

An Effective Algorithm for Creating Precise Oil Level Information

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ABSTRACT

With the new developments in electronics, use of electronic sensors is becoming more common in today's vehicles. Oil level monitoring using electronic level sensor is one of them. In this paper, an algorithm developed for Ecotorq heavy duty diesel engines is presented and software measures developed to overcome typical application challenges are described.

The sensor used on the engine has a damping tube in which the oil flows through a very small hole to dampen the oil flow. The sensing method is ultrasonic sensing. Direct calculation of total amount of oil from oil level is not possible anytime, since a portion of the oil circulated in the engine varies with engine speed and some part of the oil trapped in the different regions of the engine changes with road conditions. Additionally, lubrication oil is not still while the engine and/or vehicle is running due to effect of crankshaft oil spill and vehicle movements. In order to evaluate the oil amount in the engine precise enough, the raw value from the sensor has to be corrected by an algorithm. The algorithm uses the previously calculated oil amount to utilize long-term averaging since the oil level change is expected to be small. It also has top-up detection and leakage detection functionalities to display sudden changes. For effective usage by the customer, the very last output of the algorithm is the volume of the oil that should be top-up. The algorithm was developed in MATLAB/Simulink environment by Ford Otosan and coded by Robert Bosch GmbH. The calibration methodology and results of functional tests performed by Ford Otosan are presented.

INTRODUCTION

Oil level sensing algorithm is modelled to evaluate the amount of oil inside the engine. The oil level sensor is used to measure the amount of oil inside the oil pan. The sensor has a damping tube in which the oil flows through a very small hole and fills a gap through which ultrasonic waves are sent. The ultrasonic waves bounce back from the interface between the air and the oil. The time, until the bounced signal is received, is measured to calculate the oil level inside the damping tube.



Figure 1 – Hella Ultrasonic Oil Level Sensor (Ref.1)

The sensor has three outputs; the oil temperature, the oil level and the oil quality, which are sent in a PWM signal. Another functionality in the ECU evaluates the signal and makes plausibility tests to calculate the oil level in percentage which is sent to the oil level algorithm for further calculations.

METHODOLOGY

In this section the algorithm is explained in detail. The general signal flow throughout the algorithm is shown in Figure 2. The signal from the sensor is first sent to another sub-routine in which detailed electrical plausibility tests are performed. The healthy PWM signal is first received by the plausibility sub-routine where the signal is converted to raw percentage signal and sent as it is to the Boundary_Conditions sub-routine if it is plausible. Otherwise, a replacement value is sent.

In the "Boundary_Conditions" sub-routine some engine signals are checked if they are within the pre-defined ranges.

In the "Averaging" sub-routine long term average of the oil mass inside the engine is calculated using various correction functionalities. In this sub-routine, oil top-up and leakage checks are also performed.

The long term averaged oil mass value is used to calculate the amount of oil that should be filled and also the warning type is calculated.

The “Display” sub-routine calculates the number of lamps that should be turned on using special discretization functionality.

The details of each sub-routine are explained throughout the text.

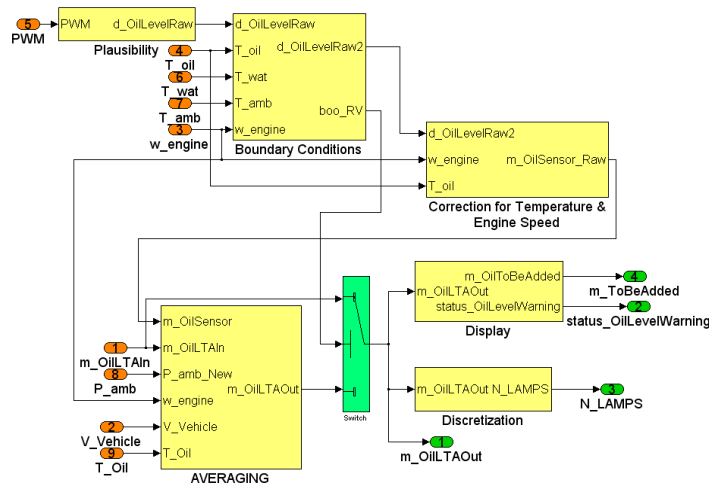


Figure 2 – General signal flow

Plausibility Sub-routine

This sub-routine converts the signal to distance value and checks if the signal duty cycle is between the predefined boundary values. Otherwise, the output is a replacement value.

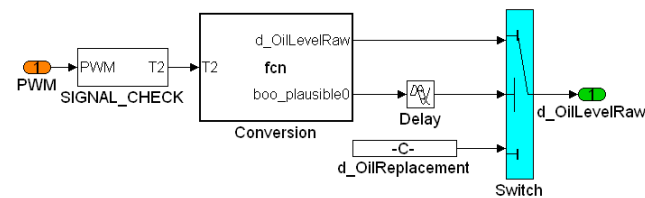


Figure 3 – Plausibility sub-routine

Boundary Conditions

This sub-routine checks if the oil temperature or water temperature is between predefined boundary values. If both of them are out of range, the replacement value is used.

Ambient temperature and engine speed values are also checked if they are within the predefined ranges.

If all the conditions are met calculated value is sent, otherwise a replacement value is used.

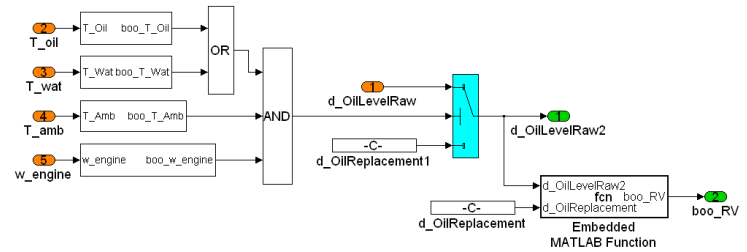


Figure 4 – Boundary conditions sub-routine

Correction for Oil Temperature and Engine Speed Sub-routine

The level signal is first converted to volume information using a curve which defines the oil pan geometry.

This volume signal, together with the oil temperature is fed to a curve to find the mass of the oil in the oil pan.

In order to find the amount of oil trapped inside the engine, a special map is used. The inputs of this map are the oil temperature and the engine speed. The mass inside the oil pan and the mass trapped inside the engine are added to find the total mass of the oil inside the engine (Figure 5). Total mass is used for all calculations.

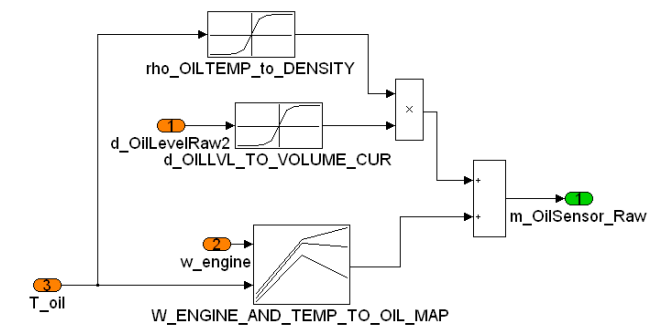


Figure – 5 Oil mass prediction sub-routine

Averaging Sub-routine

In order to get rid of the effect of instantaneous oil level changes due to waves inside the oil pan, a long term averaging is necessary. Previous long term average should be read from memory. The response time of long term averaging is a function of calibratable variables.

Since the oil is trapped in the backside of the oil pan when the vehicle is on an inclined surface, the inclination effect is taken into consideration. The maximum of values taken in a driving cycle is used to update the long term average (Figure 6).

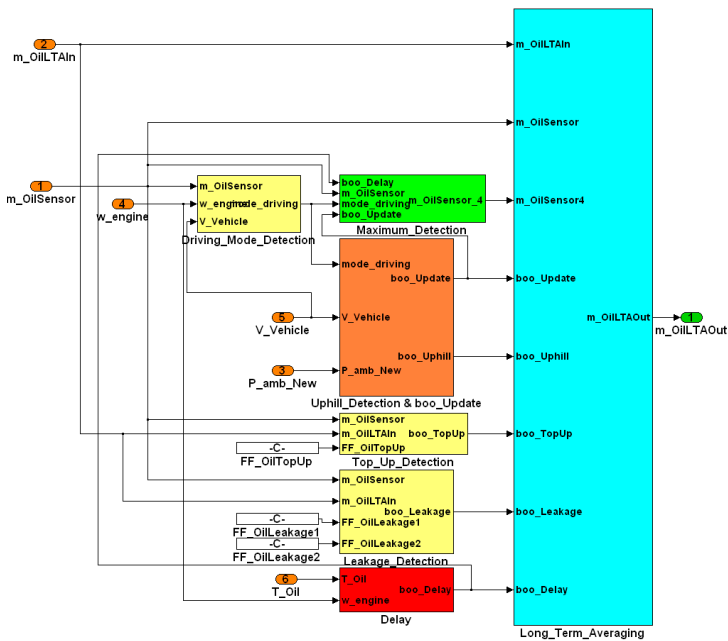


Figure 6 – Averaging sub-routine

Driving Mode Detection

The oil level signal is used only when the driving mode is set to 1 which is set when the following conditions are all satisfied as shown in Figure 7.

- The difference between PT1 filtered oil level signal and signal itself should be less than a threshold.
- Vehicle acceleration magnitude should be less than a threshold.
- Vehicle speed should be above a threshold.
- The difference between PT1 filtered engine speed signal and signal itself should be less than a threshold.
- Above conditions are satisfied for a period of time which is above a certain threshold.

If one of the above conditions are not satisfied driving mode signal is set to zero immediately.

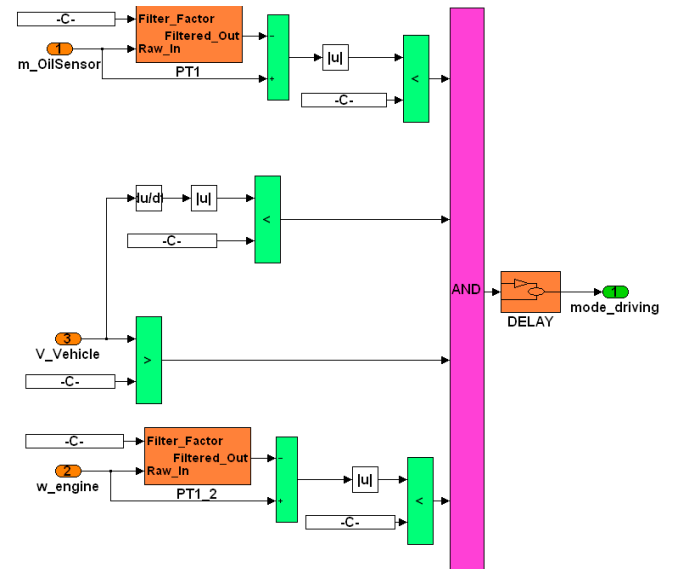


Figure 7 – Driving mode detection sub-routine

Maximum Detection

In a driving cycle which lasts for a specified vehicle travel, the maximum value of the oil level is found by “maximum detection” sub-routine (Figure 8).

Initially the oil mass signal is filtered by a PT1 filter. The output of the filter is sent to a sub-routine where the signal is compared with the previous value and the bigger value is sent as the output of this sub-routine. If mode_driving signal is zero previous value is sent as output. If the boo_delay signal or boo_update signal is one the previous value of the next time step is set to zero.

In order to use the biggest 10 maximum values to calculate the output of the “maximum detection” sub-routine, an additional function is used. This function generates a zero vector of size [10x1]. At every time step the smallest of this vector is updated with the input if the input is bigger than the smallest element of the vector. The output is simply the average of this vector.

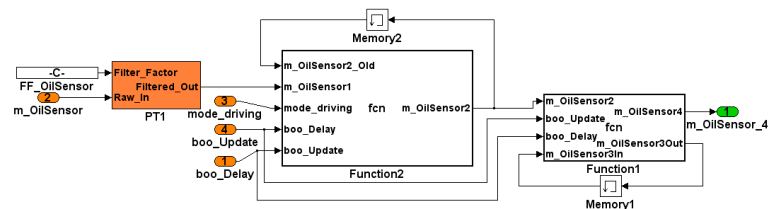


Figure 8 – Maximum detection sub-routine

Uphill Detection & Update Flag Sub-routine

The long term average is updated only when boo_Update = 1 and boo_Uphill = 0. These flags are evaluated in separate sub-routines. The mileage signal is used at each time and boo_Update signal is set to 1