BigStuff EFI Takes a Deep Dive Into Advanced EFI, Data Acquisition and Individual-Cylinder Engine Control

Modern high-horsepower engine management is no longer simply about commanding a fuel injector and controlling ignition timing. As power levels have climbed into the thousands of horsepower, the ECU has increasingly become the central control and data-acquisition system responsible for helping tuners understand—and manage—what is happening cylinder by cylinder and combustion event by combustion event.

During a recent EPARTRADE Race Industry Now webinar, “Total Power Management: Advanced EFI & Engine Control with BigStuff EFI,” Ben Davidow, owner of BigStuff EFI, joined host Brad Gillie of SiriusXM Channel 90’s Late Shift for a technical discussion covering the evolution of aftermarket EFI, methanol fuel delivery, individual-cylinder tuning, high-speed data acquisition, ignition control and the architecture behind the BigStuff Gen4 ECU.

For Davidow, understanding the current technology starts with understanding the problems that had to be solved as racers began pushing EFI into increasingly extreme applications.

EFI Built Around the Demands of High-Horsepower Racing

BigStuff’s roots trace back to EFI pioneer John Meaney, whose work in electronic fuel injection began decades before sophisticated aftermarket engine-management systems became commonplace.

Davidow described how Meaney built a fuel-injection system on a RadioShack breadboard as his final college project in the 1980s, eventually going on to develop systems including the ACCEL Gen 6, Commander 950 and FAST before creating BigStuff.

When BigStuff was formed, the emphasis shifted toward high-horsepower sportsman racing applications at a time when turbocharging and methanol were rapidly changing what racers demanded from an ECU.

Methanol presented a particularly difficult engineering challenge.

As racers including Harry Hruska and Mike Moran pushed toward increasingly powerful boosted combinations, substantially larger injectors were required to deliver the necessary fuel volume. According to Davidow, development included the ability to measure air/fuel ratios down to approximately 2.9:1 as well as external injector-driver technology capable of operating the large injectors required for alcohol-fueled engines without overloading the ECU's onboard drivers.

Fuel delivery was only part of the problem.

As injector sizes grew into the hundreds of pounds per hour, racers also needed a way to maintain drivability at lower engine loads while still supplying enough fuel under maximum boost. BigStuff addressed that through staged injection, allowing an engine to operate on a primary set of injectors and bring additional injectors online as fuel demand increased.

That development occurred alongside major advances elsewhere in drag racing: turbochargers, torque converters, transmissions, ignition systems, chassis technology and drag radial tires were all progressing rapidly.

The result was an environment in which racers could not only produce 3,000 horsepower and beyond, but increasingly had the hardware necessary to apply that power to the racetrack.

Gen4: High-Speed Ethernet Changes the Data Equation

The current BigStuff Gen4 ECU carries that high-horsepower development philosophy into a considerably more data-intensive engine-management architecture.

Physically, the Gen4 was designed as a direct replacement for the Gen3, retaining similar mounting and connector architecture to simplify upgrades for existing BigStuff users.

Internally and from a communications standpoint, however, the system represents a substantial change.

One of the key differences is its use of a true 100-megabit Ethernet connection rather than relying on traditional serial or USB communication.

Davidow emphasized just how significant that communication speed becomes when an ECU is simultaneously managing the engine and collecting large amounts of high-resolution data.

At 10,000 rpm, a four-stroke V8 completes 12 milliseconds between equivalent firing-cycle positions across all eight cylinders. BigStuff says the Gen4 architecture is capable of transmitting combustion-pressure data packets at intervals as short as 100 microseconds—fast enough to provide considerable resolution between individual firing events.

The ECU is capable of handling approximately 400 to 500 data channels, according to Davidow.

That speed is particularly important because BigStuff treats engine management and data acquisition as separate workloads. Davidow described the Gen4 architecture as effectively being divided into two sides: one dedicated to running the engine and executing fuel and ignition commands, and another dedicated to acquiring, processing and recording data.

Instead of forcing one processor to handle every task sequentially, the architecture allows engine-control operations to continue while the data side handles acquisition and storage.

Data Logging Directly to an SD Card

The Gen4 also incorporates onboard SD-card data logging.

Rather than relying solely on volatile internal storage or requiring a laptop to remain connected during a run, logs are written directly to removable media. Davidow said the system uses a 32 GB SD card and noted that a typical 20-second log can be roughly 6 MB, providing substantial recording capacity.

For race teams, that architecture has a practical benefit: the data remains physically stored on the card until the user removes it.

The system can therefore continuously collect information without requiring the tuner to download or clear logs after every run.

That becomes particularly useful in applications such as offshore powerboats, endurance operation and other environments where collecting extended data sets is more important than recording only a short dyno pull or drag-racing pass.

Treating a V8 as Eight Individual Engines

One of the most technically significant capabilities discussed during the webinar was individual-cylinder fuel and ignition control.

Rather than assuming every cylinder requires identical fuel and spark commands, the system allows the tuner to examine each cylinder independently.

As Davidow explained, every engine inevitably has cylinders doing different amounts of work. Intake-manifold distribution, exhaust configuration, thermal conditions and other variables can result in different requirements from one cylinder to another.

The objective is therefore not simply to tune “the engine,” but to optimize eight individual combustion environments.

BigStuff's individual-cylinder strategy allows fuel correction curves to be developed for each cylinder rather than relying only on a global fuel table.

The system can also use individual-cylinder feedback to help generate those curves in real time. Davidow described an auto-tuning capability that can build an individual-cylinder fuel curve through the software, rather than simply adjusting the main fuel table from one or two wideband oxygen sensors.

“This isn't just the main fuel table adjusting for a couple of O2 sensors,” Davidow explained during the webinar. “This is actually an individual hole curve being plotted for you for that fuel injector for that hole.”

The approach can be used across a range of fuels and engine combinations, including gasoline, E85 and methanol, as well as naturally aspirated, nitrous-assisted and supercharged applications, subject to system and application requirements.

The goal is not simply greater precision. It is also reducing the number of dyno pulls required to identify what an engine wants.

Instead of making repeated pulls while progressively chasing the tune, high-resolution feedback can allow the tuner to identify cylinder-specific requirements much earlier in the development process.

Using Cylinder Pressure to Refine Ignition Timing

The discussion went beyond air/fuel ratio and into combustion-pressure analysis.

Davidow described BigStuff's experience working with cylinder-pressure data to determine how ignition requirements can change not only by cylinder, but also through different operating conditions and gears.

Cylinder-pressure analysis can show the tuner what is actually occurring during combustion rather than requiring every ignition decision to be inferred from external measurements.

Davidow described situations in which spark timing was altered substantially from one operating condition to another based on combustion-pressure feedback, with the resulting pressure traces becoming visibly smoother.

For advanced engine builders and tuners, that is where high-speed engine management and combustion analysis begin to converge.

Air/fuel ratio identifies one part of the combustion equation. Cylinder pressure provides another layer of information about how efficiently—and when—the mixture is actually burning.

The ECU can then apply the resulting fuel and ignition strategy with individual-cylinder resolution.

That ability becomes increasingly important as engines operate closer to their mechanical and thermal limits.

Rather than simply operating “on the ragged edge,” Davidow's point was that better data can make the edge more precisely defined.

Remote Tuning Through Wi-Fi

Ethernet architecture also creates another capability: network-based communication with the ECU.

BigStuff offers a router configuration that allows the Gen4 to communicate over Wi-Fi. Davidow said he recently demonstrated communication with a running vehicle from more than a quarter-mile away while continuing to make calibration changes.

With an extended-range Wi-Fi system and appropriate antenna configuration, the ECU can therefore be accessed remotely rather than requiring the tuner to remain physically beside the vehicle.

For dyno cells, race teams and other specialized applications, this network architecture can provide considerable flexibility in how and where calibration and data monitoring take place.

One ECU Architecture From Street Cars to Pro Mods

Another important aspect of the Gen4 strategy is scalability.

BigStuff does not use an entirely different core ECU architecture for a relatively modest street application and a multi-thousand-horsepower racing engine.

Davidow used the example of moving from a 600-horsepower street car to a 6,000-horsepower Pro Mod. The supporting hardware and configuration requirements change substantially, but the core Gen4 ECU architecture remains applicable.

That gives racers access to the same underlying processing, communications and precision regardless of whether they initially need every capability available in the system.

The Gen4 ECU itself starts at approximately $2,000, according to Davidow. He indicated that complete basic street systems are typically around $3,500, while sophisticated alcohol-fueled Pro Mod packages can exceed $9,000 depending on configuration.

Coil-on-Plug and High-Energy Ignition Control

Ignition technology was another major part of the discussion.

BigStuff supports individual ignition coils, including its own smart-coil system. Davidow cited applications producing more than 3,000 horsepower at the tires and said customers have used the coils at power levels exceeding 4,000 horsepower at the tires.

He also highlighted one of the differences between inductive coil-on-plug ignition and conventional capacitive-discharge ignition.

Where a CDI system delivers a very high-energy but relatively short-duration discharge, Davidow said the smart coils can maintain spark activity over roughly 30 to 50 degrees of crankshaft rotation depending on operating conditions and calibration.

That longer burn duration can be particularly valuable in applications dealing with substantial cylinder pressure and fuel mass.

The ECU is not limited to BigStuff coils, however. It can also command aftermarket CDI ignition systems when the application calls for a different ignition strategy.

Class-Legal Firmware for Restricted Racing Applications

As electronics become increasingly sophisticated, sanctioning-body rules have also become an important consideration.

During the webinar, Davidow was asked how racers competing in classes with restrictions on electronic controls can demonstrate that an ECU complies with the rules.

BigStuff maintains specific firmware versions for applications where sanctioning bodies restrict ECU functionality.

Davidow cited Factory Stock Showdown as an example, explaining that the approved firmware for those vehicles has remained unchanged for years because it was certified for the class in that configuration.

That allows racers to use the ECU while maintaining the functionality limitations required by the applicable racing organization.

Engineering Around the Entire Powertrain

One of the larger themes to emerge from the discussion was that modern engine management cannot be considered in isolation.

The extraordinary increases in power seen in sportsman drag racing over the past two decades were made possible by multiple technologies advancing at roughly the same time.

Fuel injectors had to become larger and more precise. Injector drivers had to handle the electrical demands. ECUs needed greater processing power. Ignition systems had to reliably light increasingly difficult mixtures under extreme cylinder pressure. Turbocharger technology improved. Transmissions and torque converters became capable of surviving thousands of horsepower. Chassis and suspension systems evolved. Tires became capable of applying the power.

And tuners had to learn how to make all of those systems work together.

For BigStuff EFI, the ECU sits near the center of that equation.

The progression from early aftermarket EFI systems to today's high-speed Ethernet-connected engine management illustrates how dramatically the role of the ECU has changed. It is no longer simply a device that tells injectors when to open and coils when to fire.

In a modern high-horsepower racing application, it has become a high-speed control and data platform capable of monitoring hundreds of channels, recording extensive data, managing individual cylinders, communicating wirelessly and helping tuners understand the combustion process at an increasingly granular level.

And as Davidow made clear throughout the discussion, the objective behind all that technology remains remarkably straightforward: give racers the information and control necessary to make more power, tune it more precisely—and get it down the racetrack.

For more information, **watch the full webinar here.**