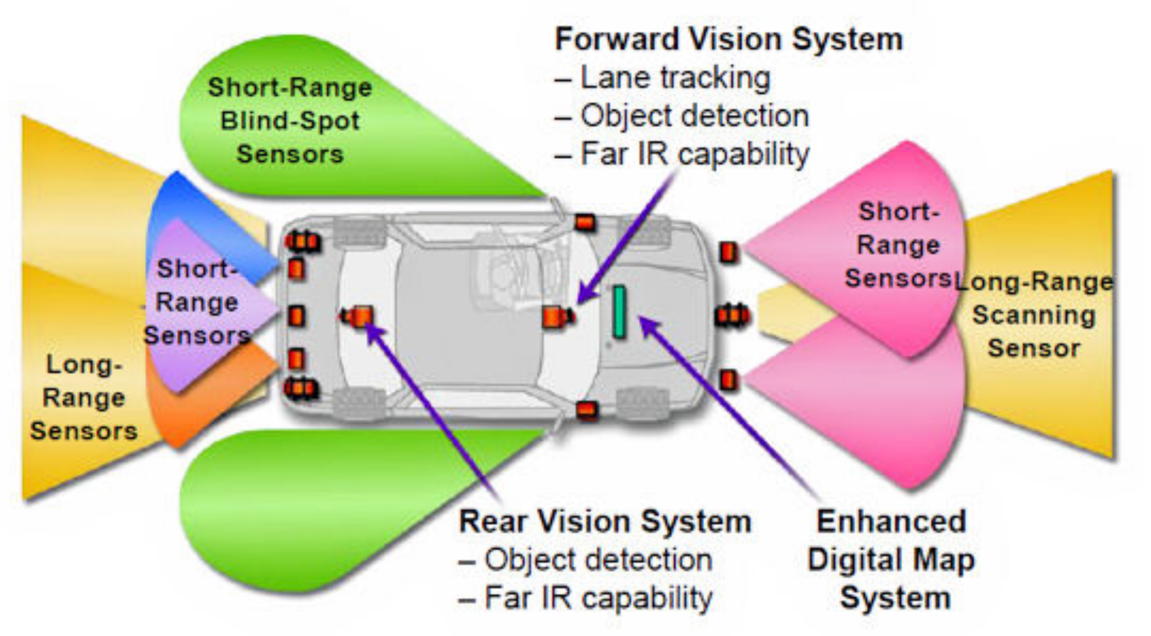
Mechatronics Module 4:

Sensors and Actuators

Dr. Vladimir V. Vantsevich
awdrive@comcast.net

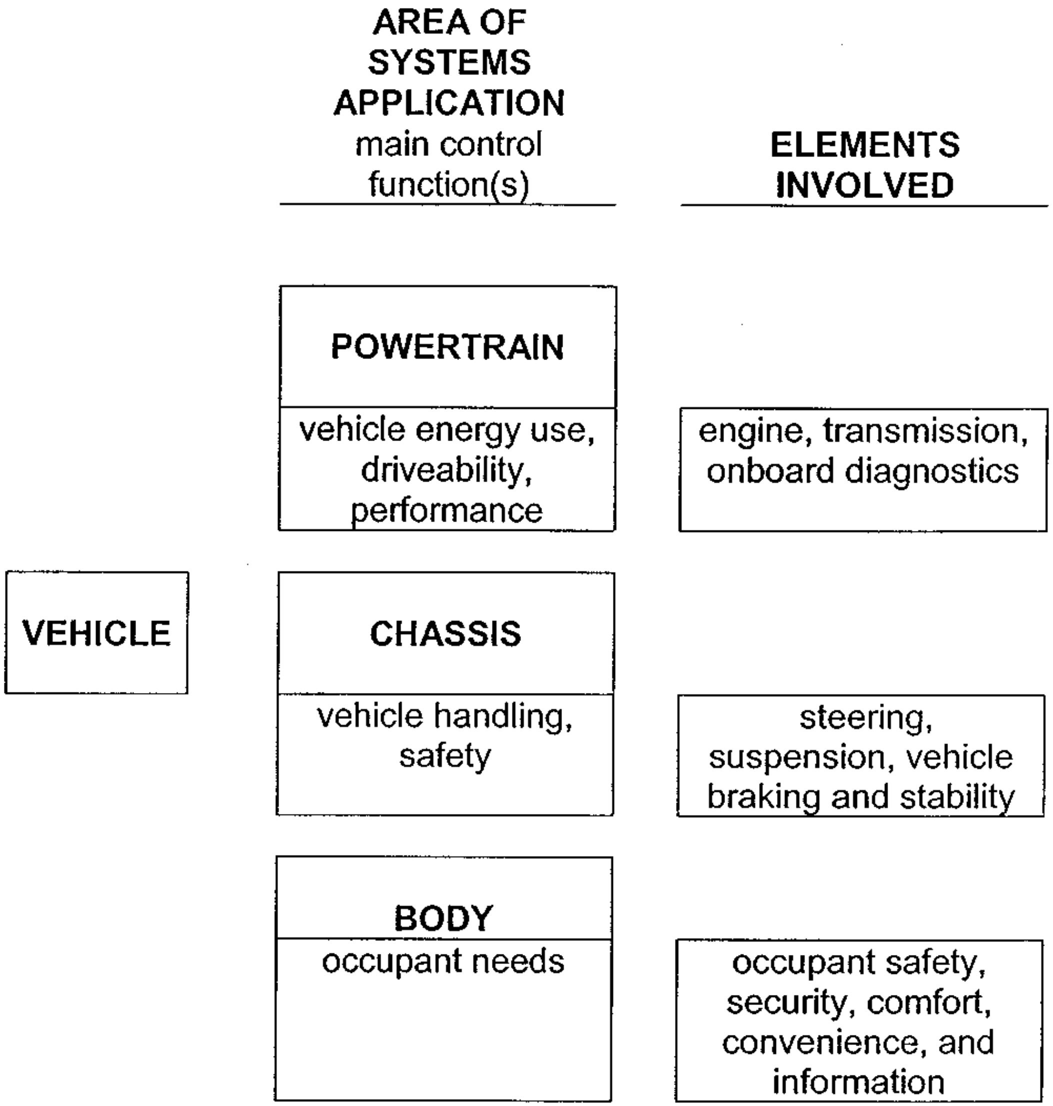
Introduction to Sensors

Sensors are essential components of automotive electronic control systems. Sensors are defined as “devices that transform (or transduce) physical quantities such as pressure or acceleration (called measurands) into output signals (usually electrical) that serve as inputs for control systems.¨



Vehicle with 360-degree sensing capability [4]

Introduction to Sensors



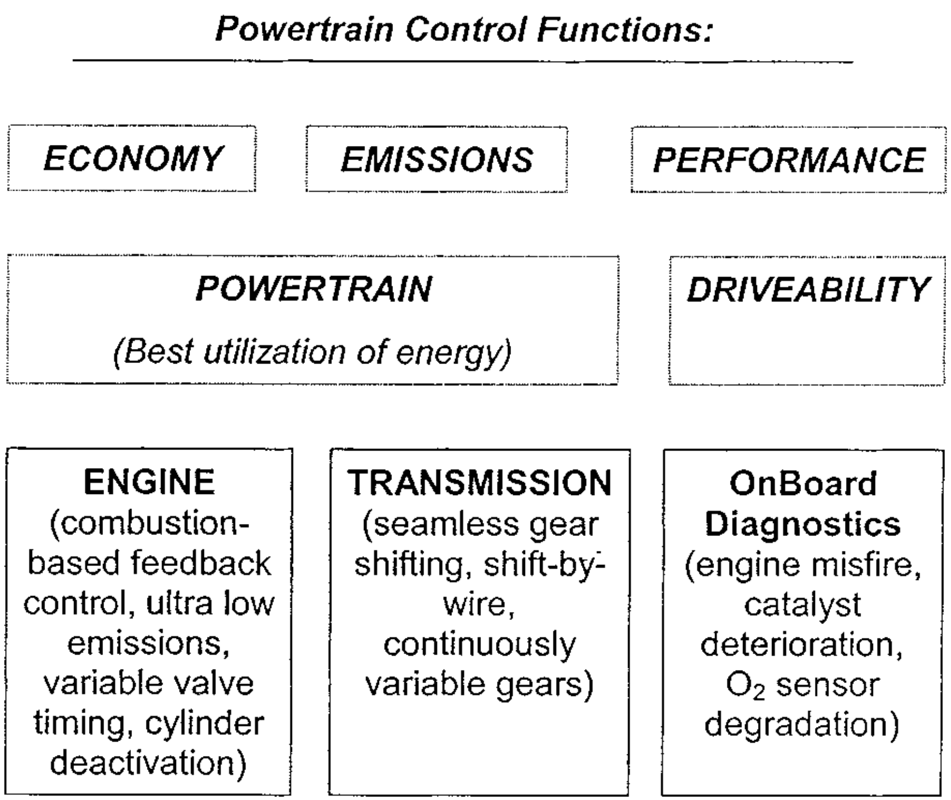
Major of systems application for automotive sensors [1]

The three major areas of systems applications for automotive sensors are the powertrain, chassis, and body.

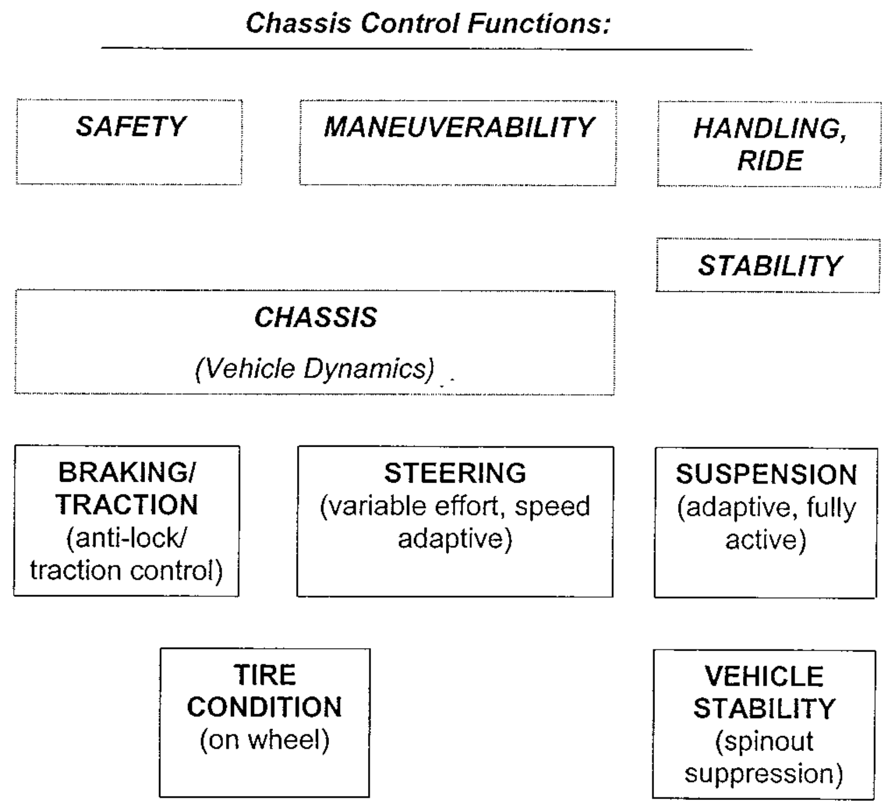
- In the present systems-classification scheme, anything that isn't powertrain or chassis is included as a body systems application.

- The automotive industry has increasingly utilized sensors
in recent years.

Introduction to Sensors

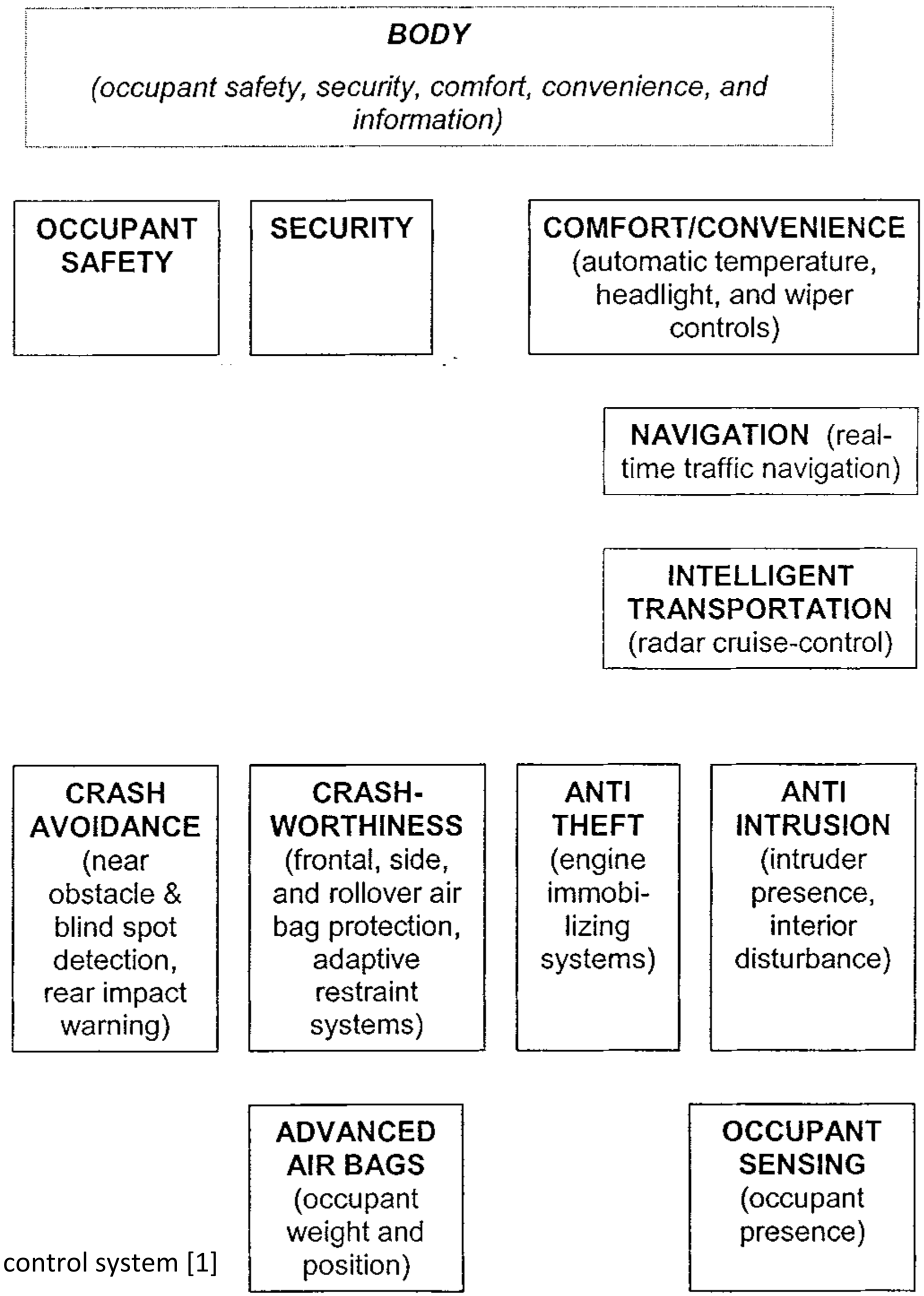


Powertrain control system [1]



Chassis control system [1]

Body Control Functions:



Body control system [1]

Current-product Sensor Technologies

Rotational motion sensors: measure shaft rotational motion (they also detect reference points such as those created by the absence of one tone-wheel tooth).

Pressure sensors: have some very diverse automotive applications. They measure pressures ranging from 10kPa to 180 MPa. This is an 18000:1 variation in full-scale pressure range measurement requirements.

Engine Knock: To obtain maximum power, high-performance engines are run at their borderline limit of incipient knock. This is done using closed-loop control of spark timing based on knock sensor feedback. Vibration/knock sensors consist of piezoelectric sensing elements in spring-mass sensor packages

Current-product Sensor Technologies

Mass Air Flow: MAF (mass air flow) sensors are used on high-performance engines, sensors based on a thermal heat-loss principle, including a hot-wire element (plus a companion compensating hot-wire element), to measure mass air flow into an engine.

Exhaust Gas: EGO (exhaust gas oxygen) sensors use in closed-loop three-way catalytic-converter emissions control of engines.

Position sensors: measure linear displacements ranging from less than one micron to over 200 mm.

Current-product Sensor Technologies

Linear Acceleration: Linear-acceleration inertial sensors are used as inputs for chassis applications such as adaptive suspension, vehicle stability, and ABS braking systems, as well as inputs for body-systems frontal, side and rollover crash-sensing applications.

Angular-rate sensors: are used as inputs for chassis suspension (vehicle roll and pitch) and for vehicle stability as well as inputs for body rollover-crash-sensing (roll) and for vehicle-heading navigation applications.

Engine-Crankshaft Speed Variation Due to Cylinder-Firings: Math algorithms are used to derive the engine torque from measurements of engine-flywheel speed modulation due to individual cylinder firings—high-resolution rotational motion sensors are utilized.

Current-product Sensor Technologies

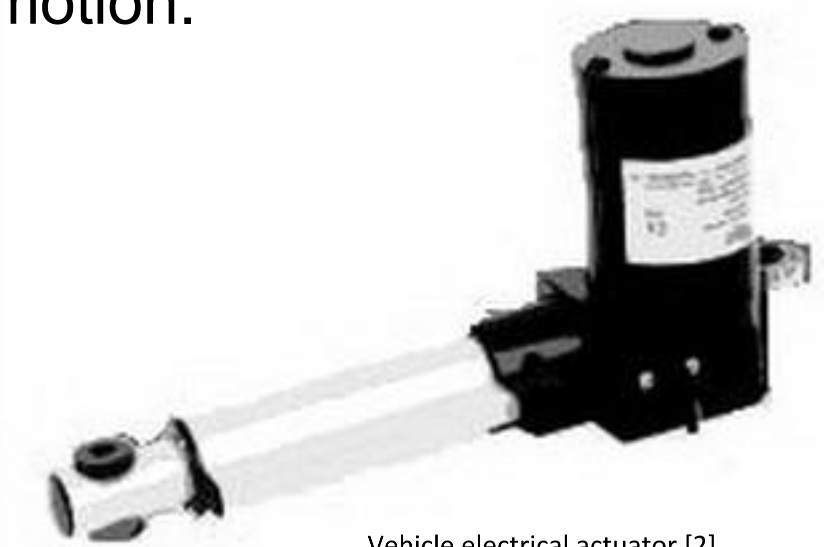
Fuel Level: optical, ultrasonic and capacitive—the potentiometer float-arm technology for fuel-level measurement prevails because of its low cost, high reliability and durability. Thick-film resistive tracks are generally used in the potentiometer. The float is designed to traverse a path near the tank's center for all fuel levels. An appropriate functional relationship between sensor angle and fuel quantity for the particular tank shape used in each vehicle is used. A running average of fuel sensor output signals is utilized to compensate for fuel slosh created due to vehicle motion.

Engine Combustion Sensors: Detects misfire and detonation/ knock; and also indicates in-cylinder peak pressure and air-fuel ratio.

Introduction to Actuators

An actuator is a type of motor for moving or controlling a mechanism or system.

➢ It is operated by a source of energy, usually in the form of an electric current, hydraulic fluid pressure or pneumatic pressure, and converts that energy into some kind of motion.

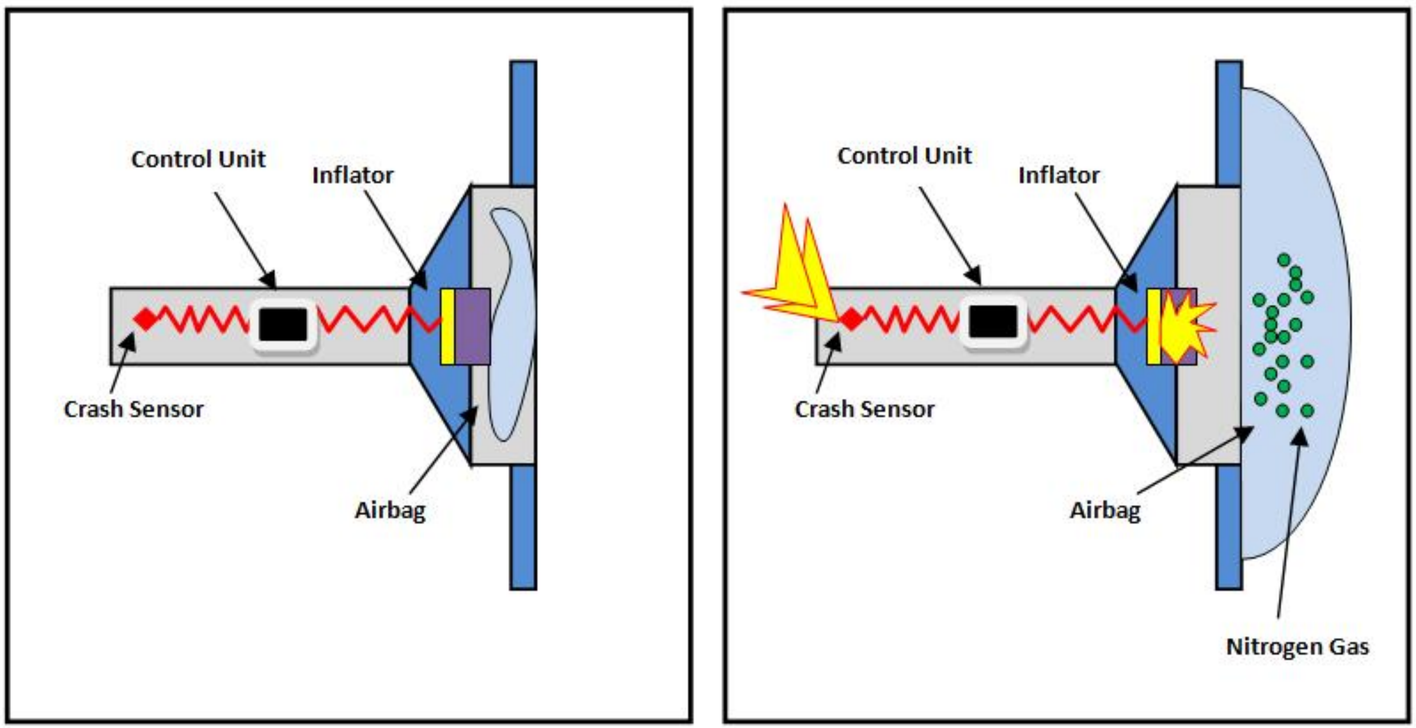


Vehicle electrical actuator [2]

➢ An actuator is the mechanism by which an agent acts upon an environment.

Automotive Electronic Actuators

The airbag inflator is one of the many components of an airbag system. The main purpose of an airbag is to slow the passenger's forward motion as evenly as possible immediately after a collision.



How the airbag system works [3]

Automotive Electronic Actuators

Fuel Pump: powered from the vehicle battery and connected to the engine ECU to give the engine the fuel at the right pressure suitable for its work.

Injector: is an injection nozzle with solenoid that is controlled by the ECM. Using intake air quantity and engine rpm, the ECM calculates basic fuel injection time and calculates corrective fuel injection period time on the basis of engine coolant temp, and feedback signal from oxygen sensor during close-loop-control.

Fuel Pressure Regulator: injection rate through injector depends on injection pressure, injection time and orifice size.

Automotive Electronic Actuators

Cooling Fan Control: in order to maximize cooling efficiency and minimize cooling fan motor drive current, radiator fan and condenser fan speeds are controlled using three speed modes such as low, medium, and high speed on the basis of coolant temperature, car speed, air conditioning switch signal, and conditioning compressor operation signal.

Generator Current Control: when turning on the headlamp or heater in idling, engine RPM will instantly fall down and then be recovered due to increased generator load. At that time increasing electrical load will generate rapid engine RPM changes, resulting in vibrations and passenger discomfort. Generator current control system depends on the engine ECU.

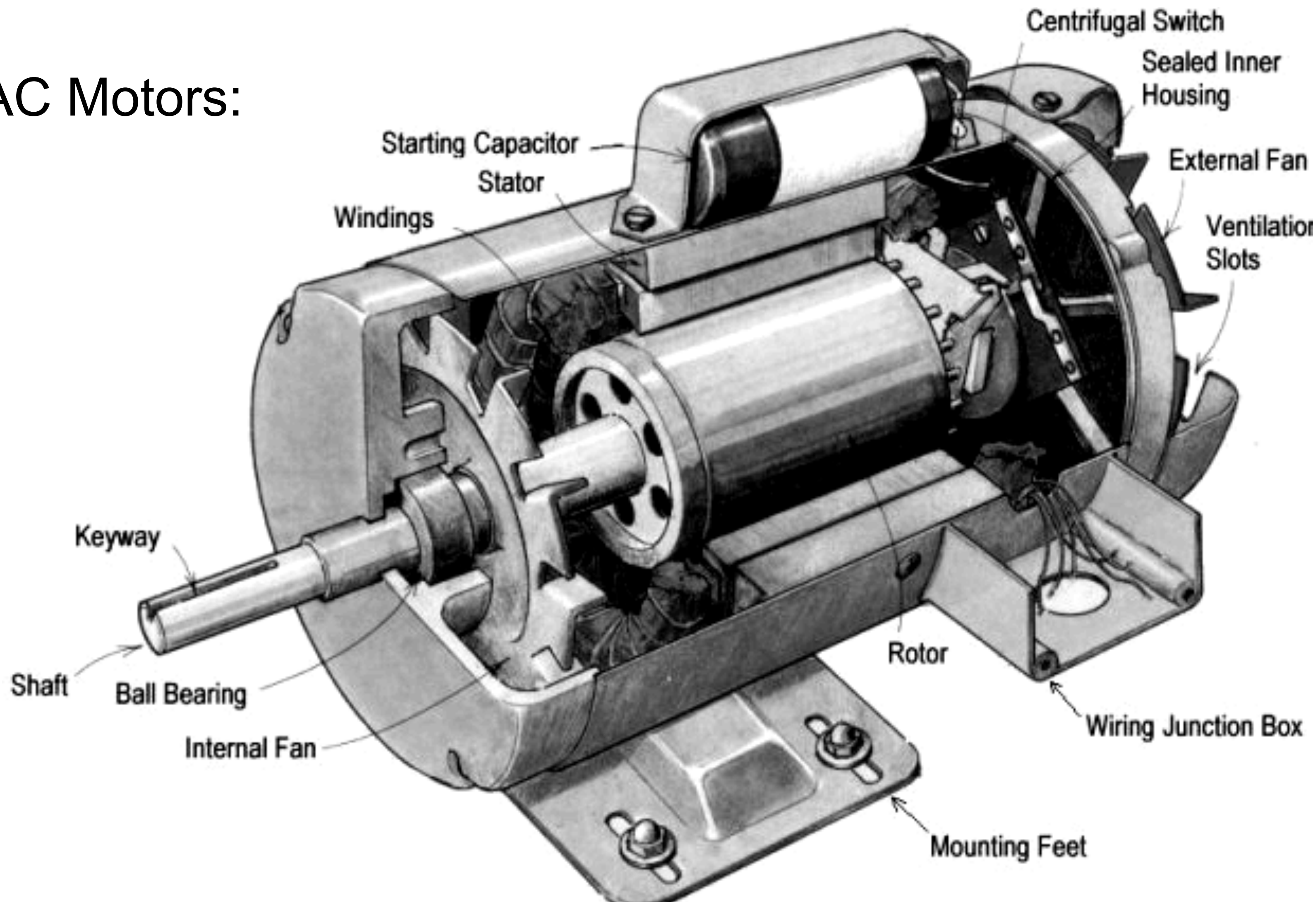
Automotive Electronic Actuators

A/C Compressor Control: A/C Compressor Control is used when accelerating or engine load is instantly increased greatly in order to improve engine acceleration by temporarily turning off A/C compressor.

Ignition coil: functions as an energy-storage device and transformer. It is supplied with DC voltage from the alternator, and provides the high tension ignition pulses for the spark plugs. The MFI engine adopts a computerized ignition system. The ECM calculates ignition timing, timing advance, and knocking control by the sensor signals.

Automotive Electronic Actuators

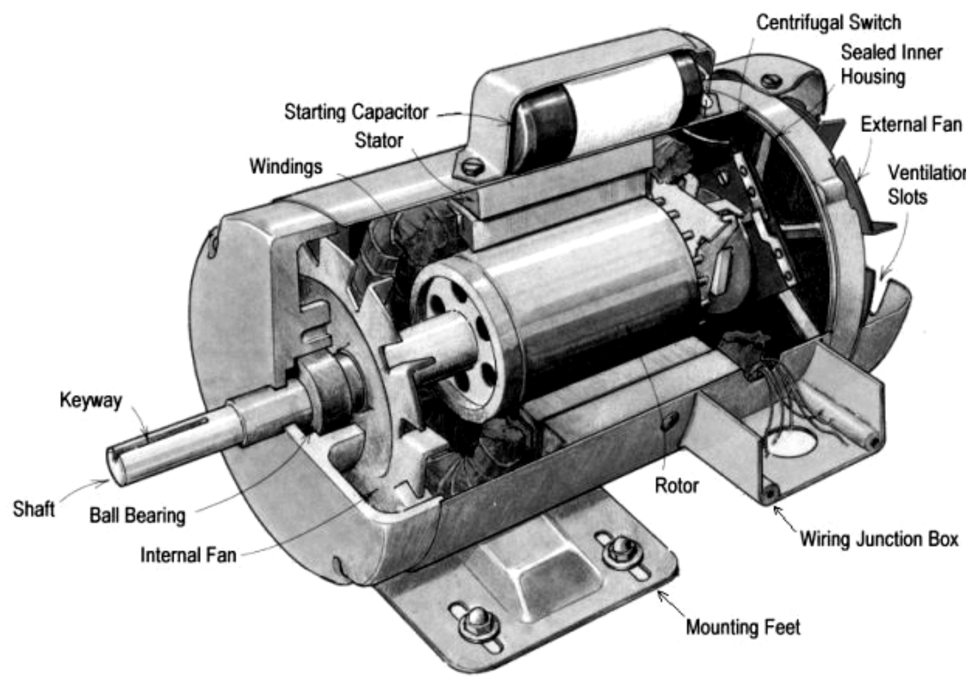
AC Motors:



AC Motors

AC Motors are electrical machines that convert electrical energy to rotational mechanical energy by the interaction of magnetic fields and conductors.

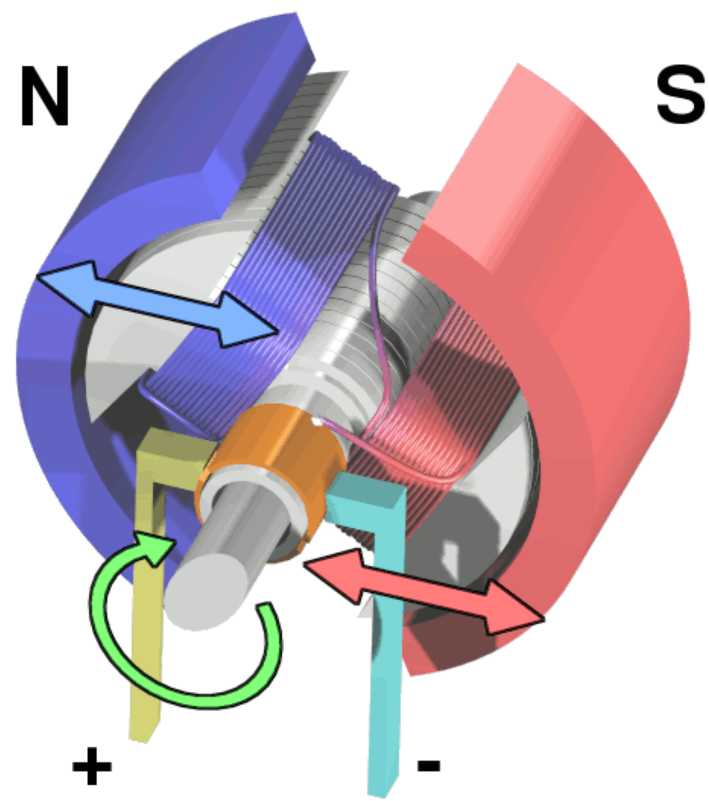
- Unlike motors that run directly on a DC current, AC motors generally do not require brushes and commutators. AC motors transfer the AC current to the mechanical rotation.



Brushed DC Motors

A brushed DC Motor consists of two magnets facing the same direction that surround two coils of wire residing in the middle of the motor around a rotor.

- ➢The coils are positioned to face the magnets, causing electricity to flow to them.
- ➢This generates a magnetic field, which ultimately pushes the coils away from the magnets they are facing and causes the rotor to turn.



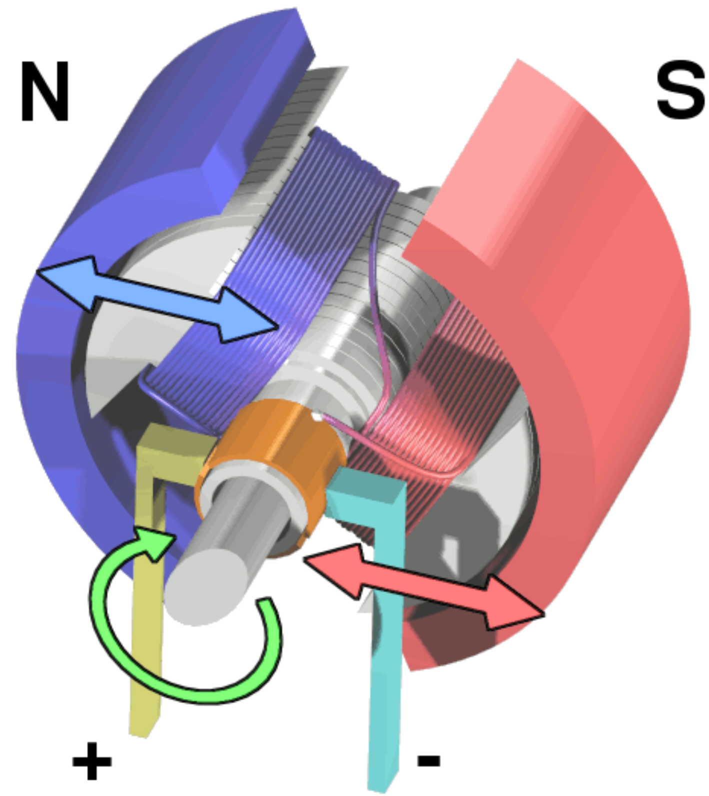
Simple Two-pole Brushed DC Motor [5]

Brushed DC Motors

Most automatic car windows and seat adjustments are operated by a brushed DC Motor.

➢ The brushed motor has been an automotive industry favorite because of its relatively low cost and simple design.

➢ A brushed DC Motor comes in all different sizes, and torque and speed specifications.



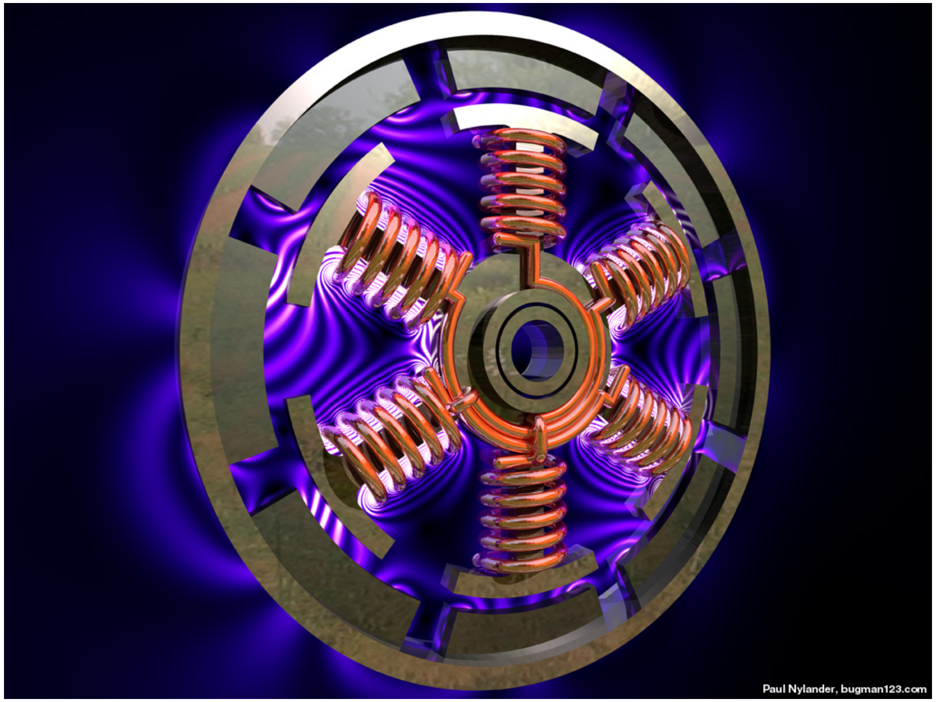
Simple Two-pole Brushed DC Motor [5]

Brushless DC Motors

Brushless DC motors generally employ a permanent magnet on the rotor and the windings are on the stator.

- Electronic controls are used to change the polarity of the current in the windings.

- Sensors monitor the position of the rotor and feed this information back to the electronic controls

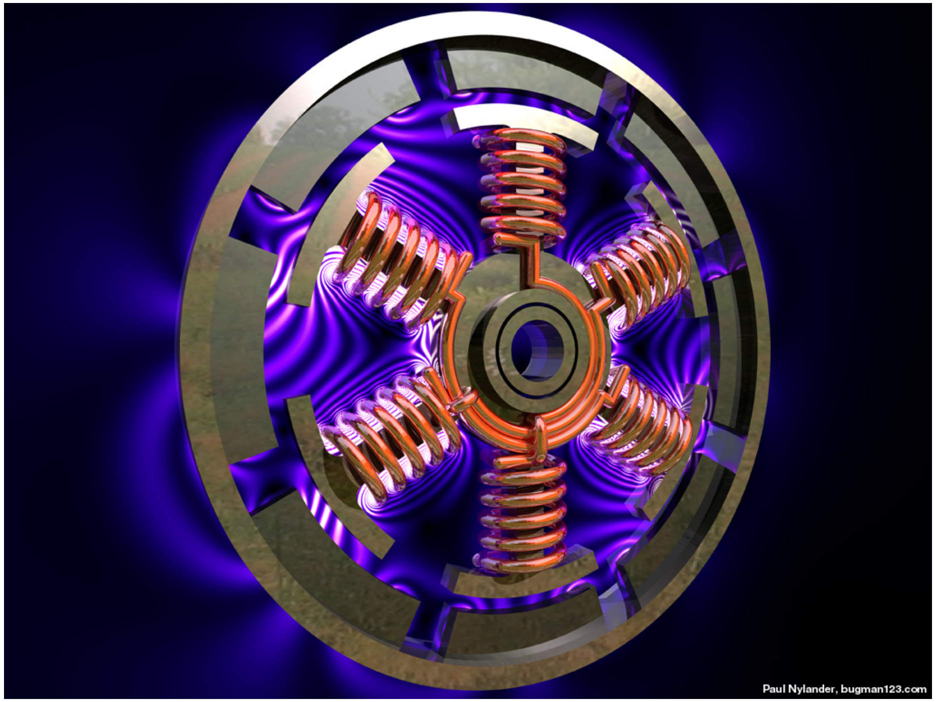


Brushless DC Motor [6]

Brushless DC Motors

Brushless DC motors are more akin to synchronous AC motors than to brushed DC motors.

DC motors transfer direct current to the mechanical energy. Until recently, most electric cars were built using DC motors.

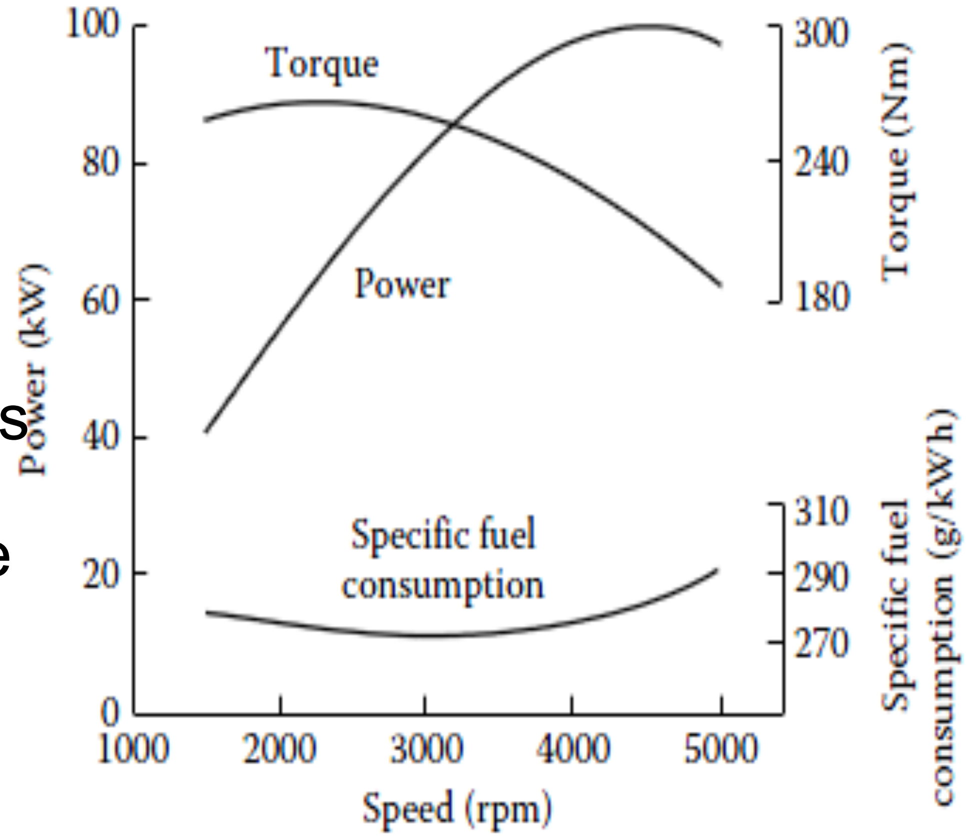


Brushless DC Motor [6]

Ground Vehicles With Mechanical Powertrains and the Reasons for HEV Development

IC engines are the most commonly used power plants for land vehicles to date.

The figure to the right shows representative characteristics of a gasoline engine, which has torque-speed characteristics far from the ideal performance characteristics required by traction.

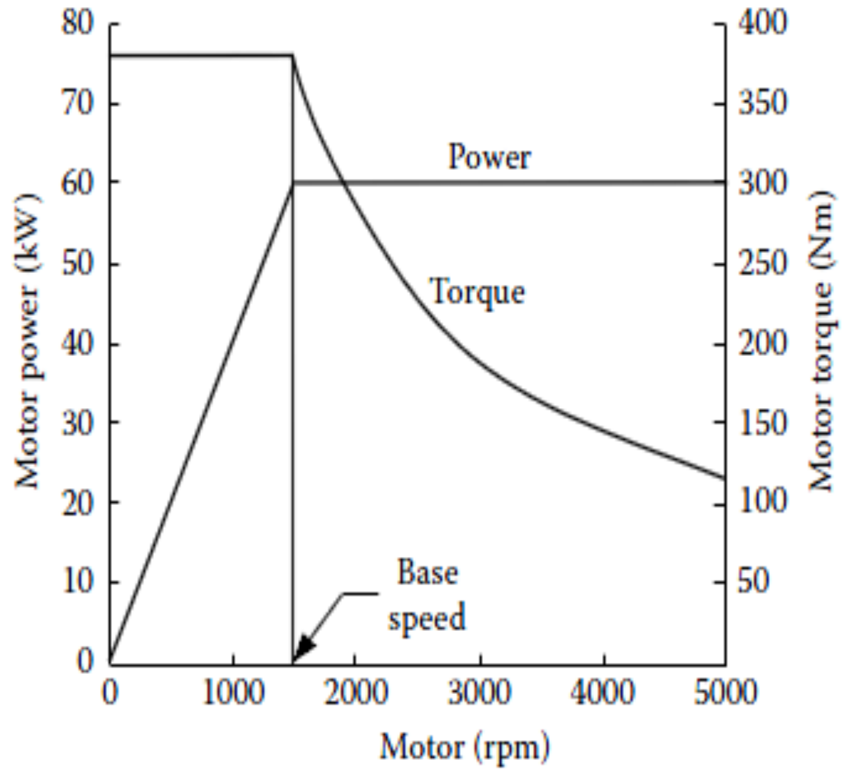


Typical performance characteristics of gasoline engines. [7]

Ground Vehicles With Mechanical Powertrains and the Reasons for HEV Development

The electric motor is another candidate as a vehicle power plant.

➢ Electric motors with good speed adjustment control usually have a speed-torque characteristic that is much closer to the ideal.



Typical performance characteristics of electric motors for traction [7]

References

[1] William J. Fleming, “Overview of Automotive Sensors”, IEEE SENSORS JOURNAL, VOL. 1, NO. 4, DECEMBER 2001.

[2] http://www.micro-tronik.com/actuators_76.html

[3] http://www.cvel.clemson.edu/auto/actuators/auto-actuators.html

[4] http://low-powerdesign.com/sleibson/2011/05/01/future-cars-the-word-from-gm-at-idc%E2%80%99s-smart-technology-world-conference/

[5] http://en.wikipedia.org/wiki/Brushed_DC_electric_motor

[6] http://jahidbdk.webnode.com/products/brushless-dc-motor/

[7] Mehrdad Ehsani, Yimin Gao, Ali Emadi, Modern Electric Hybrid Electric and Fuel Cel Vehicles Fundamentals ,Theory, and, Design; Second Edition.