Saving Time and Money:

Bringing PCB Prototype Production Back In-House through PCB Milling Technology

By Stephan Schmidt, President, LPKF Laser & Electronics USA

The days of wire wrapping and breadboarding are on the decline. While these prototyping methods have been used by students and engineers alike for decades, advances in technology, specifically the rise of surface mount technology (SMT), require the use of printed circuit boards (PCB) as many integrated circuits (ICs) are only being made available in SMT packaging which require an adapter board to make the pins accessible. The reality of this trend is stated succinctly by Tom Grady from the University of Nebraska: “You can’t experiment with a chip if you can’t connect to it.” In addition, advances in technology raise new accuracy and reliability issues that must be considered. For example, the impedance of high frequency signals used in many video and RF applications is difficult to control when wires cross over a breadboard.

In order to facilitate design, both university and industry labs require access to PCB-based prototyping capabilities. For high-volume jobs, chemical etching is often the most cost-effective PCB production method. However, the hazardous nature of etching, as well as the expense associated with storage and disposing of chemicals, has led etching to be viewed as an undesirable liability, one university administrators and corporate executives would rather avoid.

For these reasons, many designers outsource PCB production to design houses. Prototype runs, however, are typically on the order of a handful of boards. The expense of such small runs, in addition to their slow turnaround time, becomes a major impediment to the design process.

In-House Prototyping

Many designers are turning to PCB milling technology in order to bring PCB prototype production back in-house (see Figure 1).

Figure 1: The S62 PCB Mill from LPKF Laser and Electronics enables universities and businesses to bring prototype design back in- house to lower costs while reducing board turnaround time from weeks to hours

For labs turning many designs, the cost savings are attractive. Ralph Loya of University of Texas El Paso says, “With PCB milling, you can make a $1000 board for $150, which really saves students a lot of money. Also, having the machine on the premises means we can actually stop it in the middle of a process if we got something wrong, allowing us to make slight modifications.”

How quickly PCB milling equipment will pay for itself is dependent upon the volume of the lab. By estimating yearly expenses for sending boards out, it becomes possible to evaluate if the machine will save money over time. For labs using SMT components, off-the-shelf adapter boards can cost on the order of $50. Milling one’s own adapters can cut this cost in half, a significant savings when multiplied across a classroom of students. But designers will want to consider more than monetary savings.

“With production houses, you either get your boards fast and expensive or you wait forever,” says Max Keene with the University of Washington. “Being able to create a prototype board in a day lets us try out a design and see if it doesn’t work exactly like we thought or if there’s some kind of RF interference we weren’t expecting.”

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Rapid turnaround gives designers the freedom to transform new designs considered in the morning into test hardware by end of day. For groups pushing the technology envelope, such creative latitude is critical to developing breakthroughs. Having in-house prototyping capabilities also enables designers to build custom boards made of a combination of rigid and flexibility materials, a prospect difficult to coordinate with even the most cooperative board houses.

Bringing PCB prototyping back in-house also reduces cost in other ways. “PCB milling increases our ability to complete more projects,” says John Hayden from the University of New Brunswick. “If we didn’t have it, we’d need a technician here almost full-time making boards.”

Improving Quality and Reliability

Many designers prototype boards to ensure that designs are accurate before initiating high volume runs. The ability to verify a logical schematic as a hardware prototype significantly reduces the risk of having errors arise in the field (see Figure 2).

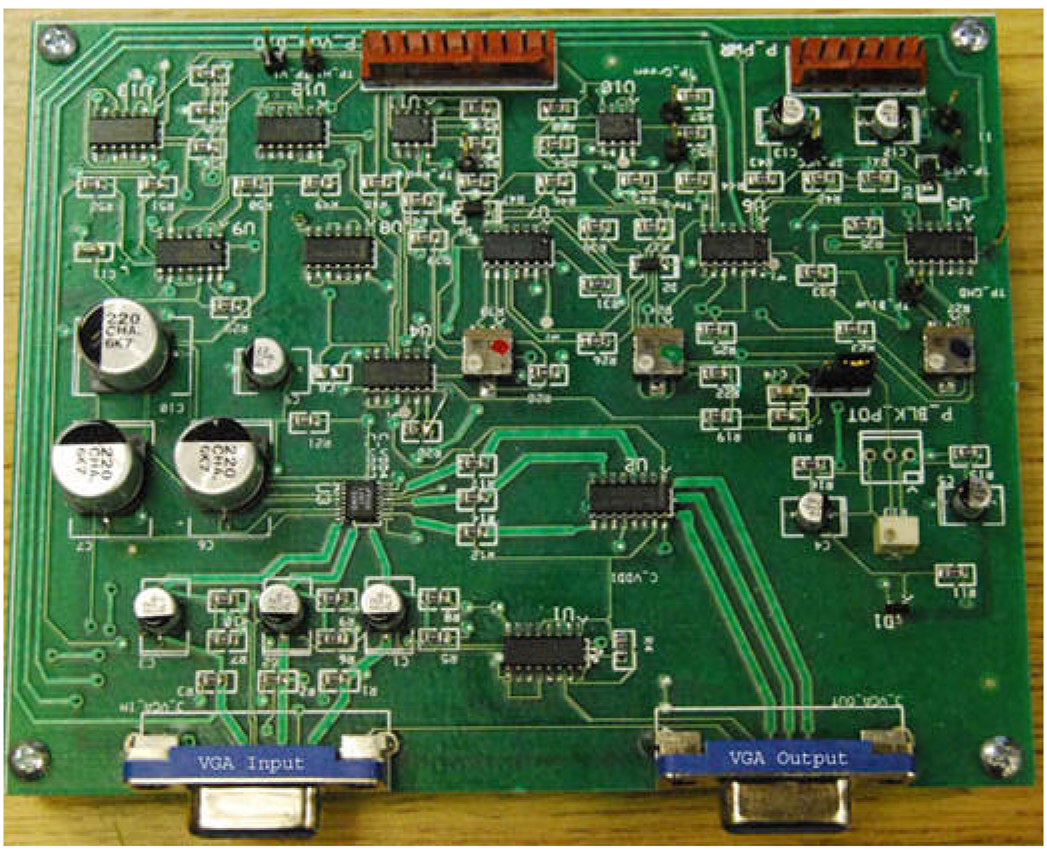

Figure 2: Many designers prototype boards using PCB mills to ensure that designs are accurate before initiating high volume runs. Verifying the logical schematic of complex designs as hardware prototypes significantly reduces the risk of having costly and time-consuming errors arise in the field.

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Mike Bailey at Indiana University says, “Once we’ve got a board that works, then we can ship it out for mass production because we know the Gerber files are right and we’ve already tested it.”

PCB milling also improves final board quality. Because it is a subtractive process, milling avoids the microcracks associated with additive processes like chemical etching. The mill also won’t veer off and break traces, and traces can be rounded and tuned in width to increase RF signal quality.

Chemicals, in contrast, can seep into every nook, etching lines where they aren’t wanted, as well as etching too much or too little. The variances of etching also limit how tight designs can be. PCB milling works across a wide range of materials, from simple FR4 to pliable materials like Rogers 5880 series material, with precise traces down to 4 mils for compact designs.

“Some PCB manufacturers guarantee that their boards are going to work,” says IU’s Bailey. “Less expensive houses counting on volume production may be inclined to not tell you if something isn’t right.” Success rides on the reliability of prototype boards, especially for students who, needing to complete a project within a semester’s window, simply cannot afford the extra weeks a manufacturer’s error may add to board delivery. Bringing PCB production in-house gives universities more control over protecting the student experience and enables students to work on projects without having to have them span multiple classes.

Student Experience

When PCBs are outsourced, many students experience the production process as little more than emailing Gerber files. With in-house prototyping, students learn firsthand essential manufacturing, test, verification, and debugging techniques and can begin to understand the impact packaging has on design. For example, there are myriad choices for any component type, and the selection process is not trivial. Stepping through this process forces students to consider what it takes to physically build a circuit as well as shows them how interconnected selection and layout decisions really are. As Ron Rizzo of Western Kentucky University sums these ideas up, “Without direct experience, they don’t know the questions to ask.”

In-house prototyping also gives students the freedom to make mistakes. U of W’s Keene says, “Students are going to make mistakes, but that’s the way you learn it.” Michael McIntire at Western Kentucky University sees additional value: “We don’t want to propagate the throw-it-over-the-wall mentality.” Understanding as many facets of board design, says McIntire, “helps close the loop on designing for manufacturability. When students have to actually make the board, build it up, solder it, and test it, they realize different ways they could have laid it out that would have made it easier to make.”

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Another advantage of PCB milling is that it promotes student autonomy. “We walked students through the etching process but it’s not something you can just say, ‘OK, here you go, here’s a bunch of hazardous chemicals and expensive darkroom materials,’” says Rizzo. Many instructors agree that with training and a bit of monitored experienced, students can operate PCB mills without supervision.

Employers value practical experience. And with the reality that there are fewer technicians in the workforce, engineers are being called upon to move beyond just theoretical design to handle more of the soldering and board design tasks. PCB design gives students direct experience with modern equipment rather than teaching them out-dated skills. In addition, their finished projects serve as concrete evidence students can use to show prospective employers that they have real-world skills that are directly applicable to today’s applications.

“There isn’t a lot of material in textbooks that present schematic to board making in a coherent fashion,” says Phillip Moore who teaches students at Julian High School in Chicago. “The hands-on process crosses boundaries, exposing students to both what the engineering team is doing as well as what the assembly team is doing. It also helps students develop project management skills, specifically learning to do things according to a plan with attention to detail and understanding electronic components in terms of operation.”

PCB Milling

When bringing board production back in-house, there are many facets for designers to consider. Tools designed specifically to mill boards tend to cost more than retrofitted metal-cutting end mills, but the difference in quality is readily apparent. Given the range of applications a lab may need to support, designers may find better value from manufacturers that offer a family of tools that don’t require them to pay for features they don’t really need.

The overall scalability of PCB milling tools gives designers many options. If they are fortunate enough to have the resources, they can buy a fully-loaded machine upfront (see Figure 3).

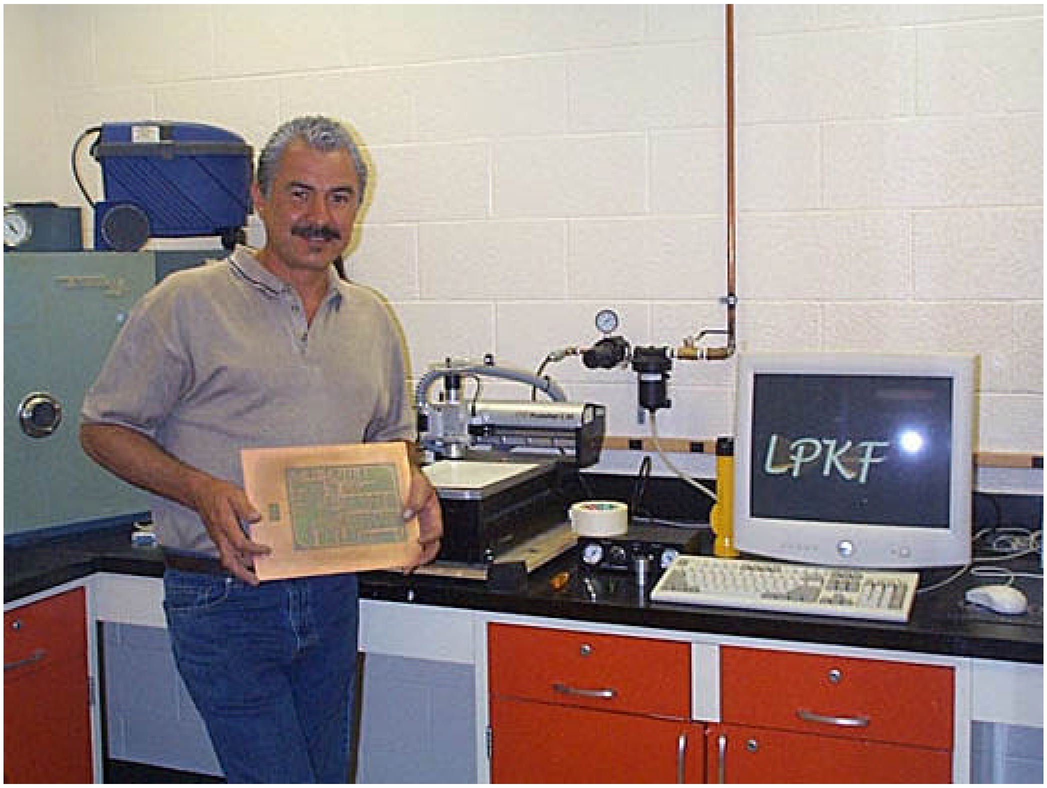

Figure 3: The scalability of PCB milling tools gives designers many options, enabling designers to bring the PCB prototyping process in-house for a lower initial investment. Rather than having to purchase a fully-loaded setup upfront, designers can reduce initial capital outlay by purchasing a basic system and delaying the purchase of labor-saving upgrades such as automatic tool changers, vacuum tables, and pick-and-place equipment.

Alternatively, they can reduce their capital outlay by purchasing a basic system and delaying the purchase of labor-saving upgrades such as automatic tool changers, vacuum tables, and pick-and-place equipment (see Table 1). This enables designers to bring the PCB prototyping process in-house for a lower initial investment.

Table 1: PCB Mill Upgrades

Automatic Tool Changer	Allows designers to run complete boards unattended
Fiducial Camera	Speeds setup through automatic alignment; eliminates the need for registration pins for front-to-back alignment.
Vacuum Table	Increases accuracy of milling when using flexible or warped materials
Acoustic Cabinet	Reduces sound in the lab
Semi-Automatic Pick-and-Place Equipment	Dispenses solder paste and populates board; reduces user error and avoids misalignment of components
Reflow Oven	Solders surface mount components by quickly melting the solder paste in a temperature controlled environment, without overheating the components itself
High-speed Spindle	Makes cleaner cuts for softer substrates and flex boards

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For labs having trouble justifying the cost of bringing a PCB mill in-house, many universities extend the value of these tools by making them available to other research departments or by prototyping boards for outside companies. Many grants don't supply enough money to support the outright purchase of tools to avoid using outside board houses. Universities which view in-house prototype development as part of their infrastructure are able to put these tools in place to assist groups across their campus in staying within tight budget constraints. For Western Kentucky University's Rizzo, "It's better when we're all working together to do things."

Stephan Schmidt

Stephan Schmidt, President, LPKF Laser & Electronics USA has been employed with LPKF since 1984 and worked at their German Headquarters before he joined LPKF Laser & Electronics USA in 1999.

About LPKF

LPKF Laser & Electronics is an ISO-9001 certified equipment manufacturer of equipment for the electronics industries; the worldwide headquarter is located in Garbsen, Germany and its North American headquarters located in Tualatin, Oregon. For more information about LPKF, visit **www.lpkfusa.com** or contact the company at 12555 SW Leveton Dr., Tualatin, OR 97062, Tel. 503-454-4200.

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Picture supplied by Ron Rizzo, Western Kentucky University

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Picture supplied by Ralph Loya, University of Texas – El Paso