TMC236 / TMC239 / TMC246 / TMC249 / A-types FAQ list:

(The term TMC236 here always refers to the complete driver family, unless otherwise noted)

1. General problems when getting started

Q: My TMC236 does not work properly at higher current settings. What can I do?

A: This often is a problem with the TMC236 detecting a short circuit condition. Try to monitor this in the SPI serial word coming from the TMC236, e.g. using an oscilloscope on the TMC236's SDO line.

The typical causes for wrong detection of a short condition are:

1. The shunt resistor on the high side has got to long/thin PCB traces. These traces can easily raise the value by several 100mOhms.
- Use thick, short and straight traces.
- Make sure, that your sense resistor traces add no substantial resistance to the high side sense resistor.
- Quick workaround: Use lower value for high side shunt or add a voltage divider for VT.

2. During switching of the coil outputs of the TMC236 voltage spikes occur on the sense resistor. This can be caused by long/thin PCB traces from GND to the sense resistor or from the sense resistor to BRA/BRB. There especially should be no parasitic inductivities in these traces.
- Use thick, short and straight traces - a massive grounding is preferable.
- Make sure, that your sense resistor traces add no substantial resistance to the sense resistors.
- Quick workaround: Increase blank time or add RC-filtering for SRA and SRB.

Q: What can be the problem when I observe reduced motor reliability at lower supply voltages?

A: This can very well be coupled to the above points.
Generally the motor current in fact is independent of the supply voltage, and the TMC236 with its low internal resistance is a very good driver for lower voltages. But one has to consider, that a lower voltage means that the current needs a longer time to reach the target level. This means, that at lower voltage level the maximum motor velocity may have to be reduced.
You can very well monitor this condition watching the open load flags of the TMC236: If they flicker during the motion, the motor velocity might be too high with regard to the actual supply voltage.

Q: My circuit uses a TMC236/TMC239 driver. Do I have to make any changes to use a TMC236A/TMC239A or a TMC246/TMC249 driver?

A: If you use the ENN pin for switching off the driver, make sure that the ENN pin is pulled up externally to at least 2.8V for circuits supplied with 5V. Do not use an open collector output to drive it.
Allow for a small increase in standby current on the VCC supply pins, because VCC feeds the ENN pin overvoltage protection comparator.

Q: I have replaced a conventional (halfstep) driver by a TMC239. Now, my motor shows more resonances than before. What can be the reason?

A: Please refer to the chapter on SPI mode programming, for halfstep patterns, if you want to stay with halfstepping. Even for halfstepping it is important to use the mixed decay feature, to get maximum performance.
Check list:

- Did you monitor the short circuit bits? Motor resonances can lead to high peak currents, which could trigger short detection, even if it is not triggered under normal circumstances.
- Are your step-pulses at equivalent distances? If you have got a problem in generating the step patterns, you might want to try the ultra-miniature, low cost, TMC428 SPI stepper motor controller.
- The remaining differences to conventional drivers are: Dramatically lower driver stage resistance – which also reduces resistive damping of the motor. To damp the motor, it is important to use the mixed decay feature properly, i.e. mixed decay switched on during falling slopes of the coil currents. In some cases continuous mixed decay improves performance.
- You could migrate from half-stepping to micro-stepping. This reduces motor resonances especially at low frequencies. At high rotation speeds, not every microstep has to be sent, but it is important to feed a jitter-free signal into the driver (motor), i.e. the microstep current should always correspond to a “snapshot” of the desired current at the time, where sending the telegram is initiated.
- Do you need high velocity? Please see the discussion on reaching maximum RPM.

Q: My application needs very high motor velocities. How can I get the maximum RPM?

A: Full stepping is a good solution for high RPM applications!
Why?
In general, RPM is just limited by the inductivity of the motor and the available supply voltage. So the answer is, use a motor with low inductivity, i.e. high coil current, and maximize supply voltage.
Microstepping does not have a major influence on motor performance at high RPM. As compared to microstepping, fullstepping control allows to get maximum current into the coils. So, when exceeding some velocity, you might reprogram your microstepping table and change into fullstepping. When you use the TMC428, you can realize this on-the-fly, by modifying the driver configuration table to all phase bits constant, or by modifying the sine wave table to a full-stepping table.

An important DO NOT for reaching high RPM: Do not set the motor current too high. To keep motor resonance low, it is important that the programmed maximum current can be reached by the application. So you will typically reach a higher velocity, with a lower current setting, when you are at the limits of the motor / supply voltage. To bes sure: Check with the oscilloscope at the sense resistor, that the motor driver starts chopping for at least a small part of each (full)step.

Q: The motor makes noise during stand still. What can I do to get it silent?

A: These are some hints for conditions, which can (but don't need to) lead to audible chopper noise, even during stand-still of the motor:

- Low chopper frequency
- Use of mixed decay mode
- Low motor supply voltage
- High motor coil resistance
- Some microstep positions with very low motor currents on one coil
- Filter elements on SRA and SRB pin required, but not used
- Blank time too low / higher than necessary
- Bad PCB layout: long / thin / bend traces between GND and sense resistors or to BRA/BRB

So, for a given application, the following main points should be checked:

- Increase chopper frequency to 36kHz.
- If resonable for your motor, it is advised to switch off mixed decay mode during stand-still. (don't do this, if the exact microstep position is very important).

Q: What are possible causes for a driver IC failing?

A: These are some hints for failure conditions, which can (but don't need to) damage the driver ICs:

- Motor Voltage above 34V (for non-A-types) / above 40V (A-types) or logic supply voltage above 8V
- Pulling motor connector during operation
- Short to GND without high side sense resistor
- Soldering problems (unconnected or shorted pins)
- Motor current set to more than 3A for extended periods of time
- Missing or far too small oscillator capacitor
- High ESD voltages applied to circuit before soldering it to board. We have never seen this happening, but please remark, that the drivers are sensitive to electrostatic (dis)charge, especially before soldering the IC onto the application board.
- Missing GND connection when powering the unit with a laboratory supply
- Missing sense resistor (or too high value)
- Missing short to GND resistor (or too high value)

All of these are severe violations of the drivers specifications. In fact the devices are very rugged and may be operated well beyond spec without problem.

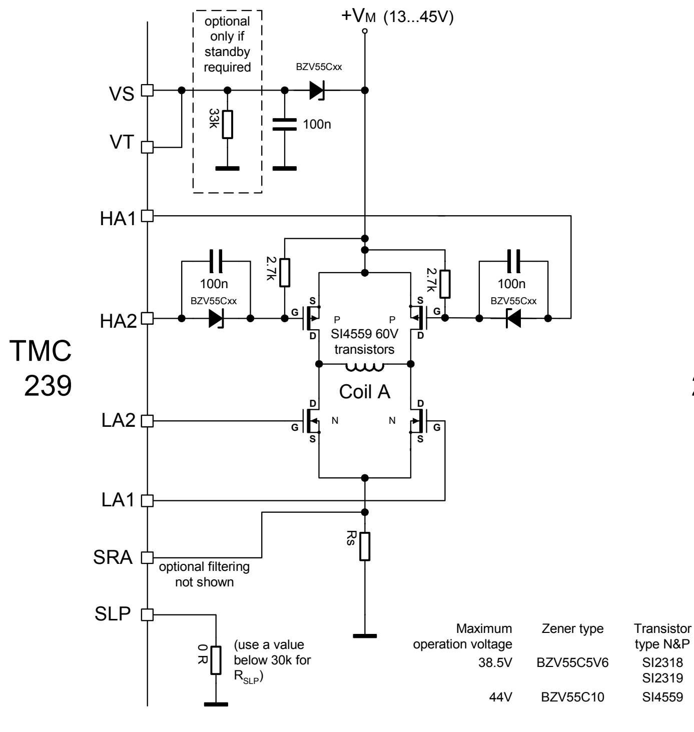
2. Higher voltage / higher current applications

Q: Can the TMC236 / TMC 246 drivers operate at voltages > 28.5V?

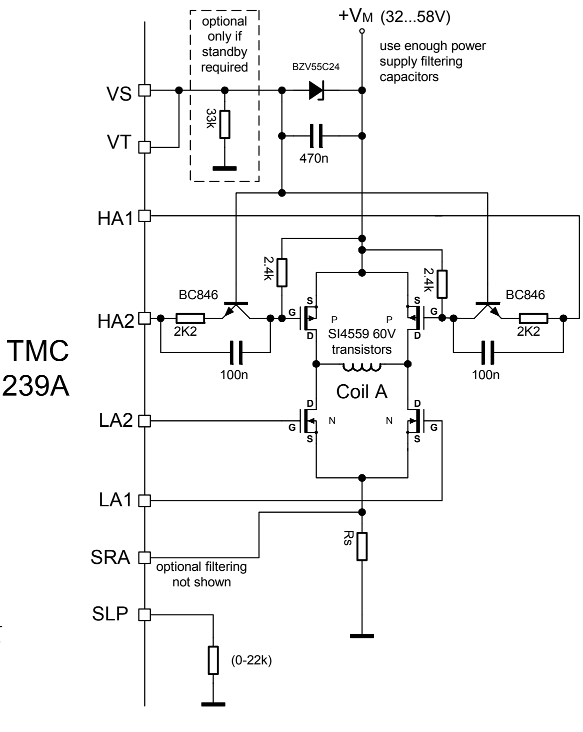
A: For the TMC236 and TMC246 operation is specified up to 28.5V Motor voltage. Typically the drivers can work at up to 33V for unlimited time, but this is not specified, as the power MOS transistors inside the driver are 30V types. The transistors generate excess heat due to zener diode effects, when their maximum drain-source voltage is exceeded. The new A-types use 40V transistors and are qualified for 34V operation.

Q: Can the TMC239 / TMC 249 drivers operate at voltages > 28.5V?

A: Yes, the TMC239 and TMC249 can be continuously operated at up to 34V (peak: 36V). There are suitable 40V and 60V P and N-channel transistors available, e.g. the 60V SI4559 (N+P pair). Using zener diodes, the maximum operation voltage of the driver circuit can be extended even beyond 50V (see schematics): The TMC239 supply voltage is reduced via a zener diode, while all P-channel transistor gates are shifted up by the same difference. For voltage differences above 10V, the transistor design (right schematic) should be preferred, because of temperature dependance of zener diode voltage. Please note, that the pull up resistor currents have to be driven by the gate driver outputs, thus setting an upper limit for the slope control resistor. The short to GND detector is not used in this application. The lower operation voltage limit is raised to 7V plus zener voltage. When using the pure zener diode based design, a careful thermal design is necessary – make sure that the zener diodes are well thermally coupled (i.e. placed near to each other).



Solution for up to 44V supply voltage



Solution for up to 58V supply voltage

Schematic: Operating the TMC239 / TMC249 at up to 58Vpeak supply voltage

Q: I want to use the TMC239 with external high voltage, high current drivers for 140V; 4.5A. Where are critical design parameters?

A: In the TMC239 data sheet you find a circuit using IR2101 power drivers. These drivers can be operated up to 500V. As a transistor you can use any high voltage MOS capable to drive the desired current, e.g. the IRF640.

1. Proper slope control is necessary: Too steep slopes can destroy the transistors because they lead to high currents.
   To control transistor slopes, you can use a gate-resistor for every transistor in the range of 50 to 470 Ohms. The design should result in slopes not faster than 50ns. To ensure a fast transistor switch-off, always use a diode like the 1N4148 to discharge the gate quickly, by bypassing the gate resistor (cathode to driver output, anode to transistor gate)!

2. Break-before-make delay is a very critical design parameter: The transistors of a half bridge are never to conduct at the same time, even not for very short times!
   The TMC239 can not monitor this, when you use external power drivers! A newer version of the IR2101, the IR2103 generates an additional 500ns dead time, which solves the problem for most transistor configurations. Using the IR2103 simplifies the circuit, by eliminating the need for the load capacitors at the TMC239 outputs, on the other hand, it has got an inverted low side input, and the user needs to provide an additional inverter, e.g. an 2N7002 N-channel MOS with 1K pullup at its drain for the low side control input!

3. For the high side gate drivers, use a 10nF capacitor and charge pump diodes, which can support the desired voltages.

4. For higher currents, a massive ground plane and a compact layout (see datasheet and sample layout) is a MUST.

5. The blank time should be set to a value of at least 1.2µs, because switching spikes are delayed due to the additional drivers.

Q: I have realized the circuit from the TMC239 / TMC249 datasheet, using external transistor drivers. My switching transistors die sometimes. What is wrong?

A: (Also refer to the previous question.)

1. Monitor the break-before-make switching using a low capacity oscilloscope probe to measure at the power transistor gates. The transistors never should switch into short circuit. If necessary, increase break-before make time. To do this, you can use IR2103 drivers. These provide additional 500ns blank time, but you need to invert the low side input.

2. Monitor the output slopes: They should be below 50ns and 300ns. Change the gate resistors, if necessary.

3. Optimizing motor performance

Q: What is the optimum supply voltage for my application?

A: The supply voltage and motor characteristics are related to each other: The supply voltage should always be at least 2 to 4 times higher than the voltage required for the motor to reach the specified coil current. However, it should not be higher than about 25 times this value, otherwise iron losses in the motor become quite high.

Example:
A motor is specified with 2.7 Ohms and 750mA coil current.
Thus the motor coil at nominal current has a voltage of 4.0 Ohm * 1.0 A = 4.0 V.
The driver supply voltage for best performance should be at least 2*4.0V = 8.0V, better 16V. A higher supply voltage gives a higher maximum motor velocity.

If the application's supply voltage is fixed or the voltage limit of the driver IC is reached, and you can not fulfil the above formula, or the motor torque at desired velocity is not sufficient, you should choose a motor with a winding designed for a higher current.

Q: I use a low inductivity motor. The microstepping does not give equal steps, especially at higher supply voltage. How can I improve this?

A: The problem with low inductivity motors at high supply voltage is, that even a very short chopper ON time leads to a high current flow. Thus, low currents, which are required for the microstepping coils, can hardly be reached. To get a good microstep behaviour, switch on mixed decay mode continuously. To avoid audible chopper noise, raise the chopper frequency to 36kHz. Since the TMC drivers automatically control the length of the mixed decay phase, this has no impact on motor dynamics.

Q: My motor shows bad microstep behaviour, what can I do?

A: Check if switching on the mixed decay mode constantly improves microstep behaviour. This often is necessary to get the motor smoothly running at more than 8 microsteps, because the driver can not bring the current to near-zero values, when mixed decay is not used (see next question). Use the new A-types: TMC236A, TMC239A, TMC246A, TMC249A. These have a more exact comparator threshold.

Q: How does the TMC236 driver handle the zero cross-over of the output current? Can it provide a true zero current?

A: At zero current the coils are completely switched off when you use the SPI interface. The integrated automatic mixed decay allows a very precise current control even at low currents. When mixed decay is switched off, low current performance is limited: The minimum reachable motor current is proportional to (blank time) * (supply voltage) / (motor resistance).

Q: What is the transfer function of the driver?

A: It has a linear transfer function, because this is most universal.

4. Increasing microstep resolution

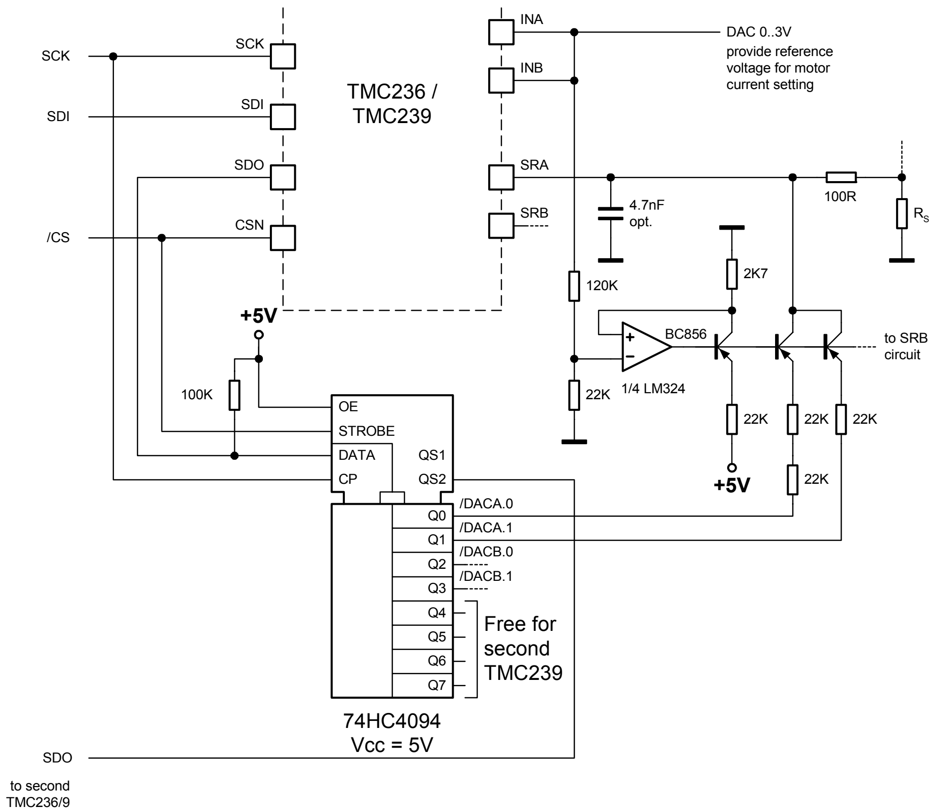
Q: The TMC236 has 4-bit DACs for 1/16 microstepping, how specifically do you implement an interface for higher resolution?

A: The TMC236 can realize more than 16 microsteps via TMC428 SPI control: Just program the TMC428 for 32 microstep mode. Due to the combination of two DACs driving the two coils, this results in a resolution somewhere between 20 and 30 microsteps.

The TMC453 directly allows driving the TMC236 with 64 microsteps or even more, using its analog interface.

To get full 64 microsteps using the TMC428, refer to the schematic example in the TMC236 data sheet (Extending the microstep resolution). Please remark, that the **lower two bits are inverted**, and the **values from 0 to 3 give a zero current**. This effectively results in a 60 level current resolution. A suitable microstep table is available from TRINAMIC. The effect of this modified DAC behaviour is, that the TMC428 ramp-phase-dependent current scaling function does not lead to a good result and should not be used! This could be improved by inverting the additional DAC-Bits.

A universal solution based on this, while giving a 64 microstep resolution at any current setting is shown in the attached schematic. It allows the use of an additional microcontroller generated current reference signal. The OPAMP controls a number of four switchable constant current sources, which add two times two bits of DAC resolution to the drivers' internal DACs. By supplying 0 to 3V to the INA/INB input, the motor current can be controlled in a wide range.



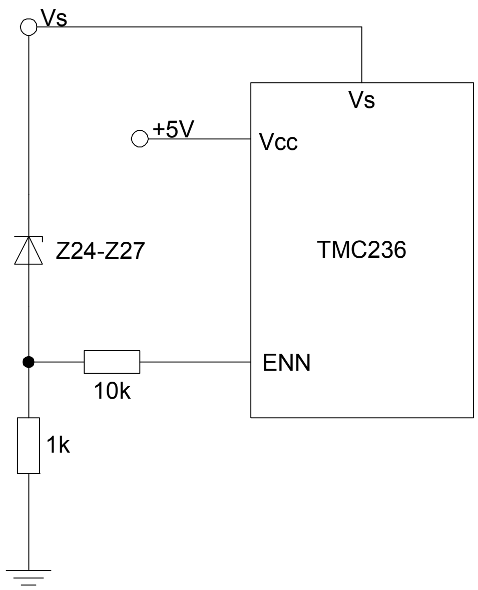
Schematics: 64 bit microstepping with scalable motor current via INA / INB

For best microstep performance run the motors with mixed decay switched on continuously and 36kHz chopper.

5. Overvoltage protection

Q: How can I realize motor supply overvoltage protection for the TMC236 / TMC239?

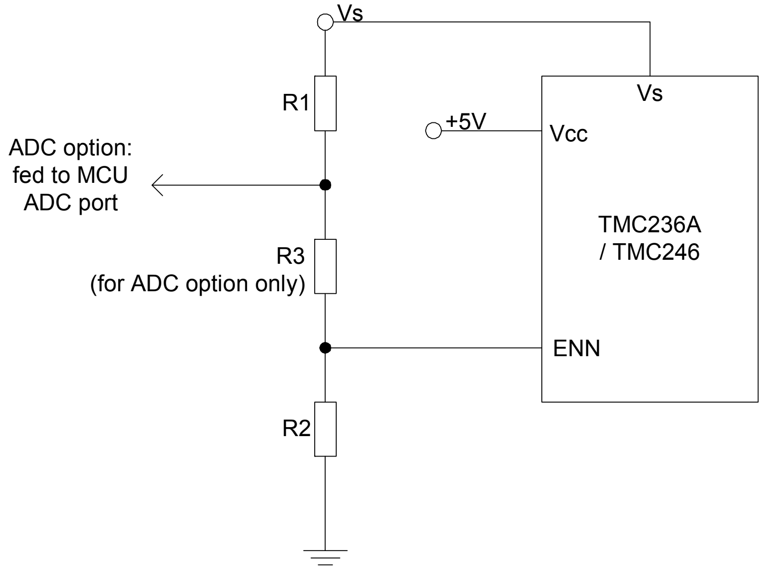
A: The TMC236 may be operated at up to 28.5V motor supply voltage V_S. Voltages above this level should be avoided as long as the TMC236 is enabled for operation (ENN input driven low), respectively enabled via SPI. However, when the TMC236 is disabled (ENN driven high) it can resist permanent V_S levels up to 35V, 40V for short times. Thus a simple way to realize overvoltage protection up to 35V is to disable the TMC236 by driving ENN high as soon and as long as V_S is above 28.5V. This can be accomplished either via software or hardware controlled. The software solution is to use an ADC to measure V_S and an output port of a microcontroller to control the ENN input. Note that driving ENN high will reset all internal registers of the TMC236. Thus in SPI mode after enabling the TMC236 again by driving ENN low an SPI telegram has to be sent to the TMC236 to restore the desired bridge currents and polarities as well as the decay modes. The hardware solution is depicted below:



As long as V_S is lower than or equal to the Zener voltage the TMC236 is enabled by a low level at ENN. Once V_S exceeds the Zener voltage by more than 2.2V ENN is at logical high level, thus disabling the TMC236 and making it overvoltage resistant up to 35 (40)V. The disable condition can be detected by monitoring the SPI output of the TMC236. It goes to a high-Z state if the TMC236 is disabled. This can be detected when “all zeros” or “all ones” are read via SPI, using an external pull up respectively pull down resistor.

Q: How can I realize motor supply overvoltage protection for the TMC246 / TMC239 / TMC249?

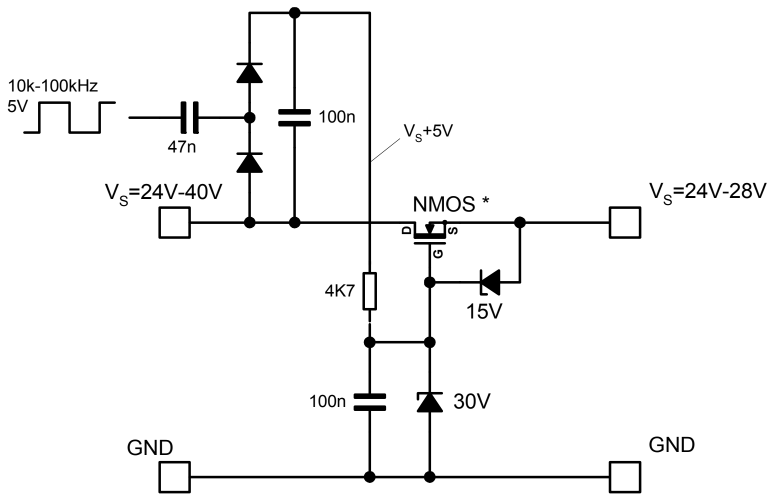
A: The answer is almost the same as for the TMC236 (see preceding Q & A) except that the ENN input of the TMC246 (and all A-types) has a dedicated switching threshold of 2.5V reducing the external circuitry to a simple voltage divider as depicted below:



The voltage divider should be dimensioned such that the ENN switching threshold of 2.5V is latest reached at a V_S level of about 30V. This will protect 30V type power MOSFETs in the TMC246 or attached to the TMC239A / TMC249A. If using a microcontroller's ADC port to measure V_S an additional resistor R3 must be used if the desired ADC voltage range differs from the ENN pin voltage divider range. In this case the extra cost for hardware overvoltage protection is just one resistor. If the ADC input level requirement meets the 2.5V threshold voltage of the driver, then R3 can be omitted and actually no extra parts for hardware overvoltage protection are needed. In this case the ENN input can be fed by the same voltage (and thus use the same voltage divider) as the ADC port does.

Q: I use an unregulated power supply with an output voltage of 24V. Under low load conditions the voltage may raise above 30V, but the drivers are not allowed to be switched off under these conditions. Is there a simple solution for multiple drivers?

A: The circuit depicted below is a voltage regulator, which operates at very low drop, if the input voltage is below or equal to 27V. As soon as the input voltage raises, the output is stabilized to the Zener voltage minus about 2 to 4 volts, depending on the NMOS threshold voltage (adapt zener voltage). Choose the NMOS according to the maximum desired current for continuous operation. However, the package should allow for dissipation of the differential voltage for the length of the overvoltage condition, when taking into account the maximum current flowing in this condition. The charge pump clock can identical to the chopper clock for the stepper drivers, using an adequate buffer circuit. If using a 74HC gate, provide an extra protection diode and series resistor to prevent capacitor loading current from destroying the output. The gate protection zener can be eliminated by using a protected MOSFET.
You also might use 40 or 60V MOSFETs, when working with TMC239A or TMC249A.



6. Using the SPI interface

Q: Does the TMC236 update the SPI datagram at once after the rising CSN edge?

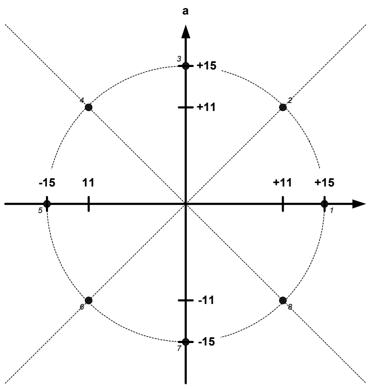
A: Yes. You can use this to synchronize the microstep timing via the CSN edge. This allows to send the SPI datagrams without strict real time requirements.

Q: My processor has an 8 bit SPI interface. How can I send 12 bit wide words?

A: You do not need to send 12 bit words. You can send 16 bit wide SPI telegrams. The first 4 bits are just shifted through the TMC236 and you can treat them as don’t care. When you send a 16 bit word to the SPI chain, this means, that the four upper bits in the processor are don’t care, the next 4 bits in this byte represent: MDA, CA3, CA2, CA1. The lower byte represents the SPI bits CA0, PHA, MDB, CB3, CB2, CB1, CB0, PHB.

Q: How can I use the TMC236/TMC239 in a half stepping application?

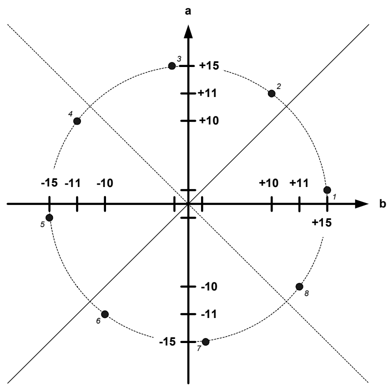
A: In principle, you can drive the coils using a standard half-stepping scheme, as depicted in the left figure. It equals a two microstep sine wave. However, this scheme does not make use of the mixed decay feature, which can dramatically improve performance, even in half stepping applications. To use mixed decay, the modified scheme rotates the fullstep / halfstep positions by some amount, always leading to values different from zero. We can also realize a symmetrical layout of the patterns, which has got an advantage concerning the distribution of power dissipation in driver and motor.



a = +11, +15, +11, 0, -11, -15, -11, 0

b = +11, 0, -11, -15, -11, 0, +11, +15

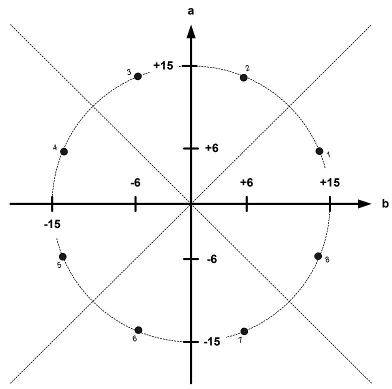
standard



a = +1, +11, +15, +10, -1, -11, -15, -10

b = +15, +10, -1, -11, -15, -10, +1, +11

modified



a = +6, +14, +14, +6, -6, -14, -14, -6

b = +14, +6, -6, -14, -14, -6, +6, +14

modified symmetric

	a	b	MDA	CA3	CA2	CA1	CA0	PHA	MDB	CB3	CB2	CB1	CB0	PHB
1	+1	+15	0	0	0	0	1	0	0	1	1	1	1	0
2	+11	+10	0	1	0	1	1	0	1	1	0	1	0	0
3	+15	-1	0	1	1	1	1	0	0	0	0	0	1	1
4	+10	-11	1	1	0	1	0	0	0	1	0	1	1	1
5	-1	-15	0	0	0	0	1	1	0	1	1	1	1	1
6	-11	-10	0	1	0	1	1	1	1	1	0	1	0	1
7	-15	+1	0	1	1	1	1	1	0	0	0	0	1	0
8	-10	+11	1	1	0	1	0	1	0	1	0	1	1	0
	a	**b**	**MDA**	**CA3**	**CA2**	**CA1**	**CA0**	**PHA**	**MDB**	**CB3**	**CB2**	**CB1**	**CB0**	**PHB**
8	-10	+11	0	1	0	1	0	1	1	1	0	1	1	0
7	-15	+1	0	1	1	1	1	1	1	0	0	0	1	0
6	-11	-10	1	1	0	1	1	1	0	1	0	1	0	1
5	-1	-15	1	0	0	0	1	1	0	1	1	1	1	1
4	+10	-11	0	1	0	1	0	0	1	1	0	1	1	1
3	+15	-1	0	1	1	1	1	0	1	0	0	0	1	1
2	+11	+10	1	1	0	1	1	0	0	1	0	1	0	0
1	+1	+15	1	0	0	0	1	0	0	1	1	1	1	0

Improved halfstepping pattern, CW and CCW direction

	a	b	MDA	CA3	CA2	CA1	CA0	PHA	MDB	CB3	CB2	CB1	CB0	PHB
1	+6	+14	0	0	1	1	0	0	0	1	1	1	0	0
2	+14	+6	0	1	1	1	0	0	1	0	1	1	0	0
3	+14	-6	0	1	1	1	0	0	0	0	1	1	0	1
4	+6	-14	1	0	1	1	0	0	0	1	1	1	0	1
5	-6	-14	0	0	1	1	0	1	0	1	1	1	0	1
6	-14	-6	0	1	1	1	0	1	1	0	1	1	0	1
7	-14	+6	0	1	1	1	0	1	0	0	1	1	0	0
8	-6	+14	1	0	1	1	0	1	0	1	1	1	0	0
	a	**b**	**MDA**	**CA3**	**CA2**	**CA1**	**CA0**	**PHA**	**MDB**	**CB3**	**CB2**	**CB1**	**CB0**	**PHB**
8	-6	+14	0	0	1	1	0	1	0	1	1	1	0	0
7	-14	+6	0	1	1	1	0	1	1	0	1	1	0	0
6	-14	-6	0	1	1	1	0	1	0	0	1	1	0	1
5	-6	-14	1	0	1	1	0	1	0	1	1	1	0	1
4	+6	-14	0	0	1	1	0	0	0	1	1	1	0	1
3	+14	-6	0	1	1	1	0	0	1	0	1	1	0	1
2	+14	+6	0	1	1	1	0	0	0	0	1	1	0	0
1	+6	+14	1	0	1	1	0	0	0	1	1	1	0	0

Improved symmetrical halfstepping pattern, CW and CCW direction

The tables show the resulting SPI datagrams. The mixed-decay-bits (**MDA** resp. **MDB**) are valid for the respective rotation directions 1,2,3,4,5,6,7,8 (CCW) and 8,7,6,5,4,3,2,1 (CW). The split tables for CW and CCW are necessary to ensure mixed decay flags to be set during phases of decreasing phase current with unchanged current direction. When the motor is at rest, the mixed decay bits (**MDA** and **MDB**) should be set to ‘0’, reducing chopper noise and power dissipation.

Concerning readout of the open load bits, these two schemes also improve the result, because the coils are never switched off. However, they should be read out during standstill, e.g. after each motor movement, since the large current steps in halfstepping could lead to wrong results of the open load detection during motor motion.

You still can take advantage of the current control feature in halfstepping, by reducing current (torque) depending on the motor action, e.g. a reduction during stand still.

7. Using stallGuard™

Q: Do I have to read out the stallGuard signal at every microstep?

A: The stallGuard is updated once per fullstep, so it is not necessary to readout more often than the actual fullstep rate.

Q: How should the stallGuard readout level differ, when I increase mechanical load on the motor?

A: The value read back from the SPI telegram decreases when the load increases. However, when you use the evaluation board software, the displays in the Windows software show "seven minus value read back", just to make the effect better visible (the visibility in a graph is better when you see a high value when you are having high load). In TMCL, also a high value means high load.

Q: When I reduce motor current via INA / INB base current setting, why does load measurement give less reliable results?

A: The load measurement accuracy decreases, when you reduce the motor current by applying an external voltage reference. To make the best use of load measurement, use the internal voltage reference, and adapt the sense resistors set the maximum current to the desired value. However, if the external voltage reference is used and it is near to 2V, the quality of the load measurement is not influenced.
This is due to the fact, that the eight stall guard levels are referenced to a fixed internal reference of the TMC246/TMC249. So, if you reduce / increase the motor current, e.g. via the current control via INA/INB, or by digitally modifying the motor current, the levels become shifted by the same amount.

Q: During motor movement I am seeing the word both increasing and decreasing in value as the load increases. Weather it increases or decreases seems to be tied to the speed of the steps and the current to the motor. So far I don't see any solid correlation between the speed/current and the increase/decrease except that it does not seem to remain constant?

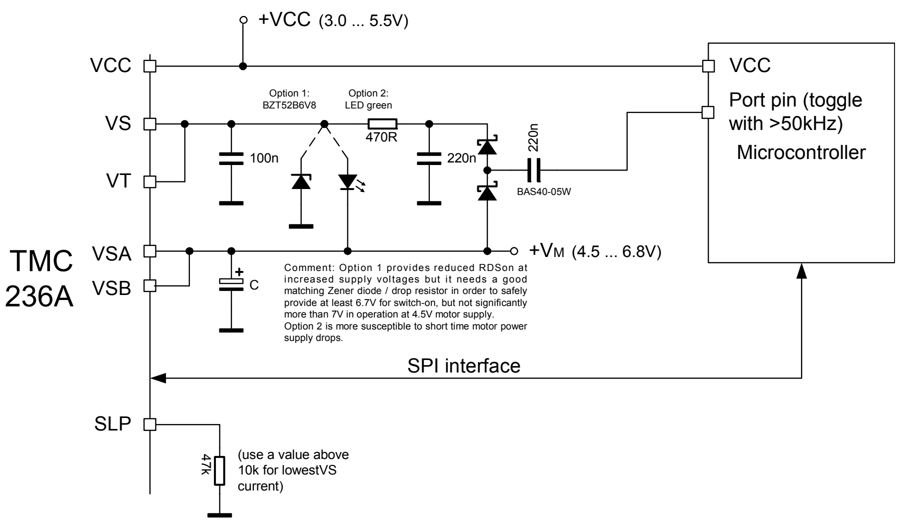
A: The load measurement sees the actual load on the motor, including the load caused by a resonance in the motor itself. So, load measurement results are dependent not only on the external mechanical load, but also on everything that influences the systems resonances: Motor current setting (at a too low current resonance is much higher!), motor velocity and dynamic motor load (flywheel mass also damps or changes resonances). For example, when you see the load indicator increasing, when you load the motor (and it should decrease) this can be, because your motor was in resonance, and you have damped the resonance with your fingers, which in fact reduces (dynamic) motor load! This is somehow tricky.
To get a reliable stall detection for mechanical reference, you should operate the motor at the specified current (by choosing fitting sense resistors) - choose a velocity where resonance is low and the load indicator shows a high value. You might want to do some software filtering, to get more stable values, e.g. find the minimum reading of a few samples of the load indicator for a number of sequential full steps.

8. Low voltage operation with TMC236 / 246

Q: Can I operate the TMC236 with a single 5V supply or with four battery cells?

A: Yes, this can be done with a simple trick, using an inexpensive low current (1.5mA) charge pump.
Background: The TMC236 family has got an undervoltage protection, which disables the circuit below 5.9 supply voltage. To power up the driver, a voltage of minimum 6.7V has to be applied.
Solution: The TMC236 VS supply normally is operated with the same supply voltage as the power bridges (VSA and VSB). However, there is no need to stick to this. The bridge voltage may be lower than the supply voltage. This enables us to use a low current 6.8V supply for the TMC236 which ensures power-on of the undervoltage detection, while the motor bridges directly work with the battery voltage. The bridge supply voltage can be up to 2 to 3V below the Vs supply, giving the possibility to operate down to 4.3V or so. Please see the schematic for a suitable circuit. This solution has got the advantage, that the low-side bridge FETs still have their extremely low RDSon, because they still have the full drive voltage. At the same time, the high side FETs are driven with a voltage reduced by the difference between VS and VSA. Since the P-channel FETs used in the TMC236 start conducting at about 2V while they are driven with 6V, they operate, but they have a slightly increased RDSon, which increases as the difference between VS and VSA / VSB goes up. The increase in the RDSon of the high side FETs has got less impact, because most time they are switched off during normal operation.

With a supply voltage of 5V to 6V the driver can still supply the full current without a major increase in thermal dissipation. Since the TMC236 consumes only about 1.5mA at VS, a simple charge pump realized with a microcontroller pin and a dual Schottky diode can supply the required current. The charge pump can be turned off in stand-by periods to save energy. When a RS232 interface circuit like the MAX202 is present, its integrated charge pump will provide enough energy to supply the TMC236 VS. In this case, just an additional 6.8V regulator consisting of a resistor and a zener diode is required.



Alternatively, to also get a higher maximum velocity for the motor, you can use any step up converter able to supply enough current for the stepper motor and supply the whole circuit with an increased voltage. However, this solution adds cost for the step up converter, while the solution depicted above is nearly cost-neutral.