

How to Optimize Performance of AMC1304/05M25 in Voltage Sensing

Polly Chung

ABSTRACT

Many applications such as motor drives and power inverters require measurements of both current and voltage to obtain motor information, for example, speed, torque, and power, to control, monitor, and protect the system. Meanwhile, these applications will be operated in harsh, noisy environments and high voltage difference between power stage and control stage. Therefore, this is very important that the device have precise performance and isolation functions simultaneously. In this case, the AMC1304/05M25 can satisfy these criteria. AMC1304/05M25 is optimized for use in current-sensing applications using low-impedance shunts. However, the device can also be used in isolated voltage sensing. In terms of that, this application note will give you an idea of how large a shunt resistor can be used that will not influence device performance and also how to optimize the system performance if you want to use large shunt resistors. In the following content, we will focus on the AMC1305M25 device.

Contents

| | | |
|---|--|---|
| 1 | Design Consideration of AMC1305M25 | 2 |
| 2 | Optimize the Performance of AMC1305M25 With Large Shunt Resistor | 5 |
| 3 | Conclusion | 8 |

List of Figures

| | | |
|----|--|---|
| 1 | First Rough Solution to Perform Isolated Voltage Monitoring..... | 2 |
| 2 | Offset Error vs Different Shunt Resistor (AMC1305M25) | 3 |
| 3 | Gain Error vs Different Shunt Resistor (AMC1305M25) | 4 |
| 4 | INL vs Different Shunt Resistor (AMC1305M25) | 4 |
| 5 | Simplified Circuit With Series Shunt Resistor | 5 |
| 6 | Offset Error vs Different Shunt Resistor With Series Shunt Resistor (AMC1305M25) | 5 |
| 7 | Gain Error vs Different Shunt Resistor With Series Shunt Resistor (AMC1305M25) | 6 |
| 8 | Rout Simulation of OPA376 | 7 |
| 9 | Simplified Circuit With OPA376 | 7 |
| 10 | Offset Error vs Different Shunt Resistor With OPA376 (AMC1305M25) | 8 |
| 11 | Gain Error vs Different Shunt Resistor With OPA376 (AMC1305M25)..... | 8 |

1 Design Consideration of AMC1305M25

Consider the input impedance of the AMC1305M25 (R_{ID} : 25 k Ω) in designs with high-impedance shunt resistors that can cause degradation of gain and offset specifications. However, the importance of this effect depends on the desired system performance. Therefore, if AMC1305M25 is designed by such applications, there are important details that need to be remembered when you choose the resistor divider.

First, in order to efficiently use the available linear input range of AMC1305M25, the voltage across R2 must be within ± 250 mV, because the linear input range of AMC1305M25 is ± 250 mV.

The first inclination to carry out the voltage sensing is to implement the circuit which is shown in [Figure 1](#).

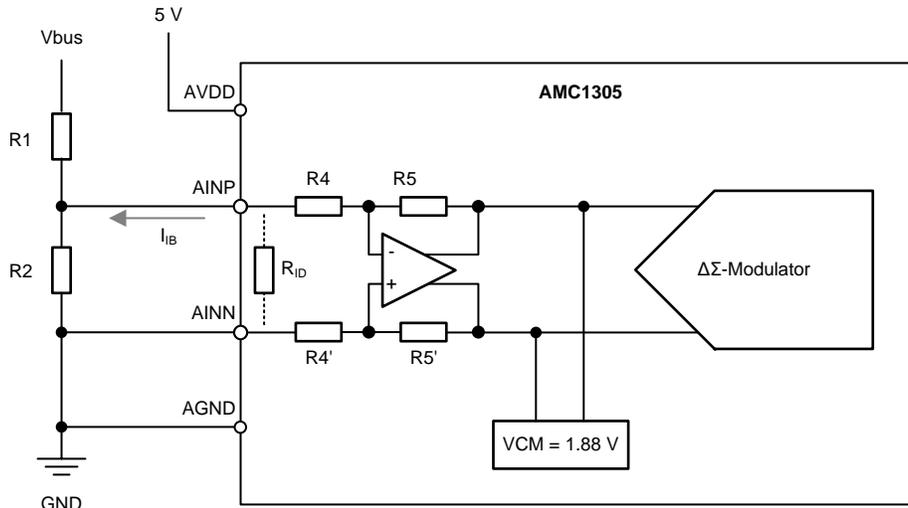


Figure 1. First Rough Solution to Perform Isolated Voltage Monitoring

The resistor divider formed by R1 and R2 in [Figure 1](#) can be governed with [Equation 1](#).

$$V_{R2} = V_{bus} \frac{R2}{R1 + R2} \quad (1)$$

Where $V_{R2} = 0.25$ V for AMC1305M25.

For instance, if the system supply is 30 V and shunt resistor is 1 k Ω , then R1 can be calculated which is 119 k Ω for AMC1305M25.

Second, as mentioned before, the larger shunt resistor is used, the larger offset, gain error will be obtained. [Equation 2](#) helps easily estimate offset error.

$$V_{OS} = R2 \times I_{ib} \quad (2)$$

Where $I_{ib} \approx 30$ μ A when $V_{cm} = 0$ V for AMC1305M25.

The gain error is calculated with [Equation 3](#):

$$E_G(\%) = \frac{V_{bus}}{R1 + (R2 // R_{IN})} \times (R2 // R_{IN}) - V_{IN} \quad (3)$$

Where $V_{IN} = 0.25$ V for AMC1305M25.

Actual influence of offset error and gain error of different shunt resistors for AMC1305M25 is shown in Figure 2 and Figure 3, Table 1 and Table 2, respectively. When the shunt resistor increases, the offset and gain error will grow linearly. For example, if the shunt resistor is equal to 0.754 Ω, the offset error and gain error is 14 μV and 0.02%. But when the shunt resistor rises to 2.4924 kΩ, the offset error and gain error will become 65.62 mV and -10.65%. That is because input bias current caused by the internal common-mode voltage at the output of the differential amplifier will flow out to shunt resistor, which will cause additional offset error. In addition, with a large shunt resistor, load effect will cause extra gain error.

In this calculation only the effect from the differential amplifier is considered, whereas both input filter and Delta-sigma modulator error are not. By contrast, the simulation considers the effect from differential amplifier and input filter, but it does not include Delta-sigma modulator error. So these will have slight differences with measurement. The simulation result is done with TI-TINA.

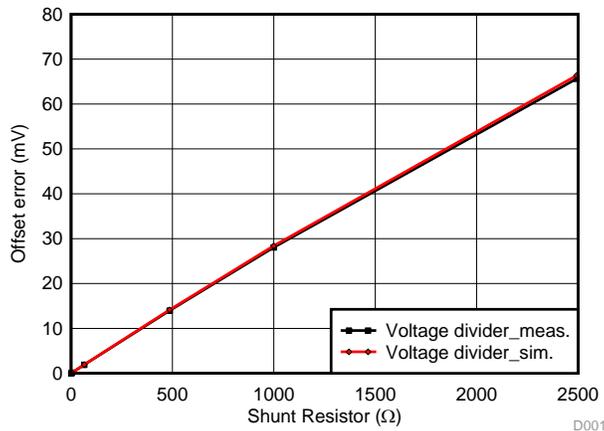


Figure 2. Offset Error vs Different Shunt Resistor (AMC1305M25)

Table 1. Offset Error vs Different Shunt Resistor (AMC1305M25)

| Offset Error-Shunt Resistor (Ω) | Voltage divider_cal. (mV) | Voltage divider_meas. (mV) | Voltage divider_sim. (mV) |
|---------------------------------|---------------------------|----------------------------|---------------------------|
| 0.754 | 0.022620 | 0.013876 | 0.022467 |
| 64.88 | 1.946400 | 1.892609 | 1.925176 |
| 486.1 | 14.58300 | 13.97162 | 14.14728 |
| 999 | 29.97000 | 28.05624 | 28.39243 |
| 2492.4 | 74.77200 | 65.61527 | 66.35166 |

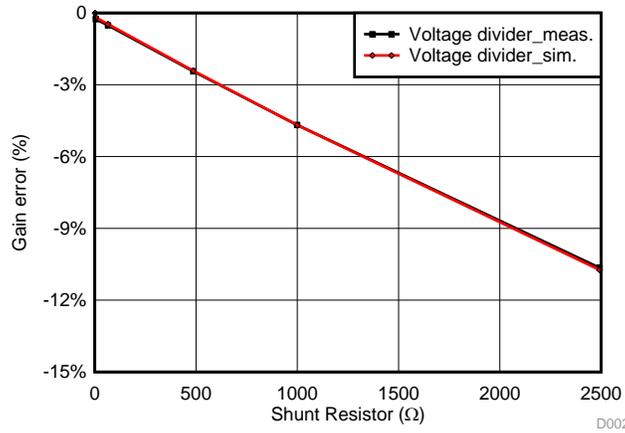


Figure 3. Gain Error vs Different Shunt Resistor (AMC1305M25)

Table 2. Gain Error vs Different Shunt Resistor (AMC1305M25)

| Gain Error-Shunt resistor (Ω) | Voltage divider_cal. (%) | Voltage divider_meas. (%) | Voltage divider_sim. (%) |
|-------------------------------|--------------------------|---------------------------|--------------------------|
| 0.754 | -0.003586% | 0.02% | -0.003587% |
| 64.88 | -0.307846% | -0.52% | -0.466670% |
| 486.1 | -2.262164% | -2.44% | -2.414913% |
| 999 | -4.539821% | -4.68% | -4.685772% |
| 2492.4 | -10.608349% | -10.65% | -10.736764% |

The INL will not be influenced by different shunt resistors. No matter how large shunt resistors will be, INL will always be within specification (max: ±4 LSB). The measurement result is shown in Figure 4 for AMC1305M25.

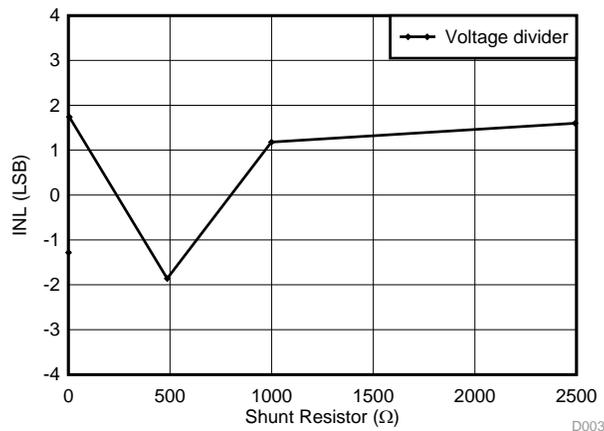


Figure 4. INL vs Different Shunt Resistor (AMC1305M25)

If the voltage sensing system is not allowed to add additional compensated circuits, but AMC1305M25's performance is desired such as offset, gain error within datasheet specification, then the shunt resistor, R2, must be lower than 0.75 Ω.

2 Optimize the Performance of AMC1305M25 With Large Shunt Resistor

If the system needs to use a large shunt resistor to realize voltage sensing, then there are two methods that can help you minimize system error.

Method 1:

Series resistor at the negative input (AINN) of the AMC1305M25 with a value equal to the shunt resistor R2 (that is R2' = R2 in Figure 5) to eliminate the effect of the bias current. This method can help minimize offset error, but will cause extra gain error. The effect can be calculated using Equation 4 with R5 = R5' = 50 kΩ and R4 = R4' = 12.5 kΩ for AMC1305M25.

$$E_G(\%) = \left(1 + \frac{R4}{R4' + R2'} \right) \times 100\% \tag{4}$$

The simulation and measurement result of AMC1305M25 is shown in Figure 6 and Figure 7. The offset error can be minimized from 13.97 / 65.62 mV to -0.123 / -0.069 mV when the shunt resistor is equal to 486.1 / 2.492 kΩ, but gain error will increase from -2.44 / -10.65% to -3.87 / -16.44%, respectively.

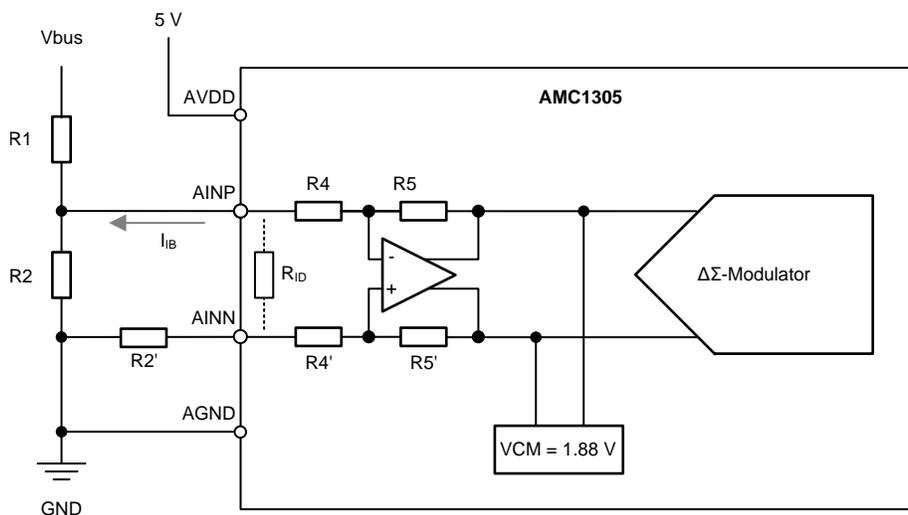


Figure 5. Simplified Circuit With Series Shunt Resistor

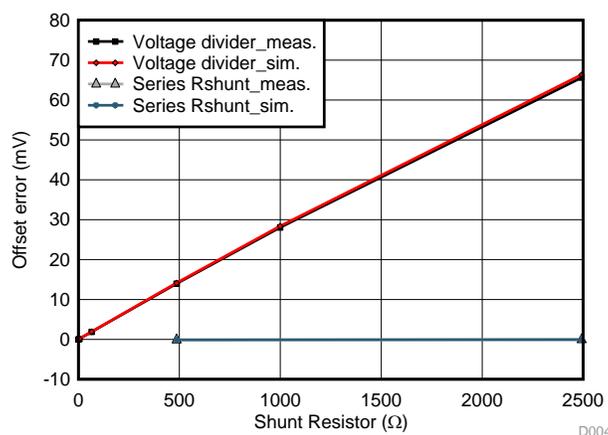


Figure 6. Offset Error vs Different Shunt Resistor With Series Shunt Resistor (AMC1305M25)

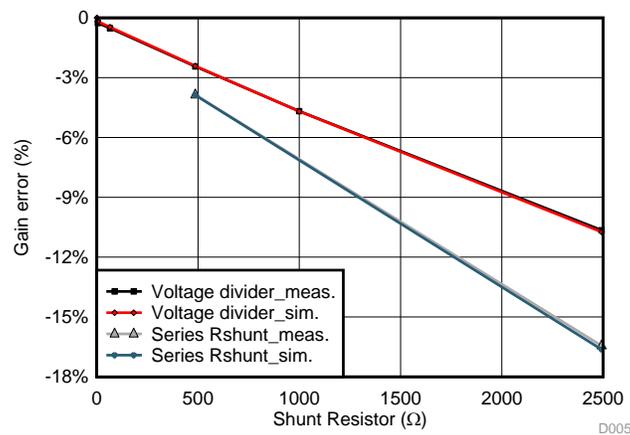


Figure 7. Gain Error vs Different Shunt Resistor With Series Shunt Resistor (AMC1305M25)

Method 2:

Adding an op amp between the voltage divider and the AMC1305M25 can optimize overall system performance. The characteristic of an op amp can help minimize both offset and gain error from bias current and load effect.

2.1 Choose Suitable Op Amp

In order to ignore errors which come from the op amp, some specifications must be considered. First of all, the offset error of the op amp must be much lower than ±150 μV. Secondly, the bandwidth of the op amp must be higher than 1 MHz. Third, the input bias current must be smaller to avoid offset error. Last, closed-loop output impedance must be smaller than 0.75 Ω. Some op amp datasheets just provide open-loop output impedance, use Equation 5 to translate or use TI-TINA to simulate.

$$R_{out} = \frac{R_o}{1 + A_{ol}\beta} \tag{5}$$

Based on this criterion, OPA376 is used.

Vos(max): 25 μV, Vos(typ.): 5 μV

GBW: 5.5 MHz

I_{ib}(max): 10 pA

R_{out} at DC: 163.5 μΩ

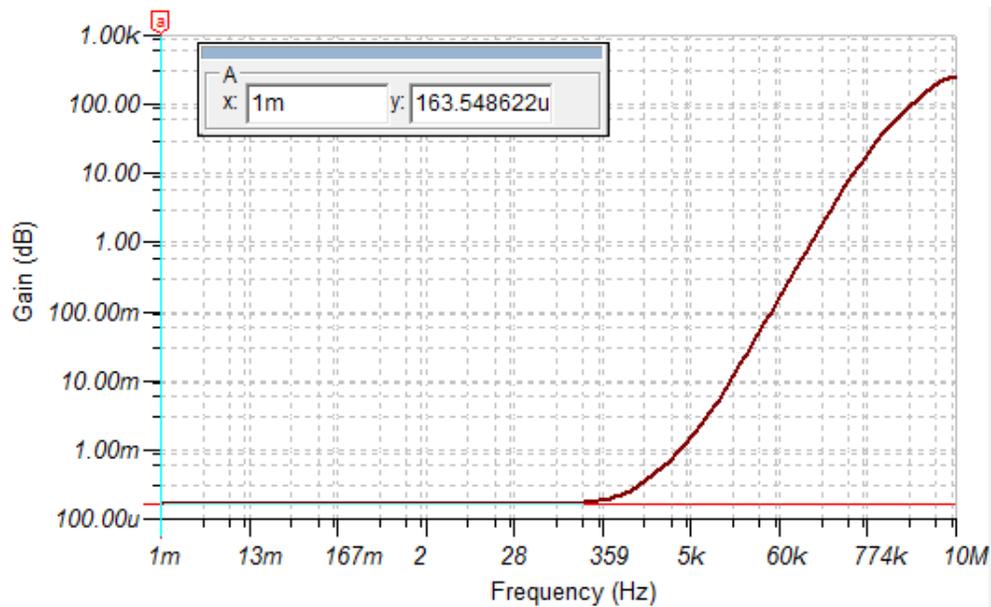


Figure 8. Rout Simulation of OPA376

The simplified circuit is presented in Figure 9. The offset and gain error can be minimized when you add OPA376 between the voltage divider and AMC1305M25. Simulation and measurement results are shown in Figure 10 and Figure 11. When the shunt resistor is equal to 486.1 / 2.492 k Ω , the offset error can be reduced from 13.97 / 65.62 mV to 0.009 / -0.007 mV and gain error will be also reduced from -2.44 / -10.65% to -0.04 / -0.04%, respectively.

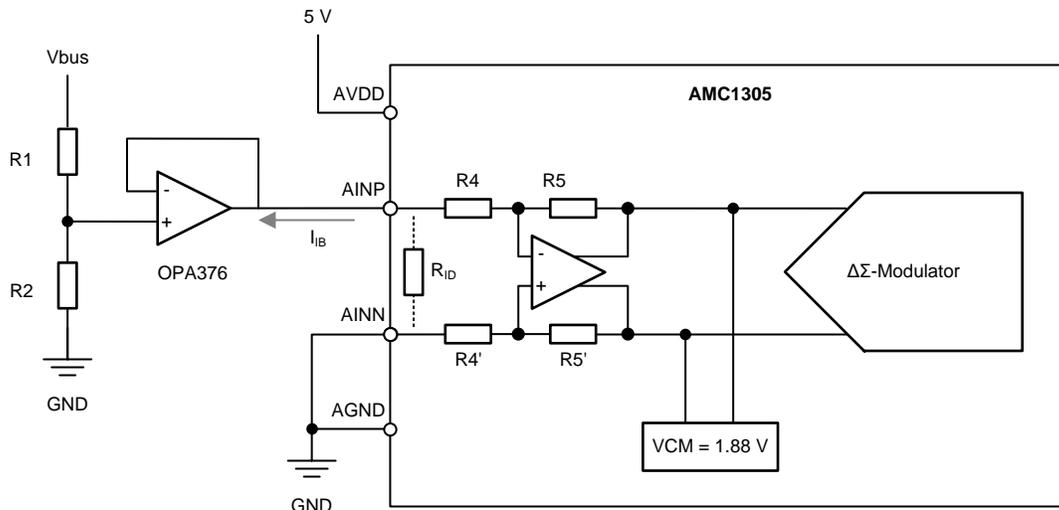


Figure 9. Simplified Circuit With OPA376

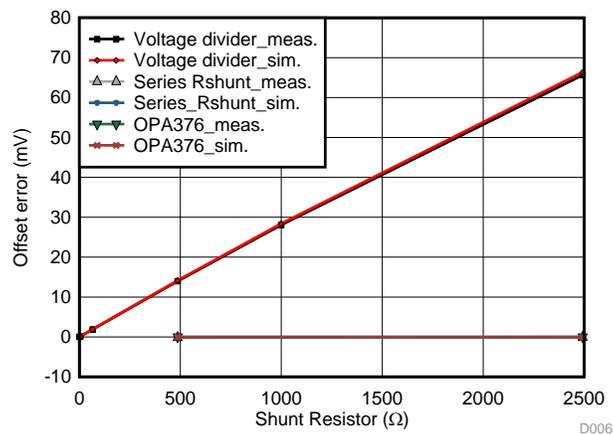


Figure 10. Offset Error vs Different Shunt Resistor With OPA376 (AMC1305M25)

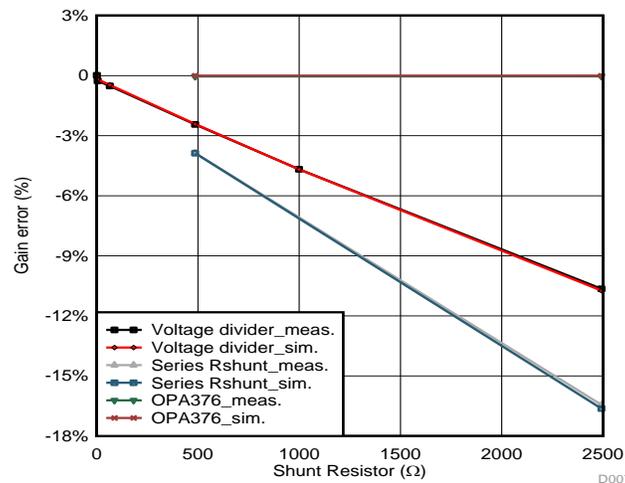


Figure 11. Gain Error vs Different Shunt Resistor With OPA376 (AMC1305M25)

The designer must be aware that if their system does not have suitable power for the op amp, you might need to design other power paths. Therefore, there is a trade-off between performance and cost.

3 Conclusion

This application report provides straightforward equations to evaluate initial performance when you add a large shunt resistor in voltage sensing, and also presents two methods to optimize performance of the AMC1304/05M25. Hence, as long as you add a suitable compensated circuit in these modulators, it can achieve good performance although TI's isolated delta-sigma modulator is optimized by current sensing.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products

| | |
|------------------------------|--|
| Audio | www.ti.com/audio |
| Amplifiers | amplifier.ti.com |
| Data Converters | dataconverter.ti.com |
| DLP® Products | www.dlp.com |
| DSP | dsp.ti.com |
| Clocks and Timers | www.ti.com/clocks |
| Interface | interface.ti.com |
| Logic | logic.ti.com |
| Power Mgmt | power.ti.com |
| Microcontrollers | microcontroller.ti.com |
| RFID | www.ti-rfid.com |
| OMAP Applications Processors | www.ti.com/omap |
| Wireless Connectivity | www.ti.com/wirelessconnectivity |

Applications

| | |
|-------------------------------|--|
| Automotive and Transportation | www.ti.com/automotive |
| Communications and Telecom | www.ti.com/communications |
| Computers and Peripherals | www.ti.com/computers |
| Consumer Electronics | www.ti.com/consumer-apps |
| Energy and Lighting | www.ti.com/energy |
| Industrial | www.ti.com/industrial |
| Medical | www.ti.com/medical |
| Security | www.ti.com/security |
| Space, Avionics and Defense | www.ti.com/space-avionics-defense |
| Video and Imaging | www.ti.com/video |

TI E2E Community

e2e.ti.com