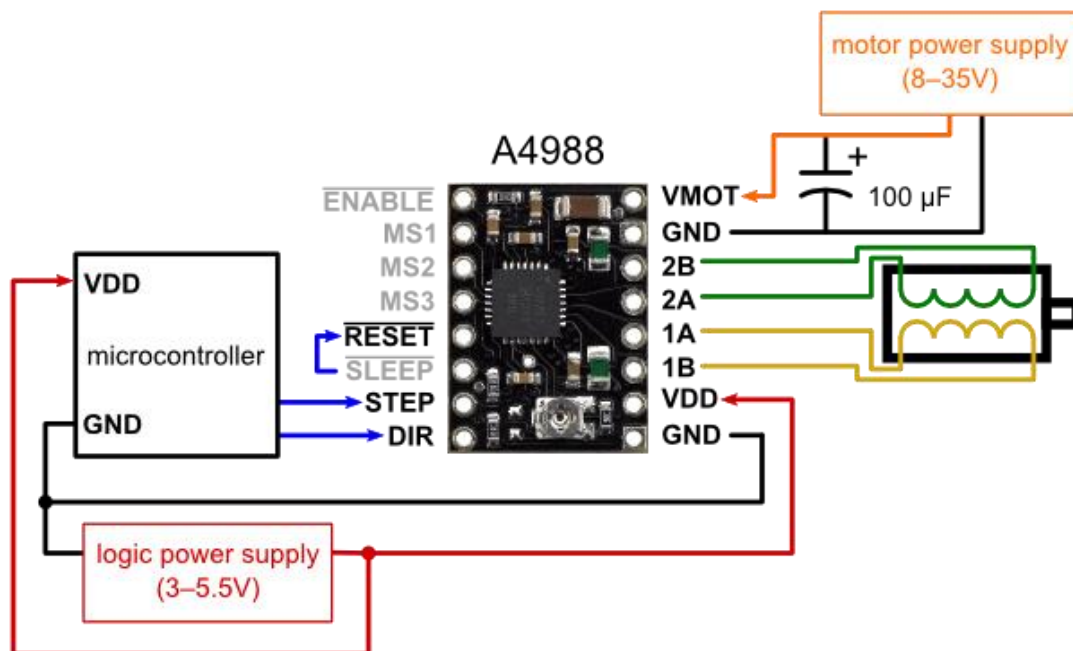


## POLOLU A4988 STEPPER MOTOR DRIVER

### CARRIER, BLACK EDITION

## USER'S GUIDE

### USING THE DRIVER



Minimal wiring diagram for connecting a microcontroller to an A4988 stepper motor driver carrier (full-step mode).

### POWER CONNECTIONS

The driver requires a logic supply voltage (3 – 5.5 V) to be connected across the VDD and GND pins and a motor supply voltage (8 – 35 V) to be connected across VMOT and GND. These supplies should have appropriate decoupling capacitors close to the board,

and they should be capable of delivering the expected currents (peaks up to 4 A for the motor supply).

**Warning:** This carrier board uses low-ESR ceramic capacitors, which makes it susceptible to destructive LC voltage spikes, especially when using power leads longer than a few inches. Under the right conditions, these spikes can exceed the 35 V maximum voltage rating for the A4988 and permanently damage the board, even when the motor supply voltage is as low as 12 V. One way to protect the driver from such spikes is to put a large (at least 47  $\mu\text{F}$ ) electrolytic capacitor across motor power (VMOT) and ground somewhere close to the board.

## MOTOR CONNECTIONS

Four, six, and eight-wire stepper motors can be driven by the A4988 if they are properly connected; a [FAQ answer](#) explains the proper wirings in detail.

**Warning:** Connecting or disconnecting a stepper motor while the driver is powered can destroy the driver. (More generally, rewiring anything while it is powered is asking for trouble.)

## STEP (AND MICROSTEP) SIZE

Stepper motors typically have a step size specification (e.g. 1.8° or 200 steps per revolution), which applies to full steps. A microstepping driver such as the A4988 allows higher resolutions by allowing intermediate step locations, which are achieved by energizing the coils with intermediate current levels. For instance, driving a motor in quarter-step mode will give the 200-step-per-revolution motor 800 microsteps per revolution by using four different current levels.

The resolution (step size) selector inputs (MS1, MS2, and MS3) enable selection from the five step resolutions according to the table below. MS1 and MS3 have internal 100k $\Omega$  pull-down resistors and MS2 has an internal 50k $\Omega$  pull-down resistor, so leaving

these three microstep selection pins disconnected results in full-step mode. For the microstep modes to function correctly, the current limit must be set low enough (see below) so that current limiting gets engaged. Otherwise, the intermediate current levels will not be correctly maintained, and the motor will skip microsteps.

MS1	MS2	MS3	Microstep Resolution
Low	Low	Low	Full step
High	Low	Low	Half step
Low	High	Low	Quarter step
High	High	Low	Eighth step
High	High	High	Sixteenth step

## CONTROL INPUTS

Each pulse to the STEP input corresponds to one microstep of the stepper motor in the direction selected by the DIR pin. Note that the STEP and DIR pins are not pulled to any particular voltage internally, so you should not leave either of these pins floating in your application. If you just want rotation in a single direction, you can tie DIR directly to VCC or GND. The chip has three different inputs for controlling its many power states: RST, SLP, and EN. For details about these power states, see the datasheet. Please note that the RST pin is floating; if you are not using the pin, you can connect it to the adjacent SLP pin on the PCB to bring it high and enable the board.

## CURRENT LIMITING

One way to maximize stepper motor performance is to use as high of a voltage as is practical for your application. In particular, increasing the voltage generally allows for higher step rates and stepping torque since the current can change more quickly in the coils after each step. However, in order to safely use voltages above the rated voltage of a stepper motor, the coil current must be actively limited to keep it from exceeding the motor's rated current.

The A4988 supports such active current limiting, and the trimmer potentiometer on the board can be used to set the current limit. One way to set the current limit is to put the driver into full-step mode and measure the current running through a single motor coil while adjusting the current limit potentiometer. This should be done with the motor holding a fixed position (i.e. without clocking the STEP input). Note that the current you are measuring is only 70% of the actual current limit setting, since both coils are always on and limited to this value in full-step mode, so if you later enable microstepping modes, the current through the coils will be able to exceed this measured full-step current by 40% ( $1/0.7$ ) on certain steps; please take this into account when using this method to set the current limit. Also, note that you will need to perform this adjustment again if you ever change the logic voltage,  $V_{dd}$ , since the reference voltage that sets the current limit is a function of  $V_{dd}$ .

**Note:** The coil current can be very different from the power supply current, so you should not use the current measured at the power supply to set the current limit. The appropriate place to put your current meter is in series with one of your stepper motor coils.

Another way to set the current limit is to calculate the reference voltage that corresponds to your desired current limit and then adjust the current limit potentiometer until you measure that voltage on the **VREF** pin. The VREF pin voltage is accessible on a via that is circled on the bottom silkscreen of the circuit board. The current limit,  $I_{MAX}$ , relates to the reference voltage as follows:

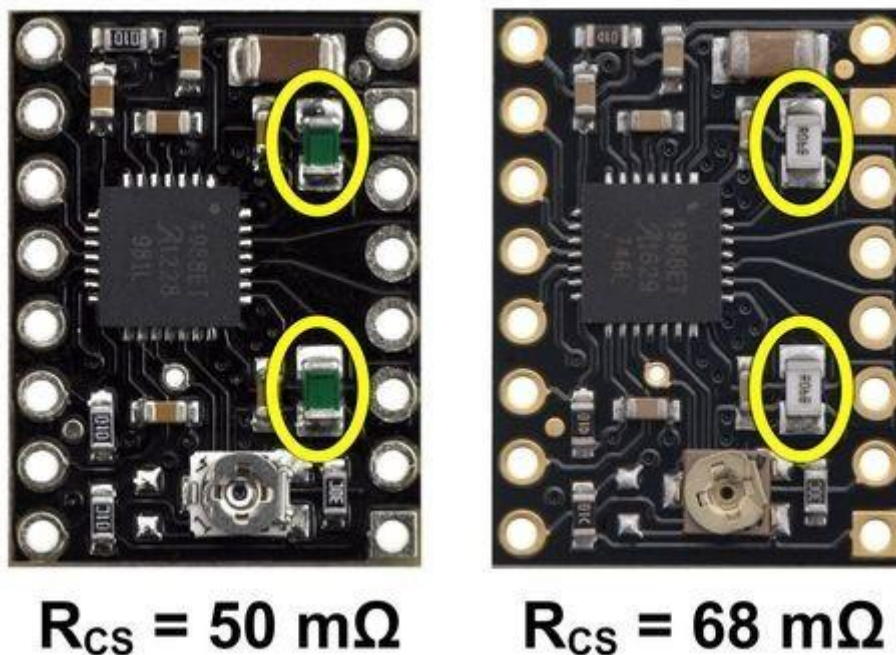
$$I_{MAX} = \frac{V_{REF}}{8 \cdot R_{CS}}$$

or, rearranged to solve for VREF:

$$V_{REF} = 8 \cdot I_{MAX} \cdot R_{CS}$$

$R_{CS}$  is the current sense resistance; original versions of this board used **0.050  $\Omega$**  current sense resistors, but we switched to using **0.068  $\Omega$**  current sense resistors in January

2017, which makes more of the adjustment potentiometer's range useful. The following picture shows how to identify which current sense resistors your board has:



Identification of original 50 mΩ sense resistors (left) and 68 mΩ sense resistors (right) introduced in January 2017.

So, for example, if you want to set the current limit to 1 A and you have a board with 68 mΩ sense resistors, you would set VREF to 540 mV. Doing this ensures that even though the current through each coil changes from step to step, the magnitude of the current vector in the stepper motor stays constant at 1 A:

$$\sqrt{I_{COIL1}^2 + I_{COIL2}^2} = I_{MAX} = 1A$$

If you instead want the current through *each coil* to be 1 A in full-step mode, you would need to set the current limit to be 40% higher, or 1.4 A, since the coils are limited to approximately 70% of the set current limit in full-step mode (the equation above shows why this is the case). To do this with a board with 68 mΩ sense resistors, you would set VREF to 770 mV.

## POWER DISSIPATION CONSIDERATIONS

The A4988 driver IC has a maximum current rating of 2 A per coil, but the actual current you can deliver depends on how well you can keep the IC cool. The carrier's printed circuit board is designed to draw heat out of the IC, but to supply more than approximately 1.2 A per coil, a heat sink or other cooling method is required (in our tests, we were able to deliver approximately 1.4 A per coil with air flow from a PC fan and no heat sink).

This product can get hot enough to burn you long before the chip overheats. Take care when handling this product and other components connected to it.

Please note that measuring the current draw at the power supply will generally not provide an accurate measure of the coil current. Since the input voltage to the driver can be significantly higher than the coil voltage, the measured current on the power supply can be quite a bit lower than the coil current (the driver and coil basically act like a switching step-down power supply). Also, if the supply voltage is very high compared to what the motor needs to achieve the set current, the duty cycle will be very low, which also leads to significant differences between average and RMS currents.

