Compumotor

IL Encoder User Guide

Compumotor Division
Parker Hannifin Corporation
p/n 88-007836-02 B

Table of Contents

List of Figures

List of Tables

Chapter 1. INTRODUCTION

Overview

This manual covers general product information, theory of operation, specifications, and general precautions you should take when you install the IL Encoder. Chapter 3, Hardware Reference, contains pertinent information that you should read and follow carefully to properly integrate the IL Encoder into your system.

Description

The IL Series is an incremental linear (IL) encoder that combines a rotary encoder with a rack and pinion mechanical system. Incremental encoders are position feedback devices that provide pulses to a counter, which maintains these counts to correspond to the encoder's mechanical position on the rack and pinion system.

Theory of Operation

The rotary incremental encoder is a simple device. It consists of five components. Figure 1-1 illustrates these components and shows their general relationship to each other.

The LEDs illuminate a light that is always on. The light is perpendicular to the disk (metal for IL), with one track of concentric slots etched through the disk. The disk is linked to a shaft that rotates with the load. Figure 1-2 shows the incremental disk.

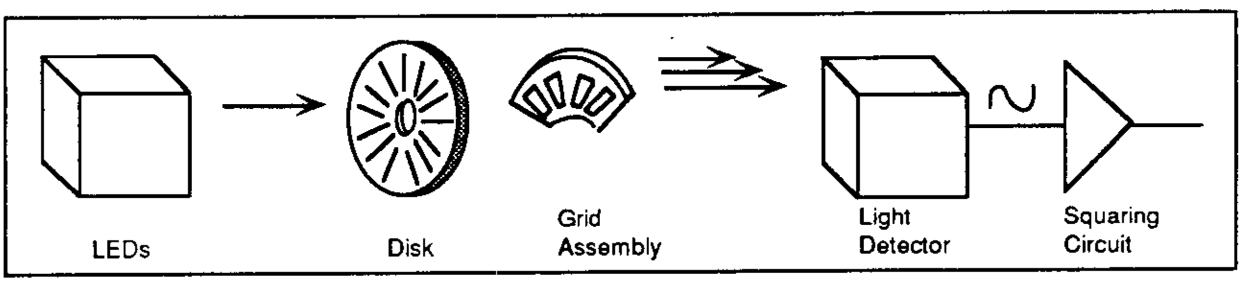

Figure 1-1. Rotary Incremental Encoder Basics

Parallel to this disk is a grid assembly or slit plate. The objective of this component is to allow light to shine through only one disk slot at a time. This light, which shines through an open slot, activates a light detector. When the light detector is activated, it generates analog output. By using two LEDs and photo-transistors (located 90 electrical degrees apart) the unit produces an analog sine and cosine signal as the system rotates the disk.

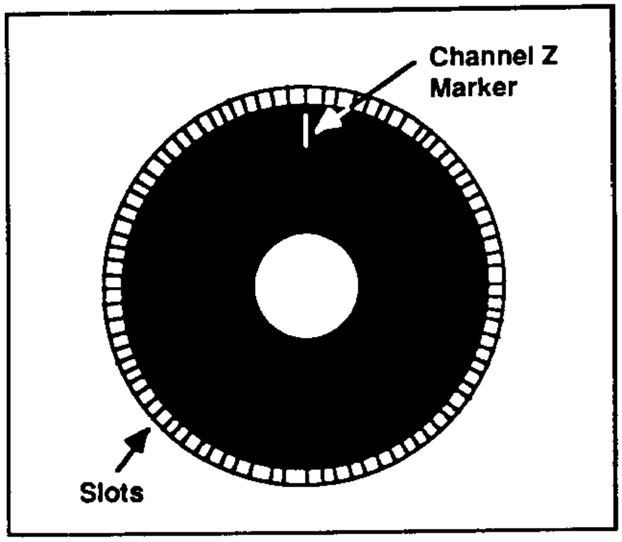

Figure 1-2. Incremental Disk

These two signals are conditioned with squaring circuitry that creates two square wave outputs 90° apart or *quadrature* outputs. These two outputs are commonly referred to as Channel A and Channel B.

You can interface these signals to a control system that maintains an overall count total (number of pulses). The counter increases in value when Channel A leads Channel B (CW), and decreases in value when Channel B leads Channel A (CCW). This value corresponds to the encoder's mechanical position on the rack and pinion system.

Figure 1-3 illustrates a quadrature detection technique. When you implement this technique, the encoder's resolution increases by four times, since there are four edges for Channels A & B combined.

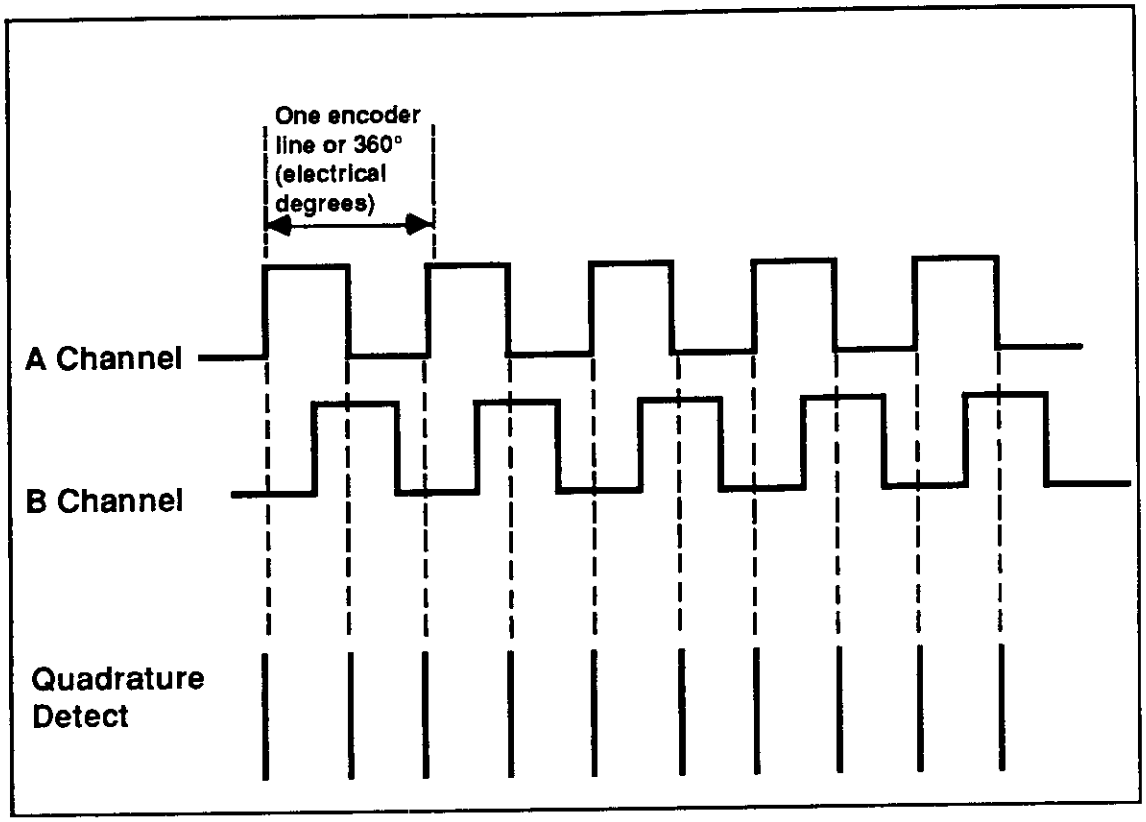

Figure 1-3. Quadrature Detection

Reducing Electrical Noise

Since most quadrature encoders are TTL-level signals (0 to +5VDC), you must take certain precautions if you install the encoder in electrically noisy environments. Electrical noise can cause the counter to miscount the encoder's pulses, which results in inaccurate reporting of the encoder's position. You can solve these problems in two ways—*complimentary outputs and line drivers.*

Complimentary Outputs

The first method of ensuring incremental encoder signal integrity is to use complimentary outputs, which decrease the miscount potential. Figure 1-4 illustrates the complimentary outputs from a quadrature encoder.

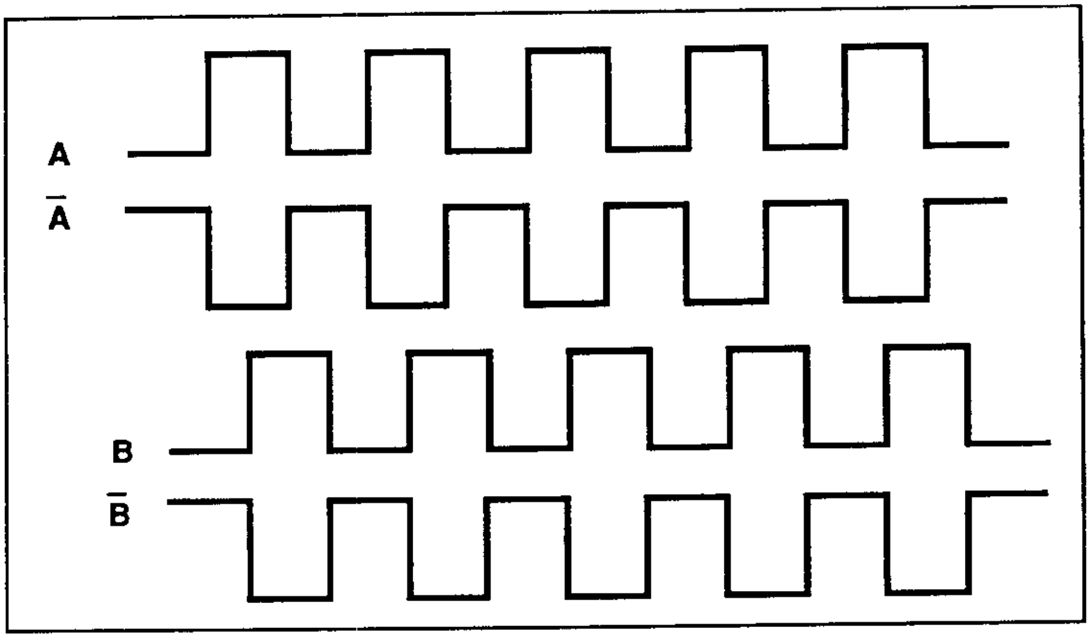

Figure 1-4. Complimentary Outputs (Differential Outputs)

The complimentary output encoder reduces the potential of a miscount by providing two additional outputs that are the inverse of the state of Channels A & B. To receive a valid count, Channel A must be high and the A compliment must be low at the same period of time. The same applies for Channel B. The A+ and A- outputs allow the voltage swing to go from 0 to 10VDC instead of 0 to 5VDC associated with a single-ended encoder. The complimentary output encoder's large voltage swing makes it less susceptible to noise. These complimentary outputs are standard on IL encoders. *Compumotor indexers are compatible with both complimentary and single-ended encoders.*

Line Drivers

The second method to ensure incremental encoder signal integrity is to use line drivers. These are similar to signal amplifiers for each channel. They increase output current strength (primarily for long cable distances, max. 250 ft.). When you implement line drivers, the control system monitors current flow versus voltage levels. As the impedance increases, the voltage drop increases. The voltage increase may be severe enough to stop transmission of output pulses at the point of cable termination. *To use the IL with Compumotor indexers, a line driver is not required. A TTL signal should be sufficient.* ***If you do use a line driver, refer to the appendix of this manual for information on line driver specifications and pin outs.***

IL Basics

The rotary encoder technology explained in this chapter facilitates linear encoding. The shaft of the rotary encoder is replaced with a pinion gear with 10 teeth. This gear is guided in a linear fashion with a rack assembly consisting of 20 teeth per inch (refer to Figure 1-5). Thus, the rotary encoder rotates 2 times per inch of travel.

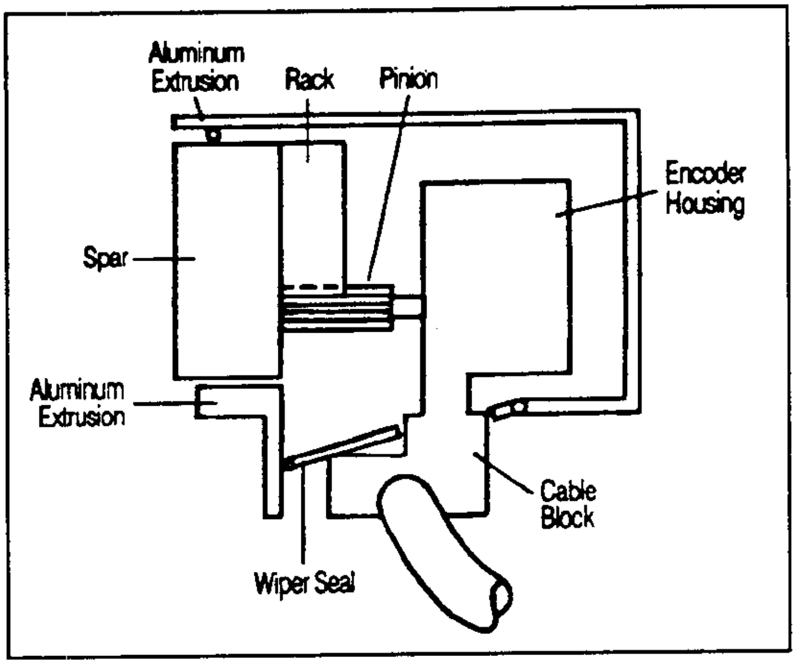

Figure 1-5. Construction of IL Encoder

The rack is constructed of precision-ground #416 stainless steel. This rack is factory-calibrated to the spar to ensure accuracy independent of length. Accuracy is maintained due to rack segments of 8" aligned with a laser interferometer.

The spar, constructed of machined steel, mounts directly to the machine and exhibits the same thermal expansion as the machined rack. The machine's accuracy does not drift (the rack expands and contracts with the machine, ensuring repeatability).

The pinion, constructed #303 stainless steel, is designed to withstand wear if it is not properly aligned with the rack. With proper alignment and preload of the pinion to the rack (place pinion firmly against the rack), this system is one of the most reliable products available for industrial environments.

The extrusion enclosure has a wiper seal and end seals to prevent fluid penetration. In addition, the encoder housing contains all of the system's electronics and is fully sealed. With the rack assembly mounted with teeth facing downward, the pinion wiper action cleans rack debris and ensures long system life and trouble-free operation.

Chapter 2. INSTALLATION

Overview

Review the following section and carefully follow the instructions to ensure proper installation and operation of the IL product.

Installation entails mounting the encoder head and rack assembly and ensuring proper alignment between the two. Proper alignment and preload is critical for long system life and maximum accuracy.

What You Should Have

Upon receiving the IL, check the package prior to removing the product. If any package damage is apparent, report this damage to the shipping company. Compumotor cannot be responsible for damage incurred by shipper mishandling. If the container is intact, open it and verify that the items listed in Table 2-1 are present and intact.

Part/Quantity	Description	Part #
IL Linear Encoder Assembly (1)	Rack/spar assembly calibrated with enclosure without encoder.	73-008073-XX (XX = " of travel)
IL Encoder Head with Integral Pinion (1)	This head will include a 10' armored cable if you are using a rack under 64". A 20' armored cable will be included if you are using a rack greater than 64". *This cable will already be installed into the pinion head.*	72-008039-10 72-008039-20
IL Series User Guide (1)		88-007836-01
Linear Encoder Mounting Guide(1)		88-009072-01

Table 2-1. IL Series Ship Kit List

Return Procedure

If you must return the unit for repair, use the following procedure:

1. Obtain the unit's serial number and purchase order (if the unit is more than one year old).

3. Call Compumotor for a return materials authorization (RMA) number at (800) 358-9068. In California, call (800) 345-2084.

4. Re-package the unit in its original box or package it with comparable protection. Compumotor cannot be held responsible for insufficient packaging.

5. Mark the RMA number clearly on the package.

6. Ship the package to the address below.

Parker Hannifin Corporation
Compumotor Division
1179 N. McDowell Blvd.
Petaluma, CA 94952
ATTN: RMA #_______________

IL Part Numbering System

Before you attempt to install the unit, verify that the part number of product you ordered corresponds to the number on the product that you received. The part numbering system follows the format shown in Figure 2-1.

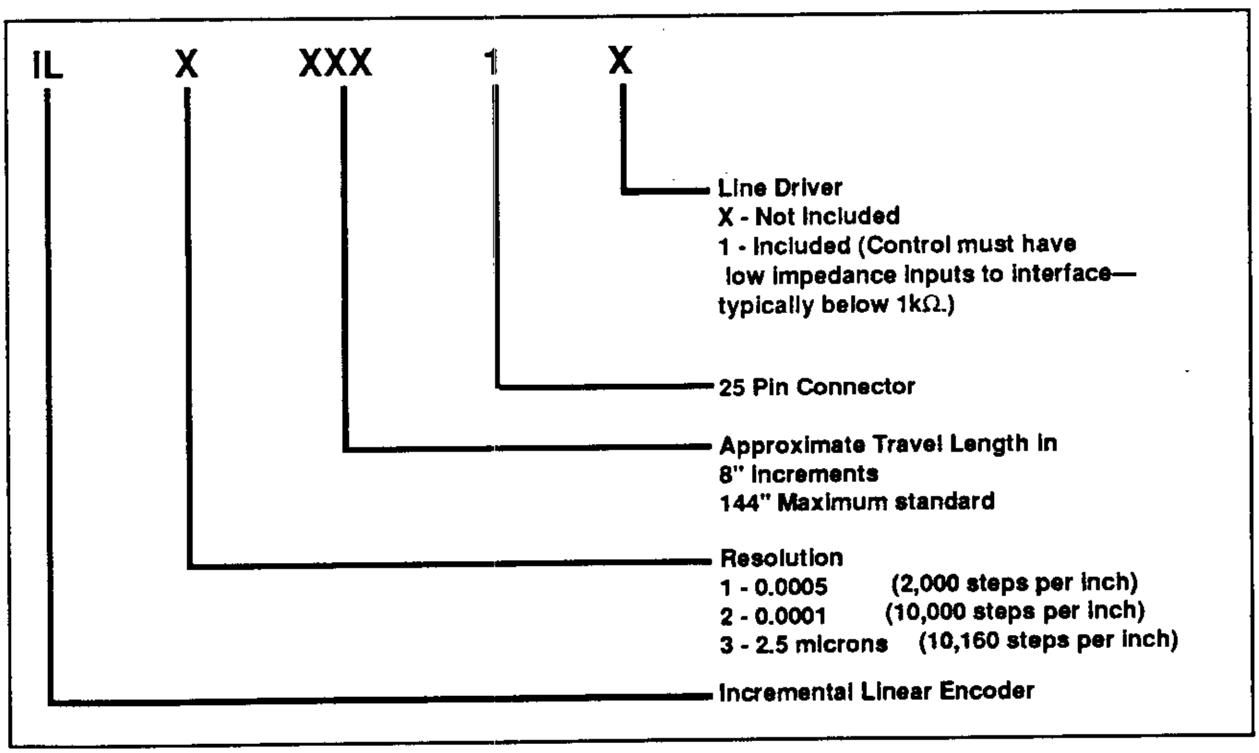

Figure 2-1. IL Part Numbering System

Application Considerations

The IL encoder provides quadrature TTL-level outputs with compliments. If you are installing the IL in an environment that contains high levels of electrical noise, refer to the precautions listed below. If you use the line driver option, the precautionary steps may not be required (depending upon the severity of noise). Below is a listing of general precautions.

1. Mount any devices that cause electrical noise (relays, coils, solenoids, or switching supplies) in an enclosure that is separate from the indexer/controller.

2. If you cannot put these devices in separate enclosures, suppress them with RC circuits or diodes (for DC relays).

3. Isolate a 5VDC power supply for the encoder from earth ground. You can do this by floating the supply ground (refer to Figure 2-2).

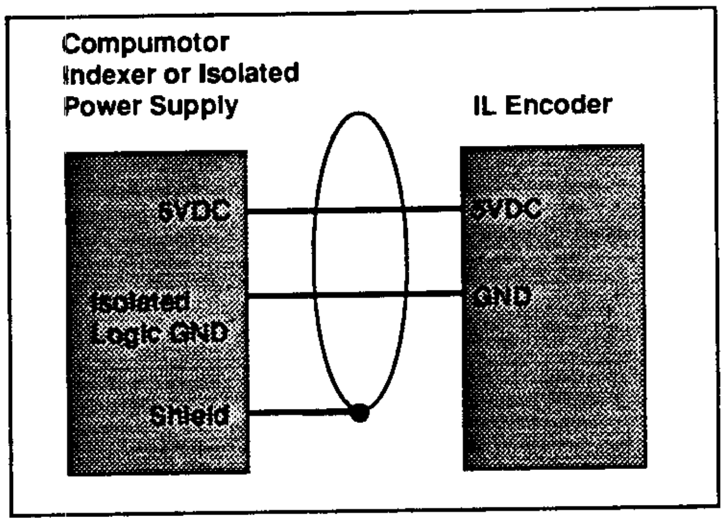

Figure 2-2. Wiring 5VDC Power Supply to the IL Encoder

4. If the encoder position report is negative or the motor does not stop (creeps) when in closed-loop mode, encoder channels A & B are reversed. You can correct this by switching encoder channel A+ with A-. *Be sure to turn the power off before reversing any wires.*

Power Supply

The power supply should be regulated +5VDC with a maximum voltage range of ±5% (4.75 - 5.25VDC). The maximum current requirement for the IL Encoder is 250 mA.

Cabling

The standard cable supplied with the IL is armored. The cable length is 10' for rack lengths up to 64", and 20' for rack lengths greater than 64".

The cable connection into the encoder head has a sealed connection; however, you should prevent fluid from flowing directly onto the connection. You can accomplish this by routing the cable down from the head. If this is not possible, loop the cable (refer to the *AL/IL Mounting Guide* for cable looping instructions).

Environment

The rack assembly has a wiper seal and end gaskets, which provide a barrier to protect the unit from the occasional splashing of fluid . *You should prevent direct fluid flow to ensure long product life.* You can prevent fluid flow by creating splash guards or by installing a mechanical device to re-route the fluid flow.

Always mount the rack assembly so the rack teeth are facing down. This allows the pinion movement on the rack to act as a wiper cleaning device. This will prevent contaminants from building up on the unit.

Mounting

Refer to the *AL/IL Linear Encoder Mounting Guide* for step-by-step procedures to mount this encoder onto your system.

Compatibility

This encoder is compatible with any device that accepts TTL-level quadrature incremental encoder signals. This means a low signal below 0.8VDC and a high signal above 2.4VDC. The indexer/control interface selected should also be able to count pulses at a rate corresponding to the speed and resolution that your application requires. The maximum pulse frequency is determined by the encoder's resolution and speed of travel. Compumotor products have a pre-quadrature input frequency capability of 50 kHz to 500 kHz, depending upon the product. Consult the product's user guide, or call Parker Compumotor if you have any questions about input frequency.

Chapter 3. HARDWARE REFERENCE

Specifications

Mechanical

Resolution	0.0005" (2,000 steps per inch) 0.0001" (10,000 steps per inch), 2.5 microns (10,160 steps per inch) *After quadrature resolution
Accuracy	±0.001" (25 microns) bidirectional Independent of length
Repeatability	±0.0001" (2.5 microns)
Hysteresis	±0.0001" (2.5 microns)
Starting Force	8.0 ozs. (225 gms.) This assumes preload of 1 - 2 lbs for pinion
Inertia	0.0003 oz-in^2 (0.5487 gm-cm)
Weight of Encoder Housing	6 ozs. (excluding the cable)
Rack Housing Material	Aluminum
Disk Material	Metal
Rack Material	#416 hardened & ground stainless steel
Maximum Speed	25.0 ips (50 rps for encoder disk)

Electrical

Input Power	+5VDC ±5 %, 250 mA Maximum required for the IL Encoder
Output Signal	Quadrature 2 phase square wave Channels A & B 90° out of phase TTL level with complimentary signals Channel Z pulse output twice per inch Sink up to 16 mA (without line driver)
Cable Length	10' for length less than 64" 20' for length greater than 64" Standard cable has armor

Environmental

Operating Temp.	32 to 140°F (0 to 60°C)
Storage Temp.	-22 to 185°F (-30 to 85°C)

Rack Length & Travel Specifications

Rack Length in (mm)	Usable Travel in (mm)	A in (mm)	B in (mm)
8 (203.2)	7.8 (198.1)	11 (279.4)	1.5 (38.1)
16 (406.4)	15.8 (401.3)	19 (482.6)	1.5 (38.1)
24 (609.6)	23.8 (604.5)	27 (685.8)	1.5 (38.1)
32 (812.8)	31.8 (807.7)	35 (889)	1.5 (38.1)
40 (1016)	39.8 (1010.9)	43 (1092.2)	1.5 (38.1)
48 (1219.2)	47.8 (1214.1)	51 (1295.4)	1.5 (38.1)
64 (1625.6)	60.8 (1544.3)	63.96 (1624.6)	3.98 (101.1)
80 (2032)	76.8 (1950.7)	79.96 (2031)	3.98 (101.1)
96 (2438.4)	92.8 (2357.1)	95.86 (2437.4)	3.98 (101.1)
112 (844.8)	108.8 (2763.5)	111.96 (2843.8)	3.98 (101.1)
128 (3521.2)	124.8 (3169.9)	127.96 (3250.2)	3.98 (101.1)
144 (3657.6)	140.8 (3576.3)	143.96 (3656.6)	3.98 (101.1)

Table 3-1. Rack Length & Travel Specifications

Refer to Figure 3-1 on the following page (IL Encoder Dimensions) for the location of the variable dimensions listed in columns A and B of Table 3-1.

Pin-Outs

25-Pin D Connector		Color Code
Pin #	Function	
1	PHASE A+	BLUE (1)
2	PHASE A-	BLACK (1)
3	PHASE B+	GREEN(2)
4	PHASE B-	BLACK (2)
5	PHASE Z+	WHITE (3)
6	PHASE Z-	BLACK (3)
8	SHIELD	DRAIN WIRE
14	GND	BLACK (4)
20	GND	Jumpered to pin 14
23	+5VDC	RED (4)

Table 3-2. Pin Outs

NOTE: There are four twisted pairs that make up this cable [(1), (2), (3), and (4)].

If the encoder position report is negative or the motor does not stop (creeps) when in closed-loop mode, encoder channels A & B are reversed. You can correct this by switching encoder channel A+ with A-. *Be sure to turn the power off before reversing any wires.*

Dimensions

Figure 3-1 contains IL Encoder dimensions. *Refer to columns A & B in Table 3-1 for the variable values associated with the dimensions indicated with A and B in Figure 3-1.*

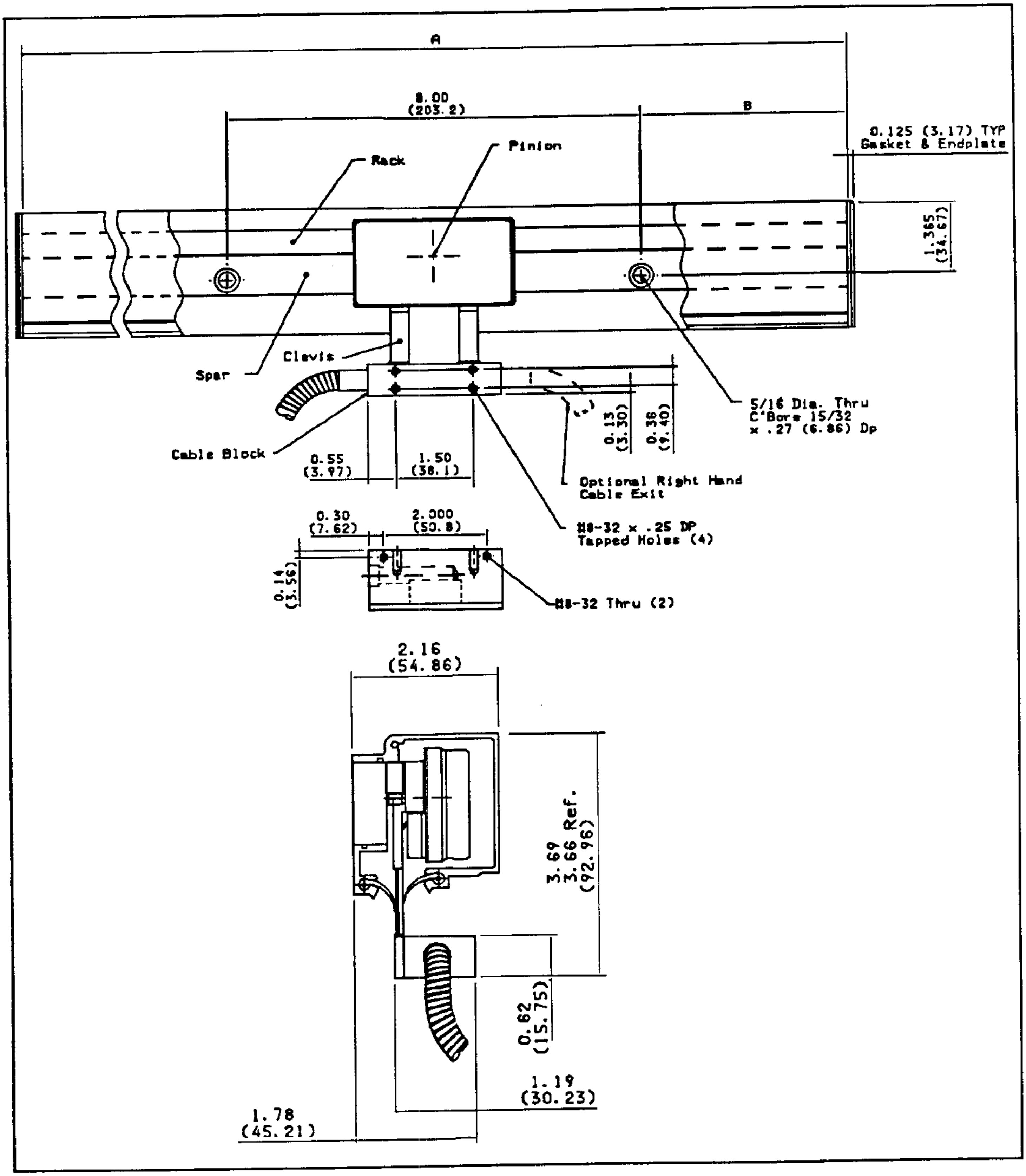

Figure 3-1. IL Dimensional Diagram

Appendices

Line Driver Option

The Line Driver interface board is an interface circuit designed to convert the TTL outputs of the Compumotor IL series and -E option incremental encoders to differential line driver signals. It is pin-for-pin compatible with these encoders and no modification is required.

Line drivers are used in conjunction with line receivers. If the receiving device has an input impedance of 1kΩ, then a line driver interface is required to enable the encoder signal to drive the input. *Do not use line drivers for single-ended operation.*

Electrical Specifications

1. Power Requirement: +5VDC ±5%, @60mA.
2. Input Signal High Level Voltage: 2.0V.
3. Input Signal Low Level Voltage: 0.8V.
4. High Level Output Signal Current: -60mA.
5. Low Level Output Signal Current: 60mA.

Mechanical Specifications

1. Input Connector: DB25S, 25-pin socket D connector.
2. Output Connector: DB25P, 25-pin plug D connector.

Evironmental Specifications

1. Operating temperature range: 0°C - 60°C
2. Storage temperature range: -25°C to 85°C

Pin-Outs

Input	Function	Output
1	A Channel	1
NC	A Channel	2
3	B Channel	3
NC	B Channel	4
5	M Channel	5
NC	M Channel	6
8	Shield	8
14 & 20	Ground	14 & 20
23	Power	23

Table A-1. Line Driver Pin-Outs

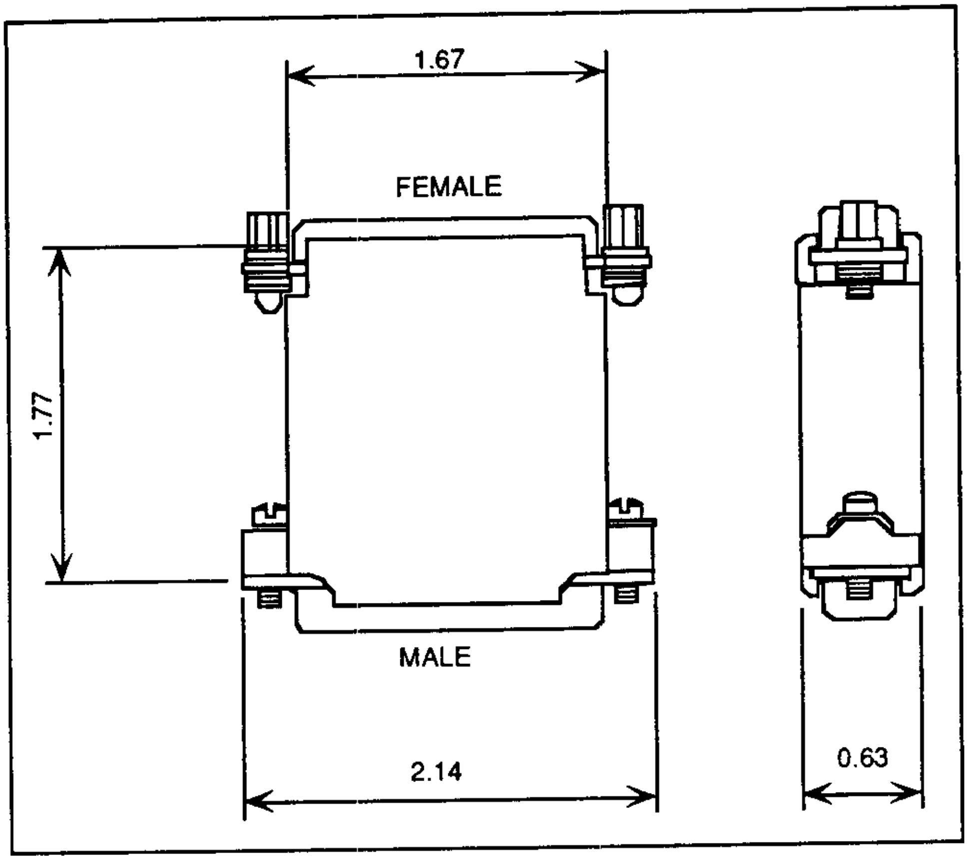

Figure A-1. Line Driver Dimensions

Glossary

Absolute Positioning
A positioning coordinate reference wherein all positions are specified relative to some reference, or "home" position. This is different from incremental programming, where distances are specified relative to the current position.

Absolute Programming
Refers to a motion control system employing position feedback devices (absolute encoders) to maintain a given mechanical location.

Acceleration
The change in velocity as a function of time. Acceleration usually refers to increasing velocity and deceleration describes decreasing velocity.

Accuracy
A measure of the difference between expected position and actual position of a motor or mechanical system. Motor accuracy is usually specified as an angle representing the maximum deviation from expected position.

Address
Multiple devices, each with a separate address or unit number, can be controlled on the same bus. The address allows the host to communicate individually to each device.

Ambient Temperature
The temperature of the cooling medium, usually air, immediately surrounding the motor or another device.

ASCII
American Standard Code for Information Interchange. This code assigns a number to each numeral and letter of the alphabet. In this manner, information can be transmitted between machines as a series of binary numbers.

Baud Rate
The number of bits transmitted per second. Typical rates include 300, 600,1200, 2400, 4800, 9600, 19,200. This means at 9600 baud, one character (-10 bits) can be sent nearly every millisecond.

BCD
Binary Coded Decimal is an encoding technique used to describe the numbers 0 through 9 with four digital (on or off) signal lines. Popular in machine tool equipment.

Bit
Abbreviation of Binary Digit, the smallest unit of memory equal to 1 or 0.

Block Diagram
A simplified schematic representing components and signal flow through a system.

Byte
A group of 8 bits treated as a whole, with 256 possible combinations of ones and zeros, each combination representing a unique piece of information. Characters are stored as bytes.

Closed Loop
A broadly applied term relating to any system where the output is measured and compared to the input. The output is then adjusted to reach the desired condition. In motion control, the term is used to describe a system wherein a velocity or position (or both) transducer is used to generate correction signals by comparison to desired parameters.

Daisy-Chain
A term used to describe the linking of several RS-232C devices in sequence such that a single data stream flows through one device and on to the next. Daisy-chained devices usually are distinguished by device addresses, which serve to indicate the desired destination for data in the stream.

Data Bits
Since the ASCII character set consists of 128 characters, computers may transmit only seven bits of data. However, most computers support an eight bit extended ASCII character set.

DCE
Data Communications Equipment transmits on pin three and receives on pin two of a 25 pin D connector.

Dead Band
A range of input signals (steps) for which there is no system response or correction.

Detent Torque
The minimal torque present in an un-energized motor. The detent torque of a Compumotor or step motor is typically about one percent of its static energized torque.

DTE
Data Communications Equipment transmits characters on pin two and receives on pin three of a 25-pin D connector.

Duty Cycle
For a repetitive cycle, the ratio of on time to total cycle time.
Duty Cycle = On Time +
(On Time + Off Time)

Efficiency
The ratio of power output to power input.

Encoder
A device which translates mechanical motion into electronic signals used for monitoring position or velocity.

Friction
A resistance to motion caused by surfaces rubbing together. Friction can be constant with varying speed (Coulomb friction) or proportional to speed (viscous friction).

Full Duplex
The terminal will display only received or echoed characters.

Half Duplex
In half duplex mode, a terminal will display every character transmitted. It may also display the received character, resulting in double character displays.

Hand Shaking Signals
RST: Request To Send
CTS: Clear To Send
DSR: Data Set Ready
DTR: Data Terminal Ready
IDB: Input Data Buffer
ODB: Output Data Buffer

Holding Torque
Sometimes called static torque, it specifies the maximum external force or torque that can be applied to a stopped, energized motor without causing the rotor to rotate continuously.

Home
A reference position in a motion control system, usually derived from a mechanical datum. Often designated as the "zero" position.

Hysteresis
The difference in response of a system to an increasing or a decreasing input signal.

IEEE-488
A digital data communications standard popular in instrumentation electronics. This parallel interface is also known as GPIB, or General Purpose Interface Bus.

Incremental Motion
A motion control term that is used to describe a device that produces one step of motion for each step command (usually a pulse) received.

Incremental Programming
A coordinated system where position or distances are specified relative to the current position.

Inertia
A measure of an object's resistance to a change in velocity. The larger an object's inertia, the larger the torque that is required to accelerate or decelerate it. Inertia is a function of an object's mass and its shape.

Inertial Match
For most efficient operation, the system coupling ratio should be selected so that the reflected inertia of the load is equal to the rotor inertia of the motor.

Limits
Properly designed motion control systems have sensors called limits that alert the control electronics that the physical end of travel is being approached and that motion should stop.

Logic Ground
An electrical potential to which all control signals in a particular system are referenced.

Microstepping
An electronic control technique that proportions the current in a step motor's windings to provide additional intermediate positions between poles. Produces smooth rotation over a wide speed range and high positional resolution.

Null Modem
A simple device or set of connectors which switches the receive and transmit lines of a three wire RS-232C connector.

Open Collector
A term used to describe a signal output that is performed with a transistor. An open collector output acts like a switch closure with one end of the switch at ground potential and the other end of the switch accessible.

Open Loop
Refers to a motion control system where no external sensors are used to provide position or velocity correction signals.

Opto-Isolated
A method of sending a signal from one piece of equipment to another without the usual requirement of common ground potentials. The signal is transmitted optically with a light source (usually a Light Emitting Diode) and a light sensor (usually a photosensitive transistor). These optical components provide electrical isolation.

Parallel
Refers to a data communication format wherein many signal lines are used to communicate more than one piece of data at the same time.

Parity
An RS-232C error detection scheme which can detect an odd number of transmission errors.

Pulse Rate
The frequency of the step pulses applied to a motor driver. The pulse rate multiplied by the resolution of the motor/drive combination (in steps per revolution) yields the rotational speed in revolutions per second.

Ramping
The acceleration and deceleration of a motor. May also refer to the change in frequency of the applied step pulse train.

Rated Torque
The torque producing capacity of a motor at a given speed. This is the maximum torque the motor can deliver to a load and is usually specified with a torque/speed curve.

Relative Accuracy
Also referred to as "Step to Step Accuracy," this specification tells how microsteps can change in size. In a perfect system, microsteps would all be exactly the same size, but drive characteristics and the absolute accuracy of the motor cause the steps to expand and contract by an amount up to the relative accuracy figure. The error in not cumulative.

Repeatability
The degree to which the positioning accuracy for a given move performed repetitively can be duplicated.

Resolution
The smallest positioning increment that can be achieved. Frequently defined as the number of steps required for a motor's shaft to rotate one complete revolution.

Ringing
Oscillation of a system following a sudden change in state.

RS-232C
A data communications standard that encodes a string of information on a single line in a time sequential format. The standard specifies the proper voltage and timing requirements so that different manufacturers' devices are compatible.

Slew
In motion control, the portion of a move made at a constant non-zero velocity.

Speed
Used to describe the linear or rotational velocity of a motor or other object in motion.

Start Bits
RS-232C character transmissions begin with a bit which signals the receiver that data is now being transmitted.

Static Torque
The maximum torque available at zero speed.

Step Angle
The angle the shaft rotates upon receipt of a single step command.

Stiffness
The ability to resist movement induced by an applied torque. Is often specified as a torque displacement curve, indicating the amount a motor shaft will rotate upon application of a known external force when stopped.

Stop Bits
When using RS-232C, one or two bits are added to every character to signal the end of a character.

Synchronism
A motor rotating at a speed correctly corresponding to the applied step pulse frequency is said to be in synchronism. Load torques in excess of the motor's capacity (rated torque) will cause a loss of synchronism. This condition is not damaging to a step motor.

Text/Echo (Off/On)
This setup allows received characters to be re-transmitted back to the original sending device. Echoing characters can be used to verify or "close the loop" on a transmission.

Torque
Force tending to produce rotation.

Torque-to Inertia Ratio
Defined as a motor's holding torque divided by the inertia of its rotor. The higher the ratio, the higher a motor's maximum acceleration capability will be.

TTL
Transistor-Transistor Logic. Describes a common digital logic device family that is used in most modern digital electronics. TTL signals have two distinct states that are described with a voltage—a logical "zero" or "low" is represented by a voltage of less than 0.8 volts and a logical "one" or "high" is represented by a voltage from 2.5 to 5 volts.

XON/XOFF
Two ASCII characters supported in some serial communication programs. If supported, the receiving device transmits an XOFF character to the host when its character buffer is full. The XOFF character directs the host to stop transmitting characters to the device. Once the buffer empties the device will transmit an XON character to signal the host to resume transmission.

Index