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STM23

Hardware Manual

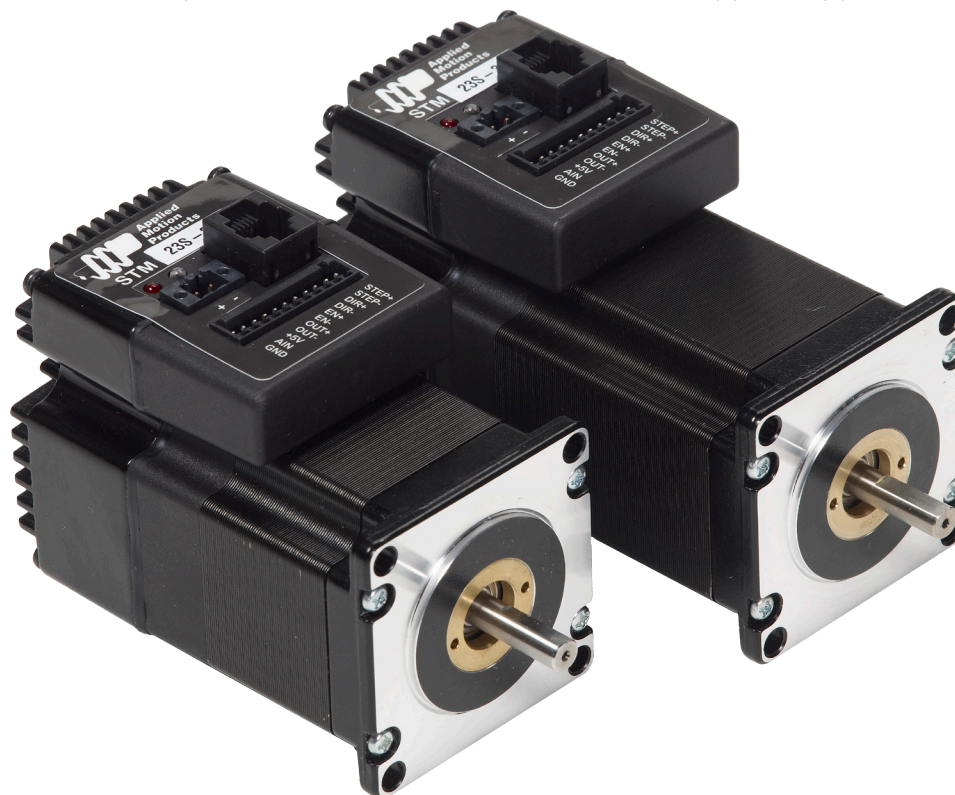


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Introduction

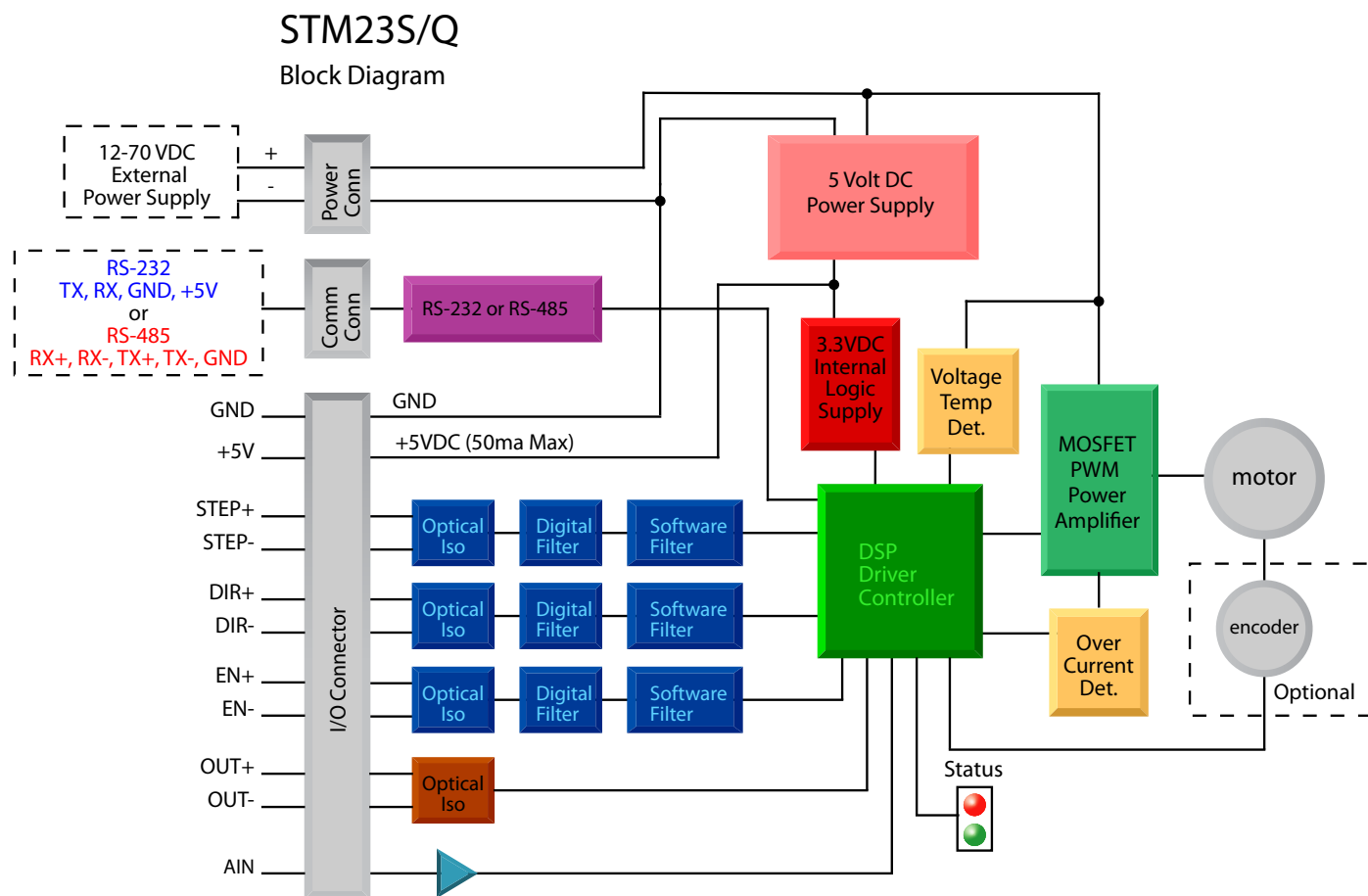
Thank you for selecting the Applied Motion Products **STM23 Motor+Drive**. We hope our dedication to performance; quality and economy will make your motion control project successful. If there's anything we can do to improve our products or help you use them better, please call or fax. We'd like to hear from you. Our phone number is (800) 525-1609, or you can reach us by fax at (831) 761-6544. You can also email support@applied-motion.com.



Features

- Programmable, micro-stepping digital Step Motor+Driver in an integrated package
- Operates from a 12 to 70 volt DC power supply
- Operates in velocity or position mode
- Mid-band anti-resonance
- Accepts analog signals, digital signals and RS-232 serial commands
- Step input signal smoothing
- RS-422/485 communication models
- Optional encoder feedback
- STM23S/Q-2 delivers up to 120 oz-in
- STM23S/Q-3 delivers up to 210 oz-in
- 3 - optically isolated, 5 to 24 volt digital inputs
- Input filtering both hardware and software
- 1 - optically isolated, 30V 40ma digital output
- 1 - 0 to 5V analog input for speed and position control

Block Diagram



I/O Configurations

STEP (5 to 24 Volts)

- : Step Input
- : Jog CW
- : Limit CW
- : Start/Stop
- : General Purpose

DIR (5 to 24 Volts)

- : Direction Input
- : Jog CCW
- : Limit CCW
- : General Purpose

EN (5 to 24 Volts)

- : Enable Input
- : Reset Input
- : Change Speed
- : General Purpose

OUT (30V, 40ma)

- : Brake Output
- : Alarm Output
- : Motion Output
- : Tach Output
- : General Purpose

Safety Instructions

Only qualified personnel are permitted to transport, assemble, commission, and maintain this equipment. Properly qualified personnel are persons who are familiar with the transport, assembly, installation, commissioning and operation of motors, and who have the appropriate qualifications for their jobs. The qualified personnel must know and observe the following standards and regulations:

IEC 364 resp. CENELEC HD 384 or DIN VDE 0100

IEC report 664 or DIN VDE 0110

National regulations for safety and accident prevention or VBG 4

To minimize the risk of potential safety problems, you should follow all applicable local and national codes that regulate the installation and operation of your equipment. These codes vary from area to area and it is your responsibility to determine which codes should be followed, and to verify that the equipment, installation, and operation are in compliance with the latest revision of these codes.

Equipment damage or serious injury to personnel can result from the failure to follow all applicable codes and standards. We do not guarantee the products described in this publication are suitable for your particular application, nor do we assume any responsibility for your product design, installation, or operation.

- Read all available documentation before assembly and commissioning. Incorrect handling of products in this manual can result in injury and damage to persons and machinery. Strictly adhere to the technical information on the installation requirements.
- It is vital to ensure that all system components are connected to earth ground. Electrical safety is impossible without a low-resistance earth connection.
- The STM23 drives contain electrostatically sensitive components that can be damaged by incorrect handling. Discharge yourself before touching the product. Avoid contact with high insulating materials (artificial fabrics, plastic film, etc.). Place the product on a conductive surface.
- During operation keep all covers and cabinet doors shut. Otherwise, there are deadly hazards that could possibly cause severe damage to health or the product.
- In operation, depending on the degree of enclosure protection, the product can have bare components that are live or have hot surfaces. Control and power cables can carry a high voltage even when the motor is not rotating.
- Never pull out or plug in the product while the system is live. There is a danger of electric arcing and danger to persons and contacts.
- After powering down the product, wait at least ten minutes before touching live sections of the equipment or undoing connections (e.g., contacts, screwed connections). Capacitors can store dangerous voltages for long periods of time after power has been switched off. To be safe, measure the contact points with a meter before touching.

Be alert to the potential for personal injury. Follow the recommended precautions and safe operating practices included with the alert symbols. Safety notices in this manual provide important information. Read and be familiar with these instructions before attempting installation, operation, or maintenance. The purpose of this section is to alert users to possible safety hazards associated with this equipment and the precautions that need to be taken to reduce the risk of personal injury and damage to the equipment.

Failure to observe these precautions could result in serious bodily injury, damage to the equipment, or operational difficulty.

Getting Started

This manual describes the use of four different drive models. What you need to know and what you must have depends on the drive model. For all models, you'll need the following:

- a 12 - 70 volt DC power supply. Please read the section entitled Choosing a Power Supply for help in choosing the right power supply.
- a small flat blade screwdriver for tightening the connectors (included).
- a personal computer running Microsoft Windows 98, 2000, NT, Me , XP or Vista.
- The Applied Motion CD (included)
- An Applied Motion programming cable (included in RS-232 Models, RS-485 converters are available from AMP)

If you've never used an STM23 drive before you'll need to get familiar with the drive and the set up software before you try to deploy the system in your application. We strongly recommend the following:

1. For -Q drives, install the *ST Configurator™* and *Q Programmer™* software applications from the CD. For S models, install the *ST Configurator™*.
2. Launch the software by clicking Start...Programs...Applied Motion...
3. Connect the drive to your PC using the programming cable. When using RS-485, it must be set up in the 4-Wire configuration (See "Connecting to a host using RS-485" below).
4. Connect the drive to the power supply.
5. Apply power to the drive.
6. The software will recognize your drive, display the model and firmware version and be ready for action.

Mounting the Motor+Drive

As with any stepper motor the STM23 Drives must be mounted so as to provide maximum heat-sinking and air-flow. Keep space around the Motor+Drive to allow convected air-flow.

- **Never use your drive in a space where there is no air flow or where other devices cause the surrounding air to be more than 40°C.**
- **Never put the drive where it can get wet or where metal or other electrically conductive particles can get on the circuitry.**
- **Always provide air-flow around the drive.**

Choosing a Power Supply

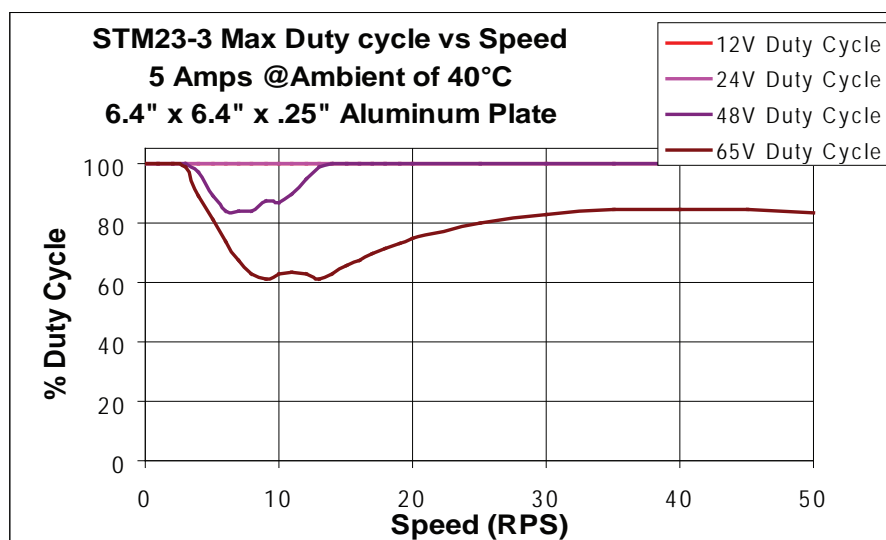
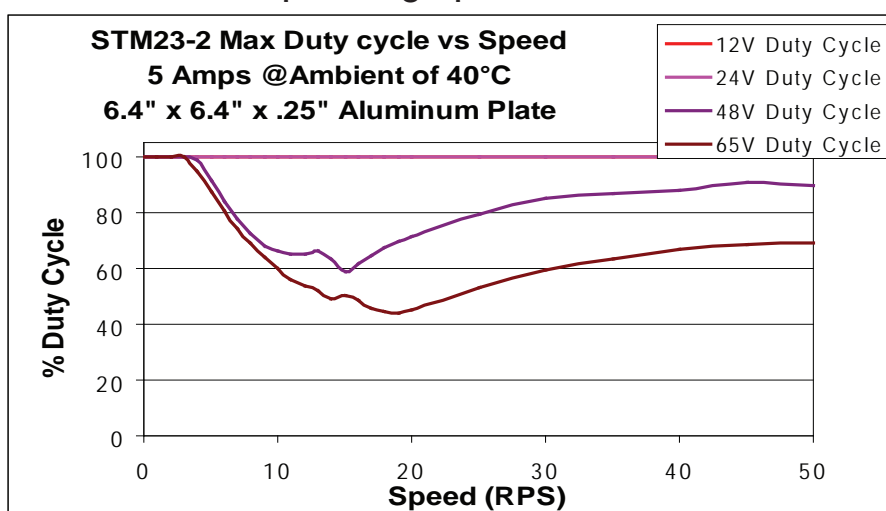
When choosing a power supply, there are many things to consider. If you are manufacturing Equipment that will be sold to others, you probably want a supply with all the safety agency approvals. If size and weight are an issue use a switching supply.

You must also decide what size of power supply (in terms of voltage and current) is needed for your application.

Voltage

The STM23 series drives are designed to give optimum performance between 24 and 48 volts DC. Choosing the voltage depends on the performance needed and Motor+Drive heating that is acceptable and/or does not cause a drive over-temperature. Higher voltages will give higher speed performance but will cause the Motor+Drive to operate at higher temperatures. Using power supplies with voltage outputs that are near the drive maximum may reduce the operational duty-cycle significantly. See the chart below to determine thermal performance at different power supply voltages

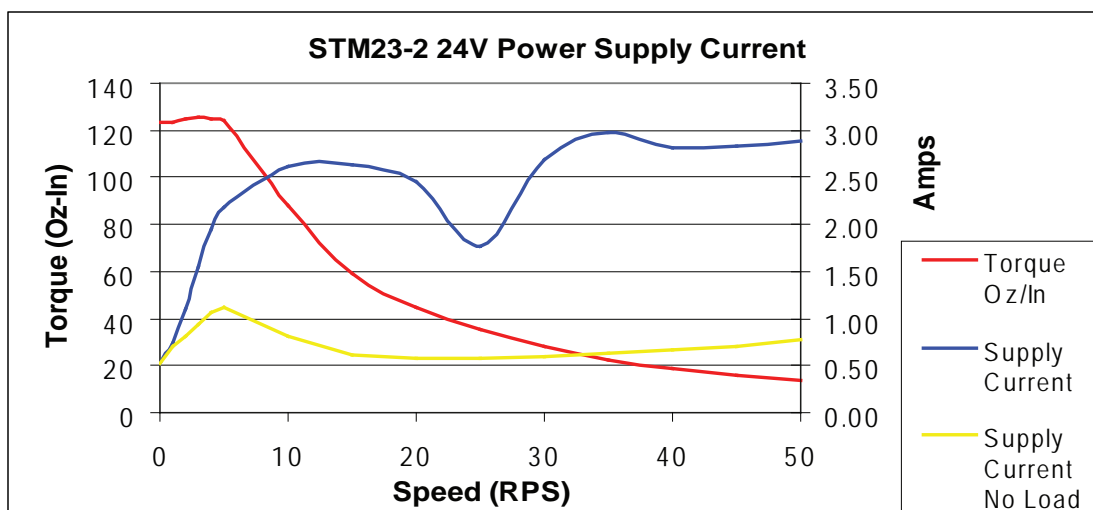
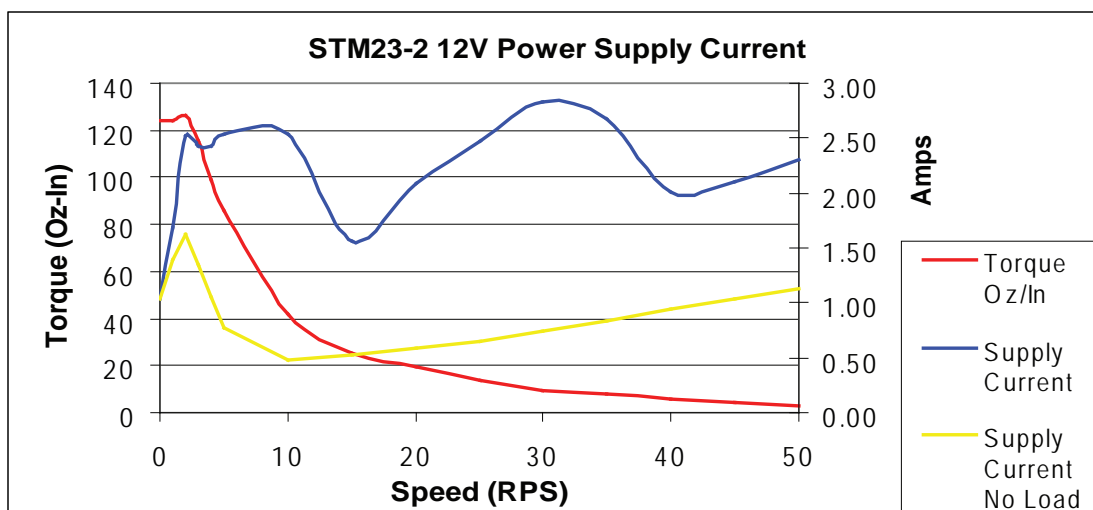
If you choose an unregulated power supply, make sure the no load voltage of the supply does not exceed the drive's maximum input voltage specification.

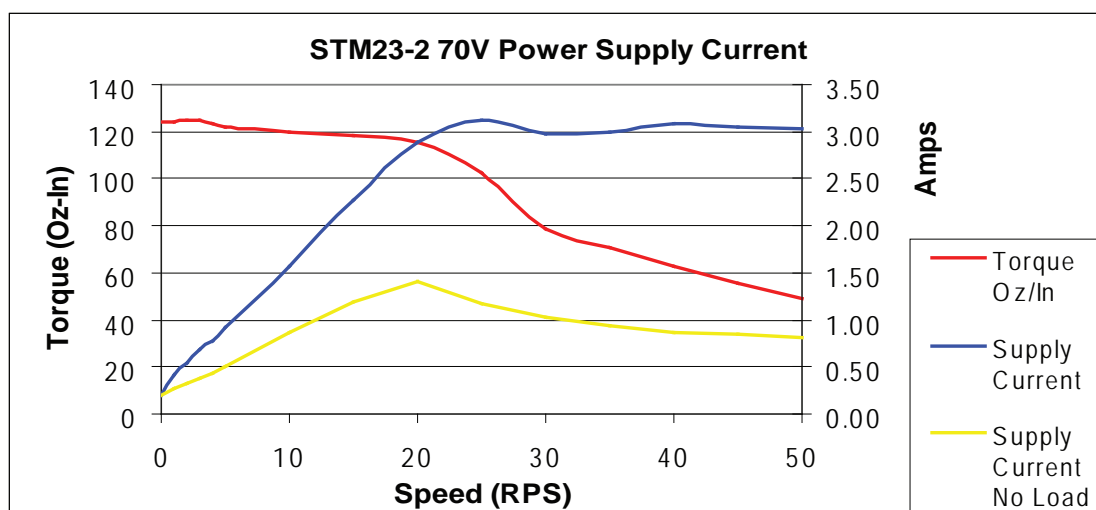
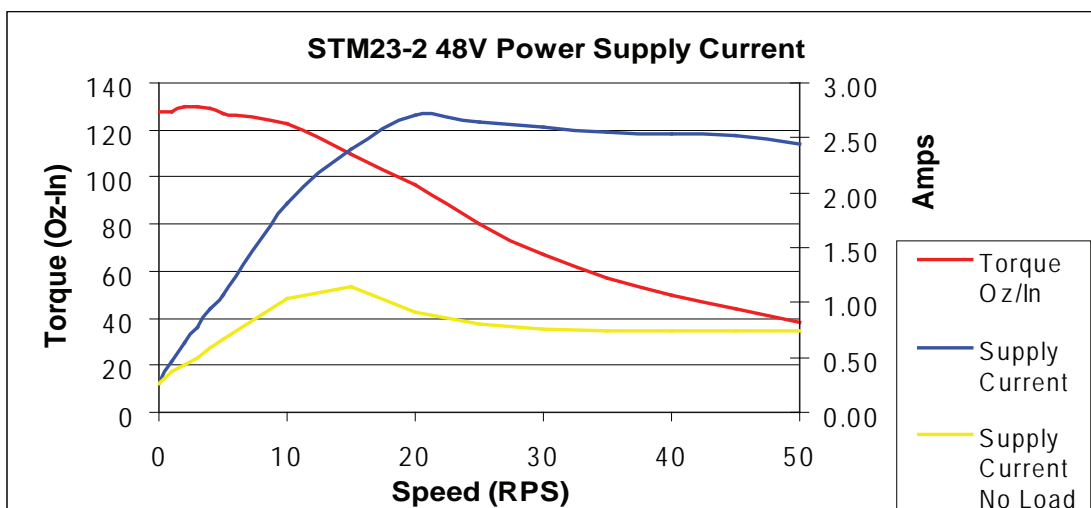


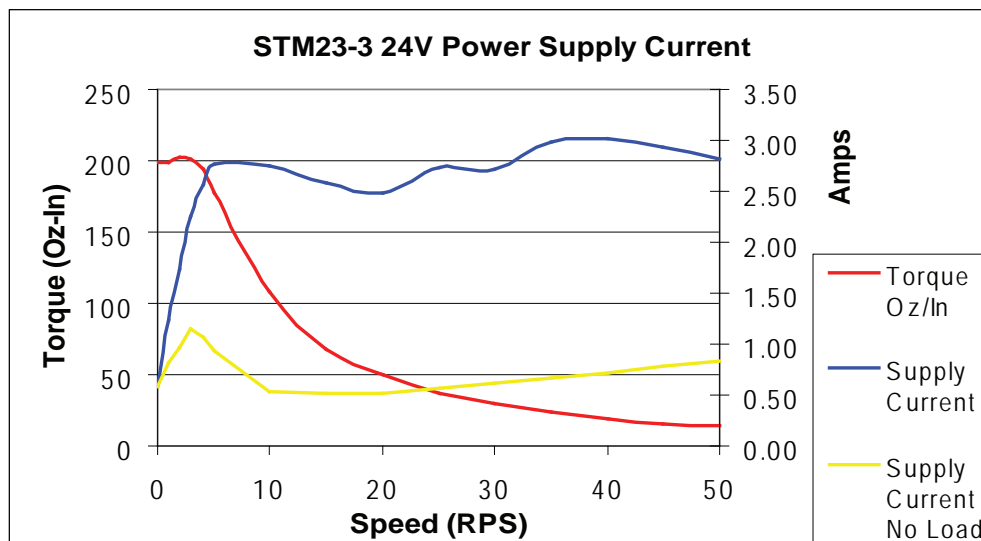
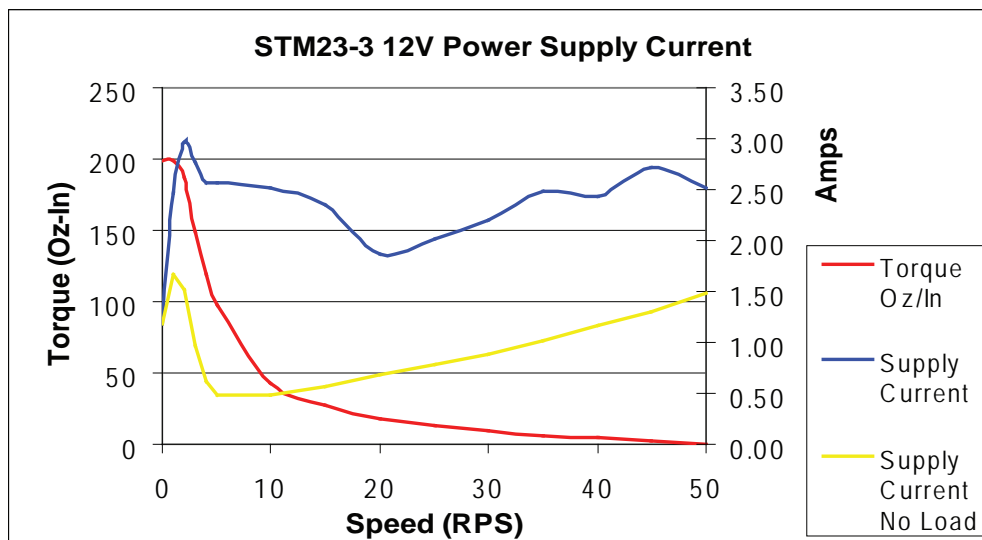
Current

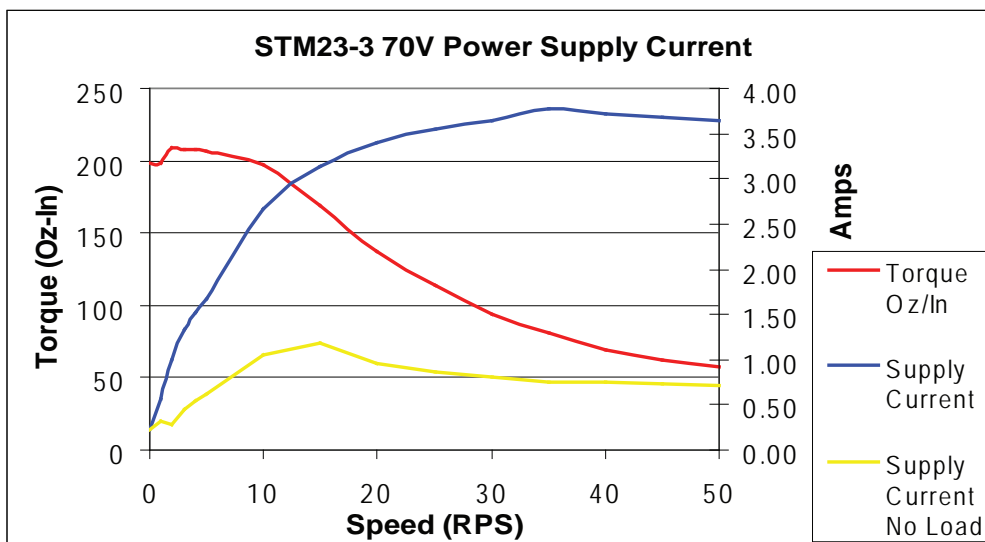
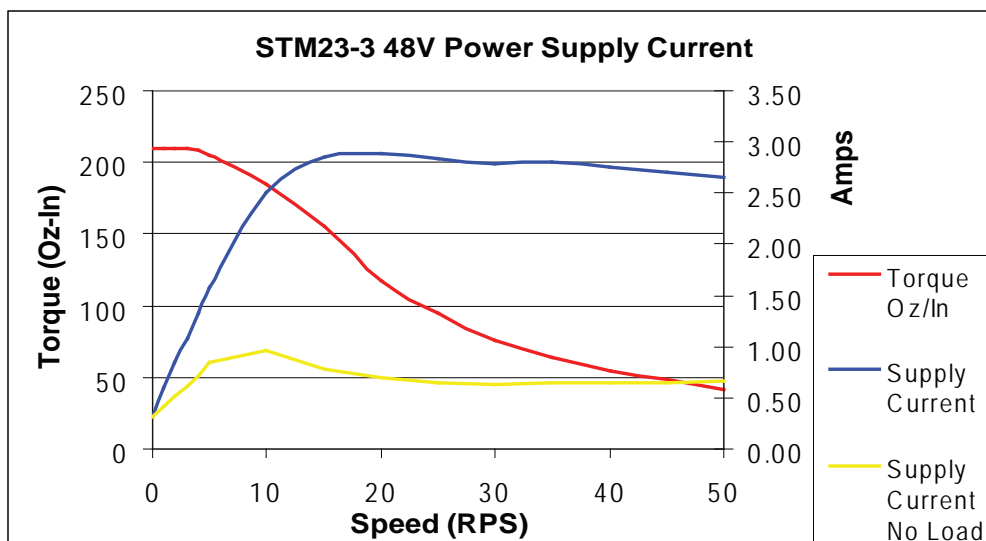
The maximum supply currents required by the STM23 Series Motor+Drives are shown in the chart below with different power supply voltage inputs. You will note in the chart that the Motor+Drive does not draw as much current as what the motor operates at. That's because the STM drives use switching amplifiers, converting a high voltage and low current into lower voltage and higher current. The more the power supply voltage exceeds the motor voltage, the less current you'll need from the power supply.

Also note that the current draw is significantly different at higher speeds depending on the torque load to the motor. Estimating your current needs may require a good analysis of the load the motor will encounter.





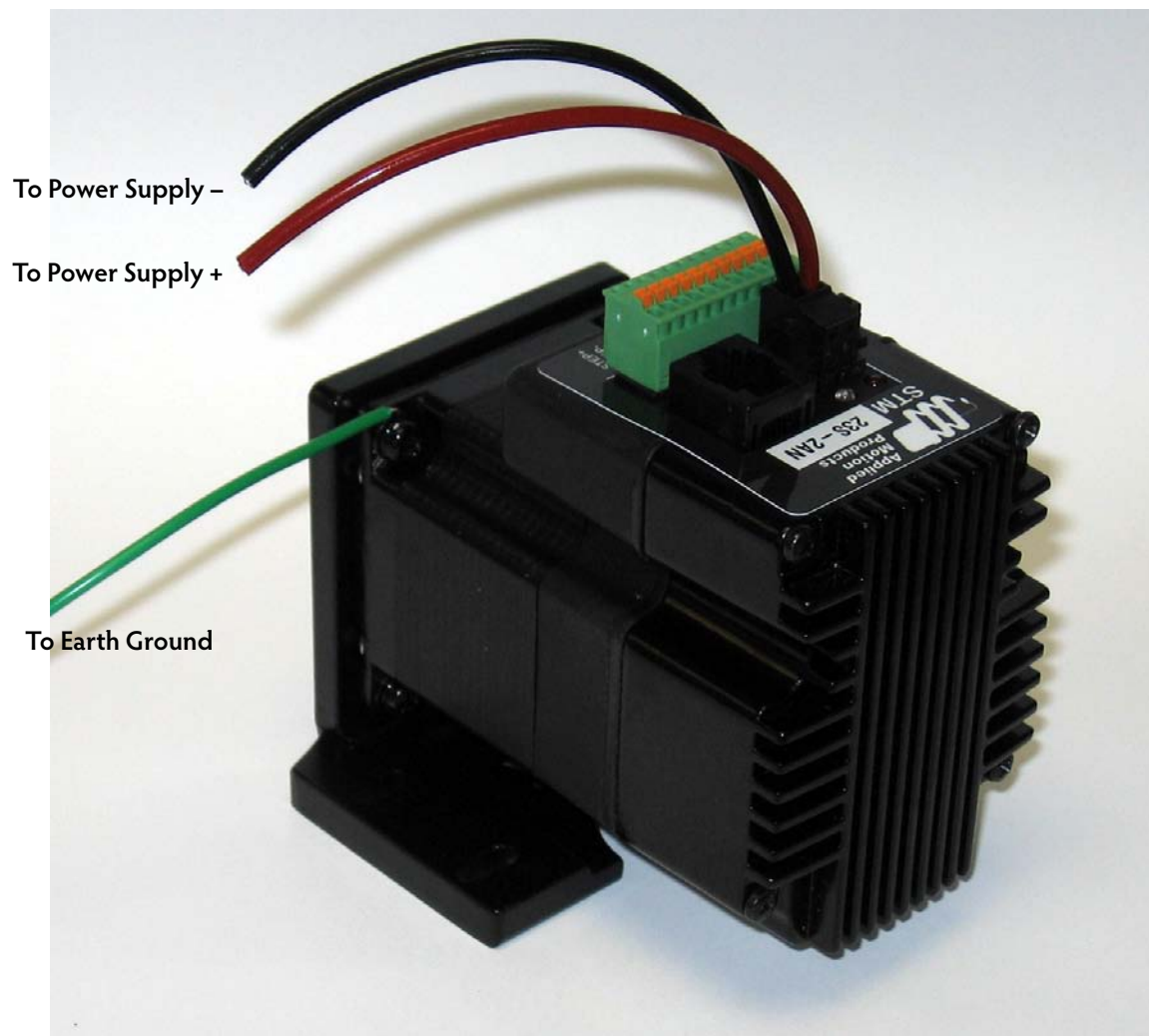




Connecting the Power Supply

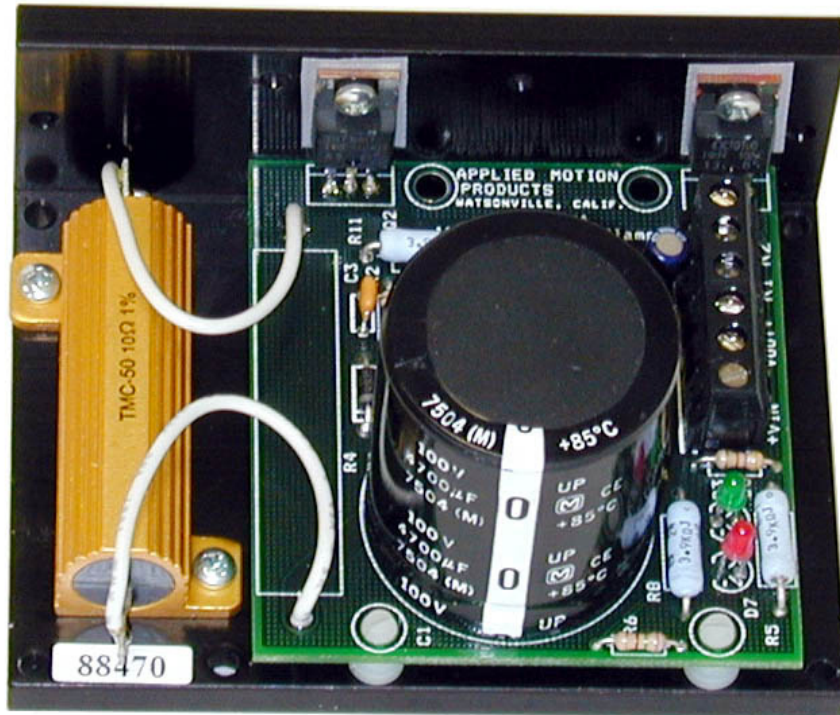
If you need information about choosing a power supply, please read "Choosing a Power Supply" located above in this manual.

Connect the motor power supply "+" terminal to the driver terminal labeled "+". Connect power supply "-" to the drive terminal labeled "-". Use 16 to 20-gauge wire. The STM23 drives contain an internal fuse that connect to the power supply + terminal. This fuse is not user replaceable. If you want to install a user serviceable fuse in your system install a 4 amp fast acting fuse in line with the + power supply lead.



Be careful not to reverse the wires. Reverse connection may open the internal fuse on your driver and void your warranty.

If you plan to use a regulated power supply you may encounter a problem with regeneration. If you rapidly decelerate a load from a high speed, much of the kinetic energy of that load is transferred back to the power supply. This can trip the over-voltage protection of a switching power supply, causing it to shut down. We offer the RC050 "regeneration clamp" to solve this problem. If in doubt, buy an RC050 for your first installation. If the "regen" LED on the RC050 never flashes, you don't need the clamp.



RC050 Regen Clamp

Connecting the STM23

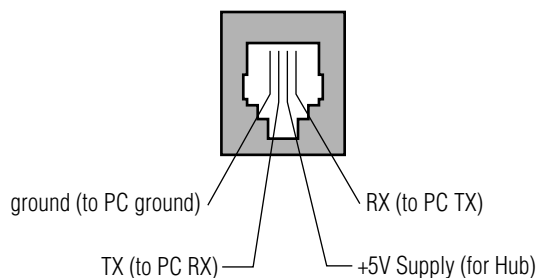
Connecting to the PC using RS-232

- Locate your computer within 8 feet of the drive.
- Your drive was shipped with a communication cable. Plug the large end into the serial port of your PC and the small end into the PC/MMI jack on your drive. Secure the cable to the PC with the screws on the sides.

Never connect a drive to a telephone circuit. It uses the same connectors and cords as telephones and modems, but the voltages are not compatible.

If your PC does not have a serial port, you should purchase a "USB Serial Converter". We have had good results with the Port Authority "USB Serial DB9" Adapter from www.CablesToGo.com and with the SW1301 from www.SewellDirect.com.

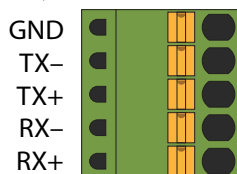
For laptops, a PCMCIA converter card is a good choice. Our applications engineers use the SSP-100 from Sewell Direct.



**Pin Assignments of the PC/MMI Port
(RJ11 connector)**

Connecting to a host using RS-485

RS-485 allows you to connect more than one drive to a single host PC, PLC, HMI or other computer. It also allows the communication cable to be long (more than 1000 feet). But the device to which you connect must have an RS-485 port



Pin diagram is shown above. Wiring diagrams can be found on the next page. We recommend the use of Category 5 cable. It is widely used for computer networks, it is inexpensive, easy to get and certified for quality and data integrity.

The STM23 drives can be used with either two-wire or four-wire RS-485 implementations, however with using *ST Configurator* the drives must be connected in the four-wire configuration. The connection can be point to point (ie. one drive and one host) or a multi-drop network (one host and up to 32 drives).

Four-Wire Systems utilize separate transmit and receive wires. One pair of wires must connect the host computer's transmit signals to each drive's RX+ and RX- terminals. Another pair connects the TX+ and TX- drive terminals to the host computer's receive signals. A logic ground terminal is provided on each drive and can be used to keep all drives at the same ground potential. This terminal connects internally to the DC power supply return (V-), so if all the drives on the RS-485 network are powered from the same supply it is not necessary to connect the logic grounds. You should still connect one drive's GND terminal to the host computer ground.

Four-wire systems are better than two-wire types because the host never needs to disable its transmitter, which simplifies your software. Some converters make this process very difficult to implement and can delay communications.

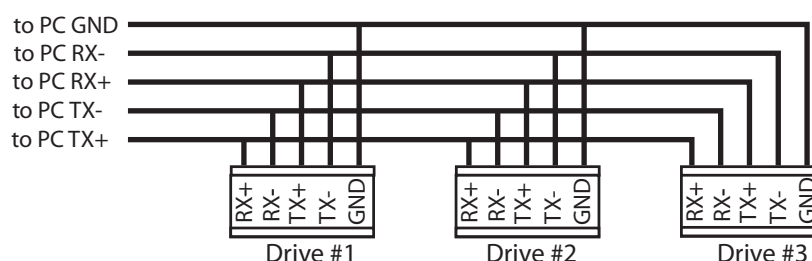
RS-232 to RS-485 4-wire Converter

Model 117701 from [Jameco Electronics](#) (800-831-4242) works well for converting your PC's RS-232 port to four wire RS-485. This adaptor is for a 25 pin serial port. If you are like most people and have a 9 pin serial port on your PC, you will also need to purchase Jameco cable 31721.

Connect as follows:

adaptor	drive
1	RX+
2	RX-
3	TX-
4	TX+

Set the switches for DCE and TxON,RxON. Don't forget to plug in the DC power adaptor that comes with the unit.



Two-Wire Systems

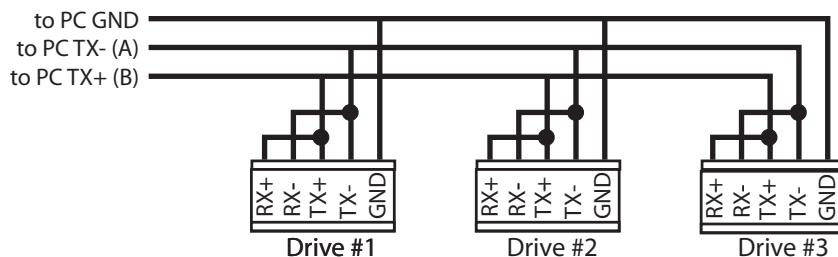
Transmit and receive on the same pair of wires can lead to trouble. The host must not only disable its transmitter before it can receive data, it must do so quickly, before a drive begins to answer a query. The ST drives include a "transmit delay" parameter that can be adjusted to compensate for a host that is slow to disable its transmitter. This adjustment can be made over the network using the TD command, or it can be set using the *ST Configurator* software. It is not necessary to set the transmit delay in a four wire system.

RS-232 to RS-485 2-wire Converter

Model 485-25E from [Integrity Instruments](http://www.integrityinstruments.com) (800-450-2001) works well for converting your PC's RS-232 port to RS-485. It comes with everything you need. Connect the adaptor's "B" pin to the STM23 drive's TX+ and RX+ terminals. Connect "A" to the drive's TX- and RX- terminals.

Converting USB to RS-485

The USB-COMi-M from www.byterunner.com is an excellent choice for USB to RS-485 conversion. Set SW1 to ON and SW2-4 to OFF. On the USB-COMi-M screw terminal connector: pin 1 goes to RX- and TX-. Connect pin 2 to RX+ and TX+. Pin 6 is ground. The DB-9 is not used.



RS-485 Two Wire System

Assigning Addresses

Before wiring the entire system, you'll need to connect each drive individually to the host computer so that a unique address can be assigned to each drive. Use the programming cable and the *ST Configurator™* software that came with your drive for this purpose.

Connect the drive to your PC and then launch the *ST Configurator™* software. Finally, apply power to your drive. If you have already configured your drive, then you should click the Upload button so that the *ST Configurator™* settings match those of your drive. Click on the Motion button, then select the "SCL" operating mode. If you have a Q drive, you may want to select "Q Programming". Either way, you'll see the RS-485 Address panel appear. Just click on the address character of your choice. You can use the numerals 0..9 or the special characters ! " # \$ % & ' () * + , - . / : ; < = > ? @ . Just make sure that each drive on your network has a unique address. If you are using a 2 wire network, you may need to set the Transmit Delay, too. 10 milliseconds works on the adapters we've tried. Once you've made your choices, click Download to save the settings to your drive.

STM23 Inputs and Outputs

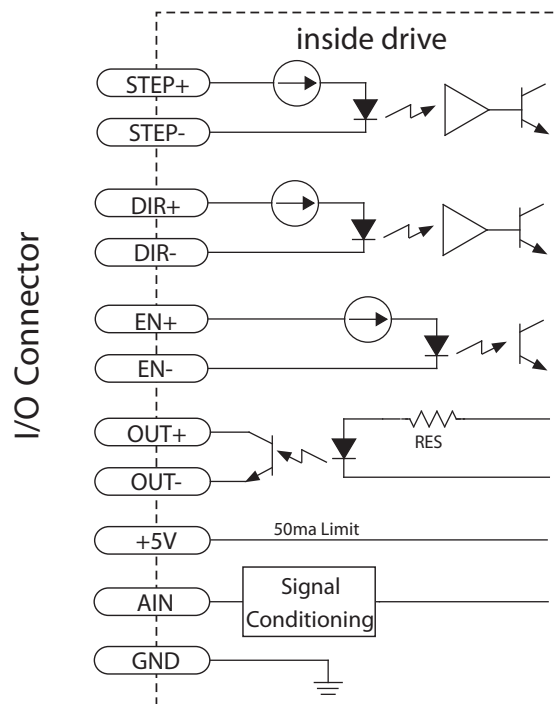
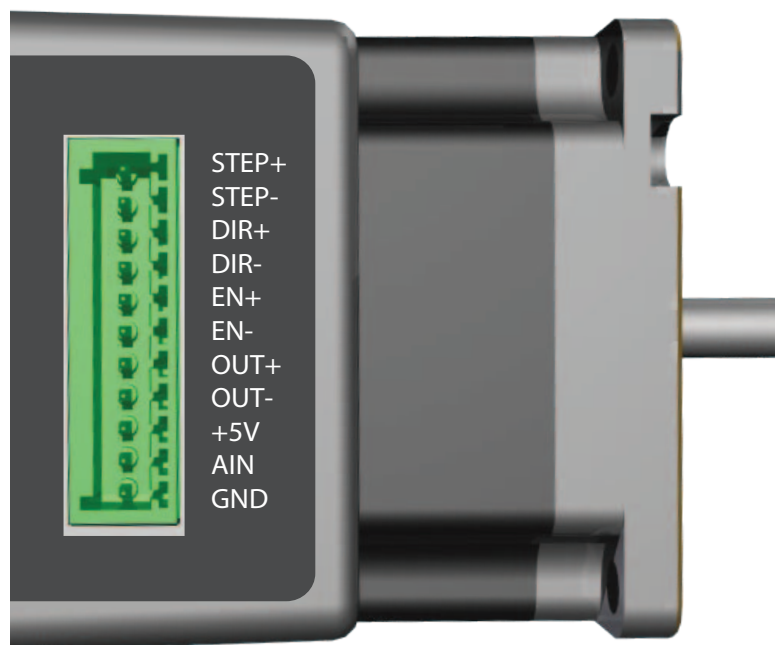
The ST drives have three types of inputs:

- High speed digital inputs for step & direction commands or encoder following, 5 to 24 volt logic
- Digital input for other signals, 5 - 24 volt logic
- Analog input for analog speed and positioning modes

All drives include 3 digital inputs and 1 analog input.

- **STEP & DIR:** digital signals for commanding position. Quadrature signals from encoders can also be used. These inputs can also be connected to sensors, switches and other devices for use with Q and Si™ commands such as Wait Input, Seek Home, Feed to Sensor, If Input and others. When not being used for the Step & Direction function these inputs can be use for CW & CCW Limit, CW & CCW Jogging and Run/Stop & Direction Velocity modes.
- **EN:** software programmable input can be used for motor enable or alarm reset. This input can also be connected to a sensor, switch and other devices for use with Wait Input, Seek Home, Feed to Sensor, If Input and other commands.
- **AIN:** analog velocity or position command signal. 0-5V with gain, filtering, offset and dead-band settings.

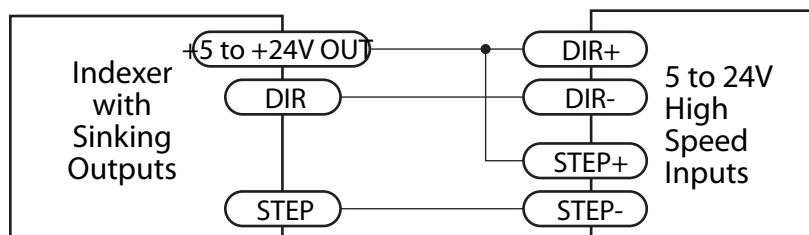
Connector Pin Diagram



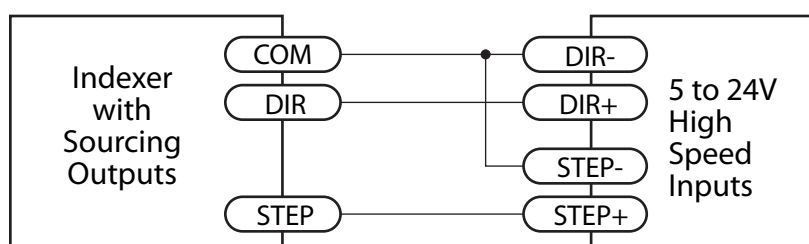
High Speed Digital Inputs

The STM23-Q and STM23-Si drives include two high-speed inputs called STEP and DIR. They accept 5 to 24 volt single-ended or differential signals, up to 2 MHz. Typically these inputs connect to an external controller that provides step & direction command signals. You can also connect a master encoder to the high-speed inputs for "following" applications. Or you can use these inputs with Wait Input, If Input, Feed to Sensor, Seek Home and other L or Q commands.

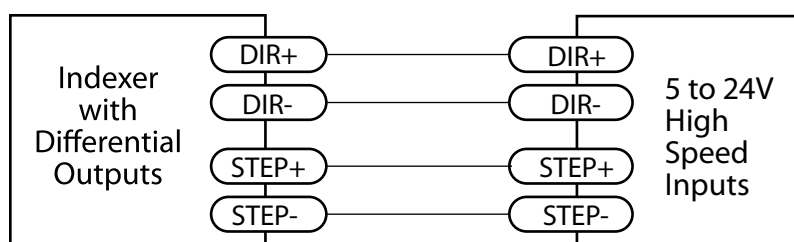
Connection diagrams follow.



Connecting to indexer with Sinking Outputs

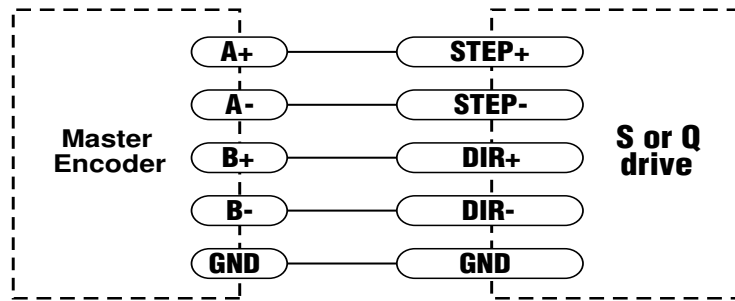


Connecting to indexer with Sourcing Outputs

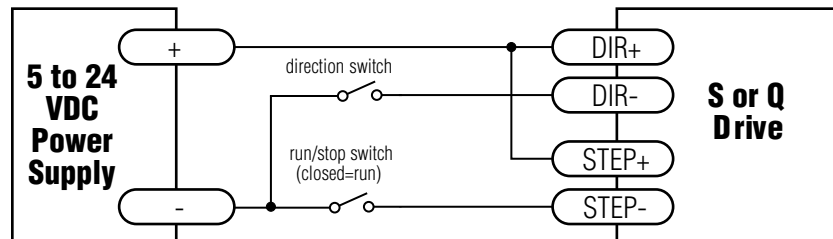


Connecting to Indexer with Differential Outputs

(Many High Speed Indexers have Differential Outputs)



Wiring for Encoder Following



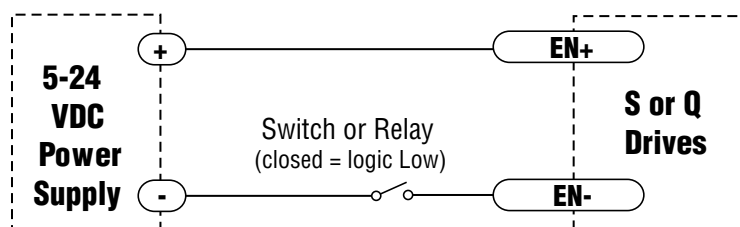
Using Mechanical Switches

The Enable (EN) Digital Input

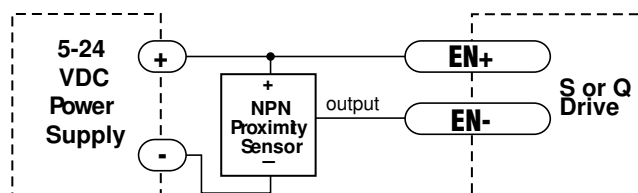
As mentioned in the previous section, the high-speed STEP and DIR inputs are designed for high speed operation. The Enable digital input is designed for low speed digital input operation between 5 and 24 volts DC.

Note: If current is flowing into or out of an input, the logic state of that input is low or closed. If no current is flowing, or the input is not connected, the logic state is high or open.

The diagrams on the following pages show how to connect the input to various commonly used devices.

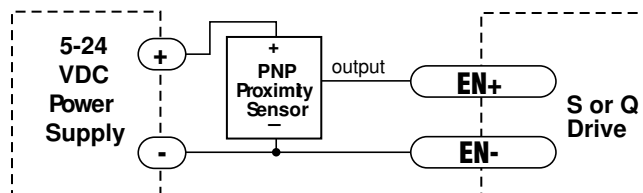


Connecting the Input to a Switch or Relay



Connecting an NPN Type Proximity Sensor to an input

(When prox sensor activates, input goes low).

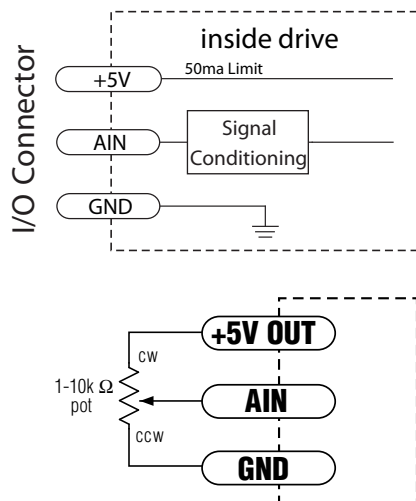


Connecting an PNP Type Proximity Sensor to an input

(When prox sensor activates, input goes low).

Analog Input

The STM23 drives feature an analog input. The input can accept a signal range of 0 to 5 VDC. The drive can be configured to operate at a speed or position that is proportional to the analog signal. Use the *ST Configurator* software to set the signal range, offset, dead-band and filter frequency. The STM23 Drives provide a +5VDC 50ma output that can be used to power external devices such as potentiometers. It is not the most accurate Supply for reference, for more precise readings use an external supply that can provide the desired accuracy.



Connecting a Potentiometer to the Analog Input

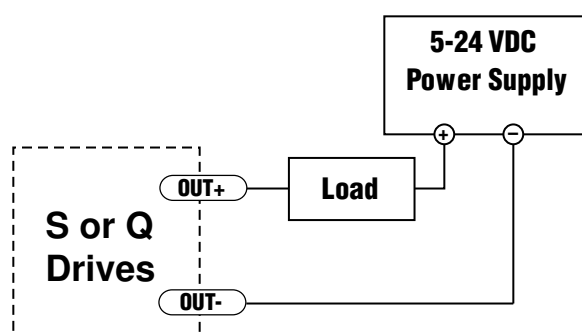
Programmable Output

The STM23 drives feature one optically isolated digital output. This output can be set to automatically control a motor brake, to signal a fault condition, to indicate when the motor is moving or to provide an output frequency proportional to motor speed (tach signal). Or the output can be turned on and off by program instructions like Set Output. The output can be used to drive LEDs, relays and the inputs of other electronic devices like PLCs and counters. The "OUT+" (collector) and "OUT-" (emitter) terminals of the transistor is available at the connector. This allows you to configure the output for current sourcing or sinking.

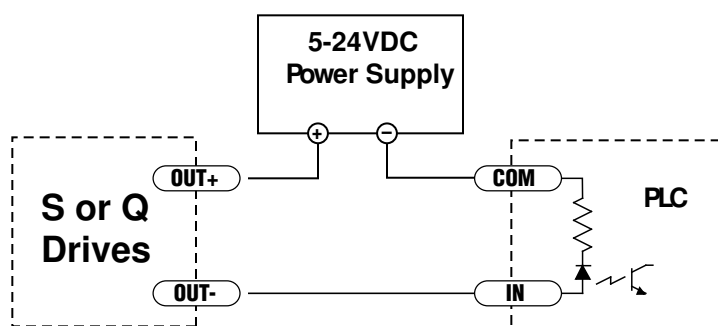
Diagrams of various connection types follow.

Do not connect the output to more than 30VDC.

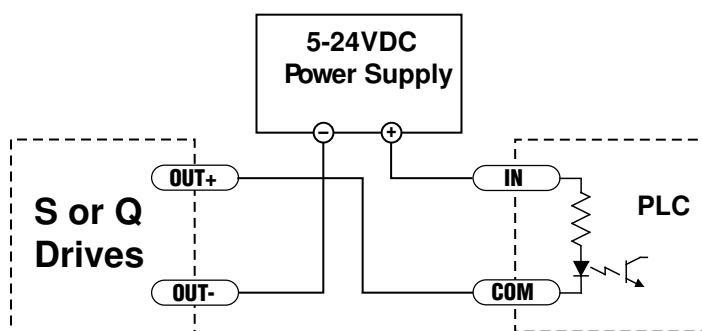
The current through the output terminal must not exceed 40mA.



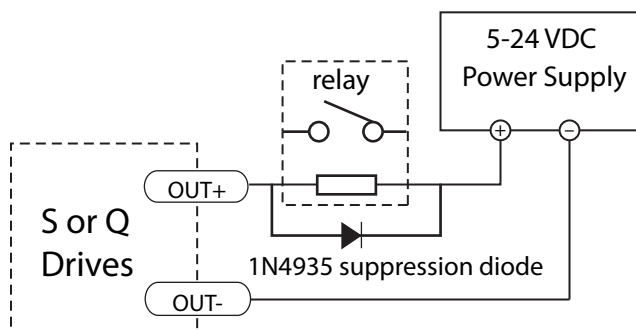
Connecting a Sinking Output



Connecting a Sourcing Output



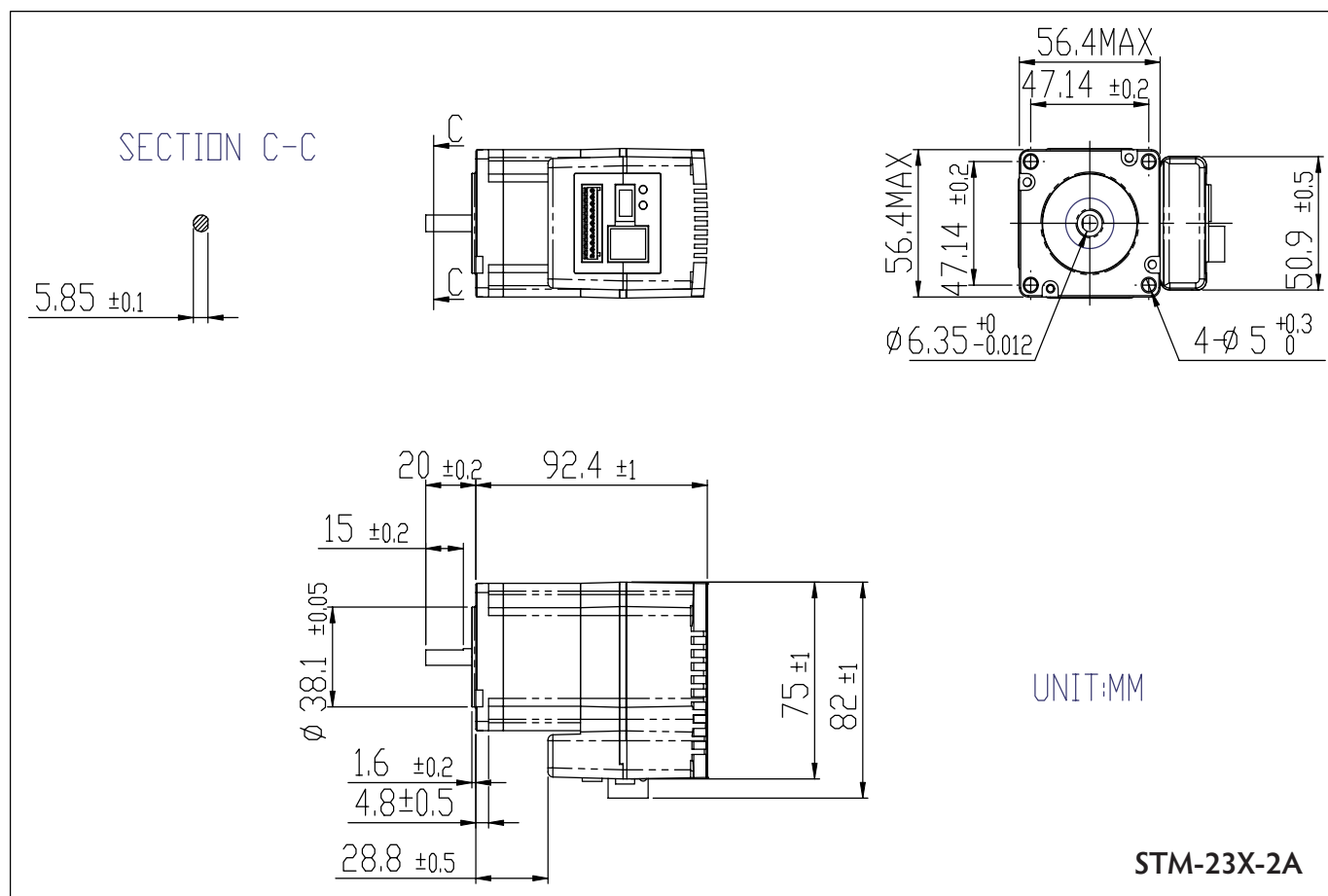
Connecting a Sourcing Output again

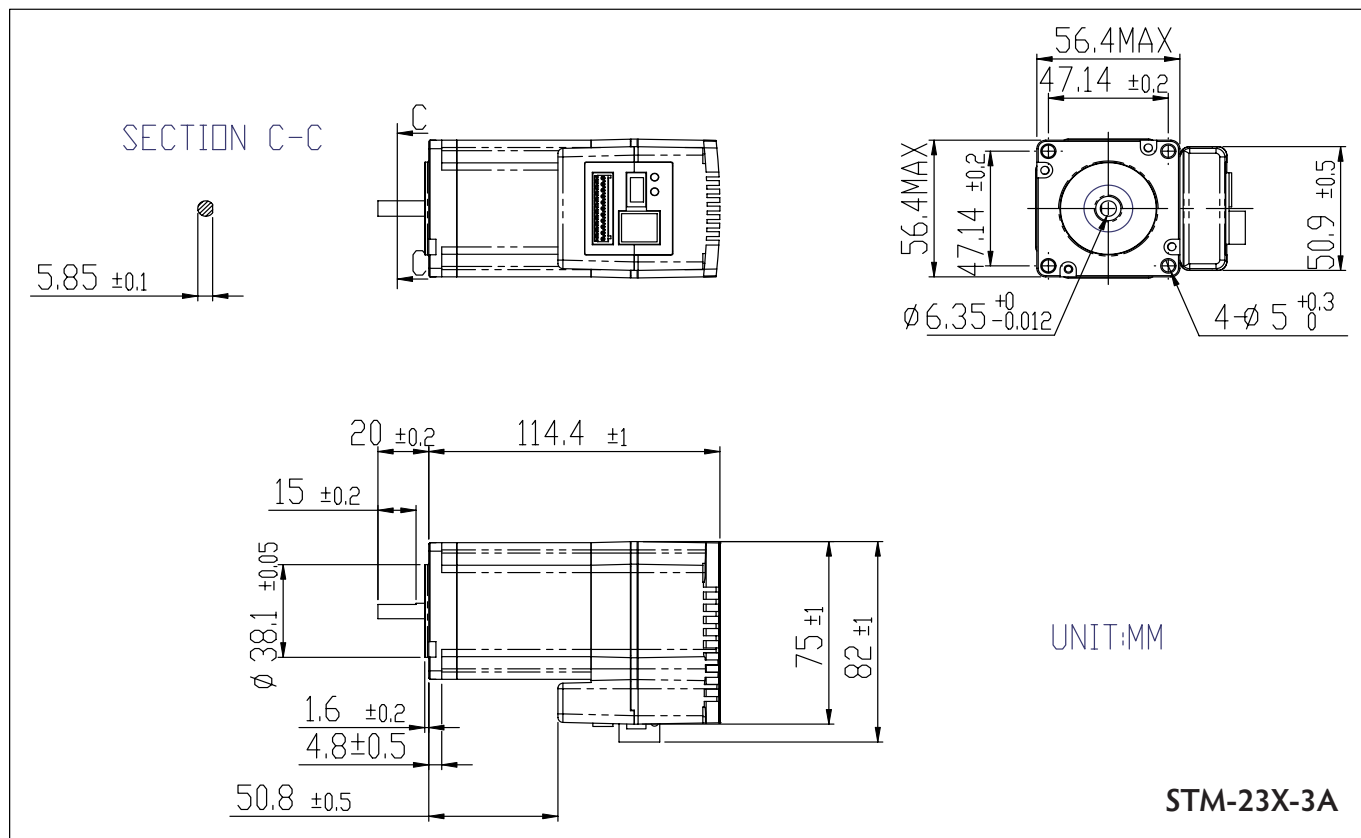
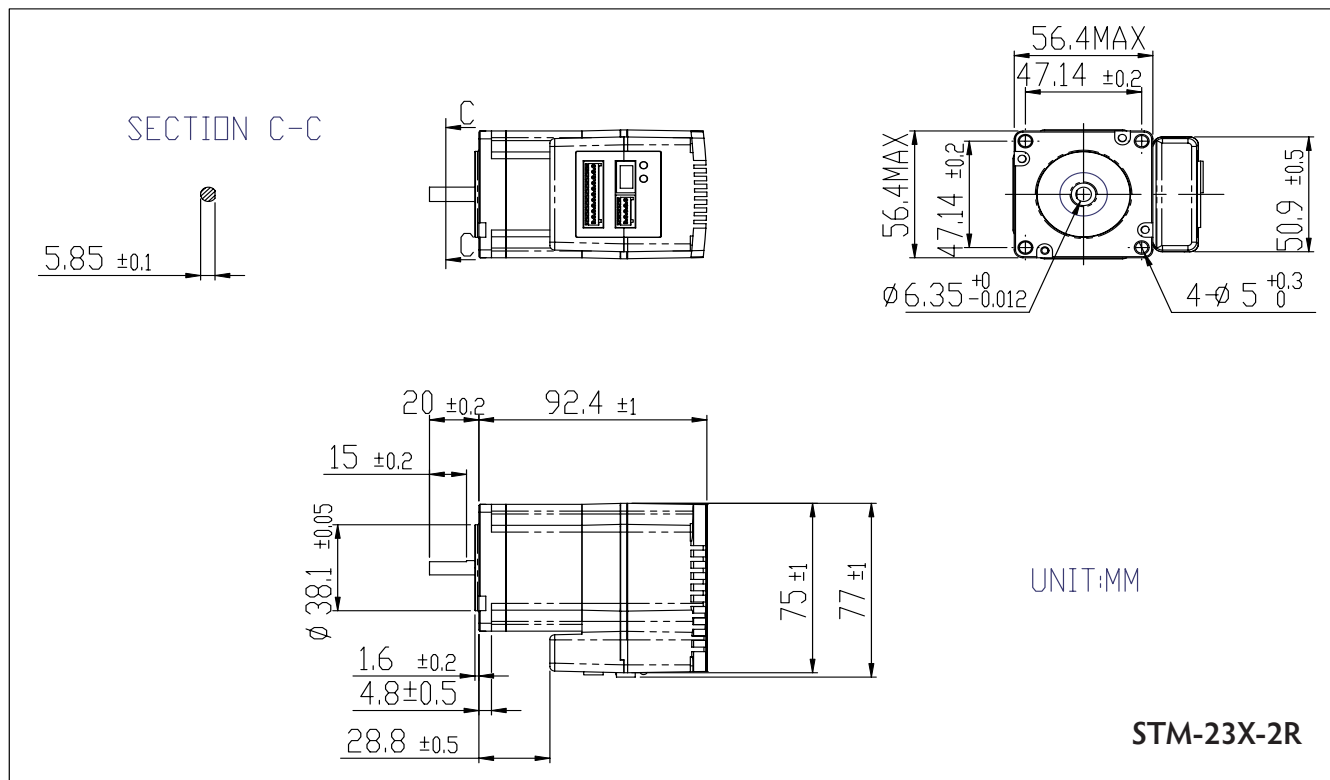


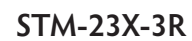
Driving a Relay

Reference Materials

Mechanical Outlines







Technical Specifications

POWER AMPLIFIER: All Models	
AMPLIFIER TYPE	Dual H-Bridge, 4 Quadrant
CURRENT CONTROL	4 state PWM at 20 KHz
OUTPUT TORQUE	STM23x-2 Series - TO 125 OZ.IN WITH SUITABLE POWER SUPPLY STM23x-3 Series - TO 210 OZ.IN WITH SUITABLE POWER SUPPLY
POWER SUPPLY	External 12 - 70 VDC Power Supply Required
INPUT Voltage RANGE	12 - 70 VDC
PROTECTION	Over-Voltage, Under-voltage, Over-Temp, Motor/wiring shorts (Phase-to-Phase, Phase-to-Ground).
IDLE CURRENT REDUCTION	Reduction range of 0 – 90% of Running Current after delay selectable in milliseconds.
AMBIENT TEMPERATURE	0 to 40°C (32 - 104°F) (mounted to suitable heatsink)
HUMIDITY	90% non-condensing.

CONTROLLER: All Models	
MICROSTEP RESOLUTION	Software selectable from 200 to 51200 steps/rev in increments of 2 steps/rev.
ANTI-RESONANCE (Electronic Damping)	Raises the system damping ratio to eliminate midrange instability and allow stable operation throughout the speed range and improves settling time.
TORQUE RIPPLE SMOOTHING	Allows for fine adjustment of phase current waveform harmonic content to reduce low-speed torque ripple in the range 0.25 to 1.5 rps
AUTO SETUP	Measures motor parameters and configures motor current control and anti-resonance gain settings
SELF TEST	Checks Internal & External Power supply voltages. Diagnoses open motor phases and motor resistance changes >40%.
MICROSTEP EMULATION	Performs high resolution stepping by synthesizing fine microsteps from coarse steps (Step & Direction Mode Only)
COMMAND SIGNAL SMOOTHING	Software configurable filtering reduces jerk and excitation of extraneous system resonances (Step & Direction Mode Only).

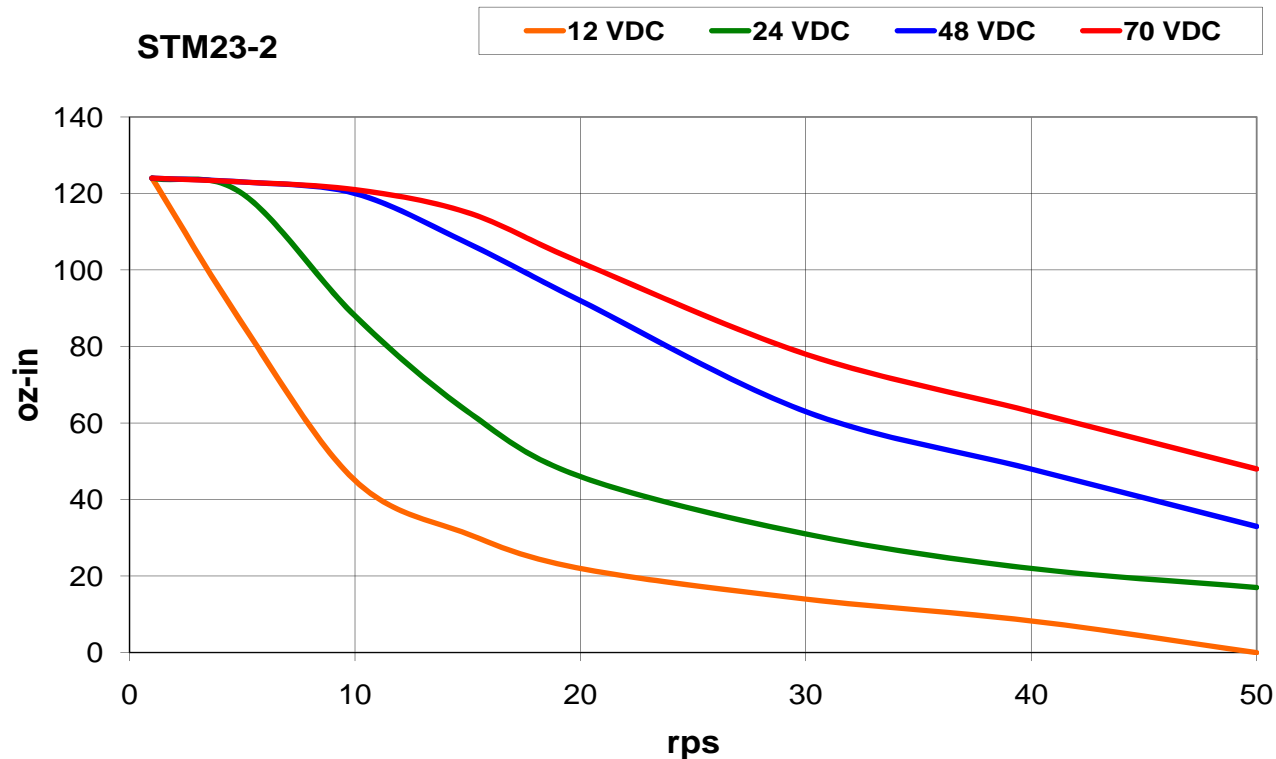
CONTROLLER: S Models	
NON-VOLATILE STORAGE	Configurations are saved in FLASH memory on-board the DSP.
MODE OF OPERATION	Step & Direction, CW/CCW, A/B Quadrature, Oscillator, Joystick, SCL, Hub.
STEP AND DIRECTION INPUTS	<p>STEP +/- Optically Isolated, 5-24 Volt. Minimum pulse width = 250 ns. Maximum pulse frequency = 3MHz. Function: Step, CW Step, A Quadrature, Encoder Following, CW Limit , CW Jog, START/STOP (Oscillator mode), General Purpose Input. Adjustable bandwidth digital noise rejection filter on all inputs</p> <p>DIR+/- Optically Isolated, 5-24 Volt. Minimum pulse width = 250 ns. Maximum pulse frequency = 3 MHz. Function: DIR, CCW Step, B Quadrature, Encoder Following, CCW Limit , CCW Jog, Sensor, DIR (Oscillator mode), General Purpose Input. Adjustable bandwidth digital noise rejection filter on all inputs</p>
ENABLE INPUT	<p>EN+/- Optically Isolated, 5-24 Volt. Minimum pulse width = 250 ns. Maximum pulse frequency = 3 MHz. Function: ENABLE, RESET , SPEED 1/SPEED 2 (Oscillator mode), General Purpose Input. Adjustable bandwidth digital noise rejection filter on all inputs</p>
OUTPUT	Optically Isolated, 30V, 40mA MAX. Function: Fault, Motion, Alarm, Tach and general purpose programmable
ANALOG INPUT RANGE	Ain Gnd Range 0 to 5VDC
ANALOG INPUT RESOLUTION	12 bits
COMMUNICATION INTERFACE	RS-232 or RS-485
+ 5 VOLT USER OUTPUT	4.8V to 5.0V @ 50ma Maximum

CONTROLLER: Q Models	
INPUTS	<p>STEP +/- Optically Isolated, 5-24 Volt. Minimum pulse width = 250 ns. Maximum pulse frequency = 3 MHz. Function: Step, CW Step, A Quadrature, Encoder Following, CW Limit , CW Jog, START/STOP (Oscillator mode), General Purpose Input. Adjustable bandwidth digital noise rejection filter on all inputs</p> <p>DIR+/- Optically Isolated, 5-24 Volt. Minimum pulse width = 250 ns. Maximum pulse frequency = 3 MHz. Function: DIR, CCW Step, B Quadrature, Encoder Following, CCW Limit , CCW Jog, Sensor, DIR (Oscillator mode), General Purpose Input. Adjustable bandwidth digital noise rejection filter on all inputs</p> <p>EN+/- Optically Isolated, 5-24 Volt. Minimum pulse width = 250 ns. Maximum pulse frequency = 3 MHz. Function: ENABLE, RESET , SPEED 1 /SPEED 2 (Oscillator mode), General Purpose Input. Adjustable bandwidth digital noise rejection filter on all inputs</p>
OUTPUT	<p>Optically Isolated, 30V, 40mA MAX. NPN/sinking. Function: Fault, Motion, Alarm, Tach or general purpose programmable</p>
ANALOG INPUT	Ain Gnd Range 0 to 5VDC
ANALOG INPUT RESOLUTION	12 bits
COMMUNICATION INTERFACE	RS-232 or RS-485
+ 5 VOLT USER OUTPUT	4.8V to 5.0V @ 50ma Maximum

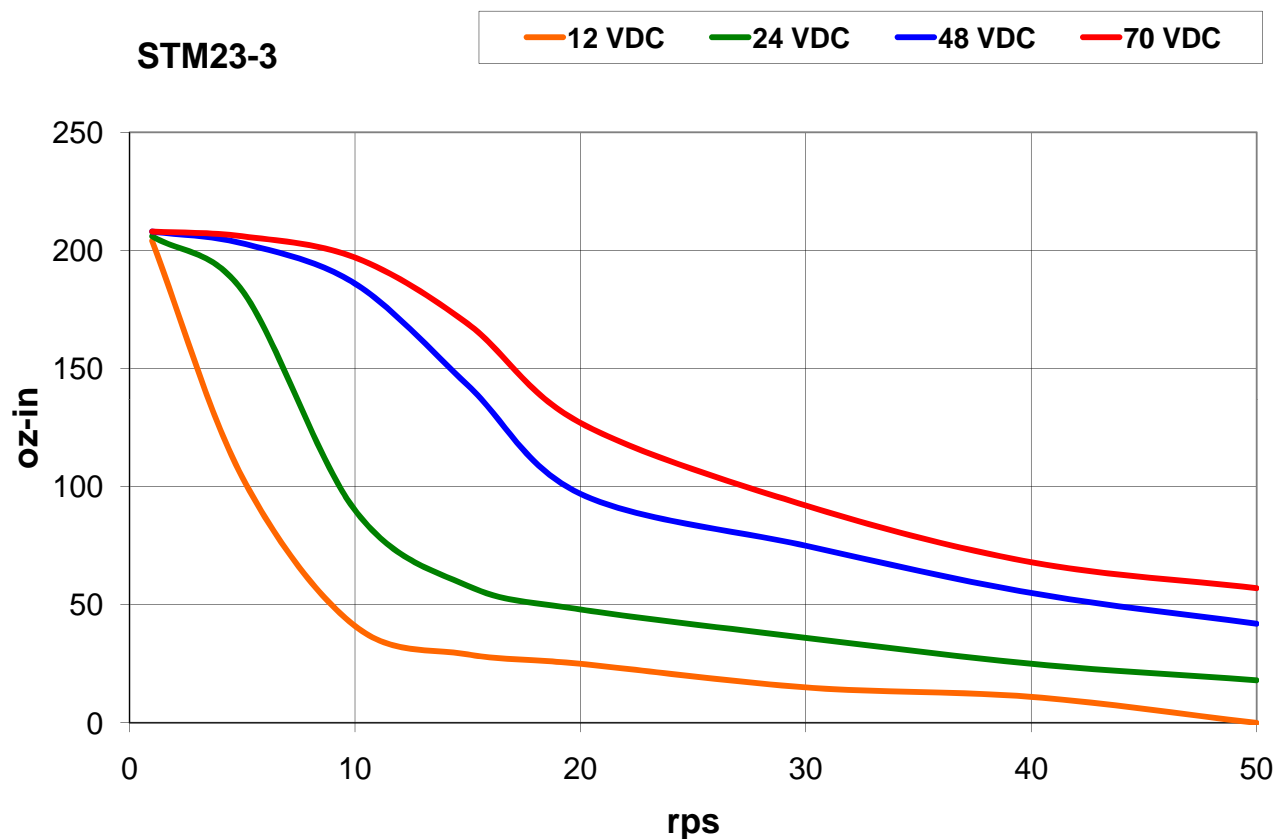
Torque-Speed Curves

Note: all torque curves were measured at 20,000 steps/rev.

STM23-2



STM23-3



Drive/Motor Heating

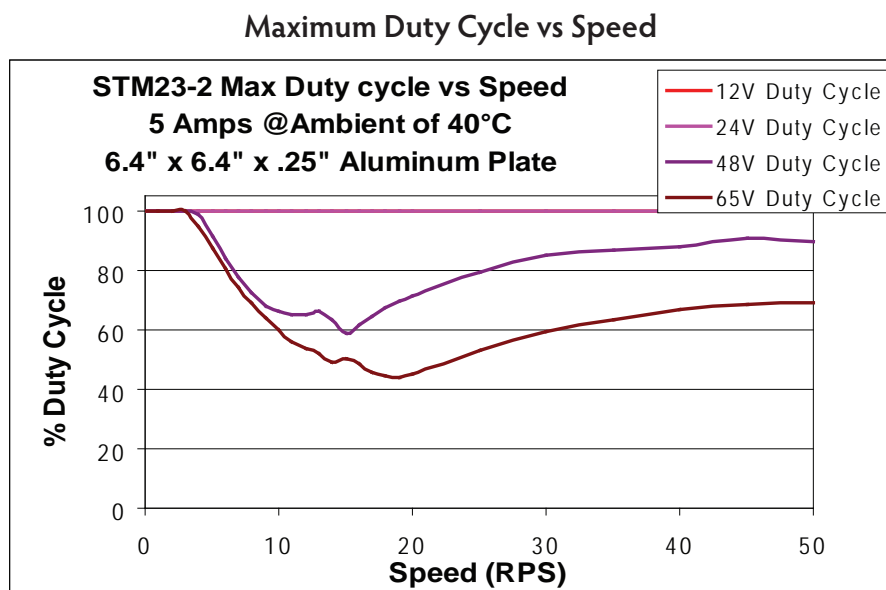
Step motors convert electrical power from the driver into mechanical power to move a load. Because step motors are not perfectly efficient, some of the electrical power turns into heat on its way through the motor. This heating is not so much dependent on the load being driven but rather the motor speed and power supply voltage. There are certain combinations of speed and voltage at which a motor cannot be continuously operated without damage.

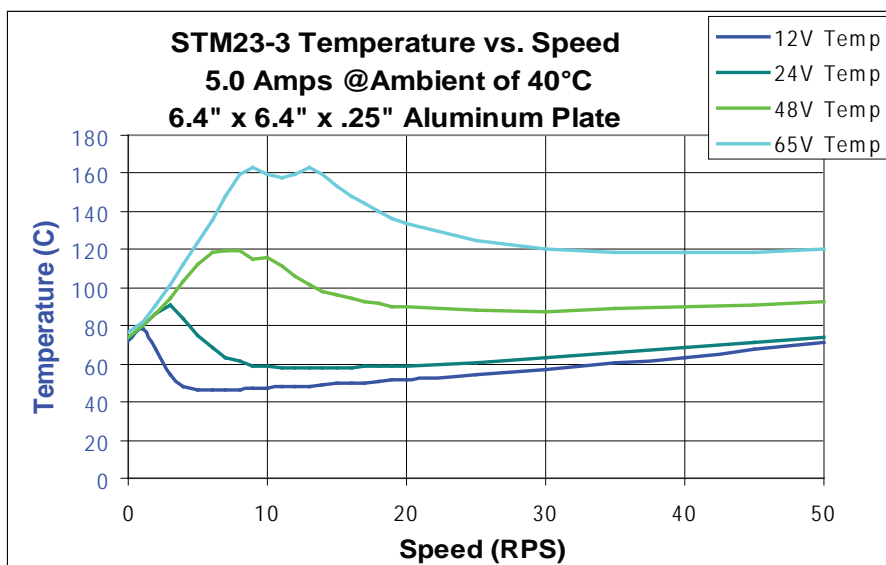
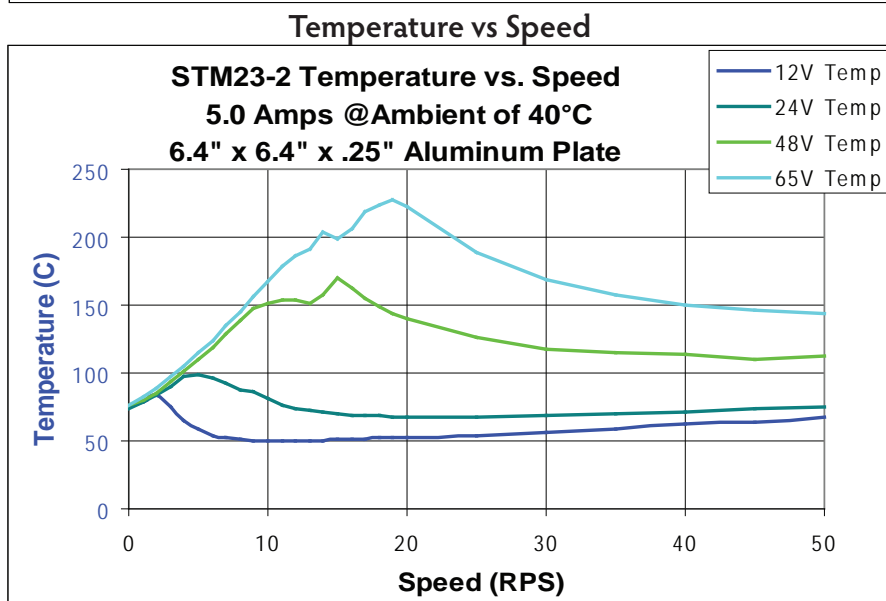
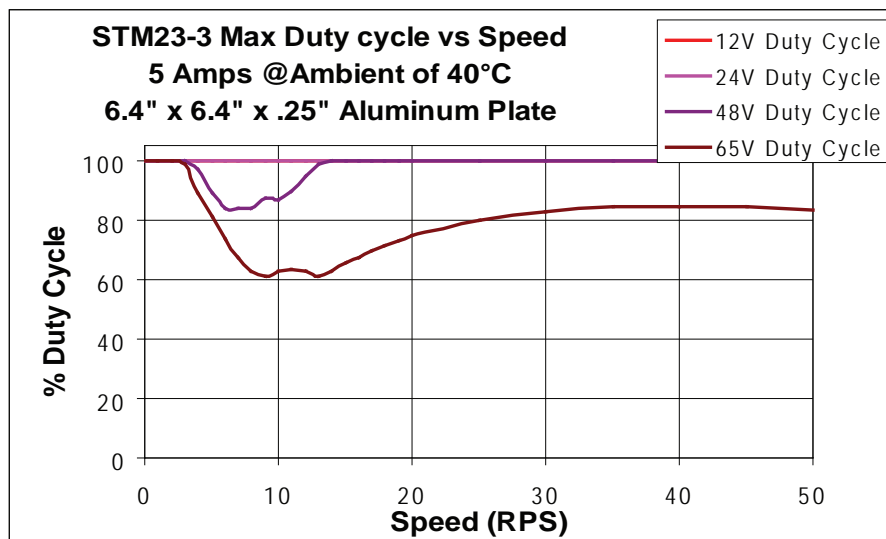
We have characterized the recommended motors in our lab and provided curves showing the maximum duty cycle versus speed for each motor at commonly used power supply voltages. Please refer to these curves when planning your application.

Please also keep in mind that a step motor typically reaches maximum temperature after 30 to 45 minutes of operation. If you run the motor for one minute then let it sit idle for one minute, that is a 50% duty cycle. Five minutes on and five minutes off is also 50% duty. However, one hour on and one hour off has the effect of 100% duty because during the first hour the motor will reach full (and possibly excessive) temperature.

The actual temperature of the motor depends on how much heat is conducted, convected or radiated out of it. Our measurements were made in a 40°C (104°F) environment with the motor mounted to an aluminum plate sized to provide a surface area consistent with the motor power dissipation. Your results may vary.

Please use the curves below, which shows the motor body temperature, to determine the maximum duty cycle of the Motor+Drive under various conditions.





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LED Error Codes

Status LED STM

The STM drive+motor includes red and green LEDs to indicate status. When the motor is enabled, the green LED flashes slowly. When the green LED is solid, the motor is disabled. Errors are indicated by combinations of red and green "flashes" as follows:

Code	Error
● solid green	no alarm, motor disabled
●● flashing green	no alarm, motor enabled
●● 1 red, 1 green	motor stall (optional encoder only)
●●● 1 red, 2 green	move attempted while drive disabled
●●● 2 red, 1 green	ccw limit
●●● 2 red, 2 green	cw limit
●●●● 3 red, 1 green	drive overheating
●●●● 3 red, 2 green	internal voltage out of range
●●●● 4 red, 1 green	power supply overvoltage
●●●● 4 red, 2 green	power supply undervoltage
●●●●● 5 red, 1 green	over current / short circuit
●●●●● 6 red, 1 green	open motor winding
●●●●●● 7 red, 1 green	serial communication error

