DT0154
Design tip

Qvar for seat-occupancy detection

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Main components	
ST sensor with Qvar. Example of products:	
ILPS22QS	Dual full-scale, 1260 hPa and 4060 hPa, absolute digital output barometer with embedded Qvar electrostatic sensor
ILPS28QSW	Dual full-scale, 1260 hPa and 4060 hPa, absolute digital output barometer with Qvar detection in a water-resistant package
LSM6DSV16BX	6-axis IMU with sensor fusion, AI, Qvar, & hearable features for TWS
LSM6DSV16X	High-performance 6-axis IMU with sensor fusion, ASC, MLC, Qvar, OIS/EIS paths
LIS2DUXS12	Ultralow-power accelerometer with Qvar, AI, & anti-aliasing
Acquisition tool. Example of product:	
STEVAL-MKI109V3	Professional MEMS tool: ST MEMS adapters motherboard based on the STM32F401VE and compatible with all ST MEMS adapters

Purpose and benefits

This design tip explains how to use Qvar sensors, integrated in the 3rd generation of ST MEMS, to detect seat occupancy.

This solution adds a new feature to complement systems already benefitting from ST sensors, for example, in applications that detect accelerations, rotations, or pressure data, without the use of extra circuitry with dedicated functionality. Using Qvar sensing to detect seat occupancy, in comparison to traditional solutions, also decreases the power consumption and the architecture can be integrated in existing applications without major modifications.

An example of an application is the usage inside a vehicle to detect whether a seat is occupied and activate the airbag. Other applications inside the cabin include personalizing sound direction, enabling/disabling speakers for sound control, or adjusting/monitoring the air conditioning.

Another example of an application is the usage of seat-occupancy detection inside a bar/restaurant to monitor the occupied table/seat and optimize the service (Figure 1).

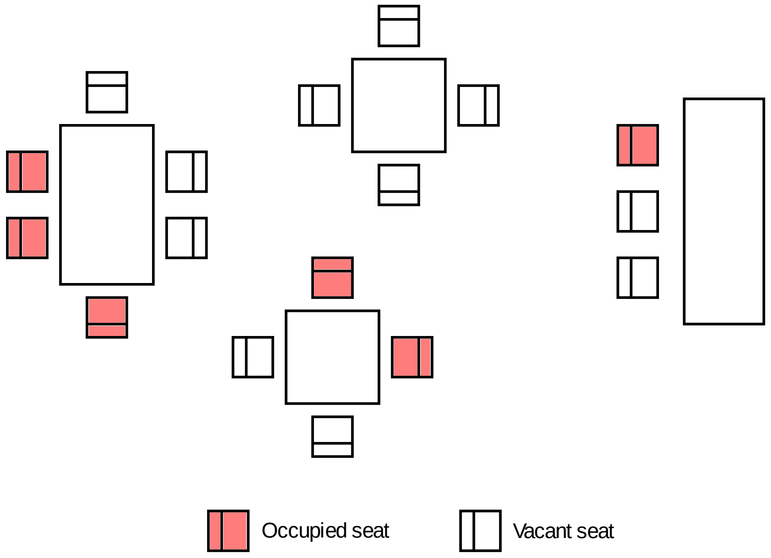

Figure 1. Example of application: detection of occupied and vacant seats in a bar

Introduction

Qvar is an electrostatic sensor from STMicroelectronics that can be used for human presence and motion detection, touch detection, and user interface (UI) applications. Qvar stands for electric charge (= Q) variation (= var). It is an electrical potential sensing channel able to measure the quasi-electrostatic potential changes using electrodes.

The applications that are appropriate for using Qvar can be differentiated based on the position of the electrodes. Examples include electrodes in direct contact with human skin, those used for proximity detection, or a dedicated electrode that can detect the electrostatic charges present in water.

As described in this design tip, Qvar can be also used to control a commercial electrode to detect seat occupancy by sensing charge variations in the conductive layers of the electrode.

For other Qvar applications, refer to the application note AN5755 “Qvar sensing” available on www.st.com.

Working principle

The Qvar sensor has a differential input with two pins called Q1 and Q2 (or Q+ and Q-). For this setup, Qvar inputs are fixed at half the power supply using a polarization network.

This feature is based on the ability of the Qvar to sense charge variations when one input is shorted to ground.

Commercial electrodes for seat-occupancy detection are made of different layers: two conductive layers kept separate by a layer of air, and two insulating layers to protect the conductive parts. When there is a force applied to the electrode (for example, the weight of a person), the two conductive layers make contact.

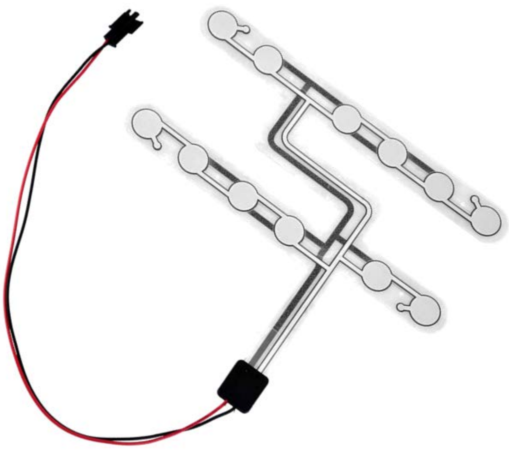

Figure 2. Commercial electrode for seat-occupancy detection

Connecting one conductive layer to the Qvar input and the other one to ground, it is possible to use the Qvar sensor to distinguish between the two states.

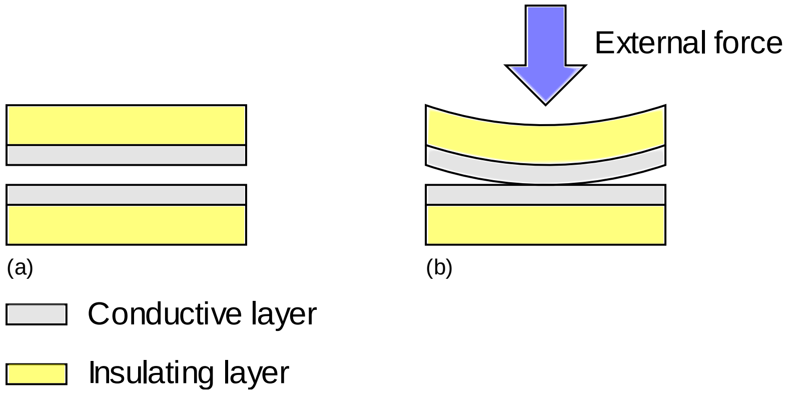

Figure 3. Section of electrode for seat-occupancy detection. In (a) the two conductive layers are isolated, separated by air. In (b) an external force pushes against the insulating layer, bringing the two conductive layers in contact.

Setup for Qvar occupancy detection

To use the Qvar sensor to control a commercial electrode for seat-occupancy detection, use the following elements:

- ST sensor with Qvar embedded (in this example, an iNEMO 6-axis IMU sensor LSM6DSV16X)
- Electrode for seat-occupancy detection (in this example, the ***custom car seat belt occupancy pressure sensor*** available on the market)
- Polarization network
- Acquisition tool (in this example, ProfiMEMS)

Figure 4 depicts the electrical connections for the iNEMO 6-axis IMU sensor, external circuitry, and electrode for seat-occupancy detection.

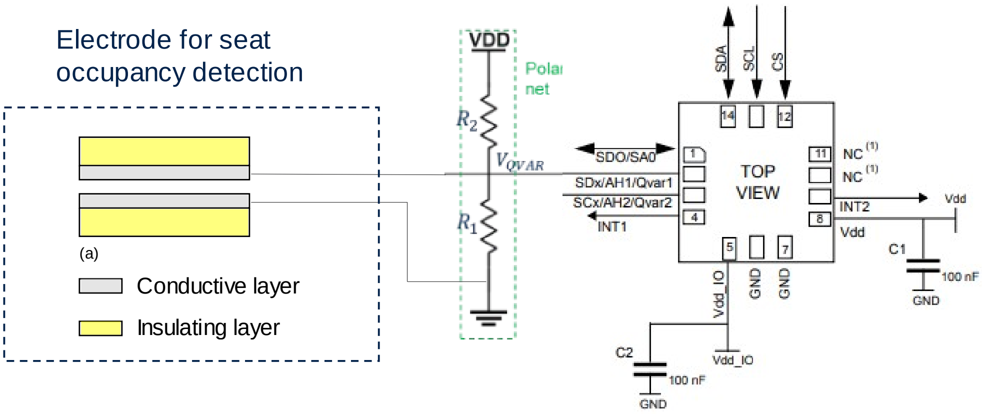

Figure 4. Electrical connections for LSM6DSV16X and electrode for seat-occupancy detection.

In this example, the iNEMO 6-axis IMU sensor was mounted on the ProfiMEMS. An external polarization network was implemented by connecting two resistors from the Qvar input to Vdd_IO and GND.

The seat-occupancy electrode has two conductive layers: one connected to a Qvar input and one connected to GND.

Using the ProfiMEMS, it is possible to use Unico software (available on st.com) to monitor the Qvar signal. It is sufficient to connect the ProfiMEMS, with the mounted iNEMO 6-axis IMU sensor, to the PC and launch Unico. After doing an easy configuration and enabling Qvar, it is possible to see the plot of the Qvar signal and monitor the seat occupancy.

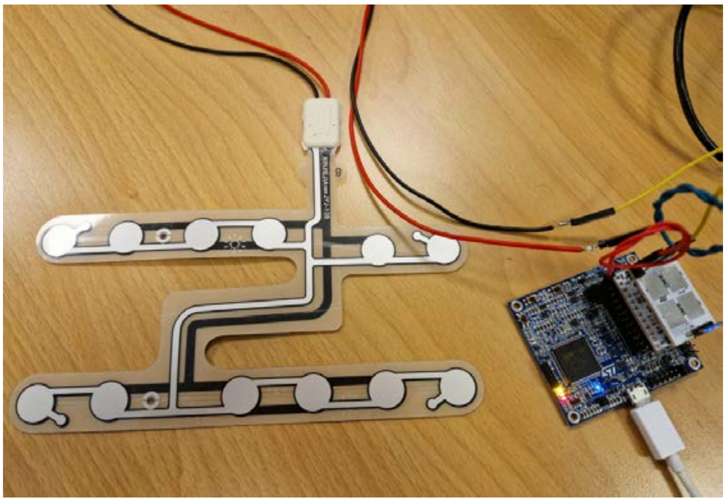

Figure 5. Example of complete setup for seat-occupancy detection

Initialization of iNEMO 6-axis IMU sensor

In this example, an iNEMO 6-axis IMU sensor is used for seat-occupancy detection, but this feature is replicable for any sensor that has an embedded Qvar sensor.

In order to enable the Qvar sensor and route the data-ready interrupt to INT2:

- ***Write(0x10, 0x07); // accelerometer turned ON in high-performance mode***
- ***Write(0x11, 0x07); // gyroscope turned ON in high-performance mode***
- ***Write(0x16, 0xC0); // QVAR_enable, QVAR_DRDY_INT2 active***

Then, to read the output data, registers 3Ah and 3Bh must be read:

- ***MultiRead(0x3A, (uint8_t*)&qvar_out, 2)***

Qvar data is stored in the variable qvar_out at a fixed 240 Hz ODR, expressed in LSB. To convert this value to mV, the value of Qvar_Gain of this sensor (78) should be used in the following formula:

- value[mV] = value[LSB] / Qvar_Gain

Moreover, Qvar data can be stored in FIFO (by setting the QVAR_BATCH_EN bit to 1 in the COUNTER_BDR_REG1 (0Bh) register) and can also be processed by MLC/FSM logic. The equivalent input impedance of the Qvar buffers can be selected by properly setting the QVAR_C_ZIN_[1:0] bits in the CTRL7 (16h) register. Finally, the QVAR_SW bit in the CTRL10 (19h) register allows internally swapping the input electrodes connected to the QVAR1 and QVAR2 pins.

For this Qvar application, data are kept in LSB because the event that must be recognized does not require a converted measurement.

For other products with an embedded Qvar sensor, refer to AN5755 for the initialization procedure.

Polarization network

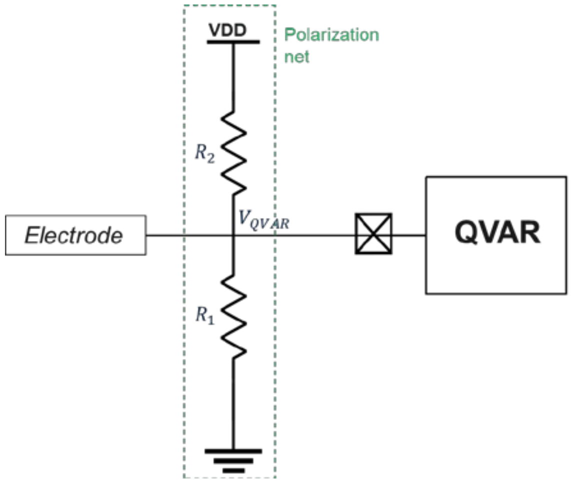

Figure 6. Polarization network for Qvar electrode

The polarization network stabilizes the operating point of the Qvar signal at this voltage:

$$V_{QVAR} = VDD\,\frac{R_1}{R_1 + R_2}$$

R_1 and R_2 have the same value of 10 MΩ, therefore, V_{QVAR} is equal to half VDD and the Qvar signal is about 0 LSB.

Using the polarization network, the Qvar signal is robust to noise, and undesired states (due to noise) are discarded.

Example of acquisition

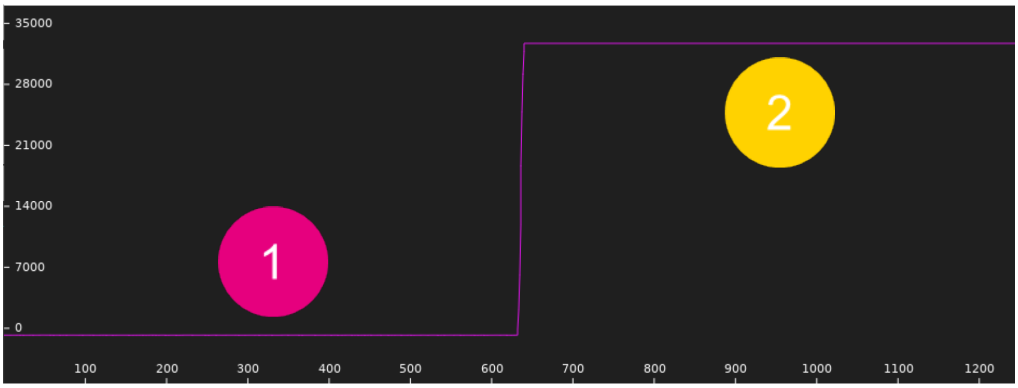

Figure 7. Example of Qvar acquisition.

This example of acquisition is made using the setup previously described and follows this sequence:

1. No one sitting on the electrode
2. Person sitting on the electrode

During period 1, nobody occupies the seat:

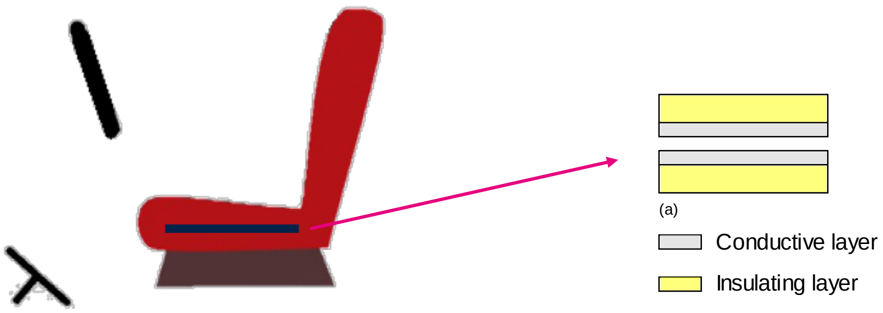

Figure 8. Nobody occupies the seat. The diagram on the right shows that the conductive layers are isolated and separated by air.

When no force is applied on the electrode (no one sitting on it), the Qvar signal remains at baseline value (around 0 LSB). Therefore, when the signal is low, the user can define an **“absence”** state.

During period 2, a person is sitting on the seat and there is a point of contact between the two conductive layers, one connected to the Qvar input and the other connected to GND.

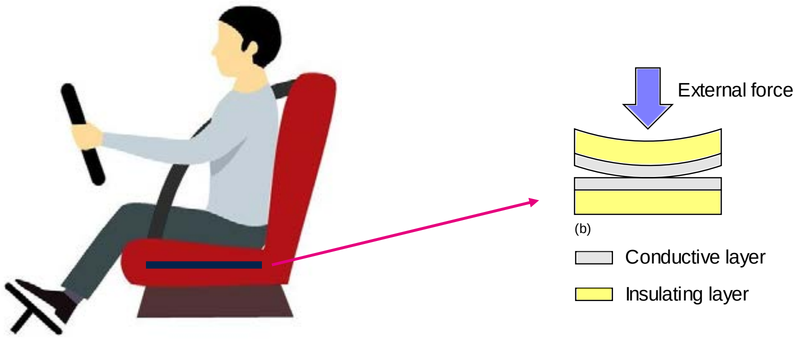

Figure 9. A person occupies the seat and the diagram on the right shows that the two conductive layers are kept in contact, shorting the Qvar pin to GND.

When there is a contact between the two layers, the Qvar signal saturates to the highest value. Therefore, when the signal is high, the user can define a **“presence”** state.

Support material

Documentation
Datasheet, LSM6DSV16X, High-performance 6-axis IMU with sensor fusion, ASC, MLC, Qvar, OIS/EIS paths
Application note, AN5755, Qvar sensing

Revision history

Date	Version	Changes
14-Dec-2022	1	Initial version