Magnetic Field Scanner

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The $G^n_E$ experiment will be conducting with a longer $^3$He target chamber. The length of the target chamber will be of 60 cm. The inhomogeneities of holding field within the target volume have to be as low as possible. The holding magnetic field in the target will be formed by two Helmholtz coils early used in the transversity experiment. The stray field from BigBite and SBS magnets simulated by TOSCA will be reduced by the iron shield covering the target set-up. The direction of the holding magnetic field keeps the direction of spin of polarized $^3$He and should be measured with precision around $\sim$1 mrad. We need know the direction relatively of the beam line. The precision of the field measurements are limited by accuracy of magnetic sensor and accuracy the spatial location of the sensors. The DRV5053 Analog-Bipolar Hall Effect Sensor was chosen as main element of measurement system. Parameters of the sensor are given Fig. 1.
Figure 1: Electrical parameters of the sensor

**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 × 1.30 mm
  - Through-Hole 3-Pin TO-92 (LPG)
    - 4.00 mm × 3.15 mm
- Protection Features
  - Reverse Supply Protection (up to –22 V)
  - Supports up to 40-V Load Dump
  - Output Short-Circuit Protection
  - Output Current Limitation

**Applications**

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

**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**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>BODY SIZE (NOM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRV5053</td>
<td>SOT-23</td>
<td>2.92 mm × 1.30 mm</td>
</tr>
<tr>
<td></td>
<td>TO-92</td>
<td>4.00 mm × 3.15 mm</td>
</tr>
</tbody>
</table>

(1) For all available packages, see the orderable addendum at the end of the data sheet.
Two sensors were glued to the aluminium holder side by side. Fig. 2 shows how they are placed. This holder was installed on the rotator stage.

Figure 2: The holder of two hall sensors with adapter.
The holder was installed on the rotation stage which turns the sensor with high precision by command from computer. The Thorlabs rotation stage declares an angular precision of $\pm 100 \mu rad$ and maximum axial wobbling of $500 \mu rad$. This precision meets to our angular accuracy required.

Figure 3: Sensors installed on the rotation stage
Appendix A  Specifications

A.1 Stage Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Range</td>
<td>360° Continuous</td>
</tr>
<tr>
<td>Max Speed</td>
<td>10 °/s</td>
</tr>
<tr>
<td>Min Speed</td>
<td>0.005 °/s</td>
</tr>
<tr>
<td>Max Acceleration</td>
<td>20° /s/s</td>
</tr>
</tbody>
</table>

*Note

The acceleration is limited by the motor force, and must be reduced for higher loads.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unidirectional Repeatability(^1)</td>
<td>± 60 µrad</td>
</tr>
<tr>
<td>Backlash</td>
<td>±200 µrad</td>
</tr>
<tr>
<td>Resolution (Theoretical)</td>
<td>0.0073° (~127 µrad)</td>
</tr>
<tr>
<td>Min. Repeatable Incremental Movement (^2)</td>
<td>0.03°</td>
</tr>
<tr>
<td>Maximum Load Capacity</td>
<td>22 N (see Section A.3.)</td>
</tr>
<tr>
<td>Absolute Accuracy(^1)</td>
<td>±0.14°</td>
</tr>
<tr>
<td>Home Location Accuracy</td>
<td>±100 µrad</td>
</tr>
<tr>
<td>Max Wobble (Axial)</td>
<td>500 µrad</td>
</tr>
</tbody>
</table>

\(^1\) Bi-directional repeatability and accuracy will be the same if Backlash Correction is enabled in the Kinesis Software.

\(^2\) Min. Repeatable Incremental Movement is the smallest controlled movement that the stage can be positioned repeatedly where the error is less than 10% of the specified step size at a 99.5% confidence level.
One can compare K10CR1 with the manual rotator (precision $\sim 1.5$ mrad). You can see how inconvenient is in reading angle and easy to bump.

Figure 5: Manual Rotation Stage
The rotator with hall probes is installed on the rail.

Figure 6: Rotator installed on the rail
Fig. 7 shows assy of the rotator with an aluminium beam to install inside one Helmholtz coil for calibrating. The direction of field in central plane of coil is calculated for a few currents and can be compared with measured one.

Figure 7: Rotator assy.
The output voltage from two sensors was reading by the ADC module and recorded by PC. We have recorded $\sim 10^3$ values of output voltages at each angle. The frequency of reading can be varied and we work at 5 Hz.

Figure 8: The screen shot of the data after ADC.
Rotator was turning by $10^\circ$ step. At each angle the output voltage was read out and recorded $\sim 10^3$ times. From this data at each angle we calculated the mean value of output and its standard deviation. So we have 35 mean values at each position rotator. It is an angular scan of magnetic field value. Fig. 9 shows typical spectra of amplitudes from two sensors.

Figure 9: Two plots of voltages outputs from two Hall sensors at one of angles
Fig. 10 shows the mean values versus rotation angle. Solid curves are fit to function:

\[ a = b + d \cos(\phi + \delta) \]

Where \( b \) is the base voltage of Hall (equal 1 Volt for \( \vec{B} = 0 \)).

\( \phi \) is the current angle of turn and \( \delta \) is angle of vector \( \vec{B} \).

There \( \vec{B} \) is a projection of \( B \) to the plane of rotation.

Figure 10: Two angular scans from two Hall probes in the point closed to the target cell.
The scans have been done in three points along the cell target at front, middle and back points. Parameters of fit are presented in the following tables for sensor a00 and a01.

### Table 1: a00 Hall probe

<table>
<thead>
<tr>
<th>parameter</th>
<th>Front point</th>
<th>Center point</th>
<th>Back point</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b$ (V)</td>
<td>1.0000±0.63E-04</td>
<td>1.0002±0.22E-04</td>
<td>0.9987±0.65E-04</td>
</tr>
<tr>
<td>$d$ (V)</td>
<td>0.14276±0.88E-04</td>
<td>0.14253±0.32E-04</td>
<td>0.14365±0.90E-04</td>
</tr>
<tr>
<td>$\delta$ (degrees)</td>
<td>2.80200±0.36E-01</td>
<td>2.89559±0.12E-01</td>
<td>3.53880±0.36E-01</td>
</tr>
<tr>
<td>$\chi^2/n(points)$</td>
<td>40/39</td>
<td>35/35</td>
<td>40/35</td>
</tr>
</tbody>
</table>

### Table 2: a01 Hall probe

<table>
<thead>
<tr>
<th>parameter</th>
<th>Front point</th>
<th>Center point</th>
<th>Back point</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b$ (V)</td>
<td>1.0029±0.55E-04</td>
<td>1.0009±0.17E-04</td>
<td>1.0032±0.24E-04</td>
</tr>
<tr>
<td>$d$ (V)</td>
<td>0.14738±0.78E-04</td>
<td>0.14736±0.24E-04</td>
<td>0.14893±0.35E-04</td>
</tr>
<tr>
<td>$\delta$ (degrees)</td>
<td>2.08967±0.30E-01</td>
<td>2.30777±0.96E-02</td>
<td>2.79449±0.13E-01</td>
</tr>
<tr>
<td>$\chi^2/n(points)$</td>
<td>45/39</td>
<td>34/35</td>
<td>35/35</td>
</tr>
</tbody>
</table>
Outline

From these tables we can see the accuracy of determination of direction of field $\vec{B}$ in range from 0.036 to 0.0096 degrees or 0.6 mrad to 0.17 mrad. This method will provide required precision $\sim 1$ mrad. The Hall probe is tiny and can be easy manipulated.

We have to do:

- We have learn how to calibrate the scanner
- We need invent a way of spatial and angular alignment to make absolute calibration with the accuracy better than 1 mrad.
- We need to develop a software for fast and remote work with the scanner.
- We need develop the technical design to integrate the scanner into construction of the polarized target.
Acknowledgment

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I want to thank Bogdan Wojtsekhowksi for attention to this work. I have to thank Vladimir Popov for the very helpful tips to choose hardware. I appreciate Al Tobias, Roman Pomatsalyuk, Nikolay Sandev for installation of soft to make measurements. I thank Huong Nguyen for help in measurements.
THANKS !