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USER MANUAL

Power Brick AC



Programmable Servo Amplifier

PBAx-xxx-xxx-xxxxxxx

July 19, 2017

DELTA TAU
Data Systems, Inc.

NEW IDEAS IN MOTION …

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Operating Conditions

All Delta Tau Data Systems, Inc. motion controller, accessory, and amplifier products contain static sensitive components that can be damaged by incorrect handling. When installing or handling Delta Tau Data Systems, Inc. products, avoid contact with highly insulated materials. Only qualified personnel should be allowed to handle this equipment.

In the case of industrial applications, we expect our products to be protected from hazardous or conductive materials and/or environments that could cause harm to the controller by damaging components or causing electrical shorts. When our products are used in an industrial environment, install them into an industrial electrical cabinet to protect them from excessive or corrosive moisture, abnormal ambient temperatures, and conductive materials. If Delta Tau Data Systems, Inc. products are directly exposed to hazardous or conductive materials and/or environments, we cannot guarantee their operation.

Safety Instructions

Qualified personnel must transport, assemble, install, and maintain this equipment. Properly qualified personnel are persons who are familiar with the transport, assembly, installation, and operation of equipment. The qualified personnel must know and observe the following standards and regulations:

IEC364resp.CENELEC HD 384 or DIN VDE 0100
IEC report 664 or DIN VDE 0110
National regulations for safety and accident prevention or VBG 4

Incorrect handling of products can result in injury and damage to persons and machinery. Strictly adhere to the installation instructions. Electrical safety is provided through a low-resistance earth connection. It is vital to ensure that all system components are connected to earth ground.

This product contains components that are sensitive to static electricity and can be damaged by incorrect handling. Avoid contact with high insulating materials (artificial fabrics, plastic film, etc.). Place the product on a conductive surface. Discharge any possible static electricity build-up by touching an unpainted, metal, grounded surface before touching the equipment.

Keep all covers and cabinet doors shut during operation. Be aware that during operation, the product has electrically charged components and hot surfaces. Control and power cables can carry a high voltage, even when the motor is not rotating. Never disconnect or connect the product while the power source is energized to avoid electric arcing.



Warning

A Warning identifies hazards that could result in personal injury or death. It precedes the discussion of interest.



Caution

A Caution identifies hazards that could result in equipment damage. It precedes the discussion of interest.



Note

A Note identifies information critical to the understanding or use of the equipment. It follows the discussion of interest.

MANUAL REVISION HISTORY				
REV	**DESCRIPTION**	**DATE**	**CHANGE**	**APPROVED**
0	Preliminary	05/28/2014	RN	RN
1	Released	07/20/2015	RN	RN
2	Updated I/O & Flags electrical specifications Updated power–up procedure Updated absolute power-on position and ongoing phase position Added A16 connector description Corrected serial clock/data pinouts Added factory reset, firmware reload procedures Added IP address change procedure Added AC induction motor setup Corrected Logic Power Connector Part Number Added Resolver Configuration Added Digital Tracking Filter Setup Added Serial Port RS-232 Description Modified STO Silkscreen Warning General Updates and Formatting	05/19/2016	DCDP / RN	RN
3	Corrected I2T Settings General Corrections & Formatting Added General Purpose I/Os Schematic Snippets	12/13/2016	RN	RN
4	Added Shunt Info Updated DC Brush Section & Current Loop Corrected External 5V Mating Connector PN Added Analog I/Os Schematic Snippets Added Limits & Flags Schematic Snippets Changed PwmSf to 95% of 16384 Removed $/2^4$ in AbsPhasePosSf 20-bit example Corrected GAR rating in electrical spec tables Updated X9-X12 DAC output example Added a note about scaling to user engineering units General Formatting	07/19/2017	RN	RN

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INTRODUCTION

The Power Brick AC is a smart servo drive package. It combines the intelligence and capability of the Power PMAC motion controller with high performance IGBT-based drives resulting into a 4-, 6-, or 8-axis compact smart drive.

The Power Brick AC is designed for up to 240 VAC main input power. It supports virtually any type of feedback device and can drive directly the following types of motors:

- 3-phase AC/DC brushless servo (synchronous) – rotary/linear
- AC Induction (asynchronous) – with or without encoder
- 2-phase DC brush



Note

The Power Brick AC can also provide pulse and direction PFM output signals to third-party stepper drives.

The number of axes in a Power Brick AC application can be expanded through MACRO or EtherCat.

The Power Brick AC carries onboard up to 32 digital inputs and 16 digital outputs (I/Os) which can also be expanded through MACRO, ModBus, or EtherCat.

The trajectory planner, built-in software PLCs (programmable in Power PMAC script and / or C language), and safety features make the Power Brick AC a fully scalable machine automation controller-drive which can be integrated in virtually any kind of motion control application.

Documentation

In conjunction with this manual, the following manuals are essential for the proper operation and use of the Power Brick AC:

- Power PMAC Software Reference Manual
- Power PMAC User Manual

These manuals are available for download, to registered members, at Delta Tau Forums.

Downloadable Power PMAC Script



Some code snippets may require the user to input specific information pertaining to their system application. Occasionally, they are denoted in a commentary ending with – **User Input**.

This manual contains downloadable code snippets in Power PMAC script. These examples can be copied and pasted into the editor area of the IDE software. Care must be taken when using pre-configured Power PMAC code, some information may need to be updated to match hardware or system specific configurations. Downloadable code found in this manual is enclosed in the following format:

```
// POWER PMAC SCRIPT CODE EXAMPLE
GLOBAL MyCounter = 0;            // Arbitrary global variable, counter
GLOBAL MyCycles = 10;            // Arbitrary global variable, number of cycles --User Input

OPEN PLC ExamplePLC              // Open PLC buffer
WHILE (MyCounter < MyCycles)     // While counter is less than number of cycles
{                                // Start while loop
    MyCounter ++                 // Increment MyCounter by 1
}                                // End while loop
MyCounter = 0                    // Reset Mycounter
DISABLE PLC ExamplePLC           // Disable PLC
CLOSE                            // Close PLC buffer
```



It is the user's responsibility to manage the application's PLCs properly. The code samples are typically enclosed in a PLC buffer with the user defined name **ExamplePLC**.

It is the user's responsibility to use the PLC examples presented in this manual properly, and incorporate the statement code in the application project accordingly.

RECEIVING AND UNPACKING

Delta Tau products are thoroughly tested at the factory and carefully packaged for shipment. When the Power Brick AC is received, there are several things to be done immediately:

- Observe the condition of the shipping container and report any damage immediately to the commercial carrier that delivered the package.
- Remove the equipment from the shipping container and remove all packing materials. Check all shipping material for connector kits, documentation, or other small pieces of equipment. Be aware that some connector kits and other equipment pieces may be quite small and can be accidentally discarded if care is not used when unpacking the equipment. The container and packing materials may be retained for future shipment.
- Verify that the part number of the product received is the same as the part number listed on the purchase order.
- Inspect the equipment for external physical damage that may have been sustained during shipment and report any damage immediately to the commercial carrier.
- Electronic components in this product are design-hardened to reduce static sensitivity. However, use proper procedures when handling the equipment.
- If the equipment is to be stored for several weeks before use, be sure that it is stored in a location that conforms to published storage humidity and temperature specifications.

Use of Equipment

The following restrictions will ensure the proper use of the Power Brick AC:

- The components built into electrical equipment or machines can be used only as integral components of such equipment.
- The Power Brick AC must not be operated on power supply networks without a ground or with an asymmetrical ground.
- If the Power Brick AC is used in residential areas, or in business or commercial premises, implement additional filtering measures.
- The Power Brick AC may be operated only in a closed switchgear cabinet, taking into account the ambient conditions defined in the environmental specifications.

SPECIFICATIONS

Part Number Designation

P	B	A	**A**	–	**B**	**C**	**D**	–	**E**	**F**	**G**	–	**H**	I	0	K	L	0	0

Option A	
4	4-axis
6	6-axis
8	8-axis

Option B	
G	800 MHz CPU
H	1.0 GHz CPU

Option C	
1	1 GB RAM
2	2 GB RAM

Option D	
1	1 GB Flash
3	4 GB Flash
4	8 GB Flash

Option E	
0	1 Gbs EtherNet
3	1 extra Eth / EtherCAT
4	2 extra Eth / EtherCAT
5	3 extra Eth / EtherCAT

Option F	
0	No EtherCAT
1	EtherCAT I/O Only
2	4 EtherCAT Servo and I/O
3	8 EtherCAT Servo and I/O
4	16 EtherCAT Servo and I/O
5	32 EtherCAT Servo and I/O
6	64 EtherCAT Servo and I/O

Option G	
0	No Gateway
1	Profibus – DP Master
2	Profibus – DP Slave
3	DeviceNet Master
4	DeviceNet Slave
5	CANopen Master
6	CANopen Slave
7	CC-Link Slave
9	EtherCAT Slave
A	Ethernet IP Scanner / Master
B	Ethernet IP Adapter / Slave
C	Open ModBus/TCP
E	ProfiNet IO RT Controller
F	ProfiNet IO RT Device

Option H	
5	5/10A
8	8/16A

P	B	A	A	-	B	C	D	-	E	F	G	-	H	I	0	K	L	0	0

Option I									
	Axis 5-6	Axis 7-8	Encoder Inputs	Digital I/Os	MACRO Nodes Servo / IOs	True DAC Analog Out	Filtered PWM Analog Out	Analog Inputs	GP Relays
0	-	-	4	16/8	-	-	-	-	-
1	-	-	4	16/8	16/12	-	4	4	4
2	-	-	8	32/16	-	-	-	-	-
3	-	-	8	32/16	32/24	-	8	8	8
4	-	-	8	32/16	32/24	4	4	8	8
F	15/30A	-	8	32/16	-	-	-	-	-
G	15/30A	-	8	32/16	32/24	-	8	8	8
H	15/30A	-	8	32/16	32/24	4	4	8	8
5	5/10A		8	32/16	-	-	-	-	-
6	5/10A		8	32/16	32/24	-	8	8	8
8	8/16A		8	32/16	-	-	-	-	-
9	8/16A		8	32/16	32/24	-	8	8	8

Option K		
	1 – 4	5 – 8
0	-	-
1	Sinusoidal	-
2	Resolver	-
3	ACI	-
5	Sinusoidal	Sinusoidal
6	Sinusoidal	Resolver
7	Resolver	Sinusoidal
A	Resolver	Resolver
B	Resolver	ACI
E	ACI	ACI
F	ACI	Resolver

Option L (ACC-84B)		
	1 – 4	5 – 8
0	-	-
2	SSI	-
3	EnDat	-
4	Hiperface	-
6	Yaskawa	-
7	Tamagawa	-
8	Panasonic	-
9	Mitutoyo	-
B	BiSS B/C	-
C	Matsushita	-
D	Mitsubishi	-
J	SSI	
K	EnDat	
L	Hiperface	
P	Yaskawa	
Q	Tamagawa	
R	Panasonic	
T	Mitutoyo	
V	BiSS B/C	
W	Matsushita	
X	Mitsubishi	

Power Brick AC Configuration

The Power Brick AC comes standard with a powerful set of hardware and software capabilities, plus a full set of options.

Standard Configuration

CPU	800 MHz Single-Core Power PC 460EX.
Memory	2 GB DDRAM3 active, 1 GB NAND Flash non-volatile.
Communication Ports	2 x Gbs Ethernet port for host communication. RS-232 Serial Port. USB 2.0 Host port. USB 2.0 Device port.
Digital I/O	16 x Inputs, fully protected at 12 – 24 V sourcing or sinking (user wiring). 8 x Outputs, fully protected at 12 – 24 V sourcing or sinking (user wiring).
Servo Interface	4 channels servo interface, each including: Quadrature encoder (differential, with index) interface. UVW digital hall sensor interface. Serial encoder interface, with software selectable protocol, from the following: ○ SSI ○ EnDat 2.1 / 2.2 (2.1-compatible features only) with delay compensation ○ Hiperface ○ Yaskawa Sigma I ○ Yaskawa Sigma II / III / V (no position reset or fault clear) ○ Tamagawa FA-Coder (no servo clock output) ○ Panasonic (no servo clock output) ○ Mitutoyo ○ Kawasaki Pulse & direction output. Position compare (EQU) output (5 V TTL). Input flags (home, + limit, – limit, user) at 5 – 24 V. Motor thermal input (PTC).
Amplifier Output	4 amplifier axes, each at 5/10A with 24V brake output.
Amplifier Safety & Features	Internal shunt / bleeding resistor built-in. External shunt connection. Shunt resistor fault detection. Hardware I2T thermal fault detection. Short circuit detection. IGBT over-temperature detection. PWM frequency out-of-range detection. No bus voltage detection. Soft start fault detection. Watchdog output (normally closed / open). Abort Input (category 2 stop). STO Input (category 0 stop).

Options

CPU	1 GHz Single-Core Power PC 460EX.
Memory	2 GB DDRAM3 active, 4 or 8 GB NAND Flash non-volatile.
Communication Ports	1 or 2 x additional Gbs Ethernet ports, EtherCAT compatible.
Digital I/O	Additional 16 x Inputs, fully protected at 12 – 24 V sourcing or sinking (user wiring). Additional 8 x Outputs, fully protected at 12 – 24 V sourcing or sinking (user wiring).
Analog I/O	4 or 8 x 16-bit analog inputs. 4 or 8 x 14-bit filtered PWM analog outputs (±10 V). 4 x 16-bit true DAC analog outputs (±10 V). 4 or 8 x Amp enable outputs (to 3rd party drives). 4 or 8 x Amp fault inputs (from 3rd party drives).
Servo Interface	4 additional channels servo interface including the same as the standard features. Sinusoidal encoder interface. Resolver encoder interface. ACC-84B serial encoder protocols: ○ Matsushita (Nikon D) ○ Mitsubishi ○ EnDat 2.2 with additional information, no delay compensation ○ BiSS-B/C ○ Yaskawa II/III/V with position reset and fault clear ○ Tamagawa FA-Coder with servo clock output ○ SSI (no capabilities over Power Brick AC's built-in interface) ○ Panasonic (no capabilities over Power Brick AC's built-in interface) ○ Mitutoyo (no capabilities over Power Brick AC's built-in interface)
Amplifier Output	4 additional amplifier axes, each at 5/10 A or 8/16 A with 24 V brake output. 2 additional amplifier axes, each at 15/30 A with 24 V brake output.
MACRO Interface	16 Servo, 12 I/O nodes interface. 32 Servo, 24 I/O nodes interface.
EtherCAT Interface	EtherCAT I/O only. 4 / 8 / 16 / 32 / 64 Servo axes plus I/O.
Fieldbus	○ EtherNet / IP Scanner / Master. ○ EtherNet / IP Adapter / Slave. ○ Open Modbus / TCP. ○ PROFINET IO RT Controller. ○ PROFINET IO RT Device. ○ CANopen Master. ○ CANopen Slave. ○ PROFIBUS-DP Master. ○ PROFIBUS-DP Slave. ○ DeviceNet Master. ○ DeviceNet Slave. ○ CC-Link Slave. ○ EtherCAT Slave. ○ Modbus.

Configuration Notes

- Quadrature encoders can always be wired in and processed regardless of the feedback options fitted.

- The following serial encoder protocols are built into (standard) the Power Brick AC – Gate3:

HiperFace	**Kawasaki**	**Tamagawa**
SSI	**EnDat 2.1 / 2.2**	**Mitutoyo**
Panasonic	**Yaskawa II / III / V**	

  Additionally, any of the listed optional protocols can be ordered (in sets of 4 channels: 1 – 4 or 5 – 8). These are processed on what is known as the ACC–84B (piggy back inside the Power Brick AC). Some protocols may overlap between the Gate3 and ACC–84B. Users may need new, updated protocols, or additional serial data information which may not be available with the standard Gate3 protocol implementation.

- With the optional ACC-84B installed, a given channel can be configured (in software) to use either one of the Gate3 serial encoder protocols or one of the ACC-84B protocols.

- If a serial encoder is used on a given channel, it is also possible to wire in on the same connector and process simultaneously a quadrature/sinusoidal/resolver encoder.

Note that pins #5, 6, 13, and 14 of the encoder feedback connectors (X1 – X8) share multiple functions: only one of these functions (per channel) can be used – configured in software – at one time:

- Hall sensors inputs (default configuration).
- Pulse and direction PFM output signals (software configuration using Flag D output, OutFlagD).
- Serial encoder inputs (software configuration enabling serial encoder line, SerialEncEna).
- Quadrature encoder inputs (serial encoder enable line must be 0).
- Alternate Sinusoidal encoder inputs (with sinusoidal encoder option).



Note

Each channel is independent of the other channels and can have its own use for these pins.

Environmental Specifications

Specification	Description	Range
Ambient operating Temperature EN50178 Class 3K3 – IEC721-3-3	Minimum operating temperature	0°C (32 °F)
	Maximum operating temperature	45°C (113 °F)
Storage Temperature Range EN 50178 Class 1K4 – IEC721-3-1/2	Minimum Storage temperature	-25°C (-13 °F)
	Maximum Storage temperature	70°C (158 °F)
Humidity Characteristics with NO condensation and NO formation of ice IEC721-3-3	Minimum Relative Humidity	10% HU
	Maximum Relative Humidity up to 35 °C (95 °F)	95% HU
	Maximum Relative Humidity from 35 °C up to 50 °C (122 °F)	85% HU
De-rating for Altitude	0 ~ 1000m (0 ~ 3300ft)	No de-rating
	1000 ~ 3000 m (3300 ~ 9840 ft)	-0.01% / m
	3000 ~ 4000 m (9840 ~ 13000 ft)	-0.02% / m
Environment ISA 71-04	Degree 2 environments	
Atmospheric Pressure EN50178 class 2K3	70 kPa to 106 kPa	
Shock	Unspecified	
Vibration	Unspecified	
Air Flow Clearances	3" (76.2 mm) above and below unit for air flow	
Cooling	Natural convection and external fan	
Standard IP Protection	IP20 IP 55 can be evaluated for custom applications	



Note

Above 40°C ambient, de-rate current output by 2.5% per °C.

Protection Specifications



Caution

The internal I^2T applies to and protects the amplifier power blocks. The software PMAC I^2T (described in a later section) must be configured properly to protect against motor / equipment damage.

Description	**Specifications**
Over Voltage	~ 307 VAC / 435 VDC (±2 %)
Under Voltage	~ 70 VAC / 100 VDC (±5 %)
AC Phase Loss Detection	Loss of one or more phases (single & three-phase operation)
Internal I^2T protection	2 seconds at rated peak Amps per axis
Over Temperature	~ 75°C
Motor Short Circuit	500 % of rated peak Amps per axis
Over Current	110 % of rated peak Amps per axis
Shunt I2T Detection	Integrated, I^2T model at 2 seconds peak
Shunt Short Detection	Shunt IGBT short circuit protection
Shunt Turn On Threshold	380 VDC
Shunt Turn Off Threshold	405 VDC
Soft Start Short Detection	Soft Start short circuit protection
PWM Out Of Range	Out of [4 – 20] kHz, or on-time exceeds 1.4 msec
Safe Torque Off STO	Cut off gate driver/motor power



Note

The under voltage fault triggers when the AC Input dips below 70 VAC (100 VDC). However, if this threshold has not been reached (i.e. Low Voltage/DC operation) the under voltage logic remains unarmed.

Electrical Specifications

4-Axis Power Brick AC

		PBA4-xxx-xxx-5xxxxxx	PBA4-xxx-xxx-8xxxxxx
Output Continuous Current per Axis	A_{rms}	5	8
Output Peak Current (2 sec) per Axis	A_{rms}	10	16
Rated Input Current @ 240 VAC 3-phase (All Axes)	A_{rms}	13	21
Max ADC (I^2T Settings)	A	15.625	25.0
Output Power per Axis (Modulation depth of 60% RMS)	Watts	1247	1995
Output Power Total	Watts	4489 W	7980
Power Dissipation	Watts	498	798
PWM Frequency Operating Range	KHz	4 – 20	
Main AC Input Line Voltage	VAC_{rms}	$110^{-20\%}$ – $240^{+10\%}$	
Main DC Input Line Voltage	VDC	12 – 340	
Logic Power Input Voltage	VDC	$24^{\pm 5\%}$	
Logic Power Input Current	A_{rms}	5	
Continuous Shunt Power Rating	Watts	4000	
Peak Shunt Power Rating	Watts	8000	
Recommended Shunt Resistor	Ohms	GAR 15 (15 Ω)	
Recommended Shunt Power Rating	Watts	300	



Note

Output power ratings specified at 12 kHz PWM.



Note

All electrical specifications are rated for three-phase 240 VAC main input. De-rating applies in single-phase AC, or DC Operation.

6-Axis Power Brick AC

		PBA6-xxx-xxx-5xxxxxx		PBA6-xxx-xxx-8xxxxxx	
Axes		**1-4**	**5-6**	**1-4**	**5-6**
Output Continuous Current per Axis	A_{rms}	5	15	8	15
Output Peak Current (2 sec) per Axis	A_{rms}	10	30	16	30
Max ADC (I^2T Settings)	A_{rms}	15.625	46.875	25.0	46.875
Rated Input Current @ 240 VAC 3-phase (All Axes)	A	33		41	
Output Power per Axis (Modulation depth of 60% RMS)	Watts	1247	3741	1995	3741
Output Power Total	Watts	12470		15462	
Power Dissipation	Watts	1247		1546	
PWM Frequency Operating Range	KHz	4 – 20			
Main AC Input Line Voltage	VAC_{rms}	$110^{-20\%}$ – $240^{+10\%}$			
Main DC Input Line Voltage	VDC	12 – 340			
Logic Power Input Voltage	VDC	$24^{\pm 10\%}$			
Logic Power Input Current	A	5			
Continuous Shunt Power Rating	Watts	7500			
Peak Shunt Power Rating	Watts	15000			
Recommended Shunt Resistor	Ohms	GAR 10 (10 Ω)			
Recommended Shunt Power Rating	Watts	300			



Note

Output power ratings specified at 12 kHz PWM.



Note

All electrical specifications are rated for three-phase 240 VAC main input. De-rating applies in single-phase AC, or DC Operation.

8-Axis Power Brick AC

		PBA8-xxx-xxx-55		PBA8-xxx-xxx-88		PBA8-xxx-xxx-58		PBA8-xxx-xxx-85	
Axes		**1 – 4**	**5 – 8**	**1 – 4**	**5 – 8**	**1 – 4**	**5 – 8**	**1 – 4**	**5 – 8**
Output Continuous Current per Axis	A_{rms}	5		8		5	8	8	5
Output Peak Current (2 sec) per Axis	A_{rms}	10		16		10	16	16	10
Max ADC (I^2T Settings)	A_{rms}	15.625		25		15.625	25	25	15.625
Rated Input Current @ 240 VAC 3-phase (All Axes)	A	24		40		32		32	
Output Power per Axis (Modulation depth of 60% RMS)	Watts	1247		1995		1247	1995		1247
Output Power Total	Watts	9976		15960		12968		12968	
Power Dissipation	Watts	998		1596		1297		1297	
PWM Frequency Operating Range	KHz	4 – 20							
Main AC Input Line Voltage	VAC_{rms}	$110^{-20\%} – 240^{+10\%}$							
Main DC Input Line Voltage	VDC	12 VDC to 340 VDC							
Logic Power Input Voltage	VDC	$24^{\pm 10\%}$							
Logic Power Input Current	A	5							
Continuous Shunt Power Rating	Watts	8000							
Peak Shunt Power Rating	Watts	8000							
Recommended Shunt Resistor	Ohms	GAR 15 (15 Ω)							
Recommended Shunt Power Rating	Watts	300							



Note

Output power ratings specified at 12 kHz PWM.



Note

All electrical specifications are rated for three-phase 240 VAC main input. De-rating applies in single-phase AC, or DC Operation.

Mounting

The location of the Power Brick AC is important. Installation should be in an area that is protected from direct sunlight, corrosives, harmful gases or liquids, dust, metallic particles, and other contaminants. Exposure to these can reduce the operating life and degrade performance of the drive.

Several other factors should be carefully evaluated when selecting a location for installation:

- For effective cooling and maintenance, the Power Brick AC should be mounted on a smooth, non-flammable vertical surface.
- At least 76 mm (3 inches) top and bottom clearance must be provided for air flow. At least 10 mm (0.4 inches) clearance is required between units (each side).
- Temperature, humidity and Vibration specifications should also be taken into consideration.



Caution

Unit must be installed in an enclosure that meets the environmental IP rating of the end product (ventilation or cooling may be necessary to prevent enclosure ambient from exceeding 45° C [113° F]).

The Power Brick AC can be mounted with a traditional 3-hole panel mount, two U shape/notches on the bottom and one pear shaped hole on top.

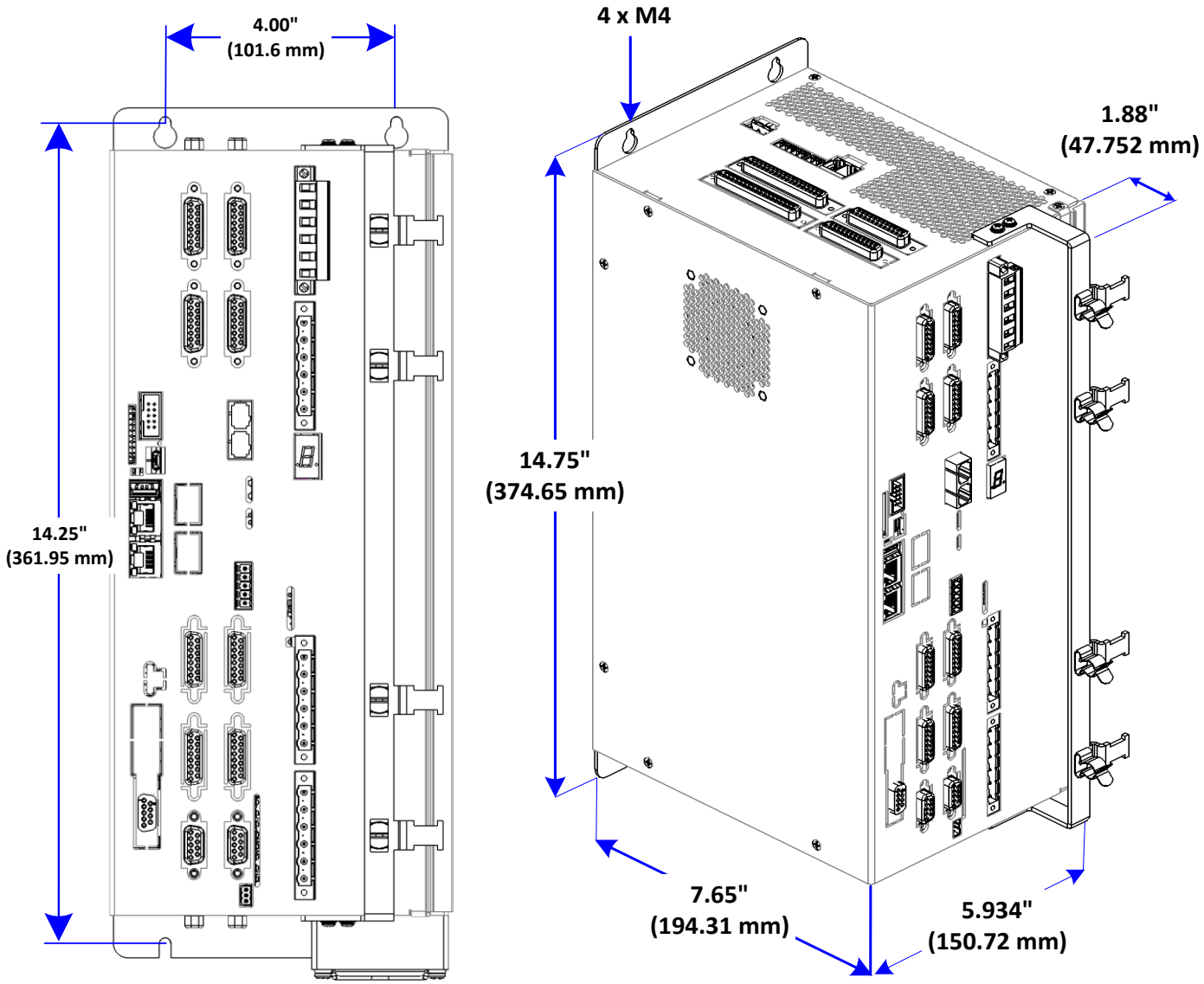
If multiple Power Brick ACs are used, they can be mounted side-by-side, leaving at least a 122 mm clearance between drives. This means a 122 mm center-to-center distance (0.4 inches). It is extremely important that the airflow is not obstructed by the placement of conduit tracks or other devices in the enclosure.

If the drive is mounted to a back panel, the back panel should be unpainted and electrically conductive to allow for reduced electrical noise interference. The back panel should be machined to accept the mounting bolt pattern of the drive.

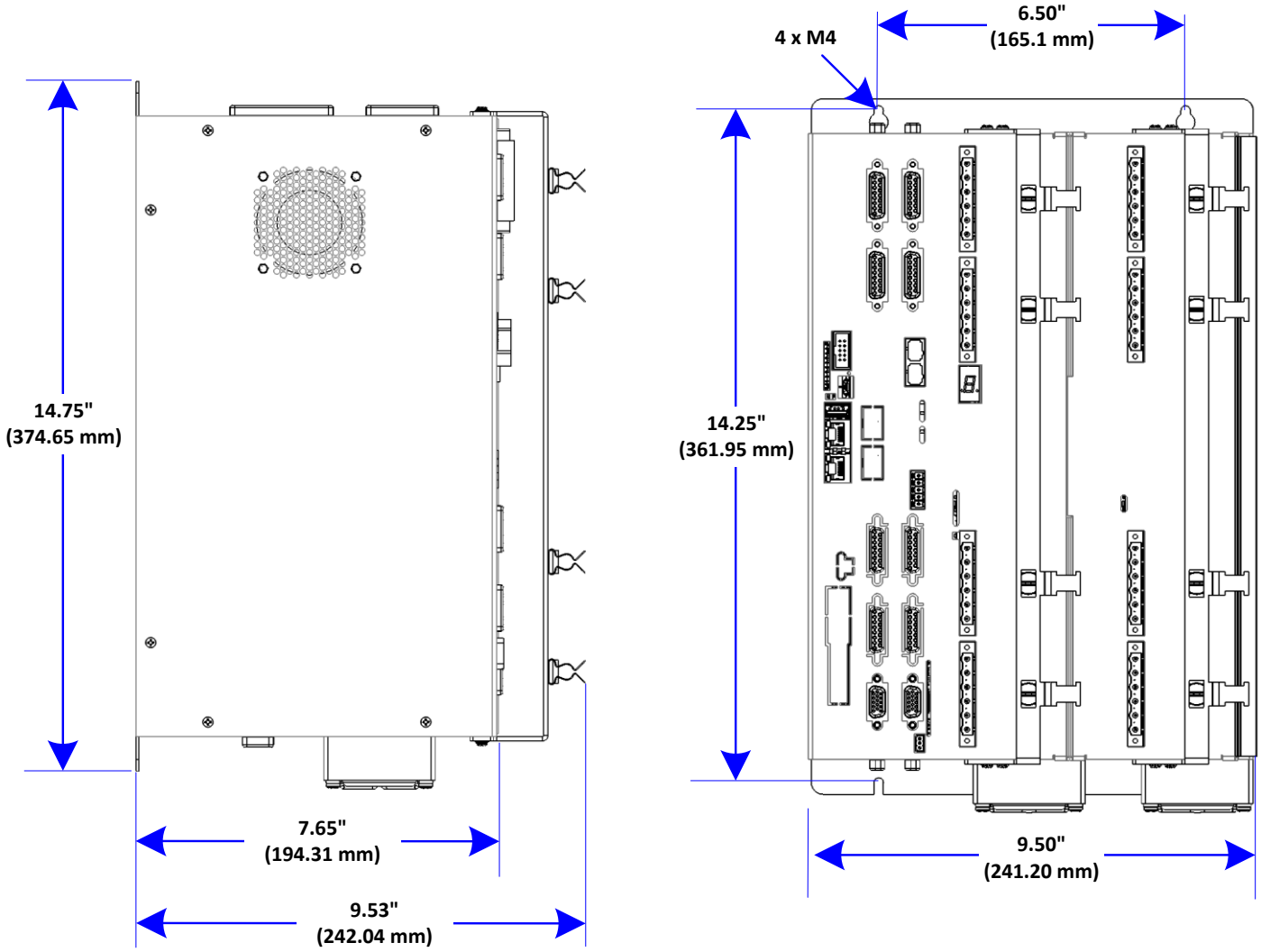
The Power Brick AC can be mounted to the back panel using M4 screws and internal-tooth lock washers. It is important that the teeth break through any anodization on the drive's mounting gears to provide a good electrically conductive path in as many places as possible. Mount the drive on the back panel so there is airflow at both the top and bottom areas of the drive (at least three inches).

Physical Specifications

4–axis Power Brick AC



6– / 8–axis Power Brick AC

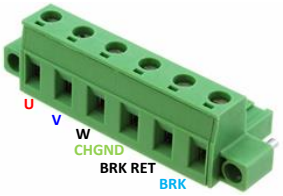


CONNECTIONS AND SOFTWARE SETUP

Warning

Installation of electrical control equipment is subject to many regulations including national, state, local, and industry guidelines and rules. General recommendations can be stated but it is important that the installation be carried out in accordance with all regulations pertaining to the installation.

A1 – A8: Motor / Brake Wiring

A1 - A8: Phoenix Contact 6-pin Female **Mating: Phoenix Contact 6-pin Male**			
Pin #	**Symbol**	**Function**	**Description**
1	U	Output	Phase 1
2	V	Output	Phase 2
3	W	Output	Phase 3
4	**CHGND**	**Chassis Ground**	
5	BRK RET	Return	Brake 0 V
6	BRK	Output	Brake 24 V
Phoenix Contact Mating Connector P/N: 1858808 Delta Tau Mating Connector P/N:			

Note

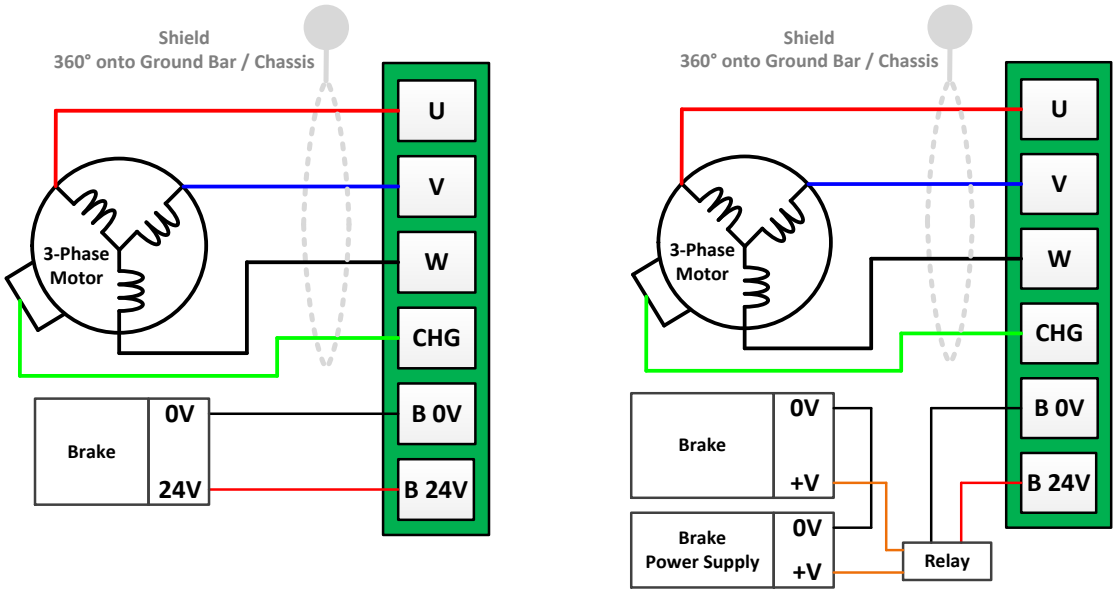
The Power Brick endorses the U, V, and W nomenclature for phases 1 through 3 respectively. Some motor manufacturers will call them A, B, and C. Others may call them L1, L2, and L3.

Caution

Brakes which require AC voltage, level other than 24V, or draw current in excess of **1 A** (at 24 VDC) must be powered using a dedicated external power supply.

If the motor brake does not draw more than **1 A** at 24 VDC (per channel), then the brake power supply provided on the A12 connector can be used to toggle the motor brake directly – left diagram (below).

If the motor brake is rated to voltage level other than 24 VDC, or draws more than **1 A** at 24 V, then the power supply provided through A12 can be used to toggle an external relay which routes the brake power from a dedicated power supply – right diagram (below).





Note

The motor's frame drain wire and the motor cable shield should be tied together to minimize noise disturbances.



Note

For two-phase DC Brush motors, use U and W, and leave V floating.

Configuring the Brake Output

The brake output is high true. It is 0V when the motor is killed (or OutFlagB = 0) and 24 V when the motor is enabled (or OutFlagB = 1). The necessary settings required to synchronize the enabling and disabling of the motor with the brake output signal are as follows:

```
Motor[1].pBrakeOut = PowerBrick[0].Chan[0].OutFlagB.a  //
Motor[1].BrakeOffDelay = 1                             // msec, Brake Off Delay --USER INPUT
Motor[1].BrakeOnDelay = 1                              // msec, Brake On Delay  --USER INPUT
Motor[1].BrakeOutBit = 9                               //
Motor[2].pBrakeOut = PowerBrick[0].Chan[1].OutFlagB.a  //
Motor[2].BrakeOffDelay = 1                             // msec, Brake Off Delay --USER INPUT
Motor[2].BrakeOnDelay = 1                              // msec, Brake On Delay  --USER INPUT
Motor[2].BrakeOutBit = 9                               //
Motor[3].pBrakeOut = PowerBrick[0].Chan[2].OutFlagB.a  //
Motor[3].BrakeOffDelay = 1                             // msec, Brake Off Delay --USER INPUT
Motor[3].BrakeOnDelay = 1                              // msec, Brake On Delay  --USER INPUT
Motor[3].BrakeOutBit = 9                               //
Motor[4].pBrakeOut = PowerBrick[0].Chan[3].OutFlagB.a  //
Motor[4].BrakeOffDelay = 1                             // msec, Brake Off Delay --USER INPUT
Motor[4].BrakeOnDelay = 1                              // msec, Brake On Delay  --USER INPUT
Motor[4].BrakeOutBit = 9                               //
Motor[5].pBrakeOut = PowerBrick[1].Chan[0].OutFlagB.a  //
Motor[5].BrakeOffDelay = 1                             // msec, Brake Off Delay --USER INPUT
Motor[5].BrakeOnDelay = 1                              // msec, Brake On Delay  --USER INPUT
Motor[5].BrakeOutBit = 9                               //
Motor[6].pBrakeOut = PowerBrick[1].Chan[1].OutFlagB.a  //
Motor[6].BrakeOffDelay = 1                             // msec, Brake Off Delay --USER INPUT
Motor[6].BrakeOnDelay = 1                              // msec, Brake On Delay  --USER INPUT
Motor[6].BrakeOutBit = 9                               //
Motor[7].pBrakeOut = PowerBrick[1].Chan[2].OutFlagB.a  //
Motor[7].BrakeOffDelay = 1                             // msec, Brake Off Delay --USER INPUT
Motor[7].BrakeOnDelay = 1                              // msec, Brake On Delay  --USER INPUT
Motor[7].BrakeOutBit = 9                               //
Motor[8].pBrakeOut = PowerBrick[1].Chan[3].OutFlagB.a  //
Motor[8].BrakeOffDelay = 1                             // msec, Brake Off Delay --USER INPUT
Motor[8].BrakeOnDelay = 1                              // msec, Brake On Delay  --USER INPUT
Motor[8].BrakeOutBit = 9                               //
```



Note

For toggling the brake output manually, set **pBrakeOut = 0** and write to the **PowerBrick[].Chan[].OutFlagB** bit element.

Motor Cable, Noise Elimination

The Power Brick ACs' voltage output has a fundamental frequency and amplitude that corresponds to motor speed, torque, and number of poles. As a Direct Digital PWM Drive, the Power Brick AC produces higher frequency voltage components corresponding to the rise, fall and repetition rate of the fast switching PWM signals. Subsequently, it could naturally couple current noise to nearby conductors. This electrical coupling can be problematic, especially in noise-sensitive applications such as using high-resolution sinusoidal encoders, or high rate of communication which could suffer from Electro-Magnetic Interference EMI. Proper grounding, shielding, and filtering can alleviate most noise issues. Some applications may require additional measures such as PWM edge filters. The following; are general guidelines for proper motor cabling:

- Use a motor cable with **high quality shield**. A combination braid-and-foil is best.
- **The motor drain wires and cable shield should be tied together, and attached at both ends of the motor and Power Brick AC chassis / ground bar**. At the motor end, make a 360 degree connection between the shield and motor frame. If the motor has a metal shell connector, then you can tie the shield directly to the metal shell of the mating connector. The connection between the cable shield and the motor frame should be as short as possible). At the Power Brick AC end, make a 360 degree connection between the shield and the chassis ground bar (protection earth).
- The motor cable should have a **separate conductor (drain wire) tying the motor frame to the Power Brick AC drive**.
- **Keep the motor cable as short as possible** to maintain lower capacitance (desirable). A capacitance of up to 50 Pico Farads per foot (0.3048 m), and runs of up to 200 feet (60 m) are acceptable with 240VAC. Exceeding these lengths requires the installation of a Snubber at the motor end or an in-series inductor at the Power Brick AC end.
- If the grounding/shielding techniques are insufficient, you may **install chokes in the motor phases at the Power Brick AC end** such as wrapping individual motor leads several times through a ferrite core ring. DigiKey, Micro-Metals (T400-26D), Fair Rite (2643540002), or equivalent ferrite cores are recommended. This adds high-frequency impedance to the outgoing motor cable thereby making it harder for high-frequency noise to leave the control area.



Note

Ferrite cores are also commonly used with lower inductance motors to enhance compatibility with the Power Brick AC, which is nominally about 2 mH.

- **Do not use a motor wire gauge less than 14 AWG for 5/10 A or 8/16 A axes, and 10 AWG for 15/30 A axes** unless otherwise specified by the motor manufacturer. Refer to Motor manufacturer and local code recommendations.
- Avoid running sensitive signal cables (i.e. encoders, small signal transducers) in the same cable bundle as the motor cable(s).
- Install dv/dt filter, Trans-coil V1K series (Optional).

Motor Selection

The Power Brick AC interfaces with a wide variety of motors. It supports virtually any kind of three-phase AC/DC rotary, linear brushless, or induction motors. Using two out of the three phases, it is also possible to drive permanent magnet DC brush motors.

Motor Inductance

Digital direct PWM control requires a significant amount of motor inductance to drive the on-off voltage signals resulting smooth current flow with minimal ripple. Typically, servomotors' phase inductance ranges from 2 to 15mH. The lower the inductance, the higher is the suitable PWM frequency.
Low inductance motors (less than 2 mH) can see large ripple currents causing excessive energy waste and overheating. Additional in-series inductance is recommended in these cases.
High inductance motors (greater than 15 mH) are slower to react and generally not considered high performance servo motors.

Motor Resistance

Motor resistance is not typically a determining factor in the drive/system performance but rather comes into play when extracting a desired torque or horsepower out of the motor is a requirement.

Motor Inertia

Motor inertia is an important parameter in motor sizing. Considering the reflected load inertia back to the motor in this process is important. In general, the higher the motor inertia, the more stable the system will inherently be. A high ratio of load to motor inertia shrinks the operating bandwidth (gain limited) of the system, especially in applications using belt or rubber based couplings. The ratio of load to motor inertia is typically around 3:1. Mechanical gearing is often used to reduce reflected inertial load going back to the shaft of the motor.

Motor Speed

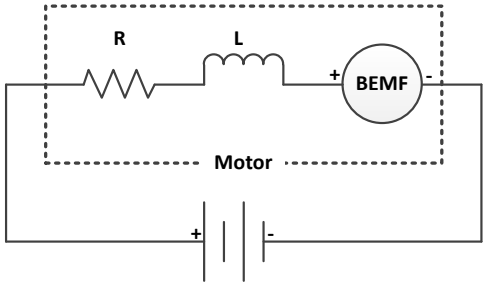
In some applications, it is realistically impossible to achieve the motors' specified maximum velocity. Fundamentally, providing sufficient voltage and proper current-loop tuning should allow attaining motor maximum speeds. Consider feedback devices being a limitation in some cases, as well as the load attached to the motor. In general, the maximum speed can be determined dividing the line-to-line input voltage by the back EMF constant Kb of the motor. Input voltage headroom of about 20% is recommended for good servo control at maximum speed.

Motor Torque

Torque requirements in an application can be viewed as both instantaneous and average
Typically, the instantaneous or peak torque is the sum of machining, and frictional forces required to accelerate the inertial load. The energy required to accelerate a load follows the equation T=JA where T is the torque, J is the inertia, and A is the acceleration. The required instantaneous torque is then divided by the motor torque constant (Kt) to determine the necessary peak current of the Power Brick AC. Headroom of about 10% is always desirable to account for miscellaneous losses (aging, wear and tear, calculation roundups).
The continuous torque rating of the motor is bound by thermal limitation. If the motor applies more torque than the specified threshold, it will overheat. Typically, the continuous torque ceiling is the RMS current rating of the motor, also known as torque output per ampere of input current.

Required Bus Voltage for Speed and Torque

For a required motor Speed, and continuous Torque, the minimum DC Bus Voltage (V_{DC}) can be estimated by looking at the equivalent single phase circuit:



The vector sum of back EMF, voltage across resistor and inductor should be less than $V_{DC}/\sqrt{6}$.

For a Rotary Motor:

$$\sqrt{V_L{}^2+(V_R+V_{BEMF})^2}=\sqrt{\left(\frac{R_{RPM}}{60}\cdot N_p\cdot 2\cdot\pi\cdot L_p\cdot\frac{T_M}{K_t}\right)^2+\left(\frac{T_M}{K_t}R_p+\frac{R_{RPM}}{60}\cdot\frac{K_t}{3}\cdot 2\cdot\pi\right)^2}\le M_{derate}\frac{V_{DC}}{\sqrt{6}}$$

Where:

V_L	: Voltage Across equivalent inductor	L_P	: Phase Inductance [H]
V_R	: Voltage Across equivalent resistor	R_P	: Phase Resistance [Ω]
V_{BEMF}	: Back electromotive force voltage	T_M	: Required Continuous Torque [N.M]
R_{RPM}	: Required Motor Speed [rpm]	K_T	: Motor Torque Constant RMS [N.M/A]
N_P	: Number of pole pairs	M_{derate}	: De-rate parameter (typically 0.8)

For a Linear Motor:

$$\sqrt{V_L{}^2+(V_R+V_{BEMF})^2}=\sqrt{\left(\frac{V_{motor}}{D_{pitch}}\cdot L_p\cdot\frac{F_M}{K_t}\right)^2+\left(\frac{F_M}{K_t}R_p+\frac{V_{motor}}{D_{pitch}}\cdot\frac{K_t}{3}\right)^2}\le M_{derate}\frac{V_{DC}}{\sqrt{6}}$$

Where:

V_L	: Voltage across equivalent inductor	L_P	: Phase Inductance [H]
V_R	: Voltage across equivalent resistor	R_P	: Phase Resistance [Ω]
V_{BEMF}	: Back electromotive Force voltage	F_M	: Required Motor Force RMS [N]
V_{motor}	: Required Motor Speed [m/s]	K_t	: Motor Force Constant RMS [N/A]
M_{derate}	: De-rate parameter (typically 0.8)	D_{Pitch}	: Magnetic Pitch [m]

Example:

An application requires running a motor at 500 RPM with a continuous torque of 30 N.M. The motor specs are as follow:

$L_p = 10\,\text{mH}$, $R_p = 2\,\text{Ohm}$, $N_p = 16$, $K_t = 2.187\,\text{Nm/Amps}$

Using the equation above, a minimum bus of 233 VDC (~165VAC) is necessary to achieve the speed and torque requirements.

A10: Logic Power Input

A10 is used to bring in the 24 VDC supply powering up the logic portion of the Power Brick AC. This power can remain on regardless of the main AC bus power, allowing the signal electronics to be active while the main motor power is passive.

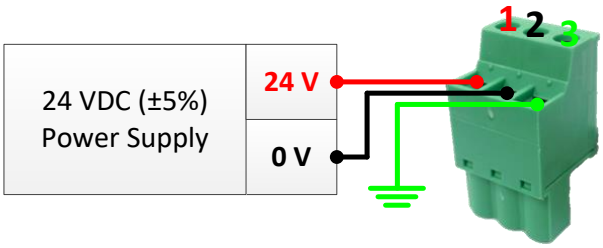


Caution

The 24V logic power must always be applied before applying main AC bus power.

The **24-Volt (±5%)** power supply unit must be capable of providing **5 amperes** per Power Brick AC. If multiple drives are sharing the same 24-Volt power supply, it is highly recommended to wire each drive back to the power supply terminals separately. This connection can be made using a 22 AWG wire directly from a protected power supply.

A10: 3-pin Female **Mating: 3-pin Male**				
Pin #	**Symbol**	**Function**	**Description**	**Notes**
1	+24 VDC	Input	Logic power input	24 VDC (±5 %)
2	+24 VDC RET	Return	Logic power return	0 VDC
3	CHGND	Chassis ground		
Phoenix Contact Mating Connector P/N: 1777293				





Note

Chassis ground (pin #3) and + 24 VDC RET (pin #2) are tied together internally.

A11: Safe Torque Off STO, Dynamic Braking

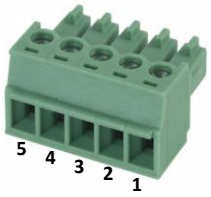
Connector A11 serves the following functions:

- Disabling the Safe Torque Off STO
- Arming / using the STO
- Using dynamic braking
- Wiring the STO feedback (output status)



Caution

Power Brick units shipped prior to the Q3 2016 had the Dynamic Brake (DYN BRAKE) and STO IN silkscreen etchings reversed.

A11: Phoenix 5-pin Female **Mating: Phoenix 5-pin Male**			
Pin #	**Symbol**	**Function**	**Description**
1	STO FB	Output	STO Feedback
2	STO IN	Input	STO
3	DYN BRAKE	Input	Dynamic Braking
4	DISABLE STO	-	Tie together to disable STO
5			
Phoenix Contact Mating Connector P/N: 1850699 Delta Tau mating connector P/N: 016-090A03-08P			

The Safe Torque Off (STO) allows the complete "hardware" disconnection of the power amplifiers from the motors by shutting down the gate-drivers power. This mechanism prevents unintentional "movement of" or torque output to the motors in accordance with IEC/EN safety standards.

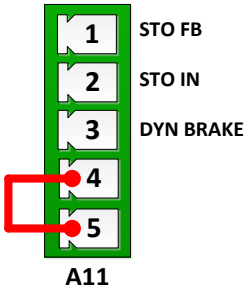
Dynamic braking forces the motors to a quick uncontrolled stop preventing them from coasting freely. This is achieved by tying the motor leads together internally.

The STO FB feedback is an indicator of the STO status. Optionally, it can be brought back into the Power Brick AC as a digital input, or wired into other machine logic device(s).

Disabling the STO

The STO can be fully disabled by tying pins #4 and #5 together.

All other pins on this connector have no practical use in this mode, and should be left floating.

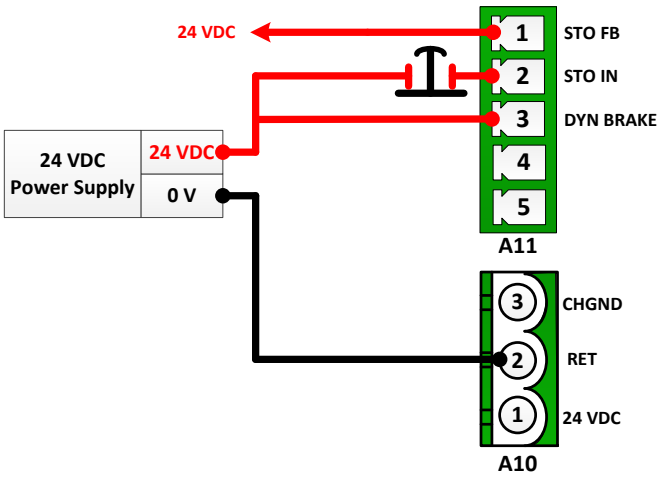


Wiring and Using the STO

This scheme is suitable for a **Category 0 safe – uncontrolled – stop** in accordance with machine safety regulations. That is removing power to the actuators immediately.

In normal mode operation, the STO must be a normally closed relay (24 VDC applied).

In normal mode operation, the STO FB feedback is at 24V.



When the STO is triggered (24 VDC disconnected):

- Power is removed immediately; the motors are killed, **coasting freely**.
- The STO Feedback level drops to 0 V.
- The 7-segment displays an **E** fault.
- The PMAC reports and latches an amplifier fault in the motor status.



Note

Power is completely removed while the 24 VDC is disconnected from the STO IN. No motor motion can be executed (amplifier fault). Once the 24 VDC is re-applied, motors are ready for motion and the display fault is cleared.



Note

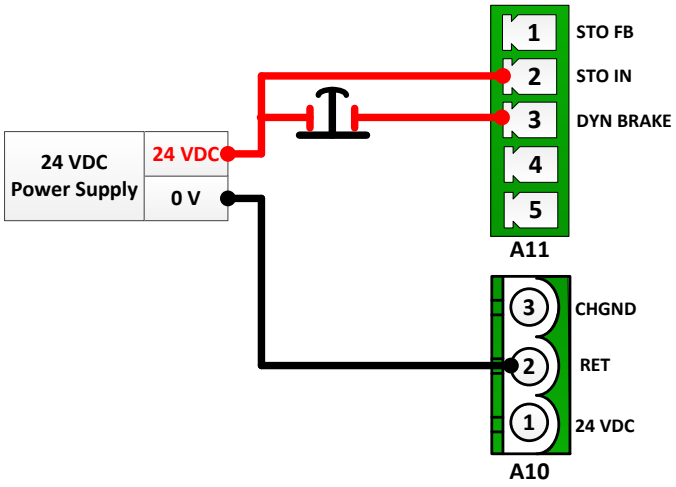
If the STO is not disabled, both STO IN and DYN BRAKE must see 24 VDC to allow motor motion.

Wiring and Using the Dynamic Braking

This scheme is used if the application mandates minimal coasting in an **uncontrolled stop** request.

Some applications may choose to use dynamic braking prior to triggering the STO.

In normal mode operation, the DYN BRAKE must be normally closed (24 VDC applied).



When the DYN BRAKE is triggered (24 VDC disconnected):

- Motors are killed, leads are shorted together (internally) bringing the motors to a quick standstill.
- The 7-segment displays a **b** fault.
- The Power PMAC reports an amplifier fault in the motor status.

Note

No motor motion is allowed while this 24 VDC is disconnected. Once re-applied, the 7-segment display fault is cleared, and the motor is ready for motion.

Note

If the STO is not disabled, both STO IN and DYN BRAKE must see 24 VDC to allow motor motion.

Note

Dynamic braking must not be confused with controlled stop, which is performed using the Abort Input (X18).

A12: Brake Power (Axes 1 – 4)

A12 is used to supply the +24 VDC brake power for axes 1 – 4.



Caution

Brakes which require AC voltage, other than 24 VDC, or draw current in excess of **1 A** (at 24 VDC, per channel) must be powered using a dedicated external power supply and not through A12.

A12: Phoenix 2-pin Female **Mating: Phoenix 2-pin Male**			
Pin #	**Symbol**	**Function**	**Description**
1	+ 24 VDC	Input	
2	+ 24 VDC RET	Input	
Phoenix Contact Mating Connector P/N: 1850660 Delta Tau mating connector P/N:			

A14: External Shunt Resistor



Caution

All applications using Power Brick AC drives (all configurations) are strongly advised to install an external shunt resistor.

A14: Phoenix 2-pin Female **Mating: Phoenix 2-pin Male**			
Pin #	**Symbol**	**Function**	**Description**
1	SHUNT+	Input	
2	SHUNT–	Input	
Phoenix Contact Mating Connector P/N: 1777723 Delta Tau mating connector P/N: 016-PL0F02-76P			

A14 is used to wire an external shunt resistor to expel the excess power during demanding deceleration profiles. The 4- and 8-axis Power Brick AC drives are designed for operation with external shunt resistors of 15 Ohms.



Caution

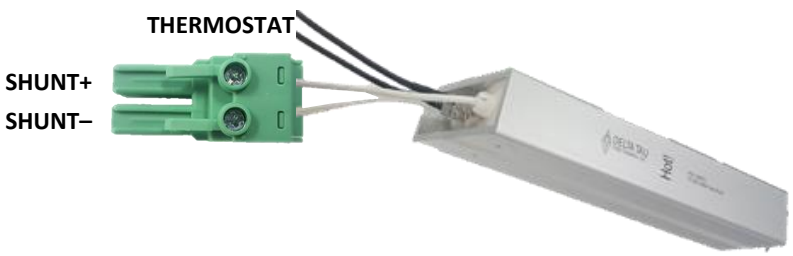
The external shunt resistor can reach temperatures of up to 200°C. It must be mounted away from other devices and ideally near the top of the cabinet, also ensure it is enclosed and cannot be touched during operation.

Delta Tau offers these resistors (GAR15) with pre-terminated cables that plug directly into A14. These resistors incorporate a normally closed (N.C.) thermal overload protection thermostat. The thermostat goes into an open state when the core temperature of the resistor exceeds 225°C (450° F). This thermostat is accessible through the two black leads. It is important that these two leads be wired into a safety circuit to halt operation should the resistor temperature exceed the specified threshold.



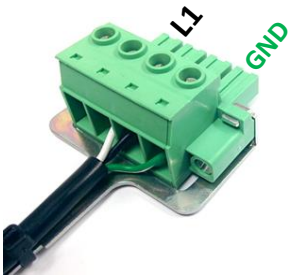
Note

The white conduits are shunt resistor leads whereas the black wires are thermostat.



A15: Main Bus Power Input

A15 is used to bring the main AC/DC bus power into the Power Brick AC.

A15: Phoenix Contact 4-pin Female **Mating: Phoenix Contact 4-pin Male**				
Symbol	**Function**	**Three Phase**	**Single Phase**	**DC**
L1	Input	AC Line Phase 1	Not Connected	Not Connected
L2	Input	AC Line Phase 2	Neutral	0 VDC
L3	Input	AC Line Phase 3	Line	DC +
GND	Ground			
Phoenix Contact Mating Connector P/N: 1970359 Delta Tau P/N: 016-197035-94P				



Note

In single phase operation, use L2 and L3, and leave L1 floating.
In DC mode operation, use L3 for DC+ and L2 for 0 V, and leave L1 floating.



Note

BrickAC.SinglePhaseIn must be set to 1 in single phase or DC operations. For this setting to take effect, **BrickAC.Reset** or **BrickAC.Config** must be set to 1 at least once.



Caution

The main AC power should NEVER be supplied to the Power Brick AC if the 24 VDC logic power is NOT applied.



Caution

Make sure that no motor commands (e.g. phasing, jogging) are being executed at the time of applying main AC power.

Advised Power On/Off Sequence



Caution

Main AC input power should never be cycled rapidly and repeatedly within a few seconds.

Powering up the Power Brick AC must obey the following sequence:

1. Make sure main bus power is disconnected (e.g. E-Stop engaged)

2. Apply 24 VDC logic power (A10).
   The STO and Dynamic Brake states are irrelevant at this point.

3. Configure the PMAC to execute the Power On Reset PLC. That is setting **BrickAC.Reset = 1** and waiting for it to return a **0** indicating a successful reset operation.

4. Apply main bus power (A15) (e.g. Releasing the E-Stop). Wait at least 1 second for the soft start circuitry to finish its task.

5. Reset STO / Dynamic Brake (if utilized).

6. Energize motors.

Powering down the Power Brick AC must obey the following sequence:

1. Disconnect main bus power (A15).
   Kill / de-energize motors simultaneously (e.g. via an E-Stop PLC).
   The STO and Dynamic Brake states are irrelevant at this point.

2. Allow approximately 1 second.

3. Disconnect 24 VDC logic power (A10).



Note

Killing all motors (in software logic, background PLC) upon engaging the E-Stop is highly recommended. This could be triggered by a general purpose input which is typically tied to the E-Stop button/circuit.

Recommended Main Bus Power Wiring / Protection



Caution

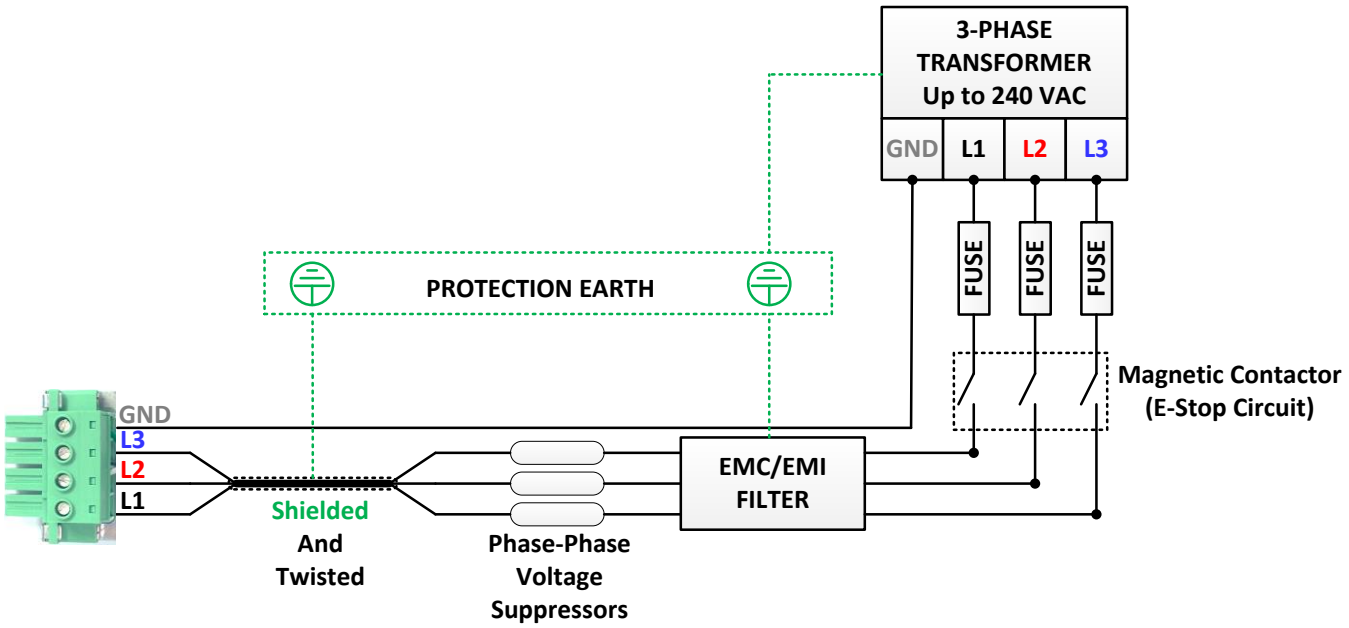
Main AC power lines should run in a separate duct at least 12” (or 30 cm) away from – and should never be bundled with – the I/O, communication, or encoder cables.

Grounding, Bonding

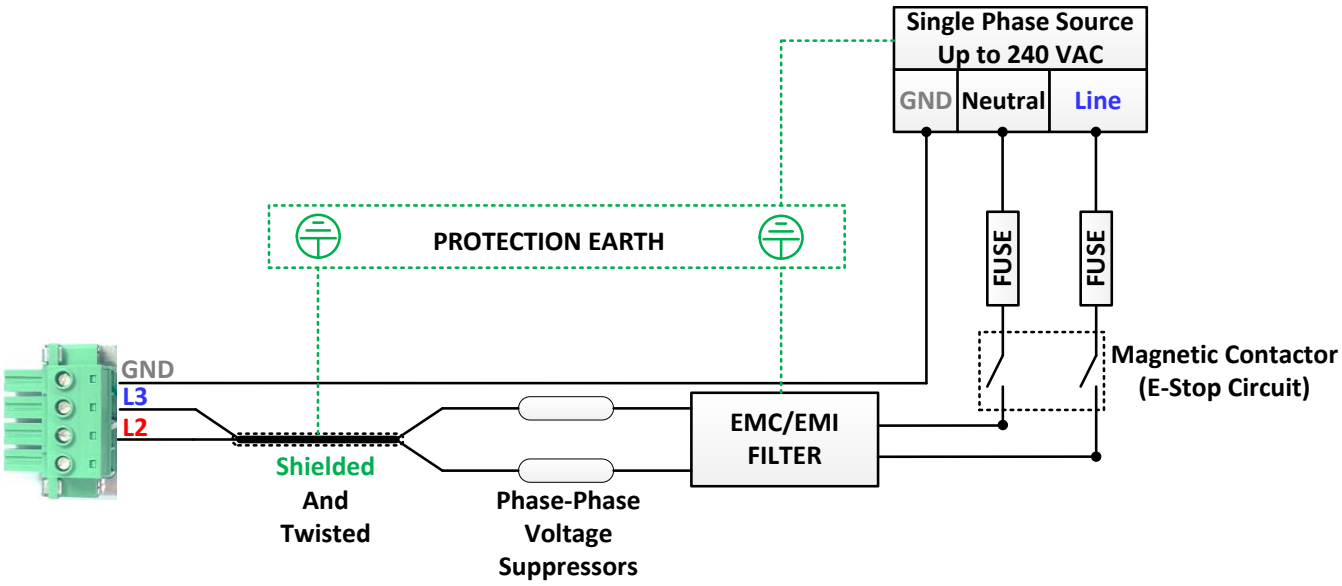
System grounding is crucial for proper performance of the Power Brick AC. Panel wiring requires that a central earth-ground (also known as ground bus bar) location be installed at one part of the panel. The ground bus bar is usually a copper plate directly bonded to the back panel. This electrical ground connection allows for each device within the enclosure to have a separate wire brought back to the central earth-ground.

- Implement a star point ground connection scheme; so that each device wired to earth ground has its own conductor brought directly back to the central earth ground plate (bus bar).
- Use an unpainted back panel. This allows a wide area of contact for all metallic surfaces, reducing frequency impedances.
- Use a heavy gauge ground earth conductors made up of many strands of fine conducts.
- The Power Brick AC is brought to the earth-ground via one or two wire(s) connected to the M4 mounting stud(s) through a heavy gauge multi-strand conductor to the central earth-ground. It can alternately be tied to the motor grounding bar.

Three-Phase Main AC Power Wiring Diagram



Single-Phase Main AC Power Wiring Diagram



Transformers

Y-Y or Y-Δ transformers should be used.

Δ-Δ Transformers are NOT advised. They try to balance phases dynamically, creating instances of instability in the Power Brick AC's rectifying circuitry.



Note

A line reactor should be installed if a transformer or reliable source of power is not available. Line reactors suppress harmonics bi-directionally, eliminating low frequency spikes.

Fuses

High peak currents and high inrush currents demand the use of slow blow time delayed type fuses. RK1 or RK5 (i.e. current limiting) classes are recommended. **FRN-R** and **LPN-RK** from **Cooper Bussmann** or similar fuses can be used.

The following table summarizes fuse gauges for three-phase bus input (240 VAC) at full load:

Model	Fuse (amps)
PBA4-xxx-xxx-5	15
PBA4-xxx-xxx-8	25
PBA6-xxx-xxx-5	35
PBA6-xxx-xxx-8	45

Model	Fuse (amps)
PBA6-xxx-xxx-55	30
PBA6-xxx-xxx-88	45
PBA6-xxx-xxx-58	35
PBA6-xxx-xxx-85	35

Specific applications fuse sizing can be done using the following equations. Take, as an example, a 4-axis Power Brick AC (5/10 A) on 240 VAC bus, and driving 4 motors (5 A continuous current rating):

DC Bus Voltage:	$V_{DCBus} = \sqrt{2} \times V_{ACBus} = 1.414 \times 240 = 339.4$	[VDC]
Motor Phase voltage:	$V_{MotorPhase} = \frac{V_{DCBus}}{\sqrt{6}} = \frac{339}{2.45} = 138.5$	[VDC]
Power per axis:	$P_{Axis} = 3 \times V_{MotorPhase} \times I_{MotorPhase} \times 0.6 = 3 \times 138.6 \times 5 \times 0.6 = 1247$	[Watts]
Total power:	$P_{Total} = \sum P_{Axis} = 4 \times 1247 = 4988.3$ Watts	[Watts]
Dissipated power:	$P_{Dis} = 0.1 \times P_{Total} = 0.1 \times 4988 = 498.8$ Watts	[Watts]
Current draw per phase (for 3Φ bus input)	$I_{3Phase} = \frac{P_{Total} + P_{Dis}}{\sqrt{3} \times V_{ACBus}} = \frac{4988 + 499}{1.732 \times 240} = 13.2$ Amps	[Amps]
Current draw per phase (for 1Φ bus input)	$I_{1Phase} = \frac{P_{Total} + P_{Dis}}{V_{ACBus}} = \frac{4988 + 499}{1.732 \times 240} = 22.8$ Amps	[Amps]

Thus, 15 and 25 amp fuses are chosen for three and single phase bus power input lines respectively.

Magnetic Contactors

SC-E series from **Fuji Electric** or similar contactor can be used.

Line Filters

Line filters eliminate electromagnetic noise in a bi-directional manner (from and into the system).
T type filters are NOT recommended. PI type line filters are highly advised:

- Filter should be mounted on the same panel as the drive and power source.
- Filter should be mounted as close as possible to the power source.
- Filter should be mounted as close as possible to incoming cabinet power.

FN-258 series from **Schaffner** or similar filter can be used.

Voltage Suppressors

Voltage suppressors eliminate undesirable voltage spikes typically generated by the magnetic contactor or external machinery in the plant.
This 3-phase **voltage arrester** from **Phoenix Contact** or similar suppressor can be used.

Bus Power Cables

The Power Brick AC electronics create a DC bus by rectifying the incoming AC lines. The current flow into the drive is not sinusoidal but rather a series of narrow, high-peak pulses. Keeping the incoming impedance small is essential for not hindering these current pulses.
Whether single- or three-phase, it is important that the AC input wires be twisted together to eliminate noise radiation as much as possible. Recommended wire gauge:

Model	Wire Gauge (AWG)
PBA4-xxx-xxx-5	12
PBA4-xxx-xxx-8	10
PBA6-xxx-xxx-5	8
PBA6-xxx-xxx-8	8

Model	Wire Gauge (AWG)
PBA6-xxx-xxx-55	10
PBA6-xxx-xxx-88	8
PBA6-xxx-xxx-58	8
PBA6-xxx-xxx-85	8



Note

All ground conductors should be 8AWG minimum using wires constructed of many strands of small gauge wire. This ensures the lowest impedance to high-frequency noises.

A16: Brake Power (Axes 5 – 8)

A16 is used to supply the +24 VDC brake power for axes 5 – 8.



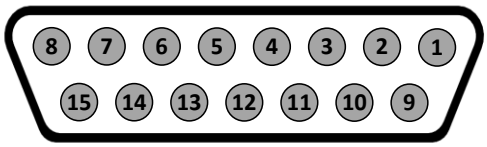
Caution

Brakes which require AC voltage, other than 24 VDC, or draw current in excess of **1 A** (at 24 VDC, per channel) must be powered using a dedicated external power supply and not through A16.

A16: Phoenix 2-pin Female **Mating: Phoenix 2-pin Male**			
Pin #	**Symbol**	**Function**	**Description**
1	+ 24 VDC	Input	
2	+ 24 VDC RET	Input	
Phoenix Contact Mating Connector P/N: 1850660 Delta Tau mating connector P/N:			

X1 - X8: Encoder Feedback, Digital Quadrature

The Power Brick AC processes digital quadrature (also known as incremental) encoder signals by default. It provides up to four counts per square cycle, and extends it using hardware-computed (ASIC) 1/T.

X1-X8: D-sub DA-15F **Mating: D-sub DA-15M**					
Pin#	**Symbol**	**Function**	**Primary Use**	**Alternate Use**	
1	CHA +	Input	Encoder A +		
2	CHB +	Input	Encoder B +		
3	CHC +	Input	Index C +	Amp. Enable +	
4	**ENCPWR**	**Output**	**Encoder Power 5 VDC (max 250 mA per channel)**		
5	CHU / DIR +	In / Out	Halls U	Direction Out +	Serial Data –
6	CHW / PUL +	In / Out	Halls W	Pulse Out +	Serial Clock –
7	2.5V	Output	2.5 VDC Reference power		
8	PTC	Input	Motor Thermal Input		
9	CHA –	Input	Encoder A –		
10	CHB –	Input	Encoder B –		
11	CHC –	Input	Index C –	Amp. Enable –	
12	**GND**	**Common**	**Common ground**		
13	CHV / DIR –	In / Out	Halls V	Direction Out –	Serial Clock +
14	CHT / PUL –	In / Out	Halls T	Pulse Out –	Serial Data +
15					



Note

Quadrature encoders can be wired in and processed regardless of the encoder feedback option(s) fitted.



Caution

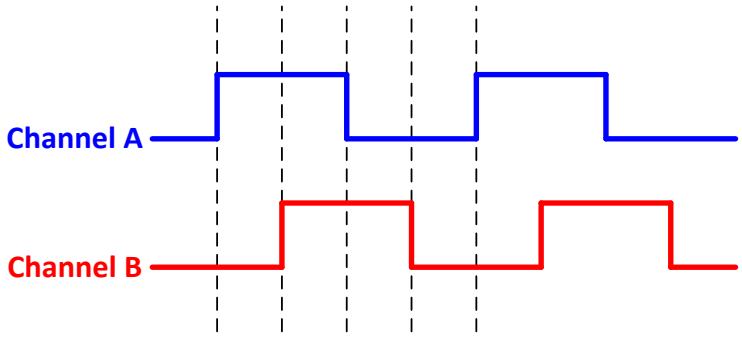
The +5 VDC encoder power is limited to ~250 mA per channel. For encoders requiring more current, the +5 VDC power can be alternately brought in externally through the +5 VDC ENC connector.



Caution

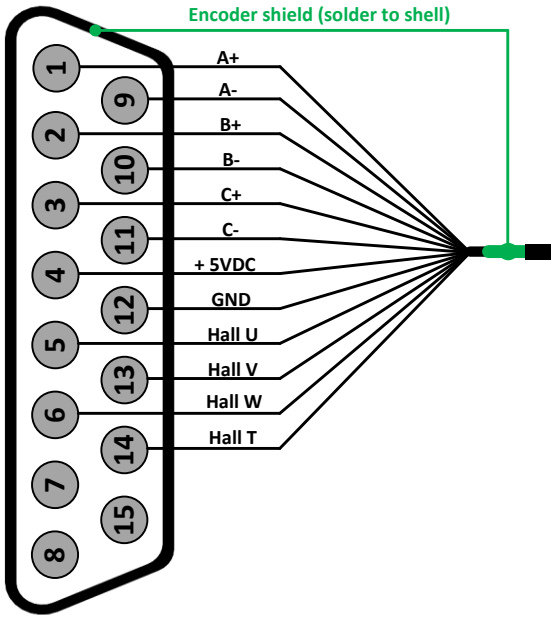
Encoders requiring voltage levels other than +5 VDC (higher or lower) should be powered directly from an external power supply.

Quadrature encoders provide two digital signals to determine the position of the motor. These signals are typically 5V TTL/CMOS level. Each nominally with 50% duty cycle, and 1/4 cycle apart. This format provides four distinct states per cycle of the signal, or per line of the encoder. The phase difference of the two signals permits the decoding electronics to discern the direction of travel, which would not be possible with a single signal.

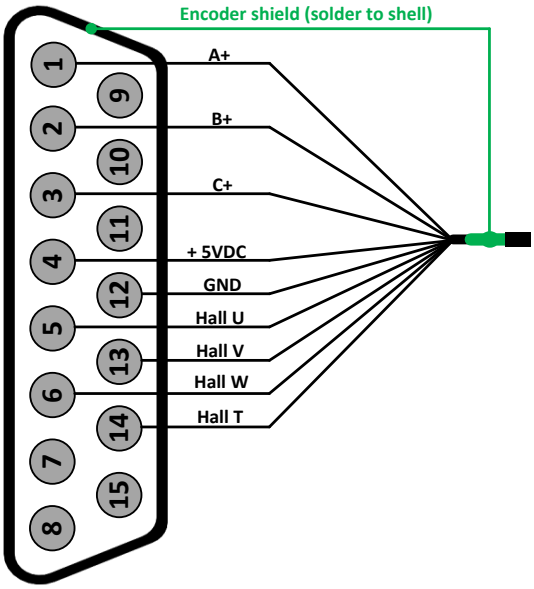


Quadrature encoders can be wired either in a differential or single-ended manner. Differential signals can enhance noise immunity by providing common mode noise rejection. Modern design standards virtually mandate their use in industrial systems.

Differential



Single-Ended





Note

In single-ended mode, leave the negative pins floating. They are terminated internally.

Configuring Quadrature Encoders

The Power Brick AC firmware is configured to process quadrature incremental encoders by default. This type of encoders is processed as a single 32-bit word in the Encoder Conversion Table (ECT). The 1/T extension is done in the DSPGate3 hardware. Starting from factory default settings, activating the channel is sufficient to display counts in the position window when the motor / encoder shaft is moved by hand.

Default Encoder Conversion Table for quadrature incremental encoders:

```
EncTable[1].type = 1
EncTable[1].pEnc = PowerBrick[0].Chan[0].ServoCapt.a
EncTable[1].pEnc1 = Sys.Pushm
EncTable[1].index1 = 0
EncTable[1].index2 = 0
EncTable[1].index3 = 0
EncTable[1].index4 = 0
EncTable[1].index5 = 0
EncTable[1].index6 = 0
EncTable[1].ScaleFactor = 1 / 256
```

Default settings for quadrature incremental encoders:

```
Motor[1].ServoCtrl = 1
Motor[1].pEnc = EncTable[1].a
Motor[1].pEnc2 = EncTable[1].a
```



Note

The hardware 1/T extension produces 8 bits of fractional data, thus the (1 / 256) 0.00390625 scale factor.

Ch. #	Source Address
1	PowerBrick[0].Chan[0].ServoCapt.a
2	PowerBrick[0].Chan[1].ServoCapt.a
3	PowerBrick[0].Chan[2].ServoCapt.a
4	PowerBrick[0].Chan[3].ServoCapt.a

Ch. #	Source Address
5	PowerBrick[1].Chan[0].ServoCapt.a
6	PowerBrick[1].Chan[1].ServoCapt.a
7	PowerBrick[1].Chan[2].ServoCapt.a
8	PowerBrick[1].Chan[3].ServoCapt.a

Quadrature Counts per User Units

With quadrature incremental encoders, the number of counts per user units (usually motor revolutions) is 4 times (depending on the setting of encoder/decode **PowerBrick[].Chan[].EncCtrl**) the specified number of lines of the encoder. For example, a 2,000–line rotary encoder should result in 8,000 motor units per revolution (before any gearing or coupling).

Quadrature Encoder Count Error

With quadrature encoders, the Power Brick AC has the capability of trapping encoder count (loss) errors. This is described in detail in the Encoder Count Error section of this manual.

Quadrature Encoder Loss Detection



Warning

Loss of the feedback sensor signal is potentially a very dangerous condition in closed-loop control, because the servo loop no longer has any idea what the true physical position of the motor is – usually it thinks it is "stuck" – and it can react wildly, often causing a runaway condition.

With quadrature encoders, the Power Brick AC has the capability of detecting the loss of an encoder signal. This is described in detail in the Encoder Loss Detection section of this manual.

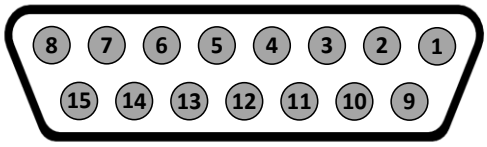


Note

Note the distinction between the encoder count error, which reports loss of counts due to bad transitions of the quadrature signals, and encoder loss, which indicates that one or more quadrature signals are missing.

X1 - X8: Encoder Feedback, Sinusoidal

The Power Brick AC can process sinusoidal encoders (up to 1.2 $V_{peak-peak}$), and provide high resolution (x 16384) interpolated position data.

X1-X8: D-sub DA-15F Mating: D-sub DA-15M						
Pin#	**Symbol**	**Function**	**Primary Use**	**Alternate Use**		
1	SIN +	Input	Sine +			
2	COS +	Input	Cosine +			
3	CHC +	Input	Index C +	Amp. Enable +		
4	**ENCPWR**	**Output**	**Encoder Power 5 VDC (max 250 mA per channel)**			
5	CHU / DIR +	In / Out	Halls U	Direction Out +	Serial Data –	AltSin +
6	CHW / PUL +	In / Out	Halls W	Step Out +	Serial Clock –	AltCos +
7	2.5V	Output	2.5 VDC Reference power			
8	PTC	Input	Motor Thermal Input			
9	SIN –	Input	Sine –			
10	COS –	Input	Cosine –			
11	CHC –	Input	Index C –	Amp. Enable –		
12	**GND**	**Common**	**Common ground**			
13	CHV / DIR –	In / Out	Halls V	Direction Out –	Serial Clock +	AltSin –
14	CHT / PUL –	In / Out	Halls T	Step Out –	Serial Data +	AltCos –
15						



Caution

The +5 VDC encoder power is limited to ~250 mA per channel. For encoders requiring more current, the +5 VDC power can be alternately brought in externally through the +5 V ENC connector.



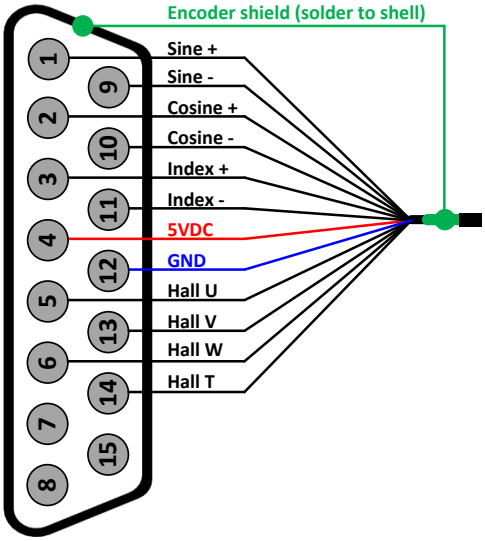
Caution

Encoders requiring a voltage level other than +5 VDC (higher or lower) should be powered directly from an external power supply.

The Power Brick AC can accept "sine" and "cosine" signals (90° out of phase with each other), of up to 1.2 V (peak-to-peak) magnitude.

Due to their inherit susceptibility to electrical noise, these signals are most commonly differential pairs, wired into the SIN+, SIN-, COS+, and COS- inputs for the channel. Differential signals can enhance immunity by providing common mode noise rejection. Single-ended inputs can also be used, wired into the SIN+ and COS+ inputs for the channel, with the SIN- and COS- inputs connected directly to the 2.5V reference (pin #7).

A good quality shielded cable with twisted-pair shielded conduits is highly recommended for sinusoidal encoder applications.



Configuring Sinusoidal Encoders

The sinusoidal encoder signals are interpolated in the ASIC (hardware); the resulting data is brought into the encoder conversion table (ECT) as a single 32-bit word without any scaling:

```
EncTable[1].type = 1
EncTable[1].pEnc = PowerBrick[0].Chan[0].ServoCapt.a
EncTable[1].pEnc1 = Sys.Pushm
EncTable[1].index1 = 0
EncTable[1].index2 = 0
EncTable[1].index3 = 0
EncTable[1].index4 = 0
EncTable[1].index5 = 0
EncTable[1].ScaleFactor = 1
```

The Arctangent calculation must be enabled for this channel. The encoder type for this motor must be set for a DSPGate3 arctangent extension. Activating the channel, should then be sufficient to display counts in the position window when the motor/encoder shaft is moved by hand.

```
PowerBrick[0].Chan[0].AtanEna = 1
Motor[1].EncType = 6

Motor[1].ServoCtrl = 1
Motor[1].pEnc = EncTable[1].a
Motor[1].pEnc2 = EncTable[1].a
```

Ch. #	Source Address
1	PowerBrick[0].Chan[0].ServoCapt.a
2	PowerBrick[0].Chan[1].ServoCapt.a
3	PowerBrick[0].Chan[2].ServoCapt.a
4	PowerBrick[0].Chan[3].ServoCapt.a

Ch. #	Source Address
5	PowerBrick[1].Chan[0].ServoCapt.a
6	PowerBrick[1].Chan[1].ServoCapt.a
7	PowerBrick[1].Chan[2].ServoCapt.a
8	PowerBrick[1].Chan[3].ServoCapt.a

The sine and cosine signals can be accessed through the following elements. This may be helpful in diagnostics, or plotting the Lissajous.

Ch. #	Signal	Element	Ch. #	Signal	Element
1	Sine	PowerBrick[0].Chan[0].AdcEnc[0]	5	Sine	PowerBrick[1].Chan[0].AdcEnc[0]
	Cosine	PowerBrick[0].Chan[0].AdcEnc[1]		Cosine	PowerBrick[1].Chan[0].AdcEnc[1]
2	Sine	PowerBrick[0].Chan[1].AdcEnc[0]	6	Sine	PowerBrick[1].Chan[1].AdcEnc[0]
	Cosine	PowerBrick[0].Chan[1].AdcEnc[1]		Cosine	PowerBrick[1].Chan[1].AdcEnc[1]
3	Sine	PowerBrick[0].Chan[2].AdcEnc[0]	7	Sine	PowerBrick[1].Chan[2].AdcEnc[0]
	Cosine	PowerBrick[0].Chan[2].AdcEnc[1]		Cosine	PowerBrick[1].Chan[2].AdcEnc[1]
4	Sine	PowerBrick[0].Chan[3].AdcEnc[0]	8	Sine	PowerBrick[1].Chan[3].AdcEnc[0]
	Cosine	PowerBrick[0].Chan[3].AdcEnc[1]		Cosine	PowerBrick[1].Chan[3].AdcEnc[1]



Note

The Sine and Cosine data is in the upper 16 bits of these 32-bit structure elements. Scaling them properly requires shifting right by 16 bits or dividing by 65,536.

Sinusoidal Counts per User Units

The (Gate 3) ASIC in the Power Brick AC has the capability of computing the sub-count interpolated position in hardware. The sub-count data is then combined with the whole-count data from the quadrature counter and latched into **PowerBrick[].Chan[].PhaseCapt** each phase cycle, and into **PowerBrick[].Chan[].ServoCapt** each servo cycle. The low 12 bits of these values represent sub-count data, so there are 4,096 states per quadrature count, or 16,384 states per encoder line, in the resulting values.

- A rotary encoder with 1,024 sine/cosine periods per revolution produces:
  1,024 x 16,384 = 16,777,216 motor units / revolution

- A 20 µm linear encoder produces:
  16,384 / 0.020 = 819,200 motor units / mm

Bias Correction

The Power Brick AC has the capability of correcting for biases of the cosine / sine signals. These corrections are suitable when interpolating in the DSPGate3 without the ACI (Auto Correcting Interpolator) option. This procedure is described in the Sinusoidal Encoder Bias Corrections section of this manual.



Note

Automatic correction for signal magnitude mismatch and phase offset at the cost of additional processor time can be obtained through use of a Type 4 Encoder Conversion Table Entry. Refer to Conversion Method Details→Type 4 under the Setting up the Encoder Conversion Table section of the Power PMAC User Manual for more details.

Sinusoidal Encoder Count Error

With Sinusoidal encoders, the Power Brick AC has the capability of trapping encoder count (loss) errors. This is described in detail in the Encoder Count Error section of this manual.

Sinusoidal Encoder Loss Detection



Warning

Loss of the feedback sensor signal is potentially a very dangerous condition in closed-loop control, because the servo loop no longer has any idea what the true physical position of the motor is – usually it thinks it is "stuck" – and it can react wildly, often causing a runaway condition.

With Sinusoidal encoders, the Power Brick AC has the capability of detecting the loss of an encoder signal. This is described in detail in the Encoder Loss Detection section of this manual.

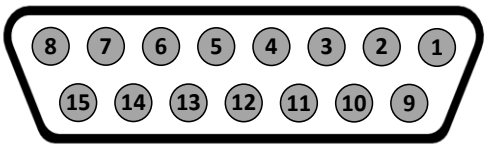


Note

Note the distinction between the encoder count error, which reports loss of counts due to bad transitions of the quadrature signals, and encoder loss, which indicates that one or more quadrature / sinusoidal signals are missing.

X1 – X8: Encoder Feedback, Resolver

The Power Brick can "optionally" accept resolver encoder input (up to 5 $V_{peak-peak}$) and provide interpolated position data.

X1-X8: D-sub DA-15F Mating: D-sub DA-15M						
Pin#	**Symbol**	**Function**	**Primary Use**	**Alternate Use**		
1	SIN +	Input	Sine +			
2	COS +	Input	Cosine +			
3	CHC +	Input	Index C +	Amp. Enable +		
4	**ENCPWR**	**Output**	**Encoder Power 5 VDC (max 250 mA per channel)**			
5	CHU / DIR +	In / Out	Halls U	Direction Out +	Serial Data –	AltSin +
6	CHW / PUL +	In / Out	Halls W	Step Out +	Serial Clock –	AltCos +
7	2.5V	Output	2.5 VDC Reference power			
8	PTC	Input	Motor Thermal Input			
9	SIN –	Input	Sine –			
10	COS –	Input	Cosine –			
11	CHC –	Input	Index C –	Amp. Enable –		
12	**GND**	**Common**	**Common ground**			
13	CHV / DIR –	In / Out	Halls V	Direction Out –	Serial Clock +	AltSin –
14	CHT / PUL –	In / Out	Halls T	Step Out –	Serial Data +	AltCos –
15	RES EXC.	Out	Resolver Excitation Output			



Caution

The +5 VDC encoder power is limited to ~250 mA per channel. For encoders requiring more current, the +5 VDC power can be alternately brought in externally through the +5 VDC ENC connector.



Caution

Encoders requiring a voltage level other than +5 VDC (higher or lower) should be powered up using an external power supply directly into the encoder.

Setting up Resolvers

Configuring a resolver requires setting up the excitation signal control. The excitation signal control element, **PowerBrick[].ResolverCtrl**, is a 4-channel saved component:

	Excitation Signal Control
Channels 1 – 4	**PowerBrick[0].ResolverCtrl**
Channels 5 – 8	**PowerBrick[1].ResolverCtrl**

The excitation signal control element is a 32-bit element wherein the upper 12 bits carry meaningful information is broken down as follows:

	Phase Shift (Delay)								Mag.		Freq.		Reserved															
Bit #:	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Binary:	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hex ($):	8				0				C				0				0				0				0				0			

Bits [31 – 24] specify the phase shift or delay of the excitation sine wave with respect to the phase clock. The unit of this field is 1 / 512 of an excitation cycle. This component is usually set experimentally to maximize the magnitude of the feedback signal.

Bits [23 – 22] specify the magnitude of the excitation output. The highest magnitude that does not cause saturation of the feedback ADCs (which occurs when values in the lower 16 bits of **PowerBrick[].Chan[].AtanSumOfSqr** exceed 32767) should be used.

Peak-Peak [Volts]	Value	Binary
3.2	**0**	00
6.2	**1**	01
8.8	**2**	10
12.2 (Max.)	**3**	11

Bits [21 – 20] specify the frequency of the excitation output. The frequency that comes closest, but slightly higher, to that recommended by the resolver manufacturer should be used.

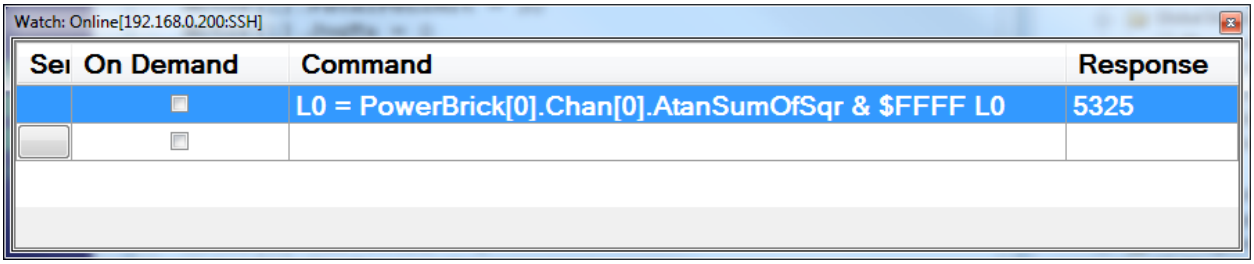
Excitation Frequency	Value	Binary
Phase Clock / 1	**0**	00
Phase Clock / 2	**1**	01
Phase Clock / 4	**2**	10
Phase Clock / 6	**3**	11

Utilizing the following expression, for channels 1 – 4 as an example:

```
GLOBAL ResExcitDelay;
GLOBAL ResExcitMag;
GLOBAL ResExcitFreqDiv;

ResExcitMag = 3        // [0 - 3]
ResExcitFreqDiv = 0    // [0 - 3]
ResExcitDelay = 65     // [0 - 255]
PowerBrick[0].ResolverCtrl = ResExcitDelay*EXP2(24) + ResExcitMag*EXP2(22) + ResExcitFreqDiv*EXP2(20)
```

And monitoring the magnitude of the signals in the lower 16 bits of **PowerBrick[].Chan[].AtanSumOfSqr** (e.g. in the watch window):



- First, set up the excitation output magnitude, **ResExcitMag**. Start with highest (value of 3). We want the value of **AtanSumOfSqr** (lower 16 bits) to be the greatest possible.
- Set up the excitation frequency divider, **ResExcitFreqDiv**. Resolver manufacturers generally specify a minimum operating frequency. Set this typically to a value of 0, same as the phase clock.
- Set up the excitation delay (from the phase clock), **ResExcitDelay**. This value is also configured experimentally to produce the greatest possible value of the signal's magnitude, which is in the lower 16 bits of **AtanSumOfSqr**.

Configuring Resolver ECT

Once, the resolver excitation signal is set up, the encoder conversion table can be configured as follows (e.g. channel 1, motor #1):

```
Motor[1].ServoCtrl = 1

EncTable[1].Type = 1
EncTable[1].pEnc = PowerBrick[0].Chan[0].AtanSumofSqr.a
EncTable[1].pEnc1 = Sys.pushm
EncTable[1].index1 = 0
EncTable[1].index2 = 0
EncTable[1].index3 = 0
EncTable[1].index4 = 0
EncTable[1].index5 = 0
EncTable[1].index6 = 0
EncTable[1].ScaleFactor = 1 / 65536
```

Resolver Counts per User Units

With resolvers, the feedback resolution is set by the ASIC interface hardware, and produces 65,536 counts per revolution.

Resolver Absolute Power-On Position

With resolvers, the absolute position is computed directly from the upper 16 bits of the **AtanSumOfSqr** register. It is set up using the following key structure elements:

- **Motor[].pAbsPos** = **PowerBrick[0].Chan[2].AtanSumOfSqr.a**
- **Motor[].AbsPosSf** = **Motor[].PosSf**
- **Motor[].ApsPosFormat = $00001010** (Upper 16 bits)
- **Motor[].HomeOffset =** user desired home offset value



Note

With resolvers, it is not recommended to use PowerOnMode (value of 2) for power-on absolute position read. Instead, it is recommended to issue a **HOMEZ** command from an initialization PLC.

Bias Correction

The resolver sine and cosine signals may be corrected for biases similarly to sinusoidal encoders. This is described in the Sinusoidal Encoder Bias Corrections section of this manual.



Note

Automatic correction for signal magnitude mismatch and phase offset at the cost of additional processor time can be obtained through use of a type 4 encoder conversion table entry. Refer to Conversion Method Details, type 4 under the setting up the encoder conversion table section of the Power PMAC User Manual for more details.

Resolver Encoder Count Error

The Power Brick AC has the capability of trapping encoder count (loss) errors for resolvers. This is described in detail in the Encoder Count Error section of this manual.

Resolver Encoder Loss Detection



Warning

Loss of the feedback sensor signal is potentially a very dangerous condition in closed-loop control, because the servo loop no longer has any idea what the true physical position of the motor is – usually it thinks it is "stuck" – and it can react wildly, often causing a runaway condition.

With Resolvers, the Power Brick AC has the capability of detecting the loss of an encoder signal. This is described in detail in the Encoder Loss Detection section of this manual.

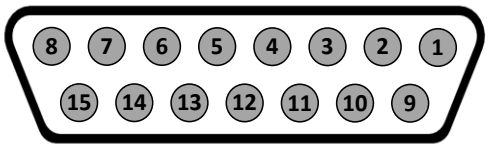


Note

Note the distinction between the encoder count error, which reports loss of counts due to bad transitions of the quadrature signals, and encoder loss, which indicates that one or more quadrature / sinusoidal signals are missing.

X1 – X8: Encoder Feedback, Serial

The Power Brick AC, in its standard configuration, accepts a variety of serial encoder protocols. These protocols are built into the DSPGate3. This section discusses the configuration of these serial encoders.

X1-X8: D-sub DA-15F **Mating: D-sub DA-15M**									
Pin #	**Symbol**	**Function**	**Hiperface**	**SSI EnDat**	**Panasonic**	**Mitutoyo**	**Sigma II/II/V/VI I**	**BiSS**	**Tamagawa**
1									
2									
3	ENA –	Output	–						$\overline{\text{SENA}}$
4	**ENCPWR**	**Output**	**Encoder Power 5 VDC (max 250 mA per channel)**						
5	DATA –	In / Out	DAT–	DAT–	$\overline{\text{PS}}$	MRR	SDI blu/blk	SLO–	$\overline{\text{SD}}$
6	CLOCK –	Output	–	CLK–	–	–	–	MA–	–
7	2.5V	Output	2.5 VDC – Reference						
8	PTC	Input	Motor Thermal Input						
9									
10									
11	ENA +	Output	–						SENA
12	**GND**	**Common**	**Common Ground**						
13	CLOCK +	Output	–	CLK+	–	–	–	MA+	–
14	DATA +	In / Out	DAT+	DAT+	PS	MR	SDO blu	SLO+	SD
15									



Caution

The +5 VDC encoder power is limited to ~250 mA per channel. For encoders requiring more current, the +5 VDC power can be alternately brought in externally through the +5 VDC ENC connector.



Caution

Encoders requiring a voltage level other than +5 VDC (higher or lower) should be powered directly from an external power supply.



Note

Quadrature / sinusoidal encoders can be wired and processed simultaneously with serial encoders on the same channel.

Pins #5, 6, 13, and 14 of the encoder feedback connectors (X1 – X8) share multiple functions: only one of these functions (per channel) can be used – configured in software – at one time:

- Hall sensor inputs (default configuration).
- Pulse and direction PFM output signals (software configuration using Flag D output, **OutFlagD**).
- Serial encoder inputs (software configuration enabling serial encoder line, **SerialEncEna**).
- Quadrature encoder inputs (serial encoder enable line must be 0).
- Alternate Sinusoidal encoder inputs (with sinusoidal encoder option).



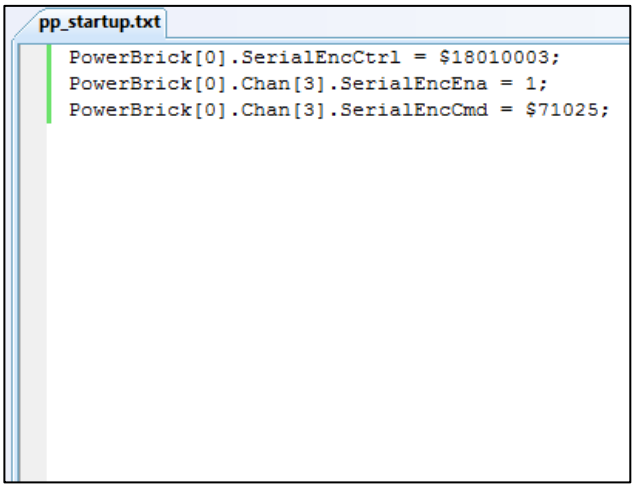
Note

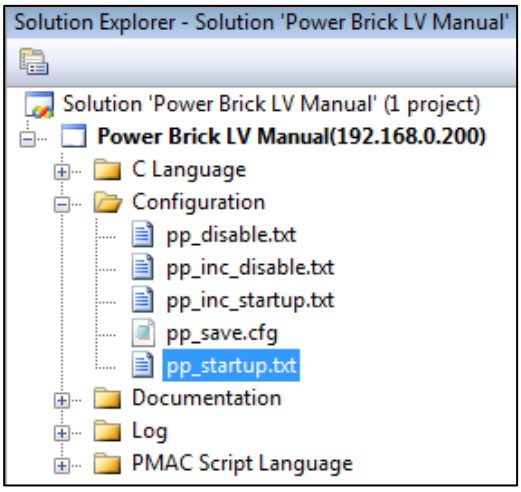
Each channel is independent of the other channels and can have its own use for these pins.

Configuring a serial encoder requires the programming of two essential structure elements, and the enabling of the serial encoder line:

- The Serial Encoder Control word, **PowerBrick[].SerialEncCtrl**
- The Serial Encoder Command word, **PowerBrick[].Chan[].SerialEncCmd**
- **PowerBrick[].Chan[].SerialEncEna = 1**

These structure elements must be initialized and can be placed in the startup file of the IDE application project under Configuration.

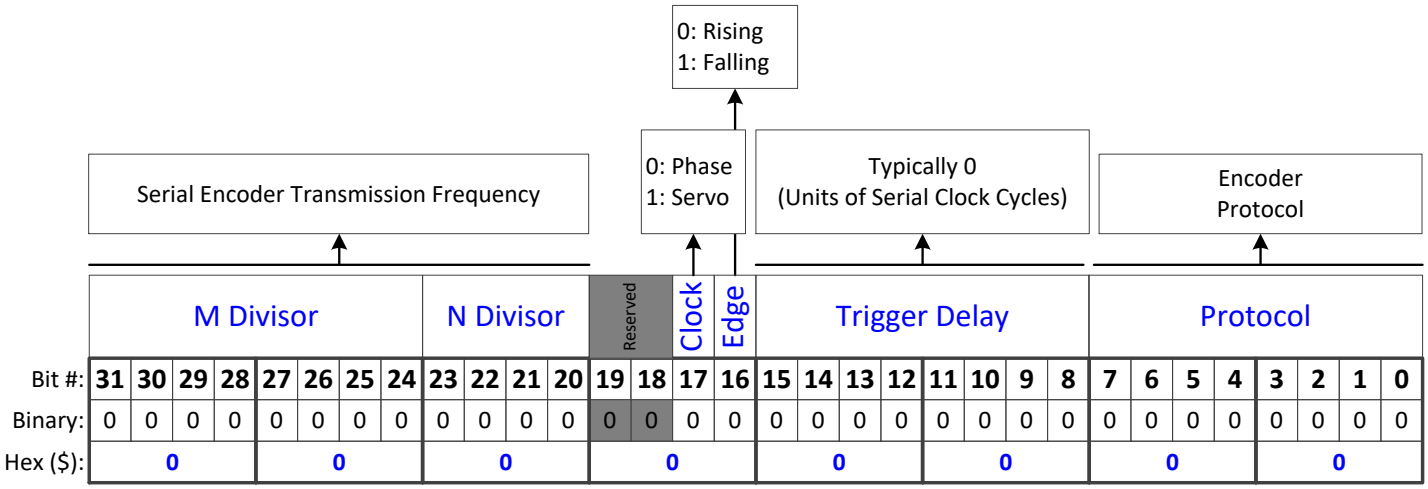




Serial Encoder Control

The Serial Encoder Control is a 32-bit, 4-channel (1 – 4, or 5 – 8), structure element. It specifies the protocol type, delay compensation time, trigger edge, trigger clock, and transmission frequency of the 4 serial encoder channels.

	Serial Encoder Control Elements
Channels 1 – 4	**PowerBrick[0].SerialEncCtrl**
Channels 5 – 8	**PowerBrick[1].SerialEncCtrl**



Bits [31 – 20] specify the serial interface transmission frequency. This frequency (or range) is usually specified by the encoder manufacturer and programmed by the user or pre-defined by the protocol.

Bit 17 specifies the trigger source; Phase clock is recommended (value 0).

Bit 16 specifies the active edge; rising edge is recommended (value 0).

Bits [15 – 8] specify the trigger delay (in units of serial clock cycles) used to compensate for transmission over long encoder lines.

Bits [3 – 0] specify the encoder protocol of the serial encoder:

Protocol	Value
–	0
–	1
SSI	2
EnDat	3

Protocol	Value
Hiperface	4
Sigma I	5
Sigma II/III/V	6
Tamagawa	7

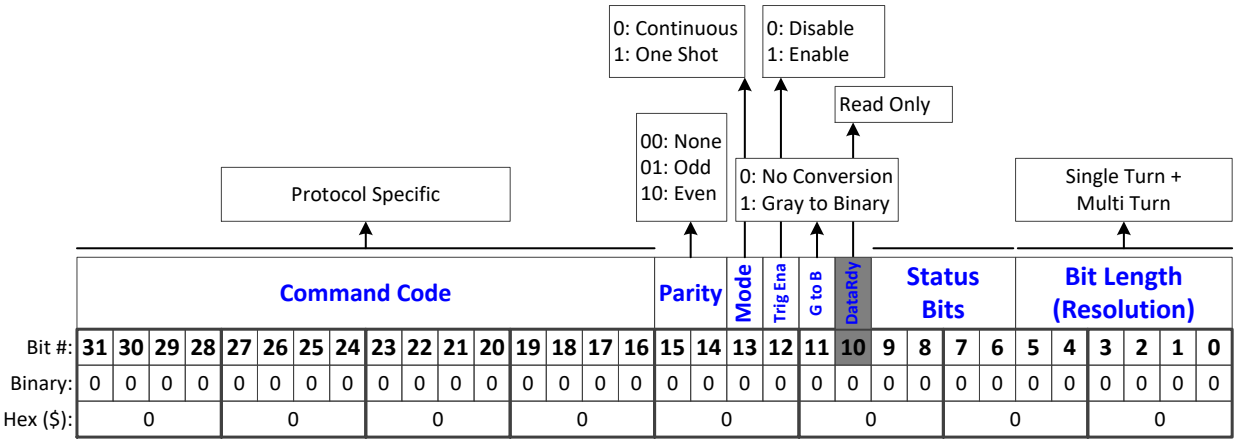
Protocol	Value
Panasonic	8
Mitutoyo	9
Kawasaki	10 ($A)
–	11 ($B)

Protocol	Value
–	12 ($C)
–	13 ($D)
–	14 ($E)
SW Ctrl	15 ($F)

Serial Encoder Command

The Serial Encoder Command is a 32-bit, channel specific, structure element. It specifies the bit length (resolution), status bits, data type, conversion method, trigger enable, trigger mode, parity, and command code of the serial encoder channel.

Ch.#	Serial Encoder Command	Ch. #	Serial Encoder Command
1	PowerBrick[0].Chan[0].SerialEncCmd	5	PowerBrick[1].Chan[0].SerialEncCmd
2	PowerBrick[0].Chan[1].SerialEncCmd	6	PowerBrick[1].Chan[1].SerialEncCmd
3	PowerBrick[0].Chan[2].SerialEncCmd	7	PowerBrick[1].Chan[2].SerialEncCmd
4	PowerBrick[0].Chan[3].SerialEncCmd	8	PowerBrick[1].Chan[3].SerialEncCmd



Bits [31 – 16] specify the command code. This field is protocol specific.

Bits [15 – 14] specify the parity. This field is protocol specific.

Bit 13 specifies the trigger mode.

Bit 12 is the trigger enable toggle.

Bit 11 specifies the conversion type. This field is protocol specific.

Bit 10 is the data ready bit, read only.

Bits [9 – 6] specify the encoder status field. This field is protocol specific.

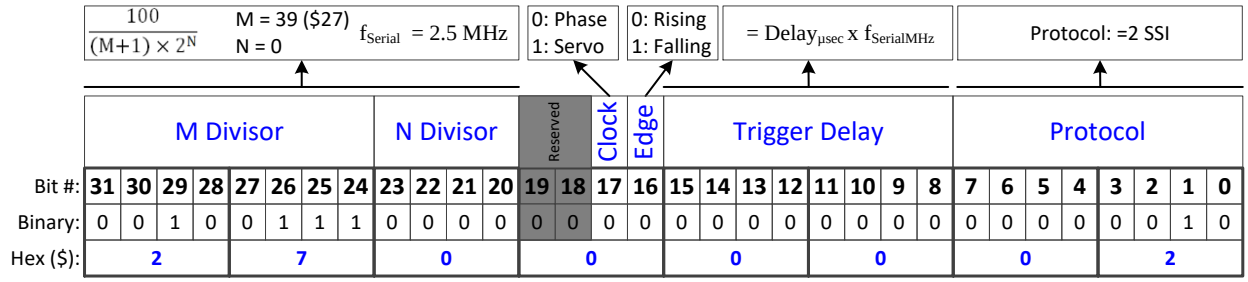
Bits [5 – 0] specify the serial encoder bit length (single-turn + multi-turn).

Following, are examples for setting up the control and command words for each of the supported protocols. Also, the resulting data registers and their format.

SSI Configuration Example

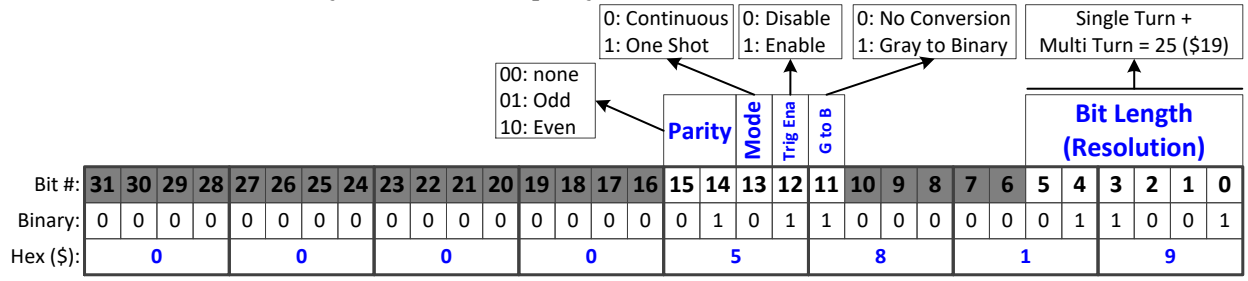
Serial Encoder Control – SSI

No trigger delay, rising edge of phase, and 2.5 MHz transmission



Serial Encoder Command – SSI

A 25-bit SSI encoder in Gray code, with odd parity

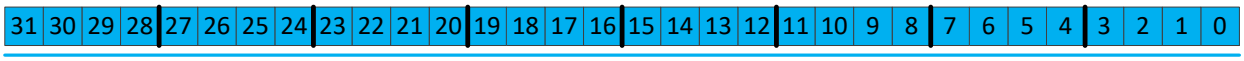



```
PowerBrick[0].SerialEncCtrl = $27000002
PowerBrick[0].Chan[0].SerialEncCmd = $5819
PowerBrick[0].Chan[0].SerialEncEna = 1
```

Serial Data Registers – SSI

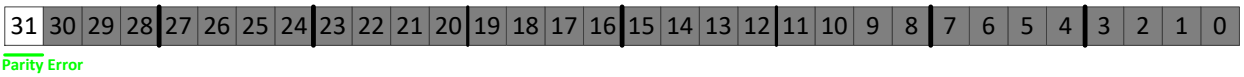
The resulting position data, status, and error bits for SSI are found in the following Serial Data Registers:

PowerBrick[].Chan[].SerialEncDataA



Possible Single/Multi-Turn Position

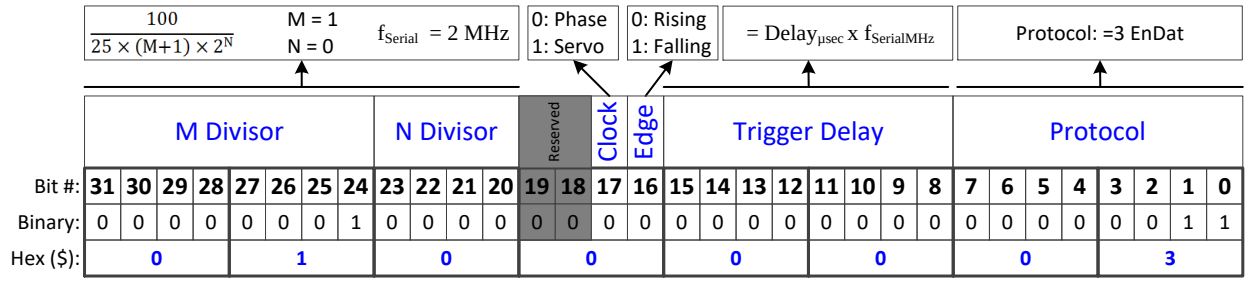
PowerBrick[].Chan[].SerialEncDataB



EnDat 2.1/2.2 Configuration Example

Serial Encoder Control – EnDat 2.1/2.2

No trigger delay, rising edge of phase, and 2.0 MHz transmission



Serial Encoder Command – EnDat 2.1/2.2

The DSPGate3 interface to EnDat supports four 6-bit command codes:

- 000111 ($7) for reporting position (EnDat2.1/2.2).
- 101010 ($2A) for resetting the encoder (EnDat2.1/2.2).
- 111000 ($38) for reporting position with possible additional information (EnDat 2.2 only)
- 101101 ($2D) for resetting the encoder (EnDat 2.2 only)



Note

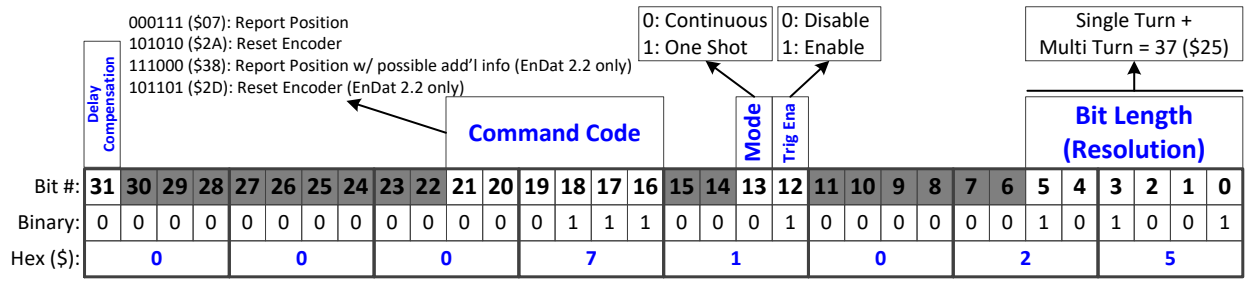
By the EnDat standard, EnDat 2.2 encoders should be able to accept and process EnDat 2.1 command codes. However, not all encoders sold as meeting the EnDat 2.2 standard can do this.



Note

With the Power Brick AC, EnDat additional information is supported via the (optional) ACC-84B serial interface.

A 37-bit EnDat 2.2 encoder for continuous position reporting:




```
PowerBrick[0].SerialEncCtrl = $1000003
PowerBrick[0].Chan[0].SerialEncCmd = $71025
PowerBrick[0].Chan[0].SerialEncEna = 1
```

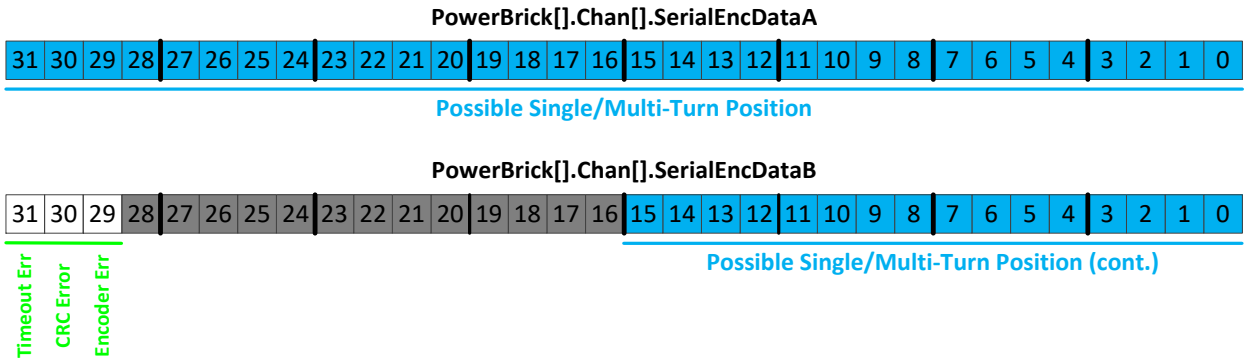
With EnDat 2.2, bit 31 is the StartDelayComp control bit. Setting this bit to 1 starts a delay identification and compensation cycle which measures the propagation delay between the encoder and the controller. The delay is measured three times and the average is used in the compensation. When these calculations are done, the StartDelayComp bit 31 is automatically cleared. This delay identification operation must be performed after every power-up cycle. Delay compensation permits high bit transmission rates over very long cables.

To perform the delay identification and compensation cycle on this encoder, set **PowerBrick[].Chan[].SerialEncCmd = $80071025**, then wait for bit #31 to clear.

This same encoder can be reset with a command code of $2A sent in one-shot mode, so by setting **PowerBrick[].Chan[].SerialEncCmd = $2A3025.**

Serial Data Registers – EnDat 2.1/2.2

The resulting position data, status, and error bits for EnDat are found in the following Serial Data Registers:

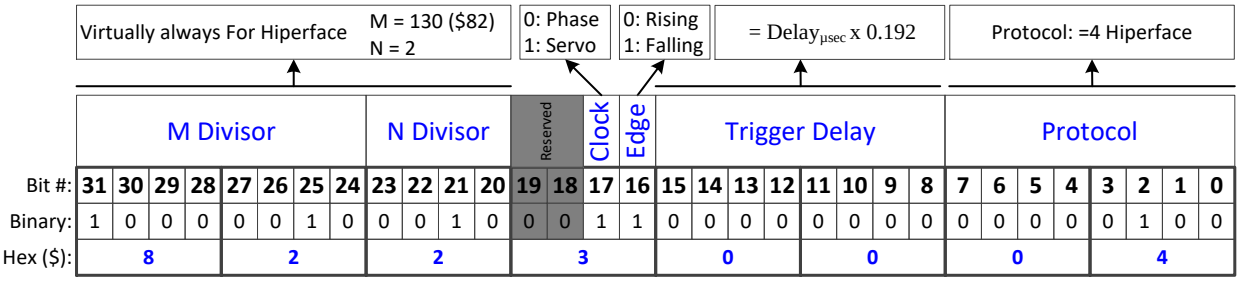


Hiperface Configuration Example

Serial Encoder Control – Hiperface

Because there is no explicit clock signal with Hiperface, the serial clock frequency is set 20 times higher than the bit transmission frequency to "oversample" the input data stream. For the default 9600 baud transmission of the Hiperface encoder, this clock frequency should be 9.6 x 20 = 192 kHz.

Divide the 100 MHz clock by M=130 ($83) and by 4 (N = 2) to get 192 kHz triggering on the falling edge of servo clock without delay. Since this is a "one-shot" read, the selection of the triggering clock edge does not matter much.



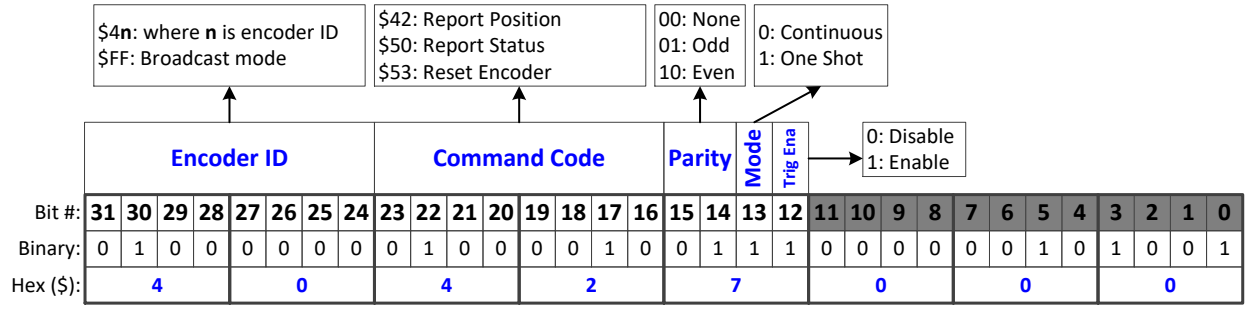
Serial Encoder Command – Hiperface

The DSPGate3 interface to Hiperface supports three 8-bit command codes:

- $42 for reporting position.
- $50 for reporting status
- $53 for resetting the encoder

These command codes reside in the lower 8 bits of the Serial Encoder Command word. The upper 8 bits contain the address of the encoder in the interface. The Hiperface protocol permits up to 8 separate encoders to be "daisy-chained" on a single multi-drop interface. While this can be done, it is expected that each channel of the Power Brick AC will be connected to a separate individual encoder, simplifying the wiring. In this configuration, this address field can either match the encoder's address value (+ $40), or it can be set to $FF (broadcast mode).

A Hiperface encoder at user address 0 with odd parity would be set up for one-shot position reporting as follows:

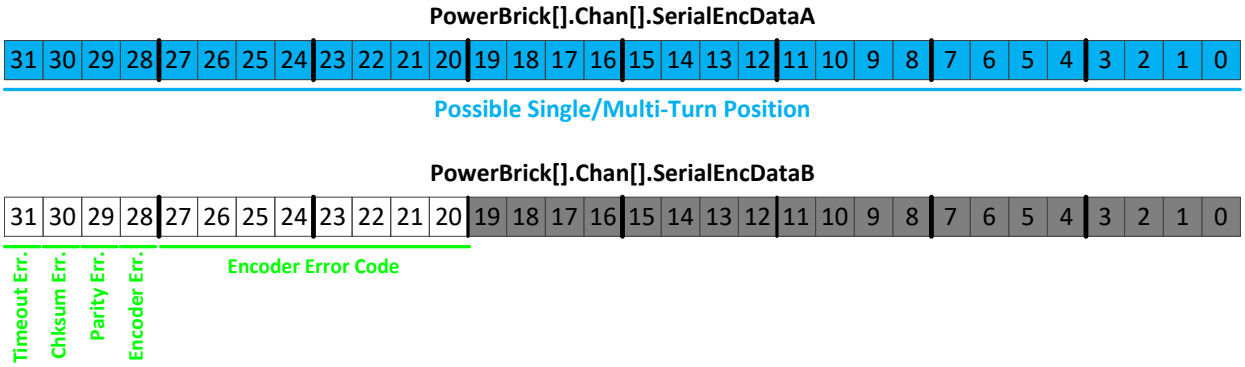


PowerBrick[].Chan[].SerialEncCmd = $40427000 or **$FF427000**

```
PowerBrick[0].SerialEncCtrl = $82230004
PowerBrick[0].Chan[0].SerialEncCmd = $40427000
PowerBrick[0].Chan[0].SerialEncEna = 1
```

Serial Data Registers – Hiperface

The resulting position data, status, and error bits for Hiperface are found in the following Serial Data Registers:

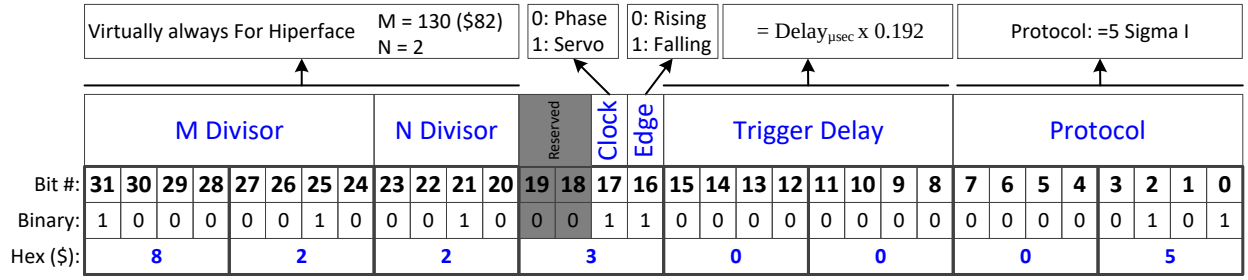


Yaskawa Sigma I Configuration Example

Serial Encoder Control – Sigma I

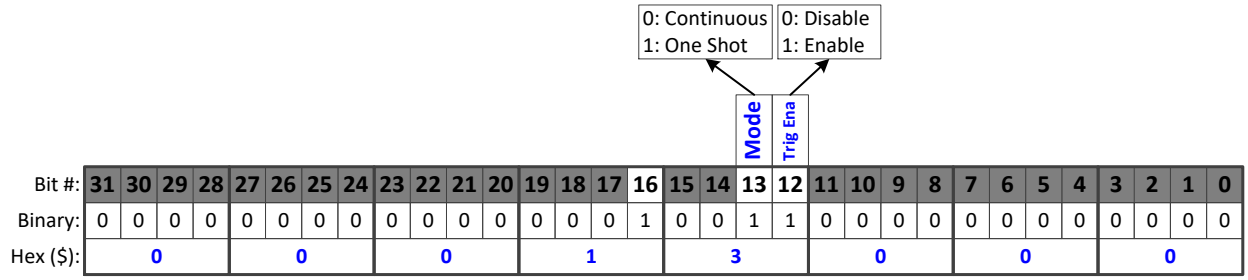
Because there is no explicit clock signal with Sigma I, the serial clock frequency is set 20 times higher than the bit transmission frequency to "oversample" the input data stream. For the default 9600 baud transmission of the Sigma I encoder, this clock frequency should be 9.6 x 20 = 192 kHz.

Divide the 100 MHz clock by M=130 ($83) and by 4 (N = 2) to get 192 kHz. triggering on the falling edge of servo clock without delay. Since this is a "one-shot" read, the selection of the triggering clock edge does not matter much. Example settings:



Serial Encoder Command – Sigma I

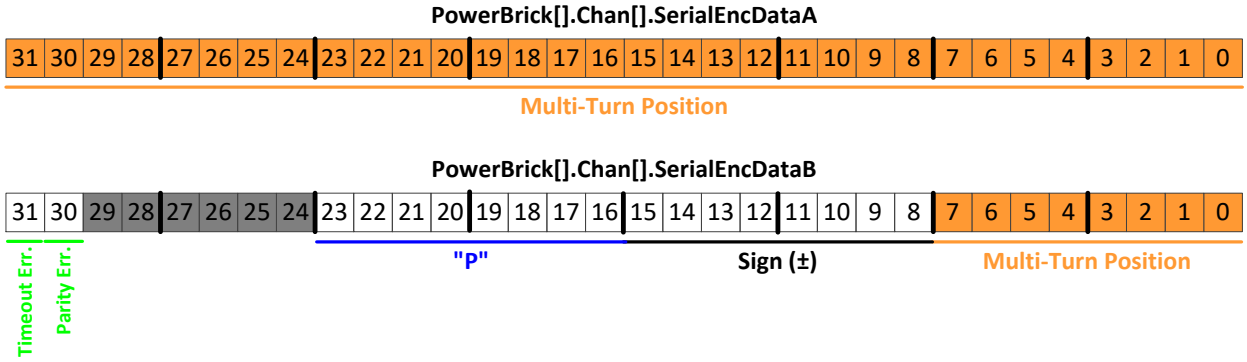
Yaskawa no longer produces Sigma I absolute encoders. However, newer generations of Yaskawa Sigma servo drives synthesize the Yaskawa Sigma I protocol for return to the controller even when using newer Sigma II, III, and V encoders. Bit 16 is set to strobe the encoder and Sigma I should use one-shot trigger, set as follows:




```
PowerBrick[0].SerialEncCtrl = $82230005
PowerBrick[0].Chan[0].SerialEncCmd = $13000
PowerBrick[0].Chan[0].SerialEncEna = 1
```

Serial Data Registers – Sigma I

The resulting position data, status, and error bits for Sigma I are found in the following Serial Data Registers:



In the Data A register, bits [7 – 0] represent the bits of the ASCII code for the "ones digit" of the turns count, bits [15 – 8] represent bits of the "tens digit", bits [23 – 16] represent bits of the "hundreds digit", bits [31 – 24] represent bits of the "thousands digit".

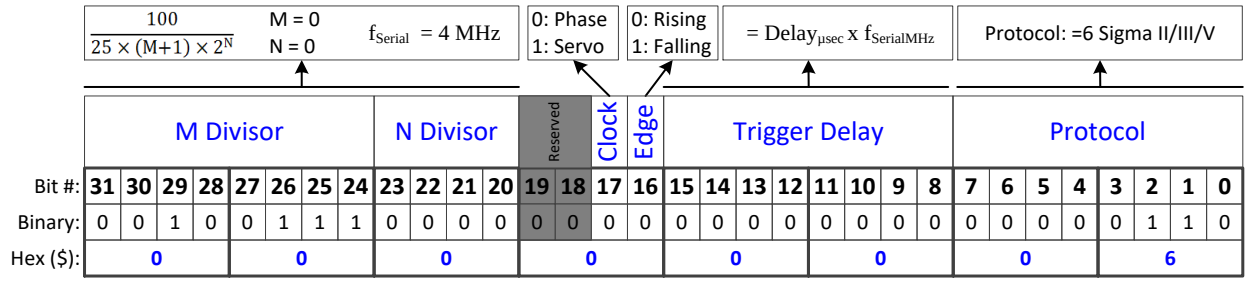
In the Data B register, Bits [7 – 0] represent bits of the "ten-thousands digit", bits [15 – 8] represent bits of the ASCII code for the plus or minus sign, bits [23 – 16] represent bits of the ASCII code for the letter "P", bits [31 – 30] represent bits of the error field (bit 30 is a parity error; bit 31 is a timeout error).

For each of the five numeric ASCII digits, the numeric value of the digit can be obtained by subtracting 48 ($30) from the value of the ASCII code.

Yaskawa Sigma II/III/V Configuration Example

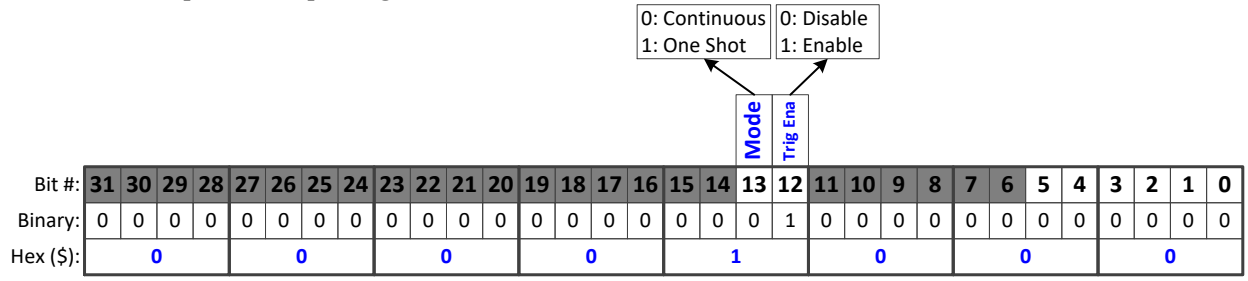
Serial Encoder Control – Sigma II/III/V

No trigger delay, rising edge of phase, and 4.0 MHz transmission:



Serial Encoder Command – Sigma II/III/V

For continuous position reporting:

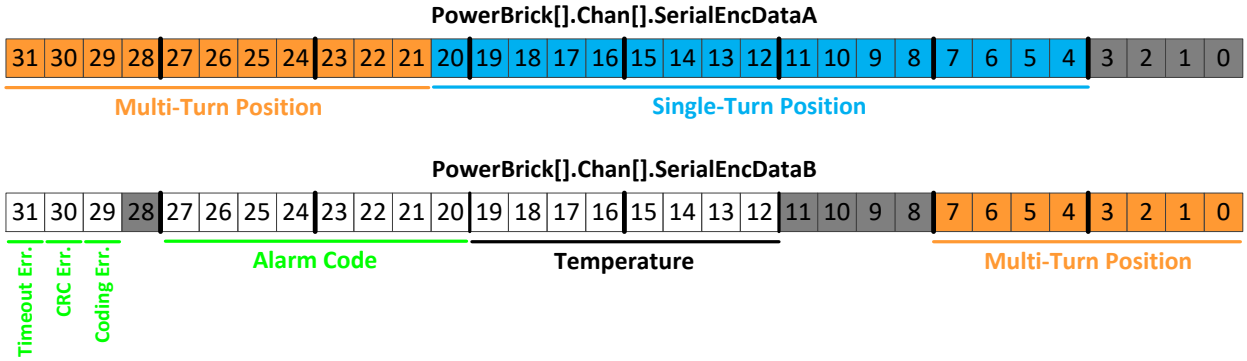



```
PowerBrick[0].SerialEncCtrl = $6
PowerBrick[0].Chan[0].SerialEncCmd = $1000
PowerBrick[0].Chan[0].SerialEncEna = 1
```

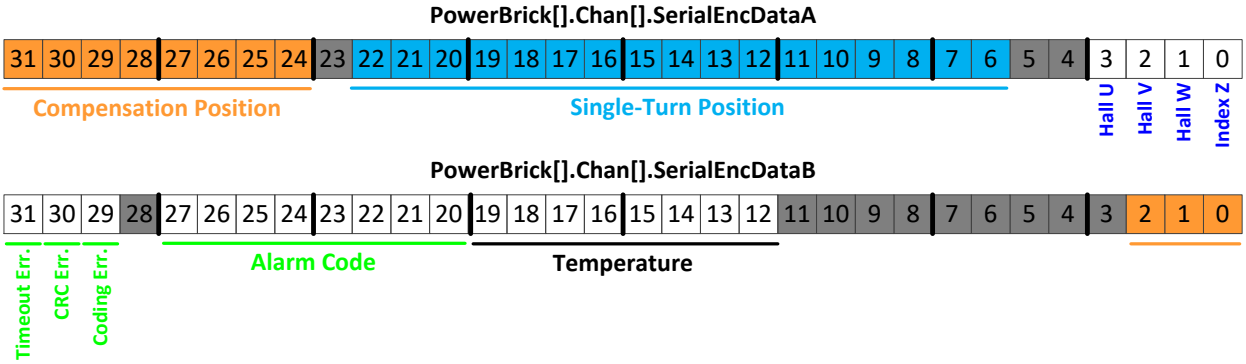
Serial Data Registers – Sigma II/III/V

The resulting position data, status, and error bits for Sigma II/III/V are found in the following Serial Data Registers:

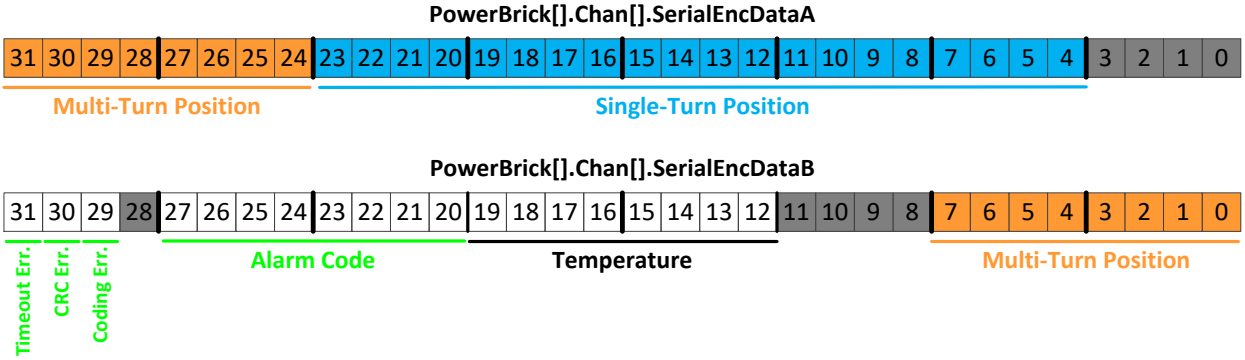
Yaskawa Sigma II (absolute 17-bit)



Yaskawa Sigma II (incremental 17-bit)



Yaskawa Sigma III/V (absolute 20-bit)



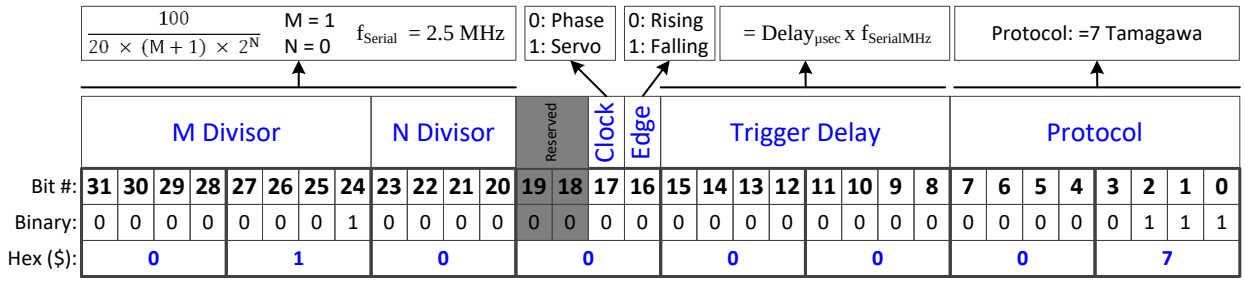
Yaskawa Sigma II/II/V Encoders Alarm Code (Serial Encoder Data B Register)

Bit #	Alarm Code
20	–
21	Power-on error self-detected
22	–
23	Revolution count (index to index) incorrect
24	–
25	–
26	Position reference (index) not found yet
27	–

Tamagawa FA-Coder Configuration Example

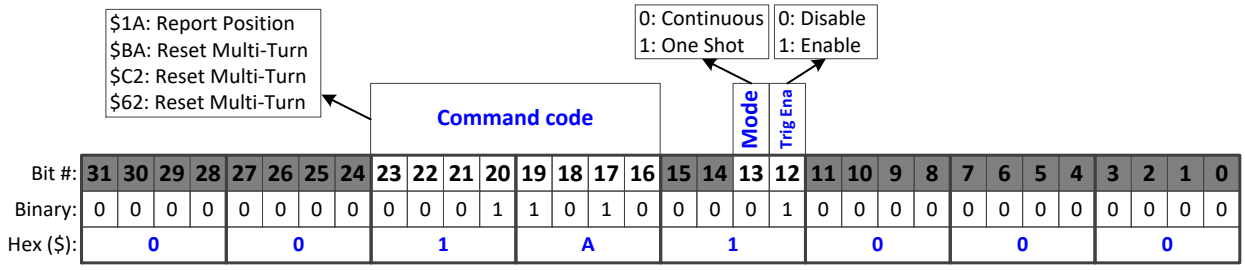
Serial Encoder Control – Tamagawa FA-Coder

No trigger delay, rising edge of phase, and 2.5 MHz transmission:



Serial Encoder Command – Tamagawa FA-Coder

For continuous position reporting:

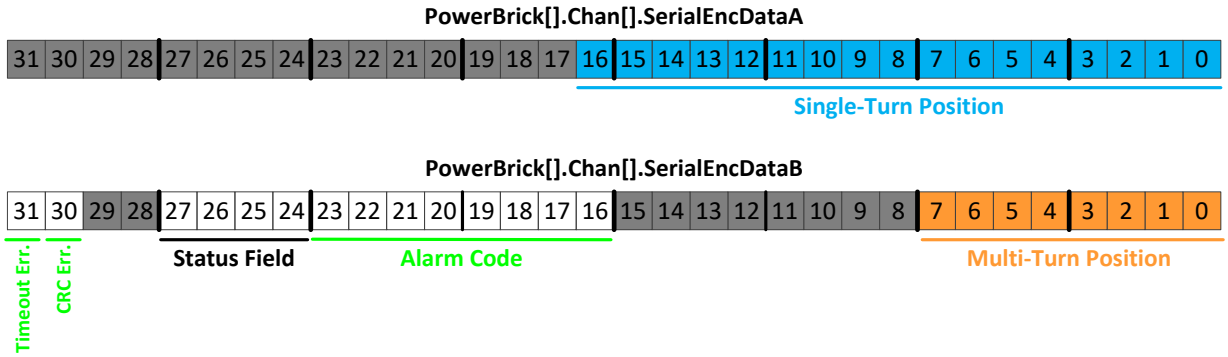


If the command code is set to $BA, $C2, or $62, the multi-turn position value in the encoder is reset to 0. This should be done in "one-shot" mode, making the element equal to $00BA3000, $00C23000, or $00623000, respectively. When the reset operation is done, the component should report as $00BA2000, $00C22000, or $00622000, respectively.

```
PowerBrick[0].SerialEncCtrl = $1000007
PowerBrick[0].Chan[0].SerialEncCmd = $1A1000
PowerBrick[0].Chan[0].SerialEncEna = 1
```

Serial Data Registers – Tamagawa FA-Coder

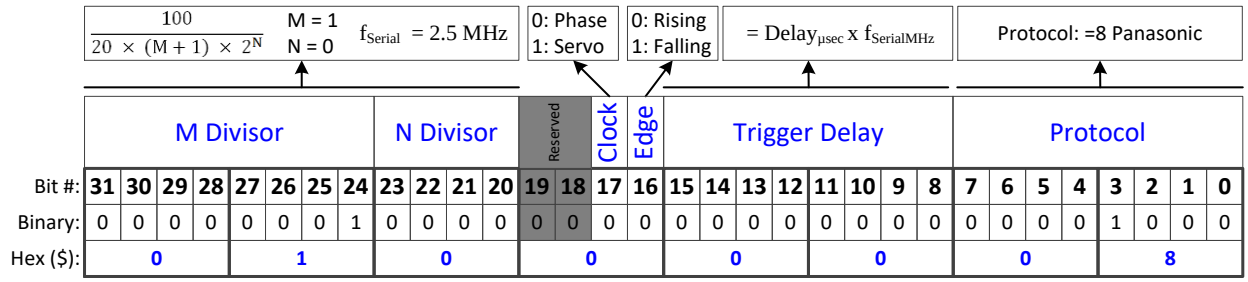
The resulting position data, status, and error bits for Tamagawa FA-Coder are found in the following Serial Data Registers:



Panasonic Configuration Example

Serial Encoder Control – Panasonic

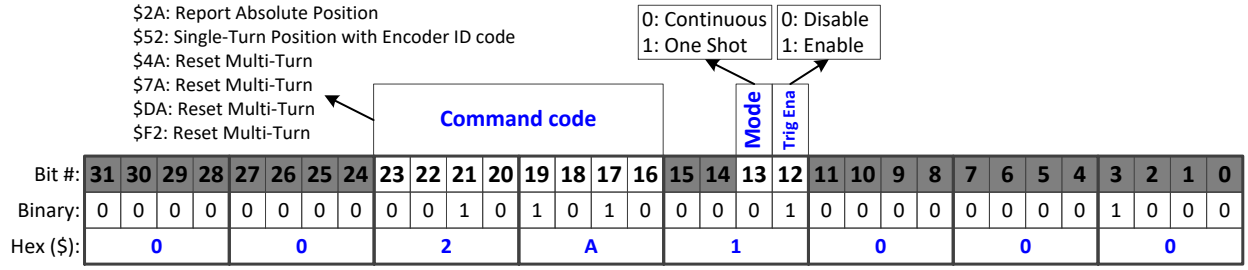
No trigger delay, rising edge of phase, and 2.5 MHz transmission:



Bit #:	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Binary:	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Hex ($):	0				1				0				0				0				0				0				8			

Serial Encoder Command – Panasonic

For continuous position reporting:



Bit #:	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Binary:	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
Hex ($):	0				0				2				A				1				0				0				0			

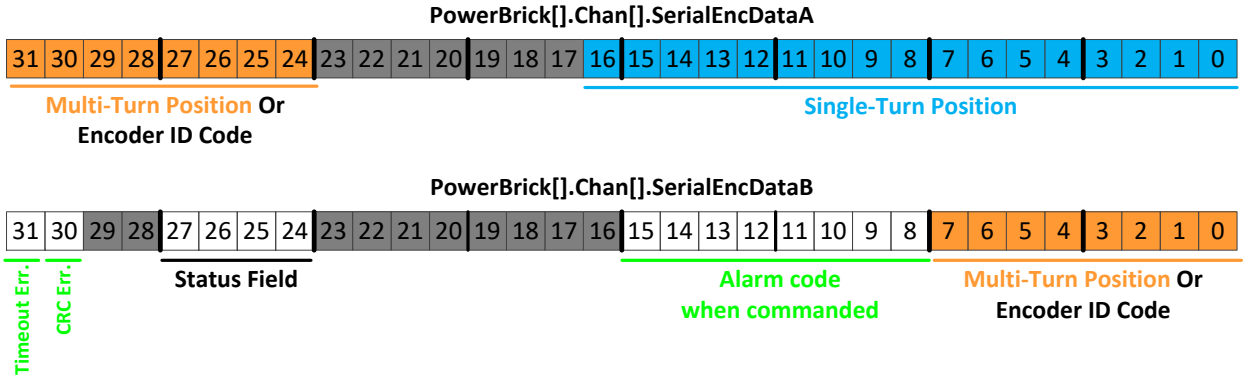
If the command code is set to $52 for single-turn position reporting with alarm code, the encoder ID value is reported where multi-turn position is normally reported.

If the command code is set to $4A, $7A, $DA, or $F2, the multi-turn position value in the encoder is reset to 0. This should be done in "one-shot" mode, making the element equal to $004A3000, $007A3000, $00DA3000, or $00F23000, respectively. When the reset operation is done, the component should report as $004A2000, $007A2000, $00DA2000, or $00F22000, respectively.

```
PowerBrick[0].SerialEncCtrl = $1000008
PowerBrick[0].Chan[0].SerialEncCmd = $2A1000
PowerBrick[0].Chan[0].SerialEncEna = 1
```

Serial Data Registers – Panasonic

The resulting position data, status, and error bits for Panasonic are found in the following Serial Data Registers:



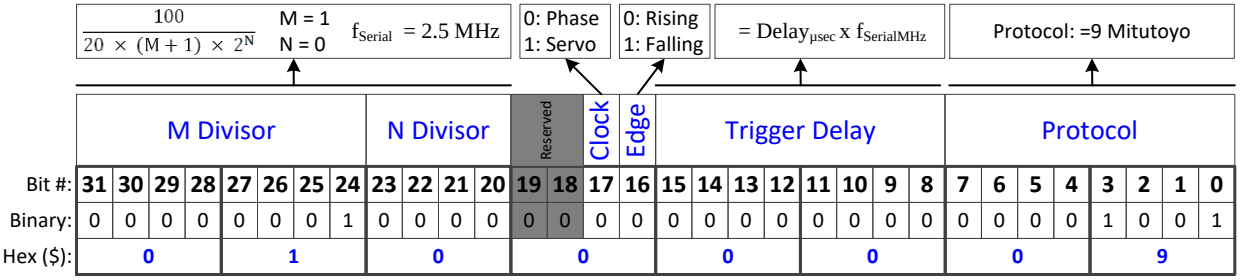
Bits 24 – 31 (**SerialEncDataA**) of the encoder ID code are fixed at a value of $11.

Bit #	Alarm Code
8	Overspeed error
9	Full resolution status; = 1 when over 100 rpm and reporting reduced resolution
10	Count Error
11	Counter Overflow
12	–
13	Multi-revolution error
14	System undervoltage error (< 2.5 V)
15	Battery low (< 3.1 V)

Mitutoyo Configuration Example

Serial Encoder Control – Mitutoyo

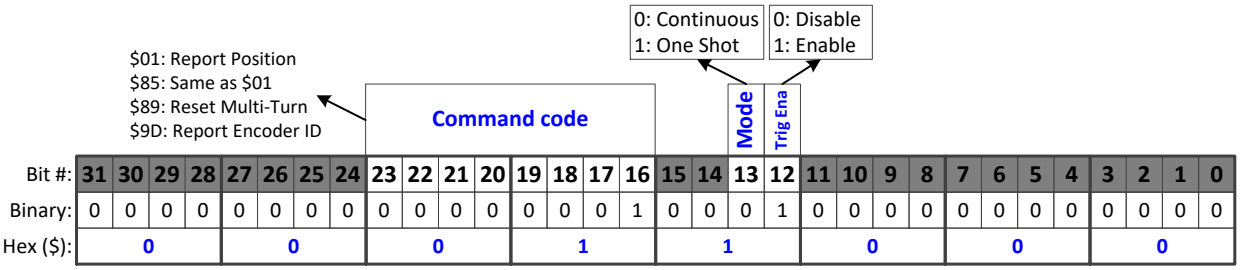
No trigger delay, rising edge of phase, and 2.5 MHz transmission:



Bit #:	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Binary:	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Hex ($):	0				1				0				0				0				0				0				9			

Serial Encoder Command – Mitutoyo

For continuous position reporting:



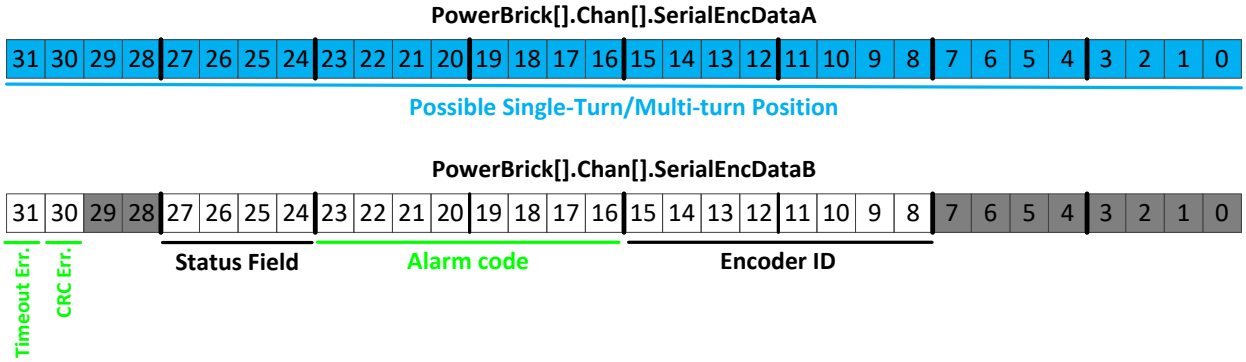
Bit #:	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Binary:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Hex ($):	0				0				0				1				1				0				0				0			

If the command code is set to $89, the multi-turn position value in the encoder is reset to 0 (after 8 cycles). If the command code is set to $9D, the encoder ID value is reported in bits 8 – 15 of **SerialEncDataB**. If the command code is set to $85, absolute position is reported, similarly to $01.

```
PowerBrick[0].SerialEncCtrl = $1000009
PowerBrick[0].Chan[0].SerialEncCmd = $11000
PowerBrick[0].Chan[0].SerialEncEna = 1
```

Serial Data Registers – Mitutoyo

The resulting position data, status, and error bits for Mitutoyo are found in the following Serial Data Registers:



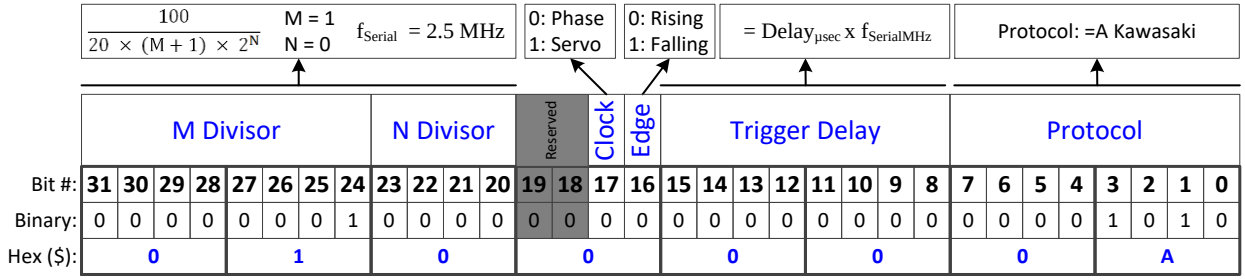
Bit #	Alarm Code
16	Initialization error
17	Mismatch of optical and capacitive sensors
18	Optical sensor error
19	Capacitive sensor error
20	CPU error (AT303); CPU/ROM/RAM error (AT503)
21	EEPROM error
22	ROM/RAM error (AT303); communication error (AT503)
23	Overspeed error

Bit #	Status Field
24	Fatal (unrecoverable) encoder error
25	–
26	Illegal command code from controller
27	–

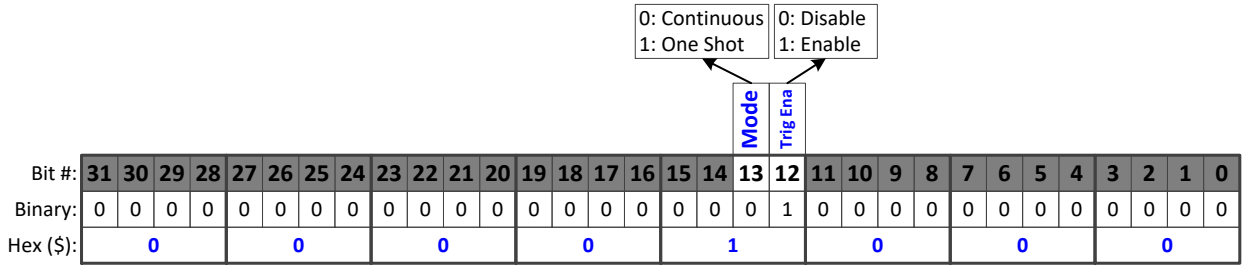
Kawasaki Configuration Example

Serial Encoder Control – Kawasaki

No trigger delay, rising edge of phase, and 2.5 MHz transmission:



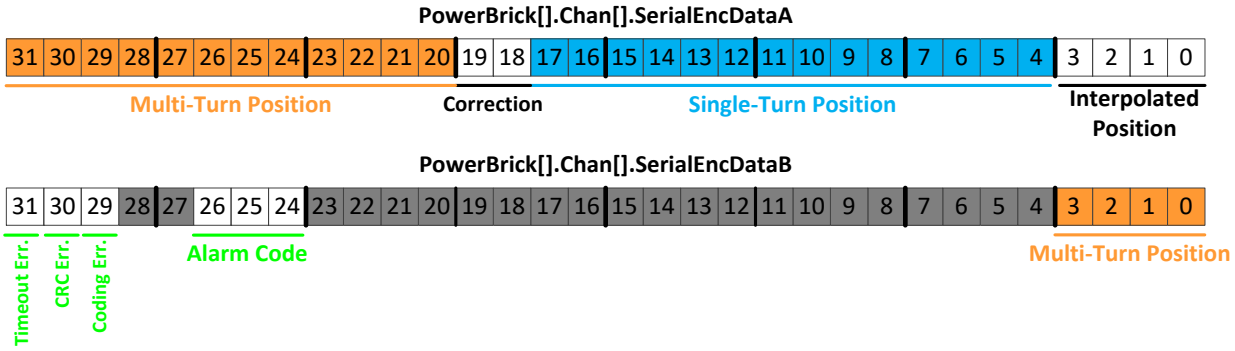
Serial Encoder Command – Kawasaki




```
PowerBrick[0].SerialEncCtrl = $100000A
PowerBrick[0].Chan[0].SerialEncCmd = $1000
PowerBrick[0].Chan[0].SerialEncEna = 1
```

Serial Data Registers – Kawasaki

The resulting position data, status, and error bits for Kawasaki are found in the following Serial Data Registers:



Bit #	Alarm code
24	Interpolator error
25	Absolute track error
26	Busy flag

Serial Encoder Ongoing Position Setup

For the ongoing "incremental" position data, it is sufficient to process whatever position data (single-turn and/or multi-turn) is available in the serial data A register. The PMAC firmware does not require processing the entire bit length because the difference change in between servo cycles is used to compute the ongoing position. This will not limit the resolution or hinder the performance. Some people may choose to use strictly the single-turn data in the Encoder Conversion Table for simplicity.

A key step, however, is to make sure that the Most Significant Bit MSB of the data chosen is most left-shifted to bit #31 in order to handle the rollover gracefully.

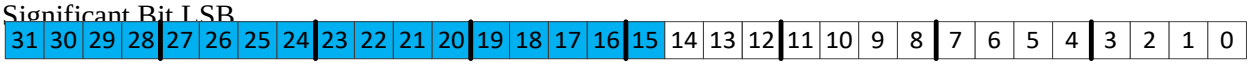
Following, are examples for setting up the Encoder Conversion Table ECT for ongoing position of various serial encoders. These settings depend primarily on the location of the position data in the serial encoder data A register.

Example: A serial encoder with 17 bits of single-turn (or an equivalent 1 µm linear scale) position data located in the lower 17 bits of serial data A register.

PowerBrick[].Chan[].SerialEncDataA



The position data should be shifted 15 bits left (using **index1**) so that the Most Significant Bit MSB is at bit #31 to handle the rollover gracefully. Also, the scale factor should reflect the new location of the Least Significant Bit LSB.




```
EncTable[1].type = 1
EncTable[1].pEnc = PowerBrick[0].Chan[0].SerialEncDataA.a
EncTable[1].pEnc1 = Sys.Pushm
EncTable[1].index1 = 15
EncTable[1].index2 = 0
EncTable[1].index3 = 0
EncTable[1].index4 = 0
EncTable[1].index5 = 0
EncTable[1].index6 = 0
EncTable[1].ScaleFactor = 1 / EXP2(15)
```

Activating the corresponding motor channel, and setting up the position and velocity pointers is sufficient to display motor/encoder units in the position window:

```
Motor[1].ServoCtrl = 1
Motor[1].pEnc = EncTable[1].a
Motor[1].pEnc2 = EncTable[1].a
```

In this case, the user will see 2^{17} = 131,072 motor units per revolution for a rotary encoder. And 1/0.001 = 1,000 motor units per mm for a linear encoder.

Example: A serial encoder with 20 bits of single-turn (or an equivalent 50 nm linear scale) position data located in serial data A register and starting at bit #4. The low nibble may contain other information, irrelevant to position data.

PowerBrick[].Chan[].SerialEncDataA

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

The position data should be first shifted 4 bits to the right (using **index2**) to eliminate the unwanted bits. Then shifted 12 bits to the left (using **index1**), so that the MSB is at bit #31 to handle the rollover gracefully. Also, the scale factor should reflect the new location of the LSB.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

```
EncTable[1].type = 1
EncTable[1].pEnc = PowerBrick[0].Chan[0].SerialEncDataA.a
EncTable[1].pEnc1 = Sys.Pushm
EncTable[1].index1 = 12
EncTable[1].index2 = 4
EncTable[1].index3 = 0
EncTable[1].index4 = 0
EncTable[1].index5 = 0
EncTable[1].index6 = 0
EncTable[1].ScaleFactor = 1 / EXP2(12)
```

Activating the corresponding motor channel, and setting up the position and velocity pointers is sufficient to display motor/encoder units in the position window:

```
Motor[1].ServoCtrl = 1
Motor[1].pEnc = EncTable[1].a
Motor[1].pEnc2 = EncTable[1].a
```

In this case, the user will see 2^{20} = 1,048,576 motor units per revolution for a rotary encoder. And 1 / 0.000050 = 20,000 motor units per mm for a linear encoder.

Example: A serial encoder with 36 bits of single-turn (or an equivalent 1 nm linear scale) position data located in serial data A and B registers consecutively.

PowerBrick[].Chan[].SerialEncDataA

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

PowerBrick[].Chan[].SerialEncDataB

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Reading and processing the 32 bits of position data in serial data register A is sufficient for producing the proper ongoing position.

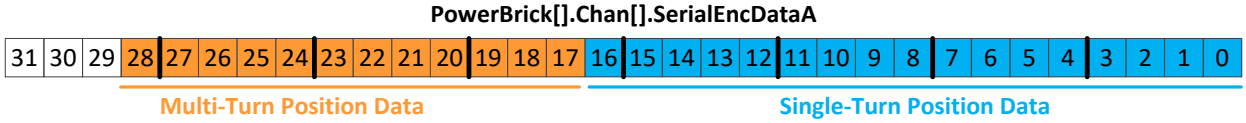
```
EncTable[1].type = 1
EncTable[1].pEnc = PowerBrick[0].Chan[0].SerialEncDataA.a
EncTable[1].pEnc1 = Sys.Pushm
EncTable[1].index1 = 0
EncTable[1].index2 = 0
EncTable[1].index3 = 0
EncTable[1].index4 = 0
EncTable[1].index5 = 0
EncTable[1].index6 = 0
EncTable[1].ScaleFactor = 1
```

Activating the corresponding motor channel, and setting up the position and velocity pointers is sufficient to display motor/encoder units in the position window:

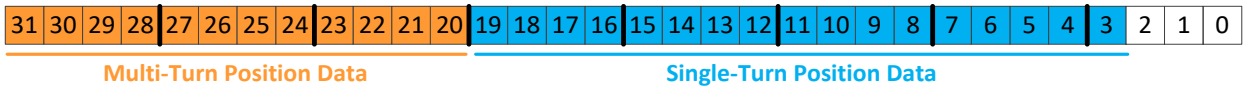
```
Motor[1].ServoCtrl = 1
Motor[1].pEnc = EncTable[1].a
Motor[1].pEnc2 = EncTable[1].a
```

In this case, the user will see $2^{SingleTurn} = 2^{36} = 68,719,476,736$ motor units per revolution for a rotary motor. And 1 / 0.000001 = 1,000,000 motor units per mm for a linear motor.

Example: A 29-bit serial encoder with 17 bits of single-turn and 12 bits of multi-turn position data starting at bit #0 of serial data A register and continuously extending to bit #28.



Both single-turn and multi-turn data can be used for ongoing position. The entire bit length is shifted left (using **index1**) 3 bits to place the MSB at bit #31.



Ongoing Position

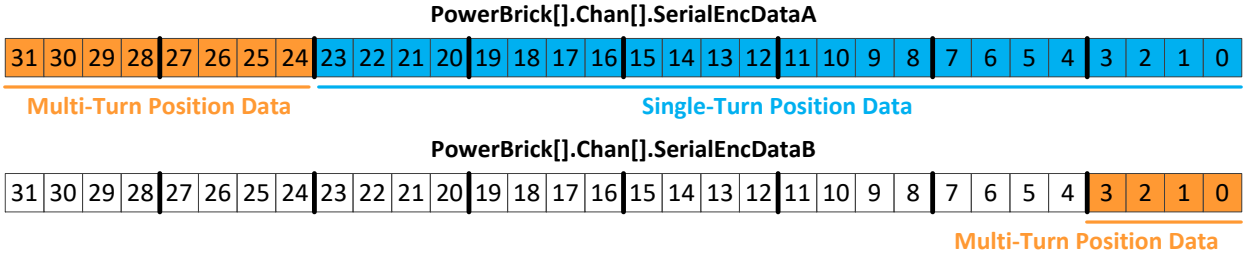
```
EncTable[1].type = 1
EncTable[1].pEnc = PowerBrick[0].Chan[0].SerialEncDataA.a
EncTable[1].pEnc1 = Sys.Pushm
EncTable[1].index1 = 3
EncTable[1].index2 = 0
EncTable[1].index3 = 0
EncTable[1].index4 = 0
EncTable[1].index5 = 0
EncTable[1].index6 = 0
EncTable[1].ScaleFactor = 1 / EXP2(3)
```

Activating the corresponding motor channel, and setting up the position and velocity pointers is sufficient to display motor/encoder units in the position window:

```
Motor[1].ServoCtrl = 1
Motor[1].pEnc = EncTable[1].a
Motor[1].pEnc2 = EncTable[1].a
```

In this case, the user will see $2^{SingleTurn} = 2^{17} = 131,072$ motor units per revolution.

Example: A 36-bit serial encoder with 24 bits of single-turn and 12 bits of multi-turn position data starting at bit #0 of serial data A register and continuously extending to bit #3 of serial data register B.



For ongoing position, we are only interested in the position data residing in serial data register A. Some people may elect to use only the single-turn data for ongoing position processing. This would require shifting to the left 8 bits (**index1 = 8**), and setting **EncTable[].ScaleFactor = 1 / 256**.

But, also it is possible to just simply process the whole 32-bit word comprised of single-turn, and multi-turn position data.

```
EncTable[1].type = 1
EncTable[1].pEnc = PowerBrick[0].Chan[0].SerialEncDataA.a
EncTable[1].pEnc1 = Sys.Pushm
EncTable[1].index1 = 0
EncTable[1].index2 = 0
EncTable[1].index3 = 0
EncTable[1].index4 = 0
EncTable[1].index5 = 0
EncTable[1].index6 = 0
EncTable[1].ScaleFactor = 1
```

Activating the corresponding motor channel, and setting up the position and velocity pointers is sufficient to display motor/encoder units in the position window:

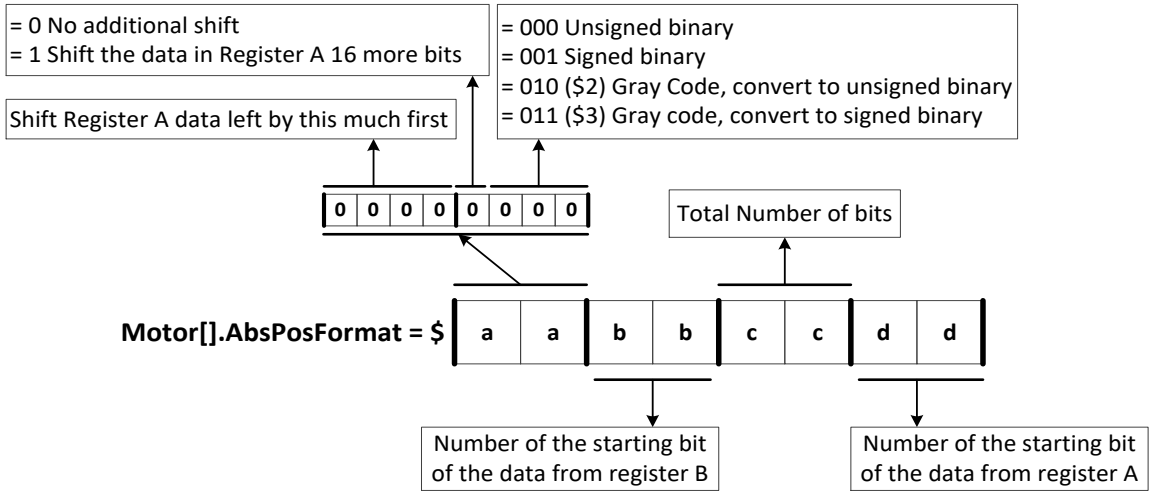
```
Motor[1].ServoCtrl = 1
Motor[1].pEnc = EncTable[1].a
Motor[1].pEnc2 = EncTable[1].a
```

In this case, the user will see $2^{SingleTurn} = 2^{24} = 16{,}777{,}216$ motor units per revolution.

Serial Encoder Power-On Absolute Position Setup

The absolute position is computed directly from the serial data registers, and set up using the following key structure elements:

- **Motor[].pAbsPos**, typically = **PowerBrick[].Chan[].SerialEncDataA.a**
- **Motor[].AbsPosSf = Motor[].PosSf**
- **Motor[].ApsPosFormat**:



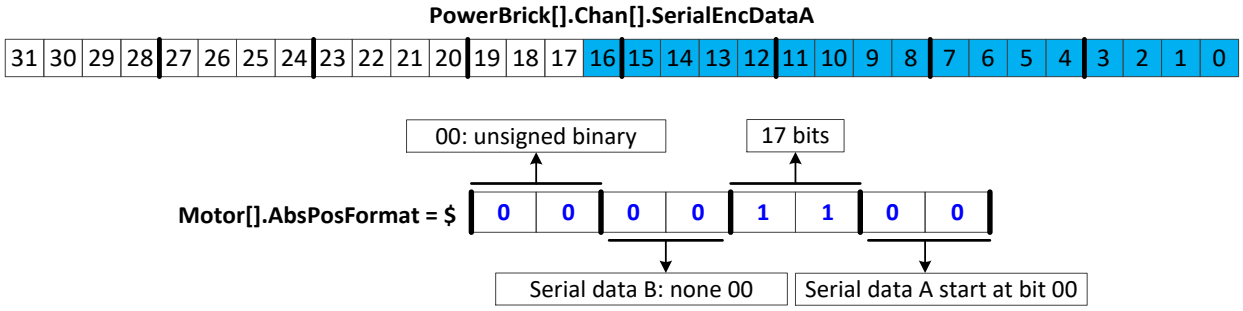


Note

Motor[].PowerOnMode (value of 2) specifies an absolute position read on power up. Alternately, **#1HMZ** from the online terminal or a **HOMEZ 1** from a PLC can be issued to retrieve the absolute position.

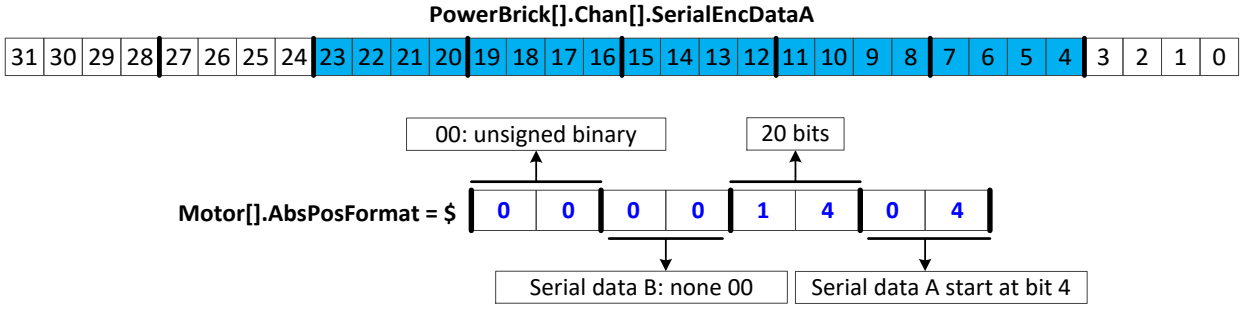
Following, are examples for setting up the absolute position read with various serial encoders. These settings depend primarily on the location of the position data in the serial encoder data A and B registers.

Example: A serial encoder with 17 bits of binary single-turn (or linear scale), and no multi-turn, position data located in the lower fields of serial data A register.



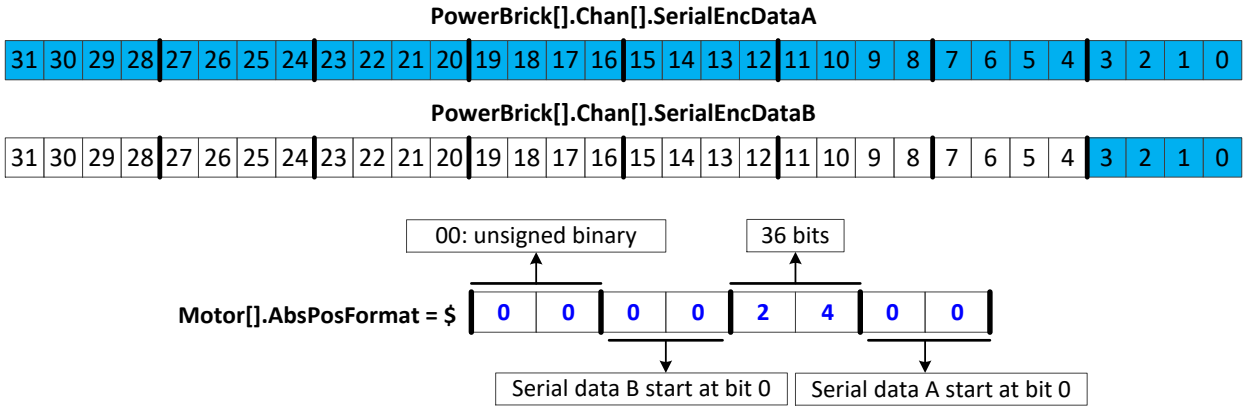

```
Motor[1].pAbsPos = PowerBrick[0].Chan[0].SerialEncDataA.a
Motor[1].AbsPosSf = Motor[1].PosSf
Motor[1].ApsPosFormat = $00001100
Motor[1].HomeOffset = 0
```

Example: A serial encoder with 20 bits of binary single-turn (or linear scale), and no multi-turn, position data starting at bit #4 of serial data A register.




```
Motor[1].pAbsPos = PowerBrick[0].Chan[0].SerialEncDataA.a
Motor[1].AbsPosSf = Motor[1].PosSf
Motor[1].AbsPosFormat = $00001404
Motor[1].HomeOffset = 0
```

Example: A serial encoder with 36 bits of single-turn (or linear scale) position data located in serial data A and B registers consecutively.



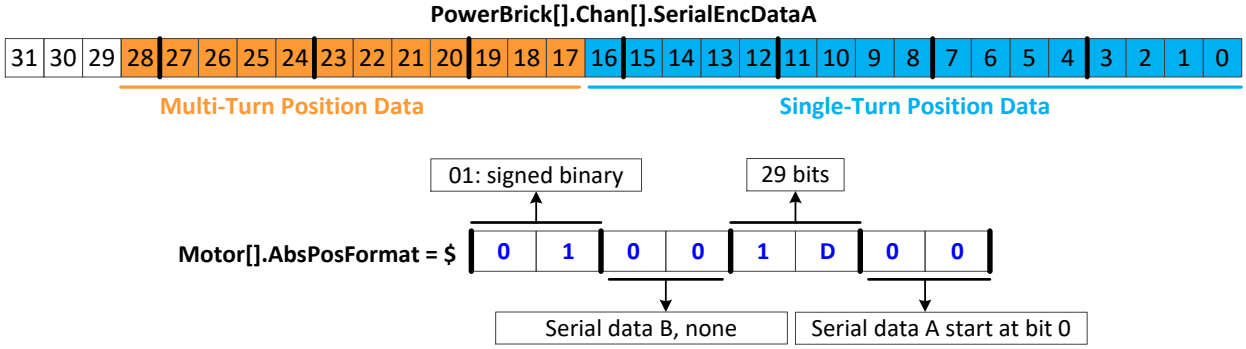

```
Motor[1].pAbsPos = PowerBrick[0].Chan[0].SerialEncDataA.a
Motor[1].AbsPosSf = Motor[1].PosSf
Motor[1].AbsPosFormat = $00002400
Motor[1].HomeOffset = 0
```



Note

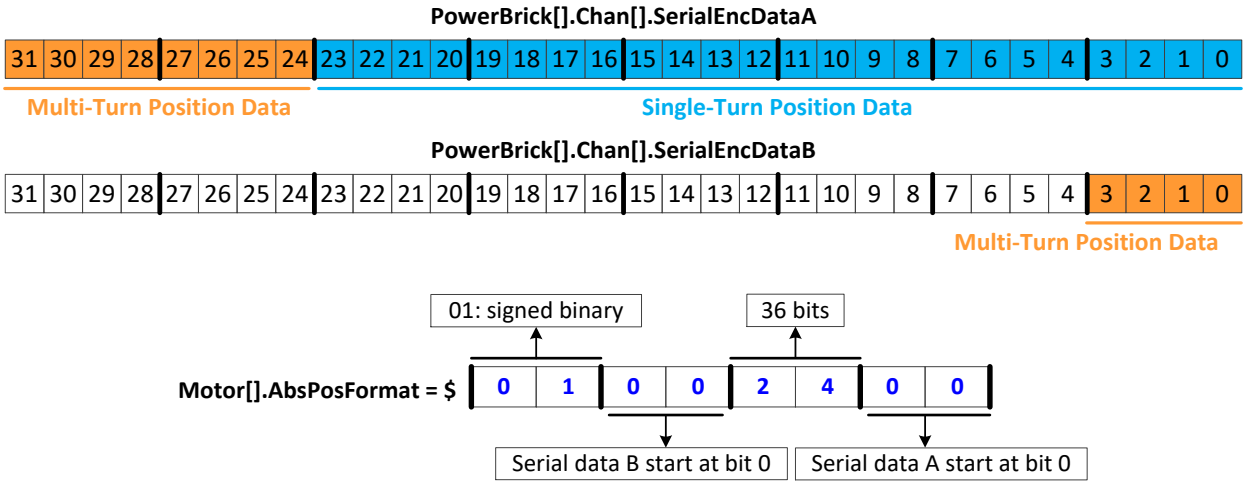
Encoders with no multi-turn position data are set up as unsigned.

Example: A 29-bit binary serial encoder with 17 bits of single-turn and 12 bits of multi-turn position data starting at bit #0 of serial data A register and continuously extending to bit #28.



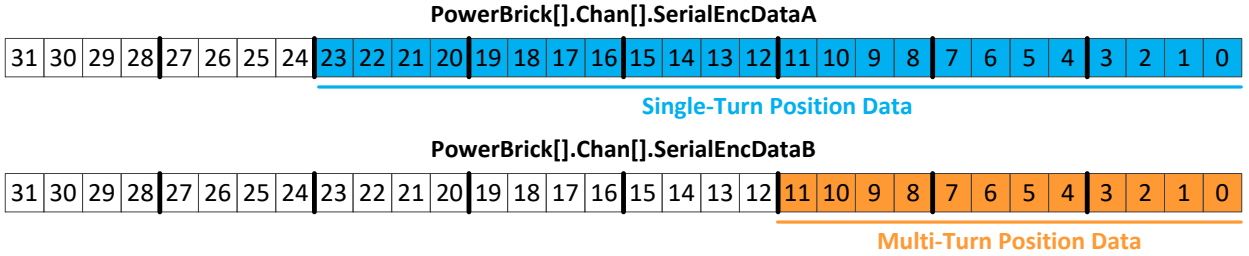

```
Motor[1].pAbsPos = PowerBrick[0].Chan[0].SerialEncDataA.a
Motor[1].AbsPosSf = Motor[1].PosSf
Motor[1].AbsPosFormat = $01001D00
Motor[1].HomeOffset = 0
```

Example: A 36-bit binary serial encoder with 24 bits of single-turn and 12 bits of multi-turn position data starting at bit #0 of serial data A register and continuously extending to bit #3 of serial data register B.

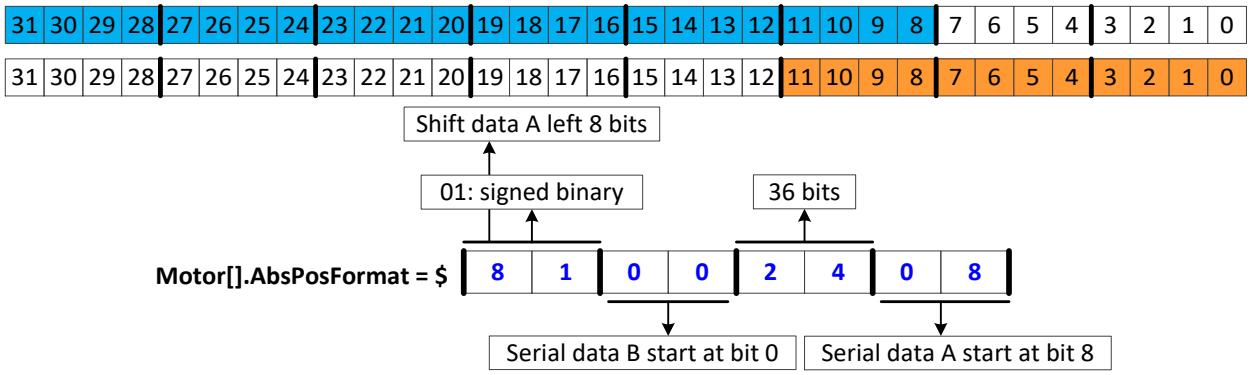



```
Motor[1].pAbsPos = PowerBrick[0].Chan[0].SerialEncDataA.a
Motor[1].AbsPosSf = Motor[1].PosSf
Motor[1].AbsPosFormat = $01002400
Motor[1].HomeOffset = 0
```

Example: A 36-bit binary serial encoder with 24 bits of single-turn in the lower fields of serial data register A, and 12 bits of multi-turn position data in the lower fields of serial data register B.

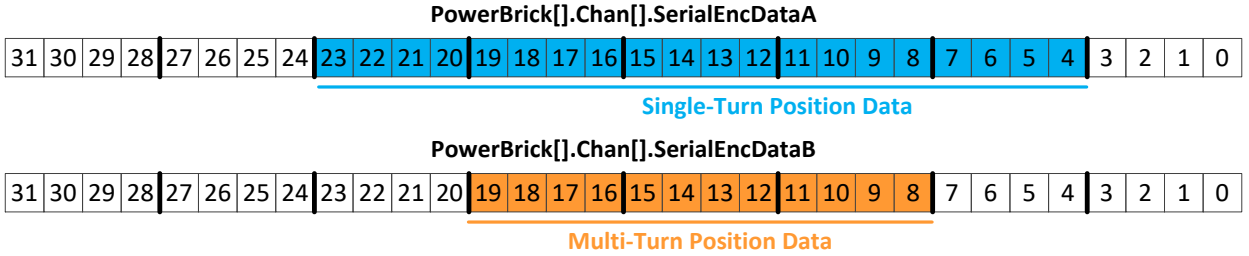


The single turn data must be shifted 8 bits left first, to make it contiguous with the multi-turn data. This shift is done using the upper 5 bits of the **$aa** byte of **Motor[].AbsPosFormat**. The data would then look like:

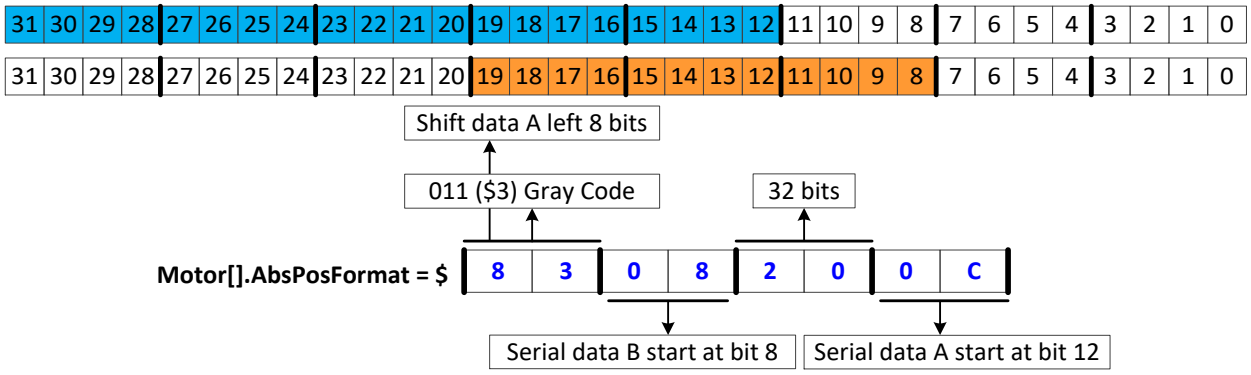



```
Motor[1].pAbsPos = PowerBrick[0].Chan[0].SerialEncDataA.a
Motor[1].AbsPosSf = Motor[1].PosSf
Motor[1].AbsPosFormat = $81002408
Motor[1].HomeOffset = 0
```

Example: A 32-bit Gray code serial encoder with 20 bits of single-turn in serial data register A starting at bit #4, and 12 bits of multi-turn position data in serial data register B starting at bit #8.



The single turn data must be shifted 8 bits left first. This shift is done using the upper 5 bits of the **$aa** byte of **Motor[].AbsPosFormat**. The data would then look like:



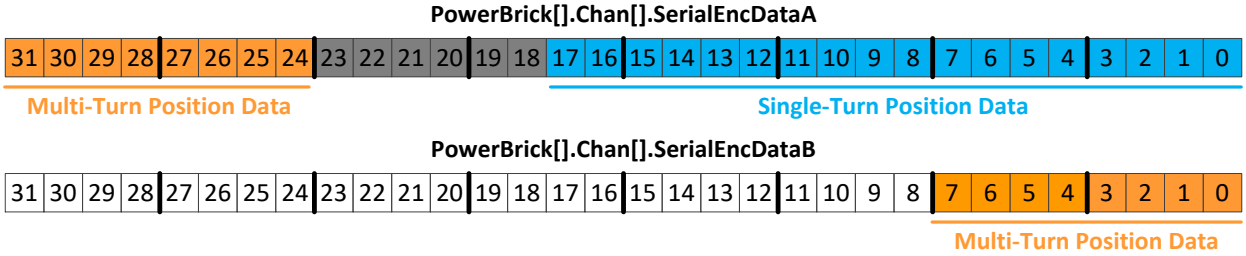

```
Motor[1].pAbsPos = PowerBrick[0].Chan[0].SerialEncDataA.a
Motor[1].AbsPosSf = Motor[1].PosSf
Motor[1].AbsPosFormat = $8308200C
Motor[1].HomeOffset = 0
```



Note

Encoders with multi-turn position data are typically set up as signed.

Example: A 33-bit binary serial encoder (for example, Panasonic) with 17 bits of single-turn and 16 bits of multi-turn position data in the following fields:



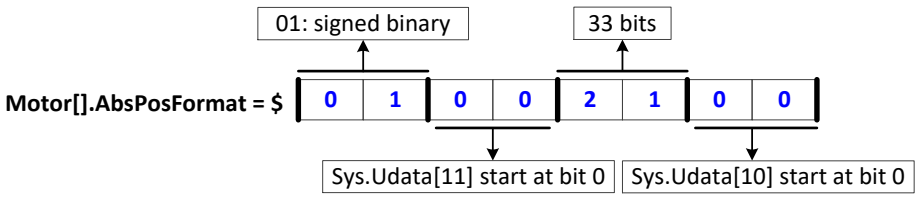
The automatic settings are not suitable for the discontinuity between the single-turn and multi-turn data. We will assemble the absolute position word manually (in a background or initialization PLC), and hold the data in two consecutive open memory registers to feed the automatic settings. Below is the example PLC for performing this operation:

```
GLOBAL Enc1StData;
GLOBAL Enc1MtData;
GLOBAL Enc1Data;

#define Enc1AbsPos1    Sys.Udata[10]
#define Enc1AbsPos2    Sys.Udata[11]

OPEN PLC PanasonicAbsPosPLC
LOCAL Enc1MtDataA, Enc1MtDataB;
Enc1StData = PowerBrick[0].Chan[0].SerialEncDataA & $1FFFF;
Enc1MtDataA = (PowerBrick[0].Chan[0].SerialEncDataA & $FF000000) >> 24;
Enc1MtDataB = PowerBrick[0].Chan[0].SerialEncDataB & $000000FF;
Enc1MtData = Enc1MtDataA + Enc1MtDataB * EXP2(8);
IF (Enc1MtData > 32768)        // NEGATIVE?
{
        Enc1Data = (Enc1StData - 131072) + (Enc1MtData - 65535) * EXP2(17);
}
ELSE                           // POSITIVE?
{
        Enc1Data = Enc1StData + Enc1MtData * EXP2(17);
}
Enc1AbsPos1 = Enc1Data & $FFFFFFFF;
Enc1AbsPos2 = (Enc1Data >> 31) & $1;
DISABLE PLC PanasonicAbsPosPLC;
CLOSE
```

The automatic settings can now be set up to read the absolute position at the first corresponding user defined register:



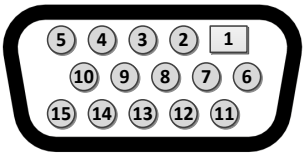

```
Motor[1].pAbsPos = Sys.Udata[10].a
Motor[1].AbsPosSf = Motor[1].PosSf
Motor[1].AbsPosFormat = $01002100
Motor[1].HomeOffset = 0
```

Once the example code in the sample PLC is executed, an **HMZ** command can be issued for an absolute position read.

X9 – X12: Analog Inputs / Outputs

Each of the analog I/O connectors (X9, X10, X11, and X12) provides:

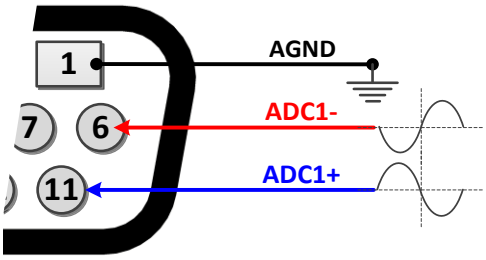
- 2 x 16-bit Analog Inputs
- 2 x ~14-bit Analog Outputs
- 2 x General Purpose Relays
- 2 x General Purpose Inputs / External Amp Faults

X9-X10: D-Sub DE-15 F **Mating: D-Sub DE-15 M**			
Pin #	**Symbol**	**Function**	**Description**
1	AGND	Ground	Common Analog Ground
2	DAC1-	Output	Analog Output 1-
3	AE-NO1	Relay	Normally Open GP Relay / Brake 1
4	ADC2+	Input	Analog Input 2+
5	AE-COM2	Common	GP Relay / Brake Common 2
6	ADC1-	Input	Analog Input 1-
7	DAC1+	Output	Analog Output 1+
8	AMPFLT1	Input	GP Input / Ext Amp Fault 1
9	DAC2-	Output	Analog Output 2-
10	AE-NO2	Relay	Normally Open GP Relay / Brake 2
11	ADC1+	Input	Analog Input 1+
12	AE-COM1	Common	GP Relay / Brake Common 1
13	ADC2-	Input	Analog Input 2-
14	DAC2+	Output	Analog Output 2+
15	AMPFLT2	Input	GP / Amp Fault Input 2

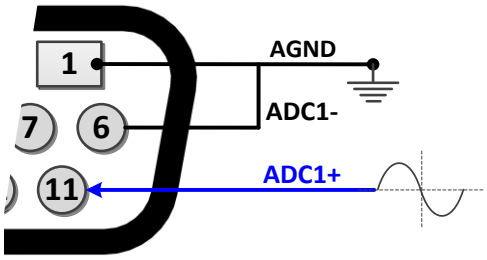
Setting up the Analog (ADC) Inputs

The analog inputs accept ±5 V differential signals, or ±10 V single-ended signals.

Differential Analog Input Signal



Single Ended Analog Input Signal





Note

For single-ended connections, tie the negative ADC pin to ground.

The ADC software data resides in the upper 16 bits of the 32-bit structure element **PowerBrick[].Chan[].AdcAmp[2]**. The structure elements do not allow bit masking (of the upper 16 bits), hence scaling (shifting) is required to obtain the raw ADC data. Using the explicit address registers makes bit masking easier:

Channel / Connector	Address	Structure Element
ADC 1, X9	$900028	PowerBrick[0].Chan[0].AdcAmp[2]
ADC 2, X9	$9000A8	PowerBrick[0].Chan[1].AdcAmp[2]
ADC 1, X10	$900128	PowerBrick[0].Chan[2].AdcAmp[2]
ADC 2, X10	$9001A8	PowerBrick[0].Chan[3].AdcAmp[2]

Channel / Connector	Address	Structure Element
ADC 1, X11	$904028	PowerBrick[1].Chan[0].AdcAmp[2]
ADC 2, X11	$9040A8	PowerBrick[1].Chan[1].AdcAmp[2]
ADC 1, X12	$904128	PowerBrick[1].Chan[2].AdcAmp[2]
ADC 2, X12	$9041A8	PowerBrick[1].Chan[3].AdcAmp[2]



Note

The explicit address register(s) can be found by subtracting **Sys.piom** from **PowerBrick[].Chan[].AdcAmp[2].a**



Note

The ADC input data must be in the "unpacked" format to be read properly; use **PowerBrick[].Chan[].PackInData = 0**.

Raw ADC Data (bits)

```
PowerBrick[0].Chan[0].PackInData = 0 // Unpack Input Data
PowerBrick[0].Chan[1].PackInData = 0 // Unpack Input Data
PowerBrick[0].Chan[2].PackInData = 0 // Unpack Input Data
PowerBrick[0].Chan[3].PackInData = 0 // Unpack Input Data
PowerBrick[1].Chan[0].PackInData = 0 // Unpack Input Data
PowerBrick[1].Chan[1].PackInData = 0 // Unpack Input Data
PowerBrick[1].Chan[2].PackInData = 0 // Unpack Input Data
PowerBrick[1].Chan[3].PackInData = 0 // Unpack Input Data

PTR ADC1X9 ->S.IO:$900028.16.16;      // ADC1 X9  [Counts]
PTR ADC2X9 ->S.IO:$9000A8.16.16;      // ADC2 X9  [Counts]
PTR ADC1X10->S.IO:$900128.16.16;      // ADC1 X10 [Counts]
PTR ADC2X10->S.IO:$9001A8.16.16;      // ADC2 X10 [Counts]
PTR ADC1X11->S.IO:$904028.16.16;      // ADC1 X11 [Counts]
PTR ADC2X11->S.IO:$9040A8.16.16;      // ADC2 X11 [Counts]
PTR ADC1X12->S.IO:$904128.16.16;      // ADC1 X12 [Counts]
PTR ADC2X12->S.IO:$9041A8.16.16;      // ADC2 X12 [Counts]
```

The analog inputs have 16 bits of resolution (65,536 software counts) spanning over the full range of the input voltage. Wiring ±10 V voltage in single-ended, or ±5 V in differential mode produces the following counts in software:

Single-Ended [VDC]	**Differential** [VDC]	**Software Counts**
-10	-5	-32768
0	0	0
10	5	+32768

Scaling the analog input Data

For general purpose usage, the ADC data (reported in bits) can be easily scaled and converted into "user" voltage or units (e.g. force, height). In the example PLC below:

- The global parameter **ADCnXxxZeroOffset** represents the voltage offset with a zero volt input. This is user adjustable.
- The pointer **ADCnXxx** reports the raw ADC data in software counts, units of 16-bit (±32768).
- The global parameter **ADCnXxxVolts** reports the ADC data in "user" volts.

Where **n** is the ADC channel number (1 or 2) of the corresponding **xx** connector (X9, X10, X11, or X12).

```
GLOBAL ADC1X9Volts = 0;                 // Voltage input, ADC1 X9  [volt]
GLOBAL ADC2X9Volts = 0;                 // Voltage input, ADC2 X9  [volt]
GLOBAL ADC1X10Volts = 0;                // Voltage input, ADC1 X10 [volt]
GLOBAL ADC2X10Volts = 0;                // Voltage input, ADC2 X10 [volt]
GLOBAL ADC1X11Volts = 0;                // Voltage input, ADC1 X11 [volt]
GLOBAL ADC2X11Volts = 0;                // Voltage input, ADC2 X11 [volt]
GLOBAL ADC1X12Volts = 0;                // Voltage input, ADC1 X12 [volt]
GLOBAL ADC2X12Volts = 0;                // Voltage input, ADC2 X12 [volt]

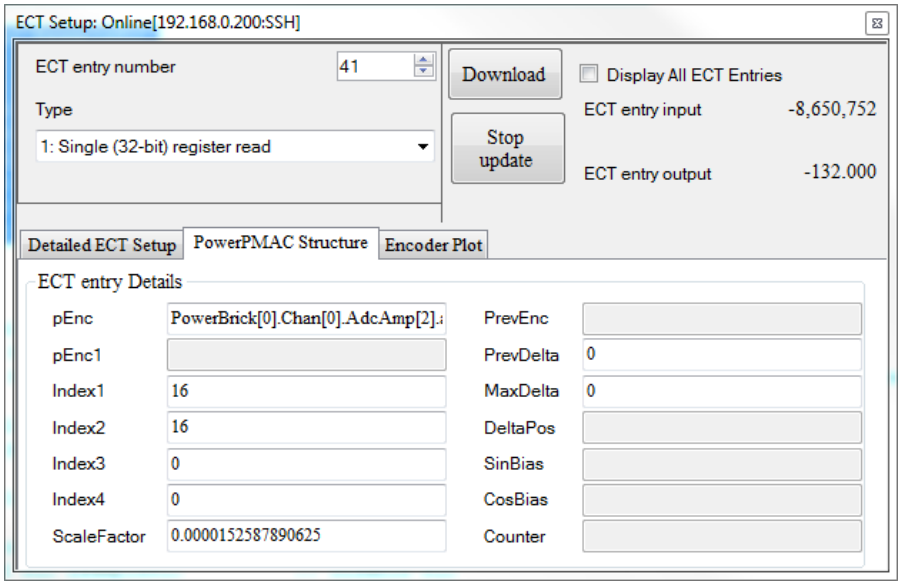
GLOBAL ADC1X9ZeroOffset = 0.038;          // Zero Volt Offset, ADC1 X9  [volt] --USER ADJUSTABLE
GLOBAL ADC2X9ZeroOffset = 0.038;          // Zero Volt Offset, ADC2 X9  [volt] --USER ADJUSTABLE
GLOBAL ADC1X10ZeroOffset = 0.038;         // Zero Volt Offset, ADC1 X10 [volt] --USER ADJUSTABLE
GLOBAL ADC2X10ZeroOffset = 0.038;         // Zero Volt Offset, ADC2 X10 [volt] --USER ADJUSTABLE
GLOBAL ADC1X11ZeroOffset = 0.038;         // Zero Volt Offset, ADC1 X11 [volt] --USER ADJUSTABLE
GLOBAL ADC2X11ZeroOffset = 0.038;         // Zero Volt Offset, ADC2 X11 [volt] --USER ADJUSTABLE
GLOBAL ADC1X12ZeroOffset = 0.038;         // Zero Volt Offset, ADC1 X12 [volt] --USER ADJUSTABLE
GLOBAL ADC2X12ZeroOffset = 0.038;         // Zero Volt Offset, ADC2 X12 [volt] --USER ADJUSTABLE

OPEN PLC ExamplePLC
ADC1X9Volts  = (ADC1X9  * 10 / 32768) - ADC1X9ZeroOffset   // ADC1, X9  [volts]
ADC2X9Volts  = (ADC2X9  * 10 / 32768) - ADC2X9ZeroOffset   // ADC2, X9  [volts]
ADC1X10Volts = (ADC1X10 * 10 / 32768) - ADC1X10ZeroOffset  // ADC1, X10 [volts]
ADC2X10Volts = (ADC2X10 * 10 / 32768) - ADC2X10ZeroOffset  // ADC2, X10 [volts]
ADC1X11Volts = (ADC1X11 * 10 / 32768) - ADC1X11ZeroOffset  // ADC1, X11 [volts]
ADC2X11Volts = (ADC2X11 * 10 / 32768) - ADC2X11ZeroOffset  // ADC2, X11 [volts]
ADC1X12Volts = (ADC1X12 * 10 / 32768) - ADC1X12ZeroOffset  // ADC1, X12 [volts]
ADC2X12Volts = (ADC2X12 * 10 / 32768) - ADC2X12ZeroOffset  // ADC2, X12 [volts]
CLOSE
```

Using the ADC for Servo Feedback

Using the ADC data for servo feedback requires bringing it into the Encoder Conversion Table (ECT) into which the motor's position and velocity elements are assigned to.

Example:



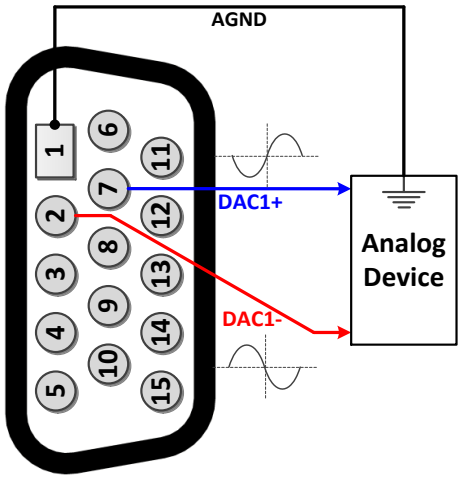

```
EncTable[9].Type = 1
EncTable[9].pEnc = PowerBrick[0].Chan[0].AdcAmp[2].a
EncTable[9].pEnc1 = Sys.pushm
EncTable[9].index1 = 16
EncTable[9].index2 = 16
EncTable[9].index3 = 0
EncTable[9].index4 = 0
EncTable[9].index5 = 0
EncTable[9].index6 = 0
EncTable[9].ScaleFactor = 1 / EXP2(16)

Motor[9].PosSf = 1
Motor[9].pEnc = EncTable[9].a
Motor[9].pEnc2 = EncTable[9].a
```

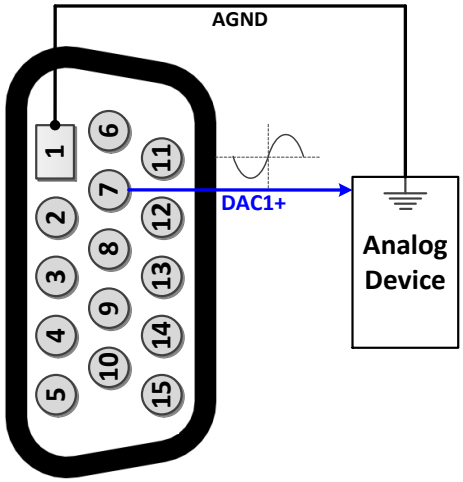
Setting up the Analog (DAC) Outputs

The analog outputs provide ±10 V signals interfacing to either differential or single-ended devices.

Differential DAC Output Signal



Single Ended DAC Output Signal



The analog output circuitry is filtered PWM optimized (in hardware) for a PWM cut off frequency of about 15 kHz. The recommended PWM frequency of 10 kHz in the Power Brick AC should be good enough for general purpose usage.



Note

These analog outputs are synthesized filtered PWM. They are designed for general purpose use; they are not industrially graded for servo use. True DAC outputs are typically used in servo applications.

The analog output command data resides in the upper 16 bits of the 32-bit structure element **PowerBrick[].Chan[].Pwm[3].** The structure elements do not allow bit masking (of the upper 16 bits), hence scaling (shifting) is required to write to the outputs properly. Using the explicit address registers makes it easier for bit masking:

Channel / Connector	Address	Channel / Connector	Address
Channel 1, X9	$90004C	Channel 1, X11	$90404C
Channel 2, X9	$9000CC	Channel 2, X11	$9040CC
Channel 1, X10	$90014C	Channel 1, X12	$90414C
Channel 2, X10	$9001CC	Channel 2, X12	$9041CC



Note

The explicit address register(s) can be found by subtracting **Sys.piom** from **PowerBrick[].Chan[].Pwm[3].a**



Note

Writing directly into **PowerBrick[].Chan[].Pwm[3]** register to produce voltage output requires shifting left by 16 bits (or multiplying by 65536).



Note

The command output data must be in the "unpacked" format; **PowerBrick[].Chan[].PackOutData = 0**.



Note

The analog outputs are generated from the fourth output channel, phase D. Therefore, it must be set for PWM mode.

Command Register Pointers

```
PowerBrick[0].Chan[0].PackOutData = 0  // DAC1, X9,  Unpack Output Data
PowerBrick[0].Chan[1].PackOutData = 0  // DAC2, X9,  Unpack Output Data
PowerBrick[0].Chan[2].PackOutData = 0  // DAC1, X10, Unpack Output Data
PowerBrick[0].Chan[3].PackOutData = 0  // DAC2, X10, Unpack Output Data
PowerBrick[1].Chan[0].PackOutData = 0  // DAC1, X11, Unpack Output Data
PowerBrick[1].Chan[1].PackOutData = 0  // DAC2, X11, Unpack Output Data
PowerBrick[1].Chan[2].PackOutData = 0  // DAC1, X12, Unpack Output Data
PowerBrick[1].Chan[3].PackOutData = 0  // DAC2, X12, Unpack Output Data

PowerBrick[0].Chan[0].OutputMode = PowerBrick[0].Chan[0].OutputMode & $7    // D phase PWM
PowerBrick[0].Chan[1].OutputMode = PowerBrick[0].Chan[1].OutputMode & $7    // D phase PWM
PowerBrick[0].Chan[2].OutputMode = PowerBrick[0].Chan[2].OutputMode & $7    // D phase PWM
PowerBrick[0].Chan[3].OutputMode = PowerBrick[0].Chan[3].OutputMode & $7    // D phase PWM
PowerBrick[1].Chan[0].OutputMode = PowerBrick[1].Chan[0].OutputMode & $7    // D phase PWM
PowerBrick[1].Chan[1].OutputMode = PowerBrick[1].Chan[1].OutputMode & $7    // D phase PWM
PowerBrick[1].Chan[2].OutputMode = PowerBrick[1].Chan[2].OutputMode & $7    // D phase PWM
PowerBrick[1].Chan[3].OutputMode = PowerBrick[1].Chan[3].OutputMode & $7    // D phase PWM

PTR DAC1X9-> S.IO:$90004C.16.16;  // DAC Channel 1, X9    [Counts]
PTR DAC2X9-> S.IO:$9000CC.16.16;  // DAC Channel 2, X9    [Counts]
PTR DAC1X10->S.IO:$90014C.16.16;  // DAC Channel 1, X10   [Counts]
PTR DAC2X10->S.IO:$9001CC.16.16;  // DAC Channel 2, X10   [Counts]
PTR DAC1X11->S.IO:$90404C.16.16;  // DAC Channel 1, X11   [Counts]
PTR DAC2X11->S.IO:$9040CC.16.16;  // DAC Channel 2, X11   [Counts]
PTR DAC1X12->S.IO:$90414C.16.16;  // DAC Channel 1, X12   [Counts]
PTR DAC2X12->S.IO:$9041CC.16.16;  // DAC Channel 2, X12   [Counts]
```

The effective resolution of the analog output circuitry is about ~13.5 bits (±13380 software counts) spanning over the full output range of ±10 V (saturates at about ~10.5 Volts). Writing to the user defined **DACnXxxInBits** pointer produces the following voltage output:

DACnXxxInBits	Single Ended [VDC]	Differential [VDC]
-13380	-10	-20
0	0	0
13380	+10	+20



Note

The output voltage is measured between AGND and DAC+ in single-ended mode. And between DAC- and DAC+ in differential mode.

Scaled DAC Output (In Volts)

The outputs can be scaled and converted into "user" voltage units. The following example PLC scales the data as needed to allow the user to command the output in units of volts:

- The global parameter(s) **DACnXxxZeroOffset** represents the voltage offset (as seen on a digital multi-meter or scope) when an output of zero is commanded. This is user adjustable.
- The global parameter **DACnXxxCtPerVolt** acts a software adjustment pot which the user can calibrate for at the rails (±10 V) of the output.
- The global parameter **DACnXxxVolts** is the output command in volts

Where **n** is the DAC channel number (1 or 2) of the corresponding **xx** connector (X9, X10, X11, or X12).

Example Code:

```
GLOBAL DAC1X9Volts = 0;            // DAC Channel 1, X9    [volts]
GLOBAL DAC2X9Volts = 0;            // DAC Channel 2, X9    [volts]
GLOBAL DAC1X10Volts = 0;           // DAC Channel 1, X10   [volts]
GLOBAL DAC2X10Volts = 0;           // DAC Channel 2, X10   [volts]
GLOBAL DAC1X11Volts = 0;           // DAC Channel 1, X11   [volts]
GLOBAL DAC2X11Volts = 0;           // DAC Channel 2, X11   [volts]
GLOBAL DAC1X12Volts = 0;           // DAC Channel 1, X12   [volts]
GLOBAL DAC2X12Volts = 0;           // DAC Channel 2, X12   [volts]

GLOBAL DAC1X9ZeroOffset = 0.05;   // DAC1 X9,  Zero Volt offset [volts] --USER ADJUSTABLE
GLOBAL DAC2X9ZeroOffset = 0.05;   // DAC2 X9,  Zero Volt offset [volts] --USER ADJUSTABLE
GLOBAL DAC1X10ZeroOffset = 0.05;  // DAC1 X10, Zero Volt offset [volts] --USER ADJUSTABLE
GLOBAL DAC2X10ZeroOffset = 0.05;  // DAC2 X10, Zero Volt offset [volts] --USER ADJUSTABLE
GLOBAL DAC1X11ZeroOffset = 0.05;  // DAC1 X11, Zero Volt offset [volts] --USER ADJUSTABLE
GLOBAL DAC2X11ZeroOffset = 0.05;  // DAC2 X11, Zero Volt offset [volts] --USER ADJUSTABLE
GLOBAL DAC1X12ZeroOffset = 0.05;  // DAC1 X12, Zero Volt offset [volts] --USER ADJUSTABLE
GLOBAL DAC2X12ZeroOffset = 0.05;  // DAC2 X12, Zero Volt offset [volts] --USER ADJUSTABLE

GLOBAL DAC1X9CtPerVolt = 1338;    // DAC1 X9,  Scale Factor Counts/Volt --USER ADJUSTABLE
GLOBAL DAC2X9CtPerVolt = 1338;    // DAC2 X9,  Scale Factor Counts/Volt --USER ADJUSTABLE
GLOBAL DAC1X10CtPerVolt = 1338;   // DAC1 X10, Scale Factor Counts/Volt --USER ADJUSTABLE
GLOBAL DAC2X10CtPerVolt = 1338;   // DAC2 X10, Scale Factor Counts/Volt --USER ADJUSTABLE
GLOBAL DAC1X11CtPerVolt = 1338;   // DAC1 X11, Scale Factor Counts/Volt --USER ADJUSTABLE
GLOBAL DAC2X11CtPerVolt = 1338;   // DAC2 X11, Scale Factor Counts/Volt --USER ADJUSTABLE
GLOBAL DAC1X12CtPerVolt = 1338;   // DAC1 X12, Scale Factor Counts/Volt --USER ADJUSTABLE
GLOBAL DAC2X12CtPerVolt = 1338;   // DAC2 X12, Scale Factor Counts/Volt --USER ADJUSTABLE

OPEN PLC ExamplePLC
DAC1X9 = (DAC1X9Volts   - DAC1X9ZeroOffset)  * ABS(DAC1X9CtPerVolt)
DAC2X9 = (DAC2X9Volts   - DAC2X9ZeroOffset)  * ABS(DAC2X9CtPerVolt)
DAC1X10 = (DAC1X100Volts - DAC1X10ZeroOffset) * ABS(DAC1X10CtPerVolt)
DAC2X10 = (DAC2X100Volts - DAC2X10ZeroOffset) * ABS(DAC2X10CtPerVolt)
DAC1X11 = (DAC1X111Volts - DAC1X11ZeroOffset) * ABS(DAC1X11CtPerVolt)
DAC2X11 = (DAC2X111Volts - DAC2X11ZeroOffset) * ABS(DAC2X11CtPerVolt)
DAC1X12 = (DAC1X122Volts - DAC1X12ZeroOffset) * ABS(DAC1X12CtPerVolt)
DAC2X12 = (DAC2X122Volts - DAC2X12ZeroOffset) * ABS(DAC2X12CtPerVolt)
CLOSE
```



Note

Using this example code, the user can command the output by writing to **DACnXxxVolts** in units of volts.

Setting up the General Purpose Relays

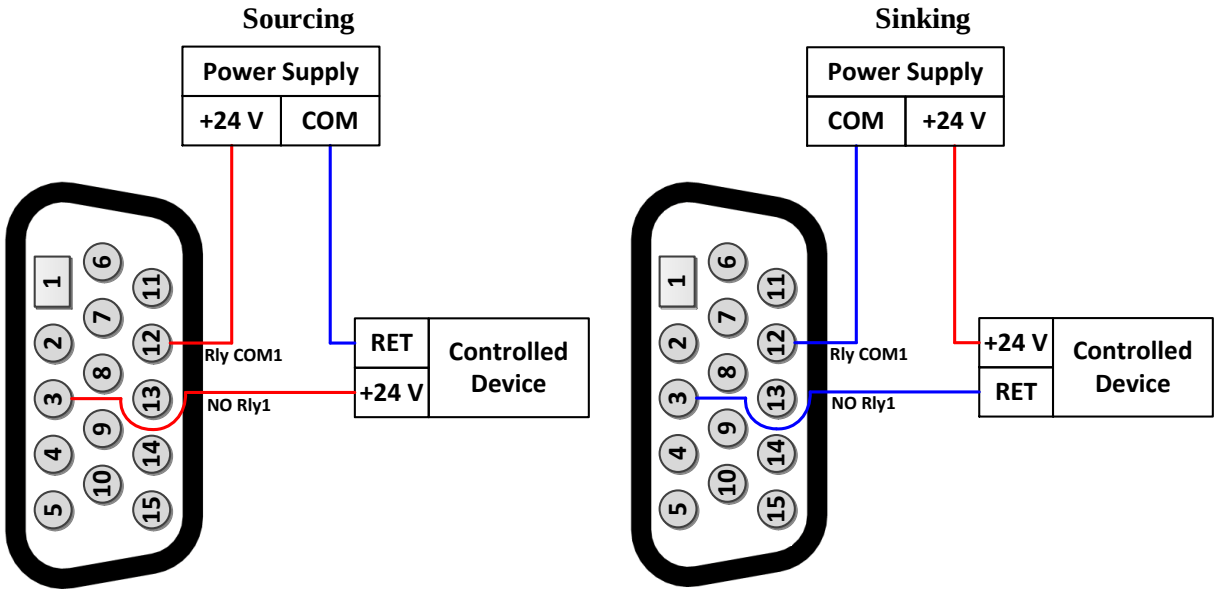
This normally open general purpose relay is operated by the structure element bit **PowerBrick[].Chan[].OutFlagC.**

Channel / Connector	Structure element bit	Channel / Connector	Structure element bit
Relay 1, X9	PowerBrick[0].Chan[0].OutFlagC	Relay 1, X9	PowerBrick[1].Chan[0].OutFlagC
Relay 2, X9	PowerBrick[0].Chan[1].OutFlagC	Relay 2, X9	PowerBrick[1].Chan[1].OutFlagC
Relay 1, X10	PowerBrick[0].Chan[2].OutFlagC	Relay 1, X10	PowerBrick[1].Chan[2].OutFlagC
Relay 2, X10	PowerBrick[0].Chan[3].OutFlagC	Relay 2, X10	PowerBrick[1].Chan[3].OutFlagC

If **PowerBrick[].Chan[].OutFlagC** = 0, the circuit between the common pin and the Relay pin is open.
If **PowerBrick[].Chan[].OutFlagC** = 1, the circuit between the common pin and the Relay pin is closed.

Structure Element Bit	Connection between Pin #3 and Pin #12	Connection between Pin #10 and Pin #5
PowerBrick[].Chan[].OutFlagC = 0	Open	Open
PowerBrick[].Chan[].OutFlagC = 1	Closed	Closed

The relay can be wired so that the current is either sourcing from or sinking into the Power Brick AC.



Caution

In sourcing mode, do NOT pass through voltage higher than 24 VDC.



Note

The commons of the general purpose inputs / amp faults (pins #8, and #15) are tied internally to relay commons 1 and 2 respectively. If the relay is wired in sourcing mode, that general purpose input cannot be used.

The structure element bits can be assigned to user defined pointers:

```
PTR GPRelay1X9->PowerBrick[0].Chan[0].OutFlagC;     // GP Relay 1, X9
PTR GPRelay2X9->PowerBrick[0].Chan[1].OutFlagC;     // GP Relay 2, X9
PTR GPRelay1X10->PowerBrick[0].Chan[2].OutFlagC;    // GP Relay 1, X10
PTR GPRelay2X10->PowerBrick[0].Chan[3].OutFlagC;    // GP Relay 2, X10

PTR GPRelay1X11->PowerBrick[1].Chan[0].OutFlagC;    // GP Relay 1, X11
PTR GPRelay2X11->PowerBrick[1].Chan[1].OutFlagC;    // GP Relay 2, X11
PTR GPRelay1X12->PowerBrick[1].Chan[2].OutFlagC;    // GP Relay 1, X12
PTR GPRelay2X12->PowerBrick[1].Chan[3].OutFlagC;    // GP Relay 2, X12
```

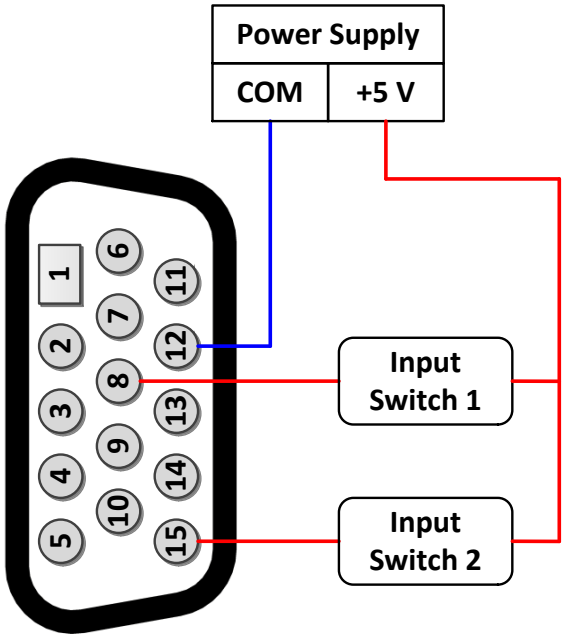
Setting up the GP Input

This input provides a general purpose input coming from an external device (e.g. amplifier fault). It is a single-ended 5 V TTL level input.



Note

The commons of the general purpose inputs / amp faults (pins #8 and #15) are tied internally to relay commons 1 and 2 respectively (pins #5 and #12). If the relay is wired in sourcing mode, creating voltage potential at the common, this GP input cannot be used.



The structure element bit reflecting the status of this input is **PowerBrick[].Chan[].T**. It is a low true input, meaning it is =1 when 0 V is connected and =0 when +5 V is connected.

```
PTR GpIn1X9->PowerBrick[0].Chan[0].T;   // Channel 1, X9 Input
PTR GpIn2X9->PowerBrick[0].Chan[1].T;   // Channel 2, X9 Input
PTR GpIn1X10->PowerBrick[0].Chan[2].T;  // Channel 1, X10 Input
PTR GpIn2X10->PowerBrick[0].Chan[3].T;  // Channel 2, X10 Input

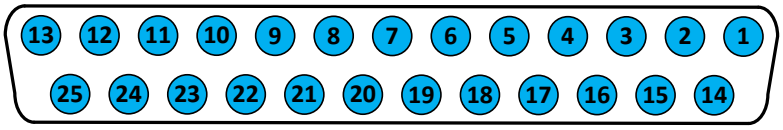
PTR GpIn1X11->PowerBrick[1].Chan[0].T;  // Channel 1, X11 Input
PTR GpIn2X11->PowerBrick[1].Chan[1].T;  // Channel 2, X11 Input
PTR GpIn1X12->PowerBrick[1].Chan[2].T;  // Channel 1, X12 Input
PTR GpIn2X12->PowerBrick[1].Chan[3].T;  // Channel 2, X12 Input
```

X13: Axis 1 – 4 Limits, Flags, EQU

X13 is used to wire the limits, flags, and EQU for axes 1 – 4. Per channel, there are 2 limit inputs (Plus and Minus), 2 flag inputs (Home and User), and 1 EQU output.

The limits and flags are auto-regulating in the 5 – 24 VDC range. The current draw for each input is about 6 – 10 mA in the 5 – 24 VDC range.

The EQU output is 5 VDC TTL level and its rise time is on the order of nanoseconds.

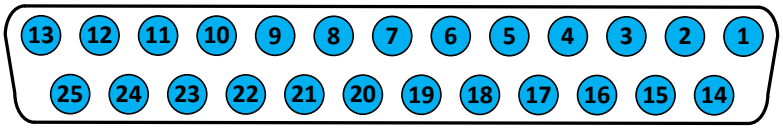
X13: D-sub DB-25F **Mating: D-sub DB-25M**			
Pin #	**Symbol**	**Function**	**Description**
1	USER1	Input	User Flag 1
2	MLIM1	Input	Negative Limit 1
3	FL_RT1	Input	Flag Return 1
4	USER2	Input	User Flag 2
5	MLIM2	Input	Negative Limit 2
6	FL_RT2	Input	Flag Return 2
7	USER3	Input	User Flag 3
8	MLIM3	Input	Negative Limit 3
9	FL_RT3	Input	Flag Return 3
10	USER4	Input	User Flag 4
11	MLIM4	Input	Negative Limit 4
12	FL_RT4	Input	Flag Return 4
13	GND	Common	
14	PLIM1	Input	Positive Limit 1
15	HOME1	Input	Home Flag 1
16	EQU1	Output	Compare Output, EQU 1 TTL (5V) level
17	PLIM2	Input	Positive Limit 2
18	HOME2	Input	Home Flag 2
19	EQU2	Output	Compare Output, EQU 2 TTL (5V) level
20	PLIM3	Input	Positive Limit 3
21	HOME3	Input	Home Flag 3
22	EQU3	Output	Compare Output, EQU 3 TTL (5V) level
23	PLIM4	Input	Positive Limit 4
24	HOME4	Input	Home Flag 4
25	EQU4	Output	Compare Output, EQU 4 TTL (5V) level

X14: Axis 5 – 8 Limits, Flags, EQU

X14 is used to wire the limits, flags, and EQU for axes 5 – 8. Per channel, there are 2 limit inputs (Plus and Minus), 2 flag inputs (Home and User), and 1 EQU output.

The limits and flags are auto-regulating in the 5 – 24 VDC range. The current draw for each input is about 6 – 10 mA in the 5 – 24 VDC range.

The EQU output is 5 VDC TTL level and its rise time is on the order of nanoseconds.

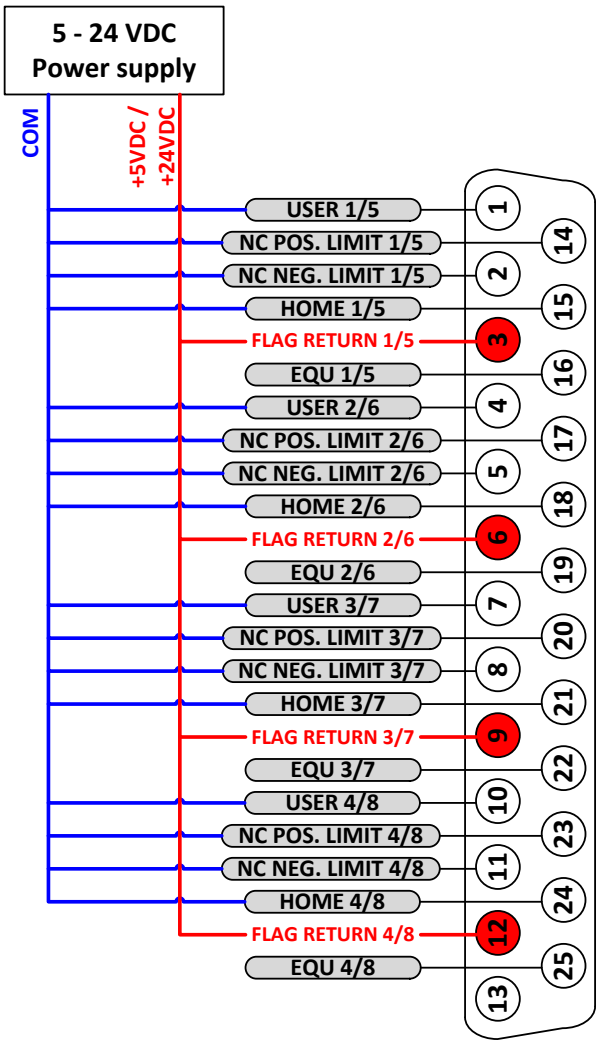
X14: D-sub DB-25F **Mating: D-sub DB-25M**			
Pin #	**Symbol**	**Function**	**Description**
1	USER5	Input	User Flag 5
2	MLIM5	Input	Negative Limit 5
3	FL_RT5	Input	Flag Return 5
4	USER6	Input	User Flag 6
5	MLIM6	Input	Negative Limit 6
6	FL_RT6	Input	Flag Return 6
7	USER7	Input	User Flag 7
8	MLIM7	Input	Negative Limit 7
9	FL_RT7	Input	Flag Return 7
10	USER8	Input	User Flag 8
11	MLIM8	Input	Negative Limit 8
12	FL_RT8	Input	Flag Return 8
13	GND	Common	
14	PLIM5	Input	Positive Limit 5
15	HOME5	Input	Home Flag 5
16	BEQU5	Output	Compare Output EQU 5, TTL (5V) level
17	PLIM6	Input	Positive Limit 6
18	HOME6	Input	Home Flag 6
19	BEQU6	Output	Compare Output EQU 6, TTL (5V) level
20	PLIM7	Input	Positive Limit 7
21	HOME7	Input	Home Flag 7
22	BEQU7	Output	Compare Output EQU 7, TTL (5V) level
23	PLIM8	Input	Positive Limit 8
24	HOME8	Input	Home Flag 8
25	BEQU8	Output	Compare Output EQU 8, TTL (5V) level

Wiring the Limits and Flags

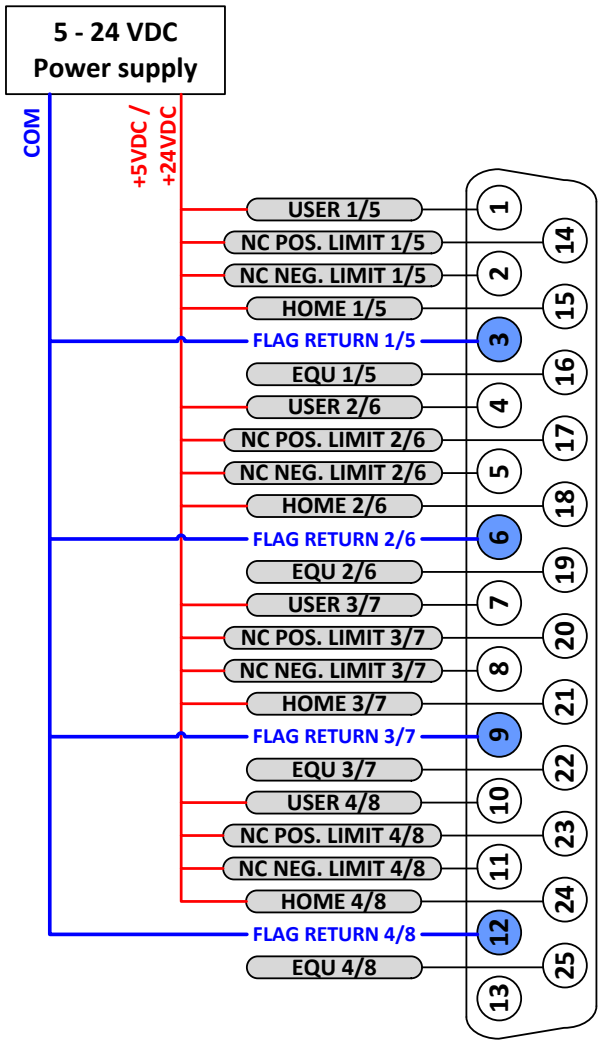
The Power Brick allows the use of sinking or sourcing limits and flags (per channel). The current flow can be from return to flag (sinking into the Brick) or from flag to return (sourcing from the Brick).

The overtravel limits must be normally closed switches. They can be disabled in software by setting **Motor[].pLimits** = 0 but their polarity is not software configurable.

Sourcing Limits And Flags



Sinking Limits And Flags





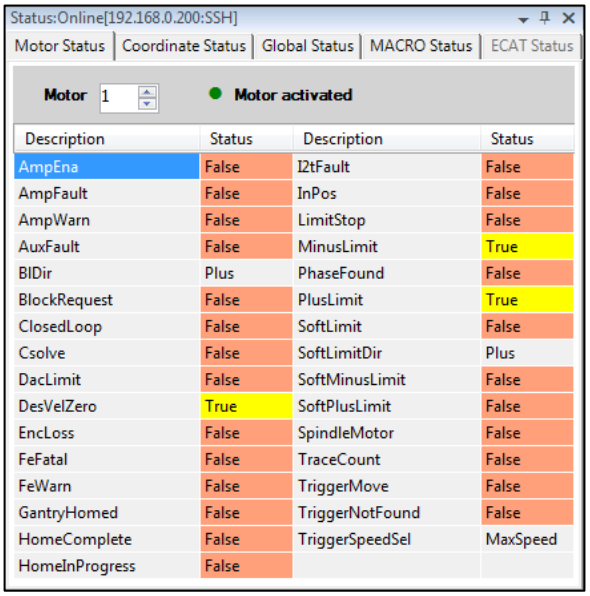
Note

The overtravel limits must be normally closed switches. They can be disabled in software, but their polarity is not configurable.

Limits and Flags Suggested Pointers

Typically, and if the corresponding channel is activated (**Motor[].ServoCtrl** = 1), the overtravel limits are monitored in the motor status window in the IDE software and the motor structure elements (i.e. **Motor[].PlusLimit**) are used in logic programming. However, if the channel is not activated, the overtravel limit inputs can be accessed through the ASIC structure elements shown below.

The User / Home flags, and EQU output are a function of the ASIC; they can always be accessed through the ASIC structure elements.



Description	Status	Description	Status
AmpEna	False	I2tFault	False
AmpFault	False	InPos	False
AmpWarn	False	LimitStop	False
AuxFault	False	MinusLimit	True
BlDir	Plus	PhaseFound	False
BlockRequest	False	PlusLimit	True
ClosedLoop	False	SoftLimit	False
Csolve	False	SoftLimitDir	Plus
DacLimit	False	SoftMinusLimit	False
DesVelZero	True	SoftPlusLimit	False
EncLoss	False	SpindleMotor	False
FeFatal	False	TraceCount	False
FeWarn	False	TriggerMove	False
GantryHomed	False	TriggerNotFound	False
HomeComplete	False	TriggerSpeedSel	MaxSpeed
HomeInProgress	False		

Channels 1 – 4 Limits and Flags Suggested Pointers (X13)

```
PTR Ch1PlusLimit->PowerBrick[0].Chan[0].PlusLimit;      // Channel 1 Positive Limit
PTR Ch1MinusLimit->PowerBrick[0].Chan[0].MinusLimit;    // Channel 1 Negative Limit
PTR Ch1UserFlag->PowerBrick[0].Chan[0].UserFlag;        // Channel 1 User Flag
PTR Ch1HomeFlag->PowerBrick[0].Chan[0].HomeFlag;        // Channel 1 Home Flag
PTR Ch1EQU->PowerBrick[0].Chan[0].Equ;                  // Channel 1 EQU

PTR Ch2PlusLimit->PowerBrick[0].Chan[1].PlusLimit;      // Channel 2 Positive Limit
PTR Ch2MinusLimit->PowerBrick[0].Chan[1].MinusLimit;    // Channel 2 Negative Limit
PTR Ch2UserFlag->PowerBrick[0].Chan[1].UserFlag;        // Channel 2 User Flag
PTR Ch2HomeFlag->PowerBrick[0].Chan[1].HomeFlag;        // Channel 2 Home Flag
PTR Ch2EQU->PowerBrick[0].Chan[1].Equ;                  // Channel 2 EQU

PTR Ch3PlusLimit->PowerBrick[0].Chan[2].PlusLimit;      // Channel 3 Positive Limit
PTR Ch3MinusLimit->PowerBrick[0].Chan[2].MinusLimit;    // Channel 3 Negative Limit
PTR Ch3UserFlag->PowerBrick[0].Chan[2].UserFlag;        // Channel 3 User Flag
PTR Ch3HomeFlag->PowerBrick[0].Chan[2].HomeFlag;        // Channel 3 Home Flag
PTR Ch3EQU->PowerBrick[0].Chan[2].Equ;                  // Channel 3 EQU

PTR Ch4PlusLimit->PowerBrick[0].Chan[3].PlusLimit;      // Channel 4 Positive Limit
PTR Ch4MinusLimit->PowerBrick[0].Chan[3].MinusLimit;    // Channel 4 Negative Limit
PTR Ch4UserFlag->PowerBrick[0].Chan[3].UserFlag;        // Channel 4 User Flag
PTR Ch4HomeFlag->PowerBrick[0].Chan[3].HomeFlag;        // Channel 4 Home Flag
PTR Ch4EQU->PowerBrick[0].Chan[3].Equ;                  // Channel 4 EQU
```

Channels 5 – 8 Limits and Flags Suggested Pointers (X14)

```
PTR Ch5PlusLimit->PowerBrick[1].Chan[0].PlusLimit;      // Channel 5 Positive Limit
PTR Ch5MinusLimit->PowerBrick[1].Chan[0].MinusLimit;    // Channel 5 Negative Limit
PTR Ch5UserFlag->PowerBrick[1].Chan[0].UserFlag;        // Channel 5 User Flag
PTR Ch5HomeFlag->PowerBrick[1].Chan[0].HomeFlag;        // Channel 5 Home Flag
PTR Ch5EQU->PowerBrick[1].Chan[0].Equ;                  // Channel 5 EQU

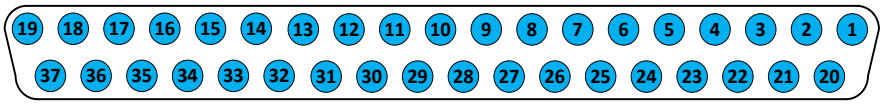
PTR Ch6PlusLimit->PowerBrick[1].Chan[1].PlusLimit;      // Channel 6 Positive Limit
PTR Ch6MinusLimit->PowerBrick[1].Chan[1].MinusLimit;    // Channel 6 Negative Limit
PTR Ch6UserFlag->PowerBrick[1].Chan[1].UserFlag;        // Channel 6 User Flag
PTR Ch6HomeFlag->PowerBrick[1].Chan[1].HomeFlag;        // Channel 6 Home Flag
PTR Ch6EQU->PowerBrick[1].Chan[1].Equ;                  // Channel 6 EQU

PTR Ch7PlusLimit->PowerBrick[1].Chan[2].PlusLimit;      // Channel 7 Positive Limit
PTR Ch7MinusLimit->PowerBrick[1].Chan[2].MinusLimit;    // Channel 7 Negative Limit
PTR Ch7UserFlag->PowerBrick[1].Chan[2].UserFlag;        // Channel 7 User Flag
PTR Ch7HomeFlag->PowerBrick[1].Chan[2].HomeFlag;        // Channel 7 Home Flag
PTR Ch7EQU->PowerBrick[1].Chan[2].Equ;                  // Channel 7 EQU

PTR Ch8PlusLimit->PowerBrick[1].Chan[3].PlusLimit;      // Channel 8 Positive Limit
PTR Ch8MinusLimit->PowerBrick[1].Chan[3].MinusLimit;    // Channel 8 Negative Limit
PTR Ch8UserFlag->PowerBrick[1].Chan[3].UserFlag;        // Channel 8 User Flag
PTR Ch8HomeFlag->PowerBrick[1].Chan[3].HomeFlag;        // Channel 8 Home Flag
PTR Ch8EQU->PowerBrick[1].Chan[3].Equ;                  // Channel 8 EQU
```

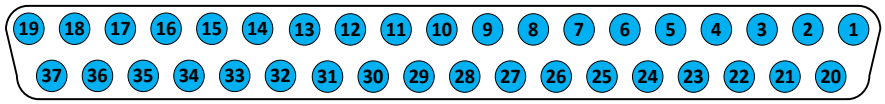
X15: Digital Inputs / Outputs

X15 is used to wire the general purpose digital I/Os (16 inputs and 8 outputs).

X15: D-sub DC-37F Mating: D-sub DC-37M			
Pin #	**Symbol**	**Function**	**Description**
1	GPI1	Input	Input 1
2	GPI3	Input	Input 3
3	GPI5	Input	Input 5
4	GPI7	Input	Input 7
5	GPI9	Input	Input 9
6	GPI11	Input	Input 11
7	GPI13	Input	Input 13
8	GPI15	Input	Input 15
9	IN_COM1-8	Common 01-08	Input 01 to 08 Common
10	OUT_RET	Return	Outputs Return
11	COM_EMT	Common	Outputs Common
12	GP01-	Output	Sourcing Output 1
13	GP02-	Output	Sourcing Output 2
14	GP03-	Output	Sourcing Output 3
15	GP04-	Output	Sourcing Output 4
16	GP05-	Output	Sourcing Output 5
17	GP06-	Output	Sourcing Output 6
18	GP07-	Output	Sourcing Output 7
19	GP08-	Output	Sourcing Output 8
20	GPI2	Input	Input 2
21	GPI4	Input	Input 4
22	GPI6	Input	Input 6
23	GPI8	Input	Input 8
24	GPI10	Input	Input 10
25	GPI12	Input	Input 12
26	GPI14	Input	Input 14
27	GPI16	Input	Input 16
28	IN_COM9-16	Common 09-16	Input 09 to 16 Common
29	COM_COL	Common	Outputs Common
30	GP01+	Output	Sinking Output 1
31	GP02+	Output	Sinking Output 2
32	GP03+	Output	Sinking Output 3
33	GP04+	Output	Sinking Output 4
34	GP05+	Output	Sinking Output 5
35	GP06+	Output	Sinking Output 6
36	GP07+	Output	Sinking Output 7
37	GP08+	Output	Sinking Output 8

X16: Digital Inputs / Outputs (Additional)

X16 is used to wire the additional general purpose digital I/Os (16 inputs, and 8 outputs).

X16: D-sub DC-37F **Mating: D-sub DC-37M**			
Pin #	**Symbol**	**Function**	**Description**
1	GPI17	Input	Input 17
2	GPI19	Input	Input 19
3	GPI21	Input	Input 21
4	GPI23	Input	Input 23
5	GPI25	Input	Input 25
6	GPI27	Input	Input 27
7	GPI29	Input	Input 29
8	GPI31	Input	Input 31
9	IN_COM 17-24	Common 17 – 24	Input 17 to 24 Common
10	OUT_RET	Return	Outputs Return
11	COM_EMT	Common	Outputs Common
12	GPO9-	Output	Sourcing Output 9
13	GPO10-	Output	Sourcing Output 10
14	GPO11-	Output	Sourcing Output 11
15	GPO12-	Output	Sourcing Output 12
16	GPO13-	Output	Sourcing Output 13
17	GPO14-	Output	Sourcing Output 14
18	GPO15-	Output	Sourcing Output 15
19	GPO16-	Output	Sourcing Output 16
20	GPI18	Input	Input 18
21	GPI20	Input	Input 20
22	GPI22	Input	Input 22
23	GPI24	Input	Input 24
24	GPI26	Input	Input 26
25	GPI28	Input	Input 28
26	GPI30	Input	Input 30
27	GPI32	Input	Input 32
28	IN_COM_25-32	Common 25 – 32	Input 25 to 32 Common
29	COM_COL	Common	Outputs Common
30	GPO9+	Output	Sinking Output 9
31	GPO10+	Output	Sinking Output 10
32	GPO11+	Output	Sinking Output 11
33	GPO12+	Output	Sinking Output 12
34	GPO13+	Output	Sinking Output 13
35	GPO14+	Output	Sinking Output 14
36	GPO15+	Output	Sinking Output 15
37	GPO16+	Output	Sinking Output 16

About the Digital Inputs and Outputs

All general purpose inputs and outputs are optically isolated. They operate in the 12 – 24 VDC range, and can be wired to be either sinking into or sourcing out of the Power Brick.



Caution

The maximum current capacity per pin is about 500 mA. The total current capacity for the entire block of I/O depends on the current capacity of the power supply used to power them.

Inputs

The inputs use the **PS2705-1NEC** photocoupler.

For sourcing inputs, connect the common lines to 12 – 24 VDC of an external power supply. The input devices are then connected to the 0 VDC of the power supply at one end, and to the Power Brick at the other.

For sinking inputs, connect the common lines to 0 VDC of an external power supply. The input devices are then connected to 12 – 24 VDC of an external power supply at one end, and to the Power Brick at the other.



Note

The inputs can be wired either sourcing or sinking in sets of eight; each set possesses its own common.

Outputs

The outputs use the **PS2701-1NEC** photocoupler. They are protected with a **ZXMS6006DG**; an enhancement mode MOSFET - diode incorporated. The protection involves over-voltage, over-current, I2T and short circuit.

For sourcing outputs, connect the common lines to 12 – 24 VDC of an external power supply. The output devices are then connected to 0 VDC of the power supply at one end, and to the Power Brick at the other.

For sinking outputs, connect the common lines to 0 VDC of an external power supply. The output devices are then connected to the 12 – 24 VDC of the power supply at one end, and to the Power Brick at the other.

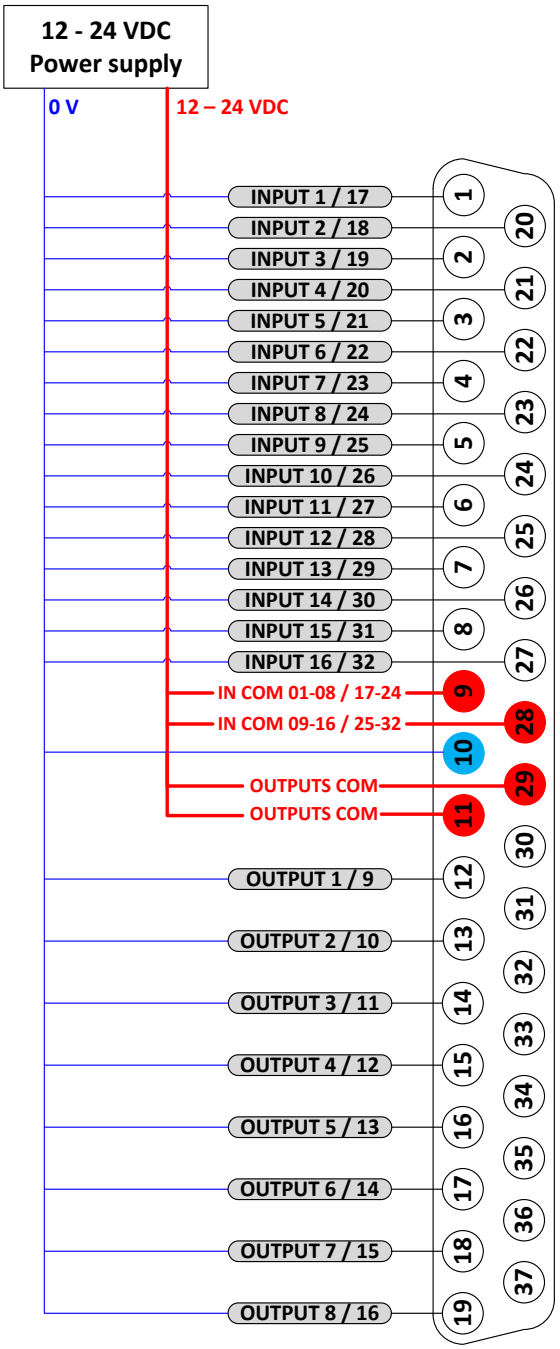


Note

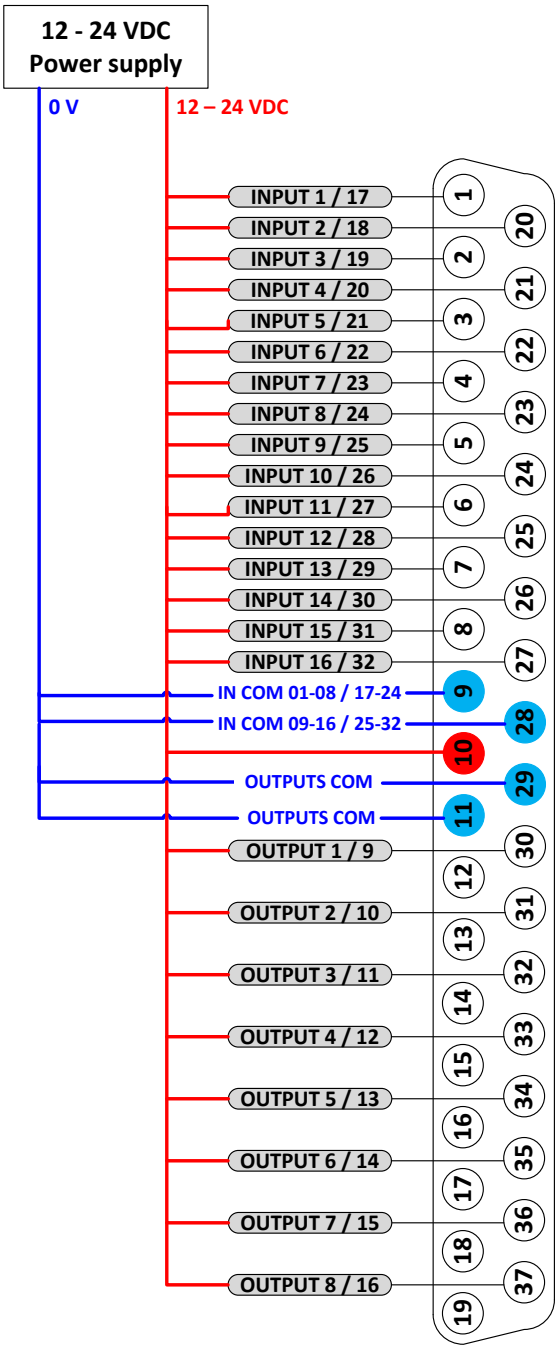
Do not mix topologies for outputs. They are all either sinking or sourcing per connector (X16 / X17).

Wiring the Digital Inputs and Outputs

Sourcing Inputs / Outputs



Sinking Inputs / Outputs



X15 Digital I/O Pointers

```
// X15 INPUTS
PTR Input1->PowerBrick[0].GpioData[0].0.1;       // Input #1, X15 Pin#1
PTR Input2->PowerBrick[0].GpioData[0].1.1;       // Input #2, X15 Pin#20
PTR Input3->PowerBrick[0].GpioData[0].2.1;       // Input #3, X15 Pin#2
PTR Input4->PowerBrick[0].GpioData[0].3.1;       // Input #4, X15 Pin#21
PTR Input5->PowerBrick[0].GpioData[0].4.1;       // Input #5, X15 Pin#3
PTR Input6->PowerBrick[0].GpioData[0].5.1;       // Input #6, X15 Pin#22
PTR Input7->PowerBrick[0].GpioData[0].6.1;       // Input #7, X15 Pin#4
PTR Input8->PowerBrick[0].GpioData[0].7.1;       // Input #8, X15 Pin#23
PTR Input9->PowerBrick[0].GpioData[0].8.1;       // Input #9, X15 Pin#5
PTR Input10->PowerBrick[0].GpioData[0].9.1;      // Input #10,X15 Pin#24
PTR Input11->PowerBrick[0].GpioData[0].10.1;     // Input #11,X15 Pin#6
PTR Input12->PowerBrick[0].GpioData[0].11.1;     // Input #12,X15 Pin#25
PTR Input13->PowerBrick[0].GpioData[0].12.1;     // Input #13,X15 Pin#7
PTR Input14->PowerBrick[0].GpioData[0].13.1;     // Input #14,X15 Pin#26
PTR Input15->PowerBrick[0].GpioData[0].14.1;     // Input #15,X15 Pin#8
PTR Input16->PowerBrick[0].GpioData[0].15.1;     // Input #16,X15 Pin#27

// X15 OUTPUTS                                                  Sourcing   Sinking
PTR Output1->PowerBrick[0].GpioData[0].16.1;     // Output #1,X15  Pin#12     Pin#30
PTR Output2->PowerBrick[0].GpioData[0].17.1;     // Output #2,X15  Pin#13     Pin#31
PTR Output3->PowerBrick[0].GpioData[0].18.1;     // Output #3,X15  Pin#14     Pin#32
PTR Output4->PowerBrick[0].GpioData[0].19.1;     // Output #4,X15  Pin#15     Pin#33
PTR Output5->PowerBrick[0].GpioData[0].20.1;     // Output #5,X15  Pin#16     Pin#34
PTR Output6->PowerBrick[0].GpioData[0].21.1;     // Output #6,X15  Pin#17     Pin#35
PTR Output7->PowerBrick[0].GpioData[0].22.1;     // Output #7,X15  Pin#18     Pin#36
PTR Output8->PowerBrick[0].GpioData[0].23.1;     // Output #8,X15  Pin#19     Pin#37
```

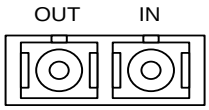
X16 Digital I/O Pointers

```
// X16 INPUTS
PTR Input17->PowerBrick[1].GpioData[0].0.1;      // Input #17,X16 Pin#1
PTR Input18->PowerBrick[1].GpioData[0].1.1;      // Input #18,X16 Pin#20
PTR Input19->PowerBrick[1].GpioData[0].2.1;      // Input #19,X16 Pin#2
PTR Input20->PowerBrick[1].GpioData[0].3.1;      // Input #20,X16 Pin#21
PTR Input21->PowerBrick[1].GpioData[0].4.1;      // Input #21,X16 Pin#3
PTR Input22->PowerBrick[1].GpioData[0].5.1;      // Input #22,X16 Pin#22
PTR Input23->PowerBrick[1].GpioData[0].6.1;      // Input #23,X16 Pin#4
PTR Input24->PowerBrick[1].GpioData[0].7.1;      // Input #24,X16 Pin#23
PTR Input25->PowerBrick[1].GpioData[0].8.1;      // Input #25,X16 Pin#5
PTR Input26->PowerBrick[1].GpioData[0].9.1;      // Input #26,X16 Pin#24
PTR Input27->PowerBrick[1].GpioData[0].10.1;     // Input #27,X16 Pin#6
PTR Input28->PowerBrick[1].GpioData[0].11.1;     // Input #28,X16 Pin#25
PTR Input29->PowerBrick[1].GpioData[0].12.1;     // Input #29,X16 Pin#7
PTR Input30->PowerBrick[1].GpioData[0].13.1;     // Input #30,X16 Pin#26
PTR Input31->PowerBrick[1].GpioData[0].14.1;     // Input #31,X16 Pin#8
PTR Input32->PowerBrick[1].GpioData[0].15.1;     // Input #32,X16 Pin#27

// X16 OUTPUTS                                                  Sourcing   Sinking
PTR Output9->PowerBrick[1].GpioData[0].16.1;     // Output #9, X16  Pin#12     Pin#30
PTR Output10->PowerBrick[1].GpioData[0].17.1;    // Output #10,X16  Pin#13     Pin#31
PTR Output11->PowerBrick[1].GpioData[0].18.1;    // Output #11,X16  Pin#14     Pin#32
PTR Output12->PowerBrick[1].GpioData[0].19.1;    // Output #12,X16  Pin#15     Pin#33
PTR Output13->PowerBrick[1].GpioData[0].20.1;    // Output #13,X16  Pin#16     Pin#34
PTR Output14->PowerBrick[1].GpioData[0].21.1;    // Output #14,X16  Pin#17     Pin#35
PTR Output15->PowerBrick[1].GpioData[0].22.1;    // Output #15,X16  Pin#18     Pin#36
PTR Output16->PowerBrick[1].GpioData[0].23.1;    // Output #16,X16  Pin#19     Pin#37
```

X17: MACRO

If a MACRO option was selected, the Power Brick AC provides the following connector for MACRO communications:

MACRO SC-Style Fiber Connector		
Pin #	**Symbol**	**Function**
1	IN	MACRO Ring Receiver
2	OUT	MACRO Ring Transmitter



Note

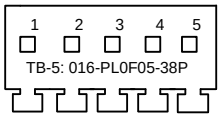
The fiber optic version of MACRO uses 62.5/125 multi-mode glass fiber optic cable terminated in an SC-style connector. The optical wavelength is 1,300 nm.

The input connector must be inserted into the MACRO output connector of the previous device on the MACRO ring. The output connector must be inserted into the input MACRO connector of the next device on the MACRO ring.

X18: Global Abort and Watchdog

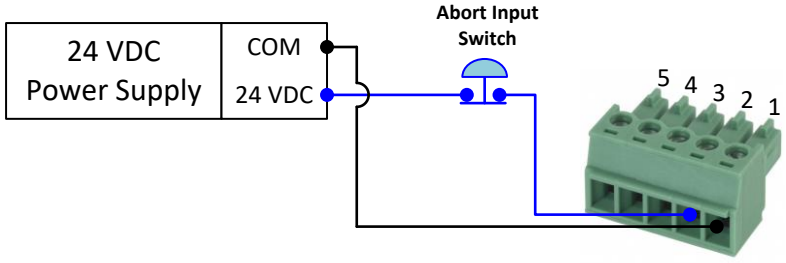
X18 has two essential functions:

- Global abort input.
- Watchdog output.

X15: Phoenix 5-pin TB Female **Mating: Phoenix 5-pin TB Male**			
Pin #	**Symbol**	**Function**	**Notes**
1	ABORT-	Input	ABORT Return
2	ABORT+	Input	ABORT Input 24VDC
3	WD N.O.	Output	Watchdog (normally open contact)
4	WD N.C.	Output	Watchdog (normally closed contact)
5	WD COM	Common	Watchdog common
Phoenix Contact Mating Connector Part #1850699			

Abort Input

The 24 VDC abort input provides a "category 2" controlled safe stop under the IEC-61800-5-2 machine safety standard, suitable for applications such as aborting motion for opening machine door, or replacing tool(s). If an Abort input button is used, it must be a normally closed switch:



If a "Category 1" safe stop under this standard – a controlled stop followed by a software-free disabling – is desired, the same action that toggles this input should also start a qualified time-delay relay which will then drop out power from a key circuit; usually either bus power (E-Stop circuit) or gate-driver power (STO).



Note

This "global abort" function is not suitable by itself in cases where power must be removed from the motor (such as Category 0 or 1 under the IEC-61800-5-2 machine safety standard) is required.

Global Abort Key Settings

The global abort input is enabled / disabled in software through **Sys.pAbortAll**.

Sys.pAbortAll	= **PowerBrick[0].GpioData[0].a**	Global abort input enabled
	= 0	Global abort input disabled

```
Sys.pAbortAll = PowerBrick[0].GpioData[0].a          // =0 global abort disabled
Sys.AbortAllBit = 31                                 // Default, do not change
Sys.AbortAllCount = 5                                // Up/down error count
Sys.AbortAllLimit = 5                                // Scan count limit threshold
```

The status of the global abort input can be monitored in the global status window in the IDE software, also it can be queried using the system element **Sys.AbortAll** (=0 deactivated or armed, =1 triggered).
The structure element **Coord[].AbortAllMode** specifies how a group of motors in a coordinate system behaves in the event of an abort trigger:

	Global Abort Trigger Action	**Equivalent Software Command**
= 0	All motors in the coordinate system are brought to a closed-loop controlled stop.	**Abort**
= 1	All motors in the coordinate system are immediately disabled (killed) without delay for brake engagement.	**Disable**
= 2	All motors in the coordinate system are first brought to a closed-loop controlled stop then as each motor reaches a desired velocity of zero, it executes a "delayed kill", with an immediate engagement of the brake (specified by **Motor[].pBrakeOut**) followed by a disabling of the motor after the interval specified by **Motor[].BrakeOnDelay**.	**Abort** Followed by **dKill**
= 3	The coordinate system is not affected by the global abort input.	-



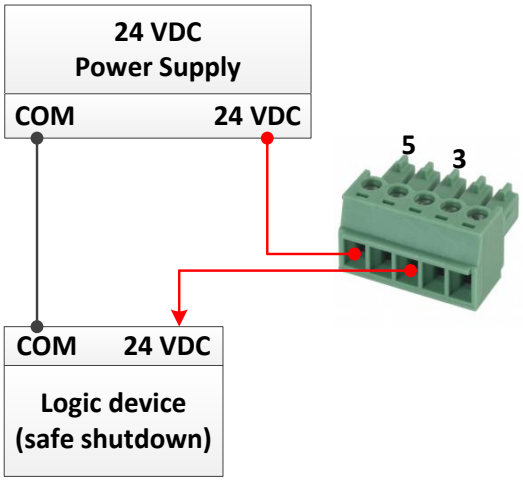
Note

By default, all motors are assigned to coordinate system 0.

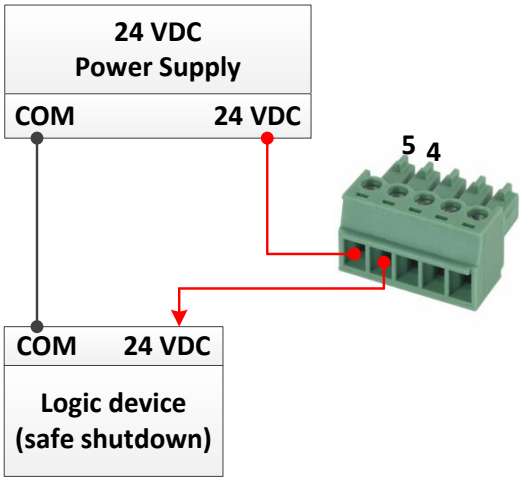
Watchdog Relay

The Watchdog relay(s) allows the user to connect to safety circuit in order to bring the machine to a stop in a safe manner in the occurrence of a watchdog. Normally open or closed contacts are available:

Normally Open



Normally Closed



The watchdog relay(s) are triggered when:

- A hard watchdog occurs, interrupting communication and killing all tasks.
- A soft watchdog occurs, killing all tasks (**Sys.WDTFault** = 1 or 2). Communication remains alive in this case.

Operation	Mode	Connection between pins #5 and #3	Connection between pins #5 and #4
Watchdog	Not Triggered	Closed	Open
	Triggered	Open	Closed

X19: External Encoder Supply

Typically, feedback devices power is supplied through the X1 – X8 connectors using the internal +5VDC power supply. However, if the total feedback devices power budget exceeds ~ 2 amperes, this connector can be used to bring in the power supply from an external source.

Caution

Encoders requiring voltage supply levels other than +5 VDC must be supplied externally, neither through X1 – X8 nor through X19.

Caution

The maximum current draw out of a single encoder channel must not exceed 500 mA.

Wiring the Encoder Supply

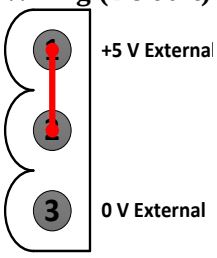
Pin#	Symbol	Description	Note
1	5 VDC External	+5 VDC Input when using external supply	
2	–	+5 VDC Output	Tie to pin #1 to use internal power supply
3	GND	0V Input when using external supply	
Mating Connector Phoenix Contact P/N: 1778845			

Caution

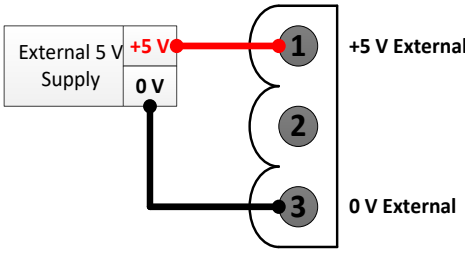
Only two of the three available pins should be used at one time. Do not daisy-chain the internal 5 V power supply with an external one.

By default, pins 1 – 2 are tied together to use the internal power supply. To wire an external power supply, remove the jumper tying pins 1 – 2 and connect the external +5 VDC to pin #1, and 0 VDC to pin #3:

Internal Power Supply Wiring (Default)



External Power Supply Wiring





Note

A jumper tying pins 1 and 2 is the default configuration. This is the configuration in which the Power Brick AC is shipped.



Note

The controller's (PMACs) 5 VDC logic is independent of this scheme, so if no encoder power is provided, the PMAC will remain powered-up (provided the standard 24 V is brought in).

Functionality, Safety Considerations

There are a couple of safety and functionality measures to take into account when an external encoder power supply is utilized:

- Power sequence: encoders versus controller/drive
  It is highly recommended to power up the encoders before applying power to the Power Brick AC

- Encoder Power Loss (i.e. power supply failure, loose wire/connector)

The Power Brick AC, with certain feedback devices, can be set up to read absolute position or perform phasing on power-up (either automatic firmware functions, or user-written PLCs). If the encoder power is not available, these functions will not be performed properly. Trying to close the loop on a motor without encoder feedback could be dangerous.



Caution

Make sure that the encoders are powered-up before executing any motor/motion commands.

Losing encoder power can lead to dangerous runaway conditions; setting up encoder loss protection, fatal following error limits, and I2T protection are highly advised.



Caution

Make sure that the encoder loss protection is active, fatal following error limit is set tightly, and I2T is configured.

With commutated motors (i.e. DC brushless), a loss of encoder generally breaks the commutation cycle causing a fatal following error or I2T fault either in PMAC or amplifier side. However, with non-commutated motors (i.e. DC brush), losing encoder signal can more likely cause dangerous runway conditions.

X20 – X23: RTETH & Fieldbus

Refer to the ACC-72EX Manual for this connector's pinout and functionality.

ETH 0/1: Ethernet Connections

The Power Brick AC comes with two Ethernet ports on the front panel: ETH 0 and ETH 1. Both ports can accept standard CAT-5 Ethernet cables with RJ-45 connectors. Both Ethernet ports provide transformer isolation to prevent ground-loop problems.

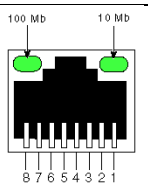
ETH 0 Ethernet Port

The ETH 0 port is the bottom Ethernet connector on the front panel. It is the primary port for communicating with the CPU board from a host computer, as when using the Integrated Development Environment (IDE) program running on a Windows™ PC for developing your application.



Note

Multiple computers on a single network can independently communicate to the Power PMAC board through this single hardware port.

ETH 0/1: 8-Pin RJ45 Receptacle			
Pin #	**Symbol**	**Function**	**Description**
1	P0MDI0+	BIDIR	LINE 0 POS
2	P0MDI0-	BIDIR	LINE 0 NEG
3	P0MDI1+	BIDIR	LINE 1 POS
4	P0MDI1-	BIDIR	LINE 1 NEG
5	P0MDI2+	BIDIR	LINE 2 POS
6	P0MDI2-	BIDIR	LINE 2 NEG
7	P0MDI3+	BIDIR	LINE 3 POS
8	P0MDI3-	BIDIR	LINE 3 NEG

This connector is used for Ethernet communications from the UMAC to a PC. The appropriate Category 5 100/1000-Base T network cable that mates to this connector can be purchased from any local computer store. The type of network cable to purchase depends on the configuration to the host PC.

ETH 1 Ethernet Port

The ETH 1 port is the second-to-bottom-connector on the front panel. It is the auxiliary Ethernet port and not intended for primary host communications, but can be used to communicate to peripheral devices. Its pinout is the same as the ETH 0 port.

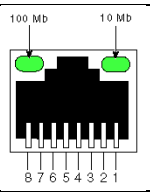
ETH 2/3: EtherCAT Connections

The user can order one to two EtherCAT Master Ports, ETH 2 and ETH 3, with the Power Brick AC. Both ports can accept standard CAT-5 Ethernet cables with RJ-45 connectors. Both EtherCAT ports provide transformer isolation to prevent ground-loop problems. Each port can control its own EtherCAT ring, allowing Power PMAC to be the master to two separate rings simultaneously.



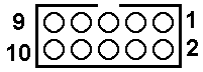
Note

Two EtherCAT rings can be controlled by one Power Brick by utilizing both ETH2 and ETH3 EtherCAT ports.

ETH 2/3: 8-Pin RJ45 Receptacle			
Pin #	**Symbol**	**Function**	**Description**
1	P0MDI0+	BIDIR	LINE 0 POS
2	P0MDI0-	BIDIR	LINE 0 NEG
3	P0MDI1+	BIDIR	LINE 1 POS
4	P0MDI1-	BIDIR	LINE 1 NEG
5	P0MDI2+	BIDIR	LINE 2 POS
6	P0MDI2-	BIDIR	LINE 2 NEG
7	P0MDI3+	BIDIR	LINE 3 POS
8	P0MDI3-	BIDIR	LINE 3 NEG

RS-232 Connection

The Power Brick provides a RS-232 port on the front panel. The connector is an IDC 10-pin connector, with the pinout arranged such that a flat cable crimped to an IDC 10-pin header at this end and a 9-pin D-sub connector at the other end will provide a standard RS-232 connection. The Delta Tau ACC-3L cable provides this connectivity.

MAIN RS232: 10-Pin Receptacle			 **Front View**	
PIN #	**SYMBOL**	**FUNCTION**	**DESCRIPTION**	**NOTES**
1	N.C.	--	NO CONNECT	
2	DTR	BIDIRECT	DATA TERM RDY	TIED TO "DSR"
3	TXD/	INPUT	RECEIVE DATA	HOST TRANSMIT DATA
4	CTS	INPUT	CLEAR TO SEND	HOST READY BIT
5	RXD/	OUTPUT	SEND DATA	HOST RECIEVE DATA
6	RTS	OUTPUT	REQ. TO SEND	PMAC READY BIT
7	DSR	BIDIRECT	DATA SET READY	TIED TO "DTR"
8	N.C.	--	NO CONNECT	
9	GND	COMMON	PMAC COMMON	
10	RESET_SW/	INPUT	SYSTEM RESET	RESET LOW, RELEASE HI



Note

This is a debug terminal that can be used for communicating with Power PMAC in the event that Ethernet communication fails (e.g. to acquire an IP address when unknown). In general, this port should not be used to communicate to external peripherals, but rather left in case of the need to debug.

MANUAL MOTOR SETUP

This section describes the step-by-step procedure for setting up motors with the Power Brick AC.



Note

Logic (24 VDC) power, encoder, motor, and main DC bus power must be wired properly, per the instructions in the connections section, prior to setting up any motor channel.

STEP 1: Global Reset

STEP 2: Dominant Clock Frequencies

STEP 3: Data Unpacking

STEP 4: Setting up the BrickAC Structure Elements

STEP 5: Power-On Reset PLC

STEP 6: Verifying Encoder Feedback

STEP 7: Brushless Motors
DC Brush Motors
Induction Motors

Global Reset

Starting from factory default settings (issuing a global reset **$$$***** followed by a **Save** and a **$$$**) is highly recommended. This ensures a good "clean" starting point.

Dominant Clock Frequencies

The choice of clock frequencies relies typically on the system requirements, hardware, and type of application.

Phase: The phase clock governs the current loop calculation, current sensor readings, and user written phase routine. Typically, the maximum phase clock frequency should not exceed twice that of the PWM. Setting it faster is meaningless and will not result in any performance enhancement.

PWM: The PWM clock governs the command output to the amplifier. In motor applications, it is directly related to the inductance and resistance of the motor. It can be determined empirically as shown in the equation below.

Servo: The Servo clock governs primarily the servo process (encoder read, motor command), and user written servo routine(s). Higher servo frequencies result, in general, in improved performance. The need for increasing the servo clock could come from several factors such as high speed/precision applications, synchronizing to external events, high speed position capture/compare, and kinematics calculation. High resolution encoders (e.g. serial, sinusoidal), linear motors, and galvanometers are usually set up with higher servo rates for best results.

Hardware: The hardware clocks govern the sampling rate of encoders, digital /analog converters, and control the pulse frequency modulation PFM output.

Minimum PWM Frequency

The minimum PWM frequency for a motor application can be computed empirically using the time constant of the motor. In general, the lower the time constant, the higher the PWM frequency should be. The motor time constant is calculated dividing the motor inductance by the resistance (phase-phase). The minimum PWM Frequency is then determined using the following relationship:

$$\tau_{\sec} = \frac{L_H}{R_{Ohms}} \qquad \tau > \frac{20}{2\pi \times PWM} \Rightarrow PWM\,(Hz) > \frac{20}{2\pi\tau_{\sec}}$$

Example: A motor with an inductance of 2.80 mH and a resistance of 14 Ω (phase-phase) yields a time constant of 200 μsec. Therefore, the minimum PWM Frequency should be about ~16 kHz.

Recommended Clock Frequencies

The recommended clock frequency settings for the Power Brick AC are 10 kHz Phase, 10 kHz PWM, and 5 kHz Servo.

- The write protection **Sys.WpKey** must be disabled to write to these key gate and system elements.
- The maximum coordinate system **Sys.MaxCoords** and motor **Sys.MaxMotors** settings are optional but strongly recommended to be limited to the actual usage. This improves overall performance.
- **Sys.ServoPeriod** and **Sys.PhaseOverServoPeriod** are critical for proper implementation of the clock settings. Make sure equations are computed.
- **Sys.RtIntPeriod** specifies the cycle of the "real-time interrupt".
- The Servo frequency is determined from the phase clock using the following equation:

$$f_{servo} = \frac{f_{Phase}}{PowerBrick[].Chan[]ServoClockDiv + 1}$$

- The PWM frequency is determined from the phase clock using the following equation:

$$f_{PWM} = \frac{PowerBrick[].Chan[]PwmFreqMult + 1}{2} \times f_{Phase}$$

```
Sys.WpKey = $AAAAAAAA
Sys.MaxCoords = 3
Sys.MaxMotors = 9

PowerBrick[1].PhaseFreq = 10000
PowerBrick[1].ServoClockDiv = 1

PowerBrick[0].PhaseFreq = 10000
PowerBrick[0].ServoClockDiv = 1

Sys.RtIntPeriod = 0
Sys.ServoPeriod = 1000 * (PowerBrick[0].ServoClockDiv + 1) / PowerBrick[0].PhaseFreq
Sys.PhaseOverServoPeriod = 1 / (PowerBrick[0].ServoClockDiv + 1)

PowerBrick[0].Chan[0].PwmFreqMult = 1
PowerBrick[0].Chan[1].PwmFreqMult = 1
PowerBrick[0].Chan[2].PwmFreqMult = 1
PowerBrick[0].Chan[3].PwmFreqMult = 1

PowerBrick[1].Chan[0].PwmFreqMult = 1
PowerBrick[1].Chan[1].PwmFreqMult = 1
PowerBrick[1].Chan[2].PwmFreqMult = 1
PowerBrick[1].Chan[3].PwmFreqMult = 1
```



Note

A **Save**, followed by a **$$$** or power cycle is advised after changing clock settings.

Data Unpacking

The ADC inputs and motor phase outputs' data is packed by default in the Power PMAC firmware into single 32-bit registers. Typically, this improves the efficiency of the computation algorithms, especially in extremely high performance applications or with a large number of axes (up to 256).

However, this enhancement may not be as noteworthy with the Power Brick AC considering the significantly lower number of axes it is usually controlling. Also, the Power Brick AC offers many functions that do not support packed data which mandates unpacking them:



Caution

Unpacking the data is critical for the proper operation of the Power Brick AC.

```
PowerBrick[0].Chan[0].PackOutData = 0
PowerBrick[0].Chan[1].PackOutData = 0
PowerBrick[0].Chan[2].PackOutData = 0
PowerBrick[0].Chan[3].PackOutData = 0
PowerBrick[1].Chan[0].PackOutData = 0
PowerBrick[1].Chan[1].PackOutData = 0
PowerBrick[1].Chan[2].PackOutData = 0
PowerBrick[1].Chan[3].PackOutData = 0

PowerBrick[0].Chan[0].PackInData = 0
PowerBrick[0].Chan[1].PackInData = 0
PowerBrick[0].Chan[2].PackInData = 0
PowerBrick[0].Chan[3].PackInData = 0
PowerBrick[1].Chan[0].PackInData = 0
PowerBrick[1].Chan[1].PackInData = 0
PowerBrick[1].Chan[2].PackInData = 0
PowerBrick[1].Chan[3].PackInData = 0
```

Setting up the BrickAC Structure Elements

The **BrickAC** data structure elements are setup / status parameters pertaining to the Power Brick AC firmware. They allow direct communication with the amplifier processor.

The **BrickAC** data structure elements consist of global (affecting all motor channels) and channel specific parameters. Certain elements can be saved others are read-only, volatile, or self-resetting.

The complete list and description of the **BrickAC** data structure elements can be found in the BrickAC Structure Elements section of this manual.

Starting from factory default settings, the necessary and sufficient **BrickAC** elements for setting up a motor safely and properly are:

BrickAC.SinglePhaseIn	= 0 = 1	For three phase AC input operation For single phase AC input operation
BrickAC.Chan[].I2tWarnOnly	= 0 = 1	Kill motor, display fault (default) Don't kill motor, report warning to the status register
BrickAC.Reset	= 1	To clear faults and save BrickAC settings. Must wait for fail/pass confirmation of the operation.


Caution

As shown in the Power-On Reset PLC example, it is strongly recommended for users to confirm the pass/fail status of the reset (**BrickAC.Reset = 1**) process.


Caution

Querying the value of the **BrickAC** structures elements does NOT guarantee that the returned value is what it is actually set to. **BrickAC.Reset = 1** must have executed at least once successfully for the BrickAC structure element settings to be applied and saved.


Caution

BrickAC.Reset should NOT be saved **= 1**, but rather set in the power-on reset plc.

```
BrickAC.SinglePhaseIn = 1

BrickAC.Chan[0].I2tWarnOnly = 0
BrickAC.Chan[1].I2tWarnOnly = 0
BrickAC.Chan[2].I2tWarnOnly = 0
BrickAC.Chan[3].I2tWarnOnly = 0
BrickAC.Chan[4].I2tWarnOnly = 0
BrickAC.Chan[5].I2tWarnOnly = 0
BrickAC.Chan[6].I2tWarnOnly = 0
BrickAC.Chan[7].I2tWarnOnly = 0
```

Power-On Reset PLC

The Power-on reset PLC serves two purposes:

- Clearing amplifier faults.
- Applying and saving (any) changes made to the **BrickAC** saved structure elements, such as **BrickAC.Chan[*j*].SinglePhaseIn**.

```
OPEN PLC PowerOnResetPLC
Sys.WDTReset = 5000 / (Sys.ServoPeriod * 2.258)
CALL Timer(0.005)

BrickAC.Reset = 1
WHILE (BrickAC.Reset == 1){}
IF (BrickAC.Reset == 0)
{
        Sys.WDTReset = 0

        // OK TO ENABLE PLCs/ENERGIZE MOTORS HERE

        DISABLE PLC PowerOnResetPLC
        CALL Timer(0.005)
}
ELSE
{
        // RESET FAILED, TAKE ACTION
        KILL 1..8
        DISABLE PLC 0..31
        SEND 1"RESET FAILED !!!"
        Sys.WDTReset = 0
        DISABLE PLC PowerOnResetPLC
        CALL Timer(0.005)
}
CLOSE
```

The process of waiting for the **BrickAC.Reset** to execute in a PLC consumes a significant amount of background cycles and risks triggering a foreground soft watchdog fault (**Sys.WDTFault = 1**), especially with higher clock frequencies. Setting **Sys.WDTReset** temporarily to a larger value (increasing the foreground watchdog timer threshold) alleviates this issue.



Note

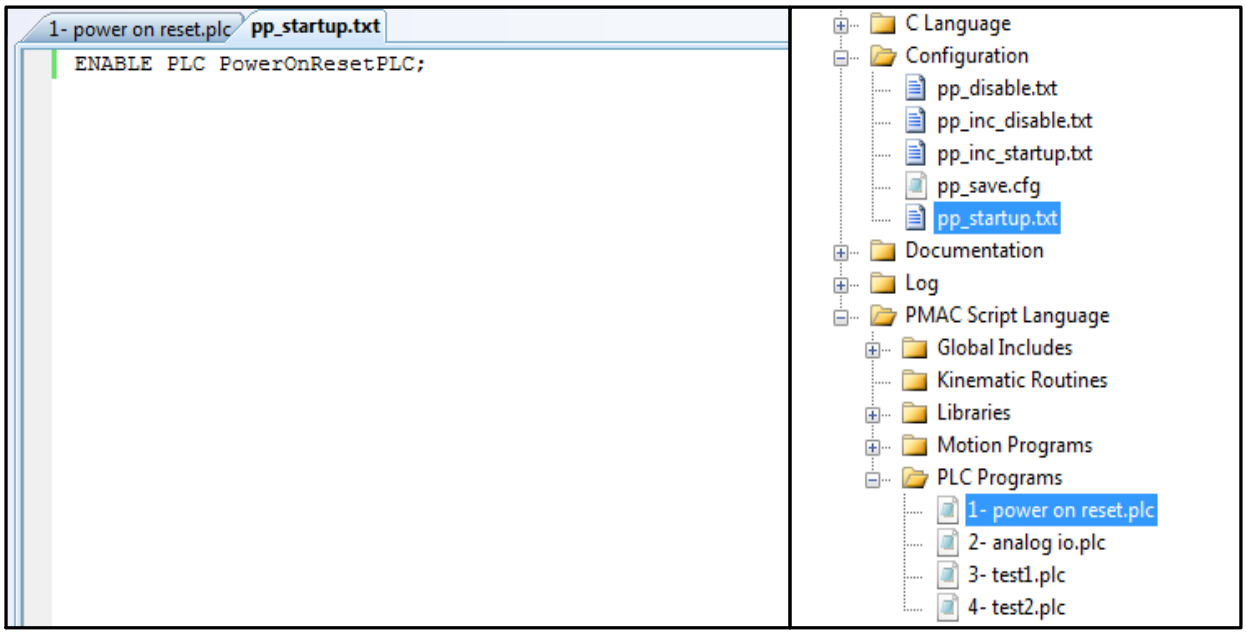
The **Sys.WDTReset** expression stated in the PLC example should ensure the proper setting regardless of the user-specified clock frequencies.

It is recommended to:

- Have this PLC scan once on power-up/reset (before enabling any motors).
- Kill motors while this PLC is executing.
- Disable other PLCs while this PLC is executing.

Forcing the PLC to scan on power-up/reset can be done by inserting the **enable plc** command in the **startup.txt** file under configuration in the IDE project.

Forcing this PLC to be number 1, hence executing first, while maintaining the user-defined name "PowerOnResetPLC" requires making sure that the IDE downloads it first (this is how the IDE indexes user named PLCs). This is done by placing the PLC atop of the PLCs' tree. Enumerating PLC files is one way to enforce this.



Verifying Encoder Feedback



Warning

The absence of encoder data is potentially a very dangerous condition in closed-loop control, because the servo loop no longer has any idea what the true physical position of the motor is – usually it thinks it is "stuck" – and it can react wildly, often causing a runaway condition.

Verifying encoder feedback is typically performed in the configuration setup section of the various feedback devices. The user should verify that:

- The feedback device is reporting data, this is commonly done by moving the motor / encoder shaft by hand and monitoring counts in the position window in the IDE software.

- The feedback device is reporting the correct number of counts. These are the motor units per user unit. Typically per revolution for rotary encoders (before gearing) or mm / inch for linear encoders.

- This is a good point of the setup to consider scaling the motor to user engineering units using **Motor[].PosSf**, and **Motor[].Pos2Sf**. Scaling to user engineering units is advantageous because it allows jogging the motor in user units instead of counts or motor units.

  Care must be taken to all motor elements (e.g. **Motor[].JogSpeed**) using motor units as they will be now in user engineering units.

  Changing **Motor[].PosSf**, and **Motor[].Pos2Sf** also affects the servo loop gains which must be tuned accordingly.

  Coordinate system axis definition, if linear (non-kinematic) assignment, can be defined as 1 (plus offset if applicable).

  Examples:

  - A linear motor with 1 nm resolution yielding 1,000,000 counts/mm desired to be programmed in millimeters. Both **Motor[].PosSf** and **Motor[].Pos2Sf** are set to 1 / 1000000.

  - A rotary motor with 131,072 counts per revolution desired to be programmed in degrees requires **Motor[].PosSf** and **Motor[].Pos2Sf** to be set to 360 / 131072**.**

  - A rotary motor with 1,0485,76 counts per revolution with a 10:1 inch gear reduction desired to be programmed in inches requires **Motor[].PosSf** and **Motor[].Pos2Sf** to be set to 10 / 1048576.

Configuring the Abort Input



Caution

If the +24 VDC abort input is not wired in or disabled in software (**Sys.pAbortAll = 0**), PMAC will try to close the loop on the motor every time it is enabled which could cause the motor the move or jump (if it has not been set up).

The abort input must be wired in (+24 VDC) or disabled in software (**Sys.pAbortAll = 0**) prior to attempting to enable the motor.

If the +24 VDC abort input is not wired in or disabled in software (**Sys.pAbortAll = 0**), PMAC will try to close the loop on the motor every time it is enabled. This could prevent setting up a motor properly, such as phasing manually or performing an open loop test.

Brushless Motors

Having performed the following:

- Global Reset (optional but recommended).
- Set up the dominant clock frequencies.
- Unpacked the ADC input and phase output data.
- Set up the **BrickAC** structure elements (e.g. **BrickAC.SinglePhaseIn**).
- Set up the power-on reset PLC.
- Verified encoder feedback.



Caution

If the +24 VDC abort input is not wired in or disabled in software (**Sys.pAbortAll = 0**), PMAC will try to close the loop on the motor every time it is enabled which could cause the motor to move or jump unexpectedly (if it has not been set up).

The abort input must be wired in (+24 VDC) or disabled in software (**Sys.pAbortAll = 0**) prior to attempting to enable the motor.

If the +24 VDC abort input is not wired in or disabled in software (**Sys.pAbortAll = 0**), PMAC will try to close the loop on the motor every time it is enabled.

Motor and channel specific parameters can now be configured to finalize the setup procedure of a brushless motor.



Note

A motor or channel parameter which is not discussed in the structure elements below is assumed – and should typically be left – at default.

Common Brushless Motor Setup Elements (e.g. Motor #1)

The following, are common motor structure elements for setting up brushless motors with the Power Brick AC.

```
Motor[1].pLimits = PowerBrick[0].Chan[0].Status.a
Motor[1].AdcMask = $FFF00000
Motor[1].AmpFaultLevel = 1
Motor[1].PhaseCtrl = 4
Motor[1].PhaseOffset = 683
```

PWM Output Scale Factor

The PWM scale factor, **Motor[].PwmSf**, specifies the maximum command output (voltage limiter). With the Power Brick AC, the nominal value is 16384.

- If the motor rated voltage is greater than > the input bus voltage:

```
Motor[1].PwmSf = 0.95 * 16384
```

- If the input bus voltage is greater than > the motor rated voltage:

```
GLOBAL DcBusInput = 340;
GLOBAL Mtr1DCVoltage = 170;

Motor[1].PwmSf = 0.95 * 16384 * Mtr1DCVoltage / DcBusInput
```

Ongoing Phase Position

Following are guidelines for setting up the ongoing phase position **(Motor[].PhasePosSf)** with various types of encoders. Some motor and encoder data sheet information is necessary to compute **Motor[].PhasePosSf** properly:

NoOfPolePairs is the number of pair poles of a rotary motor.
CountsPerRevolution is the number of raw quadrature encoder counts per revolution of a rotary motor.
LinesPerRevolution is the number of sine cycles of a sinusoidal rotary encoder/motor.
ECL$_{mm}$ is the linear motor electrical cycle length or magnetic pitch (e.g. 60.96 mm).
RES$_{mm}$ is the linear encoder resolution (a.k.a. pitch) in the same unit as the ECL (e.g. 1 µm = 0.001 mm).
ResPolePairs is the resolver number of pole pairs.

Quadrature Encoder

Motor[].pPhaseEnc = PowerBrick[].Chan[].PhaseCapt.a
Motor[].PhaseEncLeftshift = 0
Motor[].PhaseEncRightshift = 0
Rotary: Motor[].PhasePosSf = 2048 * **NoOfPolePairs** / (256 * **CountsPerRevolution**)
Linear: Motor[].PhasePosSf = 2048 * **RES$_{mm}$** / (256 * **ECL$_{mm}$**)

Sinusoidal Encoder

Motor[].pPhaseEnc = PowerBrick[].Chan[].PhaseCapt.a
Motor[].PhaseEncLeftshift = 0
Motor[].PhaseEncRightshift = 0
Rotary: Motor[].PhasePosSf = 2048 * **NoOfPolePairs** / (**LinesPerRevolution** * 16384)
Linear: Motor[].PhasePosSf = 2048 * **RES$_{mm}$** / (16384 * **ECL$_{mm}$**)

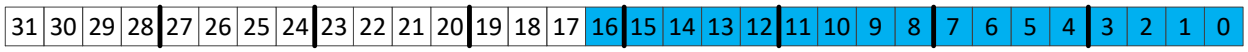
Resolver Encoder

Motor[].pPhaseEnc = PowerBrick[].Chan[].AtanSumOfSqr.a
Motor[].PhaseEncLeftshift = 0
Motor[].PhaseEncRightshift = 0
Rotary: Motor[].PhasePosSf = 2048 * **NoOfPolePairs** / (**ResPolePairs** * 4294967298)

Serial Encoder

Example: A serial encoder with 17 bits of single-turn ST data. Shift left 15 bits to MSB for rollover.

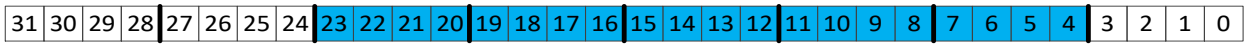
PowerBrick[].Chan[].SerialEncDataA



Motor[].pPhaseEnc = PowerBrick[].Chan[].SerialEncDataA.a
Motor[].PhaseEncLeftshift = 15
Motor[].PhaseEncRightshift = 0
Rotary: Motor[].PhasePosSf = 2048 * **NoOfPolePairs** / (2^{15} * 2^{ST})
Linear: Motor[].PhasePosSf = 2048 * $\mathbf{RES_{mm}}$ / (2^{15} * $\mathbf{ECL_{mm}}$)

Example: A serial encoder with 20 bits of single-turn ST position data located in serial data A register and starting at bit #4. Shift right 4 bits first to get rid of insignificant bits. Shift left 12 bits to MSB for rollover.

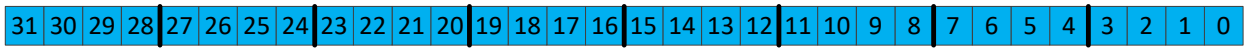
PowerBrick[].Chan[].SerialEncDataA



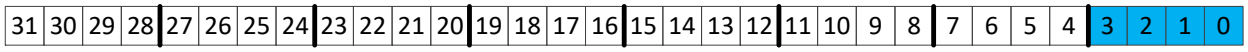
Motor[].pPhaseEnc = PowerBrick[].Chan[].SerialEncDataA.a
Motor[].PhaseEncLeftshift = 12
Motor[].PhaseEncRightshift = 4
Rotary: Motor[].PhasePosSf = 2048 * **NoOfPolePairs** / (2^{12} * 2^{ST})
Linear: Motor[].PhasePosSf = 2048 * $\mathbf{RES_{mm}}$ / (2^{12} * $\mathbf{ECL_{mm}}$)

Example: A serial encoder with 36 bits of single-turn ST position data located in serial data A and B registers consecutively.

PowerBrick[].Chan[].SerialEncDataA



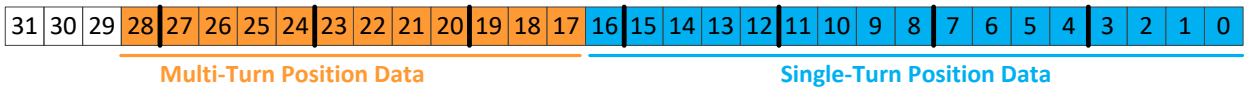
PowerBrick[].Chan[].SerialEncDataB



Motor[].pPhaseEnc = PowerBrick[].Chan[].SerialEncDataA.a
Motor[].PhaseEncLeftshift = 0
Motor[].PhaseEncRightshift = 0
Rotary: Motor[].PhasePosSf = 2048 * **NoOfPolePairs** / 2^{ST}
Linear: Motor[].PhasePosSf = 2048 * $\mathbf{RES_{mm}}$ / $\mathbf{ECL_{mm}}$

Example: A 29-bit serial encoder with 17 bits of single-turn ST and 12 bits of multi-turn position data starting at bit #0 of serial data A register and continuously extending to bit #28.

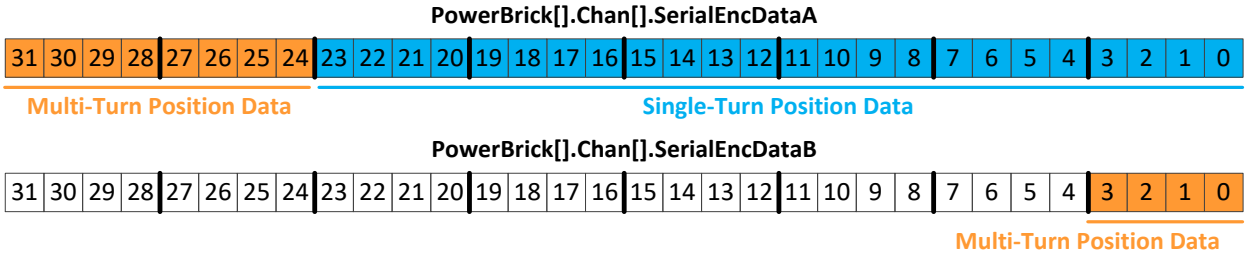
PowerBrick[].Chan[].SerialEncDataA



Motor[].pPhaseEnc = PowerBrick[].Chan[].SerialEncDataA.a
Motor[].PhaseEncLeftshift = 15
Motor[].PhaseEncRightshift = 0
Rotary: Motor[].PhasePosSf = 2048 * **NoOfPolePairs** / (2^{15} * 2^{ST})

Linear: Motor[].PhasePosSf = 2048 * **RES$_{mm}$** / (2^{15} * **ECL$_{mm}$**)

Example: A 36-bit serial encoder with 24 bits of single-turn ST and 12 bits of multi-turn position data starting at bit #0 of serial data A register and continuously extending to bit #3 of serial data register B.



Motor[].pPhaseEnc = PowerBrick[].Chan[].SerialEncDataA.a
Motor[].PhaseEncLeftshift = 8
Motor[].PhaseEncRightshift = 0
Rotary: Motor[].PhasePosSf = 2048 * **NoOfPolePairs** / (2^{8} * 2^{ST})
Linear: Motor[].PhasePosSf = 2048 * **RES$_{mm}$** / (2^{8} * **ECL$_{mm}$**)



Note

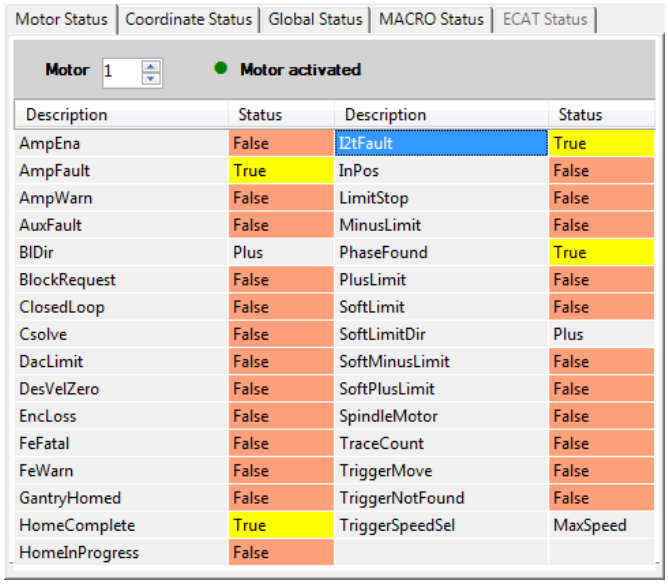
The **Motor[].PhasePosSf** is best entered as an expression (e.g. a ratio of integers) to let the Power Brick AC calculate the exact value.

I2T Protection

The Power Brick AC can be set up to fault a motor if the time-integrated current levels exceed a certain threshold. This can protect the motor (and drive) from damage due to overheating. It integrates the square of current over time – commonly known as I2T ("eye-squared-tee") protection.

For maximum protection, the Power PMAC performs the I2T calculations even when the motor is killed. In normal operation, measured currents should be very near zero in the killed state, and this is not important. However, it is possible during initial setup that incorrect settings cause Power PMAC to detect high current values, and it may take some time even after the settings have been corrected for the integrated values to "decay" to permit the amplifier to be enabled.

When an I2T fault occurs, the motor is killed, the amplifier fault and I2TFault bits are set (as seen in the motor status window in the IDE software). These bits can be accessed using the motor structure elements **Motor[].AmpFault** and **Motor[].I2TFault**.



The stricter current specifications (lesser) between the motor and the Power Brick AC channel should be used in the I2T calculations:

Peak Current Limit		
Current rating	**Value to use**	**Time at peak**
Motor < Drive	That of Motor	That of motor
Motor > Drive	That of Drive	That of drive (1 second)

Continuous Current Limit	
Current rating	**Value to use**
Motor < Drive	That of Motor
Motor > Drive	That of Drive

The maximum ADC, or full current reading, is specified per the power rating of the channel:

Channel Rating	Max ADC
5 A / 10 A	15.625 A
8 A / 16 A	25.0 A
15 A / 30 A	46.875 A



Caution

If the current limits of the motor are given as peak values, there is no need to multiply by √2 (1.414).

If the motor current limits are given in RMS values, or using those of the Power Brick AC drive:

Motor[].MaxDac = $PeakCurrent_{rms}$ * 32768 * √2 * cos(30°) / MaxAdc

Motor[].I2TSet = $ContinuousCurrent_{rms}$ * 32768 * √2 * cos(30°) / MaxAdc

Motor[].I2TTrip = (Motor[]$MaxDac^2$ – Motor[].$I2Set^2$) * TimeAtPeak

```
GLOBAL Ch1MaxAdc = 15.625;     // Max ADC reading [A peak]           --User Input
GLOBAL Ch1RmsPeakCur = 7.2;    // RMS Peak Current [A rms]           --User Input
GLOBAL Ch1RmsContCur = 3.6;    // RMS Continuous Current [A rms]     --User Input
GLOBAL Ch1TimeAtPeak = 1;      // Time Allowed at peak [sec]         --User Input
Motor[1].MaxDac = Ch1RmsPeakCur * 40132.44 / Ch1MaxAdc
Motor[1].I2TSet = Ch1RmsContCur * 40132.44 / Ch1MaxAdc
Motor[1].I2tTrip = (POW(Motor[1].MaxDac,2) - POW(Motor[1].I2TSet,2)) * Ch1TimeAtPeak
```

If the motor current limits are given in peak values:

Motor[].MaxDac = $PeakCurrent_{peak}$ * 32768 * cos(30°) / MaxAdc

Motor[].I2TSet = $ContinuousCurrent_{peak}$ * 32768 * cos(30°) / MaxAdc

Motor[].I2TTrip = (Motor[]$MaxDac^2$ – Motor[].$I2Set^2$) * TimeAtPeak

```
GLOBAL Ch1MaxAdc = 15.625;     // Max ADC reading [A peak]           --User Input
GLOBAL Ch1PeakCur = 7.2;       // Peak Current [A peak]              --User Input
GLOBAL Ch1ContCur = 3.6;       // Continuous Current [A peak]        --User Input
GLOBAL Ch1TimeAtPeak = 1;      // Time Allowed at peak [sec]         --User Input
Motor[1].MaxDac = Ch1PeakCur * 28378 / Ch1MaxAdc
Motor[1].I2TSet = Ch1ContCur * 28378 / Ch1MaxAdc
Motor[1].I2tTrip = (POW(Motor[1].MaxDac,2) - POW(Motor[1].I2TSet,2)) * Ch1TimeAtPeak
```



Note

Power PMAC's I2T is a motor thermal protection feature; the Power Brick AC amplifier(s) has its own built-in I2T model which protects the power transistors.

Current Loop tuning

Current loop tuning of brushless motors is carried out similarly to any Power PMAC digital current loop configuration. Current loop tuning is typically performed using the tuning tool in the IDE software.



Note

With some basic knowledge of motor and amplifier parameters, it is possible to calculate the current-loop gains empirically. These equations are described in the Power PMAC User manual.

The "Simple Auto-tune" and "Auto-tune" tools are straight forward tools which may be used effectively.

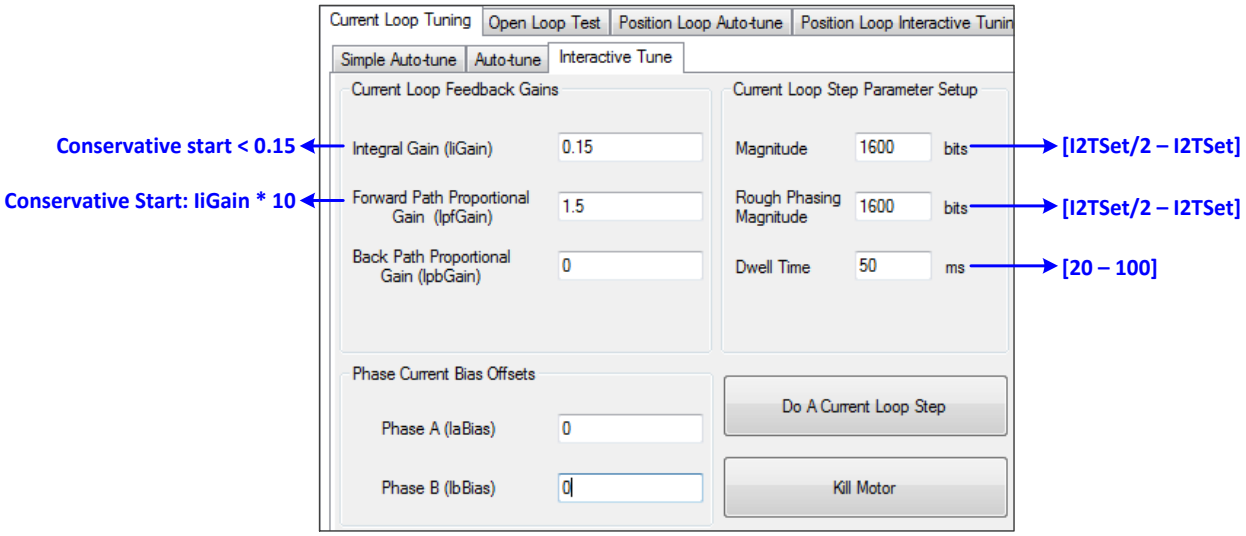
Following, is a practical description of the "Interactive tune" utility.

The current loop step test magnitude and rough phasing are typically in the range of:

Motor[].I2TSet / 2 < Magnitude < **Motor[].I2TSet**

This allows enough current to overcome static non-linear components for a good response without the risk of overheating the motor or triggering an over-current fault.

The "Dwell Time" is typically in the 50 – 100 msec range. This may be extended for slower response motors (high inductance).



Brushless motors' current loop can be, virtually, tuned using exclusively **Motor[].IiGain** and **Motor[].IpfGain**. In the Power PMAC digital current loop algorithm these gains can be thought of as:

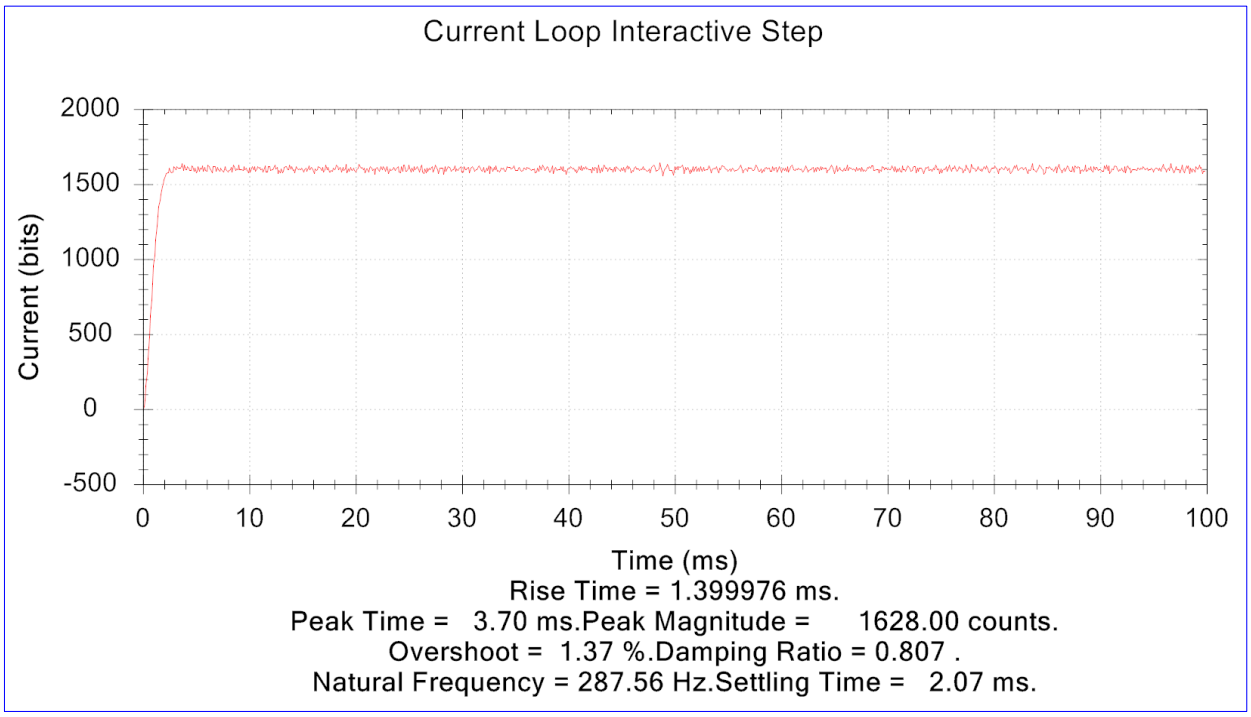
Motor[].IiGain: The transient effort (in reality integral gain).
Motor[].IpfGain: The damping gain (in reality forward path proportional gain).

Motor[].IpbGain can be optionally used in conjunction with **Motor[].IpfGain.**

Current-Loop response with natural Frequencies in the range of 200 – 500 Hz and a rise time of about 1 msec are adequate for most applications.

With higher performance motors (e.g. linear), the current loop's natural frequency can be pushed higher in the upwards of 800 Hz – 1.0 kHz with rise times around 0.5 millisecond. However, tightening the current loop with a lower performance system could have deteriorating effects on the overall position closed-loop performance.

An acceptable current-loop step response should look like:



Motor Phasing

When commutating a synchronous multi-phase motor such as a permanent-magnet brushless servo motor, the commutation algorithm must know the absolute position of the rotor within a single commutation cycle so it knows the magnetic field orientation of the rotor. The process of establishing this absolute position sense is known as "phase referencing" or "phasing".



Warning

An unreliable phasing search method can lead to a runaway condition. Test the phasing search method carefully to make sure it works properly under all conceivable conditions, and various locations of the travel. Make sure the fatal following error limit **Motor[].FatalFeLimit** is active and as tight as possible so the motor will be killed quickly in the event of a serious phasing search error.

Setting up a new motor/encoder requires performing an automatic or manual phase referencing routine. In the absence of an absolute phase reference reporting device such as digital hall sensors or absolute encoder, this phase referencing routine may be saved and implemented permanently.

With digital hall sensors, absolute power-on phasing can be configured to perform the phase referencing without the need of moving or energizing the motor. A manual force phasing routine is used to correct for hall sensors' phasing error one time per motor/encoder setup.

With absolute encoders, absolute power-on phasing can be configured to perform the phase referencing without the need of moving or energizing the motor. A manual force phasing routine is used to compute the absolute phase offset one time per motor/encoder setup.



Note

The available torque from a motor is directly proportional to the accuracy of the phase reference. The better the phasing is the less torque loss, current dissipation, and motor/drive thermal losses are.



Note

For best performance, the initial phasing routine (any method) should be done on an unloaded/uncoupled motor.



Note

Vertical axes phasing may require higher output current to overcome gravity, it is strongly advised to implement a balancing mechanism (e.g. weight, air) for these cases.

The following phasing methods are discussed in this section:

- Automatic Stepper Phasing
- Manual "Force" Phasing
- Custom "PLC" Phasing

Choosing a phasing method depends on the feedback device used with the brushless motor. The following table is a summary of the suggested phasing method to use with respect to each type of feedback device:

Type of Feedback Device	**Initial Phasing / Getting Started**	**Final Implementation / Saved Configuration**
Quadrature / Sinusoidal – No Halls	Stepper / Manual	Stepper / Manual / PLC
Quadrature / Sinusoidal – With Halls		Absolute Phasing. Halls phasing correction recommended.
Resolver		Absolute Phasing.
Serial Incremental		Stepper / Manual / PLC
Serial Absolute		Absolute Phasing.

Automatic Stepper Phasing

The automatic Stepper phasing technique is one of two phase referencing routines built into the Power PMAC firmware (the other one is the four-guess technique, not discussed here). The automatic stepper method can be used with any type of feedback device. It is simple to set up and can establish a very accurate phase reference.

Without the presence of digital hall sensors or an absolute encoder, the automatic stepper method can be saved and used in the power-up routine of the motor. Prior to implementing it permanently, it is highly recommended to test the automatic stepper method for consistency at random locations of the travel. Setting up the automatic stepper phasing technique requires configuring the following motor structure elements:

- **Motor[].PhaseFindingDac** specifies the magnitude of the output (current) used in the search move. **Motor[].I2Tset / 2** is a "good" conservative value to start with.
- **Motor[].PhaseFindingTime** specifies the amount of time (in real time interrupts) allowed for the search move. This can be computed in milliseconds, per the example equation below.
- **Motor[].AbsPhasePosOffset** specifies the minimum motion that qualifies the search as being a valid search. Typically set to 1/5th of a commutation cycle (2048 / 5).
- **Motor[].PowerOnMode** specifies whether a search move is applied on power-up. This is not advised with the automatic stepper phasing since the main bus power may not be available when the PMAC powers up. Leave bit 1 = 0.



Caution

The Stepper phasing technique is a search operation which requires the motor to move, typically in small steps. Nevertheless, caution should be taken.

Example:

```
GLOBAL Mtr1PhasingTime = 1000;                  // Total phasing time [msec] --User Input
Motor[1].PhaseFindingTime = Mtr1PhasingTime * 0.5 / (Sys.ServoPeriod * (Sys.RtIntPeriod + 1))
Motor[1].PhaseFindingDac = Motor[1].I2TSet / 2  // Phasing search magnitude  --User Input
Motor[1].AbsPhasePosOffset = 2048 / 5           // Qualifying motor movement
```



Note

The computed **Motor[].PhaseFindingTime** must be greater than 255 and less than 32,768 for the proper implementation of the automatic stepper phasing technique.

Issuing a **#n$** or setting **Motor[].PhaseFindingStep = 1** launches the stepper phasing search move. The pass/fail of the operation is reported by the motor status **Motor[].PhaseFound** bit. If the phasing fails (**Motor[].PhaseFound = 0**) repeatedly:

- Try increasing the magnitude, **Motor[].PhaseFindingDac**.
- Try extending the time allowed for phasing, **Motor[].PhaseFindingTime**.
- Try reversing the encoder decode **PowerBrick[].Chan[].EncCtrl** (e.g. 7 to 3 or vice versa). Not applicable to serial encoders (need to swap two of the motor leads).
- Try swapping two of the motor leads.
- Decouple the motor from the load, and try again.

Manual "Force" Phasing

The manual phasing method consists of locking up the motor tightly onto the zero position of the commutation cycle by forcing current into the offset of its B phase. This manual phasing works with any type of feedback device. It is particularly useful in:

- Establishing a phase reference manually.
- Troubleshooting phasing difficulties.
- Finding the absolute phase offset with absolute serial encoders.



Caution

The manual phasing technique is a search operation which requires the motor to move, typically in small steps. Nevertheless, caution should be taken.



Note

The tighter the motor is locked, the better is the phase reference.

Following, are the basic steps for performing a manual "force" phasing:

- Make sure the motor is killed and steady.
- Set **Motor[].IbBias** to a value corresponding to the amount of current to force into the phase. A conservative start is = **Motor[].I2TSet / 2.**
- Issue a **#nOut0** (where n is the motor number). The motor should lock into a position and exhibit some stiffness when trying to move it by hand.
- Increase **Motor[].IbBias** as necessary until the motor is locked tightly. Exceeding the value of **Motor[].I2TSet** indicates that there is a problem with the amplifier output or that the motor or drive is not sized properly for the load.
- Wait for the motor to settle. In some instances, it may oscillate for an extended amount of time. Some motors may be small enough to safely stabilize by hand.
- Zero the phase position register if performing a phasing routine; **Motor[].PhasePos = 0**. Or record the corresponding serial data for finding the absolute phase offset with absolute serial encoders.
- Kill the motor; **#nK**.
- Reset **Motor[].IbBias = 0**
- Set the phase found status bit; **Motor[].PhaseFound = 1**.

The motor should be phased at this point, and could be verified with an open loop test. Below are a few troubleshooting tips in case of difficulties:

- Try increasing the magnitude of **Motor[].IbBias.**
- Try reversing the encoder decode **PowerBrick[].Chan[].EncCtrl** (e.g. 7 to 3 or vice versa). Not applicable to serial encoders (need to swap two of the motor leads).
- Try swapping two of the motor leads.
- Decouple the motor from the load and try again.

Custom "PLC" Phasing

Some system may require a more specialized phasing technique due to uneven loads or friction along the travel. This manual phasing PLC may be more desirable for advanced users due to flexibility and more customization capabilities.

This travel distance should theoretically correspond to 1/6 of a commutation cycle size (in motor/encoder units). This is checked against at the end of the routine, and recorded in a pass/fail flag.

- **MtrxPhasingMag** is the amount of current to use for step phasing the motor. Conservative starting estimate **Motor[].I2TSet / 2**.
- **MtrxPhaseAPos** is the actual position of the motor when locked on to phase A.
- **MtrxPhaseBPos** is the actual position of the motor when locked on to phase B.
- **MtrxPhasingDis** is the displacement during the phasing routine.
- **MtrxDisThres** is the minimum travel indicating a successful phasing. 5th of a commutation cycle = 2048 * **EncTable[].ScaleFactor** / (5 * **Motor[].PhasePosSf**)
- **MtrxPhasingPass** is a flag indicating the pass or fail of the phasing routine. =1 pass, =0 fail.



Note

If the motor does not settle between lock-ups, increase the delay time. The threshold with which the filtered velocity is compared to may need to be tweaked as well.



Note

It is highly advised to test the motor phasing with the stepper or manual force phasing method before attempting to use a custom PLC.

```
GLOBAL Mtr1PhasingMag = Motor[1].I2TSet;
GLOBAL Mtr1PhaseAPos = 0;
GLOBAL Mtr1PhaseBPos = 0;
GLOBAL Mtr1PhasingDis = 0;
GLOBAL Mtr1DisThres = 2048 * EncTable[1].ScaleFactor / (5 * Motor[1].PhasePosSf);
GLOBAL Mtr1PhasingPass = 0;

OPEN PLC CustomPhasingPLC
Mtr1PhasingPass = 0
Motor[1].PhaseFound = 0
Motor[1].IaBias = 0 Motor[1].IbBias = 0
COUT 1:0
CALL Timer (0.100)
WHILE (ABS(Motor[1].FltrVel) > 5){}

WHILE (Motor[1].IaBias !> Mtr1PhasingMag)
{
    Motor[1].IaBias += 1   Motor[1].IbBias = 0
    CALL Timer (0.001)
}
CALL Timer (2)
WHILE (ABS(Motor[1].FltrVel) > 5){}
Mtr1PhaseAPos = ABS(Motor[1].ActPos - Motor[1].HomePos)
CALL Timer (0.250)

WHILE (Motor[1].IbBias !> Mtr1PhasingMag)
{
    Motor[1].IaBias -= 1   Motor[1].IbBias += 1
    CALL Timer (0.001)
}
CALL Timer (2)
WHILE (ABS(Motor[1].FltrVel) > 5){}
Mtr1PhaseBPos = ABS(Motor[1].ActPos - Motor[1].HomePos)
CALL Timer (0.250)

Mtr1PhasingDis = ABS(Mtr1PhaseBPos - Mtr1PhaseAPos)
IF(Mtr1PhasingDis >= Mtr1DisThres)
{
    Motor[1].PhasePos = 0
    Motor[1].PhaseFound = 1
    Mtr1PhasingPass = 1
}
ELSE
{
        Mtr1PhasingPass = 0
}
CALL Timer (0.250)

KILL 1
Motor[1].IaBias  = 0 Motor[1].IbBias  = 0
DISABLE PLC CustomPhasingPLC
CLOSE
```

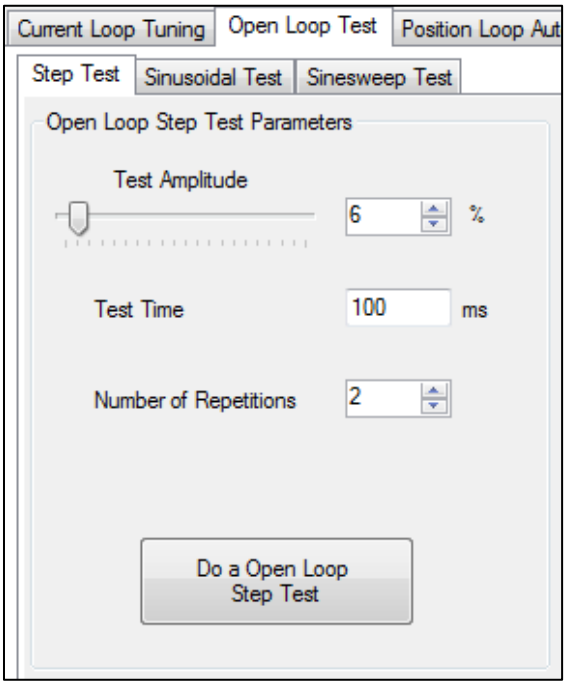
Open Loop Test

The open loop test is a critical step in verifying the proper implementation of the:

- Current loop
- Commutation
- Encoder decode/sense
- Motor phasing
- Encoder functionality

The open loop test can be executed using the open-loop test tab in the tuning utility in the IDE software.

The test amplitude depends on the load/gearing of the motor. Conservative values between 1 – 10% are good starting estimates. The test time is typically under 500 msec, nominally 100 msec. The number of repetitions is user configurable and may depend on the allowed amount of travel.

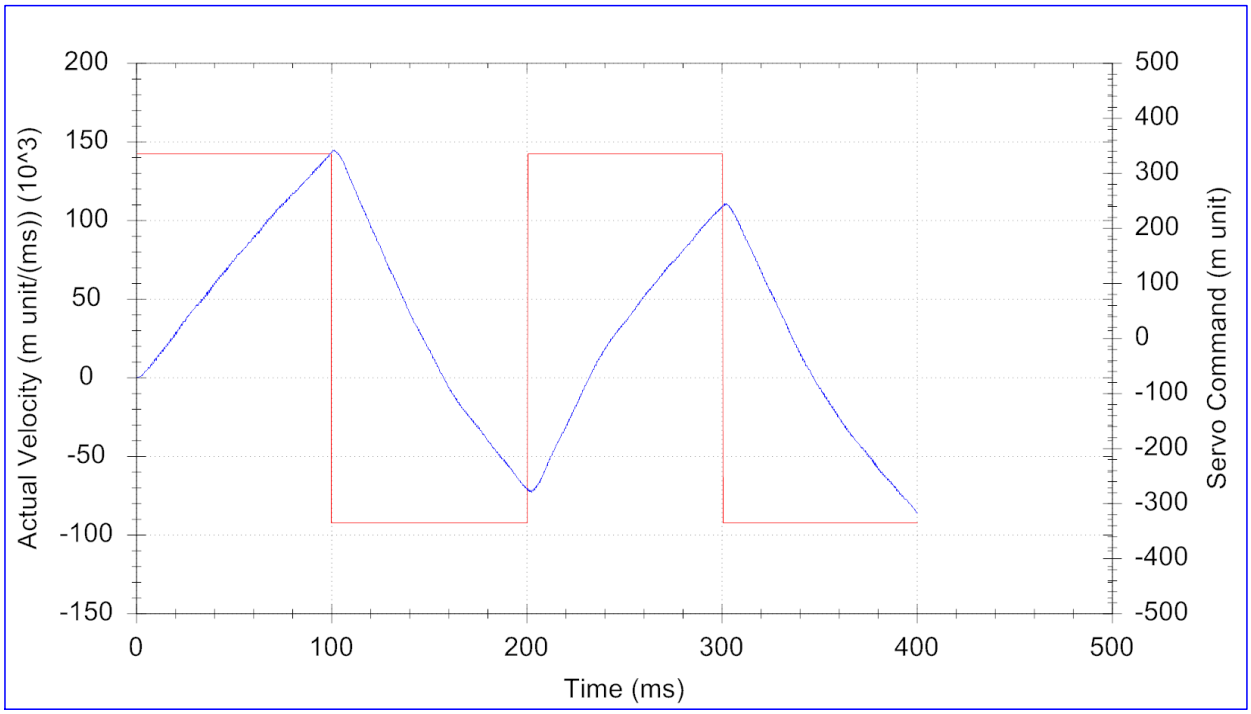




Caution

Do not attempt to close the position loop on a motor which open loop test has not passed, or shows an inverted saw tooth velocity. This may lead to dangerous runaway conditions.

A positive command should create a velocity and position counting in the positive direction; a negative command should create a velocity and position counting in the negative direction. This is typically observed in the response plot as a velocity saw tooth. A successful open-loop test response looks like:



Troubleshooting tips:
The open loop test can fail in two ways:

- Motor cogs to a phase (locks up)
- Plot shows an inverted saw tooth.

This indicates that one or a combination of the following:

- Incorrect commutation cycle size; review **Motor[].PhasePosSf**.
- Reversed encoder direction sense; review **PowerBrick[].Chan[].EncCtrl** (e.g. 7 to 3). Not applicable to serial encoders.
- Phasing was not preformed successfully; phase and try again.
- Reversed commutation direction; can be reversed in two ways:
  - Swapping any two of the motor leads.
  - Setting **Motor[].PwmSf**, and **Motor[].PhaseOffset** simultaneously to the opposite sign.

Position Loop Tuning

Position loop tuning is performed using the tuning utility in the IDE Software.



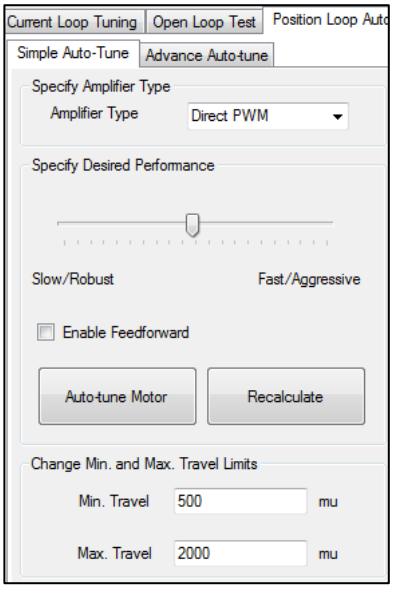
Caution

Do not attempt to close the position loop or perform position loop tuning on a motor which open-loop test has failed. This may lead to dangerous runaway conditions.

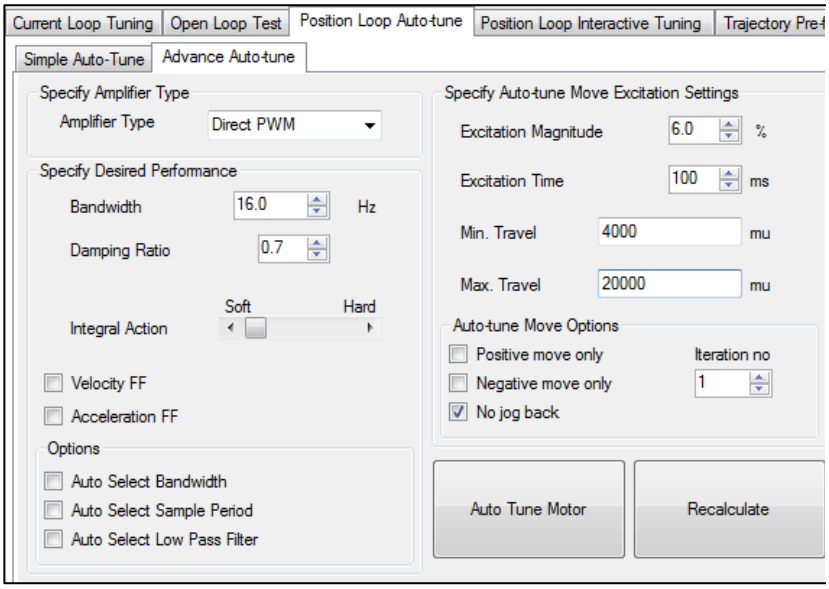
There are three main tuning sub-utilities in the tuning tool:

- Simple auto-tune.
- Advanced Auto-Tune.
- Position-Loop interactive tuning.

Simple Auto-tune



Advanced Auto-tune



For brushless motors, with the Power Brick AC, the amplifier type is always set to PWM.

The **simple auto-tune** is self-explanatory; move the slide left for a slower natural frequency and right for a higher natural frequency. Checking the "enable feedforward" box will also estimate the feedforward gains. This tuning technique may be more suitable for lightly loaded motors, and lower resolution encoders.

The **advanced auto-tune** introduces more user specific inputs, such as specifying the desired natural frequency, damping ratio, and integral action. The excitation magnitude and time are typically the same as the ones used successfully in the open-loop test.

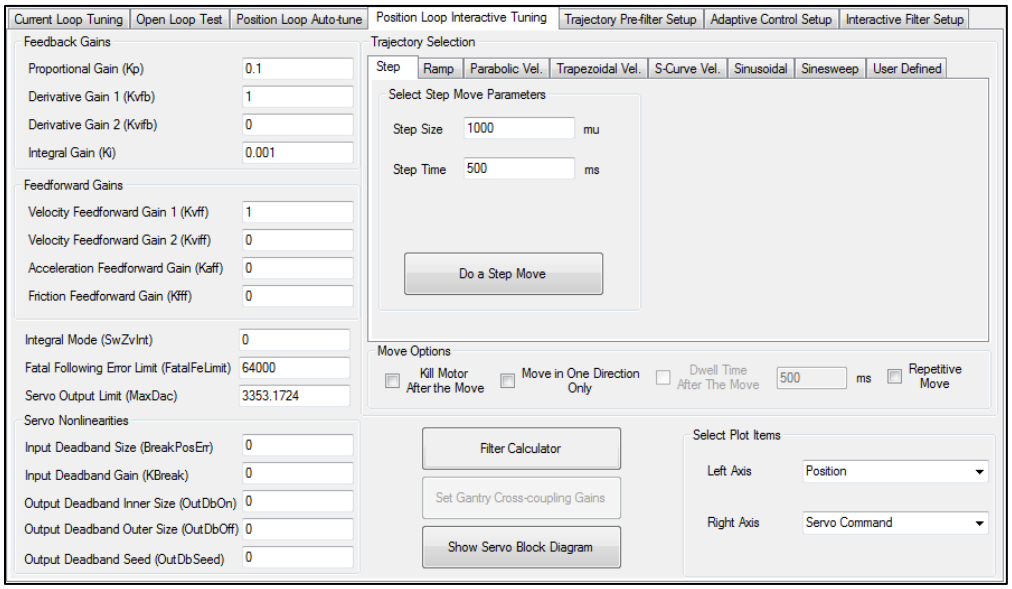


Note

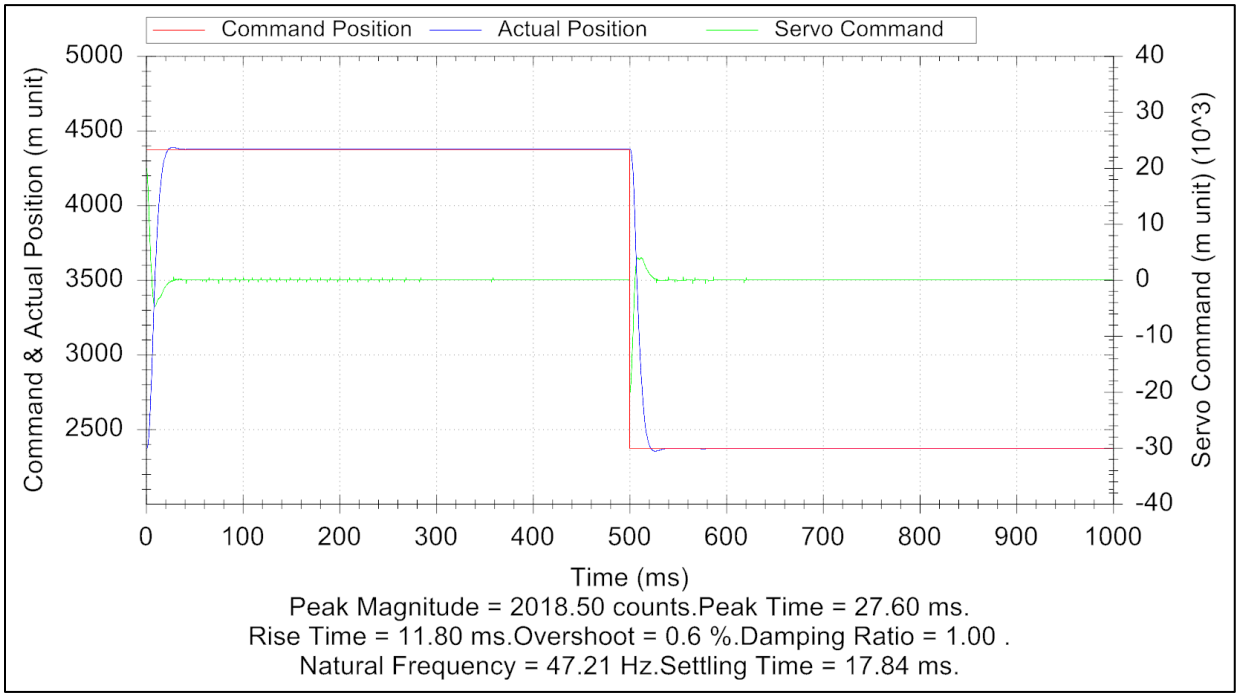
The automatic tuning techniques are conceived for rough tuning, which may be suitable for most applications. Fine tuning is typically performed using the interactive utility.

The **Position Loop Interactive Tuning** window is the fully fletched tuning interface, introducing all the gains used in the servo algorithm, various pre-configured command profiles, and filter tools. The two most common move profiles used in tuning are Step and Parabolic.

Interactive Tuning

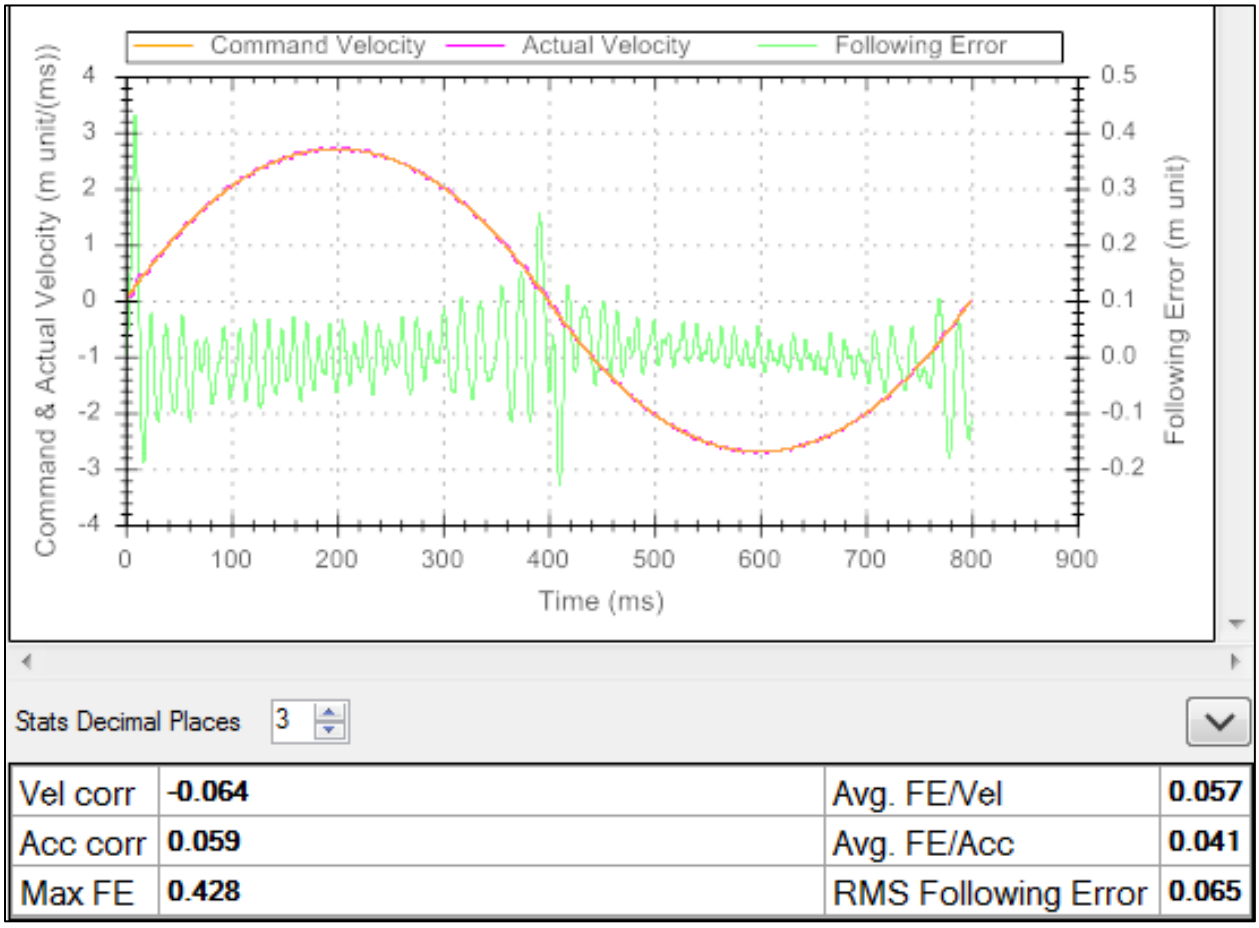


An acceptable step move response would look like:



Desirable characteristics to note: minimal overshoot, zero steady-state error, natural frequency > 20 Hz.

And an acceptable parabolic move response would look like:



Desirable characteristics to note: following error (green curve above) centered about 0 with minimal amplitude.



Note

With higher resolution encoders, the **Motor[].Servo.MaxPosErr** may need to be set to a higher than the default value allowing larger position error in the servo filter.

Absolute Power-On Phasing

Absolute power-on phasing is configurable with feedback devices providing an absolute reference capability; devices such as hall sensors, resolvers, or absolute serial encoders.

The absolute power-on phasing allows the phasing (figuring out the commutation rotor-angle position) of a motor without the need of a search move (motion) or energizing the motor.

With the 4 key motor structure elements (described in the examples below) configured and saved, issuing a **#n$** or **Motor[].PhaseFindingStep = 1** will initiate the absolute phasing computation.

A successful operation sets the **Motor[].PhaseFound** bit of the motor status to 1.

Alternately, automatic power-on absolute phasing can be configured (and saved) by setting bit #1 of the motor structure element **PowerOnMode**:

Motor[].PowerOnMode = Motor[].PowerOnMode | $2



Note

If the encoder power (5 VDC) is supplied from the X1 – X8 connectors, then the encoder is ensured to receive power by the time the PMAC boots up. However, if the encoder power is wired external, the user must ensure that this supply is turned on by the time the PMAC boots up and before phasing.

Hall Effect Phasing

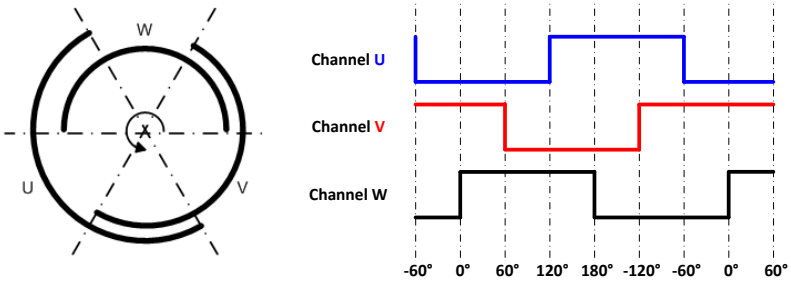
Digital Hall Effect sensors can be used for computing a rough absolute phase reference on power-up without the need for a phasing search move. They provide absolute information about where the motor is positioned with respect to its commutation cycle. They are desirable because, just like with absolute encoders, the motor can be phased on power-up without any movement.



Note

Inherently, digital hall sensors have an error of about ±30°, resulting in a loss of torque of about 15%. This should be corrected (fine phasing) for top operation.

The Power Brick AC supports both the conventional 120°, and less common 60° spacing. This section focuses on the more standard 120° spacing, each signal nominally with 50% duty cycle, and nominally 1/3 cycle apart.



Setting up digital Hall Effect sensors' absolute phasing requires:

- The motor to be phased initially (using the stepper/manual technique)
- Moving the motor either by hand or with jog commands.
  Moving the motor by hand with geared or loaded motors may not be possible. In these cases, it is recommended to perform the open loop test and rough position loop tuning first then come back for setting up the Hall sensors.

The key motor structure elements necessary for configuring Hall sensors' absolute phasing are:

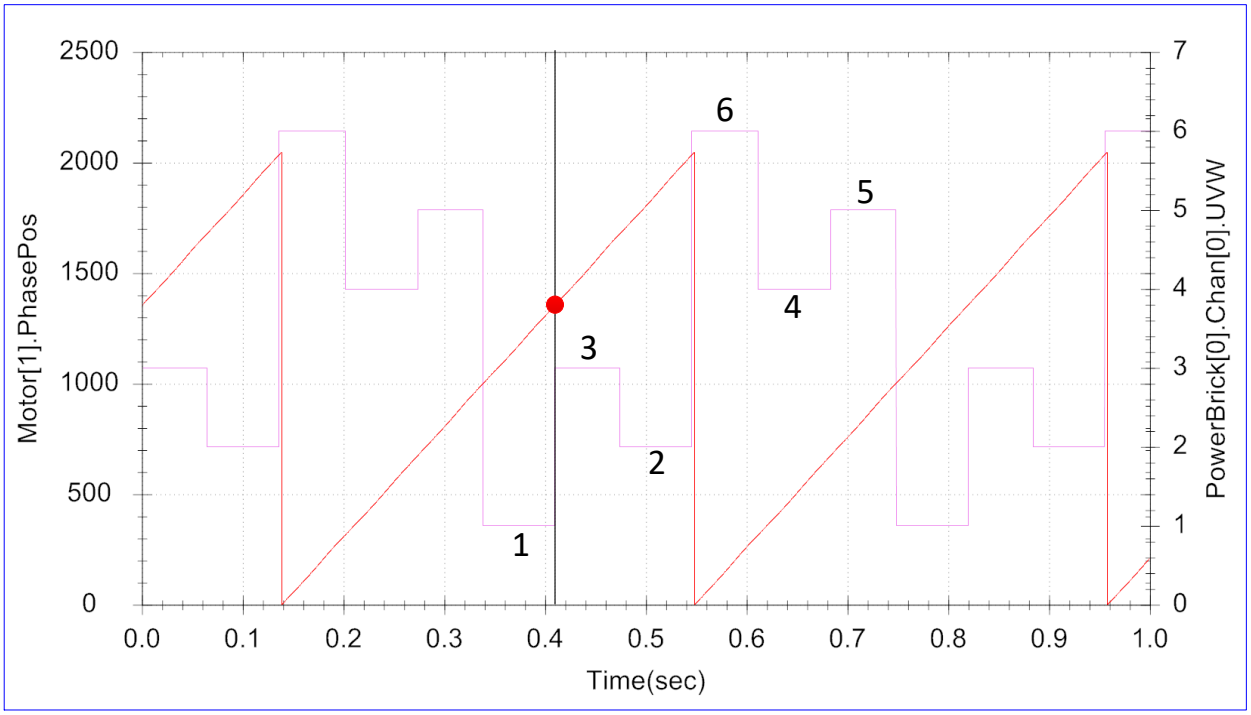
- **Motor[].pAbsPhasePos =** PowerBrick[].Chan[].Status.a

- **Motor[].AbsPhasePosFormat =** $400030C (always for halls 120° spacing)

- **Motor[].AbsPhasePosSf**
  The **Motor[].AbsPhasePosSf** reflects the direction sense of the halls with respect to the commutation counting direction. This is the UVW transition when moving the motor in the positive direction of the encoder:
  = 2048 / 12 if the **PowerBrick[].Chan[].UVW** transition is from 1 to 3
  = -2048 / 12 if the **PowerBrick[].Chan[].UVW** transition is from 3 to 1

- **Motor[].AbsPhasePosOffset**
  The **Motor[].AbsPhasePosOffset** is the phase position at that transition.

These settings can be configured using the plot utility in the IDE software. Moving or jogging the motor by hand in the **positive direction** while gathering **Motor[].PhasePos** and the corresponding **PowerBrick[].Chan[].UVW** should produce the following:



Motor[].AbsPhasePosSF =

2048 / 12	If the transition is 1-3
–2048 / 12	If the transition is 3-1

Motor[].AbsPhasePosOffset is equal to **Motor[].PhasePos** at the transition.

```
Motor[1].pAbsPhasePos = PowerBrick[0].Chan[0].Status.a
Motor[1].AbsPhasePosFormat = $400030C
Motor[1].AbsPhasePosSF = 2048 / 12    // --UserInput
Motor[1].AbsPhasePosOffset = 1362     // --UserInput
```

Alternately, the following PLC example configures the **Motor[].AbsPhasePosSf**, and **Motor[].AbsPhasePosOffset** automatically.

- Enable the PLC
- Move the motor at a slow to average speed (by hand or using jog commands) in the **positive direction** of the encoder.
- Once **Motor[].AbsPhasePosOffset** is posted, your Halls settings are finished. Discard the PLC and save the four key motor structure parameters in the project as well as in the PMAC.

```
PTR Ch1Halls->PowerBrick[0].Chan[0].UVW;

OPEN PLC HallsPLC
Motor[1].AbsPhasePosSF = 0
Motor[1].AbsPhasePosOffset = 0

// Check Direction
WHILE (Motor[1].AbsPhasePosSF == 0)
{
    IF (Ch1Halls == 1)
    {
        WHILE (Ch1Halls == 1){}
        IF (Ch1Halls == 3) {Motor[1].AbsPhasePosSF = 2048 / 12}
        ELSE {Motor[1].AbsPhasePosSF = -2048 / 12}
    }
}

// Capture Motor[].PhasePos at Transition
WHILE (Motor[1].AbsPhasePosOffset == 0)
{
    IF (Motor[1].AbsPhasePosSF > 0 && Ch1Halls == 1 && Motor[1].AbsPhasePosOffset == 0)
    {
        WHILE (Ch1Halls == 1){}
        Motor[1].AbsPhasePosOffset = Motor[1].PhasePos
    }
    IF (Motor[1].AbsPhasePosSF < 0 && Ch1Halls == 3 && Motor[1].AbsPhasePosOffset == 0)
    {
        WHILE (Ch1Halls == 3){}
        Motor[1].AbsPhasePosOffset = Motor[1].PhasePos
    }
}
DISABLE PLC HallsPLC
CLOSE
```

Hall Phasing Correction (Fine Phasing)

Inherently, digital hall sensors have an error of about ±30° resulting in a loss of torque of about 15%. Correcting for hall sensors' error can be achieved with a simple procedure. For better efficiency, this correction is strongly recommended for all applications using hall sensors for "absolute" phasing.

The hall phasing correction requires homing the motor. If the motor's position loop has not been tuned for closed loop commands it may be more practical, after phasing with the stepper/manual technique, to carry on to the open loop test and position loop tuning then come back for hall phasing correction.



Note

Hall phasing correction requires homing the motor.

The following are the necessary steps to implement the hall phasing correction:

1. Phase the motor, as best as possible, using the stepper / manual technique.
2. Home the motor to a reliable reference; encoder index or combination of flag and index.
   Not to be changed after the initial installation.
3. Record **Motor[].PhasePos**.
   This value can be saved in **Motor[].AbsPhasePosForce**.

After saving **Motor[].AbsPhasePosForce** in the project and the PMAC, and on the next power cycle:

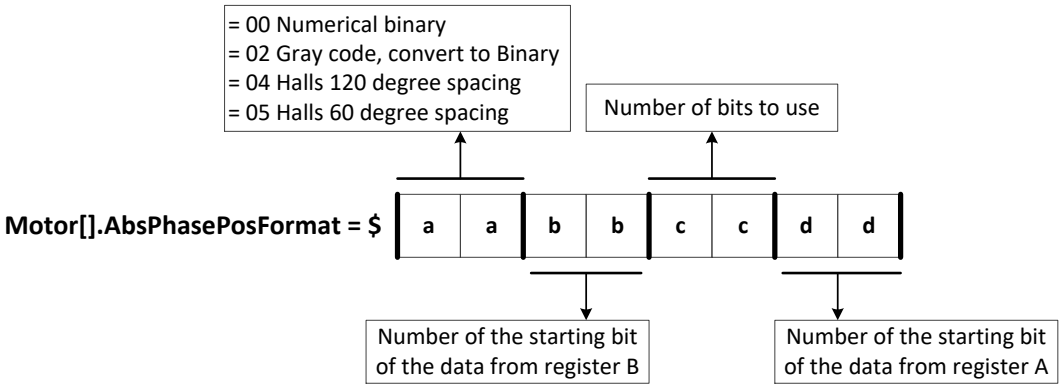
- Phase the motor using halls by issuing **#n$** or **Motor[].PhaseFindingStep = 1**
- Home the motor to the same reference used in the phase correction routine.
- Once homed and settled, set **Motor[].PhasePos = Motor[].AbsPhasePosForce**.
  The hall phasing correction is now complete.

Absolute Serial Encoder Phasing

With absolute serial encoders, the four key elements for setting up absolute phasing are:

- **Motor[].pAbsPhasePos = PowerBrick[].Chan[].SerialEncDataA.a**

- **Motor[].AbsPhasePosFormat**



- **Motor[].AbsPhasePosSf**

  Rotary: = 2048 * **NoOfPolesPairs** / $2^{\mathbf{ShiftBits}} * 2^{\mathbf{SingleTurnBits}}$

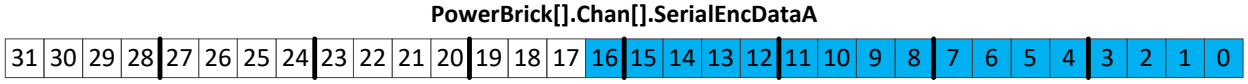
  Linear: = 2048 * $\mathbf{RES_{mm}}$ / ($\mathbf{ECL_{mm}}$ * $2^{\mathbf{ShiftBits}}$)

  Where:
  - **NoOfPolePairs** is the number of pole pairs of a rotary motor
  - **ShiftBits** is typically the starting bit # in Serial Data Register A
  - $\mathbf{ECL_{mm}}$ is the linear motor electrical cycle length or magnetic pitch (e.g. 60.96 mm)
  - $\mathbf{RES_{mm}}$ is the linear encoder resolution in the same unit as the ECL (e.g. 1 µm = 0.001 mm)

- **Motor[].AbsPhasePosOffset = –PhaseForceTest * Motor[].AbsPhasePosSf**

  Where: PhaseforceTest is the value recorded from the stepper phasing force test.

Example:
A serial encoder with 17 bits of single-turn position data located in the lower fields of serial data A register.



Motor[].pAbsPhasePos = **PowerBrick[].Chan[].SerialEncDataA.a**

Motor[].AbsPhasePosFormat = $00001100

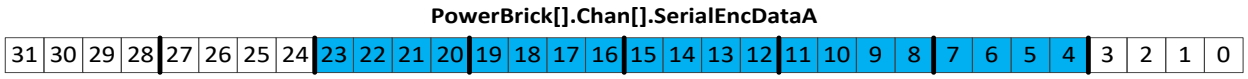
Rotary: **Motor[].AbsPhasePosSf = 2048 * NoOfPolePairs / 2^{17}**

Linear: **Motor[].AbsPhasePosSf = 2048 * RES_{mm} / ECL_{mm}**

Motor[].AbsPhasePosOffset = **–PhaseForcePos** * **Motor[].AbsPhasePosSf**

The PhaseForceTest value can be found by performing a manual force phasing (locking the motor onto phase B) and recording the 17 bits of position data. **PhaseForcePos = PowerBrick[].Chan[].SerialEncDataA & $00001FFF**.

Example:
A serial encoder with 20 bits of single-turn position data located in serial data A register and starting at bit #4. The low nibble may contain other information, irrelevant to position data.



Motor[].pAbsPhasePos = PowerBrick[].Chan[].SerialEncDataA.a

Motor[].AbsPhasePosFormat = $00001404

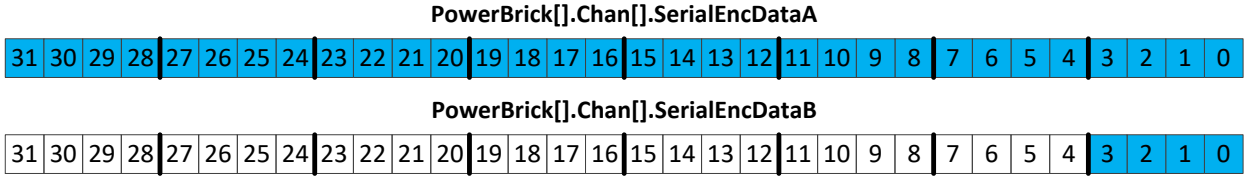
Rotary: **Motor[].AbsPhasePosSf = 2048 * NoOfPolePairs / (2^{20})**

Linear: **Motor[].AbsPhasePosSf = 2048 * RES_{mm} / (ECL_{mm})**

Motor[].AbsPhasePosOffset = –PhaseForcePos * Motor[].AbsPhasePosSf

The PhaseForceTest value can be found by performing a manual force phasing (locking the motor onto phase B) and recording the 20 bits of position data. **PhaseForcePos = (PowerBrick[].Chan[].SerialEncDataA & $00FFFFF0) / 16**.

Example:
A serial encoder with 36 bits of single-turn position data located in serial data A and B registers consecutively. We will use the lower 32 bits; that is the maximum allowed number of bits for the power-on absolute commutation.



Motor[].pAbsPhasePos = PowerBrick[].Chan[].SerialEncDataA.a

Motor[].AbsPhasePosFormat = $00002000

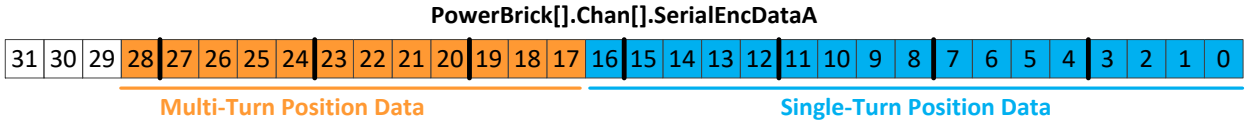
Rotary: **Motor[].AbsPhasePosSf = 2048 * NoOfPolePairs / 2^{32}**

Linear: **Motor[].AbsPhasePosSf = 2048 * RES_{mm} / ECL_{mm}**

Motor[].AbsPhasePosOffset = –PhaseForcePos * Motor[].AbsPhasePosSf

The PhaseForceTest value can be found by performing a manual force phasing (locking the motor onto phase B) and recording 32 bits of position data (serial data register A). **PhaseForcePos = PowerBrick[].Chan[].SerialEncDataA**.

Example:
A 29-bit binary serial encoder with 17 bits of single-turn and 12 bits of multi-turn position data starting at bit #0 of serial data A register and continuously extending to bit #28.



Motor[].pAbsPhasePos = PowerBrick[].Chan[].SerialEncDataA.a

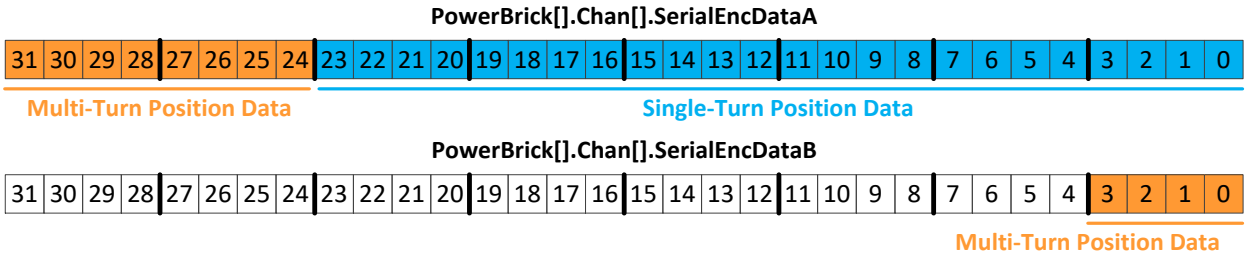
Motor[].AbsPhasePosFormat = $00001100

Motor[].AbsPhasePosSf = 2048 * NoOfPolePairs / 2^{17}

Motor[].AbsPhasePosOffset = –PhaseForcePos * Motor[].AbsPhasePosSf

The PhaseForceTest value can be found by performing a manual force phasing (locking the motor onto phase B) and recording the 17 bits of single-turn position data. **PhaseForcePos = PowerBrick[].Chan[].SerialEncDataA & $00001FFF**.

Example:
A 36-bit serial encoder with 24 bits of single-turn and 12 bits of multi-turn position data starting at bit #0 of serial data A register and continuously extending to bit #3 of serial data register B.



Motor[].pAbsPhasePos = PowerBrick[].Chan[].SerialEncDataA.a

Motor[].AbsPhasePosFormat = $00001800

Motor[].AbsPhasePosSf = 2048 * NoOfPolePairs / 2^{24}

Motor[].AbsPhasePosOffset = –PhaseForcePos * Motor[].AbsPhasePosSf

The PhaseForceTest value can be found by performing a manual force phasing (locking the motor onto phase B) and recording the 17 bits of single-turn position data. **PhaseForcePos = PowerBrick[].Chan[].SerialEncDataA & $00FFFFFF**.

Absolute Resolver Phasing

With resolvers, the four key elements for setting up absolute phasing are:

- **Motor[].pAbsPhasePos = PowerBrick[].Chan[].AtanSumOfSqr.a**

- **Motor[].AbsPhasePosFormat = $00001010**

- **Motor[].AbsPhasePosSf**
  Rotary Motor: = **2048** * **NoOfPolesPairs** / **(ResPolePairs * 65536)**

  Where:
  - **NoOfPolePairs** is the number of pole pairs of a rotary motor
  - **ResPolePairs** is the resolver number of pole pairs.

- **Motor[].AbsPhasePosOffset** = –**PhaseForceTest** * **Motor[].AbsPhasePosSf**
  Where: **PhaseforceTest** is the value recorded from the stepper phasing force test, by reading the upper 16 bits of **PowerBrick[].Chan[].AtanSumOfSqr.**

The **PhaseForceTest** value can be found by performing a manual force phasing (locking the motor onto phase B) and recording the value of the upper 16 bits of **AtanSumOfSrq** (e.g. **PhaseForceTest = PowerBrick[].Chan[].AtanSumOfSqr>>16**).

DC Brush Motors

Having performed the following:

- Global Reset (optional but recommended).
- Set up the dominant clock frequencies.
- Unpacked the ADC input and phase output data.
- Set up the **BrickAC** structure elements (e.g. **BrickAC.SinglePhaseIn**).
- Set up the power-on reset PLC.
- Verified encoder feedback.



Caution

If the +24 VDC abort input is not wired in or disabled in software (**Sys.pAbortAll = 0**), PMAC will try to close the loop on the motor every time it is enabled which could cause the motor to move or jump unexpectedly (if it has not been set up).

The abort input must be wired in (+24 VDC) or disabled in software (**Sys.pAbortAll = 0**) prior to attempting to enable the motor.

If the +24 VDC abort input is not wired in or disabled in software (**Sys.pAbortAll = 0**), PMAC will try to close the loop on the motor every time it is enabled.

Motor and channel specific parameters can now be configured to finalize the setup procedure of a DC brush motor.



Note

A motor or channel element which is not discussed in the structure elements below is assumed – and should typically be left – at default.

Common DC Brush Motor Setup Elements (e.g. Motor #1)

The following, are common motor structure elements for setting up DC brush motors with the Power Brick AC:

```
Motor[1].pLimits = PowerBrick[0].Chan[0].Status.a
Motor[1].AdcMask = $FFF00000
Motor[1].AmpFaultLevel = 1
Motor[1].PhaseCtrl = 4
Motor[1].PhaseMode = 3
Motor[1].PhaseOffset = 512
Motor[1].PhasePosSf = 0
Motor[1].pAbsPhasePos = Sys.pushm
Motor[1].PowerOnMode = 2
```

PWM Output Scale Factor

The PWM scale factor, **Motor[].PwmSf**, specifies the maximum command output (voltage limiter). With the Power Brick AC, the nominal value is 16384.

- If the motor rated voltage is greater than > the input bus voltage:

```
Motor[1].PwmSf = 0.95 * 16384
```

- If the input bus voltage is greater than > the motor rated voltage:

```
GLOBAL DcBusInput = 340;
GLOBAL Mtr1DCVoltage = 48;

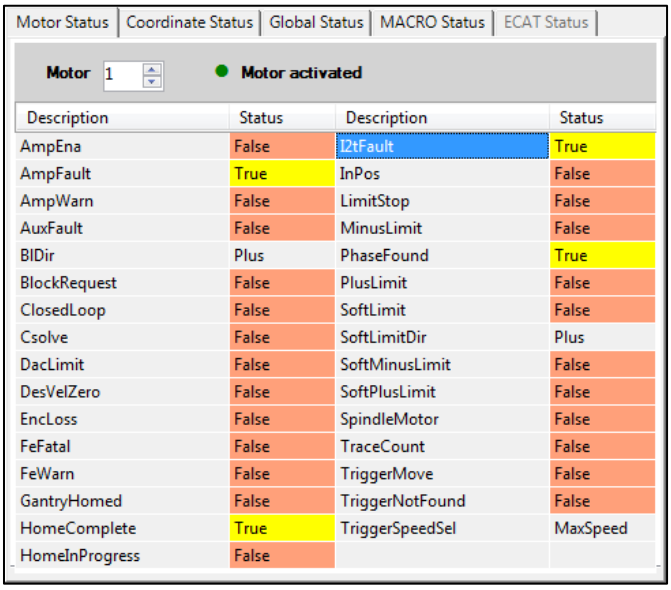
Motor[1].PwmSf = 0.95 * 16384 * Mtr1DCVoltage / DcBusInput
```

I2T Protection

The Power Brick AC can be set up to fault a motor if the time-integrated current levels exceed a certain threshold. This can protect the motor (and drive) from damage due to overheating. It integrates the square of current over time – commonly known as I2T ("eye-squared-tee") protection.

For maximum protection, the Power PMAC performs the I2T calculations even when the motor is killed. In normal operation, measured currents should be very near zero in the killed state, and this is not important. However, it is possible during initial setup that incorrect settings cause Power PMAC to detect high current values, and it may take some time even after the settings have been corrected for the integrated values to "decay" to permit the amplifier to be enabled.

When an I2T fault occurs, the motor is killed, the amplifier fault and I2TFault bits are set (as seen in the motor status window in the IDE software). These bits can be accessed using the motor structure elements **Motor[].AmpFault** and **Motor[].I2TFault**.



The stricter current specifications (lesser) between the motor and the Power Brick AC channel should be used in the I2T calculations:

Peak Current Limit		
Current rating	**Value to use**	**Time at peak**
Motor < Drive	That of Motor	That of motor
Motor > Drive	That of Drive	That of drive (1 second)

Continuous Current Limit	
Current rating	**Value to use**
Motor < Drive	That of Motor
Motor > Drive	That of Drive

The max ADC, or full current reading, is specified per the power rating of the channel:

Channel Rating	**Max ADC**
5 A / 10 A	15.625 A
8 A / 16 A	25.0 A
15 A / 30 A	46.875 A

For a DC brush motor, the I2T equations can be computed as:

Motor[].MaxDac = $PeakCurrent_{rms}$ * 32768 / MaxAdc

Motor[].I2TSet = $ContinuousCurrent_{rms}$ * 32768 / MaxAdc

Motor[].I2TTrip = (Motor[]$MaxDac^2$ – Motor[].$I2Set^2$) * TimeAtPeak

```
GLOBAL Ch1MaxAdc = 15.625;     // Max ADC reading [A Peak]   --User Input
GLOBAL Ch1PeakCur = 2.92;      // Peak Current [A]           --User Input
GLOBAL Ch1ContCur = 0.75;      // Continuous Current [A]     --User Input
GLOBAL Ch1TimeAtPeak = 1;      // Time Allowed at peak [sec] --User Input
Motor[1].MaxDac = Ch1PeakCur * 32768 / Ch1MaxAdc
Motor[1].I2TSet = Ch1ContCur * 32768 / Ch1MaxAdc
Motor[1].I2tTrip = (POW(Motor[1].MaxDac,2) - POW(Motor[1].I2TSet,2)) * Ch1TimeAtPeak
```

Current Loop Tuning

The IDE tuning software injects "direct" current to perform a current loop step response. To use this tool successfully with DC brush motors:

- **Motor[].PhaseTableBias** must be set manually to ±512 (90° electrical angle) so that direct current corresponds to A-phase current. The sign of ±512 is typically chosen so that a positive step response is produced.

- **Motor[].PhaseMode** must be set to 1 so that bit 1 is zero forcing the Id integrator to be on during tuning.



Note

Remember to set **Motor[].PhaseTableBias** back to 0, and **Motor[].PhaseMode** to 3 for normal motor operation.



Note

With some basic knowledge of motor and amplifier parameters, it is possible to calculate the current-loop gains empirically. These equations are described in the Power PMAC User manual.

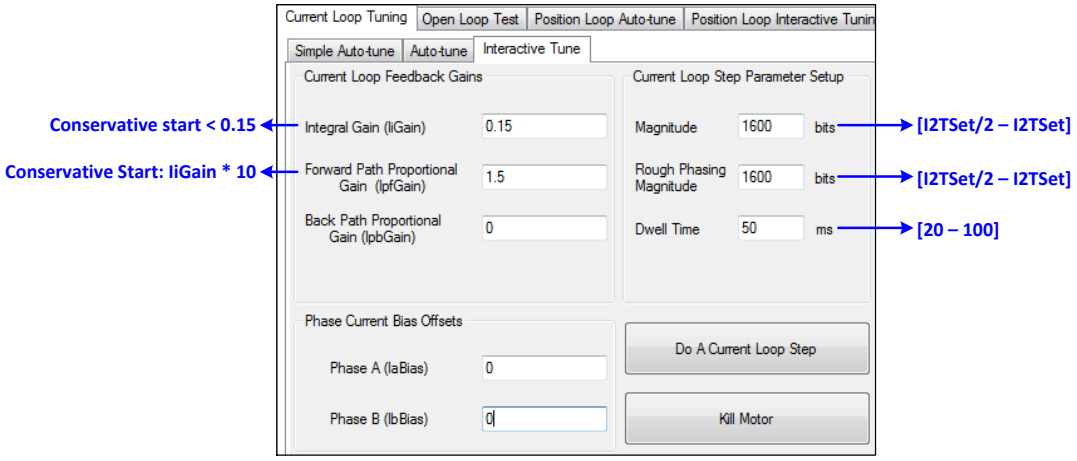
The "Simple Auto-Tune" and "Auto-Tune" tools are straight forward tools which may be used effectively. Following, is a practical description of the "Interactive Tune" utility.

The current loop step test magnitude and rough phasing are typically in the range of:

Motor[].I2TSet / 2 < Magnitude < **Motor[].I2TSet**

This allows enough current to overcome static nonlinear components for a good response without the risk of overheating the motor or triggering an overcurrent fault.

The "Dwell Time" is typically in the 20 – 100 msec range. This may be extended for slower response motors (high inductance).

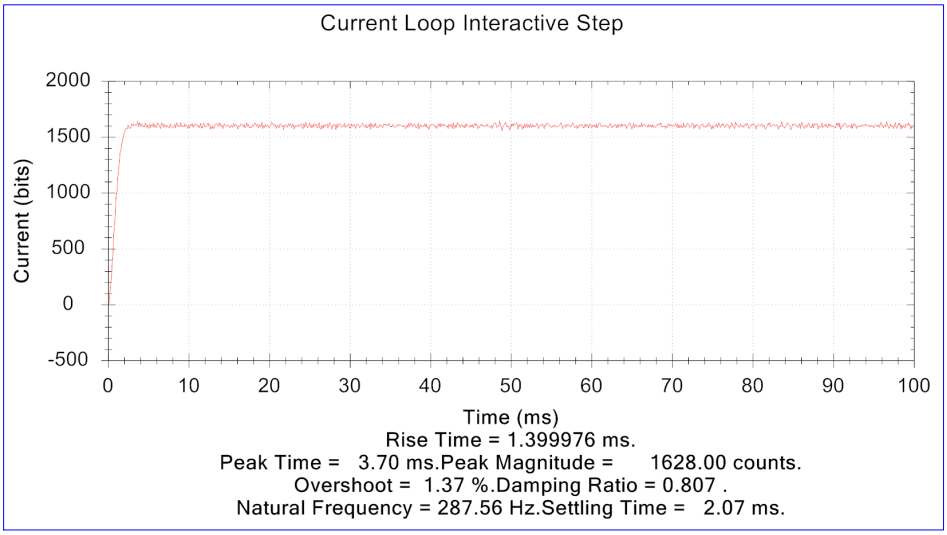


DC brush motors' current loop can be, virtually, tuned using exclusively **Motor[].IiGain** and **Motor[].IpfGain**. In the Power PMAC digital current loop algorithm these gains can be thought of as:

Motor[].IiGain: The transient effect.
Motor[].IpfGain: The damping effort.
Motor[].IpbGain can be optionally used in conjunction with **Motor[].IpfGain.**

Current-Loop Natural Frequencies in the range of 200 – 500 Hz are adequate for most applications.

With higher performance DC brush motors (e.g. a Voicecoil), the current loop's natural frequency can be pushed higher, upwards of 800 Hz – 1.0 kHz, with rise times around 0.5 millisecond. However, tightening the current loop with a lower performance system could have deteriorating effects on the overall position closed-loop performance. For example, an acceptable current step response:





Note

Remember to set **Motor[].PhaseTableBias** back to 0, and **Motor[].PhaseMode** to 3 for normal motor operation.



Note

In some cases, it may be helpful to fix the motor shaft / rod mechanically to avoid oscillations in the response.

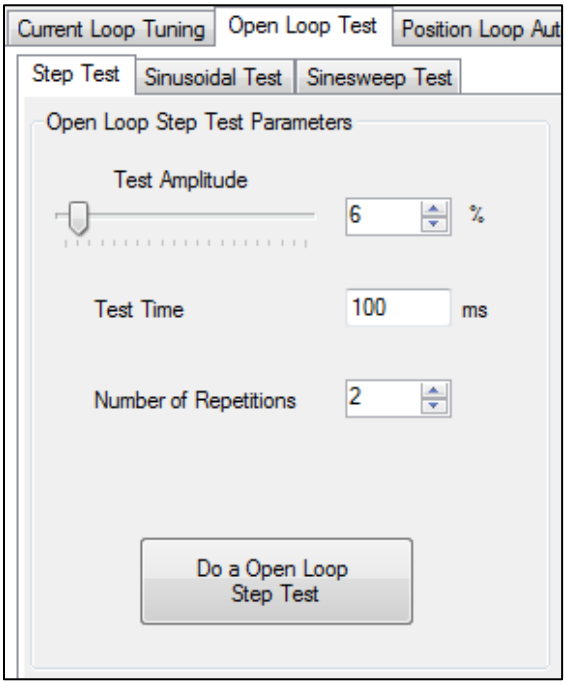
Open Loop Test

The open loop test is a critical step in verifying the proper implementation of the:

- Current loop
- Encoder decode/sense
- Encoder functionality

The open loop test can be executed using the open-loop test tab in the tuning utility in the IDE software.

The test amplitude depends on the load/gearing of the motor. Conservative values between 1-10% are good starting estimates. The test time is typically under 500 msec, nominally 100 msec. The number of repetitions is user configurable and may depend on the allowed amount of travel.

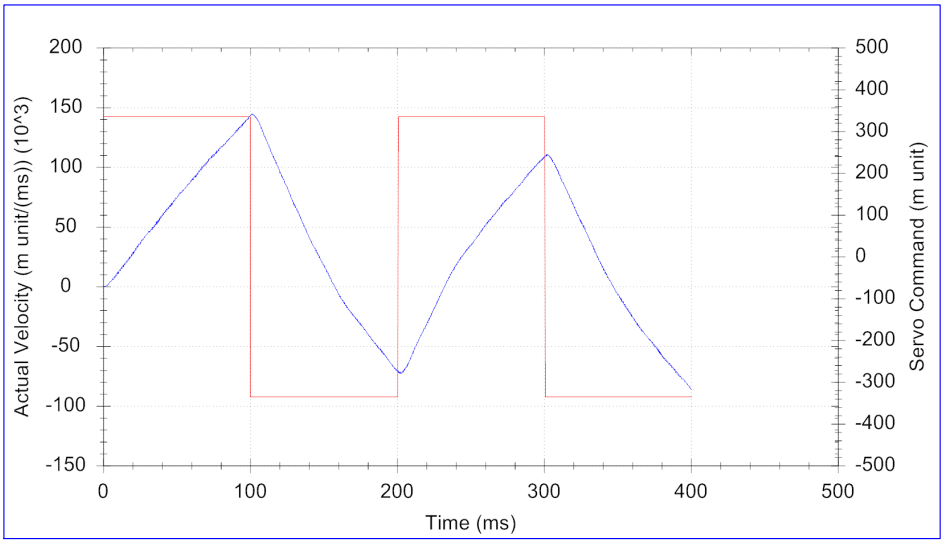




Caution

Do not attempt to close the position loop on a motor which has not passed the open loop test or show an inverted saw tooth-shaped velocity response. This may lead to dangerous runaway conditions.

A positive command should create a velocity and position counting in the positive direction; a negative command should create a velocity and position counting in the negative direction. This is typically observed in the response plot as a velocity saw tooth. A successful open-loop test response looks like:



Troubleshooting tips:

With DC brush motors, an unsuccessful open loop test (inverted saw tooth) could indicate one of the following:

- Reversed encoder direction sense; **PowerBrick[].Chan[].EncCtrl** (e.g. 7 to 3).
  Not applicable to serial encoders.
- With serial encoders, it is recommended to swap the motor leads to reverse direction.
- **Motor[].PhaseTableBias** is not set to **0**.

Position Loop Tuning

Position loop tuning is performed in the exact same manner as brushless motors.



Caution

Do not attempt to close the position loop or perform position loop tuning on a motor which open-loop test has failed. This may lead to dangerous runaway conditions.

AC Induction Motors

The setup for closed-loop control of AC Induction motors is similar to the setup of DC Brushless motors, except the magnetization current parameter **Motor[].IdCmd** must also be configured in order to run the motor.

Having performed the following:

- Global Reset (optional but recommended).
- Set up the dominant clock frequencies.
- Unpacked the ADC input and phase output data.
- Set up the **BrickAC** structure elements (e.g. **BrickAC.SinglePhaseIn**).
- Set up the power-on reset PLC.
- Verified encoder feedback.



Caution

If the +24 VDC abort input is not wired in or disabled in software (**Sys.pAbortAll = 0**), PMAC will try to close the loop on the motor every time it is enabled which could cause the motor to move or jump unexpectedly (if it has not been set up).

The abort input must be wired in (+24 VDC) or disabled in software (**Sys.pAbortAll = 0**) prior to attempting to enable the motor.

If the +24 VDC abort input is not wired in or disabled in software (**Sys.pAbortAll = 0**), PMAC will try to close the loop on the motor every time it is enabled.

Motor and channel specific parameters can now be configured to finalize the setup procedure of a brushless motor.



Note

A motor or channel parameter which is not discussed in the structure elements below is assumed – and should typically be left – at default.

Common AC Induction Motor Setup Elements

The following, are common motor structure elements for setting up induction motors:

```
Motor[1].pLimits = PowerBrick[0].Chan[0].Status.a
Motor[1].AdcMask = $FFF00000
Motor[1].AmpFaultLevel = 1
Motor[1].ServoCtrl = 1
Motor[1].PhaseCtrl = 4
Motor[1].PhaseOffset = 683
```

PWM Output Scale Factor

The PWM scale factor, **Motor[].PwmSf**, specifies the maximum command output (voltage limiter). With the Power Brick AC, the nominal value is 16,384.

- If the motor rated voltage is greater than > the input bus voltage:

```
Motor[1].PwmSf = 0.95 * 16384
```

- If the input bus voltage is greater than > the motor rated voltage:

```
GLOBAL DcBusInput = 340;
GLOBAL Mtr1DCVoltage = 170;

Motor[1].PwmSf = 0.95 * 16384 * Mtr1DCVoltage / DcBusInput
```

Ongoing Phase Position

Please refer to the

Ongoing Phase Position section of the DC Brushless motor setup as this is the same.

Magnetization Current and Slip Gain

Motor[].IdCmd must be configured before the I2T settings can be completed. An initial estimation of this setting can be obtained from the continuous current printed on the faceplate of the AC Induction motor and the full current reading, Max ADC, of the amplifier.

Channel Rating	Max ADC
5 A / 10 A	15.625 A
8 A / 16 A	25.0 A
15 A / 30 A	46.875 A

Example Settings:

```
#define Ch1MaxAdc       46.875  // Max ADC reading [A rms]          --User Input
#define Ch1RmsContCur   6.8     // RMS Continuous Current [A rms]   --User Input
Motor[1].IdCmd = Ch1RmsContCur / (2 * Ch1MaxAdc / 32767 * SQRT(2/3))
```



Note

This is only a starting point for **Motor[].IdCmd**. You should optimize it later.

Once **Motor[].IdCmd** has been configured, the slip gain, **Motor[].DtOverRotorTc,** can be computed with additional information from the faceplate as in the following example code:

```
#define Mtr1Freq       60.0    // Hz
#define Mtr1NumPoles   4.0
#define Mtr1RatedRPM   1760    // RPM
#define _PI 3.14159265359
#define we (Mtr1Freq * 2.0 * _PI)
#define wm (Mtr1RatedRPM / 60.0 * 2.0 * _PI * Mtr1NumPoles / 2.0)
#define Tp (1.0 / PowerBrick[0].PhaseFreq)
Motor[1].DtOverRotorTc = (we - wm) * Tp * Motor[1].IdCmd / 32768.0
```

Where:
Mtr1Freq is the rated frequency of the motor.
Mtr1NumPoles is the number of poles the motor has.
Tp is the phase period in milliseconds.
we and **wm** are quantities used to estimate the slip gain.

After using this to configure the I2T settings initially below, **Motor[].IdCmd** should be refined empirically (to be discussed later). After refining **Motor[].IdCmd**, **Motor[].DtOverRotorTc** should be recalculated using the new value.

I2T Protection

The maximum ADC, or full current reading, is specified per the power rating of the channel:

Channel Rating	Max ADC
5 A / 10 A	15.625 A
8 A / 16 A	25.0 A
15 A / 30 A	46.875 A



Caution

If the current limits of the motor are given as peak values, there is no need to multiply by √2 (1.414).

If the motor current limits are given in RMS values, or using those of the Power Brick AC drive:

TempMaxDac = $PeakCurrent_{rms}$ * 32768 * √2 * cos(30°) / MaxAdc
Motor[].MaxDac = SQRT(TempMaxDac^2 – Motor[].IdCmd^2)

TempI2TSet = $ContinuousCurrent_{rms}$ * 32768 * √2 * cos(30°) / MaxAdc
Motor[].I2TSet = SQRT(TempI2TSet^2 – Motor[].IdCmd^2)

Motor[].I2TTrip = (Motor[]MaxDac^2 + Motor[].IdCmd^2 – Motor[].I2Set^2) * TimeAtPeak

```
GLOBAL Ch1MaxAdc = 46.875;     // Max ADC reading [A peak]           --User Input
GLOBAL Ch1RmsPeakCur = 15;     // RMS Peak Current [A rms]           --User Input
GLOBAL Ch1RmsContCur = 7;      // RMS Continuous Current [A rms]     --User Input
GLOBAL Ch1TimeAtPeak = 1;      // Time Allowed at peak [sec]         --User Input
GLOBAL Ch1TempMaxDac;
GLOBAL Ch1TempI2TSet;
Ch1TempMaxDac = Ch1RmsPeakCur * 40132.44 / Ch1MaxAdc
Ch1TempI2TSet = Ch1RmsContCur * 40132.44 / Ch1MaxAdc
Motor[1].MaxDac = SQRT(POW(Ch1TempMaxDac,2) - POW(Motor[1].IdCmd,2))
Motor[1].I2TSet = SQRT(POW(Ch1TempI2TSet,2) - POW(Motor[1].IdCmd,2))
Motor[1].I2tTrip =(POW(Motor[1].MaxDac,2)+POW(Motor[1].IdCmd,2)-POW(Motor[1].I2TSet,2))*Ch1TimeAtPeak
```

If the motor current limits are given in peak values:

TempMaxDac = $PeakCurrent_{peak}$ * 32768 * cos(30°) / MaxAdc
Motor[].MaxDac = SQRT(TempMaxDac^2 – Motor[].IdCmd^2)

TempI2TSet = $ContinuousCurrent_{peak}$ * 32768 * cos(30°) / MaxAdc
Motor[].I2TSet = SQRT(TempI2TSet^2 – Motor[].IdCmd^2)

Motor[].I2TTrip = (Motor[]MaxDac^2 + Motor[].IdCmd^2 – Motor[].I2Set^2) * TimeAtPeak

```
GLOBAL Ch1MaxAdc = 46.875;     // Max ADC reading [A peak]           --User Input
GLOBAL Ch1PeakCur = 15;        // Peak Current [A peak]              --User Input
GLOBAL Ch1ContCur = 7;         // Continuous Current [A peak]        --User Input
GLOBAL Ch1TimeAtPeak = 1;      // Time Allowed at peak [sec]         --User Input
GLOBAL Ch1TempMaxDac;
GLOBAL Ch1TempI2TSet;
Ch1TempMaxDac = Ch1PeakCur * 28378 / Ch1MaxAdc
Ch1TempI2TSet = Ch1ContCur * 28378 / Ch1MaxAdc
Motor[1].MaxDac = SQRT(POW(Ch1TempMaxDac,2) - POW(Motor[1].IdCmd,2))
Motor[1].I2TSet = SQRT(POW(Ch1TempI2TSet,2) - POW(Motor[1].IdCmd,2))
Motor[1].I2tTrip =(POW(Motor[1].MaxDac,2)+POW(Motor[1].IdCmd,2)-POW(Motor[1].I2TSet,2))*Ch1TimeAtPeak
```

ADC Offsets

The amplifier firmware of the Power Brick AC has a built-in current ADC auto-calibration routine. It compensates dynamically (every time the channel-drive is enabled) for current sensor reading offsets. There is no practical advantage in setting those up for offset calibration purposes. Therefore, **Motor[].IaBias** and **Motor[].IbBias** should be left at the default value of zero in normal mode operation.



Note

The Power PMAC firmware also has an auto-calibration routine for current offsets compensation built into the firmware; **Motor[].CurrentNullPeriod**. This is not needed with the Power Brick AC.

Current Loop Tuning

Please refer to the Current Loop Tuning section of the DC Brushless motor setup as this is the same.

Motor Phasing

Please refer to the Motor Phasing section of the DC Brushless motor setup as it is the same.

Open Loop Test

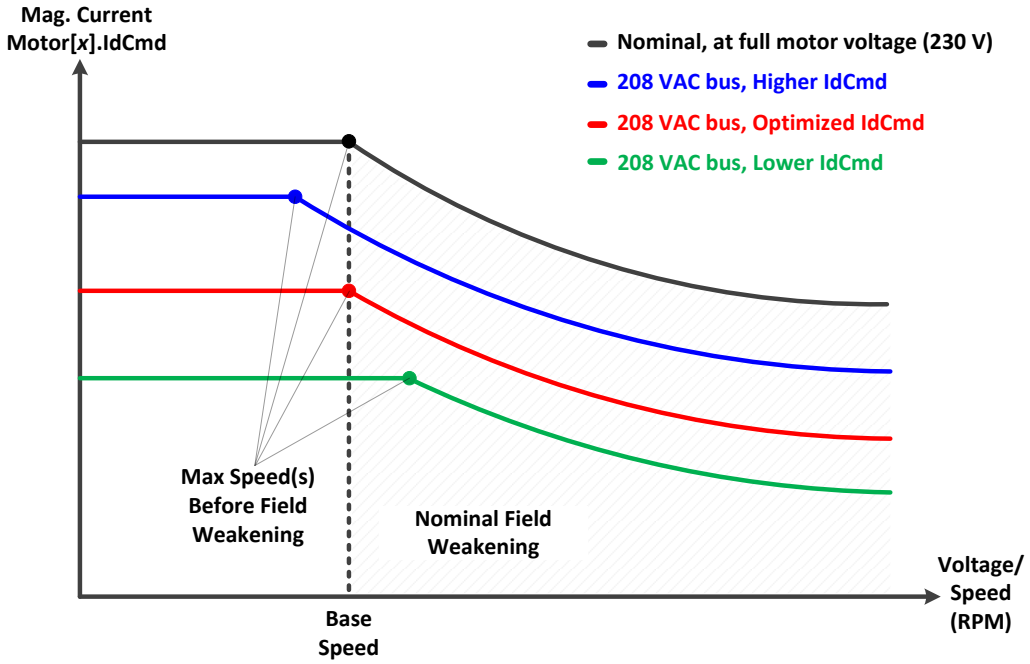
Please refer to the Open Loop Test section of the DC Brushless motor setup as it is the same.

Optimizing Magnetization Current

At this point in the setup, the magnetization current parameter, **Motor[].IdCmd**, can be optimized for better torque output. The goal is to vary **Motor[].IdCmd** until the motor achieves its rated speed from the faceplate/datasheet of the motor (e.g. 1760 RPM) with an open loop output command. Assuming the motor has been properly configured up to this point, the following procedure can be used:

1. Issue an open loop output command (e.g. **#nout25**, where **n** is the motor number) and wait for the motor to reach a steady state speed (i.e. a speed that no longer varies).
2. If the motor's speed is below the rated speed, decrease **Motor[].IdCmd** by a small amount. If the motor's speed is above the rated speed, increase **Motor[].IdCmd** by a small amount.
3. Repeat step 2 until the rated speed is stably reached.
4. Save the final **Motor[].IdCmd** value to your project files.
5. Reprogram **Motor[].I2tTrip** and **Motor[].DtRotorOverTc** using the new **Motor[].IdCmd**.

If the user wants the motor to run faster than the rated speed, a field weakening algorithm can be used. The following diagram illustrates how magnetization current affects the motor's maximum achievable speed for a given voltage:



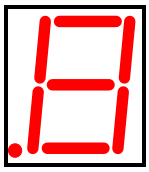
Position Loop Tuning

Please refer to the Position Loop Tuning section of the DC Brushless motor setup as it is the same.

SPECIAL FUNCTIONS & TROUBLESHOOTING

D1: Error Codes

The Power Brick AC utilizes a scrolling single-digit 7-segment display to exhibit amplifier faults. In normal operation mode (logic and DC bus power applied), the Power Brick AC will display a solid dot indicating that the software and hardware are running normally.



	Axis #1		**Axis #5**		**Shunt Over Voltage**
	**Axis #2**		**Axis #6**		**Bus Under Voltage**
	**Axis #3**		**Axis #7**		**Bus Over Voltage**
	**Axis #4**		**Axis #8**		**Phase Missing**

	**Soft Start Fault**		**Dynamic Brake**		**Thermal Dynamic Fault**
	**2nd Soft Start Fault**		**IGBT Over Temperature**		**PWM Out Of Range**
	**Shunt Resistor Fault**		**IGBT Over-Current (Short Circuit)**		**Power Fault**
	**Emergency Brake**		**I2T Fault**		**Power Brick AC OK**



Note

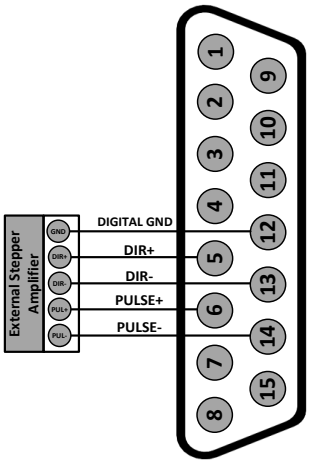
In order to reset (clear) the amplifier faults through software, the power-on reset PLC must be enabled.

Step and Direction, PFM Output

The Power Brick AC has the capability of generating step and direction output signals - aka PFM (Pulse Frequency Modulation) – for general purpose usage or control of external devices such as stepper amplifiers. The maximum pulse frequency and minimum pulse width are typically provided by the third party device manufacturer.

The step and direction outputs are RS422 compatible, +5 VDC level, and could be connected in either differential or single-ended configuration.

These PFM signals are generated out of the X1 – X8 encoder connectors, not to confuse them with the motor output connectors Amp1 – Amp8.



Pins #5, 6, 13, and 14 of the encoder feedback connectors (X1 – X8) share three different functions: only one of these functions (per channel) can be used – configured in software – at one time:

- Pulse and direction PFM output signals.
- TUVW hall flag inputs.
- Serial Encoder input.



Note

Each channel is independent of the other channels and can have its own use for these pins.

Most common usage of the PFM output signals:

- Manual modulation (from HMI or PLC, e.g. Laser modulation).
- Controlling an external stepper amplifier/motor.

Common Channel Settings for PFM Output (Example: Channel 1):

```
PowerBrick[0].Chan[0].PackOutData = 0        // Unpack Output Data
PowerBrick[0].Chan[0].OutputMode = PowerBrick[0].Chan[0].OutputMode | $8   // Force D PFM
PowerBrick[0].Chan[0].PfmFormat = 0          // =0 PFM, =1 Quadrature
PowerBrick[0].Chan[0].PfmDirPol = 0          // Non-Inverted
PowerBrick[0].Chan[0].OutFlagD = 1           // =0 for halls, =1 for PFM
```

PFM Output Signal Settings

1. Chose the maximum PFM frequency in MHz from the table below (only). This frequency must be faster than the maximum desired speed if controlling an external stepper amplifier/motor, or faster than the maximum desired frequency of whichever device it is connected to. Set **PowerBrick[].Chan[].PfmClockDiv**.

PfmClockDiv	Frequency	PfmClockDiv	Frequency
0	100 MHz	8	0.390625 MHz
1	50 MHz	9	0.1953125 MHz
2	25 MHz	10	0.09765625 MHz
3	12.5 MHz	11	0.048828125 MHz
4	6.25 MHz	12	0.024414063 MHz
5	3.125 MHz	13	0.012207031 MHz
6	1.5625 MHz	14	0.006103516 MHz
7	0.78125 MHz	15	0.003051758 MHz



Note

It is not a good practice to automatically choose the maximum frequency of 100 MHz. Faster signals trade off speed for signal quality due to quantization noise and jitter.

2. Compute the minimum possible pulse width for the chosen max frequency.

3. Choose a pulse width greater than or equal to the computed minimum pulse width. This desired pulse width must be a multiple integer of the computed minimum pulse width. Set **PowerBrick[].Chan[].PfmWidth** accordingly.

Example: Channel 1

```
GLOBAL MaxPfmFreq = 25;                          // [MHz]
GLOBAL MinPulseWidth = 1000 / MaxPfmFreq;        // 40 [nsec]
GLOBAL PulseWidth = 40 * 15;                     // 600 [nsec]

PowerBrick[0].PfmClockDiv = LOG2(100 / (MaxPfmFreq))              // 2
PowerBrick[0].Chan[0].PfmWidth = PulseWidth * MaxPfmFreq / 1000    // $F (15)
```

Maximum Achievable Frequency

The maximum achievable frequency (speed) with the chosen frequency and pulse width can be computed as follows:

```
GLOBAL PfmMaxSpeed = 1000000 / (PulseWidth + MinPulseWidth);       // [kHz]
```

Manual Modulation

The PFM Output can now be modulated manually by writing to the structure element **PowerBrick[].Chan[].Pfm,** as scaled below**.** For a 5 kHz output frequency:

```
PowerBrick[0].Chan[0].Pfm = 5 * 4294483.648 / MaxPfmFreq
```

Controlling an External Stepper Amplifier / Motor

"Closing the loop" or jogging a motor driven by an external amplifier requires the following settings.

Example, channel / motor #1:

```
PowerBrick[0].Chan[0].EncCtrl = 8             // Internal Pulse And Direction
PowerBrick[0].Chan[0].TimerMode = 3           // Read as PFM when looped back in with EncCtrl = 8
Motor[1].ServoCtrl = 1                        // Activate channel
Motor[1].pLimits = 0                          // Disable overtravel limits
Motor[1].pAmpFault = 0                        // Disable amplifier fault
Motor[1].pDac = PowerBrick[0].Chan[0].Pfm.a   // Command output, point to PFM
Motor[1].MaxDac = 2 * 32768 / (MaxPfmFreq * 1000 / (1000000 / (PulseWidth + MinPulseWidth)))

Motor[1].Servo.Kp = 50                        // Servo PID Kp Gain
Motor[1].Servo.Kvfb = 0                       // Servo PID Kvfb Gain
Motor[1].Servo.Kvff = 50                      // Servo PID Kvff Gain
Motor[1].Servo.Ki = 0.001                     // Servo PID Ki Gain
Motor[1].InPosBand = 10                       // In position Bandwidth [motor units]
Motor[1].Servo.BreakPosErr = 1                // Deadband size [motor units]
Motor[1].Servo.Kbreak = 0                     // Deadband gain

Motor[1].FatalFeLimit = 0                     // Fatal following limit
Motor[1].WarnFeLimit = 0                      // Fatal following warning
```

The **MaxDac,** computed empirically**,** is the maximum command output which produces the maximum PFM speed (frequency) with a 100% open loop output. Do not issue this command with the signals connected to an amplifier/motor/device.

The servo PID gains can be tuned experimentally, and since this is a synthetic loop, the goal is to have sufficient gains to allow the maximum desired speed, and no pulsing at standstill. Adding a small Deadband can be helpful alleviating small pulses at zero velocity (due to quantization) when higher PFM frequencies are used.



Note

The maximum value(s) which **Motor[].JogSpeed** or **Motor[].MaxSpeed** can/should be set to is the previously computed **PfmMaxSpeed**.

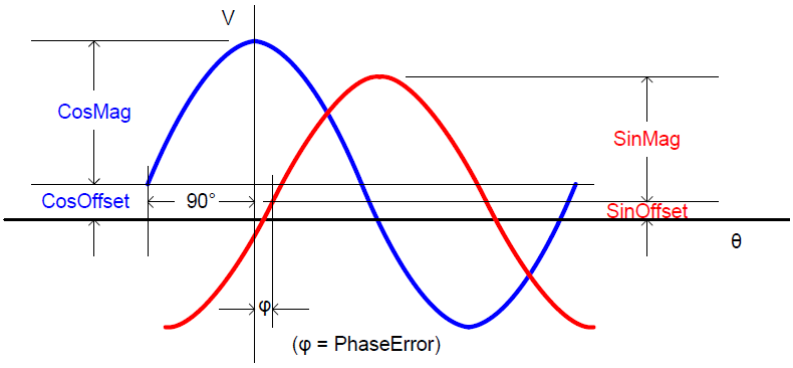


Note

It is impossible to generate a PFM frequency higher than the encoder sampling rate in this mode. The encoder clock frequency **PowerBrick[].EncClockDiv** may need to be increased from the default of 3.125 MHz if higher frequencies are required.

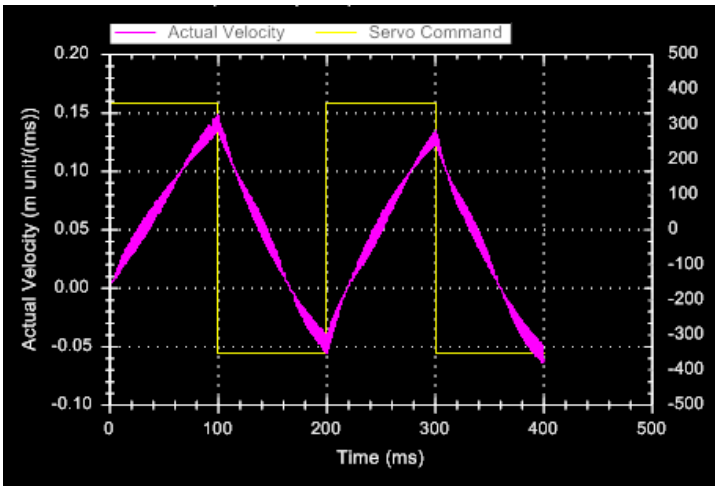
Sinusoidal Encoder Bias Corrections

Before computing the sub-count interpolated position with the arctangent calculation, the PMAC3-style ASIC can add in offset terms to the measured values in the ADC registers to compensate for voltage biases in the encoder and/or receiving circuitry.

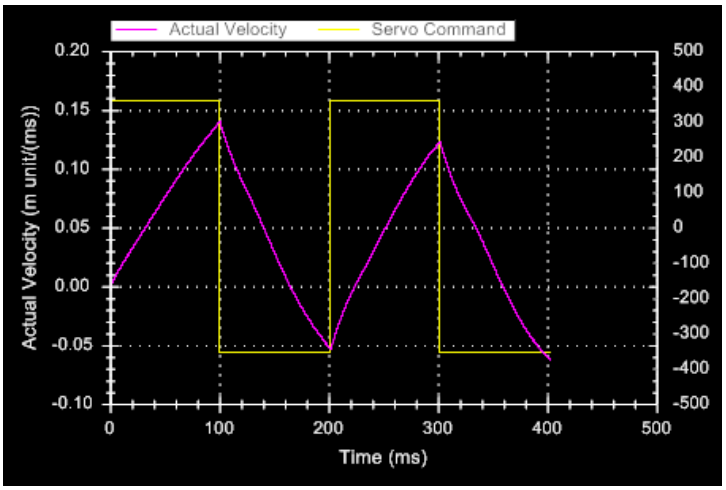


Excessive biases due to scale/read head misalignment, noise, or mechanical assembly may result in rough motion, visible velocity harmonics, and or encoder count loss. This is best seen with an open loop test:

Uncorrected



Corrected





Note

Corrections with the ACI (Auto Correcting Interpolator) are done automatically for both offsets and phase. This procedure is only suitable when interpolating with the DSPGate3 (x16384) – without the ACI option.

The Sine and Cosine offset structure elements are **PowerBrick[].Chan[].AdcOffset[0]** and **PowerBrick[].Chan[].AdcOffset[1]**, respectively.

Compensating for these offsets is done by reading the Sine – **PowerBrick[].Chan[].AdcEnc[0] –** and Cosine – **PowerBrick[].Chan[].AdcEnc[1] –** signals while moving the motor (preferably slowly) in open loop – by hand – or closed loop along the full travel, and computing their min and max values. The offset for each signal is then computed by averaging the min and the max values. The opposite value of this average is written into the corresponding offset register.

The following PLC program can assist in finding these bias offsets.

```
PTR Enc1Sine->PowerBrick[0].Chan[0].AdcEnc[0];
PTR Enc1Cosine->PowerBrick[0].Chan[0].AdcEnc[1];
GLOBAL Enc1SineOffset = 0, Enc1CosineOffset = 0;

PTR Enc2Sine->PowerBrick[0].Chan[1].AdcEnc[0];
PTR Enc2Cosine->PowerBrick[0].Chan[1].AdcEnc[1];
GLOBAL Enc2SineOffset = 0, Enc2CosineOffset = 0;

PTR Enc3Sine->PowerBrick[0].Chan[2].AdcEnc[0];
PTR Enc3Cosine->PowerBrick[0].Chan[2].AdcEnc[1];
GLOBAL Enc3SineOffset = 0, Enc3CosineOffset = 0;

PTR Enc4Sine->PowerBrick[0].Chan[3].AdcEnc[0];
PTR Enc4Cosine->PowerBrick[0].Chan[3].AdcEnc[1];
GLOBAL Enc4SineOffset = 0, Enc4CosineOffset = 0;

PTR Enc5Sine->PowerBrick[1].Chan[0].AdcEnc[0];
PTR Enc5Cosine->PowerBrick[1].Chan[0].AdcEnc[1];
GLOBAL Enc5SineOffset = 0, Enc5CosineOffset = 0;

PTR Enc6Sine->PowerBrick[1].Chan[1].AdcEnc[0];
PTR Enc6Cosine->PowerBrick[1].Chan[1].AdcEnc[1];
GLOBAL Enc6SineOffset = 0, Enc6CosineOffset = 0;

PTR Enc7Sine->PowerBrick[1].Chan[2].AdcEnc[0];
PTR Enc7Cosine->PowerBrick[1].Chan[2].AdcEnc[1];
GLOBAL Enc7SineOffset = 0, Enc7CosineOffset = 0;

PTR Enc8Sine->PowerBrick[1].Chan[3].AdcEnc[0];
PTR Enc8Cosine->PowerBrick[1].Chan[3].AdcEnc[1];
GLOBAL Enc8SineOffset = 0, Enc8CosineOffset = 0;

OPEN PLC SineCalPLC
LOCAL SineCycles = 0;
LOCAL MaxEnc1Sine, MaxEnc1Cosine, MinEnc1Sine, MinEnc1Cosine;
LOCAL MaxEnc2Sine, MaxEnc2Cosine, MinEnc2Sine, MinEnc2Cosine;
LOCAL MaxEnc3Sine, MaxEnc3Cosine, MinEnc3Sine, MinEnc3Cosine;
LOCAL MaxEnc4Sine, MaxEnc4Cosine, MinEnc4Sine, MinEnc4Cosine;
LOCAL MaxEnc5Sine, MaxEnc5Cosine, MinEnc5Sine, MinEnc5Cosine;
LOCAL MaxEnc6Sine, MaxEnc6Cosine, MinEnc6Sine, MinEnc6Cosine;
LOCAL MaxEnc7Sine, MaxEnc7Cosine, MinEnc7Sine, MinEnc7Cosine;
LOCAL MaxEnc8Sine, MaxEnc8Cosine, MinEnc8Sine, MinEnc8Cosine;
```

```
WHILE(1)
{
        // ================== ENCODER 1 BIAS CORRECTIONS ==================== //
        IF (SineCycles == 0)
        {
                MaxEnc1Sine = Enc1Sine
                MinEnc1Sine = Enc1Sine
                MaxEnc1Cosine = Enc1Cosine
                MinEnc1Cosine = Enc1Cosine
        }
        IF (Enc1Sine > MaxEnc1Sine){MaxEnc1Sine = Enc1Sine}
        IF (Enc1Sine < MinEnc1Sine){MinEnc1Sine = Enc1Sine}
        IF (Enc1Cosine > MaxEnc1Cosine){MaxEnc1Cosine = Enc1Cosine}
        IF (Enc1Cosine < MinEnc1Cosine){MinEnc1Cosine = Enc1Cosine}
        Enc1SineOffset = - (MaxEnc1Sine + MinEnc1Sine) / (2 * 65536)
        Enc1CosineOffset = - (MaxEnc1Cosine + MinEnc1Cosine) / (2 * 65536)
        // ================================================================= //

        // ================== ENCODER 2 BIAS CORRECTIONS ==================== //
        IF (SineCycles == 0)
        {
                MaxEnc2Sine = Enc2Sine
                MinEnc2Sine = Enc2Sine
                MaxEnc2Cosine = Enc2Cosine
                MinEnc2Cosine = Enc2Cosine
        }
        IF (Enc2Sine > MaxEnc2Sine){MaxEnc2Sine = Enc2Sine}
        IF (Enc2Sine < MinEnc2Sine){MinEnc2Sine = Enc2Sine}
        IF (Enc2Cosine > MaxEnc2Cosine){MaxEnc2Cosine = Enc2Cosine}
        IF (Enc2Cosine < MinEnc2Cosine){MinEnc2Cosine = Enc2Cosine}
        Enc2SineOffset = - (MaxEnc2Sine + MinEnc2Sine) / (2 * 65536)
        Enc2CosineOffset = - (MaxEnc2Cosine + MinEnc2Cosine) / (2 * 65536)
        // ================================================================= //

        // ================== ENCODER 3 BIAS CORRECTIONS ==================== //
        IF (SineCycles == 0)
        {
                MaxEnc3Sine = Enc3Sine
                MinEnc3Sine = Enc3Sine
                MaxEnc3Cosine = Enc3Cosine
                MinEnc3Cosine = Enc3Cosine
        }
        IF (Enc3Sine > MaxEnc3Sine){MaxEnc3Sine = Enc3Sine}
        IF (Enc3Sine < MinEnc3Sine){MinEnc3Sine = Enc3Sine}
        IF (Enc3Cosine > MaxEnc3Cosine){MaxEnc3Cosine = Enc3Cosine}
        IF (Enc3Cosine < MinEnc3Cosine){MinEnc3Cosine = Enc3Cosine}
        Enc3SineOffset = - (MaxEnc3Sine + MinEnc3Sine) / (2 * 65536)
        Enc3CosineOffset = - (MaxEnc3Cosine + MinEnc3Cosine) / (2 * 65536)
        // ================================================================= //
```

```
// ================== ENCODER 4 BIAS CORRECTIONS ================== //
IF (SineCycles == 0)
{
        MaxEnc4Sine = Enc4Sine
        MinEnc4Sine = Enc4Sine
        MaxEnc4Cosine = Enc4Cosine
        MinEnc4Cosine = Enc4Cosine
}
IF (Enc4Sine > MaxEnc4Sine){MaxEnc4Sine = Enc4Sine}
IF (Enc4Sine < MinEnc4Sine){MinEnc4Sine = Enc4Sine}
IF (Enc4Cosine > MaxEnc4Cosine){MaxEnc4Cosine = Enc4Cosine}
IF (Enc4Cosine < MinEnc4Cosine){MinEnc4Cosine = Enc4Cosine}
Enc4SineOffset = - (MaxEnc4Sine + MinEnc4Sine) / (2 * 65536)
Enc4CosineOffset = - (MaxEnc4Cosine + MinEnc4Cosine) / (2 * 65536)
// ================================================================ //

// ================== ENCODER 5 BIAS CORRECTIONS ================== //
IF (SineCycles == 0)
{
        MaxEnc5Sine = Enc5Sine
        MinEnc5Sine = Enc5Sine
        MaxEnc5Cosine = Enc5Cosine
        MinEnc5Cosine = Enc5Cosine
}
IF (Enc5Sine > MaxEnc5Sine){MaxEnc5Sine = Enc5Sine}
IF (Enc5Sine < MinEnc5Sine){MinEnc5Sine = Enc5Sine}
IF (Enc5Cosine > MaxEnc5Cosine){MaxEnc5Cosine = Enc5Cosine}
IF (Enc5Cosine < MinEnc5Cosine){MinEnc5Cosine = Enc5Cosine}
Enc5SineOffset = - (MaxEnc5Sine + MinEnc5Sine) / (2 * 65536)
Enc5CosineOffset = - (MaxEnc5Cosine + MinEnc5Cosine) / (2 * 65536)
// ================================================================ //

// ================== ENCODER 6 BIAS CORRECTIONS ================== //
IF (SineCycles == 0)
{
        MaxEnc6Sine = Enc6Sine
        MinEnc6Sine = Enc6Sine
        MaxEnc6Cosine = Enc6Cosine
        MinEnc6Cosine = Enc6Cosine
}
IF (Enc6Sine > MaxEnc6Sine){MaxEnc6Sine = Enc6Sine}
IF (Enc6Sine < MinEnc6Sine){MinEnc6Sine = Enc6Sine}
IF (Enc6Cosine > MaxEnc6Cosine){MaxEnc6Cosine = Enc6Cosine}
IF (Enc6Cosine < MinEnc6Cosine){MinEnc6Cosine = Enc6Cosine}
Enc6SineOffset = - (MaxEnc6Sine + MinEnc6Sine) / (2 * 65536)
Enc6CosineOffset = - (MaxEnc6Cosine + MinEnc6Cosine) / (2 * 65536)
// ================================================================ //
```

```
        // ================== ENCODER 7 BIAS CORRECTIONS ==================== //
        IF (SineCycles == 0)
        {
                MaxEnc7Sine = Enc7Sine
                MinEnc7Sine = Enc7Sine
                MaxEnc7Cosine = Enc7Cosine
                MinEnc7Cosine = Enc7Cosine
        }
        IF (Enc7Sine > MaxEnc7Sine){MaxEnc7Sine = Enc7Sine}
        IF (Enc7Sine < MinEnc7Sine){MinEnc7Sine = Enc7Sine}
        IF (Enc7Cosine > MaxEnc7Cosine){MaxEnc7Cosine = Enc7Cosine}
        IF (Enc7Cosine < MinEnc7Cosine){MinEnc7Cosine = Enc7Cosine}
        Enc7SineOffset = - (MaxEnc7Sine + MinEnc7Sine) / (2 * 65536)
        Enc7CosineOffset = - (MaxEnc7Cosine + MinEnc7Cosine) / (2 * 65536)
        // ================================================================= //

        // ================== ENCODER 8 BIAS CORRECTIONS ==================== //
        IF (SineCycles == 0)
        {
                MaxEnc8Sine = Enc8Sine
                MinEnc8Sine = Enc8Sine
                MaxEnc8Cosine = Enc8Cosine
                MinEnc8Cosine = Enc8Cosine
        }
        IF (Enc8Sine > MaxEnc8Sine){MaxEnc8Sine = Enc8Sine}
        IF (Enc8Sine < MinEnc8Sine){MinEnc8Sine = Enc8Sine}
        IF (Enc8Cosine > MaxEnc8Cosine){MaxEnc8Cosine = Enc8Cosine}
        IF (Enc8Cosine < MinEnc8Cosine){MinEnc8Cosine = Enc8Cosine}
        Enc8SineOffset = - (MaxEnc8Sine + MinEnc8Sine) / (2 * 65536)
        Enc8CosineOffset = - (MaxEnc8Cosine + MinEnc8Cosine) / (2 * 65536)
        // ================================================================= //

        SineCycles++
}
CLOSE
```

Using this PLC, and implementing the Sine and Cosine offsets:

- Delete bias corrections for channels which are not of interest.
- Enable the PLC (**ENABLE PLC SineCalPLC**).
  This PLC does not actively write to any structure element(s) or move any motor(s).
- Insert **EncXSineOffset** and **EncXCosineOffset** (for a given channel X) in the watch window.
- Move the motor (preferably slowly) along the full travel, back and forth, jogging or by hand.
- The **EncXSineOffset** and **EncXCosineOffset** will stop changing when the maximum and minimum values are reached indicating that the offsets have been computed.
- Disable the PLC (**DISABLE PLC SineCalPLC**).

- Write the computed offsets into the corresponding channel's elements (upper 16 bits):

```
PowerBrick[0].Chan[0].AdcOffset[0] = Enc1SineOffset * 65536        // Channel 1 Sine Offset
PowerBrick[0].Chan[0].AdcOffset[1] = Enc1CosineOffset * 65536      // Channel 1 Cosine Offset

PowerBrick[0].Chan[1].AdcOffset[0] = Enc2SineOffset * 65536        // Channel 2 Sine Offset
PowerBrick[0].Chan[1].AdcOffset[1] = Enc2CosineOffset * 65536      // Channel 2 Cosine Offset

PowerBrick[0].Chan[2].AdcOffset[0] = Enc3SineOffset * 65536        // Channel 3 Sine Offset
PowerBrick[0].Chan[2].AdcOffset[1] = Enc3CosineOffset * 65536      // Channel 3 Cosine Offset

PowerBrick[0].Chan[3].AdcOffset[0] = Enc4SineOffset * 65536        // Channel 4 Sine Offset
PowerBrick[0].Chan[3].AdcOffset[1] = Enc4CosineOffset * 65536      // Channel 4 Cosine Offset

PowerBrick[1].Chan[0].AdcOffset[0] = Enc5SineOffset * 65536        // Channel 5 Sine Offset
PowerBrick[1].Chan[0].AdcOffset[1] = Enc5CosineOffset * 65536      // Channel 5 Cosine Offset

PowerBrick[1].Chan[1].AdcOffset[0] = Enc6SineOffset * 65536        // Channel 6 Sine Offset
PowerBrick[1].Chan[1].AdcOffset[1] = Enc6CosineOffset * 65536      // Channel 6 Cosine Offset

PowerBrick[1].Chan[2].AdcOffset[0] = Enc7SineOffset * 65536        // Channel 7 Sine Offset
PowerBrick[1].Chan[2].AdcOffset[1] = Enc7CosineOffset * 65536      // Channel 7 Cosine Offset

PowerBrick[1].Chan[3].AdcOffset[0] = Enc8SineOffset * 65536        // Channel 8 Sine Offset
PowerBrick[1].Chan[3].AdcOffset[1] = Enc8CosineOffset * 65536      // Channel 8 Cosine Offset
```



Note

This procedure is done once per installation. These offsets must be saved in the project file(s) / configuration for the life of the motor / encoder.



Note

The PLC may be discarded once the procedure is finished. It does not need to be saved in the application project.

Reversing Motor Jogging Direction

Choosing the direction sense is possible during the normal setup of a motor. Oftentimes, users wish to reverse the direction sense after the motor has been set up. Following, are the necessary steps with respect to each type of encoder.



Caution

These settings should not be applied while the motor is energized. The motor must be killed before applying these changes.

Quadrature / Sinusoidal / Resolver

- **Motor[].PhaseOffset** = – present value
- **Motor[].PwmSf** = – present value
- **PowerBrick[].Chan[].EncCtrl** = the opposite decode of the present value (e.g. 7 or 3)

If using resolver or halls absolute power-on phasing:

- **Motor[].AbsPhasePosSf** = – present value
- **Motor[].AbsPhasePosOffset = 2048** – present value

If using resolver absolute power-on position:

- **Motor[].AbsPosSf** = – present value

Incremental Serial Encoders

- **Motor[].PhaseOffset** = – present value
- **Motor[].PwmSf** = – present value
- **Motor[].PhasePosSf** = – present value
- **Motor[].PosSf** = – present value
- **Motor[].Pos2Sf** = – present value

Absolute Serial Encoders

- **Motor[].PhaseOffset** = – present value
- **Motor[].PwmSf** = – present value
- **Motor[].PhasePosSf** = – present value
- **Motor[].PosSf** = – present value
- **Motor[].Pos2Sf** = – present value
- **Motor[].AbsPosSf** = – present value
- **Motor[].AbsPhasePosSf** = – present value
- **Motor[].AbsPhasePosOffset = 2048** – present value



Note

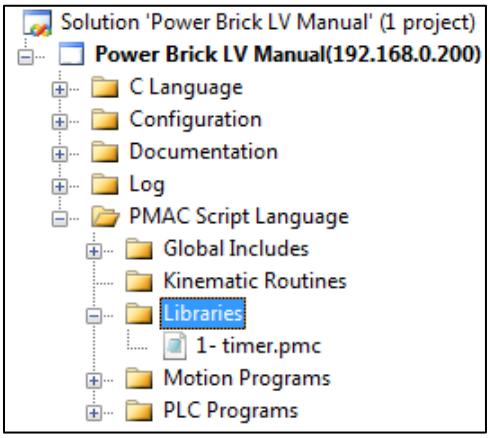
PMAC-commutated (e.g. Brushless) motors need to be phased again after applying these settings. All other settings (e.g. current & position loop tuning) should remain the same.

PLC Timer Delay

The following subprogram is a generic routine which is commonly called from PLC programs to insert a time delay in the logic process.

```
OPEN SUBPROG Timer (time)
LOCAL EndTime;
EndTime = Sys.Time + time
WHILE (EndTime > Sys.Time){}
CLOSE
```

This subprogram can be placed in the "Libraries" folder in the IDE project:



Calling the **Timer** subprogram and specifying a **time** argument in seconds causes the desired delay in a script PLC, example:

```
GLOBAL MyToggle = 0;

OPEN PLC ExamplePLC
CALL Timer (1)          // 1 second delay
MyToggle = MyToggle ^ 1 // Toggle user defined variable
CLOSE
```



Note

The Timer subprogram can be called from motion programs or other subprograms as well. However, for those types of programs the better suited and dedicated DWELL / DELAY commands are advised.

Encoder Count Error

The Power Brick AC is fitted with an encoder count error detection circuitry which supports **Quadrature**, **Sinusoidal**, **Resolver**, and **HiperFace** encoders.

The encoder count circuitry reports bad transitions of the quadrature signals. If both the A and B channels of the quadrature data change state at the decode circuitry (post-filter) in the same hardware sampling clock cycle, an unrecoverable error to the counter value will result (lost counts). **PowerBrick[].Chan[].CountError** is then set and latched to 1 (until reset or cleared). 0 indicates that there is no encoder count error.

```
PTR Enc1CountError->PowerBrick[0].Chan[0].CountError;
PTR Enc2CountError->PowerBrick[0].Chan[1].CountError;
PTR Enc3CountError->PowerBrick[0].Chan[2].CountError;
PTR Enc4CountError->PowerBrick[0].Chan[3].CountError;
PTR Enc5CountError->PowerBrick[1].Chan[0].CountError;
PTR Enc6CountError->PowerBrick[1].Chan[1].CountError;
PTR Enc7CountError->PowerBrick[1].Chan[2].CountError;
PTR Enc8CountError->PowerBrick[1].Chan[3].CountError;
```



Note

No automatic action is taken by the Power Brick AC if the encoder count error bit is set, it is the user's responsibility to trap it and create safety logic to stop the machine and / or alert the operator.

The encoder count error may not have immediate consequences on the motion, but it indicates ultimately that the motor is losing counts which could result in a fatal following error, erroneous commutation, or position drift over time.

Common root causes of the encoder count error:

- Encoder problem
- Trying to move the encoder (motor) faster than it's specification
- Using a higher resolution/speed encoder. This may require increasing the sampling clock.

The default sampling clock of ~3.125 MHz is acceptable for the majority of applications.

Increasing the encoder sampling clock is done using the structure element **PowerBrick[].EncClockDiv** (default = 5).

Setting	Frequency		Setting	Frequency	
0	100	MHz	8	390.6	kHz
1	50	MHz	9	195.3	kHz
2	25	MHz	10	97.65	kHz
3	12.5	MHz	11	48.82	kHz
4	6.25	MHz	12	24.41	kHz
5	3.125	MHz	13	12.21	kHz
6	1.562	MHz	14	3.104	kHz
7	781.2	kHz	15	3.052	kHz

Encoder Loss Detection



Warning

Loss of the feedback sensor signal is potentially a very dangerous condition in closed-loop control, because the servo loop no longer has any idea what the true physical position of the motor is – usually it thinks it is "stuck" – and it can react wildly, often causing a runaway condition.

The Power Brick AC has circuitry dedicated to monitoring the presence of a proper feedback signal. In addition, it can automatically check these circuits for loss of sensor signal and take appropriate shutdown action. This feature supports the following types of encoders:

- Digital quadrature (differential)
- Sinusoidal
- Resolver
- HiperFace
- Serial Encoders

Digital Quadrature

With digital quadrature encoders (must be differential) the encoder loss circuitry monitors each quadrature input pair with an exclusive-or XOR gate:

In normal operation mode, the two quadrature inputs should be in opposite logical states – that is one high and one low – yielding a true output from the XOR gate.

When there is no longer a proper signal driving the inputs on the interface, both lines are pulled to a high logical level internally, so the XOR gate outputs a low level indicating encoder loss.

The flag reflecting the encoder loss status is found in the Power Brick bit element **PowerBrick[].Chan[].LossStatus**:

- = 0 in normal mode.
- = 1 (and latched) upon detecting an encoder loss

```
PTR Enc1LossBit->PowerBrick[0].Chan[0].LossStatus;
PTR Enc2LossBit->PowerBrick[0].Chan[1].LossStatus;
PTR Enc3LossBit->PowerBrick[0].Chan[2].LossStatus;
PTR Enc4LossBit->PowerBrick[0].Chan[3].LossStatus;
PTR Enc5LossBit->PowerBrick[1].Chan[0].LossStatus;
PTR Enc6LossBit->PowerBrick[1].Chan[1].LossStatus;
PTR Enc7LossBit->PowerBrick[1].Chan[2].LossStatus;
PTR Enc8LossBit->PowerBrick[1].Chan[3].LossStatus;
```

Automatic Kill Action for Quadrature Encoders

Arming the automatic kill action with quadrature encoders:

```
Motor[1].pEncLoss = PowerBrick[0].Chan[0].Status.a
Motor[1].EncLossBit = 28
Motor[1].EncLossLevel = 1 // High true fault
Motor[1].EncLossLimit = 0
```

In this mode, the status of the encoder loss can be monitored in the motor status window in the IDE software or using the motor element bit **Motor[].EncLoss**.



Note

Setting **Motor[].pEncLoss** = 0 disables the automatic kill action.

Sinusoidal | Resolver | HiperFace Encoders

Analog sinusoidal encoders and resolvers provide simultaneous sine and cosine signals into the analog-to-digital converters of the Power Brick AC interface circuitry.

In proper operation, the sum of the squares of the converted values for these two signals should be roughly constant, and significantly different from zero.

The Power Brick AC ASIC computes this sum-of-squares value every sample cycle. The latest value is always available in the 16-bit element **PowerBrick[].Chan[].SumOfSquares**.
In addition, if all of the highest 4 bits of this element are zero, so the value is less than 1/16 of full range, the status bit **PowerBrick[].Chan[].SosError** is automatically set to 1.

```
PTR Enc1LossBit->PowerBrick[0].Chan[0].SosError;
PTR Enc2LossBit->PowerBrick[0].Chan[1].SosError;
PTR Enc3LossBit->PowerBrick[0].Chan[2].SosError;
PTR Enc4LossBit->PowerBrick[0].Chan[3].SosError;
PTR Enc5LossBit->PowerBrick[1].Chan[0].SosError;
PTR Enc6LossBit->PowerBrick[1].Chan[1].SosError;
PTR Enc7LossBit->PowerBrick[1].Chan[2].SosError;
PTR Enc8LossBit->PowerBrick[1].Chan[3].SosError;
```

Automatic Kill Action for Sinusoidal | Resolver | HiperFace Encoders

Arming the automatic kill action with Sinusoidal, Resolver, or HiperFace encoders:

```
Motor[1].pEncLoss = PowerBrick[0].Chan[0].SosError.a
Motor[1].EncLossBit = 31
Motor[1].EncLossLevel = 1 // High true fault
Motor[1].EncLossLimit = 5 // 5 scans
```

In this mode, the status of the encoder loss can be monitored in the motor status window in the IDE software or using the motor element bit **Motor[].EncLoss**.



Note

Setting **Motor[].pEncLoss** = 0 disables the automatic kill action.

Serial Encoders

The Power Brick AC provides interfaces for many of the most popular serial encoder protocols. For most of these interfaces, the receiving logic can detect that no data has been received in response to the cycle's "position request" output, and set a "timeout error" flag that can be read by the processor. This flag bit can be used to detect encoder loss.

This "timeout error" flag is bit 31 of the element **PowerBrick[].Chan[].SerialEncDataB**.

It is also possible to utilize an error-checking mechanism in the data such as parity or cyclic redundancy check (CRC) bits. The Power Brick AC can evaluate these mechanisms and determine whether the data set was valid or not. This is particularly recommended for the SSI protocol, where the data patterns cannot be used to detect a timeout error. For the SSI protocol, the parity error flag is bit 31 of **PowerBrick[].Chan[].SerialEncDataB**.

Automatic Kill Action for Serial Encoders

Arming the automatic kill action for serial encoder protocols with a "timeout error" flag (EnDat, HiperFace, Sigma I, Sigma II/III/V, Tamagawa, Panasonic, Mitutoyo, and Kawasaki):

```
Motor[1].pEncLoss = PowerBrick[0].Chan[0].SerialEncDataB.a
Motor[1].EncLossBit = 31  // Time out error bit number
Motor[1].EncLossLevel = 1 // High true fault
Motor[1].EncLossLimit = 0
```

In this mode, the status of the encoder loss can be monitored in the motor status window in the IDE software or using the motor element bit **Motor[].EncLoss**.



Note

Setting **Motor[].pEncLoss** = 0 disables the automatic kill action.



Note

The same settings are valid for an SSI encoder with parity checking to use the parity-error bit.

Digital Tracking Filter

The encoder conversion table's (ECT) software tracking filter is a digital low-pass filter with an integrator which is useful for reducing measurement noise (floor level and occasionally electrical) without introducing steady-state error at constant velocity or position. It is particularly useful for applications involving:

- Analog Input Signals.
- Sinusoidal Encoder Signals (with the x16384 interpolator).
- Resolver Signals.



Note

Executed in the ECT, the performance of this filter is directly proportional to the servo frequency. The higher the frequency, the faster is the sampling and better noise rejection.



Note

This filter should never be used with the Sinusoidal ACI interpolation option of the Power Brick. The ACI automatically compensates for disturbances at a much higher rate.

The following PLC depicts the digital tracking filter equations, and produces the three indexes necessary to apply the filter in the corresponding Encoder Conversion Table:

```
GLOBAL TrackFltrCutOff = 1000;        // [Hz]
GLOBAL TrackFltrDamping = 1;
GLOBAL TrackFltrIndex1, TrackFltrIndex2, TrackFltrIndex4;
GLOBAL VerifyWn, VerifyTau;

OPEN PLC TrackFltrPLC
LOCAL TrackFltrTime = Sys.Servoperiod / 1000;

TrackFltrIndex1 = 65
TrackFltrIndex2 = INT(256 - 512 * TrackFltrCutOff * TrackFltrDamping * TrackFltrTime)
TrackFltrIndex4 = 1

VerifyWn = (1 / TrackFltrTime) * SQRT(TrackFltrIndex1 / (256 * EXP2(TrackFltrIndex4)))
VerifyTau = (256 - TrackFltrIndex2) / (2 * SQRT(256 * TrackFltrIndex1 / EXP2(TrackFltrIndex4)))

WHILE (VerifyWn > TrackFltrCutOff)
{
        TrackFltrIndex4 += 1
        VerifyWn = (1 / TrackFltrTime) * SQRT(TrackFltrIndex1 / (256 * EXP2(TrackFltrIndex4)))
}

WHILE (VerifyWn < TrackFltrCutOff)
{
        TrackFltrIndex1 += 1
        VerifyWn = (1 / TrackFltrTime) * SQRT(TrackFltrIndex1 / (256 * EXP2(TrackFltrIndex4)))
}

VerifyWn = (1 / TrackFltrTime) * SQRT(TrackFltrIndex1 / (256 * EXP2(TrackFltrIndex4)))
VerifyTau = (256 - TrackFltrIndex2) / (2 * SQRT(256 * TrackFltrIndex1 / EXP2(TrackFltrIndex4)))

DISABLE PLC TrackFltrPLC
CLOSE
```

This PLC example is very simple to use:

- Specify the desired cutoff frequency (~30 – 2000 Hz)
- Specify the desired damping ratio (typically 1.0)

For example, for a 1,000 Hz cutoff frequency, and 1 damping ratio will produce:

```
TrackFltrCutOff = 1000 TrackFltrDamping = 1 ENABLE PLC TrackFltrPLC


TrackFltrIndex1,3
P8203=82
P8204=154
P8205=3
```

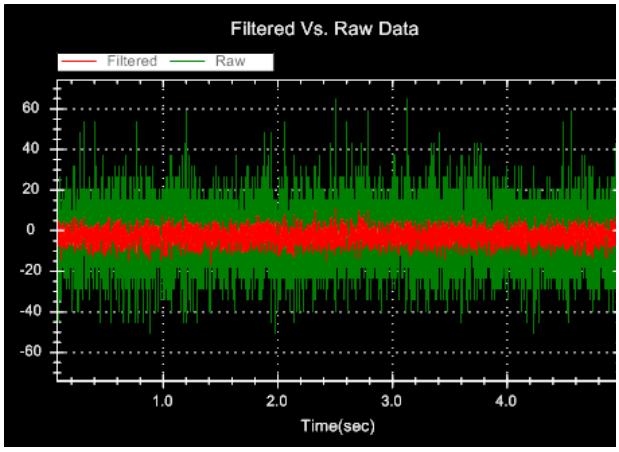
These index values copied into **EncTable[].index1**, **EncTable[].index2**, and **EncTable[].index4** respectively will apply the desired filtering.

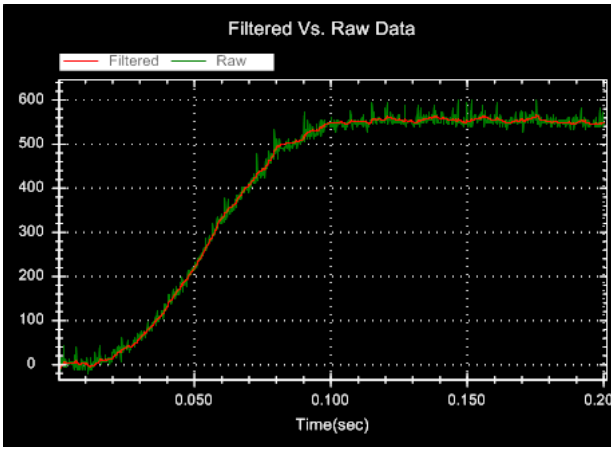


Note

If these indexes are non-zero in the ECT entry of interest, another entry needs to be created, with its source pointing to the original entry's result **EncTable[].PrevEnc.a**.

The following plots show an example of a filtered "noisy" signal, at steady state and in dynamic motion:





PTC Motor Thermal Input

The PTC motor thermal Input (pin #8 of X1-X8 connectors) is typically used to bring in motor over-temperature thermistor signal(s) into the Power Brick AC. Proper action can then be taken to safely stop operation if the motor is overheated.

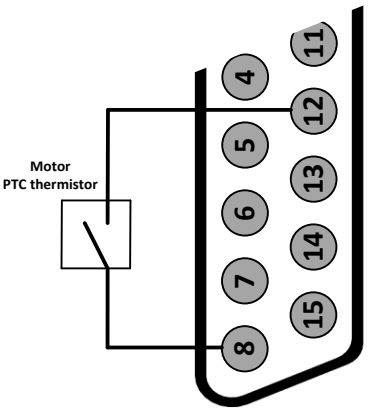


Caution

No automatic action is taken by the Power Brick AC when the PTC input is triggered, it is the user's responsibility to trap it (i.e. in a background PLC) and insert safety logic to stop the motor and / or alert the operator.

The PTC input (pin #8) is typically wired to ground (pin #12) in series with the motor PTC thermistor:

- In normal mode operation, the circuit is open and PTC (pin #8) is pulled up to +5 VDC internally, this corresponds to a setting of 1 in software.
- If the motor is overheated, the circuit is closed and PTC (pin #8) is pulled down to ground (pin #12), this corresponds to a setting of 0 in software.




```
PTR Ch1PTC->PowerBrick[0].GpioData[0].24.1; // Channel 1 PTC Input, X1
PTR Ch2PTC->PowerBrick[0].GpioData[0].25.1; // Channel 2 PTC Input, X2
PTR Ch3PTC->PowerBrick[0].GpioData[0].26.1; // Channel 3 PTC Input, X3
PTR Ch4PTC->PowerBrick[0].GpioData[0].27.1; // Channel 4 PTC Input, X4

PTR Ch5PTC->PowerBrick[1].GpioData[0].24.1; // Channel 5 PTC Input, X5
PTR Ch6PTC->PowerBrick[1].GpioData[0].25.1; // Channel 6 PTC Input, X6
PTR Ch7PTC->PowerBrick[1].GpioData[0].26.1; // Channel 7 PTC Input, X7
PTR Ch8PTC->PowerBrick[1].GpioData[0].27.1; // Channel 8 PTC Input, X8
```



Note

If the PTC function is not used, this input can be used as general purpose relay input.

LED Status

Symbol	Description	Status		Indication
WD	Watchdog	Green		Normal Mode Operation
		Red		Fault – Watchdog
MACRO Link	MACRO	Green		MACRO connected / Operational
		Red		MACRO not connected / Ring broken
RDY/WD	Ready/Watchdog	Green		PMAC Ready, Boot Complete
		Red		Fault – Watchdog
ABORT	Abort Status	Green		Enabled and 24V wired in
		Red		Disabled / Enabled and 24V not wired in

Reloading Power PMAC Firmware

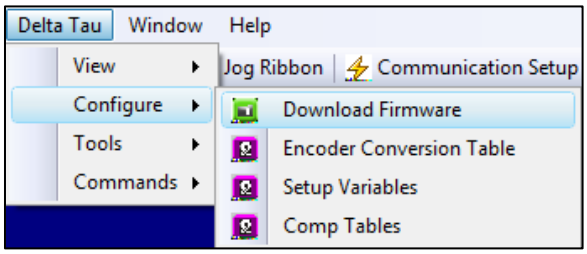
You should always use the newest released version of the Power PMAC firmware if your application permits. You may download it from the following links:

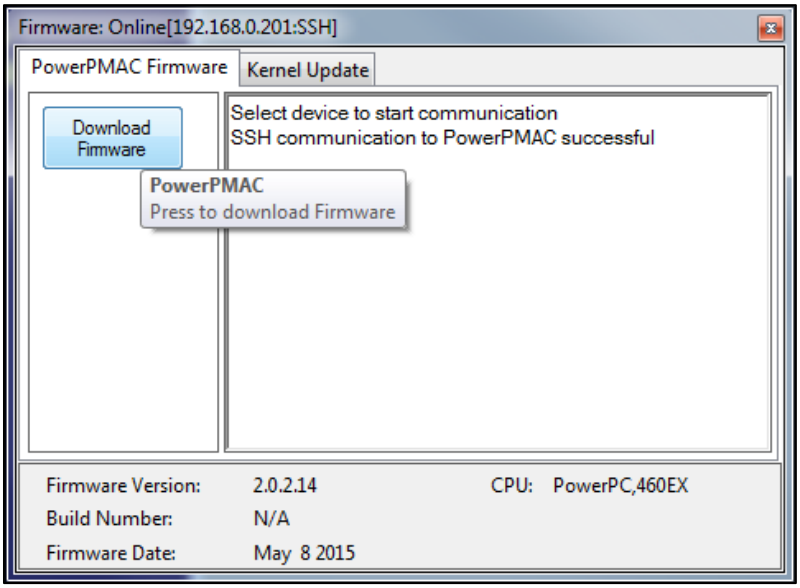
Forum Link: http://forums.deltatau.com/showthread.php?tid=152
Website Link: http://www.deltatau.com/DT_Products/SoftwareDevelopment.aspx

Power PMAC Firmware can be reloaded by means of the IDE or a USB flash drive/SD card.

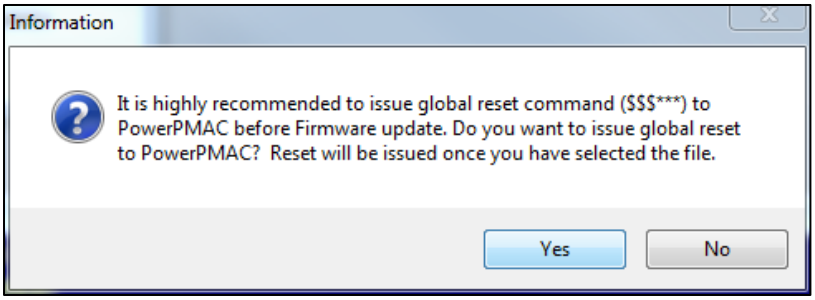
Reloading Firmware Method 1: IDE

To install the latest firmware through the IDE, click on Delta Tau→Configure→Download Firmware:

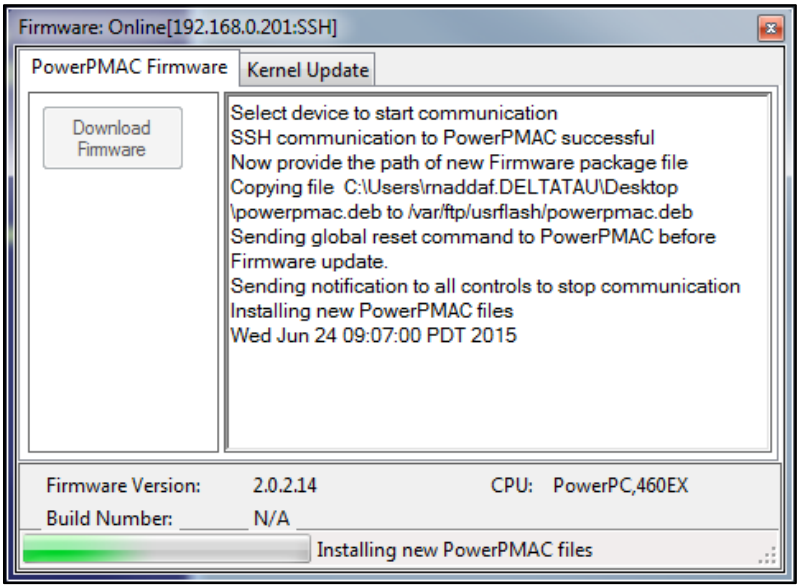




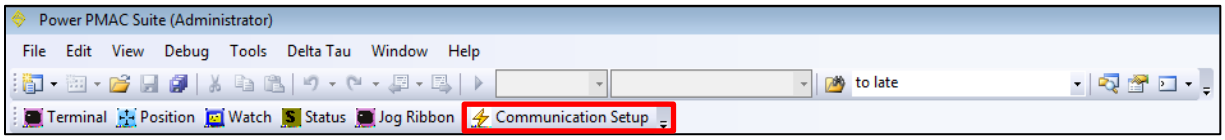
Under the "PowerPMAC Firmware" tab, click the "Download Firmware" button. On clicking the button, the IDE will ask whether it is acceptable to issue $$$*** (Global Reset) before updating the firmware. If you click "Yes," then the Power PMAC will be reset to factory default. It will then prompt you to browse for the firmware file you want to download. It is recommended to issue $$$*** and make sure that the Power PMAC is at factory default stage before downloading firmware, because the firmware download process does not kill the C background programs that are already executing. In this case, the firmware update process may not update all the files.



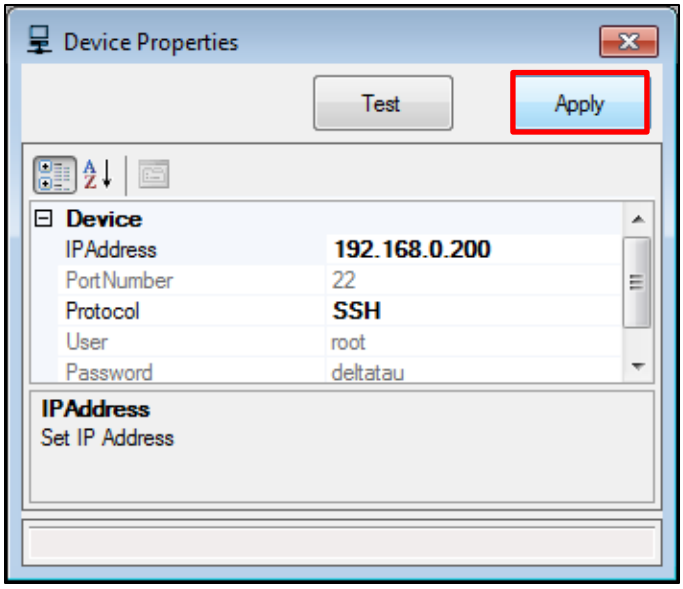
The firmware filename should be "**powerpmac.deb**":



Wait for the IDE to finish downloading the firmware file and then for Power PMAC to reboot. If it does not reconnect successfully after rebooting, click "Communication Setup" (see the red box in the image below):



Then, click "Apply" (see the red box in the image below):



If you still cannot communicate, cycle power on the UMAC rack and use the "Communication Setup" button in the IDE again until you can connect.

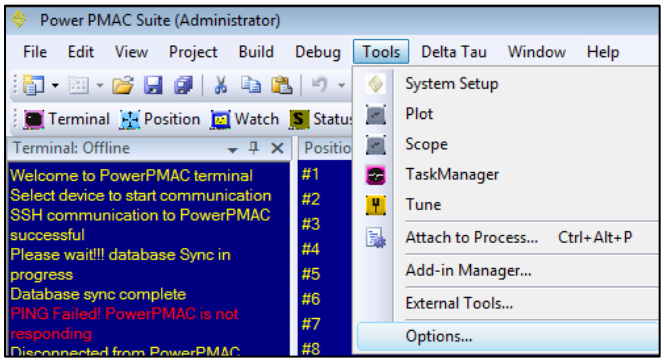
Reloading Firmware Method 2: USB Drive/SD Card

- Connect a USB memory stick/SD Card to a PC using any OS which can work with FAT32 partition.
- Create a folder named **PowerPmacFirmwareInstall** on the USB memory stick/SD Card root folder. Place the installation package "powerpmac.deb" into this folder.
- Safely remove the USB memory stick/SD Card from the PC.
- Plug the USB memory stick/SD Card into Power PMAC's USB port.
- If Power Brick is off, then power up the device. If Power Brick is on, cycle power.
- After the unit boots, the new firmware should be installed.

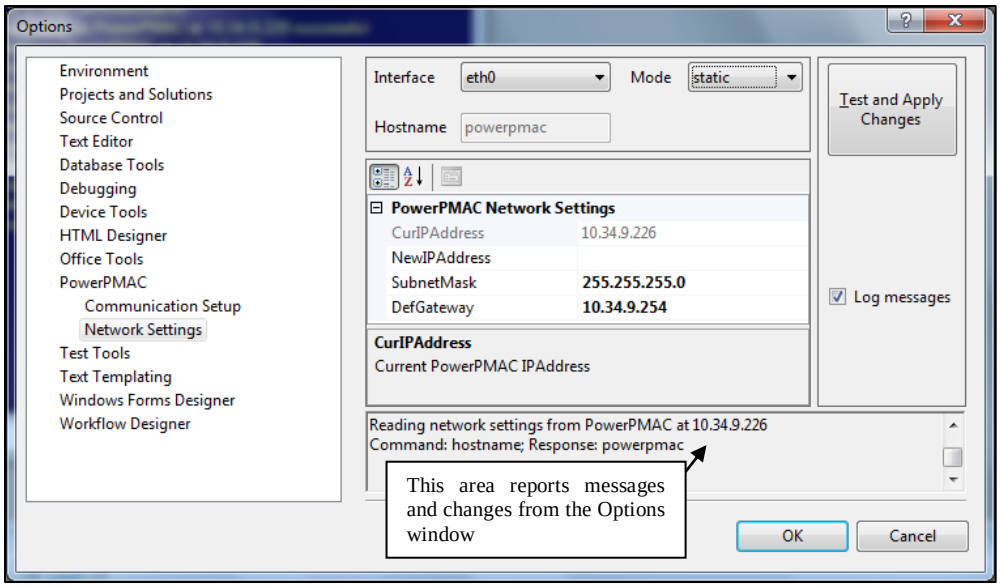
Changing Network (IP Address) Settings

Through the Power PMAC IDE

If you want to change Power PMAC's IP Address from within the IDE, click Tools→Options…



Near the bottom of the screen in the left pane, click PowerPMAC→Network Settings and then the following window should appear:



On this window, enter the **NewIPAddress** desired. You can enter this IP Address into the **DefGateway** field also. Leave the **SubnetMask** as 255.255.255.0. Then, click Test and Apply Changes.

Through USB

Below is the procedure for using a USB flash drive to detect/change the Power PMAC IP address:

1. Connect the USB memory stick/SD Card to your PC using any OS which can work with FAT32 partition.
2. Create a folder named **PowerPmacIP** on the USB memory stick/SD Card root folder.
3. Safely remove the USB memory stick/SD Card from the PC.
4. Plug the USB memory stick/SD Card into Power PMAC's USB port.
5. If Power Brick is off, then power up the device. If Power Brick is on, cycle power.
6. After the boot sequence is completed, the following files will be generated under your PowerPmacIP folder:
   boot.log
   interfaces

The **interfaces** file includes all the network settings for the Power Brick, including the IP address.

If you want to change the Power PMAC network settings, follow these steps:

1. Modify the **interfaces** file created by Power PMAC under PowerPmacIP folder by connecting the USB memory stick/SD Card on PC, opening the file using any text editor which supports simple ASCII text, and modifying the settings you want to modify. Below is an example of the **interfaces** file:

```
# This file describes the network interfaces available on your system
# and how to activate them. For more information, see interfaces(5).

# The loopback network interface
auto lo
iface lo inet loopback

iface eth0 inet static
address 10.34.9.232
netmask 255.255.255.0
gateway 10.34.9.254

iface eth1 inet static
address 192.168.0.232
netmask 255.255.255.0
gateway 192.168.0.232

auto eth0
auto eth1
```

2. Save the file and safely remove the USB memory stick/SD Card from the PC.
3. Plug the USB memory stick/SD Card into Power Brick's USB port.
4. If Power Brick is off, then power it up. If Power Brick is on, cycle power.
5. After the boot sequence is completed, Power Brick will have been updated with the new network settings.

Restoring Factory Default Configuration

Restoring Power Brick's settings to factory default can be done in two ways.

Method 1 (to be used when communicating):

Enter **$$$*** ** into the IDE Terminal Window. Issue a **SAVE**, followed by a **$$$** to maintain the factory default settings.

Method 2 (to be used when not communicating):

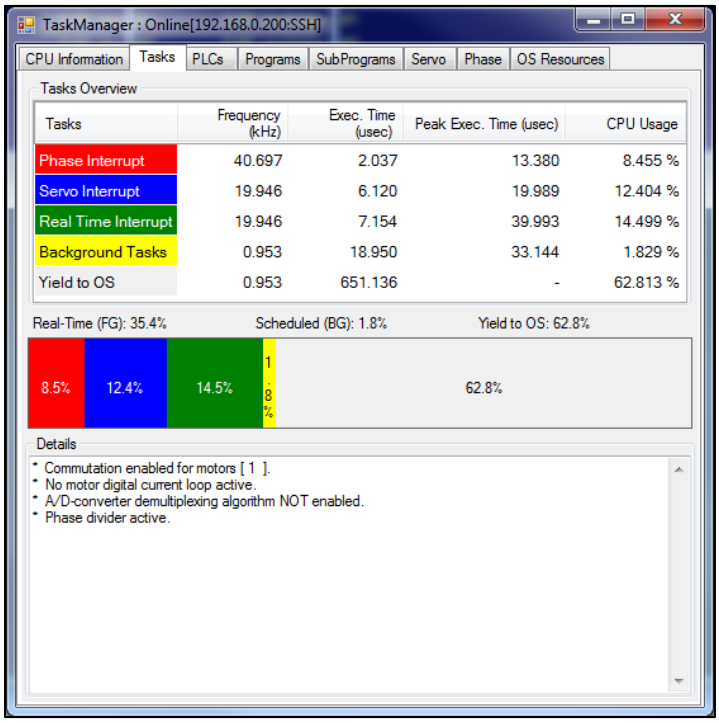
- Connect a USB memory stick or SD Card to a PC using any OS which can work with FAT32 partition.
- Create a folder named **PowerPmacFactoryReset** on the USB memory stick/SD Card root folder.
- Safely remove the USB memory stick/SD Card from the PC.
- Plug the USB memory stick/SD Card into Power PMAC's USB port.
- If Power Brick is off, then power up the device. If Power Brick is on, cycle power.
- After the boot sequence is completed, the Power Brick will be restored to factory default settings.

Watchdog Faults

Two types of Watchdog Faults can occur. The first is a "Soft Watchdog" which occurs when the CPU is starved of processing time and cannot reset the background (when **Sys.WDTFault = 2**) or the foreground (when **Sys.WDTFault = 1**) Watchdog timer. During normal operation, **Sys.WDTFault = 0**.

1. Avoid infinite loops in C programs because they can dominate the CPU and prevent background from resetting the Watchdog counter.

2. Check the CPU loading through the IDE by going to Tools→Task Manager, and then clicking the Tasks tab (see image below):



If the foreground ("Real-Time (FG)") loading is very high (e.g. 80%), you may encounter Watchdog faults at peak calculation times. You may need to reduce the Real-Time Interrupt time (i.e. set **Sys.RtIntPeriod** higher), reduce the servo/phase clock rates, or optimize your programming. If the Watchdog problem is intermittent, you may have a loading spike due to programming and you should revise your code. If the problem is not from code, it may be a hardware problem and the product will need to be sent in for repairs.

A "Hard Watchdog" occurs when the processor's Watchdog timer has been tripped, or when the processor does not receive proper logic power. All communication is lost in this case, the processor is shut down, all outputs are disabled, and the red "WD" LED on the front of the Power Brick activates. The only way to recover from this fault is to cycle power. If you receive this fault, check that +24 VDC is properly being applied to the logic power and has not sagged below +12 VDC. Since a "Hard Watchdog" can be caused by a CPU processing overload as well, the above troubleshooting steps also apply here.

BRICKAC STRUCTURE ELEMENTS

The **BrickAC** data structure elements consist of two main categories; global elements (**BrickAC.**) which affect all the channels and channel specific elements (**BrickAC.Chan[].**) which only affect the indexed channel. Each category (global or channel) consists of:

- Saved Setup Elements
- Non-saved Setup Elements (automatically reset)
- Status (read only)

The **BrickAC** data structure elements referred to in this section are "software" elements built into the Power PMAC firmware. They must not be confused with the ASIC (Gate 3) hardware elements **PowerBrick[]** and **PowerBrick[].Chan[]**.

Global Saved Setup Elements

BrickAC.MonitorPeriod

Description: Time interval for updating status registers

Range: 0 .. 4,294,967,295 (2^{32}-1)

Units: Milliseconds

Default: 0 (50 msec)

Legacy I-variable alias: none

BrickAC.MonitorPeriod tells Power PMAC software how much time there is between consecutive requests for the value of all Brick AC status registers. It is expressed in milliseconds as an integer value. If **BrickAC.MonitorPeriod** is set to the default value of 0 or any value up to 50, all Brick AC status elements are updated every 50 milliseconds. Setting the value higher will reduce the update frequency and reduces the background time which monitor process takes from the Power PMAC CPU.



Note

The value of **BrickAC.MonitorPeriod** does not affect how often the amplifier stage checks the status conditions internally. It only controls how frequently the Power PMAC CPU requests this information.

While the value of **BrickAC.MonitorPeriod** is saved, the element that starts the monitoring process itself, **BrickAC.Monitor**, is not a saved setup element. It must explicitly be set to 1 by the user application in order to start the monitoring process. Also, when either the configuration process or the fault-clearing reset process is started with **BrickAC.Config** or **BrickAC.Reset**, respectively, the monitoring process is stopped, and it is not automatically restarted. The user application must explicitly restart the monitoring process.



Note

The monitored data in the Power Brick AC is provided to the controller on the lower 10 bits of the **PowerBrick[].Chan[]AdcAmp[*k*]** registers and it is essential that **PowerBrick[].Chan[]PackInData** and **PowerBrick[].Chan[]PackOutData** are set to 0, disabling "packed" register access and allowing all ADC register bits to be read by the CPU.

BrickAC.SinglePhaseIn

Description: Expected line input type

Range: 0 .. 1

Units: none

Default: 0 (three-phase)

Legacy I-variable alias: none

BrickAC.SinglePhaseIn tells the amplifier whether to expect a single-phase line input or a 3-phase line input. If set to the default value of 0, the Power Brick AC expects a 3-phase AC line input and the **BrickAC.PhaseInMissing** monitor is active, so the amplifier will issue a warning on the loss of any of the three phases, setting status bit **BrickAC.PhaseInMissing** to 1.

If **BrickAC.SinglePhaseIn** is set to 1, the 3-phase line input monitor process is disabled and the Power Brick AC runs in single-phase input mode with no phase-loss detection. In this case, a single-phase AC line input, or a DC line input can be connected across any two of the three line inputs on the amplifier. (Loss of this input would result in a power fault condition.)

The **BrickAC.SinglePhaseIn** value is sent to the active amplifier-control circuit upon setting one of the non-saved setup elements **BrickAC.Reset** or **BrickAC.Config** equal to 1 in a Script command. It does not take effect until then.

BrickAC.UnderVoltageDisplay

Description: Undervoltage condition display control

Range: 0 .. 1

Units: Boolean

Default: 0

Legacy I-variable alias: none

BrickAC.UnderVoltageDisplay tells Power Brick AC whether to display the undervoltage status on its 7-segment display or not. If it is set to 0, no undervoltage condition status is displayed. If it is set to 1, an error code "U" is displayed in the event of a bus undervoltage condition.

This setting is purely for display-control purposes and does not affect what action the Power Brick AC takes when an undervoltage condition is detected. The separate **BrickAC.UnderVoltageWarnOnly** element controls whether an undervoltage condition should be treated as a warning or as a fault. An undervoltage condition occurs when the internal DC bus voltage drops below 100 VDC, which corresponds to about 70 VAC(rms).

The **BrickAC.UnderVoltageDisplay** value is sent to the active amplifier-control circuit upon setting one of the non-saved setup elements **BrickAC.Reset** or **BrickAC.Config** equal to 1 in a Script command. It does not take effect until then.

BrickAC.UnderVoltageWarnOnly

Description: Undervoltage condition warning/fault control

Range: 0 .. 1

Units: Boolean

Default: 0

Legacy I-variable alias: none

BrickAC.UnderVoltageWarnOnly controls whether an undervoltage condition should be treated as a warning or as an error. If it is set to the default value of 0, then Power Brick AC will treat it as a fault and stop all outputs with a fault on all channels if an undervoltage condition is detected. The amplifier stage must be reset by setting **BrickAC.Reset** to 1 in order to clear the fault and permit continued operation.
If **BrickAC.UnderVoltageWarnOnly** is set to 1, an undervoltage condition is treated only as a warning, with no automatic action taken. In either case, the **BrickAC.BusUnderVoltage** status bit reflects the current state of the undervoltage condition.

An undervoltage condition occurs when the internal DC bus voltage drops below 100 VDC, which corresponds to about 70 VAC (rms). The undervoltage status bit **BrickAC.BusUnderVoltage** is automatically cleared once the bus voltage is restored. However, any motor software fault conditions it creates are latched, and the motors must explicitly be re-enabled by command.

The **BrickAC.UnderVoltageWarnOnly** value is sent to the active amplifier-control circuit upon setting one of the non-saved setup elements **BrickAC.Reset** or **BrickAC.Config** equal to 1 in a Script command. It does not take effect until then.

Global Non-Saved Setup Elements

BrickAC.Config

Description: Amplifier configuration/initialization control

Range: -7 .. 1

Units: none

Power-on default: 0

BrickAC.Config acts as a flag for the Power PMAC firmware which controls the initialization of Power Brick AC amplifier based upon the **BrickAC.** saved setup elements. The amplifier stage is not automatically configured at power-up, so the configuration process *must* be commanded explicitly by the user application before the amplifier stage can be used.

Setting **BrickAC.Config** to 1 in a Script command starts the initialization process as a background task on Power PMAC CPU. The element stays at the set value until either the initialization process is successfully completed, in which case the value of **BrickAC.Config** is set to 0, or until a configuration error is detected, in which case the **BrickAC.Config** value is set to a negative value indicating the error in the process. The following list shows the error codes which can be encountered:

Error Code	Description
-1	The assigned value is not accepted. Only a value of 1 or 0 can be assigned by user to this data structure.
-2	The **BrickAC.Monitor** was called while either the **BrickAC.Reset** or **BrickAC.Config** process was active.
-3	The configuration process was attempted on incompatible hardware. No amplifier hardware with the matching Power Brick part number was detected.
-4	No Power Brick hardware was detected. This error is generated if incompatible output stage is detected.
-7	The configuration process attempted used on incompatible hardware. No DPSGATE3 interface ASIC was detected.

If **BrickAC.Config** is set to 1 in an on-line command, there will be a text response indicating whether the configuration completed correctly or not, and if not, what the error was.

It is strongly recommended for users to confirm the pass/fail status of the initialization process whenever **BrickAC.Config** is set to a value of 1.



Note

While setting **BrickAC.Config** to 1 as part of the standard system initialization process after power-up will load the configuration parameters into the amplifier control circuitry, it is recommended instead to set **BrickAC.Reset** to 1, which will not only load the configuration parameters, but clear any faults that may have occurred due to power-on transient conditions.



Note

Setting **BrickAC.Config** to 1 to start the amplifier configuration process automatically stops the amplifier monitoring process, and the monitoring process does *not* automatically resume when the configuration is completed. **BrickAC.Monitor** must be set to 1 again in the user Script application to resume the monitoring process.

```
OPEN PLC ExamplePLC
Sys.WDTReset = 5000 / (Sys.ServoPeriod * 2.258) // Increase Foreground WD Timer Threshold
CALL Timer(0.250)                               // 250 msec delay

BrickAC.Config = 1
WHILE (BrickAC.Config > 0) {}
IF (BrickAC.Config != 0)
{
    // Take necessary action in case of a fault
    Sys.WDTReset = 0 // Restore Foreground WD timer Threshold
}
// Continue with script process
DISABLE PLC ExamplePLC
CLOSE
```

The process of waiting for the **BrickAC.Config** to execute in a PLC consumes a significant amount of background cycles and risks triggering a foreground soft watchdog fault (**Sys.WDTFault = 1**), especially with higher clock frequencies. Setting **Sys.WDTReset** temporarily to a larger value (increasing the foreground watchdog timer threshold) alleviates this issue.



Note

The **Sys.WDTReset** expression stated in the PLC example should ensure the proper setting regardless of the user specified clock frequencies.

BrickAC.Monitor

Description: Amplifier status monitoring update control

Range: -7 .. 1

Units: none

Power-on default: 0

BrickAC.Monitor acts as a flag for the Power PMAC firmware which controls the execution of Power Brick AC amplifier status monitoring background task. This task updates the **BrickAC.** Status elements at constant period set by saved setup element **BrickAC.MonitorPeriod**.

If **BrickAC.Monitor** is set to its power-on default value of 0, there is no updating of the **BrickAC.** Status elements. In this mode none of these element values are updated and they maintain their last updated value until next reset or power cycle.

Setting **BrickAC.Monitor** equal to 1 in a Script command starts the background **BrickAC.** Status update task at a period set by **BrickAC.MonitorPeriod**. The element stays at the set value until either the user application sets the value to 0, which stops the update process, or the user application commands an initialization or reset process by setting **BrickAC.Config** or **BrickAC.Reset** to a value of 1.

If an error occurs during the monitor process, the **BrickAC.Monitor** value is set to a negative value indicating an error in the process. The following table shows the errors that can be reported. It is strongly recommended for users to confirm the pass/fail status of the monitoring initialization process whenever **BrickAC.Monitor** is set to a value of 1.

Error Code	Description
-1	The assigned value is not accepted. Only a value of 1 or 0 can be assigned by user to this data structure.
-2	The **BrickAC.Monitor** was was called while either the **BrickAC.Reset** or **BrickAC.Config** process was active.
-3	The configuration process was attempted on incompatible hardware. No amplifier hardware with the matching Power Brick part number was detected.
-4	No Power Brick hardware was detected. This error is generated if incompatible output stage is detected.
-6	Packed data mode is detected (**PowerBrick[].Chan[]PackInData** > 0). This error is only generated if the monitor process is requested.
-7	The configuration process attempted used on incompatible hardware. No DPSGATE3 interface ASIC was detected.



Note

The monitored data in the Power Brick AC amplifier is provided to the controller in the low bits of the **PowerBrick[].Chan[]AdcAmp[*k*]** registers, below the current feedback values. This data cannot be read if two phases are "packed" into one register, so it is essential that **PowerBrick[].Chan[]PackInData** and **PowerBrick[].Chan[]PackOutData** are set to 0, disabling packed data and allowing the full registers to be read by the CPU.



Note

The monitoring process is automatically halted when either **BrickAC.Config** or **BrickAC.Reset** is set to 1 to update the amplifier configuration or reset the amplifier state, respectively, with **BrickAC.Monitor** set to 0. The monitoring process is *not* automatically resumed when the configuration or reset process is finished, so it must be explicitly restarted when one of these other processes is finished.

```
OPEN PLC ExamplePLC
Sys.WDTReset = 5000 / (Sys.ServoPeriod * 2.258) // Increase Foreground WD Timer Threshold
CALL Timer(0.250)                               // 250 msec delay

BrickAC.Monitor = 1
CALL Timer(0.100)       // 100 msec delay
WHILE (BrickAC.Monitor > 0) {}
IF (BrickAC.Monitor < 0)
{
    // Take necessary action in case of a fault
    Sys.WDTReset = 0                // Restore Foreground WD timer Threshold
}
// Continue with script process
DISABLE PLC ExamplePLC
CLOSE
```

The process of waiting for the **BrickAC.Monitor** to execute in a PLC consumes a significant amount of background cycles and risks triggering a foreground soft watchdog fault (**Sys.WDTFault = 1**), especially with higher clock frequencies. Setting **Sys.WDTReset** temporarily to a larger value (increasing the foreground watchdog timer threshold) alleviates this issue.



Note

The **Sys.WDTReset** expression stated in the PLC example should ensure the proper setting regardless of the user specified clock frequencies.

BrickAC.Reset

Description: Amplifier reset/fault-clear control

Range: -7 .. 1

Units: none

Power-on default: 0

BrickAC.Reset acts as a flag for the Power PMAC firmware which controls the reset process of Power Brick AC amplifier. This reset process clears any latched faults, and loads the configuration into the active amplifier-control circuits based upon the **BrickAC** saved setup elements.

Setting **BrickAC.Reset** equal to 1 in a Script command starts the reset process as a background task on Power PMAC CPU. The value stays at this set value until either the reset process is completed, in which case the value of **BrickAC.Reset** is set to 0, or an error occurs in which case the **BrickAC.Reset** value is set to a negative value indicating an error in the process. Please refer to **BrickAC.Config** for detailed information on the error code list.

It is strongly recommended for users to confirm the pass/fail status of the reset process whenever **BrickAC.Reset** is set to a value of 1.



Note

Setting **BrickAC.Reset** to 1 to start the amplifier configuration process automatically stops the amplifier monitoring process, and the monitoring process does *not* automatically resume when the configuration is completed. **BrickAC.Monitor** must be set to 1 again in the user Script application to resume the monitoring process.

```
OPEN PLC ExamplePLC
Sys.WDTReset = 5000 / (Sys.ServoPeriod * 2.258) // Increase Foreground WD Timer Threshold
CALL Timer(0.250)                               // 250 msec delay
BrickAC.Reset = 1
while (BrickAC.Reset > 0) {}
if (BrickAC.Reset < 0)
{
        // Take necessary action in case of a fault
       Sys.WDTReset = 0                 // Restore Foreground WD timer Threshold
}
// Continue with script process
DISABLE PLC ExamplePLC
CLOSE
```

The process of waiting for the **BrickAC.Reset** to execute in a PLC consumes a significant amount of background cycles and risks triggering a foreground soft watchdog fault (**Sys.WDTFault = 1**), especially with higher clock frequencies. Setting **Sys.WDTReset** temporarily to a larger value (increasing the foreground watchdog timer threshold) alleviates this issue.



Note

The **Sys.WDTReset** expression stated in the PLC example should ensure the proper setting regardless of the user specified clock frequencies.

Global Status Elements

BrickAC.BusOverVoltage

Description: DC bus overvoltage flag

Range: 0 .. 1

Units: Boolean

The **BrickAC.BusOverVoltage** status bit indicates whether the amplifier has detected an overvoltage condition on the DC bus or not. It is set to 0 when the measured DC bus voltage is 435 VDC or less. It is set to 1 when the bus voltage has exceeded 435 VDC. This is a latching fault in the amplifier power stage and it can only be reset if the bus power is cycled to the amplifier. Please refer to the hardware reference manual for proper power cycling procedure.

This status bit is only updated if **BrickAC.Monitor** is set to 1.

If this fault is detected, the amplifier-fault lines for all channels are set to the "true" state, causing a software fault condition on all Power PMAC motors commanding these channels. After the fault is cleared, the motors will require a command to be re-enabled.



Note

The amplifier will shut down with a fault on all channels when it detects an overvoltage condition regardless of whether software status bits are updated for the processor (**BrickAC.Monitor** = 1) or not.

BrickAC.BusUnderVoltage

Description: DC bus undervoltage flag

Range: 0 .. 1

Units: Boolean

The **BrickAC.BusUnderVoltage** status bit indicates whether the bus voltage is above a minimum threshold or not. It is set to 1 when the amplifier detects an undervoltage condition on the DC bus, which occurs when the bus voltage goes below 100 VDC, corresponding to a supply voltage of about 70 VAC(rms). This status bit is only updated if **BrickAC.Monitor** is set to 1.

If **BrickAC.UnderVoltageWarnOnly** is set to its default value of 0, this is a fault condition, and the amplifier-fault lines for all channels are set to the "true" state, causing a software fault condition on all Power PMAC motors commanding these channels.

If **BrickAC.UnderVoltageWarnOnly** is set to 1, this is only a warning status bit **BrickAC.BusUnderVoltage** is a transparent status bit and it will be cleared to 0 as soon as the measured voltage exceeds 110 VDC again. However, any motor software fault conditions it creates are latched, and the motors must explicitly be re-enabled by command.



Note

The amplifier will shut down with a fault on all channels when it detects an undervoltage condition if **BrickAC.UnderVoltageWarnOnly** is set to 0 regardless of whether software status bits are updated for the processor (**BrickAC.Monitor** = 1) or not.

BrickAC.BusVoltage

Description: DC bus voltage value

Range: 0 .. 1023

Units: Volts DC

The **BrickAC.BusVoltage** status element contains the DC Bus voltage value. The value is only updated if **BrickAC.Monitor** is set to 1.

BrickAC.LineOk

Description: Power line input presence (for internal use)

Range: 0 .. 1

Units: Boolean

The **BrickAC.LineOk** status bit indicates the state of bus-power line inputs. It is set to 1 when line input power is detected. It is set to 0 within two AC line cycles after detection of complete loss of input phase power. This status bit is only updated if **BrickAC.Monitor** is set to a value greater than 0.

BrickAC.LineOk is primarily for internal use. If it is set to 0, the status bit **BrickAC.PowerFault** will be set to 1, creating a global fault condition in the amplifier.

BrickAC.PhaseInMissing

Description: Missing line input phase(s) when in 3-phase input mode

Range: 0 .. 1

Units: Boolean

The **BrickAC.PhaseInMissing** status bit indicates whether all three phases of the power line input are present or not, if the amplifier is set up to expect a 3-phase input. It is set to 1 if one or more of the three line input phases is missing when the **BrickAC.SinglePhaseIn** parameter is set to 0. It is set to 0 if all three phases are present or if **BrickAC.SinglePhaseIn** is set to 1. This status bit is only updated if **BrickAC.Monitor** is set to a value greater than 0.

BrickAC.PowerBoardId

Description: Power board ID code (for internal use)

Range: 0 .. 15

Units: none

The **BrickAC.PowerBoardId** status element contains the power board ID code, which indicates the power ratings for each channel. This parameter is for Delta Tau internal use. The value is only updated if **BrickAC.Monitor** is set to a value greater than 0.

BrickAC.PowerFault

Description: Bus power supply fault status bit

Range: 0 .. 1

Units: none

The **BrickAC.PowerFault** status element indicates whether the power supplied to the DC bus has a problem or not. All of the following criteria should be met before this flag is set to 0.

1. Input power verified (**BrickAC.LineOK** = 1).
2. Soft-start process is completed.
3. No soft-start IGBT fault has occurred.

If any of these conditions is not met, **BrickAC.PowerFault** is set to 1 and the amplifier becomes non-operational, setting the amplifier-fault signals on all channels to the "true" state. This fault flag is non-latched and it will automatically clear to 0 once all the above conditions are met. However, any motor software fault conditions it creates are latched, and the motors must explicitly be re-enabled by command.



Note

In standard operation, **BrickAC.PowerFault** will be set to 1 from the time the amplifier logic initializes after the 24VDC power is applied until several seconds after the bus power is applied and the soft-start process has completed. If the Power PMAC attempts to enable any motors that use the amplifier stage during this period, the enabling will fail due to this fault state.


Note

The amplifier will shut down with a fault on all channels when it detects a power fault regardless of whether software status bits are updated for the processor (**BrickAC.Monitor** = 1) or not.

BrickAC.RegenFault

Description: Regeneration shunt circuitry fault status bit (internal use only)

Range: 0 .. 1

Units: Boolean

The **BrickAC.RegenFault** status bit whether the regeneration shunt circuitry is in a fault condition or not. It is set to 1 if either of the following fault conditions is found:

1. The regen-shunt IGBT is experiencing an under-voltage condition (voltage is less than 12VDC)
2. Regen-shunt desaturation fault is detected. This fault is generated when the shunt resistor is pulling too much current or is shorted.

When no fault is detected, **BrickAC.RegenFault** is set to 0. This status bit is only updated if **BrickAC.Monitor** is set to 1.
The regen fault is a latching fault. Once it is detected, the fault status is latched. This fault can be cleared by setting **BrickAC.Reset** to 1.


Note

The amplifier will shut down with a fault on all channels when it detects a regeneration fault regardless of whether software status bits are updated for the processor (**BrickAC.Monitor** = 1) or not.

BrickAC.RegenOverLoad

Description: Regeneration shunt circuitry overload status bit

Range: 0 .. 1

Units: Boolean

The**BrickAC.RegenOverLoad** status bit indicates whether the shunt resistor has recently been on continually for more than 2 seconds. It is set to 1 when the resistor has been on for the past two seconds. In this eventuality, it is cleared to 0 automatically after a "cool-down" period. It is set to 0 if it has not recently been on continually for 2 seconds.

This is a warning flag; no fault is generated when it is set to 1. This status bit is only updated if **BrickAC.Monitor** is set to 1.

BrickAC.SoftStartFault

Description: Soft-start circuitry fault status bit (for internal use)

Range: 0 .. 1

Units: Boolean

The **BrickAC.SoftStartFault** status bit indicates whether a fault has been detected in the soft-start circuitry or not. It is set to 1 if either of the following conditions is detected:

1. The soft-start IGBT is experiencing an under-voltage condition (voltage is less than 12VDC)
2. Soft-start desaturation fault is detected. This fault is generated when the Bus capacitors are pulling too much current.

When no fault is detected, **BrickAC.SoftStartFault** is set to 0. This status bit is only updated if **BrickAC.Monitor** is set to 1.

BrickAC.SoftStartFault is primarily for internal use. If it is set to 1, the status bit **BrickAC.PowerFault** will be set to 1, creating a global fault condition in the amplifier. This fault flag is non-latched and it will automatically clear to 0 once all the above conditions are no longer present. However, any motor software fault conditions it creates are latched, and the motors must explicitly be re-enabled by command.



Note

The amplifier will shut down with a fault on all channels when it detects a soft-start fault regardless of whether software status bits are updated for the processor (**BrickAC.Monitor** = 1) or not.

BrickAC.STO0

Description: "Safe torque off" STO0 input state

Range: 0 .. 1

Units: Boolean

The **BrickAC.STO0** status bit indicates the status of STO0 "safe torque off" input. It reports as 0 if a 24VDC level is supplied to the STO0 input, or if the adjacent "Disable STO" pin is connected to the "Disable STO Return" pin. It reports as 1 if there is no 24VDC level applied to this input and if "Disable STO" is not connected to "Disable STO Return".

If the 24VDC level is removed from the STO0 input, there is no power supplied to the gate driver circuits that turn on the power transistors, so no electrical power can be supplied to the motors and no torque can be generated. This is known as "safe torque off" mode. This status bit is only updated if **BrickAC.Monitor** is set to 1.

The safe-torque off condition is non-latched and it will automatically clear to 0 once a 24VDC input is supplied to the STO0 input again. However, any motor software fault conditions it creates are latched, and the motors must explicitly be re-enabled by command.



Note

The amplifier will shut down with a fault on all channels when it detects a safe-torque-off condition regardless of whether software status bits are updated for the processor (**BrickAC.Monitor** = 1) or not.

BrickAC.STO1

Description: STO1 disable condition control input state

Range: 0 .. 1

Units: Boolean

The **BrickAC.STO1** status bit indicates the state of the STO1 "disable condition control" input. It reports as 0 if a 24VDC level is supplied to the STO1 input, or if the adjacent "Disable STO" pin is connected to the "Disable STO Return" pin. It reports as 1 if there is no 24VDC level applied to this input and if "Disable STO" is not connected to "Disable STO Return". This status bit is neither a fault nor a warning bit, and it is only updated if **BrickAC.Monitor** is set to 1.

If the STO inputs are configured so that **BrickAC.STO1** would report a 1, when this channel of the amplifier is disabled (except by the safe-torque-off input), the motor leads are unconnected to each other and floating. If the STO inputs are configured so that **BrickAC.STO1** would report a 1, when this channel of the amplifier is disabled for whatever reason, the motor leads are shorted together through the low side of the DC bus, and dynamic braking is possible.



Note

The functionality control of the STO1 input is observed regardless of whether software status bits are updated for the processor (**BrickAC.Monitor** = 1) or not.

BrickAC.UnderVoltageMasked

Description: Bus undervoltage condition display disabled

Range: 0 .. 1

Units: Boolean

The **BrickAC.UnderVoltageMasked** status bit indicates whether the bus undervoltage fault/warning is masked from display on the amplifier or not. It is set to 0 if the amplifier is configured to display an undervoltage condition, and to 1 if it is configured not to display an undervoltage condition.

The selection as to whether this condition is displayed or not is controlled by the value of saved setup element **BrickAC.UnderVoltageWarnOnly**, as loaded into the active amplifier control circuitry with **BrickAC.Config** or **BrickAC.Reset**. This status bit is only updated if **BrickAC.Monitor** is set to 1.



Note

The choice as to whether the amplifier will shut down with a fault when it detects an undervoltage condition is determined by the value of **BrickAC.UnderVoltageWarnOnly**. It is independent of the choice as to whether to display an undervoltage condition or not.

BrickACVers

Description: Amplifier firmware version

Range: 0.0 .. 15.15

Units: none

The **BrickACVers** status element contains the amplifier firmware version (which is distinct from the Power PMAC CPU's firmware version) with a format of [**Version].[Release]** number. This element is only updated if **BrickAC.Monitor** is set to 1.

Channel Saved Setup Elements

BrickAC.Chan[*j*].I2tWarnOnly

Description: I^2T protection-level control

Range: 0 .. 1

Units: Boolean

Default: 0

Legacy I-variable alias: none

BrickAC.Chan[*j*].I2tWarnOnly determines the course of action the amplifier hardware takes upon detection of an excess integrated current (I^2T) condition on the channel. If **BrickAC.Chan[*j*].I2tWarnOnly** is set to the default value of 0, then upon detection of a I^2T excess condition, an amplifier fault is generated, the motor is killed, the corresponding status bit is set, and the corresponding error code is displayed on the amplifier (Error Code n.L).

If **BrickAC.Chan[*j*].I2tWarnOnly** is set to a value of 1, the I^2T excess condition will be reported as a warning in the status register, but it will not generate a fault on amplifier.

The **BrickAC.Chan[*j*].I2tWarnOnly** value is sent to the active amplifier-control circuit upon setting one of the non-saved setup elements **BrickAC.Reset** or **BrickAC.Config** equal to 1 in a Script command. It does not take effect until then.

The channel index ***j*** (= 0 to 7) is one less than the corresponding hardware channel number (= 1 to 8).



Note

The integrated current (I^2T) calculations accessed by this element are performed in the amplifier stage of the Power Brick AC. These calculations are separate from those done by the Power PMAC software.

Channel Status Elements

BrickAC.Chan[*j*].I2tExcess

Description: Channel I^2T fault/warning flag

Range: 0 .. 1

Units: Boolean

The **BrickAC.Chan[*j*].I2tExcess** status bit indicates whether an excessive integrated current (I^2T) condition is present on the channel or not. It is set to 0 if the integrated current value is not excessive; it is set to 1 if it is excessive. This status flag is only updated if **BrickAC.Monitor** is set to 1.
An excessive I^2T condition is calculated to exist if a current loading on the channel over the continuous rating would produce a greater dissipation than operating at the maximum intermittent rating for over two seconds does.

An excessive I^2T condition will generate a fault if saved setup element **BrickAC.Chan[*j*].I2tWarnOnly** is set to its default value of 0. It will not generate a fault if **BrickAC.Chan[*j*].I2tWarnOnly** is set to 1.
BrickAC.Chan[*j*].I2tExcess is a transparent status bit and it will be cleared to 0 as soon as the integrated current value falls below the threshold again. However, any motor software fault conditions it creates are latched, and the motors must explicitly be re-enabled by command.

The channel index ***j*** (= 0 to 7) is one less than the corresponding hardware channel number (= 1 to 8).



Note

The channel will shut down with a fault when it detects an I^2T excess condition if **BrickAC.Chan[*j*].I2tWarnOnly** is set to 0 regardless of whether software status bits are updated for the processor (**BrickAC.Monitor** = 1) or not.



Note

The integrated current (I^2T) calculations accessed by this element are performed in the amplifier stage of the Power Brick AC. These calculations are separate from those done by the Power PMAC software.

BrickAC.Chan[*j*].IgbtOverTempFault

Description: Channel power device overtemperature fault flag

Range: 0 .. 1

Units: Boolean

The **BrickAC.Chan[*j*].IgbtOverTempFault** status bit indicates whether the calculated junction temperature of the channel's IGBT power device has exceeded its safe threshold or not. It is set to 0 if the calculated junction temperature is 120 °C or less. It is set to 1 if this temperature is over 120 °C. This status bit is only updated if **BrickAC.Monitor** is set to a value greater than 0.

BrickAC.Chan[*j*].IgbtOverTempFault is a transparent status bit and it will be cleared to 0 as soon as the calculated junction temperature value falls below the threshold again. However, any motor software fault conditions it creates are latched, and the motors must explicitly be re-enabled by command.
The calculated junction temperature is derived from the measured case temperature, the measured current levels, and the PWM switching frequency for the channel.

The channel index ***j*** (= 0 to 7) is one less than the corresponding hardware channel number (= 1 to 8).



Note

The channel will shut down with a fault when it detects an IGBT over-temperature condition regardless of whether software status bits are updated for the processor (**BrickAC.Monitor** = 1) or not.

BrickAC.Chan[*j*].IgbtTemp

Description: Channel IGBT case temperature

Range: 0 .. 255

Units: Degrees Celsius

The **BrickAC.Chan[*j*].IgbtTemp** status element contains the measured temperature IGBT case temperature for channel ***j*** of Power Brick AC. This value is only updated if **BrickAC.Monitor** is set to 1.
The channel index ***j*** (= 0 to 7) is one less than the corresponding hardware channel number (= 1 to 8).

BrickAC.Chan[*j*].InvalidPwmFreq

Description: Channel invalid PWM frequency flag

Range: 0 .. 1

Units: Boolean

The **BrickAC.Chan[*j*].InvalidPwmFreq** status bit indicates whether the PWM frequency supplied to this channel is valid or not. It is 0 if the frequency is within the valid range for the channel power device (4 kHz to 20 kHz). It is 1 if it is outside the valid frequency range for the device. This status flag is only updated if **BrickAC.Monitor** is set to a value greater than 0.

BrickAC.Chan[*j*].InvalidPwmFreq is a transparent status bit and it will be cleared to 0 as soon as the PWM frequency comes within the valid range again. However, any motor software fault conditions it creates are latched, and the motors must explicitly be re-enabled by command.
The present measured PWM frequency for the channel can be found in status element **BrickAC.Chan[*j*].PwmFreq**.

The channel index ***j*** (= 0 to 7) is one less than the corresponding hardware channel number (= 1 to 8).



Note

The channel will shut down with a fault when it detects an invalid PWM frequency regardless of whether software status bits are updated for the processor (**BrickAC.Monitor** = 1) or not.

BrickAC.Chan[*j*].OverCurrent

Description: Channel overcurrent fault flag

Range: 0 .. 1

Units: Boolean

The **BrickAC.Chan[*j*].OverCurrent** status bit indicates whether the hardware over-current detector for the channel has sensed an instantaneous overcurrent or short-circuit state for the channel or not. It is set to 0 if it has not detected this state. It is set to 1 if it has detected this state. This status flag is only updated if **BrickAC.Monitor** is set to a value greater than 0.

Over-current fault detection in Power Brick AC is performed in hardware. Once over-current fault is detected, the fault status is latched. This fault can be cleared by setting **BrickAC.Reset** equal to 1. Any motor software fault conditions it creates are also latched, and the motors must explicitly be re-enabled by command after this fault is cleared.

The channel index ***j*** (= 0 to 7) is one less than the corresponding hardware channel number (= 1 to 8).



Note

The channel will shut down with a fault when it detects an over-current condition regardless of whether software status bits are updated for the processor (**BrickAC.Monitor** = 1) or not.

BrickAC.Chan[*j*].OverTemp

Description: Channel excessive measured IGBT case temperature warning flag

Range: 0 .. 1

Units: Boolean

The **BrickAC.Chan[*j*].OverTemp** status bit indicates whether an excessive temperature is measured on the channel's IGBT case or not. It is 0 if the measured temperature is 75°C or less. It is 1 if the measured temperature is greater than 75°C. This status flag is only updated if **BrickAC.Monitor** is set to a value greater than 0.

The channel index ***j*** (= 0 to 7) is one less than the corresponding hardware channel number (= 1 to 8).
No fault is automatically generated if this status bit is set to 1; it should be considered a warning. Faults due to excessive temperature are based on the calculated "junction" temperature of the channel's power transistor block itself. The status bit for that fault is **BrickAC.Chan[*j*].IgbtOverTempFault**.
The present measured temperature for the channel's IGBT case can be found in status element **BrickAC.Chan[*j*].IgbtTemp**.

BrickAC.Chan[*j*].PwmFreq

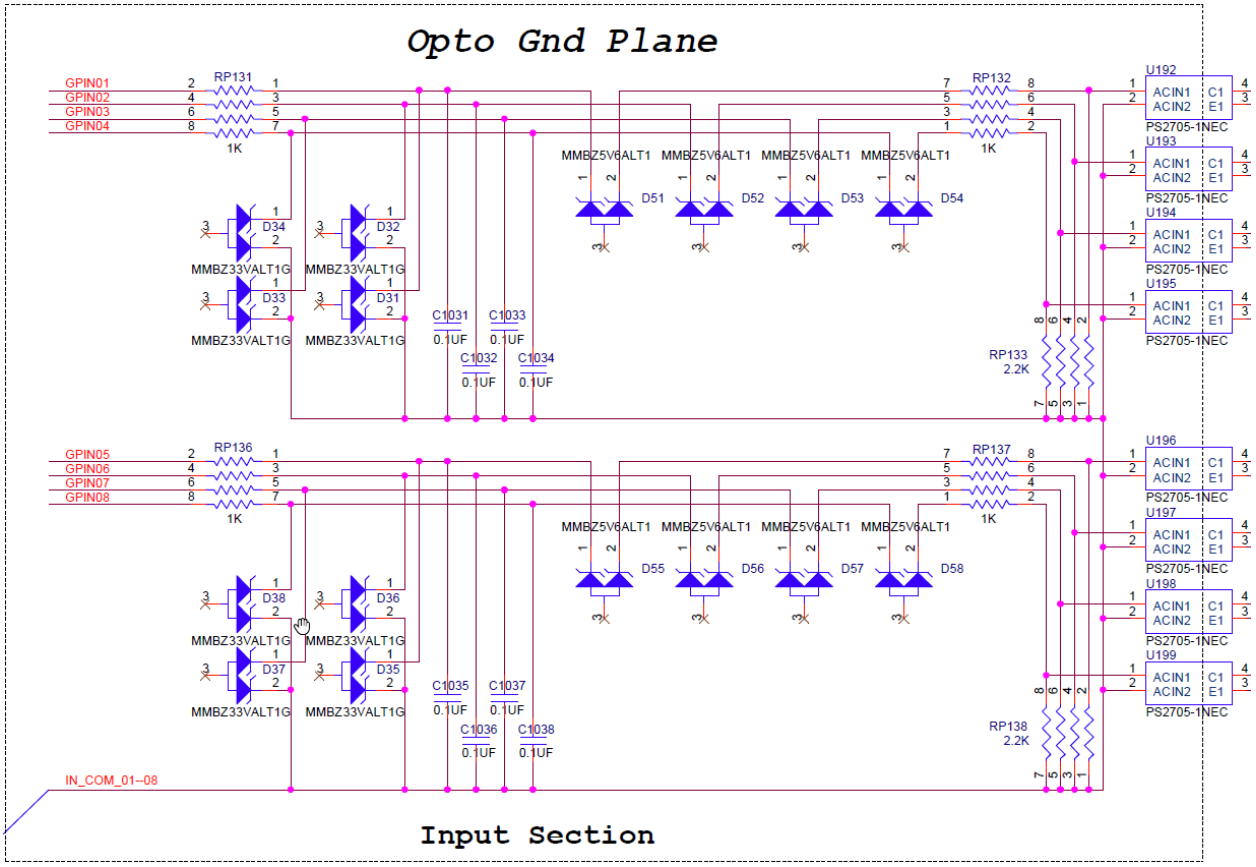
Description: Channel measured PWM frequency

Range: 0 .. 1.024.000

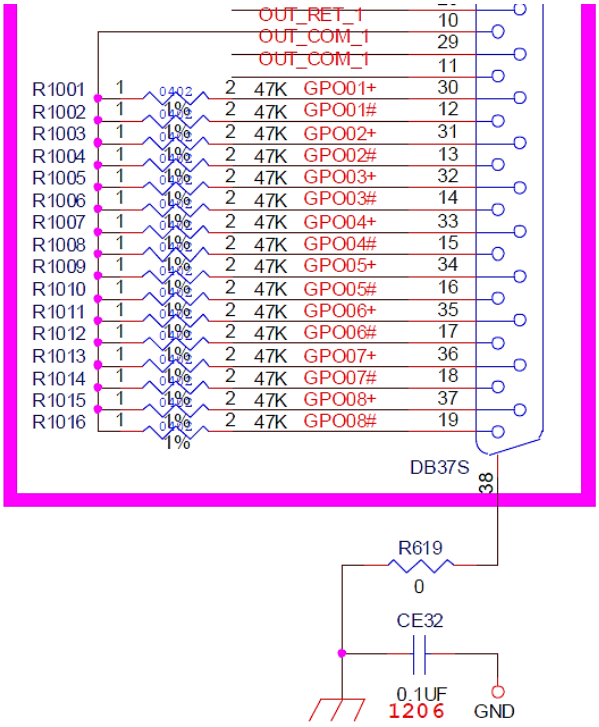
Units: Hertz

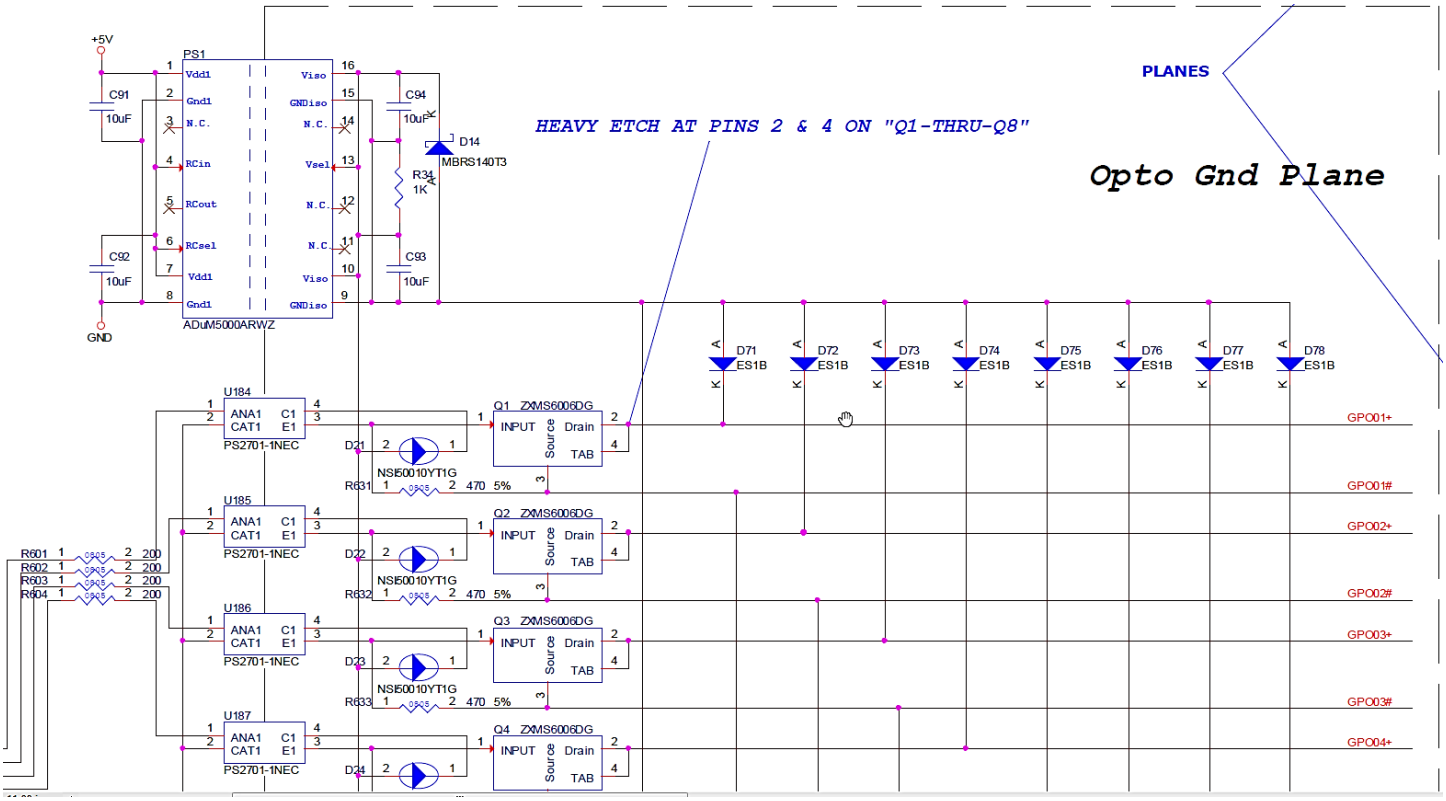
The **BrickAC.Chan[*j*].PwmFreq** status element contains the measured PWM frequency for channel ***j*** of Power Brick AC. It should match the frequency commanded by the controller stage. This value has a granularity of 100 Hz and is only updated if **BrickAC.Monitor** is set to 1.
The channel index ***j*** (= 0 to 7) is one less than the corresponding hardware channel number (= 1 to 8).

APPENDIX A: DIGITAL INPUTS SCHEMATIC

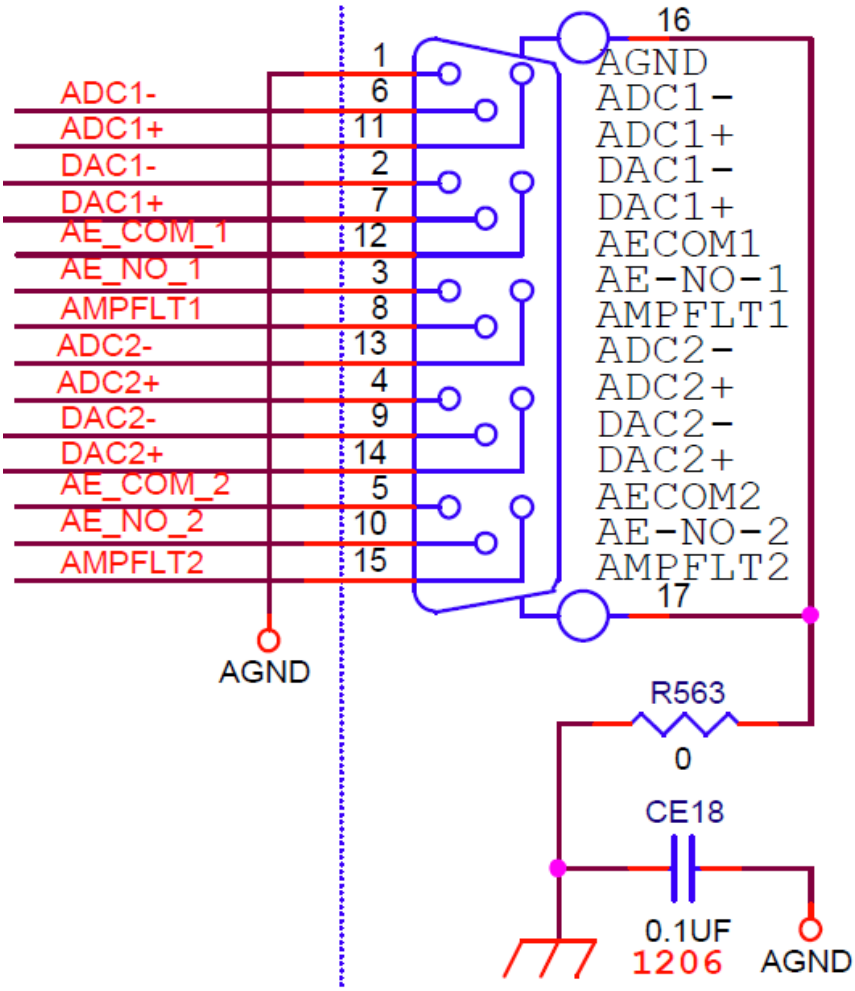


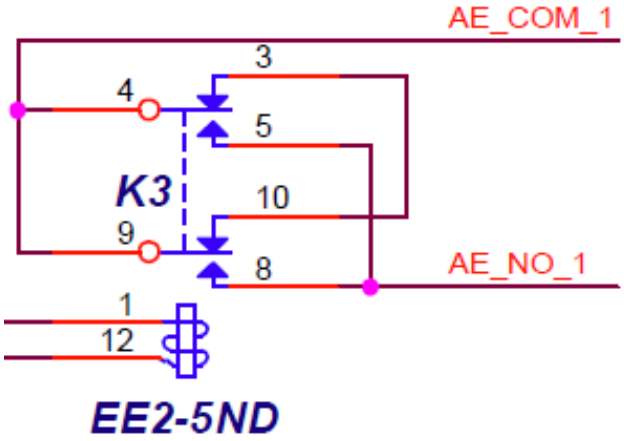
APPENDIX B: DIGITAL OUTPUTS SCHEMATIC

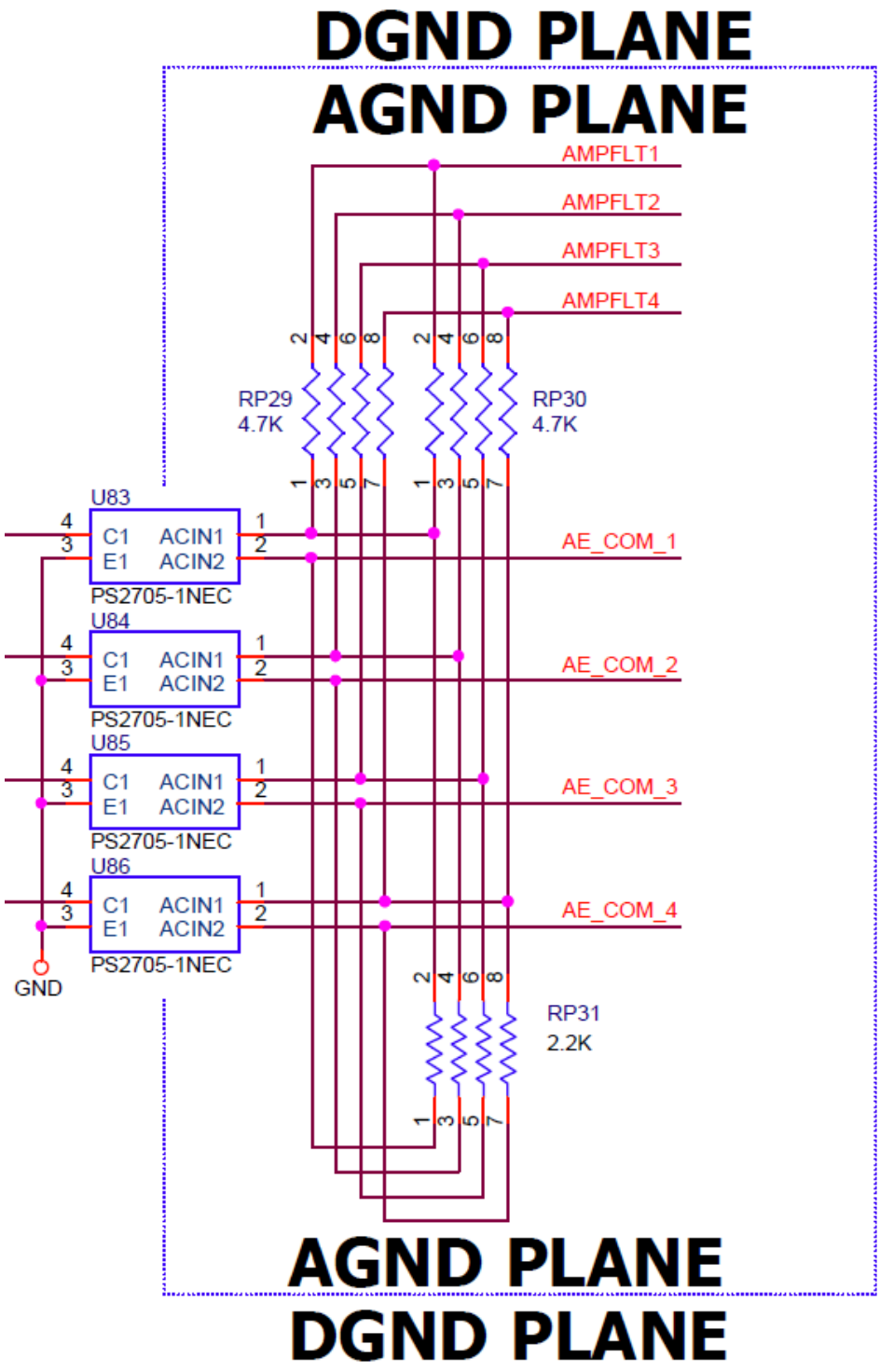




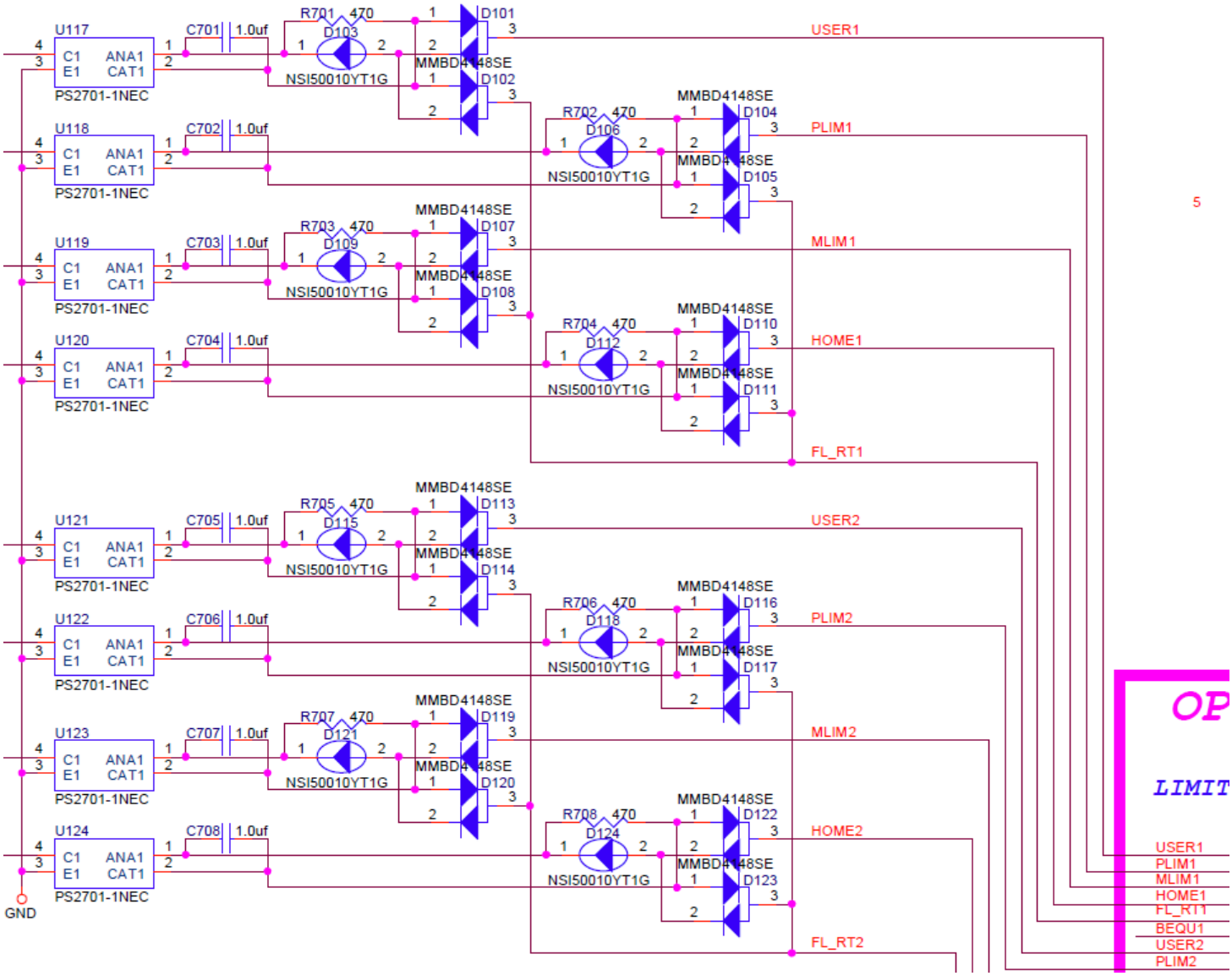
APPENDIX C: ANALOG I/OS SCHEMATICS






DGND PLANE
AGND PLANE
AMPFLT1
AMPFLT2
AMPFLT3
AMPFLT4
RP29
4.7K
RP30
4.7K
U83
U84
U85
U86
C1
E1
ACIN1
ACIN2
PS2705-1NEC
AE_COM_1
AE_COM_2
AE_COM_3
AE_COM_4
GND
RP31
2.2K
AGND PLANE
DGND PLANE

APPENDIX D: LIMITS & FLAGS SCHEMATIC



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