Timing Advance Processor for Internal Combustion Engine Running on LPG/CNG

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Abstract: *The paper is focused on the development of a universal microprocessor system for correction the timing advance of the ignition spark on internal combustion engines, running on alternative fuels like CND and LPG. Here are described the problems of the existing systems and their incompatibility with many modern engines.*

Key words: *Microprocessor systems, Real time systems, Alternative fuel.*

INTRODUCTION

Nowadays, when the world economic crisis appears to be undying, and the price of the petrol goes higher every day, the question about the alternative fuels for the transport becomes more and more serious.

During the last several years the prices of the most common used – gasoline and diesel has raised almost twice. At the same time, we are witnesses of the raising needs of transport services. That's why, saving fuel is quite important.

It is well-known fact, that the gasoline engines can be easily converted to run on compressed natural gas (CNG) or liquefied petroleum gas (LPG). The burning process is quite the same and has similar parameters, like working temperature, pressure, etc. Despite of the similarities between these gases and the gasoline, there are differences. One of the most important is the octane rating. The methane, propane and butane have a higher octane number (RON) and that's why, the burning process can be optimised for a better performance, and lower consumption. This optimisation should be provided by additional device, since the petrol engines are usually not factory equipped for alternative fuel.

LAYOUT

The electronic control unit (ECU) is programmed for optimal performance, when the vehicle is running on gasoline, but on LPG/CNG, these signals are modified by additional ECU. Usually it reads the signals for the injectors and attempts to match the same timings for the petrol injectors when the car is running on alternative fuel. The main problem here is that the ignition timing is not modified, although the octane rating of the both CNG and LPG allow higher timing advance. If this signal is processed, this will result to a better engine performance in the following aspects [1], [2]:

- more power, due to the optimised burning;
- lower pollutant emissions (mainly carbon monoxide, which could oxidised to carbon dioxide);
- lower fuel consumption.

The main ECU can not be just preprogrammed, because the vehicle should be able to run on its original fuel too. That's why, this functionality has to be provided by a separate device, that modifies the ignition signal.

There are many controllers, that perform this action, available on the market [3], [4]. The main problem with them is, that there is a specific device for specific number of cars and most of them are modifying the signal between the engine sensors and ECU. The modern engine control systems use much more complicated algorithms and more engine sensors than the cars from the past 10 years.

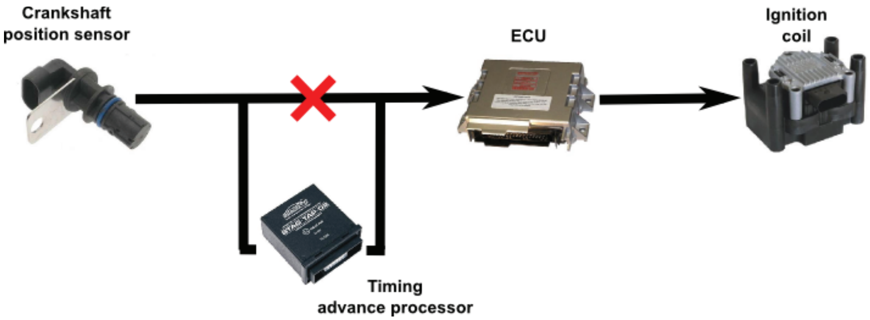

Fig. 1

Some engines are equipped with variable valve timing. This means, that the position of camshaft, relative to the crankshaft is not constant, like the classic cases. These engines have separate sensors for the position of crankshaft and camshaft(s). That's why, modifying just the one of the input signals disturbs the work of the whole system. The control systems in this case detect a mechanical problem of the engine and usually reports a problem or a failure.

In order to avoid this, the timing advance processor (TAP) should not modify the signal from the sensors (fig. 1), but the signal sent to the ignition coil(s) (fig. 2).

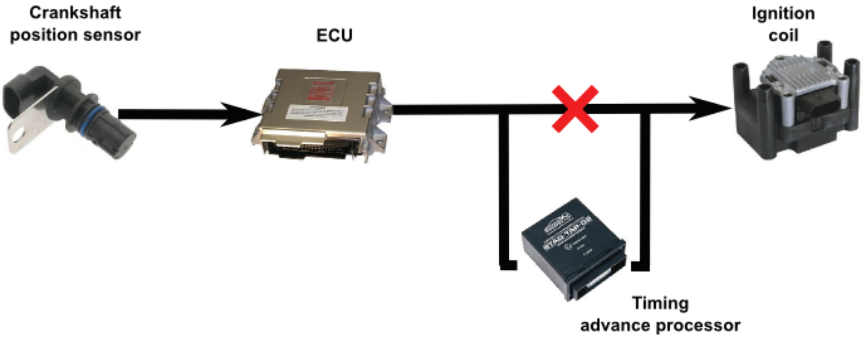

Fig. 2

Many of the control units have a system for self-diagnostics of the control system. So if we just read and modify the impulses sent to the coils, the control system may detect that there is no ignition coil, connected to it. There will be no oscillations on the line, caused by the coil inductance. That's why the TAP should have the same behaviour as the ignition coil. The decision is to build a emulator circuit, using auxiliary coil with smaller inductance and a resistor.

On fig. 3 are shown the blocks of the designed advance processor. After emulation of the ignition coil, the signal becomes noisy, and the useful component should be extracted. The moment of the ignition is easily determined, by the biggest spike on fig. 4. The problem is with determination of the start of coil charging. The noisy signal crosses the zero line several times, and every cross point is a potential charging start. The oscillations of the simulator coil disappear for about 1ms. So if a zero cross occurs 0,80ms after the first spike – it is treated as a start of charge. This job is done by the signal filter, shown on fig. 3.

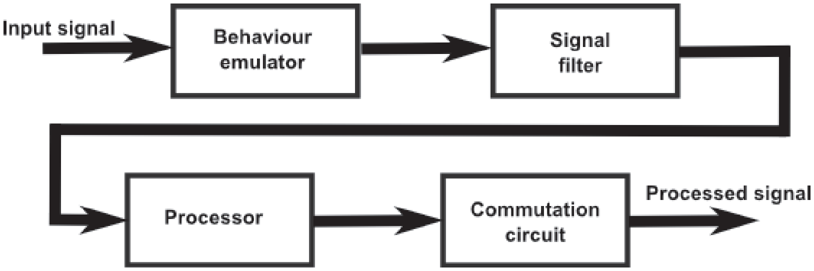

Fig. 3

The processor have to analyse the filtered signal, coming from the ECU and produce the output, advanced to 5 – 20 degrees, according to the engine's crankshaft. If the engine has four cylinders, this advance is equal to 10 – 40 degrees of the signal period.

Practically it is impossible to predict the period, because it is different for each cycle and depends of the angular speed of crankshaft. For simplicity we can assume, that two successive cycles have the same duration. In this case we can just delay, instead of advance the signal. In our case the delay is 350 – 320 degrees, which is equal to 5 – 20 degrees advance, relative to the crankshaft.

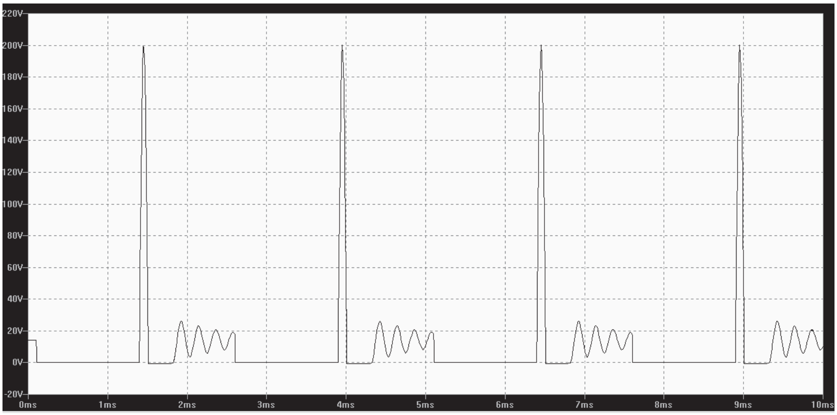

Fig. 4

To perform this task, we measure the 2 parts of the signal – Tcharge and Tdischarge. For better accuracy we assume, that the first derivative of 2 successive cycles is constant. This will provide better responsibility of the controller to the engine dynamics. In this case the calculations for the new cycles are as follows:

$$T_{charge.new}=T_{charge.last} + \Delta T_{charge} - T_{advance} \qquad (1)$$

Where:

$$\Delta T_{charge}=T_{charge.last} -.T_{charge.old}. \qquad (2)$$

From (1) and (2):

$$T_{charge.new}=2T_{charge.old} - \Delta\tau_{charge.old} - T_{advance} \qquad (3)$$

The challenge here is to measure the time and perform the calculations with a small as possible microcontroller. To achieve this, the software is split to 2 main sections – time critical, that contains the counters and sets or resets the output signal, and less time-critical – which performs the calculations and stores the data from the time counters. The source code should be perfectly balanced, so that independent of the branches, it execution have to take always the same time. Otherwise, using software timers will be incorrect.

If we take an example with 4 cylinder engine, running at 6000rpm, one angle degree of the crankshaft rotation takes about 27us. This means, that terms 'realtime' and 'time critical' are very strict. In order to control the time-performance on the controller, the software has to be developed using Assembler language

CONCLUSIONS AND FUTURE WORK

The development of the controller is in its early stage, so the in near future of this project is the building of the first prototype and testing it in the lab, and then in a real vehicle.

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The paper has been reviewed.