APS Technology

High Performance Stepper Motor Power Stage

TRANSLATION OF THE GERMAN ORIGINAL MANUAL

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In this manual you will find the descriptions of the features and specifications of the stepper motor power stage: APS01

This manual is also a supplementary to the "*phy***MOTION**™ *Modular Multi-axis Controller for Stepper Motors"* manual.

Every possible care has been taken to ensure the accuracy of this technical manual. All information contained in this manual is correct to the best of our knowledge and belief but cannot be guaranteed. Furthermore we reserve the right to make improvements and enhancements to the manual and / or the devices described herein without prior notification.

We appreciate suggestions and criticisms for further improvement.

Email address: doku@phytron.de

Questions about the use of the product described in the manual that you cannot find answered here, please contact your representative of Phytron (http://www.phytron.de/) in your local agencies.

1 Information

This manual:

Read this manual very carefully before mounting, installing and operating the device and if necessary further manuals related to this product.

- Please pay special attention to instructions that are marked as follows:

DANGER – Serious injury!	*Indicates a high risk of serious injury or death!*
DANGER – Serious injury from electric shock!	*Indicates a high risk of serious injury or death from electric shock!*
WARNING – Serious injury possible!	*Indicates a possible risk of serious injury or death!*
WARNING – Serious injury from electric shock!	*Indicates a possible risk of serious injury or death from electric shock!*
CAUTION – Possible injury!	*Indicates a possible risk of personal injury.*
CAUTION – Possible damage!	*Indicates a possible risk of damage to equipment.*
CAUTION – Possible damage due to ESD!	*Refers to a possible risk of equipment damage from electrostatic discharge.*
”Any heading“	*Refers to an important paragraph in the manual.*

Observe the following safety instructions!

Qualified personnel

WARNING – Serious injury possible!

Serious personal injury or serious damage to the machine and drives could be caused by insufficiently trained personnel!

Without proper training and qualifications damage to devices and injury might result!

- Design, installation and operation of systems may only be performed by qualified and trained personnel.
- These persons should be able to recognize and handle risks emerging from electrical, mechanical or electronic system parts.
- The qualified personnel must know the content of this manual and be able to understand all documents belonging to the product. Safety instructions are to be provided.
- The trained personnel must know all valid standards, regulations and rules for the prevention of accidents, which are necessary for working with the product.

Safety Instructions

Intended use:

The APS module is designed for operating in a drive system.

- An installation is allowed only if the requirements of the EC Machinery and EMC Directives are conformed with.

Part of a machine:

This product is used as a part of a complete system, therefore risk evaluations concerning the specific application must be made before using the product.

- Safety measures have to be taken according to the results and be verified.
- Personnel safety must be ensured by the concept of this overall system (e.g. machine concept).

WARNING – Serious injury from electric shock!

If the APS module is not operated with SELV/PELV voltages, the risk of dangerous voltages may be on the device. Touching these components carrying high voltages can cause serious injury or death from electric shock:

- Always observe the safety concept SELV / PELV to ensure safe insulation and separation of low voltage supplies from the mains.

WARNING – Serious injury from electric shock!

During electrical installation cables, connectors, etc. can be live.

- Before starting wiring, make sure that none of the power supplies are connected to the primary side of the mains supply. Isolate the power supplies from the mains or remove the appropriate fuses.
- All modules must be inserted into the terminal housing before powering up. Never operate the equipment when open.
- Do not plug or unplug the modules while powered.
- Do not plug or unplug the connectors while powered.
- If the equipment was energised, wait 3 minutes after power off to allow the capacitors to discharge and ensure that there are no residual charges on cables, connectors and boards.

2 Contents

3 APS01 Module Overview

The phytron APS module is a high performance power stage for the operation of stepper motors up to 5 A_{PEAK} at 24 - 70 V_{DC} with a shaft power up to 250 Watts.

The APS module positions with an actual step resolution of 1/512 (102,400 positions per revolution with an encoder with a 200 stepper motor). Based on our chopper technology (parameterised) and by the use of premium components with low resistance, the APS triggers with optimal timing.
So the APS technology creates a current shape close to a perfect sine wave with a minimum of heat loss in the controller. Only this highly accurate output provides low losses and attenuated resonances within the motor and fast execution of each partial step when moving to a position.

The compact and integrated APS is the core of the 1-STEP-DRIVE (for SIMATIC ET 200®S) PLC module and is available as a power stage module in our *phy***MOTION**™ system. The APS can be parameterised (run current, stop current, boost current, current delay time etc.) and diagnosed online by a ServiceBus code and is also open for instructions from the CPU in runtime within a parameterisation cycle.

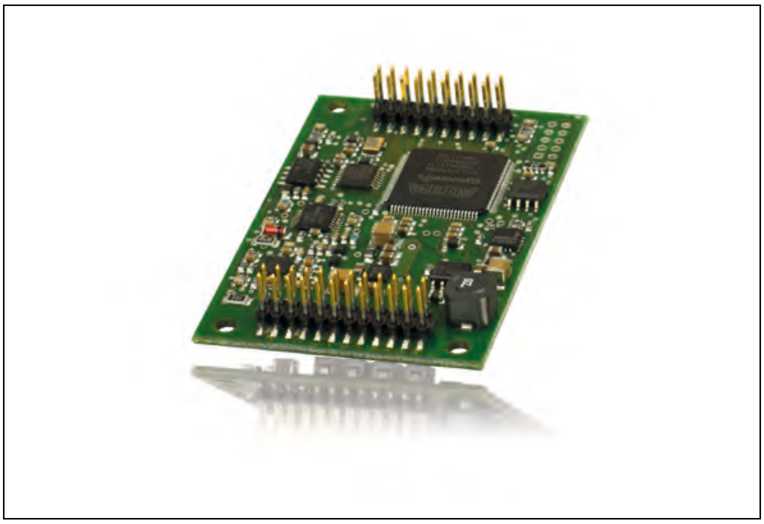


Fig. 1: View of the APS module

- OEM power stage module for 2 phase stepper motors
- Up to 5 A_{PEAK} at 24 to 70 V_{DC}
- Up to 1/512 step resolution
- Up to 500,000 steps/s
- Online parameterising and diagnostic of the power stage via Serial Peripheral Interface (SPI)
- Control via Control pulses/direction or via digital sin/cos (via SPI)

PCB connectors

Multi-pin connector 2 mm grid, 0.5 mm pin: 20 and 24 pins

SPI ServiceBus

The power stage parameters are programmed by the SPI connection:
Run-, Boost current, step resolution, motor direction, current delay time, etc.

Inputs

The input logic of Control pulses, Direction, Boost and Deactivation is defined by the ServiceBus.

Outputs

Both APS outputs – basic position and error, with 0 V / 3.3 V- level.

Mounting

The APS power stage is designed to be plugged into a motherboard.
All connections are PCB connectors with a multi-pin connector in
2 mm grid; 0.5 mm pin width (Fischer Elektronik company)
Pin: 2x10 and 2x12

Extent of supply

Included in delivery: Manual APS

4 Technical Data

4.1 Declaration of Conformity

phytron
Extreme. Precision. Positioning.

Declaration of Conformity
according to EC directive 2014/30/EU (EMC-Directive)

Name and address of the manufacturer:
Phytron GmbH,
Industriestr. 12
82194 Gröbenzell

We declare that the following product is in conformity with the EC Directives 2014/30/EU relating to EMC.

Product denomination

Part-No.	Title	
10015045	APS01.1	High-End Stepper Motor Power Stage

From serial number 1604xxxxx

Applied harmonized standards

- EN 61000-6-1: 2007-01 Electromagnetic Compatibility (EMC) - Immunity for residential, commercial and light-industrial environmental
- EN 61000-6-2: 2005-08 Electromagnetic compatibility (EMC) - Immunity for industrial environments
- EN 61000-6-2: Corrigendum 1:2011
- EN 61000-6-3: 2007-01 Electromagnetic compatibility (EMC) - Emission standard for residential, commercial and light-industrial environments
- EN 61000-6-3: A1:2011
- EN 61000-6-3: AC:2012
- EN 61000-6-4: 2007-01 Electromagnetic compatibility (EMC) - Emission standard for industrial environments
- EN 61000-6-4: A1:2011

Comment:
This declaration of conformity is valid only if the device is built in a suitable casing e.g. phyMOTION-6SL-MR-s.

Gröbenzell, 2016-04-20

Henning Brunke
Technical Director

4.2 Mechanical Data

Dimensions	60 x 40 mm
Weight	16 g
Mounting	Plug-in power stage module, also as OEM module e.g. on the phytron carrier module EVA-APS or INAM

4.3 Transport and Storage

Permissible transport- and storage conditions:

Transport and storage temperature:	-40 to +70 °C
Relative humidity	max. 95 % , no condensation and ice permissible
Package:	Always in ESD packing

CAUTION – Possible damage by ESD!

The module consists of sensitive electronic components that can be destroyed by electrostatic discharge voltages.

- Always store and transport single modules in ESD protective packaging.
- Always handle the components in compliance with the ESD protection measures.
- No liability is accepted for any consequences resulting from improper handling or non-ESD-friendly packaging.

CAUTION – Possible damage by collisions!

The APS module consists of sensitive electronic and mechanical components.

- Avoid collisions to the module.

4.4 Features

Performance Characteristics	
Stepper motor	Suitable for bipolar control of 2 phase stepper motors with 4, (6) or 8 lead wiring
Supply voltage	24…70 V_{DC} Nominal voltage: 70 V_{DC}
Phase current	0.1 to 5.0 A_{PEAK} (short-circuit-proof, overload-proof)
Current adjustment	10 mA steps
Step resolutions	Full step, half step, 1/2.5, 1/4, 1/5, 1/8, 1/10, 1/16, 1/20, 1/32, 1/64, 1/128, 1/256, 1/512 micro step
Maximum step frequency	500,000 steps/sec.
Maximum clock frequency	4 MHz
Physical resolution	Approx. 102,400 positions per revolution (0.00035° / step). The optional encoder modules should be considered for very fine positioning.
Current consumption (max.)	3.6 A_{DC} at 5.0 A_{PEAK}
Mechanical output power	Up to the 250 W range
Nominal power of the motor voltage supply	250 W
Cable length – motor	Shielded: 50 m max.
Diagnostics	Possibility for connection via 2 signal cables with 3.3 V logic level (LVTTL) LED1: power stage ready (Ready_LED_green) LED2: error (Error_LED_red)
Hardware error detection	• Over current, short circuit > 10 A • Over temperature T>85 °C

Interfaces	
Motor connection	A, B, C, D for a 2 phase stepper motor
Analogue outputs	Temp_analog: Temperature output as analogue voltage
Interface signals	Control pulses, Direction, Boost, Deactivation, Reset SPI bus interface: - Digital sin/cos presetting (48 bit for one value pair) - Online parameterisation and diagnostic (SPI1): /CS,SCLK,MISO,MOSI
Alternative interface	SPI-Bus interface (SPI2): /CS2,SCLK2,MOSI2 - Digital sin/cos presetting (32 bit for one value pair) The sin / cos replaces the default clock / direction setting. - Must be parameterised by SPI1.

5 Installation

Phytron also delivers the APS power stage with the carrier module EVA-APS as development kit or INAM01 for use in phytron's modular controller *phy***MOTION**^{TM}.

5.1 Mechanical Installation

You'll get the APS as a single module card.

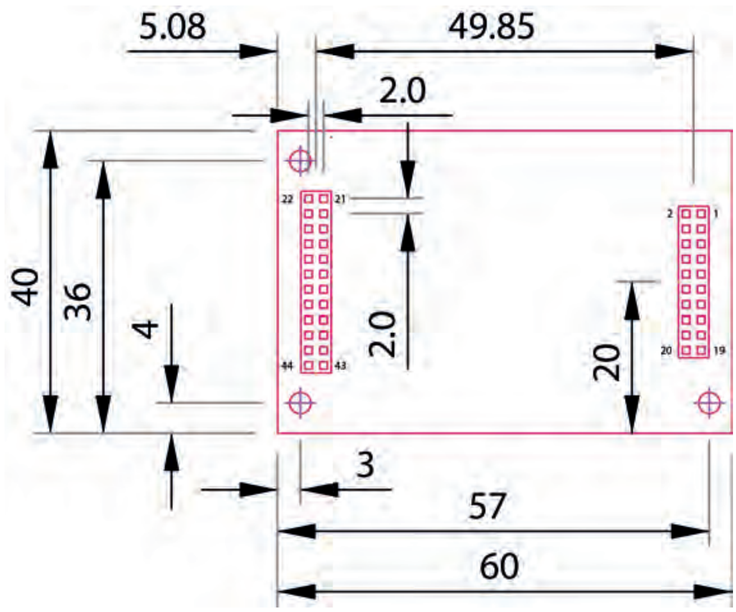


Fig. 2: Dimensions

Unpack the module carefully in ESD protected area only.

CAUTION – Possible damage by ESD!

The module consists of sensitive electronic components that can be destroyed by electrostatic discharge voltages.

- Always store and transport single modules in ESD protective packaging.
- Always handle the components in compliance with the ESD protection measures.
- No liability is accepted for any consequences resulting from improper handling or non-ESD-friendly packaging.

CAUTION – Possible damage!

The module is designed for a maximum supply voltage of 70 V_{DC}. If it is supplied with >70 V_{DC} the card might be damaged.

- Make sure that a power supply is used with less than 70 V_{DC} to avoid damage.
- By regenerative operation of the motor (deceleration) the supply voltage can rise up to 100 V_{DC}. For safety reasons, the power stage is designed for an increase of the operating voltage during operation at 100 V_{DC}.

Before integrating or switching the module always make sure that the devices are shut down and the power supply is disconnected.

WARNING – Serious injury from electric shock!

During electrical installation cables, connectors, etc. can be live.

- Before starting wiring, make sure that none of the power supplies are connected to the primary side of the mains supply. Isolate the power supplies from the mains or remove the appropriate fuses.
- Do not plug or unplug the modules while powered.
- Do not plug or unplug the connectors while powered.
- If the equipment was energised, wait 3 minutes after power off to allow the capacitors to discharge and ensure that there are no residual charges on cables, connectors and boards.

Now you can start with the electrical installation.

5.2 Electrical Installation

Ensure sufficient bending radius of the cables during installation. Do not lay the cables in tension or bend them.

If all the connections are made, the last step is to plug in the power supply to the mains.

5.2.1 Connectors - Overview

Connector	Number of pins	Connector on the module (e.g. Fischer Elektronik)	Mating connector (e.g. Fischer Elektronik)
S1	2x12	Pitch 2 mm (e.g. SLY8 SMD062-24-S)	e.g. BLY8 SMD-…
S3	2x10	Pitch 2 mm (e.g. SLY8 SMD062-20-S)	e.g. BLY8 SMD-…

5.2.2 Pin Assignment

View of the APS module:

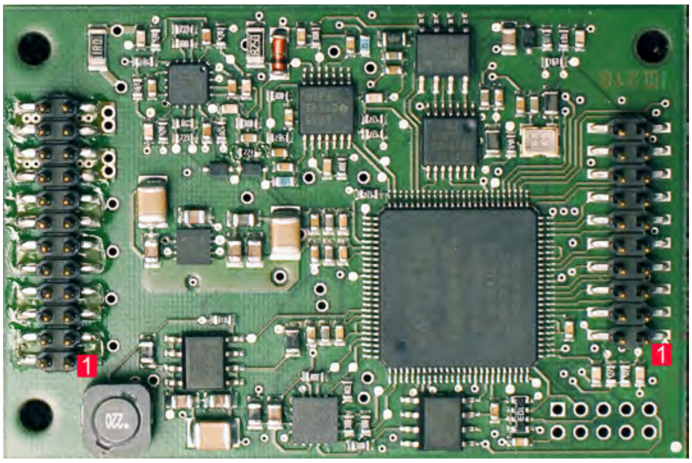


Fig. 3: Components TOP

In the following the pin assignment:

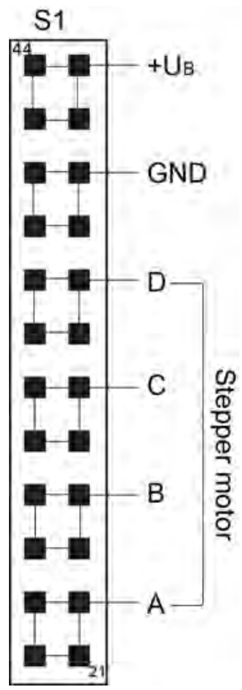


Fig. 4: Pin assignment "S1"

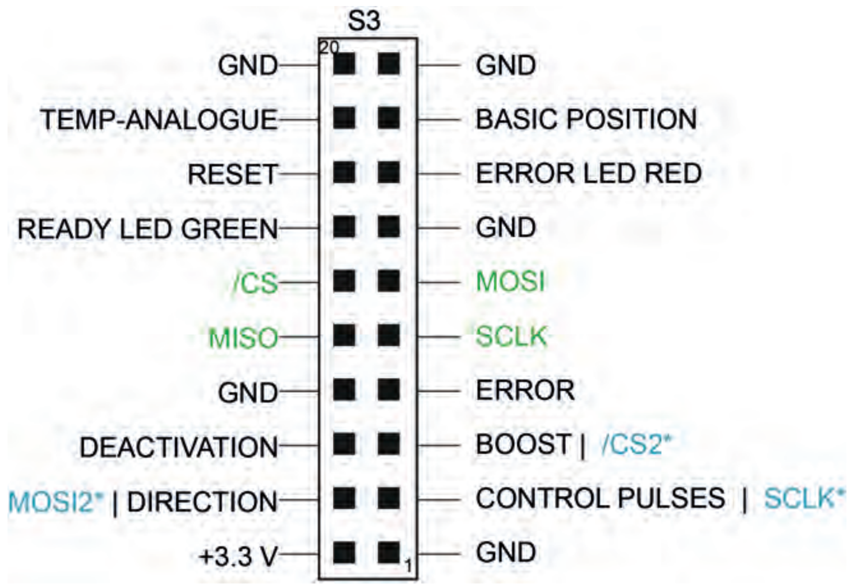


Fig. 5: Pin assignment "S3"

SPI1

*) Alternative assignment when using the SPI2

Please use the above defined or identical connectors for wiring.

5.2.3 Stepper Motor Connection

In the next chapter the connection of a 2 phase stepper motor with 4, (6), or 8 lead wiring is described.
Stepper motors with 0.1 to 5.0 A_{PEAK} can be controlled at maximum 70 V_{DC} by the APS.

Wiring schemes

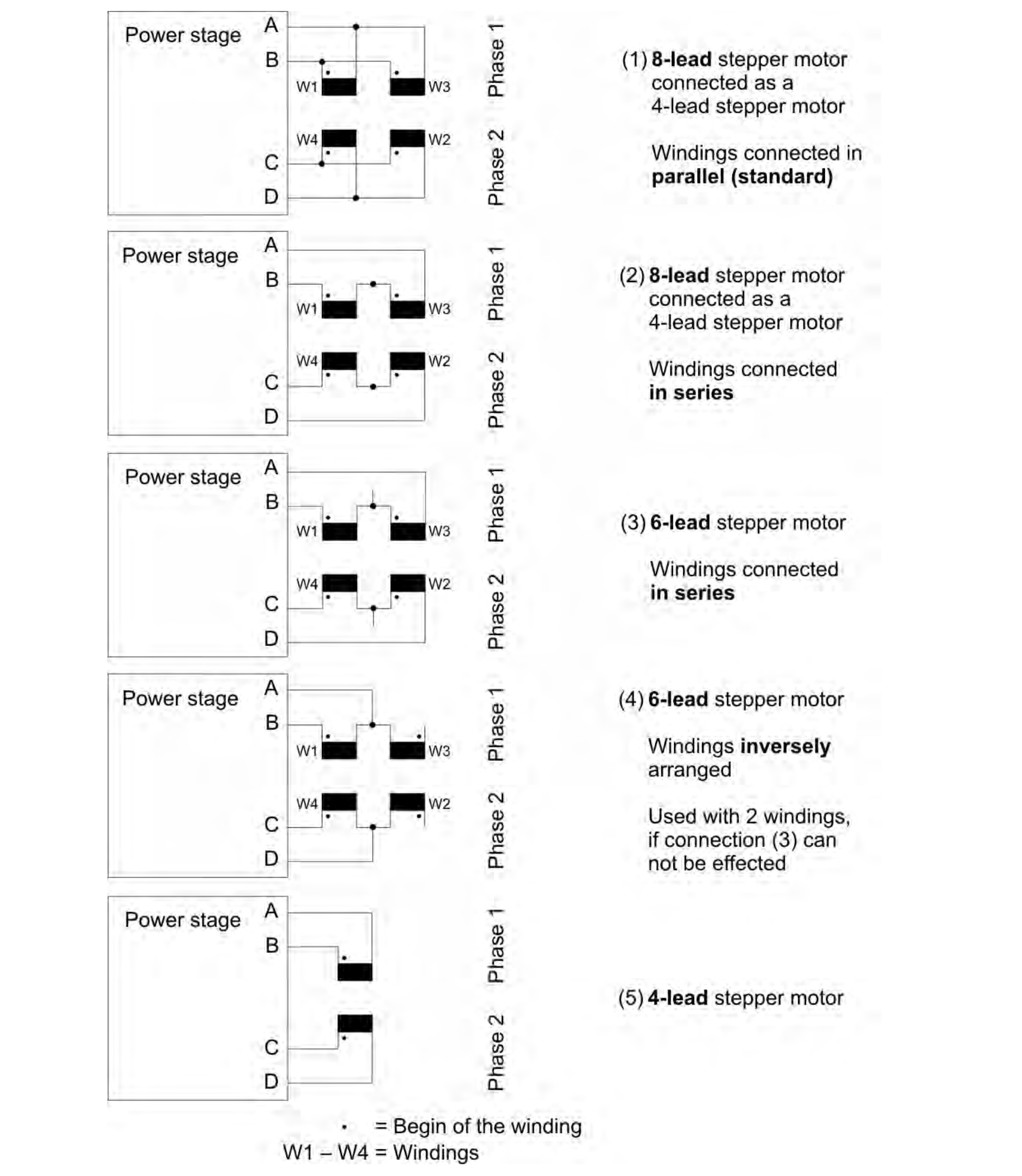


Fig. 6: Connection diagrams for 4,(6) and 8 lead stepper motors

Stepper motors with 8 leads can be connected with the windings wired in parallel (1) or series (2).

For 6 lead stepper motors, wiring scheme (3) with series windings is recommended.

If wiring scheme (3) cannot be used because of the motor construction, the motor may be operated with only two of the four windings energized according to wiring scheme (4).

i

CAUTION – Possible damage!

Destruction of the power stage by connecting a 5 phase stepper motor.

- Do not connect any 5 phase stepper motors to avoid damage.

Motor time constant τ:

$\tau = \frac{L}{R}$ applies to the electrical motor time constant τ.

The total inductance L_{total} is equal to the winding inductance in a parallel circuit, because of interlinked inductances.
L_{total}= 4 x L applies to a series circuit.

The result is an equal motor time constant τ for a serial and a parallel circuit:

Circuit	**series**	**parallel**
Resistance R_{total}	**2 x R**	$\frac{R}{2}$
Inductance L_{total}	**4 x L**	**L**
Motor time constant τ	$\tau_{series} = \frac{4 \times L}{2 \times R} = \frac{2 \times L}{R}$	$\tau_{parallel} = \frac{L}{R/2} = \frac{2 \times L}{R}$

5.2.4 Wiring

Input	3.3 V-LVTTL 5 V-TTL may cause damages
Output	3.3 V-LVTTL-level with 24 mA max. output current

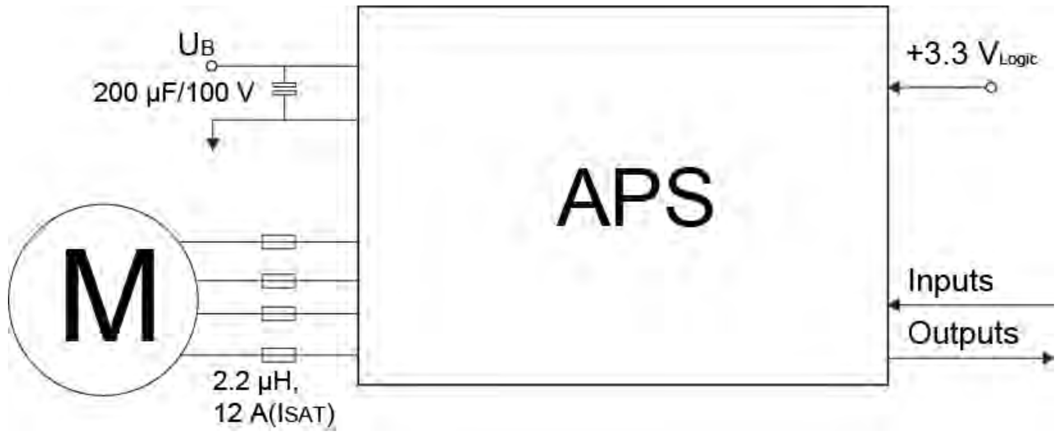


Fig. 7: Typical applications of the APS wiring

6 Commissioning

The EVA-APS is a test and evaluation board, designed for customers interested in application of the APS stepper motor power stage module. By means of EVA-APS you can test the APS module without the costs for designing a high-end stepper driver. The EVA-APS is also recommended for prototyping and small quantity production.

If the motor is back-driven at high speeds (e.g. Z axis fault), power is fed back into the APS module and can result in its failure. To avoid damage, we recommend careful sizing of the load capacitor.

CAUTION – Possible damage!

Some modules are set to a default value on delivery. So e.g., the motor current must be set to the corresponding value (see the motor data from the motor manufacturer). Connected components like motors can be damaged by incorrectly set values.

- Please check if the parameters are correct before starting.

6.1 Signal Description at the connector S3

Pin	Name	Signal description
1	GND	Signal ground / Logic ground
2	+3.3 V	Logic voltage
3	CONTROL PULSES | SCLK (SPI2) *(Input)*	The step is done with the falling flank of the control pulse. Max. Step frequency: 510 kHz *- The polarity of the CONTROL PULSES signal is reversed by the logic CONTROL PULSES* defined by ServiceBus.* *- SCLK for sin/cos mode see chap.9.4*
4	DIRECTION | MOSI (SPI2) *(Input)*	1 = positive direction (3.3 V) 0 = negative direction (0 V) *-The polarity of the DIRECTION signal is reversed by the logic DIRECTION* or the VZDR signal defined by ServiceBus.* - MOSI see chap. 9.4.
5	BOOST | /CS2 (SPI2) *(Input)*	1 = with BOOST (Boost current active), (3.3 V) 0 = without BOOST, (0 V) *-The polarity of the BOOST signal is reversed by the logic BOOST* defined by ServiceBus.*
6	DEACTIVATION *(Input)*	1 = Power stage deactivated (power stage current less), (3.3 V) 0 = Normal mode (0 V) *-The polarity of the DEACTIVATION signal is reversed by the logic DEACTIVATION * defined by ServiceBus.*
7	ERROR *(Output)*	Over current, short circuit > 10 A for a short time at the power stage, over temperature of the power stage T > 85 °C 1 = Error high active = 3.3 V for active error signal *-The polarity of the ERROR signal is reversed by the logic ERROR * defined by ServiceBus.*
8	GND	Signal- / Logic ground

9	SCLK *(Input)*	SPI-SCLK (*ServiceBus*); f_{CLKmax}= 4 MHz
10	MISO *(Output)*	SPI-MISO (*ServiceBus*)
11	MOSI *(Input)*	SPI-MOSI (*ServiceBus)*
12	/CS *(Input)*	SPI-CS (*ServiceBus*)
13	GND	Signal- / Logic ground
14	READY LED GREEN *(Output)*	1 = Power stage ready
15	ERROR LED RED *(Output)*	1 = Error
16	RESET *(Input)*	0 = RESET active
17	BASIC POSITION *(Output)*	1 = Basic position 0 = no basic position - *The polarity of the BASIC POSITION signal is reversed by the logic GST * defined by ServiceBus.* - *If an error occurs, the BASIC POSITION signal is reset.*
18	TEMP-ANALOG *(Output)*	Temperature output as analogue voltage TEMP_ANALOG = 480 mV + 15.6 mV/°C × T *T = Sensor temperature on the APS board*
19	GND	Signal / Logic ground
20	GND	Signal- / Logic ground

* *0 = negative logic*
1 = positive logic

CAUTION – Possible damage!

If the logic inputs are left open, the input level remain undefined!

- The logic inputs must be connected.

6.2 Diagnostics by Output lines for LED display

If the output lines “READY LED GREEN“ and “ERROR LED RED“ are used on the basic board for driving the LEDs, the LEDs indicate the status and error of the module:

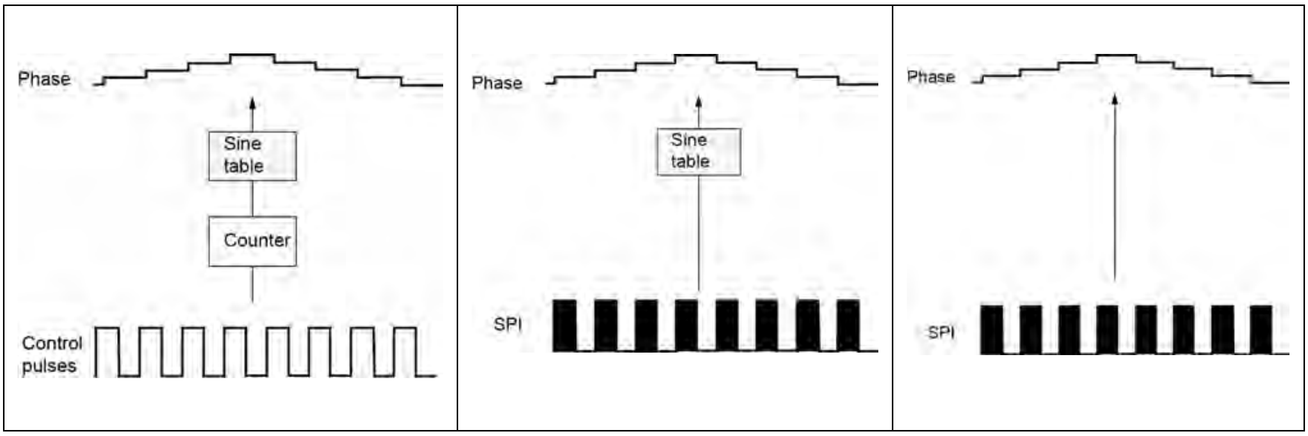
LEDs	Status
On	No power available
green	OK, ready
red	Error on the status is active (Error-Bit ‚0‘)

The outputs correspond to the LV-TTL standard and can therefore be processed using compatible logic levels.

6.3 Operating Modes of the APS Module

By default, the Control pulses/Direction interface is used to drive the power stage.

In this Control pulses/Direction mode (mode 1) the Serial Peripheral Interface (SPI1) is additionally used to parameterise the technology parameters of the power stage (e.g. run current) and read the diagnostic status.



Mode 1 Mode 2 Mode 3

Alternatively it is possible to set directly the phase current instead of the control pulses/direction signals.

This can be done via the register set (register address 10 to 13) of the SPI1 or SPI2 with the connection CONTROL PULSES, DIRECTION and BOOST.

This phase requirement can be done in two ways:

- via “ROM address“ (mode 2) or
- “directly to the DAC“ (mode 3)

6.3.1 Mode 1 ’Control pulses/Direction‘

The APS module is operated by Control pulses/Direction signals. A parameterisation of the power stage is done via the SPI1.

Select AD=0
Select DAC=0
Enable SPI2= 0

} Default after Reset in register 8

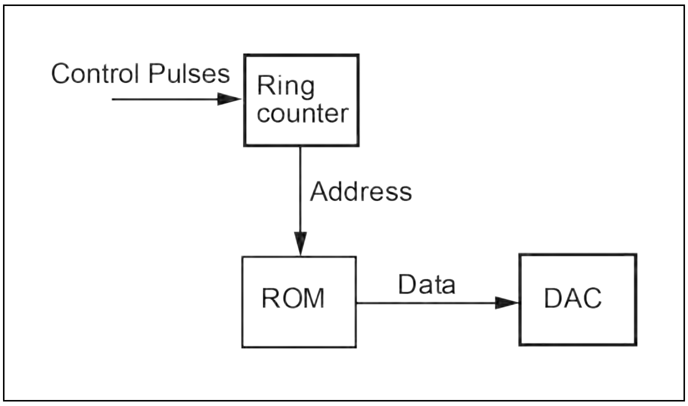


Fig. 8: ‘Control pulses/Direction‘ transmission

6.3.2 Mode 2 'Value specification via ROM address'

CONTROL PULSES, DIRECTION, BOOST have no influence on the operation of the APS. The phase current specification is either via SPI1 or SPI2.

Select AD=1
Select DAC=0
Enable SPI2= 0/1

} Register 8 must accordingly be described.

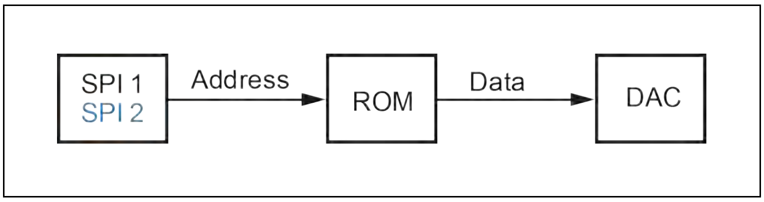


Fig. 9: Value specification via ROM address

See chapter 6.4.4

6.3.3 Mode 3 'Value specification directly to the DAC'

CONTROL PULSES, DIRECTION, BOOST have no influence on the operation of the APS in this operating mode, too. The phase specification is done via SPI1 or SPI2. The values are not transmitted unlike in mode 2 by address, but directly to the DAC.

Select AD=0
Select DAC=1
Enable SPI2= 0/1

} Register 8 must accordingly be described.

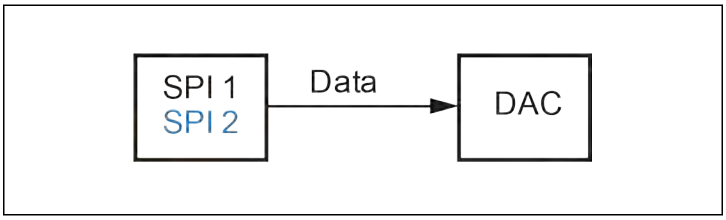


Fig. 10: Value specification directly to the DAC

See chapter 6.4.5

6.3.4 Comparison of the Modes

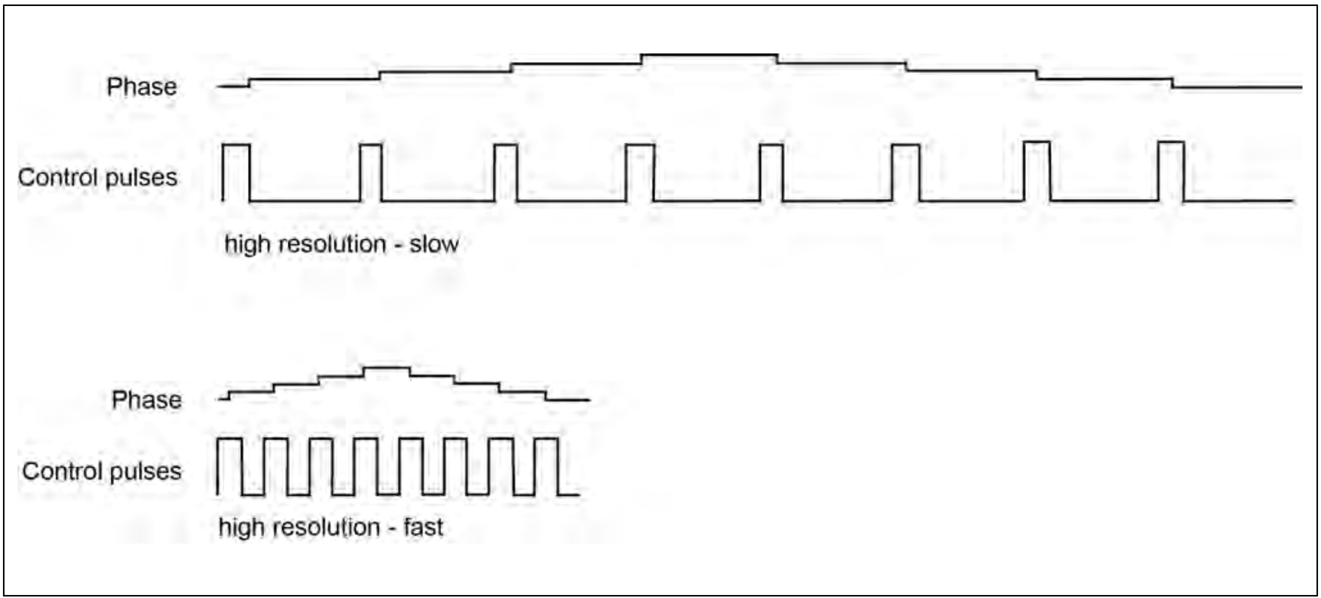


Fig. 11: Mode 1: high resolution – slow and fast

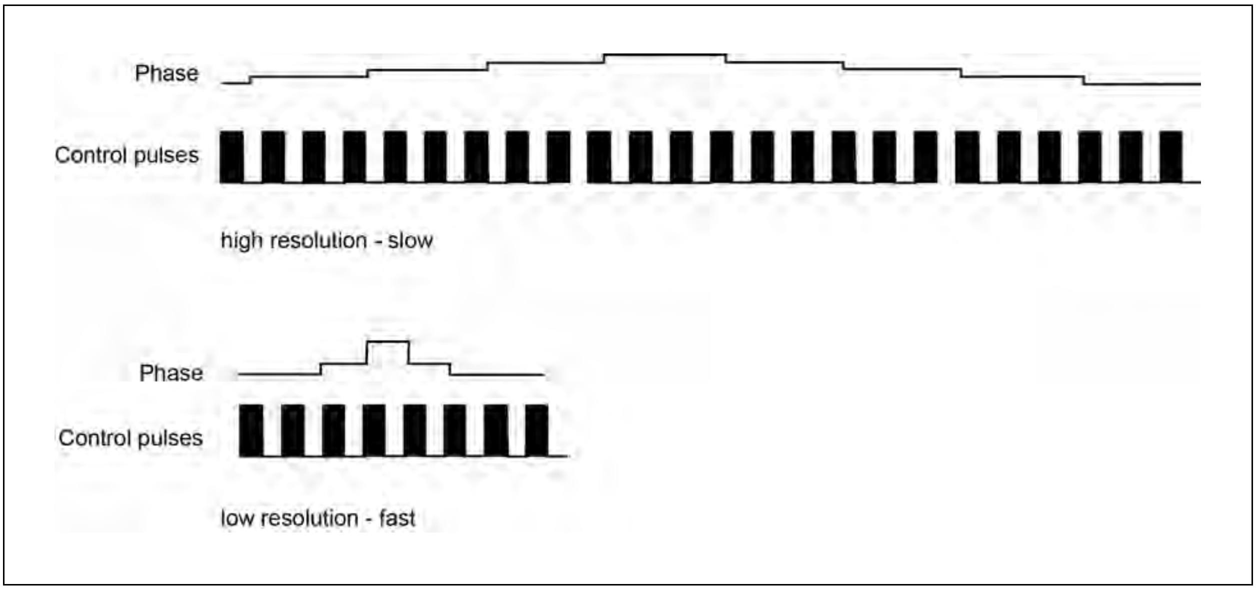


Fig. 12: Mode 2 or 3: dynamic adaption of the step resolution:
slow high and fast low resolution

Mode 2 uses the internal sin/cos-ROM of the APS. No computation is necessary.

Mode 3 can output any waveform with any amplitude levels.

6.4 Data set for Module Parameterising

The transfer to the ServiceBus consists of 3 bytes (8 bit address and 16 bit data).

Byte	Function	
1	R/W and Register address	The register address is transmitted in byte 1 (7 bit) and in addition the direction of the data flow. (MSB, 1 Bit): 1 = write 0 = read If the highest bit is set, the following two bytes are written into the registers of the FPGA. If the highest bit isn't set, the following two bytes are read out of the FPGA registers. Example: 0x80 → Write register 0 0x00 →Read register 0
2	Data: 16 Bit	
3		

6.4.1 Protocol Definition for SP1, Parameter Specification

CPOL=0 , CPHA=1, MSB-first

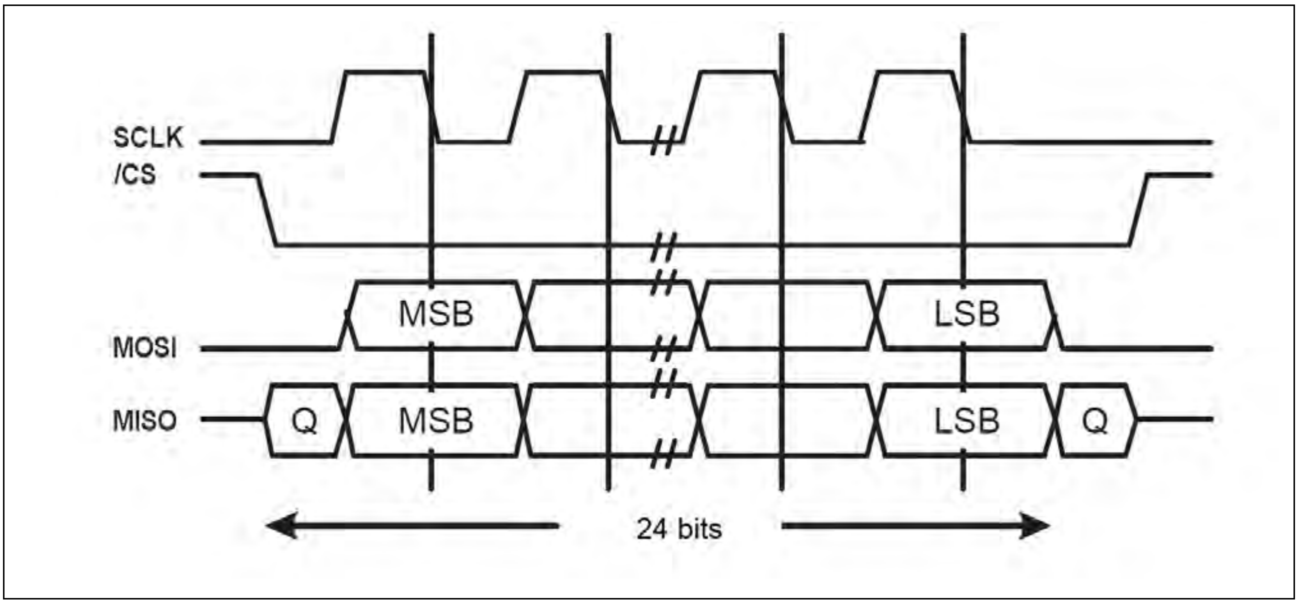


Fig. 13: SPI Frame Format mit CPOL=0 and CPHA=1; ($f_{CLK(max)}$= 4 MHz)

6.4.2 Registers

Register address	Function
0…8, 10…13	write
80, 90…93	Read

	Data Bytes																
	Function																**Default**
Register Address	**2.Byte**								**3.Byte**								
0	X	X	X	X	X	X	X	X	Enforce basic position		X	X	De-acti-vation	Over-drive on/off	X	X	0
1	Run current (r.m.s.)								Resolution 10 mA, Default: 1 A								100
2	Stop current (r.m.s.)								Resolution 10 mA, Default: 0.5 A								50
3	Boost current (r.m.s.)								Resolution 10 mA, Default: 3.5 A								350
4	Step resolution								0 : 1/1 1 : 1/2 2 : 1/2.5 3 : 1/4 4 : 1/5 5 : 1/8 6 : 1/10					7 : 1/16 8 : 1/20 9 : 1/32 10 : 1/64 11 : 1/128 12 : 1/256 13 : 1/512			11
5	Current delay time								range: 0 to (2^{16}-1)				resolution: 1 ms				20
6	Switching frequency overdrive (full steps/sec)								range: 0 to (2^{16}-1)				resolution: 1 Hz				1000
7	Chopper frequency (Frequency of the pulse width modulation for the motor current)												0 : 18 kHz 1 : 20 kHz 2 : 22 kHz 3 : 25 kHz				1

Register Address	2.Byte								3.Byte								Default
8	Select AD	Select DAC	Enable SPI2	X	X	X	Logic GST *)	Logic Error *)	X	X	Logic Control pulses *)	Logic Direction*)	Logic Deactivation *)	Logic Boost *)	X	Pref. direction	0FF
10	1	Address phase 1 for ROM table Value range: 0…2047$_D$															–
11	0	Address phase 2 for ROM table Value range: 0…2047$_D$															–
12	1	Phase 1 value for direct specification to the DAC															–
13	0	Phase 2 value for direct specification to the DAC															–
80	0	0	0	0	0	0	0	0	Basic position	X	Over temperature error	Over current error	Deactivation	Overdrive	Boost	Run	–
90	0x4150 → "AP"																
91	0x4D35 → "S5"																
92	e.g.0x3031 → "01" (revision code of the FPGA software: here e.g. 01.01)																
93	e.g. 0x3031 → "01" (revision code of the FPGA software: here e.g. 01.01)																
*)	0 = negative logic 1 = positive logic																

6.4.3 Protocol Definition for SP2, Parameter Specification

CPOL=0 , CPHA=1, MSB-first

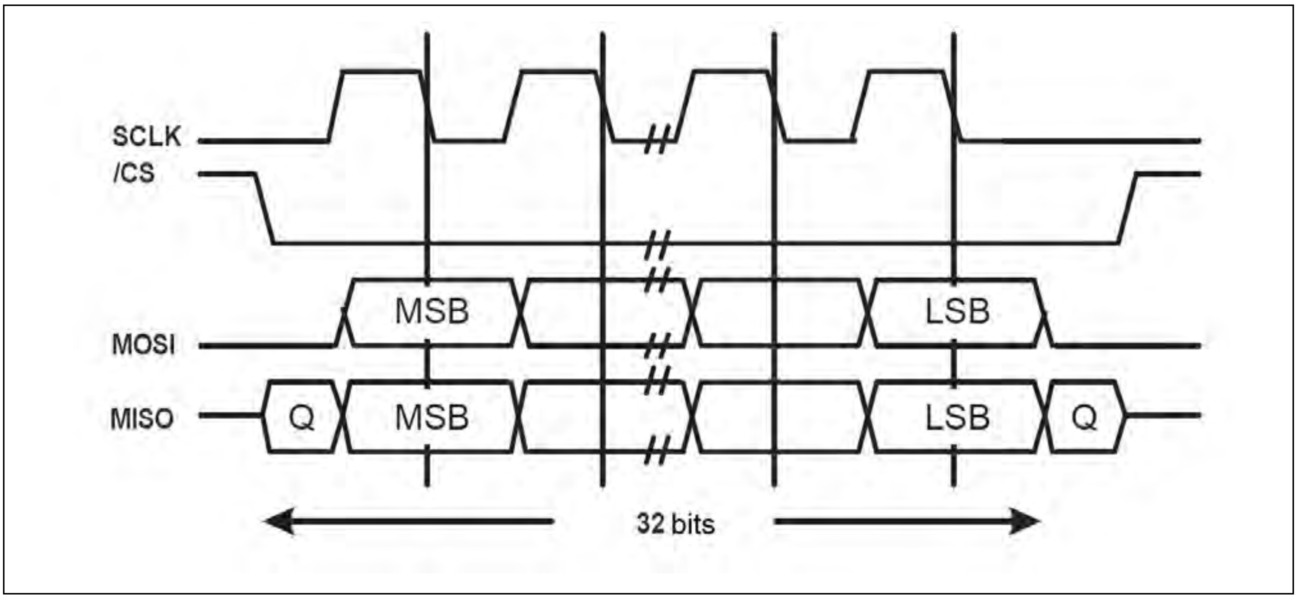


Fig. 1: SPI2 Frame Format with CPOL=0 and CPHA=1; ($f_{CLK(max)}$= 4 MHz)

6.4.4 Protocol Definition for Mode 2 'Value presetting via ROM Address'

i The written values address the sine/cosine table in the ROM and the finest resolution of 1/512 is possible

i The current amplitude is defined in this mode like mode 1via register 1,2 and 3. The maximum r.m.s. value of I=3.5 A corresponds to the maximum amplitude $\hat{i}_{max} = 5.0A$.

The sine function is stored in the following format:

$i(N) = -\hat{i} \cdot \sin\left(\frac{2\pi}{2048} \cdot N\right)$ with N = 0…2047 (= external address specification, 11 bit wide)

The phase 1 zero position is obtained for N = 1280: $i_{(1280)} = \frac{\hat{i}}{\sqrt{2}} = \hat{i} \cdot 0.707$

The phase 2 zero position is obtained for N = 1792: $i_{(1792)} = \frac{\hat{i}}{\sqrt{2}} = \hat{i} \cdot 0.707$

Transformission format by using SPI1:

Byte	1	2								3							
Phase 1	10	1				MSB											LSB
Phase 2	11	0				MSB											LSB

Transformission format by using SPI2:

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

Bit	**Function**
27..16	Address phase 1
11..0	Address phase 2
31..28	not used
15..12	

6.4.5 Protocol Definition for Mode 3 ‘Value presetting directly to the DAC‘

i The current value is directly written to the DAC in this mode (amplitude)!

The SPI2 uses the following format:

D_{max} = 1920 corresponds to 5 A

D_{min} = 0 corresponds to 0 A

In between, there is a linear relationship with $\frac{5000mA}{1920\,Bit} = \underline{\underline{2.60417\frac{mA}{Bit}}}$

Transformission format by using SPI1:

Byte	1	2								3							
Phase 1	12	1	pol	MSB											LSB		
Phase 2	13	0	pol	MSB											LSB		

Transformission format by using SPI2:

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

Bit	Wert	Funktion
30 and 14	pol = 0	current positive
	pol = 1	current negative
29..18	current value phase 1	–
13..2	current value phase 2	–
31,17,16	not used	
15,1,0		

CAUTION –
Possible damage!

- Direct entry sine/cosine value means the user must also switch from run to stop current settings themselves.

7 Service

In the case of a service order, please proceed as follows:

First try to identify the technical problem. Feel free to ask our support team for help. We are pleased to assist you.

Removal of a module:

- Power off the power supply
- Disconnect the supply voltage
- Remove the module carefully from the carrier board.
- To send a module to phytron use ESD packaging only.

8 Warranty, Disclaimer and Registered Trademarks

8.1 Disclaimer

Phytron GmbH has verified the contents of the manual to match with the hardware and software. However, errors and omissions are exempt and Phytron GmbH assumes no responsibility for complete compliance. The information contained in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

8.2 Warranty

The APS module is subject to **legal warranty**. Phytron will repair or exchange devices which show a failure due to defects in material or caused by the production process. This warranty does not include damage caused by the customer, for example, not intended use, unauthorized modifications, incorrect handling or wiring.

8.3 Registered Trademarks

In this manual several trademarks are used which are no longer explicitly marked as trademarks within the text. The lack of these signs may not be used to draw the conclusion that these products are free from third parties' rights. For example, some product names used herein are:

- *phy***MOTION**™ is a trademark of Phytron GmbH.
- *phy***LOGIC**™ is a trademark of Phytron GmbH.
- SIMATIC ET 200®S is a registered trade mark of the SIEMENS AG.
- Microsoft is a registered trade mark and WINDOWS® is a trade mark of the Microsoft Corporation in the USA and other countries.

9 Technical Glossary

9.1 Boost

The motor torque required during acceleration and deceleration is higher than that required during continuous motor operation (f_{max}). For fast acceleration and deceleration settings, (steep ramps), the motor current is too high during continuous operation and results in motor overheating. However, a lower phase current results in longer acceleration and deceleration ramps.

Therefore, different phase currents should be used:

- Continuous operation: run current
- During acceleration and deceleration: Boost current

  The Boost signal is activated by the superior controller. While input BOOST is energized, a 30 % higher current is flowing.

  In the ServiceBus mode the boost value is programmable from 0 to 3.5 $A_{r.m.s.}$

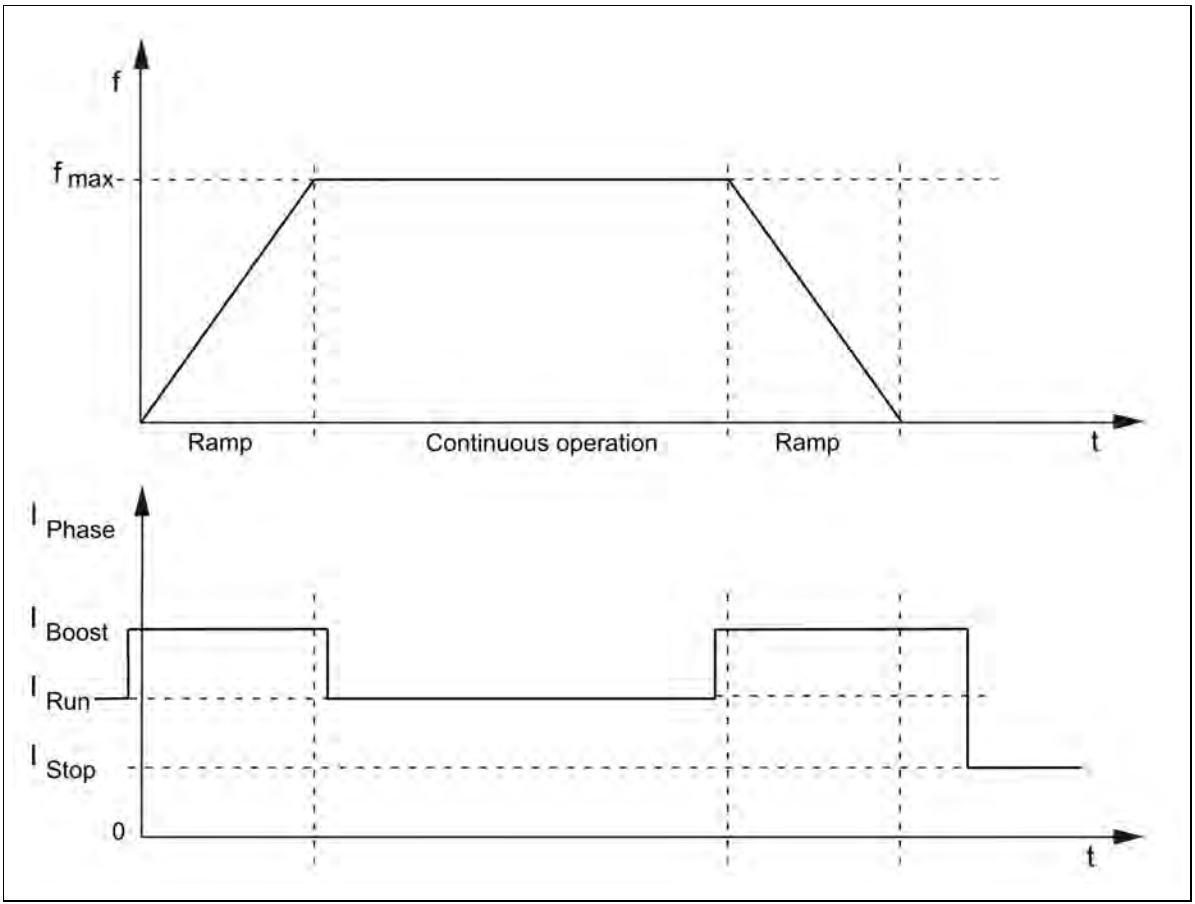


Fig. 14: Boost

9.2 Current Delay Time

After the last control pulse the stop current is activated after a time. The time after the last control pulse until the changing to the stop current is called current delay time.

We recommend to specify t_{Delay} so that the motor's oscillations are decaying after the last motor step and mispositioning is avoided.

Automatic change from run to stop current:

The ratio between both phase currents remains equal in the respective current feed pattern. Changing from run to stop current is achieved synchronously.
In the following figure the next motor step follows after every **rising** control pulse edge:

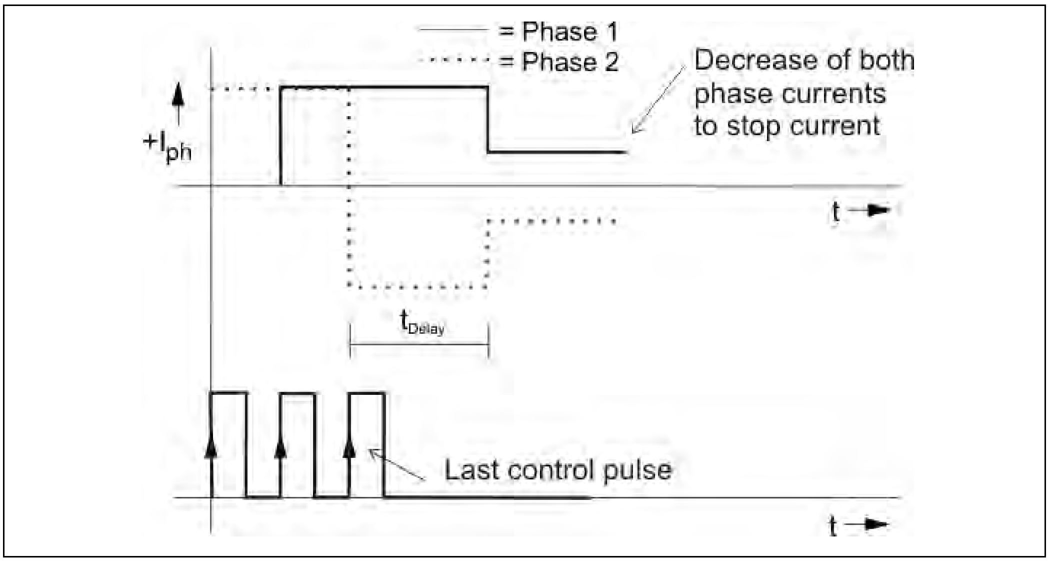


Fig. 15: Decrease to stop current after the last control pulse (full step)

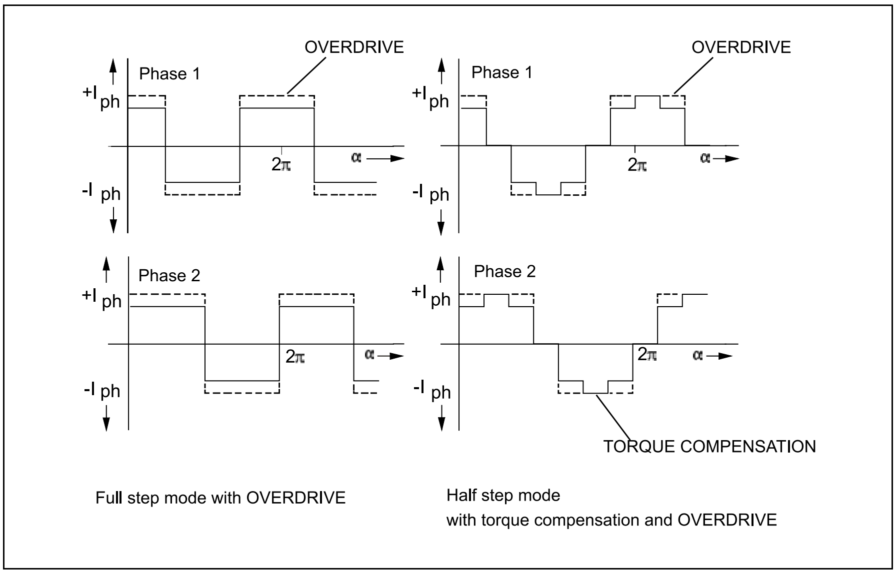
Decreasing to stop current has the following advantages:

- Motor and power stage heating is reduced.
- EMC is improved because of smaller current values.

9.3 Overdrive

Power stages can compensate the phase current decrease in the upper speed range by the Overdrive function which is independent of the motor type.

Overdrive is a dynamic boost function, which will be automatically switched on.



With increasing step frequency the stepper motor phase current decreases, caused, in part, by the back-emf of the motor. The amplitude of the current shape is smaller and the motor loses torque.
The Overdrive function works against the reducing of the torque by increasing the r.m.s. phase current automatically by a factor of $\sqrt{2}$ (generating a rectangle function). It compensates the decrease of the torque. If the speed decreases, the Overdrive is automatically switched off.
The step frequency at which the Overdrive function is switched on or off depends on the step resolution.
If a value of 1000 full steps / sec (= 1 kHz) is defined for the overdrive, you'll get the following step frequencies in dependence of the step resolution for the on-off-switching of the overdrive function:

Step resolution	**Step frequency**	
	Overdrive **on** at > [kHz]	Overdrive **off** at < [kHz]
1/1	1.0 kHz	0.9 kHz
1/2	2.0 kHz	1.8 kHz
1/4	4.0 kHz	3.6 kHz
1/5	5.0 kHz	4.5 kHz
1/10	10.0 kHz	9.0 kHz
1/20	20.0 kHz	18.0 kHz

Depending on the power stage, the Overdrive function is activated by a jumper, a switch or the ServiceBus.

9.4 Basic Principles of Stepper Motor Control

In the full step mode, both phases of a stepper motor are supplied with the same current, but with a 90° phase difference between them.

From an electrical viewpoint, the motor will perform a motion equal to 90° phase advance if it makes one full step. One full step is initiated by inverting the polarity of one phase. The magnetic axis - the stator field vector - is moved by an amount of 90° electrical. If four full steps have been completed, the magnetization is the same as at the start of the cycle.

If the motor performs one step, the rotor will be accelerated to its new destination position. If the rotor arrives at the new position, it will oscillate around this position due to the kinetic energy it has stored. This oscillation can - depending on step frequency and inertia of the system, create resonance effects. The critical frequencies where resonance effects are observed are within the range of 100..300 Hz.

To reduce these resonance effects, one remedy is to divide the full steps into smaller steps and therefore to approximate a sinusoidal current shape by introducing ministep operation.The first approximation is the half step mode with 8 step positions with a electrical phase difference of 45° from one to another. Starting in a full step position, a half step is initiated by switching one phase off. This normally would result in a lack of torque because only half the windings of the motor are energized. To compensate this torque decrease, the current in the second phase is increased by an amount of $\sqrt{2}$. The magnetic field vector in half step position will rotate by 45°electrical, the absolute value of the magnetic field stays constant.

Further increasing the number of sub-steps per full step leads to the ministep mode.

In addition to the full and half step modes the APS module offers the possibility to operate the stepper motor with 2, 2½, 4, 5, 8,10,16, 20, 32, 64, 128, 256 or 512 ministeps per full step.

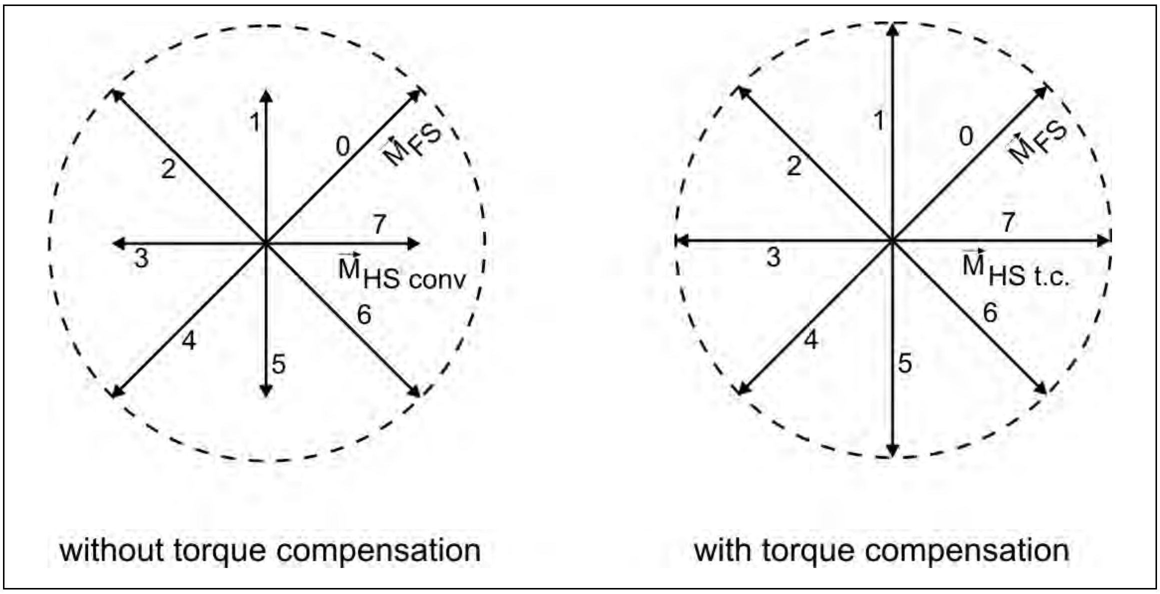


Fig. 16: Stator space vector

In the ministep mode the current shape in each phase is more and more sinusoidal as the step resolution increases. This results in improvements in the torque characteristic (less ripple per turn) and significantly reduces the noise emissions of the motor.

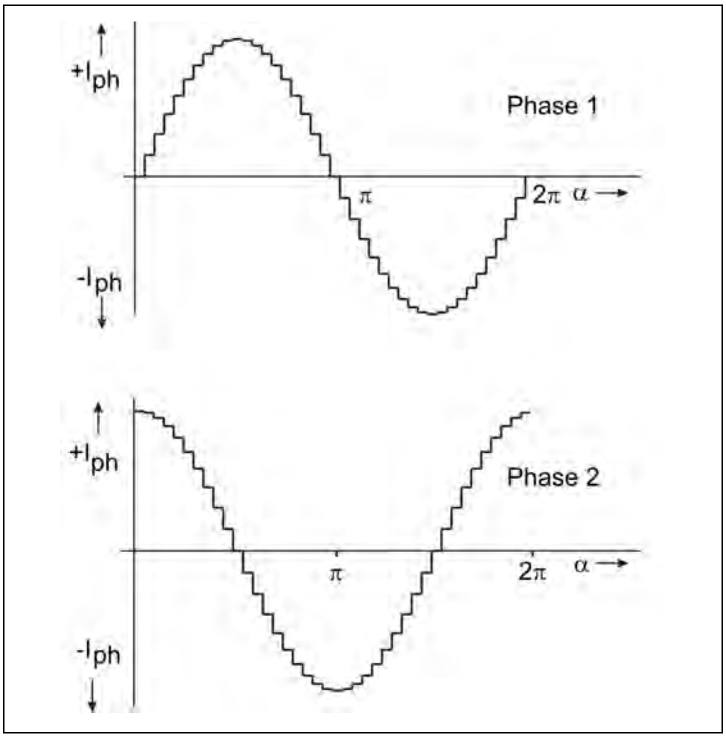


Fig. 17: Ministep 1/10

Remark:

Due to the mechanical design of standard stepper motors you cannot increase the mechanical positioning resolution if you increase the electrical resolution of your driving system. If you want to have a step resolution (mechanical) exactly equal to the step resolution (electrical), the motor would have to be optimized for this application.

The hybrid stepper motor exhibits a strong holding torque, because the salient pole geometry is attracted to preferred detent (stable) positions. The resolution of the system is a superposition of the residual torque due to the permanent magnets in hybrid stepper motors and the electromagnetic torque as defined by the power stage. The result is that a stepper motor does not execute exact equidistant steps if operated in ministep mode.

The main advantage of the ministep mode is an improvement of the operational behaviour of the stepper motor.

10 Index