Compact Router Speeds Prototype PCB Development

A portable, but rugged, circuit-board router can turn a copper-clad laminate into a working circuit in less than 15 minutes.

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ADVANCES in desktop circuit-board routers have extended the speed, safety, and convenience of mechanical printed-circuit-board (PCB) prototyping to include the most demanding applications. Unique pneumatic systems control the cutting process more precisely and gently than previous methods had, making it possible to create circuits at the desktop on highly sensitive Teflon substrates such as RT/duroid®.

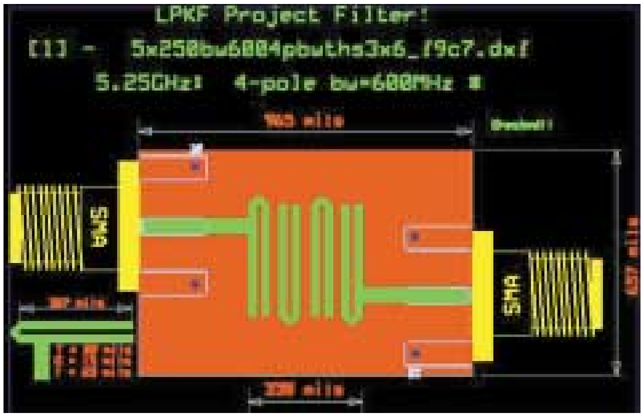
Modern circuit-board routers such as the portable machines available from LPKF (Wilsonville, OR) are capable of producing structures with track widths as fine as 100 μm, with precise cutting channels. These machines can achieve accuracy of better than 0.2 mil to ensure the faithful reproduction of fine-pitch structures and high-density circuits. One of the key advances in these machines is the use of adjustable-speed three-phase motors capable of operating to 100,000 rpm. By employing such high spindle speeds, greater geometric precision is possible, while also extending the life of the cutting tools.

1. Compact table-top circuit-board routers can provide high precision, repeatability, and fast turnaround times on circuits fabricated on Cu-clad Teflon substrates.

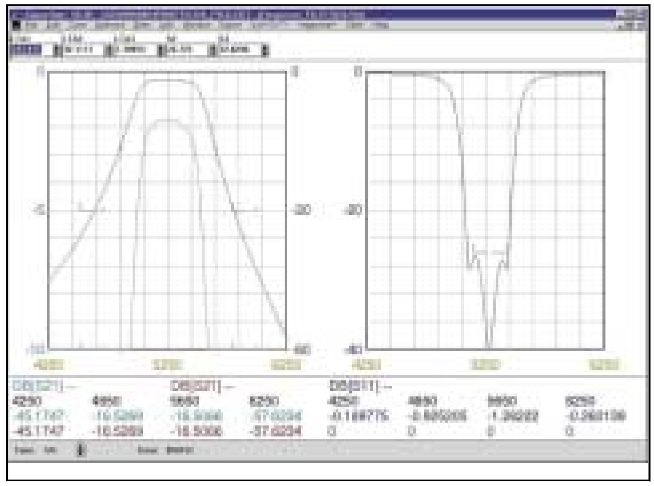
These compact routers (Fig. 1) can be used anywhere in a high-frequency electronics laboratory or production facility. Once designed solely for single-layer designs, they can now fabricate multilayer circuits with the aid of accessory presses and through-hole systems. Typical four- and six-layer circuit boards can be produced in a few hours.

GETTING THE EDGE

Since time to market and design integrity are critical factors in RF wireless communications markets, the availability of these tabletop circuit-board routing systems can provide a competitive edge for companies seeking to supply fast turnaround times and custom solutions. Producing one's own prototype circuits (rather than subcontracting the work) through mechanical milling also helps protect intellectual



2. A four-pole bandpass filter for wireless communications in the 5.2-GHz band was selected for the purposes of comparing mechanical milling and chemical-etching fabrication processes.



3. This analysis of filter behavior was performed with the help of the M/FILTER software.

property (IP) without resorting to potentially hazardous chemical processes. How well do these milled circuits compare with chemically etched circuits? And how well do both approaches correlate with predictions from computer-aided-design (CAD) programs? How well can milled-circuit prototypes be replicated when compared to mass-produced circuits made by means of chemical etching?To compare the effectiveness of the two circuit-fabrication approaches, prototype microstrip bandpass filters were fabricated on 4350 20-mil-thick laminate material with 1-oz. copper (Cu) cladding from Rogers Corp. (Chandler, AZ). The bandpass filter is a four-pole Butterworth design with an eight-percent bandwidth of 400 MHz centered at 5.25 GHz (Fig. 2). It is suitable for National Information Infrastructure (NII) receivers (Rxs). With the growth of cordless telephones and wireless local-area networks (WLANs) in the 2.4-GHz band, the 5.2- and 5.7-GHz bands have emerged as strong candidates for short-range communications.

The M/FILTER and SuperStar linear analysis programs from Eagleware (Norcross, GA) were used for the circuit design and simulation tools. Half-wave folded transmission-line elements were chosen for this design because they did not require plated-through via holes to the ground plane. Synthesis data from M/FILTER (Fig. 3) predicted a center frequency of 5.2 GHz with passband insertion loss of less than 2 dB and a return loss of 30 dB.

Filters were fabricated with both processes (Fig. 4) and measurements were taken. The measurements showed the first trail-center frequency to be 250 MHz above the design-center frequency. This was greater than expected, but still close enough to allow a comparison of the two fabrication approaches. It was determined that the rejection characteristics were at a maximum for what could be expected, given the design constraints of size and insertion loss for this type of filter circuit. The unloaded quality factor (Q) of the printed resonators is less than 100.

PRODUCING ONE'S OWN PROTOTYPE CIRCUITS (RATHER THAN SUBCONTRACTING THE WORK) THROUGH MECHANICAL MILLING HELPS PROTECT INTELLECTUAL PROPERTY (IP) WITHOUT RESORTING TO POTENTIALLY HAZARDOUS CHEMICAL PROCESSES.

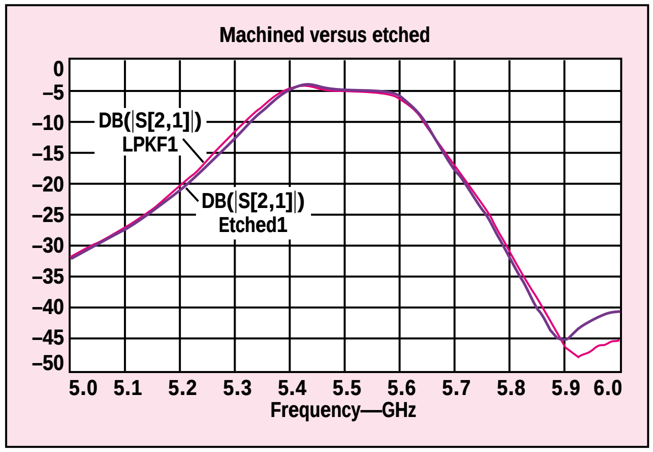
Therefore, defining a 3-dB bandwidth of less than 10 percent would result in more than 3-dB insertion loss. Measurements of the two filter versions were made with a model 8720C automatic vector-network analyzer (VNA) from Agilent Technologies (Santa Rosa, CA)[Fig. 5].

The center frequencies in the milled circuits were closer to the computer-predicted value, while those for both etched circuits were a little higher. There were no superficial differences in the two types of fabrication, but microscopic examination revealed deviations from exact design dimensions of +0.5 to +1.0 mil in the mechanically milled filter and +2.0 to +5.0 mil in the chemically etched version.

The milled circuits (Fig. 6a) provided a more precise mechanical match to the original filter-design pattern because their traces were square and sharp, just as they were defined by electromagnetic (EM) CAD images. The etching process produced softer, more rounded edges (Fig. 6b). The filter bandwidth was within specified limits for all samples, but the insertion loss was greater than expected (approximately 2 dB was predicted by synthesis) in both cases: 5 dB for the milled filter and 3 dB for the chemically etched version.

DXF files provided by M-FILTER were used to prepare the plotter to manufacture the mechanically milled filter. The milled filters were produced in approximately 15 minutes

4. Using layout files from M/FILTER, mechanically milled and chemically etched filters were fabricated.



5. The measured performance of the machined versus the chemically etched filters was plotted with the help of a model 8720C VNA from Agilent Technologies.

using built-in software to generate the layout from the downloaded design files. The same design files were sent to a local vendor for the production of the etched samples, with a turnaround time of five days. Two samples were built with each process; all were made from the same Rogers 4350 laminate panel. The resulting test assemblies (Fig. 4) revealed that the mechanically milled circuits closely matched the electrical performance of the chemically etched filters, as well as the results predicted by EM software simulations. The simulations were performed with the aid of the Microwave Office software suite from Applied Wave Research (El Segundo, CA).

This project started with the question of whether prototype microwave filters produced by a mechanical process were equivalent to those fabricated by chemical etching. Since the goal of prototyping work is to arrive at a satisfactory design, the most important requirement is to have the circuits perform properly. Although the fabricated filters from both approaches were not identical in every respect, circuits from both processes did meet that requirement.

The significant difference between the two methods was turnaround time. Since most high-frequency designs are an iterative process, the ability to have a finished prototype in hand within minutes allows users to continue to improve a design in approximately real time. Waiting five days (including layout changes) for an etched board forces an engineer to set aside a design until the new circuit boards arrive from the outside service provider. The accumulated down time could become a substantial burden to a fast-track project.

The findings showed that milled circuits accurately reflect CAD-synthesis predictions and suggest that some minor corrections may be needed to account for those variations for replicating prototypes when using chemical etching for mass production. By considering the variations, a designer can be confident that a milled circuit will be as effective as a chemically etched version for the prototyping of new, higher-frequency devices. • •

Acknowledgments

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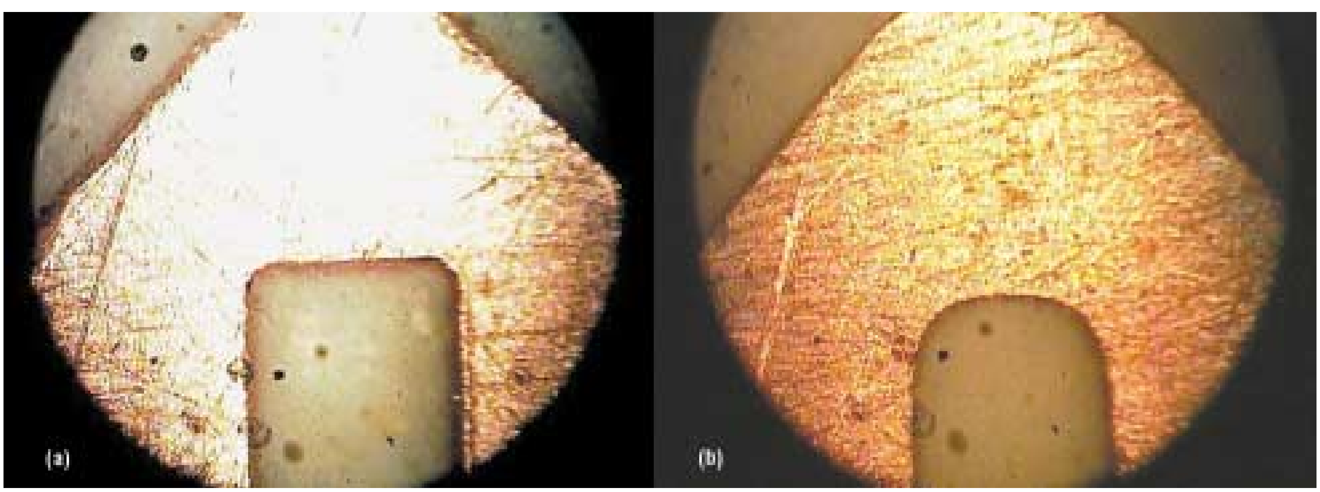

6. The mechanically milled filter circuits exhibited much sharper edges (a), in keeping with the design software requirements, compared to the rounded edges (b) of the chemically etched filters.