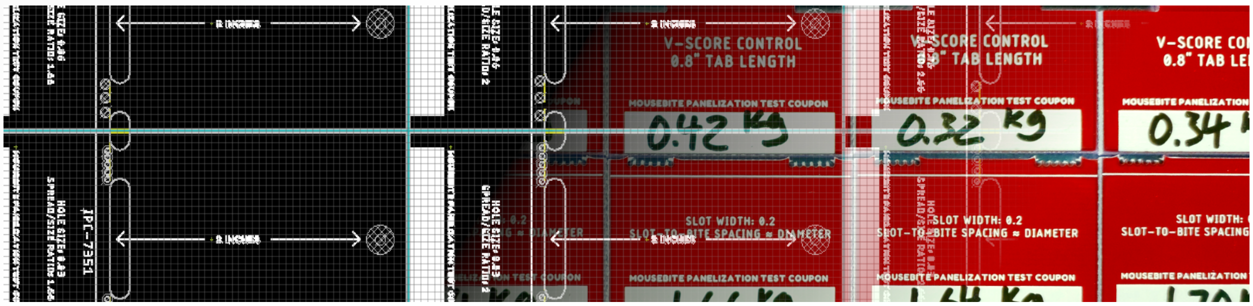
SparkFun Electronics White Paper

Building a Better Mouse Bite

Re-Examining the Conventional Wisdom on Breakaway Tabs



What are Mouse Bites?

While assembling printed circuit boards (PCBs) it's often economical to panelize a design, combining many copies of the design onto a single, large panel. These panels are easier to move between processes on the assembly floor and afterwards are separated into individual boards. In many cases, these boards can be separated by "v cuts" or "v grooves," which—as the name suggests—are v-shaped grooves cut into the PCB along which it can be cleanly snapped or cut. However, these v grooves have limitations: they must be straight, they must cross the entire length of the panel, they affect the dimensions of the board, and they may be too delicate for some applications. Mouse bites (or "perforated breakaway tabs") provide an alternative to v grooves which solves many of these problems. By drilling a series of small holes very close together, a break-away tab is created—like the perforated edge of a postage stamp—which can be used to firmly attach panelized boards while still allowing them to be easily separated.

A Search for Best Practices

When a SparkFun engineer asked the rest of the department for "best practices," we quickly discovered that many of us had personal rules-of-thumb, but no hard guidelines to point to. A survey of circuit fabricators' websites suggests that the industry has landed on the following figures: *unplated holes with a diameter of 0.020" which are spaced 0.030" apart.*

Browsing the forums suggests that this is a common convention. Some people suggest larger or smaller spacing, some suggest larger or smaller holes, but all within a few thousandths of an inch.

Bitesize Fact

Perforated breakaway tabs got the nickname "mouse-bites" (sometimes "rat-bites") because the castellated edge left behind resembles a small bite taken out of the PCB.

Professional Guidance

The trade association IPC offers *some* guidance in their publication IPC-7351, or "Generic Requirements for Surface Mount Design and Land Pattern Standard," a 100+ page document which spares a few sentences in chapter 3.4.8.3 to describe break-away tabs. The accompanying figure suggests that typical dimensions are actually *0.031" in diameter and spaced 0.050" apart.*

The Necessity for a Template

Yet other sources will suggest that a rule-of-thumb isn't helpful and that it depends on the capabilities of the circuit fab and the preferences of the assembly techs. While it is true that the fab's capabilities will dictate our design constraints, and that our assembly operation will dictate our design goals, this doesn't alleviate the need for somewhere to start. Even in the case where breakaway tabs need to be altered to better suit the manufacturing process, engineers need a boilerplate design to use on initial panels. Because no one can agree on what this boilerplate looks like, we've designed our own from scratch.

Mouse Bite Anatomy

In order to build a better mouse bite, it was important to understand the desired function of the mouse bite and the factors that contribute thereto. Discussions with our production personnel as well as PCBA contract manufacturers revealed the following considerations:

1. The resulting tab must be strong enough that the panel retains its rigidity during the assembly process. This becomes especially important in designs on 0.8mm or thinner PCBs which utilize heavy components such as ceramic antennas or transformers.

2. The tab must also be frangible enough to separate the boards without putting undue strain on any component. Excessive flexing and prying of a populated PCB can damage brittle components such as chip capacitors and crystal oscillators.
3. The edge that results from breaking the tab should require as little sanding or filing as possible in order to look presentable and be safely handled.

It was determined that the degree to which a breakaway tab meets these criteria is based largely on a few factors: hole diameter, hole spacing, edge clearance, and tab corner radius. Before we present our recommendations, let's examine each of these major factors in turn as well as a handful of minor contributing factors.

Hole Diameter and Spacing

These two factors are the most impactful and the most interrelated. For a breakaway tab of a given width, the space between holes will necessarily affect the size of the holes which are practical to place. By controlling the size and spacing of these holes, we are actually controlling the size and shape of the PCB material left behind. The size of the holes chiefly affects the cosmetic characteristics of the resulting break, with the spacing of the holes—the amount of material left holding the tab together—primarily affecting the mechanical strength.

Effects on Dimensional Tolerance and Cosmetic Appearance

Larger hole sizes seem to have advantages over smaller ones at first blush. For example, it takes fewer drill hits to create a breakaway tab of a given width. By extension, it leaves behind fewer "tooth marks" on breaking. In reality, smaller holes win out in terms of clean-up. The large "tooth marks" left by larger holes tend to be longer and may break away at any part along their length, making for a jagged edge with deeper indentations that take more post-processing to finish. In addition, the larger holes increase the amount of keep-out area required around the tab to avoid damage to traces and ground planes, taking up valuable real estate on the design.

Mouse bites comprising smaller holes leave a cleaner edge—not just by virtue of creating smaller bite marks—but also by breaking more predictably. Figure 1 shows the results of three trials with successively smaller drill hits.

These trials were conducted on breakaway tabs with a fixed ratio of hole diameter to inter-hole distance. As you can see, the larger holes do leave fewer tooth marks. However, the marks left are considerably sharper and less attractive. Also note how the larger holes encroach more closely on the white line, taking up far more space on the board. You may notice, in addition, that there are pieces on either side of the tab which protrude past the edge of the board. These can be eliminated by controlling the tab corner radius and edge clearance, which we'll discuss later. For now, it's sufficient to observe that the smaller holes left a much more cosmetically pleasing edge.

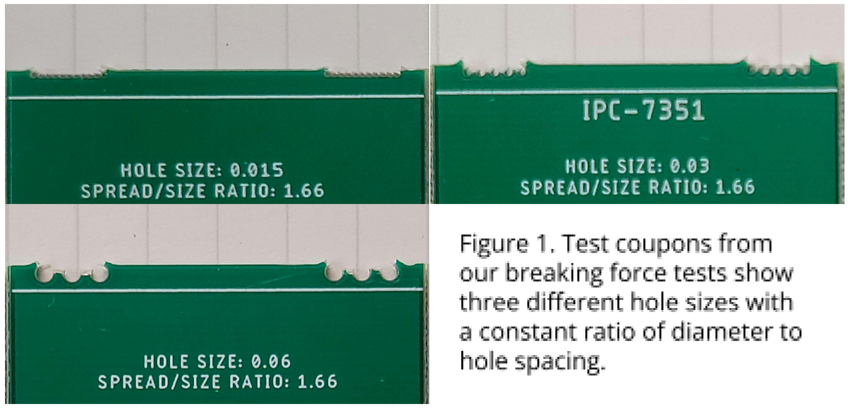


Figure 1. Test coupons from our breaking force tests show three different hole sizes with a constant ratio of diameter to hole spacing.

Effects on Mechanical Strength

Looks aside, it makes sense to investigate whether hole diameter and spacing have independent effects on the breaking strength of the resulting tab. It's logical that hole spacing, correlating directly to the total cross-sectional area of the tab, will have a strong effect on the breaking strength. Is it possible that hole size itself can also have an effect by virtue of stress concentrations or some other factor?

According to our testing, while there is a weak correlation between hole size and breaking strength, it's not a simple relationship. Compare the trials in Figure 2 to note that there is a weak trend up and back down between tabs of the same diameter-to-spread ratio with different hole diameters. Compare this to the strong correlation among each trio of trials with the same hole diameter and different spacing. This tells us that we're free to choose whatever hole diameter best suits the cosmetic considerations of our project and then tune the mechanical strength of the tab by adjusting the hole spacing.

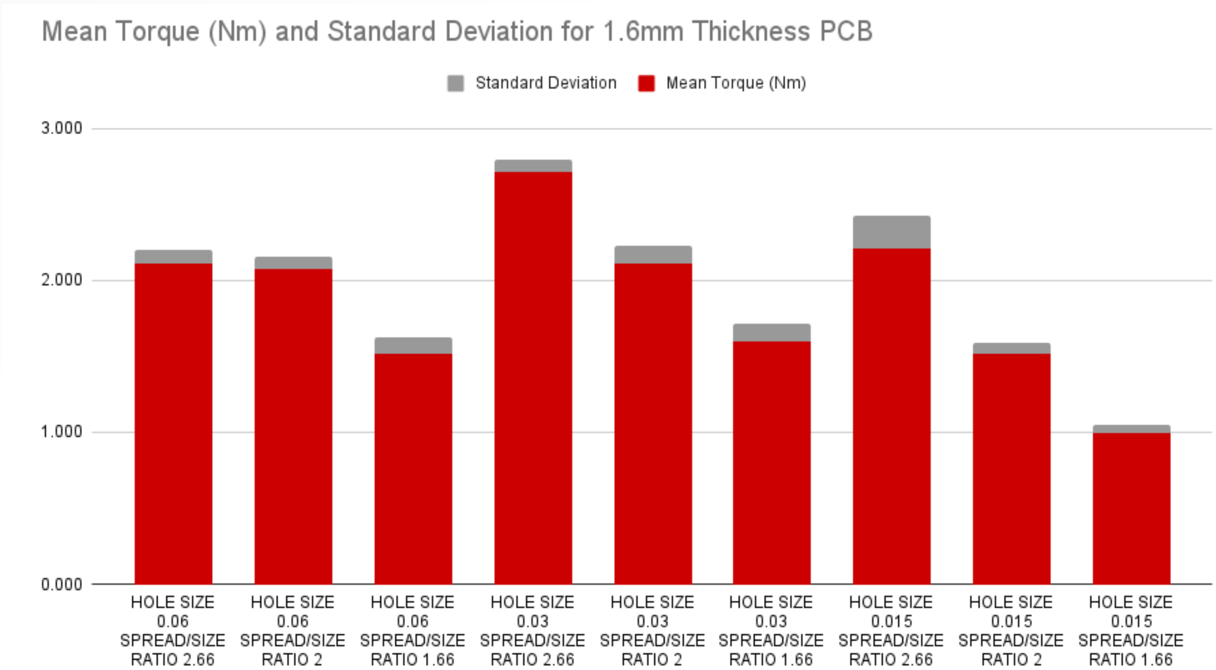


Figure 2. Torque required to break test coupons in each configuration over 5 trials

Edge Clearance

The distance between the mouse bite and the edge of the board has a dramatic effect on the shape of the resulting break. Embedding the mouse bite—such that the edge of the board is tangential to the holes—results in a break that preserves the outside dimension of the board by ensuring that no part of the remaining material protrudes past the border. This type of break makes sense for boards which are going to be mounted on rails or in a tight enclosure. In this application mouse bites can out-perform even v-grooves, which tend to leave swarf that needs to be accounted for. However, if the board is designed to be handled directly as with kits and development tools, it's beneficial to move the mouse bites directly onto the board edge. This will maximally reduce the board indentation at the cost of a slight protrusion. The resulting break is much cleaner looking and easy to sand smooth.

Finally (while we did not include this in our testing) in applications where a perfectly smooth board edge is required, it's likely that mouse bites could be extended beyond the board edge and entirely onto the tab. This would leave excess material on the board which would require sanding or filing to remove but, in exchange, there would be no remaining indentation from the tab. Notice the difference in the trials presented in Figure 3.

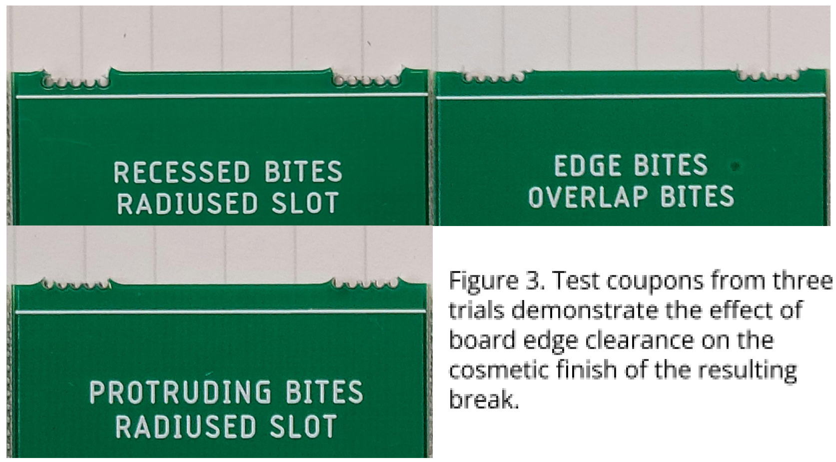


Figure 3. Test coupons from three trials demonstrate the effect of board edge clearance on the cosmetic finish of the resulting break.

What's more surprising is the effect that edge clearance has on breaking strength, as demonstrated in Figure 4. The recessed mouse bites take the greatest amount of torque to break, with the torque being reduced in a linear fashion as the bites near the edge of the board. Of course, this is easily explained by the extra material that's introduced between the outermost holes and the tab corners as the mouse bites are further recessed. Even so the effect is unexpectedly pronounced considering the minute distance required to observe it.

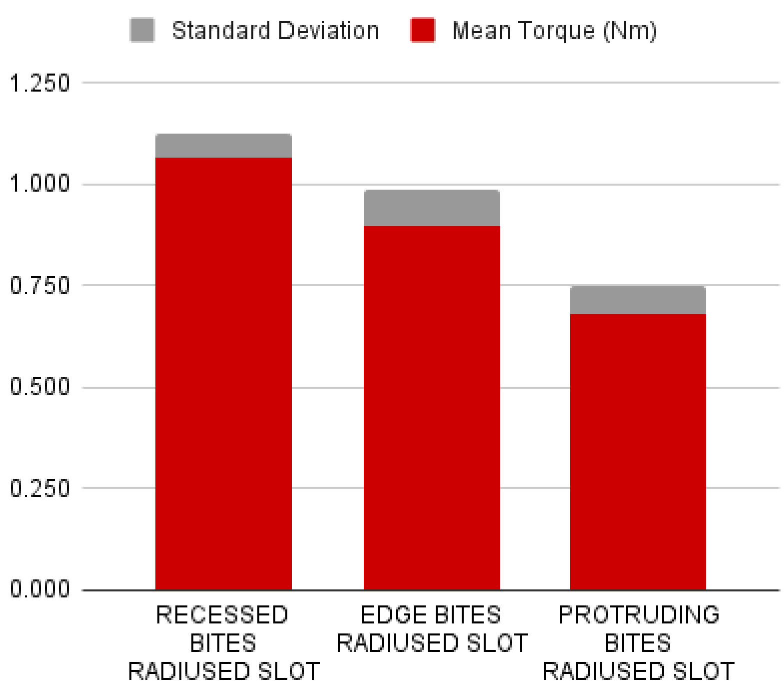


Figure 4. Breaking force and consistency vs. edge clearance.

You may notice again that, although we suggested earlier that bites which straddle the board edge leave the best cosmetic finish, the results in

Figure 3 don't appear to bear that out. Again, we're confronted with sharp protrusions on either side of the tab. This will be addressed by our final factor…

Tab Corner Radius

The last factor that we need to consider has as much to do with the routed out portion between each breakaway tab as it does the mouse bites on either end. Traditionally, the slots that separate the tabs from each other (and dictate the distance between boards) have a wide radius in the corners. This results in a breakaway tab that "flares" out as it meets the board. This flare-out is the cause of the sharp protrusions observed in earlier tests. Whether these features are intended to strengthen the breakaway tab or are simply leftover from a time before it was common for PCB manufacturers to offer detailed milling as a standard service is unclear. What is clear, as evidenced in Figure 5, is that the radiused slot is the worst option in terms of cosmetic finish.

Figure 5. Test coupons show the improvement in cosmetic finish achieved by radiused, corner drilled, and near-square slots respectively.

Figure 5 illustrates the break resulting from three different styles of slot corner. The top five trials feature a traditional style slot with a wide radius, resulting in the sharp edges that we've seen in previous tests. The second set of trials feature a slightly tighter radius with holes overlapping the corners of the tab. Finally, the bottom row features tabs which were drawn square with the understanding that the fab would route them with the smallest radius possible. In this case the fab advertises a 1mm minimum slot width, which implies a 0.5mm minimum inside corner radius. This geometry provided the cleanest break by far. Furthermore, this had very little (if any) effect on the mechanical strength of the tab.

What About the Effects of Board Thickness?

While all of the tests referenced thus far were performed on 1.6mm PCB, the conclusions drawn should apply to any thickness of board. In order to verify this, one test was run using 0.8mm PCB and the results were compared to those of the 1.6mm counterpart. Figure 6 shows that although the thinner board requires less torque to break on the whole, the same trends can be observed. The impact of each modification is scaled proportionally, but no test yielded different conclusions.

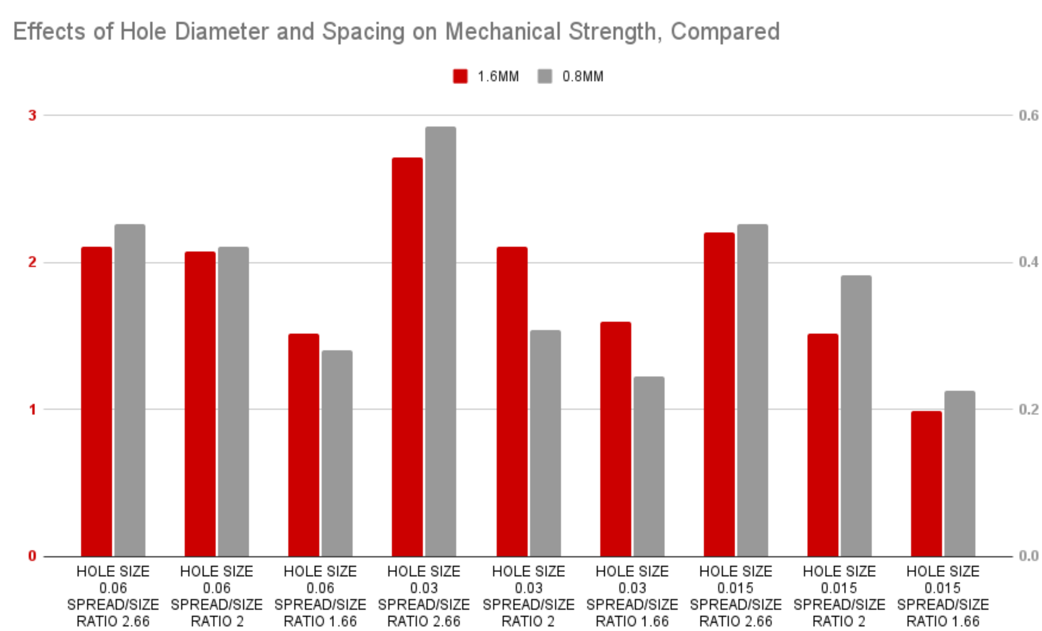


Figure 6. Mechanical strength compared between 1.6mm and 0.8mm PCBs. Note that the data is scaled for comparison. The scales, let and right, are color coded.

Our Recommendations

Considering all of these factors, we suggest the following guidelines when designing a breakaway tab:

- Hole Diameter: 0.015”
- Hole Center-to-Center Spacing: 0.025”
- Maximum Tab Width: 0.118”
- Holes should extend into the corners of the tab
- Edge clearance should be determined by application
    - In applications that demand an uninterrupted board edge, such as rail-mounted boards or boards in tight enclosures, mouse bites should be positioned tangential to the board edge
    - In applications where the boards will be handled directly, such as kit parts and development boards, the mouse bites should be centered over the board edge
- If the resulting tab breaks or bends too easily, the strength can be adjusted by increasing the spacing between the holes in the mouse bite. Alternatively, you can add more tabs to the panel, if the design supports it

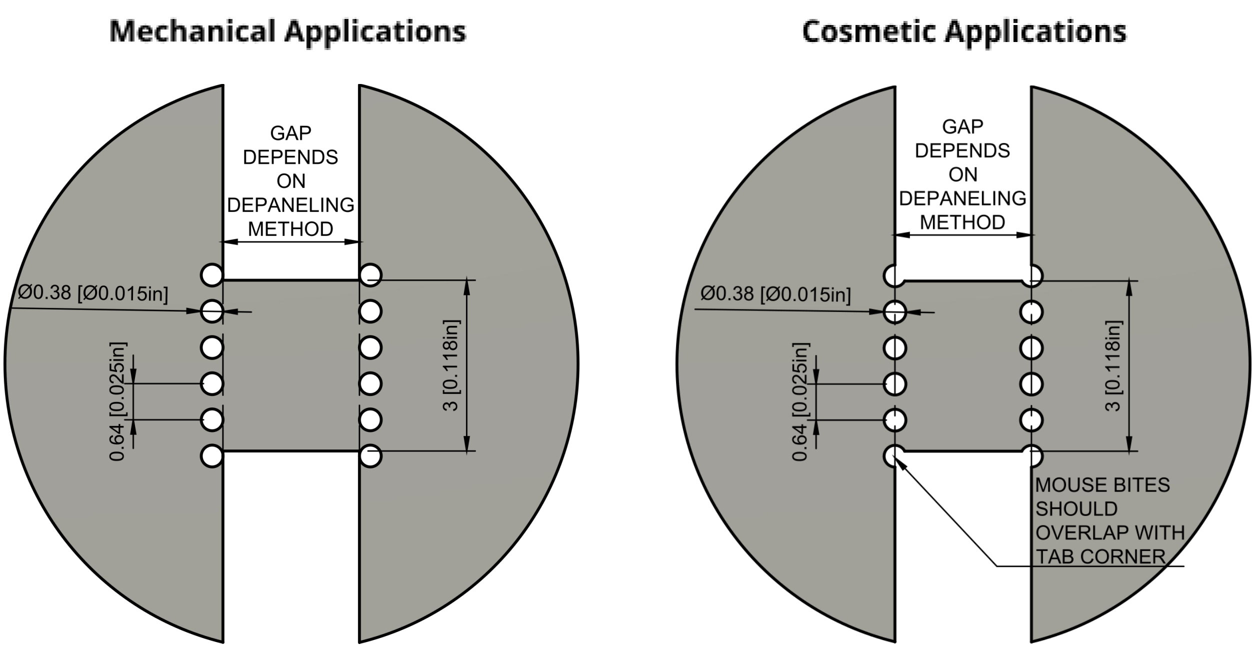


Figure 7. Dimensional drawings illustrating our recommended mouse bite pattern

How Weak is Too Weak?

The list above states that if your breakaway tab yields too easily, you may need to increase the hole spacing or add more tabs. The only way to know for certain whether your tabs are strong enough is to make sure your panel survives assembly. That said, some consideration has been given to ensuring that our guidelines create a tab that will work in most designs without modification.

V-Groove Strength Comparison

A benchmark is required to assess the yield strength of our breakaway tab. Luckily we have an ideal subject for comparison: the v-groove. Because v-grooves are designed to break easily and are used in similar applications—often in tandem—with mousebites, they represent the minimum mechanical strength acceptable in most applications.

In order to compare v-grooves with our mouse bites, we conducted a series of strength tests. Test coupons separated by varying widths of both v-groove and perforated tab were stressed to breaking. This series of experiments was performed on both 1.6mm and 0.8mm PCB.

In the case of 1.6mm PCB, the v-groove snaps at less than 10% of the torque required to separate the mouse bites. As you can see in figure 8, the strength of the tab scales in a roughly linear fashion with its width. From this, we can calculate that the v-score can withstand a torque of about 0.12Nm per centimeter of tab width and the mouse bite—being roughly 10x stronger—breaks at about 1.2Nm per centimeter of tab width. Because our maximum suggested tab width is 3mm, this data suggests a rule of thumb for tab placement: **In panels with v-groove breakaway rails, as long as there is one tab for every 33 millimeters of rail, the tabs will be at least as strong as the rail.**

The same reasoning can be applied to 0.8mm PCB. However, in this case, the v-score is consistently over 70% as strong as the mouse bite. This is due to thinner boards being easier to break in general, and the v-score already representing the low end of the scale in terms of strength. In this case, the math suggests that in order to achieve parity with the breakaway rails, there would need to be a nearly equal total cross-section of tab-width. Obviously, this isn't practical. Luckily, the linear relationship between tab width and strength has also scaled with the board thickness so that as the tab width is reduced to a reasonable size, the strength isn't reduced by the same magnitude as in the case of the thicker board. That said, It may still be necessary to increase the hole spacing to strengthen the tabs in thin panels, especially in the case of large panels which may sag under the weight of components during assembly.

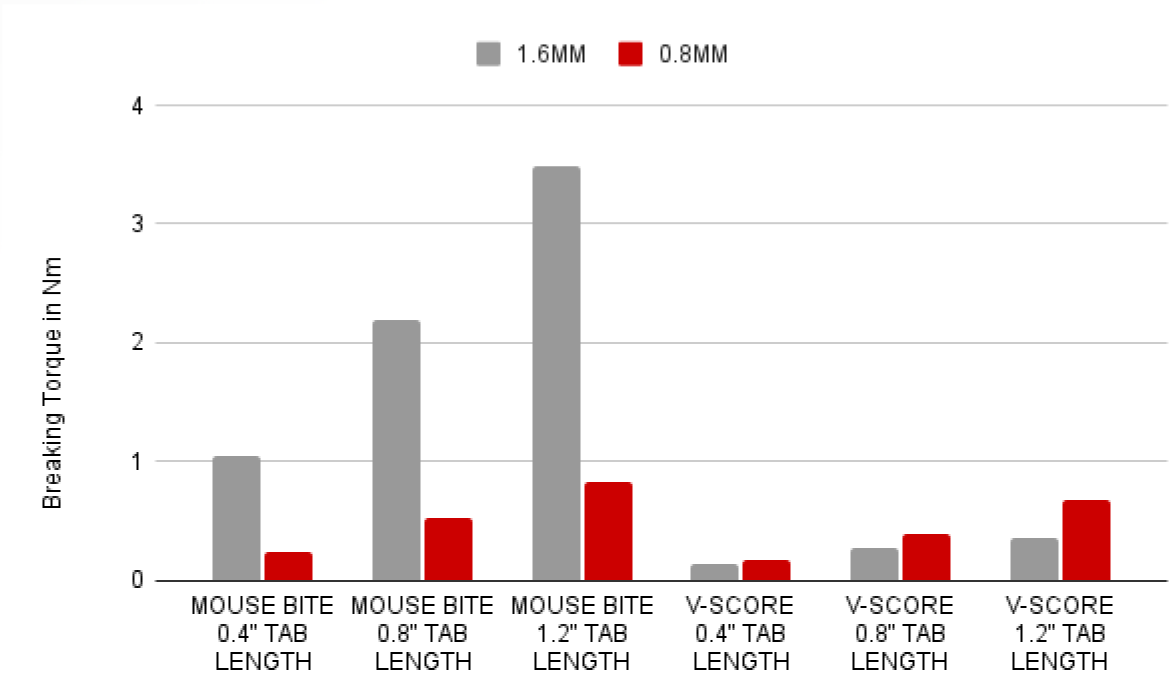


Figure 8. Breaking torque tested over various tab widths, comparing mouse bites to v-grooves

Where Did the Maximum Tab Width Come From?

Our recommended mouse bite design states that tabs should be no wider than 0.118", but we've yet to discuss where this number comes from. In this case, no trials or math are required. The 0.118" (3mm) maximum ensures that all breakaway tabs are compatible with manual depaneling tools such as the CHP DP-25. Although breakaway tabs—properly designed—can be separated without specialty tools, depaneling tools are recommended for manufacturing environments. Not only do both manual and pneumatic depaneling tools make the process faster and less physically demanding, but they reduce mechanical stress on the boards by removing the tabs without excessive flexing.

Conclusion

By means of mechanical testing and cosmetic analysis, we've discovered what we believe to be the optimal breakaway tab for the capabilities of modern board fabs. In addition to the recommendations found on page 9 of this publication, many traditional best practices hold true. For example, copper pours such as ground planes should be kept clear of the mouse bites to avoid tear-out during separation. Also, tabs should be placed as far as possible from brittle components, such as tantalum capacitors and surface mount crystals, which could be damaged by board flex during depaneling. We're confident that adopting these recommendations will improve the cosmetic finish and manufacturing flow of our own products and we appreciate the opportunity to share what we've learned with the community.

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