TMC428- The highly economical controller chip for up to three stepper motors

Bernhard Dwersteg, Lars Larsson, Michael Randt, TRINAMIC Microchips GmbH

Stepper motors have become increasingly popular in the automotive industry, since they do not only operate very precisely, reliably and quietly, but also offer a high maximum- and holding torque. The stepper motor can be manufactured very inexpensively, it needs however, comparatively complex control electronics, whose quality influences its operational properties substantially. In this article a standard microchip is introduced, which enables the optimal control of stepper motors and drastically reduces the costs of electronics, in relation to conventional solutions. Thus, stepper motors have become increasingly interesting also for applications, which were so far reserved for DC-motors due to cost reasons.

1. Introduction

A large number of precise and reliable drives is needed in automobiles. Examples are found in motor control, HVAC and comfort functions, such as mirror positioning and safety-relevant functions like the headlight systems of the next generation (with dynamic beam control, intelligent side light and situation-dependent adjustment of the light profile). The requests are usually very similar: High positioning accuracy, extreme reliability and inexpensive implementation. In many applications the dynamics and an almost noiseless operation play a substantial role. Stepper motors can meet these requirements, as they have construction dependently a very high resolution. They do not need regulation, since they operate synchronously, and even reference switches can be omitted in many cases. Contrary to DC motors, no gearing is needed in order to achieve a sufficient torque and holding torque at standstill. These are inherent characteristics of a stepper motor. Stepper motors are also favorable regarding the new 42V-powernet. Small DC motors can only be poorly implemented for the direct operation at the new operating voltage, because of problems with the electromechanical commutation, due to the extremely small wire strengths of the coil.

However, other characteristics of the stepper motor can only be achieved with suitable control: High dynamics and lack of noise, for example, are only guaranteed in micro step operation. The often used full step operation saves the danger of resonance, which can lead to a disturbing noise creation and even malfunctioning (step loss). Therefore, drives driven in full step operation must usually be oversized, which leads to disadvantages regarding costs, energy application and building space.

2. Control electronics for stepper motors

If a micro controller with suitable software is used for the controlling of a stepper motor, different problems can occur, because the controlling of a stepper motor is a real time function: The production of the control signals for a stepper motor must take place time-exactly and independently, of the extent of utilization of the micro controller concerned. In particular, a sudden communication rise or the processing of other operating system functions, must not influence the step production. If these requests can be fulfilled by a micro controller in conjunction with a real time processing system, then, for a high degree of dynamics together with a small response time, either a very efficient micro controller or even a signal processor (DSP) is necessary. Due to the high memory requirement, unjustified costs accrue. Beyond that, micro step operation requires still more processing capacity. A dedicated hardware, which, using highly integrated logic, implements cost-optimized silicon poured intelligence, as presented in this article, can obtain a higher dependability than a comparable software solution. Additionally the development time is reduced with the application of a finished hardware as a chip, since the micro controller accords only simple communication functions and all real time functions are taken over by the chip.

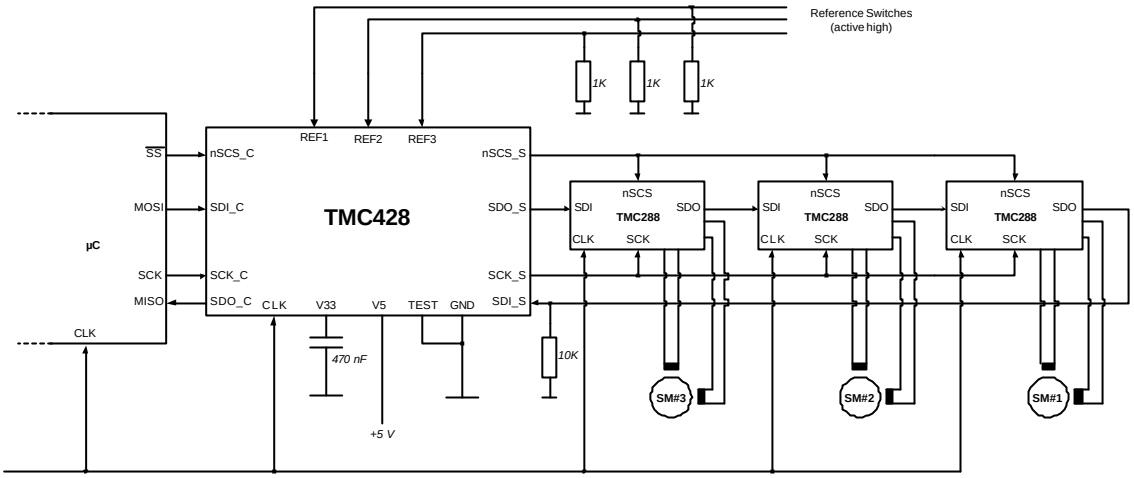

Figure: Circuit diagram of a complete three-axis control

3. Characteristics of the TMC428

The TMC428 is the newest chip of the TRINAMIC Microchips GmbH, which is due to its small size, its low price and the possibility of controlling up to three 2-phase stepper motors independently, particularly interesting for the implementation of miniaturized, cost-optimized systems in the automobile area.

The TMC428 enables the control of stepper motors with different step resolutions. The resolution is programmable individually for each motor. Beside the full - and half step operation, micro step operation with up to 64 micro steps (6 bits) per full step is possible. The micro step table of the TMC428 is stepper motor-type-specifically adaptable, so that a very calm run with small torque variations can be achieved. Programmable, automatic current scaling enables high torques in acceleration and brake phases as well as the current reduction at stand still for the reduction of the capacity and the associated heat development. Once initialized, the TMC428 performs all real time-critical functions independently. Both, the precise step production by the integrated sequencer and the calculation of the driving ramps for the achieving of the pinpoint accuracy of target positions, is completely handled by the TMC428. It is therefore possible, together with an inexpensive micro controller, to implement a complete stepper motor control for up to three axes very economically. The TMC428 relieves the micro controller significantly, so that it remains free for user-specific communication with interfaces as well as for the processing of more fastidious coordination functions of the stepper motors. Both, the communication between micro controllers and the TMC428 and the communication between the TMC428 and up to three cascaded stepper motor driver building blocks (as for instance TMC288 or TMC289), are made by a serial 4-wire-interface. The TMC428 permits the control of almost all usual market stepper motor driver. It can directly control SPI™ Smart power stepper motor driver of different manufacturers, or over additional components (e.g. a shift register of the 7êr series) conventional parallel controllable driver. Even stepper motor driver with step direction inputs can be operated in this way with the TMC428. The usage of the stepper motor driver TMC288 / TMC289 allows a particularly simple and economical implementation of a miniaturized control for up to three stepper motors and the possibility of a complete usage of the TMC428 features. These Trinamic driver will be available in specimen numbers from Q3-2001.

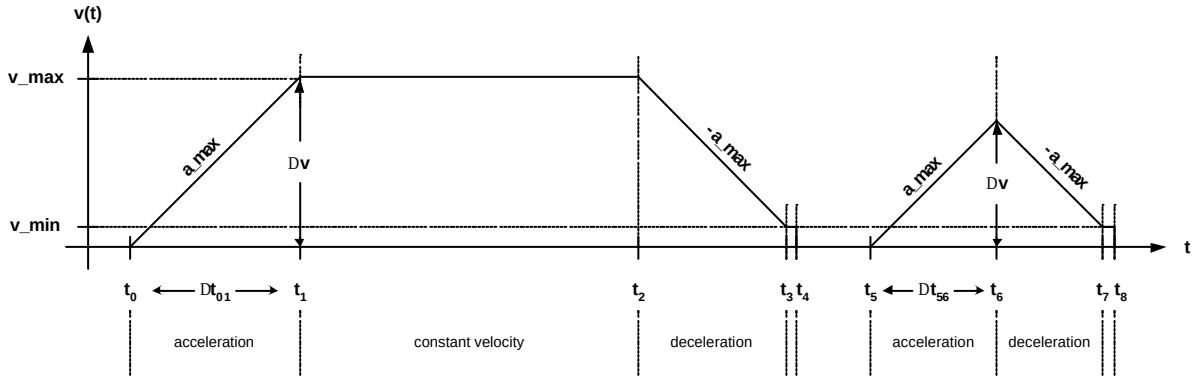

Figure: With the TMC428 generated speed profiles

4. Functional description and block diagram

The micro controller sees the interface of the TMC428 present itself as a record of registers, which can be written and read in a uniform way over the serial interface. After initialization, usually, only the target positions or target rates have to be written into the assigned registers. The TMC428 provides the current motion parameters in the appropriate registers, for the micro controller to select. An internal multiport RAM controller controls the access to the on-chip-configuration-RAM. The micro controller can therefore access all registers of the TMC428 at any time, without access conflicts. The global configuration data and motion parameter are stored in the registers. The configuration of the serial stepper motor driver interface as well as the adaptable micro step table are stored in the on-chip-RAM.

The serial interface of the TMC428 to the micro controller is very simple to use. At each communication 32 bits are transferred between the micro controller and the TMC428. The interface of the TMC428 to the stepper motor driver operates completely autonomously.

The TMC428 has four modes, which can be used individually for each of the, up to three, stepper motors. The RAMP_mode is intended for positioning tasks with trapezoidal track curves. While the SOFT_mode and the RAMP_mode are identical regarding acceleration, the SOFT_mode, however, brakes with decreasing acceleration, whereby achieving an interpolation effect. To start a new position – both in RAMP_mode and in SOFT_mode – , it is sufficient, to write the new target position into the motor assigned registers. The TMC428 then starts the new target position with consideration of all motion parameters. It also has two further modes for applications, for which stepper motors should run with given acceleration rates. In VELOCITY_mode, the stepper motor is accelerated or slowed down with max. acceleration to the given target rate. It then rotates with a constant rate, until a new target rate is written into the concerned register of the TMC428. In HOLD_mode it is switched immediately to the given target rate, so that the micro controller can produce any speed profiles. The TMC428 supplies the current motion parameters (position, rate, acceleration), independently of the mode, for the micro controller at any time.

The ramp generator monitors constantly all motion parameters, which are stored in the registers of the TMC428 and produces step impulses, which are processed by the micro step sequencer. The step production is made with consideration of the given motion parameters (max. acceleration, max. and minimum rate) and external events, like the occurrence of a stop or a slowdown condition by the optimum external three or six reference - / stop switches. Also, the for this purpose responsible parameters can be changed at any time. The serial stepper motor driver interface only transmits datagrams to the stepper motor driver chain, if it is necessary.

The interrupt controller monitors permanently conditions, which result from the reference switches and register contents of the ramp generator. The interrupt bit is directly at the disposal, both as a status bit at communications with the micro controller and multiplexed at the data output of the micro controller interface.

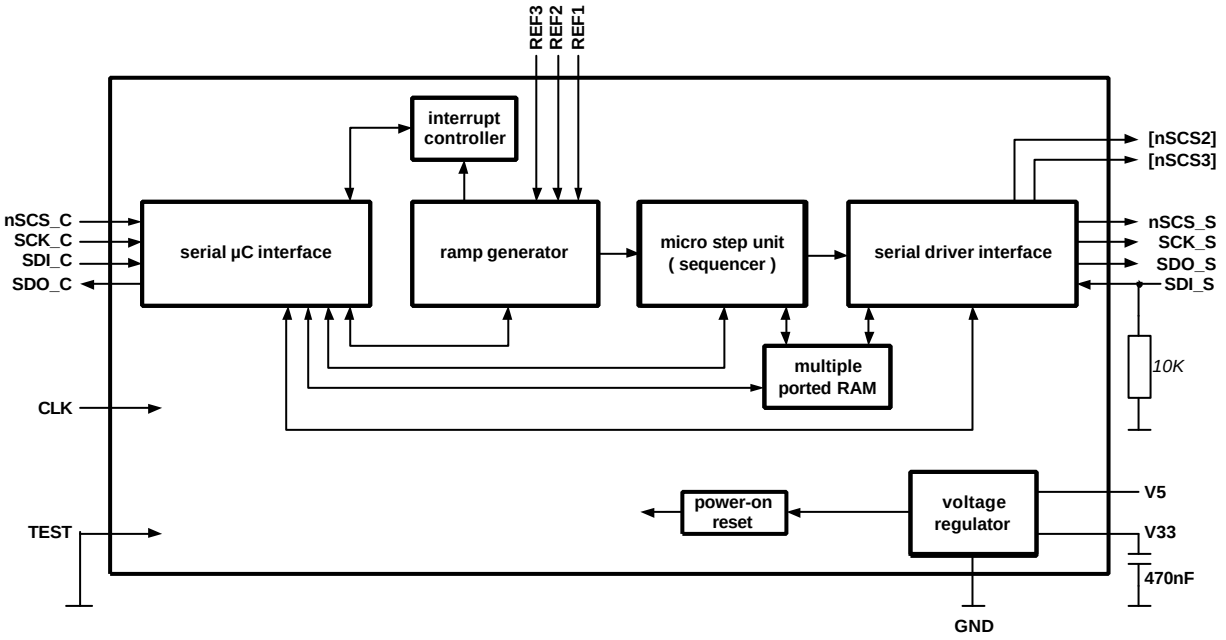

Figure: Block diagram of the TMC428

5. Summary

With the TMC428, a novel and unique electronic component is available for a simple and economical composition of dynamic stepper motors with up to three axes. One of the main applications in the automotive area is found in the control of motorized headlight systems. In addition, there is a set of applications within the comfort area and powertrain, which for the TMC428 is predestinated.

The data sheet of the TMC428 available at http://www.trinamic.com/

SPI is trademark of the Motorola, Inc..

Bernhard Dwersteg is Technical Director of the TRINAMIC Microchips GmbH. port-guesses/advises BD

Lars Larsson operates as a senior ASIC designer at the TRINAMIC Microchips GmbH. port-guesses/advises LL

Michael Randt is founder and managing director of the TRINAMIC Microchips GmbH. port-guesses/advises

TRINAMIC® Microchips GmbH
Deelboegenkamp 4C
D-22297 Hamburg
T +49 - (0) 40 - 51 48 06 - 0
F +49 - (0) 40 - 51 48 06 - 60
www.trinamic.com
info@trinamic.com