A31315 SLIDE-BY INTRODUCTORY APPLICATION GUIDE

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INTRODUCTION

The Allegro MicroSystems A31315 is a multi-axis Hall-effect sensor with advanced integrated signal processing capabilities that simplifies the numerous design challenges that the systems designer faces. The advanced linear sensor leverages two advanced linear Hall sensor channels and seamlessly integrates them into a signal processing chain that offers:

- Individual sensor gain and offset adjustment
- Two-point programming
- Four modes of output linearization
- Complex signal conditioning with rollover control
- 16-bit output/result register

These features can be configured to best fit the customer's application, thus providing the widest possible range of solutions for numerous applications and their challenges.

One challenge many systems designers face is fitting a sensor to their application's magnetic requirements. Where many other sensors are constrained and offer a 'closest match,' the A31315's signal processing blocks enable the designer to adapt the sensor around the mechanical and magnetic constraints of the system

In this application note, an off-the-shelf magnetic target SuperMagnetMan (part number C0255) will be used to briefly demonstrate the behavior/performance and advantages of the A31315. This target is a ¼" cube, of neodymium N40 material, but many other target sizes and materials are acceptable, so long as the minimum magnetic range of ±300 G peak is reached. This target will be used to demonstrate the capabilities of a slide-by motion application, just as what may be used for a brake or accelerator pedal.

This application note makes the following assumptions:

- The reader will be familiar with the A31315's programming software environment.
- The reader is familiar with the concepts of two-point programming and linearization.
- The user can communicate with the A31315 through the programming software and the appropriate programming hardware (typically an ASEK20).

INITIAL WORK

Before approaching the challenges of a particular application, it is a good idea to understand the nature of the sensing challenges to be faced. Figure 15 provided at the end of this note should be referenced for problems typically present in sensing applications. When evaluating Figure 15, keep in mind particular characteristics of the input waveforms to know what to look for.

The first step to quickly tuning the sensor for the system is to obtain a baseline read of the Hall sensors output. This step is the most important, as the input characteristic will have the largest impact on the effectiveness of the quality of output signal.

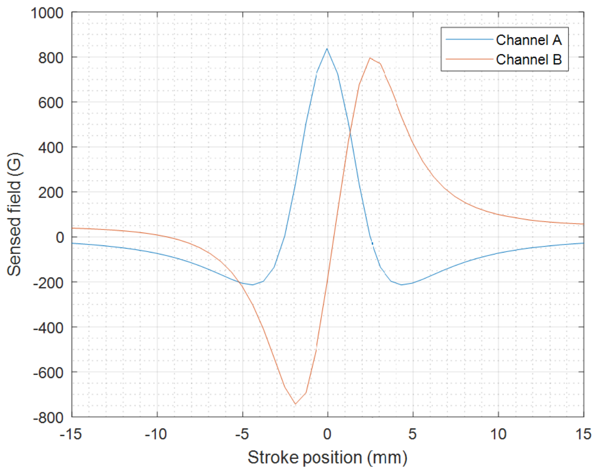


Figure 1: C0255 magnet detected field over 30 mm stroke

When the measured signal shown in Figure 1 is compared with Figure 15 at the end of this document, it aligns with the input case where the two input channels are mismatched and/or the stroke is too long. For the A31315, the user has the option to adjust the gains of the system through the following registers:

- Sens_c_a – Coarse sense adjust for channel A
- Sens_c_b – Coarse sense adjust for channel B

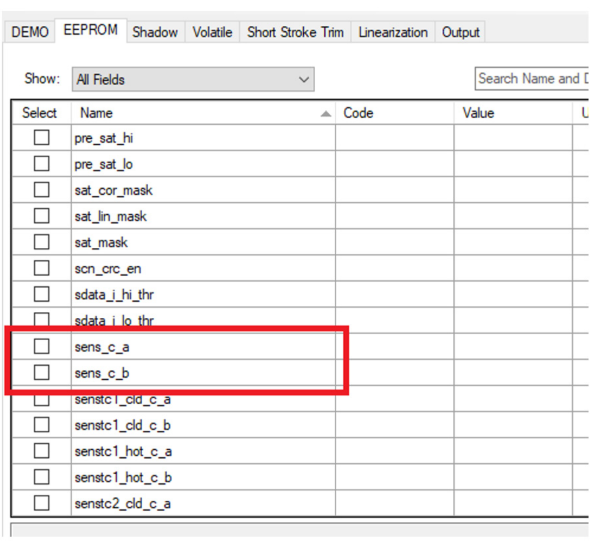


Figure 2: Sense adjust registers within the A31315 software

The A31315 also provides offset registers that help center the detected signals:

- Offs_c_a – Offset adjustment for channel A
- Offs_c_b – Offset adjustment for channel B

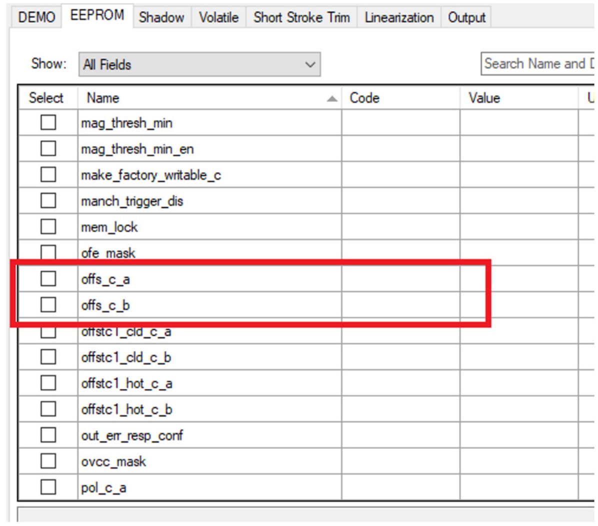


Figure 3: Offset adjust registers within the A31315 software

When adjusting these registers, the intent is to obtain input signals which most closely match sine and cosine signals. The closer the match, the more natively "linear" the output response. With the stroke illustrated in Figure 1, a stroke range from –3 mm to +3 mm is chosen for this example.

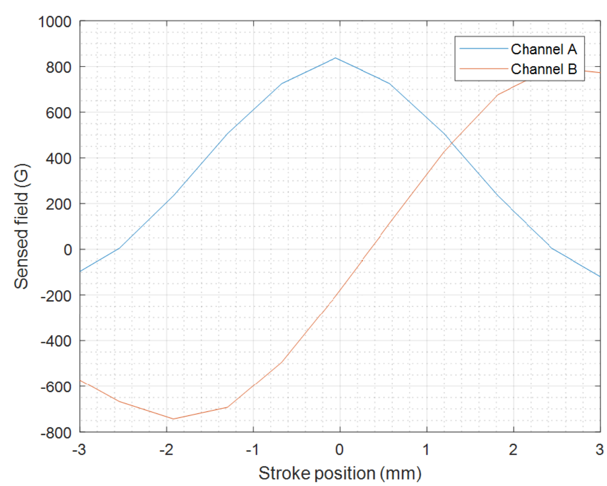


Figure 4: Close-in plot of sensed field over ±3 mm

In this case, Channel B would benefit through offset correction:

- CH_B: +50 G

The intent of adjusting gain and offset is to correct the sensed signals into being as close to sine and cosine in shape as possible.

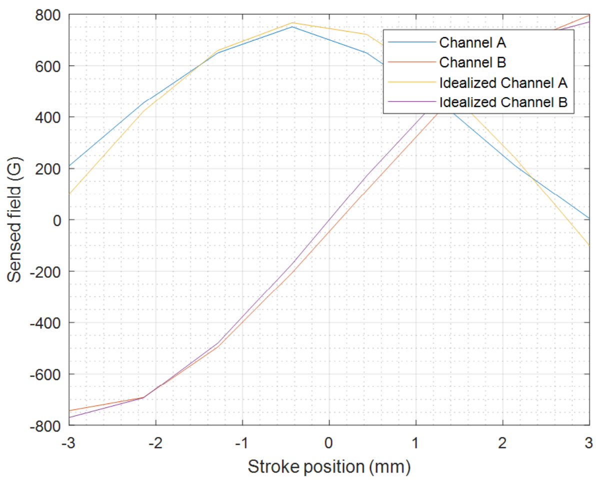


Figure 5: Real signals after gain and offset correction, with their ideal counterparts

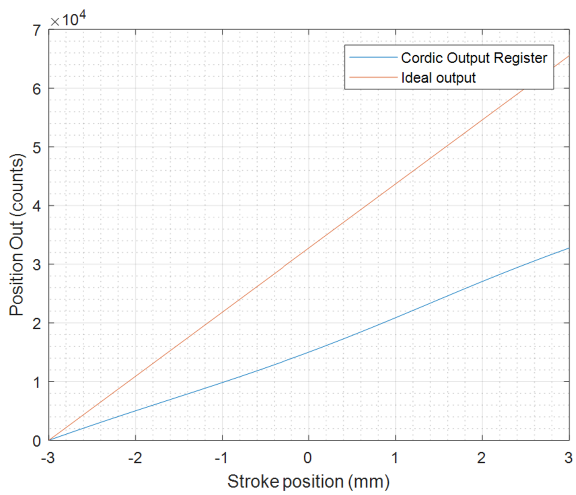


Figure 6: Output signal vs. Expected Output, negative counts are processed from a rollover

The consequence of the non-idealities in the signals (Figure 5) produces a reported position that is non-linear. The diminished output, not even reaching halfway (32768 counts), is explained through the lack of full 360° sine/cosine sensed field over the stroke. This limitation in range can be corrected for in two-point programming. The non-linearity can be further addressed with the versatile linearization engine, with up to 33 points of correction.

Using two-point programming (sometimes referred to as short stroke), the initial datapoint is moved to around 0 counts, while the final datapoint is gained up to around 65535 counts (16 bits). There are two methods to program the coefficient and offset values in the two-point programming block:

- Register manipulation via:
  - □ Angle_gain
  - □ Pre_gain_offset
- Semi-automatic via Samples Programming Software

Register Manipulation

Performing the adjustments through register manipulation is straightforward and is easily calculated by hand. Relevant registers for this block are found within the "Short-Stroke" option of the drop-down menu within the EEPROM tab.

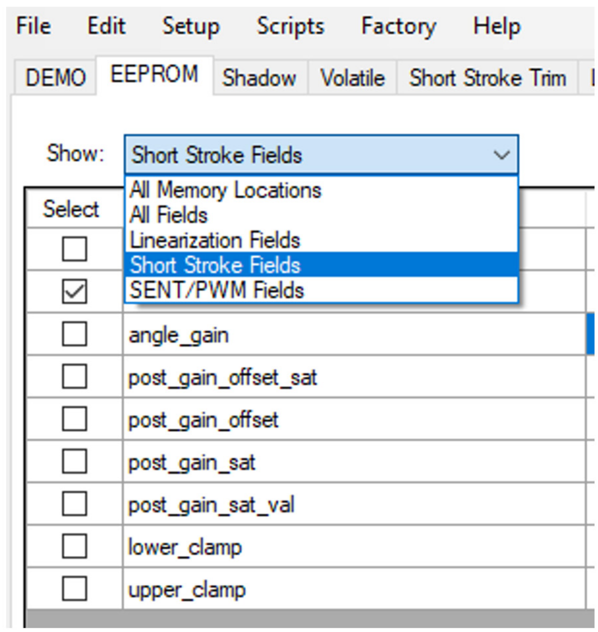


Figure 7: Two-point programming register group selection

For simplicity, the focus registers are:

- pre_gain_offset: Adds an offset to the starting value, typically a value of sizable value to push the starting point over to zero. Value ranges from 0 to 32767.
- angle_gain: Applies a gain to the reported output. 'Angle' is typical of rotary applications, but applies to linear applications as well. Values range from 0 to 65535, a gain of 1 is equivalent to 1024 counts.

For linear applications, the terminology must be aligned. The software indicates values as affecting angles; however, the term is merely used to give a reference for the output register's range of 0 to 65535. For pre_gain_offset, this register adds an offset to the output from the CORDIC engine within the A31315; if the resulting output would exceed the 16-bit register width, the net effect is a rollover of the output. This is particularly useful to zero the starting point.

While Figure 6 happens to start at zero, suppose the starting point rests at 2458 counts, setting the initial point to zero would simply require adding an offset to force the result to equal 65536:

1. Offset = 65536 – starting_point_counts
2. Offset = 65536 – 2458
3. Offset = 63078

In Figure 8, the maximum position reports an output of 32770 counts. Angle gain can correct for this easily:

4. angle_gain = desired_output / actual_output
5. angle_gain = 65535 / 32770
6. angle_gain = 1.999 (2)

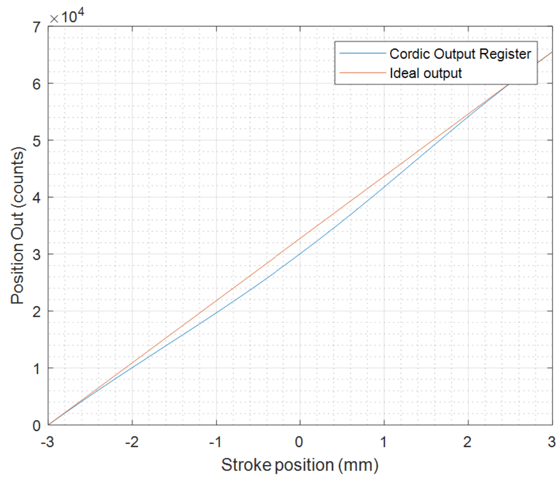


Figure 8: New output with gain applied.

Using the Short-Stroke Tool

Within the Samples software itself, the manual calculations may be skipped, and the Short-Stroke table may be used to quickly perform this step.

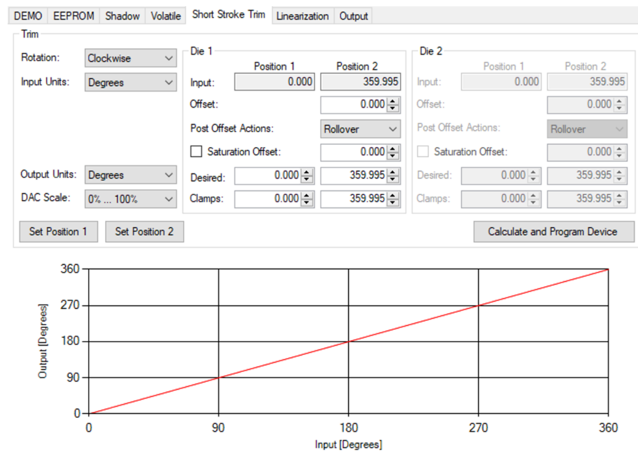


Figure 9: The Short-Stroke tab

Here, the system must be set to the minimum position, and the user need only press "Set Position 1." The software will query the A31315 and perform initial computations. Once complete, move the system to the final position and click "Set Position 2." Programming the new values is performed through clicking "Calculate and Program Device."

OUTPUT ERROR

For linear slide-by applications, output error is often expressed as either a percentage or an absolute unit of measurement. In the example shown in this note within Figure 10, the non-linear behavior is still persistent.

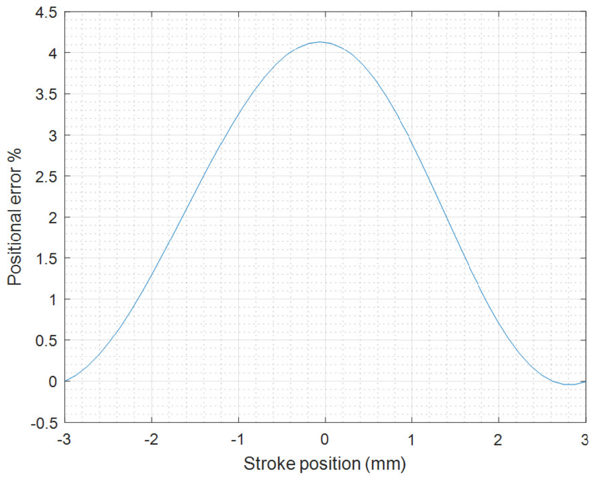


Figure 10: Output error percent without linearization

In order to correct this error, linearization must be applied. For the highest performance, more datapoints must be taken (33). In this case, the system is stepped from the starting position, to the final position, in 32 equidistant steps (33 total steps starting from 'zero'). Each step is captured in the A31315 samples programming software and is shown in Figure 11.

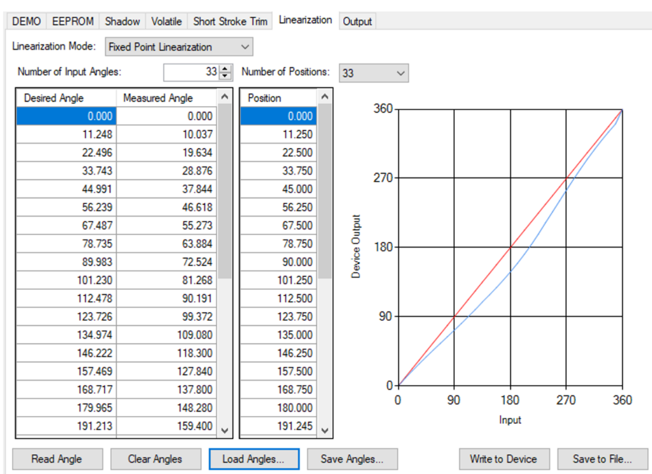


Figure 11: Linearization Tab with sensed values (as angles) recorded

Once the values are loaded, clicking "Write to Device" computes the correction coefficients and programs the target device.

In cases where the data is captured and the intended position is already recorded, linear position can be translated to "angle" for the software as:

7. angle = 360° × (count_value / 65536)

In such cases, the software will import a CSV file with the first column being the intended position, while the second column is the recorded position.

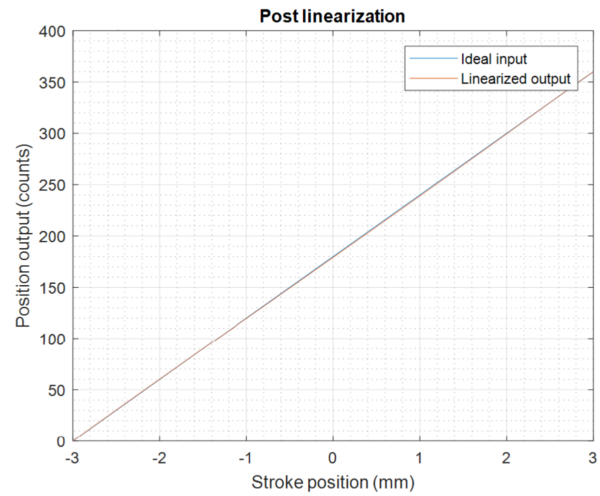


Figure 12: Resulting output after linearization.

Figure 12 presents the resulting Linearization post-processing performed on the native curve. For meaningful detail, the real signal is compared against an idealized signal that would be expected. The linearity error, typically expressed in percent, is shown in Figure 13. After the linearization, the final error was reduced from 4.2% down to 0.28 %.

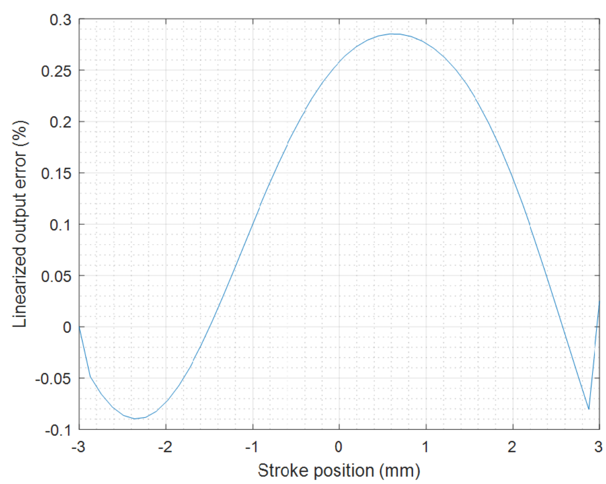


Figure 13: Linearization error as a percent over the full range, smoothing applied

ADDITIONAL PROCESSING

Once the signal of interest is processed and linearized, there are some cases where limits must be applied in order to meet certain system specifications or margining. The A31315 offers a suite of tools available to the user to adjust behavior of the output signal following linearization.

Clamping

In some applications, there is a requirement to limit signal ranges output by the sensor. Suppose as a part of the fail-safe design of the system, a minimum and maximum margin of 10% were defined. This limitation can be set through the application of the registers:

- Lower_clamp: Establish the minimum output value from the signal block. (Values from 0 to 65535 are acceptable)
- Upper_clamp: Establish the maximum output value from the signal block. (Values from 0 to 65535 are acceptable)

10% of 65535 would be about 6554, which would be set to the lower_clamp register. 90% of the maximum signal would be 58982 counts, which would be set to the upper_clamp register.

Saturation

Clamping provides a limiting function on the data it sees. However, if the data coming from the CORDIC block into the two-point programming block causes a register overflow (where data would exceed 65535 counts) as in the case of increased angle gain (see Figure 6), the output word can roll over back to zero and restart. This would be indicated by the clamped high value suddenly switching to the clamped low value, before possibly returning to a climbing output.

Saturation is a block which can inhibit this behavior by ignoring data which suggests the sensor is continuing past the current sensed limit. This functionality is managed and controlled by the following registers:

- Post_gain_sat: Set to 1 to enable saturation.
- Post_gain_sat_val: The crossover point for which the input signals are ignored, acceptable inputs are 0-255 counts.

The calculation of post_gain_sat_val has multiple steps and requires some consideration. The detailed process is described in the A31315 datasheet. Figure 14 shows a collection of these effects.

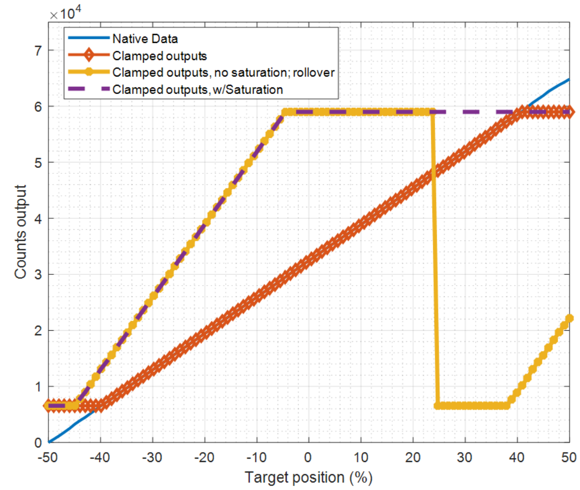


Figure 14: Various functions/effects of Clamping and Saturation features.

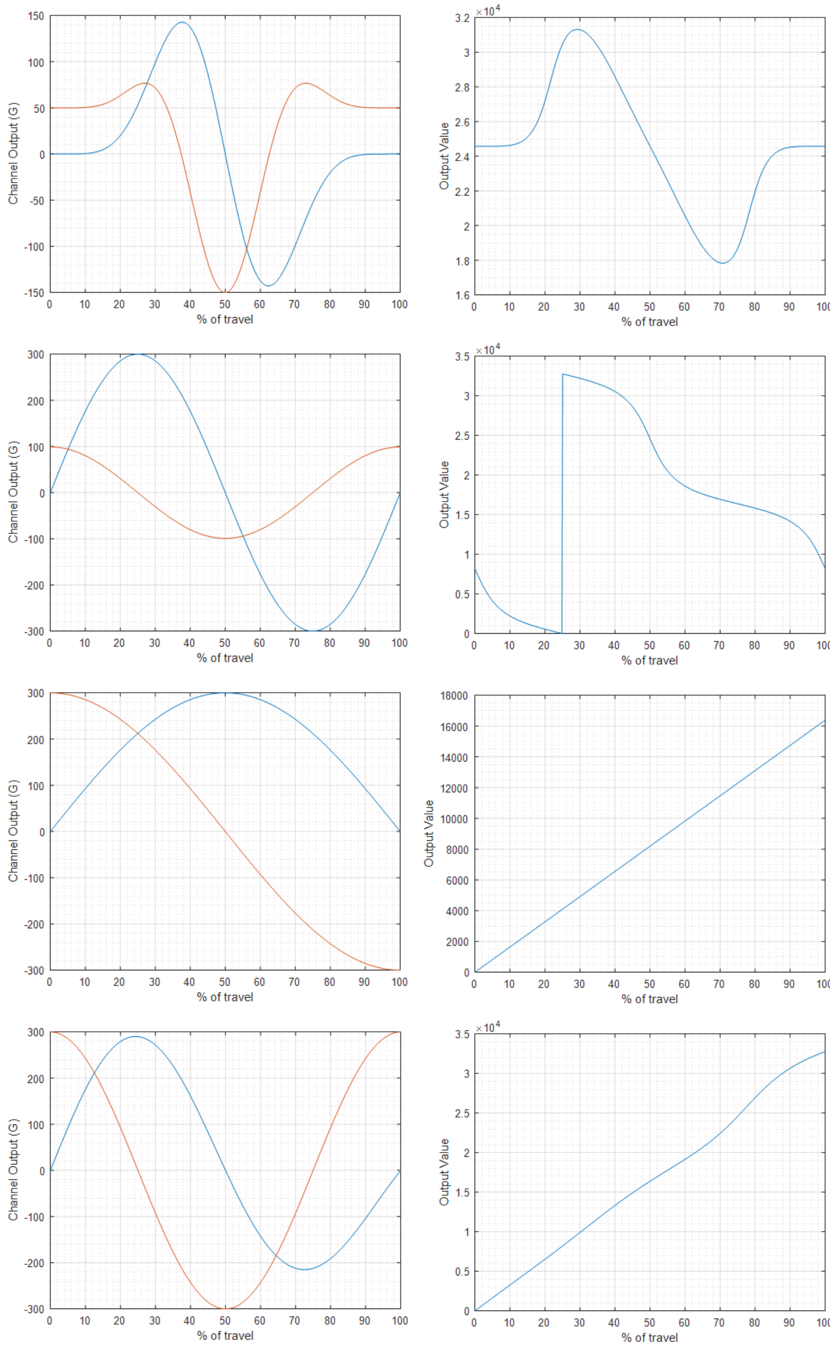
CONSIDERATIONS AND CONCLUSIONS

For the most effective design, it is worthwhile approaching the system with knowledge on what the intended output signal should look like as a function of input. When possible, select magnetics which fit the normal operating range of the sensor (±300 G to ±1000 G) to obtain the highest level of signal to noise. Determine the behavior of travel. Direct linear paths and 'linear' arc paths each have unique challenges that can be adapted to by the A31315's features.

A brief procedure for approaching system design is:

1. Obtain a sensor mapping of the magnetic field over travel.
2. Consult table 1 (at the end of this document) for a quick reference of which device features may be needed.
3. Determine mechanical operating range.
4. Apply elected signal processing blocks.

Following this procedure will minimize the development time of the system and the designer can obtain a working solution sooner. The integrated signal processing blocks enable easy tuning of the system, providing better results with less processor and software burden.



Problem	Remedy
Insufficient Signal	Decrease air-gap, decrease travel range, change target
Channel Magnitude Mismatch	Adjust sensor position to equalize signal amplitudes
Output does not reach maximum for given target travel.	Apply Short-Stroke compensation (2-point correction)
Sensed field is distorted	Apply Linearization

Figure 15. List of common input problems and their remedies.

Revision History

Number	Date	Description	Responsibility
–	August 14, 2020	Initial release	David Hunter
1	May 13, 2021	Removed duplicate paragraph from page 1	R. Couture