FEATURES

- **Drives DC brushless motors with 60° or 120° Halls in six-step (trapezoidal) mode**
- ***DriveTorque* mode switches from velocity to torque mode for fastener-driving, bottle capping, etc.**
- **External or hardwired control of peak and continuous current limits.**
- **Independent settings for peak and continuous current, and peak-time.**
- **Separate motor and signal Sub-D type connectors for simpler cabling**
- ***No Transformer Required!* Operates from power supplies that rectify the line directly with full optical isolation between signal and power stages.**
- **+5V @ 250mA powers motors with "commutating encoders"**
- **FAIL-SAFE ENABLE INPUT**
  Ground or +5V level select
  Pull-up or pull-down select
- **FAULT PROTECTIONS**
  Short-circuits
  output to output
  output to gnd
  Over / under voltage
  Over temperature
  Self-reset or latch-off
- **3kHz max bandwidth.**
  Wide load inductance range

THE OEM ADVANTAGE

- **Production amplifiers can be pre-configured at the factory for volume production**

MODEL	POWER	I-CONT (A)	I-PEAK (A)
5224DC	45~186VDC	10	20
5424DC	45~373VDC	10	20

DESCRIPTION

The 5xx4DC models are PWM servoamplifiers for Hall commutated DC brushless motors operating in six-step (trapezoidal) mode.

Built with surface-mount technology, these amplifiers offer a full complement of features for DC brushless motor control. Torque-mode operation is standard, and there are two modes of velocity-loop operation. Frequency to voltage conversion of Hall or encoder signals gives tachless velocity-loop operation. Output voltage control gives velocity loop operation without the use of encoder or Hall signals.

Torque mode is used typically with digital controllers that calculate position and velocity from the motors encoder. Hall tach operation works well for high speed applications such as spindles. Encoder tach velocity loops give a wide speed range and lower ripple near zero velocity. Voltage mode is smooth around zero, and has enough speed regulation to work well with PLC's or motion control IC's.

An internal solderless sockets permits users to configure the various gain and current limit settings to customize the amplifiers for a wide range of loads and applications. Header components permit compensation over a wide range of load inductances to maximize bandwidth with different motors.

Separate current-limits provide protection for motors while optimizing acceleration characteristics. Peak current, continuous current, and peak-time are individually settable via the internal header, or by external signals.

DriveTorque mode for fastener driving applications permits external switching between velocity and torque mode. Screws are driven in at constant speed using voltage-mode feedback until the external controller senses increased current. Then, mode is switched to torque mode to set screw at programmed torque.

The /Enable input active logic-level is switch-selectable to ground or +5V to interface with all types of control cards. Fail-safe operation in either polarity results from an internal jumper that selects the default input level and input resistor pull-up or pull-down connections so that the amplifier shuts down with no input.

Mosfet (5224DC) and IGBT (5424DC) output stages deliver four-quadrant power for bi-directional acceleration and deceleration of motors. For high-inertia loads, an external regenerative energy dissipater is available.

All models are protected against output short circuits (output to output and output to ground) and heatplate overtemperature. With the /Reset input open the amplifier will latch off until powered-down or the /Reset input is toggled.The amplifier will reset itself automatically from faults if the /Reset input is wired to GND.

TECHNICAL SPECIFICATIONS

MODEL			5224DC	5424DC
OUTPUT POWER				
	Peak power		20A @ 180VDC	20A @ 370VDC
	Peak time		2 sec at peak power independent of polarity reversal	
	Continuous power		10A @ 180VDC	10A @ 370VDC
OUTPUT VOLTAGE				
	On-resistance (Ro, ohms)		0.2	0.15
	Max PWM Peak Output Voltage		±Vout = (VDC)×(0.97) - (Ro)×(Io)	
INPUT POWER				
	DC voltage		45~186VDC	45~373VDC
	Mains current @ continuous output rating		16A	16A
	Inrush current on startup		19A	37A
	External mains fuse rating		20A/125V	20A/250V
LOAD INDUCTANCE				
	Minimum inductance		400 µH.	800 µH.
	Maximum inductance		No maximum. See chart of load inductance values. Bandwidth varies with inductance and header parts.	
BANDWIDTH	Small signal		-3dB @ 3kHz with minimum load at nominal supply voltage varies with load inductance and header values.	
PWM OUTPUTS				
	PWM frequency		25kHz	
	Modulation		Center-weighted, 50% duty cycle at 0V output	
REFERENCE INPUT			Differential, 94KΩ between inputs, ±20V maximum	
POTENTIOMETERS	Ref Gain	Default = CW	CCW attenuates Reference input from x1 to 0	
	Tach Gain	Default = CCW	CW increases speed (decreases feedback from tachometer). Note: fully CW = 5% of max	
	Loop Gain	Default = CCW	CW increases loop gain in velocity mode, current gain in torque mode	
	Integ Freq	Default = CCW	Integrator zero-gain frequency in velocity mode. CW increases stiffness	
	Balance/Test	Default = center	Use to set output current or rpm to zero; or use as ±10V test input if RH9 set to 50kΩ	
DIP SWITCHES	S1:		Velocity loop integrator control. ON: Torque mode, integrator disabled. OFF: Velocity mode, integrator enabled.	
	S2, S3:		Feedback mode control. See Applications section for details.	
	S4:		/Enable input active polarity. OFF (default): Gnd enables amplifier, open or +5V inhibits. ON: Gnd inhibits, open enables	
LOGIC INPUTS				
	/Enable	Default = GND	GND enables amplifier, open or >2.5V inhibits with S1 OFF. If S4 ON then GND inhibits See following section on Fail-Safe operation for JP4 settings. Response time: 1 ms. From enable active to amplifier output ON	
	/POS enable, /NEG enable	Default = GND	GND enables, open or >2.5V inhibits positive/negative output currents (S1 has no effect)	
	/Reset	Default = Open	GND resets latching fault condition, ground for self-reset every 50 ms.	
	/Motemp	Default = GND	Motor temperature sensor. Typically normally closed bimetal sensor. Open = overtemp	
	/Force	Default = Open	Velocity to torque mode switching control. Ground disconnects velocity loop components (Ref Gain, Tach Gain, Loop Gain, Integ Freq, and Balance pots, and all related header parts). Mode changes to torque, RH10 controls transconductance. See application section for details.	
	Input resistance		10kΩ (Jumper J4A selects connection to +5V or ground), R-C filters on inputs	
	Logic threshold voltage		2.5V (Schmitt trigger inputs with hysteresis, 74HC14)	
	Input voltage range		0V to +32VDC	
FAIL-SAFE ENABLE INPUT				
	Internal jumper JP4 selects +5V or GND connection for input pull-up resistors to /Enable input only so that amplifier will default to *disabled* condition if inputs are open-circuit, or wires are broken. (See Applications section for details)			
LOGIC OUTPUTS				
	/Normal		LO (current sinking) when Normal LED is ON; HI when LED is OFF	
	HI output voltage		+5V (no load). Output is N-channel mosfet drain terminal with10kΩ pullup resistor to +5V	
	LO output voltage		On resistance Ro = 5Ω. Max sink current of 250mA. max off-voltage = 50VDC	
	Amp OK		N-channel opto-isolator is ON when amp is OK: Buss volts OK AND NOT (output short OR overtemp)	
	ON current		4 mA.	
	Max voltage		32 VDC	
STATUS LED				
	Bicolor LED changes color and flashes to indicate amplifier operating status			
	Green = Normal		*Amplifier enabled* AND Amp OK (see above)	
	Blinking green = Ready		Amplifier OK, will *run* when enabled	
	Red = Fault, non-latching		Over or under-voltage condition or motor overtemp; Amplifier recovers when voltage or temp. is in normal range.	
	Blinking red = Latching Fault		Output overcurrent (short circuit) or amp. overtemp condition. Ground /Reset or power amp. off/on to clear condition	
MONITOR OUTPUTS				
	Current Ref		Current demand signal to PWM stage: ±10V = ±Ipeak	
	Current Monitor		Motor winding current: ±10V @ ±Ipeak (1kΩ, 33nF R-C filter)	
	Feedback		Monitor signal for Hall/encoder tachometer, voltage feedback. ±5V = 100% of feedback signal normal range	

DC POWER OUTPUTS

+5V @ 250 mA max (J2-11, J3-23). Power for Halls and/or encoder.
+10VDC @ 5mA (J3-24)
-10VDC @ 5mA (J3-25)
Note: maximum power from all dc outputs not to exceed 1.4W

PROTECTIVE FEATURES

Short circuit (output to output, output to ground)	Latches unit OFF (Power off/on, or ground at /Reset input resets)
OverTemperature	Latches unit OFF at 70°C on heatplate (Power off/on, or ground at /Reset input resets) *Wire /Reset input to ground for automatic reset after latching fault*
Undervoltage	Shutdown at DC buss < 45VDC
Overvoltage	Shutdown at DC buss > 195VDC (Model 5224DC), or DC buss > 390VDC (Model 5424DC) (Amplifier operation resumes when power is NOT undervoltage or NOT overvoltage)
Current-limiting (foldback)	Output current set by header components (peak, continuous, & peak-time)

AMPLIFIER DISSIPATION

Watts minimum	17W (Model 5224DC)	7W (Model 5424DC)
Watts @ continuous current	60W (Model 5224DC)	61W (Model 5424DC)

THERMAL REQUIREMENTS

Storage temperature range	-30°C to +85°C
Operating temperature range	0° to 70°C baseplate temperature
Thermal resistance (heatplate to ambient):	No heatsink or fan: 0.92 deg. C/W; no heatsink with fan: 0.51 deg. C/W With heatsink, no fan: 0.6 deg. C/W; with heatsink and fan: 0.23 deg. C/W

MECHANICAL

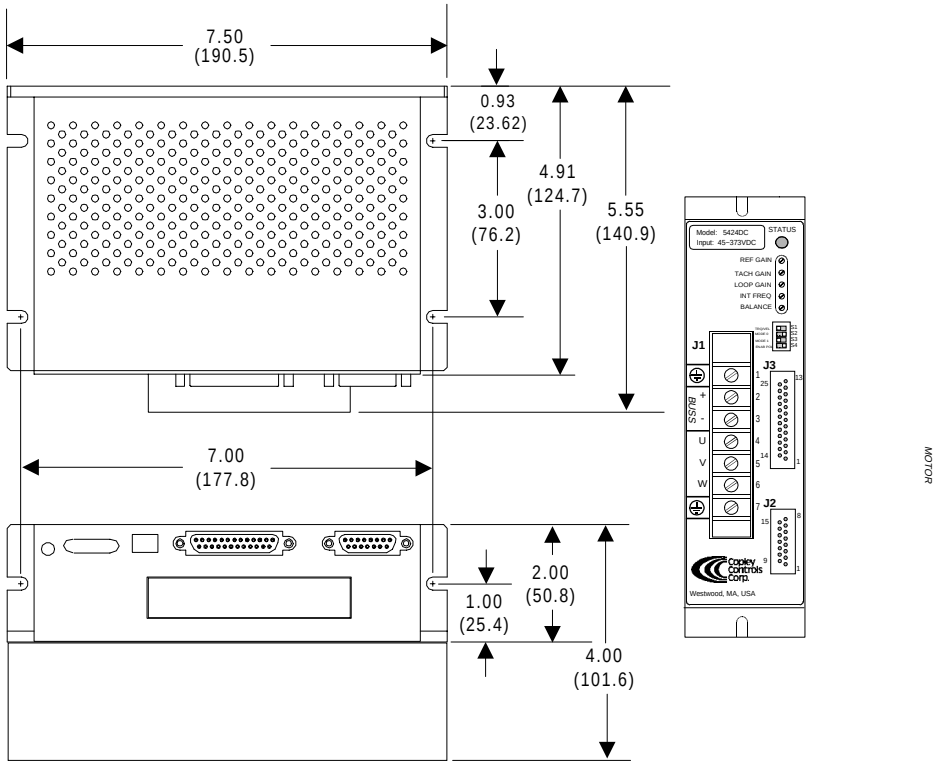
Size	7.50 x 5.55 x 2.00 in. without optional heatsink 7.50 x 5.55 x 4.00 in. with optional heatsink
Weight	2.7 lbs. (1.22 kg) without optional heatsink. Add 3.2 lbs. (1.47 kg) for heatsink.

CONNECTORS

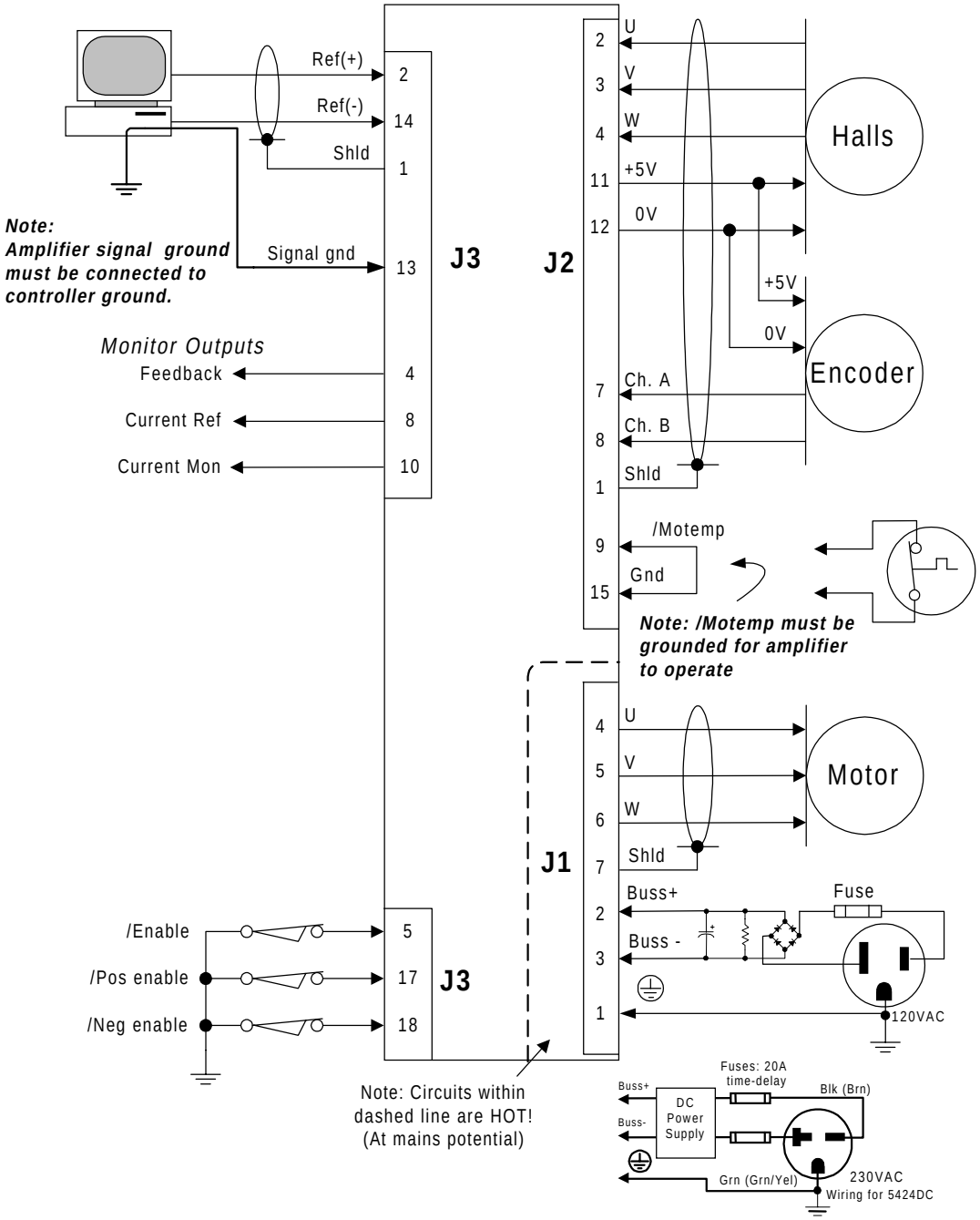
J1: Power & motor	9-position terminal strip
J2: Halls / Options	15-position female Sub-D type. #4-40 standoffs for cable shell lock screws
J3: Signal	25-position female Sub-D type. #4-40 standoffs for cable shell lock screws Connector shells are connected to amplifier chassis for grounding/shielding

OUTLINE DIMENSIONS

Dimensions in inches (mm)



AMPLIFIER CONNECTIONS



J1 POWER AND MOTOR WINDING CONNECTIONS

Connector type: Barrier-block, Screw-terminal connections, and #6-32 locking screws with cable clamps

PIN	SIGNAL	FUNCTION
1	GND	Chassis safety ground (green or green/yel wire from AC mains)
2	Buss (+)	DC power input positive terminal from DC power supply
3	Buss (-)	DC power input negative terminal from DC power supply
4	Motor U	Amplifier output to “U” winding of motor
5	Motor V	Amplifier output to “V” winding of motor
6	Motor W	Amplifier output to “W” winding of motor
7	GND	Chassis safety ground. Also for cable shield of motor cable.

J2 MOTOR HALL AND ENCODER CONNECTIONS

Connector type: Female Sub-D, 15-position, and #4-40 standoffs for cable shell

PIN	SIGNAL	FUNCTION
1	Safety GND	Chassis ground. Use to ground cable shield. Not connected to internal signal ground.
2	Hall U	Digital Hall inputs for “U”
3	Hall V	Digital Hall inputs for “V”
4	Hall W	Digital Hall inputs for “W”
5	Analog Tach	Brush tachometer input
6	N.C.	
7	Encoder B channel	
8	Encoder A channel	
9	/Motemp	***Note: Must be grounded for amplifier to operate (Connect to J2-12,14, or 15)***
10	N.C.	
11	+5V @ 250 mA.	DC power for encoders and Halls (Note 1)
12	0V.	Signal ground for +5V and Halls.
13	N.C.	
14	0V.	Signal ground for +5V and Halls.
15	0V.	Signal ground for +5V and Halls.

J3 SIGNAL CONNECTIONS

Connector type: Female Sub-D, 25-position, #4-40 standoffs for cable shells

PIN	SIGNAL	FUNCTION	PIN	SIGNAL	FUNCTION
1	Safety GND	Chassis ground. Use to ground cable shield. Not connected to internal signal ground (J3-12,13,15,16).			
2	Ref (+)	Positive terminal of differential +/-10V analog command input	14	Ref (-)	Negative terminal of differen tial +/-10V analog command input
3	Analog Tach	Brush tachometer input	15	0V.	Signal ground.
4	Feedback	Hall, encoder, or Vout FB	16	0V.	Signal ground.
5	/Enable input	Amplifier enable	17	/Pos Enable input	
6	/Normal output	Mosfet output amp status	18	/Neg Enable input	
7	Ready (-) output	Opto-isolator emitter (NPN) (NPN)	19	Ready (+) output	Opto-isolator collector
8	Current Ref output		20	Ext Ipeak	External setting of peak curr
9	Aux input		21	Ext Icont	External setting of cont curr
10	Current Monitor Out		22	/Reset input	
11	/DrivTorq	Ground enables Drive-Torque mode.	23	+5V @ 250 mA.	Auxiliary DC power for user devices (Note 1)
12	0V.	Signal ground.	24	+10V @ 5 mA	Auxiliary DC power
13	0V.	Signal ground.	25	-10V @ 5 mA	Auxiliary DC power

Notes:

1. +5V @ 250mA connects to *both* J3-23 *and* J2-11. Combined current from both pins must not exceed 250mA.

DIP SWITCH FUNCTIONS

The default configuration for the amplifier is *torque mode*. The internal velocity modes (Hall tach, encoder tach, or voltage mode) are disabled by moving the 49.9k resistor from RH22 to RH19. To enable the feedback modes described below, move the resistor from RH19, to RH22 (see signal board layout diagram for position of headers and components).

Note: Default positions shown in ***bold & italics*** (ON is toward PC board, OFF is away from PC board)

SW	NAME	SEL	DESCRIPTION
S1	INTEG	***ON***	***Velocity integrator disabled (Torque mode).***
		OFF	Velocity integrator ON. Controls stiffness in velocity mode.
S2	MODE 0	***ON***	Amplifier operating mode selection.
S3	MODE 1	***OFF***	See table below for functions
S4	EN POL	ON	/Enable input disables amplifier if ground. Open or >2.5V enables.
		OFF	***/Enable input ground-active. Open or >2.5V disables amplifier.***

Note: “X” in table below means that switch setting doesn’t matter.

S2	S3	J3-11	FUNCTION	DESCRIPTION
X	X	LO	*DriveTorque* mode	RH10 sets current-gain. All pots out of circuit.
ON	ON	HI	Hall speed control mode	Fre quency to voltage conversion of Halls
OFF	OFF	HI	Encoder speed control mode	Fre quency to voltage conversion of encoder
ON	***OFF***	***HI***	***Output voltage feedback***	***Out put voltage control***
OFF	ON	HI	Brush tach mode	Speed control using brush tachometer.

LED INDICATOR FUNCTIONS

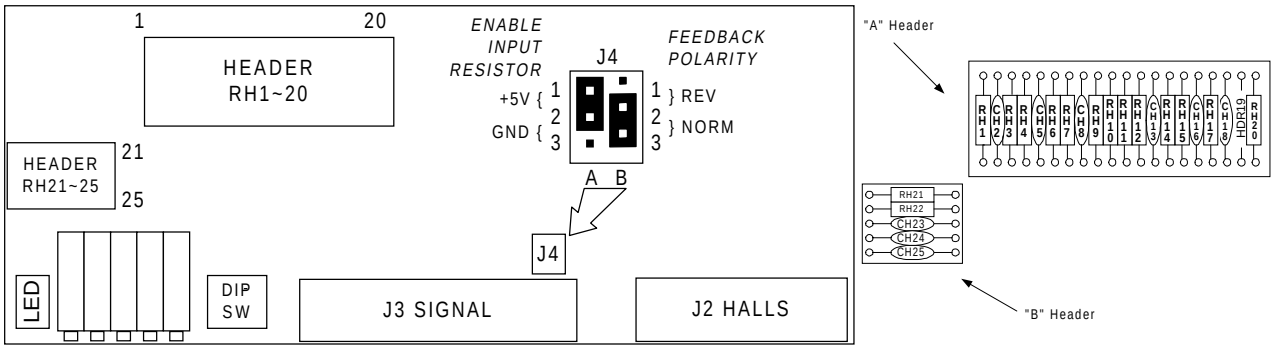
Color and state of LED indicates amp. operating conditions:

LED COLOR	CONDITION	ACTION REQUIRED TO ENABLE
Flashing Green	Ready	Ground / Enable input (J3-5)
Green	Normal	None. Normal “RUN” condition.
Red	Power Fault	Bring DC voltage into range.
Flashing Red	Latching Fault	Ground /Reset input, or cycle DC power OFF/ON

POTENTIOMETER FUNCTIONS

POT	DFLT	DESCRIPTION
REF GAIN	CW	Input reference signal attenuation. Controls overall amplifier gain (amps/volt or rpm/volt) without affecting response. Full CCW attenuates ref signal to zero.
TACH GAIN	CCW	Tachometer feedback control. CCW = maximum feedback (lowest speed, fastest response), CW = minimum feedback Range = 20:1 (max. to min speed).
LOOP GAIN	CCW	Response control for velocity loop: CW increases bandwidth, CCW decreases. In torque mode: CW increases amps/volt.
INTEG FQ	CCW	In velocity mode (S1 OFF) CW increases stiffness, CCW decreases stiffness, *Full CW leads to violent oscillation.*
BALANCE	Cntr.	Sets velocity to zero, or output current to zero with zero input.

SIGNAL BOARD AND HEADER SOCKET LAYOUT



The A and B header sockets hold the components that determine the amplifiers performance such as operating mode, current limits, and feedback type. Components are named **RH**n, **CH**n as **R**esistor **H**eader n, **C**apacitor **H**eader n, etc. Detailed instructions for the selection of these components follow.

MOTOR INDUCTANCE SETTING

Header components RH20, CH18, and CH16 control the amplifier compensation for different motors. These set the gain in the current error amplifier to give the best response for different winding *inductances*.
The tables below give values for the header parts for the two models. If the inductance of your motor is less than ½ of the value shown in the table, use the values from the next *lower* inductance range. E.g., for a 4mH motor, use the values from the 3 mH row (1/2 of 10mH is 5mH, which is greater than 4mH, so the value from the next *lower* row, 3mH, is used).

For all tables, CH18 is 15nF, and CH16 is <out>.

Model 5224DC @ 160VDC

L (mH)	RH20 (Ω)
0.3	10 k
1	***30 k***
3	100 k
10	300 k
30	1 Meg

Model 5424DC @ 339VDC

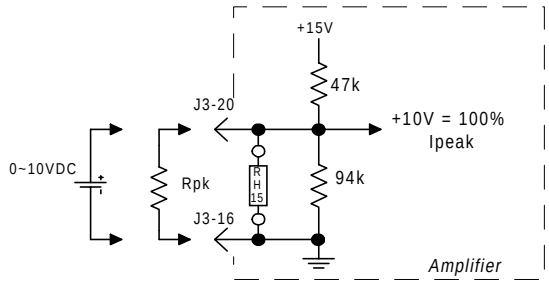
L (mH)	RH20 (Ω)
0.3	4.7 k
1	***15 k***
3	47 k
10	150 k
30	470 k

Model 5424DC @ 160VDC

L (mH)	RH20 (kΩ)
0.3	10 k
1	30 k
3	100 k
10	300 k
30	1 Meg

PEAK CURRENT LIMIT SET

Control of the peak current limits can be made externally via connector pin J3-20. A resistor can be connected between this pin and signal ground (J3-11, 13, 15, or 16), or the pin can be driven by a voltage between 0 and +10VDC. Using this technique, the current limit can be controlled over a range of 100% to 10% of the amplifier peak rated current. The figure below shows the circuit.



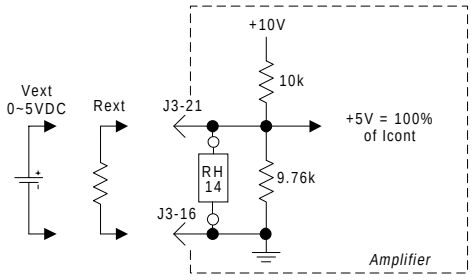
The table below gives values of the external control voltage, or external control resistor for various values of peak current:

Ipeak	**Rext**	**Vext**
20	<out>	10
18	180 k	8.8
16	91 k	7.7
14	56 k	6.6
12	39 k	5.6
10	24 k	4.6
8	15 k	3.5
6	10 k	2.5
4	5 k	1.4
2	1.2 k	0.4

These values are within 10%, typically. For greater accuracy, measure Current Ref and select parts for exact limit value.

CONTINUOUS CURRENT LIMIT SET

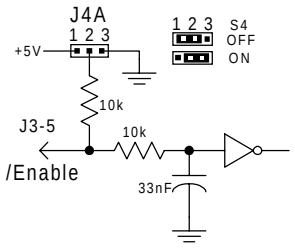
Control of the peak current limits can be made externally via connector pin J3-21. A resistor can be connected between this pin and signal ground (J3-11, 13, 15, or 16), or the pin can be driven by a voltage between 0 and +5VDC. Using this technique, the current limit can be controlled over a range of 100% to 10% of the amplifiers rated continuous current. The figure below shows the circuit.



The table below lists values for Vext and Rext to control the continuous current limit externally.

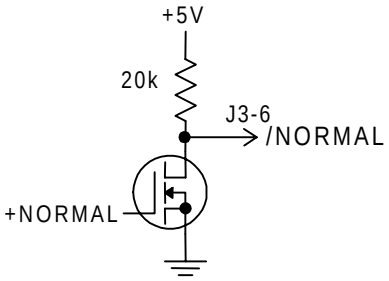
Icont	**Rext**	**Vext**
10	<out>	4.9
9	30 k	4.29
8	15 k	3.66
7	7.5 k	3.0
6	4.7 k	2.4
5	2.7 k	1.78
4	1.5 k	1.16
3	560	0.54
2.1	0 0	

FAIL-SAFE JUMPER FUNCTION



Internal jumper J4A sets the open-pin voltage for the /Enable input (J3-5). For FAIL-SAFE operation, the amplifier should shut down if J3 is disconnected, or if the wire to the /Enable input is broken.
For this to work, J4A should be set according to the position of DIP switch S4 as follows:
S4 OFF (default): /Enable input is ground active. J4A set to pins 1-2 so that input pulls up to +5V, disabling amplifier.
S4 ON: /Enable input functions as +Enable, /Disable. Set J4A to pins 2-3 so that input voltage is pulled-down to ground if input is open.

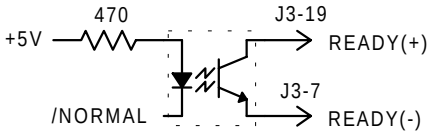
AMP-NORMAL OUTPUT



N-channel mosfet with 10k-ohm resistor connected to +5V. Maximum voltage: 50VDC. Maximum current 250mA. On-resistance = 5 ohms.
Output is LO (mosfet ON) whenever amplifier is enabled and NORMAL (LED green).
Output is HI (mosfet OFF) whenever amplifier is NOT enabled, or FAULT occurs.

OPTO-ISOLATED AMP-READY OUTPUT

The READY signal indicates amplifier ready to run status. It is completely optically isolated from the amplifier. The input of the optocoupler is driven by the amplifier logic circuits, and the output is a floating NPN transistor with both terminals brought to signal connector
J3 as shown below.



Maximum voltage = 32VDC. ON current = 4mA. minimum
Output transistor ON voltage: 0.4 at 4mA

DRIVETORQUE MODE

This mode is most useful in fastener-drive applications where the amplifier is operated in a velocity mode to drive the fastener in at a constant speed until the controller senses that the current has reached a set value. Then the controller grounds the /DRVTRQ input switching the amplifier into torque mode that applies a set current to the fastener to drive it into position at a constant torque value.
With J3-11 open (default) amplifier operates in velocity mode. This can be switch-selected to be Hall, encoder, output voltage, or analog tachometer controlled.
When J3-11 is grounded, DriveTorque mode is enabled, and amplifier switches to torque mode with transconductance controlled by RH10. The REF GAIN, LOOP GAIN, INTEG FREQ, and BALANCE pots have no effect in this mode. The current gain is controlled by this simple equation:

$$\text{Gain} = \frac{\text{RH10}}{10} \ \text{(kOhms)} \quad \text{(A/V)}$$

External current-limits still function and can override the current command at the reference input.

ORDERING GUIDE

Model 5224DC	20A peak, 10A continuous, from 45~186VDC, (32~132VAC rectified)
Model 5424DC	20A peak, 10A continuous, from 45~373VDC, (32~264VAC rectified)

Notes: 1. Add “H” to model number to specify heatsink option.
Example: Model 5424DC with heatsink would be ordered as a 5424DCH

OTHER DC BRUSHLESS AMPLIFIERS

7000 Series Five different model types for driving AC brushless motors with sinusoidal commutation using a variety of feedback and control card schemes

5xx1 Series Six models operating from +24 to +225VDC, 10~30A peak, 5~15A continuous. CE compliance available (5xx1CE models), Hall/encoder velocity feedback option and brushless tachometer option.

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