Application Note

AIC3262 Dual-Microphone Noise Canceller Tuning Guideline

February 6, 2012

1. Overview

TI AIC3262 uplink dual-mic noise canceller consists of two components; DualMic_NC_Preproc and DualMic_NC_Main. DualMic_NC_Preproc runs two adaptive filters that intend to de-correlate speech and noise signal. Practically, it reduces diffused noise in the primary channel only by 2~4 dB while it removes speech well in the reference channel. DualMic_NC_Main is a frequency-domain nonlinear noise suppressor. It uses the reference channel output of DualMic_NC_Preproc for noise reference signal and further reduces noise level in the primary channel. Noise reduction in DualMic_NC_Main is configurable and can be up to 25 dB. Normally, 15 ~ 20 dB preserve good voice quality.

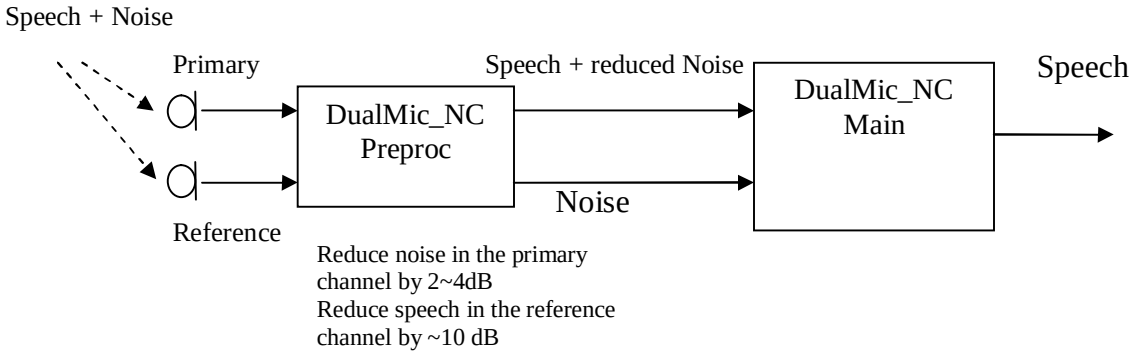

Figure 1: Dual-Microphone noise canceller overview

Note that TI dual-mic NC performance is sub-optimal in some conditions. Optimal performance requires good acoustic separation between two microphones. The primary microphone should capture voice better than the reference microphone. The primary microphone voice level should be higher than the reference by at least 5 dB. The voice level at each microphone should be measured in proper position (e.g. handheld position or handsfree position).
The following is the recommended microphone position for smart phone platform.

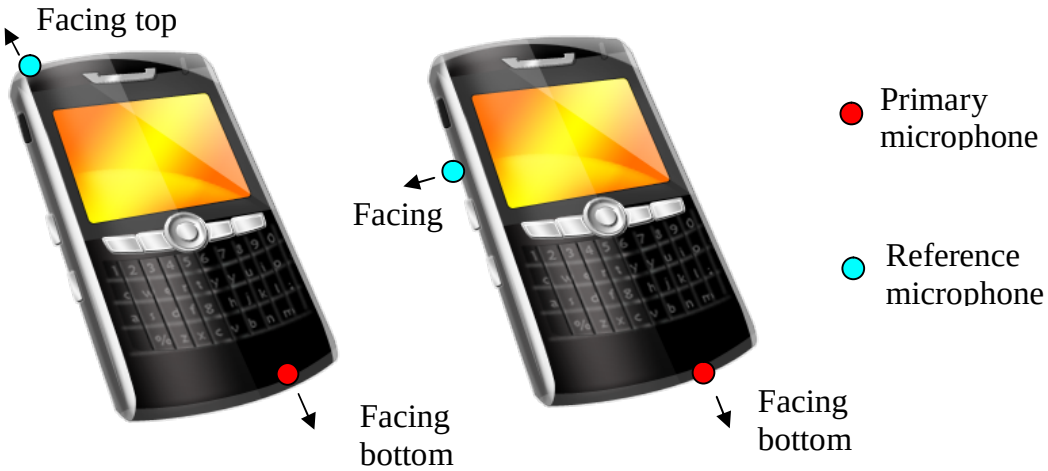

Figure 2: Recommended microphone position examples

The figure below shows an example of dual-mic noise canceller system on GDE. DualMic_NC_Preproc and DualMic_NC_Main are connected three I/O ports. There first two are the primary and reference signal paths. The third port connection is control flow for identifying initial convergence period (see Sec 2 for detail). Biquad and Shift_Scale components follow DualMic_NC_Main for uplink signal frequency shape and level adjustment.
Note that DC-removal filter should be set in Dec4xIn component. Cutoff frequency is typically set to 80 – 100 Hz. AGC_HPF_n0, AGC_HPF_n1 and AGC_HPF_d1 are coefficients of 1st order IIR filter embedded in Dec4xIn (they have nothing to do with AGC). Values in Figures are an example for 8 kHz sampling operation.

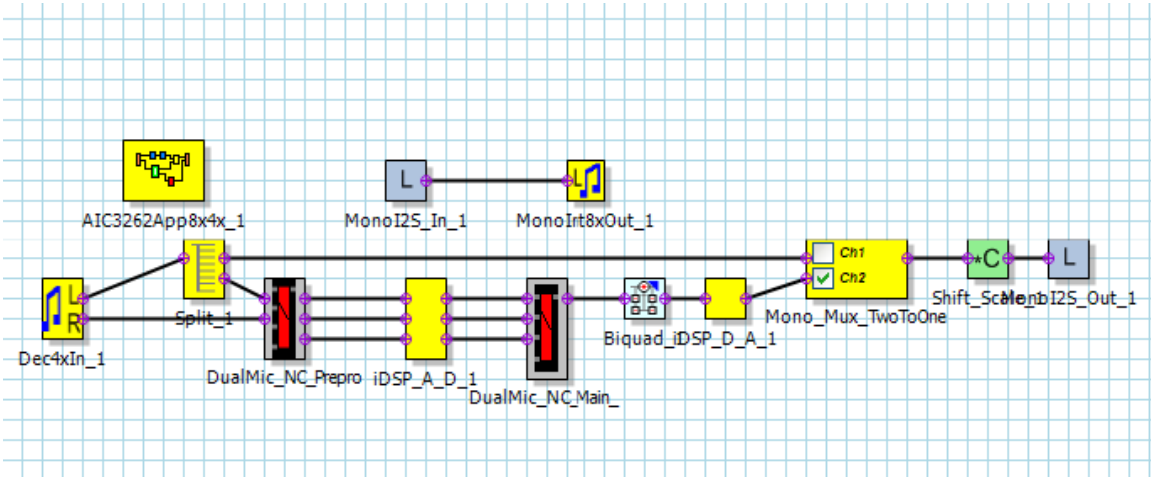

Figure 3: Dual-mic NC example process flow

Runtime Properties: All Rates	
AGC_Enable	Disable
Volume_Control_dB	0.0
Left_Fine_Gain	0dB
Right_Fine_Gain	0dB
Alpha	0.00560283660888671875
1minus2alpha	0.9887943267822265625
Energy_Time_Constant_ms	2_ms
AGC_Target_Level	-10dB
AGC_Gain_Hysteresis	Disable
AGC_Hysteresis_Setting	Disable
AGC_Noise_Threshold	-90dB
AGC_Maximum_Gain	0.0
AGC_Attack_Time	27
AGC_Attack_Time_Factor	1x
AGC_Decay_Time	43
AGC_Decay_Time_Factor	1x
AGC_Noise_Debounce_Time	128x1WordCLK
AGC_Signal_Debounce_Time	0x1WordCLK
AGC_Gain_Flag	0.0
AGC_HPF_n0	0.962188243865966796875
AGC_HPF_n1	-0.962188243865966796875
AGC_HPF_d1	0.92437744140625

Figure4 : Dec4xIn run-time parameter window

2. DualMic_NC_Preproc

DualMic_NC_Preproc component separates a primary voice signal from all other types of noise including interfering talker's voice. The component includes two adaptive filters; H1 and H2. H1 estimates noise signal in the primary channel while H2 estimates speech signal in the secondary channel.

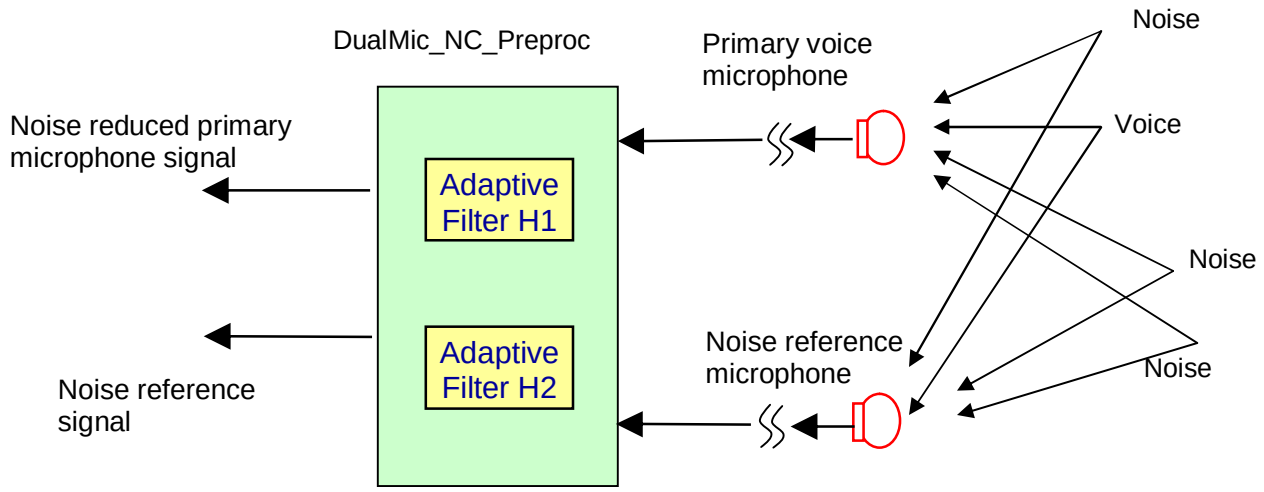

Figure 5 DualMic_NC_Preproc

a. Design-Time Properties

The table below shows a subset of DualMic_NC_preproc design-time parameters.

	Parameter Name	Description	Recommended (handset mode)	Recommended (spkphone mode)
1	mu1_step	H1 filter step size	0.0008	0.0008
2	mu2_step	H2 filter step size	0.008	0.008
3	mu1_init_step	H1 filter initial step size	0.08	0.08
4	mu2_init_step	H2 filter initial step size	0.08	0.08
5	Speech_Level_Thresh	Speech level difference	See below	1.0001
6	Power_thresh	H1/H2 maxim filter power	1.0	3.0

Table 1: DualMic_NC_Preproc design-time parameters for 8 kHz sampling rate

	Parameter Name	Description	Recommended (handset mode)	Recommended (spkphone mode)
1	mu1_step	H1 filter step size	0.0016	0.0016
2	mu2_step	H2 filter step size	0.016	0.016
3	mu1_init_step	H1 filter initial step size	0.16	0.16
4	mu2_init_step	H2 filter initial step size	0.16	0.16
5	Speech_Level_Thresh	Speech level difference	See below	1.0001
6	Power_thresh	H1/H2 maxim filter power	1.0	3.0

Table 2: DualMic_NC_Preproc design-time parameters for 16 kHz sampling rate

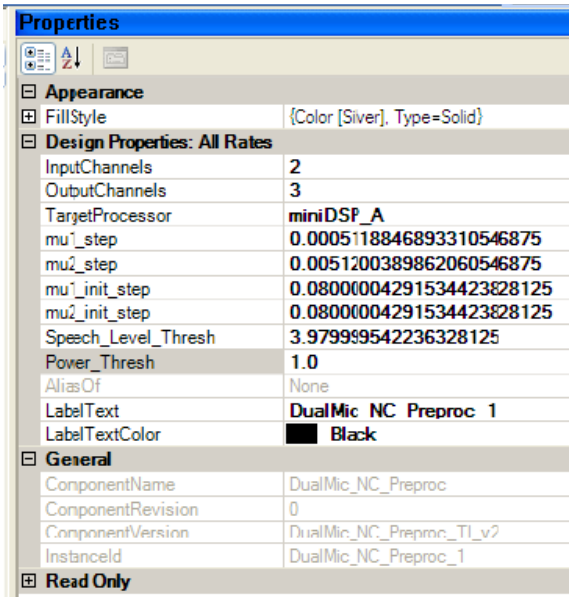

Figure 6: DualMic_NC_Preproc Design Properties window

mu1_step

H1 filter step size. Larger number makes filter converged faster for quick noise environment change, but it may cause filter divergence.

mu2_step

H2 filter step size. Larger number makes filter converged faster for quick noise environment change, but it may cause filter divergence.

mu1_init_step

H1 filter initial step size. During initial convergence period, H1 filter uses larger step size for faster convergence.

mu2_init_step

H2 filter initial step size. During initial convergence period, H2 filter uses larger step size for faster convergence.

Speech_Level_Thresh

Speech level difference between two microphone inputs. Measure speech power in normal position of use case. Conversion of speech level difference in dB is described below. It is assumed that primary microphone speech level is higher than the level in the reference microphone, and speech level difference is 0 dN or positive dB value. This parameter is a linear-scale value and need conversion below.

Speech_Level_Thresh = $10^{speech\_level\_diff\_dB / 10}$

To make the component work better, set speech_level_diff_dB 1~2 dB lower than actual measurement. For example, if speech level difference is found 6 dB, compute Speech_Level_Thresh with 4 dB.

Power_thresh

If H1 or H2 filter power exceeds this parameter value, both the filter will reset to initial condition (i.e. all zeros). This is a linear-scale value.

b. Tuning Process

i. Usually, all four step sizes do not need to be changed. If filter reset (i.e. filter divergence) is observed, reduce it a little by little.
ii. Pewer_tresh does not usually need to be changed either.
iii. Measure speech level at the primary and reference microphone and set up Speech_Level_Thresho as described in 2.a.
iv. Verify DualMic_NC_Preproc behavior by recording the primary and reference channel output of DualMic_NC_Preproc. Usually, noise level in the primary output is lower than the primary input by 2~4 dB while speech level in the reference output is 5~10 dB lower than the reference input.

3. DualMic_NC_Main

DualMic_NC_Main reduces stationary and non-stationary noise level in the primary input channel signal. The noise spectrum and level is estimated from noise reference signal in the reference input signal.

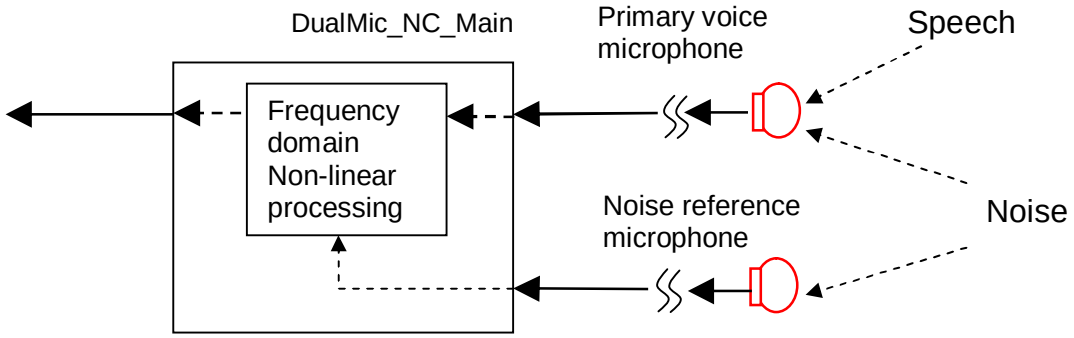

Figure 7: Dual microphone noise canceller without two-mic cross-talk coupling

The component assumes the second input port is noise reference signal. If a target system has acoustic and/or electrical cross-talk coupling between two microphones, DualMic_NC_Preproc should be used on the front end. DualMic_NC_Preproc reduces speech signal level in the reference channel and provides good noise reference signal to DualMic_NC_Main. The figure below is an example configuration.

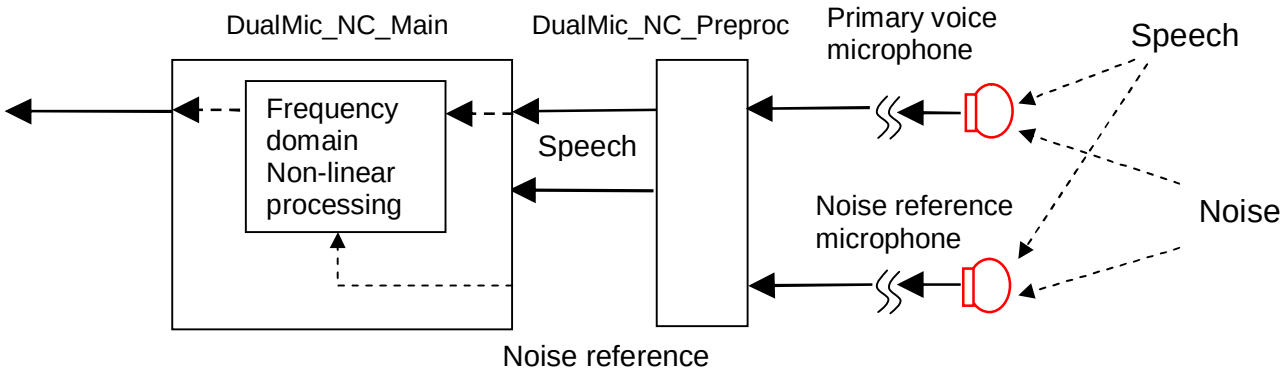

Figure 8: Dual microphone noise canceller with two-mic cross-talk coupling

If the component is used in two-way communication system, the 4th input channel should be enabled (DualMic_NC_Preproc and DualMic_NC_Main have three port connection as default – see Sec 1). The component takes downlink signal (receiving signal from the other side) in the 4th input channel and controls noise reduction strength for optimal noise canceller performance during double-talk. Note that the component does not act as an echo canceller. If echo needs to be removed, AEC component should be used along with the noise canceller component.

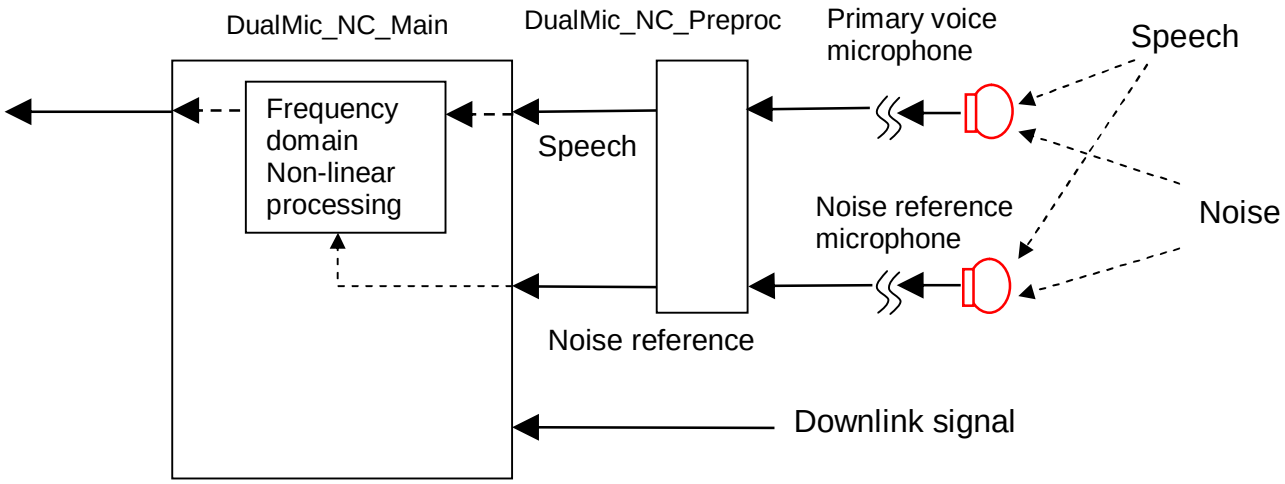

Figure 9: Dual microphone noise canceller for communication system

a. Run-Time Properties

Parameter Name	Description	Recommended value	Default Value
NR_LEVEL	Maximum Noise reduction level	0.0631 – 0.1778 (-24 dB ~ -15 dB)	0.1259 (-18 dB)
NOISE_LEVEL_Adj	Noise level adjustment	0.5 ~ 1.0	0.9

Table 3: DualMic_NC_Main run-time parameters

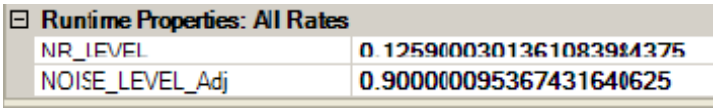

Figure 10: DualMic_NC_Main run-time properties window

NR_Level
The component suppresses noise as much as the specified level. The smaller value (stronger attenuation) will reduce noise more aggressively. It is specified in linear scale. If noise reduction level is desired to be set to -15 dB, set the to $10^{(-0.05*15)}$. The recommended range of this parameter is - 15 ~ - 24 dB.

NOISE_LEVEL_Adj
Noise spectrum and level in the primary input channel is estimated from noise reference signal in the reference channel. This parameter is gain for the reference input. The smaller value (< 1.0) reduces the estimated noise level and as a result preserves voice better while larger value (> 1.0) increases the estimated noise level and reduces noise level more aggressively with some voice distortion such as chopping artifact.

b. Design-Time Properties

Property	Description	Recommended value	Default Value
Smooth_factor	Smoothing factor for signal level estimation	0.5 – 0.95	0.8
FreqShape_table1~28	Frequency shaping factor	See below.	1.0

Table 4: DualMic_NC_Main design-time parameters

smooth_factor
Smoothing factor for signal level estimation. The smaller value indicates weaker smoothing while the larger value indicating stronger smoothing. The weaker smoothing makes voice sound brighter but produces musical tone noise. The larger value eliminates musical tone noise, but might make voice slightly sound muffled.

FreqShape_table1~28
Each table is corresponding to (0.5*Fs/28)*i , i = 1…28. The smaller value setting attenuates more aggressively with some voice signal attenuation in the corresponding frequency. The larger value preserves voice signal better but does not aggressively reduce noise level in that frequency. If voice sounds less intelligible, aggressively reduce lower frequency signal by setting them to smaller value. The following is the example setting for 8 kHz operation.

Design Properties: All Rates	
InputChannels	3
OutputChannels	1
TargetProcessor	miniDSP_D
smooth_factor	0.799999523162841796875
FreqShape_table1	0.0625019073486328125
FreqShape_table2	0.1000003814697265625
FreqShape_table3	0.5
FreqShape_table4	1.0
FreqShape_table5	1.0001010894775390625
FreqShape_table6	1.0001010894775390625
FreqShape_table7	1.0001010894775390625
FreqShape_table8	1.25
FreqShape_table9	1.25
FreqShape_table10	1.5
FreqShape_table11	1.5
FreqShape_table12	1.5
FreqShape_table13	1.5
FreqShape_table14	1.5
FreqShape_table15	1.200000762939453125
FreqShape_table16	1.0001010894775390625
FreqShape_table17	1.0001010894775390625
FreqShape_table18	1.0001010894775390625
FreqShape_table19	1.0001010894775390625
FreqShape_table20	1.0001010894775390625
FreqShape_table21	1.0001010894775390625
FreqShape_table22	1.0001010894775390625
FreqShape_table23	1.0001010894775390625
FreqShape_table24	1.0001010894775390625
FreqShape_table25	1.0001010894775390625
FreqShape_table26	1.0001010894775390625
FreqShape_table27	0.0625019073486328125
FreqShape_table28	0.0625019073486328125

Figure 11: DualMic_NC_Main design-time properties window

c. Tuning Process

a. Start with default parameter values (see Table 3 and 4)
b. If voice chopping is observed, lower NOISE_LEVEL_ADJ
c. To increase noise reduction strength, 1) decrease NR_Level, increase NOISE_LEVEL_ADJ and/or increase smooth factor.
d. If voice sounds muffled, decrease 1~3rd band frequency shaping parameters
e. If voice sounds synthetic increase 1~3rd band frequency shaping parameters
f. Adjust smooth factor to control trade off of musical tone noise/click/thumps against noise-echo (noise surge) artifact.

New Design-Time Properties – Planned to be added in v4

Two new design-time properties below plan to be added to DualMic_NC_Main. It is ideal to enable both features for the best performance, but it costs memory and cycles. Two features can be independently enabled and disabled.

- Frequency Matching in Two Channels
  If Frequency matching flag is turned on, DualMic_NC_Main will automatically compensate mismatch of noise level between the primary and reference channel. Noise frequency characteristic sometimes does not match between the primary and reference channel. It could come from enclosure difference between two microphones, or DualMic_NC_Preproc could change noise frequency characteristic after the filtering. If noise frequency characteristic is known, biquad filter can be alternatively inserted in the reference signal path instead of enabling this feature.
- Additional Noise Suppression in Long Pause
  If this feature is enabled, DualMic_NC_Main will try to suppress noise stronger than NR_LEVEL by 10 dB in long pause (non-speech) period. This is not a noise-gate and will not produce noise pumping artifact.