Texas Instruments Incorporated

Piezoelectric Airflow Sensor

Test Results
May 2014
Test Setup

The Piezoelectric Airflow Sensor was tested first in a "wind tunnel" in direct airflow from a variable speed PC fan (4", variable voltage up to 12V). The PVC pipes serves to shield disturbances from the airflow in the room. It also better conditions the airflow to simulate the tight dimensions of a server. In the picture below, the 4" fan is mounted on the left end of a 2'x4" PVC pipe, and the sensor is inserted in the right end.

Test set up. The airflow sensor is "mounted" inside the PVC wind tunnel with a clamp.

Looking down the wind tunnel from the perspective of the fan.
We also used an anemometer (airflow meter) to roughly measure the airspeed at different settings of the PC fan for reference. You can see the anemometer setup in the picture below. It should be noted that since we are working with relatively low air speeds and in a tight flow cross section, the measurement is very rough and depends on the orientation of the probe and where in the PVC the flow was measured.

Image showing the use of the anemometer to measure air flow speeds.
Test Considerations

Several things need to be noted about the test set-up.

First of all, the positioning and mounting of the airflow sensor itself (the piezo element) is extremely critical to the test output in several ways that were observed during testing:

- The airspeed seemed to be higher locally around the edges of the 'wind tunnel' and calmer in the center. This is most likely due to the fact that the airflow is more turbulent at the edges and indicates that, in an end application, the presence of other objects around the sensor can affect how relatively sensitive it is to the "same" airflow. For our testing we found placing the sensor near the sides of the PVC gave best results for the sensitivity of our particular sensor element.

- The orientation of the sensor with respect to the airflow is very important. On the left of the image below you can see 3 ways in which the airflow could hit the sensor; either on-edge to the length (red), on-edge to the width (blue), or catching it broad-side (green). We found that the blue option seems to be the best, with the sensor just slightly askew from being directly on-edge. The red option gave good sensitivity but a less consistent amplitude/frequency. The green option was very poor in low conditions and almost no response except when the airflow was quite high. All tests performed below were done with the 'blue' option.
The way that the sensor is mounted was quite important to the sensitivity. On the right side of the picture above there are 3 different arrows indicating different options for where to "hold" the sensor; held by the wires near the sensor element, held just on the edge of the sensor laminate material, and held on the sensor element itself. The main affect of this is affecting the rigidity of the sensor and therefore the level of airflow it is sensitive to: the less rigidly held, lower airspeeds gave good response, but not at higher speeds. The opposite is true for more rigid sensors. The length of the sensor used is actually also very important; the longer the sensor, the more responsive it is to low air speed. The sensor we used was ~3" long and best results were found by mounting it just on the edge of the laminate material. In our testing, almost no response is seen when using very short sensors, especially when board-mounted, or longer sensors 'choked' by mounting them further up the sensor element.
Test Results

The figures below show the output of the GUI at various fan settings/ air speeds.
GUI output of piezo sensor exposed to different air speeds. Note that the GUI is scaled for 0->3.3V although the operational range is just 1.65->3.3V.
The figure below shows an extended (20 second) time scale to show the event of suddenly removing air flow from the sensor, and it's response. I rescaled the GUI in this view so that the scale is from ~1.5V -> 3.3V.

GUI output of piezo sensor when airflow is suddenly removed, simulating fan failure in a server
Texas Instruments Incorporated ("TI") reference designs are solely intended to assist designers ("Buyers") who are developing systems that incorporate TI semiconductor products (also referred to herein as "components"). Buyer understands and agrees that Buyer remains responsible for using its independent analysis, evaluation and judgment in designing Buyer’s systems and products.

TI reference designs have been created using standard laboratory conditions and engineering practices. **TI has not conducted any testing other than that specifically described in the published documentation for a particular reference design.** TI may make corrections, enhancements, improvements and other changes to its reference designs.

Buyers are authorized to use TI reference designs with the TI component(s) identified in each particular reference design and to modify the reference design in the development of their end products. **HOWEVER, NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY THIRD PARTY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT, IS GRANTED HEREIN, including but not limited to 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.

TI REFERENCE DESIGNS ARE PROVIDED "AS IS". TI MAKES NO WARRANTIES OR REPRESENTATIONS WITH REGARD TO THE REFERENCE DESIGNS OR USE OF THE REFERENCE DESIGNS, EXPRESS, IMPLIED OR STATUTORY, INCLUDING ACCURACY OR COMPLETENESS. TI DISCLAIMS ANY WARRANTY OF TITLE AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, QUIET ENJOYMENT, QUIET POSSESSION, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS WITH REGARD TO TI REFERENCE DESIGNS OR USE THEREOF. TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY BUYERS AGAINST ANY THIRD PARTY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON A COMBINATION OF COMPONENTS PROVIDED IN A TI REFERENCE DESIGN. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, SPECIAL, INCIDENTAL, CONSEQUENTIAL OR INDIRECT DAMAGES, HOWEVER CAUSED, ON ANY THEORY OF LIABILITY AND WHETHER OR NOT TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, ARISING IN ANY WAY OUT OF TI REFERENCE DESIGNS OR BUYER'S USE OF TI REFERENCE DESIGNS.

TI reserves 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 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 for TI components 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.

Reproduction of significant portions of TI information in TI data books, data sheets or reference designs 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.

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 that anticipate dangerous failures, monitor failures and their consequences, lessen the likelihood of dangerous failures 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 Buyer’s 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 an agreement specifically governing such use.

Only those TI components that 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 that have **not** been so designated is solely at Buyer’s risk, and 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.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2014, Texas Instruments Incorporated