

Getting Started

First, connect to Grbl using the serial terminal of your choice.

Set the baud rate to **115200** as 8-N-1 (8-bits, no parity, and 1-stop bit.)

Once connected you should get the Grbl-prompt, which looks like this:

```
Grbl 1.1f ['$' for help]
```

Type \$ and press enter to have Grbl print a help message.

You should not see any local echo of the \$ and enter. Grbl should respond with:

```
$$ (view Grbl settings)
```

```
$# (view # parameters)
```

```
$G (view parser state)
```

```
$I (view build info)
```

```
$N (view startup blocks)
```

```
$x=value (save Grbl setting)
```

```
$Nx=line (save startup block)
```

```
$C (check gcode mode)
```

```
$X (kill alarm lock)
```

```
$H (run homing cycle)
```

```
~ (cycle start)
```

```
! (feed hold)
```

```
? (current status)
```

```
ctrl-x (reset Grbl)
```

The '\$' -commands are Grbl system commands used to tweak the settings, view or change Grbl's states and running modes, and start a homing cycle. The last four **non**-'\$' commands are realtime control commands that can be sent at anytime, no matter what Grbl is doing. These either immediately change Grbl's running behavior or immediately print a report of the important realtime data like current position (aka DRO).

Grbl Settings

\$\$ - View Grbl settings

To view the settings, type \$\$ and press enter after connecting to Grbl. Grbl should respond with a list of the current system settings, as shown in the example below. All of these settings are persistent and kept in EEPROM, so if you power down, these will be loaded back up the next time you power up your Arduino.

```
$0=10 (step pulse, usec)
$1=25 (step idle delay, msec)
$2=0 (step port invert mask:00000000)
$3=6 (dir port invert mask:00000110)
$4=0 (step enable invert, bool)
$5=0 (limit pins invert, bool)
$6=0 (probe pin invert, bool)
$10=3 (status report mask:00000011)
$11=0.020 (junction deviation, mm)
$12=0.002 (arc tolerance, mm)
$13=0 (report inches, bool)
$20=0 (soft limits, bool)
$21=0 (hard limits, bool)
$22=0 (homing cycle, bool)
$23=1 (homing dir invert mask:00000001)
$24=50.000 (homing feed, mm/min)
$25=635.000 (homing seek, mm/min)
$26=250 (homing debounce, msec)
$27=1.000 (homing pull-off, mm)
$100=800 (x, step/mm)
$101=800 (y, step/mm)
$102=800 (z, step/mm)
$110=635.000 (x max rate, mm/min)
$111=635.000 (y max rate, mm/min)
$112=635.000 (z max rate, mm/min)
$120=50.000 (x accel, mm/sec^2)
$121=50.000 (y accel, mm/sec^2)
$122=50.000 (z accel, mm/sec^2)
$130=225.000 (x max travel, mm)
$131=125.000 (y max travel, mm)
$132=170.000 (z max travel, mm)
```

\$x=val - Save Grbl setting

The `$x=val` command saves or alters a Grbl setting, which can be done manually by sending this command when connected to Grbl through a serial terminal program, but most Grbl GUIs will do this for you as a user-friendly feature.

To manually change e.g. the microseconds step pulse option to 10us you would type this, followed by an enter:

```
$0=10
```

If everything went well, Grbl will respond with an 'ok' and this setting is stored in EEPROM and will be retained forever or until you change them. You can check if Grbl has received and stored your setting correctly by typing \$\$ to view the system settings again.

Grbl's \$x=val settings and what they mean

NOTE: Settings numbering has changed since v0.8c for future-proofing purposes.

\$0 - Step pulse, microseconds

Stepper drivers are rated for a certain minimum step pulse length. Check the data sheet or just try some numbers. You want the shortest pulses the stepper drivers can reliably recognize. If the pulses are too long, you might run into trouble when running the system at very high feed and pulse rates, because the step pulses can begin to overlap each other. We recommend something around 10 microseconds, which is the default value.

\$1 - Step idle delay, msec

Every time your steppers complete a motion and come to a stop, Grbl will delay disabling the steppers by this value. **OR**, you can always keep your axes enabled (powered so as to hold position) by setting this value to the maximum 255 milliseconds. Again, just to repeat, you can keep all axes always enabled by setting `$1=255`.

The stepper idle lock time is the time length Grbl will keep the steppers locked before disabling. Depending on the system, you can set this to zero and disable it. On others, you may need 25-50 milliseconds to make sure your axes come to a complete stop before disabling. This is to help account for machine motors that do not like to be left on for long periods of time without doing something. Also, keep in mind that some stepper drivers don't remember which micro step they stopped on, so when you re-enable, you may witness some 'lost' steps due to this. In this case, just keep your steppers enabled via `$1=255`.

\$2 - Step port invert mask:binary

This setting inverts the step pulse signal. By default, a step signal starts at normal-low and goes high upon a step pulse event. After a step pulse time set by `$0`, the pin resets to low, until the next step pulse event. When inverted, the step pulse behavior switches from normal-high, to low during the pulse, and back to high. Most users will not need to use this setting, but this can be useful for certain CNC-stepper drivers that have peculiar requirements. For example, an artificial delay between the direction pin and step pulse can be created by inverting the step pin.

This invert mask setting is a value which stores the axes to invert as bit flags. You really don't need to completely understand how it works. You simply need to enter the settings value for the axes you want to invert. For example, if you want to invert the X and Z axes, you'd send `$2=5` to Grbl and the setting should now read `$2=5 (step port invert mask:00000101)`.

Setting Value	Mask	Invert X	Invert Y	Invert Z
0	00000000	N	N	N
1	00000001	Y	N	N
2	00000010	N	Y	N
3	00000011	Y	Y	N
4	00000100	N	N	Y
5	00000101	Y	N	Y
6	00000110	N	Y	Y
7	00000111	Y	Y	Y

\$3 - Direction port invert mask:binary

This setting inverts the direction signal for each axis. By default, Grbl assumes that the axes move in a positive direction when the direction pin signal is low, and a negative direction when the pin is high. Often, axes don't move this way with some machines. This setting will invert the direction pin signal for those axes that move the opposite way.

This invert mask setting works exactly like the step port invert mask and stores which axes to invert as bit flags. To configure this setting, you simply need to send the value for the axes you want to invert. Use the table above. For example, if want to invert the Y axis direction only, you'd send `$3=2` to Grbl and the setting should now read `$3=2 (dir port invert mask:00000010)`

\$4 - Step enable invert, bool

By default, the stepper enable pin is high to disable and low to enable. If your setup needs the opposite, just invert the stepper enable pin by typing `$4=1`. Disable with `$4=0`. (May need a power cycle to load the change.)

\$5 - Limit pins invert, bool

By default, the limit pins are held normally-high with the Arduino's internal pull-up resistor. When a limit pin is low, Grbl interprets this as triggered. For the opposite behavior, just invert the limit pins by typing `$5=1`. Disable with `$5=0`. You may need a power cycle to load the change.

NOTE: If you invert your limit pins, you will need an external pull-down resistor wired in to all of the limit pins to prevent overloading the pins with current and frying them.

\$6 - Probe pin invert, bool

By default, the probe pin is held normally-high with the Arduino's internal pull-up resistor. When the probe pin is low, Grbl interprets this as triggered. For the opposite behavior, just invert the probe pin by typing `$6=1`. Disable with `$6=0`. You may need a power cycle to load the change.

NOTE: If you invert your probe pin, you will need an external pull-down resistor wired in to the probe pin to prevent overloading it with current and frying it.

\$10 - Status report mask:binary

This setting determines what Grbl real-time data it reports back to the user when a '?' status report is sent. By default, Grbl will send back its running state (can't be turned off), machine position, and work position (machine position with coordinate offsets and other offsets applied). Three additional reporting features are available that are useful for interfaces or users setting up their machines, which include the serial RX buffer, planner block buffer usage, and limit pin states (as high or low, shown in the order ZYX).

To set them, use the table below to determine what data you'd like Grbl to send back. Select the report types you'd like to see in the status reports and add their values together. This is the value you use to send to Grbl. For example, if you need machine and work positions, add the values 1 and 2 and send Grbl `$10=3` to set it. Or, if you need machine position only and limit pin state, add the values 1 and 16 and send Grbl `$10=17`.

In general, keep this real-time status data to a minimum, since it takes resources to print and send this data back at a high rate. For example, limit pins reporting is generally only needed when users are setting up their machine. Afterwards, it's recommended to disable it, as it isn't very useful once you've got everything figured out.

Report Type	Value
Machine Position	1
Work Position	2
Planner Buffer	4
RX Buffer	8
Limit Pins	16

\$11 - Junction deviation, mm

Junction deviation is used by the acceleration manager to determine how fast it can move through line segment junctions of a G-code program path. For example, if the G-code path has a sharp 10 degree turn coming up and the machine is moving at full speed, this setting helps determine how much the machine needs to slow down to safely go through the corner without losing steps.

How we calculate it is a bit complicated, but, in general, higher values gives faster motion through corners, while increasing the risk of losing steps and positioning. Lower values makes the acceleration manager more careful and will lead to careful and slower cornering. So if you run into problems where your machine tries to take a corner too fast, decrease this value to make it slow down when entering corners. If you want your machine to move faster through junctions, increase this value to speed it up. For curious people, hit this link to read about Grbl's cornering algorithm, which accounts for both velocity and junction angle with a very simple, efficient, and robust method.

\$12 - Arc tolerance, mm

Grbl renders G2/G3 circles, arcs, and helices by subdividing them into teeny tiny lines, such that the arc tracing accuracy is never below this value. You will probably never need to adjust this setting, since 0.002mm is well below the accuracy of most all CNC machines. But if you find that your circles are too crude or arc tracing is performing slowly, adjust this setting. Lower values give higher precision but may lead to performance issues by overloading Grbl with too many tiny lines. Alternately, higher values traces to a lower precision, but can speed up arc performance since Grbl has fewer lines to deal with.

For the curious, arc tolerance is defined as the maximum perpendicular distance from a line segment with its end points lying on the arc, aka a chord. With some basic geometry, we solve for the length of the line segments to trace the arc that satisfies this setting. Modeling arcs in this way is great, because the arc line segments automatically adjust and scale with length to ensure optimum arc tracing performance, while never losing accuracy.

\$13 - Report inches, bool

Grbl has a real-time positioning reporting feature to provide a user feedback on where the machine is exactly at that time, as well as, parameters for coordinate offsets and probing. By default, it is set to report in mm, but by sending a \$13=1 command, you send this boolean flag to true and these reporting features will now report in inches. \$13=0 to set back to mm.

\$20 - Soft limits, bool

Soft limits is a safety feature to help prevent your machine from traveling too far and beyond the limits of travel, crashing or breaking something expensive. It works by knowing the maximum travel limits for each axis and where Grbl is in machine coordinates. Whenever a new G-code

motion is sent to Grbl, it checks whether or not you accidentally have exceeded your machine space. If you do, Grbl will issue an immediate feed hold wherever it is, shutdown the spindle and coolant, and then set the system alarm indicating the problem. Machine position will be retained afterwards, since it's not due to an immediate forced stop like hard limits.

NOTE: Soft limits requires homing to be enabled and accurate axis maximum travel settings, because Grbl needs to know where it is. `$20=1` to enable, and `$20=0` to disable.

\$21 - Hard limits, bool

Hard limit work basically the same as soft limits, but use physical switches instead. Basically you wire up some switches (mechanical, magnetic, or optical) near the end of travel of each axes, or where ever you feel that there might be trouble if your program moves too far to where it shouldn't. When the switch triggers, it will immediately halt all motion, shutdown the coolant and spindle (if connected), and go into alarm mode, which forces you to check your machine and reset everything.

To use hard limits with Grbl, the limit pins are held high with an internal pull-up resistor, so all you have to do is wire in a normally-open switch with the pin and ground and enable hard limits with `$21=1`. (Disable with `$21=0`.) We strongly advise taking electric interference prevention measures. If you want a limit for both ends of travel of one axes, just wire in two switches in parallel with the pin and ground, so if either one of them trips, it triggers the hard limit.

Keep in mind, that a hard limit event is considered to be critical event, where steppers immediately stop and will have likely have lost steps. Grbl doesn't have any feedback on position, so it can't guarantee it has any idea where it is. So, if a hard limit is triggered, Grbl will go into an infinite loop ALARM mode, giving you a chance to check your machine and forcing you to reset Grbl. Remember it's a purely a safety feature.

\$22 - Homing cycle, bool

Ahh, homing. For those just initiated into CNC, the homing cycle is used to accurately and precisely locate a known and consistent position on a machine every time you start up your Grbl between sessions. In other words, you know exactly where you are at any given time, every time. Say you start machining something or are about to start the next step in a job and the power goes out, you re-start Grbl and Grbl has no idea where it is. You're left with the task of figuring out where you are. If you have homing, you always have the machine zero reference point to locate from, so all you have to do is run the homing cycle and resume where you left off.

To set up the homing cycle for Grbl, you need to have limit switches in a fixed position that won't get bumped or moved, or else your reference point gets messed up. Usually they are setup in the farthest point in +x, +y, +z of each axes. Wire your limit switches in with the limit pins and ground, just like with the hard limits, and enable homing. If you're curious, you can use your limit switches for both hard limits AND homing. They play nice with each other.

By default, Grbl's homing cycle moves the Z-axis positive first to clear the workspace and then moves both the X and Y-axes at the same time in the positive direction. To set up how your homing cycle behaves, there are more Grbl settings down the page describing what they do (and compile-time options as well.)

Also, one more thing to note, when homing is enabled. Grbl will lock out all G-code commands until you perform a homing cycle. Meaning no axes motions, unless the lock is disabled (\$X) but more on that later. Most, if not all CNC controllers, do something similar, as it is mostly a safety feature to prevent users from making a positioning mistake, which is very easy to do and be saddenee when a mistake ruins a part. If you find this annoying or find any weird bugs, please let us know and we'll try to work on it so everyone is happy. :)

NOTE: Check out config.h for more homing options for advanced users. You can disable the homing lockout at startup, configure which axes move first during a homing cycle and in what order, and more.

\$23 - Homing dir invert mask, int:binary

By default, Grbl assumes your homing limit switches are in the positive direction, first moving the z-axis positive, then the x-y axes positive before trying to precisely locate machine zero by going back and forth slowly around the switch. If your machine has a limit switch in the negative direction, the homing direction mask can invert the axes' direction. It works just like the step port invert and direction port invert masks, where all you have to do is send the value in the table to indicate what axes you want to invert and search for in the opposite direction.

\$24 - Homing feed, mm/min

The homing cycle first searches for the limit switches at a higher seek rate, and after it finds them, it moves at a slower feed rate to home into the precise location of machine zero. Homing feed rate is that slower feed rate. Set this to whatever rate value that provides repeatable and precise machine zero locating.

\$25 - Homing seek, mm/min

Homing seek rate is the homing cycle search rate, or the rate at which it first tries to find the limit switches. Adjust to whatever rate gets to the limit switches in a short enough time without crashing into your limit switches if they come in too fast.

\$26 - Homing debounce, ms

Whenever a switch triggers, some of them can have electrical/mechanical noise that actually 'bounce' the signal high and low for a few milliseconds before settling in. To solve this, you need to debounce the signal, either by hardware with some kind of signal conditioner or by software

with a short delay to let the signal finish bouncing. Grbl performs a short delay, only homing when locating machine zero. Set this delay value to whatever your switch needs to get repeatable homing. In most cases, 5-25 milliseconds is fine.

\$27 - Homing pull-off, mm

To play nice with the hard limits feature, where homing can share the same limit switches, the homing cycle will move off all of the limit switches by this pull-off travel after it completes. In other words, it helps to prevent accidental triggering of the hard limit after a homing cycle.

\$100, \$101 and \$102 - [X,Y,Z] steps/mm

Grbl needs to know how far each step will take the tool in reality. To calculate steps/mm for an axis of your machine you need to know:

- The mm traveled per revolution of your stepper motor. This is dependent on your belt drive gears or lead screw pitch.
- The full steps per revolution of your steppers (typically 200)
- The microsteps per step of your controller (typically 1, 2, 4, 8, or 16). Tip: Using high microstep values (e.g., 16) can reduce your stepper motor torque, so use the lowest that gives you the desired axis resolution and comfortable running properties.

The steps/mm can then be calculated like this:

$$\text{steps_per_mm} = (\text{steps_per_revolution} * \text{microsteps}) / \text{mm_per_rev}$$

Compute this value for every axis and write these settings to Grbl.

\$110, \$111 and \$112 - [X,Y,Z] Max rate, mm/min

This sets the maximum rate each axis can move. Whenever Grbl plans a move, it checks whether or not the move causes any one of these individual axes to exceed their max rate. If so, it'll slow down the motion to ensure none of the axes exceed their max rate limits. This means that each axis has its own independent speed, which is extremely useful for limiting the typically slower Z-axis.

The simplest way to determine these values is to test each axis one at a time by slowly increasing max rate settings and moving it. For example, to test the X-axis, send Grbl something like G0 X50 with enough travel distance so that the axis accelerates to its max speed. You'll know you've hit the max rate threshold when your steppers stall. It'll make a bit of noise, but shouldn't hurt your motors. Enter a setting a 10-20% below this value, so you can account for wear, friction, and the mass of your workpiece/tool. Then, repeat for your other axes.

NOTE: This max rate setting also sets the G0 seek rates.

\$120, \$121, \$122 - [X,Y,Z] Acceleration, mm/sec²

This sets the axes acceleration parameters in mm/second/second. Simplistically, a lower value makes Grbl ease slower into motion, while a higher value yields tighter moves and reaches the desired feedrates much quicker. Much like the max rate setting, each axis has its own acceleration value and are independent of each other. This means that a multi-axis motion will only accelerate as quickly as the lowest contributing axis can.

Again, like the max rate setting, the simplest way to determine the values for this setting is to individually test each axis with slowly increasing values until the motor stalls. Then finalize your acceleration setting with a value 10-20% below this absolute max value. This should account for wear, friction, and mass inertia. We highly recommend that you dry test some G-code programs with your new settings before committing to them. Sometimes the loading on your machine is different when moving in all axes together.

\$130, \$131, \$132 - [X,Y,Z] Max travel, mm

This sets the maximum travel from end to end for each axis in mm. This is only useful if you have soft limits (and homing) enabled, as this is only used by Grbl's soft limit feature to check if you have exceeded your machine limits with a motion command.

Grbl's Other '\$' Commands

The other \$ commands provide additional controls for the user, such as printing feedback on the current G-code parser modal state or running the homing cycle. This section explains what these commands are and how to use them.

\$# - View gcode parameters

G-code parameters store the coordinate offset values for G54-G59 work coordinates, G28/G30 pre-defined positions, G92 coordinate offset, tool length offsets, and probing (not officially, but we added here anyway). Most of these parameters are directly written to EEPROM anytime they are changed and are persistent. Meaning that they will remain the same, regardless of power-down, until they are explicitly changed. The non-persistent parameters, which will not be retained when reset or power-cycled, are G92, G43.1 tool length offsets, and the G38.2 probing data.

G54-G59 work coordinates can be changed via the `G10 L2 Px` or `G10 L20 Px` command defined by the NIST gcode standard and the EMC2 (linuxcnc.org) standard. G28/G30 pre-defined positions can be changed via the `G28.1` and the `G30.1` commands, respectively.

When `$#` is called, Grbl will respond with the stored offsets from machine coordinates for each system as follows. `TLO` denotes tool length offset, and `PRB` denotes the coordinates of the last probing cycle.

```
[G54:4.000,0.000,0.000]
[G55:4.000,6.000,7.000]
[G56:0.000,0.000,0.000]
[G57:0.000,0.000,0.000]
[G58:0.000,0.000,0.000]
[G59:0.000,0.000,0.000]
[G28:1.000,2.000,0.000]
[G30:4.000,6.000,0.000]
[G92:0.000,0.000,0.000]
[TLO:0.000,0.000,0.000]
[PRB:0.000,0.000,0.000]
```

\$G - View gcode parser state

This command prints all of the active gcode modes in Grbl's G-code parser. When sending this command to Grbl, it will reply with something like:

```
[G0 G54 G17 G21 G90 G94 M0 M5 M9 T0 S0.0 F500.0]
```

These active modes determine how the next G-code block or command will be interpreted by Grbl's G-code parser. For those new to G-code and CNC machining, modes sets the parser into a particular state so you don't have to constantly tell the parser how to parse it. These modes are organized into sets called "modal groups" that cannot be logically active at the same time. For example, the units modal group sets whether your G-code program is interpreted in inches or in millimeters.

A short list of the modal groups, supported by Grbl, is shown below, but more complete and detailed descriptions can be found at LinuxCNC's website. The G-code commands in **bold** indicate the default modes upon powering-up Grbl or resetting it.

Modal Group Meaning

Member Words

Motion Mode	G0 , G1, G2, G3, G38.2, G38.3, G38.4, G38.5, G80
Coordinate System Select	G54 , G55, G56, G57, G58, G59
Plane Select	G17 , G18, G19
Distance Mode	G90 , G91
Arc IJK Distance Mode	G91.1
Feed Rate Mode	G93, G94
Units Mode	G20, G21
Cutter Radius Compensation	G40
Tool Length Offset	G43.1, G49
Program Mode	M0 , M1, M2, M30
Spindle State	M3, M4, M5
Coolant State	M7, M8, M9

In addition to the G-code parser modes, Grbl will report the active **T** tool number, **S** spindle speed, and **F** feed rate, which all default to 0 upon a reset. For those that are curious, these don't quite fit into nice modal groups, but are just as important for determining the parser state.

\$I - View build info

This prints feedback to the user the Grbl version and source code build date. Optionally, **\$I** can also store a short string to help identify which CNC machine you are communicating with, if you have more than machine using Grbl. To set this string, send Grbl **\$I=xxx**, where **xxx** is your customization string that is less than 80 characters. The next time you query Grbl with a **\$I** view build info, Grbl will print this string after the version and build date.

\$N - View startup blocks

`$Nx` are the startup blocks that Grbl runs every time you power on Grbl or reset Grbl. In other words, a startup block is a line of G-code that you can have Grbl auto-magically run to set your G-code modal defaults, or anything else you need Grbl to do everytime you start up your machine. Grbl can store two blocks of G-code as a system default.

So, when connected to Grbl, type `$N` and then enter. Grbl should respond with something short like:

```
$N0=  
$N1=  
Ok
```

Not much to go on, but this just means that there is no G-code block stored in line `$N0` for Grbl to run upon startup. `$N1` is the next line to be run.

\$Nx=line - Save startup block

IMPORTANT: Be very careful when storing any motion (G0/1,G2/3,G28/30) commands in the startup blocks. These motion commands will run everytime you reset or power up Grbl, so if you have an emergency situation and have to e-stop and reset, a startup block move can and will likely make things worse quickly. Also, do not place any commands that save data to EEPROM, such as G10/G28.1/G30.1. This will cause Grbl to constantly re-write this data upon every startup and reset, which will eventually wear out your Arduino's EEPROM.

Typical usage for a startup block is simply to set your preferred modal states, such as G20 inches mode, always default to a different work coordinate system, or, to provide a way for a user to run some user-written unique feature that they need for their crazy project.

To set a startup block, type `$N0=` followed by a valid G-code block and an enter. Grbl will run the block to check if it's valid and then reply with an `ok` or an `error:` to tell you if it's successful or something went wrong. If there is an error, Grbl will not save it.

For example, say that you want to use your first startup block `$N0` to set your G-code parser modes like G54 work coordinate, G20 inches mode, G17 XY-plane. You would type `$N0=G20 G54 G17` with an enter and you should see an 'ok' response. You can then check if it got stored by typing `$N` and you should now see a response like `$N0=G20G54G17`.

Once you have a startup block stored in Grbl's EEPROM, everytime you startup or reset you will see your startup block printed back to you and a response from Grbl to indicate if it ran okay. So for the previous example, you'll see:

```
Grbl 0.9i ['$' for help]  
G20G54G17ok
```

If you have multiple G-code startup blocks, they will print back to you in order upon every startup. And if you'd like to clear one of the startup blocks, (e.g., block 0) type `$N0=` without anything following the equal sign.

Also, if you have homing enabled, the startup blocks will execute immediately after the homing cycle, not at startup.

`$C` - Check gcode mode

This toggles the Grbl's gcode parser to take all incoming blocks process them completely, as it would in normal operation, but it does not move any of the axes, ignores dwells, and powers off the spindle and coolant. This is intended as a way to provide the user a way to check how their new G-code program fares with Grbl's parser and monitor for any errors (and checks for soft limit violations, if enabled).

When toggled off, Grbl will perform an automatic soft-reset (^X). This is for two purposes. It simplifies the code management a bit. But, it also prevents users from starting a job when their G-code modes are not what they think they are. A system reset always gives the user a fresh, consistent start.

`$X` - Kill alarm lock

Grbl's alarm mode is a state when something has gone critically wrong, such as a hard limit or an abort during a cycle, or if Grbl doesn't know its position. By default, if you have homing enabled and power-up the Arduino, Grbl enters the alarm state, because it does not know its position. The alarm mode will lock all G-code commands until the '\$H' homing cycle has been performed. Or if a user needs to override the alarm lock to move their axes off their limit switches, for example, '\$X' kill alarm lock will override the locks and allow G-code functions to work again.

But, tread carefully!! This should only be used in emergency situations. The position has likely been lost, and Grbl may not be where you think it is. So, it's advised to use G91 incremental mode to make short moves. Then, perform a homing cycle or reset immediately afterwards.

`$H` - Run homing cycle

This command is the only way to perform the homing cycle in Grbl. Some other motion controllers designate a special G-code command to run a homing cycle, but this is incorrect according to the G-code standards. Homing is a completely separate command handled by the controller.

TIP: After running a homing cycle, rather jogging manually all the time to a position in the middle of your workspace volume. You can set a G28 or G30 pre-defined position to be your post-homing position, closer to where you'll be machining. To set these, you'll first need to jog your machine to where you would want it to move to after homing. Type G28.1 (or G30.1) to have Grbl store that

position. So then after '\$H' homing, you could just enter 'G28' (or 'G30') and it'll move there auto-magically. In general, I would just move the XY axis to the center and leave the Z-axis up. This ensures that there isn't a chance the tool in the spindle will interfere and that it doesn't catch on anything.

\$RST=\$, \$RST=#, and \$RST=* - Restore Grbl settings and data to defaults

These commands are not listed in the main Grbl \$ help message, but are available to allow users to restore parts of or all of Grbl's EEPROM data. Note: Grbl will automatically reset after executing one of these commands to ensure the system is initialized correctly.

- **\$RST=\$** : Erases and restores the \$\$ Grbl settings back to defaults, which is defined by the default settings file used when compiling Grbl. Often OEMs will build their Grbl firmwares with their machine-specific recommended settings. This provides users and OEMs a quick way to get back to square-one, if something went awry or if a user wants to start over.
- **\$RST=#** : Erases and zeros all G54-G59 work coordinate offsets and G28/30 positions stored in EEPROM. These are generally the values seen in the \$# parameters printout. This provides an easy way to clear these without having to do it manually for each set with a G20 L2/20 or G28.1/30.1 command.
- **\$RST=*** : This clears and restores all of the EEPROM data used by Grbl. This includes \$\$ settings, \$# parameters, \$N startup lines, and \$I build info string. Note that this doesn't wipe the entire EEPROM, only the data areas Grbl uses. To do a complete wipe, please use the Arduino IDE's EEPROM clear example project.

Real-Time Commands: ~, !, ?, and Ctrl-X

The last four of Grbl's commands are real-time commands. This means that they can be sent at anytime, anywhere, and Grbl will immediately respond, no matter what it's doing. For those that are curious, these are special characters that are 'picked-off' from the incoming serial stream and will tell Grbl to execute them, usually within a few milliseconds.

~ - Cycle start

This is the cycle start or resume command that can be issued at any time, as it is a real-time command. When Grbl has motions queued in its buffer and is ready to go, the ~ cycle start command will start executing the buffer and Grbl will begin moving the axes. However, by default, auto-cycle start is enabled, so new users will not need this command unless a feed hold is performed. When a feed hold is executed, cycle start will resume the program. Cycle start will only be effective when there are motions in the buffer ready to go and will not work with any other process like homing.

! - Feed hold

The feed hold command will bring the active cycle to a stop via a controlled deceleration, so as not to lose position. It is also real-time and may be activated at any time. Once finished or paused, Grbl will wait until a cycle start command is issued to resume the program. Feed hold can only pause a cycle and will not affect homing or any other process.

If you need to stop a cycle mid-program and can't afford losing position, perform a feed hold to have Grbl bring everything to a controlled stop. Once finished, you can then issue a reset. Always try to execute a feed hold whenever the machine is running before hitting reset, except of course if there is some emergency situation.

? - Current status

The ? command immediately returns Grbl's active state and the real-time current position, both in machine coordinates and work coordinates. Optionally, you can also have Grbl respond back with the RX serial buffer and planner buffer usage via the status report mask setting. The ? command may be sent at any time and works asynchronously with all other processes that Grbl is doing. The \$13 Grbl setting determines whether it reports millimeters or inches. When ? is pressed, Grbl will immediately reply with something like the following:

```
<Idle,MPos:5.529,0.560,7.000,WPos:1.529,-5.440,-0.000>
```

The active states Grbl can be in are: **Idle**, **Run**, **Hold**, **Door**, **Home**, **Alarm**, **Check**

- **Idle:** All systems are go, no motions queued, and it's ready for anything.

- **Run:** Indicates a cycle is running.
- **Hold:** A feed hold is in process of executing, or slowing down to a stop. After the hold is complete, Grbl will remain in Hold and wait for a cycle start to resume the program.
- **Door:** (New in v0.9i) This compile-option causes Grbl to feed hold, shut-down the spindle and coolant, and wait until the door switch has been closed and the user has issued a cycle start. Useful for OEM that need safety doors.
- **Home:** In the middle of a homing cycle. NOTE: Positions are not updated live during the homing cycle, but they'll be set to the home position once done.
- **Alarm:** This indicates something has gone wrong or Grbl doesn't know its position. This state locks out all G-code commands, but allows you to interact with Grbl's settings if you need to. '\$X' kill alarm lock releases this state and puts Grbl in the Idle state, which will let you move things again. As said before, be cautious of what you are doing after an alarm.
- **Check:** Grbl is in check G-code mode. It will process and respond to all G-code commands, but not motion or turn on anything. Once toggled off with another '\$C' command, Grbl will reset itself.

Ctrl-x - Reset Grbl

This is Grbl's soft reset command. It's real-time and can be sent at any time. As the name implies, it resets Grbl, but in a controlled way, retains your machine position, and all is done without powering down your Arduino. The only times a soft-reset could lose position is when problems arise and the steppers were killed while they were moving. If so, it will report if Grbl's tracking of the machine position has been lost. This is because an uncontrolled deceleration can lead to lost steps, and Grbl has no feedback to how much it lost (this is the problem with steppers in general). Otherwise, Grbl will just re-initialize, run the startup lines, and continue on its merry way.

Please note that it's recommended to do a soft-reset before starting a job. This guarantees that there aren't any G-code modes active that from playing around or setting up your machine before running the job. So, your machine will always starts fresh and consistently, and your machine does what you expect it to.