TMC428 – Application Note

Stepper Motor Driver A3972 on TMC428

TRINAMIC Motion Control GmbH & Co. KG
Sternstrasse 67
D – 20357 Hamburg
GERMANY

P +49 - (0) 40 - 51 48 06 - 0
F +49 - (0) 40 - 51 48 06 - 60
www.trinamic.com
info@trinamic.com

This application note describes, how to control the A3972 with the TMC428 stepper motor controller. It is intended to be a step-by-step guide in addition to the datasheets of the two devices, that are recommended to be read first.

For TRINAMIC stepper motor drivers, the configuration of the driver datagram is described within the TMC428 datasheet. TRINAMIC drivers TMC236 / TMC239 / TMC246 / TMC249 are recommended for new designs, due to their low power dissipation without the need of external Schottky diodes, and because they provide status information for temperature, over current, under voltage. Additionally, the TMC246 / TMC249 provide the sensorless stall detection StallGuard^{TM}.

Hardware Setup

When using more than one A3972 driver chip, the 16-pin version of the TMC428 cannot be used, because this driver doesn't support daisy chaining (see chapter "general description" in the TMC428 datasheet for further details). For the A3972, individual chip select signals need to be used as provided by the 20/24 pin package (see Figure 1).

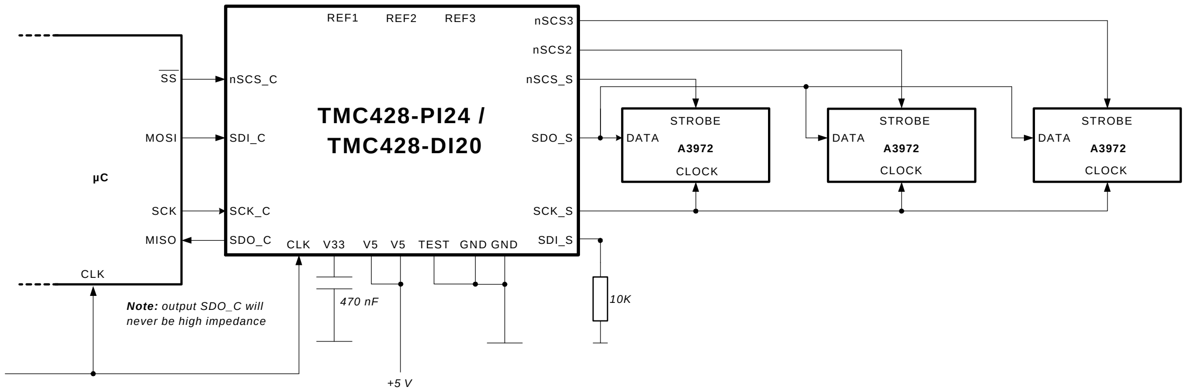


Figure 1 : interfacing up to three A3972 drivers with individual chip select lines

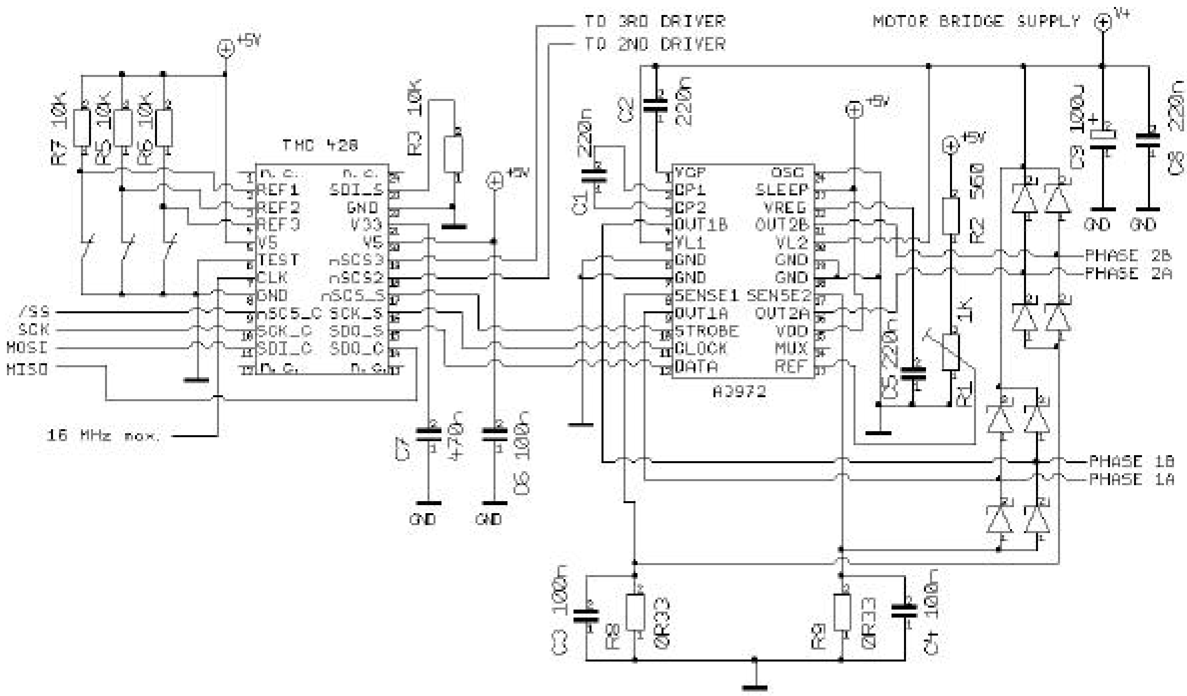


Figure 2 : setup of the TMC428 with one A3972 driver

To avoid further pitfalls caused by incorrect driver pin usage, the following schematic shows the complete setup for one driver (see Figure 2).

In this example, the maximum phase current is adjusted by a potentiometer. This current only represents the upper current limit, since the TMC428 provides three different registers for the phase current at rest and different accelerations (see "register description" in the datasheet). If the phase current is higher than approximately 0.75A, external Schottky diodes (e.g. SB560) are required. They can also be necessary, when the motor coils show high inductance and/or the step frequency is very high.

Note that the maximum DC phase voltage becomes an irrelevant value, when the maximum phase current limit is respected. For good dynamic performance, especially when using microstepping, the motor bridge supply voltage should be as high as possible (but must not exceed 48 volts).

Driver Datagram Configuration

The A3972 has one internal 19 bit wide register for the stepping data ("word 0") and another register for configuration data ("word 1"). At first we'll focus on the "word 0" datagram, looking only at a single driver on the TMC428, to understand the interfacing principle.

Configuration of the A3972 "word 0"

During operation, the TMC428 sends out the word 0 datagram for every new micro step. The bit order of this datagram has to be configured individually for the desired type of driver. One byte for the definition of each datagram bit is provided in the RAM area of the TMC428. The following scheme shows how the internal parallel outputs ("primary signals") of the TMC428 are first serialized for transmission and de-serialized afterwards inside of the A3972 (see Figure 3).

We see that the logical links realized by the RAM cells of the TMC428 have to adapt to the hard-wired, specific bit order of the driver. The RAM area for the driver datagrams (driver chain) starts at the hexadecimal address $80, which represents the first bit(s) to be sent.

Note that the TMC428 RAM is organized in registers, where one register of this area contains two bytes. They are referred to as "even" and "odd", as they can be numbered from zero to 31 within their area. In the following example, the eight bit wide absolute addresses are used. The 8 bit addresses increment in steps of two, because the LSB of the TMC428 address byte is the read/write bit. Further details can be found in the chapter "RAM Address Partitioning and Data Organization" of the TMC428 data sheet.

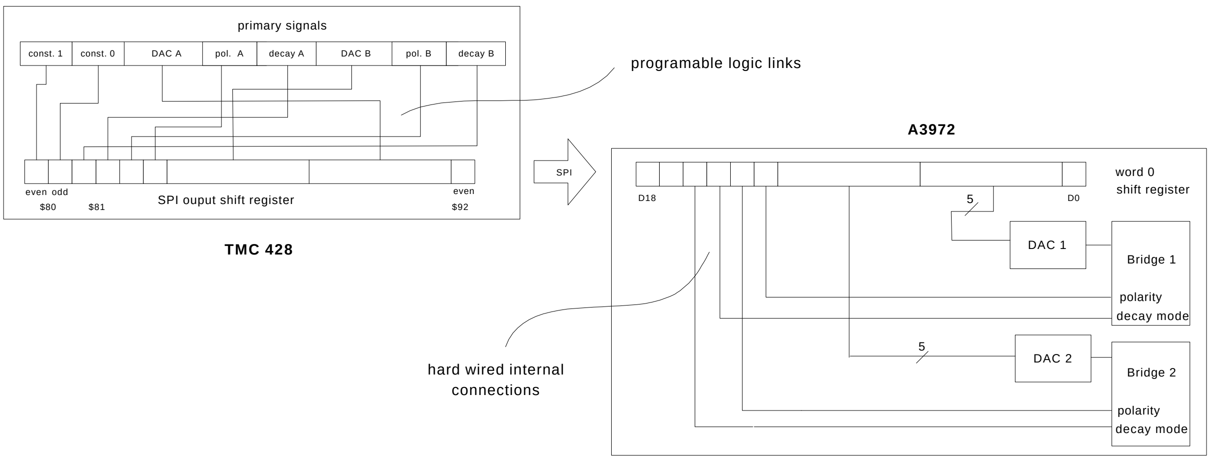
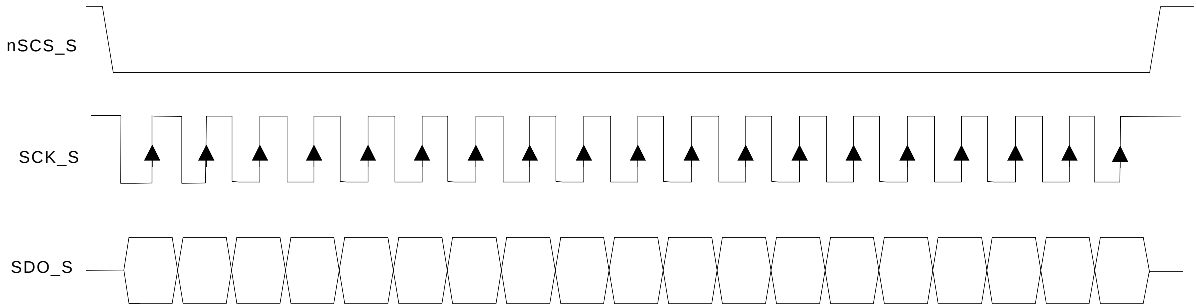


Figure 3 : phase data transmission - signal paths from the TMC428 logic to the A3972 bridges



A3972 index	D18	D17	D16	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
A3972 function	range	ref select	bridge2 mode	bridge1 mode	bridge2 phase	bridge1 phase	DAC2, MSB	DAC 2, bit 5	DAC2, bit 4	DAC 2, bit 3	DAC2, bit 2	DAC 2, bit LSB	DAC1, MSB	DAC1, bit 5	DAC1, bit 4	DAC1, bit 3	DAC1, bit 2	DAC1, LSB	word select = 0
TMC 428 RAM addr.	$80 even	$80 odd	$82 even	$82 odd	$84 even	&84 odd	$86 even	$86 odd	$88 even	$88 odd	$8A even	&8A odd	$8C even	$8C odd	$8E even	$8E odd	$90 even	$90 odd	$91 even
TMC 428 signal code	$10	$11	$07	$0F	$06	$0E	$05	$04	$03	$02	$01	$00	$0D	$0C	$0B	$0A	$09	$08	$30
TMC 428 signal	constant 0	constant 1	fast decay A	fast decay B	phase pol. A	phase pol. B	DAC B, bit 5	DAC B, bit 4	DAC B, bit 3	DAC B, bit 2	DAC B, bit 1	DAC B, bit 0	DAC A, bit 5	DAC A, bit 4	DAC A, bit 3	DAC A, bit 2	DAC A, bit 1	DAC A, bit 0	constant 0 and NxM_0

Figure 4 : timing diagram of the "word 0" datagram with description of every bit position

A complete list of the TMC428 signal codes is shown within the TMC428 datasheet (Chapter "Stepper Motor Driver Datagram Configuration"). The signal codes are only 5 bits wide (bits 0 to 4), while the sixth bit (bit 5) is used to increment the internal driver address counter. This bit is called "NxM" ("Next-Motor bit"). In this example, the increment is initiated after D0 is shifted out. By doing so, the following signal codes apply to the next motor/driver. To enable the correct setting of the chip select lines, the bit "csCommonIndividual" in the "Stepper Motor Global Parameter Register" has to be set to 1 (pls. refer the TMC428 datasheet).

By setting D18 to zero, the lower current range is selected. D17 is set to external reference for the maximum phase current. In practice, it's only D18 that might be needed to be changed during operation. Note that a change won't show effect until a new datagram is sent to the driver. By default, this only happens if a (micro-) step is generated. For permanent sending of datagrams, the bit "countinuous_update" in the "Stepper Motor Global Parameter Register" must be set to 1 (pls. refer TMC428 datasheet).

address	data byte 2	data byte 1	data byte 0
80		11	10
82		0F	07
84		0E	06
86		04	05
88		02	03
8A		00	01
8C		0C	0D
8E		0A	0B
90		08	09
92		10	30
94		07	11
96		06	0F
98		05	0E
9A		03	04
9C		01	02
9E		0D	00
A0		0B	0C
A2		09	0A
A4		30	08
A6		11	10
A8		0F	07
AA		0E	06
AC		04	05
AE		02	03
B0		00	01
B2		0C	0D
B4		0A	0B
B6		08	09
B8		00	30
BA		00	00
BC		00	00
BE		00	00

the first bit of the datagram (D18)

datagram definition for the first driver

the last bit of the datagram (D0)

datagram definition for the second driver

datagram definition for the third driver

Figure 5 : content of the driver chain RAM table for three drivers

Now we can proceed to define datagrams for a second and third driver, if required. The number of drivers must be specified by the parameter “LSMD” (last stepper motor driver), which is also located in the “Stepper Motor Global Parameter” register.

Configuration of the A3972 “word 1”

The “word 1” of the A3972 must be written at least once after power up to release the device from the idle state and to select the appropriate operation mode. This is done by a so called "cover datagram", which is a sequence of bits, that once replaces ("covers") the periodically sent word 0 datagram by the "cover datagram". This functionality is described within TMC 428 datasheet. In case of the A3972, the different word registers are selected by the last bit of the datagram (D0).

Care must be taken to select the correct number and position of the bits to cover, since a wrong configuration can cause serious problems or such that are hard to find. Although it possible to "patch" even single bits, we will focus on how to cover entire driver datagrams to set all of the 19 bits of the word 1. Three parameters are used for the cover datagram handling: “cover_position”, “cover_len” (length) and “cover_datagram”.

The cover position indicates the first bit to be covered within the chained driver datagrams. Zero, as the lowest possible value, selects "D18" of the first driver datagram. The datagram for the second driver starts 19 bits further, so $13 would be the correct value. For the third driver, $26 must be assigned. The cover length is always 19 ($13) for the word 1 access.

The cover datagram itself consists of three bytes that are passed to the above mentioned TMC428 parameter register "cover_datagram". An example for that is illustrated on the following page. A write to the "cover_datagram" register will start the transmission, when no word 0 datagram transmission is active and no previous cover_datagram is still "waiting". To ensure correct operation, the bit "CDGW" (cover datagram waiting) should be checked first.

For high phase currents the usage of external clamp diodes is recommended. With these diodes, the synchronous rectifier can be disabled (set D14 to 1). In many cases, a significant reduction of vibrations can be achieved be choosing high off-time values.

A3972 index						D18	D17	D16	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
A3972 function						Idle mode	(reserved)	(reserved)	SR control bit 2	SR control bit 1	C1 Oscillator control	CO Oscillator	Fast-Decay time	Fast-Decay time bit	Fast-Decay time bit	Fast-Decay time	Off-time MSB	Off-time bit 3	Off-time bit 2	Off-time bit 1	Off-time LSB	blank time MSB	blank time LSB	word sel. select = 1
TMC 428 bit numbers	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
example bit values	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1
example byte values	$00								$04								$81							

Figure 6 : example of a cover datagram for the A3972 word 1

Literature

?? TMC428 – Data Sheet, TRINAMIC Motion Control GmbH & Co. KG, (on-line http://www.trinamic.com/)

?? TMC236 – Data Sheet, TRINAMIC Motion Control GmbH & Co. KG, (on-line http://www.trinamic.com/)

?? TMC239 – Data Sheet, TRINAMIC Motion Control GmbH & Co. KG, (on-line http://www.trinamic.com/)

?? TMC246 – Data Sheet, TRINAMIC Motion Control GmbH & Co. KG, (on-line http://www.trinamic.com/)

?? TMC249 – Data Sheet, TRINAMIC Motion Control GmbH & Co. KG, (on-line http://www.trinamic.com/)

?? A3972 – Data Sheet, Allegro MicroSystems, Inc., (on-line http://www.allegromicro.com/)

Revision History

Version	Date	Comment
1.00	June 21, 2002	Initial version
1.00	October 1st, 2004	Changes concerning new company TRINAMIC Motion Control GmbH & Co. KG
1.00	January 24, 2006	References to outdated version of the TMC428 datasheet removed, some hints added, changed to font Arial

Please refer to www.trinamic.com for updated data sheets and application notes.

The TMCtechLIB CD-ROM including data sheets, application notes, schematics of evaluation boards, software of evaluation boards, source code examples, parameter calculation spreadsheets, tools, and more is available from TRINAMIC Motion Control GmbH & Co. KG by request to info@trinamic.com

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