

Development of Sports Car Sound for Hybrid Super Sports Cars

Steven EICH *

Jared COX *

柳 瀬 浩 **

Hiroshi YANAGASE

ABSTRACT

Developing the sports car sound for the next-generation Acura NSX Sports Hybrid required a unique approach to vehicle noise and vibration development. Starting with a holistic acoustic strategy for the vehicle platform design, insulation package and chassis isolation specifications were constructed to accentuate cabin quietness during hybrid driving. Employing multiple acoustic technologies, devices and control strategies, specific frequency and order content was enhanced to maintain the original NSX heritage sound while adding functional purpose to audibly communicate instantaneous power unit feedback to the driver. Execution of this strategy achieved the vehicle sound concept and the hybrid super sports car segment competitiveness was redefined.

1. Introduction

The fundamental goal for the second-generation NSX is to be a leader in today's cutting edge supercar market, yet pay tribute to the heritage of the original NSX, which was considered revolutionary and helped to build the Acura brand nearly 25 years before. The primary focus for the sound concept was to maintain the heritage sound of the original naturally-aspirated (NA) V6 engine. The challenge was to achieve this with the new hybrid electric twin turbo V6 engine. A secondary goal was to celebrate the electric vehicle (EV) driving capability of this next-generation supercar. This was achieved by building on the foundation of a quiet interior by using sealing, noise, vibration, and harshness (NVH) treatments, and road and engine isolation strategies. Next, power unit breathing systems were designed to celebrate the character inside the unique 75 deg V6 twin turbo engine. Finally, five specific actively controlled systems were developed and tuned to deliver the desired sound including audible feedback to the driver indicating transmission gear changes and engine speed. This enables the driver to focus on the road while minimizing distractions from driving, such as continuously looking down at the gauges for feedback. The final product is a super sports car that can transform from a quiet, luxury grand touring car, to a raucous, roaring, track monster, with just the twist of its Integrated Dynamic System (IDS) knob.

The original Acura NSX, first introduced in 1991, played a large role in the development of the next-generation Acura NSX with the intent to pay homage

Table 1 Sound characteristics of the original Acura NSX

Hardware	Sound quality contribution	Sound content
Exhaust system	Low frequency, powerful sound	3 rd order
	High RPM 'Racing' sound	6 th order
Intake system	Mid frequency 'Guttural' sound	450 Hz resonance

to the characteristics which made the original car so unforgettable and revered in the sports car market. The original car was powered by a 60 degree, naturally-aspirated V6 engine, mounted mid-ship, immediately behind the driver. This power unit provided excellent sound quality and driver feedback through several hardware systems listed in Table 1:

Figure 1 shows the cabin sound of the original NSX during full throttle acceleration in third gear. As highlighted below, each rpm range has a unique sound character.

The finely tuned specifications of the intake and exhaust systems' sound quality contributed to the driver feeling connected to the car. Pressing the accelerator pedal resulted in an increased acoustic response from the vehicle. The sound was directly linked to the acceleration feeling, a quality desired to carry forward to the next-generation NSX.

With the NA engine of the original NSX, the authentic sound quality of the engine's breathing systems is a key aspect of its character. This authenticity is also a quality desired to carry forward to the next-generation NSX.

* HONDA R&D AMERICAS, INC.

** 四輪 R&D センター

Automotive technology, construction and performance have changed considerably since the original NSX was launched, and the next-generation NSX needs to satisfy the expectations of customers in the current super sports car market. Traditional super sports cars are often defined by particularly sporty NVH characteristics, including loud combustion noise, powertrain mechanical noises, lack of road isolation, and strong vibrations. These vehicles tend to be raw and unrefined, making for a very authentic sports sound experience; however, they are also very tiring to drive, tending to wear on a driver and making anything more than a short trip uncomfortable. This segment positioning is shown in Fig. 2, along with the typical luxury sports sedan vehicle and Acura product placement.

Over the past 25 years, the introduction of electronic controlled powertrain and sound devices enabled manufacturers to better balance the general driving NVH refinement and sports car sound. These technologies permit the driver to select their desired driving setting, within some performance window, as shown in Fig. 3.

Market analysis shows the customer expectation in this segment has been raised significantly since the release of the original NSX. Most buyers expect a vehicle that is reasonably luxurious and refined, suitable for longer drives, but that can also deliver a super sports car, visceral and raw engine sound

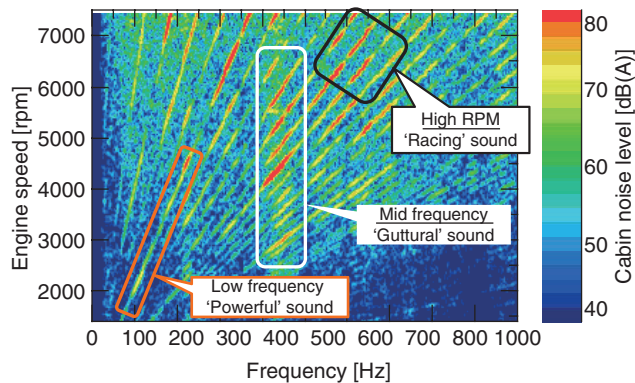


Fig. 1 Original Acura NSX cabin sound during acceleration

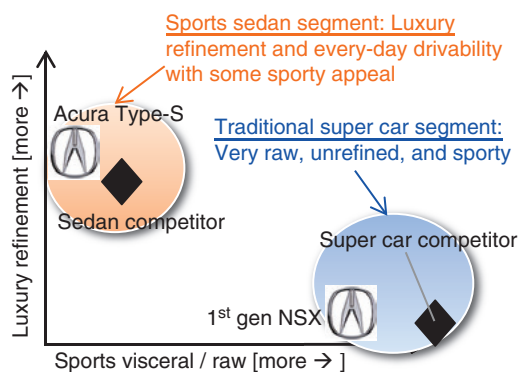


Fig. 2 1990's sports car market landscape

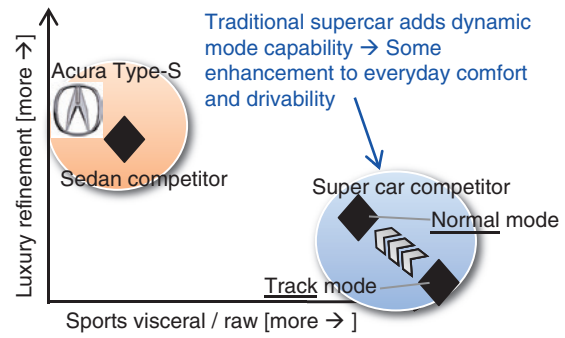


Fig. 3 2015's sports car market landscape

experience.

This paper describes the target setting and development of the NSX sports car sound, including hardware selection, specification setting, tuning, and competitive performance results.

2. Target Setting

With an understanding of the current sports car market landscape and customer expectations as indicated in the previous chapter, an engine sound concept was defined to deliver a New Sports eXperience (NSX). Every driving situation encountered by the customer was considered, such as acceleration, cruising, and gear changes. Then, the desired sound performance in each of these driving situations and IDS modes was defined, as shown in Fig. 4.

The sound concept established several 'key words' to describe critical noise performance characteristics, as listed and defined in Table 2.

IDS modes are key to this concept by creating a fully adjustable driving experience, where each mode provides the driver a different vehicle character including a tailored acoustic performance impression. Each IDS mode has a unique intended use, as summarized in Fig. 5.

Quiet mode:

The Quiet mode concept is to enable the driver

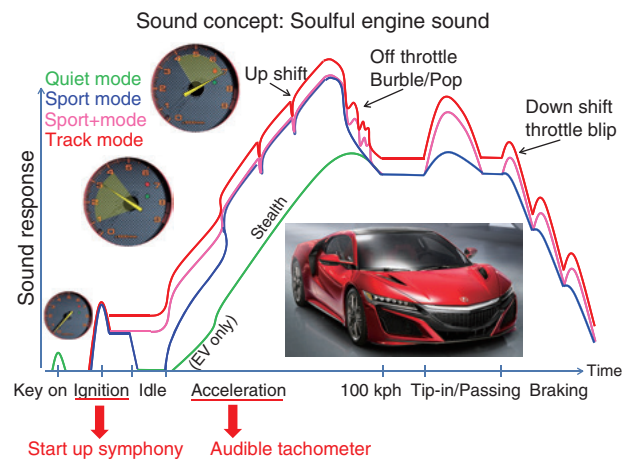


Fig. 4 Vehicle sound concept

Table 2 Target key word definitions

Target key word	Target character
Start-up symphony	Engine start-up sound, which provides audible feedback based on the selected Dynamic Mode – Quiet mode → Subdued startup maximizing quietness Sport mode → Exciting, high revving engine flare with fast, race-car like response
Audible tachometer	Sound that indicates to the driver the approximate speed of the engine, without visual reference to the tachometer. To be used as an aid, which permits the driver to keep their eyes on the road or track, but still keep exact upshift/downshift points for maximum performance

to minimize detection by the outside world as much as possible, abating noise and creating a comfortable, quiet cabin environment.

Sport mode:

The Sport mode concept is to enable the driver to experience an NSX, integrating hybrid vehicle driving with that of a super sports car with exceptional sound response to driver input, while maintaining everyday drivability. Sport mode is the default start-up mode, although Quiet mode may also be selected.

Sport+ mode:

The Sport+ mode concept is focused on winding or mountain road driving, eliminating internal combustion engine stop and giving the driver increased on-road audible feedback and performance.

Track mode:

The Track mode concept is for circuit use only, to achieve fast, repeatable lap times and give the driver maximum acoustic feedback that is even audible while wearing a helmet.

Quantitative targets are based on a metric which compares cabin sound level during full throttle acceleration to the number of orders that can be heard by the driver, known as audible orders. Audible orders are defined as orders within 7 dB(A) of the overall A-weight cabin sound. This was experimentally determined to be the threshold of order contribution to sound quality. Acceleration sound with fewer audible orders has harmonic sound, while acceleration sound with higher numbers of audible orders has modulation or a more guttural sound. Figure 6 shows the sound performance of the previous NSX as well as several



Fig. 5 IDS mode concept and intended uses

key competitors. The trend shows that louder vehicles have more audible engine orders, so the NSX target range, highlighted in blue, defines the appropriate number of orders required to achieve competitiveness in the 2015's sports car market landscape as indicated in Fig. 3, and maintain the heritage performance of the original NSX.

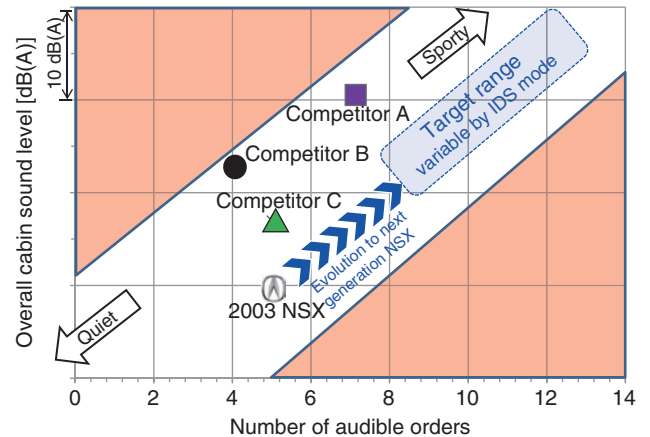


Fig. 6 Cabin sports sound target during full throttle acceleration

3. Approach

In order to achieve all aspects of the vehicle sound concept, several different hardware and software control systems were investigated⁽³⁾, as shown in Table 3.

3.1. Insulation Material Package

Traditional super sports cars are more analogous to racecars when it comes to noise and vibration cabin quietness. Of course weight is the enemy of acceleration and handling performance, so it's easy to choose lightweight or low coverage insulators in the interest of preserving maximum performance. The challenge with the NSX development is to achieve the concept of Quiet mode driving, while minimizing added weight from the material package.

This was addressed by specifying the package based on the noise source hierarchy. Figure 7 shows a representation of the input intensity of each

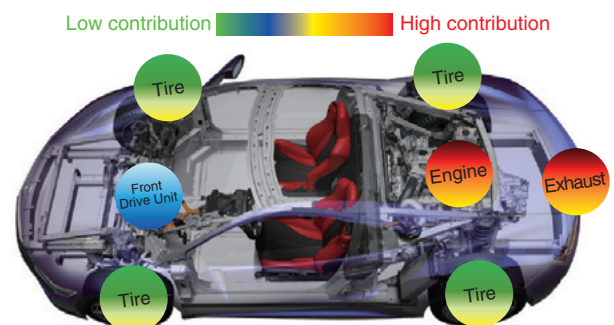


Fig. 7 Air-Bourne source noise contribution

Table 3 Concept achievement method

Sound concept component	Hardware / Software / Control system
Quiet mode, overall cabin comfort	Insulation material package
Startup symphony	Engine startup control
Balance of quietness and low frequency powerful sound	Exhaust system and active exhaust valve
Guttural sound	Intake sound control
Audible tachometer	Active sound control
Off-throttle Burble/Pop	Combustion stability control
IDS mode differentiation	Combination of all systems

noise source.

As shown in Fig. 7, the primary noise sources are behind the driver. Focus is then concentrated on treatment in this area, centralizing the weight in the rear bulkhead panel insulator, rear panel carpet, rear partition glass, and many other smaller parts to create high noise transmission loss from the engine room to the cabin. For the noise sources in the front of the vehicle, light weight absorptive materials are applied to the front bulkhead panel and wheel arch regions, where the heavier weight, barrier materials are not required.

The result of this strategic isolation is dramatic and benefits the vehicle concept in several ways:

- (1) Cabin quietness: In Quiet and Sport modes, the isolated cabin creates a smooth transition between IC engine running to full EV driving and is often imperceptible by the driver. EV driving is very quiet in the cabin and the highway cruising noise level is more like a sports sedan than a typical super sports car. Cabin quietness competitiveness is shown in Fig. 8, where NSX demonstrates best in class road noise performance.

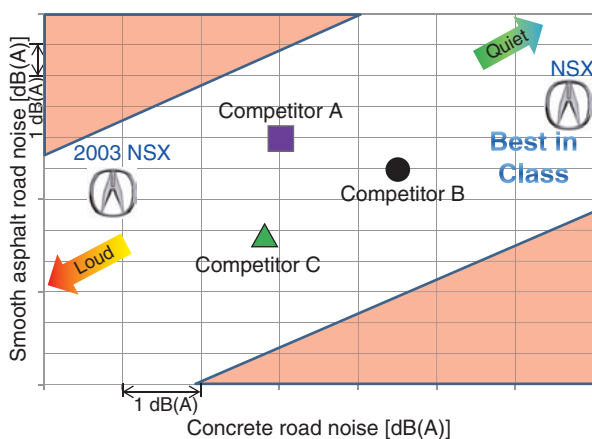


Fig. 8 Insulation material package - road noise performance

- (2) Low noise floor: With a low noise floor, undesirable noises are suppressed. This provides a clean palette for the addition of combustion and power unit related sports sounds. For example, exhaust noise is not competing with timing chain noise to reach the driver's ear. With the timing chain noise suppressed, the exhaust noise can be more clearly heard and enjoyed. Engine mechanical noise isolation during acceleration is shown in Fig. 9, where NSX realizes best in class performance.

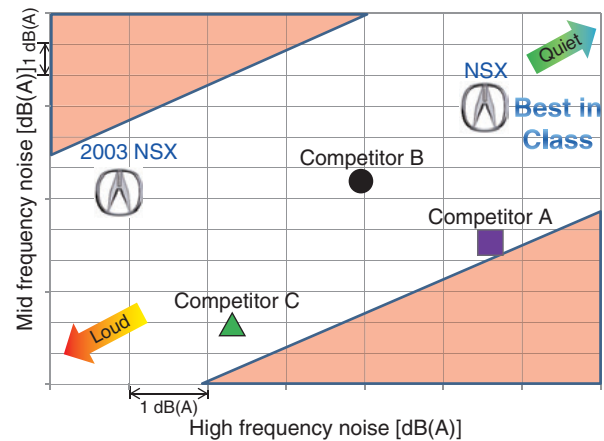


Fig. 9 Engine noise during part throttle acceleration

3.2. Engine Startup Control

Engine startup is an important part of the emotional experience with any super sports car. This is when the power unit comes to life and announces its presence to the world. It should impress upon the driver, as well as spectators outside of the car, the sportiness and high capability of the vehicle. Often, this is achieved by a loud, high revving startup, and the NSX concept is shown in Fig. 10. The challenges for the development of the NSX were twofold:

- (1) To achieve a sporty startup engine flare and corresponding sporty exhaust sound with a turbocharged engine.
- (2) To differentiate the startup sound based on the IDS mode selection of the driver. For example, keeping a subdued startup in Quiet mode, but an exciting startup in Sport mode.

To overcome these challenges, a new approach was required, and an idea was conceived to use the

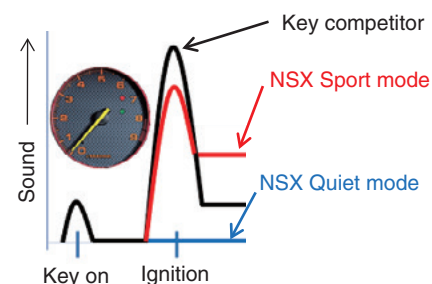


Fig. 10 Engine startup control concept

rear drive unit electric motor to control the engine flare speed and amplitude based on IDS mode. This is accomplished by using the motor torque to speed up [during RPM rise] engine speed during cranking, as shown in Fig. 11.

Additionally, engine control software was developed to consider the IDS mode at engine startup. If the driver starts the vehicle in Quiet mode, the engine performs a subdued, quiet start with minimal rev-up over idle speed. If the driver starts the vehicle in any other IDS mode, the engine executes a high revving, quick rev startup, similar to a lightweight racing engine.

3.3. Exhaust System and Active Exhaust Valve

The exhaust system of a super sports car has always been a vitally important component, and many times it is the primary sports sound device. At the start of the project, it was clear that packaging space was small and thermal requirements were severe in order to achieve Track mode performance requirements. The technical challenge was realizing the packaging and thermal requirements, while still achieving both the Quiet and Sport mode concepts, which required radically different noise levels.

To balance those requirements and minimize weight and packaging space, an Active Exhaust Valve (AEV) was introduced, creating a dual mode design that could achieve IDS mode concepts as well as all the aforementioned functional requirements.

The functional design target is to minimize weight as much as possible, while still achieving tailpipe noise targets. The traditional approach to achieve the tailpipe noise target is to use an appropriate silencer volume and then tune the attenuation characteristic and frequencies accordingly. With limited packaging space in the NSX, the approach was changed to utilize the AEVs for flow restriction. Flow restriction has a broadband noise attenuation effect, and this approach achieved the Quiet mode sound targets with the valves closed. With the valves open, the system delivers the desired sports sound and driver feedback from the tailpipe sound.

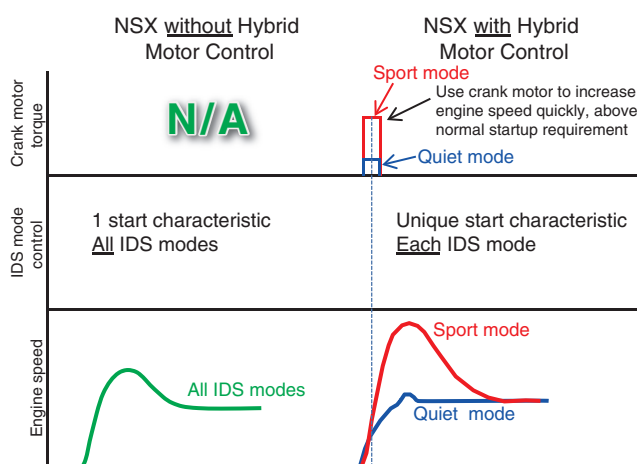


Fig. 11 Hybrid startup control concept

Table 4 Exhaust system specification detail

Specification	Valve closed	Valve open
Silencer volume and type	18 L Pass-through	18 L Side branch
Flow rate at 600 mmH ₂ O	134 L/s	444 L/s
Noise attenuation at 100 Hz	48 dB	34 dB

Table 5 Exhaust system sound IDS concept

IDS mode	Quiet	Sport	Sport+	Track
Control logic	Closed	Control by map	Open	Open
Sound concept	Maximize quietness	Balance comfort and sportiness	Max audible feedback	Max audible feedback

Silencer volume, flow rate, construction, and valve operation were thoroughly tuned to establish the final, post catalyst, specifications, listed in Table 4. An illustration of the final exhaust system with AEV is shown in Fig. 12.

Once the hardware specification was fixed, the focus shifted to the electronic control of the valves to achieve the vehicle sound concept. Each IDS mode has a different sound concept, so during extensive proving ground, on-road and dynamometer testing, the valve tuning was programmed to achieve the concept shown in Table 5.

For Sport mode, more extensive mapping was developed to ensure cruising comfort and spirited driving needs could all be met with the same setting. Maps were developed with accelerator pedal position, engine speed, and transmission gear as inputs to determine when the valve should be open or closed. Hysteresis was also included to prevent 'busyness' during driving around the map line boundary conditions as shown in Fig. 13. In other words, to prevent frequent valve operation during steady state cruising conditions.

The AEV is also used to accentuate the startup sound differences between Quiet and Sport modes. The AEV stays closed at Quiet mode startup to minimize exhaust noise and maintain the quiet character. While

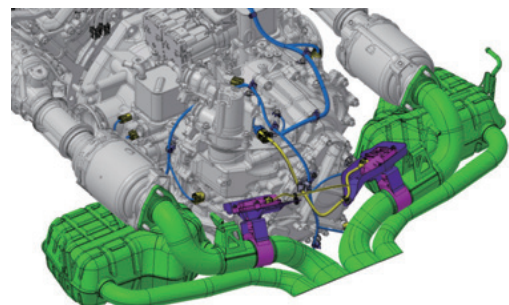


Fig. 12 Exhaust system with AEV

in Sport mode, the AEV is open during the engine startup flare to emphasize the startup sound, but closes after several seconds, to achieve the Sport mode concept of comfortable idle and cruising.

Exhaust noise performance of the final design specification has large differentiation between valve closed and valve open operation as shown in Fig. 14. The main order sound pressure level change is around 25 dB(A) and permits the customer to easily appreciate an audible sound change when switching between IDS modes.

The result of this exhaust system development is a versatile, single world specification system, which satisfies the vehicle sport sound concept, with the lowest post-catalyst system weight in its class at 12.3 kg.

3.4. Intake System and Intake Sound Control

The intake system of the original NSX is the single strongest contributor to the sports sound of that vehicle. The guttural, mid-frequency modulated intake sound is clearly audible in the cabin and very responsive to driver throttle input. This sound is created by the movement of the intake valve, and is accentuated by the VTEC™ system when valve lift increases dramatically and then becomes airborne through the air-cleaner orifice. Once the sound

becomes airborne, it can easily be heard by the driver, because the orifice is directly behind the driver's head.

On turbocharged engines, the intake valve source noise must travel the path highlighted in Fig. 15 before it can become airborne. The intake noise is significantly reduced by the increased intake pipe length, intercooler, and the turbocharger. The noise attenuation of the turbocharger varies by operating load, as highlighted in Fig. 16⁽¹⁾, and attenuates approximately 15 dB(A) in the combustion noise frequency range during acceleration. This high noise attenuation creates a significant challenge to achieve the vehicle's emotional sound target; therefore, a technical solution was devised.

After investigating multiple technologies, in an effort to provide the most authentic, guttural intake sound inside the cabin, a sound transmitting diaphragm was selected⁽⁴⁾. This technology connects to the high pressure intake duct, where the natural intake noise is present and has not been attenuated by the turbocharger. The diaphragm transfers the high pressure pulsations or source sound, to atmospheric pressure ducting, which can then be routed to the cabin and heard by the passengers, otherwise known as the output sound, as shown in Fig. 17.

Several technical challenges existed to implement this technology and achieve the vehicle concept for

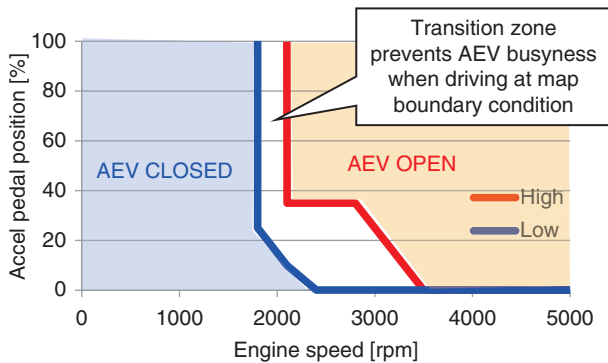


Fig. 13 AEV sport mode control logic map

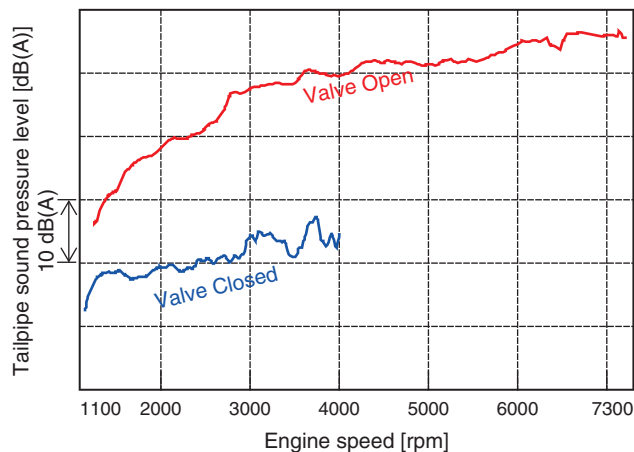


Fig. 14 Exhaust system tailpipe noise at full throttle acceleration

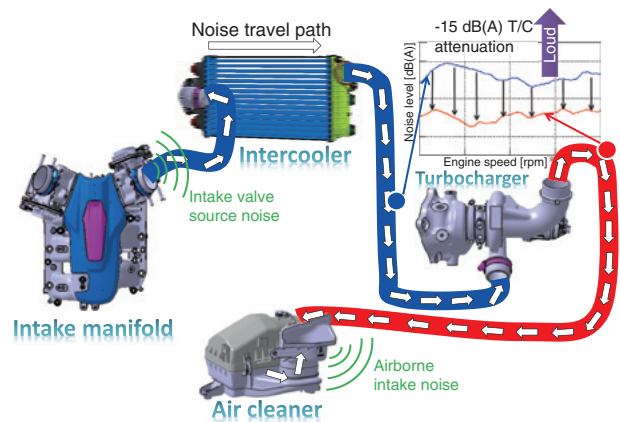


Fig. 15 Intake sound transfer path of turbocharged engine

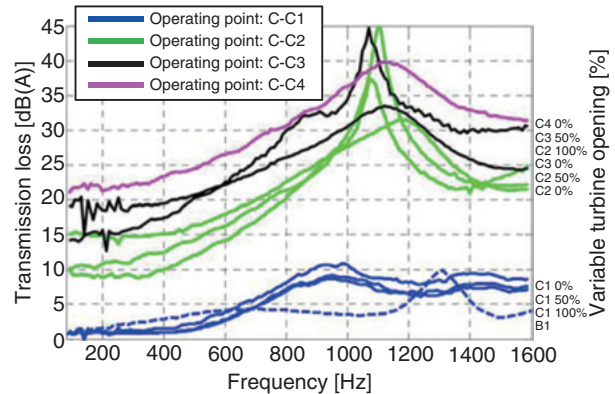


Fig. 16 Noise attenuation due to turbocharger

cabin sound and IDS mode differentiation, as shown in Table 6. The critical goal was to achieve a natural sound that has a strong link to acceleration response.

When considering the resonant frequency of the Intake Sound Control (ISC) System, there are four primary components as shown in Fig. 18.

- (1) L_1 pipe: High pressure inlet
- (2) ISC diaphragm
- (3) L_2 pipe: Ambient pressure left side duct
- (4) L_3 pipe: Ambient pressure right side duct

To achieve the desired cabin sound, these components have to work together in harmony. The diaphragm itself has some limitations, because it is an existing design. Retuning would require significant investment and R&D cost, which is not desirable on a low volume super sports car like the NSX. The challenge is to use the existing diaphragm design to match the target 450 Hz frequency range to achieve the heritage intake sound. The solution is to tune the $\frac{1}{4}$ wave resonances of the L_1 , L_2 , and L_3 pipes to coincide with the target frequency, and work with the good broadband response of the ISC diaphragm. The resonance calculation method is shown in Fig. 19. The duct resonant frequency is equal to the speed of sound in the medium (air) at the operating temperature of the engine, divided by the wavelength. The total system bench attenuation result is shown in Fig. 20.

Vehicle package studies were performed to determine feasible pipe lengths. A variety of pipe lengths were rapid prototyped and actual sound performance was measured by bench speaker frequency response testing. Using this process, the system

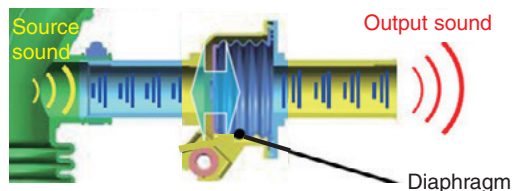


Fig. 17 Sound diaphragm functional layout

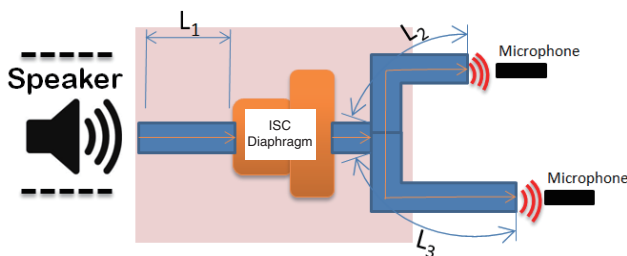


Fig. 18 Bench speaker system attenuation setup

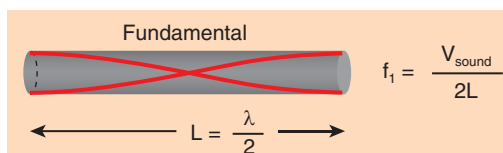


Fig. 19 $\frac{1}{4}$ pipe resonance calculation

Table 6 Intake sound control technical challenges

Technical Challenge	Solution
1. Create guttural intake sound matching NSX heritage sound	a. Tune diaphragm resonance to best match source noise input frequency and desired heritage intake frequency b. Design pre- and post-diaphragm pipe lengths of $\frac{1}{4}$ wave resonances to coincide with target frequency
2. Create IDS mode variable sound	a. Design a variable control valve with a vehicle integrated control system

performance and specifications were determined, and an illustration of the final ISC system construction is shown in Fig. 23.

Once component specifications were completed, feasible systems were installed in the vehicle and confirmed by chassis dynamometer and on-road testing. The cabin sound was evaluated by microphone data and subjective judgment. As shown in Fig. 21, the ISC system achieved the targeted frequency of the original NSX, and by subjective driving evaluation, the 'guttural intake sound' character is easy to appreciate.

In addition to the tuned pipes and diaphragm, the ISC system is equipped with an electronically controlled valve between the high pressure pipe and

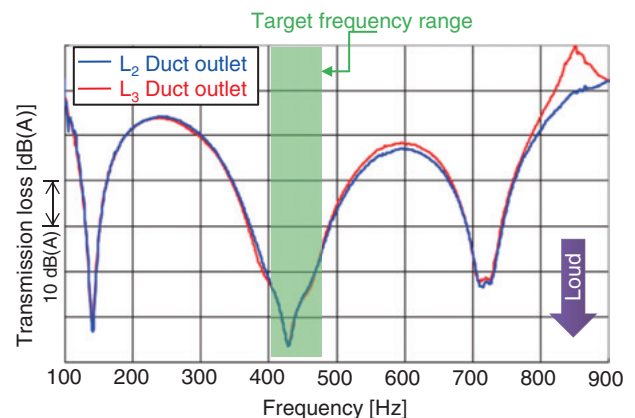


Fig. 20 Bench speaker attenuation test result

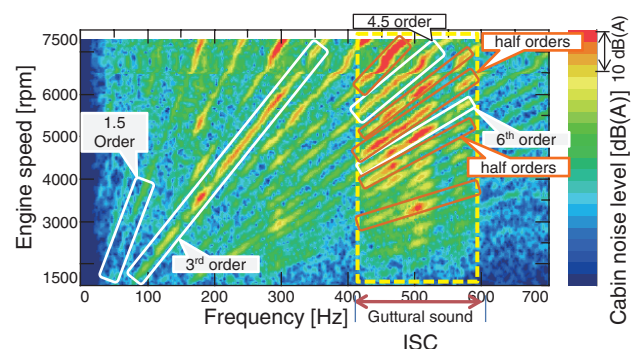


Fig. 21 Final ISC cabin sound at full throttle acceleration

the diaphragm. This valve enables control of the sound output of the system to achieve the engine sound targets for each IDS mode. In addition to separation of the IDS modes, a control map for the valve angle was developed to create a linear sound increase with RPM and avoid resonance peaks and valleys. The ISC control valve can quickly adjust position based on driver control and engine operation inputs. The inputs to this system are accelerator pedal position, engine speed, transmission gear, and IDS mode. To this end, map tuning was performed on the chassis dyno, and then confirmed on-road, to achieve the desired sound progression at various throttle angles, engine speeds, shift points, and IDS modes, as shown in Fig. 22.

Additionally, the ISC system and corresponding control valve is used to accentuate the transient sound response, as a driver aid function. For example, when the transmission downshifts, the engine throttle opens to rev-match the engine and transmission speed, and correspondingly, the ISC valve opens, and creates a short burst of sound. This sound alerts the driver that a downshift has occurred, so the driver doesn't need to look down at the gauge cluster, and can focus on driving. The blue line in Fig. 22 shows the ISC valve open angle mapping during a downshift, getting more aggressive with each IDS mode.

3.5. Active Sound Control

Active Sound Control (ASC) is a Honda-exclusive engine sound enhancement system, that uses the vehicle's audio system to add engine order sound to the cabin⁽²⁾. It uses several inputs, such as engine speed, accelerator pedal position, IDS mode⁽⁵⁾, and acceleration rate. Several engine orders can be added, and in the case of NSX, four orders were chosen, with the purpose of filling and smoothing the sound around the other sports sound devices. The orders are

separated into two separate strategies:

1. Low RPM Powerful Sound: 3rd and 1.5 orders are introduced to add to the low frequency noise floor and accentuate powerful sound during low rpm driving. This sound is appreciated at tip-in or low throttle accelerations.
2. High RPM Shrii Sound: 3.5 and 4.5 orders are introduced at high accelerator pedal position and high RPM to heighten the audible tachometer sound, helping the driver distinguish audibly when the engine is approaching redline.

The gain level of each ASC order with respect to engine speed is shown in Fig. 24

3.6. Combustion Stability Control for Emotional Exhaust Sound Feedback

One exciting aspect of super sports cars is the sound the driver experiences at transient conditions. Analogous to racecars, sports cars also tend to 'snap, burble, and pop' at shift timing or over-run situations and the NSX sound concept incorporated this spirit. This sound was achieved by creating unstable combustion at transient circumstances, by adding ignition retard, based on engine load and engine speed, as shown in Fig. 25. When the combustion is delayed, the exhaust valve begins to open before the combustion process is completed, allowing complete combustion to finish in the exhaust system, providing an audible 'snap, burble, and pop'.

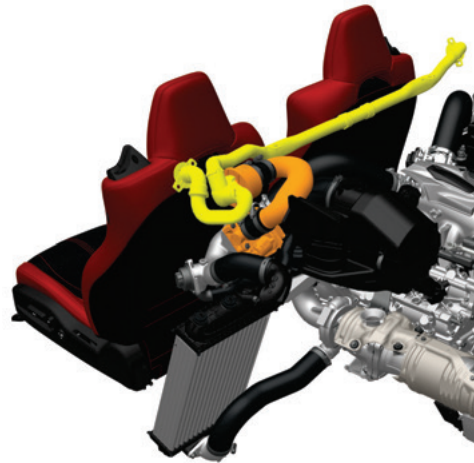


Fig. 23 Final ISC system construction

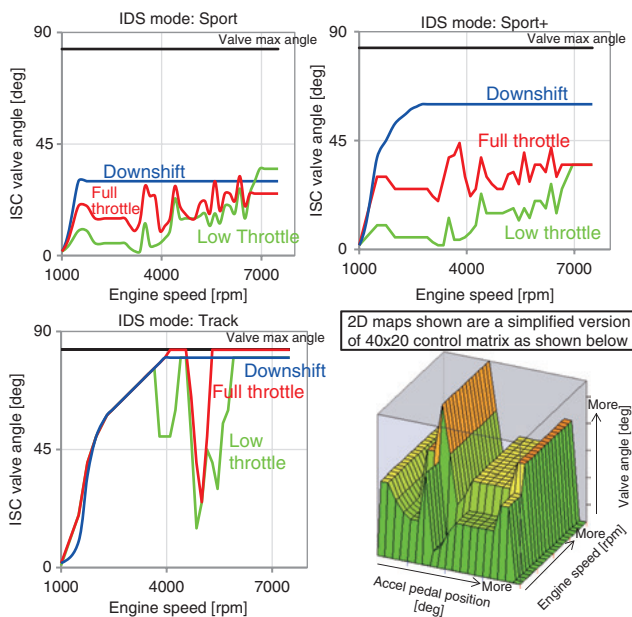


Fig. 22 ISC valve mapping by IDS mode

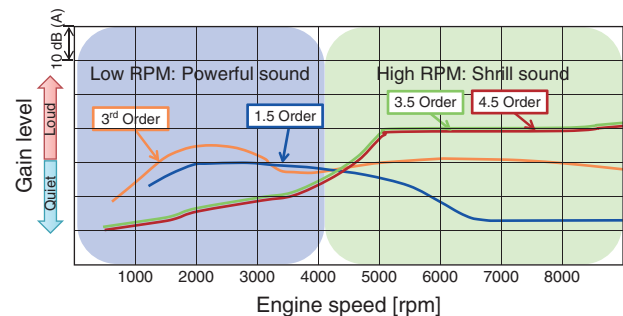


Fig. 24 ASC order gain map

This sound also has a functional purpose. The sound can be an indicator to the driver that a change has occurred. Examples are gear shifts, lift throttle, or light throttle application, where the driver might normally need to look down and check gauges to confirm gear position or engine speed; the driver can instead focus on driving with eyes on the road.

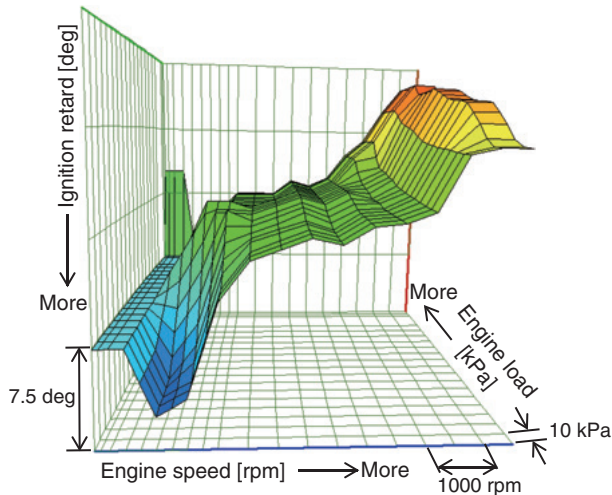


Fig. 25 Ignition retard map

4. Validation

Combining all of these sound technologies into a single package required extensive proving ground and public road driving to achieve the vehicle sound concept for each system and confirm the systems work together in harmony. Prototype vehicles were tested and tuned in the numerous situations a customer will drive their NSX. This included everything from race tracks and highways to the winding canyon roads of Malibu, the Autobahn of Germany and winding mountain roads of northern Italy and Austria.

The electronic controls for each sub-system are tuned individually to match the IDS mode intended driving conditions shown in Fig. 5. The quiet platform of the NSX enables the sport sound devices to create a wide dynamic range of sound, which can be appreciated by the driver as the sound responds directly to his or her inputs. The addition of each sound device contributes a unique flavor, combining to make the NSX character sound. Figure 26 shows the contribution of each system to the cabin sound during acceleration compared to the original NSX. Engine noise in the cabin was reduced compared to the original NSX in order to meet the Quiet mode concept, and additional technologies were added to achieve 2015's sports car market competitiveness. The contribution of intake and exhaust systems to the overall cabin sound during acceleration remains similar to the original NSX, realizing a balance that celebrates the legacy of NSX sound.

Figure 27 shows the final sound performance of

the mass production spec vehicle during full throttle acceleration in third gear. The sound performance matches the original sound concept, with sound levels that are distinctly different between IDS modes. The frequency contribution of each device is shown in Fig. 28. Each of the systems contribute to a different frequency range and combine to create a unique aural spectrum which achieves the sound concept components explained in Table 3.

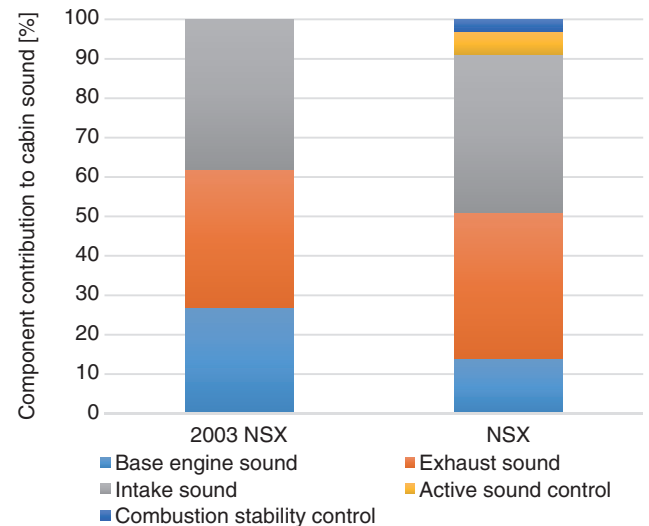


Fig. 26 Component contribution to engine sound during acceleration

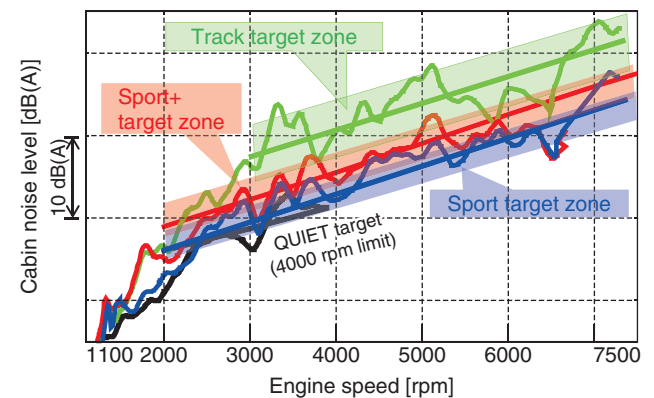


Fig. 27 Final acceleration sound in each IDS mode

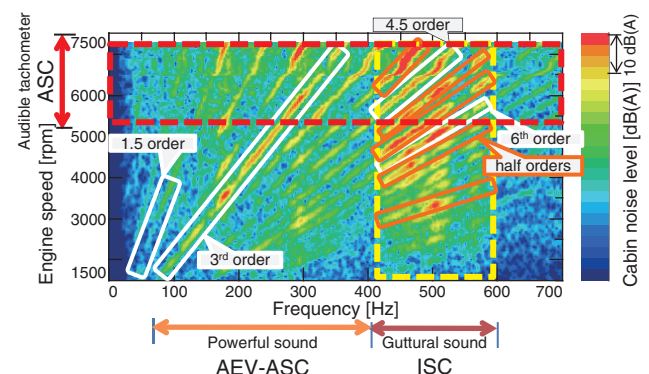


Fig. 28 Final sound achievement frequency content

Figure 29 shows the final sound quality achievement of the mass production spec vehicle during full throttle acceleration in third gear. The high number of orders is achieved by the combination of ISC, AEV, and ASC systems, combining harmonic and guttural modulation sound into a single package.

Figure 30 shows how the NSX bridges the gap between sedan and super-car, accomplished through multiple personalities, available for the driver to access with the flick of a knob. This brings a truly New Sports eXperience, a no compromise super sports car, one that can be comfortably driven every day, over short or long distances, spirited canyon road driving, or even on the racetrack.

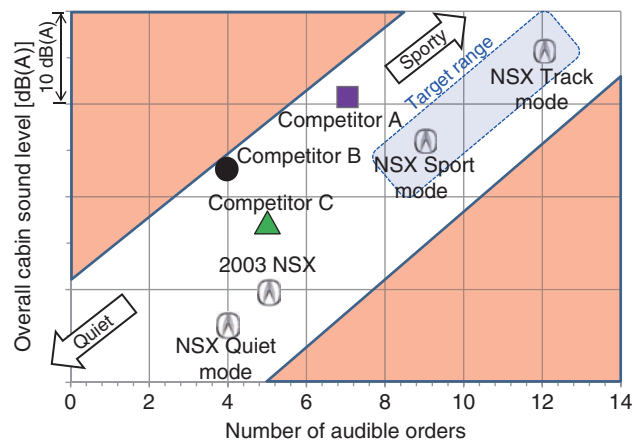


Fig. 29 Final cabin sports sound achievement during full throttle acceleration

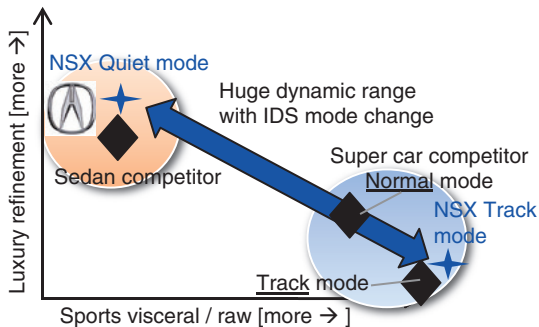


Fig. 30 Final sound achievement competitiveness

References

- (1) Tiikoja, H., Rammal, H., Abom, M., Boden, H.: Sound Transmission in Automotive Turbochargers, SAE Paper, No. 2011-01-1525
- (2) Kobayashi, Y., Inoue, T., Sano, H., Takahashi, A., Sakamoto, K.: Active Sound Control in Automobiles, in INTER-NOISE and NOISE-CON Congress and Conference Proceedings, Vol. 2008, No. 4, Institute of Noise Control Engineering, 2008, p. 5001-5009
- (3) Dunne, G.: Recent Advances in Powertrain Sound Quality Hardware Tuning Devices and Perspectives on Future Advances, SAE Paper, No. 2009-02192
- (4) Jackson, A.: A Comparison Between Active and Passive Approaches to the Sound Quality Tuning of a High Performance Vehicle, SAE Paper, No. 2013-01-1878
- (5) Park, D., Jo, E., Hong, S.: Development of Personalized Engine Sound System using Active Sound Design Technology, SAE Paper, No. 2015-01-2216

5. Summary

The system discussed in this paper was developed to realize the potential of the next-generation sports car with a New Sports eXperience. The system integrations create strong emotional sound connected with acceleration feeling, along with functional sound feedback to the driver. Additionally, the system supports the IDS concept to permit the driver to have direct control of the cabin sound experience.

■ 著 者 ■



Steven EICH



Jared COX



柳瀬 浩