Displacement sensor using a Hall position encoder

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Abstract

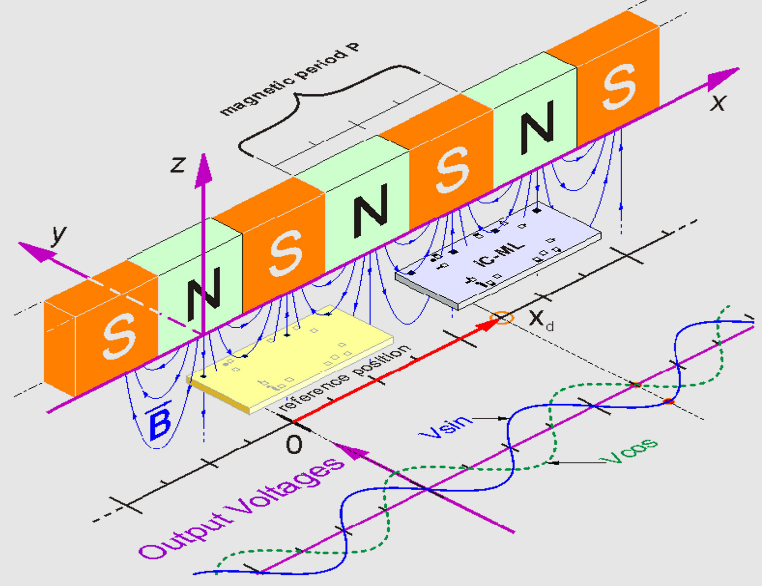
Measuring large displacements of rapidly moving objects is a frequently occurring problem in experimental physics and engineering. Here an autonomous data logger based on a novel technique is presented, which is useful in a wide range of applications.

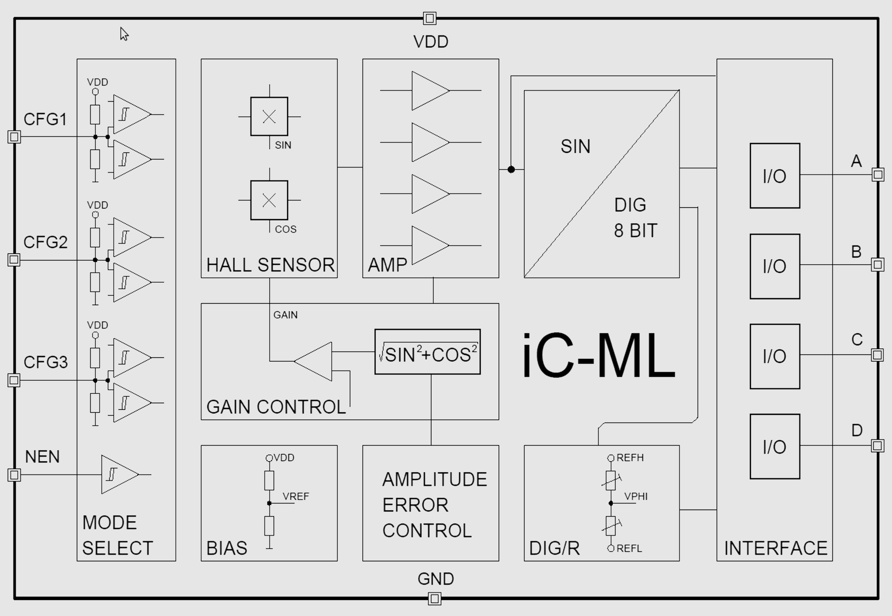
Sensor principle

One of the parts (the moving or the resting one) is equipped with a tape that exposes stripes of alternating magnetic orientation thus generating a sinusoidal magnetic filed. In the opposing sensor, Hall elements are located in a linear array, such that one magnetic period is „sampled“ four times. The outputs of the individual Hall sensors are then used pairwise: From the difference of two Hall voltages, each sensor pair generates either the sine- or the cosine signal. This yields a high immunity to external homogenious magnetic fields.

As long as the magnetic tape is near the Hall array (<4 mm), a gain control circutry ensures an output amlitude of 2 Vpp for the sine- and cosine signal. The voltages are then fed to a sine-to-digital (8 bit linear) converter. When the Hall sensor array is moved along the magnetic stripe, this converter outputs exactly 256 pulses for each magnetic period, including a signal, indicating wheather it moved left or right. With a magnetic period of 5.12 mm this results in a discretisation of 20 µm. Since the maximum output frequency is 256 kHz, the sensor can be applied for velocities up to 5 m/s. An error flag, that is set if the sensor looses contact with the magnetic stripe, is also available.

All this circuitry is embedded in the ASIC IC-ML from iC-Haus [1].

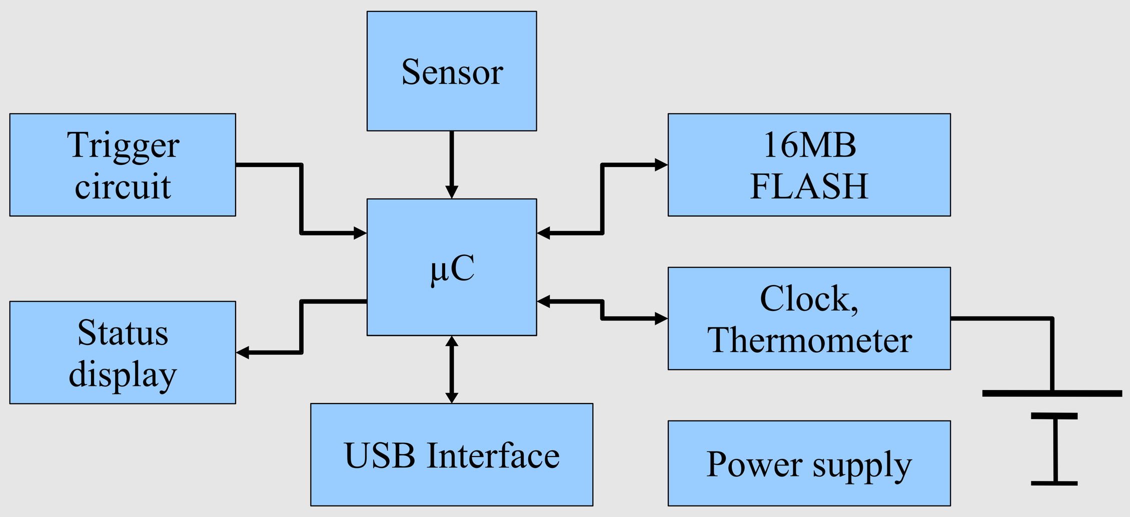




Logger configuration

The autonomous displacement logger consists of the following components:

•The sensor IC provides a spatial resolution of 20 µm
•16 Mbyte of nonvolatile memory, capable of storing about 26 min of continuous recording (at 10 ksps)
•A temperature compensated realtime clock for timestamps
•Opto-isolated interface to trigger the recording of the position
•The USB interface to download the measured data or setup for a new mission
•Three status LEDs to display the current activity
•Two linear voltage regulators to provide stable power to the circuit, even in an electrically noisy environment



Comparison

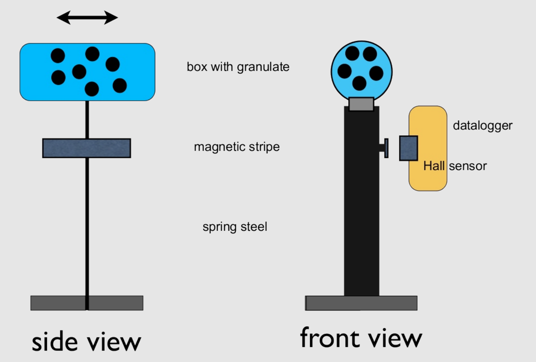
To show the advantages of this autonomous measurement technique over other comparable setups, a few characteristics are outlined in the following table:

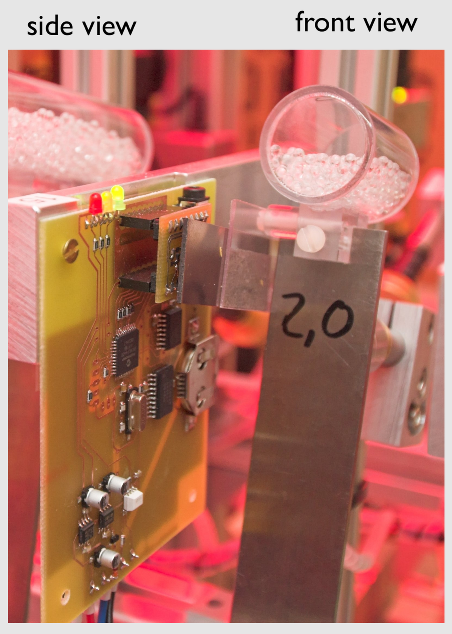
	Hall position encoder	Highspeed camera
Time resolution	100 µs	1 ms
Position resolution	20 µm	20 µm
Velocity	5 m/s	10 m/s
Lateral displacement	unlimited	20 mm
Noise immunity	high	lower
Weight	50 g	1 kg + 30 kg (PC)
Power consumption	0,25 W	600 W
Cost	50 €	15 k€

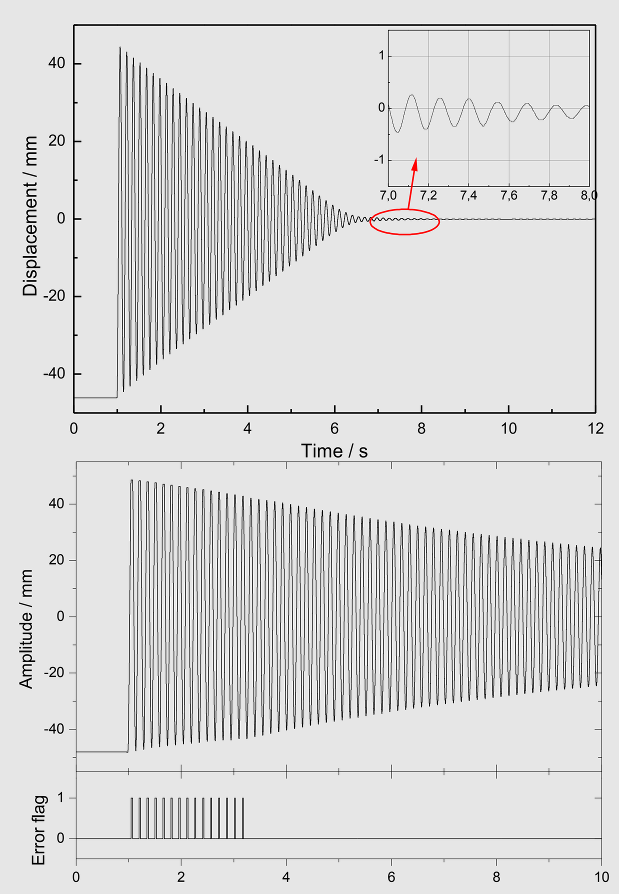
Common setups, like image recording or a Michelson interferometer, are capable of measuring the position of objects with a high spatial resolution, and the upper velocity limit can be as high as 10m/s. However, they can be too heavy for some applications and are quite expensive. Further drawbacks are the lighting of the scene and the roubustness of the image processing algorithm for high speed cameras. In contrast the Hall sensor needs only few adjustments and exhibits a high noise immunity.
Since the Hall position encoder only outputs an incremental signal and only those increments are recorded in the datalogger, the lateral displacement is limited by the data representation in the host computer only.
One disadvantage of our method is, that either the sensor IC or the magnetic tape need to be attached to the moving part, thus increasing the weight of the object.

Application

During the 13th Parabolic Flight Campaign of the „Deutsches Zentrum für Luft- und Raumfahrt“ eighteen dataloggers were used to monitor the movement of containers which each have been attached to a flat spring. Those boxes contained different types of granulate to dampen the oscillations of the spring [2].
At the beginning of the microgravity phase, the electromagnets which hold the springs in a strained position are released, and the logger starts recording the motion of the box.







On the left two examples of a measurement are shown:

In the first graph, one can clearly see the advantage of the high spatial resolution after the amplitude has fallen to within the sub-millimeter range. The electromagnet releases the spring about one second after the logger is started, and the datalogger is in no way affected by the changing magnetic field.

The second graph shows a plot of a failed measurement: The magnetic stripe is just a bit too short and in turn some peaks were clipped. Since the datalogger recorded the error bit as well, this could easily be discovered and taken into account for during evaluation of the recorded data.

Summary

The presented device is an accurate position logger with a very high spatial and temporal resolution. The design can easily be adopted to rotating objects by either using a circular magnetic tape or by employing the rotary encoder ASIC iC-MH. Despite its low power design, high versatility, robustness and small size, it is still very affordable.

[1] http://www.ichaus.com
[2] Jonathan Kollmer, Marcus Bannerman & Thorsten Pöschel, 'Properties of granular dampeners in microgravity', Poster 2009