

CHAPTER TWO

# Installation

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## IN THIS CHAPTER

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- Product Ship Kit List
  - Installation Procedure
  - Tuning
-

# What You Should Have (*ship kit*)

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If you ordered a TQ10 or TQ10SD, you should have

| <b>Part</b>                                            | <b>Part Number</b> |
|--------------------------------------------------------|--------------------|
| TQ10 Drive                                             | TQ10 or TQ10SD     |
| includes 10-pin plug (two with TQ10, four with TQ10SD) | 43-013891-01       |
| includes 7-pin plug (one included)                     | 43-013575-01       |
| Power Cable – 6 feet (1.8 m) in length                 | 44-000054-01       |
| Thermally Conductive Strip                             | 58-014871-01       |
| TQ10/TQ10SD Servo Drive User Guide                     | 88-015115-02       |

### **Accessories**

|                                        |         |
|----------------------------------------|---------|
| External Heatsink/Fan Unit             | TQ-HS3  |
| Top & Bottom Covers (to enclose drive) | TQ-ENCL |

NOTE: If you ordered a TQ10-EHS or a TQ10SD-EHS, the External Fan/Heatsink Unit and the Top & Bottom Covers are installed at the factory.

## **SM Motor Information**

| <b>SM with<br/>500 Line Encoder</b> | <b>SM with<br/>1000 Line Encoder</b> | <b>SM Motor Cables</b> |
|-------------------------------------|--------------------------------------|------------------------|
| SM161AD-N10N                        | SM161AE-N10N                         | 23TQ Cable-10          |
| SM162AD-N10N                        | SM162AE-N10N                         | (1 set/10' cables)     |
| SM161AD-NTQN                        | SM161AE-NTQN                         | 23TQ Cable-25          |
| SM162AD-NTQN                        | SM162AE-NTQN                         | (1 set/25' cables)     |
| SM231AD-NTQN                        | SM231AE-NTQN                         | Above cables are for   |
| SM232AD-NTQN                        | SM232AE-NTQN                         | Size 16 and 23 motors  |
| SM232BD-NTQN                        | SM232BE-NTQN                         |                        |
| SM233AD-NTQN                        | SM233AE-NTQN                         |                        |
| SM233BD-NTQN                        | SM233BE-NTQN                         |                        |

## **NeoMetric Motor Information**

| <b>NeoMetric with<br/>500 Line Encoder</b> | <b>NeoMetric with<br/>1000 Line Encoder</b> | <b>NeoMetric<br/>Motor Cables</b> |
|--------------------------------------------|---------------------------------------------|-----------------------------------|
| N0701DD-NTQN                               | N0701DE-NTQN                                | 70TQ Cable-10                     |
| N0701FD-NTQN                               | N0701FE-NTQN                                | (1 set/10' cables)                |
| N0702ED-NTQN                               | N0702EE-NTQN                                | 70TQ Cable-25                     |
| N0702FD-NTQN                               | N0702FE-NTQN                                | (1 set/25' cables)                |
| N0703FD-NTQN                               | N0703FE-NTQN                                | 92MS Cable-10                     |
| N0703GD-NTQN                               | N0703GE-NTQN                                | (1 set/10' cables)                |
| N0704FD-NTQN                               | N0704FE-NTQN                                | 92MS Cable-25                     |
| N0704GD-NTQN                               | N0704GE-NTQN                                | (1 set/25' cables)                |
|                                            | N0921FE-NMSN                                |                                   |
|                                            | N0921GE-NMSN                                |                                   |
|                                            | N0922GE-NMSN                                |                                   |

## **Precautions**

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The TQ10 Drive has an open-frame style of construction. The top and bottom of the sheet metal enclosure is open, and internal components are exposed. Hazardous voltages are present inside the drive and on many of its terminals. Therefore, observe the following precautions:

- Do not reach inside the drive
- Do not probe inside the drive
- Do not touch the drive's motor terminals while power is applied to the drive
- Do not touch **MOTOR TEMP+** or **MOTOR TEMP-** while power is applied to the drive
- Configure the drive's DIP switches for your application before you apply power to the drive
- Covers are available if desired

# Installation Overview

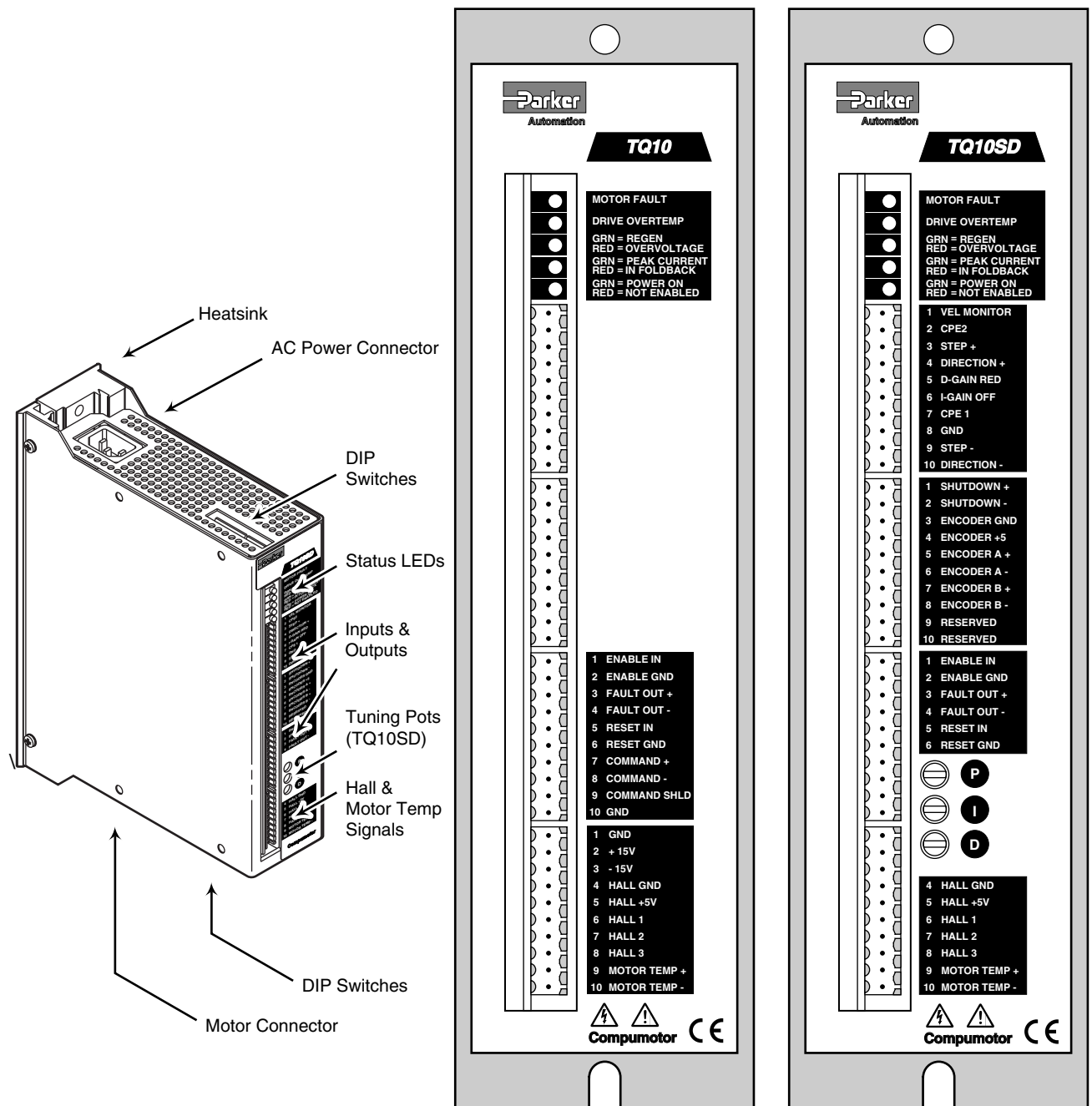
The order of topics in the installation procedure is:

- Quick Test
- DIP Switch Configuration
- Drive Mounting & Heatsinking
- Motor Mounting
- Connecting the Motor to the Drive
- Connecting a Controller
- Connecting AC Power
- Testing the System Installation
- Connecting the Motor to the Load
- Tuning

# Installation Procedure

Topics in this chapter are arranged to lead you through the installation process in a step-by-step manner. Complete each step before proceeding to the next.

The next drawing shows locations and names of the various connectors, switches, and components that you will encounter during the installation procedure.



TQ10 Torque Servo Drive

TQ10SD Step & Direction Servo Drive

TQ10 & TQ10SD – Component Locations

## Quick Test

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The following installation procedure leads you through steps to permanently install your drive. However, if you wish to familiarize yourself with the drive before you install it, you can perform a bench top *quick test*. To do so, complete the following sections, in the order given below:

- Set configuration DIP switches (on top of drive). For bench top operation, set peak current at or below the motor's continuous current rating.
- Set compensation DIP switches (on bottom of drive)
- Connect a Controller (TQ10) or Indexer (TQ10SD)
  - TQ10 Torque Drive – Connect Command Input signals
  - TQ10SD Step & Direction Drive – Connect Step and Direction Inputs
- Connect the Motor to the Drive
- Connect AC Power
- Test your system

During your permanent installation, complete the other sections in this chapter—drive and motor mounting, connecting the load, and tuning.

## Installation

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The following procedures will lead you through the steps required to permanently install your TQ10 Drive and motor.

### 1. Set DIP Switches (Top of Drive)

Configure the TQ10 Drive's DIP switches for your motor and application. Two 6-position DIP switches—Switch 1 (SW1) and Switch 2 (SW2)—are located on top of the drive. The table below summarizes their settings. A 3-position DIP switch—Switch 3 (SW3)—is located on the bottom of the drive. See the section after this for instructions on setting SW3.

#### Default Settings

The factory default position is *off* for all switches. You must set these switches appropriately for your application.

#### Peak Current

Set DIP switches SW1-#1 — SW1-#3 for the *peak current* that you want your drive to produce. If you use a high performance motor (peak current rating greater than three times the continuous current rating), such as Compumotor's SM Series servo motors, see the caution note below.

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#### CAUTION

**Peak current settings for initial drive tuning with SM and NeoMetric Motors:** Set peak current at twice the motor's continuous rated current, or less. Otherwise, motor damage due to excessive heating may result from high peak currents and improper tuning values. See *Tuning* in this chapter for a procedure to iteratively raise peak current during tuning.

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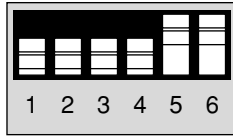
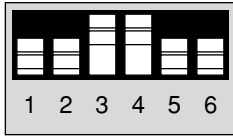
#### Time at Peak Current

Set DIP switches SW1-#4 — SW1-#6 to control the length of time the drive can produce peak current, before it goes into current foldback.

# TQ10 DIP SWITCH SETTINGS

off ↑ 1 SW 1 6 1 SW 2 6 ↑ off

Shown Configured for SM161A Motor\* →



## PEAK CURRENT

| (amps) | 1   | 2   | 3   |
|--------|-----|-----|-----|
| 0      | off | off | off |
| 1.5    | on  | off | off |
| 3.0    | off | on  | off |
| 4.4    | on  | on  | off |
| 6.0    | off | off | on  |
| 7.4    | on  | off | on  |
| 8.9    | off | on  | on  |
| 10.0   | on  | on  | on  |

## TIME AT PEAK

| (seconds) | 4   | 5   | 6   |
|-----------|-----|-----|-----|
| 1.0       | on  | on  | on  |
| 1.2       | on  | on  | off |
| 1.4       | on  | off | on  |
| 1.6       | on  | off | off |
| 3.3       | off | on  | on  |
| 5.0       | off | on  | off |
| 10.0      | off | off | on  |

| 4   | 5   | 6   | setting number |
|-----|-----|-----|----------------|
| off | off | off | 0              |
| on  | off | off | 1              |
| off | on  | off | 2              |
| on  | on  | off | 3              |
| off | off | on  | 4              |
| on  | off | on  | 5              |
| off | on  | on  | 6              |
| on  | on  | on  | 7              |

## LOOP GAIN

↑ Less Gain  
(use with lower inductance motors)  
↓ More Gain  
(use with higher inductance motors)

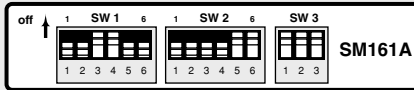
## FOLDBACK

|   |     |                   |
|---|-----|-------------------|
| 3 | off | Foldback Disabled |
|   | on  | Foldback Enabled  |
| 2 | off | High Threshold    |
|   | on  | Low Threshold     |

## FOLDBACK FAULT

|   |     |                      |
|---|-----|----------------------|
| 1 | on  | Fault on Foldback    |
|   | off | No Fault on Foldback |

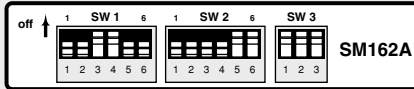
## DIP Switch Settings for Compumotor SM and NeoMetric Motors\* (with foldback enabled)



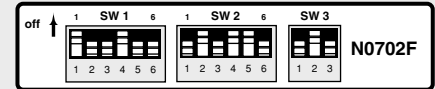
SM161A



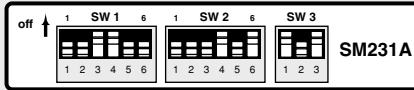
N0702E



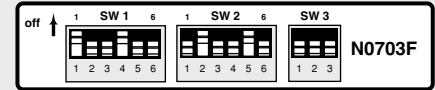
SM162A



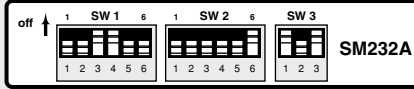
N0702F



SM231A



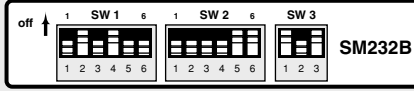
N0703F



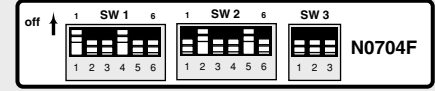
SM232A



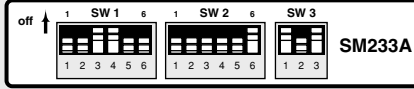
N0703G



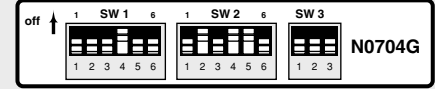
SM232B



N0704F



SM233A



N0704G



SM233B



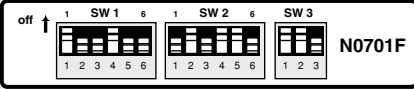
N0921F



N0701D



N0921G



N0701F



N0922G

\*Switches shown configured for initial tuning, with peak current approx. twice motor's continuous current rating. See Tuning for procedure to raise current. For SW 3 settings, see next page.

## Foldback Fault Enable

If DIP switch SW2-#1 is in the *off* position, the drive can go in and out of current foldback without affecting the fault output. If DIP switch SW2-#1 is in the *on* position, then going into foldback will cause a latched fault condition; this setting can aid in troubleshooting your system.

## Foldback Threshold

DIP switch SW2-2 sets the current threshold for the foldback circuit. This switch should be ON (low threshold) for “A” winding SM motors. It should be OFF (high threshold) for “B” winding motors, NeoMetric (70mm and 92mm) motors, and for most motors with continuous current ratings above 4 amps.

## Foldback Enable

DIP switch SW2-3 enables foldback. When this switch is ON (the default) foldback is enabled.

## Loop Gain

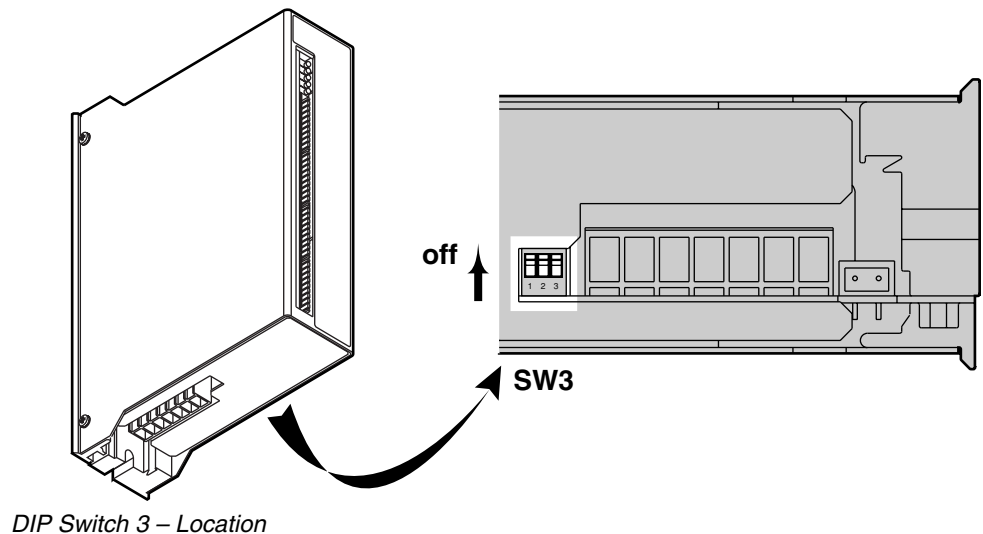
Set DIP switches SW2-#4 — SW2-#6 to control the gain of the drive’s internal current control loop. Properly setting this switch will match the drive to your motor’s parameters (inductance and resistance). The suggested settings provide wide current-loop bandwidth. In some applications, lower bandwidth may allow easier position-loop tuning. To reduce bandwidth, set the loop gain DIP switch for lower gain by one or two settings. **Do not set loop gain higher than the suggested setting.**

## DIP Switch Settings for SM and NeoMetric Motors

DIP switch settings for Compumotor SM and NeoMetric motors are shown on the previous page. If you use a non-Compumotor motor, see the *Appendix* at the end of this User Guide for information about setting DIP switches for your motor.

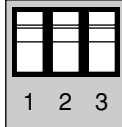
## 2. Set DIP Switches (Bottom of Drive)

Switch 3 (SW3) is a 3-position DIP switch located on the bottom of the drive, near the motor connector.



Set it to control the drive's motor pole compensation, based upon your motor's electrical time constant. The following table shows switch settings for Compumotor SM and NeoMetric Series servo motors.

TQ10 DIP SWITCH #3\*

off ↑ 

\*Located on Bottom of Drive

| MOTOR POLE COMPENSATION                                   | 1   | 2   | 3   |
|-----------------------------------------------------------|-----|-----|-----|
| SM161A, SM162A                                            | off | off | off |
| Reserved                                                  | on  | off | off |
| SM231A, SM232A+B, SM233A+B                                | off | on  | off |
| Reserved                                                  | on  | on  | off |
| N0701D, N0701F                                            | off | off | on  |
| N0702E, N0702F                                            | on  | off | on  |
| Reserved                                                  | off | on  | on  |
| N0703F, N0703G, N0704F,<br>N0704G, N0921F, N0921G, N0922G | on  | on  | on  |

If you use a non-Compumotor motor, see the *Appendix* at the end of this User Guide for information about setting DIP switches for your motor.

### Offset Potentiometer—Do Not Adjust

Located next to DIP SW3 is a small potentiometer that controls the drive's offset. It was adjusted at the factory, and requires no further adjustment.

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**WARNING**

Do not adjust the offset potentiometer. Lethal voltages are present inside the drive. Adjusting the potentiometer with AC power applied can be hazardous to personnel.

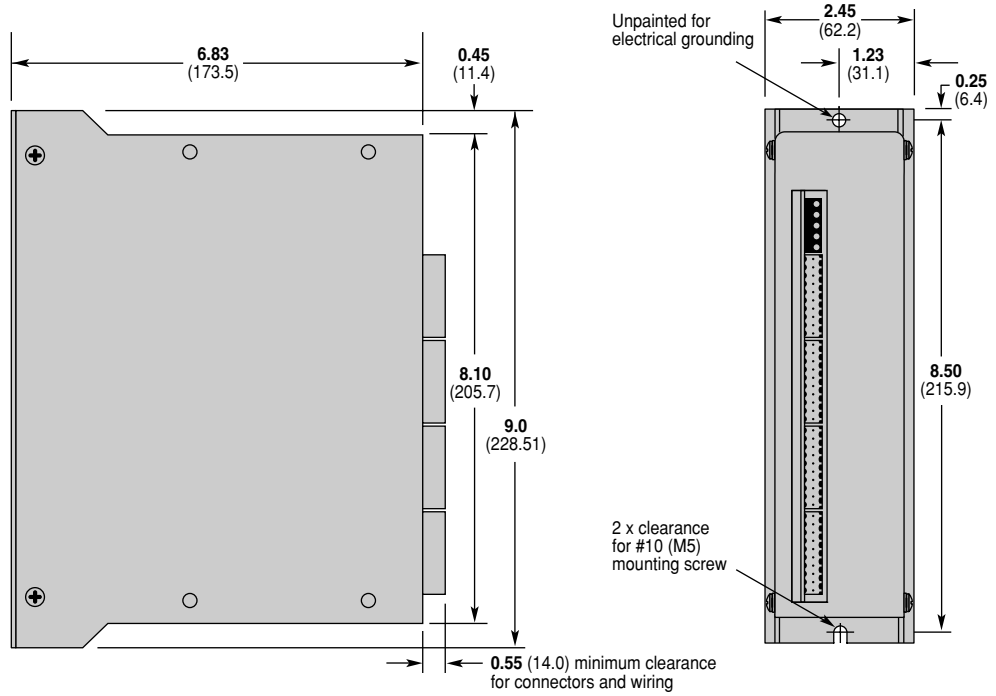
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### 3. Mount the Drive

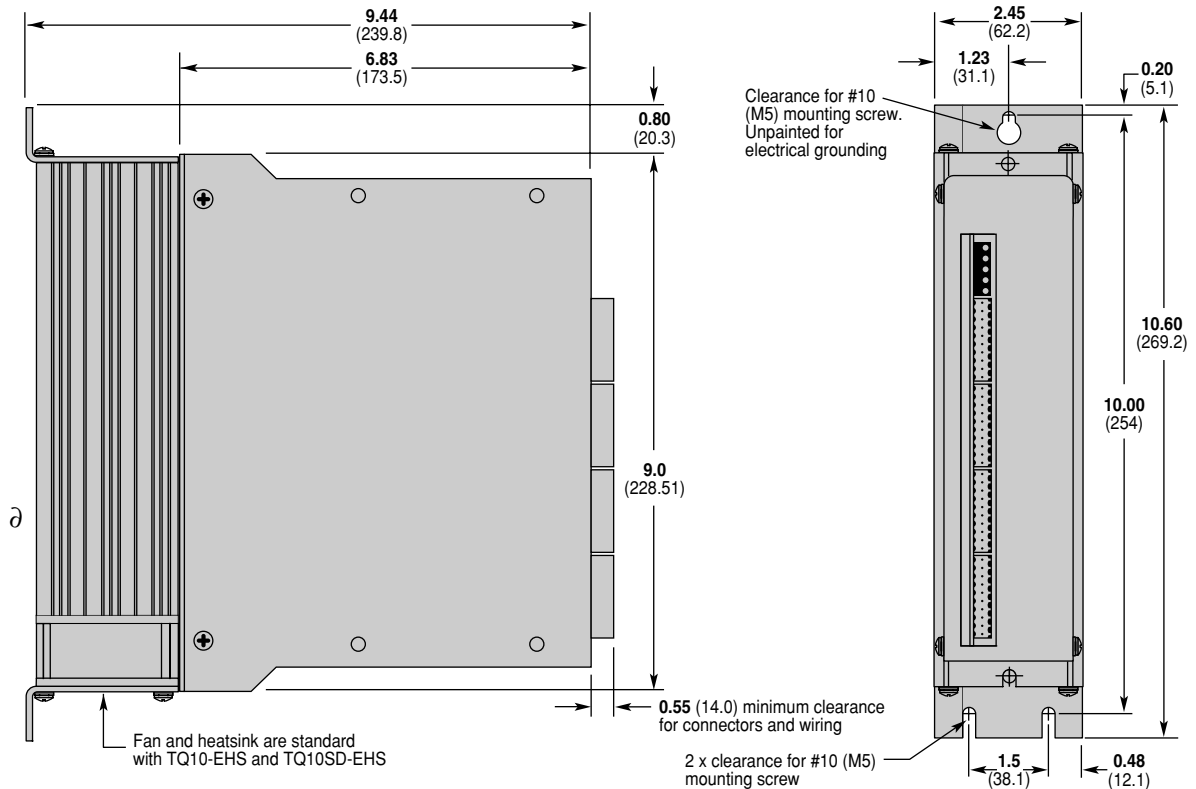
TQ10 and TQ10SD drives have “open frame” enclosures—sheet metal encloses the front and sides, but the top and bottom are open. TQ10-EHS and TQ10SD-EHS drives have top and bottom covers, and an attached heatsink and fan. You can also purchase the heatsink or covers separately, and install them on your TQ10 or TQ10SD drive.

Dimensions for each version of the drive are shown below.

#### Drive Dimensions



Dimensions — TQ10 Torque and TQ10SD Step & Direction Servo Drives



Dimensions — TQ10 and TQ10SD With Heatsink Attached

## Environmental Considerations

### Temperature Specifications

|                                          |                                     |
|------------------------------------------|-------------------------------------|
| Maximum Ambient Temperature:             | 50°C (122°F)                        |
| Minimum Ambient Temperature:             | 0°C (32°F)                          |
| Maximum Temperature of Mounting Surface: | 45°C (113°F) (for non -EHS version) |

**Humidity** Keep the relative humidity below 95%, non-condensing.

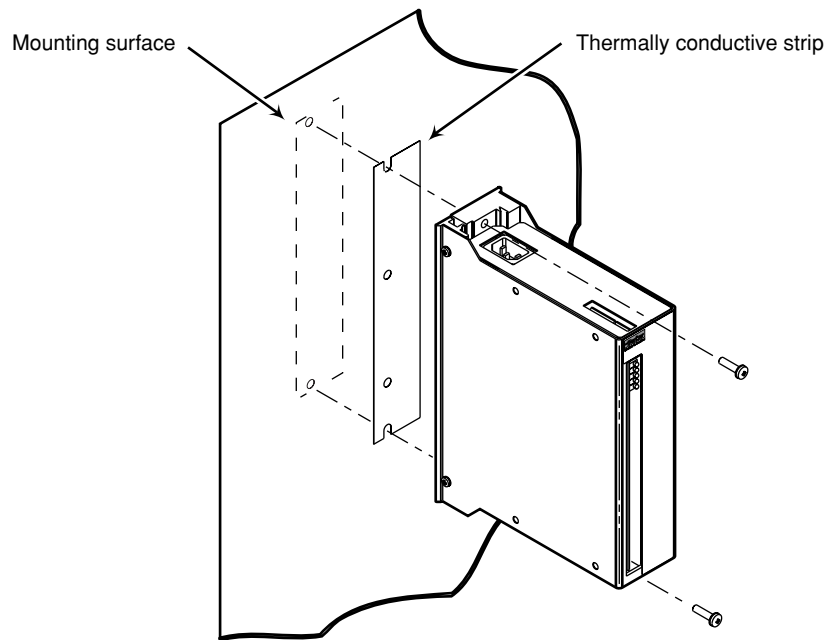
**Liquids** Do not allow liquids or fluids to come into contact with the TQ10 Drive or its cables.

**Airborne Contaminants** Particulate contaminants, especially electrically conductive material such as metal shavings or grinding dust, can damage the TQ10 drive and motor. Do not allow contaminants to come into contact with the drive or motor.

### Mounting the Drive to a Heat Sinking Surface

Mounting profiles and loads affect the amount of heat dissipated by the TQ10 Drive. If yours is a low power application with moderate ambient temperature, the drive may not need a large heatsink. The mounting surface may be adequate as a heatsink, provided it has sufficient mass and surface area.

The mounting plate at the rear of the drive is a *heatplate*—it is a thermal pathway through which the drive can dissipate its excess heat. Mount the drive to a suitable heat sinking surface. A thermally conductive strip is provided with the drive. When you mount the drive, install the strip between the drive's heatplate and the mounting surface, as the next drawing shows. Do not fold or wrinkle the strip.



*Mounting with Thermally Conductive Strip*

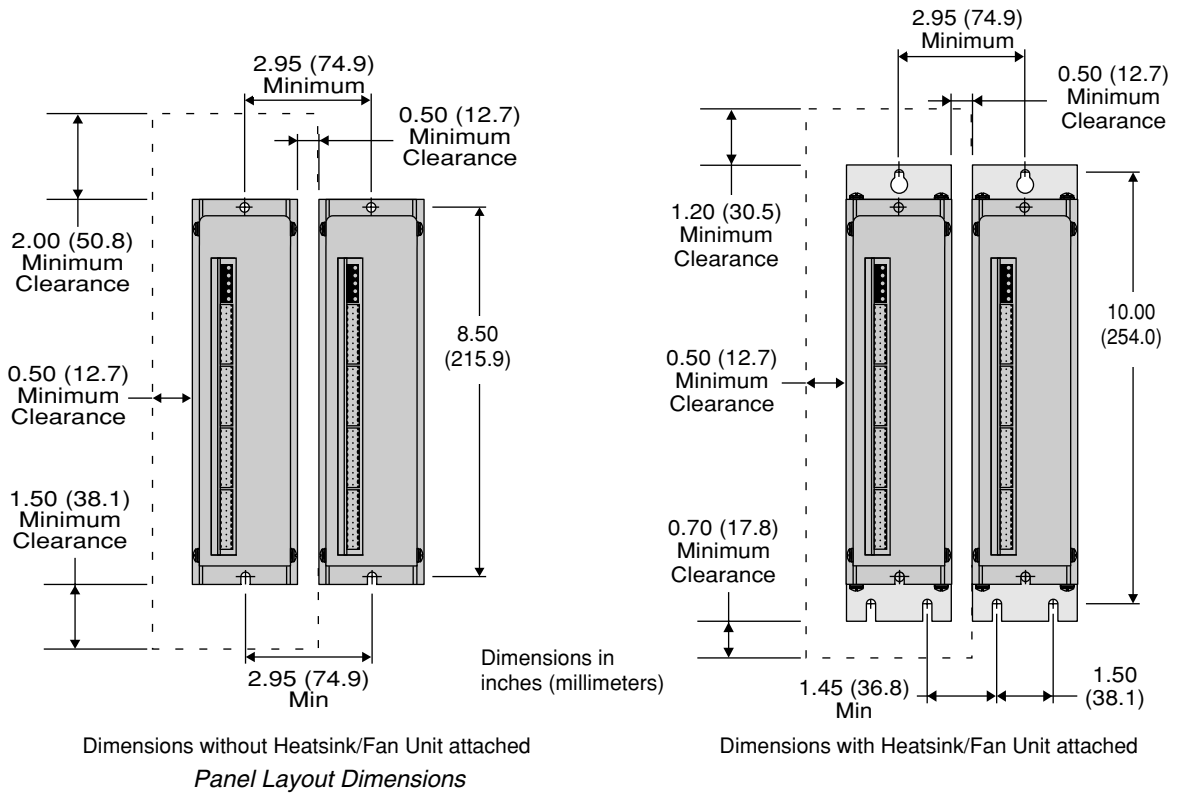
While the drive is operating, ensure that the temperature of the mounting surface is no higher than 45°C (113°F), and that the temperature of the ambient air is no higher than 50°C (122°F).

Do not mount equipment that produces substantial heat below the drive. Avoid mounting heat sensitive equipment directly above the drive.

## Panel Layout

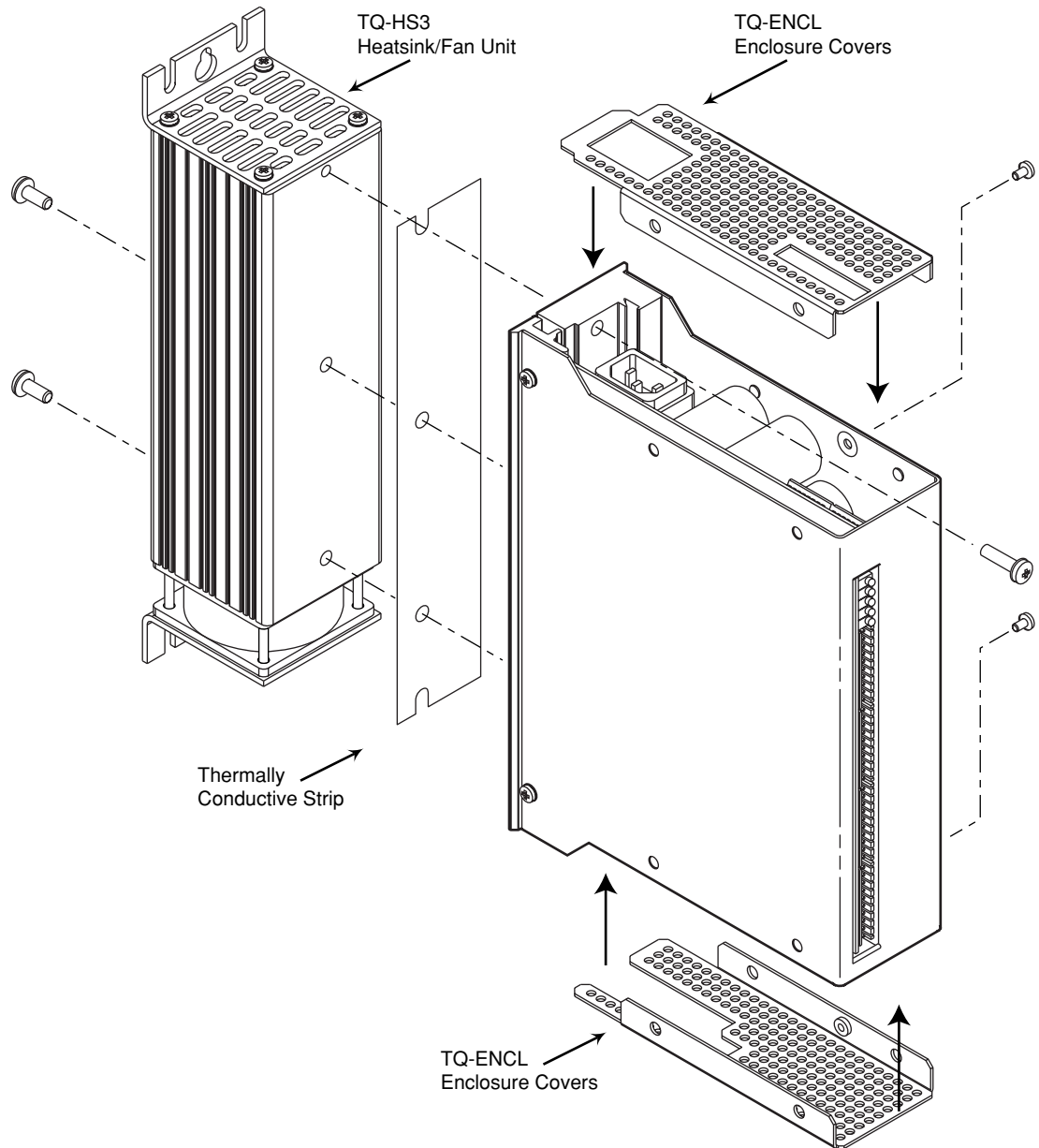
High power applications may require a heatsink. A heatsink/fan unit for the TQ10 drive is available from Compumotor (part number TQ-HS3). If you purchased a TQ10-EHS or TQ10SD-EHS Drive, the heatsink/fan unit was installed at the factory.

The next drawing shows minimum spacing and clearance requirements you should follow when you mount TQ10 Drives. Dimensions are shown with and without heatsink/fan units attached to the drive.



## Attaching Heatsink/Fan Unit and Enclosure Covers

The next drawing shows how to attach Compumotor's optional TQ-HS3 Heatsink/Fan Unit to your TQ10 Drive.

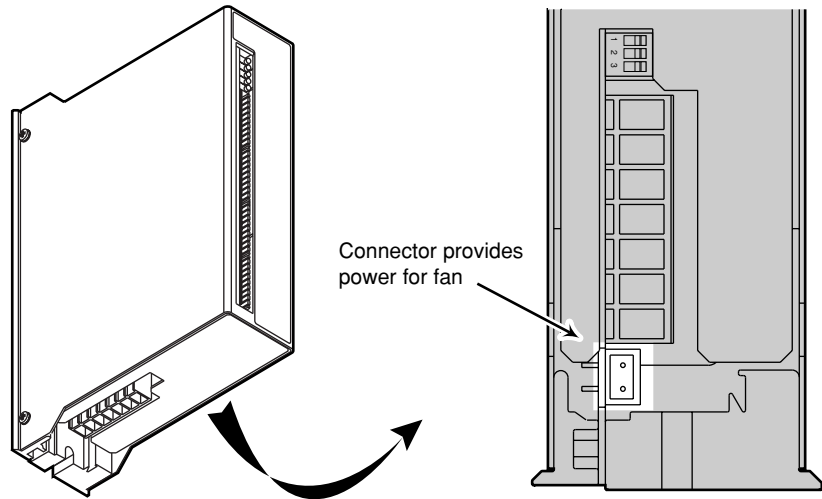


### *Heatsink/Fan Unit and Covers – Attaching to Drive*

Perforated sheet metal covers that enclose the top and bottom of the drive are available from Compumotor (part number TQ-ENCL). The drawing above shows how to attach these optional parts to your TQ10 Drive.

Because the covers will reduce convection available for cooling internal components, drive temperature may increase. You may need to reduce ambient temperature or provide forced air cooling to cool the drive. You may also need to install an external regeneration resistor (power dump), if regenerated energy causes drive overheating with the covers installed.

The heatsink/fan unit has a cable with connector attached. Plug the connector into the TQ10's fan power connector, shown below.

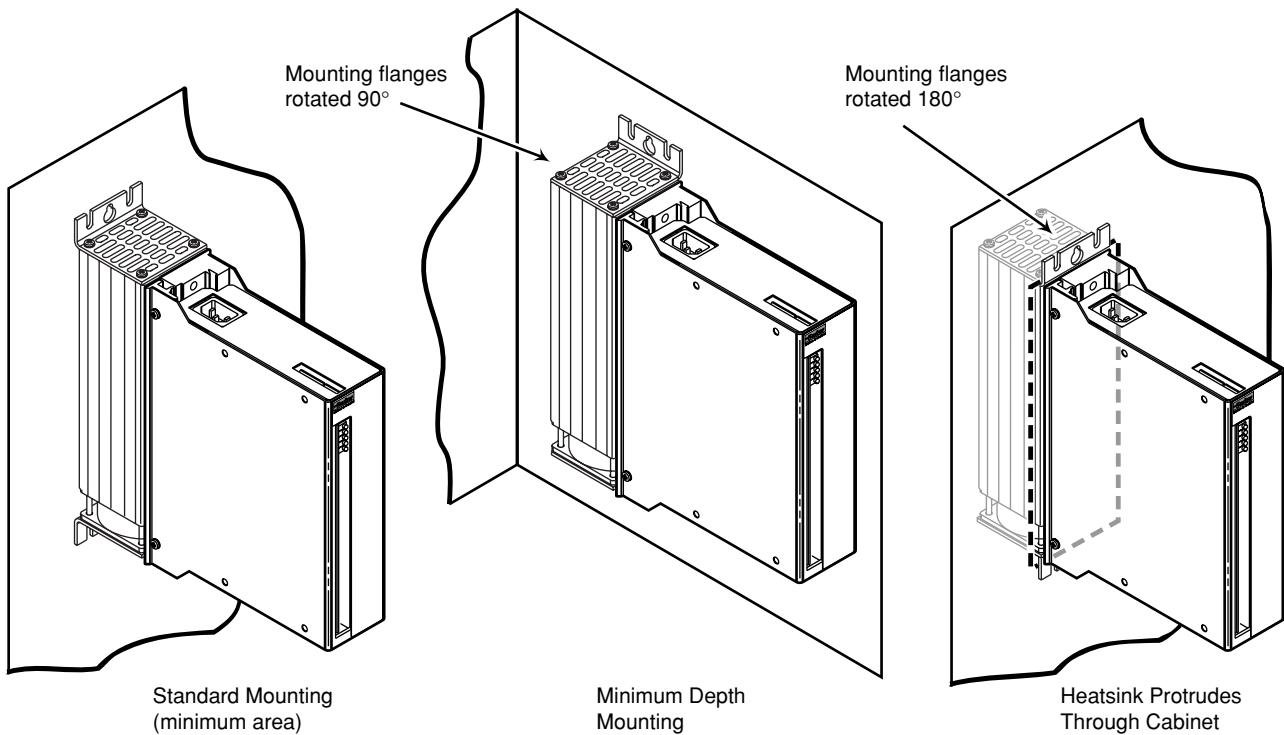


*Fan Power Connector*

### Mounting Options with Heatsink/Fan Unit

If your drive has a TQ-HS3 Heatsink/Fan Unit attached, you have several options for mounting the drive, as the next drawing shows.

You can mount the drive in a “minimum area” configuration, as shown on the left, below. Or, you can mount the drive in a “minimum depth” configuration by rotating the mounting flanges 90° (located at the top and bottom of the heatsink), as shown in the center. If you rotate the mounting flanges 180°, as shown on the right, you can mount the drive with the heatsink protruding through an opening in your equipment cabinet. This configuration may help to remove heat from the interior of your cabinet.



*Mounting Options*

## 4. Mount the Motor

The following guidelines present important points about motor mounting and its effect on performance.

For mechanical drawings of SM and NeoMetric Series servo motors, see *Chapter 3—Specifications*.

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### **WARNING**

Improper motor mounting can limit system performance and jeopardize safety of personnel.

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Servo motors should be mounted by bolting the motor's face flange to a suitable support. Foot mount or cradle configurations are not recommended because the motor's torque is not evenly distributed around the motor case. Any radial load on the motor shaft is multiplied by a much longer lever arm when a foot mount is used rather than a face flange.

Servo motors used with the TQ10 can produce large torques and high accelerations. These forces can shear shafts and mounting hardware if the mounting is not adequate. High accelerations can produce shocks and vibrations that require much heavier hardware than would be expected for static loads of the same magnitude.

Under certain move profiles, the motor can produce low-frequency vibrations in the mounting structure. If harmonic resonances are induced by the move profiles you are using, these vibrations can cause metal fatigue in structural members. A mechanical engineer should check the machine design to ensure that the mounting structure is adequate.

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### **CAUTION**

Modifying or machining the motor shaft will void the motor warranty. Call Compumotor's Application Engineers (800-358-9070) about shaft modifications as a custom product.

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## **Motor Heatsinking**

Performance of a servo motor is limited by the amount of current that can flow in the motor's coils without causing the motor to overheat. Most of the heat in a brushless servo motor is dissipated in the stator—the outer shell of the motor. Performance specifications usually state the maximum allowable winding or case temperature. Exceeding this temperature can permanently damage the motor. The maximum case temperature for Compumotor SM and NeoMetric servo motors is 70°C (158°F).

If yours is a demanding application, your motor may become quite hot. The primary pathway through which you can remove the heat is through the motor's mounting flange. Therefore, mount the motor with its flange in contact with a suitable heatsink.

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### **CAUTION**

In temporary "bench top" setups, often used for prototyping or demonstrations, motors are very vulnerable to overheating if they are not mounted to a heatsink. Limit peak current to the motor's continuous current rating if you operate your motor without a heatsink.

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Specifications for Compumotor SM and NeoMetric Series servo motors apply when the motor is mounted to a ten inch by ten inch aluminum plate,  $\frac{1}{4}$  inch thick. To get rated performance in your application, you must mount the motor to a heatsink of at least the same thermal capability. Mounting the motor to a smaller heatsink may result in decreased performance and a shorter service life. Conversely, mounting the motor to a larger heatsink can result in enhanced performance.

## 5. Connect the Motor to the Drive

The TQ10 Drive works with three-phase brushless motors equipped with Hall effect sensors. The typical motor has a permanent-magnet rotor with four poles (two pole pairs). Higher pole-count motors may also be used.

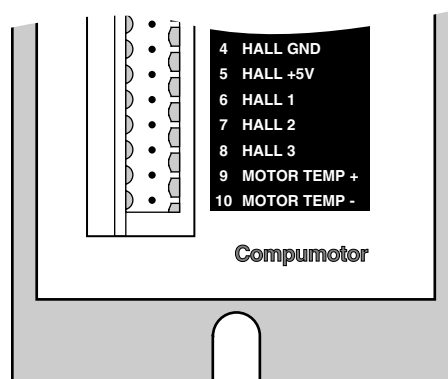
In the following installation procedure, we assume you are using a Compumotor SM or NeoMetric Series Motor with your TQ10 Drive. If you are using a non-Compumotor motor, consult the *Appendix* at the end of this User Guide for information you may need during the following installation steps.

### Connect Hall Effect Wires

The TQ10 Drive is designed to be used with motors that have single-ended, open collector Hall outputs. Internally, the drive pulls these signals up to +15V.

For best performance and reliability, the drive should be used with motors having no more than six electrical degrees of commutation error in either direction. Motors with greater commutation error may cause increased torque ripple and motor heating, reduced average torque, and greater stresses on the drive output stage.

Connect your motor's Hall effect wires to the 10-pin screw terminal on the front of the TQ10. Each terminal is labeled with the name of the wire you should connect.



*Hall Effect and Motor Temperature Connections – Front of Drive*

14 AWG (2.5 mm<sup>2</sup>) is the maximum wire size that can fit in the connector.

### Connect Motor Thermostat Wires

Connect your motor's thermostat wires to **MOTOR TEMP+** and **MOTOR TEMP-**.

If your motor does not have a thermostat, short **MOTOR TEMP+** and **MOTOR TEMP-** together by connecting an insulated jumper wire between them. The drive will experience a motor fault if neither a thermostat nor a jumper wire is attached to the **MOTOR TEMP** terminals.

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#### **WARNING**

Hazardous voltages are present on **MOTOR TEMP+** and **MOTOR TEMP-** when the drive is powered up. Use insulated wires for connections. Protect personnel from contacting these terminals or any attached wires. Do not short these terminals to earth ground.

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The TQ10's motor overtemperature fault can, in many cases, protect the motor against overheating. Through its **MOTOR TEMP+** and **MOTOR TEMP-** terminals, the drive checks for electrical continuity provided by a normally-closed thermostat mounted on the motor. If the motor overheats and the thermostat opens, the loss of continuity triggers protection circuitry in the TQ10. It will turn off power output to the motor, and illuminate the LED labeled **MOTOR FAULT**.

This is a latched fault. Wait for the motor to cool, then cycle power to resume operations (with the TQ10 Torque Drive, you can also toggle the reset input to resume operations). A motor overtemperature fault indicates improper motor sizing, or improper installation of your application.

This circuit may not protect the motor in every possible application. It works best in cases where the temperature rise occurs slowly over a long period of time. In this situation, the thermal sensor and motor windings will be at the same temperature. When the sensor and windings reach the sensor's threshold temperature, the sensor can trigger the overtemperature circuit.

In cases where the temperature rise is caused by continuous peak current flowing—such as a mechanical jam—the winding temperature may rise much more quickly than the sensor temperature does. In this situation, the windings may be damaged from overheating *before* the sensor can trigger the overtemperature circuit.

Be careful not to overheat your motor during system tuning. Allow the motor to cool for several seconds between test moves. Instability while tuning can cause rapid motor heating and possible motor damage. A thermal switch may not protect the motor if the motor heats up too quickly. Do not allow instability to persist longer than a few seconds. After each incident of instability, allow the motor to cool for several minutes.

## Connect Motor Phase Wires

Connect your motor's phase wires and ground wire to the removable 7-pin **MOTOR** connector located on the bottom of the drive. The next drawing shows the location of each terminal.

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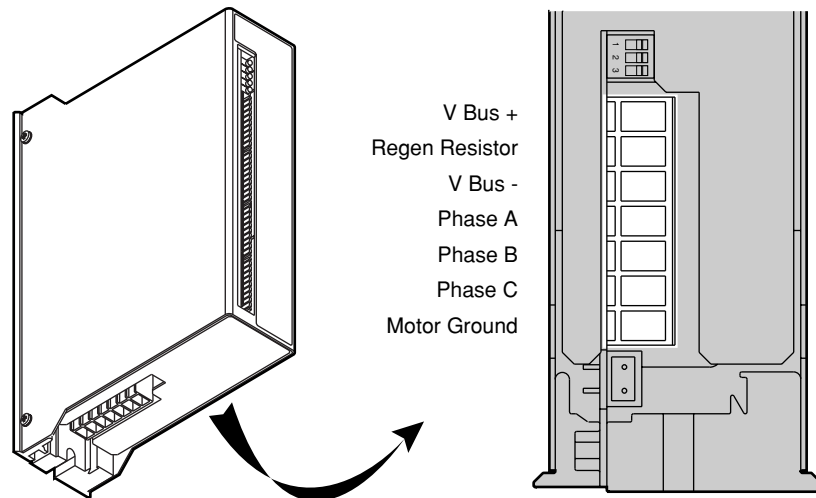
### WARNING

Potentially hazardous voltages are present on motor connector terminals when power is applied to the drive.

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Ensure the connector is aligned correctly when inserted—and not misaligned by one position.



*Motor Connector*

The terminal labeled **MOTOR GROUND** is connected internally to the **EARTH** terminal on the drive's AC power connector.

---

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### WARNING

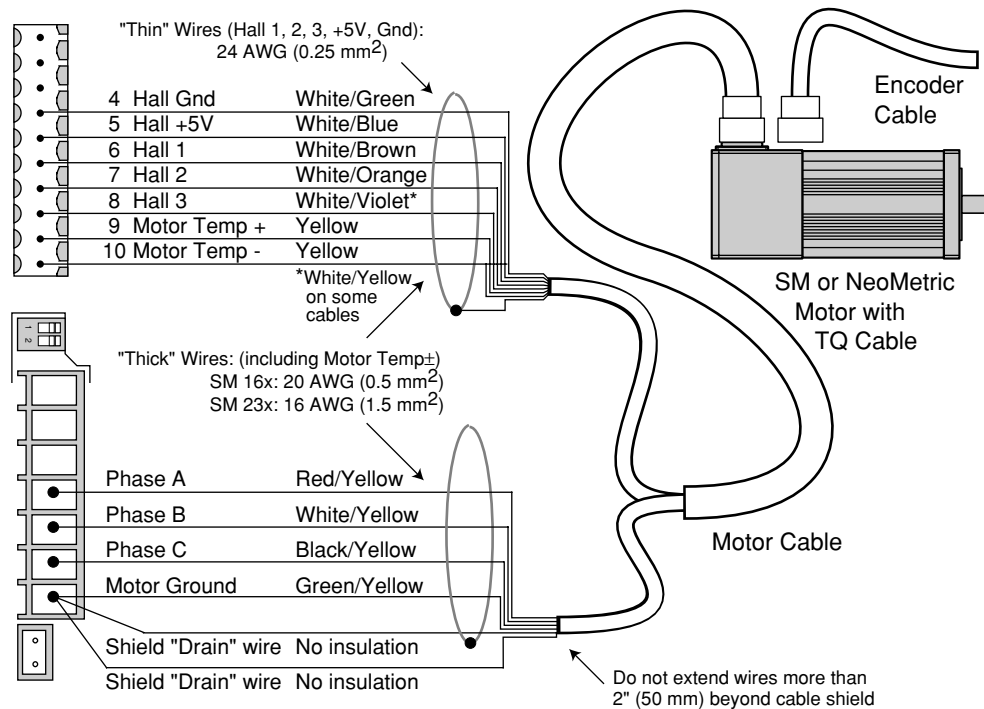
DO NOT OMIT the **Motor Ground** connection. Internal failure of motor insulation can place the motor frame at deadly potential if it is not properly grounded.

---

---

## Connecting Compumotor SM or NeoMetric Series Motors

To connect a Compumotor SM or NeoMetric Series servo motor to the TQ10, follow the color code shown in the next drawing.



### Motor Cable Connections for SM and NeoMetric Series Motors

Inside the motor cable, there are two sets of wires. One contains Hall effect and motor thermostat wires; the other contains motor phase wires. Each set of wires has its own shield and shield drain wire. As shown in the drawing, you should connect both drain wires and the green/yellow ground wire to the **MOTOR GROUND** connector.

### Optional – Connect an External Regeneration Resistor

The TQ10 Drive can dissipate regenerated energy in its internal *regeneration resistor*. If your system regenerates more energy than the internal resistor can dissipate, you can connect an external resistor between two terminals called **V Bus+** and **Regen Resistor**, located on the motor connector. The external resistor doubles the TQ10's dissipation capabilities.

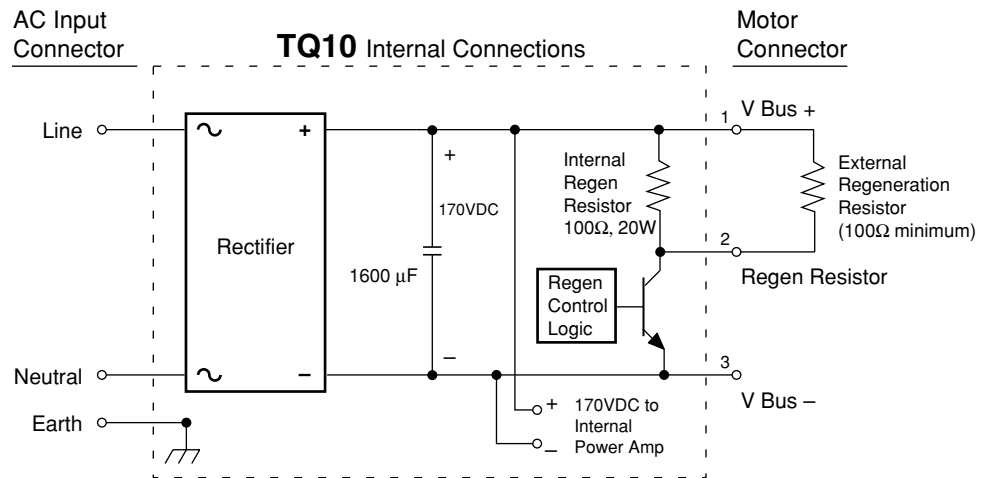
---

#### **WARNING**

Potentially hazardous voltages are present on **V Bus+** and **Regen Resistor** terminals when power is applied to the drive.

---

The next drawing shows the internal regeneration resistor, terminals for an external regeneration resistor, and the DC power bus.



### Regeneration Circuit

The TQ10's regeneration circuit works automatically—there are no adjustments to make. The circuit monitors the voltage on the power bus. If regenerated energy from the motor causes the bus voltage to rise above a threshold value, the circuit closes a switch, thus connecting the regeneration resistor between the positive and negative sides of the power bus, **V Bus+** and **V Bus-**. The energy is then dissipated in the resistor—its power capacity is 1KW for one second, or 10 watts on a continuous basis. During the regeneration event, the bicolor LED labeled **REGEN/OVERVOLTAGE** will be illuminated *green*.

The TQ10 also has an *overvoltage* circuit; it protects the drive from excessive regeneration. If the motor regenerates more energy than the internal resistor can dissipate, voltage on the power bus will rise and trigger an overvoltage fault. The drive will shut down power output to the motor. The bicolor LED labeled **REGEN/OVERVOLTAGE** will be illuminated *red*. This is a latched fault—cycle power to resume operations (with the TQ10 Torque Drive, you can also toggle the reset input to resume operations).

If excessive regeneration causes overvoltage faults in your system, you can install an external regeneration resistor. Ensure that the external resistor is adequately mounted and cooled. Excessive heating can cause the resistor to fail.

---

### CAUTION

Adequately cool the external resistor. Forced air cooling may be required. Maintain resistor temperature below its rated temperature limit.

---

The internal resistor is a 100 Ω, 10 watt, 10% non-inductive resistor. For an external resistor, we suggest:

- Manufacturer Name: Dale
- Manufacturer Part Number: NHL-55-16N-100Ω (5% – 20% is suitable)

This resistor has “faston” mounting tabs, and can be mounted with two screws. You can order this resistor, with two 18 inch (457 mm) cables, as a kit from Compumotor. The part number is:

### TQ-REGEN-KIT

Or, you may use an equivalently rated 100Ω *non-inductive* resistor for your external resistor.

To connect the external resistor, follow these steps:

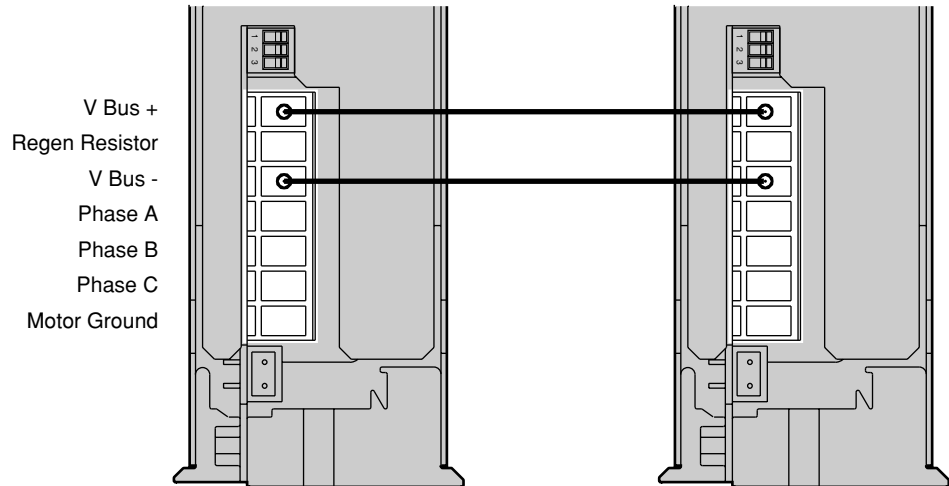
- ① Connect the resistor's two terminals to **V BUS+** and **REGEN RESISTOR**, located on the motor connector.
- ② Keep wires as short as possible, and twist them together.

The circuit will automatically dissipate half the regenerated energy in the external resistor. Total dissipation with the external resistor installed is 2KW peak, 20W continuous.

## Optional – Sharing the Power Bus

In some applications with multiple drives, one or more drives may continuously receive regenerated power from their loads. For example, in a tensioning application, two TQ10s apply tension (opposite torques) to a single moving load. In this situation, one TQ10 could receive substantial regenerated power from its motor.

In such applications, you can connect the power buses for the TQ10s in parallel, through the **V BUS+** and **V BUS-** terminals located on the motor connector, as shown below. (See the previous drawing, *Regeneration Circuit*, for an internal schematic.)



*Sharing the Power Bus*

With the buses connected in parallel, the regenerated power from one TQ10 is dissipated by the power consumption of the other.

In standard multi-axis applications, where regeneration occurs when one axis decelerates, the energy can be used by other axes if the power bus is shared. This improves system efficiency by using energy that would otherwise be wasted.

## Connecting Motors from Other Vendors

Before connecting a motor from another vendor, you must determine which motor phase wires correspond to Phase A, Phase B, and Phase C inputs on the TQ10. Similarly, you must determine which Hall effect wires correspond to Hall 1, Hall 2, and Hall 3.

Connect each wire to its appropriate terminal on the TQ10. Ensure that the Hall effect sensors accurately transmit information about rotor position, and that motor current is commutated to the correct motor phases. See the *Appendix* at the end of this User Guide for more information about using a motor from a vendor other than Compumotor.

## Connecting a Brushed DC Servo Motor

You can use the TQ10 as a drive for brushed DC servo motors. To do this, follow these steps:

- ① Connect drive terminals **HALL 1** and **HALL 2** to **HALL GND**
- ② Make no connections to drive terminal **HALL 3**
- ③ Connect the drive's **Phase A** to your motor's positive input.
- ④ Connect the drive's **Phase C** to your motor's negative input.

Under these conditions (**HALL 1** and **HALL 2** connected to ground; **HALL 3** unconnected), the drive's internal logic determines that a brushed motor is connected. The drive will send DC current out of Phase A, through the motor, and back into the drive through Phase C. The amount and polarity of the current will be determined by the command input signal.

### Shielded Motor Cables

Keep electrical noise from interfering with the signals that the Hall effect sensors send to the drive. Position the motor as close as possible to the drive. If you need to connect a long cable between the drive and motor, we recommend you use a shielded cable for the Hall wires (Hall 1, Hall 2, Hall 3, Hall +5V, Hall Gnd). Run the power wires (phase A, B, and C) separately from the Hall wires.

### Motor Grounding

For safety reasons, the motor case should be grounded. Often, the motor can be grounded through the equipment to which it is mounted. This requires a good electrical connection between the motor's mounting flange and the equipment, and that the equipment be connected to ground. Check with the National Electrical Code (NEC) and your local electrical code to ensure you use proper grounding methods.

Proper grounding can also reduce electrical noise.

#### **GROUND THE MOTOR CASE!**

The motor case must be grounded, to reduce electrical noise. An ungrounded motor can cause electrical noise problems throughout the system, particularly in encoder wiring and circuitry. This noise may cause the encoder to output erroneous information, such as missing encoder pulses. To avoid electrical noise problems, ground the motor case.

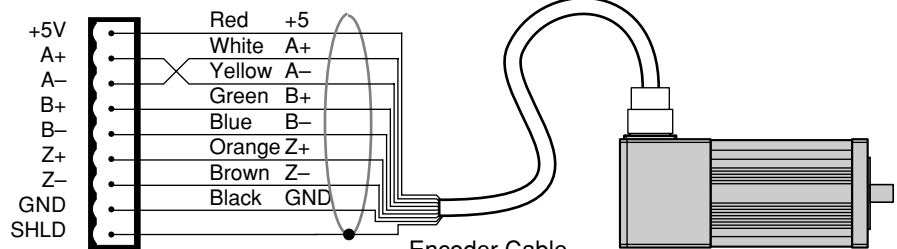
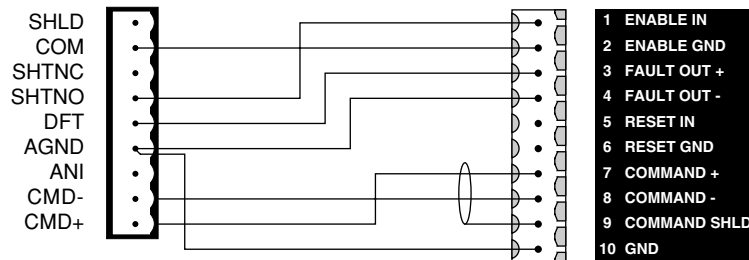
## 6A. Connect a Controller or Indexer (TQ10 and TQ10SD)

The next drawing shows how to connect a Compumotor 6250 Servo Controller to your TQ10 Torque Servo Drive. The drawing also shows the color code for Compumotor SM or NeoMetric Series servo motors equipped with TQ cables.

6250 Controller  
AT6n50 Controller

TQ10 Torque Servo Drive

Drive Connector



Encoder Connector

SM or NeoMetric Motor  
with TQ Cable

Connections to Compumotor 6250 Servo Controller

The TQ10 Torque drive and the TQ10SD Step & Direction drive have **ENABLE IN** and **FAULT OUT** terminals on their front panels. Connect your controller to these terminals on the TQ10 Torque drive; or, connect your indexer to these terminals on the TQ10SD Step & Direction drive. Instructions are given below.

## Enable Input

To enable the drive, you must connect the enable input to ground. (TQ10SD Step & Direction Drive: this connection must be made *before* applying power to the drive.)

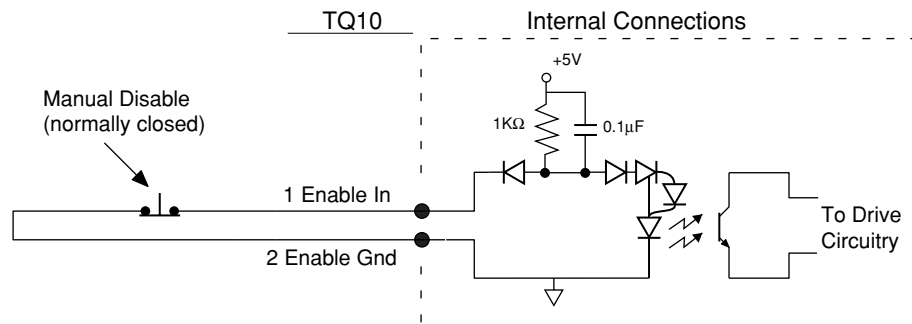
If you break the connection to ground while the drive is on, the TQ10's fault circuitry will activate, with the following results:

- The drive will shut down power output to the motor.
- The motor will freewheel (it may not stop immediately).
- The bicolor LED labeled **GRN = POWER ON, RED = NOT ENABLED** will be illuminated red.
- The fault output will become active (no current will flow through it).

To re-enable the drive, establish the connection between enable and ground. (TQ10SD Step & Direction Drive: you must cycle power to re-enable the drive, and clear fault conditions.)

In most applications, you can permanently wire the enable input to ground. This input is internally pulled up to +5V. If your equipment requires, you can connect the input to an external voltage as high as +24V. You can also connect it to a dry contact closure to ground.

If you need to disable the drive in an emergency, use the enable input. Connect a *manual disable* switch to the enable input, as the next drawing shows. The switch is normally closed. When it is opened, the drive will be disabled. The load can freewheel—therefore, you should use a brake to stop the motor immediately in applications where a freewheeling motor can cause injury or damage.



Enable Input Connected to a Switch

### WARNING

Do not use the ENABLE INPUT by itself as an emergency stop. The motor can freewheel when the drive is disabled and may not stop immediately. Use a mechanical brake or some other method to stop the motor quickly.

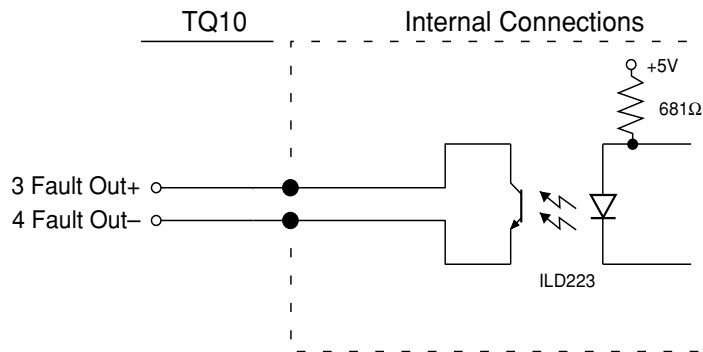
If you need to disable the TQ10SD Step & Direction drive during *normal operations*, you should use the shutdown input—it allows you to re-enable the drive from the indexer without cycling power. The shutdown input is described later in this section.

If you need to disable the TQ10SD Step & Direction drive in an *emergency*, use the enable input as described above—*not* the shutdown input.

The TQ10 Torque drive has no shutdown input.

## Fault Output (Optional)

When the TQ10 is operating normally, its fault output's internal transistor is in the "on" state, and conducts current. If the TQ10 detects a fault, it turns off the transistor, and current stops flowing.



### Fault Output

#### Specifications

|                         |                                                                                                   |
|-------------------------|---------------------------------------------------------------------------------------------------|
| Maximum Applied Voltage | 50 V                                                                                              |
| Maximum Current         | 10 mA                                                                                             |
| Active Level            | No Fault: Transistor <i>on</i> , current flows<br>Fault: Transistor <i>off</i> , no current flows |

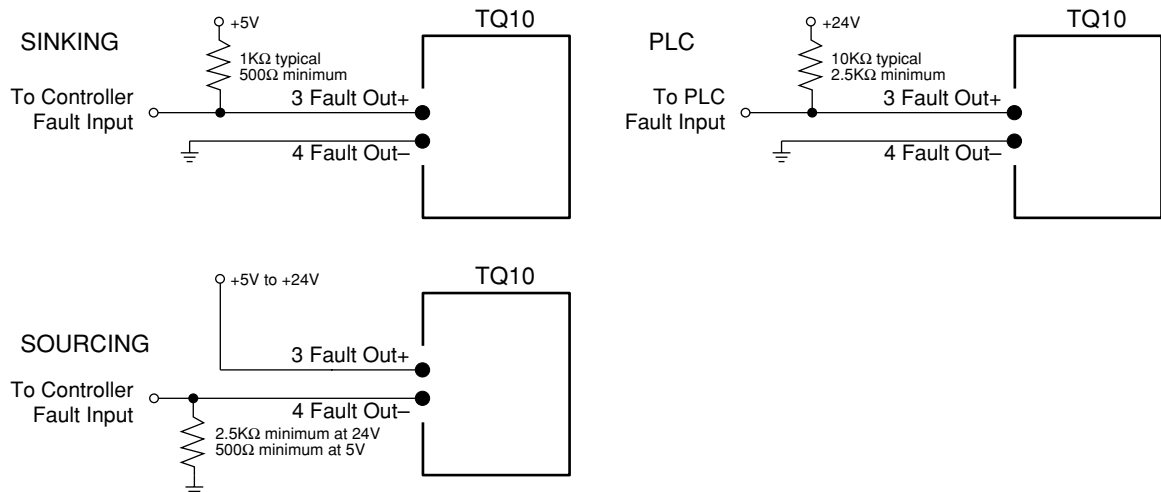
The following conditions will activate the fault output.

#### Fault Condition

|                       |                                                                  |
|-----------------------|------------------------------------------------------------------|
| Drive Not Enabled     |                                                                  |
| Over Temperature      | <i>latched</i>                                                   |
| Overvoltage           | <i>latched</i>                                                   |
| Undervoltage          | <i>not latched</i>                                               |
| Excess Position Error | <i>latched (TQ10SD only)</i>                                     |
| Short Circuit         | <i>latched</i>                                                   |
| Power Supply Fault    | <i>latched</i>                                                   |
| Foldback              | <i>foldback causes fault if DIP SW2, Position#1 is set to ON</i> |

*Latched* means you must cycle power before the drive will operate again (or, with the TQ10 Torque Drive, you can also use the reset input to reset the drive).

You can use the TQ10's fault output as a signal to a controller or PLC that a fault has occurred. The following drawing shows several ways to connect external devices to the TQ10's fault output.



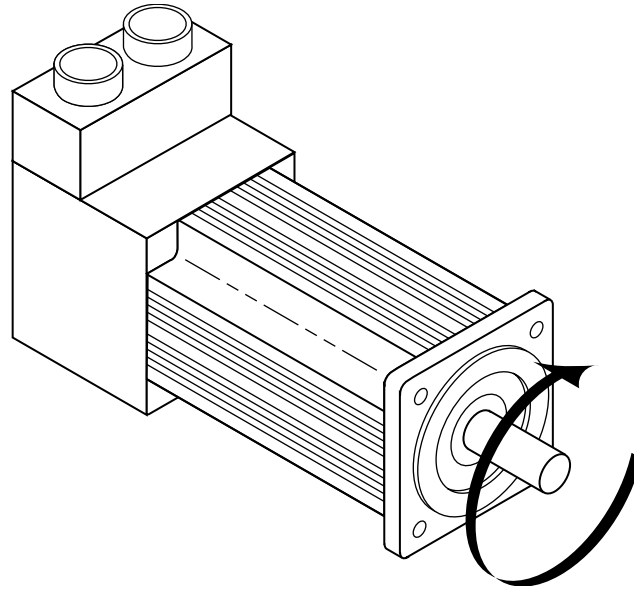
Fault Output – Typical Applications.

## 6B. TQ10 Torque Drive Only – Connect Command & Reset Inputs

The TQ10 Torque Drive monitors an analog voltage signal, called *command input*, at its input terminals (**COMMAND+** and **COMMAND-**). It sends an output current to the motor that is proportional to the command input voltage. Your controller's command voltage can range from -10VDC to +10VDC.

The TQ10 will produce 1.0 amp for each volt present at its input terminals. A 10 volt command input will result in peak current flowing to the motor. Smaller voltages result in proportionally less current, with a zero volt command input resulting in no current to the motor.

Positive voltages cause the TQ10 to produce currents that turn the motor's shaft clockwise. Negative voltages cause currents that turn the shaft counterclockwise. As the next drawing shows, shaft rotation is defined as the direction the shaft rotates, as viewed from the mounting flange end of the motor.



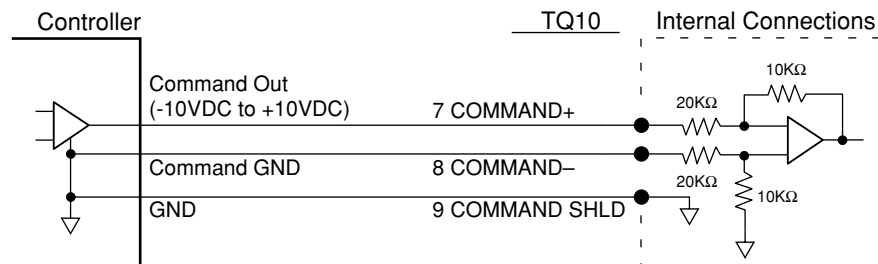
*Clockwise Shaft Rotation*

Connect your controller's command output signal to the TQ10's command input terminals. The following sections describe how to connect different types of controller outputs to the TQ10's command input terminals.

### Controller with Single-ended Output

If your controller uses a single-ended output—a single terminal that produces a voltage that ranges from -10VDC to +10VDC—connect that output to **COMMAND+** on the TQ10.

Connect wires from the TQ10's **COMMAND-** and **COMMAND SHLD** terminals to the controller's ground terminal. If you connect the wires as shown in the next drawing, you will minimize electrical noise in the circuit. You should use shielded, twisted-pair wire for your connections.



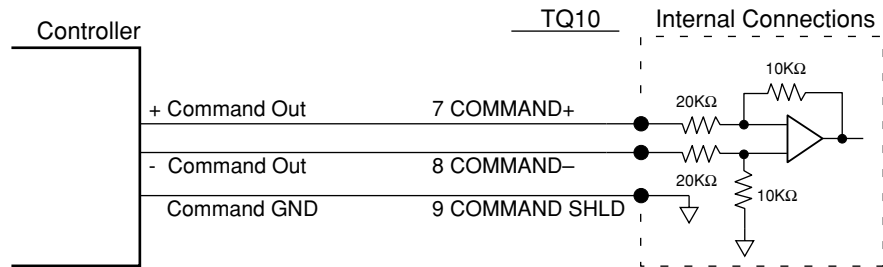
*Controller – Single-Ended Output Connections*

Bring both wires from the TQ10, and connect them both to the controller. This will ensure that the TQ10's **COMMAND-** input and **COMMAND SHLD** input are both referenced to the controller's ground terminal.

## Controller with Differential Output

If your controller has a differential output, then it has two command signals. One is a signal that ranges from -5VDC to +5VDC. The other signal ranges from +5VDC to -5VDC. The two signals mirror each other—their magnitudes are equal, but they have opposite signs.

Your controller should also have a ground terminal to use as a reference for the positive and negative command outputs.



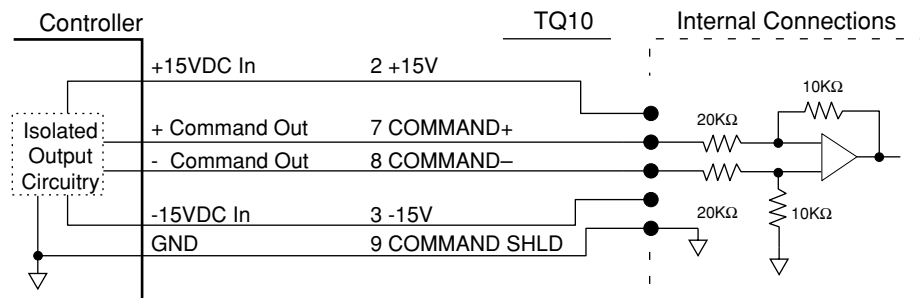
*Controller—Differential Output Connections*

The figure above shows how to connect these three outputs to the TQ10.

## Controller with Isolated Output

Some controllers have isolated command outputs, and may require a voltage source to power their outputs. The TQ10 has three pins available to power isolated outputs on a controller. These pins provide +15VDC, -15VDC, and ground.

The next figure shows a typical controller with isolated differential outputs, and illustrates how you can connect it to the TQ10.

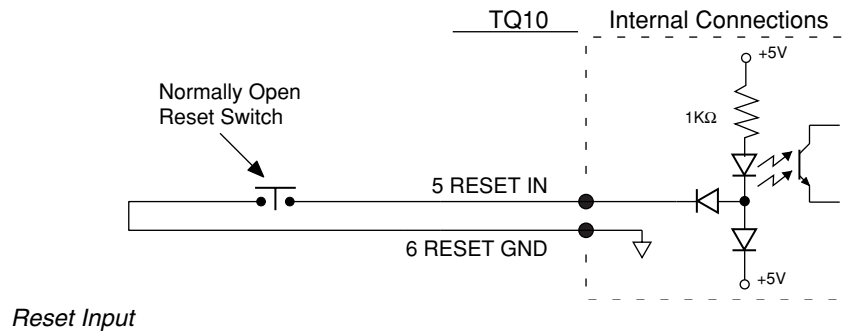


*Controller—Isolated Output Connections*

If your controller has an isolated single-ended output, connect the  $\pm 15$ VDC outputs as shown in this figure. Connect the command and ground signals as shown earlier in the section on single-ended outputs.

## Reset Input (Optional)

You can use the reset input to reset the drive. The effect of a reset is identical to cycling power. The reset input is internally pulled up to +5V. If your equipment requires, you can connect the input to an external voltage as high as +24V. You can also connect it to a dry contact closure to ground.



Reset Input

### Specifications

|                         |              |
|-------------------------|--------------|
| Maximum Applied Voltage | 30 V         |
| Maximum Current         | 5 mA         |
| Active Level            | Low to reset |

## 6C. TQ10SD Only – Connect Inputs & Outputs

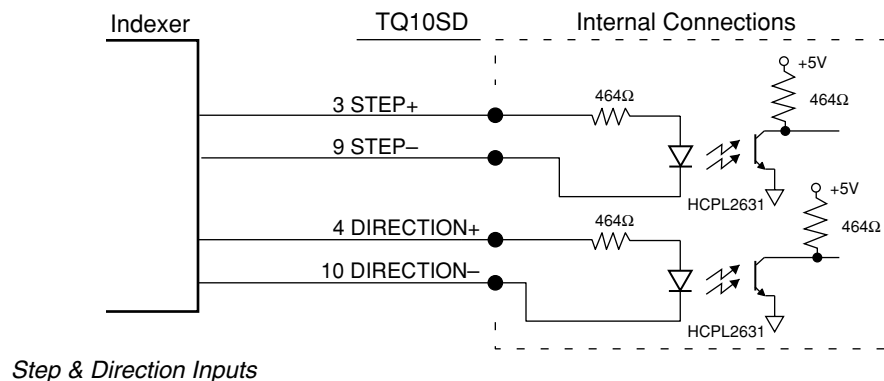
You must connect step and direction, enable, and encoder signals to the TQ10SD Step & Direction Drive for it to work. Use the drive's other inputs and outputs for your application's specific requirements.

Unlike a step motor system, which operates *open loop*, the TQ10SD is a *closed loop* servo system. It requires feedback from the encoder for stability. For each step pulse received while **Direction+** is positive, the drive will make the motor turn in the positive direction a distance of one positive encoder count.

For stability, it is important that you connect your system so that a positive step command causes the encoder position to increment, not decrement. If the system is connected incorrectly, each step pulse will cause the encoder to move in the wrong direction, causing increasing position errors. This could lead to instability and a *motor runaway*, in which the motor spins faster and faster, eventually going out of control.

### Step & Direction Inputs

Connect your indexer to the step and direction inputs, as shown in the next drawing. These inputs are optically isolated. For best performance, your indexer should drive the inputs differentially. Single-ended operation is also possible, especially at lower step frequencies (where the switching speed of the internal diode is not as critical).



Step & Direction Inputs

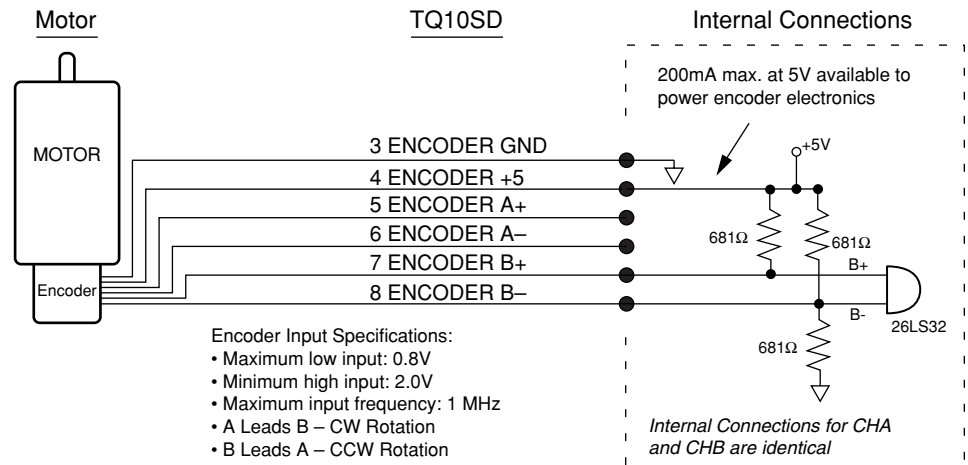
Specifications for the step and direction inputs are as follows:

| <u>Specifications</u> | <u>Step+/Step-<br/>Dir+/Dir-</u>                                                                                                                                         |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Applied Voltage       | 5 V maximum                                                                                                                                                              |
| Input Current         | 12 mA maximum<br>6.3 mA minimum                                                                                                                                          |
| Step Pulse            | 500 nsec minimum pulse width                                                                                                                                             |
| Setup Time            | Direction input may change polarity coincident with the last step pulse. The direction input must be stable for 500 nsec before the drive receives the first step pulse. |

You can use an input voltage higher than 5V if you install a resistor in series with the input, to limit current to the range specified above.

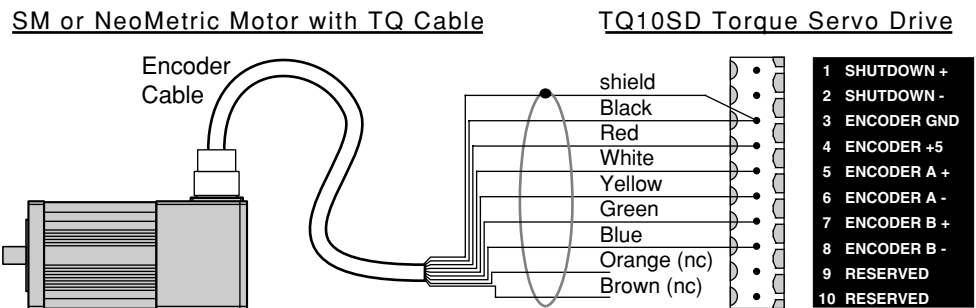
## Encoder Input Connections

You must connect an encoder to the TQ10SD's encoder inputs. These are differential inputs; therefore, your encoder should have differential outputs. Single-ended operation is possible, but is more susceptible to electrical noise and is not recommended. Up to 200 mA at 5 volts is available from the TQ10SD to power encoder electronics.



### Encoder Input

The color code for encoder wires is shown in the next drawing for Compumotor SM and NeoMetric Series servo motors.

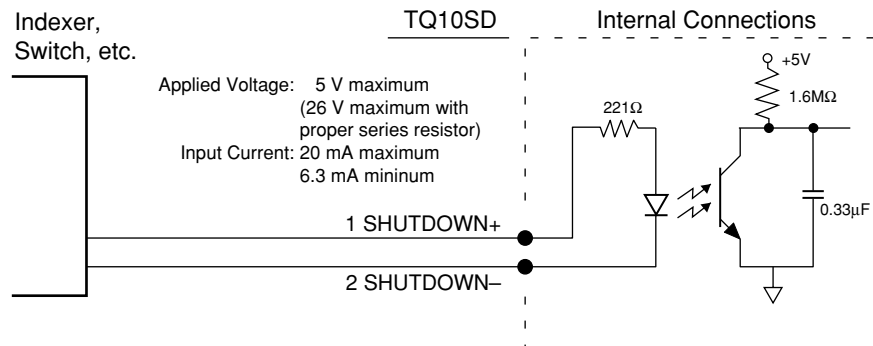


Connecting Encoder Input to SM or NeoMetric Motor Encoder Cable

The orange and brown wires connect to **INDEX+** and **INDEX-** on the encoder, which the TQ10SD does not use. Do not connect these two wires to the drive.

## Shutdown Input (Optional)

Use the shutdown input if you need to temporarily disable the drive during normal operations. You may wish to do this, for example, to manually move the load to a desired position. Make connections according to the following diagram. The inputs are designed for 5V operation. For 24V operation, install an external 2K $\Omega$  resistor in series with **Shutdown+** to limit the input current.



### Shutdown Input

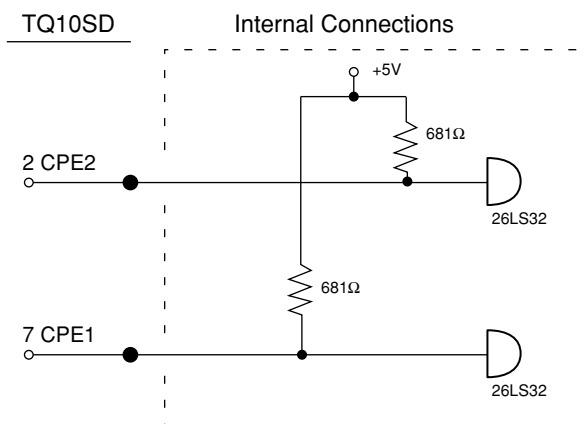
When +5V is applied to the **Shutdown+** input, the TQ10SD's power output stage remains active, but its internal controller commands zero torque. You can then manually position the motor shaft. The controller will ignore encoder counts and position error as the shaft turns. Approximately one second after you release the shutdown input, the internal controller accepts the new position as the commanded position, and reestablishes servo action.

While the TQ10SD is in shutdown, its small internal offset torque will be applied to the load. This torque is usually too low to overcome friction and cause motion. In some applications, however, the shaft may need to be held in the desired position during shutdown.

Note that shutdown in the TQ10SD functions differently than shutdown in a step motor drive. When a step motor drive is shut down, it actually shuts down its power output stage. When it comes out of shutdown, the step motor drive will command phase currents that immediately apply torque to the shaft, which holds it in some position between the poles.

## CPE1 and CPE2 – Position Error Inputs

You can *configure position error* (CPE) with two position error inputs, **CPE1** and **CPE2**. Position error faults provide warnings of impending problems such as increased friction, or of immediate problems such as a mechanical jam. Position error is measured in post-quadrature encoder counts. Four settings are available, as the next table shows.



CPE 1 and CPE 2 – Position Error Inputs

| Position Error Settings |      |                 | Number of Revolutions |                   |
|-------------------------|------|-----------------|-----------------------|-------------------|
| CPE1                    | CPE2 | Error*          | 500 Line Encoder      | 1000 Line Encoder |
| low                     | low  | 2047            | 1.024                 | 0.512             |
| high                    | low  | 4095            | 2.048                 | 1.024             |
| low                     | high | 8191            | 4.096                 | 2.048             |
| high                    | high | 16383 (default) | 8.196                 | 4.096             |

high = not connected

low = connected to ground

\*error is measured in post-quadrature encoder counts

When the TQ10SD ships from the factory, neither **CPE1** nor **CPE2** is connected to ground. This is the default setting; it selects the widest position error range. You might begin with this setting when you start configuring your system. This will give you the widest range of motion. Once your system is tuned and performing properly, you can select one of the other three settings by connecting either or both of the inputs to ground.

The position error feature works as follows. Internally, the drive generates a control voltage proportional to error counts—the difference between the number of step pulses received and the number of post-quadrature encoder counts received. The first 2047 counts in each direction produce an increasing control voltage. This causes an increasing torque to move the load towards the commanded position. After the first 2047 counts, maximum torque is being commanded. Additional error counts have no immediate effect on torque, but they are accumulated until the error is reduced by shaft motion, or the CPE limit is reached. Reaching the limit causes a fault that disables the drive and illuminates the red LED labeled **NOT ENABLED**.

To clear the position error fault, cycle power.

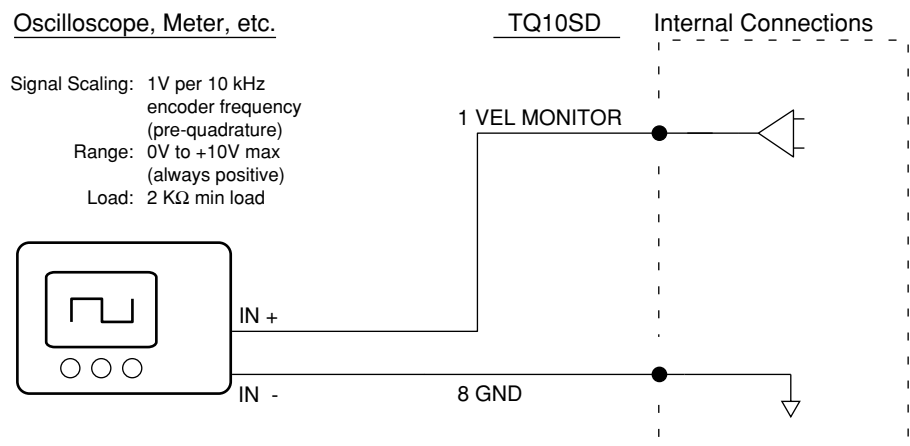
### Velocity Monitor Output (Optional)

The TQ10SD's velocity monitor output is a voltage signal proportional to encoder speed. You can connect a voltmeter to this output to measure velocity, or you can connect an oscilloscope to help you tune your system. See the *Tuning* section at the end of this chapter for more information.

The signal is always positive, regardless of the direction of encoder rotation. It is scaled so that a pre-quadrature encoder count frequency of 10 kHz produces an output of one volt. The maximum output is +10V. (For example, a 1000 line encoder rotating at 100 rps (100 kHz) will produce the maximum signal of +10V. The same encoder at 10 rps will produce a signal of +1V.)

Encoder counts come slowly at low velocities, which can cause the velocity monitor to show ripple at four times the line frequency, resulting in a “fat” trace on the oscilloscope.

The next drawing shows typical connections to the velocity monitor. Use any of the terminals labeled **GND** as a ground reference for your signal.



Velocity Monitor Output Connections

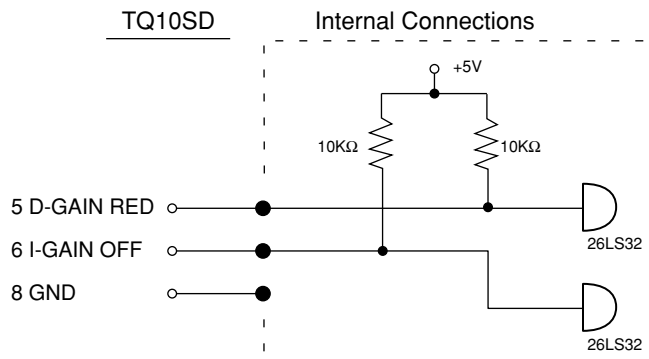
## Derivative Gain Reduction—Input (*Optional*)

This input, labeled **D-GAIN RED**, can reduce the derivative gain in the TQ10SD's internal feedback loop. If no connections are made to the input, the gain does not change. If the input is connected to ground, the drive gradually reduces derivative gain to a low value whenever motion stops. When motion is commanded again, or if the motor shaft moves, the drive instantly increases derivative gain to the value set by the derivative tuning pot. See the *Tuning* section at the end of this chapter for more information. The internal schematic for the input is shown in the next drawing.

## Integral Gain Disable—Input (*Optional*)

This input, labeled **I-GAIN OFF**, can disable the integral gain in the TQ10SD's internal feedback loop. If this input is grounded, integral gain is disabled. If it is not grounded, integral gain is determined by the tuning pot setting. (However, the tuning pot cannot reduce integral gain to zero; you must ground **I-GAIN OFF** to set integral gain to zero.)

As an initial setting to simplify tuning, we recommend disabling integral gain by grounding **I-GAIN OFF**. You can add integral gain later, if necessary. The internal schematic for the input is shown in the next drawing. See *Tuning* at the end of this chapter for more information.



*Derivative Gain Reduction & Integral Gain Disable Inputs*

## 7. Connect AC Power

At this point in your installation procedure, you should have mounted your drive and motor, and connected motor cables and controller cables (or indexer cables) to the drive.

The TQ10 does not have an *on/off* switch. When you plug the power cord into the drive, the system will turn on. Therefore, before you apply power to the TQ10, verify the following:

- Motor should be properly secured
- Load should not yet be connected to motor shaft
- Motor cable should be connected to drive
- Drive should be properly mounted
- Controller/Indexer cable should be connected to drive
- Controller/Indexer cable should not be located close to motor cable

### Apply Power

To apply power to the TQ10, plug one end of the power cord into the drive's AC Power connector (cord length is 6 feet/1.8 m). Plug the other end of the cord into an AC power source that meet these specifications:

#### Specifications – AC Power Input

|              |                                                                 |
|--------------|-----------------------------------------------------------------|
| Input Power: | 120VAC nominal<br>95VAC minimum<br>132VAC maximum<br>50 – 60 Hz |
| Fuses:       | No user serviceable fuses                                       |
| Grounding:   | You must provide a proper AC power ground                       |

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**WARNING**

The motor case and drive are grounded through the AC power connector ground pin. You must provide a proper AC power ground for safety purposes.

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## Peak Power Ratings

The amount of power the TQ10 draws from your AC power source depends upon the motor you use and upon your specific application. For high power applications, we suggest you use a dedicated 20 amp service for the TQ10. Even applications that use low *average* power may require 20 amp service if the *peak* power is high. Inadequate AC power can cause various problems that are difficult to diagnose.

## 8. Test Your System

Except for connecting the motor to the load, system installation should be complete at this point. Perform the test procedure below to verify that your system is functioning properly.

In the test procedure, you will command single revolution moves in the clockwise and counterclockwise direction. If your mechanics do not permit such moves, choose a move that allows you to easily verify correct system response.

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**CAUTION**

If you have an SM or NeoMetric Motor, use the drive's DIP switches to set the peak current at twice the motor's continuous current rating, or less. Motor damage due to excessive heating may result from the combination of high peak current and improper tuning values.

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### Test Procedure

- ① Apply 120VAC power. The bicolor LED labeled **GRN = POWER ON** should be illuminated green.
- ② Command a slow move of one revolution in the clockwise direction. Verify that the motor turns as commanded.
- ③ Command a slow move of one revolution in the counterclockwise direction. Verify that the motor turns as commanded.
- ④ Test any of the optional inputs and outputs that you have connected.

You may need to tune your system before you can obtain motion from the motor. We give tuning instructions later in this chapter.

Successful completion of this procedure will verify that your controller and motor are correctly connected to the TQ10, and that the drive is functioning properly.

If the test was unsuccessful, observe the LEDs on the front panel of the TQ10 while you try the test procedure—they may indicate the cause of the problem. (*Chapter 4, Troubleshooting* has a complete description of LED functions.) Review earlier sections of this user guide, verify that you have completed each step, and try this test procedure again.

If the test is still unsuccessful, proceed to *Chapter 4, Troubleshooting* for problem identification and solution procedures.

## 9. Connect the Motor to the Load—Couplers

Your mechanical system should be as stiff as possible. Because of the high torques and accelerations of servo systems, the ideal coupling between a motor and load would be completely rigid. Rigid couplings require perfect alignment, however, which can be difficult or impossible to achieve. In real systems, some misalignment is inevitable. Therefore, a certain amount of flexibility may be required in the system. Too much flexibility can cause resonance problems, however.

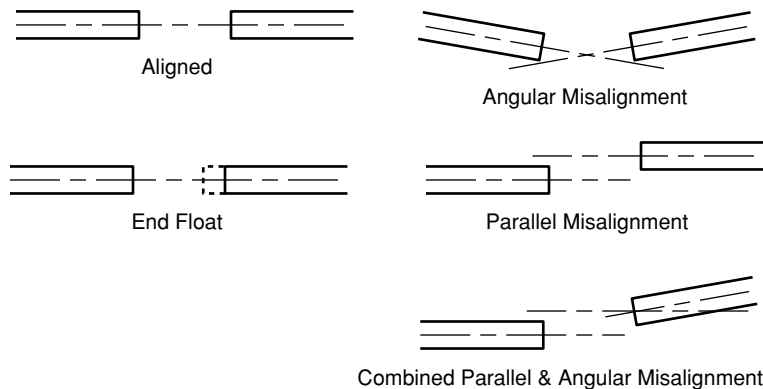
These conflicting requirements are summarized below.

- Maximum Stiffness (in the mechanical system)
- Flexibility (to accommodate misalignments)
- Minimum Resonance (to avoid oscillations)

The best design may be a compromise between these requirements.

## Misalignment & Couplers

Align the motor shaft and load as accurately as possible. In most applications, some misalignment is unavoidable, due to tolerance variations in components. However, excessive misalignment may degrade your system's performance. The three misalignment conditions, which can exist in any combination, are illustrated and described below.



### Misalignment Conditions

- Angular Misalignment: The center lines of two shafts intersect at an angle other than zero degrees.
- Parallel Misalignment: The offset of two mating shaft center lines, although the center lines remain parallel to each other.
- End Float: A change in the relative distance between the ends of two shafts.

The type of misalignment in your system will affect your choice of coupler.

### Single-Flex Coupling

Use a single-flex coupling when you have angular misalignment only. Because a single-flex coupling is like a hinge, one and only one of the shafts must be free to move in the radial direction without constraint. **Do not use a double-flex coupling in this situation:** it will allow too much freedom and the shaft will rotate eccentrically, which will cause large vibrations and catastrophic failure. **Do not use a single-flex coupling with a parallel misalignment:** this will bend the shafts, causing excessive bearing loads and premature failure.

### Double-Flex Coupling

Use a double-flex coupling whenever two shafts are joined with parallel misalignment, or a combination of angular and parallel misalignment (the most common situation).

Single-flex and double-flex couplings may or may not accept end play, depending on their design.

### Rigid Coupling

Rigid couplings are generally not recommended, because they cannot compensate for *any* misalignment. They should be used only if the motor or load is on some form of floating mounts that allow for alignment compensation. Rigid couplings can also be used when the load is supported entirely by the motor's bearings. A small mirror connected to a motor shaft is an example of such an application.

### Coupling Manufacturers

HUCO  
70 Mitchell Blvd, Suite 201  
San Rafael, CA 94903  
(415) 492-0278

ROCOM CORP.  
5957 Engineer Drive  
Huntington Beach, CA 92649  
(714) 891-9922

HELI-CAL  
P.O. Box 1460  
Santa Maria, CA 93456  
(805) 928-3851

## Resonance Issues

A coupler that is too flexible may cause a motor to overshoot its commanded position. When the encoder sends a position feedback signal, the controller will command a correction move in the opposite direction. If the resonant frequency of the system is too low (too flexible), the motor may overshoot again and again. In extreme cases, the system could become an oscillator.

To solve resonance problems, increase the mechanical stiffness of the system to raise the resonant frequency so that it no longer causes a problem.

If you use a servo as a direct replacement for a step motor, you may need to modify your mechanical coupling system to reduce resonance. For example, we recommend using a bellows-style coupler with servo motors, rather than the helical-style coupler that is often used with step motors. Helical couplers are often too flexible, with resonant frequencies that can cause problems. Bellows couplers are stiffer, and perform better in servo systems.

## Tuning – TQ10 Torque Drive

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The TQ10 Torque Drive requires no tuning adjustments. See your controller's User Guide for instructions on controller tuning adjustments.

If you use a high performance motor (peak current rating greater than three times the continuous current rating), such as Compumotor's SM and NeoMetric Series servo motors, see the *Special Considerations* section below.

### Special Considerations when Tuning with SM and N Series Motors

When using a Compumotor SM or NeoMetric Series motor, or other high performance servo motor, be careful not to overheat the motor while tuning your system. If you accidentally choose tuning gains that cause motor oscillations or instability, excess motor current can quickly overheat and damage the motor—even before the thermostat can trigger the motor overtemperature circuit.

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#### **CAUTION**

For initial tuning with an SM or NeoMetric motor, set peak current DIP switches at twice the motor's continuous rated current, or less. Otherwise, high peak currents during instability may cause motor overheating and damage.

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To avoid damage, we recommend a tuning procedure that may differ from methods you have used before. Instability sometimes *does occur* during tuning; to avoid the damaging currents that instability can cause, reduce the peak current *before* you begin the tuning process. Then, as you refine your tuning values, you can gradually increase peak current. Details of this procedure are listed below.

Because you will start with reduced peak current, at first the motor may not be able to make the move called for in your application. The best way to test the system's response under this reduced current condition is to command a short test move, and observe the results.

After you change current settings, adjust tuning gains, or command a move, closely monitor the motor. If there is any sign of uncontrolled instability, quickly disable the drive to avoid motor damage. The fastest, most reliable way to disable the drive is with a normally-closed switch connected in series with the **ENABLE IN** input.

### Tuning Procedure with SM and NeoMetric Motors:

- ① **Heatsink Your Motor:** This is especially important in temporary “bench top” procedures. SM and NeoMetric Motors dissipate excess heat through their faceplate; to ensure proper motor cooling, the faceplate must be mounted to a heatsink.
- ② **Reduce Peak Current:** Using the drive’s DIP switches, set the peak current at a level that is less than twice the motor’s continuous current rating: Following the dipswitch settings illustrated on the back cover will do this.
  - 4.4 amps for SM motors with **-A** windings
  - 7.4 amps for SM motors with **-B** windings, N0921F
  - 6.0 amps for N0701D and N0702E motors
  - 8.9 amps for N0702F, N0701F, N0703F, N0704F
  - 10.0 amps for N0703G, N0704G, N0921G, N0922G
- ③ **Select Tuning Gains:** Starting with low tuning gains (proportional gain at zero, or very low), test your system’s response. Adjust the gains until you achieve a satisfactory response and settling time. Use aggressive gains only when necessary; they are likely to cause the system to become unstable. Before proceeding to the next step, ensure that the system is stable.
- ④ **Try Your Application’s Move:** To see if current and gain settings are adequate for your system, try your actual move (rather than the test move). If the move is successful and your motion requirements are satisfied, you do not need to increase peak current any higher—tuning is complete. Proceed to *Step 7* below.

If the move is not successful, proceed to *Step 5*.
- ⑤ **Increase Peak Current:** Using the DIP switches, increase peak current to: 6.0 amps for SM motors with A windings; 10.0 amps for all other motors. Do not exceed your motor’s peak current rating, or three times its continuous current rating, whichever is lower.
- ⑥ **Repeat Steps 3, 4:** Continue repeating *Steps 3 – 4* until you achieve performance satisfactory for your application. Use only enough peak current to satisfy your motion requirements—not every application requires maximum peak current.
- ⑦ **Verify Thermal Stability:** Run your application for at least four thermal time constants to ensure that the motor stabilizes at an acceptable temperature.

**Example:** An SM232A motor’s current ratings are 2.1A continuous, 6.3A peak; its thermal time constant is 35 minutes. The motor is to be used in an application that requires 95% peak torque; required peak current is therefore  $(6.3A \cdot 0.95) = 6A$ .

**Step 1:** Start with peak current DIP switches set for 4.4A. Determine a set of initial tuning gains that is stable. If at any time the system becomes unstable, disable the drive immediately.

**Step 2:** Try the application’s move. If the application’s motion requirements are satisfied, go to *Step 4*, below

**Step 3:** If necessary, increase peak current to 6.0A and determine the final set of tuning gains. Verify that the application’s motion requirements are satisfied.

**Step 4:** Run the application for at least 4 thermal time constants (140 minutes) to ensure that the motor stabilizes at an acceptable temperature.

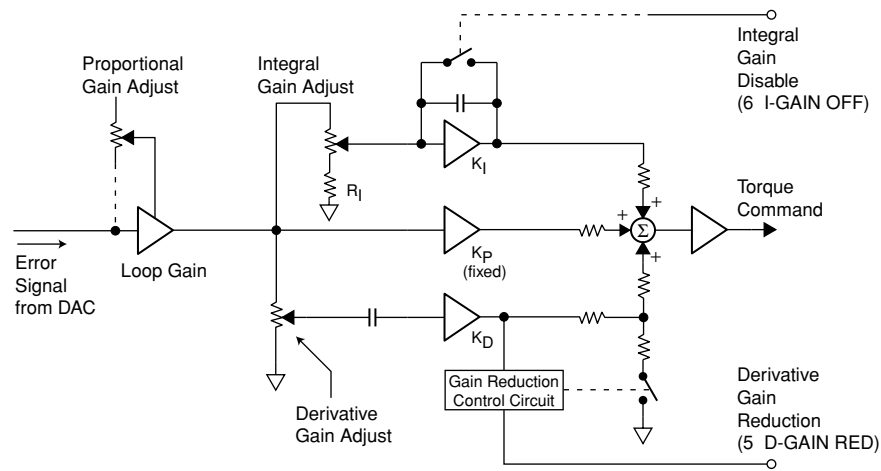
## Tuning – TQ10SD Step & Direction Drive

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You must tune the TQ10SD’s internal *Proportional Integral Derivative* (PID) servo control loop for optimum system performance. A properly tuned system will exhibit smooth motor rotation, accurate tracking, and fast settling time.

### Tuning Theory

The TQ10SD generates a move profile based upon step and direction signals from the indexer. Incoming steps represent *commanded position*, and go to a summing node. Incoming encoder counts represent *actual position*, and also go to the summing node. During a typical move, actual position will differ from commanded position by at least a few encoder counts. At the summing node, actual position is subtracted from commanded position—the resulting difference is the *position error*, which is converted into an analog voltage. This analog error signal is the input to the PID control loop, whose block diagram is shown below.



*PID Control Loop – Block Diagram*

You can adjust three potentiometers to tune the PID loop. These potentiometers control the settings for proportional gain, integral gain, and derivative gain. You can also make two other adjustments: you can connect the terminal labeled **D-GAIN RED** to ground, to reduce derivative gain; and you can connect the terminal labeled **I-GAIN OFF** to ground, to disable integral gain.

These five tuning parameters are described in the next sections.

## Proportional Gain

Proportional gain provides a torque that is directly proportional to the *magnitude* of the error signal. Proportional gain is similar to a spring—the larger the error, the larger the restoring force. It determines the stiffness of the system and affects the following error. High proportional gain gives a stiff, responsive system, but can result in overshoot and oscillation. Damping—provided by derivative gain—can reduce this overshoot and oscillation.

Notice from the block diagram that adjusting proportional gain affects the loop gain. This means that integral gain and derivative gain are both affected by changes in the proportional gain tuning potentiometer. This arrangement simplifies tuning; once you set the integral and derivative gains in the correct ratio to proportional gain, you only need to adjust proportional gain—integral and derivative gain will follow.

## Derivative Gain

Derivative gain provides a torque that is directly proportional to the *rate of change* of the error signal. When the error's instantaneous rate of change, or *derivative*, increases, derivative gain also increases. Derivative gain opposes rapid changes in velocity. It will dampen the resonance effects of proportional gain. With higher derivative gain, you can use higher proportional gain.

## Derivative Gain Reduction

Many applications require high derivative gain for proper performance. High derivative gain, however, can cause jitter and audible noise at the shaft when the motor is at rest. Many applications have enough “stiction” so that high derivative gain is not necessary for stability when the system is at rest. If your application must hold position with minimum jitter or noise, connect a wire from the terminal labeled **D-GAIN RED** to ground (see the *Inputs and Outputs* section earlier in this chapter). With this terminal grounded, the drive will gradually reduce derivative gain to a low value whenever motion stops. When motion starts again, or if the motor shaft moves, the drive will instantly increase derivative gain to the value set by the tuning potentiometer.

## Integral Gain

Integral gain provides a torque that is directly proportional to the sum, over time, of the error signal—the *integral* of the error. If the error persists, integral gain provides a restoring force that grows larger with time. Integral gain can remove steady state errors that are due to gravity or a constant static torque. It can also correct velocity lag and following error in a constant velocity system.

Too much integral gain can cause overshoot during acceleration and deceleration; this overshoot will increase settling time. You should use only as much integral gain as your application requires. If your application does not need any, you should disable it (see below).

## Integral Gain Disable

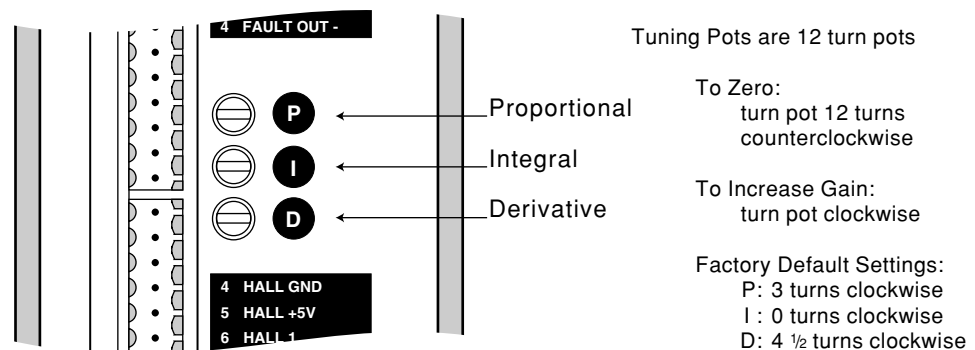
You can *permanently* disable integral gain by connecting a wire from the terminal labeled **I-GAIN OFF** to ground. Notice on the block diagram that even if you zero the integral gain potentiometer, integral gain is not reduced to zero, just to a lower value. There will still be integral gain in the system (because of voltage on resistor  $R_I$ ). The only way you can eliminate integral gain is to ground **I-GAIN OFF**.

You can use a control signal to *temporarily* disable integral gain, by connecting **I-GAIN OFF** to ground only during acceleration and deceleration. This will disable integral gain during those parts of the move, which should decrease overshoot and settling time. When the system reaches constant velocity or comes to rest, use your control signal to break the ground connection, which will re-enable integral gain.

## Tuning Procedure

In the procedure given below, you will systematically vary the tuning potentiometers until you achieve a move that meets your requirements for accuracy and response time.

You can adjust the potentiometers through three holes in the drive's front cover. Use the plastic adjustment tool supplied with the TQ10SD to make adjustments. Turn the potentiometers clockwise to increase the gains.



*Tuning Potentiometer Locations*

## Special Considerations when Tuning with SM and NeoMetric Motors

If you use a high performance motor (peak current rating greater than three times the continuous current rating), such as a Compumotor SM or NeoMetric Series motor, be careful not to overheat the motor while tuning your system. If you accidentally choose tuning gains that cause motor instability, excess motor current can quickly overheat and damage the motor—even before the thermostat can trigger the motor overtemperature circuit.

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### CAUTION

For initial tuning with an SM or NeoMetric motor, set peak current DIP switches at twice the motor's continuous rated current, or less. Otherwise, high peak currents during instability may cause motor overheating and damage.

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To avoid damage, we recommend a tuning procedure that may differ from methods you have used before. Instability sometimes *does occur* during tuning; to avoid the damaging currents that instability can cause, reduce the peak current *before* you begin the tuning process. Then, as you refine your tuning values, you can gradually increase peak current. These steps are included in the tuning procedure described below.

## Preparing the System for Tuning

Before applying power and tuning the drive, complete the following steps.

### Setup Procedure:

- ① **Heatsink your motor:** This is especially important in temporary “bench top” procedures. SM Motors dissipate excess heat through their faceplate; to ensure proper motor cooling, the faceplate must be mounted to a heatsink.
- ② **Disable Integral Gain (optional):** If you do not need integral gain in your application, connect a wire from **I-GAIN OFF** to ground; this will permanently disable integral gain. If you intend to use integral gain, tuning will be simplified if you disable it now, and re-enable it in *Step 6* of the tuning procedure.
- ③ **Set up the Velocity Monitor (optional):** Connect an oscilloscope to the velocity monitor output, as described earlier in the *Inputs and Outputs* section. Its use is optional—however, because the velocity monitor clearly shows your system's response when you adjust the potentiometers, we recommend using it.
- ④ **Set Potentiometers to their Default Values:** The tuning potentiometers were set at default values when the TQ10SD shipped from the factory. If yours is a new unit, skip this step and proceed to Step 5. Otherwise, follow this procedure to return the settings to their default values:
  1. Turn each potentiometer 12 turns counterclockwise to zero it.
  2. Turn the proportional gain potentiometer 3 turns clockwise.
  3. Leave the integral gain potentiometer at zero.
  4. Turn the derivative gain potentiometer 4½ turns clockwise.

These settings will provide a stable but “mushy” response with most motors and light loads.

- ⑤ **Reduce peak current:** Using the drive's DIP switches, set the peak current at a level that is less than twice the motor's continuous current rating.
  - 4.4 amps for SM motors with **-A** windings
  - 7.4 amps for SM motors with **-B** windings, N0921F
  - 6.0 amps for N0701D and N0702E motors
  - 8.9 amps for N0702F, N0701F, N0703F, N0704F
  - 10.0 amps for N0703G, N0704G, N0921G, N0922G

## Tuning the System

You will test your system's response as you vary the tuning gains in the procedure below. Because you will start with reduced peak current, the motor may not be able to make the move called for in your application. The best way to test the system's response under this reduced current condition is to command a short test move, and observe the results.

After you change current settings, adjust a potentiometer, or command a move, closely monitor the motor. If there is any sign of uncontrolled instability, quickly disable the drive to avoid motor damage. The fastest, most reliable way to disable the drive is with a normally-closed switch connected in series with the **ENABLE IN** input.

### Tuning Procedure:

① **Increase Proportional Gain:** Apply power to the drive. Slowly increase proportional gain by turning the potentiometer clockwise, as you test your system's response with short test moves. As soon as you notice instability in the motor (as evidenced by ringing, excessive overshoot, jitter or audible noise), immediately **decrease** the gain until the system returns to stability (at least  $\frac{1}{2}$  turn counterclockwise).

② **Increase Derivative Gain:** As you continue to test your system's response, slowly increase derivative gain by turning the potentiometer clockwise. With increased derivative gain, you should see an improvement in settling time. As soon as you notice instability in the motor (as evidenced by ringing, excessive overshoot, jitter or audible noise), immediately **decrease** the gain until the system returns to stability (at least  $\frac{1}{2}$  turn counterclockwise).

With the damping provided from higher derivative gain, you can now return to Step 1 and increase proportional gain. After doing so, proceed to *Step 3*.

③ **Try Your Application's Move:** To see if current and gain settings are adequate for your system, try your actual move. If the move is successful and your motion requirements are satisfied, you do not need to increase peak current any higher—you may proceed to *Step 6*.

If the move is not successful, proceed to *Step 4*, in which you will increase peak current.

④ **Increase peak current:** Using the DIP switches, increase peak current to: 6.0 amps for SM motors with A windings; 10.0 amps for all other motors. Do not exceed your motor's peak current rating, or three times its continuous current rating, whichever is lower. Closely monitor the motor immediately after you increase peak current. Be prepared to disable the drive, or quickly reduce proportional gain, should the motor exhibit any signs of instability.

You can change the DIP switches with power applied—the drive will immediately sense the new current setting. For safety reasons, however, we recommend removing power from the drive before changing the DIP switches.

⑤ **Repeat Steps 1 – 3:** With higher peak current, you can now increase the proportional and derivative gain settings. Continue repeating *Steps 1 – 3* until you achieve satisfactory performance.

Note: you may not need to readjust derivative gain (see *Step 2*); adjusting proportional gain may be sufficient. Because of the drive design, the derivative setting will automatically track the proportional setting.

⑥ **Adjust Integral Gain:** If you intend to use integral gain, adjust it now. Set it to the lowest value that will correct following errors and static position errors, but not increase overshoot or settling time. Adjusting integral gain may require you to readjust the derivative and integral gain potentiometers. In a system without static torque loading, you may wish to disable integral gain entirely. This is done by grounding the integral gain disable pin.

⑦ **Verify Thermal Stability:** Run your application for at least 4 thermal time constants to ensure that the motor stabilizes at an acceptable temperature.

This completes the tuning procedure.