

NBA SERIES OPERATING MANUAL

Rev 02/94

ELMO-WARRANTY PERFORMANCE

The warranty performance covers only ELMO's products and only the elimination of problems that are due to manufacturing defects resulting in impaired function, deficient workmanship or defective material. Specifically excluded from warranty is the elimination of problems which are caused by abuse, damage, neglect, overloading, wrong operation, unauthorized manipulations etc. The following maximum warranty period applies:

12 months from the time of operational startup but not later than 18 months from shipment by the manufacturing plant.

Units repaired under warranty have to be treated as an entity. A breakdown of the repair procedure (for instance of the repair of a unit into repair of cards) is not permissible.

Damage claims, including consequential damages, which exceed the warranty obligation will be rejected in all cases.

If any term or condition in this warranty performance shall be at variance or inconsistent with any provision or condition (whether special or general) contained or referred to in the Terms and Conditions of Sales set out at the back of Elmo's Standard Acknowledge Form, than the later shall prevail and be effective.

How to use this manual - Flow Chart

The NBA amplifier represents a flexible design approach which enables the use of various feedback sensors and allows several modes of operation.

Use the following flow chart in order to determine the chapters that you should read. If you are a new user of the NBA, you should read chapters 1-4 which will familiarize you with the product.

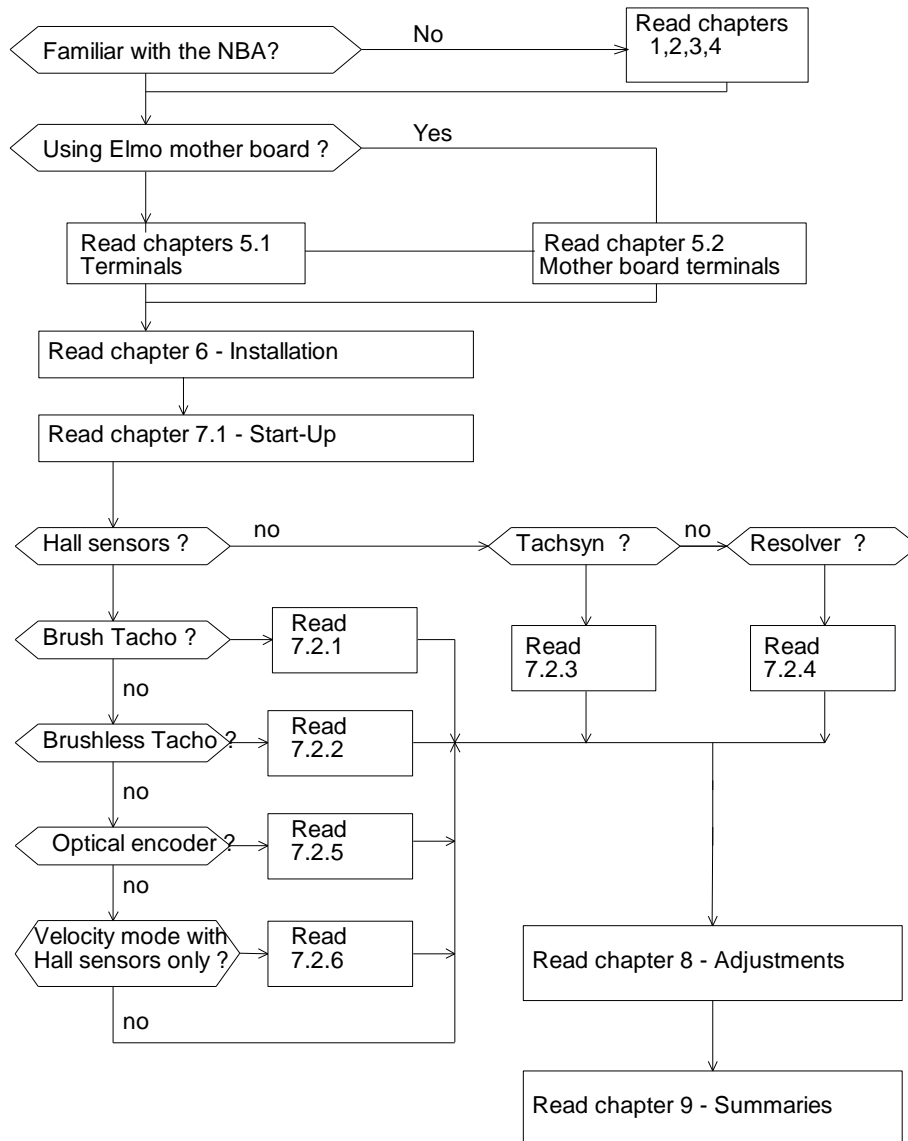


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1. Description

The NBA is a miniature PWM, full wave, three phase servo amplifier designed for high performance brushless servo motors in the range of up to 2.8KW. It utilizes power MOSFETs and Surface Mounting Technology which contribute to its high efficiency and compact design. The NBA is constructed from two PCBs mounted on a heat sink plate. The lower board contains the power switching transistors which drive the motor, control section, terminals for both the power stage and control stage, and the protection logic. The upper PCB contains the switch mode power supply.

An optional third board is installed for velocity sensors others than a brush type tacho.

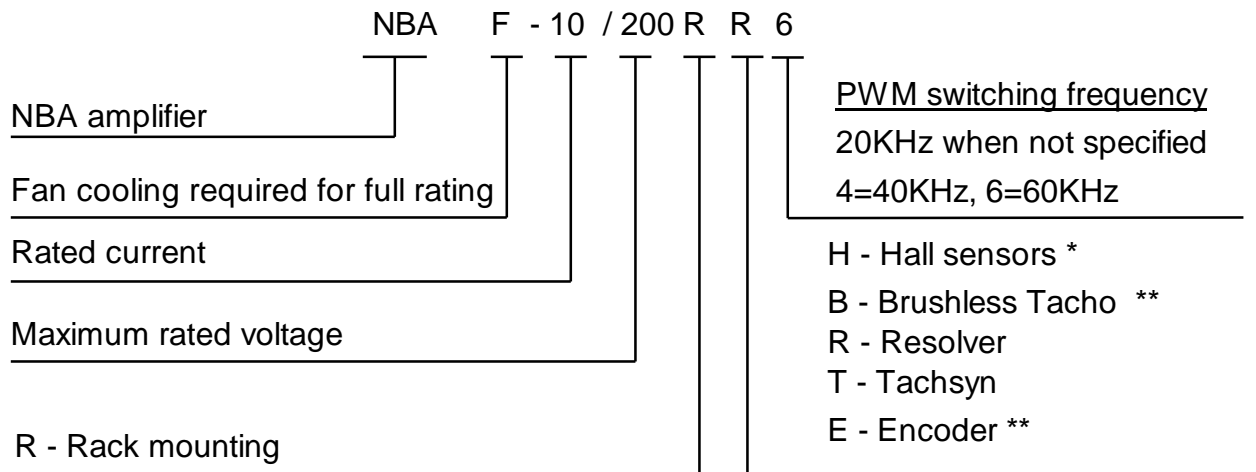
Standard Features

- * Internal DC to DC converter allows operation from a single supply.
- * 20 KHz switching frequency (40KHz or 60KHz on request).
- * 2KHz current loop response.
- * 97% efficiency.
- * Output voltage is up to 90% of input voltage.
- * Zero deadband.
- * Better than 1% linearity.
- * 2 inputs.
- * Motor current monitor.
- * Operation in velocity or current mode.
- * Opto-isolated inhibit input.
- * Opto-isolated CW and CCW inputs.
- * Inhibit/fault indication (relay output).
- * Latch/self-restart modes for protective functions.
- * Adjustable compensation.
- * External current limit input.
- * Current feedback multiplier.
- * Multiturn trimmer for easy balance adjustment (offset).
- * LED diagnostics.
- * Standard commutation: Hall effect sensors.
- * Optional commutation sensors: Resolver or Tachsyn.
- * Buffered differential encoder outputs (Resolver option)
- * Outputs voltages of +5V and +15V for external use.

The amplifier is fully protected against the following faults:

- Under/over voltage.
- Shorts between: outputs, output to ground.
- Excess temperature.
- Loss of commutation signals.

2. Type Designation



* The Hall effect version accepts a brush tachogenerator for velocity feedback and Hall effect sensors for commutation.

** The B and E versions require Hall effect sensors for commutation.

3. Technical specifications

Type	DC Supply Min.-Max.(V) *	Current limits Cont./Peak(A)	Size rack	Weight (Kg)
NBA-6/200	40-195	6/12	3U/8T	0.7
NBA-10/200	40-195	10/20	3U/15T	1.4
NBA-2.5/400	140-390	2.5/5	3U/8T	0.7
NBA-4/400	140-390	4/8	3U/8T	0.7
NBA-8/400	140-390	8/16	3U/15T	1.4

FAN COOLING RATINGS

NBAF-10/200	40-195	10/20	3U/8T	0.7
NBAF-8/400	140-390	8/16	3U/8T	0.7

- * DC output voltage is 90% of DC input voltage.
- * 20KHz, 40KHz or 60KHz switching frequency.
- * 2KHz current loop response (minimum)
- * Outputs voltages of +5V, ± 15 V for external use.
- * Efficiency at rated current - 97%.
- * Drift: 10 μ V/ $^{\circ}$ C (referred to input)
- * Operating temperature: 0-50 $^{\circ}$ C.
- * Storage temperature: -10 - +70 $^{\circ}$ C.

Resolver option features:

- 10, 12, 14 and 16 bit resolution, set by user.
- Maximum tracking rate 1040 rps (10 bit).
- Buffered differential encoder outputs.
- Programmable Index (Marker) output.

* These are the absolute minimum-maximum DC supply voltage under any condition.

Optical encoder velocity feedback features:

- Maximum input frequency: 800KHz
- Speed regulation: 500:1
- Encoder frequency: x1 or x4
- Encoder output voltage range: 2-30V
- Output supplies: 5V/250mA, 15V/100mA.

4. Operation of the servo control

In the following paragraphs, terminals of both the DIN type connector and the Elmo mother board will be referred to. The letter R will be used for the Din type connector and the letter M will be used for the mother board terminals.

4.1 Inputs

The NBA has 2 inputs: single ended input (R-2a,M-J2/1) and a differential input (R-4a,6a,M-J2/3,2). The current gain of the single ended input (current mode) is given by:

$$G_c = \frac{0.533 \times I_c}{1 + 0.1 \times R_1} \quad (\text{Amp/Volt}), \quad R_1 \text{ in Kohm}$$

I_c - amplifier rated continuous current

The current gain of the differential input for $R_3=R_2$ (current mode) is given by:

$$G_{c_d} = \frac{5.33 \times I_c}{R_3} \quad (\text{Amp/Volt})$$

R_3 in Kohm

The current gain in velocity mode is given by (place the appropriate G_c for each input):

$$G_v = \frac{50 \times G_c}{R_5} \quad (\text{Amp/Volt}), \quad R_5 \text{ in Kohm}$$

All the gains are divided by 2 if CFM is ON

The maximum input voltage at terminal R-2a,M-J2/1 is calculated by:

$$V_{3\max} = 8 + R_1 \quad (\text{Volts}), \quad R_1 \text{ in Kohm}$$

4.2 Velocity mode

In the velocity mode, op amp U1A is employed as a high gain error amplifier. The amplifier sums velocity command and the velocity feedback signal, and provides the necessary servo compensation and gain adjustments, resulting in stable, optimum servo operation.

This op amp is configured with two feedback paths:

One, in the form of a resistive T network, controls the DC gain of this amplifier. The equivalent value of a T network is given by:

$$R_f = \frac{10^{10}}{R5} \quad (\text{Ohm})$$

Resistor R5 is mounted in solderless terminals so it can be changed easily whenever the DC gain of the error amplifier is to be changed. The AC gain is controlled by C1, R4 and T4. Maximum AC gain is obtained with T4 set fully CCW. Setting T4 fully CW removes AC gain and no lag in response occurs. R4 and C1 are mounted in soldering terminals and can be easily replaced in cases when T4 range is not enough to get optimum response (See 8.4 for details).

The output of the error amplifier is:

$$V_o = (V_3 \times G_{V3} + V_d \times G_d) \times \left[\frac{1 + S \times C1 \times R4}{1 + S \times C1 \times R4 (1 + R_f \times K / R4)} \right]$$

V_3 - Input signal at input 1.

G_{V3} - Gain of differential input.

V_d - Input signal at the differential inputs (R-4a,6a,M-J2/3,2)

G_d - Gain of differential input.

K = Position factor of the wiper of T4.

Full CCW = 1

Full CW = 0.01

4.3 Velocity feedback sensors

There are three (optional) boards that are installed on top of the NBA for processing velocity sensors other than brush tacho:

E (Optical Encoder/Hall Sensors):

The encoder interface gives a bi-directional velocity feedback for 4-Q speed control when using an optical encoder or Hall effect sensors.

- Encoder: Two channels with 90° phase shift are required.
- Hall sensors: the commutation sensors can be used for high speed applications.

B (Brushless Tacho) and T (Tachsyn):

- Three phase brushless tacho (30° and 60° Hall effect can be selected).
- Tachsyn: the logic board provides the oscillator for the Tachsyn.

R (Resolver):

- Resolver: A flexible oscillator for various types of resolvers is provided.

For the above mentions "brushless" sensors, the velocity output of the velocity processor is internally connected to terminal R-18e,M-J2/6 that serves also as velocity monitor.

A filtering capacitor, C15, is placed in parallel to R4 to minimize noise carried on the input signals. This is specially beneficial when employing motors where a significant degree of electromagnetic coupling is present between armature and Tachogenerator. Values in the range of 1000pF - 6800pF are recommended.

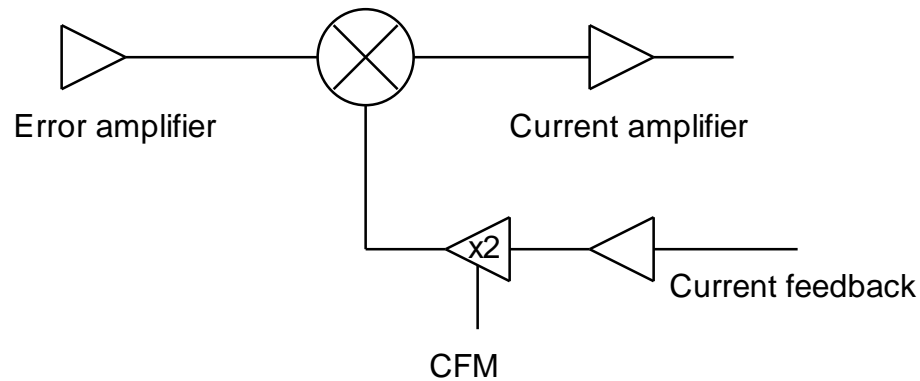
4.4 Current mode

In order to operate the servo amplifier as a current amplifier, the velocity loop should be disabled. This is done by converting the error amplifier into a low gain DC amplifier which has a flat response beyond the desired current bandwidth. In this mode, R5 and C1 have to be removed from the circuit.

Current mode operation with Resolver or Tachsyn options requires that the input resistor of the velocity signal will be removed.

4.5 Current feedback, Current feedback multiplier, Current loop

Three current feedbacks are obtained by measuring the voltage drop across current sensing resistors. These three signals are synthesized and multiplexed which result in a single voltage signal proportional to phases currents. It is then compared to the error amplifier output. The error is processed by the current amplifier to provide a voltage command to the PWM section. The actual motor current can be monitored by measuring the voltage at terminal R-2c,M-J2/4. The current monitor scale is given in 8.2.



Current loop control is obtained by op amp U1B (current amplifier) and R6, C2 which form a lag-lead network for current loop. The standard amplifier is equipped with R6 and C1 to get optimum current response for an average motor in this power range. These components are mounted in solderless terminals.

The amplifier is equipped with Current Feedback Multiplier (CFM). By turning DIP switch 4 to ON the signal of the current feedback is multiplied by 2 and consequently the following changes occur:

- Current gains are multiplied by 2.
- Current monitor is divided by 2.
- Current limits are divided by 2.
- Dynamic range is improved.
- Commutation ripple is reduced.

This function should be activated whenever the rated current AND the peak current of the motor are less than 20% of the amplifier rated continuous and peak limits respectively.

Sometimes, oscillations may occur in the current loop due to the fact that the feedback gain was multiplied. This can be resolved by substituting R6 with a lower value.

4.6 Current limits

The servo amplifier can operate in the following voltage-current plane:

-Ip	-Ic	+V	Ip
Intermittent zone	Continuous zone	Ic	-V

Ic - Continuous current Ip - Peak current

Fig. 4.1: Voltage-Current plane

Each amplifier is factory calibrated to have this shape of voltage-current operating area with rated values of continuous and peak current limits. In addition the peak current limit is time dependent as explained in 4.6.1.

4.6.1 Time dependent peak current limit

The peak current is so designed that its duration is a function of the peak amplitude and the motor operating current. The maximum peak current is available for 2.2 second. The duration of Ip is given by:

$$T_p = 3.17 \ln \frac{I_p - I_{op}}{I_p - I_c}$$

Ic - Amplifier continuous current rating.

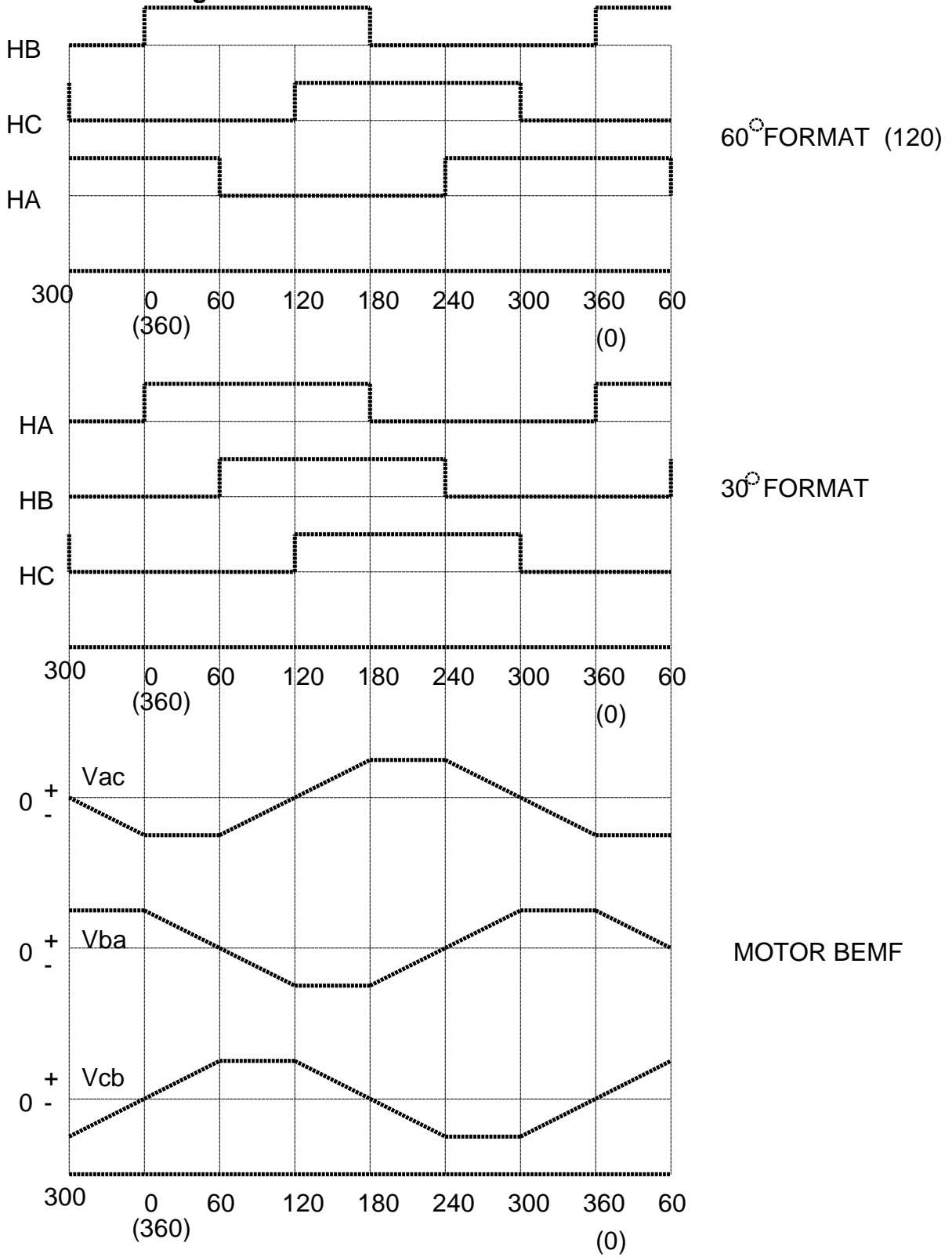
Ip - Peak demanded (not amplifier Ip)

Iop - Actual operating current before the peak demand.

Example: A motor is driven by an NBAF-10/200 amplifier at constant speed and constant current of 5A. What is the maximum possible duration of a 20A peak ?

$$T_p = 3.17 \ln \frac{20 - 5}{20 - 10} = 1.28 \text{ seconds}$$

4.7 Commutation signals format



4.8 Protective functions

All the protective functions activate internal inhibit. There are two modes of resetting the amplifier after the cause of the inhibit disappears: Auto Restart and Latch. Self Restart (DS5-OFF): The amplifier is inhibited only for the period that the inhibit cause is present. Latch (DS5-ON): All failures latch the Inhibit and the In LED. For restart (after clearing the failure source), reset has to be performed either by turning DS5 to "OFF" or by applying logic 0 at the inhibit input (terminals R-18a,20a,M-J2/8,9).

4.8.1 Short circuit protection

The short circuit protection uses the capability of the power MOSFET to tolerate high energy peaks for short periods of time. This protection is realized by sensing current in the DC line. Every current peak above a certain value will inhibit the amplifier for a period of approx. 30mS. If a short circuit condition still exists, the cycle will repeat endlessly. The amplifier is protected against shorts between outputs and output to ground.

4.8.2 Under/over voltage protection

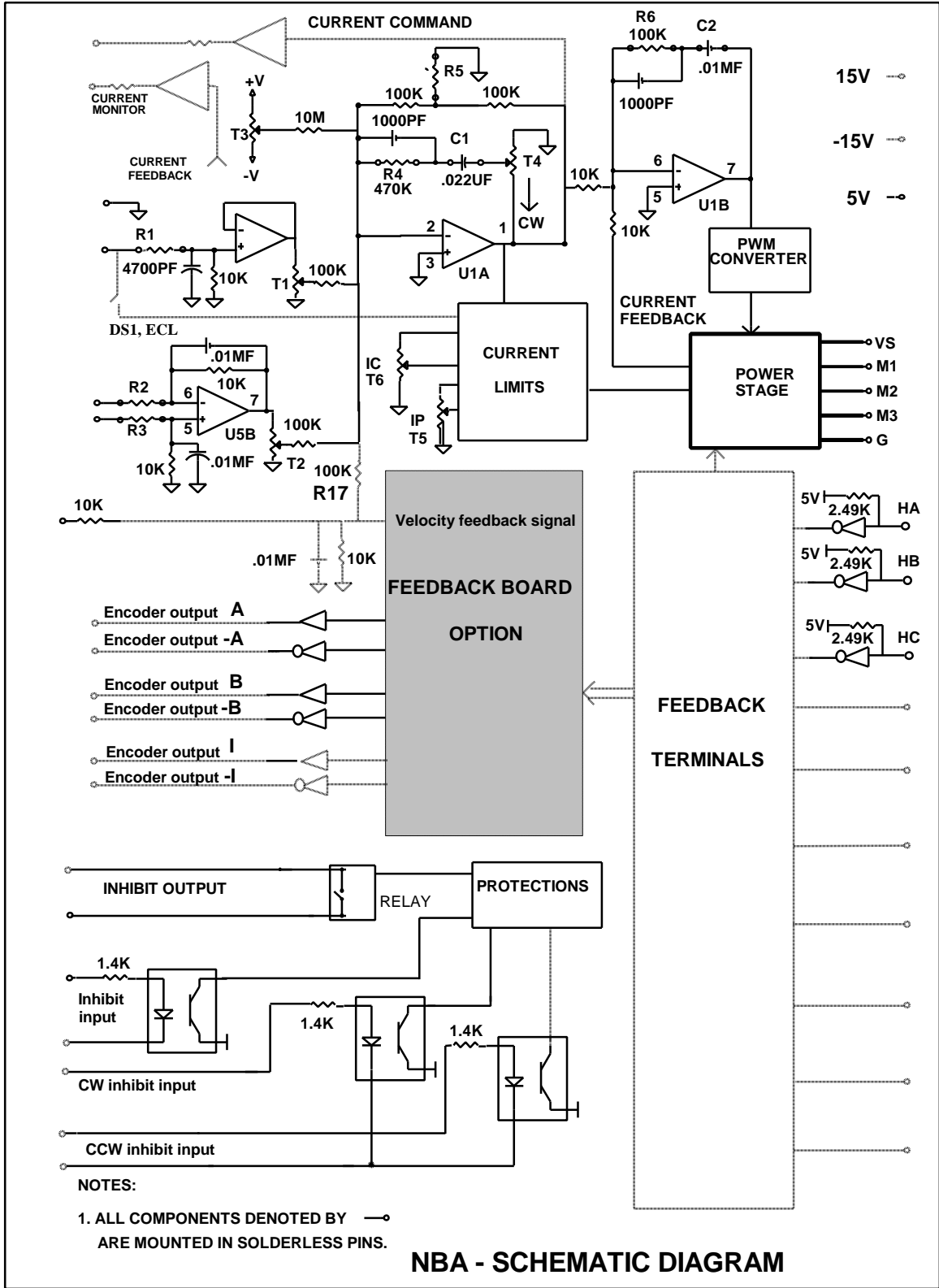
Whenever the DC bus voltage is under or over the limits indicated in the technical specifications, the amplifier will be inhibited.

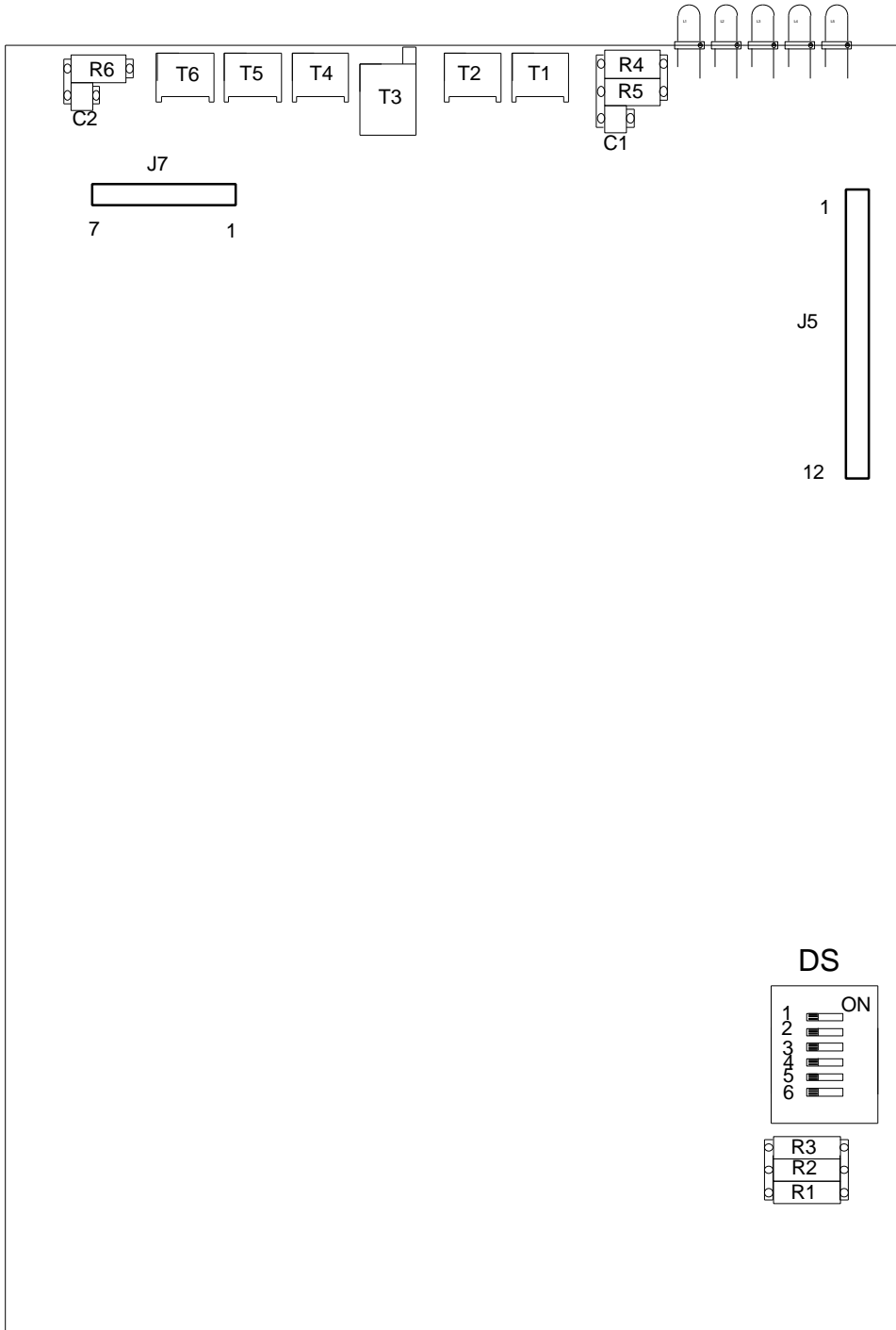
4.8.3 Temperature protection

Temperature sensor is mounted on the heatsink. If, for any reason, the temperature exceeds 85°C the amplifier will be inhibited. The amplifier will restart when the temperature drops below 80 °C.

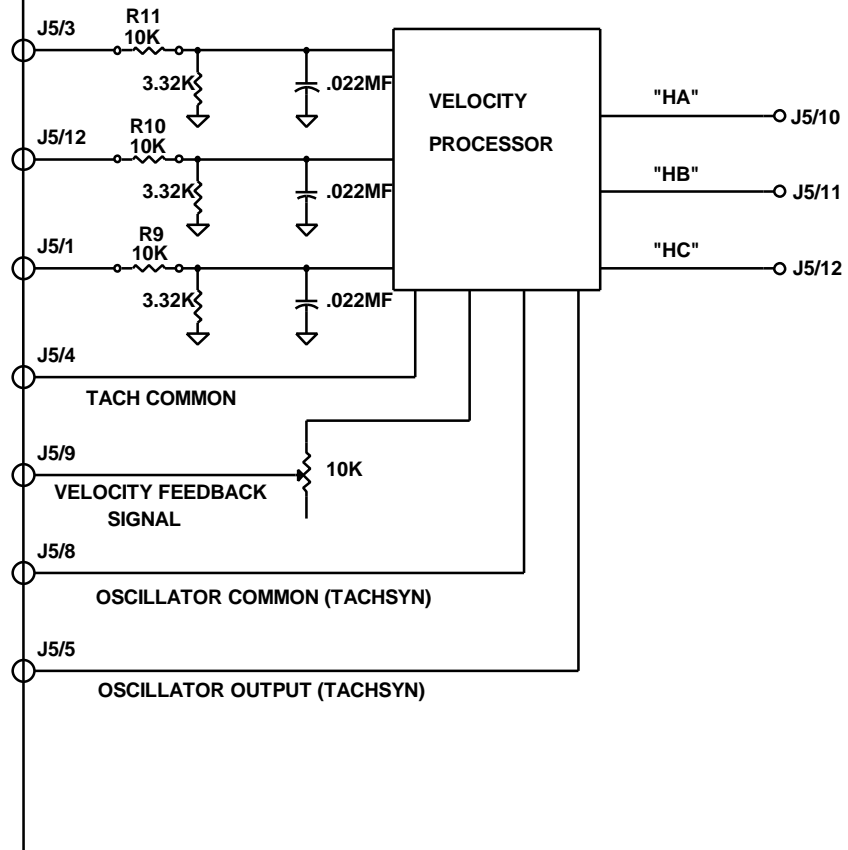
4.8.4 Loss of commutation feedback

Lack of either of the commutation signals will inhibit the amplifier.

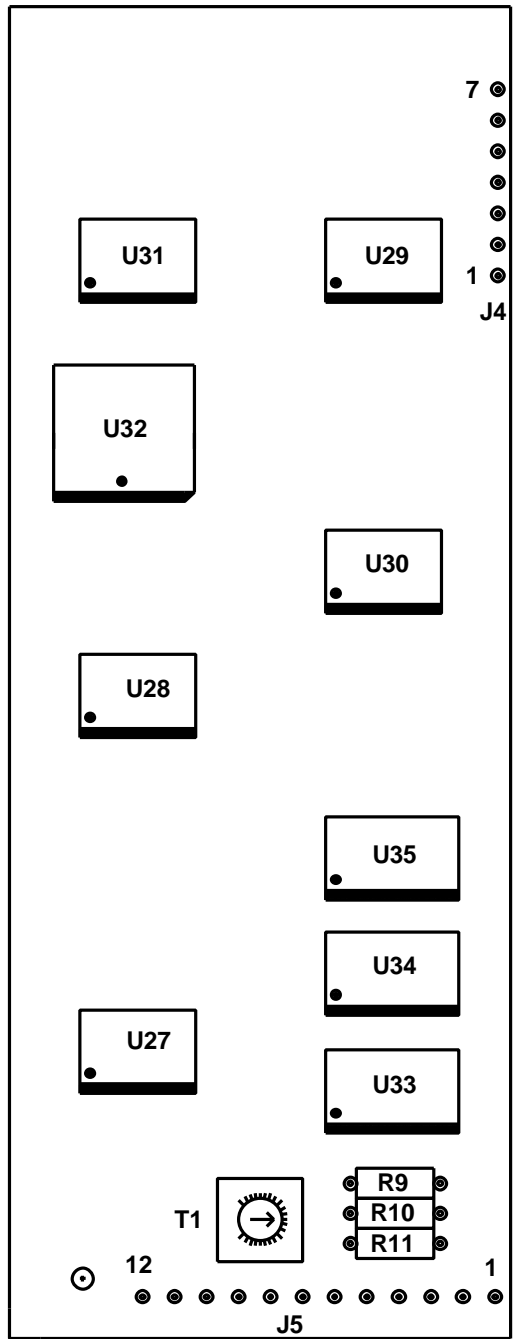




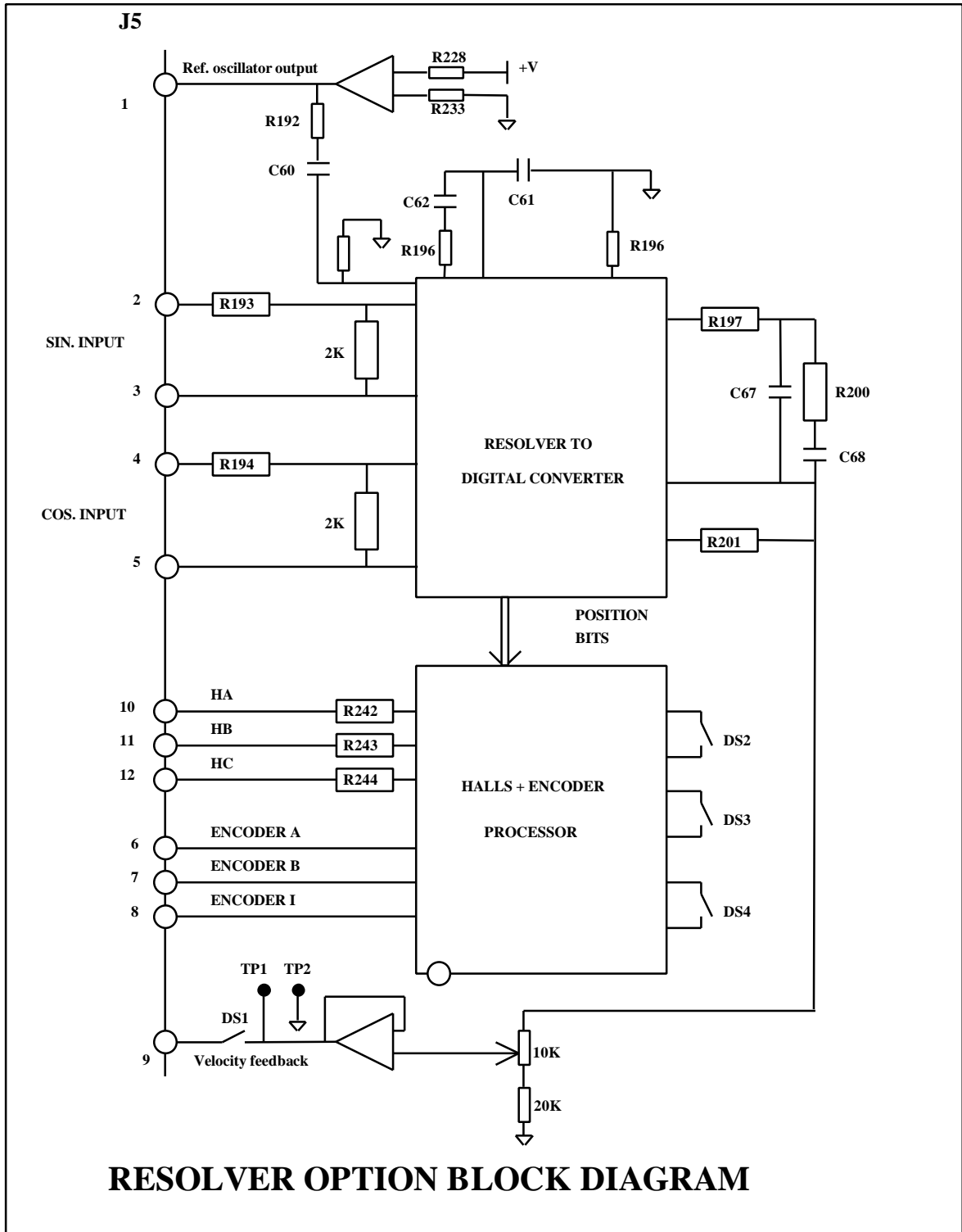
BRUSHLESS TACH., TACHSYN OPTION

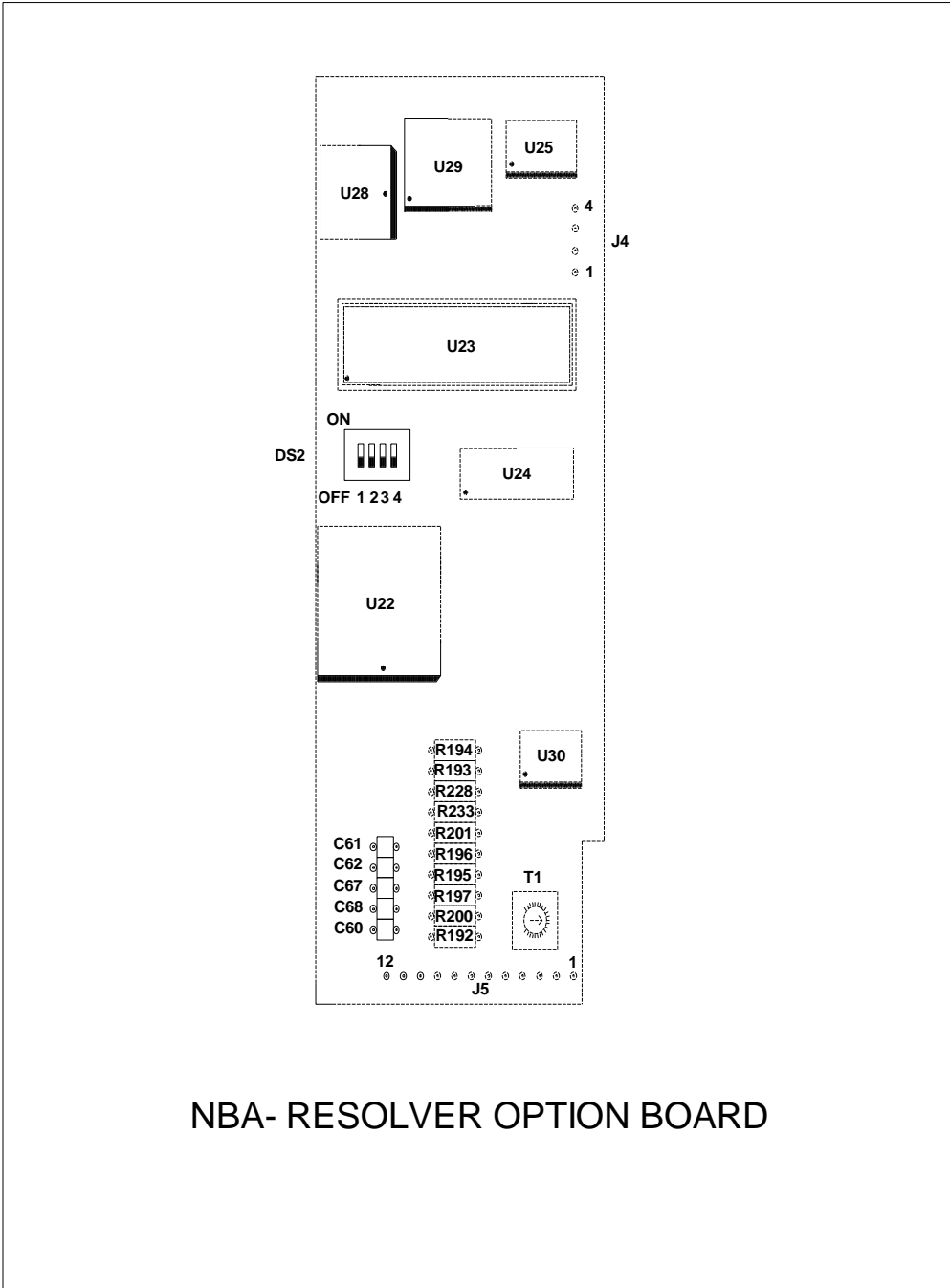


J5 - CONNECTOR BETWEEN CONTROL BOARD AND OPTION BOARD (INTERNAL CONNECTOR)

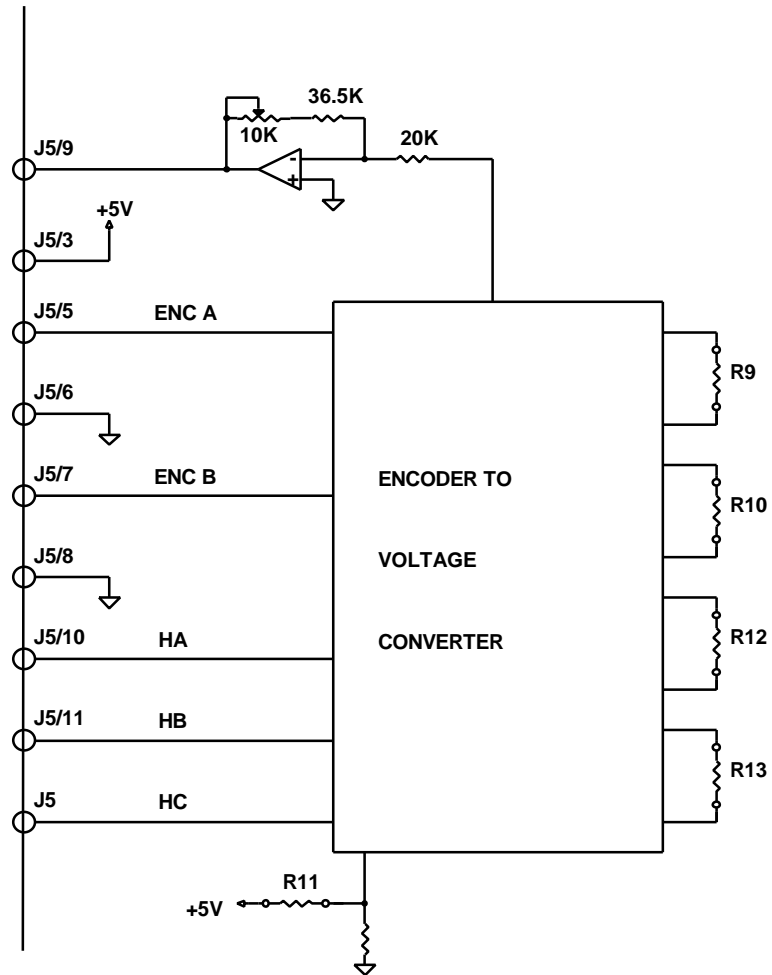


NBA- BRUSHLESS TACHO AND TACHSYN OPTION BOARD



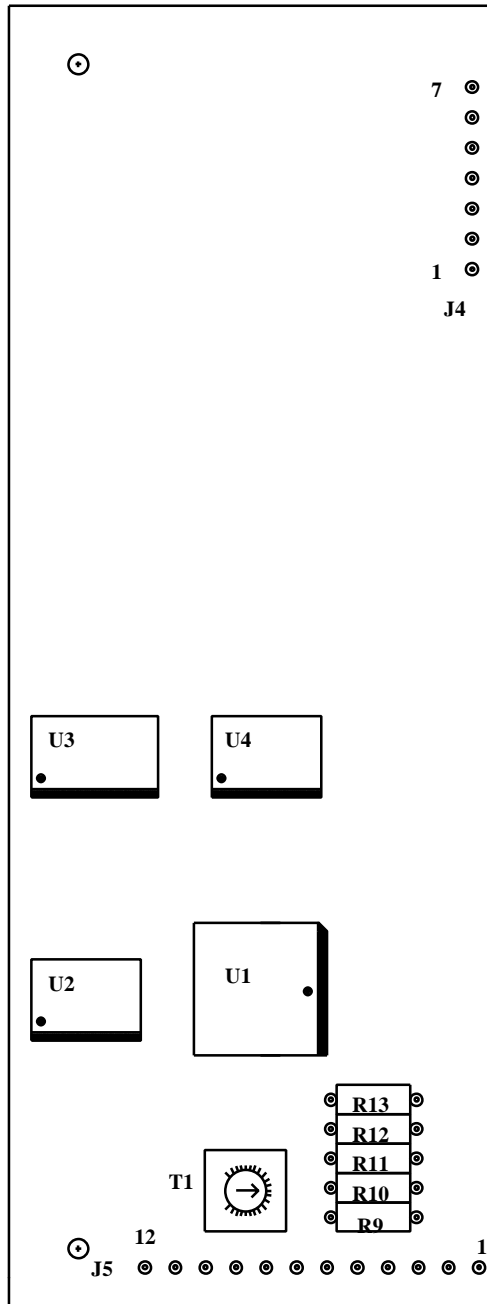


NBA- RESOLVER OPTION BOARD



J5 - CONNECTOR BETWEEN CONTROL BOARD AND OPTION BOARD (INTERNAL CONNECTOR)

NBA- ENCODER OPTION BLOCK DIAGRAM



NBA- ENCODER OPTION

5. Terminal Description

5.1 Terminals for Rack mounting

Terminal	Function	Remark
2a	Input 1./ECL	For more details see 4.1 and 8.2.
2c	Current monitor.	For more details see 4.5.
2e	Current command monitor.	This output can be used to adjust the current limits of a motor without loading or measuring the actual motor current. For more details see 8.2.
4a	Input 2(+).	Positive input of differential amplifier. For more details see 4.1.
4c	Circuit common	
4e	+15V	100ma external load.
6a	Input 2(-)	Negative input of a differential amplifier. For more details see 4.1.
6c	+5V	200ma external load.
6e	-15V	100ma external load.
8a	Hall sensor C	*
8c	Hall sensor B	*
8e	Hall sensor A	*
18a	Inhibit input(+)	Positive input to an optocoupler. The std value of 1.4k/ 0.6W is suitable for operating range of 5- 30 Vdc. Current consumption from source is: = $(V_{inh.} - 1.5)/1.4$ (ma)
18c	CW inhibit(+)	Positive input to an optocoupler. The std value of 1.4k/ 0.6W is suitable for operating range of 5- 30 Vdc. Current consumption from source is:

* $-1V \leq V_{il} < 1V$; $2V \leq V_{ih} < 30V$

Source sink capability - 2mA

		$= (\text{Vinh.} - 1.5) / 1.4 \text{ (ma)}$
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Cont.

Terminal	Function	Remark
18e	Velocity monitor	
20a	Inhibit input(-)	
20c	CCW inhibit(+)	Positive input to an optocoupler. The std value of 1.4k/0.6W is suitable for operating range of 5- 30 Vdc. Current consumption from source is: = (Vinh.- 1.5)/1.4 (ma)
20e	CW, CCW (-)	Negative input to optocouplers of CW and CCW.
22a	+24V for fan	240mA maximum output current. The fan common connect to power common.
22c,e	Inhibit output	Potential free relay contact relay. The contact is open whenever the amplifier is disabled.
24a,c,e	+Vs,power input positive	All three terminals must be shorted.
26a,c,e	Motor phase C	All three terminals must be shorted.
28a,c,e	Motor phase B	All three terminals must be shorted.
30a,c,e	Motor phase A	All three terminals must be shorted.
32a,c,e	Power input common.	All three terminals must be shorted.

Additional terminals for B versions (brushless tacho).

Terminal	Function	Remark
10a	Phase 1 - brushless tacho	
10c	Phase 2 - brushless tacho	
10e	Phase 3 - brushless tacho	
12e	Brushless tacho common	

Additional terminals for T version (Tachsyn).

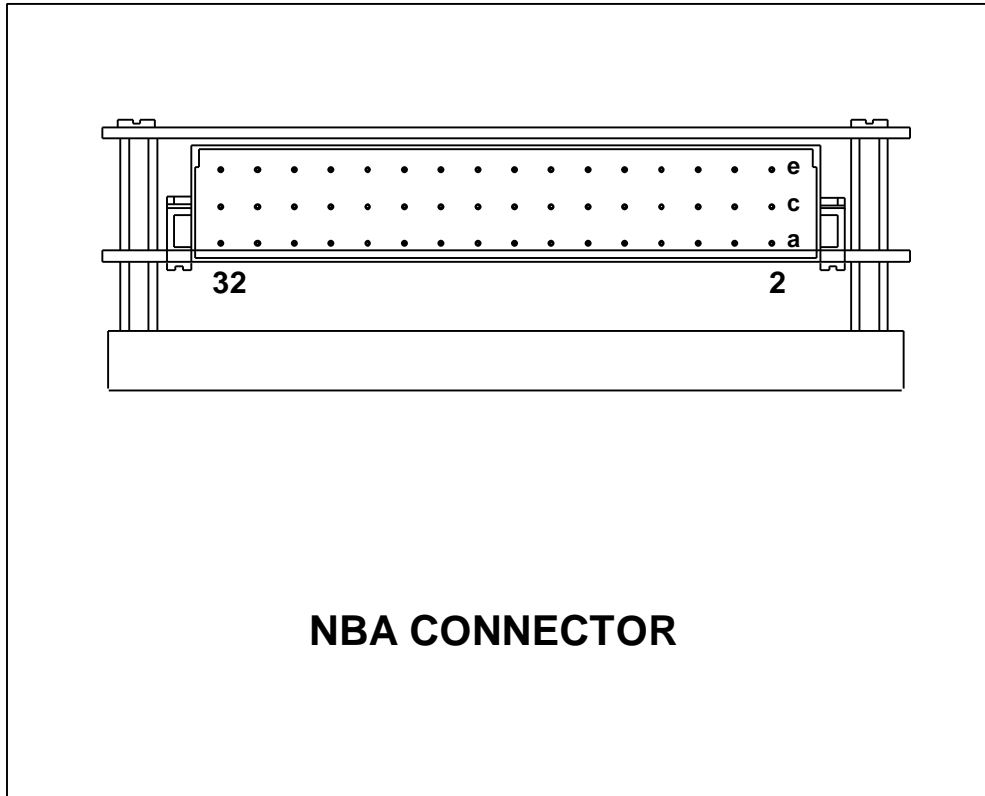
Terminal	Function	Remark
10a	Phase 1 - Tachsyn	
10c	Phase 2 - Tachsyn	
10e	Phase 3 - Tachsyn	
12c	Reference oscillator output	

Additional terminals for R version (resolver).

Terminal	Function	Remark
10a	Reference oscillator output	
10c	Sine signal input	
10e	sine input common	
12a	N/A	
12c	Cosine signal common	
12e	Cosine signal input	
14a	Channel A output	
14c	Channel B output	
14e	Index output	
16a	Channel -A output	
16c	Channel -B output	
16e	-INDEX output	

Additional terminals for E version (optical encoder).

Terminal	Function	Remark
10e	+5V for the encoder only	200ma external load. The accumulative external load should not exceed 200mA.
12a	Channel A input	
12c	Channel B input	
12e	Common of the +5V encoder supply	



5.2 Mother Boards terminals

J1 Power connector

1	Power input common.	
2	Motor phase A	
3	Motor phase B	
4	Motor phase C	
5	+Vs, power input positive	

J2 control connector (D type).

Terminal	Function	Remarks
1	Input 1/ECL.	For more details see 4.1 and 8.2.
2	Input 2(-)	Negative input of a differential amplifier. For more details see 4.1.
3	Input 2(+).	Positive input of differential amplifier. For more details see 4.1.
4	Current monitor.	For more details see 4.5.
5	Current command monitor	This output can be used to adjust the current limits of a motor without loading or measuring the actual motor current. For more details see 8.2.
6	Velocity monitor.	For more details see
7	Not connected	
8	Inhibit input(+)	Positive input to an optocoupler(anode), the std value of 1.4k/ 0.6W is suitable for operating range of 5- 30 Vdc. Current consumption from source is: = $(V_{inh.} - 1.5)/1.4$ (ma).
9	Inhibit input(-)	Negative input (cathode) to an optocoupler, see terminal 8.
10	CW inhibit(+)	Positive input to an optocoupler (anode), the std value of 1.4k/ 0.6W is suitable for operating range of 5- 30 Vdc. Current consumption from source is: = $(V_{inh.} - 1.5)/1.4$ (ma)

11	CW/ CCW inhibit common	cathodes of optocouplers.
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J2 - Cont.

Terminal	Function	Remark
12	CCW inhibit(+)	Positive input to an optocoupler (anode), the std value of 1.4k/0.6W is suitable for operating range of 5- 30 Vdc. Current consumption from source is: = (Vinh.- 1.5)/1.4 (ma)
13	Encoder A output	Buffered channel A output, +20mA max.
14	Encoder -A output	Buffered channel -A output, +20mA max.
15	Encoder B output	Buffered channel B output, +20mA max.
16	Encoder -B output	Buffered channel -B output, +20mA max.
17	Encoder I output	Buffered channel I output, +20mA max.
18	Encoder -I output	Buffered channel -I output, +20mA max.
19, 37	Inhibit output	Free contact relay, the contact is open whenever the amplifier is disabled.
20	+15V	100ma external load. The accumulative external load should not exceed 100mA
21	-15V	100ma external load. The accumulative external load should not exceed 100mA
22	+5V	200ma external load. The accumulative external load should not exceed 200mA
23	Circuut common	
24	Circuut common	
25	Circuut common	
26	Circuut common	
27	+15V	100ma external load. The accumulative external load should not exceed 100mA.
28	+15V	100ma external load. The accumulative external load should not exceed 100mA.
29	+5V	200ma external load. The accumulative external load should not exceed 200mA.
30	-15V	100ma external load. The accumulative external load should not exceed 100mA.

J2 - Cont.

Terminal	Function	Remark
31	Circuit common	
32	Circuit common	
33	Circuit common	
34	Circuit common	
35	+24V for fan	240ma max output current. The fan common connect to power common.
36	Not connected	
37, 19	Inhibit output	Free contact relay, the contact is open whenever the amplifier is disabled.

J3 BRUSHLESS TACH. (D TYPE)

Terminal	Function	Remark
1	TACH PHASE 2	
2	TACH COMMON	
3	TACH PHASE 1	
4	N/A	
5	+5V	200ma external load. The accumulative external load should not exceed 200mA.
6	CIRCUIT COMMON	
7	HALL A INPUT	*
8	HALL C INPUT	*
9	TACH PHASE 3	*
10	N/A	
11	N/A	
12	CIRCUIT COMMON	
13	+15V	100ma external load. The accumulative external load should not exceed 100mA.
14	-15V	100ma external load. The accumulative external load should not exceed 100mA.
15	HALL B INPUT	

* $-1V \leq V_{il} < 1V$; $2V \leq V_{ih} < 30V$

Source sink capability - 2mA

J3 TACHSYN. (D TYPE)

Terminal	Function	Remark
1	TACHSYN PHASE 2	
2	N/A	
3	TACHSYN PHASE 1	
4	N/A	
5	+5V	200ma external load. The accumulative external load should not exceed 200mA.
6	CIRCUIT COMMON	
7	N/A	
8	N/A	
9	TACHSYN PHASE 3	
10	OSCILLATOR REFERENCE OUTPUT	
11	OSCILLATOR COMMON	
12	CIRCUIT COMMON	
13	+15V	100ma external load. The accumulative external load should not exceed 100mA.
14	-15V	100ma external load. The accumulative external load should not exceed 100mA.
15	N/A	

J3 RESOLVER OPTION (D TYPE)

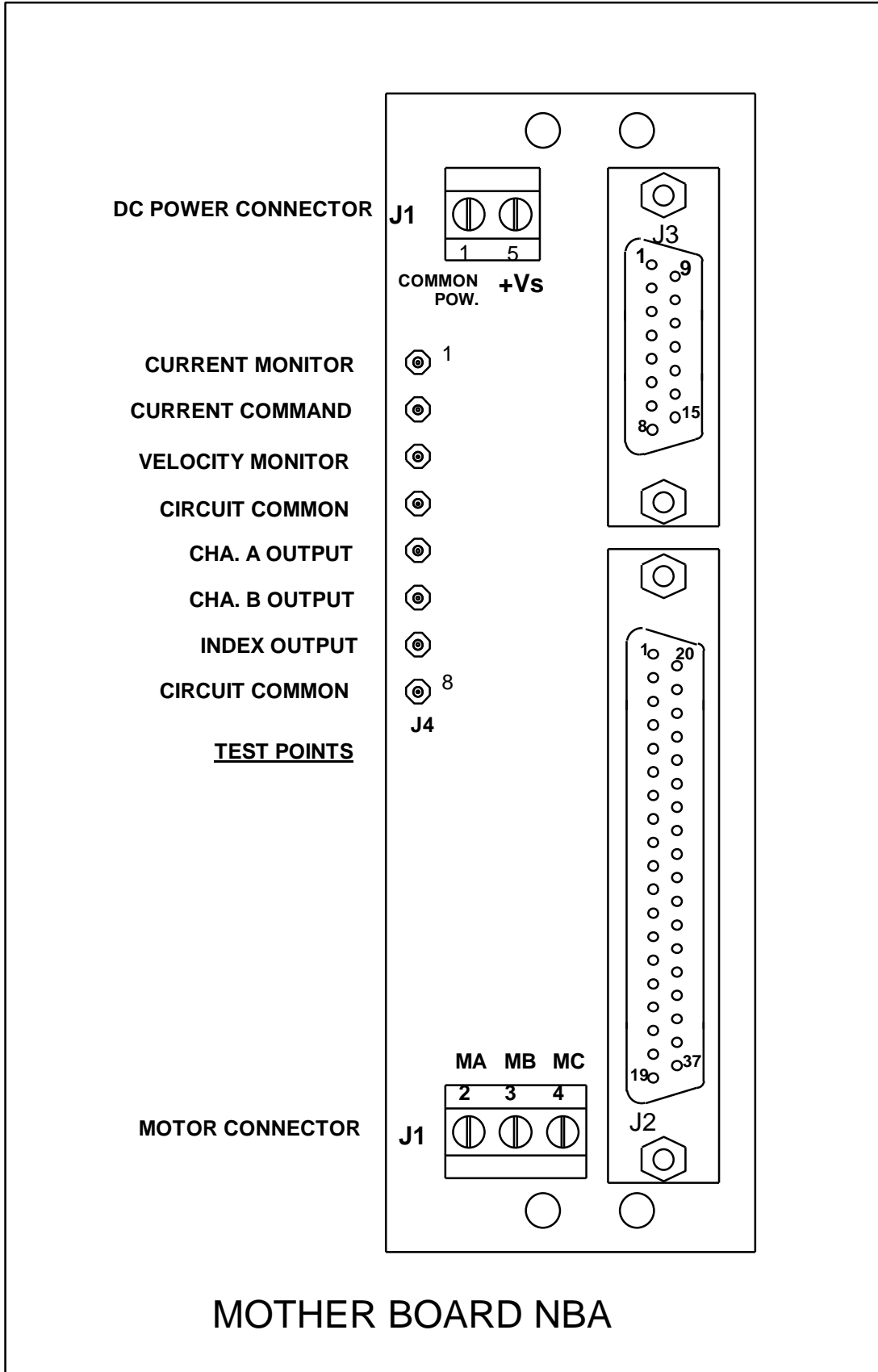
Terminal	Function	Remark
1	SIN IN	
2	COS IN	
3	REFERENCE OSC. OUTPUT	
4	N/A	
5	+5V	200ma external load. The accumulative external load should not exceed 200mA.
6	CIRCUIT COMMON	
7	N/A	
8	N/A	
9	SIN IN COMMON	
10	COS IN COMMON	
11	REF. OSC. COMMON	

J3 RESOLVER (D TYPE) - Cont.

Terminal	Function	Remark
12	CIRCUIT COMMON	
13	+15V	100ma external load. The accumulative external load should not exceed 100mA.
14	-15V	100ma external load. The accumulative external load should not exceed 100mA.
15	N/A	

J3 ENCODER (D TYPE)

Terminal	Function	Remark
1	N/A	
2	COMMON OF THE +5V ENCODER SUPPLY	
3	N/A	
4	CHANNEL A INPUT	
5	+5V	200ma external load. The accumulative external load should not exceed 200mA.
6	CIRCUIT COMMON	
7	HALL A INPUT	
8	HALL C INPUT	
9	+5V ENCODER SUPPLY ONLY	200ma external load. The accumulative external load should not exceed 200mA.
10	CHANNEL B INPUT	
11	N/A	
12	CIRCUIT COMMON	
13	+15V	100ma external load. The accumulative external load should not exceed 100mA.
14	-15V	100ma external load. The accumulative external load should not exceed 100mA.
15	HALL B INPUT	



6. Installation procedures

6.1 Mounting

The NBA series dissipates its heat by natural convection up to loads of 1200W. For higher output load the amplifier should be cooled by fan.

6.2 Wiring

Proper wiring, grounding and shielding techniques are important in obtaining proper servo operation and performance. Incorrect wiring, grounding or shielding can cause erratic servo performance or even a complete lack of operation.

- a) Keep motor wires as far as possible from the signal level wiring (feedback signals, control signals, etc.).
- b) If additional inductors (chokes) are required, keep the wires between the amplifier and the chokes as short as possible.
- c) Minimize lead lengths as much as is practical. Although the amplifier is protected against long (inductive) supply wires it is recommended to keep the leads as short as possible.
- d) Use twisted and shielded wires for connecting all signals (command and feedback). Avoid running these leads in close proximity to power leads or other sources of EMI noise.
- e) Use a 4 wires twisted and shielded cable for the motor connection.
- f) Shield must be connected at one end only to avoid ground loops.
- g) All grounded components should be tied together at a single point (star connection). This point should then be tied with a single conductor to an earth ground point.
- h) After wiring is completed, carefully inspect all conditions to ensure tightness, good solder joints etc.

6.3 Load inductance

The total load inductance must be sufficient to keep the current ripple within the limits (10%-20% of rated current is recommended). The current ripple (I_r) can be calculated by using the following equation:

$$I_r = \frac{0.5 \times V_s}{f \times L} \quad (\text{A})$$

L - load inductance in mH.

V_s - Voltage of the DC supply in Volts.

f - Frequency in KHz.

If motor inductance does not exceed this value, 3 chokes should be added (to each motor phase) summing together the required inductance

$$L_{ch} = L - L_p$$

L_{ch} - Choke inductance

L_p - Total inductance between two phases (in Y connection it is the sum of two phases).

6.4 DC power supply

DC power supply can be at any voltage in the range defined within the technical specifications. It must have the capability to deliver power to the amplifier (including peak power), without significant voltage drops. **Any voltage below the minimum or above the maximum will disable the amplifier.**

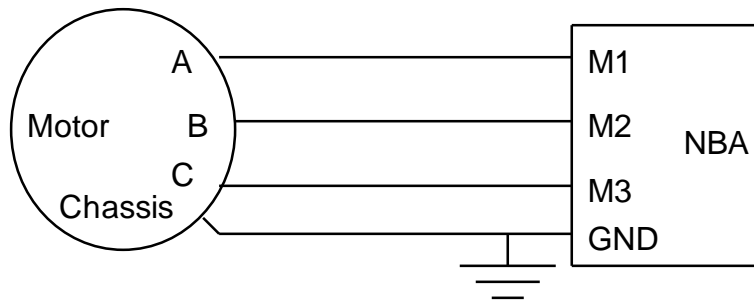
The recommended operating dc voltage is:

$$1.2 \cdot V_{dc}(\min) < V_{dc} < 0.9 \cdot V_{dc}(\max)$$

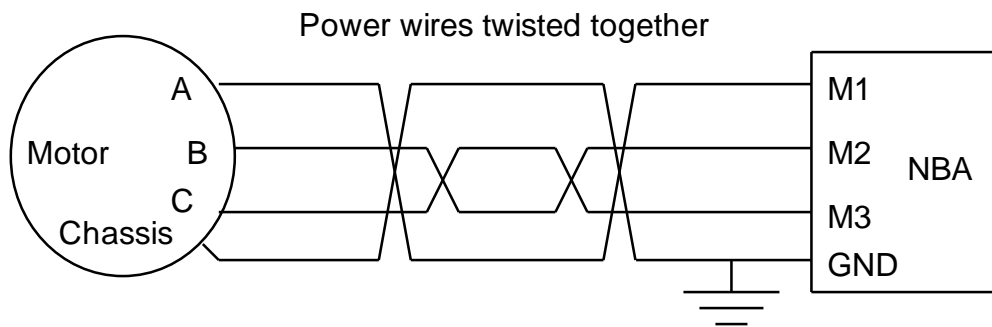
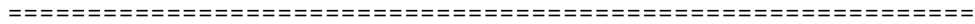
While driving high inertia loads, the power supply must be equipped with a shunt regulator, otherwise, the amplifier will be disabled whenever the capacitors are charged above the maximum voltage. See the following wiring diagrams for details.

6.5 Wiring diagrams

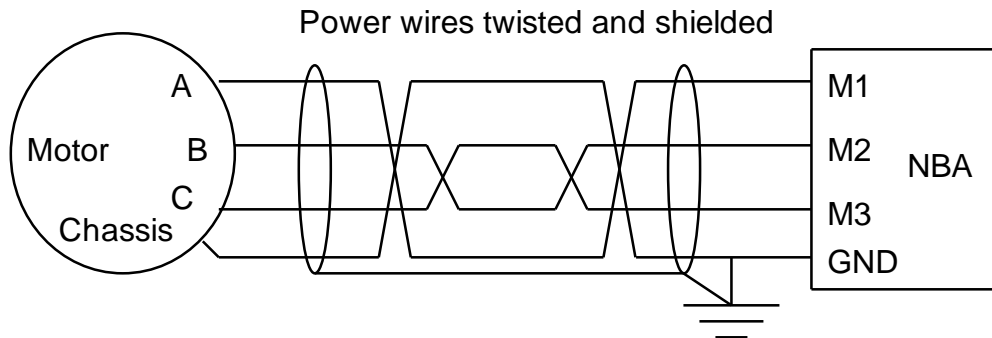
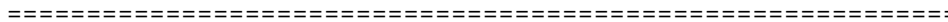
MOTOR WIRING



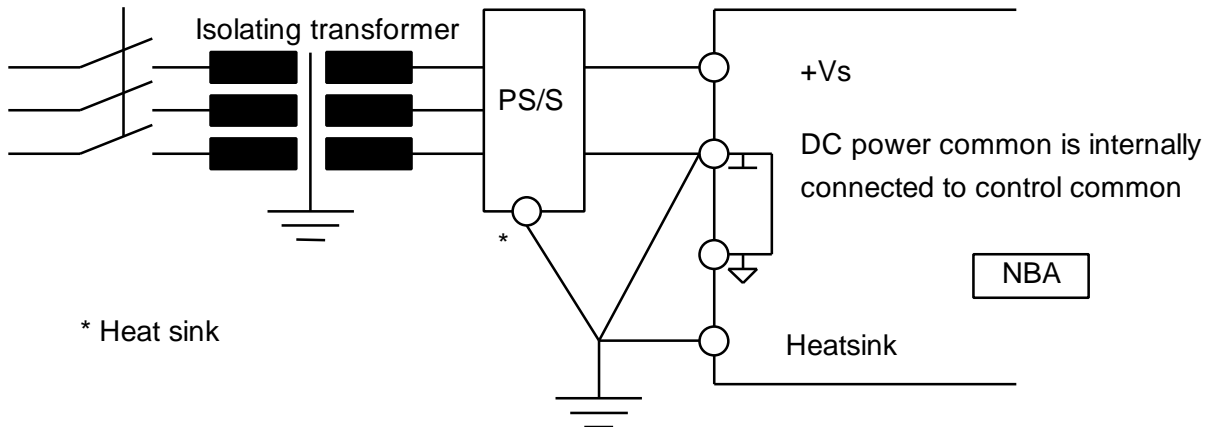
Minimum acceptance



Acceptable for most applications



Optimum wiring, minimum RFI



Guide lines for connecting a non isolated amplifier with an isolating power transformer

Ground:

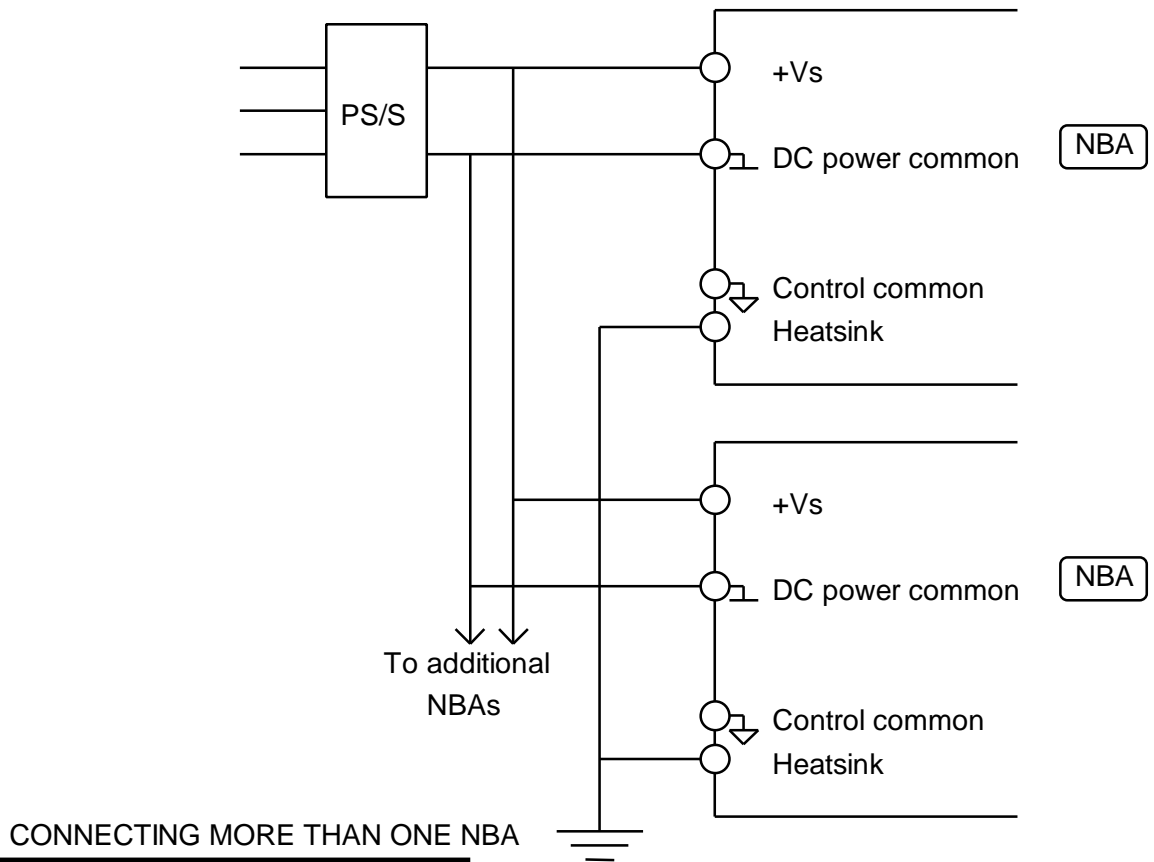
DC power common
 Motor chassis
 Amplifier's heat sink

Do not ground:

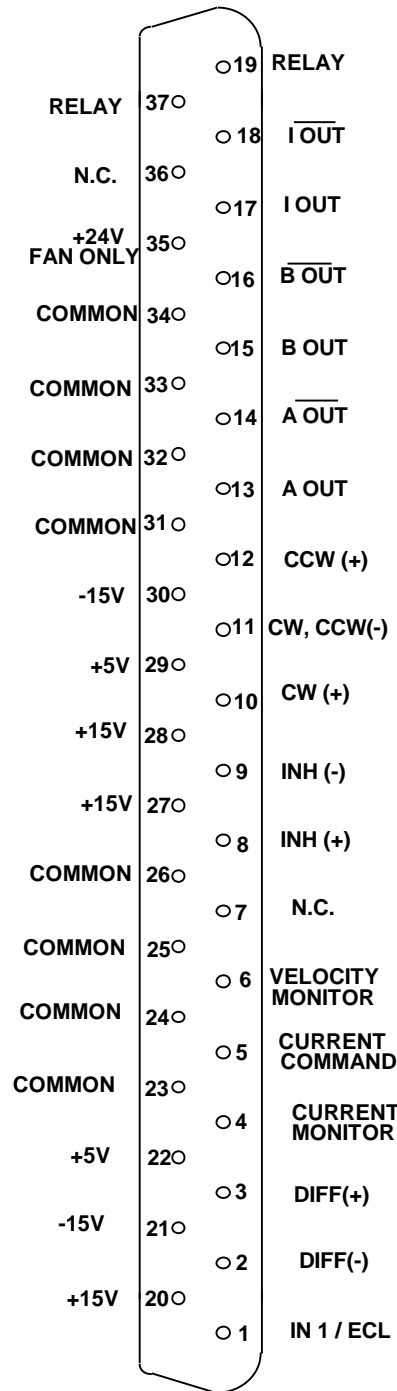
Control common - It is internally connected to the power common. Grounding the control common will create a ground loop.

Caution:

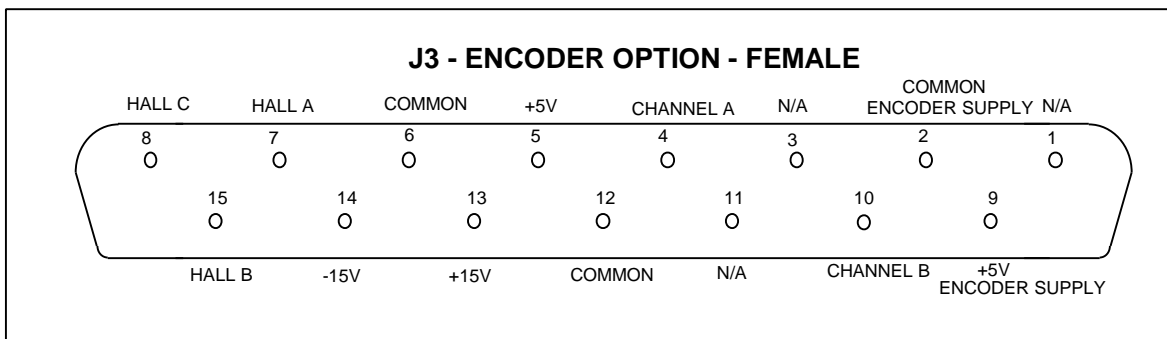
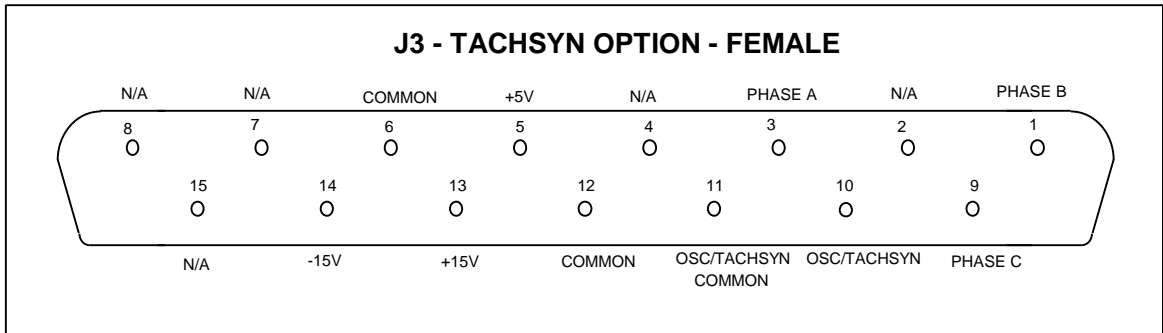
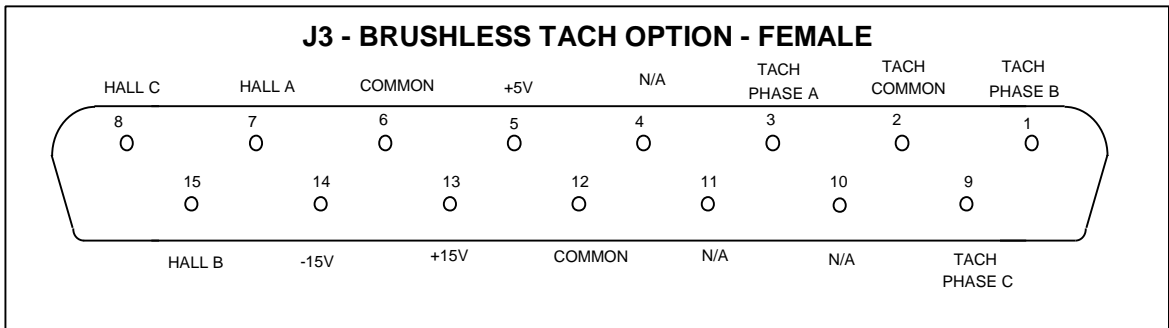
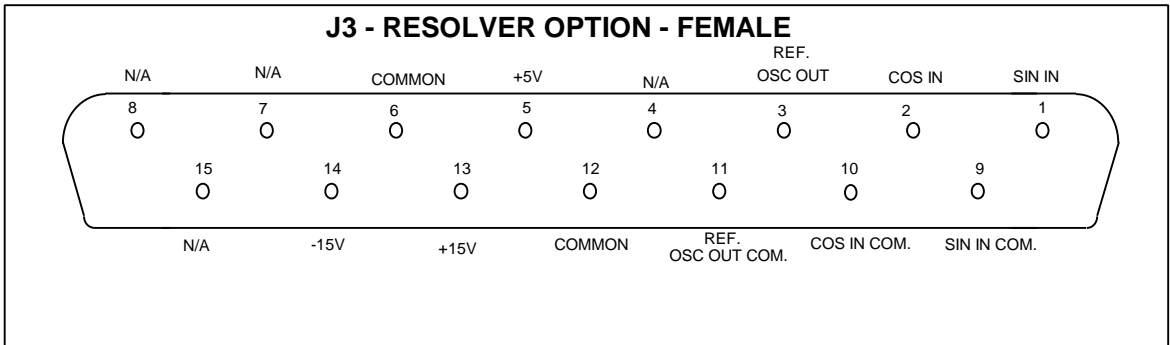
- If source of motor command is grounded, use amplifier's differential input.
 Otherwise, ground loop is created.

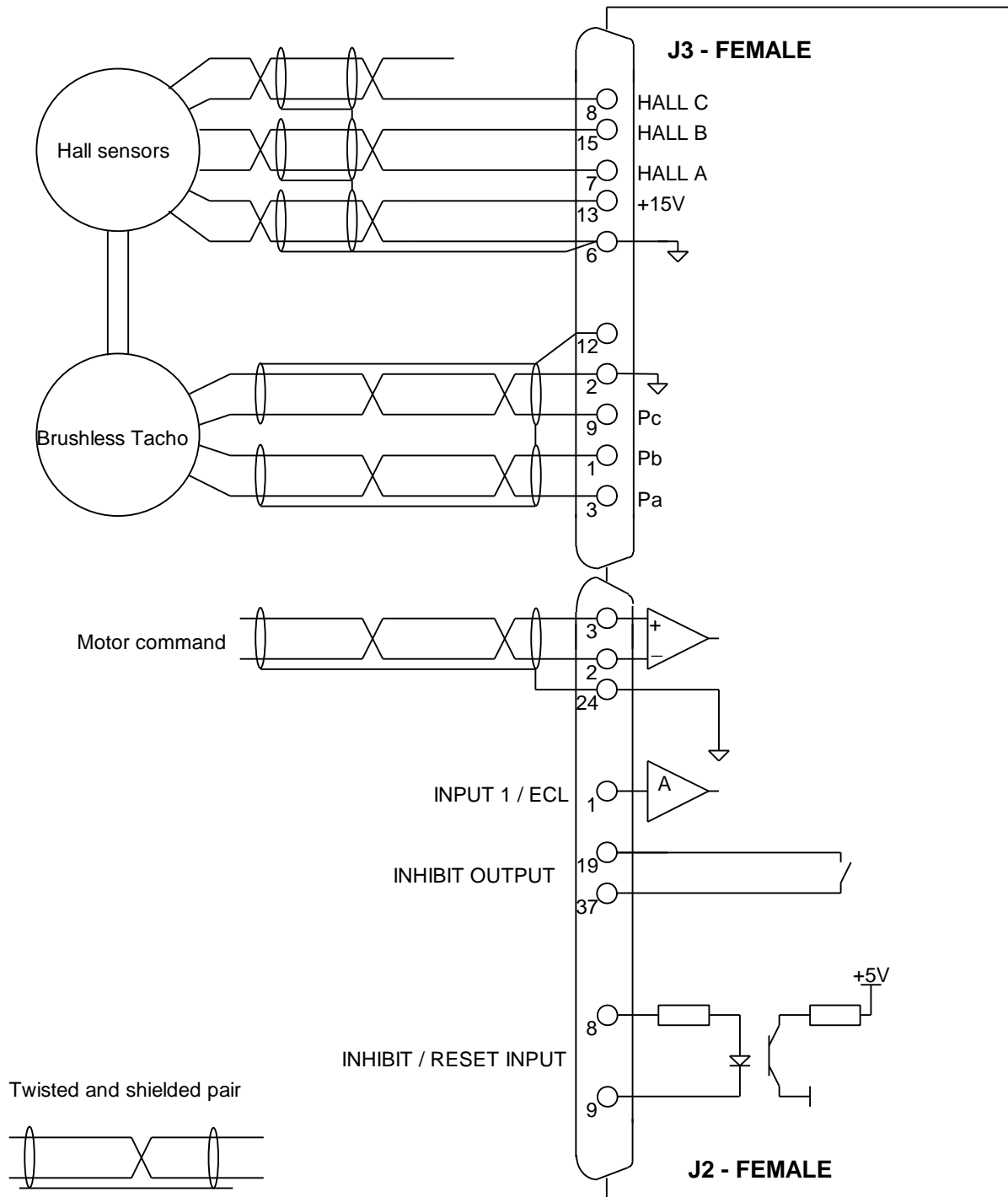


All rules about supply connections described in the previous page are also valid for multi-NBA connection.

J2 - FEMALE

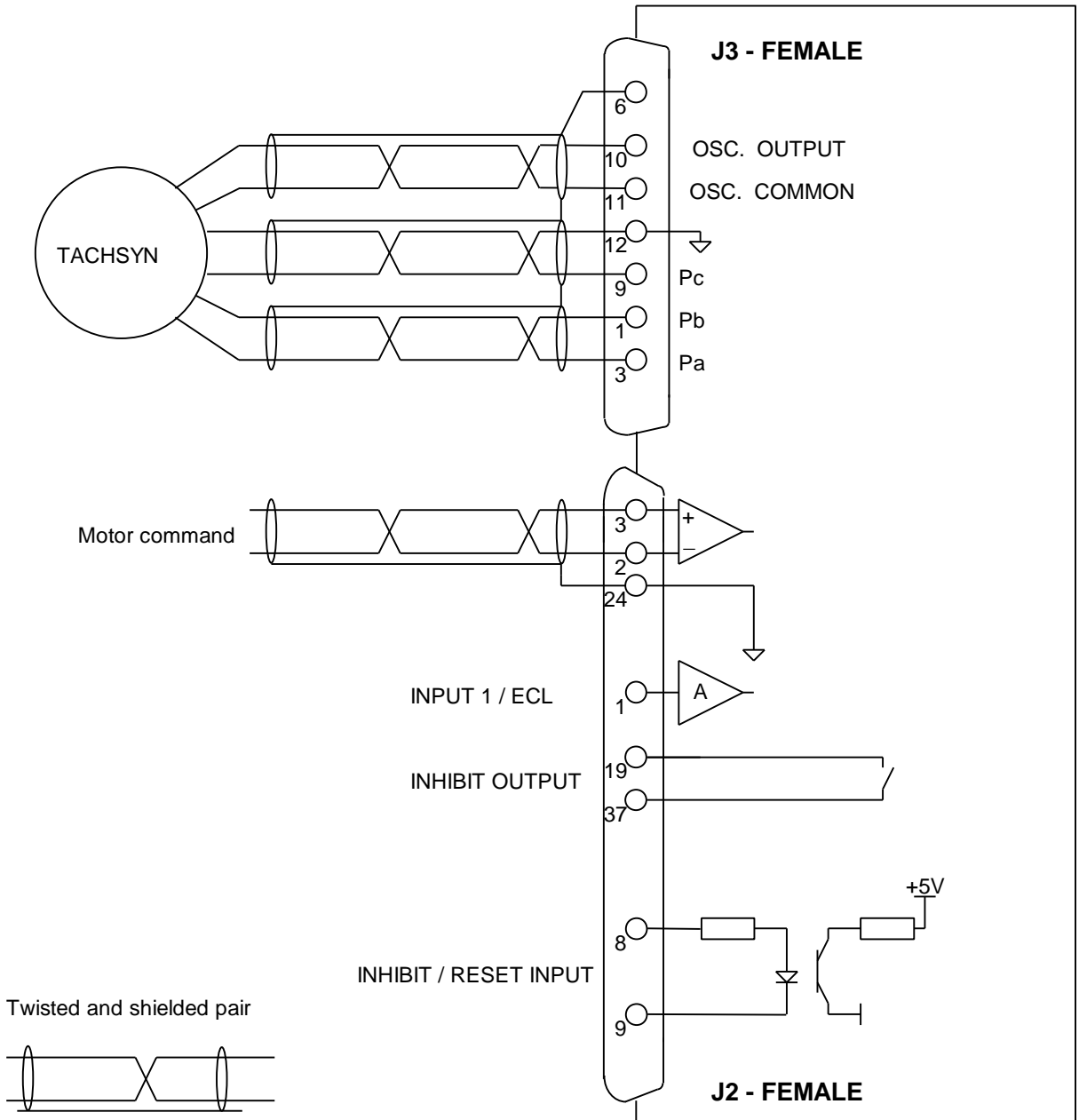
MOTHER BOARD NBA
J2, CONTROL CONNECTOR





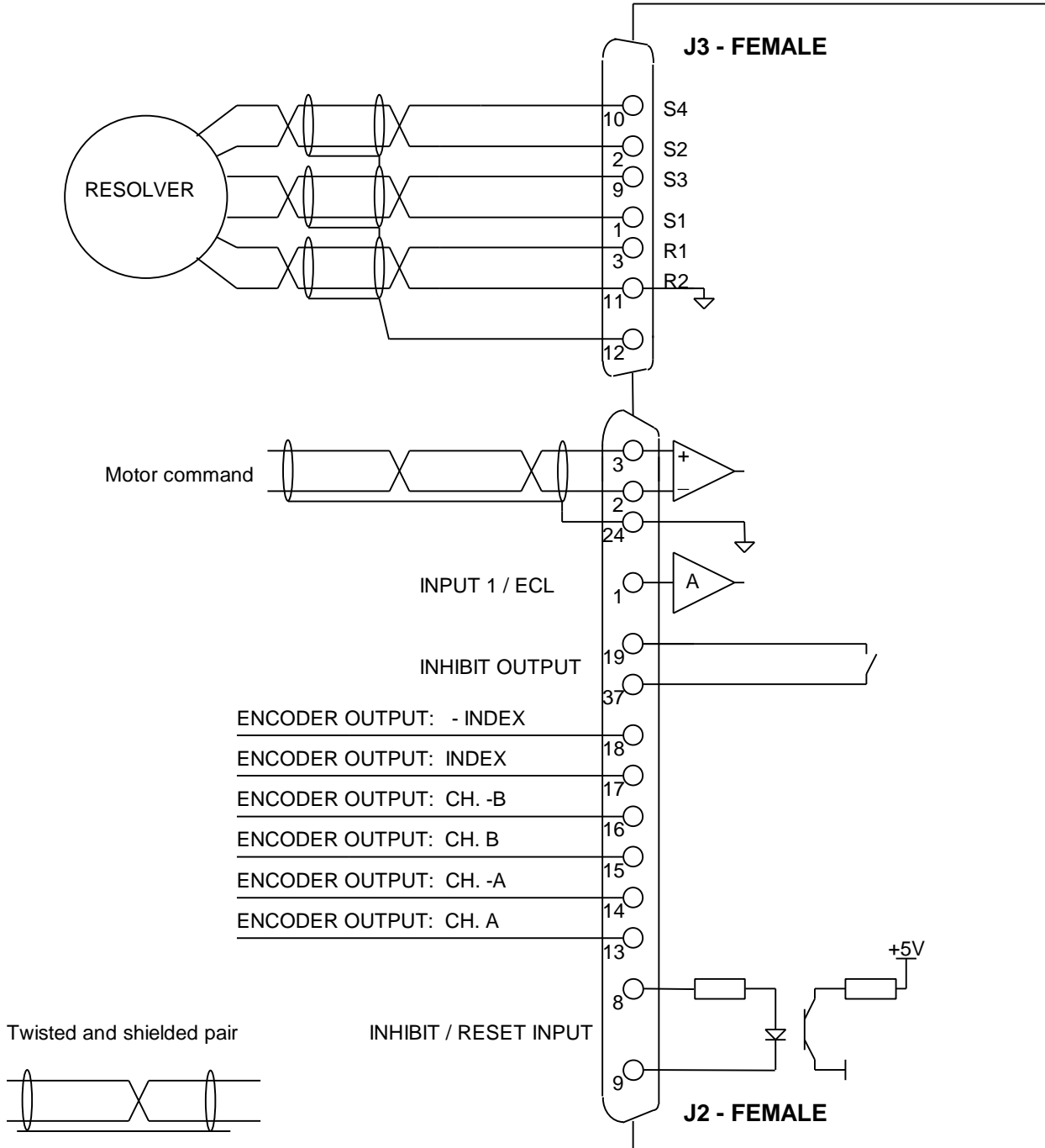
NBA CONTROL CONNECTION

BRUSHLESS TACH VERSION



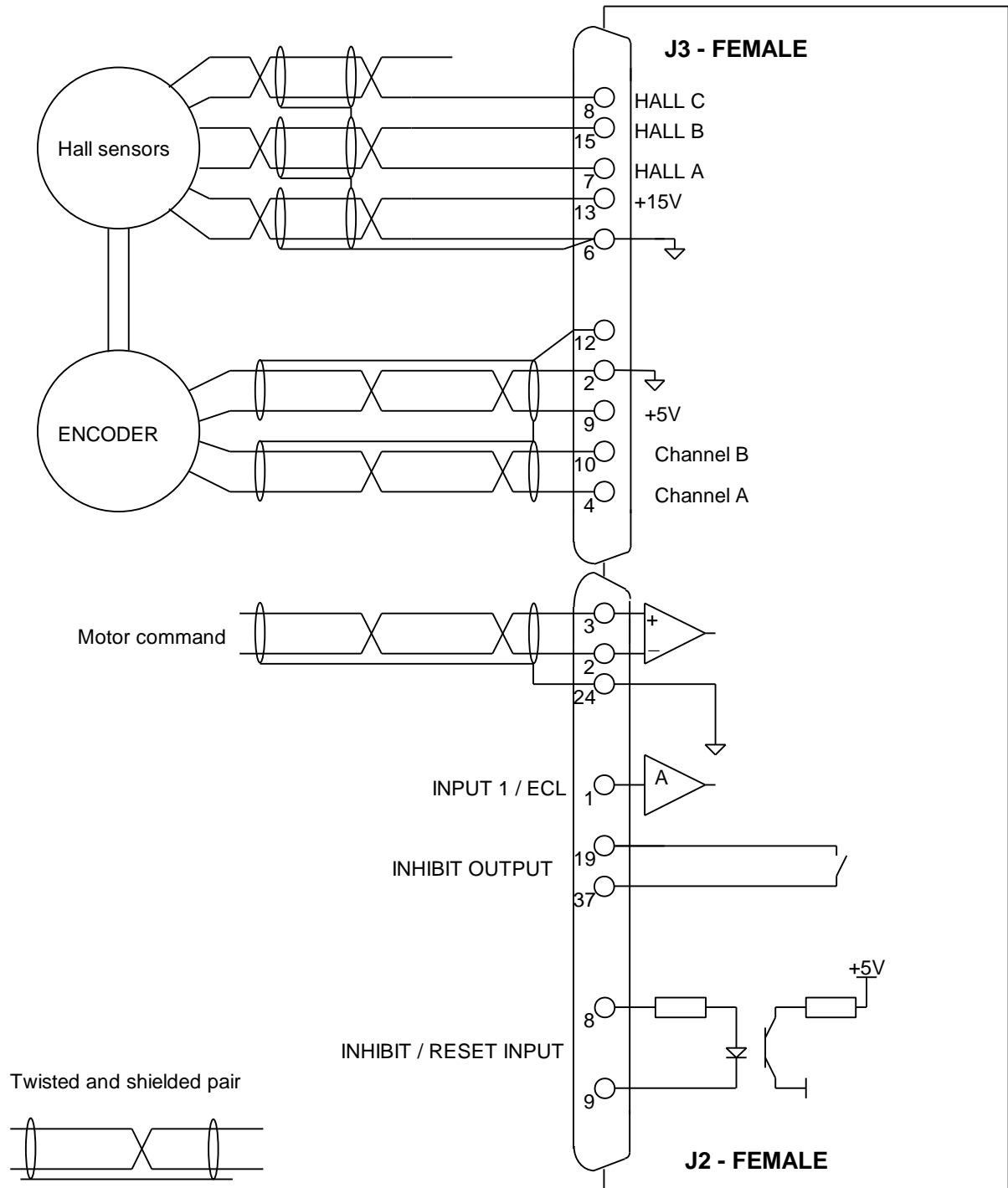
NBA CONTROL CONNECTION

TACHSYN OPTION



NBA CONTROL CONNECTIONS

RESOLVER OPTION



NBA CONTROL CONNECTION

ENCODER OPTION

7. Start - Up Procedures

7.1 Common procedures for all amplifiers types

7.1.1 Commutation signals format

Select the position of DIP switch 1 on the lower board according to the commutation signal format of the motor.

DS1 positions:	ON : 30°	OFF : 60°
----------------	----------	-----------

For all Resolver versions it should be 60°.

7.1.2 CFM function

Select the position of DIP switch 4 on the lower board according to the motor's rated current. If it is less than 20% of the amplifier's rated current select:

DS4 to ON - Active CFM

Otherwise,

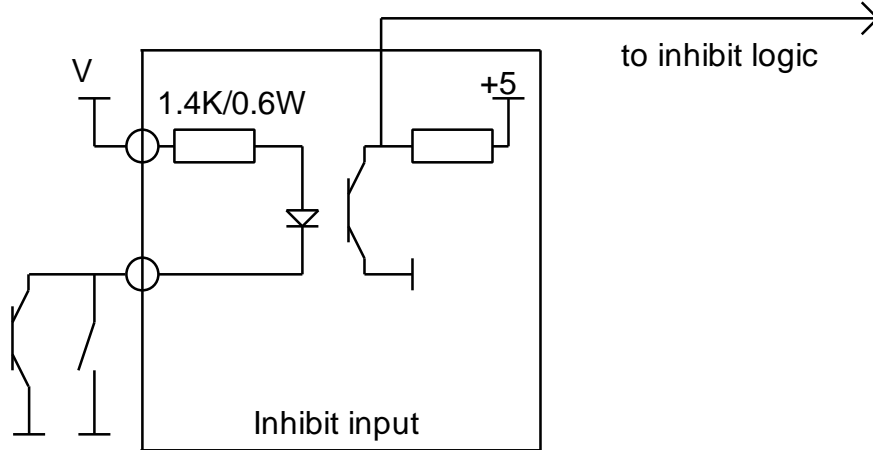
DS4 to OFF - No CFM

7.1.3 Inhibit logic

Inhibit function will be activated by connecting its inputs to a voltage signal. If no signal is applied to this input the amplifier will be disabled upon power on.

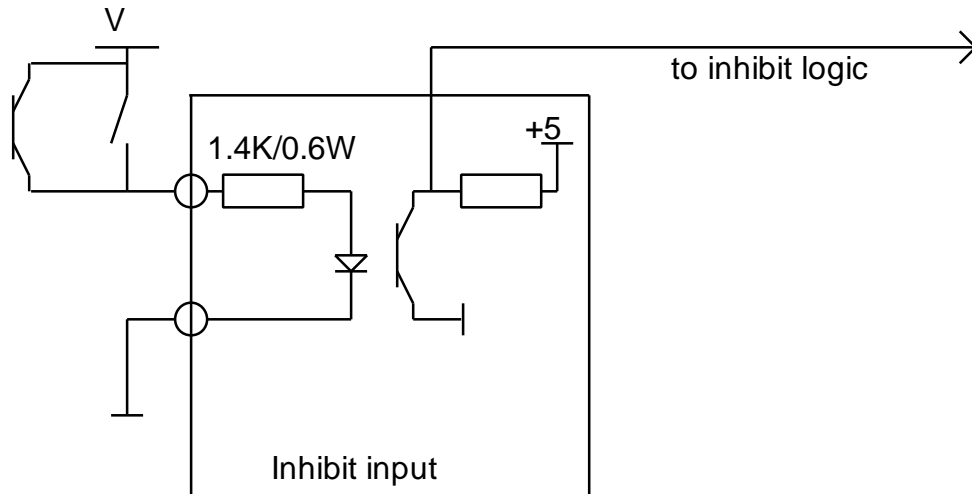
OPTO-ISOLATED INHIBIT

$5 < V < 30$



NBA enable by active "HIGH" or closed contact

$5 < V < 30$



NBA enable by active "LOW" or closed contact

Source must be capable to source or sink $(V_{inh}-1.5)/1.4$ (mA).

7.1.4 Current mode

To operate in current mode the velocity loop should be disabled by converting the error amplifier to a low gain proportional amplifier.

- Remove R5 (in solderless terminals).
- Remove C1 (in solderless terminals).

In addition, you must make sure that the velocity feedback signal is not entering the error amplifier. If a Resolver is used

open switch 1 on resolver board (doing this you disconnect the velocity monitor output). If Tachsyn or Brushless tach. options are being used, or if in resolver option you want to monitor the velocity via terminal 1, The input resistor of the velocity signal should be removed:

- Remove R17 (SMD component)

The current limits of the amplifier remain the same as in velocity mode.

7.1.5 Velocity mode

To operate in velocity mode the velocity loop should be enabled by converting the error amplifier to a high gain PI amplifier. Make sure that R4, R5 and C1 (in solderless terminals) are installed on the board.

If a Resolver board is installed on the NBA amplifier, you have to make sure that the velocity feedback signal is entering the error amplifier:

DS1 (on the Resolver board): ON.

7.1.6 Selecting the reference signal gain

The NBA has 2 inputs: single ended input and a differential input. Care must be taken not to apply input voltage above the maximum input voltage as this will cause the input op amp to operate beyond its limits (10V) and in extreme cases may even damage the op amp. The standard procedure recommends to use the single ended input for the velocity feedback signal and to use the differential input for the reference signal. Following are the input maximum voltage and impedance with the standard values of input resistors:

INPUT - RESISTOR	STANDARD VALUE	MAX. VOLTAGE	Current Gain(A/V) (in current mode)	INPUT IMPEDANCE
Terminal - R1	15 Kohm	25V	0.2xIc	25 Kohm
Differential - R2,R3	10Kohm	20V	0.533xIc	30 Kohm

All the gains are divided by 2 if CFM is ON

See chapter 4.1 for calculation of other values

7.1.8 Latch mode of the protective functions

All the protective functions activate internal inhibit. There are two modes of resetting the amplifier after the cause of the inhibit disappears:

Self Restart (DS5-OFF): The amplifier is inhibited only for the period that the inhibit cause is present.

Latch (DS5-ON): Each failure latches the Inhibit and the In LED. For restart (after clearing the failure source), reset has to be performed either by turning DS5 to "OFF" or by applying logic 0 at the inhibit input (terminals R-18a,20a,M-J2/8,9).

For safety reason it is recommended to use the amplifier in the LATCH MODE

7.2 Connecting the velocity feedback elements

7.2.1 Brush Tachogenerator

The output leads of the tacho are connected to terminal R-2a,M-J2/1 and to the circuit common (Negative feedback). The tacho voltage is adjusted by calculating R1 as follows:

$$R1 = 1.14 \times V_{Tm} - 9.1 \quad (\text{Kohm})$$

V_{Tm} - Voltage generated by tachogenerator at max velocity.

Actual resistor value should be as close as possible to the calculated value.

7.2.2 Brushless Tachogenerator

A) Three Phase Brushless Tachogenerator

Selecting this option is done by arranging the following switches:

$$DS2 = ON$$

The three leads should be connected to terminals R-10a,10c,10e,M-J3/1,2,3 - phases A,B,C. If the tacho windings are connected in Y (star) and the common connection is available as an output lead, it should be connected to the tacho common.

The output of the tacho processor is available at terminal R-18e,M-J2/6. R9, R10 and R11 should be calculated and installed as follows:

$$R9 = R10 = R11 = 0.415V_{Tm} - 3.32 \quad (\text{Kohm})$$

The speed of the motor (N) in RPM is given by:

$$N = \left(\frac{R9}{3.32} + 1 \right) \times V1 / (K_{e_{tach}} \times K_i) \quad (R9 \text{ in Kohm})$$

V_{Tm} - Voltage generated by tachogenerator at max velocity.

$K_{e_{tach}}$ - Tacho back EMF constant (Volt/RPM).

V1 - Voltage at terminal R-2a,M-J2/1.

K_i - Trimmer wiper position (0.5-1 full scale)

7.2.3 Tachsyn

Selecting this option is done by selecting DS2 = OFF. The three phases leads should be connected to terminals R-10a,10c,10e,M-J3/1,2,3 (feedback connector) -phases A,B,C. The tachsyn oscillator reference signal is at terminal R-12c,M-J3/10.

R9,R10 and R11 should be calculated and installed as follows:

$$R9=R10=R11= 0.332V_{TC} - 3.32 \quad (\text{Kohm})$$

V_{TC} - Voltage generated by Tachsyn at max velocity.

The speed of the motor (N) in RPM is given by:

$$N = \left(\frac{R9}{3.32} + 1 \right) \times V_1 / (Ke_{tC} \times Ki) \quad (\text{R9 in Kohm})$$

Ke_{tC} - tachsyn back EMF constant (Volt/RPM).

V_1 - voltage at terminal R-2a,M-J2/1.

The output of the velocity processor is available at terminal R-2a,M-J2/1.

Ki - Trimmer wiper position (0.5-1 full scale)

7.2.4 Resolver

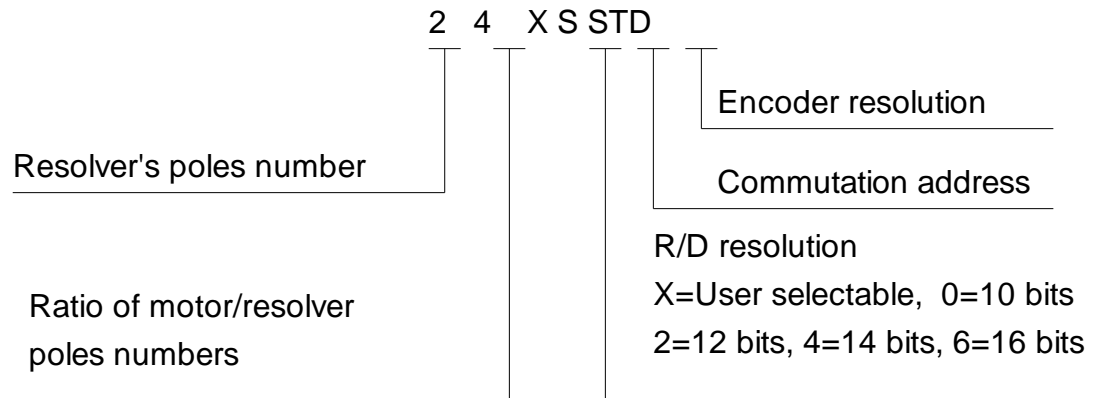
The Resolver interface circuit consists of three basic blocks:

R/D converter

The R/D conversion is done by a variable resolution, monolithic converter type 2S82 of Analog Devices. It accepts two signals from the Resolver (sine and cos.) and converts them into binary position data bits. The resolution of the position bits is user selectable 10, 12, 14 and 16 (only for standard encoder resolution). In addition, the R/D creates a signal that is proportional to the Resolver velocity. This signal is used as a velocity feedback.

EPROM

The EPROM creates "Hall" signals by mapping the position data bits accepted from R/D into suitable Hall signals to operate a specific BLM. In addition, the encoder index (marker) signal is also produced from the EPROM. The EPROM is designated as follows:



In the S (standard) version zero crossing of phases B C occurs at position address "0" of the Resolver.

The EPROM is usually supplied without any programming and in such case the amplifier will have no commutation information.

Oscillator

Creates sinusoidal waveform signal to excite the primary of the Resolver.

Oscillator Frequency/Amplitude Selection (R228,R233)

The frequency (f_r) and amplitude (V_r) needed to excite the Resolver are taken from the Resolver data sheet.

Selecting the frequency:

$$R228 = 110/fr \quad (\text{Kohm})$$

$$0.1\text{KHz} < fr \text{ (KHz)} < 20\text{KHz}$$

Selecting the amplitude:

Take care that the RMS amplitude does not exceed $7V_{rms}$ or that the peak-to-peak (ptp) value is within the range of $2V \leq V_{r_{ptp}} \leq 20V$.

For V_r in peak-to-peak value:

$$R233 = 6/(V_r - 2) \quad (\text{Kohm})$$

For V_r in RMS value:

$$R233 = 6/(2.82V_r - 2) \quad (\text{Kohm})$$

Reference Voltage level to R/D (R192)

In order to adjust the reference voltage input level to $2V_{rms}$, select R192 as follows:

$$R192 = 50 \times (V_{r_{rms}} - 2) \quad (\text{Kohm})$$

For $V_{r_{rms}} < 2V$, install $R192=100 \text{ ohm}$.

Signal input level (R193,R194)

The R/D inputs ($V_{in_{rms}}$) are adjusted to the sin/cos. Resolver outputs by:

$$\text{Resolver output} = \text{Vin}_{\text{rms}} = \text{Vr}_{\text{rms}} \times \text{Transformation ratio}$$

$$\text{R193} = \text{R194} = \text{Vin}_{\text{rms}} - 2 - \text{Rstator} \quad (\text{Kohm})$$

(R_{stator} in Kohm).

When $\text{Vin}_{\text{rms}} < 2\text{V}$, install $\text{R193}=\text{R194}=100 \text{ ohm}$.

The standard R/D converter will not operate for $\text{Vin}_{\text{rms}} < 1.8\text{V}$. Consult factory for OEM applications.

Velocity Signal

The tracking converter technique generates an internal signal at the output of the integrator that is proportional to the rate of change of the input angle. This dc analog output (velocity signal) is buffered and represented at terminal 1. It can be internally connected to input 1 (the single ended input) by turning DS1 (on the resolver board) to ON.

Max output voltage is +8V.

Select maximum actual velocity of the application and calculate the maximum tracking rate T of the Resolver as follows:

$$T = \text{rpm} \times Q / 120$$

T unit is rps: Resolver electrical revolution per second

Q - number of poles of Resolver ;

rpm - mechanical revolution per minute.

Selecting the Resolution

The resolution can be selected to be 10,12,14 or 16 bits by use of DIP switches 3 and 4. When selecting the resolution the rps limits should not be exceeded:

10 bit = 1040 rps
 12 bit = 260 rps
 14 bit = 65 rps
 16 bit = 16.5rps

Resolution	DS3	DS4
10	ON	ON
12	ON	OFF
14	OFF	ON
16	OFF	OFF

Note:

- Each resolution change must be followed by new components selection procedure.
- When changing resolution under dynamic conditions, a period of uncertainty will exist before position and velocity data is valid.

Encoder resolution

The encoder resolution is defined while programming the EPROM (use only "special" resolution when using the EEE software). The highest encoder resolution (for 2 pole Resolver) that can be achieved using different R/D resolution is given in the following list:

256 for 10 bits

1024 for 12 bits

4096 for 14 and 16 bits

In order to get the appropriate output signals make sure that

DS2 at ON

When the Resolver is more than 2 poles, the resolution for one shaft rotation will be:

$$Er = Q \times S / 8$$

Q = number of Resolver poles ;

S = resolution of converter (2^{10} , 2^{12} , or 2^{14})

HF Filter (R195, R196, C61, C62)

The function of the HF filter is to reduce the amount of noise present on the signal inputs to the 2S82, reaching the Phase Sensitive Detector and affecting the outputs. Values should be chosen so that

$$15\text{Kohm} < R195=R196 < 30\text{Kohm}$$

$$C61 = C62 = \frac{160 \times 10^3}{R195 \times fr} \quad (\text{pF})$$

fr = Reference frequency in KHz

R195 in Kohm

This filter gives an attenuation of 3 times at the input to the phase sensitive detector.

AC Coupling of Reference Input (C60)

Select C60 so that there is no significant phase shift at the reference frequency. That is,

$$C60 = \frac{10^6}{fr(\text{KHz}) \times Rx} \quad (\text{pF}) \quad Rx = \frac{100 \times R192}{100 + R192} \quad (\text{Kohm})$$

R192 in Kohm

If RX yields less than 50K, install a value of Rx=50K in the C60 equation.

Maximum Tracking Rate (R201)

The VCO input resistor R201 sets the maximum tracking rate of the converter and hence the velocity scaling as at the maximum tracking rate, the velocity output will be 8V.

Decide on your required maximum tracking rate, "T" , in Resolver electrical revolutions per second. Note that "T" must not exceed the specified maximum tracking rate or 1/16 of the reference frequency.

$$R201 = 5.92 \times 10^7 / T \times p \quad (\text{Kohm})$$

where p = bit per rev
 = 1,024 for 10 bits resolution
 = 4,096 for 12 bits
 = 16,384 for 14 bits
 = 65,536 for 16 bits

Whenever the actual tracking rate (T) is lower than half of the maximum tracking rate (see "Selecting the Resolution"), R201 should be half of the value calculated above. This improves significantly the low speed performance. In this case the velocity signal at maximum velocity will be +4V.

Closed Loop Bandwidth Selection (C67, C68, R200)

a. Choose the Closed Loop 3dB Bandwidth (f_{bw}) required ensuring that

$$f_{ref} > 10 \times f_{bw}$$

Recommended bandwidth values:

250Hz for 3KHz

300Hz for 5KHz

500Hz for 10KHz

b. Select C67 so that

$$C67 = \frac{2.5 \times 10^9}{R201 \times f_{bw}^2} \quad (\text{pF})$$

with R201 in Kohm and f_{bw} in Hz as selected above.

c. C68 is given by

$$C68 = 40 \times C67 \quad (\text{pF})$$

d. R200 is given by

$$R200 = \frac{127 \times 10^7}{f_{bw} \times C68} \quad (\text{Kohm})$$

f_{bw} in Hz, C68 in pF

R200 value should be at least three times R197.

Gain Scaling Resistor (R197)

R197 should be installed according the following table:

536Kohm for 10 bits resolution

130Kohm for 12 bits

33Kohm for 14 bits

8.2Kohm for 16 bits

7.2.5. Optical Encoder

Adjusting maximum speed

Derive the application maximum operating frequency using the following equation:

$$f_n = \frac{N \times R}{60} \quad (\text{Hz})$$

N - maximum speed in RPM

R - Encoder resolution (PPR)

If $f_n < 200,000$ Hz you can improve the low speed performance by using the frequency x4 multiplier (DS2 - OFF).

Calculate and insert R9 and R10:

$$R9 = R10 = \frac{5 \times 10^6}{K1 \times K2 \times f_n} \quad (\text{Kohm}); \quad (f_n \text{ in Hz})$$

K1 = 1.05 for 150KHz < f_n < 200K

K1 = 0.95 for 100KHz < f_n < 150KHz

K1 = 0.9 for 20KHz < f_n < 100KHz

K1 = 0.85 for 0KHz < f_n < 20KHz

K2 = 1 for x1 encoder basic frequency

K2 = 4 for x4 encoder basic frequency

K2 = 1 for Hall sensors feedback

The minimum value of R9,R10 is 5.11Kohm.

Adjusting the circuit bandwidth

Most of the applications will be well met when the f/v converter bandwidth is set to 500Hz. Adjusting the bandwidth frequency (fbw) is done by R12 and R13:

$$R12 = R13 = \frac{5000}{fbw} \quad (\text{Kohm}); \quad (\text{fbw in Hz})$$

When fast mechanical response motor is being used, the bandwidth of the f/v converter should be increased by increasing R12 and R13 till optimal performance is achieved.

7.2.6. Hall effect sensors

Set DS2 to OFF

Adjusting maximum speed

Derive the application maximum operating frequency using the following equation:

$$f_n = \frac{P \times N}{20} \quad (\text{Hz})$$

P - number of motor poles

N - maximum speed in RPM

Calculate and insert R9 and R10 as given in 1.1.

Adjusting the circuit bandwidth

The f/v bandwidth should be around 250Hz. Adjusting the bandwidth frequency (fbw) is done by R12 and R13:

$$R12 = R13 = \frac{5000}{fbw} \quad (\text{Kohm}); \quad (\text{fbw in Hz})$$

If feedback voltage causes a positive feedback, R11 should be removed.

8. Amplifier adjustment

Important remarks:

- A. If all the previous steps were accomplished you may now turn on the power and continue with the following adjustments. You may omit the step for current mode or velocity mode according to your application.
- B. In some applications, especially those where the motor electrical parameters (total inductance and resistance in the armature circuit) are much smaller or larger than normally encountered, the current loop response should be optimized before proceeding with the following steps - See Appendix A.

8.1 Balance adjustment

If the motor is rotating with the command signal at zero voltage, a balance adjustment will be necessary. Turn the balance trimmer (T3) as required until the motor stops. As a rule, have the command signal connected and set to zero when balancing the amplifier. This way, any offset in the command signal will be canceled.

8.2 Current limit adjustment

The amplifiers current limits can be adjusted either by the trimmers, or dynamically by an external voltage signal.

Static adjustment

The amplifiers' current limits can be adjusted without the need for loading. Disconnect motor leads and connect a voltmeter between the Current Command Monitor (terminal R-2e,M-J2/5) and the circuit common. Apply maximum input voltage to one of the inputs to cause an error at the error amplifier (input gain trimmer should be fully CW).

In order to adjust the continuous limit - turn T5 (Ip) fully CCW to disable Ip, then use T6 (Ic) to adjust the continuous limit by monitoring the meter readout.

Full CW rotation of T6 will result in rated current limit.

After adjusting the continuous limit, turn T5 up to the desired peak level.

The current monitor range is up to 7.5V and its scale depends on the amplifier rated continuous current (I_c) and is given by:

	Ic
Current monitor scale (A/V) :	-----
	3.75

The current monitor scale is half if CFM (DS4) is ON.

Dynamic adjustment- External Current Limit (ECL)

The ECL signal (0-8V) scales down both current limits (continuous and peak) as selected in the static adjustment. Activating the ECL is done by turning DS6 to "ON" and removing R1.

8.3 Adjusting the motor speed (velocity mode only)

Adjusting the speed is done by using the input gain trimpot:
Increasing/decreasing the command gain will increase/decrease the speed.

8.4 Response adjustment (Velocity mode only)

In most applications optimum response is achieved by adjusting the compensation (COMP) trimmer. Adjustment procedure is as follows:

- Provide the amplifier with a low frequency, bi-directional square wave velocity command (A 0.5 Hz, 2 volts waveform is often employed).
- Apply power to the amplifier, and while monitoring the tachometer signal, gradually adjust the COMP trimmer from the CW toward the CCW position. Optimum response (critically-damped) should be achieved at some position before reaching full CCW on T4. Fig 8.1 illustrates the types of waveforms observed for various setting of T4.

In some applications, especially those where the load inertia is much smaller or larger than normally encountered, the standard compensation components values of 0.022UF for C1 and 470Kohm for R4 may not allow an optimum setting of the COMP trimmer T4. In fact, the velocity loop may be unstable for any setting of T4.

In these cases different values for C1 and R4 must be chosen. The following procedure can be used to select these values:

- Short circuit C1 with a short jumper wire.
- Replace R4 with a decade resistance box Initially set the box resistance at 20Kohm.
- Set T4, the COMP trimmer to approximately midrange.
- Input a 0.5Hz, 2V bi-directional square wave velocity command signal to the amplifier.
- Apply power, and while monitoring the tachometer signal, gradually increase the value of the box resistance until optimum response as depicted in Fig 8.1 is achieved.
- Substitute the closest standard value discrete resistor for R4 and remove the decade resistance box.
- Remove the shorting jumper across C1, and again check the response using the squarewave test signal. If near optimum results are obtained, trim the response using COMP trimmer-T4 for the optimum.
- If the previous step does not yield satisfactory results, if unacceptable overshooting has been noted, substitute a larger value than 0.022UF; or, if the response is overdamped substitute a smaller value than 0.022UF. Repetition of this procedure should yield an optimum choice for C1.

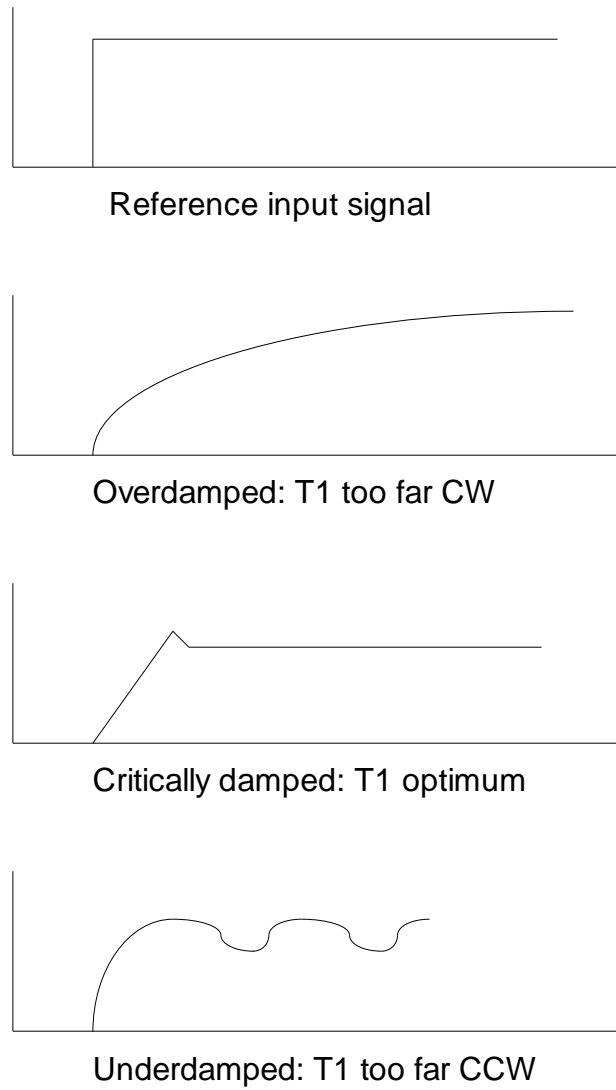


Fig. 8.1
Typical velocity response waveforms

9. Tables and Summaries

9.1 Adjusting trimmers - summary

- T1- Gain 1, cw rotation increases input 1 gain.
- T2- Gain 2, cw rotation increases input 2 gain.
- T3- Balance.
- T4- compensation, AC gain compensation of velocity loop.
- T5- Ip, CW rotation increases peak current limit.
- T6- Ic, CW rotation increases continuous current limit.

9.2 LED diagnostics

Five LEDs are installed on the lower board of the amplifier with the following designations: In, Ic, Pr, Sh, Vs. Under normal operation only Vs should illuminate (Vs indicates the existence of supply voltages). The following table represents the faults' indications of the LEDs:

	1	2	3	4	5	6
Ic(L5)				X		X
Sh(L4)			X		X	X
In(L3)	X	X	X		X	X
Pr(L2)		X			X	X
Vs(L1)	X	X	X	X	X	X

- 1- External inhibit.
- 2- Under/ Over voltage protection.
- 3- Short protection.
- 4- Continuous current limit.
- 5- Over temperature.
- 6- Loss of commutation signal.

9.3 DIP switches summary

DS1	ON	OFF
1	30° Hall sensors	60° Hall sensors
2	Brushless tacho	Tachsyn
3	Relay open for INH. + fault indication	Relay open only for fault indication.
4	CFM ON	CFM OFF
5	Latch mode	Non-latch mode
6	ECL connected, see 8.2.	ECL disconnected

9.4 Test points summary (with Elmo mother board only)

Test Point no.	Function
1	Current Monitor
2	Current Command
3	Velocity Monitor
4	Circuit Common
5	Simulated Encoder Output - Channel A Resolver option only
6	Simulated Encoder Output - Channel B Resolver option only
7	Simulated Encoder Output - Index Resolver option only
8	Circuit Common

Appendix A - Response adjustment - current loop

In most applications it is not necessary to adjust the current loop to achieve the optimum response. When there are extreme electrical parameters in the armature circuit (inductance and resistance) the standard components values of 0.01 μ F for C2 and 100Kohm for R6 may not yield with the optimum response.

The current loop should be optimized as follows:

- Turn the amplifier to a current amplifier by removing R5 and C1
- Provide the amplifier with a bi-directional square wave current command (100-200Hz, \pm 2.0V waveform is often employed).
- Apply power to the amplifier, and monitor the load current by a current probe or by the current monitor. If the current response is not critically damped, use the following procedure:
- Short circuit C2 with a short jumper wire.
- Replace R6 with a decade resistance box. Initially set the box resistance at 10Kohm.
- Apply the square wave test signal to the amplifier input.
- Apply power, and while monitoring the load current, gradually increase the value of the box resistance until optimum response as depicted in Fig A-1 is achieved.
- Substitute the closest standard value discrete resistor for R6 and remove the decade resistance box.
- Remove the shorting jumper across C2, and again check the response using the square wave test signal.
- If the previous step does not yield satisfactory results, if unacceptable overshooting has been noted, substitute a larger value than 0.01 μ F; or, if the response is overdamped, substitute a smaller value than 0.01 μ F. Repetition of this procedure should yield an optimum choice for C2.

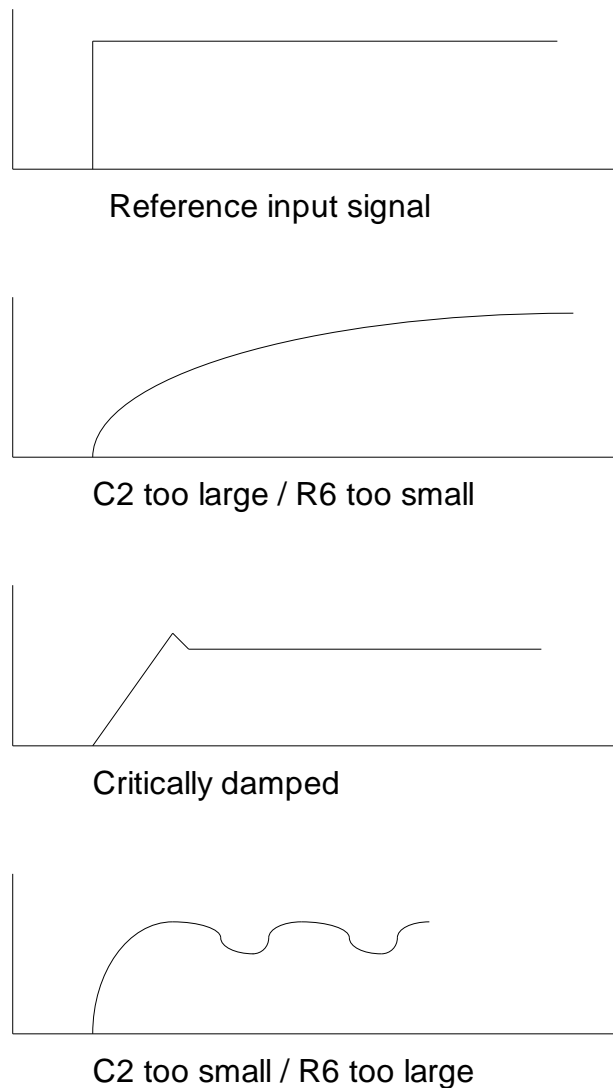
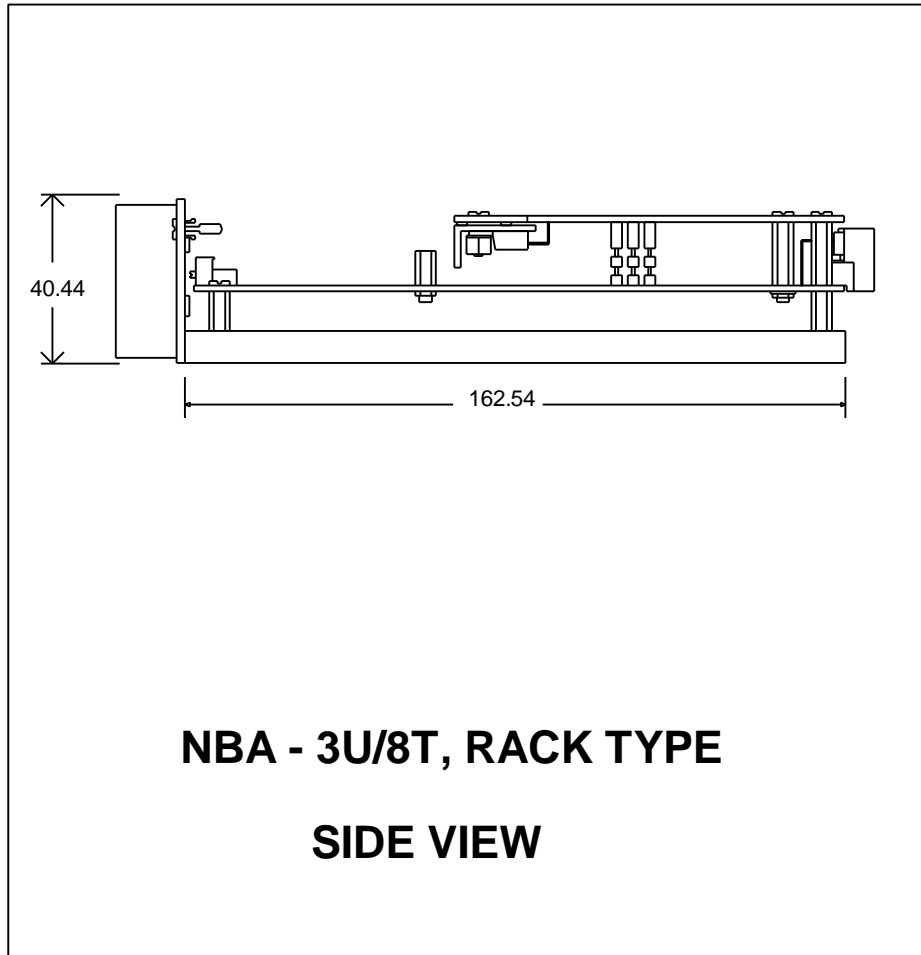
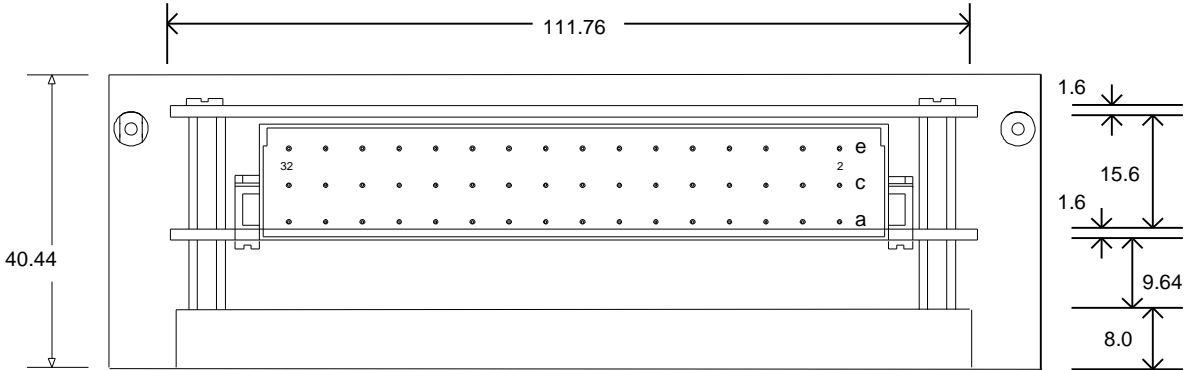


Fig. A-1

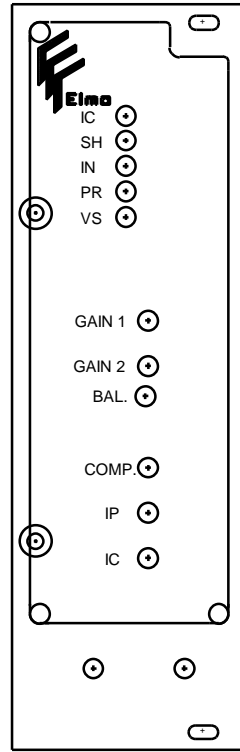
Typical current response waveforms

DIMENSIONAL DRAWINGS



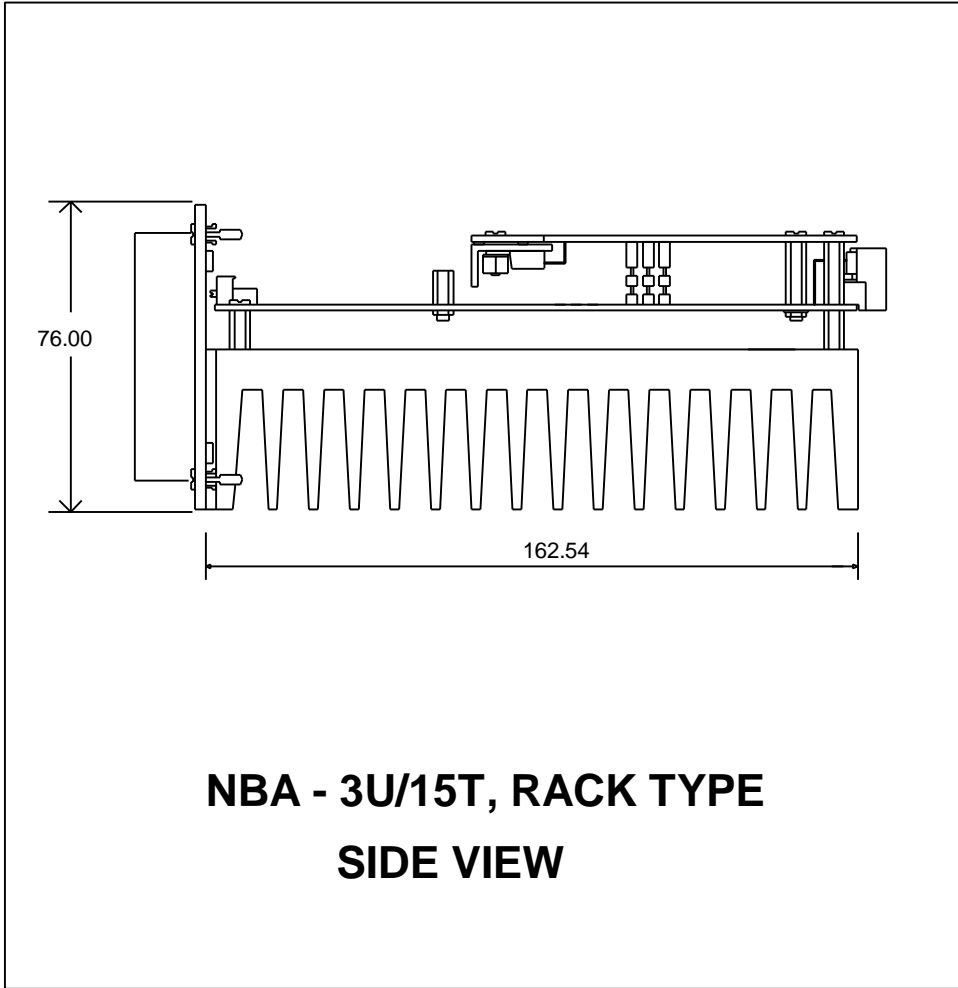


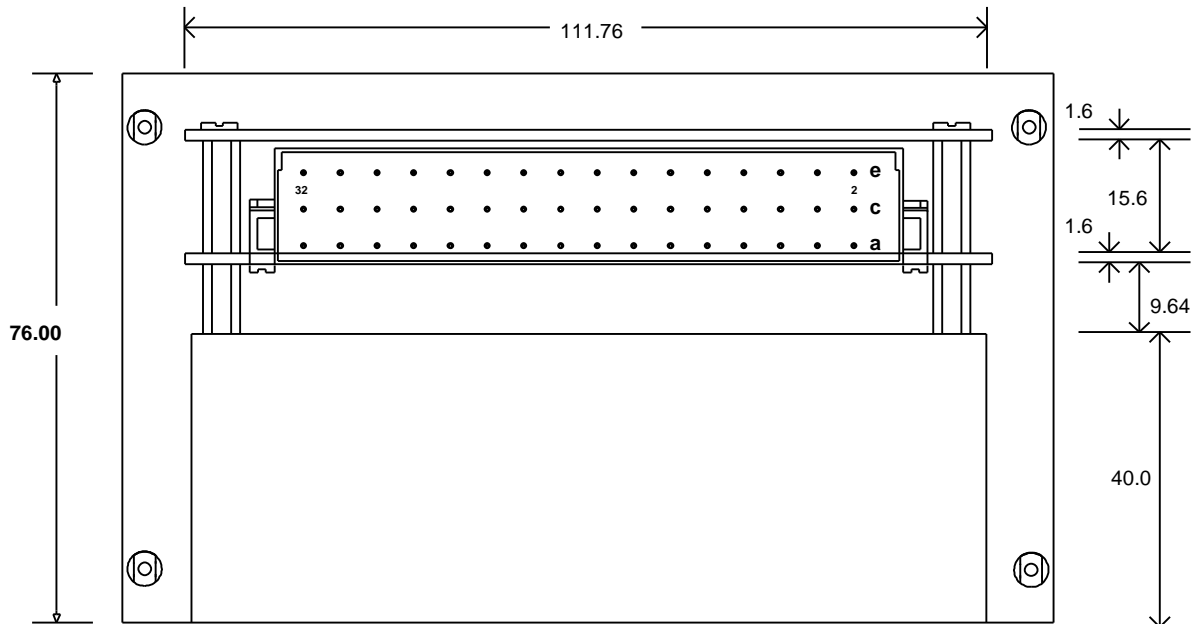
**NBA - 3U/8T, RACK TYPE
CONNECTOR SIDE VIEW**



FRONT PANEL

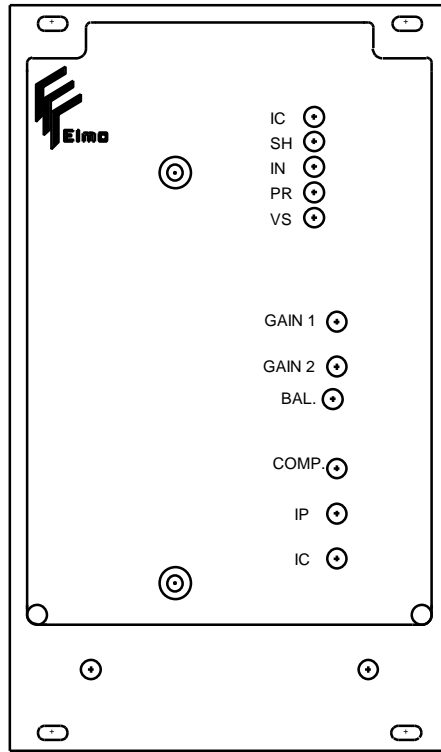
NBA - 3U/8T





NBA - 3U/15T, RACK TYPE

CONNECTOR SIDE VIEW



FRONT PANEL

NBA - 3U/15T

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