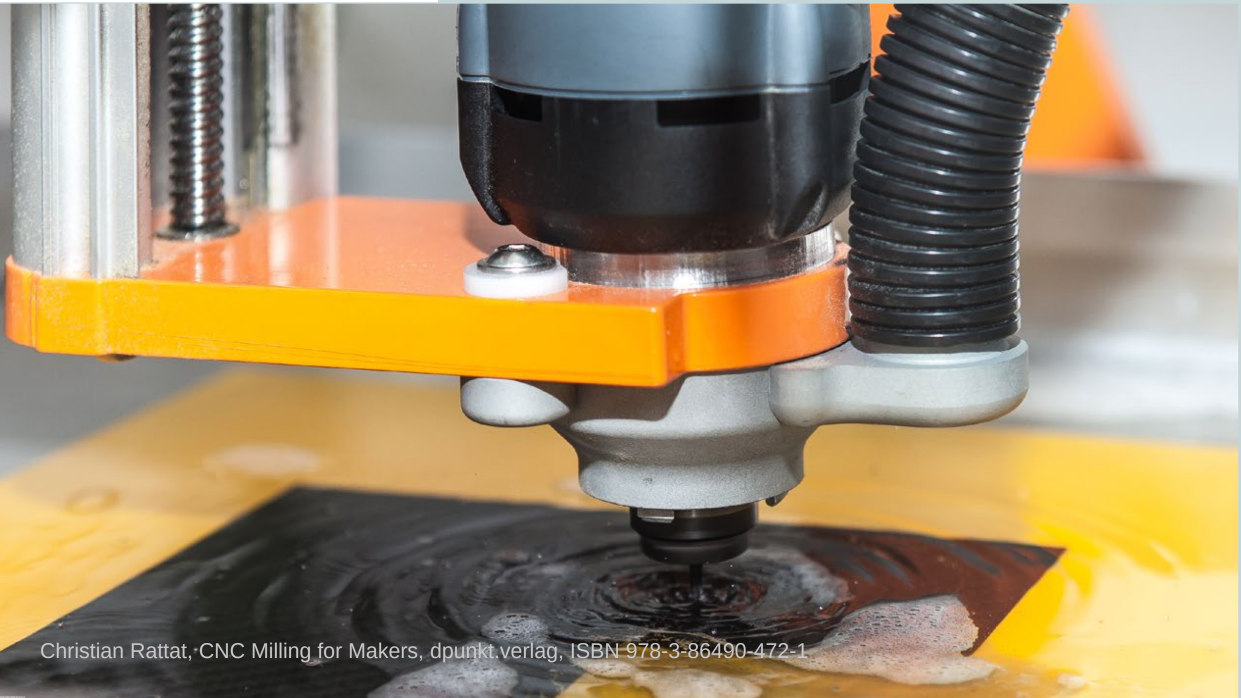
6 Advanced Milling Techniques

This chapter explains in detail how to use a gantry router to perform:

- PCB Isolation milling
- Underwater milling
- 2.5D milling using CAM software



6.1 Isolation Milling

Most hobbyists who make their own printed circuit boards (PCBs) create them using etching techniques. The simplest way to do this is to take a copper-plated board, mask the areas you don't want to etch, and place the board in an etching solution of ferric chloride or sodium persulfate. The chemical then etches away the unwanted parts of the copper plating. Both of these chemicals represent a health and environmental risk, and usually have to be disposed of professionally by a toxic waste specialist.

If you don't require the high-precision results that the etching process offers, you can use your CNC router to cut and drill PCBs. This approach also enables you to produce two-sided PCBs. A great place to start is using the Eagle software package (*www.autodesk.com/products/eagle/overview*), which is free for private use. If you need to create larger PCBs (the free version only works for designs up to 80 × 100 mm), you can upgrade to the fully featured subscription-based Standard or Premium versions, or simply switch to a different application. With a couple of simple tweaks, Eagle can be used to produce output that you can mill directly using WinPC-NC.

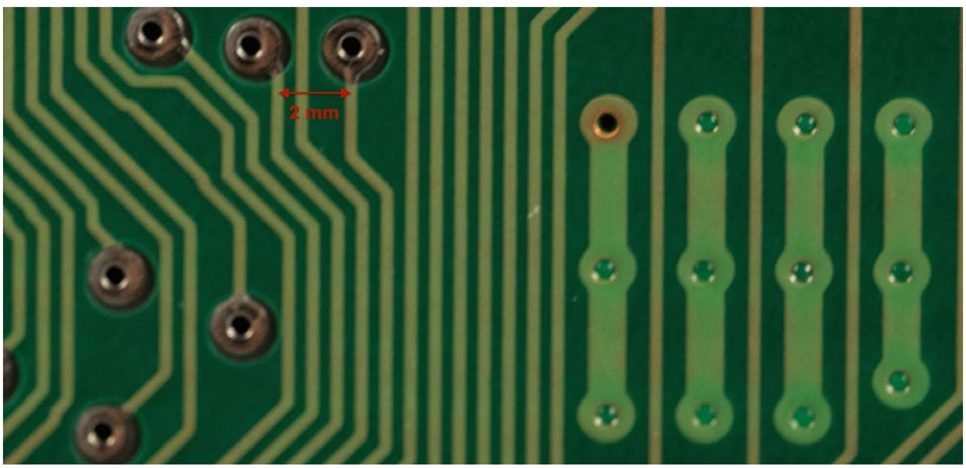


Fig. 6.1 One of the challenges involved in milling a circuit board

The real challenge involved in milling PCBs is getting your router to produce sufficiently fine structures. Integrated circuits often require traces that run between two pins, and standard PCB layouts leave just 2.54 mm (or sometimes 1.27 mm) between pins. Unfortunately, this doesn't mean you have 2.54 mm of space to play with. Soldering pins to the circuit board requires 0.8 mm holes with an additional copper surround, which leaves an effective distance of just 1.5 mm between pins, which in turn has to be milled to produce a trace and two isolating surfaces. In other words, you have to set up your machine to effectively remove copper strips that are a maximum of 0.1–0.2 mm wide.

Fig. 6.2 A 60° 0.2 mm graver

It is obvious you can't use a conventional end mill to cut such narrow traces. Furthermore, a 0.1 mm mill used at 20,000 rpm provides a cutting speed of just 6 m/min, whereas copper requires a cutting speed closer to 100 m/min. Even at 100,000 rpm, you would only reach a cutting speed of 31 m/min, which is simply not enough.

To get going, we need to make a compromise or two. The copper layer on a standard PCB is 0.035 mm thick, and the carrier layer beneath should remain unharmed if possible. If the board flexes due to uneven clamping, you won't be able to cut at a consistent depth, and setting the workpiece Z zero point is critical, as you will be cutting to a maximum final depth of between 0.1 mm and 0.3 mm.

The tool of choice for milling PCBs is an engraving bit or "graver." Gravers have V-shaped tips and are available with tip angles of 10 degrees upward and thicknesses of 0.1 mm and more. The width of the tip dictates the minimum width of the traces you can cut, while the angle of the tip determines how much wider the cut becomes the deeper you plunge into the material.

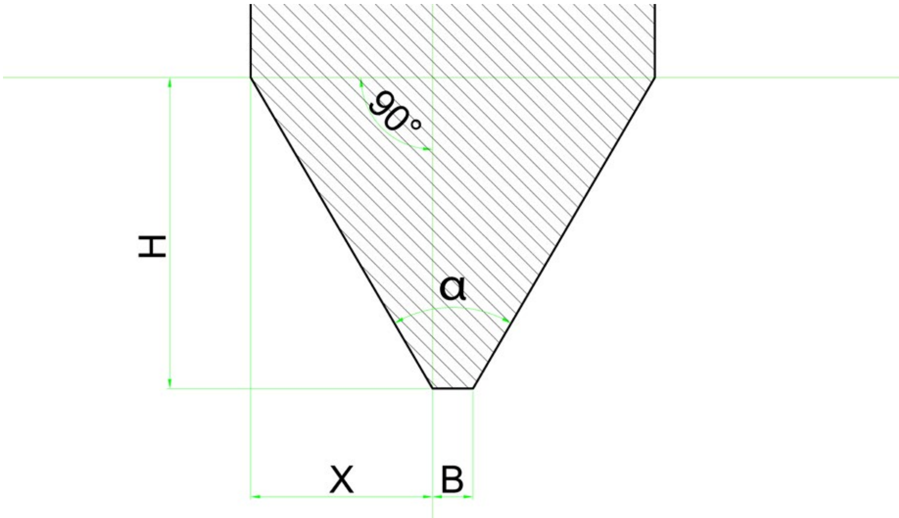


Fig. 6.3 The geometry of the tip of an engraving bit

To calculate the width of the cut, you need to know the opposite side, *X*, of the right-angled triangle formed by half the included angle of the tool tip, α (in this case, 60 degrees), and the adjacent side *H*. The cut width is then equal to 2× *X* plus the width of the tip.

$$B_{Fräsbahn} = B_{Spitze} + 2 \cdot H \cdot \tan \frac{\alpha}{2}$$

A 60-degree graver with a 0.1 mm tip used at a cut depth of 0.15 mm will produce the following cut width:

$$B_{Fräsbahn} = 0{,}1 \text{ mm} + 2 \cdot 0{,}15 \text{ mm} \cdot \tan \frac{\frac{60°}{2} \cdot \pi}{180} = 0{,}27 \text{ mm}$$

To work out the tan, the angle usually has to be converted from degrees to radians by multiplying it by $\pi/_{180}$, as these are the units used by most spreadsheets and pocket calculators.

The resulting value equates to the width of the cut at the surface of the board. If the copper layer is 0.035 mm thick, the surface width of the cut will be reduced to just 0.23 mm.