NPApm

Installation and Operation Guide

September 2020

Document Revision: 3.02

ACS MOTION CONTROL

NPApm

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Revision History

Date	Revision	Description
September 2020	3.02	Formatting, correct maximum recommended drive input
September 2017	1.90	Updated for STO, UL EMC certifications Updated list of supported motors Document reformatted
June 2016	1.80	Added content for single-phase motors Updated programmable current loop bandwidth
May 2016	1.70	Added note concerning STO
April 2016	1.60	Replaced "EndToEndCalibrationProgram.prg" program Replaced "NPACurrentLoopParametersSaveProgram.prg" program
March 2016	1.50	Changed Control Supply fuse specification to 3A
February 2016	1.40	Updated Drive Connections Figure Updated Drive Connection and Grounding Details Figure
January 2016	1.30	Reformatted Section 5 Updated label with ordered part P/N Updated Section 5.5.1 Updated Section 6.3.2 Updated Section 6.3.6.2 Replaced program in Section 7.1 Replaced program in Section 7.2 Added accessory NPApm-ACC3 accessory cable for NPApm Added new NanoPWM icon
December 2015	1.20 Draft	Numerous minor improvements
November 2015	1.10 Draft	Replaced NPDpm product name with NPApm
October 2015	1.00 Draft	First Release

Conventions Used in this Guide

Text Formats

Format	Description
Bold	Names of GUI objects or commands
BOLD + UPPERCASE	ACSPL+ variables and commands
`Monospace + grey background`	Code example
Italic	Names of other documents
Blue	Hyperlink
[ ]	In commands indicates optional item(s)
|	In commands indicates either/or items

Flagged Text

	**Note** - includes additional information or programming tips.
	**Caution** - describes a condition that may result in damage to equipment.
	**Warning** - describes a condition that may result in serious bodily injury or death.
	**Model** - highlights a specification, procedure, condition, or statement that depends on the product model
	**Advanced** - indicates a topic for advanced users.

Related Documents

Documents listed below provide additional information related to this document.
The most updated version of the documents can be downloaded by authorized users from www.acsmotioncontrol.com/downloads.

Document	Description
SPiiPlus Setup Guide	Provides guidance on how to configure and adjust the SPiiPlusNT systems to work with supported types of motors and feedback devices.
SPiiPlus MMI Application Studio User Guide	Explains how to use the SPiiPlus MMI Application Studio and associated monitoring tools.
NT PEG and MARK Operations Application Note	Provides detailed description, specification and operation instructions for PEG capabilities.
EtherCAT Network Diagnostics	An application note describing how to perform diagnostics of the EtherCAT network.
Dual Axis PEG	An application note describing dual axis PEG usage.
Using Absolute Encoders with ACS Products	An application note that addresses the physical connections, configurations and operation of absolute encoders with ACS networking products.
Safe Torque Off Function	An application note providing the technical details for implementing the STO function for drives installed in ACS Motion Control systems.
NPApm Functional Safety Manual	Describes the use of the STO function in the NPApm.

Table of Contents

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List of Tables

1. Introduction

1.1 Document Scope

This document describes the installation information for the NPMPMNPAPM.

This document is intended for the use of hardware engineers.

1.2 Product Overview

The NPMPM is a dual-axis, NanoPWM™ drive, suitable for applications that require nanometer and sub-nanometer position jitter levels.

The NPMPM operates from 12V to 100Vdc (drive supply) and provides continuous/peak current options of 3.3/10A, 6.6/20A, 10/30A, and 13.3/40A. The unit works with an ACS Motion Controller and EtherCAT master. Figure 1-1 shows the interface block diagram.

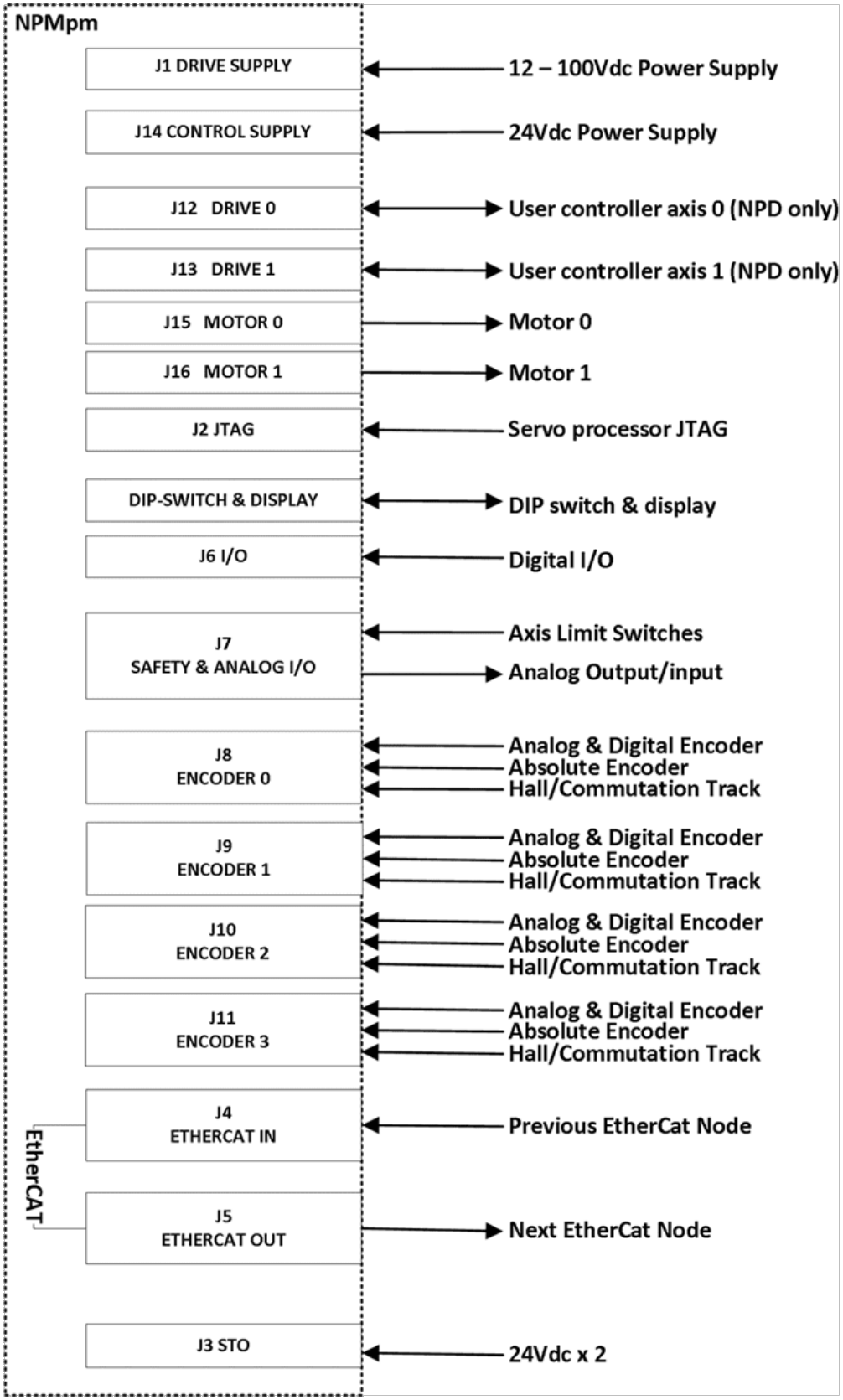


Figure 1-1. Interface Block Diagram

2. Detailed Description

2.1 Connectors, DIP Switches, and Jumper

The following figures and table shows and describes the NPAPM connectors.

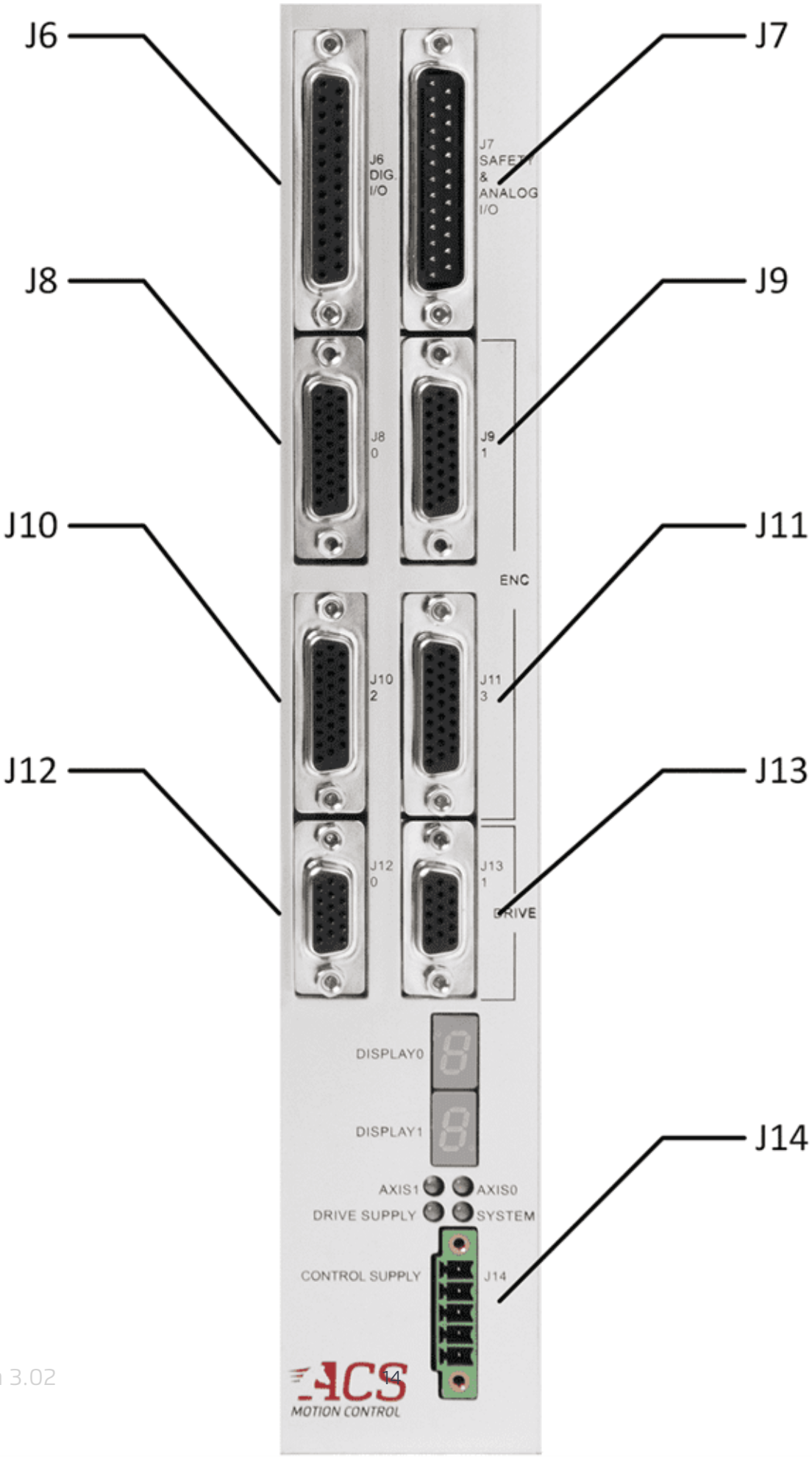

J6
J7
J8
J9
J10
J11
J12
J13
J14
J6
DIG.
I/O
J7
SAFETY
&
ANALOG
I/O
J8
0
J9
1
ENC
J10
2
J11
3
J12
0
J13
1
DRIVE
DISPLAY0
DISPLAY1
AXIS1
AXIS0
DRIVE SUPPLY
SYSTEM
CONTROL SUPPLY
J14
ACS
MOTION CONTROL

Figure 1-2. Connectors - Front View

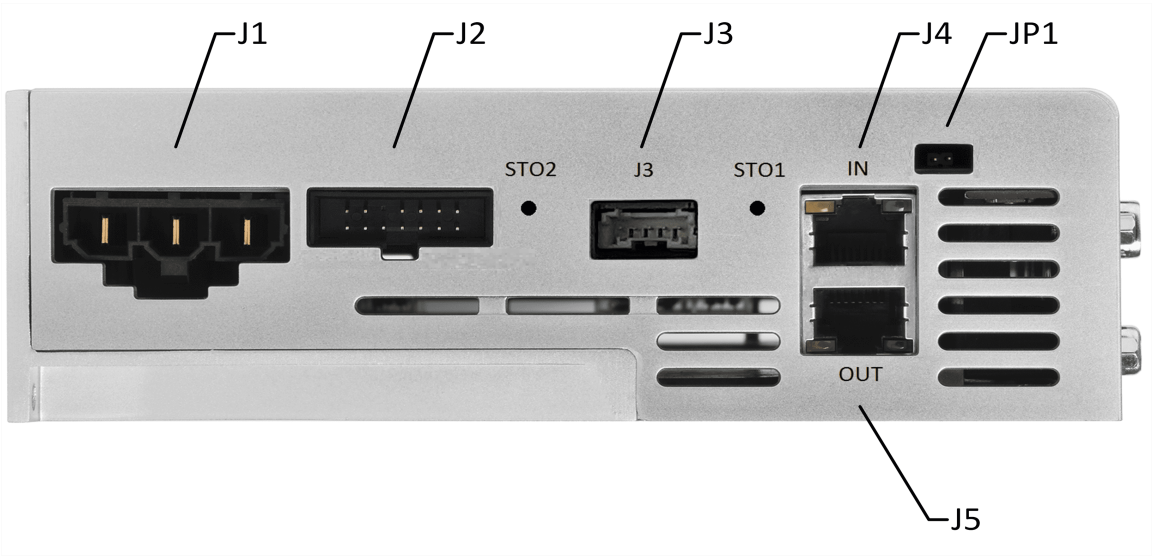


Figure 1-3. Connectors and Jumper - Top View

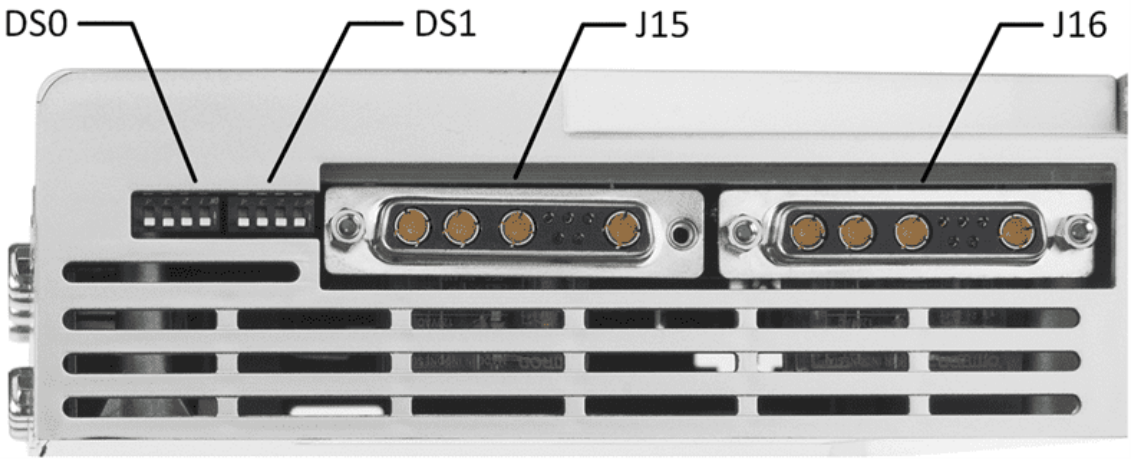


Figure 1-4. Connectors and DIP Switches - Bottom View

Table 1-1. Connections

Table 1-2. Connections

Connector Assignment	Connector Name	Description
J1	Drive supply	12 - 100Vdc, maximum recommended 96Vdc
J2	JTAG	Used by ACS to modify or upgrade the firmware.

Connector Assignment	Connector Name	Description
J3	STO	Optional
J4	EtherCAT in	Used to connect to an EtherCAT Master to fine tune the current loop filter.
J5	EtherCAT out	
J6	Motor Relay	Optional
J7	Analog output	Motor phase current
J8	(Not used)	
J9	(Not used)	
J10	(Not used)	
J11	(Not used)	
J12	Drive 0	Controller-Drive 0 interface
J13	Drive 1	Controller-Drive 1 interface
J14	Control supply	
J15	Motor 0	
J16	Motor 1	

2.1.1 DIP Switches and Jumper

The following table describes the NPAPM DIP switches and jumper.

Table 1-3. DIP Switches and Jumper

DIP Switch	Description
DS0	To select current loop filter gains for drive 0
DS1	To select current loop filter gains for drive 1
JP1	Normal operational mode when open. Setup mode when closed / installed.

2.2 Indicators

2.2.1 LED Indicators

The following figures and tables show and describe the NPAPM LED indicators.

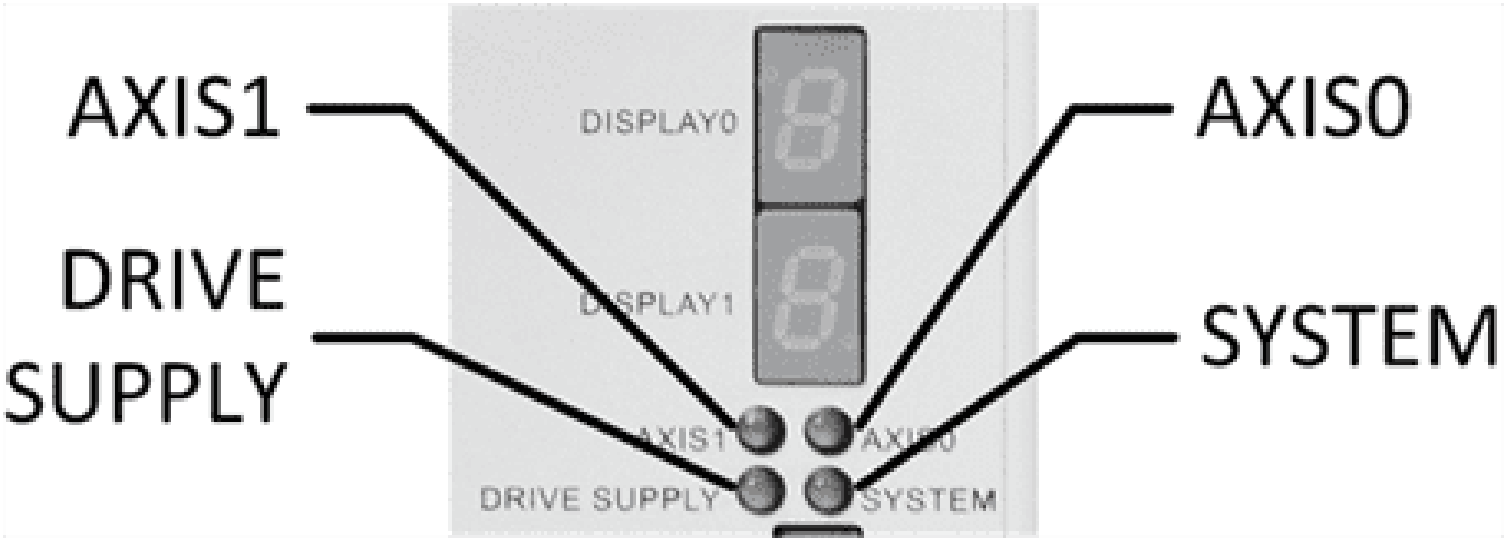


Figure 1-5. LED Indicators

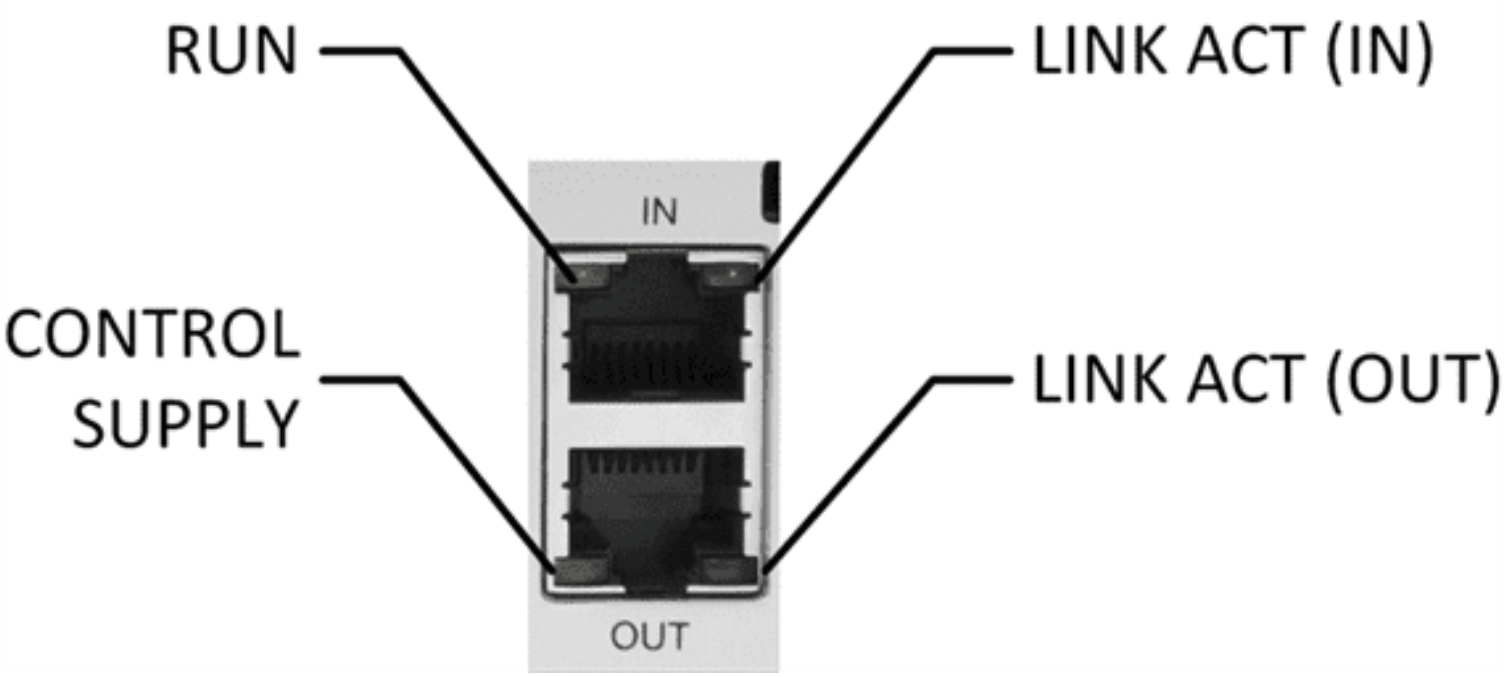


Figure 1-6. EtherCAT Indicators

Figure 1-7. STO Indicators

Table 1-4. LED Indicators Description

Indicator	Description	Remarks
Axis 0 Axis 1	One bicolor LED for each axis: > Green - Drive is enabled > Red - Drive fault > Off - Drive is disabled	AIXS0 (DRIVE0, MOTOR0) AIXS1 (DRIVE1, MOTOR1)
System	One bicolor LED: > Red - System Fault > Green - System OK > Blinking - Software command	
Drive supply	One green LED: > On - drive supply is OK. > Off - no drive supply is connected	
Control supply	One yellow LED: > On - Control supply is OK > Off - Control supply is not functioning	
Link Act	Two green LEDs (one per port) > On - Link without activity > Off - No cable is connected > Blinking - Link and active	
Run	Yellow LED: > On - network communication is OK > Blinking/Off - network communication error	
STO 1 STO 2	One green LED: > On - STO is deactivated.	

2.2.2 Axis/Drive Status Display

The following figure and table show and describe the NPAPM Axis/Drive Status Displays. There is one display for each axis.

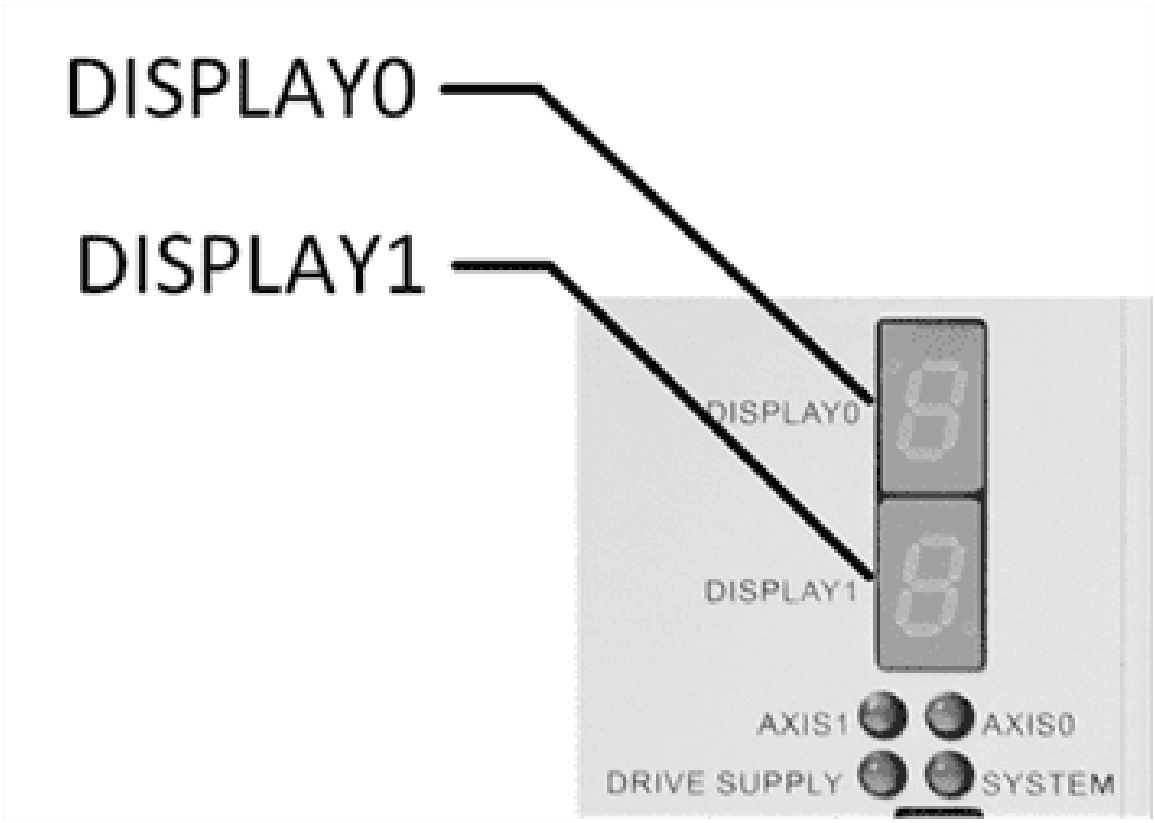


Figure 1-8. Axis/Drive Status Displays

Table 1-5. Axis/Drive Status Display Description

Code	Status	Description
C	Power up	Drive power up executed.
. (dot)	Setup mode	Drive is in Setup mode (see Operation modes).
0	No fault, enabled.	Drive enabled and no faults detected.
1	Over voltage	Drive over-voltage protection is activated. The drive is disabled. The drive supply must be reduced or a regeneration circuit must be used.
4	STO	STO is used. A 24Vdc supply is not connected to at least one of the STO input pins. Drive is disabled.
5	Short circuit	Drive short- circuit protection is activated. The drive is disabled.

Code	Status	Description
H	Over temperature	Drive over-temperature protection is activated. The drive is disabled. Forced-air cooling may be required.
h	Motor over temperature	Motor over-temperature protection is activated (indicating the motor temperature sensor (PTC) impedance is above 10kΩ or not connected) and the drive is disabled. When this protection is not used, connect the X_ OVER pin to GND.
U	Under voltage	Drive under-voltage protection is activated (indicating the drive supply is under 9Vdc or not connected) and the drive is disabled.
2	Drive over current	Drive over-current protection is activated (indicating the drive exceeded the specified motor continuous RMS current) and the drive is disabled.
L	Drive saturation	Drive saturation (due to low drive supply amplitude for the required motor velocity or at least one motor phase is disconnected). The drive is disabled.
F	Invalid EEPROM data	Invalid EEPROM data. Contact your ACS representative for repair options.

Error 5076:drive stauration - may occur if the drive exceeds the voltage saturation for a relatively long period of 0.5 sec. This fault may indicate a hardware problem like a missing motor phase or short circuit. It may also occur if the motion parameters (velocity, acceleration) are too high and the bus voltage is insufficient

2.3 Package Content

The NPAPM package contains the following items:

- NPAPM module
- STO Connector Kit P/N: STO-ACC1 (supplied only for units ordered with STO)
- Control supply mating connector (for J14), Phoenix MC 1,5/ 5-STF-3,81

2.4 Optional Accessories

2.4.1 Ethernet Cables

While in Setup mode, the unit should be connected to an ACS Motion controller using an EtherCAT cable. ACS offers the following Ethernet CAT5 cables:

Table 1-6. Ethernet Cables

Length [m]	Part Number
0.3	SP+ECAT-CA-30CM-00
0.5	SP+ECAT-CA-50CM-00
1	SP+ECAT-CA-1M-00
2	SP+ECAT-CA-2M-00
3	SP+ECAT-CA-3M-00
5	SP+ECAT-CA-5M-00
10	SP+ECAT-CA-10M-00
15	SP+ECAT-CA-15M-00
20	SP+ECAT-CA-20M-00

2.4.2 Mating Connectors Kit

P/N: NPXpm-ACC1

Description: Mating Connector Kit

This kit serves both the NPMPM and the NPAPM . Not all connectors are used by the NPAPM.

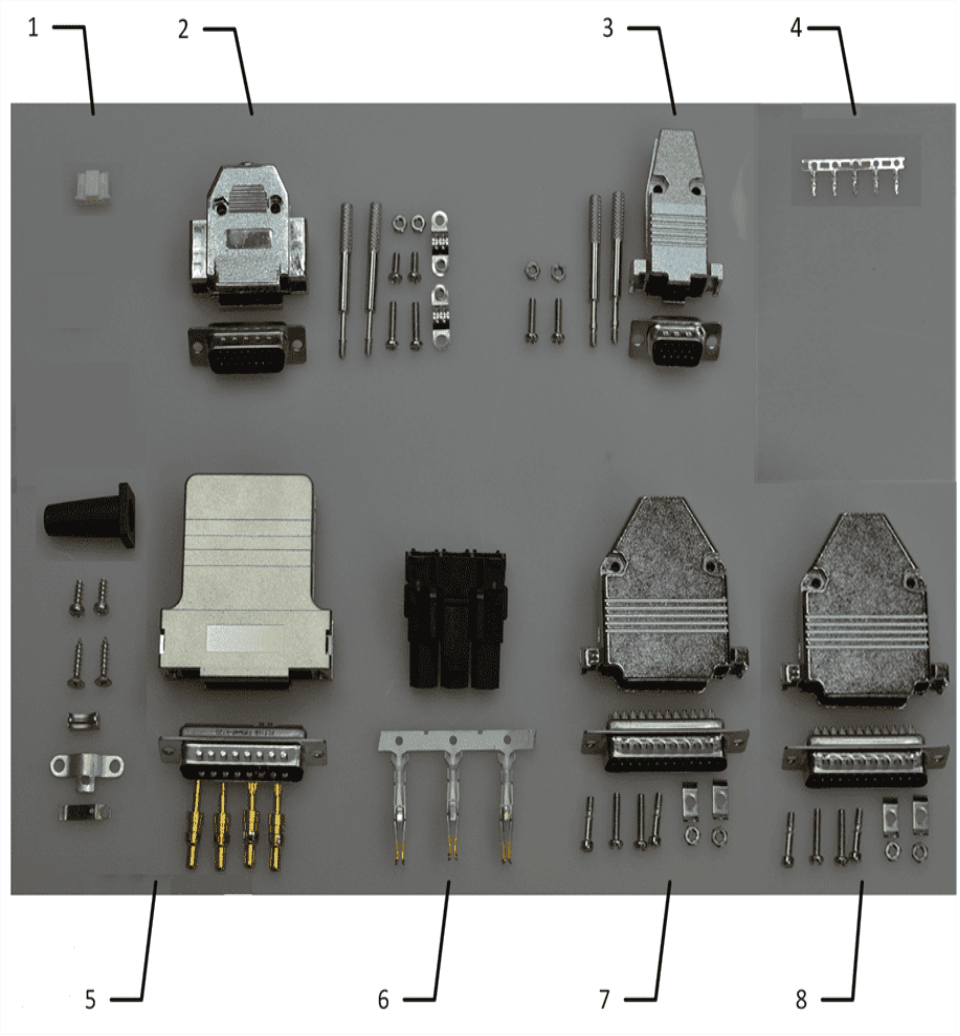


Figure 1-9. Mating Connectors Kit

Table 1-7. Mating Connector Kit

Reference	Quantity	Part Description	Connector	Manufacturer	PN
1	1	5-pin housing 2mm pitch NPB female	J3	JST	PAP-05V-S
2	4	D-type 26 pin high density male	Not used		
3	2	D-type 15 pin high density male	Not used		

Reference	Quantity	Part Description	Connector	Manufacturer	PN
4	5	Crimp Contact for 26-22AWG wire	J3 pins	JST	SPHD-001T-P0.5
5	2	Sub D 9W4 male	J15,J16	FCT	FM9W4P-K120
6	1	Molex 3 pin up to 50A per contact housing	J1	Molex	42816-0312
7	1	D-type 25 pin male	Not used		
8	1	D-type 25 pin female	J7	Many	

2.4.3 STO Accessory Kit

P/N: STO-ACC1

Description:2 meter cable with flying leads

Figure 1-10. STO-ACC1 Accessory Kit

Table 1-8. STO-ACC Pinout

Pin	Wire Color	Signal
1	Black	STO1-
2	Red	STO1+
3	Yellow	EGND
4	White	STO2+
5	Black	STO2-

2.4.4 UDMmc&NPXpm-ACC2 Accessory Cable

P/N:UDMmc&NPXpm-ACC2

Description: NPM (J1) mating 2m flying lead cable.

This kit serves both the NPMPM and the NPAPM.

Figure 1-11. UDMmc&NPXpm-ACC2 Accessory Cable

2.4.5 NPApm-ACC3 Accessory Cable

P/N: NPApm-ACC3

Description: Accessory cable for NPAPM.

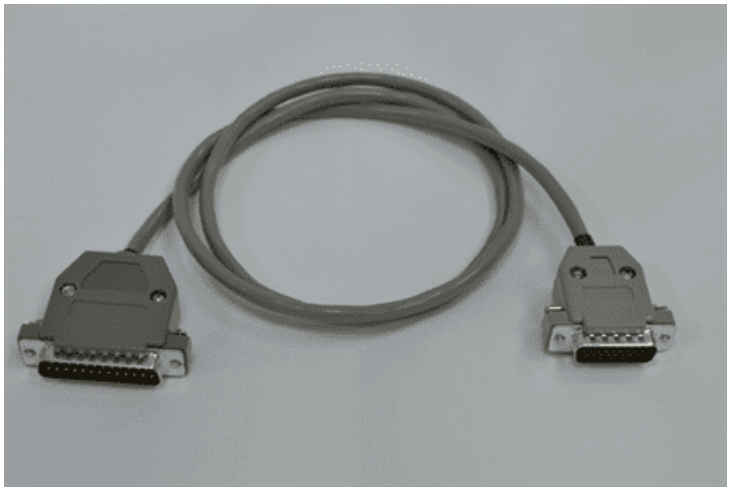


Figure 1-12. NPApm-ACC3 Accessory Cable

2.5 Order Part Number

The ordering part number (P/N) contains several characters (see example in Figure 1-13) that each specify a configuration characteristic ordered for the NPAPM module, as described in Table 1-9.

Figure 1-13. Label with Ordered P/N - Example

Table 1-9. Configuration as Indicated by P/N

Ordering Options	Field	Example User Selection	Available Ordering Option Values
Number of axes/drives	1	2	1,2
Current	2	A	A - 3.3/10A B - 6.6/20A C - 10/30A D - 13.3/40A
STO	3	Y	Y - Yes N - No
Motor relays	4	N	Y - Yes N - No
Special options	5	N	N - No
Type of motor	6	T	T - Three phase motor onlyS Single phase motor p=only

As an example, P/N NPApm2AYNNT would represent the configuration described in Table 1-10 below.

Table 1-10. P/N Example

Field		1	2	3	4	5	6
P/N	NPApm	2	A	Y	N	N	T

The NPAPM is shipped with the configuration set as ordered. Modifications can be done by ACS only.

3. Mounting and Cooling

- Unit should be mounted vertically, using M4 type Philips screws. The dimensions (in millimeters) are shown below.
- Leave sufficient clearance of 50 millimeters on all open sides for cable routing and free airflow.
- Unit operates in the temperature range of 0 to 40°C.
- See Environment for more information on environmental conditions and airflow.

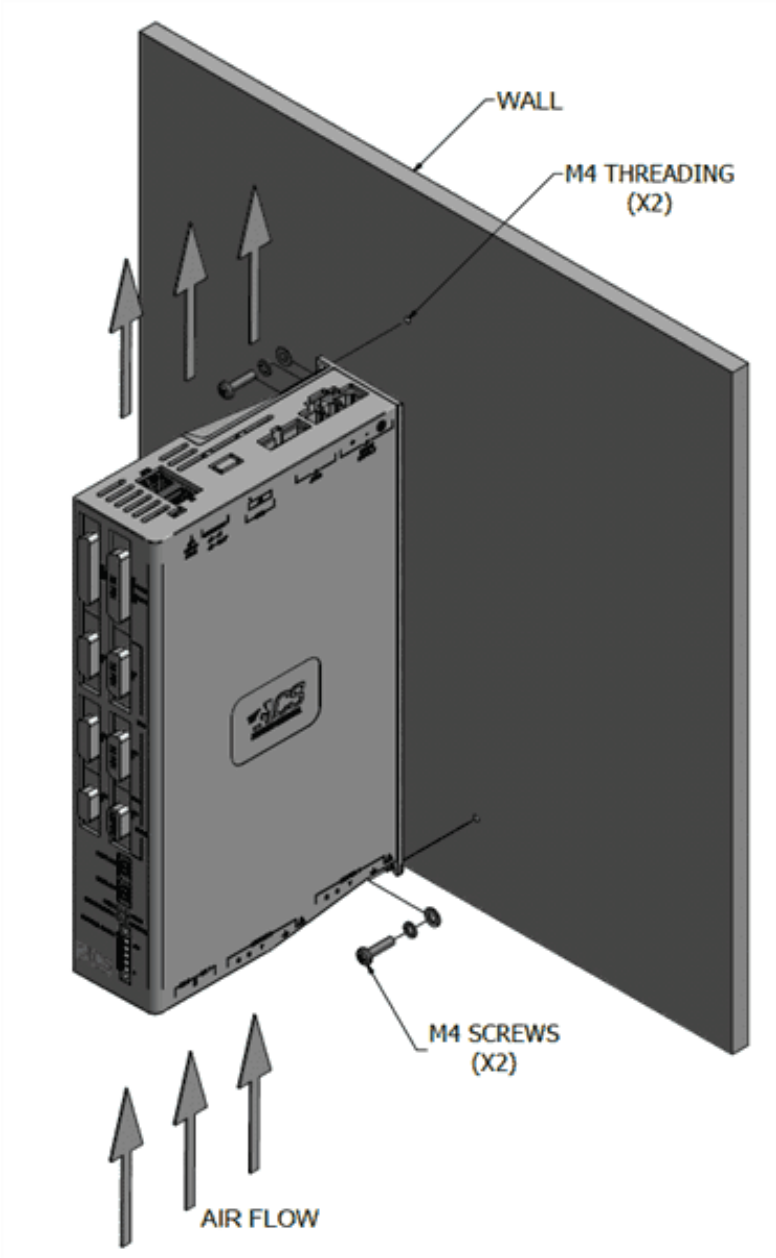


Figure 1-14. Airflow and Mounting

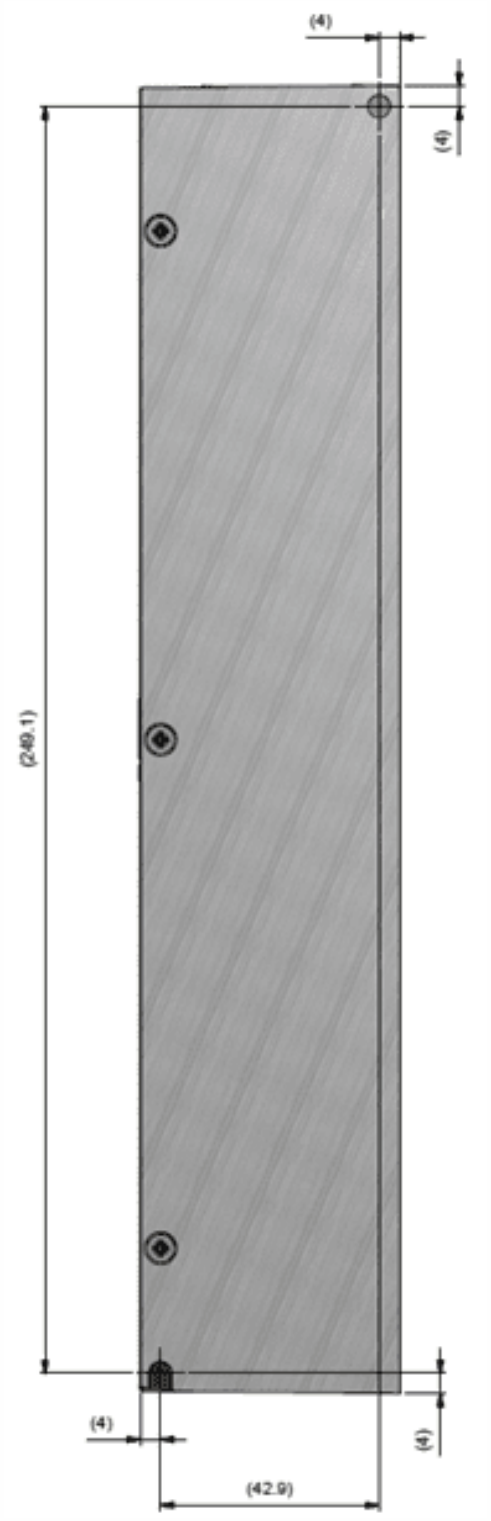


Figure 1-15. Dimensions - Rear (mounting side) View

Figure 1-16. Dimensions - Right Side View

4. Connections

This section describes how to interface with the NPAPM using proper safety, EMC and wiring guidelines.

The following diagram is a standard representation of connections and grounding. Specific settings and configurations are described in the subsections below.

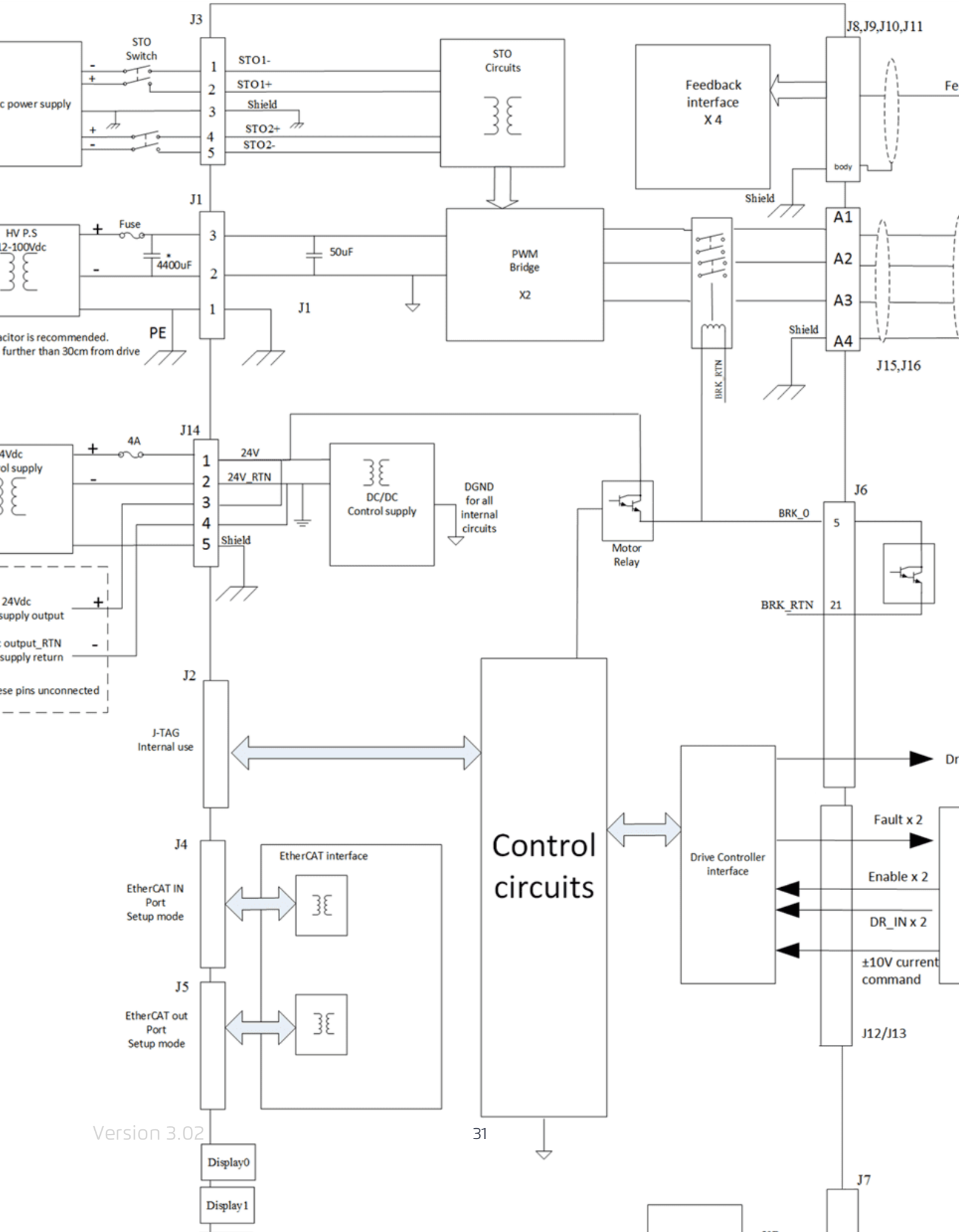

J3
STO Switch
STO1-
STO1+
Shield
STO2+
STO2-
STO Circuits
J8,J9,J10,J11
Feedback interface X 4
body
Shield
J1
HV P.S 12-100Vdc
Fuse
4400uF
50uF
PWM Bridge X2
J1
PE
A1
A2
A3
A4
Shield
J15,J16
BRK_RTN
J14
4A
24V
24V_RTN
Shield
DC/DC Control supply
DGND for all internal circuits
Motor Relay
J6
BRK_0
5
BRK_RTN
21
24Vdc supply output
output_RTN supply return
ese pins unconnected
J2
J-TAG Internal use
Control circuits
Drive Controller interface
Fault x 2
Enable x 2
DR_IN x 2
±10V current command
J12/J13
J4
EtherCAT interface
EtherCAT IN Port Setup mode
J5
EtherCAT out Port Setup mode
Display0
Display1
J7

Figure 1-17. Connections and Grounding

Table 1-11. Connections

Table 1-12. Connections

Connector Assignment	Connector Name	Description
J1	Drive supply	12 - 100Vdc, maximum recommended 96Vdc
J2	JTAG	Used by ACS to modify or upgrade the firmware.
J3	STO	Optional
J4	EtherCAT in	Used to connect to an EtherCAT Master to fine tune the current loop filter.
J5	EtherCAT out	
J6	Motor Relay	Optional
J7	Analog output	Motor phase current
J8	(Not used)	
J9	(Not used)	
J10	(Not used)	
J11	(Not used)	
J12	Drive 0	Controller-Drive 0 interface
J13	Drive 1	Controller-Drive 1 interface
J14	Control supply	
J15	Motor 0	
J16	Motor 1	

4.1 Safety, EMC and Wiring Guidelines

Read this section carefully before beginning the installation process.

Make sure that the following guidelines and procedures are addressed and observed prior to powering up and while handling any of the EtherCAT network elements.

An STO module (Safe Torque Off) is an optional feature of the unit. Additional information can be found in STO (J3).

Installation and maintenance must be performed only by qualified personnel who have been trained and certified to install and maintain high power electrical and electro-mechanical equipment, servo systems, power conversion equipment and distributed networks.

Prior to powering up the system, ensure that all EtherCAT network devices are properly installed and grounded. Further ensure that all of the attached power and signal cables are in good operating condition. Maintenance should be performed only after the relevant network devices have been powered down, and all associated and surrounding moving parts have settled in their safe mode of operation. Certain drives require a longer time to fully discharge.

To avoid electric arcing and hazards to personnel and electrical contacts, avoid connecting and disconnecting the NPAPM while the power source is on.

When connecting the NPAPM to an approved isolated control and drive supply, connect it through a line that is separated from hazardous live voltages using reinforced or double insulation, in accordance with approved safety standards.

The NPAPM is not intended for use in safety-critical applications (such as life supporting devices) where a failure of the NPAPM can reasonably be expected to cause severe personal injury or death.

J1, J15 and J16 contain hazardous voltages of 100V PWM modulated.

Perform the following instructions to ensure safe and proper wiring:

- Whenever possible, use shielded cables with braided shield of at least 80%-95% coverage.
- Follow the guidance of below, based on the current rating of your NPAPM.
- Proper wiring, grounding and shielding are essential for ensuring safe, immune and optimal servo performance. After completing the wiring, carefully inspect all wires to ensure tightness, good solder joints and general safety.

Table 1-13. Wiring Guidelines

Item	Gauge	Twisted pair
Control power supply	18AWG	No
Drive power supply	12-16AWG	No
Motor	14-16AWG	No
Motor Brake	18AWG	No
Encoders	28AWG (up to 0.6A), 26AWG (up to 1A)	Yes

4.2 Connecting the NPAPM

To connect the NPAPM:

1. Ensure that all supplies are off when preparing the unit.
2. Connect the 24Vdc control supply to J14.
3. Connect the drive supply to J1.
4. Connect motor 0 to J15.
5. Connect motor 1 to J16.
6. To verify the shape and amplitude of the drive bandwidth filter connect J7 to an oscilloscope or similar monitoring instrument.
7. Turn on the drive supply and control supply.

The supplies can be turned on and off in any order.

4.3 Power Supplies

The unit is fed by two power supplies:

> Drive Supply: 12 to 100Vdc (96Vdc recommended) (J1)

> Control Supply: 24Vdc (J14)

The power supplies must be provided by the customer and has to be UL certified. Each power supply has a LED indicator on the unit.

The supplies can be switched on and off in any order. During emergency situations, the drive supply can be disconnected while the control supply should remain connected.

4.3.1 Drive Supply (J1)

An external isolated 12Vdc to 100Vdc power supply (not included with the unit) feeds the drives and the motors.

The drive supply must be connected to the unit via fuse. The fuse rating should be calculated according to the total input current of the unit and should not exceed the ratings below.

Table 1-14. Fuse Ratings

Unit	Maximum Fuse Rating
40A peak unit	30A
30A peak unit	20A
20A peak unit	15A
10A peak unit	10A

4.3.1.1 Drive Supply Guidelines

When selecting the drive power supply, use the following guidelines:

> The NPAPM does not include a regeneration circuit. You must ensure that the DC drive supply voltage does not exceed 100V under any conditions. It is recommended to use a power supply with voltage not exceeding 96Vdc. For more details contact your ACS representative.

- The power supply must be isolated.
- The power supply must be CE and UL approved.
- The power supply must be short circuit protected.
- The power supply must have very low noise and ripple.
- Make sure the power supply can absorb the regeneration energy from the motor when it decelerates. Otherwise an external regeneration circuit is needed.
- The power supply must be able to provide the peak current required by the motor (inductance load). Adding an external capacitor of 4400uF, installed as close as possible to the drive (no further than 30cm from the drive), can help the power supply to handle the peak current and reduce the bus current ripple.
- The power supply must be selected based on the power consumed by drive 1 and drive 2 (if applicable).
- An example of a suitable 48V/1500W power supply is the XP Power P/N HPU1K5PS48 supply.

4.3.1.2 Drive Supply Description

Label: J1 DRIVE SUPPLY

Connector: 3 pin header by Molex PN 42820-3228

Mating connector: 3 pin socket by Molex PN 42816-0312; Pin: Molex PN 42815-0042; Tool: Molex PN 63811-3800

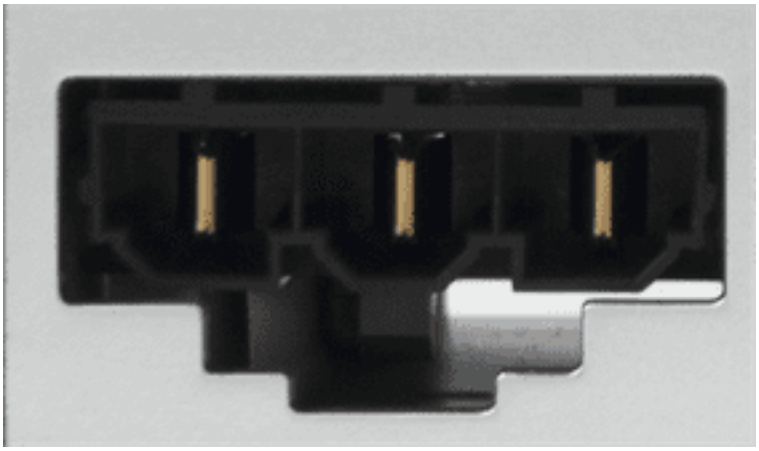


Figure 1-18. J1 - Drive Supply Connector

Table 1-15. J1 - Drive Supply Connector Pinout

Pin	Signal	Description
1	PE	Protected earth
2	VP-	Drive supply return
3	VP+	Drive supply positive edge

4.3.1.3 Drive Supply Connection Instructions

1. Use a low inductance cable with a minimum gauge of 12-16 AWG.
2. Route the drive supply and motor cables as far as possible from all other noise sensitive cables (such as encoders and I/O).
3. Connect a fast active fuse between the unit and the external power supply.
4. If required, connect the External Regeneration Circuit.
5. Connect the unit PE (Protective Earth) to the power supply PE point.

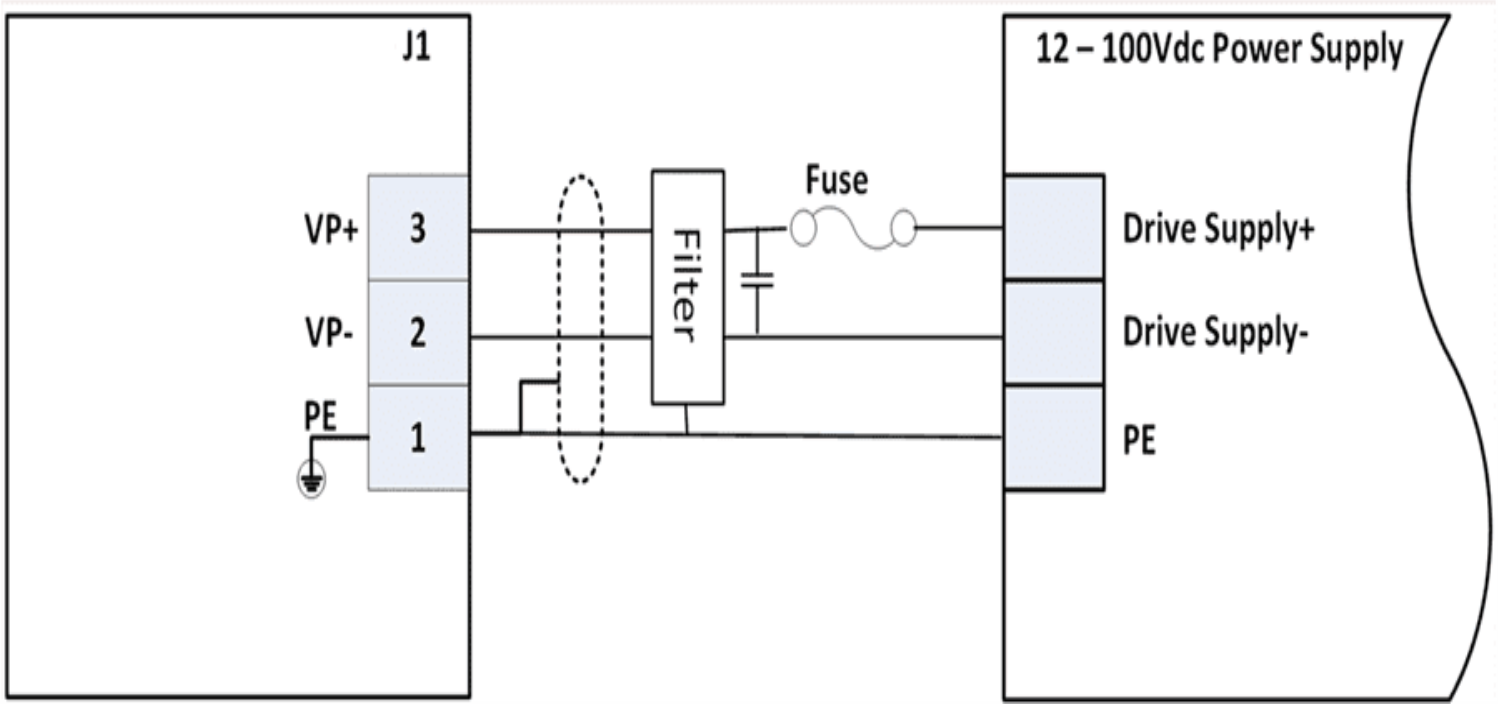


Figure 1-19. Drive Supply Connections

4.3.2 Control Supply (J14)

An external 24Vdc isolated power supply (not included with the unit) feeds all logic and control low voltage circuitry.

It is recommended to keep this power supply active (on) also during emergency stop situations, thus ensuring the continuing operation of the network, the controller, the feedback sensors and IOs.

The 24V control supply must be connected to the unit via 3A fuse.

4.3.2.1 Control Supply Guidelines

When selecting the control power supply, use the following guidelines:

- The power supply must be isolated.
- The power supply must be CE and UL approved.
- The power supply must be short circuit protected.
- The power supply must have very low noise and ripple.
- The maximum input current should not exceed 1A @ 21.6V when no external motor relays are used or 2A @ 21.6V when two external motor relays are used.
- An example of a suitable 24V/70W power supply is the XP Power P/N VCS70US24 supply.

4.3.2.2 Control Supply Description

Label: J14 24V CONTROL SUPPLY

Connector: MC 1,5/ 5-GF-3,81, by PHOENIX, PN 1827897

Mating connector: MC 1,5/ 5-STF-3,81, by PHOENIX, PN 1827732

Figure 1-20. J14 - Control Supply Connector

Pin 1 is left most pin.

Table 1-16. J14 - Control Supply Pinout

Pin	Signal	Description
1	24V_CON_SUP	24V control supply
2	24V_RTN	24V control supply return
3	BRK_SUP	Brake supply output (leave this pin unconnected)

Pin	Signal	Description
4	BRK_RTN	Brake supply output return (leave this pin unconnected)
5	EGND	Shield

4.3.2.3 Control Supply Connection Instructions

- Use a shielded cable with a minimum gauge of 18 AWG.
- Connect a 3A fuse between the NPAPM and the control supply.

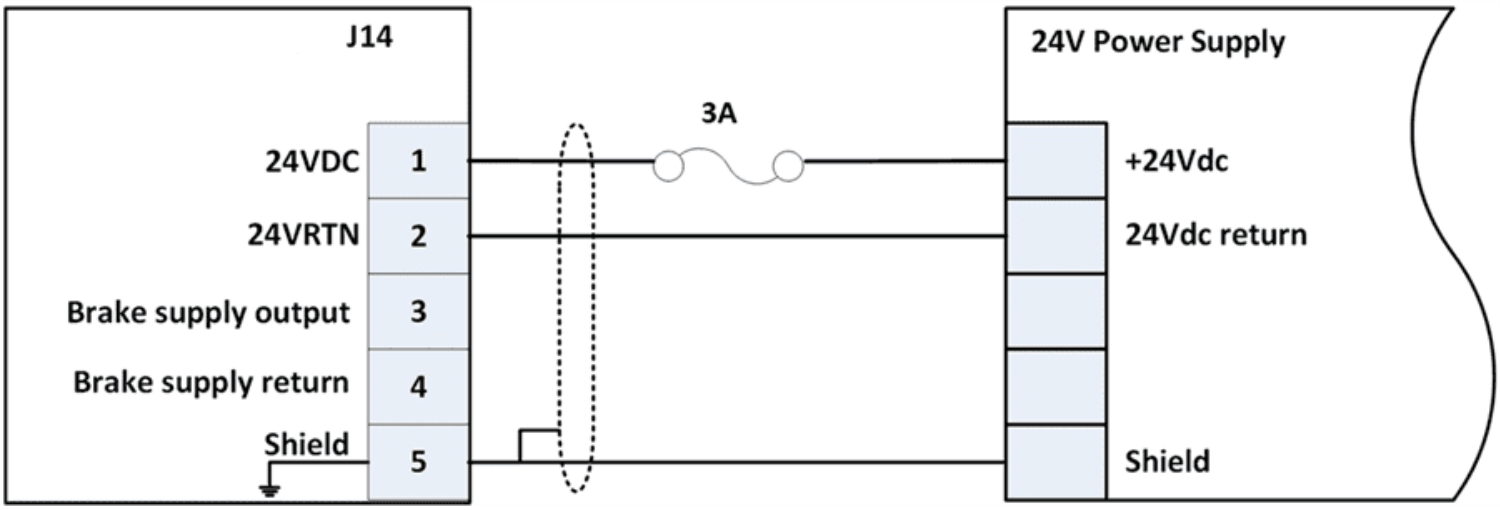


Figure 1-21. Control Supply Connections

4.4 JTAG (J2)

For ACS use only.

4.5 STO (J3)

The Safe Torque Off module is certified for use in safety applications up to and including SIL-3 according to:

- EN/IEC 61800-5-2 Ed. 2 (second environment)
- EN/ IEC 61800-5-1
- IEC 61508
- IEC 62061

Performance Level PLe and Category 3 according to:

- EN ISO 13849-1/-2

The STO is optional.

The STO (Safe Torque Off) inputs should be connected to a 24V (18Vdc to 33Vdc) source to enable the drives to generate current and feed the motors. When the 24V is removed from one or both STO inputs, the PWM signals to the power stages are blocked within 200msec. The implementation of the STO guarantees that under any foreseen circumstances, failure or damage, any of following types of motors will not move:

- AC synchronous (DC brushless)
- Step motor
- AC asynchronous (AC induction)

4.5.1 STO Description

Label: J3 STO

Connector: 5 pin 2mm male by JST P/N SM05B-PASS-1

Mating connector: 5 pin 2mm female by JST P/N PAP-05V-S; Pin: SPHD-001T-P0.5

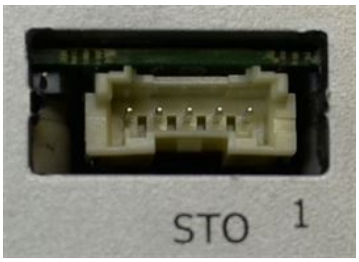


Figure 1-22. J3 - STO Connector

Table 1-17. J3 - STO Connectors Pinout

Pin	Signal	Description
1	STO1-	STO input 1 inverted input
2	STO1+	STO input 1 non inverted input
3	NC	Not connected
4	STO2+	STO input 2 non inverted input
5	STO2-	STO input 2 inverted input

4.5.2 STO Connection Instructions

The STO1 and STO2 are typically connected to a 24V source via an industry standard safety switch. This device disconnects the 24V upon opening a door, a light current tripping, or other safety related event. Details for handling STO are provided in the *Safe Torque Off Function Application Note*.

The STO circuit draws up to 50mA per STO input, with an inrush current of less than 500mA.

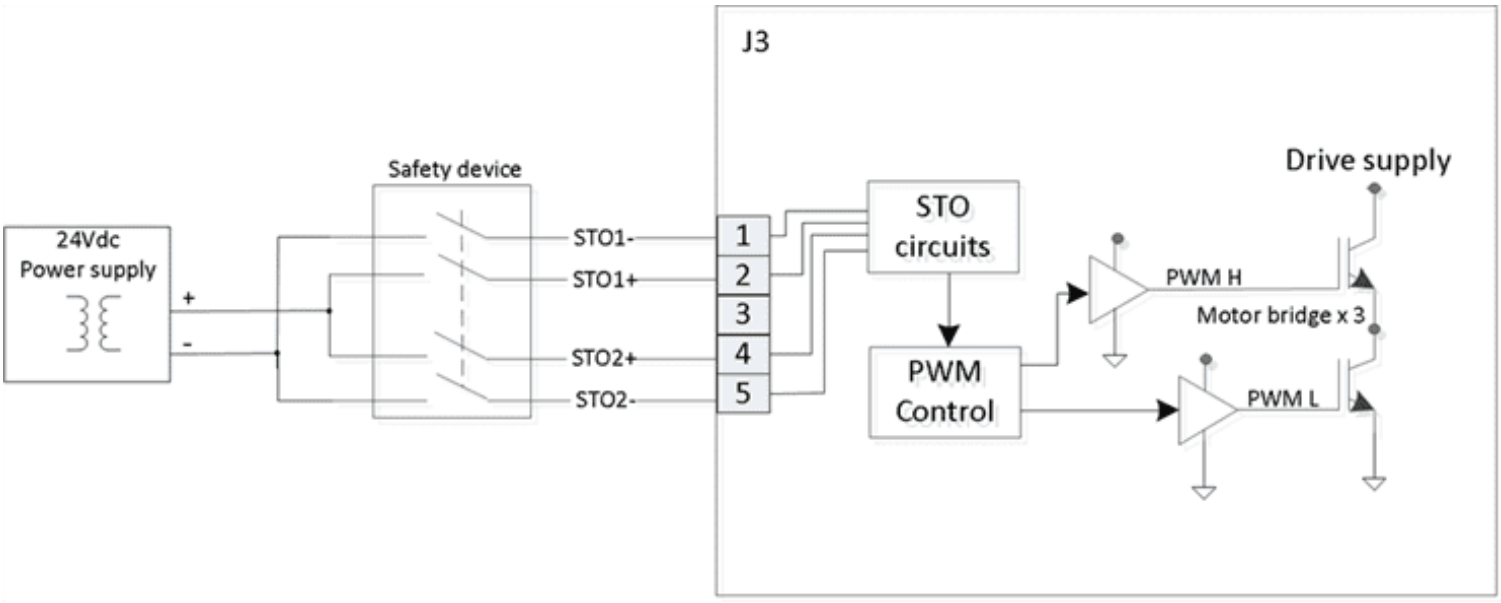


Figure 1-23. STO Connections

4.6 EtherCAT (J4, J5)

The EtherCAT is used to connect the unit to an ACS EtherCAT Master for setup purposes. When connected to such a controller, it is possible to tune the current loop filter. EtherCAT communication is active only when the unit is set to operate in setup mode by plugging a jumper to the JP1, see Calibration in setup mode.

4.6.1 EtherCAT Description

Labels: J4 EtherCAT IN, J5 EtherCAT OUT

Connectors: standard RJ45

Mating connector: Ethernet plug, Standard Ethernet CAT5e cable

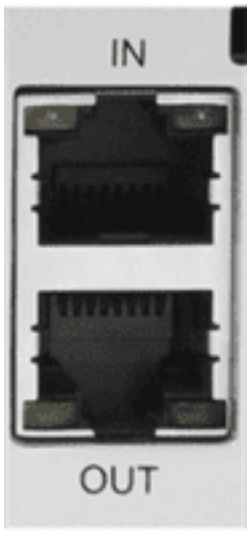


Figure 1-24. J4, J5 - EtherCAT Connectors

Table 1-18. J4, J5 - EtherCAT Connectors

Pin	Signal	Description
1	TD+	Positive transmit signal
2	TD-	Negative transmit signal
3	RD+	Positive receive signal
4	NC	Not connected
5	NC	Not connected
6	RD-	Negative receive signal
7	NC	Not connected
8	NC	Not connected

4.6.2 EtherCAT Connection Instructions

1. Use Ethernet cables CAT 5e or better. ACS offers standard cables in different lengths (see Ethernet Cables).

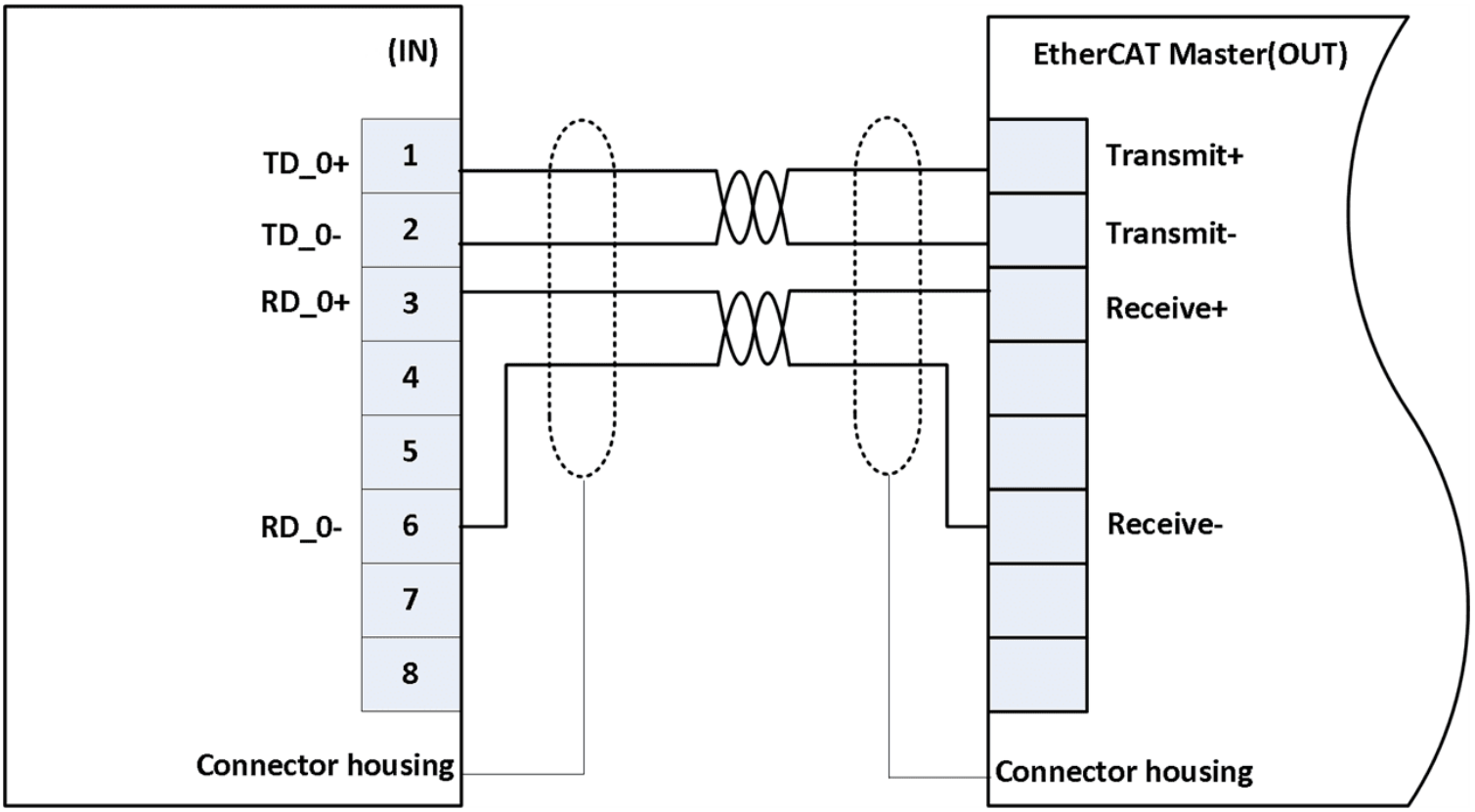


Figure 1-25. EtherCAT In (J4) Connection

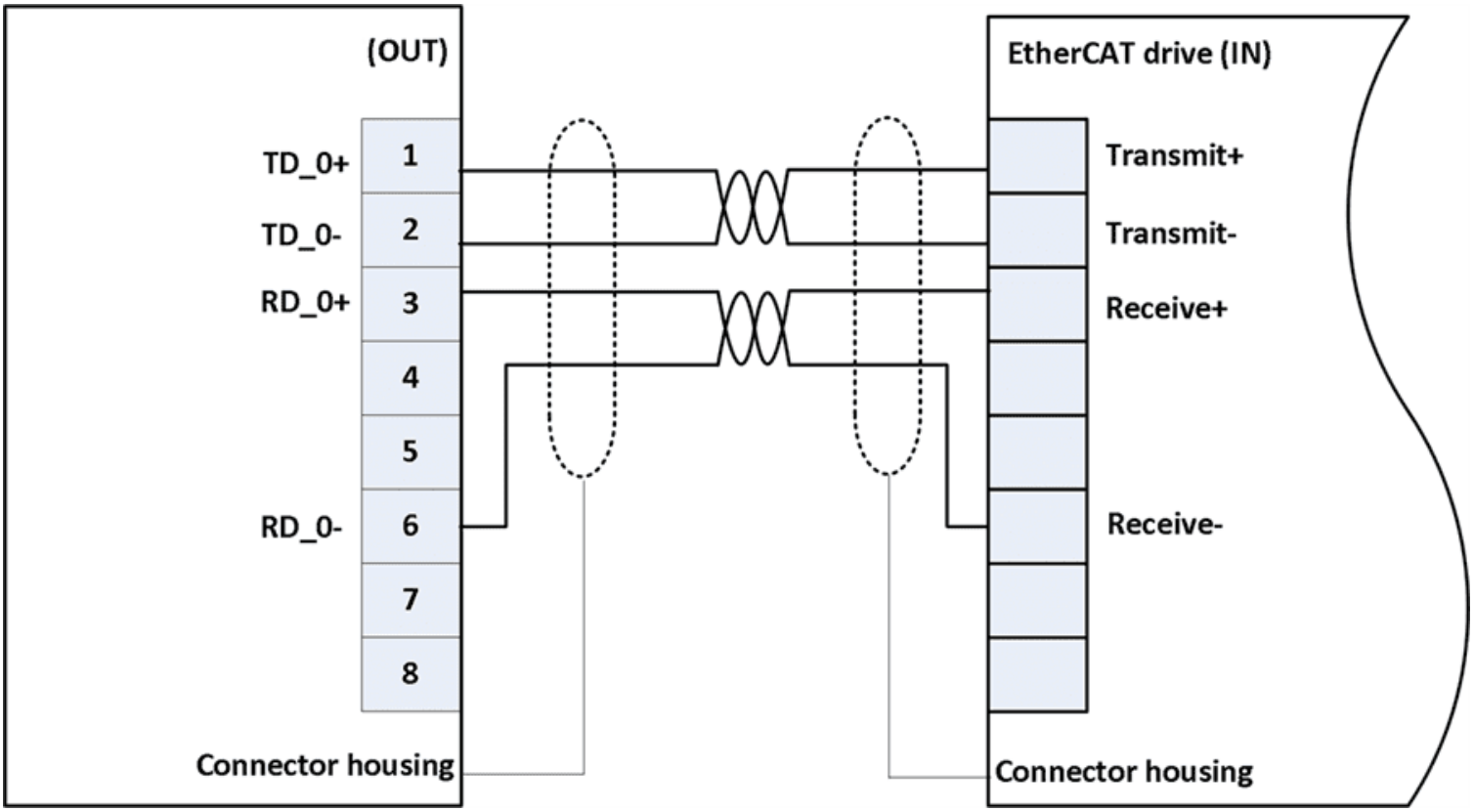


Figure 1-26. EtherCAT Out (J5) Connection

4.7 I/O

4.7.1 Analog Output(J7)

The analog output signal shows the motor phase current.

4.7.1.1 Analog Output Description

Label: J7 Analog Output

Connector: D-type 25 pin male

Mating connector: D-type 25 pin female

Figure 1-27. J7 - Analog Output Connector

Table 1-19. J7 - Analog Output Pinout

Pin	Name	Description
1	AGND	Analog ground for AIN and AOUT circuits.
2	AOUT0+	S+ phase current of axis 0
3	AOUT1+	T+ phase current of axis 0
4	AOUT2+	S+ phase current of axis 1
5	AOUT3+	T+ phase current of axis 1
6	AIN0+	Not used
7	AIN1+	Not used
8	AIN2+	Analog input 2 non inverted Not used
9	AIN3+	Not used
10	NC	Not connected
11	1_RL	Not used
12	0_RL	Not used

Pin	Name	Description
13	V_SUP_SFTY	Not used
14	AOUT0-	S- phase current of axis 0
15	AOUT1-	T- phase current of axis 0
16	AOUT2-	S- phase current of axis 1
17	AOUT3-	T- phase current of axis 1
18	AIN0-	Not used
19	AIN1-	Not used
20	AIN2-	Not used
21	AIN3-	Not used
22	NC	Not connected
23	1_LL	Not used
24	0_LL	Not used
25	V_RTN_SFTY	Not used
	Connector shell and front screw	SHIELD

4.7.1.2 Analog Output Connection Instructions

1. Use shielded cables with twisted pairs, a minimum gauge of 24 AWG and up to 10 meters in length.
2. The diagrams below show connections options for Analog output

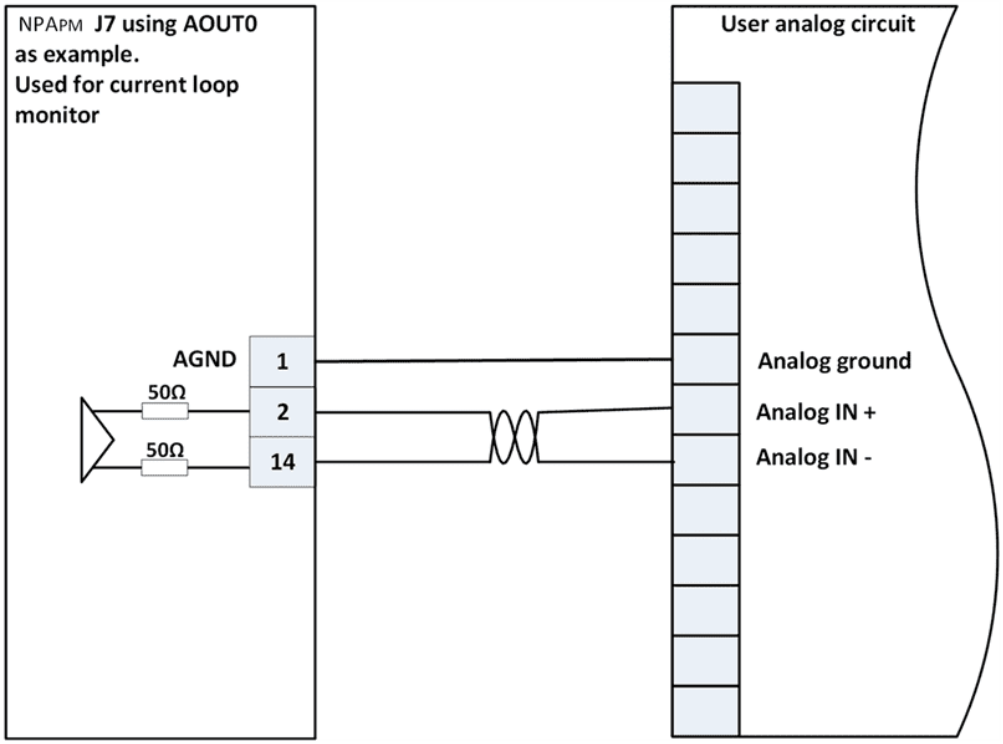


Figure 1-28. Analog Output Connection

If connecting to a single-ended scope, connect the ground of the probe to pin #1 and the positive edge to pin #2.

4.7.2 Instructions when more than one NPAPM unit is in service

When using more than one NPAPM unit use an ACS NPApm-ACC3 accessory cable to connect the units, see NPApm-ACC3 Accessory Cable. Connect the cable between J6 of the first unit and J8 of the second unit. If more than two units are used, then connect another cable between J6 of the second unit and J8 of the third unit (in a daisy chain). Follow this procedure if a fourth unit is in service.

4.8 Drive (J12, J13)

A controller that supports sinusoidal commutation of the current of the motor should be used. It should provide current commands for phases S (CMD 0) and T (CMD 1).

4.8.1 Drive Description

Label: J12 (Drive 0), J13 (Drive 1)

Connector: D-type 15 pin high density female

Mating connector: D-type 15 pin high density male

Figure 1-29. Drive Connectors

Table 1-20. J13 - Drive Connectors

Pin	Signal	Description
1	FLT_$	Drive fault output
2	DR_IN_$	Dynamic range input
3	NC	Not connected
4	CMD$_0+	Current command non inverted for S phase
5	CMD$_1+	Current command non inverted for T phase
6	ENABLE_$	Drive enable input
7	NC	Not connected
8	NC	Not connected
9	CMD$_0-	Current command inverted for S phase
10	CMD$_1-	Current command inverted for T phase

Pin	Signal	Description
11	5U	5V output for general purpose
12	DGND	Digital ground (5U return)
13	NC	Not connected
14	AGND	Analog ground
15	AGND	Analog ground
	Connector shell and front screw	SHIELD

4.8.2 Drive Connection Instructions

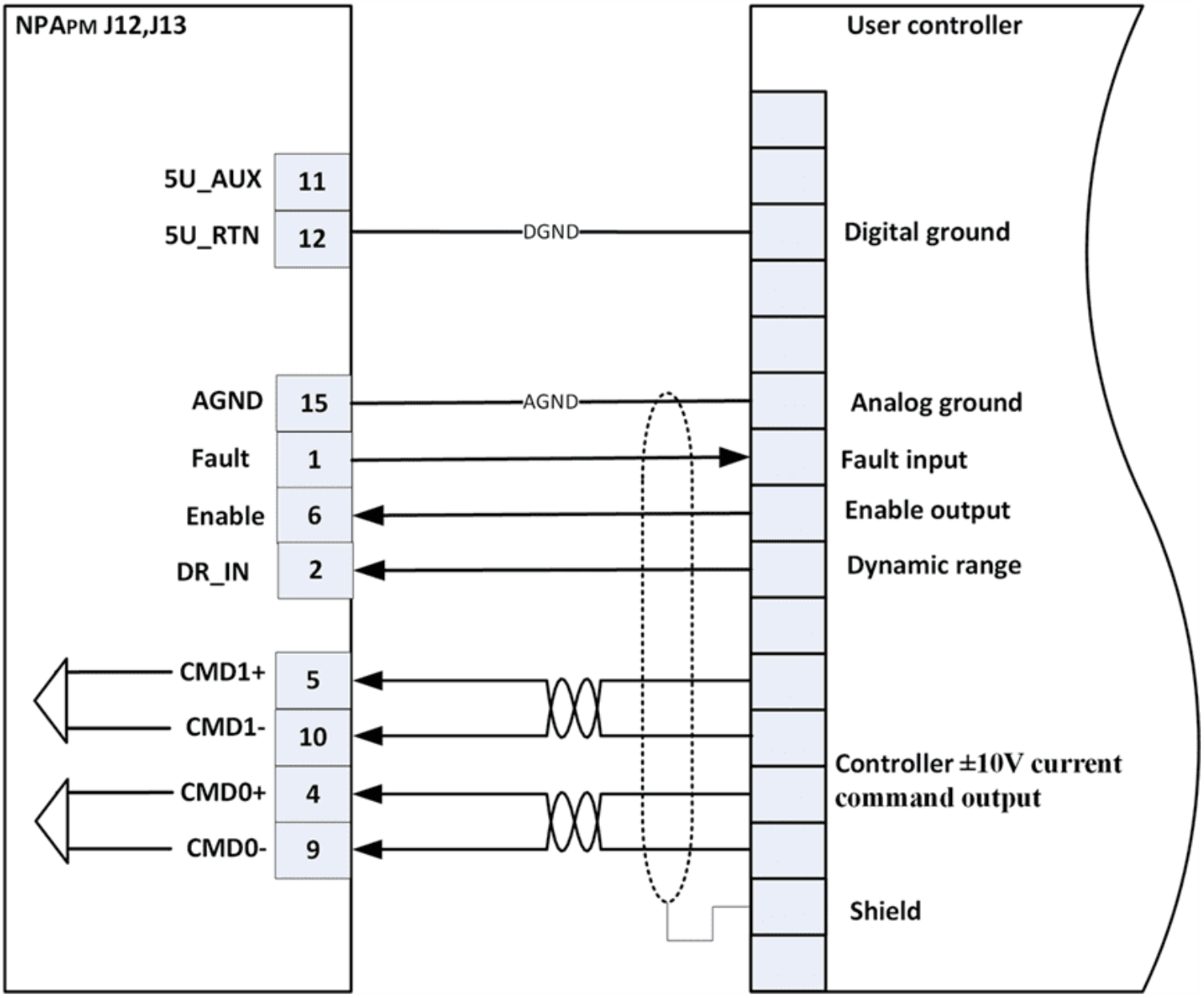


Figure 1-30. Drive Connections

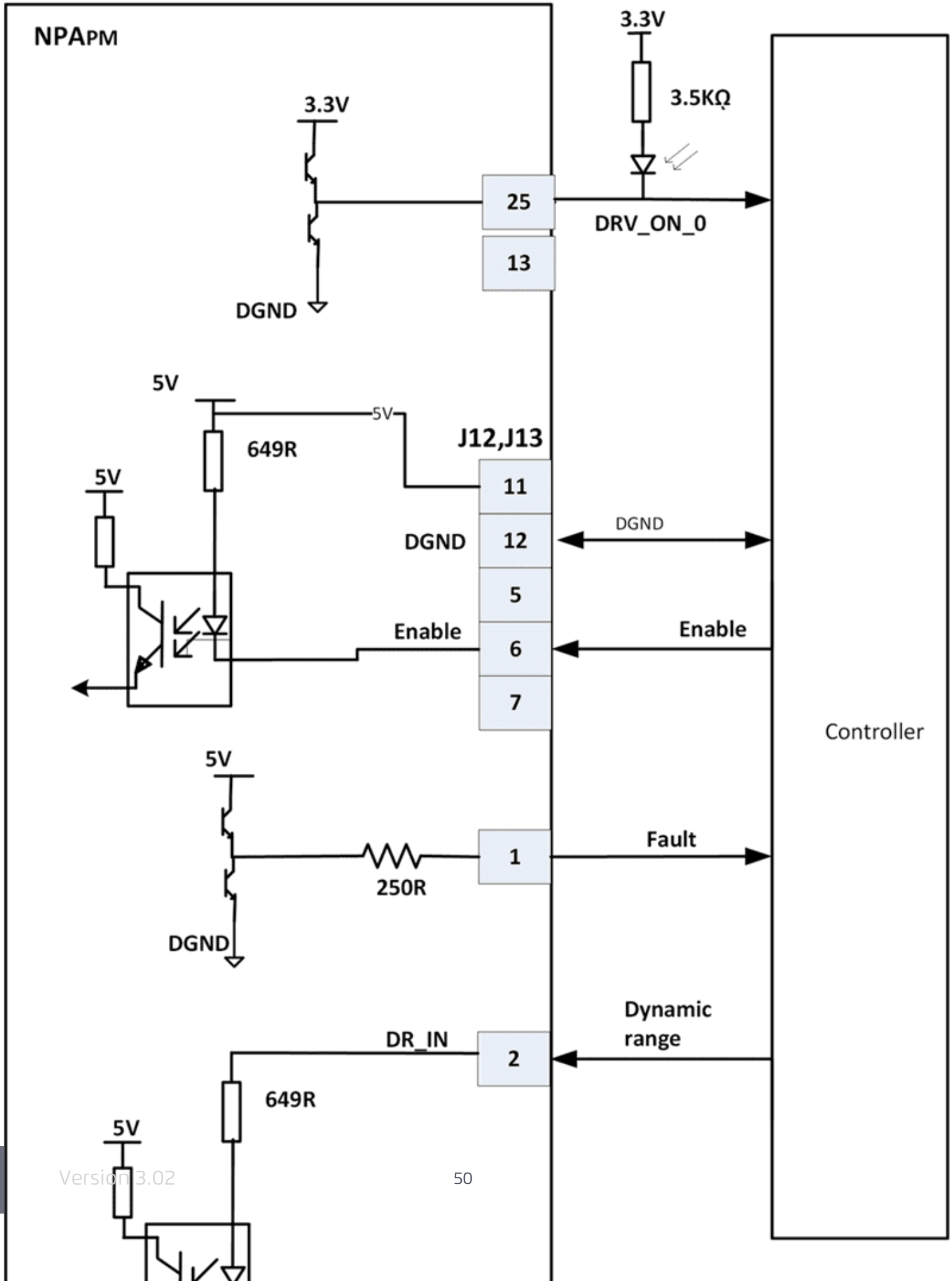

NPAPM
3.3V
3.5KΩ
3.3V
25
DRV_ON_0
13
DGND
5V
5V
649R
J12,J13
5V
11
DGND
DGND
12
5
Enable
Enable
6
7
Controller
5V
Fault
1
250R
DGND
Dynamic
range
DR_IN
2
649R
5V

Figure 1-31. Drive Connections and Grounding Details

4.9 Motors (J15, J16)

4.9.1 Motor Description

Label: J15 (Motor 0), J16 (Motor 1)

Connector: Sub D 9W4 female

Mating connector: Sub D 9W4 male. FTC PN FM9W4P-K120; Pin: FTC FMP005P103 (four required)

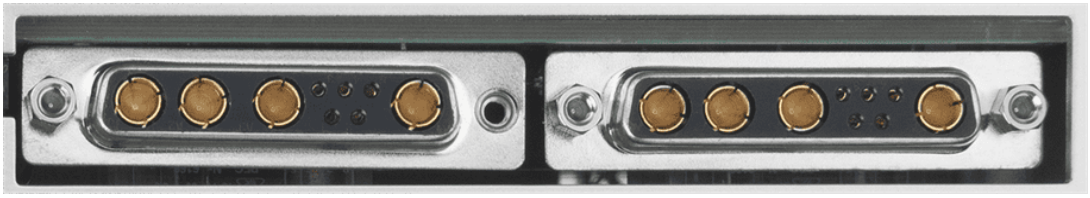


Figure 1-32. Motor Connectors

Table 1-21. J15, J16 - Motor Connectors Pinout

Pin	Signal	Description
A1	R_#	Motor R phase for DC brush, three-phase brushless motor
A2	S_#	Motor S phase for DC brush, three-phase brushless motor, single-phase motor
A3	T_#	Motor T phase for DC brush, three-phase brushless motor, single-phase motor
A4	SHIELD/PE	Motor shield
1	MTMP_#	MTMP Motor temperature sensor
2	NC	Not connected
3	MTMP_#_RTN	Return supply for MTMP
4	NC	Not connected
5	SHIELD	SHIELD
	Connector shell and front screw	SHIELD

# Denotes motor number (0,1)

Figure 1-33. Motor Connector Pin Locations

4.9.2 Motor Connection Instructions

1. Use a shielded cable with a minimum gauge of 16 AWG. It should be less than 20 meters long.
2. Route the motors' cable (and the drive supply cable) as far as possible from all other noise sensitive cables (such as encoders and I/O).
3. Connect the motors according to the figures below.

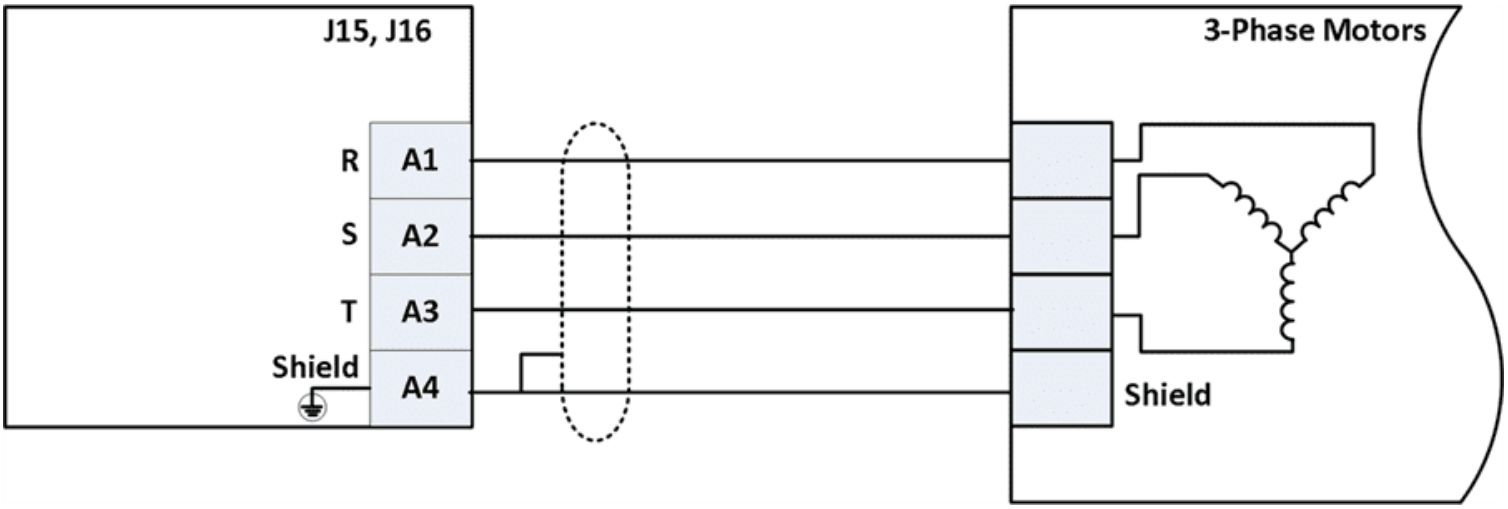


Figure 1-34. Three-Phase Motor

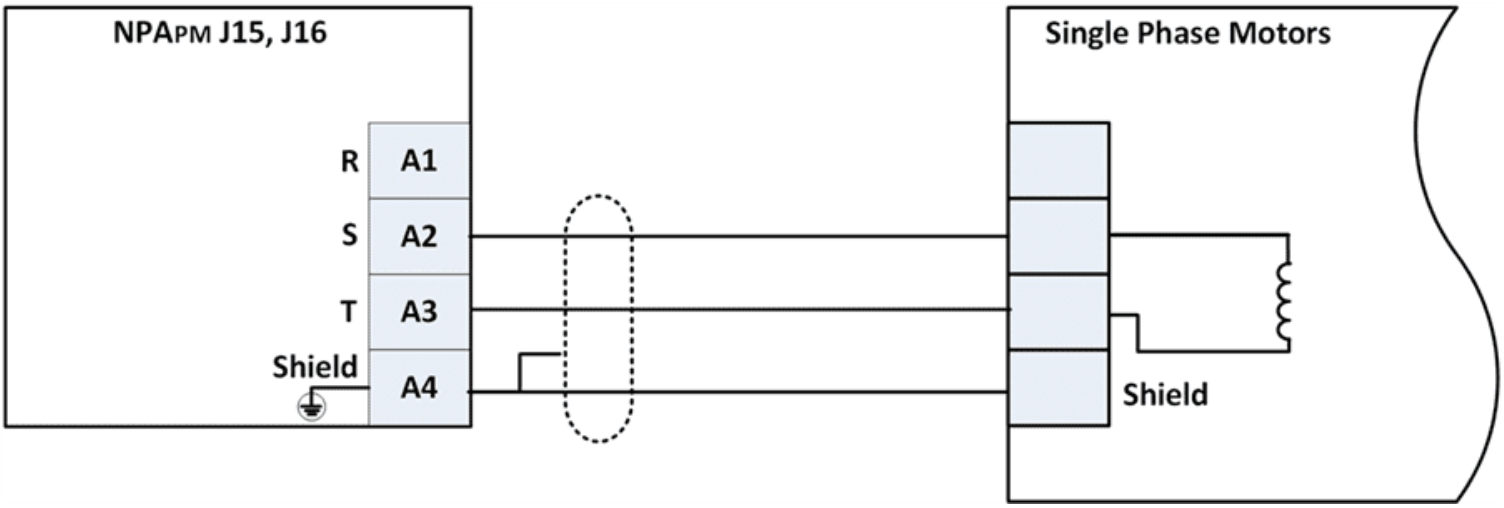


Figure 1-35. Single-phase DC brush motor or DC voice coil actuator

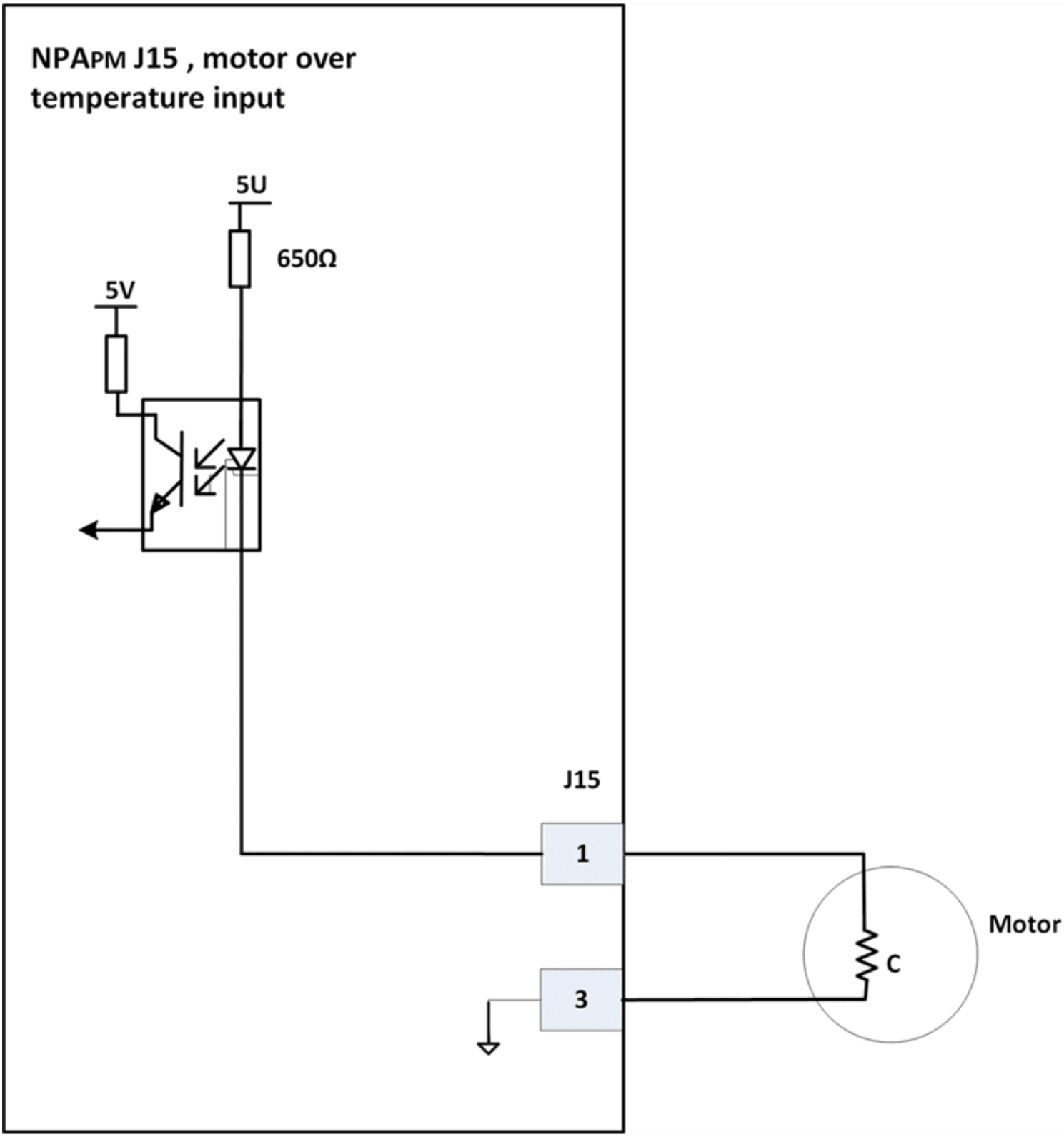


Figure 1-36. Motor Over Temperature Input

Connector J15 services Motor 0 and J16 services Motor 2.

If the motor over temperature protection is not used, then connect input pin 1 to input pin 3.

5. Product Specifications

Feature	Specifications
Drives	> Type: Digital current control with field oriented control and space vector modulation > Current ripple frequency: 40 kHz > Current loop sampling rate: 20 kHz > Programmable current loop bandwidth: up to 4 kHz. Will vary with tuning and load parameters. > Switching method: Advanced unipolar PWM > Protection: > Over & under voltage > Phase to phase > Phase to ground short  Short circuit on one of the motor phases might damage the drive. > Over current > Over-temperature  Commutation is performed using the external controller.
Supply	The module is fed by two power sources: > Motor supply > 24Vdc control supply. During emergency conditions there is no need to remove the 24Vdc control supply.
Motor Drive Supply	> Range: 12Vdc to 100Vdc, recommended 96Vdc. > Current rating of the power supply should be calculated based on actual load. > External shunt power resistor, activated at 102V, should be added in parallel to motor drive supply in the event external regeneration is required. The drive supply voltage- bus voltage must not exceed 105V under any operating conditions. > Maximum In-rush current: 100A for 40uS @100Vdc > Designation: VP, VP_RTN
Control Supply	> Range: 24Vdc ± 10% > Maximum input current / power: 0.9A @21.6V/ 20W without motor brakes > With 2 motor brakes: 1.9A @ 21.6Vdc) / 42W

Feature	Specifications
	> Protection: Reverse polarity (3Aexternal fuse must be used) > Designation: 24V_CON_SUP, CON_RTN.
Motor Type	> Two- and three- phase permnent magnet synchronous (DC brushless / AC servo) > DC brush and voice coil > Two- and three-phase stepper (micro-stepping open or closed loop)h
Drive-Controller Interface	> Current command > Type: Sin wave current commutation commands, ±10V differential, 16 bit resolution, Offset: <20mV, Bandwidth <5KHz. > Dynamic range input > 0, 5V, opto-isolated, source. Input current < 7mA. > When 0, a 10V command will generate the specified maximum current. > When 5V, a 10V command will generate 1/8 of the specified maximum current. > Drive On/Off output: TTL. 1mA. > Drive enable input: TTL, active low. Input current: <7mA. > Drive fault output: TTL, active high. Output current 1mA.
Motor relays (Optional)	> One per motor, 24V ±20% > Source, 0.5A Max > Reference: BRK_RTN > These output signals are used for external relays control (in addition to the internal ones).
Current Monitor Analog Outputs	> Four, ±10V, differential, two terminal,16 bit resolution > Offset: ±50mV, Bandwidth: 5KHz > Max. output load: 10kΩ > Noise & Ripple: <40mV > Designation: AOUT_#± (# = analog output number 0-3)
Communication (in setup mode)	> Two EtherCAT ports: In and Out > Interface: EtherCAT protocol > Speed: 100Mbps > Designation: Transmit: ETH#_TX±, Receive: ETH#_RX±
Environment	> Operating range: 0 to + 40°C > Storage and transportation range: -25 to +60°C > Humidity (operating range): 5% to 90% non-condensing

Feature	Specifications
Accessories	> NPXpm-ACC1: Mating connectors kit > UDMmc&NPXpm-ACC2: NPM (J1) mating 2m flying lead cable > STO-ACC1: STO cable > STO-ACC2: STO connector kit > Ethernet cables

Table 1-22. Drive Power Specifications

Feature	Specifications			
Per Drive	A	B	C	D
Continuous/peak current sin amplitude [A]	3.3/10	6.6/20	10/30	13.3/40
Continuous/peak current RMS per axis [A]	2.3/7	4.6/14.1	7/21.2	9.4/28.2
Maximum cont. Input current [A] @ continuous current	2.6	5.3	8	10.6
Maximum cont. Input current [A] @ peak current	8	15	24	32
Heat dissipation [W] (power loss in standby is 7[W])	7+0.9x (no. of drives)	7+2.1x (no. of drives)	7+3.7x (no of drives)	7+5.6x (no of drives)
Maximum cont./peak output power @ 100Vdc [W] (±5%)	260/780	520/1560	790/2340	1050/3120
Peak current time [sec]	1			
Minimum load inductance @100Vdc [mH] Can be derated linearly for lower voltages	0.05			
Type	3-phase NanoPWM bridge			
Phase Designation per axis	R, S, T			
Quantity	1 or 2			
Drive current loop measurement	16-bit			

Feature	Specifications
Protections	> Short & over current: 60A±5% > Over temperature: 100°C (on PCB) > Over voltage:106V±1% > Under voltage: 9V±3%

Per Module				
Control voltage input [Vdc]	24 ±10%			
Drive voltage input range [Vdc]	12 – 100 (96 recommended)			
Maximum drive voltage [Vdc]	(Vin motor) x 88%			
Maximum cont. input current per module [A]	5.2	10.6	16	21.2

Table 1-23. Motor Relay Control

Item	Description	Remarks
Designation	#_BRK	Per axis. There are two built-in relays that internally short the motor phases upon disable or drive fault. These two outputs provide up to 0.5A and work in parallel to the internal relay.
Type	24V±20%, opto-isolated, source Reference: BRK_RTN	The supply for the Brake is internal.
Output current	0.5A per output	
Protection	Short current @4A	

Table 1-24. Motor Over Temperature Specifications

Item	Description	Remarks
Designation	Motor over temperature: #_OVER_T	
Quantity	Two, one per motor	

Item	Description	Remarks
Type	> Single-ended, opto-isolated > Reference: DGND	
Threshold	> Over temperature protection is on, when the impedance between $_ Motor_OVER pin to ground is above 10kΩ > Over temperature protection is off, when the impedance between $_ Motor_OVER pin to ground is below 1kΩ	When this protection is not used, the Motor_OVER pin should be shorted to ground.
Default state	Over temperature off = Low impedance <1kΩ	

5.1 STO

Table 1-25. STO Specifications

Item	Description	Remarks
Designation	STO1±, STO2±	
Quantity	2 inputs. One input shuts off the upper part of the motor bridge and second input shuts off the lower part of the bridge.	Both drives shut off simultaneously. All drives are disabled within 200mS.
Interface	24V, two terminal for each input	
Input current (per input pin)	<50mA.	
Operation	No current -> drive off.	

5.1.1 Controller-Drive Interface

The controller-drive interface includes the following:

- 2 x Current command analog inputs
- 1 x Enable input
- 1 x Fault output
- 1 x Drive ON/OFF
- 1 x Dynamic range control input

5.1.1.1 Dynamic Range Control

This feature improves the signal/noise ratio of the current command by up to 18db. The controller should support this feature. Otherwise, it should be left unconnected. The interface includes one TTL level input per axis.

When the input is 0, a 10V command will generate the maximum current specified for the drive. For example, the output of a 10/30A drive from a 10V command generates a 30A current. When the input is 1, a 10V command will generate 1/8 (12.5%) of the maximum specified current. In the above example, 10V command will generate current of 2.5A.

The controller can dynamically change the value and thus improve the quality of the command when a low command is required, during stand still and when moving the motor at a constant speed, see Current command dynamic range activation.

Table 1-26. Dynamic Range Input

Item	Description
Designation	DR1,0
Quantity	One input per axis
Type	> TTL level > Reference: DGND
Interface	5V, opto-isolated, Source input type.
Input current	< 7mA current.
Default state	DR=0 (Actual range = Programmable range)

5.1.1.2 Drive On/Off Output

Table 1-27. Drive On/Off Output

Item	Description
Designation	DRV_ON_#±

Item	Description
Quantity	1 per axis
Interface	> TTL level > Reference: DGND
Output current	1mA per output
Logic state	> Drive On = 0 > Drive Off = 1 (3.3V)

5.1.1.3 Current Command

Table 1-28. Current Command

Item	Description
Designation	CMD0_#± CMD1_#±
Quantity	4
Interface	±10V differential input
Command input filter bandwidth	5KHz
Resolution	16-bit
Offset	<20mV
SNR	>84db

5.1.1.4 Drive Enable Input

Table 1-29. Drive Enable Input

Item	Description
Designation	ENA_#
Quantity	One per axis
Interface	> TTL level, active low. > Reference: DGND

Item	Description
Input current	< 7mA current.
Logic state	> To enable the drive, ENA pin must be asserted low (ground). > When no current flows through the input, the drive is disabled.

5.1.1.5 Drive Fault Output

Table 1-30. Drive Fault Output

Item	Description
Designation	FLT_#
Quantity	One per axis
Interface	> TTL level, active high > Reference: DGND
Output current	1mA per output
Logic state	In the event of a drive fault, the drive is disabled and the output is set to 1. Note: The drive fault is cleared by enable command. The fault reset propagation delay is 60 µsec.

5.2 Dimensions

- Length: 257 mm
- Depth: 154.9> mm
- Height: 50.9 mm

5.3 Weight

- 1.6kg

5.4 Compliance with Standards

5.4.1 Environment

The operational temperature range is from 0 to + 40°C. General guidelines are below. Use the following graphs to calculate if forced air cooling is required.

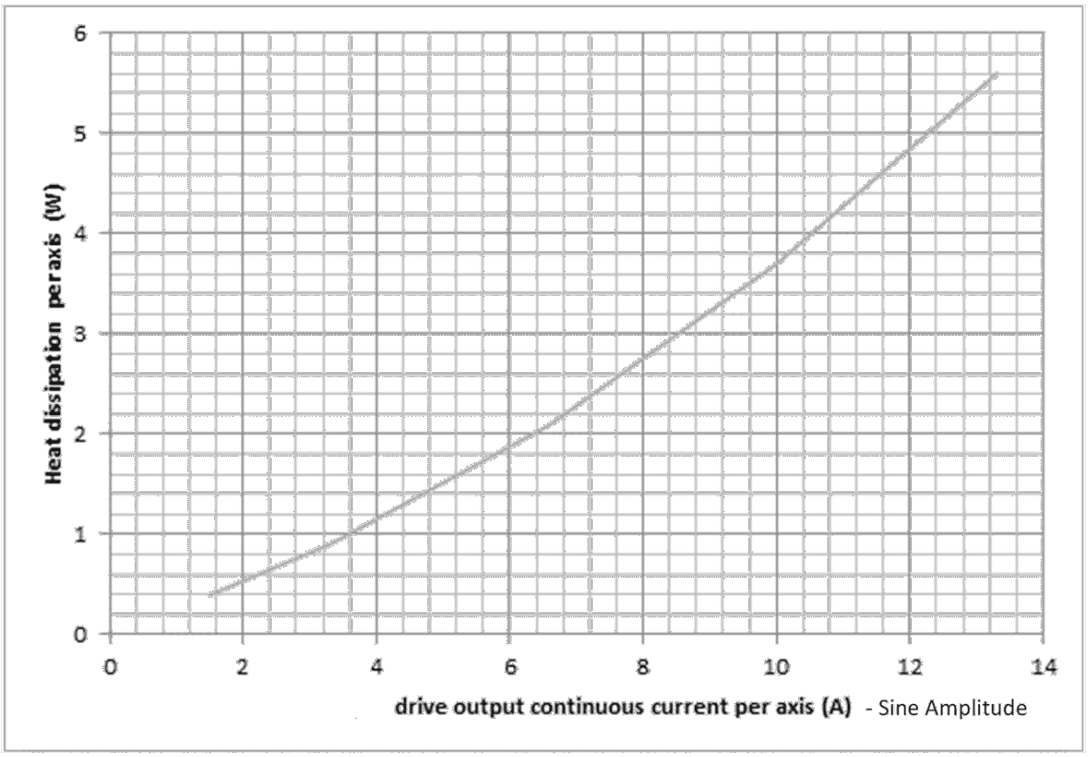


Figure 1-37. Heat Dissipation per Axis

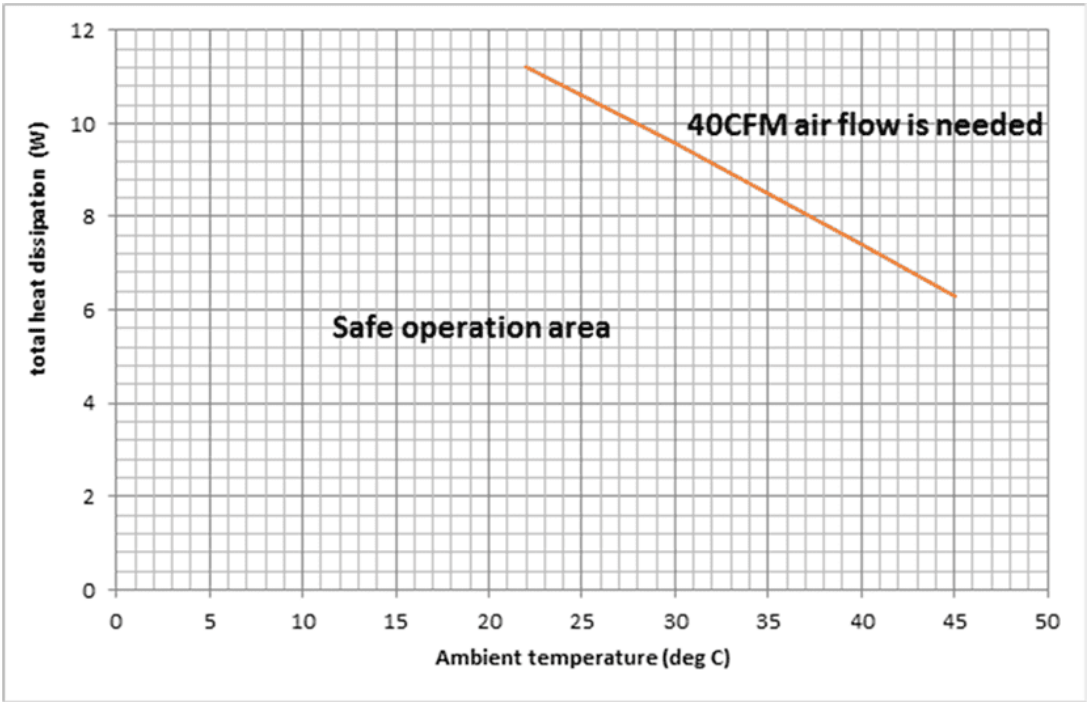


Figure 1-38. Total Heat Dissipation

5.4.2 CE

> IEC 61800-3:2012(2.1nd Edition) follwing the provisions of 2014/30/EU directive

- EN61800-5-2 follwing the provisions of 2014/30/EU directive

5.4.3 Safety

- Functional safety
  - EN 60204-1 : 2006 (+A1`:2009, + AC :2010 Stop Category 0)
  - EN ISO 13849-1 : (+ AC :2009 Category 3; PL e)
  - EN 62061 : 2005 (+ AC :2010, + A1 :2013 SIL CL 3)
  - IEC61800-5-2:2016 Safe Totque Off (STO)
  - EN 61800-5-1:2007
  - IEC 61800-3 :2017
- Electrical safety
  - UL61800-5-1
  - IEC 61800-5-1:2007 (2nd Edition) follwing the provisions of 2014/35/EU (Low Voltage Directive)

5.4.4 RoHS

- Design complies with ROHS requirements.

6. Operation modes

The NPAPM drive operates in two modes:

- Normal operation
  - The drive feeds current to the motor relative to current commands provided by an external controller. The unit is shipped from ACS set to this mode.
  - While in normal operation mode, the current loop tuning can be set to 16 different discrete values via DIP switches, see .
- Setup
  - Is used for calibration and fine tuning of the drive. All revised parameters are stored in the nonvolatile memory of the unit.
  - Requires an ACS master controller. In this mode the drive acts as an EtherCAT slave.
  - Enables calibration of the command signal offsets for an entire system consisting of the external controller and the drive ("End to End"), see . It is advisable to perform this action for controllers which do not have an offset compensation option for the command signals.

Calibration of the drive in setup mode is not mandatory. Before shipping, the current command signals are calibrated to have zero offset. The driver should be calibrated only if fine tuning of the current loop and/or “End to End” command offset calibration is required.

6.1 How to Set the Operation Mode

The operation mode is set by jumper JP1. When closed (installed), the unit is in Setup mode. When open, the unit is in Normal operation mode, see Initial System Setup for more details.

6.2 Operation in normal mode

Normal operation is the regular operation mode of the driver. The unit is shipped from ACS set to this mode.

6.2.1 Current Loop Filter Tuning in Normal Operation Mode

The current loop filter gains are set by DS0 (Drive 0) and DS1 (Drive 1) DIP switches according to the following table.

Proportional (**SLIKP**)	Integral (**SLIKI**)	DIP Switch code
Values saved in the non-volatile memory of the drive		0000
150 300 600	500	0001 0010 0011

Proportional (**SLIKP**)	Integral (**SLIKI**)	DIP Switch code
1200 2400		0100 0101
150 300 600 1200 2400	4000	0110 0111 1000 1001 1010
150 300 600 1200 2400	8000	1011 1100 1101 1110 1111

The default factory setting for SLIKP is 100 and SLIKI is 1000 with a DIP switch code 0000.

6.2.1.1 Initial Guesses for I and P Gains

The initial guess for the I and P gain parameters should be based on motor parameters.

For integral gain:

$$SLIKI = 3.2\frac{R_{p-p}}{L_{p-p}}$$

For proportional gain:

$$SLIKP = 5 \cdot BW_{CUR} I_p L_{p-p}$$

Where

$I_p\ [A]$ Peak current of the NPApm unit

$L_{(p-p)}\ [mH]$	phase to phase inductance of the motor
$R_{(p-p)}\ [\Omega]$	Phase to phase resistance of the motor
$BW_{(CUR)}\ [Hz]$	Crossover frequency of the current in "open loop" FRF

The crossover frequency of the current loop can be considered as the current loop bandwidth. Typical values are between 800 - 2000 [Hz].

6.2.1.2 Fine Tuning

To fine tune the I and P gains follow one of the methods below.

Using a current probe

1. Connect a current probe to phase "S".
2. Send a square wave command to phase "S" of the NPAPM drive.
3. Select a DIP switch combination which results in the fastest current loop response while maintaining stability.

Using a differential voltage probe

1. Measure the following signals
   a. "S" phase current of drive 0 – pins 2,14 of connector J7
   b. "T" phase current of drive 0 – pins 3,15 of connector J7
   c. "S" phase current of drive 1 – pins 4,16 of connector J7 d. "T" phase current of drive 1 – pins 5,17 of connector J7
2. Send a square wave command to phase "S" of the NPMpcNPApmNPApc drive.
3. Select a DIP switch combination which results in the fastest current loop response while maintaining stability.

Using a single ended voltage probe

1. Measure the following signals
   a. "S" phase current of axis 0 – pins 1,2 of connector J7
   b. "T" phase current of axis 0 – pins 1,3 of connector J7
   c. "S" phase current of axis 1 – pins 1,4 of connector J7
   d. "T" phase current of axis 1 – pins 1,5 of connector J7
2. Send a square wave command to phase "S" of the NPApm drive
3. Select a DIP switch combination which results in the fastest current loop response while maintaining stability.

6.2.1.3 Fine Tuning Example

Motor Parameters:

$$R_{(p-p)} = 3\,[\Omega],\ L_{(p-p)} = 2.8\,[mH]$$

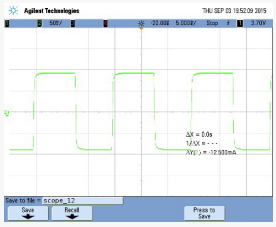
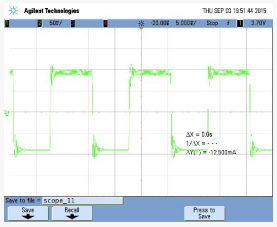
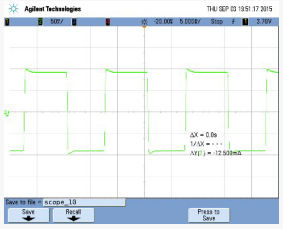
Drive parameters;

$$I_p = 20\,[A]$$

Initial guess is:

$$SLIKI = 3.2\frac{3}{2.18}1000 = 3428$$

$$SLIKP = 4 \cdot 1000 \cdot 20 \cdot 2.8 \div 1000 \ = \ 280$$

Initial Guess	First Iteration	Second Iteration
Good but may be faster	Nearly unstable	Fast and stable
DIP - 0111	DIP - 1000	DIP - 1100
SLIKP = 300, **SLIKI** = 4000	**SLIKP** =600, **SLIKI** = 4000	**SLIKP** = 300, **SLIKI** = 8000
		

6.2.2 Current Command Dynamic Range Activation

While the motor is at stand still or moving at a constant velocity, the current commands are low. The input commands can be rescaled (scale factor is 1:8) to improve the resolution and the signal to noise ratio (SNR) of the command. Improving the SNR should result in smaller stand still jitter and constant velocity following errors.

The dynamic range is enabled by setting DR_IN to a logic 1 state by providing a 5V command to pin 2,14 of connector J12 for drive 0 and to pin 2,14 of connector J13 for drive 1.

The motion controller should select the dynamic according to motion state:

1. The dynamic range should be turned OFF during acceleration/deceleration to allow high command to be received.
2. The dynamic range should be turned ON during constant velocity and right after motion to allow smoother velocity and lower stand still following error.

Dynamic Range State	DR_IN Logic State	% of Maximum Current Output from a 10V Command
OFF	0	100
ON	1	12.5

To ensure stability of the entire control loop, the controller should also modify servo gains when modifying the dynamic range.

When the dynamic range is 12.5% (DR_IN = 1), the following two parameters should be updated simultaneously with the dynamic range state.

- Proportional gain of the servo loop - "open loop" should be increased by a factor of 8.
- Acceleration feed-forward should be increased by a factor of 8.

Example:

The following ACSPL+ code illustrates the activation of the dynamic range feature with ACS controller when the motion is completed.

```
GLOBAL INT DR, AXIS ! Define variables
AXIS=0 ! Assign number to AXIS variable
ENABLE(0) ! Enable motor
PTP(0), 10 ! Start Point to point motion
STOP ! Stop program execution
ON ^MST(0).#MOVE ! Upon a state that motor does not move perform the
                 ! following
DR.AXIS = 1 ! Set internal variable to 1
RET
ON DR.AXIS ! Upon DR.AXIS is set
BLOCK ! Block means that all following command will be executed in a
single controller cycle
OUT(0).16 = 1 ! Set external output that will send
5[V] command to the NPA drive to activate
dynamic range
SLVKP(AXIS) = 1000*8 ! Multiply proportional gain by a factor
of 8
SLAFF(AXIS) = 0.268*8 ! Multiply acceleration feed forward by
factor of 8
END
RET
ON ^DR.AXIS ! Upon DR.AXIS is cleared
BLOCK ! Block means that all following command will be executed in a
      ! single controller cycle
SLVKP(AXIS) = 1000 ! Set proportional gain to its original
                   ! value
.......SLAFF(AXIS) = 0.268 ! Set acceleration feed forward to its
                           ! original value
OUT(0).16 = 0 ! Clear external output that will send 0[V]
              ! command to the NPA drive to deactivate dynamic range
END
RET
```

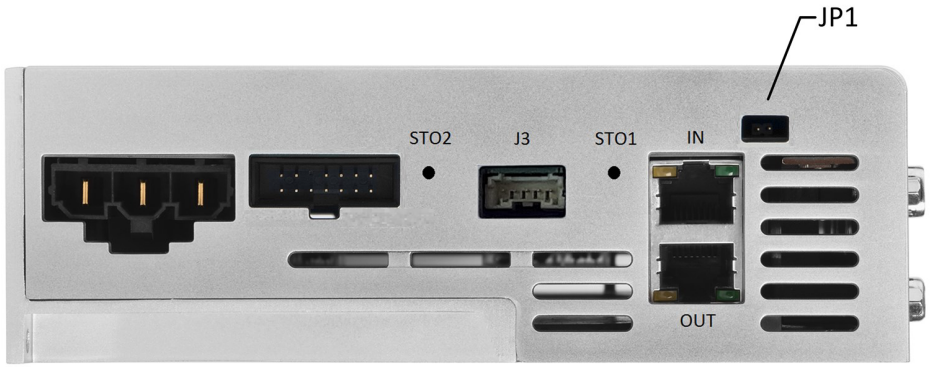
6.3 Calibration in Setup Mode

To fine tune and calibrate the drive in Setup mode any ACS EtherCAT master controller and the SPiiPlus MMI applicaton studio are needed. The SPiiPlus MMI application studio is available for download from the ACS website.

6.3.1 Initial System Setup

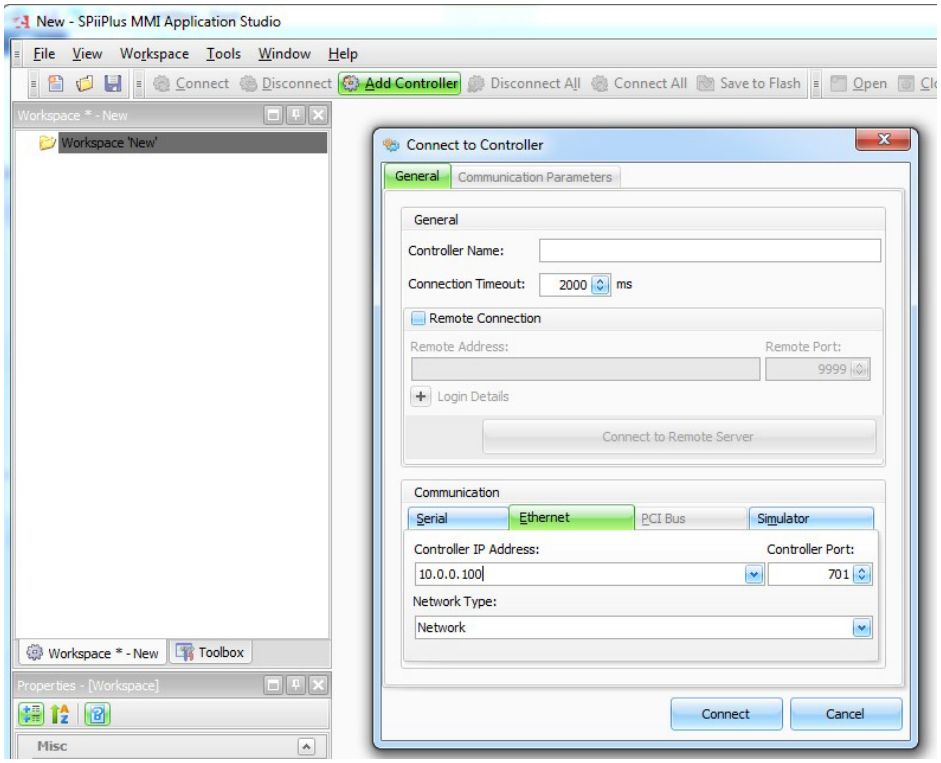
Setting up the system:

1. Turn off the control supply.
2. Turn off the drive supply.
3. Set the NPApm in setup mode by installing a jumper on JP1.
4. Connect the NPApm to an ACS motion controller using an EtherCAT cable.
5. Connect the controller to a PC that runs the SPiiPlus MMI application studio using an Ethernet cable.
6. Turn on the control supply.
7. Turn on the drive supply.



6.3.2 Establishing Communication

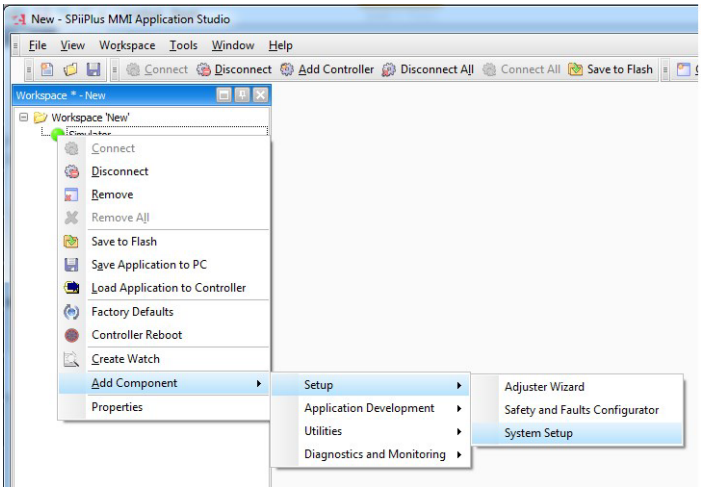
1. Open SPiiPlus MMI Application Studio.
2. From the main window, click Add Controller, the Connect to Controller window appears



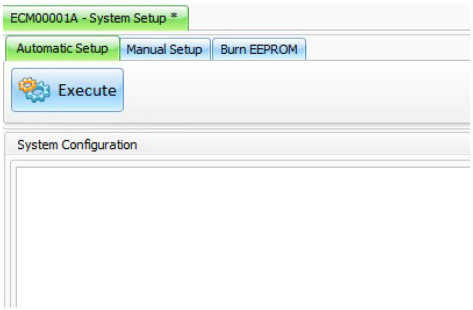
3. Select **Ethernet**

> The default IP address of the controller is 10.0.0.100.

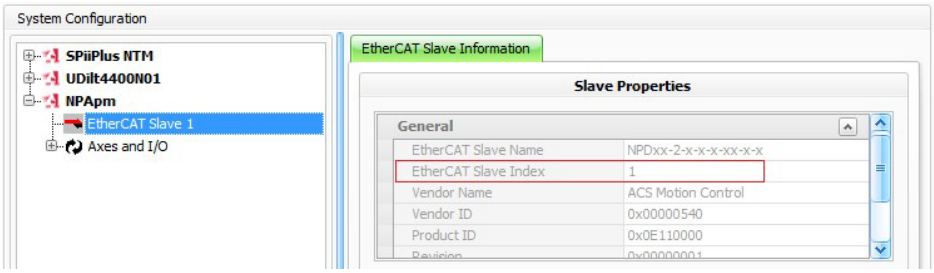
4. Click **Connect**.
5. Right-click the controller in the Workspace Tree, the Controller Right-Click Options window appears.



6. Select Add Component > Setup > System Setup, the System Setup window appears.



7. Click Execute, after the configuration process is complete, the System Configuration window appears.



The EtherCAT slave number is also available by:
1. Right-clikc the controller in the Workspace Tree (as in step 5 above); the **Controller Right-Click Options** window appears.
2. Select **Add Component > Diagnostics and Monitoring > System Viewer and Diagnostics**, **the System Viewer and Diagnostics** window appears.
3. Select **Retrieve**, the system configuration stored in the controller is displayed.

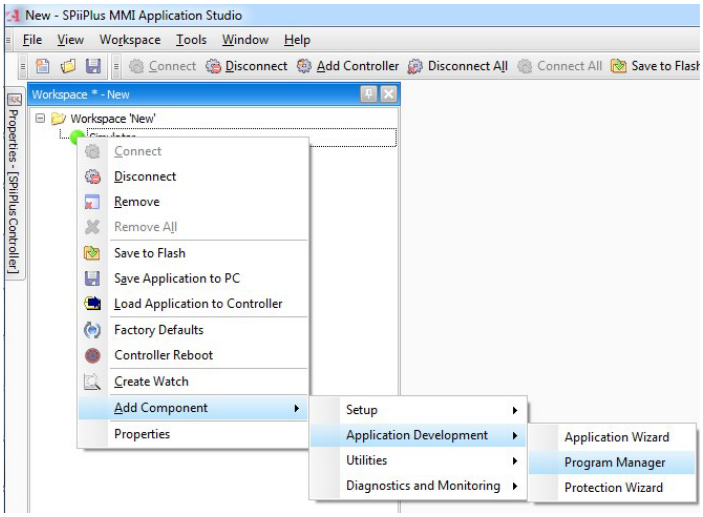
8. The EtherCAT network is identified. Note the EtherCAT Slave Index. It is a required input in the calibration program.

Now the current loop can be tuned using the MMI, see Current Loop Filter Calibration and Tuning.

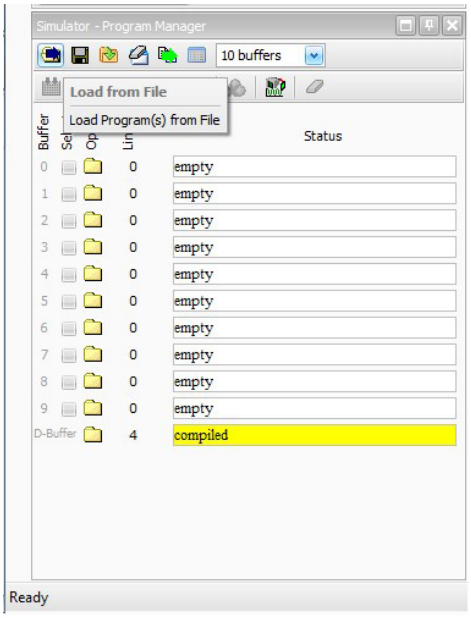
6.3.3 Command Offset Calibration

ACSPL+ programs are used for command offset calibration and to save current loop parameters to a controller's non-volatile memory, see How to perform an "End to End" calibration and Saving parameters to flash memory.

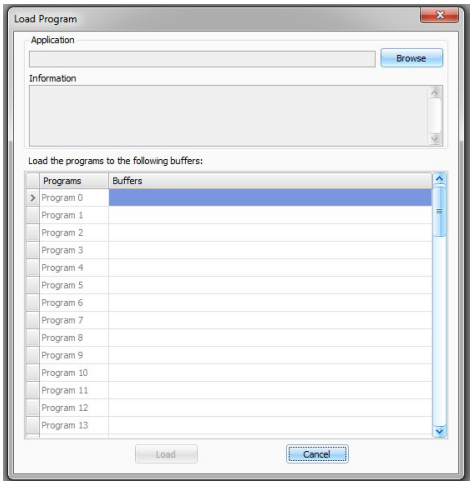
1. Right-click the controller in the Workspace Tree, the Controller Right-Click Options window appears.



2. Select Add Component > Application Development > Program Manager, the Program Manager window appears.



3. Click on **Load from file**, the **Load Program** window appears.



4. Click **Browse** to search for the file (when found, select the file).

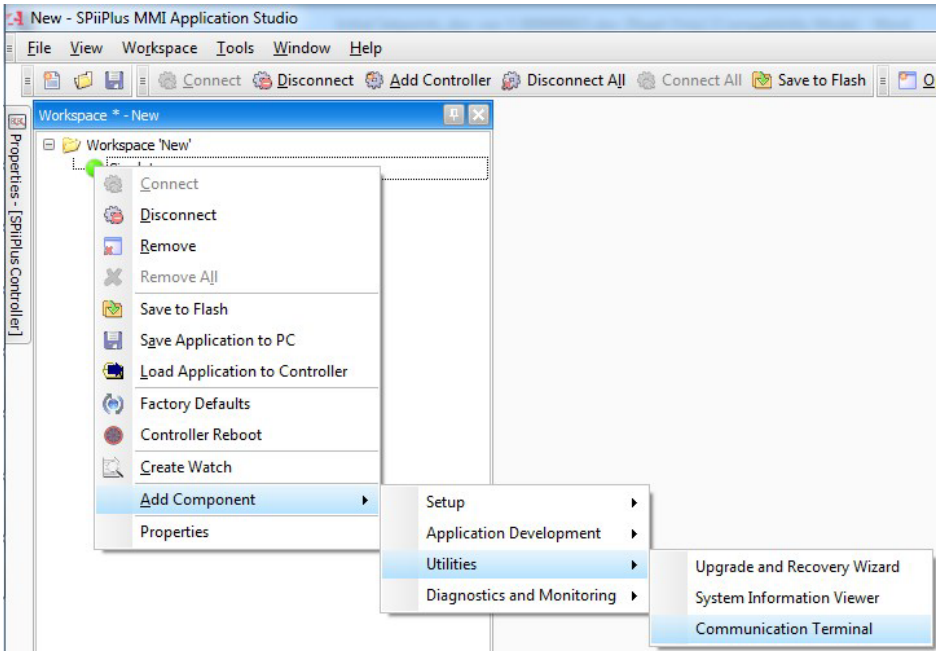
Program files have a prg extension .

5. Click OK, the file is loaded into the buffer.

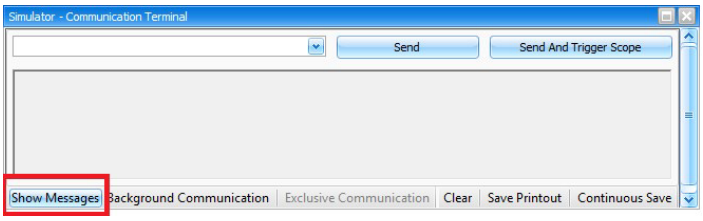
6.3.4 Monitoring Offset Calibration Progress

The Communication Terminal is used for communication between a host PC (running the MMI Application Studio) and the controller. The Communication Terminal is used to monitor offset calibration progress, see Saving Parameters to Flash Memory.

1. Right-click the controller in the Workspace Tree, the Controller Right-Click Options window appears.



2. Select **Add Component > Utilities > Communication Terminal**, the **Communication Terminal** window appears.



3. Click **Show Messages**. Messages sent by a DISP command from any program running in the controller are displayed.

6.3.5 Current Command Offset Calibration

Current commands (pins 4,9 and 5,10 in connectors J12 and J13) are calibrated at the factory to have zero offset.

After the drive is connected to a controller, the controller command analog outputs should be recalibrated so that a zero command by the controller produces zero current.

Two options are available for recalibration.

> Calibrate the external controller to have zero offset in the corresponding command signals.

> Recalibrate the NPAPM offsets "End to End".

6.3.5.1 How to Perform and "End to End" Calibration

To perform an "End to End" calibration:

1. Configure the NPAPM to operate in setup mode, see Calibration in Setup Mode.
2. Setup the EtherCAT network, see Establishing Establishing Communication.
3. Connect a controller to the NPApm drive connectors J12 an dJ13.
4. Set the controller to output zero commands as command outputs.
5. In Program Manager, load the “End2EndCalibrationProgram.prg” program, see EndToEndCalibrationProgram.prg.

When the calibration program runs, the axes are enabled. The BUS voltage should be connected during this process. A motors connection is not required.

6. Open a communication terminal and enable it to show messages, see Monitoring Offset Calibration Progress.
7. In **Program Manager**, click **Select** adjacent to the buffer where the“End2EndCalibrationProgram.prg" is stored.
8. Click, the **Run Buffer(s)** icon.
9. Follow the instructions received in the Communication Terminal.

The buffer status column is green while buffer is running. The color returns to yellow once it stops running.

6.3.6 Current Loop Filter Calibration and Tuning

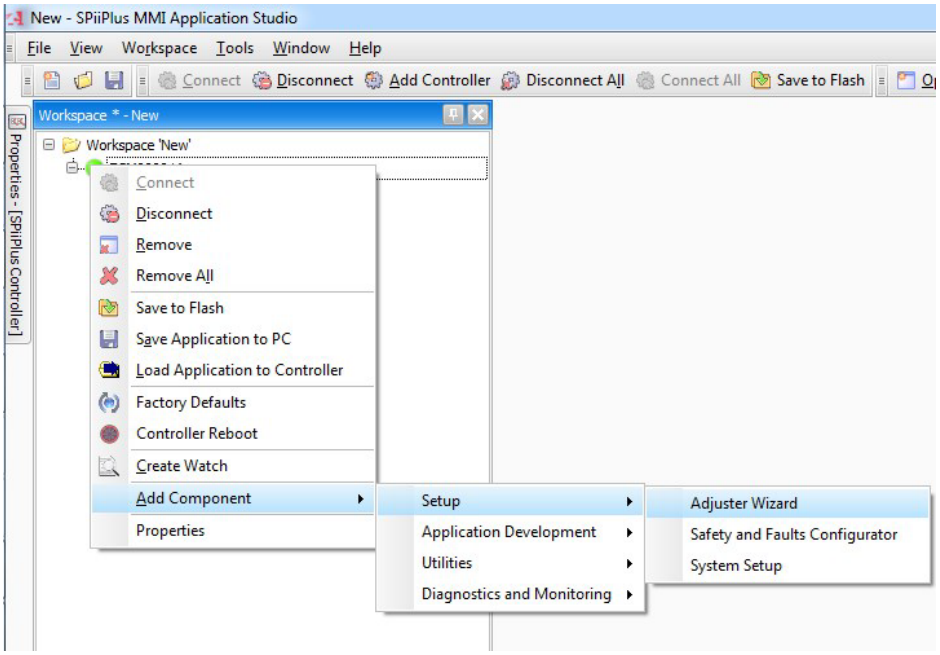
The current loop filter is a PI filter. It has two gains: proportional and integral. Both should be tuned to provide the fastest current loop response while maintaining sufficient stability margin.

The PI filter can be tuned either by selecting a set of PI gains from a pre-set group of 16 different sets of gains using a DIP switch when the unit is in the normal operational mode or by tuning the PI gains using the *SPiiPlus MMI Application Studio* with the unit placed into Setup mode, see Calibration in Setup Mode.

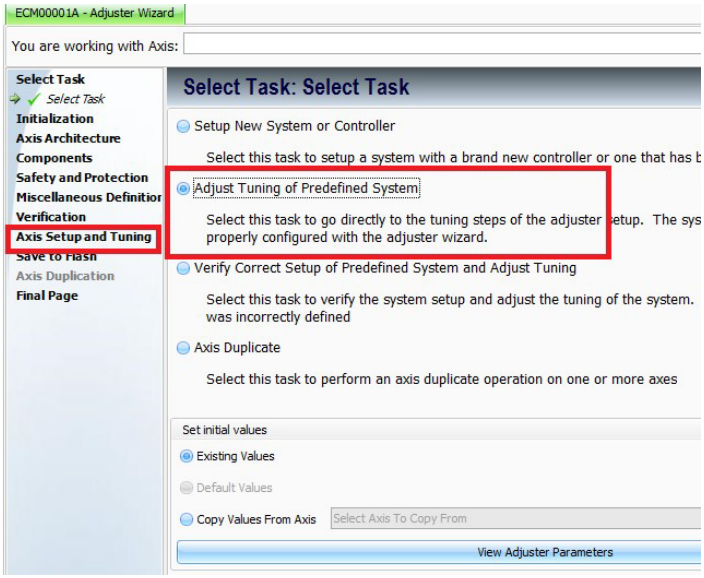
6.3.6.1 Current Loop Tuning

To tune the current loop:

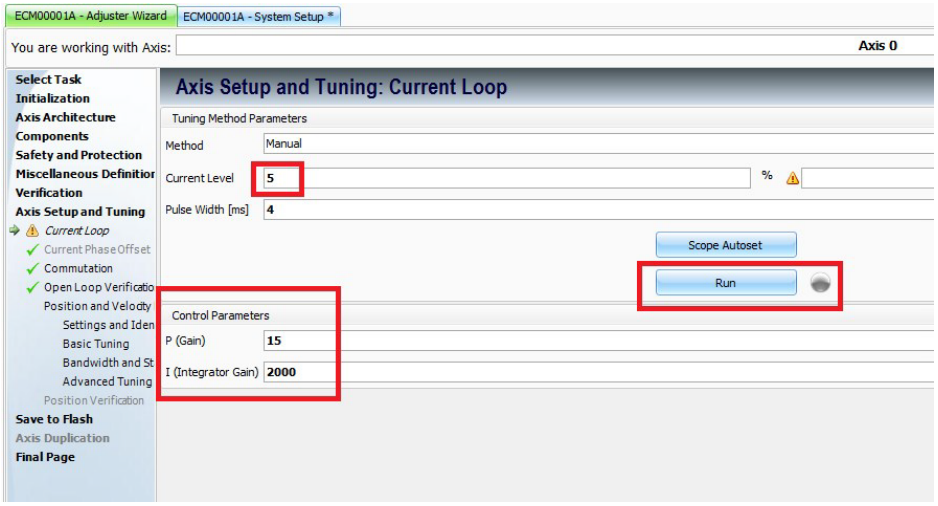
1. Right-click the controller in the Workspace Tree, the **Controller Right-Click Options** window appears.



2. Select **Add Component > Setup > Adjuster Wizard**, the Adjuster Wizard window appears.



3. Select **Adjust Tuning of Predefined System** followed by **Axis Setup and Tuning**, the **Axis Setup and Tuning: Current Loop** window appears.



4. Enter appropriate values for the parameters below.
   > Current Level [%]
   > P (Gain)
   > I (Integral Gain)
5. Click **Run**.
6. Click **Scope Autoset**. The scope is displayed.
7. Make adjustments to the P and I gains to achieve the fastest current loop response while maintaining a sufficient stability margin.

6.3.6.2 Saving Parameters to Flash Memory

1. Load the program "NPACurrentLoopParametersSaveProgram.prg" into the program manager, see NPACurrentLoopParametersSaveProgram.prg for the program code. For

instructions on loading a program, see Command Offset Calibration.

2. In the **Program Manager** pane, click the **Open Buffer** icon for buffer 0. This opens buffer 0.
3. Open a communication terminal and enable it to show messages, see Monitoring Offset Calibration Progress.
4. In the **Program Manager** pane, click **Select** adjacent to the buffer where the"NPACurrentLoopParametersSaveProgram.prg" is stored.
5. Select, **Run Buffer(s)**.
6. Follow the instructions received in the Communication Terminal.
7. In the **Program Manager** pane, select **Run Buffer** for buffer 0. This runs the buffer program.

Once the program has finished running all parameters are saved into the non-volatile memory of the drive.

6.3.7 Returning to Normal Operation Mode

To return to normal operation mode:

1. Turn off the control supply.
2. Turn off the drive supply.
3. Set the NPApm to normal operation mode by removing the jumper from JP1.
4. Set the DIP switch to 0000 (to use the saved gains of the PI filter).
5. Turn on the control supply.
6. Turn on the drive supply.

The NPApm should be returned to normal operation mode after performing all calibrations.

Be sure all EtherCAT cables are disconnected.

Appendix A. Appendices

A.1 EndToEndCalibrationProgram.prg

Copy the code below to text editor and save it with .prg extension or copy it as it is to a buffer.

```
#/ Controller version = 2.29.04.00
#/ Date = 22-Dec-15 14:50
#/ User remarks =
#0
int NUMBER_OF_AXES, INDEX
GLOBAL INT DSP_INDEX(1), ADDRESS_ERROR
GLOBAL INT OffsetPlugReady(1), NUM_OF_AXES(1), START_SAVE(1),SYSTEM_
RESTART(1)
!********************!
DSP_INDEX_LABEL:
DISP "\n\nEnter EtherCAT Slave index of the NPA as it appears in the
System Viewer and Diagnostics."
DSP_INDEX(0) = 0
INPUT (DSP_INDEX)
IF(DSP_INDEX(0) <0 | DSP_INDEX(0)>9)
DISP "DSP index out of range. Try again in range 0-9."
GOTO DSP_INDEX_LABEL
END
!********************!
DISP "Enter number of axes available in the unit. 1 - single axis unit. 2
- dual axis unit."
NUM_OF_AXES_LABEL:
NUM_OF_AXES(0) = 0
INPUT (NUM_OF_AXES)
IF(NUM_OF_AXES(0) <1 | NUM_OF_AXES(0)>2)
DISP "DSP index out of range. Try again in range 1-2."
GOTO NUM_OF_AXES_LABEL
END
NUMBER_OF_AXES = NUM_OF_AXES(0)
!********************!
global real collected_data(20000)
int cs_offset(2)
int ct_offset(2)
int u30(2)
int u40(2)
int cs_offset_read(2)
int ct_offset_read(2)
int u30_read(2)
int u40_read(2)
int sin_data_addr(4)
int cos_data_addr(4)
int cs_offset_addr(2)
int ct_offset_addr(2)
```

```
int u30_addr(2)
int u40_addr(2)
! DISABLE "INVALID EEPROM" PROTECTION
int config(2)
config(0) = getsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes
[0].flags.state.invalid_eeprom")) & 0xFFFF
setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[0].flags.state.invalid_
eeprom"), (config(0) & 0xFFFB))
config(1) = getsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes
[1].flags.state.invalid_eeprom")) & 0xFFFF
setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[1].flags.state.invalid_
eeprom"), (config(1) & 0xFFFB))
INDEX = 0
LOOP NUMBER_OF_AXES
cs_offset(INDEX) = 0
ct_offset(INDEX) = 0
u30(INDEX) = 0
u40(INDEX) = 0
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cs_offset_read(INDEX) = 0
ct_offset_read(INDEX) = 0
u30_read(INDEX) = 0
u40_read(INDEX) = 0
INDEX = INDEX + 1
END
sin_data_addr(0) = getspa(DSP_INDEX(0), "axes[0].sin")
sin_data_addr(1) = getspa(DSP_INDEX(0), "axes[1].sin")
sin_data_addr(2) = getspa(DSP_INDEX(0), "axes[2].sin")
sin_data_addr(3) = getspa(DSP_INDEX(0), "axes[3].sin")
cos_data_addr(0) = getspa(DSP_INDEX(0), "axes[0].cos")
cos_data_addr(1) = getspa(DSP_INDEX(0), "axes[1].cos")
cos_data_addr(2) = getspa(DSP_INDEX(0), "axes[2].cos")
cos_data_addr(3) = getspa(DSP_INDEX(0), "axes[3].cos")
cs_offset_addr(0) = getspa(DSP_INDEX(0), "axes[0].cs_offset")
cs_offset_addr(1) = getspa(DSP_INDEX(0), "axes[1].cs_offset")
ct_offset_addr(0) = getspa(DSP_INDEX(0), "axes[0].ct_offset")
ct_offset_addr(1) = getspa(DSP_INDEX(0), "axes[1].ct_offset")
u30_addr(0) = getspa(DSP_INDEX(0), "axes[2].u30")
u30_addr(1) = getspa(DSP_INDEX(0), "axes[3].u30")
u40_addr(0) = getspa(DSP_INDEX(0), "axes[2].u40")
u40_addr(1) = getspa(DSP_INDEX(0), "axes[3].u40")
!********************!
LABEL_OFFSET:
OffsetPlugReady(0)=0
DISP "\n\nPlug in command connector. Send zero command to NPA."
DISP "\nPress '1' when done"
INPUT (OffsetPlugReady)
```

```
IF (OffsetPlugReady(0)<>1)
disp "\n\nUnknown value, please enter again."
GOTO LABEL_OFFSET
END
DISP "Measuring offsets ..."
ADDRESS_ERROR = 0
INDEX = 0
LOOP NUMBER_OF_AXES
if (sin_data_addr(INDEX) > 0)
spdc/r collected_data, 20000, 0.05, DSP_INDEX(0), sin_data_addr(INDEX)
wait 1100
cs_offset(INDEX) = -avg(collected_data)
ELSE
ADDRESS_ERROR=1
end
if (cos_data_addr(INDEX) > 0)
spdc/r collected_data, 20000, 0.05, DSP_INDEX(0), cos_data_addr(INDEX)
wait 1100
ct_offset(INDEX) = -avg(collected_data)
ELSE
ADDRESS_ERROR=1
end
if (sin_data_addr(INDEX + 2) > 0)
spdc/r collected_data, 20000, 0.05, DSP_INDEX(0), sin_data_addr(INDEX +
2)
wait 1100
u30(INDEX) = -avg(collected_data)
ELSE
ADDRESS_ERROR=1
end
if (cos_data_addr(INDEX + 2) > 0)
spdc/r collected_data, 20000, 0.05, DSP_INDEX(0), cos_data_addr(INDEX +
2)
wait 1100
u40(INDEX) = -avg(collected_data)
ELSE
ADDRESS_ERROR=1
end
if (cs_offset_addr(INDEX) > 0)
setsp(DSP_INDEX(0), cs_offset_addr(INDEX), cs_offset(INDEX))
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ELSE
ADDRESS_ERROR=1
end
if (ct_offset_addr(INDEX) > 0)
setsp(DSP_INDEX(0), ct_offset_addr(INDEX), ct_offset(INDEX))
ELSE
```

```
ADDRESS_ERROR=1
end
if (u30_addr(INDEX) > 0)
setsp(DSP_INDEX(0), u30_addr(INDEX), u30(INDEX))
ELSE
ADDRESS_ERROR=1
end
if (u40_addr(INDEX) > 0)
setsp(DSP_INDEX(0), u40_addr(INDEX), u40(INDEX))
ELSE
ADDRESS_ERROR=1
end
INDEX = INDEX + 1
IF (ADDRESS_ERROR=1)
DISP "Parameters address read failed. Process aborted."
STOPALL
STOP
END
END
!********************!
ENTER_START_SAVE:
DISP "\n\nOffsets has been measured. Enter 1 to save them to non-volatile
memory."
DISP "All axes will be disabled during this process"
INPUT(START_SAVE)
IF(START_SAVE(0) = 1)
DISP "\n\nSaving to non-volatile memory ..."
ELSEIF(START_SAVE(0) = -1)
DISP "Process aborted."
STOPALL
STOP
ELSE
DISP "\nWrong input. Try again."
GOTO ENTER_START_SAVE
END
DISP "\n\nALL axes are being disabled"
DISABLE ALL
wait 1000
SAVE_PARAMETERS:
IF (DSP_INDEX(0) = 0)
EXEC "#SAVESPPAR 0"
ELSEIF(DSP_INDEX(0) = 1)
EXEC "#SAVESPPAR 1"
ELSEIF(DSP_INDEX(0) = 2)
EXEC "#SAVESPPAR 2"
ELSEIF(DSP_INDEX(0) = 3)
EXEC "#SAVESPPAR 3"
ELSEIF(DSP_INDEX(0) = 4)
EXEC "#SAVESPPAR 4"
```

```
ELSEIF(DSP_INDEX(0) = 5)
EXEC "#SAVESPPAR 5"
ELSEIF(DSP_INDEX(0) = 6)
EXEC "#SAVESPPAR 6"
ELSEIF(DSP_INDEX(0) = 7)
EXEC "#SAVESPPAR 7"
ELSEIF(DSP_INDEX(0) = 8)
EXEC "#SAVESPPAR 8"
ELSEIF(DSP_INDEX(0) = 9)
EXEC "#SAVESPPAR 9"
END
WAIT 5000
ECREPAIR
IF (DSP_INDEX(0) = 0)
EXEC "#LOADSPPAR 0"
ELSEIF(DSP_INDEX(0) = 1)
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EXEC "#LOADSPPAR 1"
ELSEIF(DSP_INDEX(0) = 2)
EXEC "#LOADSPPAR 2"
ELSEIF(DSP_INDEX(0) = 3)
EXEC "#LOADSPPAR 3"
ELSEIF(DSP_INDEX(0) = 4)
EXEC "#LOADSPPAR 4"
ELSEIF(DSP_INDEX(0) = 5)
EXEC "#LOADSPPAR 5"
ELSEIF(DSP_INDEX(0) = 6)
EXEC "#LOADSPPAR 6"
ELSEIF(DSP_INDEX(0) = 7)
EXEC "#LOADSPPAR 7"
ELSEIF(DSP_INDEX(0) = 8)
EXEC "#LOADSPPAR 8"
ELSEIF(DSP_INDEX(0) = 9)
EXEC "#LOADSPPAR 9"
END
WAIT 5000
ECREPAIR
DISP "\n\nProgram finished."
DISP "-----------------------------------------------"
START_RESTART:
DISP "\n\nSystem should be restarted. To restart enter 1"
INPUT(SYSTEM_RESTART)
IF(SYSTEM_RESTART(0) = 1)
EXEC "#HWRES #HWRES"
ELSE
GOTO START_RESTART
END
```

```
STOP
```

A.2 NPACurrentLoopParametersSaveProgram.prg

Copy the code below to text editor and save it with .prg extension or copy it as it is to a buffer.

```
#/ Controller version = 2.29.04.00
#/ Date = 22-Dec-15 14:51
#/ User remarks = V6
#0
GLOBAL INT DSP_INDEX(1), FIRST_AXIS_INDEX(1), START_SAVE(1), SYSTEM_
RESTART(1), NUMBER_OF_AXES(1)
GLOBAL REAL CURRENT_LOOP_PARAMETER(1)
GLOBAL INT SAT_PROTECT(2), SLILI_ORIG(2)
GLOBAL REAL COMMAND_SF(2)
GLOBAL REAL DRIVE_RESCALE(1), NEW_SCALE_FACTOR(1)
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!! User definitions
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! Change DSP index in accordance with EtherCat network configuration
! Range 0-9
DSP_INDEX(0) = -1
!********************!
ENTER_DSP_INDEX:
DISP "\n\nEnter EtherCAT Slave index of the NPA as it appears in the
System Viewer and Diagnostics."
INPUT(DSP_INDEX)
IF(DSP_INDEX(0)<0 | DSP_INDEX(0)>9)
DISP "DSP index out of 0-9 range. Try again."
GOTO ENTER_DSP_INDEX
STOP
END
! Under voltage protection
IF(getsp(DSP_INDEX(0),getspa(DSP_INDEX(0),"Vbus")) < 32767*9/200)
DISP "BUS voltage is too low. Process aborted"
STOP
END
!********************!
FIND_FIRST_AXIS_INDEX:
FIRST_AXIS_INDEX(0) = 0
WHILE(GETCONF(260, FIRST_AXIS_INDEX(0)) <> DSP_INDEX(0))
FIRST_AXIS_INDEX(0) = FIRST_AXIS_INDEX(0) + 1
END
!********************!
ENTER_NUMBER_OF_AXES:
DISP "\n\nEnter number of axes available in the unit. 1 - single axis
unit. 2 - dual axis unit."
INPUT(NUMBER_OF_AXES)
IF(NUMBER_OF_AXES(0)<1 | NUMBER_OF_AXES(0)>2)
DISP "Number of axes should be 1 or 2. Try again."
```

```
GOTO ENTER_NUMBER_OF_AXES
STOP
END
! Store parameters
SAT_PROTECT(0) = getsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[0].sat_
protect")); wait 10
SLILI_ORIG(0) = getsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes
[0].voltage_limit")); wait 10
COMMAND_SF(0) = getsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes
[0].command_sf")); wait 10
! Change parameters to enable the drive with zero command
setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[0].sat_protect"), 1e9);
wait 10
setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[0].voltage_limit"), 0);
wait 10
setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[0].command_sf"), 0); wait
10
enable(FIRST_AXIS_INDEX(0)); wait 300
disable(FIRST_AXIS_INDEX(0))
if(NUMBER_OF_AXES(0) = 2)
! Store parameters
SAT_PROTECT(1) = getsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[1].sat_
protect")); wait 10
SLILI_ORIG(1) = getsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes
[1].voltage_limit")); wait 10
COMMAND_SF(1) = getsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes
[1].command_sf")); wait 10
! Change parameters to enable the drive with zero command
setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[1].sat_protect"), 1e9);
wait 10
setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[1].voltage_limit"), 0);
wait 10

setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[1].command_sf"), 0); wait
10
enable(FIRST_AXIS_INDEX(0), FIRST_AXIS_INDEX(0)+1); wait 300
disable(FIRST_AXIS_INDEX(0), FIRST_AXIS_INDEX(0)+1)
end
!********************!
ENTER_SLIKP0:
DISP "\n\nEnter value for SLIKP(%2i", FIRST_AXIS_INDEX(0),")"
INPUT(CURRENT_LOOP_PARAMETER)
IF(CURRENT_LOOP_PARAMETER(0)<0 | CURRENT_LOOP_PARAMETER(0)>256000)
DISP "Value out of range (0-256000). Try again"
GOTO ENTER_SLIKP0
ELSE
SLIKP(FIRST_AXIS_INDEX(0)) = CURRENT_LOOP_PARAMETER(0)
END
CURRENT_LOOP_PARAMETER(0) = -1
```

```
!********************!
ENTER_SLIKI0:
DISP "\n\nEnter value for SLIKI(%2i", FIRST_AXIS_INDEX(0),")"
INPUT(CURRENT_LOOP_PARAMETER)
IF(CURRENT_LOOP_PARAMETER(0)<0 | CURRENT_LOOP_PARAMETER(0)>65000)
DISP "Value out of range (0-65000). Try again"
GOTO ENTER_SLIKI0
ELSE
SLIKI(FIRST_AXIS_INDEX(0)) = CURRENT_LOOP_PARAMETER(0)
END
CURRENT_LOOP_PARAMETER(0) = -1
!********************!
IF (NUMBER_OF_AXES(0)=2)
ENTER_SLIKP1:
DISP "\n\nEnter value for SLIKP(%2i", FIRST_AXIS_INDEX(0)+1,")"
INPUT(CURRENT_LOOP_PARAMETER)
IF(CURRENT_LOOP_PARAMETER(0)<0 | CURRENT_LOOP_PARAMETER(0)>256000)
DISP "Value out of range (0-256000). Try again"
GOTO ENTER_SLIKP1
ELSE
SLIKP(FIRST_AXIS_INDEX(0)+1) = CURRENT_LOOP_PARAMETER(0)
END
CURRENT_LOOP_PARAMETER(0) = -1
!********************!
ENTER_SLIKI1:
DISP "\n\nEnter value for SLIKI(%2i", FIRST_AXIS_INDEX(0)+1,")"
INPUT(CURRENT_LOOP_PARAMETER)
IF(CURRENT_LOOP_PARAMETER(0)<0 | CURRENT_LOOP_PARAMETER(0)>65000)
DISP "Value out of range (0-65000). Try again"
GOTO ENTER_SLIKI1
ELSE
SLIKI(FIRST_AXIS_INDEX(0)+1) = CURRENT_LOOP_PARAMETER(0)
END
END
!********************!
DISP "Following parameters will be saved to"
DISP "NPA EtherCAT Slave index is %2i", DSP_INDEX(0)
disp""
DISP "SLIKP(%2i",FIRST_AXIS_INDEX(0),")" , SLIKP(FIRST_AXIS_INDEX(0))
DISP "SLIKI(%2i",FIRST_AXIS_INDEX(0),")" , SLIKI(FIRST_AXIS_INDEX(0))
IF (NUMBER_OF_AXES(0)=2)
DISP "SLIKP(%2i",FIRST_AXIS_INDEX(0)+1,")", SLIKP(FIRST_AXIS_INDEX(0)+1)
DISP "SLIKI(%2i",FIRST_AXIS_INDEX(0)+1,")", SLIKI(FIRST_AXIS_INDEX(0)+1)
END
IF(SAT_PROTECT(0)=1e9 | SLILI_ORIG(0)=0 | COMMAND_SF(0)=0)
DISP " "
DISP "One of the following parameters is zero: SAT_PROTECT(0), SLILI_ORIG
(0), COMMAND_SF(0)"
DISP "This may be caused by stopping the calibration program previously"
```

```
DISP "Process aborted"
DISP "Restart the controller and perform calibration process again"
STOP
END
! Change drive dynamic range
DISP " "
DISP "Would you like to rescale the drive peak current rating."
DISP "Rescaling peak current will improve dynamic range."
DRIVE_RESCALE:
DISP " "
DISP "To rescale press 1 to skip this step press 2.
DISP "Skipping this step will set dynamic range to 100 percent even if"
DISP " the drive was calibrated to a different level before."
INPUT(DRIVE_RESCALE)
IF(DRIVE_RESCALE(0) = 1)
ENTER_NEW_SCALE_FACTOR_0:
DISP "Enter scale factor [0-100 percent] for axis", FIRST_AXIS_INDEX(0)
INPUT(NEW_SCALE_FACTOR)
IF(NEW_SCALE_FACTOR(0)<0 | NEW_SCALE_FACTOR(0)>100)
DISP "Value out of 0-100 range. Try again"
GOTO ENTER_NEW_SCALE_FACTOR_0
END
COMMAND_SF(0) = NEW_SCALE_FACTOR(0)/100*COMMAND_SF(0)
IF(NUMBER_OF_AXES(0) = 2)
ENTER_NEW_SCALE_FACTOR_1:
DISP "Enter scale factor [0-100 percent] for axis", FIRST_AXIS_INDEX(0)+1
INPUT(NEW_SCALE_FACTOR)
IF(NEW_SCALE_FACTOR(0)<0 | NEW_SCALE_FACTOR(0)>100)
DISP "Value out of 0-100 range. Try again"
GOTO ENTER_NEW_SCALE_FACTOR_1
END
COMMAND_SF(1) = NEW_SCALE_FACTOR(0)/100*COMMAND_SF(1)
END
ELSEIF(DRIVE_RESCALE(0) = 2)
ELSE
DISP "Wrong input. Try again"
GOTO DRIVE_RESCALE
END
ENTER_START_SAVE:
DISP "\nEnter 1 to save parameters. All axes will be disabled during this
process"
INPUT(START_SAVE)
IF(START_SAVE(0) = 1)
DISP "\n\nSaving to non-volatile memory ..."
ELSE
DISP "\nWrong input. Try again."
GOTO ENTER_START_SAVE
END
DISP "\n\nALL axes are being disabled"
```

```
DISABLE ALL
wait 1000
!!!!!!!!!!!!!!!!!!!!!!!!!!!! Automatic save procedure
!!!!!!!!!!!!!!!!!!!!!!!!!!
! Change parameters to enable the drive with zero command
setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[0].sat_protect"), SAT_
PROTECT(0)); wait 10
setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[0].voltage_limit"), SLILI_
ORIG(0)); wait 10
setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[0].command_sf"), COMMAND_
SF(0)); wait 10
IF (NUMBER_OF_AXES(0)=2)
IF(SAT_PROTECT(1)=1e9 | SLILI_ORIG(1)=0 | COMMAND_SF(1)=0)
DISP "One of the following parameters is zero: SAT_PROTECT(0), SLILI_ORIG
(0), COMMAND_SF(0)"
DISP "This may be caused by stopping the calibration program previously"
DISP "Process aborted"
DISP "Restart the controller and perform calibration process again"
STOP
END
! Change parameters to enable the drive with zero command
setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[1].sat_protect"), SAT_
PROTECT(1)); wait 10
setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[1].voltage_limit"), SLILI_
ORIG(1)); wait 10
setsp(DSP_INDEX(0), getspa(DSP_INDEX(0), "axes[1].command_sf"), COMMAND_
SF(1)); wait 10
END

IF (DSP_INDEX(0) = 0)
EXEC "#SAVESPPAR 0"
ELSEIF(DSP_INDEX(0) = 1)
EXEC "#SAVESPPAR 1"
ELSEIF(DSP_INDEX(0) = 2)
EXEC "#SAVESPPAR 2"
ELSEIF(DSP_INDEX(0) = 3)
EXEC "#SAVESPPAR 3"
ELSEIF(DSP_INDEX(0) = 4)
EXEC "#SAVESPPAR 4"
ELSEIF(DSP_INDEX(0) = 5)
EXEC "#SAVESPPAR 5"
ELSEIF(DSP_INDEX(0) = 6)
EXEC "#SAVESPPAR 6"
ELSEIF(DSP_INDEX(0) = 7)
EXEC "#SAVESPPAR 7"
ELSEIF(DSP_INDEX(0) = 8)
EXEC "#SAVESPPAR 8"
ELSEIF(DSP_INDEX(0) = 9)
EXEC "#SAVESPPAR 9"
```

```
END
WAIT 5000
ECREPAIR
IF (DSP_INDEX(0) = 0)
EXEC "#LOADSPPAR 0"
ELSEIF(DSP_INDEX(0) = 1)
EXEC "#LOADSPPAR 1"
ELSEIF(DSP_INDEX(0) = 2)
EXEC "#LOADSPPAR 2"
ELSEIF(DSP_INDEX(0) = 3)
EXEC "#LOADSPPAR 3"
ELSEIF(DSP_INDEX(0) = 4)
EXEC "#LOADSPPAR 4"
ELSEIF(DSP_INDEX(0) = 5)
EXEC "#LOADSPPAR 5"
ELSEIF(DSP_INDEX(0) = 6)
EXEC "#LOADSPPAR 6"
ELSEIF(DSP_INDEX(0) = 7)
EXEC "#LOADSPPAR 7"
ELSEIF(DSP_INDEX(0) = 8)
EXEC "#LOADSPPAR 8"
ELSEIF(DSP_INDEX(0) = 9)
EXEC "#LOADSPPAR 9"
END
WAIT 5000
ECREPAIR
DISP "\n\nProgram finished."
DISP "\n\nStored current loop values will be retrieved wneh the NPA
operates in 'Normal' mode"
DISP " and DIP switch is at 0000 position"
DISP "-------------------------------------------"
START_RESTART:
DISP "\n\nSystem should be restarted. To restart enter 1"
INPUT(SYSTEM_RESTART)
IF(SYSTEM_RESTART(0) = 1)
EXEC "#HWRES #HWRES"
ELSE
GOTO START_RESTART
END
STOP
```

A.3 End to End Calibration

End to end calibration of the command signal offsets refers to adjusting the current command sent to the drive to compensate for the controller offset and drive offset due to electronic imperfections. A schematic description of the offsets and their compensation process is shown below.

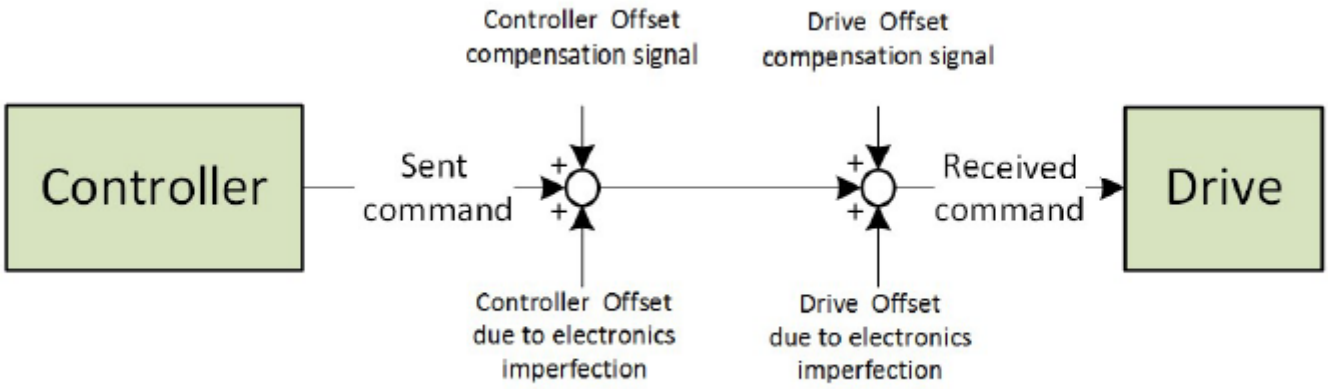

Figure 7-1. End to End Calibration Schematic

The end to end calibration proceeds in the following order:

1. Connect controller to a drive
2. Send zero command from the controller (actual command may be non-zero due to offset)
3. Read the signal received by a drive
4. Tune drive offset compensation signal such that the zero command is read

The controller offset and the drive offset can be adjusted individually. These procedures follow.

Controller offset calibration:

1. 1. Connect a controller output to scope
2. 2. Send zero command
3. 3. Tune offset compensation signal till zero signal is read by scope.

Drive offset calibration:

1. 1. Send zero command to a drive
2. 2. Read the signal received by a drive
3. 3. Tune drive offset compensation signal such that zero command is read

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