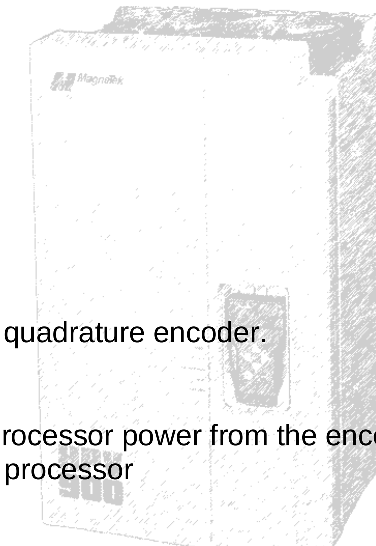
HPV 900
Encoder Applications Tips



The HPV 900 has connections for an incremental two-channel quadrature encoder.

- For better noise immunity, the HPV 900 provides…
  - an isolated power supply, which separates the microprocessor power from the encoder
  - optically isolated encoder signals from the HPV 900's processor
- The HPV 900 encoder feedback requirements are:

Supply Voltage:	12VDC or 5VDC	PPR:	600 - 10,000 cycles/revolution
Capacity:	200mA or 150mA	Maximum Frequency:	300 kHz
Input:	2 channel quadrature	5 or 12 volts dc differential	(A, /A, B, /B)

Proper encoder speed feedback is essential for a drive to provide proper motor control.

Electrical interference and mechanical speed modulations are common problems that can result in improper speed feedback getting to the drive. To help avoid these common problems, the following is suggested...

Electrical Considerations:

- Do not use encoder designs with capacitors from internal electronics to case. *(page 2)*
- Use limited slew rate differential line drivers. *(page 3)*
- If possible, insulate both the encoder case and shaft from the motor. *(page 3)*
- Use twisted pair cable with shield tied to chassis ground at drive end. *(page 4)*
- Do not exceed the operating specification of the encoder/drive. *(page 5)*
- Use the proper encoder supply voltage and use the highest possible voltage available. *(page 6)*
  (i.e. HPV 900 - 12VDC preferred)

Mechanical Considerations:

- Use direct motor mounting without couplings. *(page 6)*
- Use hub or hollow shaft encoder with concentric motor stub shaft. *(page 7)*
- If possible, use a mechanical protective cover for exposed encoders. *(page 7)*

Reviewed Encoders:

- Hollow-shaft *(page 8)*
  - Dynapar – HS35-1024-844B7-09
  - BEI – HS35F-62-R2-SS-1024-ABC-7272-SM18
- Hub-shaft *(page 8)*
  - Dynapar – H23-1024-0225D5-38
  - BEI – H20EA-62HBS-F28-SS-1024-ABC-7272-SM18-24V

Note: The specific encoders listed as 'reviewed' were selected as examples of devices available that have desirable features. For a partial list of encoder manufacturers, see page 9.

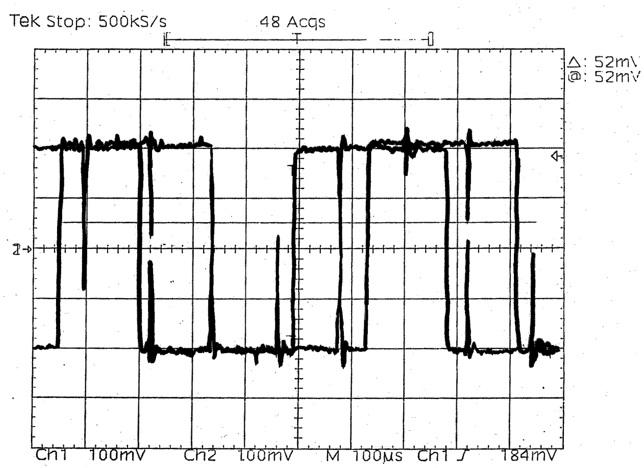
Do not use encoder designs with capacitors from internal electronics to case…
to minimize ground current noise injection and minimize the coupling of high frequency noise.

Encoders are sometimes supplied with an internal capacitor from circuit common to case ground to drain electrical noise from common to building ground. However, PWM drives have extremely high frequency noise that is coupled to the frame and shaft of the motor. A capacitor placed between the encoder case and the encoder electronics will couple this noise into the encoder, where it can interfere with normal operation.

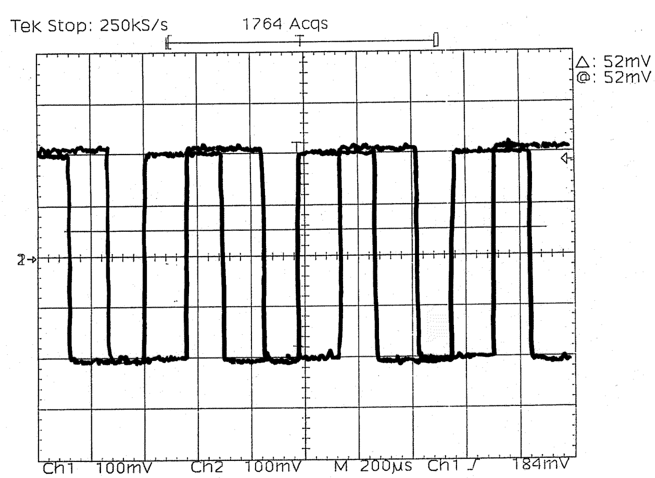
The result is intermittent rough operation, motor reversal or no operation at all. The presumption is that there is a drive or encoder problem. An improvement is to remove any internal encoder capacitors between electrical common and the case.

The above analysis assumes that the electrical wiring is correct and that the shield on the encoder cable is properly grounded. *(see page 4)*

The scope traces below show a noise comparison of output signals from similar encoders with and without internal capacitors, both connected to a motor with typical PWM switching noise on the frame.



Encoder with a capacitor
(common to ground)



Encoder with no capacitor
(common to ground)

Use limited slew rate differential line drivers …
to minimize transmission line reflections use type 7272 drivers.

Encoder's line drivers transition from logic states in a fraction of a microsecond. The fast rise and fall times of the driver's circuitry can interact with the cable impedance and create significant ringing on the receiver end of the cable. This can interfere with the encoder signals and the operation of the drive. To reduce the ringing, it is recommended that the encoder use type 7272 line drivers, which have slower rise and fall times.

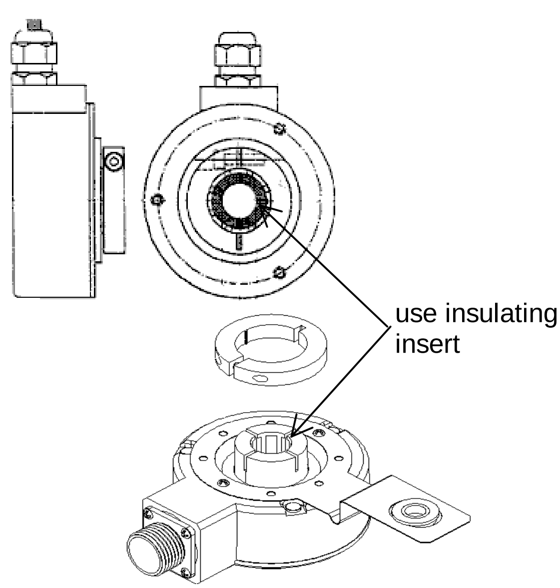
Also to improve performance, line driver outputs should use differential pairs of complementary outputs, each paired with its inverse. This allows the signal to be used with a differential line receiver, which improves the noise margin, cancels common-mode noise and helps to reject ringing from the cable.

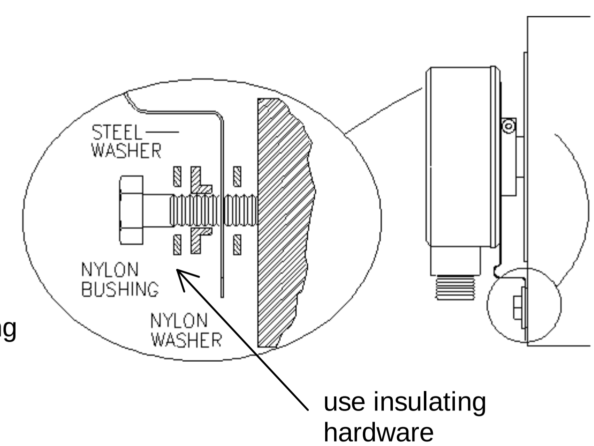
If possible, insulate both the encoder case and shaft from the motor …
to minimize encoder bearing currents and ground noise.

There will be PWM electrical noise on the motor shaft that will take the easiest path to ground. If the encoder is not electrically isolated from the motor, this path could be through the encoder bearings and/or electronics. Encoder bearing current will reduce the life of the bearings and create additional ground noise. The solution would be to electrically isolate both the encoder shaft and case from the motor.

Insulating the encoder case from the motor also reduces ground current coupling from the motor frame to the internal electronics of the encoder. Ground noise from the motor frame can disturb the operation of the encoder and propagate down the connected cable to disturb the transmission of the encoder signals. (i.e. there can be coupling from the case to the internal electronics even though a discrete capacitor is not present)

Below is shown how to insulate a hollow-shaft encoder from the motor.
(similar mounting hardware and insulating insert can be used for hub-shaft encoders)





Use twisted pair cable with shield tied to chassis ground at drive end…

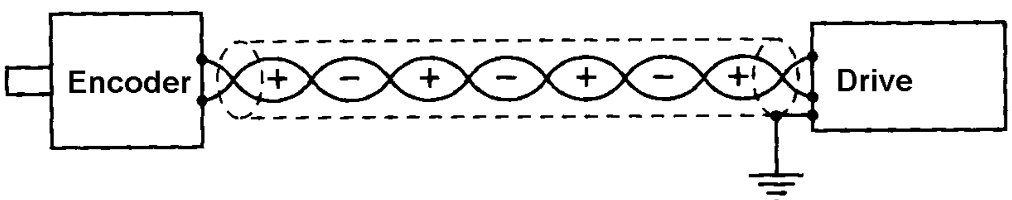
to minimize magnetic and electrostatic pick-up current and
to minimize radiated and conducted noise

Reasonable care must be taken when connecting and routing power and signal wiring. Radiated noise from nearby relays (relay coils should have R/C suppressors), transformers, other electronic drives, etc. may be induced into the signal lines causing undesired signal pulses.

Power leads and signal lines must be routed separately. Signal lines should be shielded, twisted and routed in separate conduits or harnesses spaced at least 12 inches apart from power wiring. This protects the cable from physical damage while providing a degree of electrical isolation. Also, do not run cable in close proximity to other conductors which carry current to heavy loads such as motors, motor starters, contactors, or solenoids. Doing so could result in electrical transients in the encoder cable, which can cause undesired signal pulses. Power leads are defined as the transformer primary and secondary leads, motor leads and any 120 VAC or above control wiring for relays, fans, thermal protectors, etc.

Continuity of wires and shields should be maintained from the encoder through to the controller avoiding the use of terminals in a junction box. The shield and shield drain wires must be insulated from other objects. This helps to minimize radiated & induced noise problems and magnetically induced ground loops.

Always use an encoder with complementary output signals. Connect with twisted-pair shielded wire so that wire-induced currents will self-cancel, as shown below.



NOTE: DO NOT ground the encoder through both the machine and the cable wiring. Connect the shield at the receiver device only. If the shield is connected at both ends, noise currents will flow through the shield and degraded performance will result.

Do not exceed the operating specification of the encoder/drive…

to prevent the encoder from providing incorrect data

All encoders have inherent mechanical and electronic limitations regarding speed. The combination of several design factors including bearings, frequency response of the electronics, and PPR of the encoder, etc. combine to determine "maximum operating speed". Exceeding the maximum speed may result in incorrect data or premature failure. Both the electrical and mechanical encoder specifications can be provided by the encoder manufacturer.

<u>To determine the encoder's maximum operating speed:</u>

Step 1: Determine maximum electronic operating speed in RPM.

$$RPM = \frac{Encoder\ freq.\ response\ (kHz)\ x\ 60}{Encoder\ PPR}$$

Step 2:

A. If the RPM calculated in Step 1 is less than or equal to the encoder's maximum mechanical RPM specification, then the RPM calculated in Step 1 is the maximum operating speed specification for this particular encoder application.
B. If the RPM calculated in Step 1 is greater than the encoder's maximum mechanical RPM specification, then the maximum mechanical RPM specification is the maximum operating speed for this encoder application.

Step 3:

Compare the maximum operating speed as determined in Step 2 above with the application requirements.

<u>To determine if the application exceeds the operating specification of the HPV 900:</u>

- Calculate the maximum pulses per revolution (PPR) for this application (using the HPV 900 frequency limit of 300 kHz and 120% of the application’s top speed)

$$PPR_{max} = \frac{300{,}000\ Hz\ x\ 60}{max\ application\ RPM\ \times 1.2}$$

- Verify that the selected encoder’s PPR is below the calculated maximum PPR (PPR_{max}) for this application

Use the proper encoder supply voltage and use the highest possible voltage available…

to ensure proper operation and increase noise immunity

Ensure that the voltage drop of the encoder wiring is such that the minimum power supply voltage for operating the encoder is not violated. (i.e. 5VDC ±5% power supply and 5VDC ±10% encoder specification is violated when the encoder draws 0.3 A and it is wired with 500 ft at 22 AWG)

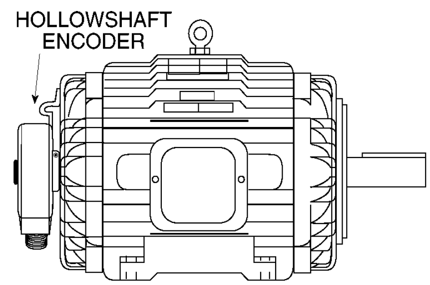
- Use an encoder with an internal supply regulator
- Use a wide supply range encoder (i.e. 5 – 15 VDC)

It is also preferred that the encoder be powered by the HPV 900's 12VDC power supply in order to help with noise immunity by having the signals at a higher voltage level.

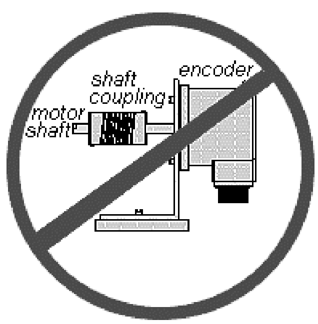
Use direct motor mounting without couplings…

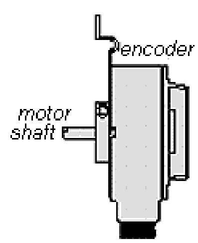
to avoid eccentricities and to provide for zero backlash

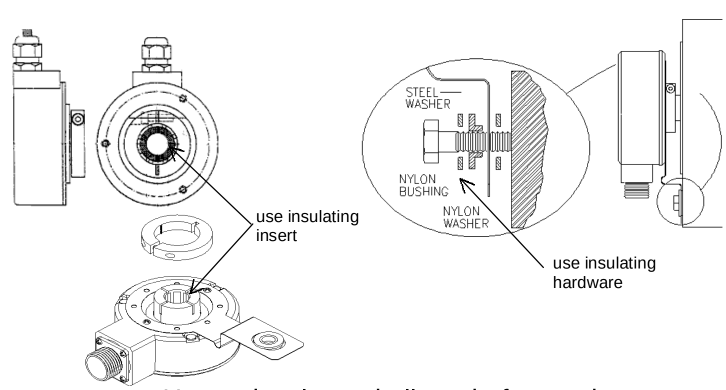
Direct mounted encoders do not have shafts and are mounted directly onto the motor shaft. Examples include hub-shaft or hollow-shaft models with integral flexible mounts. These is no separate shaft to shaft coupling. In addition, there may be no need for mounting brackets or adapters.



HUB SHAFT OR HOLLOWSHAFT MOUNT



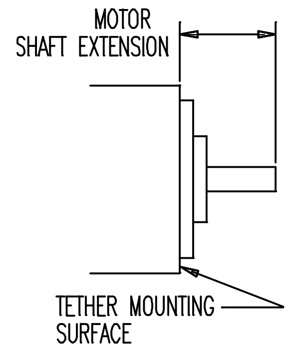




How to insulate a hollow-shaft encoder *(from page 3)*

Use hub or hollow shaft encoder with concentric motor stub shaft…

using a flexible encoder mount rather than a flexible shaft coupling



It is preferred that a solid shaft extension is specified from the motor manufacturer for a length recommended by the encoder manufacturer.

Although it is not the preferred method, installations that employ a screwed on sub shaft adapter should:

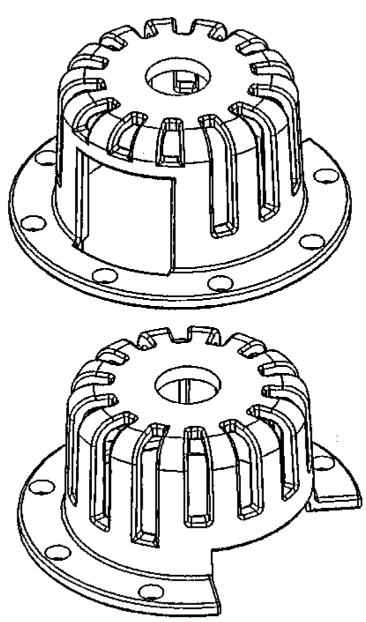
- use the original hole used to machine the motor shaft
- use locktight to hold the thread in position
- align the stub shaft to 0.002 inches TIR or less with a dial indicator.

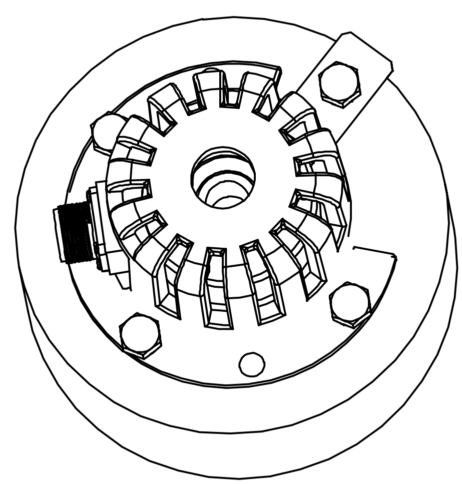
A hub-shaft or hollow-shaft encoder should be mounted so that its shaft receptacle is in as close as possible alignment with the axis of the motor shaft. Clamp or set screws should then be tightened to secure the encoder. REMEMBER: If you are following the preferred method of insulating the encoder from the motor, install the proper insulating hardware. NOTE: Do not defeat or restrict the flexure. This causes failure of the encoder or driving shaft bearings.

If possible, use a mechanical protective cover for exposed encoders …

protect the encoders from mechanical damage

Encoders are vulnerable to mechanical damage from impact. Encoders can be damaged by impact during installation or during exposed operation. Motors are even sometimes lifted by the encoders on one end. Therefore, it is preferred that the encoder be protected by a cover as shown below.





Reviewed Encoders…

<u>Hollow-Shaft</u>

- Hollow-Shaft design eliminates mounting bracket, flexible shaft coupling and installation labor
- Direct shaft mount eliminates shaft alignment procedures

- Dynapar – HS35-1024-844B7-09 *(reviewed model)*
  (Series HS35)
    - supply voltage: 5 to 26 VDC
    - pulses per revolution: 1 to 2500
    - no internal capacitors to case
    - internal supply regulator
    - type 7272 line driver
    - mechanical cover option
    - electrically insulated, if insulating hardware is installed properly

- BEI - HS35F-62-R2-SS-1024-ABC-7272-SM18 *(reviewed model)*
  (Model HS35)
    - supply voltage: 5V to 24V
    - pulses per revolution: 250 to 5000
    - no internal capacitors to case
    - type 7272 line driver
    - internal supply regulator (w/ 7272)
    - electrically insulated,
      (for shaft diameters <1 inch), if insulating hardware is installed properly

<u>Hub-Shaft</u>

- Simple installation on motor with hub-shaft and flexible spring mount

- Dynapar – HS23-1024-0225D5-38 *(reviewed model)*
  (Series HS20)
    - supply voltage: 5 to 26 VDC
    - pulses per revolution: 1 to 2540
    - no internal capacitors to case
    - internal supply regulator
    - type 7272 line driver
    - mechanical cover option

- BEI – H20EA-62HBS-F28-SS-1024-ABC-7272-SM18-24V *(reviewed model)*
  (Model H20)
    - supply voltage: 5V to 24V
    - pulses per revolution: 2 to 1024
    - no internal capacitors to case
    - type 7272 line driver
    - internal supply regulator (w/ 7272)
    - electrically insulated,
      if specified when ordered and insulating hardware is installed properly

Encoder Manufacturers...

The purpose of this document is to make users aware of potential issues associated with the use of encoders with AC motor drives and to encourage a design selection process by the user that will result in a successful installation. Resolutions of several important issues are given in the form of recommended practices.

The specific encoders listed as 'reviewed' were selected as examples of devices available that have desirable features. Other manufacturers have similar products that are also well suited for use with the HPV 900.

A partial list of manufacturers is given below. Contact them directly to inquire about their specific products and how to order an encoder with the desirable features recommended in this document to suit your particular installation.

Greenbank Machinery & Plant Ltd. Woodruffe Works, 5B Charles Street, Dukinfield, Cheshire, England. SK16 4SG Tel: 0161 308 2138 / 3716 Fax: 0161 343 1901 www.tachogenerators.co.uk/encoders.html	**GES / Industrial Encoder Corporation** 7-320 Vansickle Road St. Catharines, Ontario L2R 6P7 Toll Free: 888-277-6205 (N. America Only) Tel: 905-984-3256 Fax: 905-984-5017 www.gesgroup.org
Heidenhain Corporation 333 State parkway Schaumburg, IL 60173-5337 Tel.: 847-490-11 91 Fax.: 847-490-39 31 www.heidenhain.com	**Danaher Controls (Dynapar)** 1675 Delany Road Gurnee, IL 60031 Toll free (US & Canada): 800-234-8731 Other than US & Canada: 847-662-2666 www.dancon.com
Encoder Products Company 1601B Dover Road – Highway 2 P.O. Box 1548 Sandpoint, Idaho 83864-0879 Tel: 800-366-5412 Fax: 208-263-0541 www.encoderproducts.com	**BEI Technologies, Inc.** Industrial Encoder Division 7230 Hollister Avenue Goleta, CA 93117 Tel: 805-968-0782 Fax: 805-968-3154 www.bei-tech.com