# Product Document

Published by
ams OSRAM Group

Application Note

# AS5x70

## Linearization

## Content Guide



### Revision History

| Revision | Date | Owner | Description |
|---|---|---|---|
| 1.0 | 16.10.2017 | mzie | Initial version |

# 1 General Description

Many applications where magnetic position sensors are used today have very challenging accuracy requirements (e.g. throttle valves and gas pedals). Additional to minimal intrinsic errors from the sensor, mechanical tolerances (e.g. displacement in X/Y), non-linear systems (e.g. a gas tank) and target magnet nonlinearities increase the complexity of achieving the total system level accuracy requirements. To address these type of system errors and tolerances, magnetic position sensors from AMS like the AS5x70 family feature a linearization block. This linearization block enables system designers to meet their challenging total system level accuracy requirements. The following sections in this application note explain how the linearization block functions, and provides a couple of working examples.

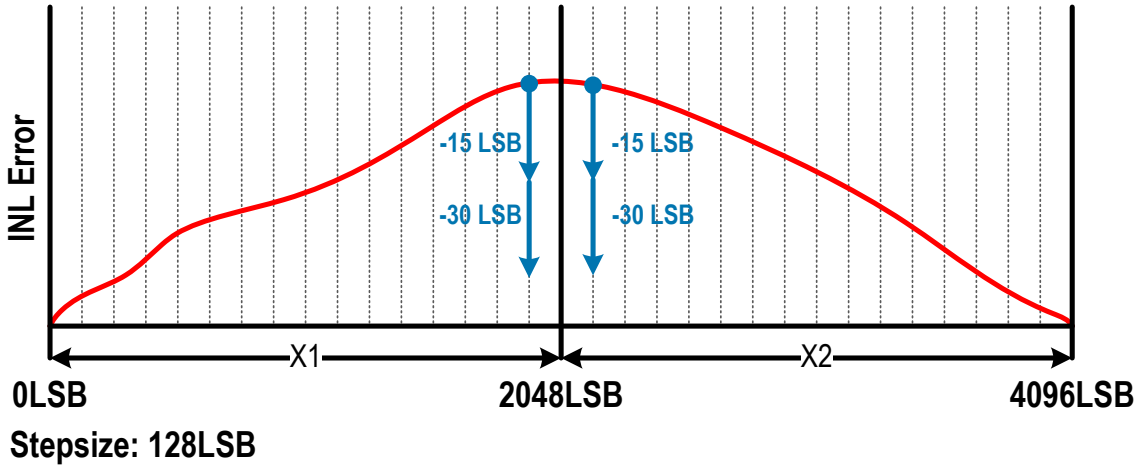
# 2 Functionality of the linearization block

The AS5x70 features four point linearization, with two points placed at the start and end points of the transfer function, and two additional programmable points that can be placed anywhere, with a step resolution of 128LSBs, within the output transfer function region.

The figure below shows a typical INL error curve (red) resulting from mechanical displacement and magnet imperfections. The output of 0 – 4096LSB (12-bit) is divided into 32 equal spaced parts with a resulting step size of 128 LSB. The output function can be corrected at two linearization points X1 and X2 which can be set in the OTP memory of the sensor. A correction of 15LSB and 30LSB can be done respectively.

The figure below shows a maximum INL error (red) at around 2048LSB. Therefore two correction points have been set which will reduce INL error at about 15LSB or even 30LSB.

**Figure 1: Typical INL error curve**



# 3 Example 1 (90 degree segment)

This example represents a short stroke throttle valve application where the angular segment is typically 90 degrees. The AS5x70 was configured in a 0-90 degree segment with SENT output (0-4096LSB). An optical reference encoder (Heidenhain ECN413) was used to calculate the INL error according following formula:

*INL Error [deg] = ECN413 [deg] – AS5170 [deg]*

The assumption was that due to mechanical tolerances the displacement between sensor center and magnet center is -1000µm.

As one can see in Figure 2: Measured INL error at X0 / Y-1000 the maximum measured INL error is roughly 0.9 degrees at the 40 to 50 degrees arc position. The 0.9 degrees of maximum error over the 90 degree arc is very close to the typical accuracy requirement of 1% for a throttle valve application.

**Figure 2: Measured INL error at X0 / Y-1000 (degree scale)**

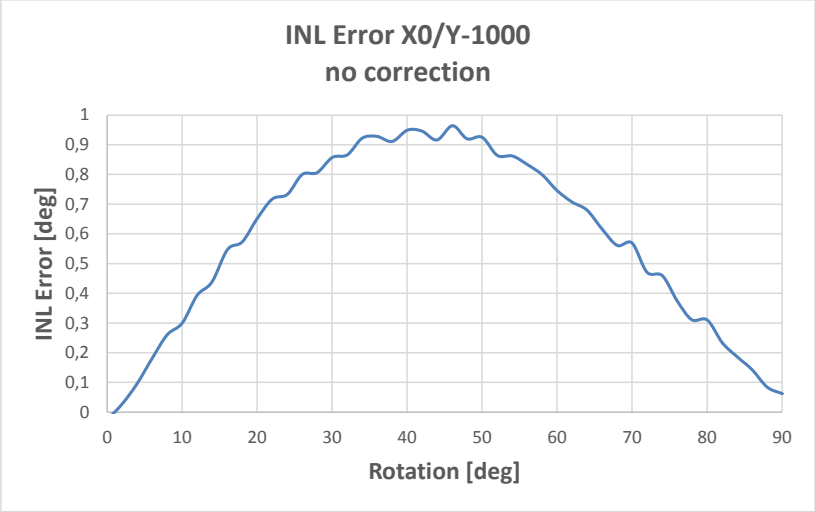
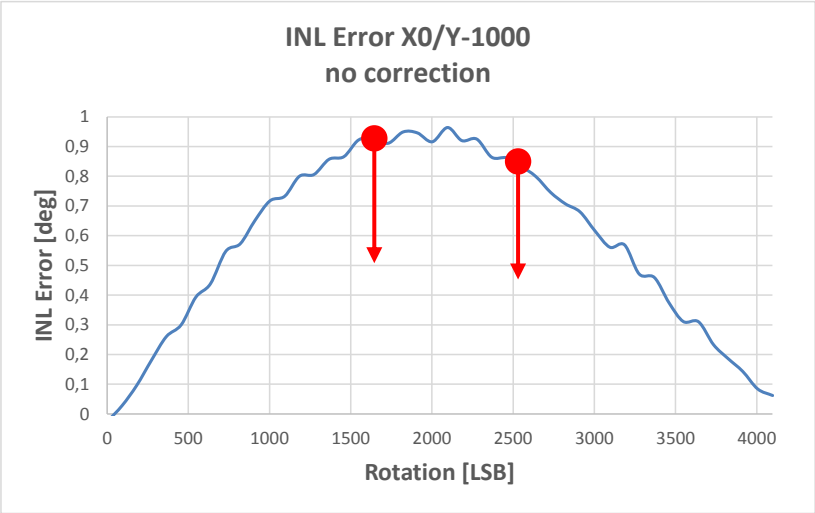


**Figure 3: Measured INL error at X0 / Y-1000 (LSB scale)**




Again, the maximum error can be observed at around 40 – 50 degrees (~2048LSB).

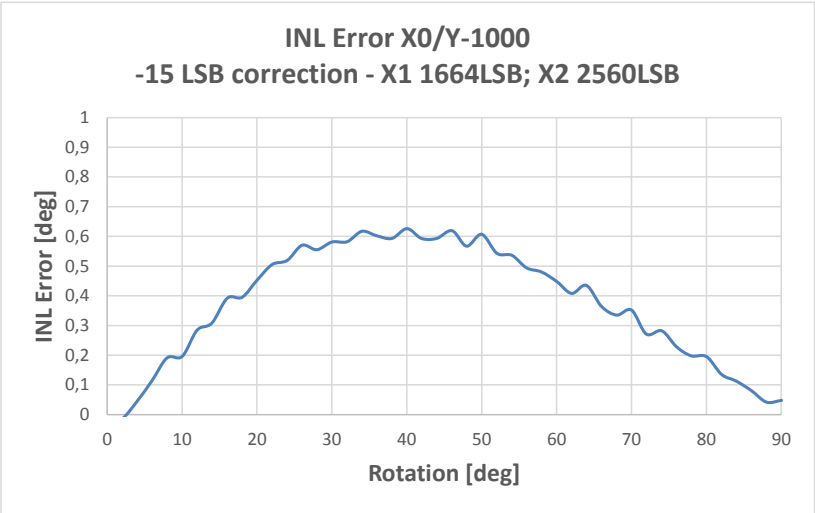
Two linearization points at position X1 – 1664LSB and X2 – 2560LSB with a correction of -15 LSB have been set.

A -15LSB correction should cause a correction of about ~0.33 degree according to the calculation below:

$$\frac{90\ degree}{4096\ LSB} * 15LSB = 0{,}33\ degree$$

The new measurement in Figure 4: Measured INL error at X0 / Y-1000 with correction of -15LSB shows an improvement from 0.9 to 0.6 degree (0.3 degree) maximum INL error.

**Figure 4: Measured INL error at X0 / Y-1000 with correction of -15LSB**



For further improvement a possible correction of -30LSB instead of -15LSB is possible. This should give an improvement of about 0.66 degree according to the calculation below:

$$\frac{90\ degree}{4096\ LSB} * 30LSB = 0{,}66\ degree$$

The measurement with -30LSB correction in Figure 5: Measured INL error at X0 / Y-1000 with correction of -30LSB shows a further improvement down to 0.3 degree maximum INL error.

**Figure 5: Measured INL error at X0 / Y-1000 with correction of -30LSB**

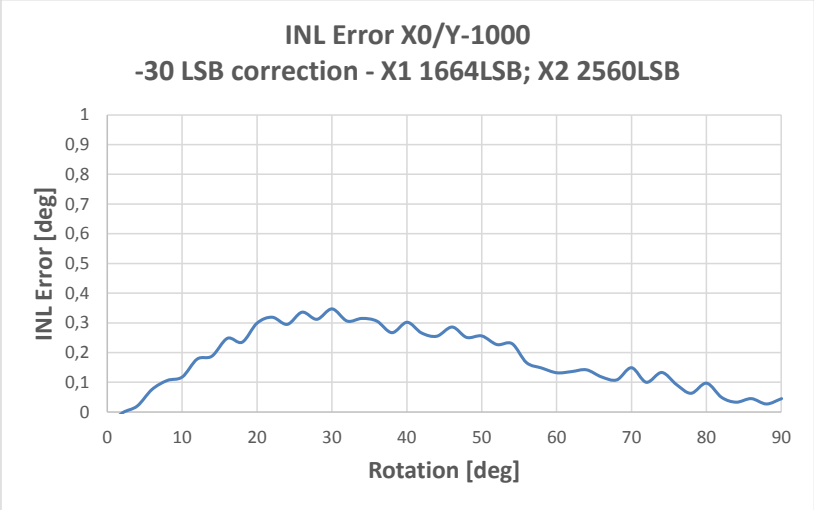
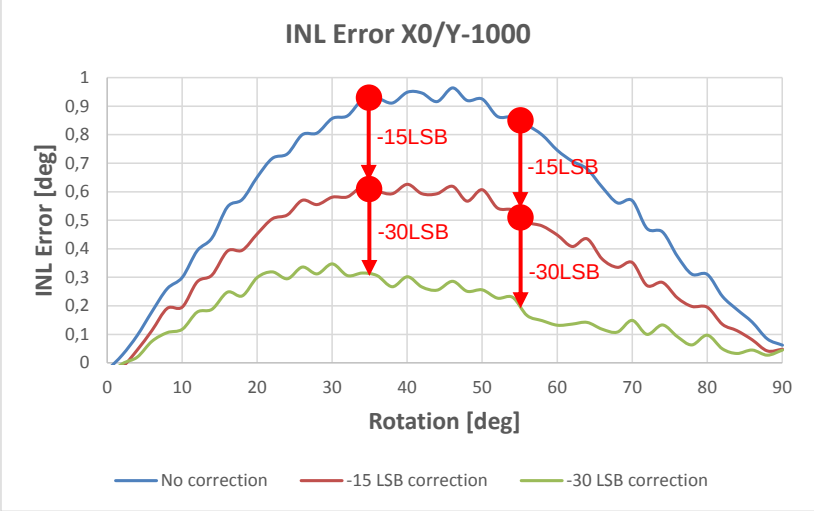



Figure 6: shows a summary of the possible INL error correction with two additional linearization points and corrections of -15LSB and -30LSB.

**Figure 6: Summary of INL error correction with two point linearization (90 degree segment)**



# 4 Example 2 (30 degree segment)

The second example shows a smaller arc segment with a 30 degree range of motion which is typically the range for gas and brake pedals. The AS5x70 was again configured with SENT output from 0-4096LSB. The Heidenhain ECN413 was used as optical reference encoder to calculate the INL error.

**Figure 7: Measured INL error at X0 / Y-1000 (degree scale)**

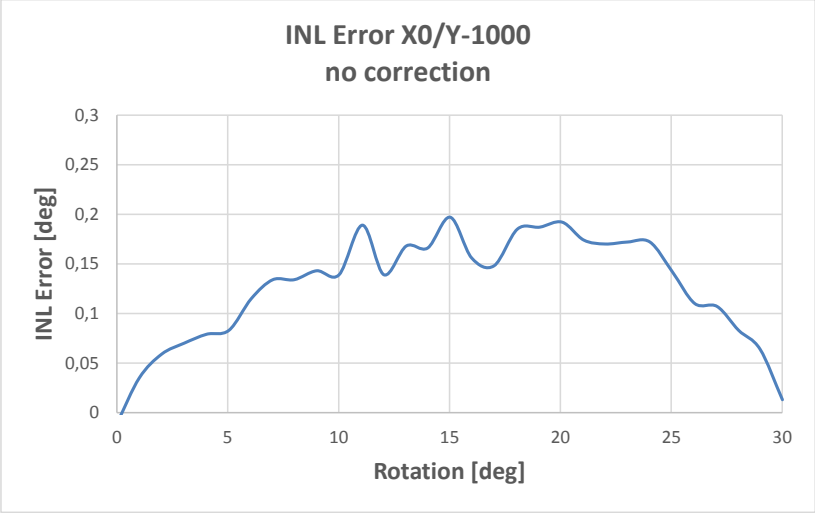



**Figure 8: Measured INL error at X0 / Y-1000 (LSB scale)**

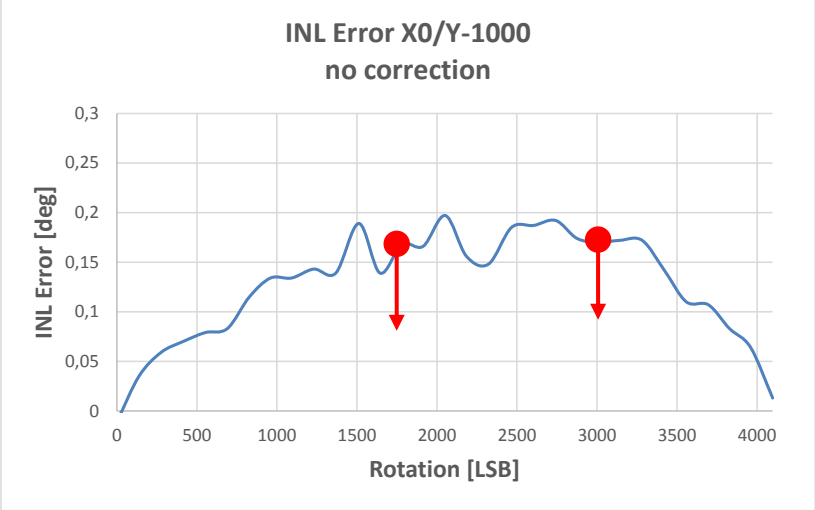



Figure 7 shows a maximum INL error of ~0.2 degree (0.66%) in a 30 degree segment. The maximum error is observed around 10 – 20 degree or 1500 – 3000 LSB, therefore again two linearization points X1 – 1792LSB and X2 – 3072LSB with a correction of -15 LSB have been set.

A -15LSB correction should result in an improvement of about 0.11 degree according to the calculation below:

$$\frac{30\ degree}{4096\ LSB} * 15LSB = 0{,}11\ degree$$

The measurement done with -15LSB correction in Figure 9 shows an improvement from 0.2 to 0.08 degree maximum INL error. (0.08 degree equals 0,26% error)

**Figure 9: Measured INL error at X0 / Y-1000 with correction of -15LSB**

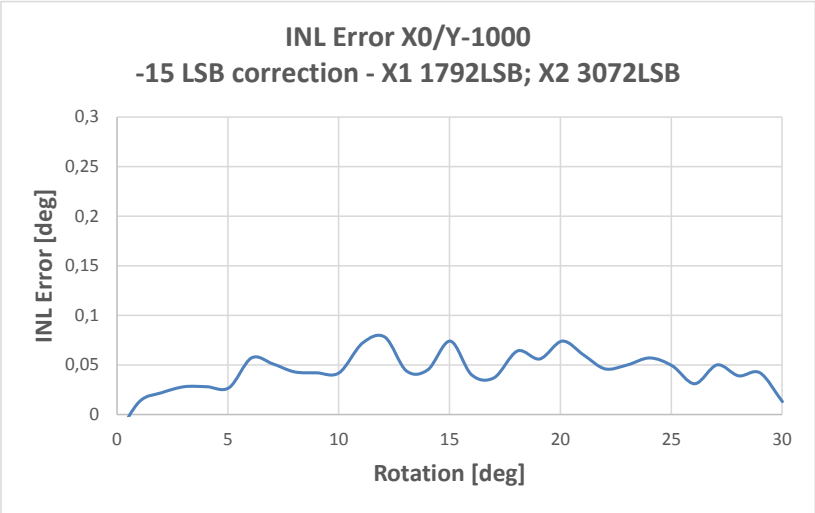
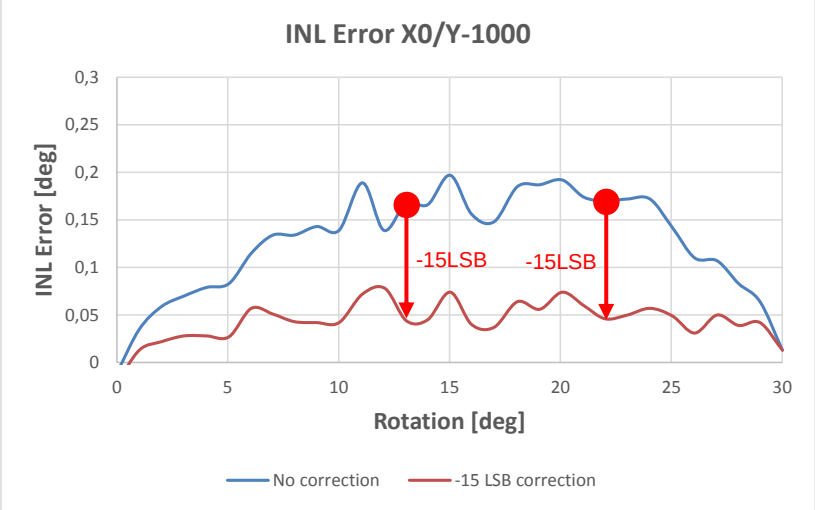



Figure 10 shows a summary of the possible INL error correction with two additional linearization points.

**Figure 10: Summary of INL error correction with two point linearization (30 degree segment)**



# 5 Summary

The linearization functionality available in the AS5x70 provides a powerful tool for increasing the total system accuracy, especially for short stroke measurement applications, where only small arc segments (e.g. 90 deg or 30 deg) of the full 360 degree range are used. This built-in programmable linearization feature can easily help to reduce the total system error by up to 50%.

The recommended procedure for this linearization is to measure at least 12 (preferably 36) equally spaced angle positions and calculate the INL error for each, by using an optical reference encoder. Then the maximum or minimum error should be determined and the correction points X1 and X2 with their respective correction factors of 15 or 30LSB should be set.

Important to note, is that the finest compensation which can be performed is 15LSB. This means in systems where the INL is already below 8 LSB, the linearization feature will provide no additional accuracy improvement.

For further information or help regarding the linearization feature/procedure please contact the technical application team from AMS.

# 6 Contact Information

**Buy our products or get free samples online at:**
www.ams.com/ICdirect

**Technical Support is available at:**
www.ams.com/Technical-Support

**Provide feedback about this document at:**
www.ams.com/Document-Feedback

**For further information and requests, e-mail us at:**
ams_sales@ams.com

**For sales offices, distributors and representatives, please visit:**
www.ams.com/contact

**Headquarters**
ams AG
Tobelbaderstrasse 30
8141 Premstaetten
Austria, Europe

Tel: +43 (0) 3136 500 0
Website: www.ams.com

# 7 Copyrights & Disclaimer



Information in this document is believed to be accurate and reliable. However, ams AG does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information.

Applications that are described herein are for illustrative purposes only. ams AG makes no representation or warranty that such applications will be appropriate for the specified use without further testing or modification. ams AG takes no responsibility for the design, operation and testing of the applications and end-products as well as assistance with the applications or end-product designs when using ams AG products. ams AG is not liable for the suitability and fit of ams AG products in applications and end-products planned.

ams AG shall not be liable to recipient or any third party for any damages, including but not limited to personal injury, property damage, loss of profits, loss of use, interruption of business or indirect, special, incidental or consequential damages, of any kind, in connection with or arising out of the furnishing, performance or use of the technical data or applications described herein. No obligation or liability to recipient or any third party shall arise or flow out of ams AG rendering of technical or other services.

ams AG reserves the right to change information in this document at any time and without notice.