NCS32100 Inductive Position Sensor Validation

AND90335/D

Introduction

This application note gives some insights to help the validation of a inductive position sensor design in a structural way.

PCB Sensor Verification

The drawing of the sensor on the PCB requires many vias and long tracks, especially for the fine receiver coils. The sensor designer can verify that the receiver coils are not open or shorted by measuring the coil resistances between the NCS32100 pads. When the device is soldered on the board, this measurement is rather difficult. But, when there are 0 Ohm resistors used in line with the receiver coil connections, this test is easy, when the resistors are removed, the measurement can be done with a multimeter. It is expected to measure the exact same resistance for the 3 coils of fine and coarse sensor. After the resistances are checked, the 0 Ohm resistors can be placed.

The excitation coil resistance and, if possible, the self-inductance can be also measured. Knowing the self-inductance, the capacitors connected to LC1 and LC2 can be calculated:

$$C_{ex} = \frac{2}{L_{ex}} \frac{1}{(2\pi\, F_{ex})^2} \qquad \text{(eq. 1)}$$

With F_{ex} the excitation frequency between 3 and 6 MHz.

A frequency chosen on the high side will reduce the current consumption. On the lower side of the range, potential parasitic capacitive couplings will be less important.

NCS32100 Connections

Once the NCS32100 is populated and under bias (5 V, current can be in the 80 mA range), the voltage on V5VO can be checked. This is the output of internal switches to VCC and to VBAT and should be no more than 200 mV below the maximum of VCC and VBAT voltages.

The voltage on the pins V2Vnn is 1.95 V typical. The DC voltage on all the RECn and DC pins is 1 V typical.

The voltages on pins LC1 and LC2 are opposite phase sine waves with a peak-to-peak amplitude of 0.5 V below V5VO and a frequency between 3 and 6 MHz. The amplitudes on LC1 and LC2 should be identical (if not, it is likely because the LC1 and LC2 capacitances are different).

UART Communication and Sensor Configuration

The UART serial communication between the sensor and the master controller can be checked quickly by sending the command “**getEncoderID (0x92)**”.

Be aware that the sensor selection register 0x5F must be programmed according to the PCB sensor geometry. E.g. 16 pole fine and 5 pole coarse. Refer to the datasheet for the proper settings.

Direct Coupling Amplitudes

The PCB sensor connections to the sensor integrated circuit introduce asymmetries in the received signals; the mutual inductances between the excitation coil and the receiver coils are not fully balanced and will cause offsets on the measured signals after demodulation. Although these offsets are compensated in the sensor interface, they should be minimized to attain the best accuracy and the lowest drift over temperature.

The direct couplings are compensated by measuring the excitation amplitude and subtracting a fraction of it from each 3-phase received signal. The excitation amplitude is sensed with a capacitive divider connected to the pins REC3 and REC4.

With the rotor moved far away from the stator, the only measured signals are the relative direct couplings. By downloading the ADC values, we can verify that the ADC3 and ADC4 output codes are larger than any of the absolute values of the other ADC outputs (ADC0, ADC1, ADC2, ADC5, ADC6, ADC7).

In a good sensor design, the ratios of ADC0, ADC1, or ADC2 to ADC3 and the ratios of ADC5, ADC6, or ADC7 to ADC4 should stay constant over voltage and temperature. The amplitudes can vary but it is important that the ratios are constant.

Collecting ADC Data over One Rotation

Preferred method:

The best setup would use an external reference encoder connected to the rotor PCB. It helps in verifying the PCB sensor accuracy.

With the rotor in place and turning in quasi-static mode (rotate by a small angular step, stop the rotor, get the data, repeat), collect the ADC values over 360 degrees using the command “**getOneADCSet (0x07)**”.

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To check the coarse sensor, the sensor designer should measure about 20 points per coarse period. With 5 counts per revolution, the angular step in the range of 3 to 4 degrees. With 3 counts per revolution, the step is 6 degrees.

To check the fine sensor at 64 counts per revolution, the angular step is in the range of 0.2 to 0.3 degree. Eventually, less measurements for the fine structure can be done. Measure over 8 fine periods separated by 45 degrees.

Alternative method:

ADC data inspection can be done without reference encoder and with less accuracy on the angle steps by turning the rotor at a low constant speed and acquiring the ADC data at a constant rate. The rotation speed must be low enough to capture the data with a fine angular resolution.

Once the data has been collected, the 4 ADC values can be inspected; we need to see 3-phase sinewaves and a constant signal. This, both for fine and coarse channels.

The sinewaves offsets must be small (less than 30% of amplitude) and the sinewaves can't saturate (above or below ±4000 ADC output code).

Jumps of 20% up or down, on one or the other channel might show up. This is the automatic gain control being active and adjusting the amplitudes of the 4 ADCs at once. It is not a problem but for easier evaluation one could freeze the gains using UART commands as documented in the datasheet.

Self-Calibration

When all data looks good, the self-calibration can be run with the command "**selfCalibrate (0xA2)**". In the firmware version 1.2, the self-calibrate command will take care of the selection matric (address 0x10) and the returns the quality of the calibration.

The command "**getAcquiredData (0x7A)**" downloads the ADC values used during self-calibration, the sinewave amplitudes and offsets can be checked, the signal peak amplitudes should reach ±3000 for good calibration.

The acquired data can be copied into the self-calibration Excel file.

The NCS32100 Self-calibration Excel file can be requested HERE.

Calibration coefficients, registers 0x12 to 0x21, can be calculated using this Excel file by filing in the "Dataset" the cells I8 to P807. In the "Calibration" sheet, the "**Reset**" macro initializes the calibration. The "**Calibrate**" macro steps in the self-calibration algorithm as implemented in the NCS32100 firmware.

The register values to be written in the NCS32100 are listed in "Results" cells N11 to N26. Of particular interest is the "Diagnostic" chart at the bottom of the "Results" worksheet. A robust calibration will show a waveform in the green zone. If any part of the waveform comes close to +0.5 or −0.5, there is a risk for the sensor to output angles with a very large error (±72 degrees for a 5-pole course or ±120 degrees for a 3-pole course geometry). The coefficients calculated in Excel might be different than the coefficients provided by the firmware. The Excel coefficients can be overwritten if entered in cells O11 to O26 before running the macro "Overwrite".

Finally, the sensor validation needs to verify the behavior over the environmental required conditions (temperature and supply voltage for example).

This by getting multiple datasets in the Excel file and verifying the diagnostic chart *without executing a new calibration sequence*. Datasets can be acquired by the NCS32100 and downloaded with the commands "**runAcquisition (0xF2)**" and "**getAcquiredData (0x7A)**". This will not affect the calibration registers.

ADDITIONAL INFORMATION

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