What is G Code?

**Description of Activity**

* General description of activity.
* Include purpose statement.
* Please include subjects and/or grades that this activity is suitable for.

**Learning Objectives:**

**(List measureable objectives)**

1. Students will identify the three axes used in 3D milling
2. Students will state the difference between jog and move motions in CNC machining
3. Students will demonstrate ability to hand code simple G-code several examples.
4. Students will demonstrate ability to interpret simple G-code by drawing the cutting toolpaths on graph paper.

**Standards:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Student Performance Objective(s):** | | | |
| **HS-ETS1-2** | Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. | | |
| Science and Engineering Practices | | Disciplinary Core Ideas | Crosscutting Concepts |
| **Constructing Explanations and Designing Solutions**   * Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2) | | **ETS1.C: Optimizing the Design Solution**  ▪ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS- ETS1-2) | **Systems and System Models**  ▪ Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions— including energy, matter, and information flows— within and between systems at different scales. |

Common Core State Standards for Mathematics:

**MP.4** Model with mathematics.

List The Common Core Math, Next Generation Science Standard and/or SME Competency Gaps. For example:

<have to dig up some standards here. Project Lead the Way Computer Integrated Manufacturing course is one possible>

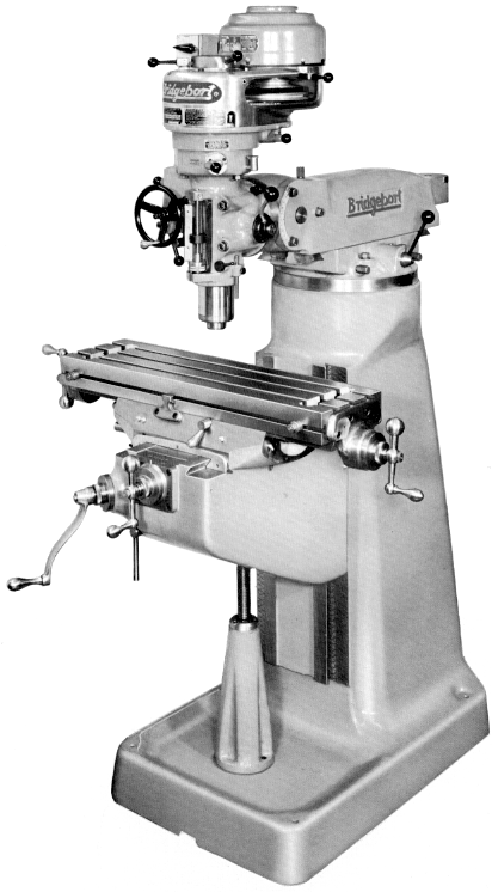
**Materials Required:**

* Pencil

**References:**

<https://en.wikipedia.org/wiki/G-code>

**Activity:**

The three axis milling machine was an important development in the industrial era, introduced in the 1860’s. Machines like the one pictured at right were pivotal in manufacturing throughout the 20th Century. Two axes – X and Y – travel horizontally in two directions of a plane. The Z axis is the third, and the cutter moves vertically, up and down.

CNC stands for Computer Numeric Control, and is the joining of computing technology to control multi-axis machining. The first computer control of a three-axis milling machine happened shortly after World War II.

The advantage of computerized control of the axes is that they can be controlled simultaneously, as opposed to a human operator controlling only one axis at a time, reading a Vernier gauge to measure travel on one axis. This simultaneous multi-axis movement has the potential to create incredibly fluid shapes rather than the rectangular type parts that humans create at a manual milling machine.

Bridgeport 3-axis manual mill



The machine pictured at left is a CNC wood router. The cutting bit travels in 3 axes, X, Y, and Z.

G code is the language computers use to control the motion along multiple axes. The basic format of the language is to indicate an axis, such as X, Y, or Z, and either an absolute value or an offset from the current location. There are many other instructions that can handle additional axes, turn cutting spindles on and off, or turn cutting coolant fluid flow on or off. G code has been expanded to include 3D printer operation also.

Forest Scientific Wood Router

In the early days of digital computers, memory and storage were at a premium. To maximize program storage space, only an axis with a changed value would be specified. While this saved considerable storage space – in an era where 1K (1,024 characters) was expensive – it can tend to make code challenging to follow.

While there are many G code instructions (see the Wikipedia reference), the two main types of motions to know about are: Jogs and Moves (or cuts). Jogs are rapid motions when the cutter is above the surface of the workpiece. Moves are slower speed motions where the cutter is removing material from the workpiece. Jog instructions begin G00 and Move instructions begin G01.

Example: G00 X4.3 Y2.9 Z1.0

This instruction will move the cutter at high speed in a direct straight line to the coordinates (4.3, 2.9, 1.0) in three dimensional space

Example: G01 Z-0.50

This instruction will move the cutter at a slower cutting speed in a direct straight line where the X anx Y axes are unchanged, but the Z axis moves to -0.50. If the top of the workpiece is considered to be zero, then this cut will plunge straight down in to the workpiece to a depth -0.5 inches below the top.

Let’s look at another example:

01: G00 Z1.00

02: G00 X-4.00 Y-4.00

03: G01 Z-.05

04: G01 Y4.00

05: G01 X4.00

06: G01 Y-4.00

07: G01 X-4.00

08: G00 Z1.00

Line 1 rapidly brings the cutter 1 inch above the top surface of the workpiece.

Line 2 rapidly moves to (-4,-4).

Line 3 slowly plunges into the workpiece, cutting to a depth of -0.05.

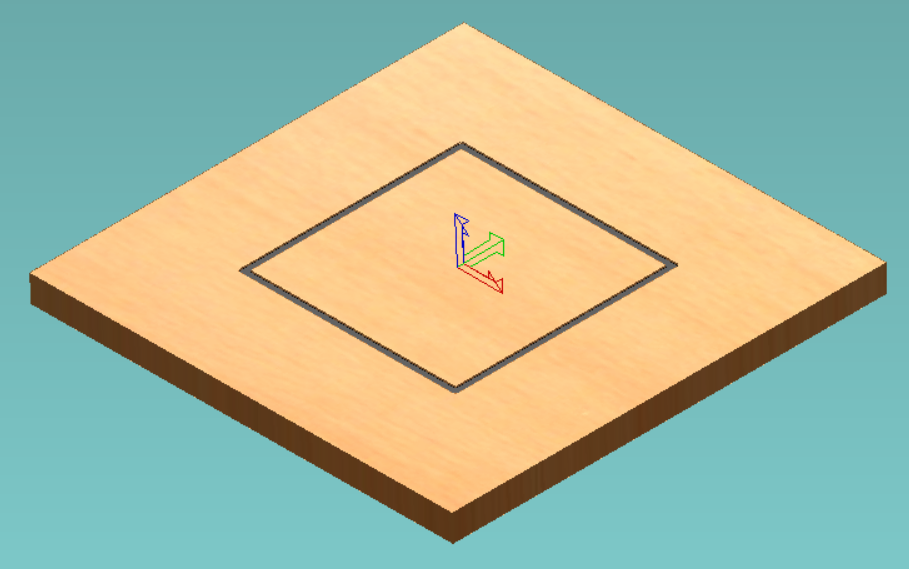
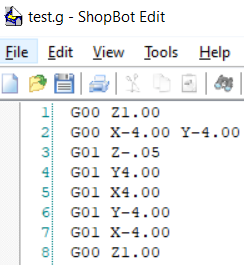
Line 4 slowly cuts along X = -4 from Y = -4 to Y = 4, a vertical distance of 8 inches.

Line 5 cuts along Y = 4 from X = -4 to X = 4, a horizontal distance of 8 inches.

Line 6 cuts along X from Y = 4 to Y = -4, a vertical distance of 8 inches.

Line 7 cuts along Y = -4 from X = 4 to X = - 4, a horizontal distance of 8 inches.

Line 8 raises the cutter up above the top of the workpieces, to a height of 1 inch above the workpiece.

It might be easier to follow the code for cutting this square if you saw all three axes for each line of code:

01: G00 Z1.00

02: G00 X-4.00 Y-4.00 Z1.00

03: G01 X-4.00 Y-4.00 Z-0.05

04: G01 X-4.00 Y4.00 Z-0.05

05: G01 X4.00 Y4.00 Z-0.05

06: G01 X4.00 Y-4.00 Z-0.05

07: G01 X-4.00 Y-4.00 Z-0.05

08: G00 X-4.00 Y-4.00 Z1.00

What follows is the format method that is used by ShopBot CNC wood routers. The ShopBot company is a popular vendor of CNC wood routers. Here is ShopBot code for the same square:

01: JZ, 1.00

02: J3, -4.00, -4.00, 1.00

03: M3, -4.00, -4.00, -0.05

04: M3, -4.00, 4.00, -0.05

05: M3, 4.00, 4.00, -0.05

06: M3, 4.00, -4.00, -0.05

07: M3, -4.00, -4.00, -0.05

08: M3, -4.00, -4.00, 1.00

ShopBot code begins instructions with a J for rapid speed jog motions, and M for slower-speed cutting motions. Rather than indicate the axis with an X, Y, or Z prefix as in G-code, ShopBot code instruction indicates whether it’s a one, two, or three-axis command.

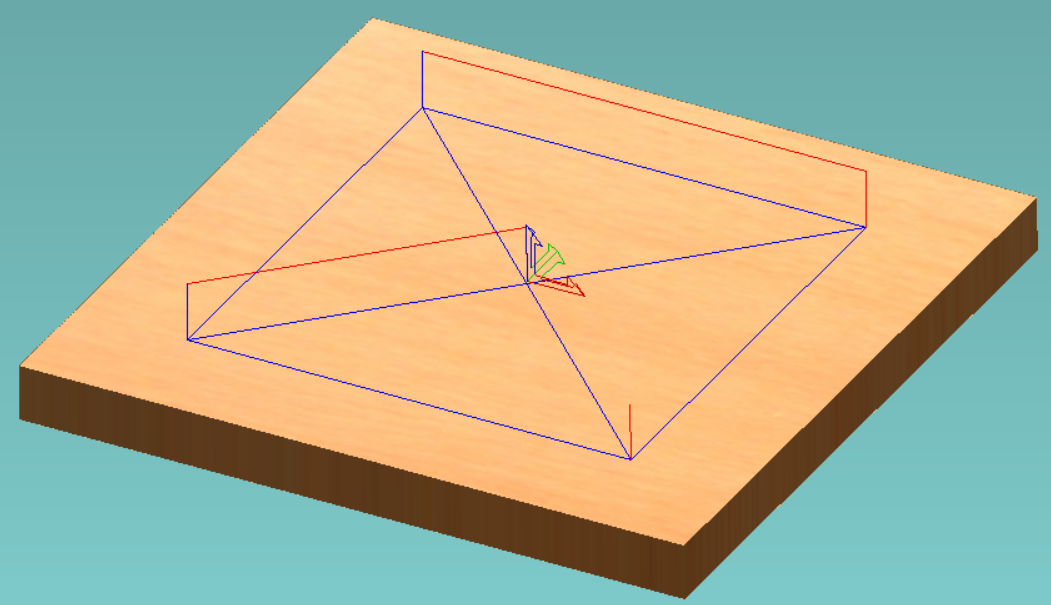
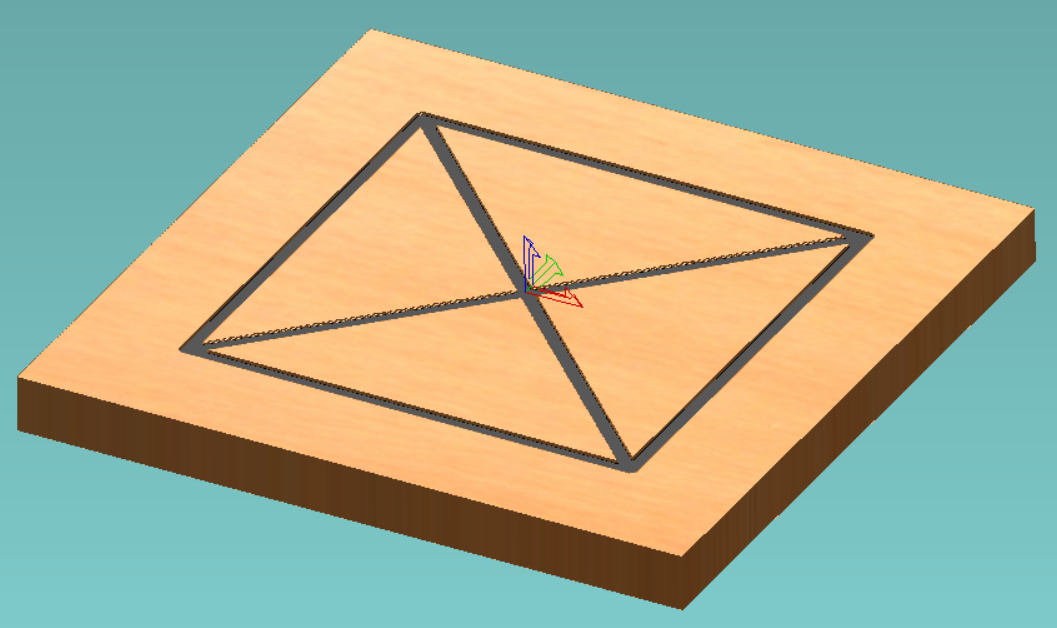
|  |  |
| --- | --- |
| JX, JY, or JZ – Jog in the X, Y, or Z axis only   * Format JX, x; JY, y; or JZ, z   J2 – Jog in the X,Y directions only   * Format J2, x, y   J3 – Jog in the X, Y, and Z axes   * Format J3, x, y, z | MX, MY, or MZ – Move in the X, Y, or Z axis only   * Format MX, x; MY, y; or MZ, z   M2 – Move in the X,Y directions only   * Format M2, x, y   M3 – Move in the X, Y, and Z axes   * Format M3, x, y, z |

If you want a way to see a machining preview of your manually created G-code or ShopBot code, you can download the latest version of ShopBot control software at:

<https://www.shopbottools.com/support/control-software>

You can preview both .g and .sbp files in the SB3 control program without a CNC router connected. The text editor SBEDIT installs as well, which is optimized for ShopBot code entry, however it works fine for G-code entry and editing. The G-code previews in this handout were made in SB3.

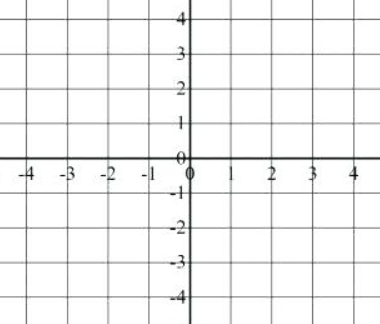
For the next exercise, write G-code (G00’s and G01’s) to create code that will machine an “X” cutting diagonally across from coordinates (-4, 4) to (4, -4) and then from (-4, -4) to (4, 4). Remember to retract the cutter after each leg of the X.

toolpaths completed machining preview

Reminder: The blue lines are moves, or cutting motions in the workpiece. The red lines are jogs, 1.00 inches above the surface of the workpiece. This Cartesian coordinates graph scratch-space may help you plan your code:

Planning Code



\* Motions along the Z axis are typically done as slow speed moves when moving downward into the material, but can be done as jogs upwards to retract quickly from the material. Just be sure X and Y coordinates do not change if you rapidly jog straight up or else the rapid lateral movement would damage the workpiece and cutter both.

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

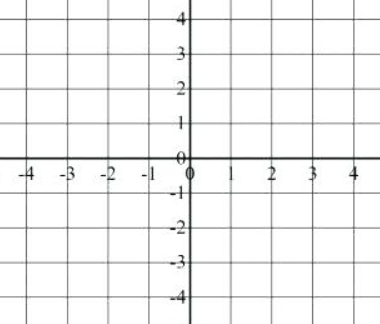
Activity:

Draw out lines for how the following section of G-code would machine.

If Z < 0, then draw a line on the paper connecting the most-recent X,Y coordinates to the current.

If Z > 0, then do not draw anything on the paper.

Code:

G00 Z1.00

G00 X-2.00 Y-1.00

G01 Z-.05

G01 Y-2.00

G01 X-1.00 Y-3.00

G01 X1.00

G01 X2.00 Y-2.00

G01 Y-1.00

G00 Z1.00

G00 X2.00 Y2.00

G01 Z-0.5

G01 Y2.50

G00 Z1.00

G00 X-2.00

G01 Z-0.5

G01 Y2.00

G00 Z1.00

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

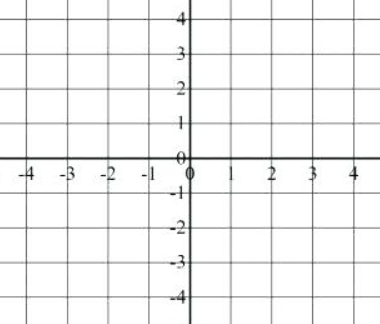
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Code:

G00 Z1.00

G00 X-2.00 Y-1.00

G01 Z-.05

G01 X-4.00

G01 Y-1.00

G01 X-2.00

G00 Z1.00

G00 X-1.00

G01 Z-.05

G01 Y1.00

G01 X1.00 Y-1.00

G01 Y1.00

G00 Z1.00

G00 X4.00

G01 Z-.05

G01 X2.00

G01 Y-1.00

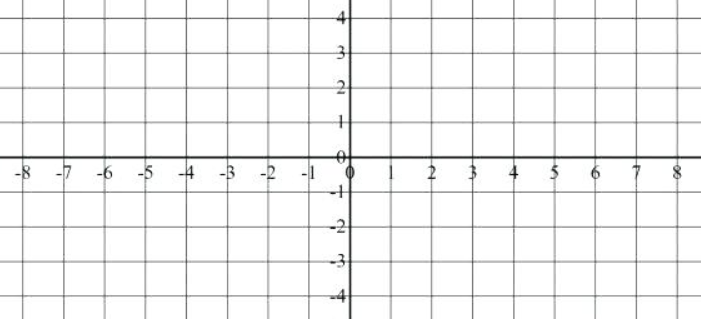
G01 X4.00

G00 Z1.00

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Activity: Develop G-code to cut your initials in a 8” wide x 8” tall work area. Use diagonal straight line segments to approximate curves for letters like D, J, O, P, or R. This Cartesian coordinates graph scratch-space may help you plan your code:

Planning



Code