Sports car racing technology

Le Mans series race car engineering reached a high-water mark in 2002, but will likely recede in 2003.

by ***Dan Carney***

The 2002 sports car racing season included **Volkswagen**'s **Audi** division reaching its goal of three successive dominant wins at the La Sarthe circuit of the 24 Hours of Le Mans. It also saw the third straight season of frustration and disappointment for **General Motors**' **Cadillac** division. The third consecutive victory earned the Audi team the right to keep the trophy in Wolfsburg rather than returning it after a year. Despite achieving nearly opposite results over the last three seasons, both factory teams reached the same conclusion after the 2002 campaign—time to stop. The independent **Panoz** team has soldiered along with variations of the same car since the 1997 season, but it still manages the occasional race win.

With the withdrawal for 2003 of the two primary factory programs, sports car racing technology will probably not advance again until 2004, when fresh rules take effect. The new rules, which permit underbody ground effects, are meant to reduce the incidence of accidental flight that has plagued the current flat-bottomed generation of cars.

Audi three-peats with FSI

Audi's domination during the 2000-2002 period has awed observers. Viewers were shocked to see the team, during the 2000 Le Mans race, bring a car into its garage and replace the entire gearbox and rear suspension assembly in a scant four and a half minutes. The team seemed to have the fastest cars, the biggest budget, and the best execution at races, and the combination made the silver cars nearly unbeatable.

But it wasn't magic that made Audi so good, according to Head of Audi Sport, Wolfgang Ullrich. It was just hard work and constant improvement to what began its existence as the best car in the series. Audi began its program in 1999, with a pair of forgettable designs—the R8R and R8C. The purpose of these conservatively designed cars was to test the waters for the new car program, which had been headed by veteran endurance racing team of Reinhold Joest.

The rules for Le Mans racing prototypes permit both open-cockpit Le Mans Prototype 900 and closed-cockpit Le Mans GTP 900 designs, but they mandate smaller tires for the more slippery closed machines so that the popular open cars can be competitive. The "900" indicates the minimum weight in kilograms for both classes. Audi wanted to determine which approach would be faster and fielded examples of each type in 1999.

The Le Mans-winning Audi R8s from 2002, 2001, and 2000 (left to right) show the slight evolution of aerodynamic detail during the era when Audi has dominated the famed race.

According to Ullrich, the cars developed in 1999 were sport prototypes or "standard" cars. "The idea was a very conservative approach," he recalled.

The company's previous experience was with touring cars built on modified production unibody chassis, so the purpose-design composite monocoque tub designs of Le Mans cars were a significant departure. "It was a quite intense step in technology and development," he said.

The result was a decision to go with the open cockpit design, but to try to minimize the aerodynamic penalty of that choice. "We took the decision to make for 2000 a new car, with new ideas," said Ullrich. "We wanted to make the car's technology under the bodywork as slim as possible to reduce drag to the minimum and try to make the aerodynamic efficiency of the car as high as possible." Packing the hardware as low in the car as possible let designers make the body sleeker and improved handling. The result is low drag for high-speed circuits and good handling for low-speed circuits and chicanes at faster tracks.

Twin polished plenums highlight an intake system designed to maximize power output despite a pair of 32.4-mm (1.28-in) intake restrictors and a 24.2-psi (167-kPa) turbo boost limit.

Abundant wind-tunnel time involving persistently whittling and smoothing of the car, rather than some hidden secret design aspect, made the car fast. "It is a lot in details. It is very efficient bodywork, very efficient aerodynamics," said Ullrich. The details included finishing cooling ducts for smoother airflow, reducing friction of moving parts, and optimizing suspension geometry on a dynamic testbed.

"The ability to run very well on either very-high-speed circuits or very-low-speed circuits is what has made this car very successful," he said. "I think this is the secret to its success." Another important factor is ease and speed of repair, because failures and damage are inevitable parts of endurance racing. "We made the car easy to maintain and major components easy to change quickly," he said.

When competing teams recovered from the sight of Audi's jaw-dropping gearbox swap at Le Mans in 2000, they scurried home to outfit their cars to allow similar service. **Cadillac** and **Panoz** now claim the ability to make a change in around five minutes, but haven't been able to demonstrate that during races because of associated damage that slowed the repairs.

Audi designed the amazing gearbox and its housing, but the all-important gears inside are provided by **Ricardo**. Shifting is by a now-conventional six-speed pneumatic paddle shift, instead of the sequential shift lever that has been commonly used until recently.

Audi didn't limit the modular design to just the rear of the car. The front impact-absorbing crash box structure and the splitter (the aerodynamic shovel-like aid on the front of the car) were designed for quick changes. The front bodywork and easily damaged cooling ducts are also made for ease of service. So the modularity extends throughout the car, according to Ullrich. "We wanted to have a low number of big components that can be changed very quickly," he said.

In an approach similar to **BMW**'s Formula One racing program, Audi decided to keep its engineering effort in-house rather than farming work out to racing specialist shops. The result has been a boost for the morale of employees, and a reduction in the typical off-season shuffling of key personnel, because the engineers were Audi workers and not members of a racing team.

"[The racing program] was like a virus that went through the company," said Ullrich. "Everyone was keen to give us support."

Despite the insistence that success was the result of a combination of small details, the Audi team did enjoy one feature that no other team employed: a gasoline direct injection system developed by **Bosch**. The original car that won Le Mans in

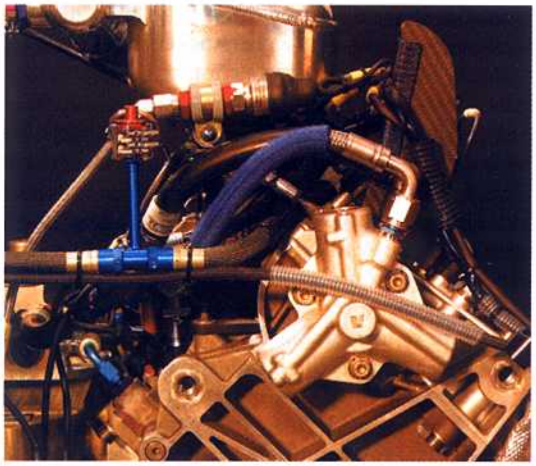
2000 used conventional port fuel injection, and its success emboldened Audi to gamble on the direct injection system. Now the 3.6-L twin-turbo V8 produces 610 hp (455 kW).

The Bosch direct injection system uses a high-pressure pump to send fuel at 1450 psi (10 MPa) to electromagnetically controlled injectors. Those injectors blast the high-pressure fuel stream directly into the combustion chamber. During partial throttle operation, direct injection supplies a stratified charge that is rich near the spark plug, but lean elsewhere to save fuel.

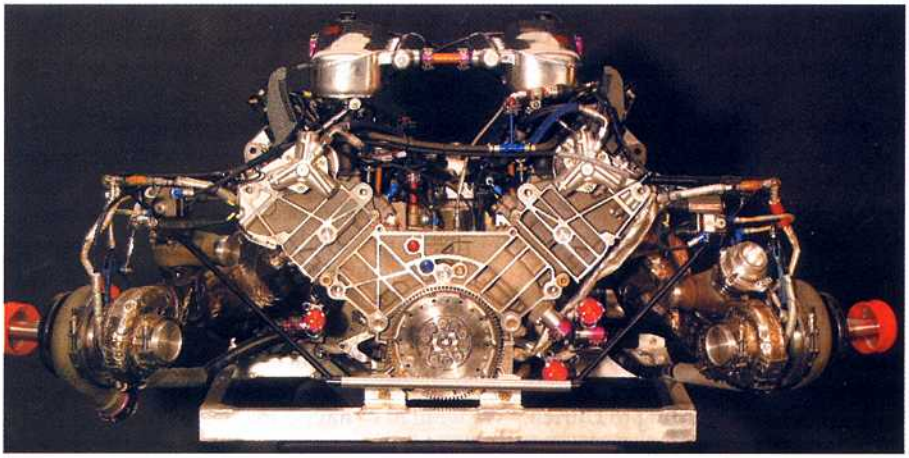
Direct injection has the potential to boost fuel economy by 15% in street applications according to many estimates, but the rigors of racing cut that to an actual 8% fuel savings in the race car. Fuel economy may seem like the least significant factor for a race car, but it is especially important in endurance racing. Better fuel economy means that a car can carry a lighter fuel load and make shorter pit stops than competitors. Or the team has the strategic option of carrying the same fuel load but stopping less frequently to refuel.

The benefit caught the attention of competing teams. "The Audis get 25% better fuel economy than we do," observed Rick Mayer, race engineer for the Panoz team's #50 car driven by David Brabham and Jan Magnussen. "So for a 2 hour 45 minute sprint race, it is a really tight two-stop green flag race for us." That means the Panoz team has to run a leaner fuel mixture than it would run for maximum power, or that it has to keep driver Brabham in the car longer, because his driving style returns better gas mileage than Magnussen's, according to Mayer.

"With better fuel efficiency, you have the advantage on strategy," acknowledged Ullrich. "You can be the last one to come in on refueling and you can tune your strategy to the race conditions."



The Bosch high-pressure fuel pump is a key component of the R8's gasoline direct injection system that delivers fuel to electromagnetically controlled injectors at 1450-psi (10-MPa) pressure.



The effort to lower the R8's center of gravity as much as possible with the 90° V8 led to mounting ancillary components on the engine's sides.

Tuning the Bosch engine management system to optimize the direct injection system was simpler than tuning Audi's production direct gasoline injection engine, according to Ullrich. "In the work that we do on the race car, low revs, low throttle angle, and exhaust emissions aren't a (focal) point for us," he said. But that doesn't mean there aren't benefits from tweaking the engine map. For the 2002 season, Audi improved on its already proven engine through such tuning. Peak power at redline is limited by a pair of 32.4-mm (1.28-in) restrictors in the air intake that limits the volume of available air. But the company improved torque characteristics and fuel efficiency by toiling on the software during the off-season. Driver Emanuele Pirro offered high praise for the twin-turbo engine: "The engine responds to the throttle like a normally aspirated unit."

For most components and subsystems on the chassis, Audi turned to traditional racing suppliers, working with them to customize components to suit the R8. **Michelin** is the dominant tire supplier in sports car racing and provides tires to Audi, which mounts them on **OZ** wheels.

Today's race cars are only as good as their dampers, popularly known as shock absorbers, so a close working relationship with the damper supplier and a lot of testing is needed to optimize the car's handling via changes to shock valving and oil. Because of the need for this relationship, Ullrich terms Audi's damper manufacturer **Ohlins** a "technical partner," because of the company's significant participation in the R8's development.

Finally, Audi's sponsor also helps with technical development, even though it is primarily a semiconductor company, not an automotive supplier. "**Infineon** is a producer of chips, so I cannot say *this* is the component they provided," said Ullrich. "But Infineon helped us a lot, and the good things are in the important places." Among other things, Infineon helped develop the automatic system for controlling the headlights. The company also makes the chips Bosch uses in its engine management system.

Privateers will run the Audi cars in 2003, so they won't be missing from the grid. But absent factory budgets, the astounding attention to detail, and choreography of pit stops that flatter the already great car will probably disappear, so the privately run cars should be more beatable.

Audi's substantial infrastructure for race development and support will be available, so it will be interesting to see how the company decides to apply this capability. It has repeatedly ruled out a rumored entry into F1, so a better bet would be a massive infusion of technology into Volkswagen's other racing division, **Bentley**, which competes with a closed-cockpit Le Mans GTP car that already borrows heavily from Audi. ***aei***