Name: Anandini Sahu
Section: S-101
ID: 2400031855

ECU

COH - HA

2marks

1. Mention two automotive examples where adaptive control is applied.

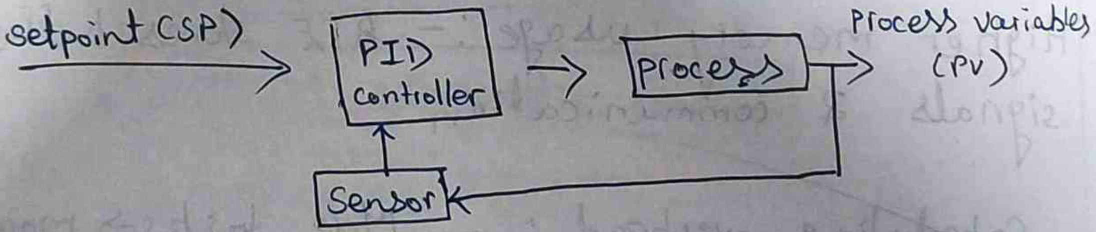
eg1: Adaptive cruise control (ACC) adjusts vehicle speed based on traffic conditions.

eg2: Adaptive suspension system - changes damping based on road surface and driving style.

2. Define Hardware in the loop (HIL) testing.

HIL testing is a simulation method where real ECU hardware is connected to a virtual vehicle model to test control algorithms in real time without using an actual vehicle.

3. Draw a PID controller based closed-loop system



4. Why FlexRay is prefered for deterministic control system

FlexRay provides high speed, time triggered and fault tolerant communication, ensuring predictable message timing for safety-critical functions like baking and steering

5. Function of sensor fusion in ADAS applications

Sensor fusion combines data from multiple sensors to create a more accurate and reliable understanding of the vehicle surroundings.

6. Two advantages of LIN communication for real time automative system.

- Low cost - suitable for simple sensors & actuators
- Deterministic communication : master slave timing ensures predictable message exchange

7. Define on board Diagnostics (OBD) and its func.

It is a system monitors and reports vehicle performance and emission faults.

It detects, records and reports diagnostic table codes.

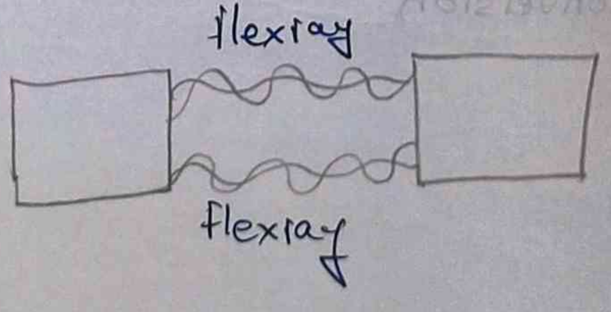
4 marks

1. Explain the role of the FlexRay protocol in achieving high - speed communication.

Role of the FlexRay protocol in achieving high-speed communication.

Flexray is an advanced automative communication protocol used for real time and high-speed data transfer between ECU (electionic control units)

- It provides data rate upto 10 Mbps, faster than CAN.

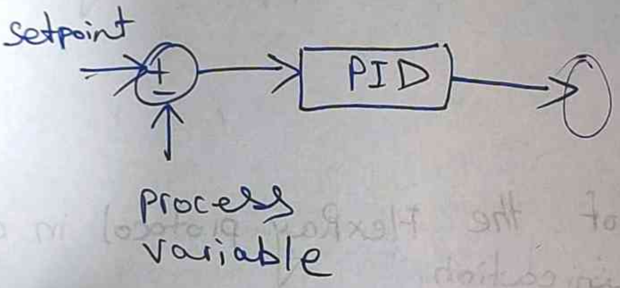


2. Describe how PID controllers are applied for engine speed or brake pressure control using feedback loops.

A PID (propotional - internal-derivative) controller maintains a target value (like engine speed or pressure) by adjusting inputs based on feedback It continuously compares actual with the desired point.

propotional term reacts to the present error

integral term removes past errors.



3. Outline the essential steps involved in acquisition and preprocessing of sensor signals in a vehicle ECU

Steps in acquistion and preprocessing of sensor signals in a vehicle ECU.

1. Sensing
2. Signal conditioning
3. Analog to Digital conversion
4. preprocessing
5. Storage processing

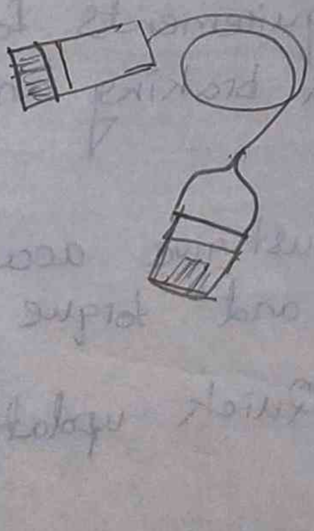
Physical sensor → Signal conditioning → Sensor interface → Preprocessing Stage → Application layer

4. Discuss the architecture and benefits of automotive ethernet in modern ECUs for ADAS.

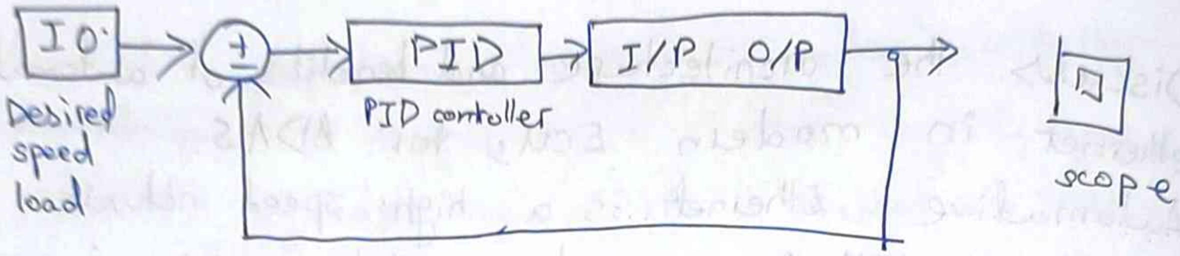
Automotive Ethernet is a high speed network technology used to connect multiple ECUs in modern cars.

Architecture: centralized communication is backbone switches connect ECUs (like camera, radar) support 1 Gbps or higher speeds.

Benefits: High bandwidth for ADAS and infotainment data.
Reduced wiring weight and cost.
Easier integration of smart sensors and cameras.
supports real-time and reliable data transfer.



5. Explain the purpose of PID controller in regulating vehicle dynamics such as speed and steering.



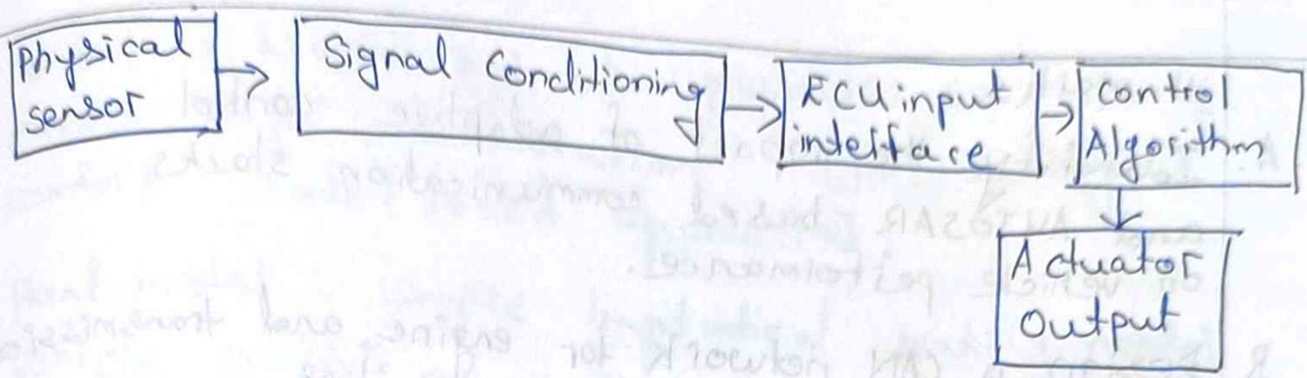
PID helps maintain smooth stable and safe vehicle behaviour under different driving conditions.

The PID controller keeps vehicle dynamics like speed steering angle or stability within safe limits. It continuously compares desired vs actual motion and adjusts throttle, brakes or steering motors.

6. Outline sensor interface requirements for accurate data acquisition in braking and traction control ECUs.

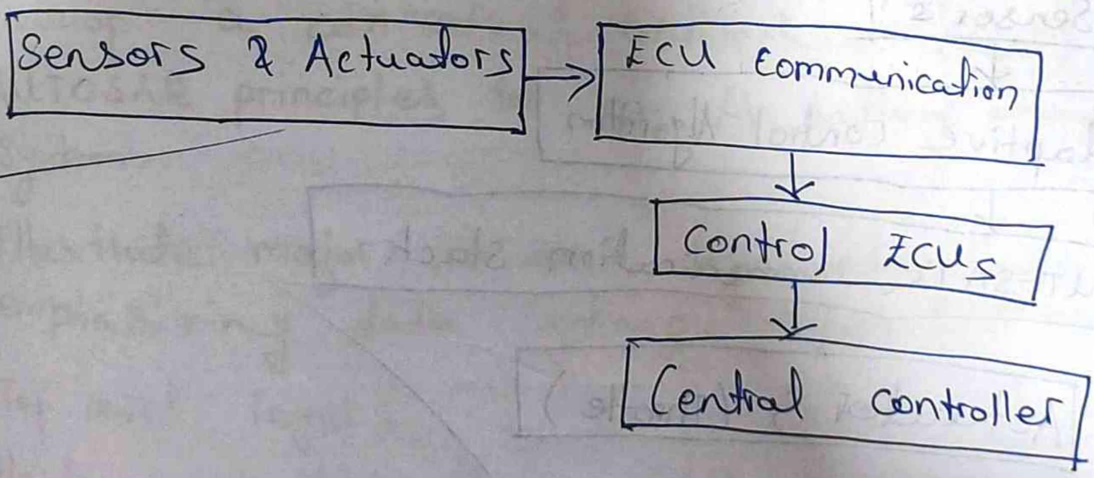
Sensor interface requirements for accurate data acquisition in braking and fraction control ECU's.

- High precision: sensor must give accurate data for pressure, speed and torque.
- Fast-response time: Quick updates to react to road contiotions.
- Noise immunity: Proper shielding and fittering to avoid signal interference.



7. Explain the significance of sensor signal conditioning in control systems used in vehicle.

- Raw sensor signals are often weak or noisy
- signal conditioning improves signal quality by amplifying small signals.
Filtering out noise
converting analog signals to digital form
calibrating the readings for accuracy.
This ensures the control system recieves clean and usable data for precise vehicle control.



11 marks

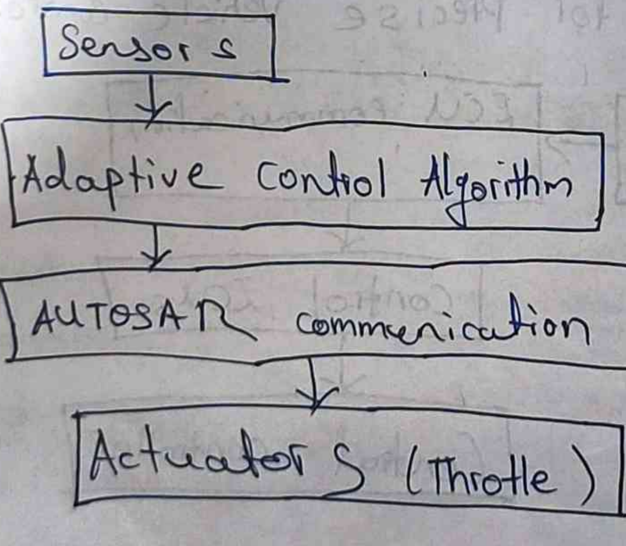
1\. A. Identify the impact of adaptive control and AUTOSAR-based communication stacks on vehicle performance.

B. Design a CAN network for engine and transmission ECUs showing messing priorities.

A. Add a radar so high-level SWcs recieve validated radar data using AUTOSAR layering & reusability

Hardware : connect radar to the ECU bus provide device driver in MCAL.

BSW :
use ethernet-NM for network ~~m~~ management if radar on automative ethernet.

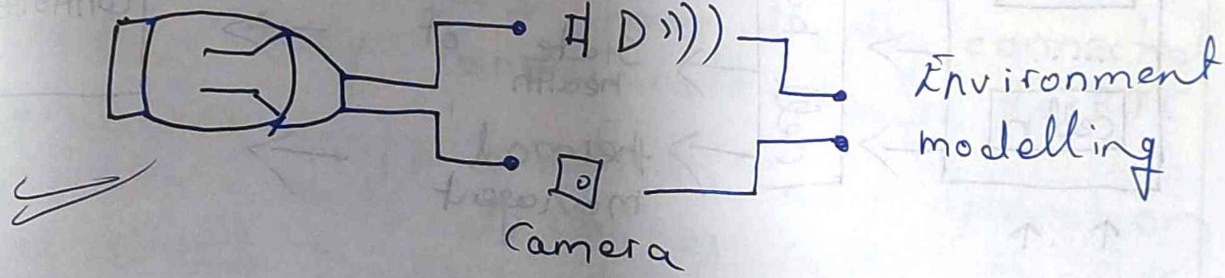


B. control actuator hydraulic pressure so braking meets target deceleration with safety & comfort model based approaches:

1. Plant-model : simple longitudinal braking model vehicle mass * a = -F -brake

2. Controller structure
Inner loop : fast PID controlling actuator to track pressure set point.

validation : simulate wide, hardware in the loop tests.



2.A Develop a conceptual architecture (ECU) using AUTOSAR principles for an EV battery management system.

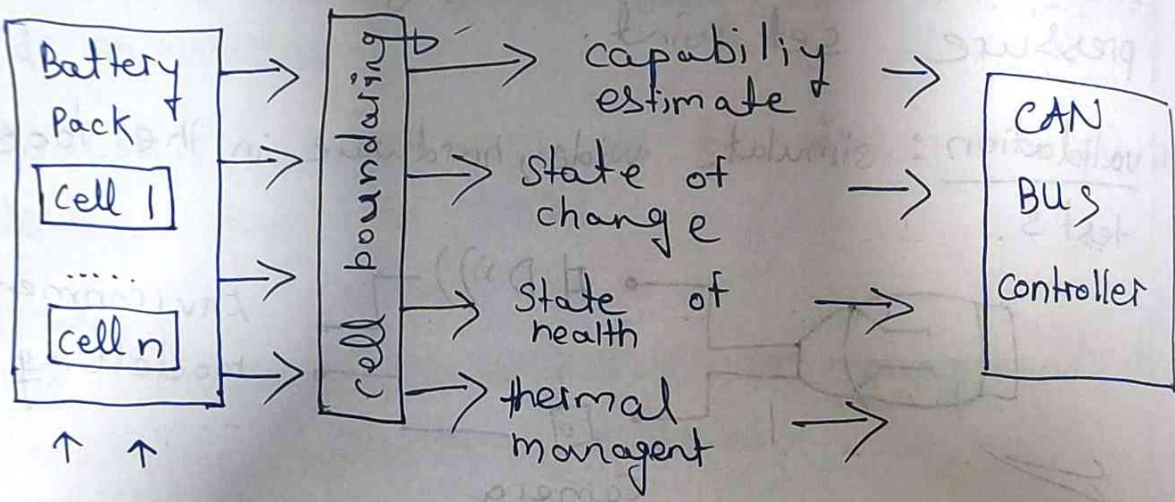
B. Illustrate major software layer interactions emphasizing data exchange through RTE and BSW

A. Top level layers
1. Hardware : MCU, ADC, CAN/ethernet
2. MCAL : ADC drivers, PWM, EEPROM
3. BSW (Basic Software)
 communication : CAN, LIN or ethernet
 system services:
 Drivers for battery:

4. RTE : Generated b/w BSW & SWCs

5. Application software components for BMS :

- cell monitor SWC
- State estimator SWC
- charge control SWC
- Diag manager SWC



2.B Sensor reading : ADC via MCAL → BSWADC driver collects raw counts .

BSW processing : ADC driver converts counts
If data travels over network signal mapping Convert PDU to AUTOSAR signals

RTE : the RTE calls the SWC runnable or delivers data to SWC port
Application software : state estimator SWC read RTE ports → computes , SOC → write outputs via RTE to other SWCs

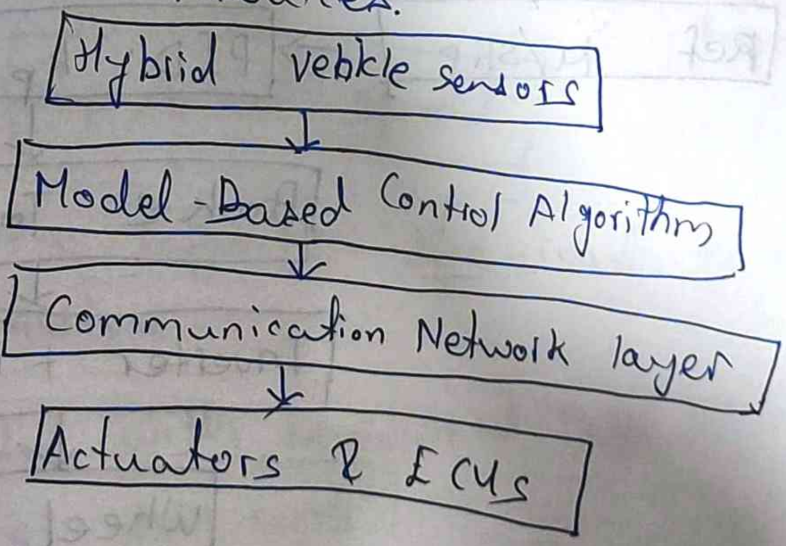
3A. Develop a model-based control strategy for hybrid vehicle ~~stability~~ energy management integrating CAN, LIN and Ethernet.

. Parameter mapping between application software components (SWCs) and BSW modules through config. files

In AUTOSAR application software components perform control logic, while basic software handles hardware access, communication, diagnostics and system services.

These two layers never directly connected in code they communicate through the RTE.

Parameter mapping defines how application signals parts or services calls in SWCs correspond to BSW resources.

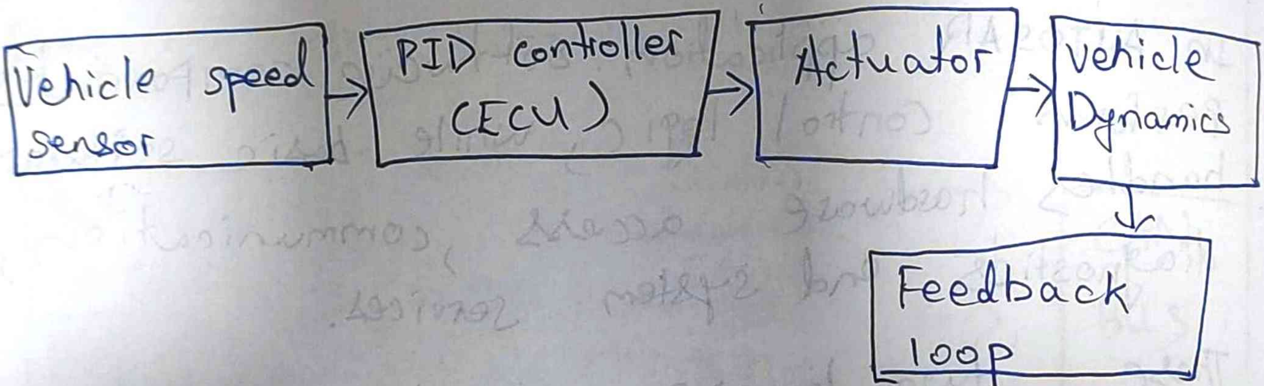


3B. Explain PID tuning and validation process

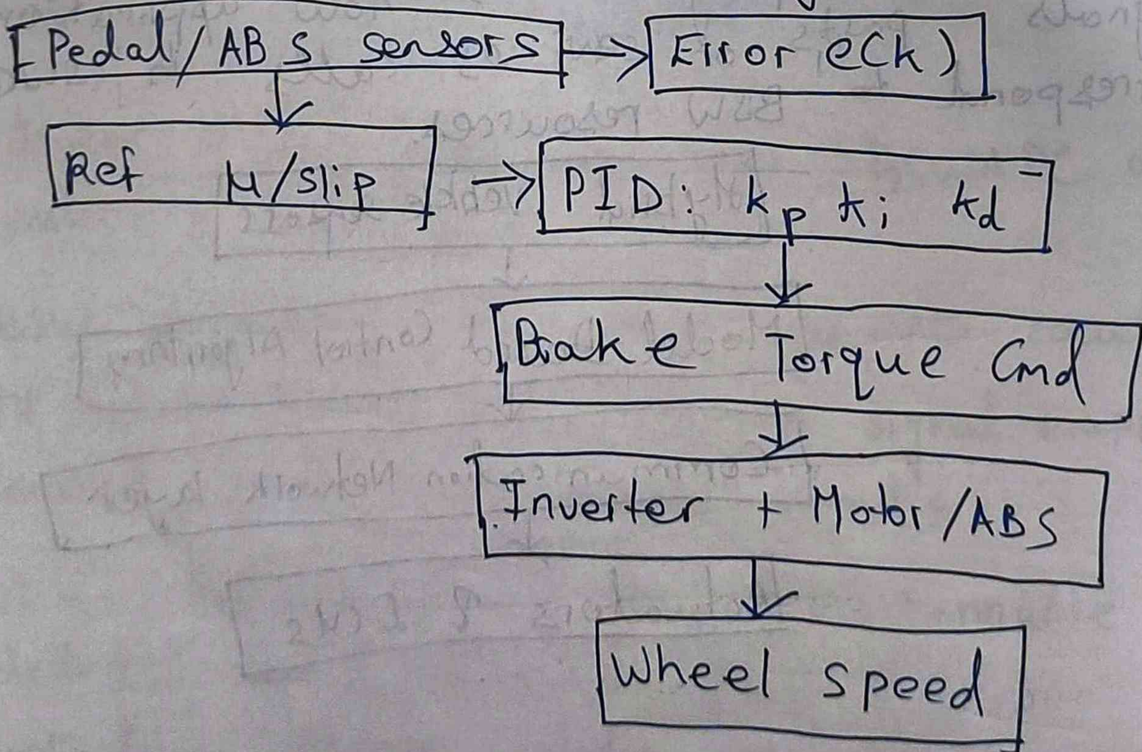
Performance Effects :

scheduling overhead : many runnables cause content switches and increased OS overhead.

RTE overhead : data copies between SWCs via RTE add latency and cpu load.

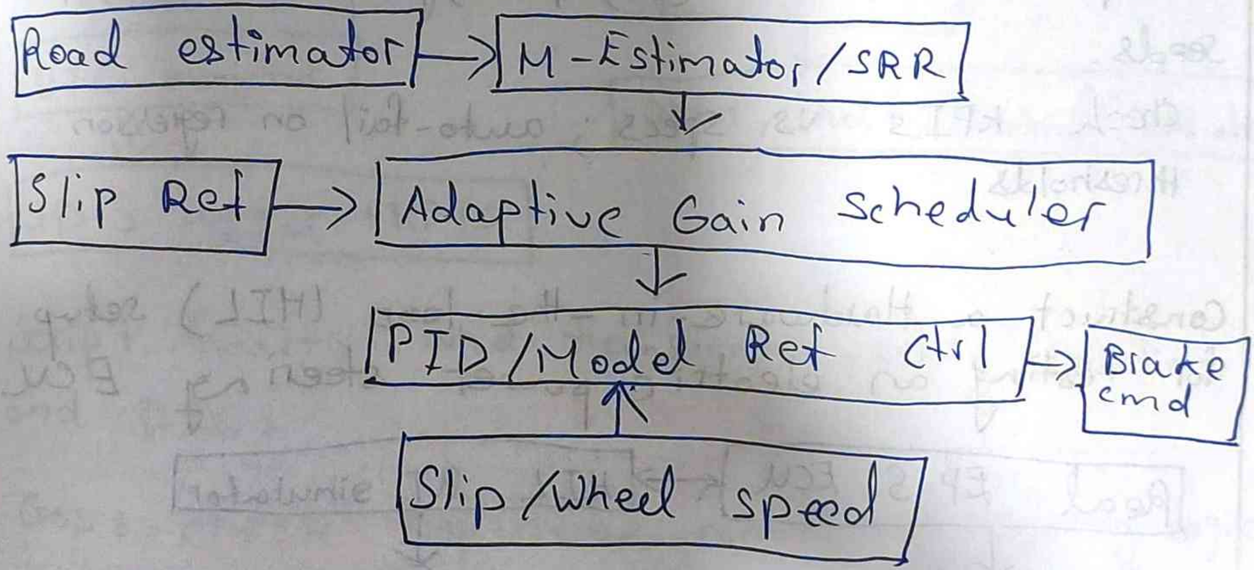


4. A. Implement a PID-based stability control mechanism for an EV braking system.



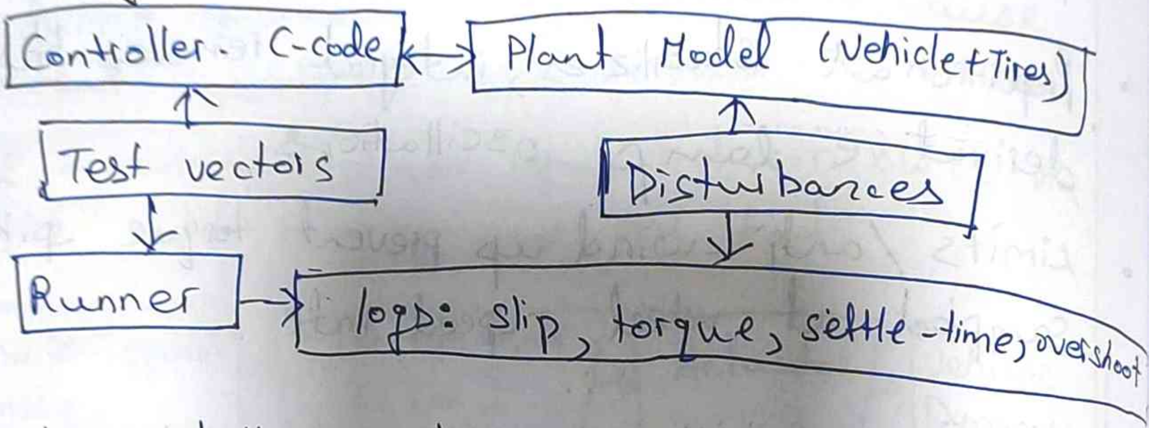
- PID tracks target slip ($\approx 20 - 20\%$) to maximize tire → road friction.
- Proportional stabilizes, integral removes bias, derivative damp oscillations.
- Limits / anti-wind up prevent torque spikes sampled at wheel-speed rate.

B. Demonstrate how adaptive control improves wheel slip response.



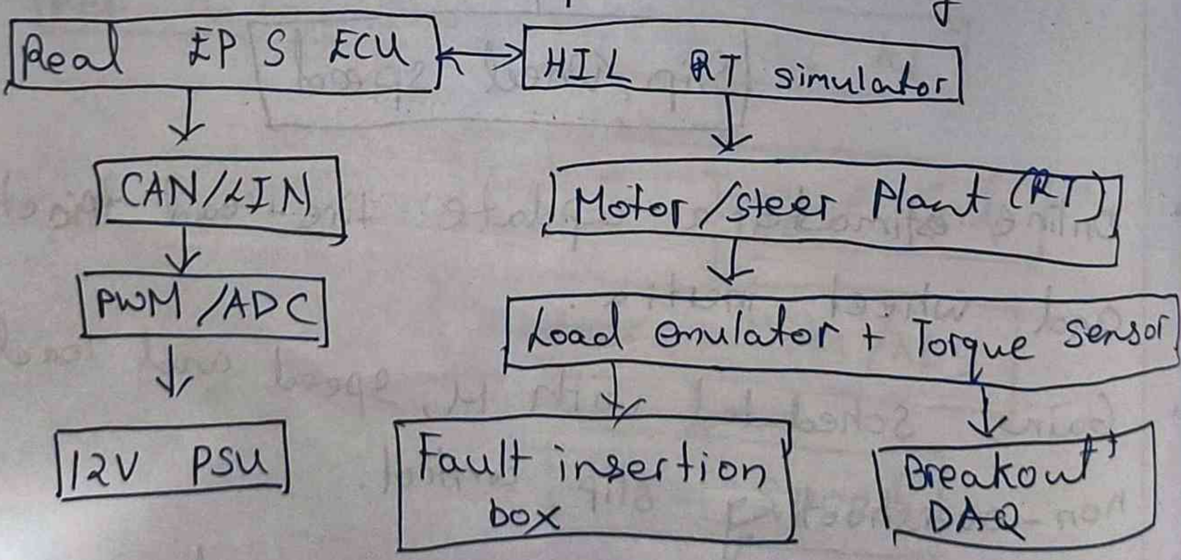
- Online estimators update tire-road friction and wheel inertia.
- Gains scheduled with M, speed and load → faster, non-overshooting slip control.
- Adapts to wet/ice transitions, reducing stopping distance and chatter.

5. A Apply Software-in-the-loop (SIL) validation methods to verify control performance.



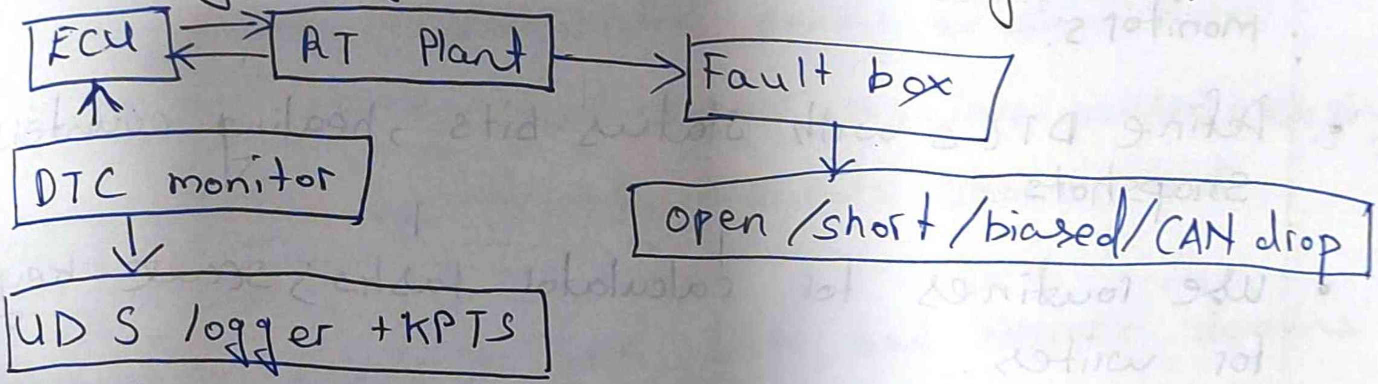
- Compile controller and run inside a PC simulation
- Sweep sceanarios (M, speed, gradient) with repeatable seeds.
- Check KPIs vs specs; auto-fail on regression thresholds.

B. Construct a Hardware-in-the-loop (HIL) setup for testing an electric power steering ECU.



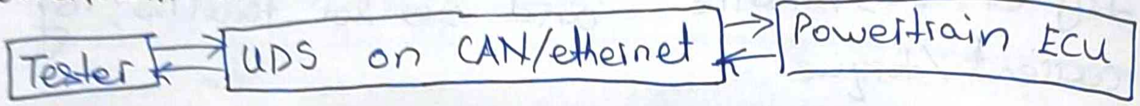
- ECU I/O wired to real-time plant; steering rack emulated.
- Inject bus/frame and sensor faults; log current/torque.
- verify assist maps, failsafes and end-stop protection.

6A. Demonstrate the application of HIL testing for validating diagnostic and control algorithms.



- Script faults and transients; verify detection time and DTCs.
- Cross-check limp-home control and recovery logic.
- Acceptance: correct DTC, debouncing and fallback torque limits.

6B. Develop an On-Board Diagnostic (OBD) structure using UDS services for detecting faults in a powertrain ECU.

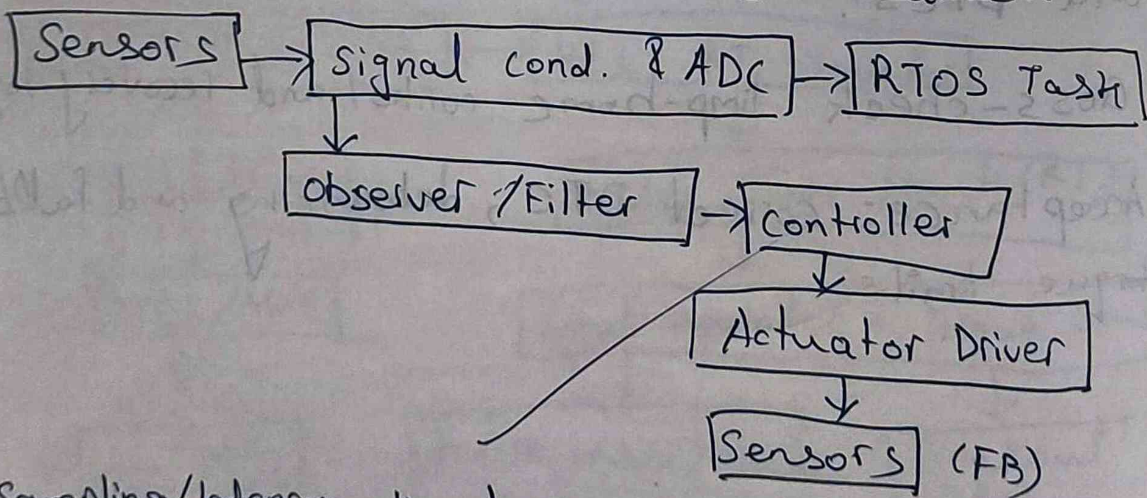


0x10 / 27 Sess / Sec   0x22 ReadDataByID   0x19 ReadDTC

0x2E WriteData   0x31 Routines   0x14 Clear DTC

- Map PIDs / DIDs to sensors, actuators and monitors.
- Define DTCs with status bits, healing counters, snapshots.
- Use routines for calculator tasks; secure-key for writes.

7.A Illustrate the control signal flow between sensor data acquisition and actuator feedback.



- Sampling/latency aligned to control bandwidths
- Filtering + observers reduce noise and estimate shares
- Closed loop with diagnostics and saturation handling.

8. Explain the role of communication protocols (CAN, LIN, Ethernet) in maintaining real-time control.

LIN → low speed local sensors

CAN → real-time control frames

Automotive Ethernet → high bandwidth data & updates

- LIN : cheap, deterministic polling for slow nodes.
- CAN/FD : priority-based, robust, ms-level control messaging.
- Ethernet/TSN : synchronized, high-rate streams and diagnostics.
- Gateways connect CAN, LIN and ethernet domains for unified control.
- Time synchronization via IEEE 802.1AS ensures coherent real-time control loops.

8/10