MIDWEST MOTION PRODUCTS

MMP SA-2550A
SERVO AMPLIFIER

Description

The MMP SA-2550A PWM servo amplifier is designed to drive brushed or brushless type DC motors at a high switching frequency. A single red/green LED indicates operating status. The drive is fully protected against over-voltage, under- voltage, over-current, over-heating and short-circuits across motor, ground and power leads. Furthermore, the drive can interface with digital controllers or be used stand-alone, and requires only a single unregulated DC power supply. Loop gain, current limit, input gain and offset can be adjusted using 14-turn potentiometers. The offset adjusting potentiometer can also be used as an on-board input signal for testing purposes. This drive can use quadrature encoder inputs, Hall Sensors, or a tachometer for velocity control.

Power Range

Peak Current	50 A
Continuous Current	25 A
Supply Voltage	20 - 80 VDC

Features

- Four Quadrant Regenerative Operation
- DIP Switch Selectable Modes
- DIP Switch Configurable Loop Tuning
- DIP Switch Configurable Current Scaling
- DIP Switch Configurable Tachometer Scaling
- Selectable Inhibit Logic
- High Switching Frequency
- Digital Fault Output Monitor
- On-Board Test Potentiometer
- Offset Adjustment Potentiometer
- Adjustable Input Gain
- Selectable 120/60 Hall Commutation Phasing
- Encoder Velocity Mode
- Hall Velocity Mode
- Velocity Monitor Output
- Current Monitor Output
- Drive Status LED

MODES OF OPERATION
- Current
- Encoder Velocity
- Hall Velocity
- Tachometer Velocity
- Duty Cycle (Open Loop)

COMMAND SOURCE
- ±10 V Analog

FEEDBACK SUPPORTED
- Hall Sensors
- Incremental Encoder
- Tachometer (±60 VDC)

MOTORS SUPPORTED
- Three Phase (Brushless)
- Single Phase (Brushed, Voice Coil, Inductive Load)

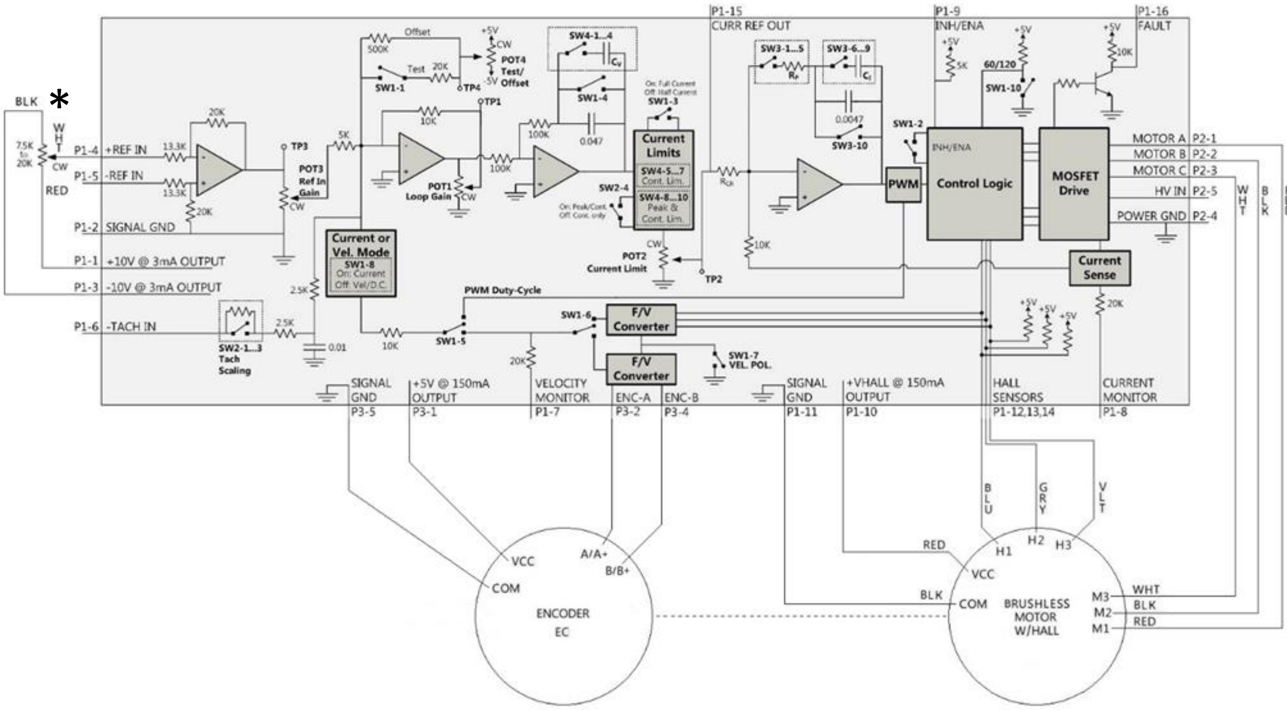
COMPLIANCES & AGENCY APPROVALS
- UL
- cUL
- CE Class A (LVD)
- CE Class A (EMC)
- RoHS II

Table of Contents

Servo Amplifier/System Usage Guidelines

When installing a motor, gearmotor, motor control or servo amplifier, universally accepted engineering practices should always be observed. Please feel free to refer to MMP's General Tips webpage for general information regarding proper motor, gearmotor, motor control and servo amplifier usage, to help ensure proper performance, and complete satisfaction with your application.

BLOCK DIAGRAM



Mode Selection Table						
Mode	**SW1-4**	**SW1-5**	**SW1-6**	**SW1-8**	**Encoder**	**Tachometer**
Current Mode	ON	OFF	OFF	ON	Not Connected	Not Connected
Duty Cycle Mode	OFF	ON	OFF	OFF	Not Connected	Not Connected
Encoder Velocity Mode	OFF	OFF	OFF	OFF	Connected	Not Connected
Hall Velocity Mode	OFF	OFF	ON	OFF	Not Connected	Not Connected
Tachometer Velocity Mode	OFF	OFF	OFF	OFF	Not Connected	Connected

LED Behavior	
Color	**Function**
Green	Normal Operation
Red	Fault Condition

Default mode is Duty Cycle Mode, with maximum current settings.
Recommended potentiometer setting for Duty Cycle Mode is:
Pot 1 = Full CCW, Pot 2 = Full CW, Pot 3 = Full CW.

Note that the above diagram is for a brushless motor with Hall effects and with or without an encoder. If you have purchased other hardware to run with the amplifier then the above wiring scheme does not apply. Contact MMP for more details.

***Potentiometer with wires and contacts are provided with this amplifier from MMP. Please see page 18 for further details.**

Information on Approvals and Compliances	
c UL us	US and Canadian safety compliance with UL 508c, the industrial standard for power conversion electronics. UL registered under file number E140173. Note that machine components compliant with UL are considered UL registered as opposed to UL listed as would be the case for commercial products.
CE	Compliant with European EMC Directive 2004/108/EC on Electromagnetic Compatibility (specifically EN 61000-6- 4:2007 for Emissions, Class A and EN 61000-6-2:2005 for Immunity, Performance Criteria A). LVD requirements of Directive 2006/95/EC (specifically, EN 60204-1:2004, a Low Voltage Directive to protect users from electrical shock).
RoHS II Compliant	The RoHS II Directive 2011/65/EU restricts the use of certain substances including lead, mercury, cadmium, hexavalent chromium and halogenated flame retardants PBB and PBDE in electronic equipment.

SPECIFICATIONS

Description	Units	Value
Power Specifications		
Description	Units	Value
DC Supply Voltage Range	VDC	20 - 80
DC Bus Over Voltage Limit	VDC	88
DC Bus Under Voltage Limit	VDC	15
Maximum Peak Output Current[1]	A	50
Maximum Continuous Output Current	A	25
Maximum Continuous Output Power at Continuous Current	W	1900
Maximum Power Dissipation at Continuous Current	W	100
Minimum Load Inductance (Line-To-Line)[2]	µH	200
Internal Bus Capacitance[3]	µF	75
Low Voltage Supply Outputs	-	±10 VDC (3 mA), +6 VDC (30 mA), +5 VDC (50 mA)
Switching Frequency	kHz	24
Control Specifications		
Description	Units	Value
Command Sources	-	±10 V Analog
Feedback Supported	-	Hall Sensors, Incremental Encoder, Tachometer (±60 VDC)
Commutation Methods	-	Trapezoidal
Modes of Operation	-	Current, Encoder Velocity, Hall Velocity, Tachometer Velocity, Duty Cycle (Open Loop)
Motors Supported	-	Three Phase (Brushless), Single Phase (Brushed, Voice Coil, Inductive Load)
Hardware Protection	-	Over-Current, Over-Temperature, Over-Voltage, Under-Voltage, Short-Circuit (Phase-Phase & Phase-Ground)
Primary I/O Logic Level	-	5V TTL
Mechanical Specifications		
Description	Units	Value
Agency Approvals	-	CE Class A (EMC), CE Class A (LVD), cUL, RoHS II, UL
Size (H x W x D)	mm (in)	186.73 x 108.8 x 26.9 (7.35 x 4.28 x 1.10)
Weight	g (oz)	518 (18.27)
Heatsink (Base) Temperature Range[4]	°C (°F)	0 - 65 (32 - 149)
Storage Temperature Range	°C (°F)	-40 - 85 (-40 - 185)
Form Factor	-	Panel Mount
P1 Connector	-	16-pin, 2.54 mm spaced, friction lock header
P2 Connector	-	5-port, 11.10 mm spaced, screw terminal
P3 Connector	-	5-pin, 5.08 mm spaced, friction lock header

Notes

1. Maximum duration of peak current is ~2 seconds. Peak RMS value must not exceed continuous current rating of the drive.
2. Lower inductance is acceptable for bus voltages well below maximum. Use external inductance to meet requirements.
3. Minimum additional 470 µF / 100 V external electrolytic capacitor between High Voltage and Power Ground is recommended.
4. Additional cooling and/or heatsink may be required to achieve rated performance.

PIN FUNCTIONS

P1 - Signal Connector			
Pin	Name	Description / Notes	I/O
1	+10V 3mA OUT	±10 V @ 3 mA low power supply for customer use. Short circuit protected. Reference ground common with signal ground.	O
2	SIGNAL GND		GND
3	-10V 3mA OUT		O
4	+REF IN	Differential Reference Input (±10 V Operating Range, ±15 V Maximum Input)	I
5	-REF IN		I
6	-TACH IN	Negative Tachometer Input (Maximum ±60 V). Use signal ground for positive input.	I
7	VEL MONITOR OUT	Velocity Monitor. Analog output proportional to motor speed. In Encoder Velocity mode, output is proportional to the encoder line frequency. Encoder Velocity scaling is 22 kHz/V. In Hall Velocity mode, output is proportional to the Hall frequency. Hall Velocity scaling is 100 Hz/V.	O
8	CURR MONITOR OUT	Current Monitor. Analog output signal proportional to the actual current output. Scaling is 8.05 A/V by default but may be reduced by half this value by setting DIP switch SW1-3 to OFF (see Hardware Setting section below). Measure relative to power ground.	O
9	INHIBIT / ENABLE	TTL level (+5 V) inhibit/enable input. Pull to ground to inhibit drive (SW1-2 ON). Pull to ground to enable drive (SW1-2 OFF). Inhibit turns off all power devices.	I
10	+V HALL 30mA OUT	Low Power Supply For Hall Sensors (+6 V @ 30 mA). Referenced to signal ground. Short circuit protected.	O
11	GND	Signal Ground	GND
12	HALL 1	Single-ended Hall/Commutation Sensor Inputs (+5 V logic level). Leave open for brushed motors.	I
13	HALL 2		I
14	HALL 3		I
15	CURR REF OUT	Measures the command signal to the internal current-loop. This pin has a maximum output of ±7.25 V when the drive outputs maximum peak current. Measure relative to power ground.	O
16	FAULT OUT	TTL level (+5 V) output becomes high when power devices are disabled due to at least one of the following conditions: inhibit, invalid Hall state, output short circuit, over voltage, over temperature, power-up reset.	O

P2 - Power Connector			
Pin	Name	Description / Notes	I/O
1	A	Motor Phase A	O
2	B	Motor Phase B	O
3	C	Motor Phase C	O
4	POWER GND	Power Ground (Common With Signal Ground)	PGND
5	HIGH VOLTAGE	DC Power Input	I

P3 – Feedback Connector			
Pin	Name	Description / Notes	I/O
1	+5V	Low Power Supply for Encoder (+5V). Internally connected to P1-10. Total current available from P3-1 to P1-10 is 150 mA. Referenced to signal ground. Sort circuit protected.	O
2	CHANNEL A	Single-ended encoder channel A input. +5 V logic level.	I
3	NC	Not Connected (Reserved)	-
4	CHANNEL B	Single-ended encoder channel B input. +5 V logic level.	I
5	SIGNAL GND	Signal Ground	SGND

HARDWARE SETTINGS

Configuration Switch Functions

SW1	Description	Setting On	Setting Off
1	Duty Cycle mode selector. Activates internal PWM feedback.	Duty Cycle mode	Other modes
2	Inhibit logic. Sets the logic level of inhibit pins.	Drive Inhibit is active low	Drive Inhibit is active high
3	Test/Offset. Switches the function of the Test/Offset pot between an on-board command input for testing or a command offset adjustment. OFF by default.	Test	Offset
4	Outer loop integration. Activates or deactivates integration. ON, by default, for current mode and OFF for other modes.	Inactive	Active
5	Mode Selection. See mode selection table below.	-	-
6		-	-
7	Velocity feedback polarity. Changes the polarity of the internal feedback signal and the velocity monitor output signal. Inversion of the feedback polarity may be required to prevent a motor run-away condition.	Standard	Inverted
8	Mode Selection. See mode selection table below.	-	-
9	Reserved	-	-
10	60/120 degree commutation phasing setting	120 degrees	60 degrees

Mode Selection Table

	SW1-4	SW1-5	SW1-6	SW1-8	Tachometer
CURRENT	ON	OFF	OFF	ON	Not Connected
DUTY CYCLE	OFF	ON	OFF	OFF	Not Connected
ENCODER VELOCITY	OFF	OFF	OFF	OFF	Not Connected
HALL VELOCITY	OFF	OFF	ON	OFF	Not Connected
TACHOMETER VELOCITY	OFF	OFF	OFF	OFF	Connected

SW2	Description	Setting On	Setting Off
1	Tachometer Input Voltage Scaling. Adjusts the maximum range of the tachometer input.	Max tachometer input values from 5V to 61V. See Maximum Tachometer Input Voltage Table below.	
2			
3			
4	Configures the drive to output either peak and continuous current values, or continuous current only.	Peak and Continuous Current	Continuous Current Only

Maximum Tachometer Input Voltage Table

Default switch settings are shaded.

Switch	Maximum Tachometer Input Voltage (± VDC)							
	61	53	45	37	29	21	13	5
SW2-1	OFF	ON	OFF	ON	OFF	ON	OFF	ON
SW2-2	OFF	OFF	ON	ON	OFF	OFF	ON	OFF
SW2-3	OFF	OFF	OFF	OFF	ON	ON	ON	ON

(Note : Drive cover must be removed to access SW4)

SW4	Description	Setting
1	Advanced Tuning (Velocity Loop Integrator Capacitance)	See SW4 table in Loop Tuning Switch Functions section for switch settings and corresponding capacitance values.
2		
3		
4		
5	Continuous Current Scaling. Configures the drive to set the continuous current limit at a percentage of the drive peak current limit.	See Continuous Current Scaling Table below for switch settings and corresponding values.
6		
7		
8	Peak and Continuous Current Scaling. Adjusts both the peak and continuous drive current limits.	See Peak and Continuous Current Scaling Table below for switch settings and corresponding values.
9		
10		

Continuous Current Scaling Table

Default switch settings are shaded.

Switch	Continuous Current Scaling (% of Peak Current)							
	50	43.6	37.6	31.6	25.6	19.7	13.7	7.75
SW4-5	OFF	ON	OFF	ON	OFF	ON	OFF	ON
SW4-6	OFF	OFF	ON	ON	OFF	OFF	ON	ON
SW4-7	OFF	OFF	OFF	OFF	ON	ON	ON	ON

Peak and Continuous Current Scaling Table

Default switch settings are shaded.

Switch	Peak and Continuous Current Scaling* (APEAK)							
	50	43.63	38.60	34.61	31.37	28.67	26.40	24.47
SW4-8	OFF	ON	OFF	ON	OFF	ON	OFF	ON
SW4-9	OFF	OFF	ON	ON	OFF	OFF	ON	ON
SW4-10	OFF	OFF	OFF	OFF	ON	ON	ON	ON

Potentiometer Functions

Potentiometer	Description	Turning CW
1	Loop gain adjustment for duty cycle / velocity modes. Turn this pot fully CCW in current mode.	Increases gain
2	Current limit. It adjusts both continuous and peak current limit while maintaining their ratio.	Increases limit
3	Reference gain. Adjusts the ratio between input signal and output variables (voltage, current, or velocity).	Increases gain
4	Offset / Test. Used to adjust any imbalance in the input signal or in the amplifier. Can also be used as an on-board signal source for testing purposes.	Adjusts offset in negative direction

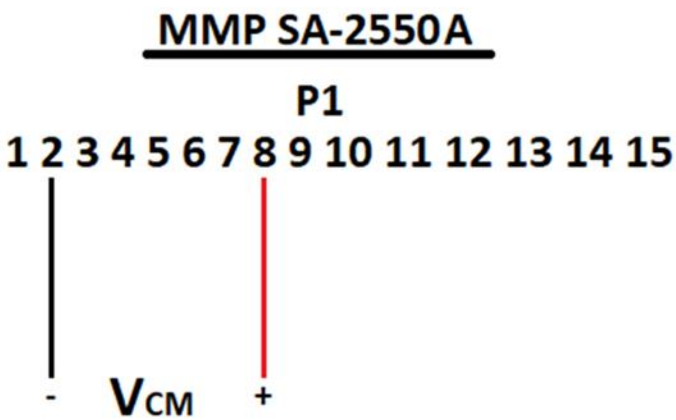
Note: Potentiometers are approximately linear and have 12 active turns with 1 inactive turn on each end. Test points are provided on the drive PCB near each potentiometer to measure the potentiometer value.

Importance of Proper Current Monitoring

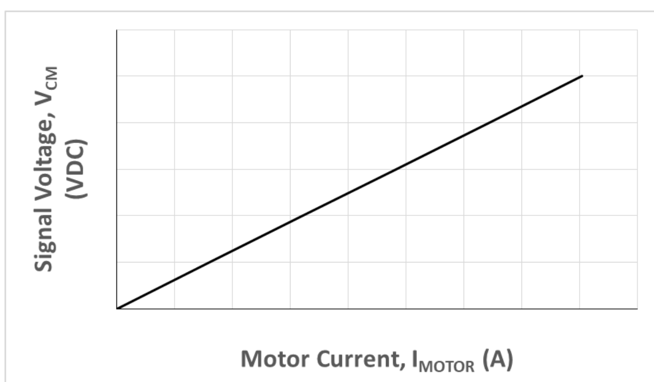
There are many factors which affect motor performance and longevity. One very important factor to motor life is motor current. An input current that is too high can cause severe, irreversible damage to a motor. One common misconception with servo amplifiers is that the input current into the amplifier and output current to the motor phases are the same amplitude:

$$\mathbf{I_{IN}} \neq \mathbf{I_{MOTOR}}\ (\boldsymbol{necessarily})$$

Due to the nature of the MMP SA-2550A the input and output currents usually correlate but are not always equal. To ensure the motor is receiving the proper amount of current we highly recommend utilizing the current monitor pin (P1-8, see page 5, Pin Functions table for further details) and measuring the voltage relative to signal ground as shown below.



The voltage output is analog and linearly scaled to the current input to the motor phases. The scale is 8.05 A/V by default as stated in the Pin Functions table on page 5.



The current monitor signal tracks current delivered to all three motors phases (where applicable).

Using an Encoder Feedback with a Servo Amplifier

Encoders can be used with the MMP SA-2550A to provide feedback to the amplifier and control speed of the motor. The default setting on the servo amplifier is duty cycle mode. This mode does not use motor feedback. If motor speed as feedback is required then using an encoder as feedback to the Servo Amplifier is recommended. For encoder feedback the MMP SA-2550A needs to be properly configured and wired.

The resolution of the encoder and speed of the motor is important for proper speed control. The MMP SA-2550A uses both parameters to input a switching frequency and thus control the motor speed. The MMP SA-2550A has a maximum switching frequency of 24 kHz (Specifications table, page 4). As long as the input frequency is no less than 10 Hz and does not exceed the maximum frequency the servo amplifier is able to control speed smoothly. Typically an encoder resolution is chosen that maximizes the input frequency without exceeding the switching frequency. The encoder resolution is also chosen based on the following guidelines for expected maximum motor speed:

Encoder Resolution (CPR)	Motor Max Recommended Speed (RPM)
1024	1406
500	2880
250	5760
100	14400

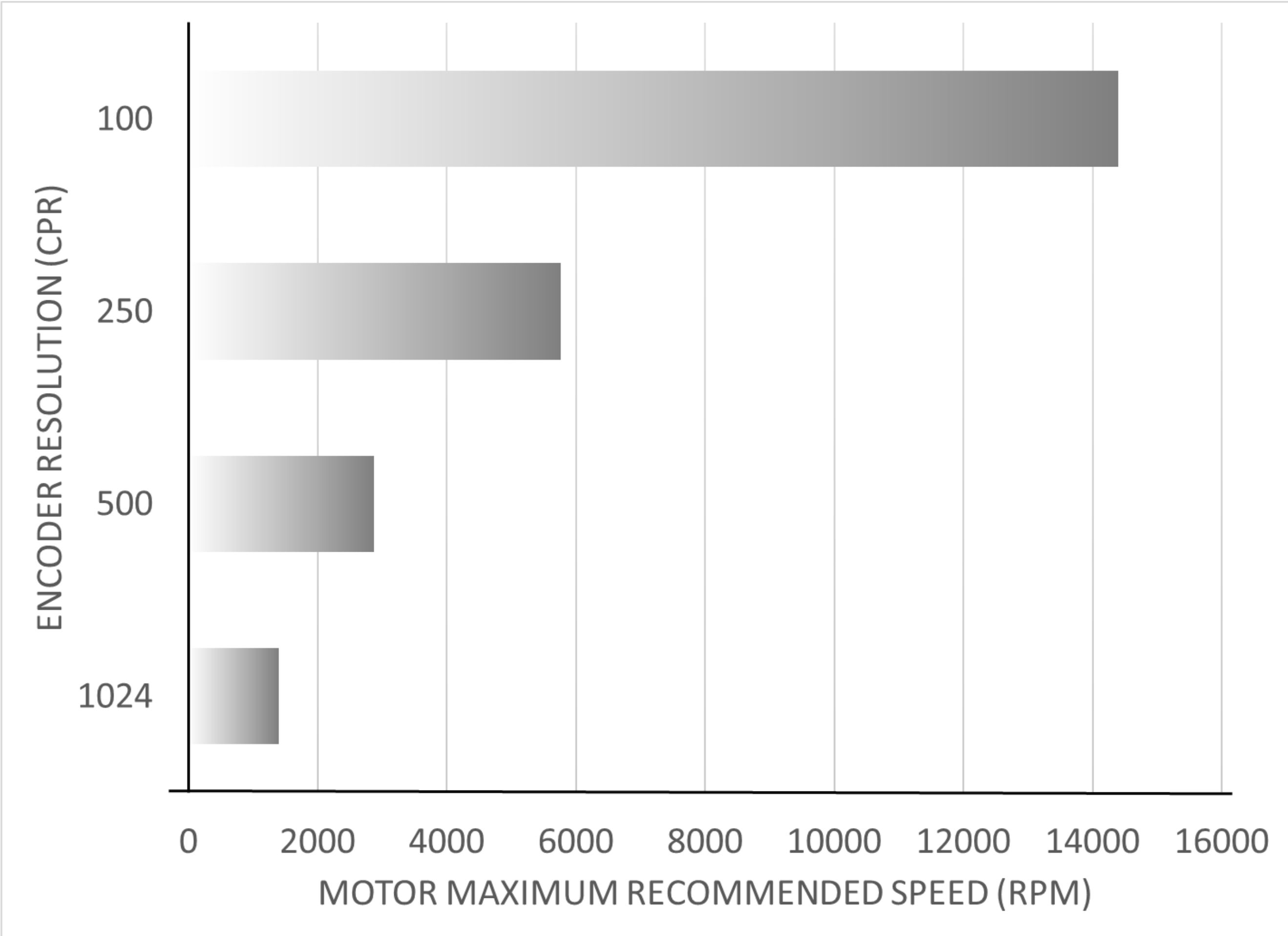


Figure 1. Maximum Recommended Motor Speed with encoder feedback, maximum switching frequency 24 kHz.

To utilize encoder feedback ensure the SW1 switches are configured as specified on page 6.

As shown below, ensure the encoder, potentiometer and external encoder source are grounded. Note that the encoder must be powered by an external source (usually 5 VDC). If the encoder channels are double ended then use the positive signal of each channel (labeled A+ and B+ on the below figure) as the feedback signal to the servo amplifier.

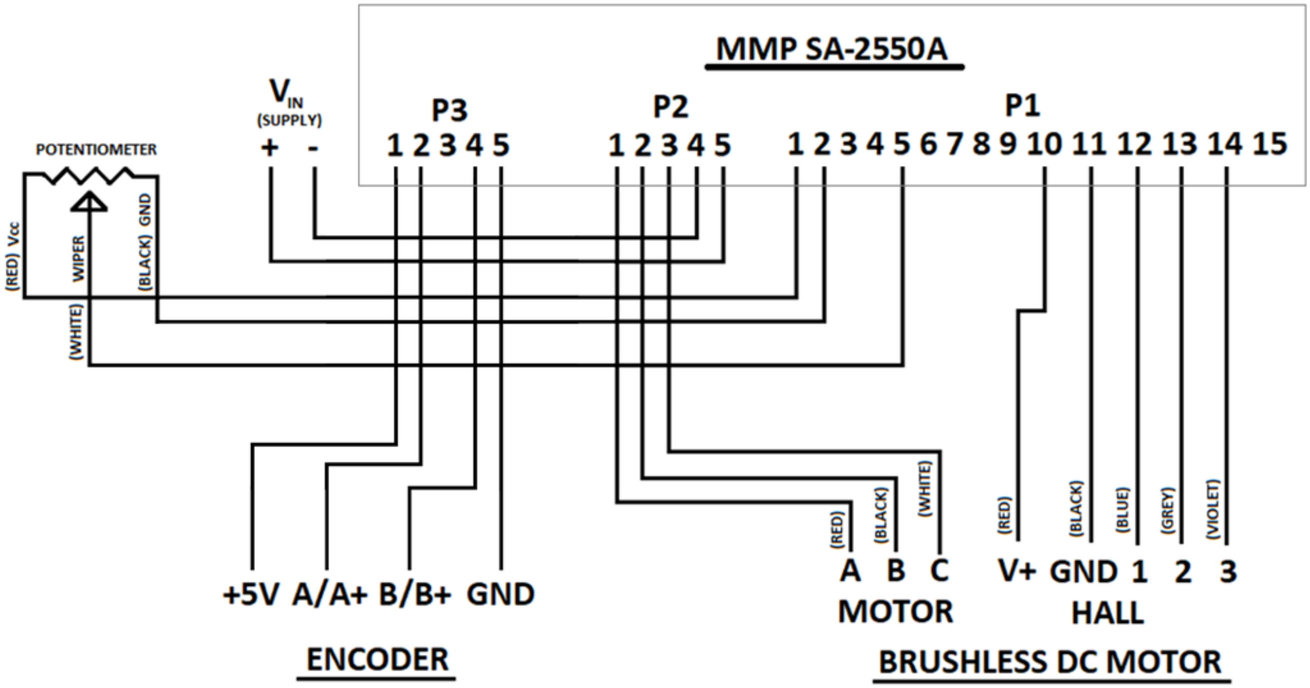


Figure 2. Encoder feedback wiring with potentiometer command.

If an external command signal (usually 10 VDC) is used in place of a potentiometer then wire as shown below. Remove connection to P1-1 and connect the signal positive to pin 5 (for %0-%100 POT effect). Ensure VCOM is grounded to P1-2.

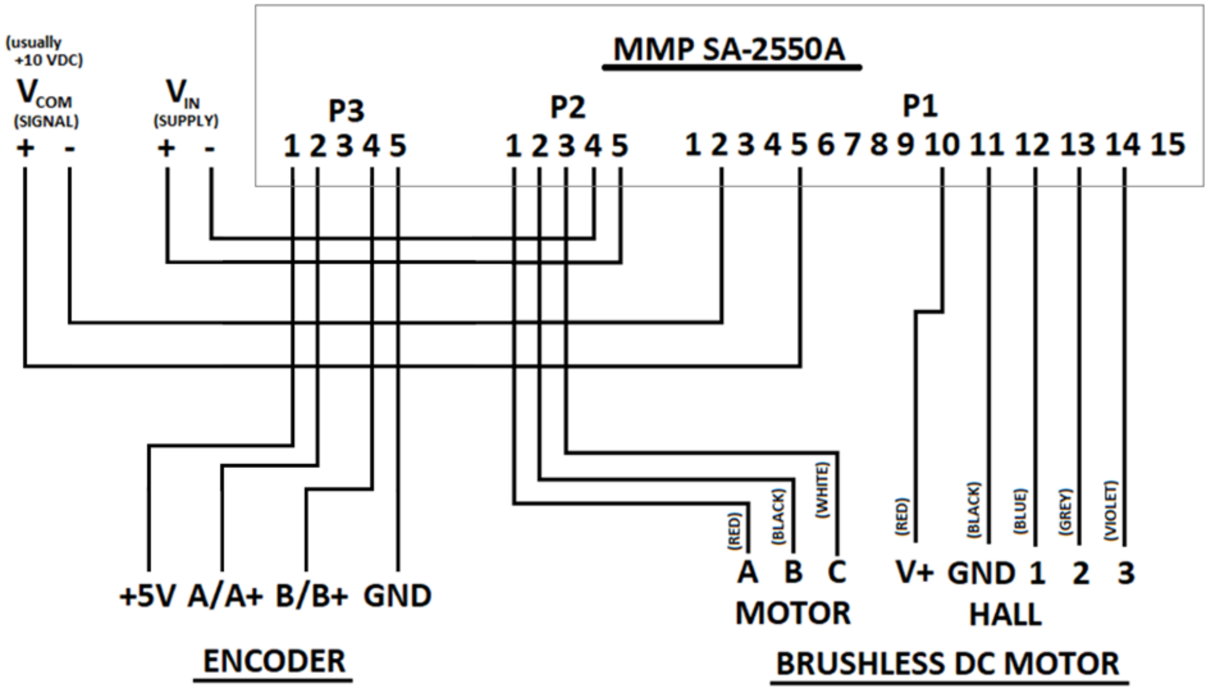


Figure 3. Encoder feedback with external command.

For further details on configuring the command signal curve, please consult the answer to question 3 in the troubleshooting guide, found on page 22.

Running a Brushed Motor with a Brushless Drive

Follow the below steps to configure a SA-2550A to run a brushed, DC motor.

Switch Setting

Set the 120°/60° PHASING dipswitch to OFF for 60° phasing. For the SA-2550A this is SW 1-10. The OFF position is toward the outside of the servo amplifier as shown in the picture below.

Note: *Make sure to disconnect all Hall sensor inputs.*

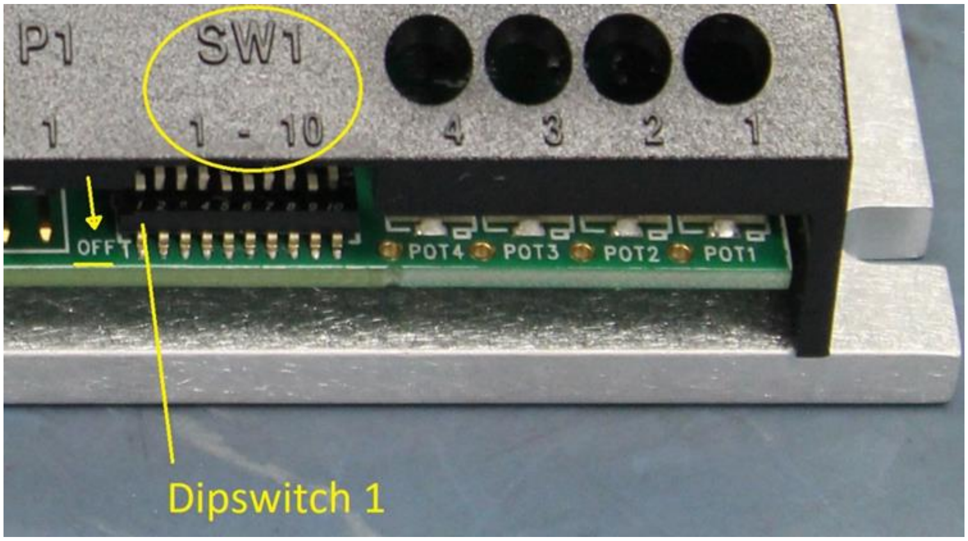


Figure 4. 120°/60° Phasing Switch Example

Motor Connections

With the 120°/60° PHASING switch OFF, the motor connections to the servo drive will be to the MOTOR A and MOTOR B terminals only.

Terminal	Connection
MOTOR A	Negative (-)
MOTOR B	Positive (+)
MOTOR C	No Connection

Table 1. Brushed Motor Connections. Note that the above assumes the polarity of the 10V @3mA and REF leads for the command signal to be opposite. Consult the second table on page 12 for further details.

How to reverse a brushless DC motor

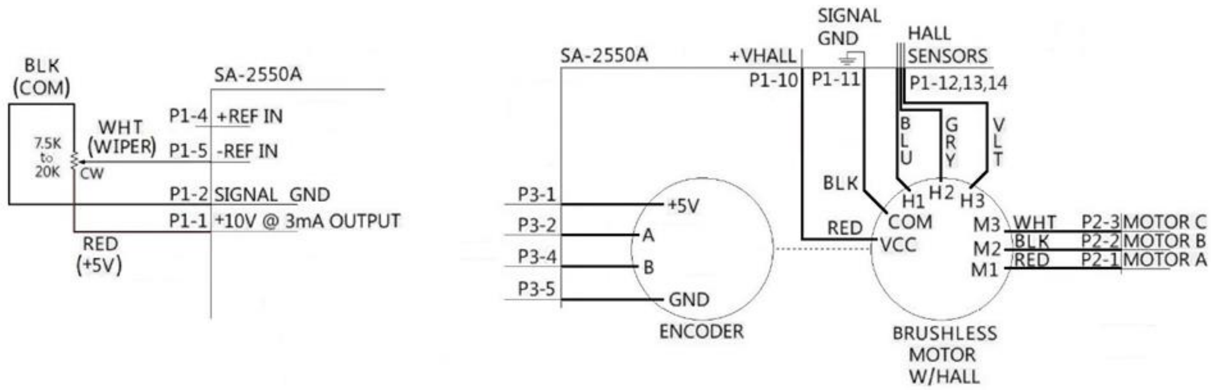


Figure 5. Typical Wiring Solution of a Brushless Motor with Encoder.

The typical wiring solution shown above results in the brushless motor to run forward (CW rotation) with the potentiometer max at the CW position. Methods to reverse the brushless motor direction via wiring are as follows:

- **Change the wiring connections of the potentiometer or jump leads.** There are many ways to wire a potentiometer to the servo amplifier or jump the potentiometer leads. Consult the tables below for what leads to connect to which pins.

Potentiometer Wiring Solutions

Connect Potentiometer Leads to Pins			Motor Direction of Rotation*	Potentiometer	
RED (+5V)	BLK (GND)	WHT (WIPER)		Range	Rotation
P1-1	P1-2	P1-5	FWD	0-100%	CW
P1-3	P1-2	P1-4	FWD	0-100%	CW
P1-1	P1-2	P1-4	REV	0-100%	CW
P1-3	P1-2	P1-5	REV	0-100%	CW
P1-2	P1-3	P1-4	FWD	100-0%	CCW
P1-2	P1-1	P1-5	FWD	100-0%	CCW
P1-2	P1-1	P1-4	REV	100-0%	CCW
P1-2	P1-3	P1-5	REV	100-0%	CCW

*Assumes that Hall Sensors and Motor Leads are wired in accordance with the above diagram.

Wire without Potentiometer (direct pin connections)

Connect Leads		Motor Direction of Rotation*	Simulated Potentiometer Output
P1-1	P1-5	FWD	100%
P1-3	P1-4	FWD	100%
P1-1	P1-4	REV	100%
P1-3	P1-5	REV	100%

*Assumes that Hall Sensors and Motor Leads are wired in accordance with the above diagram.

- **Change Motor and Hall Sensor Leads.** To reverse motor direction, consult the below table to properly change motor and hall sensor leads.

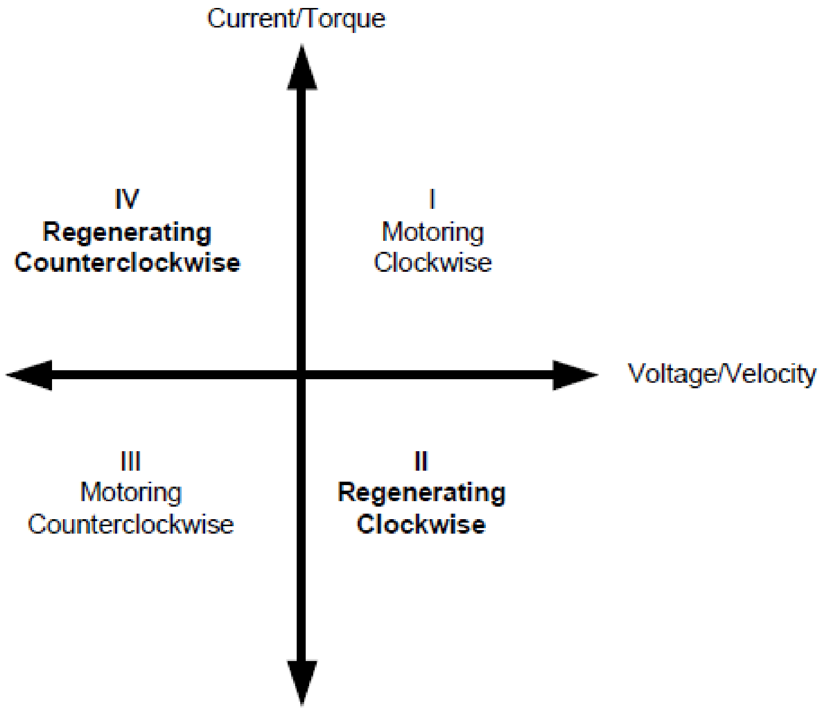
Motor Direction	Hall Sensor Connection to Drive			Motor Connection to Drive		
	H1 (BLU)	H2 (GRY)	H3 (VLT)	M1 (RED)	M2 (BLK)	M3 (WHT)
FWD	P1-12	P1-13	P1-14	P2-1	P2-2	P2-3
REV	P1-14	P1-13	P1-12	P2-2	P2-1	P2-3

WARNING : ***DO NOT*** *reverse the servo amplifier input power leads, HV (P2-5) and GND (P2-4) to reverse the direction of motor rotation. This can cause severe, irreversible damage to the servo amplifier.*

Regenerative braking with the SA-2550A

Regeneration and Shunt Regulators

Use of a shunt regulator is necessary in systems where motor deceleration or a downward motion of the motor load will cause the system's mechanical energy to be regenerated via the drive back onto the power supply.



I	Torque +	Velocity +	No Regen
II	Torque -	Velocity +	Regen
III	Torque -	Velocity -	No Regen
IV	Torque +	Velocity -	Regen

Figure 6. Four Quadrant Operation – Regeneration occurs when Torque and Velocity are opposite.

This regenerated energy can charge the power supply capacitors to levels above that of the drive over-voltage shutdown level. If the power supply capacitance is unable to handle this excess energy, or if it is impractical to supply enough capacitance, then an external shunt regulator must be used to dissipate the regenerated energy. Shunt regulators are essentially a resistor placed in parallel with the DC bus. The shunt regulator will "turn-on" at a certain voltage level (set below the drive over-voltage shutdown level) and discharge the regenerated electric energy in the form of heat.

The voltage rise on the power supply capacitors without a shunt regulator, can be calculated according to a simple energy balance equation. The amount of energy transferred to the power supply can be determined through:

$$E_i = E_f$$

Where

$E_i =$ Initial Energy
$E_f =$ Final Energy

These energy terms can be broken down into the approximate mechanical and electrical terms - capacitive, kinetic, and potential energy. The energy equations for these individual components are as follows:

$E_c = \frac{1}{2}CV_{NOM}^2$	$E_r = \frac{1}{2}J\omega^2$	$E_p = mgh$
E_c – Energy stored in capacitor (J) C – Capacitance (F) V_{NOM} – Nominal bus voltage of the system	E_r – mechanical energy of the load (J) J – moment of inertia of the load (kg-m^2) ω – angular velocity of the load (rad/s)	E_p – potential energy of load (J) m – mass of the load (kg) g – gravitational acceleration (9.81 m/s^2) h – vertical height of the load (m)

During regeneration the kinetic and potential energy will be stored in the power supply's capacitor. To determine the final power supply voltage following a regenerative event, the following equation may be used for most requirements:

$$\left(E_c + E_r + E_p\right)_i = \left(E_c + E_r + E_p\right)_f$$

$$\frac{1}{2}CV_{NOM}^2 + \frac{1}{2}J\omega_i^2 + mgh_i = \frac{1}{2}CV_f^2 + \frac{1}{2}J\omega_f^2 + mgh_f$$

Which simplifies to:

$$V_f = \sqrt{V_{NOM}^2 = \frac{J}{C}\left(\omega_i^2 - \omega_f^2\right) + \frac{2mg\left(h_i - h_f\right)}{C}}$$

The V_f calculated must be below the power supply capacitance voltage rating and the drive over voltage limit. If this is not the case, a shunt regulator is necessary. A shunt regulator is sized in the same way as a motor or drive, i.e. continuous and RMS power dissipation must be determined. The power dissipation requirements can be determined from the application move profile.

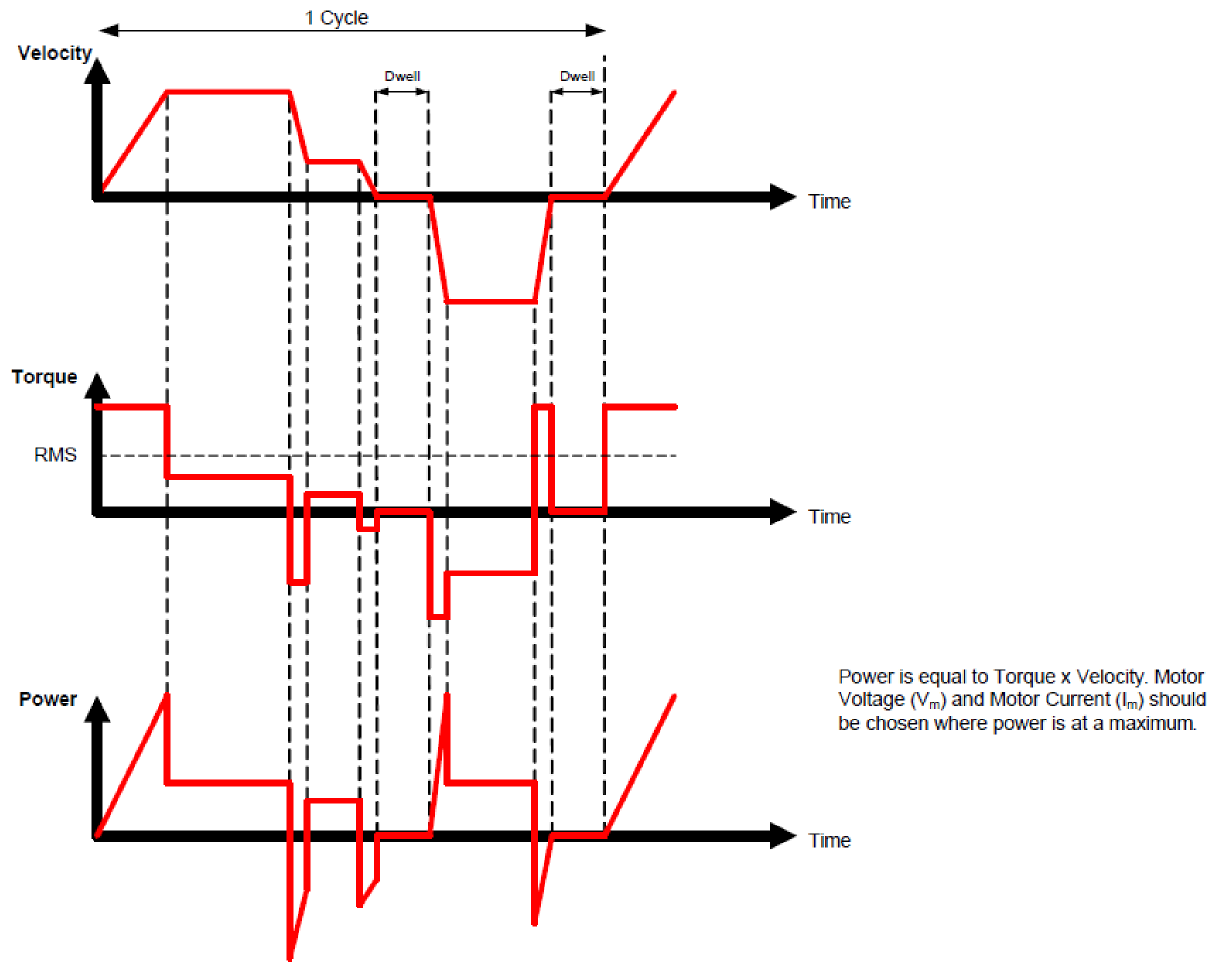


Figure 7. Example of motor profile during operation.

When choosing a shunt regulator, select one with a shunt voltage that is greater than the DC bus voltage of the application but less than the over voltage shutdown of the drive. Verify the for a shunt regulator by operating the servo drive under the worst-case braking and deceleration conditions. If the drive shuts off due to over-voltage, a shunt regulator is necessary.

Continuous Regeneration

In the special case where an application requires continuous regeneration (more than a few seconds) then a shunt regulator may not be sufficient to dissipate the regenerative energy. Some examples include:

- Web tensioning device
- Electric vehicle rolling down a long hill
- Spinning mass with a very large inertia (grinding wheel, flywheel, centrifuge)
- Heavy lift gantry

Loop Tuning Switch Functions

In general, the drive will not need to be further tuned beyond the default configuration. However, for applications requiring more precise tuning, DIP switches can be used to adjust the current and velocity loop tuning values. Some general rules of thumb to follow when tuning the drive are:

- A larger resistor value will increase the proportional gain, and therefore create a faster response time.
- A larger capacitor value will increase the integration time, and therefore create a slower response time.

Proper tuning will require careful observation of the loop response on a digital oscilloscope to find optimal DIP switch settings for the specific application.

(Note: Drive cover must be removed to access SW3 and SW4)

SW3 DIP switches add additional resistance and capacitance to the current loop tuning circuitry. SW3 switches 1-5 add additional series resistance to the current loop gain resistor, and SW3 switches 6-10 add additional parallel capacitance to the current loop integrator capacitor (see Block Diagram). The resulting capacitance and resistance values are given in the tables below along with the appropriate DIP switch settings. The default switch settings are shaded in the SW3 tables below.

SW3																
Switch	Current Loop Proportional Gain Resistance Options (kΩ)															
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
SW3-1	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
SW3-2	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF
SW3-3	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF
SW3-4	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
SW3-5	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Switch (continued	**170**	**180**	**190**	**200**	**210**	**220**	**230**	**240**	**250**	**260**	**270**	**280**	**290**	**300**	**310**	**320**
SW3-1	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
SW3-2	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF
SW3-3	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF
SW3-4	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
SW3-5	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF

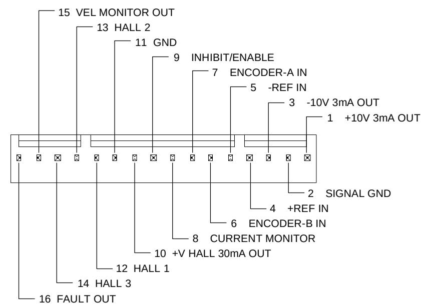
SW3																	
	Current Loop Integrator Capacitance Options (μF)																
Switch	.0047	.0094	.0247	.0294	.0517	.0564	.0717	.0764	.0987	.1034	.1187	.1234	.1457	.1504	.1647	.1694	SHORT
SW3-6	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	ON
SW3-7	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	ON
SW3-8	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON
SW3-9	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON
SW3-10	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON

SW4 DIP switches 1-4 add additional parallel capacitance to the velocity loop integrator capacitor. The resulting capacitance values are given in the table below along with the appropriate DIP switch settings. The default switch settings are shaded in the SW4 table below.

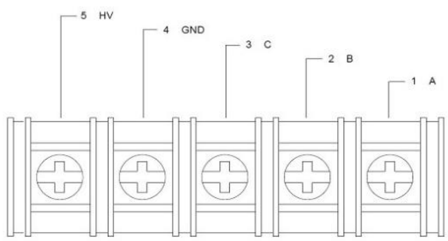
SW3																	
	Current Loop Integrator Capacitance Options (μF)																
Switch	.0047	.0094	.0247	.0294	.0517	.0564	.0717	.0764	.0987	.1034	.1187	.1234	.1457	.1504	.1647	.1694	SHORT
SW4-1	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	ON
SW4-2	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	ON
SW4-3	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON
SW4-4	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON

MECHANICAL INFORMATION

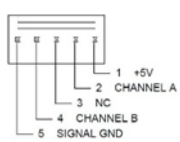
P1 - Signal Connector		
Connector Information		16-pin, 2.54 mm spaced, friction lock header
Mating Connector	Details	Molex: P/N 22-01-3167 (connector) and P/N 08-50-0114 (insert terminals)
	Included with Drive	Yes



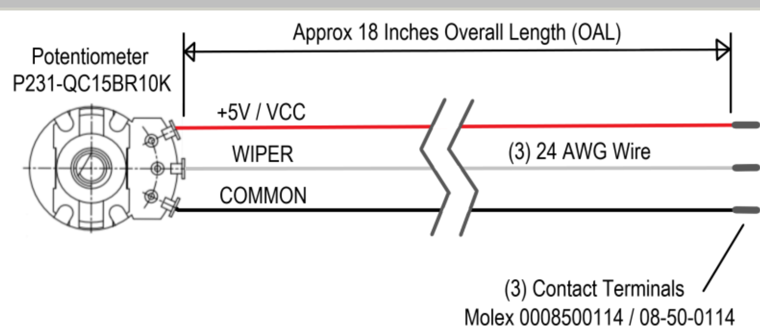
P2 - Power Connector		
Connector Information		5-port, 11.10 mm spaced, screw terminal
Mating Connector	Details	N/A
	Included with Drive	N/A



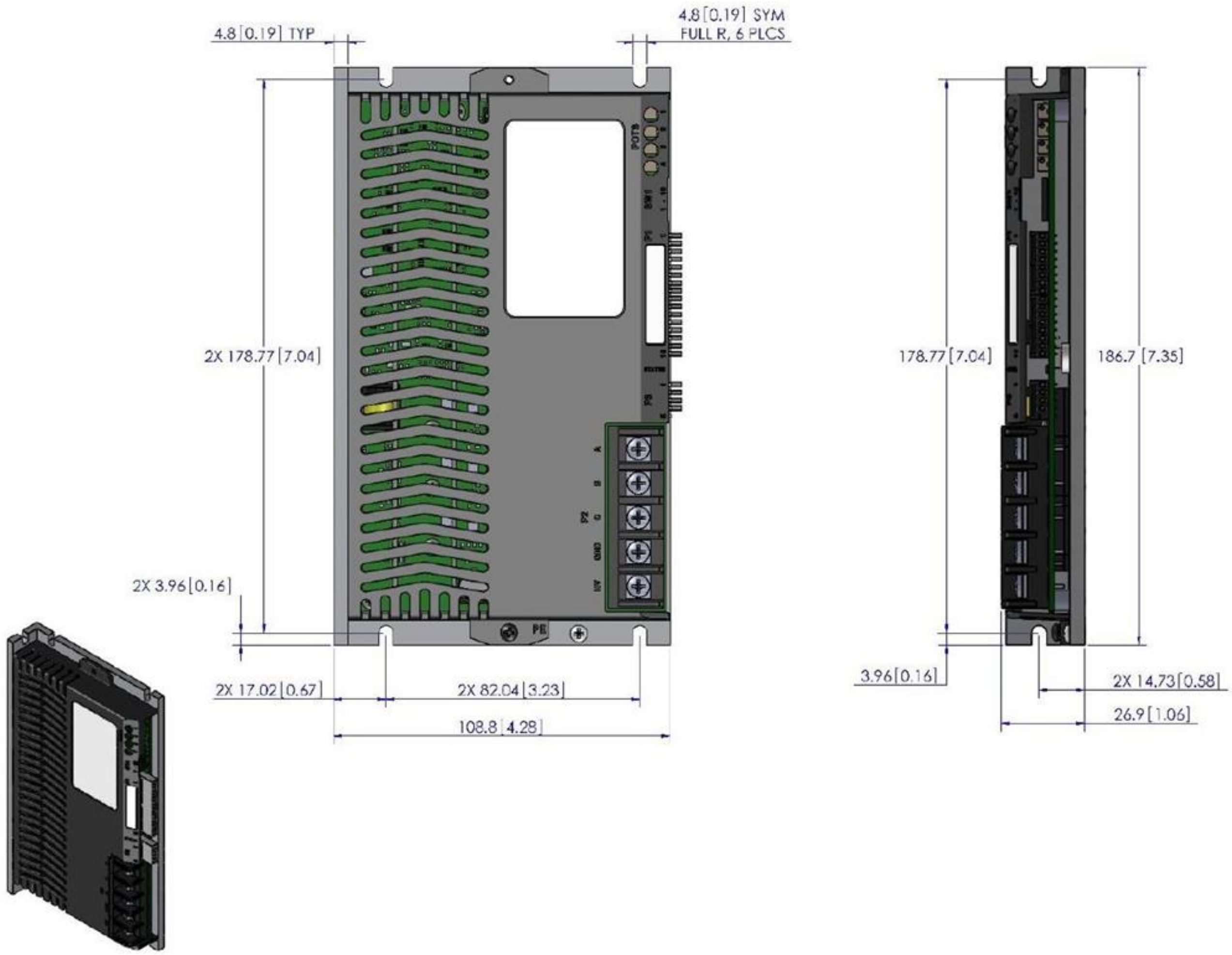
P3 - Feedback Connector		
Connector Information		5-port, 5.08 mm spaced, quick-disconnect terminal
Mating Connector	Details	Molex: P/N 22-01-3057 (connector) and P/N 08-50-0114 (insert terminals)
	Included with Drive	Yes



Included Potentiometer with Wires



MOUNTING DIMENSIONS



TROUBLESHOOTING GUIDE

Below are covered common questions and issues related to the SA-2550A servo amplifier.

1. What a red LED indicator means and how to fix it.
2. How to perform current loop tuning on the SA-2550A.
3. Adjusting the Command Signal Curve using the built in potentiometers of the SA-2550A servo amplifier.

1. Red LED indicator meaning and methods of correction

A red LED can indicate any of the following fault conditions:

- Over-voltage
- Under-voltage
- Invalid Hall State
- Drive Inhibited
- Over-temperature
- Short circuit
- Over-current
- Power-on Reset

Fault conditions are non-latching, meaning that when the fault condition is removed, the drive will enable (green LED).

Troubleshooting Instructions

1. Remove all connections from the drive. This includes the voltage supply, motor power cables, feedback and any controller I/O.
2. For a brushed drive, configure the amplifier for voltage mode. For a brushless drive, configure the amplifier for open loop mode. The switch settings for each mode can be found on the drive datasheet.
3. If using a brushless drive, set the 60 / 120 phasing switch to 60 degrees, which is the OFF position.
4. Apply power to the drive. If the drive has inverted inhibits, short the master inhibit pin to signal ground (for more information on inverted inhibits, see **Drive Inhibited** section). **The LED should be green.** The drive will fault if too much or too little voltage is applied to the drive. See **Over-voltage and Under-Voltage** section for details on this fault condition.
5. Remove power from the drive. If using a brushless motor, connect Hall sensor inputs and set the 60 / 120 phasing switch to the correct position according to the motor. Apply power to the drive and rotate the motor by hand. If the LED is red or changing between red and green, this could indicate an issue with the Hall sensor inputs. See **Invalid Hall State** section for details on this fault condition. ***Note:*** *Most motors have 120 degree Hall sensors.*
6. Remove power from the drive and connect motor power cables. Set the Test/Offset switch to the OFF position and set POT4, the Test/Offset pot, 7 turns from the full clockwise direction.
7. Apply power. If the LED is red, it could be an indication of a short circuit fault. See **Short Circuit** section for details on this fault condition.
8. Remove power and connect the controller. Remove any command from the controller to avoid unexpected motion in the motor.
9. Apply power. If the LED is red, check if the controller is disabling the drive. See **Drive Inhibited** section for more information about the inhibit input.

Fault Conditions Explained

Over-voltage and Under-voltage

An over-voltage fault occurs when the bus voltage exceeds the over-voltage limit of the drive. An under-voltage can occur if too little voltage is applied to the drive. The voltage rating can be found on the drive datasheet.

- For DC input drives, verify that the DC input voltage is within the spec of the drive.
- For AC input drives, verify that the AC input voltage is within the spec of the drive.

Regeneration

If the drive faults during a deceleration or when lowering a vertical load, it could be due to regeneration energy raising the bus voltage beyond its over-voltage limit.

During these types of moves, the system's mechanical energy gets converted into electrical energy that flows back onto the DC bus. This charges the capacitors in the power supply and raises the DC bus voltage.

A shunt regulator may be necessary to dissipate the energy regenerated by the system. See the section on regenerative braking, pages 13-15 for more details.

Invalid Hall State

Brushless drives have 3 Hall sensor inputs that determine a Hall state. The drive will fault if an invalid Hall state is detected.

If the LED is red or changing between red and green as the motor rotates, it could be an indication of an invalid Hall state.

- Connect only the Hall sensors to the drive and apply power.
- Make sure the 60 or 120 phasing switch is in the correct position according to motor.
- Verify that all Hall sensor inputs are wired correctly to the drive.
- Measure the voltage levels for all Hall sensor inputs. The voltage levels should change between 0 and 5V as the motor rotates.
- If using a motor with both Hall sensors and an encoder, make sure the supply for the feedback has enough power. Drives with onboard Hall sensor power rated at 30mA won’t have enough current and a separate supply will be required.
- If using a separate supply for the Hall sensors, make sure the ground reference for the supply is tied to the signal ground of the drive.
- Rotate the motor and verify that ALL Hall sensor inputs are changing and follow the Hall sequence in the table below.

60 Degree			120 Degree			
Hall A	Hall B	Hall C	Hall A	Hall B	Hall C	
1	0	0	1	0	0	Valid Green LED
1	1	0	1	1	0	
1	1	1	0	1	0	
0	1	1	0	1	1	
0	0	1	0	0	1	
0	0	0	1	0	1	
1	0	1	1	1	1	Invalid Red LED
0	1	0	0	0	0	

Table 4. Valid and invalid hall sensor states per brushless motor phase.

1 – Indicates high level hall sensor input (5V)
0 – Indicates low level hall sensor input (0V)

Drive Inhibited

For standard inhibits, the drive disables when the inhibit pin is grounded. For inverted inhibits, the drive enables when the inhibit pin grounded.

A drive with standard inhibits has a 0 ohm SMT resistor labeled “J1” installed on the PCB. Removing this jumper will invert the inhibits. Amplifiers can be ordered with the J1 jumper removed and have a “-INV” on the end of the part number, e.g., 12A8-INV. Some drives have a DIP switch to invert the inhibits. This option will be listed on the drive datasheet if available.

Note: *Some drives have directional inhibits (+INHIBIT / -INHIBIT) which inhibit motion in their respective directions but do NOT cause a red LED.*

- Measure the voltage of the inhibit pin. It should read 5V if left open and 0 if grounded.
- Verify if the drive is configured for standard or inverted inhibits.
- If your controller is disabling the drive, verify under what conditions this will occur, e.g., position following error, position limit reached, etc.

Over-temperature

The drive will fault if the heat sink base plate temperature exceeds 65C.

- Safely measure the heat sink base plate temperature.
- If the temperature exceeds 65C, additional cooling may be necessary.

Short Circuit

The drive will fault if a short circuit is detected on the output. ***This can occur if any of the motor phases are shorted to power ground, AC ground, or shorted together.*** Use a DMM to measure the resistance between two points of interest. A 0 ohm resistance indicates a short circuit.

- Measure the resistance between each motor phase.
- Measure the resistance between each motor phase and both the power ground and AC ground.
- Make sure the motor phases are not shorting to AC ground through the motor housing or shielding on the motor power cable.

Over-current

An over-current fault will occur if commanding a current greater than the peak rating of the drive. In most cases though, the drive will limit the current to prevent an over-current fault. PWM input and Sinusoidal input drives will alternate between an enabled and disabled state to limit current when outputting current greater than the continuous rating of the drive. The LED will alternate between red and green.

Power-on Reset

All amplifiers will have a brief flicker of a red LED during power up. This is the power-on reset that is built into the amplifier that occurs on power up.

2. How to perform current loop tuning on the SA-2550A

The servo amplifier has already been configured to handle the majority of motors. The following are indications that current loop tuning may be necessary:

- Motor rapidly overheats even at low current
- Drive rapidly overheats even at low current
- Vibration sound comes from the drive or motor
- The motor has a high inductance (+10mH)
- The motor has a low inductance (near minimum rating of the drive)
- Slow system response times
- Excessive torque ripple
- Difficulty tuning position or velocity loops
- Electrical noise problems
- High power supply voltage (power supply is significantly higher than the motor voltage rating or near the drive's upper voltage limit)
- Low power supply voltage (power supply voltage is near the drive's lower voltage limit)

To perform current loop tuning, first locate the relevant potentiometer (POT 1) as shown below:

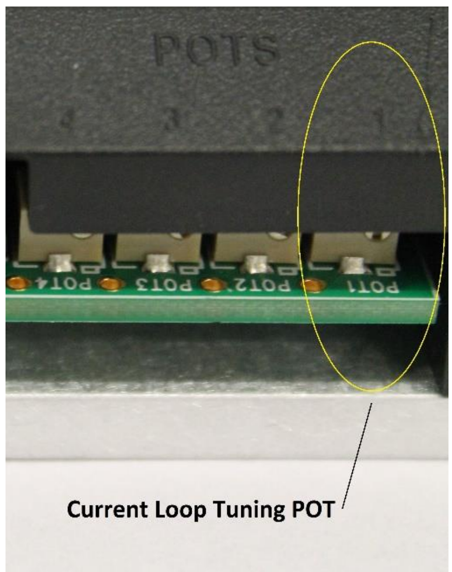


Figure 8. Location of current loop tuning potentiometer on SA-2550A Servo Amplifier.

Note: *If you are running in* ***current mode*** *then current loop* ***tuning is not necessary****; the instructions below only apply while in velocity mode. turn the loop gain potentiometer full CCW (low).*

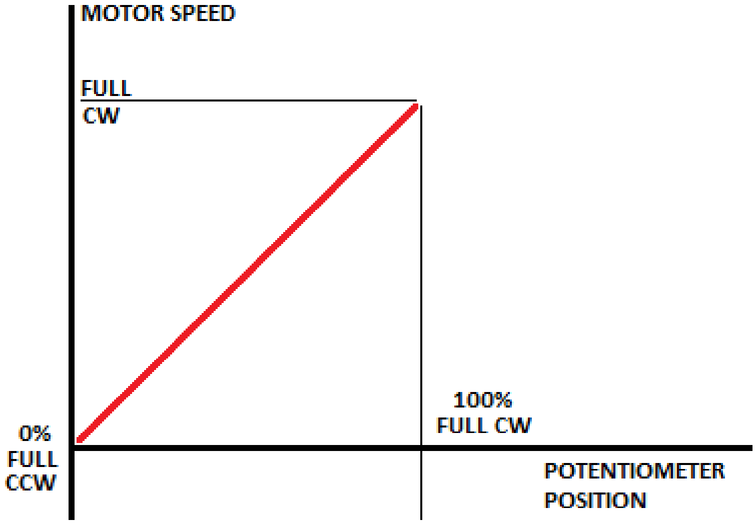
To tune the servo amplifier, follow these steps:
1. Connect the motor **with** the load attached.
2. Start the motor with load.
3. Turn the current loop tuning potentiometer clockwise until the motor begins to make audible noise.

    WARNING: *Exercise extreme caution when turning the potentiometer as it is very fragile. It is recommended to use a bent, z-shaped wire in place of a flat screw driver to minimize the possibility of damage.*

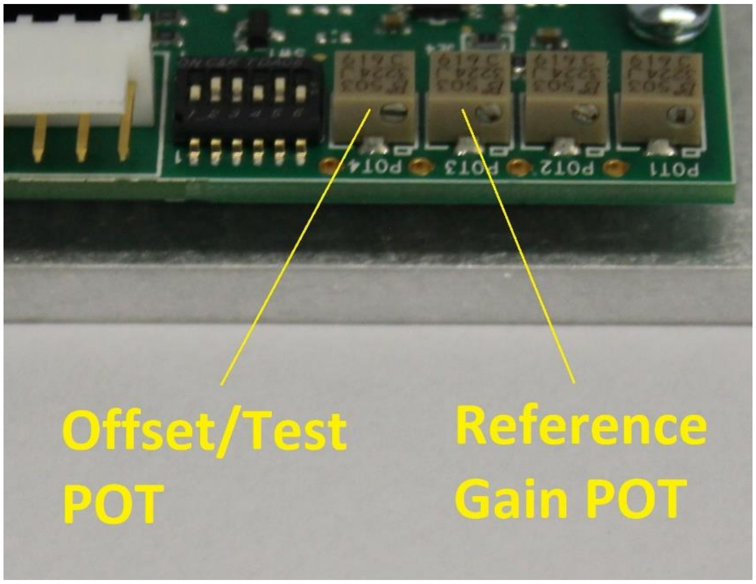
4. Turn the current loop tuning potentiometer counterclockwise slowly until the noise subsides.

3. Adjusting the Command Signal Curve using the built in potentiometers of the SA-2550A servo amplifier.

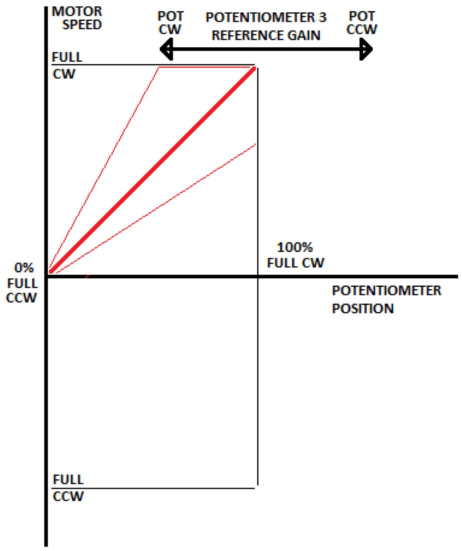
Depending on how the built in potentiometers are preset the correlation of command voltage to motor speed may result in less control of motor speed then desired. A typical command curve would appear as below if potentiometer at full CCW is 0% and full CW is 100% output.

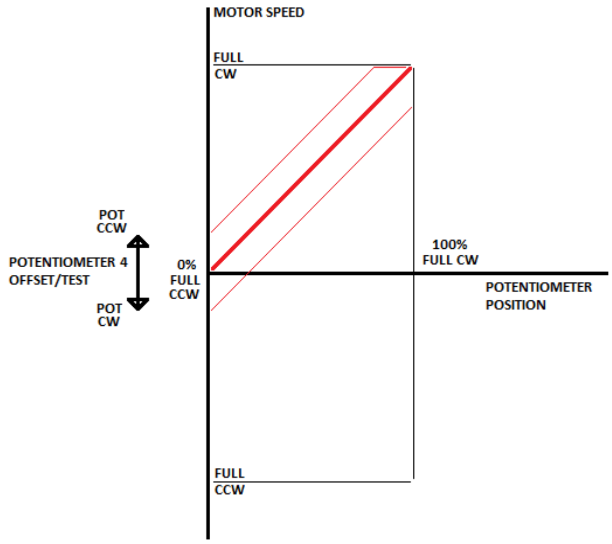


Depending on what the application demands it may be desired to change the characteristics of the command curve. On the SA-2550A the command curve can be altered by using the built in potentiometers for Reference Gain (POT 3) and Offset/Test (POT 4):



The respective potentiometers have the following effects on the command curve:





As noted in the Potentiometer Functions table on page 6, each potentiometer has approximately 12 active turns. Turning the potentiometer beyond these active points will have no effect on the command curve.