300 Series Amplifier

User's Guide

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The 300 Series Amplifier User' s Guide Rev 09 12/01/01

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Amplifier on **Eurocard** Mount with Front Panel (30xER shown)

See p. 21 for connectors & pinouts.
See. pp. 11-12 for wiring.

Introduction

The 300 Series amplifiers are second generation products designed for low cost and high performance. They can be mounted on chassis or p.c. boards and operate from 16 to 160 volt single-output DC power supplies. A wide range of inductive loads can be driven: 64 uH to 50 mH depending on model and supply voltage.

All units feature fully differential inputs for the control, or reference voltage. Enable inputs for output control, a status output, and a current monitor signal ease system interfacing.

The 22 kHz. PWM switching frequency eliminates audible noise from motor windings and fast rise and fall times give high efficiency.

A Eurocard mount is available for 3U x 220 mm. rack mounting applications. A header socket with plug-in components makes it easy to change compensation components for different loads.

The amplifier is protected against over-temperature, over-voltage and under-voltage, and output short circuits.

Getting Started

To install the amplifier you will need a control, or reference voltage, a power supply, and a load. The reference voltage can be from something as simple as a potentiometer, or as complex as a digital control system. The power supply can be supplied by the user, or ordered from Copley Controls along with the amplifier to create a complete amplifier subsystem. Loads are usually motors, but magnet coils, inductors, or other non-motor loads can also be driven.

The amplifier is typically used as a voltage-to-current converter. ±10V reference signals will drive the amplifier's peak rated current to the load in the 'flat-gain' mode. If a tachometer is used, the amplifier is still operated as a voltage to current converter, but the header components are changed to increase the gain of the servo preamplifier.

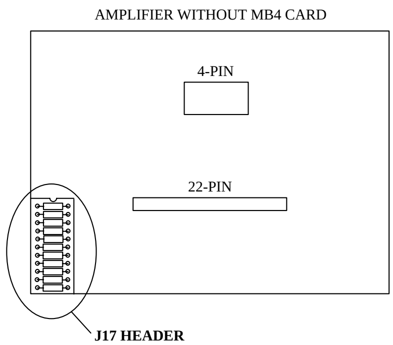
Use of the MB4 and Eurocard provides additional (optional) features such as voltage-mode operation, armature-resistance(IR) compensation, PWM inputs, and output filters.

Eurocard mounts adapt the amplifiers to 3U subrack installations. Consult the factory for Eurocard subrack systems.

J17 Component Header

This is an 11-position socket which holds resistors and capacitors which are used for tachometer scaling and compensation, amplifier compensation, and current limiting.

Location



Current-Mode Setup (Standard configuration)

This is the standard configuration as delivered from the factory. In this mode, a voltage at the reference inputs will force a *current* at the amplifier outputs. This is also called the *flat-gain* mode because it provides the maximum bandwidth which remains constant over the 3 kHz range.

Pin	Component	Pin	Value	Function as Shown
1	R1	22	10 K	Not used in current-mode
2	R2	21	40.2 K	
3	C3	20	OPEN	
4	C4	19	330 pF	Flat gain
5	R5	18	46.4 K	
6	C6	17	.01 uF	
7	R7	16	JUMPER	
8	R8	15	10 K	Current Limit ; 10K = 100% of peak rated current
9	JP9	14	JUMPER	Enable polarity ; IN = Enable, OUT = Enable
10	R10	13	49.9 K	Aux Input Gain
11	R11	12	49.9 K	Ref Gain ; amplifier gain = Ipeak/10V

Notes: 1. R1, R2, C3 and C6 have no function in current mode.
2. Current-limiting is non-linear with respect to R8. For best results, substitute 10K pot for R8, adjust for desired current-limit, and replace with fixed resistor.

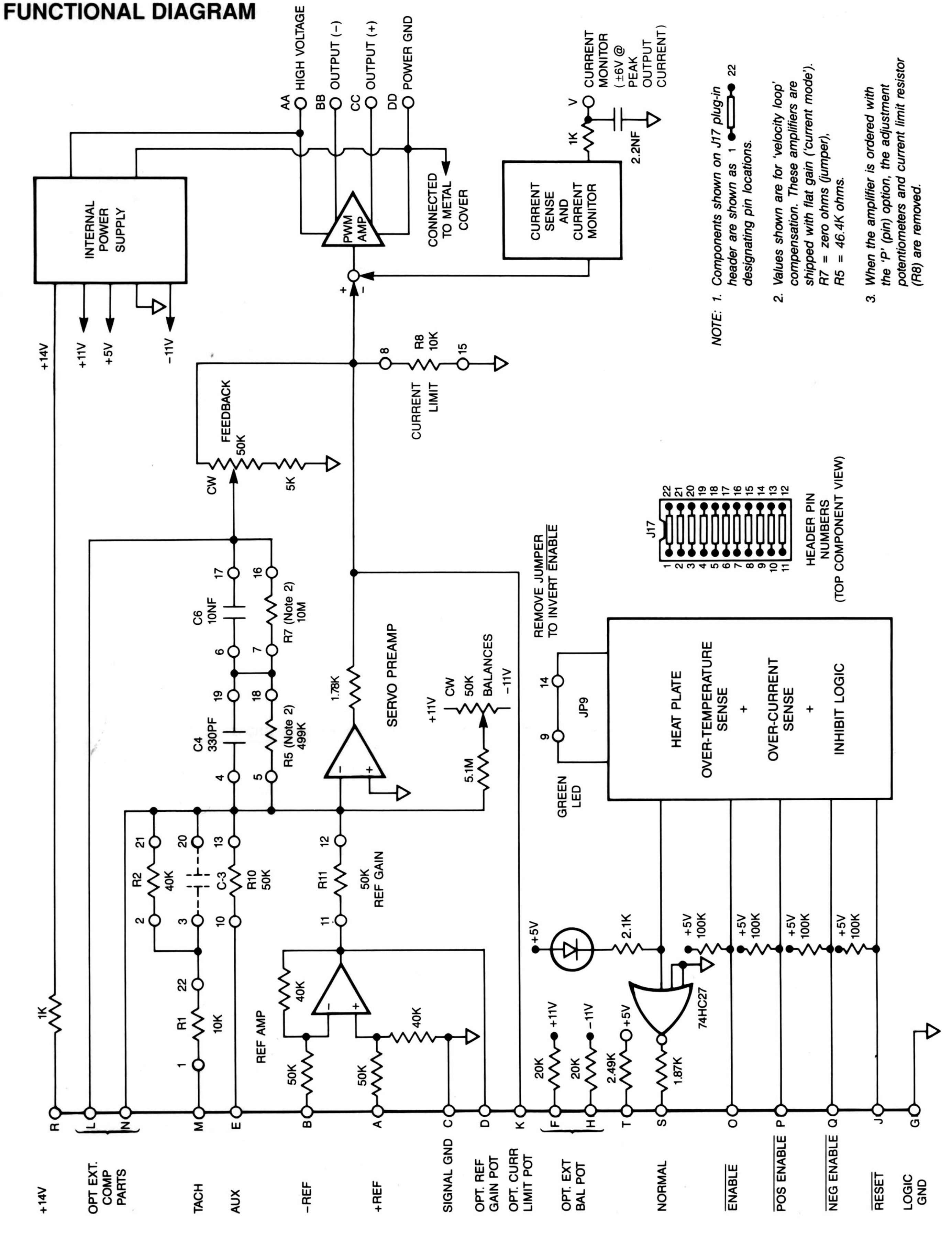
Velocity Mode Setup (Use components supplied)

Use the components supplied in the brown bag to replace R5,R7, and C6. This will setup the amplifier for use with tachometers. See ***Mode Setting*** for further details.

Pin	Component	Pin	Value	Function as Shown
1	R1	22	10 K	Tach scaling ; 10V @ Ref = 8V @ Tach (see Note 1 and Tachometer Scaling, p. 25)
2	R2	21	40.2 K	
3	C3	20	OPEN	
4	C4	19	330 pF	Compensation (see Mode Setting section, p. 23)
5	R5	18	499 K	
6	C6	17	.01 uF	
7	R7	16	10 MEG	
8	R8	15	10 K	Current Limit ; 10K = 100% of peak rated current
9	JP9	14	JUMPER	Enable polarity ; IN = Enable, OUT = Enable
10	R10	13	49.9 K	Aux Input
11	R11	12	49.9 K	Ref Gain ; servo preamp DC gain = 210

Notes: 1. R1, R2, and R11 interract to affect tachometer scaling and servo preamp gain.
2. Current-limiting is non-linear with respect to R8. For best results, substitute 10K pot for R8, adjust for desired current-limit, and replace with fixed resistor.

FUNCTIONAL DIAGRAM



NOTE: 1. Components shown on J17 plug-in header are shown as 1 ●▭● 22 designating pin locations.

2. Values shown are for 'velocity loop' compensation. These amplifiers are shipped with flat gain ('current mode'). R7 = zero ohms (jumper), R5 = 46.4K ohms.

3. When the amplifier is ordered with the 'P' (pin) option, the adjustment potentiometers and current limit resistor (R8) are removed.

TECHNICAL SPECIFICATIONS (B SERIES SPECIFICATIONS ARE SHOWN IN ( ) WHERE THEY DIFFER FROM SPECS SHOWN)

Typical specifications @ 25°C ambient. Load/Model 303: 2.5 ohms in series with 250µH at +80 VDC.
Load/Model 306: 1.0 ohms in series with 125µH at +80V. Load/Model 312: 14 ohms in series with 700µH at + 160 VDC.

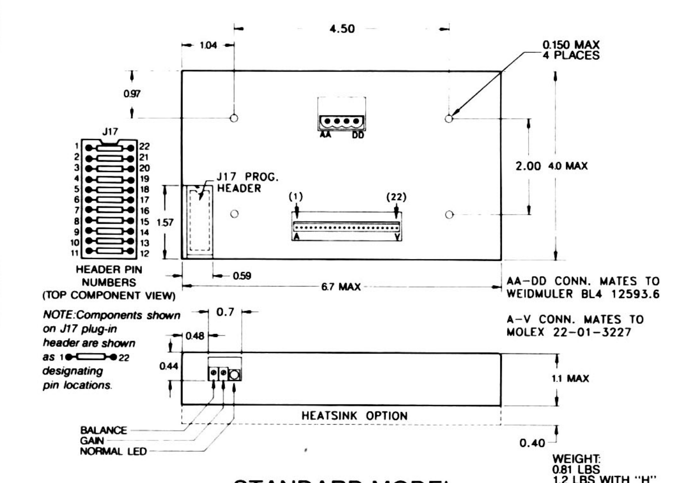
MODEL	303 (303B)	306 (306B)	306A (306AB)	312
PEAK POWER OUTPUT	±75V @ ±12A (±90V @ ±12A)	±75V @ ±25A (±90V @ ±25A)	±75V @ ±30A (±90V @ ±30A)	±150V @ ±9A
Unidirectional current change	1s			
Bidirectional current change	2s			
MAXIMUM CONTINUOUS CURRENT				
Heat sink mount @ 70°C	6A	10A	15A	4.5A
Forced air 400 cfm @ 50°C	6A	10A	15A	4.5A
With Heatsink (H)				
Ambient @ 40°C		10A	15A	4.5A
Forced air 400 cfm	6A @ 60°C	10A @ 60°C	15A @ 50°C	4.5A @ 60°C
OUTPUT VOLTAGE (V_{OUT}) where: (V_{OUT}) = voltage to motor or load; V_h = high voltage applied; I_o = current into motor or load	V_h- (0.26) (I_o)	V_h- (0.13) (I_o)		V_h- (0.60) (I_o)
MINIMUM INDUCTANCE[1]				
@ 160 Volts	NA	NA		700µH
@ 80 Volts	250µH	125µH		350µH
@ 40 Volts	125µH	64µH		175µH
CURRENT LIMIT	Adjustable from 0 to peak current			
INPUT CHARACTERISTICS				
Reference	Differential, ± 10 VDC max; 98k ohms min			
Tachometer	Single-ended, 50k ohms (scale factor adjustable)			
BANDWIDTH				
Power stage, small signal	-3dB @ 3kHz			
Slew rate	80A/ms	167A/ms	200A/ms	60A/ms
SWITCHING FREQUENCY	22kHz			
REMOTE SHUTDOWN[3]				
ENABLE, switch closure, logic low	ENABLES output			
POSITIVE ENABLE, logic low	ENABLES pos output			
NEGATIVE ENABLE, logic low	ENABLES neg output			
AMPLIFIER PROTECTION				
Overload	Current limit			
Heatsink temp	Shutdown 83° C			
Latch Off	Until reapplication of power or reset 'low' [2]			
Overvoltage, temporary	>83 VDC (>99 VDC)	>83 VDC (>99 VDC)	>83 VDC (>99 VDC)	>166 VDC
Undervoltage	<16 VDC	<16 VDC	<16 VDC	<24 VDC
Shorts	Across outputs, or either output to GND			
INDICATORS				
Current monitor	± 6 VDC/I_{max}			
Status (HCMOS)	Logic high indicates normal operation; Logic low indicates amplifier fault or amplifier is disabled			
POWER REQUIREMENTS				
High voltage supply	+ 16 to + 80 VDC (+16 to + 90 VDC)			+24 to +160 VDC
Internal capacitance	200µF			20µF
THERMAL REQUIREMENTS				
Case temperature	0 to 70°C			
Power dissipation at continuous rating	19W	30W	48W	31W
Ambient	0 to 45°C			
Heat sink mount, flat surface	0 to 70°C			
Forced air, 400 cfm	0 to 50°C			
Heatsink option (H)				
Ambient	0 to 50°C			
Forced air, 400 cfm	0 to 60°C			
Storage	-30 to +85°C			
MOUNTING OPTIONS (See Ordering Guide)				
Standard model, connector mount	22-pin snap-on, screw terminal			
PCB mount	Option "P"			
Eurocard (3U)	Option "E"			
Adapter card MB4	Option "M"			

NOTES:

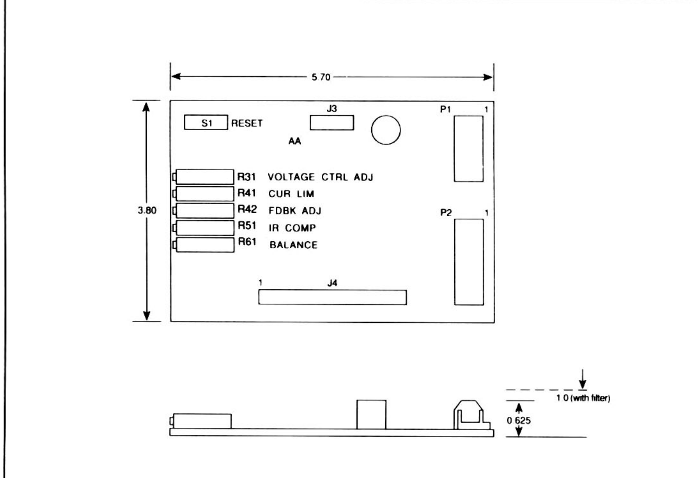
1. *For higher inductance, to maintain the bandwidth; Specify 303-1 for 4-18mH, 306-1 or 306A-1 for 2-9mH and 312-1 for 11-50mH.*
2. *If reset is low, the amplifier will attempt to reset every 25ms.*
3. *The logic sense of the 'enable' line can be reversed. See detailed description in this data sheet ("Logic inputs").*
4. *NA = not applicable*

OUTLINE DIMENSIONS

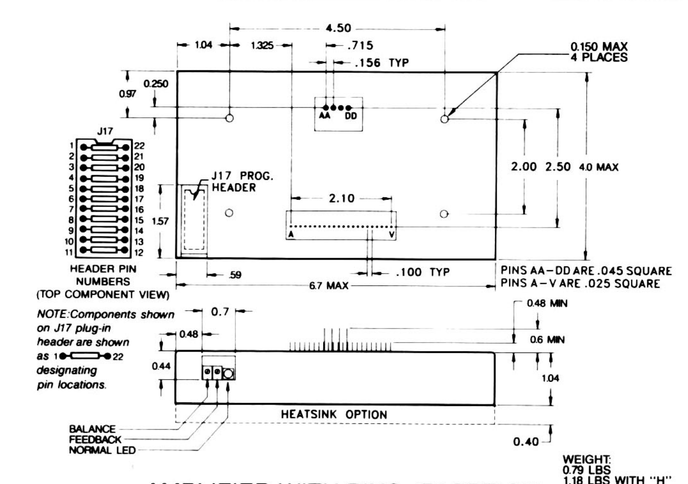
Dimensions in inches



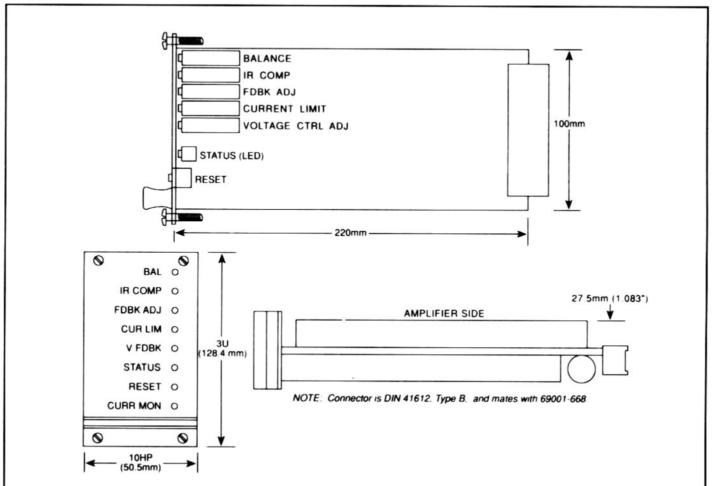
STANDARD MODEL



MB4 MOUNTING CARD, 'M' OPTION



AMPLIFIER WITH PINS, 'P' OPTION



EUROCARD MOUNTING, 'E' OPTION

APPLICATION NOTES

Minimum Inductance

The output of the servo amplifier is PWM current, and as such, a minimum inductance is required to reduce ripple current into the motor and to prevent the amplifier from becoming unstable near voltage saturation. If the amplifier is operated below maximum rated voltage, the minimum load inductance can be smaller. Also where the motor is found to be overheating, this is usually due to insufficient inductance or in some cases additional inductance may be required. The following table of minimum inductance should be used.

Table 1: Minimum Inductance

MODEL	*MINIMUM INDUCTANCE*
303, 303B	250µH at 80 volts 125µH at 40 volts 63µH at 20 volts
306, 306A, 306AB	125µH at 80 volts 63µH at 40 volts 30µH at 20 volts
312	700µH at 160 volts 350µH at 80 volts 175µH at 40 volts

Servo Compensation

Figure 1 shows the frequency response of the servo preamplifier set for FLAT GAIN as shipped from the factory; the response is 3dB down at 14kHz. This flat response configuration (sometimes called 'current mode') is used when operating with controllers that perform the control loop compensation. If R5 and R7 are changed to 499k ohms and 10m ohms respectively (as shown on the functional diagram) then the servo preamplifier response is called 'velocity loop compensation' (shown in Figure 1). The gain plot (Figure 1) is shown with the FEEDBACK potentiometer in the full CW position. Turning the potentiometer CCW raises the gain plot an additional 21dB. To obtain less gain than with the **FEEDBACK** potentiometer set fully clockwise (CW), change the values of R5, R7, C4 and C6 as shown in Table 2.

Basic Amplifier *Connectors, Signals and Pinouts*

If you are using the MB4 or Eurocard, the pinouts will be different (refer to the sections on the MB4 and Eurocard). Use this list when reading the following sections on hooking up the basic amplifier.

Types of signals are listed after the pin number or letter.

P	*Passive*	Power and ground
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.

4 Pin power connector

	Type	Remarks
AA	P	+HV, the high-voltage DC power input
BB	O	Out- , or negative output
CC	O	Out+, or positive output
DD	P	Ground and +HV power return

Table 1

22 Pin signal connector

Note that pins are referred to by letter and number. The letter refers to the functional schematic. The number is the actual connector-pin number on the cable header that connects to the amplifier.

-Pin-	Type	Signal	Remarks
1 (A)	I	+Ref	Differential (+) reference signal input
2 (B)	I	-Ref	" (-) " " "
3 (C)	P	Signal Gnd	Gnd for tachometer, signal gnd
4 (D)	O	Ref amp out	Output of differential input amplifier
5 (E)	I	Aux input	Auxiliary input
6 (F)	O	+11V	20K ohms in series with +11V
7 (G)	P	Logic gnd	Gnd for Enable inputs
8 (H)	O	-11V	20K ohms in series with -11V
9 (I)		N.C.	No connection to this pin
10 (J)	I	/Reset	LO or Gnd to reset fault condition
11 (K)	O	Preamp out	See schematic
12 (L)		Opt. ext. comp	See schematic
13 (M)	I	Tach input	Tachometer input
14 (N)		Opt. ext. comp	See schematic
15 (O)	I	/Enable	LO or Gnd to enable amplifier
16 (P)	I	/Pos Enable	LO or Gnd to enable positive output
17 (Q)	I	/Neg Enable	LO or Gnd to enable negative output
18 (R)	O	+14V	1K ohms in series with +14V
19 (S)	O	Normal	HI (+5V) when amplifier operating Normally
20 (T)	O	+5V	2.49K in series with internal +5V
21 (U)		N.C.	
22 (V)	O	Current monitor	Outputs +/-6V at amplifier peak current

Table 2

Basic Amplifier: Current-Mode, NO Tachometer

Use this checklist for applications that don't employ a tachometer. These include microprocessor control systems that get position feedback from an encoder on the motor, as well as non-motor applications such as magnet-coil, solenoids, or other loads that require a set current from the amplifier in response to a control-voltage at the inputs. The components on the J17 header come from the factory preset for this operating mode. See functional diagram on page 2.

1. Connect DC power supply to amplifier +HV and GND. Check voltage to see that is is within the amplifiers' rating.
2. Ground amplifier to chassis at GND pin DD.
3. Connect motor or load between OUT+ and OUT-. *Do not ground load!*
4. Connect reference voltage source to REF+ and REF- inputs.
5. Ground ENABLE,POS ENABLE, NEG ENABLE to amplifier logic ground.
6. Set FEEDBACK pot to full CW.
7. Set V_{ref} to 0V
8. Turn power on
9. Check for green LED indicating Normal operation.
10. Adjust BALANCE trimpot for 0.0V between OUT+ and OUT-
11. Momentarily increase Reference voltage (±10V max).
12. Check motor direction: is it OK?
    YES: continue
    NO: remove power, reverse connections to Ref+ and Ref-.
13. Set Reference voltage to maximum value (+/-10V)
14. Check load current at CURRENT MONITOR output
15. Apply step or square-wave signal to Ref-inputs, adjust FEEDBACK CCW for best response with no oscillation.

Amplifier Connections

Numbered terminals are on the brown 22-pin connector. Double-letter terminals are on the orange 4-pin connector. See appendix for connector part numbers.

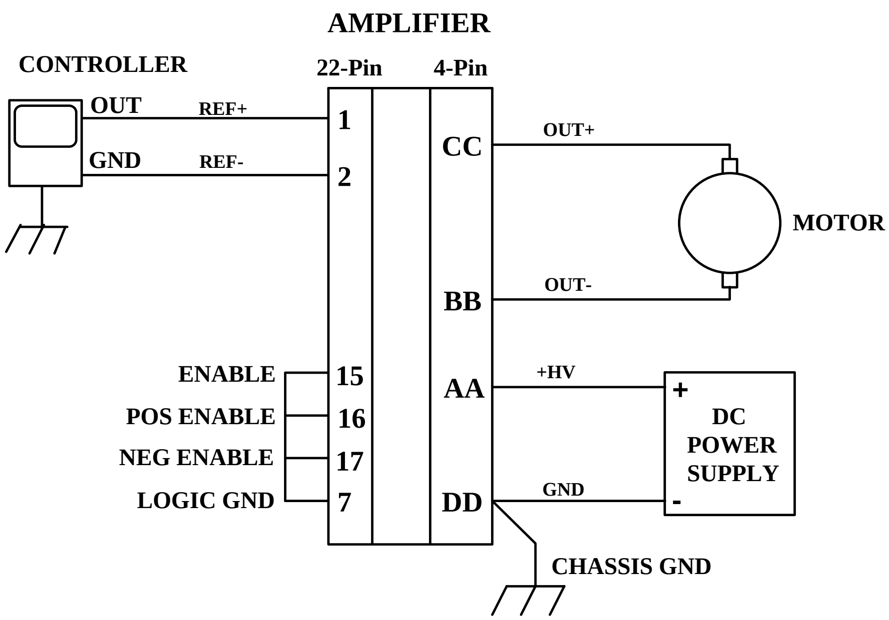


Fig. 1

Basic Amplifier: Current-Mode WITH Tachometer

1. Setup J17 header components for high gain, tachometer mode (see p.3)
2. Connect DC power supply to amplifier +HV and GND. Check voltage to see that is within the amplifiers' rating.
3. Ground amplifier to chassis at GND pin DD.
4. Connect motor or load between OUT+ and OUT-. *Do not ground load!*
5. Connect reference voltage source to REF+ and REF- inputs.
6. Connect Tachometer between tach input and signal ground.
7. Ground ENABLE,POS ENABLE, NEG ENABLE to amplifier logic ground.
8. Set FEEDBACK pot to full CW.
9. Set V_{REF} to 0V
10. Turn power on.
11. Does the motor run away?:
    YES: remove power, reverse tachometer leads
    NO: continue
12. Check for green LED indicating Normal operation.
13. Adjust BALANCE trimpot for 0.0V between OUT+ and OUT-
14. Momentarily increase Reference voltage (±10V max).
15. Check motor direction: is it OK?
    YES: continue
    NO: remove power, reverse connections to Ref+ and Ref-.
16. Set Reference voltage to maximum value (+/-10V)
17. Check load current at CURRENT MONITOR output
18. Adjust CURRENT LIMIT trimpot for desired maximum current.
19. Set Reference voltage to zero, turn feedback trimpot CCW until oscillation begins (audible squeal or noise). Back-off two turns CW or until oscillation stops.
20. Apply step or square-wave signal to Ref-inputs, adjust FEEDBACK CCW for best response with no oscillation.

Amplifier Connections

Single-letter terminals are on the brown 22-pin connector. Double-letter terminals are on the orange 4-pin connector.

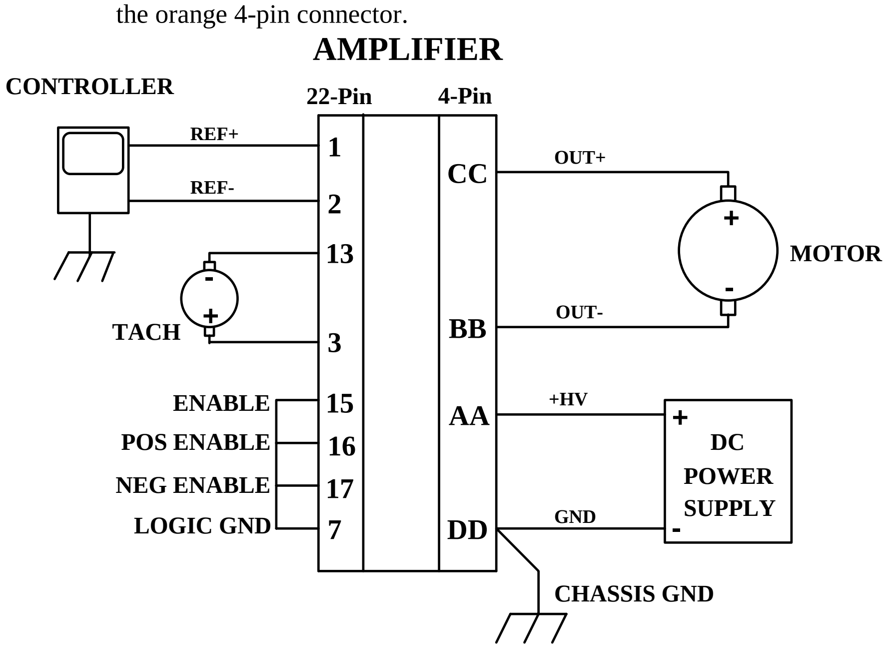


Fig. 2

Amplifier with MB4 Mounting Card: Current-Mode, NO Tachometer

Use this checklist for applications that don't employ a tachometer. These include microprocessor control systems that get position feedback from an encoder on the motor, as well as non-motor applications such as magnet-coil, solenoids, or other loads that require a set current from the amplifier in response to a control-voltage at the inputs. The components on the J17 header come from the factory preset for this operating mode. See functional diagram on page 2.

1. Connect DC power supply to MB4 card P1 (see diagram below). Check voltage to see that is is within the amplifiers' rating.
2. Ground MB4 card to chassis at pin P1-4.
3. Connect motor or load between OUT+ and OUT-. *Do not ground load!*
4. Connect reference voltage source to REF+ and REF- inputs.
5. Ground ENABLE,POS ENABLE, NEG ENABLE to amplifier logic ground.
6. Set REF GAIN pot to full CW.
7. Set FEEDBACK pot to full CW.
8. Set CURRENT LIMIT pot to full CW.
9. Set V_{ref} to 0V
10. Turn power on
11. Check for green LED indicating Normal operation.
12. Adjust BALANCE trimpot for 0.0V between OUT+ and OUT-
13. Momentarily increase Reference voltage (±10V max).
14. Check motor direction: is it OK?
    YES: continue
    NO: remove power, reverse connections to Ref+ and Ref-.
15. Set Reference voltage to maximum value (+/-10V)
16. Check load current at CURRENT MONITOR output
17. Apply step or square-wave signal to Ref-inputs, adjust FEEDBACK CCW for best response with no oscillation.

Amplifier Connections

Numbered terminals are on the brown 15-pin connector(P2). Double-letter terminals are on the orange 4-pin connector(P1). See appendix for connector part numbers.

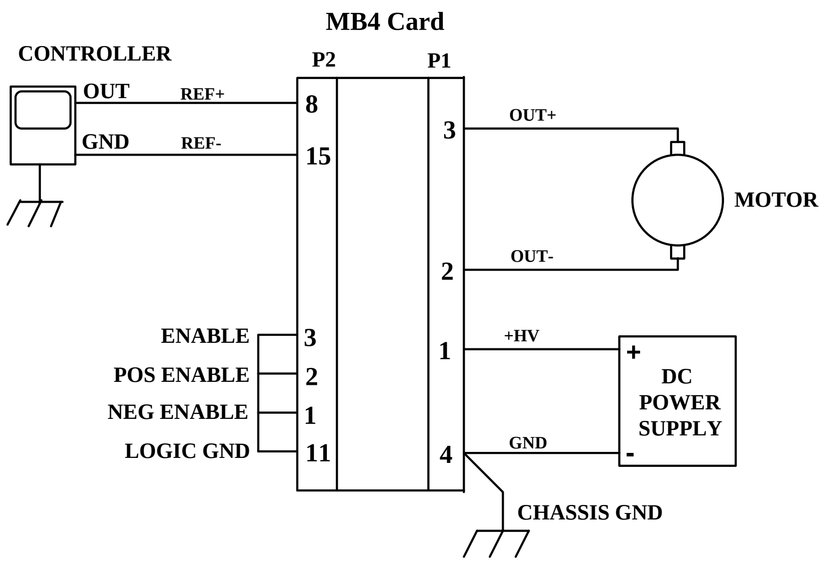


Fig. 3

Amplifier with MB4 Mounting Card: Current-Mode, WITH Tachometer

Use this checklist for applications that do employ a tachometer. These include microprocessor control systems that get position feedback from an encoder on the motor, as well as non-motor applications such as magnet-coil, solenoids, or other loads that require a set current from the amplifier in response to a control-voltage at the inputs. The components on the J17 header come from the factory preset for this operating mode. See functional diagram on page 2.

1. Connect DC power supply to MB4 card P1 (see diagram below). Check voltage to see that is is within the amplifiers' rating.
2. Ground amplifier to chassis at pin P1-4.
3. Connect motor or load between OUT+ and OUT-. *Do not ground load!*
4. Connect reference voltage source to REF+ and REF- inputs.
5. Ground ENABLE,POS ENABLE, NEG ENABLE to amplifier logic ground.
6. Set REF GAIN pot to full CW.
7. Set FEEDBACK pot to full CW.
8. Set CURRENT LIMIT pot to full CW.
9. Set V_{ref} to 0V
10. Turn power on
11. Check for green LED indicating Normal operation.
12. Adjust BALANCE trimpot for 0.0V between OUT+ and OUT-
13. Momentarily increase Reference voltage (±10V max).
14. Check motor direction: is it OK?
    YES: continue
    NO: remove power, reverse connections to Ref+ and Ref-.
15. Set Reference voltage to maximum value (+/-10V)
16. Check load current at CURRENT MONITOR output
17. Apply step or square-wave signal to Ref-inputs, adjust FEEDBACK CCW for best response with no oscillation.

Amplifier Connections

Numbered terminals are on the brown 15-pin connector. Double-letter terminals are on the orange 4-pin connector. See appendix for connector part numbers.

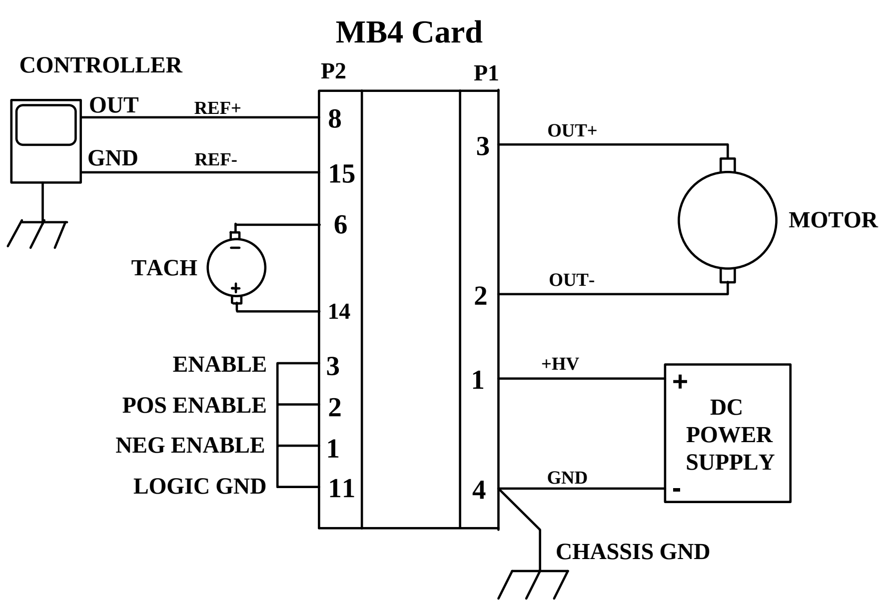


Fig. 4

Amplifier on Eurocard: Current-Mode, NO Tachometer

Use this checklist for applications that don't employ a tachometer. These include microprocessor control systems that get position feedback from an encoder on the motor, as well as non-motor applications such as magnet-coil, solenoids, or other loads that require a set current from the amplifier in response to a control-voltage at the inputs. The components on the J17 header come from the factory preset for this operating mode. See functional diagram on page 2.

1. Connect DC power supply to amplifier +HV and GND. Check voltage to see that is is within the amplifiers' rating.
2. Ground amplifier to chassis at GND pin DD.
3. Connect motor or load between OUT+ and OUT-. *Do not ground load!*
4. Connect reference voltage source to REF+ and REF- inputs.
5. Ground ENABLE,POS ENABLE, NEG ENABLE to amplifier logic ground.
6. Set REF GAIN pot to full CW.
7. Set FEEDBACK pot to full CW.
8. Set CURRENT LIMIT pot to full CW.
9. Set V_{ref} to 0V
10. Turn power on
11. Check for green LED indicating Normal operation.
12. Adjust BALANCE trimpot for 0.0V between OUT+ and OUT-
13. Momentarily increase Reference voltage (±10V max).
14. Check motor direction: is it OK?
    YES: continue
    NO: remove power, reverse connections to Ref+ and Ref-.
15. Set Reference voltage to maximum value (+/-10V)
16. Check load current at CURRENT MONITOR output
17. Apply step or square-wave signal to Ref-inputs, adjust FEEDBACK CCW for best response with no oscillation.

Amplifier Connections

Numbered terminals are on the brown 15-pin connector. Double-letter terminals are on the orange 4-pin connector. See appendix for connector part numbers.

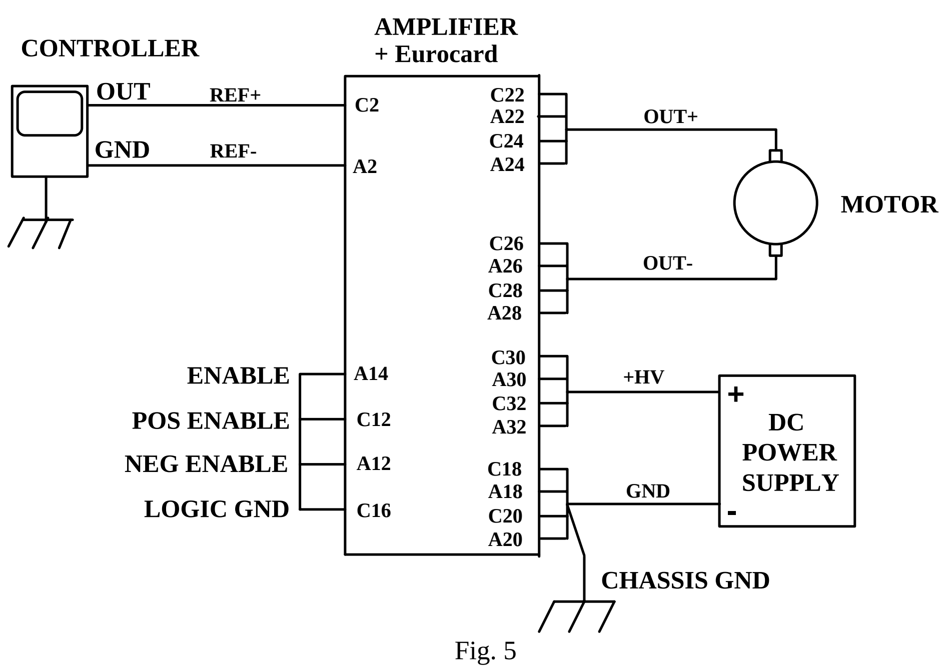


Fig. 5

Amplifier on Eurocard: Current-Mode, WITH Tachometer

Use this checklist for applications that do employ a tachometer. These include microprocessor control systems that get position feedback from an encoder on the motor, as well as non-motor applications such as magnet-coil, solenoids, or other loads that require a set current from the amplifier in response to a control-voltage at the inputs. The components on the J17 header come from the factory preset for this operating mode. See functional diagram on page 2.

1. Connect DC power supply to amplifier +HV and GND. Check voltage to see that is is within the amplifiers' rating.
2. Ground amplifier to chassis at GND pin DD.
3. Connect motor or load between OUT+ and OUT-. *Do not ground load!*
4. Connect reference voltage source to REF+ and REF- inputs.
5. Ground ENABLE,POS ENABLE, NEG ENABLE to amplifier logic ground.
6. Set REF GAIN pot to full CW.
7. Set FEEDBACK pot to full CW.
8. Set CURRENT LIMIT pot to full CW.
9. Set V_{ref} to 0V
10. Turn power on
11. Check for green LED indicating Normal operation.
12. Adjust BALANCE trimpot for 0.0V between OUT+ and OUT-
13. Momentarily increase Reference voltage (±10V max).
14. Check motor direction: is it OK?
    YES: continue
    NO: remove power, reverse connections to Ref+ and Ref-.
15. Set Reference voltage to maximum value (+/-10V)
16. Check load current at CURRENT MONITOR output
17. Apply step or square-wave signal to Ref-inputs, adjust FEEDBACK CCW for best response with no oscillation.

Amplifier Connections

Numbered terminals are on the brown 15-pin connector. Double-letter terminals are on the orange 4-pin connector. See appendix for connector part numbers.

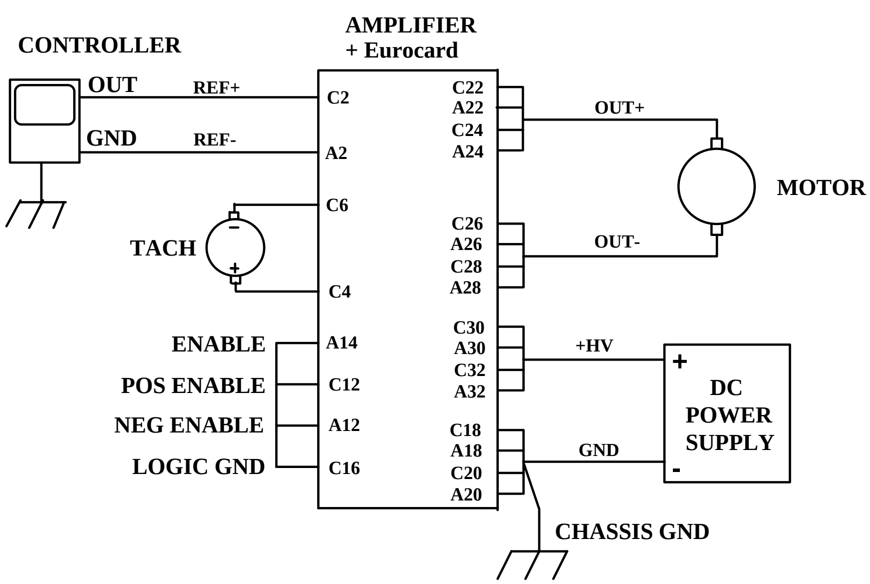


Fig. 6

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 losses in the amplifier (see p. 10, Output Voltage Swing).
   Add an extra 5-10% for power supply ripple.
   Use this value, and the amplifier's continuous current rating as your nominal power supply specification at normal line voltage.
   300 series peak currents of 2-2.5X the continuous current rating can usually be tolerated by off-the-shelf transformer-rectifier-capacitor power supplies.
   (See appendix for a complete listing of standard power supplies)
2. Where the amplifier is to be mounted more than 18" away from the power supply filter capacitor, install a 200uF. (minimum) filter capacitor across the amplifier +HV and Gnd terminals as a local bypass capacitor. The voltage rating of this capacitor should be compatible with your supply voltage.
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. When operating at lower supply voltages, such as 24V or less, check the Normal LED. If it goes out occasionally, this could mean that the buss voltage 'sag' during periods of high current demand, and is lowering the buss voltage below the under voltage cutoff point (<16V). 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 a regenerative energy dissipator, or larger filter capacitors. Whe a heavy load is decelerated, the amplifier 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 amplifier.
6. 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 amplifiers are connected to the same power supply, use a 'star' wiring configuration. Don't 'daisy-chain' amplifiers by connecting one to the next, and so on. Make connections between each individual amplifier and the power supply, and ground each amplifier at pin DD (P1-4 on the MB4 card) leaving the (-) terminal of the filter capacitor disconnected from ground. Doing this will keep the reference and logic inputs of the amplifiers referenced to ground, while the voltage at the negative terminal of the filter capacitor changes in response to the current drawn through the amplifier wiring.
8. Regulated power supplies frequently do not have adequate output filter capacity to power a servo amplifier. 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 uF).

Multiple Amplifier Power Connections

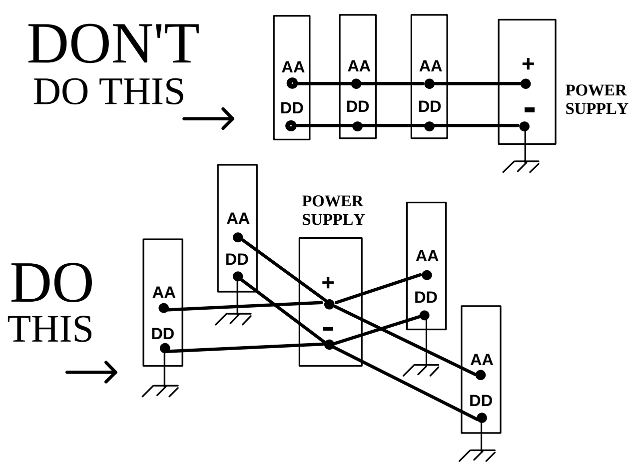


Fig. 7

Minimum Inductance

Table 3 lists the minimum inductance required for various amplifier and buss voltage combinations.

Model	20V	40V	80V	160V
303,303B	63 uH	125 uH	250 uH	N/A
306,306A,306AB	30 uH	63 uH	125 uH	N/A
312	N/A	175uH	350uH	700 uH

Table 3

Maximum Inductance

There is no maximum inductance specified for the 300 series, however larger inductances can reduce the bandwidth and produce excessive ringing in the amplifier's response. The *Standard* column in the table below shows the load inductance which are considered 'normal' for the 300 series amplifiers. The *Dash-1* column shows the range of load inductance which can be driven with amplifiers ordered with the -1 option (see ordering guide in appendix). Load inductance higher than the maximum values in the *Dash-1* column will result in lower bandwidth, and may require component changes to optimize compensation.

Model	40V		80V	
	Standard	Dash-1	Standard	Dash-1
303, 303B	63 uH to 1.9 mH	2 to 9 mH	125 uH to 3.9 mH	4 to 18 mH
306, 306A, 306AB	32 uH to 0.9 mH	1 to 4.5 mH	64 uH to 1.9 mH	2 to 9 mH
312	88 uH to 5.4 mH	5.5 to 25 mH	175 uH to 10.9 mH	11-50 mH

Table 4

Bandwidth

The bandwidth of an amplifier is the frequency at which the amplitude of the output drops to 70% of the value at a much lower frequency. The effect of bandwidth is to either limit the frequency of a sine-wave signal that can be amplified, or to limit the risetime of a step-input signal. The type of load will also have an effect on the bandwidth, particularly as the inductance increases.
Amplifiers with the -1 option (high inductance loads) will exhibit the specified bandwidth at higher values of inductance than the standard amplifiers.
Table 5 shows the load inductance and resistance at which the standard and -1 option amplifiers are rated for their 3 kHz bandwidths. As the load inductance increases beyond the values listed in table 5, the bandwidth will decrease.

Model	BW	R	L (std)	L (-1)
303,303B	3kHz	2.5	250 uH	4 mH
306,306B	3kHz	1.0	125 uH	2 mH
306A,306AB	3kHz	1.0	125 uH	2 mH
312	3kHz	14	700 uH	11 mH

Table 5

BW ; -3dB small-signal bandwidth
R ; Load resistance in ohms
L (std) ; Load inductance in microhenries for standard amplifier
L (-1) ; Load inductance in millihenries for amplifiers with -1 option

Enable Inputs

The polarity of the amplifier's output can be controlled with the Positive and Negative enable inputs, and the outputs can be completely disabled with the Enable input.
Output polarity control is usually used on motion control systems that use travel -limit switches. If a moving member hits one of these switches, it is supposed to disable the amplifier, preventing further travel into a mechanical stop. At the same time, it should be possible to reverse the direction of the motor to 'back-out' of the limit. Positive and Negative enable inputs are provided for this function.
For a shutdown of the amplifier (both outputs *off*), use the Enable input. This signal will also cause the Normal LED to turn off, and the Normal output to go LO.
The enable inputs use +5V logic signals, external dry-contact, or NPN current-sinking drivers. Ground is the level required to make the function logically *true*, and +5V (or open-circuit) will make the function *false* (true = enabled, false = disabled).
The Enable signal only may have its' *true* logic-level inverted by removing the jumper in header J17 at position-9 (see functional diagram). When this is done, leaving the Enable input open, or at +5V will enable the amplifier, and grounding it will shut it down.

Note: The Positive and Negative Enable inputs must always be grounded to enable the respective outputs.

Current Monitor

This is a signal that is a measure of the output current of the amplifier.
The scale factor in amps/volt is listed below. All of the 300 series output a +/-6V signal when the current is at the *peak* rated value.

Amplifier	Amps/Volt
303,303B	2.0
306, 306B	4.17
306A,306AB	5.0
312	1.5

Table 6

Status LED

A green Normal LED is on the basic amplifier, the MB4 card, and Eurocard.
It will be ON when operation is Normal:
    Buss voltage is within normal limits.
    Enable input is *true*. (See above for details on Enables)
    Chassis temperature is <83°C.
    No short circuits between outputs, or between outputs and ground.
It will be OFF during a fault condition:
    Buss voltage is over or under normal limits.
    Enable input is *false.*
    Chassis temperature is >83°C.
    A short-circuit has occurred at the outputs.

The short-circuit, and overtemp faults are *latching* type, that is, they will disable the amplifier until power is cycled off and on, or until the Reset input is toggled.

Note: The Positive and Negative enable inputs will not affect the status of the Normal LED or Normal output.

Normal Output

This is a +5V CMOS output signal in series with an internal 1.87K resistor.
It will be HI (+5V) when the Normal LED is *on*, and LO (ground) when the Normal LED is *off*. It can drive an external low-current LED, or CMOS logic compatible inputs to user equipment.

Reset Input

A +5V CMOS logic input which is normally pulled-up to +5V by an internal 100K resistor. Ground this signal momentarily to reset a fault condition caused by overtemp, or output short-circuit.
Do not ground this input continuously, as this could cause overloading of the output stage of the amplifier. If you want to shutdown the amplifier, use the Enable input.

Current Limit

On the basic amplifier, component R8 on header J17 controls the maximum current delivered by the amplifier. A value of 10K ohms is standard and will let the amplifier deliver the maximum rated peak current. Substitute smaller values to reduce the limiting current.
The MB4 and Eurocard come with potentiometers that lets you adjust the maximum current to any set value from 0, to the maximum rated peak current.
In either case, whenever the current-limit is greater than the continuous current rating of the amplifier, it will fold-back to the continuous current rating after 1 second for unipolar currents, or 2 seconds for bipolar currents.

Output Voltage Swing

300 series amplifiers use MOSFET transistors in the output stages. These have no inherent 'saturation' voltage like bipolar transistors. Instead, they look like low value resistors in series with the power supply. The table below lists the on-resistance and output voltage-drop for the various amplifiers.
Note that output voltage swing is relative to the instantaneous supply voltage. Therefore, if you have an application that requires a particular voltage swing, you must add to this the output voltage-drop, power supply ripple voltage, and use this as your low-line power supply operating voltage.

Amplifier	**Rout**	**Vsat**
303,303B	0.26	3.12
306,306B	0.13	3.25
306A,306AB	0.13	3.9
312	0.60	5.4

Table 7

Rout is the amplifier output resistance.
Vsat is the voltage-drop (also called *saturation voltage*) across the amplifier at peak current.

DC Power Outputs

All internal supply voltages are derived from the high-voltage supply. These internal voltages are available at the signal connector for certain user applications. All are current-limited by series resistors (Rser) and are intended for low-power applications. Table 8 lists the connector pin, voltage, and series resistance for each of these outputs:

Vout	**Std**	**MB4**	**Eur**	**Rser**	**Iout**
	22 pin	**P2**	**DIN**		
+5	20	n/a	n/a	2.49 K	100 uA
+**11**	6	n/a	n/a	20 K	50 uA
-11	8	n/a	n/a	20 K	50 uA
+**14**	18	5	C8	1 K	3 mA
-14	n/a	13	A8	None	1 mA

Table 8

Std ; Standard amplifier without MB4 card. Pin numbers refer to 22 pin connector.
MB4 ; Amplifier + MB4 card combination. Pin numbers refer to MB4 15 pin connector P2.
Eur ; Amplifier + EC2 Eurocard combination. Pin numbers refer to Eurocard DIN connector P2.
Rser ; Internal resistance in series with voltage source shown.
Iout ; Permissible current to external loads.

Mounting

Standard Mounting

The *standard* model comes with plug-in cable connectors. (See appendix for a list of connector types)
The chassis can be mounted to flat surfaces with four #6 screws that go through four holes in the amplifier chassis. The mounting surface may provide adequate heat-sinking, or the amplifier can be ordered with a standard (-*H option*) or extended -*HX option*) heatsink. (See section on cooling for heatsink recommendations)

PC Board Mounting (-P option)

This option changes the connectors from plug-in cable connectors to extended male pins. These pins permit either soldering directly into p.c. boards, or can plug into spring-loaded pin sockets like the ones used on the MB4 and Eurocard. Part numbers for these pin-sockets are listed below:

Connector	**Pin-Socket**
22 pin signal connector	AMP: 50864-5
4 pin power connector	AMP: 1-50871-0

When mounting on p.c. boards, consider the airflow across the amplifier and ambient temperature to determine if a heatsink is required.

MB4 Card Mounting (-M option)

The *MB4* mounting card must be used with amplifiers ordered with the -*P* option. The card pushes onto the pins in a piggy-back fashion. Thereafter, connections are made to the MB4 card which connects to the amplifier via the pins.
A *Current-limit* trimpot is standard on the MB4 card, as are *Balance*, and *Feedback* (internal loop-gain) trimpots.
The MB4 provides additional functions not available on the standard amplifier. These are:
Voltage-Mode operation with IR compensation (-V option)
PWM Inputs (-P option)
Edge Filters (-F option)
See section on MB4 card for additional information.

Eurocard Mounting (-E and -ER options)

A 3U x 10HP extended Eurocard mount (220 mm) is available with (-*ER option)*, or without (-*E option)* a front panel. Trimpots are accessible from the front panel, as are the current monitor output, status LED, and Reset push-button switch. Power and signal connections are all made via a DIN 41612 type “D” connector on the backplane end of the card.

MB4 Mounting Card

The MB4 card adds features and options to the 300 series amplifiers that are not available on the basic unit. These include PWM inputs, voltage-mode amplification, IR compensation, and output 'edge' filters.
The MB4 card connects to the amplifier via connectors J3 & J4. The user makes connections to the amplifier/card assembly via connectors P1 (motor, and high voltage DC supply) , and P2 (reference, tach, and aux inputs, and Enable signals).

Notes on Nomenclature

I,O,P ; **I**nputs TO MB4 Card, and **O**utputs FROM MB4 Card, **P** = Passive
P1 ; Motor & DC Power connections to the MB4
P2 ; Signal connections to the MB4
J3 ; Motor & Power connections between the amplifier & MB4 card
J4 ; Signal connections between the amplifier & MB4 card
N.C. ; No Connection

P1: 4 Pin power connector

P1	J3	Signal Name	Function
1	AA	High Voltage	Power input to card
2	BB	Neg Output	Amplifier output (-)
3	CC	Pos Output	Amplifier output (+)
4	DD	Power Ground	Power return

Table 11

P2: 15 Pin signal connector

Pin	Type	Signal	Remarks
1	I	/Neg Enable	GND Enables, open-circuit Disables
2	I	/Pos Enable	GND Enables, open-circuit Disables
3	I	/Enable	GND Enables, open-circuit Disables
4	O	Normal	HI when Normal, LO if fault
5	O	+14V output	14V in series with 1K ohms
6	I	Tach	Tachometer voltage input
7	I	Aux	Single-ended control voltage input
8	I	+Ref Input	Analog input voltage (+) terminal
9	I	PWM Pulse Input	(Only with -D option)
10	I	/Reset	GND momentarily to reset fault
11	P	Ground	Use for Enable signals
12	I	PWM Direction Input	(Only with -D option)
13	O	-14V Output	(with -V option only)
14	P	Ground	Tacho return input or signal ground
15	I	-Ref Input	Analog input voltage (-) terminal

Table 12

Status Output

The Normal output signal from the amplifier can be routed directly through the MB4 card to this output pin, or can drive an open-drain MOSFET that will be OFF during normal operation, and turn ON during a fault condition. In this way several amplifiers can be 'wire-ORed' together to a 'system-OK' line that will be normally HI, and go LO if any amplifier goes into a fault condition.

Output type	JP-104	Rating
MOSFET output	1-2	50V, 100mA
Amplifier Normal	2-3	HCMOS in series with 1.87K

Table 13

Amplifier Signal Connector (J4)

These are the connections between the amplifier and the MB4 card.

They are listed here for information only.
The *type* of signal (output, input, passive) is *relative to the MB4 card*, i.e. pin A is the Ref+ signal that is an *output from* the card *to* the amplifier.

Pin	Type	Description
A	O	+Ref
B	O	-Ref
C	P	Signal Ground
D	P	Ref Amp Output
E	O	Aux. Input
F	I	+11V Output from Amplifier
G	P	Logic Ground
H	I	-11V Output from Amplifier
I		N.C.
J	O	/Reset
K	I	Preamp Output (To Curr-Lim & Feedback Gain trimpots)
L	O	Wiper from Preamp-Out trimpot (Feedback Gain)
M	O	Tachometer Input
N	P	Summing Junction of Servo Preamp in 30X amplifier
O	O	/Enable
P	O	/Pos Enable
Q	O	/Neg Enable
R	I	+14V Output from Amplifier
S	I	Normal Signal from Amplifier
T	I	+5V VREF Output from Amplifier
U		N.C.
V	I	Current Monitor Output

Table 14

MB4 Card Options

The various options available with the MB4 card are described below.

Voltage-Mode (-V option)

Voltage mode changes the amplifier from a voltage-in, current-out operating mode to voltage-in, voltage-out. (See p. 26 for further information)

IR-Comp (included with -V option)

This can be enabled with jumpers when operating in the voltage mode. IR comp will increase the amplifier output voltage as the load current increases. When properly adjusted, it will compensate for the loss of armature voltage that occurs because of the resistance of the motor-armature, and can provide constant velocity operation without using a tachometer. (See p. 27 for further information)

PWM Inputs (-D option)

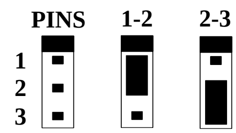
Digital inputs are converted to ±Ref voltages with this option. Useful with microprocessor controllers, this mode takes a 0-100% PWM and a direction signal as inputs, or a single PWM signal that outputs a 50% duty cycle as the 0 level, and changes from 0-100% to emulate full-scale ±Ref voltages. (See p. 29 for further information)

Edge filters (-F option)

An L-R-C filter network that will slow down the rise and fall times (the 'edges') of the output waveform. This reduces the electrical noise that can couple from motor cables into surrounding electrical equipment. Another purpose for this option is to supply the minimum inductance that the amplifier needs to operate printed-circuit, or other low inductance motors without having to use an external inductor.

MB4 Card Jumper Settings

Table 15 shows the settings of the on-card jumpers for the various card and setup options. Jumpers consist of two-pin shorting connectors on three-pin p.c. board headers. The shorting connector can connect pins 1-2, or 2-3, as shown below.



	Amplifier Mode			Input Type		
	Curr	**Volt**	**IR Comp**	**Analog**	**PWM 0-100%**	**PWM 50%**
JP02					1-2	2-3
JP182				2-3	1-2	1-2
JP72				2-3	1-2	1-2
JP62	1-2	1-2	2-3			
JP63	1-2	1-2	2-3			
JP64	2-3	1-2	1-2			

Table 15

Notes on Modes & Jumpers

Positions in the table with no entries indicate that the jumper has no effect on this mode.

Current mode is the default mode. If the card is ordered with no other options this mode will be in effect. A voltage at the reference inputs will force a current at the amplifier outputs.

Voltage mode is delivered with the -V option. The amplifier functions as a voltage amplifier. A voltage at the reference inputs will force a voltage at the amplifier outputs.

IR Comp is available only with the voltage option. When using this option the amplifier output voltage depends both on the reference inputs, and the load current. As the motor draws more current, the output voltage will increase to compensate for the loss of armature voltage due to motor's internal resistance. Use this option when you need speed regulation without a tachometer.

Analog inputs are the default type of input. An analog signal, typically a ±10V signal controls the amplifier's output. This is true regardless of the selection of current, voltage, or IR comp modes.

PWM 100% inputs consist of two digital (+5V CMOS logic) inputs instead of the ±10V signals normally used. The *pulse* input is a 0-100% duty cycle pulse-width-modulated (PWM) signal, and the *direction* signal controls the polarity of the output signal. Circuitry on the MB4 card converts these digital signals into a +/-5V analog signal that then is sent to the amplifier.

PWM 50% mode uses only one digital PWM input connected to to pin 12 of P2. For an output of zero, the PWM signal must be 50% duty cycle. Thereafter, changing the signal from 0 to 100% duty cycle will force the amplifier to swing its' outputs from maximum positive, to maximum negative condition.

Eurocard Mount

All connections to the amplifier are made via the DIN connector.
The Eurocard may be ordered with the same additional options as the MB4 card:
Voltage-Mode operation with IR compensation (-V option)
PWM Inputs (-D option)
Edge Filters (-F option)
Heatsink options available with the Eurocard mounting are the *-H*, and *-HX*, for standard and extended heatsink. The 10HP spacing will accept the *-H* heatsink, but a wider spacing is required for the *-HX* extended heatsink.

DIN Connector Pinouts

	C	Pin	A	
+Ref Input	■	**2**	■	-Ref Input
Signal Ground	■	**4**	■	Signal Ground
Tach Input	■	**6**	■	Aux Input
+14V	■	**8**	■	-14V
Logic Ground	■	**10**	■	Current Monitor
/Pos Enable	■	**12**	■	/Neg Enable
/Reset	■	**14**	■	/Enable
Logic Ground	■	**16**	■	Status
Power Ground	■	**18**	■	Power Ground
Power Ground	■	**20**	■	Power Ground
Pos Output	■	**22**	■	Pos Output
Pos Output	■	**24**	■	Pos Output
Neg Output	■	**26**	■	Neg Output
Neg Output	■	**28**	■	Neg Output
High Voltage	■	**30**	■	High Voltage
High Voltage	■	**32**	■	High Voltage

Viewed from backplane wiring-side.

Table 16

Note that the power ground, pos/neg outputs, and high voltage signals each share four pins. These pins should be wired together on the backplane so that the higher currents carried by these these signals are shared by the pins.

Jumper Settings

1. *Basic*: Standard voltage to current configuration
2. *Voltage Mode*: Voltage-in to voltage-out mode.
3. *IR Comp* Voltage mode with armature resistance compensation
4. *PWM 0-100%*: PWM signal applied to REF+ input, Direction signal applied to REF- input.
5. *PWM 50%*: PWM signal applied to REF- input, 50% duty cycle gives 0 output, 0 and 100% duty cycle give max positive/negative outputs.

JUMPER	**BASIC**	**VOLTAGE only**	**IR COMP**	**PWM 0-100%**	**PWM 50%**	**Signal**
JP-101	1-2	1-2	2-3			Amp Aux
JP-102	1-2	1-2	2-3			Curr Mon
JP-104				1-2	2-3	PWM type
JP-105	2-3	2-3	2-3	1-2	1-2	Amp Ref+
JP-106	2-3	2-3	2-3	1-2	1-2	Amp Ref-
JP-107	2-3	1-2	1-2			Amp Tach
JP-108	1-2	1-2	1-2	2-3	2-3	Card Ref+
JP-109	1-2	1-2	1-2	2-3	2-3	Card Ref-

Table 17

Status Output Jumper

JP-103: 1-2 for open-drain MOSFET output, 2-3 for HCTTL output. Normal = HI (HCTTL), or off (MOSFET), fault = LO (HCTTL), or ON (MOSFET).

Tuning and Adjustments

First we describe the operation of the trimpots on the basic amplifier, and the MB4 and Eurocard. Next are more detailed sections on particular subjects such as tachometer scaling, voltage-gain, and so on. For more detailed theory and practice, a list of references is included in the appendix.

Trimpots

Balance and Feedback trimpots come on both basic amplifier and MB4 card. Current-limit comes only with the MB4 card and Eurocard. Voltage-feedback and IR-Comp are only installed on MB4 and Eurocards with the *-V* option (armature-voltage feedback).

Balance

Used to 'null' the output of the amplifier when the reference inputs are at 0V. Adjust the pot for zero-current (or zero-volts measured between Out+ and Out-) when the input to the amplifier is zero.

Feedback

Sets the gain of the servo preamplifier. Usually set to minimum (fully CW) in current-mode operation for maximum bandwidth. When using tachometers, turn this pot CCW until oscillation begins, and then back off 1-2 turns for stable operation. Adjustment of this pot affects the response of the amplifier to a step-input.

Current Limit

Controls the peak current that the amplifier can output to the load. Fully CW the amplifier will drive the rated peak current. As this is turned CCW, the maximum current will gradually decrease. Useful for protecting mechanical parts when the maximum current required by the load is less than that of the amplifiers peak rating.

Voltage Feedback

Sets the voltage-gain of amplifiers ordered with the MB4 or Eurocard with voltage-feedback (*-V*) option. The gain of the amplifier is x22 with this pot fully CCW, and can be adjusted upward by rotating this pot CW. See the following section (p.27) on voltage-gain adjustment for more information on this trimpot.

IR Comp

Used in voltage-feedback mode with jumpers set for IR-comp. Adjusts the amount of positive-feedback from the current-sense circuit. This feedback increases the output voltage when drawing higher currents in the load. Because this is *positive* feedback, too much of it can cause severe oscillation. When adjusted correctly the motor speed will remain constant within several percent as the load changes without using a tachometer.

Mode Setting: Flat-Gain vs. Tachometer

In *current mode* operation, the amplifier functions as a single-input, single-output transducer that converts an input voltage to an output current. Use of a tachometer is optional.

When no tachometer is used, the amplifier is operated in the *flat gain* mode. This configuration gives the maximum bandwidth. When driving motors, it is usually preferred over voltage-mode operation because it makes the motor respond faster. A large signal, V_{ref}, is sent to the servo preamplifier, so the gain of the servo preamplifier is set to a low value. The overall gain of the amplifier is typically Ipeak / 10V, and remains relatively constant over the amplifiers bandwidth.

Using a tachometer means that the servo preamplifier now must amplify the *difference* between the reference input signal, and the signal from the tachometer. Since this is a much smaller signal, the servo preamplifier is operated at a much higher gain. This gain must also change with frequency, to compensate for the characteristics of the motor-tachometer combination.

The components on the J17 header socket determine the overall response of the amplifier. The standard setup is for flat gain. Some components must be changed for tachometer operation. If the gain is too high in tachometer mode, alternate component values are suggested which will reduce the gain by a factor of 3, and 5. The table below lists the components on J17 for the various setups:

	Flat	**Tach**	**Tach/3**	**Tach/5**
C4	330 pF	330 pF	1 nF	1.5 nF
R5	46.4 K	499 K	150 K	100 K
C6	10 nF	10 nF	33 nF	47 nF
R7	0	10 M	3 M	2 M

Table 18

The diagram on the following page illustrates the frequency response of the servo preamplifier in the different gain configurations. Here are some equations for the important points on the performance curve. These all apply to the servo preamplifier stage as driven by the input differential amplifier through a 50K ohm resistor (R11) , with tachometer feedback coming through a 50K ohm resistor (R1+R2), and with the Feedback trimpot set to the fully CW position. Turning this pot fully CCW will add an additional 21dB gain while maintaining the same frequency response. (See functional diagram)

Parameter	**Equation**	**Flat**	**Tach**	**Tach/3**	**Tach/5**	**Unit**
DC Gain	$A_{DC} = \frac{R5 + R7}{R11}$	0.93	210	63	42	n/a
Low-frequency Break	$f1 = \frac{1}{2 \times \pi \times R7 \times C6}$	n/a	1.59	1.61	1.69	Hz
Low-frequency Zero	$f2 = \frac{1}{2 \times \pi \times R5 \times C6}$	n/a	32	32	34	Hz
Mid-frequency Gain	$A_{MID} = \frac{R5}{R11}$	0.93	10	3	2	n/a
High-frequency Break	$f3 = \frac{1}{2 \times \pi \times R5 \times C4}$	10.4	0.97	1.06	1.06	KHz

Frequency Response with Tachometer

The curves below show the gain and phase for the servo preamplifier when using the J17 components setup for normal tachometer mode, and for the 1/3 and 1/5 gain modes as shown in the table on the preceding page.

Tachometer Scaling

As delivered, a +/-10V reference signal will drive the motor to a speed at which the tachometer produces a -/+8V signal, regardless of RPM. Tachometer scaling refers to the selection of components on the J17 header so that a particular signal at the reference inputs will drive a motor to a particular RPM. Before you begin, you must know the RPM of the motor when your control system is delivering its' maximum signal to the amplifier. In addition, you must know the voltage coefficient of the tachometer (usually in volts per thousand RPM or V/KRPM) and the amplitude of the signal the control system puts out at maximum. The figure below shows the relation of the components that are used in tachometer scaling:

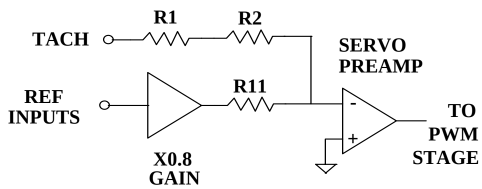


Fig. 8

R1, R2, and R11 are found on the J17 component header.
Stock values are:
R1 = 10K
R2 = 40K
R11 = 50K

We can treat R1 and R2 as a single resistor, and compute the value of this resistor while keeping R11 at the stock value of 50K. Let V_{tach} be the tachometer voltage at maximum RPM, and let V_{in} be the reference voltage at maximum RPM. The value of R1+R2 will now be seen as:

$$(R1 + R2) = \frac{50K \times Ktach \times KRPM}{0.8 \times Vref}$$

Fig. 9

Suppose that you have a motor that is to run at 4000 RPM (4 KRPM) with a reference signal of +/-8V, and a tachometer with Ktach = 7 V/KRPM. We can now compute (R1+R2) as:

$$(R1 + R2) = \frac{50K \times 7V / KRPM \times 4KRPM}{0.8 \times 8V}$$

Fig. 10

This will give us 218.8K as the value of R1+R2. This is close to 220K, a stock value. Now R2 = 40K, so this leaves R1 = 180K, also a stock value. Change the component R1 on header J17 to a 180K resistor to complete the procedure.

Note that tachometer scaling is a DC gain setting process. Additional compensation may be required (i.e. *lead* networks in the tachometer input circuit) to optimize AC operation with a tachometer. Component C3 on the J17 header can be used in conjunction with R1 and R2 to create such networks. Calculation of these values is beyond the scope of this manual (see Reference section in appendix).

Voltage-Mode Gain

This setup applies to MB4 and Eurocards that have been ordered with the *-V* option, for voltage feedback.
A voltage-sensing circuit attenuates the amplifier's output voltage by a factor of 22. This voltage is then fed-back into the Tach input. Setting the voltage-gain then is similar to setting-up a system with a tachometer.
Notice the similarities between the circuit below, and the one shown above for a tachometer-feedback system:

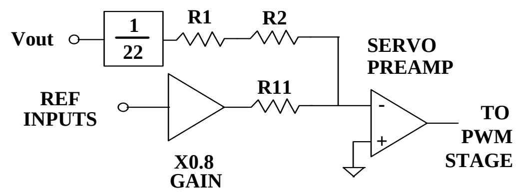


Fig. 11

We can now express the voltage gain like this:

$$\frac{Vout}{Vref} = 0.8 \times \left[\frac{22 \times (R1 + R2)}{R11} \right]$$

Fig. 12

And rearrange to solve for R11 like this:

$$R11 = \frac{17.6 \times (R1 + R2) \times V_{ref}}{V_{out}}$$

Fig. 13

This equation holds true when R31, the voltage-gain trimpot is set fully CCW (counter-clockwise). As this pot is turned CW (clockwise) the gain will increase to a value limited only by the gain of the servo preamplifier stage. The best procedure is to set the gain by the equation above to a value slightly less than the ideal, using stock resistor values. Then adjust R31 for the exact gain desired, which must always be slightly greater than the gain set by the equation.

Changing R2 from 40K to 0 ohms (jumper), and R11 from 50K to 180K will result in a voltage gain of 0.98, as R1 = 10K, which is the minimum value that you should use for the (R1+R2) equivalent. Adjusting R31 will now set the gain to 1.00 which means that a reference voltage of 10V will drive the outputs to 10V.

Suppose that you are operating at a nominal 75V buss, and want to control a 60V swing at the outputs with a 10V reference signal. The voltage gain would be 60/10 or 6.0.

Use these values in the equation above and see that the new value of R11 would be 29.3K ohms. By using a 33K ohm value, the trimpot R31 on the MB4 can then be used to adjust the gain upwards slightly to an exact 6.0.

$$R11 = \frac{17.6 \times 10K \times V_{ref}}{V_{out}}$$

$$R11 = \frac{17.6 \times 10K \times 10V}{60V}$$

$$R11 = 29.3 Kohms$$

Fig. 14

IR-Comp

Setup Procedure

Two methods are presented here. Use the one that seems to be the most appropriate to your installation, and equipment available.

First, remember that IR-comp is used in the *voltage* mode. So determine that the voltage gain of the amplifier has been set correctly (see proceeding section).

Next set the trimpots as follows:

Feedback pot (R42)	=	Max CW	; Minimum loop gain
Voltage Feedback pot (R31)	=	Max CCW	; Lowest voltage gain
IR Comp pot (R51)	=	Max CCW	; Zero IR comp
Current Limit pot (R41)	=	Max CW	; Maximum current
Balance pot (R61)	=	Centered	; Minimum offset

Finally, be sure that the p.c. board jumpers are set correctly:

Jumper	Pins
JP 62	2-3
JP 63	2-3
JP 64	1-2

Table 19

Static Setup Method

Equipment required: Voltmeter, DC source (A 1.5V battery and a switch will do)

1. Adjust the Feedback pot CCW until oscillation appears (squealing sound). Turn pot 2 turns CW. Oscillation should cease.
2. Find motor armature resistance from datasheet. Add to this the motor brush resistance to find total resistance seen by amplifier.
3. Adjust Reference voltage for a test current that is about 20% of full value. Check current monitor to confirm this current. I.e., the current monitor shows 6.0V at amplifier peak current. Adjust V_{ref} for a monitor output of 1 volt.
4. Compute the test current as follows:

$$I_{arm} = \frac{V_{mon} \times I_{peak}}{6V}$$

Fig. 15

I_{arm}	=	Motor armature current
$V_{monitor}$	=	Current monitor voltage
I_{peak}	=	Amplifier peak current rating

5. Lock the motor shaft to prevent rotation, and with the test current flowing through the load, adjust the IR Comp pot (R51) such that the output voltage *increases* by an amount *Vdiff:*

   Vdiff = I_{arm} X R_{arm} (Output voltage increase)
   I_{arm} = Armature current
   R_{arm} = Armature resistance

6. Monitor the motor for overheating while performing this procedure. Apply the test voltage in an on-adjust-off fashion. Note that the motor must be stationary while making this adjustment.

Dynamic Setup Method

Equipment required: Oscilloscope, signal generator (square wave, 1 Hz.)

1. Adjust the Feedback pot CCW until oscillation appears (squealing sound). Turn pot 2 turns CW. Oscillation should cease.
2. Apply square wave to Reference voltage inputs. Monitor current monitor test point (TP2) with oscilloscope.
3. Adjust IR comp pot (R51) CCW while monitoring waveform on the oscilloscope.
4. Response time of current to square wave should gradually decrease. Stop turning R51 when waveform begins to show overshoot.

Notes on IR Compensation

IR compensation works as a form of positive feedback that increases the amplifier output voltage to compensate for the voltage lost across the motors' internal resistance. If this compensation is increased too much, the system will oscillate. Correct compensation will be found as the point where the motor load can be increased, and the motor speed will be maintained at a relatively constant value. If motor speed increases when a load is applied, there is too much IR comp, and R51 should be turned CW until speed remains constant under load. On the other hand, if motor speed decreases too much under load, turn R51 more CCW until speed is held constant.

If you are in a situation where you cannot apply either of the two methods described above, you can still adjust IR comp relatively well by simply setting the pots as described above, and then turning R51 (IR comp) gradually CCW while operating the motor under changing load conditions. By noting that IR comp is too much, or too little you can find a setting that compensates best without oscillation and overshoot, or slowing down under load.

If you have to change the speed of the motor in response to the reference voltage (i.e., the voltage-gain) this is done by setting R31 (Voltage feedback pot) with R51 at the fully CW setting. Once the speed is set correctly, begin adjusting R51 (IR comp) to its best setting. These two pots will interact, so it is important to set the speed first, and then adjust the IR comp pot next

When adjustment is complete, continue to cycle the motor under varying load conditions to confirm the pot settings under all of the anticipated load conditions.

PWM Operation

PWM signals are of two distinct types that we refer to as *0-100%* and *50%*.
The *0-100%* type uses two signals: one to control the amplitude and the other to control direction. The *50%* type uses only one signal that is at 50% duty cycle for a zero output from the amplifier, and changes to 0, or 100% for full output in the positive, or negative directions.

The table of jumper setting shows how to setup the MB4 card for the different modes.

Connections for the *0-100%* type of inputs are shown below:

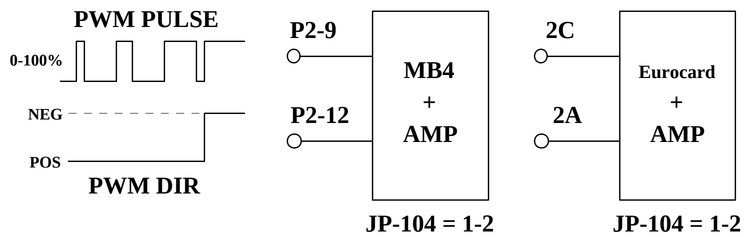


Fig. 16

The PWM signals should be +5V CMOS compatible, and the *0-100%* signal should be normally LO, going HI for 0-100% duty cycle to enable the amplifier.
The DIR signal will cause an immediate change in the polarity of the voltage going to the amplifier. Control systems will usually change the polarity of this signal when the *0-100%* signal is at 0% to eliminate jerkiness in the motor.

Here are the connections for a *50%* type of PWM system:

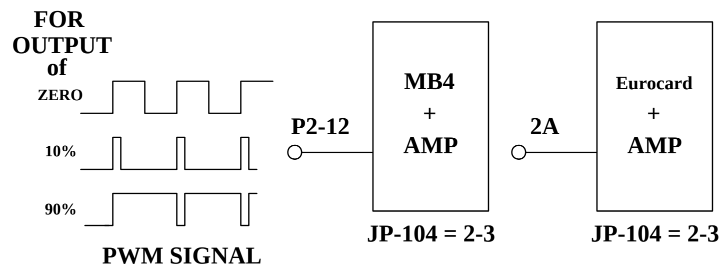


Fig. 17

Note that a 50% duty cycle signal now produces zero current at the output of the amplifier. Changing from 50-0% duty cycle will increase the current in the positive direction, and going from 50-100% increases the current from 0-100% in the negative direction.
PWM inputs can be used in either the current or voltage modes of operation.
In current-mode, the feedback trimpot may have to be adjusted to increase the gain of the amplifier because of the lower (±2.5V) signals that now control the amplifier.
In voltage mode, adjust the voltage gain based on a reference voltage of 2.5V (see previous section on voltage-mode and gain-setting).

Appendix

Connector Part Numbers

Here are the Copley Controls Corp.(CCC), and OEM part numbers for the connectors used with the 300 series amplifiers:

Basic Amplifier 4-pin power/motor connector
CCC No. 57-0073 (Weidmuller BL4.12593.6)

Basic Amplifier 22-pin signal connector (housing only)
CCC No. 57-0074 (Molex 22-01-3227)

MB4 Card: 4 pin power/motor connector
CCC No. 57-0073 (Weidmuller BL4.12593.6)

MB4 Card: 15 pin signal connector (housing only)
CCC No. 47-0006 (Molex 22-01-2157)

Pins for 15, 22 pin signal connector
CCC No. 46-0000 (Molex 08-50-0114, crimp-tool 11-01-0037)

DIN backplane connector for Eurocard mount
CCC No. 57-   (Schroff 69001-698)

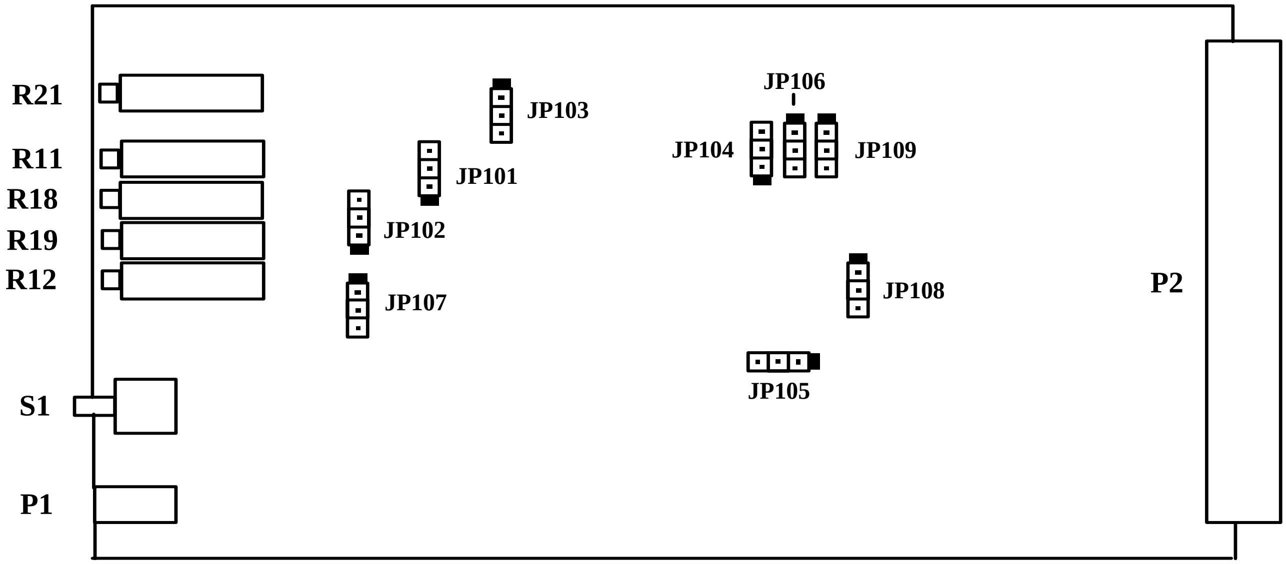
References

1. Electrocraft Corp., *DC Motors, Speed Controls, Servo Systems*, (Electrocraft Corp., 1980)
2. Benjamin C. Kuo, *Automatic Control Systems*, (Englewood Cliffs, NJ: Prentice-Hall, Inc., 1982)
3. Jacob Tal, *Motion Control Applications*, (Palo Alto, CA: Galil Motion Control, 1989)
4. Richard C. Dorf, *Modern Control Systems*, (Reading, MA: Addison-Wesley Publishing Company, 1980)
5. Richard W. Miller, *Servomechanisms: Devices & Fundamentals*, (Preston, 1977)

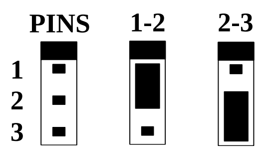
Standard Power Supplies

MB4 Card Layout

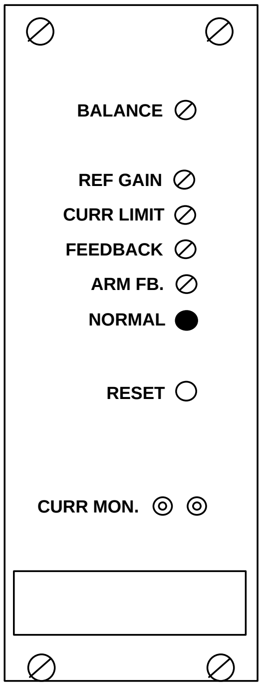
Eurocard Layout



Jumper Pin Numbering



Panel Layout



Ordering Guide for 300 Series

Model 303,	75 volt	@ 12A peak,	6A continuous	
Model 306,	75 volt	@ 25A peak,	10A continuous	
Model 306A,	75 volt	@ 30A peak,	15A continuous	
Model 303B,	90 volt	@ 12A peak,	6A continuous	
Model 306B,	90 volt	@ 25A peak,	10A continuous	
Model 306AB,	90 volt	@ 30A peak,	15A continuous	
Model 312,	150 volt	@ 9A peak,	4.5A continuous	

Model XXXX XX XX XX X X

Amplifier (XXXX)
303,
306,
306A,
303B,
306B,
306AB
312

Amplifier Connector Version (XX)
(Blank), Standard
P , Pin Type[2]

Mounting Board Option[1] (XX)
M , MB4 Card
E , Extended Eurocard
ER , Extended Eurocard, with front panel

Added Functions (XX)
F , Adding edge filter
D , Adding PWM input
V , Adding voltage control

Heatsink (X)
H, 0.35" heatsink
HX, 1.25" heatsink

High Inductance Load (X)
(Blank), Standard
–1 , High Inductance Load Option

NOTES: 1. When ordering any mounting option, order the amplifier with suffix 'P' (Pin Type).
2. When the amplifier is ordered with the P (pin) option, the adjustment potentiometers, current limit resistor (R8) and LED are removed. These parts will be shipped with the amplifier, to be used if needed.

Example: Model 303,	Model 303, standard mount.
Model 306H-1,	Model 306, standard mount with heatsink, plus high inductance load.
Model 303BPEF,	Model 303B, Pin mounting on Eurocard mount with output filter.
Model 303BPEFD,	Model 303B, Pin mounting on Eurocard mount with output filter and PWM input.