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G-Volution Optimiser

1. Introduction

The function of the ECU is to control the engine. The most demanding part of which is the generation of the fuel control signals. These must be generated in real time to a high degree of accuracy. The fuel control signals are generated as the output from a closed loop control system, the primary input to which is throttle demand.

Because the fuelling is normally controlled solely by the ECU, the fuel control signals are supplied only to the fuel injectors. Therefore, there is no requirement for the ECU to either broadcast these signals or accept external inputs to modify them. Even if these features were added to ECU SW and the CAN catalogue, the latency associated with external communications or other general purpose inputs / outputs would be too great to provide fuel control with the required accuracy and timing.

2. Operation and Benefits

Emulating and translating the primary injector control signals allows the original fuel demand to be mapped into individual demands for a number of fuels (primary, secondary, tertiary etc). This principle is protected by patent GB2372835 (owned by G-Volution). Additionally, patent GB2447046 (also owned by G-Volution) details the implementation and techniques necessary to modify the primary fuel injector control signal and generate a viable multi-fuel system. The Optimiser is unique as it is the only patented system of this type.

Operating in this mode provides a number of significant benefits.

The ECU remains the master for the engine control loop. The Optimiser acts as a slave, translating the primary fuel control signals and managing the alternative fuel system. The Optimiser is effectively transparent to the ECU and thus the original ECU continues to operate normally.

The original engine power and torque characteristics are maintained because the engine is running on the original maps under the control of the original ECU at all times. It is only the ratio of fuels used that is changed by the Optimiser. The Optimiser and alternative fuel system is calibrated to ensure that there is effectively no difference in the performance or response of the engine.

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Because the Optimiser operates on the primary fuel control signals, it is inside the control system feedback loop. Therefore it works in sympathy with the control loop, rather than against it. For example changing the throttle pedal demand or altering the fuel rail pressure to reduce the primary fuelling would perturb the control loop and potentially introduce instability or force it to a new operating point.

The fact that the Optimiser works in real time inside the control loop, means that it can operate effectively all of the time. Therefore there are no conditions which prevent operation on multiple fuels (including during gear changes and high transient operation).

Because of the OEM ECU retains control of the engine all of the emission control strategies remain unaffected. The start of injection (hence ignition timing), which is not affected by the Optimiser, nor is the control of EGR or SCR systems.

The Optimiser does however provide the capability to change the ratio of the multiple fuels in real time dependent on the operation conditions of the engine. This provides a new degree of freedom in fuelling the engine, allowing optimisation for power, economy or emissions dependent on the characteristics of the individual fuels used.

The original engine control system will be a safety integrity level (SIL) 2 implementation. Because the original ECU is unaffected and continues to operate normally, the original system safety case will not be compromised. Additional analysis will only be required for the Optimiser and associated systems. Similar arguments apply in the case of reliability, failure mode analysis and hazops. Therefore, the use of the Optimiser to provide a multi-fuel solution provides the lowest risk solution with the minimum associated verification and certification costs.

3. Commercial

The Optimiser is an add-on system that it ideally suited for retrofit applications. Because it interacts only with the primary fuel control signals there is actually very little characterisation required for different engine types. Engines of the same type always have the same mapping. The Optimiser mapping is primarily set for the characteristics of the alternative fuel types used which are effectively constant.

In summary use of the Optimiser as the multi-fuel control system has significant benefits in reduced time to market and therefore cost for any one seriously considering offering a multi-fuel solution.

Additionally, because the Optimiser is inside the fuel control feedback loop it represents a significant step towards an OEM integrated solution. It can be seen that by combining the primary fuel control SW algorithms from the OEM ECU and the SW for the multi-fuel control algorithms from the Optimiser, a complete control solution could be synthesised. This modular approach is ideally suited to development and proving of the SW functionality.

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The hardware platform would be a single integrated control unit, combining both the functions of the original ECU and Optimiser, thus generating an OEM solution with the minimum development and production cost.

4. Competitive Systems

We are a company focused on technical and commercial excellence and either own or control the IP in our products. We believe that this sets us apart from our competitors who do not own significant IP, but are well financed.

It is clear that there is a growing customer demand for multi-fuel vehicles. OEM manufacturers will struggle to meet this in the short to medium term due to their traditionally long development timescales and thus have been forced to partner with external companies. These "partner" solutions range from re-powering (swapping engine suppliers) to offering a factory warranty on retro-fit kits.

We believe that working together, firstly on a retro-fit solution and then on an OEM integrated solution within an integrated development programme is the optimum solution to this problem.

There are two principle methods used by our competitors to reduce the primary fuel demand to allow a secondary fuel to be introduced.

4a. ECU interface Modification

The first, attempts to reduce the throttle demand by modifying the input CAN signal from this device. The throttle demand is an input to the control loop and thus will select a different operating position for the loop. However, because the engine is receiving additional secondary fuelling, this new loop operating position will be inconsistent with the control loop prediction. Therefore a number of original ECU inputs and control outputs are also likely to also be inconsistent. This presents a significant problem for systems which are integrated with the ECU. For systems such as the automated gearbox these problems will be insurmountable. The "solution" would be to "spoof" all associated CAN messages and sensor signals to make it appear the engine operation appear consistent. This is very difficult to do with the required timing and accuracy and requires detailed knowledge of all the vehicle systems, not just the engine.

Fundamentally the throttle position is an input demand. The introduction of a fuel (albeit primary or secondary) produces power. Therefore, the two are not equivalent and cannot be traded simply be traded off in this fashion.

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The end result is a hugely complex system that at best provides an approximate operating point of the engine. This requires an entirely new safety case and verification / certification as the ECU is no longer controlling the engine and the exact operational condition is not known.

This system is effectively just a means to deliver a multi-fuel vehicle in the short term. It is not a technological solution that has any longevity, as it is clearly non optimal.

4b. ECU Reprogramming

The second changes the ECU maps by reprogramming to reduce the amount of primary fuelling. The majority of the engine power is derived from the secondary fuel with the primary fuel being used for ignition.

Although in theory this system appears closer to an integrated OEM solution, this is not the situation in practice.

Once the OEM ECU is reprogrammed it becomes a new design. Therefore all of the safety case and associated verification / certification will have to be repeated. This is a massive task for an ECU containing algorithms that represent hundreds of man years of SW effort. Furthermore, this solution is only available to an OEM if they generate and control all the SW for the ECU. This is unlikely to be the case if the ECU is sourced from a Tier 1 supplier.

This work has to be done for each vehicle type and each controller type. Because of the difficulty and sheer scale of this undertaking we do not believe that this represents a solution that is commercially viable in the short or medium term.

Because the initial implementations still use two ECUs (OEM ECU and Multi-fuel ECU) the fundamental problem still exists that the OEM ECU is not in full control of the engine and does not know the exact operating point of the engine.

5 Competitor Summary

Both primary competitors use different methods of achieving the same end result, with the same problems. Basically, by convincing the OEM ECU that the engine is in a low power or idle condition, a secondary fuel can be added to provide the majority of the engine power.

The G-volution system does not do this, as the OEM ECU is unaffected and continues to operate the engine normally. This allows the G-volution system to operate more efficiently, all of the time, producing significant cost savings.

We believe that this offers a significant advantage to OEMs, dealers and customers alike during what is clearly a transition period for multi-fuelling technology.

The service and dealer networks are largely unaffected. There will be additional checks for the gas system, but fundamentally all of the current practices, diagnostic facilities and knowledge base for diesel only vehicles will carry over directly.

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The tracking, telematics, logistics and planning systems used by the operators are unaffected.

Finally, an important point to make is that our competitors only offer diesel-gas dual fuelling. G-volution is not a single fuel company. We have the ability to (within reason) operate with any type of fuel and any number of fuels. This is the principle at the heart of the Optimiser design and why we differentiate between a control system and a delivery system. We are actively investing in research into alternative fuels types with leaders in the field, in the knowledge that we already have an optimal control system.

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