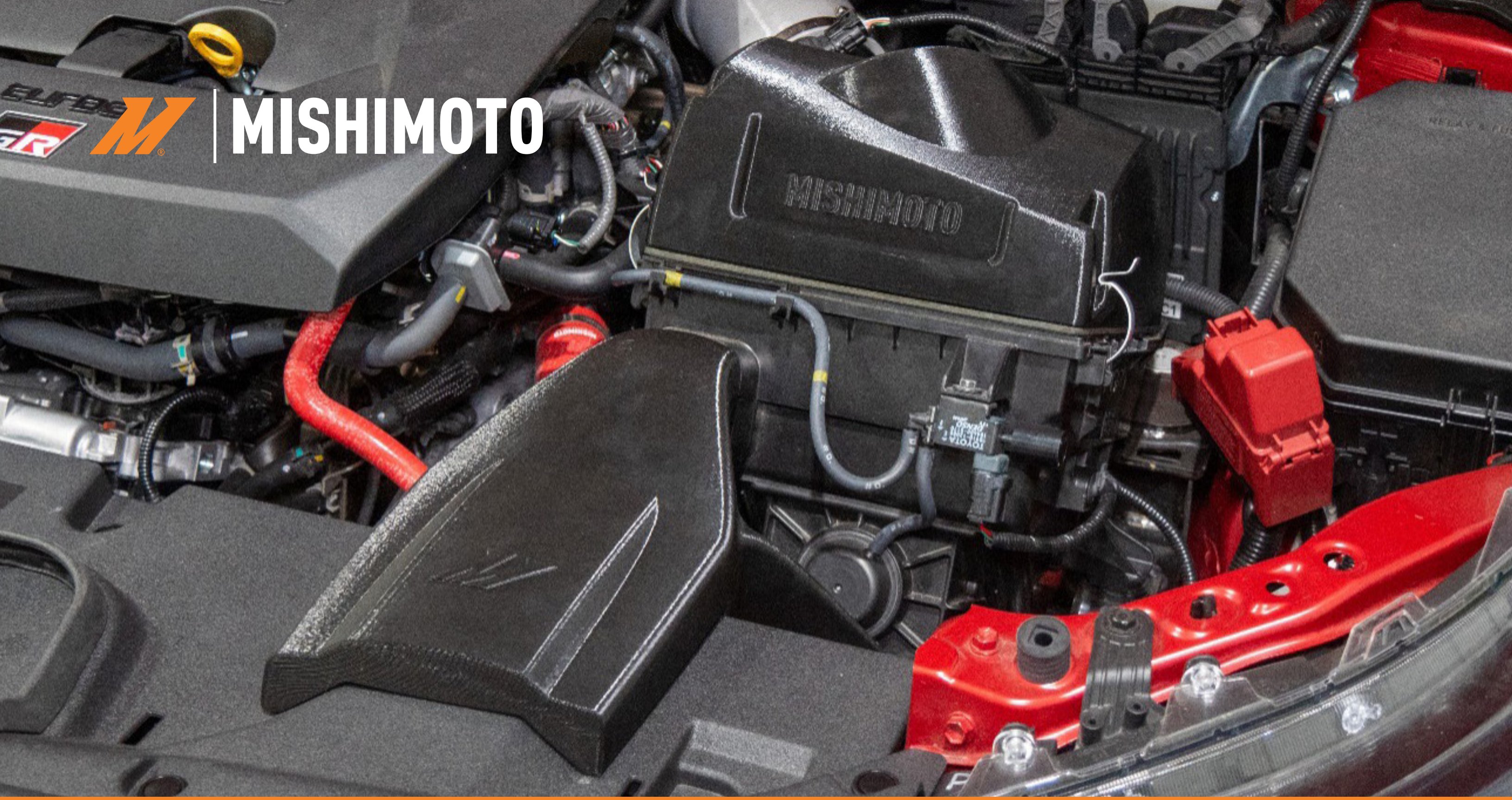

ENGINEERING REPORT

2023+ Toyota GR Corolla Intake | SKU: MMAI-GRC-23

By: Ye Liu, *Mishimoto Product Engineer III*

INTRODUCTION

The 2023 Toyota GR Corolla is a high-performance hatchback engineered with a focus on agility, power, and driving excitement. Like all production vehicles, its stock air intake system is designed to balance performance, fuel efficiency, and noise regulations, which can limit its full potential. However, unlike most other production vehicles, the GR Corolla introduced an extremely sensitive Positive Crankcase Ventilation (PCV) system monitoring logic that makes aftermarket intake development extra tricky.

This engineering report outlines the extensive R&D we underwent to create an air intake that provides safe performance gains on the stock tune.

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TRIAL AND ERROR

The stock intake system of the 2023 Toyota GR Corolla features a conventional cold air intake layout with a primary airbox that houses the air filter and channels air from outside the engine bay. However, a distinctive component of this system is the vacuum-controlled valve located at the bottom of the airbox.

This vacuum-controlled valve is an integral part of the intake's design, functioning as a dynamic air management feature. When the engine is operating under low load conditions—such as during cruising or light throttle application—the valve remains closed to restrict airflow. This helps maintain smooth drivability, reduce intake noise, and improve fuel efficiency by optimizing the air-fuel mixture for lower engine demands.

Under heavy acceleration or higher throttle inputs, a vacuum signal opens the valve, allowing additional air to flow into the intake. This additional airflow increases engine breathing capacity, contributing to enhanced power output and more responsive throttle performance when needed. This dual-stage intake strategy provides a balance between everyday drivability and high-performance demands, but the restrictive nature of the valve can limit the overall airflow potential, particularly during aggressive driving or modifications aimed at maximizing engine power.

Our first design concept was to replace the entire stock airbox to maximize airflow and its performance potential, removing this valve from the engine airflow equation. With this design, the vacuum solenoid is still retained and connected to the main harness, but without the valve mechanism, its functionality is effectively deleted. With maximum airflow funneled through the intake system through the entire load and RPM range, this prototype reduced air restriction by up to 76% compared to the stock intake and showed significant power gains on the dyno. However, we later encountered a Check Engine Light (CEL) issue during the road test, leading us back to the drawing board.

We encountered a P2C90 code triggered by a sensor that monitors crankcase ventilation system pressure. Now, how is the PCV system related to the intake system?

When blowby gas is introduced from the crankcase to the intake system, fresh air is introduced to maintain pressure inside the crankcase through the intake system. To prevent leaks from the fresh air hose during boosting, the intake airflow and PCV pressure are monitored to detect hose detachment or damage. If the change in PCV pressure does not correlate within the threshold value in response to an increase in the intake airflow, it is determined that the hose is detached or damaged, and a Diagnostic trouble code (DTC) is stored.

With our previous design, intake airflow is massively increased throughout the load range due to the deletion of the vacuum valve. However, at low load range, this monitor set by the ECU is still looking for the same range of resulting PCV pressure values over a certain amount of time, mathematically referred to as pressure integral, where the intake airflow should be restricted to a lower value. This discrepancy is the cause of the P2C90 code.

Following this logic set by the ECU, we explored many options, including artificially restricting the PCV hose and the feeder hose to the sensor. We went through over 12 different iterations and prototypes, some made as far as 850 miles without CEL or pending DTCs. However, none were reliable enough not to set a pending DTC for 1000 miles, which is our road test mileage target before releasing any intake design to the next stage of R&D.

Pending DTCs are temporary codes that are logged when the system detects a potential issue but the malfunction has not occurred enough times to be confirmed as a set code. Pending codes may indicate an intermittent or early-stage problem, and they do not trigger the "Check Engine" light unless they persist and convert into set DTCs after further verification by the system. Essentially, set DTCs to confirm an ongoing problem, while pending DTCs highlight potential issues still under observation. It is critical for us to track any pending DTCs even when they do not trigger a CEL to ensure the highest standard of reliability of our products.

Figure 1: *First design iteration in 3D*

Figure 2: *First design prototype*

NEW DESIGN

After extensive testing and analysis, it became clear that the solution required more than just maximizing airflow—it demanded a design that would work harmoniously with the sensitive PCV system and the ECU's strict monitoring logic. Instead of simply deleting or bypassing the vacuum-controlled valve, we shifted our focus to refining the intake system in a way that maintained a balance between increased performance and the factory-set thresholds for PCV pressure. Our new approach aimed to preserve the valve's functionality during low-load conditions while allowing significant airflow gains under high-demand scenarios. This led us to develop a hybrid intake design that retains the dual-stage airflow control but optimizes the overall flow characteristics, ensuring that both the intake and PCV systems operate within acceptable parameters. By doing so, we could prevent the P2C90 code from being triggered while still delivering meaningful performance improvements.

The stock intake system uses a duct connected to a small port molded into the bumper to funnel air through the system. This is the very beginning of the intake air path, and our search for extra airflow started here.

It is easy to create a significantly oversized inlet duct to replace the stock one, but does that translate to extra airflow going into the system? We created multiple prototypes and designed a test to find out.

Placing the vehicle in front of our dyno fan set to 60mph, we used a hot-wire anemometer to measure the airspeed at the center points of the entry and exit of the stock air duct. Then, we installed our prototype duct and repeated the test. Not surprisingly, the new duct took in almost three times more airflow at the entry point and increased exiting flow by 42% at the exit. However, if the exit area remains the same on the new duct, we observed barely any increase in exiting flow. These results can be found in Figure 6 below. Some trimming of the plastic radiator cover panel is required to fit the new duct, but it should be a small trade-off to open up the bottleneck of the flow path and achieve meaningful improvement in airflow.

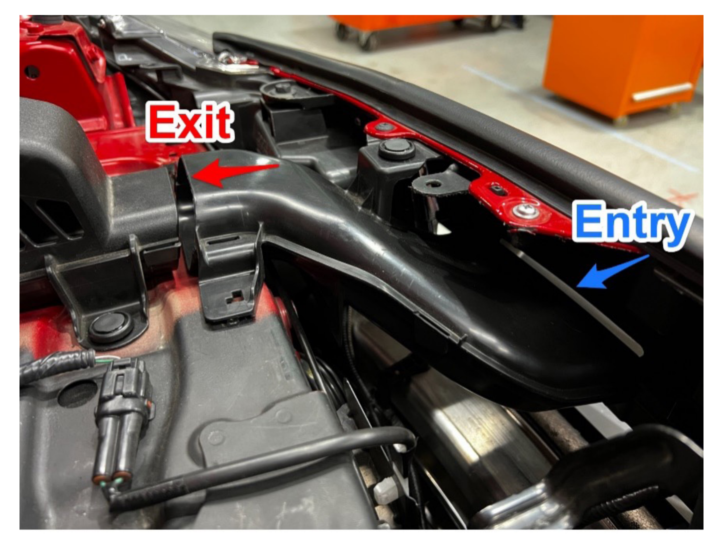

Figure 3: *Airflow speed sampling points*

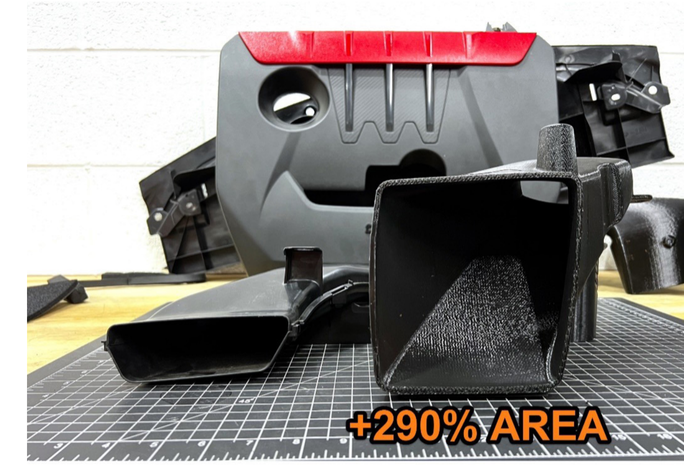

Figure 4: *Stock and Mishimoto inlet duct prototype comparison (entry side)*

Figure 5: *Stock and Mishimoto inlet duct prototype comparison (exit side)*

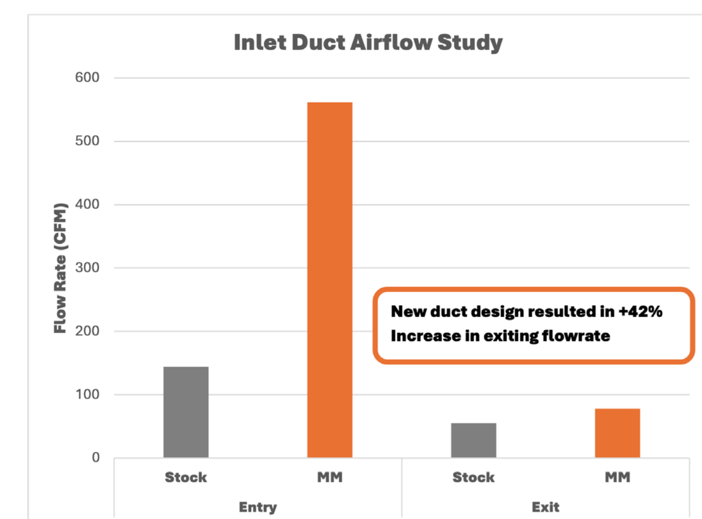

Figure 6: *Inlet duct airflow study results*

After introducing extra flow potential in the first stage of the system, we set out to find an optimized path to deliver this resource into the airbox. During baseline dyno testing, we observed a significant increase in intake air temperature under high load conditions. This is caused by the vacuum valve on the bottom of the airbox inducting hot engine bay air into the intake system. As the new design will retain the stock lower airbox and its vacuum valve mechanism, we addressed this issue by simply directing some of the cold air introduced by the inlet duct to where the vacuum valve is located. We created a snorkel component that split the inlet air into two streams: one goes directly into the lower airbox through the square port at the front, and the other dives down under the airbox to feed it to the vacuum valve. This design ensures that only cold air is introduced into the intake system.

The rest of the new design is centered around safe performance and optimum fitment. We created a rotational molded upper airbox that latches onto the lower airbox with the original spring clip. The upper box includes a rubber gasket with the right amount of compression to create a good weather seal and latch tension on the clips. Our injection-molded MAF housing is calibrated to ensure MAF sensor readings do not deviate from stock values and to keep AFR and fuel trims within a safe range. The new upper airbox houses a high-flow conical filter, which increases the effective filtration area by 37% compared to the stock panel filter. Once the new prototype was 3D printed and assembled, we moved on to performance testing.

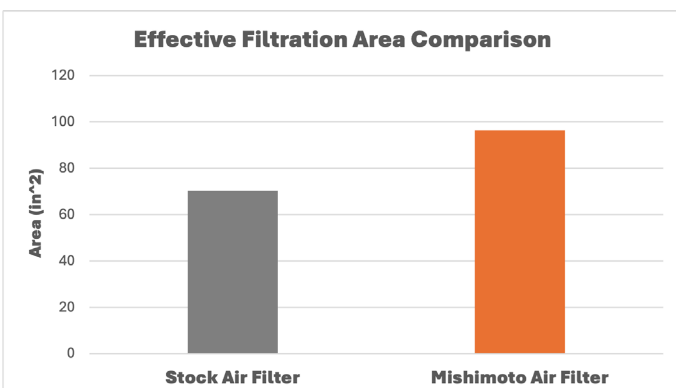

Figure 7: *Air filter effective filtration area comparison*

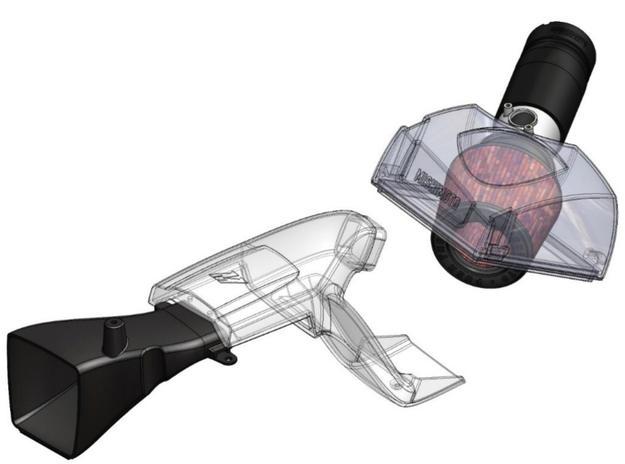

Figure 8: *New design in 3D*

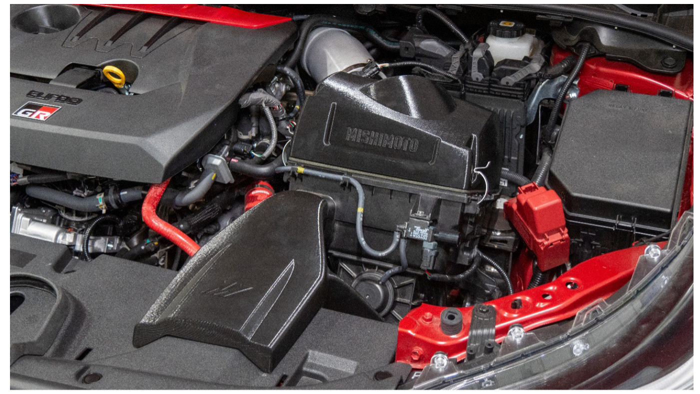

Figure 9: *New design prototype*

PERFORMANCE TESTING

With the new intake design finalized, the next crucial step was to validate its performance through rigorous flow bench and dyno testing.

The Mishimoto intake prototype, in its low load range configuration with the vacuum valve closed, showed 10.5% less restriction than the stock intake. For the high load range configuration with the vacuum valve open, the prototype performed worse than the stock intake. This is because, in this state, the airflow path is fundamentally altered for the Mishimoto intake prototype, which renders the test an unfair comparison that provides very little insight into how the intake would perform in the real world.

On the flow bench, the snorkel that feeds a second stream of cold air to the vacuum valve effectively obstructs the air path, whereas the stock setup has nothing in front of the valve. Because a flow bench only calculates volumetric airflow rate, not mass airflow rate, its pressure drop readings do not take air density into account. A "less open" design will always be more restrictive on the flow bench, regardless of its effect on mass airflow, which is what really matters when it comes to real-world performance. Simply put, a design that looks restrictive in a flow bench test might still deliver better performance in real driving conditions. With this in mind, we move on to dyno testing.

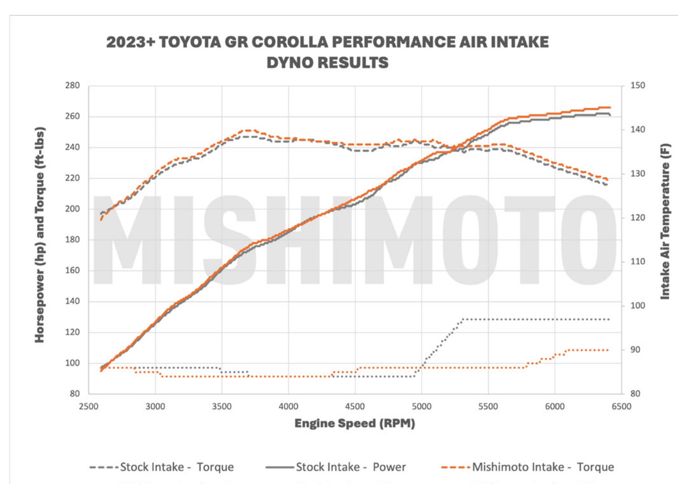

Figure 10: *Dyno results*

The Mishimoto intake prototype showed consistent horsepower and torque gains toward the higher RPM range, with max gains of 4hp and 4 ft-lbs. It is worth noting that at around 4900RPM, with the vacuum valve fully open, the stock intake air temperature spikes up to 97F, while the Mishimoto intake air temperature remains flat at around 86F. This reduction in IAT directly translates to denser air entering the engine at the high load range, a crucial characteristic of any high-performance intake system.

While dyno testing provides controlled, quantifiable data on the performance improvements of the new intake, long-term road testing is essential to validate its real-world functionality and reliability. At Mishimoto Engineering, we subject all air intake prototypes to a minimum of 1000 miles of on-road testing. The goal of the road test is to ensure that the intake system operates smoothly under a variety of driving conditions, from daily commuting to aggressive, high-load scenarios. This testing phase is crucial, especially due to the PCV system code we encountered during the initial design. We also closely monitor and compare the fuel trim values before and after the road test to ensure the ECU is not compensating for any abnormal rich/lean conditions through the fuel trim strategy, which could indicate an issue with MAF sensor readings. We did not encounter any more PCV system DTCs. The new intake design performed well and met all the test criteria set by our engineering standards.

In comparison to the stock intake, the new Mishimoto intake design also provides a noticeable improvement in acoustic performance. By featuring a more open and less restrictive air path, the enhanced airflow produces a deeper, more aggressive intake sound, particularly during acceleration, appealing to those seeking a more engaging driving experience.

CONCLUSION

In conclusion, the development of the Mishimoto intake for the 2023 Toyota GR Corolla successfully addressed the balance between performance gains and the constraints of the vehicle's sensitive PCV system and ECU monitoring. Through extensive testing and multiple design iterations, we achieved a system that reduces airflow restriction, lowers intake air temperatures, and delivers measurable horsepower and torque gains. The final design reduced airflow restriction by 10.5% in low-load conditions and maintained cooler intake air temperatures during high-load driving, resulting in maximum gains of 4 horsepower and 4 ft-lbs of torque at higher RPMs. This intake provides a reliable, real-world performance enhancement without triggering diagnostic trouble codes, making it a significant upgrade over the stock system while ensuring long-term engine safety and drivability.

TESTING DONE BY:

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