FEATURES

- *Three independent servoamplifiers in one compact footprint*
- *No external potentiometers!*
- **Efficient use of space**
- **Simplified Mounting and Cabling**
- ***Flexibility!* Internal 18-pin socket configures amp with no soldering**
- **Separate channel Current limits**
- **No integrator windup when disabled**
- **Fault protections:
Short-circuits from output to output, output to ground
Over/under voltage
Over temperature
Self-reset or latch-off modes**
- **3kHz Bandwidth**
- **Wide load inductance range: 0.2-40 mH.**
-
- **Surface mount technology construction, lower part count.**

APPLICATIONS

- **X-Y-Z stages**
- **Robotics**
- **Automated assembly machin-ery**
- **Magnetic bearings**

THE OEM ADVANTAGE

- **Conservative design for high MTBF**
- **No soldering required to change header parts.**
- **Custom configurations available (contact factory)**

MODEL	POWER	I-LIMIT
4113	+24 to +90 VDC	10

DESCRIPTION

Model 4113 consists of three independent transconductance amplifiers constructed onto a single printed circuit board. Operating from +22 to +90VDC isolated power supplies, each channel can output 10A continu-ously in four quadrants, accelerating and decelerating the motor in both directions.

Each of the three channels of the 4113 can drive an independent motor or inductive load. These may be dc brush or other single-coil motors, or multi-coil motors such as stepper or brushless motors where the coil-drive signals originate in an external controller.

Transconductance is fixed at 1A / V. Current limit, and load inductance compensation are set with components in a socket on the amplifier p.c. board.

MOSFET transistors form three H-bridge output stages that operate in PWM (pulse-width modulated) mode for high efficiency and low ripple current in the motor.

Precise adjustment of positive-negative gain symmetry, and dc balance is possible via three internal trimmer potentiometers for each channel.

Each channel has independent Enable and Brake inputs. The braking feature provides dynamic braking of the motor up to the amplifiers built in current limit.

The 25 kHz switching frequency eliminates audible noise from motor windings and provides fast rise and fall times for efficient operation. Output modulation minimizes ripple currents in motor windings to reduce thermal and mechanical stress and maintain high bandwidth. The combination of these characteristics are particularly useful for driving low-inductance motors.

The 4113 is self-protected against over-temperature, over-voltage and under-voltage conditions, and for short circuits from output-to-output, and output-to-ground

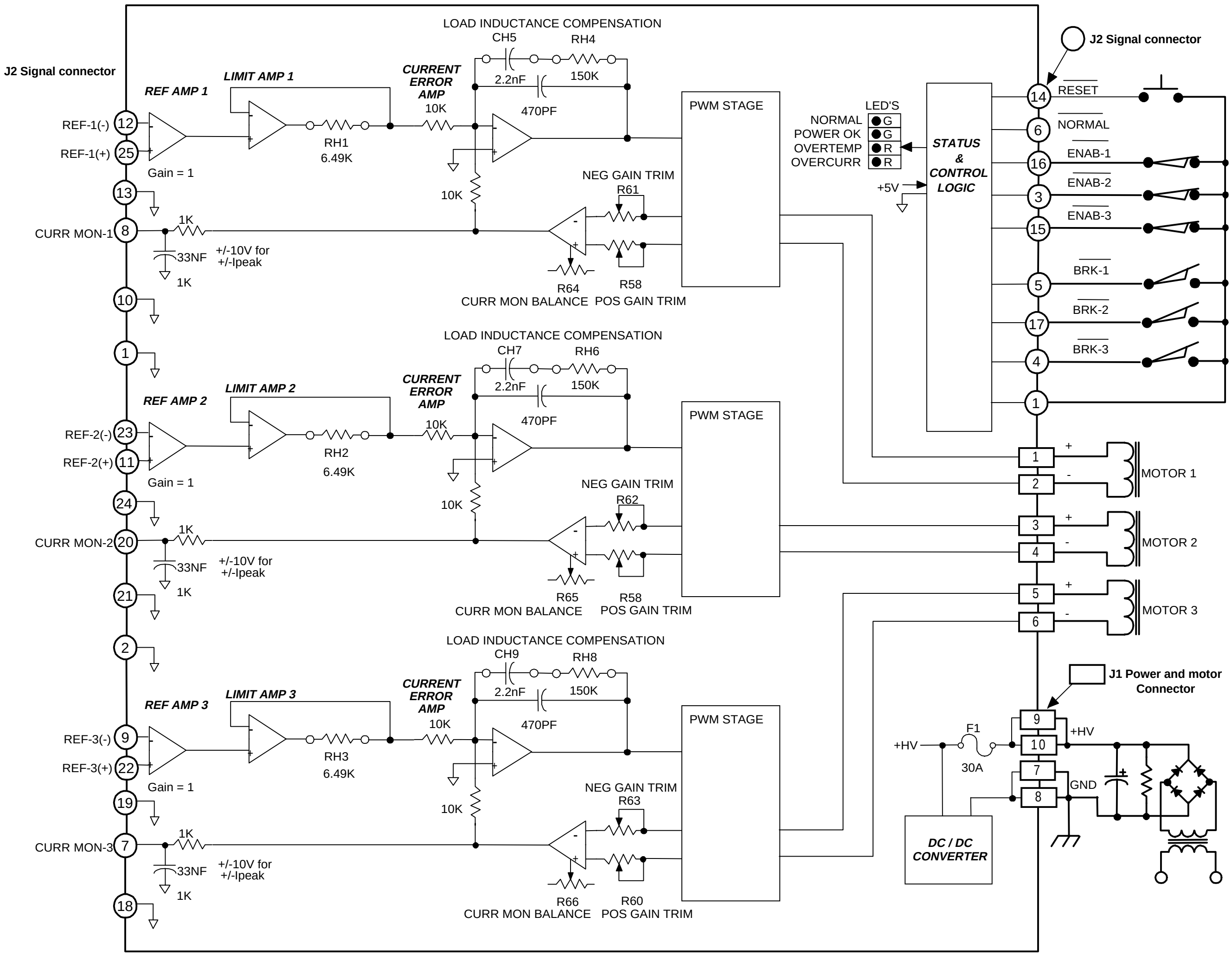
Technical Specifications

Test conditions: 25°C ambient. +HV = 90VDC, load: 1mH. In series with 1Ω

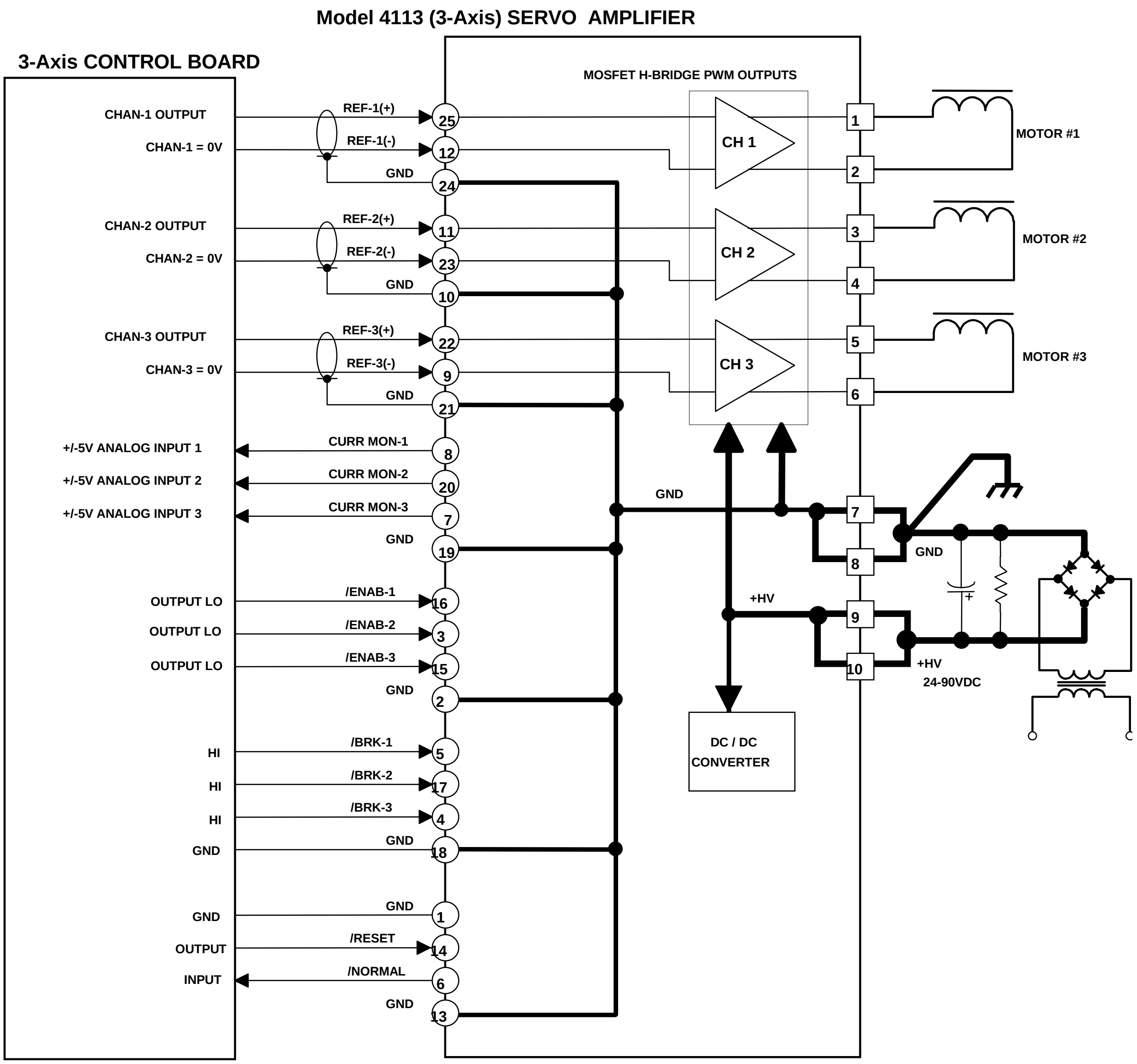
OUTPUT POWER	
Continuous, each channel±10A @ ±90VDC	
OUTPUT VOLTAGE	V_{out} = ±HV*(0.97)-(0.2)(I_{out})
MAXIMUM CONTINUOUS OUTPUT CURRENT	
Convection cooled, no conductive cooling	±10A @ 35°C ambient
Mounted on narrow edge, on steel plate, fan-cooled 400 ft/min	±5A @ 55°C
LOAD INDUCTANCE	
Selectable with components on header socket	200 µH to 40mH (Nominal)
	Factory settings are for 8mH load in series with 8Ω
BANDWIDTH Small signal	-3dB @ 1kHz with 8mH load @ +HV = 90VDC
Note: bandwidth varies with supply voltage, load inductance, and header component selection	
PWM SWITCHING FREQUENCY	25kHz ±3kHz
ANALOG INPUT CHARACTERISTICS	
Reference	Differential, 94K between inputs, ±20V maximum
GAINS	
Transconductance	10A / 10V (1Amp/Volt)
Gain Tolerance	Settable to ±0.5% with internal potentiometers
OFFSET	
Output offset current (Vref = 0V)	±50 mA max
Input offset voltage (Iout = 0A)	±50 mV max
LOGIC INPUTS	
/Enable1, /Enable2, /Enable3	LO enables drive, open or +5V inhibits; 5ms turn-on delay
/Brake1, /Brake2, /Brake3	LO brakes motor, open or +5V normal operation
/Reset	LO resets latching fault condition on any channel
	ground for self-reset every 50mS
Logic Input Structure	10kΩ pullup resistor to +5V, followed by low-pass filter
	to CMOS Schmitt trigger with 2.5V threshold
LOGIC OUTPUTS	
/Normal	LO when all 3 channels operating normally, HI if overtemp, output short, or power NOT-
OK	
Output voltage levels	LO: 0.5Vmax @ 4mA max, HI: 2.4V min at -4mA max
Maximum output voltage:	+5V
INDICATORS (LED's)	
Normal (green)	ON = (Power OK) AND (NOT overtemp) AND (NOT output short)
Power OK (green)	ON = (+HV > 22V) AND (+HV < 93V)
Overcurrent (red)	ON = Output short-circuit on any channel (latches unit off)
Overtemp (red)	ON = heatplate >70°C
MONITOR OUTPUT	
Current monitor	-/+5V @ +/-10A (-2A/volt), 1kΩ, 33nF R-C filter
PROTECTION	
Internal fuse	30A, 125VDC, time-dslay
Output short circuit (output to output, output to ground)	Latches unit OFF (self-reset every 50mS if /RESET input
	grounded, or reset when power cycled off/on)
Overtemperature	Shutdown at 70°C on heatplate (operation resumes when heatplate <70°C)
Power supply voltage too low (Undervoltage)	Shutdown at +HV < 22VDC (operation resumes when power > 22VDC)
Power supply voltage too high (Overvoltage)	Shutdown at +HV > 93VDC (operation resumes when power <93VDC)
Current-limiting	Output current for each channel set by header components
POWER REQUIREMENTS	
DC POWER (+HV)	**+24~90 VDC @ 30A MAX.**
MINIMUM POWER CONSUMPTION	**3 W**
THERMAL REQUIREMENTS	
Storage temperature range	-30 to +85°C
Operating temperature range	0 to 70°C baseplate temperature
MECHANICAL	
Size	4.7 x 8.3 x 1.4 in. (119.4 x 211 x 35.6mm)
Weight	1.75 lb (0.8 kg.)
CONNECTORS	
Amplifier J1: Signal connector	25 position male "Sub-D" style connector
J2: Power & motor connector	10 position Euro-style male connector, black, 5.08mm pitch
	Beau/Vernitron 861910 or AMP 1-786488-9
Cable P1: Signal plug	25 position female "Sub-D" with screw-locks
P2: Power & motor plug	Beau/Vernitron 860510, Phoenix: 17-57-09-3

Copley Controls Corp.

FUNCTIONAL DIAGRAM



TYPICAL CONNECTIONS



Notes *Important: Transconductance amplifiers produce torque in a motor, and this in turn produces acceleration. Velocity is not controlled. An unloaded motor will spin-up to its maximum speed when torque is applied. Velocity control is produced by feedback from the motor to the control system and not within the amplifier.*

Connectors and Pinouts

Two connectors interface the drive to power, signals, and motor.
Types of signals are listed after the pin number or letter.

P	*Passive*	Power and ground
M	*Motor connections*	
I	*Input*	Analog or digital signal inputs
O	*Output*	Signal, logic, and power-stage outputs

Note: See appendix for complete listing of connectors and part-numbers.

J1: SIGNAL CONNECTIONS

25 position male 'Sub-D' connector on amplifier.

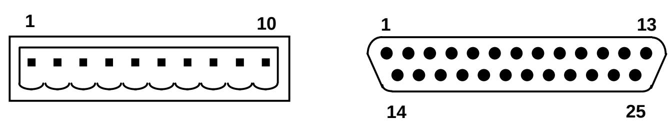
Pin	Type	Signal	Remarks
1	P	Gnd	Signal & logic ground
2	P	Gnd	Signal & logic ground
3	I	/Enable-2	Channel 2 Enable Input (Ground = Enable)
4	I	/Brake-3	Channel 3 Brake Input (Ground = Brake)
5	I	/Brake-1	Channel 1 Brake Input (Ground = Brake)
6	O	/Normal	Normal Output (LO: Chan 1 AND 2 AND 3 are Normal, +5V: Fault on *any* channel)
7	O	Curr Mon-3	Channel 3 Current Monitor Output
8	O	Curr Mon-1	Channel 1 Current Monitor Output
9	I	Ref-3(-)	Channel 3 (-) Reference Input
10	P	Gnd	Signal & logic ground
11	I	Ref-2(+)	Channel 2 (+) Reference Input
12	I	Ref-1(-)	Channel 1 (-) Reference Input
13	P	Gnd	Signal & logic ground
14	I	/Reset	Reset input (Ground resets fault on *any* channel)
15	I	/Enable-3	Channel 3 Enable Input (Ground = Enable)
16	I	/Enable-1	Channel 1 Enable Input (Ground = Enable)
17	I	/Brake-2	Channel 2 Brake Input (Ground = Brake)
18	P	Gnd	Signal & logic ground
19	P	Gnd	Signal & logic ground
20	O	Curr Mon-2	Channel 2 Current Monitor Output
21	P	Gnd	Signal & logic ground
22	I	Ref-3(+)	Channel 3 (+) Reference Input
23	I	Ref-2(-)	Channel 2 (-) Reference Input
24	P	Gnd	Signal & logic ground
25	I	Ref-1(+)	Channel 1 (+) Reference Input

J2: MOTOR & POWER CONNECTIONS

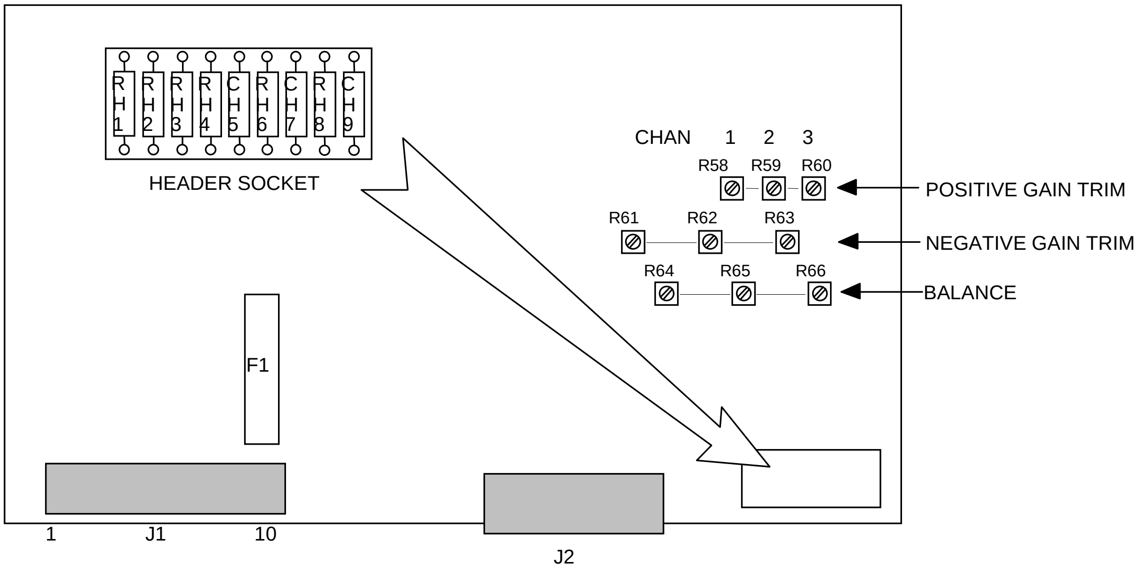
10 position male Euro-style connector, 5.08mm pitch.

Pin	Type	Remarks
1	M	Channel 1 Motor (+) Output
2	M	Channel 1 Motor (-) Output
3	M	Channel 2 Motor (+) Output
4	M	Channel 2 Motor (-) Output
5	M	Channel 3 Motor (+) Output
6	M	Channel 3 Motor (-) Output
7	P	Power Ground
8	P	
9	P	High Voltage Input (24-90VDC)
10	P	

J2: POWER & MOTOR CONNECTOR **J1: SIGNAL CONNECTOR**



COMPONENT HEADER



ARMATURE INDUCTANCE
In this chart R represents RH4, RH6, RH8, and C is for CH5, CH7, and CH9

Load (mH)	R	C	BW @ 90V
0.2	6.04k	33nF	2.3kHz
1	20k		2kHz
3	49.9k		1.7kHz
10	100k	22nF	1kHz
33	220k		700Hz
40	301k		600Hz

Note: R = 150K, C = 2.2nF are factory installed standard. Values shown are for 90V. At lower supply voltages R may be increased and C decreased.

CURRENT LIMIT

In this chart, R represents RH1, RH2, or RH3. The factory installed value of 6.49kΩ permits the peak rated output current of 10A to flow, and limits at about 10.2A.

The table below gives values for typical limiting currents. Standard resistor values may give slightly different limits. For limits not in the table, see following section “Customizing Current Limits”.

Ipeak (A)	R (Ω)
10	7.5k
9	10k
8	14k
7	20k
6	25k
5	35k
4	49k
3	71k
2	109k
1	250k

APPLICATION INFORMATION

A BASIC CHECKLIST

The following equipment is needed for basic operation.

1. A transformer-isolated dc power supply with output voltage within the range of 24 to 90VDC.
2. A reference-voltage source, equipped with switchable polarity and amplitude. Square wave output will be most useful for setting up the motor inductance compensation and current limits.
3. A motor, or other inductive load in the range of 0.25 to 40 mH.
4. An oscilloscope for monitoring the signal at the current monitor.

ADDITIONAL TIPS

1. Use *both* reference signal inputs. Do not connect REF- to signal ground. If your power supply is grounded at the negative terminal of the bypass capacitor, for example, the signal ground may not be at 0V relative to REF- ground due to I-R drops in connector cables. Separating ground nodes and using both reference inputs will ensure true differential operation, maximize system accuracy, and reject any potential difference in voltage between ground and drive or signal source inputs.
2. Be sure to separate motor and signal wires in cable bundles wherever possible. Remember, crosstalk and the pickup of noise is maximized when wires run parallel to one another. Twisted motor cables will minimize the coupling of noise to other circuits; shielded cable will reduce crosstalk.

POWER SUPPLY CONSIDERATIONS

1. Determine the maximum voltage required to drive your motor or load at peak current and peak RPM (in the case of a motor).
   Add extra for IR losses in the drive (Vout = HV 0.97- [Io*0.2Ω]).
   Add an extra 5-10% for power supply ripple.
   Use this value, and the drive's continuous current rating as your nominal power supply specification at normal line voltage.
   Peak currents of 2-2.5X the continuous current rating can usually be tolerated by off-the-shelf transformer-rectifier-capacitor power supplies.
2. The 4113 has 1400µF of internal filter capacitance which makes it unnecessary to add external capacitors to bypass power supply lead inductance. However, the main filter capacitor should still be sized for ripple voltage under maximum load currents, and for absorption of regenerative energy.
3. Use the current monitor output to check for clipping when your system is up and running. This could be an indication that there is insufficient buss voltage to drive the commanded current through the load.
4. If operating at lower supply voltages, near the 24V lower supply limit, check the NORMAL LED. If it goes out occasionally, this could mean that the buss voltage 'sags' during periods of high current demand, and is lowering the buss voltage below the under voltage cutoff point (<22 V). If this occurs, consider using a larger filter capacitor, or raising the supply voltage.
5. If the load has a high inertia, you may need Copley Controls' model 121 regenerative energy dissipater, or larger filter capacitors. When a heavy load is decelerated, the drive will transfer energy *from* the motor *to* the power supply. This will 'pump-up' the buss voltage, and can cause either an overvoltage shutdown, or damage the drive. If you see the NORMAL LED go out when the load is decelerated, it is a sign that the buss is "pumping-up", and you will have to take measures as suggested above, lower the buss voltage, or decelerate the load more slowly.
7. When multiple drives are connected to the same power supply, use a 'star' wiring configuration. Don't 'daisy-chain' drives by connecting one to the next. Make connections between each individual drive and the power supply, and ground each drive at J2-7 or J2-8 leaving the (-) terminal of the filter capacitor disconnected from ground. Doing this will keep the reference and logic inputs of the drives referenced to ground, while the voltage at the negative terminal of the filter capacitor changes in response to the current drawn through the drive wiring.
8. Regulated power supplies frequently do not have adequate output filter capacity to power a servo drive. They can go into over-current foldback during periods of high output currents. If using such supplies, it may be necessary to add an external filter capacitor (4-5000 µF).

GROUNDING

All signal and power grounds are common. All grounds 'share copper'. However, the current paths and conductor widths within the amplifier are different depending on their function.

The illustration below shows the current path at the instant of time that the bridge is ON, and current is flowing into the load. The rapidly changing current creates a noise voltage in the inductance and resistance of the power supply wiring. When the ground connection is made at the amplifier power ground terminal, then this voltage will not be seen at the signal grounds.

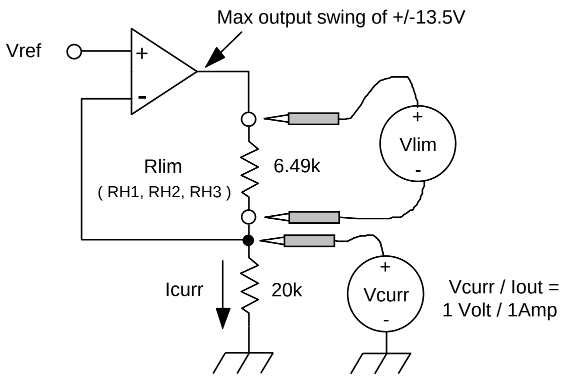
In the case of multiple amplifiers, there is still the possibility that ground currents could circulate between amplifiers via their ground terminals. For this reason, it is recommended that the power ground terminals be connected to a system 'star' ground point using heavy wire (AWG 14). This approach is better than using the signal ground pins for the main grounding connection because the signal ground etch is of smaller width and has higher resistance, and lower current-carrying capability than the heavier power-ground etch.

GROUNDING (cont'd)

Notice that the Reference inputs are *differential* inputs, and that they will reject noise that comes from differences in ground potential between the amplifier and controller. However, the digital inputs (brake, reset, and enables) are referenced to the amplifier ground. Thus the logic threshold is measured by the amplifier against its own ground point. Noise between amplifier and controller grounds can add or subtract from control signals, so it is important to keep amplifier and controller grounds at the same potential if possible.

CUSTOMIZING CURRENT LIMITS

Here is the equivalent circuit of the current-limit function:



In this model, the voltage across the 20kΩ resistor determines the output current with a scale factor of 1A of output current for 1V across the resistor (Iout ∝ Vcurr).

Thus, if we wanted to limit current to 3.5A, then we would limit the voltage across the 20kΩ resistor to 3.5V. The limiting action is provided by the output voltage swing of the op-amp which clamps at ±13.5V. Under normal (non-limiting) operation, the op-amp will keep the voltage Vcurr equal to Vref.. Limiting occurs when the required output voltage swing exceeds the ±13V range of the op-amp, and the output 'clamps'. So, to find the value of Rlim, we simply solve the equation for the voltage divider setting the voltage Vcurr to be equal to the limiting current in amps:

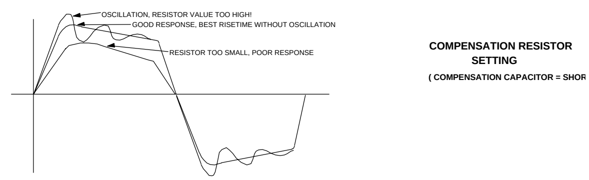
$$R\lim = \frac{13.5V \times 20k}{Vcurr} - 20k$$

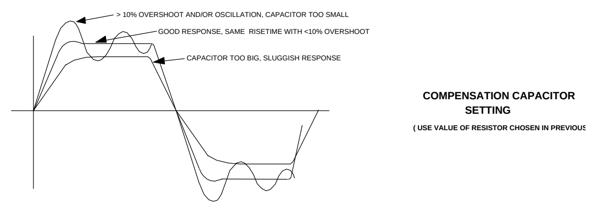
In our example, a limiting value of 3.5A would yield a value for Rlim of 57kΩ.
The factory installed value for the 10.2A limit is 6.49kΩ. To check the value, view the current monitor with a sinusoidal or triangular waveform at Vref. It is easy to see the limiting action occurs when the waveform is 'clipped'. The limiting current is then found as Vmon * (-2).

CUSTOMIZING LOAD INDUCTANCE COMPENSATION

Important: always power-down when changing components in the header socket.

1. Use a square-wave test waveform of ±0.5. Set the power supply to the anticipated operating voltage.
2. Replace the compensation capacitor with a short (jumper)
3. Observing the signal at the current monitor, pick a value for the compensation resistor that gives a clean step response. Do not consider the 'flat-top' portion of the waveform.
4. Install the capacitor. Select the smallest value that does not result in excessive (>10%) overshoot and/or oscillation.
5. Switch to a sine-wave signal of the same amplitude. Sweep the frequency over the range of interest and note the frequency at which amplitude drops to 0.707 of the amplitude at 100Hz.





Notes:

1. **** Standard values installed at factory are shown in italics.***
2. Bandwidth and values of R & C are affected by supply voltage and load inductance. Final selection should be based on customer tests using actual motor at nominal supply voltage.

NORMAL OPERATION & FAULTS

NORMAL OPERATION

Buss voltage is >22V and <93V
Heatplate temperature is <70°C.
No short circuits between outputs, or between outputs and ground

FAULTS

Power Fault: Buss voltage is <22V or >93V; non-latching
Overtemp Fault: Heatplate temperature is >70°C; non-latching
Shorts: A short-circuit has occurred at the outputs; latching

LATCHING VS. NON-LATCHING FAULTS

Non-latching faults go away when the condition that created the fault is removed.

Buss voltage and overtemp faults are non-latching faults, and will go away when the voltage returns to normal operating range (see above), or if the heatplate cools to <70°C. If operating at voltages close to the lower or upper limits beware of loads that cause transient over or undervoltage conditions. In these cases, the LED will blink on acceleration or deceleration of the motor. If **overvoltage** occurs on deceleration, more capacitance is needed, or in some cases, a regenerative dissipater (Model 121) may be needed. **Undervoltage** on acceleration is an indication that more capacitance or a higher power supply voltage is required.

Latching faults act like toggle switches that have been switched ON. Once switched, they remain so until some kind of action (Reset) occurs to switch them OFF. Output short circuit faults are latching faults. Reset action is provided by either turning the power off and back on, or by grounding the /Reset input. If automatic recovery from these faults is preferred, then simply ground the /Reset input, and recovery will occur in 50mS after the condition that produced the fault is removed.

Logic Inputs

ENABLE INPUT

The /ENABLE input functions as an on/off switch for each channel. When active, the drive functions normally. When inactive, the output power stages and brake functions are disabled.

There is a 5mS delay after the Enable input is activated.

When the amplifier is driving a motor, disabling will cause the motor to coast as if it had been disconnected from the load. *Disabling will not decelerate or dynamically brake a motor.*
The active state of /ENABLE is ground (LO). If the /Enable input
is open, or at +5V, the channel is disabled.

BRAKE INPUTS

There is a brake input for each channel. Grounding the brake input overrides the voltage at Vref, and will brake the motor to a stop by driving the back-emf of the motor to zero. During this process, the output current will be limited to 12A, and the deceleration will be proportional to the motor torque generated by 12A drive currents. Once stopped, the motor will resist rotation as long as the brake input is grounded and the channel is enabled.
When the brake inputs are left open-circuit, or switched to +5V the output current will then follow Vref as long as the channel is enabled.
Note that the brake inputs do not function when /Enable is inactive (+5V or open).

RESET INPUT

Ground this signal momentarily to reset a fault condition caused by output short-circuits. If this is permanently grounded, then latching faults will self-reset after the fault condition is removed. In the case of output short circuits, the drive will try and reset every 50 mS.

As long as the output short remains, it will shut down until the next re-try. When the short is removed, normal operation will resume within 50 mS.

LOGIC OUTPUT

/NORMAL OUTPUT

This is an output signal which is LO (current-sinking) when the normal LED is lit. When a fault occurs, the output will be HI (+5V). It follows the same logic as the LED described above. Electrical specifications for this output are:

Normal condition: V_{OL} = 0.5 V max. @ I_{OL} = 2.4 mA max.
Fault condition: V_{OH} = 2.4 V min. @ I_{OH} = -2.4 mA max.
V_{OH} = +5V max.

CAUTION! <u>Do not</u> connect this output to devices such as PLC's that have pullup resistors to voltages greater than +5V! Doing so may damage the amplifier. This output is intended to drive control cards with +5 logic-level inputs. To drive relays, PLC's, or other loads that use higher voltages or currents, buffer the Normal output with an opto-coupled relay or equivalent device.

CURRENT MONITOR

This signal is an image of the motor current flowing between the two active output terminals of the drive. The scale factor is 2 amps/volt. There is a 10 kΩ resistor in series with the op-amp that drives this output. The signal is bipolar to indicate polarity as well as magnitude of output current.

The current monitor output will be -/+5V when the output current is +/-10A. The polarity of the monitor is the *reverse* of the output

current polarity. See "Amplifier Polarity Conventions" for an explanation of signal polarities.

Indicator LED's

NORMAL

This green LED will be ON whenever all three channels are operating normally.

Normal operation is defined as:

1. Operating voltage (+HV) is within min/max limits (>22V and <93V)
2. Heatplate temperature is <70° C.
3. No short circuits at motor outputs.

POWER OK

ON when power is normal (>22V OR <93V).
Typically you will see this lamp come on during power-up as the supply voltage rises to >22V.
If the led blinks during normal operation, you may have excessive 'pump-up' of the supply because of decelerating a heavy load. If this is the case, increase the size of the filter capacitor in the power supply, or install a regenerative energy dissipater such as the Copley model 121.

If you are operating at low supply voltages (near 24V) blinking may indicate that the supply is 'sagging' below the undervoltage cut-out (22V) during heavy current demand. To remedy this, increase the size of the filter capacitor, or use a transformer that has better regulation. If this is not sufficient, a regulated power supply may be necessary.

Power OK
ON when power is normal (>22V OR <93V).
Typically you will see this lamp come on during power-up as the supply voltage rises to >22V.
If the led blinks during normal operation, you may have excessive 'pump-up' of the supply because of decelerating a heavy load. If this is the case, increase the size of the filter capacitor in the power supply, or install a regenerative energy dissipater such as the Copley model 121.

OVER TEMP (OV-TEMP)

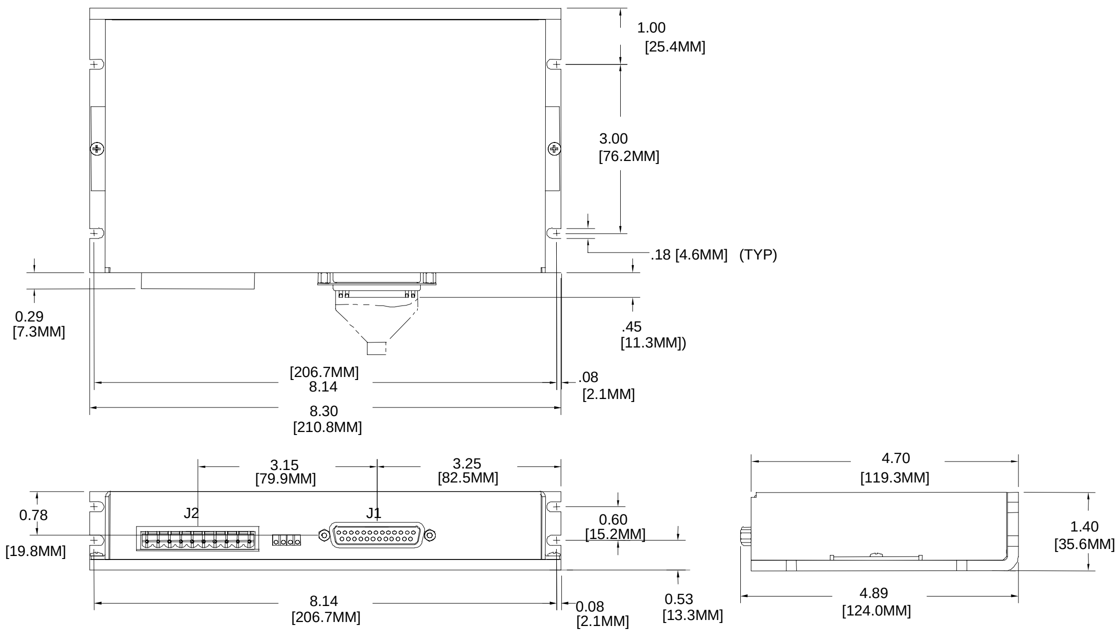
ON if heatsink >70°C. Check chassis temperature if this led goes on. If it is cool, it is likely that an output short-circuit has occurred. Check wiring if this is the case.
If the chassis seems hot, you may have to improve either the mounting or add forced ventilation to remove heat from the chassis to keep its temperature within tolerable limits.

OVER CURRENT (OV-CURR)

ON if a short-circuit (over current) has occurred between outputs, or between an output and ground.
This also is a latching fault, requiring /Reset or power off/on to reset the condition.

OUTLINE DIMENSIONS

Dimensions in inches (mm.)



OTHER DC BRUSH SERVO AMPLIFIERS

400 Family	Six models operating from 24-225VDC, 5-15A continuous, 10-30A peak. Fully featured with adjustment potentiometers, voltage feedback with IR compensation.
Model 403	For torque-mode only applications at low cost. +18 to +55VDC operation, 5A continuous, 10A peak

ORDERING GUIDE

Model 4113	10A peak, 10A continuous, +24 to +90VDC Three-channel DC brush motor amplifier

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