CHAPTER TWO

Installation

IN THIS CHAPTER

- ❑ Inspect the shipment
- ❑ Configure DIP switches
- ❑ Mount the APEX Drive and motor.
- ❑ Connect resolver, motor, and controller cables.
- ❑ Tune the system

INSTALLATION OVERVIEW

This chapter contains information you need to install your APEX Drive. Sections in the chapter are presented in the following order:

- Inspect the Shipment
- Set DIP Switches
- Mount the Drive
- Mount the Motor
- Connect the Resolver Cable
- Connect the Motor Cable
- Connect AC Power
- Adjust the Offset Balance potentiometer
- Connect the Drive to the Controller
- Connect the Encoder to the Controller
- Test the System—read the encoder, and turn the motor
- Connect the Motor to the Load
- Tune the System

To install your drive, complete each section in the order presented.

INSPECT THE SHIPMENT

Inspect your APEX shipment for obvious damage to its shipping container. Report any damage to the shipping company as soon as possible. Parker Compumotor cannot be held responsible for damage incurred in shipment. The items below should be present and in good condition. See Appendix A for APEX Motor Options/Accessories.

Part				**Part Number**
APEX10 Analog Servo Drive				APEX10
APEX20 Analog Servo Drive				APEX20
APEX40 Analog Servo Drive				APEX40
Ship kit:	8-pin Plug	(motor conn.)	(one included)	43-014533-01
	7-pin Plug	(AC input)	(one included)	43-013575-01
	7-pin Plug	(I/O)	(one included)	43-013801-01
	13-pin Plug	(I/O)	(two included)	43-013802-01
	Jumper Wires		(two included)	71-015237-01
	User Guide			88-013904-02

Options/Accessories		**Part Number**
SM Series Motor:	(motor with resolver)	SM-231AR SM-232AR SM-233BR
Resolver Cable:	(SM-23_R motors)	71-015870-xx
Resolver Hi-Flex:	(SM-23_R motors)	71-016374-yy
Motor Cable:	(SM-23_R motors)	71-014675-yy
Motor Hi-Flex:	(SM-23_R motors)	71-016023-yy
Cable Kit:	(Resolver & MotorCables for SM-23)	23RS CABLE-xx:

Options/Accessories *(continued)*		Part Number
NeoMetric Motors:	(motors with resolver)	N0701-R, N0341-R
		N0702-R, N0342-R
		N0703-R, N0343-R
		N0704-R, N0344-R
		N0921-R, N0922-R
		N0923-R, N0924-R
J-Series Motors:	(motors with resolver)	J0701_R, J0341_R
		J0702_R, J0342_R
		J0703_R, J0343_R
		J0921_R, J0922_R
		J0923_R
Resolver Cable:	(NeoMetric & J-Series Motors)	71-015870-xx
Resolver Hi-Flex:	(NeoMetric & J-Series Motors)	71-016374-yy
Motor Cable:	(NeoMetric & J-Series 70mm & 34-frame)	71-015531-xx
	(NeoMetric & J-Series 92mm)	71-015532-xx
Motor Hi-Flex:	(NeoMetric & J-Series 70mm & 34-frame)	71-016529-yy
	(NeoMetric & J-Series 92mm)	71-016530-yy
Cable Kit:	(Resolver & Motor for 70mm & 34-frame)	70RS CABLE-xx
	(Resolver & Motor for 92mm)	92RS CABLE-xx

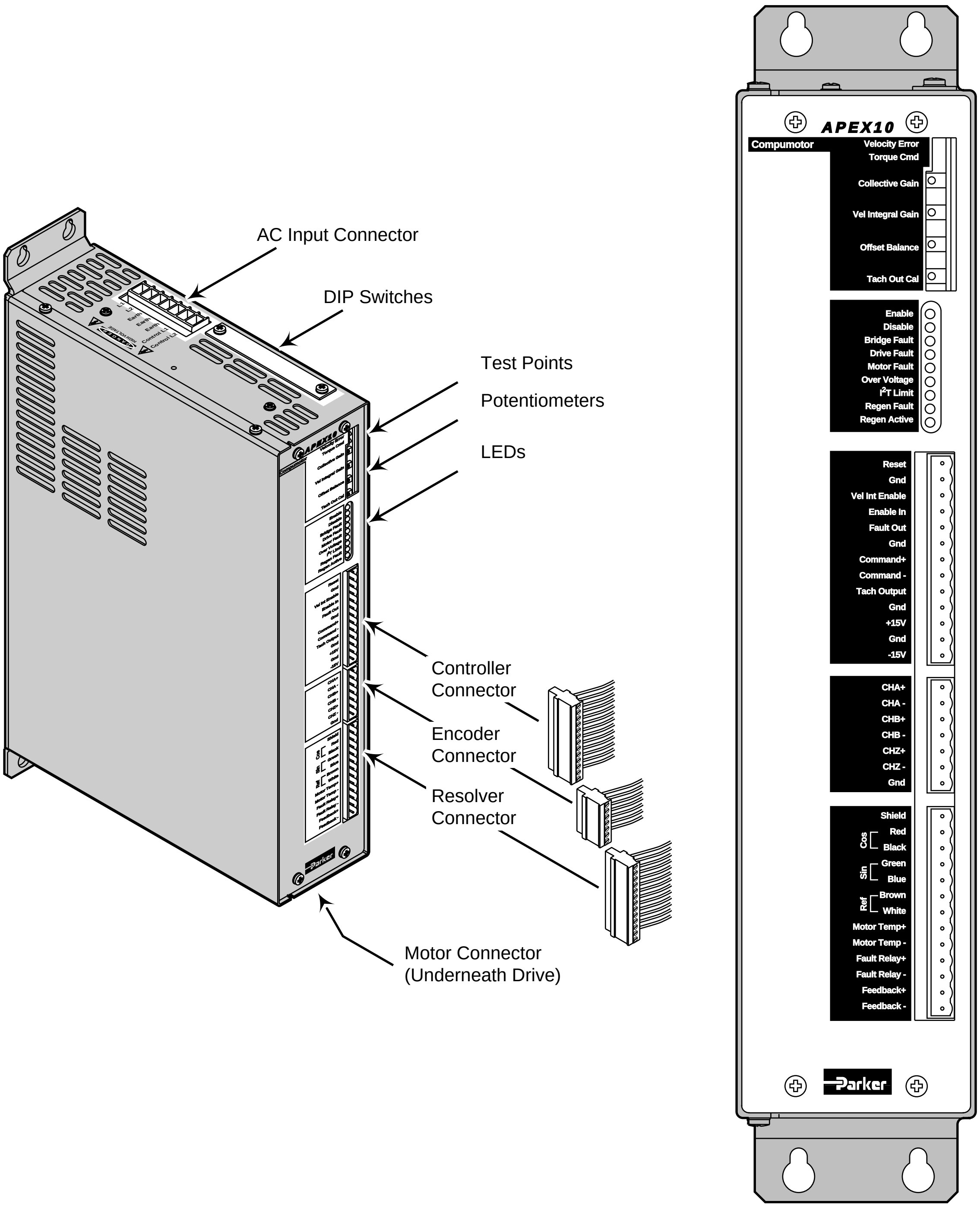
xx can be 10, 25, 35, 40 or 50 feet
yy can be 10, 25, 35 or 50 feet

APEX Drive – Component Locations

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

Illustrations in this User Guide

We will usually show the APEX10 Drive in the illustrations for this user guide. The APEX20 and APEX40 Drives have similar features.



Component Locations

BENCH TEST – GETTING STARTED QUICKLY

To familiarize yourself with the APEX Drive, you may wish to perform a *bench test* before you permanently install the drive. To do so, read this installation chapter, and perform the procedures that are necessary to produce motion:

- Set DIP Switches
- Connect the Resolver Cable
- Connect the Motor Cable
- Connect AC Power
- Adjust the Offset Balance potentiometer
- Connect the Drive to the Controller
- Connect the Encoder to the Controller
- Test the system—read the encoder, and turn the motor

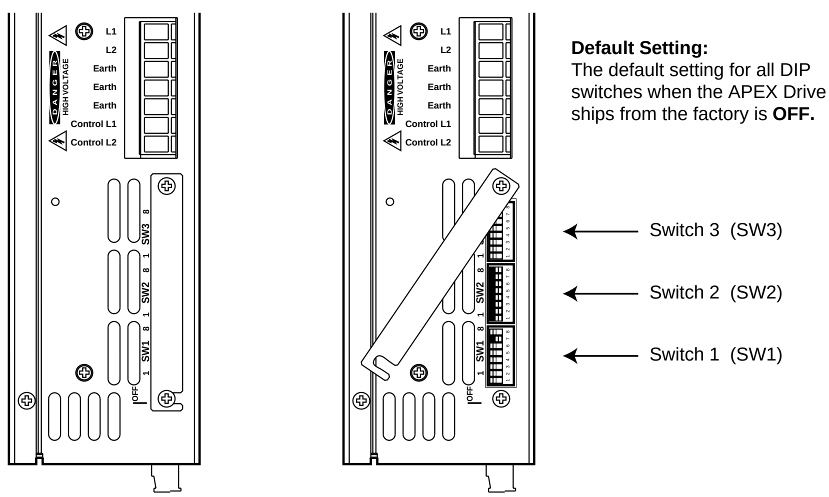
Read, but do not perform, permanent installation procedures:

- Mount the Drive
- Mount the Motor
- Connect the Motor to the Load
- Tune the System

When you are ready to permanently install your drive, you can complete these last four procedures.

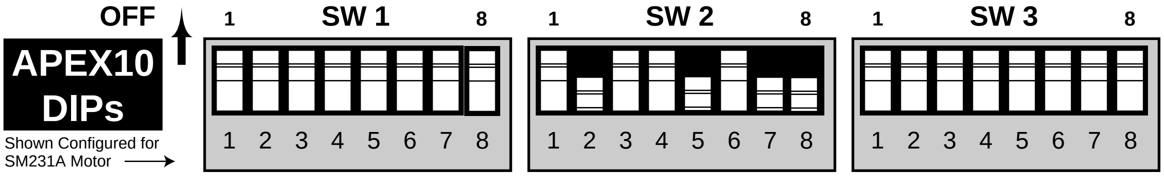
CONFIGURE THE APEX DRIVE'S DIP SWITCHES

The APEX Drive has three 8-position DIP switches, located behind a small access cover on top of the drive. Loosen the two screws that hold the access cover. Rotate the cover to expose the DIP switches.



DIP Switch Location, with Cover Closed and Open

Set the switches to configure the drive for your application. The drive ships from the factory with all switches in the OFF position. Use a small screwdriver to set each switch. Tables on the next pages summarize switch settings for APEX10, APEX20, and APEX40 Drives. Small diagrams on the following pages show how to configure the drive for each SM or NeoMetric motor that we recommend for use with that drive. Instructions for setting each switch follow the tables. See *Appendix A* for APEX Motor Settings.



SW 1

	1
REGEN FAULT	
Enable	OFF
Disable	ON

Setting	2
HALL DEGREES	
120∞ Hall motor	OFF
60∞ Hall motor	ON

Setting	3
RESERVED	
Off	OFF

	4	5
POLE PAIR NUMBER		
2	OFF	OFF
3	OFF	ON
Reserved	ON	OFF
Reserved	ON	ON

	6
RESOLVER SPEED	
1	OFF
2	ON

CURRENT LOOP COMPENSATION (motor inductance) with 120VAC Input:	with 240VAC Input:	7	8
1 – 2 mH	Not Applicable	OFF	OFF
2 – 5 mH	5 – 20 mH	OFF	ON
5 – 60 mH	20 – 60 mH	ON	OFF
Reserved		ON	ON

SW 2

CONTINUOUS CURRENT (peak of sine wave)	1	2	3
1.8 amps	OFF	OFF	OFF
2.6	OFF	OFF	ON
3.4	OFF	ON	OFF
4.0	OFF	ON	ON
5.0	ON	OFF	OFF
6.0	ON	OFF	ON
7.0	ON	ON	OFF
8.0	ON	ON	ON

PEAK CURRENT	4	5	6
6.5 amps	OFF	OFF	OFF
7.5	OFF	OFF	ON
9.5	OFF	ON	OFF
11.0	OFF	ON	ON
12.5	ON	OFF	OFF
14.0	ON	OFF	ON
15.0	ON	ON	OFF
16.0	ON	ON	ON

MOTOR THERMAL TIME CONSTANT	7	8
2 minutes	OFF	OFF
4	OFF	ON
8	ON	OFF
10	ON	ON

SW 3

	1
VELOCITY INTEGRATOR	
No	OFF
Yes	ON

Setting	2
ALIGNMENT MODE	
No	OFF
Yes	ON

Setting	3
COMMUTATION TEST MODE	
No	OFF
Yes	ON

Setting	4
HALL SELECT	
Resolver Mode	OFF
Hall Mode	ON

	5
TACH SCALING	
One speed resolver (1V = 1,000 RPM with a one speed resolver)	OFF
Two speed resolver (1V = 1,000 RPM with a two speed resolver)	ON

COMMAND INPUT SCALING	6	7
10V = 16.0 amps	OFF	OFF
10V = 12.0 amps	OFF	ON
10V = 8.0 amps	ON	OFF
10V = 7.0 amps	ON	ON

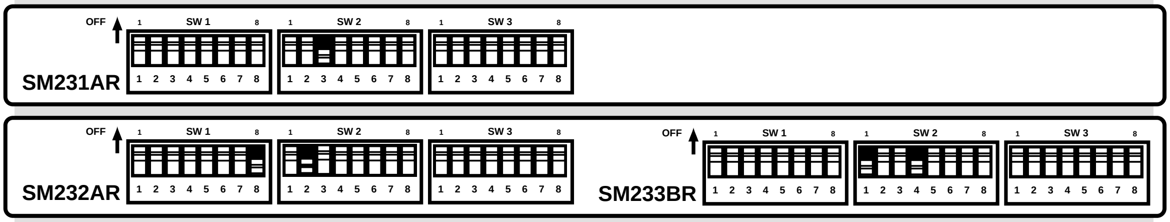
	8
COLLECTIVE GAIN	
Off	OFF
On	ON

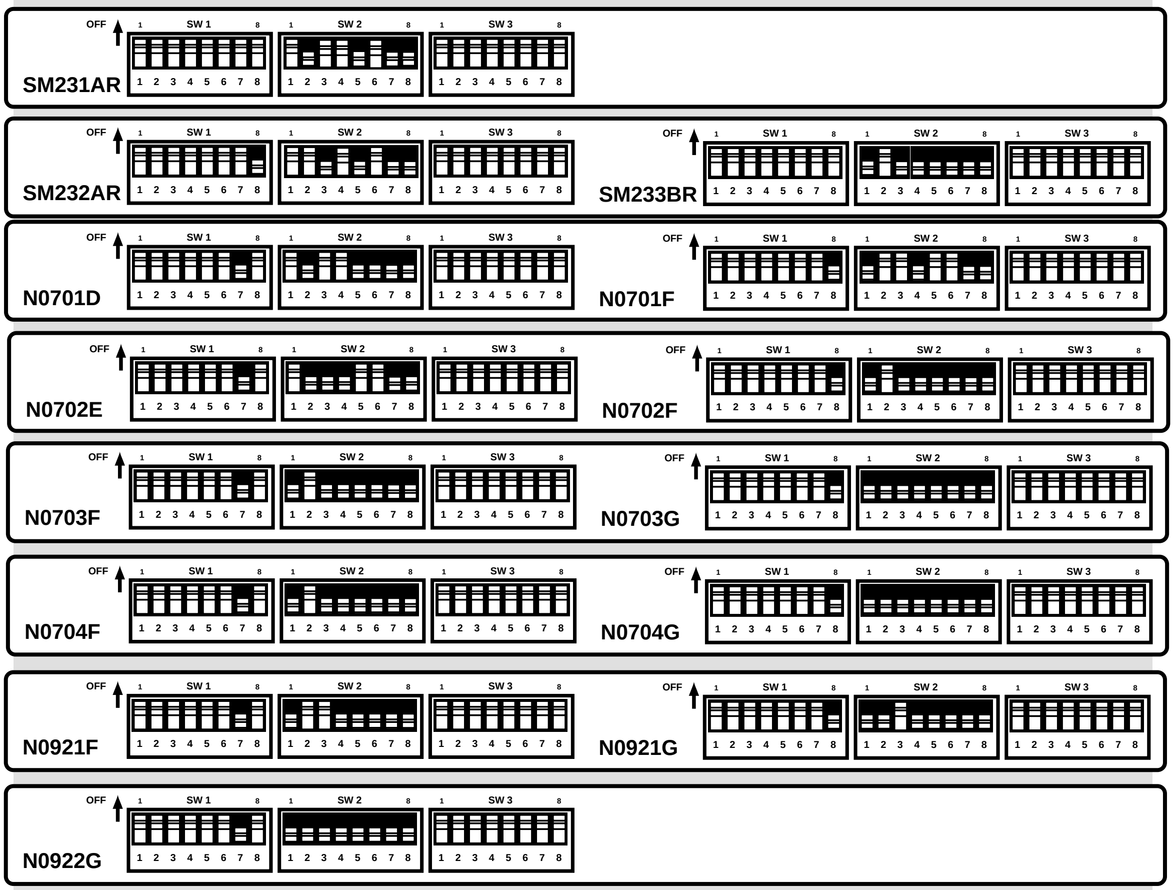
Note: $\sqrt{2}\,A_{rms}$ will give Amps per phase

APEX10
DIP SWITCH SETTINGS

OFF ↑

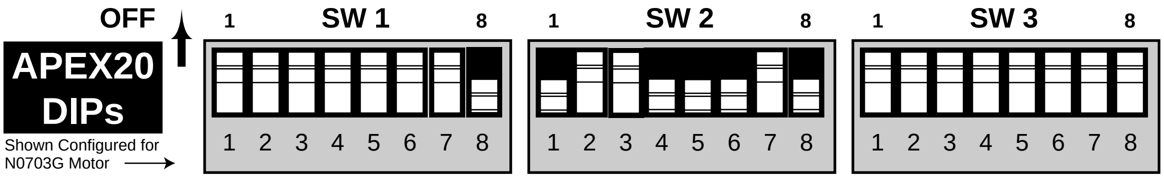
Initial Values for Tuning





These settings are valid for APEX10 units with serial numbers greater than: 9702700070. Call Compumotor's Applications Department for settings prior to this serial number.

See Appendix A for APEX Motor Settings.



SW 1

REGEN FAULT	1
Enable	OFF
Disable	ON

HALL DEGREES	2
120° Hall motor	OFF
60° Hall motor	ON

RESERVED	3
Off	OFF

POLE PAIR NUMBER	4	5
2	OFF	OFF
3	OFF	ON
Reserved	ON	OFF
Reserved	ON	ON

RESOLVER SPEED	6
1	OFF
2	ON

CURRENT LOOP COMPENSATION (motor inductance)	7	8
20 mH – 50 mH	OFF	OFF
4 mH – 10 mH	OFF	ON
10 mH – 20 mH	ON	OFF
Reserved	ON	ON

SW 2

CONTINUOUS CURRENT (peak of sine wave)	1	2	3
3.0 amps	OFF	OFF	OFF
4.2	OFF	OFF	ON
5.4	OFF	ON	OFF
6.6	OFF	ON	ON
7.8	ON	OFF	OFF
9.0	ON	OFF	ON
10.2	ON	ON	OFF
12.0	ON	ON	ON

PEAK CURRENT	4	5	6
9.0 amps	OFF	OFF	OFF
10.8	OFF	OFF	ON
13.2	OFF	ON	OFF
15.0	OFF	ON	ON
17.4	ON	OFF	OFF
19.2	ON	OFF	ON
21.6	ON	ON	OFF
24.0	ON	ON	ON

MOTOR THERMAL TIME CONSTANT	7	8
10 minutes	OFF	OFF
20	OFF	ON
30	ON	OFF
40	ON	ON

SW 3

VELOCITY INTEGRATOR	1
No	OFF
Yes	ON

ALIGNMENT MODE	2
No	OFF
Yes	ON

COMMUTATION TEST MODE	3
No	OFF
Yes	ON

HALL SELECT	4
Resolver Mode	OFF
Hall Mode	ON

TACH SCALING	5
One speed resolver (1V = 1,000 RPM with a one speed resolver)	OFF
Two speed resolver (1V = 1,000 RPM with a two speed resolver)	ON

COMMAND INPUT SCALING	6	7
10V = 24.0 amps	OFF	OFF
10V = 19.2 amps	OFF	ON
10V = 14.4 amps	ON	OFF
10V = 13.2 amps	ON	ON

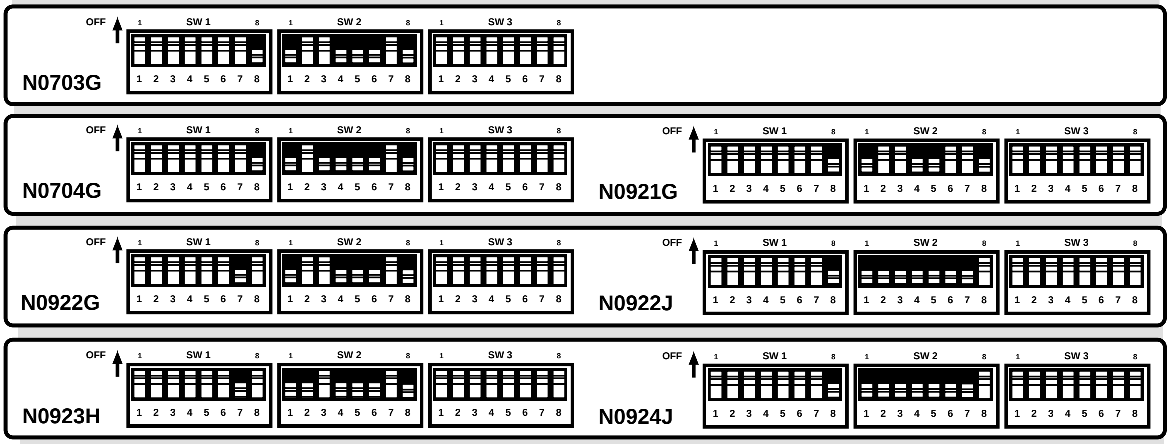
COLLECTIVE GAIN	8
Off	OFF
On	ON

Note: $\sqrt{2}\,A_{rms}$ will give Amps per phase

APEX20
DIP SWITCH SETTINGS

OFF ↑

Use these settings for your final configuration

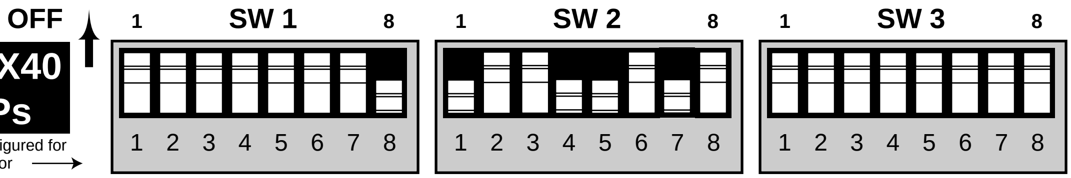


These settings are valid for APEX20 units with serial numbers greater than: 97073000109. Call Compumotor's Applications Department for settings prior to this serial number.

See Appendix A for APEX Motor Settings.

APEX40 DIPs

Shown Configured for N0922J Motor



SW 1

REGEN FAULT	1
Enable	OFF
Disable	ON

HALL DEGREES	2
120° Hall motor	OFF
60° Hall motor	ON

RESERVED	3
Off	OFF

POLE PAIR NUMBER	4	5
2	OFF	OFF
3	OFF	ON
Reserved	ON	OFF
Reserved	ON	ON

RESOLVER SPEED	6
1	OFF
2	ON

CURRENT LOOP COMPENSATION (motor inductance)	7	8
20 mH – 50 mH	OFF	OFF
4 mH – 10 mH	OFF	ON
10 mH – 20 mH	ON	OFF
Reserved	ON	ON

SW 2

CONTINUOUS CURRENT (peak of sine wave)	1	2	3
5.0 amps	OFF	OFF	OFF
7.0	OFF	OFF	ON
9.0	OFF	ON	OFF
11.0	OFF	ON	ON
13.0	ON	OFF	OFF
15.0	ON	OFF	ON
17.0	ON	ON	OFF
20.0	ON	ON	ON

PEAK CURRENT	4	5	6
15.0 amps	OFF	OFF	OFF
18.0	OFF	OFF	ON
22.0	OFF	ON	OFF
25.0	OFF	ON	ON
29.0	ON	OFF	OFF
32.0	ON	OFF	ON
36.0	ON	ON	OFF
40.0	ON	ON	ON

MOTOR THERMAL TIME CONSTANT	7	8
10 minutes	OFF	OFF
20	OFF	ON
30	ON	OFF
40	ON	ON

SW 3

VELOCITY INTEGRATOR	1
No	OFF
Yes	ON

ALIGNMENT MODE	2
No	OFF
Yes	ON

COMMUTATION TEST MODE	3
No	OFF
Yes	ON

HALL SELECT	4
Resolver Mode	OFF
Hall Mode	ON

TACH SCALING	5
One speed resolver (1V = 1,000 RPM with a one speed resolver)	OFF
Two speed resolver (1V = 1,000 RPM with a two speed resolver)	ON

COMMAND INPUT SCALING	6	7
10V = 40.0 amps	OFF	OFF
10V = 32.0 amps	OFF	ON
10V = 25.0 amps	ON	OFF
10v = 22.0 amps	ON	ON

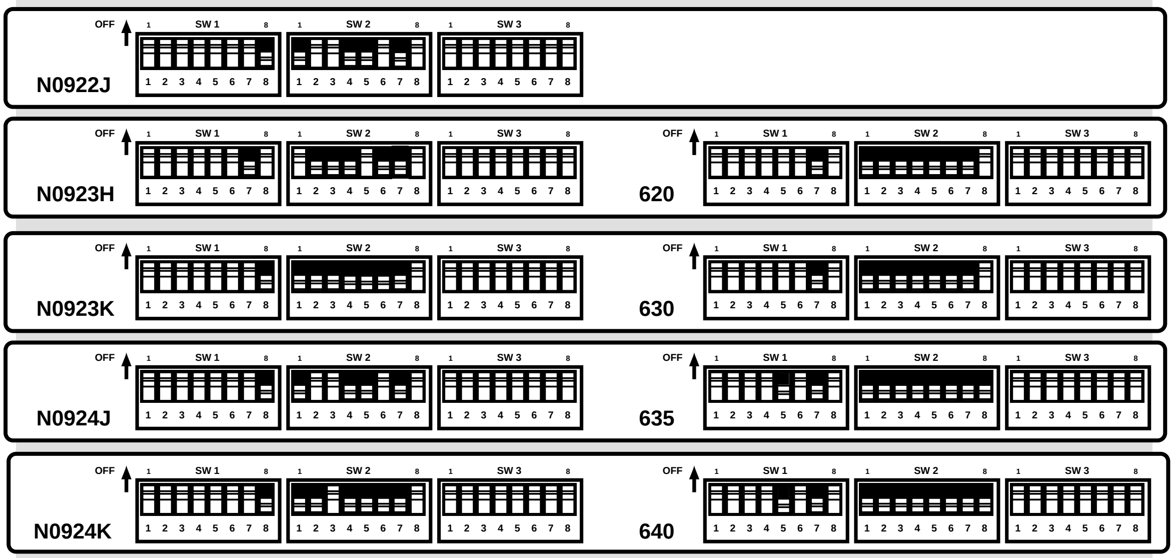
COLLECTIVE GAIN	8
Off	OFF
On	ON

Note: $\sqrt{2}\,A_{rms}$ will give Amps per phase

APEX40
DIP SWITCH SETTINGS

OFF ↑

Use these settings for your final configuration



These settings are valid for APEX40 units with serial numbers greater than: 97073000109. Call Compumotor's Applications Department for settings prior to this serial number.

See Appendix A for APEX Motor Settings.

SWITCH 1 (SW1)

Regen Fault (position #1): Set this switch in the OFF position for normal operation of the APEX Drive's *internal* regeneration circuit. For most applications, this switch should be OFF. If you construct your own *external* regeneration circuit, set this switch ON to disable the APEX Drive's regeneration fault. For more information, see the discussion of regeneration in *Chapter 3 Special Features*.

Hall Sensor Degrees (position #2): Set this switch in the OFF position if you use a motor with a resolver, or with 120° Hall effect sensors. Set this switch in the ON position if you use a motor with 60° Hall effect sensors.

Reserved (position #3): Set this switch in the OFF position.

Motor Pole Pair Number (position #4, #5): Set these two switches according to the number of pole pairs your motor has. All APEX, SM and NeoMetric motors have two pole pairs (four poles), except the APEX635 and APEX640, which have three pole pairs (six poles).

Resolver Speed (position #6): For a motor with a single speed resolver, turn this switch OFF. This switch should be OFF for APEX, SM Series or NeoMetric motors, which have single-speed resolvers. For a motor with a two-speed resolver, turn this switch ON.

Current Loop Compensation (position #7, #8): These two switches control the dynamics of the APEX Drive's current feedback loop. Use these switches to match the drive's performance to your particular motor's characteristics. For APEX, SM and NeoMetric motors, set the switches according to the preceding dip switch tables. If you use a motor from another vendor, call Compumotor's Applications Department for instructions on setting these two DIP switches for your motor. (The toll-free telephone number is listed on the inside front cover of this manual.)

SWITCH 2 (SW2)

Continuous Current (position #1, #2, #3): If the APEX Drive goes into current foldback, it reduces its output current down to the continuous current level set by these three switches. For APEX, SM and NeoMetric motors, set the switches according to the preceding tables.

Peak Current (position #4, #5, #6): These three switches set the peak current that the APEX Drive will produce. For APEX, SM and NeoMetric motors, set the switches according to the preceding tables.

CAUTION

If you use an SM Motor, set the drive's DIP switches at the lowest peak current level for initial drive tuning. Motor damage due to excessive heating may result from high peak currents and improper tuning values.

Maximum peak current for SM and NeoMetric motors can be three times higher than the continuous current rating. If the motor oscillates during your tuning procedure, high peak current may cause overheating and damage the motor. When you tune your system, therefore, we recommend that you start with the lowest value for peak current. As you tune the drive and refine your gains, you can raise the peak current level. See *Tuning* at the end of this chapter for more details.

Time Constant (position #7, #8): These two switches set the motor thermal time constant, which the foldback circuit uses to estimate motor behavior. Consult your motor specifications to determine your motor's thermal time constant. The DIP switch tables show switch settings for time constants of 2, 4, 8, and 10 for the APEX10 and 10, 20, 30, and 40 for the APEX20 and APEX40. For APEX, SM and NeoMetric motors, set the switches according to the tables.

The time constant is ***NOT*** the time until foldback occurs. It is a parameter based upon the motor's physical characteristics, with the motor mounted to a suitable heatsink. For a full explanation of the foldback circuit, including the time constant, see *Chapter 3 Special Features*.

SWITCH 3 (SW 3)

Velocity Integrator (position #1): This switch controls the velocity integrator. Set the switch according to how you plan to operate the drive:

If you use the drive in:		SW
Torque Mode	(do not use the velocity integrator)	OFF
Velocity Mode	if you do not intend to use the velocity integrator	OFF
	if you intend to use the velocity integrator	ON

See *Tuning* at the end of this chapter for more information about the velocity integrator feature.

Alignment Mode (position #2): Turn this switch OFF. If you need to align the resolver, you will turn this switch ON during the alignment procedure, and turn it OFF when you have finished aligning the resolver. This switch must be OFF during normal operating conditions. See *Chapter 3 Special Features* for more information.

Commutation Test Mode (position #3): Turn this switch OFF. If you need to operate the drive in commutation test mode during a trouble-shooting procedure, you will turn this switch ON during the procedure, and turn it OFF when you are finished. This switch must be OFF during normal operating conditions. *See Chapter 5 Troubleshooting* for more information.

Hall Select (position #4): Turn this switch OFF if your motor has a resolver. This switch should be OFF for APEX, SM and NeoMetric Series servo motors, which have resolvers. Turn this switch ON if your motor has Hall effect sensors instead of a resolver.

Tachometer Scaling (position #5): This switch scales the drive's tachometer output. If you use a motor that has a single speed resolver, turn this switch OFF to scale the tachometer output to equal 1 volt per 1,000 rpm. This switch should be OFF for APEX, SM or NeoMetric Series servo motors, which have single-speed resolvers. If you use a motor that has a two-speed resolver, turn this switch ON. This will adjust gains of the internal circuitry, so that the tachometer output is scaled to equal 1 volt per 1,000 rpm for two speed resolvers.

Command Input Scaling (position #6, #7): Use these two switches to scale the relationship (full-scale) between command input voltage and motor output current. For full current, with a 10V input corresponding to maximum peak output current, both switches should be OFF. Set the switches according to the preceding DIP switch tables for other currents.

Collective Gain (position #8): This switch controls the collective gain function. Set the switch according to how you plan to operate the drive:

If you use the drive in:		SW
Torque Mode	collective gain is not used in torque mode	OFF
Velocity Mode	collective gain is used in velocity mode	ON

See *Tuning* later in this chapter for more information about collective gain.

Mount the APEX Drive

The APEX Drive should be installed in an enclosure that will protect it from atmospheric contaminants such as oil, metallic particles, moisture, and dirt. The National Electrical Manufacturers Association (NEMA) has established standards that define the degree of protection that electrical enclosures provide. Because industrial application environments may contain airborne contaminants, the enclosure you use should, as a minimum, conform to a NEMA TYPE 12 standard.

Installation Precautions

To ensure personal safety and long life of system components, pay special attention to the following installation precautions.

Temperature

Maximum Ambient Temperature:	50°C	(122°F)
Minimum Ambient Temperature:	0°C	(32°F)

Humidity

Maximum Relative Humidity: 95% (non-condensing)

Liquids

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

Airborne Contaminants

The APEX Drive's fan provides internal forced air cooling whenever the drive is powered. However, the drive ***does not have*** any type of intake air filter. You must protect the drive's intake air supply from contamination if you operate the drive in an environment where dust or metallic particles are present, or where there may be airborne condensing moisture, solvents, or lubricants.

Electrical Noise

Minimize the possibility of electrical noise problems *before* installing the APEX Drive, rather than attempting to solve such problems after installation. Prevent electrical noise problems by observing the following guidelines:

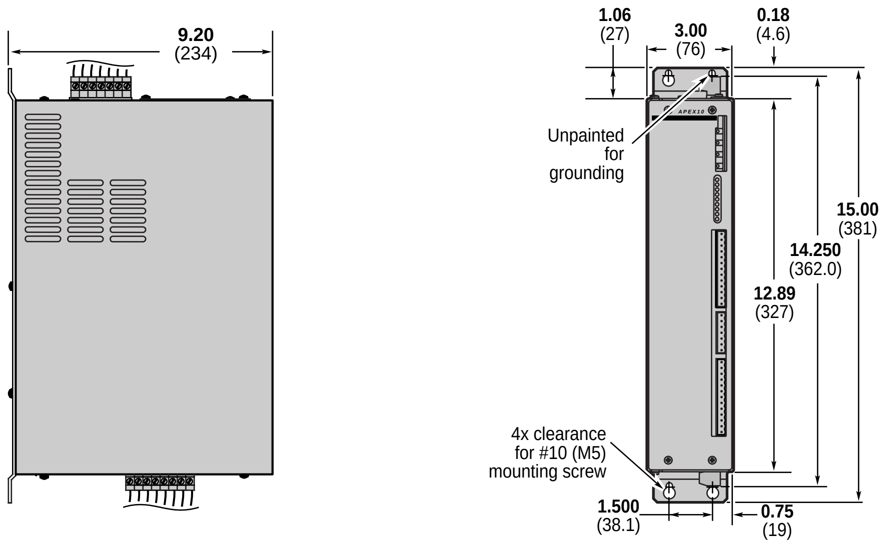
- ❏ Do not route high-voltage wires and low-level signals in the same conduit.
- ❏ Ensure that all components are properly grounded
- ❏ Ensure that all wiring is properly shielded

Mounting and Grounding

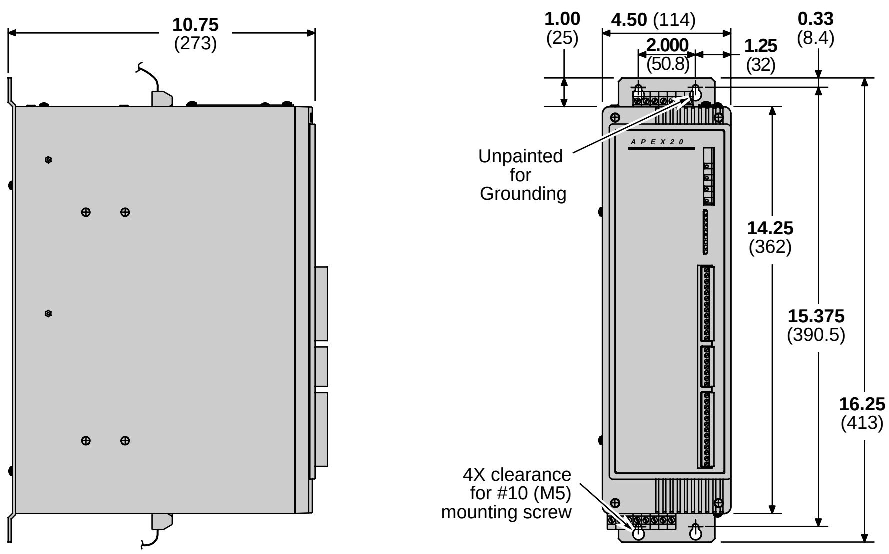
The APEX Drive's mounting bracket is notched with keyhole type slots to accept four screws for flat panel surface mounting. One of the slots—upper right—is unpainted. You can use a star washer between the mounting screw and this slot, to help provide additional electrical grounding between the APEX Drive and the mounting surface. The drive must also be grounded through the Earth terminal on the AC power connector.

DIMENSIONS

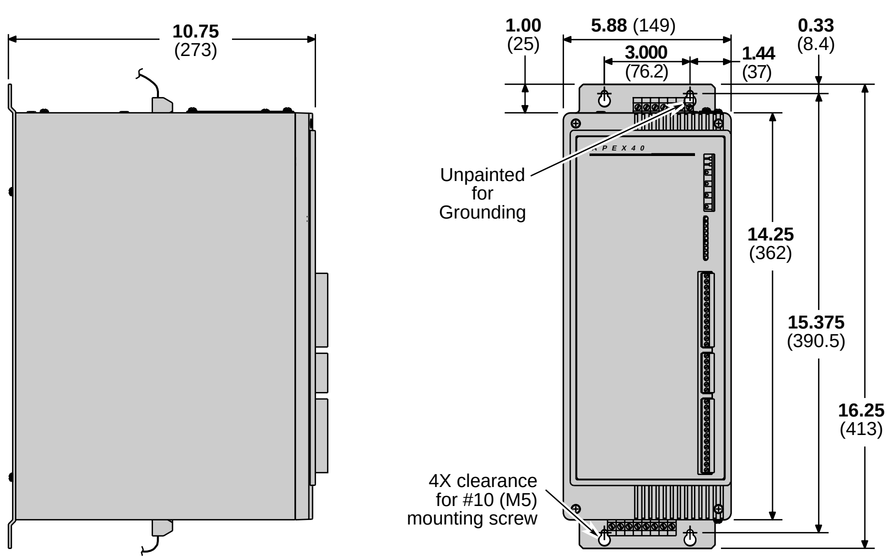
APEX10 Dimensions



APEX20 Dimensions



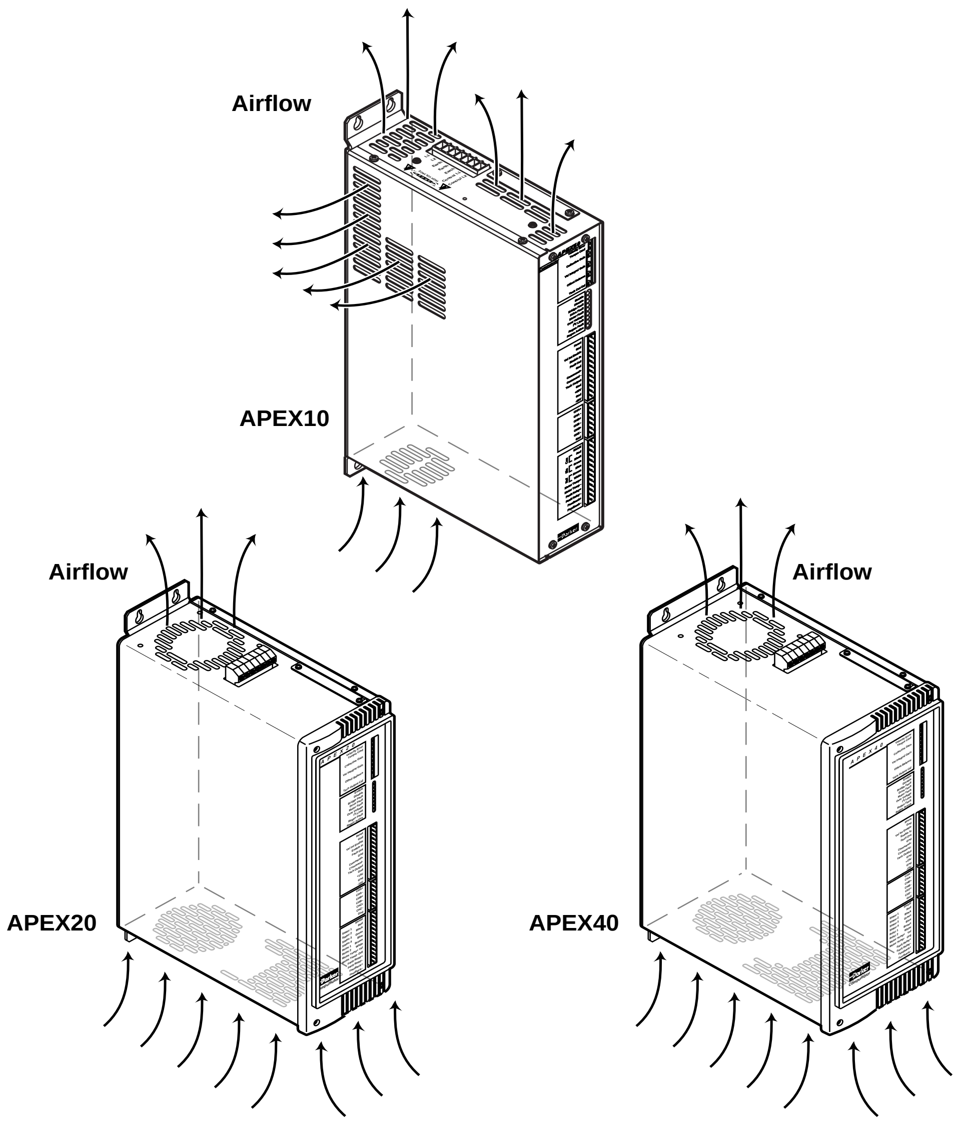
APEX40 Dimensions



Dimensions in
inches (millimeters)

Airflow & Cooling

You can operate the APEX Drive in an ambient temperature environment of 0°C to 50°C (32°F to 122°F). It is cooled by an internal fan mounted at the bottom of the drive. The fan draws air in through the bottom, forces it upward over the heatsink, and out the top of the drive (APEX20 and APEX40); or out the side and top of the drive (APEX10). The air directly beneath the APEX Drive must not exceed 50°C (122°F).



Airflow through APEX Drives

Maximum Dissipation

The APEX Drive produces heat that must be dissipated. Heat produced by drives operating at maximum continuous current may be as much as that shown in the following table.

Drive	Continuous Current (amps)	Maximum Dissipation (watts)
APEX10	8 A	100 W
APEX20	12 A	150 W
APEX40	20 A	200 W

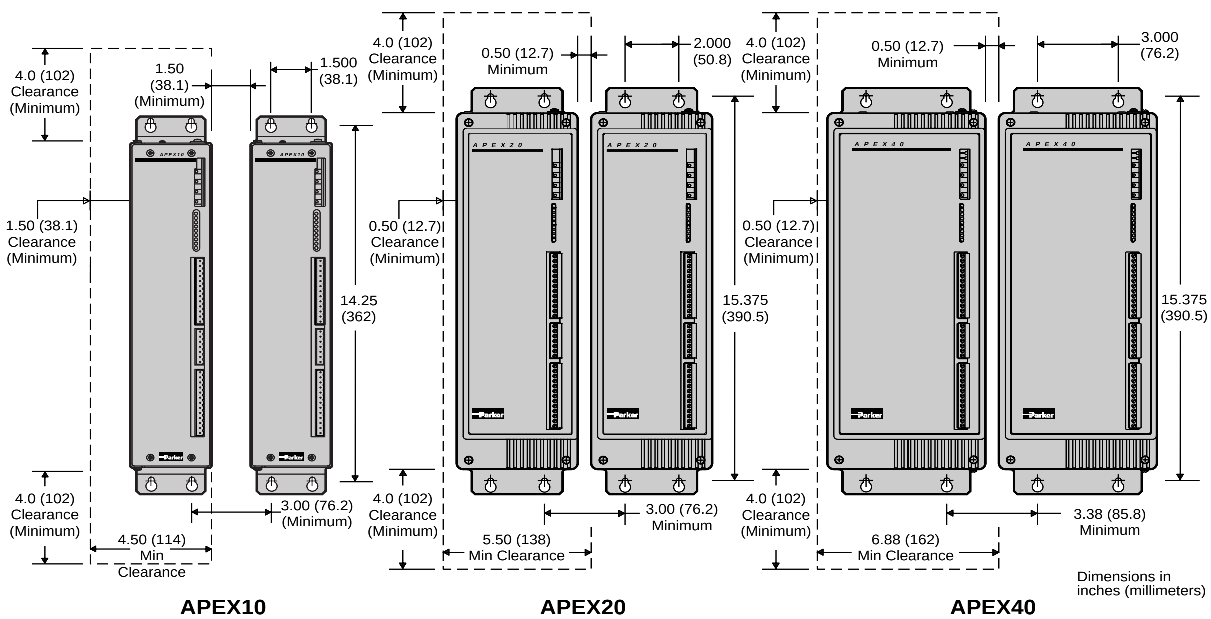
The actual dissipation will vary depending on the application duty cycle, motor size, and load inertia.

INTERNAL TEMPERATURE SENSORS

The APEX Drive has two temperature sensors. One is mounted on the control board, near the microprocessor. The other is mounted within the power bridge. If the internal temperature is too high—perhaps because of blocked airflow, a fan that has stopped working, or external ambient temperatures higher than 50°C (122°F)—one of these sensors will shut down the drive. When the sensor on the control board shuts down the drive, it also illuminates the Drive Fault LED. When the sensor on the power bridge shuts down the drive, it illuminates the Bridge Fault LED.

PANEL LAYOUT

Panel layout dimensions are shown below.



When you design your panel layout, follow these precautions for adequate cooling:

① The vertical distance between the APEX Drive and other equipment, or the top and bottom of the enclosure, should be no less than 4 inches (100 mm).

② The horizontal distance between the APEX10's side air vents and other equipment should be no less than 1.5 inches (38.1 mm).

③ Do not mount the APEX Drive directly below heat-sensitive equipment, such as a controller.

④ Large heat-producing equipment (such as a transformer) should not be mounted directly beneath the APEX Drive.

MOUNT THE MOTOR

The following guidelines present important points about motor mounting and its effect on performance. For dimensions and specifications for APEX, SM and NeoMetric Series servo motors, see *Chapter 4 Hardware Reference*.

Warning
Improper motor mounting can jeopardize personal safety and reduce system performance.

Servo motors used with the APEX Drive 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.

The motor, under certain move profiles, can produce low-frequency vibrations in the mounting structure. These vibrations can cause metal fatigue in structural members. Have a mechanical engineer check the machine design to ensure that the mounting structure is adequate.

CAUTION
Modifying or machining the motor shaft will void the motor warranty. Contact a Compumotor Applications Engineer (800-358-9070) about shaft modifications as a custom product.

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.

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. 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.

Current foldback (I^2T Limit) settings and motor specifications assume that the motor is mounted to an aluminum plate of the following dimensions:

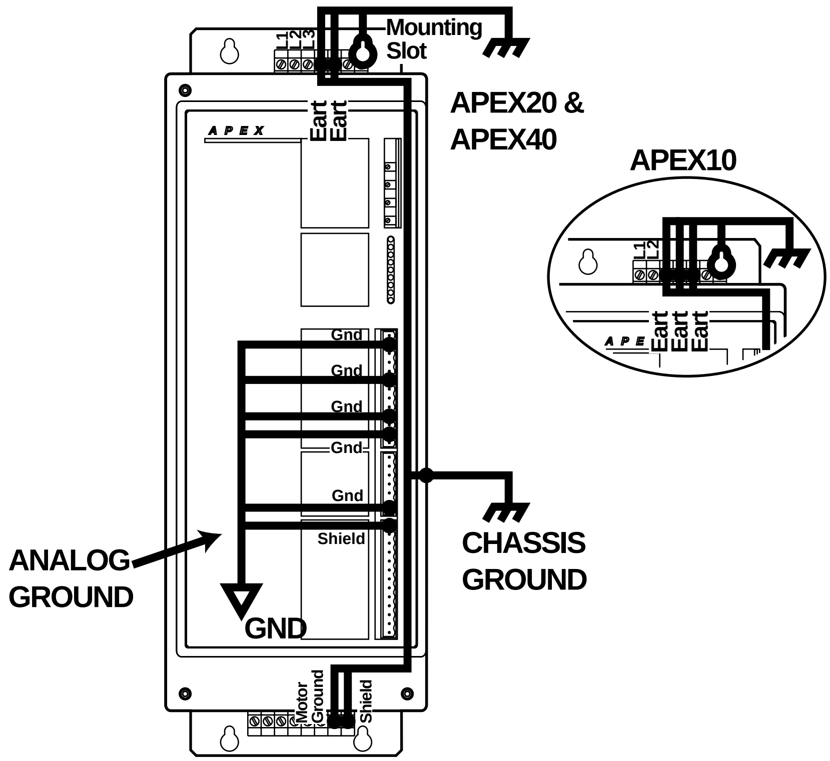
SM Series Motors	NeoMetric
10" x 10" x 0.25" aluminum	10" x 10" x 0.25" aluminum
(250 x 250 x 6.3 mm)	(250 x 250 x 6.3 mm)

To get rated performance in your application, you must mount the motor to a heatsink of at least the same thermal capability as those listed above. 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.

WARNING
The motor case can become very hot, even under normal operating conditions. Do not touch or contact the motor. Keep heat-sensitive equipment away from the motor.

Ground System

The APEX Drive has two ground systems, shown in the next drawing.



Apex Drive – Ground System

Chassis Ground

The following terminals are internally connected to each other, and to the chassis. You can connect these terminals to an external earth ground by connecting any of the **Earth** terminals on the **AC Input** power connector the external earth ground.

Motor Ground	The **Motor Ground** terminal on the motor connector connects to chassis ground.
Shield	The **Shield** terminal on the motor connector connects to chassis ground.
Earth	All terminals labeled **Earth** on the **AC Input** power connector connect to chassis ground. (Multiple **Earth** terminals are provided for convenience.)
Mounting Slot	The upper right mounting slot is unpainted. You can use a star washer with the mounting screw in this slot to provide a grounding path from the chassis ground to the mounting surface.

Circuit Ground (Gnd)

The following terminals are internally connected to each other. They are not connected to the chassis ground.

Gnd All terminals labeled **Gnd** are internally connected.

Shield The **Shield** terminal on the resolver connector is internally connected to the **Gnd** terminals.

Connect the Resolver Cable

The *resolver cable* connects the motor's resolver output to the APEX Drive's resolver input. APEX, SM and NeoMetric resolver cables are shielded, and have an MS style connector on the end that attaches to the motor. You must wire the other end of the cable to the APEX Drive's resolver connector, which is a 13-pin removable connector. The connector can accept wire diameters as large as 12 AWG (4 mm^2).

Hall Effect Motors

For instructions on connecting a Hall effect motor, rather than a motor with a resolver, see *Chapter 4 Hardware Reference*.

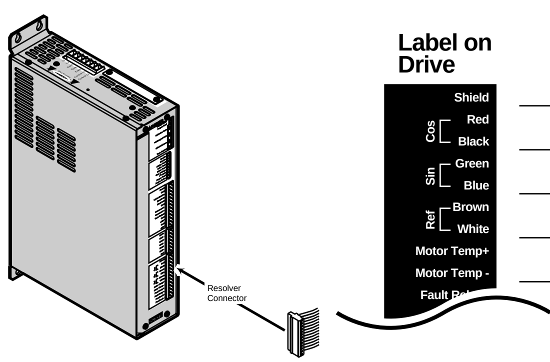
Separate Conduits

Compumotor recommends installing the motor and resolver cables in separate conduits for safety, and to minimize electrical noise problems.

Resolver Connections (Cos, Sin, Ref)

Use the color code shown in the next drawing when you connect SM or NeoMetric resolver cables. This code is also printed on the front panel of the APEX Drive, near the resolver connector.

The **Shield** terminal is internally connected to **Gnd** (ground) terminals on the front panel of the drive. If you make your own resolver cable, use shielded cable to keep electrical noise from corrupting the resolver signal.



Label on Drive	Function	SM/NeoMetric Cable Color Code
Shield	Shield	Uninsulated
Cos Red	Stator 3	Red
Cos Black	Stator 1	Black
Sin Green	Stator 2	Green
Sin Blue	Stator 4	Blue
Ref Brown	Rotor 1	Brown
Ref White	Rotor 2	White
Motor Temp+	Motor Temp+	Yellow
Motor Temp -	Motor Temp -	Yellow

Refer to Appendix A for APEX Motor information.

Resolver Cable Color Code

MOTOR TEMPERATURE (MOTOR TEMP±)

To connect your motor's thermostat, follow these instructions:

- ❑ APEX Motor – connect the yellow wire in the resolver cable to **Motor Temp+**. Connect the orange wire to **Motor Temp–**.
- ❑ SM Motor – both wires are yellow. Connect one to **Motor Temp+**, the other to **Motor Temp–**.
- ❑ Other Motors – for motors with normally-closed temperature sensors, connect the sensor's two wires to **Motor Temp–** and **Motor Temp–**.
- ❑ Motor with no Thermostat – 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.

The APEX Drive's motor temperature 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 APEX Drive. It will turn off power output to the motor, and illuminate the LED labeled **Motor Fault**.

The thermostat 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 thermostat and motor windings will be at the same temperature. When the windings and thermostat reach the thermostat's threshold temperature, the thermostat can trigger the over-temperature circuit.

In cases where the temperature rise is caused by a flow of continuous peak current—an unstable or oscillating motor during tuning, or a mechanical jam, for example—the winding temperature may rise much more quickly than the thermostat temperature rises. In this situation, the windings may be damaged from overheating *before* the thermostat can trigger the overtemperature circuit.

MOTOR BRAKING (FAULT RELAY±)

If the APEX Drive faults, for any reason, the drive will be disabled and the motor will freewheel. (Refer to *Chapter 5 Troubleshooting* for a list of all fault conditions.) If a freewheeling load is unacceptable, you can use the fault relay terminals, **Fault Relay +** and **Fault Relay–**, to control a motor brake. For complete instructions, see *Chapter 3 Special Features*.

FEEDBACK±

If you operate the APEX Drive in torque mode, make no connections to the **Feedback+** or **Feedback–** terminals.

If you operate the APEX Drive in velocity mode, connect the **Feedback** input terminals to a tachometer output signal. If you use the APEX Drive's internal tachometer:

① Connect **Tach Output** on the controller connector to **Feedback+** on the resolver connector.

② Connect any of the **Gnd** (ground) terminals on the controller connector to **Feedback–** on the resolver connector.

If you use an external tachometer:

① Connect the tachometer's output to **Feedback+** on the resolver connector.

② Connect the tachometer's ground to **Feedback–** on the resolver connector.

Use twisted pair wire for these connections, to minimize noise problems.

See *Chapter 4 Hardware Reference* for a schematic diagram of the **Feedback±** input terminals.

CONNECT THE MOTOR CABLE

After wiring the connector to the resolver cable, as described above, connect the motor cable to the motor and to the APEX Drive.

CONNECT THE MOTOR CABLE

The *motor cable* connects the APEX Drive's power output terminals, located on the bottom of the drive, to the motor's power input terminals. APEX, SM and NeoMetric motor cables have an MS style connector on the end that attaches to the motor. You must wire the other end of the cable to the APEX Drive's motor connector, which is an 8-pin removable connector located on the bottom of the drive. The connector can accept wire diameters as large as 10 AWG (6 mm^2).

SEPARATE CONDUIT

Compumotor recommends installing the motor and resolver cables in separate conduits to minimize electrical noise problems, as well as for safety.

MOTOR CONNECTIONS

Wire the cable to the motor connector. Use the following color code for SM and NeoMetric motor cables.

Connector Terminal	SM/NeoMetric Cable Wire Color
Phase A	Red/Yellow
Phase B	White/Yellow
Phase C	Black/Yellow
Motor Ground	Green/Yellow
Shield	Uninsulated

Motor Grounding

The motor cable should have a motor ground wire and also a cable shield wire. Connect the ground wire to the terminal labeled **Motor Ground**. Connect the shield wire to the terminal labeled **Shield**. Inside the drive, the **Motor Ground** and **Shield** terminals are connected to each other, and to the **Earth** terminal on the **AC Input** power connector. On some APEX or SM cables, the ground wire and shield wire are crimped together when the cables are manufactured. You can insert both cables into the **Motor Ground** terminal.

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. Do not rely solely on mounting bolts for motor grounding.

Regen Resistor

The APEX Drive can dissipate regenerated energy in its internal regeneration resistor. If your system must dissipate more energy than the resistor is rated for, use the Regen Resistor terminal to connect an external regeneration resistor on either an APEX 10 or 40. Refer to *Chapter 3 Special Features* for instructions on connecting an external regeneration resistor.

V_{Bus}+, V_{Bus}–

These terminals can connect the high voltage power bus between two or more APEX Drives. Use these terminals to allow one drive to use the power another drive produces during regeneration. Refer to *Chapter 3 Special Features* for instructions on using this feature.

Connect the Cable

After wiring the connector to the cable, attach the motor end of the cable to the motor. Plug the drive end of the cable into the APEX Drive's motor connector.

WARNING

The motor connector and cable produce lethal voltages. Never insert or remove the motor cable with AC power turned on to the APEX.

Connect Power

Connect AC power to the APEX Drive's **AC Input** connector, which is a 7-pin removable connector located on top of the drive. The connector can accept wire diameters as large as 10 AWG (6 mm^2).

The AC power requirements for each model of APEX Drive are as follows:

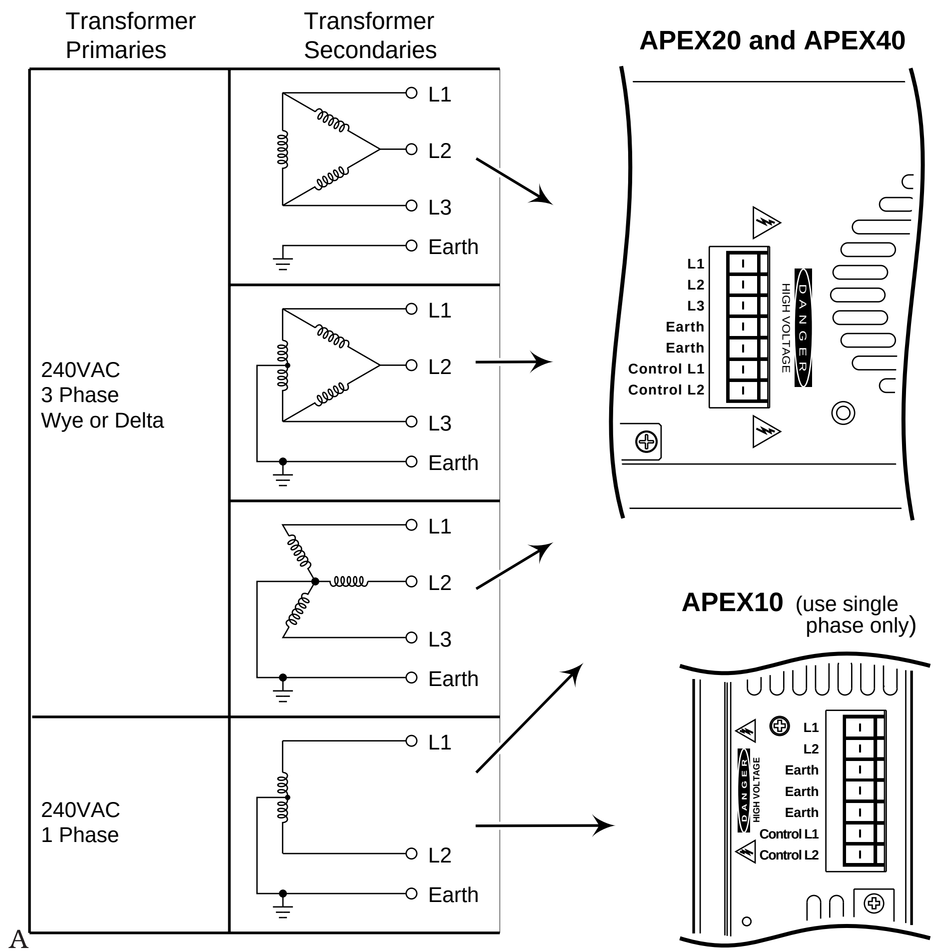
AC Power Requirements

APEX10 Drive	APEX20 Drive	APEX40 Drive
85 – 252VAC Single Phase (SM Motor: 120VAC only)	85 – 252VAC 3-ph greater than 202VAC preferred; or 1-ph	85 – 252VAC 3-ph greater than 202VAC preferred; or 1-ph

Note: Input power less than 202VAC 3-phase severely decreases the potential speed of the motor

AC Power Connections

The next drawing shows several ways to connect a 240VAC power system to the **L1**, **L2**, and **L3** terminals on the APEX20 and APEX40; or to the **L1** and **L2** terminals on the the APEX10.



AC Power System – Connections to APEX Drive Input Terminals

Equation for the transformer KVA:

$$KVA = \frac{\frac{Pout}{eff} + 80W}{PF}$$

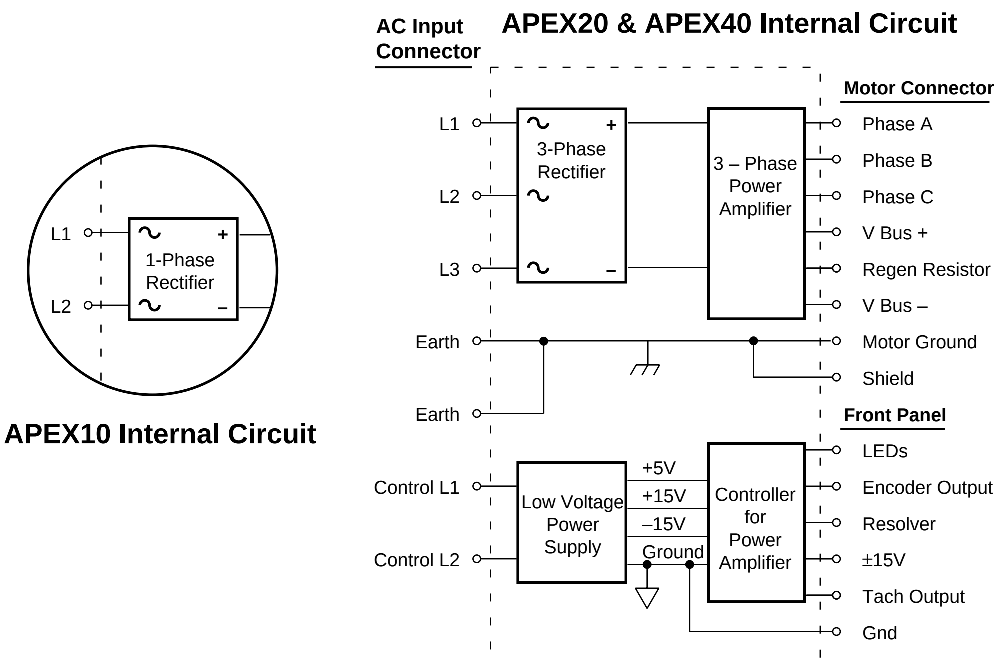
Pout: power out of the drive
eff: drive efficiency
PF: power factor
80W: max. power draw of internal power supply

Consult the Compumotor Applications Department for more information.

Connect AC Power in Two Places

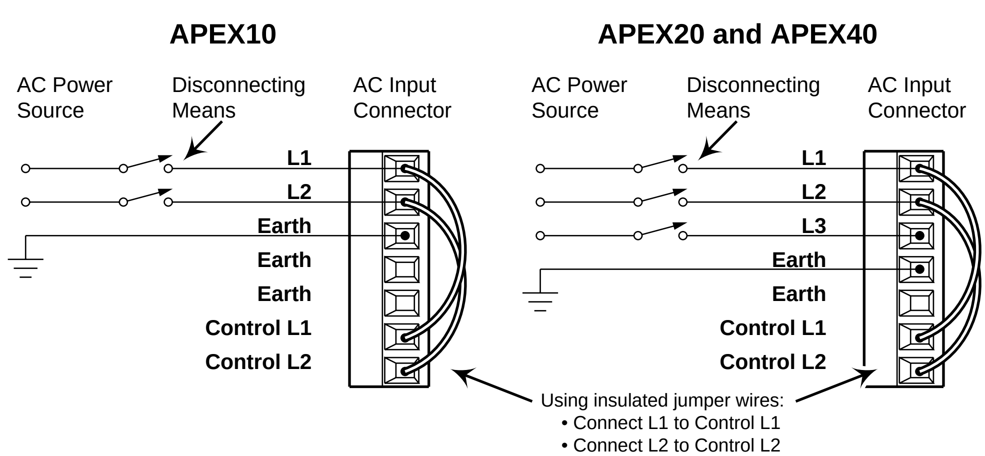
Inside the APEX Drive, there are two power systems, each with its own AC input terminals. One system provides high voltage power to the power amplifier—its terminals are labeled **L1**, **L2**, and **L3** (or **L1** and **L2** on the APEX10 Drive). The other system provides low voltage power to the power amplifier's controller—its terminals are labeled **Control L1** and **Control L2** **and have the same power specs as listed above**. Two AC Power inputs allow you to remove power from the motor, but continue to power internal control circuits.

These two internal power systems are shown in the next drawing.



AC Power – Internal Connections

You must connect AC power to both **L1/L2/L3** and **Control L1/Control L2** (or to both **L1/L2** and **Control L1/Control L2** on the APEX10). The next drawing shows a simple way to do this.



AC Connector with Jumpers Attached

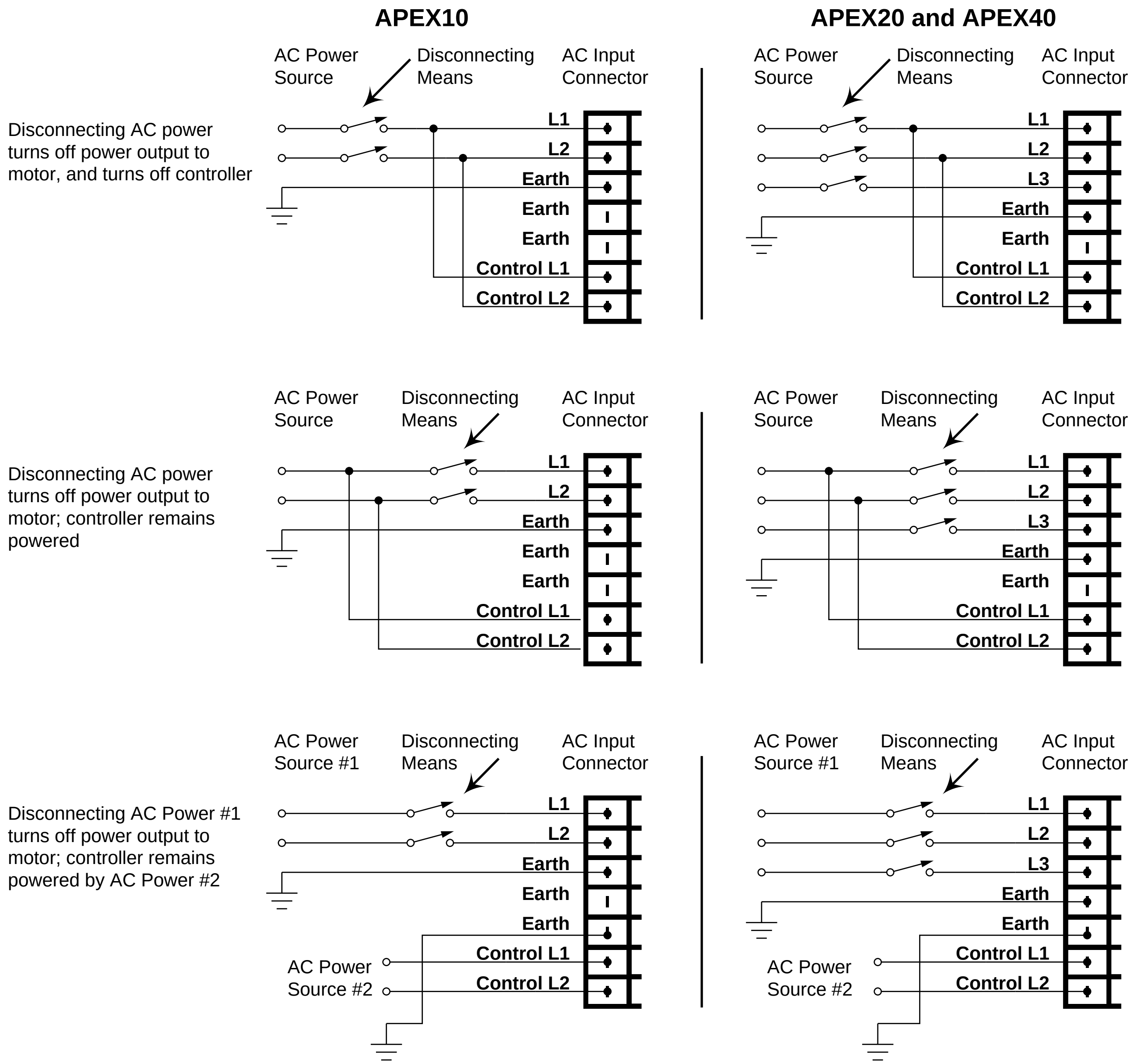
Follow these steps in making connections:

1. Connect your AC input lines to **L1, L2** and **L3** on the AC input connector (**L1** and **L2** on the APEX10).
2. Using insulated wire jumpers (provided in the ship kit), connect **L1** to **Control L1**, and connect **L2** to **Control L2**.
3. Connect your AC ground to **Earth** on the AC input connector.

Wiring Options

The diagram below illustrates options for connecting AC power.

- If you want to completely shut down the drive when you disconnect AC power, follow the top connection diagram. (This is a schematic version of the previous drawing.) Use insulated wire jumpers (provided in the ship kit) to connect **L1** to **Control L1**, and to connect **L2** to **Control L2**.
- If you want to shut down power to the motor when you disconnect AC power, but keep the amplifier controller energized, follow the middle connection diagram. This shows that **Control L1** and **Control L2** are connected to the AC power source *before* the disconnecting means.
- If you want to use separate AC power sources for **L1/L2** and **Control L1/Control L2**, follow the bottom connection diagram. For example, you can connect 240VAC and a disconnecting means to **L1** and **L2**, and connect 120VAC to **Control L1** and **Control L2**.



AC Power – Connections

USING SINGLE PHASE AC POWER WITH APEX20 AND APEX40

If you use single phase AC power with the APEX20 or APEX40, connect your two power wires to the **L1** and **L2** terminals on the APEX Drive.

Fuse recommendations given above are for three phase, 240VAC operation, with a drive and motor operating at rated speed, rated torque, and 100% duty. To choose a fuse for single phase operation, scale the above value by your actual requirements, and obtain a de-rated fuse value.

Connecting AC Ground

The terminals labeled **Earth** are internally connected to the APEX Drive's chassis, and to the **Motor Ground** and motor **Shield** terminals. For safety, connect the ground from your AC power system to at least one of the **Earth** terminals (for convenience, multiple terminals are provided).

WARNING
DO NOT OMIT the AC Ground connection. Be sure the APEX Drive's chassis is properly and securely grounded to reduce the chance of electrical shock.

Fusing Information

The APEX Drive has no internal fuses. For safety purposes, you should provide a fuse in each of the AC input lines. Recommended fuses are:

Fuse Recommendations

APEX10 Drive (240VAC)	APEX20 Drive (240VAC)	APEX40 Drive (240VAC)
250V Slow Blow 12 – 15 amp Littelfuse 326-012 or equivalent	250V Slow Blow 12 – 15 amp Littelfuse 326-012 or equivalent	250V Slow Blow 20 – 25 amp Littelfuse 326-020 or equivalent
APEX10 Drive (120VAC)		
125V Slow Blow 15 – 25 amp Littelfuse 326-025 or equivalent		

Also provide a fuse for the Control L1/L2 inputs: 250V Slow Blow
3 amp
Littelfuse 326-003 or equivalent

WARNING
The APEX Drive has no internal fuses. For safety purposes, provide a fuse in each of the AC input lines.

Plug in the Connector

After wiring the connector to the cable, plug the cable into the APEX Drive's input power connector. ***Do not energize*** the power at this time. The APEX Drive does not have an ON/OFF switch. You must provide a safe means of energizing AC power to the drive (indicated as "disconnecting means" in the previous drawings). Use a safety interlock switch or resettable circuit breaker to conveniently de-energize the drive in an emergency and/or service situation.

WARNING
The motor connector and cable produce lethal voltages. Never insert or remove the motor cable with AC power turned on to the APEX Drive.

ADJUST OFFSET BALANCE

Follow the procedure below to adjust the APEX Drive's offset balance potentiometer. This procedure also serves as a quick test to verify that all system connections made thus far have been done correctly. Because the motor will turn during this procedure, make sure that all components are properly mounted or supported.

WARNING
Even a small offset can cause the motor to quickly accelerate up to high speeds. Please use extreme care and be ready to disable the drive if necessary.

Proceed to the appropriate option below—*Torque Mode* or *Velocity Mode*—based upon how you intend to use the APEX Drive.

OPTION 1: TORQUE MODE

If you intend to operate your system in torque mode, perform the following procedure. The controller and encoder output should be disconnected from the drive; the motor should be disconnected from the load.

① Power to the APEX Drive should be OFF when you begin this procedure.

② Connect a wire between **Enable In** and Ground (**Gnd**) on the controller connector. This shorts the enable input to ground, and enables the APEX Drive when you turn on AC power.

NOTE: The next two steps – ③ & ④ – were performed at the factory. If yours is a new APEX Drive, you do not need to perform these two steps—use the default factory settings. You can proceed to step ⑤.

③ Turn the **Collective Gain** and **Vel Integral Gain** potentiometers at least 15 turns counterclockwise. This will ensure that the collective gain and velocity integral gain functions are turned off.

④ Center the **Offset Balance** potentiometer—turn it at least 15 turns clockwise, then back it off approximately 7 1/2 turns counterclockwise, to put it in the center of its travel.

⑤ Turn on AC power to the APEX Drive.

⑥ If the motor shaft is turning, adjust the **Offset Balance** potentiometer to stop the shaft from turning. (For smaller motors, the null range may be quite narrow—it may be difficult to find the exact position where the motor shaft stops completely.)

⑦ **TEST**: Turn the **Offset Balance** potentiometer clockwise. The motor shaft should turn clockwise (when viewed from the front of the motor).

⑧ **TEST**: Turn the **Offset Balance** potentiometer counterclockwise. The motor shaft should turn counterclockwise.

⑨ After you have performed these tests, adjust the **Offset Balance** potentiometer to stop the motor shaft from turning.

⑩ Turn off AC power; remove the wire between enable input and ground.

Successful completion of these tests verifies that the APEX Drive is configured correctly, and that the AC power cable, motor cable, and resolver cable are properly wired. Proceed to *Connect a Controller* below.

If your motor does not turn, or does not turn in the correct direction, check the DIP switch settings and cable connections, and perform the test procedure again.

OPTION 2: VELOCITY MODE

If you intend to operate your system in velocity mode, perform the following procedure before you connect a controller. The controller and encoder output should be disconnected from the drive; the motor should be disconnected from the load.

① Power to the APEX Drive should be OFF when you begin this procedure.

② Connect a wire between **Enable In** and Ground (**Gnd**) on the controller connector. This shorts the enable input to ground, and will enable the APEX Drive when you turn on the AC power.

NOTE: The next two steps – ③ & ④ – were performed at the factory. If yours is a new APEX Drive, you do not need to perform these two steps—use the default factory settings. You can proceed to step ⑤.

③ Turn the **Collective Gain** and **Vel Integral Gain** potentiometers at least 15 turns counterclockwise. This will ensure that the collective gain and velocity integral gain functions are turned off. (These functions may or may not be turned off on DIP switch #3, positions 1 and 8, depending upon how you configured the drive for velocity mode.)

④ Center the **Offset Balance** potentiometer—turn it at least 15 turns clockwise, then back it off approximately 7 1/2 turns counterclockwise, to put it in the center of its travel.

⑤ Connect **Tach Output** (on the controller connector) to **Feedback+** (on the resolver connector). Connect **Gnd** (next to **Tach Output**) to **Feedback–**. Use twisted pair wire for these connections, to minimize noise problems.

(Optional: if you are using an external tachometer, connect its output to **Feedback+**. Connect its ground to **Feedback–**. Make no connections to the APEX Drive's **Tach Output**).

See *Chapter 4 Hardware Reference* for a schematic drawing of these terminals.

⑥ Turn on AC power to the APEX Drive.

⑦ If the motor shaft is turning, adjust the **Offset Balance** potentiometer to stop the shaft from turning. (For smaller motors, the null range may be quite narrow—it may be difficult to find the exact position where the motor shaft stops completely.)

⑧ **TEST**: Turn the **Offset Balance** potentiometer clockwise. The motor shaft should turn clockwise (when viewed from the front of the motor).

⑨ **TEST**: Turn the **Offset Balance** potentiometer counterclockwise. The motor shaft should turn counterclockwise.

⑩ After you have performed these tests, adjust the **Offset Balance** potentiometer to stop the motor shaft from turning. Turn off AC power, and remove the wire between enable input and ground.

Successful completion of these tests verifies that the APEX Drive is configured correctly, and that the AC power cable, motor cable, and resolver cable are properly wired. Proceed to *Connect a Controller* below.

If your motor does not turn, or does not turn in the correct direction, check the DIP switch settings and cable connections, and perform the test procedure again.

Connect a Controller

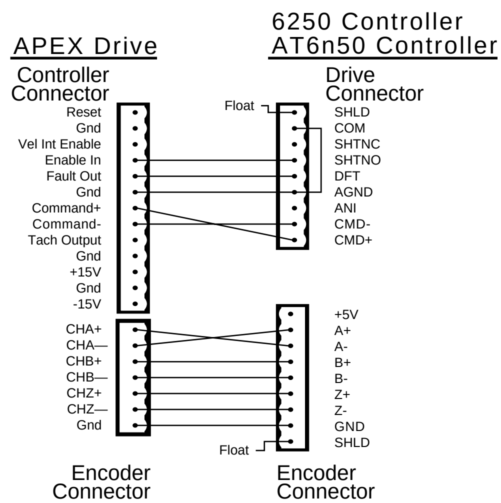
The above procedures were done without a controller connected. This should have made it easy to isolate and fix any problems. In this section, you will connect your controller to the APEX Drive.

The controller connector is a removable 13-pin connector located on the front panel of the APEX Drive. The connector can accept wire diameters as large as 12 AWG (4 mm^2). Wire your controller cable to the connector, according to the following instructions.

For detailed descriptions of each terminal, including schematic diagrams, see *Chapter 4 Hardware Reference*.

Connections to Compumotor Controllers

The next drawing shows how to connect an APEX Drive to Compumotor's 6250 or AT6n50 servo controllers.



Connections to Compumotor Controllers

Connections to other controllers are described in the following sections.

Connections to Non-Compumotor Controllers

Command Input

If your controller has a *differential output*:

① Connect the controller's positive command output to the APEX Drive's **Command+** input.

② Connect the controller's negative command output to the APEX Drive's **Command–** input.

③ Connect the controller's signal ground to any of the ground inputs (labeled **Gnd**) on the APEX Drive's controller connector.

If your controller has a *single-ended output*:

① Connect the controller's command output to the APEX Drive's **Command+** input.

② Connect the controller's signal ground to the APEX Drive's **Command–** input.

③ Connect a wire between the APEX Drive's **Command–** input and any of the ground inputs (labeled **Gnd**) on the APEX Drive's controller connector. This will reference the **Command–** input to ground.

If your controller has *isolated outputs*: some controllers have isolated command outputs, and may require a voltage source to power their outputs. The APEX Drive has ±15V available to power isolated outputs on a controller.

① Connect the APEX Drive's ±15V outputs to your controller's ±15V inputs.

② Connect your controller's single-ended or differential outputs to the APEX Drive, as described above.

See *Chapter 4 Hardware Reference* for a schematic of the command input.

Enable Input

Connect the controller's enable output to the APEX Drive's enable input, labeled **Enable In**. The enable input is *active low*—this means that when it is connected to ground, the APEX Drive is enabled. Therefore, your controller must pull the APEX Drive's enable input low (0 – 1.0VDC) to enable the drive. See *Chapter 4 Hardware Reference* for a schematic of the enable input.

Fault Output

Connect the APEX Drive's fault output, labeled **Fault Out**, to the controller's fault input. The fault output is *active high*—under normal conditions, the drive holds the fault output low (0 – 1.0VDC). To signal a fault, the drive will let the fault output float. Your controller may need to pull up the fault output signal to an appropriate level. See *Chapter 4 Hardware Reference* for a schematic of the fault output.

Ground

Connect the controller's signal ground to one of the ground inputs on the APEX Drive's controller connector. All of the ground inputs (labeled Gnd) on the front panel of the APEX Drive are connected together internally. They are isolated from the chassis, from **Motor Ground**, and from **Earth** on the AC input connector.

Reset (optional)

If the controller has a reset output, and you wish to use it, connect it to the APEX Drive's reset input (labeled **Reset**). The reset input is *active low*. To reset the APEX Drive's processor, the controller must pull the reset input low (less than 1.0V) for at least 20 milliseconds. Reset begins upon release of the low level. See *Chapter 4 Hardware Reference* for a schematic of the reset input.

CONNECT ENCODER TO CONTROLLER

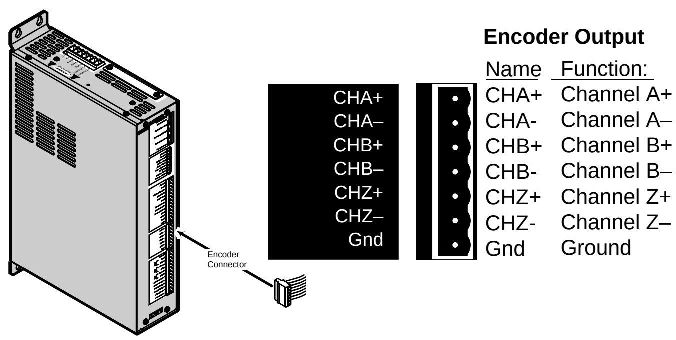
Connect the APEX Drive's encoder output to the controller. The encoder connector is a removable 7-pin connector located on the front panel of the APEX Drive. The connector can accept wire diameters as large as 12 AWG (4 mm^2).

The APEX Drive uses a resolver–to–digital converter to produce its encoder outputs. Encoder features are:

ENCODER RESOLUTION:	1024 counts per revolution, pre-quadrature 4096 counts per revolution, post-quadrature
CLOCKWISE ROTATION:	Channel A leads Channel B
COUNTERCLOCKWISE ROTATION:	Channel B leads Channel A

See *Chapter 4 Hardware Reference* for complete encoder specifications.

The encoder on the APEX Drive has the following outputs:



Connect these outputs to your controller's encoder inputs. If you use a Compumotor controller, see the connection diagram in the previous section. (See pg. 37: A+ connected to A-; A- connected to A+)

If the motor has Hall Effects instead of a resolver, the Hall Effects connect to the Encoder Output connector, as shown in Chapter 4, and the encoder on the motor goes to the connector.

TEST: ROTATE MOTOR SHAFT

Perform the following steps to verify that the encoder is connected properly.

① Disable the APEX Drive. (Use your controller to disable the drive, or remove the wire between the enable input and ground on the controller connector.)

② Turn on power to the APEX Drive. The drive should power up, but be disabled. The **Disable** LED should illuminate to indicate that the drive is disabled.

③ Note the encoder position. (Use your controller, or any other method you prefer, to read the encoder position.)

④ With the motor disconnected from the load, manually rotate the motor shaft clockwise, approximately one revolution. Read the new encoder position. One revolution *exactly* will produce 4,096 counts, post-quadrature. Your reading should be approximately near this number, and should be positive for clockwise rotation.

If you intend to operate the APEX Drive in torque mode, successful completion of the above procedures verifies that your APEX Drive is configured and operating properly in torque mode. You may now proceed to *Preliminary Tuning* below.

If you intend to operate the APEX Drive in velocity mode, you should calibrate the tachometer, as described immediately below, before tuning your system.

CALIBRATE TACHOMETER (VELOCITY MODE ONLY)

In the procedures above, you connected the tachometer output (**Tach Output** on the APEX Drive's controller connector) to the velocity feedback signal, **Feedback+**, on the resolver connector. (See "Adjust Offset Balance")

In this procedure, you will adjust two potentiometers on the front panel of the APEX Drive—**Offset Balance** and **Tach Out Cal**—to precisely calibrate the APEX Drive's tachometer output.

① Energize AC power to the APEX Drive and enable the drive.

② Use your controller to command a velocity of zero (ØV input to the drive). Adjust the **Offset Balance** potentiometer so that motor shaft velocity is zero (the shaft does not turn).

③ Use your controller to command a positive velocity. Monitor the actual shaft velocity, and adjust the **Tach Out Cal** potentiometer so that actual velocity matches commanded velocity.

EXAMPLE: For a system that will run at a maximum of 4,000 rpm, command a velocity of 4,000 rpm (4.0V command input). As you monitor shaft velocity, adjust the **Tach Out Cal** potentiometer so that actual motor shaft velocity is 4,000 rpm.

If you intend to operate the APEX Drive in velocity mode, successful completion of the above procedures verifies that your APEX Drive is configured and operating properly in velocity mode. You may now proceed to *Preliminary Tuning,* below.

PRELIMINARY TUNING (WITH NO LOAD ATTACHED)

Before you attach the motor to the load, use your controller to perform preliminary tuning on your system. Consult your controller's user guide for instructions on how to tune your system with no load attached. Setting tuning gains now will ensure that your system behaves predictably when you first turn it on with a load attached to the motor.

TUNING WITH SM MOTORS

Maximum peak current for SM motors can be three times higher than the continuous current rating. If the motor oscillates during your tuning procedure, high peak current may cause overheating and damage the motor. When you tune your system, therefore, we recommend that you start with the lowest value for peak current. As you tune the drive and refine your gains, you can raise the peak current level. See *Tuning* at the end of this chapter for more details.

CAUTION

If you use an SM Motor, set the drive's DIP switches at the lowest peak current level for initial drive tuning. Motor damage due to excessive heating may result from high peak currents and improper tuning values.

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 coupler joining a motor and load would be completely rigid. Rigid couplers 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 solution may be a compromise between these requirements.

CAUTION

Modifying or machining the motor shaft will void the motor warranty. Contact a Compumotor Applications Engineer (800-358-9070) about shaft modifications as a custom product.

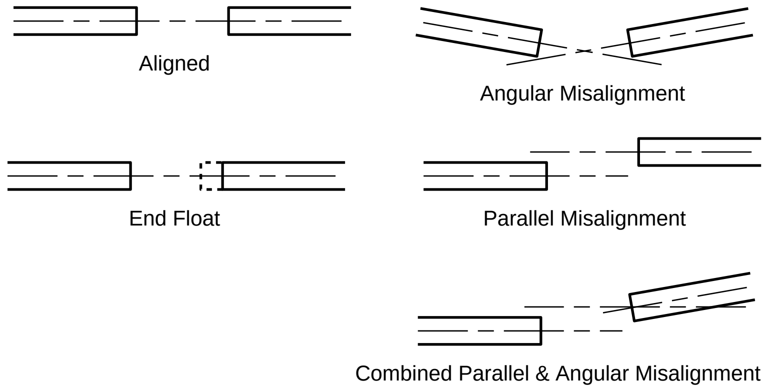
MISALIGNMENT & COUPLERS

Align the motor shaft and load as accurately as possible. In most applications, some misalignment is unavoidable, due to tolerance buildups in components. However, excessive misalignment may degrade your system's performance.

There are three 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.

These conditions can exist in any combination. They are illustrated below:



Misalignment Conditions

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

Single-Flex Coupler

Use a single-flex coupler when you have angular misalignment only. Because a single-flex coupler 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 coupler 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 coupler with a parallel misalignment***: this will bend the shafts, causing excessive bearing loads and premature failure.

Double-Flex Coupler

Use a double-flex coupler 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 couplers may or may not accept end play, depending on their design.

Rigid Coupler

Rigid couplers 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 couplers 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.

Coupler 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. Box1460
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

Servo systems rely on feedback to control the motor motion. A servo loop consists of the forward path through the motor, and the feedback path to the drive. You can tune your system to optimize performance.

The APEX Drive can be configured as either a velocity or torque servo. When operated in torque mode, the APEX Drive amplifies a torque command, but does not actually close a servo loop around the motor. Velocity measured by the resolver is used as a feedback signal. The APEX Drive *does* close an inner current loop, which ensures that actual current matches commanded current. When operated in velocity mode, the APEX Drive closes a servo loop around the motor and drive.

When using the APEX Drive with a PID servo controller, you should operate the APEX Drive in torque mode. In this mode minimal tuning is required at the drive. When using the APEX Drive as a stand alone velocity controller, or with a controller requiring additional damping, you should operate the APEX Drive in velocity mode. Since brushed servo motors are traditionally operated in velocity mode, controllers in PLC and CNC type systems operate better when the drive is in velocity mode.

The APEX Drive is a reliable and simple component in a complete motion control system. Unless you are operating it as a stand-alone velocity system, the real tuning of your system will take place in the controller servo algorithm. The entire tuning process of the drive itself should take only a few minutes, and should be completed before tuning the controller. Your goal in tuning the APEX Drive is to make it perform responsively and predictably.

Tuning with SM Motors

Maximum peak currents for APEX, SM, and NeoMetric Motors are three times higher than the motor's continuous current rating. If your system is not tuned properly, and the motor oscillates or becomes unstable, excessive peak currents may cause the motor to overheat. The motor may be quickly damaged, before the thermostat can trigger the drive's **Motor Fault** circuit.

To avoid motor damage, we recommend the following iterative tuning procedure for a system.

① Adequately heatsink your motor, especially in temporary "bench top" procedures. Motors dissipate excess heat through their faceplate; the faceplate must be mounted to a heatsink to ensure proper motor cooling.

② Set the drive's DIP switches for the lowest peak current.

③ Apply tuning gains, and test your system's response. Adjust the gains until you achieve a satisfactory response. Before proceeding to the next step, ensure that the system is stable and that there are no mechanical problems that cause binding or jamming.

④ Using the drive's DIP switches, increase peak current to the next higher level. Do not set the peak current higher than that specified for your particular motor.

⑤ Repeat steps 3 and 4 until you achieve performance satisfactory for your application.

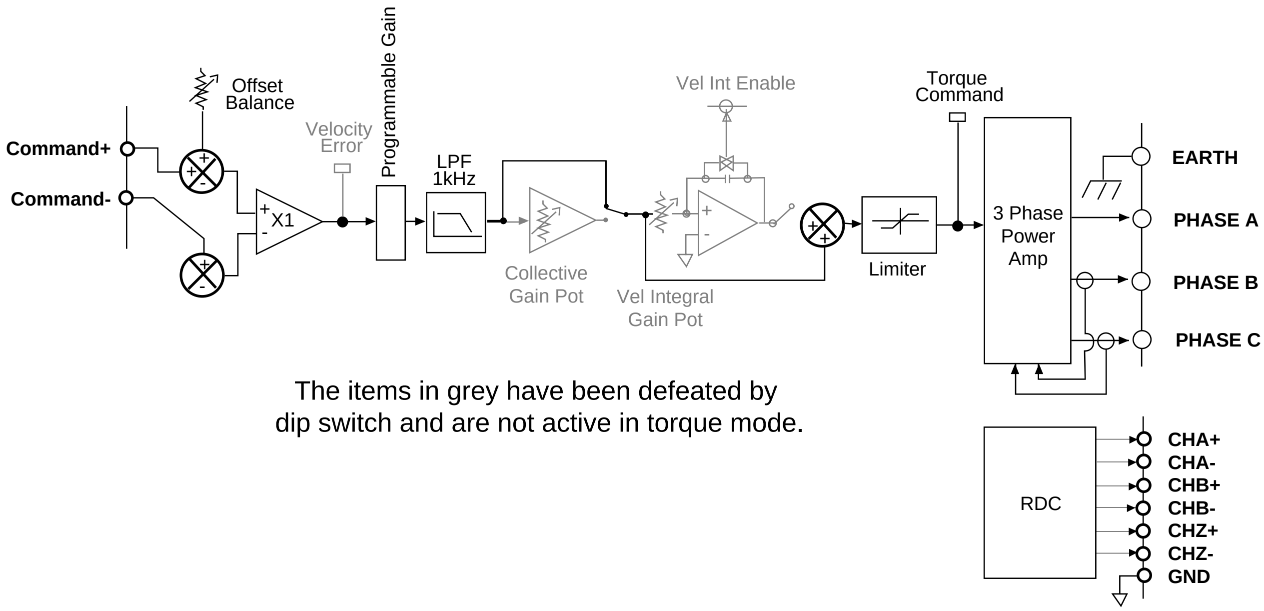
CAUTION

If you use an SM Motor, set the drive's DIP switches at the lowest peak current level for initial drive tuning. Motor damage due to excessive heating may result from high peak currents and improper tuning values.

Torque Mode Tuning

In torque mode, the drive is a block of fixed gain (transconductance) set at 5 mhos (amp/volt). The bandwidth of the drive is approximately 1 KHz.

APEX TORQUE LOOP



TORQUE MODE TUNING – PROCEDURE

In torque mode the only adjustment is to the **Offset Balance** potentiometer. This adjustment can remove, or zero, a DC voltage offset in the torque amplifier. The procedure for adjusting the **Offset Balance** potentiometer was described earlier in this chapter.

SYMPTOMS

You will need to balance the Offset Balance potentiometer if your system displays the following symptoms:

Offset Voltage: If the position controller is required to output a command voltage larger than 0.25V, the balance may need adjustment. This condition is only detrimental if it limits the top end command. If the load is affected by gravity or large amounts of friction, the controller may need to command a higher voltage to overcome these forces and should not be balanced.

Motor Runs Away: If the motor runs away when enabled (without a position loop closed) you should adjust the offset to zero.

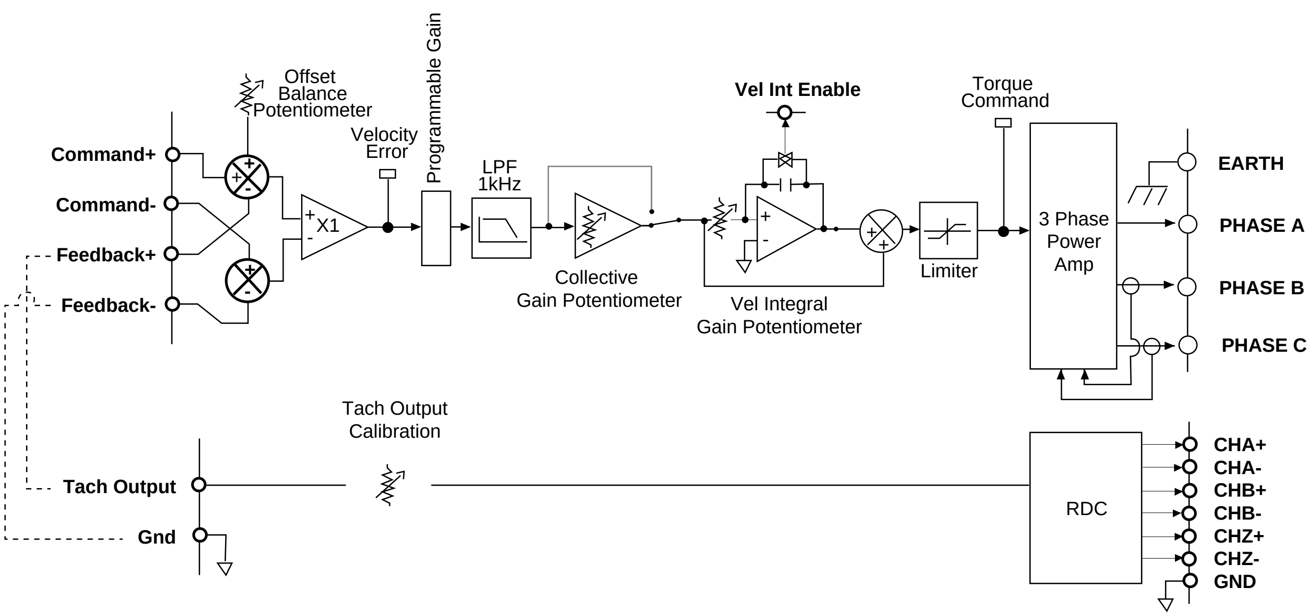
VELOCITY MODE TUNING

VELOCITY LOOP

In velocity mode, the gain is adjustable from 5 to 30 mhos and provision is made for analog velocity feedback from a tachometer. Additionally, the APEX Drive incorporates an optional integrator in the forward path which may be useful in spindle applications. The integrator is normally disabled (zero gain) unless it is enabled by a logic signal at the **Vel Int Enable** input. This allows the integrator to be selectively left out of the loop at certain times so that it does not participate in gross move dynamics, such as acceleration/deceleration transients.

When you tune in velocity mode, you will adjust the overall collective gain (and the integrator gain if used). Unlike the **Offset Balance** and **Tach Output Cal** potentiometers, the tuning controls are not used to compensate for spurious variations from one unit to the next. Rather they are set according to system requirements and their settings should be identical among all similar APEX Drives. Test points are provided to allow the potentiometers to be set to the desired values using a digital voltmeter while the drive is powered down. The test moves described in the following are more for prototyping than for production testing.

APEX VELOCITY LOOP



ADJUSTMENTS

In velocity mode the **Offset Balance**, **Collective Gain**, and **Vel Integral Gain** potentiometers are the active adjustments.

Adjustment	Type	Description
Offset Balance	15 (±3) turn pot	Positive and negative adjustment of the DC value of the velocity command signal.
Collective Gain	15(±3) turn pot	Overall amplification of the velocity error. This adjustment should be used as velocity gain when operating with a position c ontroller. The gain will be high with large inertia and will add damping to a position servo system. This gain is defeatable by dip switch.
Velocit Integral Gain	15(±3) turn pot	Corrects for steady state errors in velocity. Should only be used in stand alone velocity applications. This gain is defeatable by dip switch.

SYMPTOMS

You will need to adjust the velocity gains if your system displays any of the following symptoms:

Offset Voltage: If the position controller is required to output a command voltage larger than 0.25V when the motor is under no load, the balance may need adjustment. This condition is only detrimental if it limits the top end command. If the load is affected by gravity or large amounts of friction, the controller may need to command a higher voltage to overcome these forces and should not be balanced.

Motor Runs Away: If the motor runs away when enabled (without a position loop closed) the offset can be adjusted to zero so the motor will not run away when enabled.

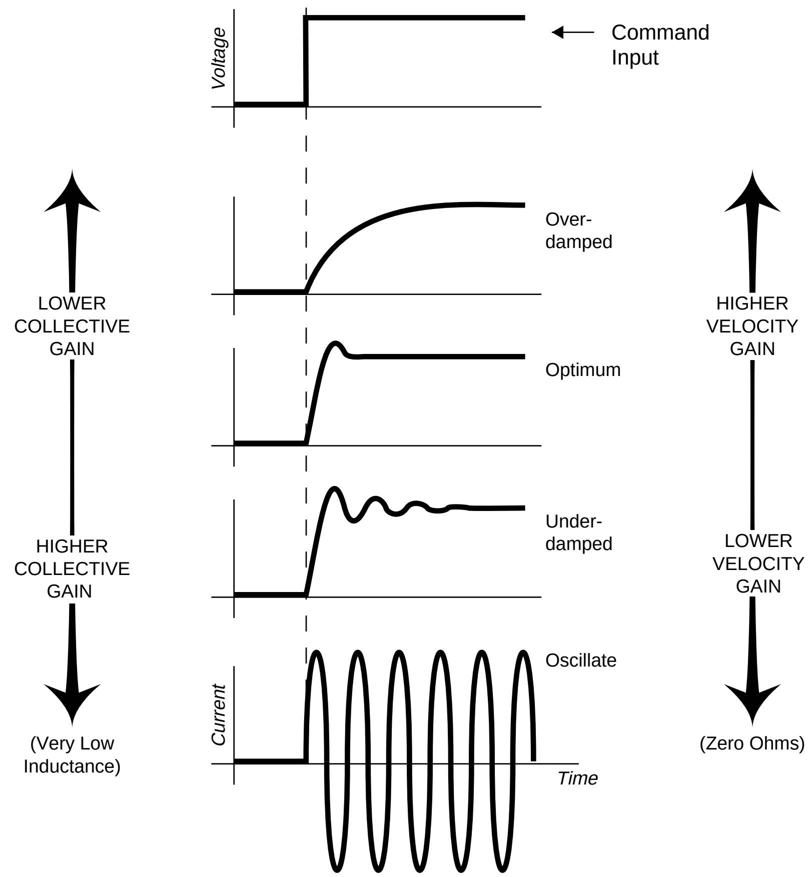
Sluggish System: If the motor lacks stiffness, the collective gain is too low. When the load inertia increases, the collective gain must be increased proportionally.

Ringing: If the system rings excessively when changing position and velocity, your system is either underdamped or aggravating a mechanical resonance in the system. By increasing the Collective gain you will increase the responsiveness of the velocity loop and increase damping.

Steady State Errors: This will occur when operating the APEX Drive in a velocity mode only (no position controller). If the motor will not reach the commanded velocity, an external force such as friction is restraining the motor. By increasing the Velocity Integral Gain, the APEX Drive will increase the command voltage to overcome steady state velocity errors.

Velocity Mode Tuning – Procedure

For best results tune the gains in the order presented here. The velocity loop gains should be tuned independently and prior to the tuning of the position loop gains.



Response Waveforms

Adjust Offset Balance

The procedure for adjusting the **Offset Balance** potentiometer was described earlier in this chapter.

Adjust Collective Gain

The **Collective Gain** potentiometer is a 15 turn potentiometer with zero at fully counterclockwise and maximum at 15 turns clockwise. The factory default is fully counterclockwise and should be verified before beginning this procedure.

The best way to gauge velocity loop response is to command a velocity step with a function generator and measure the tach output signal (the tach output signal needs to remain connected to the **Feedback+/-** input). Many controllers, such as the 6250 from Compumotor, have utilities and commands for velocity loop tuning and for interpreting the results. Consult the appropriate user guides for more information.

① With the APEX Drive enabled, command a voltage step.

② Measure the tach out signal with an oscilloscope or with a software data acquisition package that can plot the results.

③ When the DC voltage input is changed the APEX Drive will attempt to track that change as quickly as possible. With the Collective Gain high, the APEX Drive is very responsive to changes. With the Collective Gain low, the APEX Drive is less responsive to these changes. The Collective Gain should be set as high as possible without causing the system to oscillate when it changes velocity.

Velocity Integral Gain

The velocity integral gain is only required in applications for stand alone velocity control. Stand alone velocity control is defined as an application where motor position is not measured. The system is required to respond to and maintain a commanded velocity based on the ±10 volt velocity command. In these applications, friction or other external forces can keep the motor from attaining the commanded velocity. Raising the velocity integral term will improve velocity accuracy.

The **Vel Integral Gain** potentiometer is set empirically. The velocity integral gain is adjusted by a 15 turn pot with zero at fully counterclockwise and maximum at 15 turns clockwise. The factory default is fully counterclockwise and should be verified before beginning this procedure.

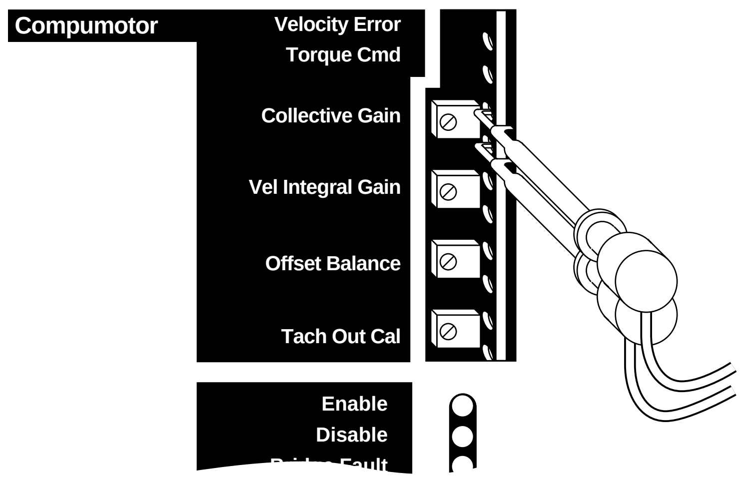
① With the APEX Drive enabled, command a voltage step.

② Measure the tach out signal with an oscilloscope or with a software data acquisition package that can plot the results.

③ When the DC voltage input is changed the APEX Drive will attempt to track that change as quickly as possible. The Velocity Integral Gain should be set to a level where the response does not ring and has only a small amount of overshoot.

Tuning Multiple Systems

If you have more than one APEX Drive doing the same application, you can use the gain values from a prototype system to configure the subsequent systems. By measuring the resistance of the potentiometer with the power off, as shown in the figure, a value of Collective or Velocity Integral Gain can be attained. On the second APEX Drive simply turn the potentiometer until the resistance matches the value of the prototype APEX Drive.



Tuning Potentiometers - Measuring Resistance