White Paper

One-Touch Energy-Harvesting Multi-Turn and MLS-INC Single-Turn Accuracy Calibration

Introduction

Motion control encoders are precision devices that convert mechanical motion—either rotational or linear—into electrical signals for interpretation by control systems such as microcontrollers, programmable logic controllers (PLCs), and industrial PCs. These encoders are essential for enabling accurate position, velocity, and directional feedback in a wide range of applications, including robotics, CNC machinery, and automated manufacturing systems.

Modern encoders are available in various configurations, primarily categorized into rotary and linear types. Rotary encoders measure angular displacement, whereas linear encoders track straight-line movement. Depending on the application requirements, encoders can be further classified as incremental or absolute. Incremental encoders provide relative motion information, whereas absolute encoders deliver an unambiguous position value at any point in time, even after power cycles.

Advancements in encoder technology have led to the adoption of various sensing methods—optical, magnetic, capacitive, and inductive—each offering distinct advantages in terms of resolution, robustness, and environmental resistance. Furthermore, modern encoders increasingly support high-speed, high-resolution operation and integrate digital communication interfaces such as Synchronous Serial Interface (SSI), Bidirectional Synchronous Serial (BiSS), and Serial Peripheral Interface (SPI).

Broadcom Optical Encoders: Precise Position Construction

Broadcom’s modern motion control encoders meet stringent requirements for precise positioning and velocity sensing across a wide range of applications. These include industrial machinery, robotic arms, LiDAR systems, automated guided vehicles (AGVs), solar panel tracking, and more.

The encoders offer robust performance across wide thermal operating ranges and are resistant to electromagnetic interference and power supply disruptions. This is achieved through a combination of incremental signals, MLS signals, and EHMT (energy-harvesting multi-turn) technology.

Incremental Signals (INC-Signals)

Incremental signals provide relative information regarding position changes, speed, and the direction of the system.

MLS Code-Signals

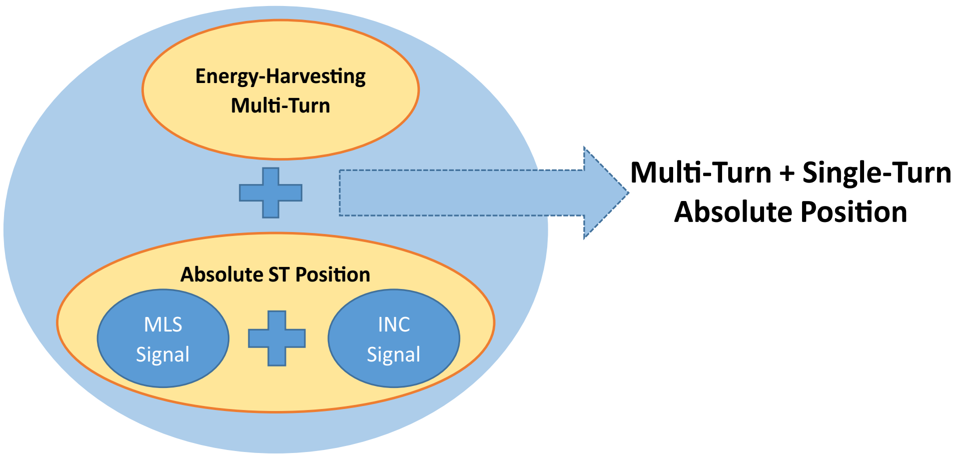
Maximum length sequence (MLS) decodes the unique absolute code pattern to a single-turn raw position, providing absolute position information.

Energy-Harvesting Multi-Turn (EHMT)

The energy-harvesting multi-turn technology converts the rotating magnetic field into electrical energy, which powers the revolution-tracking circuit regardless of the encoder rotation speed and direction. There is no loss of revolution count even in the absence of an external power supply.

By combining incremental signals, MLS signals, and EHMT functional blocks, a precise multi-turn and single-turn absolute position will be generated. However, each functional block requires a distinctive calibration to ensure a precise absolute position.

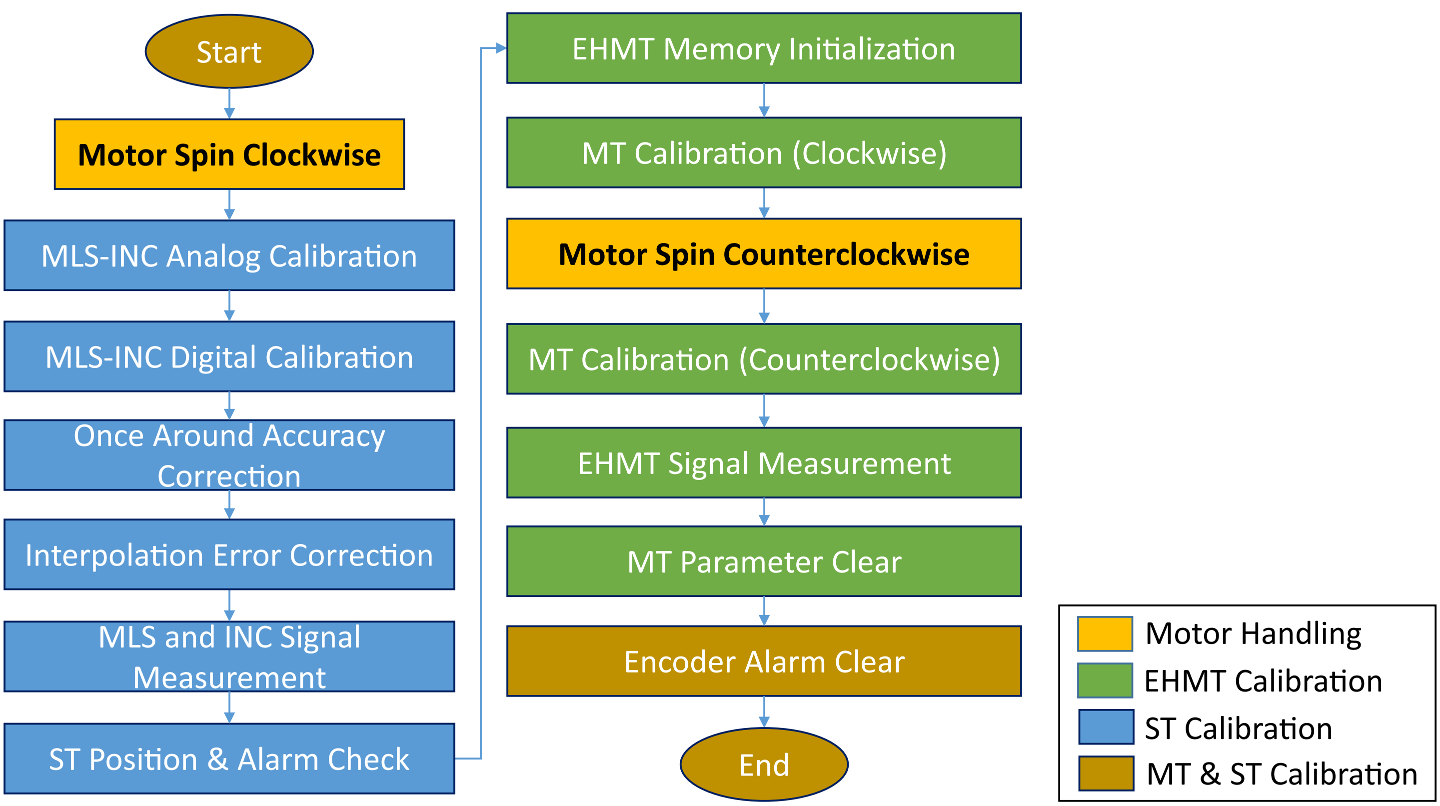
Figure 1: Broadcom Encoder Block Diagram



Existing Absolute Encoder Calibration Flow

Calibration ensures that each functional block of the encoder outputs accurate results, because there are various factors that can cause discrepancies between the actual position and the encoder signal.

Figure 2: Absolute Encoder Calibration Flow



Incremental Signal Calibration

On an optical sensor, the electrical signal generated by photodiodes varies by factors such as mechanical imperfection, circuit variation, and optical imperfection. To perform incremental signal calibration, users must probe out the incremental sin and cos signal with a spinning code disk and then adjust and calibrate the analog signal to the designated gain and offset.

LED Gain Calibration

The LED is the light source that transmits the code disk pattern to the encoder receiver. Various factors affect the light transmission, such as the distance of the code disk to the receiver or emitter (LED). Thus, the LED strength will be calibrated when mounted to a motor system. To perform calibration, probe out the incremental sin and cos signal with a spinning code disk. Next, adjust the LED gain step-by-step to get the desired LED gain reference to the incremental sin and cos signal peak to peak.

MLS Signal Calibration

MLS gain and Vmid calibration are similar to the incremental signal of optical sensors and electrical signals generated by photodiodes affected by various factors such as mechanical imperfection, circuit variation, and optical imperfection.

To calibrate the MLS signal, probe out the MLS signal with a spinning code disk. Then adjust and calibrate the MLS signal to designated gain and Vmid.

MLS-INC phase calibration corrects the accuracy of the MLS signal to the INC signal on code strips. Manual calibration is done by probing out the digital signal output with a spinning code disk, measuring the phase of each digitalized MLS signal reference to the INC signal. Then calibration is done to get the most optimum phase settings.

Accuracy Correction

Accuracy correction improves the position feedback of the encoder by compensating for errors generated by different systems, especially mechanical installation errors and mechanical noise.

The Once Around Correction (OAC) feature identifies potential errors in the encoder’s mounting assembly, such as variations in the alignment and position of the motor shaft, code wheel, and hub. Once the errors are identified, the OAC feature uses electronic compensation to correct these variations. This compensation is performed by adjusting the encoder’s internal calibration data, effectively mapping the encoder’s position to the correct physical position. By electronically correcting for mechanical errors, OAC improves the overall accuracy of the encoder’s position measurements.

The Interpolation Error Correction (IEC) feature identifies potential sub-grating errors generated from raw material variations such as a code-wheel or code-strip mismatch. Once the sub-grating errors are identified, the IEC feature uses electronic compensation to correct these variations. This compensation is performed by adjusting the encoder’s internal calibration data, effectively mapping the encoder’s position to compensate for the code-wheel or code-strip mismatch, which improves the speed accuracy on the system.

MLS-INC Signal, ST Position, and Alarm Check

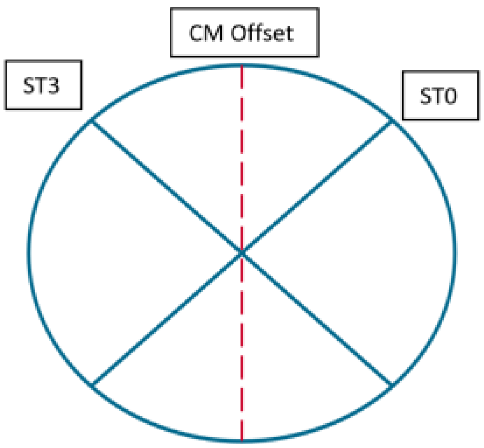
Various checks are performed after completing the single-turn calibrations. First, measure the offset, gain, Vmid, and phase for the MLS-INC signal. Next, read out the single-turn position and alarm with a spinning code disk. And then calculate the position delta versus the spinning speed and polling rate.

MT Calibration – Code Wheel-Magnet Alignment (CMA)

Code wheel-magnet alignment (CMA) is the calibration to accurately align the changes in magnetic polarity corresponding to the code wheel's rotational position.

To perform manual calibration, first rotate the code wheel-magnet in a clockwise direction, and then locate and record the optical position (ST0) corresponding to the magnetic polarity triggered. Next, rotate the code wheel-magnet in a counterclockwise direction, and then locate and record the optical position (ST3) corresponding to the magnetic polarity triggered. Calculate and store the CMA offset (the center position of ST0 and ST3) in the encoder memory.

Figure 3: CMA Calibration



EHMT Signal Measurement

Collect the EHMT pulse for multiple revolutions in power-off mode, and plot out the distribution of the pulse.

MT Parameter and Alarm Clear

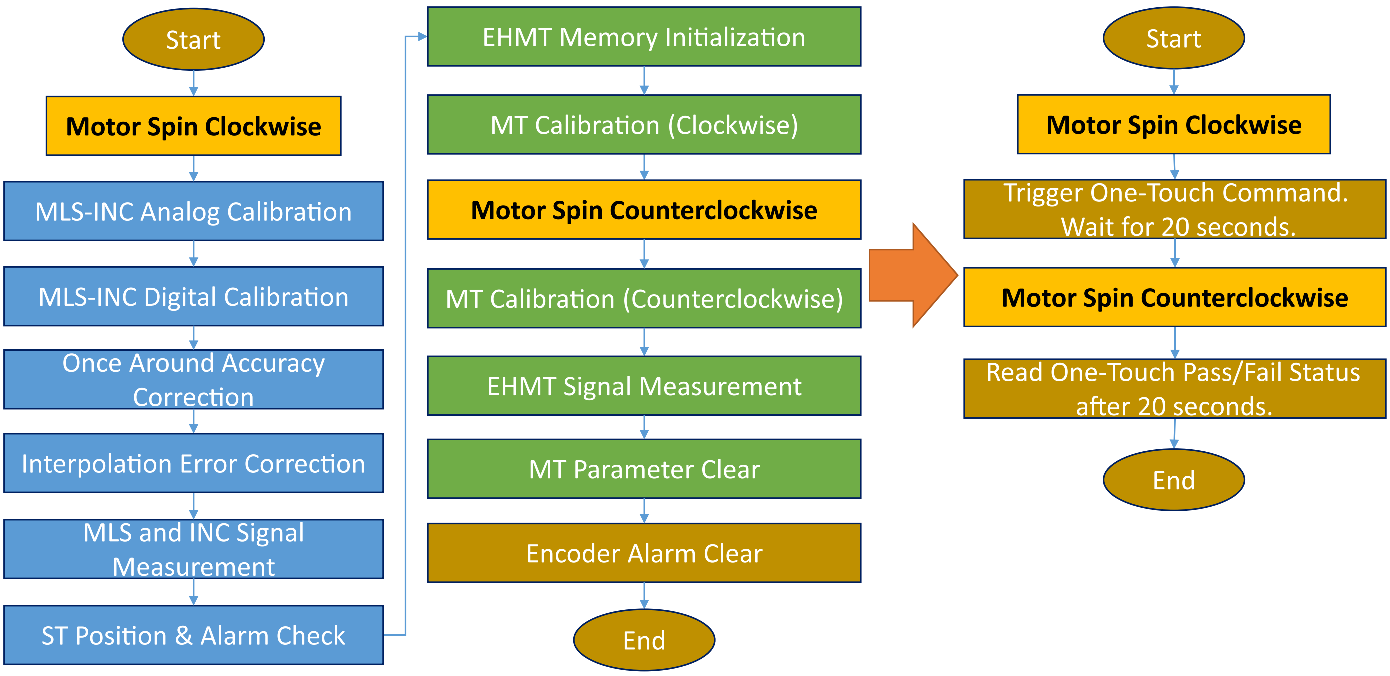
Reset the energy-harvesting multi-turn counter to zero, reset the MT parameter setting, and clear out the encoder alarm, which triggers before the encoder has been calibrated.

Next-Gen One-Touch Calibration Flow

One-Touch EHMT and MLS-INC ST Accuracy Calibration

One-touch calibration performs calibration of all MT and ST calibration blocks inside the ASIC within a single process flow, while measuring and recording the status of each signal internally by the ASIC. A Pass/Fail status is output by the ASIC. The calibration flow is simplified significantly as follows.

Figure 4: Existing Encoder Calibration Flow (Left) Versus Next-Gen One-Touch Calibration Flow (Right)



Advantages

With the introduction of next-gen one-touch calibration, substantial enhancements across multiple areas can be achieved.

The calibration flow has been greatly simplified, making it easier to understand and execute. Full calibration can now be performed without requiring deep technical knowledge of the absolute encoder's internal mechanisms. This user-friendly approach not only reduces operator training time but also minimizes the potential for operational errors during calibration.

The need for complex and costly test equipment has been reduced. The new system requires the tester only to send and receive basic commands and to control motor handling, unlike previous systems that demanded coordination with additional equipment such as PicoScopes and load boards. This results in a notable reduction in test equipment investment and setup complexity.

The calibration process now achieves notable reductions in test time and unit cost. Calibration tasks—including signal measurement, encoder setting adjustments, calculations, and validation—are fully executed internally by the ASIC. All operations are completed through a single command that provides a straightforward Pass/Fail status. This high level of automation substantially reduces the overall calibration time, leading directly to lower unit costs.

The new approach greatly improves test system noise immunity. Because all signal measurements and calibrations are performed internally within the ASIC, sensitive analog signals must no longer be transferred externally to a PC for analysis. This elimination of external wiring minimizes exposure to system noise, improving the reliability and consistency of the calibration results.

Production capacity is significantly improved with test time reductions and enhanced isolation from tester noise. Failures caused by external factors are minimized, which leads to a higher yield and better overall efficiency in the manufacturing process.