Lauritzen Inc.
Bringing new ideas to renewable energy

Encoders, Limit Switches and their use in Lauritzen Controllers

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1. Introduction

The purpose of this application note is to illustrate the usage of motor encoders and limit switches with Lauritzen Solar Tracker controllers.

2. Encoders, Purpose & Functionality

A **rotary encoder**, also called a **shaft encoder**, is an electro-mechanical device that converts the position or motion of a shaft or axle to an analog or digital code. The output of incremental encoders provides information about the *motion* of the shaft which is typically further processed elsewhere into information such as speed, distance, RPM and position. An incremental encoder, coupled with a geared absolute limit switch is used in most solar tracker applications in order to determine the tracker position.

3. Encoder single versus dual-channel

Lauritzen solar tracker controllers may operate with a either a single channel or dual-channel (quadrature) encoder styles.

A single channel encoder will emit a given set of pulses, typically 1 to 8, per shaft revolution. By knowing the motor power polarity, the directional rotation can be inferred, and the controller's encoder counter can be either incremented or decremented per encoder pulse.

A dual-channel encoder, or popularly referred to as quadrature encoder, where the encoder signals are labeled A and B, will emit overlapping A/B pulses as seen in Figure 1. Given the A/B signal phase shift, the encoder counter algorithm can infer the directional shaft rotation.

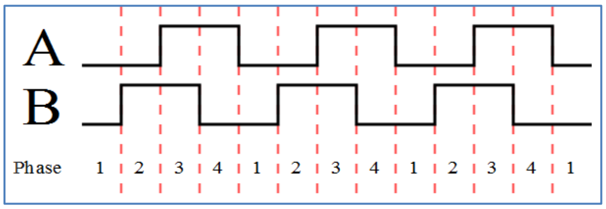


Figure 1; Quadrature Encoding

4. Encoder Slippage

If a mechanical actuator movement can take place without proper encoder feedback, it is referred to as encoder slippage. In the case of solar trackers, unintentional actuator movement is not unusual when strong wind gusting will force an actuator to move – even if ever so slight. If a single-channel encoder is used in such a drive, encoder slippage occurs. In this event, the Solar Tracker Controller will void the respective encoder counter if the accumulated slippage count exceeds a preset threshold. In dual-channel encoder applications, the encoder counter can be correctly adjusted according to the slippage.

Regardless of whether encoder slippage occurs or not, the solar tracker controller can be configured to periodically void the encoder counters. The recommended encoder-void value for single-channel encoders is once every 4-7 days, and 180 days for a dual-channel encoder.

5. Encoder Input

The solar tracker controller's encoder input is designed to operate in a noisy environment, and therefor includes both a low-pass filter to prevent RF interference (including that produced by PWM motor supply) and zener diode to protect against voltage spikes. The TCX2P0 and TCX2P1 controllers use a 10k pullup resistor, and the encoder input voltage should be limited to 8V to 0V. Because of the low-pass filter, an encoder pulse should not be shorter than 2.5ms.

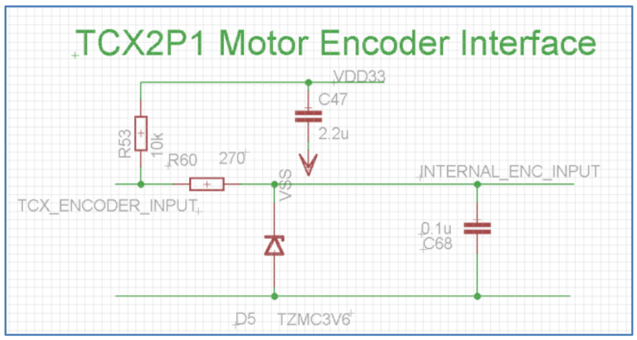


Figure 2; TCX2P1 Motor Encoder Input

Starting with TCX2P3 controllers, the encoder input has been changed so that the input voltage can be in the range of 0V to +24V, and a programmable termination resistor can be used to pullup (to +5V), pulldown (to 0V) or left floating.

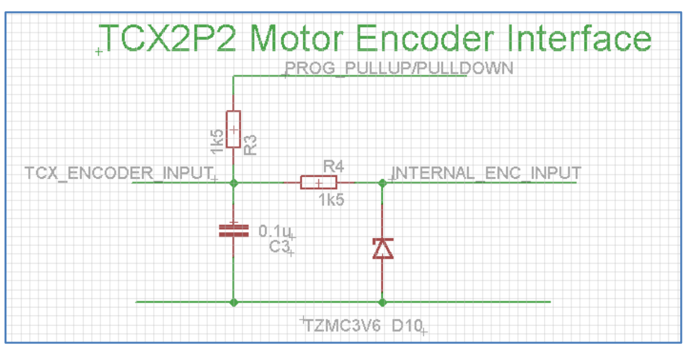
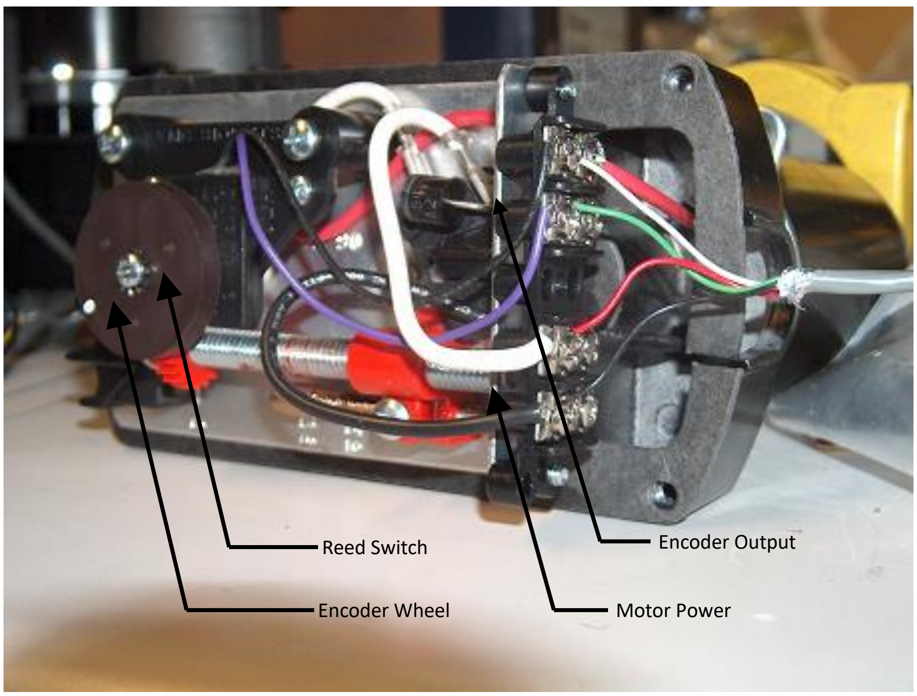


Figure 3; TCX2P2 Motor Encoder Input

6. Reed Switch Encoder

A reed switch based encoder provides a very cost effective method of implementing an encoder. It is an electro-mechanical switch operated by an applied magnetic field. The switch is typically hermetically sealed within a glass bulb, and has excellent mean time between failures (MTBF) characteristics. Because of its mechanical construction, a reed switch is limited with respect to its operating frequency (open/close cycle). A reed switch based encoder is often found with linear actuators where an 8-pole magnetic disc is mounted as an extension to the actuators' screw. Thus for every turn screw turn, the encoder will detect 8 north and south pole pairs which translates into 8 switch closed and open state pairs.

It is not possible to tell rotational direction when using a single reed switch as a motor encoder. Therefore, proper solar tracker operation must rely on correct motor polarity.



Picture 1; Reed Switch Encoder

When using a single channel Reed Switch Encoder, only the primary encoder input xx0 and NEG is connected. Encoder wiring polarity is irrelevant.

IMPORTANT: If the Reed switch encoder is connected to motor power, the switch will suffer immediate and permanent damage.

7. HALL Effect Encoder

A Hall Effect sensor encoder is an electrical device which varies its output voltage in response to changes in a magnetic field. The sensed voltage is weak, and must be amplified for use in applications such as an encoder. A typical Hall sensor typically includes both sensor and amplifier, and must therefore be supplied with 5-24VDC in order to operate. When Hall sensors are used as motor encoders, they are often fabricated as a pair where each Hall sensor is offset with respect to the other by 90 degrees as outlined in *Figure 1.*

The Hall sensors amplifier must be supplied with a small amount of power. The STX controller has a 5V power port located adjacent to the encoder terminal block for just that purpose.

IMPORTANT; WHEN CONNECTING HALL SENSORS MAKE SURE +5V AND GND IS CONNECTED CORRECTLY AS THE HALL SENSOR MAY OTHERWISE SUFFER INSTANT DAMAGE.

NOTE: Hall sensors require all ENC0_xx, ENC1_xx, GND and +5V connections.

8. Encoder Input LED

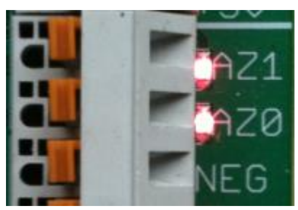
Each encoder input has a corresponding LED. The LED is illuminated when the encoder input is open, and off when the input is closed. The LED is operated by the controller’s micro-processor, and therefore represents the actual input state seen by the controller.

9. Testing of Encoder Input with Controller

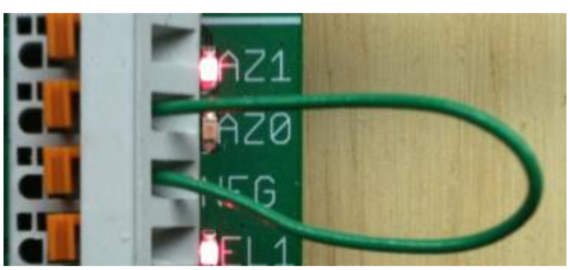
After an encoder (and motor) has been connected to a controller, testing of the encoder must be done prior to system operation. Assuming proper motor and encoder configuration has been entered into the controller, the following steps should be performed:

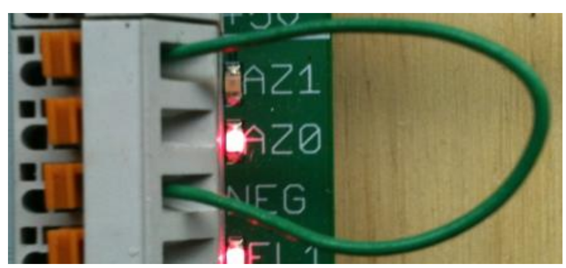
1) Place controller in Service Mode (if not already)
2) Attempt to drive motor, using motor directional push buttons, in either direction for less than the pre-configured servo-timeout. The timeout is typically set to 4-5 seconds. Observe motor power LED's when motor power is applied.
3) As the motor is operated, observe encoder LED flickering at the corresponding encoder input. Important; if the az-motor is operated, the az-encoder LED must flicker. Similarly, if the el-motor is operated, the corresponding el-encoder LED must flicker.
4) If proper encoder input is not detected by the controller's servo within the specified servo-timeout parameter, the servo will enter into a fault, and must be reset before additional operation can take place.
5) In the case where dual-channel encoders are used, the corresponding motor must be operated for a minimum of 10 seconds in either direction so that the servo can self-learn the proper encoder phase relationship with-respect-to shaft rotational direction.

If a faulty controller encoder input is suspected, disconnect the encoder inputs and observe the two encoder LED's being lit:



The LED's are being driven by the on board micro-processor, so they represent a view of the encoder-logic state as understood by the controller. The next step is to check each encoder input which is done by inserting a shunt between one input and NEG:





Upon inserting the shunt, the corresponding LED should turn-off, indicating a functioning encoder input.

10. Testing of Dual-Channel Encoder with DVM

Motors with dual-channel encoders can be difficult to test, especially without a properly configured controller. This section highlights how testing can be done with a few discrete components and a Digital Voltmeter (DVM).

Most dual-channel encoder motors in the solar industry use a 6+1 pin Amphenol socket with the following pinout;

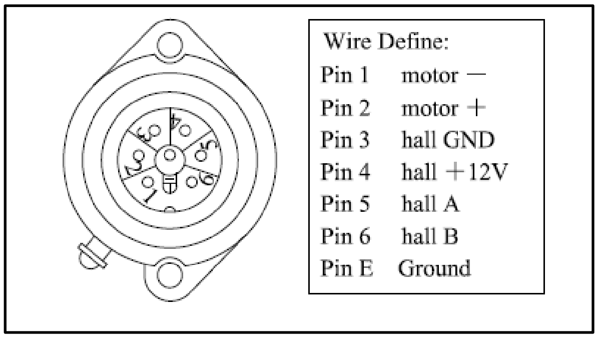


Figure 4; Motor with Dual-Channel Encoder Pinout

The hall effect encoder is typically designed to work with a voltage supply range of 5 to 24VDC.

NOTE; connecting motor supply to encoder terminals will result in immediate encoder damage.

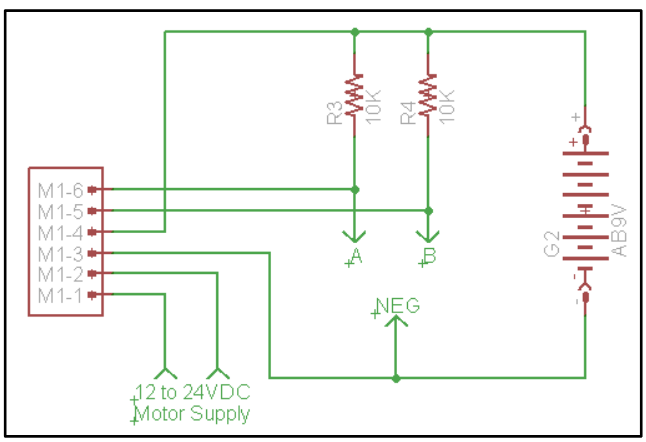


Figure 5; DVM Testing of Dual-Channel Encoder

Using a 9V battery for the encoder supply, and two 10K resistors, a small circuit can be created to test the dual-channel encoder as illustrated in the schematic above. The voltage is recorded between A/NEG and B/NEG. The motor is now moved a little by applying motor power, and the encoder voltage is recorded again. The encoder voltages will be random since the motor will stop at random positions. However, after some repeated attempts, all four encoder states can be observed as in the following table.

Encoder State	Channel-A (V)	Channel-B (V)
AB (low, low)	0.0 to 0.6	0.0 to 0.6
AB (low, high)	0.0 to 0.6	2.0 to 9.0
AB (high, low)	2.0 to 9.0	0.0 to 0.6
AB (high, high)	2.0 to 9.0	2.0 to 9.0

Figure 6; Measuring Encoder States with DVM

11. Linak Actuators and 24VDC Hall Encoders

When using 24VDC supplied Hall encoders, care must be taken to prevent damage to TCX2P1 solar tracker controller's encoder input. In the case of the Linak 24VDC powered hall encoder, the signal output is either sourced to 24VDC or has a weak current sinking capability. A simple series resistor would correctly signal and protect the encoder input during an encoder high state. However, the weak current sink capability is insufficient to provide a satisfactory low state for the encoder input. Instead, the following voltage divider, which solves both the current sourcing and sinking capability of the Linak encoder as well as the encoder input voltage requirements is recommended:

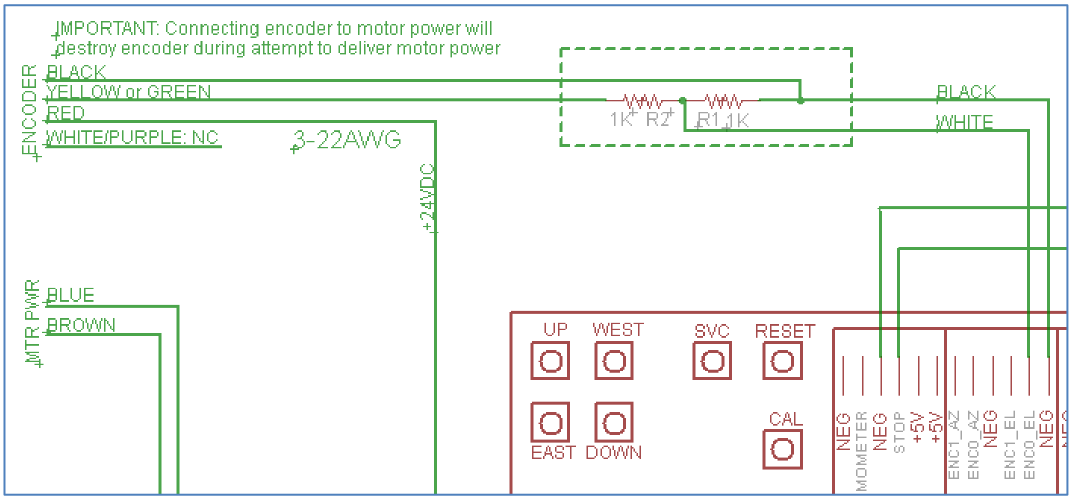


Figure 7; TCX2P1 Linak Encoder Interface

Starting with TCX2P2 controllers, the encoder inputs are 24V tolerant, the Linak actuators encoder output can be directly connected to the TCX2P2's encoder input. Supply voltage (+24V) for the actuator's HAL sensor can be sourced from the controller's AUX output assuming the AUX control parameter has been enabled.

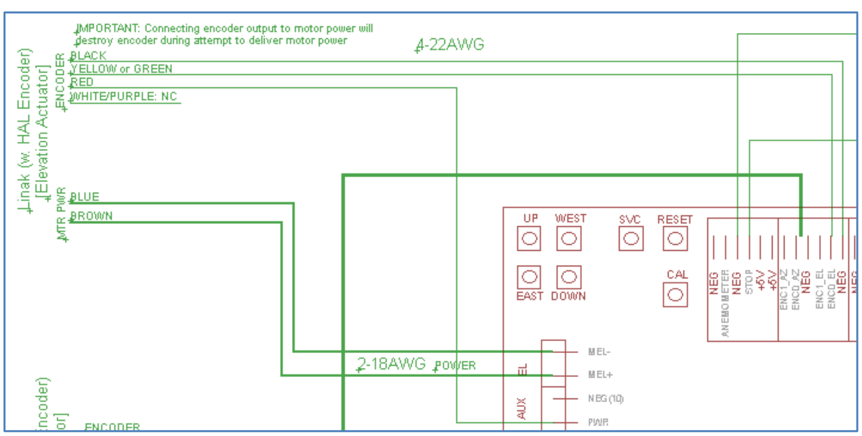


Figure 8; TCX2P2 with Linak Actuator

12. Limit Switches, Purpose & Functionality

Limit switches in solar trackers serve two purposes;

1) To prevent an actuator from travelling outside of defined range of motion
2) To define an absolute zero point-of-reference from where the encoder-counter can be reset.

The azimuth actuator is governed by the East and West limit switch, while the elevation is governed by the Up and Down limit switch. For conventional dual-axis trackers, up is referred to as moving the tracker array toward horizontal, while down is referred to as moving the tracker array toward vertical. For single axis, and dual-axis-sync trackers, the “up” limit switch is synonymous with the “east” limit, and “down” is synonymous to “west” limit. There are two methods of limit switch configurations;

1) Implied limit switch. A Normally-Closed switch(s) is inserted into the motor power circuit.
2) External limit switch. A Normally Closed switch(s) is connected to the external limit switch inputs of the controller.

The Target Finder module can be enabled to ensure the physical range of motion in any one direction remains within a defined range. The purpose of the software check is to provide a last defense against the tracker spinning out of control. If the software Maximum-Turn is triggered, it will immediately halt all motor operation and place the controller in an error mode which can only be recovered through a controller reset. Note; the software Maximum-Turn range must be larger than the physical range as defined by the limit switches.

IMPORTANT; as part of the system commissioning checkout, all limit switches must be checked for proper operation. The controller is placed in Service Mode, and the tracker is moved against the respective limit switches.

IMPORTANT; a solar tracker must NOT be allowed to be parked, or rest, against a limit switch for a longer duration of time. This is because, if a tracker is back-driven by wind, the limit switch will get damaged. To prevent this from happening, the controller enforces an Operational Range to an axis. The Operational Range is typically defined to be at least 2 degrees from the physical limit switch.

12.1. Implied Limit Switches

An implied limit switch, when engaged, will break the motor power circuit. A bypass diode is placed across the switch to allow the motor to be backed away from an engaged limit switch. Detection of an engaged (open) Implied Limit switch is done by sensing no motor current AND no encoder pulses.

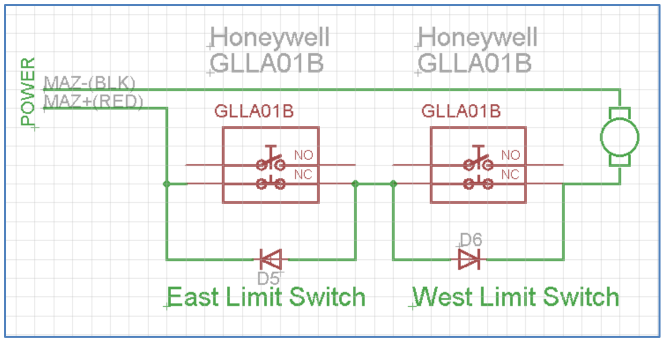


Figure 9; Implied Limit Switches

The relationship between the placement (east/west or up/down), the diodes and motor polarity defines the range of motion of the actuator. Note; the motor polarity from the controller (MAZ+/MAZ-) does not influence the limit switch to motor relationship. All things being equal implied limit switches have been found to be most reliable and cost effective.

12.2. External Limit Switches

External limit switches are often used in High Voltage (AC) applications to avoid running high voltage through the limit switch.

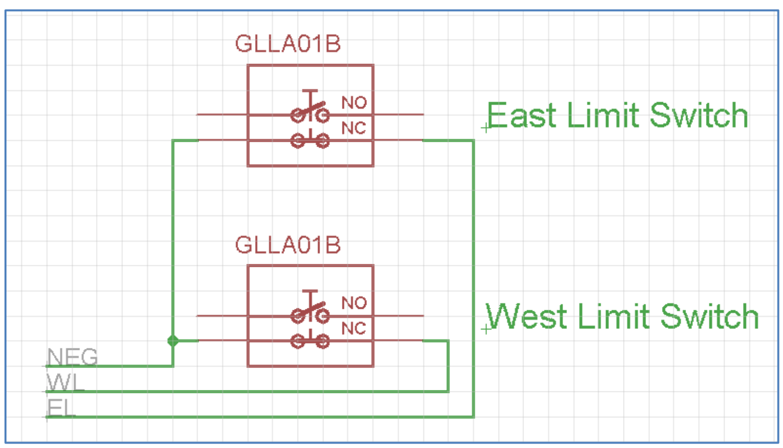


Figure 10; External Limit Switches

When the actuator reaches the switch, it is opened, and all actuator movement in the switch direction is halted by the controllers PWM and Servo modules. A possible failure mode of external limit switches is a stuck-closed limit switch. Hence, when the actuator is backed away from the switch, a software sanity check of the limit switch is called upon to ensure the switch is re-closed. In case it is not, the controller will enter a fault mode which must be cleared through a reset.

13. Kinematics, Titanhorse and other slewing drives

Slewing drives from Kinematics, Titanhorse and other slewing drive manufacturers employ dual-channel 5V Hall encoders. The drives use a 6-pin Amphenol all-weather connector, and the following wiring diagram is typically used for the encoder interconnection and slewing drive limit switches:

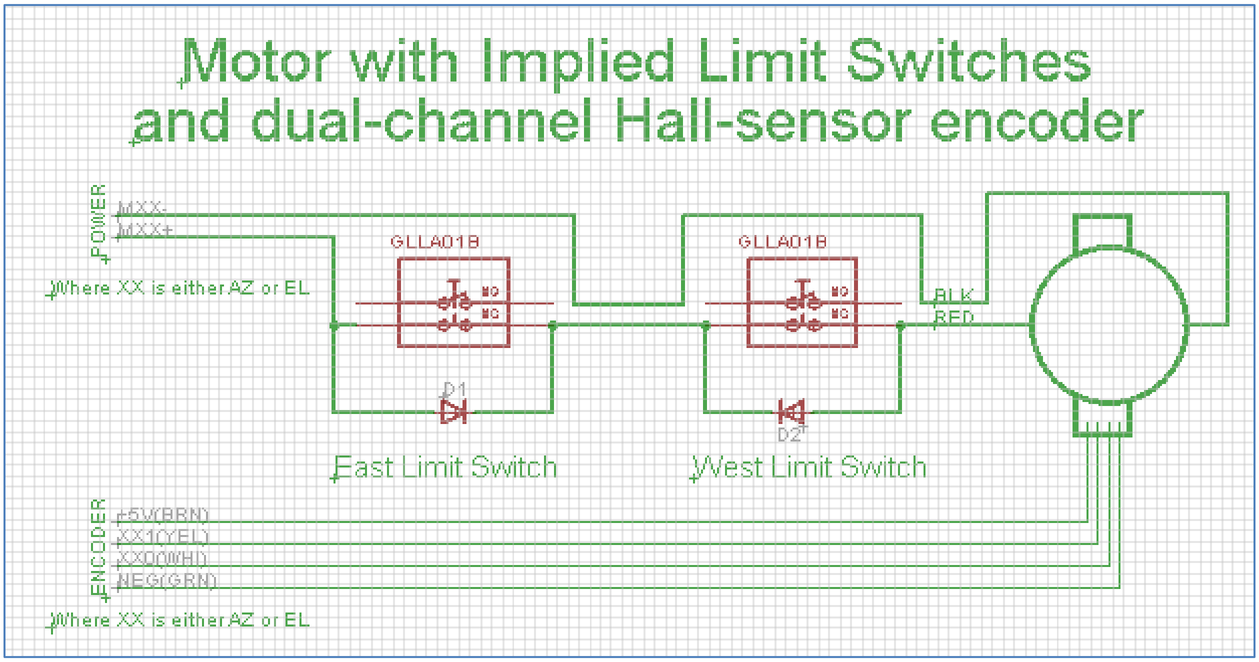


Figure 11; Slewing Drive Interconnection

The 6-pin mating female connector for the slewing drive is an Amphenol C016-30D006-100-12, and the pinout is as follows:

Pin#	Signal Name	Lauritzen Cable Slewing Drive Conductor Color
1	Motor Power (pos)	Red
2	Motor Power (neg)	Black
3	Encoder Power (neg)	Blue
4	Encoder Power (+5V)	Brown or Orange
5	Encoder Channel-A	Green
6	Encoder Channel-B	White

Figure 12; Slewing Drive Pin-Out

14. Revision History

Revision	Release Date	Comments/Changes
V1.0	Jan-1-2010	Initial Release.
V1.1	Jun-1-2017	
V1.2	Aug-4-2019	Added DVM encoder test

15. Contact and Support

Please contact your local tracker manufacturer for support and warranty issues.

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Information in this manual is subject to change…