MODEL 405
DC SERVO AMPLIFIER WITH ENCODER TACHOMETER

±50 Volts output at ±10A Peak, ±5A Continuous

FEATURES

- **Velocity mode operation from quadrature encoder or brush tachometer**
- **+5V @ 200mA for encoders**
- **Enable polarity selectable to +5 or ground active**
- **Single supply voltage: +18 to +55VDC**
- **5A continuous, 10A peak more than double the power output of servo chip sets**
- **Fault protections:**
  Short-circuits from output to output, output to ground
  Over/under voltage
  Over temperature
  Self-reset or latch-off
- **2.5kHz bandwidth**
- **Wide load inductance range: 0.2-40 mH.**
- **Separate continuous, peak, and peak-time current limits**

APPLICATIONS

- **Velocity loops for PLC's or for speed controls**
- **Belt, fan, or spindle drives**

THE *OEM* ADVANTAGE

- **Conservative design for high MTBF**
- **Low cost solution for small motors to 1/3 HP**
- **Small size from SMT design 4.75" x 3.27" x 1.28"**
- **Solderless socket for configuration components**

PRODUCT DESCRIPTION

Model 405 operates DC brush motors in tachless velocity loops using A&B signals from incremental quadrature encoders. It can also operate from dc brush tachometers.

Frequency to voltage conversion of encoder signals creates a digital pulse-train that is low-pass filtered to form the analog tachometer signal that is proportional to motor speed and direction. Spindle drives and other speed controls benefit from this form of velocity control.

Power delivery is four-quadrant for bi-directional acceleration and deceleration of motors.

The Model 405 features 500W peak power output in a compact package using surface mount technology.

An internal header socket holds components which configure the various gain and current limit settings to customize the 405 for different loads and applications.

Separate peak and continuous current limits allow high acceleration without sacrificing protection against continuous overloads. Peak current time limit is settable to match amplifier to motor thermal limits.

Header components permit compensation over a wide range of load inductances to maximize bandwidth with different motors.

Logic inputs include remote inhibit/enable, and Pos/Neg enable inputs for connection to limit switches. Amplifier Enable input has selectable polarity for easy interface to all types of motion-control cards. Directional (Pos & Neg) enables always use fail-safe (ground to enable) logic.

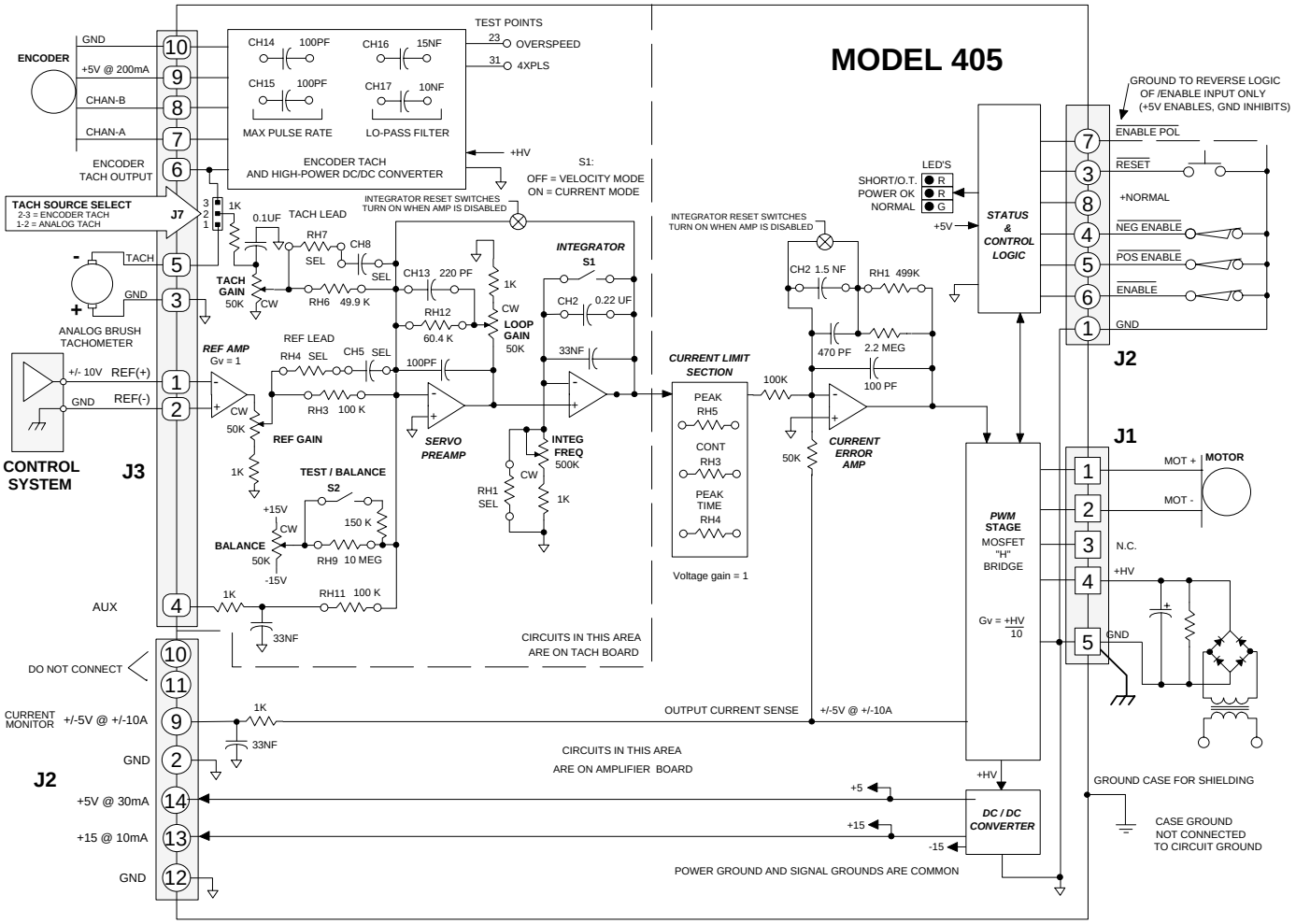
Package design places all connectors along one edge for easy connection and adjustment while minimizing footprint inside enclosures.

High quality components and conservative ratings insure long service life and high reliability in industrial installations.

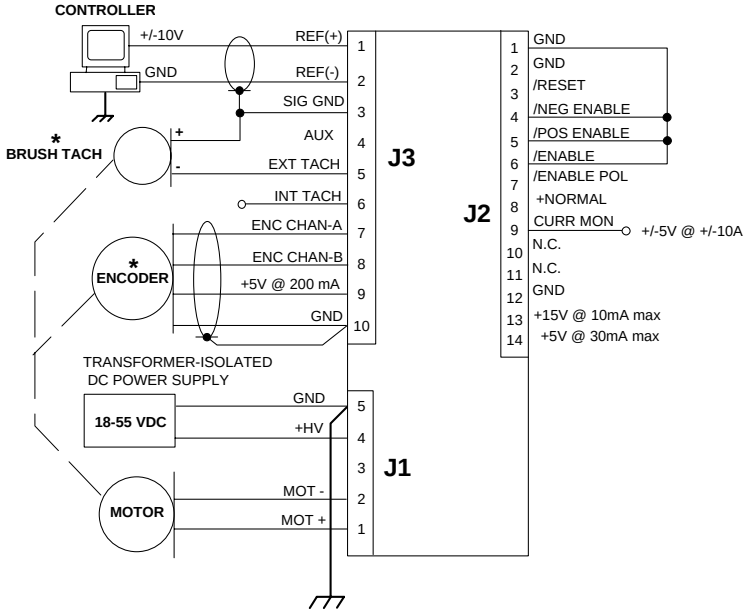
A differential amplifier buffers the reference voltage input to reject common-mode noise resulting from potential differences between controller and amplifier grounds.

Output short circuits and heatplate overtemperature cause the amplifier to latch into shutdown. Grounding the /Reset input will enable an auto-reset from such conditions when this feature is desired.

FUNCTIONAL DIAGRAM

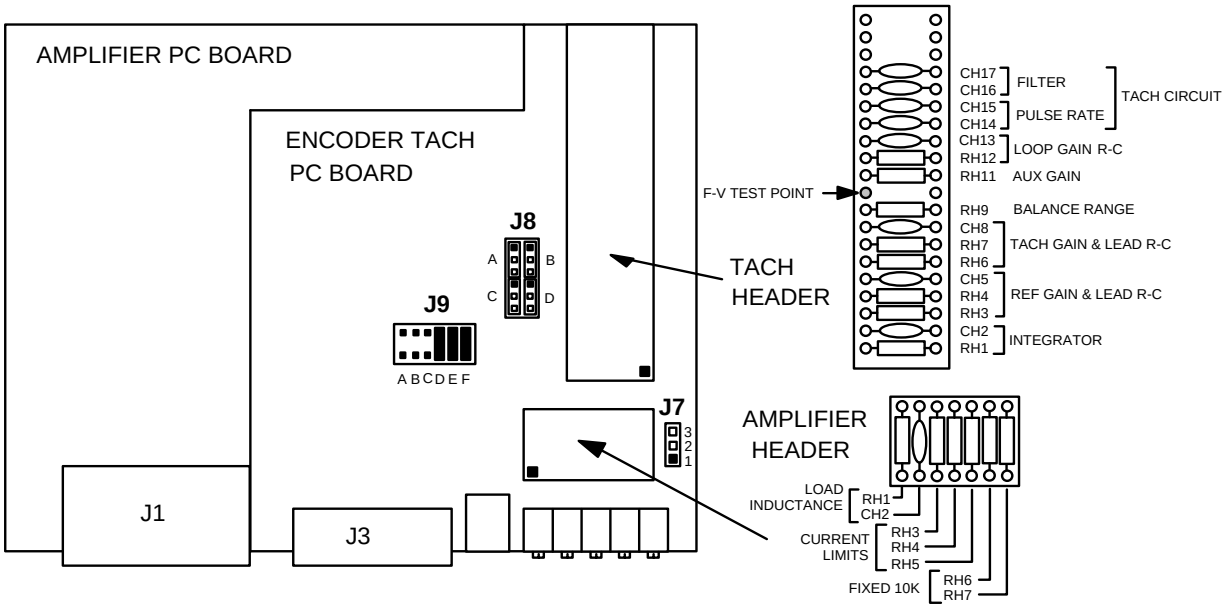


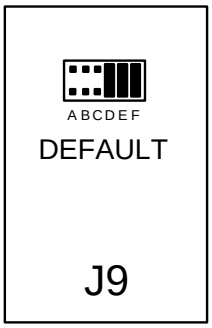
TYPICAL CONNECTIONS

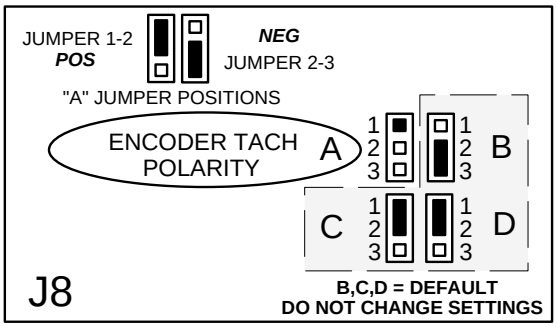


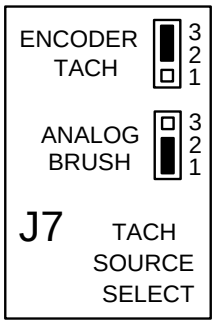
* Wiring shows wiring for both encoder tachometer, and analog brush tachometer. In practice, only one would be wired.

INTERNAL SOCKETS & JUMPERS

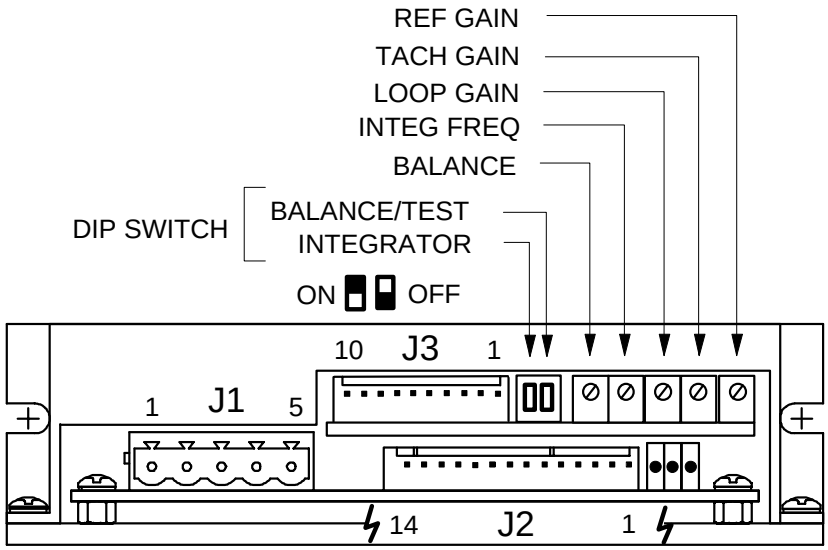








AMPLIFIER LAYOUT



J1	Motor & Power Supply	5 position Euro: Weidmuller BL-12594.6, Phoenix MSTB 2.5/5-ST-5.08
J2	Amplifier Signals	14 position 0.1” centers: Molex 22-01-3147 with 08-50-0114 terminals
J3	Tach Card Signals	10 position 0.1” centers: Molex 22-01-3107 with 08-50-0114 terminals

CONNECTORS AND PINOUTS

J1: MOTOR & POWER CONNECTIONS

Pin	Signal	Remarks
1	Motor (+) Output	Amplifier output to motor
2	Motor (-) Output	Amplifier output to motor
3	N.C.	No Connection
4	+HV	18-55V DC power supply input
5	GND	Power supply return. Connect to system ground at this pin *

* Amplifier case may be grounded for lower emitted noise.
Case and amplifier ground are not connected.

J2: AMPLIFIER BOARD CONNECTIONS

Pin	Signal	Remarks
1	GND	Signal ground (Note 2)
2	GND	Signal ground (Note 2)
3	/RESET	Normally open. Ground to clear overtemp or short circuit fault. Wire to ground for self-reset from fault every 50 mS.
4	/NEG ENAB	Negative rotation enable (ground to enable, open inhibits)
5	/POS ENAB	Positive rotation enable (ground to enable, open inhibits)
6	/ENABLE	Amplifier enable. Ground to enable amp, open inhibits. 50 mS delay between Enable active and amp outputs ON
7	/ENABLE POL	/Enable polarity With J2-7 open, ground @ J2-6 enables amp. With J2-7 grounded: +5V or open enables amp, ground inhibits
8	+ NORMAL	HI (+5 V) if amplifier operating normally (No faults) LO if amp disabled, +HV over or undervoltage, overtemp, or output short circuit.
9	CURR MON	2A/Volt current monitor output (bipolar)
10	Do Not Use	No connection. Pins used by tach card.(Note 1.)
11	Do Not Use	No connection. Pins used by tach card. (Note 1.)
12	GND	Signal ground (Note 2)
13	+15 V	+15 V at 10 mA (total power from +5 and +15
14	+5 V	+5 V at 30 mA outputs not to exceed 200mW)

J3: TACH BOARD CONNECTIONS

Pin	Signal	Remarks
1	Ref(+) Input	±10V reference input.
2	Ref(-) Input	Reference ground (connect to gnd at reference voltage source)
3	Gnd	Brush tachometer (+), or reference cable shield
4	Aux Input	Auxiliary input (single-ended analog input)
5	Ext. Tach Input	External brush tachometer (-), or analog velocity feedback
6	Int. Tach Output	Encoder tach output (±10V at max pulse-rate)
7	Encoder A Chan	Quadrature encoder channel-A
8	Encoder B Chan	Quadrature encoder channel B
9	Encoder +5V	+5V @ 200mA powers encoder
10	Encoder Gnd	0V or ground for encoder (also connect to encoder cable shield)

Notes
1. Pins J2-**10,11** are Ref inputs on model 403. DO NOT USE on model 405, these connect to tachometer board internally.
   Reference inputs are on tach card, J3 pins **1** and **2**.
2. All amplifier grounds are electrically common. J1-**5**, J2-**1**, J2-**2**, J2-**12**, J3-**3**, & J3-**10** are all connected inside the amplifier. *The amplifier circuitry is isolated from the case*.

DIP SWITCH FUNCTIONS

S1: Integrator — ON = flat gain (integrator OFF)
OFF = tachometer mode (integrator ON, Integ Freq pot adjusts stiffness)

S2: Test / Balance — ON = test mode (Balance pot has ±10V range)
OFF = balance mode (set output current to zero with zero input)

TECHNICAL SPECIFICATIONS

Typical specifications @ 25°C ambient, +HV = +55VDC. Load = 200µH. in series with 1 ohm unless otherwise specified.

AMPLIFIER SPECIFICATIONS

OUTPUT POWER		
	Peak power	
	Unidirectional	±10A @ 50V for 0.5 second, 500W
	After direction change	±10A @ 50V for 1 second, 500W
	Continuous power	±5A @ 50V, 250W
OUTPUT VOLTAGE		Vout = (0.97)(HV) - (0.4)(Iout)
MAXIMUM CONTINUOUS OUTPUT CURRENT		
	Convection cooled, no conductive cooling	±2A @ 35°C ambient
	Mounted on narrow edge, on steel plate, fan-cooled 400 ft/min	±5A @ 55°C
LOAD INDUCTANCE		
	Selectable with components on header socket	200 µH to 40mH (Nominal, for higher inductances consult factory)
BANDWIDTH		
	Small signal	-3dB @ 2.5kHz with 200µH load
	Note: actual bandwidth will depend on supply voltage, load inductance, and header component selection	
PWM SWITCHING FREQUENCY		25kHz
ANALOG INPUTS		
	Reference ± Inputs	Differential, 94kΩ between inputs, ±10V typical, ±20V max
	Auxiliary Input	Single-ended, 1kΩ/33nF input filter to RH11 on header
	Tachometer	Single-ended, 1kΩ/0.1µF input filter to 50kΩ pot with tap to RH6, RH7 on header
LOGIC INPUTS		
	Logic threshold voltage	HI: ≥ 2.5V , LO: ≤1.0V
	Input voltage range	Gnd to +5V maximum
	/Enable	LO enables amplifier (/Enable Pol open) , HI inhibits; 50 ms turn-on delay
	/POS enable, /NEG enable	LO enables positive/negative output currents, HI inhibits
	/Reset	LO resets latching fault condition, ground for self-reset every 50 ms.
	/Enable Pol (Enable Polarity)	LO reverses logic of /Enable input (HI enables unit, LO inhibits) /POS and /NEG enable inputs not affected by /Enable Pol selection
LOGIC OUTPUTS		
	+Normal	HI when unit operating normally, LO if overtemp, output short, disabled, or power supply (+HV) out of tolerance
	Definitions:	HI output voltage = 2.4V min at -3.2 mA max., LO output voltage = 0.5V max at 24 mA max.
		+5V maximum, do NOT connect to devices operating at greater than +5V
INDICATORS (LED's)		
	Normal (green)	ON = Amplifier enabled, no shorts or overtemp, power within limits
	Power fault (red)	ON = Power fault: +HV <18V OR +HV > 55V
	Short/Overtemp (red)	ON = Output short-circuit or over-temperature condition
MONITOR OUTPUT		
	Current monitor	±5V @ ±10A (2A/volt), 10kΩ, 3.3nF R-C filter
DC POWER OUTPUTS		
	+5VDC (J2-14)	30mA
	+15VDC (J2-13)	±10mA max.
	Encoder +5VDC (J3-9)	200mA max.
PROTECTION		
	Output short circuit (output to output, output to ground)	Latches unit OFF (self-reset if /RESET input grounded)
	Overtemperature	Shutdown at >70°C on heatplate (Latches unit OFF)
	Power supply voltage out of tolerance	Shutdown at +HV <18VDCor +HV >55VDC (operation resumes when supply in tolerance)
POWER REQUIREMENTS		
	DC power (+HV)	18-55 VDC @ 10A peak.
	Minimum power consumption	2.5 W
	Power dissipation at 5A output, 55VDC supply	10W
	Power dissipation at 10A output, 55VDC supply	40W
THERMAL REQUIREMENTS		
	Storage temperature range	-30 to +85°C
	Operating temperature range	0 to 70°C baseplate temperature
MECHANICAL		
	Amplifier case size	4.75 x 3.27 x 1.28 in. (121 x 83 x 32.5 mm)
	Weight	0.61 lb. (0.28 kg.)
CONNECTORS		
	Power & motor	Weidmuller: BL-125946; Phoenix: MSTB 2.5/5-ST-5.08
	Signal	Molex 22-01-3147 housing with 08-50-0114 contacts (14)
	Encoder Tach board`	Molex 22-01-3107 housing with 08-50-0114 contacts (10)

ENCODER TACHOMETER SPECIFICATIONS

MAXIMUM FREQUENCIES		
	Encoder	150,000 lines / sec
	F/V clock internal pulse rate (encoder frequency X 4)	600,000 pulse / sec
LINEARITY		
	< 0.1% of full scale over a 1000:1 rpm range	
SPEED RANGE		1000:1 typical, greater with customization of f-v pulse-rate and low-pass filter parts

APPLICATION INFORMATION

Follow these steps to place amplifier into service in ***encoder tach mode***:

1. Setup amplifier header for motor inductance and current limits.
2. Select tachometer header components for maximum motor speed.
3. Select tach card header components for low-pass filter.
4. Test & adjust potentiometers for optimal velocity-loop operation.

1. MOTOR INDUCTANCE

Note: for this procedure , remove jumper from J7 on tach card, set switch S1 ON, and turn Loop Gain pot fully CCW. Ground J2-4,5,6 to J2-1 to enable amplifier.

RH1 & CH2 on amplifier header socket match amplifier to motor inductance. For easy setup, use chart to select values closest to your motor inductance. If this is done, then install parts in header and proceed to next step. Default components will work with many motors.
To optimize compensation using function generator and oscilloscope: First replace CH2 with a jumper (short). Use reference input of square wave at ±1V, 10Hz. Select RH1 for the best transient response (lowest risetime with minimal overshoot). Once RH1 has been set. select the smallest value of CH2 that does not cause additional overshoot or degradation of the step response.
Select values of RH3, RH4, and RH5 if motor current limits are less than amplifiers 5A continuous, 10A peak rating. Pick starting values from charts. Fine-tune limits by using current monitor and adjusting values for exact limit desired.

2. TOP SPEED SETUP

Note: for this procedure, install jumper at J7 pins 2-3 on tach card, set switch S1 OFF. Begin with Loop Gain and Integ Freq pots fully CCW. If motor runs away, reverse position of jumper J8-A.

GENERAL CONSIDERATIONS

Encoder tachometer mode gives a wide speed range combined with a fast velocity-loop response. Useable speed ranges of 1000:1 or greater are possible with optimal settings of the max pulse rate and low-pass filter settings.

The top speed setting controls the frequency to voltage conversion scale factor so that the tach voltage will be about ±5V at top speed. The low pass filter controls the time constant of the velocity loop, and has a large effect on the ripple at low speeds. As speed drops, ripple will increase. At a standstill, there will be no feedback between encoder transitions, resulting in jitter. This may be acceptably small for an encoder application with higher (500 lines or greater) line counts, or unacceptably rough for low line-count encoders. Use the Enable input to disable the amplifier if zero-output is required.

F-V SETUP

An f-v pulse train is generated that is 4X the encoder line frequency. The maximum f-v clock rate is 600kHz. Before proceeding, check to make sure that your f/v clock will be in limits.

$$\text{f - v Encoder} = \frac{Lines \times rpm}{15}$$

If the rate is greater than 600kHz, then maximum rpm must be reduced.
If the rate is acceptable, select the f-v capacitors CH14 & CH15 as follows: Select CH14 & CH15 based on this equation:

$$C = \frac{1 \times 10^9}{Lines \times rpm} \quad (C = pF)$$

Select a capacitor with the closest value. This should produce a tach-voltage of about ±5V at the rpm used in the equations.

3. LOW-PASS FILTER

The choice of low-pass filter will determine both the useable rpm range of the f-v converter and the effective response time of the velocity-loop (or effective bandwidth). For widest speed range, set the low-pass filter frequency to a lower value. For faster response times (higher velocity loop bandwidth) set the frequency to a higher value. Filter frequency is:

$$F = \frac{1590}{CH17} \quad \text{(nF)}$$

$$CH16 = 1.5 \times CH17$$

As delivered, the 405 has a filter frequency of 159Hz. This should work well for encoder-tach modes with a wide variety of motors in the size range that the 405 can drive. This frequency is high enough so that the velocity loop response will be affected mainly by the tach-rpm / volt gain, and the tuning of the Loop Gain and Integ Freq potentiometers. In general, use the lowest frequency possible that does not begin to slow down the response of the loop to a step input. This will give the widest rpm range.

4. VELOCITY LOOP TUNING

Begin with S1 ON, Ref Gain pot fully CW, Tach Gain pot fully CCW, Loop Gain pot fully CCW. *Motor should be disconnected from load until initial setup is complete*. Enable amplifier and rotate shaft slightly. If motor runs away, reverse position of jumper J8A. Tachometer polarity should now be correct, and motor should remain at rest with no reference inputs.

STATIC SETUP

Set switch S2 ON. Rotate Balance pot fully CW. This will be equivalent to applying +10V to Ref inputs. Measure tach voltage at J3-6. This should be about +5V if CH14 & 15 have been chosen correctly. Motor rpm can be measured by viewing any encoder signal and calculating as follows:

$$RPM = \frac{60}{Tenc \times Lines}$$

Where Tenc is the *period* of one encoder line (channel A or B).

DYNAMIC SETUP

Set switch S1 ON, and S2 OFF. Use a function generator with a square wave output. Connect to reference inputs and adjust frequency so that motor can change direction and settle to a set speed. Connect oscilloscope to J3-6 to monitor tachometer voltage. If possible, also connect to J2-9, current monitor. Adjust Loop Gain pot for fastest response that does not produce oscillation or excessive ringing of either tach signal, or current monitor. When Loop Gain is adjusted, set S1 OFF. Adjust Integ Freq CW until overshoot on tach signal rings and back off for stable response. CW adjustment increases stiffness (speed stability), but too much will produce oscillation. With Loop Gain and Integ Freq adjusted properly, response to step inputs will be smooth, and free from oscillation.

GROUNDING & POWER SUPPLIES

Power ground and signal ground are connected internally in the Model 405. These grounds are isolated from the amplifier case which can then be grounded for best shielding while not affecting the power circuits.

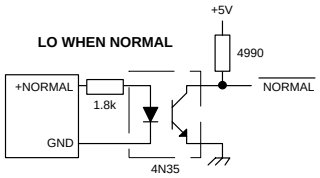
Currents flowing in the power supply connections will create noise that can appear on the amplifier grounds.

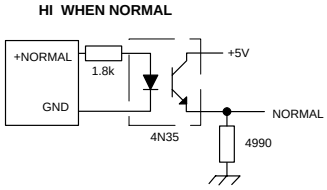
This noise will be rejected by the differential amplifier at the reference input, but will appear at the digital inputs. These are filtered, but for lowest noise, leave the power-supply capacitor floating, and ground each amplifier at its power ground terminal (J1-5). In multiple amplifier configurations, always use separate cables to each amplifier, twisting these together for lowest noise emission. Twisting motor leads will also reduce radiated noise from pwm outputs. If amplifiers are more than 1m. from power supply capacitor, use a small (200-500µF.) capacitor across power inputs for local bypassing.

NORMAL OUTPUT

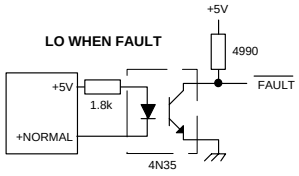
This is a +5V logic level signal that will be HI (+5V) when the amplifier is operating normally, and will go LO (ground) if there is a fault condition, or if the amplifier is disabled (inhibited).

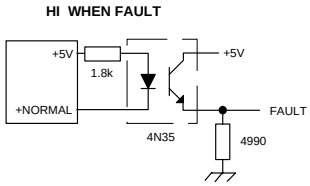
It can source or sink 2mA, which can then be used to drive an optocoupler, if isolation for the signal is desired. The illustrations below show an optocoupler used to make either a LO or HI active Normal signal.





If a FAULT signal is required, then reversing the connections to the input led of the optocoupler will provide it, as shown below.





AMPLIFIER COMPONENT HEADER

CURRENT-LIMITS

I-Peak	RH5
10A	***Open****
8A	12k
6A	4.7k
4A	2k
2A	750

I-Cont	RH3
5A	***Open****
4A	20k
3A	8.2k
2A	3.9k
1A	1.5k

T-Peak	RH4
0.5s	***Open****
0.4s	10 Meg
0.2s	3.3 Meg
0.1s	1 Meg

LOAD INDUCTANCE

Load (mH)	RH1	CH2
0.2	49.9 k	1.5 nF
1	150 k	1.5 nF
3	***499 k****	***1.5 nF***
10	499 k	3.3 nF
33	499 k	6.8 nF
40	499 k	10 nF

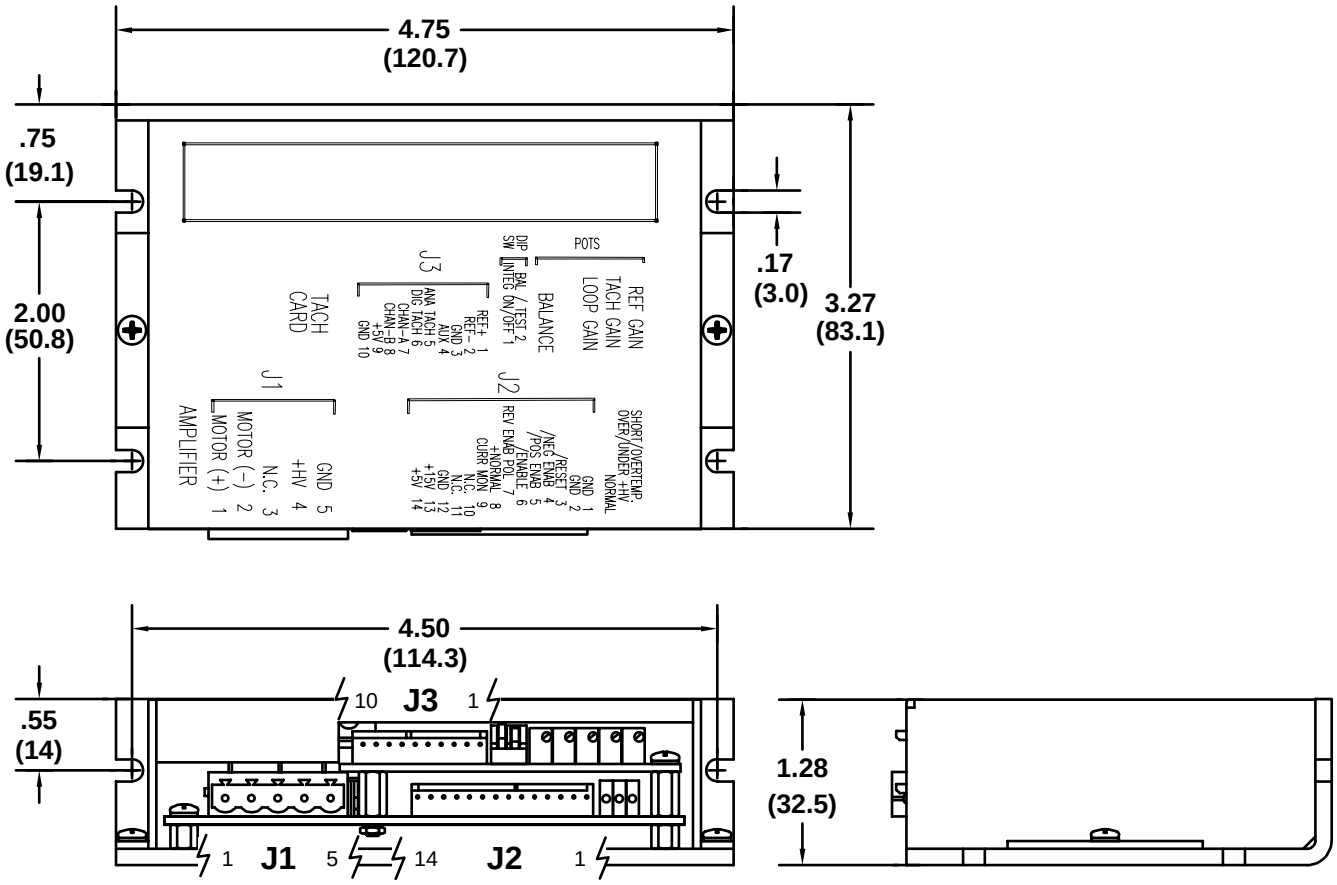
Notes:

**** Standard values installed at factory are shown in italics.***

1. Bandwidth and values of RH1, CH2 are affected by supply voltage and load inductance. Final selection should be based on customer tests using actual motor at nominal supply voltage.
2. Peak current setting should always be greater than continuous current setting.
3. Peak times will double when current changes polarity.
   Peak times decrease as continuous current increases.

OUTLINE DIMENSIONS

Dimensions in inches (mm.)



WEIGHT:	0.61 lb (0.28 kg)	
CONNECTORS	Power & motor	Weidmuller: BL-125946; Phoenix: MSTB 2.5/5-ST-5.08
	Signal	Molex 22-01-3147 housing with 08-50-0114 contacts (14)
	Encoder Tach board`	Molex 22-01-3107 housing with 08-50-0114 contacts (10)

ORDERING GUIDE

Model 405	5A Continuous, 10A Peak, +18 to +55V DC Brushless Servoamplifier with Encoder Tach

OTHER DC SERVO AMPLIFIERS

Model 403 Same power specifications as 405. Torque mode only, no encoder tach.

400 Series Six models: +24 to +225V operation, 5-15A continuous, 10-30A peak.

Copley Controls Corp.

Corporate Office, USA

20 Dan Road
Canton, MA 02021
Tel: 781-828-8090
Fax: 781-828-6547