Efficient PCB prototype manufacturing encompasses a number of important traits. Among the more prevalent are quick-turn capabilities, manufacturing flexibility, easy GUI, quick changeover adaptability, higher technology level, proactive and trained staff, equipment, and capacity levels. Additionally, the savvy contract manufacturer (CM) or EMS provider has a flexible procurement system, strong process capabilities, an array of fixtures, and balanced SMT lines.

Standard turn, also known as extended turnaround time, refers to the time between order entry and customer-ready prototype, and it differs among CMs and EMS providers. Some advertise one week as their standard turn; others, two to three weeks. Time factors are of prime concern because an OEM customer can incur extra costs and time-to-market loss by naively relying on three weeks delivery, when in reality, the time extends out to six to eight weeks, if all the manufacturing processes are not properly scheduled and planned.

**Flexibility is key**

A prototype line must be flexible in terms of accepting different sizes of boards and different complexity levels. Prototyping for both PCB fabrication and assembly is, in effect, R&D since a product is not yet mature. It deals with a number of design changes involving specifications, features, and countless product aspects.

For instance, a re-programmable FPGA's power and ground pin-outs may change to comply with different power and voltage requirements on a PCB. Or internal planes between analog and digital sections may need to be swapped, depending on the impedance control requirements on the board.

By its nature, a prototype incurs constant change, even on the last day when the product is ready to be shipped to the customer. The OEM may change a resistor or capacitor value, for example, just before the product is shipped out. Flexibility should be embedded in the process and procedures from layout design to assembly. At times, 100-percent review may not happen due to time constraints, and the OEM skips intermediate steps to rush the product out the door. This is when an EMS company that’s flexible comes in handy to incorporate all these last minute changes and modifications that were overlooked during the internal design review cycles.

As shown in Figure 1, an easy-to-use GUI is important for helping the technical staff
and SMT programmers to quickly re-program prototype line systems. In doing so, the EMS provider can easily and quickly execute a changeover to a new prototype job. Re-programming should take no more than a few hours, not days, so that multiple jobs can be executed on the same prototype line on any given day. Easy prototype programming is important because prototyping requires quick format change over to maintain a steady and smooth flow of other incoming jobs.

As for technology level, a prototype line demands the latest technology available to include automatic optical inspection (AOI). If a fabrication shop is involved, it’s important to know the kind of inner-layer inspection and lamination registration and verification tools and capabilities this shop will be using during the fabrication process. It’s also important to know how many layers they’re capable of building for multi-layer boards and how complex boards can be manufactured.

A proactive sales and program management team plays a major role in a highly successfully prototype line because it acts as an early warning system to advise the OEM of possible pending issues, concerns, or questions. Being alert to any possible problems assures that a prototype project stays on track and on schedule. This alertness is particularly valuable to avoid thousands of dollars of extra cost and inordinate time delays.

Also, it is important to note that successful prototype lines require the right kind of equipment to support the latest technology prototype projects. This includes an SMT line that is easy to program, an AOI machine for checking and inspecting defects, a paste height inspection system, a flying probe tester, and BGA/CSP installation capability. Equipment like this ensures that jobs can be efficiently and successfully performed. Along this line, it’s important to know the level of capacity an EMS provider offers and its limitations.

Flexible procurement, strong process capabilities
As noted earlier, at the NPI stages, a PCB designer often makes changes to a prototype even at the point of being shipped to an OEM customer. Minor changes demand a flexible and agile procurement system allowing adjustments to a prototype to be made correctly and expeditiously.

But strong procurement capabilities are a vital part of that flexible procurement system. While some aspects of a prototype design may appear mundane on the surface, they may have the potential of causing adverse effects during manufacturing. Therefore, processes must be strong and robust enough to catch and correct any out-of-the-ordinary issue.

Let’s say for example, you’re dealing with a hybrid leaded and lead-free prototype. A leaded component is inadvertently included in a lead-free kit or vice-versa, for that matter. A good, efficient process should be able to catch that mistake. Processes must be tightly disciplined and have multiple checks and balances. Hence, the correct processes involving engineering and documentation must not only be in place, but in place to make changes quickly and efficiently.

Prototype fabrication
The ideal prototype fabrication shop turns product around within 24 to 48 hours, if extra-fast turn around is required. It possesses current technology to effectively handle components like fine pitch BGAs and CSPs and turns out cutting edge PCBs with finer capabilities. This means fabricating boards with 3 mil trace spacing and 3 mil air gaps between traces, plus successfully etching pads of extra fine pitch devices such as BGA with 0.4 mil pitch, and fine CSP and QFN, which is difficult to fabricate.

Also, this prototype fab house uses laser drilling technology for smaller drill sizes. It continues to use mechanical drills for up to 6 to 8 mil holes. However, laser drills are used for the smaller 4 to 5 mil holes. As for surface finishes, the prototype customer should have a full selection readily avail-

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<table>
<thead>
<tr>
<th>PCB Surface Finishes</th>
<th>Different Board Finishes Compared</th>
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<tbody>
<tr>
<td>HASL</td>
<td>OSP</td>
</tr>
<tr>
<td>Flatness</td>
<td>NO</td>
</tr>
<tr>
<td>Solderjoint</td>
<td>Cn-Sn</td>
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<tr>
<td>Wirebond</td>
<td>NO</td>
</tr>
<tr>
<td>Cost</td>
<td>$</td>
</tr>
<tr>
<td>Reflows</td>
<td>6</td>
</tr>
<tr>
<td>Shelf Life</td>
<td>18 Months</td>
</tr>
</tbody>
</table>

Fig 2 Different types of PCB surface finishes
length that stops at a specific internal layer with the board stack up and does not go through all the way to the bottom side of the board.

A flying probe tester’s speed is another important aspect (Figure 3). Does the prototype fab shop have a four- or eight-header tester? Is it a one- or two-sided flying probe tester? Testing speeds are crucial to prevent bottlenecks so that the fab shop can churn out multiples of products at a time. Further, is the technology available for catching and inspecting inner-layer registrations? This is especially vital for multilayer, let’s say 10 or more layer boards. It’s important to inspect and evaluate internal layer registration to prevent mis-aligned layers, which can cause registration related defects in the boards.

Handling BGA and CSP devices

Selection criteria for a prototype assembly shop include capabilities for efficiently handling fine pitch BGA and CSP devices. These particular capabilities should include not only BGAs to be installed using a pick and place machine, but also have a separate re-work BGA station, as shown in Figure 4.

Other criteria involve hand loading to avoid programming charges, if possible, especially for smaller quantities—say between 1 and 10, ability to do consigned versus turnkey assembly, exemplary inventory management control, top-notch test capabilities, component procurement capability for smaller and larger BOMs, as well as the ability to cross reference the parts, which may include hard-to-find and obsolete components.

Fixtures should also get special attention because they can accelerate prototype manufacturing. For example, considerable time is involved when 20 boards are assembled individually. However, manufacturing time is significantly reduced when five panels with four boards on each panel are used.

Flexibility to do machine loading versus hand loading is also important. That’s because the project may deal with small quantities involving moderate technology. Hence, it may be easier and faster to hand load the project. A prototype assembly shop should be flexible enough to do turnkey versus consigned assembly jobs because different projects and different customers have different needs, hence flexibility comes in handy to support them.

Two other important areas are offline programming and balanced SMT lines. Manufacturing flexibility is especially important when it comes to surface mount programming. A CM or EMS provider should be able to perform offline programming. That way, offline programming is being done for the next quick-turn job. It’s always a good idea to do all programming offline and avoid tying up the SMT machine to perform programming, while it could be used to run a project.

Here’s an example. Ideally, there are three sets of feeders for a prototype line. While job one is being done, offline programming and setting up the second set of feeders are being performed for job two. The third set of feeders is available in case something was to overflow or if the job is put on hold, for example.

Lastly, it’s crucial to maintain efficiently balanced SMT lines. It’s not a good idea for an OEM to consider a prototype house with only one line. It’s best to go to one with three or four SMT lines. Going to a single SMT line prototype house poses major issues. A single SMT line prototype house has to rely on maintenance personnel to adjust or repair the line in case of problems. On the other hand, critical redundancy is built in with multiple SMT lines. This way, those lines efficiently balance the load so there’s always at least one line available for quick-turn prototypes.

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