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Application Note: MSS-8310
Glossary of Encoder Terms

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- **Absolute Position:**
- **Accuracy:**
- **Acceleration:**
- **AD Converter:**
- **Air Gap:**
- **Air Gap Alarm:**
- **Ambient Temperature:**
- **Angular Misalignment:**
- **ASCII**
- **Axial End Play:**
- **Axial Loading:**
- **Axial Load (Maximum):**
- **AWG:**
- **Baud Rate:**
- **BCD Binary Coded Decimal:**
- **Binary:**
- **BIT**
- **Channel:**
- **Code:**
- **Complementary:**
- **Current Sinking Output:**
- **Current Sourcing Output:**
- **Counts (Cycles) Per Revolution (CPR):**
- **Cycle Error**
- **DA Converter:**
- **Differential Line Driver:**
- **Differential Output:**
- **Direction of Rotation:**
- **Disk /Encoder Wheel:**
- **Dual Channel:**
- **Duty Cycle:**
- **Edge:**
- **Edge Separation:**
- **Electrical Degree**
- **EMI**
- **Encode**
- **Encoder (Modular Type)**
- **End Play:**
- **Error:**
- **Frequency Response:**
- **Gated Index:**
- **Incremental Encoder:**
- **Incremental Output:**
- **Index Reference/Signal:**
- **Input Frequency:**
- **Interpolation:**
- **IP 50 Protection Rating**
- **IP 64 Protection Rating**
- **IP 65 Protection Rating**
- **IP 66 Protection Rating**
- **Jitter:**
- **Kilohertz (KHZ):**
- **Line Count:**
- **Line Driver:**
- **Logic State Width Error:**
- **Measuring Step:**
- **Negative Going Pulse:**
- **NEMA 4**
- **NEMA 13**
- **NEMA 56C**
- **Noise:**
- **NPN**
- **Open Collector Output:**
- **Open Drain:**
- **Operating Temperature:**
- **Output**
- **Output Frequency:**
- **Output Waveform**
- **Parity:**
- **Period:**
- **Phase:**
- **Phase Error:**
- **Position Error:**
- **Positive Going Pulse:**
- **Pulses Per Revolution (PPR)**
- **Pulse Polarity:**
- **Pulse Width:**
- **Quadrature:**
- **Quadrature Decode (or 4X Decode):**
- **Quadrature Error:**
- **Radial Play**
- **Reference Input:**
- **Reference Pulse:**
- **Repeatability:**
- **Resolution:**
- **RFI**
- **Rise Time:**
- **Running Torque:**
- **Shaft Loading:**
- **Shaft Run Out:**
- **Shock:**
- **Short Circuit Protection:**
- **Single Channel**
- **Square Wave:**
- **Serial Interface SSI and SPI:**
- **Stability:**
- **Starting Torque:**
- **State:**
- **State Width:**
- **Symmetry:**
- **TIR**
- **Torque:**
- **Torque (Running)**
- **Torque, Starting (Breakaway):**
- **TTL**
- **Unidirectional:**
- **Vibration**
- **Zero Speed Encoder:**
- **Zero Index**

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- **Absolute Position:**
  An absolute position encoder is an encoder that is capable of indicating its true angular position with respect to its own zero position at power on and without any motion. The output from an absolute position encoder can be provided by a parallel output data word, or more commonly by a serial or bus type interface. A typical interface for an absolute position encoder is the SSI or SPI interface.

- **Accuracy:**
  Accuracy is the measure of the encoder's ability to correctly indicate a location or position. Accuracy can be expressed as the relative length of a period to the ideal length of a period or it can be expressed as the error in exact location of any edge with respect to the ideal position of that edge over one revolution of the encoder.

- **Acceleration:**
  The rate of change in velocity of a moving object expressed in units of distance per second squared or in radians per second squared.

- **AD Converter:**
  A device that converts a sampled analog signal to a digital code that represents the amplitude of the original sample

- **Air Gap:**
  Air gap is the space between the sensor (ASIC) and the target wheel. For optical encoders it is the space between the metal or Mylar disk/target and the optical sensor. For magnetic sensors it is the distance between the target and the magnetic sensor.

- **Air Gap Alarm:**
  Some encoders and encoder chips like Timken's MPS160 encoder chip are capable of indicating when they are operating outside of their recommended parameters. The MPS160 is capable of producing an air gap alarm signal if its magnetic input signal rises above or below specification limits. This signal can be sent out as a digital signal on a diagnostic line or it can be used to force the A, B, and C signals into an undefined state. This undefined state can be useful if the air gap signal is desired, but an extra interface line is not available.

- **Ambient Temperature:**
  The average or mean temperature of the surrounding air which comes in contact with the equipment and instruments under test.

- **Angular Misalignment:**
  The maximum deviation in perpendicularity between the encoder shaft and the face of the mounting surface. It is the total of shaft misalignment, shaft run out and mounting face run out.

- **ASCII**
  This most common code is the American Standard Code for Information Interchange; it is seven or eight bit code consisting of ones and zeros that represent letters, numbers and control characters. Seven bits allow for the encoding of 128 possible values.

- **Axial End Play:**
  The variation in shaft end surface position with reference to the motor mounting surface with a specified axial load applied in each direction.

- **Axial Loading:**
  The force applied to a shaft end surface directed along the axis of rotation.

- **Axial Load (Maximum):**
  Maximum axial load is the maximum force that may be applied to the shaft without reducing the rated operating life or causing deviation from the rated performance.

- **AWG:**
  A rated standard of American Wire Gauge that indicates the diameter of the wire or groups of wires.

B

- **Baud Rate:**
  The rate at which each bit is transferred to and from a device.

- **BCD Binary Coded Decimal:**
  A number representation system in which each decimal digit is identified by a unique arrangement of binary digits.

- **Binary:**
  Refers to the number 2 or a system with a radix of 2 (base 2); e.g. the function of a switch (on/off) can be represented by ones and zeros.

- **BIT**
  An abbreviation for BInary digiT; it refers to the smallest element of RESOLUTION.

C

- **Channel:**
  Each channel is a unique incremental output of the encoder also referred to as an information path.

- **Code:**
  A system of representation for a finite number of values in a particular sequence.

- **Complementary:**
  Complementary is the term for two identical periodic signals where one signal is electrically inverted from the other. Example of single channel electrically inverted. Complementary signals are typically generated by inversion of the electrical output from a single channel.

- **Current Sinking Output:**
  A logic form that requires current flow out of the input of the PLC or counter and back to the output of the encoder. The encoder sinks this current, which is sourced by the input circuitry. This is the most common output circuit configuration. It uses an NPN output transistor or an N channel FET in the encoder.

- **Current Sourcing Output:**
  A logic form that requires current flow from the output of the encoder to the input of the counter or PLC. The encoder sources the current and the input circuitry of the counter or PLC sinks this current. This output circuit is seldom used. It usually requires a PNP output transistor or a P channel FET in the encoder.

- **Counts (Cycles) Per Revolution (CPR):**
  The number of increments (resolution) in an incremental encoder. A one thousand increment encoder has a CPR of 1000. Can mean either cycles per revolution or counts per revolution

- **Cycle Error**
  The difference between the actual cycle width and the theoretically correct cycle width which is nominally 1/resolution and expressed in electrical degrees or in percent of cycle width.

D

- **DA Converter:**
  Digital or Analog converter; a circuit that accepts digital input signals and converts them to analog output signals.

- **Differential Line Driver:**
  See Line Driver definition

- **Differential Output:**
  Refers to the complementary outputs from a feedback device when the signals are excited by a line driver. Best performance occurs when the receiver input impedance is matched to the line driver output.

- **Direction of Rotation:**
  In a bi-directional incremental encoder, Channel A will lead Channel B for one direction of rotation. If the direction of the rotation is reversed, Channel B will lead Channel A.

- **Disk /Encoder Wheel:**
  Typically made of metal with a polymer magnet and an imbedded magnetic pattern. The pattern or number of magnet pairs (pole pairs) is a factor in determining the resolution or CPR of the encoder.

- **Dual Channel:**
  A dual-channel encoder produces two incremental outputs. These two outputs are generally in quadrature (90° phase separation) relationship to each other. They are typically referred to as Channel A and Channel B.

- **Duty Cycle:**
  Duty cycle is the relationship between the on time and the off time of the A or B channel output signal. The typical output signal has a duty cycle of 50 / 50 being on for 50% of the time and off for the other 50% of the time. A signal that was on 40% of the time and off for 60% of the time would have a duty cycle of 40 / 60.

E

- **Edge:**
  An edge is defined as a transition from one logic state to another on either of the two quadrature output lines. The edge count of a quadrature encoder is 4 times the CPR of the encoder. i.e. a 1,000 CPR encoder has 4,000 Edges per revolution.

- **Edge Separation:**
  The separation between a transition in the output of Channel A and the neighboring transition in the output of Channel B. There are four states per cycle, each nominally 90 electrical degrees apart for quadrature output.

- **Electrical Degree**
  An electrical degree is 1/360 of a cycle and is related to mechanical degree through resolution. It is mathematically expressed as follows: Resolution x360 electrical degrees= 360 mechanical degrees**.**

- **EMI**
  Electromagnetic Interference

- **Encode**
  To express given information by means of a code.

- **Encoder (Modular Type)**
  An encoder is an electro-mechanical device that translates mechanical motion (such as position, velocity, acceleration, speed, direction) into electrical signals. It uses the shaft and bearings of the motor or device as the spindle for the encoder.

- **End Play:**
  Amount of shaft axial movement with maximum axial load.

- **Error:**
  The algebraic difference between the indicated value and the true value of the input

F

- **Frequency Response:**
  Frequency response for an incremental encoder is the encoder's electronic speed limit or the maximum frequency of the output signal expressed in kilohertz (1 kHz = 1000 Hz = 1000 cycles/sec). For calculations, rotational speed must be in rev/sec (rps = rpm/60); linear speed must be either in/sec or mm/sec, depending on the scale line count. (cycles/rev) x (rev/sec)/1000 = kHz

G

- **Gated Index:**
  A type of circuit that causes the marker pulse to arrive coincidentally with a specific state of the A and B channels. Example: The C index occurs when both A and B are at Logic 1.

I

- **Incremental Encoder:**
  An incremental encoder is a device that provides a series of periodic signals due to mechanical motion. The number of successive cycles (signals) corresponds to the resolvable mechanical increments of motion or position.

- **Incremental Output:**
  An incremental output encoder is an encoder that typically has two quadrature output channels and may or may not have an index output. The signals from an incremental encoder can be use to detect relative position or speed. An incremental encoder must be moved past its index pulse if the absolute position of the encoder is desired.

- **Index Reference/Signal:**
  The index is a once-per-rev output used to establish a reference or return to a known starting position. It is a separate output generated by a special track which produces a single cycle (or transition change) at a unique position or positions such as center, home, zero, or reset point. Sometimes referred to as a marker pulse.

- **Input Frequency:**
  This is unique for magnetic encoders and is the frequency of the magnetic target pole pairs. A 25 pole pair target spinning at 10,000 rpm will have an input frequency of: 25 *10,000 / 60 = 4,167 Hz

- **Interpolation:**
  A process that involves an electronic technique for increasing the resolution from the number of cycles on a target disc or scale to a higher number of quadrature square waves per revolution or per unit length. These square waves can then be QUADRATURE DECODED.

- **IP 50 Protection Rating**
  Protected against dust. Limited ingress (no harmful deposit).

- **IP 64 Protection Rating**
  Totally protected against dust. Protected against water sprayed from all directions. Limited ingress permitted.

- **IP 65 Protection Rating**
  Totally protected against dust. Protected against low pressure jets of water from all directions. Limited ingress permitted.

- **IP 66 Protection Rating**
  Totally protected against dust. Protected against strong jets of water. Limited ingress permitted.

J

- **Jitter:**
  The angular amount of variation seen on a rising or falling edge of the A or B signal as the encoder moves at a steady speed. This can be called out in electrical degrees (360 degrees electrical = one period) or in mechanical degrees (360 degrees = one turn of the encoder)

K

- **Kilohertz (KHZ):**
  A measure of frequency

L

- **Line Count:**
  Line count is the number of equally spaced radial lines or magnetic pole pairs per 360 mechanical degrees on the incremental encoder target disk.

- **Line Driver:**
  A line driver is a common option for the encoder output signal. With a line driver output the encoder produces a differential signal for both the A, B and Reference pulse signals. Each of the signals is driven both high and low on separate wires. The signal from the A channel is transmitted as both an A signal and an A NOT signal. The two signals are equal an opposite and are designed to be received by a Line Receiver chip. Line driver signals are well suited for transmission over a long distance and/or transmission in an electrically noisy environment. The line driver / receiver pair effectively reduces the occurrence of common mode noise that can be introduces during transmission. While it is possible to use only one line from the line driver output the best performance is achieved when a compatible line receiver is used. Note: the circuitry used to drive the output signal both high and low is sometimes referred to as a push – pull output or a totem pole output.

- **Logic State Width Error:**
  The deviation in electrical degrees of the state width from the ideal value. In a quadrature encoder, the ideal state width is 90 degrees.

M

- **Measuring Step:**
  The smallest RESOLUTION element; it assumes QUADRATURE DECODE.

N

- **Negative Going Pulse:**
  When activated, the pulse goes low (logic 0) or in a negative direction. Do not be confused by negative going, meaning the pulse goes negative in relationship to the signal common or reference level. These statements are for positive logic only. Most shaft encoders are based on positive logic.

- **NEMA 4**
  An enclosure rating intended for indoor or outdoor use primarily to provide a degree of protection against windblown dust and rain, splashing water, and hose directed water; undamaged by the formation of ice on the enclosure.

- **NEMA 13**
  Enclosures are intended for indoor use primarily to provide a degree of protection against dust, spraying of water, oil and noncorrosive coolants.

- **NEMA 56C**
  National Electrical Manufacturers Association Type 56C; A standard motor face whereby mounting to the motor requires a device with similar bolt hole dimensions, etc.

- **Noise:**
  An undesirable electrical signal from an external source such as an AC power line, motors, generators, transformers, fluorescent lights, CRT displays, computers, radio transmitters, and others.

- **NPN**
  A type of transistor with a P-type base sandwiched between an N-type emitter and an N-type collector.

O

- **Open Collector Output:**
  Taking the signal directly off the collector element of the output transistor. This is the electronic equivalent of a mechanical switch closure to common. The input device of the PLC or counter is effectively placed in a series circuit that includes the output transistor and input device, which is often an optosolator and the positive voltage supply. When the output transistor turns on, the circuit is completed and current will flow. The output signal can not be observed unless the circuit is completed externally.

- **Open Drain:**
  Open drain is a common option for the encoder output signal. With an open drain output the encoder either pulls the output line to ground or leaves it in a high impedance state. It is up to the user to provide an external pull up resistor to pull the output line high during the time the line is not being pulled low by the open drain output. Note: This type of output is 100% compatible with an Open Collector output. Note: The external pull up resistor should be connected to a voltage that does not exceed the maximum voltage rating of the encoder. The value of the pull up resistor should be selected not to exceed the rated current rating of the encoder's output driver.

- **Operating Temperature:**
  The temperature range over which a product will operate and maintain its specified performance criteria.

- **Output**
  The quantity such as current, voltage or switching that a device delivers.

- **Output Frequency:**
  This is the frequency of the signal from the A or B outputs. A 1,000 CPR encoder spinning at 10,000 rpm will have an output frequency of: 1,000 *10,000 / 60 = 166,667Hz on channel A and on channel B

- **Output Waveform**
  The graphical representation of the output during one pulse interval.

P

- **Parity:**
  Addition of all the bits in a word is compared to the parity bit (even or odd). If they are both the same, the data is accepted. Otherwise, it is rejected.

- **Period:**
  The angle or distance between consecutive rising edges on a channel. (See graphic for quadrature term)

- **Phase:**
  The relationship between the A and B signals in the amount that they lead or lag each other. The typical phase is 90 (electrical) degrees, or 25% of a full period, for a quadrature signal. The length of a full period is defined as 360 degrees (electrical). (See graphic for quadrature term).

- **Phase Error:**
  The deviation in electrical degrees from a specified phase relationship between any two channels. This is nominally 90 degrees in a quadrature encoder.

- **Position Error:**
  Position error is the difference between the theoretically correct shaft position and its position as indicated by the encoder cycle count.

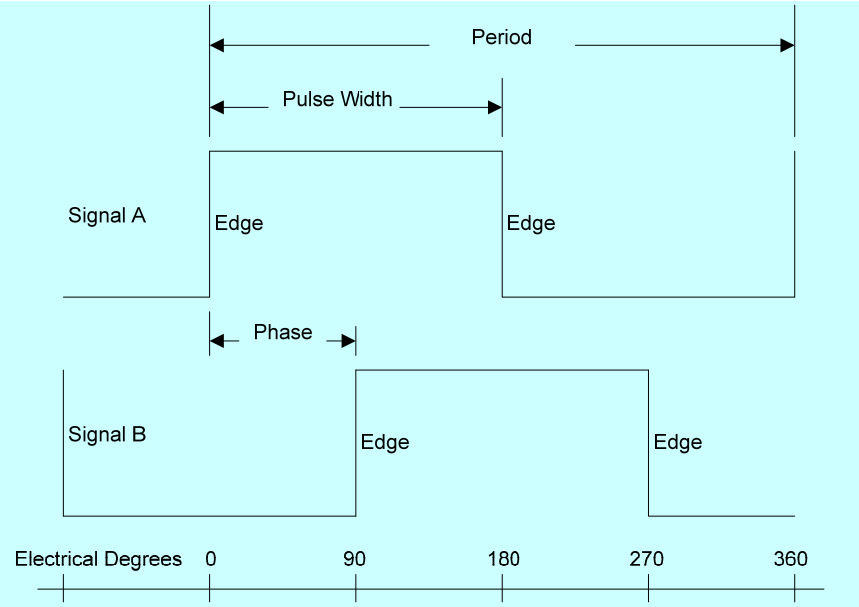
- **Positive Going Pulse:**
  In the low or logic 0 state, it is in the quiescent state. It goes high or logic 1 when activated. This is a transition in the positive going direction.

- **Pulses Per Revolution (PPR)**
  Number of pulses occurring in one revolution of the encoder shaft. Commonly (but mistakenly) used instead of cycles/rev when referring to Quadrature square wave output

- **Pulse Polarity:**
  Either positive going or negative going. A pulse has two logic states: activated or inactivated. These two states are opposite. When the pulse is in its quiescent state (high or low), it is at one particular logic level (1 or 0). When the pulse hits or is in the activated state, this logic level reverses itself for the duration of the pulse.

- **Pulse Width:**
  This is the length of the high portion of the signal on channel A or B and is typically half the length of the period. (see graphic below)

Q



Quadrature Waveform

- **Quadrature:**
  Quadrature is the standard output configuration for an incremental encoder. There are two output signals typically referred to as A and B outputs. Each output is a square wave with a duty cycle of 50%. The A and B outputs are shifted from each other by 90 degrees (Electrical). This phase shift is useful in that the shift can be used to determine the direction of rotation after any change in the A or the B output signal. (See graphic above)

Quadrature State:	A Output	B Output
A	0	0
B	1	0
C	1	1
D	0	1
A	0	0
B	1	0

Note: Moving up the list is defined as moving in the CW – Clockwise direction and moving down the list is defined as moving in the CCW or Counter Clockwise direction

Note: This is a Gray code pattern having only one line A or B change at a time. If both A and B change together or there is a jump/skip in the order then an error condition is present.

- **Quadrature Decode (or 4X Decode)**
  Refers to the common practice of counting all 4 quadrature states (or square wave transitions) per cycle of quadrature square waves. Thus, an encoder with 1000 cycles/rev, for example, has a resolution of 4000 counts/rev. (See the technical article Understanding Quadrature)

- **Quadrature Error**
  Quadrature error is the phase error when the specified phase relationship between two channels is nominally 90 electrical degrees. It is inherent in all digital systems; it reflects the fact that you have no knowledge of how close you are to a transition. It is commonly accepted as being equal to ±1/2 bit.

R

- **Radial Play**
  The amount of shaft radial movement with the maximum radial load.

- **Reference Input:**
  The input on the control device that takes in the reference position of the encoder.

- **Reference Pulse:**
  A Reference pulse is a signal that is produced from an incremental encoder on a separate line from the A and B quadrature outputs. The reference pulse line is sometimes referred to as the C channel, the Z channel, a marker pulse or an Index channel. A typical encoder will produce one reference pulse at the zero degree position of the target wheel. The index pulse is often gated to coincide with one state of the quadrature signal. The Timken encoder produces an index pulse “C” that is 90 degrees (electrical) in length and corresponds to the quadrature state “C” where both the A channel and the B channel are at a logic 1.

- **Repeatabiltiy:**
  A measure of how close the output is this time to where it was last time, for input motion in the same direction. It's not usually specified explicitly, but it is included in the accuracy figure.

- **Resolution:**
  Encoder resolution is expressed in CPR (Cycles per Revolution). This is the number of On – Off cycles on each output wire. A typical encoder will have two channels A and B. The CPR rating is for one channel. A four time’s multiplication of the CPR is achieved by evaluating the rising and falling edges on the two channels. Therefore a 1000 CPR encoder produces 4,000 edges per revolution that can be used by a controller. Note CPR is also interchangeable with “Lines” referring to the lines on a target wheel and PPR – Pulse per Revolution**.**

- **RFI**
  Radio Frequency Interference

- **Rise Time:**
  The interval between the points that the instantaneous value rises from 10% to 90% of the specified upper limit.

- **Running Torque:**
  Rotary force that is necessary to keep an encoder shaft turning. It is typically expressed in ounce inches.

S

- **Shaft Loading:**
  Amount of force that can be applied to a shaft radially or axially; usually measured in pounds**.**

- **Shaft Run Out:**
  Amount of shaft movement while spinning.

- **Shock:**
  A transient motion which is capable of exciting mechanical resonances.

- **Short Circuit Protection:**
  A feature that causes the solid state output to either withstand or turn off if exposed to a short circuit load condition.

- **Single Channel**
  A single channel encoder produces one incremental output. They are often used for tachometry applications.

- **Square Wave:**
  A repetitive waveform whose shape is essentially square or rectangular (usually with an equal duty cycle)

- **Serial Interface SSI and SPI:**
  SSI (Synchronous Serial Interface) and SPI (Serial Peripheral Interface) - A 3-wire serial interface developed by Motorola) are common interfaces capable to transmitting position, and diagnostic data from rotary and linear encoders. The interface and further defined by the bit rate. The Timken MPS160 has a maximum data at a bit rate of 1 MHz

- **Stability:**
  Ability of an encoder to retain its performance characteristics over a long period of time.

- **Starting Torque:**
  The rotary force required to overcome friction and cause the encoder shaft to begin rotating. Also referred to as breakaway.

- **State:**
  This usually refers to the logic level at a given instant

- **State Width:**
  Same as edge separation

- **Symmetry:**
  The ratio of the ON time to the OFF time of the output signal for one channel. This ratio is optimally 50-50.

T

- **TIR**
  Total Indicator Reading

- **Torque:**
  A twisting effect or movement exerted by force acting as a distance on a body equal to the force multiplied by the perpendicular distance between the line of action of the force and the center of rotation at which it is exerted.

- **Torque (Running)**
  Running torque is the rotary force required to keep an encoder shaft turning. It is typically expressed in ounce-inches.

- **Torque, Starting (Breakaway):**
  Starting (breakaway) torque is the rotary force required to overcome static friction and cause the encoder shaft to begin rotating.

- **TTL**
  Transistor Transistor Logic

U

- **Unidirectional:**
  Unidirectional refers to an encoder output code format from which direction of travel cannot be determined.

V

- **Vibration**
  Periodic chance in displacement with respect to a fixed reference**.**

Z

- **Zero Speed Encoder:**
  An encoder which will give output signal down to zero speed

- **Zero Index**
  An output signal from an encoder produced once in some specified displacement