# G-Code, GCode, gcode

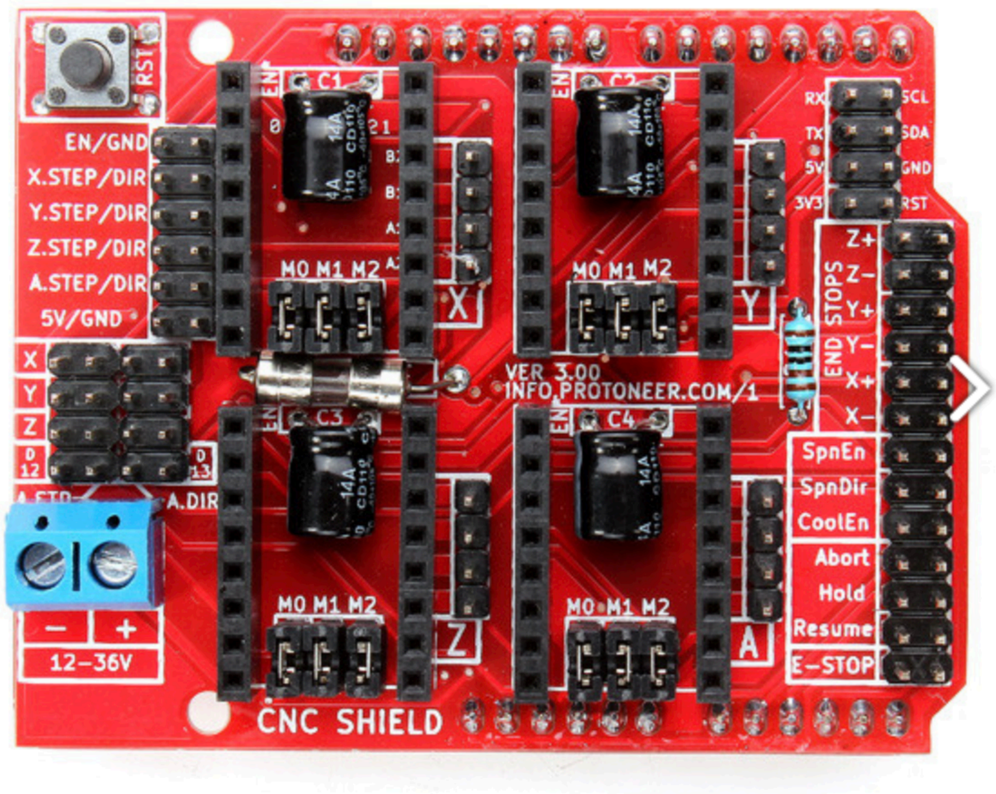
CNC machine codes, software tools, and music(?!?)

# Announcements

- **Bay Area Maker Faire** (May 17-19)
- **Thursday:**
  - Recap of Assignment #1 submissions
  - Lecture: Computer-Aided Manufacturing (CAM)
- **Next Tuesday**, April 30: **Short project pitches**
  - Project Proposals due **May 9**
- **Assignment #3: T-Bot**
  - Optional: limit switches
  - Optional: design a holder for a pen, etc.
  - Bonus: Improve design
    - e.g., reduce "binding" forces

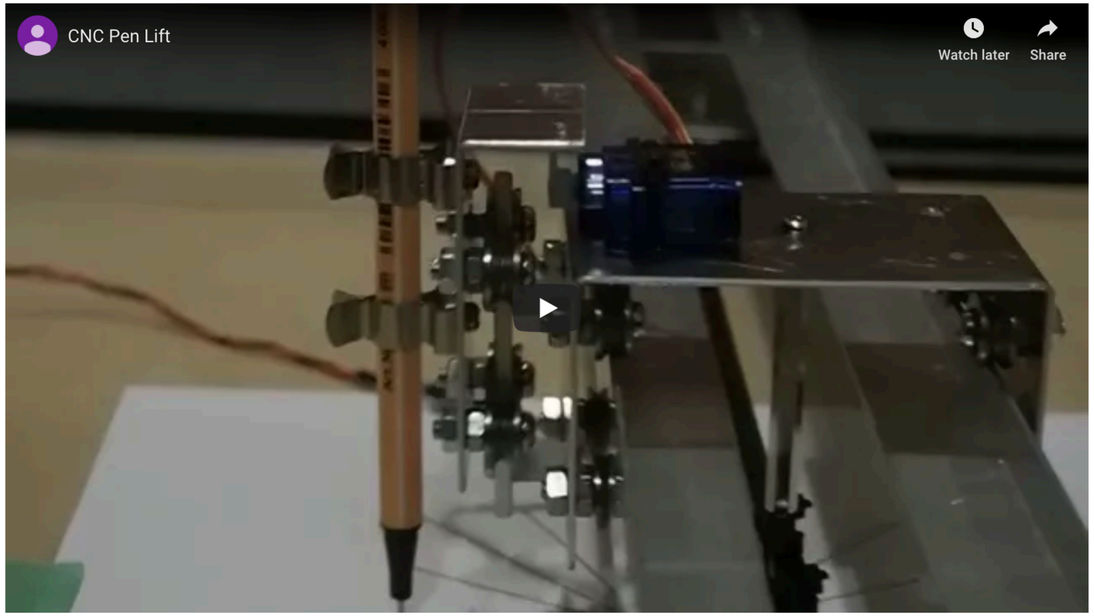
# Re: Limit Switches

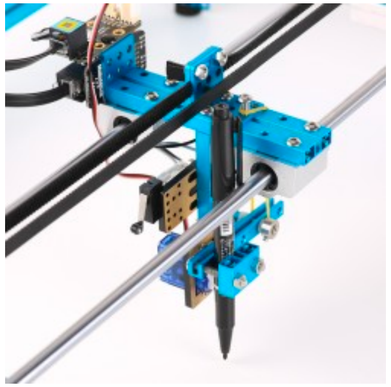
- Wire them up to your CNC SHIELD
- Take a look at grbl settings:
  - $21 - Hard limits, boolean
  - $5 - Limit pins invert, boolean




- General info on wiring limit switches:
  - https://github.com/gnea/grbl/wiki/Wiring-Limit-Switches

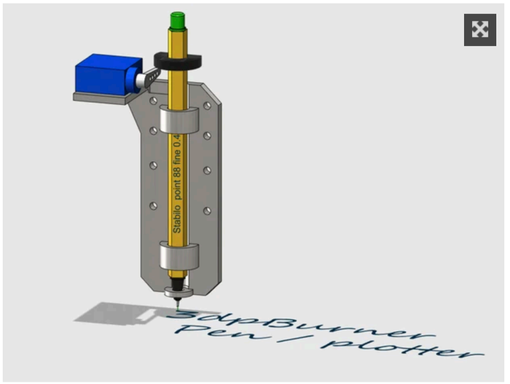
# Some Pen-Holder Designs



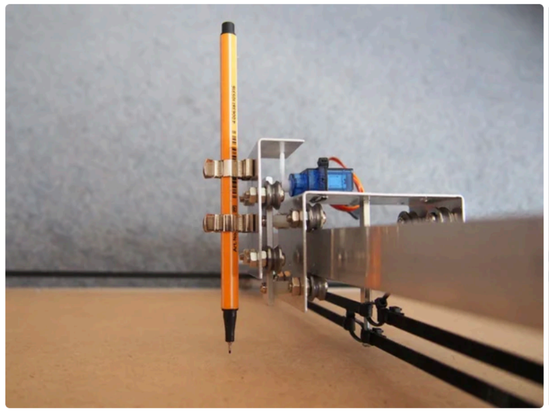



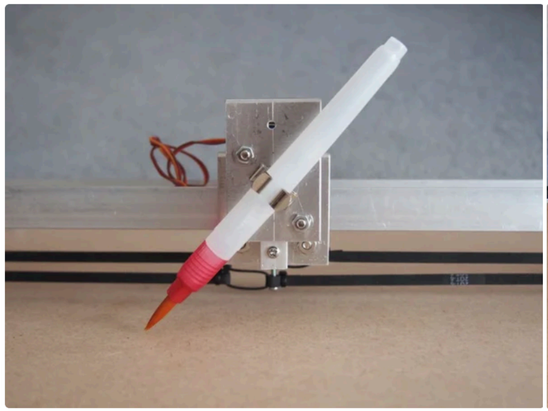
https://www.makeblock.com/project/xy-plotter-robot-kit

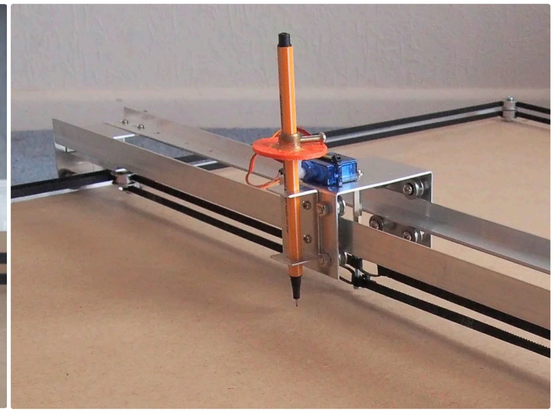
https://www.axidraw.com



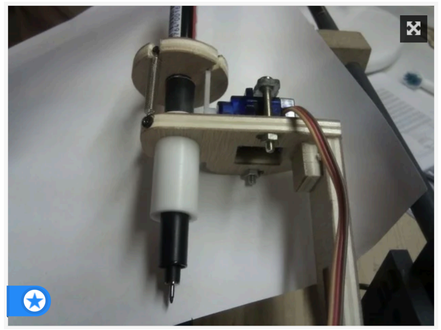

https://www.thingiverse.com/thing:1451492



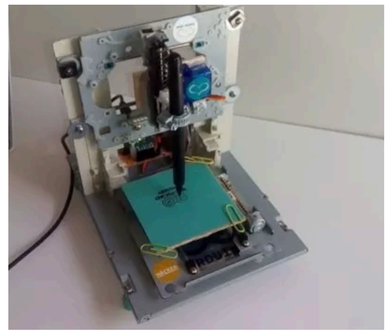




https://www.instructables.com/id/CNC-Pen-Lift



https://www.thingiverse.com/thing:13407



https://create.arduino.cc/projecthub/Yogeshmodi/sketch-it-cnc-plotter-95019d

# G-Code, GCode, gcode

CNC machine codes, software tools, and music(?!?)

# Why use G-Code to make things?

# We could write CNC code like this...

```
/ / The following is a simple stepper motor control procedures,

# define EN 8 / / stepper motor enable , active low
# define X_DIR 5 / / X -axis stepper motor direction control
# define Y_DIR 6 / / y -axis stepper motor direction control
# define Z_DIR 7 / / z axis stepper motor direction control
# define X_STP 2 / / x -axis stepper control
# define Y_STP 3 / / y -axis stepper control
# define Z_STP 4 / / z -axis stepper control
/ *
/ / Function : step . function: to control the direction of the stepper motor , the number of steps .
/ / Parameters : dir direction control , dirPin corresponding stepper motor DIR pin , stepperPin corresponding stepper motor " step " pin , Step number of step of no return value.

* /
void step (boolean dir, byte dirPin, byte stepperPin, int steps)
{
digitalWrite (dirPin, dir);
delay (50);
for (int i = 0; i digitalWrite (stepperPin, HIGH);
delayMicroseconds (800);
digitalWrite (stepperPin, LOW);
delayMicroseconds (800);
}
}
void setup () {/ / The stepper motor used in the IO pin is set to output
pinMode (X_DIR, OUTPUT); pinMode (X_STP, OUTPUT);
pinMode (Y_DIR, OUTPUT); pinMode (Y_STP, OUTPUT);
pinMode (Z_DIR, OUTPUT); pinMode (Z_STP, OUTPUT);
pinMode (EN, OUTPUT);
digitalWrite (EN, LOW);
}
void loop () {
step (false, X_DIR, X_STP, 200); / / X axis motor reverse 1 ring, the 200 step is a circle.
step (false, Y_DIR, Y_STP, 200); / / y axis motor reverse 1 ring, the 200 step is a circle.
step (false, Z_DIR, Z_STP, 200); / / z axis motor reverse 1 ring, the 200 step is a circle.
delay (1000);
step (true, X_DIR, X_STP, 200); / / X axis motor forward 1 laps, the 200 step is a circle.
step (true, Y_DIR, Y_STP, 200); / / y axis motor forward 1 laps, the 200 step is a circle.
step (true, Z_DIR, Z_STP, 200); / / z axis motor forward 1 laps, the 200 step is a circle.
delay (1000);
}
```

# Why is this not great for makers?

# G-Code

- Most common language for CNC machines
- Developed in `50s at MIT Servomechanisms Lab
- Simple commands for simple machines
- Many common codes that are universal to most machines / parsers
- Many machine-specific code interpretations, (ISO) standards, and G-Code dialects
- https://en.wikipedia.org/wiki/G-code

*"This simple aluminum ashtray represents a revolution in the machine tool industry. It was produced in 1959 as part of a demonstration of a milling machine controlled by a computer punch tape instead of a human operator. The development of this machine was more than a decade in the making and the result of a complex story about competing visions for this technology. After World War II, the U.S. Air Force gave several contracts to the Parsons Corporation to develop further the numerically control machining innovations made by its founder John Parsons. Interested in experiments being conducted at the MIT Servomechanisms Laboratory, Parsons proposed in 1949 that MIT become a project subcontractor to provide expertise on automatic control. Over the next 10 years, MIT gained control over the entire project as the Servomechanisms Laboratory vision of "three-axis continuous path control" supplanted the original Parsons conception of "plunge-cutting positioning." Conflict always shapes technology but this particular story, chronicled by historian David Noble, has become a significant object lesson in the history of technology."*

http://museum.mit.edu/150/86

# G-Code Overview

- An introduction from linuxcnc:
  - **Overview:** http://linuxcnc.org/docs/html/gcode/overview.html
  - **G Codes:** http://linuxcnc.org/docs/html/gcode/g-code.html
  - **M Codes:** http://linuxcnc.org/docs/html/gcode/m-code.html
- Some key items:
  - Format of a line
  - Commands and machine modes
  - Modal groups, e.g., for motion commands
  - "Order of Execution" & "Best Practices"
  - Parameters/variables, operators, functions, ...

## 22. G Code Order of Execution

The order of execution of items on a line is defined not by the position of each item on the line, but by the following list:

- O-word commands (optionally followed by a comment but no other words allowed on the same line)
- Comment (including message)
- Set feed rate mode (G93, G94).
- Set feed rate (F).
- Set spindle speed (S).
- Select tool (T).
- HAL pin I/O (M62-M68).
- Change tool (M6) and Set Tool Number (M61).
- Spindle on or off (M3, M4, M5).
- Save State (M70, M73), Restore State (M72), Invalidate State (M71).
- Coolant on or off (M7, M8, M9).
- Enable or disable overrides (M48, M49,M50,M51,M52,M53).
- User-defined Commands (M100-M199).
- Dwell (G4).
- Set active plane (G17, G18, G19).
- Set length units (G20, G21).
- Cutter radius compensation on or off (G40, G41, G42)
- Cutter length compensation on or off (G43, G49)
- Coordinate system selection (G54, G55, G56, G57, G58, G59, G59.1, G59.2, G59.3).
- Set path control mode (G61, G61.1, G64)
- Set distance mode (G90, G91).
- Set retract mode (G98, G99).
- Go to reference location (G28, G30) or change coordinate system data (G10) or set axis offsets (G92, G92.1, G92.2, G94).
- Perform motion (G0 to G3, G33, G38.n, G73, G76, G80 to G89), as modified (possibly) by G53.
- Stop (M0, M1, M2, M30, M60).

http://linuxcnc.org/docs/html/gcode/overview.html#_g_code_order_of_execution

# LinuxCNC "G-Code" Quick Reference

http://linuxcnc.org/docs/html/gcode.html

LinuxCNC "G-Code" Quick Reference

| Code | Parameters | Description |
|---|---|---|
| **Motion** | (X Y Z A B C U V W apply to all motions) | |
| G0 | | Rapid Move |
| G1 | | Linear Move |
| G2, G3 | I J K or R, P | Arc Move |
| G4 | P | Dwell |
| G5 | I J P Q | Cubic Spline |
| G5.1 | I J | Quadratic Spline |
| G5.2 | P L | NURBS |
| G38.2 - G38.5 | | Straight Probe |
| G33 | K | Spindle Synchronized Motion |
| G33.1 | K | Rigid Tapping |
| G80 | | Cancel Canned Cycle |
| **Canned cycles** | (X Y Z or U V W apply to canned cycles, depending on active plane) | |
| G81 | R L (P) | Drilling Cycle |
| G82 | R L (P) | Drilling Cycle, Dwell |
| G83 | R L Q | Drilling Cycle, Peck |
| G73 | R L Q | Drilling Cycle, Chip Breaking |
| G85 | R L (P) | Boring Cycle, Feed Out |
| G89 | R L (P) | Boring Cycle, Dwell, Feed Out |
| G76 | P Z I J R K Q H L E | Threading Cycle |
| **Distance Mode** | | |
| G90, G91 | | Distance Mode |
| G90.1, G91.1 | | Arc Distance Mode |
| G7 | | Lathe Diameter Mode |
| G8 | | Lathe Radius Mode |
| **Feed Rate Mode** | | |
| G93, G94, G95 | | Feed Rate Mode |
| **Spindle Control** | | |
| M3, M4, M5 | S | Spindle Control |
| M19 | | Orient Spindle |
| G96, G97 | S D | Spindle Control Mode |
| **Coolant** | | |
| M7, M8, M9 | | Coolant Control |
| **Tool Length Offset** | | |
| G43 | H | Tool Length Offset |
| G43.1 | | Dynamic Tool Length Offset |
| G43.2 | H | Apply additional Tool Length Offset |
| G49 | | Cancel Tool Length Compensation |
| **Stopping** | | |
| M0, M1 | | Program Pause |
| M2, M30 | | Program End |
| M60 | | Pallet Change Pause |
| **Units** | | |
| G20, G21 | | Units (inch, mm) |
| **Plane Selection** | (affects G2, G3, G81…G89, G40…G42) | |
| G17 - G19.1 | | Plane Select |
| **Cutter Radius Compensation** | | |
| G40 | | Compensation Off |
| G41,G42 | D | Cutter Compensation |
| G41.1, G42.1 | D L | Dynamic Cutter Compensation |
| **Path Control Mode** | | |
| G61 G61.1 | | Exact Path Mode |
| G64 | P Q | Path Blending |
| **Return Mode in Canned Cycles** | | |
| G98, G99 | | Canned Cycle Return Level |
| **Other Modal Codes** | | |
| F | | Set Feed Rate |
| S | | Set Spindle Speed |
| T | | Select Tool) |
| M48, M49 | | Speed and Feed Override Control |
| M50 | P0 (off) or P1 (on) | Feed Override Control |
| M51 | P0 (off) or P1 (on) | Spindle Speed Override Control |
| M52 | P0 (off) or P1 (on) | Adaptive Feed Control |
| M53 | P0 (off) or P1 (on) | Feed Stop Control |
| G54-G59.3 | | Select Coordinate System |

| **Flow-control Codes** | | |
|---|---|---|
| o sub | | Subroutines, sub/endsub call |
| o while | | Looping, while/endwhile do/while |
| o if | | Conditional, if/else/endif |
| o repeat | | Repeat a loop of code |
| [] | | Indirection |
| o call | | Call named file |
| M70 | | Save modal state |
| M71 | | Invalidate stored state |
| M72 | | Restore modal state |
| M73 | | Save and Auto-restore modal state |
| **Input/Output Codes** | | |
| M62 - M65 | P | Digital Output Control |
| M66 | P E L Q | Wait on Input |
| M67 | T | Analog Output,Synchronized |
| M68 | T | Analog Output, Immediate |
| **Non-modal Codes** | | |
| M6 | T | Tool Change |
| M61 | Q | Set Current Tool |
| G10 L1 | P Q R | Set Tool Table |
| G10 L10 | P | Set Tool Table |
| G10 L11 | P | Set Tool Table |
| G10 L2 | P R | Set Coordinate System |
| G10 L20 | P | Set Coordinate System |
| G28, G28.1 | | Go/Set Predefined Position |
| G30, G30.1 | | Go/Set Predefined Position |
| G53 | | Move in Machine Coordinates |
| G92 | | Coordinate System Offset |
| G92.1, G92.2 | | Reset G92 Offsets |
| G92.3 | | Restore G92 Offsets |
| M101 - M199 | P Q | User Defined Commands |
| **Comments & Messages** | | |
| ;(...) | | Comments |
| (MSG,...) | | Messages |
| (DEBUG,...) | | Debug Messages |
| (PRINT,...) | | Print Messages |

**Note: Not all available in grbl.**


## About Grbl

Grbl is a free, open source, high performance software for controlling the motion of machines that move, that make things, or that make things move, and will run on a straight Arduino. If the maker movement was an industry, Grbl would be the industry standard.

Most open source 3D printers have Grbl in their hearts. It has been adapted for use in hundreds of projects including laser cutters, automatic hand writers, hole drillers, graffiti painters and oddball drawing machines. Due to its performance, simplicity and frugal hardware requirements Grbl has grown into a little open source phenomenon.

https://github.com/gnea/grbl/wiki


## Who should use Grbl

Makers who do milling or laser cutting and need a nice, simple controller for their system that will run on the ubiquitous Arduino Uno. People who loathe to clutter their space with legacy PC-towers just for the parallel-port. Tinkerers who need a controller written in tidy, modular C as a basis for their project.

## Nice features

Grbl is great for light duty production. We use it for all our milling, running it from our laptops or Raspberry Pis using superb GUIs written for Grbl to stream G-code jobs. Grbl is written in highly optimized C utilizing all the clever features of the Arduino's Atmega328p chips to achieve precise timing and asynchronous operation. It is able to maintain more than **30kHz** step rate and delivers a clean, jitter free stream of control pulses.

Grbl is for three axis machines. No rotation axes (yet) – just X, Y, and Z.

The G-code interpreter implements a subset of the LinuxCNC standard and is supported by most CAM-tools with no issues. For descriptions of these G-codes, see LinuxCNC's superb documentation for their G-code descriptions, (G-code Quick Reference), and the Shapeoko wiki which attempts to list all codes supported by Grbl with appropriate commentary. Note that there are only a handful of deviations from the written G-code standard listed below. If you notice any other discrepancies, please let use know!

https://github.com/gnea/grbl/wiki


Supported G-Codes in **v1.1**

- **G0, G1:** *Linear Motions*
- **G2, G3:** *Arc and Helical Motions*
- **G4:** *Dwell*
- **G10 L2, G10 L20:** *Set Work Coordinate Offsets*
- **G17, G18, G19:** *Plane Selection*
- **G20, G21:** *Units*
- **G28, G30:** *Go to Pre-Defined Position*
- **G28.1, G30.1:** *Set Pre-Defined Position*
- **G38.2:** *Probing*
- **G38.3, G38.4, G38.5:** *Probing*
- **G40:** *Cutter Radius Compensation Modes OFF (Only)*
- **G43.1, G49:** *Dynamic Tool Length Offsets*
- **G53:** *Move in Absolute Coordinates*
- **G54, G55, G56, G57, G58, G59:** *Work Coordinate Systems*
- **G61:** *Path Control Modes*
- **G80:** *Motion Mode Cancel*
- **G90, G91:** *Distance Modes*
- **G91.1:** *Arc IJK Distance Modes*
- **G92:** *Coordinate Offset*
- **G92.1:** *Clear Coordinate System Offsets*
- **G93, G94:** *Feedrate Modes*
- **M0, M2, M30:** *Program Pause and End*
- **M3, M4, M5:** *Spindle Control*
- **M7* , M8, M9:** *Coolant Control*
- **M56* :** *Parking Motion Override Control*

# LinuxCNC "G-Code" Quick Reference

http://linuxcnc.org/docs/html/gcode.html

LinuxCNC "G-Code" Quick Reference

| Code | Parameters | Description |
|---|---|---|
| **Motion** | (X Y Z A B C U V W apply to all motions) | |
| G0 | | Rapid Move |
| G1 | | Linear Move |
| G2, G3 | I J K or R, P | Arc Move |
| G4 | P | Dwell |
| G5 | I J P Q | Cubic Spline |
| G5.1 | I J | Quadratic Spline |
| G5.2 | P L | NURBS |
| G38.2 - G38.5 | | Straight Probe |
| G33 | K | Spindle Synchronized Motion |
| G33.1 | K | Rigid Tapping |
| G80 | | Cancel Canned Cycle |
| **Canned cycles** | (X Y Z or U V W apply to canned cycles, depending on active plane) | |
| G81 | R L (P) | Drilling Cycle |
| G82 | R L (P) | Drilling Cycle, Dwell |
| G83 | R L Q | Drilling Cycle, Peck |
| G73 | R L Q | Drilling Cycle, Chip Breaking |
| G85 | R L (P) | Boring Cycle, Feed Out |
| G89 | R L (P) | Boring Cycle, Dwell, Feed Out |
| G76 | P Z I J R K Q H L E | Threading Cycle |
| **Distance Mode** | | |
| G90, G91 | | Distance Mode |
| G90.1, G91.1 | | Arc Distance Mode |
| G7 | | Lathe Diameter Mode |
| G8 | | Lathe Radius Mode |
| **Feed Rate Mode** | | |
| G93, G94, G95 | | Feed Rate Mode |
| **Spindle Control** | | |
| M3, M4, M5 | S | Spindle Control |
| M19 | | Orient Spindle |
| G96, G97 | S D | Spindle Control Mode |
| **Coolant** | | |
| M7, M8, M9 | | Coolant Control |
| **Tool Length Offset** | | |
| G43 | H | Tool Length Offset |
| G43.1 | | Dynamic Tool Length Offset |
| G43.2 | H | Apply additional Tool Length Offset |
| G49 | | Cancel Tool Length Compensation |
| **Stopping** | | |
| M0, M1 | | Program Pause |
| M2, M30 | | Program End |
| M60 | | Pallet Change Pause |
| **Units** | | |
| G20, G21 | | Units (inch, mm) |
| **Plane Selection** | (affects G2, G3, G81…G89, G40…G42) | |
| G17 - G19.1 | | Plane Select |
| **Cutter Radius Compensation** | | |
| G40 | | Compensation Off |
| G41,G42 | D | Cutter Compensation |
| G41.1, G42.1 | D L | Dynamic Cutter Compensation |
| **Path Control Mode** | | |
| G61 G61.1 | | Exact Path Mode |
| G64 | P Q | Path Blending |
| **Return Mode in Canned Cycles** | | |
| G98, G99 | | Canned Cycle Return Level |
| **Other Modal Codes** | | |
| F | | Set Feed Rate |
| S | | Set Spindle Speed |
| T | | Select Tool) |
| M48, M49 | | Speed and Feed Override Control |
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| M53 | P0 (off) or P1 (on) | Feed Stop Control |
| G54-G59.3 | | Select Coordinate System |

| **Flow-control Codes** | | |
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| o sub | | Subroutines, sub/endsub call |
| o while | | Looping, while/endwhile do/while |
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| o repeat | | Repeat a loop of code |
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| M70 | | Save modal state |
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| **Input/Output Codes** | | |
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| **Non-modal Codes** | | |
| M6 | T | Tool Change |
| M61 | Q | Set Current Tool |
| G10 L1 | P Q R | Set Tool Table |
| G10 L10 | P | Set Tool Table |
| G10 L11 | P | Set Tool Table |
| G10 L2 | P R | Set Coordinate System |
| G10 L20 | P | Set Coordinate System |
| G28, G28.1 | | Go/Set Predefined Position |
| G30, G30.1 | | Go/Set Predefined Position |
| G53 | | Move in Machine Coordinates |
| G92 | | Coordinate System Offset |
| G92.1, G92.2 | | Reset G92 Offsets |
| G92.3 | | Restore G92 Offsets |
| M101 - M199 | P Q | User Defined Commands |
| **Comments & Messages** | | |
| ;(...) | | Comments |
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| G5 | I J P Q | Cubic Spline |
| G5.1 | I J | Quadratic Spline |
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| G33 | K | Spindle Synchronized Motion |
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| G85 | R L (P) | Boring Cycle, Feed Out |
| G89 | R L (P) | Boring Cycle, Dwell, Feed Out |
| G76 | P Z I J R K Q H L E | Threading Cycle |
| **Distance Mode** | | |
| G90, G91 | | Distance Mode |
| G90.1 G91.1 | | Arc Distance Mode |
| G7 | | Lathe Diameter Mode |
| G8 | | Lathe Radius Mode |
| **Feed Rate Mode** | | |
| G93, G94, G95 | | Feed Rate Mode |
| **Spindle Control** | | |
| M3, M4, M5 | S | Spindle Control |
| M19 | | Orient Spindle |
| G96, G97 | S D | Spindle Control Mode |
| **Coolant** | | |
| M7, M8, M9 | | Coolant Control |

| | | |
|---|---|---|
| **Tool Length Offset** | | |
| G43 | H | Tool Length Offset |
| G43.1 | | Dynamic Tool Length Offset |
| G43.2 | H | Apply additional Tool Length Offset |
| G49 | | Cancel Tool Length Compensation |
| **Stopping** | | |
| M0, M1 | | Program Pause |
| M2, M30 | | Program End |
| M60 | | Pallet Change Pause |
| **Units** | | |
| G20, G21 | | Units (inch, mm) |
| **Plane Selection** | (affects G2, G3, G81…G89, G40…G42) | |
| G17 - G19.1 | | Plane Select |
| **Cutter Radius Compensation** | | |
| G40 | | Compensation Off |
| G41,G42 | D | Cutter Compensation |
| G41.1, G42.1 | D L | Dynamic Cutter Compensation |
| **Path Control Mode** | | |
| G61 G61.1 | | Exact Path Mode |
| G64 | P Q | Path Blending |
| **Return Mode in Canned Cycles** | | |
| G98, G99 | | Canned Cycle Return Level |
| **Other Modal Codes** | | |
| F | | Set Feed Rate |
| S | | Set Spindle Speed |
| T | | Select Tool) |
| M48, M49 | | Speed and Feed Override Control |
| M50 | P0 (off) or P1 (on) | Feed Override Control |
| M51 | P0 (off) or P1 (on) | Spindle Speed Override Control |
| M52 | P0 (off) or P1 (on) | Adaptive Feed Control |
| M53 | P0 (off) or P1 (on) | Feed Stop Control |
| G54-G59.3 | | Select Coordinate System |

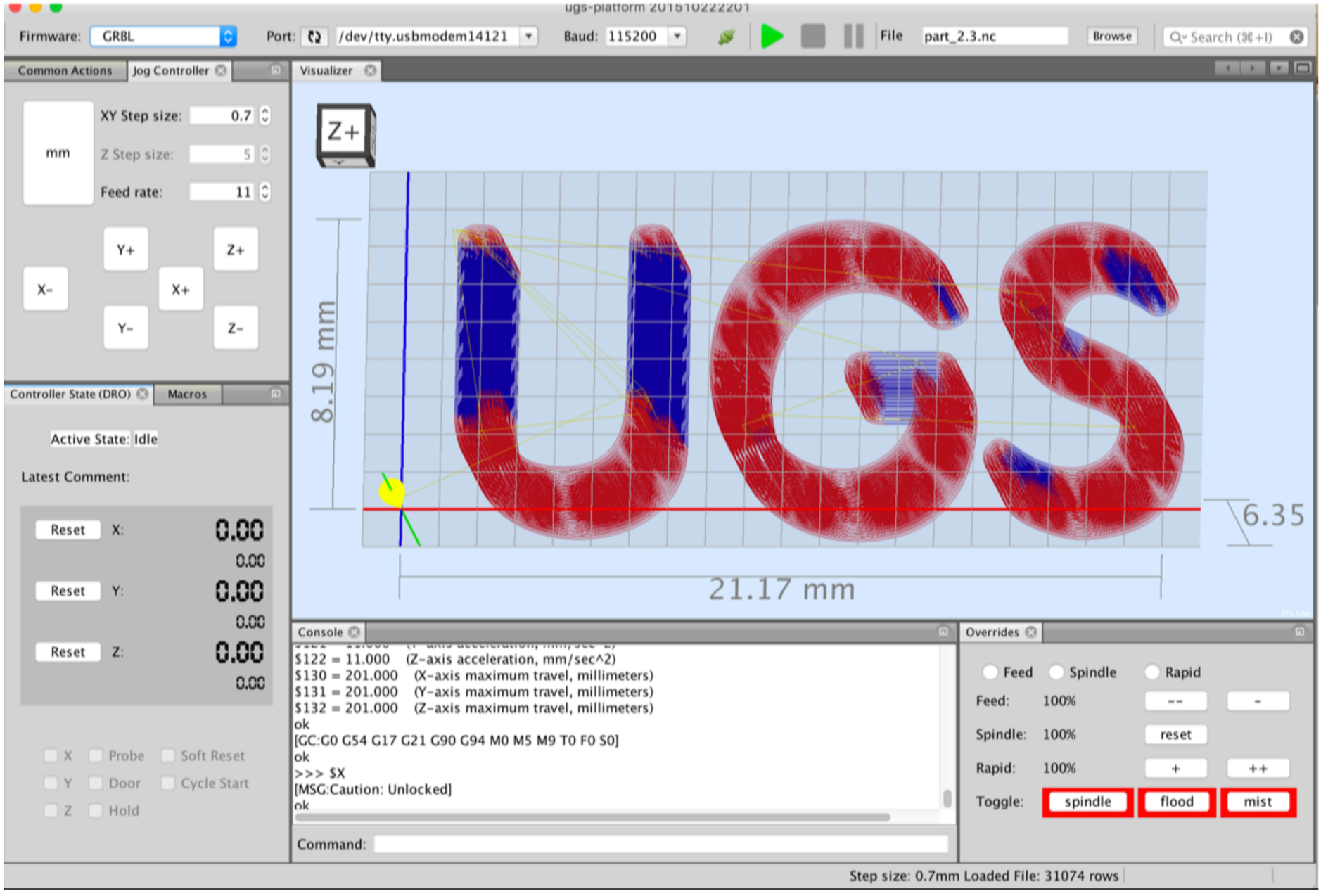
| | | |
|---|---|---|
| **Flow-control Codes** | | |
| o sub | | Subroutines, sub/endsub call |
| o while | | Looping, while/endwhile do/while |
| o if | | Conditional, if/else/endif |
| o repeat | | Repeat a loop of code |
| [] | | Indirection |
| o call | | Call named file |
| M70 | | Save modal state |
| M71 | | Invalidate stored state |
| M72 | | Restore modal state |
| M73 | | Save and Auto-restore modal state |
| **Input/Output Codes** | | |
| M62 - M65 | P | Digital Output Control |
| M66 | P E L Q | Wait on Input |
| M67 | T | Analog Output,Synchronized |
| M68 | T | Analog Output, Immediate |
| **Non-modal Codes** | | |
| M6 | T | Tool Change |
| M61 | Q | Set Current Tool |
| G10 L1 | P Q R | Set Tool Table |
| G10 L10 | P | Set Tool Table |
| G10 L11 | P | Set Tool Table |
| G10 L2 | P R | Set Coordinate System |
| G10 L20 | P | Set Coordinate System |
| G28, G28.1 | | Go/Set Predefined Position |
| G30, G30.1 | | Go/Set Predefined Position |
| G53 | | Move in Machine Coordinates |
| G92 | | Coordinate System Offset |
| G92.1, G92.2 | | Reset G92 Offsets |
| G92.3 | | Restore G92 Offsets |
| M101 - M199 | P Q | User Defined Commands |
| **Comments & Messages** | | |
| ; (...) | | Comments |
| (MSG,...) | | Messages |
| (DEBUG,...) | | Debug Messages |
| (PRINT,...) | | Print Messages |

**Note: Not all available in grbl.**


- "$" overrides grbl gcode interpreter
- "$$" returns current machine parameter settings stored in EEPROM
- Can set values, e.g.,
  - $100 = 80.0

```
**** Connected to /dev/tty.usbmodem14401 @ 115200 baud ****
  
Grbl 1.1g ['$' for help]
>>> $$
$0 = 10    (Step pulse time, microseconds)
$1 = 25    (Step idle delay, milliseconds)
$2 = 0    (Step pulse invert, mask)
$3 = 0    (Step direction invert, mask)
$4 = 0    (Invert step enable pin, boolean)
$5 = 0    (Invert limit pins, boolean)
$6 = 0    (Invert probe pin, boolean)
$10 = 1    (Status report options, mask)
$11 = 0.010    (Junction deviation, millimeters)
$12 = 0.002    (Arc tolerance, millimeters)
$13 = 0    (Report in inches, boolean)
$20 = 0    (Soft limits enable, boolean)
$21 = 0    (Hard limits enable, boolean)
$22 = 0    (Homing cycle enable, boolean)
$23 = 0    (Homing direction invert, mask)
$24 = 25.000    (Homing locate feed rate, mm/min)
$25 = 500.000    (Homing search seek rate, mm/min)
$26 = 250    (Homing switch debounce delay, milliseconds)
$27 = 1.000    (Homing switch pull-off distance, millimeters)
$30 = 1000    (Maximum spindle speed, RPM)
$31 = 0    (Minimum spindle speed, RPM)
$32 = 0    (Laser-mode enable, boolean)
$100 = 80.000    (X-axis travel resolution, step/mm)
$101 = 80.000    (Y-axis travel resolution, step/mm)
$102 = 250.000    (Z-axis travel resolution, step/mm)
$110 = 2500.000    (X-axis maximum rate, mm/min)
$111 = 2500.000    (Y-axis maximum rate, mm/min)
$112 = 500.000    (Z-axis maximum rate, mm/min)
$120 = 200.000    (X-axis acceleration, mm/sec^2)
$121 = 200.000    (Y-axis acceleration, mm/sec^2)
$122 = 10.000    (Z-axis acceleration, mm/sec^2)
$130 = 200.000    (X-axis maximum travel, millimeters)
$131 = 200.000    (Y-axis maximum travel, millimeters)
$132 = 200.000    (Z-axis maximum travel, millimeters)
ok
>>> $G
[GC:G0 G54 G17 G21 G90 G94 M5 M9 T0 F0 S0]
ok
```

# Software Tools




# universal gcode sender

# webgcode

## G-Code Q'n'dirty toolpath simulator

Fork me on GitHub

Paste your g-code in the left-hand window and see the preview of your tool path on the right.
The right-hand pane are interactive, drag them to change the point of view.

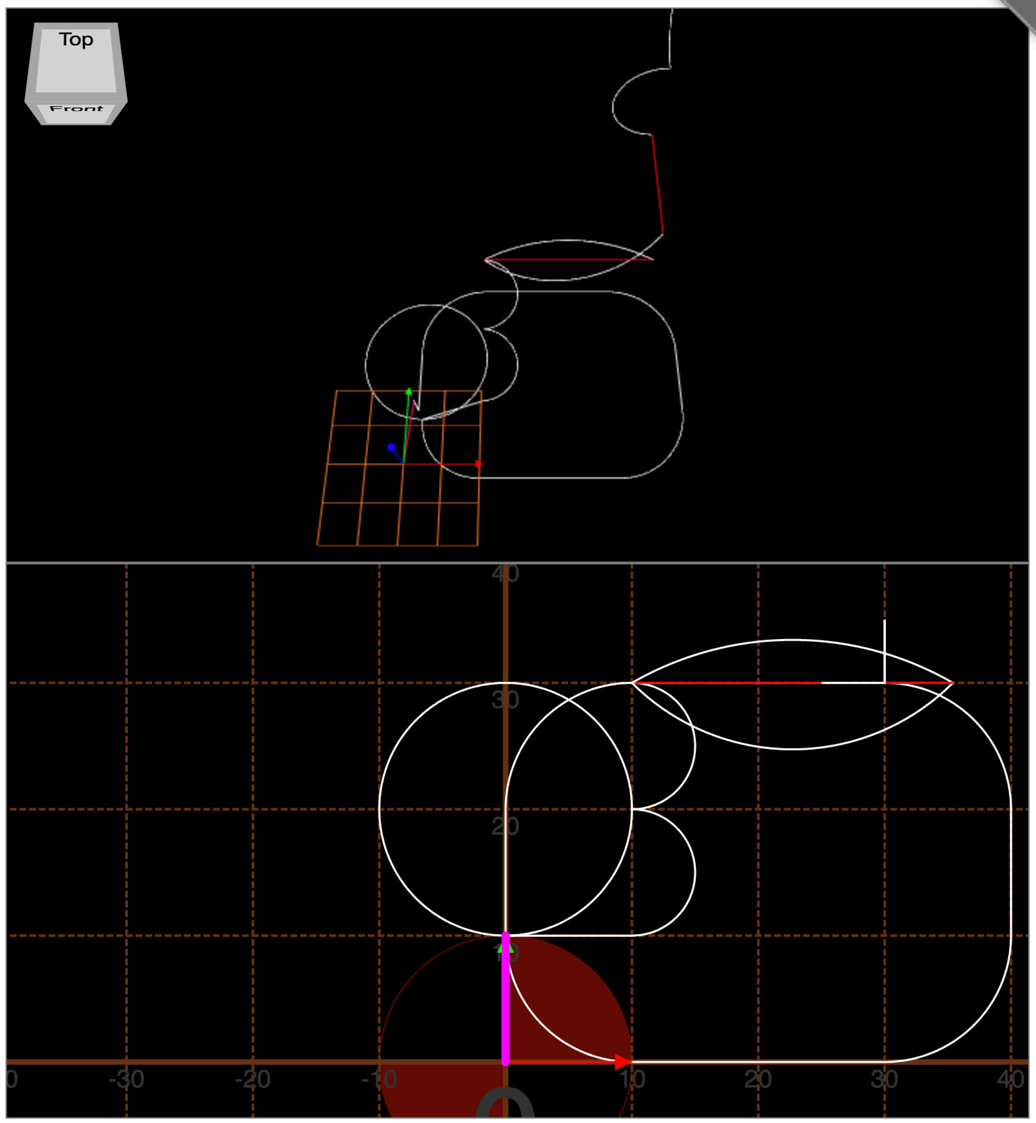
```
1  G0 Y10 Z-5
2  G1 Z-10
3  G1 Y20
4  G02 X10 Y30 R10
5  G1 X30
6  G2 X40 Y20 R10
7  G1 Y10
8  G2 X30 Y0 R10
9  G1 X10
10 G2 X0 Y10 Z-15 R10 (yeah spiral !)
11 G3 X-10 Y20 R-10 (yeah, long arc !)
12 G3 X0 Y10 I10 (center)
13 G91 G1 X10 Z10
14 G3 Y10 R5 Z3 (circle in incremental)
15 Y10 R5 Z3 (again, testing modal state)
16 G20 G0 X1 (one inch to the right)
17 G3 X-1 R1 (radius in inches)
18 G3 X1 Z0.3 I0.5 J0.5 (I,J in inches)
19 G21 (back to mm)
20 G80 X10 (do nothing)
21 G90
22 G0 X30 Y30 Z30
```

Simulate | Load a bigger sample

Total Duration:
1m39s

Bounds (@tool center):

| | min | max |
|---|---|---|
| X | -10 | 40 |
| Y | 0 | 34.9901 |
| Z | -15 | 50 |




- https://nraynaud.github.io/webgcode
- https://github.com/nraynaud/webgcode

# gcmc: G-code Meta Compiler

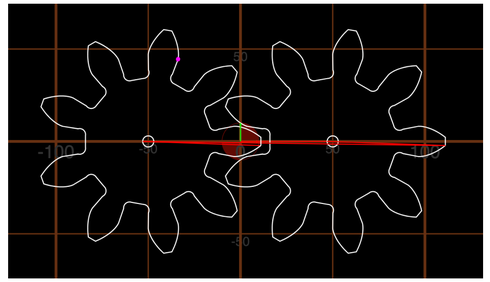
```
/* Trace a path at given offset */
function trace(path, offset)
{
        goto(path[-1] + offset);
        foreach(path; v) {
                move(v + offset);
        }
}

/* Make a hole at center point with given radius */
function hole(point, radius)
{
        goto(point - [radius]);
        circle_cw_r([radius, 0]);
}

/* -------------------- Main Program -------------------- */

HD = 6.0mm;      // Gear center-hole diameter
N = 9;           // Number of teeth
PA = 20.0deg;    // Pressure angle
D = 100.0mm;     // Pitch diameter
P = N/D;         // Diametral pitch

// First gear
hole([D/2.0, 0.0mm], HD/2.0);
trace(gear_P(N, PA, P), [D/2.0, 0.0mm]);

// Second gear
hole([-D/2.0, 0.0mm], HD/2.0);
trace(gear_P(N, PA, P), [-D/2, 0.0mm]);
```

**involute-gear.gcmc**

**gcmc**

```
(gcmc compiled code, do not change)
(2019-04-22 22:33:48)
(-- prologue begin --)
G17 ( Use XY plane )
G21 ( Use mm )
(G40) ( Cancel cutter radius compensation )
G49 ( Cancel tool length compensation )
G54 ( Default coordinate system )
G80 ( Cancel canned cycle )
G90 ( Use absolute distance mode )
G94 ( Units Per Minute feed rate mode )
G64 ( Enable path blending for best speed )
(-- prologue end --)
F600.00000000
G0 X47.00000000 Y0.00000000
G2 X47.00000000 Y0.00000000 I3.00000000 J0.00000000
G0 X111.07016798 Y-2.23662350
G1 X111.07016798 Y-0.00000000
G1 X111.07016798 Y2.23662350
G1 X110.18361185 Y2.90060651
G1 X109.12860272 Y3.63953515
G1 X108.09645894 Y4.31001572
...
```

**involute-gear.gcode**



**CNC result**

- http://www.vagrearg.org/content/gcmc
- http://www.vagrearg.org/content/gcmc-intro

# pygcode

"This library came from my own needs to interpret and convert erroneous arcs to linear segments, and to expand canned drilling cycles, but also as a means to *learn* GCode."

- https://github.com/fragmuffin/pygcode
- https://github.com/fragmuffin/pygcode/wiki
- Useful commands:
  - **pygcode-norm:** Normalizes gcode from different software; intended as a preprocess for more reliable interpreting, e.g., by your CNC machine
  - **pygcode-crop:** Cropping script
- Other useful features:
  - writing
  - parsing
  - interpretation/simulation via virtual machine

# https://github.com/linuxcnc/simple-gcode-generators

README.md

## Simple G-Code Generators

This repository contains a collection of Python scrips that generate simple G-Code for LinuxCNC. For me to fire up a high dollar CAD program and the use the POST processor to generate simple routines is a waste of time. So I'm writing a series of Python programs to do this. If you did an LinuxCNC install, or have Mac OS X, you already have all you need.

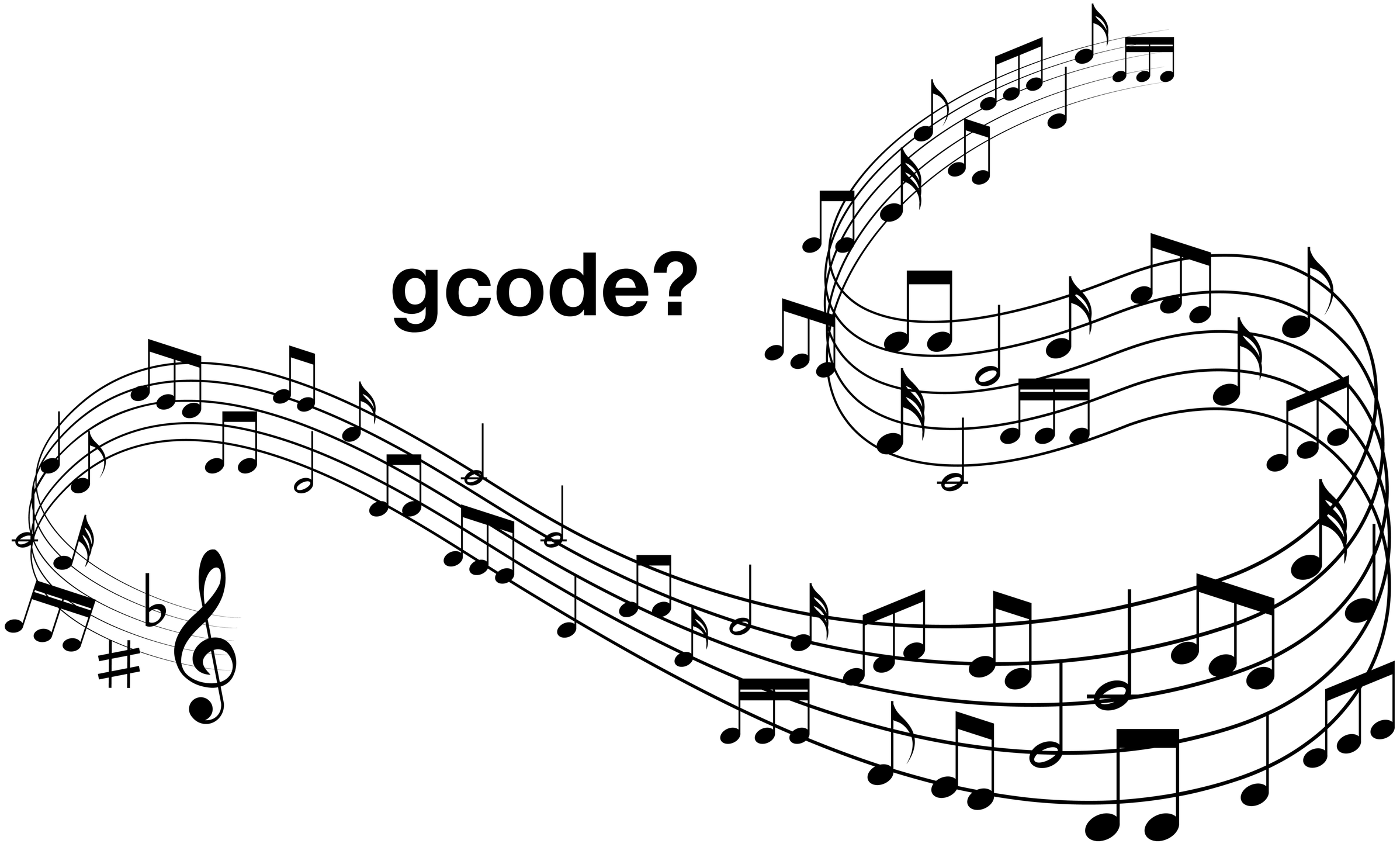
You can either clone this repository using Git or download the whole repository as a zip file.



### The Scripts

- Airfoil Generator - 3-4 Axis XY-XYUV Foam EDM Style airfoil generator
- Arc Generator - generate an arc from the diameter, the start and end angle
- Bezel Engraving - engraves a bezel like you would see on the front panel of a stereo around the volume control knobs
- Bolt Circle Array - generates a circular array for canned drill cycles
- Counterbore - generates the G-code for counterbores for socket head cap screws
- Drilling Speeds-n-Feeds - helps you to calculate the speeds and feeds for drilling
- Facing Software - super simple facing Generator
- Grid - generate various shapes of grid to test the speed and the accuracy of a milling machine
- Grill - drills a circular array of holes typically used as a speaker grill or as ventilation holes in a chassis panel
- Pocketing - Rectangular-Circular Pocketing Generator
- Text Engraving - This software engraves a text string
- Multi-line Text Engraving - Engrave up to 10 lines of text
- Ruler Engraving - Engrave generic ruler in metric or standard with text

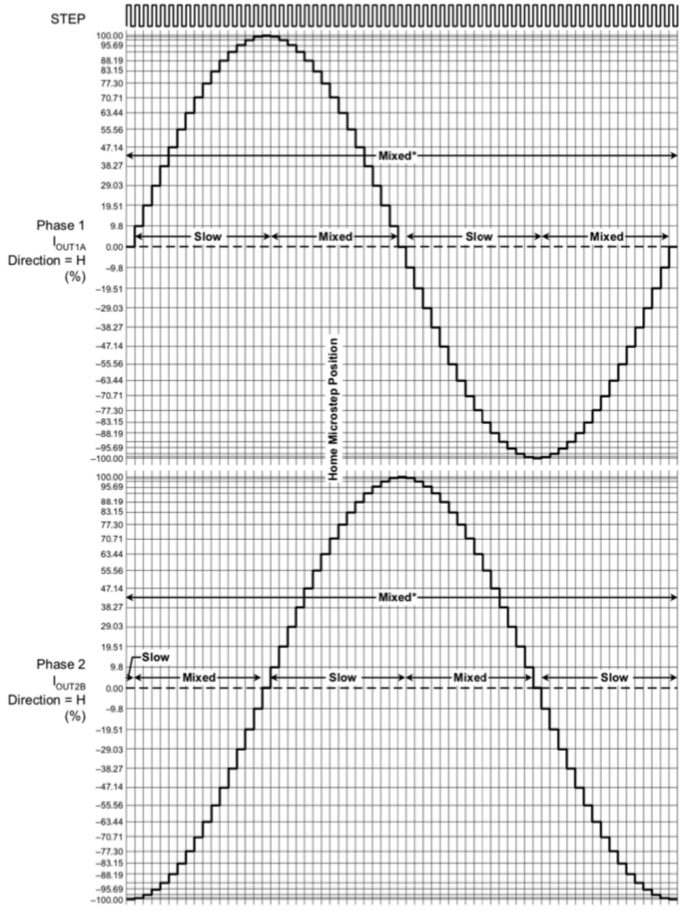
# gcode?



# Stepper motor music (floppy drives, etc.)


Star Wars - Imperial March on Eight FIoppy Drives
1,636,213 views
https://www.youtube.com/watch?v=cM_sAxrAu7Q

# Recall micro-stepping




16 Step

## GRBL Settings

**Specification**

**$$**

**Calculation of grbl settings for GT2 belts**

**$100=80 // x steps per mm = 16 * 200 / 40**

**$101=80 // y steps per mm**

# Stepping frequency

- **Steps per mm, S**
- **Feed rate, F** (in mm/min)
- **Stepping frequency** (steps/sec):

  **f = S** [steps/mm] * **F** [mm/min] * **1/60** [min/sec]

  **= S * F / 60** [in Hz]

- **In our case**: S=80 steps/mm, so we have

  **f = 4/3 F** [in Hz] ⟷ **F = 3/4 f** [in mm/min]

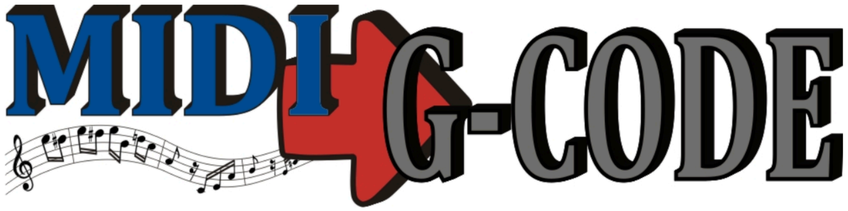
- **Example:** middle C is 261.6 Hz ==> F = 196 mm/min
- **Map notes to feed rates** using lookup table, F(f)

# Turning music into motion

- Assume **monophonic** track for now
- To play note at frequency f for time dt, move distance F*dt at feedrate F.
- Simulate rests using very low feedrates.

# https://www.ultimatesolver.com/en/midi2gcode

## Midi → G-Code Converter




| | |
|---|---|
| **Version** | 2.7.3 |
| **Description** | This converter can convert music files (MIDI files) into G-code (for CNC milling machines).<br>So with each CNC milling machine that is driven by stepping motors, it is possible to create music. |
| **Statistics** | The converter was used about 84.800 times. |
| **MIDI file selection (*.mid)** | Choose File No file chosen<br><br>(max. 800 kB) |
| **Processing** | Analyze file |

# xyMerge: Manually mix gcode music tracks
## (the painful way)

- **Problem:** Midi tracks don't always stick to stepper motors, even for monophonic tracks :/
- **Solution:** Merge mono gcode files into a polyphonic gcode file *(Yes, this is an exercise in gcode)*
- Given 2 monophonic gcode trajectories, X(t) and Y(t) sampled using G01 cmds
  - G01 X## F##
  - G01 Y## F##
- Determine shortest note time, dt  = MIN ( dtx=dx/Fx , dty=dy/Fy )
- Play both notes as an XY trajectory with X motion of Fx*dt, and Y motion of Fy*dt
  - In incremental distance mode (G91) this would look like
    - G01 Xdtx Ydty Ffeedrate
  - Where the magic feedrate is Sqrt( Fx*Fx + Fy*Fy ).
  - Note: Outputs are actually all absolute distance mode (G90)

# G-Code Music Demo

## Related gcode files:

- GameofThrones_-_1voice_-_bass.nc
- GameofThrones_-_1voice_-_melody.nc
- GameofThrones_-_2voice_-_xyMerge.nc
- Program: xyMerge.py


- **Warning:** Only valid for unconstrained stepper motors. Do not run on the t-bot!

**https://cs448m.github.io/lectures/gcode/stepperMusic**