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**APPLICATION NOTE**



## Performance of LC823455 Noise Canceller

### Introduction





This application note describes the performance of LC823455 Noise Canceller.

The canceller enables customers to improve audio characteristics for products such as Wireless headsets, Wireless speakers or Voice recorders.

The intended audience is customers who are developing audio application using LC823455.

### Overview of Noise Canceller

The table in Figure 1 shows the types of noise canceller implemented within LC823455.

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 

NOTE: "Large distance between mics for HF" is the same as "Voice close to mic" from an internal processing perspective.

**Figure 1. Types of Noise Canceller for LC823455**

The 1 mic noise canceller (small distance between mics for HF) assumes that the distance between the 2 microphones is very small, as is the case with Earbuds. This is achieved by combining the 1 mic noise canceller with spatial techniques such as beam forming. The 1 mic noise canceller is intended for stationary noise. Therefore, non-stationary noise such as background babbling cannot be reduced using 1 mic noise canceller.

The 2 mic noise canceller (Close talk for REC) assumes that the distance between the 2 mics is large and the main mic is near the mouth as in the case of a smart phone. The 2 mic noise canceller can reduce stationary and non-stationary noise. For the most effective performance, the power difference between the microphones must be greater than 12 dB.

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

"Large distance between mics for HF" is equivalent to "Voice close to mic for REC" from an internal processing point of view.

### Evaluation Environment and Condition

In the absence of an anechoic room suitable for use as the evaluation environment, reflection off wall surfaces will influence the resulting data when using the microphones implemented on the EVK. Therefore, the performance evaluation was carried out in simulation on a PC. For 2 mic noise canceller (Close talk for REC), we used real data captured with EVK.

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

**1 mic Noise Canceller (small mic distance for HF)**

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

**Table 1. EVALUATION CONDITION FOR 1 MIC NOISE CANCELLER (Small Mic Distance for HF)**

Items	Contents
Parameters of 1 mic 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) to 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 already had the ambient noise reduced using the sound tool (Goldwave).

Furthermore, 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 to the 1 mic noise canceller performance for the sound which comes from the front direction.

**2 mic Noise Canceller (Close Talk for REC)**

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

**Table 2. EVALUATION CONDITION FOR 2 MIC NOISE CANCELLER (Close Talk for REC)**

Items	Contents
Parameters of 2 mic 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) was adjusted so that Rch (main) is +18 dB 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 already had the ambient noise reduced using the sound tool (Goldwave).

**2 mic Noise Canceller (Far Talk for REC)**

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

**Table 3. EVALUATION CONDITION FOR 2 MIC NOISE CANCELLER (Far Talk for REC)**

Items	Contents
Parameters of 2 mic 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 1 mic noise canceller) CF = Weak, NC = Weak CF = Strong, NC = Strong
Test data	Male data (male.wav) and female data (female.wav) To create conditions that simulate a target signal arriving from the front direction, the signal in the Rch signal is the same as in the Lch. To 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. (The noise data arrives from an angle of 90 degrees on the left side.) To calculate PESQ score correctly, male.wav or female.wav already had the ambient noise reduced using the sound tool (Goldwave).

**Measurement of Evaluation**

We evaluated performance of the noise canceller by using following parameters.

**Table 4. MEASUREMENT OF EVALUATION**

Improvement of SNR	This evaluation uses SNR which is calculated using 8000 samples of silence area of before-cancel data and after-cancel data. To reduce the influence of direct current, the signal goes through a high-pass filter (Fc = 100 Hz) before calculating SNR.
Improvement of PESQ score	This evaluation uses the improvement in PESQ scores calculated before and after noise cancellation.

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**

**1 mic Noise Canceller (small mic distance for HF)**

**Table 5. SNR IMPROVEMENT OF 1 MIC 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 6. PESQ SCORE IMPROVEMENT OF 1 MIC 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

**2 mic Noise Canceller (Close talk for REC)**

**Table 7. SNR IMPROVEMENT OF 2 MIC 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 8. PESQ SCORE IMPROVEMENT OF 2 MIC 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	6 dB	0.52	0.55
		12 dB	0.48	0.52
		18 dB	0.56	0.59
	Babble noise	6 dB	0.47	0.49
		12 dB	0.45	0.49
		18 dB	0.45	0.50
	Pink noise	6 dB	0.62	0.72
		12 dB	0.63	0.80
		18 dB	0.74	0.72

2 mic Noise Canceller (Far talk for REC)

Table 9. SNR IMPROVEMENT OF 2 MIC 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 10. PESQ SCORE IMPROVEMENT OF 2 MIC 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

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

Table 11. SNR IMPROVEMENT OF 2 MIC NOISE CANCELLER WITH 1 MIC 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

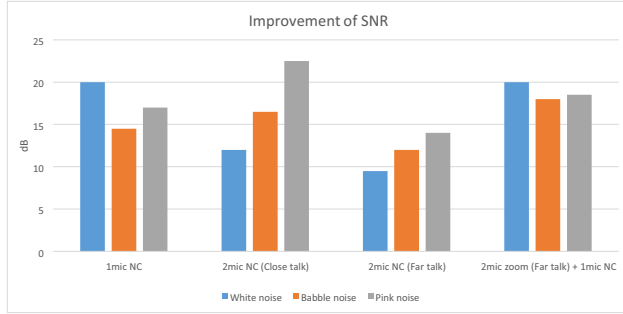
Table 12. PESQ SCORE IMPROVEMENT OF 2 MIC NOISE CANCELLER WITH 1 MIC NOISE CANCELLER EVALUATION (Far talk for REC)

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

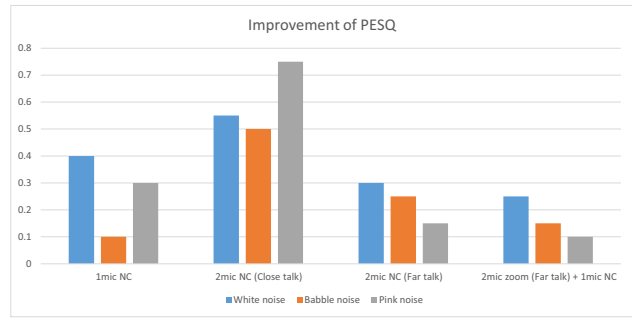
**Compare Performance of each Noise Canceller**

Figure 2 and Figure 3 show a comparison of improvement of each noise canceller. In these figure, 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 2. Improvement of SNR of each Noise Canceller**



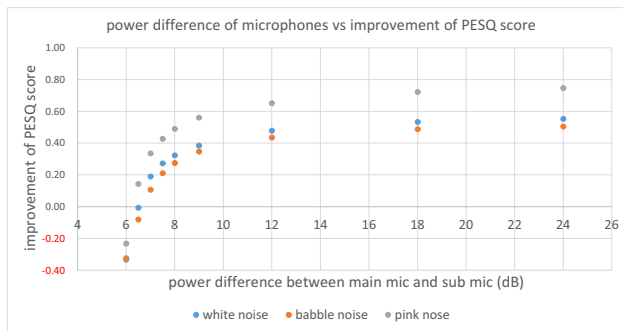
**Figure 3. Improvement of PESQ Score of each Noise Canceller**

**Relationship between Noise Cancelling Performance and Mic Power Difference of 2 mic Noise Canceller (Close talk for REC)**

This section explains the relationship between the noise cancelling performance and the mic power difference for the 2 mic noise canceller.

**Table 13. POWER DIFFERENCE OF MICROPHONE vs PESQ IMPROVEMENT OF 2 MIC 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 4. Power Difference of Microphone vs PESQ Improvement of 2 mic Noise Canceller (Close talk for REC)**

The performance of the 2 mic canceller is a function of the difference in sound pressure between the 2 microphones. Therefore, in order to achieve adequate performance, the difference in sound pressure must be more than 12 dB.


**Evaluation in a Real Environment**

For evaluation in a real environment, we collected test data for the 2 mic noise canceller (Voice Close to Mic for REC) using the LC823455 EVK. This was done with the noise cancelling level set to "Strong" in the parameter settings.

**Table 14. IMPROVEMENT OF 2 MIC 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	-

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