Heed the DRAFT

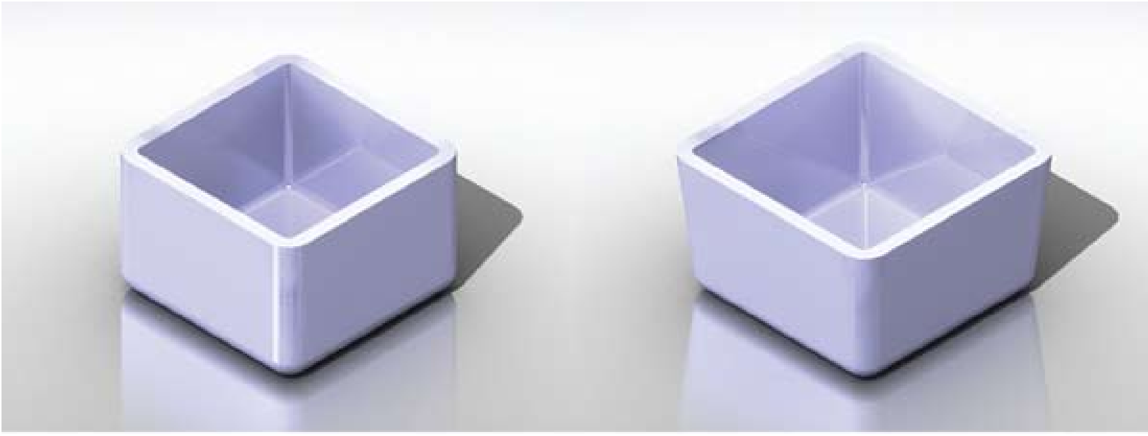

Fig. 1. Example of an undrafted (left) and drafted (right) part design.

Remember draft angles when designing injection-molded parts.

by brad cleveland

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Injection molding is the most commonly used method of manufacturing any significant volume of plastic components. The process uses metal molds to produce parts with high accuracy and cosmetic surface finishes, accommodates a vast variety of engineering-grade resins and can be highly cost effective in mid- to high-volume runs.

High-volume injection molding for runs of tens of thousands or more parts uses multi-cavity, water-cooled steel molds to minimize the cycle time and, therefore, the cost of each part. Millions of shots are routinely obtained from these molds, and there simply is no other cost-effective way to achieve the same results.

However, in conventional injection molding there is typically a long lead time and high cost associated with the manufacture of the mold, which has historically made injection molding a less attractive option for obtaining prototype or low volumes of plastic components. Over the past nine years it has been the mission of Protomold (a service of Proto Labs, Inc.) to reduce the cost and time associated with obtaining small quantities of injection molded parts.

The company's general approach has been to automate most of the engineering out of the process through the use of proprietary mold design and toolpath generation software that runs on high performance computer clusters in each of its global manufacturing centers. The method also uses aluminum instead of steel for the molds, which reduces manufacturing time, costs and helps to reduce cycle time without the need for expensive and time consuming cooling systems.

The concept is called "rapid injection molding," and it currently allows a lead time as short as one business day and very low tooling charges.

However, there is still a universal design characteristic that Protomold or any other tooling maker requires in the design of the part to be injection molded: draft. There are several key points to consider in regards to draft and the design of injection-molded parts.

Keeping it simple

While injection molding can produce parts of great complexity, experienced designers strive to simplify their part designs wherever possible. This helps to simplify production and reduce cost, and can even impact aesthetics. Part of this simplification is designing parts that can be made in two-part, so called "straight-pull" molds. In some cases, however, part designs include unavoidable "undercuts," features that would be entrapped in a straight pull mold. These can be produced using side-actions, cams that produce the desired feature and then withdraw as the mol d opens to allow the part to be ejected. While they are useful, side actions increase the complexity and cost of production and should be avoided if possible.

Why draft?

In a straight-pull mold, any part surface that is parallel to the direction of mold opening will drag along the mold face as the mold opens, resulting in damage to the part. Similarly, two mold surfaces that meet parallel to the direction of mold opening can be damaged as the metal surfaces rub against one another during mold opening and closing. (Such interfaces are called telescoping, or sliding shutoffs.)

To avoid damage to parts or molds, all of these surfaces must be "drafted." Drafting angles surfaces away from the direction of mold opening so that the surfaces — part and mold or mold and mold — move away from one another as the mold opens. This eases ejection of parts during production, and eliminates the likelihood of damage to parts or molds. ***See Fig. 1*** for an example of an undrafted and drafted design.

Determining amount of draft

The amount of draft required will depend on geometry and characteristics such as surface texture, but, in general, more is better. Here are some guidelines we suggest for our rapid injection molding process. ***(See Fig. 2.)***

- Use at least 0.5 degrees on all "vertical" (parallel to direction of mold opening) faces.
- Add 1 degree of draft for each inch of part depth: two degrees for a part 2-in. deep, three degrees for a part 3-in. deep.

Texture on a vertical surface is essentially a field of small undercuts that can catch on the mold face as the part is ejected. For this reason, textured surfaces require a high degree of draft to prevent damage.

- Three degrees of draft for light texture (PM-T1).
- Five degrees or more for heavy texture (PM-T2).

Telescoping or sliding shutoffs

A telescoping shutoff, as seen in ***Fig. 3***, is any place where metal surfaces slide against one another as the mold closes and opens. Undrafted telescoping shutoffs can lead to mold breakage and wear resulting in problems like flash. These problems can be prevented by drafting the mold surfaces where they meet.

A telescoping shutoff

In ***Fig. 4***, the blue face of the vertical clip is created by an extension of one mold half protruding through the hole in the base of the part. The sides of this metal protrusion meet the walls of the other mold half to create a shutoff. If the sides of the clip are parallel to the direction of mold opening, metal from the two mold halves will rub as the mold opens and closes. This can be prevented by drafting the sides of the clip as shown in the diagram on the right by a minimum of three degrees.

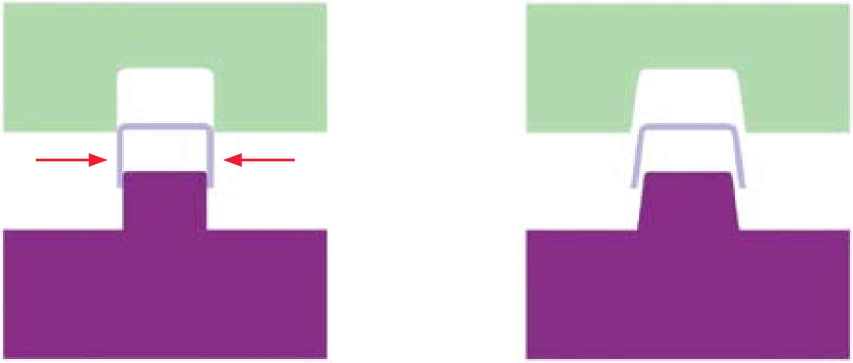

Fig. 2. Illustration shows undrafted (left) vs. drafted (right) part/mold cross-sections. On left, arrows point to undrafted part surfaces that will scrape against the mold during ejection.

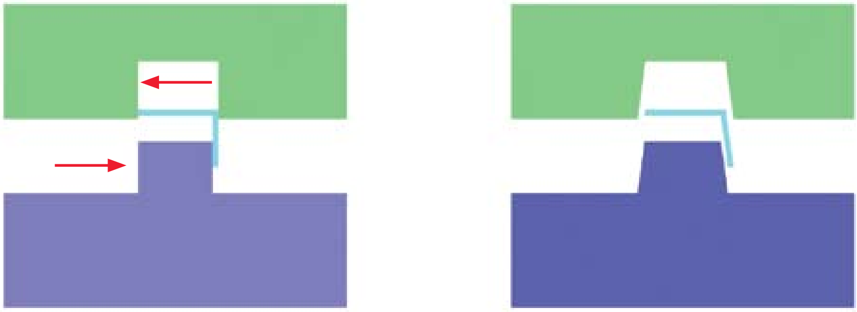

Fig. 3. Illustration shows the use of a telescoping shutoff without draft (left) and with draft (right). On the left, the arrows point to where tool wear will occur without drafting.

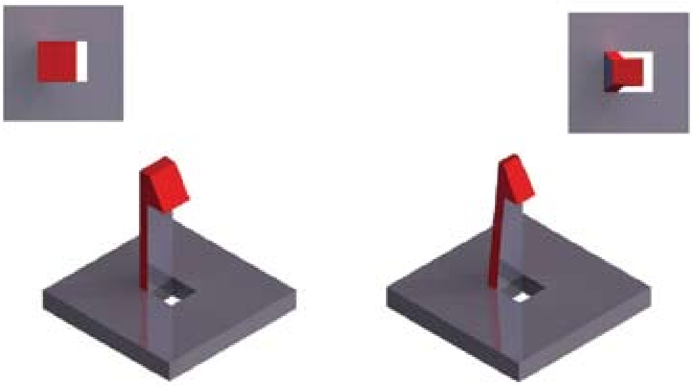

Fig. 4. Illustration of a clip feature produced using telescoping shutoffs. At left is top view and angled view showing how the lack of draft results in sliding parallel mold surfaces. At right, top view and angled view show how draft yields improved mold shutoff surfaces.

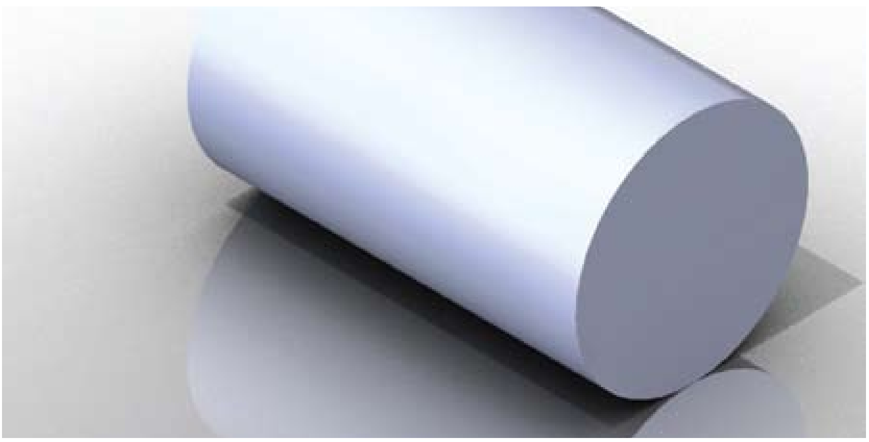

Fig. 5. Undrafted dowel.

Fig. 6. Part design resulting from rotational draft method.

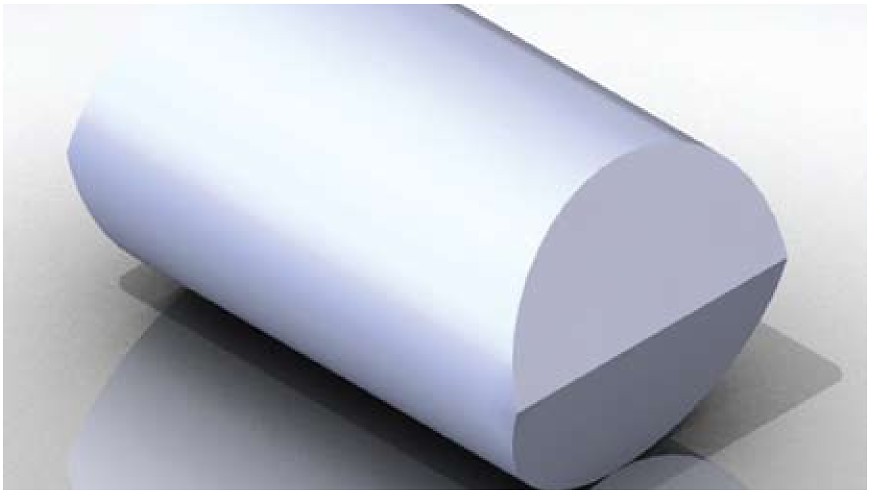

Fig. 7. Part design resulting from planar draft method.

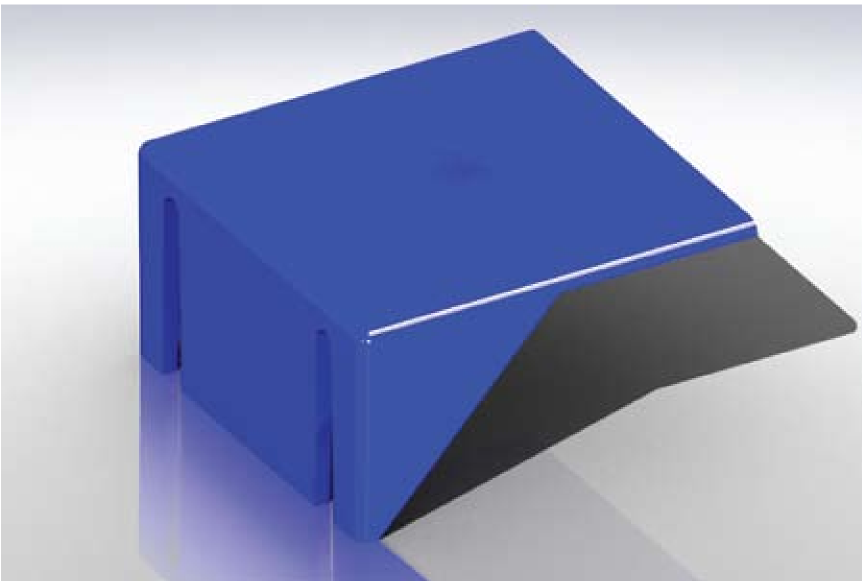

Fig. 8. Example of a bracket design that may not accommodate draft.

Draft and rotational symmetry

There are special cases when considering the role of draft, such as when designing a plastic part with rotational symmetry. As simple example, consider a dowel. In CAD software one might create the shape of half the cross-section — a rectangle — and rotate that shape through 360 degrees to create the solid. ***(See Fig. 5.)***

However, knowing that the part is going to be injection molded and that the parting line of the mold will run along the length of the dowel, it becomes apparent that the end faces of the dowel need to be drafted. There are two ways to draft those ends, one of which works better than the other.

The obvious, but problematic, approach is to tilt the ends slightly when laying out the cross section. When rotated, this cross section makes the ends of the finished design shallow cones instead of flat disks. ***(See Fig. 6.)*** This is "rotational drafting."

The preferred method, however, from the standpoint of minimizing tooling complexity is "planar drafting," which requires a separate step from the rotation that creates the basic part. In this case, each half of the end surface is drafted separately in a plane angled away from the parting line. ***(See Fig. 7.)***

The key difference between these two approaches is what happens as the drafted surface approaches the parting line. Rotational draft leaves the end face of the dowel nearly vertical at the parting line, while planar draft keeps the same degree of draft at every point on the end faces of the dowel.

Dodging the draft

While drafting is the key to simplicity of design, ease of molding, and cost control, sometimes a part demands a surface parallel to the direction of mold opening.

Probably the most common reason not to draft a surface is to make it fit with other parts of a finished product. ***Fig. 8*** shows a bracket that bolts to a machine. If the mating face were drafted, the top face would tilt at an angle, which is unacceptable for this application

In such a situation, the feature can be formed using a cam-driven side action in a mold. Side actions are typically used to form undercuts that could not be molded in a simple two-part mold. But because cams move perpendicular to the direction of primary mold opening, they can also be used to produce surfaces that are undrafted in relation to the A- and B-side mold halves. In other words, if the surface cannot be drafted, allowing the part to move away from the mold as the part is ejected, one can make the mold move away from the part using a side-action cam.

Another application for side actions is raised lettering on a face parallel to the direction of mold opening. This would present a problem even if the face was drafted, but a side action solves the problem. ***(See Fig. 9.)***

Similarly, heavy texture on a low-draft face, which might not be reproducible in a straight-pull mold, can be produced using side actions. The same is true of decal recesses on vertical faces. These are shallow undercuts that simplify the placement of decals. Proto Labs' free online quoting and analysis engine points out areas that can be produced using side actions, giving users the option of redesigning their parts for standard straight-pull molds or using this more advanced capability.

There is, of course, additional cost for side actions and the possibility of flash between the side action face and the rest of the mold. Therefore, side actions are an option with tradeoffs rather than a panacea.

Eliminating side-actions

There are some designs that appear to require side actions but that, because they are drafted, can be made in simple two-part molds. Take, for example the part shown in ***Fig. 10***. It would seem that a mold feature protruding inward from the A-Side of the mold or outward from the B-Side would be entrapped in the window when the mold opened.

Actually, however, this part can be made in a straight pull mold because the walls are drafted. ***Fig. 11*** shows how this works.

In this figure, the yellow area is the part, the green area is the A side of the mold, and the blue area is the B side of the mold. As can be seen, the window on the part can be formed by partially extending both the A and B sides of the mold. When the mold is closed, as in the illustration, the two mold halves meet in the window. Because the mold faces are drafted at that area, the two mold halves move away from the part (and from one another at the shutoff) as the mold opens and the part is ejected. No part of either mold half is entrapped in the window; therefore, no side action is required.

Part designers must keep in mind that the shutoff must be drafted a minimum of 3 degrees. But because the shutoff is angled relative to the wall itself, the draft of the wall must be greater than 3 degrees to allow a 3 degree draft of the shutoff. The required amount of wall draft will vary directly

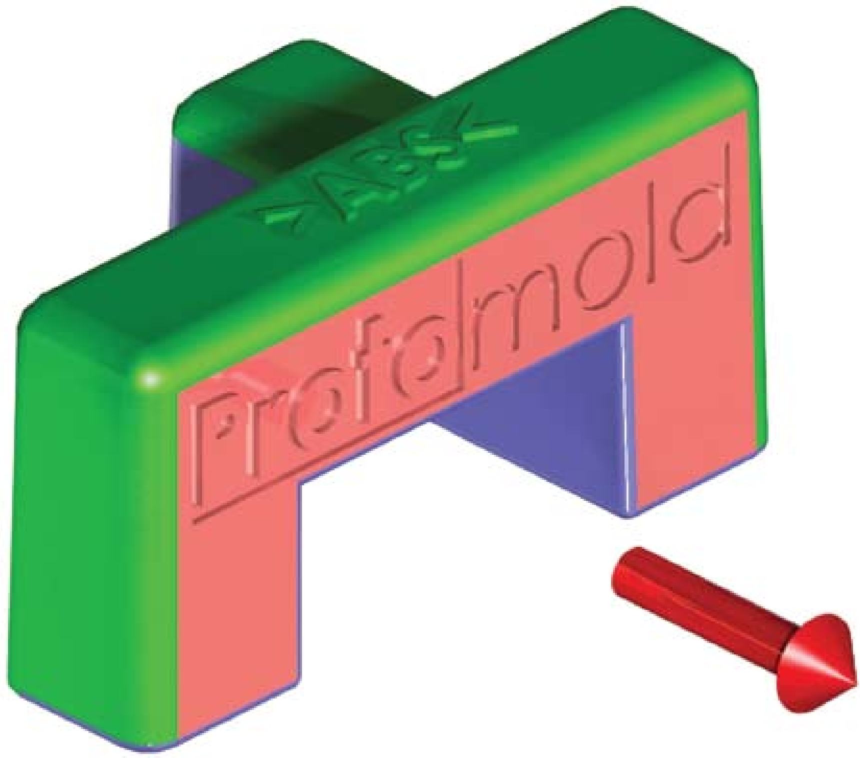

Fig. 9. Illustration of the use of a cam to produce lettering on the side of a part.

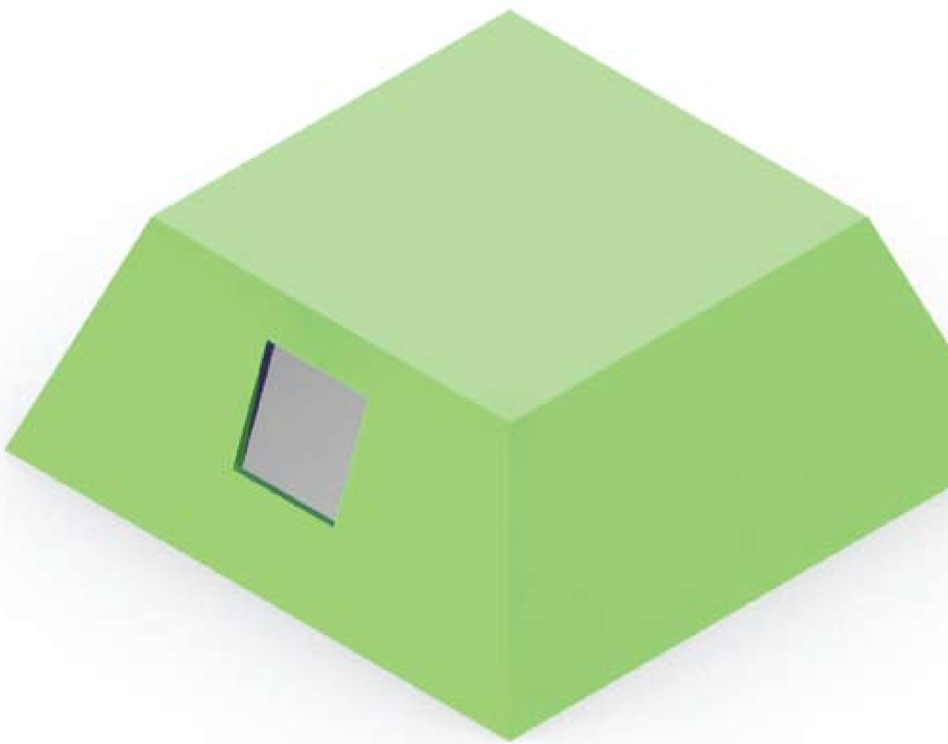

Fig. 10. Example of a window that appears to require a side action.

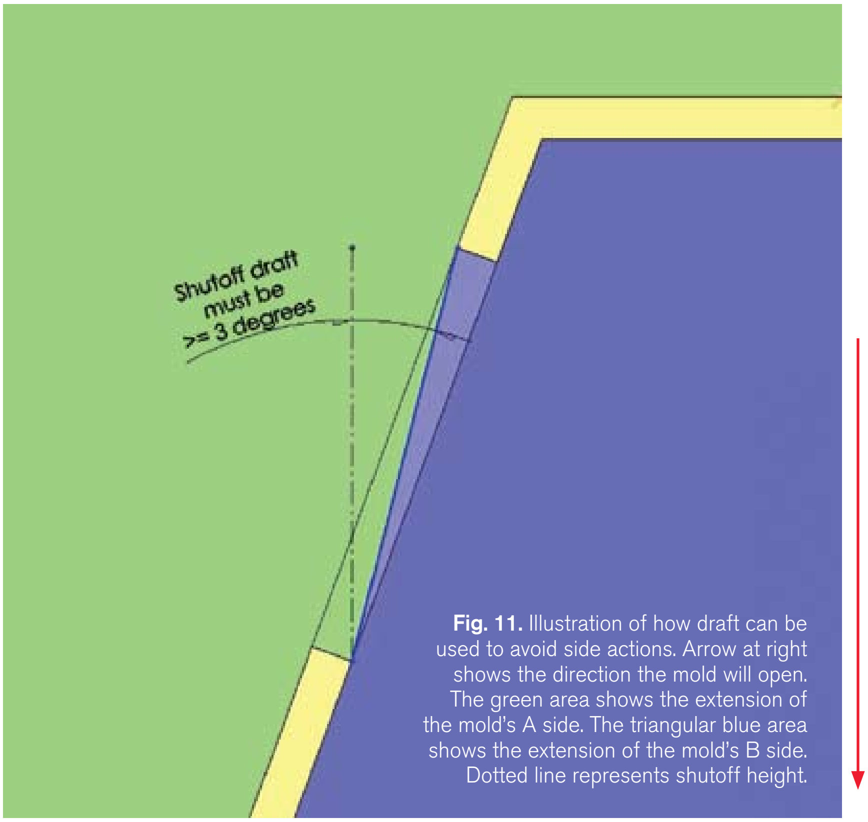

Fig. 11. Illustration of how draft can be used to avoid side actions. Arrow at right shows the direction the mold will open. The green area shows the extension of the mold's A side. The triangular blue area shows the extension of the mold's B side. Dotted line represents shutoff height.

with wall thickness and inversely with window height (shutoff height), as shown in ***Fig. 11***. Most CAD programs can help determine the proper degree of wall draft to create the required 3 degrees of draft at the shutoff.

Conclusion

Wherever a surface of a mold is parallel to the direction of mold opening (or cam withdrawal), the surface must be drafted to avoid damage to the mold or the part. A number of factors determine the degree of draft including part geometry, wall height, and surface texture. If, for any reason, the surface cannot be drafted, it may be possible to form the part using side action cams. On the other hand, drafting a surface may actually eliminate the need for side action cams in forming certain features in or on that surface.

3D CAD programs can simplify the process of adding draft. For designers who are uncertain where, or how much draft is necessary, analytical programs like Proto Labs' free online ProtoQuote™ system can help provide guidance. ■

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