

How to Efficiently Drive 12-v and 24-v Engine Loads in Automotive Systems



Aaron Barrera

An internal combustion engine (ICE) is a mechanical system that has been around since the 19th century (Figure 1). It's amazing how it works, considering that it only takes fuel to generate thousands of horsepower and make a car go from 0 to 60 mph in under 3 seconds. But all good things must come to an end; stricter government standards such as Tier 3, Euro 6 and China 6a are requiring exported automobiles to reduce emissions to minimal levels. In response, the automotive industry is electrifying (literally) to create electric vehicles (EVs) and hybrid electric vehicles (HEVs) that have electric subsystems inside the conventional ICE.



Figure 1. A conventional ICE

View our Automotive 12-V to 24-V Engine Load Interface Reference Design.



[Ready to design?](#)

But wait, how can you electrify an engine?

Well obviously, you can't electrify the combustion process itself. However, the rest of the engine platform has a myriad of engine sensors to continuously monitor system parameters such as temperature, position and exhaust (Figure 2). The sensors send data to the engine control unit (ECU) to calculate the engine's current performance and compare it to its desired performance. Solenoids, relays and DC motors are controlled by the ECU, to open or close valves and correct the amount of fluid flowing through the subsystem. This "corrects" the system performance, and the closed-loop cycle continues as long as the engine is running.

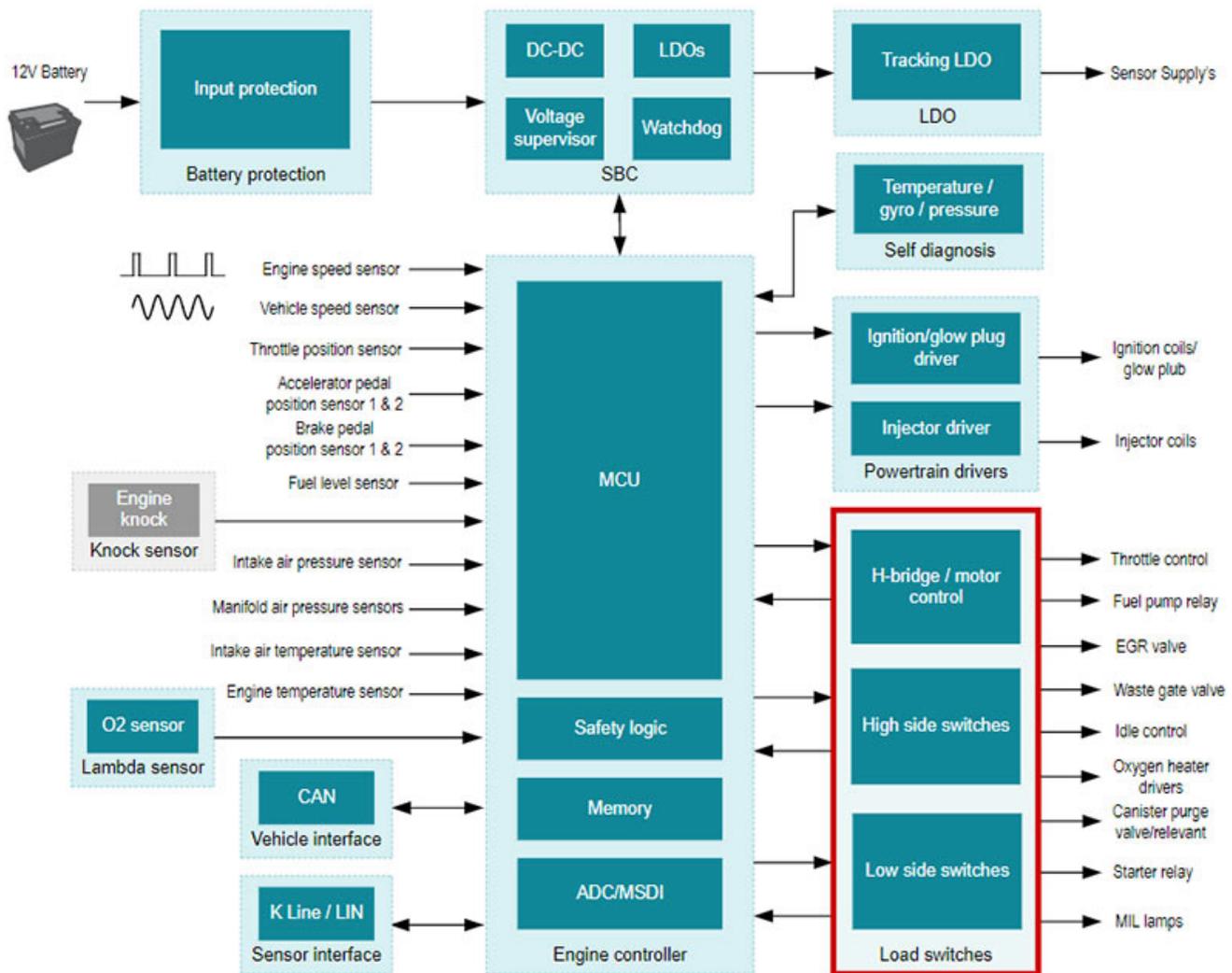


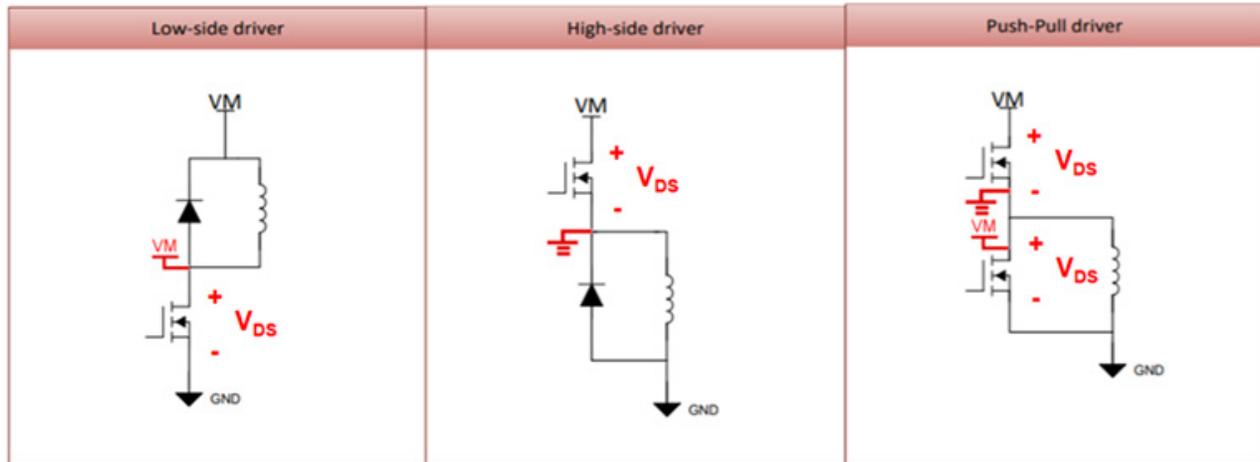
Figure 2. Block diagram overview of an engine platform design, including input sensors and output load switches (highlighted in red) that interface with the ECU

By using electric sensors and engine loads powered from the 12-V or 24-V battery, the engine reduces dramatically in size and limits emissions from the exhaust while continuing to utilize combustion as the main source of engine power. The main caveat to electrification in automotive applications is ensuring that all electrical components are automotive-qualified and have temperature grade 1 or 0. This allows for engineers to design systems that are compliant with International Organization for Standardization standards (ISO 26262) and be Automotive Safety Integrity Level (ASIL) certified for functional safety.

How can you drive these engine loads?

Solenoids and DC motors use a power metal-oxide semiconductor field-effect transistor (MOSFET) stage to drive inductive loads, with configurability for added protection. N-type MOSFETs can drive up to tens of amps when actuated, and the number of MOSFETs you'll need depends on what configuration you want to drive your load.

Solenoids can be driven with a high-side (HS), low-side (LS), or push-pull configuration (Figure 3). These configurations provide trade-offs on their implementation, number of components needed and protection(s) offered to the power stage.



- + One FET needed
- + Short to BAT
- Short to GND
- Recirculation diode

- + One FET needed
- + Short to GND
- Short to BAT
- Recirculation diode

- + Short to BAT and GND
- + No recirculation diode
- Two FETs needed
- “Sneak” paths introduced

Figure 3. Trade-offs of various solenoid driver configurations

To efficiently drive solenoids, you can use pulse-width modulation (PWM) signals from the gate driver to regulate current. It takes a larger amount of current to actuate the solenoid, but only a smaller amount of current to hold it in place. By switching to a lower PWM duty cycle once the solenoid is on, less power will dissipate through the solenoid windings to lower thermals and increase the longevity of the load.

An automotive device like the [DRV8343-Q1](#) can drive up to six independent loads using independent MOSFET mode. It is rated for up to 60 V, integrates three current shunt amplifiers, and includes protection features and diagnostics for the implemented configurations. If you’re looking for a more integrated automotive solution, the [DRV8876-Q1](#), [DRV8874-Q1](#), and [DRV8873-Q1](#) can each drive up to two independent solenoids and include integrated MOSFETs and current regulation. These devices are rated up to 37 V and have varying peak current and total $R_{DS(on)}$ values to support a wide range of solenoid currents.

Both solutions ([Figure 4](#)) are Automotive Electronics Council (AEC)-Q100 qualified for automotive applications and temperature grade 1 (-40°C to 125°C ambient).

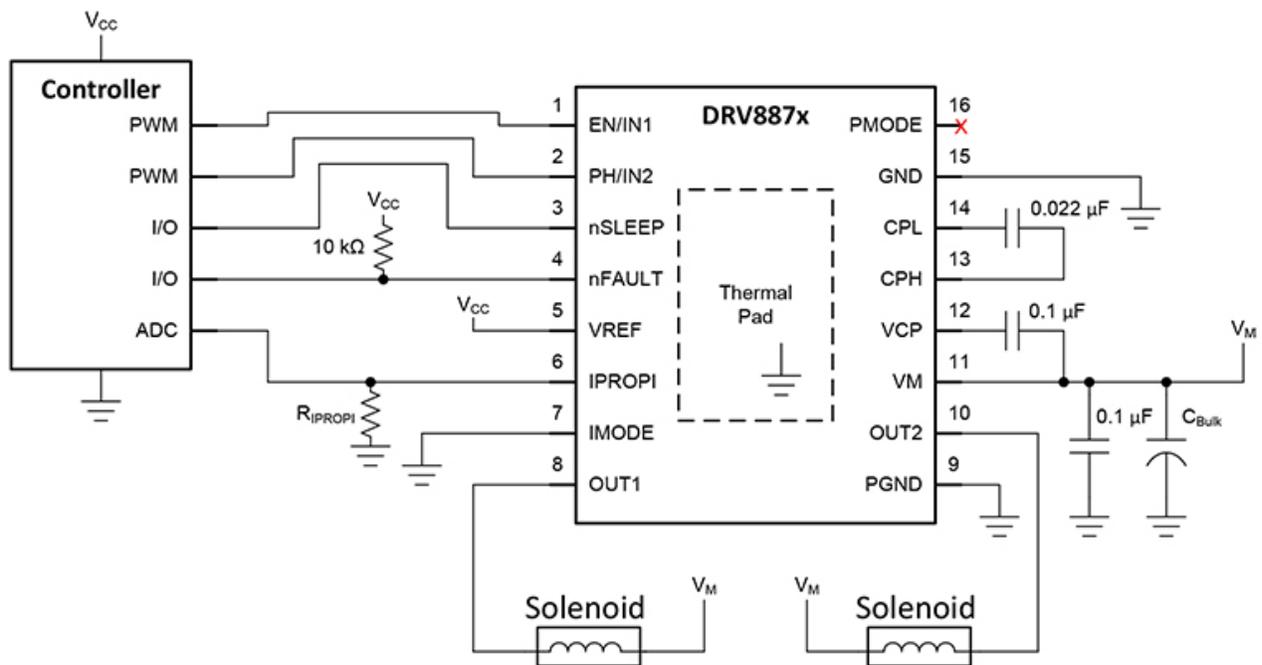
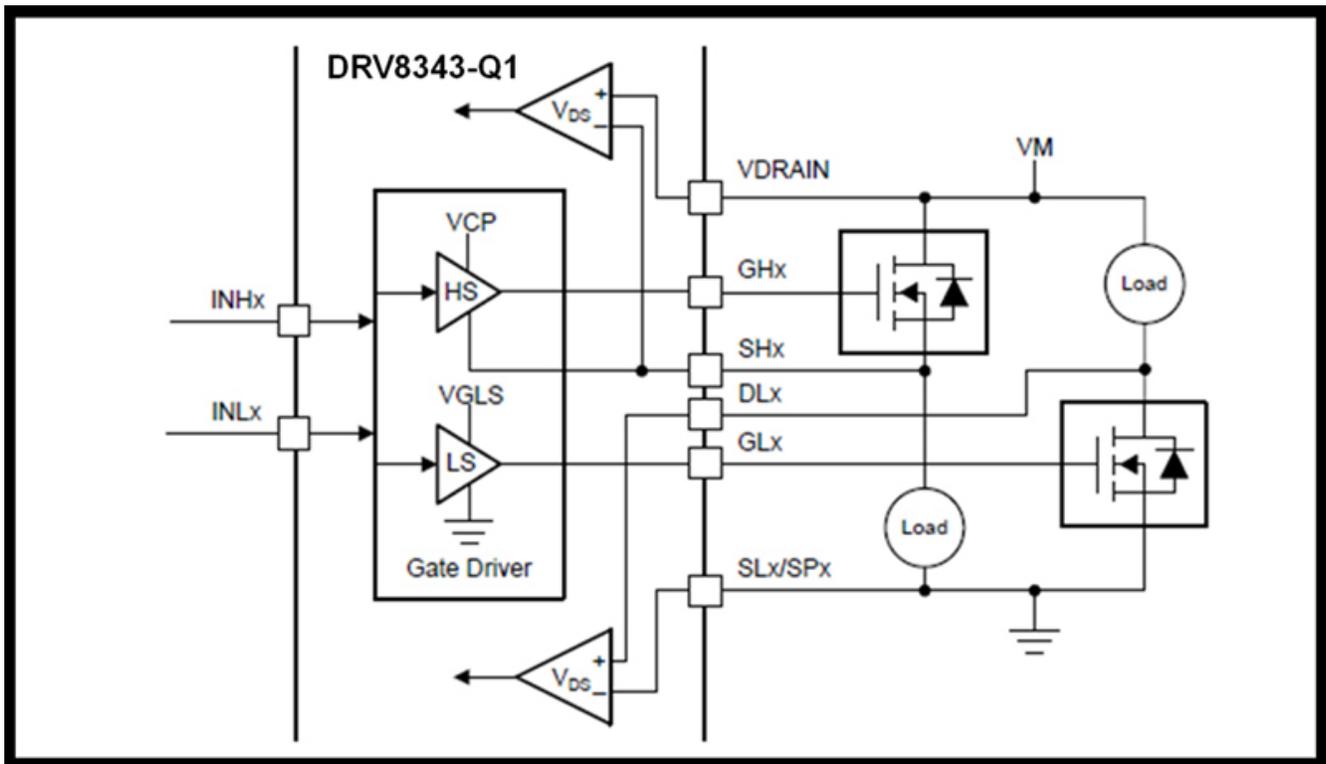


Figure 4. Driving solenoids using the DRV8343-Q1 or DRV887x-Q1

If you're ready to jump right into a design, check out our [Automotive 12-V to 24-V Engine Load Interface Reference Design \(Figure 5\)](#). This solution is rated for both 12-V and 24-V automotive systems and drives engine loads in four distinct configurations (HS driver, LS driver, HS + LS driver, and push-pull driver) with a microcontroller and the DRV8343-Q1 gate driver. The design also includes reverse polarity protection, integrates protection and diagnostic features, and is less than 16 square inches in size.

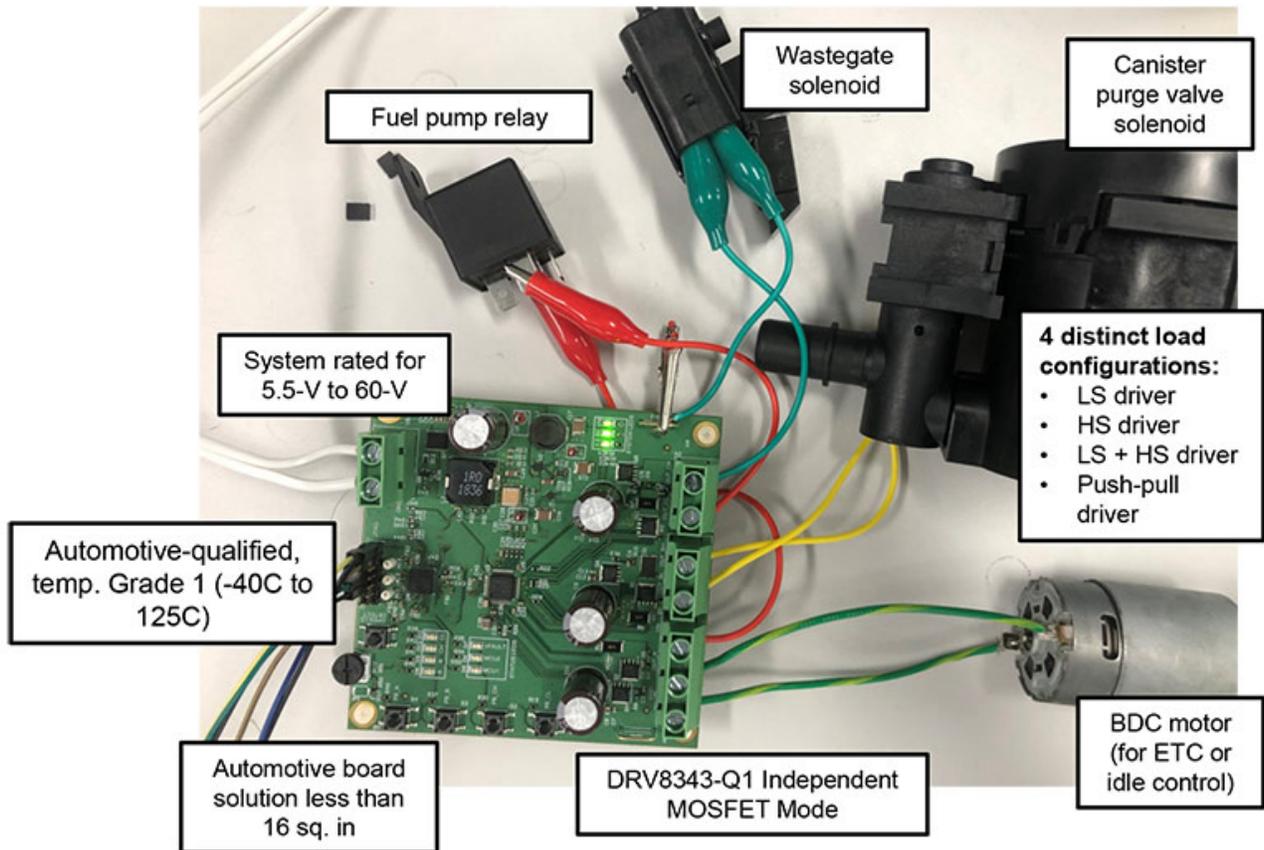


Figure 5. Engine load interface solution for 12-V and 24-V automotive systems

Now that I have shared the various options TI offers to interface with engine loads, I should mention that there is also plenty of content and knowledge available on TI.com to assist you in your engine platform printed circuit board design. Although ICEs are mechanically complex, they don't have to be electrically!

What features are most important for your engine platform design? Please share in the comments below so that we can highlight these in our devices. Make sure to check out our [Gasoline and Diesel Engine platform page](#) for products and designs to make your engine platform design the way you want it.

Additional resources

- Read the application reports, “[Using DRV to Drive Solenoids – DRV8876/DRV8702-Q1/DRV8343-Q1](#)” and “[Automotive Reverse Polarity Protection](#).”
- Download the [DRV8343-Q1](#) and [DRV8873-Q1](#) data sheets.
- Watch the YouTube video “[Motor Drivers in Engine Control Units](#)” from Texas Instruments

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2023, Texas Instruments Incorporated