Anatomy of a Plastic Part

Design for Manufacture

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BiPAC 7800VDOX

The Billion BiPAC 7800VDOX is a wireless modem and router used for antiquated ADSL2+ connection standards. Many of Billion's current routers are built on a similar physical platform as this 2014 model.

Summary

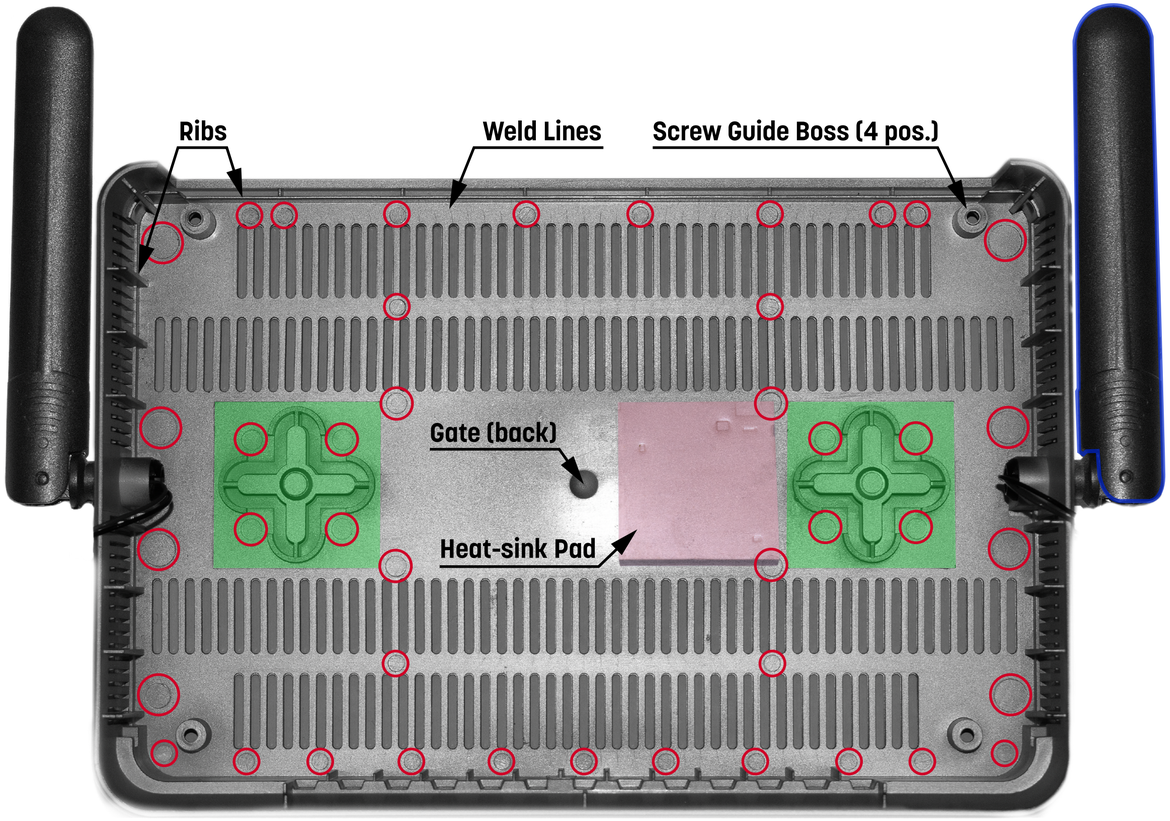
Most parts are made of ABS, which is one of the cheapest and most abundant thermoplastics for injection moulding. Most, if not all parts are hand assembled given the high number of variations Billion makes based on the same housing and platform. Most tools used for injection moulding are of good quality, with only minor defects.

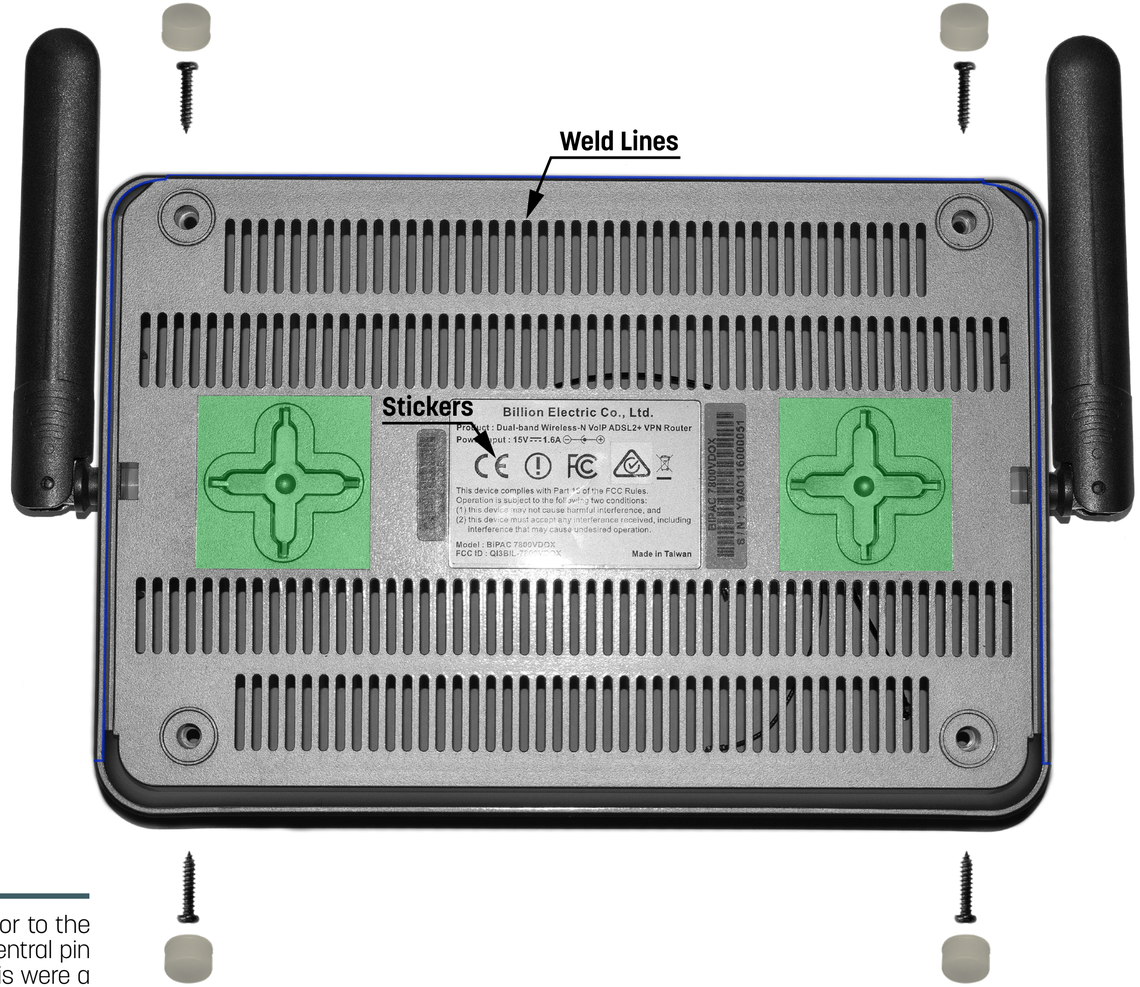
Total Part Count: 22
Plastic Part Count: 13
Materials: ABS, PMMA (Acrylic), Silicone, Steel
Processes: Injection Moulding, Compression Moulding

Analysis Key

- **Ejector Pins**
- **Tool Direction**
- **Part Line**
- **Side Core Direction**
- **Insert**
- **Angled Lifter**

Made in Taiwan



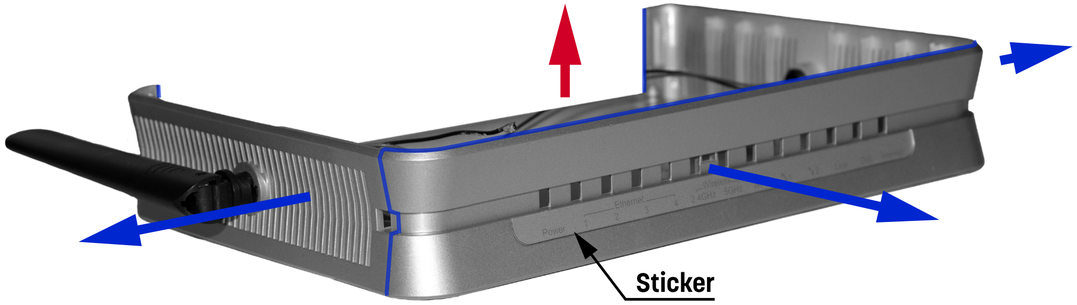


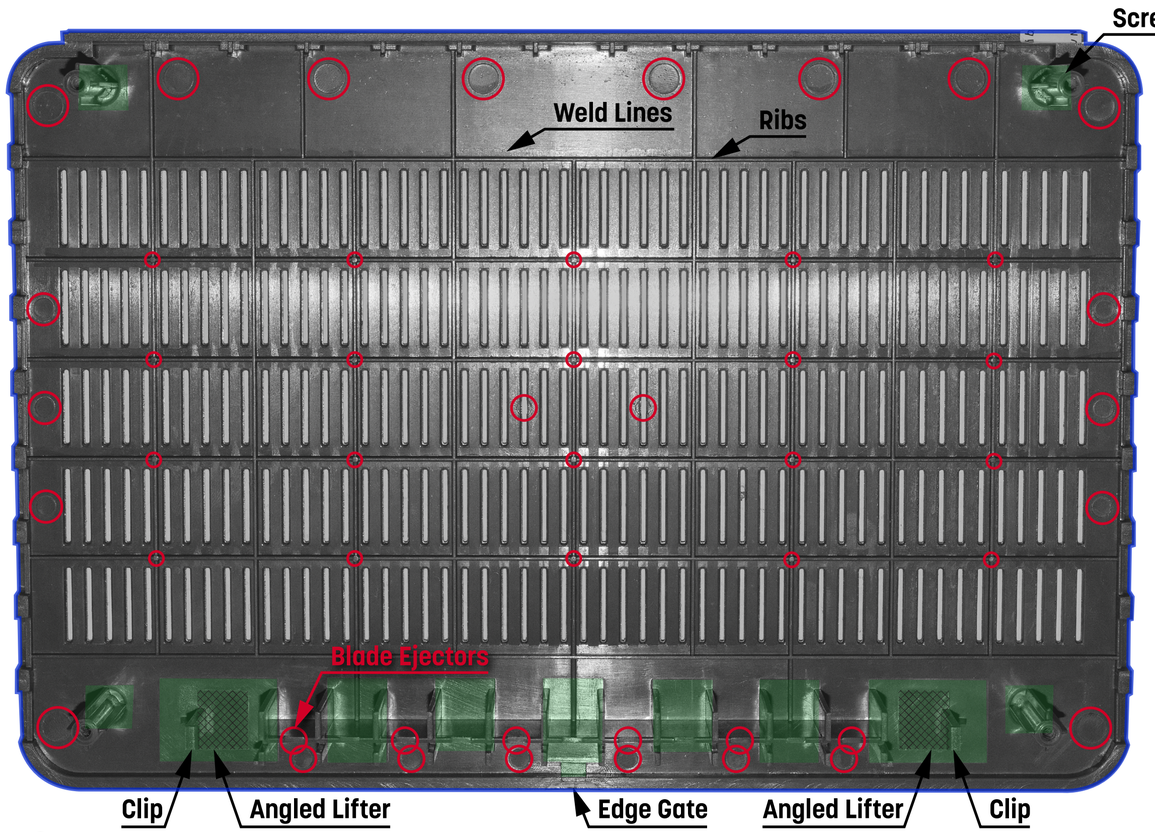
Case and Antenna Assembly

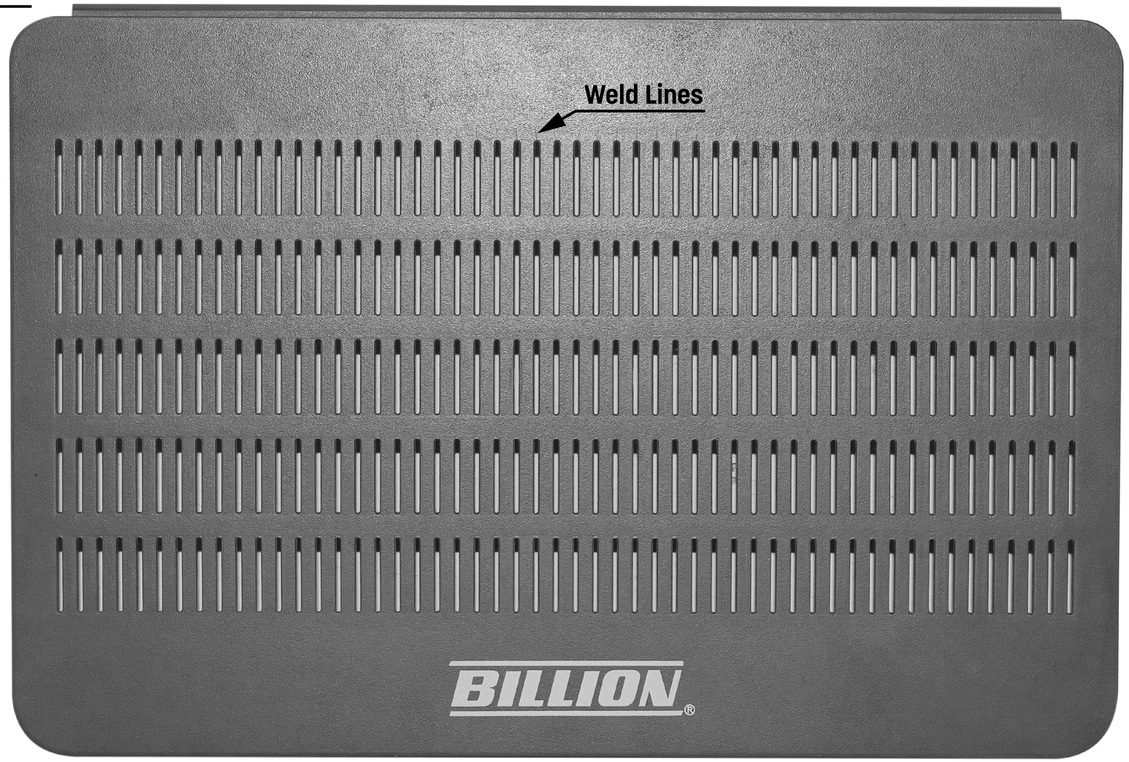
The case is injection moulded in a tool with three side cores. One for the front which has a shut-face for each indicator to the moving half of the tool, and two for each side where shut-faces are used for air vents and the antenna hole. Due to the central pin gate location and the complexity of the tool, this is most likely single-cavity. A hot runner system would likely be used if this were a multi-cavity tool. Many ejector pins are used around the edges and near critical features such as the wall mounts and screw guide bosses. The top two screw guide bosses have protrusions which help locate the PCB mounting holes during installation, suggesting hand assembly for this step. The four-way wall mounts are achieved with a very narrow bypass shut-face attached to mould inserts on both the moving and stationary side of the tool. Inserts are used for these shut-faces to allow the mating surface to be reconditioned easily once it becomes worn. The part lines made by the main tool and the side cores are visible in the vents where more flash is present given the tool wear that occurs on these shut-faces.

The antenna are also injection moulded, one part to cover the antenna itself and another to act as a detent hinge and passthrough for the wires. The antenna cover has a part line on the midplane suggesting the hollow area inside is achieved with a long side core, likely hydraulically actuated given the aspect ratio. The antenna cover clips onto the hinge piece that clips into the case through a shut-face hole. The antenna covers use two edge gates at their base, with the hinge using one. Their small size, use of edge gates, and inclusion in other Billion products means it's likely these antenna parts are injection moulded in a tool with two or more cavities.

The case is painted ABS which is visible in internal corners where the metallic spray paint did not reach. Painting the surface reduces the visibility of artifacts such as weld lines, while a sticker is used to cover the gate. This case is used on other Billion routers by painting it different colours, further amortising the tooling cost while allowing the use of a cheaper base material.







Top Cover

The top cover also appears to be injection moulded ABS, this time with a texture instead of paint. The position of the edge gate indicates that this is a multi-cavity tool, supported by the fact that Billion uses a high quantity of this top cover in other ABS colours on other models. Ejector pins are used around the edge, at some of the rib junctions, and near the middle on top of vent shut-faces. The air vents are designed such that the inside is larger than the outside by around 0.3mm. This gives the outside appearance of the vents a cleaner look as the flash is not as visible, and the alignment of the tool is not as critical. The tool direction is into the page with no side cores. The Billion logo is most likely screen printed given the alignment to the flat surface.

The front of the top cover uses a structure of ribs to hold the LED indicator lens, which will be discussed later. This structure holds the lens in place via two clips on the left and right near the screw bosses. These clips are moulded within an insert which contains an angled lifter to achieve the clip undercut. The rib structure which locates the lens uses blade ejectors with inserts on alternating ribs that can be removed for easier tool reworking. These inserts may be removed allowing easy polishing of the rib surfaces to ensure they are ejected cleanly given their considerable height and minimal draft. These ribs create almost imperceptible sink marks on the reverse side.

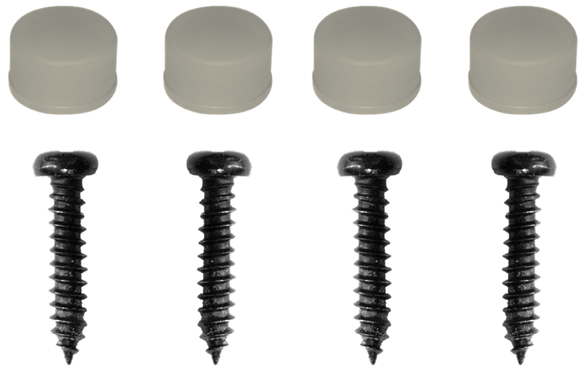
Inserts are also visible under each screw boss. This is unlikely to be an angled lifter as there is no undercut present. Instead, these inserts may have been to adjust the tools boss position, to facilitate boss repair, adjust the thickness of material to mitigate sink marks, or to more easily polish the boss ribs given the minimal draft angle.

Screws and Adhesive Pads

The four self-tapping screws are driven into the bosses of the top cover through the screw guides in the case. The screws are then be covered by four silicone pads within the circles on the bottom of the case as shown on the previous page.

The screws are made of steel given their magnetic properties. These self-tapping screws are coated with a black oxide finish to improve their corrosion resistance. Self-tapping screws eliminate the need for expensive metal threaded inserts that add complexity to the tool, while sacrificing the number of fastening cycles before breakage. For this low cycle application these screws are sufficient.

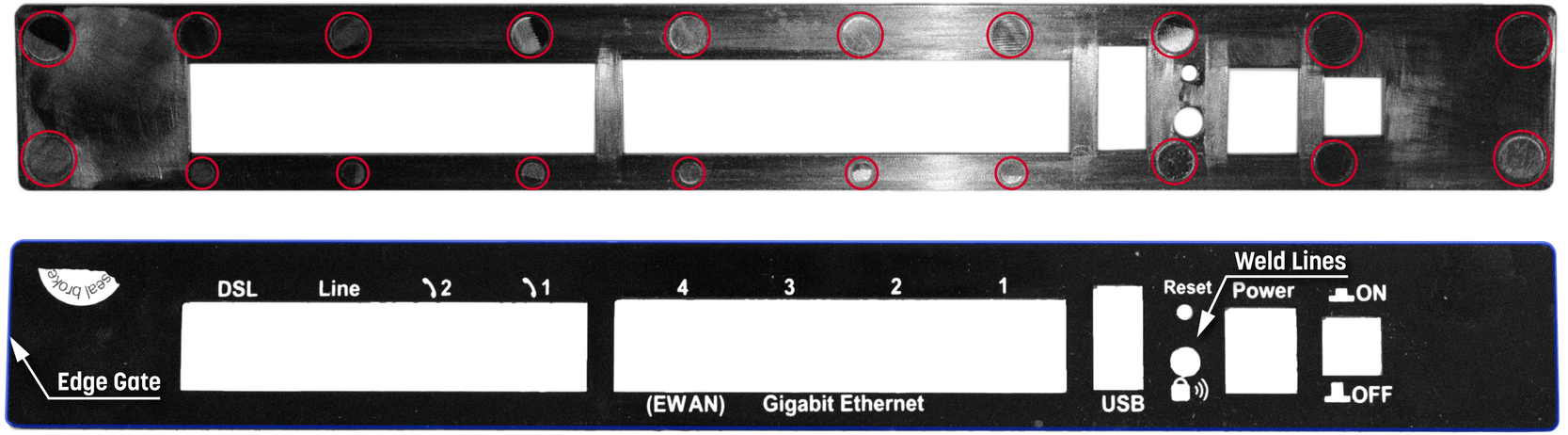
The silicone pads are likely compression moulded as there is no visible gate. The tool would contain many cavities given their use across many Billion products. They appear to be silicone as it is one of the only high friction and translucent materials.

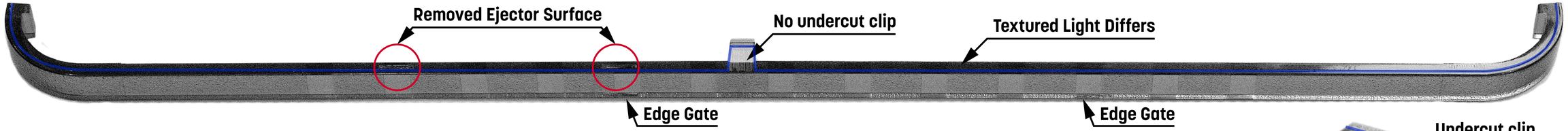


Rear Panel

The rear panel appears to also be made of ABS with a very simple injection moulding tool. Multiple shut-faces are achieved in the tool direction for the rear input and output ports. The moving side of the tool that creates the non-appearance side is much lower quality than other parts in this product. The tool is not polished in any consistent direction, possibly as this is a lower quality tool for a lower quantity product configuration. These interchangeable rear panels allow Billion to manufacture multiple routers in the same case with different input and output configuration simply by changing the circuit board and this part. An edge gate is used, meaning this could be a multi-cavity tool although there is no indication of cavity numbers.

The legend is raised slightly, indicating the use of a printing process. It is unlikely to be pad-printing which is more suitable for smaller areas of curved surfaces. Instead, it is most likely to be a form of screen-printing (silk-screen) where a stencil is used with an ink dragged over top. The printing stencils are low cost and easily replaced for printing on other product rear panels.

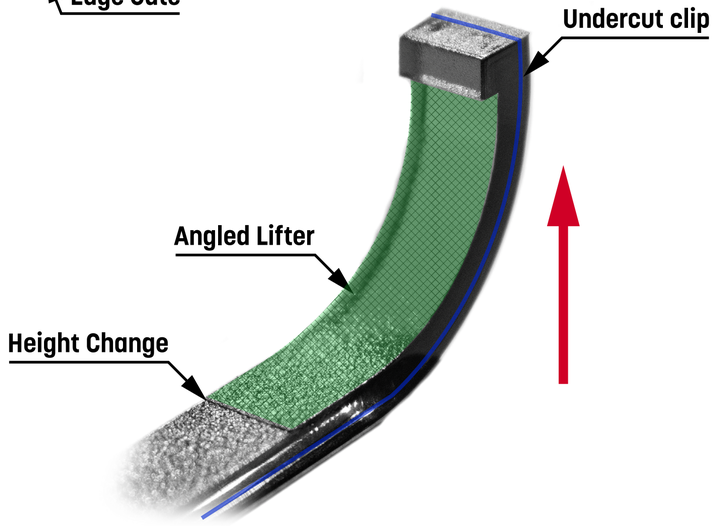




Tinted Indicator Visor

The visor that the LED indicators are light-piped through is a piece of tinted PMMA also known as acrylic, used for its optical clarity. This is injection moulded with textures sections on one side to promote a controlled diffusion of light from the light-pipes. The non-textured sections are lower than the textured areas which indicates the texturing was added after running the tool for first-offs. The central clip is achieved with no undercut as it is aligned with the main tool direction. There are no side cores, but an angled lifter is used to achieve the undercut present on the left and right side clips. There is a distinct line where the angled lifter is used in the textured section of the part. The surface of the angled lifter is higher than the main part as to not collide with the texture as it lifts away.

There are two edge gates on the bottom of the part which are not placed symmetrically across the part. This indicates the presence of additional material that was removed from the part after forming. There are two marks on the top of the part which appear similar to the edge gates, though there is little reason to include any more gate locations. Therefore, this is most likely an additional piece that ejector pins can hit without disturbing the appearance of the part. This tab would later be removed either by secondary operation or automatically with the movement of the mould.



PCB Assembly and LED Lens

The PCB is assembled with electrical and electromechanical parts. The switches and buttons at the top of the PCB are assembled from both injection moulded plastic and stamped metal parts. The leftmost toggle switch is made of stamped steel that shields a main injection moulded plastic assembly. The barrel jack and the two smaller buttons are made with an overmoulding process. The metal leads are formed with a stamping die to then be placed in an injection moulding die that creates the main housing around the leads. The USB connector is formed with a progressive die stamping machine that slowly cuts and bends in stages to form a closed housing that also contains an injection moulded connector receiver. The RJ-45 connectors are injection overmoulded onto an assembly of internal metal pins, which is then covered by a stamped steel case. The RJ-12 connectors have the correct number of wires for the connector added as a secondary process to the injection moulding of the housing. There is visible heat-staking over these wires in the RJ-12 connectors to hold them in place.

The lens is made of clear acrylic and sits over the array of LEDs to direct the light 90 degrees and out of the acrylic visor at the front of the case. The 90 degree turn is achieved by a textured side on the prism which receives the light from the LEDs, this reflected light then travels through the acrylic and out of the textured emitter to the visor. The texture on the emitter cannot be achieved by the main tool direction. The tool uses two side cores, evident from the multiple separated part lines, to achieve the prism and emitter texturing.

Ejector pins are used on the back of each light-pipe with alternating blade ejectors. The part is visibly warped, which is corrected for when clipped into the rib structure of the top cover. Two pin gates are used symmetrically across the part, suggesting it may be part of a multi-cavity tool when also considering the cavity number. This part could be used across all Billion routers of this design, so a tool with four or more cavities is possible. One downside to this lens design is that is can be installed in reverse. As this product is mostly hand assembled, the part should be designed such that it can only be installed one way.

The lens has some visible flash at the part line, suggesting higher tool wear in this location where the side cores meet the main tool dies.

There is also a mould defect on the leftmost and rightmost light-pipes. This appears to be a sink mark from the additional thickness added by the clip receiver section which is not present on other light-pipes. The sink mark occurs in thicker sections where the plastic takes longer to cool, causing it to contract and pull cooler material inward. This appears to be the case, where the cooler material touching the tool was puled inward by this thicker section of the part.