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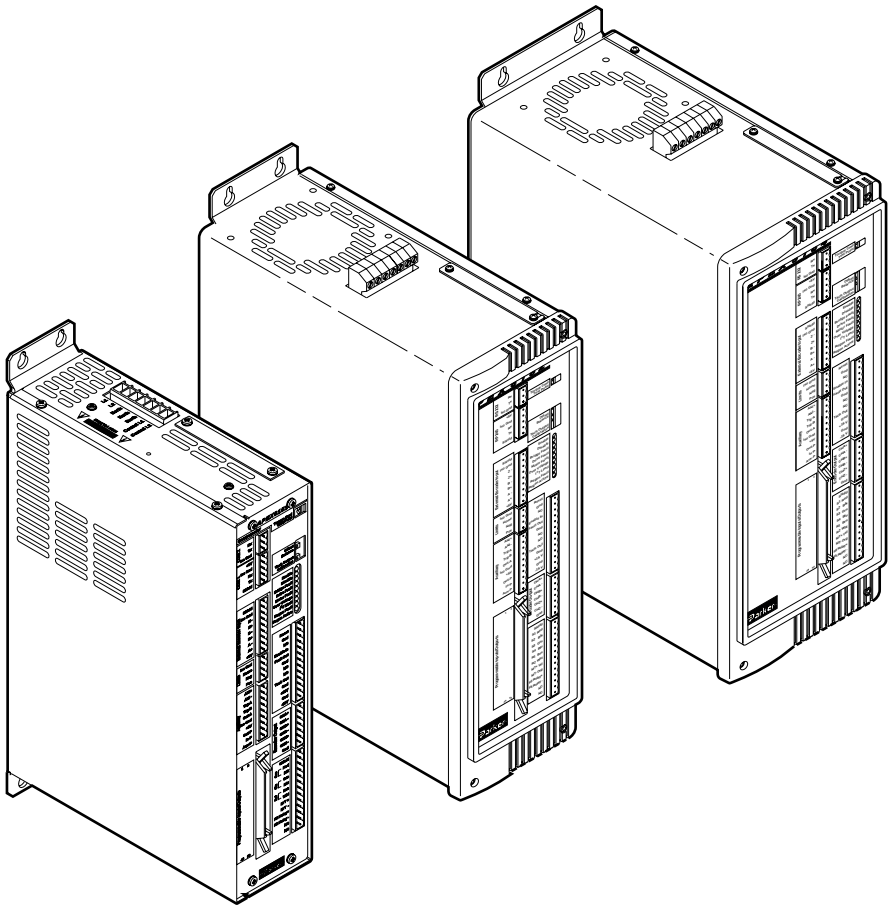
Find the *Parker / Compumotor APEX6152* at our website: *Click HERE*

Compumotor

APEX615n

Servo Controller / Drive

Installation Guide



Compumotor Division
Parker Hannifin Corporation
p/n 88-016148-01 A March 1997

Parker

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IMPORTANT

User Information

⚠ WARNING ⚠

6000 Series products are used to control electrical and mechanical components of motion control systems. You should test your motion system for safety under all potential conditions. Failure to do so can result in damage to equipment and/or serious injury to personnel.

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Motion & Control

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Purpose of This Guide

This document is designed to help you install and troubleshoot your APEX615n hardware system. Programming related issues are covered in the *6000 Series Programmer's Guide* and the *6000 Series Software Reference*.

"APEX615n" Synonymous with "615n"

The APEX615n product is often referred to the as the "615n" because it is part of the 6000 family of products. The APEX615n's software and the 6000 Series software documentation (e.g., *6000 Series Software Reference*) refer to this product as the "615n."

What You Should Know

To install and troubleshoot the APEX615n, you should have a fundamental understanding of:

- Electronics concepts, such as voltage, current, switches.
- Mechanical motion control concepts, such as inertia, torque, velocity, distance, force.
- Serial communication and terminal emulator experience: RS-232C and/or RS-485

Related Publication

- *6000 Series Software Reference*, Parker Hannifin Corporation, Compumotor Division; part number 88-012966-01
- *6000 Series Programmer's Guide*, Parker Hannifin Corporation, Compumotor Division; part number 88-014540-01
- Current *Parker Compumotor Motion Control Catalog*
- Schram, Peter (editor). *The National Electric Code Handbook (Third Edition).* Quincy, MA: National Fire Protection Association

Online Manuals This manual (in Acrobat PDF format) is available from our web site: `http://www.compumotor.com`

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APEX615n CONTROLLER/DRIVE: LVD Installation Instructions



Product Type: APEX6151, APEX6152 and APEX6154 Servo Controller/Drives

The above products are in compliance with the requirements of directives

- 72/23/EEC Low Voltage Directive
- 93/68/EEC CE Marking Directive

APEX615n Controller/Drives, when installed according to the procedures in the main body of this installation guide, may not necessarily comply with the Low Voltage Directive (LVD) of the European Community. To install an APEX615n Controller/Drive so that it complies with LVD, you must follow the additional procedures described in Appendix D, under *LVD Installation Instructions*. If you do not follow these instructions, the protection of the product may be impaired.

The APEX615n Series of Controller/Drives are sold as complex components to professional assemblers. As components, they are not required to be compliant with Electromagnetic Compatibility Directive 89/336/EEC. However, information is offered in Appendix E on how to install these drives in a manner most likely to minimize the effects of controller and drive emissions and to maximize the immunity of controllers and drives from externally generated interference.

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CHAPTER ONE

1 Installation

IN THIS CHAPTER

• Product ship kit list
• Things to consider before you install the APEX615n
• General specifications table
• Optional pre-installation alterations
  - DIP switch settings – motor current, device address, autobaud feature
  - Changing the COM 2 port from RS-232C to RS-485
• Mounting the APEX615n
• Connecting all electrical components (includes specifications)
• Testing the installation
• Motor mounting and coupling guidelines
• Preparing for what to do next

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What You Should Have *(ship kit)*

If an item is missing, call the factory (see phone numbers on inside front cover).

Part Name			Part Number
One of the following line items:			
APEX615n standard product (with ship kit)			**APEX615n**
APEX615n standard product (with ship kit)			**APEX615n**
APEX615n standard product (with ship kit)			**APEX615n**
The part number will say APEX6151, APEX6152, or APEX6154, depending on which version you ordered.			
Ship kit:	3-pin Plug	(one included: COM 1 connector)	43-009055-01
	5-pin Plug	(one included: COM 2 connector)	43-005561-01
	9-pin Plug	(one included: Ext. Encoder Input connector)	43-008755-01
	4-pin Plug	(one included: Limits connector)	43-005560-01
	11-pin Plug	(one included: Auxiliary connector)	43-008885-01
	13-pin Plug	(two included: Drive Aux. and Resolver connectors)	43-013802-01
	7-pin Plug	(one included: Encoder Output connector)	43-013801-01
	7-pin Plug	(one included: Power connector)	43-013575-01
	8-pin Plug	(one included; Motor connector)	43-014533-01
	Cable, Jumper	(2 included, for AC power connector)	71-015237-01
	22 AWG, .2" c/c, Yellow	(4 included, Jumper Wires)	44-011061-01
	22 AWG, .8" c/c, White	(1 included, Jumper Wire)	44-015830-01
	This installation guide (*APEX615n Installation Guide*)		88-016148-01
	6000 Series Software Reference		88-012966-01
	6000 Series Programmer's Guide		88-014540-01
	Motion Architect diskettes:	Disk 1	95-013070-01
		Disk 2	95-013070-02

Options/Accessories		Part Number
APEX Series Motor	(brushless motor with resolver)	APEX602-MO, APEX603-MO
Motor Cable:	(For APEX602, APEX603 Motors)	71-013863-xx
Resolver Cable	(For APEX602, APEX603 Motors)	71-013862-xx
Resolver Cable	(For APEX602, APEX603 with brake)	71-014082-xx
SM Series Motor	(brushless motor with resolver)	SM-231AR, SM-232AR, SM-233BR
Resolver Cable	(for SM-231AR, SM-232AR, SM-233BR)	71-015019-yy
Motor Cable:	(for SM-231AR, SM-232AR, SM-233BR)	71-015078-yy
Cable Kit:	(Resolver & Motor Cables for SM-23 motors)	23RS CABLE-10, 23RS CABLE-25

NOTES: Cable lengths, represented by "xx," can be NC (no cable), 25, 50, or 100 feet.
Cable lengths, represented by "yy," can be 10 or 25 feet.

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Before You Begin

> **⚠ WARNINGS ⚠**
>
> The APEX615n is used to control your system's electrical and mechanical components. Therefore, you should test your system for safety under all potential conditions. Failure to do so can result in damage to equipment and/or serious injury to personnel.
>
> **Always remove power to the APEX615n before:**
> - Connecting any electrical device (e.g., motor, encoder, inputs, outputs, etc.)
> - Adjusting the DIP switches, jumpers, or other internal components

Recommended Installation Process

This chapter is organized sequentially to best approximate a typical installation process.

1. Review the general specifications
2. Perform configuration/adjustments (if necessary)
3. Mount the APEX615n
4. Connect all electrical system components
5. Test the installation
6. Mount the motor and couple the load
7. Tune the APEX615n servo controller.
8. Program your motion control functions. Programming instructions are provided in the *6000 Programmer's Guide* and the *6000 Software Reference*. We recommend using the programming tools provided in Motion Architect for Windows (found in your ship kit). You can also benefit from an optional iconic programming interface called Motion Builder (sold separately).

Electrical Noise 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.
- Noise suppression guidelines for I/O cables are provided on page 33 and in Appendix B.

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General Specifications

Parameter	Specification
Input Power	
Voltage Range	APEX6151: 85-252VAC (1-phase) APEX6152: 205-252 VAC (1- or 3- phase) APEX6154: 205-252 VAC (1- or 3- phase)
Frequency Range	47-66 Hz
Current (max. cont.)	APEX6151: 14A (rms) at 120 VAC; 10A (rms) at 240 VAC APEX6152: 8A (rms) 3- phase APEX6154: 15A (rms) 3- phase
Power (max. cont.)	APEX6151: 2.4 KVA APEX6152: 3.3 KVA APEX6154: 6.2 KVA
Fuses	No internal fuses. Recommended external fuse:** APEX6151: 120 VAC Operation: 25A slow blow (Littelfuse #326-025 or equivalent) 240 VAC Operation: 15A slow blow (Littelfuse #326-015 or equivalent) APEX6152: 12A slow blow (Littelfuse #326-012 or equivalent) APEX6154: 20A slow blow (Littelfuse #326-020 or equivalent)
Isolation Transformer	Not required
	*For operation from single phase power, derate system performance according to motor size and total system performance.
	**The actual input power and current is a function of the motor's operating point (speed and torque) and the duty cycle. You can de-rate the fuses by scaling the above numbers by your actual requirements. The numbers above reflect the servo motor and drive operating at rated speed and rated torque at 100% duty.
Output Power	
Voltage	APEX6151: 170-340 VDC (nominal), 420 VDC (maximum) APEX6152: 340 VDC (nominal), 420 VDC (maximum) APEX6154: 340 VDC (nominal), 420 VDC (maximum)
Frequency	APEX6151: 0-400 Hz fundamental (15 KHz PWM) APEX6152: 0-400 Hz fundamental (8 KHz PWM) APEX6154: 0-400 Hz fundamental (8 KHz PWM)
Current (max. cont.)	APEX6151: 8A continuous per phase sinusoidal (5.66A rms) 16A peak per phase sinusoidal (11.31A rms) APEX6152: 12A continuous per phase sinusoidal (8.5A rms) 24A peak per phase sinusoidal (17.0A rms) APEX6154: 20A continuous per phase sinusoidal (14.14A rms) 40A peak per phase sinusoidal (28.3A rms)
Environmental	
Operating Temperature	32 to 122°F (0 to 50°C)
Storage Temperature	-22 to 185°F (-30 to 85°C)
Humidity	0 to 95% non-condensing
Performance	
Position Range	±2,147,483,648 steps
Velocity Range	0.001-200 counts/sec
Acceleration Range	0.001-999.9999 units/sec^2
Velocity Repeatability	±0.02% of set rate
Velocity Accuracy	±0.02% of maximum rate
PositionalRepeatability	±0.088 degrees, unloaded
Positional Accuracy	Resolver Accuracy: ±10 arc minutes Resolver-to-Digital Converter Accuracy: ±10 arc minutes
Positional Resoluton	Resolver-to-Digital Converter Resolution: 4096 counts/rev
Motion Trajectory Update Period	Default is 1.7 ms (depends on SSFR value)
Servo Sampling Update Period	Default is 400 µs (depends on SSFR value)
System Update Period	Default is 1.7 ms (depends on SSFR value)

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Serial Communication	*RS-485 requires internal jumper and DIP switch configuration (see page 10).*
Connection Options	RS-232C (3-wire); RS-485 (2- or 4-wire); Change internal switches SW1, SW2, and SW3, and internal jumper JU2 to position 3 to select RS-485 communication for COM 2 port.. Default for RS-485 is 2-wire. Change internal switch SW3 to select 4-wire.
Maximum units in daisy-chain or multi-drop	99 (use ADDR command to set individual addresses for each unit)
Communication Parameters	9600 baud , 8 data bits, 1 stop bit, no parity; RS-232: Full or half duplex; RS-485: Half duplex (see page 10)
Inputs	***ALL INPUTS ARE OPTICALLY ISOLATED****
Home, POS/NEG Limits	Switching voltage levels based on **V_I/O***; internal 6.8 KΩ pull-ups to **AUX-P** terminal (connect **AUX-P** to **+5V** or external power supply to source current or connect **AUX-P** to **ISO GND** to sink current); voltage range is 0-24V.
Encoder	Differential comparator accepts two-phase quadrature incremental encoders with differential (recommended) or single-ended outputs. Maximum voltage = 5VDC. Switching levels (TTL-compatible): Low ≤ 0.4V, High ≥ 2.4V. Maximum frequency = 1.2 MHz. Minimum time between transitions = 833 ns.
16 General-Purpose Programmable	HCMOS compatible* with internal 6.8 KΩ pull-ups to **IN-P** terminal (connect **IN-P** to **+5V** to source current or connect **IN-P** to **Iso GND** to sink current). Voltage range = 0-24V.
Triggers: TRG-A and TRG-B	Switching voltage levels based on **V_I/O***; internal 6.8 KΩ pull-ups to **AUX-P** terminal (connect **AUX-P** to **+5V** or external power supply to source current or connect **AUX-P** to **Iso GND** to sink current); voltage range is 0-24V.
Outputs	***ALL OUTPUTS ARE OPTICALLY ISOLATED*****
9 Programmable (includes **OUT-A**)	Open collector output with 4.7 KΩ pull-ups. Can be pulled up by connecting **OUT-P** to **+5V**, or to user-supplied voltage of up to 24V. Max. voltage in the OFF state (not sinking current) = 24V, max. current in the ON state (sinking) = 300mA. Includes the 8 general-purpose outputs on the **Programmable I/O** connector, and the **OUT-A** terminal on the **I/O** connector.
+5V Output	+5V terminals are available on the **COM2**, **ENCODER, AUXILIARY** and **I/O** connectors. Load limit (total load for all I/O connections) is 100mA.
Weights	
Unit Weight	APEX6151: 10.7 lbs. (4.9 kg) APEX6152: 16.6 lbs. (7.6 kg) APEX6154: 21.5 lbs. (9.8 kg)
Shipping Weight	APEX6151: 18 lbs. (8.2 kg) APEX6152: 25 lbs. (11.4 kg) APEX6154: 30 lbs. (13.7 kg)

* Switching voltage levels for HOM, POS, NEG, TRG-A , TRG-B are based on V_I/O input voltage level:
Low ≤ 1/3 (**V_I/O) volts**, High ≥ 2/3 (**V_I/O) volts.**

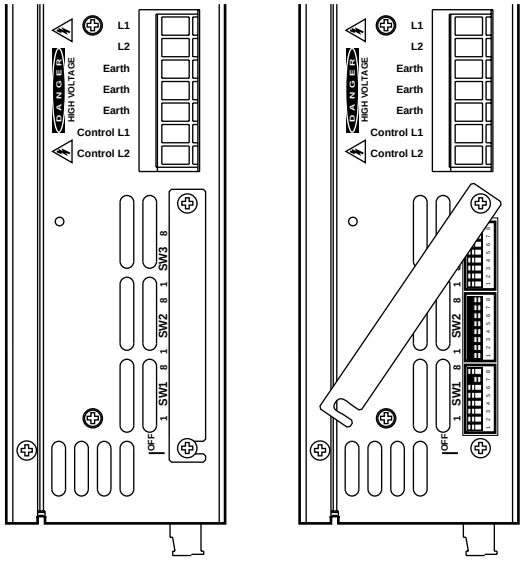
** HCMOS-compatible voltage levels (low ≤ 1.00V, high ≥ 3.25V).

*** Inputs and outputs are optically isolated from the internal microprocessor, but not isolated from other inputs or outputs.

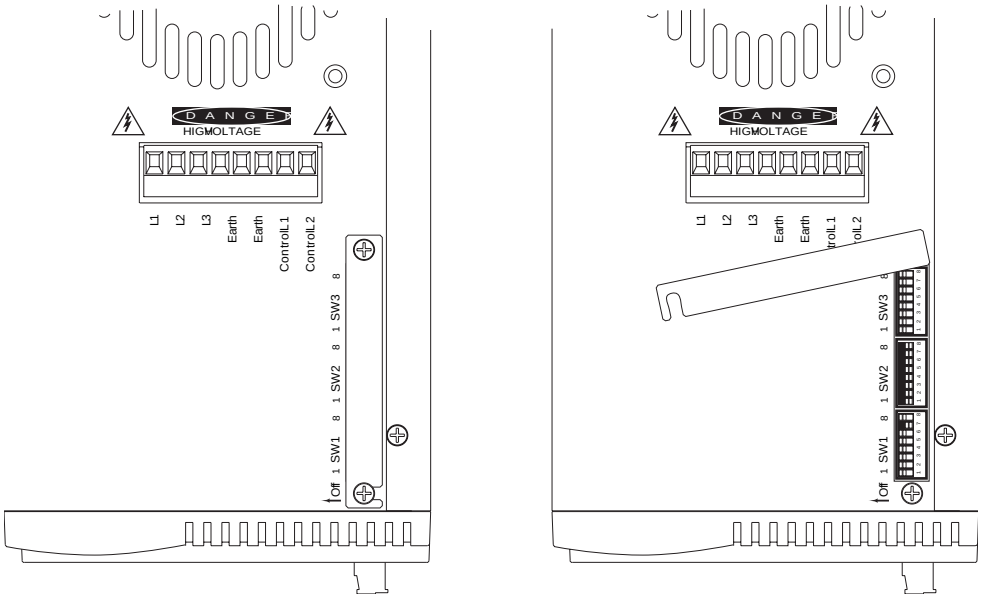
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DIP Switch Settings – Motor Current, Feedback Options, Drive Features

The APEX615n has three 8-position DIP switches. The switches are located behind a small metal cover on top of the APEX615n. Loosen the two screws that hold the access cover. Move the cover out of the way to expose the DIP switches.



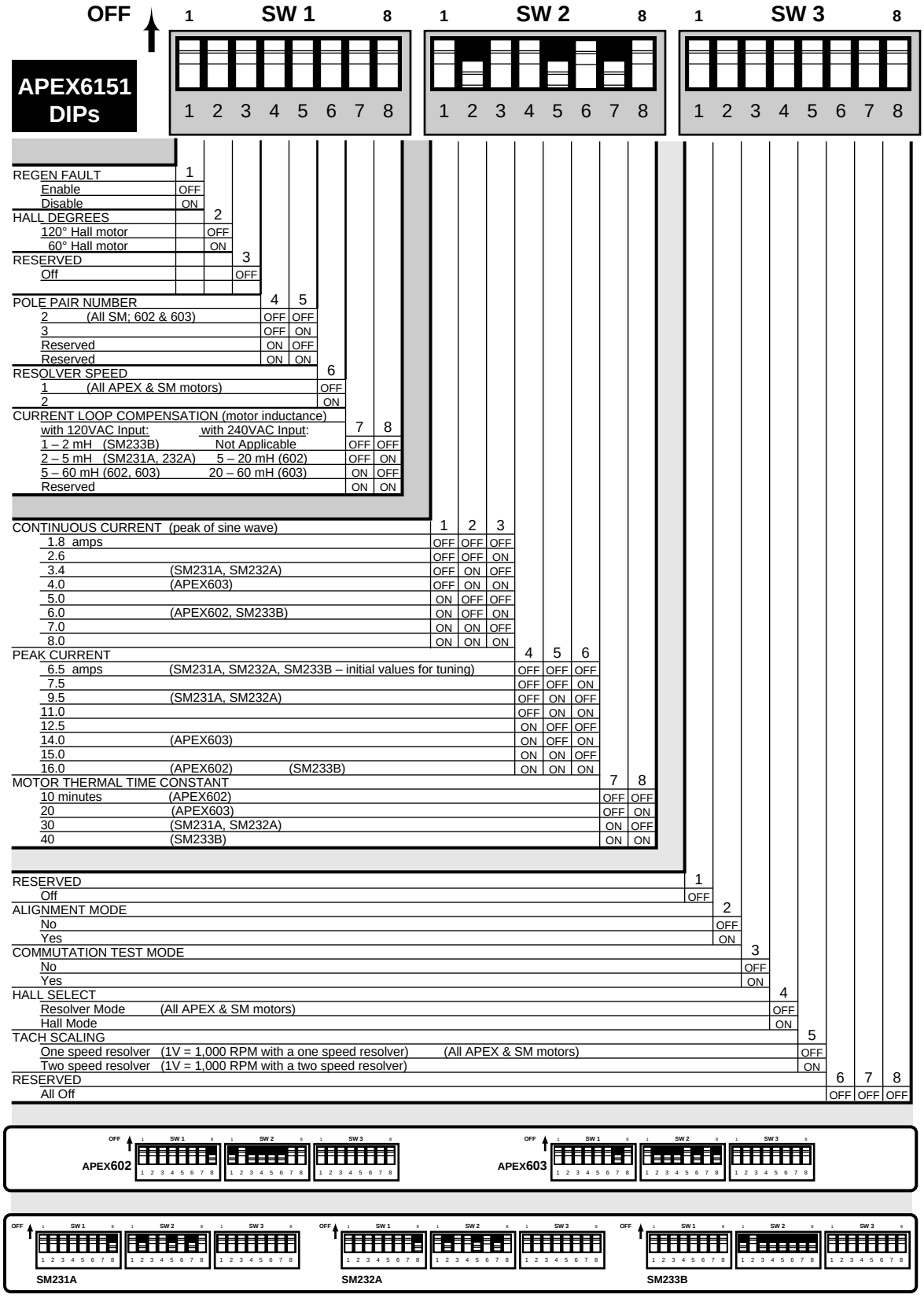
APEX6151 DIP Switch Location, with Cover Closed and Open



APEX6152/6154 DIP Switch Location, with Cover Closed and Open

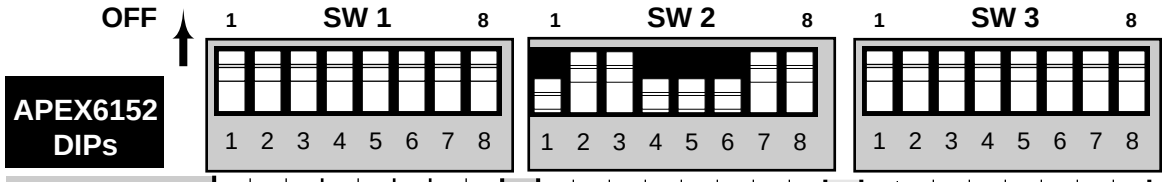
The default setting for all DIP switches when the APEX615n ships from the factory is off. You must set these switches to configure the drive for your particular application. Use a small screwdriver to set the switches. The next section summarizes the function of each switch. See Appendix F for additional description of DIP switch functions.

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DEFAULT SETTINGS: The default setting for all DIP switches when the APEX6151 ships from the factory is **OFF.**

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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 (APEX604; 605 & 606)				OFF	OFF			
3				OFF	ON			
Reserved				ON	OFF			
Reserved				ON	ON			
RESOLVER SPEED						6		
1 (APEX604; 605 & 606)						OFF		
2						ON		
CURRENT LOOP COMPENSATION (motor inductance)							7	8
25 – 40 mH (APEX605,606)							OFF	OFF
5 – 15 mH (APEX604)							OFF	ON
15 – 25 mH							ON	OFF
Reserved							ON	ON

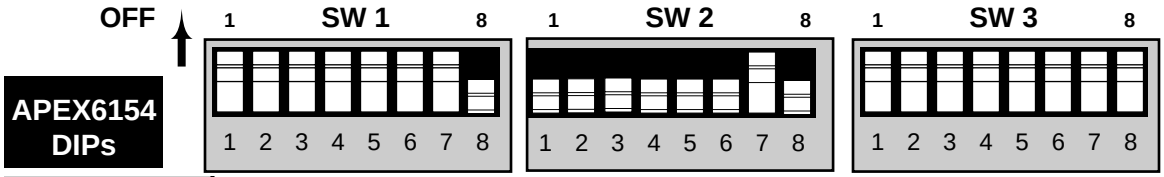
CONTINUOUS CURRENT (peak of sine wave)	1	2	3					
3.0 amps	OFF	OFF	OFF					
4.2	OFF	OFF	ON					
5.4	OFF	ON	OFF					
6.6	OFF	ON	ON					
7.8 (APEX605, 606)	ON	OFF	OFF					
9.0 (APEX604)	ON	OFF	ON					
10.2	ON	ON	OFF					
12.0	ON	ON	ON					
PEAK CURRENT				4	5	6		
9.0 amps				OFF	OFF	OFF		
10.8				OFF	OFF	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 (APEX604, 605, 606)				ON	ON	ON		
MOTOR THERMAL TIME CONSTANT							7	8
10 minutes (APEX604, 605, 606)							OFF	OFF
20							OFF	ON
30							ON	OFF
40							ON	ON

RESERVED	1							
Off	OFF							
ALIGNMENT MODE		2						
No		OFF						
Yes		ON						
COMMUTATION TEST MODE			3					
No			OFF					
Yes			ON					
HALL SELECT				4				
Resolver Mode (APEX604, 605, 606)				OFF				
Hall Mode				ON				
TACH SCALING					5			
One speed resolver (1V = 1,000 RPM with a one speed resolver) (APEX604, 605, 606)					OFF			
Two speed resolver (1V = 1,000 RPM with a two speed resolver)					ON			
RESERVED						6	7	8
All Off						OFF	OFF	OFF



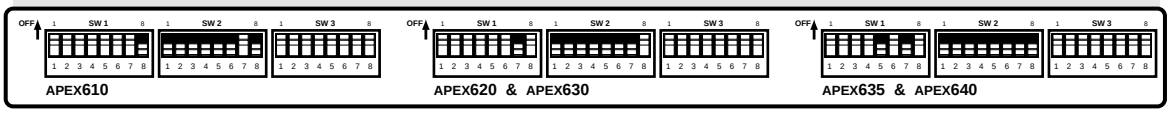
DEFAULT SETTINGS: The default setting for all DIP switches when the APEX6152 ships from the factory is **OFF..**

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APEX6154 DIPs

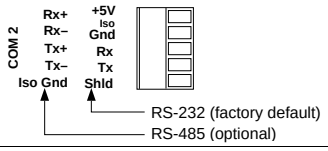
REGEN FAULT	1																							
Enable	OFF																							
Disable	ON																							
HALL DEGREES		2																						
120° Hall motor		OFF																						
60° Hall motor		ON																						
RESERVED			3																					
Off			OFF																					
POLE PAIR NUMBER				4	5																			
2 (APEX610 - 630)				OFF	OFF																			
3 (APEX635, 640)				OFF	ON																			
Reserved				ON	OFF																			
Reserved				ON	ON																			
RESOLVER SPEED						6																		
1 (All APEX Motors: 610 - 640)						OFF																		
2						ON																		
CURRENT LOOP COMPENSATION (motor inductance)							7	8																
25 – 40 mH							OFF	OFF																
5 – 15 mH (APEX610)							OFF	ON																
15 – 25 mH (APEX620, 630, 635, 640)							ON	OFF																
Reserved							ON	ON																
CONTINUOUS CURRENT (peak of sine wave)									1	2	3													
5 amps									OFF	OFF	OFF													
7									OFF	OFF	ON													
9									OFF	ON	OFF													
11									OFF	ON	ON													
13									ON	OFF	OFF													
15									ON	OFF	ON													
17									ON	ON	OFF													
20 (APEX610 - 640)									ON	ON	ON													
PEAK CURRENT												4	5	6										
15 amps												OFF	OFF	OFF										
18												OFF	OFF	ON										
22												OFF	ON	OFF										
25												OFF	ON	ON										
29												ON	OFF	OFF										
32												ON	OFF	ON										
36												ON	ON	OFF										
40 (APEX610 - 640)												ON	ON	ON										
MOTOR THERMAL TIME CONSTANT															7	8								
10 minutes															OFF	OFF								
20 (APEX610)															OFF	ON								
30 (APEX620, 630)															ON	OFF								
40 (APEX635, 640)															ON	ON								
RESERVED																	1							
Off																	OFF							
ALIGNMENT MODE																		2						
No																		OFF						
Yes																		ON						
COMMUTATION TEST MODE																			3					
No																			OFF					
Yes																			ON					
HALL SELECT																				4				
Resolver Mode (All APEX Motors: 610 - 640)																				OFF				
Hall Mode																				ON				
TACH SCALING																					5			
One speed resolver (1V = 1,000 RPM with a one speed resolver) (All APEX Motors: 610 - 640)																					OFF			
Two speed resolver (1V = 1,000 RPM with a two speed resolver)																					ON			
RESERVED																						6	7	8
All Off																						OFF	OFF	OFF



DEFAULT SETTINGS: The default setting for all DIP switches when the APEX6154 ships from the factory is **OFF..**

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Changing the COM 2 Connector from RS-232 to RS-485



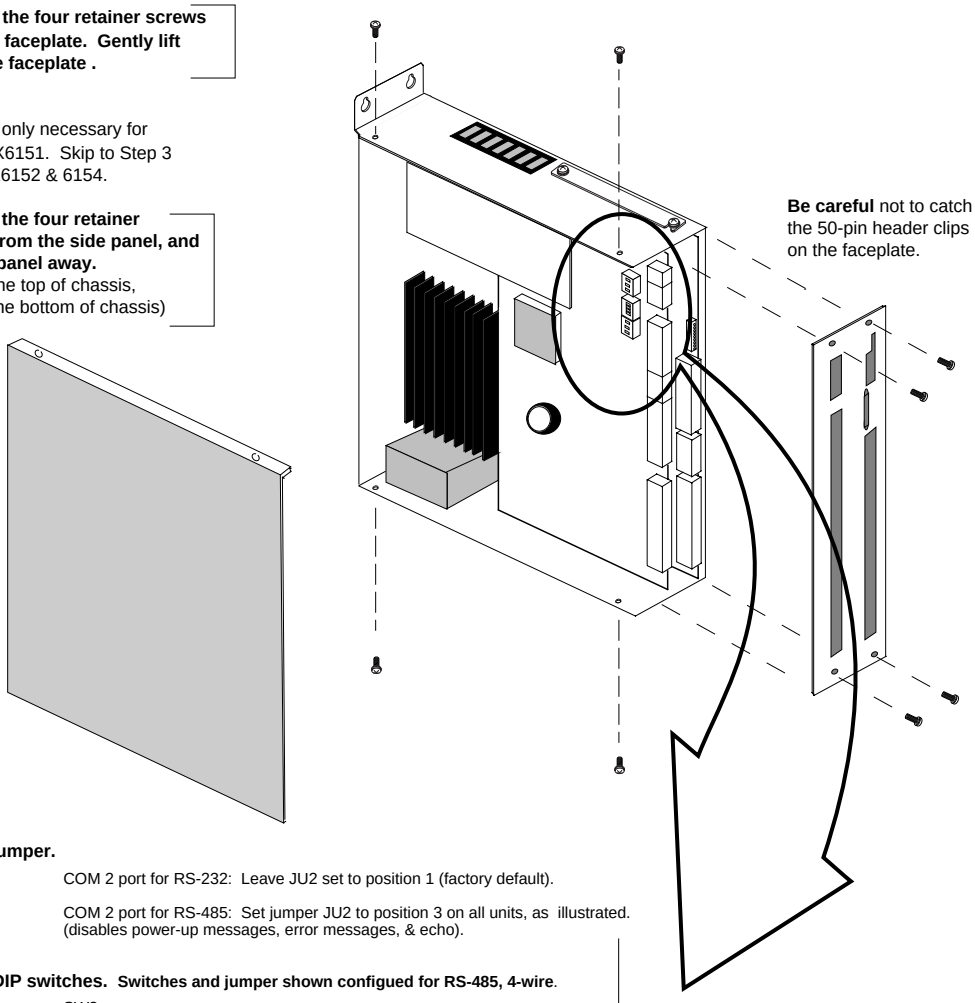
RS-232C Users

The APEX615n's **COM 2** port is factory configured for RS-232C communication (use the right-hand pin descriptions). If you do not need to use RS-485 communication, you may ignore this section and proceed to the *Mounting* instructions.

1. **Remove the four retainer screws from the faceplate. Gently lift away the faceplate .**

2. Step 2 is only necessary for the APEX6151. Skip to Step 3 for APEX6152 & 6154.

Remove the four retainer screws from the side panel, and pull the panel away. (two on the top of chassis, two on the bottom of chassis)



Be careful not to catch the 50-pin header clips on the faceplate.

3. **Set the jumper.**

COM 2 port for RS-232: Leave JU2 set to position 1 (factory default).

COM 2 port for RS-485: Set jumper JU2 to position 3 on all units, as illustrated. (disables power-up messages, error messages, & echo).

4. **Set the DIP switches. Switches and jumper shown configued for RS-485, 4-wire**.

SW3 (Rocker-style switch — depress raised side of switch to change states. Shown in ON position.)

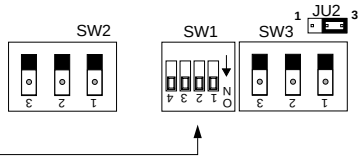
DIP switch #3: OFF= 2-wire, ON= 4-wire*
DIP switch #2: Turn ON for RS-485
DIP switch #1: Turn ON for RS-485

SW2 (Rocker-style switch — depress raised side of switch to change states. Shown in ON position.)

DIP switch #3: Turn ON for RS-485
DIP switch #2: Turn ON for RS-485
DIP switch #1: Turn ON for RS-485

SW1

DIP switch #4: Rx Termination Resistor.....120 Ω
DIP switch #3: Tx+ Bias Resistor.....681 Ω
DIP switch #2: Tx Termination Resistor.....120 Ω
DIP switch #1: Tx– Bias Resistor.....681 Ω



NOTE: Set the switches of SW1 to ON (as illustrated) to use the internal resistors. Typically do this for a single unit or for the last unit in a multi-drop. If these resistor values are not appropriate for your application, set the switches to OFF and connect your own external resistors. See page 25 for resistor calculations and wiring instructions.

*4-wire = full duplex (transmit **and** receive at the same time); 2-wire = half-duplex (transmit **or** receive at any time);

5. **Reattach the side panel and faceplate and replace the retainer screws.**

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Mounting the APEX615n

Before you mount the APEX615n

Make sure you have performed all the necessary configuration tasks that require accessing internal components (DIP switches and jumpers).

- **Select motor current (DIP switches)**. See pages 6-9.
- **Select serial communication method (jumper & DIP switches)**. If you are using RS-232C to communicate with the APEX615n, use the factory settings. If you need to change these settings (i.e., for RS-485), refer to page 10 for instructions.

The APEX615n 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

Provide a minimum of 1 inch of unrestricted air-flow space around the APEX615n chassis. The APEX615n will shut itself down if its internal sensor reaches 131°F (55°C).

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

Internal Temperature Sensors

The APEX615n has two temperature sensors. One is mounted on the drive 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 drive 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.

Humidity

- Maximum Relative Humidity: 95% (non-condensing)

Liquids

Do not allow liquids or fluids to come into contact with the APEX615n or its cables.

Airborne Contaminants

The APEX615n's fan provides internal forced air cooling whenever the drive is powered. However, theAPEX615n ***does not have*** any type of intake air filter. Particulate contaminants, especially electrically conductive material, such as metal shavings and grinding dust, can damage the APEX615n and the APEX motor. You must protect the APEX615n'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 APEX615n, 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.

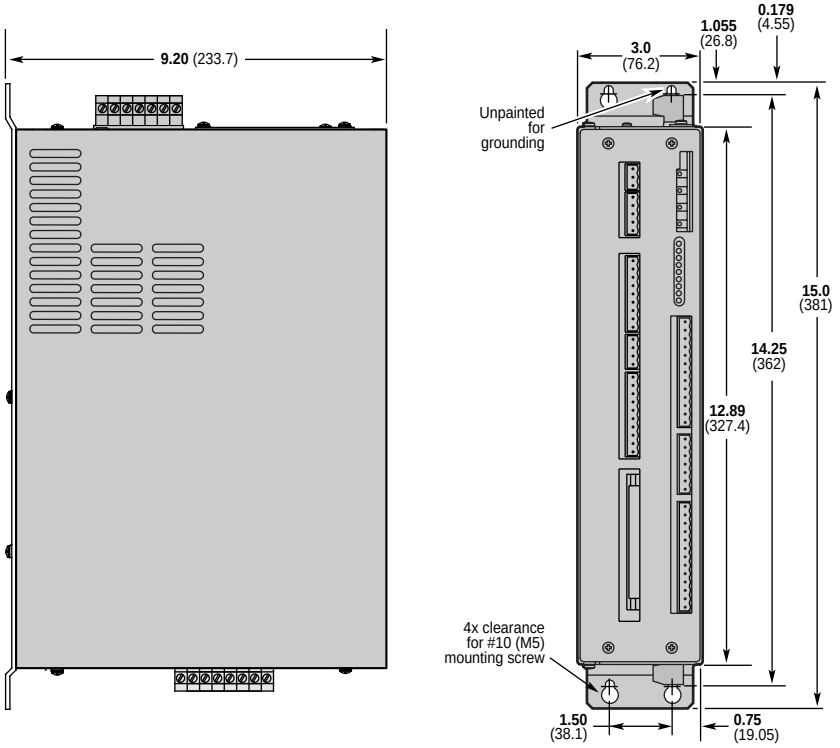
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Mounting Slots and Grounding

The APEX615n's mounting bracket is notched with keyhole type slots to accept four screws for surface mounting on a flat panel. 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 APEX615n and the mounting surface. The drive must also be grounded through the Earth terminal on the AC power connector.

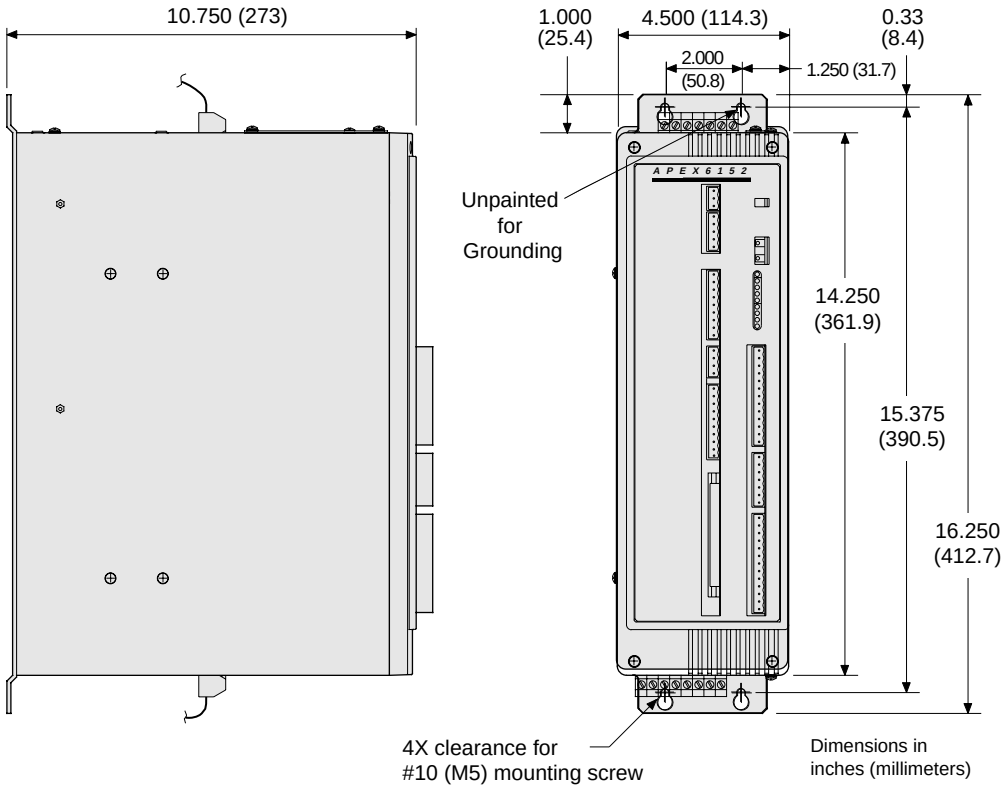
Dimensions

APEX6151

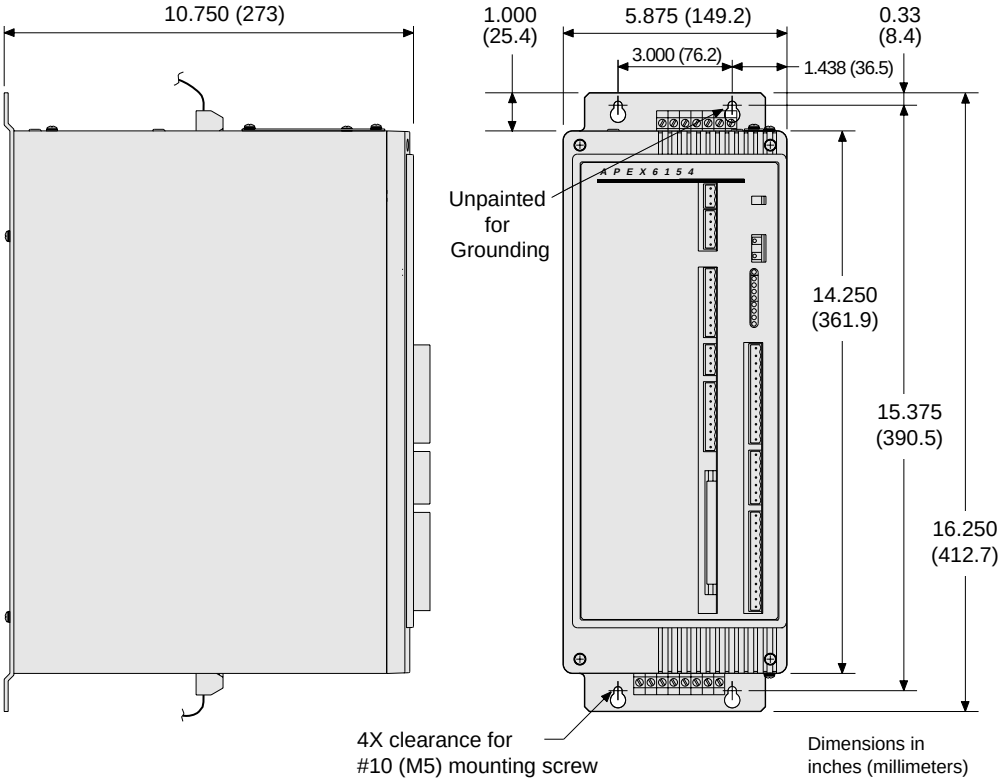


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APEX6152



APEX6154

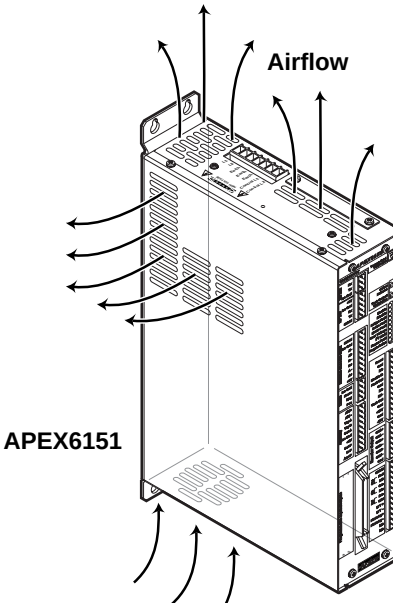


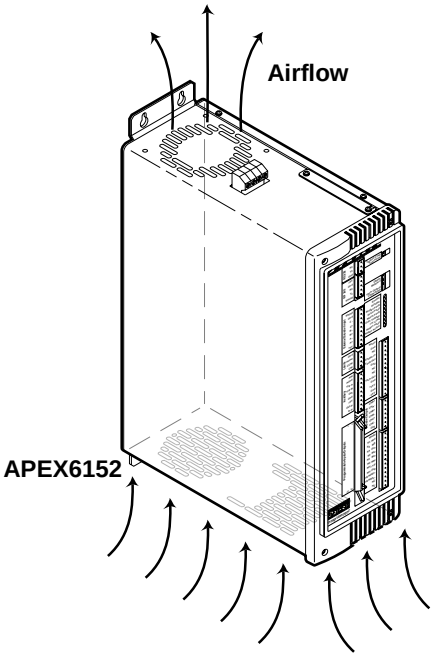
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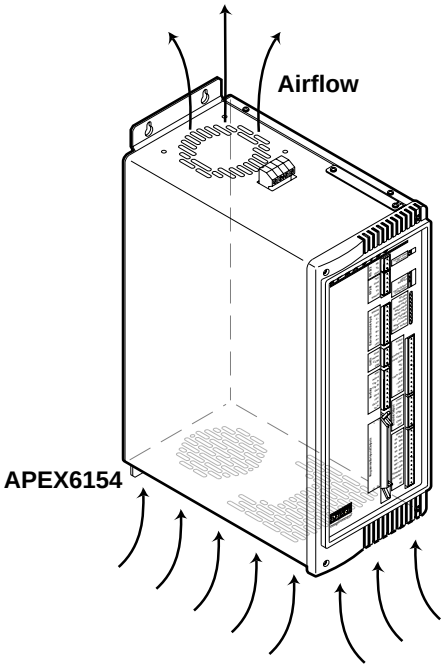
Airflow & Cooling

The APEX615n can operate 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 top of the drive. The fan draws air in through the bottom and upward over the internal heatsink. The air directly beneath the APEX615n must not exceed 50°C (122°F).

The APEX615n does not have an air filter. You must protect its intake air supply from contamination.







Panel Layout

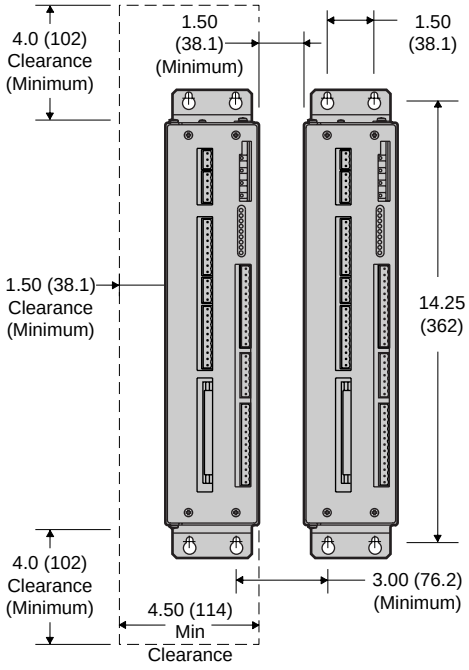
When designing the panel layout, remember that the APEX615n produces heat that must be dissipated. Heat produced may be as high as:

- 100 watts for an APEX6151 operating continuously at 8 amps
- 150 watts for an APEX6152 operating continuously at 12 amps
- 200 watts for an APEX6154 operating continuously at 20 amps

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

Panel layout dimensions are shown below.

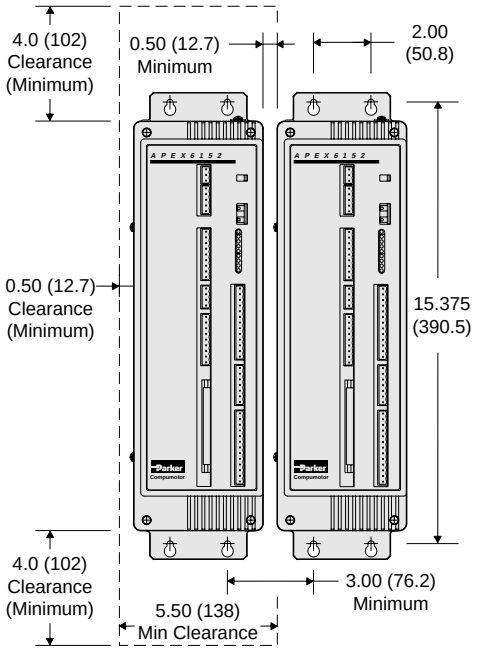
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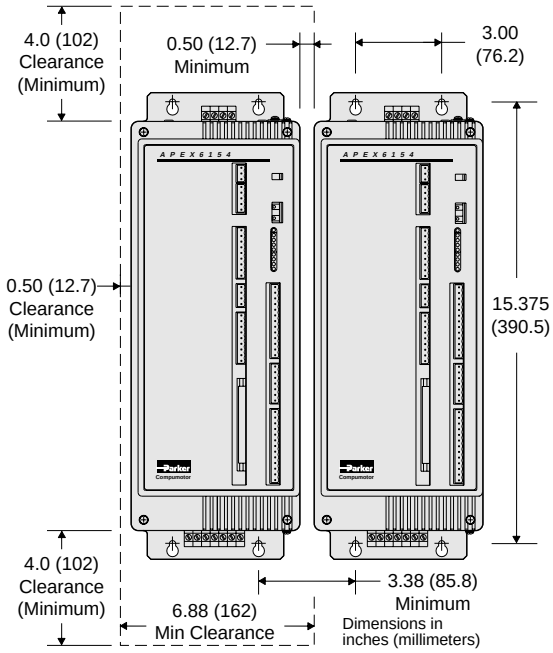
APEX6151

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

- The vertical distance between the APEX615n and other equipment, or the top and bottom of the enclosure, should be no less than 4 inches (100 mm).
- The horizontal distance between the APEX6151's side air vents and other equipment should be no less than 1.5 inches (38.1 mm). The horizontal distance between the sides of the APEX6152 or APEX6154 and other equipment should be no less than 0.50 inches (12.7 mm).
- Do not mount the APEX615n directly below heat-sensitive equipment.
- Large heat-producing equipment (such as transformers) should not be mounted directly beneath the APEX615n.

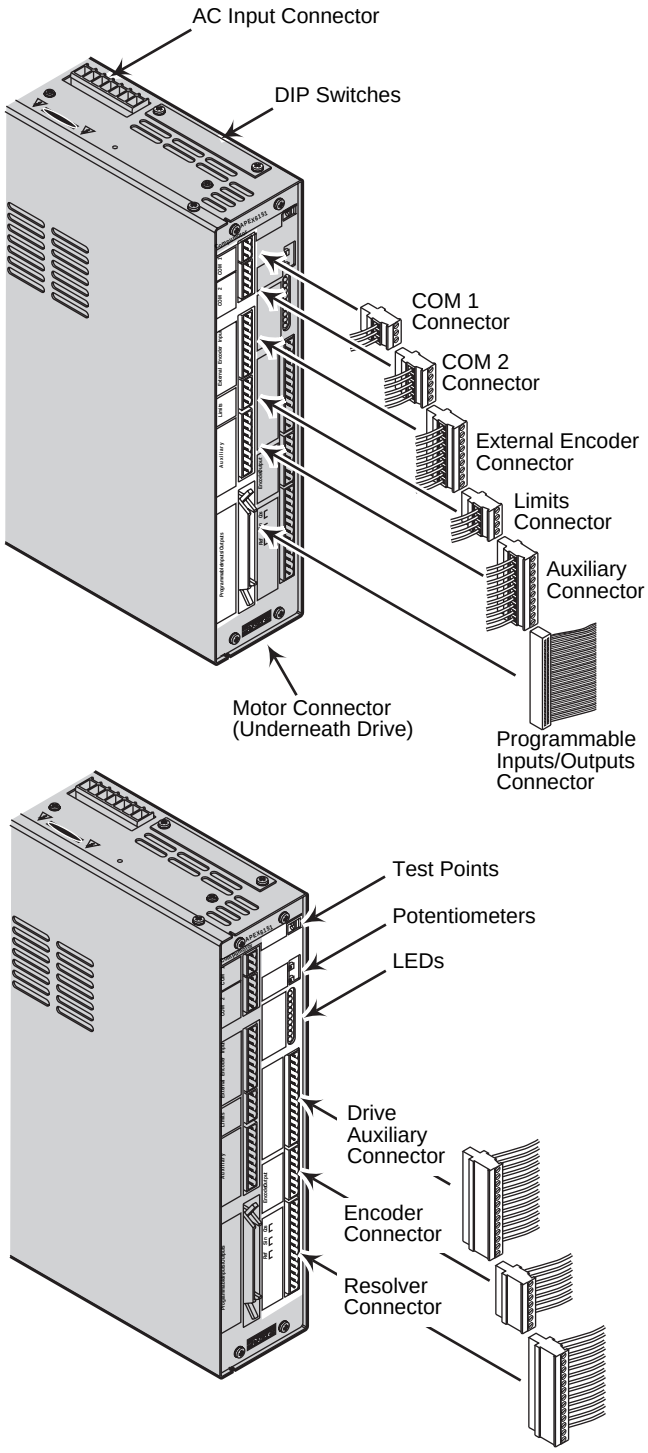


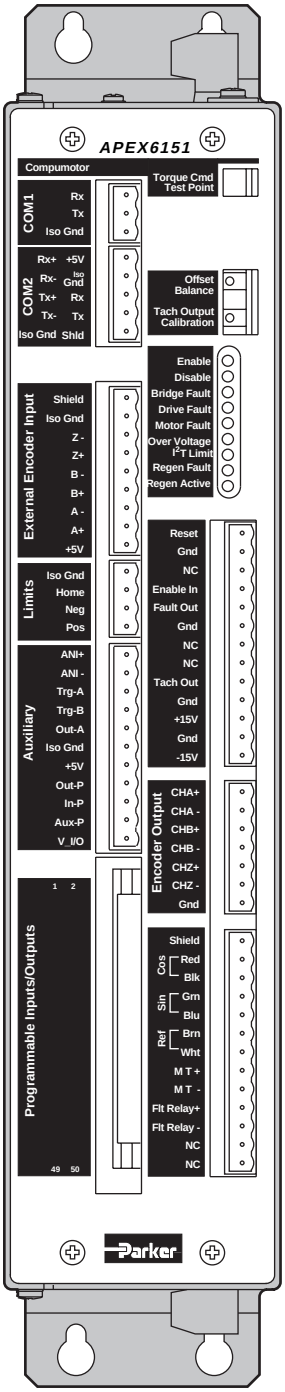
APEX6152



APEX6154

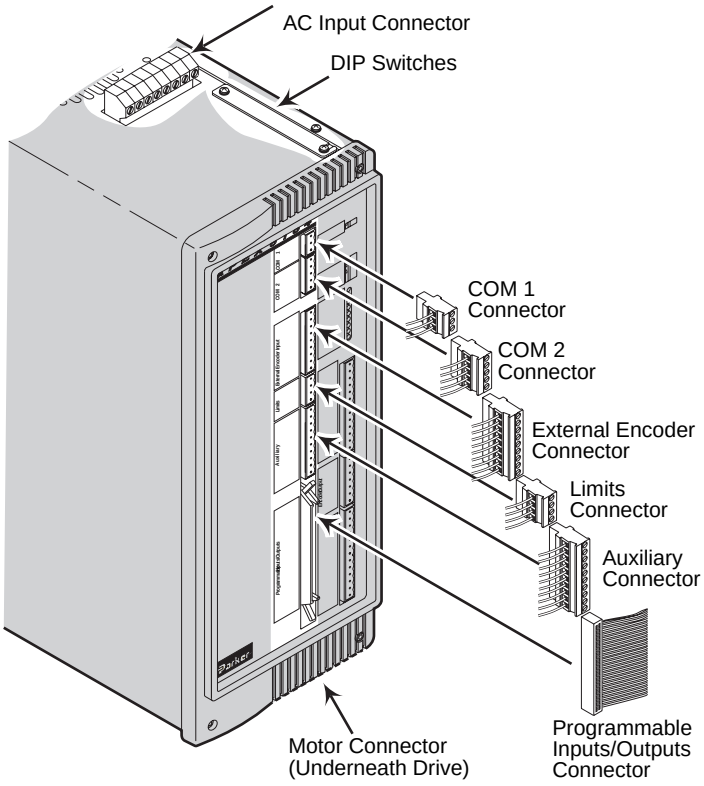
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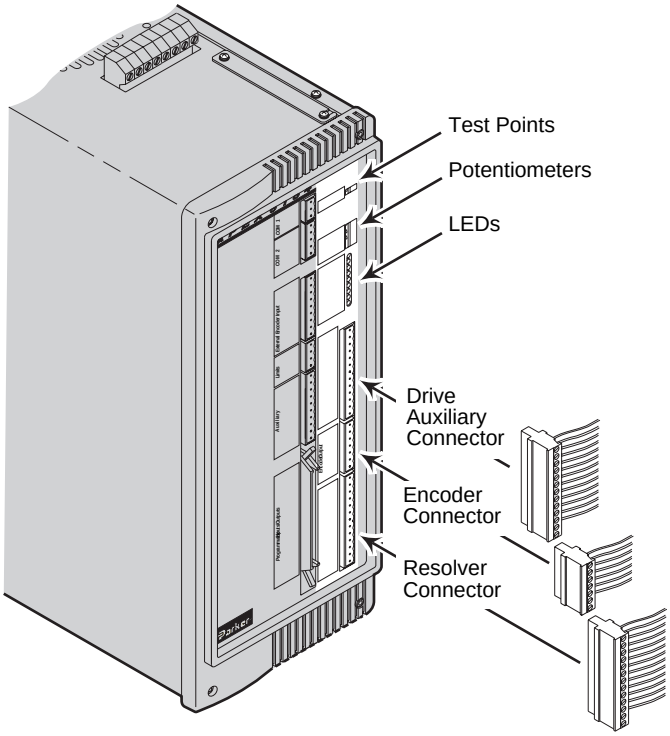


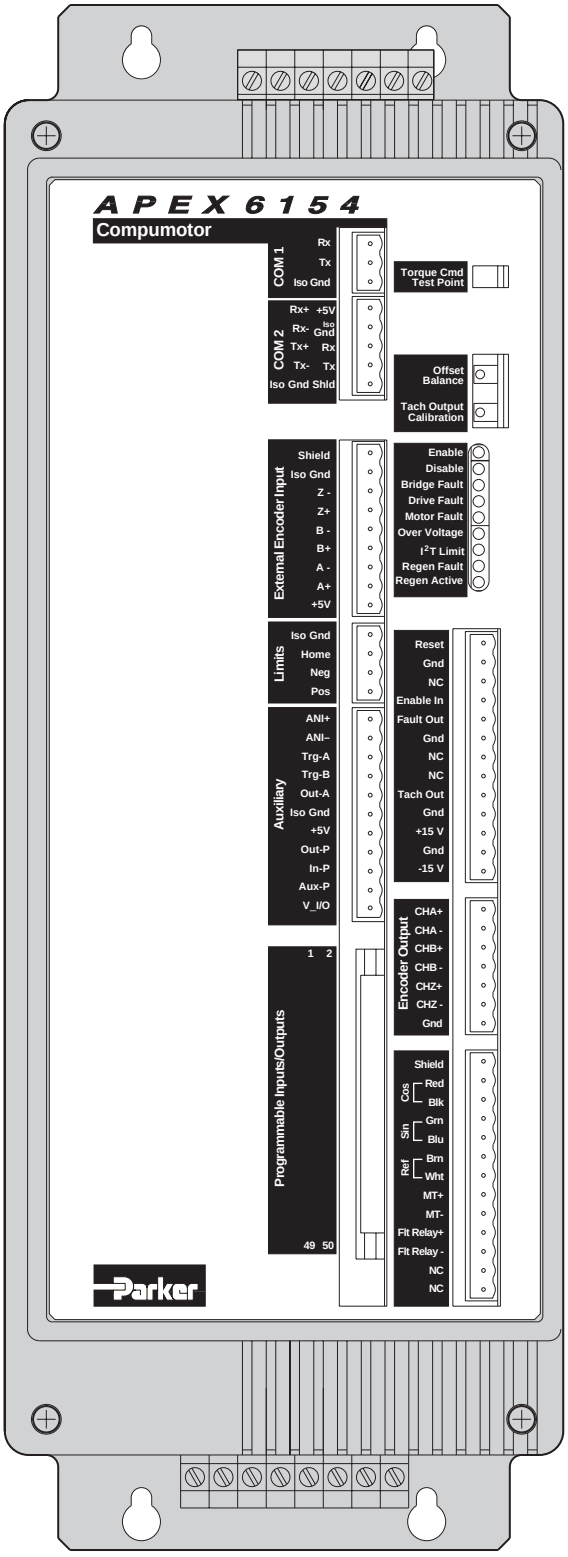


Connector Locations

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Connector Locations

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Ground Connections

The APEX615n has three internal ground systems: two floating ground systems (Isolated Ground and Analog Ground) and one Earth ground system (Chassis Ground). The table below identifies the terminals that are associated with each ground system. Refer to the following drawings to locate the grounding points. Note that Pin 5 on the COM 2 port serves as Iso GND when the port is used for RS-485 communication, and serves as Shield when the port is used for RS-232 communications (default condition).

Ground System	**Shared Terminals** (internally connector to each other)	
Isolated Ground.	Iso Gnd	All terminals labeled "**Iso Gnd**". The "Iso Gnd" terminal on the COM 2 port when the port is used for RS-485 communications.
Recommended for low-level control and I/O signals.	I/O Gnd	All even numbered pins on the 50-pin **Programmable Inputs/Outputs** connector.
Analog Ground	Gnd	All terminals labeled "**Gnd**".
	Shield	The "**Shield**" terminal on the Resolver connector only.
Chassis Ground	Earth	The "Earth" terminal on the AC Input power connector. (Multiple Earth terminals are provided for convenience.)
	Shield	All terminals labeled "**Shield**" — excluding the Shield terminal on the Resolver connector. Includes the terminal labeled "Shld" on the COM 2 port when it is used for RS-232 communications.
*You must reference this ground to earth ground by Connecting the **EARTH** terminal on the AC Input connector to the external earth ground.*	Motor Gnd	"**Motor Ground**" terminal on the motor connector
	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.

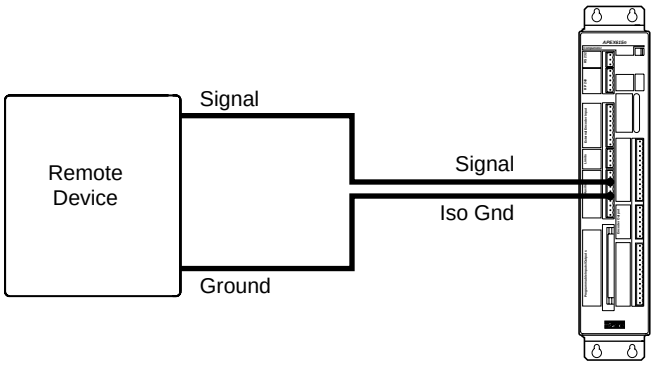
Grounding Procedure

When you connect grounds from other devices, remember that the APEX615n's isolated ground (**Iso GND**) is *not* internally connected to the analog ground (**GND**). To prevent electrical noise problems, the APEX615n is designed so that grounds on remote I/O devices (triggers, RS-232C terminals, inputs and outputs, PLCs, etc.) can be kept isolated from the APEX615n's analog and chassis ground.

Follow the guidelines below to make ground connections in your system.

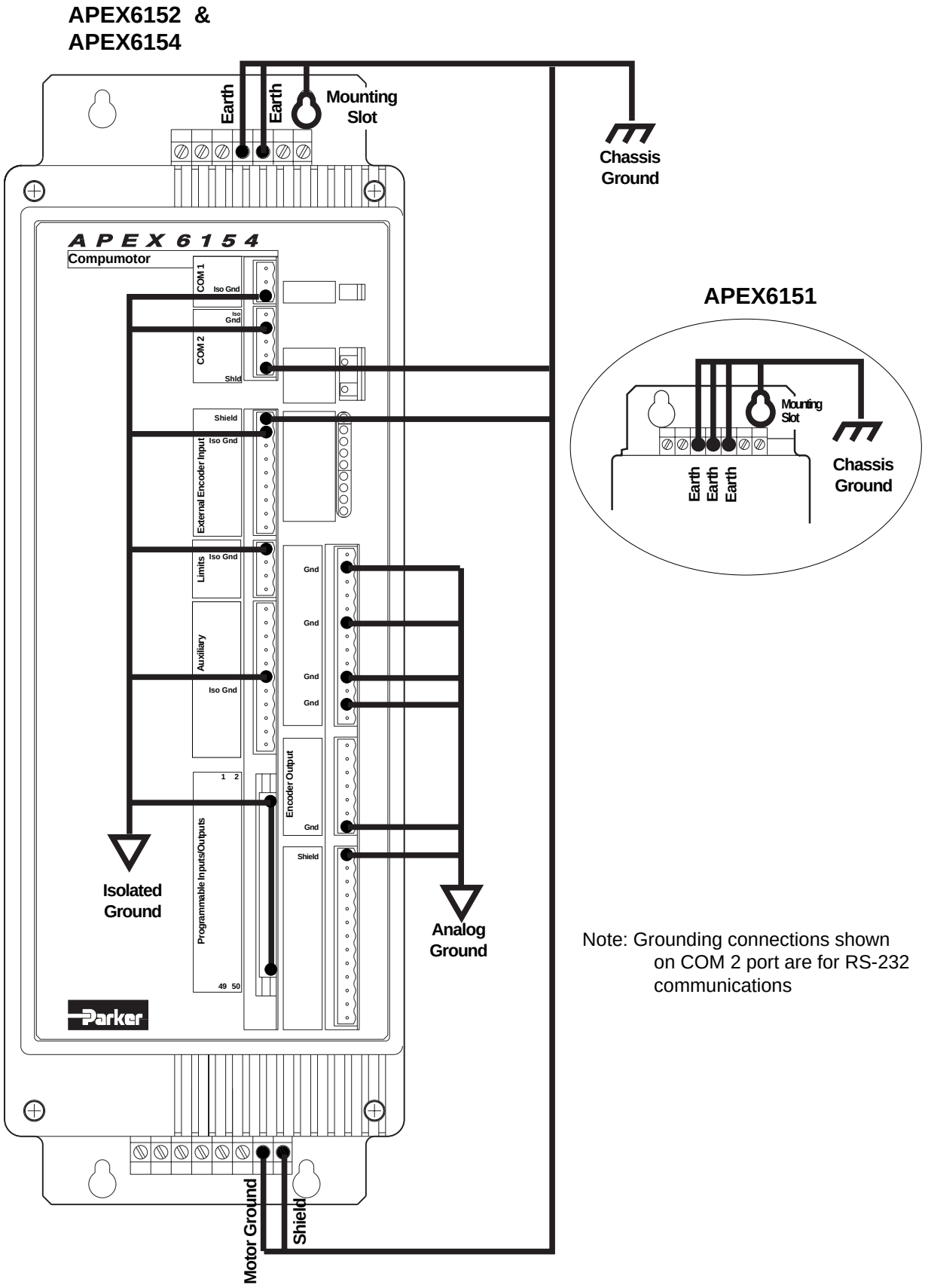
1. Only connect to Iso GND, if possible.

For most applications, there is no need to connect to the **GND** terminals. If you connect external devices only to the left row of connectors, then make ground connections only to **Iso GND** (not to **GND**). The next drawing shows such a connection.



Ground Connection to **Iso GND** *Only*

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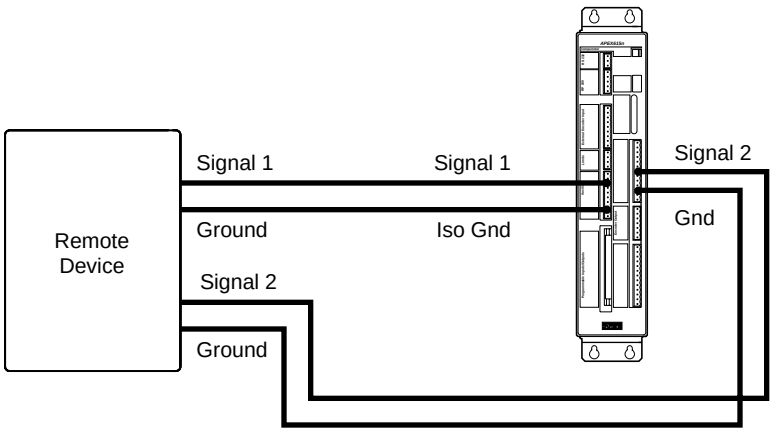
Note: Grounding connections shown on COM 2 port are for RS-232 communications

APEX615n Ground Systems

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2. If you must connect to a GND terminal, use a separate ground wire from your remote device. Do not put a jumper between GND and Iso GND.

If you connect signals from an external device to terminals on both the left row of connectors and the right row of connectors, then run two separate ground wires from the remote device to the APEX615n. Connect one wire to **Iso GND**, and connect the other to **GND**. The next drawing shows how to make these connections.

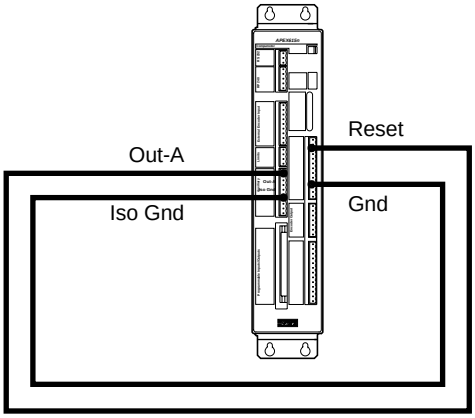


Ground Connection to both **Iso GND** *and* **GND**

Separate ground wires will ensure that the isolated ground remains truly isolated from the chassis ground.

***3. If you make connections between terminals on the left row of connectors and the right row of connectors, connect the internal grounds together by placing a jumper between* Iso GND *and* GND.**

As an example, the next drawing shows the output **OUT-A** controlling the **RESET** input on the Drive Auxiliary connector.



Notice that a jumper connects **Iso GND** to **GND**. This ensures that both signals—**OUT-A** and **RESET**—are referenced to the same ground level.

Ground Connection Between **Iso GND** *and* **GND**

4. Connect shields on interface cables at the remote device only. Do not connect the shields at the APEX615n end.

The cable shield from a remote device, such as an external encoder or an RP240 Remote Operator Panel, should not be connected to the APEX615n.

EXCEPTION: The shield on the motor cable should be connected to the **MOTOR GROUND** terminal on the motor connector. The shield on the resolver cable should be connected to the **SHIELD** terminal on the resolver connector.

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AC Input Connector

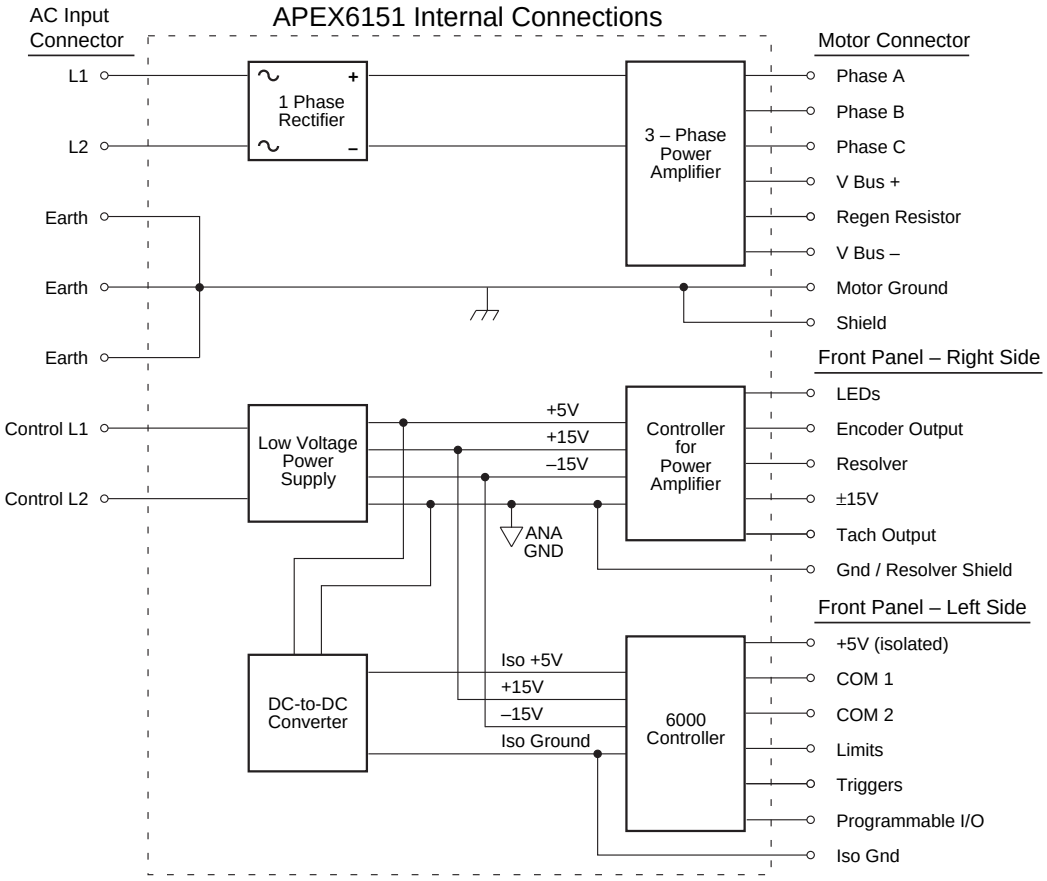
Connect AC power to the APEX615n's AC Input connector, which is an 8-pin removable connector located on top of the unit. The connector can accept wire diameters as large as 10 AWG (6mm)

The AC power requirements for each model of the APEX615n are as follows:

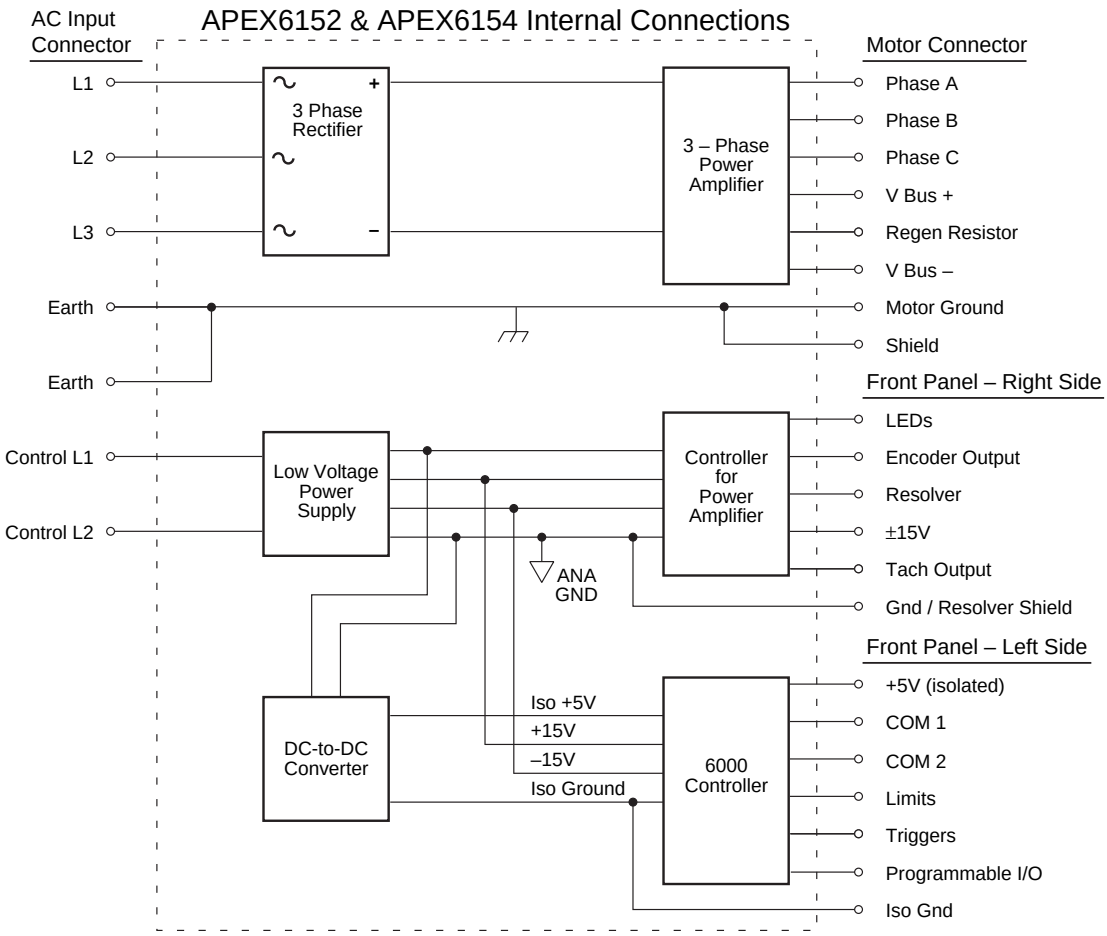
APEX6151:	85-252VAC, Single Phase, (SM Motor - 120VAC only)
APEX6152:	85-252VAC, 3-phase>202VAC preferred, or Single Phase
APEX6154:	85-252VAC, , 3-phase>202VAC preferred, or Single Phase

CONNECT AC POWER IN TWO PLACES

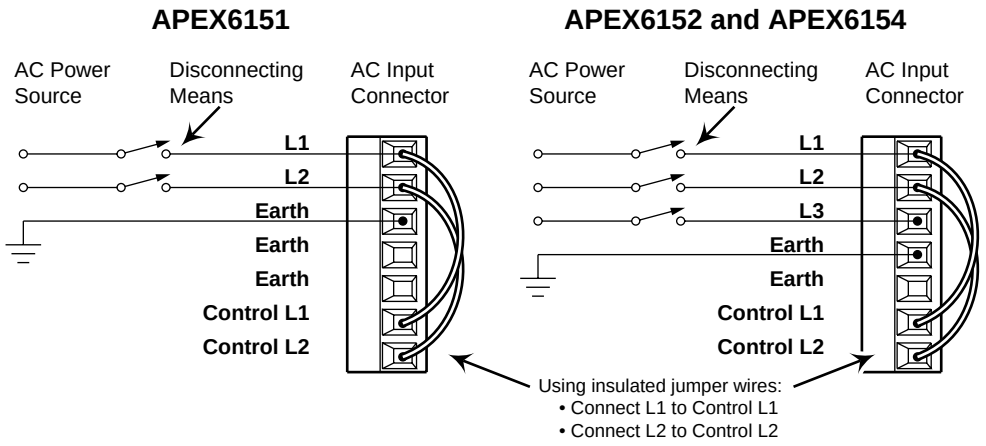
Inside the APEX615n, there are two power systems, each with its own AC input terminals. Ones system provides high voltage power to the power amplifier — its terminals are labeled **L1**, **L2**, and **L3** (or **L1** and **L2** on the APEX6151) The other system provides low voltage power to the power amplifier's controller and the 6000 controller — its terminals are labeled **Control L1**, **Control L2.**



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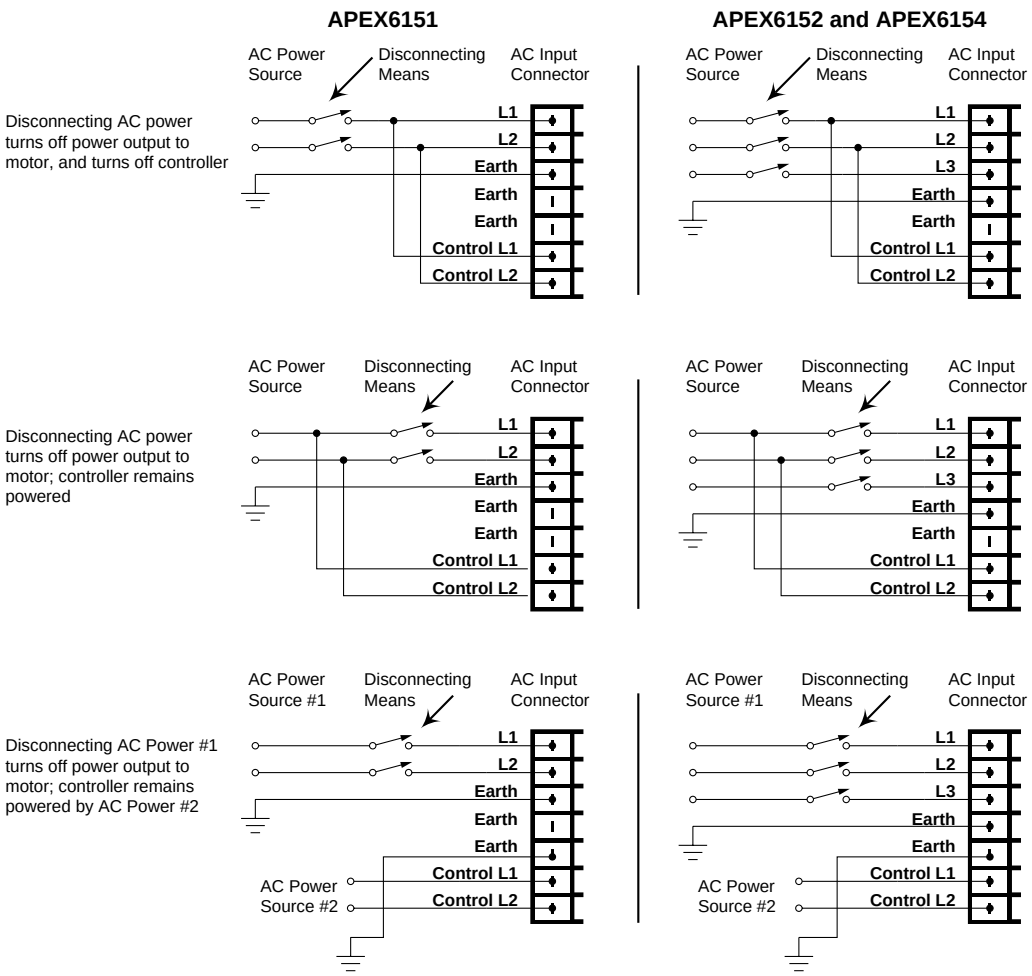


You must connect AC power to both **L1/L2/L3** and **Control L1/Control L2** (or to both **L1/L2** and **Control L1/Control L2** on the APEX6151. The next drawing shows a simple way to do this.



AC Connector with Jumpers Attached

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Disconnecting Power to the Drive

Removing power to the drive portion of the APEX615n (**L1/L2/L3** or **L1/L2**) will result in a Drive Fault due to an under-voltage condition on the drive bus. There may be a delay from when power is removed from the drive to when the Drive Fault condition is communicated to the controller due to the time necessary to dissipate power from the drive bus capacitor. This power dissipation rate is situation-dependent.

When the Drive Fault signal is received by the controller, the motion program will be immediately killed (see `!K` command in the 6000 Series Software Reference). However, if the controller has `INFEN0` or `DRIVE0` when the signal is received, the Drive Fault will be ignored and the program being executed will continue to run.

To ensure that the controller is immediately aware of power being removed from the drive, Compumotor recommends that the drive power terminals (**L1/L2/L3** or **L1/L2**) be configured with the **ENABLE INPUT** on the Drive Auxiliary connector. When the controller detects that the **ENABLE INPUT** has changed state, it issues an Immediate Kill (`!K`) command, regardless of any other conditions.

Bit 4 of the `TASX` command (`TASX.4`) returns the current status of the Drive Fault.

Bit 6 of the `TINO` command (`TINO.6`) returns the current status of the **ENABLE INPUT.**

Bit 4 of the `ERROR` command (`ERROR.4`) enables the error checking function such that the controller will branch to the designated error program (`ERRORP`) when a Drive Fault is detected. (Refer to the 6000 Series Software Reference for additional information about 6000 Series commands.)

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Disconnecting Power to the Controller

Removing power to the controller portion of the APEX615n (**Control L1** and **Control L2**) will trigger a Drive Fault, plus the controller will issue a "shutdown" signal to the drive that is equivalent to the `DRIVE0` command.

When power is restored to the controller, the drive will need to be reset using the either the `DRESET` command or the **RESET** Input on the Drive Auxiliary connector. (The `DRESET` command is the equivalent of the **RESET** Input.)

Fusing Information

Recommended fuse sizes are:

APEX6151 (120 VAC):	15-25A slow blow type, Littelfuse p/n 326-025 (or equiv.)
APEX6151 (240 VAC):	12-15A slow blow type, Littelfuse p/n 326-015 (or equiv.)
APEX6152 (240 VAC):	12A slow blow type, Littelfuse p/n 326-012 (or equivalent)
APEX6154 (240 VAC):	20A slow blow type, Littelfuse p/n 326-020 (or equivalent)

⚠ WARNING ⚠

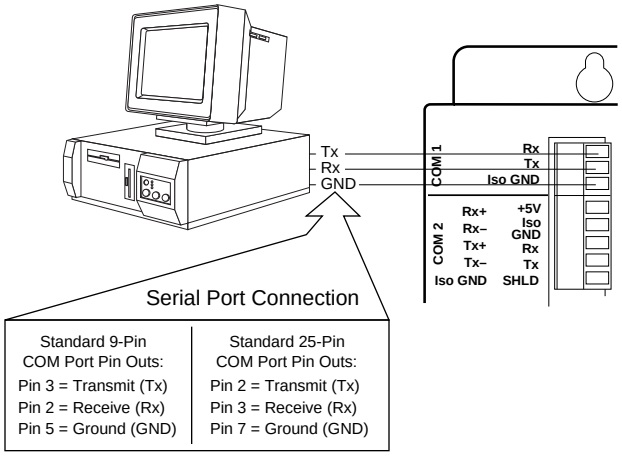
The APEX615n has no internal fuses. For safety purposes, provide a fuse in each of the AC input lines.

The actual input power and current is a function of the motor's operating point (speed and torque) and the duty cycle. The fuse value given above is for a drive and motor operating at rated speed and rated torque at 100% duty. You can de-rate the fuse by scaling the above value by your actual requirements.

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Serial Communication

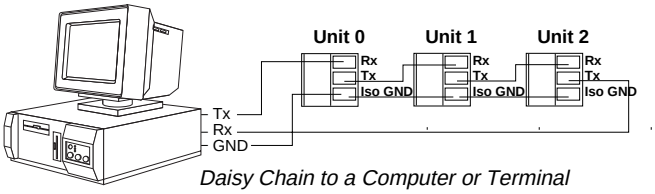
RS-232C Connections



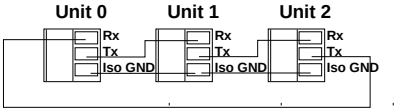
Standard 9-Pin COM Port Pin Outs:	Standard 25-Pin COM Port Pin Outs:
Pin 3 = Transmit (Tx)	Pin 2 = Transmit (Tx)
Pin 2 = Receive (Rx)	Pin 3 = Receive (Rx)
Pin 5 = Ground (GND)	Pin 7 = Ground (GND)

NOTE: Maximum RS-232C cable length is 50 feet (15.25 meters)

RS-232C Daisy-Chain Connections*



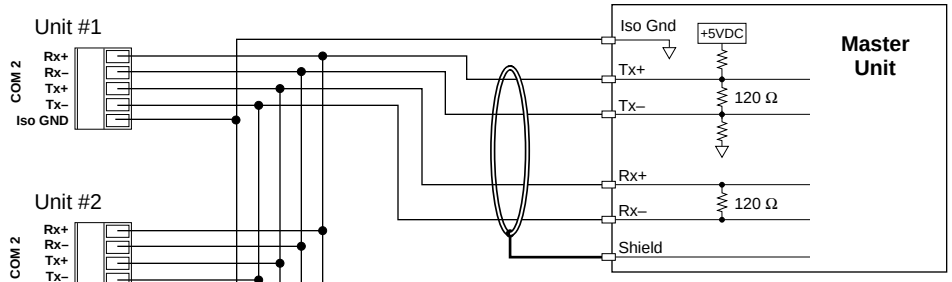
Daisy Chain to a Computer or Terminal



Stand-Alone Daisy Chain

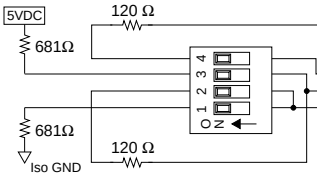
* Be sure to set unique devices addresses for each unit using the ADDR command (see *6000 Series Software Reference*).

RS-485 Connections (4-wire interface)



RS-485 Configuration

Before you can use RS-485 communication, you must re-configure the COM 2 port by setting internal jumper JU2 to position 3, and setting DIP switches 1-3 on SW2 and DIP switches 1-2 on SW3 to the ON position. Set DIP switch 3 on SW3 to ON position for 4-wire interface (2-wire is default, using Tx+ and TX- terminals on COM2 port).
Refer to page 10 for instructions.

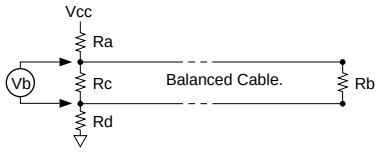


DIP switch selects internal resistor values (ON selects the resistor).
Use these resistors only for the last unit (or for a single unit).

If your application requires terminating resistors other than 120Ω, and/or bias resistors other than 681Ω, then make sure the internal DIP switches are set to OFF and connect your own external resistors. To calculate resistor values:

NOTE: Maximum RS-485 cable length is 4000 feet (1220 meters)

Calculating Resistor Values



Example Assumptions: The cable's characteristic impedance (Zo) = 120Ω. Rc and Rb are equal and are selected to match Zo (Rc = Rb = Zo = 120Ω).

Step 1 Calculate the equivalent resistance (Req)* of Rc / / Rb:
Rc / / Rb = 120Ω / / 120Ω = 60Ω

Step 2 Calculate the pull-up and pull-down resistor values knowing that the FAILSAFE bias is 200mV and Vcc = 5V:
Vb = Vcc (Req / (Ra + Req + Rd))
solving for R' (defined as Ra + Rd)
R' = ((Req) Vcc / Vb) - Req
R' = ((60Ω) 5V / 0.2V) - 60Ω = 1440Ω
Since Ra and Rd are equal, Ra = Rd = 1440Ω / 2 = 720Ω

Step 3 Recalculate the equivalent resistance of RC / / (Ra + Rd):
Rc / / (Ra + Rd) = 120Ω / / (720Ω + 720Ω) = 110.77Ω

Since the equivalent resistance is close (within 10%) to the characteristic impedance of the cable (Zo), no further adjustment of resistor values is required.

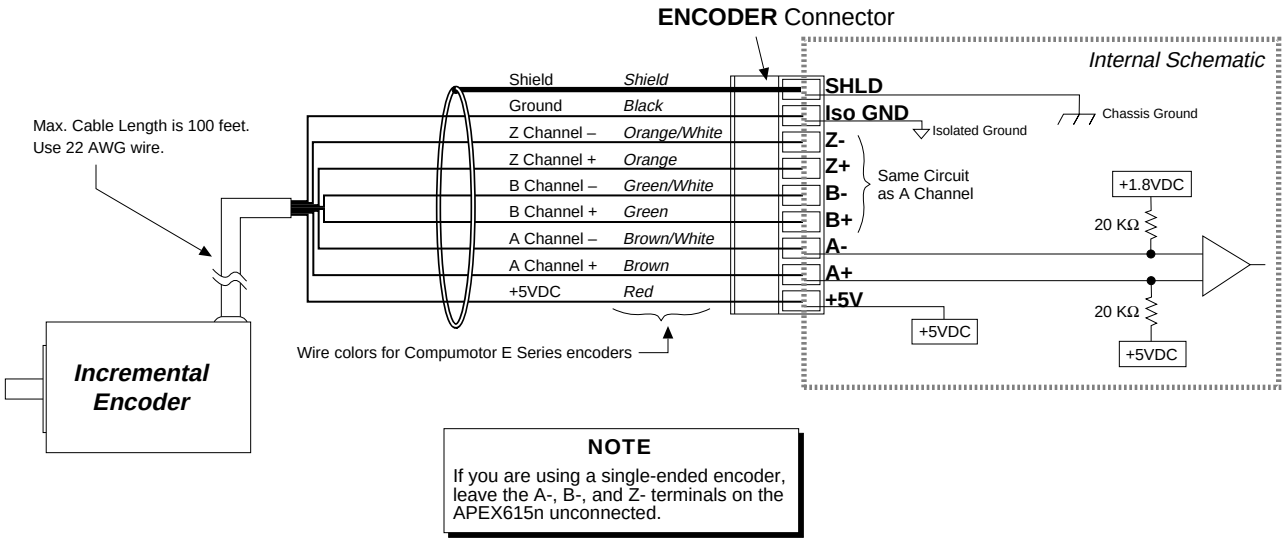
* Actual calculation for equivalent resistance (e.g., R_1 / / R_2): $\frac{R_1 R_2}{(R_1 + R_2)}$

For further information, consult a communications interface reference.

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External Encoder

CONNECTIONS & INTERNAL SCHEMATICS



NOTE

If you are using a single-ended encoder, leave the A-, B-, and Z- terminals on the APEX615n unconnected.

PIN OUTS & SPECIFICATIONS *(9-pin ENCODER Connector)*

Pin Name	In/Out	Description
SHLD	-----	*Shield*—Internally connected to chassis ground (earth).
ISO GND	-----	Isolated logic ground.
Z–	IN	Z– Channel signal input.
Z+	IN	Z+ Channel signal input.
B–	IN	B– Channel quadrature signal input.
B+	IN	B+ Channel quadrature signal input.
A–	IN	A– Channel quadrature signal input.
A+	IN	A+ Channel quadrature signal input.
+5V	OUT	+5VDC output to power the encoder.

Specification for all encoder inputs

Differential comparator accepts two-phase quadrature incremental encoders with differential (recommended) or single-ended outputs. Max. frequency is 1.2 MHz.
Minimum time between transitions is 833 ns.
TTL-compatible voltage levels: Low ≤ 0.4V, High ≥ 2.4V.
Maximum input voltage is 5VDC.

Requirements for Non-Compumotor Encoders

- Use incremental encoders with two-phase quadrature output. An index or *Z channel* output is optional. **Differential outputs are recommended.**
- It must be a 5V (< 200mA) encoder to use the APEX615n's **+5V** output. Otherwise, it must be separately powered with TTL-compatible (low ≤ 0.4V, high ≥ 2.4V) or open-collector outputs.

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End-of-Travel and Home Limit Inputs

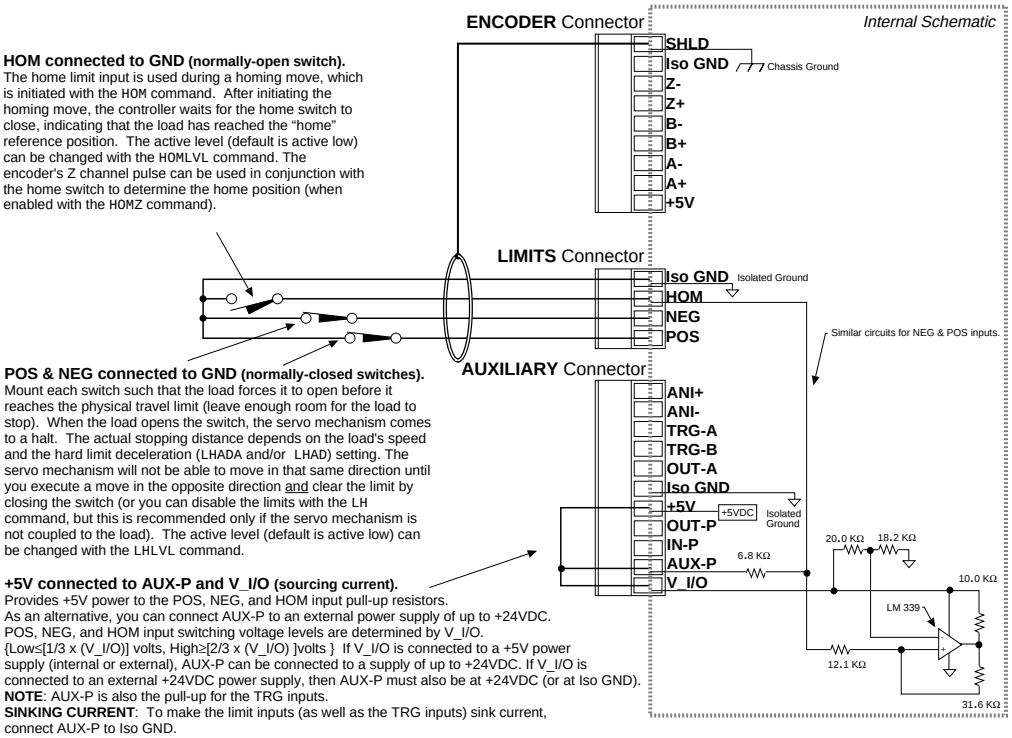
NOTES

- Motion will not occur until you do one of the following:
  - Install end-of-travel (**POS** & **NEG**) limit switches
  - Disable the limits with the LHØ command (recommended only if load is not coupled)
  - Change the active level of the limits with the LHLVL command
- Refer to the *Basic Operations Setup* chapter in the *6000 Series Programmer's Guide* for in-depth discussions about using end-of-travel limits and homing.

⚠ WARNING ⚠

If a *runaway* occurs (motor starts moving, usually at the fastest possible velocity, due to servo instability), the APEX615n will shut down power output to the motor if the maximum position error (set with the SMPER command) is exceeded **before** an end-of-travel limit (either hardware of software) is encountered. However, if the maximum position error is **not** exceeded by the time the limit is encountered, the APEX615n **may not be able to stop the servo mechanism**.

CONNECTIONS & INTERNAL SCHEMATICS



HOM connected to GND (normally-open switch).
The home limit input is used during a homing move, which is initiated with the HOM command. After initiating the homing move, the controller waits for the home switch to close, indicating that the load has reached the "home" reference position. The active level (default is active low) can be changed with the HOMLVL command. The encoder's Z channel pulse can be used in conjunction with the home switch to determine the home position (when enabled with the HOMZ command).

POS & NEG connected to GND (normally-closed switches).
Mount each switch such that the load forces it to open before it reaches the physical travel limit (leave enough room for the load to stop). When the load opens the switch, the servo mechanism comes to a halt. The actual stopping distance depends on the load's speed and the hard limit deceleration (LHADA and/or LHAD) setting. The servo mechanism will not be able to move in that same direction until you execute a move in the opposite direction and clear the limit by closing the switch (or you can disable the limits with the LH command, but this is recommended only if the servo mechanism is not coupled to the load). The active level (default is active low) can be changed with the LHLVL command.

+5V connected to AUX-P and V_I/O (sourcing current).
Provides +5V power to the POS, NEG, and HOM input pull-up resistors. As an alternative, you can connect AUX-P to an external power supply of up to +24VDC. POS, NEG, and HOM input switching voltage levels are determined by V_I/O. {Low≤[1/3 x (V_I/O)] volts, High≥[2/3 x (V_I/O)]volts } If V_I/O is connected to a +5V power supply (internal or external), AUX-P can be connected to a supply of up to +24VDC. If V_I/O is connected to an external +24VDC power supply, then AUX-P must also be at +24VDC (or at Iso GND).
NOTE: AUX-P is also the pull-up for the TRG inputs.
SINKING CURRENT: To make the limit inputs (as well as the TRG inputs) sink current, connect AUX-P to Iso GND.
CAUTION: Disconnect jumper to +5V before connecting external power supply to either IN-P, OUT-P, AUX-P, or V_I/O.

PIN OUTS & SPECIFICATIONS *(4-pin LIMITS Connector)*

Name	In/Out	Description
Iso GND	—	Isolated ground.
HOM	IN	Home limit input.
NEG	IN	Negative-direction end-of-travel limit input.
POS	IN	Positive-direction end-of-travel limit input.

Specification for all limit inputs

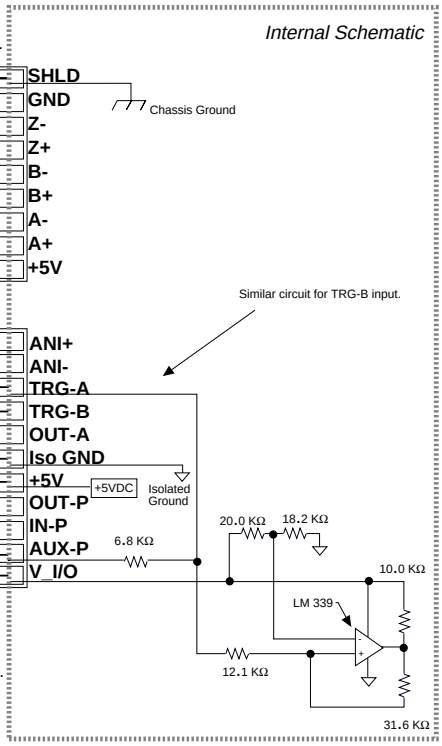
Switching voltage levels determined by V_I/O. Low ≤ 1/3 (**V_I/O**) volts, High ≥ 2/3 (**V_I/O**) volts; internal 6.8 KΩ pull-ups to AUX-P terminal ; voltage range is 0-24V.

Active level for HOM is set with the HOMLVL command (default is active low, requiring normally-open switch).

Active level for POS & NEG is set with the LHLVL command (default is active low, requiring normally-closed switch).

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Trigger Inputs



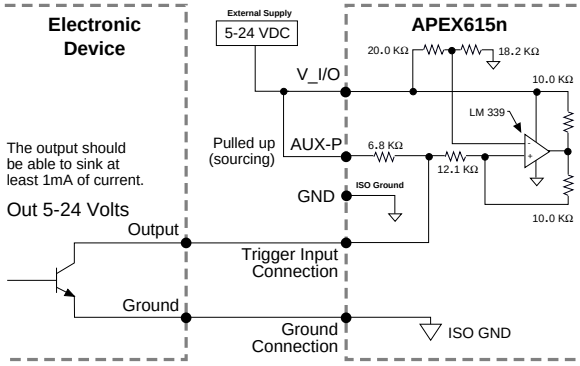
TRG-A/B connected to Iso GND (normally-open switches).

The active level (default is active low) can be changed with the `INLVL` command.

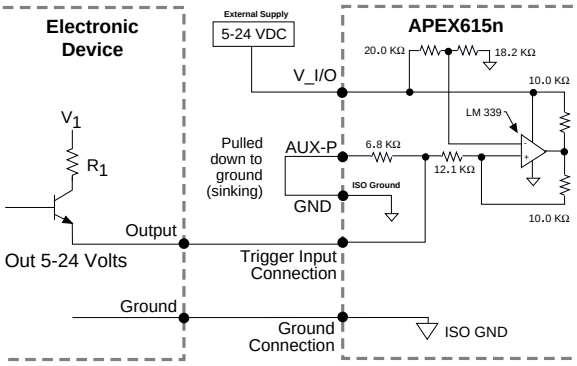
These inputs are like the general-purpose inputs on the 50-pin header. The differences are (1) the triggers are pulled up via the AUX-P pull-up terminal; and (2) the triggers can be programmed with the `INFNCi-H` command to function as position capture inputs and registration inputs.

+5V connected to AUX-P and V_I/O (sourcing current).
Provides power to the TRG input pull-up resistors. As an alternative, you can connect AUX-P to an external power supply of up to +24VDC. TRG input switching voltage levels are determined by V-I/O. {Low≤[1/3 x (V_I/O)] volts, High≥[2/3 x (V_I/O)]volts } If V_I/O is connected to a +5V power supply (internal or external), AUX-P can be connected to a supply of up to +24VDC. If V_I/O is connected to an external +24VDC power supply, then AUX-P must also be at +24VDC (or at Iso GND).
NOTE: AUX-P is also the pull-up for the HOM, NEG & POS inputs.
SINKING CURRENT: To make the trigger inputs (and HOM, NEG & POS) sink current, connect AUX-P to Iso GND.
CAUTION: Disconnect jumper to +5V before connecting external power supply to either IN-P, OUT-P, AUX-P, or V_I/O.

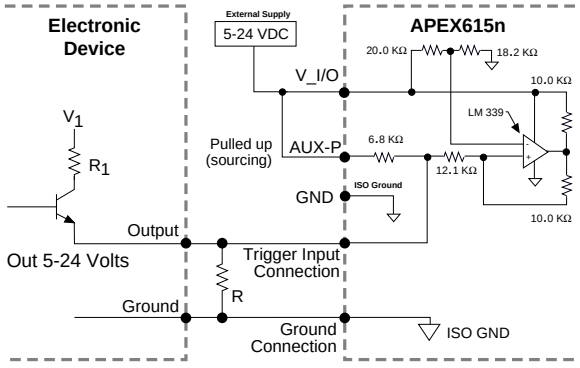
Connection to a Sinking Output Device



Connection to a Sourcing Output Device



Connection to a Combination of Sinking & Sourcing Outputs



Typical value for R = 450Ω (assuming R_1 = 0)
Note: The value of R may vary depending on the value of R_1 and V_1.

If you will be connecting to a combination of sourcing and sinking outputs, connect **AUX-P** to **+5V** to accommodate sinking output devices. Then for each individual input connected to a sourcing output, wire an external resistor between the APEX615n's trigger input terminal and ground (see illustration). The resistor provides a path for current to flow from the device when the output is active.

PROGRAMMING TIP

Connecting to a sinking output? Set the trigger input's active level to low with the `INLVL` command (Ø = active low, *default setting*).

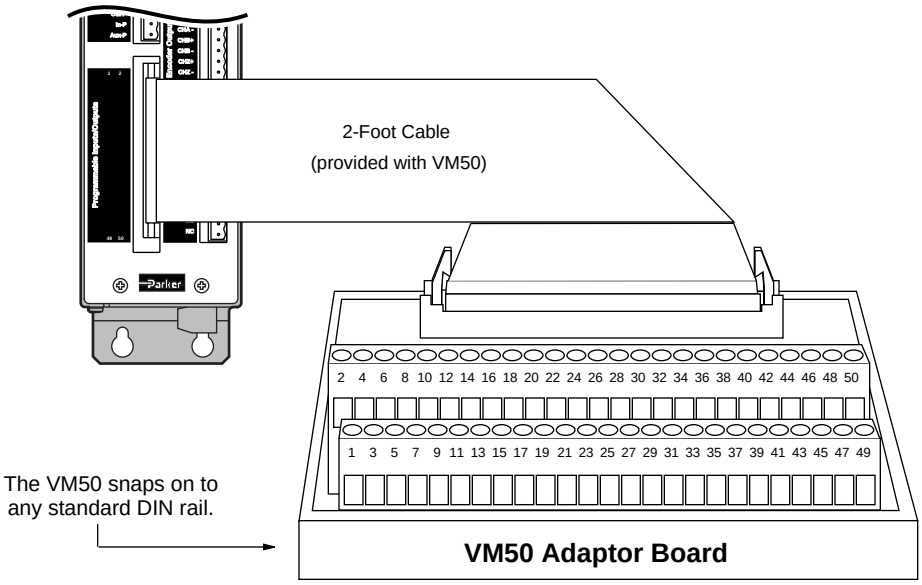
Connecting to a sourcing output? Set the trigger input's active level to high with the `INLVL` command (1 = active high).

Thus, when the output is active, the `TIN` status command will report a "1" (indicates that the input is active), regardless of the type of output that is connected.

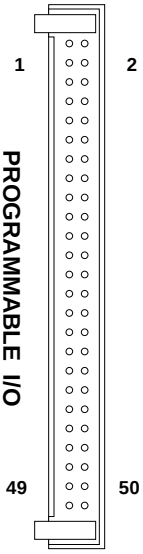
For details on setting the active level and checking the input status refer to the `INLVL` and `TIN` command descriptions in the *6000 Series Software Reference .*

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VM50 ADAPTOR — *for screw-terminal connections*



PIN OUTS & SPECIFICATIONS

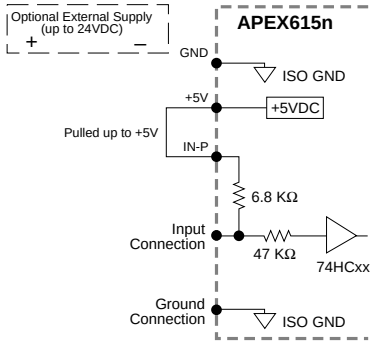


50-pin plug is compatible with OPTO-22™ signal conditioning equipment.

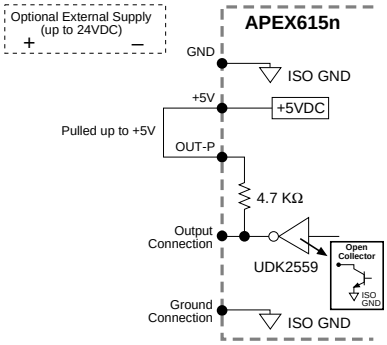
Pin #	Function
1	Input #16 (MSB of inputs)
3	Input #15
5	Input #14
7	Input #13
9	Input #12
11	Input #11
13	Input #10
15	Input #9
17	Output #8 (MSB of outputs)
19	Output #7
21	Output #6
23	Output #5
25	Input #8
27	Input #7
29	Input #6
31	Input #5
33	Output #4
35	Output #3
37	Output #2
39	Output #1 (LSB of outputs)
41	Input #4
43	Input #3
45	Input #2
47	Input #1 (LSB of inputs)
49	+5VDC

Internal Schematics

Inputs



Outputs



Specifications

Inputs

HCMOS-compatible voltage levels (low ≤ 1.00V, high ≥ 3.25V).

Voltage range = 0-24V.

Sourcing Current: On the **I/O** connector, connect **IN-P** to **+5V** or connect **IN-P** to your own power supply of up to 24VDC.

Sinking Current: On the **I/O** connector, connect **IN-P** to **GND**.

STATUS: Check with the `TIN` or `INFNC` command.

Active level: Default is active low, but can be changed to active high with the `INLVL` command.

Outputs

Open collector output.

Pull-up connection on **I/O** connector: Connect **OUT-P** to **+5V**, or to an external supply of up to 24V.

Max. voltage in the OFF state (not sinking current) = 24V, max. current in the ON state (sinking) = 300mA.

STATUS: Check with the `TOUT` status command.

Active level: Default is active low, but can be changed to active high with the `OUTLVL` command.

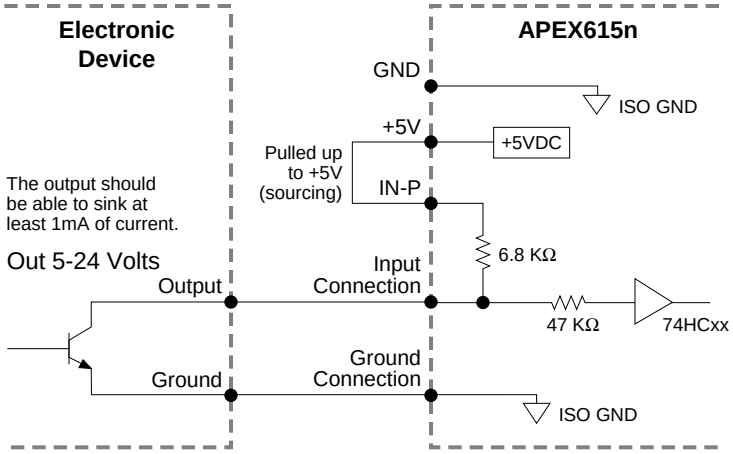
NOTE1: All even-numbered pins are connected to a common logic ground (DC ground).
LSB = least significant bit; MSB = most significant bit

NOTE 2: Disconnect jumper to +5V before connecting external power supply to either IN-P, OUT-P, or AUX-P.

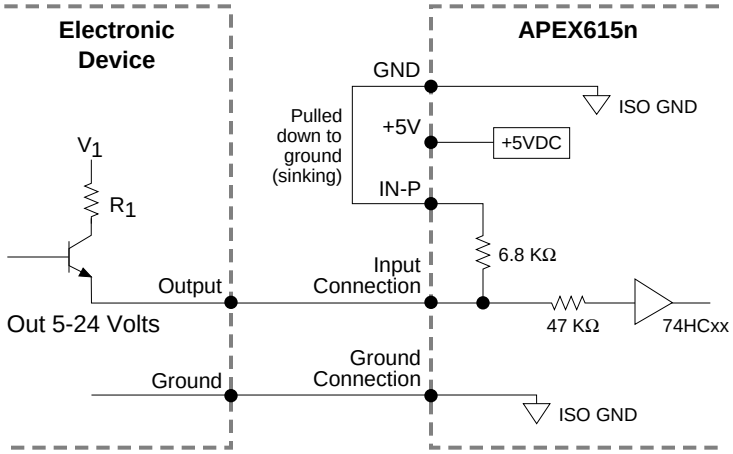
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INPUT CONNECTIONS — *Connecting to electronic devices such as PLCs*

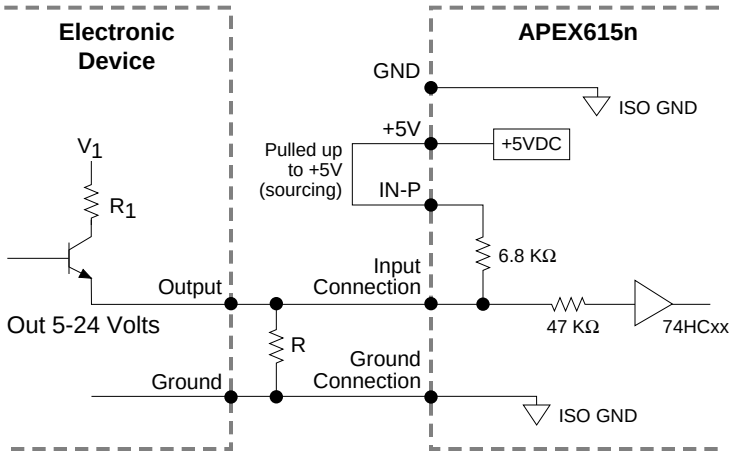
Connection to a Sinking Output Device



Connection to a Sourcing Output Device



Connection to a Combination of Sinking & Sourcing Outputs



Typical value for R = 450Ω (assuming R_1 = 0)

Note: The value of R may vary depending on the value of R_1 and V_1.

PROGRAMMING TIP

Connecting to a sinking output? Set the input's active level to low with the `INLVL` command (Ø = active low).

Connecting to a sourcing output? Set the input's active level to high with the `INLVL` command (1 = active high).

Thus, when the output is active, the `TIN` status command will report a "1" (indicates that the input is active), regardless of the type of output that is connected.

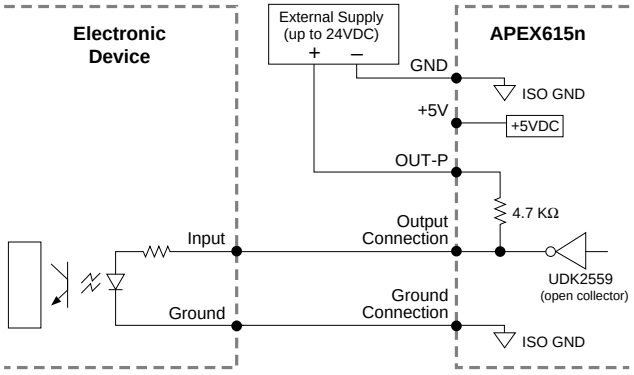
Details on setting the active level and checking the input status are provided in the *6000 Series Programmer's* Refer also to the `INLVL` and `TIN` command descriptions in the *6000 Series Software Reference* .

NOTE: If you will be connecting to a combination of sourcing and sinking outputs, connect **IN-P** to **+5V** to accommodate sinking output devices. Then for each individual input connected to a sourcing output, wire an external resistor between the APEX615n's programmable input terminal and ground (see "R" in above drawing). The resistor provides a path for current to flow from the device when the output is active.

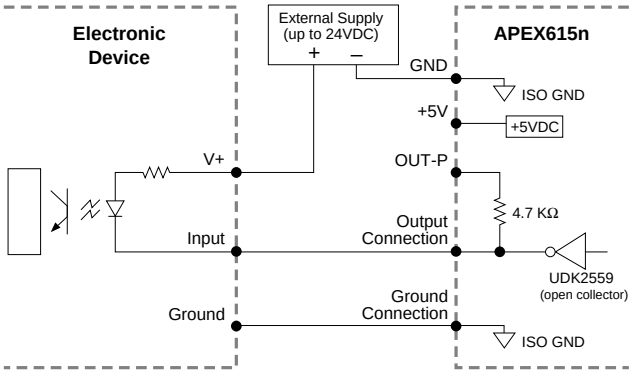
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OUTPUT CONNECTIONS (includes OUT-A) — *for electronic devices such as PLCs*

Connection to a Sinking Input (active high)

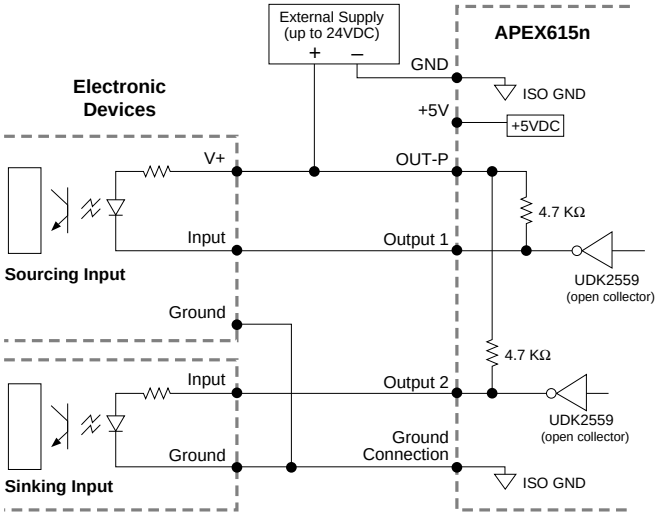


Connection to a Sourcing Input (active low)



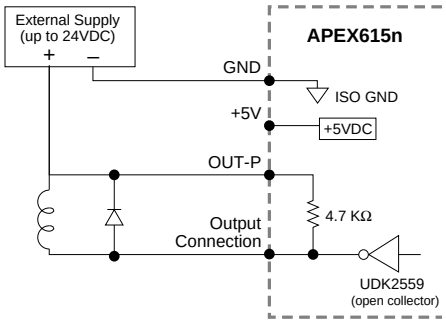
NOTE: It is not necessary to use the OUT-P pin for a sourcing input.

Connection to a Combination of Sinking & Sourcing Inputs



Combinations of sourcing and sinking inputs can be accommodated at the same voltage level. Be aware of the input impedance of the sourcing input module, and make sure that there is enough current flowing through the input module while in parallel with the OUT-P pull-up resistor.

Connection to an Inductive Load (active low)



Use an external diode when driving inductive loads. Connect the diode in parallel to the inductive load, attaching the anode to the APEX615n output and the cathode to the supply voltage of the inductive load.

PROGRAMMING TIP

Connecting to an active-high sinking input? Set the output's active level to high with the OUTLVL command (1 = active high).

Connecting to an active-low sourcing input? Set the output's active level to low with the OUTLVL command (Ø = active low).

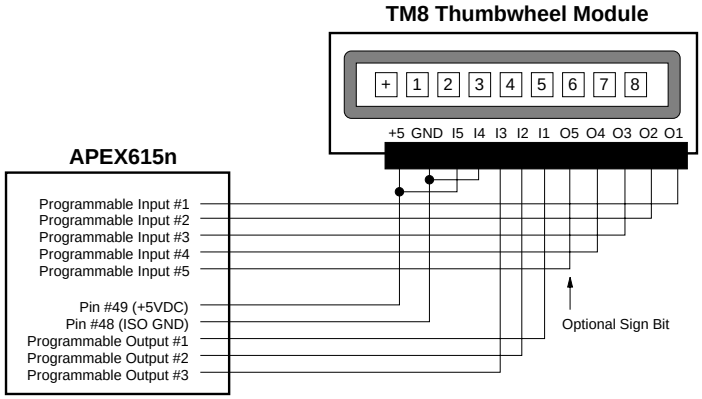
Thus, when the APEX615n's output is activated, current will flow through the attached input and the TOUT status command will report a "1" (indicates that the output is active), regardless of the type of input that is connected.

Details on setting the active level and checking the output status are provided in the *6000 Series Programmer's Guide*. Refer also to the OUTLVL and TOUT command descriptions in the *6000 Series Software Reference* .

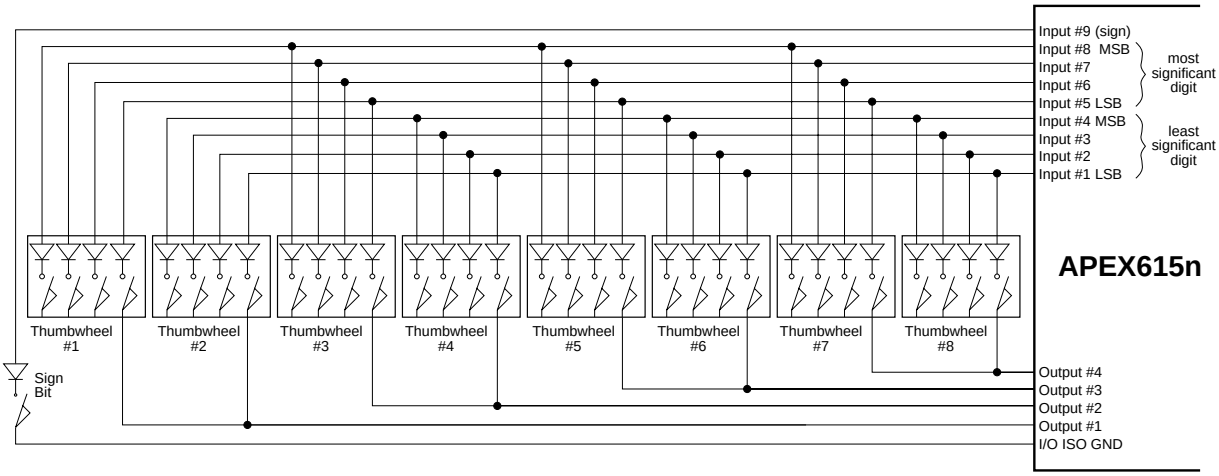
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THUMBWHEEL CONNECTIONS — *for entering BCD data*

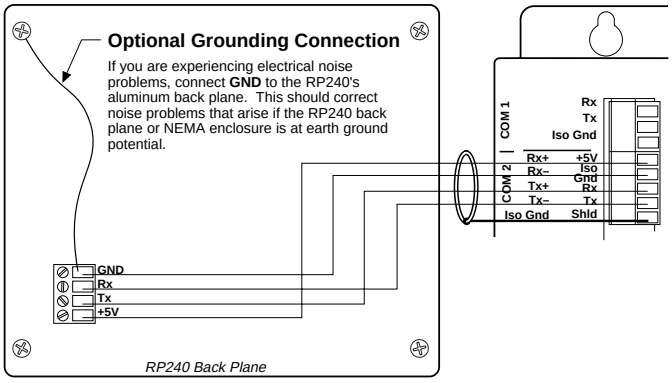
Connection to the Compumotor TM8 Module

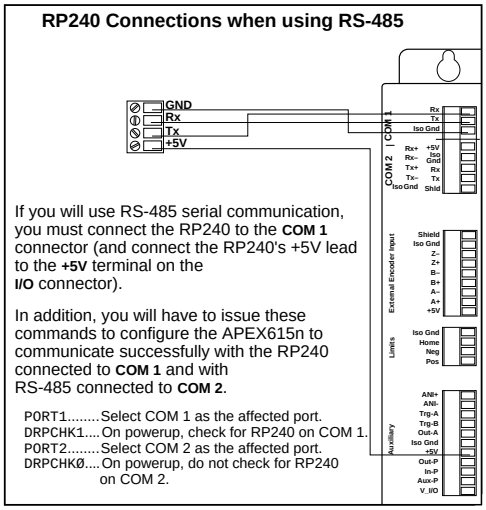


Connection to your own Thumbwheel Module



RP240 Remote Operator Panel





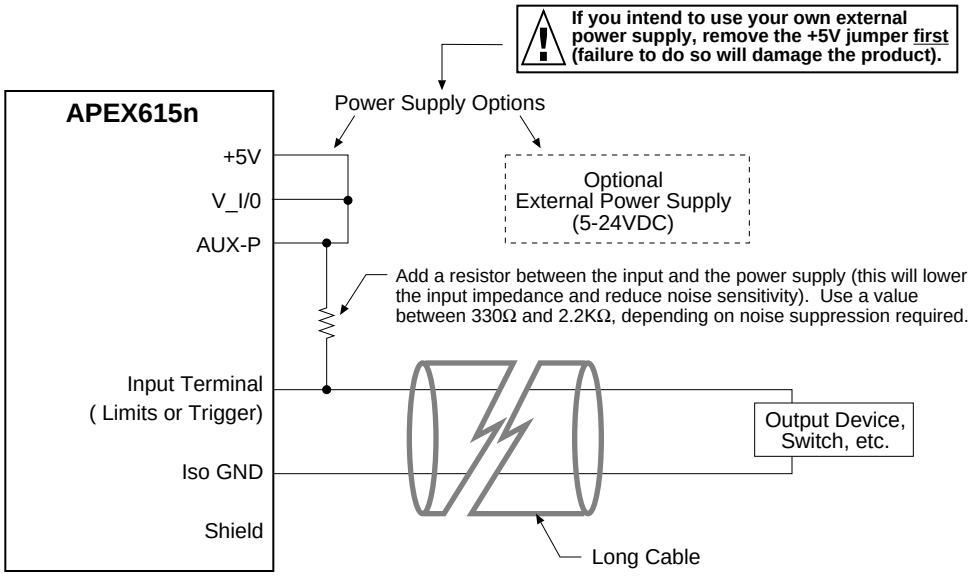
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Lengthening I/O Cables

Bear in mind that lengthening cables increases noise sensitivity. (The maximum length of cables is ultimately determined by the environment in which the equipment will be used.) If you lengthen the cables, follow the precautions below to minimize noise problems.

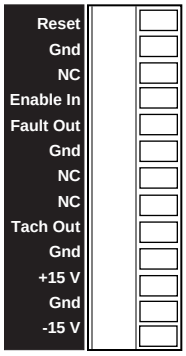
- Use a minimum wire size of 22 AWG.
- Use twisted pair shielded cables and connect the shield to the earth ground of the remote device. Leave the other end of the shield disconnected.
- Do not route I/O signals in the same conduit or wiring trays as high-voltage AC wiring or motor cables.

Reducing noise on limit and trigger inputs. If you are experiencing noise problems, try adding resistors to reduce noise sensitivity (see illustration below).



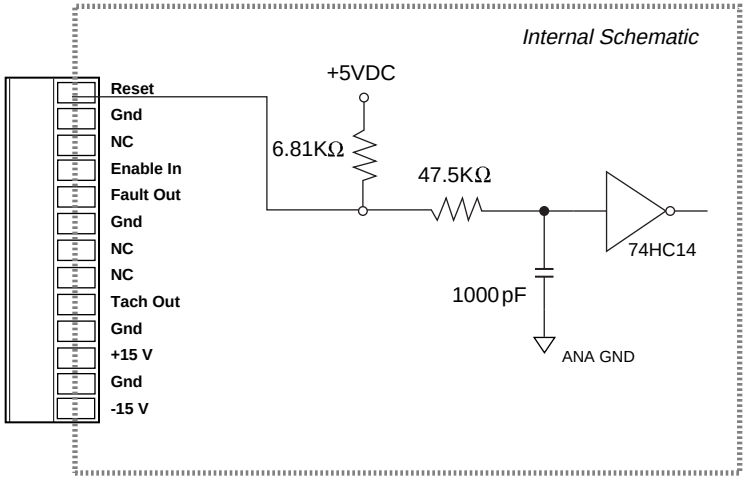
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Drive Auxiliary Connector



Pin #:	Function:
1	Reset
2	Ground (tied to AC earth ground)
3	No Connection
4	Enable In
5	Fault Output
6	Ground (tied to AC earth ground)
7	No Connection
8	No Connection
9	Tachometer Output
10	Ground (tied to AC earth ground)
11	+15V
12	Ground (tied to AC earth ground)
13	-15V

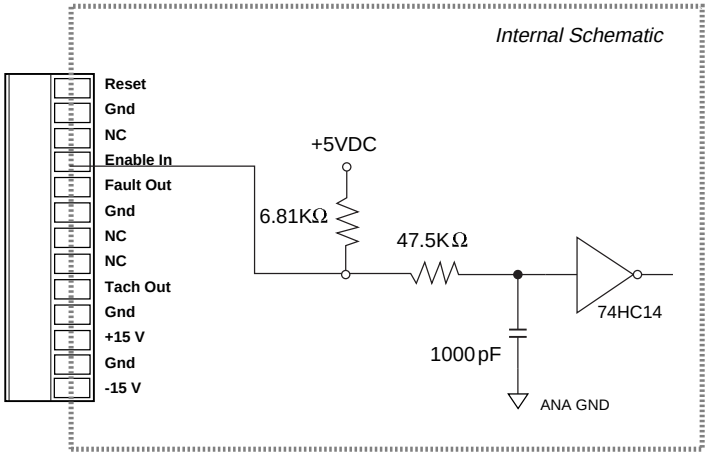
Reset Input



- *Active Low:* to reset drive, hold **RESET** input at low voltage for at least 20 milliseconds.
- Voltage Low = 1.0V maximum
- Voltage High = 3.25V – 24V
- Reset will begin when input reset signal (a low voltage) is released.
- **RESET** input resets drive functions; RESET command resets controller. See *Recovering From Faults* in Chapter 2: *Troubleshooting* for more information.

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Enable Input



- *Active Low:* to enable the APEX615n, hold **ENABLE IN** at low voltage.
- Voltage Low = 1.0V maximum
- Voltage High = 3.25V – 24V

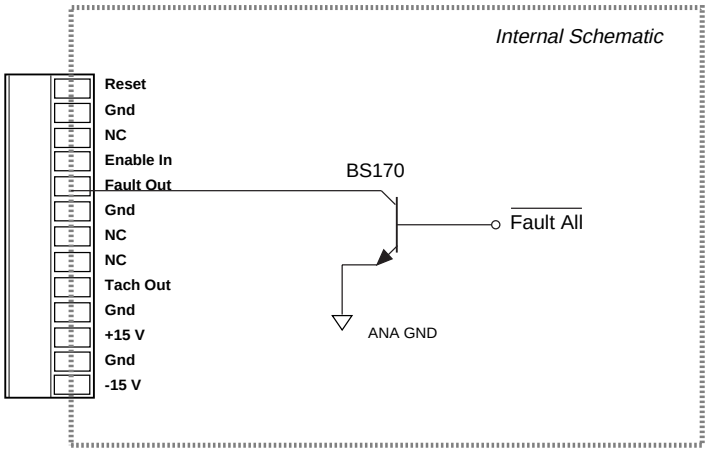
A switch wired between **ENABLE IN** and GND can be used as a manual disable switch. Opening the switch disables the APX615n, which shuts down power output to the motor, turns off the **ENABLE** LED, and illuminates the **DISABLE** LED. When the controller detects that **ENABLE IN** has changed state, it issues an Immediate Kill (`!K`) command to stop the program in progress. If motion is commanded while **ENABLE IN** is not grounded, motion will not occur and the error message "WARNING: ENABLE INPUT INACTIVE" will appear in the terminal emulator. See the *6000 Series Software Reference* for information on commands.

Bit 6 of the `TINO` command (`TINO.6`) returns the current status of the **ENABLE INPUT.**

WARNING

Do not use **ENABLE IN** 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 in an emergency.

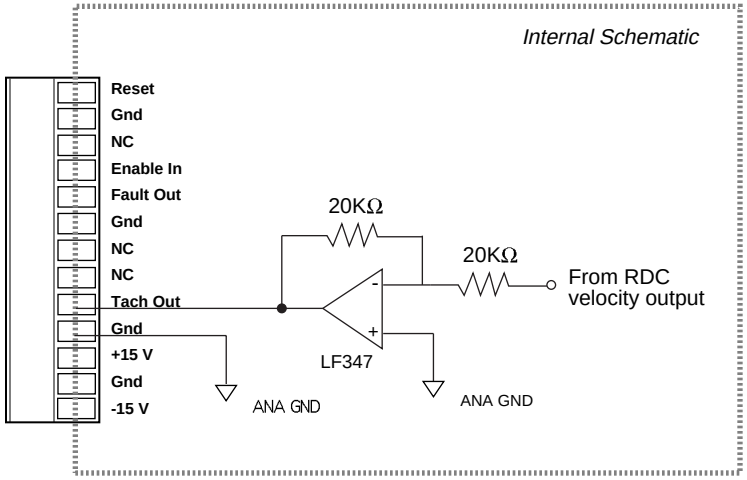
Fault Output



- Active *HIGH* — NO FAULT = Output will be low; FAULT = Output will float (go HIGH)
- Maximum Applied Voltage: 40VDC
- Maximum Current 200mA

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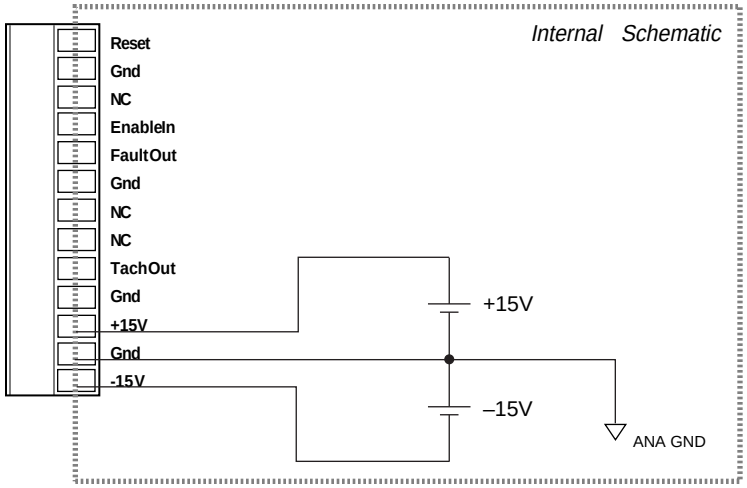
Tachometer Output



Tachometer Output: ±10V at 15mA (max)

- Use DIP Switch #3, position 5, to scale output:
- OFF = 1V/1000 rpm for one speed resolvers
- ON = 1V/1000 rpm for two speed resolvers.

±15V Output



+15V Output: +15V ±5% at 15 mA

–15V Output: –15V ±5% at 15 mA

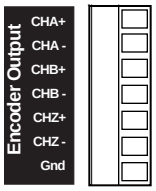
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Encoder Output Connector

The encoder output connector is a dual use connector. It can be used for either Encoder Output or for Hall Effect Input. Use DIP Switch #3, position 4, to select desired function.

OFF = Encoder Output (derived from the resolver input)

ON = Hall Effect Input mode

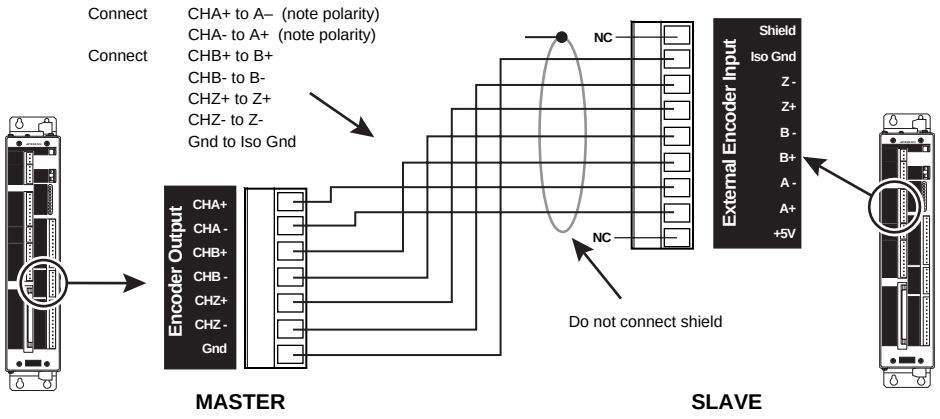


Encoder Output		Hall Effect Input	
Pin #:	Function:	Pin #:	Function:
1	Channel A+	1	No Connect
2	Channel A–	2	No Connect
3	Channel B+	3	Hall +5VDC
4	Channel B–	4	Hall 1
5	Channel Z+	5	Hall 2
6	Channel Z–	6	Hall 3
7	Ground	7	Hall Ground

Schematic diagrams of the Encoder Output circuit and of the Hall Effect Input circuit are shown in the next sections.

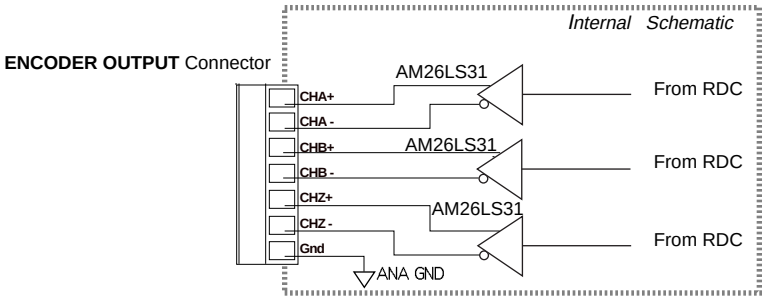
Encoder Output to External Devices

The encoder output can be used to send information to an external device. In multi-axis applications, for example, with APEX615ns running in *following* mode, you can connect the encoder output from the master unit to the encoder input of the slave unit, as shown in the next drawing. See the *Programmer's Guide* for details.



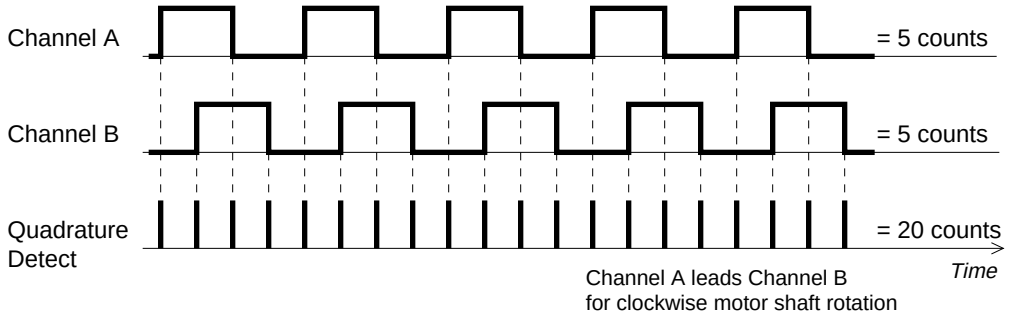
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Encoder - Quadrature Outputs



The APEX615n's encoder outputs are pseudo-quadrature outputs. These quadrature outputs are called ***pseudo*** because they are hardware–derived from resolver information and not from an actual encoder. The resolution is 1024 counts per revolution (pre-quadrature), or 4096 counts per revolution (post-quadrature).

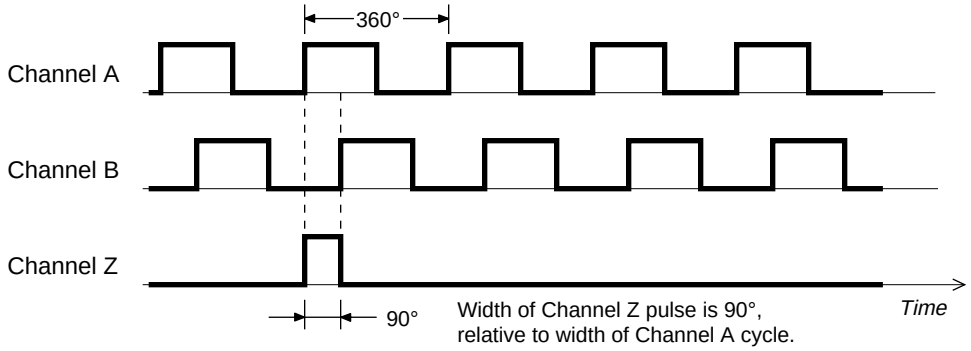
The position of the motor shaft can be determined by counting pulses. The APEX615n has a *quadrature detect circuit* that enhances resolution. Channels A and B produce two square waves that are 90 electrical degrees apart. By monitoring the rising and falling edges of CHA and CHB, each pulse is equivalent to four counts. In this way, the 1024 counts are translated into 4096 counts, as the next figure shows.



Direction can be determined by comparing the phase shift of Channel A relative to Channel B. For example, if Channel A leads channel B, as shown in the previous drawing, the motor shaft is turning in a clockwise direction.

The quadrature outputs are true differential (or complementary) outputs. The use of differential outputs increases the system's noise immunity. When Channel A+ goes high, Channel A- goes low, and vice versa.

The Z Channel, or marker, provides a reference pulse once per revolution. The Z channel outputs (CHZ+, CHZ–) are true differential, or complementary, outputs.

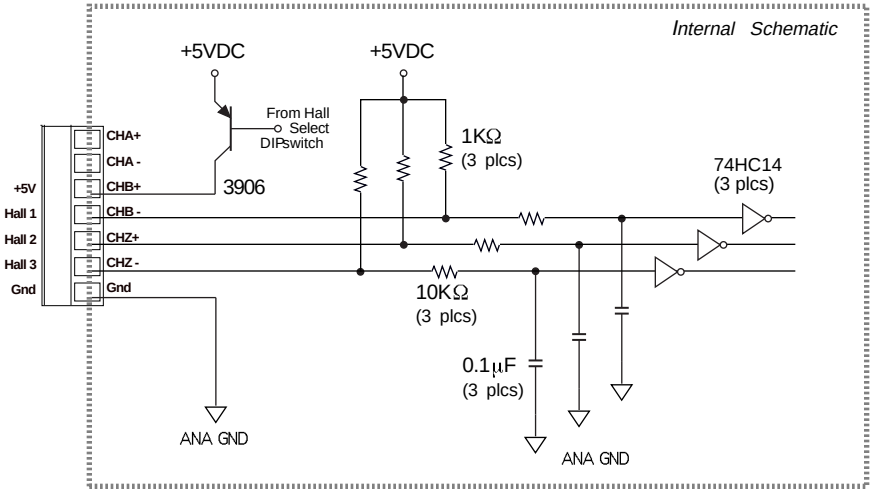


The width of the Z channel pulse, relative to the A channel cycle, is 90°.

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Hall Effect Input

The following circuit is internally connected to the encoder connector when DIP Switch #3, position 4 is turned ON.

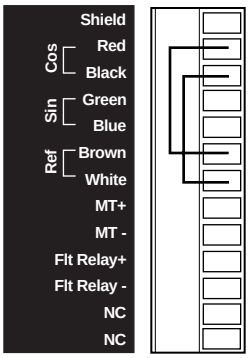


When this circuit is active, the Encoder Output connector can be used for Hall effect sensor inputs. The APEX615n uses the Hall sensor information to determine rotor position, so that it can commutate the motor correctly.

With this circuit turned off, the APEX615n uses resolver inputs to determine rotor position. It derives encoder signals from the resolver inputs, and sends the encoder signals out through the Encoder Output connector, as described in the previous section.

Resolver Connector Jumpers When in Hall Effect Mode

When using the APEX615n in Hall effect mode, Compumotor recommends installing jumper wires on the resolver connector as shown below. Also use the SFB1 command in your start-up program to select an external encoder as your feedback source. Direct questions on this topic to the Compumotor Applications Department at the phone numbers provided on the inside front cover of this document.



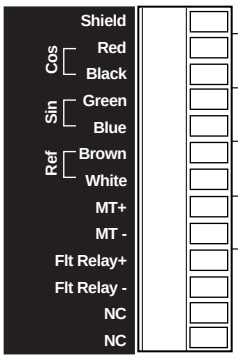
Jumpers:
Red to Brown
Black to White

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Resolver Connector

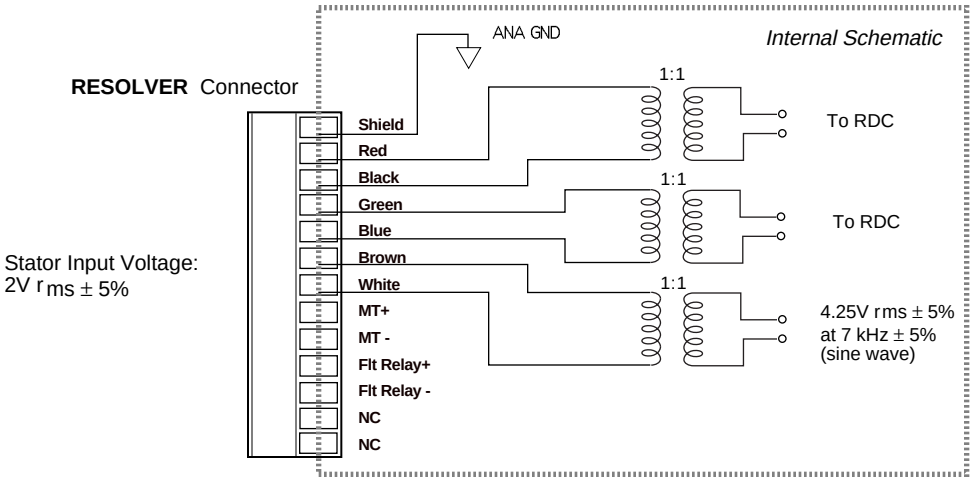
Connect the motor end of the resolver cable to the motor. Cables are available for SM motors in 10 and 25 foot lengths; and for APEX Series motors in 10, 25, 50, and 100 foot lengths. The cables have MS-type connectors on the motor end of the cable. You can also order custom cables of any length. Call Compumotor's Customer Service Department at the phone numbers provided on the inside front cover of this document.. Cable lengths in excess of 100 feet are not recommended.

Plug the drive end of the cable into the APEX615n's resolver input connector. (The drive end of the cable should already be wired to the removable 13-pin resolver connector, as shown below. The connector can accept wires as large as 12 AWG (4 mm^2).)



Function	APEX Cable Color Code	SM Cable Color Code
Shield	Uninsulated	Uninsulated
Stator 3	Red	Red
Stator 1	Black	Black
Stator 2	Green	Green
Stator 4	Blue	Blue
Rotor 1	Brown	Brown
Rotor 2	White	White
Motor Temp+	Yellow	Yellow
Motor Temp -	Orange	Yellow
Fault Relay+		
Fault Relay -		
No Connection		
No Connection		

Schematic diagrams of each input and output on the resolver connector are shown below.



DIP Switch #3, position 4, must be OFF so that:

- Internal microprocessor uses resolver information for commutation
- Encoder output will be enabled
- Hall Effect input will be disabled

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Motor Temperature Sensor Input

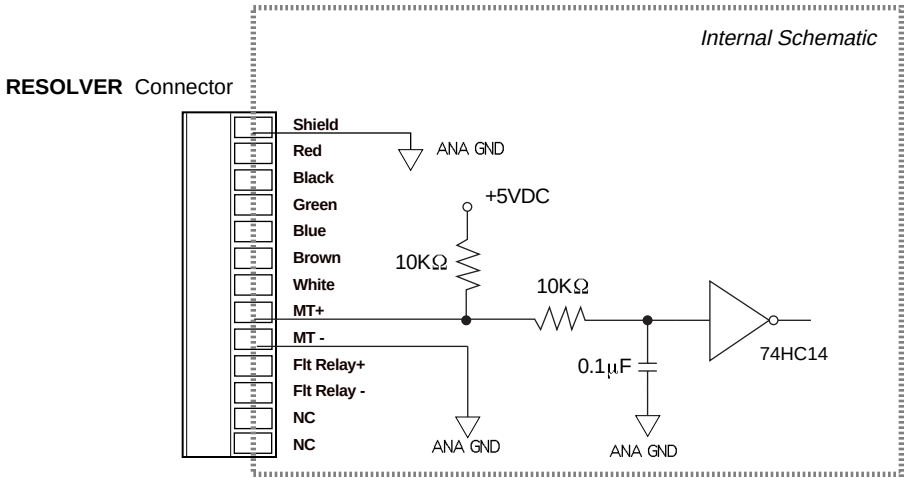
The resolver connector has two terminals through which the APEX615n can monitor motor temperature. The terminals, labeled **MT+** and **MT–**, should be connected to the two leads of a normally-closed temperature sensor mounted on the motor. When the motor is within its temperature limits, the sensor will be closed, thus shorting together **MT+** and **MT–**. If the motor overheats, the sensor will open. Circuit continuity will be broken, which triggers protection circuitry in the APEX615n. It will shut down its power output, and illuminate the red LED labeled **Motor Fault**.

For APEX Series motors, connect the yellow wire in the resolver cable to **MT+**. Connect the orange wire to **MT–**. For SM Series motors, both wires are yellow; connect one to **MT+** and the other to **MT-**.

For other motors with normally-closed temperature sensors, connect the sensor's two wires to **MT+** and **MT–**.

NOTE

If your motor has no temperature sensor, use a wire to short together **MT+** and **MT–** on the resolver connector. The drive will not operate unless these two terminals are shorted together.

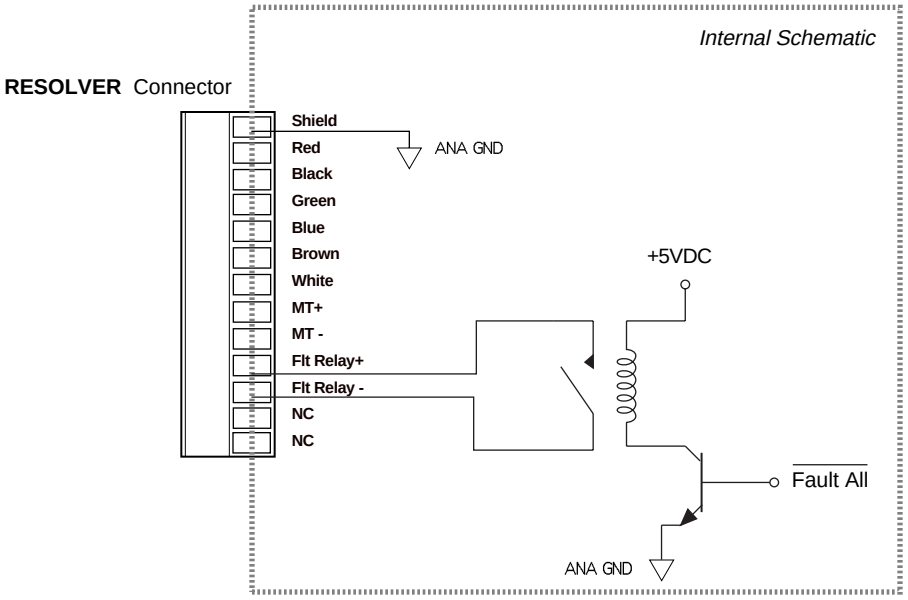


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Motor Braking — Fault Relay Terminals

If the APEX615n faults, for any reason, the drive will be disabled and the motor will freewheel. Refer to *Chapter 2: Troubleshooting* for all fault conditions. If a freewheeling load is unacceptable, use the fault relay terminals Fault Relay+ and Fault Relay– to control a motor brake.

The fault relay inside the APEX615n is *normally open*. This means that when the drive is faulted or disabled, or when the power is off, the relay will be open. When the APEX615n is enabled, it energizes the relay coil, and holds the relay closed. The relay is rated for 5 amps at 24VDC or 120VAC.

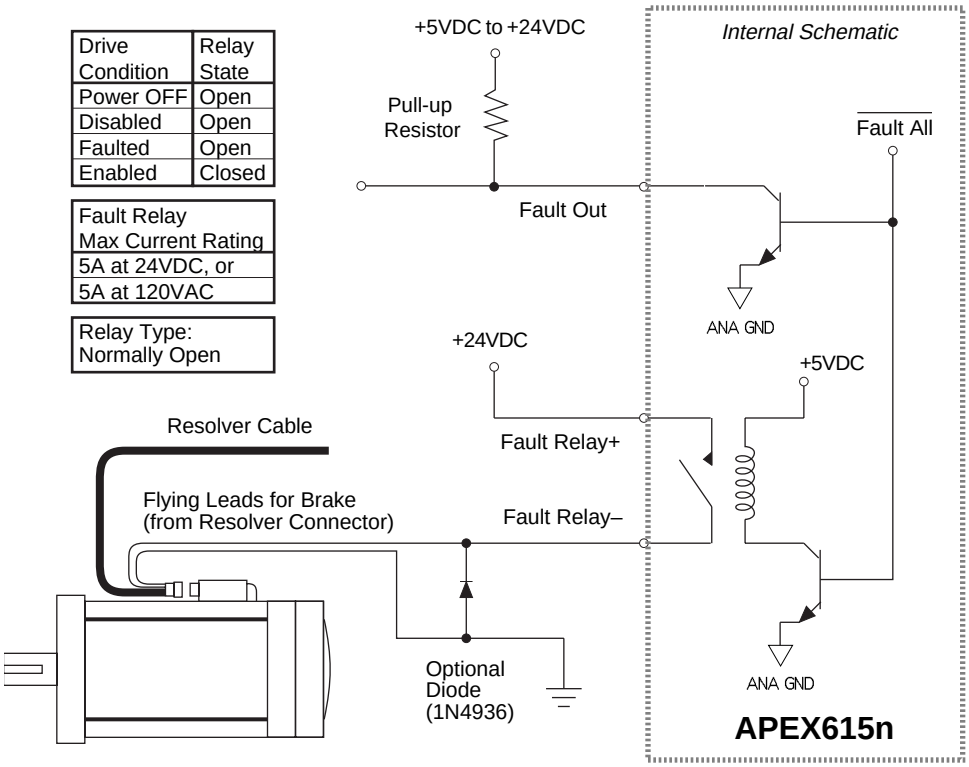


Most motor brakes have a coil that, when energized, will release the brake. To control a brake with the fault relay terminals:

- Connect the power source for the brake to one of the fault relay terminals.
- Connect the other fault relay terminal to the brake.
- If you use a DC power source, you may need to connect a diode across the brake coil to reduce voltage spikes when the brake is engaged or disengaged. A 1N4936 diode (or equivalent) should be sufficient.

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EXAMPLE 1: APEX Series motors are available from Compumotor with an optional mechanical brake. Call Compumotor's Customer Service Department (800-722-2282) for more information. The next drawing shows how to connect the brake to the fault relay terminals.



Fault Relay with Mechanical Brake

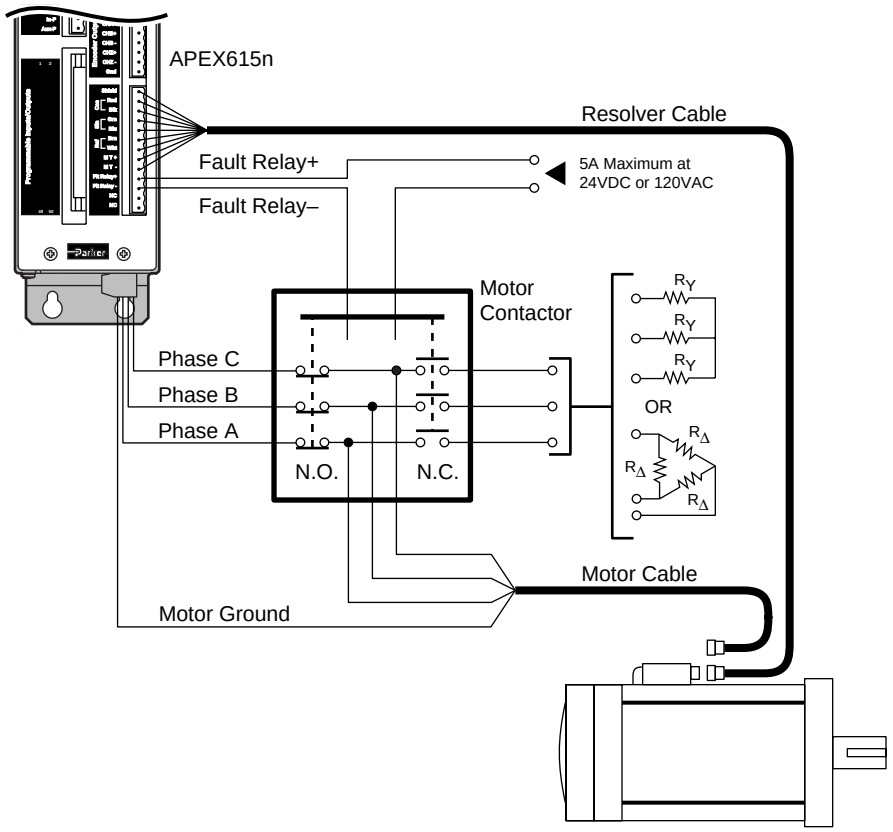
24VDC is applied, through the fault relay terminals, to one of the flying leads on the motor's resolver connector. The other lead is connected to ground. An optional diode is shown installed between the two leads. The diode's polarity is correct as shown.

The drawing also shows that the fault output and the fault relay are controlled by the same internal signal. Any fault condition that triggers the fault output will also cause the fault relay to turn off (relay will be opened).

You can also use external resistors for motor braking, as the next example shows.

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EXAMPLE 2: The next drawing illustrates how to connect auxiliary resistors to control motor braking. The drawing shows that during normal operations, the motor contactor is energized and provides a direct connection between the motor and drive. The motor contactor *(N.O. = normally open with power removed; N.C. = normally closed with power removed)* is controlled by the fault relay terminals on the APEX6151's resolver connector. If the drive faults or if the line voltage is disconnected, the contactor connects the motor braking resistors across the motor.



Motor Braking with Resistors

The braking resistors can be sized by analyzing specific applications. If the total load inertia is less than five times the rotor inertia, non-inductive 200 watt power resistors can be used as the braking resistors. For a wye configuration, use 5 ohms or more ($R_Y = 5\Omega$). For a delta configuration, use 15 ohms or more ($R_\Delta = 15\Omega$). If quicker stopping is required, the braking resistor values can be lowered, but you must increase their power ratings.

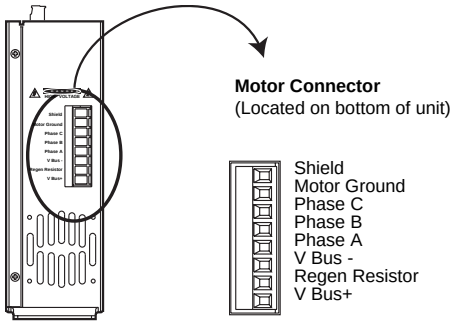
CAUTION

Braking resistors provide very little braking at zero velocity. If standstill braking or emergency stopping is required, you can order the optional spring-type mechanical brake described in *Example 1* above.

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Connecting the Motor

The *motor cable* connects the APEX615n's power output, located on the bottom of the drive, to the motor's power input. APEX and SM 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 APEX615n's motor connector, which is a 8-pin removable connector located on the bottom of the cabinet. The connector can accept wire diameters as large as 10 AWG (6 mm^2).



Connector Terminal	APEX Motor Cable Wire Color	SM Motor Cable Wire Color
Phase A	Orange	Red/Yellow
Phase B	Blue	White/Yellow
Phase C	Gray	Black/Yellow
Motor Ground *	Green	Green/Yellow
Shield *	Unshielded	Unshielded

* **Motor Ground** and **Shield** are connected internally to the **Earth** terminal on the AC power connector

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.

At this time, make no attachments to the remaining three positions on the motor connector: **V Bus+**, **V Bus–**, **Regen Resistor**.

After wiring the connector to the cable, connect the motor cable to the motor and to the APEX615n.

WARNING

The motor connector and cable produce lethal voltages. Never insert or remove the motor cable with AC power turned on to the APEX615n.

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Regeneration Resistor

The APEX615n can dissipate regenerated energy in its internal *regeneration resistor*. If an APEX615n system regenerates more energy than the internal resistor can dissipate, you can connect an external resistor between the two terminals labeled **V Bus+** and **Regen Resistor**, located on the motor connector. The external resistor will double the APEX615n 's dissipation capabilities.

The APEX615n'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 **VBus–**. The energy is then dissipated in the resistor. During the regeneration event, the red LED labeled **Regen Active**, located on the APEX615n's front panel, will be illuminated.

See Chapter 2: Troubleshooting for additional information about the regeneration LEDs. See Appendix G for information on how to determine if an external regeneration resistor is necessary for your system, and if so, how to calculate the proper regeneration resistor value.

Testing the Installation

⚠ WARNING ⚠

This test procedure allows you to control I/O and produce motion. Make sure that exercising the I/O will not damage equipment or injure personnel. We recommend that you leave the motor uncoupled from the load, but if you have coupled the load to the motor, make sure that you can move the load without damaging equipment or injuring personnel.

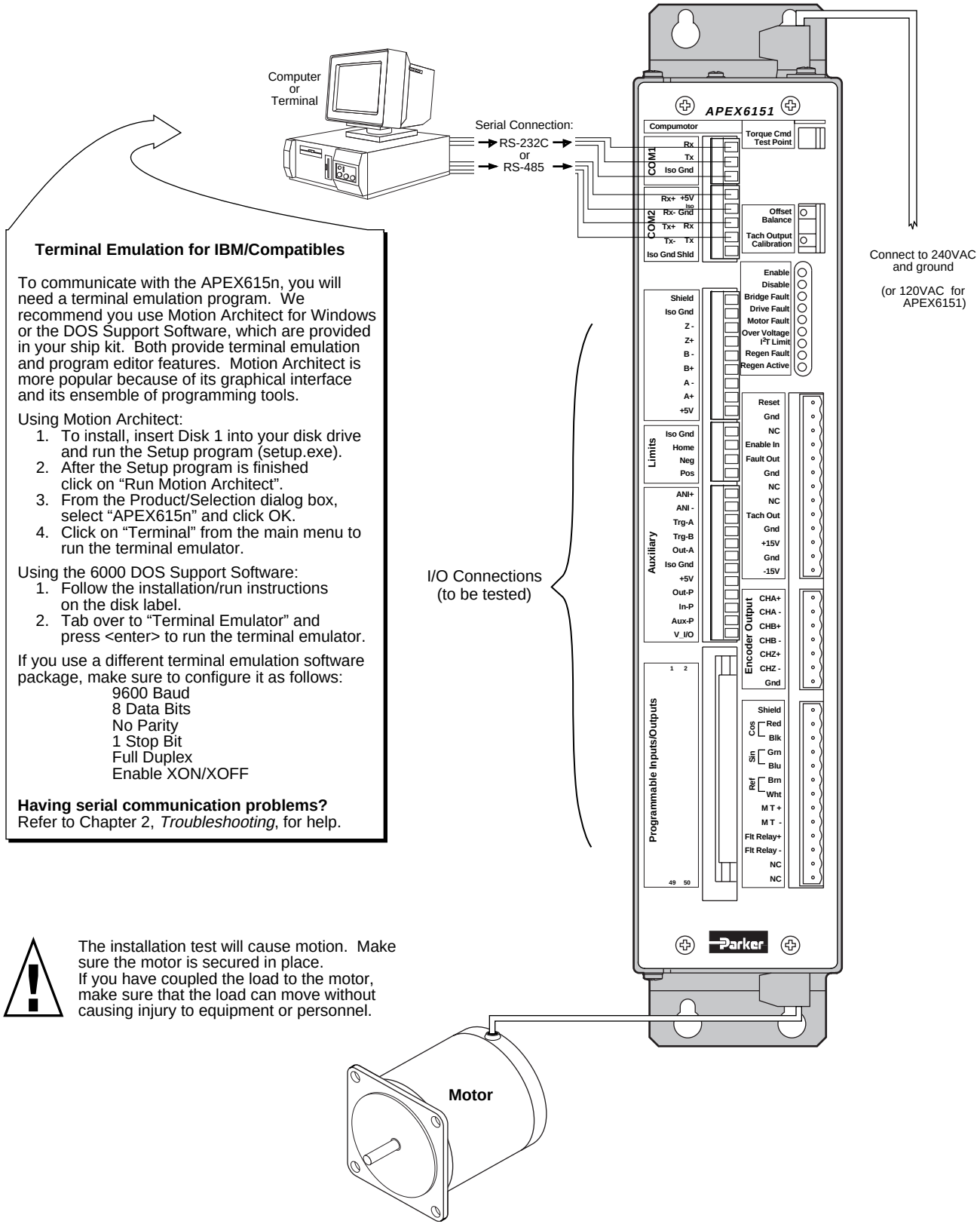
NOTE

The test procedures in the table are based on the factory-default active levels for the APEX615n's inputs and outputs. Verify these settings with the following *status* commands:

Command Entered	Response Should Be
INLVL	*INLVLØØØØ_ØØØØ_ØØØØ_ØØØØ_ØØ
HOMLVL	*HOMLVLØ
LHLVL	*LHLVLØØ
OUTLVL	*OUTLVLØØØØ_ØØØØ_Ø

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Test Setup



Terminal Emulation for IBM/Compatibles

To communicate with the APEX615n, you will need a terminal emulation program. We recommend you use Motion Architect for Windows or the DOS Support Software, which are provided in your ship kit. Both provide terminal emulation and program editor features. Motion Architect is more popular because of its graphical interface and its ensemble of programming tools.

Using Motion Architect:

1. To install, insert Disk 1 into your disk drive and run the Setup program (setup.exe).
2. After the Setup program is finished click on “Run Motion Architect”.
3. From the Product/Selection dialog box, select “APEX615n” and click OK.
4. Click on “Terminal” from the main menu to run the terminal emulator.

Using the 6000 DOS Support Software:

1. Follow the installation/run instructions on the disk label.
2. Tab over to “Terminal Emulator” and press <enter> to run the terminal emulator.

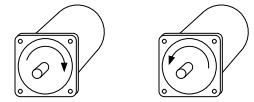
If you use a different terminal emulation software package, make sure to configure it as follows:

9600 Baud
8 Data Bits
No Parity
1 Stop Bit
Full Duplex
Enable XON/XOFF

Having serial communication problems?
Refer to Chapter 2, *Troubleshooting*, for help.

The installation test will cause motion. Make sure the motor is secured in place.
If you have coupled the load to the motor, make sure that the load can move without causing injury to equipment or personnel.

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Connections	Test Procedure	Response Format (left to right)
End-of-travel and Home limits	**NOTE**: If you are not using end-of-travel limits, issue the Disable Limits (LHØ) command and ignore the first two bits in each response field. 1. Enable hard limits using the LH3 command. 2. Close the end-of-travel switches and open the home switch. 3. Enter the TLIM command. The response should be *TLIM11Ø. 4. Open the end-of-travel switches and close the home switch. 5. Enter the TLIM command. The response should be *TLIMØØ1. 6. Close the POS end-of-travel switch and open the home switch. 6. Enter the TLIM command. The response should be *TLIM1ØØ.	TLIM response: bit 1 = POS limit bit 2 = NEG limit bit 3 = home limit
Internal Encoder Feedback (Resolver-based Encoder)	1. Enter these commands: L<cr>, TPE<cr>, T.3<cr>, and LN<cr>. This will begin a continuous display of the encoder's position. Press the <return> key to move the display to the next line and save the current value. 2. Manually rotate the encoder shaft and verify that the position changes as you rotate the encoder shaft. If you connected the encoder as instructed earlier in this chapter, turning the shaft clockwise should increase the position reading. If the reading does not change, or if the direction is reversed, check the connections. 3. When finished, enter the !K (immediate Kill) command to stop the continuous report-back.	TPE response (encoder counts): ±encoder counts
Motor (motion)	**NOTE:** Use default settings for all parameters (if necessary, issue a RESET command to return the settings to their defaults). Make sure that the motor is properly supported, with no load attached to the shaft. 1. Enter the DRIVE1 command to enable the drive. The Enable LED will illuminate, and the Disable LED will turn off. 2. Enter the LH0 command to disable the hard limits. 3. Enter the GO command. to initiate motion. The motor turns one revolution in the clockwise direction, using the default motor parameters (A=10.0000, V=1.0000, D=+4096). 4. Enter the D- command to change the move direction to counterclockwise (D=-4096). 5. Enter the GO command. to initiate motion. The motor turns one revolution in the counterclockwise direction. **NOTE:** If the 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. If you change DIP switch settings, cycle power before you continue operations.	Direction of rotation:  Clockwise (positive counts) Counter-clockwise (negative counts)
Programmable Inputs (incl. triggers)	1. Open the input switches or turn off the device driving the inputs. 2. Enter the TIN command. The response should be *TINØØØØ_ØØØØ_ØØØØ_ØØØØ_ØØ. 3. Close the input switches or turn on the device driving the inputs. 4. Enter the TIN command. The response should be *TIN1111_1111_1111_1111_11.	TIN response: bits 1-16 = prog. inputs 1 - 16 bits 17 & 18 = TRG-A & TRG-B
Programmable Outputs	1. CAUTION: Disconnect all programmable outputs before proceeding to step 2. 2. Enter the OUTALL1,9,1 command to turn on (sink current on) all outputs. 3. Enter the TOUT command. The response should be *TOUT1111_1111_1. 4. Enter the OUTALL1,9,Ø command to turn off all outputs. 5. Enter the TOUT command. The response should be *TOUTØØØØ_ØØØØ_Ø.	TOUT response: bits 1-8 = prog. outputs 1 - 8 bit 9 = OUT-A
RP240	1. Cycle power to the APEX615n. 2. If the RP240 is connected properly, the RP240's status LED should be green and one of the messages on the computer or terminal display should read *RP24Ø CONNECTED. If the RP240's status LED is off, check to make sure the power connections are secure. If the RP240's status LED is green, but the message on the terminal reads "*NO REMOTE PANEL", the RP240 Rx and Tx lines are probably switched. Remove power and correct. 3. Assuming you have not written a program to manipulate the RP240 display, the RP240 screen should display the following: COMPUMOTOR 615N SERVO CONTROLLER RUN JOG STATUS DRIVE DISPLAY ETC	

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⚠ WARNINGS ⚠

- Improper motor mounting and coupling can jeopardize personal safety, and compromise system performance.
- Never disassemble the motor; doing so will cause contamination, significant reduction in magnetization, and loss of torque.
- Improper shaft machining will destroy the motor's bearings, and void the warranty. Consult a factory Applications Engineer (see phone number on inside of front cover) before you machine the motor shaft.

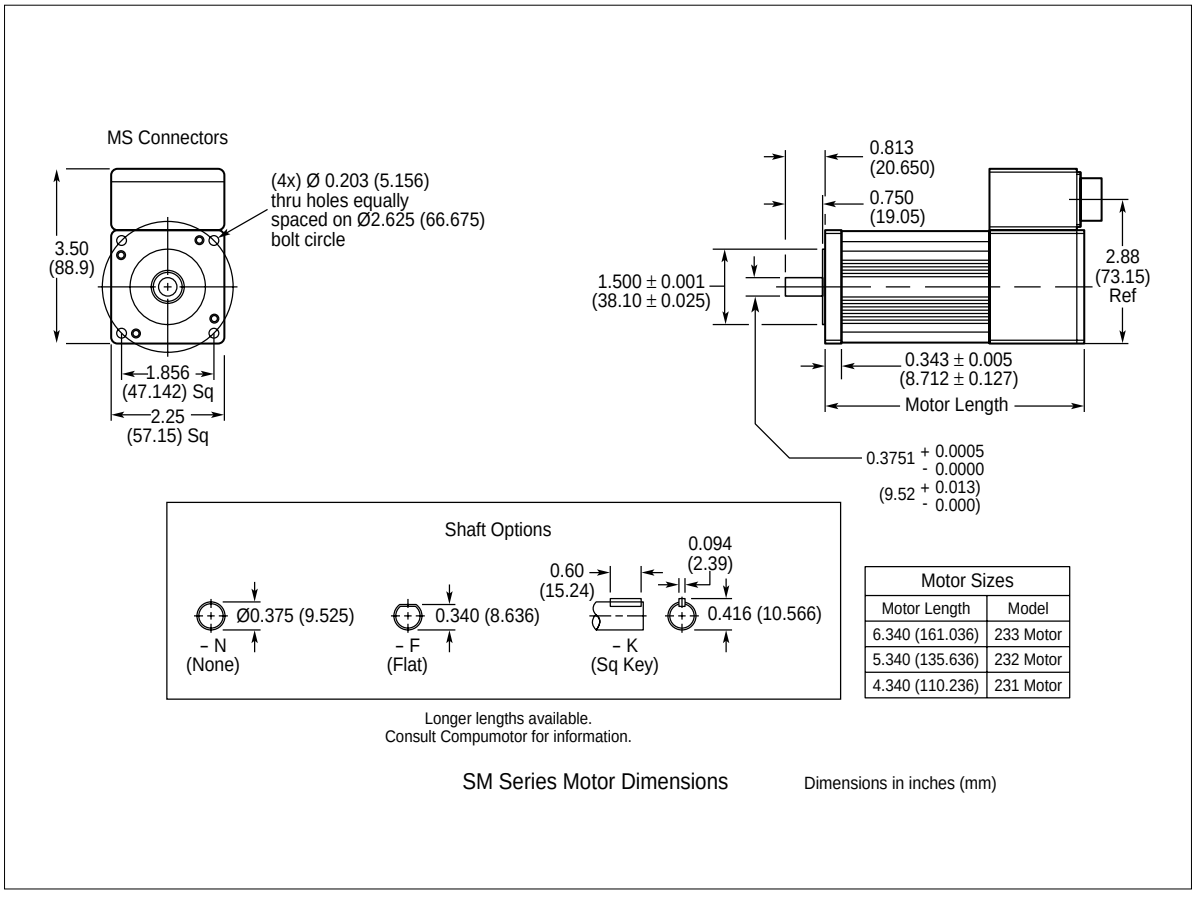
Mounting the Motor

Servo motors used with the APEX615n can produce very high torque and acceleration. If the mounting is inadequate, this combination of high torque/high acceleration can shear shafts and mounting hardware. High accelerations can produce shocks and vibrations that require much heavier hardware than for static loads of the same magnitude.

Under certain move profiles, the motor can produce low-frequency vibrations in the mounting structure that can cause fatigue in structural members. A mechanical engineer should check the machine design to ensure that the mounting structure is adequate.

Use flange bolts to mount servo motors. The *pilot*, or centering flange on the motor's front face, can help you position the motor. Foot-mount or cradle configurations are not recommended, because the motor's torque is not evenly distributed around the motor case. When a foot mount is used, for example, any radial load on the motor shaft is multiplied by a much longer lever arm.

APEX Motor Dimensions



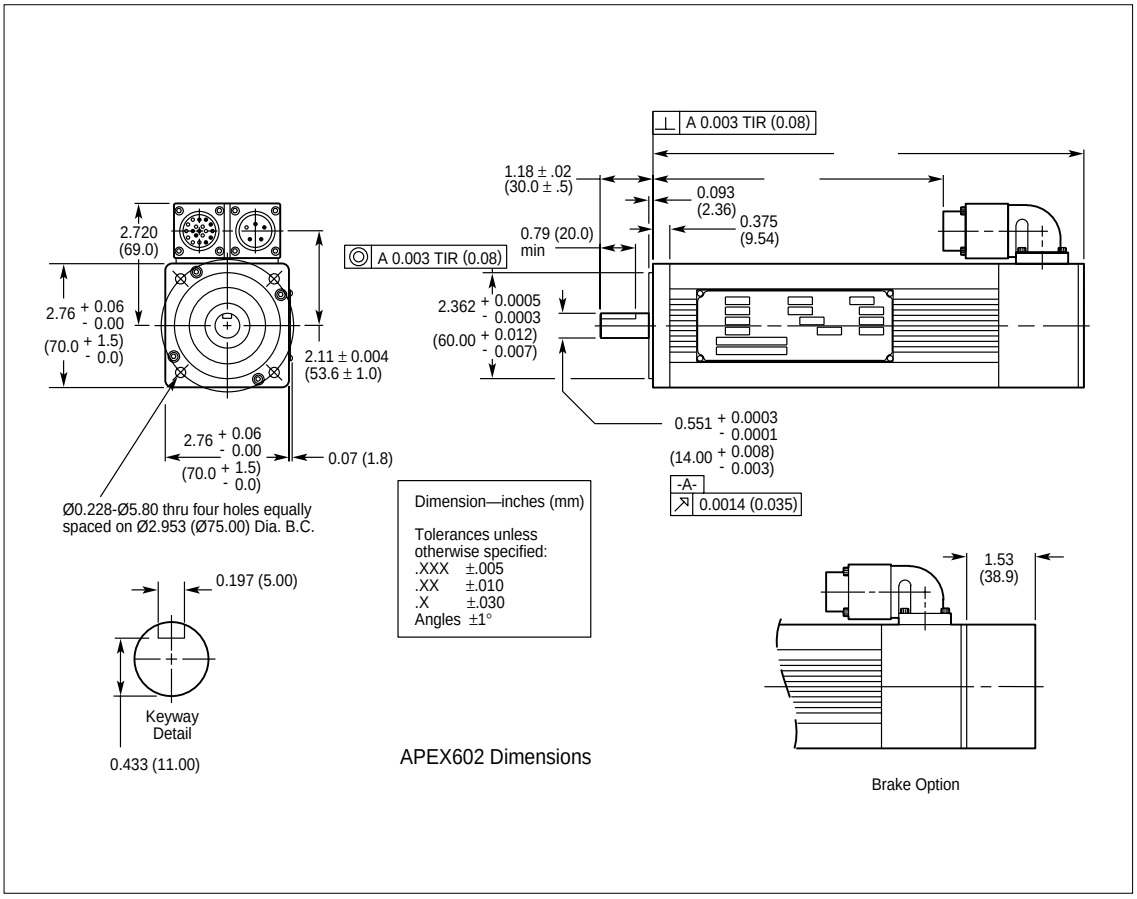
Motor Sizes	
Motor Length	Model
6.340 (161.036)	233 Motor
5.340 (135.636)	232 Motor
4.340 (110.236)	231 Motor

Longer lengths available.
Consult Compumotor for information.

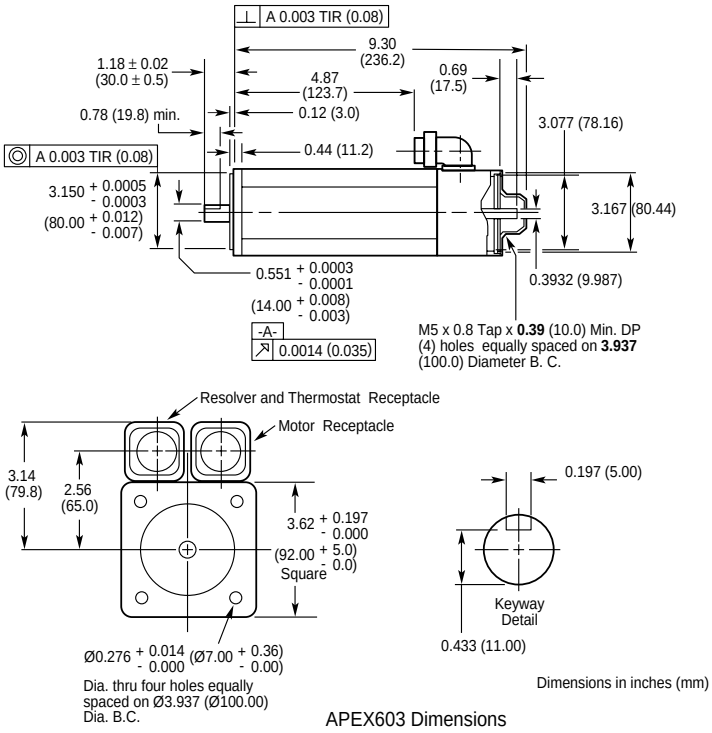
SM Series Motor Dimensions

Dimensions in inches (mm)

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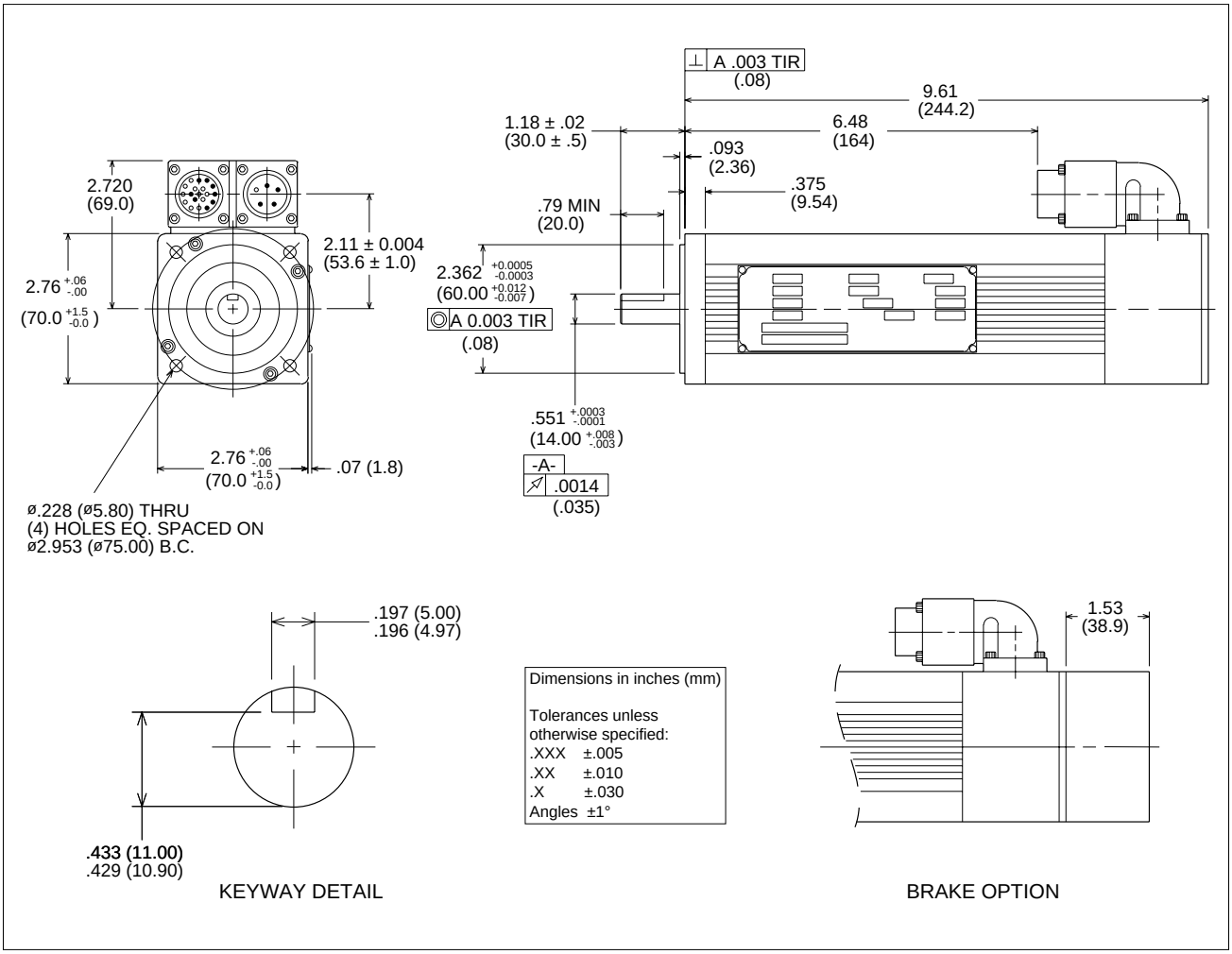


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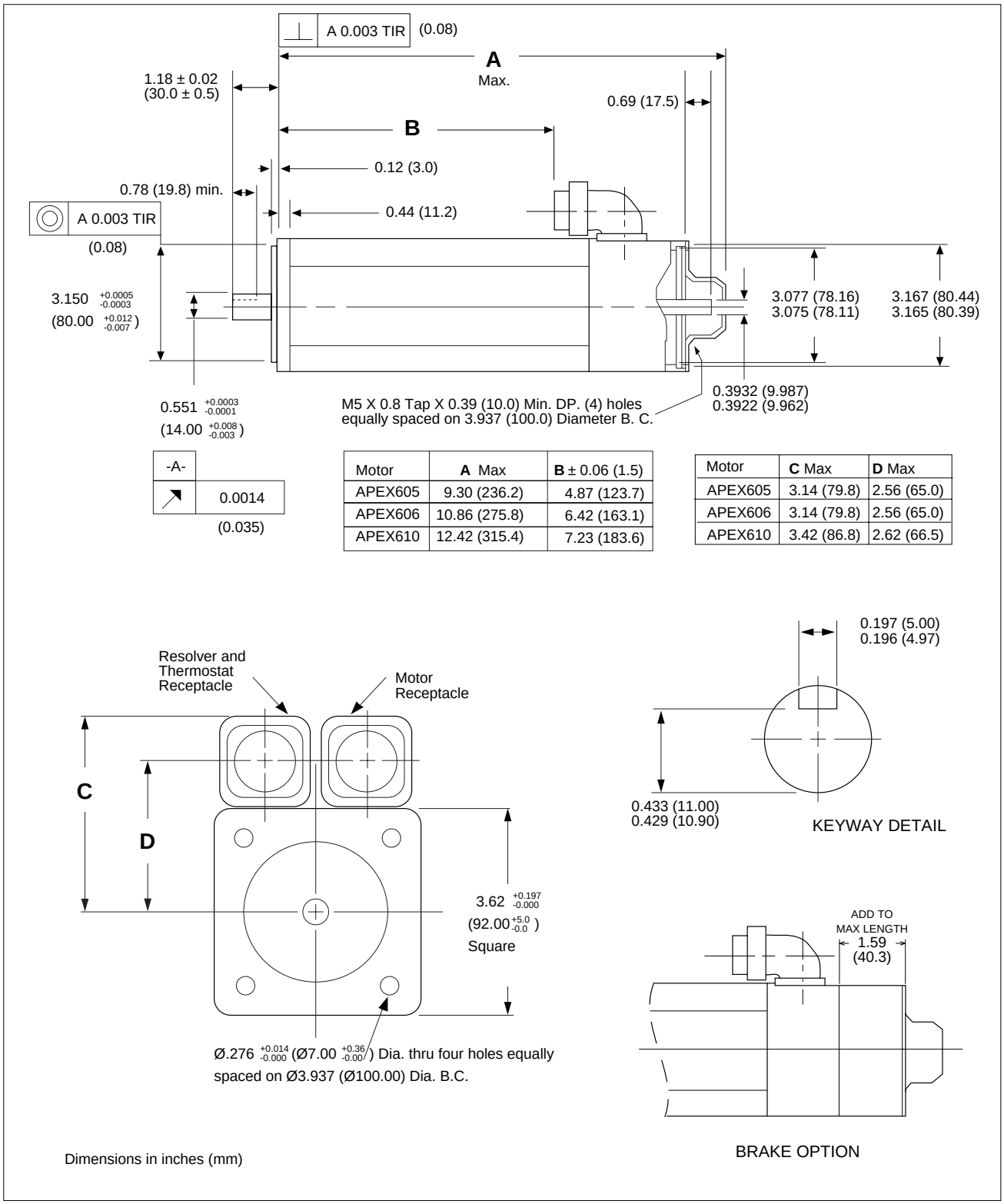
APEX603 Dimensions

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APEX604 Dimensions

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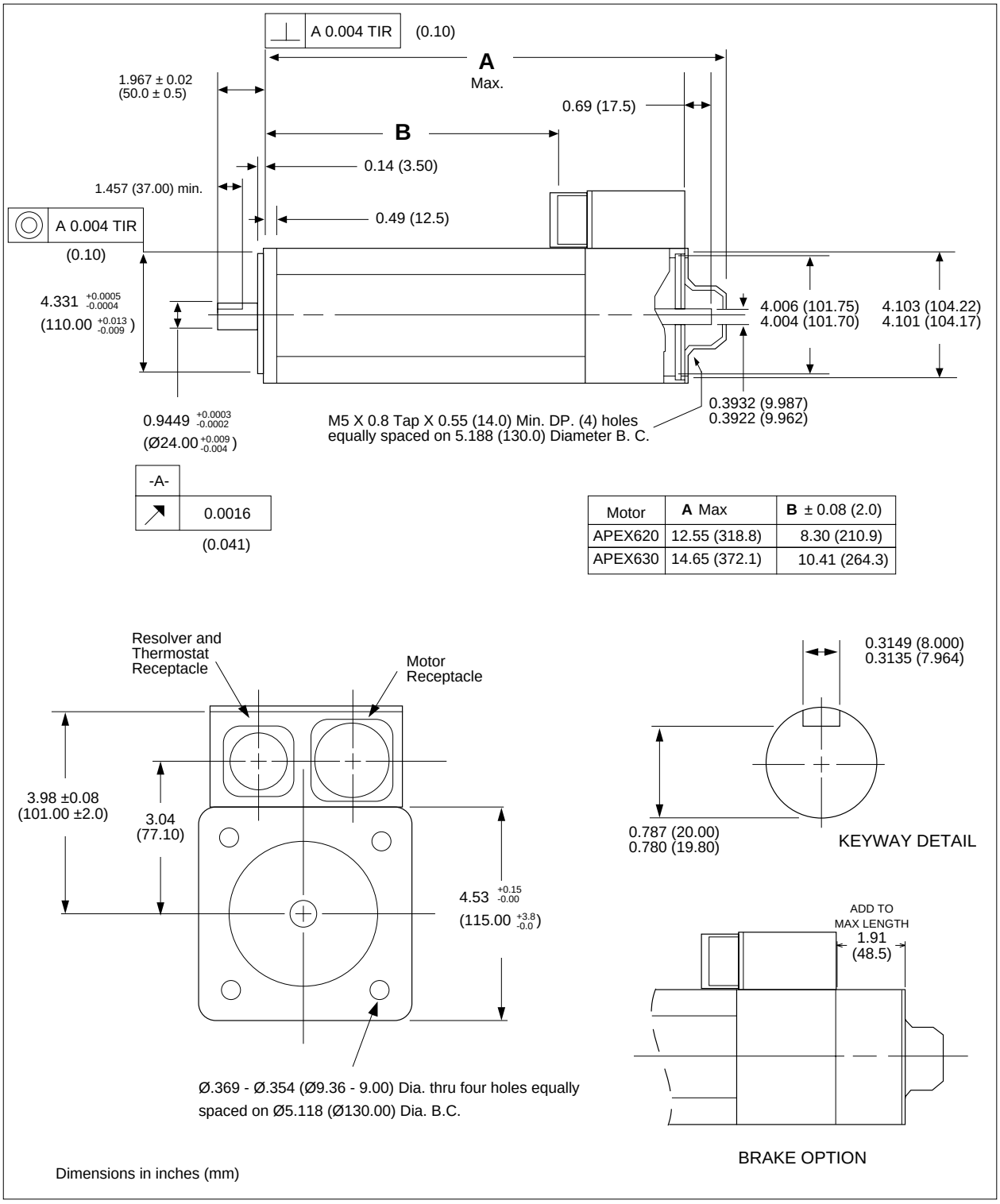


Motor	**A** Max	**B** ± 0.06 (1.5)
APEX605	9.30 (236.2)	4.87 (123.7)
APEX606	10.86 (275.8)	6.42 (163.1)
APEX610	12.42 (315.4)	7.23 (183.6)

Motor	**C** Max	**D** Max
APEX605	3.14 (79.8)	2.56 (65.0)
APEX606	3.14 (79.8)	2.56 (65.0)
APEX610	3.42 (86.8)	2.62 (66.5)

APEX605, 606, and 610 Dimensions

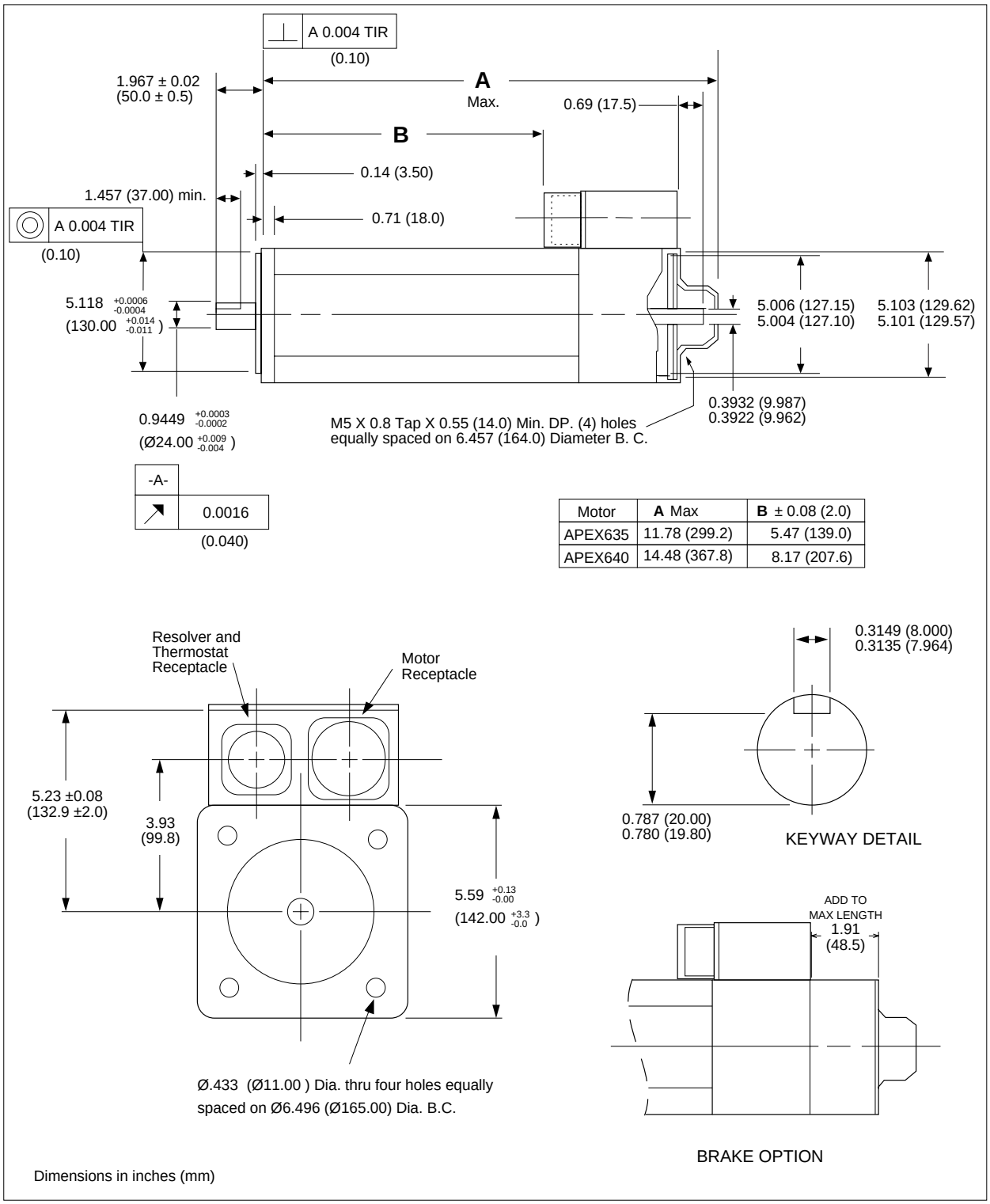
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Motor	**A** Max	**B** ± 0.08 (2.0)
APEX620	12.55 (318.8)	8.30 (210.9)
APEX630	14.65 (372.1)	10.41 (264.3)

APEX620, and 630 Dimensions

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Motor	**A** Max	**B** ± 0.08 (2.0)
APEX635	11.78 (299.2)	5.47 (139.0)
APEX640	14.48 (367.8)	8.17 (207.6)

APEX635, and 640 Dimensions

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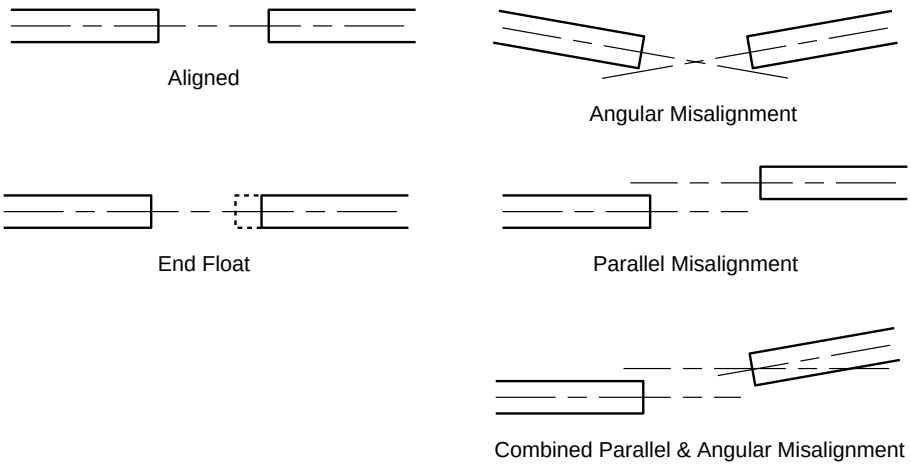
Motor Heatsinking

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. 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 APEX Series motor specifications assume that the motor is mounted to a ten inch by ten inch aluminum plate, 1/2 inch thick (250mm x 250mm x 13mm). 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 large heatsink can result in enhanced performance. You can also use a fan to blow air across the motor for increased cooling, if you do not get enough cooling by conduction through the face flange.

Coupling the Motor

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. The three misalignment conditions, which can exist in any combination, are illustrated below. The type of misalignment in your system will affect your choice of coupler (described below).



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, as shown above. 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.

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.

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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

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What's Next?

By now, you should have completed the following tasks, as instructed earlier in this chapter:

1. Review the general specifications — see page 4.
2. Perform configuration/adjustments, as necessary — see pages 6-10.
3. Mount the APEX615n — see page 11.
4. Connect all electrical system components — see pages 16-46.
5. Test the installation — see pages 46-48.
6. Mount the motor and couple the load — see pages 49-57.

Program Your Motion Control Functions

You should now be ready to program your APEX615n for your application. Knowing your system's motion control requirements, refer now to the *6000 Series Programmer's Guide* for descriptions of the APEX615n's software features and instructions on how to implement them in your application. Be sure to keep the *6000 Series Software Reference* at hand as a reference for the 6000 Series command descriptions.

For assistance with your programming effort, we recommend that you use the programming tools provided in Motion Architect for Windows (found in your ship kit). Additional powerful programming and product interface tools are available (see below).

Motion Architect

Motion Architect® is a Microsoft® Windows™ based 6000 product programming tool (included in your ship kit). Motion Architect provides these features:

- **System configurator and code generator**: Automatically generate controller code for basic system set-up parameters (I/O definitions, feedback device operations, etc.).
- **Program editor**: Create blocks or lines of 6000 controller code, or copy portions of code from previous files. You can save program editor files for later use in BASIC, C, etc., or in the terminal emulator or test panel.
- **Terminal emulator**: Communicating directly with the APEX615n, you can type in and execute controller code, transfer code files to and from the APEX615n.
- **Test panel and program tester**: You can create your own test panel to run your programs and check the activity of I/O, motion, system status, etc. This can be invaluable during start-ups and when fine tuning machine performance.
- **On-line context-sensitive help and technical references**: These on-line resources provide help information about Motion Architect, as well as interactive access to the contents of the *6000 Series Software Reference* and the *6000 Series Programmer's Guide*.

Other Software Tools Available

Motion Builder™. A Windows-based iconic programming interface that removes the requirement to learn the 6000 programming language.

CompuCAM™. A CAD-to-Motion (CAM) program that allows you to easily translate DXF, HP-GL, and G-Code files into 6000 Series Language motion programs. Windows environment.

DDE6000™. Facilitates data exchange between the APEX615n and Windows™ applications that support the dynamic data exchange (DDE) protocol. NetDDE™ compatible.

Motion Toolbox™. A library of LabVIEW® virtual instruments (VIs) for programming and monitoring the APEX615n. Available for Windows and Mac environments.

How To Order

To order these software packages, contact your local Automation Technology Center (ATC) or distributor.

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CHAPTER TWO

2 Troubleshooting

IN THIS CHAPTER

- Troubleshooting basics:
  - Diagnostic LEDs for hardware problems
  - Reducing Electrical Noise
  - Error message and debug tools
  - Technical support
- Solutions to common problems
- RS-232C troubleshooting
- Faults caused by excessive regeneration
- Current foldback
- Offset balance adjustment
- Aligning the resolver
- Commutation test mode
- Product return procedure

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Troubleshooting Basics

When your system does not function properly (or as you expect it to operate), the first thing that you must do is identify and isolate the problem. When you have accomplished this, you can effectively begin to resolve the problem.

The first step is to isolate each system component and ensure that each component functions properly when it is run independently. You may have to dismantle your system and put it back together piece by piece to detect the problem. If you have additional units available, you may want to exchange them with existing components in your system to help identify the source of the problem.

Determine if the problem is mechanical, electrical, or software-related. Can you repeat or re-create the problem? Do not attempt to make quick rationalizations about problems. Random events may appear to be related, but they are not necessarily contributing factors to your problem. You must carefully investigate and decipher the events that occur before the subsequent system problem.

You may be experiencing more than one problem. You must isolate and solve one problem at a time. Log (document) all testing and problem isolation procedures. You may need to review and consult these notes later. This will also prevent you from duplicating your testing efforts.

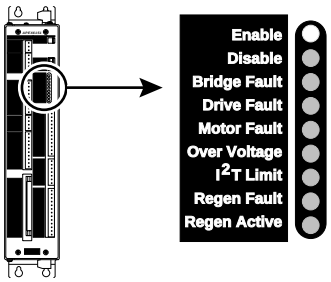
If you are having difficulty isolating a problem be sure to document all occurrences of the problem along with as much specific information, such as time of occurrence, APEX615n status, and anything else that was happening when the problem occurred.

Once you have isolated a problem, take the necessary steps to resolve it. Refer to the problem solutions contained in this chapter. If your system's problem persists, contact Technical Assistance at the numbers listed on the inside cover of this document.

Diagnostic LEDs for Hardware Problems

The APEX615n has a bank of nine light emitting diodes (LEDs) on its front panel. Use these LEDs to isolate and identify hardware problems with the APEX615n.

The LED portion of the front panel is shown below. The **Enable** LED, when illuminated, is green. All other LEDs are red when illuminated.



If a problem arises with the APEX615n, first check the LEDs for an indication of the problem's origin. The next table explains situations that can illuminate each LED, and provides the method to reset relevant fault conditions. Note that you should rectify the cause of the fault before resetting the fault condition as noted in the table below; otherwise, the fault is likely to reoccur.

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LED	Description	Latched (yes/no)	How to reset the fault (see *Recovering from Faults* below for additional details)
Enable	Indicates drive is enabled	no	n/a
Disable	Indicates drive is disabled	no	Issue the DRIVE1 command
Bridge Fault *	Power stage over-temperature Power stage over-current Motor short circuit	yes yes yes	Note 1 Note 1 Note 1
Drive Fault *	Control board over-temperature Under-voltage (brownout)	yes yes	Note 1 Note 2
Motor Fault *	Resolver not connected Motor over-temperature Motor thermostat not connected	yes yes yes	Note 1 Note 1 Note 1
Over Voltage Fault *	Bus voltage exceeded 420VDC	yes	Note 1
I^2T Limit	I^2T limit. Drive is in foldback. Output is limited to continuous current setting.	no	Note 3
Regen Fault *	Excessive regeneration (external regeneration resistor may be required)	yes	Note 1
Regen Active	Regeneration circuit active (regeneration resistor is turned on, and dissipating excess power)	no	Note 4

* When these faults occur, the 615n's output current is latched off.

Note 1 Activate drive RESET input on the DRIVE AUXILIARY connector (hold the input to less than 1.0V for at least 20 milliseconds; reset begins upon release of the low voltage), issue the DRESET command, or cycle power.

Note 2 When the bus voltage drops below 85VAC 120VDC the **Drive Fault** LED will latch, indicating a under-voltage condition. The controller will then disable the drive. When the bus voltage has recovered there are 3 ways to clear the drive fault: (1) issue a reset via the drive reset input, (2) enter the DRESET command, or (3) enable the drive with the DRIVE1 command.

Note 3 This fault condition is ***not latched***. It indicates that the APEX615n is in current foldback, with its output current limited to the continuous current level. An I^2T Limit usually indicates that something is wrong with your system—a mechanical jam, the motor is undersized, the move is too aggressive for the motor, etc.

The drive may recover on its own, if the level of continuous current is low enough to permit the motor to cool. Under some conditions, the drive may not recover on its own—it may stay in current foldback. To recover, disable the drive with the DRIVEØ command. Wait for the motor to cool before you re-enable the drive (DRIVE1 command) and resume operations.

CAUTION: Do not use the **RESET** input or RESET or DRESET commands to clear the fault. If you do so, the protective circuit loses all information about motor temperature. It assumes the motor operates from a cold start, and it may not protect the motor from overheating if the motor is hot at the time the reset occurs.

The motor has less torque during an I^2T Limit. If you configure your controller to detect position errors (based on the maximum allowed position error set with the SMPER command), then an I^2T Limit will probably cause a position error fault. See the Current Foldback section of this chapter.

Note 4 This is not a fault condition. When the LED turns on, it indicates that the internal regeneration resistor is dissipating excess regenerated power. The LED will turn off when the resistor stops dissipating power. If the APEX615n experiences excessive regeneration, it will fault and the Regen Fault LED will illuminate; in this situation, you may wish to consider installing an external regeneration resistor.

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Recovering from Faults

Many of the fault conditions will shut down the APEX615n's output current to the motor. Before trying to restart your system, you should first solve the problem that caused the fault. For example, if a short circuit in a motor cable caused a Drive Fault, the same fault will probably occur when you restart the drive—unless you first fix the problem.

Most of the fault conditions are *latched*. Once the problem is fixed, the APEX615n will not start up again on its own. You must first cycle power, or reset the drive/controller (see Notes 1 & 2 above).

To *cycle power*, remove AC power from the **Control L1** and **Control L2** terminals on the APEX615n, then turn the power back on. Note that there is a dual voltage supply—one for the internal drive/controller electronics, **Control L1/L2**, and one for the motor, **L1/L2** (see connection instructions in Chapter 2).

To *reset* the APEX615n, send a reset signal to the APEX615n's **RESET** input, located on the **DRIVE AUXILIARY** connector, or issue the DRESET command.

Reset the APEX615n

There are two ways to reset the APEX615n:

- The **RESET** input is a *hardware* reset—it resets the drive functions within the APEX615n. (To reset the drive, hold the reset input at a low voltage, less than 1.0V, for at least 20 milliseconds. Reset will begin upon release of the low voltage.) NOTE: An alternative is to issue the DRESET command.
- The reset command (RESET) is a *software* reset—it resets the controller functions within the APEX615n.

The two reset functions are independent, and do not directly affect each other. This means that if you use the **RESET** input or the DRESET command to reset the drive, the controller will remain up and running. Similarly, if you issue a RESET command to return the controller to power-up conditions, the drive functions will not automatically be reset (e.g., the drive will retain information about motor temperature—see Note 3 above).

Reducing Electrical Noise

For detailed information on reducing electrical noise, refer to Appendix B.

Error Messages and Debug Tools

A list of all possible error messages, and their causes, is provided in the ***6000 Series Software Reference***. For instructions on using the APEX615n's program debug tools (Trace mode, Single-Step mode, I/O activation, bad command detection, etc.) refer to *Program Debug Tools* in the *Programming Guide* section of the ***6000 Series Software Reference***.

Technical Support

If you cannot solve your system problems using this documentation, contact your local Automation Technology Center (ATC) or distributor for assistance. If you need to talk to our in-house application engineers, please contact us at the numbers listed on the inside cover of this manual. (These numbers are also provided when you issue the HELP command.)

NOTE: Compumotor maintains a BBS that contains the latest software upgrades and late-breaking product documentation, a FaxBack system, and a tech support email address.

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Common Problems & Solutions

The following table presents some guidelines to help you isolate problems with your motion control system. Some common symptoms are listed along with a list of possible causes and remedies.

- Look for the symptom that most closely resembles what you are experiencing.
- Look through the list of possible causes so that you better understand what may be preventing proper operation.
- Start from the top of the list of remedies and use the suggested procedures to isolate the problem.
- Refer to other sections of the manual for more information on APEX615n set up, system connections, and feature implementation. You may also need to refer to the ***6000 Series Software Reference***.

Problem	Cause	Solution
Erratic operation	1. Electrical Noise 2. Improper wiring	1. Reduce electrical noise or move the APEX615n away from noise source (refer also to Appendix A) 2. Check wiring for opens, shorts, and mis-wired connections
LEDs: DISABLE is red	1. Shutdown input active 2. Position error	1. Issue `DRIVE1` command 2. Issue `DRIVE1` command
LEDs: ENABLE LED is off	1. No AC power	1. Check AC power
Missing counts from feedback device	1. Improper wiring 2. Feedback device slipping 3. Feedback device too hot 4. Electrical noise 5. Feedback device frequency too high	1. Check wiring 2. Check and tighten feedback device coupling 3. Reduce encoder temperature with heatsink, thermal insulator, etc. 4a. Shield wiring (refer also to Appendix A) 4b. Use encoder with differential outputs 5. Peak encoder frequency must be below 1.2 MHz post-quadrature; peak frequency must account for velocity ripple
No Motion	1. ENABLE LED off 2. Limits engaged 3. Improper wiring 4. Load is jammed 5. No torque from motor 6. Maximum position error exceeded 7. ENABLE IN input is not grounded to GND	1. See Enable LED problems above. 2a. Move load off of limits or disable limits with `LHØ` 2b. If using soft limits, make sure `LSCW>LSCCW` 3. Check enable, fault, and limit connections. 4. Remove power and clear jam 5. See problem: *No Torque* 6. Check to see if `TAS` bit #23 is set, and issue the `DRIVE1` command 7. Ground ENABLE IN to GND and reset or cycle power

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Problem	Cause	Solution
No RS-232C Communication	1. Improper RS-232C Interface or communication parameters 2. RS-232C disabled 3. In daisy chain, unit may not be set to proper address	1. See *RS-232C Troubleshooting* section 2. Enable RS-232C with the E command (all units if daisy-chained) 3. Verify proper application of the ADDR command
No Torque/Force	1. Improper wiring 2. No power to motor 3. Shutdown issued	1. Check wiring to the motor, as well as other system wiring 2. Check power at motor 3. Enable drive with DRIVE1
Power-up Program does not execute	1. ENABLE IN input is not grounded to GND 2. STARTP program is not defined	1. Ground ENABLE IN to GND and reset or cycle power 2. Check the response to the STARTP command. If no program is reported, define the STARTP program and reset
Program access denied: receive the message *ACCESS DENIED when trying to use the DEF, DEL, ERASE, INFNC, or MEMORY commands	1. Program security function has been enabled (INFNCi-Q) and the program access input has not been activated	1a. Activate the assigned program access input, perform your programming changes, then deactivate the program access input. 1b. Refer to the instructions in the INFNC command description in the ***6000 Series Software Reference***
Program execution: stops at the INFEN1 command	1. INFEN1 enables drive fault monitoring, but the drive fault level (DRFLVL) command is set incorrectly for the drive being used.	1. Issue the correct DRFLVL command for your drive (refer to the DRFLVL command)
Program execution: the first time a program is run, the move distances are incorrect. Upon downloading the program the second time, move distances are correct.	1. Scaling parameters were not issued when the program was downloaded; or scaling parameters have been changed since the program was defined	1. Issue the scaling parameters (SCALE1, SCLA, SCLD, SCLV) before saving any programs
Programmable inputs not working	1. IN-P or AUXP (input pullup) not connected 2. If external power supply is used, the grounds must be connected together 3. Improper wiring	1a. When inputs will be pulled down to 0V by an external device, connect IN-P and/or AUX-P to +5V or to another positive supply 1b. When inputs will be pulled up to 5V or higher by an external device, connect IN-P and/or AUX-P to 0V 2. Connect external power supply's ground to ISO GND 3. Check wiring for opens, shorts, and mis-wired connections
Programmable outputs not working	1. Output connected such that it must source current (pull to positive voltage) 2. OUT-P not connected to +5V or other positive voltage source 3. If external power supply is used, the grounds must be connected together 4. Improper wiring	1. Outputs are open-collector and can only sink current–change wiring. 2. Connect OUT-P to +5V supplied or other voltage in system 3. Connect external power supply's ground to ground ISO GND 4. Check wiring for opens, shorts, and mis-wired connections
Trigger, home, or end-of-travel inputs not working.	1. If external power supply is used, the grounds must be connected together. 2. Improper wiring.	1. Connect external power supply's ground to APEX615n's ground . 2.a. Check wiring for opens, shorts, and mis-wired connections. 2.b. When inputs are pulled down to 0V by an external device, connect AUX-P to +5V supplied or to an external +5-24V supply (but not to both). 2.c. When inputs are pulled to 5-24V by external device, connect AUX-P to 0V. 2.d. Make sure a 5-24V power source is connected to the V_I/O terminal.
Wrong Direction—Stable	1. Phase of encoder reversed	1. Switch CHA+ with CHA- connection from APEX615n to encoder
Wrong Direction—Unstable	1. Not tuned properly 2. Phase of encoder reversed	1. Refer to Chapter 4 for tuning instructions 2. Switch CHA+ with CHA- connection from APEX615n to encoder
Wrong Speed or Distance	1. Wrong resolution setting 2. Wrong scaling value	1. Encoder feedback: Check and set resolution on APEX615n with ERES set to 4096. 2. Check the scaling parameters (SCALE1, SCLA, SCLD, SCLV)

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Troubleshooting Serial Communication Problems

General Notes

- Power up your computer or terminal *BEFORE* you power up the APEX615n.
- Make sure the serial interface is connected as instructed on page 25. Shield the cable to earth ground at one end only. Check to make sure you are using **Iso GND** as your reference, not **GND**. The maximum RS-232 cable length is 50 feet (15.25 meters).
- RS-232: Handshaking must be disabled. Most software packages allow you to do this. You can also disable handshaking by jumpering some terminals on the computer's/ terminal's serial port: connect RTS to CTS (usually pins 4 and 5) and connect DSR to DTR (usually pins 6 and 20).
- RS-485: Make sure internal DIP switches and jumpers are configured as shown on pg. 10.

Test the Interface

1. Power up the computer or terminal and launch the terminal emulator.
2. Power up the APEX615n. A power-up message (similar to the following) should be displayed, followed by a prompt (>):

```
*PARKER COMPUMOTOR 615n SERVO CONTROLLER
*RP240 CONNECTED

>
```

3. Type "TREV" and press ENTER key. (The TREV command reports software revision.) The screen should now look as follows (if not, see Problem/Remedy table below).

```
*PARKER COMPUMOTOR 6151 SERVO CONTROLLER
*RP240 CONNECTED

>TREV
*TREV92-014016-01-4.1 6151
```

Problem	Remedy (based on the possible causes)
No Response	• COM port not enabled for 6000 language communication. If RS-232 connected to COM 1: issue "PORT1" and "DRPCHKØ" commands. If RS-232 connected to COM 2: issue "PORT2" and "DRPCHKØ" commands. If RS-485 connected to COM 2: issue "PORT2" and "DRPCHKØ" commands. • RS-232: Echo may be disabled; enable with the ECHO1 command. • If using an RS-232 connection between the host computer and master APEX615n connected to multiple APEX615ns in an RS-485 multi-drop, make sure the master has these settings in the order given (place these settings in STARTP program): PORT1 (select RS-232 port, COM1, for configuration) ECHO3 (echo to both COM ports) PORT2 (select RS-485 port, COM2, for configuration) ECHO2 (echo to the other COM port, COM1) • Faulty wiring. See instructions on page 25. RS-485: verify internal DIP switch and jumper settings on page 10. Also check for shorts or opens. • Is the cable or computer/terminal bad? Here's a test: 1. Disconnect the serial cable from the APEX615n end only. 2. Connect cable's Rx and Tx lines together (echoes characters back to host). 3. Issue the TREV command. If nothing happens, the cable or computer/terminal may be faulty.
Garbled Characters	• Verify setup: 9600 baud ,8 data bits, 1 stop bit, no parity; RS-232: Full duplex; RS-485: Half duplex . • RS-485: Transmission line not properly terminated. See page 10 for internal DIP switch and jumper settings. See page 25 for connections and calculating termination resistors (if not using the internal resistors via internal DIP switches). • Faulty wiring. See instructions on page 25. RS-485: verify internal DIP switch and jumper settings on page 10. Also check for shorts or opens.
Double Characters	• Your terminal emulator is set to half-duplex; set it to full-duplex.

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Faults Caused by Excessive Regeneration

The APEX615n's protection circuitry monitors regeneration activity, and can trigger one of two fault conditions if excess regeneration occurs. Exceeding the regeneration resistor's *continuous* power rating will cause a *Regen Fault*. Exceeding the resistor's *peak* power rating will cause an *Overvoltage Fault*. Either of these faults will shut down the APEX615n, to safeguard the system.

Important specifications for the regeneration circuit are:

	Nominal Operating Voltage: (based on AC input)	**Regen Resistor Turns ON:**	**Overvoltage Fault Turns ON:**
APEX6151	170VDC-340VDC	390VDC	420VDC
APEX6152	340VDC	390VDC	420VDC
APEX6154	340VDC	390VDC	420VDC

Dissipation ratings for the internal regeneration resistor are:

	Continuous Power Dissipation Rating	**Peak Power Dissipation Rating**
APEX6151	50 watts	1 KW
APEX6152	80 watts	3 KW
APEX6154	90watts	6 KW

Details regarding the Regen Fault and overvoltage fault are explained below.

Regen Fault

A regen fault indicates that the *continuous* power dissipation capabilities of the regeneration resistor have been exceeded.

When the resistor is on and dissipating power, its temperature rises. When the resistor turns off, its temperature falls. The temperature is determined by the *average* power dissipation, over time, and is affected by such things as the length of time the resistor is on, how much power it dissipates while it is on, and the length of time it is off. During a repetitive move profile, the resistor's temperature will increase during deceleration, when regeneration occurs. The temperature will decrease after regeneration stops—when the motor is accelerating, slewing, or at rest.

If the average power dissipated in the resistor is less than 40W , the resistor's temperature will stay below damaging levels. If the average power dissipated is greater than these values, the resistor temperature may rise to a level that can permanently damage the resistor. Before temperatures reach this level, however, the regen fault circuit will shut down the drive. The purpose of the regen fault is to protect the regeneration resistor from damage due to high temperatures.

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CAUTION
Repeatedly cycling power or resetting the APEX615n to clear regeneration faults may damage the regeneration resistor.

You can clear the regen fault by cycling power or by resetting the drive. To cycle power, turn off AC power to the to the **Control L1/L2** terminals on the AC power connector, then turn the power back on; however, if the resistor has not had adequate time to cool, and the conditions leading to the regen fault persist, **you may damage the regen resistor by cycling power repeatedly**. Information about continuous power dissipation in the regen resistor is lost when power is cycled. To reset the drive, activate the **RESET** input on the **DRIVE AUXILIARY** connector (hold the input to less than 1.2V for at least 20 milliseconds; reset begins upon release of the low voltage), or issue the `DRESET` (Drive Reset) command.

Overvoltage Fault

An overvoltage fault indicates that the *peak* power dissipation capabilities of the regeneration resistor have been exceeded.

Regeneration causes the voltage on the DC power bus to rise. The regeneration resistor will turn on when the bus voltage reaches 390VDC. Peak power dissipation occurs at the moment the resistor turns on. The peak power value is determined by the size of the resistor, and the voltage across it:

$$APEX10\ Peak\ Power = \frac{V^2}{R} = \frac{(390VDC)^2}{150\Omega} \approx 1000W \quad (1KW)$$

As soon as the resistor turns on, regenerated power begins to be dissipated in the resistor, and, in most applications, bus voltage drops. When the voltage falls below 375VDC, the resistor turns off. If the motor is still producing regenerated power, the bus voltage will rise again, the resistor will turn on at 390VDC, and the cycle will repeat over and over until the motor no longer produces enough power to turn on the regeneration resistor.

However, some applications can regenerate more than 1 KW of peak power. Too much peak power can overwhelm the regeneration circuit—the bus voltage will continue to rise, even while the resistor is on. To protect the system from excessive voltages, an overvoltage circuit monitors the bus voltage, and triggers the overvoltage fault if the voltage exceeds 420VDC.

An overvoltage fault will shut down the drive. The red LED labeled *Over Voltage*, located on the APEX6151's front panel, will be illuminated. You can clear the fault by cycling power, or by pulling the **RESET** input low (**RESET** is located on the **DRIVE AUXILIARY** connector).

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Current Foldback (I^2T Limit)

The purpose of the current foldback circuit is to protect the motor from overheating due to prolonged high currents. The eight switches of DIP Switch#2 are used to set the parameters for the current foldback circuit. These parameters are:

- **PEAK CURRENT**—the highest current that the APEX615n will produce. Peak current can be set between 6.5A and 16.0 A for the APEX6151, between 9.0A and 24.0A for the APEX6152, and between 15A and 40A for the APEX6154..
- **CONTINUOUS CURRENT**—the APEX615n reduces its current to this level when it goes into current foldback. Continuous current can be set between 1.8A and 8.0A, between 3.0A and 12.0A for the APEX6152, and between 5A and 20A for the APEX6154..
- **TIME CONSTANT**—the motor's thermal time constant, which is a physical parameter usually specified by the motor's manufacturer. The time constant can be set between 10 minutes and 40 minutes on the APEX615n.

The APEX615n uses an internal circuit to model the motor's thermal behavior, and predict motor temperature. Heat dissipated in the motor's windings is directly proportional to I^2, the square of the motor current, and the length of time the current flows.

The APEX615n monitors motor current, and uses its internal microprocessor to simulate a capacitor being charged by the motor current. The result is a number, similar to voltage on a capacitor, that represents an average, over time, of the motor's temperature.

The following equation gives an approximate time before foldback occurs, for a motor that operates from a cold start, when $I_{actual} > I_{continuous}$.

$$time_{(minutes)} = Time\ Constant\left\{-\ln\left[1-\left(\frac{I_{continuous}}{I_{actual}}\right)^2\right]\right\}$$

Three variables affect this equation:

- $I_{continuous}$ is the continuous current (set by DIP switches)
- *Time Constant* is the motor's time constant (set by DIP switches)
- I_{actual} is the current that actually flows in the motor. It can be as low as Ø amps, or as high as the peak current (which was set by DIP switches).

The shortest time until foldback occurs will be when $I_{actual} = I_{peak}$. Notice that this can be much shorter than the time constant in the equation above.

When current foldback occurs, the APEX615n clamps its output current at the $I_{continuous}$ level, and illuminates the LED labeled I^2T Limit, located on the drive's front panel. The drive does not put out a fault signal on its fault output. However, because torque will be reduced as a result of the lower motor current, excess position or following error may result.

To recover from current foldback, there are three options:

- **WAIT**—allow a period of time to pass for the motor to cool. Usually, several minutes will be required.
- **REDUCE COMMAND INPUT**—lower the commanded current to a level below continuous current. This will bleed off the voltage on the simulated capacitor, and clear the foldback condition.
- **RESET**—Pull the **RESET** input low (the **RESET** input is located on the APEX615n's **DRIVE AUXILIARY** connector). An alternative is to issue the DRESET command or cycle power on **Control L1/L2**. This will reset the drive, and clear the foldback condition. However, this method is not recommended if the motor is actually hot, because the motor temperature information in the controller will be lost. The motor should be allowed to cool before the APEX615n is reset, and operations continue. (**RESET** input and DRESET command resets drive functions; RESET command resets controller.

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Offset Balance Adjustments

The offset balance potentiometer (offset pot) adjusts the offset voltage of the APEX615n's internal command signal. The offset is zeroed at the factory, with the pot set near the middle of its range of travel. Normally, you do not need to adjust it. However, if you suspect the pot's setting has been altered, the procedure below will explain how to adjust it to zero the offset balance.

NOTE

This procedure—adjusting the offset balance potentiometer—was performed at the factory. If yours is a new APEX615n, you do not need to perform this step. You can use the default factory settings.

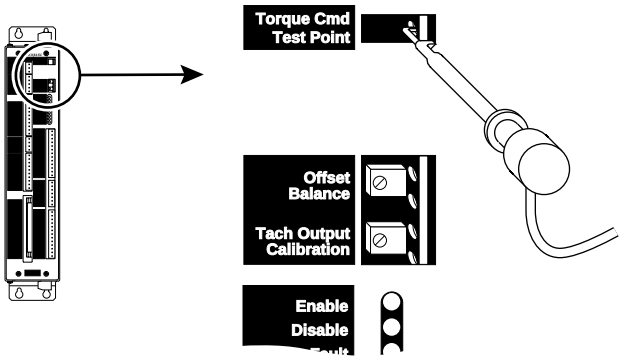
A small offset will not normally cause a problem—the APEX615n's internal controller can automatically compensate for any offset. If the offset is excessive, though, you may notice that the motor reaches a higher speed in one direction than the other. If this causes a problem in your application, follow the procedure below to zero the offset.

1. Remove the load from the motor. The motor's shaft must be free to turn.
2. Turn on AC power to the APEX615n.
3. Disable hardwired limits: `(LHØ)`
4. Disable monitoring of maximum allowable position error: `(SMPERØ)`
5. Set all servo gains to zero: `(SGPØ, SGIØ, SGVØ, SGAFØ, SGVFØ)`

CAUTION

If there is little or no load on the motor shaft, any internal offset may cause an acceleration to a high speed.

6. Set the commanded offset voltage to zero: (SOFFSØ)
7. Enable the drive with the DRIVE1 command.
8. With all gains set to zero, the APEX615n is now operating open loop. Any motion of the motor shaft is due to an internal offset. You can measure the offset by connecting a digital volt meter (DVM) to the Torque Cmd Test Point test point, as shown below. Connect the probe's negative lead to any of the GND terminals on the Drive Auxiliary connector.



The offset voltage should be very close to ØV. If it is not, zero the offset by turning the Offset Balance pot. This is a 15-turn pot, located on the front panel of the APEX615n. The null position—where the voltage approaches zero, and the motor stops turning—will be near the center of the pot's range of travel.

When you have zeroed the offset voltage, and the motor stops turning, this procedure is complete.

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Tachometer Output Calibration

Use the Tachometer Output Calibration potentiometer to precisely calibrate the APEX615n Controller/Drive's tachometer output, while monitoring the actual tachometer output at the Tach Out pin on the Drive Auxiliary connector. For example, a commanded velocity of 4000 rpm should produce Tach Out signal of 4 volts. Adjust the potentiometer until the Tach Out signal is measured at 4 volts.

Aligning the Resolver

You can operate the APEX615n in *alignment mode* if you need to align your motor's resolver.

This is a rarely used feature. Resolvers on APEX Series motors are aligned at the factory, and need no further adjustments. It is usually not necessary to align resolvers on other manufacturer's motors.

However, if you need to replace the resolver on a motor, if you have a motor with unknown characteristics, or if poor speed/torque performance leads you to suspect that the resolver is out of alignment, you can follow the procedure below.

To align the resolver, perform the following steps.

1. Turn OFF AC power to the APEX615n and remove the load from the motor. The motor's shaft must be free to turn.
2. Turn DIP Switch#3, position 2, ON. Turn ON AC power to the APEX615n.
3. Set all servo gains to zero `[SGPØ, SGIØ, SGVØ, SGAFØ, & SGVFØ]`.
4. For 2-pole-pair motor: Set offset voltage to negative one half volt `[SOFFS-Ø.5]`.
   For 3-pole-pair motor: Set offset voltage to positive one half volt `[SOFFSØ.5]`.
5. Enable the APEX615n drive `[DRIVE1]`. The motor shaft should turn and lock into position. If it does not lock into position, increase `SOFFS` slightly. Use only enough current in the motor to maintain holding torque. Excess current may cause motor overheating.
6. With the motor shaft locked in the alignment position, loosen the screws on the resolver so that it can turn.
7. Slowly rotate the resolver while you observe the APEX615n's front panel LEDs. When the resolver is in the correct position, both the MOTOR FAULT and the I^2T LIMIT LEDs will be illuminated. When the resolver is close to the correct position, only one of the LEDs will be illuminated. When the rotor is not close to the correct position, no LED will be illuminated.
8. With the resolver in the correct position (both LEDs illuminated), tighten the screws on the resolver so that its case can no longer rotate.
9. Turn off AC power, and turn DIP Switch#3, position 2, OFF.

Resolver alignment is now complete. You can resume normal operations.

While the APEX615n is in alignment mode, it commutates current as follows:

- For 2–pole motors: Current out of Phase B and into Phase C
- For 3–pole motors: Two equal currents out of Phases B and C. Both currents into Phase A

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Commutation Test Mode

You can operate the APEX615n in *commutation test mode* to help identify and isolate problems. When it runs in commutation test mode, the APEX615n does not use any motor feedback information for commutation. It ignores the resolver or the Hall effect sensor input, and commutates the motor in an open loop fashion at one revolution per second. The current it sends to the motor will be proportional to the internal command voltage.

You can use commutation test mode to verify that your APEX615n is commutating properly, and that the motor phases are wired correctly.

To operate in commutation test mode:

1. Turn off AC power to the APEX615n.
2. Turn DIP Switch#3, Position#3, ON.
3 Turn on AC power to the APEX615n.
4. The APEX615n should begin commutating the motor clockwise at the following speeds:
   - 1 rps (for 2-pole motors)
   - 2/3 rps (for 3-pole motors)
5. Depending upon your application, you may need to remove the load from the motor, or adjust the internal command voltage with the `SOFFS` command to get adequate motor current. You may also need to set the servo gains to zero `(SGPØ, SGIØ, SGVØ, SGAFØ & SGVFØ)`

Returning the APEX615n

Step 1

Record the serial number and the model number of the defective unit, and secure a purchase order number to cover repair costs in the event the unit is determined by the manufacturers to be out of warranty.

Step 2

Before you return the unit, have someone from your organization with a technical understanding of the APEX615n system and its application include answers to the following questions:

- What is the extent of the failure/reason for return?
- How long did it operate?
- Did any other items fail at the same time?
- What was happening when the unit failed (e.g., installing the unit, cycling power, starting other equipment, etc.)?
- How was the product configured (in detail)?
- Which, if any, cables were modified and how?
- With what equipment is the unit interfaced?
- What was the application?
- What was the system environment (temperature, enclosure, spacing, contaminants, etc.)?
- What upgrades, if any, are required (hardware, software, user guide)?

Step 3

Call for return authorization. Refer to the *Technical Assistance* phone numbers provided on the inside front cover of this document. The support personnel will also provide shipping guidelines.

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Appendix A

Servo Tuning

In a Hurry?

We strongly recommend tuning the APEX615n before attempting to execute any motion functions. If you **must** execute motion quickly (e.g., for testing purposes), you should at least complete this appendix's *Controller Tuning Procedure* and find a proportional feedback gain that gives a stable response for your system. Then you can proceed to execute your motion functions. Later on, you should read through this entire *Servo Tuning* appendix and follow its procedures to ensure your system is properly tuned.

Servo System Terminology

This section gives you an overall understanding of the principles and the terminology used in tuning the APEX615n Servo Controller/Drive.

Servo Tuning Terminology

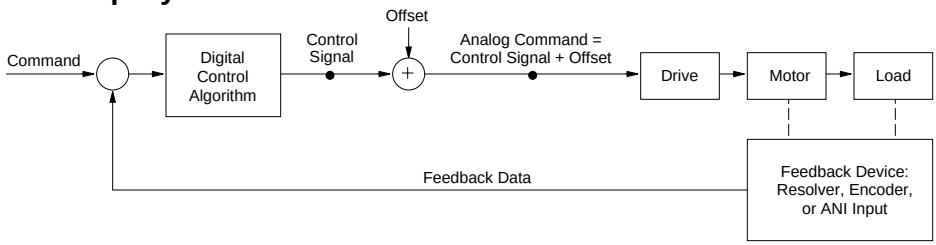
The APEX615n uses a digital control algorithm to control and maintain the position and velocity. The digital control algorithm consists of a set of numerical equations used to periodically (once every **servo sampling period**) calculate the value of the **control signal** output. The numerical terms of the equations consist of the current commanded and actual position values (plus several values from the previous sampling period) and a set of control parameters. Each control parameter, commonly called a **gain**, has a specific function (see *Servo Control Techniques* later in this chapter). **Tuning** is the process of selecting and adjusting these gains to achieve optimal servo performance.

When this control algorithm is used, the whole servo system is a **closed-loop** system (see diagram below). It is called closed loop because the control algorithm accounts for both the **command** (position, velocity, tension, etc.) and the **feedback data** (from the resolver, encoder, or ANI input); therefore, it forms a *closed loop* of information flow.

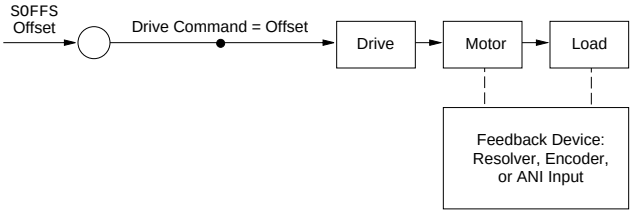
When all gains are set to zero, the digital control algorithm is disabled. During system setup or troubleshooting, it may be desirable to disable the algorithm and use the SOFFS command to directly control the motor current; then you can test the drive/motor operation independently from the controller.

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Closed Loop System



Servo Algorithm Disabled



Internally, the APEX615n has two main sections—a *controller section* and a *drive section*. The controller accepts a motion command, and uses its digital control algorithm to calculate a *digital* control signal. This digital value is sent from the digital signal processor (DSP) to the digital-to-analog converter (DAC). The DAC has an analog output range of -10V to +10V.

The DAC's output, an *analog* control signal, is sent to the APEX615n's drive section. The drive produces motor current that is proportional to the voltage level of the analog signal.

It is possible that the digital control signal calculated by the control algorithm can exceed the ±10V limit. When this happens, the analog output will stay, or *saturate*, at the maximum limit until the position error changes such that the control algorithm calculates a control signal less than the limit. This phenomenon of reaching the output limit is called **controller output saturation**. When saturation occurs, increasing the gains does not help improve performance since the DAC is already operating at its maximum level.

Position Variable Terminology

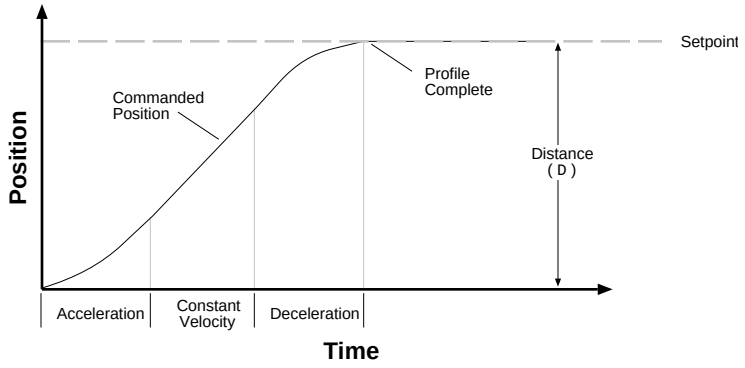
In a servo system, there are two types of **time-varying** (value changes with time) position information used by the controller for control purposes: commanded position and actual position. You can use this information to determine if the system is positioning as you expect.

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Commanded Position

The **commanded position** is calculated by the motion profile routine based on the acceleration (A, AA), deceleration (AD, ADA), velocity (V) and distance (D) command values and it is updated every servo sampling period. Therefore, the commanded position is the intended position at any given point of time. To view the commanded position, use the TPC (Transfer Commanded Position) command; the response represents the commanded position at the instant the command is received.

When this user guide refers to the *commanded position*, it means the calculated time-varying commanded position, *not* the distance (D) command. Conversely, when this user guide refers to the **position setpoint**, it means the final intended distance specified with the distance (D) command. The following plot is a typical profile of the commanded position in preset (MCØ) mode.



Actual Position

The other type of time-varying position information is the **actual position**; that is, the actual position of the motor (or load) measured with the feedback device (resolver, encoder or ANI input). Since this is the position achieved when the drive responds to the commanded position, we call the overall picture of the actual position over time the **position response** (see further discussion under *Servo Response Terminology*).

To view the actual position, use the TFB (Transfer Position of Feedback Device) command; the response represents the actual position at the instant the command is received. The goal of tuning the servo system is to get the actual position to track the commanded position as closely as possible.

The difference between the commanded position and actual position is the **position error**. To view the position error, use the TPER (Transfer Position Error) command; the response represents the position error at the instant the command is received. When the motor is not moving, the position error at that time is called the **steady-state position error** (see definition of steady-state under *Servo Response Terminology*). If a position error occurs when the motor is moving, it is called the **position tracking error**.

In some cases, even when the system is properly tuned, the position error can still be quite significant due to a combination of factors such as the desired profile, the motor's limitations, the dynamic characteristics of the system, etc. For example, if the value of the velocity (V) command is higher than the maximum velocity the motor can physically achieve, then when it is commanded to travel at this velocity, the actual position will always lag behind the commanded position and a position error will accumulate, no matter how high the gains are.

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Servo Response Terminology

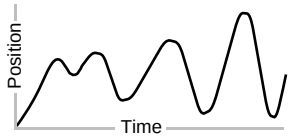
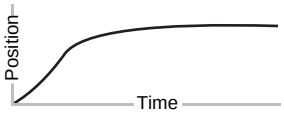
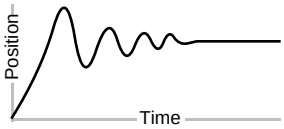
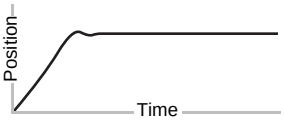
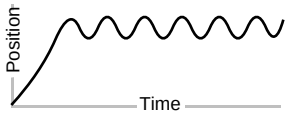
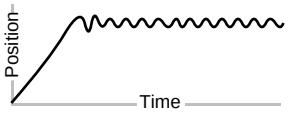
Stability

The first objective of tuning is to stabilize the system. The formal definition of **system stability** is that when a bounded input is introduced to the system, the output of the system is also bounded. What this means to a motion control system is that if the system is **stable**, then when the position setpoint is a finite value, the final actual position of the system is also a finite value.

On the other hand, if the system is **unstable**, then no matter how small the position setpoint or how little a disturbance (motor torque variation, load change, noise from the feedback device, etc.) the system receives, the position error will increase continuously (and exponentially in almost all cases.) In practice, when the system experiences instability, the actual position will oscillate in an exponentially diverging fashion as shown in the drawing below. The definition here might contradict what some might perceive. One common perception shared by many is that whenever there is oscillation, the system is unstable. However, if the oscillation finally diminishes (damps out), even if it takes a long time, the system is still considered stable. The reason for this clarification is to avoid misinterpretation of what this user guide describes in the following sections.

Position Response Types

The following table lists, describes, and illustrates the six basic types of position responses. The primary difference among these responses is due to **damping**, which is the suppression (or cancellation) of oscillation.

Response	Description	Profile (position/time)
Unstable	Instability causes the position to oscillate in an exponentially diverging fashion.	
Over-damped	A highly damped, or *over-damped*, system gives a smooth but slower response.	
Under-damped	A slightly damped, or *under-damped*, system gives a slightly oscillatory response.	
Critically damped	A critically-damped response is the most desirable because it optimizes the trade-off between damping and speed of response.	
Oscillatory	An oscillatory response is characterized by sustained position oscillations of equal amplitude.	
Chattering	Chattering is a high-frequency, low-amplitude oscillation which is usually audible.	

Performance Measurements

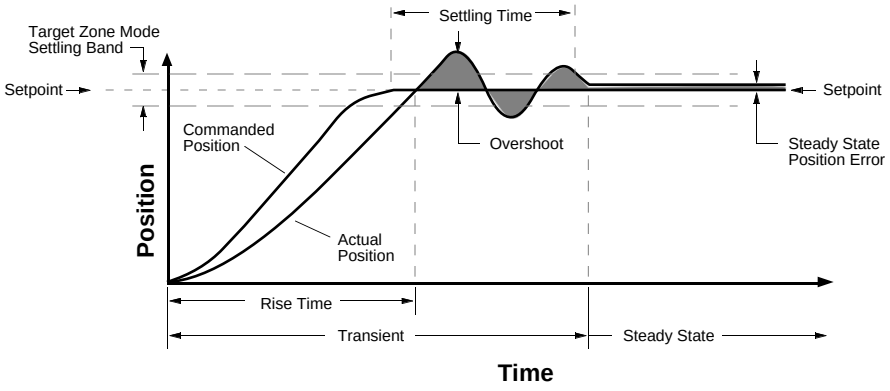
When you investigate the plot of the position response versus time, there are a few measurements that you can make to quantitatively assess the performance of the servo:

- **Overshoot** – the measurement of the maximum magnitude that the actual position exceeds the position setpoint. It is usually measured in terms of the percentage of the setpoint value.
- **Rise Time** – the time it takes the actual position to pass the setpoint.
- **Settling Time** – the time between when the commanded position reaches the setpoint and the actual position settles within a certain percentage of the position setpoint. (Note the settling time definition here is different from that of a control engineering text book, but the goal of the performance measurement is still intact.)

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These three measurements are made before or shortly after the motor stops moving. When it is moving to reach and settle to the setpoint, we call such a period of time the **transient**. When it is not moving, it is defined as **steady-state**.

A typical stable position response plot in preset mode (MCØ) is shown below.



6000 Series Servo Commands

NOTE

The following list briefly describes each servo-related 6000 Series command. More detailed information can be found in the rest of this chapter and within each command's description in the ***6000 Series Software Reference***.

Command	Title	Brief Description (detailed descriptions in *6000 Series Software Reference*)
SFB	*Select Servo Feedback Source*	Selects the servo feedback transducer. You can select resolver, encoder, or ANI feedback. (SFB4, resolver, is the default selection.)
SGAF	*Acceleration Feedforward Gain*	Sets the acceleration feedforward gain in the PIV&**F$_a$** servo algorithm.
SGENB	*Servo Gain Set Enable*	Enables a previously-saved set of PIV&F gains. A set of gains (specific to the current feedback source selected with the SFB command) is saved using the SGSET command.
SGI	*Set Integral Feedback Gain*	Sets the integral gain in the P**I**V&F servo algorithm.
SGILIM	*Set Integral Windup Limit*	Sets a limit on the correctional control signal that results from the integral gain action trying to compensate for a position error that persists too long.
SGP	*Proportional Feedback Gain*	Sets the proportional gain in the **P**IV&F servo algorithm.
SGSET	*Save a Set of Servo Gains*	Saves the presently-defined set of PIV&F gains as a particular *gain set* (specific to the current feedback source). Up to 5 gain sets can be saved and enabled at any point in a move profile, allowing different gains at different points in the profile.
SGV	*Set Velocity Feedback Gain*	Sets the velocity gain in the PI**V**&F servo algorithm.
SGVF	*Velocity Feedforward Gain*	Sets the velocity feedforward gain in the PIV&**F$_v$** servo algorithm.
SMPER	*Maximum Allowable Position Error*	Sets the maximum allowable error between the commanded position and the actual position as indicated by the feedback device. If the error exceeds this limit, the APEX615n shuts down power output to the motor. The motor will freewheel to a stop. You can enable the ERROR command to continually check for this error condition, and when it occurs to branch to a programmed response defined in the ERRORP program.
SOFFS	*Servo Control Signal Offset*	Sets an offset to the commanded analog output voltage, which is sent to the drive system.
SSFR	*Servo Frequency Ratio*	Sets the ratio between the update rate of the move trajectory and the update rate of the servo action. The intermediate position setpoints calculated by the trajectory generator is updated at a slower rate then the servo position correction. This command allows you to optimize this for your application. The default setting (SSF4) is sufficient for most applications.

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STRGTE STRGTD STRGTV STRGTT	*Target Zone Mode Enable* *Target Zone Distance* *Target Zone Velocity* *Target Zone Timeout Period*	When using the Target Zone Mode, enabled with the STRGTE command, the actual position and actual velocity must be within the *target zone* (that is, within the distance zone defined by STRGTD and within the velocity zone defined by STRGTV). If the motor/load does not settle into the target zone before the timeout period set by STRGTT, the APEX615n detects an error. To prevent subsequent commands/moves from being executed when this error condition occurs, you must enable the ERROR command to continually check for this error condition, and when it occurs to branch to a programmed response defined in the ERRORP program. Otherwise, subsequent commands/moves can be executed regardless of the actual position and velocity. This feature is explained in greater detail later in the *Target Zone* section.
TFB and [FB]	*Position of Servo Feedback Devices*	Transfers [or assigns/compares] the actual position of the transducer selected for feedback (see SFB).
TDAC and [DAC]	*Value of DAC Output*	Transfers [or assigns/compares] the output from the APEX615n's digital-to-analog converter. This is the analog control signal output to the APEX615n's internal drive.
TGAIN	*Transfer Servo Gains*	Transfers the currently active set of PIV&F gains. The servo gain set reported represents the last gain values specified with the individual servo gain commands (SGI, SGP, SGV, SGAF, and SGVF), or the last gain set enabled with the SGSET command.
TPC and [PC]	*Position Commanded*	Transfers [or assigns/compares] the commanded position (intermediate position setpoint).
TPER and [PER]	*Position Error*	Transfers [or assigns/compares] the error between the commanded position (TPC) and the actual position (TFB, TPE, or TANI) as measured by the feedback device.
TSGSET	*Transfer Servo Gain Set*	Transfers a previously-saved set of servo gain parameters. A gain set is saved with the SGSET command.
TSTLT	*Transfer Servo Settling Time*	Transfers the time it took the last move to settle within the *target zone* (that is, within the distance zone defined by STRGTD and within the velocity zone defined by STRGTV). The Target Zone Mode does not need to be enabled to use this command.

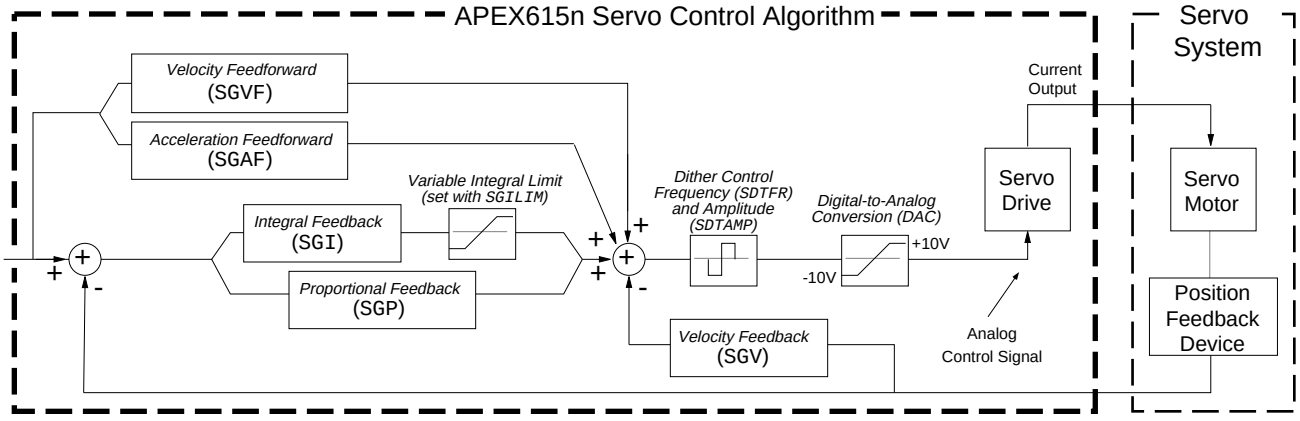
Servo Control Techniques

To ensure that you are tuning your servo system properly, you should understand the tuning techniques described in this section.

The APEX615n employs a *PIV&F* servo control algorithm. The control techniques available in this system are as follows:

P ..... Proportional Feedback (controlled with the SGP command)
I ..... Integral Feedback (controlled with the SGI command)
V ..... Velocity Feedback (controlled with the SGV command)
F ..... Velocity and Acceleration Feedforward (controlled by the SGVF and SGAF commands, respectively)

The following block diagram shows these control techniques in relation to the servo control algorithm configuration. The table presents a condensed summary of each control's effect on the servo system.



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Gain	Stability	Damping	Disturbance Rejection	Steady State Error	Tracking Error
Proportional (SGP)	Improve	Improve	Improve	Improve	Improve
Integral (SGI)	Degrade	Degrade	Improve	Improve	Improve
Velocity Feedback (SGV)	Improve	Improve	----------	----------	Degrade
Velocity Feedforward (SGVF)	----------	----------	----------	----------	Improve
Acceleration Feedforward (SGAF)	----------	----------	----------	----------	Improve

Proportional Feedback Control (SGP)

***Proportional feedback* is the most important feedback for stabilizing a servo system.** When the APEX615n uses *proportional feedback*, the control signal is linearly proportional to the position error (the difference between the commanded position and the actual position—see TPER command). The proportional gain is set by the Servo Gain Proportional (SGP) command. Proportional feedback can be used to make the servo system more responsive, as well as reduce the steady state position error.

Since the control is proportional to the position error, whenever there is any disturbance forcing the load away from its commanded position (such as torque ripple or a spring load), the proportional control can immediately output a signal to move it back toward the commanded position. This function is called *disturbance rejection.*

If you tune your system using only the proportional feedback, increasing the proportional feedback gain (SGP value) too much will cause the system response to be oscillatory, underdamped, or in some cases unstable.

NOTE

The proportional feedback gain (SGP) should never be set to zero, except when open-loop operation is desired.

Integral Feedback Control (SGI)

Using *integral feedback control*, the value of the control signal is integrated at a rate proportional to the feedback device position error. The rate of integration is set by the Servo Gain Integral (SGI) command.

The primary function of the integral control is to overcome friction and/or gravity and to reject disturbances so that steady state position error can be minimized or eliminated. This control action is important for achieving high system accuracy. *However, if you can achieve acceptable position accuracy by using only the proportional feedback (SGP), then there is no need to use the integral feedback control.*

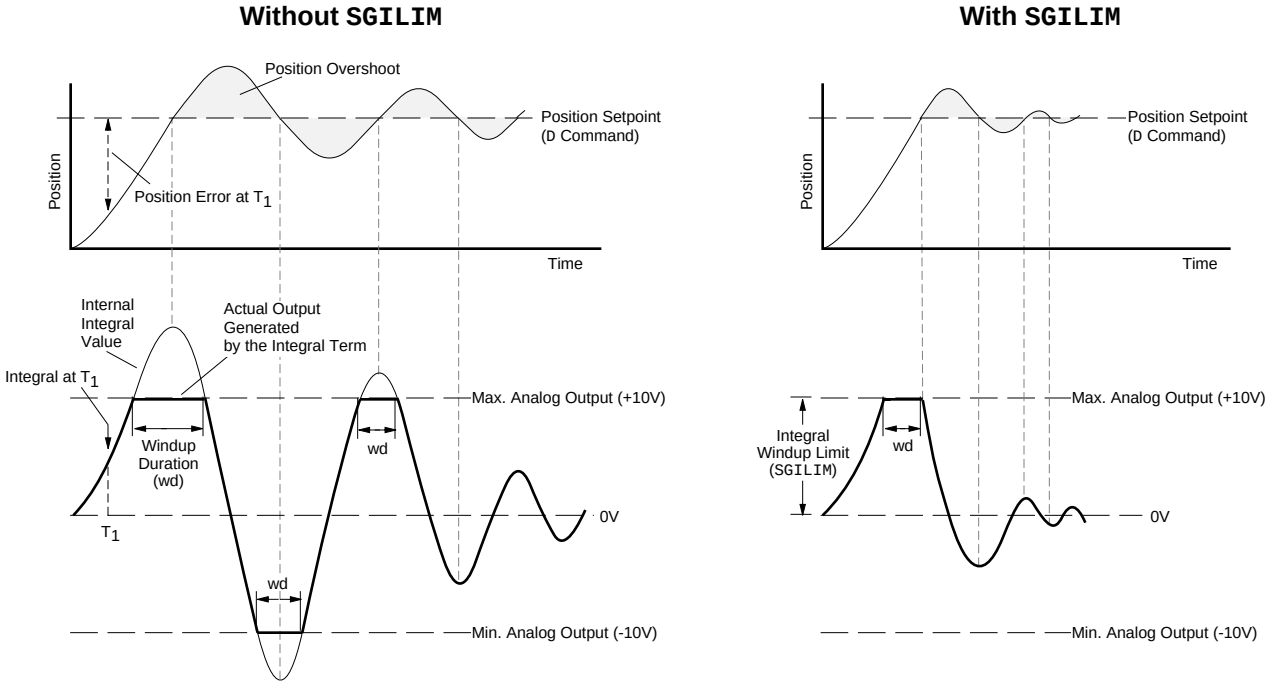
In the task of reducing position error, the integral gain (SGI) works differently than the proportional gain (SGP); this is because the magnitude of its control signal is not dependent on the magnitude of the position error as in the case of proportional feedback. If any position error persists, then the output of the integral term will ramp up over time until it is high enough to drive the error back to zero. Therefore, even a very small position error can be eliminated by the integral feedback control. By the same principle, integral feedback control can also reduce the tracking error when the system is commanded to cruise at constant velocity.

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Controlling Integral Windup

If integral control (SGI) is used and an appreciable position error has persisted long enough during the transient period (time taken to reach the setpoint), the control signal generated by the integral action can end up too high and saturate to the maximum level of the controller's analog control signal output. This phenomenon is called *integral windup*.

After windup occurs, it will take a while before the integrator output returns to a level within the limit of the controller's output. Such a delay causes excessive position overshoot and oscillation. Therefore, the integral windup limit (SGILIM) command is provided for you to set the absolute limit of the integral and, in essence, turn off the integral action as soon as it reaches the limit; thus, position overshoot and oscillation can be reduced (see illustration below). The application of this feature is demonstrated in Step 5 of the *Controller Tuning Procedure* below.



Velocity Feedback Control (SGV)

When *velocity feedback control* is used, the control signal is proportional to the feedback device's velocity (rate of change of the actual position). The Servo Gain Velocity (SGV) command sets the gain, which is in turn multiplied by the feedback device's velocity to produce the control signal. Since the velocity feedback acts based upon the feedback device's velocity, its control action essentially anticipates the position error and corrects it before it becomes too large. Such control tends to increase damping and improve the stability of the system.

A high velocity feedback gain (SGV) can also increase the position tracking error when traveling at constant velocity. In addition, setting the velocity feedback gain too high tends to slow down (*overdamp*) the response to a commanded position change. If a high velocity feedback gain is needed for adequate damping, you can balance the tracking error by applying velocity feedforward control (increasing the SGVF value—discussed below).

Since the feedback device's velocity is derived by differentiating the feedback device's position with a finite resolution, the finite word truncation effect and any fluctuation of the feedback device's position would be highly magnified in the velocity value, and even more so when multiplied by a high velocity feedback gain. When the value of the velocity feedback gain has reached such a limit, the motor will *chatter* (high-frequency, low-amplitude oscillation) at steady state.

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Velocity Feedforward Control (SGVF)

The purpose of velocity feedforward control is to improve *tracking performance*—that is, reduce the position error when the system is commanded to move at constant velocity. The tracking error is mainly attributed to three sources—friction, torque load, and velocity feedback control (SGV).

Velocity feedforward control is directed by the Servo Gain Velocity Feedforward (SGVF) setting, which is in turn multiplied by the rate of change (velocity) of the commanded position to produce the control signal. Consequently, because the control signal is now proportional to the velocity of the commanded position, the APEX615n essentially anticipates the commanded position and initiates a control signal ahead of time to more closely follow (*track*) the commanded position.

Applications requiring contouring or linear interpolation can benefit from improved tracking performance; however, *if your application only requires short, point-to-point moves, velocity feedforward control is not necessary.*

Because velocity feedforward control is not in the servo feedback loop (see *Servo Control Algorithm* drawing above), it does not affect the servo system's stability. Therefore, there is no limit on how high the velocity feedforward gain (SGVF) can be set, except when it *saturates the control output* (tries to exceed the APEX615n's analog control signal range of ±10V).

Acceleration Feedforward Control (SGAF)

The purpose of acceleration feedforward control is to improve position tracking performance when the system is commanded to accelerate or decelerate.

Acceleration feedforward control is directed by the Servo Gain Acceleration Feedforward (SGAF) setting, which is in turn multiplied by the acceleration of the commanded position to produce the control signal. Consequently, because the control signal is now proportional to the acceleration of the commanded position, the APEX615n essentially anticipates the velocity of the commanded position and initiates a control signal ahead of time to more closely follow (*track*) the commanded position.

Same as velocity feedforward control, this control action can improve the performance of linear interpolation applications. In addition, it also reduces the time required to reach the commanded velocity. *However, if your application only requires short, point-to-point moves, acceleration feedforward control is not necessary.*

Acceleration feedforward control does not affect the servo system's stability, nor does it have any effect at constant velocity or at steady state.

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Controller Tuning Procedure

The *Controller Tuning Procedure* leads you through the following steps:

1. Turn on AC power to the APEX615n.
2. Setup up for tuning.
3. Select the 615n's servo Sampling Frequency Ratios (SSFR).
4. Set the Maximum Position Error (SMPER).
5. Optimize the Proportional (SGP) and Velocity (SGV) gains.
6. Use the Integral Feedback Gain (SGI) to reduce steady state error.
7. Use the Velocity Feedforward Gain (SGVF) to reduce position error at constant velocity.
8. Use the Acceleration Feedforward Gain (SGAF) to reduce position error during acceleration and deceleration.

Tuning with Servo Tuner™:

Compumotor also offers Servo Tuner™, a Microsoft® Windows™ based program designed to help you tune your motion control servo system. Refer to the Servo Tuner User Guide for tuning procedures.

Before you tune the 615n:

If your application requires switching between feedback sources on the same axis, then for each feedback source on each axis you must select the feedback source with the SFB command and repeat steps 4-8.

EMERGENCY SHUTDOWN

If you need to shutdown the APEX615n during the tuning process (for instance, if the system becomes unstable or experiences a runaway), issue the DRIVEØ command.

Step 1 **Turn on AC power to energize the APEX615n.**

Step 2 Use a computer (with a terminal emulator) or a dumb terminal to enter the commands noted in the steps below. To monitor system performance, you may use visual inspection, or use an analog type position transducer (potentiometer, LVDT, RVDT, etc.) to pick up the load's or motor's position displacement and monitor the transducer output on a digital storage oscilloscope.

Step 3 **Select the Sampling Frequency Ratio (SSFR):**

The APEX615n's control signal is computed by the digital signal processor (DSP). The velocity of the commanded position, the velocity of the feedback device's position, and the integral of the position error are used for various control actions. These measurements are derived by the DSP from the position values sampled periodically at a fixed rate; this sampling rate is called the *servo sampling frequency* (samples/second).

NOTE

The SSFR setting affects the dither frequency ratio (SDTFR setting). Refer to the SSFR and SDTFR command descriptions in the ***6000 Series Software Reference*** for details.

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Higher sampling frequencies improve the accuracy of the derived velocity and integral values. A higher sampling frequency can also improve the tracking of a rapidly changing or oscillating position. Therefore, the servo sampling frequency is a key parameter that influences the servo system's stability and closed loop bandwidth.

In addition to computing the APEX615n's control signal, the DSP also computes the commanded position trajectory. When the servo sampling frequency is increased, the motion trajectory update rate has to be decreased, and vice versa. The ratio between the servo sampling frequency and the trajectory update rate, called the *sampling frequency ratio*, depends on the requirements of your application and/or the dynamic characteristics of the system. The Servo Sampling Frequency Ratio (SSFR) command offers four selectable ratio settings. These four ratios and the actual sampling frequencies and sampling periods (reciprocal of sampling frequency) are shown below.

SSFR	Servo Sampling Update		Motion Trajectory Update		System Update	
Command Setting	Frequency (samples/sec.)	Period (μsec)	Frequency (samples/sec.)	Period (μsec)	Frequency (samples/sec.)	Period (μsec)
SSFR1	3030	330	3030	330	757	1320
SSFR2	5405	185	2703	370	675	1480
SSFR4	6250	160	1563	640	520	1920
SSFR8	6667	150	833	1200	417	2400

The general rule for determining the proper SSFR value is to first select the slowest servo sampling frequency that is able to give a satisfactory response. This can be done by experiment or based on the closed-loop bandwidth requirement for your application. (Keep in mind that increasing the SSFR value allows for higher bandwidths, but produces a rougher motion profile; conversely, decreasing the SSFR value provides a smoother profile, but makes the servo system less stable and slower to respond.)

As an example, if your application requires a closed-loop bandwidth of 350 Hz, you can use the following guideline to determine the minimum servo sampling frequency: set the servo sampling frequency at least 8 times higher than the bandwidth frequency. The required minimum servo sampling frequency would be 2800 Hz.

The table below provides guidelines for various application requirements.

Application Requirement	SSFR1	SSFR2	SSFR4	SSFR8
XY Linear Interpolation	4	4		
Fast point-to-point motion			4	4
Regulation (speed, torque, etc.)			4	4
High natural frequency system				4

Setting the Sampling Frequency Ratio

Select a sampling ratio (with the SSFR command) appropriate to your system now, before you proceed to tune each gain.

If you change the sampling frequency ratios (SSFR) after the tuning is complete and the new servo sampling frequency is lower than the previous one, the response may change (if your system bandwidth is quite high) and you may have to re-tune the system.

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Step 4 **Set the Maximum Position Error (SMPER)**:

The SMPER command allows you to set the maximum position error allowed before an error condition occurs. The position error, monitored once per system update period, is the difference between the commanded position and the actual position as read by the feedback device selected with the last SFB command. *Larger values allow greater oscillations/motion when unstable; therefore, smaller SMPER values are safer.*

When the position error exceeds the value entered by the SMPER command, an error condition is latched (see TAS or AS bit #23) and the 6000 controller issues a shutdown to the faulted axis and sets its analog output command to zero volts. To enable the system again, the appropriate DRIVE1 command must be issued, which also sets the commanded position equal to the actual feedback device position (incremental devices will be zeroed).

If the SMPER value is set to zero, the position error condition is not monitored, allowing the position error to accumulate without causing a fault.

Step 5 **Optimize the Proportional (SGP) and Velocity (SGV) gains (*see illustration for tuning process*)**:

a. Enter the following commands to create a step input profile *(use a comma in the first data field when tuning axis 2—e.g.,* D,1ØØ*)*:

Command	Description
> A999	Set acceleration to 999 units/sec^2
> AD999	Set deceleration to 999 units/sec^2
> V3Ø	Set velocity to 30 units/sec
> D1ØØ	Set distance to 100 units

b. Start with an SGP command value of 0.5 (SGPØ.5 or SGP,Ø.5).

c. Enter the GO1 or GO,1 command depending on which axis is being tuned at the time.

d. Observe the plot of the commanded position versus the actual position on the oscilloscope. If the response is already very oscillatory, lower the gain (SGP); if it is *sluggish* (overdamped), increase the SGP gain.

Repeat Steps 4.c. and 4.d. until the response is slightly under-damped.

e. Start with an SGV command value of 0.1 (SGVØ.1 or SGV,Ø.1).

f. As you did in Step 4.c., enter GO1 or GO,1.

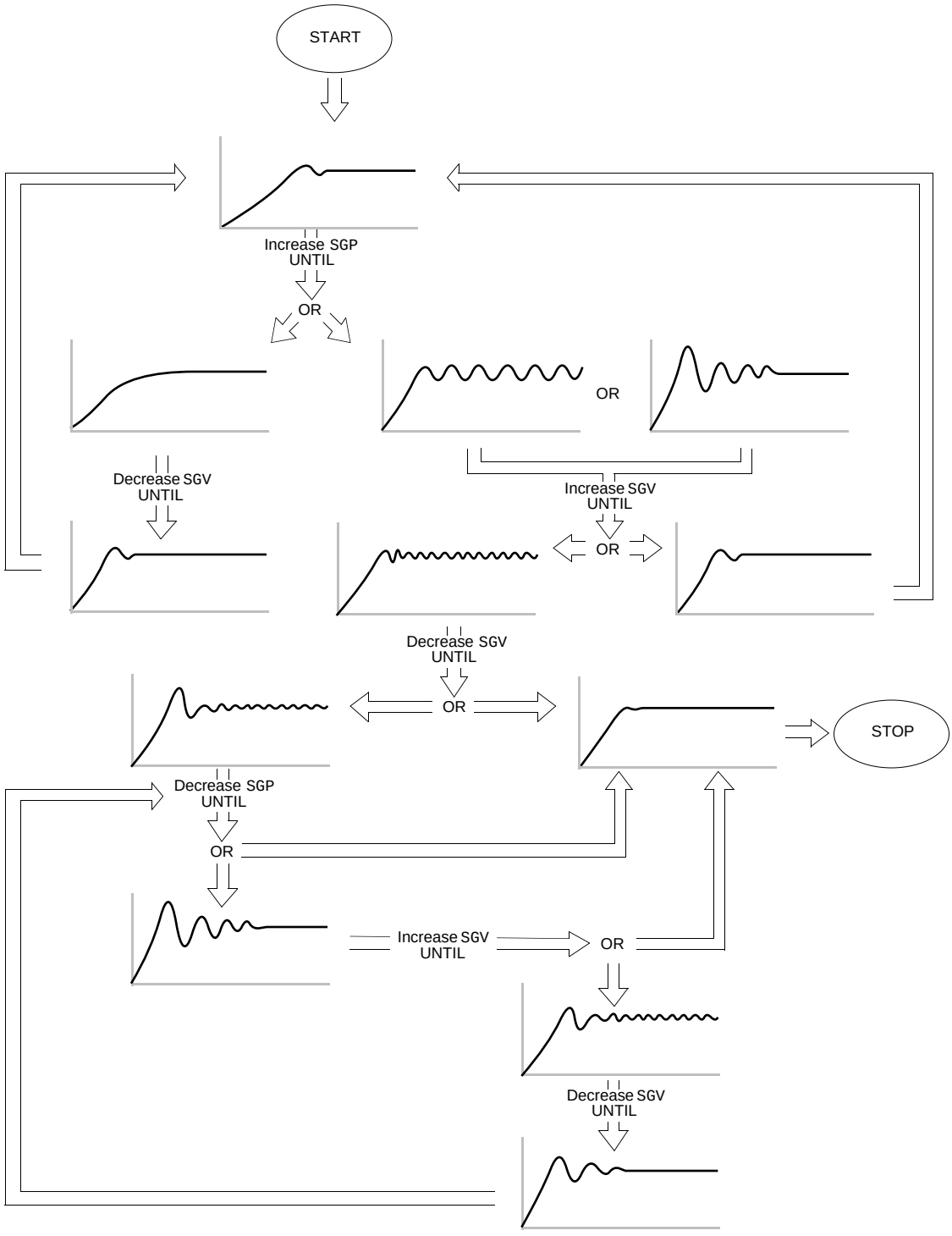
g. Observe the plot on the oscilloscope. If the response is *sluggish* (overdamped), reduce the SGV gain. *Repeat Steps 4.f. and 4.g. until the response is slightly under-damped.*

☞ *Refer to the* Tuning Scenario *section later in this chapter for a case example.*

h. The flow diagram below shows you how to get the values of the proportional and velocity feedback gains for the fastest, well-damped response in a step-by-step fashion. The tuning principle here is based on these four characteristics:

- Increasing the proportional gain (SGP) can speed up the response time and increase the damping.
- Increasing the velocity feedback gain (SGV) can increase the damping more so than the proportional gain can, but also may slow down the response time.
- When the SGP gain is too high, it can cause instability.
- When the SGV gain is too high, it can cause the motor (or valve, hydraulic cylinder, etc.) to chatter.

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Step 6 **Use the Integral Feedback Gain (SGI) to reduce steady state error:**

☞ *Steady state position error is described earlier in the* Performance Measurements *section.*

a. Determine the steady state position error (the difference between the commanded position and the actual position). You can determine this error value by the TPER command when the load is not moving.

> **NOTE**
> If the steady state position error is zero or so small that it is acceptable for your application, **you do not need to use the integral gain**. For hydraulic applications, it is usually best to use a small SGI value, or use SGIØ while moving and use SGIn when stopped. The use of the Target Zone Settling Mode (STRGTE) is recommended.

b. If you have to enter the integral feedback gain to reduce the steady error, start out with a small value (e.g., SGIØ.1). After the gain is entered, observe two things from the response:

- Whether or not the magnitude of steady state error reduces
- Whether or not the steady state error reduces to zero at a faster rate

c. Keep increasing the gain to further improve these two measurements until the overshoot starts to increase and the response becomes oscillatory.

d. There are three things you can do at this point (If these three things do not work, that means the integral gain is too high and you have to lower it.):

1st Lower the integral gain (SGI) value to reduce the overshoot.

☞ *If you are using current control, convert the offset from milliamps to volts and enter the result in the* SGILIM *command.*

2nd Check whether the 615n's analog output saturates the ±10V limit; you can do this by observing the signal from a digital oscilloscope. If it saturates, then lower the integral output limit by using the SGILIM command. This should help reduce the overshoot and shorten the settling time. Sometimes, even if the analog output is not saturated, you can still reduce the overshoot by lowering SGILIM to a value less than the maximum output value. *However, lowering it too much can impair the effectiveness of the integral feedback.*

3rd You can still increase the velocity feedback gain (SGV value) further, provided that it is not already at the highest possible setting (causing the motor or valve to chatter).

Step 7 **Use the Velocity Feedforward Gain (SGVF) to reduce position error at constant speed:**

a. Execute a continuous (MC1 command) move, setting the acceleration, deceleration and velocity values appropriate to your application. Set the SGVF value to be the product of SGP ∗ SGV (if SGV = zero, set SGVF equal to SGP).

b. Check the position error at constant velocity by issuing the TPER command.

c. Increase SGVF to reduce the position error (repeat steps a and b as necessary).

Step 8 **Use the Acceleration Feedforward Gain (SGAF) to reduce position error during acceleration:**

a. Execute a continuous (MC1 command) move, setting the acceleration, deceleration and velocity values appropriate to your application. Set SGAF to 0.01 (SGAFØ.Ø1).

b. Check the position error during acceleration by issuing the TPER command.

c. Increase SGAF to reduce the position error (repeat steps a and b as necessary).

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Tuning Scenario

This example shows how to obtain the highest possible proportional feedback (SGP) and velocity feedback (SGV) gains experimentally by using the flow diagram illustrated earlier in Step 5 of the *Tuning Procedure*.

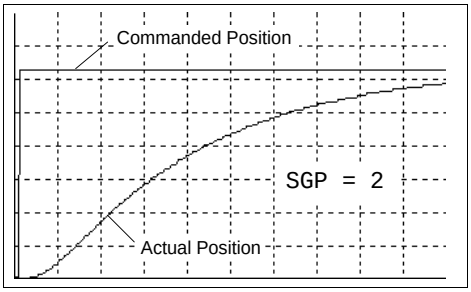
NOTE

The steps shown below (steps 1 - 11) represent the major steps of the process; the actual progression between these steps usually requires several iterations.

The motion command used for this example is a step command with a step size of 100. The plots shown are as they appear in Motion Architect's Controller Tuner Module (X axis = time, Y axis = position).

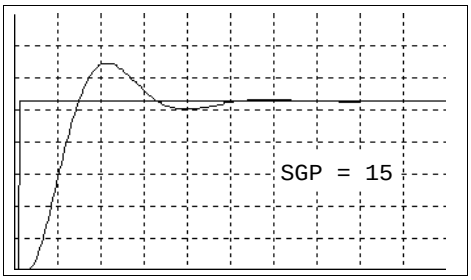
Step 1 For a starting trial, we set the proportional feedback gain (SGP) to 2. As you can see by the plot, the response is slow.

In the next step, we should increase SGP until the response is slightly underdamped.



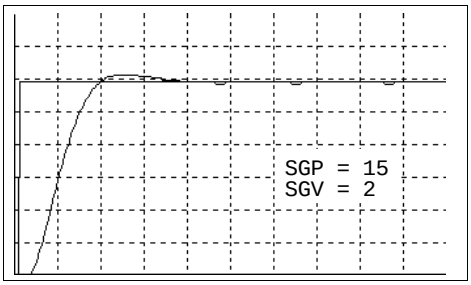
Step 2 With SGP equal to 15, the response becomes slightly underdamped (see plot).

Therefore, we should introduce the velocity feedback gain (SGV) to *damp out* the oscillation.



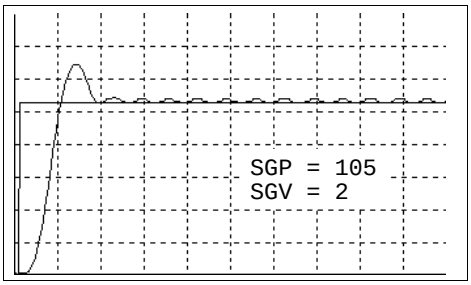
Step 3 With SGV equal to 2, the response turns out fairly well damped (see plot).

At this point, the SGP should be raised again until oscillation or excessive overshoot appears.



Step 4 As we iteratively increase SGP to 105, overshoot and chattering becomes significant (see plot). This means either the SGV gain is too low and/or the SGP is too high.

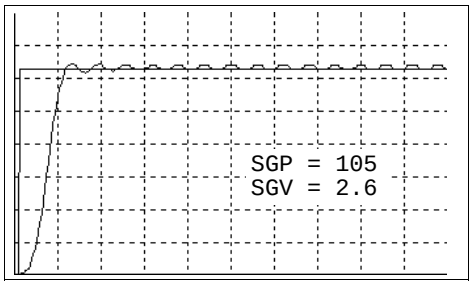
Next, we should try raising the SGV gain to see if it could damp out the overshoot and chattering.



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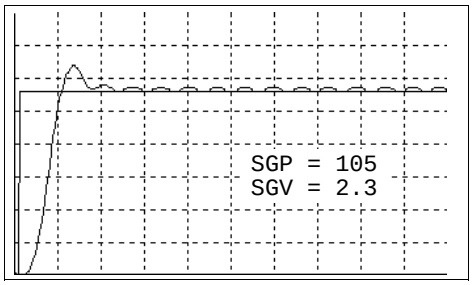
Step 5 After the SGV gain is raised to 2.6, the overshoot was reduced but chattering is still quite pronounced. This means either one or both of the gains is too high.

The next step should be to lower the SGV gain first.



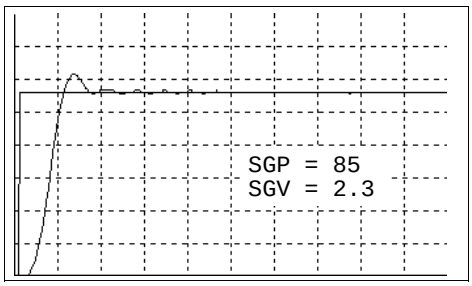
Step 6 Lowering the SGV gain to 2.3 does not help reduce the chattering by much.

Therefore, we should lower the SGP gain until chattering stops.



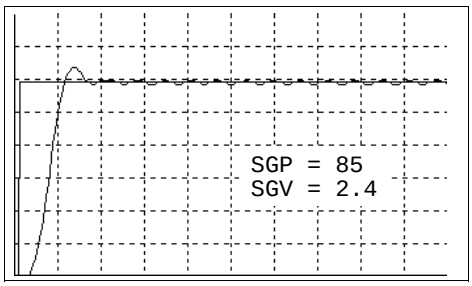
Step 7 Chattering stops after reducing the SGP gain to 85. However, the overshoot is still a little too high.

The next step should be to try raising the SGV to damp out the overshoot.



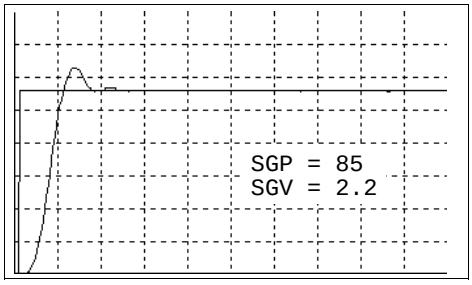
Step 8 After raising the SGV gain to 2.4, overshoot is reduced a little, but chattering reappears. This means the gains are still too high.

Next, we should lower the SGV gain until chattering stops.



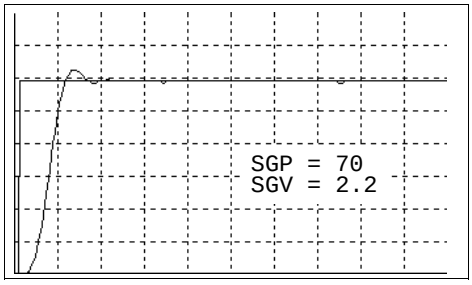
Step 9 After lowering the SGV gain to 2.2 (even less than in Step 7—2.3), chattering stops.

Next we should lower the SGP gain.



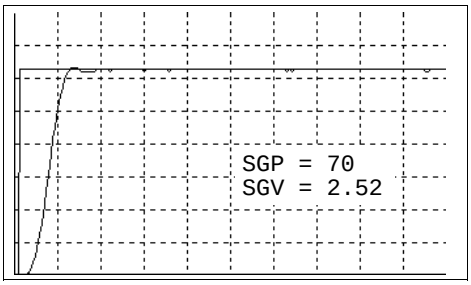
Step 10 Overshoot is reduced very little after lowering the SGP gain to 70. (The SGV gain might have been lowered too much in Step 9.)

Next, we should try raising the SGV gain again until the overshoot is gone.



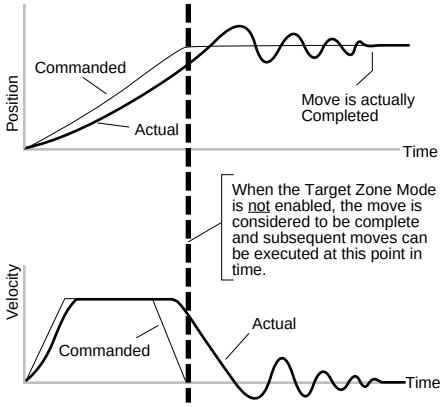
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Step 11 When we raised the SGV gain to 2.52, the step response became fast and very stable.



Target Zone (Move Completion Criteria)

Under default operation (Target Zone Mode not enabled), the APEX615n's move completion criteria is simply derived from the move trajectory. The APEX615n considers the current preset move to be complete when the commanded trajectory has reached the desired target position; after that, subsequent commands/moves can be executed for that same axis. Consequently, the next move or external operation can begin **before** the actual position has settled to the commanded position (see diagram).



Target Zone Mode

To prevent premature command execution before the actual position settles into the commanded position, use the *Target Zone Mode*. In this mode, enabled with the STRGTE command, the move cannot be considered complete until the actual position and actual velocity are within the *target zone* (that is, within the distance zone defined by STRGTD and less than or equal to the velocity defined by STRGTV). If the load does not settle into the target zone before the timeout period set with the STRGTT command, the APEX615n detects a *timeout error* (see illustration below).

Refer to the Error Handling *section in the* **6000 Series Software Reference** *for error program examples*

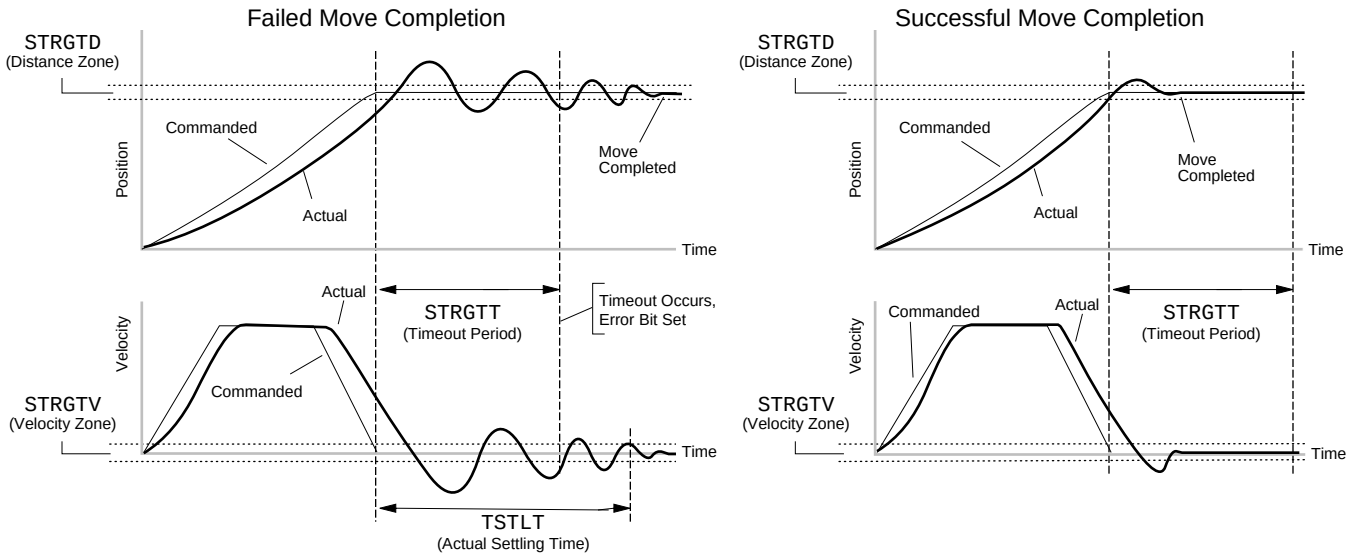
If the timeout error occurs, you can prevent subsequent command/move execution only if you enable the ERROR command to continually check for this error condition, and when it occurs to branch to a programmed response you can define in the ERRORP program.

As an example, setting the distance zone to ±5 steps (STRGTD5), the velocity zone to ≤0.5 rps (STRGTVØ.5), and the timeout period to 1/2 second (STRGTT5ØØ), a move with a distance of 8,000 steps (D8ØØØ) must end up between position 7,995 and 8,005 and settle down to ≤0.5 rps within 500 ms (1/2 second) after the commanded profile is complete.

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Damping is critical

To ensure that a move settles within the distance zone, it must be damped to the point that it will not move out of the zone in an oscillatory manner. This helps ensure the actual velocity falls within the target velocity zone set with the STRGTV command (see illustration below).



Checking the Actual Settling Time

Using the TSTLT command, you can display the actual time it took the last move to settle into the target zone (that is, within the distance zone defined by STRGTD and less than or equal to the velocity defined by STRGTV). The reported value represents milliseconds. **This command is usable whether or not the Target Zone Settling Mode is enabled with the STRGTE command.**

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Appendix B

Reducing Electrical Noise

Noise-related difficulties can range in severity from minor positioning errors to damaged equipment from runaway loads crashing blindly through limit switches. In microprocessor-controlled equipment such as the APEX615n, the processor constantly retrieves instructions from memory in a controlled sequence. If an electrical disturbance occurs, it may cause the processor to misinterpret an instruction or access the wrong data. This can be catastrophic to the program and force you to reset the processor.

Sources of Noise

Being invisible, electrical noise can be very mysterious, but it invariably comes from the following sources:

- Power line noise
- Externally conducted noise
- Transmitted noise
- Ground loops

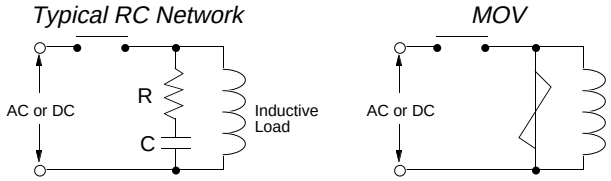
The following electrical devices are notorious for generating unwanted electrical noise conditions:

- Coil-driven devices: conducted and power line noise
- SCR-fired heaters: transmitted and power line noise
- Valves, motors & motor drives: transmitted and power line noise
- Welders (electric): transmitted and power line noise

Power Line Noise

Power line noise is usually easy to resolve due to the wide availability of line filtering equipment for the industry. Only the most severe situations call for an isolation transformer. Line filtering equipment is required when other devices connected to the local power line are switching large amounts of current, especially if the switching occurs at a high frequency.

Any device having coils is likely to disrupt the power line when it is switched off. Surge suppressers, such as metal oxide varistors (MOVs) are capable of limiting this type of electrical noise. A series resistor/capacitor (RC) network across the coil is also effective (resistance: 500 to 1,000 Ω; capacitance: 0.1 to 0.2 µF). Coil-driven devices (inductive loads) include relays, solenoids, contactors, clutches, brakes, and motor starters.



Internal Switching Noise

This noise directly relates to the high *dv/dt* from the internal switching of the IGBT power block of the APEX615n's drive. This high *dv/dt* creates a large earth ground *di/dt* through the motor case. This may cause the ground to jump if a solid earth connection is not present. Depending on how the drive and other equipment are connected to the earth ground, users may experience voltage spikes on I/O lines. Systems involving data acquisition from low level analog and digital signals are most vulnerable.

The best method to limit the *dv/dt* is to add a filter between the drive output and the motor. This reduces the *dv/dt* and decreases the *di/dt* a great deal. These filters have been installed by Compumotor in several applications with good results. Another method that can be used to reduce noise is to install AC line input filters. Compumotor has found from our own testing that properly installed AC line filters, on the drive as well as the controller, reduce noise on both analog and digital inputs and outputs.

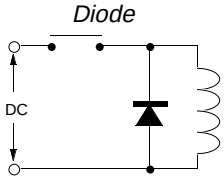
Compumotor has located a series of suitable AC line filters and motor output filters that can be purchased for use in applications as needed. These filters are manufactured by the SCHAFFNER Co. and may be purchased by contacting the manufacturer or the stocking distributor listed at the end of this appendix. The suitable motor output filters are listed below. The suggested AC line filters are listed in the "Filtering the AC mains supply" section of Appendix E of this document.

	Manufacturer	**Part Number**
APEX6151	Schaffner Co.	FN 510-8/29
APEX6152	Schaffner Co.	FN 510-8/29
APEX6154	Schaffner Co.	FN 510-16/29

Externally Conducted Noise

Externally-conducted noise is similar to power line noise, but the disturbances are created on signal and ground wires that are connected to the APEX615n. This kind of noise can get into logic circuit ground or into the processor power supply and scramble the program. The problem here is that control equipment often shares a common DC ground wire that may be connected to several devices, such as a DC power supply, programmable controller, remote switches, etc. When a noisy device such as a relay or solenoid is attached to the DC ground, it may cause disturbances within the APEX615n.

To solve a noise problem caused by DC mechanical relays and solenoids, you can connect a diode backwards across the coil to clamp the induced voltage *kick* that the coil will produce. The diode should be rated at 4 times the coil voltage and 10 times the coil current. Using solid state relays is another way to eliminate this problem.



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Multiple devices on the same circuit should be grounded together at a single point.

Furthermore, power supplies and programmable controllers often have DC common tied to Earth (AC power ground). As a rule, it is preferable to have the APEX615n Iso GND floating with respect to Earth. This prevents noisy equipment that is grounded to Earth from sending noise into the APEX615n. When floating the signal ground is not possible, you should make the Earth ground connection at only one point.

In many cases, optical isolation may be required to completely eliminate electrical contact between the APEX615n and a noisy environment. Solid state relays provide this type of isolation.

Transmitted Noise

Transmitted noise is picked up by external connections to the APEX615n, and in severe cases can attack the APEX615n when there are no external connections. The APEX615n's sheet metal enclosure will typically shield the electronics from this, but openings in the enclosure for connections and front panel controls may *leak*.

When high current contacts open, they draw an arc, producing a burst of broad spectrum radio frequency noise that can be picked up on a limit switch or other wiring. High-current and high-voltage wires have an electrical field around them and may induce noise on signal wiring, especially when they are tied in the same wiring bundle or conduit.

When this kind of problem occurs, you should consider shielding signal cables or isolating the signals. A proper shield surrounds the signal wires to intercept electrical fields, but this shield must be tied to Earth to drain the induced voltages. At the very least, wires should be run in twisted pairs to limit straight line antenna effects.

Installing the APEX615n in a NEMA enclosure ensures protection from this kind of noise, unless noise-producing equipment is also mounted inside the enclosure. Connections external to the enclosure must be shielded.

Even the worst noise problems in environments near 600 amp welders and 25kW transmitters have been solved using enclosures, conduit, optical isolation, and single-point ground techniques.

Ground Loops

Ground Loops are the most mysterious noise problems. They seem to occur most often in systems where a control computer is using RS-232C communication. Symptoms like garbled transmissions and intermittent operation are typical.

The problem occurs in systems where multiple Earth ground connections exist, particularly when these connections are far apart.

Ground Loops—Noise Scenario

Suppose an APEX615n is controlling a motor, and the limit switches use an external power supply. The APEX615n is controlled by a computer in another room. If the power supply Common is connected to Earth, the potential exists for ground loop problems. This is because most computers have their RS-232C signal common tied to Earth. The loop starts at the APEX615n system limit switch ground, goes to Earth through the drive, and on to Earth at the computer. From there, the loop returns to the APEX615n system through RS-232C signal ground. If a voltage potential exists between drive Earth and remote computer Earth, ground current will flow through the RS-232C ground, creating unpredictable results.

The way to test for and ultimately eliminate a ground loop is to lift or *cheat* Earth ground connections in the system until the symptoms disappear.

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Defeating Noise

The best time to handle electrical noise problems is before they occur. When a motion system is in the design process, the designer should consider the following set of guidelines for system wiring (in order of importance):

1. Put surge suppression components on all electrical coils: Resistor/capacitor filters, MOVs, Zener and clamping diodes.
2. Shield all remote connections, use twisted pairs. Shields should be tied to Earth at one end.
3. Put all microelectronic components in an enclosure. Keep noisy devices outside. Watch internal temperature.
4. Ground signal common wiring at one point. Float this ground from Earth if possible.
5. Tie all mechanical grounds to Earth at one point. Run chassis and motor grounds to the frame, and the frame to Earth.
6. Isolate remote signals. Solid state relays or opto isolators are recommended.
7. Filter the power line. Use common RF filters, and use an isolation transformer for worst case.
8. Filter the lines between the drive output and the motor.

A noise problem must be identified before it can be solved. The obvious way to approach a problem situation is to eliminate potential noise sources until the symptoms disappear, as in the case of ground loops. When this is not practical, use the above guidelines to *shotgun* the installation.

References

Information about the equipment referred to may be obtained by calling the numbers listed below.

- Corcom line filters, (214) 386-5515
- Opto-22 optically isolated relays, (408) 496-6611
- Crydom optically isolated relays, (415) 463-2250
- Potter Brumfield optically isolated relays, (812) 386-1000
- Teal power line isolation filters, (800) 888-8325

SCHAFFNER EMC, Inc.
12 Hughes St.
Suite D-106
Irvine, CA 91718-1901

Phone: 714-457-9400
Fax: 714-457-9510

SCHAFFNER EMC, Inc.
9B Fadem Road
Springfield, NJ 07081

Phone: 201-379-7778
Fax: 201-379-1151

Kam Electronics (Stocking Distributor)
400 Boren Ave. North
Seattle, WA 98109

Phone: 206-382-1300
Fax: 206-382-0186

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Appendix C

Motor Specifications

Motor Specifications

Speed/torque curves, motor specifications, and dimensions are shown on the following pages.

Motor Brakes

Motor brakes are mounted directly behind the motor and are pre-assembled at the factory. When ordering the brake option, specify the motor type.

Brake Characteristics	APEX604	APEX605/606/610	APEX620/630/635	APEX640	Units
Supply voltage	24	24	24	24	VDC
Supply current	0.57	0.57	0.93	1.27	A
Static braking torque	326 (2.3)	850 (6.0)	1130 (8.0)	6800 (48)	oz-in (Nm)

APEX6xx Motor Brake Characteristics

Motor Data

The data sheets show motor characteristics. Torque specifications are with rated and peak current for the *motor*. Rated and peak current for the *drive* may be lower—thus, torque may be lower. Consult the data sheets for *motor* capabilities. Consult the speed/torque curves for APEX615n *system* capabilities.

Positional Repeatability

Repeatability: ±0.088 degrees, unloaded

Positional Accuracy

Resolver Accuracy: ±10 arc minutes

Resolver-to-Digital Converter Accuracy: ±10 arc minutes

Resolver-to-Digital Converter Resolution: 4096 counts/rev

Selecting Controller/Drive/Motor Combinations

We recommend selecting motors for use with the APEX615n Controller/Drives as follows:

APEX6151: SM-231A, SM232A, SM-232B, APEX602, APEX603

APEX6152: APEX604, APEX605, APEX606

APEX6154: APEX610, APEX620, APEX630, APEX635, APEX640

Speed/Torque Curves

The following speed/torque curves represent the available shaft torque at different operating speeds, under the following conditions. Actual motor torque may vary ±10% due to motor manufacturing variances.

SM Motors:

25°C (77°F) ambient temperature
Nominal torque constant K_t
Motor mounted to heatsink:
10" x 10" x0.25" aluminum

Apex Motors:

40°C (104°F) ambient temperature
Nominal torque constant K_t
Motor mounted to aluminum heatsink:
8" x 12" x0.25" for APEX602 - APEX630
11.5" x 12" x0.75" for APEX635, APEX640

Actual motor torque may vary ±10% due to motor manufacturing variances.

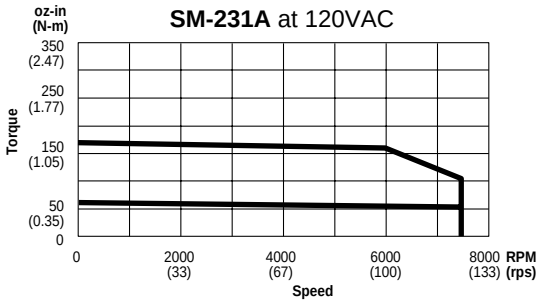
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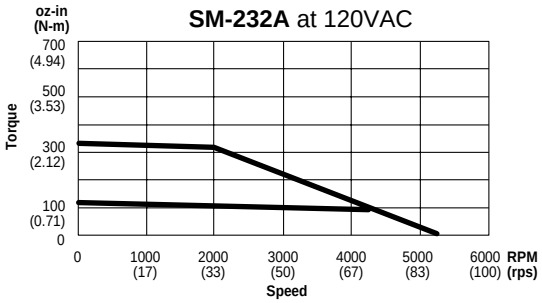
Continuous Duty means steady state operation for drive ambient temperatures of 0°C to 50°C. ***Intermittent Duty*** means operation for shorter periods of time.

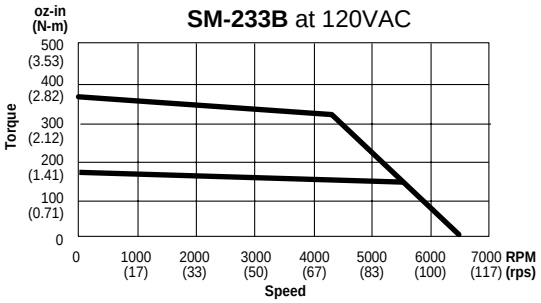
240VAC SINGLE PHASE OPERATION: You must limit single phase operations to current levels that do not blow the AC input fuse. Dotted lines on the speed torque curves show maximum single phase current (8A rms for APEX604, 605, 606 motors; 20A rms for APEX610, 620, 630, 635, 640 motors). If you use single phase power, you must operate your motor in the region below the dotted line.

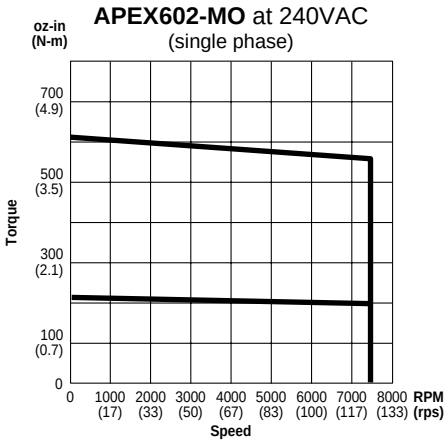
CAUTION

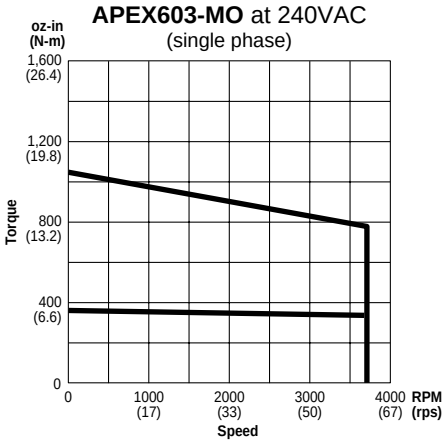
SM Series Servo Motors are optimized for operation with APEX615n controller/drives at 120VAC. Do not power the controller drive with 240VAC if you use an SM Motor.





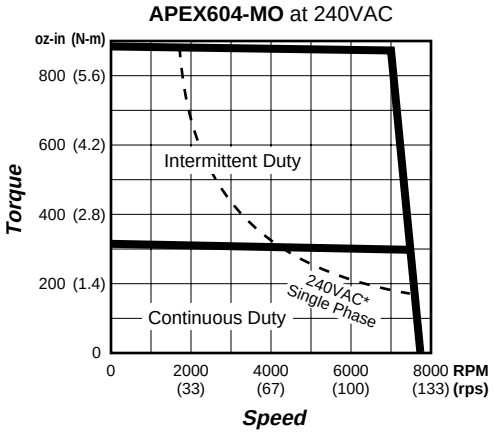


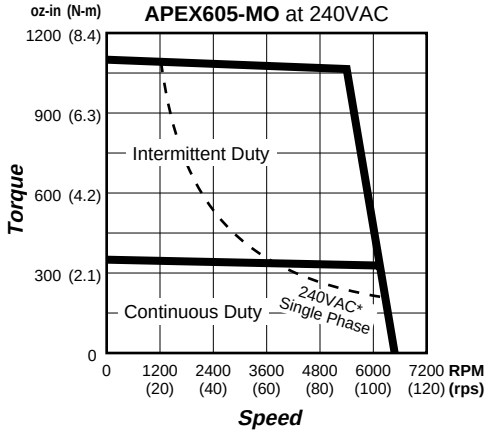


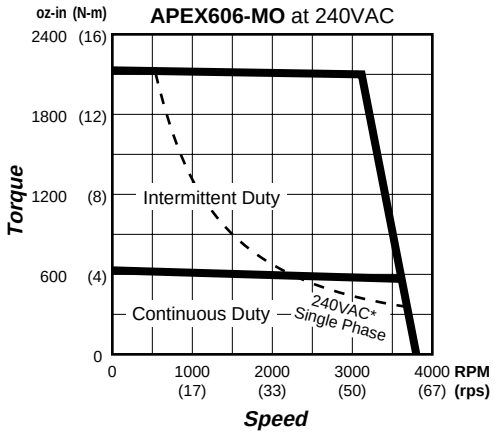


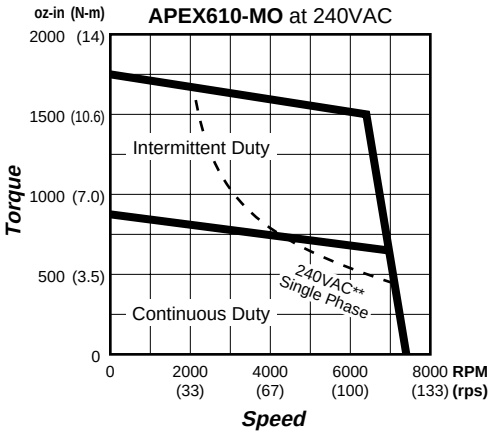
Speed/Torque Curves

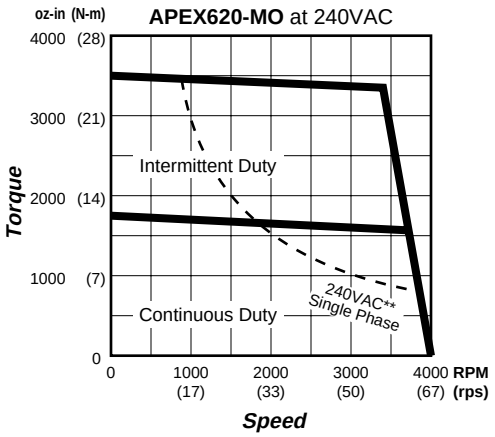
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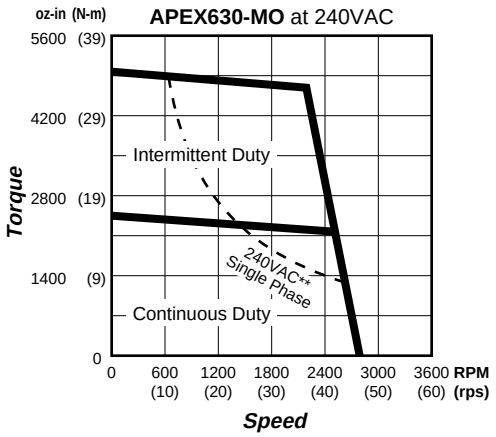


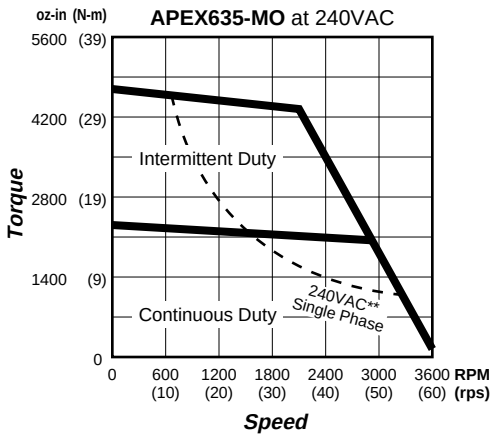


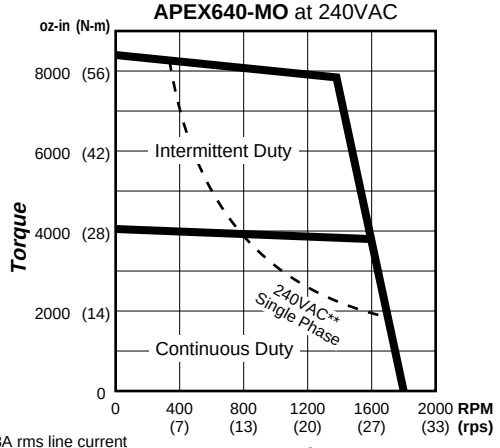












*240VAC single phase, 8A rms line current
**240VAC single phase, 20A rms line current

Speed/Torque Curves (at nominal value for torque constant)

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SM Motor Specifications

Parameter	Symbol	Units	SM231AR	SM232AR	SM233BR
Stall Torque Continuous [1]	T_{cs}	lb.in. oz. in. Nm	3.5 56 0.40	6.7 107 0.76	10.2 163 1.15
Stall Current Continuous [1]	I_{cs}	amperes - rms	2.0	2.0	3.9
Rated Speed	w_r	rpm rps	7500 125	4250 71	6000 100
Peak Torque [1, 6]	T_{pk}	lb.in. oz. in. Nm	17.5 280 1.98	33.4 535 3.78	50.9 815 5.76
Peak Current, rms [1]	I_{pk}	amperes	10	10	19.5
Torque @ Rated Speed[1]	T_c	lb.in. oz. in. Nm	2.8 46 0.32	6.0 96 0.68	9.0 145 1.02
Rated Power -- Output Shaft [1]	Po	watts hp	250 0.34	302 0.40	643 0.86
Voltage Constant [3,4,]	K_b	volts/radian/sec	0.161	0.310	0.242
Voltage Constant [3,4,]	K_e	volts/KRPM	16.86	32.45	25.33
Torque Constant [3,4, 7]	K_t	oz. in./ amp rms Nm/amp rms	27.82 0.20	53.54 0.38	41.76 0.29
Resistance [1,3]	R	ohms	5.22	7.5	2.58
Inductance [5]	L	millihenries	1.64	2.9	1.06
Thermal Resistance [1]	R_{th}	°C/watt	2.23	1.58	1.26
Motor Constant	Km	oz.in./÷watt Nm/÷watt	9.58 0.07	15.99 0.11	21.25 0.15
Viscous Damping	B	oz. in./Krpm Nm/Krpm	1.24 8.76×10^{-3}	2.07 14.76×10^{-3}	2.86 20.20×10^{-3}
Torque - Static Friction	T_f	oz. in. Nm	1.2 8.47×10^{-3}	2.0 14.10×10^{-3}	2.25 15.90×10^{-3}
Thermal Time Constant	t_{th}	minutes	30	35	40
Electrical Time Constant	t_e	milliseconds	0.31	0.39	0.41
Mechanical Time Constant	t_m	milliseconds	13.7	8.6	7.0
Rotor Inertia	J	$lb.in.sec^2$ $kgm^2 * 1E\text{-}6$	0.00048 54.23	0.00084 94.91	0.00119 134.50
Weight	#	pounds kg	2.6 1.18	3.5 1.59	4.4 2.00
Winding Class			H	H	H

[1] @ 25°C ambient w/ 10x10x0.25 inch mounting plate, 150°∞C winding temperature
For 40°C ambient operation, reduce values by 12%.

[3] ± 10%, line-to-line

[4] peak value

[5] ± 30%, line-to-line, inductance bridge measurement method @ 1kHz

[6] Peak current for 1 sec with initial winding temperature of 60°C or less.

[7] Effective torque constant when applied with a sinusoidal amplifier.

All specifications are subject to engineering change

APEX and SM Resolver Specifications

Parameter	Value
Input voltage @ 7000 Hz	4.25 volts
Input current, max.	55 ma
Input power, nominal	0.12 watts
Impedance ZSO (@90∞)	58 +j145 ohms
Impedance ZRO	53 +j72 ohms
Impedance ZRS	42 +j55 ohms
Transformation ratio	0.470 ±5%
Output voltage	2.0 ±5% volts
D.C. rotor resistance	23 ±10% ohms
D.C. stator resistance	19 ±10% ohms
Sensitivity	35 mV/Degree
Max. Error from EZ	±10 minutes
Phase shift, open circuit	5∞ leading ±3"
Null voltage (total)	20 mV rms
Impedance ZSS	50 +j128 ohms
Inertia	included in motor specification

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	Motor Size:	**APEX602**	Value	Units	Tolerance
1	Constant (s):	Torque	52.6 (0.37)	oz-in/A rms (Nm/A rms)	± 10%
2		Voltage (Sinusoidal)	22.5	V rms/Krpm	± 10%
3		Electrical Time	5.3	milliseconds	nominal
4		Mechanical Time	1.40	milliseconds	nominal
5		Thermal	11.0	minutes	nominal
6	Torque (s):	Continuous, Stall	236 (1.67)	oz-in (Nm)	min. [1]
7	(NOTE: Values are with	Continuous, Stall	223 (1.57)	oz-in (Nm)	min. [2]
8	rated and peak current,	Continuous, Rated	202 (1.43)	oz-in (Nm)	min. [2]
9	lines 15 & 16 below.	Peak, Max w/o Saturation	630 (4.45)	oz-in (Nm)	min. [1]
10	Drive current, and thus	Static Friction	7.68 (0.05)	oz-in (Nm)	max.
11	torque, may be lower.)	Ripple (of Rated Torque)	5	percent	max. [3]
12	Speed:	Rated	7500 (125)	rpm (rps)	reference
13		Maximum	7500 (125)	rpm (rps)	reference
14	Frequency	Rated	250	Hz	max.
15	Current:	Rated	4.2	A rms	max. [1]
16		Peak	12.6	A rms	nominal
17	Voltage:	Rated	240	V rms	reference
18		Max	250	V rms	maximum
19	Output Power	Rated	1.12 (1.5)	kWatts (hp)	min. [1]
20	Inductance	Terminal (line-line)	14.4	mH	± 30%
21	D.C. Resistance	Terminal (line-line)	2.72	ohms	± 10 % [1]
22	Acceleration at Rated Torque		96500	rads/sec^2	Theoretical
23	Rotor Inertia		2.52 (46.1)	oz-in^2 (kgm^2 ∗ 1E-6)	nominal
24	Damping		0.384 (0.0027)	oz-in/krpm (Nm/krpm)	nominal
25	Weight		7.0 (3.17)	lbs. (kg)	max.
26	Winding Temperature		170°C (338°F) [4]	°C (°F)	max.
27	Winding Temperature Rise (Above Ambient) [1]		145°C (293°F)	°C (°F)	reference
28	Insulation Class		H	—	reference
29	Thermostat TRIP Temperature		170°C (338°F)	°C (°F)	± 5° C
30	Thermostat RESET Temperature		135°C (275°F)	°C (°F)	± 10° C
31	Dielectric Strength, (Winding-to-Frame)		1750	VAC	min.
32	Winding Capacitance-to-Frame		0.000898	µF	max.
33	IP Classification		65 [8]	rated	standard
34	Shaft: Radial-Play	At End	12E-6 (68E-9)	in/lb (m/N)	reference
		At Faceplate	7.0E-6 (40E-9)	in/lb (m/N)	reference
35	Material [5]		RC-#30	—	reference
36	Magnet Type		NdFeB	—	—
37	Loading [6]	1000 rpm (17 rps)	81 (360)	lbs. (N)	max. [7]
		2000 rpm (33 rps)	65 (289)	lbs. (N)	max. [7]
		3000 rpm (50 rps)	56 (249)	lbs. (N)	max. [7]
		4000 rpm (67 rps)	51 (227)	lbs. (N)	max. [7]
		5000 rpm (83 rps)	48 (213)	lbs. (N)	max. [7]
38	Motor Vibration		N	ISO 2373	Standard
39	Bearing Class, Internal/External		1/Class 3	ABEC/AFBMA	reference
40	Bearing Grease		SRI #2	Manufacturer	reference
41	Shaft Seal Pressure		3 (0.21)	psi (kg/cm^2)	max.
42	Basic Motor Design		3 phase *wye* connected 2(P/2)		
43	Stator Phase Sequence		A-C-B (viewed from front face plate)		
44	Vendor/Supplier		Industrial Drives B-104-B		
45	Resolver Type/Accuracy		Single-Speed; Rotor-Excited; ± 10 arc min.; Resolution is 4096 counts/rev post-quadrature		
46	Resolver Manufacturer/Model #		Fasco # 21-BRCX-335-J39		
47	Standard Resolver Cable Part Number		71-011777-xx		
48	Standard Motor Cable Part Number		71-011774-xx		
49	Options:	Brake—24VDC (0.57A)—326 oz-in (2.3 Nm) Holding Torque			(requires resolver
		IP67 Classification	No Keyway		cable 71-014082-xx)
		Incremental Encoder	Shaft Modifications		
		Tachometer	IP65 Shaft Seal		

[1] 25°C (77°F) Ambient
[2] 40°C (104°F) Ambient
[3] Measured at 60 rpm (1 rps) in Velocity Mode
[4] Rated for 20,000 Hours or 40,000 Hours @ 155° C (311°F)
[5] Rotor steel is rated as *fatigue proof*
[6] Loads centered 1 inch from mounting flange
[7] Loads may be radial and axial such that the sum of the radial and two times the axial does not exceed this figure.
[8] Motor shaft is IP30 rated.

APEX602 Motor Specifications

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	Motor Size:	**APEX603**	Value	Units	Tolerance
1	Constant (s):	Torque	114.6 (0.81)	oz-in/A rms (Nm/A rms)	± 10%
2		Voltage (Sinusoidal)	49.0	V rms/Krpm	± 10%
3		Electrical Time	9.7	milliseconds	nominal
4		Mechanical Time	-----	milliseconds	nominal
5		Thermal	18	minutes	nominal
6	Torque (s):	Continuous, Stall	367 (2.59)	oz-in (Nm)	min. [1]
7	(NOTE: Values are with	Continuous, Stall	346 (2.44)	oz-in (Nm)	min. [2]
8	rated and peak current,	Continuous, Rated	356 (2.51)	oz-in (Nm)	min. [2]
9	lines 15 & 16 below.	Peak, Max w/o Saturation	1046 (7.38)	oz-in (Nm)	min. [1]
10	Drive current, and thus	Static Friction	12.0 (0.08)	oz-in (Nm)	max.
11	torque, may be lower.)	Ripple (of Rated Torque)	5	percent	max. [3]
12	Speed:	Rated	3800 (63)	rpm (rps)	reference
13		Maximum	3800 (63)	rpm (rps)	reference
14	Frequency	Rated	126.7	Hz	max.
15	Current:	Rated	3.0	A rms	max. [1]
16		Peak	9.6	A rms	nominal
17	Voltage:	Rated	240	V rms	reference
18		Max	250	V rms	maximum
19	Output Power	Rated	1.0 (1.3)	kWatts (hp)	min. [1]
20	Inductance	Terminal (line-line)	68	mH	± 30%
21	D.C. Resistance	Terminal (line-line)	7.0	ohms	± 10 % [1]
22	Acceleration at Rated Torque		74150	rads/sec^2	Theoretical
23	Rotor Inertia		5.45 (99.6)	oz-in^2 (kgm^2 * 1E-6)	nominal
24	Damping		0.960 (0.0068)	oz-in/krpm (Nm/krpm)	nominal
25	Weight		9.0 (4.08)	lbs. (kg)	max.
26	Winding Temperature		170°C (338°F) [4]	°C (°F)	max.
27	Winding Temperature Rise (Above Ambient) [1]		145°C (293°F)	°C (°F)	reference
28	Insulation Class		H	—	reference
29	Thermostat TRIP Temperature		170°C (338°F)	°C (°F)	± 5° C
30	Thermostat RESET Temperature		135°C (275°F)	°C (°F)	± 10° C
31	Dielectric Strength, (Winding-to-Frame)		1750	VAC	min.
32	Winding Capacitance-to-Frame		0.00122	µF	max.
33	IP Classification		65 [8]	rated	standard
34	Shaft: Radial-Play	At End	14E-6 (80E-9)	in/lb (m/N)	reference
		At Faceplate	8.0E-6 (45E-9)	in/lb (m/N)	reference
35	Material [5]		RC-#30	—	reference
36	Magnet Type		NdFeB	—	—
37	Loading [6]	1000 rpm (17 rps)	85.4 (380)	lbs. (N)	max. [7]
		2000 rpm (33 rps)	67.8 (302)	lbs. (N)	max. [7]
		3000 rpm (50 rps)	59.1 (263)	lbs. (N)	max. [7]
		4000 rpm (67 rps)	53.8 (239)	lbs. (N)	max. [7]
		5000 rpm (83 rps)	50 (222)	lbs. (N)	max. [7]
38	Motor Vibration		N	ISO 2373	Standard
39	Bearing Class, Internal/External		1/Class 3	ABEC/AFBMA	reference
40	Bearing Grease		SRI #2	Manufacturer	reference
41	Shaft Seal Pressure		3 (0.21)	psi (kg/cm^2)	max.
42	Basic Motor Design		3 phase *wye* connected 2(P/2)		
43	Stator Phase Sequence		A-C-B (viewed from front face plate)		
44	Vendor/Supplier		Industrial Drives B-202-B		
45	Resolver Type/Accuracy		Single-Speed; Rotor-Excited; ± 10 arc min.; Resolution is 4096 counts/rev post-quadrature		
46	Resolver Manufacturer/Model #		Fasco # 21-BRCX-335-J39		
47	Standard Resolver Cable Part Number		71-011777-xx		
48	Standard Motor Cable Part Number		71-011774-xx		
49	Options: Brake—24VDC (0.57A)—845 oz-in (5.97 Nm) Holding Torque (requires resolver cable 71-014082-xx) IP67 Classification Incremental Encoder Tachometer No Keyway Shaft Modifications IP65 Shaft Seal				

[1] 25°C (77°F) Ambient
[2] 40°C (104°F) Ambient
[3] Measured at 60 rpm (1 rps) in Velocity Mode
[4] Rated for 20,000 Hours or 40,000 Hours @ 155° C (311°F)
[5] Rotor steel is rated as *fatigue proof*
[6] Loads centered 1 inch from mounting flange
[7] Loads may be radial and axial such that the sum of the radial and two times the axial does not exceed this figure.
[8] Motor shaft is IP30 rated.

APEX603 Motor Specifications

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	Motor Size:	**APEX604**	Value	Units	Tolerance
1	Constant (s):	Torque	52.6 (0.37)	oz-in/A rms (Nm/A rms)	± 10%
2		Voltage (Sinusoidal)	22.5	V rms/Krpm	± 10%
3		Electrical Time	58.7	milliseconds	nominal
4		Mechanical Time	1.30	milliseconds	nominal
5		Thermal	12	minutes	nominal
6	Torque (s):	Continuous, Stall	334 (2.36)	oz-in (Nm)	min. [1]
7	(NOTE: Values are with	Continuous, Stall	315 (2.22)	oz-in (Nm)	min. [2]
8	rated and peak current,	Continuous, Rated	269 (1.90)	oz-in (Nm)	min. [2]
9	lines 15 & 16 below.	Peak, Max w/o Saturation	899 (6.35)	oz-in (Nm)	min. [1]
10	Drive current, and thus	Static Friction	9.6 (0.07)	oz-in (Nm)	max.
11	torque, may be lower.)	Ripple (of Rated Torque)	5	percent	max. [3]
12	Speed:	Rated	7500 (125)	rpm (rps)	reference
13		Maximum	7500 (125)	rpm (rps)	reference
14	Frequency	Rated	250	Hz	max.
15	Current:	Rated	6.0	A rms	max. [1]
16		Peak	18.8	A rms	nominal
17	Voltage:	Rated	240	V rms	reference
18		Max	250	V rms	maximum
19	Output Power	Rated	1.5 (2.0)	kWatts (hp)	min. [1]
20	Inductance	Terminal (line-line)	9.4	mH	± 30%
21	D.C. Resistance	Terminal (line-line)	1.6	ohms	± 10 % [1]
22	Acceleration at Rated Torque		82980	rads/sec^2	Theoretical
23	Rotor Inertia		4.18 (76.5)	oz-in^2 (kgm^2 * 1E-6)	nominal
24	Damping		0.580 (0.0041)	oz-in/krpm (Nm/krpm)	nominal
25	Weight		8.5 (3.86)	lbs. (kg)	max.
26	Winding Temperature		170°C (338°F) [4]	°C (°F)	max.
27	Winding Temperature Rise (Above Ambient) [1]		145°C (293°F)	°C (°F)	reference
28	Insulation Class		H	—	reference
29	Thermostat TRIP Temperature		170°C (338°F)	°C (°F)	± 5° C
30	Thermostat RESET Temperature		135°C (275°F)	°C (°F)	± 10° C
31	Dielectric Strength, (Winding-to-Frame)		1750	VAC	min.
32	Winding Capacitance-to-Frame		0.00122	µF	max.
33	IP Classification		65 [8]	rated	standard
34	Shaft: Radial-Play	At End	12E-6 (68E-9)	in/lb (m/N)	reference
		At Faceplate	5.6E-6 (32E-9)	in/lb (m/N)	reference
35	Material [5]		RC-#30	—	—
36	Magnet Type		NdFeB	—	—
37	Loading [6]	1000 rpm (17 rps)	84 (374)	lbs. (N)	max. [7]
		2000 rpm (33 rps)	67 (298)	lbs. (N)	max. [7]
		3000 rpm (50 rps)	58 (258)	lbs. (N)	max. [7]
		4000 rpm (67 rps)	53 (236)	lbs. (N)	max. [7]
		5000 rpm (83 rps)	49 (218)	lbs. (N)	max. [7]
38	Bearing Class, Internal/External		1/Class 3	ABEC/AFBMA	reference
39	Bearing Grease		SRI #2	Manufacturer	reference
40	Shaft Seal Pressure		3 (0.21)	psi (kg/cm^2)	max.
41	Basic Motor Design		3 phase *wye* connected 2(P/2)		
42	Stator Phase Sequence		A-C-B (viewed from front face plate)		
43	Vendor/Supplier		Industrial Drives B-106-B		
44	Resolver Type/Accuracy		Single-Speed; Rotor-Excited; ± 10 arc min.		
45	Resolver Manufacturer/Model #		Fasco # 21-BRCX-335-J39		
46	Standard Resolver Cable Part Number		71-013862-xx		
47	Standard Motor Cable Part Number		71-013863-xx		
48	Options:	Brake—24VDC (0.57A)—326 oz-in (2.3 Nm) Holding Torque IP67 Classification Incremental Encoder Tachometer No Keyway			

[1] 25°C (77°F) Ambient
[2] 40°C (104°F) Ambient
[3] Measured at 60 rpm (1 rps) in Velocity Mode
[4] Rated for 20,000 Hours or 40,000 Hours @ 155° C (311°F)
[5] Rotor steel is rated as *fatigue proof*
[6] Loads centered 1 inch from mounting flange
[7] Loads may be radial and axial such that the sum of the radial and two times the axial does not exceed this figure.
[8] Motor shaft is IP30 rated.

APEX604 Motor Specifications

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	Motor Size:	**APEX605**	Value	Units	Tolerance
1	Constant (s):	Torque	68.7 (0.49)	oz-in/A rms (Nm/A rms)	± 10%
2		Voltage (Sinusoidal)	29.4	V rms/Krpm	± 10%
3		Electrical Time	10.68	milliseconds	nominal
4		Mechanical Time	1.46	milliseconds	nominal
5		Thermal	18	minutes	nominal
6	Torque (s):	Continuous, Stall	367 (2.59)	oz-in (Nm)	min. [1]
7	(NOTE: Values are with	Continuous, Stall	346 (2.44)	oz-in (Nm)	min. [2]
8	rated and peak current,	Continuous, Rated	321 (2.27)	oz-in (Nm)	min. [2]
9	lines 15 & 16 below.	Peak, Max w/o Saturation	1085 (7.66)	oz-in (Nm)	min. [1]
10	Drive current, and thus	Static Friction	0.96 (0.007)	oz-in (Nm)	max.
11	torque, may be lower.)	Ripple (of Rated Torque)	5	percent	max. [3]
12	Speed:	Rated	6200 (103)	rpm (rps)	reference
13		Maximum	6200 (103)	rpm (rps)	reference
14	Frequency	Rated	207	Hz	max.
15	Current:	Rated	5	A rms	max. [1]
16		Peak	16.6	A rms	nominal
17	Voltage:	Rated	240	V rms	reference
18		Max	250	V rms	maximum
19	Output Power	Rated	1.5 (2.0)	kWatts (hp)	min. [1]
20	Inductance	Terminal (line-line)	25	mH	± 30%
21	D.C. Resistance	Terminal (line-line)	2.3	ohms	± 10 % [1]
22	Acceleration at Rated Torque		76870	rads/sec^2	Theoretical
23	Rotor Inertia		5.43 (99.6)	oz-in^2 (kgm^2 * 1E-6)	nominal
24	Damping		0.96 (0.0068)	oz-in/krpm (Nm/krpm)	nominal
25	Weight		10 (4.5)	lbs. (kg)	max.
26	Winding Temperature		170°C (338°F) [4]	°C (°F)	max.
27	Winding Temperature Rise (Above Ambient) [1]		145°C (293°F)	°C (°F)	reference
28	Insulation Class		H	—	reference
29	Thermostat TRIP Temperature		170°C (338°F)	°C (°F)	± 5° C
30	Thermostat RESET Temperature		135°C (275°F)	°C (°F)	± 10° C
31	Dielectric Strength, (Winding-to-Frame)		1750	VAC	min.
32	Winding Capacitance-to-Frame		0.00122	µF	max.
33	IP Classification		65 [8]	rated	standard
34	Shaft: Radial-Play	At End	14E-6 (80E-9)	in/lb (m/N)	reference
		At Faceplate	8E-6 (45E-9)	in/lb (m/N)	reference
35	Material [5]		RC-#30	—	—
36	Magnet Type		NdFeB	—	—
37	Loading [6]	1000 rpm (17 rps)	85.4 (380)	lbs. (N)	max. [7]
		2000 rpm (33 rps)	67.8 (301)	lbs. (N)	max. [7]
		3000 rpm (50 rps)	59.1 (263)	lbs. (N)	max. [7]
		4000 rpm (67 rps)	53.8 (239)	lbs. (N)	max. [7]
		5000 rpm (83 rps)	50 (222)	lbs. (N)	max. [7]
38	Bearing Class, Internal/External		1/Class 3	ABEC/AFBMA	reference
39	Bearing Grease		SRI #2	Manufacturer	reference
40	Shaft Seal Pressure		3 (0.21)	psi (kg/cm^2)	max.
41	Basic Motor Design		3 phase *wye* connected 2(P/2)		
42	Stator Phase Sequence		A-C-B (viewed from front face plate)		
43	Vendor/Supplier		Industrial Drives B-202-C		
44	Resolver Type/Accuracy		Single-Speed; Rotor-Excited; ± 10 arc min.		
45	Resolver Manufacturer/Model #		Fasco # 21-BRCX-335-J39		
46	Standard Resolver Cable Part Number		71-013862-xx		
47	Standard Motor Cable Part Number		71-013863-xx		
48	Options:	Brake—24VDC (0.57A)—850 oz-in (6.0 Nm) Holding Torque			
		IP67 Classification			
		Incremental Encoder			
		Tachometer			
		No Keyway			

[1] 25°C (77°F) Ambient
[2] 40°C (104°F) Ambient
[3] Measured at 60 rpm (1 rps) in Velocity Mode
[4] Rated for 20,000 Hours or 40,000 Hours @ 155° C (311°F)
[5] Rotor steel is rated as *fatigue proof*
[6] Loads centered 1 inch from mounting flange
[7] Loads may be radial and axial such that the sum of the radial and two times the axial does not exceed this figure.
[8] Motor shaft is IP30 rated.

APEX605 Motor Specifications

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	Motor Size:	**APEX606**	Value	Units	Tolerance
1	Constant (s):	Torque	120 (0.85)	oz-in/A rms (Nm/A rms)	± 10%
2		Voltage (Sinusoidal)	51.2	V rms/Krpm	± 10%
3		Electrical Time	15.32	milliseconds	nominal
4		Mechanical Time	0.896	milliseconds	nominal
5		Thermal	20	minutes	nominal
6	Torque (s):	Continuous, Stall	672 (4.75)	oz-in (Nm)	min. [1]
7	(NOTE: Values are with	Continuous, Stall	634 (4.48)	oz-in (Nm)	min. [2]
8	rated and peak current,	Continuous, Rated	576 (4.07)	oz-in (Nm)	min. [2]
9	lines 15 & 16 below.	Peak, Max w/o Saturation	1957 (13.82)	oz-in (Nm)	min. [1]
10	Drive current, and thus	Static Friction	0.96 (0.007)	oz-in (Nm)	max
11	torque, may be lower.)	Ripple (of Rated Torque)	5	percent	max. [3]
12	Speed:	Rated	3600 (60)	rpm (rps)	reference
13		Maximum	3600 (60)	rpm (rps)	reference
14	Frequency	Rated	120	Hz	max.
15	Current:	Rated	5.3	A rms	max. [1]
16		Peak	17.2	A rms	nominal
17	Voltage:	Rated	240	V rms	reference
18		Max	250	V rms	maximum
19	Output Power:	Rated	1.6 (2.1)	kWatts (hp)	min. [1]
20	Inductance:	Terminal (line-line)	38	mH	± 30%
21	D.C. Resistance	Terminal (line-line)	2.48	ohms	± 10 % [1]
22	Acceleration at Rated Torque		80000	rads/sec^2	Theoretical
23	Rotor Inertia		9.44 (172.9)	oz-in^2 (kgm^2 ∗ 1E-6)	nominal
24	Damping		1.344 (0.0095)	oz-in/krpm (Nm/krpm)	nominal
25	Weight		13.4 (6.1)	lbs. (kg)	max.
26	Winding Temperature		170°C (338°F) [4]	°C (°F)	max.
27	Winding Temperature Rise (Above Ambient) [1]		145°C (293°F)	°C (°F)	reference
28	Insulation Class		H	—	reference
29	Thermostat TRIP Temperature		170°C (338°F)	°C (°F)	± 5 °C
30	Thermostat RESET Temperature		135°C (275°F)	°C (°F)	± 10 °C
31	Dielectric Strength, (Winding-to-Frame)		1750	VAC	min.
32	Winding Capacitance to Frame		0.00201	µF	max.
33	IP Classification		65 [8]	rated	standard
34	Shaft:	Radial-Play At End	14E-6 (80E-9)	in/lb (m/N)	reference
		At Faceplate	8E-6 (45E-9)	In/lb (m/N)	reference
35		Material [5]	RC-#30	—	—
36		Magnet Type	NdFeB	—	—
37		Loading [6] 1000 rpm (17 rps)	90.1 (401)	lbs. (N)	max. [7]
		2000 rpm (33 rps)	71.6 (318)	lbs. (N)	max. [7]
		3000 rpm (50 rps)	62.4 (278)	lbs. (N)	max. [7]
		4000 rpm (67 rps)	N/A	lbs. (N)	max. [7]
		5000 rpm (83 rps)	N/A	lbs. (N)	max. [7]
38	Bearing Class, Internal/External		1/Class 3	ABEC/AFBMA	reference
39	Bearing Grease		SRI #2	Manufacturer	reference
40	Shaft Seal Pressure		3 (0.21)	psi (kg/cm^2)	max.
41	Basic Motor Design		3 phase *wye* connected 2(P/2)		
42	Stator Phase Sequence		A-C-B (viewed from front face plate)		
43	Vendor/Supplier		Industrial Drives B-204-B		
44	Resolver Type/Accuracy		Single-Speed; Rotor-Excited; ± 10 arc min.		
45	Resolver Manufacturer/Model #		Fasco # 21-BRCX-335-J39		
46	Standard Resolver Cable Part Number		71-013862-xx		
47	Standard Motor Cable Part Number		71-013863-xx		
48	Options:	Brake—24VDC (0.57A)—850 oz-in (6.0 NM) Holding Torque IP67 Classification Incremental Encoder Tachometer No Keyway			

[1] 25°C (77°F) Ambient
[2] 40°C (104°F) Ambient
[3] Measured at 60 rpm (1 rps) in Velocity Mode
[4] Rated for 20,000 Hours or 40,000 Hours @ 155° C (311°F)
[5] Rotor steel is rated as *fatigue proof*
[6] Loads centered 1 inch from mounting flange
[7] Loads may be radial and axial such that the sum of the radial and two times the axial does not exceed this figure.
[8] Motor shaft is IP30 rated.

APEX606 Motor Specifications

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	Motor Size:	**APEX610**	Value	Units	Tolerance
1	Constant (s):	Torque	61.4 (0.43)	oz-in/A rms (Nm/A rms)	± 10%
2		Voltage (Sinusoidal)	26.2	V rms/Krpm	±10%
3		Electrical Time	13.16	milliseconds	nominal
4		Mechanical Time	0.762	milliseconds	nominal
5		Thermal	21	minutes	nominal
6	Torque (s):	Continuous, Stall	977 (6.90)	oz-in (Nm)	min. [1]
7	(NOTE: Values are with	Continuous, Stall	921.6 (6.51)	oz-in (Nm)	min. [2]
8	rated and peak current,	Continuous, Rated	653 (4.61)	oz-in (Nm)	min. [2]
9	lines 15 & 16 below.	Peak, Max w/o Saturation	2630 (18.57)	oz-in (Nm)	min. [1]
10	Drive current, and thus	Static Friction	0.96 (0.007)	oz-in (Nm)	max
11	torque, may be lower.)	Ripple (of Rated Torque)	5	percent	min. [3]
12	Speed:	Rated	7000 (117)	rpm (rps)	reference
13		Maximum	7000 (117)	rpm (rps)	reference
14	Frequency	Rated	233	Hz	max.
15	Current:	Rated	15	A rms	max. [1]
16		Peak	45	A rms	nominal
17	Voltage:	Rated	230	V rms	reference
18		Max	250	V rms	maximum
19	Output Power:	Rated	3.3 (4.5)	kWatts (hp)	min. [1]
20	Inductance:	Terminal (line-line)	5	mH	± 30%
21	D.C. Resistance	Terminal (line-line)	0.38	ohms	± 10 % [1]
22	Acceleration at Rated Torque		73934	rads/sec^2	Theoretical
23	Rotor Inertia		13.72 (251.2)	oz-in^2 (kgm^2 ∗ 1E-6)	nominal
24	Damping		1.728 (0.0122)	oz-in/krpm (Nm/krpm)	nominal
25	Weight		16.35 (7.43)	lbs. (kg)	max.
26	Winding Temperature		170°C (338°F) [4]	°C (°F)	max.
27	Winding Temperature Rise (Above Ambient) [1]		145°C (293°F)	°C (°F)	reference
28	Insulation Class		H	—	reference
29	Thermostat TRIP Temperature		170°C (338°F)	°C (°F)	± 5 °C
30	Thermostat RESET Temperature		135°C (275°F)	°C (°F)	± 10 °C
31	Dielectric Strength, (Winding-to-Frame)		1750	VAC	min.
32	Winding Capacitance-to-Frame		0.00205	µF	max.
33	IP Classification		65 [8]	rated	standard
34	Shaft: Radial-Play	At End	14E-6 (80E-9)	in/lb (m/N)	reference
		At Faceplate	8E-6 (45E-9)	in/lb (m/N)	reference
35	Material [5]		RC-#30		
36	Magnet Type		NdFeB		
37	Loading [6]	1000 rpm (17 rps)	93.5 (416)	lbs. (N)	max. [7]
		2000 rpm (33 rps)	74.2 (330)	lbs. (N)	max. [7]
		3000 rpm (50 rps)	64.8 (288)	lbs. (N)	max. [7]
		4000 rpm (67 rps)	59 (262)	lbs. (N)	max. [7]
		5000 rpm (83 rps)	54.7 (243)	lbs. (N)	max. [7]
38	Bearing Class, Internal/External		1/Class 3	ABEC/AFBMA	reference
39	Bearing Grease		SRI #2	Manufacturer	reference
40	Shaft Seal Pressure		3 (0.21)	psi (kg/cm^2)	max.
41	Basic Motor Design		3 phase *wye* connected 2(P/2)		
42	Stator Phase Sequence		A-C-B (viewed from front face plate)		
43	Vendor/Supplier		Industrial Drives B-206-D		
44	Resolver Type/Accuracy		Single-Speed; Rotor-Excited; ± 10 arc min.		
45	Resolver Manufacturer/Model #		Fasco # 21-BRCX-335-J39		
46	Standard Resolver Cable Part Number		71-013862-xx		
47	Standard Motor Cable Part Number		71-013864-xx		
48	Options:	Brake—24VDC (0.57A)—850 oz-in (6.0 Nm) Holding Torque			
		IP67 Classification			
		Incremental Encoder			
		Tachometer			
		No Keyway			

[1] 25°C (77°F) Ambient
[2] 40°C (104°F) Ambient
[3] Measured at 60 rpm (1 rps) in Velocity Mode
[4] Rated for 20,000 Hours or 40,000 Hours @ 155° C (311°F)
[5] Rotor steel is rated as *fatigue proof*
[6] Loads centered 1 inch from mounting flange
[7] Loads may be radial and axial such that the sum of the radial and two times the axial does not exceed this figure.
[8] Motor shaft is IP30 rated.

APEX610 Motor Specifications

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	Motor Size:	**APEX620**	Value	Units	Tolerance
1	Constant (s):	Torque	124.2 (0.877)	oz-in/A rms (Nm/A rms)	± 10%
2		Voltage (Sinusoidal)	53	V rms/Krpm	± 10%
3		Electrical Time	23.4	milliseconds	nominal
4		Mechanical Time	0.82	milliseconds	nominal
5		Thermal	22	minutes	nominal
6	Torque (s):	Continuous, Stall	1974 (13.94)	oz-in (Nm)	min. [1]
7	(NOTE: Values are with	Continuous, Stall	1862 (13.15)	oz-in (Nm)	min. [2]
8	rated and peak current,	Continuous, Rated	1632 (11.52)	oz-in (Nm)	min. [2]
9	lines 15 & 16 below.	Peak, Max w/o Saturation	5299 (37.42)	oz-in (Nm)	min. [1]
10	Drive current, and thus	Static Friction	25 (0.176)	oz-in (Nm)	max.
11	torque, may be lower.)	Ripple (of Rated Torque)	4.5	percent	min. [3]
12	Speed:	Rated	3700 (62)	rpm (rps)	reference
13		Maximum	3700 (62)	rpm (rps)	reference
14	Frequency	Rated	123	Hz	max.
15	Current:	Rated	15	A rms	max. [1]
16		Peak	45	A rms	nominal
17	Voltage:	Rated	230	V rms	reference
18		Max	250	V rms	maximum
19	Output Power:	Rated	4.5 (6)	kWatts (hp)	min. [1]
20	Inductance:	Terminal (line-line)	15	mH	± 30%
21	D.C. Resistance	Terminal (line-line)	0.64	Ohms	± 10 % [1]
22	Acceleration at Rated Torque		57025	rads/sec^2	Theoretical
23	Rotor Inertia		35.8 (656)	oz-in^2 (kgm^2 ∗ 1E-6)	nominal
24	Damping		2.496 (0.0176)	oz-in/krpm (Nm/krpm)	nominal
25	Weight		29 (13.2)	lbs. (kg)	max.
26	Winding Temperature		170°C (338°F) [4]	°C (°F)	max.
27	Winding Temperature Rise (Above Ambient) [1]		145°C (293°F)	°C (°F)	reference
28	Insulation Class		H	—	reference
29	Thermostat TRIP Temperature		170°C (338°F)	°C (°F)	± 5 °C
30	Thermostat RESET Temperature		135°C (275°F)	°C (°F)	± 10 °C
31	Dielectric Strength, (Winding-to-Frame)		1750	VAC	min.
32	Winding Capacitance-to-Frame		0.0034	µF	max.
33	IP Classification		65 [8]	rated	standard
34	Shaft:	Radial-Play At End	20E-6 (114E-9)	in/lb (m/N)	reference
		At Faceplate	7E-6 (40E-9)	in/lb (m/N)	reference
35		Material [5]	RC-#30	—	—
36		Magnet Type	NdFeB	—	—
37		Loading [6] 1000 rpm (17 rps)	154.7 (688)	lbs. (N)	max. [7]
		2000 rpm (33 rps)	122.8 (546)	lbs. (N)	max. [7]
		3000 rpm (50 rps)	107.2 (477)	lbs. (N)	max. [7]
		4000 rpm (67 rps)	N/A	lbs. (N)	max. [7]
		5000 rpm (83 rps)	N/A	lbs. (N)	max. [7]
38	Bearing Class, Internal/External		1/Class 3	ABEC/AFBMA	reference
39	Bearing Grease		SRI #2	Manufacturer	reference
40	Shaft Seal Pressure		3 (0.21)	psi (kg/cm^2)	max.
41	Basic Motor Design		3 phase *wye* connected 2(P/2)		
42	Stator Phase Sequence		A-C-B (viewed from front face plate)		
43	Vendor/Supplier		Industrial Drives B-404-D		
44	Resolver Type/Accuracy		Single-Speed; Rotor-Excited; ± 10 arc min.		
45	Resolver Manufacturer/Model #		Fasco # 21-BRCX-335-J39		
46	Standard Resolver Cable Part Number		71-013862-xx		
47	Standard Motor Cable Part Number		71-013864-xx		
48	Options:	Brake—24VDC (0.93A)—1130 oz-in (8.0 Nm) Holding Torque IP67 Classification Incremental Encoder Tachometer No Keyway			

[1] 25°C (77°F) Ambient
[2] 40°C (104°F) Ambient
[3] Measured at 60 rpm (1 rps) in Velocity Mode
[4] Rated for 20,000 Hours or 40,000 Hours @ 155° C (311°F)
[5] Rotor steel is rated as *fatigue proof*
[6] Loads centered 1 inch from mounting flange
[7] Loads may be radial and axial such that the sum of the radial and two times the axial does not exceed this figure.
[8] Motor shaft is IP30 rated.

APEX620 Motor Specifications

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	Motor Size:	**APEX630**	Value	Units	Tolerance
1	Constant (s):	Torque	175.3 (1.24)	oz-in/A rms (Nm/A rms)	± 10%
2		Voltage (Sinusoidal)	74.9	V rms/Krpm	± 10%
3		Electrical Time	26.7	milliseconds	nominal
4		Mechanical Time	0.68	milliseconds	nominal
5		Thermal	28	minutes	nominal
6	Torque (s):	Continuous, Stall	2788 (19.69)	oz-in (Nm)	min. [1]
7	(NOTE: Values are with	Continuous, Stall	2630 (18.57)	oz-in (Nm)	min. [2]
8	rated and peak current,	Continuous, Rated	2304 (16.27)	oz-in (Nm)	min. [2]
9	lines 15 & 16 below.	Peak, Max w/o Saturation	7488 (52.88)	oz-in (Nm)	min. [1]
10	Drive current, and thus	Static Friction	40.7 (0.287)	oz-in (Nm)	max.
11	torque, may be lower.)	Ripple (of Rated Torque)	4.5	percent	min. [3]
12	Speed:	Rated	2500 (42)	rpm (rps)	reference
13		Maximum	2500 (42)	rpm (rps)	reference
14	Frequency	Rated	83	Hz	max.
15	Current:	Rated	15	A rms	max. [1]
16		Peak	45	A rms	nominal
17	Voltage:	Rated	230	V rms	reference
18		Max	250	V rms	maximum
19	Output Power:	Rated	4.3 (5.7)	kWatts (hp)	min. [1]
20	Inductance:	Terminal (line-line)	20	mH	± 30%
21	D.C. Resistance	Terminal (line-line)	0.75	Ohms	± 10 % [1]
22	Acceleration at Rated Torque		56934	rads/sec^2	Theoretical
23	Rotor Inertia		50.7 (929)	oz-in^2 (kgm^2 * 1E-6)	nominal
24	Damping		2.88 (0.020)	oz-in/krpm (Nm/krpm)	nominal
25	Weight		32 (14.5)	lbs. (kg)	max.
26	Winding Temperature		170°C (338°F) [4]	°C (°F)	max.
27	Winding Temperature Rise (Above Ambient) [1]		145°C (293°F)	°C (°F)	reference
28	Insulation Class		H	—	reference
29	Thermostat TRIP Temperature		170°C (338°F)	°C (°F)	± 5 °C
30	Thermostat RESET Temperature		135°C (275°F)	°C (°F)	± 5 °C
31	Dielectric Strength, (Winding-to-Frame)		1750	VAC	min.
32	Winding Capacitance to Frame		0.0038	µF	max.
33	IP Classification		65 [8]	rated	standard
34	Shaft:	Radial-Play At End	20E-6 (114E-9)	in/lb (m/N)	reference
		At Faceplate	7E-6 (40E-9)	in/lb (m/N)	reference
35		Material [5]	RC-#30	—	—
36		Magnet Type	NdFeB	—	—
37		Loading [6] 1000 rpm (17 rps)	160 (712)	lbs. (N)	max. [7]
		2000 rpm (33 rps)	127.1 (565)	lbs. (N)	max. [7]
		3000 rpm (50 rps)	N/A	lbs. (N)	max. [7]
		4000 rpm (67 rps)	N/A	lbs. (N)	max. [7]
		5000 rpm (83 rps)	N/A	lbs. (N)	max. [7]
38	Bearing Class, Internal/External		1/Class 3	ABEC/AFBMA	reference
39	Bearing Grease		SRI #2	Manufacturer	reference
40	Shaft Seal Pressure		3 (0.21)	psi (kg/cm^2)	max.
41	Basic Motor Design		3 phase *wye* connected 2(P/2)		
42	Stator Phase Sequence—CW rotor rotation		A-C-B (viewed from front face plate)		
43	Vendor/Supplier		Industrial Drives B-406-D		
44	Resolver Type/Accuracy		Single-Speed; Rotor-Excited; ± 10 arc min.		
45	Resolver Manufacturer/Model #		Fasco # 21-BRCX-335-J39		
46	Standard Resolver Cable Part Number		71-013862-xx		
47	Standard Motor Cable Part Number		71-013864-xx		
48	Options:	Brake—24VDC (0.93A)—1130 oz-in (8.0 Nm) Holding Torque IP67 Classification Incremental Encoder Tachometer No Keyway			

[1] 25°C (77°F) Ambient
[2] 40°C (104°F) Ambient
[3] Measured at 60 rpm (1 rps) in Velocity Mode
[4] Rated for 20,000 Hours or 40,000 Hours @ 155° C (311°F)
[5] Rotor steel is rated as *fatigue proof*
[6] Loads centered 1 inch from mounting flange
[7] Loads may be radial and axial such that the sum of the radial and two times the axial does not exceed this figure.
[8] Motor shaft is IP30 rated.

APEX630 Motor Specifications

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	Motor Size:	**APEX635**	Value	Units	Tolerance
1	Constant (s):	Torque	164.0 (1.158)	oz-in/A rms (Nm/A rms)	± 10%
2		Voltage (Sinusoidal)	70	V rms/Krpm	± 10%
3		Electrical Time	0.77	milliseconds	nominal
4		Mechanical Time	20.8	milliseconds	nominal
5		Thermal	28	minutes	nominal
6	Torque (s):	Continuous, Stall	2605 (18.39)	oz-in (Nm)	min. [1]
7	(NOTE: Values are with	Continuous, Stall	2458 (17.36)	oz-in (Nm)	min. [2]
8	rated and peak current,	Continuous, Rated	2054 (14.50)	oz-in (Nm)	min. [2]
9	lines 15 & 16 below.	Peak, Max w/o Saturation	7008 (49.49)	oz-in (Nm)	min. [1]
10	Drive current, and thus	Static Friction	69 (0.49)	oz-in (Nm)	max.
11	torque, may be lower.)	Ripple (of Rated Torque)	4.5	percent	min. [3]
12	Speed:	Rated	3000 (50)	rpm (rps)	reference
13		Maximum	3000 (50)	rpm (rps)	reference
14	Frequency	Rated	150	Hz	max.
15	Current:	Rated	15	A rms	max. [1]
16		Peak	45	A rms	nominal
17	Voltage:	Rated	230	V rms	reference
18		Max	250	V rms	maximum
19	Output Power:	Rated	4.5 (6.1)	kWatts (hp)	min. [1]
20	Inductance:	Terminal (line-line)	14	mH	± 30%
21	D.C. Resistance	Terminal (line-line)	0.647	Ohms	± 10 % [1]
22	Acceleration at Rated Torque		48945	rads/sec^2	Theoretical
23	Rotor Inertia		56.1 (1028)	oz-in^2 (kgm^2 ∗ 1E-6)	nominal
24	Damping		2.88 (0.020)	oz-in/krpm (Nm/krpm)	nominal
25	Weight		37 (16.8)	lbs. (kg)	max.
26	Winding Temperature		170°C (338°F) [4]	°C (°F)	max.
27	Winding Temperature Rise (Above Ambient) [1]		145°C (293°F)	°C (°F)	reference
28	Insulation Class		H	—	reference
29	Thermostat TRIP Temperature		170°C (338°F)	°C (°F)	± 5 °C
30	Thermostat RESET Temperature		135°C (275°F)	°C (°F)	± 5 °C
31	Dielectric Strength, (Winding-to-Frame)		1750	VAC	min.
32	Winding Capacitance to Frame		0.0038	µF	max.
33	IP Classification		65	rated	standard
34	Shaft:	Radial-Play At End	20E-6 (114E-9)	in/lb (m/N)	reference
		At Faceplate	7E-6 (40E-9)	in/lb (m/N)	reference
35		Material [5]	RC-#30		
36		Magnet Type	NdFeB		
37		Loading [6] 1000 rpm (17 rps)	243.5 (1,083)	lbs. (N)	max. [7]
		2000 rpm (33 rps)	193.3 (860)	lbs. (N)	max. [7]
		3000 rpm (50 rps)	168.8 (751)	lbs. (N)	max. [7]
		4000 rpm (67 rps)	N/A	lbs. (N)	max. [7]
		5000 rpm (83 rps)	N/A	lbs. (N)	max. [7]

38	Bearing Class, Internal/External	1/Class 3	ABEC/AFBMA	reference
39	Bearing Grease	SRI #2	Manufacturer	reference
40	Shaft Seal Pressure	3 (0.21)	psi (kg/cm^2)	max.
41	Basic Motor Design	3 phase *wye* connected 2(P/2)		
42	Stator Phase Sequence—CW rotor rotation	A-C-B (viewed from front face plate)		
43	Vendor/Supplier	Industrial Drives B-602-C		
44	Resolver Type/Accuracy	Single-Speed; Rotor-Excited; ± 10 arc min.		
45	Resolver Manufacturer/Model #	Fasco # 21-BRCX-335-J39		
46	Standard Resolver Cable Part Number	71-013862-xx		
47	Standard Motor Cable Part Number	71-013865-xx		
48	Options:	Brake—24VDC (0.93A)— 1130 oz-in(8.0 Nm) Holding Torque IP67 Classification Incremental Encoder Tachometer No Keyway		

[1] 25°C (77°F) Ambient
[2] 40°C (104°F) Ambient
[3] Measured at 60 rpm (1 rps) in Velocity Mode
[4] Rated for 20,000 Hours or 40,000 Hours @ 155° C (311°F)
[5] Rotor steel is rated as *fatigue proof*
[6] Loads centered 1 inch from mounting flange
[7] Loads may be radial and axial such that the sum of the radial and two times the axial does not exceed this figure.
[8] Motor shaft is IP30 rated.

APEX635 Motor Specifications

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	Motor Size:	**APEX640**	Value	Units	Tolerance
1	Constant (s):	Torque	291.5 (2.06)	oz-in/A rms (Nm/A rms)	± 10%
2		Voltage (Sinusoidal)	124.5	V rms/Krpm	± 10%
3		Electrical Time	26.2	milliseconds	nominal
4		Mechanical Time	0.55	milliseconds	nominal
5		Thermal	33	minutes	nominal
6	Torque (s):	Continuous, Stall	4640 (32.76)	oz-in (Nm)	min. [1]
7	(NOTE: Values are with	Continuous, Stall	4378 (30.92)	oz-in (Nm)	min. [2]
8	rated and peak current,	Continuous, Rated	3955 (27.93)	oz-in (Nm)	min. [2]
9	lines 15 & 16 below.	Peak, Max w/o Saturation	12461 (87.99)	oz-in (Nm)	min. [1]
10	Drive current, and thus	Static Friction	73 (0.52)	oz-in (Nm)	max.
11	torque, may be lower.)	Ripple (of Rated Torque)	4.5	percent	max. [3]
12	Speed:	Rated	1600 (27)	rpm (rps)	reference
13		Maximum	1600 (27)	rpm (rps)	reference
14	Frequency	Rated	80	Hz	max.
15	Current:	Rated	15	A rms	max. [1]
16		Peak	45	A rms	nominal
17	Voltage:	Rated	230	V rms	reference
18		Max	250	V rms	maximum
19	Output Power:	Rated	4.7 (6.3)	kWatts (hp)	min. [1]
20	Inductance:	Terminal (line-line)	20	mH	± 30%
21	D.C. Resistance	Terminal (line-line)	0.763	Ohms	± 10 % [1]
22	Acceleration at Rated Torque		43667	rads/sec^2	Theoretical
23	Rotor Inertia		111.0 (2034)	oz-in^2 (kgm^2 * 1E-6)	nominal
24	Damping		15.36 (0.1085)	oz-in/krpm (Nm/krpm)	nominal
25	Weight		51 (23.2)	lbs. (kg)	max.
26	Winding Temperature		170°C (338°F) [4]	°C (°F)	max.
27	Winding Temperature Rise (Above Ambient) [1]		145°C (293°F)	°C (°F)	reference
28	Insulation Class		H	—	reference
29	Thermostat TRIP Temperature		170°C (338°F)	°C (°F)	± 5 °C
30	Thermostat RESET Temperature		135°C (275°F)	°C (°F)	± 10 °C
31	Dielectric Strength, (Winding-to-Frame)		1750	VAC	min.
32	Winding Capacitance to Frame		0.0082	µF	max.
33	IP Classification		65 [8]	rated	standard
34	Shaft:	Radial-Play At End	10E-6 (57E-9)	in/lb (m/N)	reference
		At Faceplate	4E-6 (23E-9)	in/lb (m/N)	reference
35		Material [5]	RC-#30	—	—
36		Magnet Type	NdFeB	—	—
37		Loading [6] 1000 rpm (17 rps)	255.6 (1,130)	lbs. (N)	max. [7]
		2000 rpm (33 rps)	N/A	lbs. (N)	max. [7]
		3000 rpm (50 rps)	N/A	lbs. (N)	max. [7]
		4000 rpm (67 rps)	N/A	lbs. (N)	max. [7]
		5000 rpm (83 rps)	N/A	lbs. (N)	max. [7]
38	Bearing Class, Internal/External		1/Class 3	ABEC/AFBMA	reference
39	Bearing Grease		SRI #2	Manufacturer	reference
40	Shaft Seal Pressure		3 (0.21)	psi (kg/cm^2)	max.
41	Basic Motor Design		3 phase *wye* connected 3(P/2)		
42	Stator Phase Sequence—CW rotor rotation		A-C-B (viewed from front face plate)		
43	Vendor/Supplier		Industrial Drives B-604-D		
44	Resolver Type/Accuracy		Single-Speed; Rotor-Excited; ± 10 arc min.		
45	Resolver Manufacturer/Model #		Fasco # 21-BRCX-335-J39		
46	Standard Resolver Cable Part Number		71-013862-xx		
47	Standard Motor Cable Part Number		71-013865-xx		
48	Options:	Brake—24VDC (1.27A)—6800 oz-in (48 Nm) Holding Torque IP67 Classification Incremental Encoder Tachometer No Keyway			

[1] 25°C (77°F) Ambient
[2] 40°C (104°F) Ambient
[3] Measured at 60 rpm (1 rps) in Velocity Mode
[4] Rated for 20,000 Hours or 40,000 Hours @ 155° C (311°F)
[5] Rotor steel is rated as *fatigue proof*
[6] Loads centered 1 inch from mounting flange
[7] Loads may be radial and axial such that the sum of the radial and two times the axial does not exceed this figure.
[8] Motor shaft is IP30 rated.

APEX640 Motor Specifications

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Appendix D

LVD Installation Instructions

For more information about LVD, see 73/23/EEC and 93/68/EEC, published by the European Economic Community (EEC).

Environmental Conditions

Pollution Degree

APEX615n Controller/Drives are designed for pollution degree 2.

Installation Category

APEX615n Controller/Drives are designed for installation category II.

Electrical

Connecting and Disconnecting Power Mains

The APEX615n Controller/Drive's protective earth connection is provided through its power mains connector. You must reliably earth the APEX615n Controller/Drive's protective earth connection.

Attach or remove the APEX615n Controller/Drive's power plug only while input power is OFF.

Using an Isolation Transformer

The APEX615n Controller/Drive's mains voltage is limited to 240 VAC nominal. If your mains voltage is higher, use an isolation transformer located between the power mains and the APEX615n Controller/Drive. Your isolation transformer should be insulated to ~2300V rms.

Do not interrupt the protective earth conductor between the source mains and the isolation transformer's secondary. The core of the isolation transformer and the drive's protective conductor terminal must *both* be connected to the main's protective earth conductor.

CAUTION
Do not use an autotransformer.

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Line Fuses

Line fuses need to be added to protect the transformer and associated wiring. If the live wire cannot be readily identified, fuse both phase conductors. The value of fuse required is given by:

(1.5 x VA)/(supply volts) [amps]

Fuse types should be anti-surge HBC.

WARNING

Safety Ground (Earth Ground) should **never** be fused.

Connecting the Protective Conductor Terminal to Earth

You must provide a connection from the APEX615n Controller/Drive's protective conductor terminal to the protective earth conductor of the mains. This connection is *in addition* to the protective earth connection provided through the APEX615n Controller/Drive's mains connector.

The protective conductor terminal is marked with a label on the product bearing the following symbol:



Protective Conductor Terminal Marking

To connect the protective conductor terminal to earth, complete these steps:

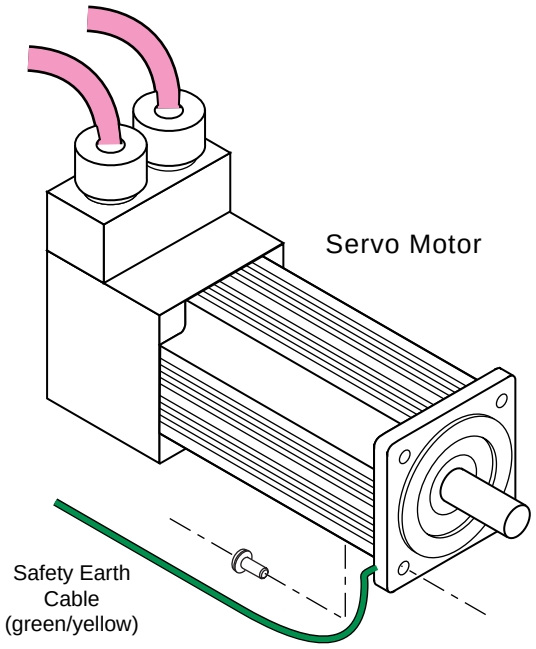
1 Use a spade lug in combination with a star washer to make good contact with the bare metal surface of the APEX615n Controller/Drive.
2 Use a green and yellow wire to reliably earth the protective conductor terminal. Wire gauge must be no thinner than the current-carrying wire in the product's mains supply.
3 Resistance between the protective conductor terminal and earth must be no greater than 0.1 W. Use thicker gauge wire if the resistance is too high.

Providing a Protective Earth Connection for Motors

You must provide a connection from the APEX motor to a reliable earth system. This connection provides a protective earth for the motor, and is *in addition* to the earth connection provided by the earth wire in the motor's power cable. The motor's protective earth connection is important for safety reasons, and *must not be omitted*.

Make connections according to the following instructions and diagram:

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Providing Protective Earth Connection for Motor

1 Use a spade lug in combination with a star washer and mounting bolt to make good contact with the bare metal surface of the motor's mounting flange.
2 Use a green and yellow striped wire to make the connection between the motor and earth. Wire gauge must be no thinner than the current carrying wire in the motor's power cable.
3 Resistance between the motor and earth must be no greater than 0.1 W. Use thicker gauge wire if the resistance is too high.

Mechanical

Installing in an Enclosure

The APEX615n Controller/Drive must be installed within an enclosure. The enclosure's interior must not be accessible to the machine operator. The enclosure should be opened only by skilled or trained service personnel.

Servicing the APEX Drive

Changing Firmware Only skilled or trained personnel should change firmware.

Changing Batteries The APEX615n Controller/Drive contains a replaceable lithium battery, of type Duracell DL2450, or Sanyo CR2450, or equivalent. Only skilled or trained personnel should change batteries.

Disposal of Batteries Dispose of batteries in accordance with local regulations.

Do Not Replace Fuses The APEX 615n Controller/Drive has no fuses designed to be replaced by the user. Fuse failure indicates that other components have also failed. Fuses and other components should only be replaced by Compumotor or its designated repair facilities.

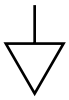
Thermal Safety

The Motor May Be Hot The motor may reach high temperatures during normal operations, and may remain hot after power is removed.

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Table of Graphic Symbols and Warnings

The following symbols may appear in this user guide, and may be affixed to the products discussed in this user guide.

Symbol	Description
	Earth Terminal
	Protective Conductor Terminal
	Frame or ChassisTerminal
	Equipotentiality
	Caution, Risk of Electric Shock
	Caution, Refer to Accompanying Text
	Hot Surface

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Appendix E

EMC Installation Guidelines

General Product Philosophy

Compumotor products that were not designed originally for EMC compliance, such as the APEX615n, will require specific measures to be taken during installation. These measures vary according to the type of product. The ultimate responsibility for ensuring that the EMC requirements are met rests with the systems builder.

It is important to remember that for specific installations, the full protection requirements of the EMC Directive 89/336/EEC need to be met before the system is put into service. This must be verified either by inspection or by testing. The following EMC installation instructions are intended to assist in ensuring that the requirements of the EMC directive are met. It may be necessary to take additional measures in certain circumstances and at specific locations.

It should be stressed that although these recommendations are based on expertise acquired during tests carried out on each of the product types, it is impossible for Compumotor to guarantee the compliance of any particular installation. This will be strongly influenced by the physical and electrical details of the installation and the performance of other system components. Nevertheless it is important to follow ***all*** the installation instructions if an adequate level of compliance is to be achieved.

Safety Considerations

These products are intended for installation according to the appropriate safety procedures including those laid down by the local supply authority regulations. The recommendations provided are based on the requirements of the Low Voltage Directive and specifically on EN60204. It should be remembered that safety must never be compromised for the purpose of achieving EMC compliance. Therefore in the event of a conflict occurring between the safety regulations and the following recommendations, ***the safety regulations always take precedence.***

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General Considerations Applicable to all Products

External enclosures

The measures described in these recommendations are primarily for the purpose of controlling conducted emissions. To control radiated emissions, all drive and control systems must be installed in a steel equipment cabinet which will give adequate screening against radiated emissions. This external enclosure is also required for safety reasons. There must be *no user access* while the equipment is operating. This is usually achieved by fitting an isolator switch to the door assembly.

Packaged products must be mounted to a conductive panel. If this has a paint finish, it will be necessary to remove the paint in certain areas where specified.

To achieve adequate screening of radiated emissions, all panels of the enclosure must be bonded to a central earth point. The enclosure may also contain other equipment and the EMC requirements of these must be considered during installation. Always ensure that drives and controllers are mounted in such a way that there is adequate ventilation.

AC supply filtering

These recommendations are based on the use of proprietary screen filter units which are readily available. However the full EMC test includes a simulated lightning strike which will damage the filter unless adequate surge suppression devices are fitted. These are not normally incorporated into commercial filters since the lightning strike test can be destructive. This test is normally carried out on the overall system and not on individual components, therefore the surge protection should be provided at the system boundary.

Try to arrange the layout of drive and filter so that the AC input cable is kept away from the filter output leads. It is preferable for the current path to be as linear as possible without doubling back on itself - this can negate the effect of the filter. Mount the filter within 2 inches (50mm) of the drive or transformer, if required, and run the input cable and any earth cables close to the panel.

The next section of this Appendix lists the recommended AC Input Power Filter for the APEX615n.

Control signal connections

High-quality braided-screen cable should be used for control connections. In the case of differential inputs, it is preferable to use cable with twisted pairs to minimize magnetic coupling. This applies to both analog and digital signals. Control cables leaving the enclosure should have the cable screen returned to a local ground point near the product. Where screened leads are used in control circuits that are only opto-isolated at one end, the screen must be referenced to earth at the non-isolated end. Where there is isolation at both ends of the connection, earth the screen at the receiving end. This is to give protection against coupled noise impulses and fast transient bursts.

Remember to route control signal connections well away (at least 8 inches) from relays and contactors. Control wiring should not be laid parallel to power or motor cables and should only cross the path of these cables at right angles. Bear in mind that control cables connected to other equipment within the enclosure may interfere with the controller or drive, particularly if they have come from outside the cabinet. Take particular care when connecting external equipment with the cabinet door open, for instance a computer or terminal; static discharge may cause damage to unprotected inputs.

Motor Cabling

In order to prevent electrical cross-talk, motor cables not incorporating a braided screen shield must remain within earthed metal conduit the entire exposed length of travel. It is advised that each high power motor cable utilize its own conduit.

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Ferrite absorber specifications

The absorbers described in these installation recommendations are made from a low-grade ferrite material which has high losses at radio frequencies. They therefore act like a high impedance in this waveband.

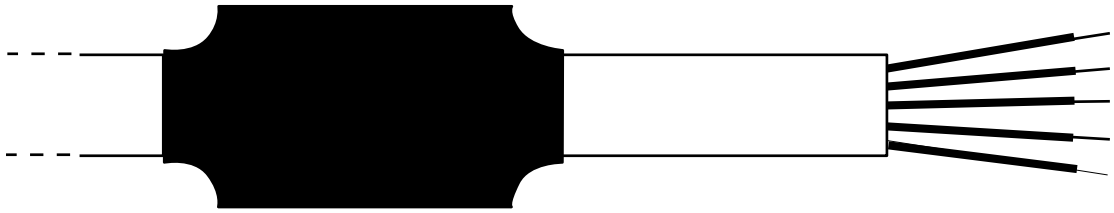
The recommended components are produced by Parker Chomerics (617-935-04850) and are suitable for use with cable having an outside diameter up to 10—13mm. The specification is as follows:

Chomerics part number	83-10-M248-1000	83-10-A637-1000
Outside diameter	17.5mm	28.5mm
Inside diameter	10.7mm	13.77mm
Length	28.5mm	28.57mm
Impedance at 25MHz	80Ω	135Ω
Impedance at 100MHz	120Ω	210Ω
Curie temperature	130°C	130°C

(*the device should not be operated near this temperature*)

Handling and installing the ferrite absorbers

Take care when handling the absorbers - they can shatter if dropped on a hard surface. For this reason the suggested method of installation is to use a short length of 19mm diameter heat-shrink sleeving (See figure 1). This gives a degree of physical protection while the cable is being installed. The sleeving should have a shrink ratio of at least 2.5:1. Cable ties may be used as an alternative, however they give no physical protection to the absorber.



Ferrite absorber
retained by
heatshrink sleeving

Figure 1 - Ferrite Sleeve Installation

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P-Clip Installation Details

The function of the P-Clip is to provide a 360 degree metallic contact and thus a convenient means of ensuring a proper R.F. ground. When dealing with EMI issues, it is important to remember that continuity, a DC connection, does not at all speak to the integrity of an AC (high-frequency) connection. High-Frequency bonding typically involves wide, flat cabling to establish a suitable system ground. When applied properly, the P-Clip has been shown to give an adequate high-frequency contact.

When installing a P-Clip, Figure 2, install as close to the cable end as possible, provided a suitable ground, backplane, earth stud or bus bar is accessible, (this may mean removing the paint from a cabinet or panel). Remove only the outer (vinyl) jacket of the braided screen cable (this allows the braid to continue to the cable connector), be careful not to damage the braid. Snap the P-clip over the exposed braid, and adjust for a tight fit. Secure the clip to the designated ground with a machine screw and lock washer. The use of brass or other inert conductive metal P-Clip is recommended. Cover any exposed bare metal with petroleum jelly to resist corrosion.

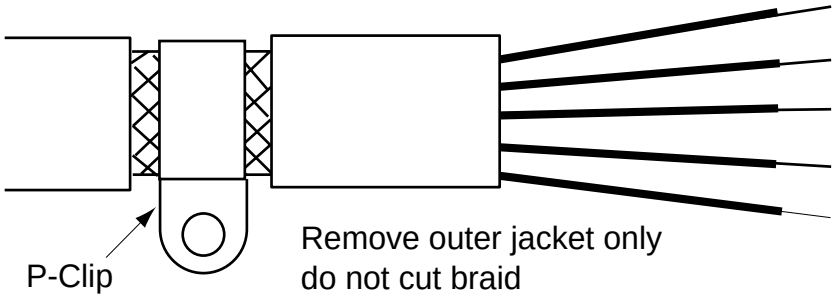


Figure 2 - P-Clip Installation

APEX615n Servo Controller/Drive

Applicable Products: **APEX6151, APEX6152, APEX6154**

Please read this in conjunction with the general considerations applicable to all products.

To insure proper grounding of the APEX615n Controller/Drive, remove paint from the rear panel that is located behind the upper right mounting slot on the drive. The upper right 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 unpainted mounting surface. After mounting the unit use petroleum jelly on the exposed metal to minimize the risk of future corrosion.

Filtering the AC mains supply

A filter must be installed between the incoming AC supply and the input to the drive. Suitable filters are:

Controller/ Drive	Filter Manufacturer	AC Control Filter 120/240VAC	AC Mains Filter 1-Phase 120/240VAC	AC Mains Filter 3-Phase 120/240VAC
APEX6151	Schaffner	FN610-3-06	FN2070-16-06	Not Applicable
	Schaffner	FN2070-3/06		Not Applicable
	Corcom	3EB1	*	Not Applicable
APEX6152	Schaffner	FN610-3-06	FN258-16-07	FN258-16-07
	Schaffner	FN2070-3/06		Not Applicable
	Corcom	3EB1	*	20AYT6C
APEX6154	Schaffner	FN610-3-06	FN258-16-07	FN258-16-07
	Schaffner	FN2070-3/06		FN258-30-07
	Corcom	3EB1	*	20AYT6C

* Test Pending

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Mount the filter within 2 inches (50mm) of the drive as shown in Figure 4. Ensure that there is no paint on the mounting panel under the filter mounting lugs - it is vital that there is large-area conductive contact between the filter and the panel.

Connect the incoming AC supply cable to the push-on or screw type terminals on the filter, with the earth lead connected to a local earth stud, bus bar or metal back-plane. Route the supply cable so that it runs close to the walls of the enclosure. Connect the earth terminal on the filter case to earth.

Figure 3 shows the controller/drive system with two separate AC line filters. Another option is to use the AC mains filter to power the AC control input.

Fit a ferrite absorber, Figure 1, over the cable before wiring the filter output terminals to the AC input on the drive, see Figure 4. Locate the absorber as close as possible to the drive using heat-shrink sleeving. Take the drive earth connection from the same stud that retains the filter case earth.

Motor Connections

Standard Compumotor Motors

Compumotor servo motor systems ship with motors that do not incorporate the use of a braided screen to control conducted emissions. Therefore when used in installations where the motor cable is not within earthed conduit the entire length of travel, the standard motor cable should not be used.

For motors with exposed cabling (not within earthed conduit), follow the guidelines below:

Removable cabling ……Remove the motor cable from the standard motor, and replace with a suitable cable described below, see *Motor Cables.*

Permanent cabling …….Cut off cable in excess of approximately 4 inches (10 cm), and attach a suitable cable described below, see *Motor Cables.*

Termination of the braid shield at the motor must be made using a 360° bond to the motor body or mounting flange, and this may be achieved by using a suitable clamp. Many servo motors are designed to accommodate MS style connections or an appropriate terminal gland which can be used for this purpose, (in the case of MS style connectors, ensure that the cable braid is in full contact with the metal MS connector body). If this is not the case, P-clip the braid, see Figure 2, to the rear end bell of the motor housing, (on Compumotor Servo Motors rather than securing the cable braid to the motor end bell, P-clip the braid to the conductive motor mounting surface as shown in Figure 3). This will not only provide a good high frequency bond, but strain relief as well.

At the drive end of the motor cable, fit a ferrite absorber over the cable before wiring to the motor connector (it may be necessary to remove the existing connector). Locate the absorber as close as possible to the connector using heat-shrink sleeving. Run the motor cable down to the mounting panel, expose a short length of braiding and anchor to the panel with a P-clip. The APEX615n Controller/Drive requires a safety earth connection to the motor (green and yellow striped wire) - take this from the stud or bus bar. Run the safety earth lead alongside the motor lead. Note that the motor cable should be kept away from I/O cables carrying control signals.

Motor Cables

Braided Screen cable with at least 80% coverage should be used for after-market motor cables. Consult the APEX User Guide for require cable gages and number of conductors.

There must be no break in the 360° coverage that the screen provides around the cable conductors. If a connector must be used it should retain the 360° coverage, possibly by the use of an additional metallic casing where it passes through the bulkhead of the enclosure. The cable screen must *not* be connected to the cabinet at the point of entry. Its' function is to return high-frequency chopping current back to the drive or controller. This may require mounting the connector on a sub-panel insulated from the main cabinet, or using a connector having an internal screen which is insulated from the connector housing.

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Within the cabinet itself, all the motor cables should lie in the same trunking as far as possible. They must be kept separate from any low-level control signal cables. This applies particularly where the control cables are unscreened and run close to the drive or other sources of electrical noise.

Motor Feedback Cables

Feedback devices such as encoders, tachometers, Hall effect sensors, and resolvers also require the use of high-quality braided screen cable. If it is necessary to replace the standard feedback cable, select a braided screen cable that matches the gage of the devices original cable and attach as close to the transducer as possible. Avoid complex and bulky connections that can cause degradation in feedback signal quality. If possible, use in-line cable splicing techniques, and cover the splice point with heat-shrink tubing. Remove a section of the braided shield cable's insulation to expose the braid, and tie the braid to earth using the same P-clip 360° bond as shown in Figure 2. Differential signals should use twisted pair cable to minimize magnetic coupling. At the receiving end, fit a ferrite absorber over the feedback cable before wiring the connector, then P-clip the braid to a suitable ground, (metal back-plane of drive mounting panel, or earth point of device that receives the feedback), Figure 4.

Servo Motors

It is preferable to use motors with screw terminations whenever possible. If flying-lead motors are used, it is important that the unscreened leads are converted into a braided-screen cable within 4 inches (10cm) of the motor body. A separate terminal box may be used for this purpose but the braided cable screen must be properly strapped to the motor body.

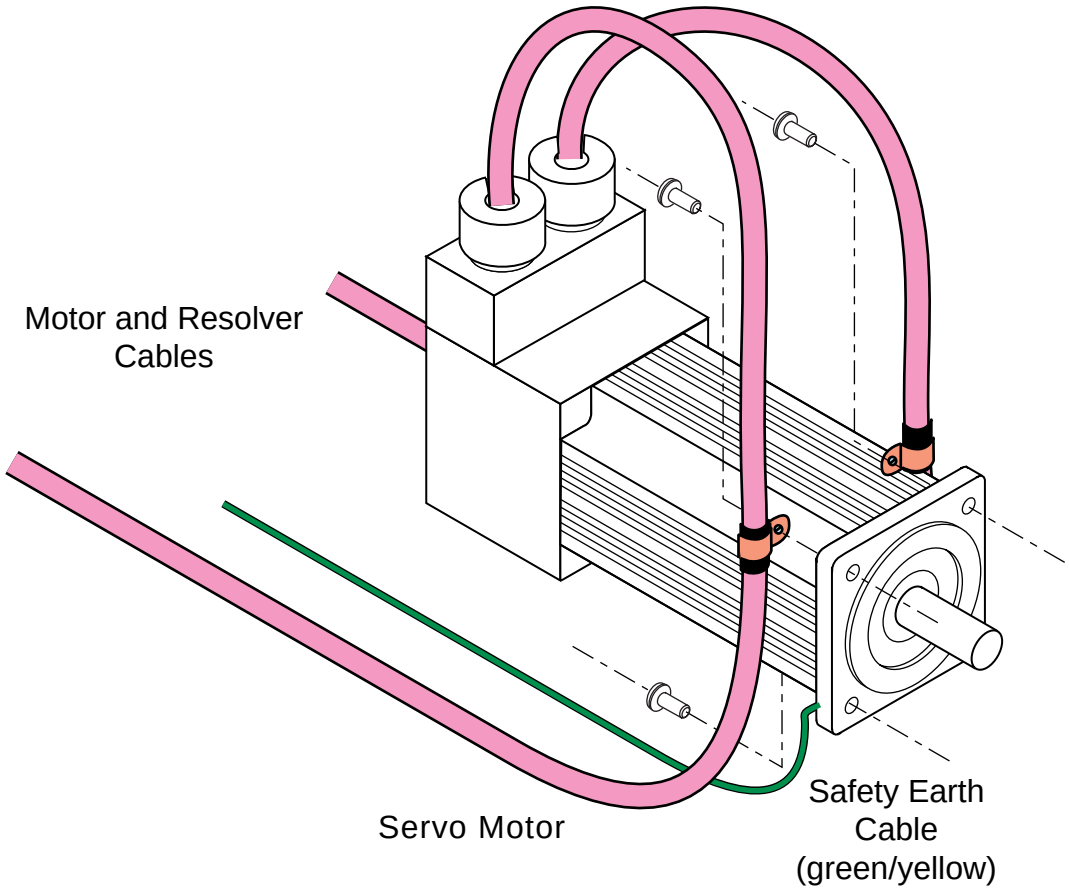


Figure 3: Servo Motor Detail - P-Clip, Safety Earth

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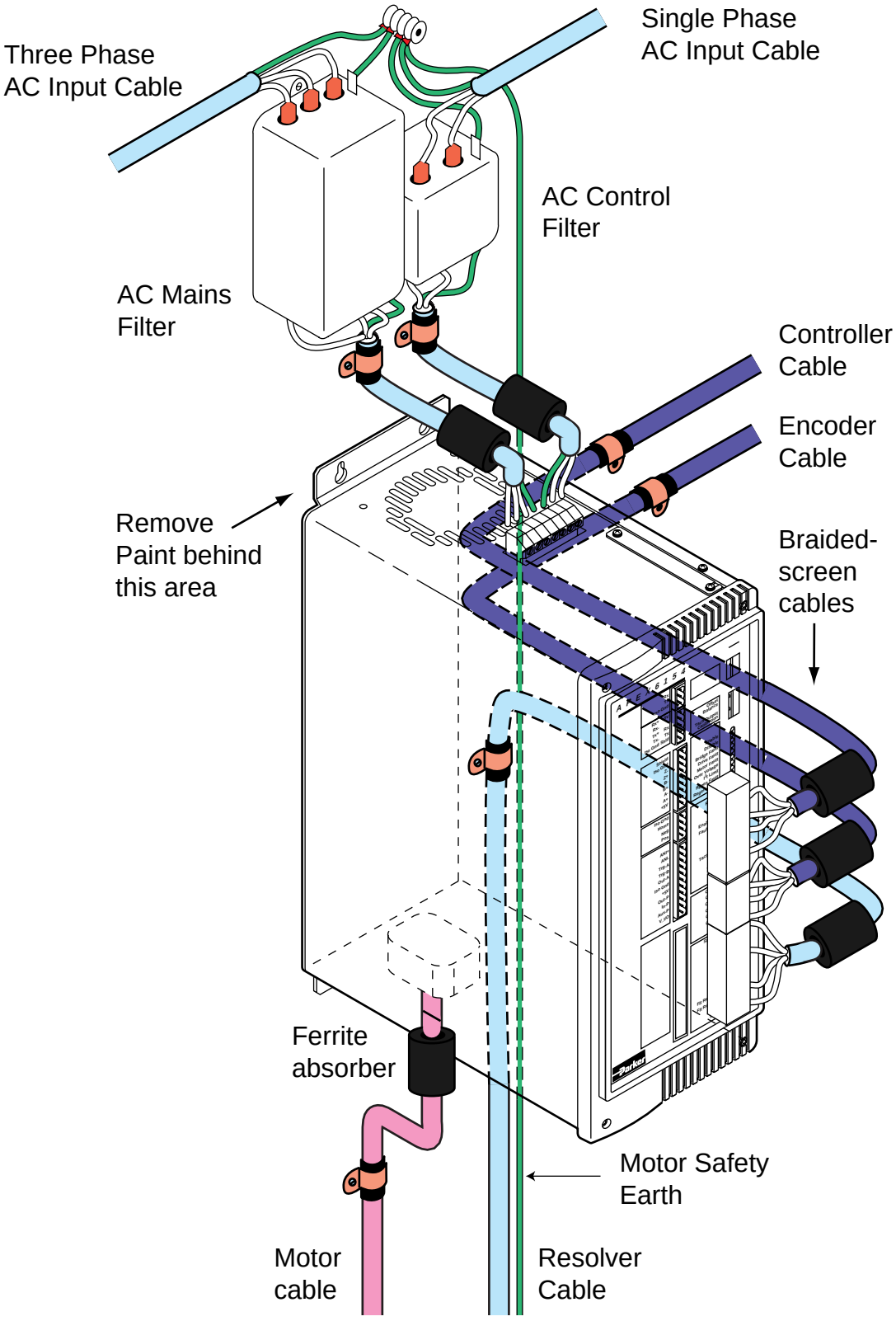


Figure 4 - APEX 615n AC, Motor, Drive Cables and Filters

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Control Signal Wiring

High-quality braided screen cable should be used for control connections. In cases where the signal transmission is in differential mode, it is preferable to use cable with twisted pairs to minimize magnetic coupling. No connection is made to the cable screen at the drive itself. Fit a ferrite absorber close to the I/O connector and run the cable down to the mounting panel as shown in Fig. 5. Expose a short length of the braided screen and anchor to the panel with a P-clip.

The level at which the I/O operates means that the signals are unlikely to meet EMC immunity requirements if taken outside the enclosure without proper screening.

Communications ……. In applications that require serial communications with the APEX615n, special care must be taken in assuring proper wiring practices are utilized. Good quality braided screen cable should be used for the communication cabling. No connection is made to the cable screen at the drive itself. Fit a ferrite absorber close to the communications connector and run the cable down to the mounting panel as shown in Figure 5. Expose a short length of the braided screen and anchor to the panel with a P-clip. Avoid routing communication cables near high power lines, and sources of high energy impulses.

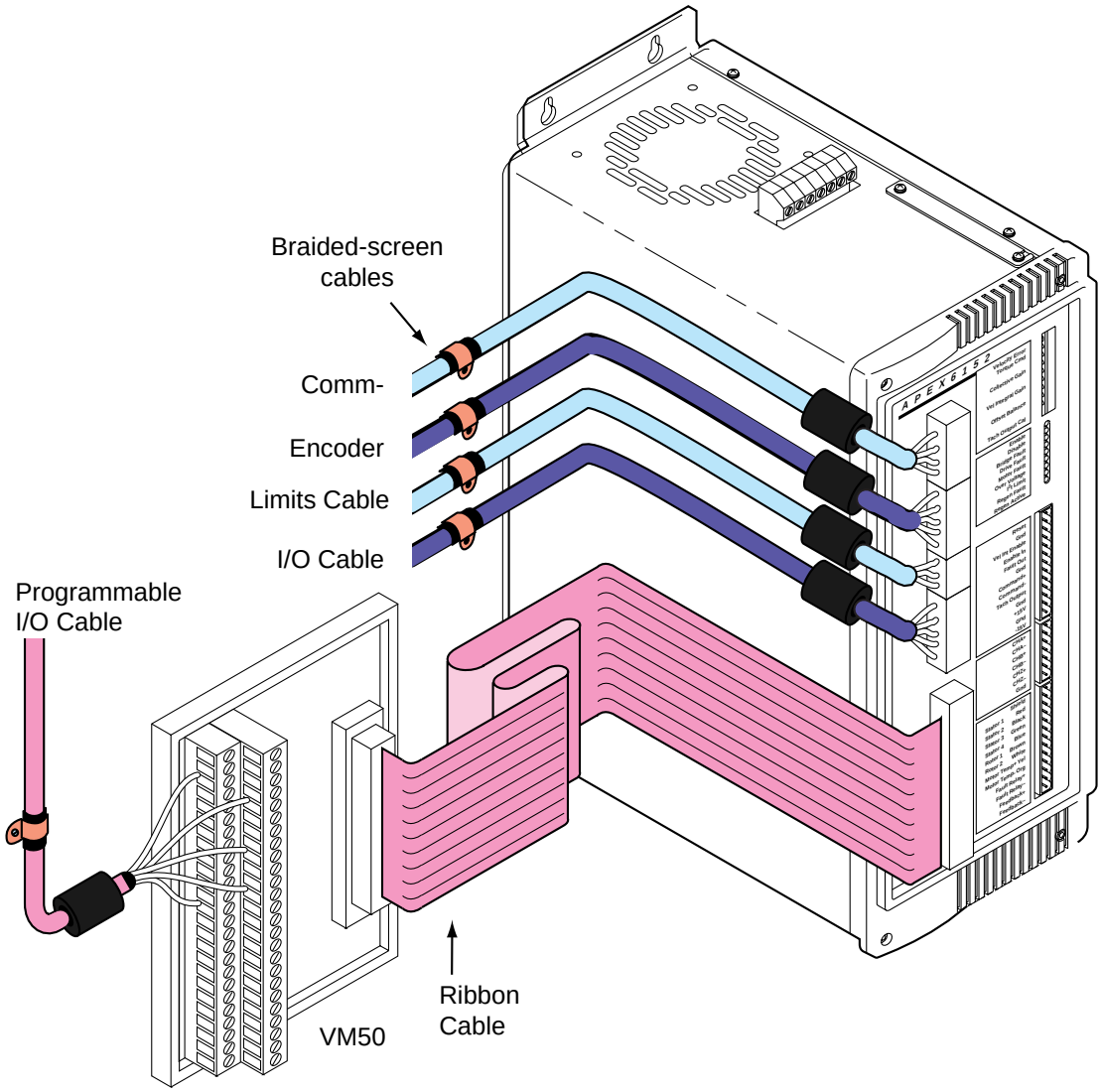


Figure 5 - APEX 615n Controller Cables

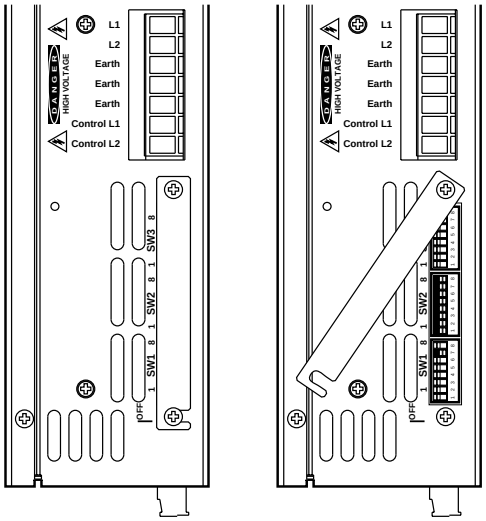
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Appendix F

Configuring DIP Switches

APEX6151 DIP Switches

The APEX6151 has three 8-position DIP switches. The switches are located behind a small metal cover on top of the APEX6151. Loosen the two screws that hold the access cover, and move the cover to expose the DIP switches.



DIP Switch Location, with Cover Closed and Open

The default setting for all DIP switches when the APEX6151 ships from the factory is off. You must set these switches to configure the drive for your particular application. Use a small screwdriver to set the switches. The next section summarizes the function of each switch.

A diagram showing DIP switch functions shown on page 7.

Switch 1 (**SW 1**)

REGEN FAULT — #1: Set this switch in the OFF position for normal operation of the APEX6151'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 APEX6151's regeneration fault. For more information, see the discussion of regeneration in Chapter 5.

HALL SENSOR DEGREES — #2: Set this switch in the OFF position if you use a motor with 120° Hall effect sensors. Set this switch in the ON position if you use a motor with 60° Hall effect sensors.

RESERVED — #3: Set this switch in the OFF position.

MOTOR POLE PAIR NUMBER — #4 & #5: Set these two switches according to the number of pole pairs your motor has. APEX and SM Series motors, which have two pole pairs (four poles) require switches #4 & #5 to be OFF.

RESOLVER SPEED — #6: For a motor with a single speed resolver, turn #6 OFF. (This switch should be OFF if you use an APEX or SM motor, all of which have single-speed resolvers.) For a motor with a two-speed resolver, turn #6 ON.

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CURRENT LOOP COMPENSATION — #7 & #8: These two switches control the dynamics of the APEX6151's current feedback loop. Use these switches to match the drive's performance to your particular motor's characteristics. For Compumotor APEX and SM motors, set the switches according to the table below. If you use a motor from another vendor, call Compumotor's Applications Department for instructions on setting these two DIP switches for your motor. (see toll-free number on inside front cover)

APEX or SM MOTOR	#7	#8
SM233B	OFF	OFF
APEX602, SM231A, SM232A	OFF	ON
APEX603	ON	OFF
RESERVED	ON	ON

Switch 2 (**SW 2**)

CONTINUOUS CURRENT — #1, #2, #3: If the APEX6151 goes into current foldback, it reduces its output current down to the continuous current level set by these three switches.

MOTOR	SET CONTINUOUS CURRENT TO	#1	#2	#3
SM231A, SM232A	3.4 amps	OFF	ON	OFF
APEX603	4.0 amps	OFF	ON	ON
SM233B, APEX602	6.0 amps	ON	OFF	ON

PEAK CURRENT — #4, #5, #6: These three switches set the peak current that the APEX6151 will produce.

MOTOR	SET PEAK CURRENT TO	#4	#5	#6
SM231A, SM232A	9.5 amps	OFF	ON	OFF
APEX603	14 amps	ON	OFF	ON
APEX602, SM233B	16 amps	ON	ON	ON

TIME CONSTANT — #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 following table shows switch settings for time constants of 10, 20, 30, and 40 minutes. The table also shows the switch settings to use for APEX and SM motors.

TIME CONSTANT	MOTOR	#7	#8
10 Minutes	APEX602	OFF	OFF
20 Minutes	APEX603	OFF	ON
30 Minutes	SM231A, SM232A	ON	OFF
40 Minutes	SM233B	ON	ON

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.

Three variables (continuous current, actual current, and time constant) affect the amount of time that the foldback circuit allows operations to continue before foldback occurs. For a full explanation of the foldback circuit, see *Chapter ƒ Advanced Features*. The following equation gives an approximate time, in minutes, for a motor that operates from a cold start.

$$time_{(in\ minutes)} = Time\ Constant\left\{-\ln\left[1-\left(\frac{I_{continuous}}{I_{actual}}\right)^2\right]\right\}$$

$I_{continuous}$ is the continuous current, which you selected when you set switches #1, #2, and #3. I_{actual} is the actual peak current, whose maximum value you selected when you set switches #4, #5, and #6.

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Switch 3 (**SW 3**)

RESERVED — #1: Set this switch in the OFF position.

ALIGNMENT MODE — #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 ƒ Advanced Features* for more information.

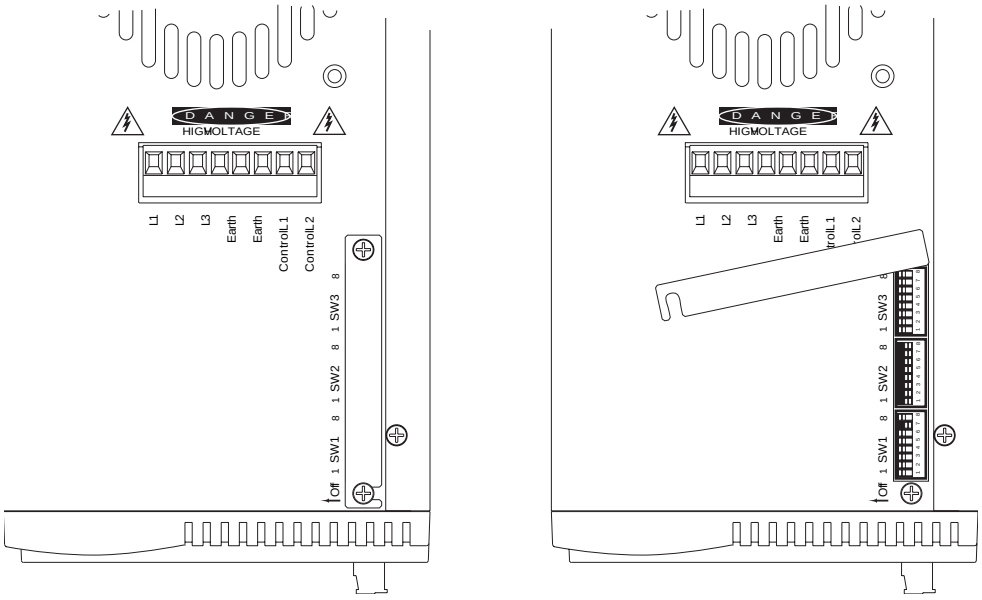
COMMUTATION TEST MODE — #3: Turn this switch OFF. If you need to operate the drive in commutation test mode during a troubleshooting procedure, you will turn this switch ON during the procedure, and turn it OFF when you are finished. This switch must be OFF during normal operating conditions. *See Chapter Δ Troubleshooting* for more information.

HALL SELECT — #4: Turn this switch OFF if your motor has a resolver. (This switch should be OFF if you use an APEX or SM Series servo motor, all of which have resolvers.) Turn this switch ON if your motor has Hall effect sensors instead of a resolver.

TACHOMETER SCALING — #5: This switch scales the 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 if you use an APEX or SM Series servo motor, all of 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.

RESERVED — #6, #7, #8: Set these three switches in the OFF position.

APEX6152/6154 DIP Switches



APEX6152/6154 DIP Switch Location, with Cover Closed and Open

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Switch 1 (SW 1)

RESERVED — #1, #2, #3: Set these three switches in the OFF position.

MOTOR POLE PAIR NUMBER — #4, #5: Set these two switches according to the number of pole pairs your motor has. All APEX motors have two pole pairs (four poles), except the APEX635 and APEX640, which have three pole pairs (six poles).

RESOLVER SPEED — #6: For a motor with a single speed resolver, turn #6 OFF. (This switch should be OFF if you use an APEX motor, all of which have single-speed resolvers.) For a motor with a two-speed resolver, turn #6 ON.

CURRENT LOOP COMPENSATION — #7 & #8: These two switches control the dynamics of the APEX615n's current feedback loop. Use these switches to match the drive's performance to your particular motor's characteristics. Based on the motor's inductance, set the switches according to the following table. The table also shows the switch setting for each APEX motor.

MOTOR INDUCTANCE	APEX MOTOR	#7	#8
25 mH to 40 mH	605, 606	OFF	OFF
5 mH to 15 mH	604, 610	OFF	ON
15 mH to 25 mH	620, 630, 635, 640	ON	OFF
Reserved		ON	ON

Switch 2 (SW 2)

CONTINUOUS CURRENT — #1, #2, #3: If the APEX615n goes into current foldback, it reduces its output current down to the continuous current level set by these three switches.

MOTOR	DRIVE	CONTINUOUS CURRENT	#1	#2	#3
APEX604	APEX6152	9.0 amps	ON	OFF	ON
APEX605,606	APEX6152	7.8amps	ON	OFF	OFF
APEX610-640	APEX6154	20 amps	ON	ON	ON

PEAK CURRENT — #4, #5, #6: These three switches set the peak current that the APEX615n will produce.

MOTOR	DRIVE	PEAK CURRENT	#4	#5	#6
APEX604,605,606	APEX6152	24 amps	ON	ON	ON
APEX610-640	APEX6154	40 amps	ON	ON	ON

TIME CONSTANT — #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 following table shows switch settings for time constants of 10, 20, 30, and 40 minutes. The table also shows the switch settings to use for APEX motors.

TIME CONSTANT	APEX MOTOR	#7	#8
10 Minutes	604,605, 606	OFF	OFF
20 Minutes	610	OFF	ON
30 Minutes	620, 630	ON	OFF
40 Minutes	635, 640	ON	ON

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The time constant is ***NOT*** the time until foldback occurs. It is a parameter based upon the motor's physical characteristics.

Three variables (continuous current, actual current, and time constant) affect the amount of time that the foldback circuit allows operations to continue before foldback occurs. For a full explanation of the foldback circuit, see *Chapter ƒ Advanced Features*. The following equation gives an approximate time, in minutes, for a motor that operates from a cold start.

$$time_{(in\ minutes)} = Time\ Constant\left\{-\ln\left[1-\left(\frac{I_{continuous}}{I_{actual}}\right)^2\right]\right\}$$

$I_{continuous}$ is the continuous current, which you selected when you set switches #1, #2, and #3. I_{actual} is the actual peak current, whose maximum value you selected when you set switches #4, #5, and #6.

Switch 3 (SW 3)

RESERVED — #1: Set this switch in the OFF position.

ALIGNMENT MODE — #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 ƒ Advanced Features* for more information.

COMMUTATION TEST MODE — #3: Turn this switch OFF. If you need to operate the drive in commutation test mode during a troubleshooting 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 Δ Troubleshooting* for more information.

HALL SELECT — #4: Turn this switch OFF if your motor has a resolver. (This switch should be OFF if you use an APEX motor, all of which have resolvers.) Turn this switch ON if your motor has Hall effect sensors instead of a resolver.

TACHOMETER SCALING — #5: This switch scales the 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 if you use an APEX motor, all of 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.

RESERVED — #6, #7, #8: Set these three switches in the OFF position.

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Appendix G

Regeneration

The APEX615n can dissipate regenerated energy in its internal *regeneration resistor*. If an APEX615n system regenerates more energy than the internal resistor can dissipate, you can connect an external resistor between two terminals labeled **V Bus+** and **Regen Resistor**, located on the motor connector. The external resistor will double the dissipation capabilities of the APEX6151 and APEX6154. To increase the APEX6152's dissipation capabilities, you can add a resistor network, as explained later in this appendix..

The APEX6151'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 **VBus–**. The energy is then dissipated in the resistor. During the regeneration event, the red LED labeled **Regen Active**, located on the APEX615n's front panel, will be illuminated.

The next drawing shows a schematic that includes the internal regeneration resistor, terminals for

When Do You Need an External Regeneration Resistor?

The APEX6151's regeneration control circuit was designed to automatically deal with regenerated power from almost all applications. Occasionally, however, an application situation arises in which regeneration will cause more power dissipation than the internal resistor can safely tolerate. In this situation, you can connect an external regeneration resistor to double the power that the system can dissipate.

To determine whether or not you need an external resistor, you can use one of two methods:

- Empirical Method
- Calculation Method

Empirical Method

The empirical method uses a trial procedure to determine whether excess regeneration will cause a regen or overvoltage fault. Operate your system (or a prototype of your system) and observe the results of regeneration. When your system decelerates, the *Regen Active* LED will be illuminated whenever regeneration turns on the internal resistor.

If the system's regeneration levels are too high, eventually either a regen fault or an overvoltage fault will shut down the APEX6151. (Be sure to let your system run for a long enough time to see if the regen fault will be triggered.) At this point, you have two options:

- Modify the system's move profile
- Install an external regeneration resistor

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By changing the move profile—less torque, slower velocities, or a longer time between moves, for example—you may be able reduce the regeneration to a lower level, so that the fault no longer occurs.

By installing an external resistor, you can double the regeneration circuit's power dissipation capabilities. With the resistor installed, the circuit's specifications become:

	Continuous Power Dissipation Rating	Peak Power Dissipation Rating
APEX6151	100 watts	2 KW
APEX6152	N/A	N/A
APEX6154	180 watts	12 KW

After you alter the move profile, or install the external resistor, run the system again to verify that regeneration no longer causes a fault.

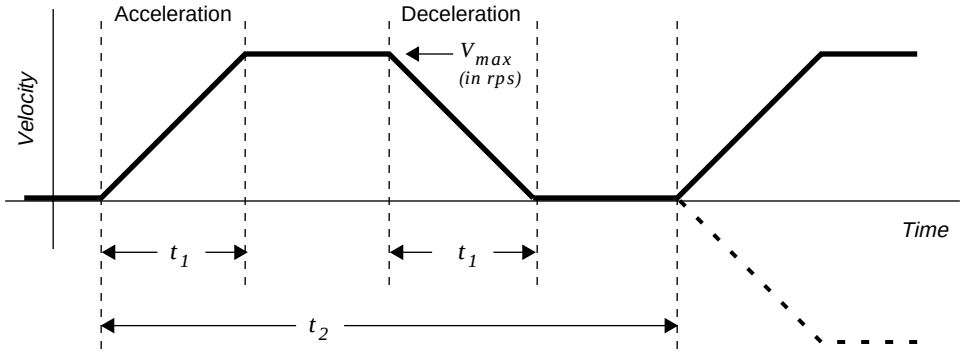
Calculation Methods

You can use the calculation method to predict peak power dissipation and average power dissipation. If peak power is greater than one kilowatt, or average power is greater than 50W, you should install an external regeneration resistor.

A NOTE ABOUT UNITS: We want a solution for power that is express in *watts*. To be consistent, we will use SI (metric) units in the following equations. If you want to use other units, apply conversion factors in the appropriate places.

Calculating Peak Power

A typical trapezoidal move profile is shown below.



Move Profile for Regeneration Calculations

Regeneration only occurs during the deceleration portion of the move. At any moment during deceleration, the amount of power regeneration is equal to the shaft power:

$$P_{shaft} = \omega T = 2\pi v T$$

where

T = torque, in newton meters (Nm)

ω = shaft velocity, in radians per second

v = shaft velocity, in revolutions per second (rps)

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Peak power regeneration occurs at the moment deceleration begins, when the velocity is highest.

$$P_{shaft(peak)} = 2\pi v_{max} T$$

Not all of this peak power must be dissipated in the power resistor. Some of it will be dissipated in the copper windings of the motor—these power losses are known as *copper losses*.

$$P_{copper} = I^2 R = \tfrac{3}{2}\left(\frac{|T|}{k_T}\right)^2 R$$

where

I = motor current, in amps *(A)*

R = line – to – line motor resistance, in ohms *(Ω)*

k_t = motor torque constant, in newton meters per amp rms *(Nm / A rms)*

Power is also dissipated in the drive itself—these losses are known as *drive losses*. (Notice that we use the absolute value of the torque.)

$$P_{drive} = 5\sqrt{2}\left(\frac{|T|}{k_T}\right)$$

The peak power dissipated in the regeneration resistor, then, is equal to the peak shaft power, less copper and drive losses.

$$P_{peak} = P_{shaft} - P_{copper} - P_{drive}$$

Substituting the values from the previous equations, we obtain the equation for calculating peak power:

$$P_{peak} = \left(2\pi v_{\max} T\right) - \tfrac{3}{2}\left(\frac{T}{k_T}\right)^2 R - 5\sqrt{2}\left(\frac{|T|}{k_T}\right)$$

Substitute values from your application into this equation.

- If P_{peak} is less than the Peak Power Dissipation Rating, the internal resistor is adequate.
- If P_{peak} is greater than the Peak Power Dissipation Rating, install an external resistor.

Calculating Average Power

Time plays a role in average power calculations. Total regenerated energy is equal to the area of the triangle under the deceleration portion of the move profile. In the move profile shown earlier, the time of deceleration is t_1. Total energy, W, is therefore:

$$W_{regen} = \tfrac{1}{2}(height)(base) = \tfrac{1}{2}\left(2\pi v_{max} T\right)t_1$$

During the deceleration time, copper losses and drive losses will dissipate some of the regenerated energy. To determine how much energy these losses will dissipate, each of these losses must be multiplied by the time t_1:

$$W_{copper} = \left[\tfrac{3}{2}\left(\frac{T}{k_T}\right)^2 R\right]t_1 \qquad W_{drive} = \left[5\sqrt{2}\left(\frac{|T|}{k_T}\right)\right]t_1$$

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The total energy that must be dissipated in the regen resistor consists of the total regenerated energy, less copper and drive losses:

$$W_{total} = \left[\tfrac{1}{2}\left(2\pi v_{\max} T\right) - \tfrac{3}{2}\left(\frac{T}{k_T}\right)^2 R - 5\sqrt{2}\left(\frac{|T|}{k_T}\right) \right] t_1$$

To find the average power, we must consider how frequently energy is "dumped" into the resistor. The period of the move profile is the time t_2. Frequency and period are related by:

$$frequency = f = \frac{1}{t_2}$$

To find the average power dissipation in the resistor, we can multiply the equation for total energy by the frequency, or, as shown below, we can divide by the period of the repetitive move profile.

Finally, we obtain the equation for average power:

$$P_{average} = \left[\tfrac{1}{2}\left(2\pi v_{\max} T\right) - \tfrac{3}{2}\left(\frac{T}{k_T}\right)^2 R - 5\sqrt{2}\left(\frac{|T|}{k_T}\right) \right] \frac{t_1}{t_2}$$

Substitute values from your application into this equation.

- If $P_{average}$ is less than the Continuous Power Dissipation Rating, the internal resistor is adequate.
- If $P_{average}$ is greater than the Continuous Power Dissipation Rating, install an external resistor.

Installing an External Regeneration Resistor

If you install an external resistor, ensure that it is adequately mounted and cooled. The internal resistor is cooled by the APEX615n's fan. The external resistor should be maintained at the same temperature, or cooler, as the internal resistor. Excessive heating of the external resistor can cause component failure.

CAUTION

Adequately cool the external resistor. Forced air cooling may be required. Maintain resistor temperature at same or lower temperature as internal resistor.

Specifications for the internal resistor are as follows:

APEX6151:

- Resistor Size and Type — 150 ohm, 95 watt, 5% non-inductive resistor:
- Manufacturer Name: — Dale
- Manufacturer Part Number: — NHL-95-16N 150 OHM 5%, 3/16 QUICK CONNECT
- Compumotor Part Name — APEX10 REGEN KIT

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APEX6152: (for reference only: do not install external resistor)

- Resistor Size and Type — 50 ohm, 100 watt, 5% non-inductive resistor:
- Manufacturer Name: — Memcor-Truohm Inc.
- Manufacturer Part Number: — FRV01006-2500-QM-NI ("NI " - Non Inductive)
- Mounting Bracket: — Memcor-Truohm Inc. Part Number 1141-006-001

APEX6154:

- Resistor Size and Type — 25 ohm, 100 watt, 5% non-inductive resistor:
- Manufacturer Name: — Memcor-Truohm Inc.
- Manufacturer Part Number: — FRV01006-2250-QM-NI ("NI " - Non Inductive)
- Mounting Bracket: — Memcor-Truohm Inc. Part Number 1141-006-001
- Compumotor Part Name — APEX40 REGEN KIT

Use these, or an equivalently rated resistors, for your external resistor. Be sure to specify a *non-inductive* resistor.

To connect the external resistor, wire its two terminals to **V BUS+** and **Regen Resistor**, located on the motor connector. Do not install more than one external resistor. The regeneration control circuit will automatically dissipate half of the excess regenerated power in the external resistor (provided that it is the the value indicated above).

CAUTION

Do not install more than one external regeneration resistor with the APEX6151 or APEX6154. Do not install an external regeneration resistor with the APEX 6152.

Building Your Own Regeneration Circuit

If you need more continuous power dissipation than the internal and external resistors provide for the APEX6151 and APEX6154, or the internal resistor provides for the APEX6152, you can design and build your own network of external regeneration resistors.

The next table shows specifications for maximum continuous and peak dissipation that the APEX615n can sustain. It also shows the minimum resistance for an external network. Do not use a resistor network with less resistance than the values in this table.

	Continuous Power Dissipation	Peak Power Dissipation	Resistance (min.)
APEX6151	286 W	2080 W	75 ohms
APEX6152	1560 W	3112 W	50 ohms
APEX6154	5760 W	12480 W	12.5 ohms

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The APEX615n controller/drive's internal IGBT power switch is the component that determines the above specifications. With the standard external resistors discussed previously, the switch is already at its peak power dissipation level. However, the switch can dissipate more continuous power than the standard resistors allow. Your network, therefore, can dissipate additional continuous power, but must not dissipate more peak power. This is shown in the table above.

To use an external network, you must take the following two steps.

1. Set DIP Switch 1, position #1, in the ON position. This disables the APEX615n's Regen Fault circuit.
2. Disconnect the internal regeneration resistor.

Step 2 above requires opening the APEX615n's cover. Please call Compumotor's Application Engineering Department (see the inside front cover of this Installation Guide for the toll free number) for instructions on opening the cover and disconnecting the resistor, and to obtain information about designing your external resistor network.

Sharing the High Voltage Power Bus, using *V Bus+* and *V Bus–*

In some applications with multiple APEX615n units, one or more may continuously receive regenerated power from their loads. For example, in a tensioning application, two APEX615n units apply tension (opposite torques) to a single moving load. In this situation, one APEX615n could receive substantial regenerated power from its motor.

In such applications, you can connect the power buses from the APEX615n in parallel, through the **V BUS+** and V **BUS–** terminals, located on the motor connector. With the buses connected in parallel, the regenerated power from one APEX615n is dissipated by the power consumption of the other. Otherwise, all of the regenerated power would be continuously dumped into the APEX615n's own internal resistor.

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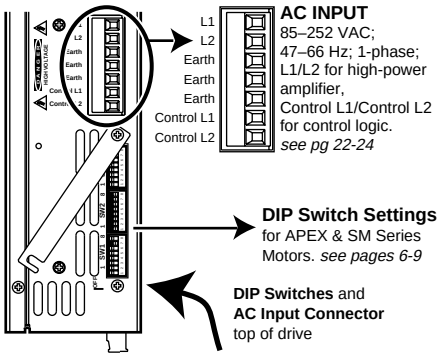
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APEX6151 Servo Controller/Drive Quick Reference

TROUBLESHOOTING TIPS

- **TO ALLOW MOTION:**
  - – Power must be on. (Is at least one LED on?)
  - – ENABLE IN must be grounded.
  - – Connect (or disable) limits. LH (LHØ) command.
  - – Set (or disable) position error. SMPER (SMPERØ)
  - – Set reasonable gains for system. (*see Tuning*)
  - – Check encoder (TPE); increments for CW move?
  - – Check A, V, D. (If D = Ø, no motion will occur.)
- **EXAMINE LEDs** for indication of problem. *pg 60*
- **PROBLEM REPORT:** TAS command reports problems. TFS command reports Following status.
- **INPUTS or OUTPUTS not working:** Programmable input (INFNC) functions and drive fault detection will not operate until you enable input functions with the INFEN1 command.

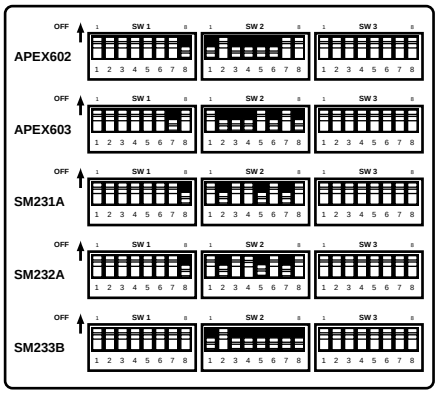
  Programmable output (OUTFNC) functions will not operate unless enabled with OUTFEN1 command.

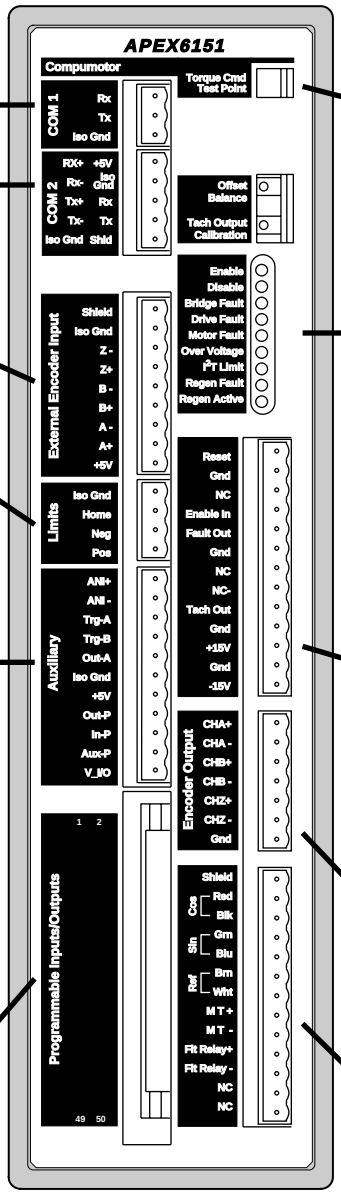


AC INPUT
85–252 VAC; 47–66 Hz; 1-phase; L1/L2 for high-power amplifier, Control L1/Control L2 for control logic.
see pg 22-24

DIP Switch Settings
for APEX & SM Series Motors. *see pages 6-9*

DIP Switches and **AC Input Connector**
top of drive





COM 1

Set-up: 9600 baud, 8 data bits,1 stop bit, no parity, full duplex. *pages 25*

COM 2

Connections – see pages 25 & 32
Configuring for RS-485 – see page 10

EXTERNAL ENCODER INPUT

Optically isolated. Encoder must be: Incremental; 2-ph. quadrature;differential (recommended) or single-ended; HCMOS compatible*; Max. freq.=1.2MHz; Min. between transitions = 833 ns. *see page 26*

LIMITS

Home, Pos, Neg: V_I/O sets switching voltage levels; internal 6.8 KΩ pull-ups through AUX-P to 5V or ext. 0–24V supp. *see pg 27*

AUXILIARY

Name	Description
ANI+ **ANI–**	Analog Input. Not applicable.
TRG-A	Input #17. Optically isolated. Internal 6.8 KΩ pull-ups through AUX-P to 5V or external 0–24V. *see pg 28.* Use for position capture input (INFNC).
TRG-B	General purpose input #18. Otherwise same as Trg-A.
OUT-A	Output #9. Use for output on position (OUTFNC). Circuit identical to prog. outputs. *pg 28, 29*
Iso GND	Isolated ground. *see pg 18,19*
+5V	Connect to OUT-P, IN-P, and/or AUX-P to power I/O. 100mA limit. *see pg 27, 28, 30, 31*
OUT-P	Pull-up resistors for prog.outputs and OUT-A. *pg 29, 31*
IN-P	Pull-up resistors for programmable inputs. *pg 29, 31*
AUX-P	Pull-up resistors for Home, Neg, Pos, Trg-A/B. *pg 27, 28, 30*

Connect **V_I/O**, **Out-P**, **In-P**, **Aux-P** to +5V for HCMOS compatability.* Connect to 0 – 24V supply for other compatibility. *pg 5, 6, 27-31*

PROGRAMMABLE I/O

Pin	I/O Number	Pin	I/O Number
1	Input #16	25	Input #8
3	Input #15	27	Input #7
5	Input #14	29	Input #6
7	Input #13	31	Input #5
9	Input #12	33	Output #4
11	Input #11	35	Output #3
13	Input #10	37	Output #2
15	Input #9	39	Output #1
17	Output #8	41	Input #4
19	Output #7	43	Input #3
21	Output #6	45	Input #2
23	Output #5	47	Input #1
		49	+5VDC

Even numbered pins connect to ISO GND.

I/O are optically isolated**; HCMOS compatible.* Plug is compatible with OPTO-22.

INPUTS: Connect internal 6.8KΩ pull-ups through In-P to +5V or 0–24V supply.

OUTPUTS: Open-collector outputs. Connect internal 4.7KΩ pull-ups through Out-P to +5V or 0 – 24V supply.

See I/O Device Interface – pages 29-31

**HCMOS-compatibility: Low ≤ 1.0V, High ≥ 3.25V*
**Optical isolation between I/O GND and internal microprocessor ground, but not between inputs and outputs.

TEST POINT

1 volt = 2 amps commanded torque
see page 69

LEDs

Name	Description/Problem *pg 60*
Enable	Indicates drive is enabled.
Disable	Indicates drive is disabled.
Bridge Fault	Power stage overtemp. Power stage overcurrent. Motor short circuit.
Drive Fault	Control board overtemp. Undervoltage (brownout).
Motor Fault	Resolver not connected. Motor overtemperature. Motor thermostat not connected.
Over Voltage	Bus voltage exceeded 420VDC.
I^2T Limit	I^2t Limit exceeded. Drive is in foldback. Output limited to continuous current setting.
Regen Fault	Drive faulted–excessive regen.
Regen Active	Regeneration resistor on, and dissipating excess power.

DRIVE AUXILIARY CONNECTOR

RESET	Active Low, ≤1.0V *pg 34, 62*
GND	Internally isolated from EARTH terminal. *see pages 18,19*
ENABLE IN	Active Low, ≤1.0V *pg 35, 63*
FAULT OUT	Active HIGH (floats if faulted) (Output is held low if no fault) *page 35*
TACH OUT	1V/1000 rpm for 1-speed resolver. Scale by DIP SW3-#5 *page 36, 70*
±15V	15 mA at ±15V *page 36*

ENCODER OUTPUT

Counts/Rev:	1024 counts, pre-quadrature 4096 counts, post-quadrature
CW Rotation:	Ch A leads Ch B
Ch Z:	Ch Z pulse width is 90° *pg 37, 38*

RESOLVER CONNECTOR

Resolver: Resolution is 4096 counts/rev

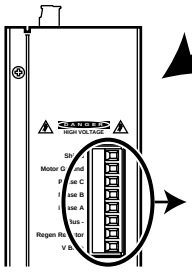
Color Code: APEX & SM Resolver Cables

	Function	APEX	SM
	Shield	------	------
Cos	Stator 3	Red	Red
Cos	Stator 1	Black	Black
Sin	Stator 2	Green	Green
Sin	Stator 4	Blue	Blue
Ref	Rotor 1	Brown	Brown
Ref	Rotor 2	White	White
Motor Temp+		Yellow	Yellow
Motor Temp–		Orange	Yellow

MT± Short MT+ to MT– if the motor has no temperature sensor *pg 41*

Flt Relay± Relay type: Normally Open
Max Current: 5A at 24VDC or 5A at 120VAC
see page 42 for more info
see Motor Braking *on pg 42-44*

MOTOR CONNECTOR
(Underneath unit)
See pages 45



Motor Cable Color Codes

	APEX	SM
Shield		
Motor Ground	Green	Green/Yellow
Phase C	Gray	Black/Yellow
Phase B	Blue	White/Yellow
Phase A	Orange	Red/Yellow
V Bus -		
Regen Resistor		
V Bus+		

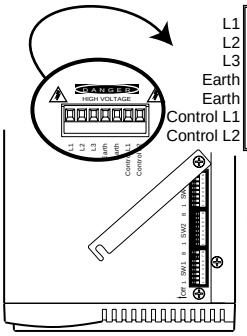
See Reverse for APEX6152 & APEX6154 Quick Reference

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APEX6152 &APEX6154 Servo Controller/Drive Quick Reference

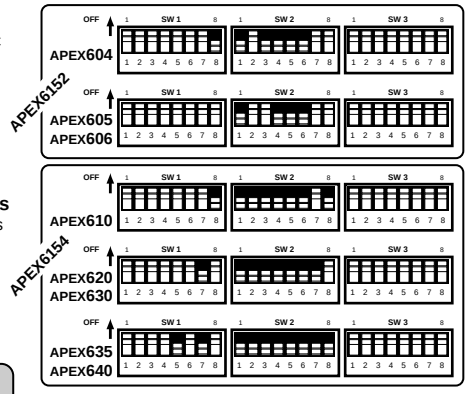
TROUBLESHOOTING TIPS

- **TO ALLOW MOTION:**
  - Power must be on. (Is at least one LED on?)
  - ENABLE IN must be grounded.
  - Connect (or disable) limits. LH (LHØ) command.
  - Set (or disable) position error. SMPER (SMPERØ)
  - Set reasonable gains for system. (*see Tuning*)
  - Check encoder (TPE); increments for CW move?
  - Check A, V, D. (If D = Ø, no motion will occur.)
- **EXAMINE LEDs** for indication of problem. *pg 60*
- **PROBLEM REPORT:** TAS command reports problems. TFS command reports Following status.
- **INPUTS or OUTPUTS not working:** Programmable input (INFNC) functions and drive fault detection will not operate until you enable input functions with the INFEN1 command.
  Programmable output (OUTFNC) functions will not operate unless enabled with OUTFEN1 command.



AC INPUT
202 – 252 VAC
47 – 66 Hz
3-ph or 1-ph
(Use L1 & L2 for 1-ph)
pg 5, 23

DIP Switch Settings
for APEX Series Motors
see page 7-9



COM 1

Set-up: 9600 baud, 8 data bits,1 stop bit, no parity, full duplex. *see page 25*

COM 2

Connections – see pages 25 & 32
Configuring for RS-485 – see page 10

EXTERNAL ENCODER INPUT

Optically isolated. Encoder must be: Incremental; 2-ph. quadrature;differential (recommended) or single-ended; HCMOS compatible*; Max. freq.=1.2MHz; Min. between transitions = 833 ns. *see page 26*

LIMITS

Home, Pos, Neg: V_I/O sets switching voltage levels; internal 6.8 KΩ pull-ups through AUX-P to 5V or ext. 0–24V supp. *see pg 27*

AUXILIARY

Name	Description
ANI+ ANI–	Analog Input. Not applicable.
TRG-A	Input #17. Optically isolated. Internal 6.8 KΩ pull-ups through AUX-P to 5V or external 0–24V. *see pg 28.* Use for position capture input (INFNC).
TRG-B	General purpose input #18. Otherwise same as Trg-A.
OUT-A	Output #9. Use for output on position (OUTFNC). Circuit identical to prog. outputs. *pg 28, 29*
ISO GND	Isolated ground. *see pg 18, 19*
+5V	Connect to OUT-P, IN-P, and/or AUX-P to power I/O. 100mA limit. *see pg 27, 28, 30, 31*
OUT-P	Pull-up resistors for prog. outputs and OUT-A. *pg 29,31*
IN-P	Pull-up resistors for programmable inputs. *pg 29, 31*
AUX-P	Pull-up resistors for Home, Neg, Pos, Trg-A, Trg-B *pg 27, 28, 30*

Connect **V_I/O**, **Out-P**, **In-P**, **Aux-P** to +5V for HCMOS compatability.* Connect to 0 – 24V supply for other compatibility. *pg 5, 6, 27-31*

PROGRAMMABLE I/O

Pin	I/O Number	Pin	I/O Number
1	Input #16	25	Input #8
3	Input #15	27	Input #7
5	Input #14	29	Input #6
7	Input #13	31	Input #5
9	Input #12	33	Output #4
11	Input #11	35	Output #3
13	Input #10	37	Output #2
15	Input #9	39	Output #1
17	Output #8	41	Input #4
19	Output #7	43	Input #3
21	Output #6	45	Input #2
23	Output #5	47	Input #1
		49	+5VDC

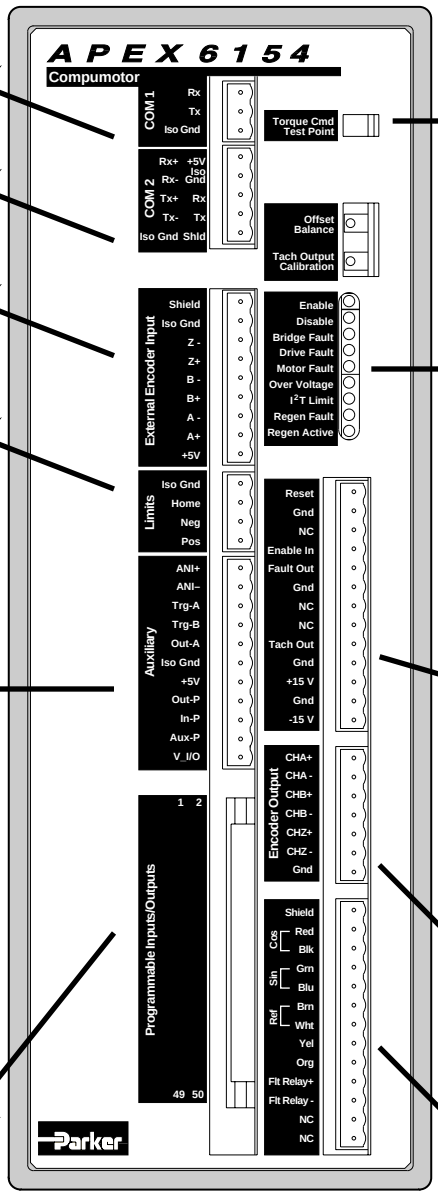
Even numbered pins connect to ISO GND.

I/O are; optically isolated; HCMOS compatible.* Plug is compatible with OPTO-22.

INPUTS: Connect internal 6.8KΩ pull-ups through In-P to +5V or 0 – 24V supply.

OUTPUTS: Open-collector outputs. Connect internal 4.7KΩ pull-ups through Out-P to +5V or 0 – 24V supply.

See I/O Device Interface – pages 29-31



TEST POINT

APEX6152	1 volt = 3 amps cmd. torque
APEX6154	1 volt = 5 amps cmd. torque *see page 69*

LEDs

Name	Description/Problem *pg 60*
Enable	Indicates drive is enabled.
Disable	Indicates drive is disabled.
Bridge Fault	Power stage overtemp. Power stage overcurrent.
Drive Fault	Motor short circuit. Control board overtemp. Undervoltage (brownout).
Motor Fault	Resolver not connected. Motor overtemperature. Motor thermostat not connected.
Over Voltage	Bus voltage exceeded 420VDC.
I2T Limit	I2t Limit exceeded. Drive is in foldback. Output limited to continuous current setting.
Regen Fault	Drive faulted–excess regen.
Regen Active	Regen resistor on, and dissipating excess power.

DRIVE AUXILIARY CONNECTOR

RESET	Active Low, ≤1.0V *pg 34, 62*
GND	Internally isolated from EARTH terminal. *see page 18, 19*
ENABLE IN	Active Low, ≤1.0V *page 35, 63*
FAULT OUT	Active HIGH (floats if faulted) (Output is held low if no fault) *page 35*
TACH OUT	1V/1000 rpm for 1-speed resolver. Scale by DIP SW3-#5 *page 36, 70*
±15V	10 mA at ±15V *page 36*

ENCODER OUTPUT

Counts/Rev:	1024 counts, pre-quadrature 4096 counts, post-quadrature
CW Rotation:	Ch A leads Ch B
Ch Z:	Ch Z pulse width is 90° *pg 37, 38*

RESOLVER CONNECTOR

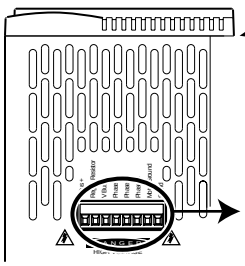
Resolver: Resolution is 4096 counts/rev

Color Code: APEX Resolver Cable

	Connector	Wire Color
	Shield	------
Cos	Stator 3	Red
Cos	Stator 1	Black
Sin	Stator 2	Green
Sin	Stator 4	Blue
Ref	Rotor 1	Brown
Ref	Rotor 2	White
	Motor Temp+	Yellow
	Motor Temp–	Orange

MT± Short MT+ and MT- if motor has no temperature sensor *pg 41*

Flt Relay± Relay type: Normally Open
Max Current: 5A at 24VDC or 5A at 120VAC
see page 42 for more info
see Motor Braking *on pg 42-44*



MOTOR CONNECTOR
(Underneath unit)
page 45

	Color Code APEX Motor Cable
V Bus +	
Regen Res / N C	
V Bus -	
Phase A	Orange
Phase B	Blue
Phase C	Gray
Motor Ground	Green & Shield
Shield	

*HCMOS-compatibility: Low ≤ 1.0V, High ≥ 3.25V
**Optical isolation between I/O GND and internal microprocessor ground, but not between inputs and outputs.

See Reverse for APEX6151 Quick Reference

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