BITS Pilani
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Control Systems

Sajeeth Kumar

Lecture 06 - Control System Design Part 2
Air & Fuel Requirements

Scope

Engine Control Systems

- Air Mass Calculation – Measured vs Predicted
- Fuel Mass Calculation

SI Engine Control System

Air & Fuel Requirements

Air Mass Calculation

Measured vs Predicted

- Air mass measurement not very accurate – Transient conditions
- Measured vs Predicted – Usual cases converges within limits
- Measured – Use MAP / MAF sensor
- Predicted – Use TPS sensor
- Predicted values used for fail safe scenarios as well

Air Mass Calculation

Air Mass from MAP sensor

$$PV = mRT$$

- P – Pressure of air inside the cylinder - reading from MAP sensor in Pa
- V – Volume of air inside the cylinder in m^3
- R – Gas constant – 287 J/KgK
- T – Temperature of air inside the cylinder – reading from Intake Air Temperature Sensor in K
- m – Mass of Air in Kg / Stroke

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$$m = (MAP) * \frac{Cyl\ Vol\ * VE}{T + 273} * (\frac{1}{R})$$

Air Mass Calculation

Air Inlet Temperature Model

- Temperature of air is an important factor in accurately measuring air mass
- Air Temp dependent on
  - Temp of air at inlet
  - Heat soak
  - Engine temperature
- IAT sensor alone will not suffice
- Temperature compensation model is built – DOE & Testing
- Air temperature is offset based on values from LUT
- Compensate for air temperature increase due to other factors

Air Mass Calculation

Air Mass from MAF sensor

- MAF sensor calibrated to read air mass in g/s
- Total air mass flowing into engine measure directly
- Required in cases where engine VE is high – Example?
- Forced induction setups – ready around 200-250 kPa (positive pressures)
- MAP sensor is less accurate and slow
- MAF reading immediate – BUT
- MAF measured just behind air filter
- MAP measured in manifold
- Variations between MAP and MAF denote leak in intake
- MAP sensor on Intercoolers – Charge Pressure Sensor / Boost Pressure Sensor

Air Mass Calculation

Air Mass Predictions

- TPS vs RPM -> VE map -> Theoretical Air Mass in cylinder
- Atmos Pr vs TPS -> Vol Correction
- Air Temp vs TPS -> Temp Correction
- Predicted Air Mass = (Th Air Mass + Vol Correction) * Temp Correction * Density / Atmos Pressure
- Predicted air flow can be used when sensor failures occur
- Fail safe scenarios for multiple sensor failures
- Trade-Off between Predicted and Measured air mass for consideration

Air Mass Calculation

Air Mass Predictions

- TPS vs RPM -> VE map -> Theoretical Air Mass in cylinder
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Fuel Mass Calculation

Fuel Mass Predictions

- Once Air Mass is resolved -> Fuel Mass Calculation
- Base Fuel predictions – closed loop or open loop
- Closed Loop – Target AFR
- Open Loop – LUT, applicable load factor
- Corrections to base fuel – Steady state or transients
- Steady State – Warm-Up Enrichment – Summative
- Warm Up Offset – Summative

Fuel Mass Calculation

Fuel Mass Predictions

- Other Corrections
  - Closed Loop Correction
  - Fuel Trims – STFT & LTFT
  - Flaring Correction
  - Medium Transients
  - Wall Wetting

- Fast Transient – Corrections?
- Applied as a correction factor – Total Fuel Corrections

Thank You!

In our next session:

Correction factors for Transients