Sound's Important

SAE 2009 Noise and Vibration Conference and Exhibition

Luncheon keynote speech
May 19, 2009

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Technical Director
Motor Trend Magazine

Thanks for that introduction, and I do appreciate the opportunity to be here and share some thoughts on how the nature of **a vehicle's sound and vibration** can impact the way customers and the press perceive its build quality and refinement, which ultimately affects its sales potential. I'm also looking forward to making a direct, personal plea for some NVH developments I'd like to see. I should note that I drove my vintage 1967 Maserati Ghibli over here from Detroit to reacquaint myself with how much cars have improved in terms of road and wind noise, how irrelevant sound systems once were, and what automakers can still aspire to in terms of engine noise.

I'm sure most of you are already avid readers, but for anyone who isn't, *Motor Trend* magazine and *MotorTrend.com* comprise one of the biggest automotive enthusiast media brands in the U.S., with circulation of about 1.1 million per month in print and some 3-1/2 million unique visitors per month on the web. **How did a master's degreed** mechanical engineer who hasn't had an **English** class since high school end up evaluating and writing about cars?

Well it all started back in 1963, when I was born in nearby Chicago with a stainless dipstick in my mouth. The memory is admittedly hazy, but I think I recall noting the slightly harsh ride quality of the 1960 Chevy Bel Air 2-door sedan I rode home from the hospital in. My car evaluation career really took off when I became able to speak well enough to **talk different families** into driving me home from Sunday school in their cars. Since then, almost every dollar I've earned has been in the car business, and it usually has involved driving someone else's car for money. I started out in high school as a parts runner for an Olds dealership, then midway through college I got a summer internship with Chrysler that resulted in a permanent job offer in the Chrysler Institute training program, where I met Greg Goetchius, now of MSC. (It's Greg's fault I'm here today.) I spent six wonderful years at Chrysler, ending up in **Advanced Vehicle Packaging**, where I frequently drove competitive vehicles to evaluate their interiors and ergonomics. Then one day the phone rang, and a friend told me about a job opening at a car magazine. It was the automotive equivalent of running off to join the circus, and I couldn't resist. I spent 13 years at that other magazine whose name escapes me just now, before switching to *Motor Trend* five years ago. I took a big pay cut to join the circus, and I'll never make as much as captains of industry like my pal Greg, but I now drive someone else's car every day, and it is tons of fun.

As I mentioned in my abstract, reviewing cars is a lot like **test-driving** a car at the dealership, which I'm sure you've all done at some point or other. Part of the job is gathering and reporting the first impressions a vehicle makes on all of the driver's senses. In that way, spending a day or week in an important new car is a lot like spending a day or a week in an interesting **foreign city**. All senses go on heightened alert, recording every nuance of the vehicle's tactile, audible, visual, and emotional expression. Vehicles are complex creatures with personalities, and each one of them is trying to say something if you can tune in to what it is. You've probably all rented cars that may have told you pretty loud and clear **"I'm a pitiful unloved orphan that only a tight fleet accountant would order,"** right? But tuning into the messages more sophisticated cars are trying to get across requires skills like those of a character actor. Because before any driving impression can be converted into words of evaluation, the driver needs to channel the psyche; the wants, needs, aspirations and life stage of the target buyer the vehicle in question is intended to appeal to.

One day I may need to wriggle into the skin of a college student with bad credit sweating it out in a **$9995 Nissan,** cursing my decision to purchase a noisy, crude brand new car with no air conditioning, realizing how many sins of NVH a radio can cover, and wishing I'd opted for a two-year-old Honda Fit decked out with a smooth, sonorous engine and all the mod-cons. The next day I may be an important plutocrat, piloting a BMW 7 series and wondering how the company imagined a guy accustomed to yelling "JUMP" and hearing his underlings whimper "how high?" could possibly tolerate an insubordinate user interface like the **first-generation iDrive?** Once in a while I need to imagine being a short female with fingernails evaluating a low-priced two door coupe with a manual transmission like the Ford Focus. Okay, in these cases I usually try to enlist the help of an actual short, finger-nailed woman. Only very occasionally do I get to relax and sample a car like the Ford Fusion Hybrid, which seems tailor-made for mid-life nerdy geeks who can derive endless entertainment hypermiling to generate leaves and stalks on the dash display and feathering the accelerator to remain in silent-running mode as much as possible.

Some exercises make this acting challenge easy, like when we gather 10 mid-size four-cylinder family-sedans in one place and get the entire staff to drive the cars back to back over the same roads. These sorts of exercises always draw stark contrasts, as happened in August 2008 when we described the VW **Passat's** turbo engine as **"charismatic,"** the Toyota **Camry's "silently unobtrusive,"** the Accord's a **"Revvy gem,"** and the Ford **Fusion's** as **"obtrusive" and "hoarse."** Perhaps not surprisingly, that was their finishing order. By way of constructive criticism of the fifth place finishing Fusion we actually implored Ford to "Bring the NVH guys doughnuts and coffee for a nonstop month of overtime. Trust us, you'd be nipping at first place here." (Any Ford NVH guys here that can confirm whether that happened or not?) Actually, the evidence suggests it did, because Ford HAS redesigned the Fusion since then, improving refinement exponentially, allowing it to finish in a near dead heat with the Accord just last month.

Other occasions like our annual Car of the Year competition presents a daunting character-acting challenge, as we each cycle through 20 or more cars that may have nothing in common except that they're brand new that year. Still, driving, testing, poking, and prodding that many cars back to back prompts many useful observations.

We described the door- and trunklid closure sound of the otherwise charmingly ’70s retro Dodge Challenger as **“disconcertingly Nixon-era.”** The Pontiac G8 had a similarly tinny, rattly timbre that suggests low build quality and parts moving around more than they should. Both of those cars scored tops in engine note for their spectacular fourth-order V-8 rumbles, but neither managed to advance as a top-ten finalist.

By and large your community has much to be proud of, because it seems that every time a vehicle is redesigned, the new version is **smoother, quieter, and more refined** than the one it replaces. It’s almost becoming an expected truism like Moore’s Law—though I’m not sure I’d peg the improvement as exponential at this point. And while the computer community expects the **Moore’s Law doubling** every two years of computer processing speed, memory capacity, etc. to continue through at least 2015, I rather suspect that vehicle NVH is approaching an asymptote of minimum achievable sound level (in fact, there is already a movement afoot to **add noise back into** silent-running EVs and HEVs for blind pedestrian protection). But for now Quiet Steel, acoustic windshields, and laminated side glass and similar NVH abatement terms seem to crop up in most new vehicle launches I attend these days.

It’s a sign of how far automotive quality has come in the last decade that things like wind noise and squeaky brakes now rank as the top reported complaints in **JD Power and Associates** surveys. We’re keeping our fingers crossed that the resolve to eliminate noise and improve those Power rankings survives the dual pressures of **cost-cutting** and **weight-reduction/fuel-economy** improvement that all manufacturers are feeling.

Of course, I don’t need to tell you that every improvement one of you achieves makes life more difficult for someone else in this room. Muffle the **sizzling white noise of the tires**, stifle a few of the most unpleasant frequencies of engine noise and suddenly the sound made by the squirrel-cage blower becomes noticeable and a bit unpleasant. Hush that and a hundred other quiet interruptions break the newfound silence, some of which will surely manifest as JD Power liabilities if they don’t register as a test-drive turn off in the first place, killing the sale. We’re back to those first impressions. That tinny door-slam sound is a potential deal-killer. Some other egregious noises I made note of during the 2009 “of the year” contests include a buzz in the headliner of the Toyota Matrix that, in combination with its excessive wind noise would definitely have killed the sale for me and helped eliminate it from serious contention;

…the **Jaguar XF Supercharged** sedan's engine rocked the car at idle, there was an unseemly concentration of wind rush at the driver's mirror, and its steering wheel transmitted unwanted vibrations from road imperfections. These deficiencies helped spoil an otherwise scintillating driver's car. Of course, plenty of cars registered positive impressions as well. In our SUV of the year contest, the new Chevy Traverse crossover's direct-injected V-6 sounded far sportier and more engaging than the similar-sized sixes in the Ford Flex and Dodge Journey. And Hyundai's new Genesis luxury sedan distinguished itself as the quietest car on our road-noise and vibration evaluation loop.

Throughout my 18 years scribbling about cars, I can recall plenty of comparison tests in which first impressions of sound quality have helped a car win. The world's biggest engine manufacturer, Honda, has outsung its rivals plenty of times, often in econobox or family sedan comparisons where the Civic or Accord invariably out-revved its competition, making smooth, sweet music as it did and helping establish a sporting character missing in its Toyota or Nissan rivals that helped give it a leg up when the rest of the cars' attributes were too close to call.

Anyone who reads any car magazine knows that the stirring note of a **BMW straight six** has proven irresistible to magazine editors for decades, though more recently high prices, controversial styling, and iDrive frustrations have occasionally knocked the Roundel brand off the winner's podium. I can also think of a few cases in which a stirring engine note **made a car seem faster than it was**. The new Hyundai Genesis Coupe V-6 is a case in point where most editors have been surprised to find performance numbers that were lower than expected after driving the car. Of course, I suppose this is better than having a car that sounds slower than it is.

There is also such a thing as not enough engine sound. I recently test drove the all new Ford Taurus SHO, with a twin-turbo 3.5-liter EcoBoost V-6 engine. It makes a rousing **365 horsepower and 350** pound-feet of torque, and its standard all-wheel-drive system puts the power down nicely, but the sound level is perhaps a bit too subdued for a sport sedan, and there's absolutely no whistle or wastegate noise coming in from the turbos. That seems to be a trend these days. BMW's twin-turbo six has no audible turbo soundtrack, nor can you really hear the whine of the supercharger on the latest **four-lobe Eaton units** powering the Corvette ZR-1, Cadillac CTS-V or Jaguar XFR. Maybe I'm old school, but I always kind of got a kick out of those noises we used to pay a lot to hear.

So we've covered some examples of sound quality or quantity making a good or bad first-impression during a customer's test-drive that could influence a sale one way or the other. NVH can also have a huge impact on brand loyalty over the longer run. Some companies strive for a signature sound quality that keeps customers coming back and often compensates for myriad shortcomings. Case in point: The Ferrari 308/328/348. Aside from its Pininfarina styling, the unmistakable wail of that flat-plane-crankshaft Ferrari V-8 was perhaps its **only redeeming feature** (those were truly bad cars—underpowered, unreliable, evil handling—especially at speed). Actually, Ferrari's a great case in point for tailoring engine sound quality. These days Ferrari casts, machines and assembles a V-8 for four very different cars: it's own front-engine California and mid-engine F430 and Maserati's GranTurismo coupe and Quattroporte sedan. All four start with the exact same casting and the machining and assembly happens in the same room. But the Maseratis use a more typical cruciform crankshaft while the Ferraris use flat-plane cranks. The bores and strokes are different, as is most of the hardware, allowing the **Ferraris to rev to 8500 rpm**, wailing all the way in that stunning tenor range, while the Maseratis spin to 6500 or 7000 rpm and sing in a much deeper register—one that even forty years later sounds directly descended from my Ghibli, and utterly unrelated to its **historical archrival Ferrari**. They all sound spectacular and pay homage to their respective brands, pleasing the faithful of each.

Similarly, there's no mistaking the sound of the boxer-six engines that power the Porsche 911, Boxster, and Cayman. And in the more down-to-earth price range, **Subaru flat-four and six** cylinder engines have a characteristic sound that fans of the brand have come to love, especially aficionados of the Impreza WRX and STI. **Nissan's VQ** family of V-6 engines have a distinctive bark that the Z crowd has come to revere, though to these ears the latest version displacing 3.7 liters is now bordering on harsh.

Most of what customers and the press perceive as "Good" NVH has to do with the **Noise leg of the tripod,** so that's what we've concentrated on thus far. I can't think of any good harshness, but there are vibrations that we auto-writer types love to wax rhapsodic about, and those are the little twitches and wiggles that travel up through the steering wheel and brake pedal to tell the enthusiast driver what's happening down where the rubber meets the road. These particular vibrations can inform an experienced driver about how close the tires are to their limits of adhesion, how the road's **coefficient of friction** might be changing, and how the available grip is being apportioned between lateral (cornering) and longitudinal (acceleration/braking) duties.

Transmitting these **little twitches and wiggles** up through the suspension and steering system is pretty easy in light-weight cars that carry way under half their weight on the nose. Rear- or mid-engine cars like the Porsche 911, Boxster and Cayman; the Lotus Elise and Exige, Ferrari F430, Audi R8, and others never fail to inspire **purple prose amongst the Fourth Estate**. The task of transmitting these wiggles and jiggles becomes more difficult as the front-axle load increases and front tire width goes up, but a few manufacturers still manage to filter out the unwanted road impacts while delivering the good vibes. BMW has been in the vanguard, though some recent entries, like the current 5 and 6 series are less impressive in this regard. In any case, the engineering challenge of leaving these vibrations in appears to be much greater than that of removing all vibration, but I hope some of you are up to that challenge.

I am impressed by some of the ingenious ways sound is being engineered into cars these days, sometimes by simple methods like altering the way the pipes in a true dual-exhaust system communicate with each other. The Corvette is a perfect example of this. The big-lunged 7.0-liter Z06 bellows an entirely different exhaust note than its big brother the 6.2-liter supercharged ZR1 does, and it's mostly to do with the exhaust crossover.

In the Z06 there's a perpendicular H-pipe connecting the left and right banks. In the ZR1, there's a true X-pipe that **commingles the exhaust** and sound pulses that go with it, transforming the Z06s' guttural, angry tone into a more refined and high-strung note. Still other cars utilize sound pipes to direct desirable engine sounds directly into the cabin. Ford's V-8 Mustang does this. A pipe connects to the intake manifold, separated by a membrane that vibrates like a speaker to transmit sound without permitting any airflow in or out, and this pipe broadcasts that sound against the firewall. It's effective. Having recently sampled all the Detroit-Three's pony cars back-to-back, I can tell you that Ford's original pony produces the most pleasing V-8 rumble in the herd. BMW's Z4 and others are using similar approaches.

Then of course there's better sound through electronics, aka active noise cancellation, which for the moment is mostly being used to stifle unpleasant engine frequencies. Honda's Odyssey minivan was one of the first to employ the vehicle's stereo system to produce an out-of-phase boom to counteract the one coming from its V-6 engine when operating in 3-cylinder mode. It's hard to believe this approach could really make much difference—until you drive an Odyssey with the system disabled.

Others have jumped on this bandwagon, one of the most recent being the 2010 Chevy Equinox/GMC Terrain small crossover utes, which employ a similar system that incorporates a microphone above the first row of seats that samples cabin sound and directs the stereo speakers to generate tones needed to quell any booming produced when the base four-cylinder engine operates under low-speed, high-load conditions with the torque converter locked. Obviously both of these cases offer an opportunity for **sound engineers to help enable fuel-saving technologies** with little or no weight penalty and minimal cost, perhaps offsetting other NVH countermeasures that may present fuel-economy challenges. I believe there have also been active noise cancellation research projects that sought to relieve exhaust backpressure by canceling sound waves electronically, but developing a speaker that will tolerate the extreme temperature environment of the exhaust system has proved daunting.

Of course, my absolute favorite NVH “cheat” is Sound Synthesis, or active noise creation if you will. It’s part of a suite of active noise technologies Lotus appears poised to commercialize along with its **Active Road Noise Cancellation** and **Active Engine Order Cancellation**, which work as described above.

Sound Synthesis adds new and **presumably more pleasing** engine orders, played over the sound-system loudspeakers as a function of both the engine speed and throttle position to produce a more sporty sound and in many cases compensate for exhaust notes hushed in order to pass strict European noise pass-by regulations. I haven't had a chance to sample the Lotus system, but I did try out a different riff on this idea presented by **Siemens** in 2002 at SAE Convergence. Their system placed a dedicated noise-generating speaker up in the intake system, driven by the engine-control unit. The demonstration vehicle was an ordinary Honda Accord V-6 sedan, but as I drove around the city streets outside Detroit's Cobo Hall, the engineer in the passenger seat twiddled his laptop computer, transforming the typical V-6 growl into an utterly convincing V-8 burble, then to an ultra-smooth V-12's turbine hum. I believe they even had a setting that kind of aped a V-10, though that one didn't register as quite as convincing to me (and in any case, I tend to think multiples of 5 just sound wrong). I was blown away by the effectiveness of this system, which struck me as a marvelous way for a large, multi-brand corporation like GM to achieve product differentiation with enhanced brand character across a line of vehicles sharing common powertrain architectures.

At the time, the Siemens reps claimed that the cost of its system was roughly the same as the fairly extensive array of resonators and acoustic dampers that were then being applied to Lexus's flagship LS sedan, but that costs could likely drop with further development and wider use. They also claimed that at that point the technology could not be applied to four-cylinder engines in a cost-effective manner (too many additional resonators and so forth were required). Siemens sold its automotive division to Continental AG, who apparently sold this division to Mahle, and I have been unable to track down what's become of it since then, though I hope someone in this room is toiling away on commercializing it ASAP.

Speaking of which, let's get to that personal wish list of NVH causes I hope someone out there will champion:

1. **Fourth-order for four-bangers.** Whether we need speakers in the intake, exhaust, or cabin, or some new passive technology that I haven't heard of yet, I want four cylinders to sound like eight. With green technology and fuel savings all the rage, the future existence of the V-8s I grew up loving is in danger, but if we could make these proliferating four-cylinder engines sound bigger and richer, it would will make them a whole lot easier to accept.

2. **Bank-vault door-slams for all.** Surely accomplishing a solid-sounding door slam is achievable without resorting to pricey electronics or even thick, heavy mastics, right? Making better use of the various goop and pads that go into a door already and coordinating that material to work better with the increasingly modular components that mount inside the door can certainly be made to end tinny, rattly door slams in our lifetime, right?
3. **Good vibrations.** It's time someone cracked the code to determine how it is some car companies manage to take all the good wiggles and twitches generated by the tires and send them up through the various suspension hardware to the steering wheel for the enjoyment of the enthusiast driver. BMW, Maserati, and a handful of automakers have had a lock on outstanding steering feel for long enough. I have the sense that the chassis dynamics folks have been working on this project alone, and maybe they could use some help from their pals in the NVH arena.
4. **Cool Sounding Electric and Hybrid Vehicles.** We may need some serious innovation here, because simply playing a synthetic internal-combustion engine note over an electric motor seems like cheating and is ultimately looking backward. The enthusiasts of the future are going to need something to make them love inherently quieter cars like the Tesla Roadster. Maybe gear whine and the resonance hum of a high-voltage controller can be combined to generate the "it" sound of the 21st century. Maybe electrics need stepped-gear transmissions just to provide that rising and falling engine note we're accustomed to. I don't know what it will sound like, but I trust you'll give me an electric-car sound I can wax poetic about.

So to sum up, customers in this shrinking new-car market are becoming pickier than ever, and they're telling folks like JD Power and Associates that NVH is incredibly important to them. The sounds and vibrations a vehicle produces have always been important to those of us who drive and report on all new vehicles, and differences in sound quality or quantity play an important role in determining the outcome of crucial comparison tests and of-the-year awards, which ultimately influence car sales (or at least that's the story our ad sales guys pitch). In any case, your work is important and your job has never been more difficult as the industry faces a drive toward reduced mass and cost while improving overall efficiency, and as we gradually move toward vehicle electrification. But I have every confidence in your ability to leverage current and future technologies like noise cancellation and synthesis to meet the challenges ahead.

Thank you.

Sound's Important

Frank Markus

Technical Director,

Motor Trend Magazine

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Technical Director,

Motor Trend Magazine

★ CROSSOVER COMPARO: VENZA VS. EDGE VS. MURANO ★

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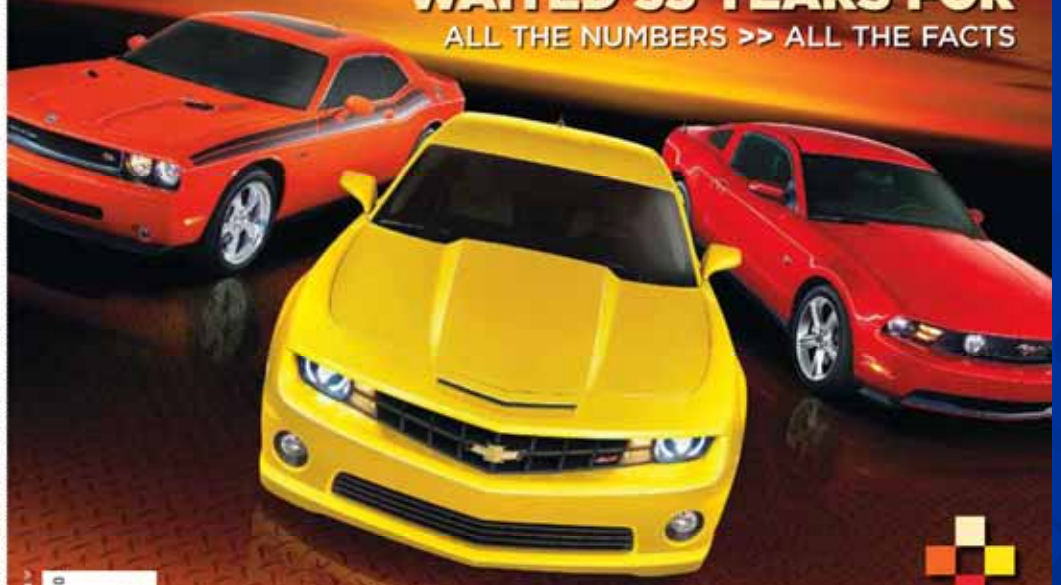

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JUNE 2009 VOL 51, NO. 6

The budding auto critic…

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The whole small car category has just been upgraded. Our new Omega is a revolutionary small car.

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Omega is quick and agi rack-and-pinion steering. A Omega ride is smooth.

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Remember, the circled E is for comparisons to other c mileage depends on speed, and trip length; your actual mileage will probably be lower than the highway estimate. California

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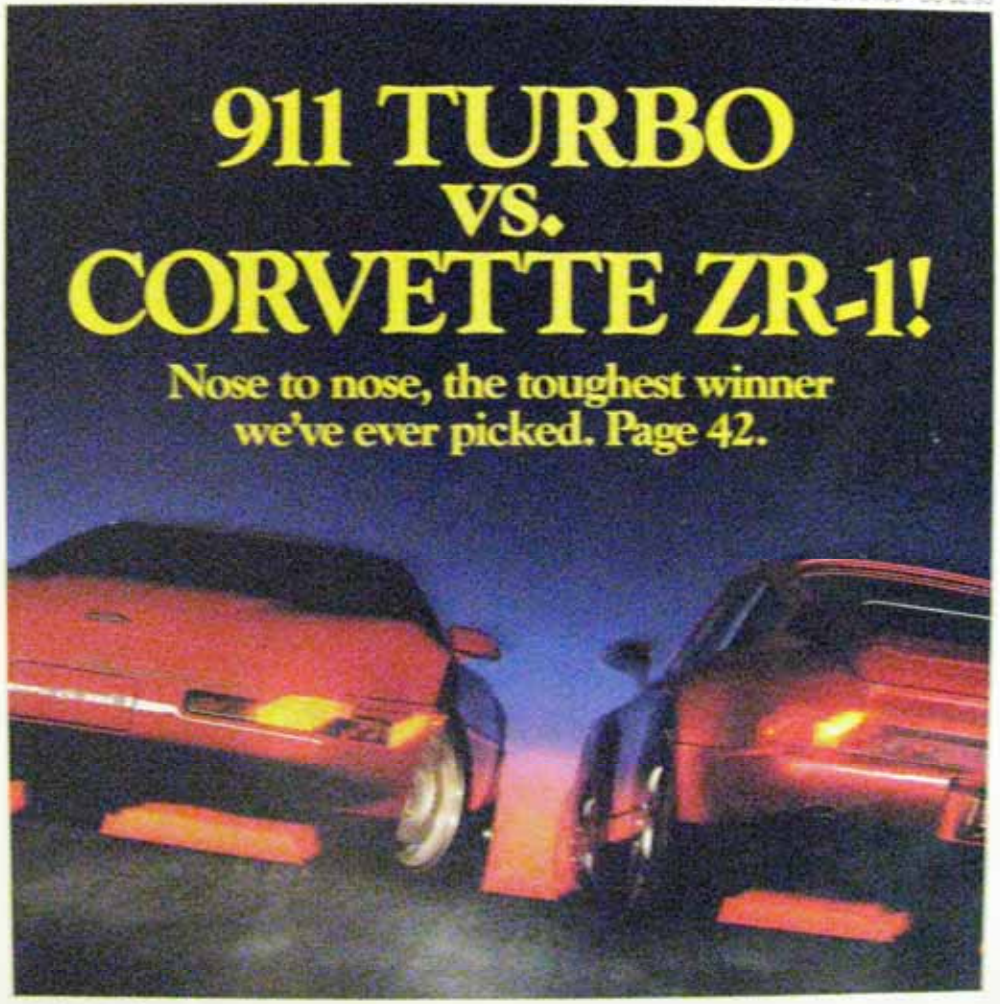
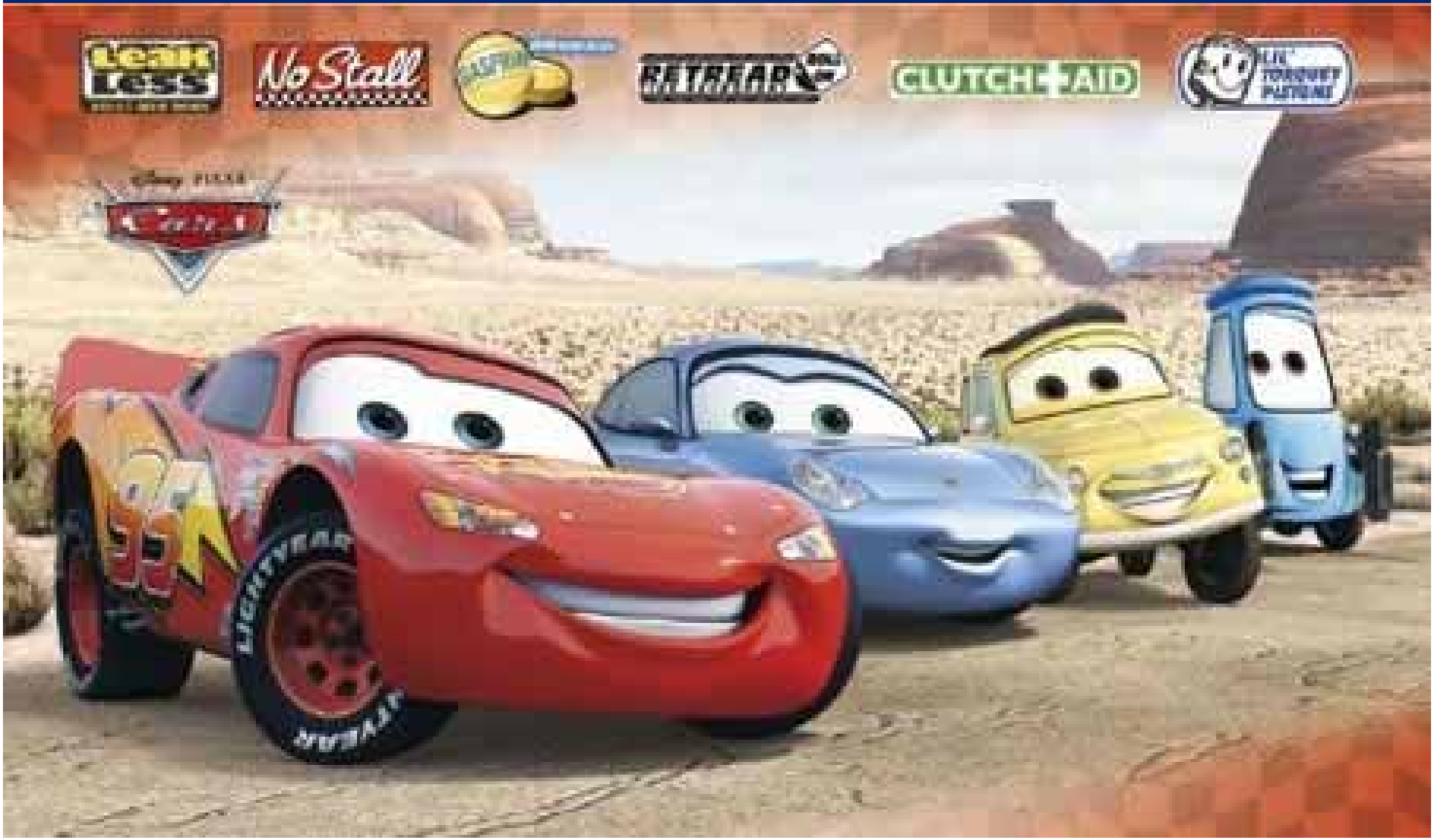
911 TURBO vs. CORVETTE ZR-1!

Nose to nose, the toughest winner we've ever picked. Page 42.



Outrage: An official of your own government actually admits to enjoying performance cars.
Outrageous: World's fastest (175 mph) sedan.

All cars have something to say…



(comparison) NISSAN VERSA

THE GOOD
No A/C—nice in Santa Barbara
Quiet interior
Plush ride
Rear doors
Surprising rear room
Lockable trunk
It's shiny and new

THE BAD
No A/C—bad in Phoenix
Roll-up windows provide exercise
Manual door locks
No clock
Who shrunk the engine?
Try selling it

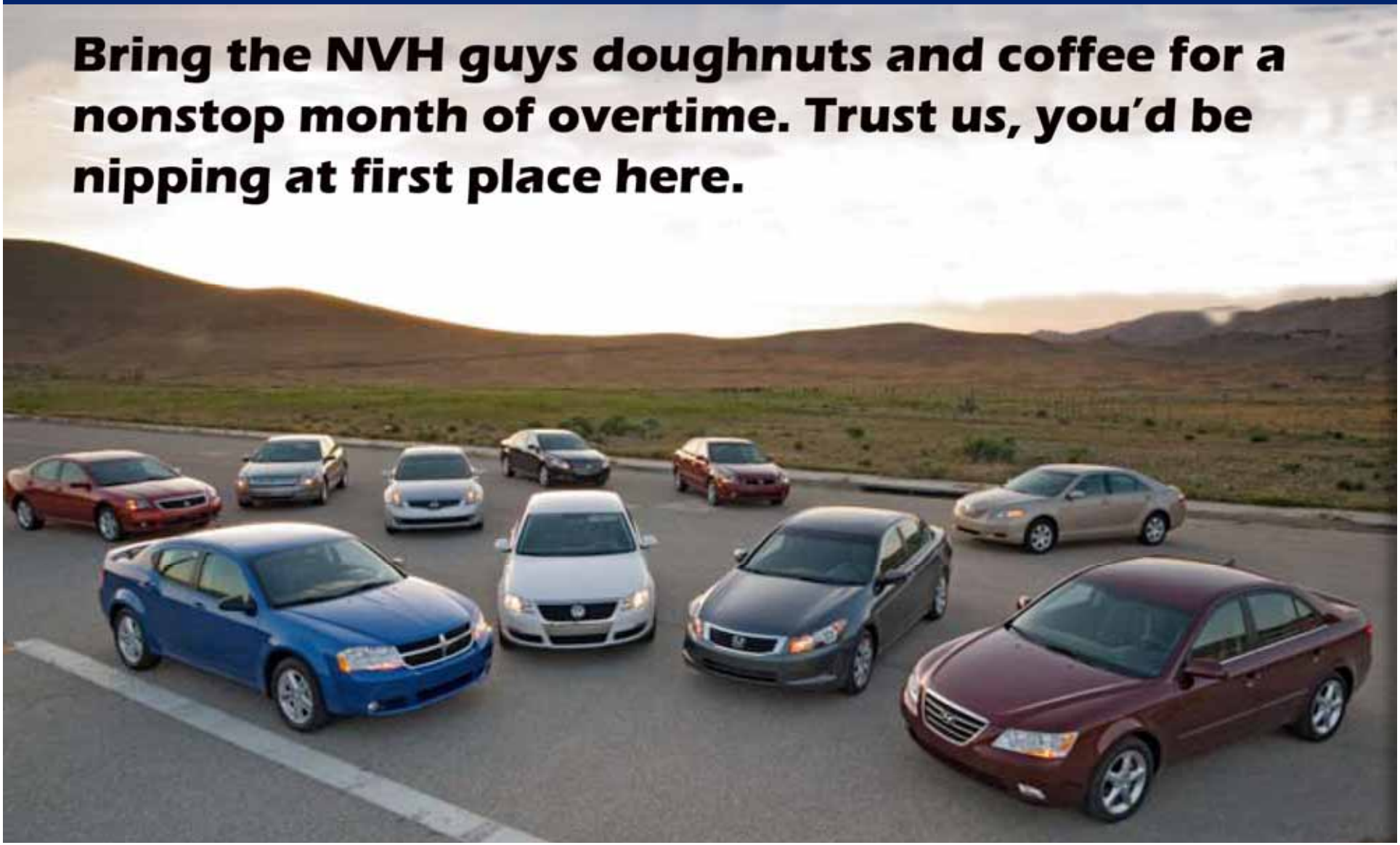
THE UGLY
Interchangeable driver and passenger experience
Container Store design motif
Comatose steering

BMW i(nsubordinate)Drive

Fusion Hybrid: Geek-friendly display

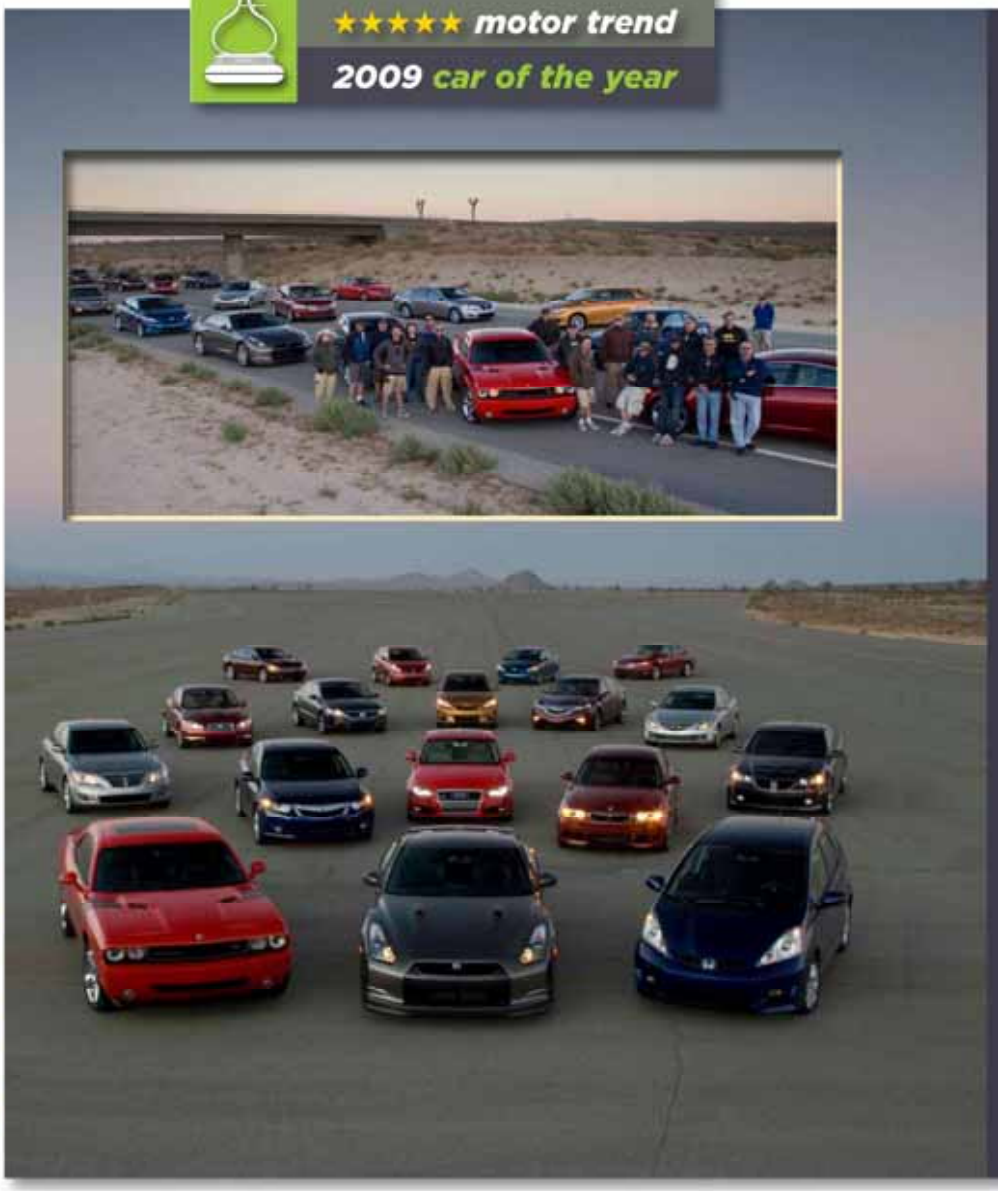
10 Sedan Comparison Test

10 Sedan Comparison Test



★★★★★ motor trend

2009 car of the year



the best of years, the worst of years

AS THE ECONOMY TANKS, THE AUTO INDUSTRY ROLLS OUT ONE OF THE STRONGEST COTY FIELDS EVER

• words **motor trend editors** • photographs **brian vance/julia lapalme/william walker**

WHAT A YEAR! A struggling auto industry, already knocked sideways by $4/gallon gas, has been king-hit by the meltdown on Wall Street in 2008. It's a tough, bloody business out there for every automaker—no matter how good the performance, the styling, the gas mileage, the value; without credit a lot of people simply aren't buying new cars.

The irony is 2008 was a vintage year for cool, interesting, and compelling cars. Of the 17 all-new or significantly upgraded vehicles eligible for the 2009 Car of the Year award, a bunch were real show-stoppers. Hero cars included the Euro-chic Jaguar XF, the star-spangled Dodge Challenger, and the techno-thrill Nissan GT-R. BMW's tight, taut 1 Series, Pontiac's suavely muscular G8, and Audi's coolly restrained A4 promised real driver entertainment. Hyundai's surprising Genesis, Honda's cheeky Fit, and Lincoln's glitzy MKS were all hugely significant contenders, for widely differing reasons. Stylemeisters included the Volkswagen Passat CC, the Mazda6, and the Nissan Maxima.

But only one could be voted Car of the Year.

Widely imitated and frequently copied, *Motor Trend*'s Car of the Year award dates back to 1949, making it the oldest in the world. It's not a comparison test—each vehicle is judged against the three criteria: significance, superiority, and value—and the award is open only to new or significantly upgraded new cars on sale from January 1 each year. That's why you don't see our personal favorite cars recycled on these pages year after year.

No other award in this country has such clearly stated criteria or is backed by hands-on testing and analysis like ours. In fact, one Web site last year actually boasted its awards process took just two hours and $120 worth of Chinese food. We spend a little more time and money than that: *Motor Trend*'s Car of the Year judging is an exhaustive process that involves more than a week of detailed track testing, driving evaluations on real world roads, and lots of in-depth discussion and debate. See for yourself by checking out the videos at motortrend.com.

But to begin the car-by-car countdown to the winner, just turn the page.

THE CRITERIA

SUPERIORITY
Engineering excellence, advancement in design, utilization of resources and safety. Vehicle concept and execution are important, as are use of materials, packaging, dynamics, styling, and fuel consumption.

SIGNIFICANCE
How well does the vehicle do the job its maker intended it to do? And how does it impact or change its particular market segment, influence consumer perceptions, and transform product development trends?

VALUE
How does each vehicle compare against its direct rivals? A vehicle with a low sticker price might not be as good a value as a more expensive vehicle that delivers outstanding performance, quality, and functionality.

THE JUDGES

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JIM HALL
Grand Vacuator
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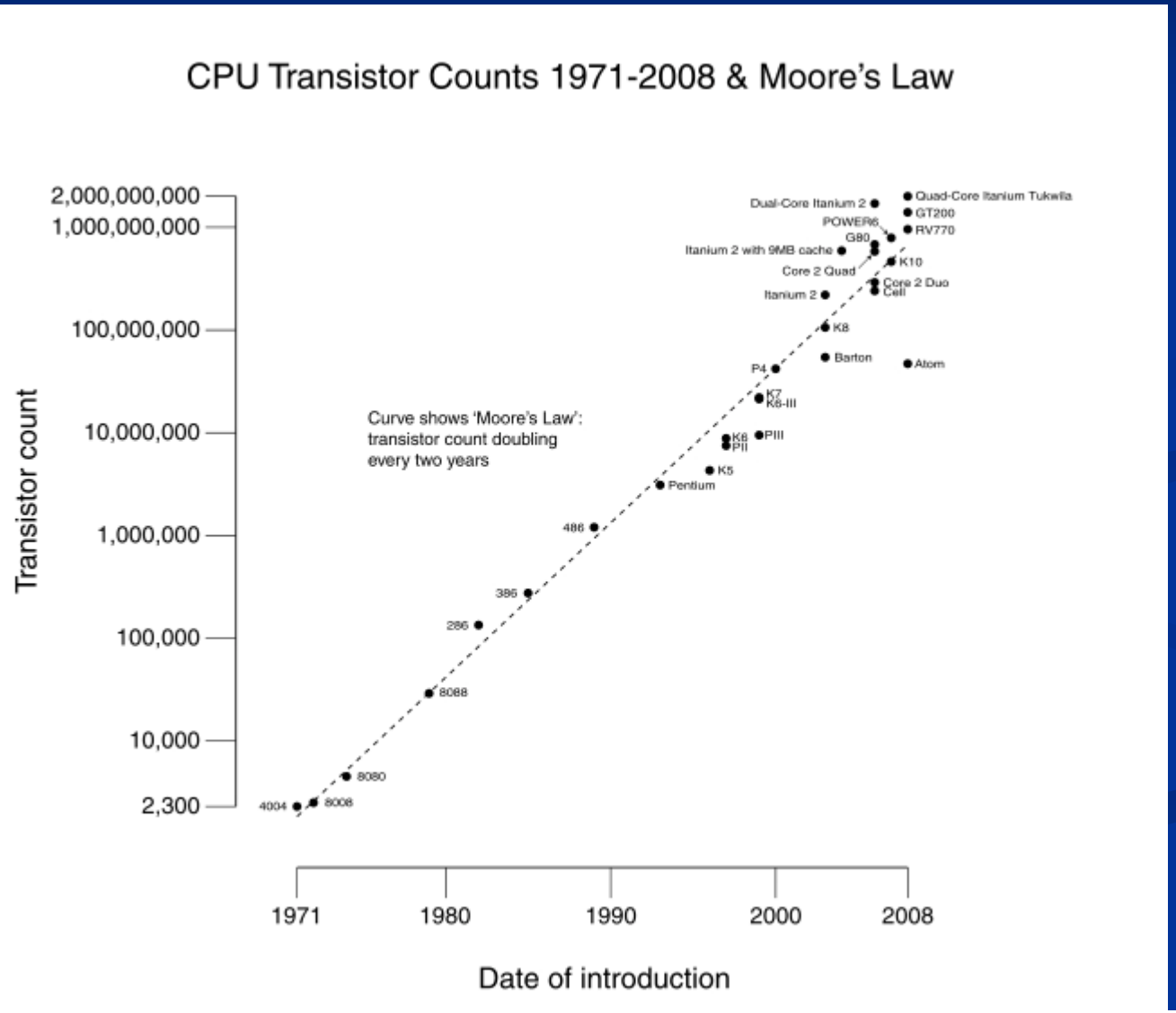
Moore's Law


CPU Transistor Counts 1971-2008 & Moore's Law
Transistor count
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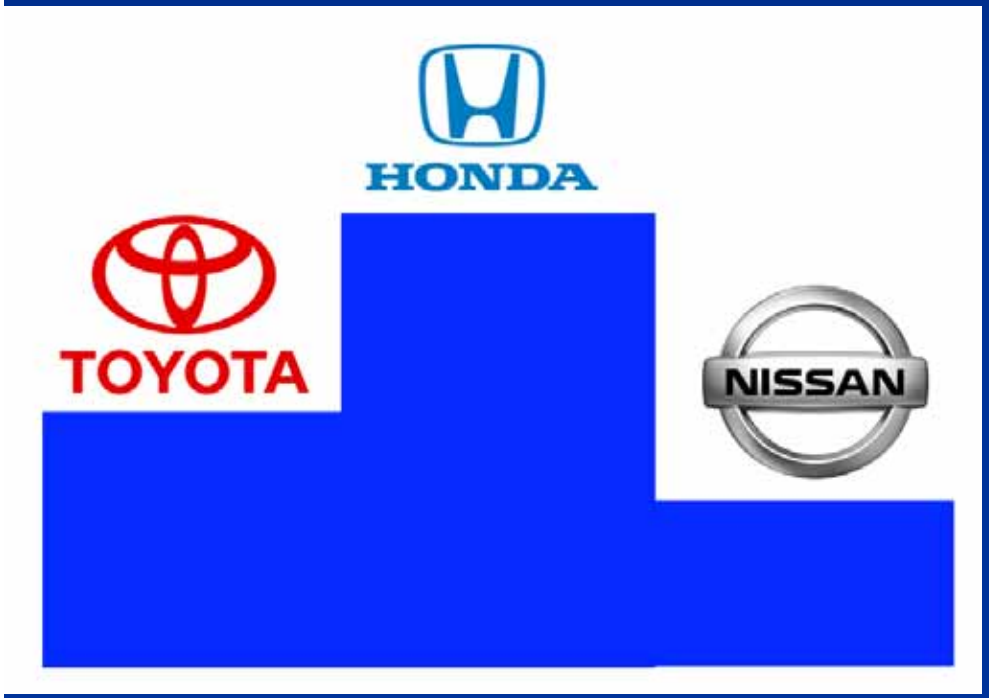
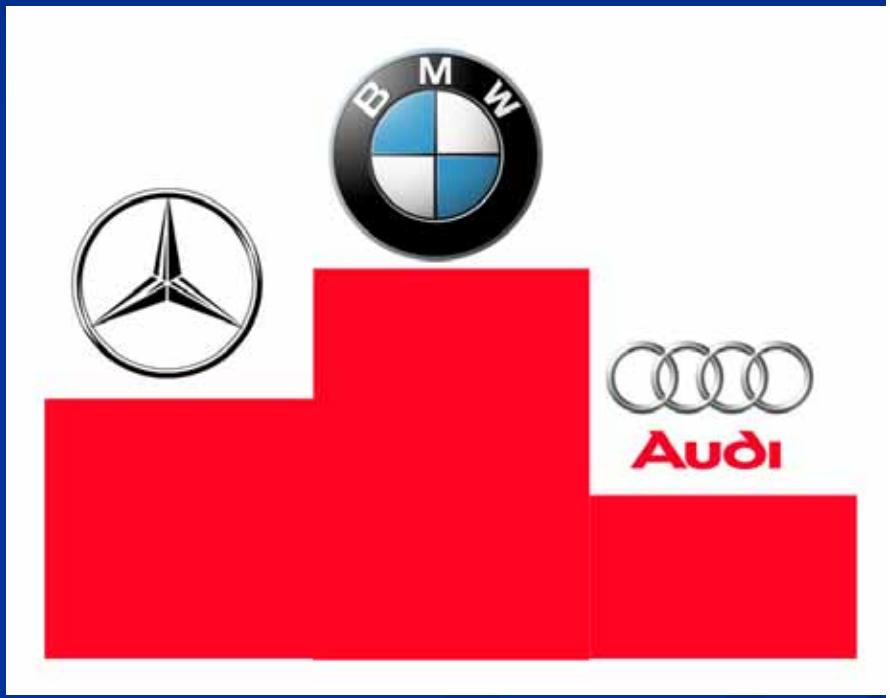
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
2,300
Curve shows 'Moore's Law': transistor count doubling every two years
Dual-Core Itanium 2
Quad-Core Itanium Tukwila
GT200
POWER6
RV770
G80
Itanium 2 with 9MB cache
K10
Core 2 Quad
Core 2 Duo
Cell
Itanium 2
K8
Barton
Atom
P4
K7
K8-III
K8
PII
PIII
K5
Pentium
486
386
286
8088
8080
8008
4004
1971
1980
1990
2000
2008
Date of introduction

NVH cost these four…

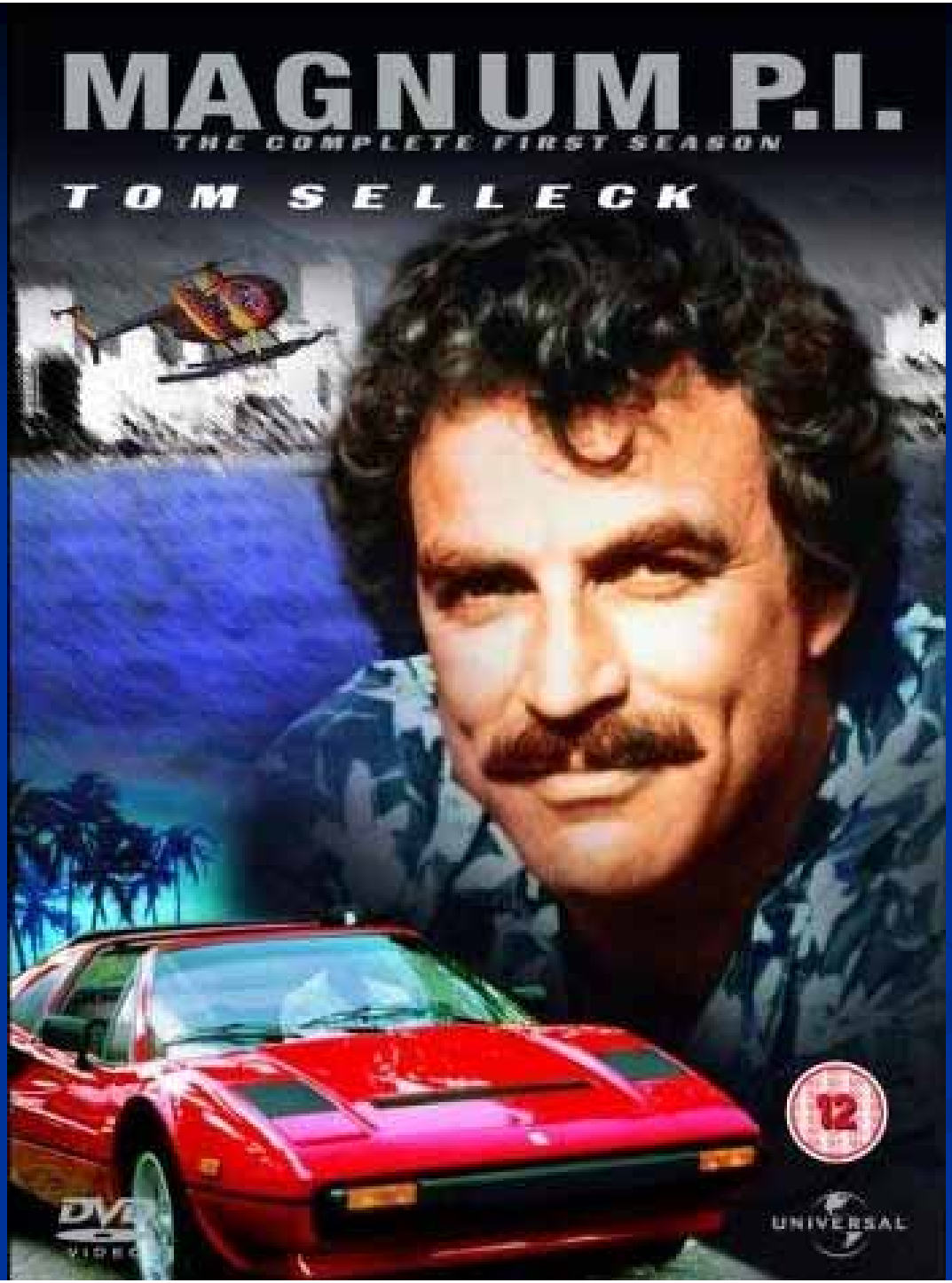
. . . and helped these 2

Perennial NVH Champs





2010 Ford Taurus SHO


MAGNUM P.I.
THE COMPLETE FIRST SEASON
TOM SELLECK
12
UNIVERSAL

4 very different personalities, 1 engine casting

Ferrari California

Ferrari F430

Maserati GranTurismo (left) and Quattroporte (below)

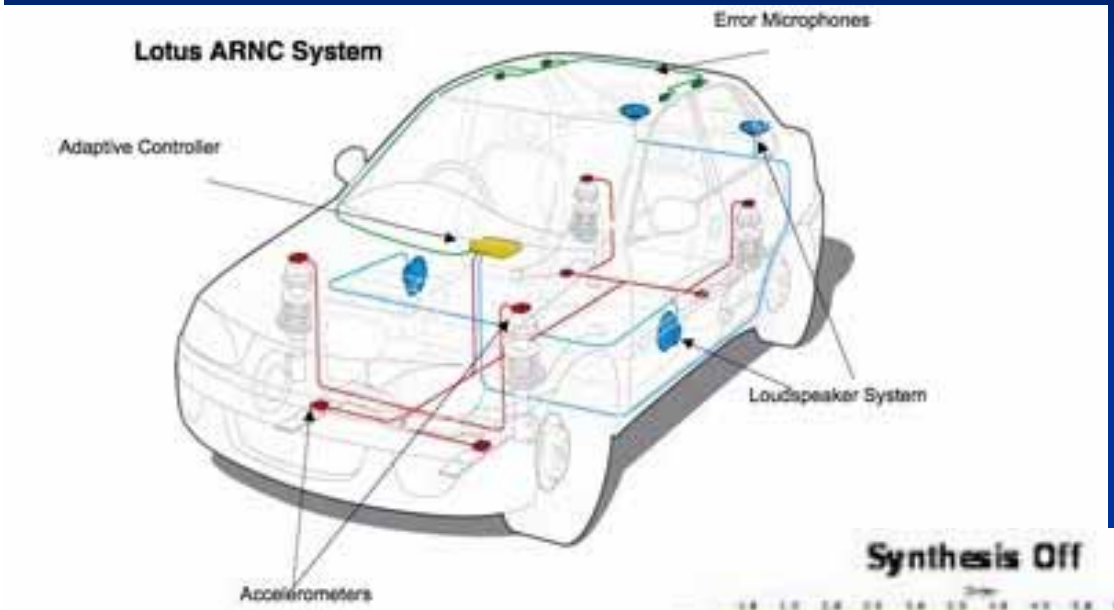
Perennial Sound Favorites

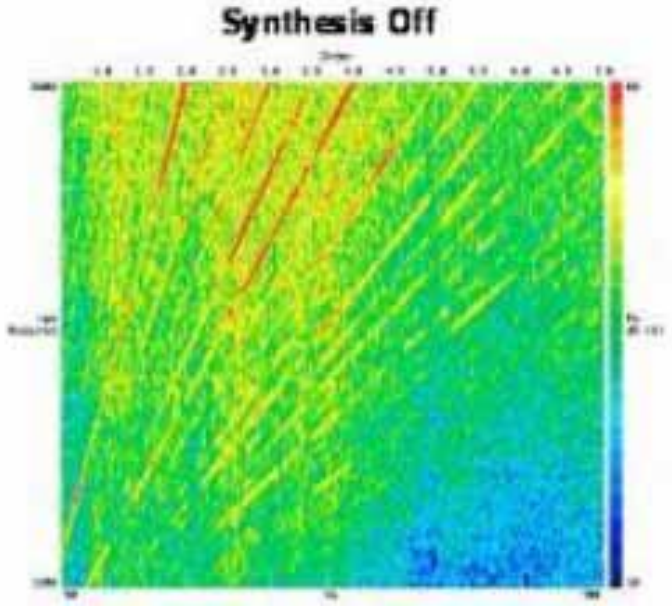
Good Vibrations

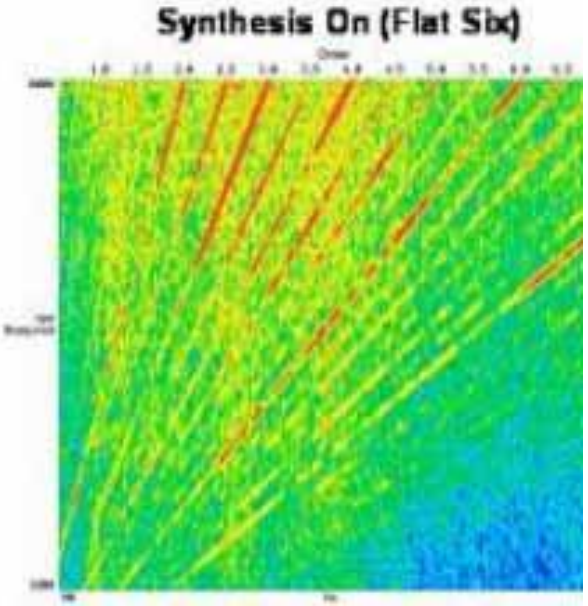
X- versus H-pipe

Noise Cancellers

Lotus Sound Synthesis







Frank's NVH Wish List

1. Fourth-order for four-bangers
2. Bank-vault door-slams for all
3. Good vibrations
4. Cool Sounding Electric and Hybrid Vehicles.

Thank you!