CAPABILITY ENHANCEMENT OF ELECTRONICS AND SOFTWARE
Module1 - BSVI ECU, ARCHITECTURE and RELATED SENSORS / CTM

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I. **ECU - Electronic Control Unit**
   a) Basic Functions
   b) BSVI Architecture
   c) Internal Circuits
   d) Protection circuits

II. **ECU – Sensors, Switches and actuators**
   a) Speed Sensor – Crankshaft & Camshaft Speed / Vehicle Speed
   b) Temperature Sensor
   c) Pressure Sensor
   d) Water in Fuel Sensor
   e) Actuators – ITV, EGR
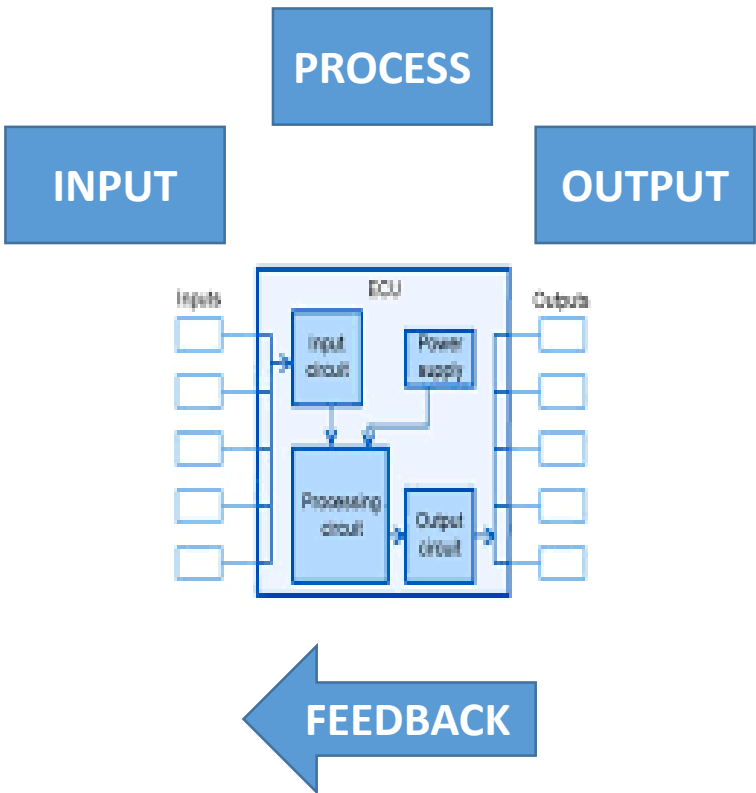
III. **ISO 26262 – Introduction to automotive functional safety**

Electronic Control Unit (ECU)

What is ECU?

➢ An ECU is generally abbreviated as Electronic Control Unit, is any embedded system in automotive electronics that controls one or more of the electrical systems or subsystems in a vehicle.

PROCESS

INPUT   **OUTPUT**

FEEDBACK

Electronic Control Units	Sub-System / Electrical system
Engine control unit (ECU)	Engine Management System
Aftertreatment Control Unit (ACU)	Exhaust Aftertreatment System (EATS)
Body Control Unit (BCU)	Vehicle Electrical system
Transmission control unit (TCU)	Gearbox (AMT / AT) system
Anti-lock Braking system (ABS)	Braking system
Door Control Unit (DCU)	Doors
Electrical Power Steering Control Unit (EPSC)	Steering
Battery Management System (BMS)	Power supply management
Others like ESC (Electronic Stability Control) / RCU (Retarder Control Unit)	Braking system
Electronically Controlled Air Suspension (ECAS)	Suspension

In-vehicle Networking of Electronic Control Units (ECU's)

ECU'S ARE NETWORKED THROUGH CAN (CONTROLLER AREA NETWORK) BUS – SAE J1939 PROTOCOL
(Below picture is just for illustration purpose)
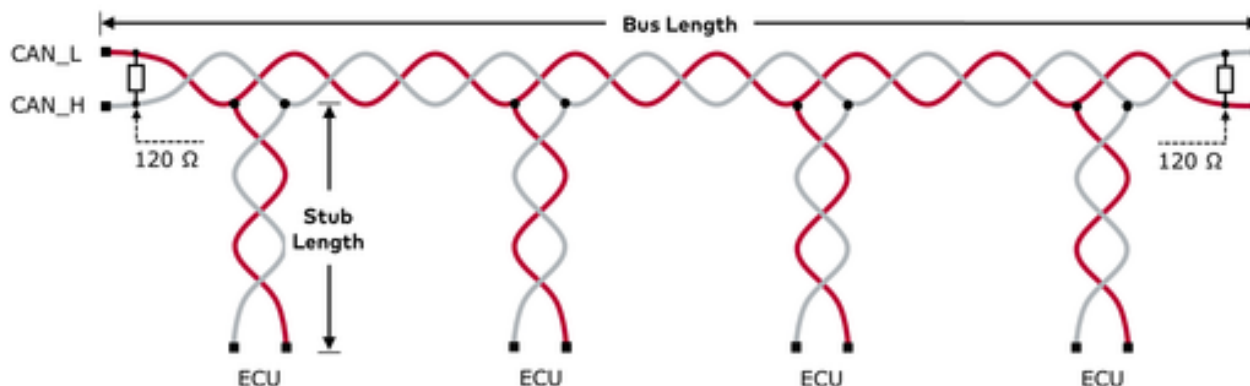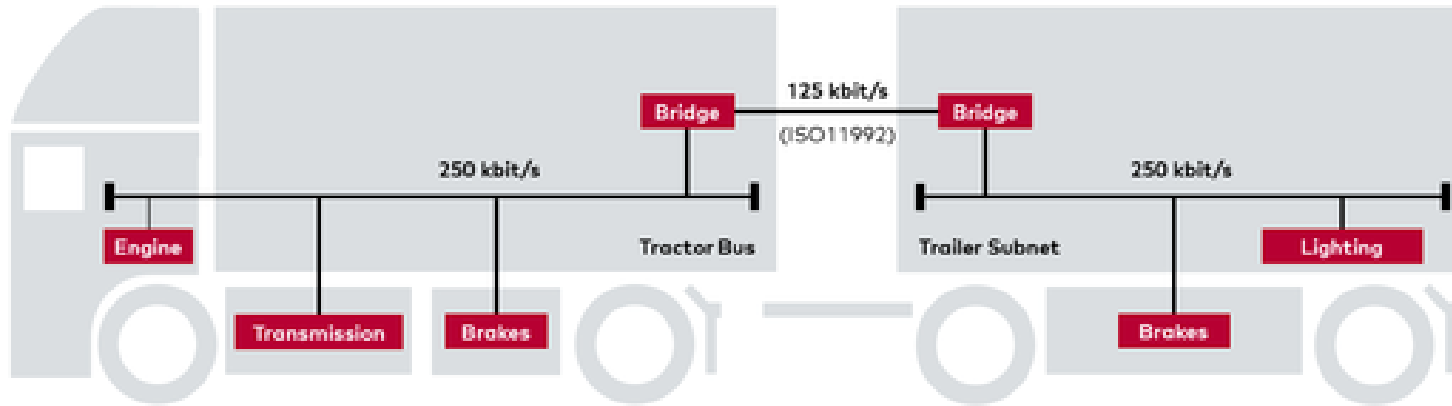
CAN (Controller Area Network) an inexpensive low-speed serial bus for interconnecting automotive components – **Commonly used in AL-Trucks & Buses**

Other common vehicle bus protocols include:
- ❖ **MOST** (Media Oriented Systems Transport) a high-speed multimedia interface
- ❖ **LIN** (Local Interconnect Network) a very low cost in-vehicle sub-network
- ❖ **FlexRay** - a general purpose high-speed protocol with safety-critical features
- ❖ **KWP 2000** (Keyword Protocol 2000) - a protocol for automotive diagnostic devices (runs either on a serial line or over CAN)
- ❖ **UAVCAN** (Uncomplicated Application-level Vehicular Communication And Networking) mostly used in electric aircraft, drones, satellites, and robotics.
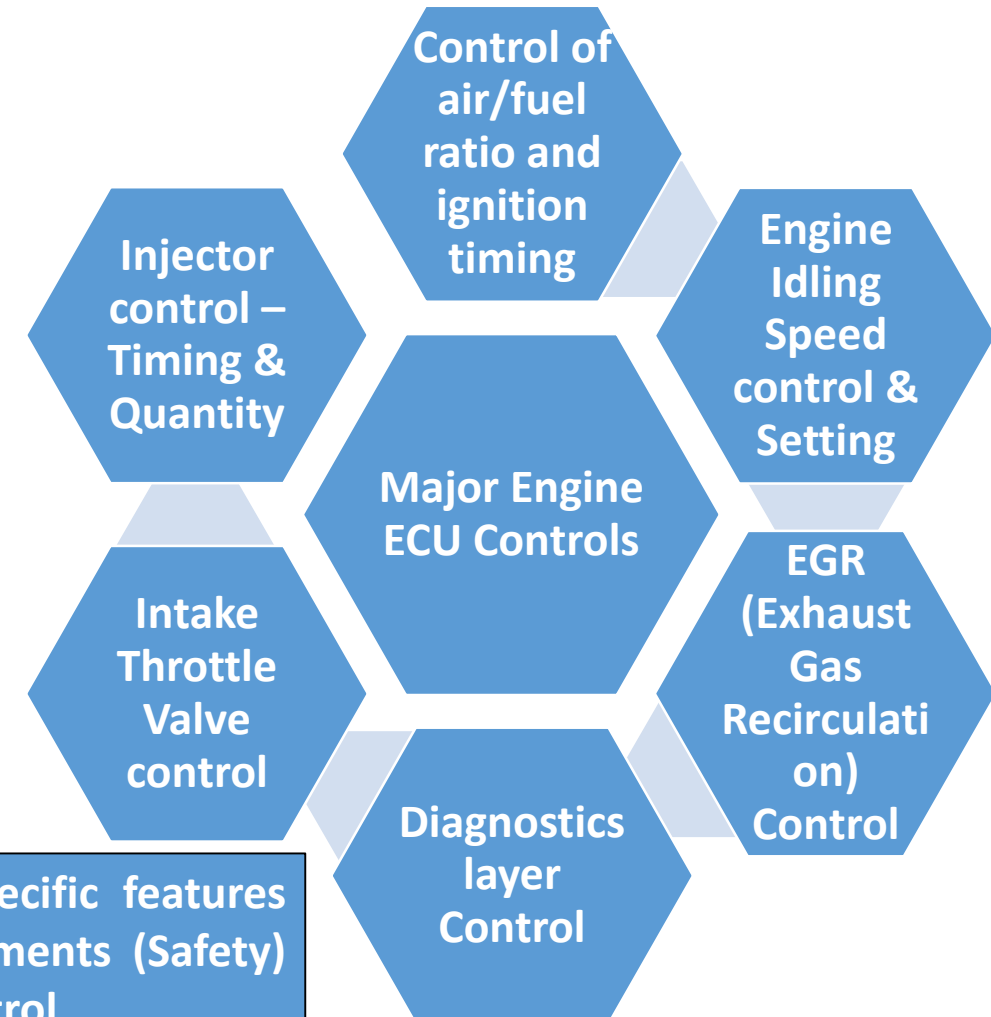- ❖ Others – **A²B, J1850, ISO9141-2, VAN**

Engine Control Unit (ECU)

➢ The Engine Control Unit (ECU) is also called as Powertrain Control Module (PCM) or Engine control module (ECM) is the brain (intelligence) of the Engine management system.

Major functions of ECU:

Depending on the Sensor signals, the ECU calculates **fuel injection rate, injection timing and quantity,** controls a series of actuators on an IC Engine to ensure optimal engine performance – Meet Emission requirements & better fuel control.

Control of air/fuel ratio and ignition timing

Injector control – Timing & Quantity

Engine Idling Speed control & Setting

Major Engine ECU Controls

Intake Throttle Valve control

EGR (Exhaust Gas Recirculation) Control

Diagnostics layer Control

In addition, other customer specific features control (Comfort), CTM requirements (Safety) & Legislative requirements - Control

ECU – Architecture & Internal / Protection Circuits
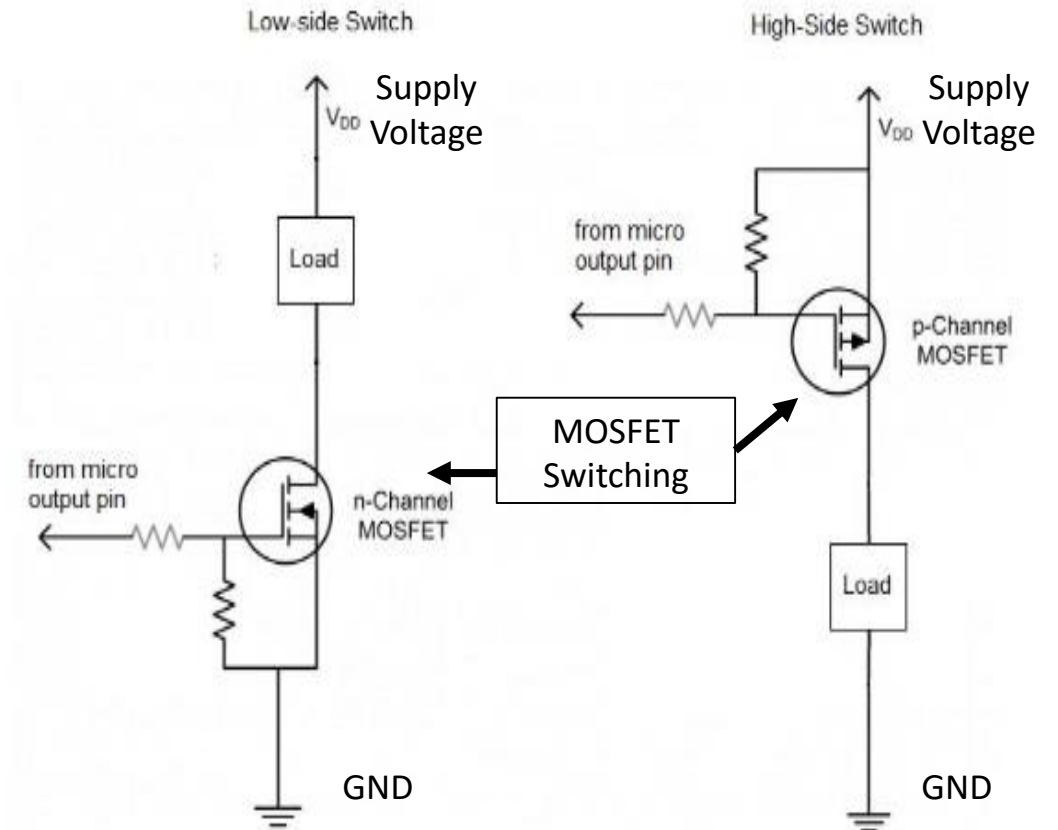
ECU – General Architecture
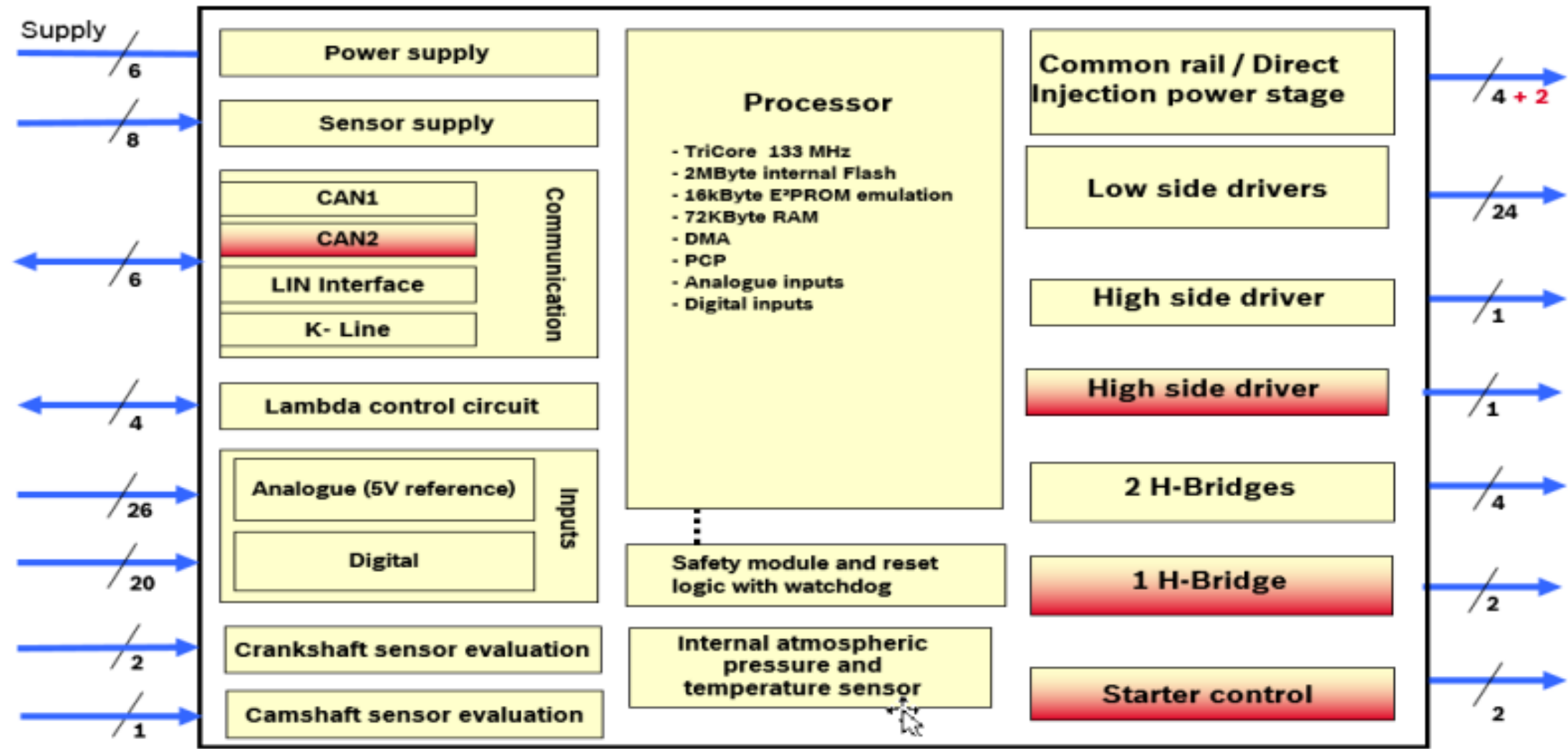
Low Side & High Side Driver (Switch)

A **low side driver** is one in which the switching element is between the load and GND.

Application: Grid heater relay, AC Relay, Exhaust brake Relay, Starter relay (Lo side), Diagnostic Lamp (Lo side)

A **high side driver** is one in which the switching element is between Supply Voltage and the load.

Application: Metering Unit, Starter relay (Hi side), Diagnostic Lamp (Hi side)

Low-side Switch

V_{DD} Supply Voltage

Load

from micro output pin

n-Channel MOSFET

GND

High-Side Switch

V_{DD} Supply Voltage

from micro output pin

p-Channel MOSFET

MOSFET Switching

Load

GND

H-Bridge Circuit

An H-bridge circuit is a configuration made to apply either reversible polarity drive to a load, like a motor in which it may need to go forwards or backwards or just stop under ECU control
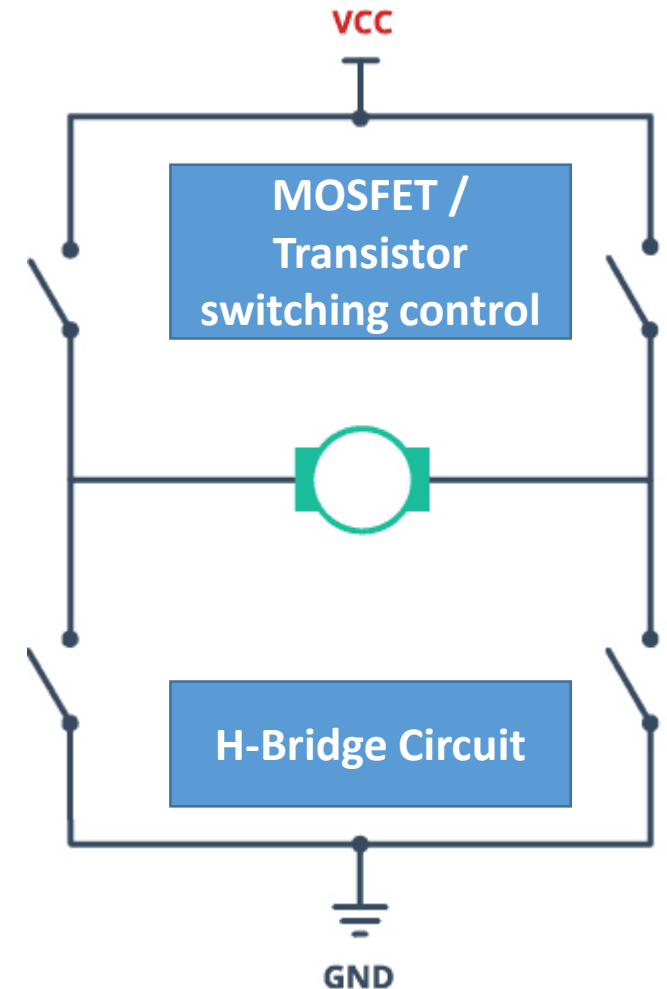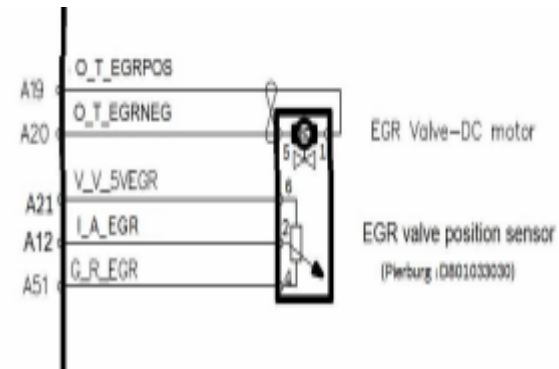
Application

Intake Throttle Valve, EGR Valve, Brushless DC Motors

Intake Throttle Valve Control

EGR Valve Control

VCC

MOSFET / Transistor switching control

H-Bridge Circuit

GND

Voltage Regulators

Voltage regulator module steps down the 24 / 12V from battery for internal circuits

Voltage output : 5V, 3.3V, 1.5V DC

It provides the supply voltage to different sensors / loads interfaced (24/12/5 V DC)

Performs a major role in Reset mechanism

Contribute for internal and external ECU communication CAN, K-Line, SPI

BLOCK DIAGRAM OF IC VOLTAGE REGULATOR

Commonly used Voltage regulators are LM317, LM78XX, LM723 series

A circuit element (usually a transistor), in series with the load, that controls the output voltage by dropping a variable portion of the input voltage
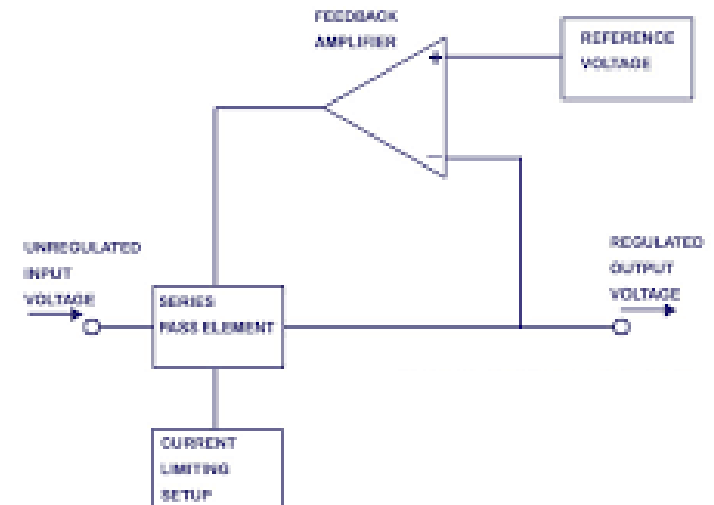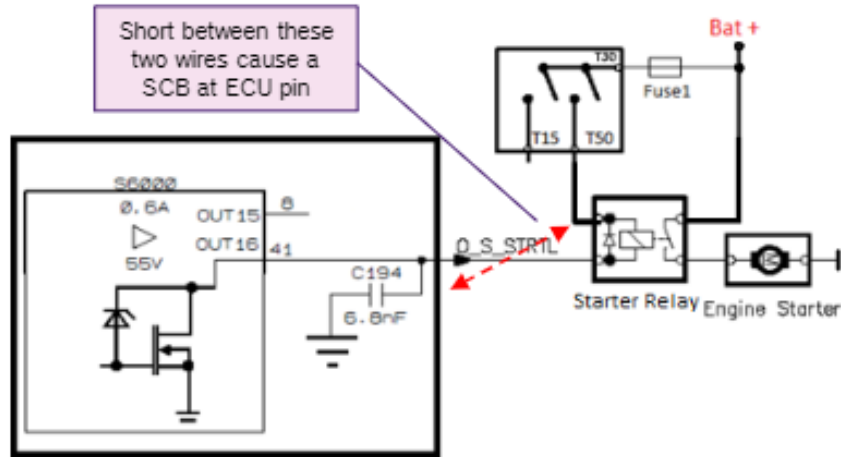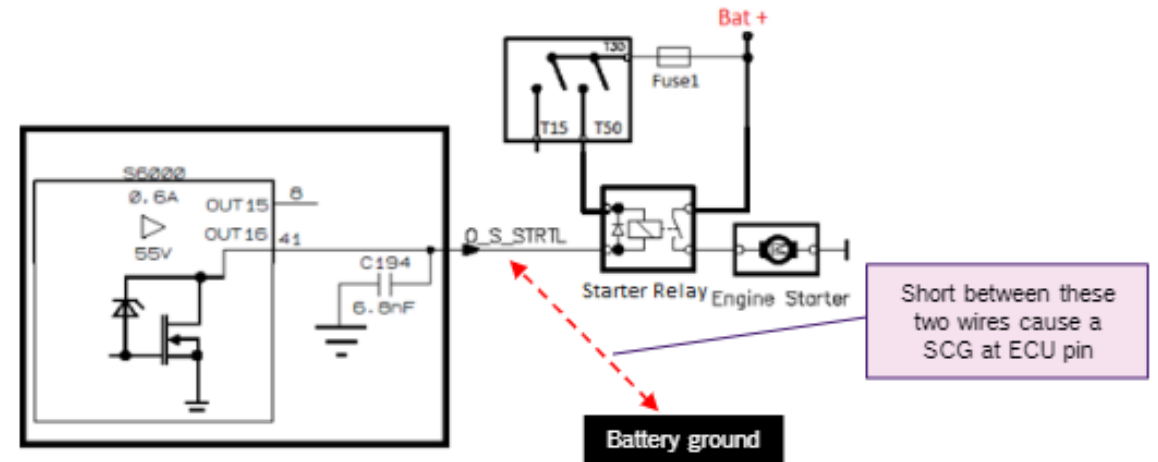
Short circuit Protection

SCB – Short circuit to Battery

> SCB at the ECU pin will create a shorting of Battery and ground
> During short Huge current flow will be there in ECU pin and it will get damaged if not protected
> SCB Protection system inside this pin will switch off the switch by sensing huge current flow

SCG – Short circuit to Ground

> SCG at the above ECU pin will switch on the relay without the control of ECU
> During short the relay is continuously ON without the intention of the ECU
> SCG Protection system inside this pin will indicate through MIL by sensing the diagnosing current flow
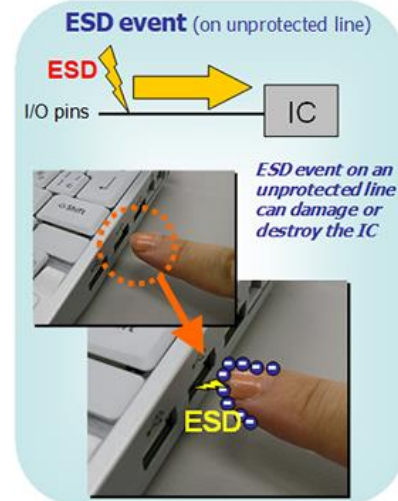
ELECTROSTATIC DISCHARGE (ESD)

When two electrically charged objects, such as the human body and an electronic device come into contact with each other, static electricity is discharged. This phenomenon is called ESD (Electrostatic Discharge).
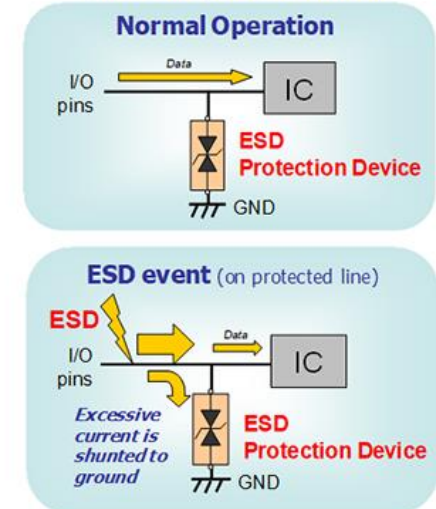ESD generated from the human body can be of the order of several thousand volts

Tvs diodes are used for protection

ECU is generally protected against ESD up to ± 2 KV. However, it is generally advised not to touch the ECU pins directly.

https://www.youtube.com/watch?v=XKAhx4NdJTs – Informative Video on ESD

BSVI Sensors and Actuators – Engine ECU Related
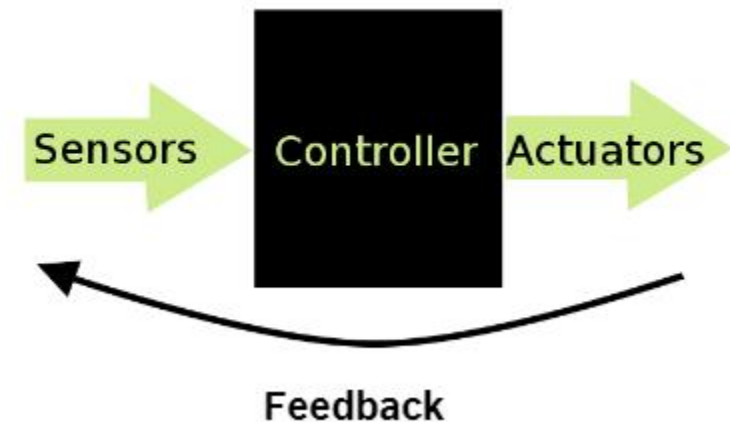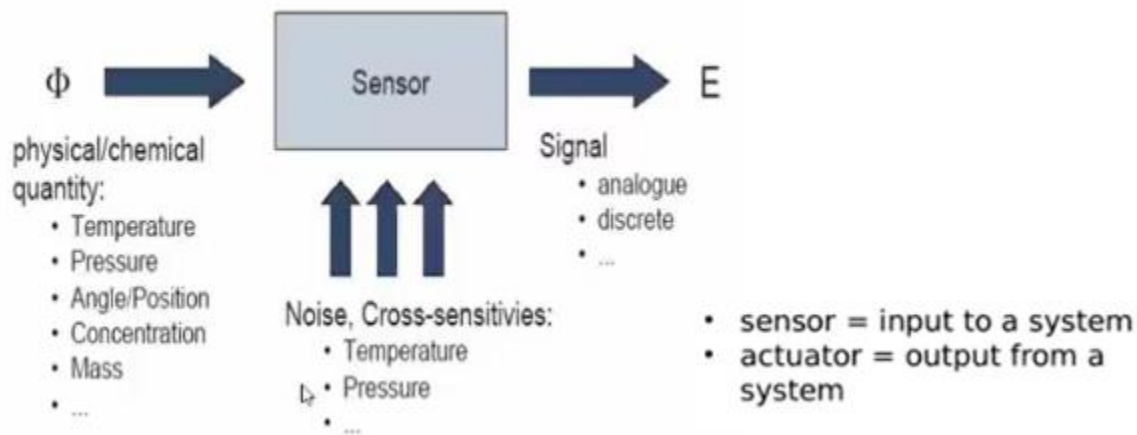**Basic Principle of operation & application**

Sensors & Actuators

Sensors - Sensor is a device used for the conversion of physical events or characteristics into the electrical (analog or digital) signals (Temperature, speed, Position, Pressure). This is a hardware device that takes the input from environment and gives to the system by converting it.
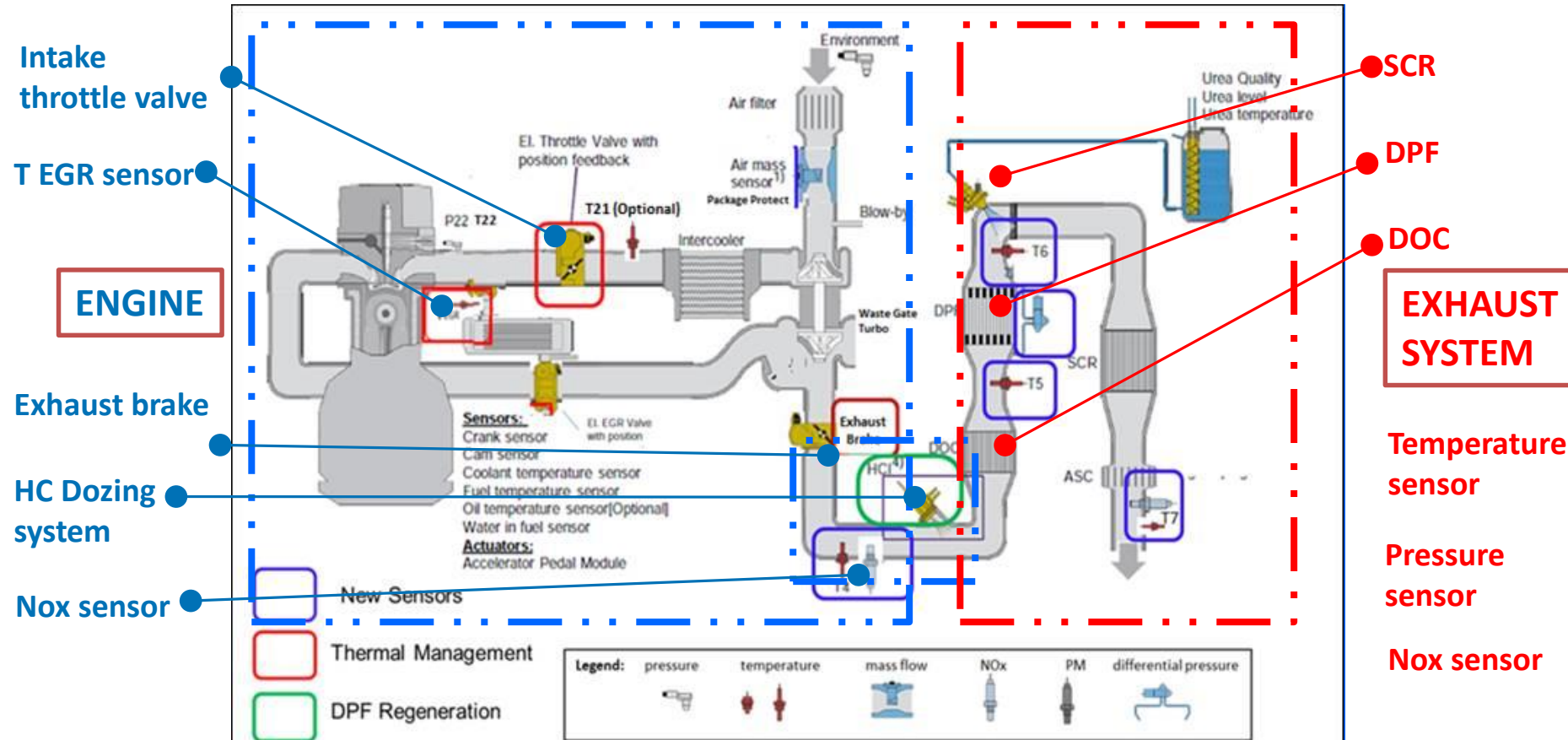
Actuator – Actuator is a device that converts the electrical signals into the physical events or characteristics. It takes the input from the system and gives output to the environment.
ECU uses the sensor data to control different systems (Engine, Air bag, ABS etc.) on a vehicles through the use of actuators. (different kinds of valves, A/C compressor, Idle speed actuators etc.)

Φ → Sensor → E

physical/chemical quantity:
- Temperature
- Pressure
- Angle/Position
- Concentration
- Mass
- ...

Noise, Cross-sensitivies:
- Temperature
- Pressure
- ...

Signal
- analogue
- discrete
- ...

- sensor = input to a system
- actuator = output from a system

Sensors → Controller → Actuators

Feedback

Changes from BSIV to BSVI – an overview

Crankshaft or Camshaft Speed Sensor

Principle - Inductive type rotational speed sensor

The inductive crankshaft speed sensor is constructed of a permanent magnet with a coil around it. The magnetic field strength changes when a magnetism sensitive object passes through the magnetic field of the magnet. This changing of the magnetic field induces a voltage in the coil which determines the position
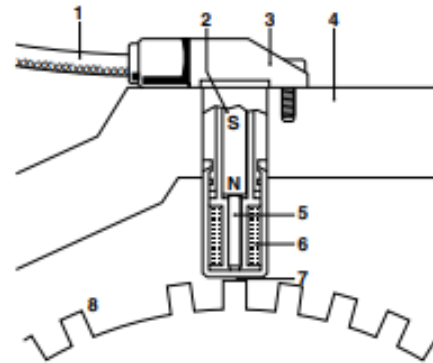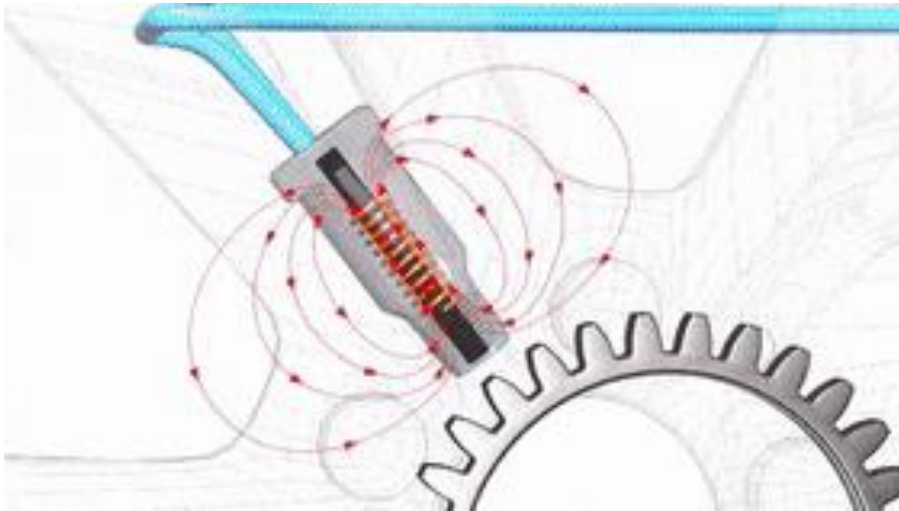
1. Cable
2. Permanent magnet
3. Sensor housing
4. Housing block
5. Soft-iron core
6. Coil
7. Air gap
8. Trigger wheel with reference mark

Mounting Location: Flywheel housing (Crankshaft speed Sensor) & FIP (Camshaft Speed Sensor)

Specifications (Bosch - Reference):
- ❖ Typical Output Voltage: 0 to 200V
- ❖ Speed range: 20 to 7000 RPM
- ❖ Winding resistance @ 20deg C: 860 ± 10% Ohms
- ❖ Inductance: 370 ± 15% mH
- ❖ Degree of Protection: IP67

Temperature sensors

A **thermistor** is a temperature sensitive resistor where its resistance changes with respect to temperature. Made from a polycrystalline silicon material, it provides the greatest resistance change with small changes in temperature.

Principle - Negative temperature Co-efficient Thermistor
NTC thermistors have a negative temperature coefficient, i.e. their electrical conductivity increases with increasing temperature: Their resistance decreases.

Application – Coolant temperature sensor, Boost temperature sensor , Oil temperature sensor
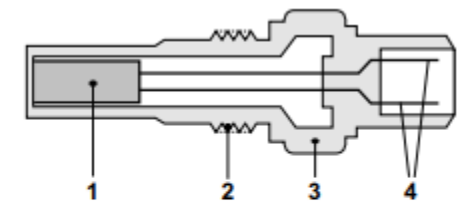
Principle - Positive temperature Co-efficient Thermistor
PTC thermistors have a positive temperature coefficient, i.e. their electrical conductivity decreases with increasing temperature: Their resistance increases.

PTC Application – EGR temperature sensor
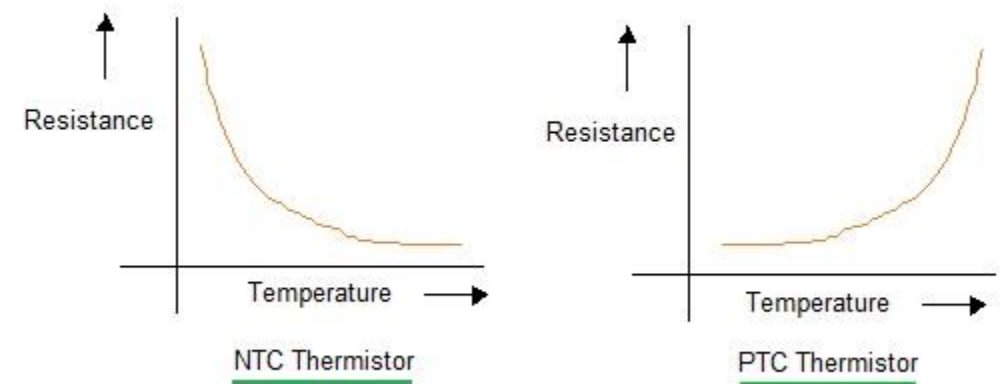
NTC Thermistor – Block Diagram

1   Electrical connection
2   Housing
3   NTC thermistor

Pressure sensors

Principle - Piezo resistive

In the measuring process, pressure is applied to a silicon diaphragm to which to which are attached piezo resistive resistors. Using their integrated electronic circuitry, the sensors provide an output signal the voltage of which is proportional to the applied pressure

Application: Boost Pressure Sensor / MAP Sensor

Pin 1   Ground
Pin 2   NTC thermistor
Pin 3   +5V
Pin 4   Output signal
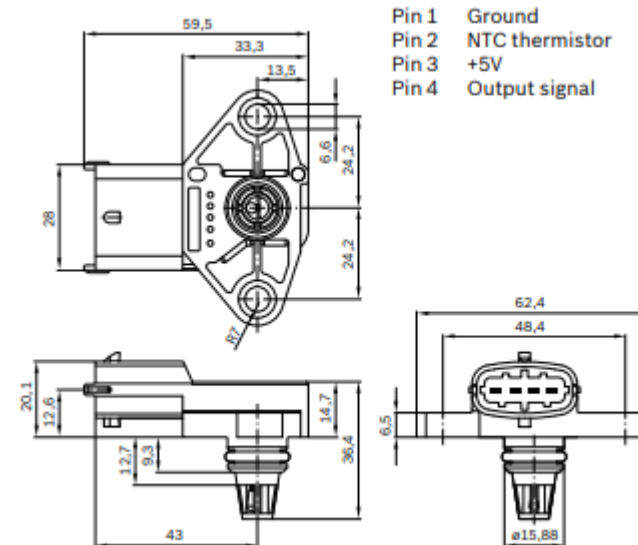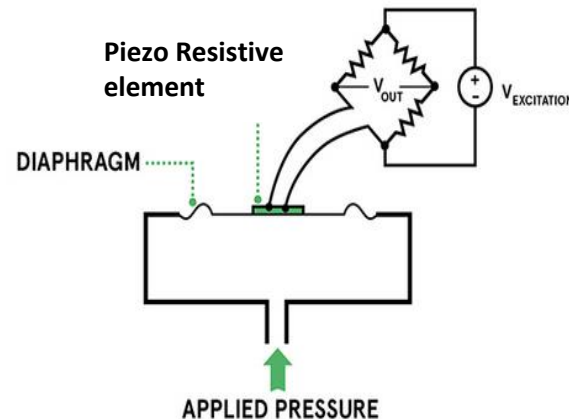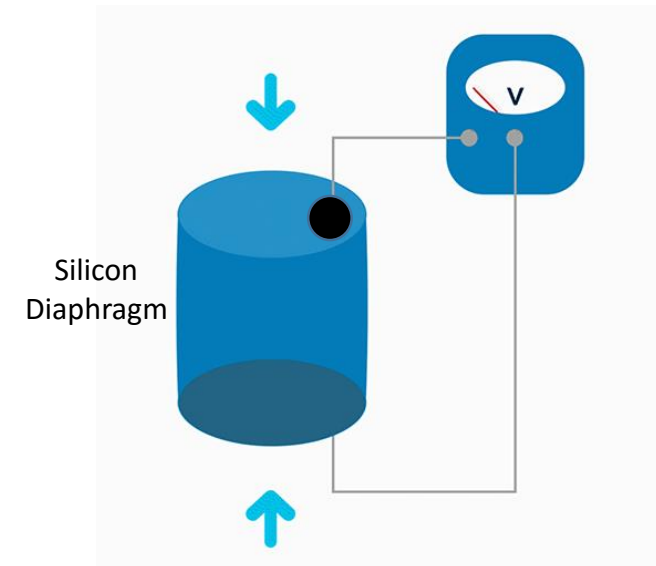
Water in Fuel Sensor

Principle - The operation of the sensor is based on the resistive measurement method.

Water is detected because it has a lower resistance than diesel fuel. Measurement of fluid resistance is performed between the two electrodes (for sensor options with two electrodes), or between an electrode and a ground (for option with single electrode).

The purpose of the sensor is to detect the presence of water in diesel fuel. The sensor is mounted inside of the fuel filter and has two main output signal stages, low level and high level, which identify the presence and absence of water. The output signal level is changed when water reaches a defined water level in the fuel filter.
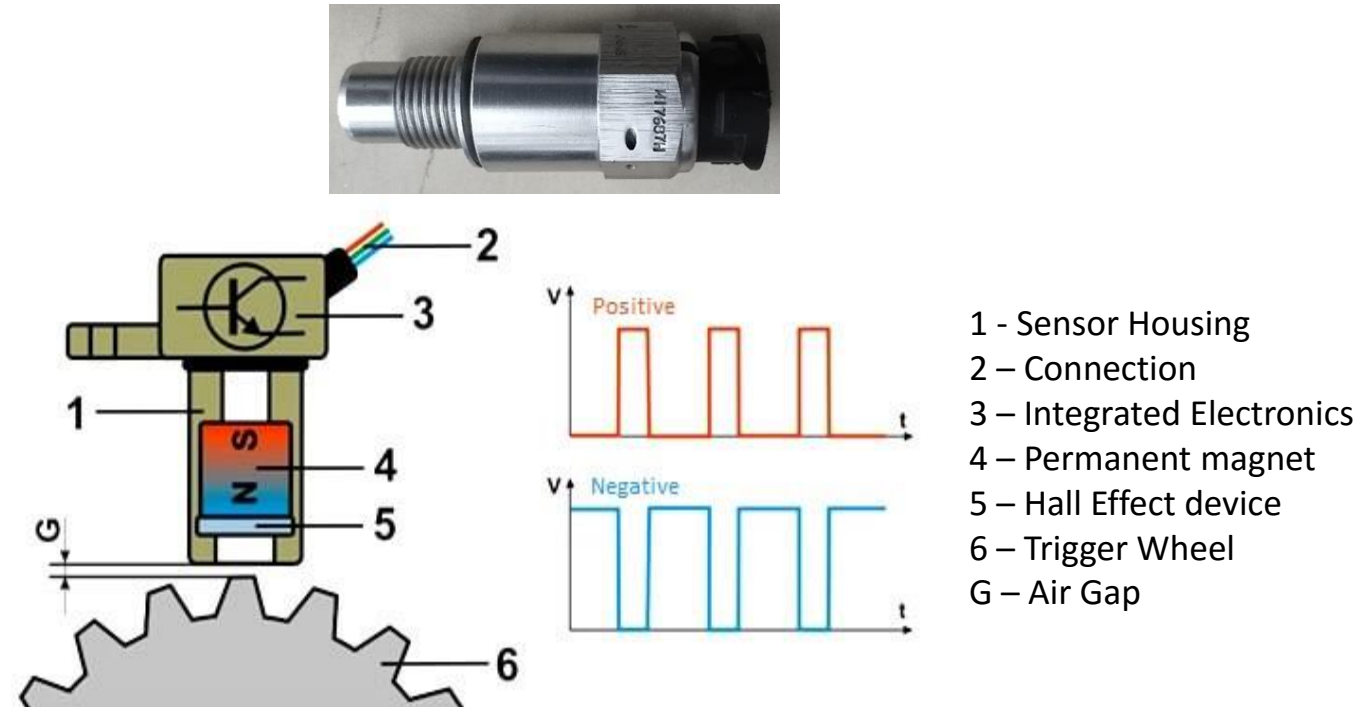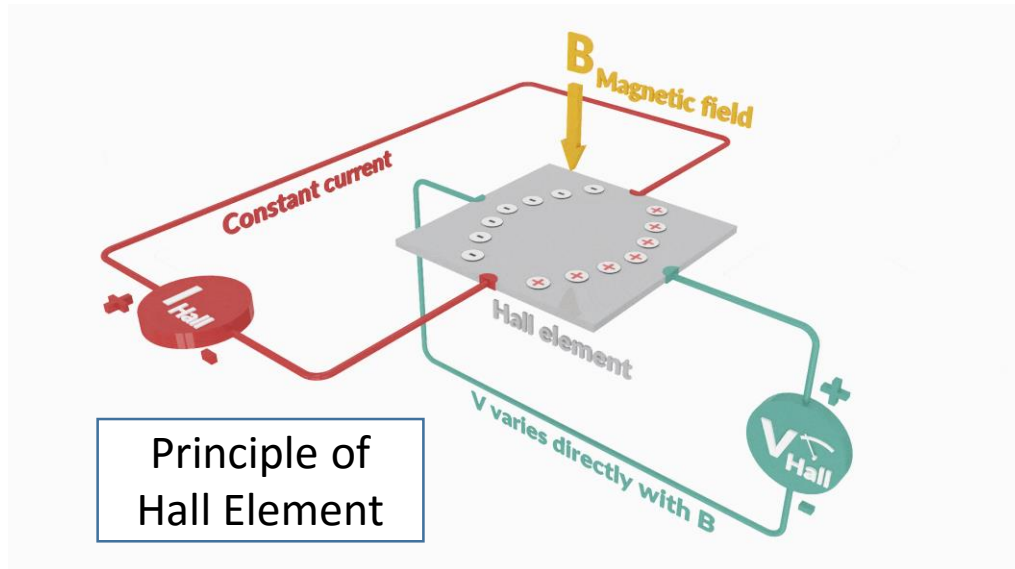

FUEL

WATER

W.I.F. SENSOR
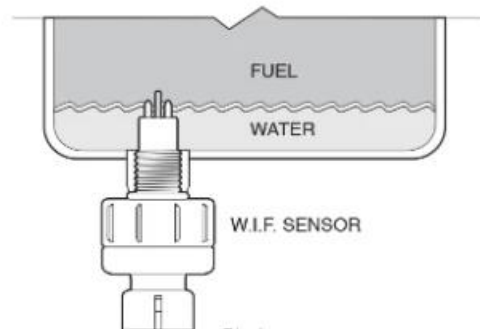
Vehicle Speed Sensor

Principle - Hall Effect Type

A Hall effect sensor is an electronic device that varies its output voltage in response to changes in magnetic field density.

The principal sensor components are either Hall elements or magneto-resistive elements. Both elements generate a voltage which is governed by the magnetic flux through the measurement element.

Hall sensors consist of a semiconductor wafer with integrated driver circuits (e.g. Schmitt trigger) for signal conditioning, a transistor as output driver and a permanent magnet.
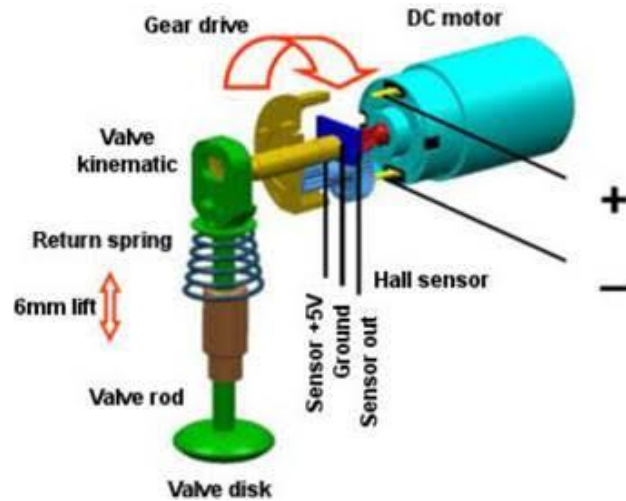

Principle of Hall Element

1 - Sensor Housing
2 – Connection
3 – Integrated Electronics
4 – Permanent magnet
5 – Hall Effect device
6 – Trigger Wheel
G – Air Gap

Construction of a Hall Effect Speed Sensor
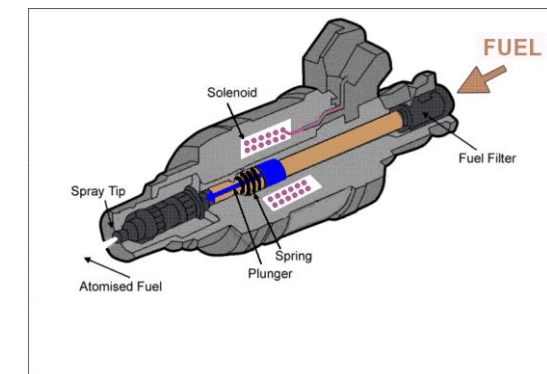
EGR Valve & Intake Throttle Valve (ITV)

EGR Valve Function - To control Exhaust gas recirculation.
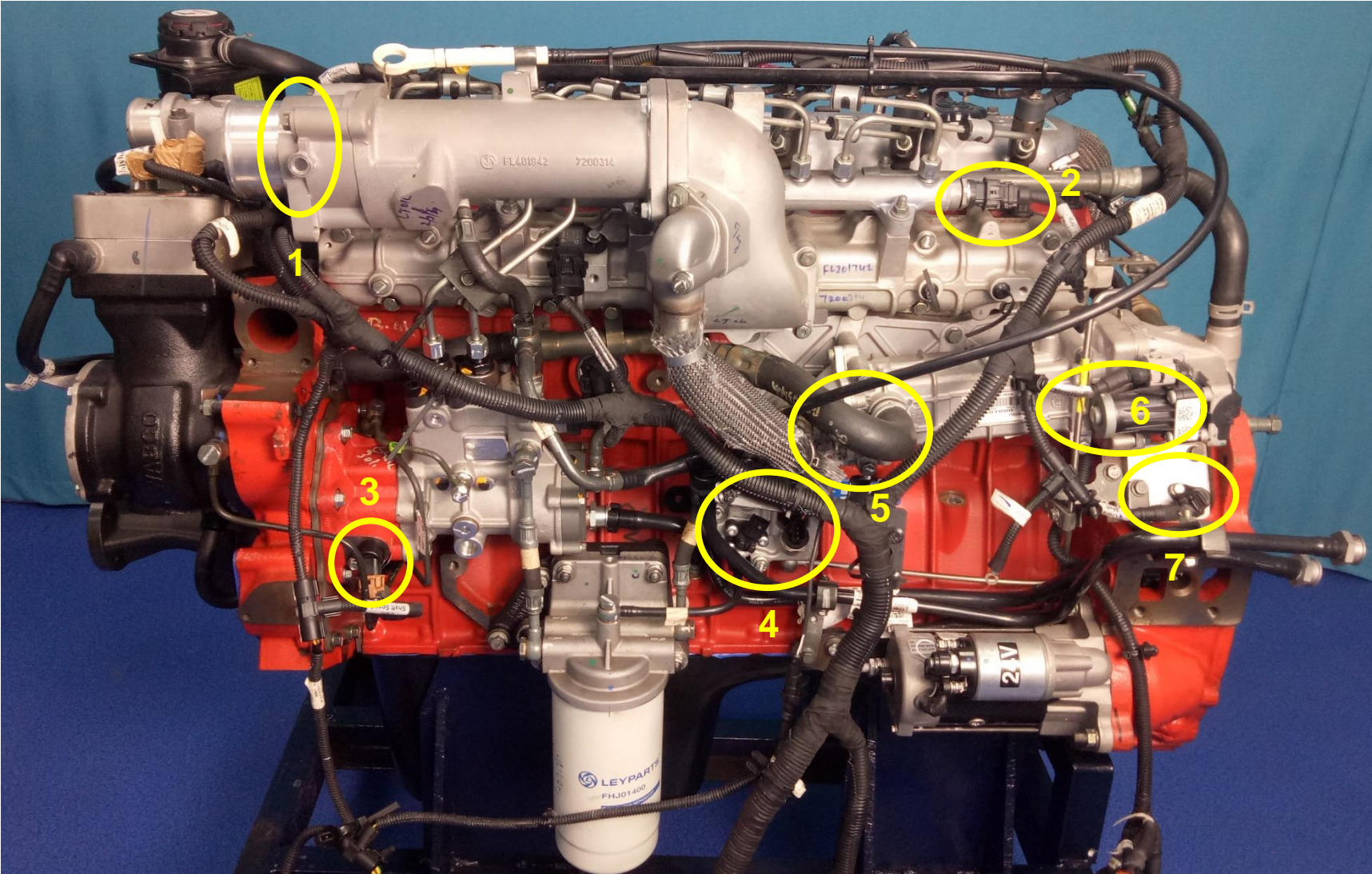Controlled by pulse width modulation(PWM) through ECU

ITV Function - To control Intake air flow for thermal management. Controlled by pulse width modulation(PWM) through ECU

Injector Function - To inject atomize fuel in combustion chamber - Solenoid controlled

Location of Engine Related Sensors in H6 2V Bosch BSVI Engine (For Reference)

No	Sensors
1	Intake Throttle Valve
2	Rail pressure sensor
3	Cam speed sensor
4	HC Metering unit
5	T-EGR sensor
6	EGR Valve
7	Crank speed sensor

References

Sensors for Automotive Applications By Hans-Peter Trah, Yasutoshi Suzuki - 2006

Bosch Automotive Handbook

Electrostatic Discharge Protection: Advances and Applications – Juin Liou – 2015

ISO 26262 Training - Automotive functional safety – Organized by TUV

https://www.youtube.com/watch?v=XKAhx4NdJTs – Informative Video on ESD

Hall-effect sensors Book by Ed Ramsden

Protection of Electronic Circuits from Over Voltages – Ronald B. Strandler

The 2018-2023 World Outlook for Automotive Electronic Control Unit (ECU) Safety Systems – By ICON group international

I. Basic architecture and Functions of EATS
   a) Compact S type
   b) Compact linear type
   c) Emission limit and OBD limit
   d) DOC
   e) DPF
   f) SCR
II. OBD - Introduction
III. ACU – Sensors and actuators
   a) Exhaust gas temperature sensor
   b) Nox Sensor
   c) Delta pressure sensor
   d) HC dozer architecture
   e) DEF header unit architecture
   f) Ambient air temperature sensor
   g) Urea Dosing system

Q & A
Assessment
Feedback Questionnaire

Thank you!

Any Questions?