BITS Pilani
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Control Systems

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Lecture 05 - Control System Design Part 1
Crank Shaft Position Sensor

Scope

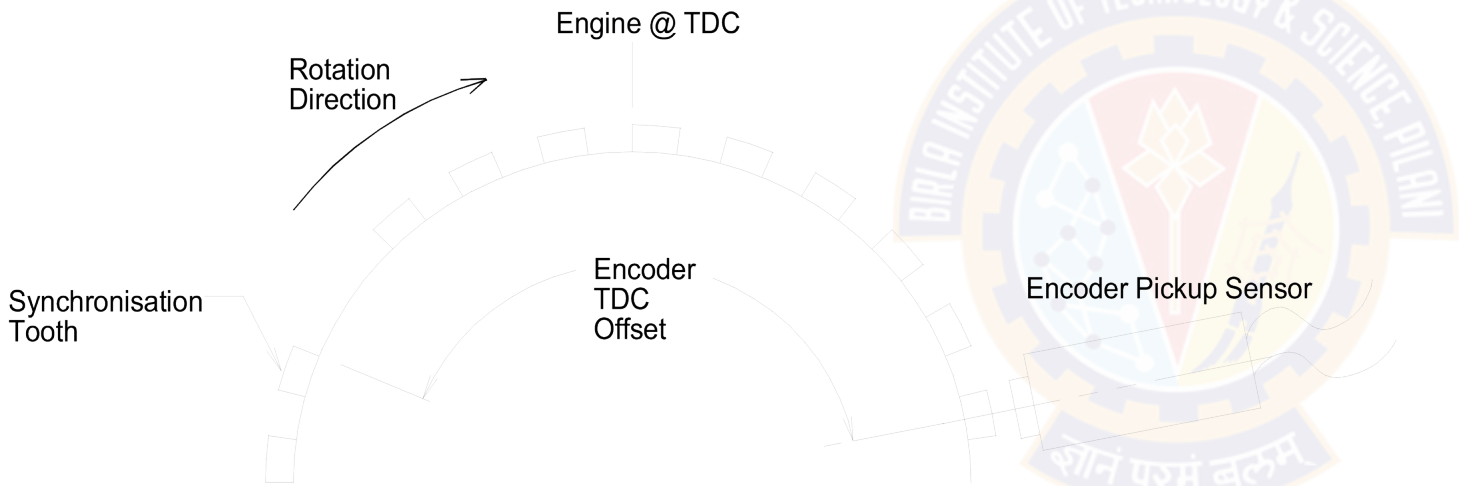
Engine Control Systems

- Crankshaft Speed Resolution
- Engine State Recognition
- Phase Recognition

SI Engine Control System

Crankshaft Speed Resolution

Engine RPM



- Naming Nomenclature Total – Missing
- Eg 36 – 1
- RPM resolution
- TDC resolution – Soft TDC
- Need for Phase recognition
- Other use cases

Crankshaft Speed Resolution

Engine RPM

- Engine is running 36-1 configuration, 14 teeth between TDC and sync tooth
- Calculate the soft TDC angle
- Calculate the frequency of pulses at 3000 rpm

Crankshaft Speed Resolution

Engine RPM – Advanced Algorithms

- How is Engine RPM related to Vehicle Speed?
- Engine is rotating at 4000 rpm in 3rd gear, 3rd gear ratio is 1.3, final drive ratio is 3.2
- Calculate the wheel speed
- If the wheel size is 205/60/R16, calculate the vehicle speed
- What is happening, if the wheel speed suddenly increases?
- What is the maximum engine RPM allowed?

Crankshaft Speed Resolution

Max Engine RPM – Mean Piston Speed

- How is maximum engine rpm calculated?
- Stress acting on the piston assembly – Tensile and Compressive
- Mean piston speed = 2* RPS * Stroke
- Limiting factor of max engine rpm
- Usual values
  - Low Speed Diesel – 8.5 m/s
  - Normal Diesel Engines – 11 m/s
  - Regular Petrol Engines – 18 m/s
  - Sports Cars – 25 m/s

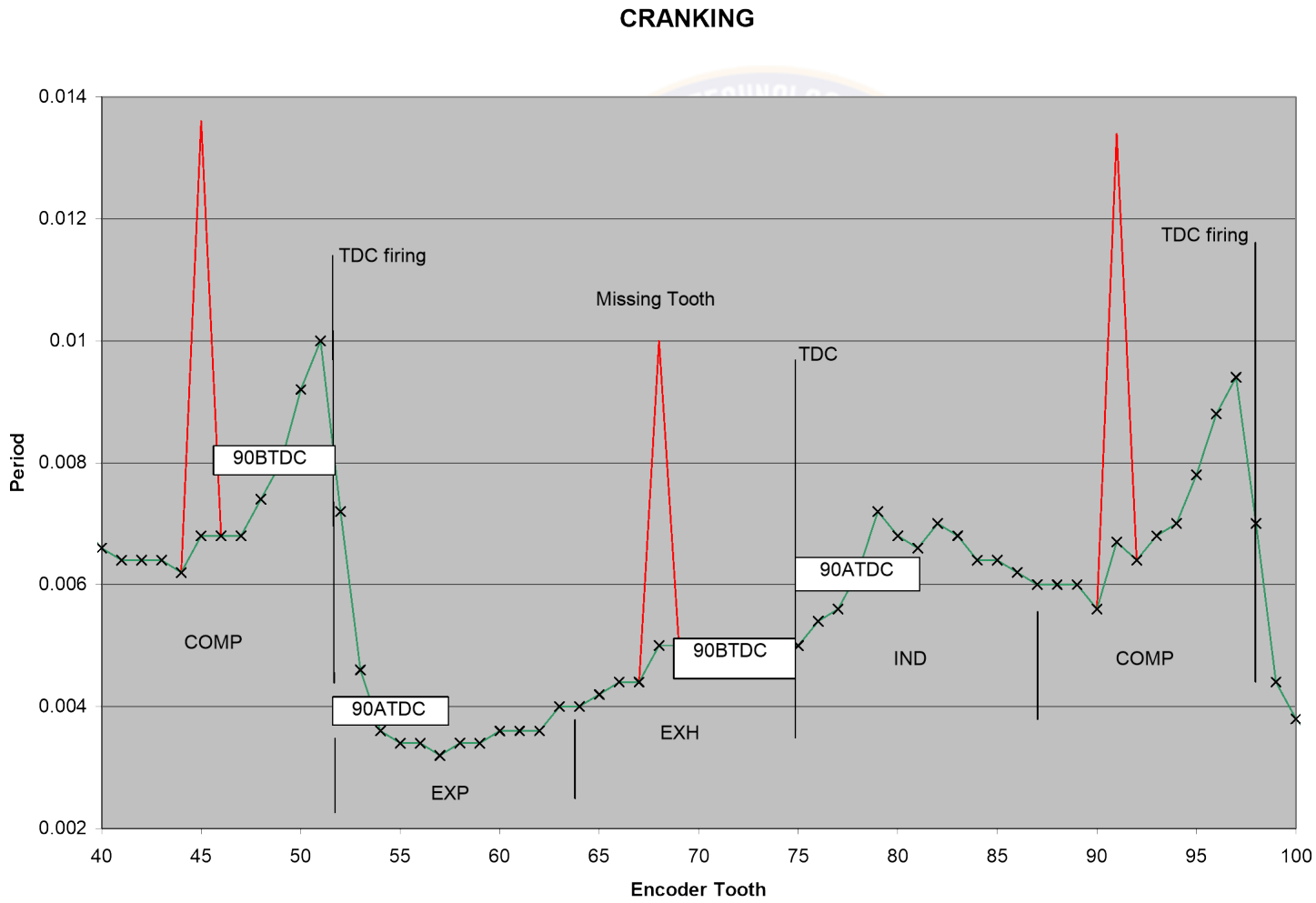
Engine Phase Recognition

Engine Phase – Stroke in Progress

- Essential to identify the exact stroke
- Fuel injection – Before suction stroke
- Diesel Engines – Pilot, Main and Post injections
- Recognized by speed variations
- Engine RPM measure at
  - 90 BTDC – Average of 4-10 Teeth Speeds
  - 90 ATDC – Average of 4-10 Teeth Speeds

Engine Phase Recognition

Engine Phase – Stroke in Progress



Engine Phase Recognition

Engine Phase – Exceptions

- While cranking – Interaction between starter motor and flywheel might disrupt readings
- Misfire – Reduction in engine speed during power stroke
- Encoder error
- ECU runs in sequential mode only when conditions are normal
- Runs in non-sequential mode otherwise
- Capable of forced non-sequential mode by external triggers

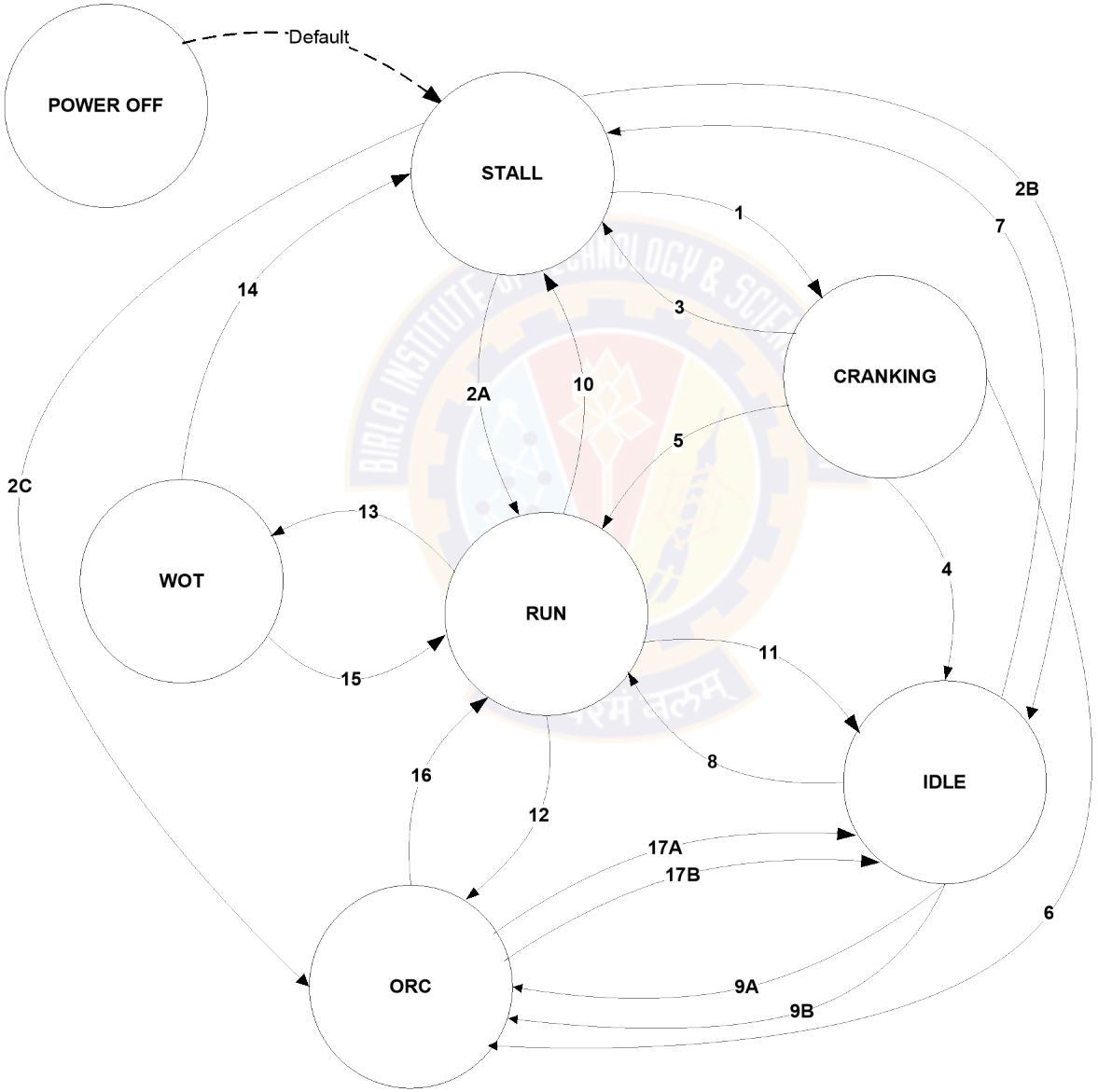
Engine State Resolution

Engine State

- Refers to the operating condition of the engine
- Primary states are
  - Stall
  - Cranking
  - Running
  - Over-Run

Engine State Resolution

Engine State



Engine State Resolution

Engine State

- How does the engine enter ORC from Stall?
- Why do we need to capture engine states?
- Who defines the engine states?
- Steady state and transients

Engine State Resolution

Engine State

Engine State	Engine RPM	Throttle Position
Stall	Zero	NA
Cranking	0 < RPM < Crank Threshold	TPS <= Flood Clear
Flood Clear	0 < RPM < Crank Threshold	TPS > Flood Clear
Run – Closed Loop	Idle Limit < RPM < Max RPM	TPS < Closed Loop Limit
Run – Open Loop	Idle Limit < RPM < Max RPM	TPS > Closed Loop Limit
Idle	Crank Threshold < RPM < Idle Limit	TPS = 0
WOT	Idle Limit < RPM < Max RPM	WOT Limit < RPM
ORC	ORC Limit < RPM < Max RPM	TPS = 0

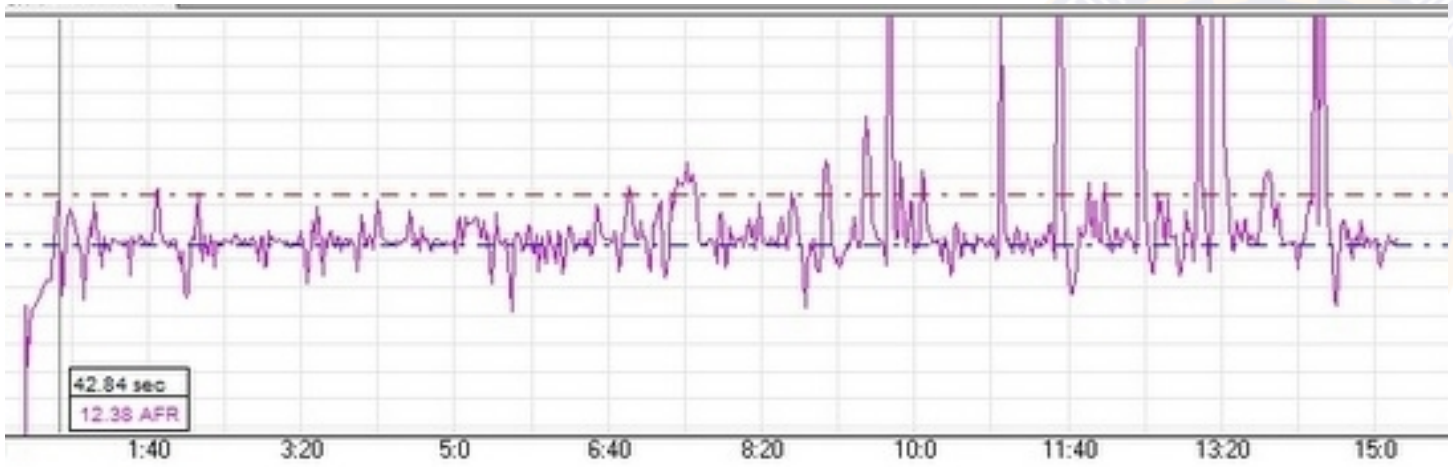
Engine State Resolution

Engine State – Closed Loop Operation

- To meet emissions targets – Engine runs in closed loop mode
- Closed Loop enabled only when
  - Throttle position less than threshold
  - Coolant temperature inside limits
  - No errors in O2 sensor or related circuits
- Control System targets fueling to achieve a stoichiometric mixture
- PID control on injector pulse width

Engine State Resolution

Engine State – Closed Loop Operation



- Variations in measured AFR – Changes in throttle & load
- PID control / calibration determines effectiveness
- Essential to maintain slightly richer than stoichiometric to ensure TWC operation
- PID calibration – Limitations
- Hence narrow operating window
- Closed loop operates on spark advance as well – but LUT based
- Injection PWM is commanded, based on RPM and Load, LUT supplies base advance
- Advance varied within limits to achieve target AFR

Thank You!

In our next session:

Plant Model Development