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Testing and application of an integrated fluxgate sensor DRV425

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The article presents testing of a miniature fluxgate sensor developed and manufactured by Texas Instruments as well as an application of the sensor in a compact magnetic field probe with USB interface and LabView based software. Several basic properties of the sensor were evaluated and compared with the datasheet specifications. Offset stability measurements have indicated some possible problems for applications that require very high DC and low-frequency precision. Jumps in offset were present for some of the devices, frequency and duty of the jumps varying between individual pieces and with respect to the supply voltage. Magnetic probe for fast and handy measurements of DC and AC (up to 30 kHz) magnetic fields (up to ± 1 mT) is also presented. The probe contains 24-bit analog to digital converter, microcontroller and high-speed USB interface which allows a live view of the signal in time and spectral charts. The probe proved to be very useful for the DRV425 debugging, application development, EMC measurements and magnetic field demonstrations activities.

K e y w o r d s: integrated fluxgate sensor, magnetic field measurement, offset stability

1 Introduction

Fluxgate sensors are typically used for precise measurements of weak magnetic fields in a wide area of laboratory and industrial applications (*eg* compassing, navigation generally, Earth's magnetic field monitoring and zeroing, current sensing, *etc.*). Typical fluxgates are bulky, very expensive and power consuming devices [1]. Newly developed miniaturized and integrated fluxgate sensor DRV425 [2–4] opens new area of possibilities in the application of fluxgates [5–8]. The dimensions of the sensor are $4 \times 4 \times 0.8$ mm and power consumption is < 30 mW (if operated continuously). The chip contains a traditional micro-sized fluxgate sensor – Förster design with two rod-cores and three interwound solenoid coils – for excitation, pick-up and compensation. All the necessary excitation and signal conditioning electronics is integrated on the chip to provide convenient analog output. The electric circuitry allows several different configurations – using internal or external compensation, voltage reference, and a difference amplifier. This variability allows adjusting the sensor connection for each specific task – using the in-built compensation for differential current measurement and general field measurement tasks, using a single external precise voltage reference for setups of multiple sensors for current or position measurements, direct digitizing of the compensation current, etc. The paper presents several parameter measurements done to compare the measured values with datasheet specification (linearity, time-temperature offset stability, noise). The measurement of offset stability is discussed more in detail as it provided some unexpected behavior. Finally, an interesting application of the DRV425 fluxgate sensor is presented. USB based single axis magnetic probe with a specific LabView software provides an excellent tool for evaluation of the DRV425 sensor and also for evaluation of its possible applications. The probe tip has the smallest dimensions possible so it can easily fit any desired measurement or testing setup. The effective and low-cost design of the probe might allow widespread of the tool also for demonstration and teaching activities connected with the low-intensity magnetic field.

2 Experiment setup

The following paragraph mentions instruments and methods used to characterize the DRV425 main parameters. Several independent setups were used to characterize the sensor noise which is a very important parameter for most of the applications. At first, the output of the sensor was directly sampled by an AC coupled Agilent 35670A FFT Dynamic Signal Analyzer (DC-102.4 kHz). Later PXI-5122 card (14-bit 100 MSa/s) was used during the offset stability measurements. The card has lower resolution, but we were interested if the spectra at higher frequencies differ somehow between the investigated parts. The noise spectrum was calculated offline in MATLAB from the recorded data (using pwelch function – Welch's power spectral density estimate with overlapped segment averaging estimator). Another possibility to sample the DRV425 output signal (and calculate the noise spectrum) provided two AD converters used in applications (USB-Probe which is described here later and gradiometric metal detection). Both of them were 24-bit $\Delta\Sigma$ AD converters (ADS127L01 in the USB Probe and MCP3912). Very long records (several hours) were made using the AD converters, and thus noise spectrum at milli-Hertz frequencies was obtained.

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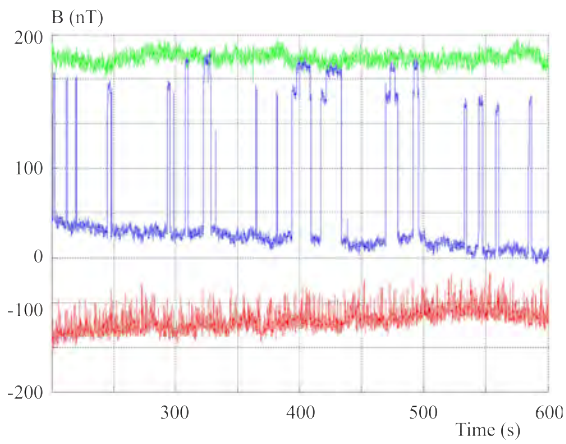

Fig. 1. Signal acquired from three different DRV425 sensors – normal data (green, top chart), very jumping output (blue, middle), jumpy with less amplitude but higher frequency (red, bottom)

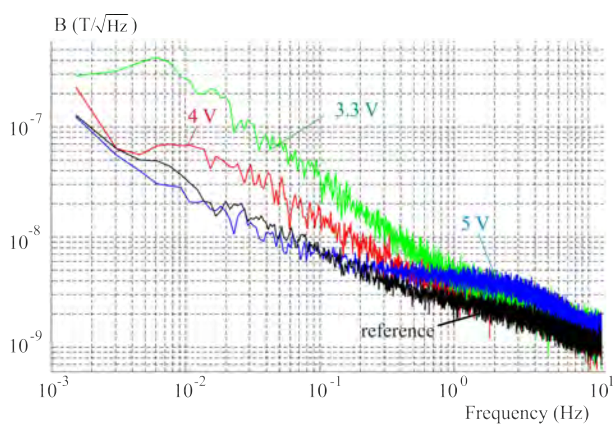

Fig. 2. Low frequency noise spectrum charts of the DRV425 sensor for different power supply voltages(ref.is another DRV425 which does not show the problems with offset stability)

DRV425 sensor linearity was measured with a custom setup consisting of a precise computer controlled current supply (linearity better than 8 ppm), and the data were again sampled by the ADC of the USB-Probe. So the measured linearity includes the THS4531 driver linearity. Six layers magnetic shielding equipped with a thermostated chamber was used for the offset temperature stability measurements. The temperature of the thermostated chamber was recorded as well as the output of four DRV425 sensors connected to a custom 24-bit DAQ card. We monitored also the outputs of the voltage references (which supports the differential amplifiers in the DRV425) but their influence was almost negligible compared to the temperature dependence of the fluxgate sensor.

During the application of the DRV425 sensors, we noticed a strange behavior for some of the sensors concerning their low-frequency offset stability. There were "jumps" in the offset of various amplitude and duration/frequency. Several different methods were used to be sure that a real output of the sensor is observed and not some measurement or data acquisition and processing artifact.

First was a SR560 Low-noise voltage preamplifier (Stanford Research Systems) which was used to amplify the output signal of the DRV425 sensor by a factor of 5000 (input was AC coupled). The output was observed with a digital oscilloscope (due to frequency limit of the amplifier there was no risk of some aliasing with the scope sampling at 250 kSa/s). Second method was direct very fast sampling with the PXI-5122 DAQ card (National Instruments) with subsequent data processing in MATLAB (averaging – filtering). As already mentioned the effect was observed at first in an application were static magnetic field was measured with high-resolution AD converter.

3 Results and discussion

Figure 1 shows the outputs of three DRV425 sensors sampled by 24-bit ADC. Top (green) trace represents a sensor with standard offset behavior and thus nominal noise. The middle sensor (blue) outputs a low-frequency high amplitude (150 nT) peaks. The bottom trace (red) represents a sensor with lower amplitude but higher frequency offset jumps. The amplitude (50–200 nT), frequency (0.003–200 Hz), duration, and polarity of the jumps were power supply voltage dependent. Best results (almost no jumps) were obtained for $V_{\rm cc} = 5$ V (but it was completely vice versa for another piece of DRV425). This is strange as the excitation amplitude should be stabilized concerning supply voltage. Measurement directly on the shunt resistor proved that the peaks do not come from the differential amplifier. We also prepared a tool that allowed us to proceed with the offset stability measurements without soldering the chips (as there were doubts concerning possible mechanical stress introduction during "non-professional" soldering).

The manufacturer specification for the DRV425 noise is given in the datasheet [4] as a typical value of 17 $\rm nT_{RMS}$ in a band of 0.1–10 Hz and 1.5 $\rm nT/\sqrt{Hz}$ at 1 kHz. There is also a noise density chart from 0.1 Hz to 100 kHz for the fluxgate sensor front-end. Measured values were typically perfectly below or matching the datasheet specifications for the noise at 1 kHz and for the noise in band 0.1–10 Hz (measured by spectrum analyzer or calculated using Matlab's "bandpower" function), even for the sensors with jumping offset (but we did not do any specific tuning of the jumping frequency to the 0.1–10 Hz band). Figure 2 presents noise spectrum charts for two pieces of DRV425. Three noise charts are shown for three different power supply voltage levels for one sensor. For comparison there is also a noise chart for another sensor which did not exhibit any problems. It is visible from Fig. 2 that at least for some sensors the noise at 0.1 Hz can be higher than presented in the datasheet. There was no difference in the spectrum at higher frequencies (100 kHz – 25 MHz) between the normal and offset jumping parts.

The linearity of DRV425 is given as a typical value (±0.1 %) and charts concerning its dependency on temperature, and power supply voltage are also provided

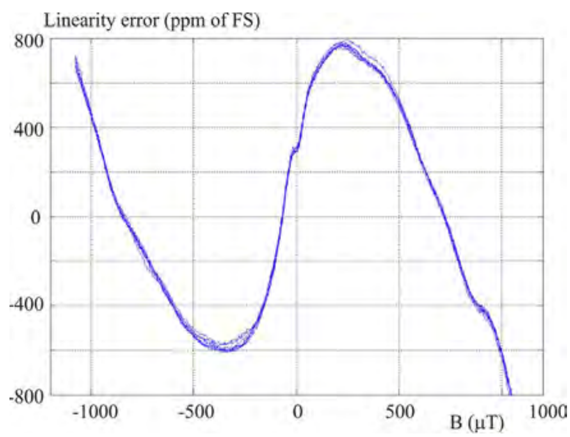

Fig. 3. Linearity error of the DRV425 sensor, eight sweeps shown, each with 800 points

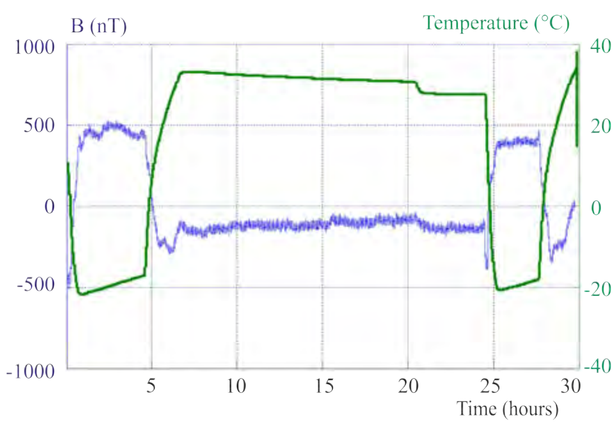

Fig. 4. Offset temperature dependence measured in a thermostated magnetic shielding

as well as a histogram of its values. Our results (typical measurement in Fig. 3) are perfectly in-line with the datasheet values. In our case, it also includes the whole measurement chain not only the fluxgate front-end as in the datasheet.

Our testing indicated a bit higher offset temperature dependence (10–16 nT/K) than is mentioned in the datasheet (±5 nT/K). Measurement shown on Fig. 4 lasted almost 30 hours and included two phases of cooling to −20 °C. Lower slope of the curve means a very slow natural change of the temperature while the steep parts come from forced cooling or heating.

4 DRV425 application

Several interesting applications of the DRV425 integrated fluxgate were presented by its manufacturer (Texas Instruments) and other authors [5–8]. USB interfaced probe with the DRV425 sensor was built to make the development of new applications easier, faster and more effective.

Figure 5 shows the block diagram of the probe's electronic circuits. The electric performance matches the sensor parameters so basically full potential of the sensor can be used (field range ±1 mT, bandwidth DC to 30 kHz). The signal from the fluxgate sensor goes through differential driver which also serves as an anti-aliasing filter for the precise 24-bit ΔΣ AD converter. Single-chip microcontroller reads the data from the ADC and sends them to the computer (at 64 kSa/s). Mechanical design of the probe allows installation of the DRV425 sensor even to very space constrained setups. LabView based program for data processing offers live signal visualization and spectrum processing, it has "oscilloscope like" features including AC/DC coupling, triggering and timebase. The data can also be recorded for later processing. The main purpose of the probe was meant to be further application development but it also proved to be very useful on its own as a tool for EMC measurements, current tracing, and various magnetic demonstration activities. Visit [9] for further information.

5 Conclusions

The measurement results presented in this paper indicate that the main characteristics mentioned in the

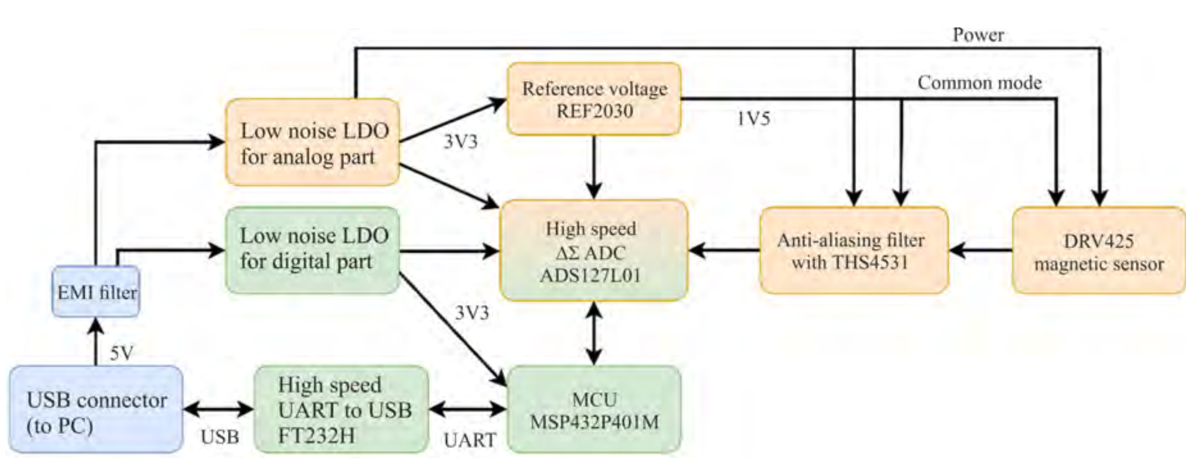

Fig. 5. Block diagram of the USB-DRV probe electronics

DRV425 datasheet are valid. Unfortunately, the problem with the offset stability occurred for a relatively high amount of the parts (10–20 % concerning the batch coming from multiple orders from different suppliers). In case of an application sensitive to low-frequency noise, we suggest presorting the parts before soldering. We discussed the issue with the manufacturer but without any conclusion on the cause of the behavior or its possible elimination.

In any case, the integrated fluxgate proved to be a very useful part by a combination of its parameters – small size, low power, low cost while still providing very sensitive and relatively stable measurements of weak magnetic fields. The presented magnetic field probe with USB interface is a nice example of its application.

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