INNOVATION WITH PURPOSE

GUIDELINES FOR MEASURING VIBRATION IMMUNITY FOR SPEED SENSORS

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INTRODUCTION

Vibrations in a speed sensor application can be thought of random movements of the target or air gap independent of each other. Such movements may create changes in the magnetic signal at the sensing elements of the sensor, which make it difficult to distinguish vibrations from a normal rotation of the target. Under these conditions, a device that is sensitive to vibrations will output direction pulses. This behavior is undesired in speed sensor applications, especially in transmission systems. Therefore, Allegro's transmission sensors employ various active vibration algorithms to ensure that the sensor does not output direction pulses when exposed to vibrations. A sensor that does not output direction pulses when exposed to vibration amplitudes up to the datasheet specified limits is said to be vibration immune.

This application note provides guidelines on how to measure a speed sensor's response to vibration and analyzes the results to find the vibration immunity of speed sensors. For the sake of illustration, the ATS19520 is used in this document.

DEFINITIONS

Air Gap

In this document, air gap is defined as the distance from the sensor housing to the target surface, also referred to as package air gap.

Calibration Mode

Calibration mode is the state the sensor starts in following a power-on event. In this mode of operation, the direction information is not available, and the sensor is in process of validating target direction.

Running Mode

After calibration is complete and the target rotation direction becomes available, the part enters running mode. This is the normal mode of operation in which the sensor outputs the correct direction information. The direction information is communicated through an output protocol such as the variable pulse-width protocol. In running mode, signal tracking algorithms are employed to maintain the high accuracy of output switching.

Air Gap Vibration

Air gap vibration is the vibration of only the distance between the sensor and the target (air gap). Figure 1 shows the measured magnetic differential signal during air gap vibrations.

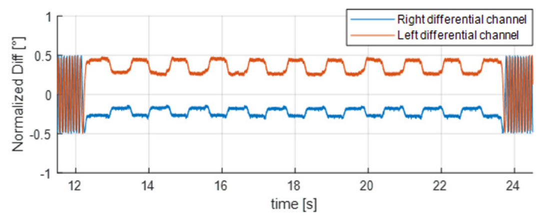

Figure 1: Magnetic differential signals captured during air gap vibrations of 1 mm amplitude on an Allegro 60-0 ferrous target.

Angular Vibration

Angular vibration is the vibration of only the angular motion of the target. Figure 2 shows the measured magnetic differential signal during angular vibrations.

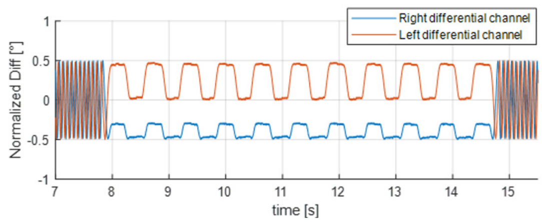

Figure 2: Magnetic differential signals captured during angle vibrations of 1° amplitude on an Allegro 60-0 ferrous target.

SETUP AND MEASUREMENT PROCEDURE

Rotation of the target is controlled by a high-resolution motorized rotation stage that can provide a precise, backlash-free operation. The air gap between the target and the sensor is controlled by a motorized linear stage. These stages are connected to a PC-connected controller that is used to automate the movement of the stages for the vibration measurements. For this document, MATLAB is used to interface with the described hardware equipment. The output of the sensor can be captured and saved using a logic analyzer. In this document, the Saleae logic analyzer (Logic Pro 8) is used. This tool offers high sampling rates (up to 500 MSamples/s) and is remotely controlled by the Saleae software GUI and interfaced in MATLAB. Figure 3 and Figure 4 show the connection block diagram and the picture of the physical setup, respectively.

The output of the sensor is measured simultaneously with a signal that provides the position of the target. This signal can be taken from the high-resolution optical encoder on the rotary stage or can be generated using an ASEK20 (Allegro standard programming tool) e.g. the ASEK20 can be programmed to generate an edge on a programmable pin every time a command to change direction is sent to the rotary stage. These signals are used when analyzing the output of the sensor.

To capture all possible scenarios, the setup is programmed to run four events in a sequence; see Figure 6. These four events of the vibration measurement are:

1. Vibration in calibration
2. Normal rotation after vibration in calibration
3. Vibration in running mode
4. Normal rotation after vibration in running mode.

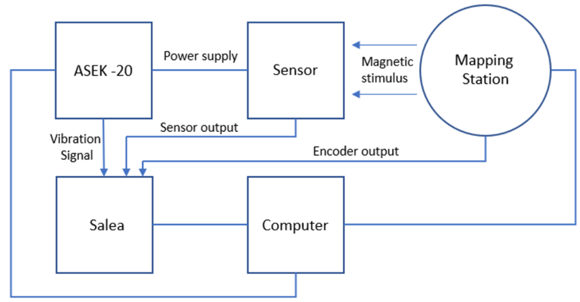

Figure 3: Connection block diagram of the vibration measurement setup.

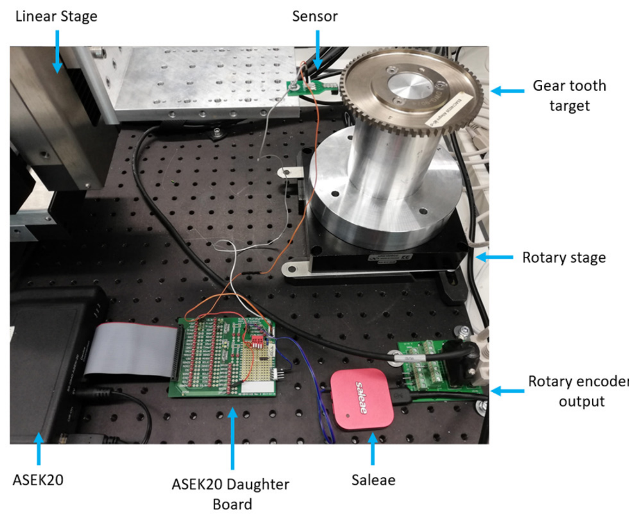

Figure 4: Physical setup for the vibration measurement.

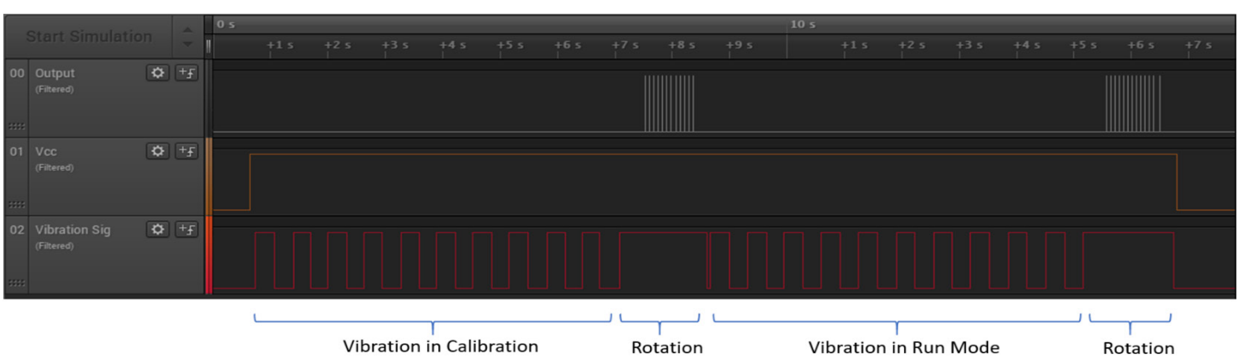

Figure 5: A single vibration capture showing a simultaneous measurement of the sensor output (top), V_{CC} (center) and ASEK20-generated vibration signal (bottom). In the case captured in this figure, the sensor is programmed to suppress all pulses during vibration.

This sequence can be modified depending on the sensor and events of interest. The logic analyzer captures all signals simultaneously for this sequence of events. Figure 5 shows an example of one Saleae capture. Figure 6 shows the target rotation angle as decoded from the high-resolution encoder signals captured during the vibration measurement. The captured data is saved along with the information of the vibration amplitude, starting phase angle, and the air gap where the capture was taken. This sequence is repeated over all vibration amplitudes, at all starting phase angles and at all starting air gaps within the air gap range of the sensor.

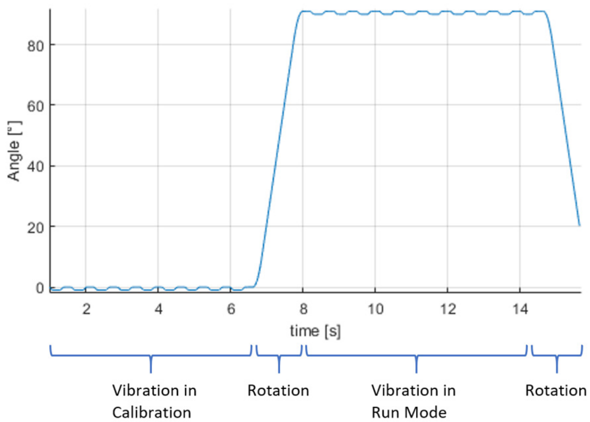

Figure 6: The rotation angle vs. time as read by the high-resolution optical encoder. The figure shows how the target moves during the events of a single vibration capture when vibration amplitude is set to 1° and normal rotation is set to 90°.

DATA ANALYSIS AND PRESENTATION OF RESULTS

Once the measurements are complete, the data saved from each capture is exported to MATLAB and analyzed.

The goal of the analysis is to find the following results:

1. Total number of pulses during each event of the vibration measurement.
2. Number of forward, reverse, and/or non-directional pulses during each event of the vibration measurement.
3. The maximum vibration amplitude at which the sensor does not show any direction pulses. This defines the vibration immunity of the device.

These results can be visually represented on color maps. For example, Figure 7 shows binary color maps indicating whether any direction pulses were detected during the different events of the vibration measurement. This measurement was performed on a transmission device programmed with high vibration immunity that is specified to suppress direction pulses up to a vibration amplitude of one target period or 1 T_{CYCLE}. The plots confirm this specification since no direction pulses are detected during vibrations of up to this amplitude.

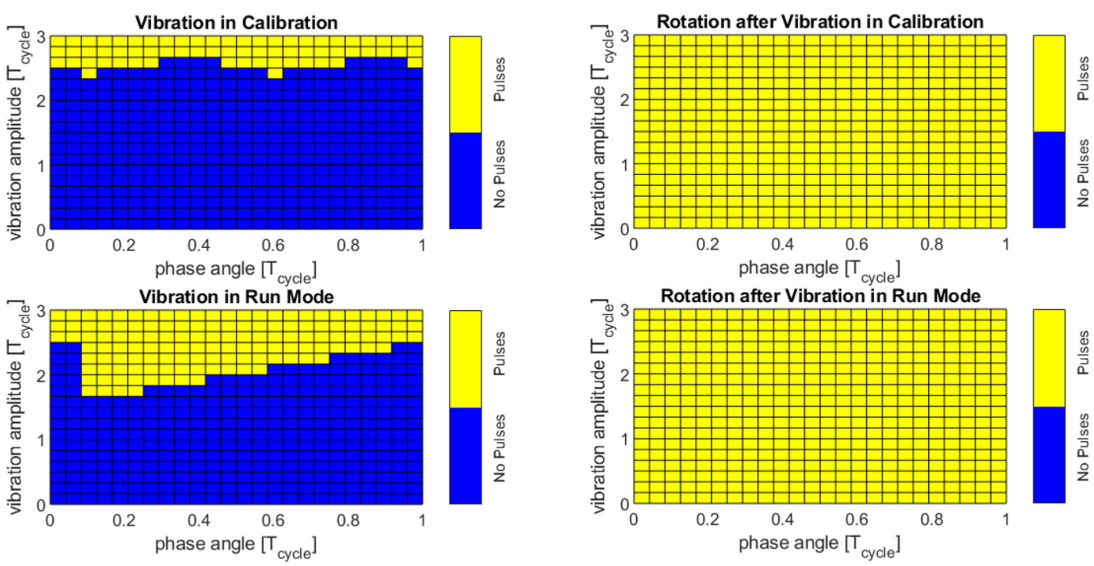

Figure 7: Binary color maps showing whether the sensor outputs direction pulses in the four different events of the vibration measurement that are described in the 'Setup and Measurement Procedure' section.

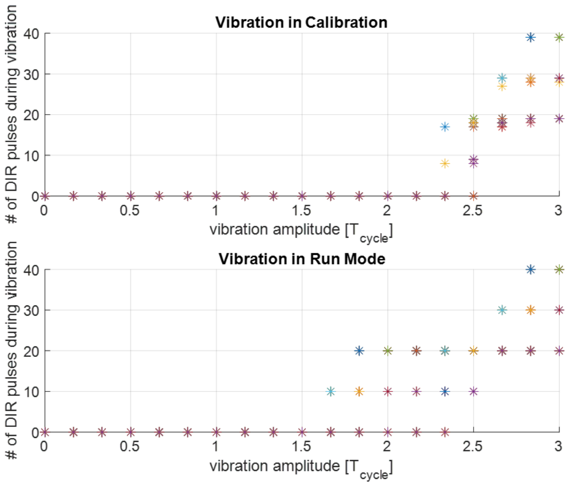

Figure 8: Plots showing the number of direction pulses vs. vibration amplitude.

Vibration immunity can be found by looking at the maximum vibration amplitude where the sensor does not output any direction pulses. A simpler way to plot the results is shown in Figure 8, which shows the plot for number of direction pulses versus vibration amplitude and clearly shows a vibration immunity of greater than one T_{CYCLE} in both calibration and running mode. The part also allows for a margin to take environmental variations such as temperature into account.

This analysis can also be extended to create plots to find the number of forward, reverse, or non-directional pulses separately during the events of the vibration measurement.

CONCLUSION

This application note describes methods to measure the response of speed sensors to vibrations and analyzes the results to quantify the vibration behavior.

It describes the measurement setup and the procedure to create controlled vibration events in detail and suggests different ways in which the results can be presented to provide a visual representation for the vibration immunity of speed sensors.

Revision History

Number	Date	Description	Responsibility
–	September 1, 2020	Initial release	Syed Bilal Ali

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