

# ON Semiconductor

## Is Now

# onsemi™

To learn more about onsemi™, please visit our website at  
[www.onsemi.com](http://www.onsemi.com)

---

**onsemi** and **onsemi** and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "**onsemi**" or its affiliates and/or subsidiaries in the United States and/or other countries. **onsemi** owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of **onsemi** product/patent coverage may be accessed at [www.onsemi.com/site/pdf/Patent-Marking.pdf](http://www.onsemi.com/site/pdf/Patent-Marking.pdf). **onsemi** reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and **onsemi** makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does **onsemi** assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using **onsemi** products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by **onsemi**. "Typical" parameters which may be provided in **onsemi** data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. **onsemi** does not convey any license under any of its intellectual property rights nor the rights of others. **onsemi** products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use **onsemi** products for any such unintended or unauthorized application, Buyer shall indemnify and hold **onsemi** and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that **onsemi** was negligent regarding the design or manufacture of the part. **onsemi** is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner. Other names and brands may be claimed as the property of others.

## Performance of Noise Canceller of LC823450



ON Semiconductor®

[www.onsemi.com](http://www.onsemi.com)

### INTRODUCTION

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





The customer can improve of audio characteristics by using this canceller. Its function can be used for various products such as Wireless headset, Earbuds, 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

### APPLICATION NOTE

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 anechoic 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 hereafter). 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<br>FFT size : 256<br>Noise cancel level (parameter is H_min) :<br>0.25 (H_min is 0x20000000)<br>0.125 (H_min is 0x10000000)<br>0.0625 (H_min is 0x08000000)<br>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.<br><br>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<br>FFT size: 256<br>Noise cancel level<br>“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<br><br>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<br>FFT size: 256<br>HPF: Off<br>Stereo Emphasis:<br>mic distance: 2 samples.<br>Emphasis gain: 0.5<br>Noise cancel level<br>(2mic noise canceller)<br>CF = Weak, NC = Off<br>CF = Strong, NC = Off<br>(2mic noise canceller with 1mic noise canceller)<br>CF = Weak, NC = Weak<br>CF = Strong, NC = Strong                                                                                                                                                                           |
| Test Data                          | Male data (male.wav) and female data (female.wav)<br><br>To create condition that target signal is arrived from front direction, R ch signal is same as L ch<br><br>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)<br><br>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 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                 |

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 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                    |

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                  |

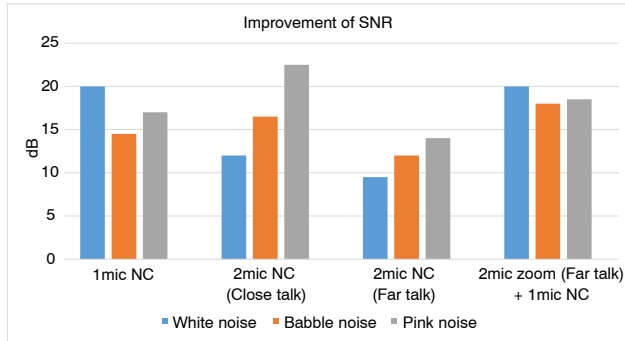
Table 13. PESQ SCORE IMPROVEMENT OF 2MIC NOISE CANCELLER WITH 1MIC NOISE CANCELLER EVALUATION (FAR TALK FOR REC)

| 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                    |

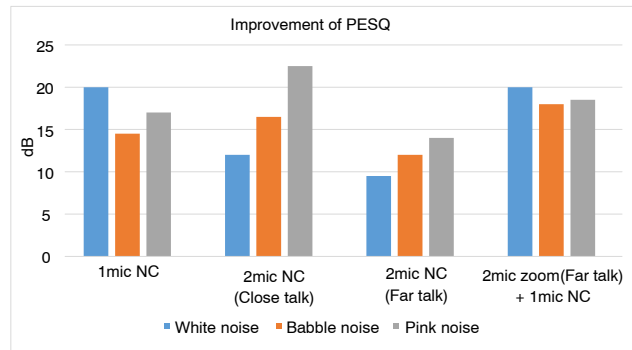
**Compare performance of each noise canceller**

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**



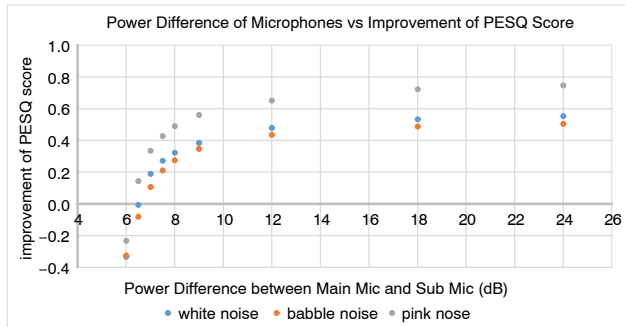
**Figure 2. Improvement of PESQ Score of each Noise Canceller**

**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  | –    |

ON Semiconductor and  are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at [www.onsemi.com/site/pdf/Patent-Marking.pdf](http://www.onsemi.com/site/pdf/Patent-Marking.pdf). ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

## PUBLICATION ORDERING INFORMATION

### LITERATURE FULFILLMENT:

Literature Distribution Center for ON Semiconductor  
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA  
**Phone:** 303-675-2175 or 800-344-3860 Toll Free USA/Canada  
**Fax:** 303-675-2176 or 800-344-3867 Toll Free USA/Canada  
**Email:** [orderlit@onsemi.com](mailto:orderlit@onsemi.com)

**N. American Technical Support:** 800-282-9855 Toll Free  
USA/Canada  
**Europe, Middle East and Africa Technical Support:**  
Phone: 421 33 790 2910

**ON Semiconductor Website:** [www.onsemi.com](http://www.onsemi.com)

**Order Literature:** <http://www.onsemi.com/orderlit>

For additional information, please contact your local  
Sales Representative