TIMKEN

Application Note: MSS -7305

Techniques to obtain absolute position using the MPS160

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Reference Documents:

MPS160 series data sheet

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Overview:

One of the features of the MPS160 Encoder ASIC is the ability to provide exact position within one magnetic pole pair of the high resolution track. The encoder ASIC does not discriminate which pole pair, thus as a stand alone is unable to provide one turn or phased absolute position. Absolute position can be achieved at power on using additional sensor inputs or with some initial movement. This application note discusses a number of methods to obtain the exact absolute position within 360° of rotation or a full revolution of the magnet.

The MPS160 provides live (not time-interpolated) information and its angle-based interpolator does interpolation over many poles around a circumference (instead of just one pole pair at the center of rotation) providing better accuracy. It is designed for harsh environment applications and has an off-axis compact design.

Sensing absolute position using the MPS160 - Two basic approaches

A) **Quasi–Absolute**: Requires some amount of motion to obtain absolute position
B) **Full Absolute**: Sensor knows the exact position on power-up

A Quasi–Absolute

1) Using the Reference / index pulse: When using the reference/index pulse the shaft/magnet is rotated through the marker pulse location. When the index pulse occurs the computer/controller can zero its location counter. From that point on the quadrature signal from the A and B channels is used to count up and down. While the MPS160 is normally a relative position sensor when the marker pulse is used the user can detect the exact angular position of the magnet with respect to the marker pulse location. The marker pulse can either be put at the customer TDC (Top Dead Center) location or it can be offset by some amount.

2) Using a number of index pulses for single turn absolute position: The MPS160 can provide both a “C” pulse and a “D” pulse. One of these can be provided per magnet pole pair. The C pulse occurs at the magnetic N-S transition where channel A and B are both logic “1”. The “D” pulse occurs at the S-N transition where channel A is logic “0” and B is logic “1”. For example: A 32 pole pair magnet can have any number of “C” pulses between 0 and 32. The same holds for the “D” pulses. By using a combination of “C” and “D” pulses at predefined locations, forming a gray scale, the controller is able to determine the exact position within a much smaller angle of rotation than with a single index pulse. Based on a target design, the target may only need to rotate 3 to 6 pole pairs to determine the exact single turn position.

The following illustration demonstrates this with an 8 pole pair magnet configuration.

Pole pair #	1	2	3	4	5	6	7	8
Code	C0	CD	0D	CD	00	00	C0	0D

Each C or D pulse (or a zero) would occur every 22.5 degrees. In this case the magnet would have to rotate through 3-4 pulses or between 67.5 and 90 mechanical degrees. Using this technique on a motor where the position was needed within a motor pole phase and where 8 pole pairs were used for each motor pole, the position is identified within ¼ of a motor pole phase.

3) Using a number of index pulses for motor phase absolute position: Finding the position within a motor phase is much simpler as this angle is smaller and the non-repeating pattern will be much smaller as well. If this technique is combined with the use of 1 or 2 external Halls the angle can be very small. For example, a 3 pole motor using an 18 pole pair target magnet and 2 external Halls would require only 10 mechanical or 30 electrical degrees of rotation to determine the exact position in the motor phase. The system controller would need to run an algorithm to start the motor and provide initial motor control based on direction information from the ASIC's A&B quadrature signals alone. The motor would have to operate based on quadrature and / or back EMF until the motor had moved far enough CW or CCW to indicate an absolute position based on the sequence of RP-C and Rp-D transitions encoded in the target magnet.

B Techniques to obtain full absolute position on power up

There are three basic methods described below to obtain full absolute position on power up:

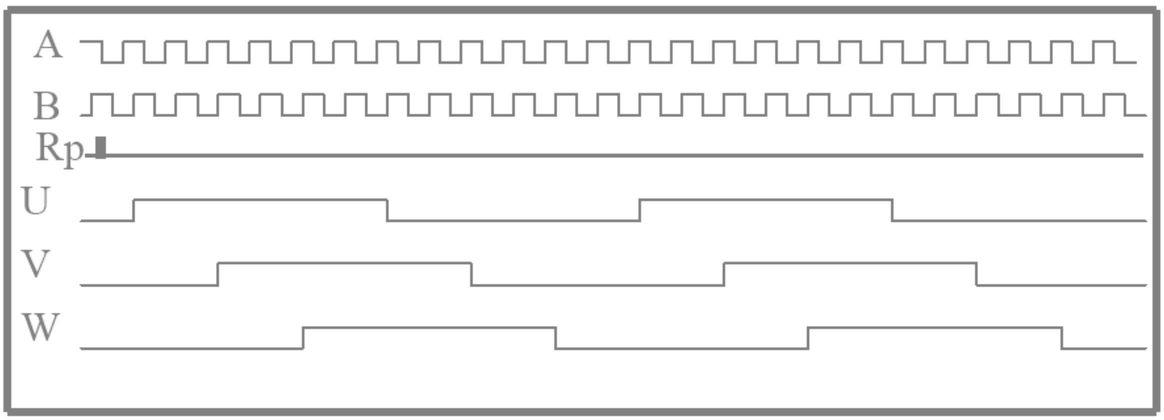
1) Use external Halls on a second magnetic track for motor phase absolute position and incremental A&B quadrature count to establish absolute position (Commutation track usually used for motor start up).
2) Use external Halls on a second magnetic track for pole pair identification.
3) Use two MPS160 chips with two magnet tracks having N and N+1 poles.

Any of these three methods can be used to optimize a particular application.

A detailed description of these follows:

1) **Use external Halls for course absolution position and incremental A&B quadrature to establish absolute position (commutation track usually used for motor start up):** When a

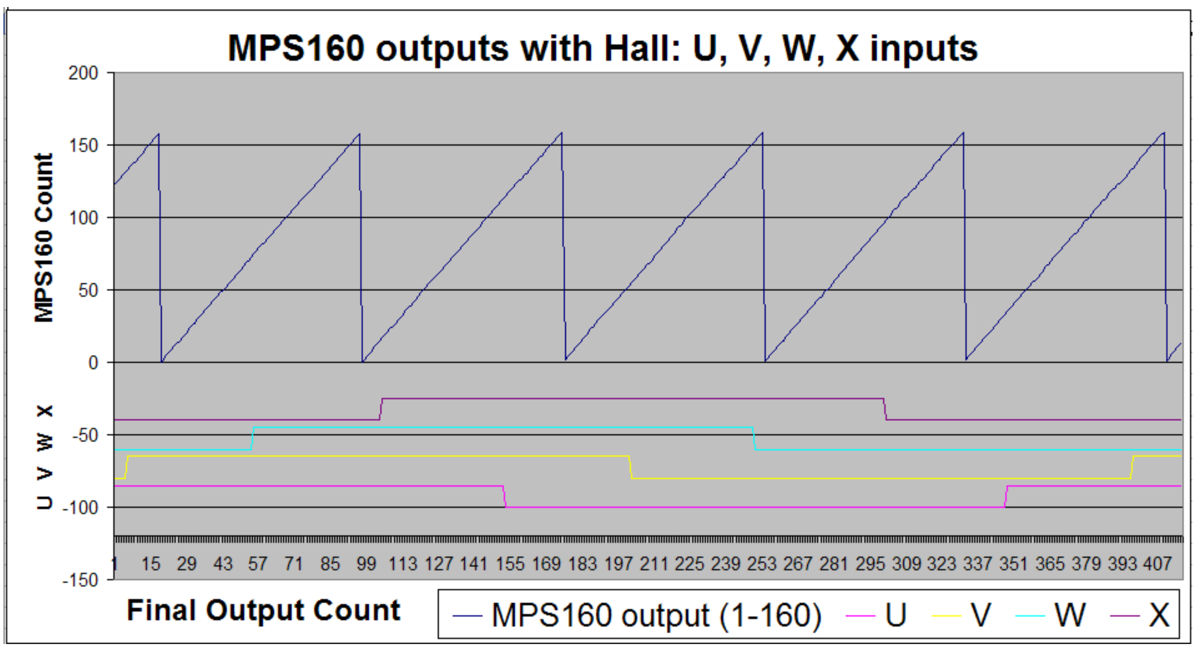
BLDC (Brushless DC) motor starts it can be started by turning on the appropriate motor windings so that the motor rotor will rotate in the proper direction. The absolute angular position of the rotor must be known so that power can be applied to the appropriate motor windings. Normally only a course position identification is sufficient for startup. A commutation track normally provides three digital signals where each signal is on for half of a motor phase and off for the other half of the motor phase and are separated by 120 electrical degrees (see figure below). These three signals will provide six states (six positions) within a motor phase so the motor position is known within 1/6th of a motor phase. This is usually enough resolution to start the motor. Then after the motor starts, when an edge from one of the commutation tracks is crossed the exact position is known and the A & B quadrature outputs can be used to count up or down to continuously monitor the exact rotor position.



2) **Use external Halls on a second magnetic track for pole pair identification (see drawing figures below).** The MPS160 includes a standard 3-wire SPI serial interface feature which can be used to achieve absolute position feedback. The MPS160 breaks each pole pair into 160 positions. When the magnet is located over the ASIC the 8 bit word in the SPI protocol contains the absolute position within the pole pair. The MPS160 chip on its own is not able to determine which pole pair is over the chip. Using external Hall signals, similar to the commutation signals noted in the previous method, divides the single turn rotation into a specific number of states or positions. When the number of states or positions exceeds the number of pole pairs on the high resolution track the specific pole pair of the target wheel can be identified. With the pole pair is over the MSP160 is identified the absolute position can now be determined.

The MPS160 can accept up to four digital signals from a second track (typically 4 digital Hall devices are used) and made available on the SPI line (called U, V, W, X - see figure below). During each SPI read operation there is an 8-bit status word and an 8-bit data word that are read. The four Hall signals are available as four of the bits on the status word. The limitation to the available inputs to the MPS 160 is that only 8 states (or positions) can be identified with the four Hall lines. This limits the number of pole pairs that can be identified to about 5 or 6 maximum (some overlap is required because of tolerances). With a wide pole pair of 8mm (normal mode of operation for the MPS160) this limits the maximum magnetic lineal distance (circumference) to 48mm long for the 6 pole pairs or a target diameter of approximately 15 mm OD. Additional Hall devices could be used and directly read to increase the number of identifiable states. These will need to be read outside the SPI interface, requiring extra wires for each device. The additional Halls would increase the number of identifiable states by two for each added. This allows more pole pairs on the magnet. Each pole pair would add another 8mm linear distance which equates to larger diameter. A tolerance stack up needs to be done to determine the maximum number of magnetic poles that will fit in the range of Hall positions and to guarantee that the proper pole pair is identified. The primary tolerances to include are Hall switchpoint tolerances, air gap shifting the angle where the Hall switchpoint changes and Hall placement on the PCB pads. Some safety factor needs to be included for electrical and magnetic noise.

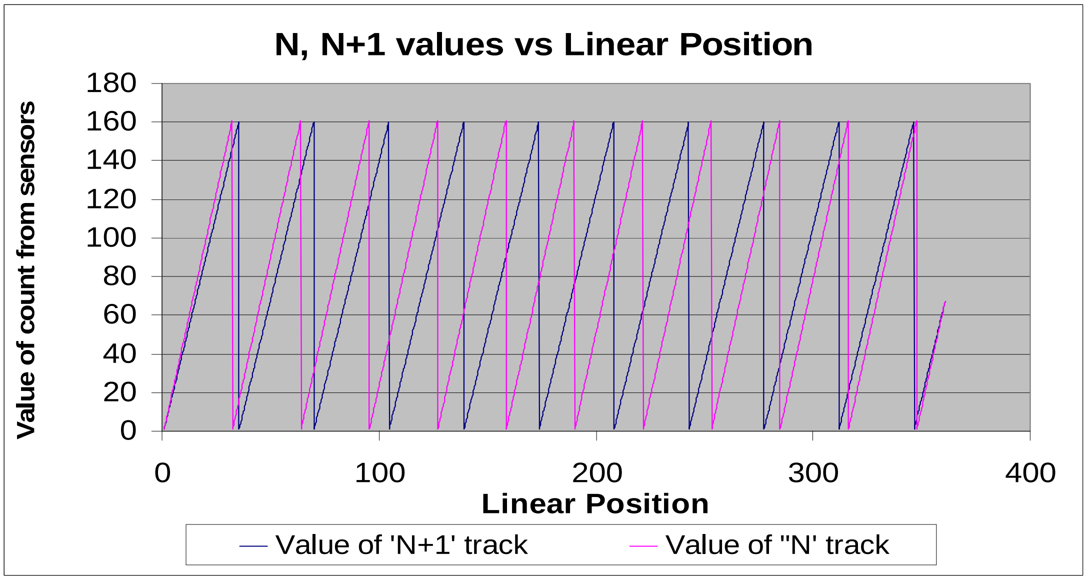
For BLDC motor applications where the absolute position is required only within a motor phase this is usually enough linear distance to obtain absolute position over the motor phase.



3) **Use two MPS160 chips with two magnet tracks having N and N+1 poles.** For this technique two MPS160 encoder ASICs are used. Each one is positioned to read one of two tracks on a rotating or linear magnet. One is magnetized with a number of magnetic poles N. The magnet on the other track is magnetized with N+1 poles (high resolution track). Each

sensor chip thus reads either N or N+1 poles over the absolute position sensing distance.

Each encoder ASIC interpolates every pole pair into 160 positions. The ASICs output a number between 1 and 160 corresponding to the absolute location of the magnetic pole pair over each ASIC. By analyzing the phase shift between outputs from each encoder ASIC first the rough position and then the absolute position are determined. The graph below illustrates the gradual phase shift in the ASIC outputs between the N and N+1 tracks. The phase shift is zero at the left side and gradually increases over the full sensing angle to the right. This phase shift alone does not have sufficient precision for absolute position; however, the outputs do have enough precision to identify which pole pair is over the high resolution (N+1) track. Once the pole pair is identified the exact position over that pole pair is already known and the exact position of the magnet is determined.



The maximum phase shift between pole N and N+1 cannot be larger than the accumulation of all errors or the wrong pole will be identified. Because a large portion of the errors are predictable and repeatable, a look up table can be used to compensate for these errors. More error can be taken out by building a look up table where each part is individually calibrated with it's own look up table. In addition, designs with less phase shift (N + X, where X>1) will offer lower errors and will need additional Hall sensors and track to determine the segment being evaluated.

CONCLUSION

The Timken MPS160 encoder ASIC offers absolute position feedback over a pole pair. Other features on the integrated circuit provide a number of solutions for achieving absolute position feedback using magnetic technology. This includes simple gray scale code configurations using small shaft movements for quasi-absolute position to full absolute position using additional Hall devices or MPS160 circuits.

The simplest solution and most economical configuration requires a small amount of shaft movement to determine absolute position for a quasi-absolute technique. This solution uses the multiple index pulse capability of the MPS 160 encoder ASIC to generate a gray scale to identify which pole pair the MPS160 encoder ASIC is over. Power on absolute position is available over a motor phase or over a single turn. For absolute position over a motor phase for brushless motor applications an additional commutation track using Hall devices is used in conjunction with the MPS160 encoder ASIC incremental outputs. The commutation track is used for startup. Once a commutation edge is detected the high resolution incremental A and B outputs from the MPS160 can be counted up and down to provide absolute position. Absolute position on power-up for either single turn or over a motor phase uses the MPS160 SPI interface with a second magnetic track. For applications with smaller diameters external Hall signals from a second track (which are all available through the SPI interface) provide the required pole identification information. For medium and large diameters the “N, N+1” technique can be used with a second MPS160 encoder ASIC.

The MPS160 provides live (not time-interpolated) information. Its angle-based interpolator does interpolation over many poles (instead of just one pole) providing better accuracy. The off-axis compact design of the MPS160 encoder ASIC makes it ideal for operating in harsh environment applications where absolute position needs to be integrated into a mechanical assembly.