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SAMOTRONIC101 (4 636 6608 0)
SAMOTRONIC101 MPT (4 636 6608 3)

Manual – Motor driver unit for unipolar stepper

1. General Information

1.1. Intended operation

The SAMOTRONIC101 is a driver unit to control unipolar stepper motors with four phases in constant-voltage mode. The PCB is a complete power stage unit (driver) with internal step generator. The appliance may be used only for its intended purpose. This product is intended for use by qualified personnel like electrical engineers or special trained operators. The product is suited for tests in laboratories as well as under industrial operation conditions.

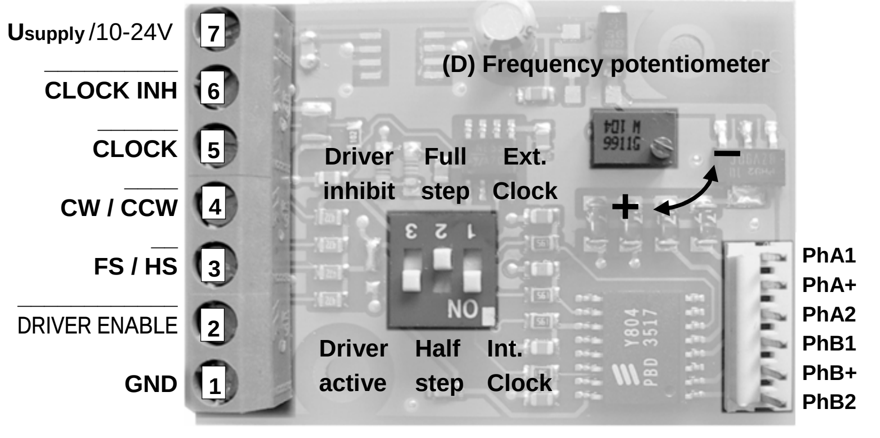
1.2. Safety instructions

Stepper motor operation can cause a high temperature increase of the electronic power stages and the motor parts. **There is danger of burns.** Do not exceed the limits specified in this manual. Please control the supplied voltage and check the maximum phase current in your application. Furthermore calculate the expected power dissipation for the connected stepper motor. Use only a power supply that is insulated against the mains supply, otherwise a fatal electric shock **could be caused.**

The SAMOTRONIC101 hasn't a short circuit protection or a current fuse. Please protect your appliance against shorts and incorrect current flows. Read this manual carefully to avoid injury and prevent damages. Take notice of special application hints and EMC requirements.

1.3. Quick start up procedure

Please unpack the PCB in an electrostatic discharge (ESD) free environment. Connect a unipolar stepper motor from Saia-Burgess with MTA100-receptacle to the terminal (B). To connect a motor type with wire ends please read the details in chapter 5. For a first test use the configuration settings of the DIP-switch (C) as shown in the figure below. Adjust the step frequency to the minimum setting by screwing the potentiometer (D) about 10 times in counter clockwise direction. Choose a laboratory power supply unit according to the required input power of the stepper motor for both phases. Do not apply a voltage to a terminal that is outside the range specified in this manual. Watch the polarity and connect the wires to terminal (A) pins 1 and 7. After power up the circuitry the motor starts continuously stepping.



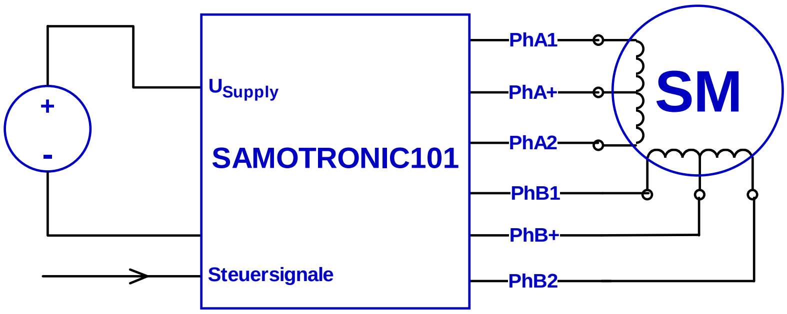
(A) Input terminal (C) Configuration switch SW (B) Motor terminal

2. Functional description

2.1. System overview

Stepper motors have a need for a driver circuit, which energizes the windings in the right order. Switching the phases results in a rotation of the stator magnetic field. The permanent-magnetic rotor follows and moves the motor shaft. The frequency between two switching points is named step frequency f_S. You can calculate the speed n in revolutions per minute with this step frequency and a specific step angle of the motor α_S by the equation below.

The driver unit SAMOTRONIC101 operates in constant-voltage mode. With external control signals you can control the driver behavior like direction, half stepping and start/stop procedures. An external clock generator initiates a step with each falling edge at the clock input \CLOCK. Optional an internal clock generator can be used by selecting a DIP-switch on the printed circuit board. In this mode the step frequency can be adjusted by a potentiometer.



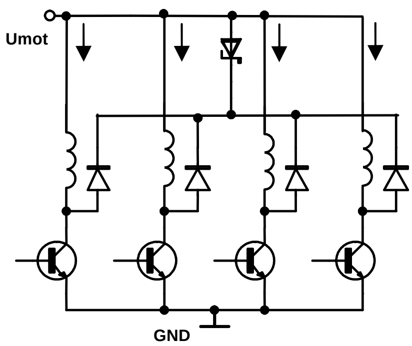
$$n := \frac{\left(f_S \cdot \alpha_S \cdot 60\ s\right)}{360\ \text{Grad}}$$

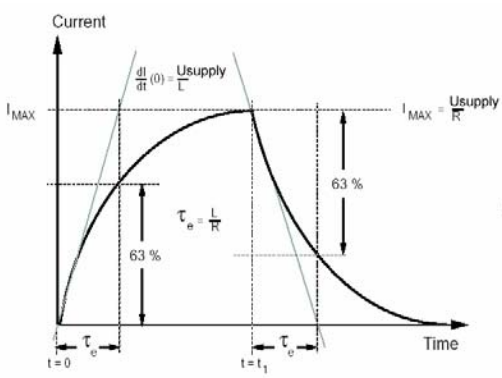
(n: speed [1/min])

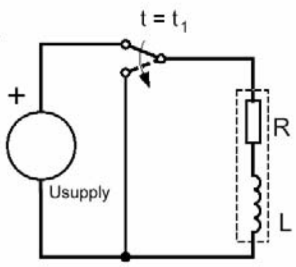
A constant voltage source U_{Supply} supplies the logic part of the electronic and the common motor pins of the phases PhA+/PhB+. Only four low-side switches are required to switch the motor phases PhA1/PhA2/PhB1/PhB2 to ground potential GND. For the right pattern of the phase signals the integrated circuit NJM3517 (JRC) includes a state machine for half step mode and full step mode.

2.2. Constant voltage mode

Constant voltage mode for a unipolar motor requires only four transistors and this is the lowest cost stepper motor driver circuit. The supply voltage U_{Supply} is lead directly to center-tap of each stator winding. Flux direction is reversed by switching the current from one half of a stator winding to the other half. For an easy modeling let us assume an ideal transistor switch and a series of a resistance and an inductance. After switch on a constant voltage impulse over the winding by a transistor, the current rises exponentially up to the time t_1. For an everlasting impulse the current reaches I_{MAX}. This maximum is only limited by the phase current of the motor current. Do never exceed the limits of SAMOTRONIC101 specified in this manual!



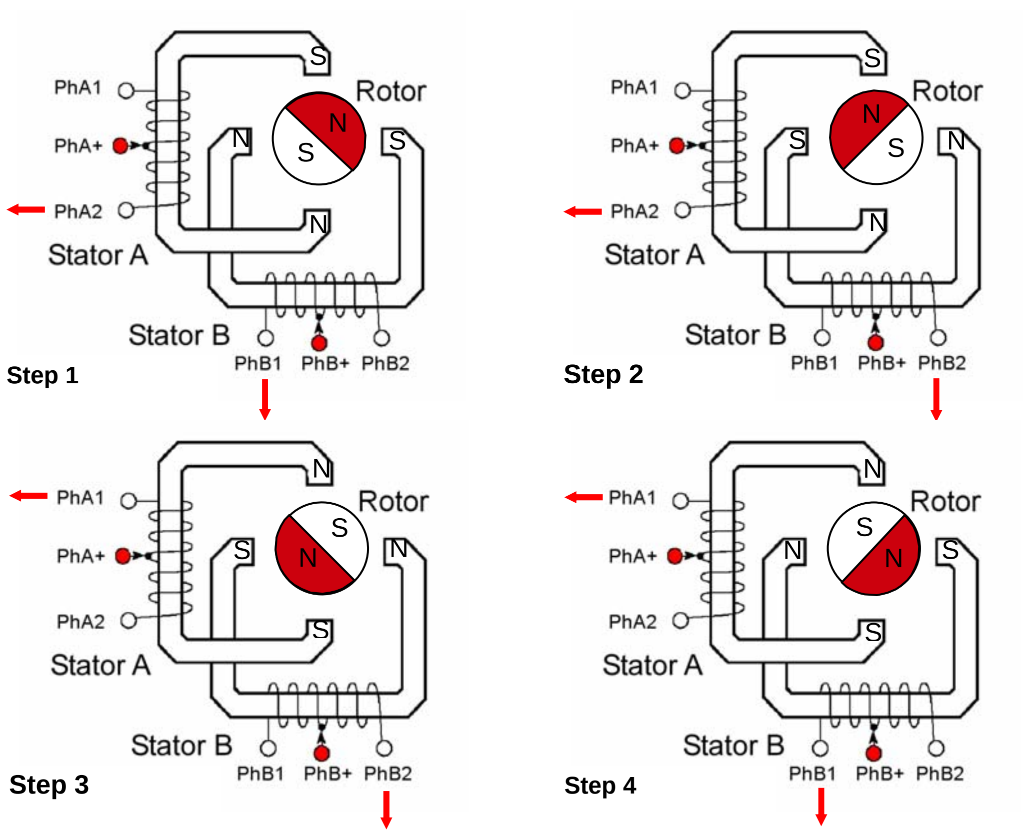




2.3. Full and half step mode

The SAMOTRONIC101 supports two step modes: full step operation with four steps and half step operation with 8 steps. For the following discussions please refer to the figure below. It shows the **Full step operation** at a simple two-phase stepper with only two poles. Therefore this model has a mechanical step angle of 90° and needs only four steps for one complete revolution. Classic tin can motors have much more poles and act with step angles 7.5°, 11.25°, 15° or 18°. In this way a motor with step angle 15° takes 24 steps for one revolution.

Our simple model shows, both common motor pins PhA+ / PhB+ are supplied by the motor supply voltage continuously. In **Step 1** two transistors switch the wire ends phase PhA2 and PhB1 to ground. The energized coils generate a magnetic field and the rotor aligns between two magnetic stator poles. Note, in full step mode you are energizing two phases at any given time. In **Step 2** we change the direction of the magnetic field in stator B by energizing PhB2. The magnetic vector is shifted 90° forward. The rotor follows with a counter clockwise movement. In **Step 3** stator A is changed, stator B keeps its polarity. **Step 4** completes one revolution in this model. If we perform the sequence backwards, the motor will run clockwise.



Half step mode means that at every second step only one stator half is energized and 8 steps are needed to repeat the signal pattern. Between the fist step and the second step in the drawing above stator B is completely switched off. Now the rotor north pole is aligned to the stator south pole and the rotor south pole to the stator north pole. With such additional positions between full step alignments the motor moves only the half angle of full stepping. With the same step frequency the motor shaft rotates in half step mode only at half the speed of full step mode. Furthermore, the motor torque is less, because the de-energized stator does not contribute to the force. Advantages of this principle are smoother movement, lower noise emission and less resonances of the motor.

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3. Terminals and control elements

3.1. Inputs

This chapter describes the functionality and the rating of the input terminals (A).

Nr.	Name	Function	Level	Description
7	Usupply	supply voltage	10 … 26,4VDC	common positive supply line for logic and motor
6	$\overline{\text{CLOCK INH}}$	stop internal clock generator	low active signal	**Attention, motor stops, but the coils are still energized!** **Attention, do not supply an active signal to this input! Please use either a mechanical switch or a transistor with open collector to switch to ground potential GND!**
5	$\overline{\text{CLOCK}}$	external step frequency input	LS-TTL (0 …5V) low active signal	a falling edge on this input line results in one step according to the internal stepping state machine **Attention, switch off the internal clock source (SW1=OFF)!**
4	CW / $\overline{\text{CCW}}$	direction of movement (view on the motor shaft side)	LS-TTL (0 …5V) low active signal	open input is interpreted as high signal, the motor runs clock wise if a low signal occurs the motor reverses its direction to counter clock wise (the direction depends on the motor wiring, please check it)
3	FS / $\overline{\text{HS}}$	driver mode	LS-TTL (0 …5V) low active signal	open input is interpreted as high signal, the motor runs in full step mode (4steps with two coils on) if low level on this pin occurs, motor runs in half step mode **Attention, switch off the internal pre selection (SW2=OFF)!**
2	$\overline{\text{DRIVER ENABLE}}$	enable signal for the power stage	LS-TTL (0 …5V) low active signal	open input is interpreted as high signal and switches off all phase outputs, the motor is not energized and produces only its detent torque low level on this pin enables the current output pattern **Attention, switch off the internal driver inhibit (SW3=OFF), otherwise the motor stops generally**
1	GND	ground potential	GND	negative potential for the supply voltage of motor, logic and input signals

3.2. Frequency potentiometer

With potentiometer (D) the internal clock source can be adjusted. Watch the frequency stability, because the internal clock generation is based on a simple RC-oscillator!

Function	Range	Tolerance	Note
Adjustment of internal clock generator	50 … 360 Hz	+/-20%	absolute tolerance over the whole range
		<10%	frequency stability after adjustment

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3.3. Power outputs

This chapter describes the technical details of the motor outputs (B). See the terminal position on page 1 and the relevant wiring for the unipolar motor on page 2.

Name	PhB2	PhB+	PhB1	PhA2	PhA+	PhA1
Function	open collector-output	motor supply voltage	open collector-output	open collector-output	motor supply voltage	open collector-output
phase current I_{max}	350mA	-	350mA	350mA	-	350mA
U_{sat} (I=200mA)	0,30V	-	0,30V	0,30V	-	0,30V
U_{sat} (I=350mA)	0,60V	-	0,60V	0,60V	-	0,60V

The output stages consist of four open-collector transistors. Each transistor can carry a maximum current of 350mA. A voltage drop, specified as saturation voltage, occurs over each transistor being switched on. This voltage drop depends on the phase current (see the differences in the table above). The free wheeling circuit includes a Zener-diode Uz=10V. Based on this component the phases are de-energized rapidly when being turned off. Resulting from this higher operating frequencies and higher output torques can be reached. A disadvantage is the lost energy in the Zener-diode which results in cooling problems. Please, check the maximum allowed step frequency in chapter 4.3.!

SAMOTRONIC101 is available in two versions with two motor terminals. You can choose between a “Tyco” plug and play connector and a flexible “Phoenix Contact” screw terminal.

Version	ASN	Connector on PCB	Required motor cable
SAMOTRONIC101	4 636 6608 0	MTA100-6 header	MTA100-6 receptacle for AWG26: ASN 4 408 4892 0 AWG24: ASN 4 408 5042 0 motor cable with connector B for UBL: ASN 4 408 5044 0
SAMOTRONIC101 MPT	4 636 6608 3	MPT 0,5/6-2,54 screw terminal	wires up to 0,5mm² cross section (AWG26/24/22)

If you want to connect an unknown motor with wires to the SAMOTRONIC101 MPT, you have to find out the true wiring. Please check the motor ends with an ohmmeter. Use only the three wires of first stator half. Find out one wire number „1“ which has the same resistance to two other ends „2“ and „3”. Wire „1“ is then the common pin, please connect this line to “motor supply voltage” of motor terminal (B). Both ends „2“ and „3“ are then coil ends, please connect these coil ends to Phx1 und Phx2 of the first stator. Repeat the test procedure for the other half.

3.4. Configuration switches

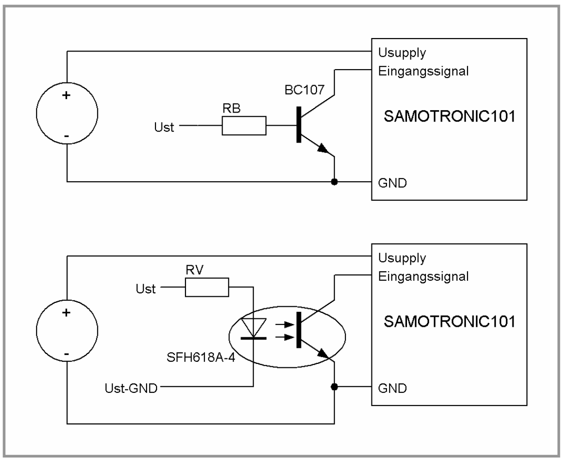
This chapter describes a setup via a DIP-switch SW (C) of the supported different operation modes. Keep in mind, there is a relationship between the setup done by the DIP-switches and the input channels. Please switch off all DIP-switches to use input signals.

SW Nr.	„ON“	„OFF“	Description
1	internal clock enable	use a extern clock	use input pin 5 to apply an external clock or measure the frequency of the internal clock
2	half step mode	full step mode	half step mode results in half motor speed and less motor torque
3	driver enable	driver inhibit	with driver enable motor coils are energized

4. Special application hints

4.1. Connection to a master control unit

Very simple means for master control are switches, connected to the input pins. Based on the low-active input logic there is need to switch against ground potential GND. For high-level the inputs are pulled up to the logic supply rail.



Furthermore, some of the input channels can not be driven by active logic levels. To use a microcontroller or a programmable logic control unit (PLC) as master controller in front of the SAMOTRONIC101, one of the following two interface circuits are required. Practical resistance values are: RB=10kΩ with Ust=5V...24V and RV=1,8kΩ with Ust=5V or RV=12kΩ with higher voltage Ust=24V.

4.2. Start-stop-procedure

The load torque at which a stepper is able to start without losing synchronization depends on the load inertia and the step frequency. The higher the start frequency the lower the starting torque. The pull-in curve defines an area referred to start-stop region. This is the maximum frequency at which the motor can start and stop, at a certain load torque, without losing steps.

To reach higher operating frequencies there is need for a ramp. This means an acceleration and deceleration of the motor by using different step frequencies. To start the motor you increase the step frequencies from a low frequency value (start frequency) to the higher operation frequency. Typically this procedure takes 5 to 10 steps only.

The SAMONTRONIC101 doesn't support automatic ramp generation. With the internal clock generator you can only work in start-stop-mode. If higher operating frequencies are required or your application has a high inertia, we recommend using an external clock source and increasing the speed slowly.

4.3. Check of operating frequency

The SAMOTRONIC101 includes a Zener-diode to make the current decay faster. Motors with relative high time constants ($\tau = L/R$ >1ms) have longer decay times. If a phase current is from one coil to another, the current will circulate through the free wheeling path. Mainly the Zener-diode consumes the lost energy. This leads to a strong temperature rise in this component (P_{max}=0,5W). Each new step repeats this cycle. Use the following expression to check the maximal permissible step frequency for a special stepper motor.

$$f_{MAX}\,(Hz) \approx \frac{100 \cdot R_{Phase}\,(\Omega)}{I_{MAX}\,(A) \cdot L(mH)}$$

Based on this simple equation a 12V winding motor, series UFB2 with a phase resistance 61Ω and phase inductance L=90mH (defined for 100Hz), can't work beyond of 340Hz operating step frequency. This is the upper limit for a reliable operation under all specified conditions. With a higher supply voltage of 18V (duty cycle permissible only 45%) the upper limit is only 230Hz. We recommend you to check the surface temperature of the Zener-diode in all critical applications.

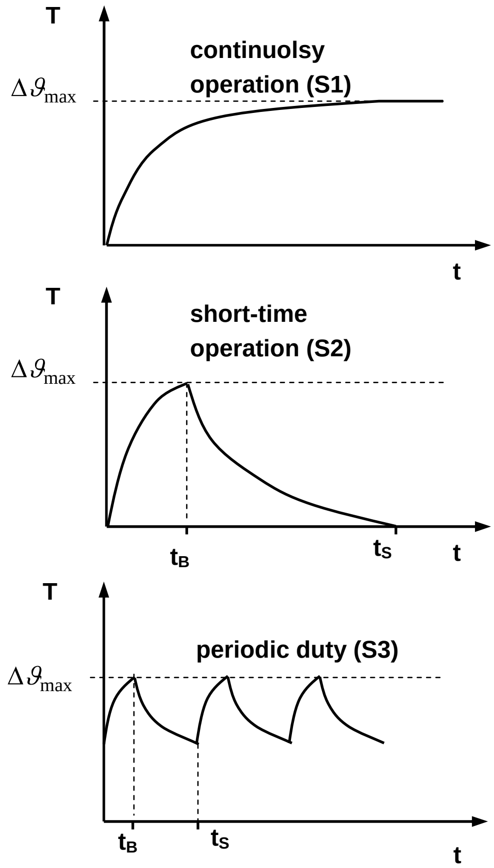
4.4. Motors with reduced duty cycle ED

Stepper motors with reduced duty cycle are used in many applications to increase the output power. This means the motor works with higher ratings, but not continuously. After an ON-TIME in common operation the motor stops for an OFF-TIME. In this break without movement and theoretical without holding current the motor cools down to the ambient temperature (see figure, S2). The whole period is named CYCLE TIME t_S. The Saia-Burgess standard cycle time is five minutes, except for the small series like URG.

The ratio of ON-TIME and CYCLE TIME is the DUTY CYCLE (ED), often used in percent. DUTY CYCLE, alternatively named DUTY RATIO or RELATIVE ON-TIME, is very important for short-time operation and specified for all customer specific windings.

With the following calculation you can determine a higher supply voltage for a stepper motor application with reduced duty cycle.

From the Saia-Burgess catalogue the user gets the coil resistance of a selected motor. The motors are designed for continuously operation (ED=100%, see figure, S1) under the condition of rated voltage (U_N). The rated power of one stator is given by:



$$P100 = \frac{(U_N)^2}{R_{Phase}}$$

For a short time higher power dissipation can be accepted. This input power Px for short-time operation depends on the rated power P100 and the expected duty cycle in the application ED. Remember, don't exceed the cycle time of the motor (5 minutes).

$$Px = \frac{P100}{ED}$$

With the next equation you get the supply voltage Ux for your short-time application:

$$Ux = \sqrt{R_{Phase} \cdot Px}$$

Keep care and do not use a holding current in the OFF-TIME duration, use DRIVER ENABLE\ to switch off all outputs.

4.5. Check of supply voltage

For a given motor, with defined coil resistance, we want to check the supply voltage. Are the maximum phase currents within the specification? Check it by the following expression and note, this easy calculation is always needed.

$$I_{MAX} = \frac{U_{Supply}}{R_{Phase}}$$

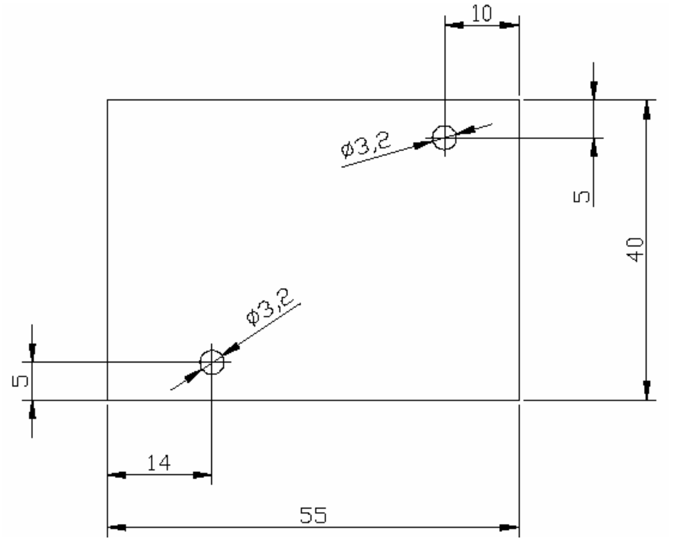
5. Specifications

5.1. Technical details

Following see the absolute maximum ratings and the mechanical dimensions.

Operating temperature range:	-5°C … 50°C
Storage temperature range:	-20°C … 70°C
Supply voltage range:	10VDC … 26,4VDC
Maximum step frequency:	2kHz (external clock source required)
Maximum phase current:	0,35A

Mechanical dimensions:



5.2. EMC requirements and standards

The product SAMOTRONIC101covers all rules according to the EMC-directive 89/336/EEC and is in accordance with:

emission:
EN55011:1998+A1:1999+A2:2002, class B

immunity:
EN61000-6-2:2001

The CE marking on the product and our EC declaration of conformity are related only to the EMC-directive. Saia-Burgess tested the EMC requirements under typical working conditions like maximum voltage and maximum phase current. Saia-Burgess didn't test under all possible operating conditions of later customer applications. Therefore you should regard the following hints.
The product requires a case against electrostatic discharges or an antistatic ambient. The cable length of each control wiring is limited to max. 3meters. To use an external clock source we recommend a shielded or twisted pair signal line. Keep the motor lines as short as possible.

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Smart solutions for comfort and safety

EG-Konformitätserklärung

Hersteller
Name / Anschrift: Saia-Burgess Dresden GmbH, Wilhelm-Liebknecht-Strasse 6, 01257 Dresden

Wir erklären hiermit in alleiniger Verantwortung, dass das folgende Produkt Schrittmotoransteuerung in der gelieferten Ausführung

Produktbezeichnung: **SAMOTRONIC101**
SAMOTRONIC101 MPT

Serien- / Typbezeichnung: 4 636 6608 0, 4 636 6608 3

auf das sich diese Erklärung bezieht, den Bestimmungen folgender EU-Richtlinien:

- **89/336/EWG** über die elektromagnetische Verträglichkeit

und folgenden harmonisierten Normen entspricht:

EN 55011:1998+A1:1999+A2:2002, Grenzwertklasse B	Industrielle, wissenschaftliche und medizinische Hochfrequenzgeräte (ISM-Geräte) — Funkstörungen — Grenzwerte und Messverfahren
EN 61000-6-2:2001	Elektromagnetische Verträglichkeit (EMV) — Teil 6-2: Fachgrundnormen — Störfestigkeit — Industriebereich

Geprüft von der zuständigen Stelle 0494
(Prüfbericht 1096-04-EE-04-PB001)
SLG Prüf-und Zertifizierungs GmbH
D-09232 Hartmannsdorf / Chemnitz

Diese EG-Konformitätserklärung verliert ihre Gültigkeit, wenn das Produkt ohne Zustimmung umgebaut oder verändert wird.

Dresden, den 10.9.2004

ppa. Peter V. Rauchfuß
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