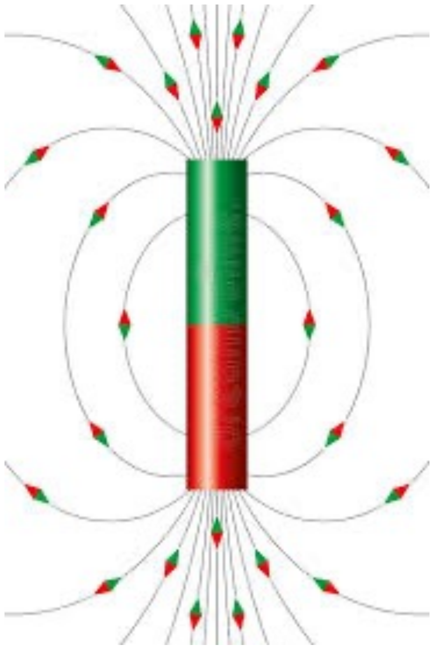
Applied physics innovations from the SBS project

B. Wojtsekhowski

- High accuracy magnetic compass
- Method of a sharp imaging CT scan

Compass



The traditional compass originated
in China around the 4th century BC

In this magnetic compass, torque (T= M x B)
is used to orient the magnetic arrow.
The achievable accuracy is about 0.5 degree

- GEn-II needs to know the polarization direction
- Vector property of the magnetic field
- Accuracy is based on an oscillating signal
- Spinning Hall probe compass (used in GEn-II)
- Spinning field concentrator compass

A polarized e⁻ beam on a polarized target => A => GEn/GMn

$$A_{\rm phys} = -\frac{2\sqrt{\tau(\tau+1)}\tan(\frac{\theta}{2})G_E^n G_M^n \sin\theta^* \cos\phi^*}{(G_E^n)^2 + (G_M^n)^2(\tau + 2\tau(1+\tau)\tan^2(\frac{\theta}{2}))}$$

~ 90 deg.

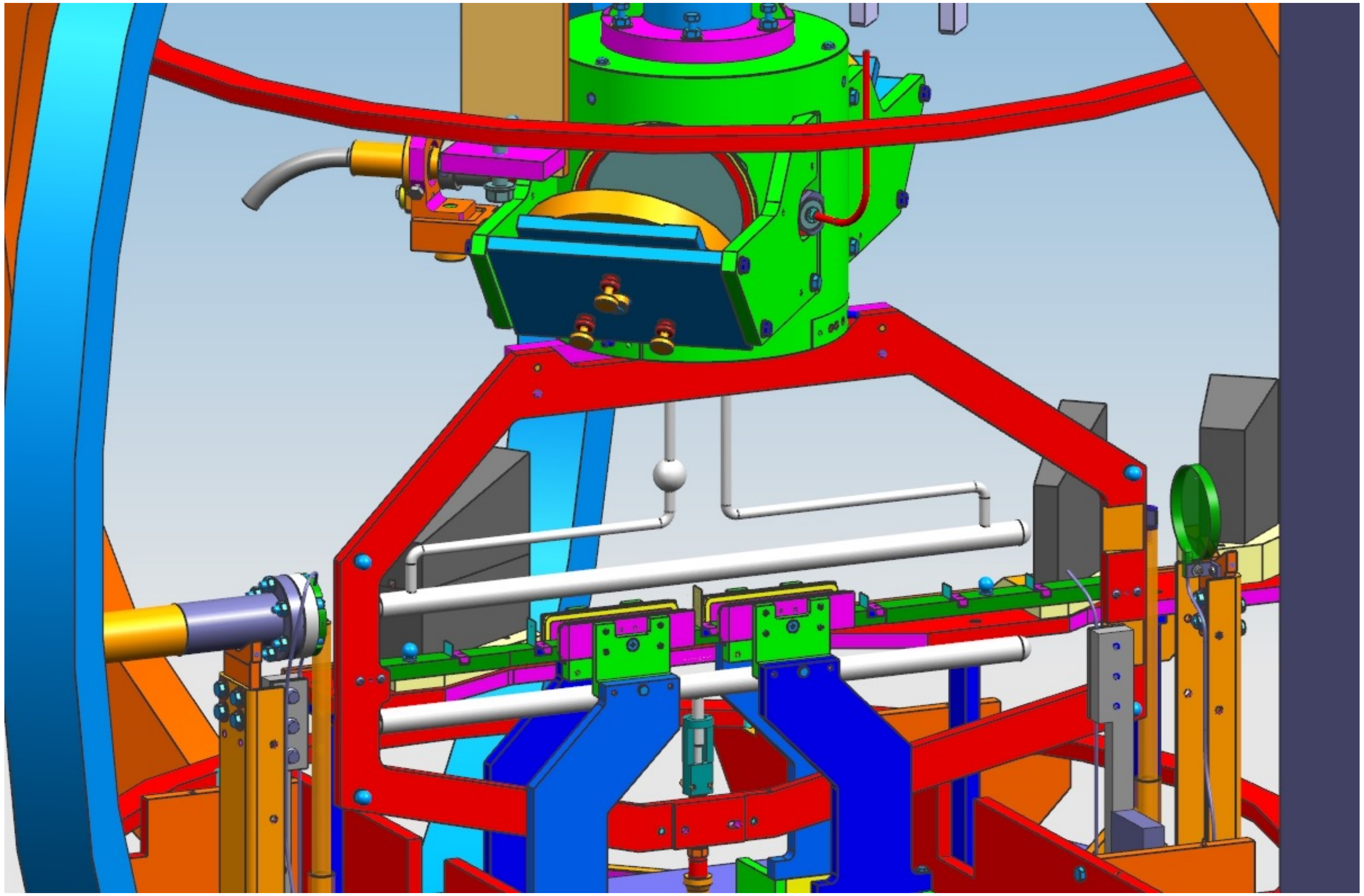
$$-\frac{2\tau\sqrt{1+\tau+(1+\tau)^2\tan^2(\frac{\theta}{2})}\tan(\frac{\theta}{2})(G_M^n)^2\cos\theta^*}{(G_E^n)^2 + (G_M^n)^2(\tau + 2\tau(1+\tau)\tan^2(\frac{\theta}{2}))}$$

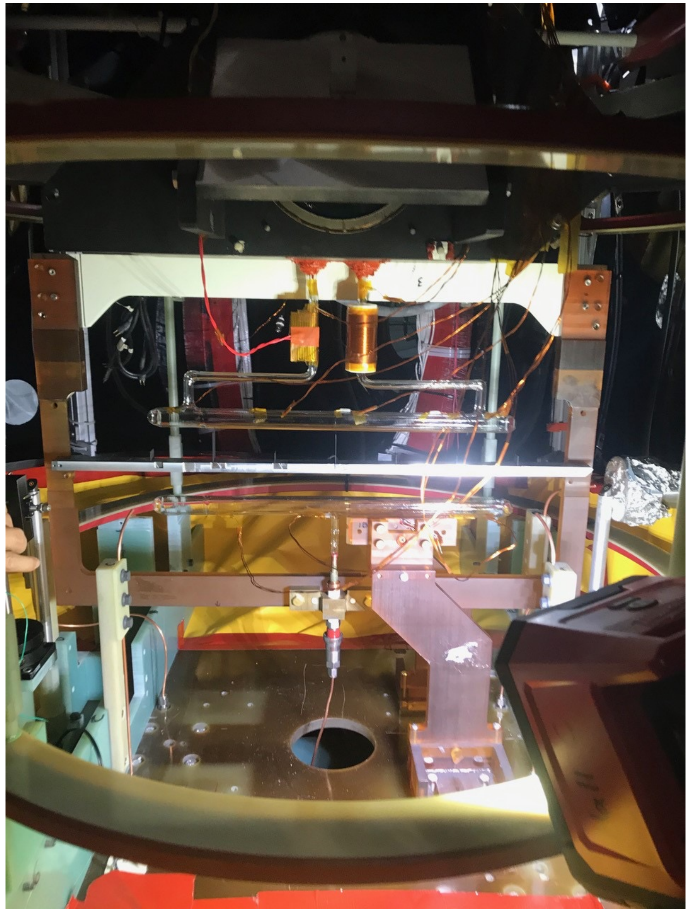
For 11 GeV beam, $Q^2 = 10$ GeV^2

the relative uncertainty (for Galster's GEn)

$\delta A/A \sim 0.01$ for $\delta\theta^* = 1$ mrad

A He-3 polarized target





Concept of a new compass

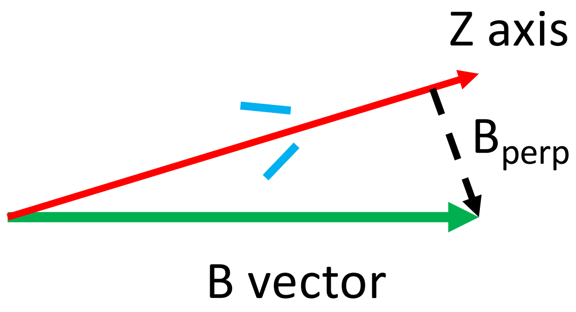
Separate functions: detection of misalignment and correction of the spin direction

a) Detection of the field vector and the compass axis misalignment with B vector by using the transverse component of the magnetic field –> oscillating signal from a Hall probe. No problem with calibration, sensitivity drift, alignment of the probe's plane.

b) Correction of the compass axis direction by means of e.g. a set of fine screws

c) Direction of the rotation axis determination by using a laser and a mirror

The B vector has no transverse components relative to itself!



when B_{perp} = 0, the compass is aligned!
and the rotation axis is parallel to the B vector

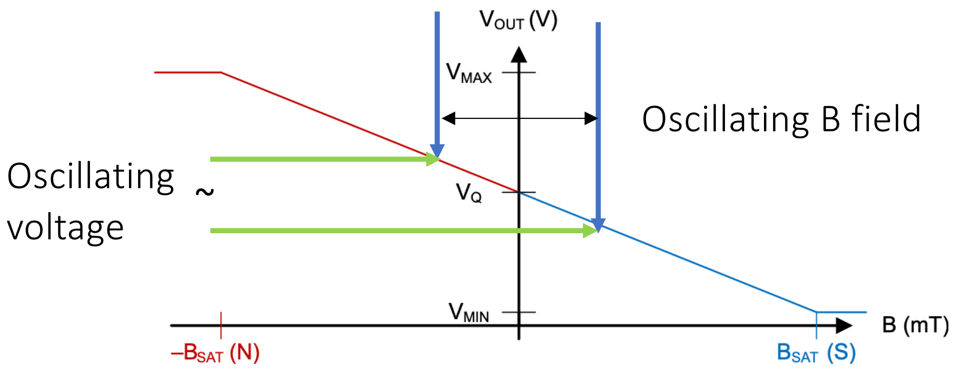


Figure 8. DRV5053 – Negative Sensitivity

Electronic noise is below 0.5 mV at 10 Hz

Inexpensive Hall probe

Product Folder | Order Now | Technical Documents | Tools & Software | Support & Community

TEXAS INSTRUMENTS

DRV5053

SLIS153C – MAY 2014 – REVISED DECEMBER 2015

DRV5053 Analog-Bipolar Hall Effect Sensor

1 Features

- Linear Output Hall Sensor
- Superior Temperature Stability
  - Sensitivity ±10% Over Temperature
- High Sensitivity Options:
  - –11 mV/mT (OA, See Figure 17)
  - –23 mV/mT (PA)
  - –45 mV/mT (RA)
  - –90 mV/mT (VA)
  - +23 mV/mT (CA)
  - +45 mV/mT (EA)
- Supports a Wide Voltage Range
  - 2.5 to 38 V
  - No External Regulator Required
- Wide Operating Temperature Range
  - T_A = –40 to 125°C (Q, see Figure 17)
- Amplified Output Stage
  - 2.3-mA Sink, 300 µA Source
- Output Voltage: 0.2 ~ 1.8 V
  - B = 0 mT, OUT = 1 V
- Fast Power-On: 35 µs
- Small Package and Footprint
  - Surface Mount 3-Pin SOT-23 (DBZ)
    - 2.92 mm × 2.37 mm
  - Through-Hole 3-Pin TO-92 (LPG)

2 Applications

- Flow Meters
- Docking Adjustment
- Vibration Correction
- Damper Controls

3 Description

The DRV5053 device is a chopper-stabilized Hall IC that offers a magnetic sensing solution with superior sensitivity stability over temperature and integrated protection features.

The 0- to 2-V analog output responds linearly to the applied magnetic flux density, and distinguishes the polarity of magnetic field direction. A wide operating voltage range from 2.5 to 38 V with reverse polarity protection up to –22 V makes the device suitable for a wide range of industrial and consumer applications.

Internal protection functions are provided for reverse supply conditions, load dump, and output short circuit or overcurrent.

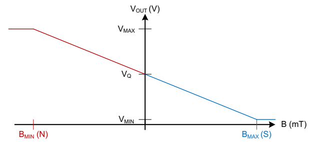
Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
DRV5053	SOT-23 (3)	2.92 mm × 1.30 mm
	TO-92 (3)	4.00 mm × 3.15 mm

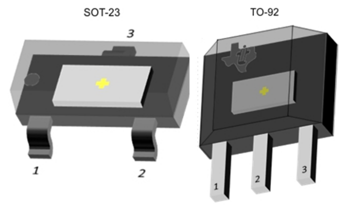
(1) For all available packages, see the orderable addendum at the end of the data sheet.

- **Protection Features**
  - Reverse Supply Protection (up to –22 V)
  - Supports up to 40-V Load Dump
  - Output Short-Circuit Protection
  - Output Current Limitation

Output State

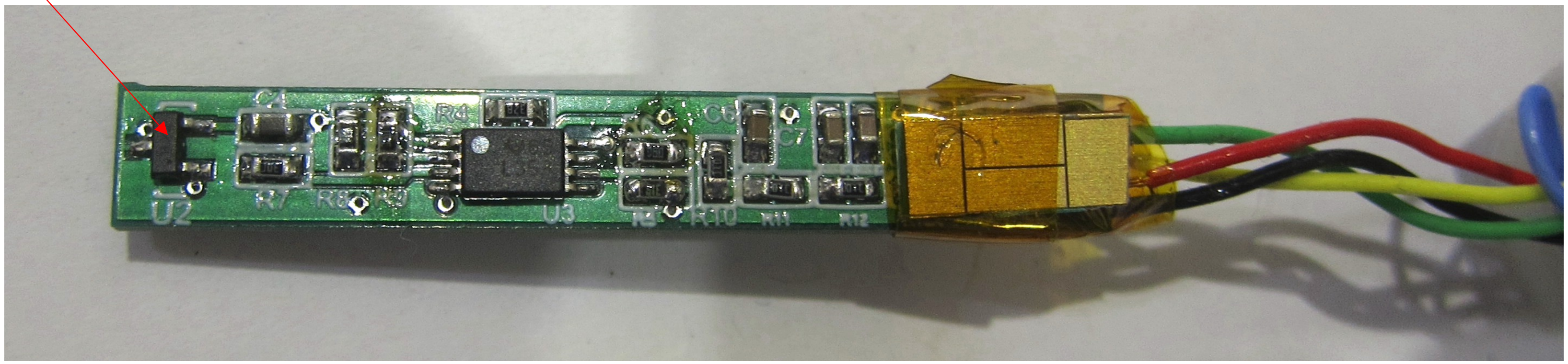


Device Packages



Sensor with the front-end

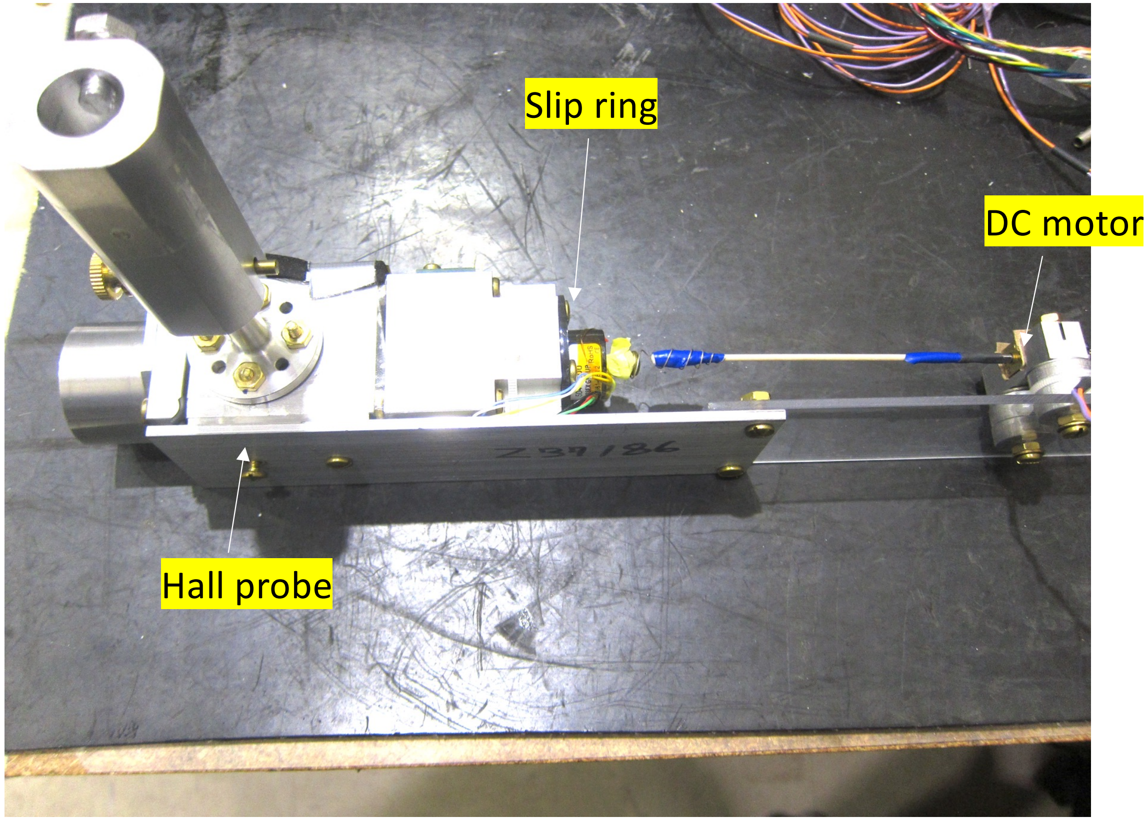
Hall probe



Front-end provides an additional signal gain by a factor of 10

Thanks to Chris Cuevas and Jeff Wilson

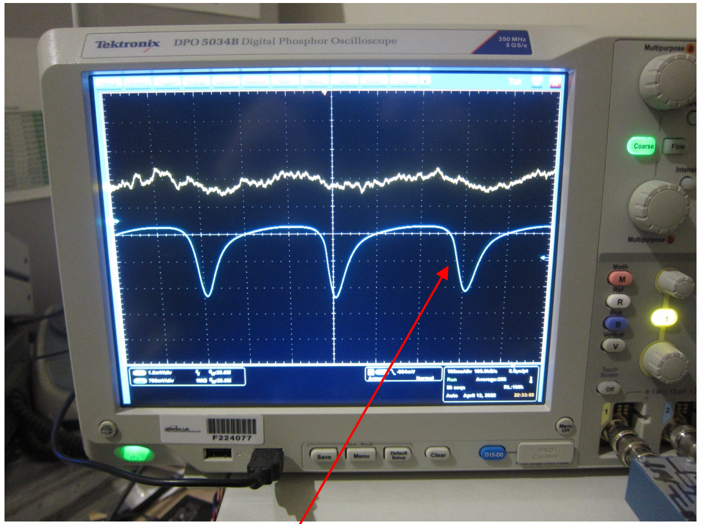
Spinning HP Prototype

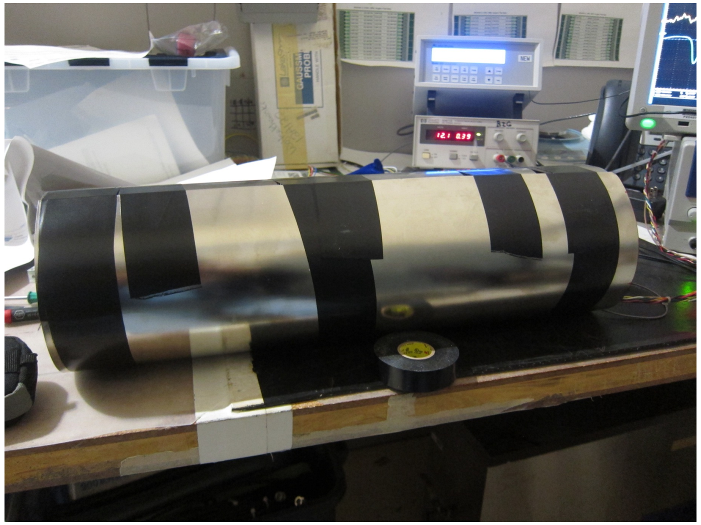


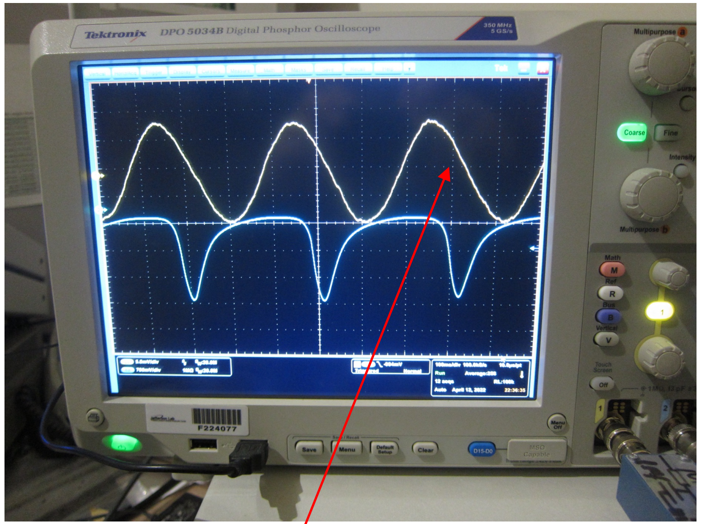
Test in Earth's field

Inside magnetic shield ~ 0.5 mV
noise level of 0.1 mV

In ~ 0.50 Gauss => 17 mV



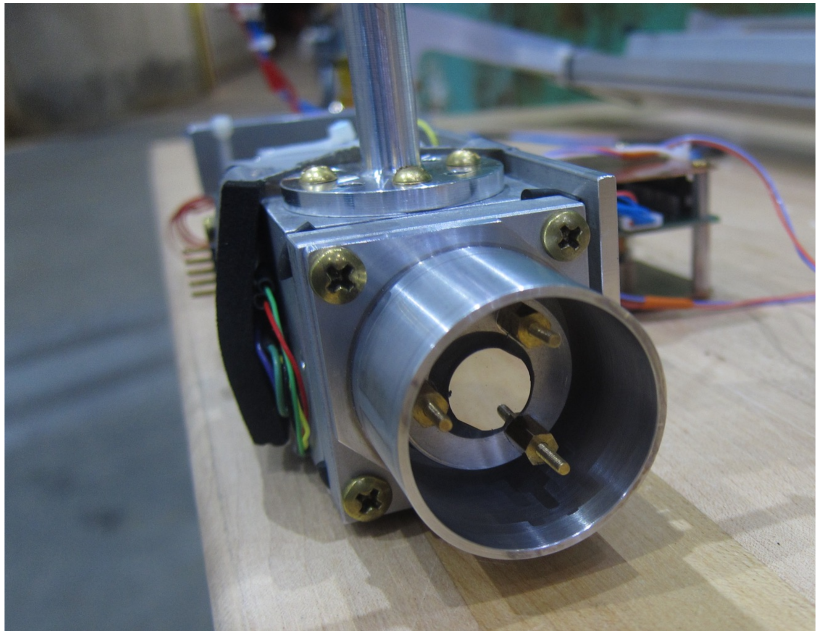


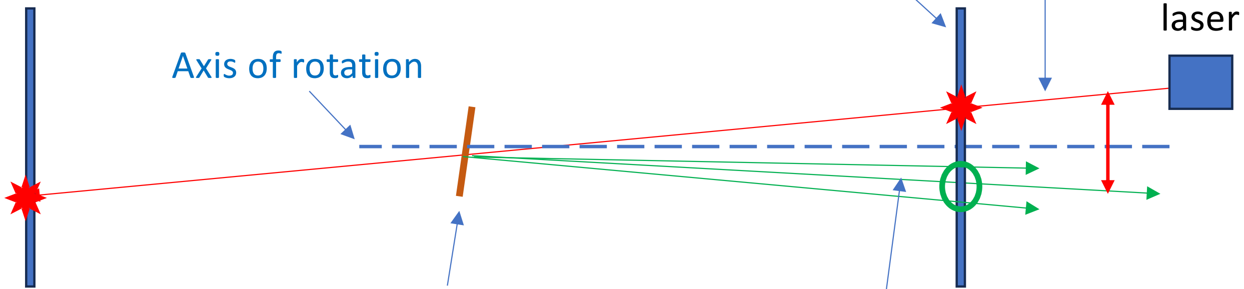


reference signal from spinning LED

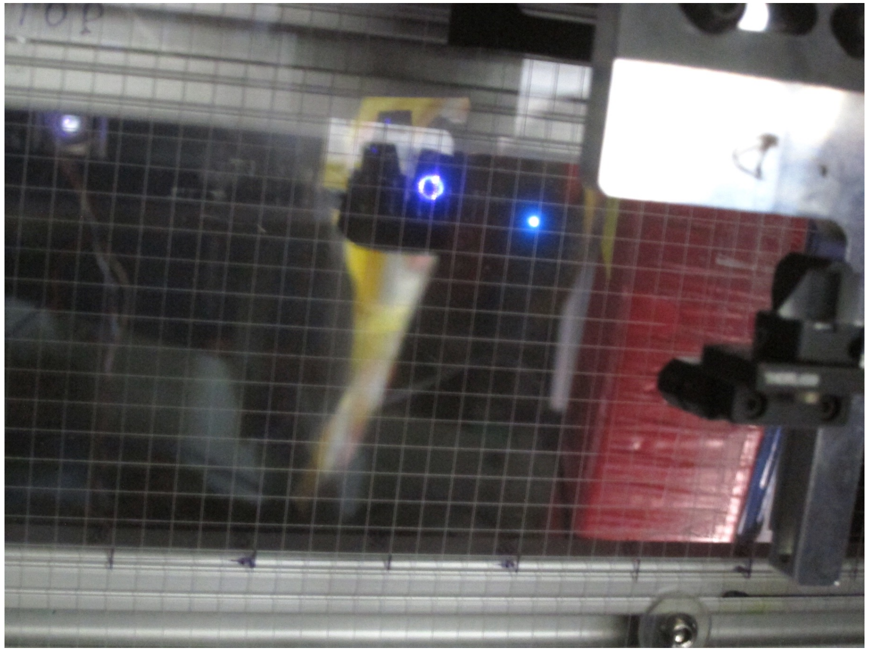
Hall probe signal

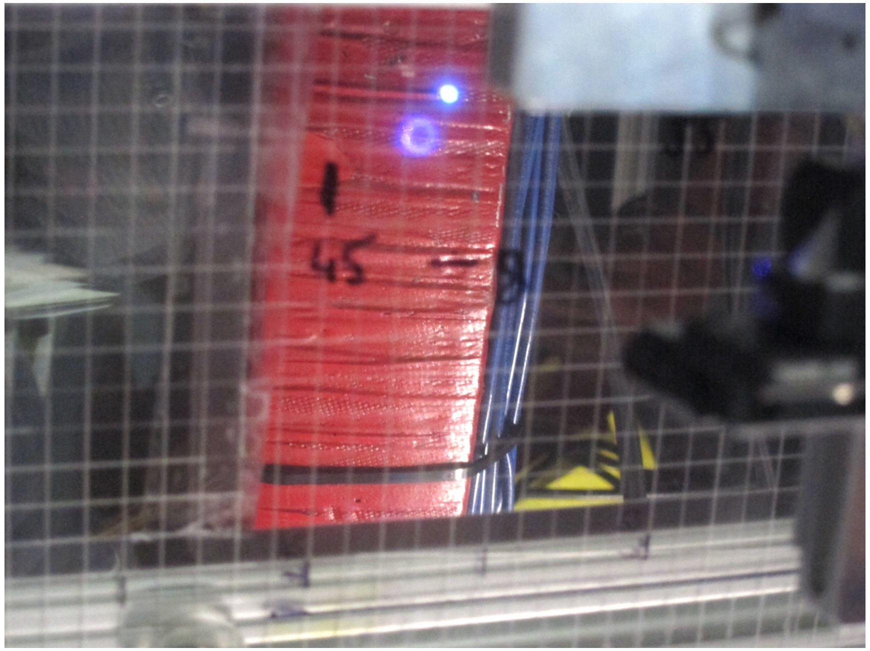
Determination of the direction of the axis of rotation





Spinning Compass in action for GEn-II





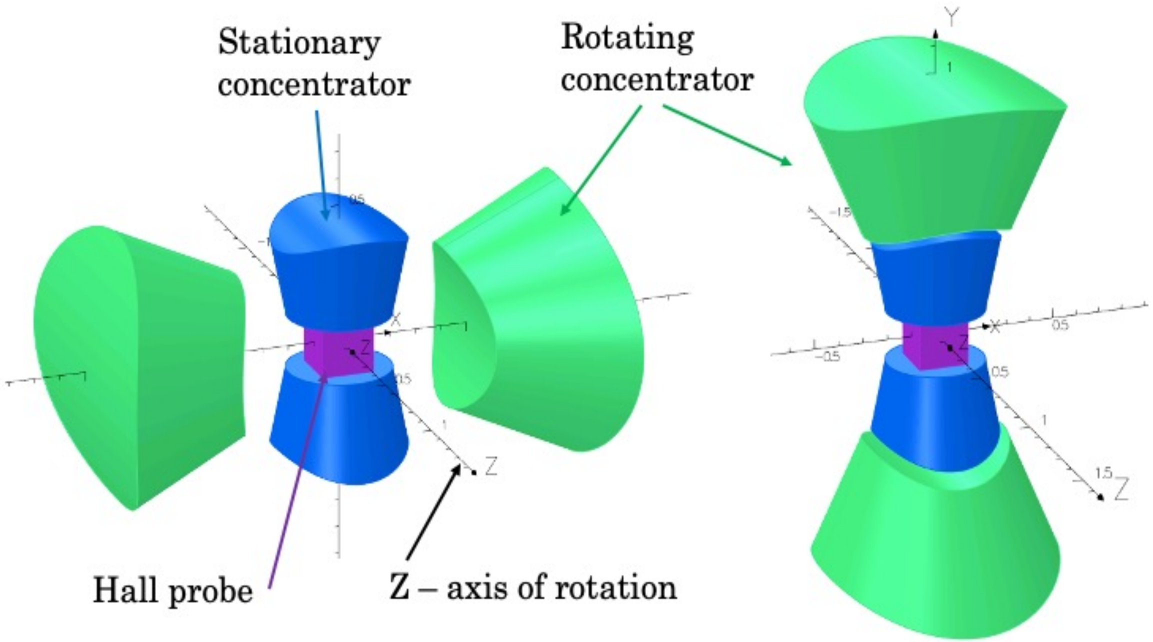
Spinning Hall probe compass: patent granted

Patent number: 12104903
Type: Grant
Filed: Feb 14, 2022
Date of Patent: Oct 1, 2024
Patent Publication Number: 20220282970
Assignee: JEFFERSON SCIENCE ASSOCIATES, LLC (Newport News, VA)
Inventors: Bogdan Wojtsekhowski (Yorktown, VA), Guy Ron (Mevaseret Zion)
Primary Examiner: George B Bennett
Application Number: 17/671,112

Classifications

Current U.S. Class: **Fluid, Suspension Or Control (33/327)**
International Classification: G01C 17/32 (20060101); G01R 33/07 (20060101);

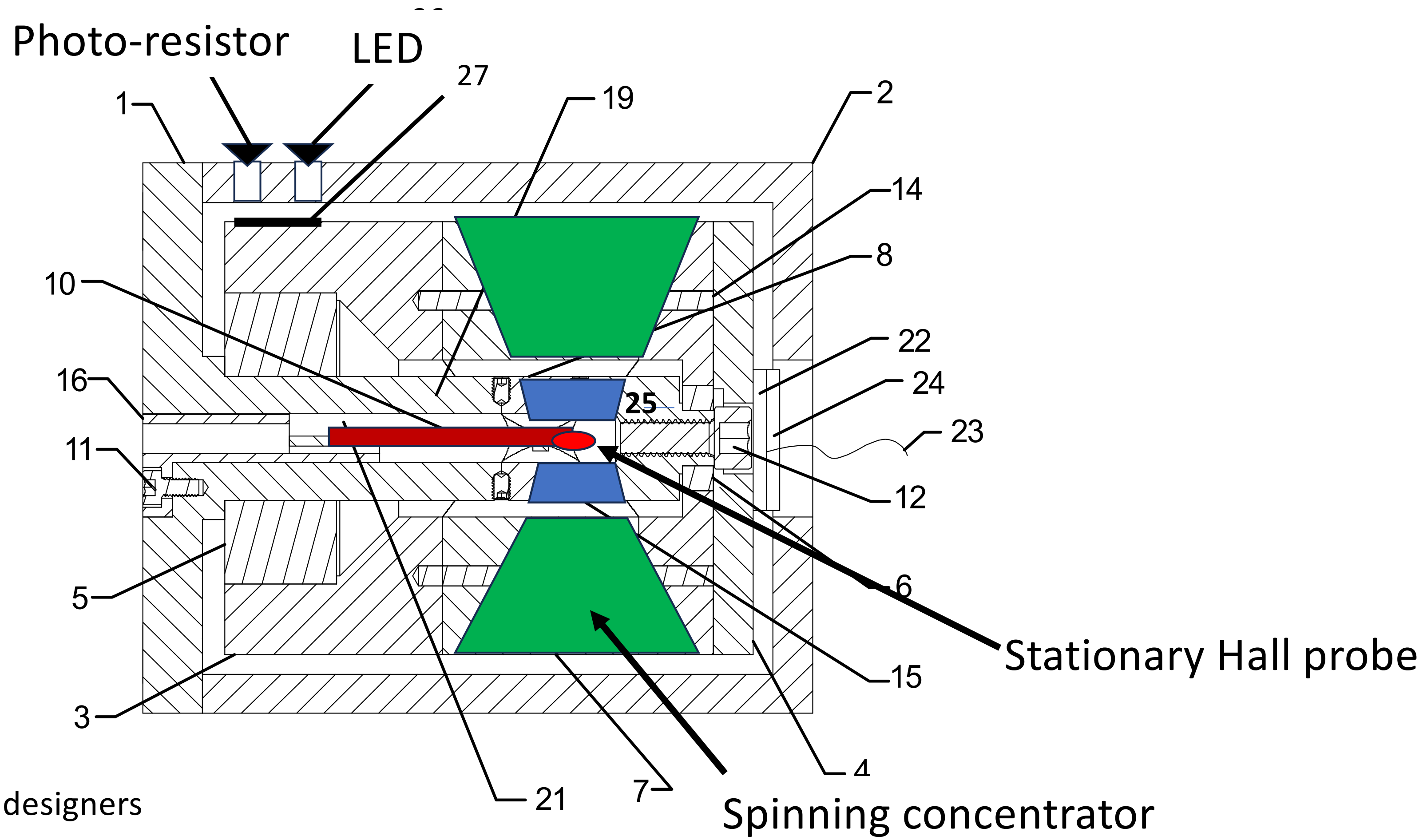
Rotating field concentrator



Rotation of the external (green) concentrators leads to an oscillating signal from the Hall probe.

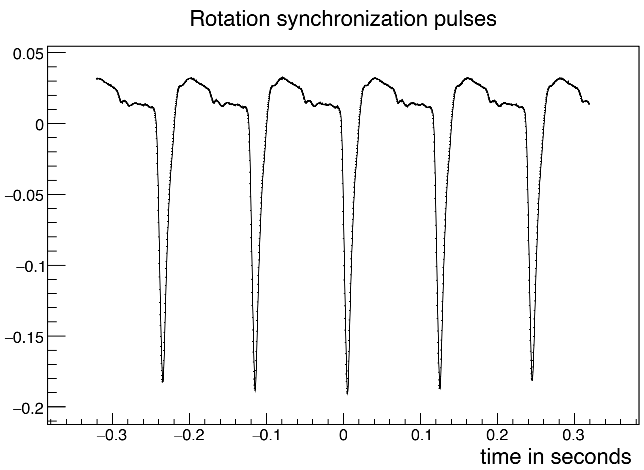
The field on the Hall probe induced by the external field has the double frequency of oscillation.
The signal due to residual magnetization of the poles has the same frequency as the rotation.

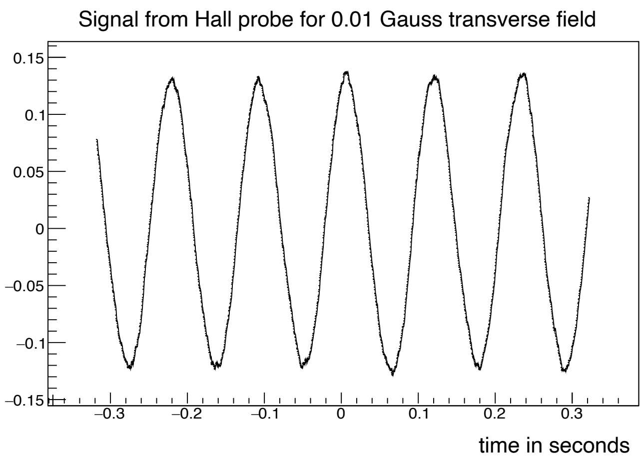
The compass prototype, thanks to UVa



Thanks for Hall C designers

Signal from a stationary Hall probe vs. rotation phase



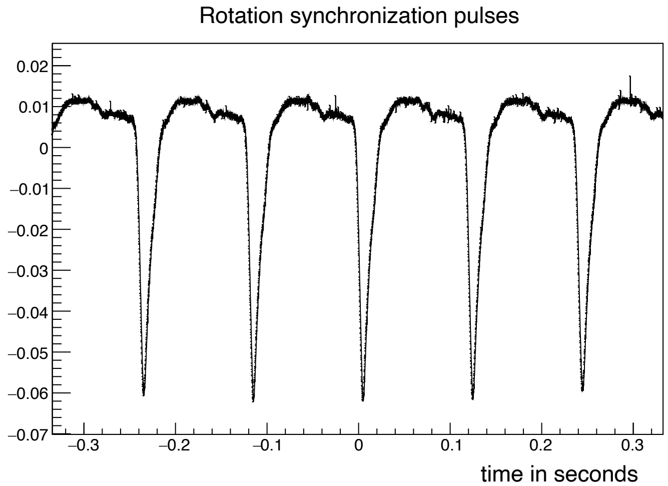


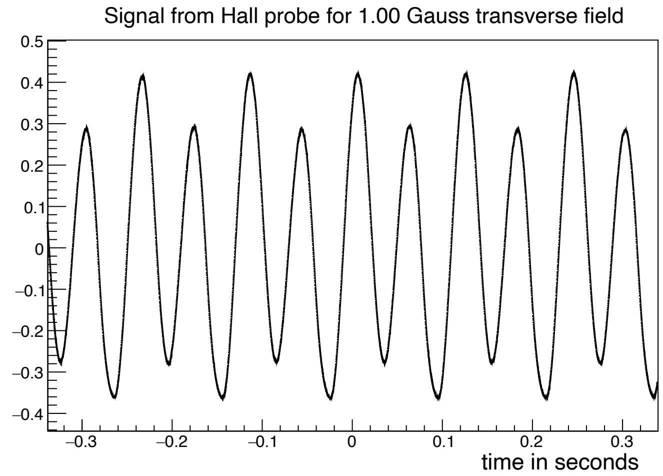
The signal from the oscilloscope (upper panel) with synchronization pulses (8 Hz rotation rate).

The signal from the Hall probe (lower panel) for a transverse field of 0.01 Gauss, which leads to a very small value of the second harmonic.

The first harmonic signal is from residual magnetization of the carbon steel iron poles.

Signal from a stationary Hall probe vs. rotation



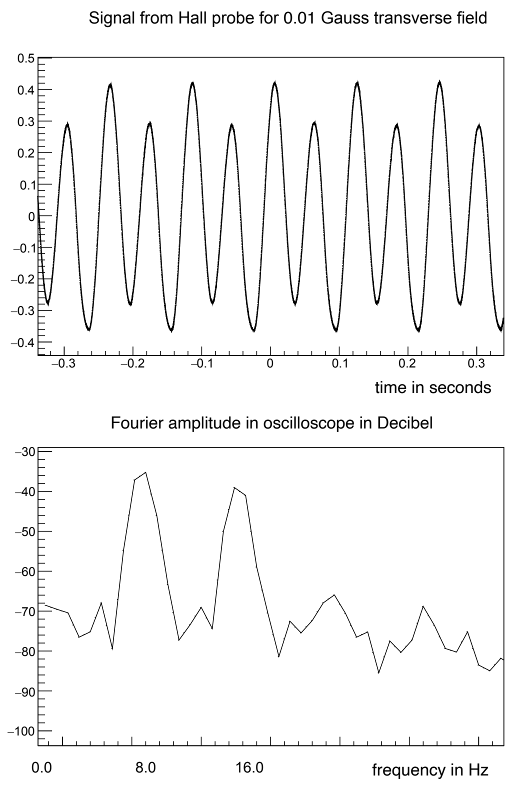


The signal from the oscilloscope (upper panel) with synchronization pulses (8 Hz rotation rate).

The signal from the Hall probe (lower panel) for a transverse field of 1.00 Gauss, which leads to a larger value of the second harmonic.

The second harmonic signal is from induced magnetization by the external field.

Harmonics of the signal

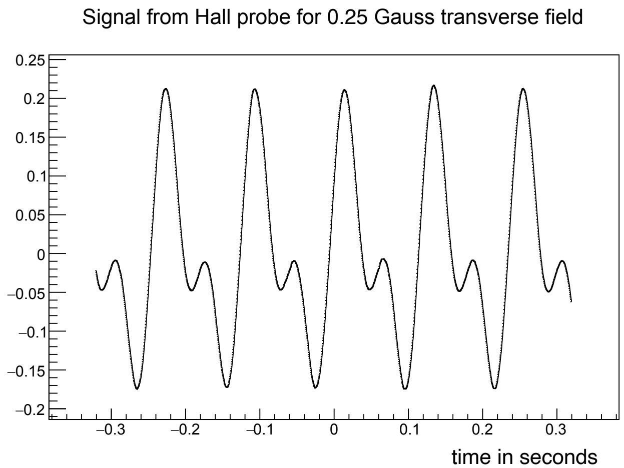


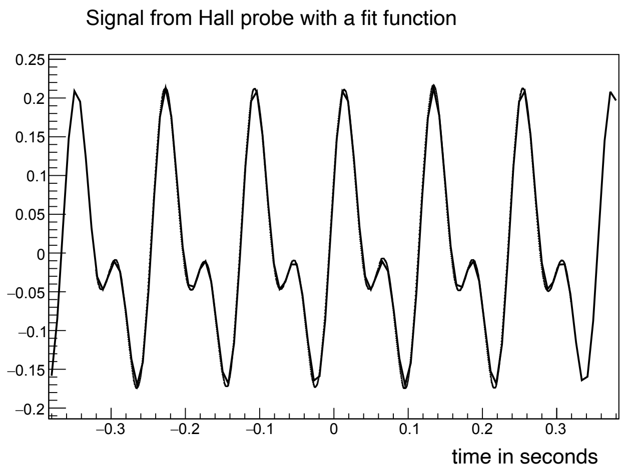
Harmonics analysis

The Hall probe signal from the oscilloscope (upper panel)

The amplitude of the Fourier transform of the Hall probe signal (lower panel) for a transverse field of 0.9 Gauss, which shows a large value of the second harmonic (at 16 Hz). The first harmonic (at 8 Hz) is also large.

Observed accuracy of the compass





Fit of the data taken from oscilloscope

The Hall probe signal from the oscilloscope (upper panel) for a 0.25 Gauss transverse field (horizontal Earth field)

The same with a fit by a five-parameter function where parameters are A, B, Ω, t0, and phase as shown below
A x sin (Ω x (time-t0)) + B x sin(2 x Ω x (time-t0) + phase)

The fit result for B = 0.25 +/- 0.00020 Gauss, so the relative accuracy is better than 1/1000.

This confirms that the angular accuracy 1 milli radian is achieved in 10 seconds with an 8 Hz rotation rate.

Spinning Field Concentrator Magnetic Compass: patent application

US 20250251239A1

(19) **United States**
(12) **Patent Application Publication**
WOJTSEKHOWSKI

(10) **Pub. No.: US 2025/0251239 A1**
(43) **Pub. Date: Aug. 7, 2025**

(54) **SPINNING FIELD CONCENTRATOR MAGNETIC COMPASS**

(71) Applicant: **JEFFERSON SCIENCE ASSOCIATES, LLC**, newport news, VA (US)

(72) Inventor: **BOGDAN WOJTSEKHOWSKI**, Yorktown, VA (US)

(21) Appl. No.: **19/066,439**

(22) Filed: **Feb. 28, 2025**

Related U.S. Application Data

(60) Provisional application No. 63/627,913, filed on Feb. 1, 2024.

Publication Classification

(51) **Int. Cl.**

G01C 17/30	(2006.01)
G01R 33/00	(2006.01)
G01R 33/07	(2006.01)

(52) **U.S. Cl.**
CPC ***G01C 17/30*** (2013.01); ***G01R 33/0029*** (2013.01); ***G01R 33/072*** (2013.01)

(57) **ABSTRACT**

A high precision magnetic compass based on a stationary Hall probe and a spinning two-poles mu-metal field concentrator. The spinning poles lead to an oscillating magnetic field at the location of the Hall probe. The Hall probe sensitivity direction is oriented at an angle of 90 degrees to the rotation axis of the device. A second harmonic of oscillating component, or double frequency, of the signal from the probe, synchronized with the device rotation, is used to align the axis of rotation to be parallel to the magnetic field. The device does not require prior calibration. It is insensitive to drift of the probe parameters and can provide an angle with precision equal to or better than a 0.05 degree.