Gasoline Strategy Feature Overview

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Revision History see version control tool

Abstract

This document provides an overview of the features contained in the gasoline strategies developed by Pi Innovo. The descriptions contained within are intended to convey the content, depth, and robustness of the strategies. This is not intended to replace the existing software requirements or design documents.

Contents

1. Introduction and Scope 4
2. Overview 4
3. Functional Behavior 4
3.1 Engine Running Mode 4
3.2 Target Air Fuel Ratio 5
3.3 Air Charge Measurement & Base Fuel 5
3.4 Fuel Control 5
3.4.1 Closed Loop 5
3.4.2 Transient Fuel 5
3.4.3 Deceleration Fuel Shut Off 6
3.4.4 Canister Purge 6
3.4.5 Adaptive Fuel 6
3.4.6 Final Fuel 6
3.5 Spark Control 7
3.5.1 Base Spark 7
3.5.2 Spark Modifiers 7
3.5.3 Spark Arbitration 7
3.6 Idle Speed Control 7
3.7 Electronic Throttle Control 8
3.8 Air Conditioning Control 8
3.9 Cooling Fan Control 8
3.10 Calculated Signals 8
3.11 Diagnostics 9
3.11.1 Out of Range 9
3.11.2 Rationality 9
3.12 Miscellaneous Features 9
3.12.1 Engine Speed Limiter 9
3.12.2 Catalyst Protection 9
3.12.3 Manual Calibration Override 9
3.12.4 CAN Communications 9
4. Frequently Asked Question 10

4.1 Are the strategies production ready? 10

4.2 What emissions level can they achieve? 10

4.3 Do they have diagnostics? 10

4.4 Do you support OBD? 10

4.5 Can the strategies be used in other ECUs? 10

4.6 What engines can they be used on? 10

4.7 How are the strategies sold or licensed? 11

5. Terms and Abbreviations 11

1. Introduction and Scope

The gasoline strategies were developed by Pi Innovo over time based on experience gained in multiple projects and revised subsequently to include additional functions and features. This document describes the features contained in the strategies, where the strategies have been used, and common questions people have about the strategies.

2. Overview

The gasoline strategies are developed in Matlab Simulink. C language versions of the strategies are not available. The strategies are appropriate for use on OpenECU, as well as other 3rd party ECUs. Use on 3rd party ECUs may require some software manipulation to meet the destination ECUs operating system needs.

The Simulink strategies use floating point arithmetic and native Simulink blocks in the core of the application. No proprietary OpenECU blocks are used in the core of the application, thus the strategy can be more easily ported to a 3rd party ECU.

The gasoline strategy currently (Dec 2013) consumes the following resources:

- 15,522 lines of code
- 13,608 effective lines of code (without comments)
- 283,500 bytes of strategy memory used
- 42,716 bytes of calibration memory
- 22,910 bytes of workspace / displayable memory used
- 5,120 bytes of stack
- 1,380 calibration items (scalar, vector, and map)

3. Functional Behavior

3.1 Engine Running Mode

Stateflow based logic to process an enumeration to determine if the engine is:

- Stopped
- Cranking
- Running

This feature also provides an output of the time since engine start which is used elsewhere in the software to control start and post-start behavior.

3.2 Target Air Fuel Ratio

This feature determines the desired air fuel ratio for the engine based on operating state and sensor inputs. The target air fuel ratio (AFR) can be modified for cold start, hot soak, and high load operation. Ideally the engine will operate at a stoichiometric mixture for optimum behavior, however under these three conditions additional enrichment or enleanment may be required.

High load operation provides a multiplier to the base fuel amount via a lookup table based on speed and load.

Hot soak operation provides a multiplier to the base fuel amount via a lookup table. This amount will be ramped out based on coolant temperature and the duration the engine has been stopped.

Cold start operation provides a multiplier to the base fuel amount based on coolant temperature which can be decayed to zero based on engine speed and load.

3.3 Air Charge Measurement & Base Fuel

The strategy uses a speed density model to determine the air mass in the cylinder. Using the standard speed density equation and lookup tables for volumetric efficiency, charge pressure, and charge temperature, the milligrams of air per cylinder is determined.

The target AFR is used with the milligrams of air per cylinder to determine the desired fuel mass.

This fuel mass is the base fuel that will be subject to additional modifications described elsewhere in the document.

3.4 Fuel Control

3.4.1 Closed Loop

This feature reads the HEGO sensor feedback and makes adjustments to the delivered fuel to ensure the target AFR value is achieved. Logic exists to limit the enablement of close loop fuel control by considering DFSO, injector faults, engine run time, and coolant temperature. The logic monitors the switching of the sensor between rich and lean and determines a fuel multiplier.

3.4.2 Transient Fuel

Transient fuel provides enrichment during changes in engine speed and load. Transient fuel can be enabled for tip-in and tip-out events. Once enabled, the transient fueling logic allows for tuning of fast and slow transient fuel compensations. Transient fuel is an additive parameter.

3.4.3 Deceleration Fuel Shut Off

This feature provides the ability to linearly ramp out, and ramp in fuel, as well as retard spark, and provide DFSO enrichment during exit events. The logic monitors the driver request throttle, engine speed, and engine runtime to enable DFSO.

3.4.4 Canister Purge

Canister purge controls the evaporative emissions container and recovering fuel vapor by introducing it to the intake manifold. The logic contains enable logic to govern when purge can be active, as well as logic to control the amount of purge demand requested by the ECU. The purge logic calculates the purge flow and determines the correction to the delivered fuel due to the purge flow.

3.4.5 Adaptive Fuel

The adaptive fuel feature stores a scalar gain and offset which is used to compensate for errors in the base fuel delivery. The logic is enabled by a range of inputs ensuring the value to be stored is in fact stable and reliable. The logic then stores in NVM the offset and gain values and uses these values on subsequent drive cycles.

3.4.6 Final Fuel

The final fuel feature combines all of the fuel correction sources with the base fuel to determine the final fuel quantity, and determines the specific injection timing for each individual injector. The feature sums up the base fuel and nine other correction factors to determine a final fuel correction. The factors are:

- Base Fuel
- RPM Limiter Correction
- DFSO Correction
- Catalyst Protection Correction
- Closed Loop Fuel Correction
- Injector Fault Correction
- Transient Fuel Correction
- Purge Fuel Correction
- Adaptive Fuel Correction

The final fuel logic also has a feature to disable all fuel injectors should the possibility of over-enrichment during engine cranking occur. This is otherwise known as anti-flood control.

The final fuel logic also determines the fuel injector timing, in addition to the fuel injector duration. The timing logic compensates for the start of injection (SOI) to ensure injection always occurs on a closed intake valve.

3.5 Spark Control

3.5.1 Base Spark

The base spark is determined by a lookup table of engine speed and load.

3.5.2 Spark Modifiers

The base spark value is modified by the following parameters:

- Charge air temperature
- Knock spark offset
- Drivability/Transient spark

The drivability/transient spark provides the ability to retard the spark briefly during a transient engine event to avoid spark knock.

3.5.3 Spark Arbitration

The spark arbitration feature takes the base spark value and the various modifiers and arbitrates a final spark advance, as well as managing the dwell period for the coils.

The arbitration looks at inputs from:

- Cranking spark
- Running spark
- Catalyst spark offset

The spark arbitration manages the dwell control for the coils and compensates for battery voltage. The final outputs of the spark arbitration are the coil on-angle and the coil off-angle.

3.6 Idle Speed Control

The idle control feature start by determining what state of idle the engine is operating.

- Closed loop idle
- Engine cranking
- Return to idle
- Drivability

The idle control logic works by adjusting both spark timing and (IAC or ETC) to regulate the desired idle speed and torque.

The desired idle speed for closed loop idle is determined by engine temperature, time since engine start, alternator load, and air conditioning compressor load.

A feed-forward and feedback control scheme using a PID is used to regulate the idle speed of the engine. Feed-forward tables for the various idle states are developed to set the IAC or ETC air position. Spark control is only used in closed loop idle speed control.

For the case of IAC based systems, provisions for ensuring the stepper position limits are not reached are included, as well as learning the stepper position.

3.7 Electronic Throttle Control

The driver accelerator pedal position sensors are read and converted to a throttle demand through a lookup table. The throttle demand is further controlled through rate limiting functions to provide smooth operation. The throttle demand is then processed through a series of feedforward and feedback control loops to determine a duty cycle for the H-bridge output.

3.8 Air Conditioning Control

The air conditioning feature manages the control of the air conditioning compressor and the cooling fans. The air conditioner logic allows for the compressor to be turned off during WOT or high RPM operation to provide additional driving torque to the vehicle. Additionally the logic supports the idle speed control logic in anticipating the load from the air conditioning compressor, and compensating for compressor cycling.

3.9 Cooling Fan Control

This logic monitors the engine coolant temperature and operates the low speed and high speed cooling fans. This logic also monitors battery voltage to ensure sufficient voltage is present to operate the fans. Additionally the cooling fan control conducts diagnostic tests of the fans to ensure they are operating normally.

3.10 Calculated Signals

The strategy provides estimates for the following signals based on models, or derivations of sensed inputs.

- Engine coolant temperature
- Ambient air temperature
- Engine oil temperature
- Barometric pressure
- Charge air temperature
- Current transmission gear

3.11 Diagnostics

3.11.1 Out of Range

All analog inputs are checked for out of range (OOR) low, high, and open circuit.

Fuel injectors are diagnosed for output drive monitor faults

Canister purge is diagnosed for output drive monitor faults

3.11.2 Rationality

All analog inputs are checked for slew rate.

Certain sensors have additional rationality checks:

- MAP vs. TPS rationality
- Accelerator pedal1 vs. Accelerator pedal2
- TPS1 vs. TPS2

3.12 Miscellaneous Features

3.12.1 Engine Speed Limiter

Provides engine speed limitation via fuel shut off on a per-gear basis. Logic compensates for slight enrichment after engine speed limited is disabled to reinstate wall wetting.

3.12.2 Catalyst Protection

The catalyst protection feature estimates the exhaust gas temperature by a simple model that considers speed, load, AFR, and spark advance. The exhaust gas temperature is used to estimate the catalyst exotherm and compensate for heat loss in the exhaust. The final catalyst temperature estimate is used to determine if catalyst protection should be enabled.

Once enabled the catalyst protection feature will adjust the fuel mixture and the spark timing to reduce the exhaust gas temperature, and thus cool the catalyst.

3.12.3 Manual Calibration Override

All features have the ability to take manual calibration override to help the process of engine calibration and tuning.

3.12.4 CAN Communications

Some basic CAN messaging is built into the strategies currently. The strategies will output engine speed, vehicle speed, MIL state, odometer, fuel quantity, and ambient temperature. Additional CAN outputs can be easily configured using OpenECU CAN transmit blocks, as needed.

No CAN inputs are currently used in the strategies.

4. Frequently Asked Question

4.1 Are the strategies production ready?

Depends on what market or industry is being targeted. For modern production automotive applications the strategies are a great place to start but the diagnostic and OBD features required of modern automotive control systems would need to be added. The strategies are intended to jump start the development of production strategies and get a development team up and running quickly.

4.2 What emissions level can they achieve?

The gasoline strategies are capable of meeting Euro3 emissions in their current configuration. Typically, for more stringent emissions levels, a system approach is desired looking at the combined interaction between engine system hardware, aftertreatment, and the control strategies. Pi Innovo engineering has worked as part of an OEM team implementing a system to meet Euro 6 level emissions requirements.

4.3 Do they have diagnostics?

The strategies have some basic diagnostics for sensor faults as well as some rationality checks. These diagnostics do not include any OBD major monitor diagnostics. The gasoline strategies have approximately 80-90% of the comprehensive component diagnostics and 0% of the major monitor diagnostics required for a production program.

4.4 Do you support OBD?

Pi Innovo offers an OBD infrastructure handler separate from the gasoline strategies. The OBD infrastructure handler can be integrated with the strategies to provide all of the service tool support and communications.

4.5 Can the strategies be used in other ECUs?

Yes. The strategies are built from pure Simulink and can thus be easily ported to other ECUs that support model based development.

4.6 What engines can they be used on?

The gasoline strategies can be used on engines matching the following configuration:

Number of cylinders:	1 to 8
Injectors per cylinder	8cyl: 1, 6cyl: 1, 4cyl 2
Injector type:	Strategy independent, hardware dependant

Coil type:	Smart coil only
Coil quantity	1 to 8
Crank wheel configuration	12 – 60 teeth with 1, 2, or 3 missing teeth
Cam wheel configuration	1 – 8 teeth
Number of cam wheel	1

4.7 How are the strategies sold or licensed?

The gasoline strategies can be licensed with our without source code. Users can receive a pre-flashed ECU that can be calibrated and tuned via CCP, or they can receive raw source code.

5. Terms and Abbreviations

AFR	Air Fuel Ratio
DFSO	Deceleration Fuel Shut Off
ETC	Electronic Throttle Control
IAC	Idle Air Control
IAT	Intake (manifold) Air Temperature
MAP	Manifold Absolute Pressure
OBD	On-board Diagnostics
OOC	Out of correlation
OOR	Out of range
RS	Recommended section
TPS	Throttle Position Sensor