With the blessings of Their Holinesses

Sri Chandrasekharendra Saraswathi Viswa Maha Vidyalaya

(University Established under section 3 of UGC Act 1956)

Enathur, Kanchipuram

Accredited with Grade 'A' by NAAC

AUTOMOTIVE INSTRUMENTATION

COURSE MATERIAL

(EIGTH SEMESTER - EIE)

(For the Academic year - 2020-2021)

PREPARED BY

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Pre – requisite: Basic measurement and Instruments.

AIM
To provide an overview of the concepts involved Automotive Instrumentation.

Course Objectives

The objective of the course is to impart knowledge on:
1. To impact knowledge on automobile system, its subsystems and components.
2. To expose the students to the concepts of various sensors used in automobile systems.
3. To teach the basic and advanced controls in automotive systems.
4. To impact a clear understanding about safety system.
5. To impact knowledge about the electronics and software involved in automotive systems.

UNIT-I INTRODUCTION OF AUTOMOBILE SYSTEM

Current trends in automobiles with emphasis on increasing role of electronics and software, overview of generic automotive control ECU functioning, overview of typical automotive subsystems and components, AUTOSAR.

UNIT- II ENGINE MANAGEMENT SYSTEMS

Basic sensor arrangement, types of sensors such as oxygen sensors, crank angle position sensors, Fuel metering/ vehicle speed sensors, flow sensor, temperature, air mass flow sensors, throttle position sensor, solenoids etc., algorithms for engine control including open loop and closed loop control system, electronic ignition, EGR for exhaust emission control.

UNIT- III VEHICLE POWER TRAIN AND MOTION CONTROL

Electronic transmission control, adaptive power Steering, adaptive cruise control, safety and comfort systems, anti-lock braking, traction control and electronic stability, active suspension control.

UNIT-IV ACTIVE AND PASSIVE SAFETY SYSTEM

Body electronics including lighting control, remote keyless entry, immobilizers etc., electronic instrument clusters and dashboard electronics, aspects of hardware design for automotive including electro-magnetic interference suppression, electromagnetic compatibility etc., (ABS) antilock braking system, (ESP) electronic stability program, air bags.

UNIT- V AUTOMOTIVE STANDARDS AND PROTOCOLS

Automotive standards like CAN protocol, LIN protocol, FLEX RAY, Head-Up Display (HUD), OBDII, CAN FD, automotive Ethernet etc. Automotive standards like MISRA, functional safety standards (ISO 26262).

System design and energy management: BMS (battery management system), FCM (fuel control module), principles of system design, assembly process of automotives and instrumentation systems.

Course Outcomes

On completion of this course, the students will be able to,

CO1. Understand depth knowledge on automobile system, its subsystems and components.
CO2. Know about the concepts of various sensors used in automobile systems.
CO3. Know the basic and advanced controls in automotive systems.
CO4. Understand about safety system clearly.
CO5. Understand depth knowledge about the electronics and software involved in automotive systems.

TEXT BOOKS

1. William B. Ribbens, Understanding Automotive Electronics, Butterworth-Heinemann publications, 7th Edition, 2012.
2. Walter E, Billiet and Leslie .F, Goings, ‘Automotive Electric Systems’, American Technical Society,Chicago, 1971.
3. Judge.A.W, ‘Modern Electric Equipments for Automobiles’, Chapman and Hall, London, 1975.
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1. Sonde.B.S., ‘Transducers and Display System’, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1977.
2. W.F. Walter, ‘Electronic Measurements’, Macmillan Press Ltd., London.
3. E.Dushin, ‘Basic Metrology and Electrical Measurements’, MIR Publishers, Moscow, 1989.
4. Young A.P., Griffiths L., Automotive Electrical Equipment, ELBS & New Press, 2010.
5. Tom Weather Jr., Cland C. Hunter, Automotive computers and control system, Prentice Hall Inc., New Jersey,2009.
6. Crouse W.H., Automobile Electrical Equipment, McGraw Hill Co. Inc., New York, 2005.

Mapping of COs with POs												
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1			√		√	√			√	√		
CO2		√	√	√	√				√			
CO3			√		√	√			√	√		
CO4			√		√	√			√	√		
CO5			√		√	√			√	√		

AUTOMOTIVE INSTRUMENTATION

UNIT-I INTRODUCTION OF AUTOMOBILE SYSTEM

EVOLUTION OF AUTOMOTIVE ELECTRONICS

Electronics have been relatively slow in coming to the automobile primarily because of the relationship between the added cost and the benefits. Historically, the first electronics (other than radio) were introduced into the commercial automobile during the late 1950s and early 1960s. However, these features were not well received by customers, so they were discontinued from production automobiles.

Microelectronics will provide many exciting new features for automobiles. Two major events occurred during the 1970s that started the trend toward the use of modern electronics in the automobile:

(1) The introduction of government regulations for exhaust emissions and fuel economy, which required better control of the engine than was possible with the methods being used; and

(2) The development of relatively low cost per function solid-state digital electronics that could be used for engine control and other applications.

Electronics are being used now in the automobile and probably will be used even more in the future. Some of the present and potential applications for electronics are

1. Electronic engine control for minimizing exhaust emissions and maximizing fuel economy
2. Instrumentation for measuring vehicle performance parameters and for diagnosis of on-board system malfunctions
3. Driveline control
4. Vehicle motion control
5. Safety and convenience
6. Entertainment/communication/navigation

CURRENT TRENDS IN AUTOMOBILES WITH EMPHASIS ON INCREASING ROLE OF ELECTRONICS AND SOFTWARE

Disruption: Technology Trends in the Automotive Industry

It used to be that all you had to do was look under the hood to understand how your car worked. However, it's no longer that simple. Modern automobiles are designed with many digital features that require millions of lines of code to ensure that they function reliably and safely.

These technological enhancements have introduced new challenges for automotive software developers. What's more, if teams are unprepared or unfamiliar with these disruptive automotive industry trends, it could negatively impact development time and quality.

However, by reviewing the most significant trends, your teams can adequately prepare. Here are the most significant automotive trends of 2019.

Connectivity

Connectivity has become a common feature for nearly every electronic device — including automobiles. Drivers want access to their apps, wireless devices, music, and more while they're behind the wheel. That means that many embedded devices installed in vehicles are cellular, Wi-Fi, or Bluetooth-enabled.

However, each embedded device provides cybercriminals with another opportunity to hack the vehicle and all connected devices. For that reason, it is important that automotive software development teams use secure coding practices to ensure that there are no gaps in a vehicle's cyber security.

Autonomous Driving

Even though fully autonomous vehicles are unlikely to become commonplace in the very short term, automotive developers are making great strides to make that technology a reality. However, even when the technology becomes available, it may take drivers a bit longer to adjust.

A significant challenge for automotive software development teams is to convince the public thatself-driving cars are safe. A simple — yet necessary — practice to achieve this goal is for automotive software development teams to follow SOTIF (ISO/PAS 21448).

SOTIF provides guidance on design, verification, and validation measures. Applying these measures ensures safety without failure in situations such as a self-driving car sharing the road with human drivers.

Safety Improvements

Human error accounts for 94% of all car crashes, according to the most recent research from the National Highway Traffic Safety Association. To compensate for this staggering number, automotive developers are making vehicles safer by making them smarter.

These safety features — such as blind-spot monitoring, driver-attention monitoring, and forward-collision warning — rely on the sensors installed in the automobile to be aware of its constantly changing surroundings. This presents a challenge for automotive software developers to ensure that the embedded devices for these safety features are adaptive, reliable, and efficient.

Key Automotive Industry Trends for Software Development Teams

To better understand the ongoing challenges affecting automotive software developers, we surveyed over 400 of them. In the survey, we asked about the current automotive trends that impacted them the most and how they handled those difficulties.

We recorded all of their responses in the 2019 State of Automotive Software Development Survey. Here are some of the key findings:

Security

Hackers are the largest security concern for over half of the automotive software developers that we surveyed. As more software is installed into a vehicle, there is a greater risk that hackers could gain access to the onboard and off board systems. In fact, the number of cyber attacks on automobiles increased 500% from 2014 to 2018, according to cyber security company Upstream Security.

Connected and Autonomous Vehicles

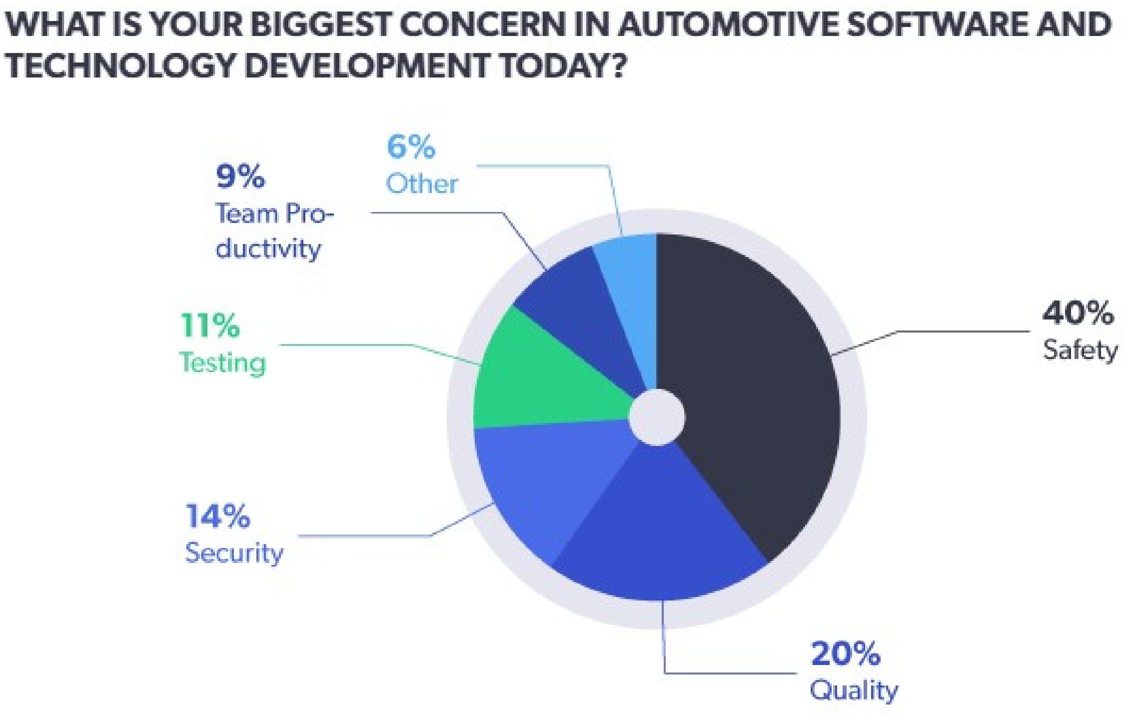
Design is most impacted by connected vehicles, according to the software developers that we surveyed. Connectivity impacts how both software and hardware are designed. What's more, the feature will be standard for many vehicles, as there will be an estimated 470 million connected cars on the road by 2025, according to the Digital Auto Report 2017 from Strategy &, PwC's strategic consulting team.

However, connectivity is not the only automotive trend that software developers are facing. Nearly half of the automotive software developers we surveyed are working on some autonomous vehicle components, while 22% are focused on designing a fully autonomous vehicle. Similar to connectivity-enabled vehicles, the number of autonomous vehicles is expected to steadily increase over the next several years.

ISO 26262

Over two-thirds of the automotive software developers that we surveyed are required to comply with ISO 26262, a complex functional safety standard. What's more, the top concern of those surveyed was how difficult it is to fulfill every ISO 26262 requirement. Proving compliance is a time-consuming challenge.

In fact, verifying and validating software was the most time-consuming task for nearly a third of the automotive software developers surveyed — with documenting work a close second. Both of these activities are key for ensuring safety and proving compliance.

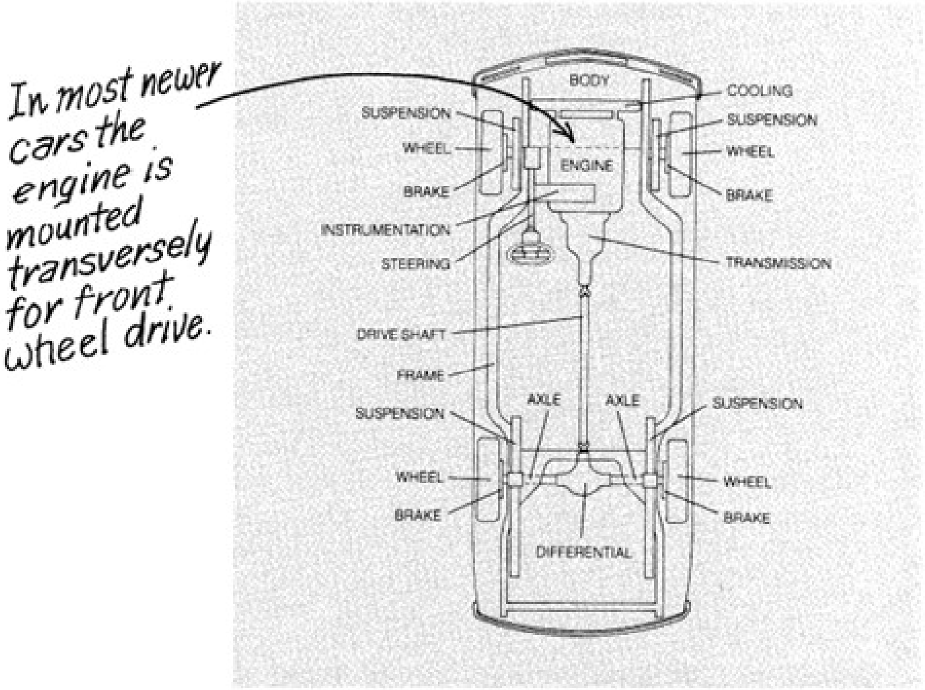


THE AUTOMOBILE PHYSICAL CONFIGURATION

The earliest automobiles consisted of carriages (similar to those drawn by horses) to which a primitive engine and drive train and steering controls were added. Typically, such cars had a strong steel frame that supported the body of the car. The wheels were attached to this frame by a set of springs and shock absorbers that permitted the car to travel over the uneven road surfaces of the day while isolating the car body from many of the road irregularities. This same general configuration persisted in most passenger cars until sometime after World War II, although there was an evolution in car size, shape, and features as technology permitted. Beginning in the late 1960s, government regulations imposed severe design constraints on automobiles that led (as will be shown) to an evolution of electronic systems in automotive design. It is this evolution that is the primary focus of this book.

For the remainder of this chapter, the basic automobile components and systems are reviewed as they pertained to the post–World War II, pre emissions control era. This review provides a framework within which the present day automobile with its extensive use of electronics can be understood. In this sense, the motivation for applying electronics to solve regulatory problems imposed on the industry can readily be seen. Readers with a solid background in basic automotive systems may want to skip the remainder of the present chapter. This early configuration is depicted in Figure, in which many of the important automotive systems are illustrated. These systems include the following:

1. Engine
2. Drivetrain (transmission, differential, axle)
3. Suspension
4. Steering
5. Brakes
6. Instrumentation
7. Electrical/electronic
8. Motion control
9. Safety
10. Comfort/convenience
11. Entertainment/communication/navigation



In most newer cars the engine is mounted transversely for front wheel drive.

SYSTEMS OF THE AUTOMOBILE

In Figure the frame or chassis on which the body is mounted is supported by the suspension system. The brakes are connected to the opposite end of the suspension components. The steering and other major mechanical systems are mounted on one of these components and attached as necessary through mechanical components to other subsystems. This basic vehicle configuration was used from the earliest cars through the late 1960s or 1970s, with some notable exceptions. The increasing importance of fuel efficiency and government-mandated safety regulations led to major changes in vehicle design. The body and frame evolved into an integrated structure to which the power train, suspension, wheels, etc., were attached. Once again with a few notable exceptions, most cars had an engine in a front configuration with the drive axle at the rear. There are advantages in having the engine located in the front of the vehicle (e.g., crash protection, efficient engine cooling). Until recently, the so-called drive wheels through which power is delivered to the road have been the rear wheels (as depicted in Figure). This configuration is known as rear wheel drive. For safety and stability the front wheels are used to steer the vehicle. This rear wheel drive configuration is not optimal from a traction standpoint since the relatively large weight of the engine/transmission is primarily on the front wheels. In order to take advantage of the engine weight for traction, many present-day cars combine steering and drive wheels in the front (i.e., so-called front wheel drive cars). In achieving front wheel drive, certain compromises must be made with respect to complexity and steering radius. Moreover, there is a tendency for the torque applied to the front wheels to adversely affect steering through a phenomenon known as “torque steer.” Nevertheless, the technology of front engine front wheel steering is quite mature and has become commonplace in modern cars. In front wheel drive cars the engine is mounted transversely (i.e., with the rotation axis orthogonal to the vehicle axis as opposed to along the vehicle axis). In automotive parlance the traditional engine orientation is referred to as North-South, and the transverse orientation as East-West. The transmission is mounted adjacent to the engine and oriented with its axis parallel to the engine axis. The differential and drive axle configuration is normally mounted in the transmission; the combined unit is thus called the transaxle. All of the systems listed above have been impacted by the introduction of electronics. The evolution of these electronics has been so rapid that a book such as this requires continuous revision to have any hope of reflecting the latest state of the art. New applications of electronics to each of the above systems continually supplement those already in use resulting in an environment in which electronics represents something of the order of 20% of the cost of a modern car.

OVERVIEW OF TYPICAL AUTOMOTIVE SUBSYSTEMS AND COMPONENTS

EVOLUTION OF ELECTRONICS IN THE AUTOMOBILE

The application of modern solid-state electronics to the various automotive subsystems described above. In order to give the evolution of electronics in automobiles a suitable perspective, it is helpful to consider the history of automotive electronics. Apart from auto radios, some turn signal models, and a few ignition systems, there was very little use of electronics in the automobile until the early 1970s. At about this time, government-mandated emission regulations, fuel economy, and safety requirements motivated the initial use of electronics. The dramatic performance improvements and relatively low cost of electronics have led to an explosive application of electronics in virtually every automotive subsystem. The relative cost/benefit of electronic subsystems in automobiles is largely affected by the production volume. (Some 15 to 16 million new cars and light trucks are sold in the United States each year.) Such a large production volume significantly lowers the unit cost for any electronic system relative to aerospace volumes.

SURVEY OF MAJOR AUTOMOTIVE SYSTEMS

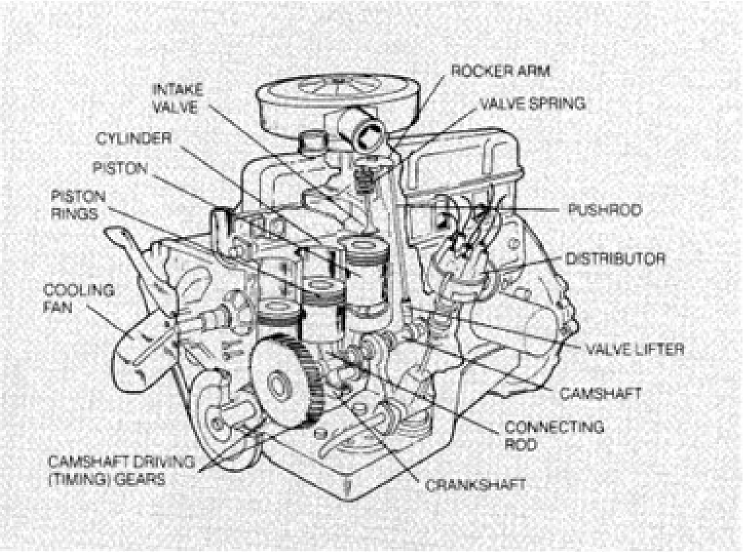
We will be exploring these electronic systems in great detail later , but first it is helpful to review the basic mechanical configurations for each component and subsystem. Modern automotive electronics were first applied to control the engine in order to reduce exhaust emissions and somewhat later to improve fuel economy. Consequently, we review the engine configuration first in this survey.

THE ENGINE

The engine in an automobile provides all the power for moving the automobile, for the hydraulic and pneumatic systems, and for the electrical system. A variety of engine types have been produced, but one class of engine is used most: the internal combustion, piston-type, 4-stroke/cycle, gasoline fueled, spark-ignited, liquid-cooled engine. This engine will be referred to in this book as the spark-ignited, or SI, engine. Although rapid technological advances in the control of the SI engine have been achieved through the use of electronics, the fundamental mechanical configuration has remained unchanged since this type of power plant was first invented. In addition, the introduction of modern materials has greatly improved the packaging, size, and power output per unit weight or per unit volume. In order that the reader may fully appreciate the performance improvements that have been achieved through electronic controls, we illustrate the engine fundamentals with an example engine configuration from the pre-electronic era.

Figure is a partial cutaway drawing of an SI engine configuration commonly found in the period immediately following World War II. The engine there illustrated is a 6-cylinder, overhead-valve, inline engine. Alternate engine configurations today are either a 4-cylinder inline or a V-type engine with either 6 or 8 cylinders (although there are exceptions). Moreover, the materials found in present-day engines permit greatly reduced weight for a given engine power. Nevertheless, modern electronically controlled engines have much in common with this example configuration. For example, the vast majority of aspirated, and water cooled. By illustrating the fundamentals of engine operation using the example engine of Figure, we can thus explain the differences that have occurred with modern electronic controls. The major components of the engine include the following:

1. Engine block
2. Cylinder
3. Crankshaft
4. Pistons
5. Connecting rods
6. Camshaft
7. Cylinder head
8. Valves
9. Fuel control system
10. Ignition system
11. Exhaust system
12. Cooling system
13. Electrical system



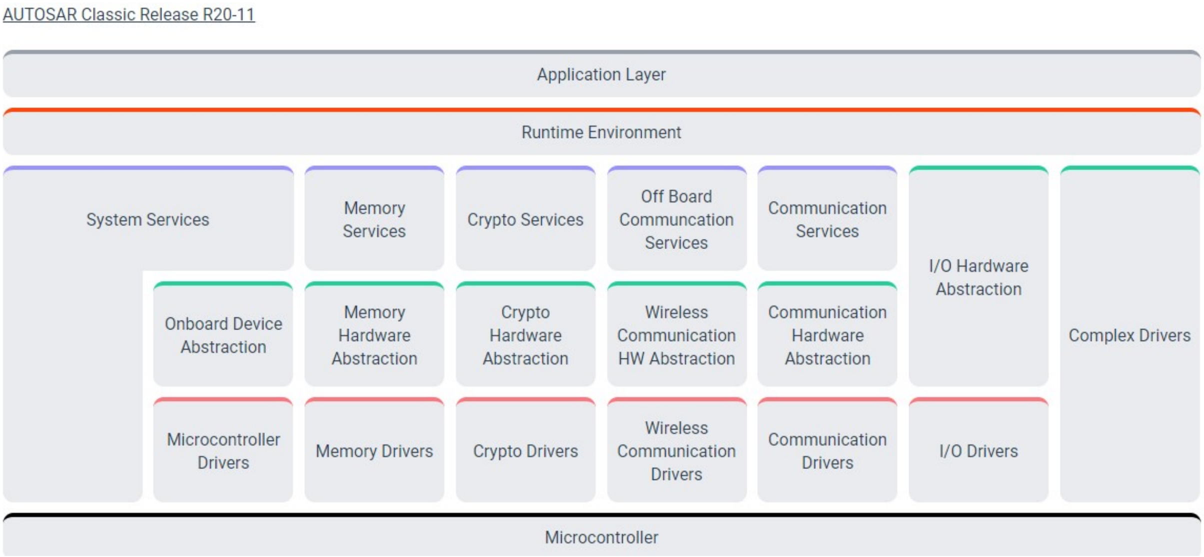
CUTE WAY VIEW OF A 6-CYLINDER, OVERHEAD-VALVE, INLINE ENGINE

Electronics play a direct role in all aspects of controlling engine operation, including the fuel and air flow control, ignition, exhaust and evaporative emission systems, and diagnostic and maintenance operations as well as many other secondary functions. In order to meet government regulations for exhaust emissions and fuel economy, these systems combine to optimize performance within regulatory requirements. In the earliest days of government regulation, electronic controls were applied to existing engine designs. However, as electronic technology evolved, the engine mechanical configuration was influenced (at least indirectly) by the electronic controls that were intended to be applied. The evolution of engine control electronics is explained.

AUTOSAR

The AUTOSAR Classic Platform architecture distinguishes on the highest abstraction level between three software layers which run on a microcontroller: application, runtime environment (RTE) and basic software (BSW).

- The application software layer is mostly hardware independent.
- Communication between software components and access to BSW via RTE.
- The RTE represents the full interface for applications.
- The BSW is divided in three major layers and complex drivers: Services, ECU (Electronic Control Unit) abstraction and microcontroller abstraction.
- Services are divided furthermore into functional groups representing the infrastructure for system, memory and communication services.



AUTOSAR CLASSIC RELEASE R 20-11

One essential concept is the virtual functional bus (VFB). This virtual bus decouples the applications from the infrastructure. It communicates via dedicated ports, which means that the communication interfaces of the application software must be mapped to these ports. The VFB handles communication both within the individual ECU and between ECUs. From an application point of view, no detailed knowledge of lower-level technologies or dependencies is required. This supports hardware-independent development and usage of application software.

The AUTOSAR layered architecture is offering all the mechanisms needed for software and hardware independence. It distinguishes between three main software layers which run on a Microcontroller (µC): application layer, runtime environment (RTE), and basic software (BSW).

The applications of the different automotive domains interface the basic software by means of the RTE.

In addition to defining architecture and interfaces, AUTOSAR also defines a methodology which enables the configuration of the complete AUTOSAR stack and enhances interoperability between different tool chains. On the one hand this is important for the collaboration within development projects and on the other hand this is important to cut down development costs.

UNIT- II ENGINE MANAGEMENT SYSTEMS

BASIC SENSOR ARRANGEMENT

Sensor

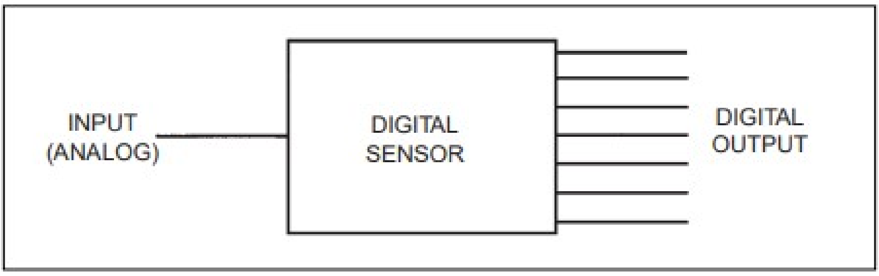
A sensor is a device that converts energy from the form of the measurement variable to an electrical signal. An ideal analog sensor generates an output voltage that is proportional to the quantity q being measured:

$$v_i = \mathrm{k}_i q$$

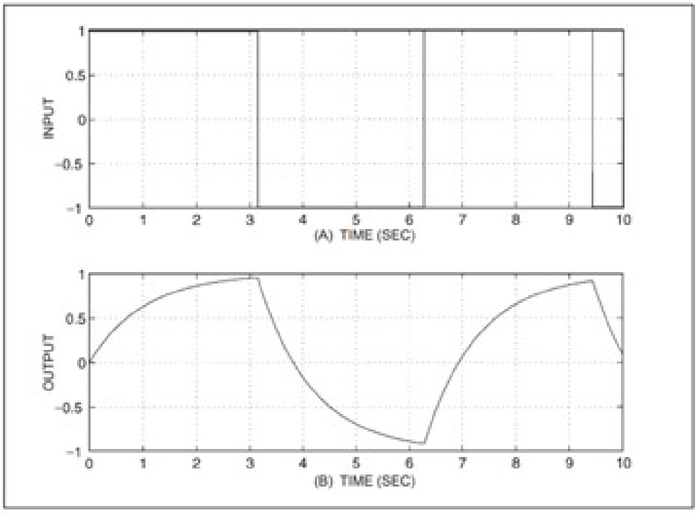
where k_i is the sensor calibration constant. By way of illustration, consider a typical automotive sensor—the throttle-position sensor. The quantity being measured is the angle (theta) of the throttle plate relative to closed throttle. Assuming for the sake of illustration that the throttle angle varies from 0 to 90 degrees and the voltage varies from 0 to 5 volts, the sensor calibration constant K_i is

$$K_i = \frac{5}{90^\circ} = .056\,\text{volt/degree}$$

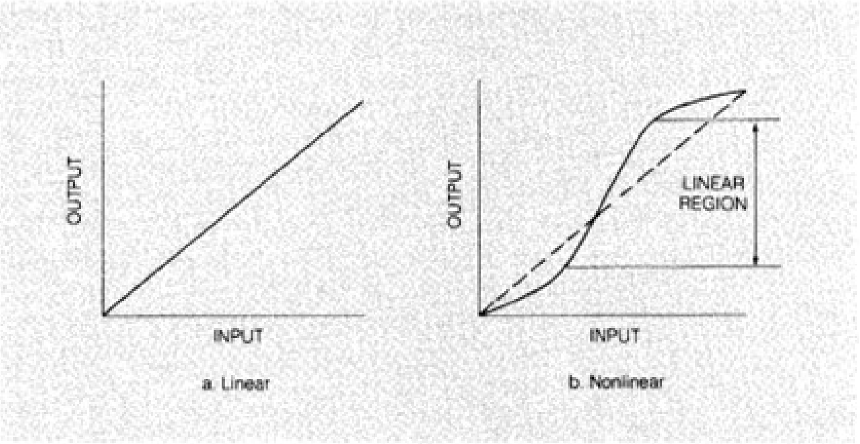
Alternatively, a sensor can have a digital output, making it directly compatible with digital signal processing. For such sensors, the output is an electrical equivalent of a numerical value, using a binary number system as described earlier in this chapter. Figure illustrates the output for such a sensor. There are N output leads, each of which can have one of two possible voltages, representing a 0 or 1. In such an arrangement, 2N possible numerical values can be represented. For automotive applications, N ranges from 8 to 16, corresponding to a range of 64 (28) to 256 (216) numerical values. Of course, a sensor is susceptible to error just as is any system or system component. Potential error sources include loading, finite dynamic response, calibration shift, and nonlinear behavior. Often it is possible to compensate for these and other types of errors in the electronic signal processing unit of the instrument. If a sensor has limited bandwidth, it will introduce errors when measuring rapidly changing input quantities. Figure illustrates such dynamic errors for an analog sensor measuring an input that abruptly changes between two values (this type of input is said to have a square wave waveform). Figure depicts a square wave input to the sensor. Figure illustrates the response that the sensor will have if its bandwidth is too small. Note that the output doesn’t respond to the instantaneous input changes. Rather, its output changes gradually, slowly approaching the correct value. An ideal sensor has a linear transfer characteristic (or transfer function), as shown in Figure. Thus, some signal processing is required to linearize the output signal so that it will appear as if the sensor has a straight line (linear) transfer characteristic, as shown in the dashed curve of Figure. Sometimes a nonlinear sensor may provide satisfactory operation without linearization if it is operated in a particular “nearly” linear region of its transfer characteristic. Moreover, signal processing can be used to “correct” any nonlinearities of a given sensor, yielding a correct value of the variable being measured. This signal processing would perform the nonlinear correction by suitable calculation on the data from the sensor output. Random errors in electronic sensors are caused primarily by internal electrical noise. Internal electrical noise can be caused by molecular vibrations due to heat (thermal noise) or random electron movement in semiconductors (shot noise). In certain cases, a sensor may respond to quantities other than the quantity being measured. For example, the output of a sensor that is measuring pressure may also change as a result of temperature changes. An ideal sensor responds only to one physical quantity or stimulus. However, real sensors are rarely perfect and will generally respond in some way to outside stimuli. Signal processing can potentially correct for such defects.



DIGITAL SENSOR CONFIGURATION



SENSE ERROR CAUSED BY LIMITED DYNAMIC RESPONSE OF SENSOR

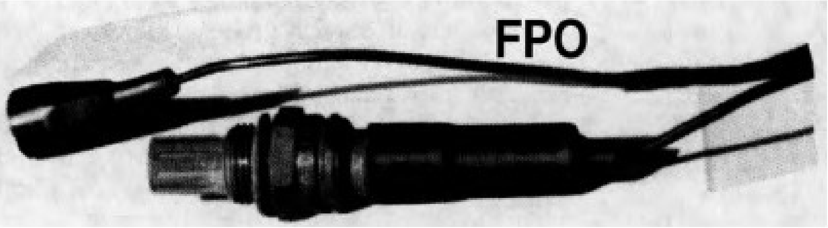


SENSOR TRANSFER CHARACTERISTICS

EXHAUST GAS OXYGEN SENSOR

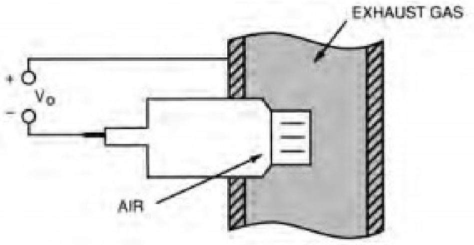
Recall from Chapter 5 that the amount of oxygen in the exhaust gas is used as an indirect measurement of the air/fuel ratio. As a result, one of the most significant automotive sensors in use today is the exhaust gas oxygen (EGO) sensor. This sensor is often called a lambda sensor from the Greek letter lambda (l), which is commonly used to denote the equivalence ratio:

$$\lambda = \frac{(\text{air}/\text{fuel})}{(\text{air}/\text{fuel at stoichiometry})}$$

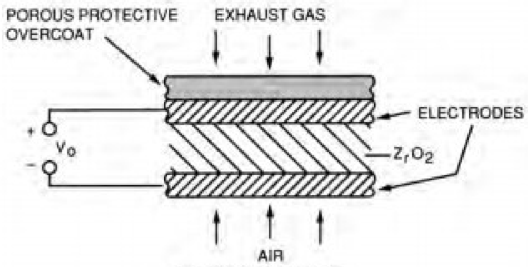


ZIRCONIUM DIOXIDE(ZrO_2) EGO SENSOR

Whenever the air/fuel ratio is at stoichiometry, the value for l is 1. When the air–fuel mixture is too lean, the condition is represented by lambda greater than one (denoted l > 1). Conversely, when the air–fuel mixture is too rich, the condition is represented by an equivalence ratio of lambda less than one (l < 1). The two types of EGO sensors that have been used are based on the use of active oxides of two types of materials. One uses zirconium dioxide (ZrO2) and the other uses titanium dioxide (TiO2). The former is the most commonly used type today. Figure is a photograph of a typical ZrO2 EGO sensor and Figure shows the physical structure. Figure indicates that a voltage, Vo, is generated across the ZrO2 material. This voltage depends on the exhaust gas oxygen concentration, which in turn depends on the engine air/fuel ratio. In essence, the EGO sensor consists of a thimble-shaped section of ZrO2 with thin platinum electrodes on the inside and outside of the ZrO2. The inside electrode is exposed to air, and the outside electrode is exposed to exhaust gas through a porous protective overcoat. A simplified explanation of EGO sensor operation is based on the distribution of oxygen ions. An ion is an electrically charged atom. Oxygen ions have two excess electrons and each electron has a negative charge; thus, oxygen ions are negatively charged. The ZrO2 has a tendency to attract the oxygen ions, which accumulate on the ZrO2 surface just inside the platinum electrodes. The platinum plate on the air reference side of the ZrO2 is exposed to a much higher concentration of oxygen ions than the exhaust gas side. The air reference side becomes electrically more negative than the exhaust gas side; therefore, an electric field exists across the ZrO2 material and a voltage, Vo, results. The polarity of this voltage is positive on the exhaust gas side and negative on the air reference side of the ZrO2. The magnitude of this voltage depends on the concentration of oxygen in the exhaust gas and on the sensor temperature.



a. Sensor Mounted in Exhaust Manifold



b. Inside the Sensor Tip

A. SENSOR MOUNTED IN EXHAUST MANIFOLD, B. INSIDE THE SENSOR TIP

The quantity of oxygen in the exhaust gas is represented by the oxygen partial pressure. Basically, this partial pressure is that proportion of the total exhaust gas pressure (nearly at atmospheric pressure) that is due to the quantity of oxygen. The exhaust gas oxygen partial pressure for a rich mixture varies over the range of 10-16 to 10-32 of atmospheric pressure. The oxygen partial pressure for a lean mixture is roughly 10-2 atmosphere. Consequently, for a rich mixture there is a relatively low oxygen concentration in the exhaust and a higher EGO sensor output. Correspondingly, for a lean mixture the exhaust gas oxygen concentration is relatively high (meaning that the difference between exhaust gas and atmospheric oxygen concentrations is lower), resulting in a relatively low EGO sensor output voltage. For a fully warmed EGO sensor the output voltage is about 1 volt for a rich mixture and about 0.1 volt for a lean mixture.

DESIRABLE EGO CHARACTERISTICS

The EGO sensor characteristics that are desirable for the type of limit-cycle fuel control system that was discussed in Chapter 5 are as follows:

1. Abrupt change in voltage at stoichiometry

2. Rapid switching of output voltage in response to exhaust gas oxygen changes

3. Large difference in sensor output voltage between rich and lean mixture conditions

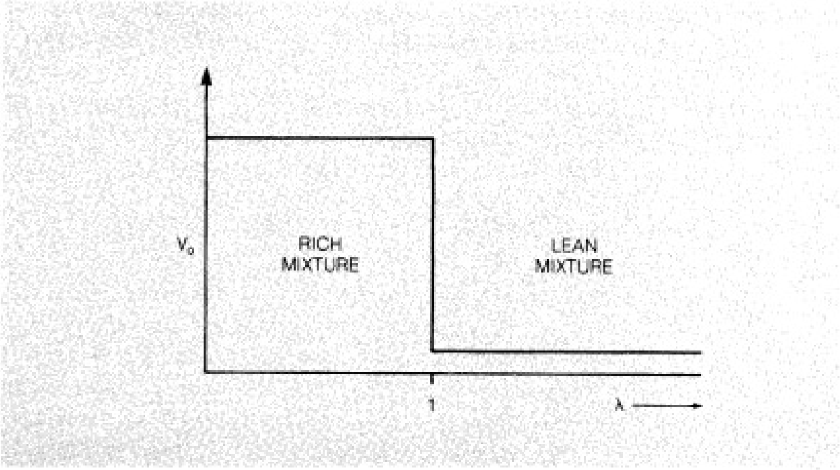
4. Stable voltages with respect to exhaust temperature

SWITCHING CHARACTERISTICS

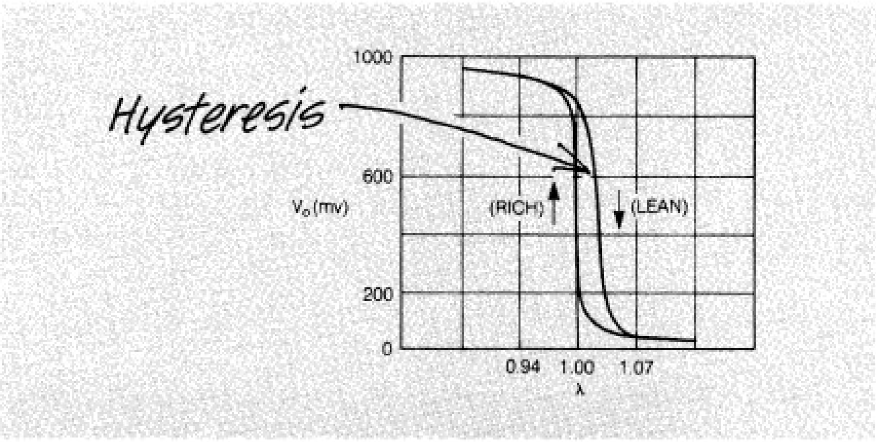
The switching time for the EGO sensor also must be considered in control applications. An ideal characteristic for a limit-cycle controller is shown in Figure . The actual characteristics of a new EGO sensor are shown in Figure. These data were obtained by slowly varying air/fuel ratios across stoichiometry. The arrow pointing down indicates the change in Vo as the air/fuel ratio was varied from rich to lean. The up arrow indicates the change in Vo as the air/fuel ratio was varied from lean to rich. Note that the sensor output doesn't change at exactly the same point for increasing air/fuel ratio as for decreasing air/fuel ratio. This phenomenon is called hysteresis. Temperature affects switching times and output voltage. Switching times at two temperatures are shown in Figure. Note that the time per division is twice as much for the display at 350°C as at 800°C. This means that the switching times are roughly 0.1 second at 350°C, whereas at 800°C they are about 0.05 second. This is a 2 : 1 change in switching times due to changing temperature. The temperature dependence of the EGO sensor output voltage is very important. The graph in Figure shows the temperature dependence of an EGO sensor output voltage for lean and rich mixtures and for two different load resistances—5 megohms (5 million ohms) and 0.83 megohm. The EGO sensor output voltage for a rich mixture is in the range of about 0.80 to 1.0 volt for an exhaust temperature range of 350°C to 800°C. For a lean mixture, this voltage is roughly in the range of 0.05 to 0.07 volt for the same temperature range.

Under certain conditions, the fuel control using an EGO sensor will be operated in open-loop mode and for other conditions it will be operated in closed-loop mode (as will be explained in

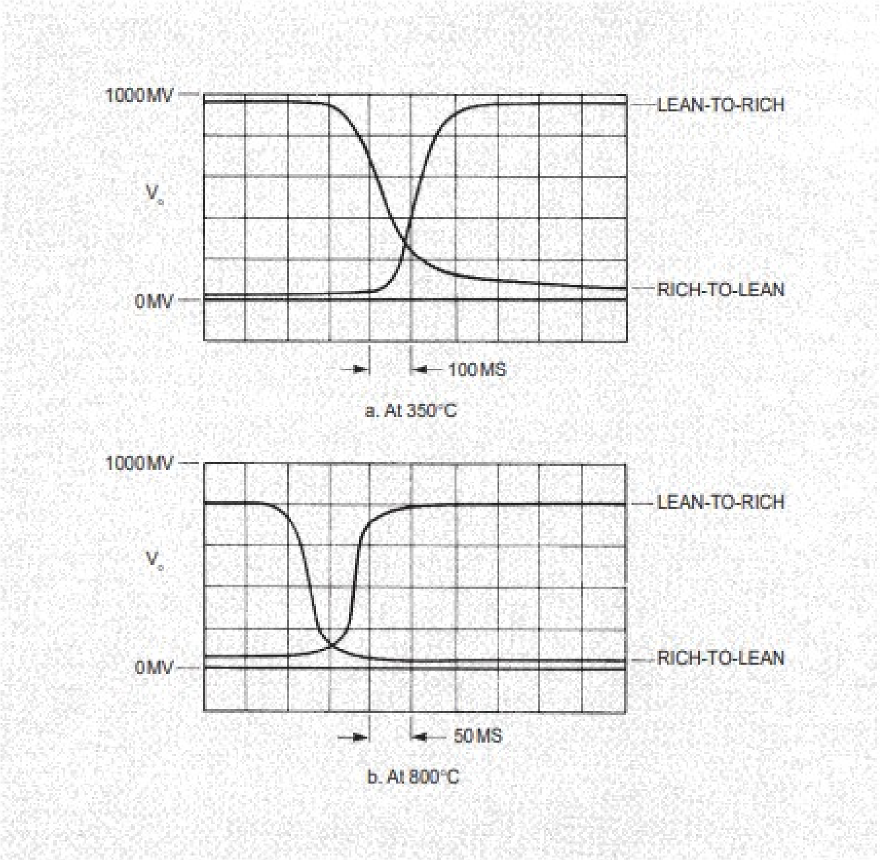
Chapter 7). The EGO sensor should not be used for control at temperatures below about 300°C because the difference between rich and lean voltages decreases rapidly with temperature in this region. This important property of the sensor is partly responsible for the requirement to operate the fuel control system in the open-loop mode at low exhaust temperature. Closed-loop operation with the EGO output voltage used as the error input cannot begin until the EGO sensor temperature exceeds about 300°C. Heated EGO Sensors The increasingly stringent exhaust emission requirements for automobiles in the 1990s have forced automakers to shorten the time from engine start to the point at which the EGO sensor is at operating temperature. This requirement has led to the development of the heated exhaust gas oxygen (HEGO) sensor. This sensor is electrically heated from start-up until it yields an output signal of sufficient magnitude to be useful in closed-loop control. The HEGO sensor includes a section of resistance material. Electrical power from the car battery is applied at start-up, which quickly warms the sensor to usable temperatures. This heating potentially shortens the time interval until closed-loop operation is possible, thereby minimizing the time during warm-up that the air/fuel ratio deviates from stoichiometry and correspondingly reduces undesirable exhaust gas emissions.



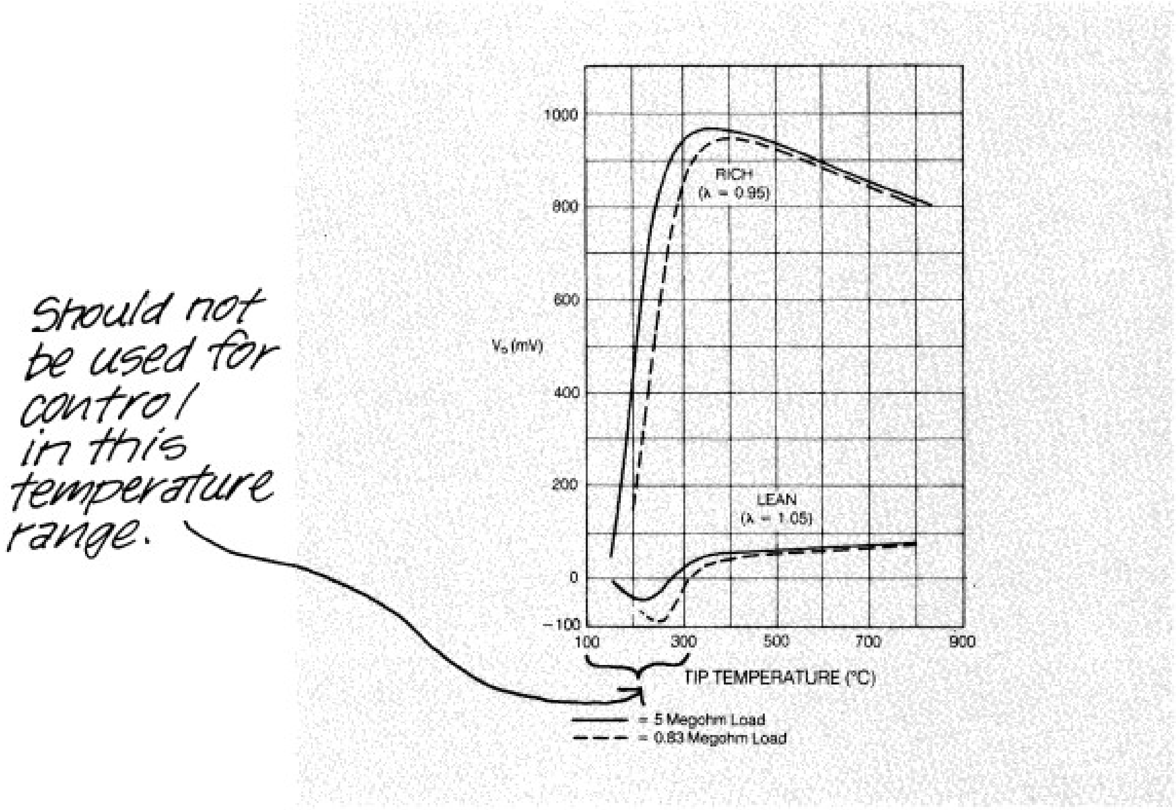
IDEAL EGO SWITCHING CHARACTERISTICS



TYPICAL EGO SENSOR CHARACTERISTICS



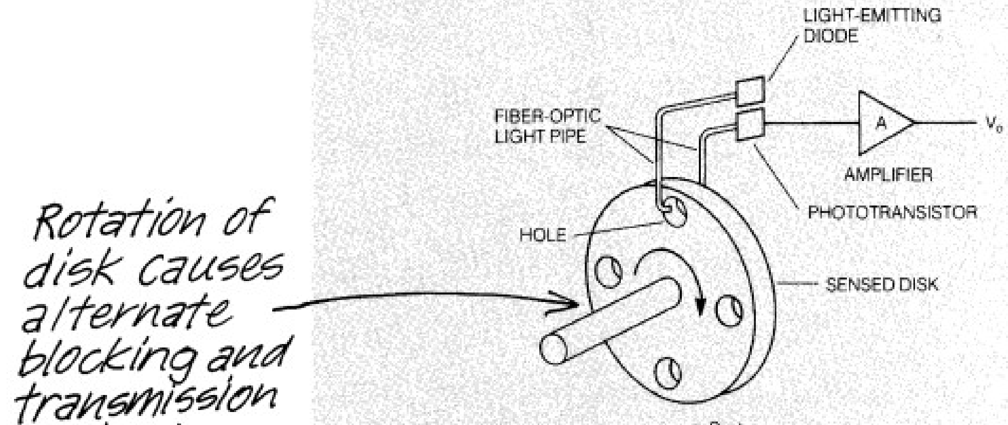
TYPICAL VOLTAGE SWITCHING CHARACTERISTICS OF EGO SENSOR



TYPICAL INFLUENCE OF MIXTURE AND TEMPERATURE ON EGO OUTPUT VOLTAGE

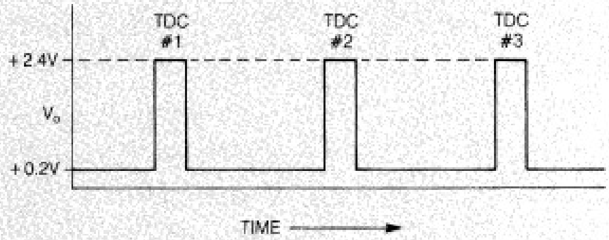
CRANK ANGLE POSITION SENSORS

In a sufficiently clean environment a shaft position can also be sensed using optical techniques. Figure illustrates such a system. Again, as with the magnetic system, a disk is directly coupled to the crankshaft. This time, the disk has holes in it that correspond to the number of tabs on the disks of the magnetic systems. Mounted on each side of the disk are fiber-optic light pipes. The hole in the disk allows transmission of light through the light pipes from the light-emitting diode (LED) source to the phototransistor used as a light sensor. Light would not be transmitted from source to sensor when there is no hole because the solid disk blocks the light. As shown in Figure, the pulse of light is detected by the phototransistor and coupled to an amplifier to obtain a satisfactory signal level. The output pulse level can very easily be standard transistor logic levels of +2.4 V for the high level and +0.8 V for the low level. Used as pulses, the signals provide time-referenced pulses that can be signal processed easily with digital integrated circuits. One of the problems with optical sensors is that they must be protected from dirt and oil; otherwise, they will not work properly. They have the advantages that they can sense position without the engine running and that the pulse amplitude is constant with variation in speed.



Rotation of disk causes alternate blocking and transmission of light.

a. System



b. Pulse Output

CRANK ANGLE POSITION SENSORS

ENGINE SPEED SENSOR / VEHICLE SPEED SENSOR

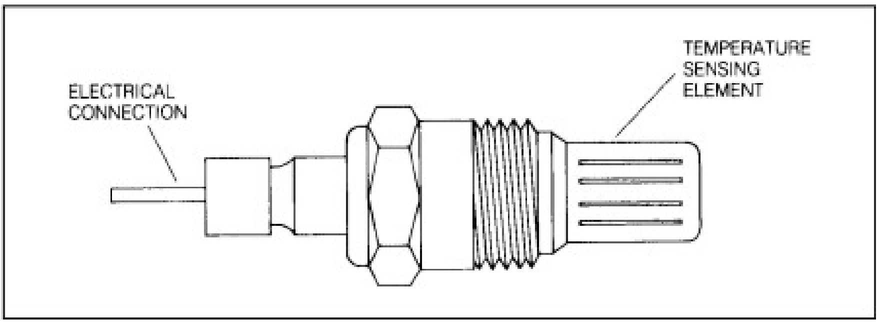
An engine speed sensor is needed to provide an input for the electronic controller for several functions. The position sensor discussed previously can be used to measure engine speed. The reluctance sensor is used in this case as an example; however, any of the other position sensor techniques could be used as well. Refer to Figure and notice that the four tabs will pass through the sensing coil once for each crankshaft revolution. Therefore, if we count the pulses of voltage from the sensing coil in one minute and divide by four, we will know the engine speed in revolutions per minute (RPM). This is easy to do with digital circuits. Precise timing circuits such as those used in digital watches can start a counter circuit that will count pulses until the timing circuit stops it. The counter can have the divide-by-four function included in it, or a separate divider circuit may be used. In many cases, the actual RPM sensor disk is mounted near the flywheel and has many more than four tabs; in such cases, the counter does not actually count for a full minute before the speed is calculated, but the results are the same.

TEMPERATURE SENSORS

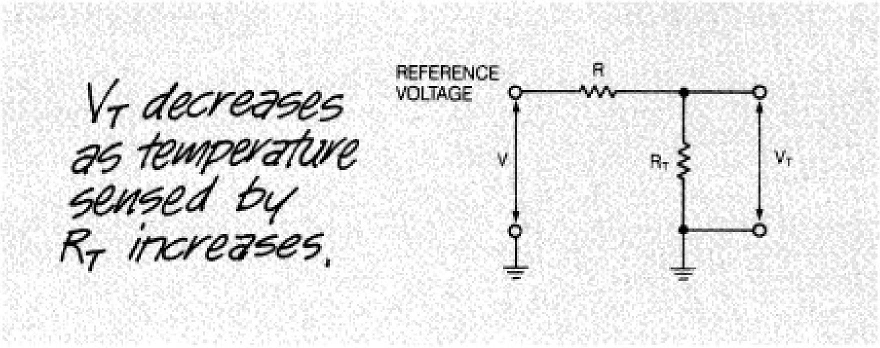
Temperature is an important parameter throughout the automotive system. In operation of an electronic fuel control system it is vital to know the temperature of the coolant, the temperature of the inlet air, and the temperature of the exhaust gas oxygen sensor (a sensor to be discussed in the next section). Several sensor configurations are available for measuring these temperatures, but we can illustrate the basic operation of most of the temperature sensors by explaining the operation of a typical coolant sensor. Typical Coolant Sensor A typical coolant sensor, shown in Figure, consists of a thermistor mounted in a housing that is designed to be inserted in the coolant stream. This housing is typically threaded with pipe threads that seal the assembly against coolant leakage. A thermistor is made of semiconductor material whose resistance varies inversely with temperature. For example, at -40°C a typical coolant sensor has a resistance of 100,000 ohms. The resistance decreases to about 70,000 ohms at 130°C. The sensor is typically connected in an electrical circuit like that shown in Figure, in which the coolant temperature sensor resistance is denoted RT. This resistance is connected to a reference voltage through a fixed resistance R. The sensor output voltage, VT, is given by the following equation:

$$V_T = V \frac{R_T}{R + R_T}$$

The sensor output voltage varies inversely with temperature; that is, the output voltage decreases as the temperature increases.



COOLANT TEMPERATURE SENSOR



TYPICAL COOLANT TEMPERATURE SENSOR CIRCUIT

AIR FLOW RATE SENSOR

In we showed that the correct operation of an electronically controlled engine operating with government-regulated exhaust emissions requires a measurement of the mass flow rate of air (Rm) into the engine. The majority of cars produced since the early 1990s use a relatively simple and inexpensive mass air flow rate (MAF) sensor. This is normally mounted as part of the air cleaner assembly, where it measures air flow into the intake manifold. It is a ruggedly packaged, single-unit sensor that includes solid-state electronic signal processing. In operation, the MAF sensor generates a continuous signal that varies nearly linearly with true mass air flow Rm. The MAF sensor is a variation of a classic air flow sensor that was known as a hot wire anemometer and was used, for example, to measure wind velocity for weather forecasting. In the MAF, the hot-wire, or sensing, element is replaced by a hot-film structure mounted on a substrate. On the air inlet side is mounted a honeycomb flow straightener that “smooths” the air flow (causing nominally laminar air flow over the film element). At the lower portion of the structure is the signal processing circuitry. The film element is electrically heated to a constant temperature above that of the inlet air. The latter air temperature is sensed using a solid-state temperature sensor (explained later in this chapter). The hot-film element is incorporated in a Wheatstone bridge circuit . The power supply for the bridge circuit comes from an amplifier. The Wheatstone bridge consists of three fixed resistors R1, R2, and R3 and a hot-film element having resistance RHW. With no air flow the resistors R1, R2 , and R3 are chosen such that voltage va and v b are equal (i.e., the bridge is said to be balanced). As air flows across the hot film, heat is carried away from the film by the moving air. The amount of heat carried away varies in proportion to the mass flow rate of the air. The heat lost by the film to the air tends to cause the resistance of the film to vary, which unbalances the bridge circuit, thereby producing an input voltage to the amplifier. The output of the amplifier is connected to the bridge circuit and provides the power for this circuit. The amplified voltage changes the resistance in such a way as to maintain a fixed hot-film temperature relative to the inlet temperature. The amplifier output voltage vc varies with

MAF and serves as a measure of Rm. Typically the conversion of MAF to voltage is slightly nonlinear, as indicated by the calibration curve depicted in Figure. Fortunately, a modern digital engine controller can convert the analog bridge output voltage directly to mass air flow by simple computation. In which digital engine control is discussed, it is advantageous to convert analog sensor voltages to a digital format within the solid-state electronics associated with the sensor. This conversion is convenient since it eliminates the need for an analog-to-digital converter, which can be relatively expensive. One scheme for converting the analog output voltage to a digital signal uses a device that is known as a voltage-to-frequency (v/f) converter. This circuit is a variable-frequency oscillator whose frequency f is proportional to the input voltage (in this case, the amplifier output voltage). The variable-frequency output voltage (vf) is applied through an electronic gate, which is essentially an electrically operated switch. Control circuitry (also part of the sensor solid-state electronics) repeatedly closes the switch for a fixed interval t. Then it opens it for another fixed interval. During the first interval the variable-frequency signal from the v/f circuit is connected to the binary counter (BC) (see Chapter 3). The BC counts (in binary) at the instantaneous frequency of the v/f, which is proportional to the amplifier output voltage vf , which in turn varies with mass air flow rate. During each cycle of the electronic gate, the BC contains a binary number given by the product of the v/f frequency and the time interval. For example, if the mass air flow were such that the v/f frequency were 1,000 cycles/sec and the switch were closed for 0.1 sec, then the BC would contain the binary equivalent of decimal 100 (i.e., 1,000 ¥ 0.1 = 100). If the mass air flow increased such that the v/f frequency were 1,500 cycles/sec, then the BC count would be the binary equivalent of 150. In mathematical terms, the BC count B is given by the binary equivalent of

$$B = ft$$

Where

B = BC count

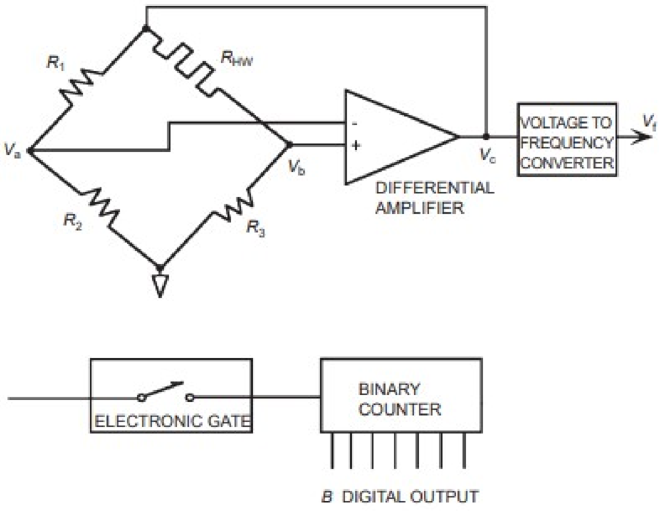
f = frequency of v/f

t = duration of closure of electronic gate

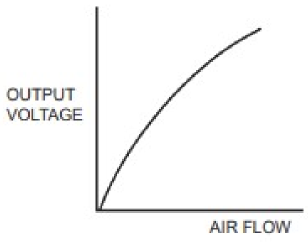
After the engine controller reads the count, the BC is reset to zero to be ready for the next sample. In actual operation, repeated measurements of frequency f are made under control of the digital engine control module . This conversion of voltage to frequency is advantageous in digital engine control applications because the frequency is readily converted to digital format without requiring an analog-to-digital converter.

Indirect Measurement of Mass Air Flow Recall that presented an alternative to direct mass air flow measurement in the form of the so-called speed-density method. This method computes an estimate of mass air flow from measurements of manifold absolute pressure (MAP), RPM, and inlet air temperature. We consider first sensors for measuring manifold absolute pressure. MAP

Sensor Concepts Several MAP sensor configurations have been used in automotive applications. The earliest sensors were derived from aerospace instrumentation concepts, but these proved more expensive than desirable for automotive applications and have been replaced with more cost-effective designs. It is interesting to note that none of the MAP sensors in use measures manifold pressure directly, but instead measure the displacement of a diaphragm that is deflected by manifold pressure. The details of the diaphragm displacement and the measurement of this displacement vary from one configuration to another. Strain Gauge MAP Sensor One relatively inexpensive MAP sensor configuration is the silicondiaphragm diffused strain gauge sensor shown in Figure. This sensor uses a silicon chip that is approximately 3 millimeters square. Along the outer edges, the chip is approximately 250 micrometers (1 micrometer = 1 millionth of a meter) thick, but the center area is only 25 micrometers thick and forms a diaphragm. The edge of the chip is sealed to a Pyrex plate under vacuum, thereby forming a vacuum chamber between the plate and the center area of the silicon chip.



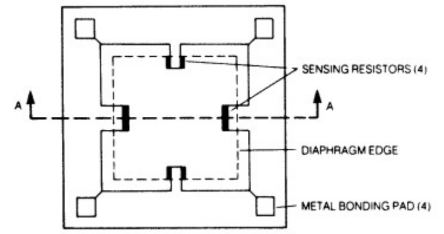
(a) Circuit configuration



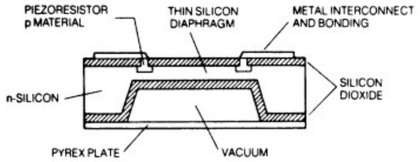
(b) Calibration curve

A. CIRCUIT CONFIGURATION B. CALIBRATION CURVE

A set of sensing resistors is formed around the edge of this chamber, as indicated in Figure. The resistors are formed by diffusing a doping impurity into the silicon. External connections to these resistors are made through wires connected to the metal bonding pads. This entire assembly is placed in a sealed housing that is connected to the intake manifold by a smalldiameter tube. Manifold pressure applied to the diaphragm causes it to deflect. The resistance of the sensing resistors changes in proportion to the applied manifold pressure by a phenomenon that is known as piezoresistivity. Piezoresistivity occurs in certain semiconductors so that the actual resistivity (a property of the material) changes in proportion to the strain (fractional change in length). The strain induced in each resistor is proportional to the diaphragm deflection, which, in turn, is proportional to the pressure on the outside surface of the diaphragm. This pressure is the manifold pressure. A pressure sensor having the configuration of Figure is also used for measuring absolute atmospheric pressure. It will be shown in that this absolute pressure can be used in engine control applications, as can the manifold pressure. An electrical signal that is proportional to the manifold pressure is obtained by connecting the resistors in a circuit called a Wheatstone bridge, as shown in the schematic of Figure . Note the similarity in the Wheatstone bridge of Figure with that employed in the MAF sensor of Figure . The voltage regulator holds a constant dc voltage across the bridge. The resistors diffused into the diaphragm are denoted R1, R2, R3, and R4 in Figure. When there is no strain on the diaphragm, all four resistances are equal, the bridge is balanced, and the voltage between points A and B is zero. When manifold pressure changes, it causes these resistances to change in such a way that R1 and R3 increase by an amount that is proportional to pressure; at the same time, R2 and R4 decrease by an identical amount. This unbalances the bridge and a net difference voltage is present between points A and B. The differential amplifier generates an output voltage proportional to the difference between the two input voltages (which is, in turn, proportional to the pressure), as shown in Figure.



a Top View



b Section A-A

TYPICAL SILICON DIAPHRAGM STRAIN GAUGE MAP SENSOR

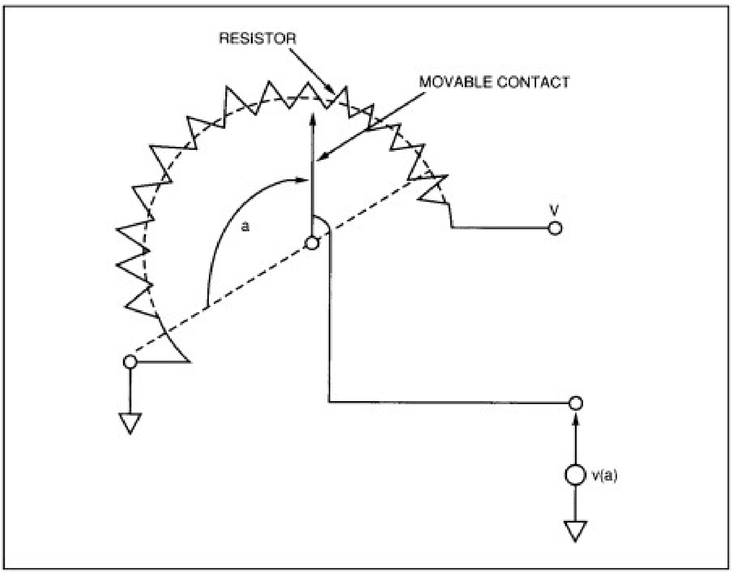
THROTTLE ANGLE SENSOR

Still another variable that must be measured for electronic engine control is the throttle plate angular position. As explained in the throttle plate is linked mechanically to the accelerator pedal. When the driver depresses the accelerator pedal, this linkage causes the throttle plate angle to increase, allowing more air to enter the engine and thereby increasing engine power. Measurement of the instantaneous throttle angle is important for control purposes, as will be explained in Chapter. Most throttle angle sensors are essentially potentiometers. A potentiometer consists of a resistor with a movable contact, as illustrated in Figure.

A section of resistance material is placed in an arc around the pivot axis for the movable contact. One end of the resistor is connected to ground, the other to a fixed voltage V (e.g., 5 volts). The voltage at the contact point of the movable contact is proportional to the angle (a) from the ground contact to the movable contact. Thus,

$$v(a) = ka$$

where v(a) is the voltage at the contact point, k is a constant, and a is the angle of the contact point from the ground connection. This potentiometer can be used to measure any angular rotation. In particular, it is well suited for measuring throttle angle. The only disadvantage to the potentiometer for automotive applications is its analog output. For digital engine control, the voltage v(a) must be converted to digital format using an analog-to-digital converter.



THROTTLE ANGLE SENSOR: A POTENTIOMETER

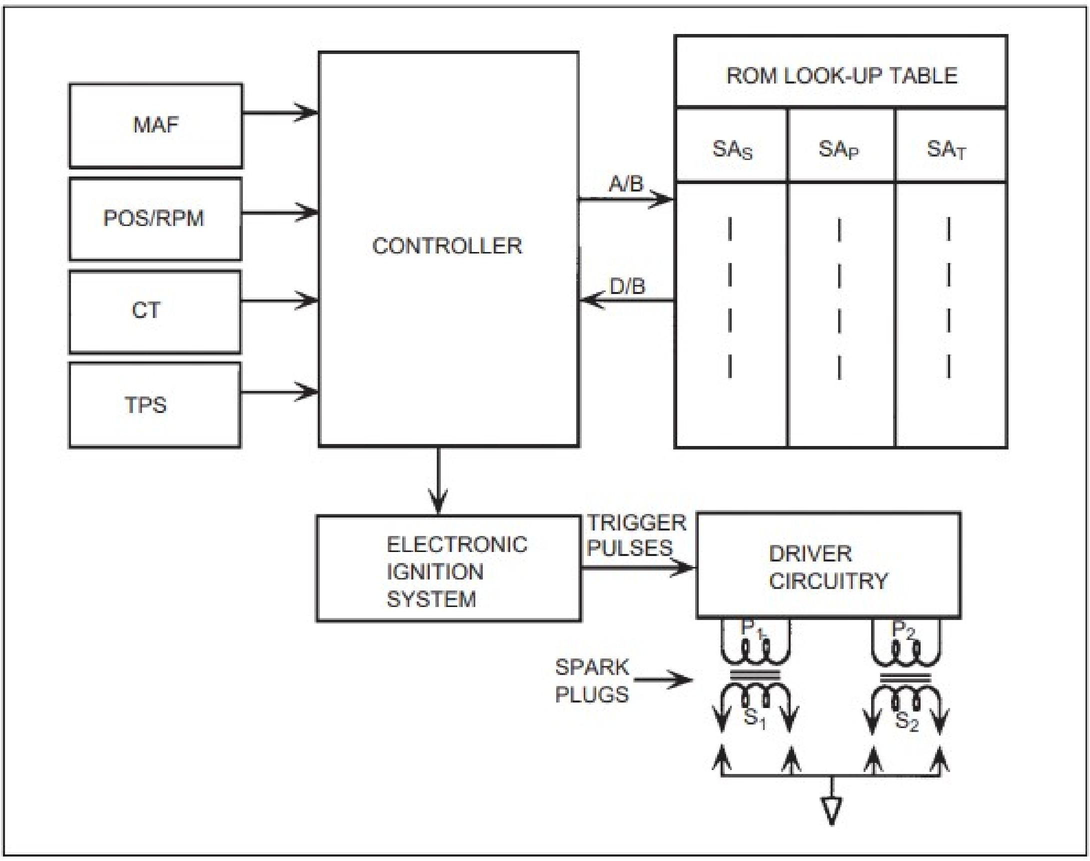
ELECTRONIC IGNITION CONTROL

An engine must be provided with fuel and air in correct proportions and the means to ignite this mixture in the form of an electric spark. Before the development of electronic ignition the traditional ignition system included spark plugs, a distributor, and a high-voltage ignition coil . The distributor would sequentially connect the coil output high voltage to the correct spark plug. In addition, it would cause the coil to generate the spark by interrupting the primary current (ignition points) in the desired coil, thereby generating the required spark. The time of occurrence of this spark (i.e., the ignition timing) in relation of the piston to TDC influences the torque generated. In most present-day electronically controlled engines the distributor has been replaced by multiple coils. Each coil supplies the spark to either one or two cylinders. In such a system the controller selects the appropriate coil and delivers a trigger pulse to ignition control circuitry at the correct time for each cylinder. (Note: In some cases the coil is on the spark plug as an integral unit.) Figure illustrates such a system for an example 4-cylinder engine. In this example a pair of coils provides the spark for firing two cylinders for each coil. Cylinder pairs are selected such that one cylinder is on its compression stroke while the other is on exhaust. The cylinder on compression is the cylinder to be fired (at a time somewhat before it reaches TDC). The other cylinder is on exhaust. The coil fires the spark plugs for these two cylinders simultaneously. For the former cylinder, the mixture is ignited and combustion begins for the power stroke that follows. For the other cylinder (on exhaust stroke), the combustion has already taken place and the spark has no effect. Although the mixture for modern emission-regulated engines is constrained by emissions regulations, the spark timing can be varied in order to achieve optimum performance within the mixture constraint. For example, the ignition timing can be chosen to produce the best possible engine torque for any given operating condition. This optimum ignition timing is known for any given engine configuration from studies of engine performance as measured on an engine dynamometer. Figure is a schematic of a representative electronic ignition system. In this example configuration the spark advance value is computed in the main engine control (i.e., the controller that regulates fuel). This system receives data from the various sensors (as described above with respect to fuel control) and determines the correct spark advance for the instantaneous operating condition. The variables that influence the optimum spark timing at any operating condition include RPM, manifold pressure (or mass air flow), barometric pressure, and coolant temperature. The correct ignition timing for each value of these variables is stored in a ROM lookup table. For example, the variation of spark advance (SA) with RPM for a representative engine is shown in Figure. The engine control system obtains readings from the various sensors and generates an address to the lookup table (ROM). After reading the data from the lookup tables, the control system computes the correct spark advance. An output signal is generated at the appropriate time to activate the spark. In the configuration depicted in Figure , the electronic ignition is implemented in a stand-alone ignition module. This solid-state module receives the correct spark advance data and generates electrical signals that operate the coil driver circuitry. These signals are produced in response to timing inputs coming from crankshaft and camshaft signals (POS/RPM). The coil driver circuits generate the primary current in windings P1 and P2 of the coil packs depicted in Figure . These primary currents build up during the so-called dwell period before the spark is to occur. At the correct time the driver circuits interrupt the primary currents via a solid-state switch.

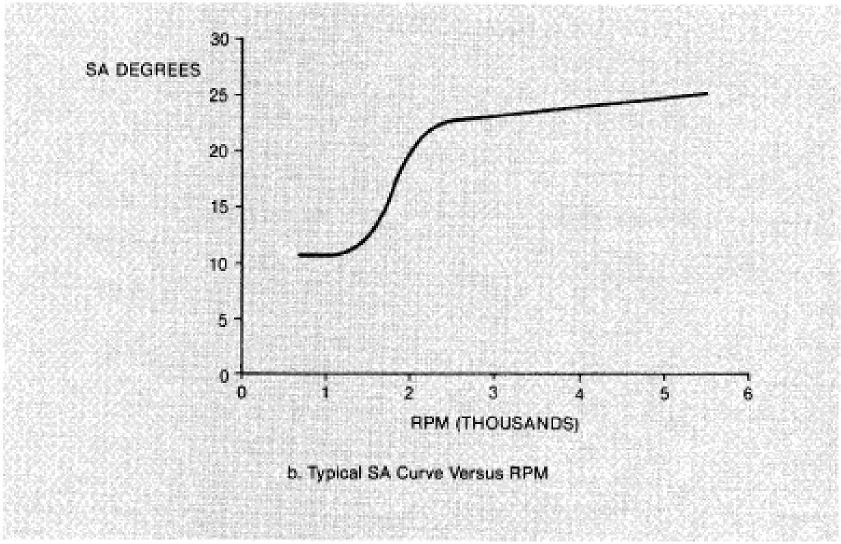
This interruption of the primary current causes the magnetic field in the coil pack to drop rapidly, inducing a very high voltage (20,000–40,000 volts) that causes a spark. In the example depicted in Figure, a pair of coil packs, each firing two spark plugs, is shown. Such a configuration would be appropriate for a 4-cylinder engine. Normally there would be one coil pack for each pair of cylinders. The ignition system described above is known as a distributorless ignition system (DIS) since it uses no distributor. There are a number of older car models on the road that utilize a distributor. However, the electronic ignition system is the same as that shown in Figure, up to the coil packs. In distributor-equipped engines there is only one coil, and its secondary is connected to the rotary switch (or distributor) as described. In a typical electronic ignition control system, the total spark advance, SA (in degrees before TDC), is made up of several components that are added together: The first component, SAS, is the basic spark advance, which is a tabulated function of RPM and MAP.

The control system reads RPM and MAP, and calculates the address in ROM of the SAS that corresponds to these values. Typically, the advance of RPM from idle to about 1200 RPM is relatively slow. Then, from about 1200 to about 2300 RPM the increase in RPM is relatively quick. Beyond 2300 RPM, the increase in RPM is again relatively slow. Each engine configuration has its own spark advance characteristic, which is normally a compromise between a number of conflicting factors (the details of which are beyond the scope of this book). The second component, SAP, is the contribution to spark advance due to manifold pressure. This value is obtained from ROM lookup tables. Generally speaking, the SA is reduced as pressure increases. The final component, SAT, is the contribution to spark advance due to temperature. Temperature effects on spark advance are relatively complex, including such effects as cold cranking, cold start, warm-up, and fully warmed-up conditions and are beyond the scope of this book.

$$SA = SA_S + SA_P + SA_T$$



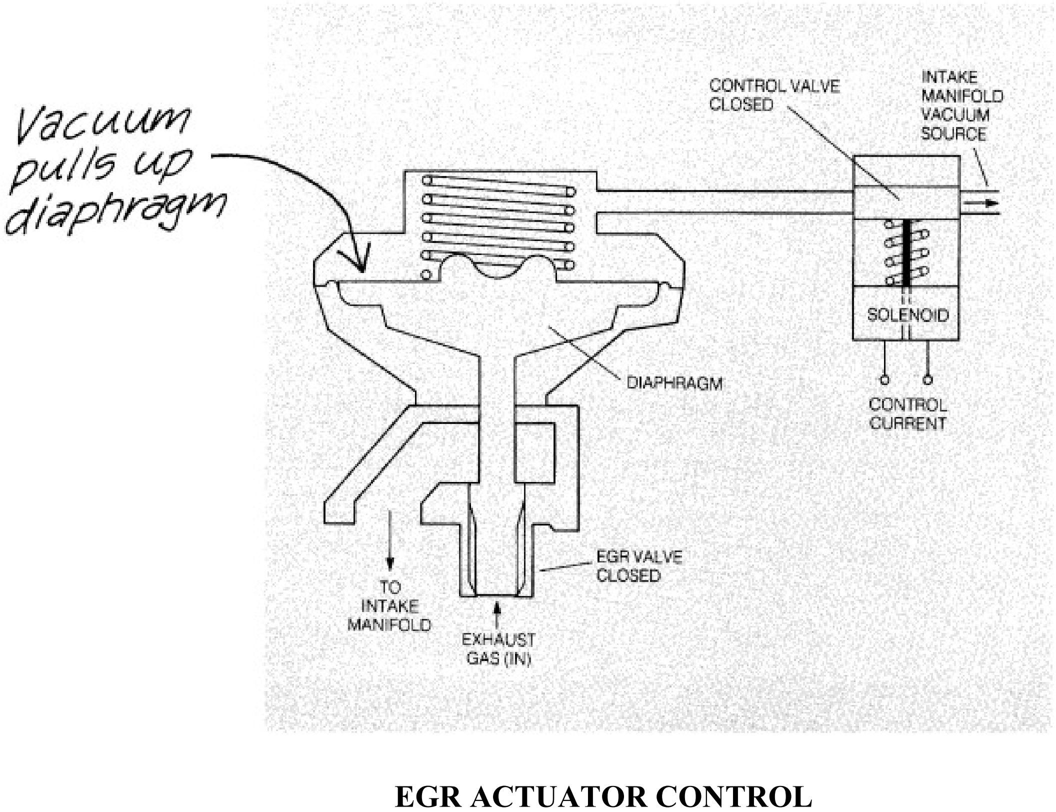
DISTRIBUTORLESS IGNITION SYSTEM



SPARK ADVANCE VERSUS RPM

EXHAUST GAS RECIRCULATION ACTUATOR

It was explained that exhaust gas recirculation (EGR) is utilized to reduce NOx emissions. The amount of EGR is regulated by the engine controller, as explained in Chapter. When the correct amount of EGR has been determined by the controller based on measurements from the various engine control sensors, the controller sends an electrical signal to the EGR actuator. Typically, this actuator is a variable-position valve that regulates the EGR as a function of intake manifold pressure and exhaust gas pressure. Although there are many EGR configurations, only one representative example will be discussed to explain the basic operation of this type of actuator. The example EGR actuator is shown schematically in Figure. This actuator is a vacuum-operated diaphragm valve with a spring that holds the valve closed if no vacuum is applied. The vacuum that operates the diaphragm is supplied by the intake manifold and is controlled by a solenoid operated valve. This solenoid valve is controlled by the output of the control system.



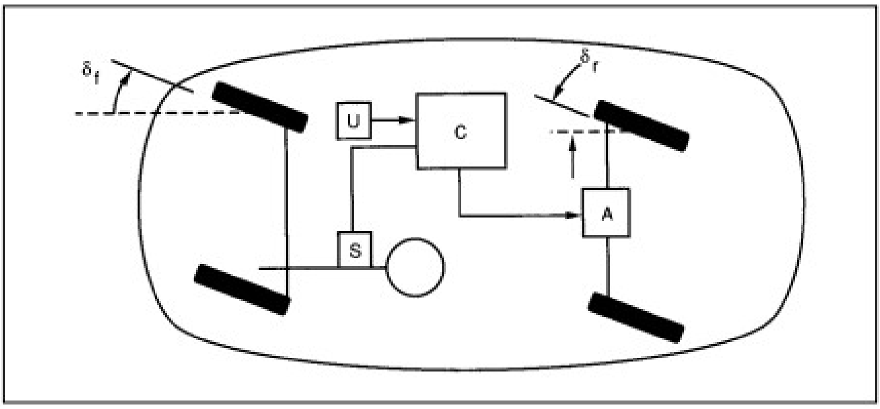
EGR ACTUATOR CONTROL

This solenoid operates essentially the same as that explained in the discussion on fuel injectors. Whenever the solenoid is energized (i.e., by current supplied by the control system flowing through the coil), the EGR valve is opened by the applied vacuum. The amount of valve opening is determined by the average pressure on the vacuum side of the diaphragm. This pressure is regulated by pulsing the solenoid with a variable-duty-cycle electrical control current. The duty cycle (see discussion on fuel injectors) of this pulsing current controls the average pressure in the chamber that affects the diaphragm deflection, thereby regulating the amount of EGR.

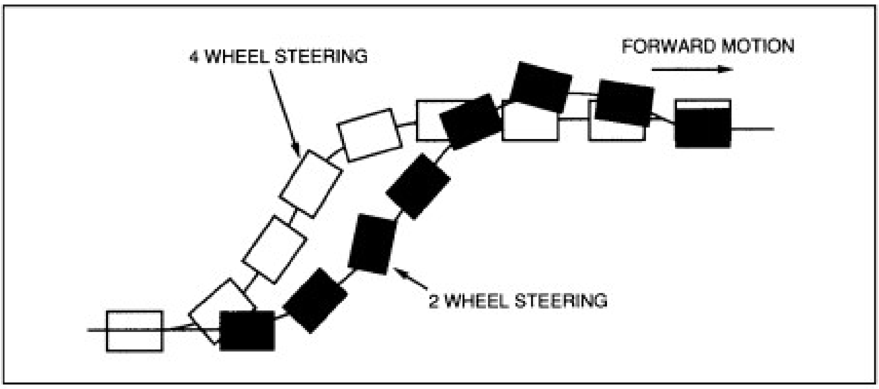
UNIT- III VEHICLE POWER TRAIN AND MOTION CONTROL

ELECTRONIC STEERING CONTROL

The steering system was explained. There it was shown that the steering effort required of the driver to overcome restoring torque generally decreases with vehicle speed and increases with steering angle. Traditionally, the steering effort required by the driver has been reduced by incorporating a hydraulic power steering system in the vehicle. Whenever there is a steering input from the driver, hydraulic pressure from an engine-driven pump is applied to a hydraulic cylinder that boosts the steering effort of the driver. Typically, the effort available from the pump increases with engine speed (i.e., with vehicle speed), whereas the required effort decreases. It would be desirable to reduce steering boost as vehicle speed increases. Such a feature is incorporated into a power steering system featuring electronic controls. An electronically controlled power steering system adjusts steering boost adaptively to driving conditions. Using electronic control of power steering, the available boost is reduced by controlling a pressure relief valve on the power steering pump. An alternative power steering scheme utilizes a special electric motor to provide the boost required instead of the hydraulic boost. Electric boost power steering has several advantages over traditional hydraulic power steering. Electronic control of electric boost systems is straightforward and can be accomplished without any energy conversion from electrical power to mechanical actuation. Moreover, electronic control offers very sophisticated adaptive control in which the system can adapt to the driving environment. An example of an electronically controlled steering system that has had commercial production is for four-wheel steering systems (4WS). In the 4WSequipped vehicles, the front wheels are directly linked mechanically to the steering wheel, as in traditional vehicles. There is a power steering boost for the front wheels as in a standard two-wheel steering system. The rear wheels are steered under the control of a microcontroller via an actuator. Figure is an illustration of the 4WS configuration. In this illustration, the front wheels are steered to a steering angle df by the driver’s steering wheel input. A sensor (S) measures the steering angle and another sensor (U) gives the vehicle speed. The microcontroller (C) determines the desired rear steering angle dr under program control as a function of speed and front steering angle. The details of the control strategy are proprietary and not available for this book. However, it is within the scope of this book to describe a representative example control strategy as follows. For speeds below 10 mph, the rear steering angle is in the opposite direction to the front steering angle. This control strategy has the effect of decreasing the car’s turning radius by as much as 30% from the value it has for front wheel steering only. Consequently, the maneuvering ability of the car at low speeds is enhanced (e.g., for parking). At intermediate speeds (e.g., 11 mph < U < 30 mph), the steering might be front wheel only. At higher speeds (including highway cruise), the front and rear wheels are steered in the same direction. At least one automaker has an interesting strategy for higher speeds (e.g., at highway cruise speed). In this strategy, the rear wheels turn in the opposite direction to the front wheels for a very short period (on the order of one second) and then turn in the same direction as the front wheels. This strategy has a beneficial effect on maneuvers such as lane changes on the highway. Figure illustrates the lane change for front wheel steering and for this latter 4WS strategy, in which the same front steering angle was used. Notice that the 4WS strategy yields a lane change in a shorter distance and avoids the overshoot common in a standard-steering vehicle. Turning the wheels in the same direction at cruising speeds has another benefit for a vehicle towing a trailer. When front and rear wheels turn in the same direction, the angle between the car and trailer axes is less than it is for front wheel steering only. The reduction in this angle means that the lateral force applied to the rear wheels by the trailer in curves is less than that for front wheel only steering. This lateral force reduction improves the stability of the car or truck/trailer combination relative to front steering only



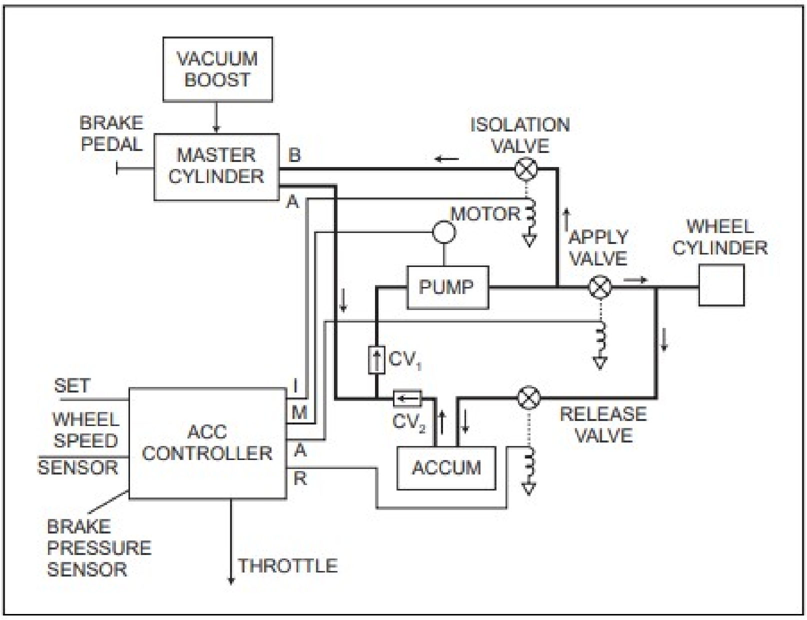
4WS CONFIGURATION



LANE CHANGE MANEUVER

ADVANCED CRUISE CONTROL

The cruise control system previously described is adequate for maintaining constant speed, provided that any required deceleration can be achieved by a throttle reduction (i.e., reduced engine power). The engine has limited braking capability with a closed throttle, and this braking in combination with aerodynamic drag and tire-rolling resistance may not provide sufficient deceleration to maintain the set speed. For example, a car entering a long, relatively steep downgrade may accelerate due to gravity even with the throttle closed. For this driving condition, vehicle speed can be maintained only by application of the brakes. For cars equipped with a conventional cruise control system, the driver has to apply braking to hold speed. An advanced cruise control (ACC) system has a means of automatic brake application whenever deceleration with throttle input alone is inadequate. A somewhat simplified block diagram of an ACC is shown in Figure emphasizing the automatic braking portion. This system consists of a conventional brake system with master cylinder wheel cylinders, vacuum boost (power brakes), and various brake lines. Figure shows only a single-wheel cylinder, although there are four in actual practice. In addition, proportioning valves are present to regulate the front/rear brake force ratio. In normal driving, the system functions like a conventional brake system. As the driver applies braking force through the brake pedal to the master cylinder, brake fluid (under pressure) flows out of port and through a brake line to the junction of check valves CV1 and CV2. Check valve CV2 blocks brake fluid, whereas CV1 permits flow through a pump assembly P and then through the apply valve (which is open) to the wheel cylinder(s), thereby applying brakes. In cruise control mode, the ACC controller regulates the throttle (as explained above for a conventional cruise control) as well as the brake system via electrical output signals and in response to inputs, including the vehicle speed sensor and set cruise speed switch. The ACC system functions as described above until the maximum available deceleration with closed throttle is inadequate. Whenever there is greater deceleration than this maximum valve, the ACC applies brakes automatically. In this automatic brake mode, an electrical signal is sent from the M (i.e., motor) output, causing the pump to send more brake fluid (under pressure) through the apply valve (maintained open) to the wheel cylinder. At the same time, the release valve remains closed such that brakes are applied. The braking pressure can be regulated by varying the isolation valve, thereby bleeding some brake fluid back to the master cylinder. By activating isolation valves separately to the four wheels, brake proportioning can be achieved. Brake release can be accomplished by sending signals from the ACC to close the apply valve and open the release valve. Another potential future application for automatic braking involves separate brake pressure applied individually to all four wheels. This independent brake application can be employed for improved handling when both braking and steering are active (e.g., braking on curves). A further application of the ACC involves maintaining a constant headway (separation) behind another vehicle on the road. A discussion of this application is deferred to the final chapter.

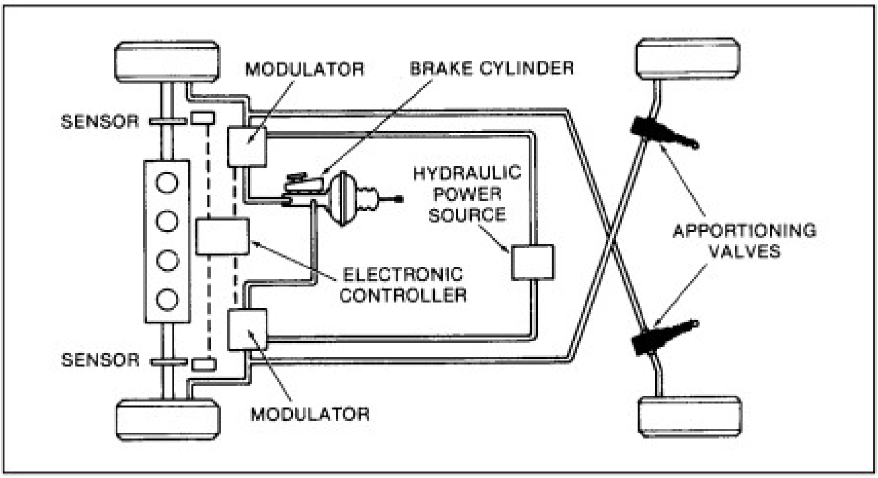


ACC EMPHASIZING THE AUTOMATIC BRAKING PORTION

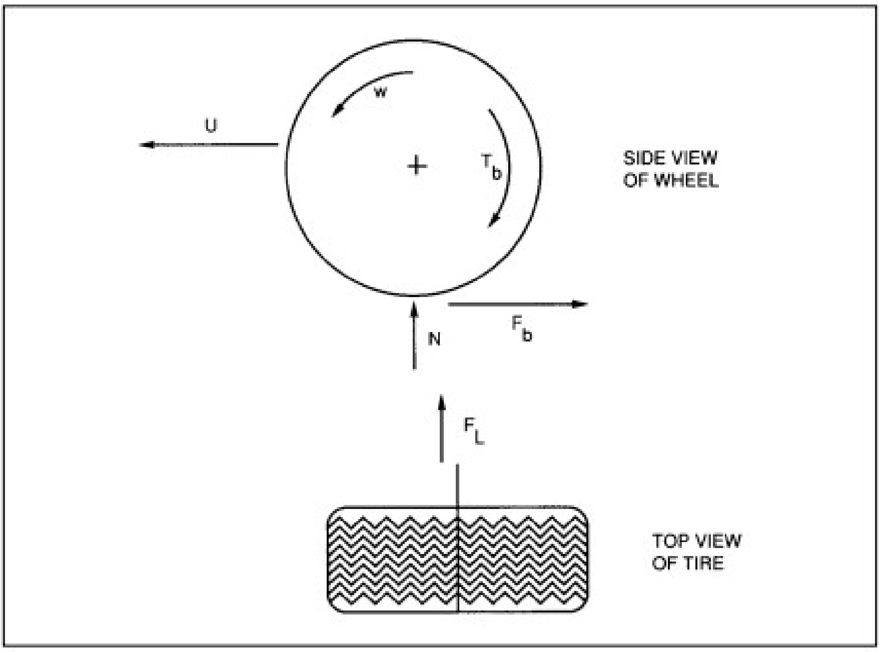
ANTILOCK BRAKING SYSTEM

One of the most readily accepted applications of electronics in automobiles has been the antilock brake system (ABS). ABS is a safety-related feature that assists the driver in deceleration of the vehicle in poor or marginal braking conditions (e.g., wet or icy roads). In such conditions, panic braking by the driver (in non-ABS-equipped cars) results in reduced braking effectiveness and, typically, loss of directional control due to the tendency of the wheels to lock. In ABS-equipped cars, the wheel is prevented from locking by a mechanism that automatically regulates braking force to an optimum for any given low-friction condition. The physical configuration for an ABS is shown in Figure. In addition to the normal brake components, including brake pedal, master cylinder, vacuum boost, wheel cylinders, calipers/disks, and brake lines, this system has a set of angular speed sensors at each wheel, an electronic control module, and a hydraulic brake pressure modulator (regulator). In order to understand the ABS operation, it is first necessary to understand the physical mechanism of wheel lock and vehicle skid that can occur during braking. Figure illustrates the forces applied to the wheel by the road during braking. The car is traveling at a speed U and the wheels are rotating at an angular speed w where

$$w = \frac{\pi \text{RPM}}{30}$$



ANTILOCK BRAKING SYSTEM



FORCES DURING BRAKING

where RPM is the wheel revolutions per minute. When the wheel is rolling (no applied brakes),

$$U = Rw$$

where R is the tire radius. When the brake pedal is depressed, the calipers are forced by hydraulic pressure against the disk, as explained. This force acts as a torque Tb in opposition to the wheel rotation. The actual force that decelerates the car is shown as Fb in Figure. The lateral force that maintains directional control of the car is shown as FL in Figure. The wheel angular speed begins to decrease, causing a difference between the vehicle speed U and the tire speed over the road (i.e., wR). In effect, the tire slips relative to the road surface. The amount of slip (S) determines the braking force and lateral force. The slip, as a percentage of car speed, is given by

$$S = \frac{U - wR}{U} \times 100\%$$

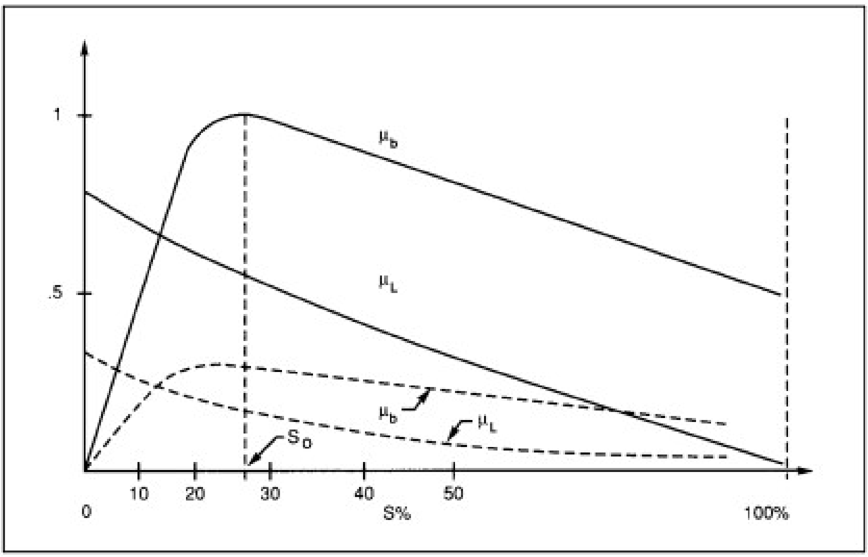
Note: A rolling tire has slip S = 0, and a fully locked tire has S = 100%. The braking and lateral forces are proportional to the normal force (from the weight of the car) acting on the tire/road interface and the friction coefficients for braking force (F_b) and lateral force (F_L):

$$F_b = N\mu_b$$
$$F_L = N\mu_L$$

where

μ_b is the braking friction coefficient
μ_L is the lateral friction coefficient

These coefficients depend markedly on slip, as shown in Figure. The solid curves are for a dry road and the dashed curves for a wet or icy road. As brake pedal force is increased from zero, slip increases from zero. For increasing slip, mb increases to S = So. Further increase in slip actually decreases mb, thereby reducing braking effectiveness. On the other hand, mL decreases steadily with increasing S such that for fully locked wheels the lateral force has its lowest value. For wet or icy roads, mL at S = 100% is so low that the lateral force is insufficient to maintain directional control of the vehicle. However, directional control can often be maintained even in poor braking conditions if slip is optimally controlled. This is essentially the function of the ABS, which performs an operation equivalent to pumping the brakes (as done by experienced drivers before the development of ABS). In ABS-equipped cars under marginal or poor braking conditions, the driver simply applies a steady brake force and the system adjusts tire slip to optimum value automatically. In a typical ABS configuration, control over slip is effected by controlling the brake line pressure under electronic control. The configuration for ABS is



BRAKING COEFFICIENTS VERSUS TIRE SLIP (SOLID CURVES FOR DRY ROAD, DASHED CURVES FOR WET OR ICY ROAD)

shown in Figure. This ABS regulates or modulates brake pressure to maintain slip as near to optimum as possible . The operation of this ABS is based on estimating the torque Tw applied to the wheel at the road surface by the braking force F_b:

$$T_w = RF_b$$

In opposition to this torque is the braking torque Tb applied to the disk by the calipers in response to brake pressure P: where k $_b$ is a constant for the given brakes. The difference between these two torques acts to decelerate the wheel. In accordance with basic Newtonian mechanics, the wheel torque T_w

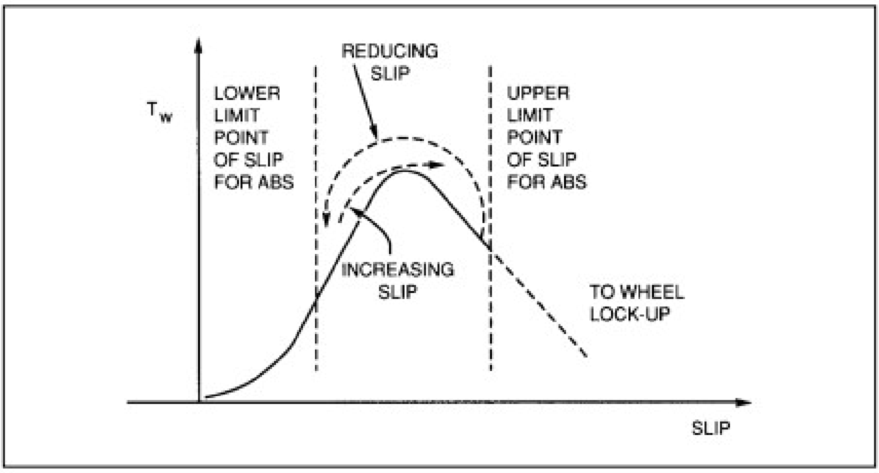
$$T_b = k_b P$$

$$T_w = T_b + I_w \dot{w}$$

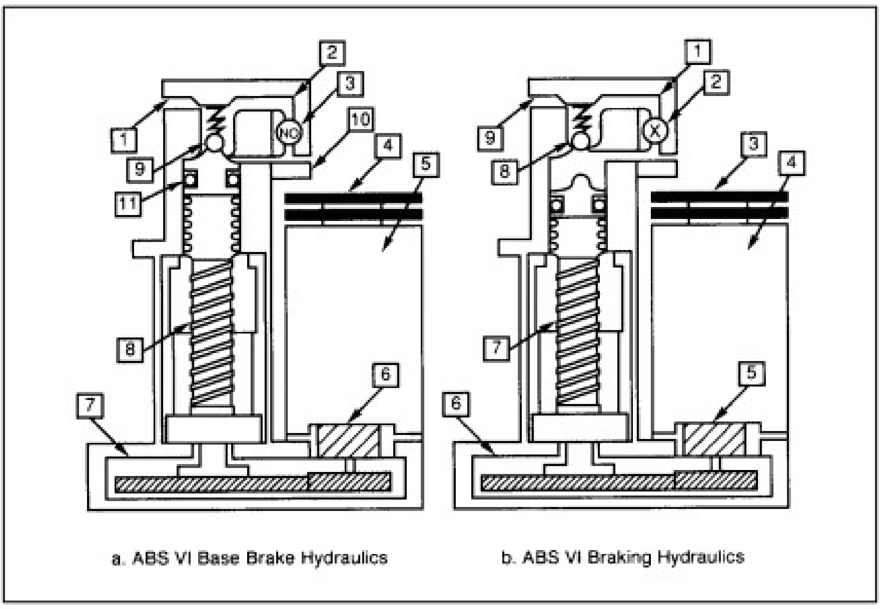
is related to braking torque and wheel deceleration by the following equation: where Iw is the wheel moment of inertia and w · is the wheel deceleration (dw/dt, that is, the rate of change of wheel speed). During heavy braking under marginal conditions, sufficient braking force is applied to cause wheel lock-up (in the absence of ABS control). We assume such heavy braking for the following discussion of the ABS. As brake pressure is applied, Tb increases and w decreases, causing slip to increase. The wheel torque is proportional to mb, which reaches a peak at slip So. Consequently, the wheel torque reaches a maximum value (assuming sufficient brake force is applied) at this level of slip. Figure is a sketch of wheel torque versus slip illustrating the peak Tw. After the peak wheel torque is sensed electronically, the electronic control system commands that brake pressure be reduced (via the brake pressure modulator). This point is indicated in Figure as the limit point of slip for the ABS. As the brake pressure is reduced, slip is reduced and the wheel torque again passes through a maximum.

The wheel torque reaches a value below the peak on the low slip side and at this point brake pressure is again increased. The system will continue to cycle, maintaining slip near the optimal value as long as the brakes are applied and the braking conditions lead to wheel lock-up. The mechanism for modulating brake pressure is illustrated in Figure. The numbers in Figure refer to the following:

1. Applied master cylinder pressure
2. Bypass brake fluid
3. Normally open solenoid valve
4. EMB braking action
5. DC motor pack
6. ESB braking
7. Gear assembly
8. Ball screw
9. Check valve unseated
10. Outlet to brake cylinders
11. Piston



WHEEL TORQUE VERSUS SLIP



a. ABS VI Base Brake Hydraulics

b. ABS VI Braking Hydraulics

BRAKE PRESSURE MODULATING MECHANISM

The numbers in Figure refer to the following:

1. Trapped bypass brake fluid
2. Solenoid valve activated
3. EMB action released

4. DC motor pack

5. ESB braking action released

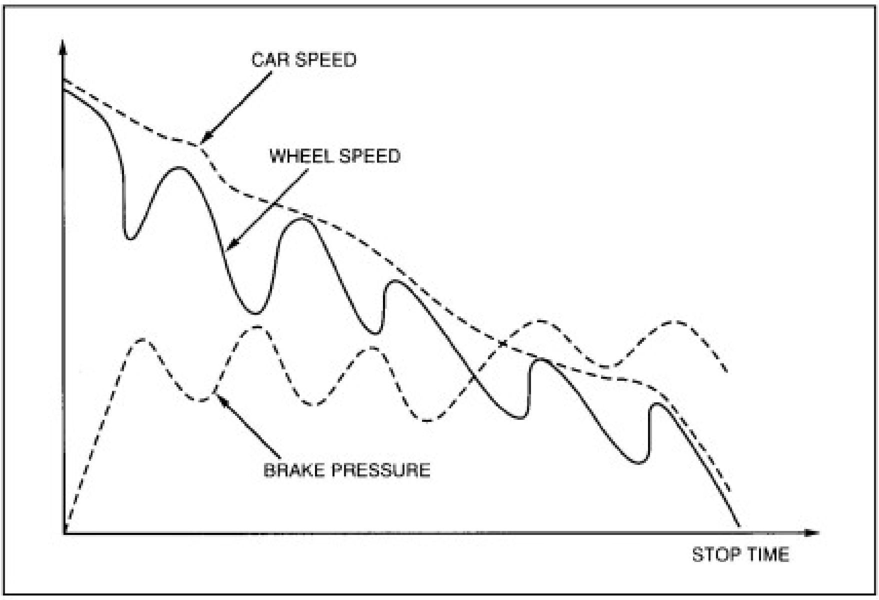
6. Gear assembly

7. Ball screw

8. Check valve seated

9. Applied master cylinder pressure

Under normal braking, brake pressure from the master cylinder passes without reduction through the passageways associated with check valve 9 and solenoid valve 3 in Figure . Whenever the wheel slip limit is reached, the solenoid valve is closed and the piston (11) retracts, closing the check valve. This action effectively isolates the brake cylinders from the master cylinder, and brake line pressure is controlled by the position of piston 11. This piston retracts, lowering the brake pressure sufficiently so that slip falls below So. At this point, the control system detects low Tw and the piston moves up, thereby increasing brake line pressure. The ABS system will continue to cycle until the vehicle has stopped, the braking conditions are normal, or the driver removes the brake pressure from the master cylinder. In the latter case, the operation of the brake pressure modulator restores normal braking function. For example, should the driver release the brake pedal, then the pressure at the inlet (1) is reduced. At this point, the check valve (9) opens and brake line pressure is also removed. The solenoid valve opens and the piston returns to its normal position (fully up) such that the check valve is held open. Figure illustrates the braking during an ABS action. In this illustration, the vehicle is initially traveling at 55 mph and the brakes are applied as indicated by the rising brake pressure. The wheel speed begins to drop until the slip limit is reached. At this point, the ABS reduces brake pressure and the wheel speed increases. With the high applied brake pressure, the wheels again tend toward lock-up and ABS reduces brake pressure. The cycle continues until the vehicle is stopped. It should be noted that by maintaining slip near So, the maximum deceleration is achieved for a given set of conditions. Some reduction in lateral force occurs from its maximum value by maintaining slip near So. However, in most cases the lateral force is large enough to maintain directional control. In some antilock brake systems, the slip oscillations are shifted below So, sacrificing some braking effectiveness to enhance directional control. This can be accomplished by adjusting the upper and lower slip limits.

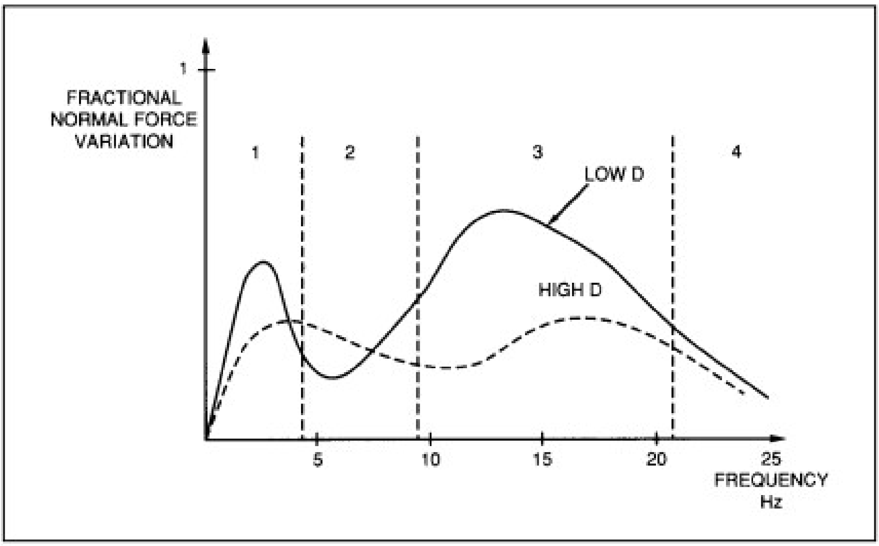


ABS BRAKING ACTION

ELECTRONIC SUSPENSION SYSTEM

We described automotive suspension systems as consisting of springs, shock absorbers, and various linkages to connect the wheel assembly to the car frame. The purpose of the suspension system is to isolate the car body motion as much as possible from wheel motion due to rough road input. It was shown that the performance of the suspension system is strongly influenced by the damping parameter of the shock absorber. The two primary subjective performance measures are ride and handling. Ride refers to the motion of the car body in response to road bumps or irregularities. Handling refers to how well the car body responds to dynamic vehicle motion such as cornering or hard braking. Generally speaking, ride is improved by lowering the shock absorber damping, whereas handling is improved by increasing this damping. In traditional suspension design, the damping parameter is fixed and is chosen to achieve a compromise between ride and handling (i.e., an intermediate value for shock absorber damping is chosen). In electronically controlled suspension systems, this damping can be varied depending on driving conditions and road roughness characteristics. That is, the suspension system adapts to inputs to maintain the best possible ride subject to handling constraints that are associated with safety. There are two major classes of electronic suspension control systems: active and semiactive. The semiactive suspension system is purely dissipative (i.e., power is absorbed by the shock absorber under control of a microcontroller). In this system, the shock absorber damping is regulated to absorb the power of the wheel motion in accordance with the driving conditions.

In an active suspension system, power is added to the suspension system via a hydraulic or pneumatic power source. At the time of the writing of this book, commercial suspension systems are primarily semiactive. The active suspension system is just beginning to appear in production vehicles. In this chapter, we explain the semiactive system first, then the active one. The primary purpose of the semiactive suspension system is to provide a good ride for as much of the time as possible without sacrificing handling. Good ride is achieved if the car's body is isolated as much as possible from the road. A semiactive suspension controls the shock absorber damping to achieve the best possible ride. In addition to providing isolation of the sprung mass (i.e., car body and contents), the suspension system has another major function. It must also dynamically maintain the tire normal force as the unsprung mass (wheel assembly) travels up and down due to road roughness. Recall from the discussion of antilock braking that cornering forces depend on normal tire force. Of course in the long-term time average, the normal forces will total the vehicle weight plus any inertial forces due to acceleration, deceleration, or cornering. However, as the car travels over the road, the unsprung mass moves up and down in response to road input. This motion causes a variation in normal force, with a corresponding variation in potential cornering or braking forces. For example, while driving on a rough curved road, there is a potential loss of steering or braking effectiveness if the suspension system doesn't have good damping characteristics. Figure illustrates typical tire normal force variation as a function of frequency of excitation for a fixed-amplitude, variable-frequency sinusoidal excitation. The solid curve is the response for a relatively low-damping-coefficient shock absorber and the dashed curve is the response for a relatively high damping coefficient. In Figure, the ordinate is the ratio of amplitude of force variation to the average normal load (i.e., due to weight). There are two relative peaks in this response. The lower peak is approximately 1 to 2 Hz and is generally associated with spring/sprung mass oscillation. The second peak, which is in the general region of 12 to 15 Hz, is resonance of the spring/unsprung mass combination. Generally speaking, for any given fixed suspension system, ride and handling cannot both be optimized simultaneously, as explained. A car with a good ride is one in which the sprung mass motion/acceleration due to rough road input is minimized. In particular, the sprung mass motion in the frequency region from about 2 to 8 Hz is most important for good subjective ride. Good ride is achieved for relatively low damping .



TIRE FORCE VARIATION

For low damping, the unsprung mass moves relatively freely due to road input while the sprung mass motion remains relatively low. Note from Figure that this low damping results in relatively high variation in normal force, particularly near the two peak frequencies. That is, low damping results in relatively poor handling characteristics. With respect to the four frequency regions of Figure , the following generally desired suspension damping characteristics can be identified.

Region	Frequency (Hz)	Damping
1: Sprung mass mode	1–2	High
2: Intermediate ride	2–8	Low
3: Unsprung mass resonance	8–20	High
4: Harshness	>20	Low

Another major input to the vehicle that affects handling is steering input that causes maneuvers parallel to the road surface (e.g., cornering). Whenever the car is executing such maneuvers, there is a lateral acceleration. This acceleration acting through the center of gravity causes the vehicle to roll in a direction opposite to the maneuver. Car handling generally improves if the amount of roll for any given maneuver is reduced. The rolling rate for a given car and maneuver is improved if spring rate and shock absorber damping are increased. Although the semiactive control system regulates only the damping, handling is improved by increasing this damping as lateral acceleration increases.

Lateral acceleration AL is proportional to vehicle speed and input steering angle:

$$A_L = kVq_s$$

where

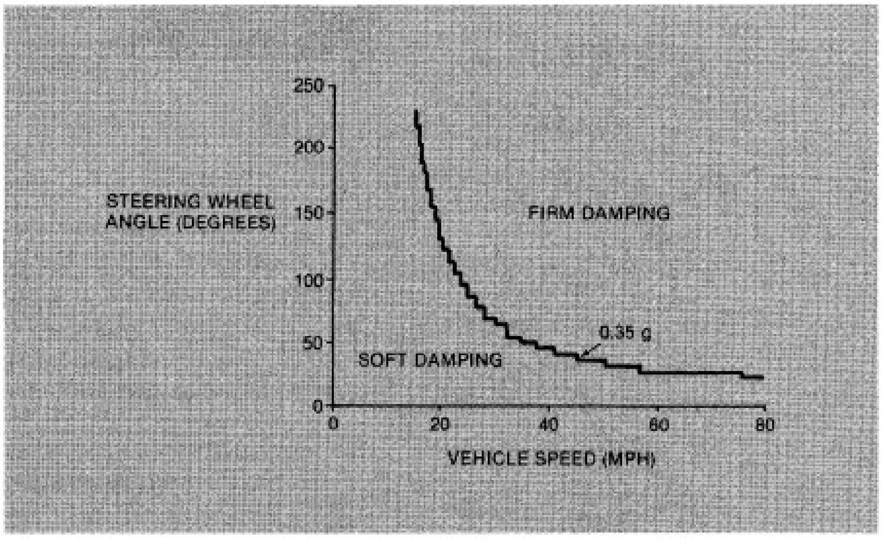
V is the speed of the car

qs is the steering angle

In Chapter 2, we discussed the dynamics of a spring/mass/damping system, identifying resonant frequency and critical damping Dc:

$$D_c = 2\sqrt{KM}$$

For good ride, the damping should be as low as possible. However, from practical design considerations, the minimum damping is generally in the region of $0.1 < D/Dc < 0.2$. For optimum handling, the damping is in the region of $0.6 < D/Dc < 0.8$. Technology has been developed permitting the damping characteristics of shock absorber/strut assembly to be varied electrically, which in turn permits the ride/handling characteristics to be varied while the car is in motion. Under normal steady-cruise conditions, damping is electrically set low, yielding a good ride. However, under dynamic maneuvering conditions (e.g., cornering), the damping is set high to yield good handling. Generally speaking, high damping reduces vehicle roll in response to cornering or turning maneuvers, and it tends to maintain tire force on the road for increased cornering forces. Variable damping suspension systems can improve safety, particularly for vehicles with a relatively high center of gravity (e.g., SUVs). The damping of a suspension system is determined by the viscosity of the fluid in the shock absorber/strut and by the size of the aperture through which the fluid flows as the wheel moves relative to the car body. The earliest active or semiactive suspension systems employed variable aperture. One scheme for achieving variable damping is to switch between two aperture sizes using a solenoid. Another scheme varies aperture size continuously with a motor-driven mechanism. Although there are many potential control strategies for regulating shock absorber damping, we consider first switched damping as in our example. In such a system, the shock absorber damping is switched to the higher value whenever lateral acceleration exceeds a predetermined threshold. Figure illustrates such a system in which the threshold for switching to firm damping (i.e., higher damping) is 0.35 g. The variation in shock absorber damping is achieved by varying the aperture in the oil passage through the piston. In practical semiactive suspension systems, there are two means used to vary this aperture size—a solenoid-operated bypass valve and a motor-driven variable-orifice valve. Figure is an illustration of the force/relative velocity characteristics of a shock absorber having a solenoid-switched aperture.



SWITCHING THRESHOLD VERSUS SPEED AND STEERING INPUTS

TRACTION CONTROL

It was explained that the transmission output shaft is coupled to the drive axles via the differential. The differential is a necessary component of the drivetrain because the left and right drive wheels turn at different speeds whenever the car moves along a curve (e.g., turning a corner). Unfortunately, wherever there is a large difference between the tire/road friction from left to right, the differential will tend to spin the low friction wheel. An extreme example of this occurs whenever one drive wheel is on ice and the other is on dry road. In this case, the tire on the ice side will spin and the wheel on the dry side will not. Typically, the vehicle will not move in such circumstances. Certain cars are equipped with so-called traction control devices that can overcome this disadvantage of the differential. Such cars have differentials that incorporate solenoid-activated clutches that can “lock” the differential, permitting power to be delivered to both drive wheels. It is only desirable to activate these clutches in certain conditions and to disable them during normal driving, permitting the differential to perform its intended task. A traction control system incorporates sensors for measuring wheel speed and a controller that determines the wheel slip condition based on these relative speeds. Wherever a wheel spin condition is detected, the controller sends electrical signals to the solenoids, thereby activating the clutches to eliminate the wheel slip.

UNIT-IV ACTIVE AND PASSIVE SAFETY SYSTEM

BODY ELECTRONICS INCLUDING LIGHTING CONTROL

Create body electronics and lighting systems that are more advanced, efficient and flexible. Our interactive system block diagrams guide you to a robust catalog of ICs, reference designs and supporting content that empowers you to design next-generation body electronics and lighting systems. Jump-start your designs now.

HEADLIGHT

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REMOTE KEYLESS ENTRY

A smart entry system is an electronic lock that controls access to a building or vehicle without using a traditional mechanical key. The term *keyless entry system* originally meant a lock controlled by a keypad located at or near the driver's door, which required entering a predetermined (or self-programmed) numeric code. Such systems now have a hidden touch-activated keypad and are still available on certain Ford and Lincoln models.

The term remote keyless system (RKS), also called keyless entry or remote central locking, refers to a lock that uses an electronic remote control as a key which is activated by a handheld device or automatically by proximity.

Widely used in automobiles, an RKS performs the functions of a standard car key without physical contact. When within a few yards of the car, pressing a button on the remote can lock or unlock the doors, and may perform other functions. A remote keyless system can include both a remote keyless entry system (RKE), which unlocks the doors, and a remote keyless ignition system (RKI), which starts the engine.

One of the first introductions was in 1980 on the Ford Thunderbird, Mercury Cougar, Lincoln Continental Mark VI, and Lincoln Town Car, which Ford called Keyless Entry System (later renamed SecuriCode). It was a keypad on the driver-side exterior door above the door handle. It consisted of a keypad with five buttons that when the code was entered, would unlock the driver's door, with subsequent code entries to unlock all doors, and the trunk. Nissan offered the same technology on the Nissan Maxima and Nissan Fairlady beginning in 1984, essentially using the same approach as Ford, with the addition of being able to roll the windows down and open the optional moonroof from outside the vehicle on the door handle installed keypad on both the driver's and front passengers door.

The remote keyless systems using a handheld transmitter first began appearing on the French made Renault Fuego in 1982, and as an option on several American Motors vehicles in 1983, including the Renault Alliance. The feature gained its first widespread availability in the U.S. on several General Motors vehicles in 1989.

Keyless remotes contain a short-range radio transmitter, and must be within a certain range, usually 5–20 meters, of the car to work. When a button is pushed, it sends a coded signal by radio waves to a receiver unit in the car, which locks or unlocks the door. Most RKEs operate at a frequency of 315 MHz for North America-made cars and at 433.92 MHz for European, Japanese and Asian cars. Modern systems since the mid-1990s implement encryption as well as rotating entry codes to prevent car thieves from intercepting and spoofing the signal. Earlier systems used infrared instead of radio signals to unlock the vehicle, such as systems found on Mercedes-Benz, BMW and other manufacturers.

The system signals that it has either locked or unlocked the car usually through some fairly discreet combination of flashing vehicle lamps, a distinctive sound other than the horn, or some usage of the horn itself. A typical setup on cars is to have the horn or other sound chirp twice to signify that the car has been unlocked, and chirp once to indicate the car has been locked. For example, Toyota, Scion, and Lexus use a chirp system to signify the car being locked/unlocked. While two beeps means that driver's door is unlocked, four beeps means all doors are unlocked. One long beep is for the trunk or power tailgate. One short beep signifies that the car is locked and alarm is set.

The functions of a remote keyless entry system are contained on a key fob or built into the ignition key handle itself. Buttons are dedicated to locking or unlocking the doors and opening the trunk or tailgate. On some minivans, the power sliding doors can be opened/closed remotely. Some cars will also close any open windows and roof when remotely locking the car. Some remote keyless fobs also feature a red panic button which activates the car alarm as a standard feature. Further adding to the convenience, some cars' engines with remote keyless ignition systems can be started by the push of a button on the key fob (useful in cold weather), and convertible tops can be raised and lowered from outside the vehicle while it's parked.

On cars where the trunk release is electronically operated, it can be triggered to open by a button on the remote. Conventionally, the trunk springs open with the help of hydraulic struts or torsion springs, and thereafter must be lowered manually. Premium models, such as SUVs and estates with tailgates, may have a motorized assist that can both open and close the tailgate for easy access and remote operation.

For offices, or residences, the system can also be coupled with the security system, garage door opener or remotely activated lighting devices.

ROLLING CODE

Most keyless systems use a technique called rolling code to avoid replay attacks, in which the open command is intercepted to be used by a thief at a later time. In the rolling code, a pseudorandom number generator is used to generate a different unlock sequence to be sent each time the car is unlocked.

IMMOBILIZERS

An immobiliser or immobilizer is an electronic security device fitted to a motor vehicle that prevents the engine from running unless the correct key (*transponder* or *smart key*) is present. This prevents the vehicle from being hotwired after entry has been achieved and thus reduces motor vehicle theft. Research shows that the uniform application of immobilisers reduced the rate of car theft by 40%.

The electric immobiliser/alarm system was invented by St. George Evans and Edward Birkenbuel and patented in 1919. They developed a 3x3 grid of double-contact switches on a panel mounted inside the car so when the ignition switch was activated, current from the battery (or magneto) went to the spark plugs allowing the engine to start, or immobilizing the vehicle and sounding its horn. The system settings could be changed each time the car was driven. Modern immobiliser systems are automatic, meaning the owner does not have to remember to activate it.

Immobilisers have been mandatory in all new cars sold in Germany since 1 January 1998, in the United Kingdom since 1 October 1998, in Finland since 1998, in Australia since 2001 and in Canada since 2007. Early models used a static code in the ignition key (or key fob) which was recognised by an RFID loop around the lock barrel and checked against the vehicle's engine control unit (ECU) for a match. If the code is unrecognised, the ECU will not allow fuel to flow and ignition to take place. Later models use rolling codes or advanced cryptography to defeat copying of the code from the key or ECU.

The microcircuit inside the key is activated by a small electromagnetic field which induces current to flow inside the key body, which in turn broadcasts a unique binary code which is read by the automobile's ECU. When the ECU determines that the coded key is both current and valid, the ECU activates the fuel-injection sequence.

In some vehicles, attempts to use an unauthorised or "non-sequenced" key cause the vehicle to activate a timed no-start condition and in some highly advanced systems, even use satellite or mobile phone communication to alert a security firm that an unauthorised attempt was made to code a key.

Coincidentally, this information is often recorded in modern automobile ECUs, which may record many other variables including speed, temperature, driver weight, geographic location, throttle position and yaw angle. This information can be used during insurance investigations, warranty claims or technical troubleshooting.

ELECTRONIC INSTRUMENT CLUSTERS

In an automobile, an electronic instrument cluster, digital instrument panel or *digital dash* for short, is a set of instrumentation, including the speedometer, that is displayed with a digital readout rather than with the traditional analog gauges. Many refer to it simply as a *digital speedometer.*

The first application of an electronic instrument cluster, in a production automobile, was in the 1976 Aston Martin Lagonda. The first American manufacturer application was the 1978 Cadillac Seville with available Cadillac Trip Computer. In the United States they were an option in many motor vehicles manufactured in the 1980s and 1990s, and were standard on some luxury vehicles at times, including some models made by Cadillac, Chrysler and Lincoln. They included not only a speedometer with a digital readout, but also a trip computer that displayed factors like the outdoor temperature, travel direction, fuel economy and distance to empty (DTE). In 1983, the Renault 11 Electronic was the first European hatchback to have a digital dashboard. Many vehicles made today have an analog speedometer paired with the latter in digital form. In the late 1980s into the early 1990s, General Motors had touch-screen CRTs with features such as date books and hands-free cell phone integration built into cars such as the Oldsmobile Toronado, Buick Riviera and Buick Reatta.

DASHBOARD ELECTRONICS

A dashboard (also called dash, instrument panel (IP), or fascia) is a control panel usually located directly ahead of a vehicle's driver, displaying instrumentation and controls for the vehicle's operation.

Originally, the word *dashboard* applied to a barrier of wood or leather fixed at the front of a horse-drawn carriage or sleigh to protect the driver from mud or other debris "dashed up" (thrown up) by the horses' hooves. Commonly these boards did not perform any additional function other than providing a convenient handhold for ascending into the driver's seat, or a small clip with which to secure the reins when not in use.

When the first "horseless carriages" were constructed in the late 19th century, with engines mounted beneath the driver such as the Daimler Stahlradwagen, the simple dashboard was retained to protect occupants from debris thrown up by the cars' front wheels. However, as car design evolved to position the motor in front of the driver, the dashboard became a panel that protected vehicle occupants from the heat and oil of the engine. With gradually increasing mechanical complexity, this panel formed a convenient location for the placement of gauges and minor controls, and from this evolved the modern instrument panel, although retaining its archaic common name.

The first mass-produced automobile, the Oldsmobile Curved Dash, got its name from its dashboard, which was curved like that of a sleigh.

DASHBOARD INSTRUMENTS DISPLAYING VARIOUS CAR AND ENGINE CONDITIONS

ELECTRO-MAGNETIC INTERFERENCE SUPPRESSION

Electromagnetic interference (**EMI**), also called **radio-frequency interference** (**RFI**) when in the radio frequency spectrum, is a disturbance generated by an external source that affects an electrical circuit by electromagnetic induction, electrostatic coupling, or conduction. The disturbance may degrade the performance of the circuit or even stop it from functioning. In the case of a data path, these effects can range from an increase in error rate to a total loss of the data.[2] Both man-made and natural sources generate changing electrical currents and voltages that can cause EMI: ignition systems, cellular network of mobile phones, lightning, solar flares, and auroras (northern/southern lights). EMI frequently affects AM radios. It can also affect mobile phones, FM radios, and televisions, as well as observations for radio astronomy and atmospheric science.

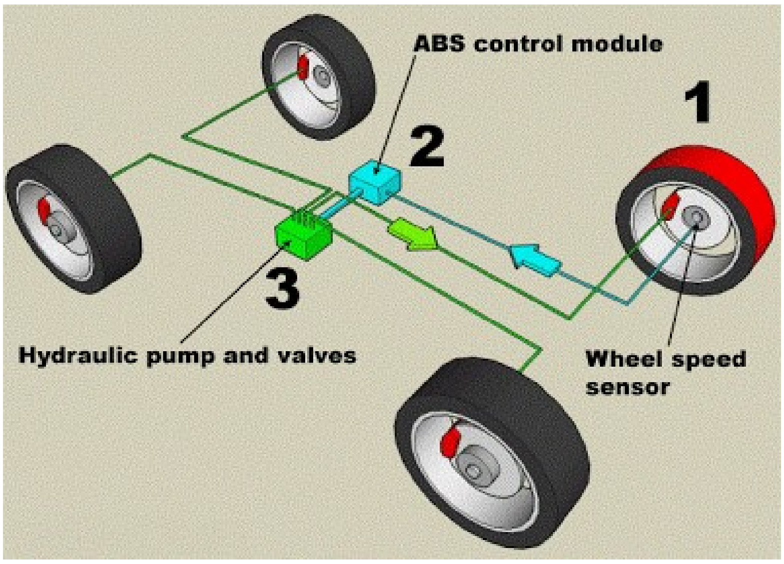
ANTILOCK BRAKING SYSTEM

An **anti-lock braking system** (**ABS**) is a safety anti-skid braking system used on aircraft and on land vehicles, such as cars, motorcycles, trucks, and buses. ABS operates by preventing the wheels from locking up during braking, thereby maintaining tractive contact with the road surface and allowing the driver to maintain more control over the vehicle.

ABS is an automated system that uses the principles of threshold braking and cadence braking, techniques which were once practiced by skillful drivers before ABS was widespread. ABS operates at a much faster rate and more effectively than most drivers could manage. Although ABS generally offers improved vehicle control and decreases stopping distances on dry and some slippery surfaces, on loose gravel or snow-covered surfaces ABS may significantly increase braking distance, while still improving steering control. Since ABS was introduced in production vehicles, such systems have become increasingly sophisticated and effective. Modern versions may not only prevent wheel lock under braking, but may also alter the front-to-rear brake bias. This latter function, depending on its specific capabilities and implementation, is known variously as electronic brakeforce distribution, traction control system, emergency brake assist, or electronic stability control (ESC).

Piston Systems: The pressure release in this system is realized through the movement of a spring-tensioned piston. When pressure should be released, a linear motor pulls back the plunger piston and opens up more space for the fluid. The system was used for example in the ABS I (1988) and ABS II (1993) of BMW. The ABS II differed in size and an electronically controlled friction clutch was mounted on the shaft instead of a plunger. Further displacement sensors record the travel distance of the piston to allow the control unit a more precise regulation. Honda also uses this system of pressure modulation for big sports and touring bikes.

Valve and Pump Systems**:** The main parts which are part of the pressure modulation system are solenoid inlet and outlet valves, a pump, motor, and accumulators/reservoirs. The number of the valves differs from model to model due to additional functionalities and the number of brake channels. Based on the input of the ECU, coils operate the inlet and outlet valves. During pressure release, the brake fluid is stored in accumulators. In this open system approach, the fluid is then brought back in the brake circuit via a pump operated by a motor that is felt through pulsation on the brake lever.



ANTILOCK BRAKING SYSTEM

TYPES

Anti-lock braking systems use different schemes depending on the type of brakes in use. They can be differentiated by the number of channels: that is, how many valves that are individually controlled—and the number of speed sensors.

1) Four-channel, four-sensor ABS

There is a speed sensor on all four wheels and a separate valve for all four wheels. With this setup, the controller monitors each wheel individually to make sure it is achieving maximum braking force.

2) Three-channel, four-sensor ABS

There is a speed sensor on all four wheels and a separate valve for each of the front wheels, but only one valve for both of the rear wheels. Older vehicles with four-wheel ABS usually use this type.

3) Three-channel, three-sensor ABS

This scheme, commonly found on pickup trucks with four-wheel ABS, has a speed sensor and a valve for each of the front wheels, with one valve and one sensor for both rear wheels. The speed sensor for the rear wheels is located in the rear axle. This system provides individual control of the front wheels, so they can both achieve maximum braking force. The rear wheels, however, are monitored together; they both have to start to lock up before the ABS will activate on the rear. With this system, it is possible that one of the rear wheels will lock during a stop, reducing brake effectiveness. This system is easy to identify, as there are no individual speed sensors for the rear wheels.

4) Two-channel, four-sensor ABS

This system, commonly found on passenger cars from the late '80s through the mid-1990s, uses a speed sensor at each wheel, with one control valve each for the front and rear wheels as a pair. If the speed sensor detects lock up at any individual wheel, the control module pulses the valve for both wheels on that end of the car.

5) One-channel, one-sensor ABS

This system is commonly found on pickup trucks, SUVs, and vans with rear-wheel ABS. It has one valve, which controls both rear wheels, and a one-speed sensor, located in the rear axle. This system operates the same as the rear end of a three-channel system. The rear wheels are monitored together and they both have to start to lock up before the ABS kicks in. In this system it is also possible that one of the rear wheels will lock, reducing brake effectiveness. This system is also easy to identify, as there are no individual speed sensors for any of the wheels.

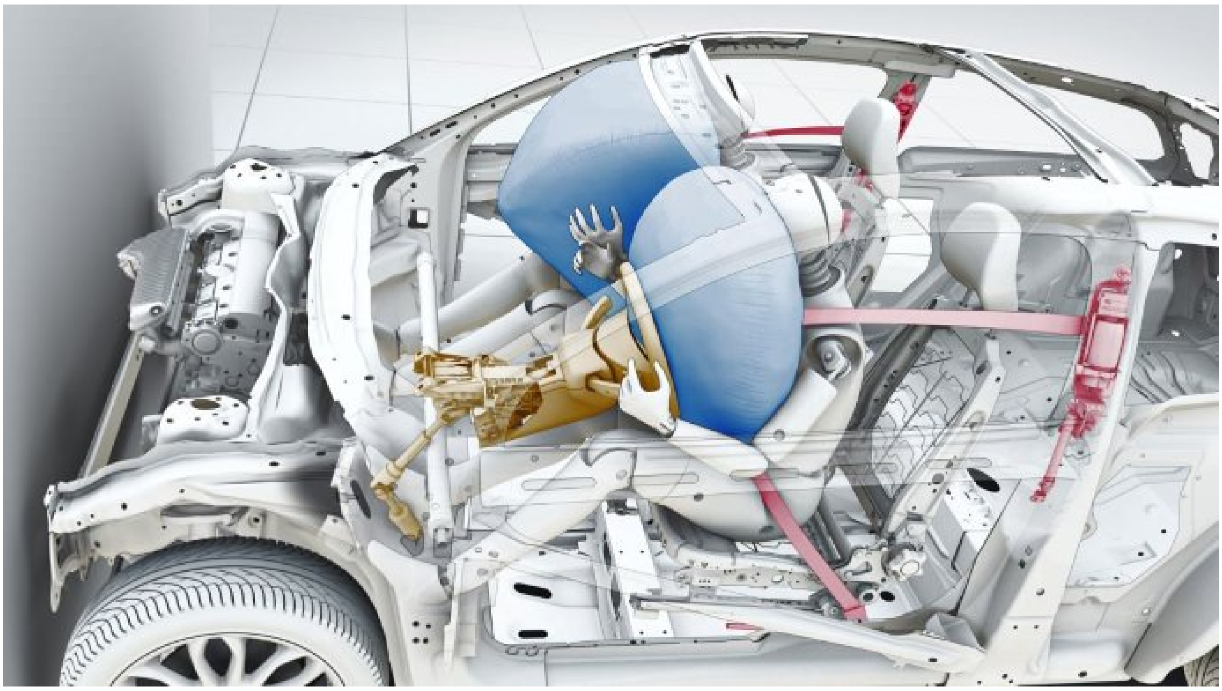
AIRBAGS

An airbag is a vehicle occupant-restraint system using a bag designed to inflate extremely quickly, then quickly deflate during a collision. It consists of the airbag cushion, a flexible fabric bag, an inflation module, and an impact sensor. The purpose of the airbag is to provide a vehicle occupant with a soft cushioning and restraint during a crash event. It can reduce injuries between the flailing occupant and the interior of the vehicle.

The airbag provides an energy-absorbing surface between the vehicle's occupants and a steering wheel, instrument panel, body pillar, headliner, and windshield. Modern vehicles may contain up to 10 airbag modules in various configurations, including: driver, passenger, side-curtain, seat-mounted, door-mounted, B and C-pillar mounted side-impact, knee bolster, inflatable seat belt, and pedestrian airbag modules.

During a crash, the vehicle's crash sensors provide crucial information to the airbag electronic controller unit (ECU), including collision type, angle, and severity of impact. Using this information, the airbag ECU's crash algorithm determines if the crash event meets the criteria for deployment and triggers various firing circuits to deploy one or more airbag modules within the vehicle. Working as a supplemental restraint system to the vehicle's seat-belt systems, airbag module deployments are triggered through a pyrotechnic process that is designed to be used once. Newer side-impact airbag modules consist of compressed-air cylinders that are triggered in the event of a side-on vehicle impact.

The first commercial designs were introduced in passenger automobiles during the 1970s, with limited success, and actually caused some fatalities. Broad commercial adoption of airbags occurred in many markets during the late 1980s and early 1990s with a driver airbag, and a front-passenger airbag, as well, on some cars, and many modern vehicles now include six or more units.



AIRBAGS

UNIT- V AUTOMOTIVE STANDARDS AND PROTOCOLS

AUTOMOTIVE STANDARDS LIKE CAN PROTOCOL

Automotive electronic subsystems have become numerous and interdependent, requiring subsystem intercommunication. This need for digital communication between all on-board digital systems has led to the creation of a standard automotive communication network known as Control Area Network (CAN). Originally developed for passenger car applications, CAN is a form of local area network that permits data to be shared. In the CAN concept, each electronic subsystem incorporates communication hardware and software, permitting it to function as a communication module referred to as a gateway. CAN is based on the so-called broadcast communication mechanism in which communication is achieved by the sending gateway (i.e., subsystem) transmitting messages over the network (e.g., wire interconnect). Each message has a specific format (protocol) that includes a message identifier. The identifier defines the content of the message, its priority, and is unique within the network. In addition to the data and identifier, each message includes error-checking bits as well as beginning and end of file. The CAN communication system has great flexibility, permitting new subsystems to be added to an existing system without modification, provided the new additions are all receivers. Each gateway (subsystem) can be upgraded with new hardware and software at any time with equipment that was not available at the time the car left the manufacturing plant or even when it left the dealer. Essentially, the CAN concept with its open standards frees the development of new telematics applications from the somewhat lengthy development cycle of a typical automobile model. Furthermore, it offers the potential for the aftermarket addition of new subsystems.

LIN PROTOCOL

LIN (**Local Interconnect Network**) is a serial network protocol used for communication between components in vehicles. The need for a cheap serial network arose as the technologies and the facilities implemented in the car grew, while the CAN bus was too expensive to implement for every component in the car. European car manufacturers started using different serial communication technologies, which led to compatibility problems.

In the late 1990s, the LIN Consortium was founded by five automakers (BMW, Volkswagen Group, Audi, Volvo Cars, Mercedes-Benz), with the technologies supplied (networking and hardware expertise) from Volcano Automotive Group and Motorola. The first fully implemented version of the new LIN specification (LIN version 1.3) was published in November 2002. In September 2003, version 2.0 was introduced to expand capabilities and make provisions for additional diagnostics features. LIN may be used also over the vehicle's battery power-line with a special LIN over DC power line (DC-LIN) transceiver.

LIN over DC power line (DC-LIN) was standardized as ISO/AWI 17987-8.

CAN in Automation has been appointed by the ISO Technical Management Board (TMB) as the Registration Authority for the LIN Supplier ID standardized in the ISO 17987 series.

NETWORK TOPOLOGY

LIN is a broadcast serial network comprising 16 nodes (one master and typically up to 15 slaves).

All messages are initiated by the master with at most one slave replying to a given message identifier. The master node can also act as a slave by replying to its own messages. Because all communications are initiated by the master it is not necessary to implement a collision detection.

The master and slaves are typically microcontrollers, but may be implemented in specialized hardware or ASICs in order to save cost, space, or power.

Current uses combine the low-cost efficiency of LIN and simple sensors to create small networks. These sub-systems can be connected by back-bone-network (i.e. CAN in cars).

The LIN-Master uses one or more predefined scheduling tables to start the sending and receiving to the LIN bus. These scheduling tables contain at least the relative timing, where the message sending is initiated. One LIN Frame consists of the two parts header and response. The header is always sent by the LIN Master, while the response is sent by either one dedicated LIN-Slave or the LIN master itself.

Transmitted data within the LIN is transmitted serially as eight bit data bytes with one start bit, one stop-bit, and no parity (break field does not have a start bit and stop bit). Bit rates vary within the range of 1 kbit/s to 20 kbit/s. Data on the bus is divided into recessive (logical HIGH) and dominant (logical LOW). The time normal is considered by the LIN Masters stable clock source, the smallest entity is one bit time (52 µs @ 19.2 kbit/s).

Two bus states — Sleep-mode and active — are used within the LIN protocol. While data is on the bus, all LIN-nodes are requested to be in active state. After a specified timeout, the nodes enter Sleep mode and will be released back to active state by a WAKEUP frame. This frame may be sent by any node requesting activity on the bus, either the LIN Master following its internal schedule, or one of the attached LIN Slaves being activated by its internal software application. After all nodes are awakened, the Master continues to schedule the next Identifier.

The LIN bus is an inexpensive serial communications protocol, which effectively supports remote application within a car's network. It is particularly intended for mechatronic nodes in distributed automotive applications, but is equally suited to industrial applications. It is intended to complement the existing CAN network leading to hierarchical networks within cars.

In the late 1990s the Local Interconnect Network (LIN) Consortium was founded by five European automakers, Mentor Graphics (Formerly Volcano Automotive Group) and Freescale (Formerly Motorola, now NXP). The first fully implemented version of the new LIN specification was published in November 2002 as LIN version 1.3. In September 2003 version 2.0 was introduced to expand configuration capabilities and make provisions for significant additional diagnostics features and tool interfaces.

The protocol’s main features are listed below:

- Single master, up to 16 slaves (i.e. no bus arbitration). This is the value recommended by the LIN Consortium to achieve deterministic time response. Slave Node Position Detection (SNPD) allows node address assignment after power-up
- Single wire communications up to 19.2 kbit/s @ 40 meter bus length. In the LIN specification 2.2, the speed up to 20 kbit/s.
- Guaranteed latency times.
- Variable length of data frame (2, 4 and 8 byte).
- Configuration flexibility.
- Multi-cast reception with time synchronization, without crystals or ceramic resonators.
- Data checksum and error detection.
- Detection of defective nodes.
- Low cost silicon implementation based on standard UART/SCI hardware.
- Enabler for hierarchical networks.
- Operating voltage of 12 V.

Data is transferred across the bus in fixed form messages of selectable lengths. The master task transmits a header that consists of a break signal followed by synchronization and identifier fields. The slaves respond with a data frame that consists of between 2, 4 and 8 data bytes plus 3 bytes of control information.

LIN MESSAGE FRAME

A message contains the following fields:

- Synchronization break
- Synchronization byte
- Identifier byte
- Data bytes
- Checksum byte

FRAME TYPES

1. UNCONDITIONAL FRAME

These always carry signals and their identifiers are in the range 0 to 59 (0x00 to 0x3b). All subscribers of the unconditional frame shall receive the frame and make it available to the application (assuming no errors were detected).

2. EVENT-TRIGGERED FRAME.

The purpose of this is to increase the responsiveness of the LIN cluster without assigning too much of the bus bandwidth to the polling of multiple slave nodes with seldom occurring events. The first data byte of the carried unconditional frame shall be equal to a protected identifier assigned to an event-triggered frame. A slave shall reply with an associated unconditional frame only if its data value has changed. If none of the slave tasks responds to the header the rest of the frame slot is silent and the header is ignored. If more than one slave task responds to the header in the same frame slot a collision will occur, and the master has to resolve the collision by requesting all associated unconditional frames before requesting the event-triggered frame again.

3. **SPORADIC FRAME**

   This frame is transmitted by the master as required, so a collision cannot occur. The header of a sporadic frame shall only be sent in its associated frame slot when the master task knows that a signal carried in the frame has been updated. The publisher of the sporadic frame shall always provide the response to the header.

4. **DIAGNOSTIC FRAME**

   These always carry diagnostic or configuration data and they always contain eight data bytes. The identifier is either 60 (0x3C), called master request frame, or 61(0x3D), called slave response frame. Before generating the header of a diagnostic frame, the master task asks its diagnostic module if it shall be sent or if the bus shall be silent. The slave tasks publish and subscribe to the response according to their diagnostic module.

5. **USER-DEFINED FRAME**

   These can carry any kind of information. Their identifier is 62 (0x3E). The header of a user-defined frame is always transmitted when a frame slot allocated to the frame is processed

6. **RESERVED FRAME**

   These shall not be used in a LIN 2.0 cluster. Their identifier is 63 (0x3F).

FLEXRAY

FlexRay is an automotive network communications protocol developed by the FlexRay Consortium to govern on-board automotive computing. It is designed to be faster and more reliable than CAN and TTP, but it is also more expensive. The FlexRay consortium disbanded in 2009, but the FlexRay standard is now a set of ISO standards, ISO 17458-1 to 17458-5.

FlexRay is a communication bus designed to ensure high data rates, fault tolerance, operating on a time cycle, split into static and dynamic segments for event-triggered and time-triggered communications.

FEATURES

FlexRay supports data rates up to 10 Mbit/s, explicitly supports both star and "party line" bus topologies, and can have two independent data channels for fault-tolerance (communication can continue with reduced bandwidth if one channel is inoperative). The bus operates on a time cycle, divided into two parts: the static segment and the dynamic segment. The static segment is preallocated into slices for individual communication types, providing stronger determinism than its predecessor CAN. The dynamic segment operates more like CAN, with nodes taking control of the bus as available, allowing event-triggered behavior.

DETAILS

CLOCK

The FlexRay system consists of a bus and ECUs (Electronic control unit). Each ECU has an independent clock. The clock drift must be not more than 0.15% from the reference clock, so the difference between the slowest and the fastest clock in the system is no greater than 0.3%.

This means that, if ECU-s is a sender and ECU-r is a receiver, then for every 300 cycles of the sender there will be between 299 and 301 cycles of the receiver. The clocks are resynchronized frequently enough to assure that this causes no problems. The clock is sent in the static segment.

BITS ON THE BUS

<table>
<tr><td>000000|11111111|0000
00000000|11111111|00
Correct averaging in case of no errors. The signal is merely delayed by 2 cycles.</td></tr>
<tr><td>000000|11110111|0000
00000000|11111111|00
Errors near the middle of 8-cycle region are canceled.</td></tr>
<tr><td>00010|11111111|0000
0000001|11111111|00
Errors near the boundary of 8-cycle region may affect the boundary bit.</td></tr>
</table>

At each time, only one ECU writes to the bus. Each bit to be sent is held on the bus for 8 sample clock cycles. The receiver keeps a buffer of the last 5 samples, and uses the majority of the last 5 samples as the input signal.

Single-cycle transmission errors may affect results near the boundary of the bits, but will not affect cycles in the middle of the 8-cycle region.

SAMPLED BITS

The value of the bit is sampled in the middle of the 8-bit region. The errors are moved to the extreme cycles, and the clock is synchronized frequently enough for the drift to be small. (Drift is smaller than 1 cycle per 300 cycles, and during transmission the clock is synchronized more than once every 300 cycles).

FRAME

All the communication is sent in the form of frames. The message consists of bytes , packed in the following way:

- Transmission Start Signal (TSS) – bit 0
- Frame Start Signal (FSS) – bit 1
- *m* times:
  - Byte Start Signal 0 (BSS0) – bit 1
  - Byte Start Signal 1 (BSS1) – bit 0
  - 0th bit of *i*-th byte
  - 1st bit of *i*-th byte
  - 2nd bit of *i*-th byte
  - ...
  - 7th bit of *i*-th byte
- Frame End Signal (FES) – bit 0
- Transmission End Signal (TES) – bit 1

If nothing is being communicated, the bus is held in state 1 (high voltage), so every receiver knows that the communication started when the voltage drops to 0.

The receiver knows when the message is complete by checking whether BSS0 (1) or FES (0) was received.

Note that 8-cycle per bit has nothing to do with bytes. Each byte takes 80 cycles to transfer. 16 for BSS0 and BSS1 and 64 for its bits. Also note that BSS0 has value 1, and BSS1 has value 0.

CLOCK SYNCHRONIZATION

Clocks are resynchronized when they voted signal changes from 1 to 0, if the receiver was in either idle state or expecting BSS1.

As synchronization is done on the voted signal, small transmission errors during synchronization that affect the boundary bits may skew the synchronization no more than 1 cycle. As there are at most 88 cycles between synchronization (BSS1, 8 bits of the last byte, FES and TES - 11 bits of 8 cycles each), and the clock drift is no larger than 1 per 300 cycles, the drift may skew the clock no more than 1 cycle. Small transmission errors during the receiving may affect only the boundary bits. So in the worst case the two middle bits are correct, and thus the sampled value is correct.

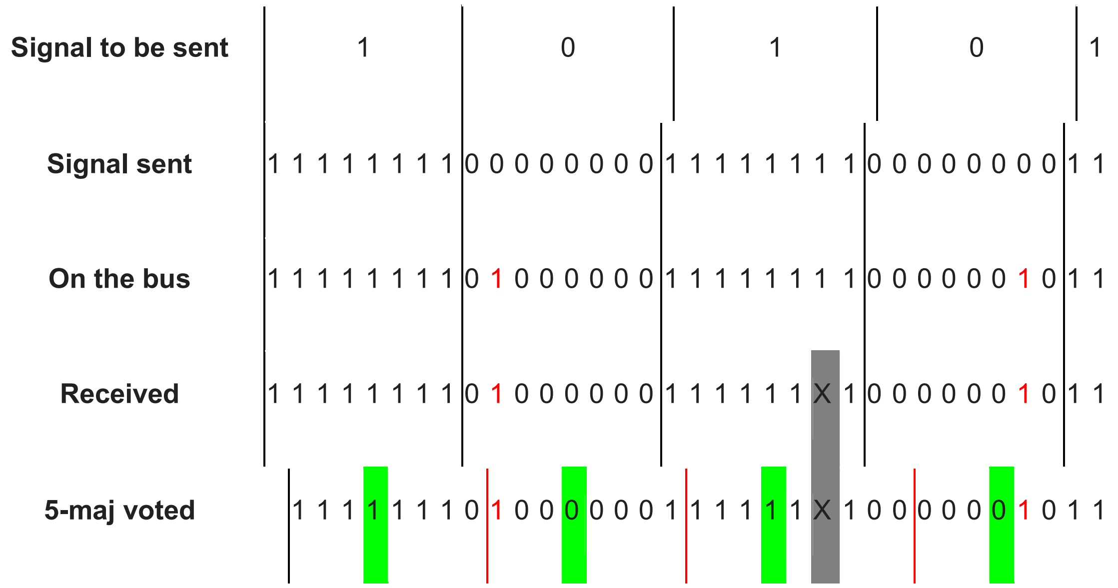
Here's an example of a particularly bad case - error during synchronization, a lost cycle due to clock drift and error in transmission.

Errors that happened in the example:

- Because of a single-bit error during synchronization, the synchronization was delayed by 1 cycle
- Receiver clock was slower than sender clock, so receiver missed one cycle (marked X). This will not happen again before the next synchronization due to limits on maximum allowable clock drift.
- Because of a single-bit error during transmission, a bit was voted wrongly near the result.

Despite so many errors, the communication was received correctly.

The green cells are sampling points. All except the first are synchronized by the 1->0 edge in the transmission fragment shown.



Signal to be sent | 1 | 0 | 1 | 0 | 1

Signal sent | 1 1 1 1 1 1 1 1 | 0 0 0 0 0 0 0 0 | 1 1 1 1 1 1 1 1 | 0 0 0 0 0 0 0 0 | 1 1

On the bus | 1 1 1 1 1 1 1 1 | 0 1 0 0 0 0 0 0 | 1 1 1 1 1 1 1 1 | 0 0 0 0 0 0 1 0 | 1 1

Received | 1 1 1 1 1 1 1 1 | 0 1 0 0 0 0 0 0 | 1 1 1 1 1 1 X 1 | 0 0 0 0 0 0 1 0 | 1 1

5-maj voted | 1 1 1 1 1 1 1 0 | 1 0 0 0 0 0 0 1 | 1 1 1 1 1 X 1 0 0 | 0 0 0 0 1 0 1 1

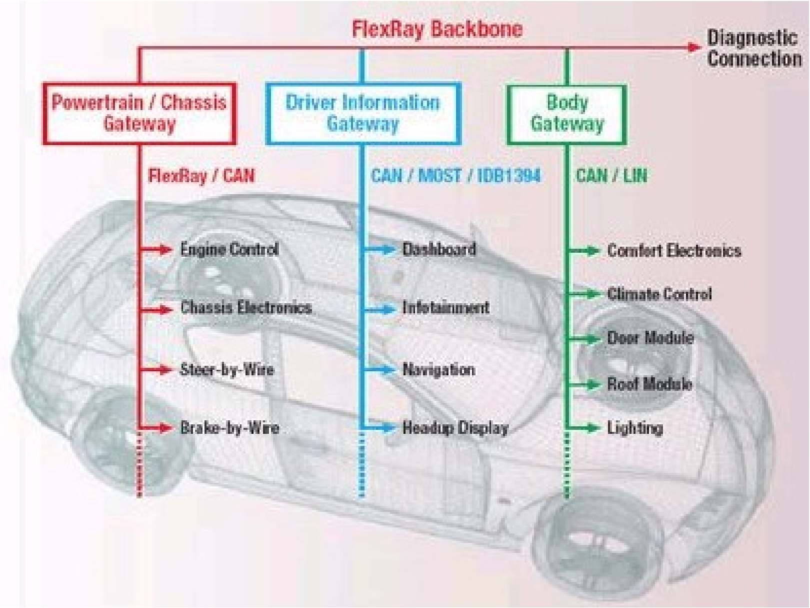
DEVELOPMENT TOOLS

When developing and/or troubleshooting the FlexRay bus, examination of hardware signals can be very important. Logic analyzers and bus analyzers are tools which collect, analyze, decode, store signals so people can view the high-speed waveforms at their leisure.

THE FUTURE OF FLEXRAY

The bus has certain disadvantages like lower operating voltage levels and asymmetry of the edges, which leads to problems in extending the network length.

Ethernet may replace FlexRay for bandwidth intensive, non-safety critical applications.



FLEXRAY

HEAD UP DIAPLAY

A head-up display or heads-up display, also known as a HUD (/hʌd/), is any transparent display that presents data without requiring users to look away from their usual viewpoints. The origin of the name stems from a pilot being able to view information with the head positioned "up" and looking forward, instead of angled down looking at lower instruments. A HUD also has the advantage that the pilot's eyes do not need to refocus to view the outside after looking at the optically nearer instruments.

Although they were initially developed for military aviation, HUDs are now used in commercial aircraft, automobiles, and other (mostly professional) applications.

A typical HUD contains three primary components: a *projector unit*, a *combiner*, and a *video generation computer*.

The projection unit in a typical HUD is an optical collimator setup: a convex lens or concave mirror with a cathode ray tube, light emitting diode display, or liquid crystal display at its focus. This setup (a design that has been around since the invention of the reflector sight in 1900) produces an image where the light is collimated, i.e. the focal point is perceived to be at infinity.

The combiner is typically an angled flat piece of glass (a beam splitter) located directly in front of the viewer, that redirects the projected image from projector in such a way as to see the field of view and the projected infinity image at the same time. Combiners may have special coatings that reflect the monochromatic light projected onto it from the projector unit while allowing all other wavelengths of light to pass through. In some optical layouts combiners may also have a curved surface to refocus the image from the projector.

The computer provides the interface between the HUD (i.e. the projection unit) and the systems/data to be displayed and generates the imagery and symbology to be displayed by the projection unit.

TYPES

Other than fixed mounted HUD, there are also head-mounted displays (HMDs). Including helmet-mounted displays (both abbreviated HMD), forms of HUD that features a display element that moves with the orientation of the user's head.

Many modern fighters (such as the F/A-18, F-16, and Eurofighter) use both a HUD and HMD concurrently. The F-35 Lightning II was designed without a HUD, relying solely on the HMD, making it the first modern military fighter not to have a fixed HUD.

GENERATIONS

HUDs are split into four generations reflecting the technology used to generate the images.

- First Generation—Use a CRT to generate an image on a phosphor screen, having the disadvantage of the phosphor screen coating degrading over time. The majority of HUDs in operation today are of this type.
- Second Generation—Use a solid state light source, for example LED, which is modulated by an LCD screen to display an image. These systems do not fade or require the high voltages of first generation systems. These systems are on commercial aircraft.
- Third Generation—Use optical waveguides to produce images directly in the combiner rather than use a projection system.
- Fourth Generation—Use a scanning laser to display images and even video imagery on a clear transparent medium.

Newer micro-display imaging technologies are being introduced, including liquid crystal display (LCD), liquid crystal on silicon (LCoS), digital micro-mirrors (DMD), and organic light-emitting diode (OLED).

DEVELOPMENT AND EXPERIMENTAL USES

HUDs have been proposed or are being experimentally developed for a number of other applications. In the military, a HUD can be used to overlay tactical information such as the output of a laser rangefinder or squadmate locations to infantrymen. A prototype HUD has also been developed that displays information on the inside of a swimmer's goggles or of a scuba diver's mask. HUD systems that project information directly onto the wearer's retina with a low-powered laser (virtual retinal display) are also in experimentation.

ON-BOARD DIAGNOSTICS (OBD)

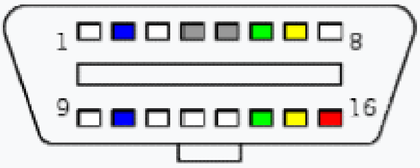
On-board diagnostics (OBD) is an automotive term referring to a vehicle's self-diagnostic and reporting capability. OBD systems give the vehicle owner or repair technician access to the status of the various vehicle sub-systems. The amount of diagnostic information available via OBD has varied widely since its introduction in the early 1980s versions of on-board vehicle computers. Early versions of OBD would simply illuminate a malfunction indicator light or "idiot light" if a problem was detected but would not provide any information as to the nature of the problem. Modern OBD implementations use a standardized digital communications port to provide real-time data in addition to a standardized series of diagnostic trouble codes, or DTCs, which allow a person to rapidly identify and remedy malfunctions within the vehicle.

OBD-II

OBD-II is an improvement over OBD-I in both capability and standardization. The OBD-II standard specifies the type of diagnostic connector and its pinout, the electrical signalling protocols available, and the messaging format. It also provides a candidate list of vehicle parameters to monitor along with how to encode the data for each. There is a pin in the connector that provides power for the scan tool from the vehicle battery, which eliminates the need to connect a scan tool to a power source separately. However, some technicians might still connect the scan tool to an auxiliary power source to protect data in the unusual event that a vehicle experiences a loss of electrical power due to a malfunction. Finally, the OBD-II standard provides an extensible list of DTCs. As a result of this standardization, a single device can query the on-board computer(s) in any vehicle. This OBD-II came in two models OBD-IIA and OBD-IIB. OBD-II standardization was prompted by emissions requirements, and though only emission-related codes and data are required to be transmitted through it, most manufacturers have made the OBD-II Data Link Connector the only one in the vehicle through which all systems are diagnosed and programmed. OBD-II Diagnostic Trouble Codes are 4-digit, preceded by a letter: P for engine and transmission (powertrain), B for body, C for chassis, and U for network.

OBD-II DIAGNOSTIC CONNECTOR

Female OBD-II connector on a car



Female OBD-II connector pinout - front view

The OBD-II specification provides for a standardized hardware interface—the female 16-pin (2x8) J1962 connector. Unlike the OBD-I connector, which was sometimes found under the hood of the vehicle, the OBD-II connector is required to be within 2 feet (0.61 m) of the steering wheel (unless an exemption is applied for by the manufacturer, in which case it is still somewhere within reach of the driver).

SAE J1962 defines the pinout of the connector as:

1	Manufacturer discretion. GM: J2411 GMLAN/SWC/Single-Wire CAN. VW/Audi: Switched +12 to tell a scan tool whether the ignition is on.	**9**	Manufacturer discretion. GM: 8192 baud ALDL where fitted. BMW: RPM signal.
2	Bus positive Line of SAE J1850 PWM and VPW	**10**	Bus negative Line of SAE J1850 PWM only (not SAE 1850 VPW)

3	Manufacturer discretion. Ford DCL(+) Argentina, Brazil (pre OBD-II) 1997–2000, USA, Europe, etc. Chrysler CCD Bus(+) Ethernet TX+ (Diagnostics over IP)	**11**	Manufacturer discretion. Ford DCL(-) Argentina, Brazil (pre OBD-II) 1997–2000, USA, Europe, etc. Chrysler CCD Bus(-) Ethernet TX- (Diagnostics over IP)
4	Chassis ground	**12**	Not connected Manufacturer discretion: Ethernet RX+ (Diagnostics over IP)
5	Signal ground	**13**	Manufacturer discretion. Ford: FEPS - Programming PCM voltage Ethernet RX- (Diagnostics over IP)
6	CAN high (ISO 15765-4 and SAE J2284)	**14**	CAN low (ISO 15765-4 and SAE J2284)
7	K-line of ISO 9141-2 and ISO 14230-4	**15**	L-line of ISO 9141-2 and ISO 14230-4
8	Manufacturer discretion. Many BMWs: A second K-line for non OBD-II (Body/Chassis/Infotainment) systems. Activate Ethernet (Diagnostics over IP)	**16**	Battery voltage

The assignment of unspecified pins is left to the vehicle manufacturer's discretion.

CAN FD

CAN FD (Controller Area Network Flexible Data-Rate) is a data-communication protocol typically used for broadcasting sensor data and control information on 2 wire interconnections between different parts of electronic instrumentation and control system. This protocol is used in modern high performance vehicles. CAN FD is an extension to the original CAN bus protocol that was specified in ISO 11898-1. Developed in 2011 and released in 2012 by Bosch, CAN FD was developed to meet the need to increase the data transfer rate up to 5 times faster and with larger frame /message sizes for use in modern automotive Electronic Control Units (ECU)s. As in the classic CAN, CAN FD protocol is designed to reliably transmit and receive sensor data, control commands and to detect data errors between electronic sensor devices, controllers and microcontrollers. Although CAN FD was primarily designed for use in high performance vehicle ECUs (Electronic Control Units), the pervasiveness of classic CAN in the different industries will lead into inclusion of this improved data-communication protocol in a variety of other applications as well, such as in electronic systems used in robotics, defense, industrial automation, underwater vehicles, medical equipment, avionics, down-hole drilling sensors, etc.

The primary difference between the classical CAN (Controller Area Network) and CAN FD is the Flexible Data (FD). Using CAN FD, Electronic Control Unit (ECU)s can dynamically switch to different data-rate and with larger or smaller message sizes. Enhanced features in CAN FD includes the capability to dynamically select and switch to faster or slower data rate, as and when required, and to pack more data within the same CAN frame / message and transport it over the CAN BUS / network in less time. Faster data speed and more data capacity enhancements results in several system operational advantages compared to the classic CAN. Using CAN FD, sensor and control data can be sent and received by the ECU (Electronic Control Unit) software much quicker. Commands issued by the executing ECU software reaches the output controller much faster. CAN FD is typically used in high performance ECUs of modern vehicles. A modern vehicle can have more than 70 ECUs that use CAN FD to exchange information over the CAN Bus when the engine is running or when the vehicle is moving.

In CAN FD, the frame/message ID uses the 29-bits format used in the Extended ID version of classic CAN (Standard ID is 11 bits long). The message payload size has been increased to 64 bytes of data in each CAN-frame / message, compared to only 8-bytes in the classic CAN frame. CAN FD can handle CAN frames/messages with 11-bit ID as well. A frame is a message transmitted as a sequence of binary bit-pattern. In CAN FD, the data rate (i.e. number of bits transmitted per second) is increased to be 5 times faster than the classic CAN (5Mbit/s for the data payload only, the arbitration bit rate is still limited to 1Mbit/s for compatibility). CAN FD protocol specification includes some other enhancements as well, such as better detection of errors in the received CAN message and the executing software flexibility to dynamically select (from a list) and switch to faster or slower data rate transfer, as and when required. On the CAN FD BUS, some sensors may operate at slower data rate while others at faster data rate. CAN BUS is a shared pair of wires onto which electronic sensors, controller units and ECUs are connected. CAN Bus is used for exchanging information between operational units periodically or on demand. The electrical condition and configuration of the CAN Bus, i.e. the total number of units connected, the length of the CAN Bus wires and other electro-magnetic factors determines the fastest data transfer rate possible on that CAN Bus. The CAN protocol (and by extension CAN FD) has an excellent collision resolution mechanism that depends on the propagation time of the signal and the network configuration (ring, bus or star), and to a lesser extent the number of units on the bus. Therefore a physically long network may limit the data rate below the theoretical maximum.

CAN-FD Busload that was developed by "De Andrade's" equation based on Tindel's equation.[1][3][4]

$\beta = \tau/\omega$ (1) (β = Busload) , (τ = time of slow bits more faster bits) , ω (time in seconds of measurement). $\tau = Ts + Tf$ (2)

CAN-FD protocol defines five different error detection mechanisms: Two of them work at the bit level, and the other three at the message level. They are

(i) Bit Monitoring,

(ii) Bit Stuffing,

(iii) Frame Check,

(iv) Acknowledgement Check and

(v) Cyclic Redundancy Check.

There are two options of CRC which should be denoted as for CRC length of 17 bits or for CRC length of 21 bits.

Ts = ([(SOF+ID+r1+IDE+EDL+r0+BRS/2+CRCdel/2)* 1,2]+ACK+DEL+EOF+IFS)/t_x (3) Tf = (⟦[(D⟧_f+BRS/2+ESI+DLC+CRCdel/2)*1,2]+⟦CRC⟧_17+5)/t_y (4)

where SOF (Start of Frame) + ID (Identifier) + r1 (reserved bit 1) + IDE + EDL(Extended Data Length) + r0(reserved bit 0) + BRS/2 (Bit Rate Switch) + CRCdel/2 (CRC delimiter)= 17 bits, 1.2 is the factor of the worst case bit stuffing, which means it is necessary to divide by 5. It is considered BRS and CRCdel divided by 2, because they are exactly in the shift of bit rate transition. The ACK (Acknowledge) + DEL (Delimiter) + EOF (End-of-Frame) + IFS (Interframe Spacing) = 12 bits without bit stuffing. The CAN-FD payload size may be 0, 8, 12, 16, 20, 24, 32, 48, 64 Bytes. t_X is the transmission bandwidth for the message header (up to 1 Mbps).

For data < 16 Bytes

β = ((SOF+ID+r1+IDE+EDL+r0+BRS/2+CRCdel/2 * 1,2)+ACK+DEL+EOF+IFS)/t_x + (⟦[(D⟧_f+BRS/2+ESI+DLC+CRCdel/2)*1,2]+⟦CRC⟧_17+5)/t_y)/ω (5)

For data >= 16 Bytes β= ((SOF+ID+r1+IDE+EDL+r0+BRS/2+CRCdel/2 * 1,2)+ACK+DEL+EOF+IFS)/t_x + (⟦[(D⟧_f+BRS/2+ESI+DLC+CRCdel/2)*1,2]+⟦CRC⟧_21+6)/t_y)/ω (6)

CAN FD also has decreased the number of undetected errors through increases in the performance of the CRC-algorithm. In addition, CAN FD is compatible with existing CAN 2.0 networks, allowing the new protocol to function on the same network as classic CAN. CAN FD has been estimated to transmit data up to 30 times faster than classic CAN.

Due to higher communication speed, CAN FD constraints are tougher in terms of line parasitic capacitance. Therefore, all components on the line have seen their "capacitance" budget reduced compared to regular CAN bus. That is the reason why semiconductor suppliers have released new components approved by car makers. This approval reflects the need for interoperability between all CAN FD systems. Indeed, selected ESD protection components are compatible with all transceivers (CAN or CAN FD) and withstand ISO7637-3.

Despite a higher stand-off voltage (37 V), devices for truck applications must also comply with the low capacitance requirement (3.5 pF).

CAN + CANFD -TP Header

	7 .. 4 (byte 0)	3 .. 0 (byte 0)	15 .. 8 (byte 1)	23..16 (byte 2)	(byte 3)	(byte 4)	(byte 5)	(byte 6)	....
Single Frame (SF)	0	size (0..7)	Data						
		0	size (0..62)	Data					
First Frame (FF)	1	size (8..4095)		Data					
		0	00	size (4bytes ~4GB)				Data	
Consecutive Frame (CF)	2	index (0..15)	Data						
Flow Control Frame (FC)	3	FC flag (0,1,2)	Block size	ST	Unused				

The above table explains the transfer protocol defined for CAN + CANFD.

In specific to CANFD,

- if the first byte of SF=0, then second byte specifies the size of the data.
- if the first 2 bytes of FF=0x10 00, then following 4 bytes specifies the size of data in high byte first order. This virtually enables to send ~4GB (approx.) data in CAN FD.

AUTOMOTIVE ETHERNET

Featured snippet from the web

Automotive Ethernet. It is a physical layer standard designed for use in automotive connectivity applications. IEEE standardized the technology with 802.3bw (100BASE-T1) expanded to add

802.3bp (1000BASE-T1). In the chart below we compare automotive Ethernet to the more familiar version of Ethernet (100BASE-TX).

Automotive standards like MISRA

MISRA C is a set of software development guidelines for the C programming language developed by MISRA (Motor Industry Software Reliability Association). Its aims are to facilitate code safety, security, portability and reliability in the context of embedded systems, specifically those systems programmed in ISO C / C90 / C99.

FUNCTIONAL SAFETY STANDARDS (ISO 26262)

ISO 26262, titled "Road vehicles – Functional safety", is an international standard for functional safety of electrical and/or electronic systems in serial production road vehicles, defined by the International Organization for Standardization (ISO) in 2011, and revised in 2018.

Functional safety features form an integral part of each automotive product development phase, ranging from the specification, to design, implementation, integration, verification, validation, and production release. The standard ISO 26262 is an adaptation of the Functional Safety standard IEC 61508 for Automotive Electric/Electronic Systems. ISO 26262 defines functional safety for automotive equipment applicable throughout the lifecycle of all automotive electronic and electrical safety-related systems.

The first edition (ISO 26262:2011), published on 11 November 2011, was limited to electrical and/or electronic systems installed in "series production passenger cars" with a maximum gross weight of 3500 kg. The second edition (ISO 26262:2018), published in December 2018, extended the scope from passenger cars to all road vehicles except mopeds.

The standard aims to address possible hazards caused by the malfunctioning behaviour of electronic and electrical systems in vehicles. Although entitled "Road vehicles – Functional safety" the standard relates to the functional safety of Electrical and Electronic systems as well as that of systems as a whole or of their mechanical subsystems.

Like its parent standard, IEC 61508, ISO 26262 is a risk-based safety standard, where the risk of hazardous operational situations is qualitatively assessed and safety measures are defined to avoid or control systematic failures and to detect or control random hardware failures, or mitigate their effects.

GOALS OF ISO 26262:

- Provides an automotive safety lifecycle (management, development, production, operation, service, decommissioning) and supports tailoring the necessary activities during these lifecycle phases.

- Covers functional safety aspects of the entire development process (including such activities as requirements specification, design, implementation, integration, verification, validation, and configuration).
- Provides an automotive-specific risk-based approach for determining risk classes (Automotive Safety Integrity Levels, ASILs).
- Uses ASILs for specifying the item's necessary safety requirements for achieving an acceptable residual risk.
- Provides requirements for validation and confirmation measures to ensure a sufficient and acceptable level of safety is being achieved.

MANAGEMENT OF FUNCTIONAL SAFETY

ISO 26262 provides a standard for functional safety management for automotive applications, defining standards for overall organizational safety management as well as standards for a safety life cycle for the development and production of individual automotive products. The ISO 26262 safety life cycle described in the next section operates on the following safety management concepts:

HAZARDOUS EVENT

A *hazardous event* is a relevant combination of a vehicle-level *hazard* and an operational situation of the vehicle with potential to lead to an accident if not controlled by timely driver action.

SAFETY GOAL

A *safety goal* is a top-level safety requirement that is assigned to a system, with the purpose of reducing the risk of one or more *hazardous events* to a tolerable level.

AUTOMOTIVE SAFETY INTEGRITY LEVEL

An *Automotive Safety Integrity Level* (ASIL) represents an automotive-specific risk-based classification of a *safety goal* as well as the validation and confirmation measures required by the standard to ensure accomplishment of that goal.

SAFETY REQUIREMENT

Safety requirements include all *safety goals* and all levels of requirements decomposed from the safety goals down to and including the lowest level of functional and technical safety requirements allocated to hardware and software components.

SYSTEM DESIGN AND ENERGY MANAGEMENT

Energy management is the process of tracking and optimizing energy consumption to conserve usage in a building. There are few steps for the process of energy management: Collecting and analyzing continuous data. Identify optimizations in equipment schedules, set points and flow rates to improve energy efficiency.

BATTERY MANAGEMENT SYSTEM

A battery management system (BMS) is any electronic system that manages a rechargeable battery (cell or battery pack), such as by protecting the battery from operating outside its safe operating area, monitoring its state, calculating secondary data, reporting that data, controlling its environment, authenticating it and / or balancing it.

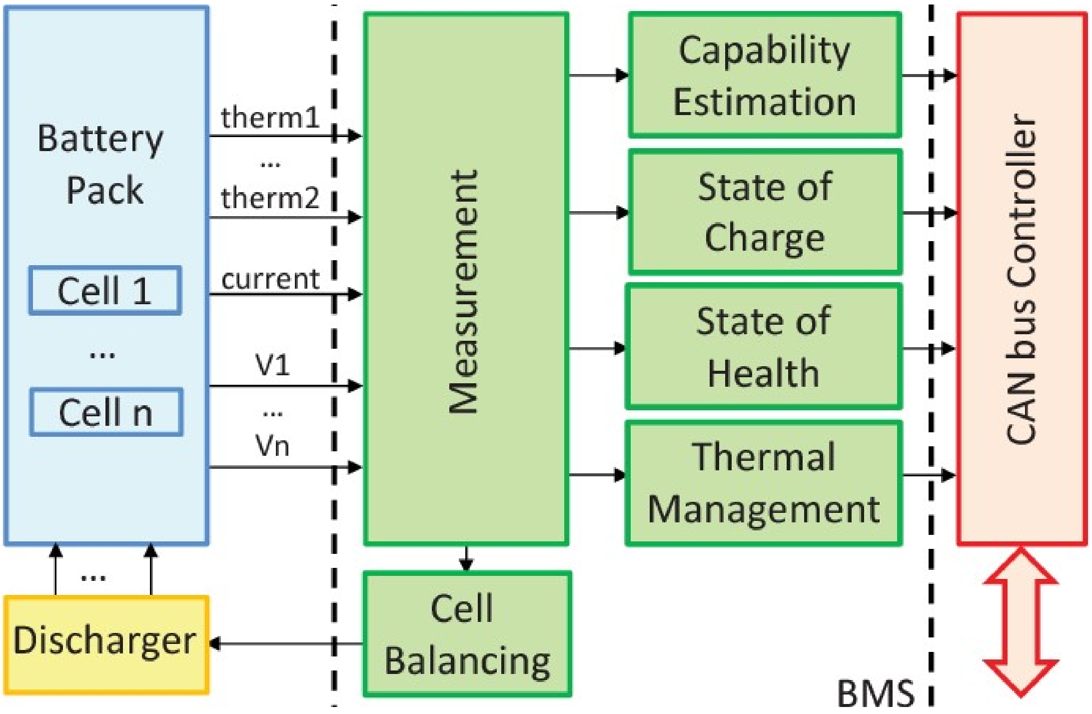
A battery pack built together with a battery management system with an external communication data bus is a smart battery pack. A smart battery pack must be charged by a smart battery charger.

Function

Monitor

A BMS may monitor the state of the battery as represented by various items, such as:

- Voltage: total voltage, voltages of individual cells, or voltage of periodic taps
- Temperature: average temperature, coolant intake temperature, coolant output temperature, or temperatures of individual cells
- Coolant flow: for air or fluid cooled batteries
- Current: current in or out of the battery



BATTERY MANAGEMENT SYSTEM

ELECTRIC VEHICLE SYSTEMS: ENERGY RECOVERY

The BMS will also control the recharging of the battery by redirecting the recovered energy (i.e.- from regenerative braking) back into the battery pack (typically composed of a number of battery modules, each composed of a number of cells).

THERMAL MANAGEMENT

Battery thermal management systems can be either passive or active, and the cooling medium can either be air, liquid, or some form of phase change. Air cooling is advantageous in its simplicity. Such systems can be passive, relying only on the convection of the surrounding air, or active, utilizing fans for airflow. Commercially, the Honda Insight and Toyota Prius both utilize active air cooling of their battery systems. The major disadvantage of air cooling is its inefficiency. Large amounts of power must used to operate the cooling mechanism, far more than active liquid cooling. The additional components of the cooling mechanism also add weight to the BMS, reducing the efficiency of batteries used for transportation.

Liquid cooling has a higher natural cooling potential than air cooling as liquid coolants tend to have higher thermal conductivities than air. The batteries can either be directly submerged in the coolant or coolant can flow through the BMS without directly contacting the battery. Indirect cooling has the potential to create large thermal gradients across the BMS due to the increased length of the cooling channels. This can be reduced by pumping the coolant faster through the system, creating a tradeoff between pumping speed and thermal consistency.

COMPUTATION

Additionally, a BMS may calculate values based on the above items, such as:

- Voltage: minimum and maximum cell voltage
- State of charge (SOC) or depth of discharge (DOD), to indicate the charge level of the battery
- State of health (SOH), a variously-defined measurement of the remaining capacity of the battery as % of the original capacity
- State of power (SOP), the amount of power available for a defined time interval given the current power usage, temperature and other conditions
- State of Safety (SOS)
- Maximum charge current as a charge current limit (CCL)
- Maximum discharge current as a discharge current limit (DCL)
- Energy [kWh] delivered since last charge or charge cycle
- Internal impedance of a cell (to determine open circuit voltage)
- Charge [Ah] delivered or stored (sometimes this feature is called Coulomb counter)
- Total energy delivered since first use
- Total operating time since first use
- Total number of cycles

COMMUNICATION

The central controller of a BMS communicates internally with its hardware operating at a cell level, or externally with high level hardware such as laptops or an HMI.

High level external communication are simple and use several methods:

- Different types of serial communications.
- CAN bus communications, commonly used in automotive environments.
- Different types of Wireless communications.

Low voltage centralized BMSs mostly do not have any internal communications. They measure cell voltage by resistance divide.

Distributed or modular BMSs must use some low level internal cell-controller (Modular architecture) or controller-controller (Distributed architecture) communication. These types of communications are difficult, especially for high voltage systems. The problem is voltage shift between cells. The first cell ground signal may be hundreds of volts higher than the other cell ground signal. Apart from software protocols, there are two known ways of hardware communication for voltage shifting systems, Optical-isolator and wireless communication. Another restriction for internal communications is the maximum number of cells. For modular architecture most hardware is limited to maximum 255 nodes. For high voltage systems the seeking time of all cells is another restriction, limiting minimum bus speeds and losing some hardware options. Cost of modular systems is important, because it may be comparable to the cell price. Combination of hardware and software restrictions results to be a few options for internal communication:

- Isolated serial communications
- wireless serial communications

PROTECTION

A BMS may protect its battery by preventing it from operating outside its safe operating area, such as

- Over-current (may be different in charging and discharging modes)
- Over-voltage (during charging), especially important for lead–acid and Li-ion cells
- Under-voltage (during discharging)
- Over-temperature
- Under-temperature
- Over-pressure (NiMH batteries)
- Ground fault or leakage current detection (system monitoring that the high voltage battery is electrically disconnected from any conductive object touchable to use like vehicle body)

The BMS may prevent operation outside the battery's safe operating area by:

- Including an internal switch (such as a relay or solid state device) which is opened if the battery is operated outside its safe operating area
- Requesting the devices to which the battery is connected to reduce or even terminate using the battery.
- Actively controlling the environment, such as through heaters, fans, air conditioning or liquid cooling

BATTERY CONNECTION TO LOAD CIRCUIT

A BMS may also feature a precharge system allowing a safe way to connect the battery to different loads and eliminating the excessive inrush currents to load capacitors.

The connection to loads is normally controlled through electromagnetic relays called contactors. The precharge circuit can be either power resistors connected in series with the loads until the capacitors are charged. Alternatively, a switched mode power supply connected in parallel to loads can be used to charge the voltage of the load circuit up to a level close enough to battery voltage in order to allow closing the contactors between battery and load circuit. A BMS may have a circuit that can check whether a relay is already closed before precharging (due to welding for example) to prevent inrush currents to occur.

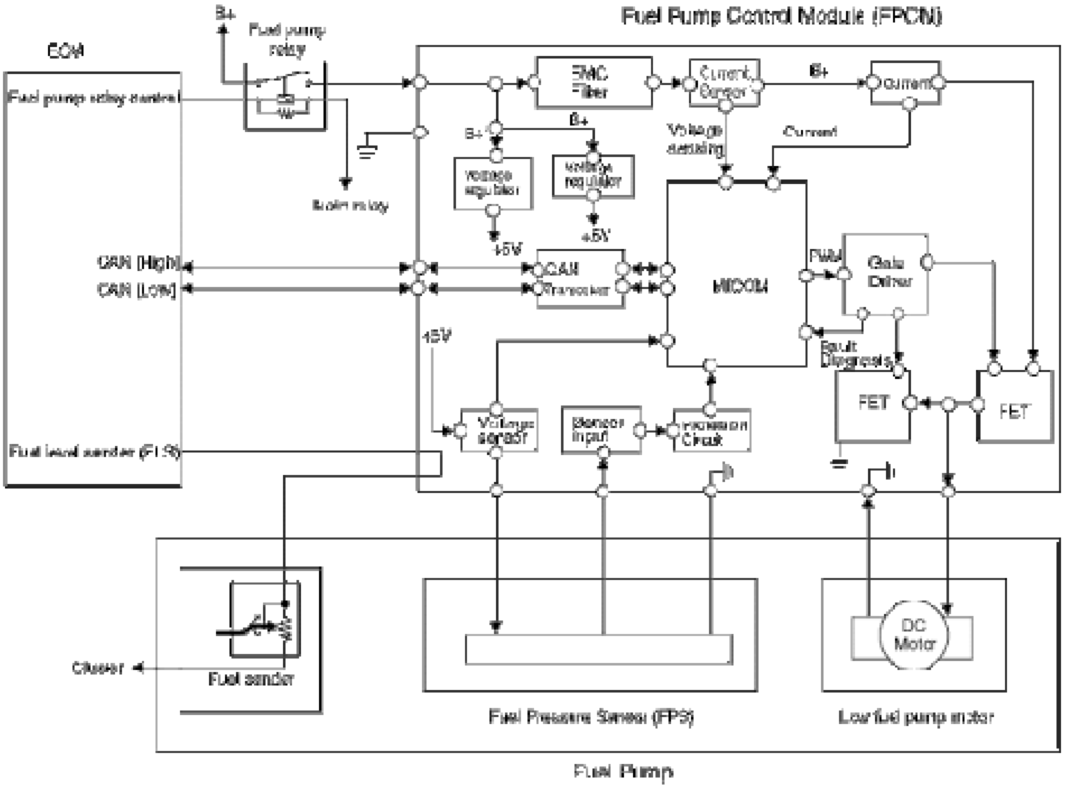
OPTIMIZATION

In order to maximize the battery's capacity, and to prevent localized under-charging or over-charging, the BMS may actively ensure that all the cells that compose the battery are kept at the same voltage or State of Charge, through balancing. The BMS can balance the cells by:

- Wasting energy from the most charged cells by connecting them to a load (such as through passive regulators)
- Shuffling energy from the most charged cells to the least charged cells (balancers)
- Reducing the charging current to a sufficiently low level that will not damage fully charged cells, while less charged cells may continue to charge (does not apply to Lithium chemistry cells)
- Modular charging

FUEL CONTROL MODULE

The fuel control module in your car is a crucial bit of machinery. With its numerous components, it controls how efficiently your fuels are used to cool, control and run your vehicle.



FUEL CONTROL MODULE

MANUFACTURING PROCESS & ASSEMBLY OF AUTOMOBILE

1. Our project is on manufacturing process of automobiles. • History of automobile started with the first steam, electrical, wind-mill, powered and gasoline cars. • Here we are going to describe about various process being carried out while production of automobile.

2. The chassis production unit. The e-coating the surface finish center. The pre-assembly. The final assembly line.

3. Building a frame or body is most challenging work. An automobile's body is made up of aluminium rather than steel which makes the body stiffer and saves the cars weight. There are around 2000 welds in chassis production which only well skilled workers can perform it.

4. After chasis production. The car's body is moved to another unit where it is protected by corrosion. The body is submerged in chemical where it is roated in 360 degrees to get coated from inside and outside. The coating is of: nickel manganese zinc then the car is emerged in an electrical charge solution where these coating sticks to the body like apermanent magnet and prevents it from rusting.

5. Here the workers build the major components of car like: doors. Instrument panel the engine the workers polish the body and make a perfect finish. Then an inspector inspects it and even the slightest and minor mistakes don't move the car to another unit.

6. The final assembly line is later divided.

7. Here associates installs blocks of high density foam and thin sound proofing sheet like material to prevent low and high frequency noise.

8. In this section, wiring is done all over the body which powers and controls cars all electronic components

9. Here the technicians install strong and stiff instrument panel made of cast magnesium weighing up to 15 pounds.

A. 1. Production becomes very fast. 2. The product obtained is relatively perfect. 3. Chances of faults and mistakes are negligible. 4. Human or manual efforts are reduced to greater extent. 5. The production takes place very systematically and in a proper sequential order as it is desired. 6. Accidents occurring due to operations like cutting, drilling, grinding, etc are very rare. 7. Objects like glass and such other heavy and fragile parts can be handled by robots. 8. The automobile firms gain profit as they have to spend more money on human workers so they prefer to have robotic and computerized production. 9. Automobile firm owners have a big benefit of these that they don't go on strikes. 10. The product gained by the automated, computerized and robotically manufacturing is comparatively very advanced.

B. 1. Due to the installation of robotic and computer operated machining there has been a substantial decrease in the employment of skilled workers. 2. There are problems like lower build qualities. 3. Higher initial capital investment. 4. Assembly lines typically cannot modified easily or cheaply to create different products, resulting in inflexibility. 5. Sometimes an assembly line can also allow a robot to do the work of many, which may lead to a loss of overall production.

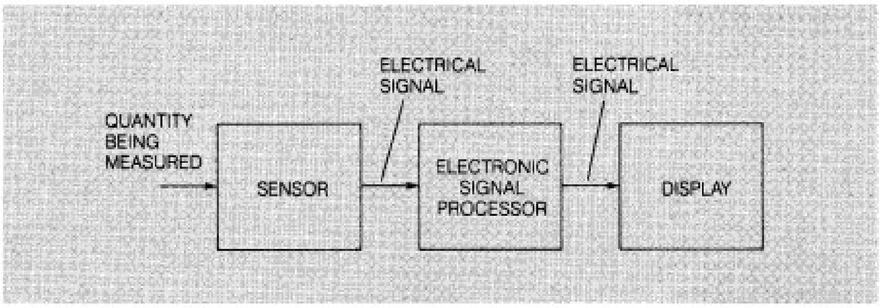
The automotive manufacturing processes play a major role in deciding on the vehicles' design characteristics and the overall cost. Thus it is very important for designers and engineers to understand the current manufacturing infrastructure available in their company's production lines. This will pinpoint the manufacturing capabilities and limitations. At the end of the day, the designer will specify the design tolerances but the machine will control the achieved tolerances. Also, we finally come to the conclusion that automated manufacturing and assembly of automobiles have relatively much more influence in terms of quality as well as performance.

MODERN AUTOMOTIVE INSTRUMENTATION

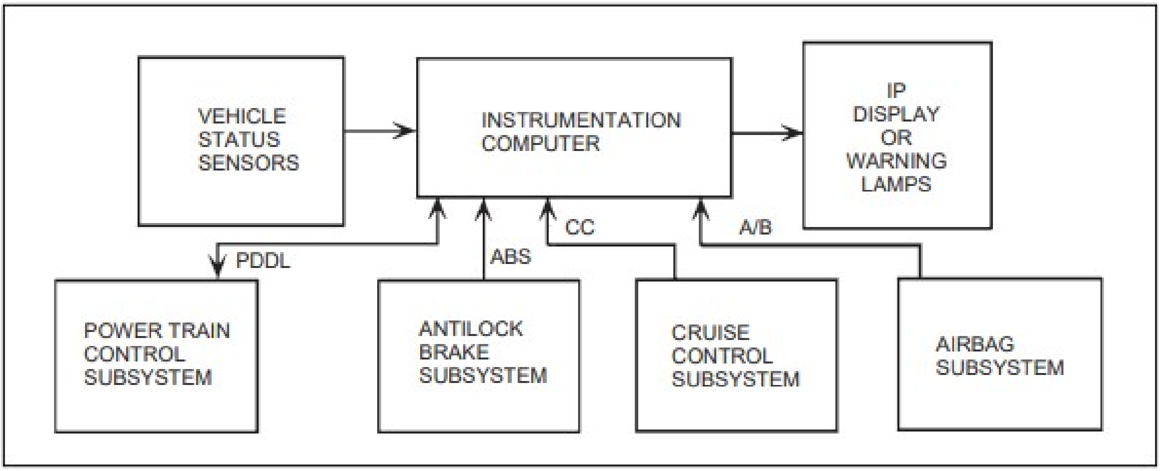
The evolution of instrumentation in automobiles has been influenced by electronic technological advances in much the same way as the engine control system, which has already been discussed. Of particular importance has been the advent of the microprocessor, solid-state display devices, and solid-state sensors. In order to put these developments into perspective, recall the general block diagram for instrumentation (first given in Chapter 2), which is repeated here as Figure 9.1. In electronic instrumentation, a sensor is required to convert any nonelectrical signal to an equivalent voltage or current. Electronic signal processing is then performed on the sensor output to produce an electrical signal that is capable of driving the display device. The display device is read by the vehicle driver. If a quantity to be measured is already in electrical form (e.g., the battery charging current) this signal can be used directly and no sensor is required. In some modern automotive instrumentation, a microcomputer (or related digital subsystem) performs all of the signal processing operations for several measurements. The primary motivation for computer-based instrumentation is the great flexibility offered in the design of the instrument panel. A block diagram for such an instrumentation system is shown in Figure. All measurements from the various sensors and switches are processed in a special-purpose digital computer. The processed signals are routed to the appropriate display or warning message. It is common practice in modern automotive instrumentation to integrate the display or warning in a single module that may include both solid-state alphanumeric display, lamps for illuminating specific messages, and traditional electromechanical indicators. For convenience, this display will be termed the instrument panel (IP). The inputs to the instrumentation computer include sensors (or switches) for measuring (or sensing) various vehicle variables as well as diagnostic inputs from the other critical electronic subsystems. The vehicle status sensors may include any of the following:

1. Fuel quantity
2. Fuel pump pressure
3. Fuel flow rate
4. Vehicle speed
5. Oil pressure
6. Oil quantity
7. Coolant temperature
8. Outside ambient temperature
9. Windshield washer fluid quantity
10. Brake fluid quantity

In addition to these variables, the input may include switches for detecting open doors and trunk, as well as IP selection switches for multifunction displays that permit the driver to select from various display modes or measurement units. For example, the driver may be able to select vehicle speed in miles per hour (mph) or kilometers per hour (kph). An important function of modern instrumentation systems is to receive diagnostic information from certain subsystems and to display appropriate warning messages to the driver. The powertrain control system, for example, continuously performs self-diagnosis operations (see Chapter 10). If a problem has been detected, a fault code is set indicating the nature and location of the fault. This code is transmitted to the instrumentation system via a powertrain digital data line (PDDL in Figure). This code is interpreted in the instrumentation computer and a “Check Engine” warning message is



GENERAL INSTRUMENTATION BLOCK DIAGRAM



COMPUTER-BASED INSTRUMENTATION SYSTEM

MULTIPLE CHOICE QUESTIONS WITH ANSWER

UNIT -I

1. The term TDC refers to

a. the engine exhaust system

b. rolling resistance of tires

c. crankshaft position corresponding to a piston at the top of its stroke

d. the distance between headlights

2. The distributor is

a. a rotary switch that connects the ignition coil to the various spark plugs

b. a system for smoothing tire load

c. a system that generates the spark in the cylinders

d. a section of the drive train

3. The air–fuel ratio is

a. the rate at which combustible products enter the engine

b. the ratio of the mass of air to the mass of fuel in a cylinder before ignition

c. the ratio of gasoline to air in the exhaust pipe

d. intake air and fuel velocity ratio

4. Ignition normally occurs

a. at BDC

b. at TDC

c. just after TDC

d. just before TDC

5. Most automobile engines are

a. large and heavy

b. gasoline-fueled, spark-ignited, liquid-cooled internal combustion type

c. unable to run at elevations that are below sea level

d. able to operate with any fuel other than gasoline

6. An exhaust valve is

a. a hole in the cylinder head

b. a mechanism for releasing the combustion products from the cylinder

c. the pipe connecting the engine to the muffler

d. a small opening at the bottom of a piston

7. Power is produced during

a. intake stroke

b. compression stroke

c. power stroke

d. exhaust stroke

8. The transmission

a. converts rotary to linear motion

b. optimizes the transfer of engine power to the drive train

c. has four forward speeds and one reverse

d. automatically selects the highest gear ratio

9.The suspension system

a. partially isolates the body of a car from road vibrations

b. holds the wheels on the axles

c. suspends the driver and passengers

d. consists of four springs

10. The camshaft

a. operates the intake and exhaust valves

b. rotates at the same speed as the crankshaft

c. has connecting rods attached to it

d. opens and closes the breaker points

11. An SI engine is

a. a type of internal combustion engine

b. a Stirling engine

c. always fuel injected

d. none of the above

12. The intake system refers to

a. the carburetor

b. a set of tubes

c. a system of valves, pipes, and throttle plates

d. the components of an engine through which fuel and air are supplied to the engine

MULTIPLE CHOICE QUESTIONS WITH ANSWER

UNIT -II

1. What does a sensor do?

a. It selects transmission gear ratio.

b. **It measures some variable.**

c. It is an output device.

d. It sends signals to the driver.

2. What does an actuator do?

a. It is an input device for an engine control system.

b. It provides a mathematical model for an engine.

c. It causes an action to be performed in response to an electrical signal.

d. It indicates the results of a measurement.

3. What is a MAP sensor?

a. a sensor that measures manifold absolute pressure

b. a vacation route planning scheme

c. a measurement of fluctuations in manifold air

d. an acronym for mean atmospheric pressure

4. What is an EGO sensor?

a. a measure of the selfcenteredness of the driver

b. a device for measuring the oxygen concentration in the exhaust of an engine

c. a spark advance mechanism

d. a measure of crankshaft acceleration

5. The crankshaft angular position sensor measures

a. the angle between the connecting rods and the crankshaft

b. the angle between a line drawn through the crankshaft axis and a mark on the flywheel and a reference line

c. the pitch angle of the crankshaft

d. the oil pressure angle

6. The Hall effect is

a. the resonance of a long, narrow corridor

b. the flow of air through the intake manifold

c. zero crossing error in camshaft position measurements

d. a phenomenon occurring in semiconductor materials in which a voltage is generated that is proportional to the strength of a magnetic field

7. A mass air flow sensor measures

a. the density of atmospheric air

b. the composition of air

c. the rate at which air is flowing into an engine measured in terms of its mass

d. the flow of exhaust out of the engine

8. A thermistor is a.

a semiconductor temperature sensor

b. a device for regulating engine temperature

c. a temperature control system for the passenger

d. a new type of transistor

9. Piezoresistivity is

a. a property of certain semiconductors in which resistivity varies with strain

b. a resistance property of insulators

c. metal bonding pads

d. an Italian resistor

10. Reluctance is

a. the reciprocal of permeability

b. a property of a magnetic circuit that is analogous to resistance in an electrical circuit

c. a line of constant magnetic flux

d. none of the above

11. An optical crankshaft position sensor

a. senses crankshaft angular position

b. operates by alternately passing or stopping a beam of light from a source to an optical detector

c. operates in a pulsed mode

d. all of the above

12. The resistance of a thermistor

a. varies inversely with temperature

b. varies directly with temperature

c. is always 100,000ohms

d. none of the above

13. Duty cycle in a fuel injector actuator refers to the ratio of

a. fuel on time to fuel off time

b. fuel off time to fuel on time

c. fuel on time to fuel on time plus fuel off time

d. none of the above

14. An EGO sensor is

a. a perfectly linear sensor

b. a sensor having two different output levels depending on air/fuel ratio

c. unaffected by exhaust oxygen levels

d. unaffected by temperature

15. A potentiometer is

a. a variable-capacitance circuit component

b. sometimes used to sense air flow

c. usable in a throttle angle sensor

d. all of the above

MULTIPLE CHOICE QUESTIONS WITH ANSWER

UNIT - III

1. A typical cruise control system senses the difference between

a. vehicle speed and tire speed

b. set speed and actual vehicle speed

c. engine angular speed and wheel speed

d. none of the above

2. A cruise control system controls vehicle speed using

a. a feedback carburetor

b. a distributorless ignition system

c. a throttle actuator

d. an MAF sensor

3. One of the major drawbacks to a proportional controller is

a. steady-state error

b. integral of the error

c. gain error

d. all of the above

4. A critically damped system has a response to a step input that

a. has overshoot

b. rises smoothly to the final value with no overshoot

c. can only be achieved with a proportional control system

d. is the slowest of all possible responses

5. A digital cruise control system

a. operates on samples of the error signal

b. computes a control signal numerically

c. obtains a digital measurement of vehicle speed

d. all of the above

6. In the example digital cruise control system of this chapter, the vehicle speed sensor

a. counts pulses of light at a frequency that is proportional to vehicle speed

b. generates an analog signal

c. measures crankshaft rotation speed directly

d. none of the above

7. One advantage of a digital motion control system is

a. the ability to work with analog signals

b. the stability of operation with respect to environmental extremes

c. the exclusive ability to generate integrals of the error signal

d. all of the above

8. A practical tire-slip controller is based on measurement of

a. wheel speed

b. vehicle speed

c. both of the above

d. neither of the above

9. An ideal antilock braking system measures skid by

a. measuring the difference between wheel speed and vehicle speed

b. differentiating vehicle speed with respect to time

c. measuring crankshaft angular speed

d. none of the above

10. The example digital ride control system of this chapter incorporates

a. a special electrically adjustable shock absorber

b. a measurement of steering angle

c. a measurement of vehicle speed and brake line pressure

d. all of the above

MULTIPLE CHOICE QUESTIONS WITH ANSWER

UNIT -IV

1. On modern cars, safety systems are put into how many groups?

a. Two
b. One
c. Three
d. Four

2. A Passive safety system is there to?

a. Avoid an accident from happening
b. Passively do nothing during an accident
c. Protect and limit injury during an accident
d. Protect the car from damage

3. An example of a Passive safety system is?

a. Parking Assist Sensors
b. Anti Lock Brakes (ABS)
c. Adaptive Cruise Control
d. Crumple Zone

4. If a car safety system acts to limit injury and protect during an accident. What type of system do we call it?

a. Passive
b. Responsive
c. Inactive
d. Active

5. An Active safety system is there to?

a. Protect and limit injury during an accident
b. Passively do nothing during an accident
c. Avoid an accident from happening
Protect the car from damage

6. An example of an Active safety system is?

a. Crumple Zone
b. Air Bags
c. Energy Absorbing Bumpers
d. Park Assist Sensors

7. If a car safety system tries to prevent or avoid an accident from happening. What type of system is it called?

a. Passive
b. Responsive
c. Inactive
d. Active

8. What types of safety systems are these?
Parking Assist Sensors
Stability Control
Anti Lock Brakes

a. Passive
b. Responsive
c. Active
d.Inactive

9. What types of safety systems are these?
Air Bags
Crumple Zones
Side Impact Protection System

a. Passive
b. Responsive
c. Active
d. Inactive

10. What are the benefits of vehicle safety systems?

a. There are no benefits
b. Drivers can drive faster
c. Drivers and passengers are receiving far more serious injuries
d. Drivers and passengers are receiving far less serious injuries

11. What are the two types of safety systems called?

a. Passive and Inactive
b.Passive and Active
c. Responsive and Active
d. Active and Inactive

12. The function of anti-lock brake system (ABS) is that is

a. Reduces the stopping distance

b. Minimizes the brake fade

c. **Maintains directional control during braking by preventing the wheels from locking**

d. Prevents nose dives during braking and thereby postpones locking of the wheels

13. The basic characteristics of brake fluid is

a. A high boiling point
b. Low viscosity

c. Compatibility with rubber and metal parts

d. **All of these**

14. Wheel base of the vehicle is

a. **Distance between the centres of the front and rear wheels**

b. Distance between the centres of the front tyres

c. Distance between the centres of the rear tyres

d. Extreme length of the vehicle

15.The negative plate of lead acid battery is

a. Lead peroxide (PbO_2)

b. **Spongy lead (Pb)**

c. Lead sulphate ($PbSO_4$)

d. Sulphuric acid (H_2SO_4)

16. The positive plate of lead acid battery as

a. **Lead peroxide (PbO_2)**

b. Spongy lead (Pb)

c. Lead sulphate ($PbSO_4$)

d. Sulphuric acid (H_2SO_4)

MULTIPLE CHOICE QUESTIONS WITH ANSWER

UNIT – V

1. The key element of a protocol is ________________.

a. Syntax

b. Semantics

c. Timing

d. All of the above

2. ______________ refers to the structure of format of the data, the order in which they are presented

a. **Syntax**

b. Semantics

c. Timing

d. All of the above

3. What is the primary purpose of automotive instrumentation?

a. to indicate to the driver the value of certain critical variables and parameters

b. to extend engine life

c. to control engine operation

d. entertainment of passengers

4. What are the three functional components of electronic instrumentation?

a. sensor, MAP, display

b. sensor, signal processing, error amplifier

c. display, sensor, signal processing

d. none of the above

5. What is the function of a multiplexer in computer-based instrumentation?

a. it measures several variables simultaneously

b. it converts sensor analog signals to digital format

c. it sequentially switches a set of sensor outputs to the instrumentation computer input

d. rate of change

6. What is sampling?

a. a signal processing algorithm

b. a selective display method

c. a method of measuring a continuously varying quantity at discrete time instants

d. the rate of change of battery voltage

7. What is an A/D converter?

a. a device that changes a continuously varying quantity to a digital format

b. an 8-bit binary counter

c. an analog-to-decimal converter

d. a fluid coupling in the transmission

8. What type of sensor is commonly used for fuel quantity measurement?

a. a thermistor

b. a strain gauge

c. a potentiometer whose movable arm is connected to a float

d. a piezoelectric sensor

9. How is coolant temperature measured?

a. with a mercury bulb thermometer

b. with a strain gauge

c. with a thermistor as a sensor

d. none of the above

10. A digital vehicle speed sensor incorporates

a. a variable-frequency pulse generator and digital counter

b. a variable resistor

c. a variable capacitance

d. none of the above

11.What sensor input variables are used in a typical trip computer system?

a. manifold pressure and engine speed

b. RPM, barometric pressure, and fuel quantity remaining

c. MPG and fuel consumption

d. car speed, fuel flow rate, fuel quantity remaining in tank

12. A CRT display device uses

a. a cathode ray tube scanned in a raster pattern

b. a vacuum-fluorescent tube

c. an incandescent light source

d. none of the above

13. In the digital video signal generator used with a CRT display

a. each bit in the shift register corresponds to a pixel location

b. each pixel on the screen corresponds to a specific video voltage level

c. scanning of the CRT by the electron beam is from right to left and from bottom to top

d. all of the above are true

14. The term MUX refers to

a. an electronic switch that selects one of a set of inputs per an input code

b. a digital output device

c. a time slot

d. none of the above

15. A D/A converter

a. is a disk access device

b. enters digital data in a computer

c. stores analog data

d. enters digital data in a computer

16. LED refers to

a. level-equalizing detector

b. light-emitting diode

c. liquid crystal display

d. none of the above

17. An LCD display uses

a. a nematic liquid

b. an incandescent lamp

c. large electrical power

d. a picket fence

18. Light is produced in a VFD by

a. ionic bombardment of a filament

b. ambient temperature

c. bombardment of a phosphor by energetic electrons

d. chemical action

19. Fuel economy is calculated in a trip computer by:

a. S ·F

b. F/S

c. S/F

d. none of the above

20. Engine performance may be improved in the future by

a. tuning the intake manifold

b. use of variable compression ratio

c. variable valve timing

d. all of the above

21. One potential engine control strategy based on a feedback signal from cylinder pressure may incorporate

a. a piezoelectric cylinder pressure sensor

b. a new MAP sensor

c. an exhaust air/fuel sensor

d. none of the above

22. An airbag is

a. a mechanism for occupant protection in a car

b. a container for use in case of airsickness

c. an impact sensor

d. all of the above

23. One concept for automotive collision avoidance involves

a. braking rapidly in dangerous situations

b. measuring the round-trip time of a radar pulse from protected car to collision object

c. aircraft surveillance of highways

d. wheel speed sensors

24. Doppler shift has potential automotive application for

a. measuring the speed of passing trains

b. automatic gear changing

c. measuring vehicle speed over the road

d. none of the above

25. A fuel-cell powered vehicle

a. can be implemented using multiple proton exchange membrane cells

b. is an electric vehicle

c. can be fueled with hydrogen

d. all of the above

26. A CRT-type display has potential automotive application for

a. controlling vehicle motion

b. recording vehicle transient motion

c. monitoring entertainment systems

d. displaying information to the driver

27. The term HUD refers to

a. housing and urban development

b. heads up display

c. heads up driver

d. none of the above

28. Speech synthesis is

a. a system that automatically recognizes human speech

b. an automatic checkbook balancing system

c. a visual display of speech waveforms

d. a means of electronically generating human speech

29. An optical fiber is

a. a tiny beam of light

b. an optical waveguide that is often called a light pipe

c. an optical switch

d. none of the above

30. An inertial navigation system incorporates the following sensors:

a. radio receivers

b. Doppler radar

c. gyros and accelerometers

d. none of the above

ASSIGNMENT / QUESTION BANK

UNIT – I INTRODUCTION OF AUTOMOBILE SYSTEM

PART – A

1. What is autosar used for?

2. What is autosar ECU?

3. What is basic software in autosar?

4. Is autosar open source?

5. Is autosar an RTOS?

6. What is ComStack?

7. What is autosar BSW?

8. What is autosar methodology?

9. CAN protocol in autosar?

10. What is autosar meta model?

11. What is post build configuration in autosar?

12. What is MCAL layer?

13. Why RTE is necessary in autosar?

14. What is Arxml?

PART – B

1. Describe about the Current trends in automobiles with emphasis on increasing role of electronics and software.

2. Illustrate about the overview of generic automotive control ECU functioning with neat diagram.

3. Explain about the overview of typical automotive subsystems and components with neat sketch.

4. Discuss about the AUTOSAR with draw the necessary diagram.

UNIT- II ENGINE MANAGEMENT SYSTEMS

PART - A

1. Which sensor is used in Automobile?

2. How does the car sensor work?

3. How many sensors are in a car?

4. What are the different types of sensor?

5. How do crank position sensors work?

6. Where is the crank angle sensor located?

7. Is a crank angle sensor the same as a crankshaft sensor?

8. What type of sensor is a crankshaft position sensor?

9. Does crank sensor control fuel pump?

10. Can a car run without a crankshaft position sensor?

11. How does a flow sensor work?

12. What is the use of flow sensor?

13. How much is an air flow meter?

14. What are the flow sensor types?

15. What is flow and level sensor?

16. How do throttle position sensors work?

17. Can you fix a throttle position sensor?

18. What is the acronym for EGR in emission control system?

19. Does EGR valve affect emissions?

20. What does the EGR valve control?

21. How does EGR reduce combustion temperatures?

22. Does EGR reduce power?

23. How does EGR increase fuel economy?

24. How does the EGR system work?

25. What is electronic ignition?

26. What are the advantages of electronic ignition?

27. What are the 3 types of ignition systems?

28. What are the requirements of ignition system?

29. What is the difference between an ignition coil and a spark plug?

30. Does electronic ignition increase horsepower?

PART – B

1. Mention the types of sensors such as oxygen sensors. Explain any one with neat diagram.

2. Describe about the crank angle position sensors with neat sketch.

3. With neat diagram, explain the Fuel metering/ vehicle speed sensors.

4. Discuss about the flow sensor and temperature sensor with neat diagram.

5. Illustrate with neat sketch of the air mass flow sensors and throttle position sensor.

6. Explain about the algorithms for engine control including open loop and closed loop control system.

7. Explain about the electronic ignition and solenoids with neat sketch.

8. Discuss about the neat sketch of EGR for exhaust emission control.

UNIT- III VEHICLE POWER TRAIN AND MOTION CONTROL

PART – A

1. What is electronic transmission control?

2. What are symptoms of a bad transmission control module?

3. Which is a part of electronic control transmission?

4. What sensors are in a transmission?

5. How do you fix a transmission sensor?

6. What is the difference between input and output speed sensor?

7. Where is the transmission input speed sensor?

8. What is adaptive power steering?

9. How does adaptive steering work?

10. What is difference between power steering and normal steering?

11. Which is better power steering or electric steering?

12. What does adaptive cruise control do?

13. Will adaptive cruise control stop the car?

14. How safe is adaptive cruise control?

15. How does anti lock braking system work?

16. What does anti lock brakes allow you to do?

17. When would Anti lock brakes start to work?

18. What Is Traction Control And How Does It Work?

19. What does electronic stability mean?

20. How does electronic stability program work?

PART – B

1. Describe about the Electronic transmission control with neat diagram.

2. with neat sketch, Explain about the adaptive power Steering and adaptive cruise control.

3. Explain about the anti-lock braking and traction control with neat sketch.

4. Discuss about the safety and comfort systems in auto mobile system.

5. Illustrate about the electronic stability and active suspension control with neat sketch.

UNIT-IV ACTIVE AND PASSIVE SAFETY SYSTEM

PART – A

1. What does remote keyless entry mean?

2. Is remote keyless entry push to start?

3. How does an immobilizer work?

4. What is an immobilizer in a car?

5. Which items are located on the dashboard?

6. What does dashboard mean?

7. What are the dashboard symbols?

8. What does electromagnetic interference cause?

9. What is RFI electrical?

10. How does anti lock braking system work?

11. How does electronic stability program work?

12. Is electronic stability control necessary?

13. How do air bags work?

14. How fast do airbags deploy mph?

15. Why is electromagnetic compatibility important?

PART – B

1. Explain briefly about the remote keyless entry and immobilizers with neat diagram.

2. Describe about the electronic instrument clusters and dashboard electronics.

3. Discuss about the aspects of hardware design for automotive including electro-magnetic interference suppression.

4. with neat diagram, Explain about the electromagnetic compatibility and antilock braking system.

5. Describe about the electronic stability program and air bags with neat diagram.

UNIT- V AUTOMOTIVE STANDARDS AND PROTOCOLS

PART – A

1. CAN protocol basics?

2. What is CAN open protocol?

3. What does LIN bus stand for?

4. What is Lin used for?

5. What is the difference between CAN and LIN?

6. How is LIN bus diagnosed?

7. What type of vehicle network is Flex Ray?

8. What are the 2 communication segments in a FlexRay network?

9. What is FlexRay communication?

10. How does a heads up display work?

11. What does obdII mean?

12. What is the difference between OBD and obd2?

13. Can FD in autosar?

14. What is L PDU in autosar?

15. Why can is used in automotive?

16. What does Misra mean?

17. What is Misra coding standards?

18. What does a battery management system do?

19. What is BMS circuit?

20. Why is BMS important?

21. Where is the fuel pump control module?

22. What is automotive process?

23. What are the types of instrumentation?

24. What is the purpose of instrumentation system?

25. What are the general concerns for instrumentation system?

PART - B

1. Explain in detail about the automotive standards like CAN protocol with neat sketch.

2. Describe about the LIN protocol and FLEX RAY with neat diagram.

3. Explain the terms of OBDII, CAN FD.

4. Discuss about the automotive standards like MISRA.

5. Write the functional safety standards (ISO 26262) and it's explained.

6. with neat diagram, Explain in detail about the BMS and FCM.

7. Discuss about the assembly process of automotives and instrumentation systems.

USEFUL VIDEO LINK

Unit – I **INTRODUCTION OF AUTOMOBILE SYSTEM**

AUTOSAR

https://www.youtube.com/watch?v=NfZI8wvgZPo

GENERIC AUTOMOTIVE CONTROL ECU FUNCTIONING

https://www.youtube.com/watch?v=4AQ-Bm-KU5k

AUTOMOTIVE SUBSYSTEMS AND COMPONENTS

https://www.youtube.com/watch?v=o7zUaqu4R7c

CURRENT TRENDS IN AUTOMOBILES WITH EMPHASIS ON INCREASING ROLE OF ELECTRONICS AND SOFTWARE

https://www.youtube.com/watch?v=C8UtbkXw82s

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UNIT- II **ENGINE MANAGEMENT SYSTEMS**

BASIC SENSOR ARRANGEMENT IN AUTOMOBILE

https://www.youtube.com/watch?v=8e4QB1DYYJU

OXYGEN SENSORS

https://www.youtube.com/watch?v=4VItybZ2Ryc

CRANK ANGLE POSITION SENSORS

https://www.youtube.com/watch?v=RuIislTGOwA

FUEL METERING

https://www.youtube.com/watch?v=xEssM_sYtd8

VEHICLE SPEED SENSORS

https://www.youtube.com/watch?v=A4Z_uDLcCoA

FLOW SENSOR

https://www.youtube.com/watch?v=KfBhVttKN4o

TEMPERATURE SENSOR

https://www.youtube.com/watch?v=TKE1SzDwKBo

THROTTLE POSITION SENSOR

https://www.youtube.com/watch?v=OUK6va6pBC0

SOLENOIDS

https://www.youtube.com/watch?v=BbmocfETTFo

ALGORITHMS FOR ENGINE CONTROL INCLUDING OPEN LOOP AND CLOSED LOOP CONTROL SYSTEM

https://www.youtube.com/watch?v=g_vbIQNMREI

ELECTRONIC IGNITION

https://www.youtube.com/watch?v=QYx8J_5l5wY

EGR FOR EXHAUST EMISSION CONTROL

https://www.youtube.com/watch?v=EkzaV3Or4WM

UNIT- III VEHICLE POWER TRAIN AND MOTION CONTROL

ELECTRONIC TRANSMISSION CONTROL

https://www.youtube.com/watch?v=2bw06loc99s

ADAPTIVE POWER STEERING

https://www.youtube.com/watch?v=Fkgp64e-nNQ

ADAPTIVE CRUISE CONTROL

https://www.youtube.com/watch?v=own_VaRZ9M8

SAFETY AND COMFORT SYSTEMS

https://www.youtube.com/watch?v=CeEvO47_owY

https://www.youtube.com/watch?v=P_A3gymVhW4

ANTI-LOCK BRAKING

https://www.youtube.com/watch?v=98DXe3uKwfc

TRACTION CONTROL

https://www.youtube.com/watch?v=ZcrA51GPMCQ

ELECTRONIC STABILITY

https://www.youtube.com/watch?v=LVz9f5WQhCI

ACTIVE SUSPENSION CONTROL

https://www.youtube.com/watch?v=jE8s1qZy61Q

UNIT-IV ACTIVE AND PASSIVE SAFETY SYSTEM

BODY ELECTRONICS INCLUDING LIGHTING CONTROL

https://www.youtube.com/watch?v=mszPzLvOROI

REMOTE KEYLESS ENTRY

https://www.youtube.com/watch?v=pPmli4truBc

IMMOBILIZERS

https://www.youtube.com/watch?v=lUuk9jl7q-c

ELECTRONIC INSTRUMENT CLUSTERS AND DASHBOARD ELECTRONICS

https://www.youtube.com/watch?v=u_RcFkexfkM

ASPECTS OF HARDWARE DESIGN FOR AUTOMOTIVE INCLUDING ELECTRO-MAGNETIC INTERFERENCE SUPPRESSION

https://www.youtube.com/watch?v=c_fKsQSlbSE

ELECTROMAGNETIC COMPATIBILITY

https://www.youtube.com/watch?v=yxbshDyGPng

ELECTRONIC STABILITY PROGRAM

https://www.youtube.com/watch?v=5IP-pgKrNV8

ANTILOCK BRAKING SYSTEM

https://www.youtube.com/watch?v=0Tu9LShl9VU

AIR BAGS

https://www.youtube.com/watch?v=R4ekbB5EzZM

UNIT- V AUTOMOTIVE STANDARDS AND PROTOCOLS

AUTOMOTIVE STANDARDS LIKE CAN PROTOCOL

https://www.youtube.com/watch?v=jnQoR67lIug

LIN PROTOCOL

https://www.youtube.com/watch?v=TresvW4dxlc

FLEX RAY

https://www.youtube.com/watch?v=V7nhDUA37dk

HEAD-UP DISPLAY

https://www.youtube.com/watch?v=ZHeoYmRxaCk

OBDII

https://www.youtube.com/watch?v=OhShoU_E-0g

CAN FD

https://www.youtube.com/watch?v=KqV5nIkGKFs

AUTOMOTIVE ETHERNET

https://www.youtube.com/watch?v=HgZ5Dtm_CIo

AUTOMOTIVE STANDARDS LIKE MISRA

https://www.youtube.com/watch?v=PaDfrHqWg5A

FUNCTIONAL SAFETY STANDARDS (ISO 26262)

https://www.youtube.com/watch?v=12eUOwIvpy4

BATTERY MANAGEMENT SYSTEM

https://www.youtube.com/watch?v=q4wDa_m9-8E

FUEL CONTROL MODULE

https://www.youtube.com/watch?v=ZhmcwSCsnT4

ASSEMBLY PROCESS OF AUTOMOTIVES AND INSTRUMENTATION SYSTEMS

https://www.youtube.com/watch?v=pW7ztL48LUk

CONCLUSION

In the course material a deep explanation of automobile system and its various components and uses of sensors in automobile system are discussed. A brief discussion on advanced control in automobile system and its safety measures is done. The basics of automobile system and its various sensor used in are given with the electronics and software involved methods.

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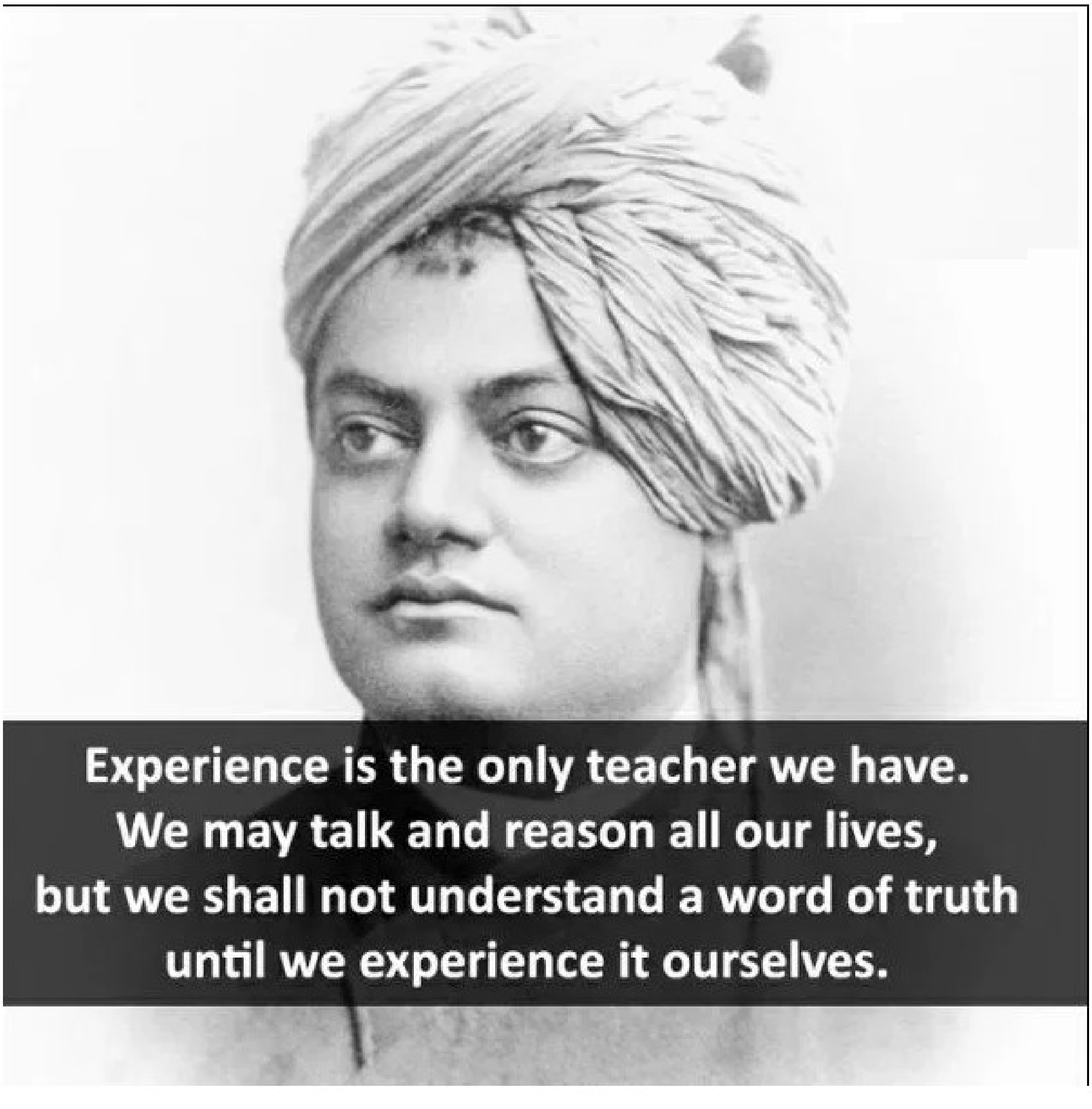

Experience is the only teacher we have.
We may talk and reason all our lives,
but we shall not understand a word of truth
until we experience it ourselves.