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Implementation of Electronic Fuel Injection using State Flow

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Abstract:- Electronic devices in automotive area have been used on large scale and a control unit is mandatory for greater engine efficiency. By performing the spark advance and injection timing correctly in internal-combustion engines, an engine control unit improves drivability and helps to reduce fuel consumption. Before ECUs, air-fuel mixture, ignition timing, and idle speed were mechanically set and dynamically controlled by mechanical and pneumatic means. The fuel injection system has the major role to control the engine's fuel supply. The application of soft computing technique for Electronic Fuel Injection improves the efficiency of the system. Our project is to develop a state flow based Electronic Fuel Injection system for a Single Cylinder Spark Ignition Engine. State Flow based model is designed and developed in MATLAB. To validate the simulation results, state flow is implemented in a Microcontroller. Further as the Electronic Control Unit is programmable, it could be used to enhance the performance of different Engines.

I. INTRODUCTION

The ignition timing and injection time has a significant effect on fuel consumption, torque, drivability and exhaust emissions. The three most important pollutants are hydrocarbons (HC), carbon monoxide (CO) and nitrogen oxides (NOx). The HC emissions increase as timing is advanced. NOx emissions also increase with advanced timing due to the higher combustion temperature. CO changes very little with timing and is mostly dependent on the air–fuel ratio. As is the case with most alterations of this type, a change in timing to improve exhaust emissions will increase fuel consumption. With the leaner mixtures now prevalent, a larger advance is required to compensate for the slower burning rate. This will provide lower consumption and high torque but the mixture must be controlled accurately to provide the best compromise with regard to the emission problem. As the requirements for lower and lower emissions continue, together with the need for better performance, other areas of engine control are constantly being investigated. This control is becoming even more important as the possibility of carbon dioxide emissions being included in future regulations increases. Some of the current and potential areas for further control of engine operation are included in this section.

On-board diagnostics (OBD) is an automotive term referring to a vehicle's self-diagnostic and reporting capability. OBD systems give the vehicle owner or repair technician access to the status of the various vehicle subsystems. The amount of diagnostic information available via OBD has varied widely since its introduction in the early 1980s versions of on-board vehicle computers. Early versions of OBD would simply illuminate a malfunction indicator light. If a problem was detected but would not provide any information as to the nature of the problem. Modern OBD implementations use a standardized digital communications port to provide real-time data in addition to a standardized series of diagnostic trouble codes, or DTCs, which allow one to rapidly identify and remedy malfunctions within the vehicle.

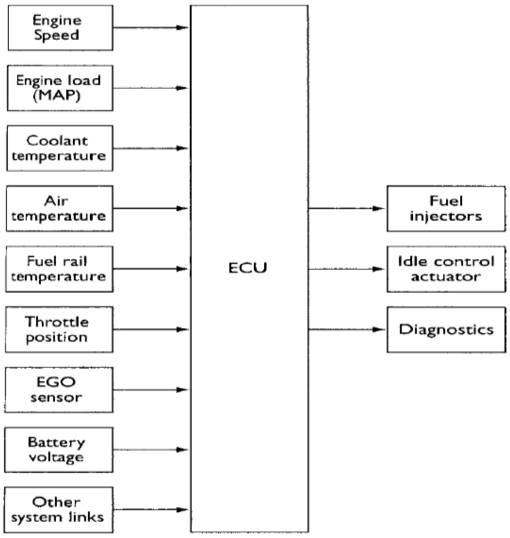


Fig 1:- Sensors and Actuators

II. LITERATURE SURVEY

A. An Add-On Module To Ecu For Extending The Functionalities Of Efi Tune-Up Process Authors

Suneth Pathirana, Cyril Gajanayake, Charith W. Vithanage, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 7, July 2013. ABSTRACT: The paper focuses on the ideology, procedures followed in order to implement, and the experimental results of an electronic device developed to extend the functionalities of an Electronic Control Unit (ECU) employed in the automobiles equipped with Electronic Fuel Injection (EFI) technology. The EFI system is empowered with a computing unit, ECU.

B. Application of Hybrid Fuzzy Logic Controller for Controlling Afr Engine Authors

Mohammad Javad Nikole, Journal of Ocean, Mechanical and Aerospace -Science and Engineering-, Vol.41 March 30, 2017, Ocean & Aerospace Research Institute, Indonesia. ABSTRACT: This paper mainly focuses on new simulation model using MATLAB Simulink for a SI (Spark-Ignition) engine has been developed that included all engine dynamic models such as dynamic model of the throttle body, a lambda dynamic model, a model of the intake manifold dynamic, and models of engine torque and fuel injection dynamic. Then, to control the AFR in SI engines hybrid fuzzy logic controller (HFLC) was created by combining a PID control and fuzzy control to maximize fuel economy and minimize exhaust emissions.

III. PROPOSED SYSTEM

This paper presents the development of State flow based injection control system for a single cylinder SI engine. The state flow controller (SFC) was designed and developed in MATLAB. The inputs to the SFC are engine speed, oxygen sensor and throttle position and the output is Fuel Injection time. The Fuel rate value obtained from the MATLAB simulation for different fault conditions is found. To validate the simulation results, the state flow is implemented in a microcontroller with oxygen sensor simulator.

IV. OBJECTIVE OF THE PROJECT

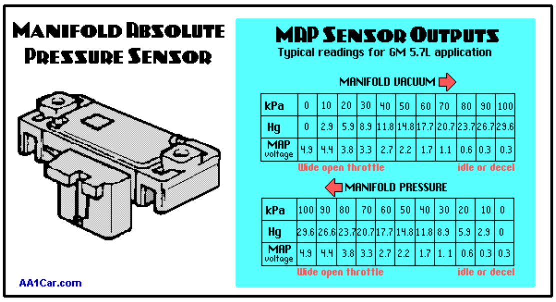
To validate the simulation results, the state flow is implemented in a microcontroller with oxygen sensor simulator. The fuel rate control uses signals from the system's sensors to determine the fuel rate which gives a stoichiometric mixture. The fuel rate combines with the actual air flow in the engine gas dynamics model to determine the resulting mixture ratio as sensed at the exhaust. The model uses three subsystems to adjust the fuel rate to give a stoichiometric ratio based on the sensor input and feedback signals.

V. MODELLING

Faults may occur in the fuel system due to malfunctioning of any of the sensors

A. *MAP Sensor (Manifold Absolute Pressure Sensor):*

The purpose of the MAP sensor or Manifold absolute pressure sensor is to provide information about the air pressure in the intake manifold to the ECU.



MAP Sensor Outputs
Typical readings for GM 5.7L application

MANIFOLD VACUUM

kPa	0	10	20	30	40	50	60	70	80	90	100
Hg	0	2.9	5.9	8.9	11.8	14.8	17.7	20.7	23.7	26.7	29.6
MAP voltage	4.9	4.4	3.8	3.3	2.7	2.2	1.7	1.1	0.6	0.3	0.3

Wide open throttle idle or decel

MANIFOLD PRESSURE

kPa	100	90	80	70	60	50	40	30	20	10	0
Hg	29.6	26.6	23.7	20.7	17.7	14.8	11.8	8.9	5.9	2.9	0
MAP voltage	4.9	4.4	3.8	3.3	2.7	2.2	1.7	1. 1	0.6	0.3	0.3

Wide open throttle idle or decel

Fig 2:- Manifold Absolute Pressure Sensor

B. *EGO Sensor (Exhaust Gas Oxygen Sensor)*

This device provides information to the ECU on exhaust gas oxygen content. From this information, corrections can be applied to ensure the engine is kept at or very near to stoichiometry.

Fig 3:- Oxygen Sensor

C. *Temperature Sensor*

A simple thermistor provides engine coolant temperature information and it measures the temperatures of fluids or parts in the engine and report it to the ECU.

Fig 4:- Temperature Sensor

D. *Speed Sensor:*

Most injection systems, which are not combined directly with the ignition, take a signal from the coil negative terminal. This provides speed data but also engine position to some extent.

Fig 5:- Engine Speed Sensor

VI. DESIGN

- Software used for simulation – MATLAB R2017a. (State Flow Model is developed using MATLAB)
- Inputs to Electronic Control Unit (ECU)

a) MAP Sensor
b) EGO

c) Temperature sensor
d) Speed sensor

- Output – Injection Time, Fuel Rate (g/s).

A single State flow chart, consisting of a set of six parallel states, implements the control logic in its entirety. The four parallel states corresponds to the four individual sensors. The remaining two parallel states are for multiple faults. The model synchronously calls the entire State flow diagram at a regular sample time interval of 0.01 sec. This permits the conditions for transitions to the correct mode to be tested on a timely basis.

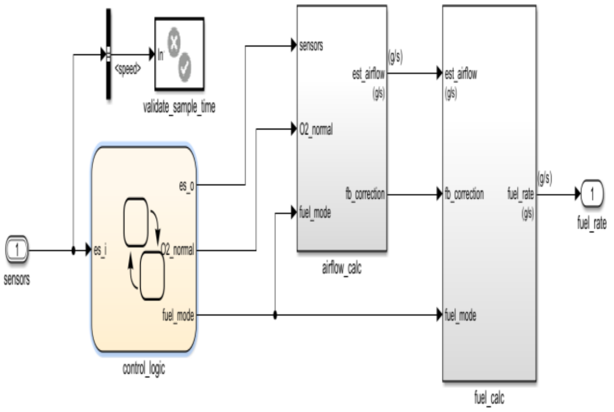


Fig 6:- The Control Logic Chart

When execution begins, all of the states start in their normal mode with the exception of the oxygen sensor (EGO). The O2_warmup state is entered initially until the warm up period is complete. The system detects throttle and pressure sensor failures when their measured values fall outside their nominal ranges. A manifold vacuum in the absence of a speed signal indicates a speed sensor failure. The oxygen sensor also has a nominal range for failure conditions but, because zero is both the minimum signal level and the bottom of the range, failure can be detected only when it exceeds the upper limit. Every sensor has two states

a) No fault (all sensor functions normally)
b) Fail state (one or more sensor fails)

Regardless of which sensor fails, the model always generates the directed event broadcast Fail.INC. In this way the triggering of the universal sensor failure logic is independent of the sensor. The model also uses a corresponding sensor recovery event, Fail.DEC. The Fail state keeps track of the number of failed sensors. The counter increments on each Fail.INC event and decrements on each Fail.DEC event. The model uses a super state, Multi, to group all cases where more than one sensor has failed.

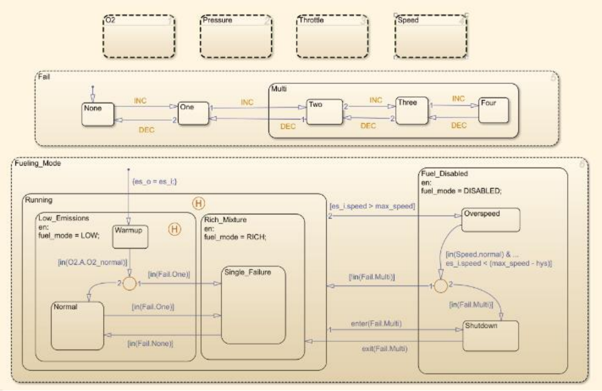


Fig 7:- The Control Logic Subsystem

The bottom parallel states represents the fuelling mode of the engine. If a single sensor fails, operation continues but the air/fuel mixture is richer to allow smoother running at the cost of higher emissions. If more than one sensor has failed, the engine shuts down as a safety measure, since the air/fuel ratio cannot be controlled reliably.

During the oxygen sensor warm-up, the model maintains the mixture at normal levels. If this is unsatisfactory, the user can change the design by moving the warm-up state to within the Rich_Mixture super state. If a sensor failure occurs during the warm-up period, the Single_Failure state is entered after the warm-up time elapses. Otherwise, the Normal state is activated at this time.

A protective over speed feature has been added to the model by creating a new state in the Fuel Disabled super state. Through the use of history junctions, we assured that the chart returns to the appropriate state when the model exits the over speed state.

As the safety requirements for the engine become better specified, we can add additional shutdown states to the Fuel Disabled super state.

VII. SENSOR OPERATION

When a sensor fails, an estimate of the sensor is computed. For example, open the pressure sensor calculation. Under normal sensor operation the value of the pressure sensor is used. Otherwise, the value is estimated.

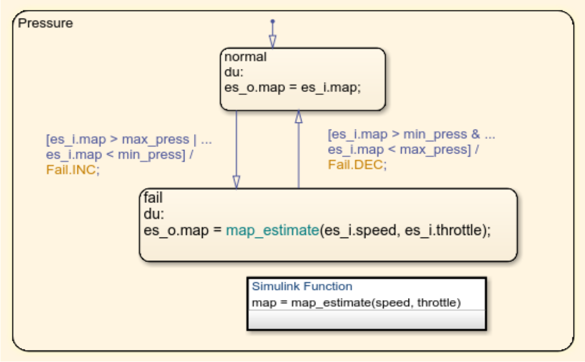


Fig 8:- The Control Logic Subsystem

The estimate of manifold pressure is computed as a function of engine speed and throttle position.

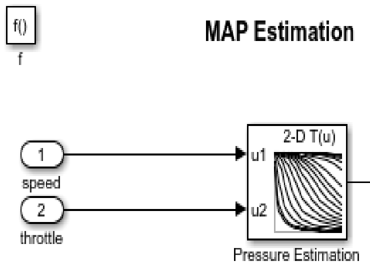


Fig 9:- Manifold Absolute Pressure Sensor Estimation

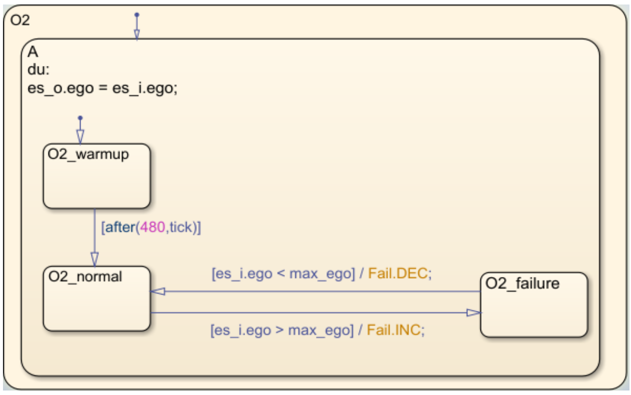


Fig 10:- Oxygen Sensor Correction

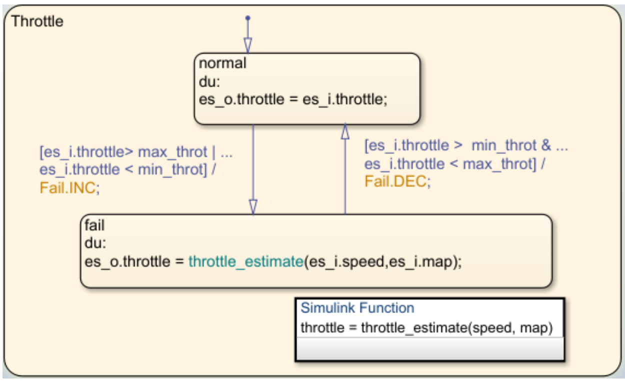


Fig 11:- Throttle Sensor Correction

VIII. OXYGEN SENSOR SIMULATOR

The O2 or Oxygen sensor is in charge of providing the ECM a measurement of Oxygen content in the exhaust. Automotive oxygen sensors, colloquially known as Oxygen ("lambda") sensors, make modern electronic fuel injection and emission control possible. They help determine, in real time, whether the air–fuel ratio of a combustion engine is rich or lean. The ECM then uses said value to control fuel injection pulse width. The input is analog from lambda sensor, passed through a Low pass filter to remove noise above 1 Hz. There is a voltage divider network producing 0.45 V and 0.5 V as reference for the op-amp comparators. This leaves a ±25mV wide window between lean and rich. The outputs can interrupt the microcontroller. The lambda sensor produces a voltage proportional to oxygen content, i.e. proportional to Air Fuel Ratio. An output voltage of 0.2 V (200 mV) DC represents a "lean mixture" of fuel and oxygen, where the amount of oxygen entering the cylinder is sufficient to fully oxidize the carbon monoxide (CO), produced in burning the air and fuel, into carbon dioxide(CO_2). An output voltage of 0.8 V (800 mV) DC represents a "rich mixture", which is high in unburned fuel and low in remaining oxygen. The ideal set point is approximately 0.45 V (450 mV) DC. This is where the quantities of air and fuel are in the optimal ratio, which is ~0.5% lean of the stoichiometric point, such that the exhaust output contains minimal (CO) Carbon monoxide. At ideal AFR = 14.7:1 (l =1), the output voltage = 475 mV. Closed-Loop in automotive technology terms, is referred to as the closed relationship of Oxygen sensor voltage, to ECM injector pulse-width control, and then back to Oxygen sensor voltage. The Oxygen Sensor Simulator, is a simple piece of equipment that mimics the output signal of an Oxygen sensor. It is calibrated to output a complete swing of voltage every 2.5 to 3 seconds, which is perfect for a simulator

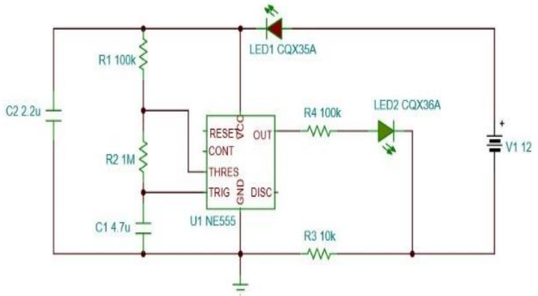


Fig 12:- Oxygen Sensor Simulator Circuit

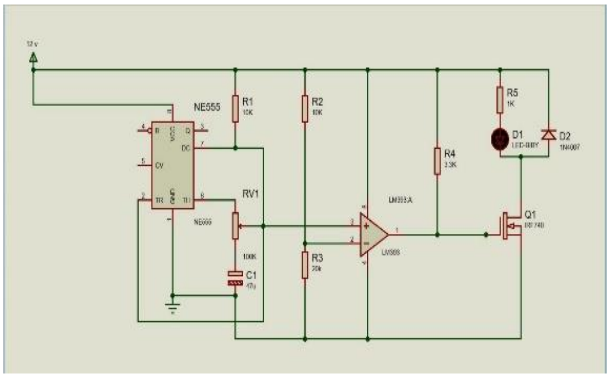


Fig 13:- Fuel Injector Pulser Circuit

IX. CONCLUSION

Thus the Fault Tolerance in controlling the fuel map is done by predicting the expected failures to occur in the sensor unit of the internal system (Fuel Map) and necessary compensatory process is made to ensure the continuation of the work of the engine on an ongoing basis with a failure until the failure treatment or programmatically change the system on part if necessary. This project can be implemented in an electronic control unit with all the sensors and actuators in coming years.

X. ACKNOWLEDGEMENT

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