Level | |
			CF = Weak NC = Off	CF = Strong NC = Off
SNR improvement	White noise	6 dB	8.3	9.5
		12 dB	8.1	9.2
		18 dB	7.3	7.9
	Babble Noise	6 dB	11.7	14.2
		12 dB	11.3	13.3
		18 dB	9.9	11.1
	Pink Noise	6 dB	10.4	12.1
		12 dB	9.8	11.1
		18 dB	8.3	9.3

Table 11. PESQ SCORE IMPROVEMENT OF 2MIC NOISE CANCELLER EVALUATION (FAR TALK FOR REC)

| Item | Test Data | | Improvement of PESQ Score | |
| | Type | Segmental SNR | Noise Cancel Level | |
			CF = Weak NC = Off	CF = Strong NC = Off
PESQ Score Improvement	White Noise	6 dB	0.26	0.28
		12 dB	0.23	0.24
		18 dB	0.27	0.28
	Babble Noise	6 dB	0.23	0.25
		12 dB	0.20	0.21
		18 dB	0.21	0.22
	Pink Noise	6 dB	0.17	0.17
		12 dB	0.15	0.16
		18 dB	0.21	0.21

2mic Noise Canceller with 1mic Noise Canceller (Far Talk for REC)

Table 12. SNR IMPROVEMENT OF 2MIC NOISE CANCELLER WITH 1MIC NOISE CANCELLER EVALUATION (FAR TALK FOR REC)

| Item | Test Data | | Improvement of SNR (dB) | |
| | Type | Segmental SNR | Noise Cancel Level | |
			CF = Weak NC = Weak	CF = Strong NC = Strong
SNR Improvement	White Noise	6 dB	15.5	19.8
		12 dB	14.2	17.8
		18 dB	11.5	14.4
	Babble Noise	6 dB	16.0	18.0
		12 dB	14.7	16.6
		18 dB	12.3	14.5
	Pink Noise	6 dB	15.4	18.5
		12 dB	13.6	16.4
		18 dB	11.2	13.8

Table 13. PESQ SCORE IMPROVEMENT OF 2MIC NOISE CANCELLER WITH 1MIC NOISE CANCELLER EVALUATION (FAR TALK FOR REC)

| Item | Test data | | Improvement of PESQ Score | |
| | Type | Segmental SNR | Noise Cancel Level | |
			CF = Weak NC = Weak	CF = Strong NC = Strong
PESQ Score Improvement	White Noise	6 dB	0.23	0.27
		12 dB	0.19	0.23
		18 dB	0.24	0.26
	Babble Noise	6 dB	0.13	0.13
		12 dB	0.11	0.12
		18 dB	0.15	0.16
	Pink Noise	6 dB	0.11	0.11
		12 dB	0.10	0.12
		18 dB	0.15	0.15

Compare performance of each noise canceller

Figure 1 and Figure 2 show a comparison of improvement of each noise canceller. In these figures, segmental SNR of test data are 6 dB. Noise cancel level of each noise canceller are as follows:

- 1mic noise canceller: 0.0625 (H_min = 0x08000000)
- 2mic noise canceller for close talk: Strong
- 2mic noise canceller for far talk:
  CF = Strong, NC = Off
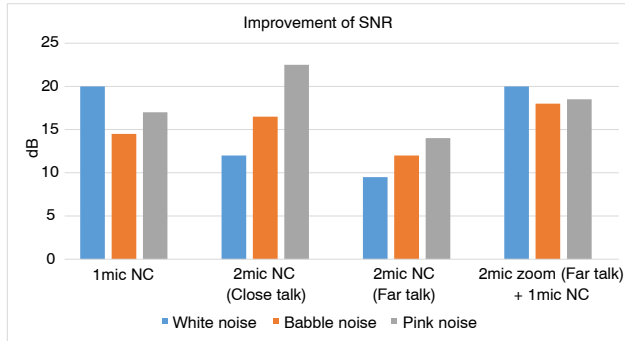- 2mic noise canceller + 1mic noise canceller for far talk:
  CF = Strong, NC = Strong

**Figure 1. Improvement of SNR
of each Noise Canceller**
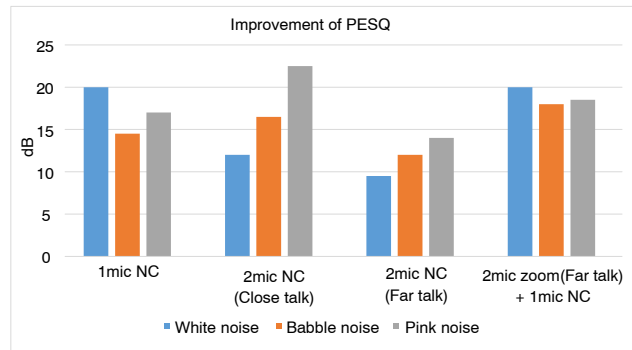
**Figure 2. Improvement of PESQ Score
of each Noise Canceller**

Relationship between Noise Cancel Performance and Mic Power Difference of 2mic Noise Canceller (Close Talk for REC)

This section explains the relationship between noise cancel performance and mic power difference of 2mic noise canceller.

Table 14. POWER DIFFERENCE OF MICROPHONES VS PESQ IMPROVEMENT OF 2MIC NOISE CANCELLER (CLOSE TALK FOR REC)

Noise Type	Sound Level Difference between Main Mic and Sub Mic								
	6 dB	6.5 dB	7 dB	7.5 dB	8 dB	9 dB	12 dB	18 dB	24 dB
White	−0.33	−0.01	0.19	0.27	0.32	0.38	0.48	0.53	0.55
Babble	−0.33	−0.08	0.11	0.21	0.27	0.35	0.43	0.49	0.50
Pink	−0.23	0.14	0.34	0.43	0.49	0.56	0.65	0.72	0.75
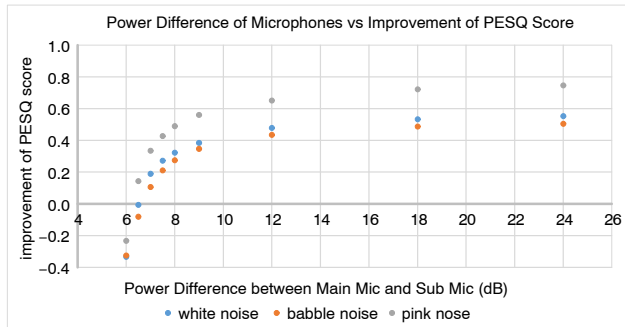
Figure 3. Power Difference of Microphones vs PESQ Improvement of 2mic Noise Canceller (Close Talk for REC)

To obtain enough performance of 2mic noise canceller which uses difference of sound pressure between microphones, the difference of sound pressure is more than 12 dB.

Evaluation of real environment

For evaluation of real environment, we collect test data using LC823450 EVK for 2mic noise canceller (Close talk for REC). We selected "Strong" parameter of noise cancel level from default parameter setting.

Table 15. IMPROVEMENT OF 2MIC NOISE CANCELLER (CLOSE TALK FOR REC) IN REAL ENVIRONMENT

Parameter	Test Conditions	Value	Unit
SNR Improvement	White Noise, 6 dB SNR	18.0	dB
	Babble noise, 6 dB SNR	19.5	dB
	Pink Noise, 6 dB SNR	20.0	dB
PESQ improvement	White Noise, 6 dB SNR	0.40	–
	Babble noise, 6 dB SNR	0.55	–
	Pink noise, 6 dB SNR	0.45	–