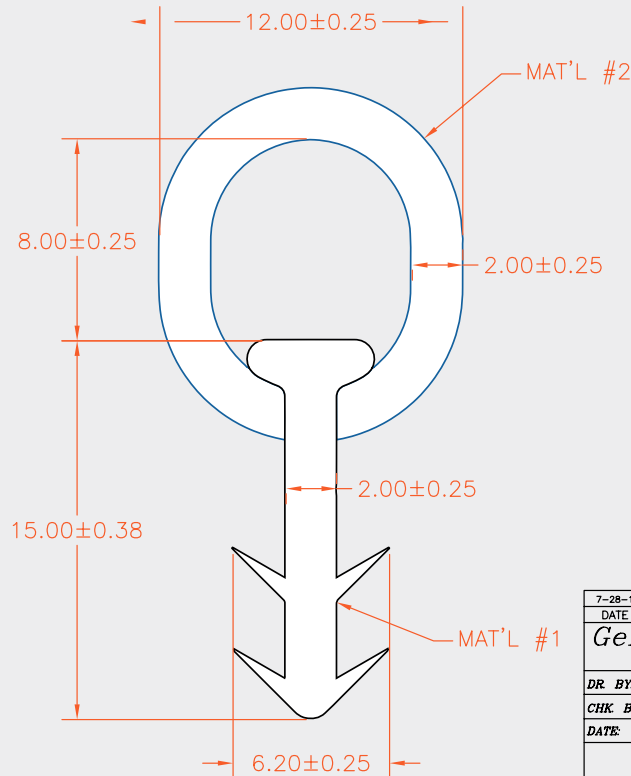


GPI, Sierra Plastics, & GPM

PLASTIC EXTRUSION DESIGN GUIDE



D5953



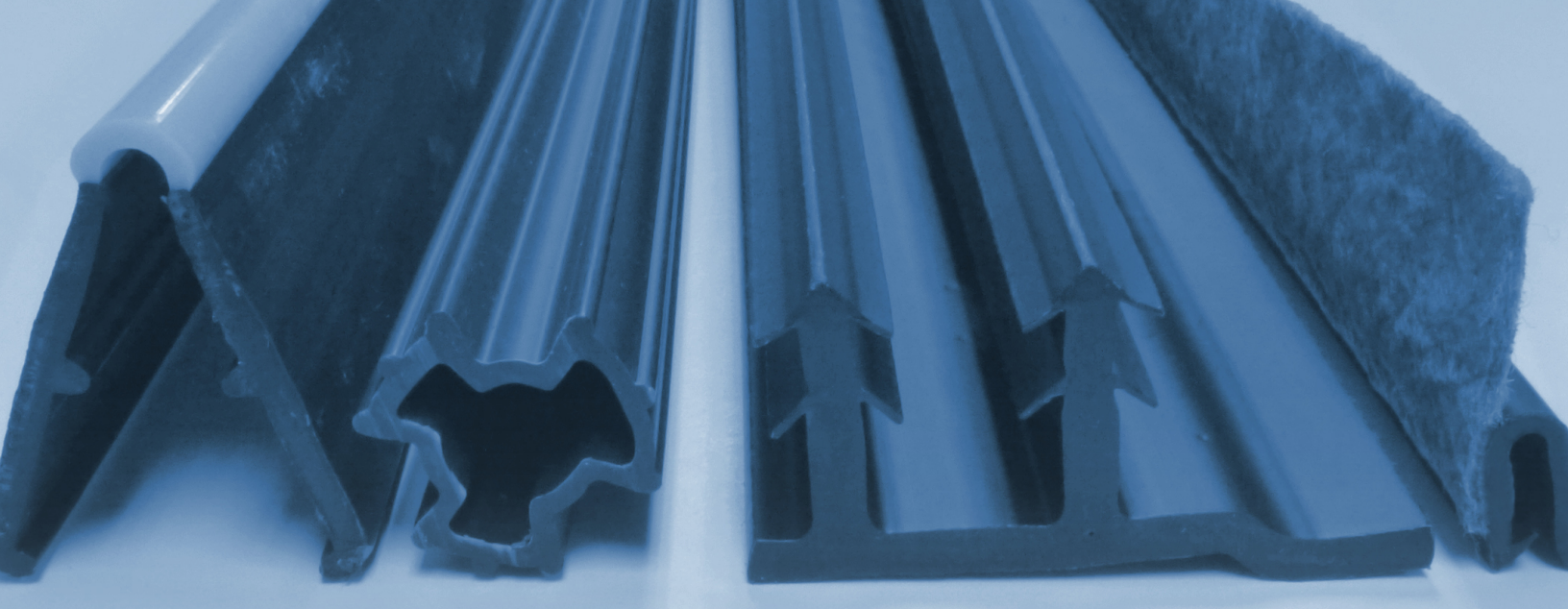
ACTUAL SIZE

AREA = .059 SQ. IN.
AREA = .104 SQ. IN.

MATERIAL #1 : TPE 87 SHORE A
MATERIAL #2 : TPE 60 SHORE A

DATE	REL.	REV.	APP.
7-28-16			-
<i>Gemini Plastics, Inc.</i> Udly, Michigan			
DR. BY:	NAK	SCALE:	5 = 1
CHK. BY:		CHANGE LEVEL:	REL
DATE:	7-28-18		
ALL DIMENSIONS MM			
PART NAME:	SEAL		
PRINT #:	D5953		





The key to a successful extrusion is to create harmony between profile design and material – and the team at Gemini has been doing just that since 1973.

We've learned something new from each of the 6,000 profiles we've helped develop and the dozens of resins we've worked with, and it is an honor to share some of those lessons with you through this guide.

How to Use This Guide

This guide contains an overview of the extrusion process and its design considerations. It is not exhaustive; the amount of information available is simply too great. However, it serves as a starting point to better understand the capabilities and limitations of extruded part design.

If you're new to the extrusion process, start with the *Understanding Extrusion* section. It provides an introduction to extrusion, including the manufacturing process, its benefits, and cost-drivers.

If you're ready to start designing, jump to the *Extrusion Design Considerations* section. It illustrates the design principles for the most critical aspects of extruded part design and describes the most common failure modes.

Questions?

We've found that the most important factor for success in plastic product design is partnering with our customers early in the design stage. So don't hesitate to reach out to us if you have questions regarding what you find on the following pages or how it relates to your specific application.

Our technical sales team can be reached at plasticsales@geminigroup.net or 248-435-7271.

Enjoy!

UNDERSTANDING EXTRUSION

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EXTRUSION DESIGN CONSIDERATIONS

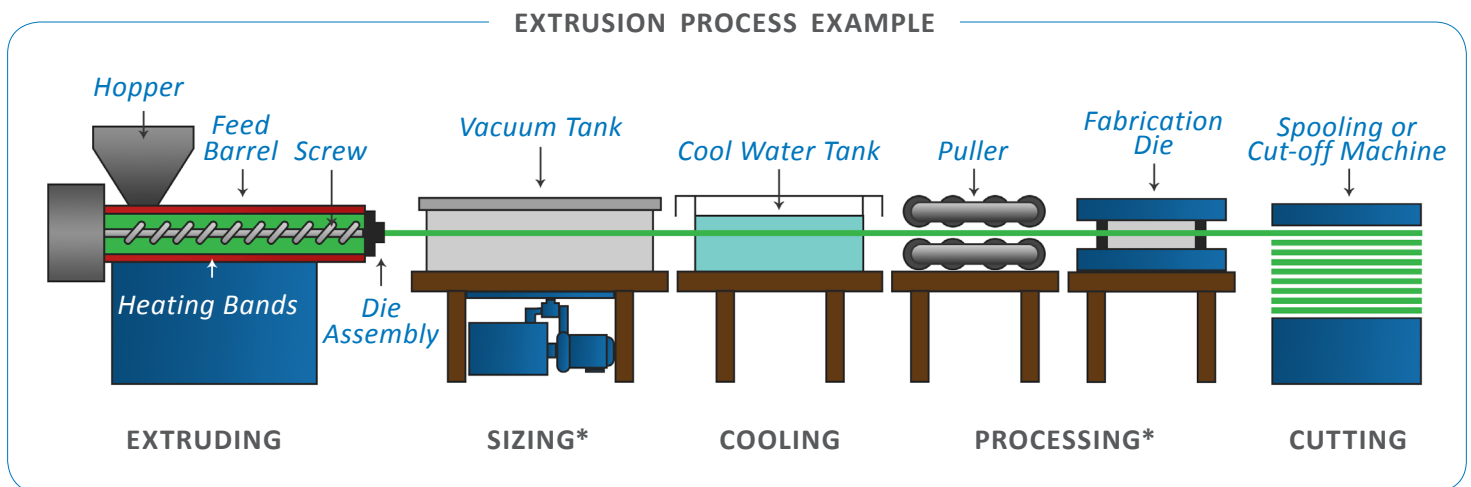
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Extrusion Process

Plastic profile extrusion is a molding method in which plastic resin is continuously melted, pushed through a die with the desired cross-section (a “profile”), and then pulled through a water bath until fully cooled. The formed plastic can then be fabricated and either cut into multiple parts or wound as a single part.



There are four zones through which the material moves through:

- **Extruding zone**, in which resin is melted, additives such as talc, foaming agents, glass, or color may be added, and the material is forced through the extruder die assembly.
- **Sizing zone**, in which a pull vacuum is used to prevent collapse and control warpage as the plastic hardens. This step is only used in profiles with one or more hollows.
- **Cooling zone**, in which the plastic is ran through cool water tanks until it hardens completely.
- **Processing zone**, in which the extrusion is measured for quality and processed in-line with the application of adhesion promoters, tape, slip coating, and/or ink-jet printing. This step is optional.
- **Cutting zone**, in which the extrusion is cut to desired lengths or spooled.

Advantages and Disadvantages

Compared to other forming and molding processes, extrusion has a number of advantages and disadvantages:

ADVANTAGES

- High production rates
- Low cost tooling
- Short tooling lead times
- Many types of raw materials
- Lowest cost conversion processes for plastics
- Can combine multiple durometers in a single extrusion

DISADVANTAGES

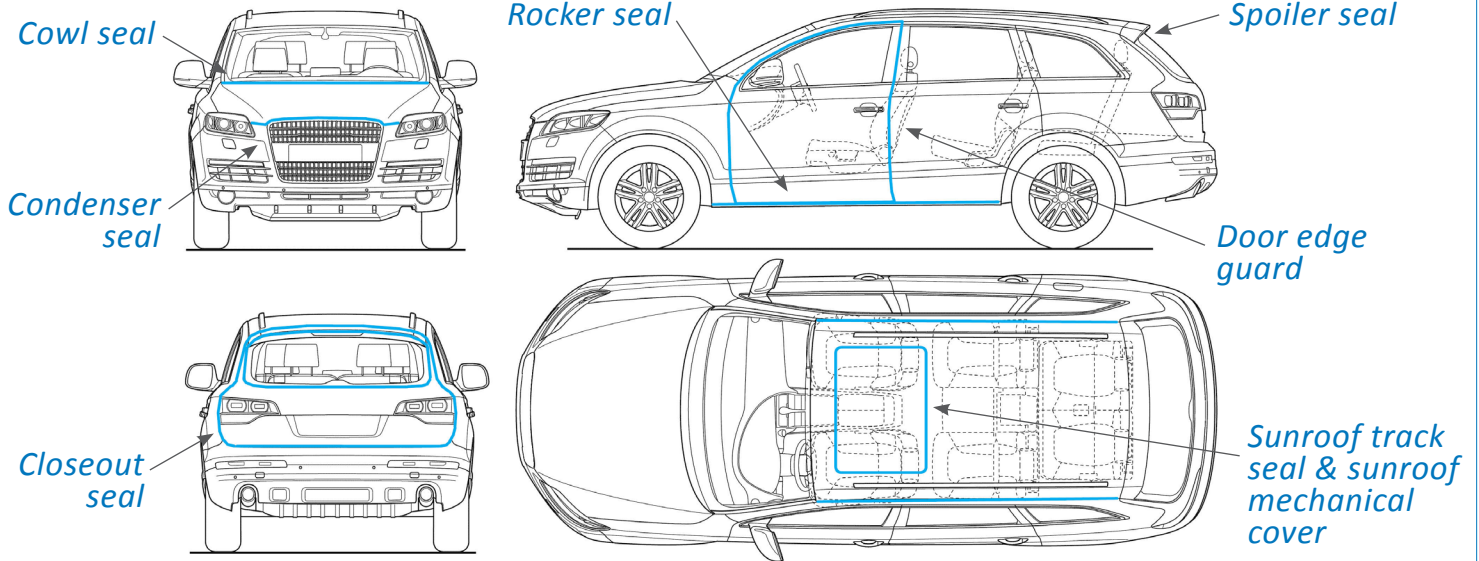
- Only provides a uniform cross sectional shape
- Surface area is not class A for all materials
- Tolerances are greater than injection mold
- Secondary operations required to add a third dimension to the design

Applications

Extrusion produces a continuous two-dimensional part with a fixed cross-sectional profile, but that's just the beginning. Once the plastic cools, a third dimension can be added in-line by processes such as cutting, drilling, punching, printing, and stamping to achieve complex geometries. Conversely, it can be left as-is and simply cut to desired lengths or wound around a core.

From your home to the office, from school to the sports field, beneath your feet and above your head, extrusions are everywhere! There are hundreds of applications in automotive alone. Let's take a look.

SEALS

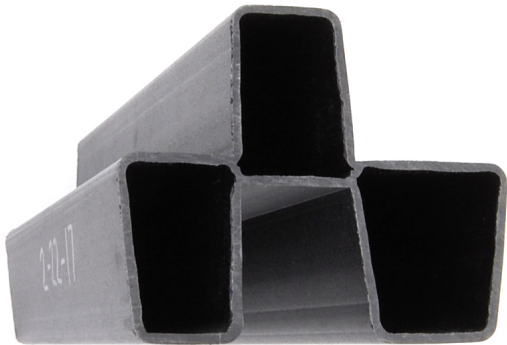


- Air guides/deflectors
- Instrument panel seals
- Sunroof seals
- Pillar seals
- Condenser/HVAC seals
- Radiator seals

- Hood seals
- Cowl seals
- Rocker seals
- Roof line seals
- Belt line seals
- Window slider channels

Applications (continued)

STRUCTURAL



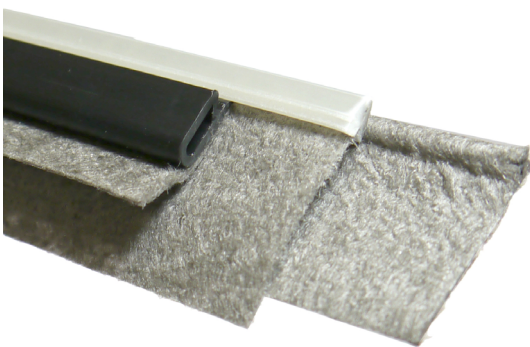
- A, B, and C pillars
- Crash box reinforcements
- Side impact reinforcements
- Rocker reinforcements
- Running board reinforcements
- Roof rail inserts
- Bumper inserts

SAFETY



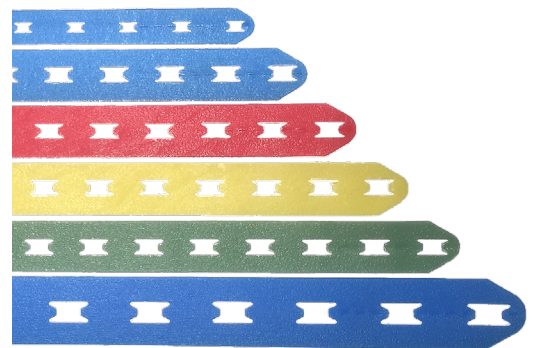
- Ramps, housings
- Routing channels
- Shape maintainers

SEATING



- Stiffeners
- J & arrow retainers
- Beaded duon – PP, wire, fiberglass

OTHER



- Locking and overlap closures
- Electrical close-outs, tie-downs
- Wiring harness protection

Cost Drivers

Cost creep can kill your project. While it’s impossible to predict every single cost, you can take steps to minimize unpredictability and risk. Consider these major cost drivers:

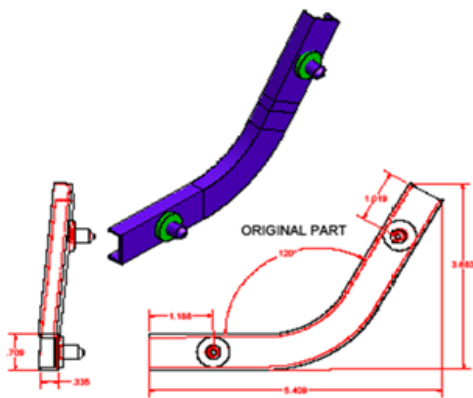
Profile Complexity: Typically, the more complex the profile design, the more expensive it will be to engineer and manufacture. Features to avoid include hollows, semi-hollows, narrow die sections, non-identical thicknesses, tight tolerances, and metal reinforcements. Your manufacturer may be able to offer alternatives to complex features that achieve the same outcome, so it’s wise to include them in the initial design discussions.

Design Changes: Changes to a quoted design often result in increased cost, especially if the change is requested after the initial tooling has been built. To mitigate against this, we conduct extensive feasibility testing and process simulations to balance the melt flow before tooling is built. We also offer rapid prototyping for our customers and all tooling is built in-house to minimize tooling lead time.

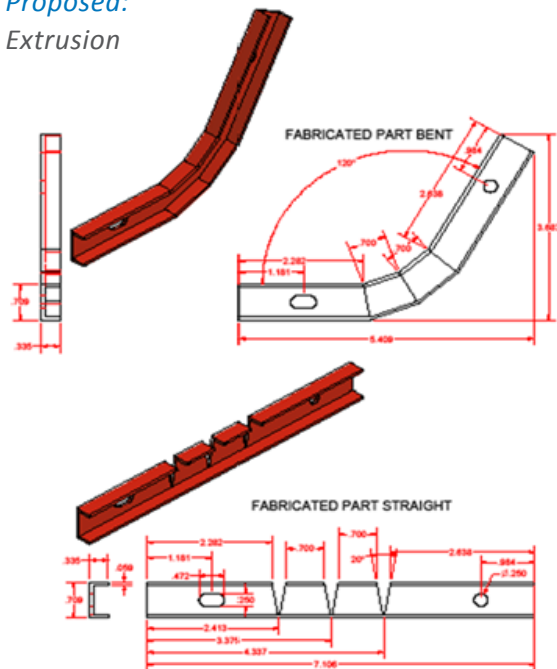
Tooling: While there is more to tooling than the extrusion die itself, a more complex die is usually more expensive to make. Also consider whether any trim or fabrication tools will be needed after the initial part is extruded, as well as fixtures and gauges to support the part during secondary operations.

INJECTION MOLDING VS EXTRUSION

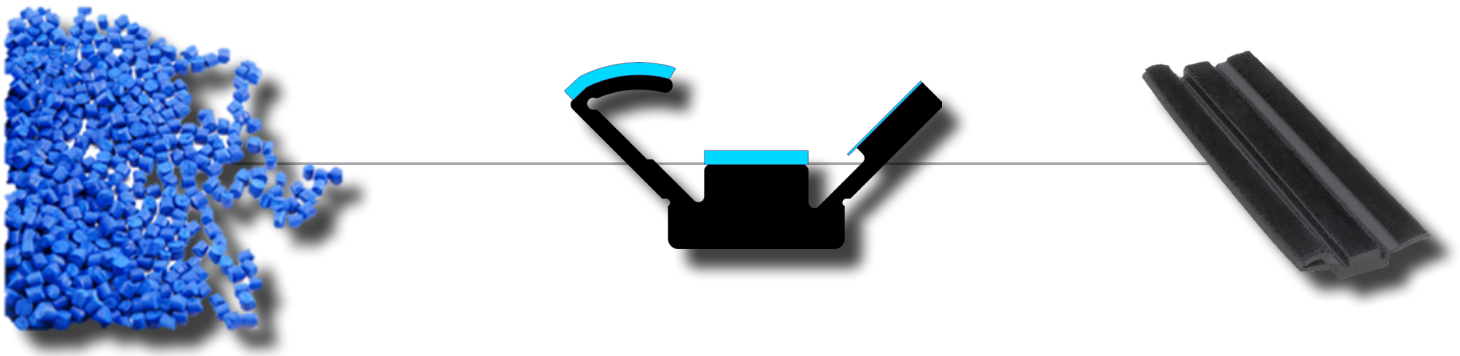
*Original:
Injection Mold*



*Proposed:
Extrusion*



	INJECTION MOLD	EXTRUSION	% SAVINGS
PIECE PRICE	\$0.93	\$0.39	58%
TOOLING COST	\$60,000 (two-cavity)	\$7,800 (extrusion + fab)	87%
TOOLING LEAD TIME	16 weeks	6 weeks	62%



Material

Material selection is one of the most important, yet daunting aspects of ensuring your extruded part manufactures successfully, performs properly, and is delivered to you at the lowest possible cost.

MATERIAL PROPERTIES

- Bending stiffness
 - *Does the part need to be flexible or rigid?*
 - *What should the part's bending strength or deflection be?*
- Impact resistance
 - *What level of hardness or surface toughness does the part require?*
 - *Will the part need to withstand impact forces without shattering or breaking?*
- Tensile and compression strength
 - *Will the part need to withstand pull-apart or compression forces?*
- Temperature exposure
 - *What are the minimum and maximum temperatures the part will be exposed to?*
- Interfacing components and assembly
 - *Does the part stand alone or is it part of an assembly?*
 - *How will the part be joined to the interfacing parts (e.g., welding, adhesive, mechanically, fasteners, etc.)?*
- Appearance
 - *Does the part need to have a particular color, grain, texture and/or gloss?*
- UV resistance
 - *Will the part be used in outdoor settings or otherwise exposed to UV rays?*
- Chemical exposure
 - *What chemicals (e.g., gasoline, diesel fuel, antifreeze, etc.) might this part be exposed to that could compromise function?*
- Aging
 - *What shelf life and product life is required of this part?*
- Material/process consolidation
 - *If one material cannot meet all functional and performance requirements, and additional components or processes are required such as tape, inserts, surface treatments, reinforcements, and/or fasteners, can their assembly be integrated into the processing of the plastic part? In other words, can this be a multi-durometer, co-extruded, or insert-molded part?*

Material (continued)

EXTRUSION RESINS

After you’ve determined which material properties your part requires, you can begin your search for a resin.

Not all resins are suitable for the extrusion process, nor are all extruders suitable for your ideal resin.

As such, we strongly encourage you to collaborate with a raw material supplier and/or an experienced extruder for this step. They can make recommendations based on your design and part requirements, reducing risk of costly tooling changes and part failure in the future.

The most widely used resins are included in the table below along with a corresponding rating for some of their critical material properties. These resins can also be enhanced with additives to better meet your required material properties.

MATERIAL TYPE	RIGIDITY	HEAT STABILITY	CHEMICAL RESISTANCE	IMPACT STRENGTH	RELATIVE COST
Polypropylene (PP)	Excellent	Excellent	Excellent	Excellent	Low
Low Density Polyethylene (LDPE)	Poor	Poor	Good	Excellent	Low
Medium Density Polyethylene (MDPE)	Good	Poor	Good	Excellent	Low
High Density Polyethylene (HDPE)	Excellent	Poor	Good	Excellent	Low
Thermoplastics (TPR, TPV, TPO, TPE)	Varies	Excellent	Excellent	Excellent	High
Acrylonitrile Butadiene Styrene (ABS)	Excellent	Poor	Poor	Excellent	Medium
Polyvinyl Chloride (PVC)	Varies	Poor	Poor	Excellent	Medium
Polycarbonate (PC)	Excellent	Excellent	Fair	Excellent	High
Nylon (PA)	Excellent	Excellent	Excellent	Excellent	High

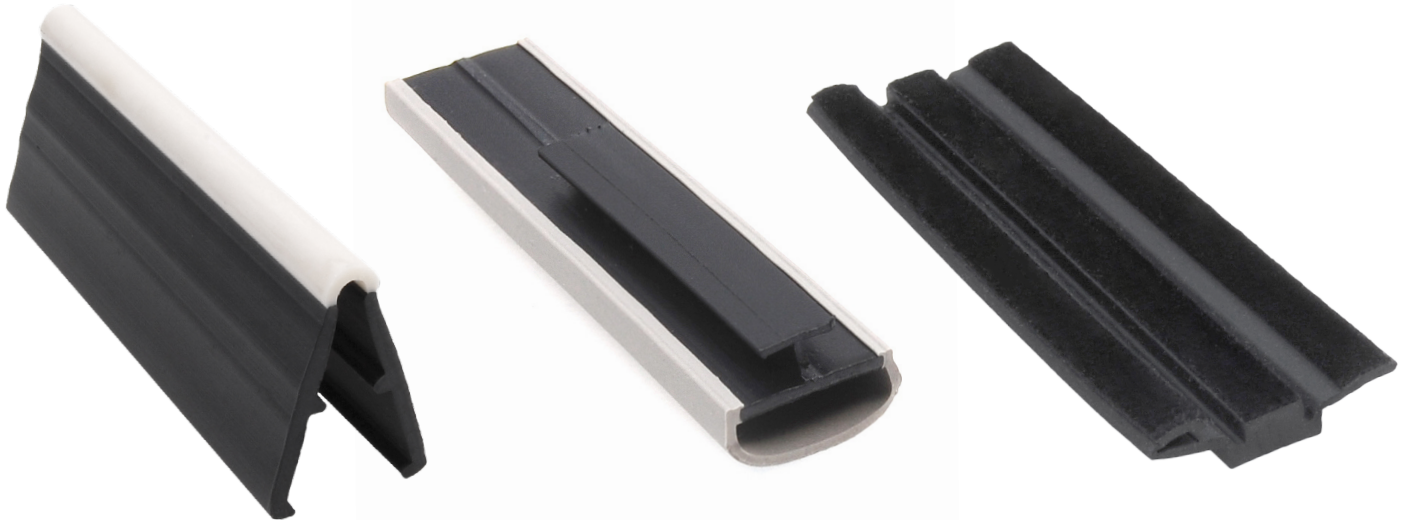
Again, we strongly recommend that you consult with a material supplier or extruder to make the best selection for your unique part design and performance requirements.

Material (continued)

COMBINING MATERIALS

Gemini has the ability to extrude two or more materials through a process called co-extrusion in which two materials merge together into a single profile before cooling.

Each material used maintains its desired characteristics (such as stiffness, impermeability, or environmental-resistance). The result is a specific shape of constant cross section to be used as used as specific products, assembly components, or as raw stock material for further processing.



Dual density co-extrusion: To achieve a dual- hardness density co-extrusion with both rigid and flexible properties, two machines are used to feed two different materials through the same die. Co-extrusion allows for rigid profiles to have flexible lips or flaps or for two rigid profiles to be joined by a flexible hinge.

Two-color co-extrusion: It is possible to combine two different colors in the same extrusion or to produce a two-color extrusion with a dominant color and a stripe in a second color.

Secondary Operations

A variety of secondary operations can be performed to achieve the final desired part:



Thermal bending, in which heat is applied to bend or form an extruded profile. It combines the cost saving benefits of extrusion with the forming benefits of injection molding.

Ultrasonic plastic welding, in which high frequency energy is converted into a mechanical motion (vibrations) to create frictional heat in a focused area. This melts the plastic, forming a molecular bond. Ultrasonic plastic welding can be used to join plastic to plastic, plastic to vinyl, and plastic to metal.

Assembly, decoration, packaging, and more!

Tolerances

Length tolerances: Where possible, design a little tolerance into your required extrusion length. Thermoplastics contract and expand with temperature and cutting plastic profiles to a very critical length may add unnecessary cost. Extrusions requiring very tight tolerances are generally cut out of line, incurring higher processing and handling costs.

Use the tables below for additional tolerances.

PROFILE DIMENSIONS	TOLERANCE
.00 - 12.7 mm	+/- 0.25 mm
12.71 - 25.4 mm	+/- 0.38 mm
25.41 - 63.5 mm	+/- 0.50 mm
63.51 - 101.6 mm	+/- 0.76 mm

LENGTH (NO FAB)	TOLERANCE
.00 - 25.4 mm	+/- 1.5 mm
25.41 - 50.0 mm	+/- 2.0 mm
50.01 - 500.0 mm	+/- 3.0 mm
500.01 - 1000.0 mm	+/- 4.0 mm
Over 1000 mm	+/- 5.0 mm

WALL THICKNESS	TOLERANCE
.00 - 2.0 mm	+/- 0.25 mm
2.01 - 3.18 mm	+/- 0.30 mm
3.19 - 5.0 mm	+/- 0.38 mm

LENGTH (FAB)	TOLERANCE
.00 - 100.0 mm	+/- 1.0 mm
100.1 - 500.0 mm	+/- 2.0 mm
500.1 - 1000.0 mm	+/- 3.0 mm
Over 1000 mm	+/- 4.0 mm

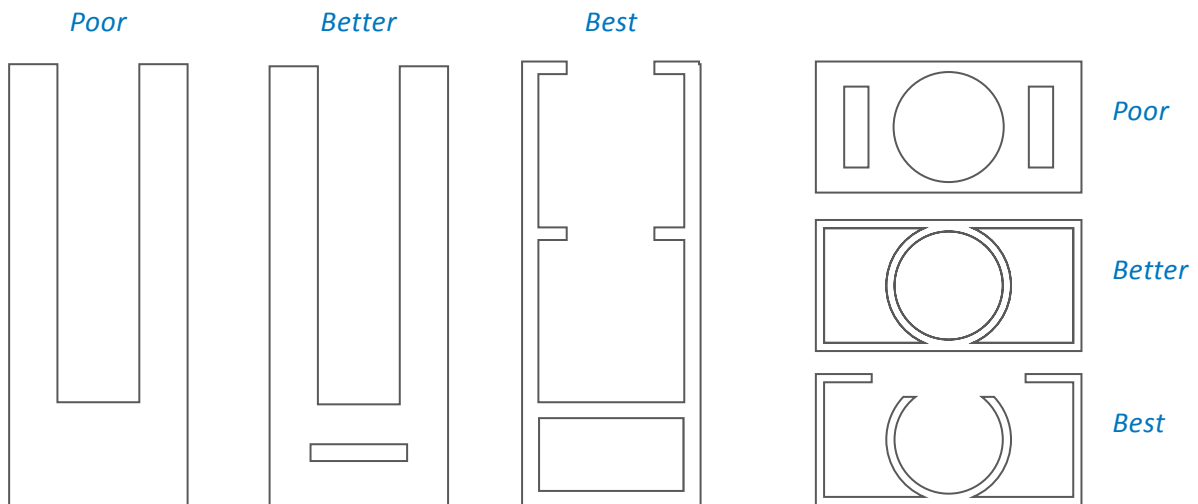
HOLE SIZE	TOLERANCE
	+/- 0.30 mm

* These are general guidelines. Actual tolerances may vary based on material and part design.

Wall Thickness

Design for uniform wall thickness: The extrusion process depends on flow characteristics of the material. Variations in thickness can make the flow of plastic material through the tool difficult to regulate, which causes the extrusion to cool at different rates, distorting the finished profile.

Uniform walls aid in creating a balanced extrusion and make cooling more even – necessary to prevent bow and twist. As such, an extrusion design should have an even wall thickness.

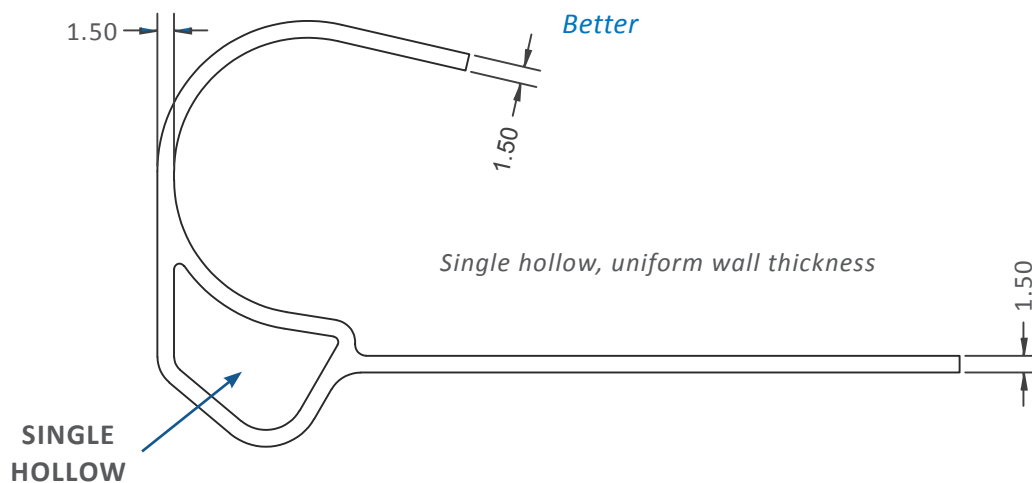
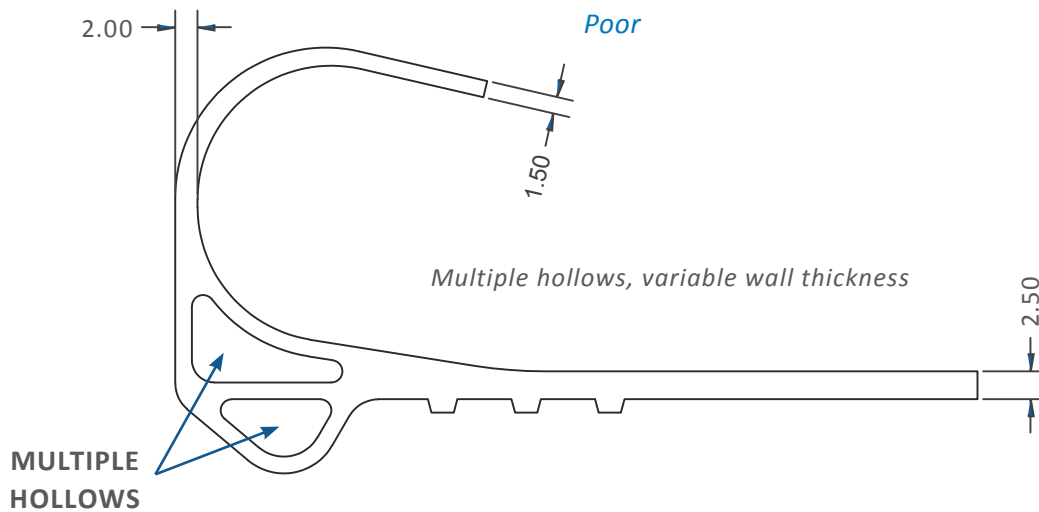


Hollows

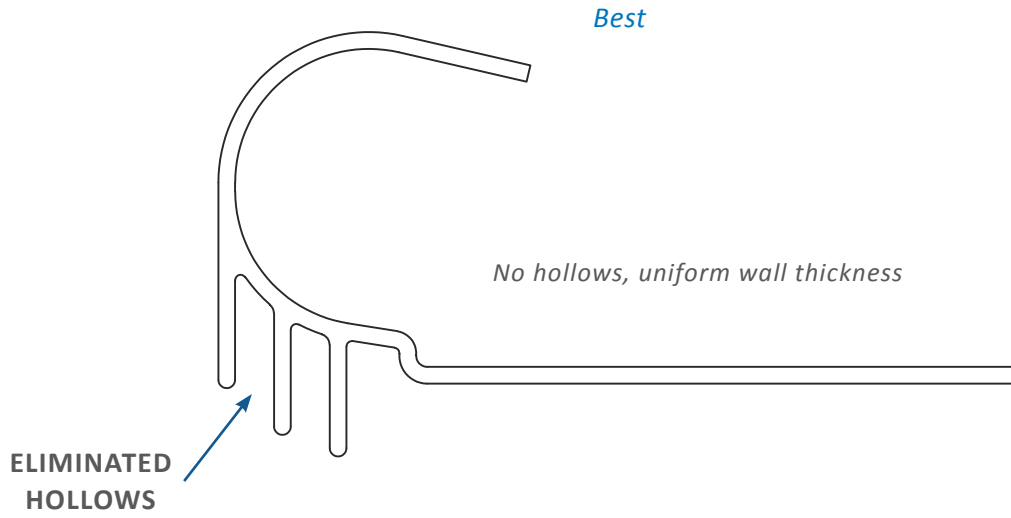
Limit detail in hollow profiles: Internal definition in extruded hollow sections is difficult to regulate, so good profile design generally discourages the use of hollow sections. Tolerances are greater with hollows and the cost generally increases because the process usually requires air pressure, internal mandrels and/or vacuum sizing to maintain the shape of the part while it cools.

If a hollow is necessary, a few design precautions will help minimize potential problems.

- Avoid hollow sections with internal legs or projections. If such a leg is absolutely essential, it should project into the hollow no deeper than the thickness of the wall.
- Avoid hollows within hollows. A hollow within another hollow cannot be held in position; as such it will inevitably force the intended design out of shape before the thermoplastic solidifies.

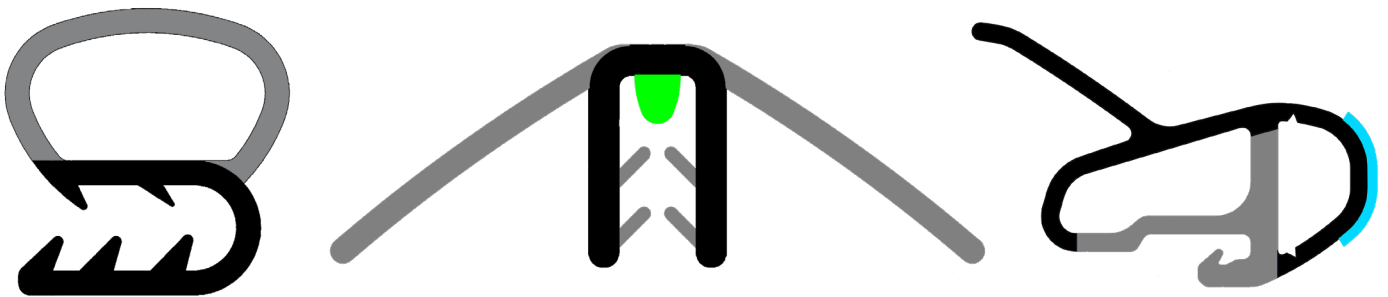


Hollows (continued)



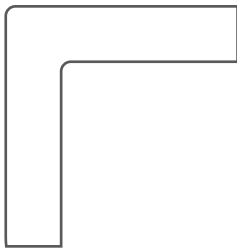
Internal Details

Provide good access for internal detail: Design an opening in the part to incorporate legs, grooves, snap-in features, and other detailed features internally.

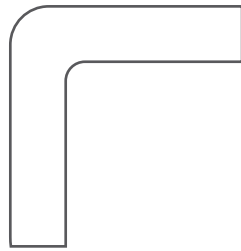


Corner Radius

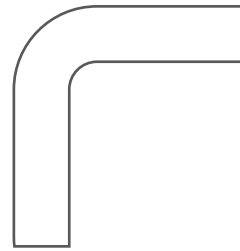
Avoid sharp corners: All extrusion profile corners should be designed with a radius. Sharp corners can result in a stress concentration where the profile may have a tendency to warp and break. Inside and outside radii should be offset of one another to maintain a uniform wall. The sharpest controllable outside corner is 1/64-inch and we recommend the inside radius be a minimum of 1/64-inch. This will eliminate a notch-sensitive situation that could cause a break, especially in rigid materials.



Sharpest Possible
.010R.



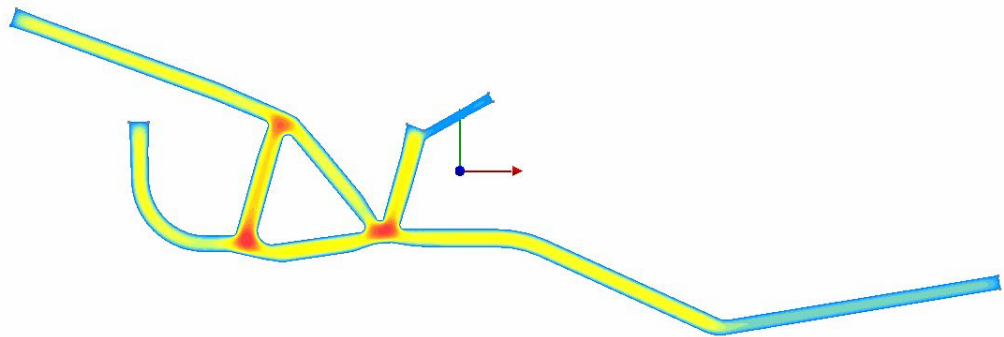
Typical
Diameter equals
wall thickness



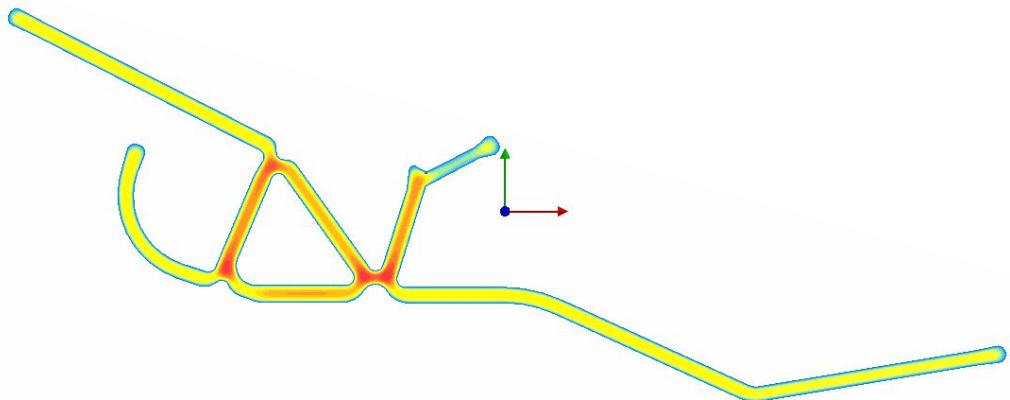
Ideal
Outside radius has
same center as
inside radius

MATERIAL FLOW SIMULATION

Sharp Corners:
Unbalanced Flow



Ideal Corners:
Balanced Flow



Mating Parts

Know your mating part: Custom plastic profiles often need to fit another component. Providing a sample of the mating part will facilitate the tool design stage and ensure an accurate fit when trialing the plastic profile.

Attachment

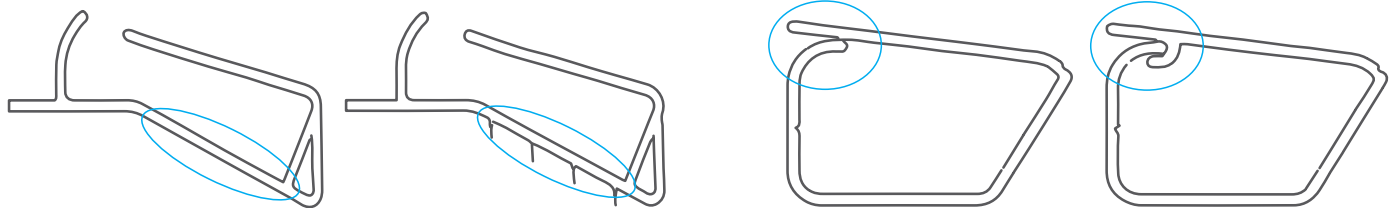
Design mechanical attachment into the part: When possible, avoid the use of tape to attach your part, as post-assembly tape and adhesive application unnecessarily increases labor and material costs. Instead, design a mechanical attachment directly into the profile as illustrated below.

*Current
BSR Tape*

Proposed

*Current
Closure Tape*

Proposed



Adhesive: As noted above, avoid the use of tape and adhesive when possible and opt for a mechanical attachment feature instead.

If an adhesive or tape must be used, the attachment surface should be wider than 1/8" and the adhesive placement should be on flat surfaces on both the extrusion and the substrate to ensure proper adhesion. The thickness of the adhesive itself should be taken into consideration when determining the overall height of the extruded profile.

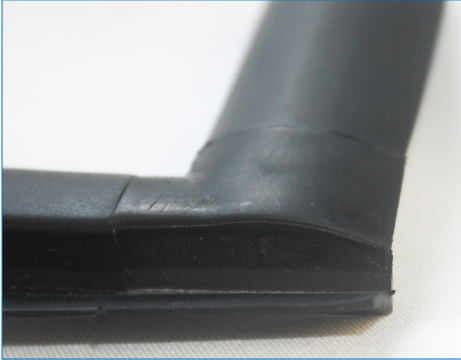
Transfer adhesives generally perform better than supported adhesives (adhesives that use a carrier) when it comes to bending around radii. On the other hand, supported adhesives help prevent stretching of the part during application better than transfer adhesives.

With these things in mind, ask yourself the following questions to determine what type of adhesive you will need:

- To what type of substrate will the adhesive be attached?
- In what temperature range will the adhesive be expected to perform, and with what chemicals will it come into contact?
- Will it come into contact with moisture or sunlight?
- Will the adhesive be functional after installation?
- Will the adhesive be in shear?
- What type of radius will the adhesive need to go around?
- Is an adhesion promoter necessary?

Fabricated Corners

Corners can be fabricated into a variety of configurations through molding or hot splicing.



- **Overmolding:** Overmolded corners yield the best results. In this case, plastic is injected under high pressure to bond the two pieces into a complete corner.
- **Welding:** Welding uses a method similar to overmolding. However, welding bonds the corner extrusions by melting the ends and combining the parts into a complete corner.

Failure Modes

Don't wait until your part is broken to find out what made it break. Through predictive modeling and analysis, it's possible to predict failures in your part before it hits the field.

There are many factors that can lead to extruded part failure, including:

- Choice of material
- Component design
- Interfacing components
- Processing specifications
- Storage conditions
- Assembly techniques
- Inspection techniques
- System changes
- Human error

In an ideal world, failure analysis would be performed with full knowledge of the system variables. In practice, however, failure analysis is largely based on experience combined with analytical techniques.

With over 45 years of experience, Gemini has the knowledge and techniques to help you avoid disaster. No one can predict all failure modes, but we can come pretty darn close.

If you need assistance with a failure modes and effects analysis (FMEA) for your part, we're here to help! Contact Gemini Group's extrusion experts at plasticsales@geminigroup.net or 248-435-7271.

Case Study

When a Tier 1 OEM supplier had an extruded U-channel seal fail just weeks before delivery, Gemini Group's extrusion division stepped in to help. A week later, the customer had a part with improved performance and reduced cost. More importantly, they had a part that actually worked.

THE CHALLENGE

The incumbent supplier's extruded seal didn't set right. The walls of the U-Channel were collapsing and causing undue friction and squeaking. With a delivery date just weeks away, there was no time for a new design. The solution had to come from within the manufacturing process.

THE SOLUTION

Through Gemini's testing and troubleshooting process, we identified a flaw in the incumbent supplier's material choice. So we proposed a better grade of material that would perform given the current profile design.

In the span of five days we built the tooling in-house, completed a small production run, and delivered a dozen prototype parts, enabling the customer to meet their build dates.

KEY TAKEAWAYS

A mistake in material selection can have devastating consequences in terms of processability, performance, cost, and delivery time. Mitigate against your risk with these three tips:

1. Never approach an extruder without knowing what types of materials will work for your part. At the very least, you need a basic understanding of extruded material characteristics.
2. Don't allow an extruder to push you into their pet material. Make sure the material you choose is best for your part, not the extruder.
3. If you're unsure of an extruder's experience working with a material, ask for samples of their past work similar to your current design.

With over 6,000 extrusion profiles under our belt, we recognize that material selection plays a critical role in extrusion design, especially extruded seals. To learn more about material selection for seals, download our [Extruded Seal Material Selection Guide](#). **Because sometimes the simplest things are the hardest to get right.**

A Word of Advice

Plastic profile extrusion is easy to understand, but difficult to master – especially for highly complex profiles. Involve your supplier from the start. Tell them what you intend to accomplish. Let them help you succeed!

Our design and process engineers add DFM/DFA to their 40+ years of tool building and manufacturing experience to make your plastic profile design a reality. As a Tier 1 and Tier 2 automotive supplier, Gemini is comfortable being responsible with the entire design project or assisting you as a design partner.

Gemini Group’s horizontal integration is what drives this approach. Our plastic processing expertise includes:

- *Profile extrusion*
- *Two-shot injection molding*
- *Technical blow molding*
- *Baypreg, compression molding, thermoforming, and more*

Using the expertise of all our divisions along with offering rapid prototyping, in-house tooling and material expertise enables us to evaluate multiple processes and material selection for your unique application.

Gemini Group's Extrusion Business Units



Gemini Plastics, Inc.

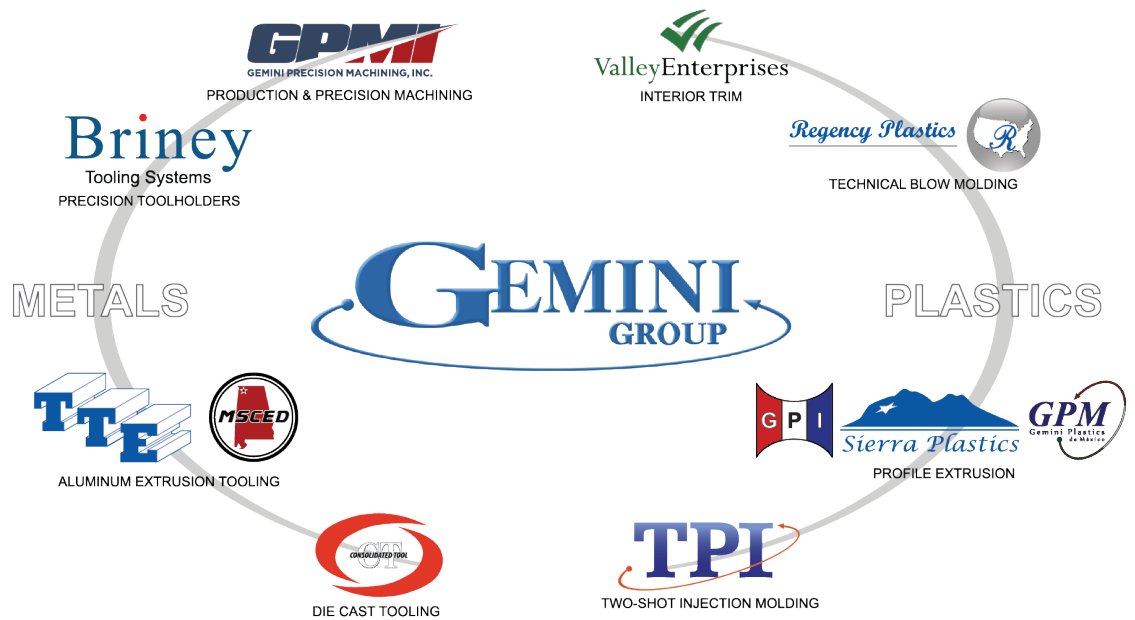


Sierra Plastics, Inc.



Gemini Plastics de Mexico

Fact: 9 out of 10 of Gemini Group's largest customers purchase products from two or more of our business units.



For more information about how Gemini Group’s innovative approach to manufacturing can help optimize your extruded part design, or to partner on a new product, please contact us at:

Gemini Group, Inc.
 Customer Technical Center
 3250 University Drive, Ste. 110
 Auburn Hills, MI 48326
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 248-435-7271