

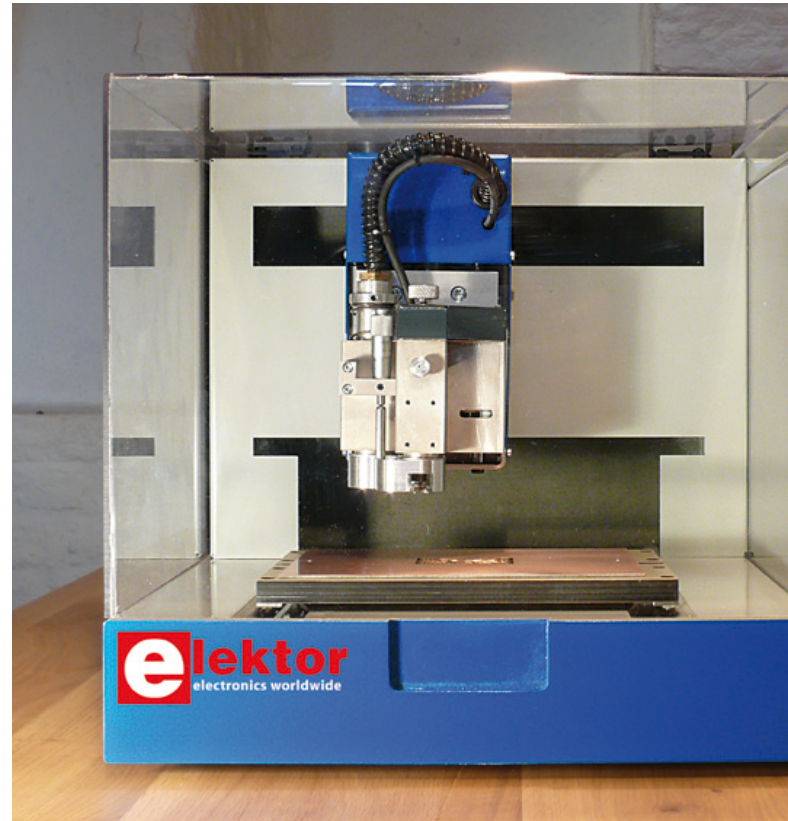
# Elektor PCB Prototyper

By Harry Baggen (Elektor Editorial Netherlands)

Do you want to rout PCBs with isolation tracks only 100 µm wide and 0.2-mm holes? The Elektor PCB Prototyper takes it all in stride. This compact, professional PCB router also has a lot more to offer. Thanks to the modular architecture of both the software and the hardware, you can easily extend it to create a multipurpose automated work centre for your lab or workshop. Colinbus has developed an entirely new drive system, along with an engraving module that makes it possible to offer a machine with this level of precision and versatility at a very attractive price – much lower than comparable products.

When we presented the Elektor Profiler in our magazine in January 2007, we didn't expect to receive so many enquiries about using the machine for routing PCBs. The Profiler is designed for general milling work, but not specifically for routing PCBs. Although it can be used for this purpose with suitable effort and skill on the part of the user, the results are nowhere near what can be achieved with a true PCB router. Users who only want to make run-of-the-mill PCBs for conventional (through-hole) components have been reasonably satisfied with the results from the Profiler, but many other users long for higher precision and more convenience. However, a true PCB router is expensive, and with good reason. The mechanical components must be very precise, and furthermore, it takes a lot of specialised expertise and technology to make such machines – and there are only a few manufacturers in the world who have these capabilities in house.

The Colinbus design staff faced two challenges in designing a new PCB router. The first challenge was to reduce the price of the entire machine to a level that would make it attractive for small companies, schools, universities, and hobbyists willing to invest a bit of money in their hobby – considering that you have to make a lot of circuit boards to recover your investment in a machine of this sort. The second challenge was to make the machine more versatile, so it could be used for many different jobs – not just



routing PCBs. It took a few years, but now we are able to present the PCB Prototyper: an extremely compact machine that fulfils both of the above requirements.

## Design

The PCB Prototyper is a compact, nearly cubicle machine that takes up only a small amount of space on your workbench. All moving parts are screened by a Plexiglas cover, which results in a quiet and dust-free working environment. The cover is also fitted with a safety switch that stops the machine when the cover is opened.

The PCB Prototyper design is based on professional PCB routers, which means that all guides and drives are extremely precise and that the embedded software includes special routines that facilitate PCB routing at a professional level.

The PCB Prototyper is the first PCB router with a modular design. The work table can be replaced by all sorts of other tables, the multifunctional head housing the high-speed spindle motor can be removed or modified, and there are provisions for fitting a camera, dispenser or other accessories. The multifunctional head clips in place, so it can easily be adapted to the job on hand, and the air feed and suction lines are integrated into the machine and can easily be connected or disconnected. The hinged rear panel can be opened to increase the working area of the machine or allow tubes or cables

# A professional PCB router with many extension options



## Technical specifications

Workspace:	220 × 150 × 40 mm (X × Y × Z)
Resolution:	1.8 μm
X/Y/Z drives:	Hybrid motors
Max. spindle motor speed:	40,000 rpm (adjustable under software control)
Machine table:	Precision table with single T slot
Tool changing:	Manual (automatic tool changer available as an optional accessory)
Tool collet:	1/8" standard (other sizes available as optional accessories)
Engraving module:	Adjustable, with integrated micrometer
Dust extraction:	Integrated in engraving module
Dimensions:	440 × 350 × 350 mm (W × D × H)
Supply voltage:	110–240 V <sub>AC</sub> , 50/60 Hz
Weight:	approx. 35 kg (78 lbs)
Software:	Accompanying CAM and control software (runs under Windows XP, Windows Vista or Windows 7)
Communication with PC:	USB port

to be fed in conveniently. These are only a few of the features of the PCB Prototyper, which is truly a multipurpose machine that can perform dozens of tasks in your shop or lab.

The PCB Prototyper comes with the ColiBri control software, a shell program that holds all of the software modules used to operate the machine. The main software module included with the machine as standard is the PCB module. This CAM package, which is specifically designed for routing PCBs, is unquestionably one of the most powerful and user-friendly packages on the market.

### Mechanics

It is generally known that routing PCBs on normal milling machines yields poor results, which is largely related to the mechanical design of the machines. This doesn't mean that some machines are worse than others, but rather that they are simply designed to meet different requirements. The small details are what make the difference.

In the first place, a PCB router must be stable, and this is achieved by making its structure massive. For this reason, the PCB Prototyper features all-steel construction. The steel structure also ensures that the sturdy precision-ground guide rods for the sliding bushes don't move. Even the slightest deflection or motion of the guide

rods causes major errors in the finished product. A deflection of only 0.01 mm causes a routing error that is larger than the width of an isolation track, which makes it unacceptable in a PCB router. The PCB Prototyper is also equipped with anti-backlash ball nuts on the drive screws. These special nuts prevent mechanical play when the drives change direction, which is particularly important for routing small pads and narrow tracks.

### Electronics and embedded software

The biggest difference between a conventional milling machine and a PCB router is not in the mechanical components, but instead in the software that calculates the motions and controls the motors. It's obvious that making hundreds of small circles and tracks requires entirely different routines than milling objects such as front panels. It is therefore perfectly possible that a conventional milling machine with a top speed of 500 mm/s will take much longer to rout a PCB than a true PCB router with a top speed of 100 mm/s. The maximum speed is a secondary consideration for PCB routing; the acceleration and deceleration characteristics of the machine and the computation algorithms that are used are much more important. This is because the machine can never reach its top speed when routing a PCB, since the motions are much too small.

The controller for the PCB Prototyper is built around an ARM7 32-bit RISC microcontroller and an FPGA. This usually provides sufficient

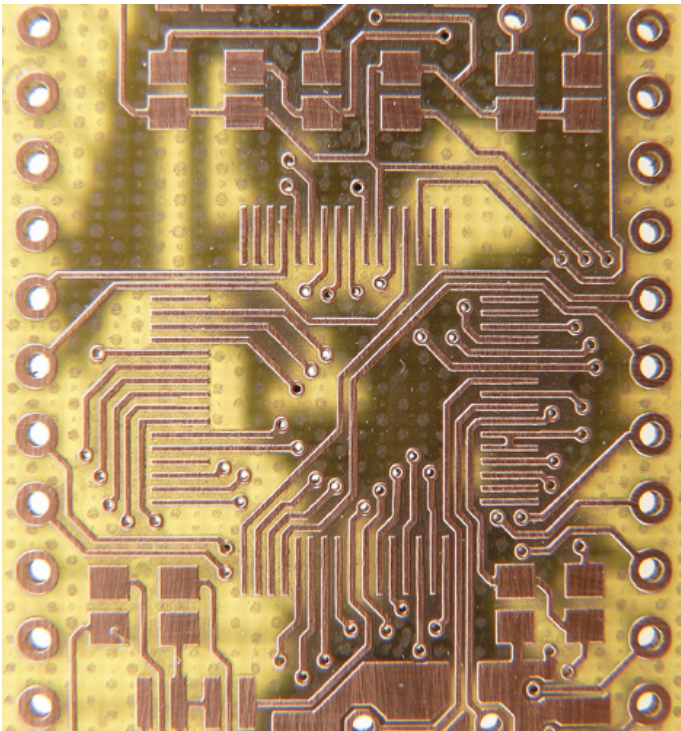


Figure 1. Detail of a PCB milled by the PCB Prototyper. Some of the isolation tracks are only 0.15 mm wide.

processing power to allow the machine to operate independently, but not always. For this reason, the PCB Prototyper controller is able to hand off specific tasks to the connected PC, which opens up unprecedented possibilities.

The built-in microcontroller allows the machine to calculate all of its motions without being dependent on the operating system running on the PC, but at the same time it can make use of the high

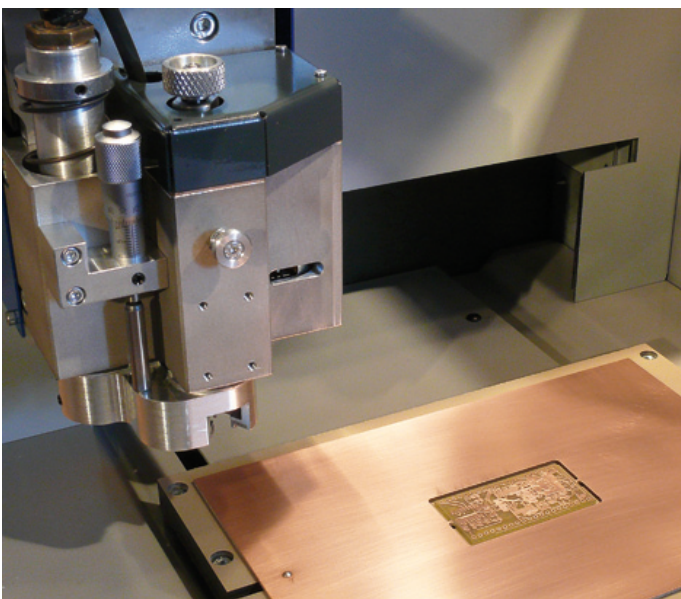


Figure 2. The engraving module with a PCB mounted on the table below. The entire table slides for motions along the X axis.

processing power of the PC. This approach utilises the advantages of both systems and eliminates their disadvantages.

### Multifunctional head

The multifunctional head is mounted on the Z axis of the PCB Prototyper. This module houses a high-precision spindle motor with air feed and dust extraction lines, a micrometer for depth adjustment, and a precision engraving module with a cyclone chamber. It also has provisions for mounting a camera, dispenser or other accessories.

The operating speed of the high-speed spindle motor can be adjusted under software control, with a maximum speed of 40,000 rpm. A handy tool lock knob and pivoting engraving module make tool changing easy. This considerably simplifies working with very fine drills and routing bits.

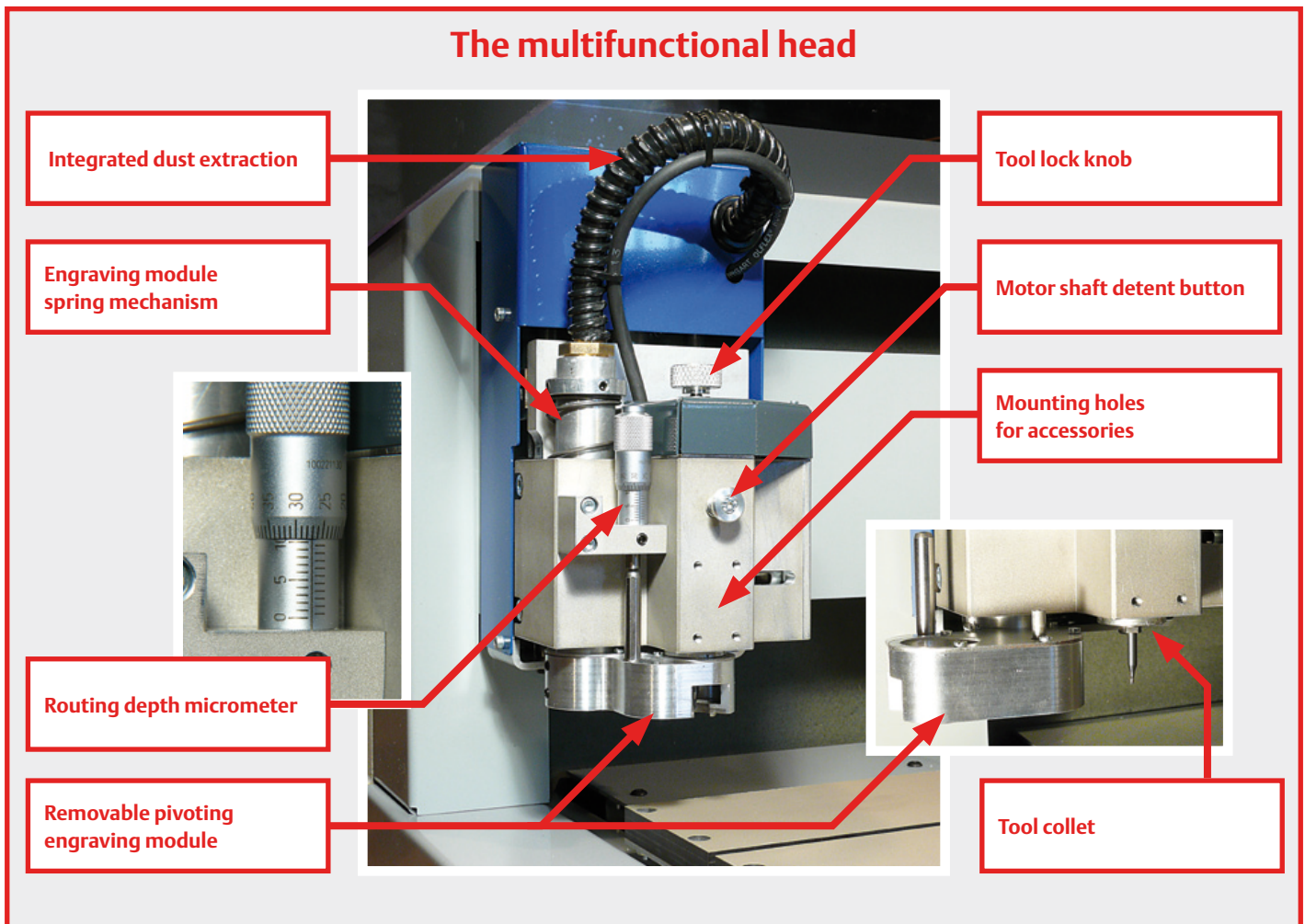
The dust extraction pickup is integrated into the engraving module. The major advantage of this is that the engraving module can be pivoted aside without disconnecting any hoses. The combination of a cyclone chamber and direct suction through the motor block effectively removes even the smallest dust particles.

The routing depth is set by a micrometer. This makes it possible to rout perfect isolation tracks, even with a conical routing bit. If you use the PCB Prototyper for other tasks, the micrometer can also be used for very precise adjustments or making measurements.

### A versatile machine

As already mentioned, the PCB Prototyper is more than just a PCB router. It can easily be adapted for performing other tasks. This applies not only to the mechanical aspects of the machine, but also the included software. The biggest challenge in developing a machine with this versatility was maintaining the necessary precision, since any time you can fiddle with a machine there's a chance of making mistakes. Several innovative solutions have been devised to achieve this:

- Like most PCB routers, the standard version of the PCB Prototyper is equipped with a flat table having a T slot in the middle. This slot holds sliding blocks with small pins for securing the PCB material. This is perfect for making double-sided PCBs, but it is not suitable for making other types of objects, such as 3D workpieces. The PCB Prototyper design allows the standard work table to be replaced by an aluminium table with T slots, a vacuum table, or a customer-specific table.
- The engraving module has an exchangeable depth sensor. The standard version of the machine is supplied with a depth sensor for routing the most common types of PCBs. For routing HF PCBs or very soft materials, it may be helpful to replace the standard depth sensor by a more suitable type.
- Almost all PCB routers have a fixed engraving module. This is ideal for routing PCBs, but it is entirely unsuitable for other types of jobs. The PCB Prototyper is equipped with the unique 'Pivo' system, which allows the engraving module to be swung aside. In addition to simplifying the fitting of delicate routing bits, this allows the engraving module to be removed easily. When it is removed, the dust extraction connector is exposed



and a different suction nozzle can be fitted if desired. This ensures that adequate suction is available, even with complex routing or milling jobs.

- The PCB Prototyper multifunctional head is designed for especially easy fitting of accessories such as a camera, measuring device or dispenser. The workspace of the machine is specifically adapted to this, so the spindle motor and fitted accessories can cover the full working area.
- A handy hatch door at the rear of the machine allows users to mount workpieces that are longer than the worktable. This enables users to machine specific locations on long objects without difficult manipulations, or to machine an entire object by marking reference points and sliding the object through the machine.
- It is even possible to remove the complete multifunctional head and use the machine for entirely different purposes. Thanks to handy quick-release couplings, the air lines built into the machine as standard can still be used for air supply and suction.

### Included software

The software included with a PCB router is very important. Users must be able to import files from their favourite PCB layout programs and have them converted into PCBs ready for assembly, all without any difficulties. Even highly complex designs should be processed smoothly. The PCB software module included as standard

with the PCB Prototyper is able to do this and much more.

As already mentioned, the PCB Prototyper comes with ColiBri, a versatile software shell that holds all of the software modules for operating the machine. The idea behind this approach is that the user simply clicks a file, and ColiBri ensures that the right work environment is opened. For making PCBs, the PCB module is selected, and for making 3D objects the 3D module would be selected. This gives users a clear overview of all of their files, and each file is linked automatically to the right software module for the task concerned.

The PCB Prototyper is supplied with ColiBri and the PCB module as standard, which means that the PCB Prototyper is a full-fledged PCB router as delivered. If you need other modules, you can write your own (the entire command set is available to users) or purchase them for seamless integration with ColiBri.

### PCB module

The PCB module is a software package that complies with the latest software standards. The 'Office Fluent' user interface with Windows 7 look and feel makes working with the machine intuitive. The machine control software and CAM package are integrated seamlessly in the PCB module, which eliminates the need for manually transferring files from one environment to the other. This makes everything a lot simpler, since every modification made

## ELEKTOR PCB MILLING MACHINE

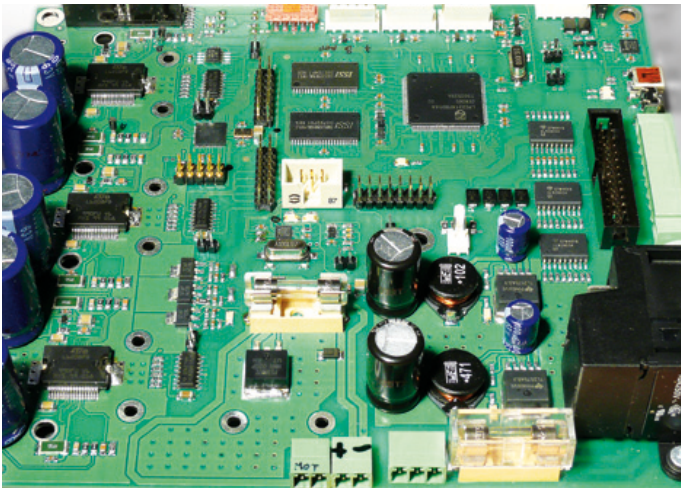


Figure 3. The PCB Prototyper controller board is built around a 32-bit RISC processor and an FPGA.

in the CAM environment is copied automatically to the control environment, and vice versa. Despite this coupling, you can process other PCBs in the CAM environment and generate contours for them without interrupting the routing activities of the machine.

The PCB module is free of the restrictions usually encountered with comparable packages. Capabilities that manufacturers often restrict in their basic packages, such as multilayer, residual copper removal, spike removal, different contour strategies for different tools, design rule checking, and a choice of metallised or non-metallised holes, are all standard features of the PCB module.

With the PCB Prototyper, routing PCBs is easy and errors are rare, but as with any mechanical process it's always possible for something to go wrong. The 'selective remake' function of the PCB module comes in handy here. Suppose a drill or routing bit breaks while a PCB is being made. You can select the poorly routed or unrouted area or feature and have this area, track, hole or whatever be remade, with everything else left alone. Without this function, your only choice would be to make a new PCB from scratch.

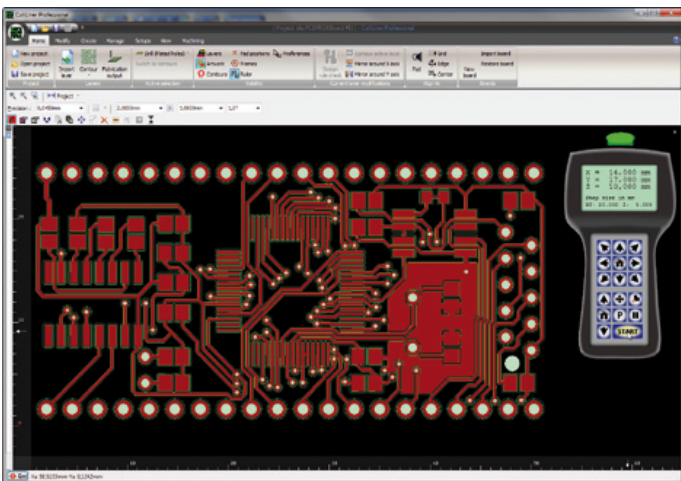


Figure 4. PCB contours computed using the new ColiBri program with the integrated PCB software module.

To see just what this PCB module can do, we used four similar CAM packages to generate contours for ten different PCBs, consisting of several HF boards requiring only residual copper removal, a few complex multilayer boards, and a couple of analogue and digital boards. In most cases (but not always) the PCB module took the least time to do the job, and it was able to generate routing files for all of the PCBs — which was not the case with the other packages.

There's not enough room here to describe all the functions and features of the PCB module. If you want to know more about what it can do, visit the Colinbus website at [www.colinbus.com/pcbprototyper](http://www.colinbus.com/pcbprototyper) for a detailed description.

### Ordering

The Elektor PCB Prototyper is supplied as a fully assembled and aligned machine with an integrated high-speed spindle motor. The included control software consists of the ColiBri shell with the PCB module. Please use the order form on the Elektor website to place your order ([www.elektor.com/PCB Prototyper](http://www.elektor.com/PCB Prototyper)).

The price is € 3500 / £3100 / US\$4900 plus taxes (if applicable) and shipping charges. The shipping charges depend on the country and are stated on the website.

The machine is delivered and invoiced directly by Colinbus.

Various software and hardware extensions for the PCB Prototyper are currently under development. They will be announced in *Elektor* and on the website when they are available.

### The proof of the pudding

Of course, it's not possible to give you a full picture of the capabilities and features of the Elektor PCB Prototyper with text and photos alone. What you really need is to inspect the results with your own eyes and a good loupe.

Unfortunately, we cannot invite every reader to a demo session, but we can report that our Elektor design staff are completely convinced after examining several PCBs routed by the PCB Prototyper — and they're very exacting when it comes to the quality of their boards. We're certain that the Elektor lab will soon boast a PCB Prototyper for making PCBs that need to be ready right away.

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**P.S. We're doing our best to arrange for a live demonstration of the PCB Prototyper at the ElektorLive! event on 20 November next, so everyone there can see what outstanding results this machine can deliver. This is provisional at present; check [www.elektorlive.nl](http://www.elektorlive.nl) for the latest news.**