MACCON
MOTION UNDER CONTROL

Torque, Linear and Custom Motors

Stepper, Servo and Traction Motors

Drive Electronics and Controllers

Actuators and Sensors

CAE Tools and Engineering

Motion Control Systems

SINE WAVE COMMUTATED SERVO MODULE

SWM7S – Standard Version and SWM7 – 300/600

User Manual

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Only qualified personnel are permitted to perform activities such as transportation, installation, commissioning, operating and maintenance.

The qualified personnel must know the standards and guidelines for mechanical and electrical installation, hazardous voltages and prevention of accidents and need to be familiar with handling of electrostatic sensitive devices. The SWM contains electrostatically sensitive components which can be damaged by improper handling.

The SWM7 family is intended for use of qualified personnel only in prototypes in separate protection enclosures.

Be familiar in detail with the complete documentation before unpacking, handling, installing, commissioning and operating the device. Incorrect handling, installing and operating of the SWM devices can lead to death, injury or damage. Check the type-plate of the current device.

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1 Introduction

This User Manual describes the SWM7S series of digital servo controllers

- Handling and Package, see chap. 2
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- EMC Considerations see chap. 6
- SetUp Tool SWM7.exe, see chap. 7
- System Parameter Setup, see chap. 8

All the operation functionality is accessible via the user-friendly and customizable Graphical User Interface (GUI), including:

- Displays for all operational states, parameters and measurement values
- Settings for configuration and optimization
- Clear text error messenger

The SetUp Tool **`SWM7.exe`** allows set-up and fine tuning of connected hardware (e.g. sensors, motors, etc.), and firmware updates.

The user gets flexible framework, so additional functionality can easily and efficiently be implemented according to the individual needs.

Software and User Manual is electronically available on CD-ROM.

Pay attention to the Safety Instructions and follow the guidelines for hardware connections, powering of the device, software usage and respect the datasheet limits, to avoid any risk of injury and damage.

Apply the required DIN ISO standards for your application.

Only qualified personnel is permitted to perform activities such as transportation, installation, commissioning and maintenance.

In case of errors, hardware problems (e. g. fuses, connectors, capacitor reforming, user-specific settings etc.) or other service related questions please contact MACCON technical support.

1.1 About this Manual

This User Manual is available in a PDF formatted file, it can be read and printed with any commercial and freeware PDF reader.

1.2 Safety Instructions

Each chapter contains specific instructions to avoid any hazardous situation which could result in death, injury or damage.

MACCON disclaims all responsibility and guarantee in case of misuse of hardware and failure to comply with the instructions provided in this manual.

1.3 Typographical Conventions

Graphical user interface text

Text of the graphical user interface (window titles, button descriptions, etc.) is placed inside quotation marks.

Example:

In the “POSITION CONTROL” tab choose in the control window “Start Current (DC)” the start value of `5.0 %`

File names

File names and paths are represented by a special font.

Example:

Start the **`SWM7.exe`** file. Install the program in the following directory:
`d:\Programs\SWM7`

Variables

Place holders for real names and values are represented additionally in italics and angle brackets.

Example:

Use the *.exe file *`<installation path>\SWM7.exe`*

2 Handling and Package

Only qualified personnel is allowed unpack and to handle the device. Consider ESD protection while handling the device.

After a storage period of more than 12 months check with MACCON technical support if any capacitor reforming might be necessary before powering the device! Powering the drive after long storage time without capacitor reforming might damage capacitors inside the drive and possibly the supply fuse as a result of high currents.

Check completeness of accessories just after receiving a new device.

Keep the delivery papers for service requests and the original box for any further transport.

2.1 Packaging, Transport and Storage

- Max. stacking height ≤ 8 cartons
- For transport keep the original box and insert for any transport of the device.
- Storage temperature −25 to +55° C, ⌊95 %, 2 years
  Storage only in the manufacturer’s original recyclable packaging.

2.2 Maintenance and Cleaning

No customer maintenance is necessary. Opening the device means loss of warrenty.

Enclosure cleaning can be done with Isopropanol to remove thermal interface paste. Do not immerse or wash directly in the fluid.

2.3 Unmounting the Controller

Unmounting procedure (e.g. for replacement). Unmount the servo amplifier (reverse of the procedure described in chap. 4, Mechanical Installation).

Only qualified personnel is allowed to work on electrical connections and to handle the device.

Consider ESD protection while handling the device.

Switch off the main switch and measure if the correct circuit has been switched off.

Wait at least eight minutes after disconnecting the servo amplifier from the main supply and measure the voltage in the DC supply if it has fallen below 40 V before touching or removing conductors, contacts or connectors.

Remove the connectors. Disconnect the earth (ground) connection at last.

Please refer also to the chapters 5.1 Safety Instructions and 5.2 Installation Instructions.

Check temperature: During operation the heat sink of the servo amplifier may reach temperatures above 80° C (176° F). Before touching the device, check the temperature and wait until it has cooled down below 40° C (104° F).

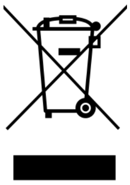
2.4 Repair Instructions

Repair of the servo amplifier must be done by the manufacturer.

Opening the devices means loss of warranty.

In case of service related questions please contact MACCON technical support.

2.5 Disposal



Unmount the equipment as described in chap. 2.4 and send it in the original packaging to the address given in the dispatch information.

Old electronic equipment needs to be disassembled at special recycling companies for electronic equipment.

2.6 Package

When a controller from the SWM7 series is ordered, the following is supplied (please check while unpacking):

- Servo controller SWM7
- CD-ROM, contains SWM7 software, firmware for microcontroller, DSP, FPGA
- Customer specific parameters (optional)
- Mating connectors for the motor and the DC/auxiliary supply
- RS-232 cable for the PC user interface

Accessories (must be ordered separately, if required, please contact MACCON Sales)

- Motor cable assembly with shield clamp, or cable and power connectors
- Feedback cable assembly or cable and connectors
- Motor choke 3YL/3YLN, for motor cables longer than 25 meters
- Engineering service e.g. customized CAN profile or parameter file
- USB to RS232 converter
- SubD connectors

2.7 Type Label

Please be prepared to identify the present hardware (HW) and software (SW) before contacting the MACCON technical support.

2.7.1 Hardware Revision

The type label, see Tab. 2.1, and is placed on the back of the SWM7S housing. It includes information about type, version, part number, serial number and option.

Type:	SWM7S-048-50-ET		
Supply:	48-60V		
Modification:	n/a		
Version:	Rev. D4	**Option:**	D2
Part No.	12.0251	**Serial No.:**	1428.7027

Tab. 2.1: SWM7S Type Plate (Example)

2.7.2 Firmware Revision

The actual firmware version can be read in the PC graphical user interface SWM.exe.
The firmware consists of three separate modules for µC, DSP and FPGA.
The DSP and FPGA firmware versions are displyed in the “SWM STATUS” tab.
The µC firmware version is reported as first message after start-up in the message window.

2.8 Capacitor Reforming Process after long Storage Times

The internal isolation barrier of electrolytic aluminum capacitors can degrade at storage times longer than 12 months. This degrading can be restored by applying carefully supply voltage, a re-forming process. The isolation barrier is growing again under the influence of applied voltage, but the voltage must not too high at the beginning to cause a breakthrough at a potential weak isolation area or the current needs to be limited to prevent local overheating inside the capacitor.

There are different ways of reforming capacitors depending on the purpose. IEC 60384-4 for example describes a reforming intended to prepare qualification tests of capacitors to guarantee comparable test results. This kind of reforming assumes capacitors with perfect internal isolation, therefor the external series resistance can be chosen quite low, too low to protect isolation weaknesses from overheating.

This reforming method is not useful for reforming of capacitors after long storage times with possible weaknesses in their internal isolation barrier, which need to be restored very carefully. For this purpose, the external chosen series resistor needs to limit the current to prevent internal local overheating at potential weak isolation areas.

The reforming of capacitors in the auxiliary supply needs to be done without series resistor in multiple voltage steps while the reforming of the DC-link capacitors is performed with series resistor.

The reforming of auxiliary supply and DC-link must not be done simultaneously.

Auxiliary supply (DC-link = 0V):

- Apply 12VDC for 5 minutes minimum
- then increase to 24VDC for 5 minutes minimum
- then increase to 48VDC for 5 minutes minimum

DC-link supply (auxiliary supply = 0V)

- Only qualified personal is allowed for capacitor reforming, please respect high voltages!
- Do not leave the powered test unattended.
- Respect discharge time of DC-link capacitor to 0V before touching or disassembling.
- Choose series resistor equal to discharge resistor for 2W at SWM7 nominal voltage:
- Example: R = (48V)^2 / 2W = 1,2kOhms for a 48V SWM7.
- Alternatively choose 12kOhms for a 150V SWM7.
- Connect voltmeter 1 direct at the power supply.
- Connect voltmeter 2 direct at the input of the DC-link supply SWM7
- Connect series and discharge resistors (2W minimum types!).
- Apply the nominal SWM7 supply voltage at the power supply (Voltmeter 1) for 10 minutes
- Switch off power supply and observe voltmeter 2 until the voltage is 0V.

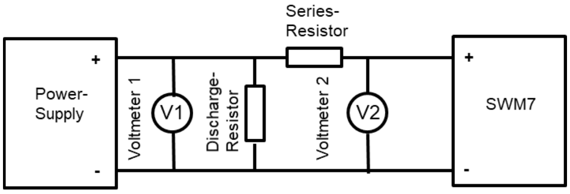


Figure 1: Schematic for DC-Link Capacitor Reforming

3 Technical Description

3.1 Family of Digital Servo Controllers

The SWM7 is a family of high performance motor controllers with very fast current control loop and high PWM frequency power stage for high dynamic or low inductance motor applications. Multiple communication and sensor interfaces without the need of expansion cards offer a quick solution for most standard and advanced applications. The SWM is result of 20 years development of motor and drives and application experience in industrial, military and vehicle drive systems. Adaptations in hard- and firmware can be done on request.

This motor controller family combines the benefits of fast digital signal processing technology with modern power electronics. The members of the family cover a wide voltage and current range area of applications.

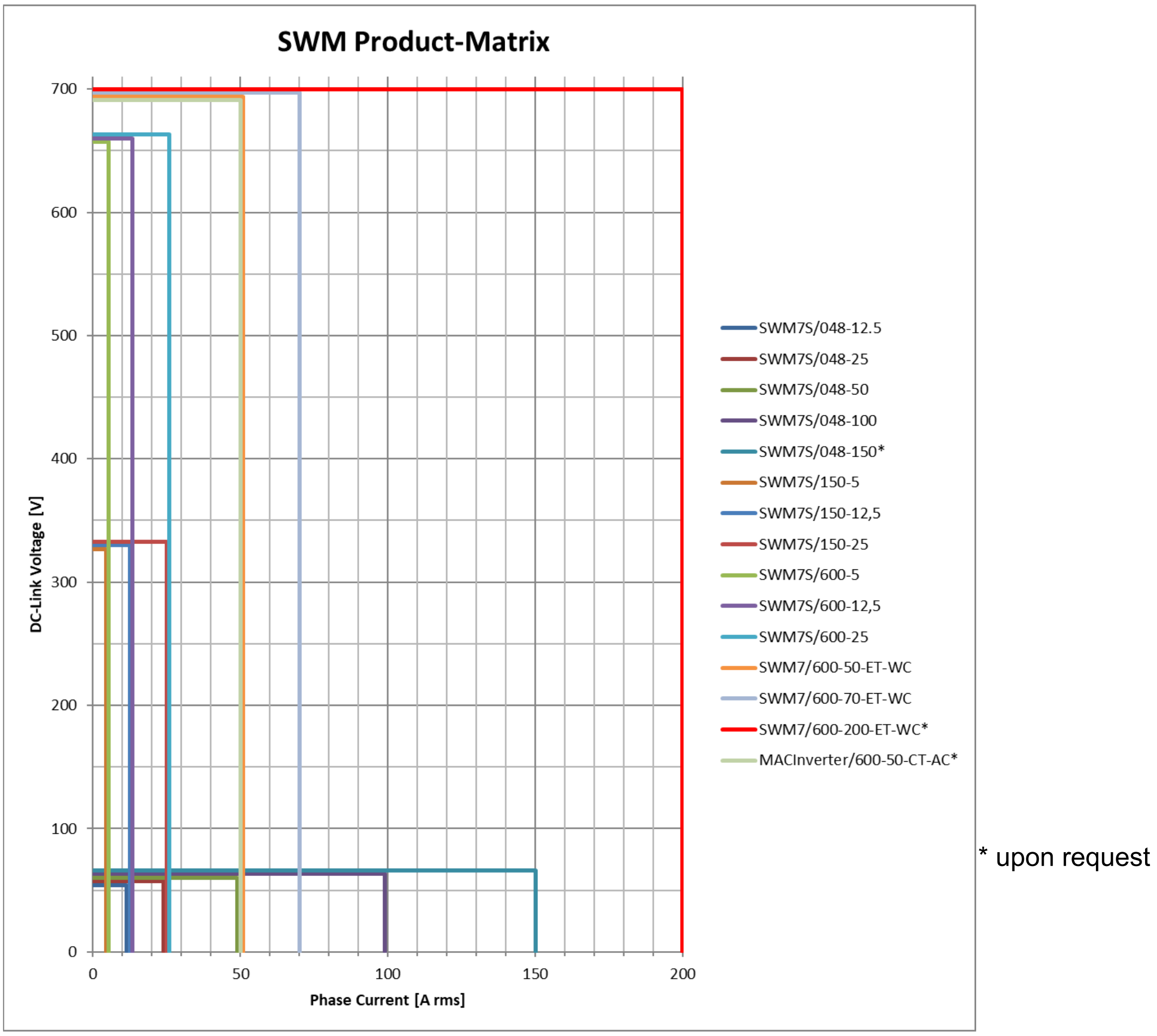


Figure 2: SWM Product Matrix

SWM-family: DIN EN 61800-5-1 Overvoltage Category 1: External circuitry to reduce transient overvoltages might be required.

3.2 Drive with linear Power Stage (Non-Switching)

A drive version with a linear power stage (non-switching) is available in the same housing and with the same motor and control interface configurations as the SWM7S. The LWM7S has excellent linearity around zero current, unsurpassed EMC- characteristics and no PWM- jitter.

It is ideal for precision applications in science, medicine and semiconductor industry e.g. for positioning with sub- nanometer resolutions.

3.3 Technical Data

The following tables give an overview of the SWM family. For detailed technical data refer to the detailed datasheet of the required member of the SWM family.

Version	CT	ET	MT [1]
Temperature range	0° C... +45	-40° C... +65° C	-40° C ... +65° C
	32° F...113° F	-40° F...149° F	-40° F...149° F

[1] conformal coating and mechanical hardening

Tab. 3.1: Temperature Range Options

Order- No.	Supply Voltage [VDC]					I_rms Phase [A]	I_rms Phase 2sek [A] *	Cooling
	12 – 60	12 – 330	24 – 475	24 – 660	24 – 700	Long term, adequate cooling	Cool device (25°C), adequate cooling	
SWM7S/048-12.5	●					12.5	25	X/AC
SWM7S/048-25	●					25	50	X/AC
SWM7S/048-50	●					50	100	X/AC
SWM7/048-100	●					100	200	X/AC
SWM7/048-150**	●					150	150	X/AC
SWM7S/150-12.5		●				12.5	25	X/AC
SWM7S/150-25		●				25	50	X/AC
SWM7S/300-05			●			5	10	X/AC
SWM7S/300-12.5			●			12.5	25	X/AC
SWM7S/300-25			●			25	50	X/AC
SWM7S/600-12.5				●		12.5	25	AC
SWM7S/600-25				●		25	50	AC/WC
SWM7S/600-50					●	50	50	WC
SWM7S/600-70					●	70	70	WC
SWM7S/600-200**					●	200	200	WC

Tab. 3.2: **Cooling Options:** (Specified Current Ratings valid for Baseplate Temperatures below 40°C)

X Contact Cooling (Standard, no external heatsink)
AC Option Air Cooling
WC Option Water Cooling
* rms Phase current for 2sek max, assuming adequate heat sink and cool device (heatsink below 25°C)
** Upon request

Parameter	**Rated Electrical Data**
Current resolution	16 Bit
Max. commutation frequency	2 kHz
Analog inputs: Voltage range	±10 V
Analog inputs: Input impedance	50 kOhm
Digital control inputs	5...36 V DC
High speed Digital Input HS_IN 1, 2, 3	3.3V
Digital control outputs	Open-collector, max. 30 VDC / 100 mA
Relay contacts	max. 30 VDC / 42 VAC / 500 mA
Min./max. output current to brake	2 A, separated external supply

Tab. 3.3: SWM7 General Electrical Data

Current-Sense:

Motor phase currents are measured in the phases U and W.

The ADC sampling frequency of the current signal sensing circuit depends on the selected PWM frequency:

PWM Frequency	ADC Sampling Frequency
10 kHz	40 kHz
15 kHz	60 kHz
20 kHz	80 kHz
25 kHz	100 kHz
30 kHz	60 kHz
40 kHz (Default)	80 kHz (Default)
50 kHz	100 kHz

Tab. 3.4: Current-Sense: Dependency of ADC Sampling Frequency from PWM Frequency

Order- No.	Denomination / used for
SWM7/CAN	CAN bus activation and test (standard profile)
CAN-Profile	Customized CAN profile
SWM7/TB	Test box for SWM7
SWM7/FBM	Base Plate for front mounting, SWM7(S)/150 and SWM7(S)/300
SWM7G/MB	Mounting bracket with fan, SWM7(S)/150 and SWM7(S)/300
PSU-600-50-R	Power Supply Unit for 600 V with regeneration protection
SWM/PSU-600-45	Power Supply Unit for two SWM controllers with ext. regeneration resistor

Tab. 3.5: SWM7 Accessories

3.4 Ambient Conditions, Ventilation and Mounting

Storage Temperature Range	0...+ 55°C equals 32 °F...131 °F
Transportation temperature (Short Period)	– 20...+ 70°C equals -4 °F...158 °F
Operating Temperature CT-Grade	0...+ 45°C equals 32 °F...113 °F
Operating Temperature CT-Grade with phase current derating 2.5%/°C	+ 40...+ 55°C equals 104 °F...131 °F
Operating Temperature ET/MT-Grade	– 40...+ 65°C equals -40 °F...149 °F
rel. humidity storage and transportation	≤ 95 %, no condensation
rel. humidity operation	≤ 85 %, no condensation
Max. Storage Time	12 months, after that, reforming of capacitors required
Operating altitude	up to 1000m over sea without derating, with DC-link voltage derating of 1.5%/100m 1000m... 2500m over sea
Enclosure protection	IP50
Mounting & Cooling	Ensure free convection for the enclosure to guarantee the maximum specified ambient air temperature (depending on the temperature-grade of the device). The maximum baseplate temperature for contact cooling devices is 85°C.

Tab. 3.6: SWM7 Environmental Data

3.5 Dimensions

	SWM7/048–* SWM7–PSU	SWM7/048 100 & 150	SWM7/x00–12.5 & 25– AC	SWM7/x00–12.5 & 25– WC
Length / mm	186	187	214	254 (230)[1)]
Width / mm	189	181	216	260 (218)[1)]
Height / mm	92.5	113	155	125
Weight / kg	2.0	2.5	7.5	3.5

AC: Forced Air Cooling
WC:Water Cooling

* SWM7S/... Version with 65 mm Height available
[1)] Dimension Heatsink

Tab. 3.7: SWM7 Dimensions

3.6 Ground Systems

The SWM7 contains the following isolated ground systems:

1. Internal digital and analog circuits, feedback sensor interfaces and analog inputs
2. Digital 24V inputs/outputs, optically isolated
3. Common ground for RS-232 and CAN

3.7 Application Hints and Warnings

- Opening the device means loss of warranty.
- Connect wires and cables with adequate cross section according to IEC 204-1.
- Ensure proper grounding for safety and EMC reasons.
- For SWMs with contact cooling use adequate thermal interface material, preferred electrically non-conducting if thermal performance is sufficient.
- Add external fuses, filters, voltage suppressors, precharge- and discharge circuits if required.
- Power-up sequence: Auxiliary supply first, then DC-link supply. When the power stage does not have any auxiliary supply, the gates of the transistors cannot be pulled low actively with low impedance, they are just pulled low passively via high impedance resistors. If, for example, the DC-link supply is rising very fast without any auxiliary supply applied, parasitic capacitances inside the transistors might overdrive the passive pull down circuit. This might switch on transistors and damage the drive.
- Apply forced air cooling (fan) to SWMs with AC-option to reach full performance.
- Pay attention to the different grounding systems.
- Please also consider all hints and warnings in the specific chapters of this manual.

4 Mechanical Installation

The mechanical installation has to be planned carefully in accordance with the technical data, ambient conditions and regulatory technical standards. The electrical standard DIN EN 61800-8-1 for electrical drive systems with variable speed, for example, demands minimum enclosure thickness and other mechanical, surface and distance requirements.

Mechanical, thermal and electrical issues need to be considered during the mechanical installation or during construction of the high level system. Close cooperation between electrical and mechanical designer prior to the mechanical system design phase is strongly recommended.

Detailed shielding and grounding concept for cables and component, also cooling concept for baseplate and enclosure of the drive is required while planning an external enclosure and mounting environment.

4.1 Safety Instructions

- Apply precautions against ESD discharge while unpacking and handling the device.
- Avoid any damage of isolation or of the baseplate planarity during handling and mounting.
- High performance thermal interface materials often are highly electrical conductive, they can contain materials like silver or graphite. They need to be handled very clean and careful to ensure required isolation strength at insulators. Even microscopic thin, invisible films of these materials on the surface of an insulator can cause extreme hazards of death, injury and damage. If possible, use electrically isolating thermal interface materials.

In case of errors, hardware problems (e.g. fuses, connectors, capacitor reforming, user-specific settings etc.) or other service related questions please contact MACCON technical support.

4.2 Mechanical

- Plan for sufficient mechanical thickness and stability of the mounting location.
- Avoid mounting locations with mechanical shock or vibration.
- The mounting area must be clean and free from conductive or corrosive materials.

4.3 Thermal

To ensure free convection around the enclosure, a minimum distance of 30mm to the next wall is recommended. The maximum enclosure temperature according to the temperature grade must not be exceeded. Do not plan walls around the whole drive to prevent heat build-ups, or consider a fan also for the cooling of the enclosure. The SWM will switch off at extreme baseplate temperatures, but extreme enclosure temperatures can shorten lifetime or even damage the device.

4.3.1 Air Cooling (AC) Option

For the air cooling (AC) option, clean forced airflow from a fan is required at the attached heatsink for maximum performance. Small particles of dust could degrade the heatsink performance over time.

4.3.2 Water Cooling (WC) Option

- Please check material compatibility of the whole cooling system to avoid corrosion. Some members of the SWM family have an aluminum based heatsink, others have a copper based heatsink. Please contact MACCON when other coolants are planned to check sealing material compatibility.
- Provide sufficient flow of clean coolant with the correct inlet temperature for maximum performance.
- For the case of load dumps or emergency switch-off at inlet coolant temperatures below air ambient temperature, please consider condensing water. This needs safely to be evaporated before switching on again. Switching on with rests of condensing water might cause death, injury or damage. Provide a safe path and reservoir for condensing or possibly leakage water.

4.3.3 Contact Cooling (Standard Device)

For contact cooling (standard device), sufficient external heatsink and adequate thermal interface material (electrically non-conducting, if possible) need to be added for maximum performance. The thermal interface material should be electrically non-conducting, if possible. The maximum baseplate temperature at full load must not exceed 85°C.

4.4 Electrical

- Plan for minimum bending radius for the connected cables or cooling hoses
- Plan for short distance between drive and motor, if possible, or consider a motor cable choke close to the drive.
- Avoid mounting in strong magnetic field areas. This could influence internal devices or circuits of the drive.
- The EMC concept needs to be planned for the whole machine or assembley, not only for single components like drive or motor. For this concept, it can be important to have electrically conducting mounting areas for motor and drive with other corrosion protection than paint. Anodized aluminum acts similar to painted metal. Please also refer to the EMC related chapter of this document to consider e.g. separate wiring of power and control- and sensor cables.

4.5 Drawings

4.5.1 Base Plate SWM6

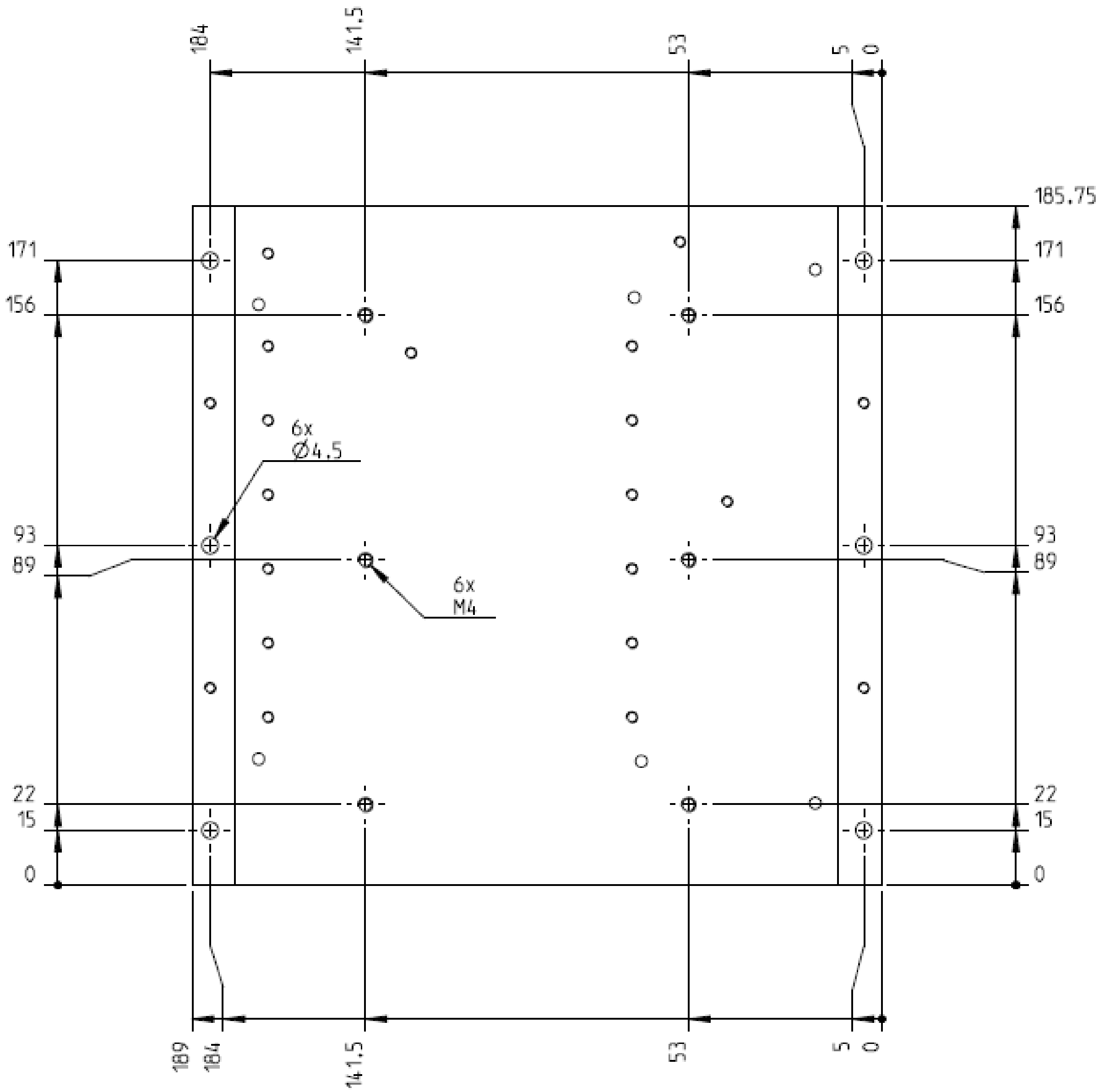


Figure 3: Mounting Drawing Base Plate SWM6

4.5.2 Base Plate SWM7-48/100

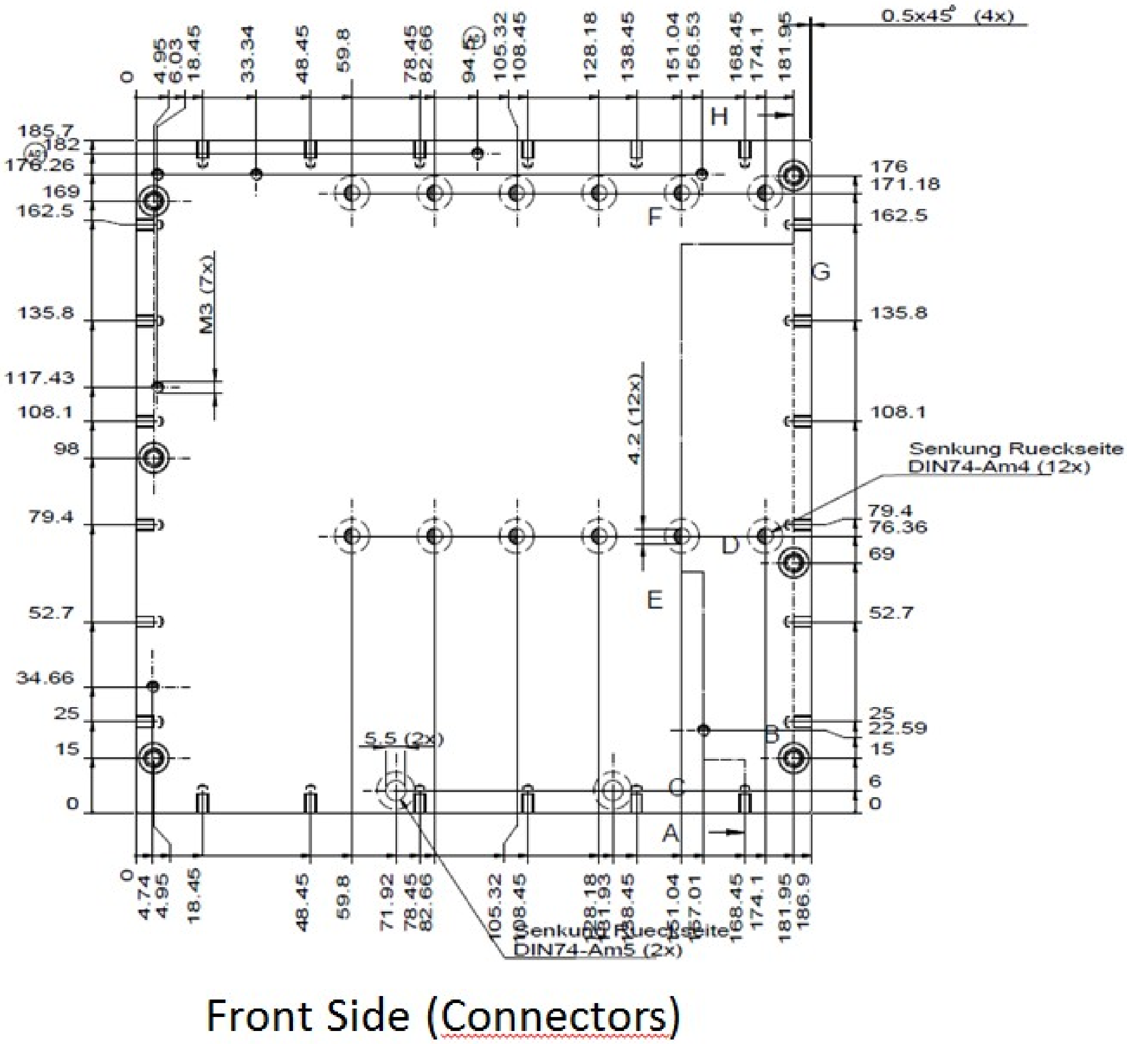


Figure 4: Mounting Drawing for Base Plate SWM7-48/100

4.5.3 Base Plate SWM7-600/25

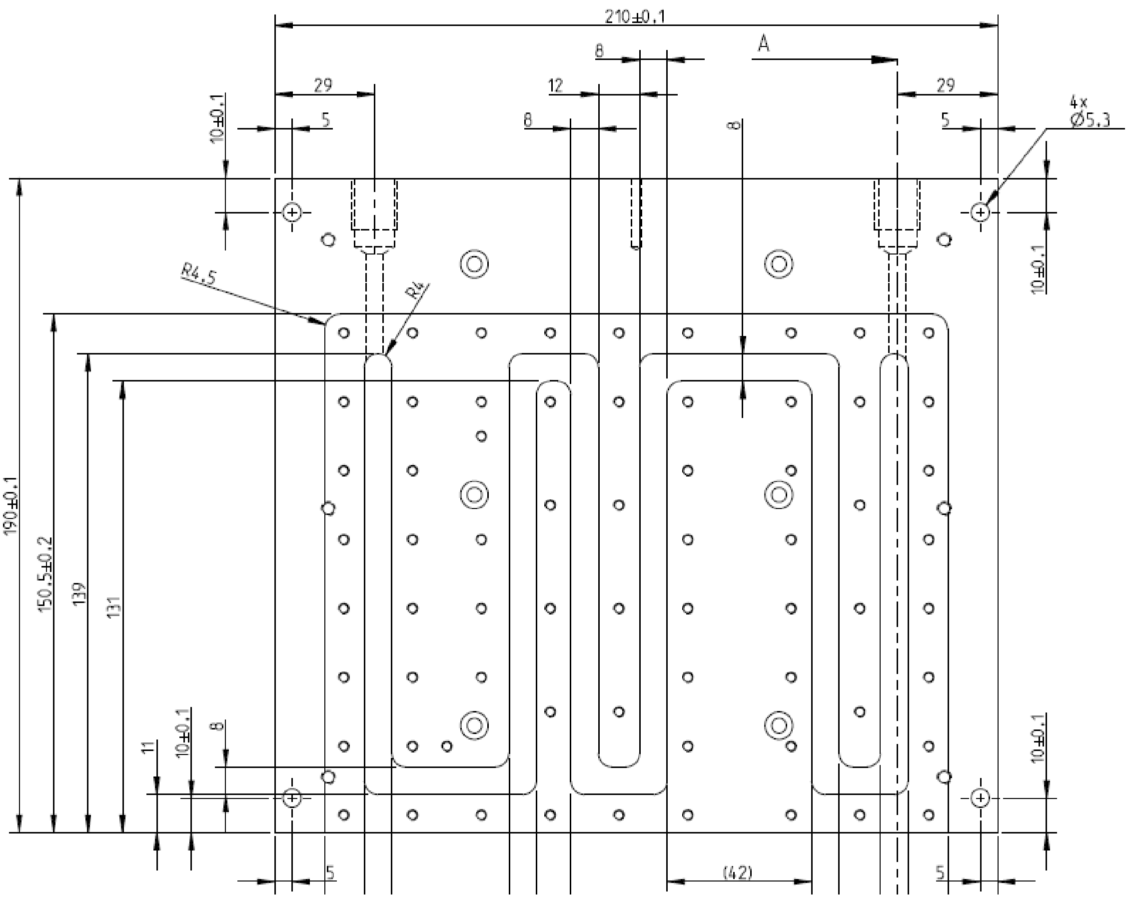


Figure 5: Mounting Drawing Base Plate SWM7-600/25

4.5.4 SWM7/600-25-xT

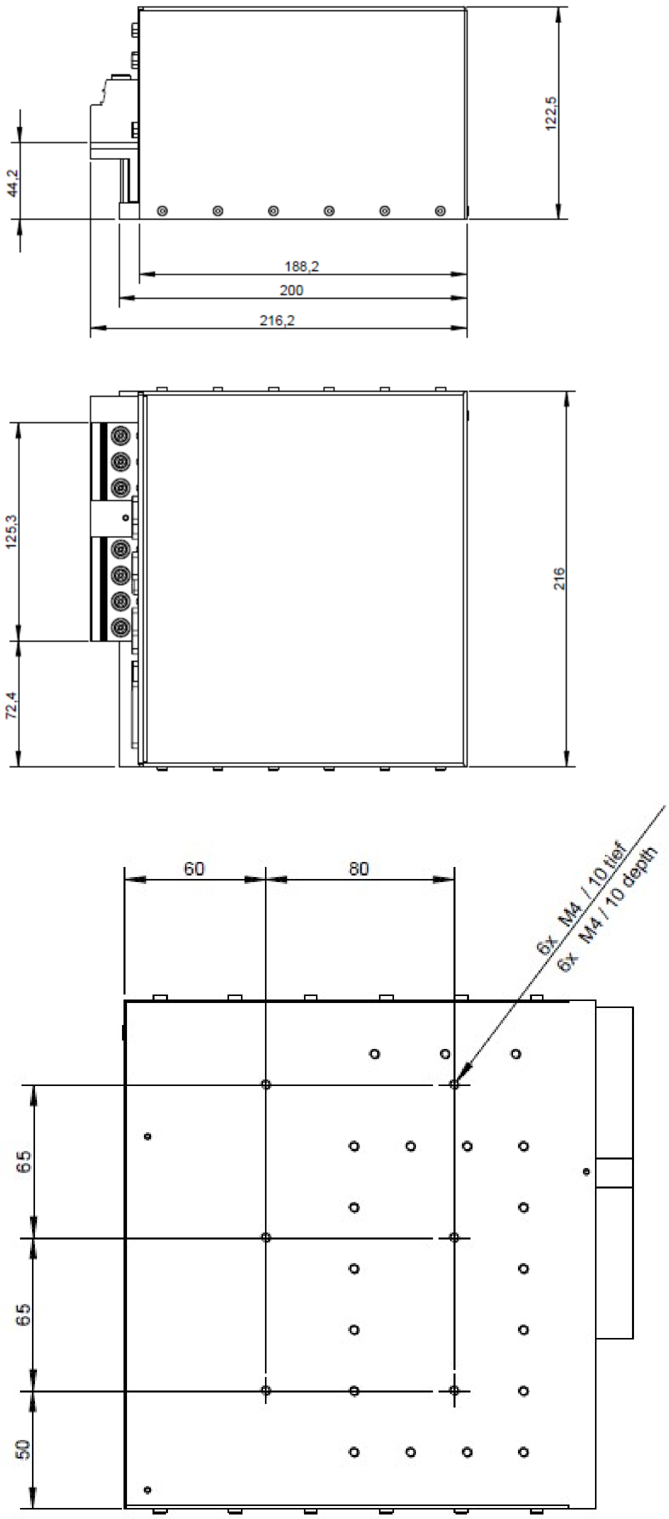


Figure 6: Mounting Drawing Base Plate SWM7/600-25-xT

4.5.5 SWM7/600-25-xx-AC1

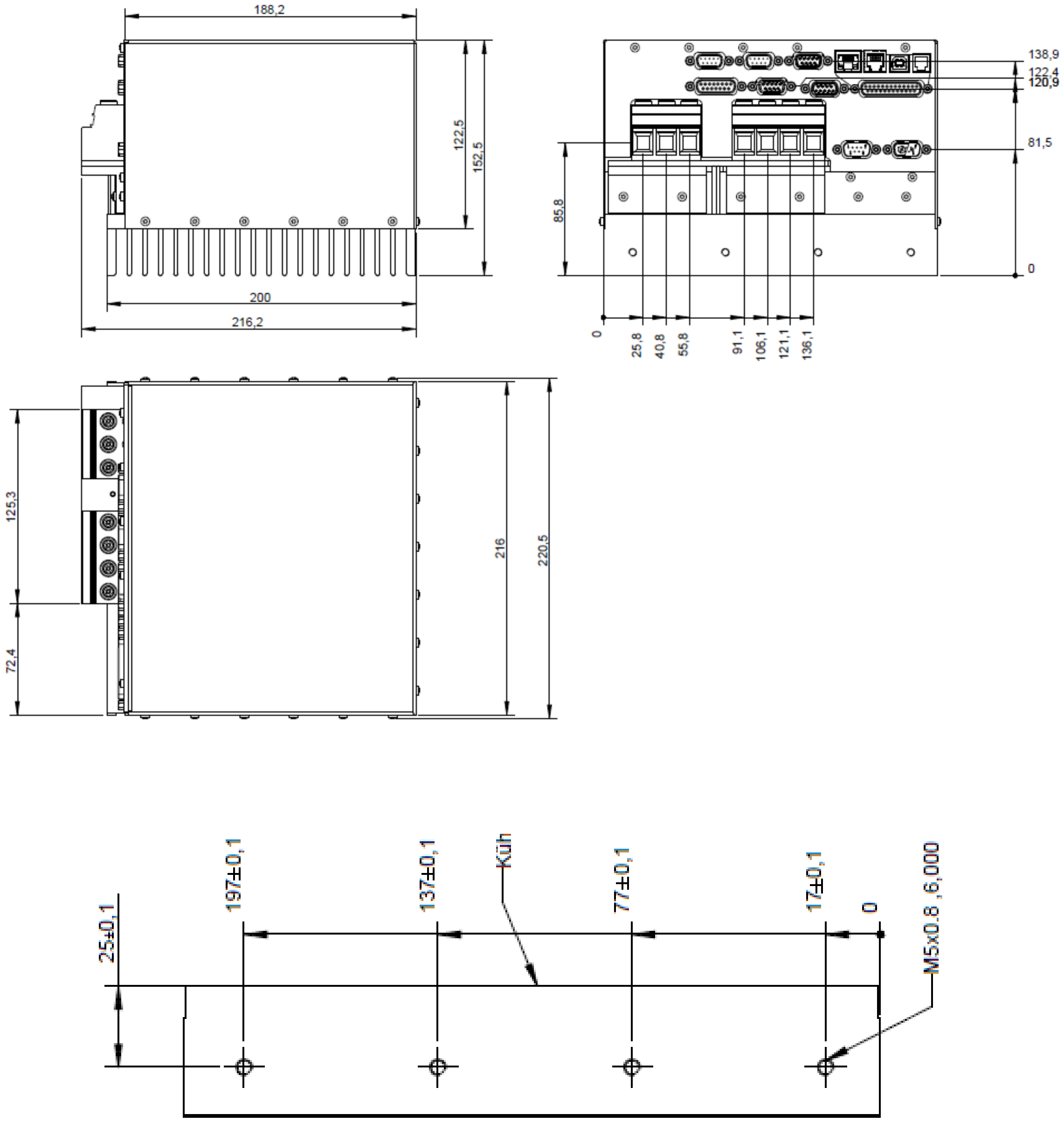


Figure 7: Mounting Drawing Base Plate SWM7/600-25-xx-AC1

4.5.6 SWM7/600-25-xx-WC

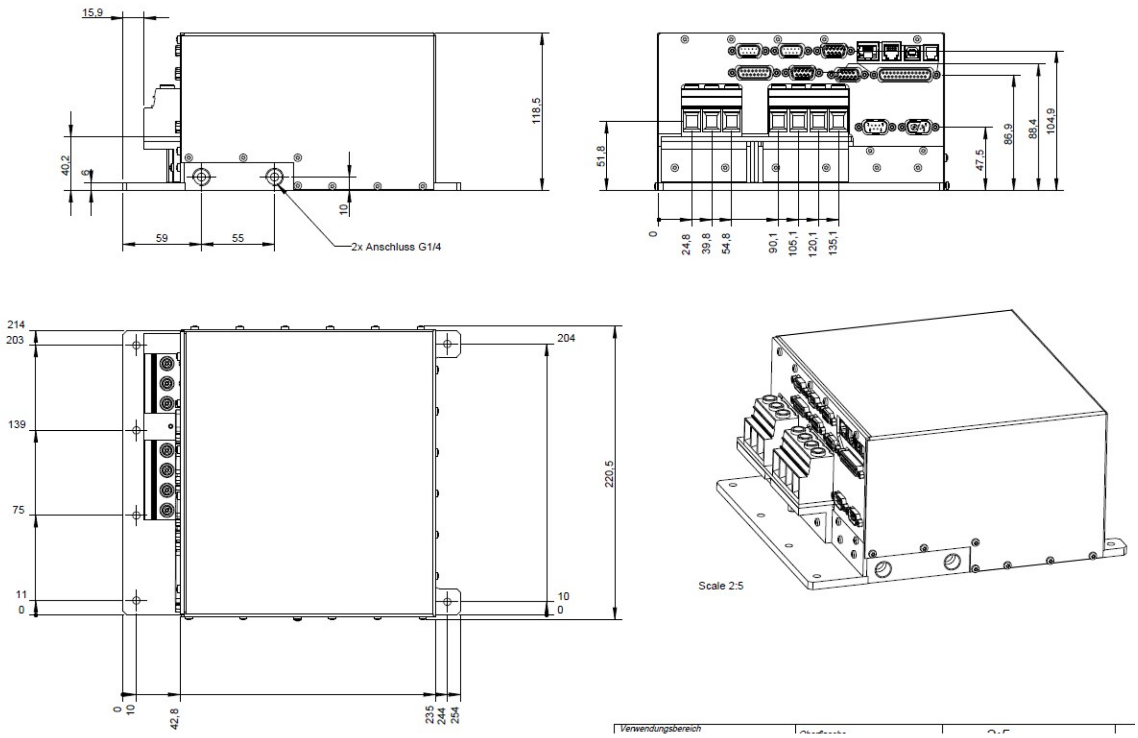


Figure 8: Mounting Drawing Base Plate SWM7/600-25-xx-WC

4.5.7 Base Plate SWM7S

The device SWM7S is mounted from below by six M4 screws according to the drawing below.

Do not mount screws > 6 mm + material thickness of mounting plate used!

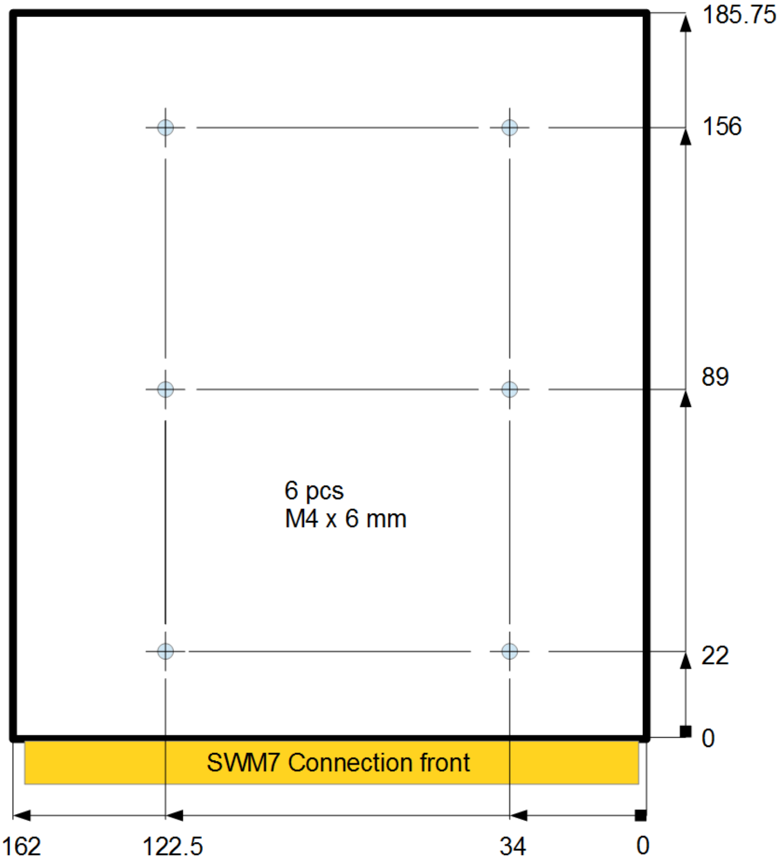


Figure 9: Mounting Drawing for SWM7S Baseplate (Side Wall Thicknesses excluded)

4.5.8 SWM7/600-25 Wall-Mount Version

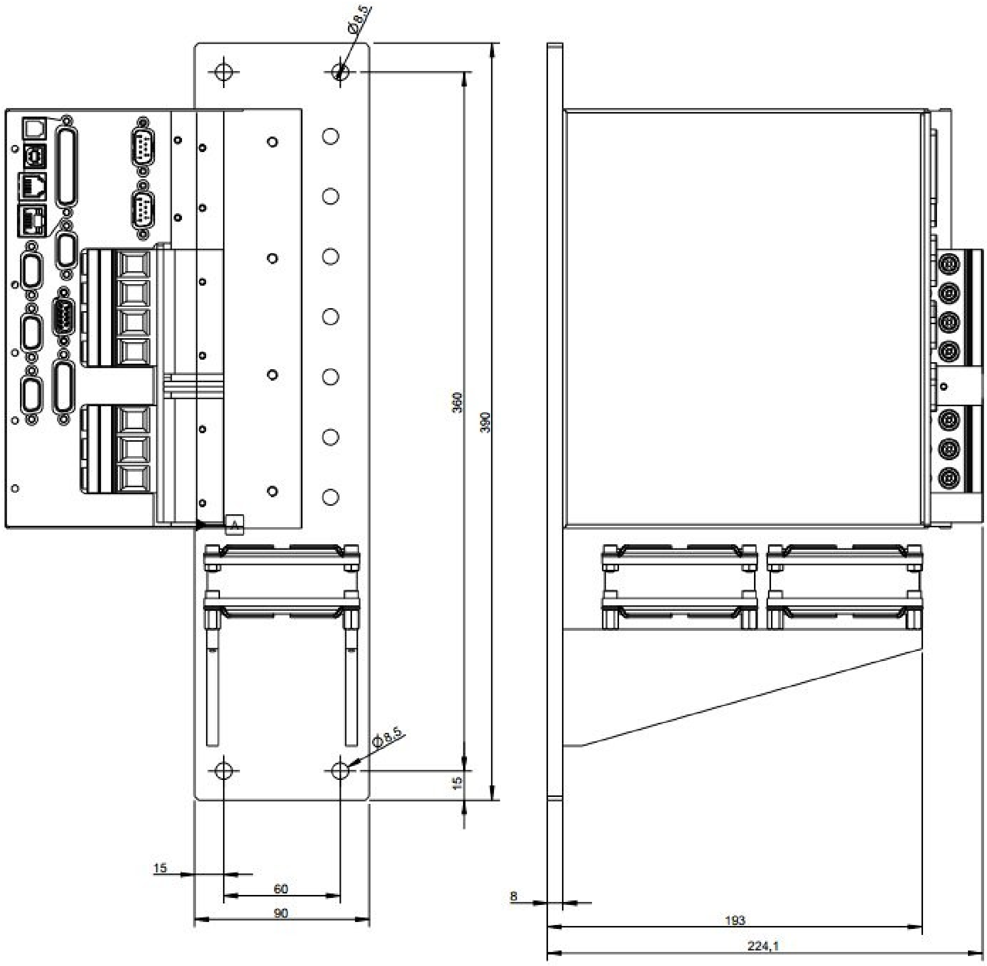


Figure 10: Mounting Drawing for SWM7/600-25 Wall Mount Version

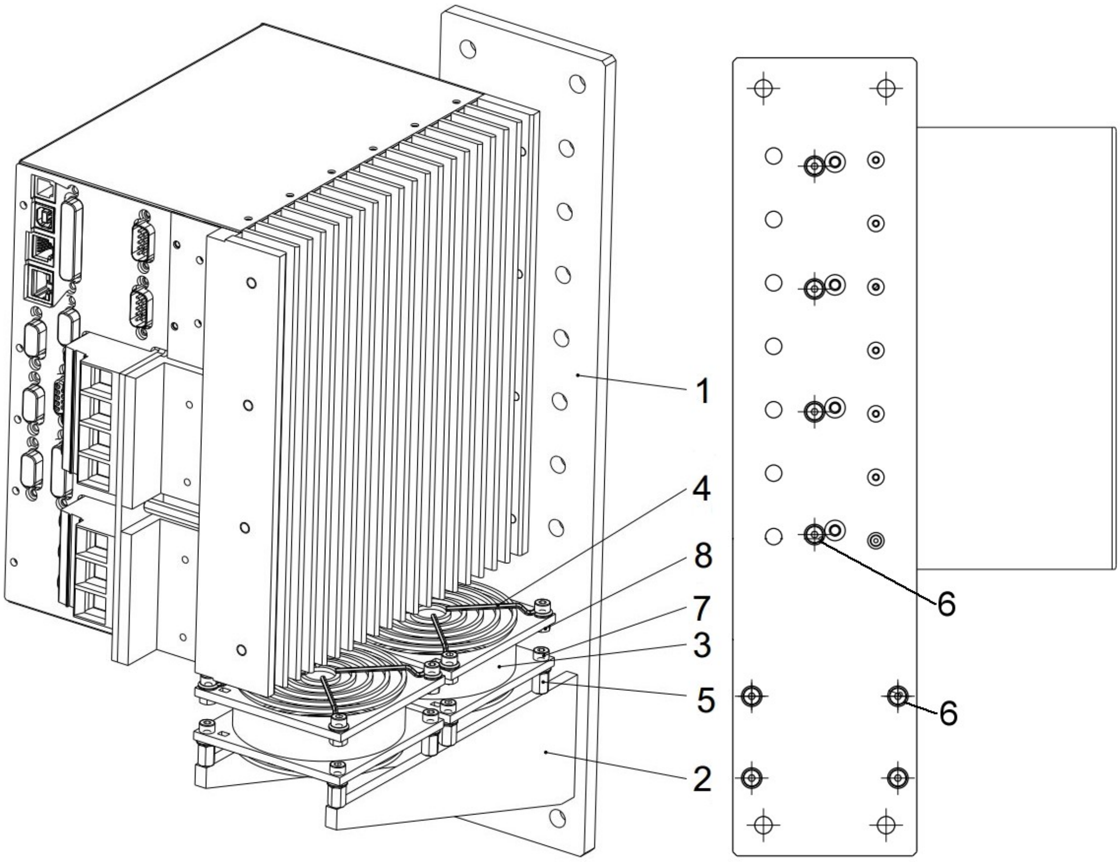


Figure 11: 3D Drawing of SWM7/600-25 Wall Mount Version

Position	Designation
1	Mounting Plate
2	Support
3	Ventilating Fan
4	Protective Grating
5	M4 Spacer
6	Cylinder Head Screws M5x10 (8 pcs. Cylinder Head Screws for mounting on Pos. 1)
7	Cylinder Head Screws M5x10
8	Hex-Nut

5 Electrical Installation

5.1 Safety Instructions

- Electrical installation must be done only by qualified personal according to the actual DIN ISO standards for the location of operation (isolation, wire diameter, grounding...).
- Pay attention to the safety instructions, datasheet limits and working instructions to avoid any risk of death, injury or damage caused by dangerous voltages, high temperatures, unexpected motor movements or other.
- Be familiar with the datasheet and the operation manual in detail before installing and powering the device.
- Active braking in normal mode or switching off the drive in field weakening operation mode might cause excessive voltage levels on the DC-link with high energy levels. Plan for independent chopper which reliably and safely works in these situations when the supply source is not able to sink energy to prevent death, injury and damage.
- Plan for external snubbers according to the required overvoltage category of the supply and for external fuses, precharge- and discharge circuits and voltage symmetrizing circuit for floating DC-link supply (e.g. battery), if required.
- After switching off the supply, internal capacitors might need discharge time. Always measure the DC-link voltage after switch-off before unplugging the device or touching conductors to ensure the correct supply has been switched off and internal capacitors are discharged.
- Applying voltage to the DC-link after long storage times of more than two years without powering the device might damage the device. A capacitor reforming process is recommended. The isolation layer thickness in aluminum electrolytic capacitors can decrease over time. The decreased layer does not have the voltage isolation strength any more. Reforming is a slow voltage increasing process which restores the isolation layer to previous thickness and isolation strength. For detailed procedure please contact MACCON.
- Never connect filter capacitors directly to the motor output of the drive: Neither between the motor phases nor between motor phase and GND. This might damage the drive.
- Ensure proper connection of all sensor- signal- and power connections before powering the device.
- Power-up sequence is auxiliary supply first, then DC-link supply.
- For water cooled option please refer to the additional warnings in chapter 4.3.2 Water Cooling (WC) Option on page 21. Important issue is condensing water.
- During operation, servo controllers may have hot surfaces. The base plate may reach temperatures up to 85°C, i. e. 185°F.

5.2 Installation Instructions

- Plan for an auxiliary power supply which can deliver 10A minimum start-up current. The working current will be much lower.
- Respect minimum bending radius of electrical wires and cooling hoses.
- Pay attention to sharp edges that cooling hoses or isolation of conductors will not be damaged over time.
- Route power leads and control cables separately.
- For EMC optimized design in grounded circuits, a strong grounding connection between drive, mounting plate and motor is recommended. Plan for short cables between drive and motor, if possible. Recommended are motor cables with ≤ 150 pF/m. For these cables at length ≥ 25 meters, consider a choke (3YL/3YLN) in the motor power lines close to the drive. Always use shielded signal cables for sensors and analog signals. If required, also use shielded power cables. Connect the shield only on one side of the cable directly at the drive. If the shield of the cable needs to be connected on both cable sides, a strong additional separate ground wiring in parallel to the shield might be required at high ground currents (caused by other components of the system). For more details please refer to the separate EMC-chapter of this document.

In case of errors, hardware problems (e.g. fuses, connectors, capacitor reforming, user-specific settings etc.) or other service related questions contact MACCON technical support.

5.3 General Connection Scheme

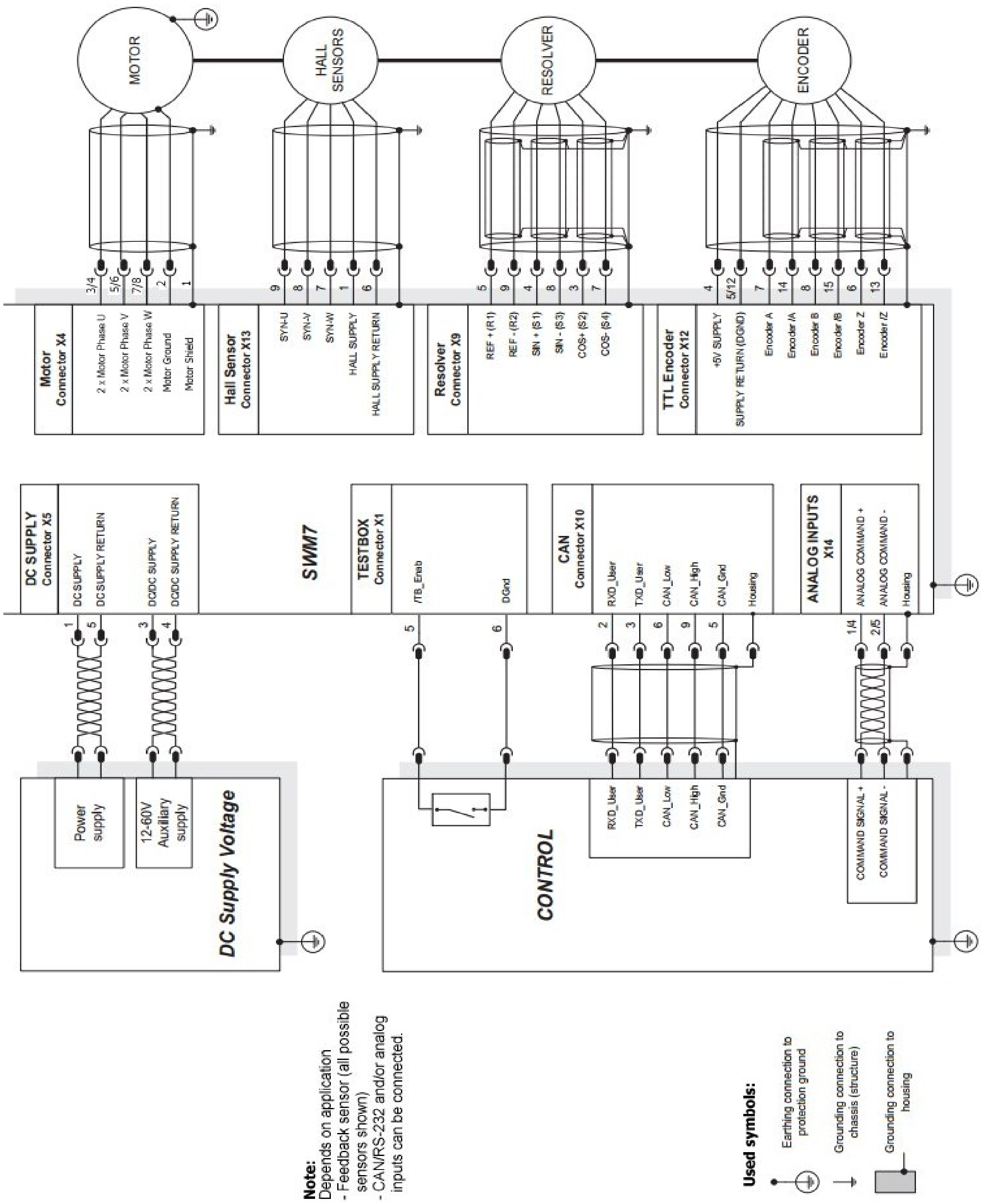


Figure 12: General Connection Scheme

5.4 SWM7S-150: Connector Assignment

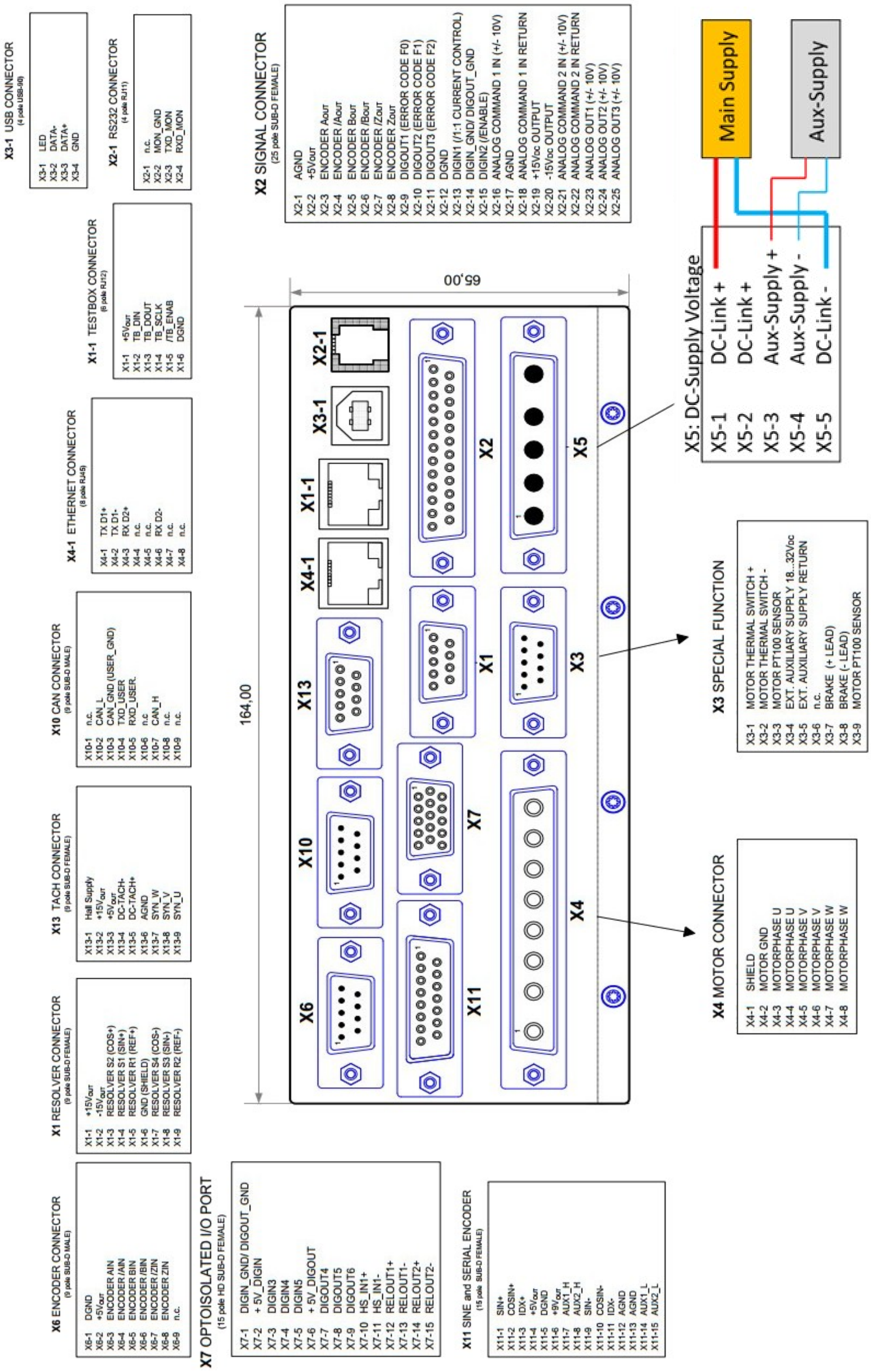


Figure 13: SWM7S-150: Connector Assignment

5.5 SWM7-150 with extended I/Os: Connector Assignment

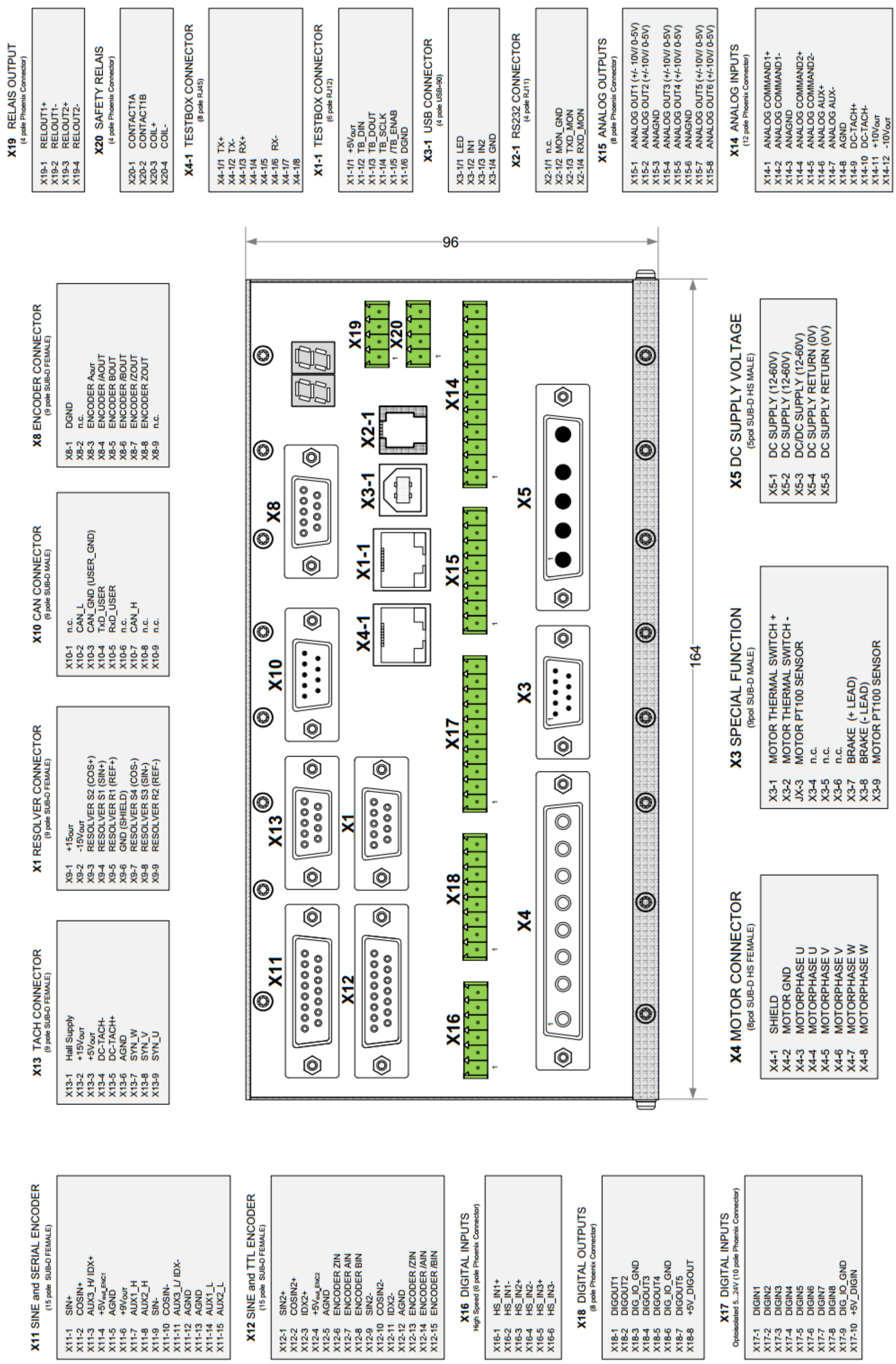


Figure 14: SWM7-150 with extended I/Os: Connector Assignment

5.6 SWM7-48/100: Connector Assignment

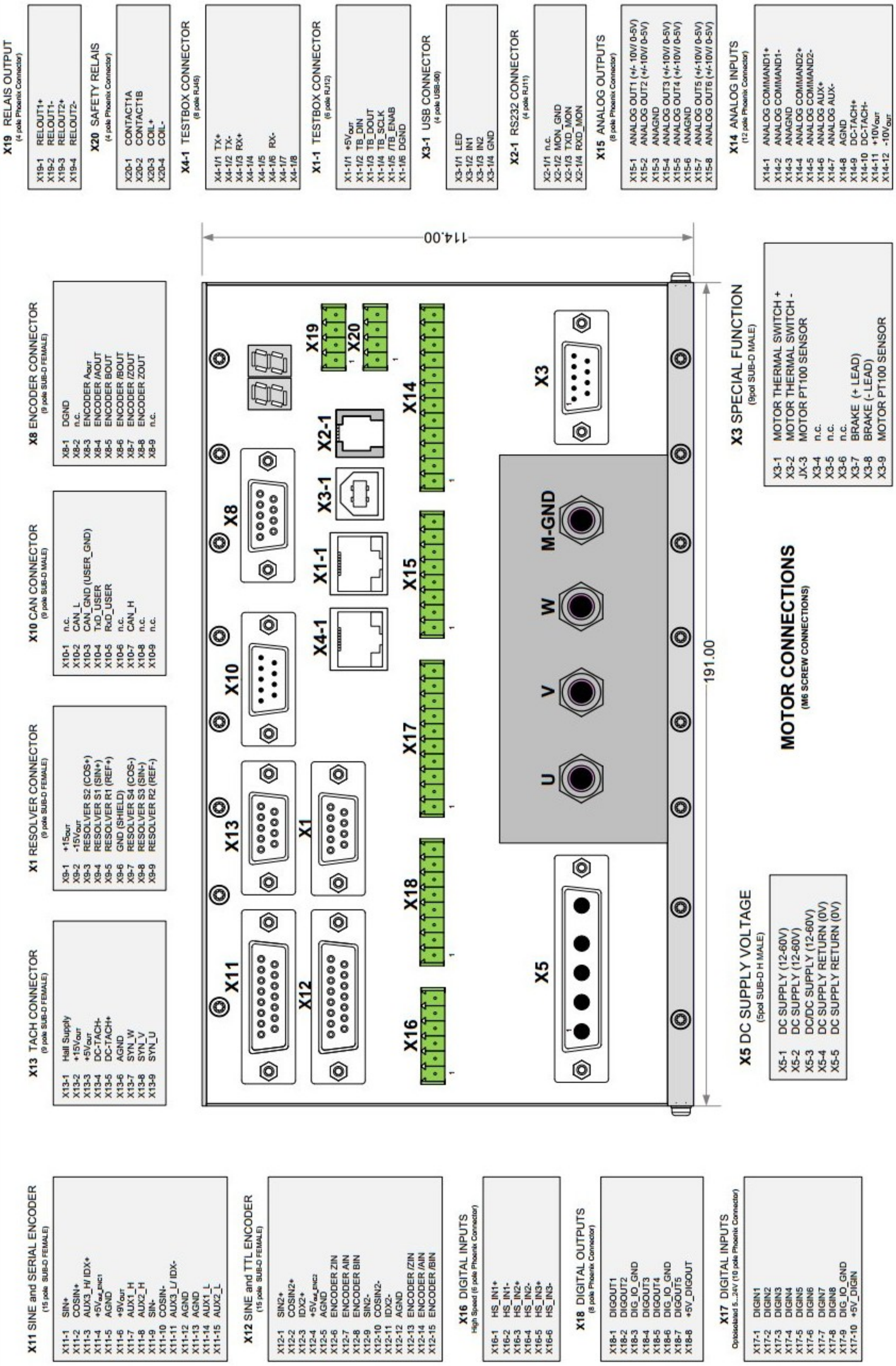


Figure 15: SWM7-48/100: Connector Assignment

5.7 SWM7-300, SWM7-600: Connector Assignment

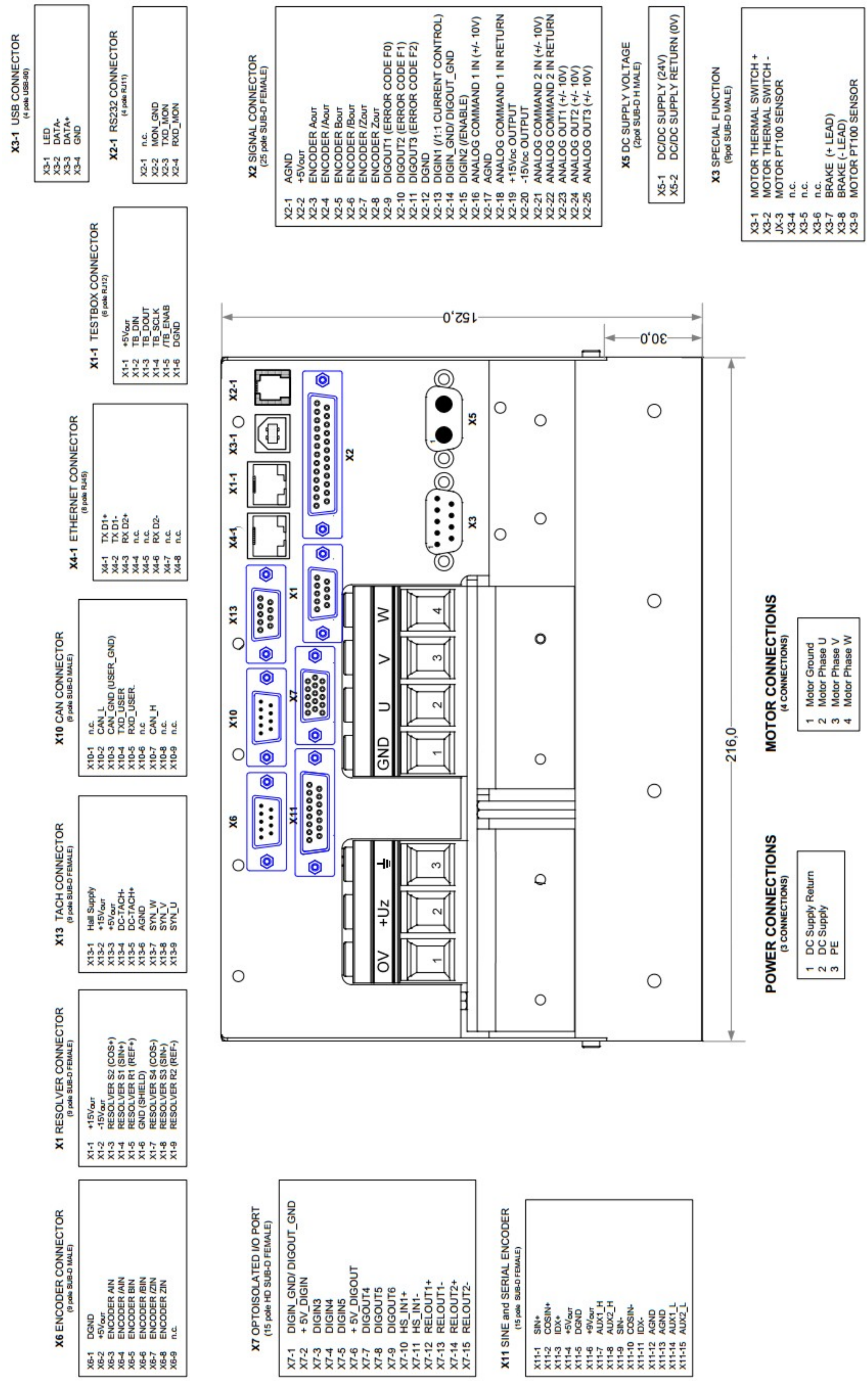


Figure 16: SWM7-300, -600: Connector Assignment

5.8 Power Supply

Different members of the SWM family have different auxiliary and DC-link supply voltages, currents and connections. Please refer for detailed information to the datasheet of the specific device.
Important notes for the DC-link- and the auxiliary power supply can be found under 5.1 Safety Instructions and 5.2 Installation Instructions.

5.9 Temperature Supervision (X3)

The X3 connection diagram is common for the SWM7 family.

Some members of the SWM family have additional connections for temperature sensors. For the additional connections, options for PT100 and NTC are available. Please refer for detailed information to the datasheet of the specific device.

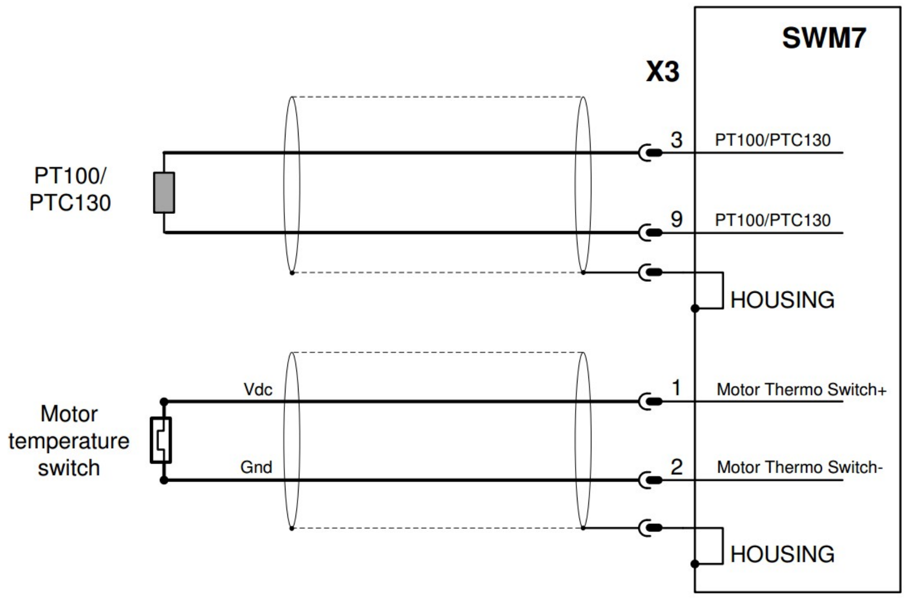
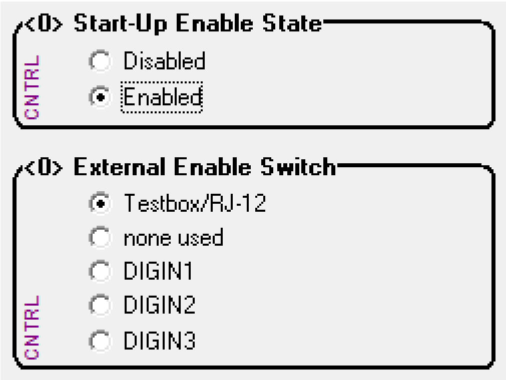


Figure 17: External Temperature Sensors (X3)

5.10 Enable Interface (X1-1)

A hardware (HW) enable signal is not necessarily needed. The HW enable signal can be disabled in the “COMMAND INPUT SELECT” tab to “none used” or enabled to different signal input options. Standard configuration is enabled on Testbox/RJ12.



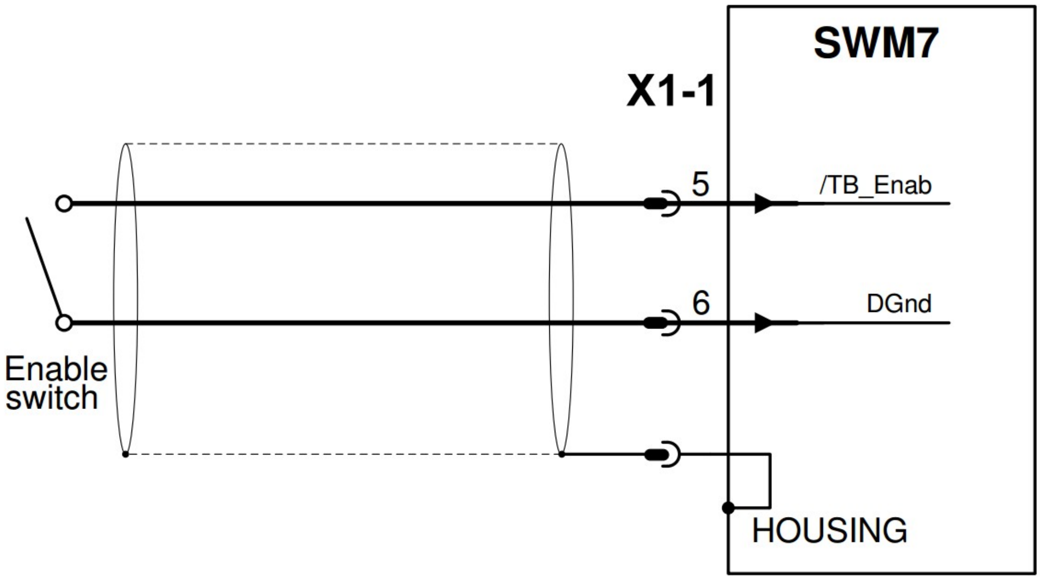


Figure 18: Enable Interface (X1-1)

5.11 Command Interface (X2)

The command interface on X2 includes two differential analog inputs and three analog outputs with +/-10V signal voltage range. The analog inputs can be used to include the SWM into a system with complete analog signal environment. The analog outputs can be configured do display many internal parameters like phase currents. Connecting an oscilloscope to these analog outputs, this acts like a real time debug display for fast signals.

Also available are galvanically isolated two digital inputs and three digital outputs referenced to DIGIN-GND/DIGOUT-GND. With the standard firmware, the digital outputs are configured to display a three bit failure code.

Last, a TTL encoder interface completes the functional range of this connector.

5.11.1 Analog Inputs

- 2 differential inputs (ANACMD1, 2)
- Differential input range max ±10 V
- Common mode range max ±13 V
- Differential input resistance 20 kOhm
- Reference is AGND (available at X2-1)

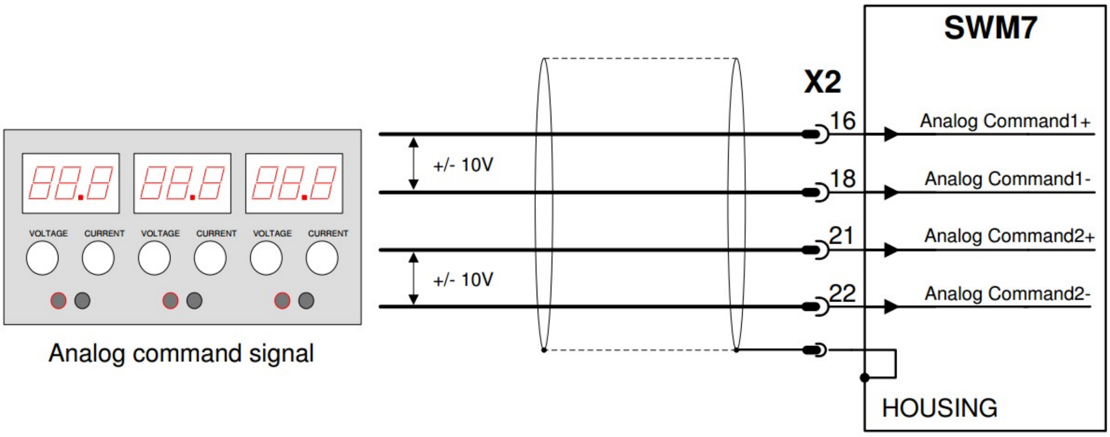


Figure 19: Command Interface (X2). Application Example: Usage of Analog Inputs.

5.11.2 Analog Outputs

- 3 analog outputs (ANALOG OUT1, 2, 3)
- Output range is max ±10V
- Sink/source capability max. 10 mA
- Reference is AGND (available at X2-1)

5.11.3 Digital Inputs

- 2 digital galvanically isolated inputs (DIGIN1, 2)
- Input level (nom.) +5V
- Input level (max.) +24V
- Vil max. = 1V
- Vih min. = 2.5V
- Input resistance 4 kOhm (Pull-Down)
- Reference is DIGIN_OUT_GND (available at X2-14)

No.	Signal		Pin	Description
1	X2	DIGIN1	X2-13	1:1 CURRENT CONTROL switches between current- and speed control if the SWM7 commanded externally (without PC or CAN)
2	X2	DIGIN2	X2-15	ENABLE serves as a hardware enable input. 5V = Enable, 0V = Disable
3	X2	GND	X2-14	DIGIN_OUT_GND

Tab. 5.1: SWM7 Digital Inputs on X2

The status of the digital inputs can be monitored in the “Data Aquisition” tab. The 5V on X2 pin 2 is galvanically isolated from the digital inputs. If the 5V on X2 shall be used for digital inputs connect grounds X2 pin 12 with pin 14 if possible in your application. Otherwise use external 5V referenced to X2 pin 14 as ground.

5.11.4 Digital Outputs

- 3 digital galvanically isolated outputs (DIGOUT1, 2, 3)
- Open-Collector, 40VDC max.
- Sink capability max. 80 mA
- Reference is DGND (available at X2-14)

No.	Signal		Pin	Description
1	X2	DIGOUT1	X2-9	FAILURE CODE F0 signals failure conditions to external circuits
2	X2	DIGOUT2	X2-10	FAILURE CODE F1 signals failure conditions to external circuits
3	X2	DIGOUT3	X2-11	FAILURE CODE F2 signals failure conditions to external circuits
3	X2	GND	X2-14	DIGIN_OUT_GND

Tab. 5.2: SWM7 Digital Outputs on X2

5.11.5 Encoder Outputs

- 3 differential encoder outputs
- Reference is DGND (available at X2-12)

No.	Signal		Pin	Description
1	X2	A_Out	X2-3	Output A
2	X2	/ A_Out	X2-4	Inverting Output A
3	X2	B_Out	X2-5	Output B
4	X2	/ B_Out	X2-6	Inverting Output B
5	X2	Z_Out	X2-7	Output Z
6	X2	/ Z_Out	X2-8	Inverting Output Z
7	GND		X2-12	

Tab. 5.3: SWM7 Encoder Outputs on X2

If inductive loads like relay coils are directly connected to the digital outputs, please add external clamping circuitry to prevent high voltage peaks at switching-off the inductive load.

5.12 Optoisolated I/O - Port (X7)

Additional to the isolated digital I/O signals with fix functionality from X2, connector X7 provides additional 3 digital inputs and 3 additional digital outputs free programmable for customer use. The digital inputs from X2, digital outputs from X2, digital inputs from X7 and digital outputs from X7 use a common ground, which is isolated from the internal controller ground, the DIGIN-GND/DIGOUT-GND. It is available on X2-14 and X7-1.

To supply the digital I/O circuits, two independent isolated voltages both referenced to DIGIN-GND/DIGOUT-GND are available on X7: The +5V_DIGIN and the +5V_DIGOUT.

If inductive loads like relay coils are directly connected to the digital outputs, please add external clamping circuitry to prevent high voltage at switching-off the inductive load.

Each of the digital supply voltages is capable of delivering up to 150 mA.

It's not allowed to connect digital outputs in parallel to increase current.

5.12.1 Digital Inputs

- 3 digital galvanically isolated inputs (DIGIN3, 4, 5)
- Input level (nom.) +5V nom, +24V max.
- Vil max. = 1V
- Vih min. = 2.5V
- Input resistance 4 kOhm
- Reference is DGND (available at X7-1)
- Isolation: Functional, maximum 50Vpk

No.	Connection front No.		Pin-No.	Hints
3	X7	DIGIN3	X7-3	can be configured for customer purposes
4	X7	DIGIN4	X7-4	
5	X7	DIGIN5	X7-5	

Tab. 5.4: SWM7 Digital Inputs on X7

5.12.2 Digital Outputs

- 3 digital galvanically isolated outputs (DIGOUT4, 5, 6)
- Open-Collector, 40VDC max.
- Sink capability max. 80 mA
- Reference is DGND (available at X7-1)
- Isolation: Functional, maximum 50Vpk

No.	Connection front No.		Pin no	Hints
4	X7	DIGOUT4	X7-7	can be configured for customer purposes
5	X7	DIGOUT5	X7-8	
6	X7	DIGOUT6	X7-9	

Tab. 5.5: SWM7 Digital Outputs on X7

5.12.3 “Relay” Outputs

- Compared to the real relay contact of the SWM6, the SWM7 uses solid state AC photomos coupler outputs. External overvoltage protection circuitry is required for connecting inductive loads. Capacitive loads without current limiting series resistor must not be connected.
- 2 digital galvanically isolated AC/DC outputs (RELOUT1, 2)
- Bidirectional (AC capable), 50Vpk max, 80mA max, 20 Ohms max.
- Isolation: Functional, maximum 50Vpk

No.	Connection front No.		Pin no	Hints
1	X7	RELOUT1	X7-12, 13	Switches after successful start-up self check
2	X7	RELOUT2	X7-14, 15	Passive by default, can be factory-configured for customer purposes

Tab. 5.6: SWM7 “Relay” Outputs on X

5.13 Motor Power Connector (X4)

The SWM drives are extreme flexible devices. They are prepared to drive many different types of motors to cover most applications within their power range.

The examples show connection of a three phase motor and a single phase motor.

A two phase motor is connected by connecting first motor phase to controller phase U, second motor phase to controller phase V and the common of both motor phases to controller phase W.

The power connections vary with the type of SWM.

The motor power mating connector will be delivered together with the SWM7. For the case that a second connector is required, the mating connector type is FM8W8S-K121 from FCT.

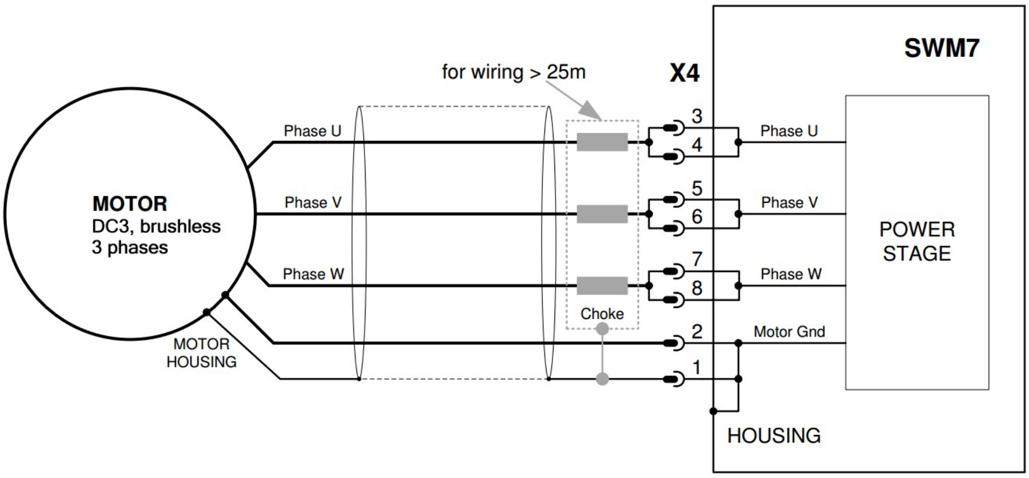


Figure 20: Motor Power Connector (X4): Three-Phase Motor at SWM7S-150

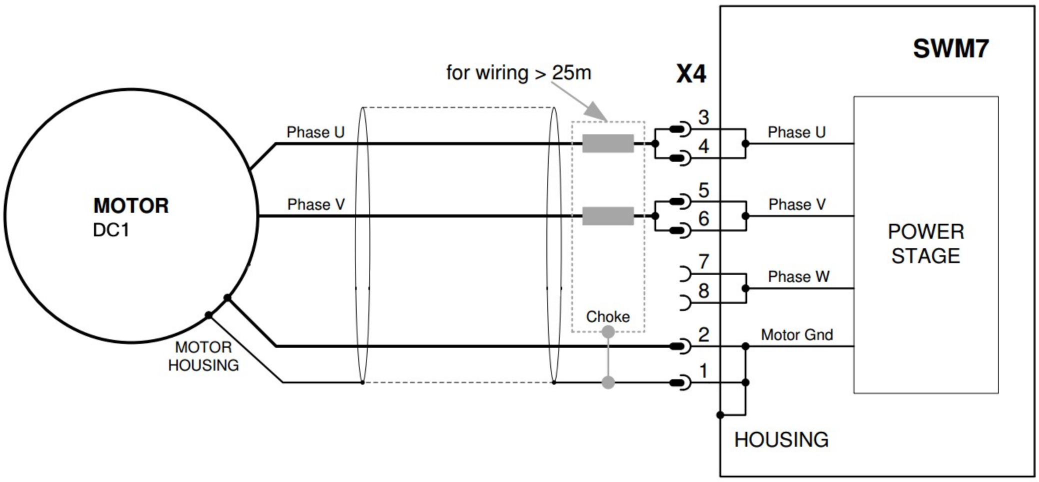


Figure 21: Motor Power Connector (X4): Single Phase Motor (Brushed DC) at SWM7S-150

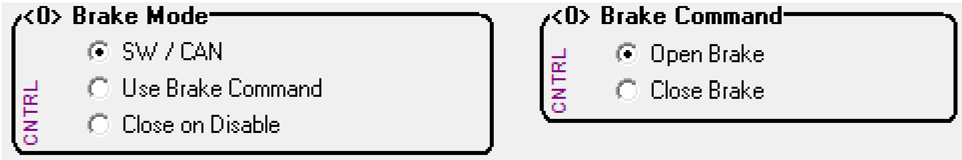
5.14 Mechanical Brake (X3)

Please refer to chapter 5.1 Safety Instructions when active electrical braking is required!

Please note that the mechanical brake circuitry is not functional save according to the definitions of the DIN ISO standards and must not be used for safety critical applications. If a brake for safety critical applications is required, a second mechanical brake with independent control needs to be added.

The SWM is prepared for connection of an external mechanical 24V brake. It requires an additional power supply connection, possibly from the auxiliary supply source of the SWM.

The brake can be configured and used via the PC software user interface in the “COMMAND INPUT SELECT” tab:



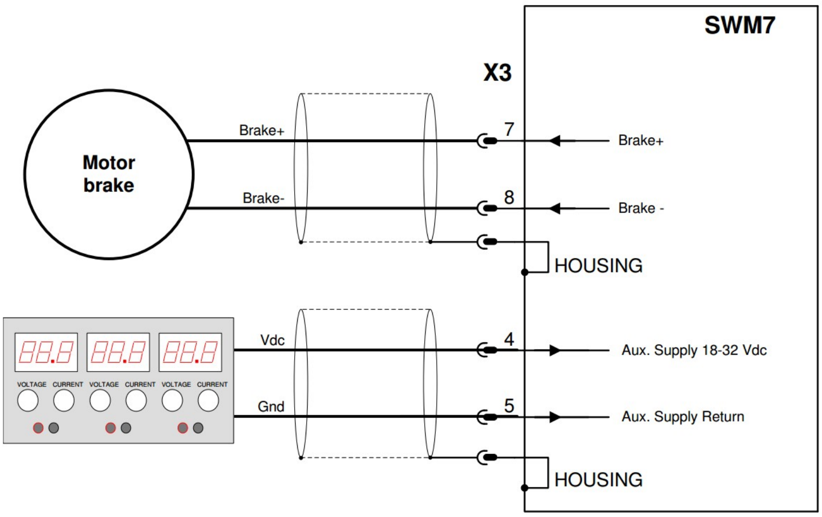


Figure 22: Mechanical Brake (X3)

5.15 Feedback Sensors

Every closed servo system will normally require at least one mechanical feedback device for sending actual values from the motor to the servo drive. Depending on the type of feedback-sensor, the controller can regulate on speed or on position. If a position sensor is used, the drive can be configured to position control or speed control.

In most applications (3-phase), a commutation signal is required. This information can also be taken from the position sensor, to have only one sensor in the system.

A brushed DC-motor does not need a commutation signal, it can be driven in speed control mode with a simple analog tachometer feedback signal. Commutation is mechanically controlled from the brushes on the collector.

The SWM also provides a sensorless mode, but this can only be used for special applications with certain limitations.

The SWM as extreme universal drive controller is prepared for most modern feedback interfaces without the requirement of an expansion card.

5.16 Hall Sensors (X13)

X13 is a multi-functional sensor interface. It provides connections for three digital Hall sensors with open collector outputs and an analog +/10V tachometer input. The pull-up resistor voltage for the Hall signals can be configured to 5V or 15V.

The Hall sensor is a simple and robust, but rough method of position control with low resolution (three pulses per turn of the motor shaft). This principle is ideal for cost optimized drives, but it does not work at low speed. Three hall sensors with open collector outputs can be connected to the SWM at connector X13, see Fig. 23. There are also encoders available with internal Hall emulation circuit which behaves like discrete Hall sensors.

If Hall Sensors are used, the Phase-Finding Algorithm is deactivated!

Standard MACCON colour code for Hall-Sensors is:

Vcc = blue	**Signal U = brown**
GND = green	**Signal V = orange**
	Signal W = yellow

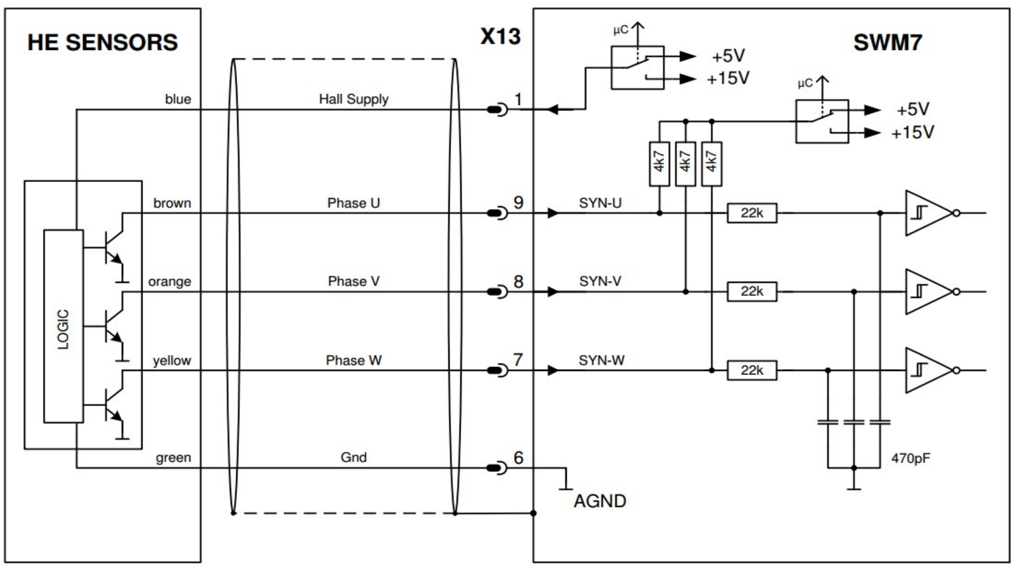


Figure 23: Hall Sensor Interface (X13)

5.24 Discrete Hall Sensors or Encoder with Hall Emulation (X13)

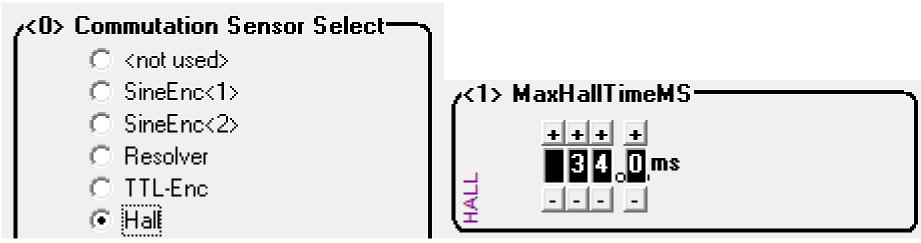
To ensure a smooth start of a motor with hall effect sensors, the position of the sensors must be accurately aligned to the electrical position of the motor. Inaccurate mounting of the sensors also can also result in wrong signals at high motor currents or at high motor speed.

It is recommended to measure a test sequence of the hall signals before starting the bring-up of the drive.

When hall sensors are used at frameless motors, the hall sensors must be completely covered by the rotor magnets at the switching point.

A special feature of the SWM drives is the possibility of sinewave commutation with digital (!) hall sensors:

When the hall sensor is defined as commutation sensor in the “SPEED / CURRENT CONTROL” tab, the operation mode is dependent on the value of the “MaxHallTimeMS” in the “MOTION SENSORS” tab.



When this value is zero, automatically block commutation is enabled. When this value is not zero, the controller works in block commutation at commutation frequencies below 1Hz and in sinewave mode above 1Hz. For a 12-pole machine (6 pole pairs), the minimum speed for the “quasi sinewave mode” is 10rpm, dependent on the setup.

5.17 DC Tachometer (X13)

The DC-tachometer is possibly the oldest type of feedback sensors for speed control. The signal input on X13 is normalized for ±10V max. voltage input. This voltage range must not exceeded!

For tachometer sensors with maximum output voltages up to 50VDC, the controller input may be adapted to the signal level of the DC tachometer by external resistors or factory-customizing internal resistor values. Details can be provided on request. Sensors with maximum voltages above 50VDC are not allowed, not even with voltage adaptation.

A software filter for the tachometer signal input can be adjusted when the drive is working in noisy environments (see figure Fehler: Verweis nicht gefunden on page Fehler: Verweis nicht gefunden).

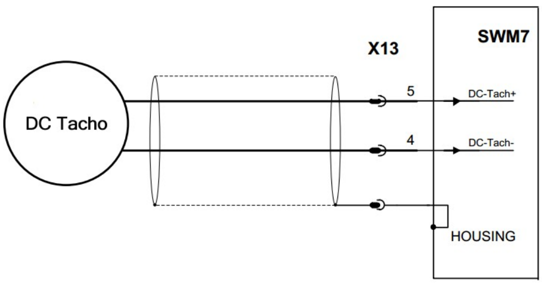


Figure 24: DC Tacho

5.18 Resolver (X9)

The resolver is a robust commutation and position feedback device with medium accuracy.

The SWM servo controller allows connection of a 2-pole or a multi-pole resolver.

The resolver excitation voltage is fix, 20Vpp.

Maximum resolver excitation current is 75mA peak.

Useful input signal range for sin and cos input is 5Vpp to 10Vpp.

Signal input impedance for sin+, sin-, cos+ and cos- is 24kOhm.

The maximum achievable resolver interface signal resolution of the SWM is 16 Bit. This is much higher than the mechanical accuracy of any resolver. A 2-pole resolver (1 electrical cycle per revolution) can deliver a position resolution of: 360° / 65.536 = 0,0055° (0,33` arc minutes)

Due to the limited „Tracking Rate“ of the internal Resolver-to-Digital converter, the maximum achievable position resolution depends on the maximum speed.

The limits are (valid for a 2-pole resolver):

• 16 Bit for ≤ 1.000 rpm

• 14 Bit for ≤ 4.000 rpm

• 12 Bit for ≤16.000 rpm

• 10 Bit for ≤ 64.000 rpm.

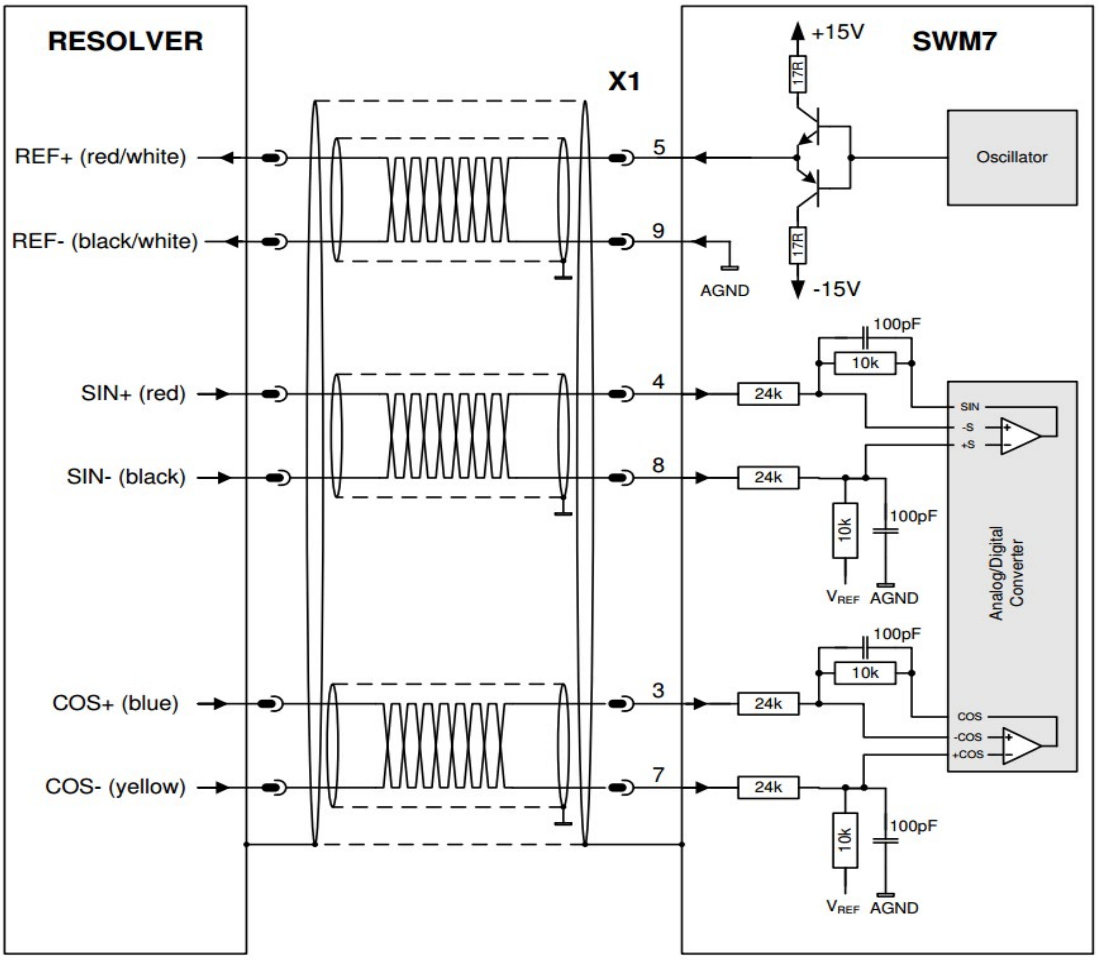


Figure 25: Resolver (X9)

5.19 Digital Encoder (X6)

The encoder is a digital feedback system which can have very high resolutions. Low encoder resolutions are 500 to 1000 lines, but encoders can have up to 18000 lines resolution.

There are incremental encoders with or without index pulse available, as well as absolute encoders for single- and multi turn.

Incremental encoders need to be initialized to the absolute position, in most applications after each power cycle. The SWM provides a software routine for initializing (phase finding).

The physical signal interface can be software-configured to simple single-ended (TTL) or to differential (RS422) for improved common mode noise immunity and higher data transmission rates. The receiving interface of the SWM can handle both signal variants. The maximum permissible input frequency is 4MBaud.

The maximum permissible resulting velocity is:

10^6 [Hz] * 60 / Resolution [lines/rev] = [rev/min]

For an encoder with 5.000 lines per revolution the motor can be operated up to a speed of 12.000 rpm.

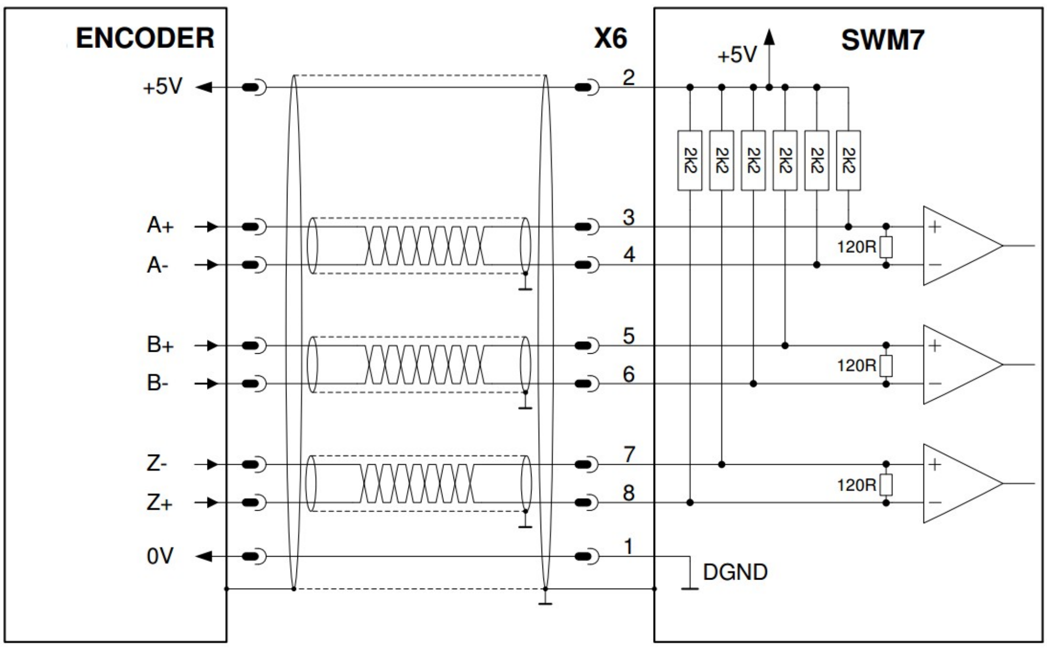


Figure 26: Encoder: Differential Signals

When the digital encoder inputs on connector X6 are configured as TTL, the inputs A- (Pin4), B- (Pin6) and Z- (Pin7) must remain unconnected, see figure 27.

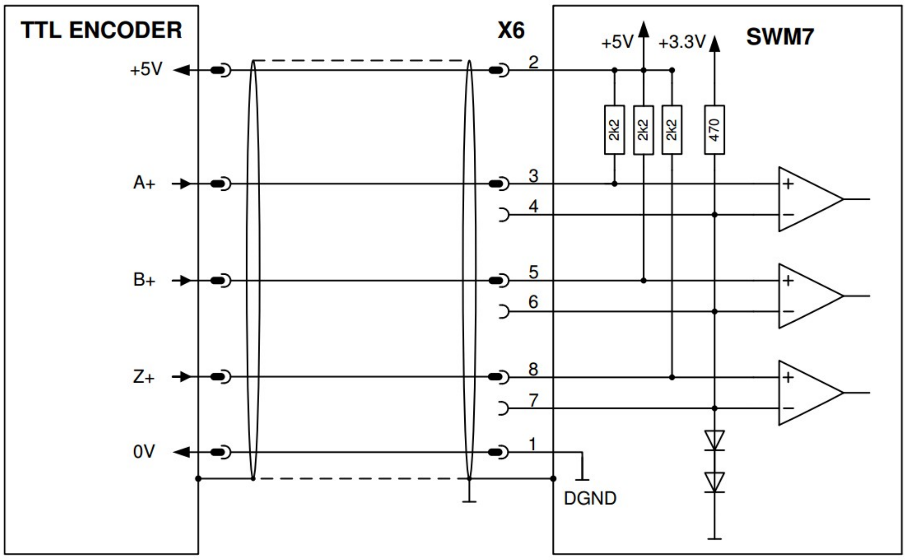


Figure 27: Encoder: Single-Ended Signals (TTL)

5.20 SIN/COS Encoder (X11)

Connector X11 provides a complex sensor interface with two differential analog 1Vss inputs for sin and cos signal, two differential digital RS422 inputs and a 5V sensor supply. This allows connection of different types of sensors from a simple analog sin/cos encoder over a complex EnDat 2.2 up to a Netzer encoder.

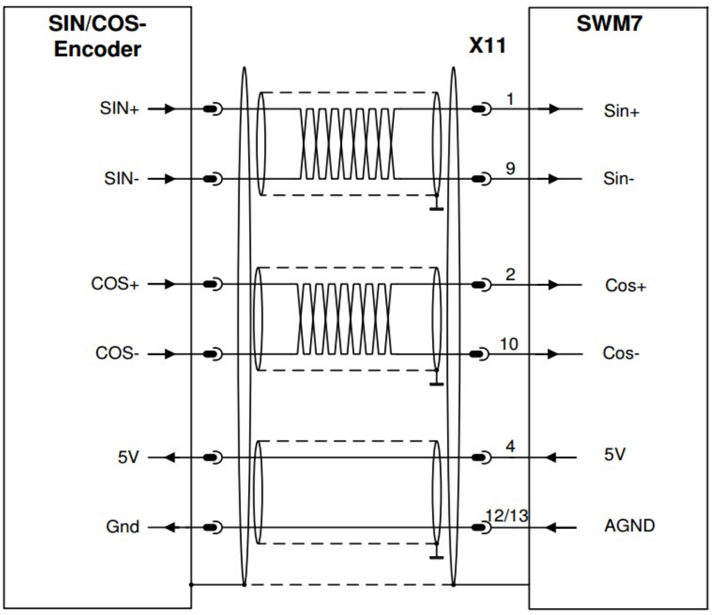


Figure 28: SIN/COS Encoder

5.21 Sine Encoder with EnDat 2.2 (X11)

The sine encoder with ENDAT interface provides a mixture of differential analog sin/cos signals in combination with differential digital signals.

The SWM7/LWM7 fetches the position data at a rate of 10 and 20 kHz. Reading will be done with 2 MHz.

Signal delay compensation for long cables is not supported, but this should be no problem in normal applications.

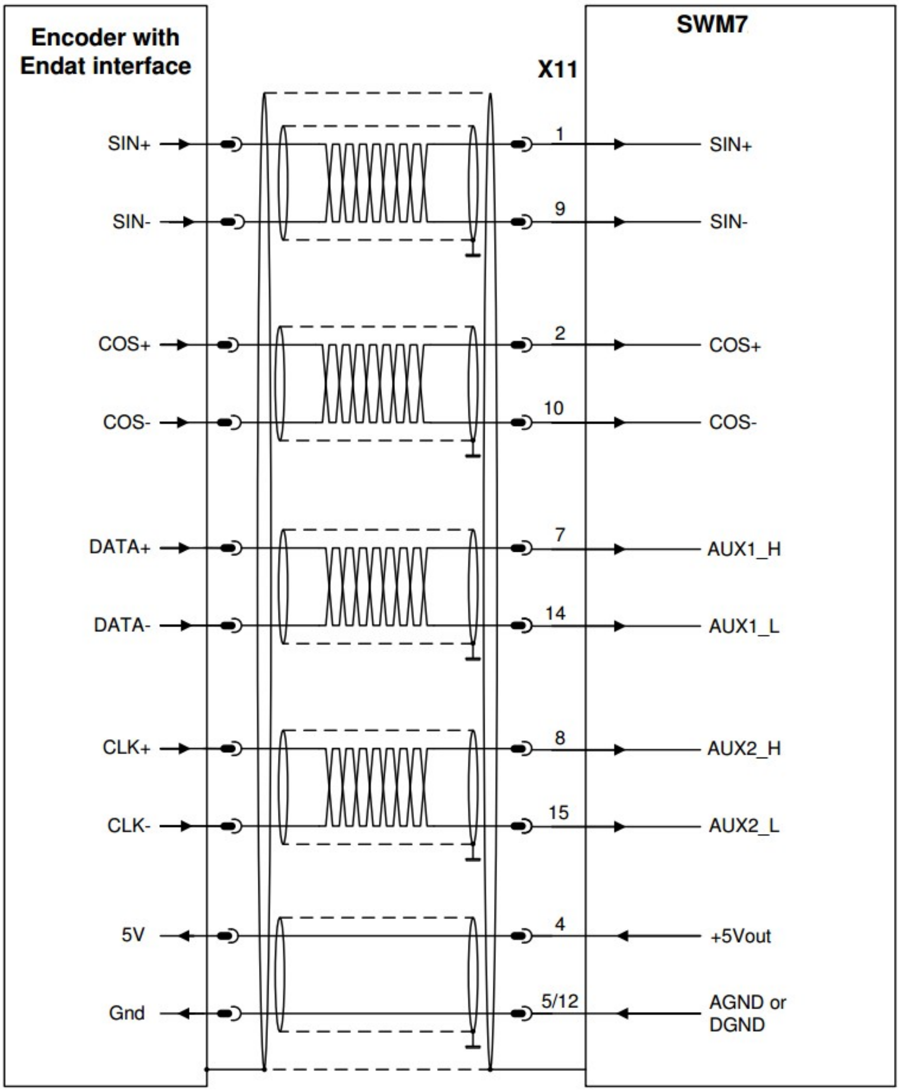


Figure 29: Encoder with EnDat

5.22 Netzer Encoder (X11)

The Netzer encoder uses a capacitive measuring principle and provides analog output signals.

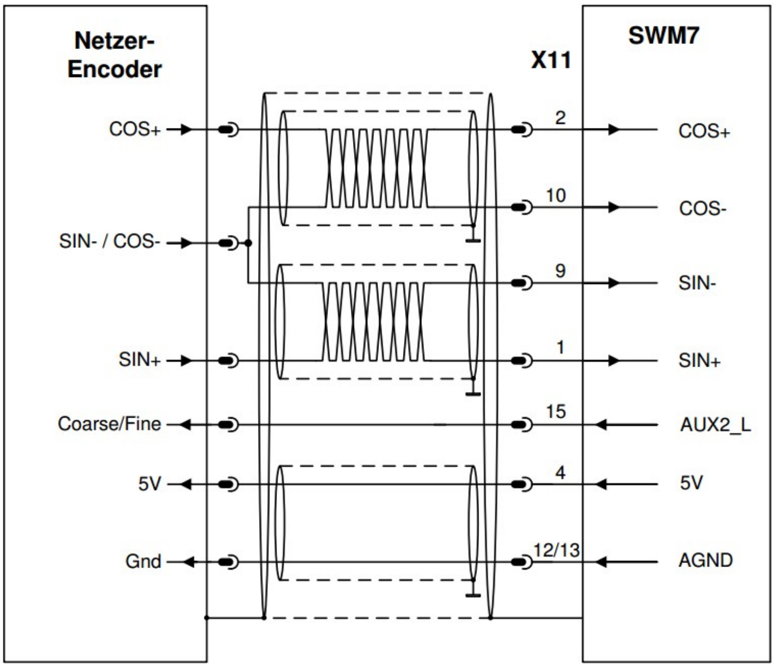


Figure 30: Netzer Encoder

5.23 Encoder with BiSS/SSI (X11)

The BISS encoder uses the only the pure digital interface portion of X11 and the sensor supply. The SWM7 supports BISS-C (no safety), but without line delay compensation for long bus lines. For SSI use X11 Pin 8 for Clock+, Pin 15 for Clock-, Pin 7 for Data+ and Pin 14 for Data-.

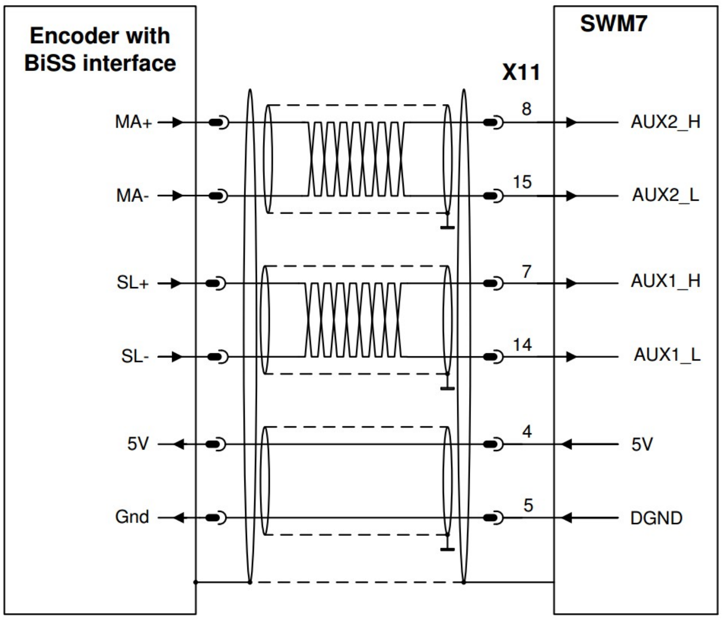


Figure 31: Encoder with BiSS

MA(ster) sends clock, SL(ave) responds with data

5.24 AMR-Encoder (X11)

An AMR encoder works on the base of the anisotrop magneto resistive effect. It is chosen as example for connection of an analog signal sensor with single-ended sin and cos signal.

For connection of single ended signals, the AMR-option of the SWM needs to be ordered!

With AMR-option, the input voltage range for sin- and cos- to AGND is 2,5V (zero) +/- 1,2V.

Software configuration for AMR sensors need to be to SineEnc<1 or 2> for commutation.

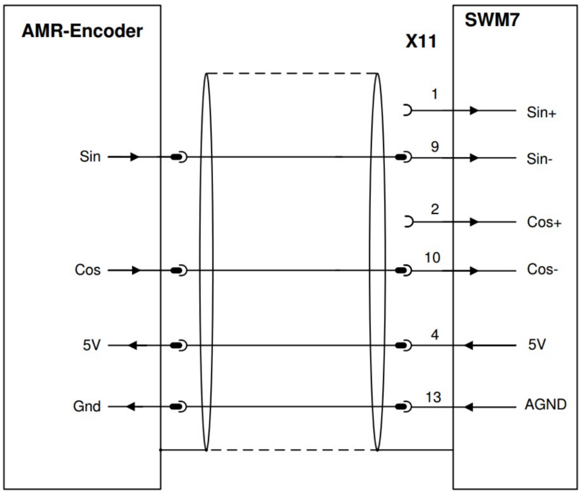


Figure 32: AMR- Encoder (X11)

5.25 RS-232 Interface, PC-Connection (X2-1)

The RS232 interface can be used for PC connection. The software for a graphical user interface which provides parametrization and remote control functionality will be delivered on CD with each SWM.

Switch off the power supply of both participants before connecting the RS232 interface (X2-1).

The RS232 interface interface is galvanically isolated, but uses a common ground together with the CAN interface on X10.

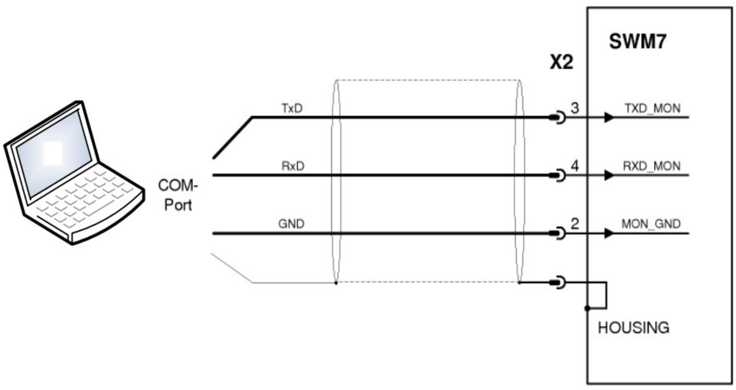


Figure 33: PC Connection to SWM7

5.26 CAN Interface (X10)

The CAN communication profile is a MACCON standard. A customized profile can be provided on request.

The graphical user interface provides a separate page for CAN. Parameter setting windows and display windows facilitate set-up and debug of the CAN communication interface.

The CAN interface is galvanically isolated. It uses a common ground together with the RS232 interface on connector X2-1.

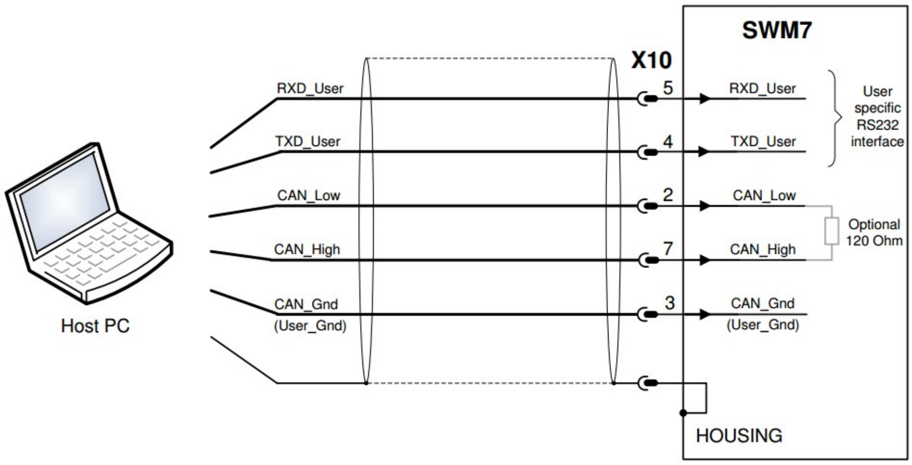


Figure 34: CAN Connection to SWM7

5.27 Ethernet Interface

Upon request.

5.28 EtherCAT Interface

Upon request.

5.29 USB Interface (X3-1)

The USB interface requires a very old windows driver and is not recommended for any kind of application any more, not even for parametrization of the device.

5.30 Power Supply Connector (X5)

The power supply mating connector will be delivered together with the SWM7. For the case that a second connector is required, the mating connector type is FM5W5P-K120 from FCT.

6 EMC Considerations

The SWM servo controllers are designed for functional prototypes. They use internal noise reduction technology like most other switching drive controllers, but they are optimized on seize, not on EMC. When these drives should be used in systems with strict and clearly defined DIN ISO EMC standards, additional external filters and grounding and shielding effort might be required.

EMC cannot be solved on a component level, it needs to be solved on the system level. MACCON as component supplier gives some recommendations and suggestions for integrating the SWM into a system with external EMC requirements.

6.1 AC-Grid Supply

The SWM7 servo controllers are designed for DC power input. They do not have internal overvoltage suppression circuits. Please consider the overvoltage category of the AC supply and the functional elements between SWM and AC supply to decide if and which voltage suppressors are required.

If the SWMs need to be powered from the public AC-grid, external components like power factor correction supply unit, transformer, rectifier, capacitors or even voltage suppressor elements might be required.

For applications where transformer, rectifier and filter unit still is sufficient to fulfill the grid requirements, an AC-filter is recommended at the transformer input due to the good dampening characteristics of transformers to conducted noise. A selection of different filters can be found in Tab. 6.1. MACCON offers different integrated power supply units (PSU), one available with integrated chopper.

In most AC grid supply applications, an active power factor correction unit might be required. These units might include voltage suppressors and have their own specific recommendations for filters.

If active breaking of the motor is required in AC grid supply applications, please consider that standard power factor correction units or simple rectifier supply circuits are blocking the reverse braking energy transfer back into the grid. Either an adequate brake chopper in addition to the supply or an active bidirectional power factor correction unit is required. Active braking with a standard single-quadrant supply will destroy the drive, which might cause also injury or death.

6.2 AC Mains Filter

Filter type	Input	Nominal current	Power dissipation	Weight	Used for SWM
FN351-5/29	3 x 400 V, 3 Phases	5 A	6 W	1.1 kg	48/12.5 – 25
FN351-8/29	3 x 400 V, 3 Phases	8 A	7 W	0.8 kg	48/50/100
FN351-16/29	3 x 400 V, 3 Phases	16 A	8 W	1.3 kg	48/50/100
FN351-25/33	3 x 400 V, 3 Phases	25 A	8 W	1.4 kg	300/25
FN350-8/29	1 x 250 V	8 A	5.2 W	0.7 kg	
FN350-12/29	1 x 250 V	12 A	6.1 W	0.7 kg	

Tab. 6.1: AC Mains Filter (at Transformer Input). Manufacturer: Schaffner

6.3 Motor Filters

Motor chokes can solve different problems.

Differential mode inductors can be used to improve the PWM ripple at low inductance motors.

Motor cables are critical for EMC because they are directly connected to the fast switching PWM outputs of the drive controller. Their parasitic capacitance builds a noticeable capacitive load to the output stage of the controller. For motor cables (≥ 25 m) a motor choke close to the controller is strongly recommended to decouple the controller output stage from the parasitic capacitance of the cable. This reduces the capacitive loading of the output stage and reduces EMI currents to ground.

Tab. 6.2. lists a choice of standard motor chokes. More motor chokes and accessories can be found at the MACCON website.

Type	Inductance	Nominal current	Dimension diameter x height	Weight	Remarks
L100/3K	1 mH	3 A	45 x 30 mm	0.25 kg	Toroid core; fit for PWM; f_{max} 50 kHz
L020/6K	0.2 mH	6 A	60 x 40 mm	0.6 kg	
L050/8K	0.12 mH	8 A	60 x 41 mm	0.6 kg	
L012/20k	9.12 mH	20 A	60 x 41 mm	0.6 kg	

Tab. 6.2: Motor chokes (optional)

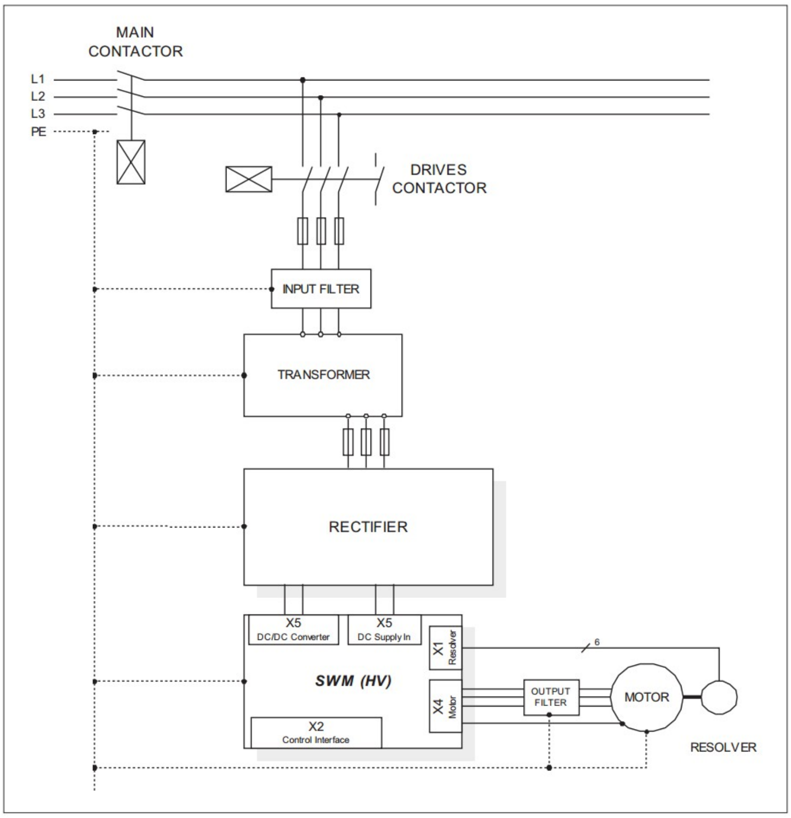
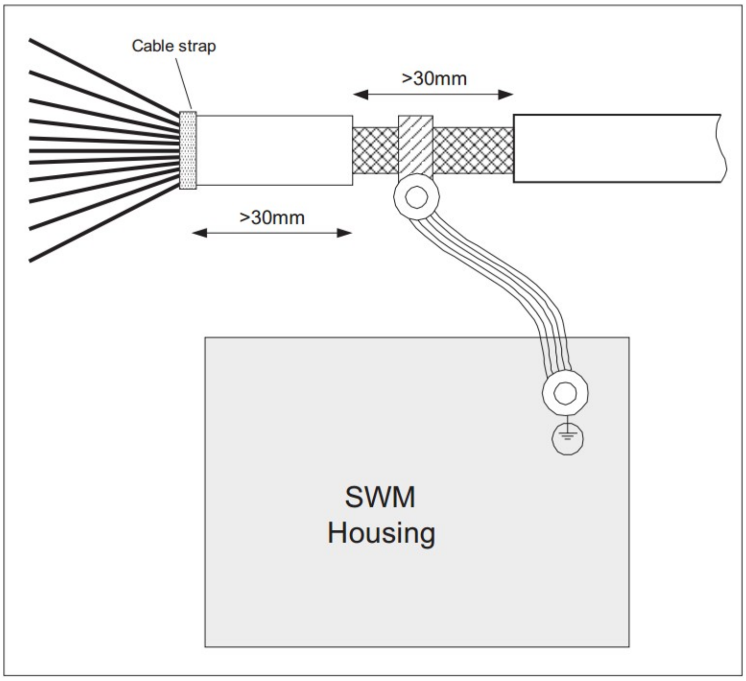


Figure 35: SWM Controller AC Supply Example for no Active Braking

6.4 Mounting Instructions

- A metallic cabinet or enclosure is recommended where large ground contact areas can provide low high frequency impedance for ground connections.
- All siganl cables from and to the SWM7S servo controller need to be shielded.
- Shielded motor cables are strongly recommended.
- To avoid noise coupling from power lines to signal lines, they should be routed separately, if possible at minimum distance of 25cm where they have to be routed in parallel.
- Both ends of the load cable shields have to be connected via low impedance (large contact area) to the chassis ground point.
- To prevent potential differences between motor and controller (mainly in the case of long cables) it is necessary to ensure an equipotential bonding for all components.
- Signal cable shields should be connected only at the SWM side of the cable.
- Each SWM has to be grounded to the central grounding point of the cabinet, minimum cross section = 2.5 mm^2.
- The line filters should be installed at the cabinet entry point with high surface connection (low impedance) to the chassis of the cabinet.
- Wiring should be performed close to the grounded enclosure.



Remove outer insulation over a length of about 30 mm without damaging screen. Fix cable with an earthing clip.

Connect this clip via copper braid to the closely situated earthing screw on the SWM7S housing.

Figure 36: SWM7S Cable Shield

In case of EMC related questions contact MACCON technical support.

MACCON MOTION UNDER CONTROL

7 SetUp Tool SWM7.exe

The SWM7 Setup tool provides a PC user interface which can be used for:

- Configuration and parametrization of the SWM
- Monitoring paramertes for observations, bringup and debug
- Customization of the PC user interface as application specific display

MACCON offers training courses on request.

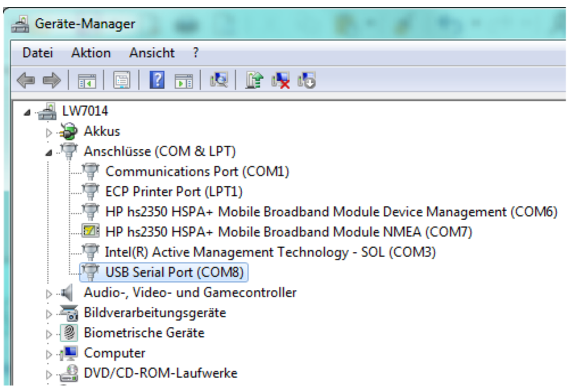
7.1 Hardware Requirements

- Windows PC with RS232 interface or additional USB to RS232 converter for PCs without integrated RS232 interface. Example for the USB to RS232 converter can be the EXSYS EX-1302IS.
- Sub-D, 9 pole to RJ-12 cable, which is part of the SWM7 package.
- SWM Software CD, delivered together with each SWM. The CD-ROM contains the SWM7.EXE incl. graphical user interface (GUI), firmware for µC, DSP, FPGA, and optional customer specific parameter files.

The serial interface (X2-1, RS-232) of the servo controller is galvanically isolated from internal circuits.

7.2 Installation

- Before attempting to install, service or maintain this unit always read the manual and the specific safety instructions.
- Unpack servo controller and accessories, check completeness of the accessories and mount the servo controller as described in the manual for the actual type of motor and feedback-sensor and leave the SWM unpowered.
- For PCs without integrated RS232 interface, plug the USB to RS232 converter in a free USB port of the PC and install the software according to the manual of the converter. Reboot the computer.
- Identify the actual COM port number for the RS232 on your PC: Open System Control/Device Manager. In this example, the port is COM8. Do not change the USB connector for the USB to RS232 converter again, this will change the COM port number.



- Create a working directory on your PC and copy at minimum the “swm7.exe” and the “complete functionality.mac” files from the SWM Software CD into your working directory. The .mac file represents the layout of the user interface and can be customized.
- Double-click the “swm7.exe” in your working directory will open the clean user interface.
- Define the PC COM port number for the setup tool with: Settings/COM Port and choose the same number like observed in the PC device manager. COM8 for this example.

7.3 Working with the SWM7 SetUp Tool

7.3.1 General

The setup software is intended to be used for altering and saving the operating parameters for the SWM7 servo controllers.

The attached servo controller can be configured. During this procedure the drive can be controlled directly by the service functions, see buttons “Enable Drive” and “Disable Drive”.

Exclusively qualified personnel is allowed to do the bring-up procedure, load parameter files and control the SWM via PC user interface.

Please always make sure that loaded configuration and parameter files fit to your motor and sensor setup and contain the original data. Please check if they did not have been modified unintentionally or by other persons. This could result in unexpected movement of the motor, injury or damage.

The CD supplied with each SWM contains motor-specific default sets of data for the most common combinations of servo controller and motor. In most applications you will be able to use these default values as a starting point to get your drive running.

In case of errors, hardware problems (e.g. fuses, connectors, capacitor reforming, user-specific settings etc.) or other service related questions contact MACCON technical support.

7.3.2 Offline-Operation: PC without Connected Drive

Before the physical connection to the SWM is connected, the “swm7.exe” can work offline. In this mode you can prepare the setup of the drive and the graphical user interface:

- Load or manually prepare the specific set of parameters that fits to your hardware configuration. (drive, sensors, resolvers, encoders or ext. controls). For the first steps with the setup-tool it is recommended to load the full functionality *.mcap file, which can be stored under a different name and which can be modified. After loading the file, The complete standard user interface with all buttons and parameter displays should appear. This setting will be stored for future software starts until the actual .mac file is replaced or removed from the working directory.

  Parameter-files can be uploaded from the PC with: “File”/”Load parameters” and specify the desired *.mcap file.

  Saving a set of parameters on the PC can be done with: “File”/”Save parameters as” and specify a name for the new *.mcap file.
- For preparation of the CAN settings, a separate document with the standard CAN protocol is available.
- If desired, you can change the layout of the graphical user interface from the full-function standard design to a custom specific version manually, or you can load a custom specific configuration from the PC.

  Configuration-files can be loaded from the PC with: “File”/”Open” and specify the desired *.mac file.

  Saving the actual configuration on the PC can be done with: “File”/”Save as” and specify a name for the new *.mac file.
- Make sure that you have stored an actual configuration file and an actual parameter file on the PC. Both files should be saved at the same time to make sure they fit together.

7.3.3 Online-Operation: Connecting the Drive to the PC

- Before connecting the drive please make sure that the actual configuration and parameter files from the offline operation have been stored on the PC. This is important because connecting the drive will load the possibly old parameters from inside the drive into the graphical user interface and overwrite the prepared parameters. The layout of the graphical user interface remains the same.
- Make sure that both, auxiliary supply and DC-link supply of the SWM are off. Connect the RS232 cable from the PC to the SWM X2-1. Check all wiring connected to the SWM.
- Turn on the auxiliary supply of the SWM. A blue progress bar appears at the bottom of the user interface window. A lot of question marks appear in the displays until the valid data from the SWM has been loaded. If loading of the data is complete, a thick red cross is visible on some displays or buttons, which are not valid for the actual configuration.

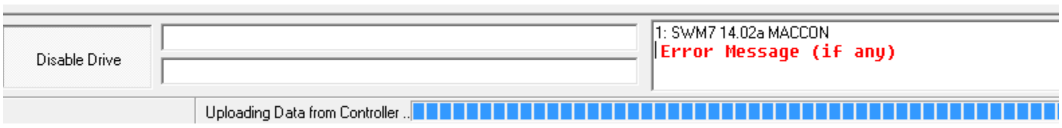


Figure 37: SWM Message Window (Example: No Error)

- Check the RS232 connection between PC and SWM: Data transfer on the RS232 interface can be observed with: Service/Show Communication. It is recommended to spread the “Telegramme” window that wide to see a whole telegram in one line.

  If the RS232 connection does not work, please check the COM port settings in the setup tool and in your computer like described in the installation chapter.

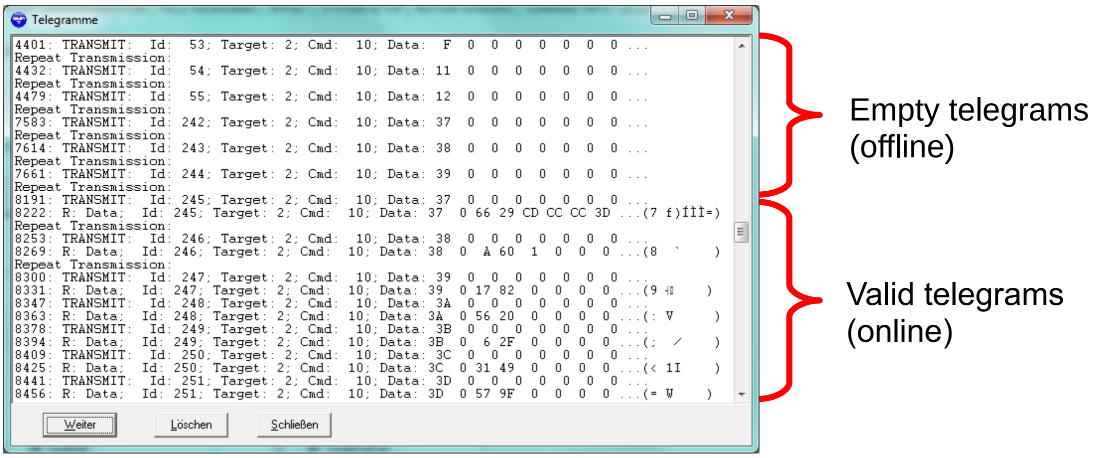


Figure 38: RS232 Telegrams

- If the SWM is new, it is unlikely that the actual settings of the graphical user interface from inside the SWM fit to the actual application. Save the parameter *.mcap file as backup on the PC. Load the prepared correct configuration *.mac file and the actual parameter *.mcap file from the PC and store it inside the SWM using the “Write Parameters to Flash” button.

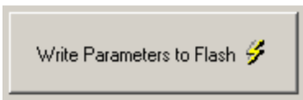


Figure 39: "Write Parameters to Flash" Button

- If either changes in settings or parameters had been done with connected SWM, click the “Write Parameters to Flash” button before you switch off the auxilary supply of the SWM or close the “swm7.exe” program.
- **Before changing parameters online please always check if the drive is disabled or click the “Disable Drive” button.**

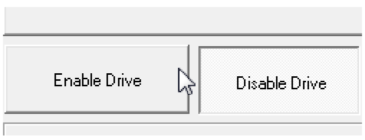


Figure 40: "Enable Drive" and "Disable Drive"

7.3.4 Bringup to Full Functional Drive System

Working in ONLINE mode connected to a powered drive, parameters can quickly be changed and tested. This mode is helpful for bringup and tests.

- Ensure that both, auxiliary supply and DC-link supply of the SWM are off.
- Check all wiring of the drive system: To the supplies, to the sensors, to the motor, and if applicable to the host, PLC or other.
- Restore the complete setup from the online operation including powering the auxiliary-supply from the SWM and loading the setup and parameter files for the actual hardware configuration. The DC-link supply remains off.
- Make sure that the motor is mechanically mounted that uncontrolled movements cannot result in injury or destruction.
- Choose a supply source for the DC-link of the SWM. Please consider if the motor is braking, a large amount of energy is generated from the motor which normally cannot be stored in the output capacitors of the power supply. Either the DC supply source needs to be able to sink energy or an adequate chopper needs to be connected in parallel to the DC source to burn the braking energy in a resistor.
- Choose the DC-link supply and chopper voltage settings for the SWM for bringup: Recommended is a voltage much lower than nominal voltage and below 50V to try first steps at a mechanically unloaded motor, if possible. A sourcing current limit of the supply might be useful. For a 2- or 4-quadrant source please ensure that the sinking current limit is higher than the expected worst case generated braking current.
- Switch on the DC-link supply for the SWM and start with the first careful steps to the movement of the motor. Depending on the type of motor and feedback sensor, different steps can be useful:

  For a brushed DC motor, a manual current control mode without feedback sensor over the setup tool is possible.

  For a brushless DC motor with incremental encoder, the automatic phase finding with the setup tool might be the first useful step.

  Each motor operation can be started with the “Enable Drive” Button. Parameters should only be changed when the drive is disabled.

7.3.5 Usage of the SWM7.exe

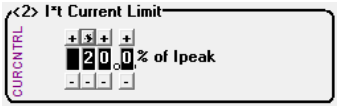
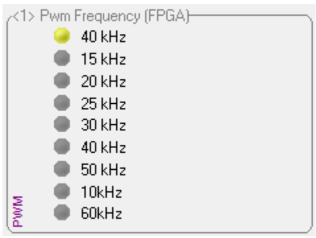
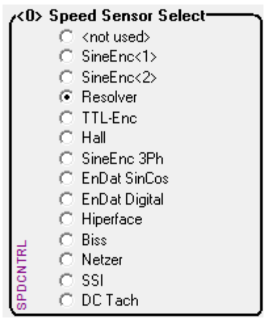
This chapter describes the possibilities for using the SWM7.exe, its functions, menus, tabs, displays and buttons.

Frame layout and font of the windows indicate the importance for standard applications of a function window:

Expertise	Frame	Title
Standard Application	**Thick Black**	**Bold Black**
Advanced Application	Thin Black	Normal Black
Debug or MACCON Technical Support	Thin Grey	Normal Grey

Tab. 7.1: Font Description for Graphical User Interface

Typical Measure and Control Windows

Window name	Example	Remarks
Parameter display		Using the "+" and "-" keys you can adjust the desired parameter value, even as the sign of the value.
		Use or no use of parameter "Index Pulse"
Measuring display		Display "Abs. Position" is valid. green = valid
		Display "Pwm Frequency (FPGA)" is actually 40kHz
		Measuring display: "Index Pulse" not used grey = not used red = used
		Display "FPGA Status Flags 2" grey = not used green = used/active
Selection window		This selection window allows the choice of one of the displayed group
		Direction "not inverted" or "inverted"

Tab. 7.2: Typical Measure and Control Windows

7.3.6 Analyzing Parameter Files

Shows the parameter values stored in a `*.macp` file and allows the export into `*.csv` or into `*.txt` file format.

Choose in menu item “File” ➪ “Examine Parameter file...”, and select a `*.macp` file. The result is shown in Fig. 41 below:

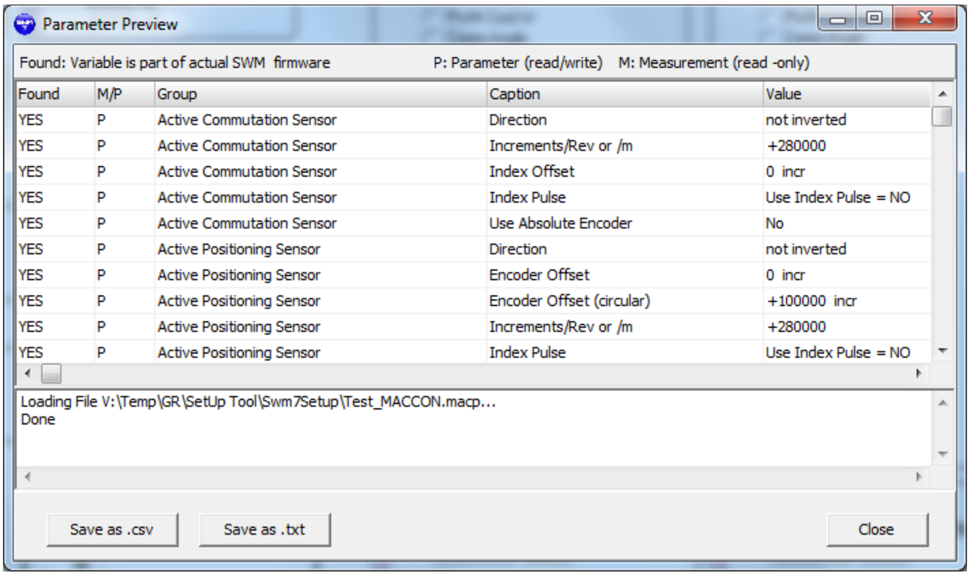


Figure 41: “Parameter Preview” Window

Result:

- in column “Found” will be displayed “YES”, if the parameter found in SWM firmware
- the column “M/P” informs the user, which parameter is
  – (read/write) = P
  – (read- only) = M.

7.3.7 Customization of the Graphical User Interface

7.3.7.1 Adding Parameter Displays

The menu item “Parameters” opens a window which allows selecting additional parameters for display. The window is empty if no SWM is connected or if the connected SWM is unpowered. When the connected SWM is powered, simply move the desired parameter to the certain setup page by drag-and-drop, see below:

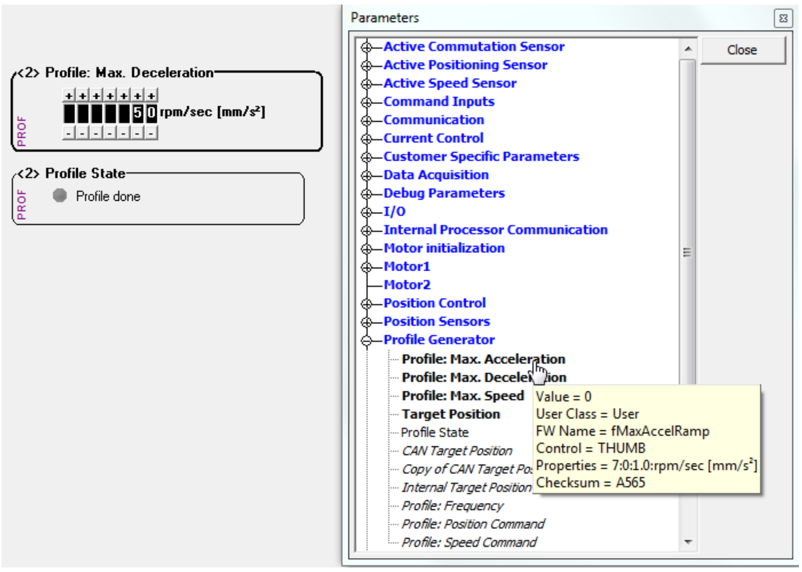


Figure 42: Example of Adding the Parameter “Profile: Max. Acceleration” to a Section

The parameters can be used simultaneously in several tabs of the graphical user interface.

7.3.7.2 Deleting Parameter Displays

You can delete parameters in a section. Choose in menu item “Service” ➪ “Modify”.
Then select the control window, e.g. “Encoder Offset (circular)” in Fig. 42 and right-click the mouse to delete.

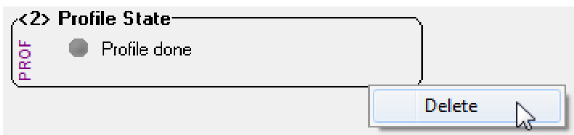


Figure 43: Delete Measuring Window “Profile State” (Example)

Confirm message “Are you sure to delete” with “OK” button.
The measuring window “Profile State” is deleted now.

7.3.7.3 Creating user-defined Tabs

You have the ability to create your own tabs (parameter page(s)) for controlling and monitoring your drive system. Choose in menu item “Service” ⇨ “Modify”.
Then right-click on a **free area in the tool bar** to open the context menu, see Fig. 43.

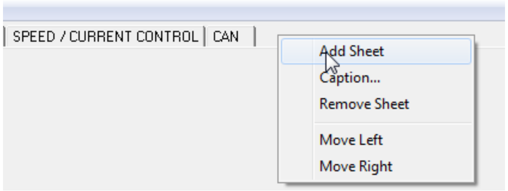


Figure 44: "Add Sheet" Option

Click on “Add Sheet” and enter a user-specific name for this window e.g. “Voltages”.

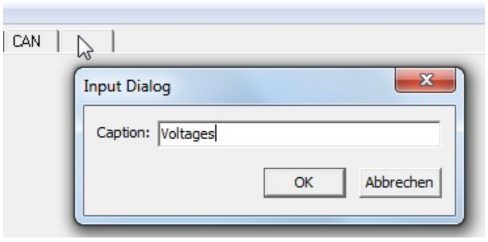


Figure 45: Create Caption "Voltages" (Example)

Confirm with “OK” to create the new tab.
Then you can add your user-specific control windows.
At least you need to save your new graphical user interface configuration in the `*.mac`- file, see menu item “File” ⇨ “Save”.

7.3.7.4 Deleting user-defined Tabs

You can delete your own tabs (parameter page(s)). First choose in menu item “Service” ⇨ “Modify”.
Then right-click on the tab e.g. “VOLTAGE” to be deleted and select “Remove Sheet”.

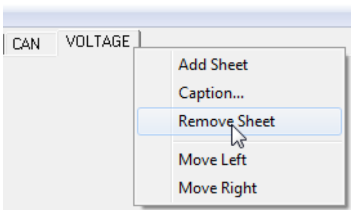


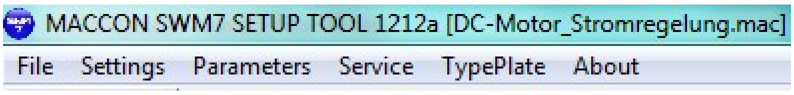
Figure 46: “Remove Sheet” Selection

Save your new graphical user interface layout in the `*.mac`- file, see menu item “File” ⇨ “Save”.

7.3.7.5 Restoring the default Graphical User Interface Layout

For restoring the default values copy the original *.mac file from the CD into the working directory and load it from the SWM7.exe. with: “File”/”Open” and choose the desired “complete functionality.mac” file.

7.4 Description of Menus and Windows



The menu items are described in the following. You can open the menu items using
– the mouse pointer or
– <ALT> key followed by the underlined letter e.g. <ALT+f> to open the “File” menu.

7.4.1 File Menu

Menu item	Description	<ALT+f>
New	Create a blank parameter window “Page1” with a MACCON configuration file name “`Untiteled0.mac`”	**<ALT+f+n>**
Open	Opens a window for selection of a MACCON configuration file `*.mac`	**<ALT+f+o>**
Save as	Opens a window for – saving a new file (i.e. overwrite `Untitled0.mac`) or – overwrite the present configuration `*.mac` file.	**<ALT+f+a>**
Load Parameters	Loads a parameter value file `*.macp`	**<ALT+f+p>**
Save Parameters as	To save/overwrite a parameter value file `*.macp`	**<ALT+f+v>**
Examine Parameter File	Opens a MACCON parameter file `*.macp` and displays all parameter values in the “Parameter Preview” window. File export as `*.csv`- or `*.txt` file is possible.	**<ALT+f+m>**
Exit	Closes the program with or without saving changes.	**<ALT+f+e>**

Tab. 7.3: File Menu Shortcuts

7.4.2 Settings Menu

COM port selection for genuine COM ports and USB-to-serial adapters.

7.4.3 Parameters Menu

The user can select any additional control windows or tabs, it is used for customization of the graphical user interface.

Requirement for this function is a connected, powered SWM. A list of functional elements appears in the “Parameters” window. If no SWM is connected or the SWM is not powered, this window is empty.

7.4.4 Service Menu

Menu item	Description	<ALT+e>
Modify	If selected (active) "✓Modify" it is possible to – change the location of any control element and/or – add additional elements or tab sheets. Save the new settings in your "personnel GUI" layout `*.mac` file.	**<ALT+e+m>**
Go Offline	Disables communication (for MACCON technical support.)	**<ALT+e+o>**
Show Communication	Displays in the "Telegram" window the running communication. You can "Stop" or "Pause" logging or "Delete" the communication log.	**<ALT+e+s>**
Show Database	Displays the internal data base of controller parameters.	**<ALT+e+d>**
Re-read Parameters	Re-read the parameter from the connected SWM7	**<ALT+e+r>**
Firmware Update Tool 	Opens a "Firmware Maintenance" window. **Permitted only with assistance of MACCON technical support.**	**<ALT+e+u>**
Upload Controller Flash	Upload controller data into a file for MACCON technical support.	**<ALT+e+L>**
Show Groups	Displays parameter groups, used by MACCON technical support.	**<ALT+e+g>**

Tab. 7.4: Service Menu Shortcuts

7.4.5 Type-Plate Menu

Displays (and modify) the type plate data stored in the drive (will be used in a next version).

7.4.6 About Menu

Displays the current software version.

7.5 Error Messages

This chapter describes some error messages in the status line of the SWM7 graphical user interface.

7.5.1 Parameter Window or Measuring Window marked in Red

In case that the current firmware does not contain a specific parameter which is part of the current graphical user interface layout, this window is marked as "Not valid", crossed out in red.

This is not really an error, just an information that this parameter is not available in the actual configuration.

Figure 47: Windows Crossed-Out in Red

7.5.2 RS-232 Communication Errors

7.5.2.1 Message “Transmitting Telegram: No Response”

Indicates that the SWM7 unit is not responding. Check power supply, cabling and COM port setting.

7.5.2.2 Message “COM Error 0x02”

If you use a build-in COM port and frequently get an error message like “COM Error 0x02” in the status line of SWM7 program, it is necessary to change the serial port setting.
(This applies to communication chips of type 16C550)

Changing the serial port setting:

1. Open the Windows device manager and select the used COM port e.g. COM1.

Figure 48: The Microsoft Windows “Device Manager”

2. Check the properties of the COM port and click “Advanced” button.

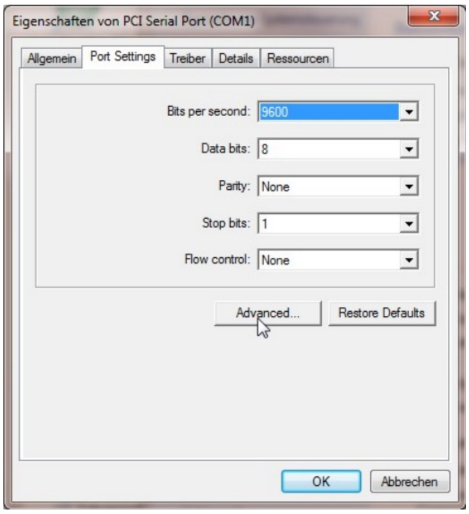


Figure 49: COM Port Settings (Default)

3. Reduce settings for receive buffer to 4.

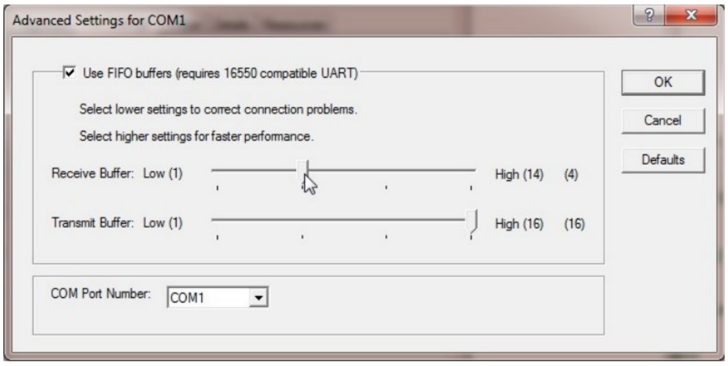


Figure 50: Adjust Receive Buffer for COM Port

4. Click “OK” to close all device manager windows.
5. Restart Windows to make these changes become effective.

Now the warnings should not appear any more.

7.5.3 Invalid Combination of Feedback Sensors

Due to hardware restrictions, some combinations of feedback sensors are not possible.

E.g., it is not possible to use “Sine encoder 2” and “Endat” at the same time. In case of invalid sensor settings, one of the following error messages appears in the message window, see Figure 51:

– "Duplicate Use Of Encoder Input 1"
– "Duplicate Use Of Encoder Input 2", or
– "Resolver disables Encoder Input 2".

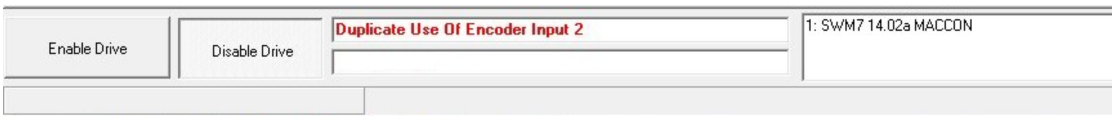


Figure 51: Failure: “Duplicate Use Of Encoder Input 2”

7.5.4 Missing Motion Sensors

A missing sensor is displayed in the message window, see Fig. 52:

– "No Commutation Sensor defined"
– "No Speed Sensor defined", or
– "No Positioning Sensor defined".

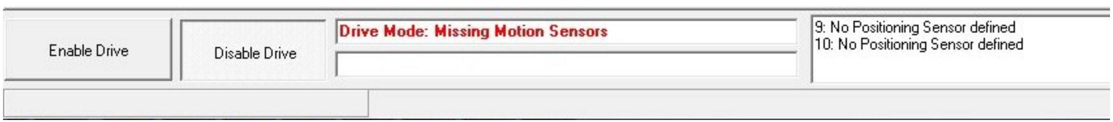


Figure 52: Failure “Missing Motion Sensors”

7.5.5 Incomplete Sensor Definitions

Some sensors need additional configuration, e. g. if you select “Hall sensors” as feedback sensor you also have to define the hall switch type (supply voltage).

Otherwise, an error message is output:

Figure 53: Failure “No Hall Sensor Type defined”

7.5.6 Runtime Errors

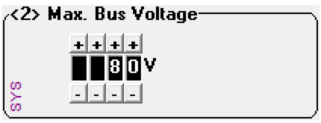
Runtime errors appear during operation, if a safety limit is reached. In this case, the drive will be disabled immediately. The error message is cleared if the cause of the error is removed and the drive is disabled and re-enabled by the user.

7.5.7 Over Voltage

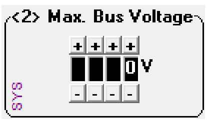
The message “Over Voltage” appears, if the actual bus voltage exceeds the allowed maximum, see Fig. 54.

Figure 54: Failure “Over Voltage”

This may also be caused by a wrong setting of parameter “Max. Bus Voltage” in tab. “DATA AQUISITION”:



Standard Value = 80 V



0 V Setting will cause an Error Message

7.5.8 Under Voltage

This error indicates that the DC-link voltage is below the limit.

7.5.9 Over Current

This message indicates, that the motor current is above the limit.

7.5.10 Over Temperature Motor

This messages indicates, that the motor temperature is above the limit.

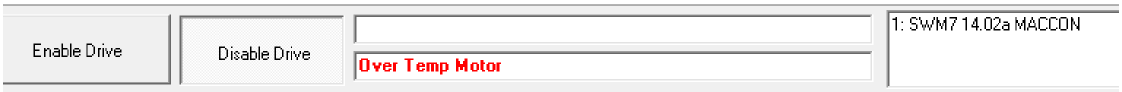
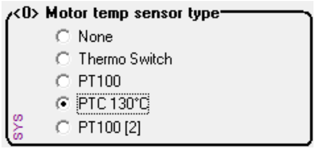


Figure 55: Failure "Over Temperature Motor"

Example:
Choice of motor temperature sensors: Currently used, the PTC130°C.



7.5.11 Resolver Error

Resolver does not work properly, please check cabling and resolver and settings.

7.5.12 I*t Warning

The I*t limit allows peak currents for a defined short time within the thermal constants of the drive.

This warning indicates, the current has exceeded the max. current but not the I*t limit defined in tab "SPPED / CURRENT CONTROL". The timer for "I*t Limited Current Time" will be started.

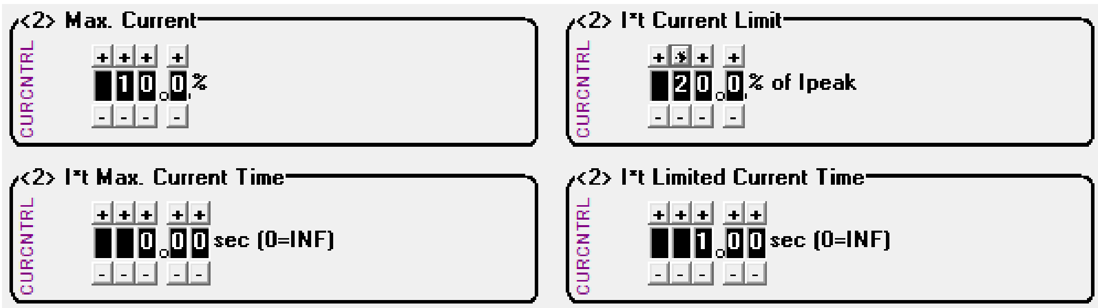


Figure 56: I*t Warning

7.5.13 I*t Error

The I*t error occurs when the current is in the I*t area above the "Max. Current" and below the " I*t Current Limit" for longer than the defined "I*t Limited Current Time".

This will shut down the SWM7 automatically.

7.5.14 Other Error Messages

In the case of specific, not described errors messages displayed in the status line, please contact MACCON technical support.

7.5.15 SWM Failure Codes

The SWM6 and SWM7 have internal failure codes. The SWM6 has 3 Bit and the SWM has 4 Bit failure codes. There are small differences in the failure interpretation of the F0...F2 bit code between SWM6 and SWM7, see table below. Bit F3 offers additional failure modes only for the SWM7. The setup tool is decoding the failures and displays them as clear text message.

The SWM7/48-100 has a 2-digit green LED-Display to indicate operating modes and failure codes. The description of the LED-codes can also be found in the table below. Code 88 means that the drive has an internal error and needs to be sent back to MACCON for further analysis and repair. Please contact MACCON for an offer for the repair and for the procedure when you decide to send the drive back to MACCON.

X2-9	X2-10	X2-11						
DIGOUT1	DIGOUT2	DIGOUT3						
F0	**F1**	**F2**	**F3**	**Failure Nr.**	**Error Coding over CAN**	**SWM7-48-100 LED-Display**	**Failure SWM6**	**Failure SWM7**
0	0	0	0	F0	0	0	No failure, drive disabled	
0	0	0	0	F0	0	1	No failure, drive enabled	
1	0	0	0	F1	1	alternating F - 01	overvoltage	
0	1	0	0	F2	2	alternating F - 02	undervoltage	
1	1	0	0	F3	3	alternating F - 03	overcurrent	
0	0	1	0	F4	4	alternating F - 04	over temperature heatsink or motor	over temperature electronic
1	0	1	0	F5	5	alternating F - 05	not specific failure e.g. resolver	over temperature motor
0	1	1	0	F6	6	alternating F - 06	I^2t error	
1	1	1	0	F7	7	alternating F - 07	I^2t warning	
0	0	0	1	F8	8	alternating F - 08	-	Phase Finding Error
1	0	0	1	F9	9	alternating F - 09	-	resolver error
0	1	0	1	F10	10	alternating F - 10	-	Encoder Error
1	1	0	1	F11	11	alternating F - 11	-	CAN Message Error
0	0	1	1	F12	12	alternating F - 12	-	CAN Timeout Error
1	0	1	1	F13	13	alternating F - 13	-	(Customer-specific Error 1)
0	1	1	1	F14	14	alternating F - 14	-	(Customer-specific Error 2)
1	1	1	1	F15	15	alternating F - 15	-	Reserved
					15	alternating F - 16	-	Reserved
					15	alternating F - 17	-	Reserved
				F91...F99	15	alternating F - F91...F99	-	Processor Error

Tab. 7.5: Failure Code Table for SWM6 vs. SWM7

Attention: The described logic states in the table mean 0= output inactive, 1= output active.

Referred to a digital open collector output with external pull-up resistor, the logic states from the table need to be inverted to see the real circuit logic states at the digital output.

F91 in combination with the failure messages (DSP Timeout, and DSP not running: try reset) in the SWM7 PC user interface could be an indication of a wrong DSP firmware.

Opening the device means loss of warranty!

Please be prepared to know SWM7 Type, serial number, firmware revision, ideally DSP firmware revision before contacting MACCON.

7.6 Firmware Update

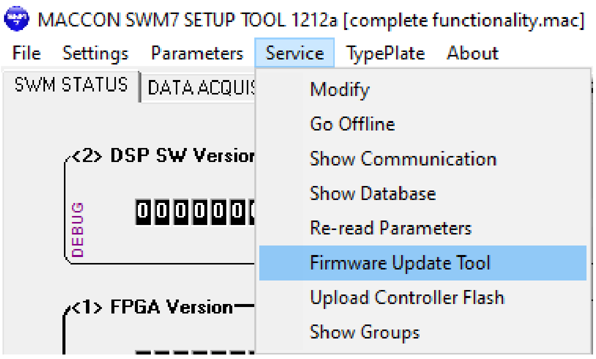
The SWM7.exe provides a tool for firmware updates. The internal SWM control card is a highly complex digital controller consisting microcontroller, DSP and FPGA. The update can be done either for the microcontroller, for the DSP or for the FPGA.

NEVER do firmware updates without written approval of MACCON for a specific device. The SWM7 drives work best with delivered firmware, and do not need any firmware updates. Updating firmware without written approval of MACCON results in loss of warranty and any kind of support.

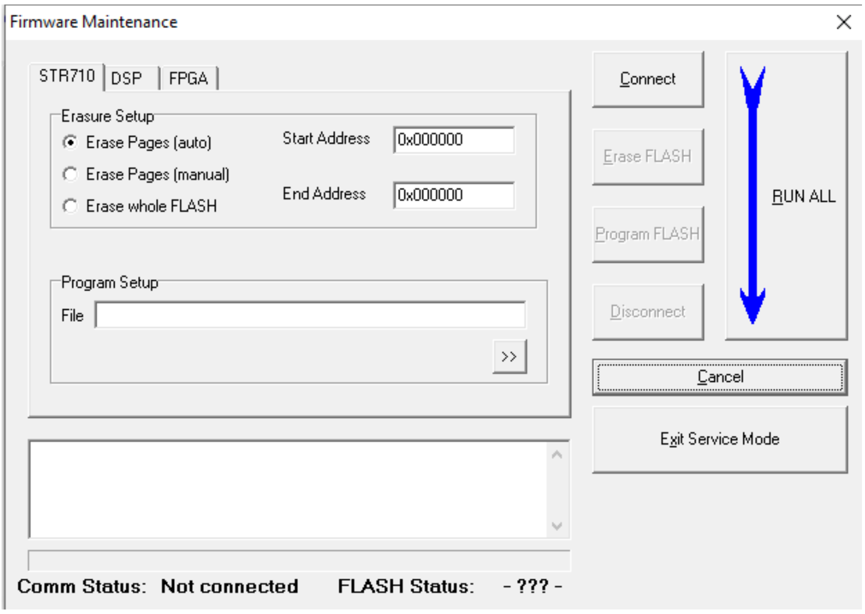
Please create a backup of your .macp and for your .mac file on a PC. These files inside the SWM7 could be destroyed during a firmware update process.

Erase the memory prior to a new programming.

Open the Firmware Update Tool in the Service Tab of the SWM7.exe Software:



The main Window of the Firmware Update Tool includes tabs for the microcontroller (STR710), for the DSP and for the FPGA:



The main window is self-explaining for erasing the memory, choosing a programming file (Program Setup) and for programming it into the controller. File Rev. 1904 means April 2019.

8 System Parameter Setup

This User Manual describes the control tabs and functions of the SWM7.exe and typical application examples for the SWM7 servo controller family.

Pay attention to the Safety Instructions, to avoid any risk for dangerous voltages, temperatures and hardware damage.

Software and User Manual for the SWM7 is available on CD-ROM. The actual version of the manual can be downloaded from the MACCON website:

https://www.maccon.de/antriebselektronik/maccon/swm7.html

Features:

Using the SWM7 software allows:

- Setup the hardware configuration (motor, sensor, interfaces)
- Monitoring the drive and motor parameters (e.g. temperature, velocity, current)
- Speed Control, see measuring window “Speed Control: Actual Speed” in “SPEED / CURRENT CONTROL” tab
- Current Control, see in control windows for “Current Control P gain”, “Current Control I gain”, “Current Control D gain” in “SPEED / CURRENT CONTROL” tab
- Phase Finding
  To detect initial commutation angle if no absolute position sensors (like hall sensors, resolvers, absolute encoders) are present.
- Field Weakening mode
  To set up field weakening to reach higher motor speeds with a given supply voltage.
- Setup and configuration of external interfaces (e.g. analog outputs, external enable inputs)
- Optimization, Troubleshooting and data acquisition for MACCON technical support.

Only professional personnel who have the relevant expertise are permitted to carry out online parameter settings for a drive that is running.

In case of errors, hardware problems or other service related questions contact MACCON technical support.

In this manual, only the default parameters (~ 270) of over 500 possible control windows are described.

Also, the arrangement of the SWM7 tabs and control windows depends on the project and may differ from this description.

Some parameters can only be set/adjusted while the drive is disabled (like sensor configurations), others can only be adjusted while the drive is enabled.

8.1 SWM7 Control Tabs

This chapter describes all control windows of the SWM7.exe:

All control tabs are listed in the sequence of the standard configuration of the “complete functionality.mac” file for the SWM7.exe. Depending on the SWM7 configuration and the supplied firmware version, not all control windows are might be part of the description or some windows might be arranged differently.

The arrangement of the tabs can be customized.

8.1.1 Frequently Asked Questions:

Question 1: Where do percentage current values refer to?
Answer: To nominal current of the device: SWM7-48-100 has 200A nominal (peak-)current.

Question 2: Why does a setting jump back to old value, setting of new value is impossible?
Answer: SWM needs to be disabled. Set-Value option must not be CAN.

8.1.2 SWM STATUS

On this tab, firmware versions and internal status flags are displayed. This information might be required for MACCON technical support.

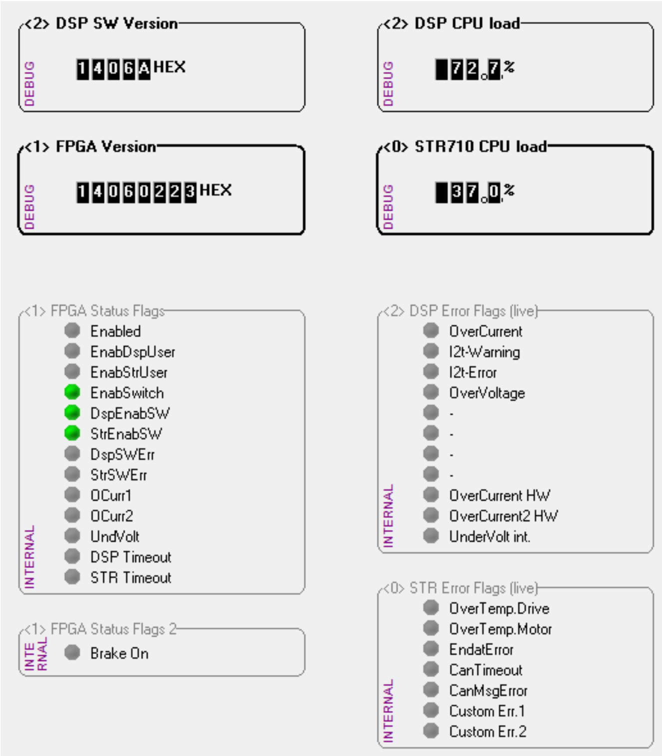
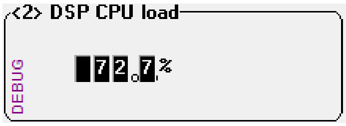
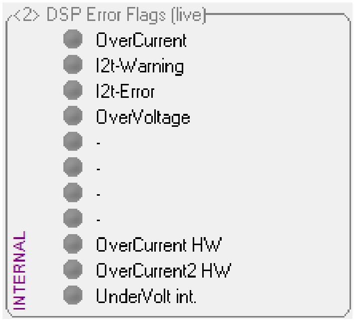
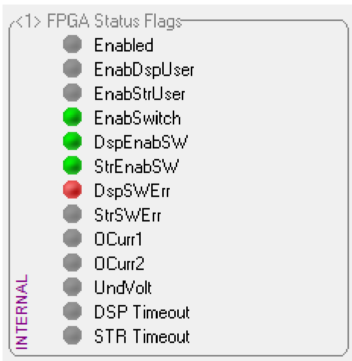


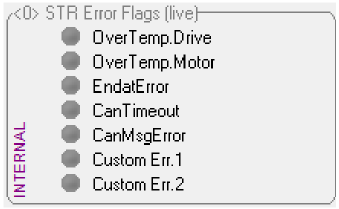
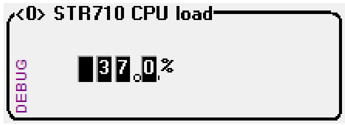
Figure 57: STATUS Tab

Control Windows in the "SWM STATUS" Tab

SWM STATUS

Control window (in alphabetic order)	**Explanation** *Input values*
	DSP CPU load Display percentage DSP processing load. *For MACCON tech assistance only.*
	DSP Error Flags (live) Displays the DSP error flags.
	DSP SW Version Display of the SW version of DSP. *For MACCON tech assistance only.*
	FPGA Status Flags 2 Displays state of brake. *For MACCON tech assistance only.*
	FPGA Status Flags Displays internal enable and error flags. *For MACCON tech assistance only.*
	FPGA Version Display of FPGA code version. *For MACCON tech assistance only.*

SWM STATUS

Control window (in alphabetic order)	**Explanation** *Input values*
	STR Error Flags (live) Displays the µC flags.
	STR710 CPU load Display percentage of µC load. *For MACCON tech assistance only.*

Tab. 8.1: Control Windows in the "SWM STATUS" Tab

8.1.3 DATA ACQUISITION

The “DATA ACQUISITION” tab is used for:

- defining DC_link parameter limits
- configuring the analog hardware outputs for monitoring and debug
- monitoring internal failures and FPGA status

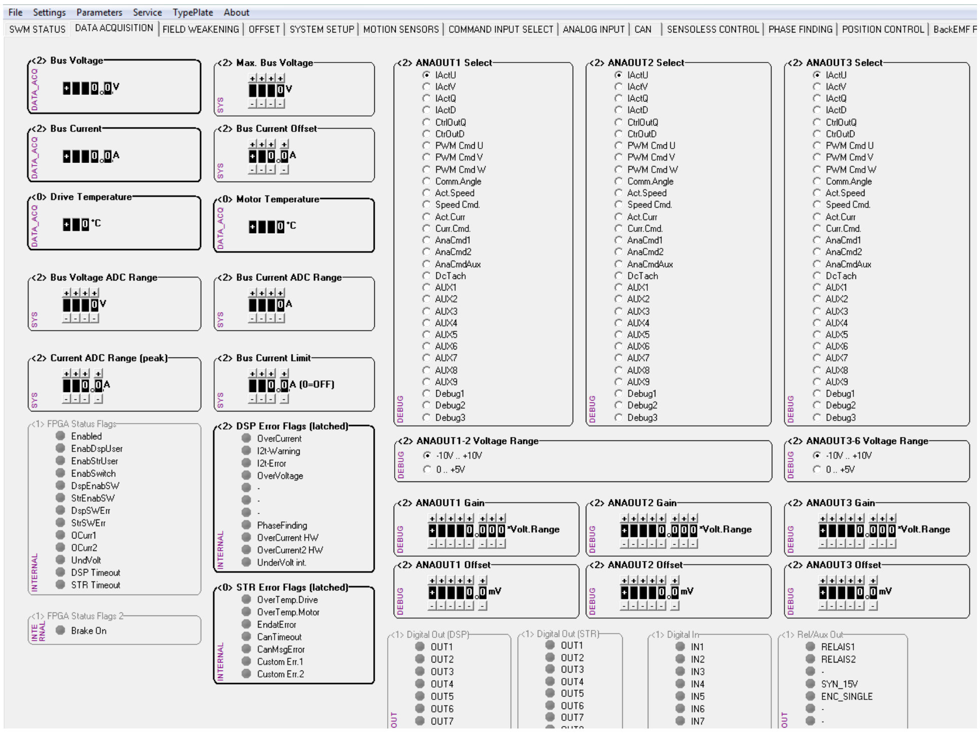


Figure 58: DATA ACQUISITION Tab

Internal Debug-Variables:

<Digital Out (DSP)>:

- OUT1..OUT8: Digital-outputs of SWMs, controlled from internal DSP

<Digital Out (STR)>:

- OUT1..OUT8: Digital-outputs of SWMs, controlled from internal microcontroller
- mux1..mux8: If active, the microcontroller controls the state of the outputs. If not, the DSP takes control of the outputs.

<Digital In>:

- IN1..IN8: State of the digital inputs of the SWM
- HS1..HS3: State of the fast digital inputs of the SWM (HS=high speed)

<Rel/Aux Out>:

Internal hardware control signals

- RELAIS1, RELAIS2: State of solid-state relay 1 and 2
- SYN_15V: Switching Hall input pull-ups to +15V (standard +5V)
- ENC_SINGLE: Switching TTL-encoder-inputs to single-ended (standard differential)
- PT100_ON: Supply of PT100-temperature sensor

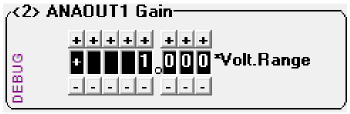
<DIGOUT test val>:

For Hardware Test

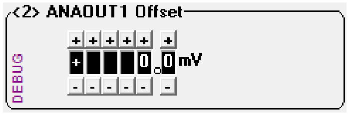
- If not zero, outputs will be set (Bit0 = Out1 etc.)

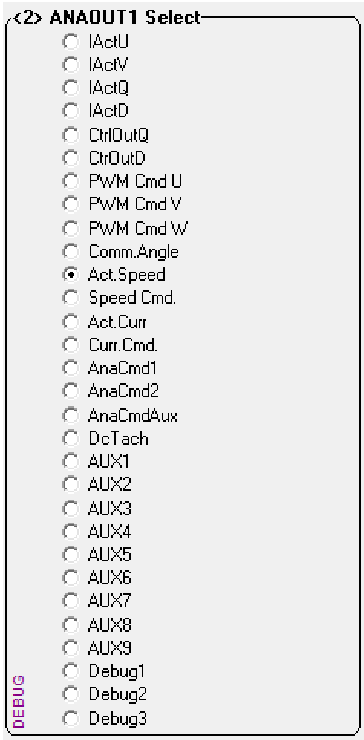
Control Windows in the "DATA ACQUISITION" Tab

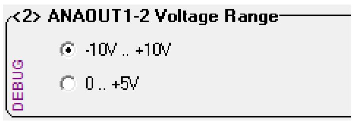
DATA ACQUISITION

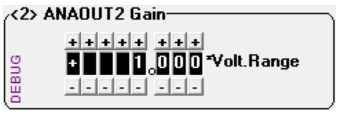
<table>
<tr><th>Control window
(in alphabetic order)</th><th>Explanation
Input values</th></tr>
<tr><td></td><td>ANAOUT1 Gain

Gain for analog output #1

Gain 1.0 outputs
– -10 V...+10 V or
– 0...+5 V *
for signal values of -1.0 ... +1.0
(*) Depends on parameter “ANAOUT1 Voltage Range”.</td></tr>
<tr><td></td><td>ANAOUT1 Offset

Offset for analog output #1</td></tr>
<tr><td></td><td>ANAOUT1 Select

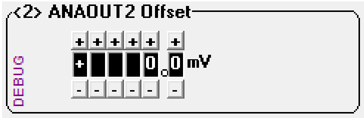
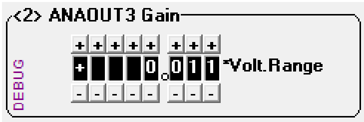
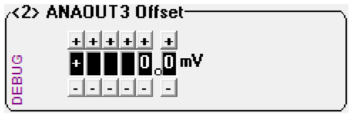
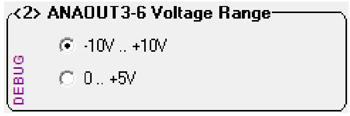
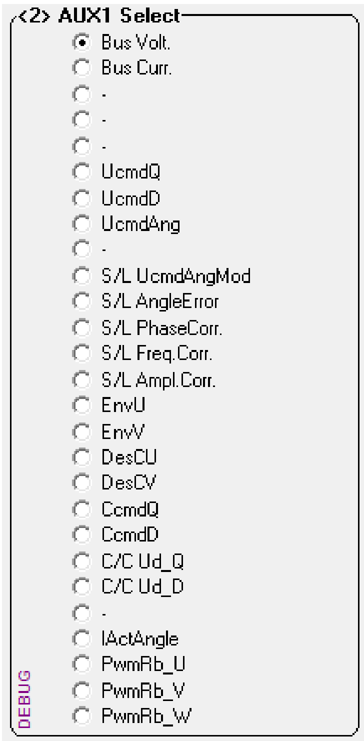
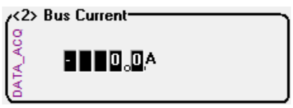
Selection of internal signal assigned to analog output #1.</td></tr>
<tr><td></td><td>ANAOUT1-2 Voltage Range

Voltage range selection for analog output #1 and #2.</td></tr>
<tr><td></td><td>ANAOUT2 Gain

Gain adjust for analog output #2

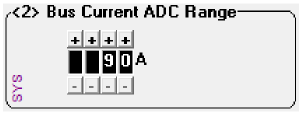
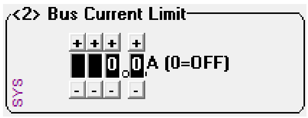
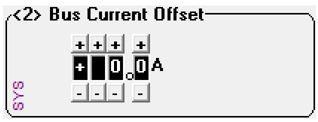
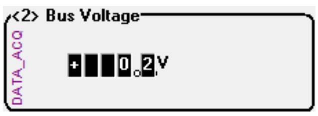
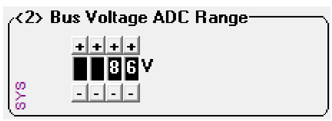
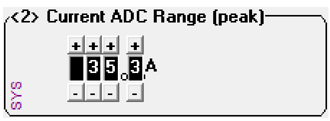
see “ANAOUT1 Gain”</td></tr>
</table>

DATA ACQUISITION

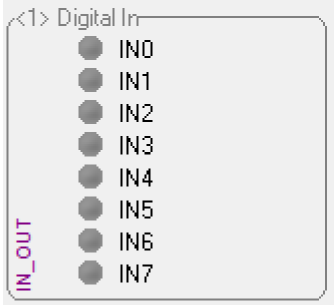
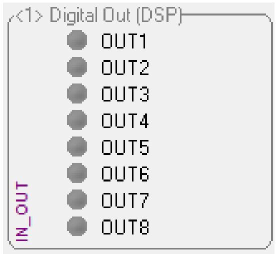
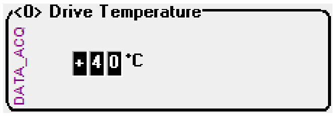
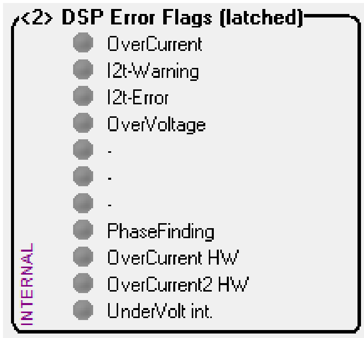
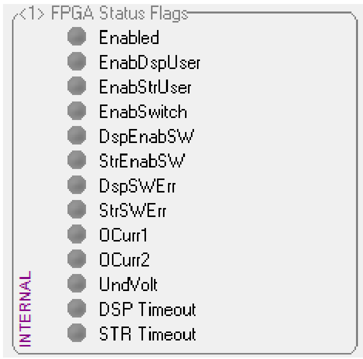
Control window (in alphabetic order)	**Explanation** *Input values*
	ANAOUT2 Offset Offset adjust of analog output #2
	ANAOUT3 Gain Gain adjust of analog output #3 *see "ANAOUT1 Gain"*
	ANAOUT3 Offset Offset adjust of analog output #3
	ANAOUT3-6 Voltage Range Voltage range selection for analog output #3 - #6.
	AUX1 Select Selection of internal signal assigned to analog output AUX1. *For MACCON tech assistance only.*
	Bus Current Actual DC bus current. If incorrect values occurs, ADC range setting might be incorrect. Not all SWM drives have bus current sensors

MACCON MOTION UNDER CONTROL

DATA ACQUISITION

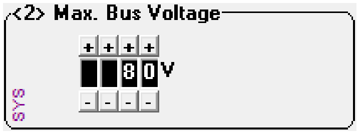
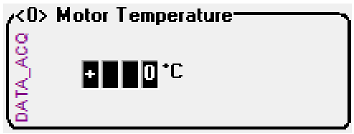
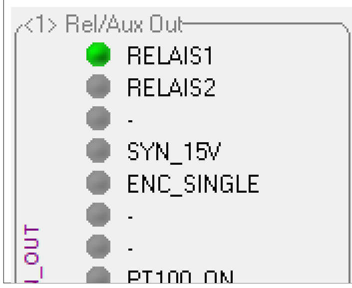
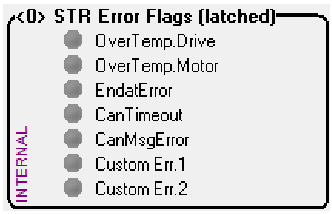
Control window (in alphabetic order)	**Explanation** *Input values*
	Bus Current ADC Range
	Sets the scaling for ADC converter. This value is constant for each device and must **not be changed** by the user.
	Change only when asked by MACCON technical support.
	Bus Current Limit
	Limitation for DC bus current. At zero the limit is disabled.
	Bus Current Offset
	Sets the calibrating offset for ADC converter. Adjust to get zero reading while drive is disabled.
	Change only when asked by MACCON technical support.
	Bus Voltage
	Actual DC bus voltage. If incorrect values occur, ADC range setting might be incorrect.
	Not all SWM drives have bus voltage sensors
	Bus Voltage ADC Range
	Sets the scaling for AD converter. This value is constant for each device and must not be changed by the user.
	Change only when asked by MACCON technical support.
 *This value is constant for each device and must not be changed by the user.*	Current ADC Range (peak)
	Motor current ADC range, sets the scaling for AD converter.
	Change only when asked by MACCON technical support.

DATA ACQUISITION

Control window (in alphabetic order)	**Explanation** *Input values*
	Digital In Status display of digital inputs. *For customer specific applications only.*
	Digital Out (DSP) Status display of digital outputs as commanded by DSP. *For MACCON tech assistance only.*
	Drive Temperature Actual drive temperature on °C. [°F]= 1.8 x [°C] + 32
	DSP Error Flags (latched) Displays DSP error flags (latched). *For MACCON tech assistance only.*
	FPGA Status Flags Displays internal enable and error flags. *For MACCON tech assistance only.*

MOTION UNDER CONTROL

DATA ACQUISITION

Control window (in alphabetic order)	**Explanation** *Input values*
	FPGA Status Flags 2 Displays state of brake.
	Max. Bus Voltage DC bus voltage limit for generating over-voltage error. *Standard value:* *80 Volt for 48 V units*
	Motor Temperature Actual motor temperature in °C. [°F]= 1.8 x [°C] + 32
	Rel/Aux Out Internal control flags.
	STR Error Flags (latched) Displays µC error flags.

Tab. 8.2: Control Windows in the "DATA ACQUISITION" Tab

8.1.4 FIELD WEAKENING

Field weakening can be used to drive a motor at a higher speed than nominal for a given DC supply voltage with reduced torque.

The field weakening effect is achieved by influencing the ID and IQ current vectors. The current control mode of the SWM needs to be configured as “Field Orientated”, of course.

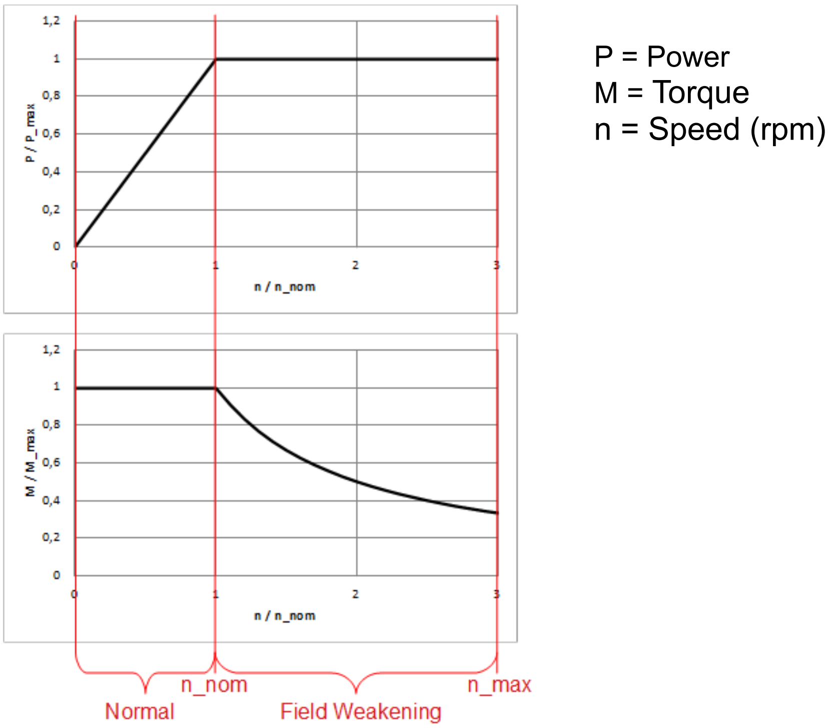


Figure 59: Field Weakening Diagrams: Power and Torque Dependency from Speed

The normal operation area of a motor is accelerating the motor to nominal speed (n_nom) and the power (P) is rising linear with the speed while the torque (M) is constant at maximum. Field weakening causes further increase of the motor speed at constant maximum power while the torque is decreasing with 1/n. Speed limit is the maximum speed specification of the motor datasheet (n_max).

Applying these operating areas to a voltage- and to an I_D / I_Q current pointer diagram:

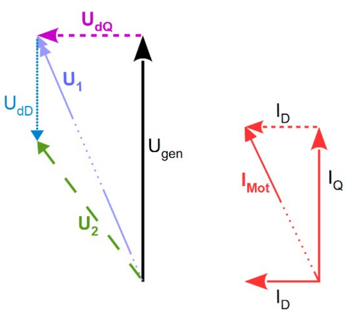


Figure 60: Field Weakening: Rotor Vector Diagram for Voltage and Current

Setting only an effective current vector I_Q, the reaction is an output voltage of U1. If this voltage increases the bus voltage, no further current can be supplied and the motor speed reaches its limit.

Adding a reactive current I_D, the inductive loss of voltage U_{dD} leads to the output voltage U2, which is lower. With this effect the motor speed can be further increased.

The SWM7 provides several field-weakening modes, depending on the firmware version:

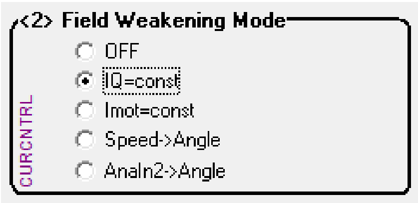


Figure 61: Settings Window for Field Weakening Mode Selection

I_Q = const. I_Q is defined by the current setpoint, I_D is zero at the beginning.

When the bus voltage (back EMF limit) is reached additional reactive current I_D is applied; the absolute value of the effective current remains unchanged.

This results in nearly constant torque, the motor current gets higher than commanded.

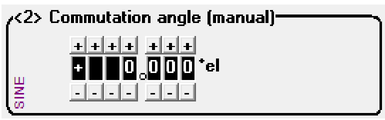
I_{mot} = const. I_Q is defined by the current setpoint, I_D is zero at the beginning. When the bus voltage (back EMF limit) is reached additional reactive current I_D is applied; the absolute value of the effective current is reduced.

Hereby, the torque is reduced, the motor current stays at the commanded value.

Speed->Angle Speed dependent angle adjust can be implemented via the parameters: Static Phase Adv, Max Phase Adv, Phase Adv.: Start Speed and Phase Adv.: Max Speed, see Figure 62 and 63.

AnaIn->Angle Analog input number 2 can be used to manipulate the Angle dynamically: +/-10V equals +/-90°.

In this operation mode, the value of “Commutation angle (manual)” in the “PHASE FINDING” tab is added to the value from analog input 2.



Digital alternative to the analog angle correction might be separate programming of d- and q- currents via CAN.

Manual control of field weakening operation can be achieved by the following procedure:

- Increase Q current until maximum speed is reached.
- Start increasing D current and watch increasing speed.

Generally, reducing I_Q component causes proportional torque reduction and anti-proportional speed increase.

Normal application of field weakening is to set Id and Iq via CAN in current control mode. This is often used in motor test applications.

Second proven application is the field weakening mode “AnaIN2→Angle”.

Caution: The “Speed→Angle” mode in speed control mode might be critical because the EMF constant is estimated from the motor data which might cause local torque weaknesses over the speed range. This mode has not been used very often yet, so the algorithm might have still some bugs. There is no warranty of functionality for this mode!

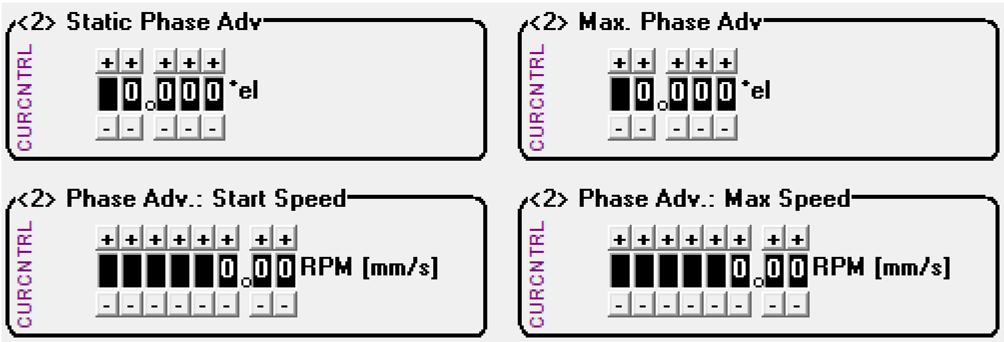


Figure 62: Field Weakening: Parameters for Speed Dependent Phase Angle Adjust

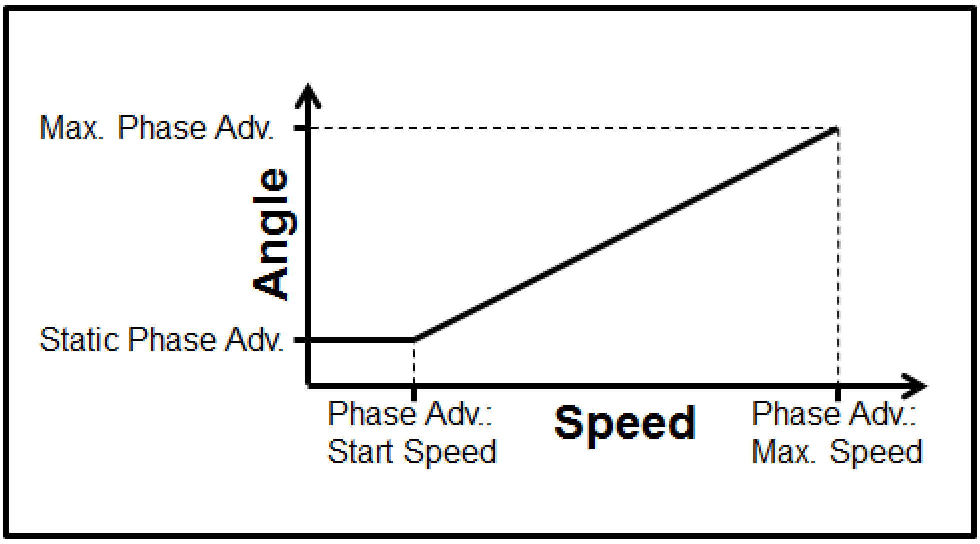


Figure 63: Field Weakening: Speed Dependent Phase Angle Adjust

A dynamic angle adjust via analog inputs is also be possible by setting Id and Iq:

Configure analog input for Id signal and activate in the SWM7 setup tool in the “ANALOG INPUT” Tab the Parameter “Use Ana2 as Id”, set it to YES.

The Phase Angle Adjust at zero speed can be used to utilize reluctance effects.

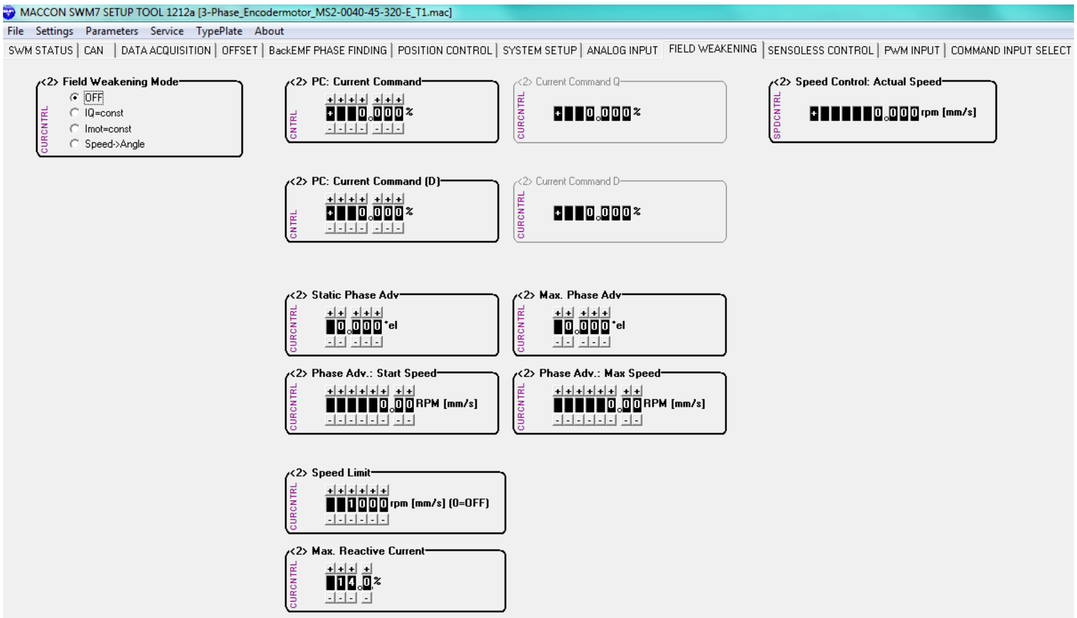
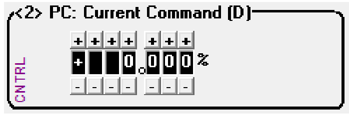
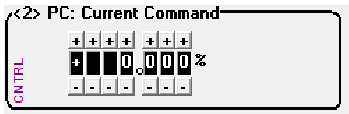
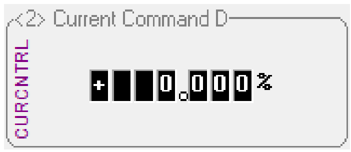
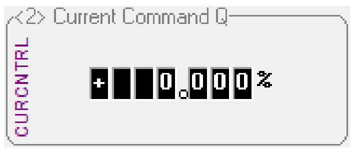
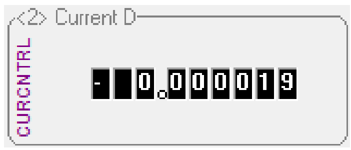
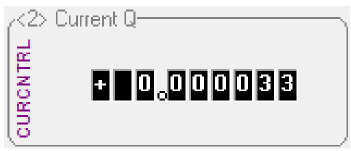
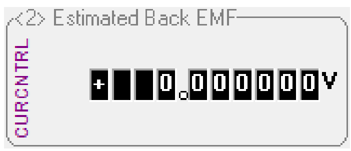


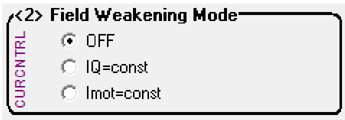
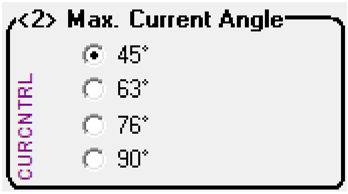
Figure 64: FIELD WEAKENING Tab

Control Windows in the "FIELD WEAKENING" Tab

FIELD WEAKENING

Control window (in alphabetic order)	**Explanation** *Input values*
	Current Command D
	Command Value for D Current
	Current Command Q
	Command Value for Q Current
	Current Command D
	Display for actual current loop command (D vector)
	D vector resulting from speed controller.
	Current Command Q
	Display for actual current loop command (Q vector)
	Q vector resulting from speed controller.
	Current D
	Display for actual motor current (D vector)
	D vector of measured motor current
	Current Q
	Display for actual motor current (Q vector)
	Q vector of measured motor current
	Estimated Back EMF
	Back EMF is estimated from operation point and motor data.
	RMS value of single phase equivalent circuit

FIELD WEAKENING

Control window (in alphabetic order)	**Explanation** *Input values*
	Field Weakening Mode
	Field weakening mode selection.
	IQ=const: IQ=commanded current, ID is set by algorithm *Imot=const: current magnitude = commanded current;* *ratio between IQ and ID set by algorithm*
	Max. Current Angle
	Choice of maximum current angle.
	Only relevant for auto field weakening mode.
	Max. Reactive Current
	Limitation of Reactive Current vector based on the "‘Current ADC range"’ of the motor.
	Current limitation setting *(D vector)*

Tab. 8.3: Control Windows in the "FIELD WEAKENING" Tab

If the supply is switched off when the motor works in the field weakening area (emergency stop or defect), due to the high speed of the motor, the back emf can induce an extreme high voltage at the motor terminals of permanent excited motors. Please also consider rest magnetization of other types of motors.

8.1.5 OFFSET

The “OFFSET” tab allows manual offset calibration of the analogue inputs, the phase currents and the DC tachometer input.

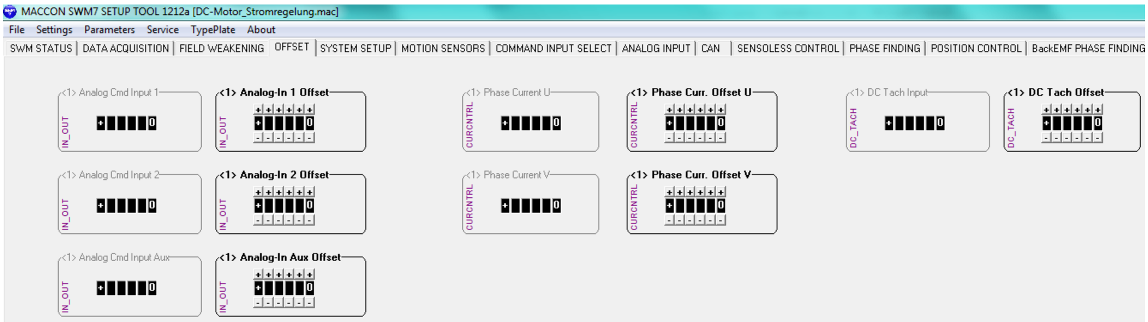
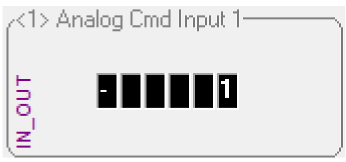
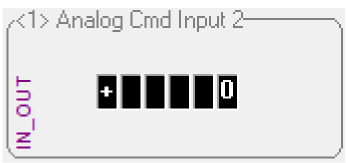
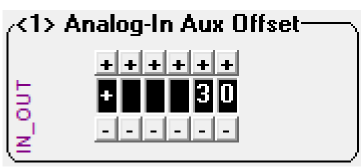


Figure 65: OFFSET Tab

Pay attention to **Phase Curr. Offset** U and V: These Parameters only can changed at enabled drive. Changes should be done only in small steps to avoid uncontrolled movement of the drive. After disabling the drive, the automatic offset control at disabled drive will reset the manual offset settings.

Control Windows in the “OFFSET” Tab

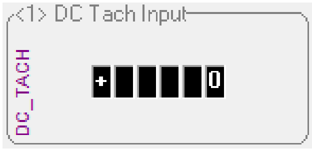
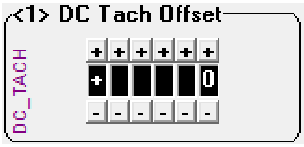
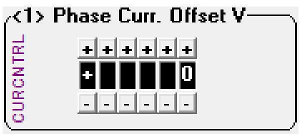
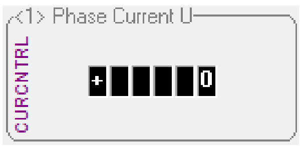
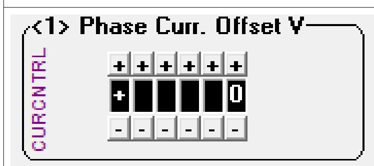
OFFSET

Control window (in alphabetic order)	**Explanation** *Input values*
	Analog Cmd Input 1
	Actual value of analog input #1
	Standard: 0 *Range -32768 to +32767*
	Analog Cmd Input 2
	Actual value of analog input #2
	Standard: 0 *Range -32768 to +32767*
	Analog Cmd Input Aux
	Actual value of analog input AUX
	Standard: 0 *Range -32768 to +32767*
	Analog-In Aux Offset
	Offset adjust of analog input AUX
	Standard: 0

OFFSET

See warning above!

See warning above!

Control window (in alphabetic order)	**Explanation** *Input values*
	Analog-In 1 Offset Offset adjust of analog input #1 *Standard: 0*
	Analog-In 2 Offset Offset adjust of analog input #2 *Standard: 0*
	DC Tach Input Actual value of DC tachometer input *Range -32768 to +32767*
	DC Tach Offset Offset adjust of DC tachometer input *Adjust to get a zero reading on non-rotating motor shaft*
	Phase Curr. Offset U Offset adjust current sensor motor phase U *Set by auto compensation algorithm while drive is disabled*
	Phase Curr. Offset V Offset adjust current sensor motor phase V *Set by auto compensation algorithm while drive is disabled*
	Phase Current U Actual value of current sensor of phase U *Range -32768 to +32767*
	Phase Current V Actual value of current sensor phase V *Range -32768 to +32767*

Tab. 8.4: Control Windows in the OFFSET Tab

8.1.6 SYSTEM SETUP

The “SYSTEM SETUP” tab is very important because it defines the properties of the motor and the switching frequency of the SWM.

Also temperature limits can be defined and temperatures can be measured.

Before setup check the connected hardware (motor data sheet, sensor type).

Recommended examples for settings/checks are:

- Motor Winding
- Motor Type
- Motor temperature sensor type
- Motor Inductance
- Back EMF Const
- Pole Pairs
- Pole Pitch
- ...

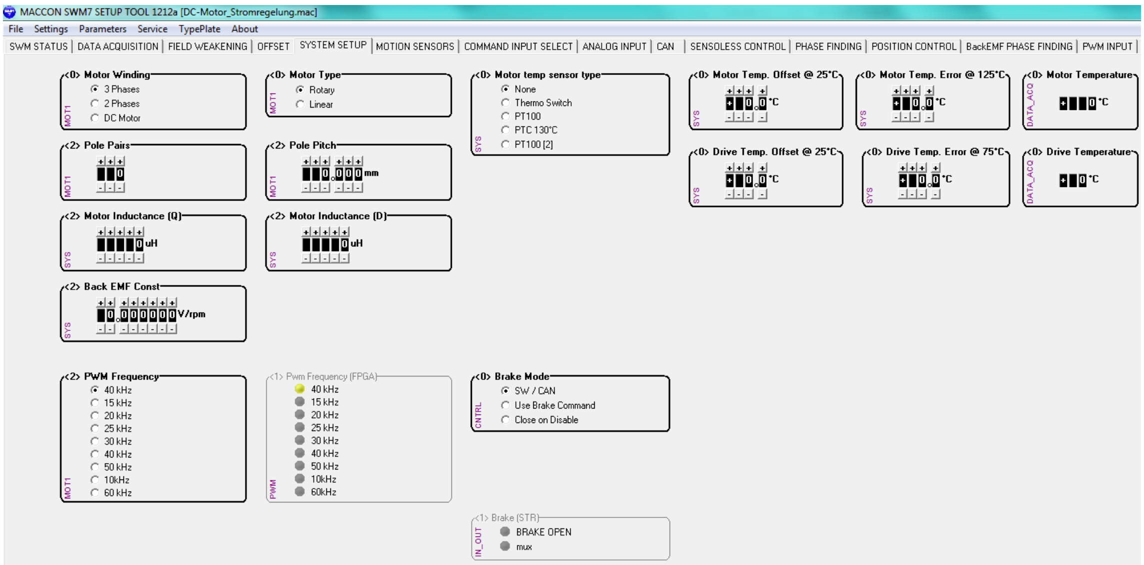
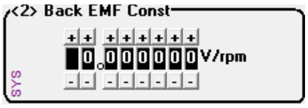
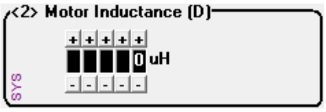
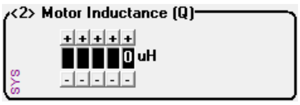
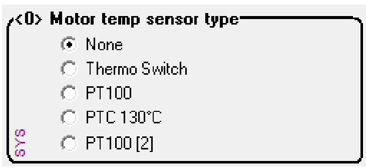
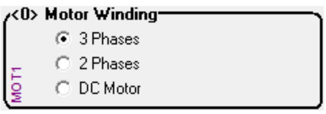


Figure 66: SYSTEM SETUP Tab

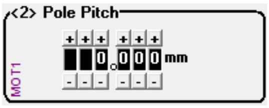
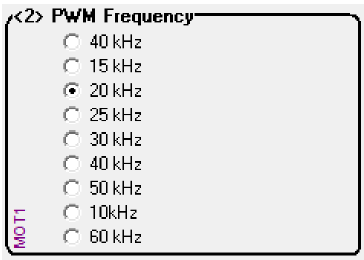
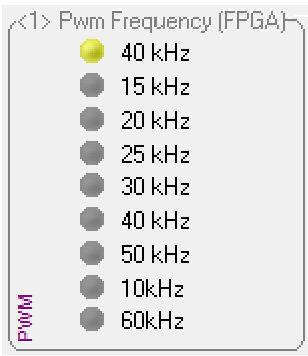
Control Windows in the "SYSTEM SETUP" Tab

SYSTEM SETUP

Control window (in alphabetic order)	**Explanation** *Input values*
	Back EMF Const
	EMF constant of single phase circuit.
	The EMF value measured between two motor phases (RMS) has to be divided by $\sqrt{3}$ *Enter the value according to your motor data sheet.*
	Motor Inductance (D)
	D component of motor inductance of single phase equivalent circuit. Enter the value according to your motor data sheet. The inductance measured between two motor phases has to be divided by 2.
	This parameter is split into Motor Inductance "Q" and "D" to improve field weakening capabilities.
	Motor Inductance (Q)
	D component of motor inductance of single phase equivalent circuit. Enter the value according to your motor data sheet. The inductance measured between two motor phases has to be divided by 2.
	see above – Motor Inductance (D)
	Motor temp sensor type
	Selection of motor temperature sensor
	Motor Type
	Selection of motor geometry.
	`Rotary` or `Linear`
	Motor Winding
	Selection of motor type.

SYSTEM SETUP

Please do not exceed 40kHz, this might damage the device!

Control window (in alphabetic order)	**Explanation** *Input values*
	Pole Pairs Selection of number of motor pole-pairs *Only for **rotary** motors.*
	Pole Pitch **Motor Type = Linear** Selection of pole pitch for linear motor *Only for **linear** motors.*
	PWM Frequency Selection of power stage PWM frequency: Maximum is 40kHz, higher only upon request for special applications with low currents → please consult MACCON if required.
	PWM Frequency (FPGA) Displays the PWM frequency of the power stage.

Tab. 8.5: Control Windows in the "SYSTEM SETUP" Tab

MACCON MOTION UNDER CONTROL

8.1.7 MOTION SENSORS

The “MOTION SENSORS” tab is used to define the settings for the chosen feedback sensor.

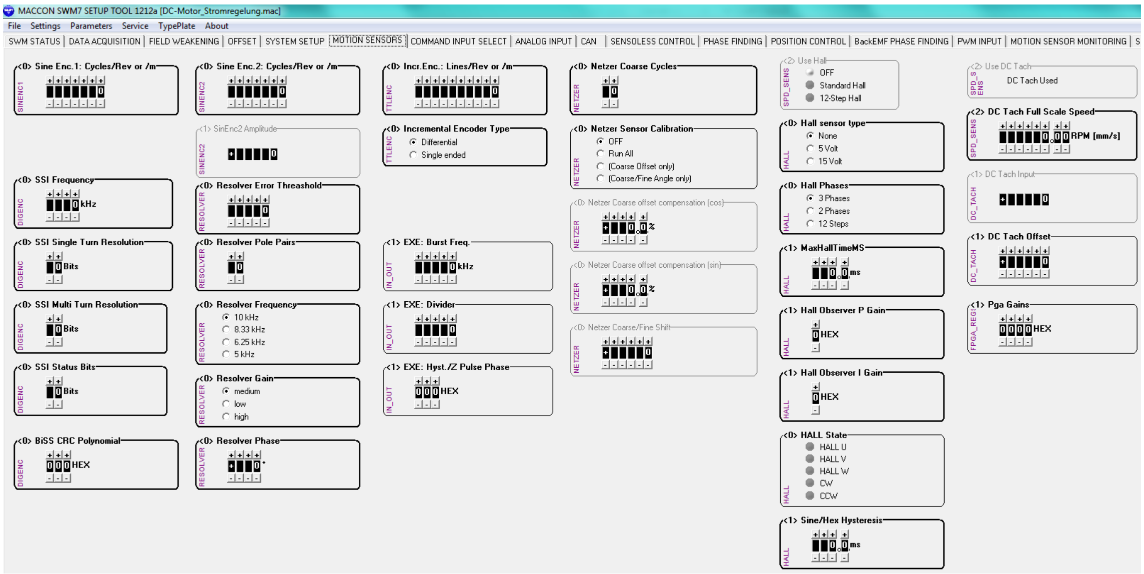
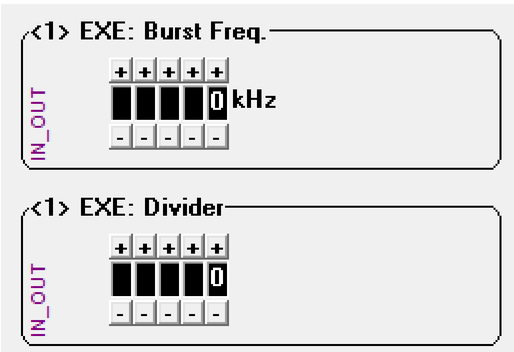


Figure 67: MOTION SENSORS Tab

Encoder



EXE = TTL encoder emulation, indicates actual position of commutation sensor. This can be each position sensor except a Hall sensor.

<EXE: Burst Freq.> :	Maximum frequency of emulated encoder
<EXE: Divider> :	Resolution of original sensor

<EXE: Divider> = 1, will result in the following resolutions:
- For commutation sensor = TTL-encoder: Same as commutation sensor
- For commutation sensor = Resolver: 2^16 slopes (= 2^14 pulses) per resolver polepair
- For commutation sensor = Sine-encoder: 2^16 slopes (= 2^14 pulses) per sine cycle
- For digital sensors (EnDat etc) : 1 slope per increment

<EXE: Divider> > 1 defines the dividing ratio of pulses/slopes

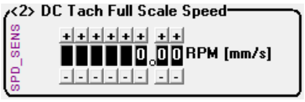
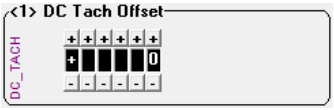
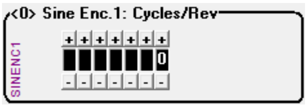
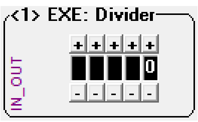
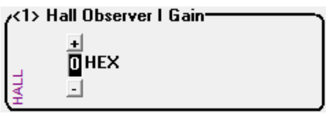
HALL

The SWM has an implemented position estimating algorithm when only hall sensors are available. This works better for higher speed, for lower speed it has some limitations.

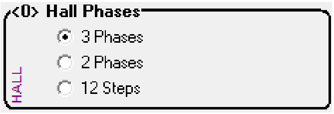
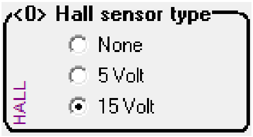
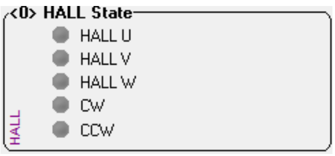
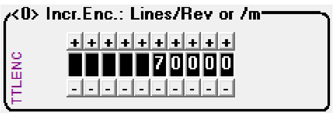
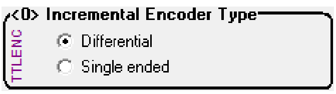
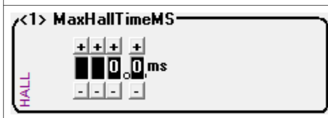
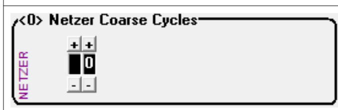
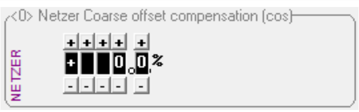
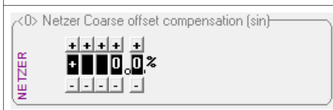
<MaxHallTimeMS>:	Largest Hall period time (= lowest speed), for functional Hall observer to interpolate the position. At low speed, the position is switched hard with each Hall signal slope (hex-commutation). (Large values result in the disadvantage of increasing dead times, so smaller values are recommended).
<Sine/Hex Hysteresis>:	Prevents permanent switching between sine- and hex commutation mode if the speed is close to the mode changing point.
<HallState>:	Monitors the level of the three hall sensor signals and the direction.
<Hall Observer I Gain>:	Observer speed controller integral gain

Control Windows in the "MOTION SENSORS" Tab

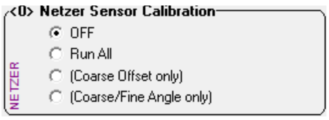
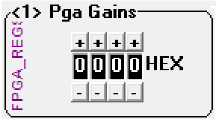
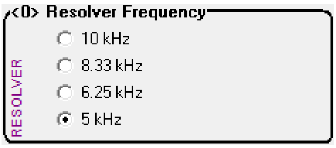
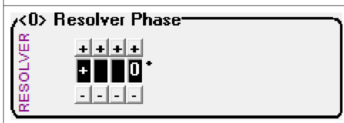
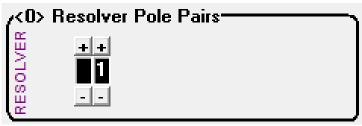
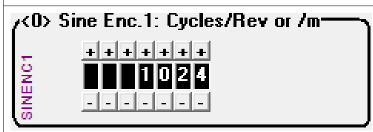
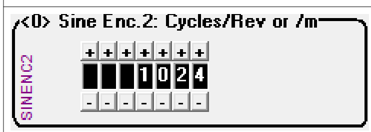
MOTION SENSORS

Control window (in alphabetic order)	**Explanation** *Input values*
	DC Tach Full Scale Speed
	DC tachometer scaling range
	DC Tach Input
	Actual value of DC tachometer input.
	Range -32768 to +32767
	DC Tach Offset
	DC tachometer input offset adjust
	Adjust to get a zero reading on parameter "DC Tach Input" at non-rotating motor shaft
	Sine Enc. 1 Cycles/Rev
	Resolution of Sine Encoder 1 (sine cycles per revolution or sine cycles per meter for linear sensors).
	EXE: Burst Freq.
	Parameter for emulation of an incremental encoder, which may be used to drive an external position controller.
	Maximum pulse frequency for encoder output.
	EXE: Divider
	Scaling factor for encoder output, depends on position sensor resolution.
	The emulated incremental encoder has a resolution of the sensor used for commutation (as shown in the parameter "COMM_SENS: Increments /Rev or /m") divided by this factor.
	Hall Observer I Gain
	Gain of the hall position observer loop.
	Hall Observer P Gain
	P gain of the hall position observer loop.

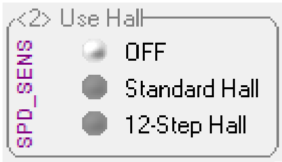
MOTION SENSORS

Control window (in alphabetic order)	**Explanation** *Input values*
	Hall Phases Hall sensor configuration: 3 Phases: Using 3 hall sensors with 120 degree spacing 2 Phases: Using 3 hall sensors with 120 degree spacing 12 Steps: for special use only
	Hall sensor type Supply voltage of connected hall sensor.
	HALL State Signal state and rotating direction of the hall sensors. *Display only*
	Incr. Enc.: Lines/Rev or /m Set up the encoder lines per revolution. *1...9999999999*
	Incremental Encoder Type Electrical interface of connected encoder
	MaxHallTimeMS Hall pulse duration for switching between hex step and sine commutation
	Netzer Coarse Cycles Coarse track cycles of attached Netzer sensor
	Netzer Coarse offset compensation (cos) Offset voltage of coarse track (cos); Result of auto offset compensation, can be adjusted manually. *Used by MACCON technical support.*
	Netzer Coarse offset compensation (sin) Offset voltage of coarse track (sin); Result of auto offset compensation, can be adjusted manually. *Used by MACCON technical support.*

MOTION SENSORS

Control window (in alphabetic order)	**Explanation** *Input values*
	Netzer Coarse/Fine Shift
	Phase shift between coarse and fine track. Result of auto offset compensation, can be adjusted manually.
	Used by MACCON technical support.
	Netzer Sensor Calibration
	Customization of automatic Netzer calibration
	Used by MACCON technical support.
	Pga Gains
	Gain settings for DC tachometer input and phase voltage measurement
	Used by MACCON technical support.
	Resolver Frequency
	Resolver excitation frequency
	Resolver Gain
	Resolver gain adjust: “Low” Gain1, “Medium” Gain2, “High” Gain4
	Resolver excitation should not be too small for optimum signal to noise ratio but must not reach the saturation limit
	Resolver Phase
	Manual phase adjust between sensor and motor position
	Resolver Pole Pairs
	Pole pairs of resolver
	Sine Enc. 1 Cycles/Rev or /m
	Set up of resolution in full sinusoidal cycles per revolution.
	Sine Enc. 2 Cycles/Rev or /m
	Set up of resolution in full sinusoidal cycles per revolution.

MOTION SENSORS

Control window (in alphabetic order)	**Explanation** *Input values*
	Sine Enc2 Amplitude
	Amplitude of sine encoder 2 or resolver
	Used by MACCON technical support.
	Use DC Tach
	Indicates DC tachometer as selected feedback sensor
	Display only.
	Use Hall
	Indicates Hall as selected feedback sensor
	Display only.

Tab. 8.6: Control Windows in the "MOTION SENSORS" Tab

8.1.8 COMMAND INPUT

This section defines the command source for the SWM drive. The drive can be controlled via this tab on the PC, CAN or analog or PWM hardware inputs.

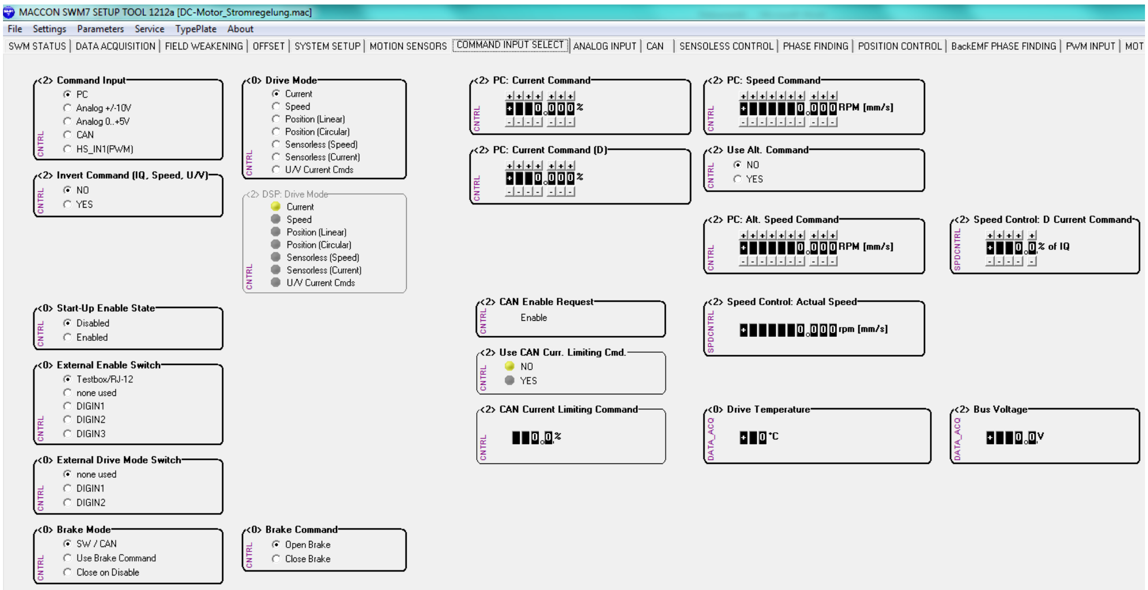
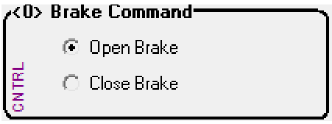
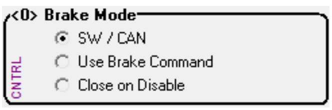
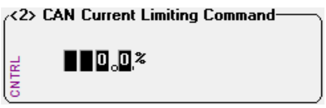


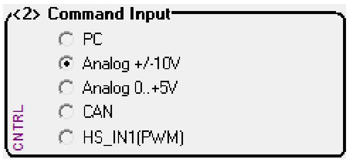
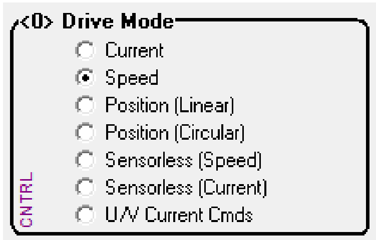
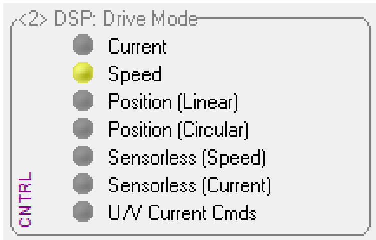
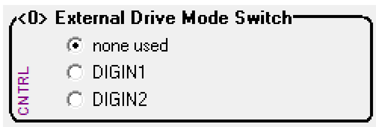
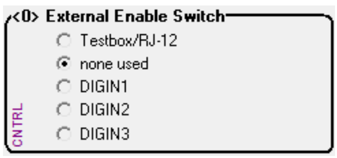
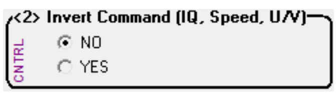
Figure 68: COMMAND INPUT Tab

Control Windows in the "COMMAND INPUT SELECT" Tab

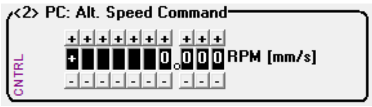
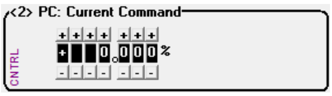
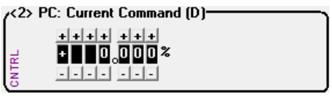
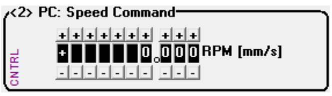
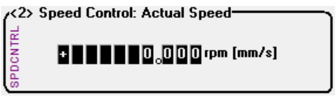
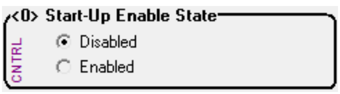
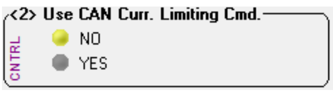
COMMAND INPUT SELECT

Control window (in alphabetic order)	**Explanation** *Input values*
	Brake Command
	Manual brake control for external electromechanical brake
	Brake Mode
	Brake mode definition
	"Close on Disable" : Brake will be activated when drive is disabled
	CAN Current Limiting Command
	Actual CAN value for current limitation in %.
	Usage depends on CAN firmware (customer specific).

COMMAND INPUT SELECT

<table>
<tr><th>Control window
(in alphabetic order)</th><th>Explanation
Input values</th></tr>
<tr><td>
</td><td>CAN Enable Request
Status of CAN Enable request.
Usage depends on CAN firmware</td></tr>
<tr><td>
</td><td>Command Input
Selection of desired command channel for operation.
Use “Analog” when connecting an external function generator.</td></tr>
<tr><td>
</td><td>Drive Mode
Selection of required drive mode.</td></tr>
<tr><td>
</td><td>DSP Drive Mode
Confirmation of the selected drive mode
Used by MACCON technical support.</td></tr>
<tr><td>
</td><td>External Drive Mode Switch
Configuration of external drive mode signal. Independent of the selected input, logic low is always current control and logic high is always speed control. If analog input control is selected, analog input 1 acts either as current command or as speed command, depending on the setting of the drive mode switch.
For standard firmware</td></tr>
<tr><td>
</td><td>External Enable Switch
Configuration of hardware enable signal</td></tr>
<tr><td>
</td><td>Invert Command (IQ, Speed, U/V)
Inverts polarity of command signal
Do not switch at enabled drive!</td></tr>
</table>

COMMAND INPUT SELECT

Control window (in alphabetic order)	**Explanation** *Input values*
 Can be used for fast switching and generating a step behavior.	PC: Alt. Speed Command Second speed setpoint
	PC: Current Command Manual current setpoint (Q vector) *“Command input” is set to “PC”.*
	PC: Current Command (D) Manual current setpoint (D vector) *“Command input” is set to “PC”.*
	PC: Speed Command Manual speed setpoint *“Command input” is set to “PC”.*
	Speed Control: Actual Speed Actual speed value
	Start-Up Enable State This allows the drive to auto-enable on power-up. Enabling the drive at power-up should only be used in completely verified drive systems! Additional hardware signals like hardware enable might be required.
	Use Alt. Command Switches between the two setpoints. Attention at enabled drive and rotating motor!
	Use CAN Curr. Limiting Cmd. Acknowledge-Flag for CAN current limitation. *Used by MACCON technical support.*

Tab. 8.7: Control Windows in the "COMMAND INPUT SELECT" Tab

8.1.9 ANALOG INPUT

The "ANALOG INPUT" tab configures offset, gain and scaling of the analog inputs.

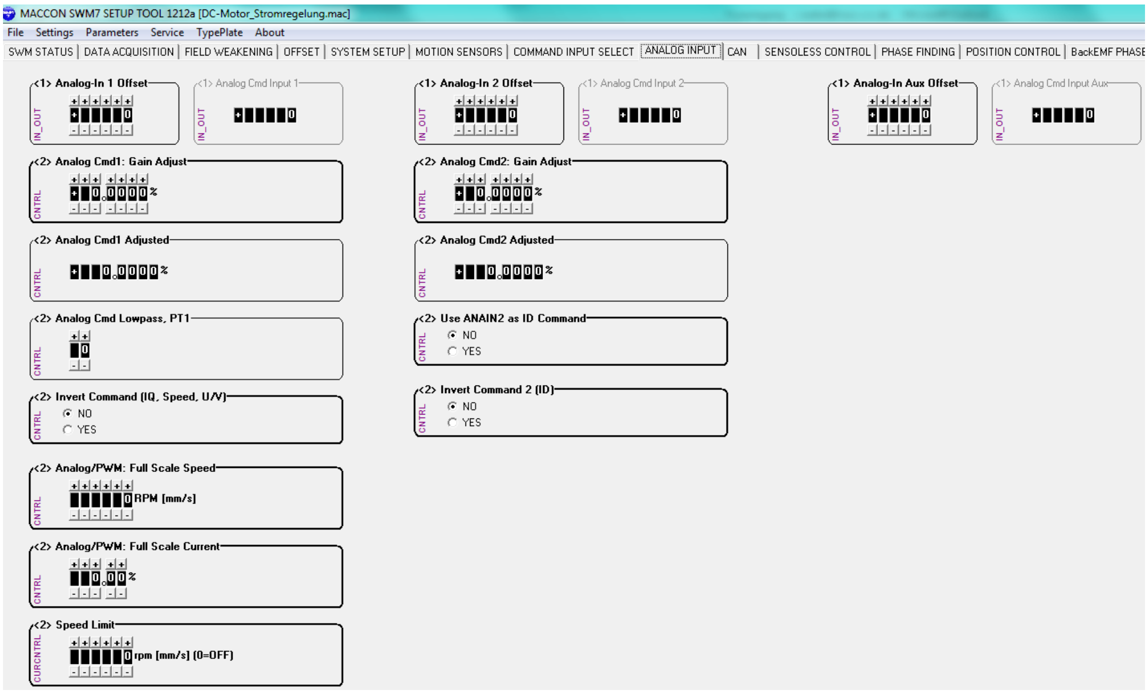
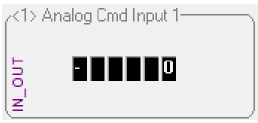
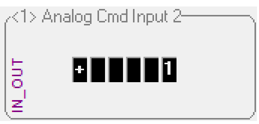
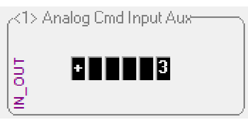
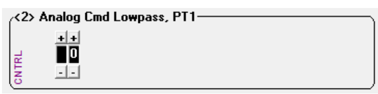


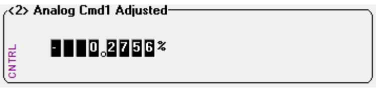
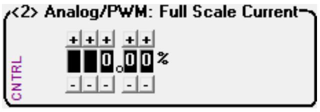
Figure 69: ANALOG INPUT Tab

Control Windows in the "ANALOG INPUT" Tab

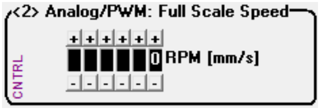
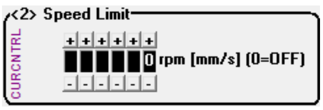
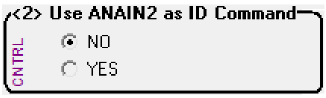
ANALOG INPUT

Control window (in alphabetic order)	**Explanation** *Input values*
	Analog Cmd Input 1
	Analog Input #1 Command Value
	Analog Cmd Input 2
	Analog Input #2 Command Value
	Analog Cmd Input Aux
	Analog Input “AUX” Command
	Analog Cmd Lowpass, PT1
	Lowpass filter setting for analog tachometer input signal
	See Figure Fehler: Verweis nicht gefunden

ANALOG INPUT

Control window (in alphabetic order)	**Explanation** *Input values*
	Analog Cmd1 Adjusted Scaled value of analog command input signal #1
	Analog Cmd1: Gain Adjust Gain adjust for analog command input signal #1
	Analog Cmd2 Adjusted Scaled value of analog command input signal #2
	Analog Cmd2: Gain Adjust Gain adjust for analog command input signal #2
	Analog-In 1 Offset Offset adjust for analog command input signal #1 *Adjust to set “Analog Cmd Input 1” to zero at 0 V input voltage*
	Analog-In 2 Offset Offset adjust for analog command input signal #2 *Adjust to set “Analog Cmd Input 2” to zero at 0 V input voltage*
	Analog-In Aux Offset Offset adjust for analog Aux input. *Adjust to set “Analog Cmd AUX” to zero at 0 V input voltage*
	Analog/PWM: Full Scale Current Scaling of analog- or PWM-input command signal, must not be zero, at zero input signal is disabled.

ANALOG INPUT

Control window (in alphabetic order)	**Explanation** *Input values*
	Analog/PWM: Full Scale Speed
	Full scale definition of speed command for digital (PWM) or analog command input
	Invert Command (IQ, Speed, U/V)
	Inverts the command channel 1
	Do not use at enabled drive!
	Invert Command 2 (ID)
	Inverts the command channel #2
	Do not use at enabled drive!
	Speed Limit
	Speed limit for protection
	Useful for bring-up
	Use ANAIN2 as ID Command
	Defines analog input #2 as ID current command
	To be used in current control mode for manual field weakening operation.

Tab. 8.8: Control Windows in the "ANALOG INPUT" Tab

8.1.10 CAN

In general, compared to a standard SWM without CAN, the customer needs to purchase the CAN activation if CAN communication is required. This includes the standard CAN protocol of the SWM which is described later.

If the customer needs a custom protocol, this can be programmed but needs a separate contract. For custom protocols, all functionality accessible via PC interface can be programmed CAN-accesible.

The “CAN” tab provides configuration settings and debug displays for SWM CAN-communication:

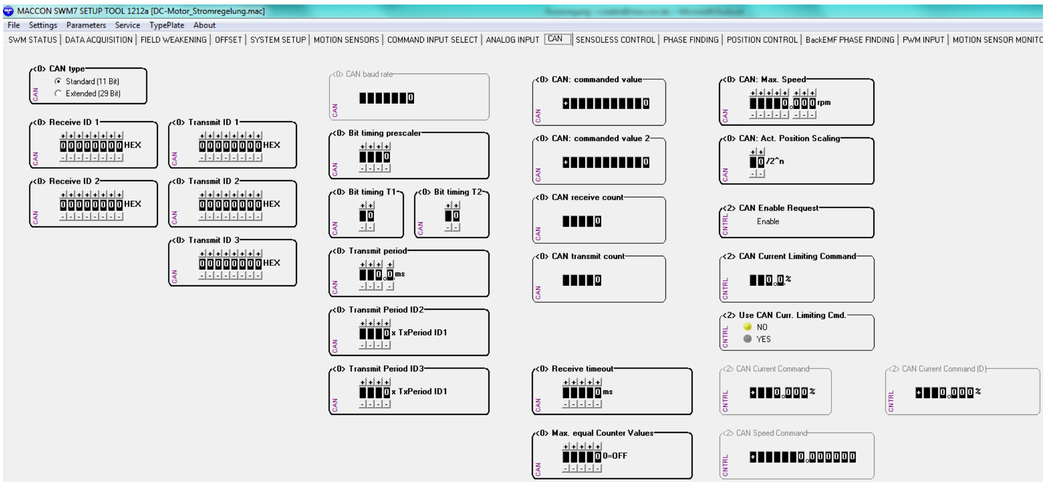


Figure 70: CAN Tab

It is very important to set useful values for Transmit Period, Transmit Period ID2 and Transmit Period ID3, otherwise the SWM sends frames but the frame data does not change.

The receive counter and the transmit counter show if and how the CAN is working.

The SWM allows otimizing the timing of a single CAN-bit. For example, non-optimal wiring can cause ringing after a signal slope. The sampling point for reading a bit can be shifted by a certain time till the ringing has been abated to an acceptable level. Figure 71 shows the timing of a single CAN bit.

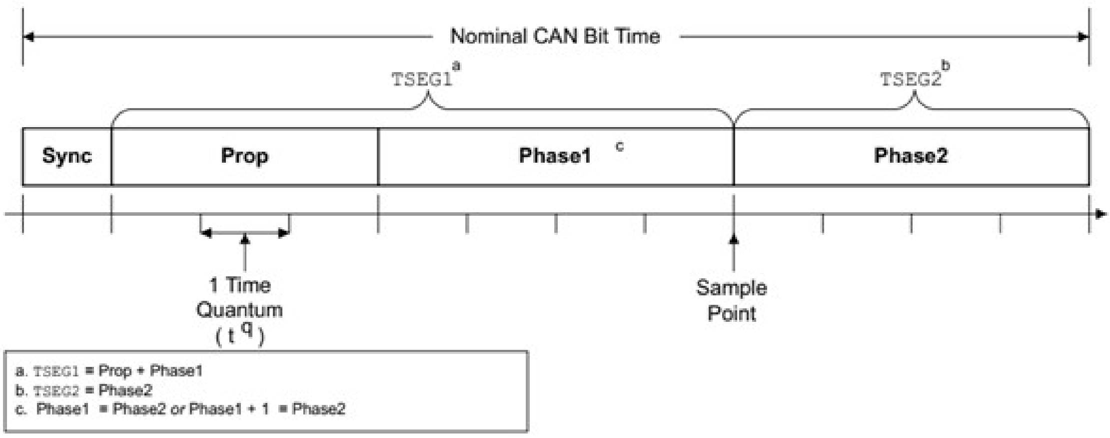


Figure 71: Single CAN Bit Timing

Bit Timing T1 (1..16) = TSEG1

Bit Timing T2 (1..8) = TSEG2

Time Quantum tq = 20ns * <Bit Timing Prescaler>

Bit Timing Prescaler = 1..1024 (0 will be corrected to 1, values will be limited to <= 1024)

<CAN baudrate> = 1 / (tq * (<Bit Timing T1> + < Bit Timing T2> + 1))

<CAN Type>:	CAN-adress-type of the telegram: Number and content of the CAN-telegrams are custom/firmware specific.
<Transmit ID 1> :	CAN-Identifier transmit telegram 1 (SWM to Host)
<Transmit ID 2> :	CAN-Identifier transmit telegram 2 (SWM to Host)
<Transmit ID 3> :	CAN-Identifier transmit telegram 3 (SWM to Host)
<Receive ID 1> :	CAN-Identifier receive telegram 1 (Host to SWM)
<Receive ID 2> :	CAN-Identifier receive telegram 2 (Host to SWM)
<Transmit period> :	Temporal distance of telegrams with <Transmit ID 1>
<Transmit period ID 2> :	Temporal distance of telegrams with <Transmit ID 2>
<Transmit period ID 3> :	Temporal distance of telegrams with <Transmit ID 3>

CAN Standard Protocol:

CAN-Baudrate: Free configurable via timing-parameters

CAN-ID's: 11 or 29 Bit

Repetition interval: 1ms ... 100ms

<u>Telegram 1 from SWM to Host (8 Byte):</u>

Parameter	Actual-Position Encoder	Actual-Speed	Actual-Current
Format	int	int	uint
Resolution	32 Bit	16 Bit	16 Bit
Position	Byte 0,1,2,3	Byte 4,5	Byte 6,7
Offset	0	0	0
Max.-Value	t.b.d.	32767 = Nmax	1000.0A
Min.-Value	t.b.d.	-32768 = -Nmax	-1000.0A
Resolution	1 Incr.	1	0.1 A

Tab. 8.9: CAN Telegram 1 from SWM to Host

Operating mode: 0 = Current, 1 = Speed, 2 = Position, 3 = reserved

Nmax: Parameter "CAN: Max. Speed"

The actual position from an encoder is just an example in the table. The value from all other types of connected position sensors can be transmitted from the SWM to the host.

<u>Telegram 2 from SWM to Host (8 Byte):</u>

Parameter	Bus-Voltage	Bus-Current	Motor-Temperature	SWM-Temperature	Enable/Disable Status	Operation-Mode	Error-Code	reserved	Counter	reserved
Format	uint	uint	uint	int	-	-				
Resolution	16 Bit	16 Bit	8 Bit	8 Bit	1 Bit	2 Bit	3 Bit	2 Bit	4 Bit	4 Bit
Position	Byte 0,1	Byte 2,3	Byte 4	Byte 5	Byte 6	Byte 6	Byte 6	Byte 6	Byte 7	Byte 7
Offset	0	0	0	0	-	-			-	
Max.-Value	800V	102.4A	255	100°C	1 (Enable)	2			15	
Min.-Value	0	0	0	-50°C	0 (Disable)	0			0	
Resolution	0,1V	0,1A	1°C	1°C	-	-			1	

Tab. 8.10: CAN Telegram 2 from SWM to Host

Error-Codes:

Value	Status	Value	Status
000	OK, no fault	100	Overtemperature heatsink
001	Overvoltage	101	Error Resolver-/Encoder
010	Undervoltage	110	I2t warning
011	Overcurrent	111	I_2t Error

Tab. 8.11: Device Failure-Codes in CAN-Protocol

<u>Telegram 1 from Host to SWM (8 Byte):</u>

Parameter	Desired Value: Position	Desired Value: Current/Speed	Enable/Disable Status	Operation-Mode
Format	uint	uint	-	-
Resolution	32 Bit	16 Bit	1 Bit	2 Bit
Position	Byte 0,1,2,3	Byte 4,5	Byte 6	Byte 6
Offset	0	0	-	-
Max.-Value	8388607	32767 = Nmax	1 (Enable)	2
Min.-Value	-8388607	-32768 = -Nmax	0 (Disable)	0
Resolution	1	1	-	-

Tab. 8.12: CAN Telegram 1 from Host to SWM

Operating mode: 0 = Current, 1 = Speed, 2 = Position, 3 = reserved. The other modes known from the PC user interface cannot be addressed with the standard CAN protocol.

Nmax: Parameter "CAN: Max. Speed"

Current scaling: +/1000A equals 2000A equals 16Bit

Not all members of the SWM7 family have sensing circuits for DC-link (bus-) voltage or current.

Scaling factors for voltage, current, temperature or other parameters can be different at custom specific CAN telegrams.

Standard setting is that first enabling of the device needs to be done via PC user interface for safety reasons. This helps to prevent starting the device with possibly wrong parameters. The start sequence can be changed in the “COMMAND INPUT SELECT” tab with parameter “Start-Up Enable State”, but this is not recommended!

CAN Protocol "Standard 1.2":

This is an extended CAN protocol which can be requested without extra charge.

CAN-Baud rate: User-programmable via Timing-Parameter
CAN-ID's: User-programmable, 11 or 29 Bit
Byte order: Intel Format
Repetition rate: User-programmable: 1ms ... 100ms

Telegram 1 from SWM to Host Control:

Telegram Structure: Length 8 Byte

actual position (selected position sensor) X_IST	**actual speed** N_IST	**actual current** Signed I_IST [√(Iq²+Id²)]
32 Bit (16 Bit)	16 Bit	16 Bit
Byte 0,1,2,3	Byte 4,5	Byte 6,7

Normilization:

Parameter	actual position	actual speed	actual motor current (DC value - vector length)
Format	int	int (2´s complement)	int (2´s complement)
Offset	0	0	0
Max. value	t.b.d.	32767=Nmax	32767 (ref. to 100%)
Min. value	t.b.d	-32768=-Nmax	-32768 (ref. to -100%)
Resolution	1 increment	1 (normalized vs. Nmax)	1

Telegram 2 from SWM to Host:

Telegram format: Length 8 Byte

current command Iq CURR_CMD_Iq	**current command Id** CURR_CMD_Id	**commutation angle** COMM_ANGLE	**control mode** ST_CONTROL	**enable/disable state** ST_ENABLE	**error code** ST_ERROR	**phase finding** ST_PF_STD_1	**phase finding** ST_PF_STD_2	**phase finding** ST_PF_STD_3
16 Bit	16 Bit	14 Bit	2 Bit	1 Bit	4 Bit	1 Bit	1 Bit	1 Bit
Byte 0,1	Byte 2,3	Byte 4,5	Byte 5	Byte 6	Byte 6	Byte 6	Byte 6	Byte 6

Normalization:

Parameter	current command Iq	current command Id	commutation angle	control mode	enable/disable	phase finding	phase finding	phase finding
Format	int (2´s complement)	int (2´s complement)	int (2´s complement)	-	-	-	-	-
Offset	0	0	0	-	-	-	-	-
max. value	32767 (ref. to 100%)	32767 (ref. to 100%)	360° (electrical angle)	2	1 (Enabled)	1 (running)	1 (success)	1 (error)
min. value	-32768 (ref. to -100%)	-32768 (ref. to -100%)	-360° (electrical angle)	0	0 (Disabled)	0 (off)	0 (off)	0 (off)
resolution	1	1	0,1°	-	-			

Control Mode:

Bit	Control Mode
0	current control
1	velocity control
2	position control
3	not used

Error code:

Value	error state	Value	error state	Value	error state	Value	error state
0000	OK, no fault	0100	over temperature heatsink	1000	Phase Finding Error	1100	CAN Timeout Error
0001	overvoltage	0101	over temperature motor	1001	resolver error	1101	(Customer-specific Error 1)
0010	undervoltage	0110	It error	1010	Encoder Error	1110	(Customer-specific Error 2)
0011	overcurrent	0111	It warning	1011	CAN Message Error	1111	Processor Error

Telegram 3 from SWM to Host Control:

Telegram structure: Length 8 Byte

Bus voltage U_BUS	Bus current I_BUS	Motor Temperature TEMP_MOTOR	SWM Temperature TEMP_SWM	DIG_IN Status ST_DIG_INX	HS_IN Status ST_HS_INX	Brake Status ST_BRAKE	Counter ZAEHLER
16 Bit	16 Bit	8 Bit	8 Bit	8 Bit	3 Bit	1 Bit	4 Bit
Byte 0,1	Byte 2,3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 7	Byte 7

Data Values:

Parameter	Bus voltage	Bus current	Motor Temperature	SWM Temperature	DIG_IN Status	HS_IN Status	Brake Status	Counter
Format	int (unsigned)	int (unsigned)	int (unsigned)	int (2´s complement)	-	-	-	-
Offset	0	0	0	0	-	-	-	-
Max. value	800	102.4A	255	+100	1 (active)	1 (active)	1 (open)	15
Min. value	0	0	0	-50	0 (off)	0 (off)	0 (closed)	0
Resolution	0,1V	0,1A	1°C	1°C	-	-	-	1

DIG INPUT Status:

Bit	DIGITAL INPUT
0	DIG IN 1
1	DIG IN 2
2	DIG IN 3
3	DIG IN 4
4	DIG IN 5
5	DIG IN 6
6	DIG IN 7
7	DIG IN 8

HS INPUT Status:

Bit	HIGH SPEED INPUT
1	HS 1
2	HS 2
3	HS 3

Telegram 1 from Host Control to SWM:

Telegram structure: Length 8 Byte

desired position (position control mode) X_SET	velocity command (velocity control mode) N_SET	enable/disable setting ENABLE_SET	control mode setting CONTROL_SET	Brake control BRAKE_SET
position command	speed command	set enable or disable	set control mode	set brake on/off
32 Bit	16 Bit	1 Bit	2 Bit	1 Bit
Byte 0,1,2,3	Byte 4,5	Byte 6	Byte 6	Byte 6

Normierungen: Nmax: Parameter "CAN: Max. Speed"

Parameter	position Command	velocity ommand	enable/disable setting	control mode	brake control
Format	int (2´s complement)	int (2´s complement)	-	-	-
Offset	0	0	-	-	-
Max. value	t.b.d.	32767=Nmax	1 (Enable)	2	1 (open)
Min. value	t.b.d.	-32768=-Nmax	0 (Disable)	0	0 (close)
Resolution	1	1 (normalized vs. Nmax)	-	-	-

Control Mode:

Value	Control Mode
0	current control
1	velocity control
2	position control
3	not used

Telegram 2 from Host to SWM:

Telegram format: Length 8 Byte

current command Iq Iq_SET	current command Id Id_SET	commutation angle (manual) COMM_ANGLE_SET	enable commutation angle setting ENAB_COMM_ANGLE_SET
Set current command Iq	Set current command Id	Set commutation angle	Enabling to set commutation angle
16 Bit	16 Bit	14 Bit	1 Bit
Byte 0,1	Byte 2,3	Byte 4,5	Byte 5

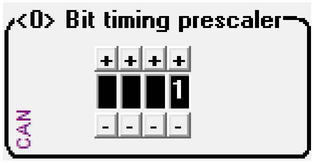
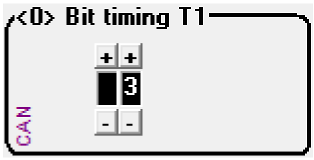
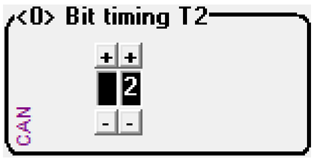
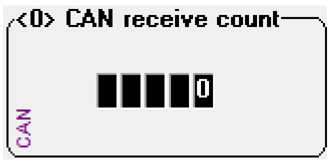
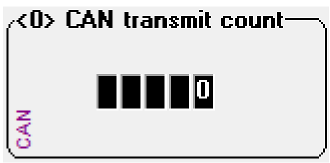
Normalization:

Parameter	current command Iq	current command Id	commutation angle (manual)	enable commutation angle setting
Format	int (2´s complement)	int (2´s complement)	int (2´s complement)	-
Offset	0	0	0	-
max. value	32767 (ref. to 100%)	32767 (ref. to 100%)	360° (electrical angle)	1 (setting of commutation angle enabled)
min. value	-32768 (ref. to -100%)	-32768 (ref. to -100%)	-360° (electrical angle)	0 (setting of commutation angle disabled)
resolution	1	1	0,1°	-

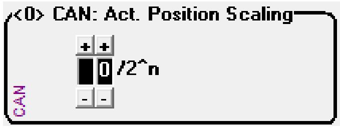
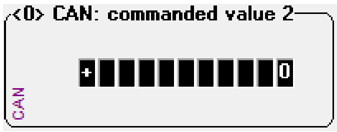
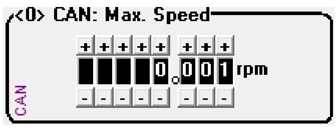
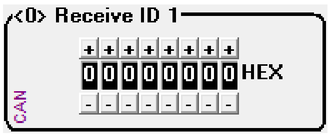
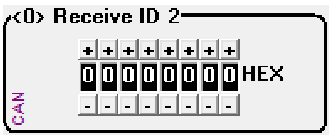
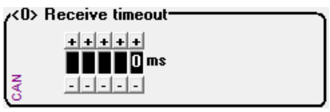
MACCON
MOTION UNDER CONTROL

Control Windows in the “CAN” Tab

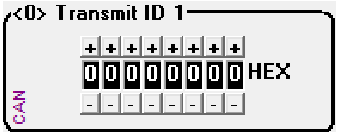
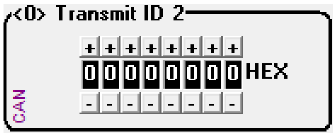
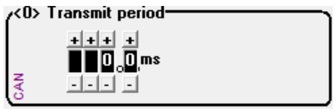
CAN

Control window (in alphabetic order)	**Explanation** *Input values*
	Bit timing prescaler Prescaler for achieving baud rate *see below “Bit timing T1, T2”*
	Bit timing T1 CAN Baud rate setting *Initial Values* `T1 = 4`*, change prescaler for achieving correct baud rate*.
	Bit timing T2 CAN Baud rate setting *Initial Values* `T2 = 5`*, change prescaler for achieving correct baud rate.*
	CAN baud rate Actual CAN baud rate as calculated from bit timing T1/T2 and prescaler. *Display only.*
	CAN receive count CAN telegram counter for valid telegrams in receive direction
	CAN Transmit count CAN telegram counter for valid telegrams in transmit direction
	CAN type CAN identifier length must be set according to master setting

CAN

Control window (in alphabetic order)	**Explanation** *Input values*
	CAN: Act. Position Scaling
	CAN: commanded value Display of commanded setpoint (dependent on current or speed control mode) for CAN operation
	CAN: commanded value 2 Display of commanded setpoint (dependent on current or speed control mode) for CAN operation
	CAN: Max. Speed Maximum operating speed in CAN control mode.
	Receive ID 1 CAN identifiers for transmit and receive telegrams have to be set corresponding to master controller.
	Receive ID 2 CAN identifiers for transmit and receive telegrams have to be set corresponding to master controller.
	Receive timeout This timeout can be used for a security shutdown of the drive if no CAN telegram is received. *Set to zero to disable timeout detection.*

CAN

Control window (in alphabetic order)	**Explanation** *Input values*
	Transmit ID 1 CAN identifiers for transmit and receive telegrams have to be set corresponding to master controller.
	Transmit ID 2 CAN identifiers for transmit and receive telegrams have to be set corresponding to master controller.
	Transmit period Time between 2 transmit telegrams of ID1. The transmit periods for telegrams 2 (and 3) can be indirectly set by multipliers of this value.

Tab. 8.13: Control Windows in the CAN Tab

8.1.11 SENSORLESS CONTROL

Sensorless control is not useful for all applications, it has some limitations. It might work in applications with constant mechanical load, preferable with small speed variation requirements.

If a customer considers the use of sensorless control, it is strongly recommended to contact MACCON technical support, provide detailed application description including load profile and motor datasheet, that MACCON can decide if sensorless control is feasable in the specific requested application.

Because of the complexity of parametrization of sensorless control, MACCON does not provide remote parametrization support. If sensorless control is required and feasible, MACCON provides factory parametrization support with the original motor on site in Munich, which needs to be ordered separately.

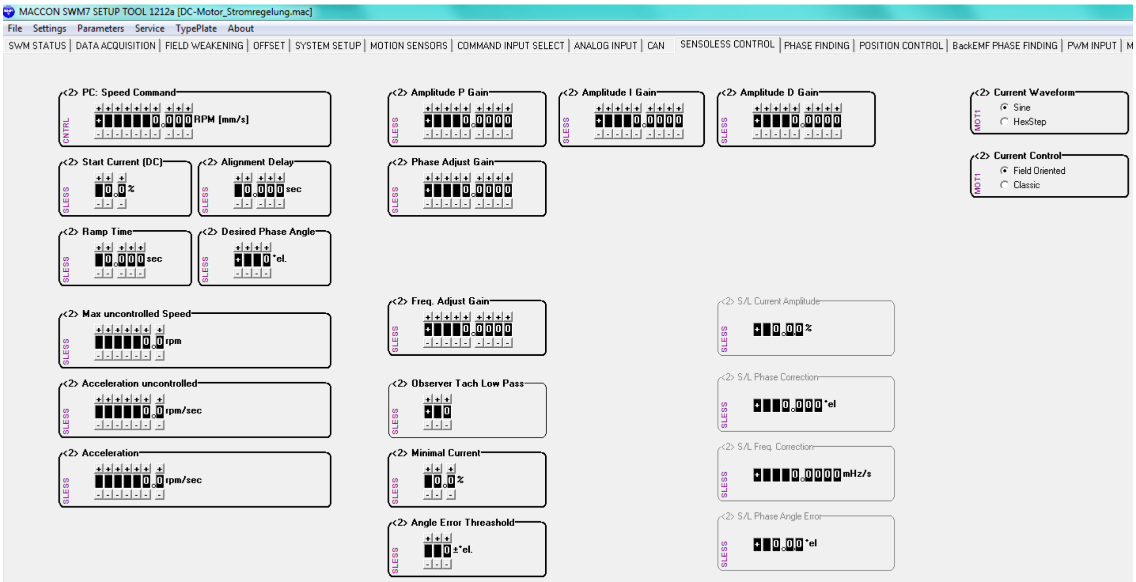
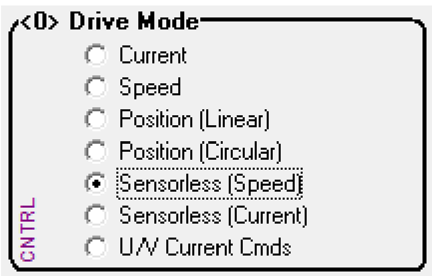


Figure 72: SENSORLESS CONTROL Tab

<u>The sensorless control option provides two different operation modes:</u>

- **Sensorless control with speed signal target value** and
- **Sensorless control with current signal target value**

The choice of the desired operation mode can be done in the COMMAND INPUT tab:



Start-Sequence:

The start sequence is the same for both operating modes. It includes three functional steps:

- **DC-Current Motor Alignment:** The motor shaft will be aligned with DC-current. A from zero rising current will be driven. The current rises within a programmed <RampTime> to a current value of <Start Current(DC)>. After that, the current remains constant for a programmed time of <Alignment Delay>.
- **Steered Ramp:** The motor will be driven at a constant current amplitude of still <Start Current(DC)> at rising frequency. The speed ramps via programmed ramp <Acceleration uncontrolled> to a programmed speed of <Max uncontrolled Speed>.
- **Transition to the Sensorless Control**: A smooth transition between steered mode to regulated mode. Within a time of <Alignment Delay> the gains for sensorless control will be increased to the programmed values.

Sensorless control with speed signal target value:

Acceleration phase: After completed start sequence, the motor will be accelerated to the programmed speed. The acceleration ramp is programmed with parameter <Acceleration>.

Stationary phase: The commutating frequency remains constant now. At load variations, phase angle and motor current amplitude will be regulated. The SWM works in speed control mode.

Sensorless control with current signal target value

Acceleration phase: A motor current value is programmed. After completed start sequence, the motor will be driven with constant current amplitude with the value of <Minimal Current>. The commutation frequency will be regulated.

Stationary phase: The SWM works in current control, phase angle and frequency (speed) will be regulated dynamically. A stationary state dependent from current and load arises.

Position Observer

For determination of position, a motor model is used which calculates the expected angle between voltage and current in the actual working point. The actual working point is defined from the internally supplied parameters speed and current.

The SWM7 is fitted with a field oriented current controller with the input parameters d- and q-portion of current, electric angle and the output parameters d- and q-portion of motor voltage.

From the current- and voltage-values, the connecting angle can be calculated.

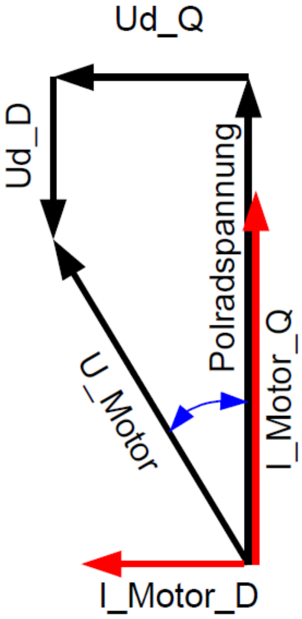
The deviation between expected and measured angle between current and voltage is used to correct the expected motor position and speed.

The time constant of the position observer can be controlled via the parameter <Observer Low Pass>. Adjustment can be done in second power steps: Default is zero, -1 means halving and +1 means doubling the time constant value. For small motors with low inertia, a good choice is -4.

Motor Model:

The behavior of a standard motor model can be visualized with pointer diagrams:

The motor inductance causes a phase shift between motor current and terminal voltage.



If the estimated mechanical angle does not fit to the actual position (Iq not in phase with induced voltage called Polradspannung), the angle (blue) between current and voltage differs.

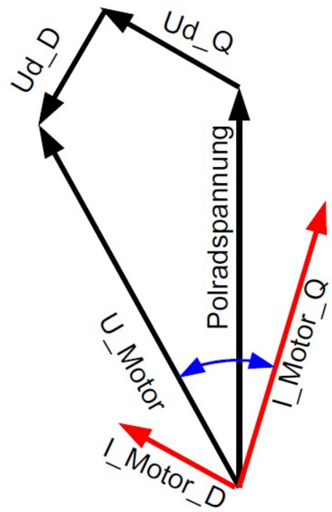


Figure 73: Pointer Diagrams of Motor Model for Sensorless Control

Motor-Parameters

For characterization of the motor the following parameters are required:

<Back EMF Const> in V/rpm

<Motor Inductance> in µH

These parameters are based on the single phase equivalent circuit diagram. The measured terminal values are different:

The inductance of the single phase equivalent circuit diagram equals half the measured inductance between two motor terminals.

The back EMF of the single phase equivalent circuit diagram equals the measured rms voltage between two motor terminals divided by √3.

Conversion Vs/rad -> V/rpm:
1Vs/rad = 2*PI/60 V/rpm = 0.105 V/rpm
1mVs/rad = 2*PI/60000 V/rpm = 0.000105 V/rpm

Sensorless Controller

The deviation between internal and calculated motor position is input for three partial controllers which influence the commutation angle, commutation frequency and the amplitude of the motor current.

This results in a corrected motor position via PI-controller. The <Phase Adjust Gain> parameters can be programmed separately for the three functional phases DC Alignment, uncontrolled Ramp and for the regulated state.

This also results in a correction of the commutation frequency via PI-controller. The gain of this PI controller can be programmed with <Freq. Adjust Gain>. This is highly important for sensorless operation with current setpoint signal, because the only parameter to change the speed is the commutation frequency.

For speed setpoint signal only, it also results in a motor current correction via P-controller and D-controller. Programming parameters are Parameter <Amplitude P Gain> and < Amplitude D Gain>.

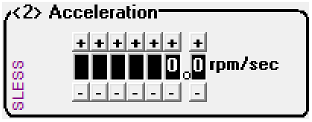
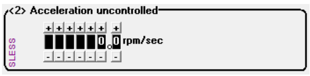
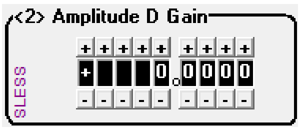
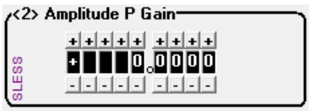
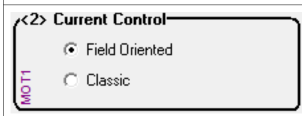
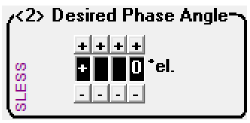
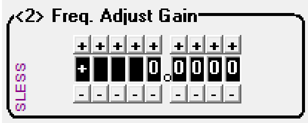
Desired Commutation Angle:

The parameter <Desired Phase Angle> defines the desired commutation angle between current and back-EMF voltage.

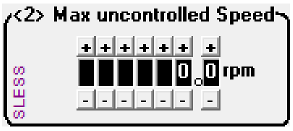
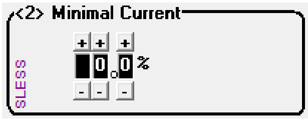
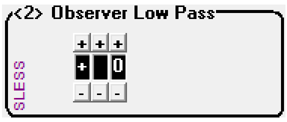
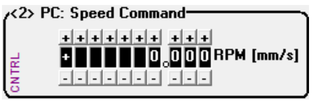
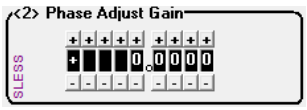
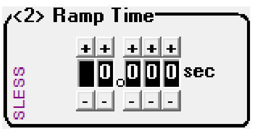
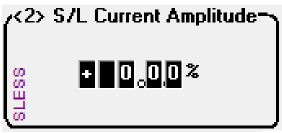
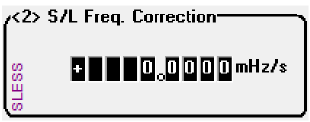
A zero deg angle would result in maximum torque, but this operation point would be extreme instable: Even if the rotor has a little lag angle, the torque is reduced and without angle regulation, this would result in a kind of latch-up. From this perspective, an advanced angle of 25deg is highly recommended.

Control Windows in the "SENSORLESS CONTROL" Tab

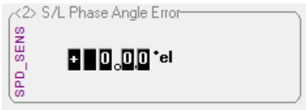
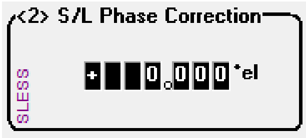
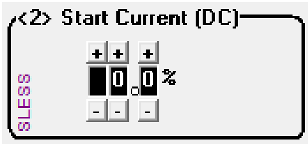
SENSORLESS CONTROL

Control window (in alphabetic order)	**Explanation** *Input values*
	Acceleration Speed ramp for closed loop continuation of speed ramp.
	Acceleration uncontrolled Speed ramp for open-loop startup.
	Alignment Delay Time for changing parameters from open to closed loop control.
	Amplitude D Gain D gain of PD sensorless current controller in speed mode.
	Amplitude P Gain P gain of PD sensorless current controller in speed mode
	Current Control
	Desired Phase Angle The desired phase angle has to be optimized between high torque and a stable operating point. A setting of 20°...30° el. phase angle is suggested.
	Freq. Adjust Gain P gain for motor frequency control.

SENSORLESS CONTROL

Control window (in alphabetic order)	**Explanation** *Input values*
	Max. uncontrolled Speed Maximum speed for open-loop startup.
	Minimal Current Set the minimal current. *Setting for sensorless control.*
	Observer Low Pass Logarithmic setting of position observer gain. Each +1 digit doubles the time constant. *Use* **–4** *as start value for small, low inertia motors.*
	PC: Speed Command Speed setpoint via PC for sensorless control in speed mode.
	Phase Adjust Gain P gain for phase angle control (controlled operation)
	Ramp Time Current ramp time for motor alignment.
	S/L Current Amplitude Monitoring values for optimizing sensorless control.
	S/L Freq. Correction Monitoring values for optimizing sensorless control.

SENSORLESS CONTROL

Control window (in alphabetic order)	**Explanation** *Input values*
	S/L Phase Angle Error
	Monitoring values for optimizing sensorless control.
	S/L Phase Correction
	Monitoring values for optimizing sensorless control.
	Start Current (DC)
	Initial current for motor alignment
	Suggested start value 5 %

Tab. 8.14: Control Windows in the "SENSORLESS CONTROL" Tab

8.1.12 PHASE FINDING

Before running the “PHASE-FINDING” function please make sure that the motor is unloaded and that the current control loop has been tuned like described in chapter 8.3 Current Control Loop.

Phase finding does not work in current control mode because current control mode works without sensor signal. Please ensure to select speed control mode or position control mode before executing the phase finding algorithm.

Current control mode of the SWM7 does not require alignment between sensor position and commutation angle because it works independent of the sensor signal. This makes the current control mode very helpful for testing, debug and first bring-up. Phase finding is required for speed control mode or position control mode.

The “PHASE FINDING” tab provides a tool to calibrate the commutation angle between position sensor and motor shaft position. This angle needs to be calibrated once for absolute sensors like resolvers (click “Write Parameters to Flash” after successful result), it needs to be calibrated at each power-up minimum for relative sensors. It can be calibrated at each enabling of the SWM, if required. In this “PHASE FINDING” function, the motor is driven in current control mode.

The parameters may be optimized to achieve a smoother or shorter phase finding cycle. If current values are too low or selected times are too short the convergence quality will get lower.

If the “Shake Amplitude” is above 5 deg, the pulse time should be reduced.

The “Convergence Quality” should higher than 90%.

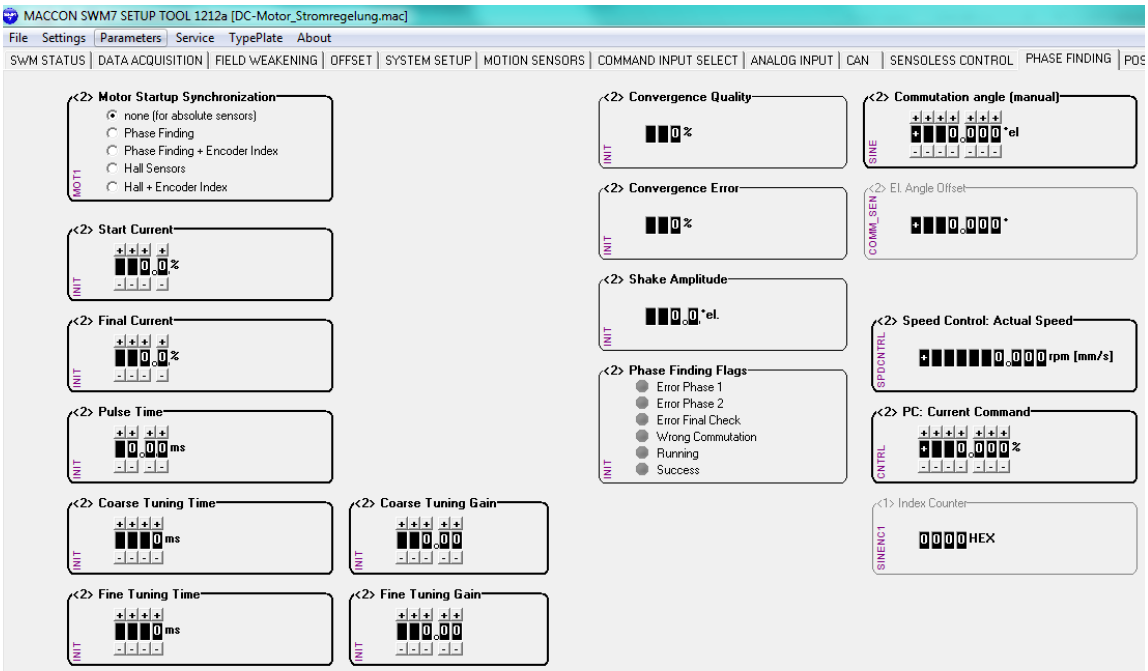


Figure 74: PHASE FINDING Tab

Investigation of the actual motor position is done in two steps:

At first, the actual measured position from the feedback sensor will be stored.

Coarse Tuning

The controller applies equally distributed space current vectors V1...V5 to the motor and senses the shaft acceleration for each vector. From the sum of the measured X coordinates and Y coordinates of the acceleration vectors, a virtual coordinate system for the rotor position (thick arrow) will be calculated. This coordinate system will be rotated into the desired position without rotating the shaft of the motor. The new position of the coordinate system is base for the fine tuning procedure.

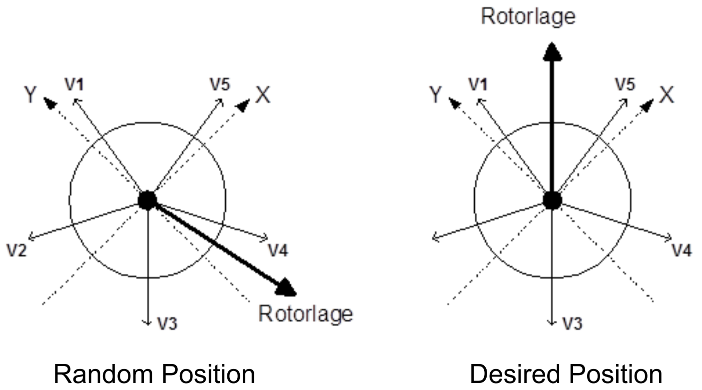


Figure 75: Rotor Position Correction with PHASE FINDING Tool

Detailed Procedure of coarse tuning:

Applying of the current vectors will be repeated multiple times.

Two acceleration vectors will be determined:

- Speed X = Sum of X coordinate acceleration vectors
- Speed Y = Sum of Y coordinate acceleration vectors

If the position of the calculated rotor angle is not in the quadrant between X axis and Y axis, the system will be rotated in 45° steps for coarse positioning of the coordinate system.

If the position of the calculated rotor angle is in the correct quadrant, the rotor angle will be corrected in small steps till the X coordinate and the Y coordinate of the acceleration vectors have the same absolute numerical value (vector length).

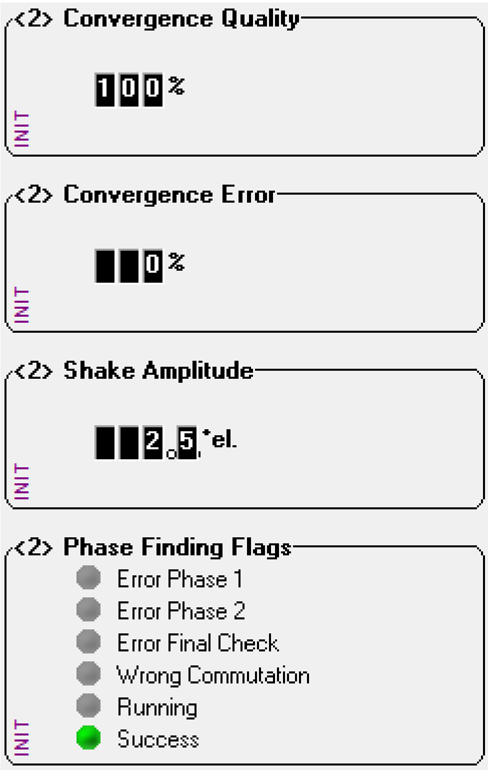
Fine Tuning

Fine tuning applies a DC-current to the motor based on the angle result of the coarse tuning procedure. This current vector will be continuously increased, the direction will be adjusted at deviations.

The difference between previous feedback sensor position and angle result from the phase finding procedure acts as angle offset for the control vectors to rotate the motor.

Parameters

- The Convergence Quality should be more than 90%.
- The Convergence Error should be lower than 10%.
- The shake amplitude should be smaller than 5°el.
- The ideal result of the phase finding procedure in the “PHASE FINDING” tab looks like:



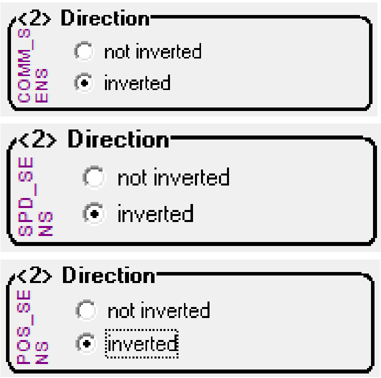
If the “PHASE-FINDING” process works reliably but the motor does not turn, the shaft just jumps to the next magnetic pole, the sensor signal possibly needs to be inverted.

After inverting the sensor signal, the “PHASE-FINDING” procedure needs to be repeated.

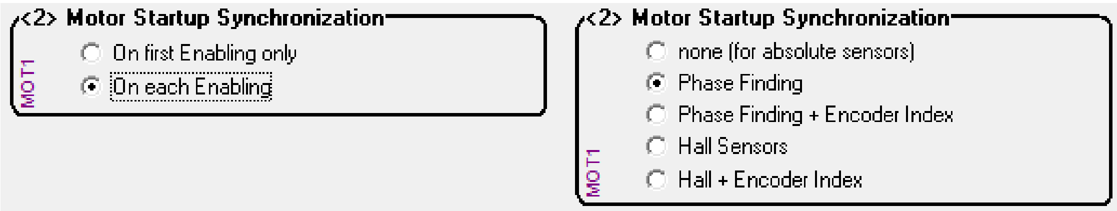
If the “PHASE-FINDING” does not work any more after inverting the sensor signals, the parameters of the phase finding need to be adjusted at disabled drive till it works reliably successful again.

Inverting of the sensor signals:

Please ensure that the drive is disabled. Go to the “SPEED / CURRENT CONTROL” tab and invert the commutation sensor signal and additionally the speed sensor signal and the position sensor signal:



Make sure that in the same tab the following settings for the phase finding are checked. This ensures that a phase finding process will be done with each enabling of the drive.



Change to the “PHASE FINDING” tab to optimize the phase finding parameter settings, if required. It is recommended to start optimizing the Pulse Time if optimizing is required.

For testbed applications, a special firmware with a different phase finding method, the “Back-EMF Phase Finding” is available on request:

If the SWM driven motor can be driven mechanically in both directions, like from a load machine in testbed applications, the commutation angle adjustment can be done based on a back-EMF measuring method. This method requires a special firmware. It can be more accurate than the standard phase finding tool and can be used when the standard tool has problems on special motor characteristics.

The Back-EMF Phase Finding can be controlled via graphical user interface, via digital inputs or via CAN:

Control via Graphical User Interface

1.) Command: Enable Phase-Finding („Busy“ = yellow
2.) Drive the motor with external load machine at useful speed („Min.Speed reached“ = green)
3.) Click „Capture“ to save the voltage angle („CW Angle Captured“ = grün)
4.) Drive the motor with external load machine at same speed in reverse direction
5.) Click „Capture“ to save the voltage reverse voltage angle („CCW Angle Captured“ = grün)
6.) The commutation angle will be calculated automatically („Angle Calculated“ = grün)
7.) Click „Use Calculated Angle“ to adopt the commutation angle („Done“ = grün)
8.) Click “OFF” to disable Phase-Finding („Busy“ = off)

Remote-Control via Digital Inputs DIGIN3 to 5:

1.) DIGIN3 = High: Enable Phase-Finding (DIGOUT4 (busy) appears, DIGOUT5 (done) dis-appears)
2.) Drive the motor with external load machine at useful speed
3.) Send pulse > 20ms to DIGIN4 to save the voltage angle
4.) Drive the motor with external load machine at same speed in reverse direction
5.) Send pulse > 20ms to DIGIN4: to save the reverse direction voltage angle
6.) The commutation angle will be calculated automatically
7.) Send pulse > 20ms to DIGIN5: to adopt the commutation angle (DIGOUT5 appears
8.) DIGIN3 = Low to disable Phase-Finding (DIGOUT4 disappears)

Digital Inputs	**Digital Outputs**
DIGIN3 = Run	DIGOUT4 = Busy (while DIGIN3 is active)
DIGIN4 = Capture	DIGOUT5 = Done (angle calculated and adopted)
DIGIN5 = Copy Commutation Angle	

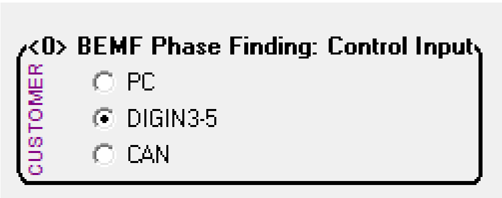
Remote-Control via CAN:

1.) Bit „Run“ = 1: Enable Phase-Finding
2.) Drive the motor with external load machine at useful speed
3.) Bit „Capture“ = 1: Save the voltage angle
4.) Bit „Capture“ = 0
5.) Drive the motor with external load machine at same speed in reverse direction
6.) Bit „Capture“ = 1: Save the reverse direction voltage angle
7.) Bit „Capture“ = 0
8.) The commutation angle will be calculated automatically
9.) Bit „Copy Commutation Angle“ = 1: Adopt the commutation angle
10.) Bit „Copy Commutation Angle“ = 0
11.) Bit „Run“ = 0: Disable Phase-Finding

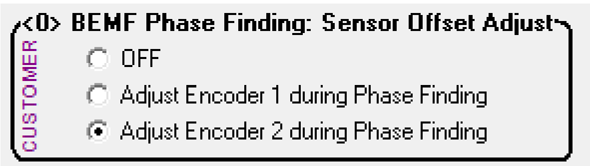
Telegram 2 from Host to SWM:
- Byte 7 Bit 0: Run
- Byte 7 Bit 1: Capture
- Byte 7 Bit 2: Copy Commutation Angle

Telegram 2 from SWM to Host
- Byte 7 Bit 0: Busy
- Byte 7 Bit 1: Min. Speed Reached
- Byte 7 Bit 2: CW Angle Captured
- Byte 7 Bit 3: CCW Angle Captured
- Byte 7 Bit 4: Angle Calculated
- Byte 7 Bit 5: Done (commutation angle will be calculated automatically and adopted)
- Byte 7 Bit 6: Error

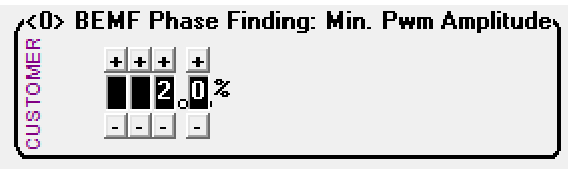
Choice of Control Source



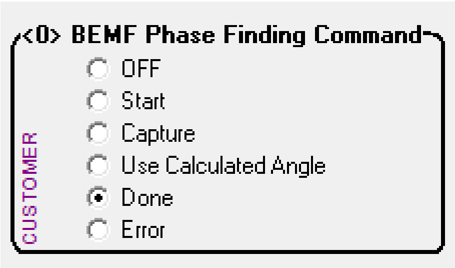
Optional Sensor-Offset-Adjust



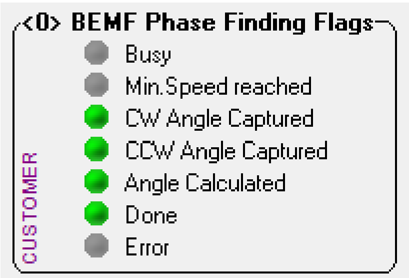
Setting of Minimum PWM Amplitude



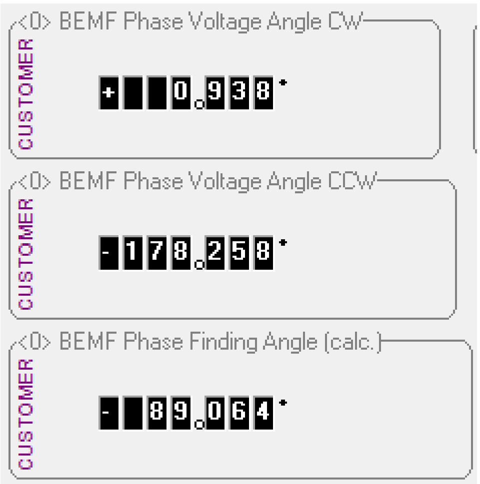
Phase Finding Control via PC (Graphical User Interface):



Status-Flags:

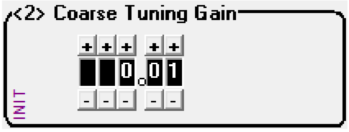
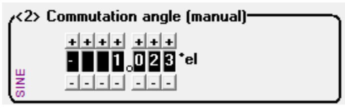
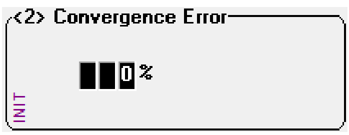
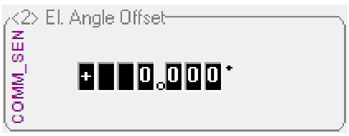
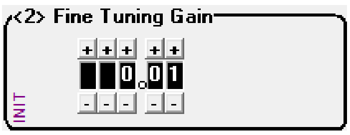
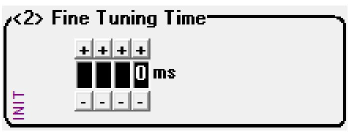


Calculated Values:

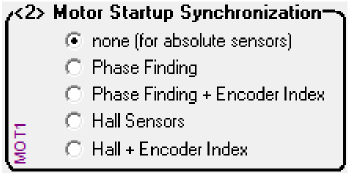
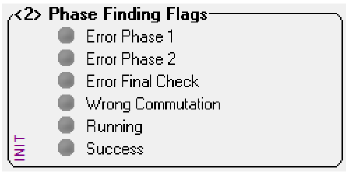
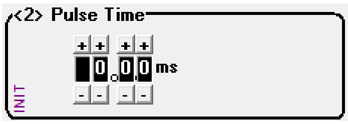
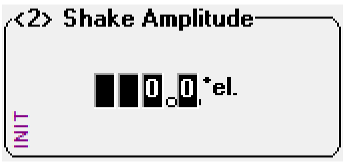
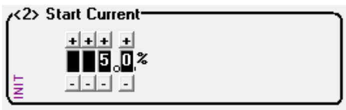
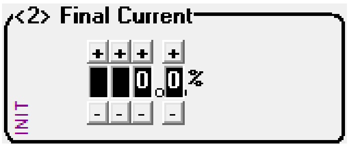


Control Windows in the "PHASE FINDING" Tab

Phase Finding

Control window (in alphabetic order)	**Explanation** *Input values*
	Coarse Tuning Gain
	Amplitude for coarse tuning cycle.
	Coarse Tuning Time
	Suggested start value: `1000 ms`
	Communication angle (manual)
	Can be adjusted manually for special requirements
	Is set automatically from the phase finding algorithm
	Convergence Error
	Displays the convergence error
	The smaller the error, the better the convergence quality
	Convergence Quality
	Result of phase finding algorithm
	Should be more than `90 %`.
	El. Angle Offset
	Electrical angle between motor phase and sensor orientation
	Display only
	Fine Tuning Gain
	Control loop gain for fine tuning cycle
	Fine Tuning Time
	Duration of fine tuning cycle
	Suggested start value: `1000 ms`

Phase Finding

Control window (in alphabetic order)	**Explanation** *Input values*
 After first enabling, the phase finding result can be used until power-off. The phase finding can also be performed on each enabling.	Motor Startup Synchronization The “Phase Finding” is used to align sensor and motor position for absolute feedback sensors like absolute encoders or resolvers. It can also be used for incremental encoders, but not for Hall sensors. The parameters may be optimized manually to improve convergence quality or to optimize calibration time. *The convergence quality should be above* `90%`.
	Phase Finding Flags Indicates state of running or finished phase finding algorithm. *Display only.*
	Pulse Time Duration of current pulses applied during coarse tuning cycle *Suggested start value: 10 ms*
	Shake Amplitude Displays max. motor movement during phase finding *Should be lower than 4%*
	Start Current Initial pulse amplitude for coarse tuning cycle *Suggested start value:* `5 %`
	Final Current Final pulse amplitude for coarse tuning cycle *Suggested final value:* `10...100 %`

Tab. 8.15: Control Windows in the "PHASE FINDING" Tab

8.1.13 POSITION CONTROL

The "POSITION CONTROL" tab includes settings and parameter displays for the position sensors and for position control mode.

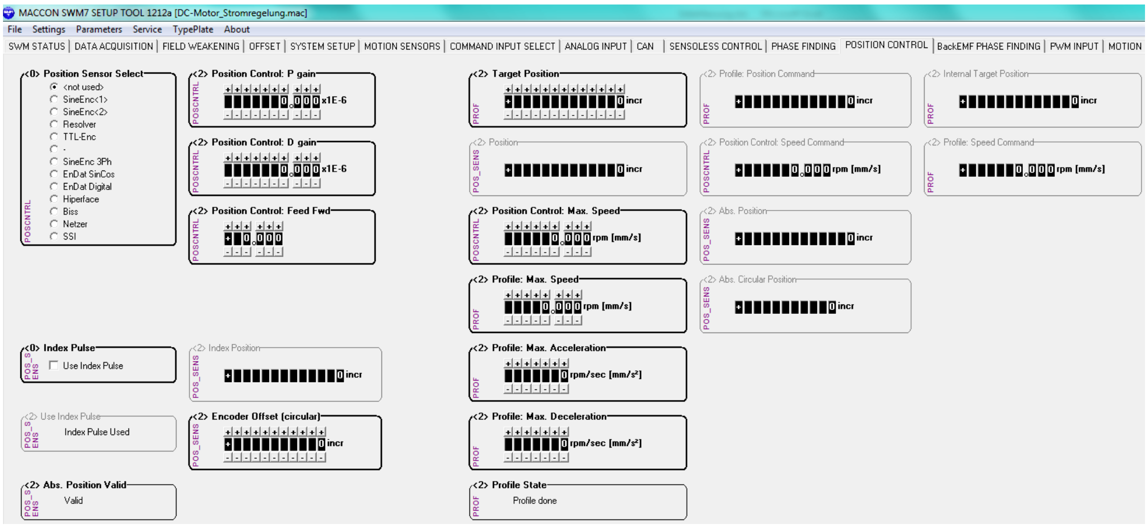
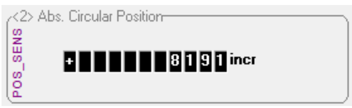
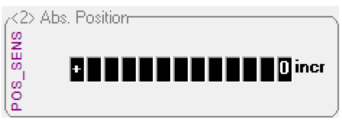
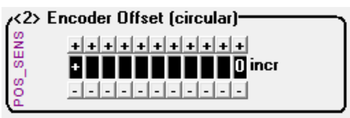


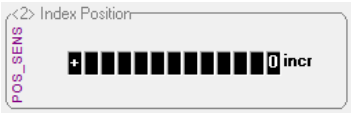
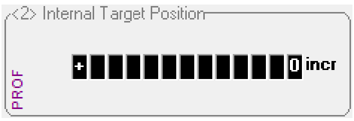
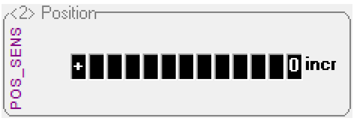
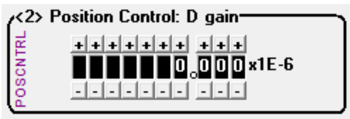
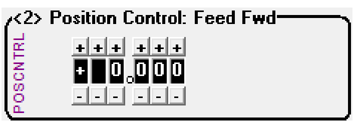
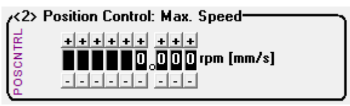
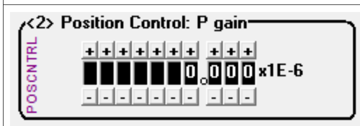
Figure 76: POSITION CONTROL Tab

Control Windows in the "POSITION CONTROL" tab

POSITION CONTROL

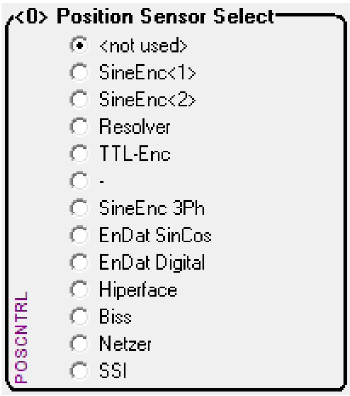
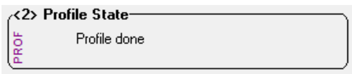
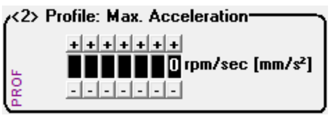
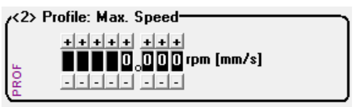
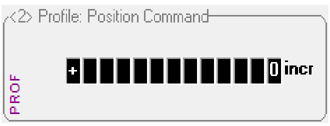
Control window (in alphabetic order)	**Explanation** *Input values*
	Abs. Circular Position
	Displays the circular position of the motor
	None
	Abs. Position
	Displays the current position of the motor
	None
	Abs. Position Valid
	Display the validity of the position, i.e. Abs. Position is inside range
	Display `Valid` or `Not valid`
	Encoder Offset (circular)
	Offset adjust for connected encoder
	-------------*Input values*-------------

POSITION CONTROL

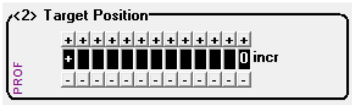
Control window (in alphabetic order)	**Explanation** *Input values*
	Index Position
	Displays the index position
	None
	Index Pulse
	Selection of "Use Index Pulse" for commutation
	Choose `Use` or `not used`
	Internal Target Position
	Displays the internal target position of profile generator
	None
	Position
	Displays the current position
	None
	Position Control: D Gain
	Position controller: D gain adjust
	For systems with fast load changes
	Position Control: Feed Fwd
	Additional control parameter for optimized response and low long term error
	Position Control: Max. Speed
	General speed limit for position profile mode
	Position Control: P gain
	Position controller: P gain adjust

MACCON MOTION UNDER CONTROL

POSITION CONTROL

Control window (in alphabetic order)	**Explanation** *Input values*
	Position Control: Speed Command
	Speed command resulting from position profile generator
	Position Sensor Select
	Defines the type of position feedback sensor
	Display only
	Profile State
	State of profile generator
	Display only
	Profile: Max. Acceleration
	Specifies the acceleration limit for position control mode
	Useful for protection during bring-up
	Profile: Max. Deceleration
	Specifies the deceleration limit for position control mode
	Useful for protection during bring-up
	Profile: Max. Speed
	Specifies the speed limit for position control mode
	Useful for protection during bring-up
	Profile: Position Command
	Profile: Speed Command

POSITION CONTROL

Control window (in alphabetic order)	**Explanation** *Input values*
	Target Position
	Target position of the profile generator
	Use Index Pulse
	Displays state of index pulse.
	Displays `Index Pulse Used`, if “Use Index Pulse” was selected.

Tab. 8.16: Control Windows in the "POSITION CONTROL” Tab

8.1.14 MOTION SENSOR MONITORING

The "MOTION SENSOR MONITORING” tab includes settings and parameter displays for the motion sensors and for speed control mode.

For sinusoidal encoders, an automatic offset compensation routine is available. The compensation values can be adjusted manually.

EnDat sensors are initialized automatically.

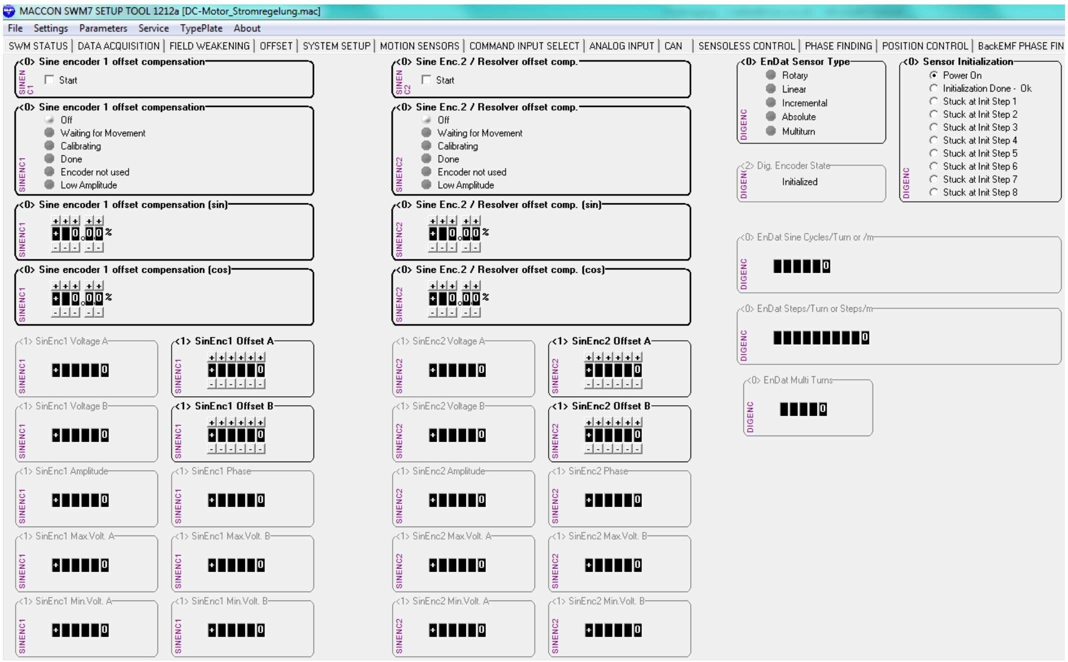
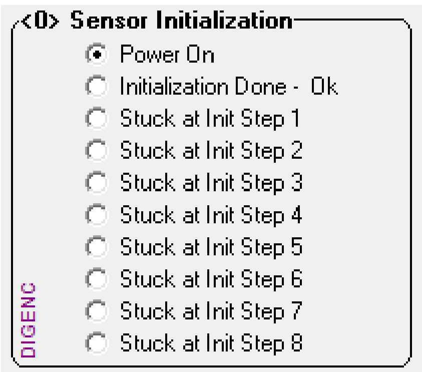


Figure 77: MOTION SENSOR MONITORING Tab



<Sensor Initialization>: Initialization-status of digital sensors (EnDat, BiSS, ...)

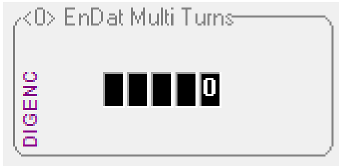
- Power On: Not yet initialized
- Initialization Done – Ok: Successful initialization
- Stuck at Init Step x: Failure during initialization (commutation failure, non expected sensor feedback,...). Exact interpretation depends on type of sensor

Control Windows in the "MOTION SENSOR MONITORING" Tab

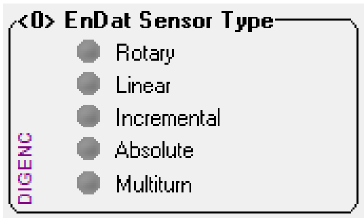
MOTION SENSOR MONITORING

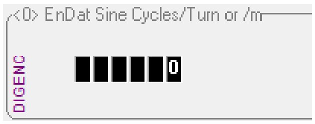
<table>
<tr><th>Control window
(in alphabetic order)</th><th>Explanation
Input values</th></tr>
<tr><td>
</td><td>Dig. Encoder State

Indicates initialized sensor

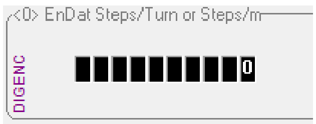
Display only</td></tr>
<tr><td>
</td><td>EnDat Multi Turns

Multi-turns of connected EnDat position sensor, read from sensor

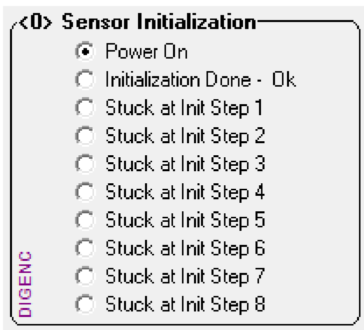
Similar to electronic data sheet</td></tr>
<tr><td>
</td><td>EnDat Sensor Type

Type of EnDat-Sensor</td></tr>
<tr><td>
</td><td>EnDat Sine Cycles/Turn or /m

Resolution of sine cycles per turn or per meter, read from sensor

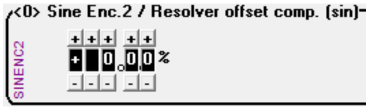
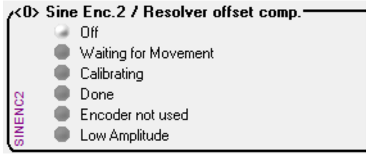
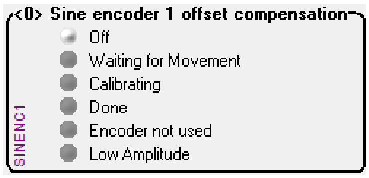
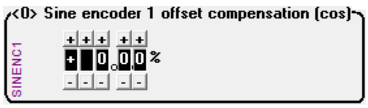
Similar to electronic data sheet</td></tr>
<tr><td>
</td><td>EnDat Steps/Turn or Steps/m

Resolution of steps per turn or steps per meter, read from sensor

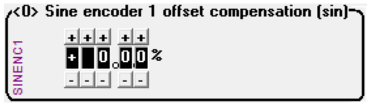
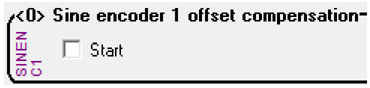
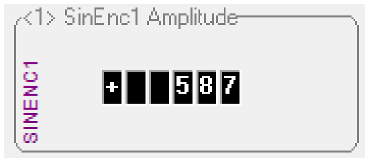
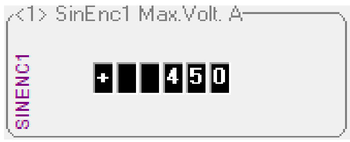
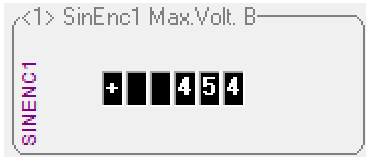
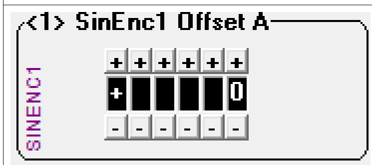
Similar to electronic data sheet</td></tr>
<tr><td>
</td><td>Sensor Initialization

Definition when the initialization parameters should be accepted as valid</td></tr>
</table>

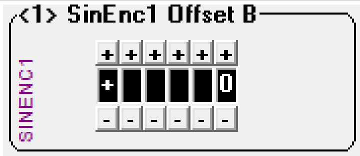
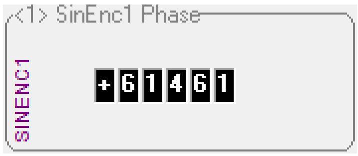
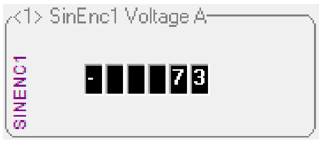
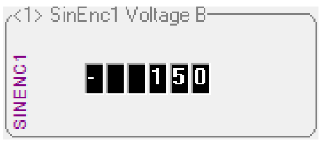
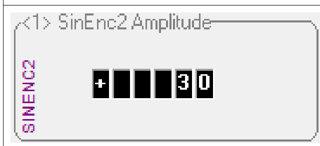
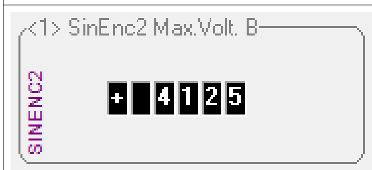
MOTION SENSOR MONITORING

Control window (in alphabetic order)	**Explanation** *Input values*
	Sine Enc.2 / Resolver offset comp. (cos) Offset compensation value for cosine channel of sine encoder 2 (or resolver). *Set by auto compensation algorithm, can also be adjusted manually.*
	Sine Enc.2 / Resolver offset comp. (sin) Offset compensation value for sine channel of sine encoder 2 (or resolver). *Set by auto compensation algorithm, can also be adjusted manually.*
	Sine Enc.2 / Resolver offset comp. State / result of automatic offset compensation of analog inputs of sine encoder #2 (or resolver)
	Sine Enc.2 / Resolver offset comp. (Start) Check to start automatic offset calibration of analog inputs of sine encoder #2 (also used for resolver)
	Sine encoder 1 offset comp. State/result of automatic offset compensation of analog inputs of sine encoder #1
	Sine encoder 1 offset comp. (cos) Offset compensation cosine channel of sine encoder #1 *Set by auto compensation algorithm.* *Can also be adjusted manually.*

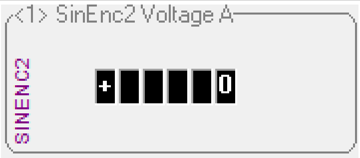
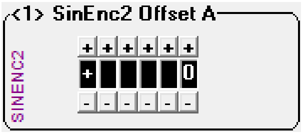
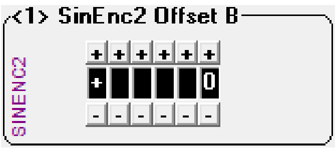
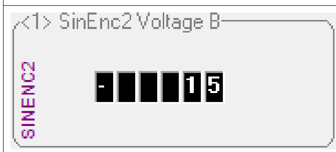
MOTION SENSOR MONITORING

Control window (in alphabetic order)	**Explanation** *Input values*
	Sine encoder 1 offset comp. (sin) Offset compensation sine channel of sine encoder #1 *Set by auto compensation algorithm.* *Can also be adjusted manually.*
	Sine encoder 1 offset comp. (Start)
	SinEnc1 Amplitude Actual data for checking operation of sin/cos encoder
	SinEnc1 Max. Voltage A Positive peak voltage of sine signal of sine encoder #1
	SinEnc1 Max. Voltage B Positive peak voltage of cosine signal of sine encoder #1
	SinEnc1 Min. Volt. A Negative peak voltage of sine signal of sine encoder #1
	SinEnc1 Min. Volt. B Negative peak voltage of cosine signal of sine encoder #1
	SinEnc1 Offset A Offset compensation value sine channel of sine encoder #1 *Set by software.* *Use "Sine encoder 1 offset comp. (sin)" to manually adjust offset*

MOTION SENSOR MONITORING

Control window (in alphabetic order)	**Explanation** *Input values*
	SinEnc1 Offset B
	Offset compensation cosine channel of sine encoder #1
	Set by software. Use "Sine encoder 1 offset comp. (cos)" to manually adjust offset.
	SinEnc1 Phase
	Actual electrical angle of sine encoder 1 sin/cos signals.
	Range 0..65535 = 0..360 deg (el)
	SinEnc1 Voltage A
	Analog voltage of sine channel of sine encoder #1
	Range -32768 to +32767
	SinEnc1 Voltage B
	Analog voltage of sine channel of cosine encoder #1
	Range -32768 to +32767
	SinEnc2 Min. Volt A
	Negative peak voltage of sine signal of sine encoder #2 (or resolver)
	Range -32768 to +32767
	SinEnc2 Amplitude
	Amplitude of sine encoder #2 or resolver
	Used by MACCON technical support
	SinEnc2 Max. Volt. B
	Positive peak voltage of cosine signal of sine encoder #2 (or resolver
	Range -32768 to +32767

MOTION SENSOR MONITORING

Control window (in alphabetic order)	**Explanation** *Input values*
	SinEnc2 Voltage A
	Analog voltage of sine channel of sine encoder #2 (or resolver)
	Range -32768 to +32767
	SinEnc2 Min. Volt. B
	Negative peak voltage of cosine signal of sine encoder #2 (or resolver)
	Range -32768 to +32767
	SinEnc2 Offset A
	Offset compensation sine channel of sine encoder #2 (or resolver)
	Set by software. *Use “Sine encoder 2 /Resolver offset comp. (sin)” to manually adjust offset.*
	SinEnc2 Offset B
	Offset compensation value channel of cosine encoder #2 (or resolver).
	Set by software. *Use “Sine encoder 2 /Resolver offset comp. (sin)” to manually adjust offset.*
	SinEnc2 Phase
	Actual electrical angle of sine encoder #1 sin/cos signals
	Range 0..65535 = 0..360 deg (el)
	SinEnc2 Max. Volt. A
	Positive peak voltage of sine signal of sine encoder #2 (or resolver)
	Range -32768 to +32767
	SinEnc2 Voltage B
	Analog voltage of sine channel of sine encoder #2 (or resolver)
	Range -32768 to +32767

Tab. 8.17: Control Windows in the "MOTION SENSOR MONITORING" Tab

8.1.15 SPEED / CURRENT CONTROL

The SWM drive, of course, provides the well known standard cascaded controller architecture of current control loop as inner loop and the speed control loop as outer control loop.

The "SPEED / CURRENT CONTROL" tab defines the control parameters for the current and for the speed control loop. The current and speed control loops can be optimized by monitoring the step response of the system, e.g. while applying a square wave voltage as current or speed command at an analog input of the SWM, see chapters 8.3 Current Control Loop on page 155, 8.4 Speed Control Loop on page 161 and 8.5 Position Control Loop on page 166.

It is necessary to match the servo controller to the mechanics of the drive system in order to optimize performance. Optimizing of control loops is compensating of time constants. The current control loop compensates electrical time constants of the motor like winding inductances. The speed control loop compensates mechanical time constants like the moment of inertia. More details to the theory and important practical hints are listed in the next chapter.

It is also important to select and to parametize the connected sensors correctly and optimized.

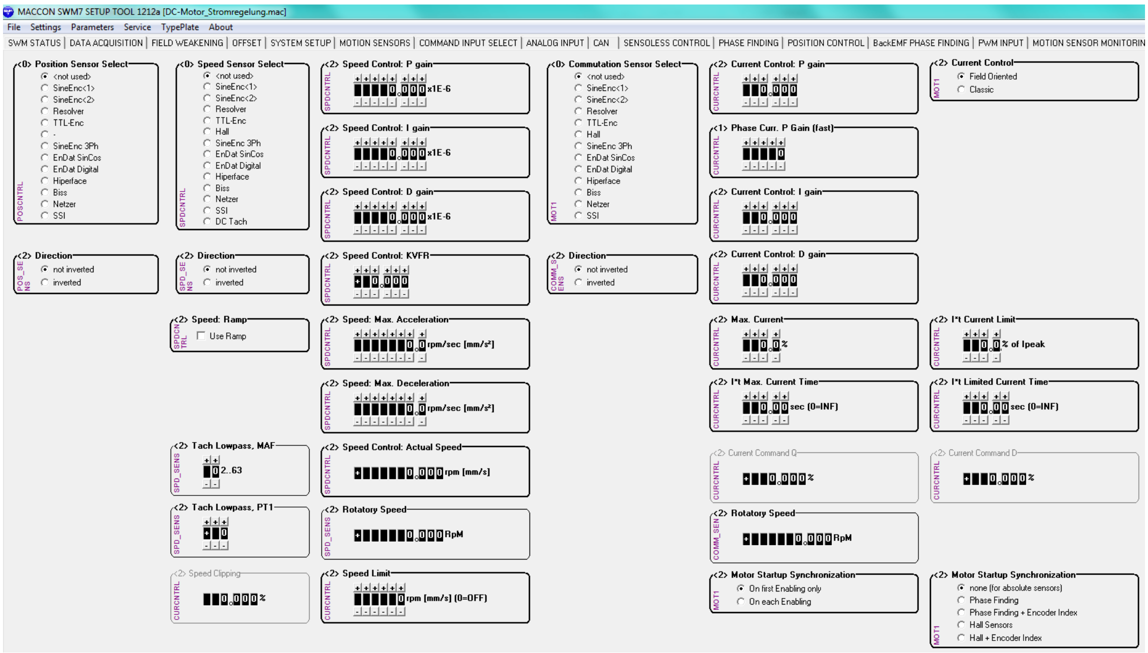


Figure 78: SPEED / CURRENT CONTROL Tab

Setting the Feedback Sensor Input Filters

Resolver: Tach Lowpass, MAF (Moving Average Lowpass Filter)

Sets number of taps (and cut-off frequency) of the moving-average lowpass for speed sensors (not effective for hall sensors or DC tach).

In case of resolver operation the lowpass has to be configured according to the Tab. 8.18:

		PWM frequency (kHz)					
		15	**20**	**25**	**30**	**40**	**50**
		Lowest filter value, or a multiple					
Resolver frequency (kHz)	10	6	8	10	6	8	10
	8	15	10	25	15	10	25
	6.6666	18	24	30	18	24	30
	5	12	16	20	12	16	20

Tab. 8.18: Lowpass Configuration Values for Resolver Operation

Tachometer: Tach Lowpass, PT1

Fig. 79 shows the PT1 filter for smoothing the speed loop reaction.

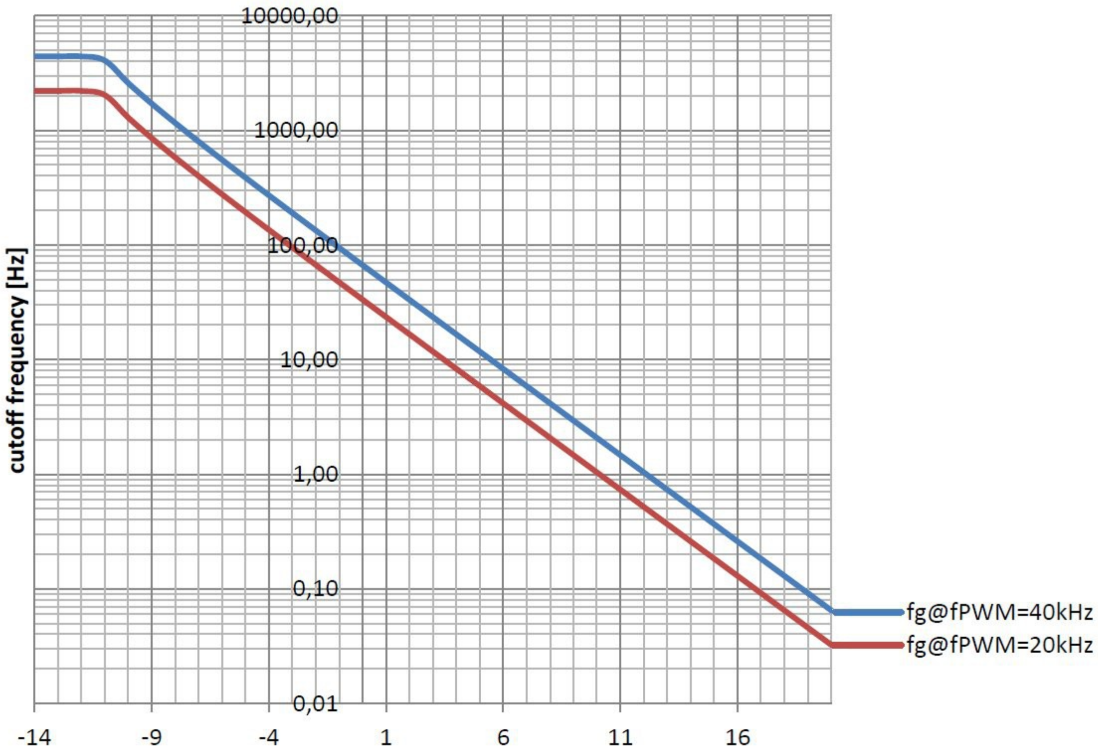
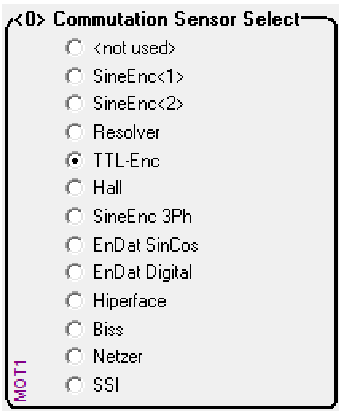
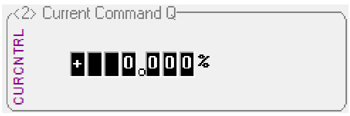
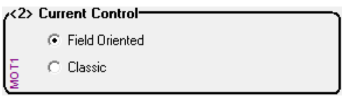
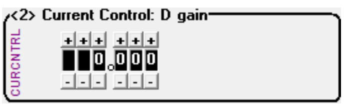
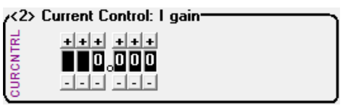


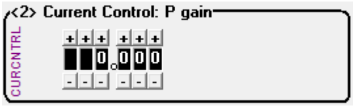
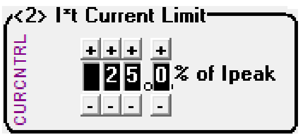
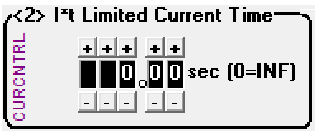
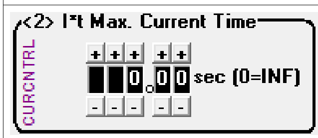
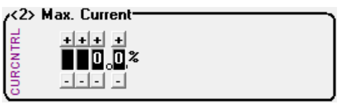
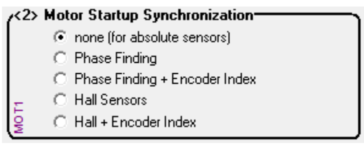
Figure 79: Parameter "Tach Lowpass, PT1", X-Axis is the Parameter Value to choose.

Control Windows in the "SPEED / CURRENT CONTROL" Tab

SPEED / CURRENT CONTROL

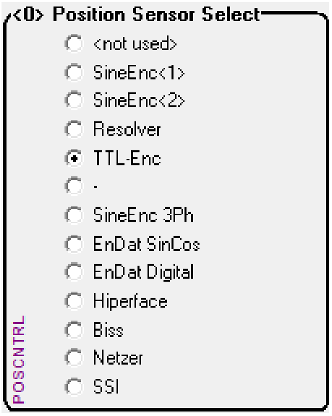
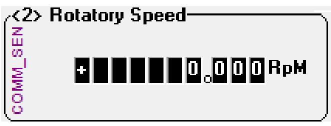
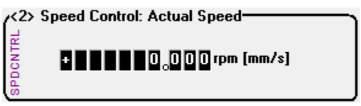
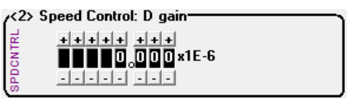
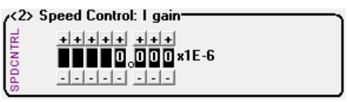
Control window (in alphabetic order)	**Explanation** *Input values*
	Commutation Sensor Select
	Defines the feedback system which is used for commutation
	In most cases, the commutation sensor is the same as for speed or position, because normally only one senor is mounted at the motor
	Current Command D
	Display of actual current loop command (D vector)
	Current Command Q
	Display of actual current loop command (Q vector)
	Current Control
	Current Regulation Algorithm
	Current Control: D gain
	D gain adjust of current controller
	Set D gain only, if fast load changes are expected
	Current Control: I gain
	I gain adjust of current controller

SPEED / CURRENT CONTROL

Control window (in alphabetic order)	**Explanation** *Input values*
	Current Control: P gain P gain adjust of current controller
	Direction Direction setting for commutation sensor, depending on which side of the motor the commutation sensor is mounted
	I*t Current Limit I∗t monitoring limit for creating a warning / error
	I*t Limited Current Time I*t monitoring limit for creating a warning / error
	I*t Max. Current Time I*t monitoring limit for creating a warning / error
	Max. Current Phase current limit
	Motor Startup Synchronization Definition: Time of Motor Startup Synchronization
	Motor Startup Synchronization *Choose "Phase Finding" when* *– no hall sensors and* *– no analog encoder are present*

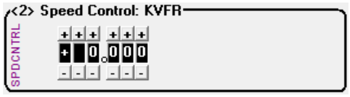
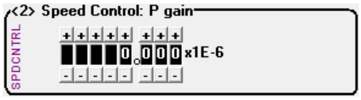
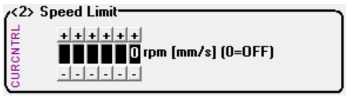
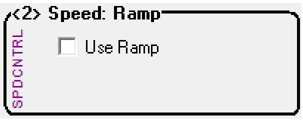
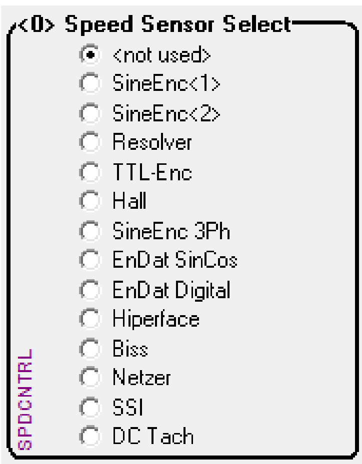
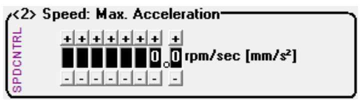
MACON MOTION UNDER CONTROL

SPEED / CURRENT CONTROL

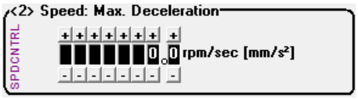
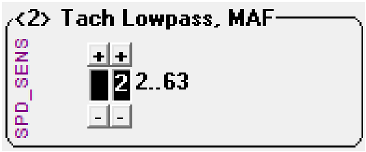
Control window (in alphabetic order)	**Explanation** *Input values*
	Phase Curr. P Gain (fast) Fast phase current controller, used in parallel to the slower field-oriented controller, to increase loop bandwidth
	Position Sensor Select Defines the feedback system which is used for position control loop
	Rotatory Speed Rotatory motor: Speed as derived from active speed sensor
	Speed Clipping Displays current reduction caused by overspeed protection. See parameter “Speed Limit”
	Speed Control: Actual Speed Actual speed value
	Speed Control: D gain D gain adjust of speed controller *Only if fast load changes are expected.*
	Speed Control: I gain I gain adjust of speed controller

MACCON MOTION UNDER CONTROL

SPEED / CURRENT CONTROL

Control window (in alphabetic order)	**Explanation** *Input values*
	Speed Control: KVFR
	Speed control feed forward for faster reaction of speed controller.
	Speed Control: P gain
	P gain adjust of speed controller
	Speed Limit
	Speed limit in current control mode
	Useful for protection during bring-up
	Speed Ramp
	Check to enable slope control of internal speed command. see *parameters* – “Speed: Max. Acceleration” and – “Speed: Max. Deceleration”
	Useful for protection during bring-up
	Speed Sensor Select
	Defines the feedback system which is used for speed control loop
	Speed: Max. Acceleration
	Acceleration limit for speed control mode. (If enabled; see parameter “Speed: Ramp”). Reduces the slope of the speed command if necessary
	Useful for protection during bring-up

SPEED / CURRENT CONTROL

Control window (in alphabetic order)	**Explanation** *Input values*
	Speed: Max. Deceleration
	Deceleration limit for speed control mode. (If enabled; see parameter “Speed: Ramp”). Reduces the slope of the speed command if necessary
	Useful for protection during bring-up
	Tach Lowpass, MAF
	For resolver operation.
	Details see Tab. 8.18
	Tach Lowpass, PT1
	PT1 filter for tachometer signal, see chap. 7.1.2
	Higher numbers result in lower bandwidth; each increment reduces the bandwidth by 0.7.

Tab. 8.19: Control Windows in the "SPEED / CURRENT CONTROL" Tab

8.2 Control-Structures

The SWM contains multiple control loops interfering with each other. This chapter provides an overview of the internal structure and their parameters, which are accessible from the PC control interface.

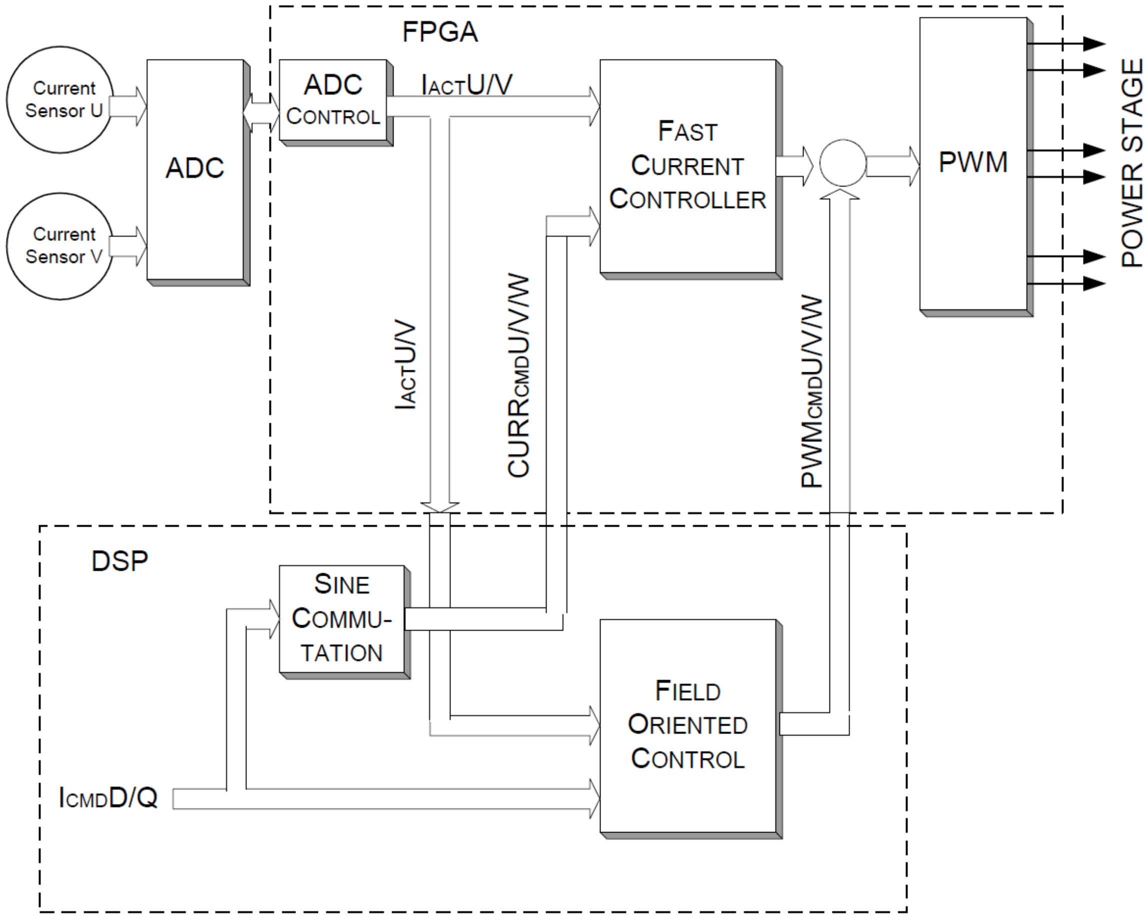


Figure 80: Overall Control Structure

Normalizing of the internal Current:

The internal current value I[intern] can vary between -1 and +1. The measured current I is divided by the defined ADC full scale current MAX_CURRENT_ADC.

I [intern] = I [Amp] / MAX_CURRENT_ADC [Amp]

Normalizing of the internal DC-Link Voltage:

The internal value for the DC-link voltage (if available), U[intern], can vary between -1 and +1. The measured voltage U is divided by the defined ADC full scale voltage “Max. Bus Voltage”.

Not all SWM7 types are fitted with DC-link voltage sensing circuit!

U[intern] = U [Volt] / Max. Bus Voltage [Volt].

Conventional Current Control

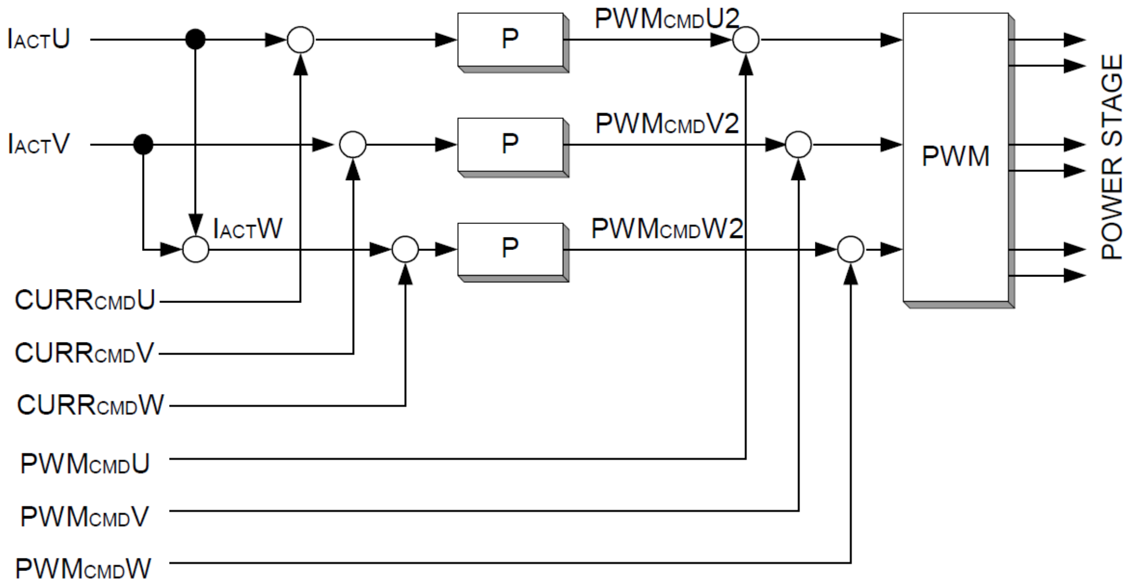


Figure 81: Block Diagram: Conventional Current Control

In conventional current control mode, the SWM has one current control loop per motor phase. The calculation frequency equals the ADC sampling frequency for the current signals, which is dependent on the programmed PWM frequency. The dependency between programmed PWM frequency and ADC sampling frequency is described in table 3.4 on page 17.

Field Oriented Control

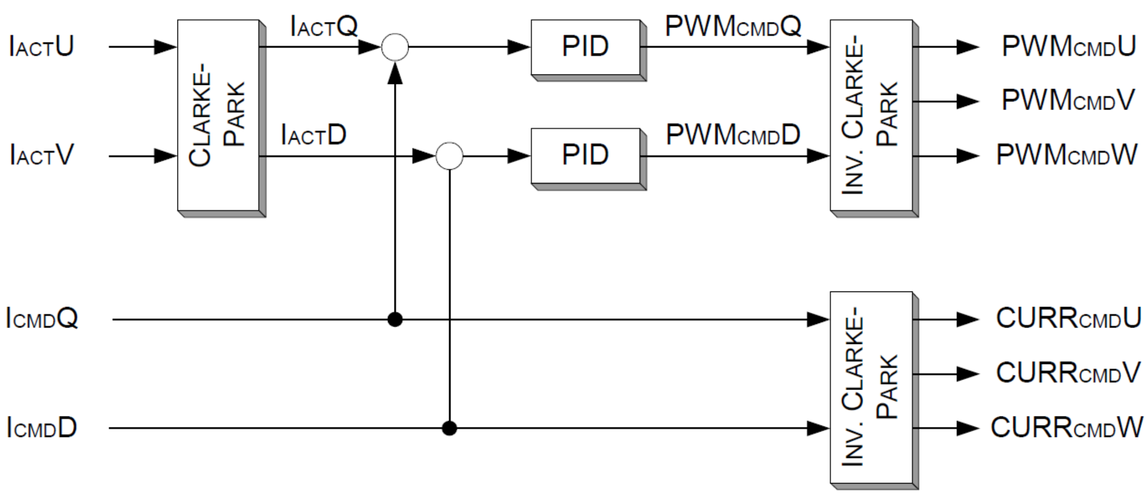


Figure 82: Block Diagram: Field Oriented Control

Field oriented control is implemented in almost all performance drives. The calculation frequency equals the programmed PWM frequency of the drive.

8.3 Current Control Loop

An optimum matching of the current controller to the electrical time constants of the motor ensures accurate torque control and dynamic response.

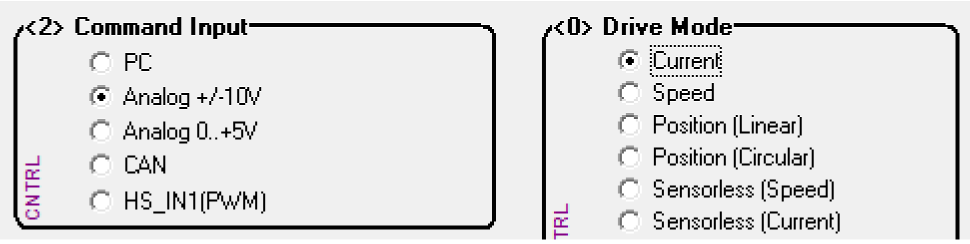
The electric time constant of a motor is the inductance of the winding. This is a first order system which cannot oscillate itself.

A PI-controller is added to compensate this time constant of winding inductance. When the I-gain of the PI controller is zero, the total system, inductance plus P-controller, remains a first order system which cannot oscillate independent of the P-gain of the controller. That is the reason why the first step of optimizing the current control loop is to optimize the P-gain.

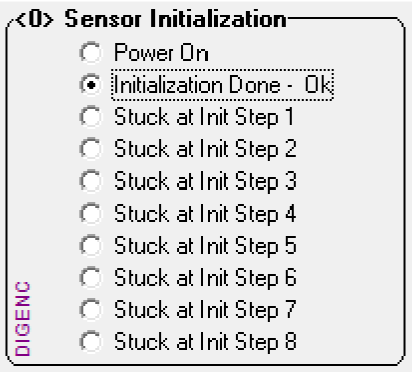
With perfect adjusted current controller, the maximum slope of winding current is the magnetization slope L*dU/dt at PWM duty cycle of 100% (switch always on).

Configure the SWM to current control with external rectangle frequency generator on an analog input as signal source. Change settings only when the SWM is disabled (Disable Drive button!).

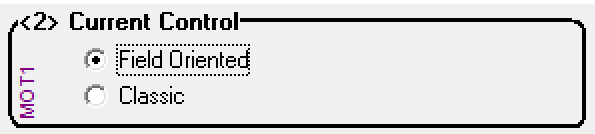
“COMMAND INPUT SELECT” tab

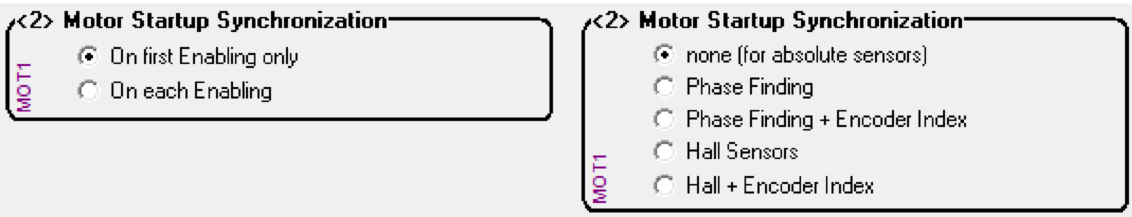


“MOTION SENSOR MONITORING”

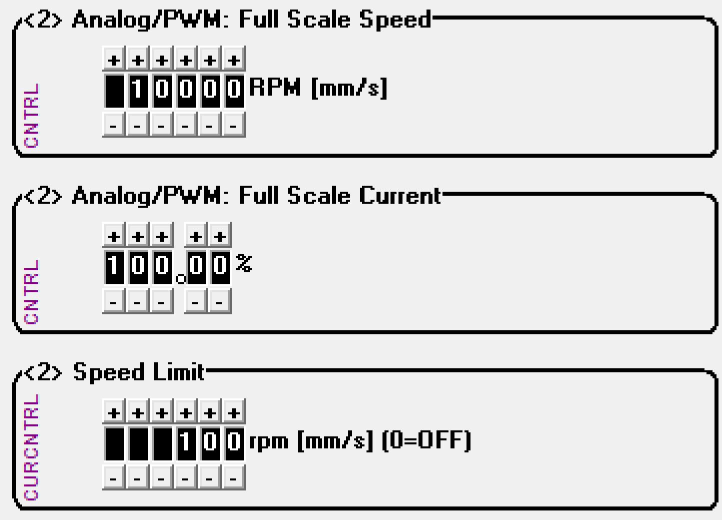


“SPEED / CURRENT CONTROL” tab





None of these parameters in the “ANALOG INPUT” tab must be zero.



Apply the +/-1V rectangle voltage to “ANALOG COMMAND 1 IN”:

For **SWM7S and SWM7-300/600 types** on connector X2: Pin 16 is signal input, pin 18 is the ground. Please ensure that both ground signals on X2 (pin 17 and 18) are connected together.

For **SWM7-150 or SWM7-48 types** on connector X14: Pin 1 is signal input, pin 2 is the ground.

Connect an oscilloscope to “ANALOG OUT 1”:

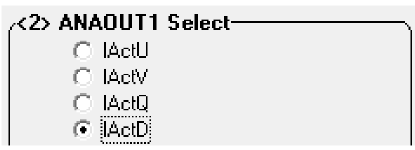
For **SWM7S and SWM7-300/600 types** on connector X2, pin 23 is the signal output, pin 17 is the ground.

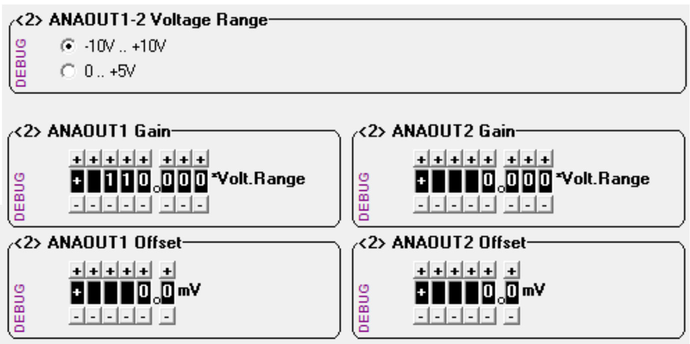
For **SWM7-150 or SWM7-48 types** on connector X15, pin 1 is the signal output, pin 3 is the ground.

Measure the motor IactD signal on “ANALOG OUT 1” together with the rectangle source signal on an oscilloscope:

In the “DATA AQUISITION” tab. configure the signal IactD for the analog output for the oscilloscope, set the voltage range to +/-10V and define offset and gain of the analog output.

Be aware that signals on analog outputs are not in saturation. Adapt ANAOUT Gain if necessary. A displayed rectangle or full scale DC signal could be a different shaped signal in saturation.





The settings for the current controller can be found in the “SPEED / CURRENT CONTROL” tab.

Set the I-gain and the D-gain to zero. P gain also remains zero, only P-gain-fast will be set.

Set the P-gain-fast to a very high value, e.g. 90000.

Set the frequency of the external rectangle generator to get a similar oscilloscope picture like in Fig. 83. For normal motors this picture ensures no movement of the motor shaft. The stimulus frequency always needs to be high enough to prevent any motor shaft movements. During a measurement, the shaft position needs to be constant.

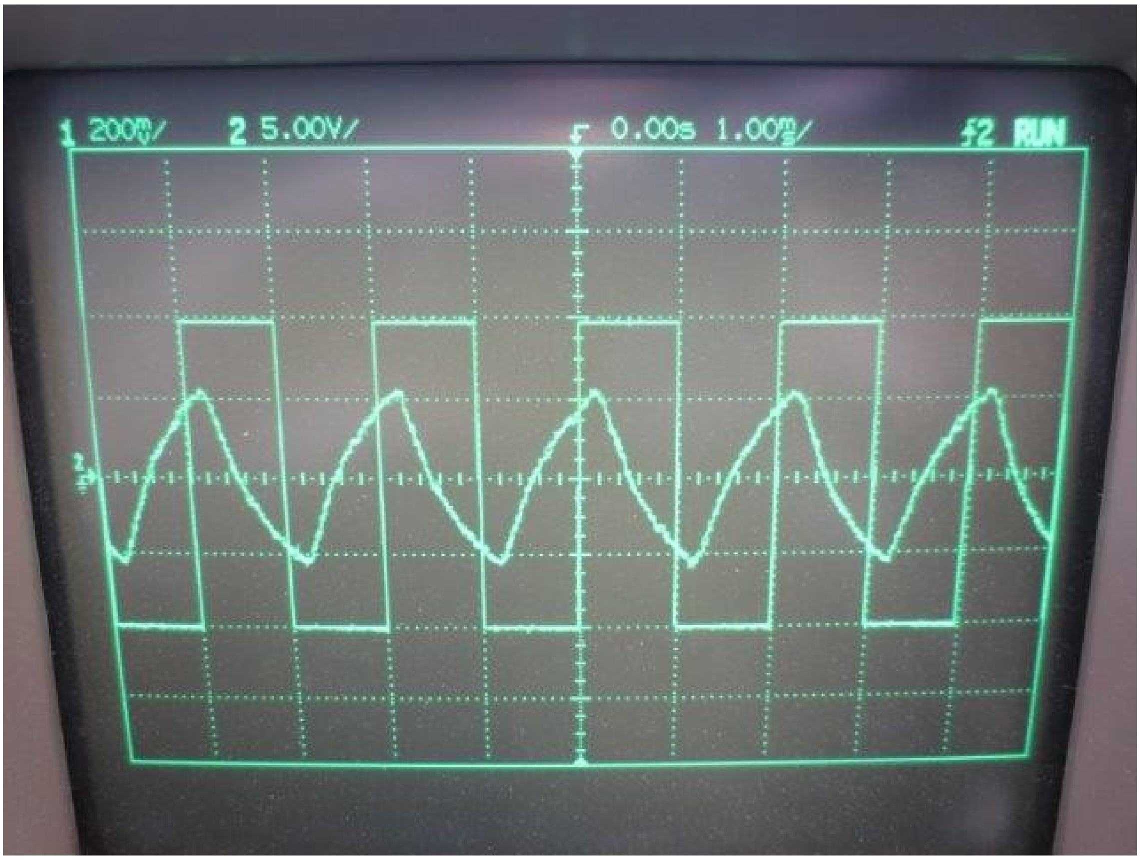
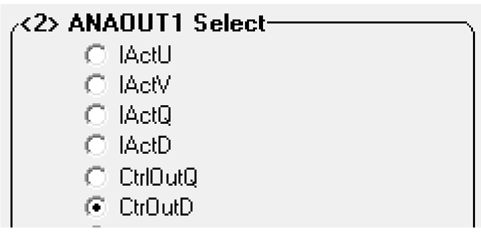


Figure 83: Setting Current Controller P-Gain: Oscilloscope: Rectangle Stimulus and IActD

Turn the shaft of the motor carefully manually, that signal IactD has maximum amplitude. Be always prepared for uncontrolled movement, never wear gloves.

Reduce P-gain till the amplitude of IactD begins to shrink. This is the correct P-gain value. Because of the difficulties of this measurement, it should be repeated for different motor positions. There are some motor positions which are practical for this measurement and some are not. When the “correct” P-gain is extreme high or low, the actual position might be not practical.

For adjusting the I-gain of the controller route the CtrlOutD signal to the oscilloscope analog output per “DATA AQUISITION” tab.



Reduce the frequency of the rectangle generator by the factor of eight This will generate similar oscilloscope display. If this picture does not appear please turn shaft of the motor carefully.

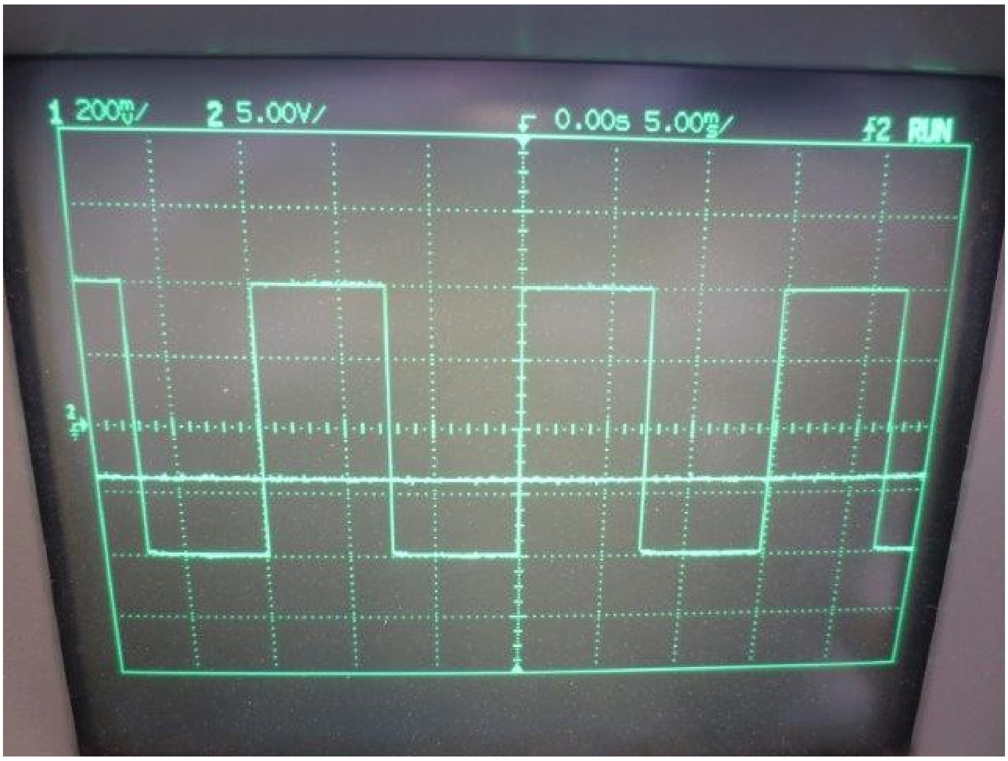


Figure 84: Setting Current Controller I-Gain: Rectangle Stimulus and CtrlOutD, I-Gain is zero

When the I-gain is zero, the CtrlOutD signal is a DC-signal. The offset of the CtrlOutD can be anywhere, mostly negative.

Adding carefully I-gain will cause smooth AC portion of the CtrlOutD.

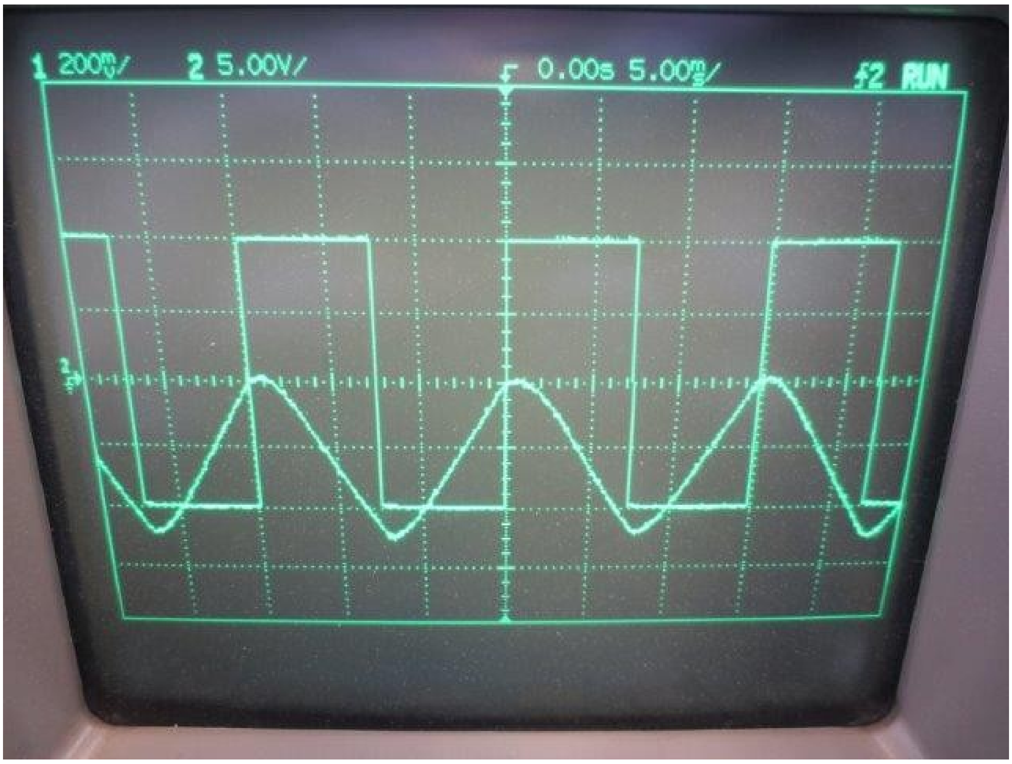


Figure 85: Setting Current Controller I-Gain: Rectangle Stimulus and CtrlOutD, I-Gain too small (1)

Increasing the I-gain shapes the AC-portion more to rectangle shape and shifts the offset.

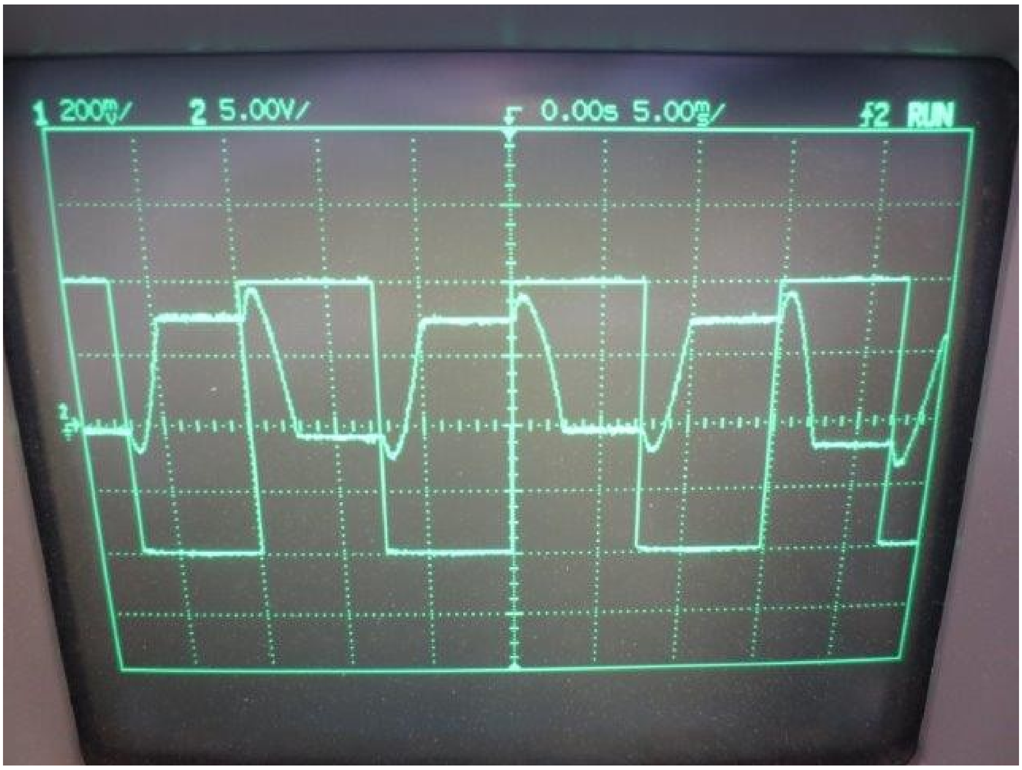


Figure 86: Setting Current Controller I-Gain: Rectangle Stimulus and CtrlOutD, I-Gain too small (2)

Further increasing the I-gain approaches the flat parts of the AC-portion to the zero-line.

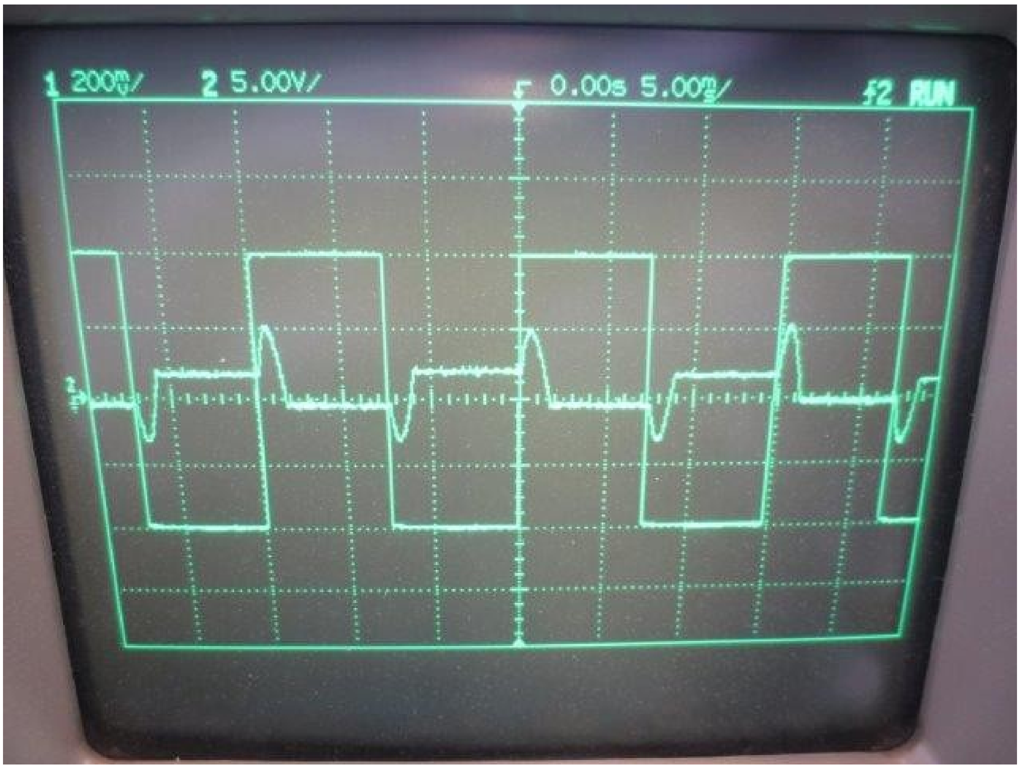


Figure 87: Setting Current Controller I-Gain: Rectangle Stimulus and CtrlOutD, I-Gain too small (3)

Further increasing the I-gain brings both flat parts of the AC-portion to the zero-line. That moment when both flat parts reach the zero line represents the perfect I-gain.

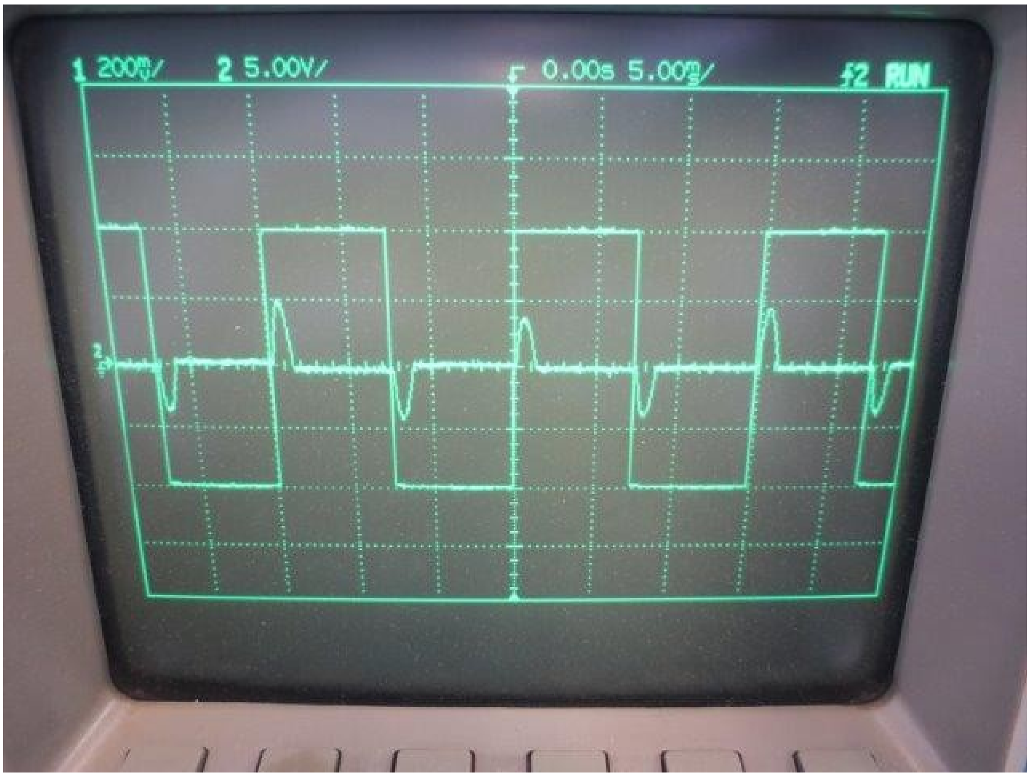


Figure 88: Setting Current Controller I-Gain: Rectangle Stimulus and CtrlOutD, I-Gain Perfect

Adding more I-gain would increase the pulses and decrease the current controller adjustment accuracy.

Depending on the customer specific firmware version the D gain is not present in the SWM7 software. The D gain is not necessary for perfect current controller adjustment.

A check of the success of the current controller adjustment can be done with the phase finding tool. The following changes in the settings need to be done to activate the phase finding tool.

8.4 Speed Control Loop

The speed control loop includes the time constant till the motor reaches the desired speed. Assuming a well tuned current control loop, the speed control is a first order system which can be compensated with a PI controller, similar to the current control loop.

This procedure causes active braking. The DC-link supply either needs to be able to sink energy or an adequate brake chopper needs to be connected in parallel to a single quadrant DC-source to burn the braking energy. Otherwise high voltages would be generated at the DC-link which could damage controller and power supply. This also could cause injury or death.

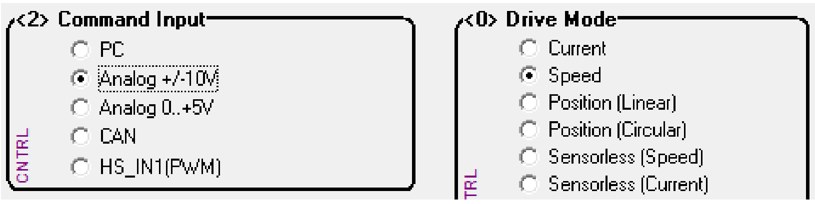
The procedure to adjust the speed controller is only siutable for drive systems which are not sensitive to regulation oscillations.

Always disable the drive before changing parameters.

Assumption is a well tuned current control loop.

A method to adjust the speed controller could be:

Similar to the current controller adjustment setup, set in the “COMMAND INPUT SELECT” tab the Analog +/-10V as signal source but set the drive mode to speed control.



Apply the +/-1V rectangle voltage to “ANALOG COMMAND 1 IN”:

For **SWM7S and SWM7-300/600 types** on connector X2: Pin 16 is signal input, pin 18 is the ground. Please ensure that both ground signals on X2 (pin 17 and 18) are connected together.

For **SWM7-150 or SWM7-48 types** on connector X14: Pin 1 is signal input, pin 2 is the ground.

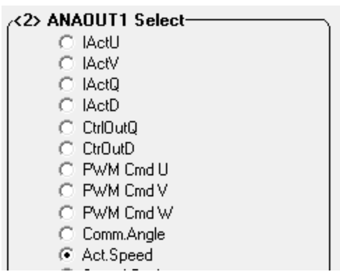
Set the frequency to a value that the motor can safely reach the programmed speed before the direction reverses.

Connect an oscilloscope to “ANALOG OUT 1”:

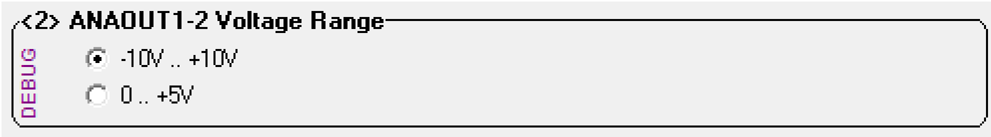
For **SWM7S and SWM7-300/600 types** on connector X2, pin 23 is the signal output, pin 17 is the ground.

For **SWM7-150 or SWM7-48 types** on connector X15, pin 1 is the signal output, pin 3 is the ground.

Choose the actual speed In the “DATA AQUISITION” tab to be monitored on the oscilloscope.

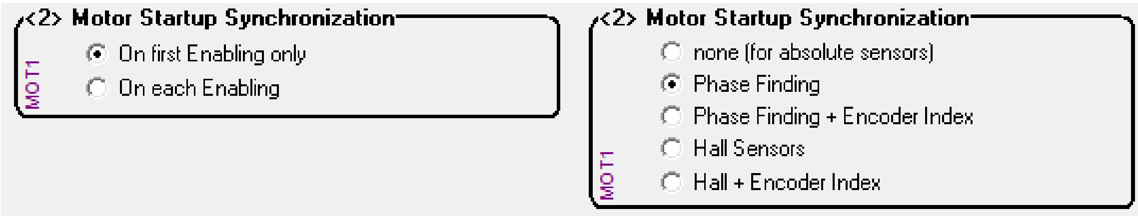


Set the voltage range to +/-10V and define offset and gain of the analog output.



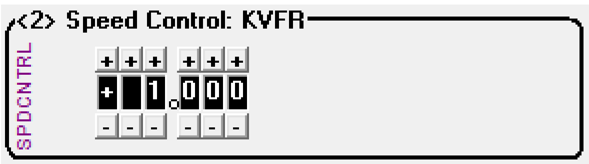
Be aware that signals on analog outputs do not reach the saturation limit, even at overshoots at 50% of expected nominal signal. Run the motor and adapt ANAOUT Gain if necessary. Be sure that you are able to measure overshoots without reaching the saturation limit.

Open the “SPEED / CURRENT CONTROL” tab and set the following parameters:
Disable the phase finding for each enabling.

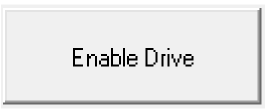


Uncheck the Speed Ramp.

The speed controller parameters are located in the same tab. Set the D-gain to zero, the P-gain and the I-gain to a small value above zero and the KVFR to 1.000.



Always disable the drive before changing parameters!
Start with a small and safe amplitude of the rectangle signal generator.



The P-gain is responsible for the slope.

The I-gain is responsible for long term changes.

The D-gain can help to reduce oscillations.

Increase the P-gain together with the D-gain until the speed ramp does not ramp faster with increasing P-gain and the signal does not have oscillations any more.

Increase the I gain until an overshoot occurs and reduce it again just until the overshoot disappears.

The following screenshots show the effects of P, I and D gain based on a perfect reference waveform:

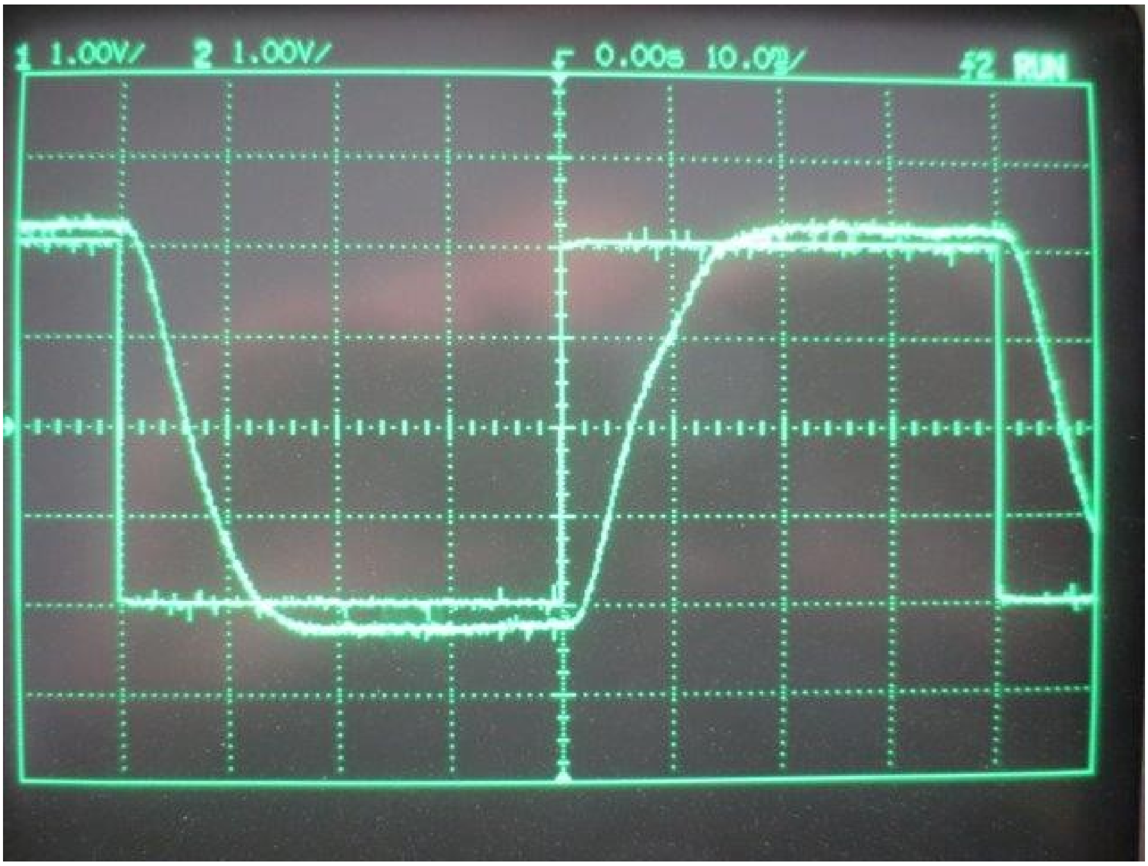


Figure 89: Reference Waveform of perfect adjusted Speed Controller

The following waveforms show the deviations from the reference waveform when only one parameter is tuned massively wrong.

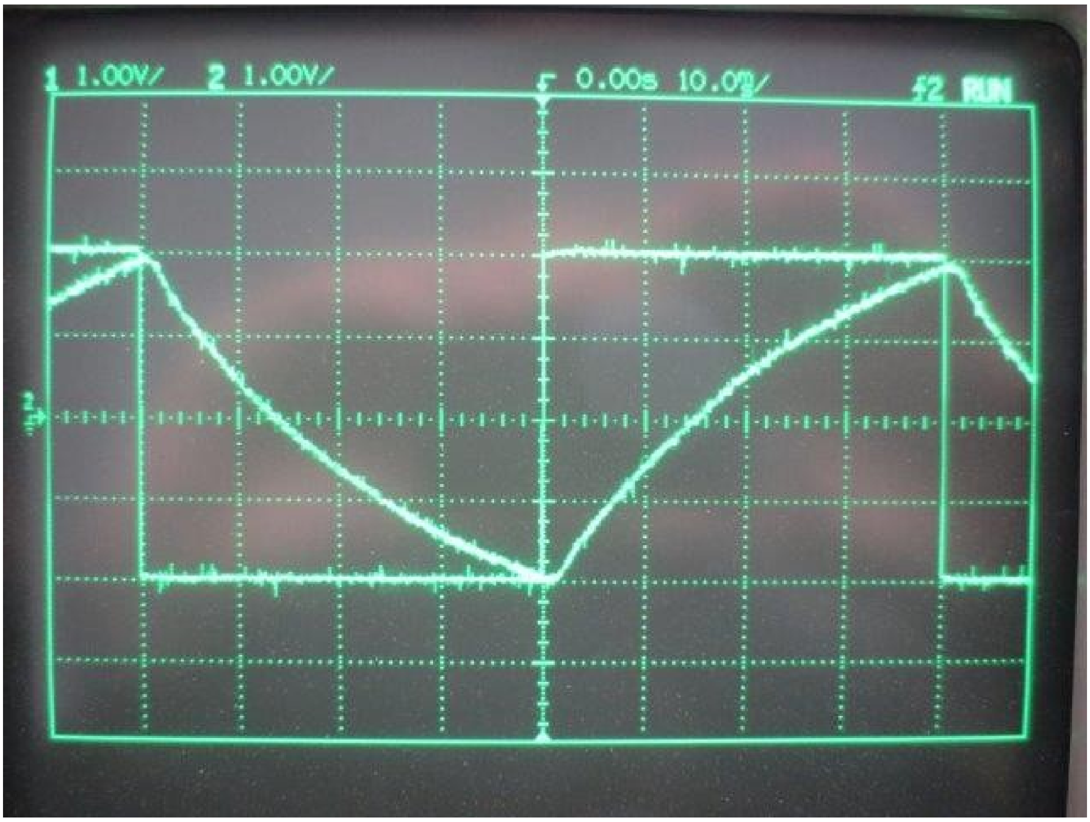


Figure 90: P-Gain too small: The Acceleration-Slope is too slow.

Figure 91: D-Gain too small: Oscillations.

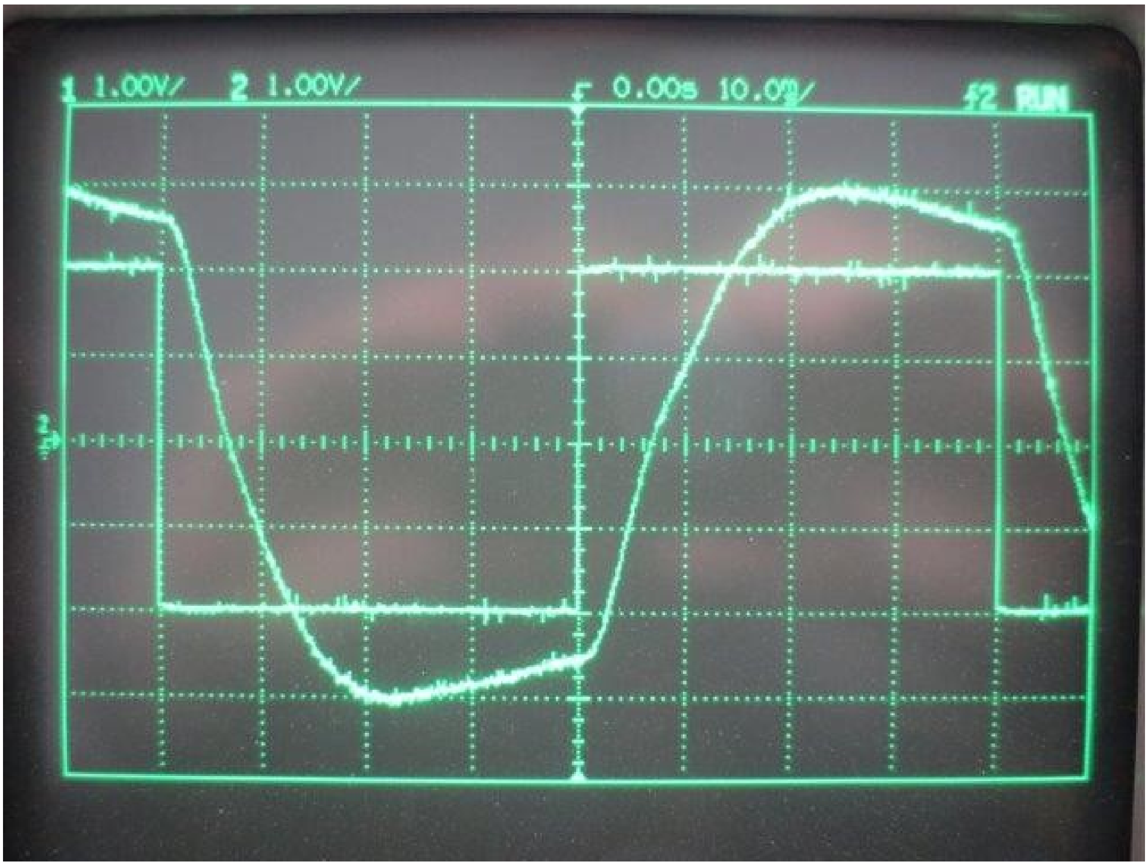


Figure 92: I-Gain too high: Massive Overshoots

Depending on the connected mechanical system, speed controller adjustment is not trivial.

The described procedure gives a basic guideline for simple systems, it shows how P, I and D component of the controller act in the drive system. Based on these descriptions speed controller adjustments also in more complex systems should be possible.

8.5 Position Control Loop

The position controller has two different modes: For circular and for linear motors. The difference is, that the mode for linear motors applies to an absolute position. The mode for linear motors refers to one revolution of a circular motor and is optimized to find programmed position quick. It automatically decides direction of motor speed when a position higher than one motor turn is programmed. For multi turn positioning of circular motors, the mode for linear motors is required.

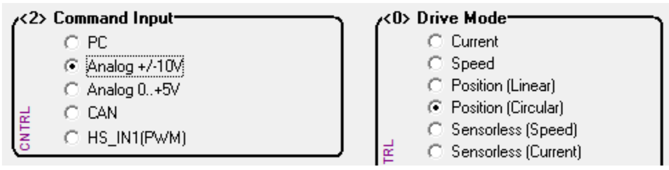
The position control loop can be adjusted when current control loop and speed control loop are adjusted. To adjust the position controller, the desired position is given as rectangle function from an external frequency generator and the speed is measured with an oscilloscope.

Pay attention to movement of motor shaft: Check if programmed movement and vibration of the motor shaft can be tolerated from the system before position controller adjustment.

Protect operators from uncontrolled motor movement.

Limitation of speed, acceleration and deceleration limits in the “POSITION CONTROL” tab might reduce risk of injury and damage.

In the “COMMAND INPUT SELECT” tab an analog input needs to be defined as signal source and the drive mode to circular position control.



In the “DATA AQUISITION” tab, the actual speed command needs to be defined for the analog output #1 where the oscilloscope should be connected. Voltage range and gain should be adapted to the source signal from the external frequency generator which needs to be connected to a second channel of the oscilloscope to compare both signals on the oscilloscope screen.

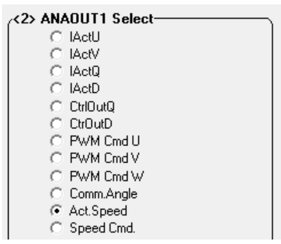


Figure 93 shows position step function of the external frequency generator compared with the actual speed signal. It is not possible to show the actual position directly on the oscilloscope, so the actual speed command is used as response signal from the position control loop.

After a step from the generator, the system drives until programmed position is reached. This causes the pulse of the speed command, which goes down to zero when programmed position is reached.

To adjust the position controller settings, it is useful to increase the generator frequency until the system cannot reach programmed end position any more and peak of the speed signal decreases visibly (figure 94).

Increase “Position Control: P gain” in the “POSITION CONTROL” tab until the speed command oscillates (figure 95) and reduce it again to a safe value with some margin.

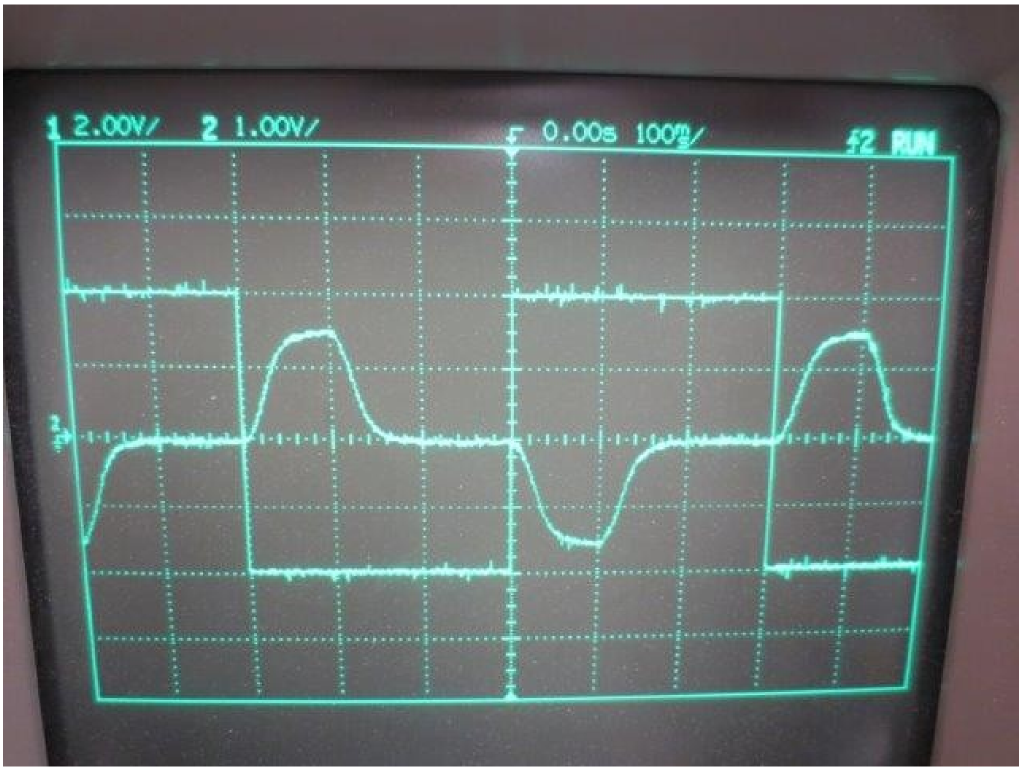


Figure 93: Position Controller: Position Step Function and Speed Command Response

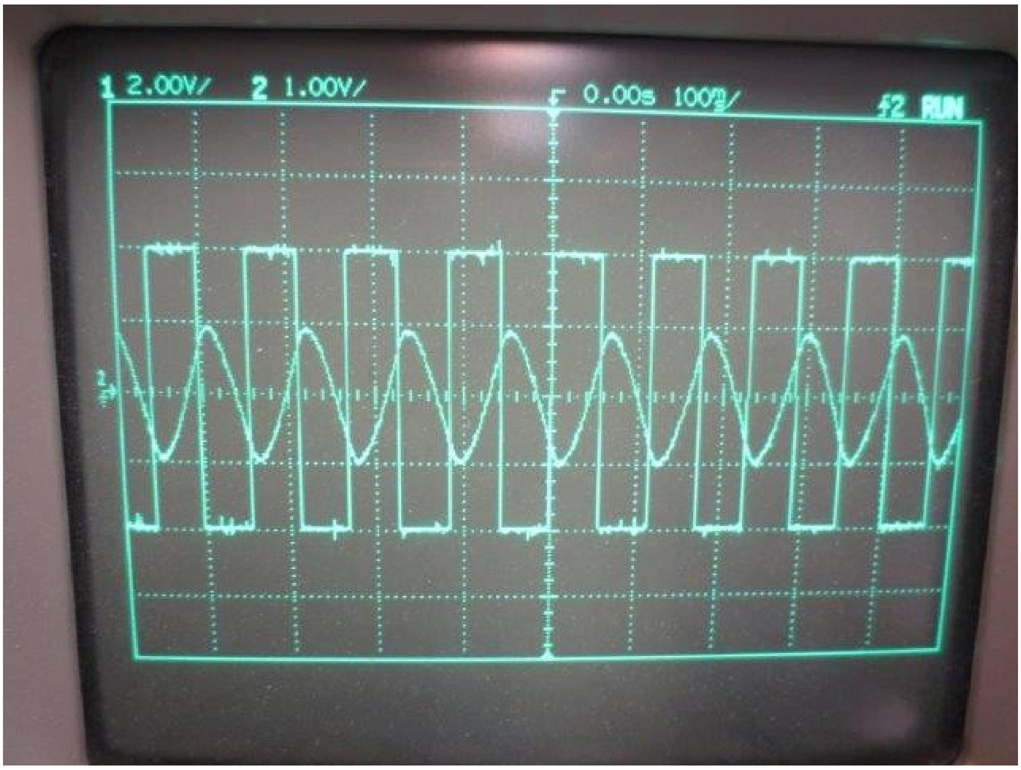


Figure 94: Position Controller Adjust: Position Step Function and no Oscillations on Speed Signal

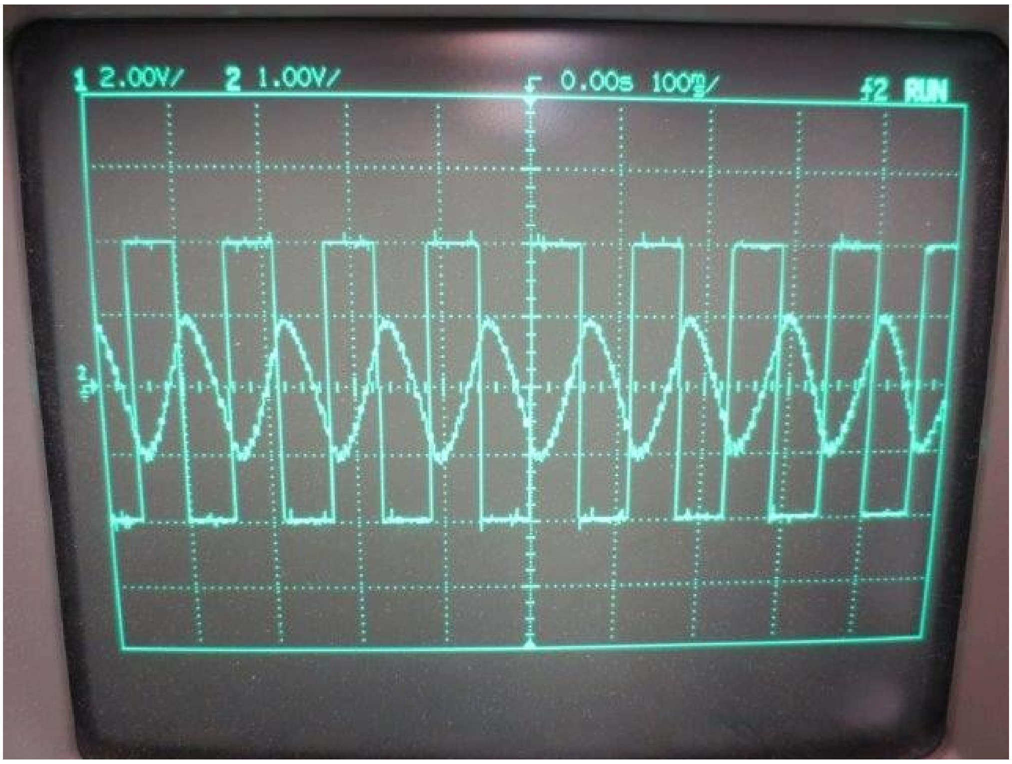
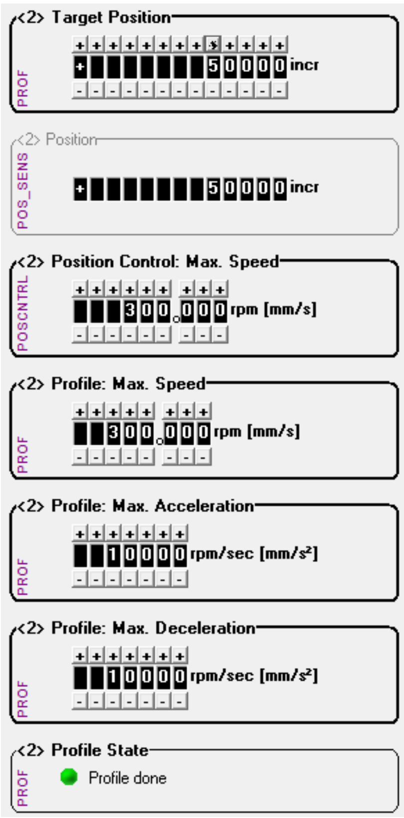


Figure 95: Position Controller Adjust: Position Step Function and Oscillations on Speed Signal

A movement profile can be programmed in the “POSITION CONTROL” tab defining “Target Position”, “Position Control: Max. Speed”, “Profile: Max. Speed”, “Profile: Max. Acceleration” and “Profile: Max. Decceleration”. After enabling the drive the profile will be executed and acknowledged when done from the “Profile State” display.



8.6 PWM Modulation Method

The SWM-family uses center-aligned PWM.

One advantage of this method is zero phase voltage ripple and current ripple at modulation points 50% / 50%, 100% / 0% and 0% / 100%.

Second advantage is effectively double PWM frequency at phase outputs while all power switches are working at single PWM frequency. This reduces the phase current ripple without increasing switching losses.

Additionally, the well known third harmonic injection method is implemented. This method can increase about 15% output power when the DC-link voltage is limited.

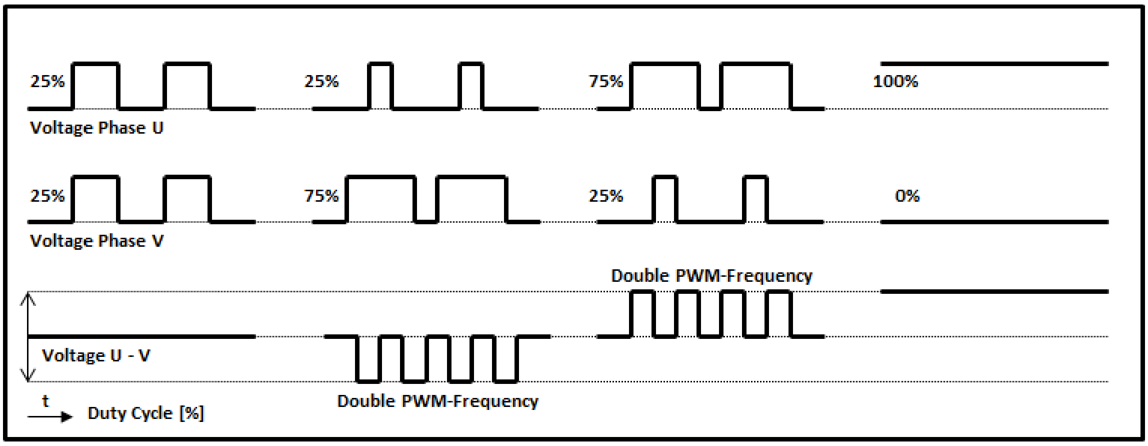


Figure 96: PWM Sequences

The SWM controllers often are used in motor test benches to drive the DUT (Device Under Test) motor. In these applications low current ripple is mandatory. One method minimizing the current ripple is the described PWM scheme.

Based on many years experience in this field, MACCON offers a special firmware for the SWM7 family optimized for applications where low current ripple is required and two electric motors are mechanically coupled at the shaft.

8.7 Trouble Shooting

Fault	Possible causes	Measures
Error Message: Communication fault	Wrong cable used	Use the original cable delivered together with each SWM
	Wrong PC interface selected	Correct COM port settings
	Problems with RS232/USB converter	Repeat driver installation procedure of the converter according to the converter manual
Motor does not rotate	SWM is still disabled	Check ENABLE settings and signal
	SWM in failure mode	Check failure display and fix the problem
	Power supply	Check main- and auxiliary supply
	Drive is mechanically blocked	Check mechanics, load and brake
	Motor definitions incorrect	Correct motor definitions
	Feedback sensor definitions incorrect or sensor defect or badly aligned to the motor shaft	Check feedback sensor, sensor definitions and mounting
	Hardware connections	Check all cable connections
Motor oscillates	Current- speed- or position controller settings wrong	Adjust settings of current- speed- and position controller
	Position or speed sensor defect or bad aligned to the motor shaft	Check feedback sensor, sensor definitions and mounting
	EMC problem	Check for broken cable shields and other EMC related issues
	GND problem	Check grounding
Drive reports following error	Irms or Ipeak set too low	Increase Irms or Ipeak (keep within motor ratings!)
	Acceleration / deceleration ramp is too long	Shorten ramp
Motor overheating	Wrong temperature limits	Define correct temperature limits and offset
	Irms/Ipeak or I*t time too high	Reduce Irms/Ipeak or I*t time
	Insufficient motor cooling	Check motor cooling system
Axis drifts at setpoint = 0 V	Offset not correctly adjusted for analog setpoint provision	Adjust offset (analog I/O)
	Ground Shift at analog control	Set control mode to PC and check if zero drift remains. If not connect AGND and controller GND

Tab. 8.20: Trouble Shooting for different Faults (Examples)

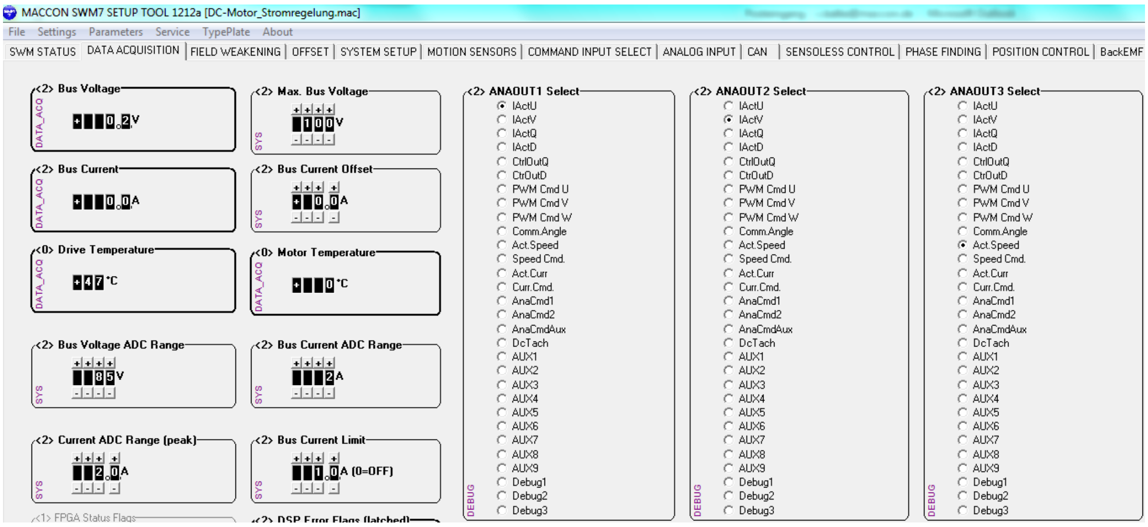
For other problems please contact MACCON technical support for further assistance.

8.8 Simple Start- or Debug Applications

Currents: DC-link, Phase, Measurement

To measure the motor current, the SWM provides three physical analog outputs which can be configured for different parameters, e.g. the phase current for the motor. These outputs are fast enough to connect an oscilloscope to measure transients. The percentage of the SWM7.exe display is just a quantitative parameter, not related to the maximum current of the type of SWM. For example: for a SWM7S-150-25-ET, 100% equals 75A. But this is not valid for all types of SWM.

The analog outputs for debug can be configured on the DATA AQUISITION tab (ANAOUT1/2/3):
Depending on the type of SWM, the analog outputs are available at different connectors, see the connector description for your type of SWM.



Please be aware that the motor current is not equal with the DC-link supply current. An example for a brushed DC-motor visualizes this effect:

If the SWM regulates a current of 1A in a mechanically blocked motor, the motor voltage of 2V is much lower than the DC-link supply voltage of 10V. In this example, the DC-link supply current would be only 200mA at a motor current of 1A. This is important for considerations of setting the current limit of the DC-link voltage source.

At pure inductive loads and high DC-link supply voltages, the phase current can be more than 100 times larger than the DC-link supply current. This is also valid for other types of motors.

If manual phase current offset adjustment should be required, please read carefully the part of this manual which explains the OFFSET tab of the SWM7.exe.

8.8.1 Brushed DC-Motor Direct Current Control

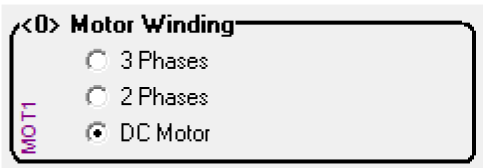

For tests and bringup, a low voltage of the DC-link supply can reduce risks. In this case, increasing the regulated current results in a maximum speed. Further increase of current does not further increase in speed, because the programmed DC-link voltage is limiting the speed of the motor. Increasing the DC-link voltage would increase the maximum speed. But: Increasing of the current always results in faster acceleration of the motor and in higher torque at a blocked motor, independent of the DC-link voltage. Exemption is when the DC-link voltage is that low that the SWM cannot drive the programmed current any more.

Do not reverse currents with changing current values or current offsets while the drive is enabled or the motor is rotating if your DC-link source is not able to sink energy or no braking chopper is used. This most likely will destroy the SWM and the DC-link source.

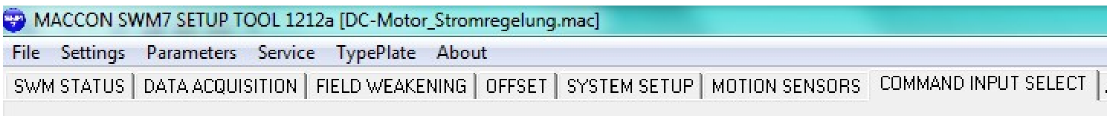
The following example describes how to drive a brushed DC-Motor in direct current control without any motion or position feedback sensor. This example is ideal for bring-up or debug of brushed DC-Motor applications. The following settings are mandatory:

First settings need to be done on the SYSTEM SETUP tab:

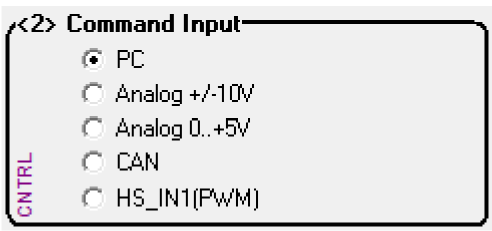
Define the motor as DC-motor.



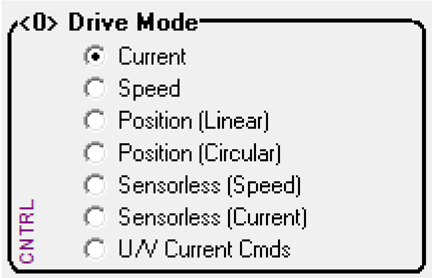
Settings need to be done on the COMMAND INPUT SELECT tab:



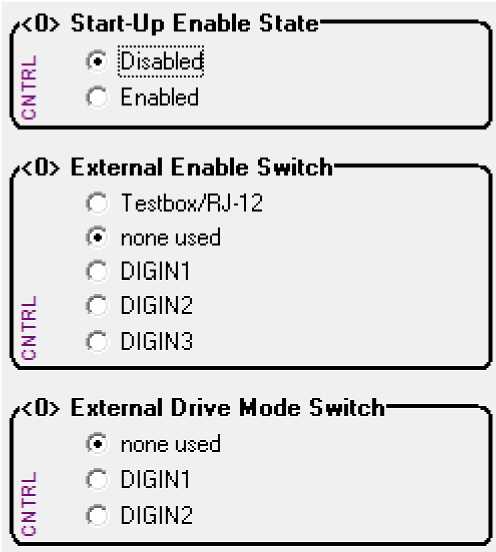
Define the PC as command input device.



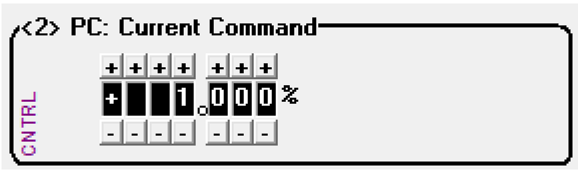
Set the drive mode to Current Control.



For save device handling without need of external hardware enable please set:



The motor current can be controlled with the following window:



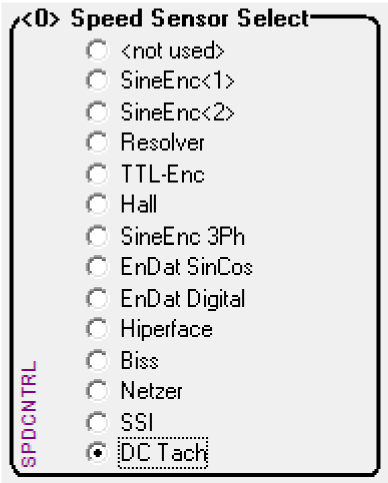
8.8.2 Adding a Tachometer Feedback Sensor for Speed Control

In this chapter, the pure basic current control of the motor will be extended to a speed control. As speed sensor, a tachometer is used.

After hardware connection of the tachometer, the following settings and changes in the SWM7.exe are required based on the previous pure current control example:

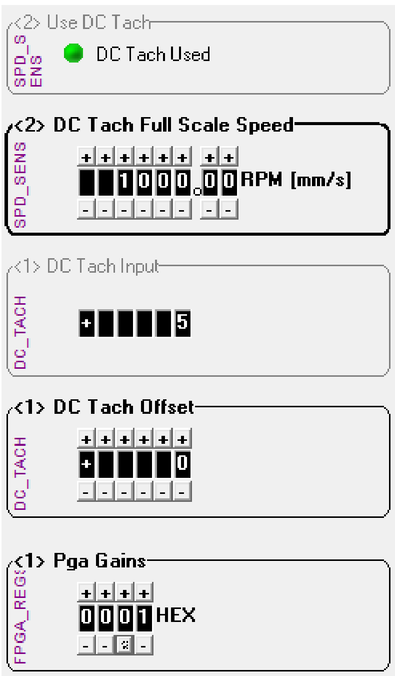
SPEED / CURRENT CONTROL tab

Choose the DC-tacho as speed sensor.



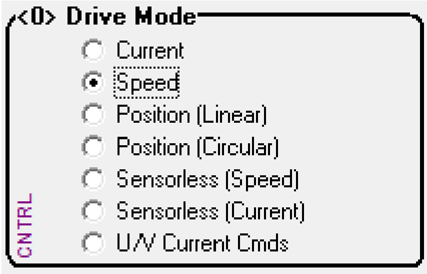
MOTION SENSORS tab

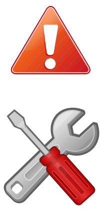
DC Tach Full Scale Speed: Full scale for the Tachometer input is -10V...+10V. Please define in this field the rpm-value at 10V tachometer output voltage from the tachometer specification.



COMMAND INPUT SELECT

Change the regulation mode from the current control of the previous example to speed control.





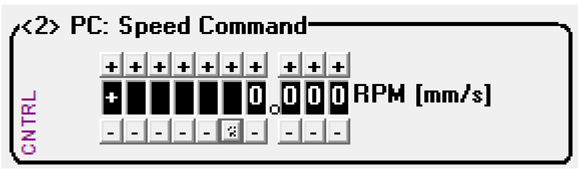
Please do not change the speed at enabled drive because decreasing the speed causes active braking, so the DC-link voltage source needs to be able to sink energy or a chopper is required in parallel to the source to burn braking energy in a resistor.

Active braking without chopper or DC-link source without energy sinking capability most likely will destroy the SWM and the DC-link source.

Please ensure that the maximum programmed speed is always with margin below the defined “DC Tach Full Scale Speed”. If the available tachometer does not fit to the required speed range, external adaptation circuitry might be required.

COMMAND INPUT SELECT

Use the PC: Speed Command to set the required speed.



8.8.3 Resolver-Setup

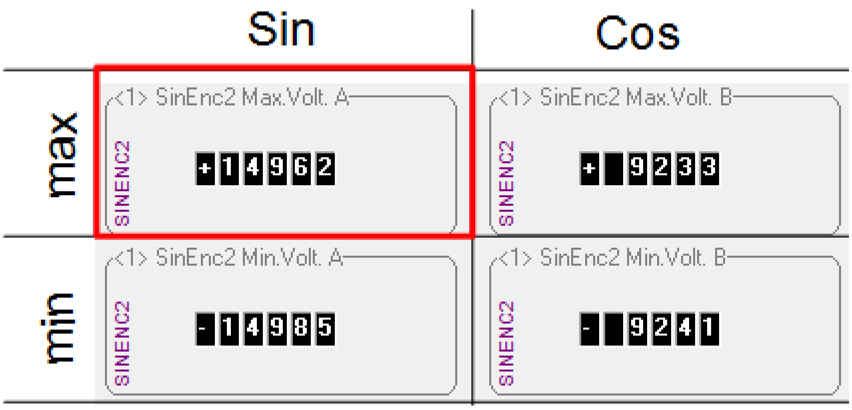
Example is a 3-Phase permanent magnet synchronous machine application. These motors need a position feedback sensor for commutation, even when they run in current control mode.

In this example, the position feedback sensor is a resolver, an absolute feedback sensor with the advantage of measuring the absolute position, even after a power cycle. A resolver needs to be adjusted once, ideally to zero offset angle while mounting to the shaft of the motor to compensate the offset angle between electrical motor position and measured position. Often, the offset angle is not zero, so this offset needs to be programmed into the motor controller. The adjustment procedure for an unknown resolver will be described later.

A resolver also can have multiple cycles on one turn of the motor shaft for better accuracy. This factor is important for the drive controller. Normally a resolver has one cycle per turn of the motor shaft. If the resolver is unknown, the following steps might help to find the multiplying ratio:

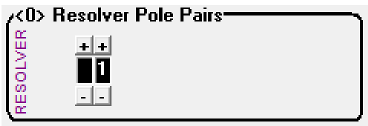
- mark shaft position (one point at the shaft and a second point at the motor housing)
- turn slowly the motor shaft one turn and look at the modulated resolver sin or cos signal.

Assuming no offset, the abs value of the min and max value for sin and cos should be nearly the same. Count the number of signal minima per turn. Write down the maximum abs value of “SinENC2 Max.Volt. A” which you noticed during one shaft turn. The Value should have margin to the maximum range limit of 32767 and should be above 12000. If it is not in this range, level adjustment of the sensor excitation signal is required, see below.



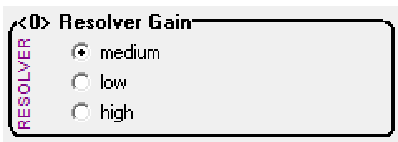
Peak values of modulated resolver signals

If two minima per shaft turn have been counted, in the “MOTION SENSORS” tab, the number of resolver pole pairs need to be set to 1. (4 counted minima are 2 resolver pole pairs…).



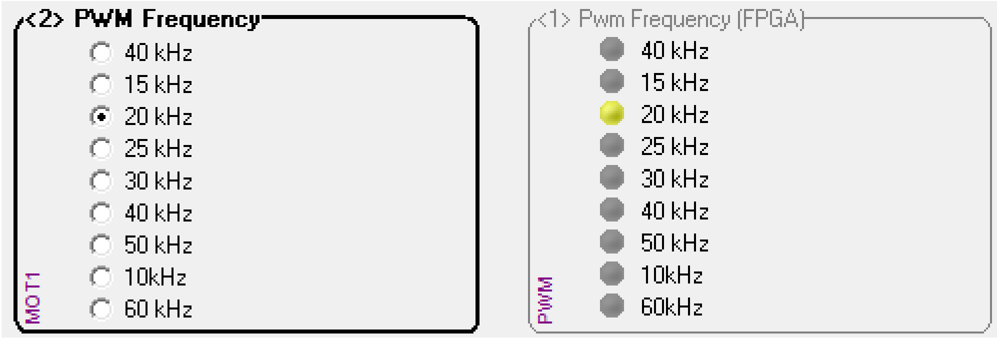
The resolver excitation can be adjusted in the “MOTION SENSORS” tab with the parameter “Resolver Gain”. Assuming “low” as gain 1, “medium” is gain 2 and “high” is gain 4.

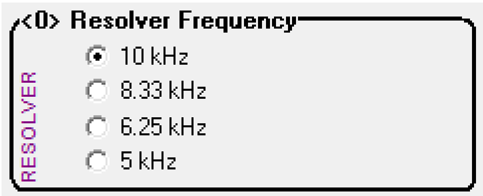
This compensates the transformation ratio between excitation coil and sin/cos receiver coils, which can be very different between different resolvers.



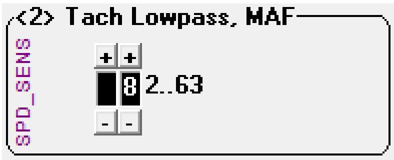
- Set the resolver input signal filter according to the PWM frequency of the SWM:

Check the actual PWM frequency in the “SYSTEM SETUP” tab and the actual resolver excitation frequency in the “MOTION SENSORS” tab:

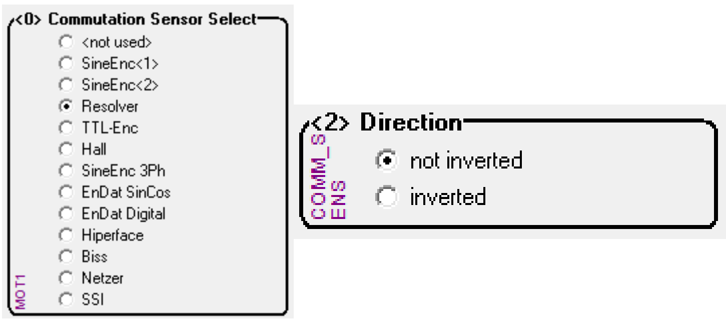




Combine both values with table 8.18 to generate the filter setting value in the “SPEED / CURRENT CONTROL” tab, the Tach Lowpass, MAF (Moving Average Lowpass Filter) value.



Now the resolver for motor commutation is configured. It still needs to be activated in the



“SPEED / CURRENT CONTROL” tab. Depending on which side of the motor the resolver is mounted, the signal can be inverted if required. Depending on the desired control mode, the resolver can be activated additionally for speed- or position control in the same tab at other control windows. If the resolver is defined for commutation only, current control mode is possible.

After defining the resolver settings, a phase finding procedure is required to align the electrical position of the motor to the resolver position. This procedure is described in the chapters

- 8.1.12 PHASE FINDING on page 127.
- Fehler: Verweis nicht gefunden Fehler: Verweis nicht gefunden on page Fehler: Verweis nicht gefunden.

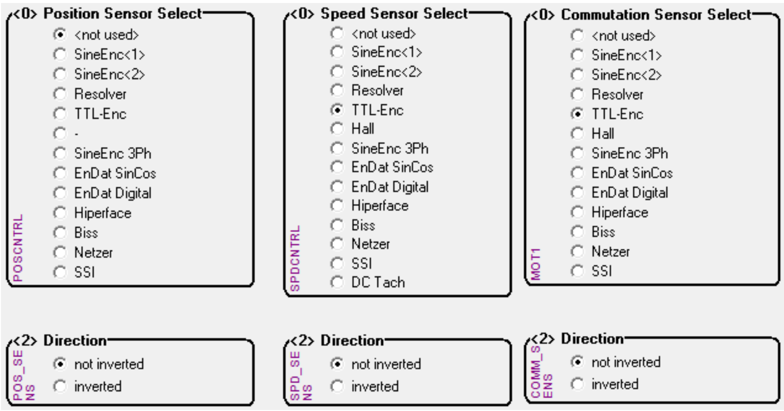
8.8.4 Encoder Setup

There are much different types of Encoders available. They can be different from:

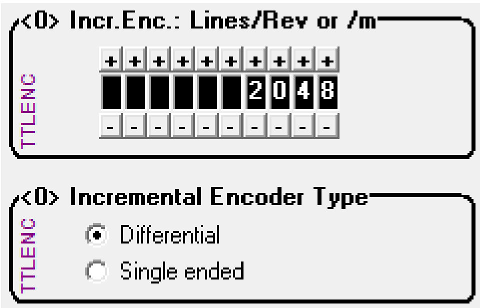
- the physical sensing technology (optical, magnetic, capacitive, …)
- the property (relative, absolute, single-turn, multi turn, …)
- their interface (single ended TTL, differential, ...)

The SWM supports a wide bandwidth of different types from both sides, the hardware interface side and the software parametrization side.

As first step, the SWM needs the definition of the type of feedback sensor. This can be defined in the “SPEED / CURRENT CONTROL” tab.

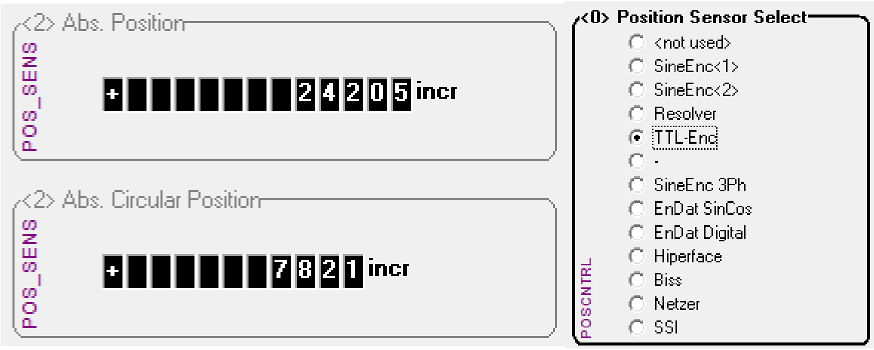


Then, the closer definitions of the chosen sensor need to be done. In the “MOTION SENSORS” tab, the resolution can be defined.



When the shaft of the motor is turned manually, the actual speed can be read in the “SPEED / CURRENT CONTROL” tab.

A check if the encoder works can be done in the “POSITION CONTROL” tab. Choose the actual sensor as position sensor. Turn the shaft of the motor one turn and read the “Abs. Position”. An encoder with 2048 lines/rev will show 8192 increments per turn. The reason for this is that signal A and B are 90° shifted rectangle signals. Each signal has one pulse per same line. Each pulse has a rising and a falling edge (slope). If each slope of both signals is taken for position sensing, four slopes per encoder line are available for position sensing. The number of counts is four times the number of lines.



The difference between “Abs. Position” and “Abs. Circular Position” becomes visible at more than one turn of the motor shaft:

The “Abs. Circular Position” in this example can reach a maximum of 8192, it shows the position of the shaft.

The “Abs. Position” can reach much higher values, after one turn of 8192 in this example, it keeps on counting in the second and more turns and shows the absolute position for multiturn applications.

When the “Position Sensor Select” is set to <not used>, the counters for “Abs. Position” and “Abs. Circular Position” will get a reset.

After defining the encoder settings, a phase finding procedure is required to align the electrical position of the motor to the encoder position. This procedure is described in the chapters

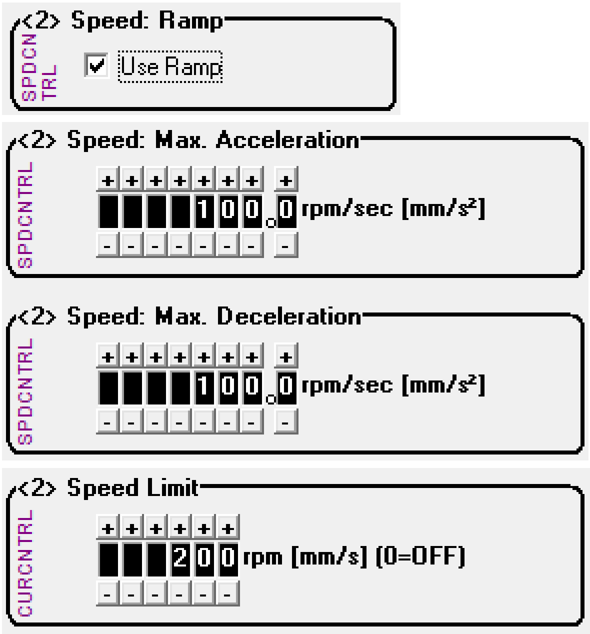
- 8.1.12 PHASE FINDING on page 127.

- Fehler: Verweis nicht gefunden Fehler: Verweis nicht gefunden on page Fehler: Verweis nicht gefunden.

8.8.5 Netzer Setup and Calibration

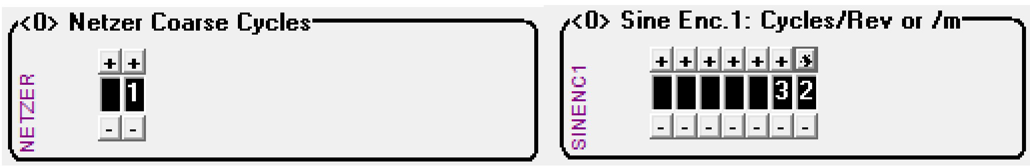
The basic settings for using a Netzer encoder need to be done in the “SPEED / CURRENT CONTROL” tab: “Commutation Sensor Select” and “Speed Sensor Select” need to be set to “Netzer”.

For safety reasons the following settings are strongly recommended to limit the mechanical reaction of the system during the setup and calibration process. After calibration, the acceleration ramp and the speed limit can be disabled again to reach full performance.



Further settings need to be done in the “MOTION SENSOR tab in the Netzer section.

Course and fine resolution of the Netzer need to be defined:



iv. Resolver Interpolation -> No Resolver

v. Hall sensor type -> None

Fenster Netzer

vi. Positioning P Gain, -> z.B. 1000

(Proportionalverstärkung des spezieller Positionsreglers;
verwendet zum automatischen Vermessen des Netzergebers)

8.8.6 3-Phase Permanent Magnet Synchronous Machine

A **p**ermanent **m**agnet **s**ynchronous **m**achine (PMSM), connected to an electronic motor controller, needs a commutation sensor even when the motor is driven in current control mode only.

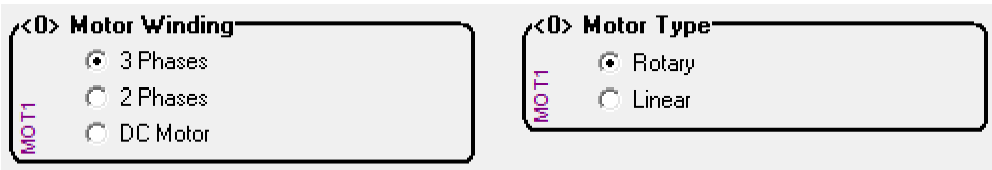
Based on the previous chapter, the commutation sensor of this example is a resolver.

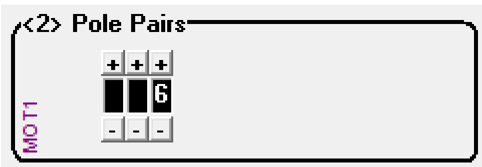
For tests and bringup, a low voltage of the DC-link supply can reduce risks. In this case, increasing the regulated current results in a maximum speed. Further increase of current does not further increase in speed, because the programmed DC-link voltage is limiting the speed of the motor. Increasing the DC-link voltage would increase the maximum speed. But: Increasing of the current always results in faster acceleration of the motor and in higher torque at a blocked motor, independent of the DC-link voltage. Exemption is when the DC-link voltage is that low that the SWM cannot drive the programmed current any more.

Do not reverse currents with changing current values or current offsets while the drive is enabled or the motor is rotating if your DC-link source is not able to sink energy or no braking chopper is used. This most likely will destroy the SWM and the DC-link source.

The following steps describe the required parameter settings in the SWM.exe:

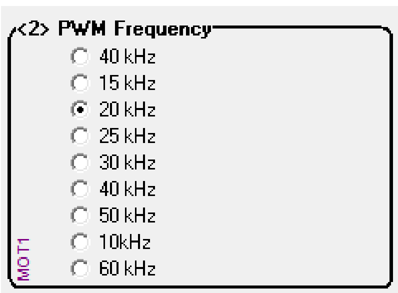
Define the type of motor in the “SYSTEM SETUP” tab:



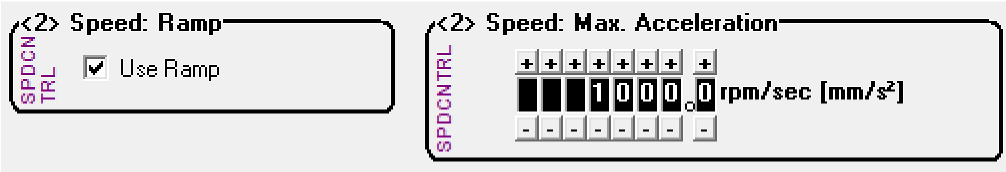


If the number of pole pairs is unknown it can be investigated in most cases: Turn the motor shaft manually one turn and count the number of magnetic ripples. Divided by the number of three phases will give the number of poles. Divided by two will give the number of pole pairs.

The PWM frequency for the controller is also defined in the “SYSTEM SETUP” tab:

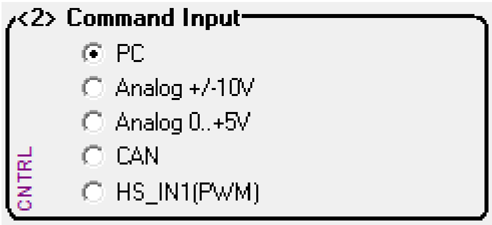


Define in the SPEED / CURRENT CONTROL tab an acceleration ramp. This is very helpful to smooth movements of the motor and to prevent the DC-link power supply to run into current limit at acceleration steps, if a small power supply is used for experiments or bringup:

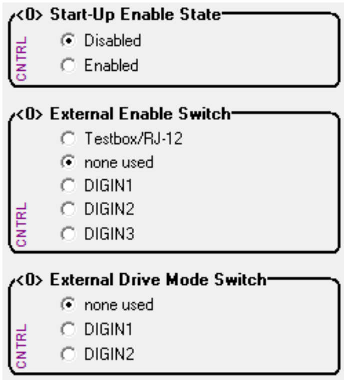


Assuming manual control mode via PC user interface, the "COMMAND INPUT SELECT" tab needs to be configured:

The PC is defined as command source:

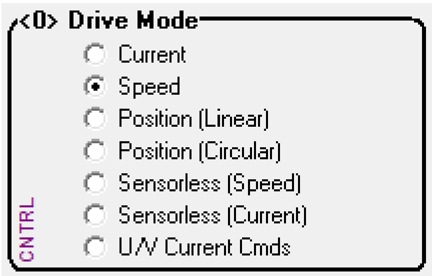


Start-up behaviour:

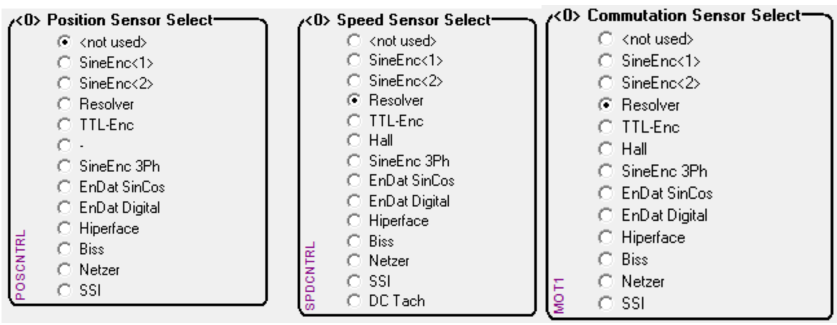


Set the „Drive Mode" to „Speed"

Choose the speed control mode:



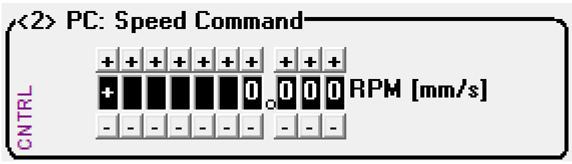
Now, the correct sensor setup needs to be defined which fits to the motor and the chosen control mode. This needs to be done in the "SPEED / CURRENT CONTROL" tab. Mandatory is the selection of the commutation sensor independent on the chosen control mode. For this example of the speed control mode, also the speed sensor needs to be defined, of course.



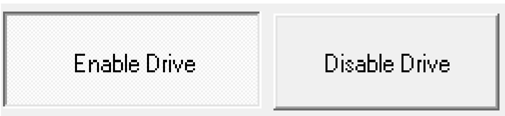
Now, the settings and calibration procedure for the chosen sensors need to be done:
If a resolver is used, please refer to chapter 8.8.3 Resolver-SetupResolver-Setup on page 176.
If an encoder is used, please refer to chapter 8.8.4 Encoder Setup on page 178.

Please change parameters only when the drive is disabled! Decreasing command parameters at enabled drive might not be possible!

Define a slow “PC: Speed Command” to set the shaft of the motor carefully into movement.



Enable the drive in the bottom line the “COMMAND INPUT SELECT” tab:



If the motor does not rotate properly, excluding hardware issues, this might have different causes in the parameter settings:

1. The commutation sensor settings might be incorrect. If a resolver is used, please refer to chapter 8.8.3 Resolver-SetupResolver-Setup on page 176 to debug the resolver settings For example, a resolver could have an offset between mechanical and electrical angle position. This offset can be adjusted in the “MOTION SENSORS” tab. If an encoder is used, please refer to chapter 8.8.4 Encoder Setup on page 178 to debug the encoder settings.

2. The current- or the speed controller might have wrong settings. These can be adjusted in the “SPEED / CURRENT CONTROL” tab.

If no failure can be found in the settings please check the hardware again in detail.