



EFI | An Integrated Approach To Engine Management

WITH BOTH NASCAR and NHRA's Pro Stock class embracing electronic fuel injection in recent years, there has been renewed interest in EFI, including its advantages *and* disadvantages, and the best ways to implement it into specific race programs.

Racers have also sought out experts with the know-how to set up and tune these powerful systems. "All that buzz has really motivated a lot of manufacturers to step up their game, which is a great thing for the consumer," said Matt Wright from Haltech Engine Management Systems, Lexington, Kentucky. "From a technical perspective, ever-increasing power of silicon chips and processing units is allowing engine management systems to do more, to operate faster, and to store more information. It wouldn't be uncommon in the past to have eight or 10 separate pieces of electronics each with their own specific purpose. In a drag car, for example, a fairly standard setup would have been to have a boost controller, nitrous controller, transbrake controller, programmable ignition system, EFI system, data logger and a display panel. We are starting to move toward a much more integrated approach, where the engine control unit handles all of these functions from the one central unit."

Wright noted the landscape for EFI systems is diverging, as individual markets require solutions tailored specifically to the particular form of racing or modification

being undertaken. "Features beyond just supplying fuel and spark are now pretty much the norm for an EFI system," Wright said. "For a drag racing application, features like EGT monitoring, transbrake control and launch control are now essential parts of the EFI system; for circuit racing, data logging, track mapping and GPS inputs are becoming an essential part of doing business; and for the street car, features like traction control, engine protection and vehicle integration—the ability for the EFI system to integrate seamlessly into the rest of the vehicle electronics like the instrument cluster, radio and transmission—are essential. So the individual markets are really dictating the direction of many products."

As EFI has become more widely accepted by enthusiasts, David Page from Fuel Air Spark Technology (FAST), part of the COMP Performance Group based in Memphis, Tennessee, noted that there are more first-time EFI users who may have vast engine tuning experience but are accustomed to using wrenches and screwdrivers instead of keyboards. "The industry has responded by making systems simpler to install and operate, and making the software more user friendly and intuitive for a guy used to dealing with carburetors," he said. "EFI is not just for us geeks anymore!"

Engine Control

The ability to integrate multiple controls into one system versus simply the ability to control fuel and spark events has been addressed by several leading manufacturers. For example, Hawthorne, California-based AEM Performance Electronics has stayed ahead of the curve by offering features like boost control, nitrous control, traction control, launch control, data logging, flex fuel/multi fuel and more, in addition to proper engine tuning using an airflow-based VE tuning model. These features are included in AEM systems fully enabled, meaning there is no charge to unlock them; updates and added features are included.

Additionally, Lawson Mollica sees a trend in the ability to fully utilize the advanced systems of modern engines like drive-by-wire and variable cam timing control.

"AEM was the first aftermarket company to release a standalone EFI system for the Coyote engine that provides complete control of the Ti-VCT system's intake and exhaust cams, and the drive-by-wire throttle body, and as long as we support the factory cam/crank timing pattern, the ability to control this on any engine resides in

the Infinity ECU," said Mollica. "Our Infinity ECU has robust logging capability, but until recently the only way to roll this data into chassis and track data was to send it out to another logger via CAN bus. So we created a Vehicle Dynamics Module (VDM) that connects to the Infinity via CAN bus, and allows you to log chassis and track info along with your engine logs. The VDM has an on-board 3-axis gyrometer, 3-axis accelerometer and GPS/GLONASS to provide yaw/pitch, G loads and highly accurate track mapping capability."

Because racers, teams and engine builders expect a quality product and good value for their dollar, FAST has added more advanced features built into the ECU, eliminating the need to purchase additional electronic components. The XFI 2.05, for example, has standard features like progressive, four-stage, wet or dry nitrous control, patented transbrake

Seamless compatibility is the new mantra for manufacturers of EFI systems and their components, making these products easier than ever to install and optimize for exceptional performance.



creep control, and time- or speed-based boost control, each eliminating the need to purchase another control unit. There are also optional features such as internal data logging and intelligent traction control that allow customers to bundle all their engine and drivetrain management into one hardware and software package.

"One of my favorite new features of XFI 2.05 is Dynamic Fuel Pressure Compensation, which adjusts injector pulse-width based on readings from the fuel pressure sensor," said Matt Maxwell at COMP Performance Group. "This feature actually saved a customer's nitrous engine! His fuel filter had become clogged, and fuel pressure was dropping from 45 psi to about 20 psi in the upper rpm's. The XFI 2.05 saw the pressure drop and instantly reacted by lengthening the injector pulse enough to maintain a safe air/fuel ratio."

Each new race season brings numerous cutting-edge developments in EFI components and engine management systems. Whereas supplying fuel and spark were prominent features of the first generation of engine management systems, more of today's products are being designed specifically for individual racing applications such as drag, oval track and road racing, among others.

According to Matt Cramer from Atlanta Georgia-based MS3-Pro Engine & Powertrain Management Systems, one of the biggest areas of development has been power management and traction control. “The options available to most drag racers have been pretty crude—either a ‘slew control’ setup that works purely off rpm or a single driveshaft speed sensor,” said Cramer. “OEMs have been comparing the speed on driven and non-driven wheels for quite a while, and we’re bringing the ability to run this—and tune it—to the drag racing world. Our MS3-Pro ECU can use this dual VSS traction control strategy without the need for any expensive add-on boxes; the only other thing you need is the wheel speed sensors.”

Cramer noted that the MS3-Pro includes another trick or two to help drag cars put down as much power as possible. “It has timers that reduce timing and boost when the two step is released, cutting power on

As EFI gains wider acceptance among enthusiasts, more first-time EFI users with vast engine tuning experience are making the transition, trading their wrenches and screwdrivers for keyboards. As a result, manufacturers of engine management systems have developed products that are simpler to install and operate. Software, too, has become more user-friendly and intuitive for those accustomed to working with carburetors. Photo courtesy of FAST.

launch so you don’t just boil the tires,” he said. “Then it adds these back in once you get moving.”

The MS3-Pro already has a wide range of additional functions, and the company has brought out a new option called the IO Box that lets users add even more inputs and outputs to run more devices at once. “You can daisy chain up to three IO Boxes if you need to control a lot of devices,” he added.

Haltech recently released its Race Expansion Module (REM) that integrates with its Elite Series engine control units



to provide a host of additional inputs and outputs directed specifically at the domestic drag racing market. Some of these features include additional injector outputs (up to 64 fuel injectors now can be run directly from the ECU/REM combination), twin solenoid (CO2) boost control, flexible torque management strategies that allow tuners to intelligently program a desired rate of acceleration (driveshaft, rpm, wheel speed, etc. can be used as

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targets for the desired acceleration rate), transbrake control with staging creep functionality, and six-stage fully flexible dry nitrous control, as well as the standard features like closed loop O2 learning, knock control, launch control, etc.

Bill Wetzel from Bowling Green, Kentucky-based Quick Fuel Technology noted that drivers and teams are focused on the synergy between reliability and ease of use with overall functionality and tuneability to meet the demands of specific engine requirements and driving styles. And the trend now is to offer OEM-style controllers and ECUs that are designed to provide real-time diagnostics and self-learning capabilities. "Quick Fuel Technology will be expanding its footprint in the fuel injection market this year with the addition of a tuned port injection system to augment our existing throttle body fuel injection systems," said Wetzel. "We will also be offering a dual quad (2x4)

system designed to support up to 1200 horsepower engines."

Holley Performance Products of Bowling Green, Kentucky, offers EFI systems for vehicles participating in everything from drag racing and autocross to circle track, desert truck racing, road racing, marine and more. For example, according to Blane Burnett, since 2013, Holley's HP EFI unit has come standard on the COPO Camaro. In 2014, Holley EFI became the standard EFI controller for use on the new ARCA Ilmor 396 engine. And for 2016, NHRA Pro Stock made the switch from carburetion to Holley EFI.

"In the street performance space, Holley has made replacing your carburetor with a self-learning EFI system easier than ever with our no-laptop-required Terminator EFI capable of supporting up to 600 horsepower," said Burnett. In the next couple of months, Holley will release its Sniper EFI, a self-tuning EFI system

that supports engines ranging from 250 to 600 horsepower (a 1200 horsepower-capable unit is coming soon), requires no laptop to tune, and installs via a simple four-wire vehicle connection."

What's more, Burnett announced the release of Holley's dual sync distributors that are direct plug-and-play with its EFI. The high-quality pieces will feature CNC-machined billet aluminum housings, integrated LEDs for simplified setup, and a Hall effect sensor design. "This design provides precise timing control and noise immunity," he said.

Customers are expecting faster processors and more features in the same package, and BigStuff3 from Precision Turbo & Engine in Hebron, Indiana, is designed to exceed those expectations. "The new BS3 GEN4 PRO XTREME (eXtreme Total Racing Engine Management Electronics) system will raise the bar just as the GEN3 PRO SEFI

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Infinity Programmable ECU
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<http://primag.org/16efi3>

system did 10-plus years ago, and establish itself as the premier aftermarket engine management system of choice for race enthusiasts," said Pete Barton. "With significantly improved processor (32 bit, 266 MHz dual core processor) and on-board data acquisition (dual, 4 GB SD cards) as well as a high-speed Ethernet communication interface (100 Mb), the BS3 GEN4 PRO XTREME will prove to be an engine management system to stand the test of time. BS3's offerings are true, fully functioning ECUs with no extra add-on boxes needed."

He added, "Two of the most important new features are the incorporation of Ethernet and multiple CAN busses. With Ethernet, tuners can access and review a car's data wirelessly, even before it returns to the pits. The multiple CAN busses are extremely useful for measuring multiple EGT or wideband O2 sensors, and much more."

"Racers and teams expect consistent, reliable performance whether they are in South Florida or the mountains of Colorado," observed Mike Monroe of Performance Electronics (PE), Cincinnati, Ohio, a supplier of engine control units. "Engine builders demand every bit of horsepower and torque out of their builds along with protection and data logging to support their customer long term. PE provides all this and more along with highly valuable real time online setup and tuning support available to any tuner of a PE system from our simplest ignition-only system through our most complex full build PE3-8400 family."

Aftermarket diesel tuning software is the focus of EFiLive in Howick, Auckland, New Zealand. With the release of the 2016 2.8L Duramax, EFiLive now offers a custom tuning solution for these vehicles. The DSP4 custom operating system allows customers to switch "on the fly"

between four tunes, which are stored in the ECM's flash memory. Having multiple tunes available allows the user to quickly change the tunes to suit different driving conditions, and the ECM no longer needs to be reflashed each time a different tune is chosen.

A+ Game

Pat Musi of Musi Racing in Mooresville, North Carolina, distributes Edelbrock's EFI systems. He believes many of the EFI systems on the market today are over complicated with too many bells and whistles. "You hear all this talk about self learning," he said. "Self learning is for your street car that you drive for an hour.... Self-learning in a drag car, if we're talking about a Pro Mod car like we run, there isn't enough time for that air/fuel sensor to correct, pick it up, correct the ECU, and then if it has a hiccup.... The trend that I've seen is that our competitors are basically telling the consumer to just put

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- Ideal for high-horsepower applications.
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FlashScan V2
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- Supports selected GM and Dodge Cummins engine and transmission controllers.
- Designed to be a data logger and calibration programmer in either standalone mode (FlashScan V2 to vehicle connection), or in pass through mode (PC/laptop to FlashScan V2 vehicle connection).
- Out of box, it's capable of tuning four supported engine controllers (ECM or PCM) and four supported transmission controllers (TCM).
- Includes EFiLive Scan and Tune software installation CD.

Get more info at:
<http://primag.org/16efi5>



Fuel Air Spark Technology

XFI Sportsman Engine Management System
www.fuelairspark.com

- EFI setup is designed to be simple, programmable and fully custom-tunable with software included.
- Provides power and adjustability, and includes a 4150-style, eight-injector, 1200-horsepower-capable throttle body for easy installation when upgrading a previously carbureted setup.
- Features full tables to monitor fueling, acceleration fuel, timing and air/fuel targets.

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their stuff on there and it will teach itself, it will add the fuel accordingly, or timing, etc. Guess what? It doesn't work. It's just not that easy. At the end of the day, you have to be a tuner."

Musi added that users "need to understand fuel, how much fuel it takes. You need to take a horsepower number that you think the engine is going to make and then start out by building a fuel table. So, you need user-friendly software. You need a company that's got good tech; that's really important.... A lot of our stuff now, we can actually tune online. I could have a guy out at the race track, go on his computer and tune for him if we need to. So, you need to get with somebody that's going to support you."

Throttle Devices

While racers and engine builders tend to zero in on performance and power, Alex Borla at Johnson City, Tennessee-based Borla Performance told us that EFI systems

as a rule do not deliver more horsepower than a carburetor. "The challenge that we all face in the EFI business is to exceed the carburetor's ability to deliver horsepower and, in addition, to make the vehicle more drivable," Borla said. "Borla is designing and producing more efficient throttle bodies, which deliver more air and therefore make more power."

The company is developing lower profile throttle bodies that allow packaging under lower profile hoods, while at the same time using modern injectors and delivering more air and fuel to the engine. Borla is also developing in-house carbon fiber filter housings for owners and builders who show their vehicles.

Jenvey Dynamics in Bridgnorth, Shropshire, United Kingdom, launched its new electronic throttle actuator. The unit is highly modular, making it compatible with a large range of aftermarket independent throttle body kits for road or race applica-

tions, and offers precise control over throttle actuation to help optimize induction systems. It provides durability, size and weight-saving advantages over OE alternatives. Indeed, advantages of electronic throttle include idle air control, programmable pedal maps, auto blip on down shift, launch control and traction control.

"We have identified the need for a highly configurable, fit-and-forget electronic actuator that is good enough to be used in international race series, yet is more attainable than often complicated, cost- or compatibility-prohibitive bespoke fly-by-wire systems," said Mike Jenvey. "The Jenvey actuator is competition-proven, having completed its first 24-hour race on a GT car without issue, as part of a rigorous in-house testing procedure."

Additionally, the company has launched its new downdraft throttle body kit for the Chevrolet LS3 V8 engine to meet high demand from the US and within Europe.

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- Full system design includes expansive tech support.



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Holley Performance Products

Terminator LS
www.holley.com

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- Control fuel, drive-by-wire and electronic transmissions (4L60E and 4L80E) through the Terminator's new 3.5-inch touchscreen.
- Available in throttle body or multi-port systems for most popular LS engines.
- Controls fueling and ignition, and is available for electronic transmission control and drive-by-wire support.



Get more info at:
<http://primag.org/16efi9>



A growing selection of available EFI products, coupled with more widespread acceptance of the technology, has created an expansive customer base that includes, among others, vintage race car owners and builders. For example, seen here is a Kinsler big block Ford Super Cobra Jet manifold with EFI installed.

The LS3 is a popular engine choice for high-end sports car builders for road and race, and the new kit is designed to provide a high-quality downdraft alternative to the crossover option already available from Jenvey. "The modular design

and light weight of the LS3 downdraft kit is perfect for highly configurable, bespoke vehicle builds where space may be at a premium or customers require a choice of engine bay aesthetics," said Jenvey.

Fueling a Need

Gasoline direct injection (GDI) is among the technologies gaining significant traction in the new engine market. Representing a major shift for the high-performance aftermarket, regarding the North American market, "GDI penetration into new engines has grown from just 3 percent in 2008 to 30 percent in 2013, and will soon surpass 50 percent of new cars," said Sam Barros from Ann Arbor, Michigan-based Nostrum Energy. "These high-pressure fuel systems go far beyond traditional PFI and incorporate complex fueling strategies that manage the number of injection events per cycle, start of injection timing, and total injection duration dynamically according to

fuel pressure, because GDI high-pressure fuel systems do not operate at a static pressure differential.

"The exponential growth in engine complexity has driven increases not only in engine controller (ECM) hardware capabilities, such as onboard memory and processing speeds, but has driven the complexity and lines of code in software by orders of magnitude," Barros said. "This has dramatically increased the time and cost required to 'crack' such systems, and also demands more highly skilled tuners, who now need to understand how all these parameters behave when changes are made to increase performance."

As is often the case with new technologies, with greater challenges also come great opportunities. "GDI is of particular interest to the racing and performance industry, not only due to its growth in the market, but also due to its performance benefits," said Barros. "By moving the fuel

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injection event out of the intake ports and into the cylinder, GDI allows an increase in charge cooling, which improves the knock threshold and thereby the ability to run higher compression ratios, higher levels of boost, or combinations thereof.”

Nostrum launched its K-DI gasoline direct injector line at the 2015 SEMA Show.

According to David Deatsch from DeatschWerks in Oklahoma City, Oklahoma, GDI is drastically changing the high-performance aftermarket. “GDI fuel systems place the fuel injector inside the combustion chamber and operate at pressures up to 3000 psi, which increases both power and efficiency. GDI injectors and pumps are significantly different than those used in traditional port fuel injection,” said Deatsch. “This radical change in hardware has created both opportunities and challenges to manufacturers in the high-performance fuel injection industry.”

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Quick Fuel Technology

QFI 8i

www.quickfueltechnology.com

- Supports naturally aspirated engines up to 1200 horsepower.
- Three-bar MAP controls up to 25 psi of boost, two nitrous inputs, one nitrous relay driver.
- Self-learning, handheld controller with touchscreen menus, data logging, live telemetry and more.
- Eight-hole patented venture sleeve design for superior fuel atomization.
- New throttle lever design accommodates GM 200 and 700R4, Ford and Chrysler OD transmissions.

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DeatschWerks has been developing GDI fuel injectors for the past three years, and last year released its Ford EcoBoost injectors for three different engines. “In 2015, DeatschWerks released the HDEV1700, which was the industry’s first high-flow GDI injector along with full tuning data,” Deatsch said. “The DeatschWerks HDEV1700 is a drop-in fitment injector for Ford EcoBoost engines that flows 30 percent more than OE. In addition to EcoBoost, DeatschWerks is developing GM high-flow GDI injectors.”

“Nowadays, where highly tuned 1000-plus horsepower full interior road cars are being driven to and from the track, with owners expecting fully operational in-car electronics, OE compatible data is a must,” said Jens von Holten from Fuel Injector Clinic, Hobe Sound, Florida. “And that’s where the OE injector data Fuel Injector Clinic develops comes into play.”

The company has spent hours converting standard injector offset and flow data into tuner-friendly formats. This highly specific fuel injector compensation data is developed through extensive bench testing, as well as in-car verification. According to von Holten, profiling just one injector at multiple pressures, voltages, temperatures and fuel combinations takes days, but the benefits to the tuner are undeniable. “After intensive data collection, we go through a lengthy process to bring this data into native formats for each OE manufacturer’s software, including GM, Ford, Dodge and Subaru,” he said. “The easy-to-use tuning data makes Fuel Injector Clinic a popular choice for tuners and performance shops. This fueling table data, used with OE flash tuner software, is part of Fuel Injector Clinic’s Data Match Technology,” which provides optimum flow matching and latency value information. The Data Match Technology information sheet provided with each set of matched Fuel Injector Clinic injectors gives the customer Dynamic Slope Flow Rates for each individually serial numbered injector, and Individual Injector Offset Values for each serial numbered injector in the set.

When it comes to fuel supply to the injectors, “The electronic fuel controls

available today are truly amazing,” said Jim Kinsler from Kinsler Fuel Injection, Troy, Michigan. “The best of them can update the fuel rate after each injection and can self-learn, but they can only send a signal to the injector. In order to obtain the fuel rate that you have programmed into your control, you need to control the ‘instantaneous’ fuel pressure at the injector at the instant that it is triggered.”

Kinsler went on to discuss the problem: “When a very large EFI injector is pulsed (opened), it takes a very quick ‘gulp’ of fuel out of the rail, causing a large instantaneous pressure drop,” he said. “These pressure drops can reinforce each other in a random ram tuning within the rail and attached fuel hoses that cause chaotic pressure pulsing; we have seen plus and minus 30 psi on a 130 psi supply (100–160 psi range). As the pressure waves travel through the fuel rail, some injectors are likely to open when there is a high or low local pressure.... This causes very significant cycle-to-cycle rich and lean conditions to the cylinders, as once the injector opens, it’s simply a function of the pressure acting across its outlet orifice(s). A pressure gauge will not respond to these pulses, as they are way too fast; Kinsler uses very fast response Kistler piezoelectric pressure transducers to analyze these systems.”

Kinsler described the reason why larger rails help: “All fuel has some air in it, especially after the system has run a little, because the return fuel absorbs more air as it falls back into the tank. This makes the fuel a bit compressible, thus the larger rail assists the ability to take a ‘gulp’ with less pressure fluctuation. We have seen the pressure fluctuations reduced just by switching from our 8 AN to our 12 AN rails,” he said. “NHRA’s move to EFI in Pro Stock for the 2016 race season was announced last July, and drove development of new products and technology,” observed Kyle Fickler of Aeromotive, Lenexa, Kansas. “By utilizing brushless technology, we were able to reduce amperage draw by over 50 percent and static weight of the fuel pump by 40 percent. This brushless EFI fuel pump

PN 11180 is used in conjunction with fuel pressure regulator PN 13134 to create the ideal system for the NHRA mandated maximum pressure of 90 psi.” He noted that this fuel pressure regulator allows for base fuel pressures up to 120 psi.

Due to increased use of E85 fuel in both street-driven and race applications, Fickler reported that Aeromotive has released E85 compatible 340-lph fuel pumps that are a direct retrofit for many OE applications, as well as being used throughout the company’s line of Phantom in-tank kits and Stealth tanks. Aeromotive also offers a 10-micron micro glass filter for EFI applications, which is available in a variety of filter configurations (AN and ORB) or as a replacement element.

Opportunities for Implementation

As EFI expands throughout the racing industry, it creates opportunities for entrepreneurs to provide more comprehensive, integrated engine management

solutions to suit their customers’ needs. Carson, California-based Mountune, for example, actively uses EFI to develop and package the engines it sells and leases to teams, and Eric Hsu believes that with the advent of faster processors, low-cost memory and Ethernet communications, data logging has become much more powerful and effective.

“ECU manufacturers are responding quickly to control newer engines also (for example, direct fuel injection engine and pump control, fly-by-wire, throttle control, and planetary gear cam control),” Hsu explained. “The complexity of modern engines requires extensive development from ECU manufacturers, and oftentimes extensive time calibrating on engine dynamometers. As engine technology progresses, the costs of high-tech racing engines and EFI components will inherently increase. While this isn’t necessarily a positive point, the result is that engines



Engine management systems have more capabilities, operate faster, and store more information than ever before thanks to the power of today’s silicon chips and processing units. And, suppliers of these systems are moving toward an even more integrated approach, where the engine control unit will be able to handle a broader array of functions from one central unit.

will perform better overall with increased power output for a given displacement, burn cleaner, and are oftentimes more efficient, which is a positive outcome for teams and drivers alike.”



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