Measurement Technology and Uncertainty Analysis – E7021E
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Lab 1

Navigation using a 2-axis accelerometer

Goal: The lab is intended to bring knowledge in using and interfacing a 2-axis, low-g accelerometer for navigation purposes, and to get familiar with the lab hardware and data acquisition software used throughout the course.

The lab is set to illustrate principles and applications for modern MEMS device as well as illustrates the basic principles behind inertial navigation. In the lab, PC:s equipped with a data acquisition card will be used for sampling of signals and subsequent calculations of position. Parts of the necessary MATLAB code for sampling is given but you have to write some own routines for the actual data processing.

Equipment and components

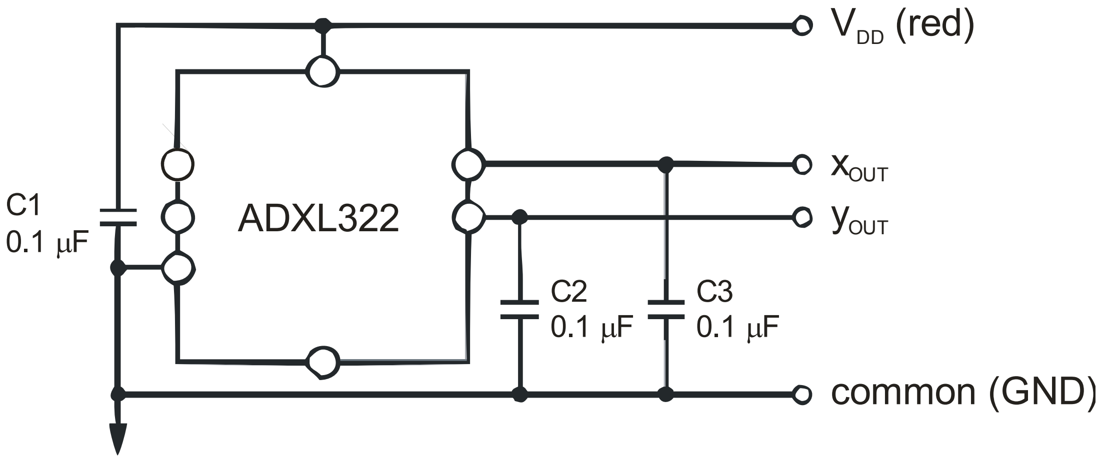

Fig 1. The ADXL320 sensor and the circuit board, with connectors. Use a maximum of +5V as supply voltage.

The sensor used is a MEMS device, the ADXL322 from Analog Devices. The accelerometer chip is mounted at a circuit board for easier handling. The circuit board contains the accelerometer, a few capacitors and a connection cable. Connect the accelerometer to the lab deck and then to the Nidaq box.

The capacitors at the circuit board are used for decoupling (C1) and for reducing the bandwidth of the sensor to 50 Hz (C1 and C2).

Please Note! The sensor is rated for 2g *only* so please handle it carefully! Dropping it on a hard surface generates thousands of g's and that might destroy the sensor.

Please Note! Do not reverse the voltage on the power input, they are not protected. Reverse voltage will damage the sensor.

Lab assignments

Connect the circuit board to the connector block and also connect the power to the board. Make sure that the circuit board is resting horizontally on the foam pad. When the circuit board is connected, check the function of the sensor by carefully moving the board around Use the MATLAB functions given to you, modified as you see fit.

The board needs power; for that we will use the power source on the lab bench. Make sure you do not supply more than +5 V to the accelerometer.

Using MATLAB, you need to sample the signal from each of the axes at some rate higher than twice the bandwidth of 50Hz the sensor is set for. You need to decide on what sample rate to use as well as how the software (the m-files) is modified to make the measurements. This should be included in your report.

Make sure that your modified MATLAB software is doing the sampling correctly before moving on to the navigation part of the lab.

Inertial navigation

Draw the path shown in Fig. 2 on a paper (make sure to use as large area as possible. Position the sensor at the start of the path.

1. Start the sampling in MATLAB and move the sensor along the path. Since the sensor can not follow rotations, make sure that the rotation of the sensor when it is following the path is minimal. Examine what happens if you don't. Make sure that the sensor is moved at accelerations lower than its maximum rating of 2 g, or the sensor output will be saturated and therefore useless.

   Note that the output of the sensor at rest is about half the supply voltage. You will have to compensate for this during the calculations. By placing the sensor vertically, one of the axes will pick up the earth's gravitation. Use this to compensate for the bias voltage.

   To calibrate the sensor, hold it with one axis vertically and the move it a known distance. Then do the same with for the other axis. See below for calculations.

2. Move the sensor along the path back to the starting position. Use both Path A and Path B (2 different runs). Do path A slowly as well as fast.

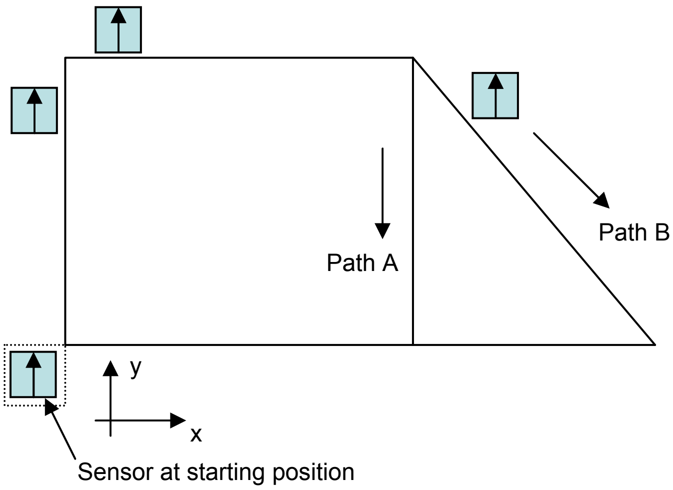

Fig 2. Movement of the sensor along the path.

3. Make one run with the sensor at rest. The time for the run should be about the same as for a "normal" run following a path. Save that to file as all other runs. This run will be used to determine the bias level for each axis.

4. After all measurements have been done, you need to use the measurements of acceleration to calculate the position of the sensor. Let's study only one axis, the y-axis. The sensors acceleration in this direction is

$$\ddot{y}(t)$$

To get position in y, we need to integrate the acceleration with respect to time

$$\dot{y}(t) + k_1 = \int_{t\_start}^{t\_stop} \ddot{y}(t)dt$$

This introduces one unknown constant, k_1, the velocity of the sensor at $t = t\_start$. By integrating once more we can obtain the position, in y, for the sensor

$$y(t) + k_2 = \int_{t\_start}^{t\_stop} \dot{y}(t)dt$$

The unknown constant, k_2, introduced is the y-position for the sensor at $t = t\_start$. The integration constants could be set to zero if the velocity and position are zero at the start of the data acquisition from each run. Use MATLAB to do the calculation of position in x and y direction for the sensor. Use some integration function, for instance *quad* or use some lower order quadrature routine e.g. trapezoidal rule or forward or backward Euler method. Note that you need to remove the bias levels before integrating. You should also try to smooth the data using MATLAB. When doing the calculations of position use both unsmoothed and smoothed data and compare the results.

5. Plot the path of the sensor for each measurement (each path) using MATLAB. Plot both the path marked on the table (ideal path) and the calculated path for each run.

6. Does the calculated path follow the "ideal" path (the one outlined on the table)? Does the calculated stop position (end of the path) of the sensor coincide with the start position (beginning of path)? If there they differ, why is that?

7. Calculate position in x and y from the data when the sensor was at rest. Is the resulting position the same (zero) for all t? Plot the calculated position.

8. If you were to propose improvements to increase the precision of this inertial navigation system, what would you suggest?

Results

The lab should be documented well in a written report. The report should be written in such a way that other students in your class are able to understand what you have done, how you did it, what the results were and to be able to repeat your experiment. Graphs, circuit diagrams, calculations, experiment physical layouts are also to be included in the report.

You are allowed to use *any* source of help, information etc. to do this project, but please include these in the reference list.

The practical part of the lab should be done in pairs or groups of three students, but the report is individual.

MATLAB hints

To get help on a specific MATLAB function, type `help functionname` at the MATLAB prompt.

You may find the following MATLAB functions useful:

- trapz, cumtrapz (numerical integration)
- detrend (removes average or linear trends)
- plot, xlabel, ylabel, legend (plotting functions).
- butter, filter (functions to design filters and to filter data).

Save plots and include in your reports.

Dual-Axis Accelerometer Evaluation Board

ADXL320EB

GENERAL DESCRIPTION

The ADXL320EB is a simple evaluation board that allows quick evaluation of the performance of the ADXL320 dual-axis ±5 *g* accelerometer. The ADXL320EB has a 5-pin, 0.1 inch spaced header for access to all power and signal lines that the user can attach to a prototyping board (breadboard) or wire using a standard plug. Four holes are provided for mechanical attachment of the ADXL320EB to the application.

The ADXL320EB is 20 mm × 20 mm, with mounting holes set 15 mm × 15 mm at the corners of the PCB.

CIRCUIT DESCRIPTION

The schematic of the ADXL320EB is shown in Figure 1. Analog bandwidth can be set by changing capacitors C2 and C3. See the ADXL320 data sheet for a complete description of the operation of the accelerometer.

The part layout of the ADXL320EB is shown in Figure 2. The ADXL320EB has two factory-installed 100 nF capacitors (C2 and C3) at X_{OUT} and Y_{OUT} to reduce the bandwidth to 50 Hz. Many applications require a different bandwidth, in which case the user can change C2 and C3, as appropriate.

SPECIAL NOTES ON HANDLING

The ADXL320EB is not reverse polarity protected. Reversing the +V supply and ground pins can cause damage to the ADXL320.

Dropping the ADXL320EB on a hard surface can generate several thousand *g* of acceleration and might exceed the data sheet absolute maximum limits. See the ADXL320 data sheet for more information.

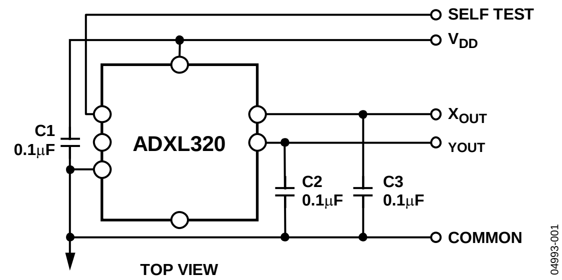

Figure 1. ADXL320EB Schematic

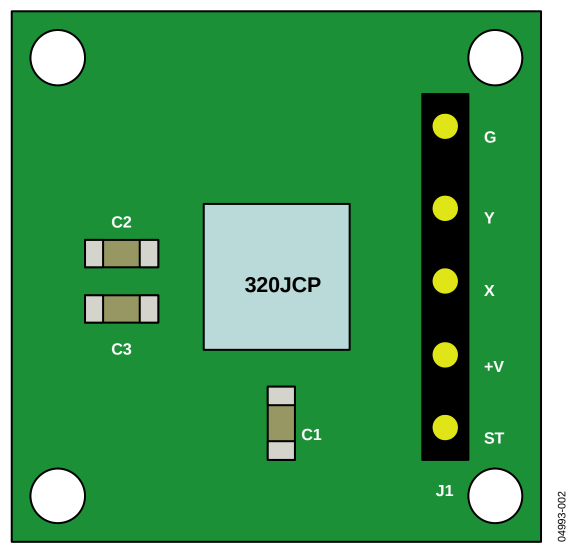

Figure 2. ADXL320EB Physical Layout

ORDERING GUIDE

Model	Package Description
ADXL320EB	Evaluation Board

Rev. 0

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