

1 Principles of Operation

The TMC2160 driver chip is an intelligent power component interfacing between a motion controller and a high-power stepper motor. It uses stealthChop, dcStep, coolStep, and stallGuard2 automatically to optimize every motor movement. The TMC2160 ideally extends the TMC2100 and TMC2130 family to higher voltages and higher motor currents.

THE TMC2160 OFFERS TWO BASIC MODES OF OPERATION:

MODE 1: Step & Direction Driver

An external high-performance S-ramp motion controller like the TMC4361 or a central CPU generates step & direction signals synchronized to other components like additional motors within the system. The TMC2160 takes care of intelligent current and mode control and delivers feedback on the state of the motor. The microPlyer automatically smoothens motion.

MODE 2: Simple Step & Direction Driver

The TMC2160 positions the motor based on step & direction signals. The microPlyer automatically smoothens motion. No CPU interaction is required; configuration is done by hardware pins. Basic standby current control can be done by the TMC2160. Optional feedback signals allow error detection and synchronization. Enable this mode by tying pin SPI_MODE low.

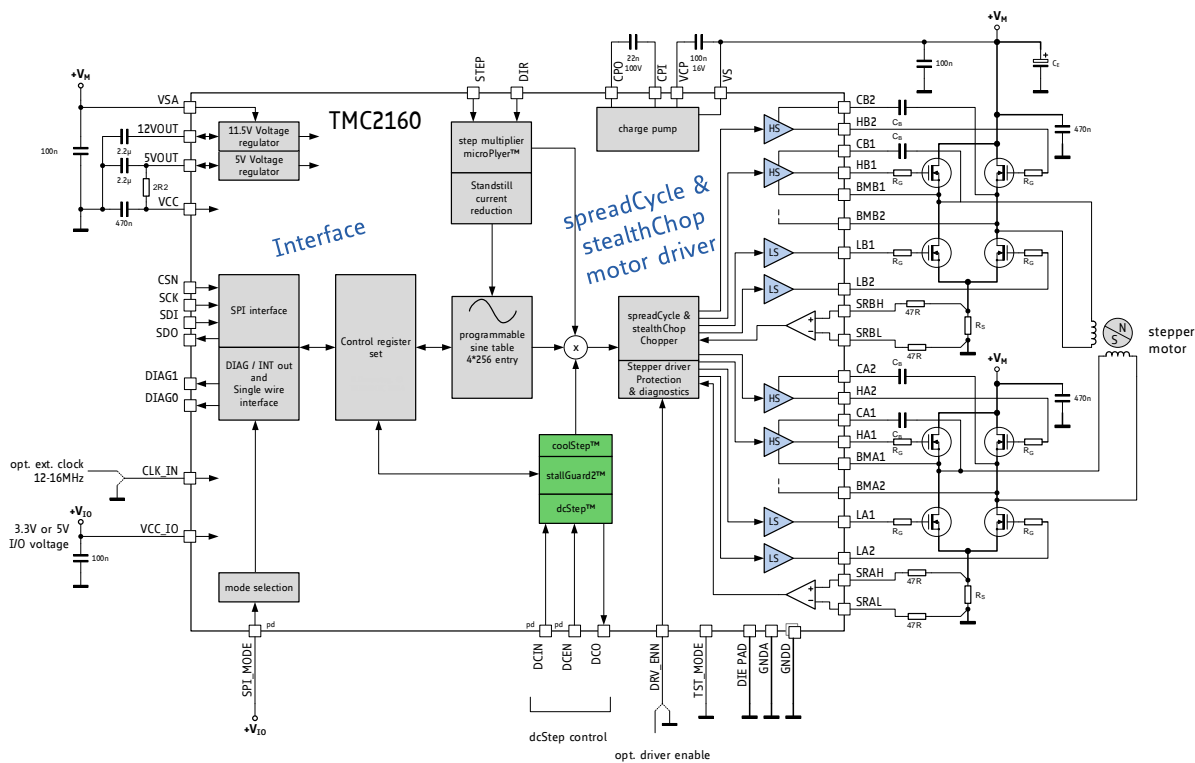


Figure 1.1 TMC2160 STEP/DIR application diagram

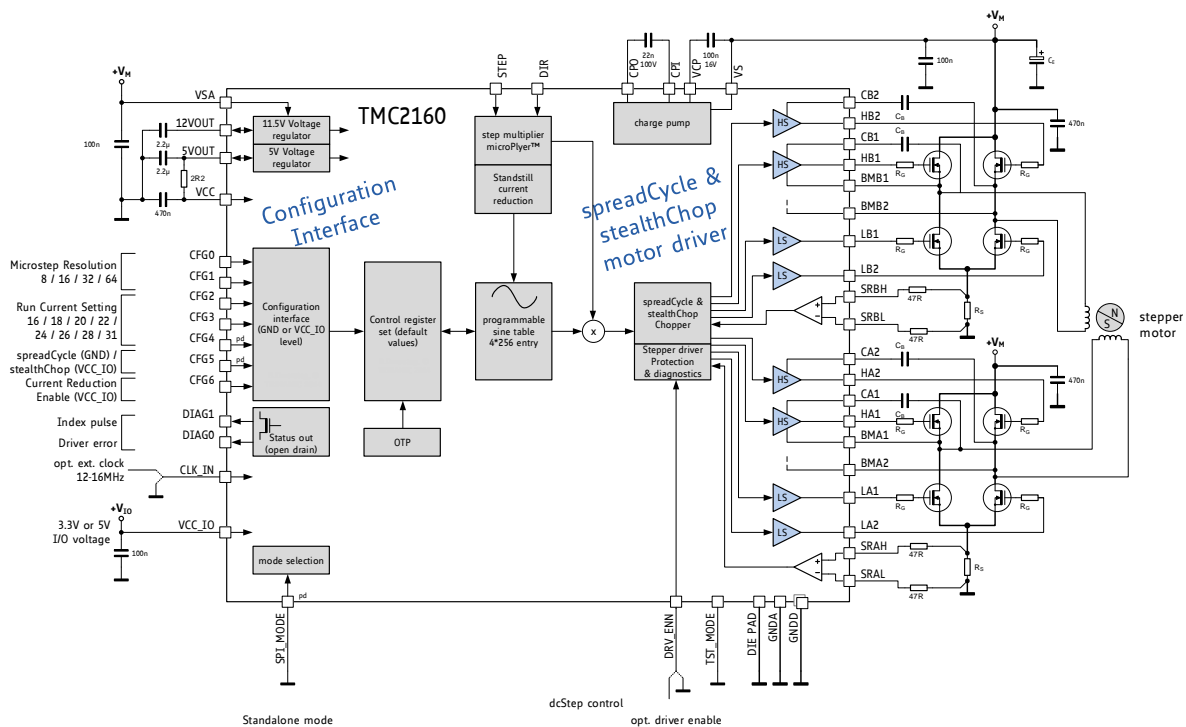


Figure 1.2 TMC2160 standalone driver application diagram

1.1 Key Concepts

The TMC2160 implements advanced features which are exclusive to TRINAMIC products. These features contribute toward greater precision, greater energy efficiency, higher reliability, smoother motion, and cooler operation in many stepper motor applications.

stealthChop2™ No-noise, high-precision chopper algorithm for inaudible motion and inaudible standstill of the motor. Allows faster motor acceleration and deceleration than stealthChop™ and extends stealthChop to low stand still motor currents.

spreadCycle™ High-precision chopper algorithm for highly dynamic motion and absolutely clean current wave. Low noise, low resonance and low vibration chopper.

dcStep™ Load dependent speed control. The motor moves as fast as possible and never loses a step.

stallGuard2™ Sensorless stall detection and mechanical load measurement.

coolStep™ Load-adaptive current control reducing energy consumption by as much as 75%.

microPlyer™ Microstep interpolator for obtaining full 256 microstep smoothness with lower resolution step inputs starting from fullstep

In addition to these performance enhancements, TRINAMIC motor drivers offer safeguards to detect and protect against shorted outputs, output open-circuit, overtemperature, and undervoltage conditions for enhancing safety and recovery from equipment malfunctions.

1.2 Control Interfaces

The TMC2160 supports an SPI interface for parameter setting and diagnostics. Additionally, a standalone mode is provided for pure STEP/DIR operation without use of the serial interface. Selection of the actual interface is done via the configuration pin SPI_MODE, which can be hardwired to GND or VCC_IO depending on the desired interface.

1.2.1 SPI Interface

The SPI interface is a bit-serial interface synchronous to a bus clock. For every bit sent from the bus master to the bus slave another bit is sent simultaneously from the slave to the master. Communication between an SPI master and the TMC2160 slave always consists of sending one 40-bit command word and receiving one 40-bit status word.

The SPI command rate typically is a few commands per complete motor motion.

1.3 Software

From a software point of view the TMC2160 is a peripheral with a number of control and status registers. Most of them can either be written only or read only. Some of the registers allow both read and write access. In case read-modify-write access is desired for a write only register, a shadow register can be realized in master software.

1.4 Moving the Motor

1.4.1 STEP/DIR Interface

The motor is controlled by a step and direction input. Active edges on the STEP input can be rising edges or both rising and falling edges as controlled by another mode bit (*dedge*). Using both edges cuts the toggle rate of the STEP signal in half, which is useful for communication over slow interfaces such as optically isolated interfaces. On each active edge, the state sampled from the DIR input determines whether to step forward or back. Each step can be a fullstep or a microstep, in which there are 2, 4, 8, 16, 32, 64, 128, or 256 microsteps per fullstep. A step impulse with a low state on DIR increases the microstep counter and a high state decreases the counter by an amount controlled by the microstep resolution. An internal table translates the counter value into the sine and cosine values which control the motor current for microstepping.

1.4.2 SPI direct mode

The direct mode allows control of both motor coil currents and polarity via SPI. It mainly is intended for use with a dedicated external motion controller IC with integrated sequencer. The sequencer applies sine and cosine waves to the motor coils. This mode is specially designed for combination with the TMC4361 motion controller.

1.5 Automatic Standstill Power Down

An automatic current reduction drastically reduces application power dissipation and cooling requirements. Modify stand still current, delay time and decay via register settings. Automatic freewheeling and passive motor braking are provided as an option for stand still. Passive braking reduces motor standstill power consumption to zero, while still providing effective dampening and braking! An option for faster detection of standstill is provided for use with highly frequent motion commands.

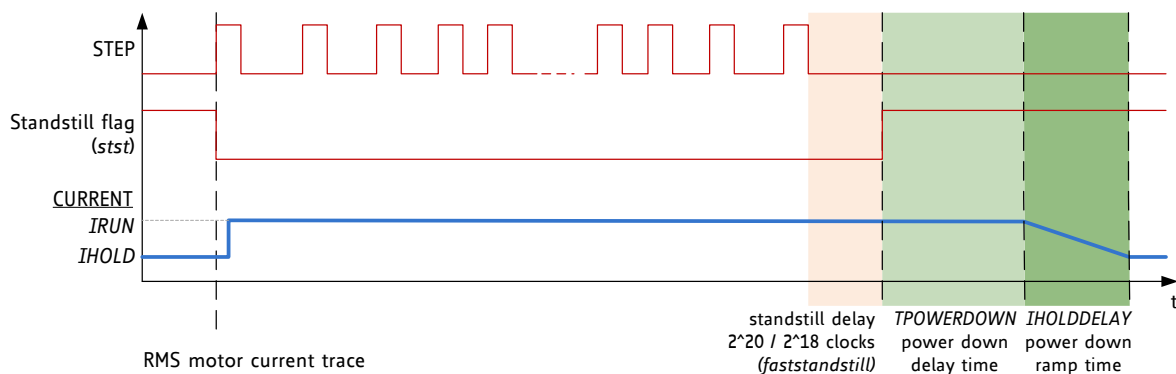


Figure 1.3 Automatic Motor Current Power Down

1.6 stealthChop2 & spreadCycle Driver

stealthChop is a voltage chopper based principle. It especially guarantees that the motor is absolutely quiet in standstill and in slow motion, except for noise generated by ball bearings. Unlike other voltage mode choppers, stealthChop2 does not require any configuration. It automatically learns the best settings during the first motion after power up and further optimizes the settings in subsequent motions. An initial homing sequence is sufficient for learning. Optionally, initial learning parameters can be pre-configured via the interface. stealthChop2 allows high motor dynamics, by reacting at once to a change of motor velocity.

For highest dynamic applications, spreadCycle is an option to stealthChop2. It can be enabled via input pin (standalone mode) or via SPI interface. stealthChop2 and spreadCycle may even be used in a combined configuration for the best of both worlds: stealthChop2 for no-noise stand still, silent and smooth performance, spreadCycle at higher velocity for high dynamics and highest peak velocity at low vibration.

spreadCycle is an advanced cycle-by-cycle chopper mode. It offers smooth operation and good resonance dampening over a wide range of speed and load. The spreadCycle chopper scheme automatically integrates and tunes fast decay cycles to guarantee smooth zero crossing performance.

Benefits of using stealthChop2:

- Significantly improved microstepping with low cost motors
- Motor runs smooth and quiet
- Absolutely no standby noise
- Reduced mechanical resonance yields improved torque

1.7 stallGuard2 – Mechanical Load Sensing

stallGuard2 provides an accurate measurement of the load on the motor. It can be used for stall detection as well as other uses at loads below those which stall the motor, such as coolStep load-adaptive current reduction. This gives more information on the drive allowing functions like sensorless homing and diagnostics of the drive mechanics.

1.8 coolStep – Load Adaptive Current Control

coolStep drives the motor at the optimum current. It uses the stallGuard2 load measurement information to adjust the motor current to the minimum amount required in the actual load situation. This saves energy and keeps the components cool.

Benefits are:

- | | |
|------------------------------------|---|
| - <i>Energy efficiency</i> | power consumption decreased up to 75% |
| - <i>Motor generates less heat</i> | improved mechanical precision |
| - <i>Less or no cooling</i> | improved reliability |
| - <i>Use of smaller motor</i> | less torque reserve required → cheaper motor does the job |

Figure 1.4 shows the efficiency gain of a 42mm stepper motor when using coolStep compared to standard operation with 50% of torque reserve. coolStep is enabled above 60RPM in the example.

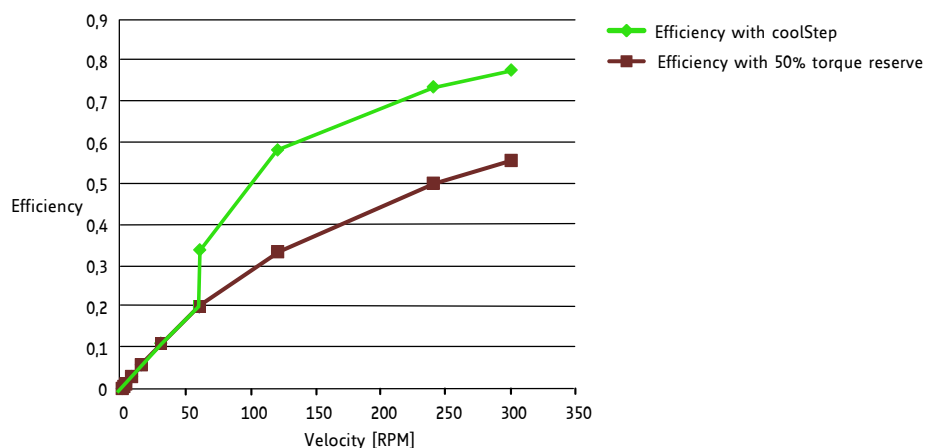


Figure 1.4 Energy efficiency with coolStep (example)

1.9 dcStep – Load Dependent Speed Control

dcStep allows the motor to run near its load limit and at its velocity limit without losing a step. If the mechanical load on the motor increases to the stalling load, the motor automatically decreases velocity so that it can still drive the load. With this feature, the motor will never stall. In addition to the increased torque at a lower velocity, dynamic inertia will allow the motor to overcome mechanical overloads by decelerating. dcStep directly integrates with the ramp generator, so that the target position will be reached, even if the motor velocity needs to be decreased due to increased mechanical load. A dynamic range of up to factor 10 or more can be covered by dcStep without any

step loss. By optimizing the motion velocity in high load situations, this feature further enhances overall system efficiency.

Benefits are:

- Motor does not lose steps in overload conditions
- Application works as fast as possible
- Highest possible acceleration automatically
- Highest energy efficiency at speed limit
- Highest possible motor torque using fullstep drive
- Cheaper motor does the job