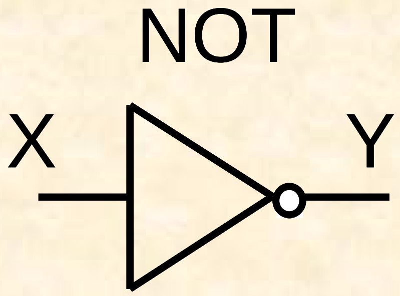
Basic Logic Gates and Basic Digital Design

- **NOT, AND, and OR Gates**
- NAND and NOR Gates
- DeMorgan's Theorem
- Exclusive-OR (XOR) Gate
- Multiple-input Gates

NOT Gate -- Inverter



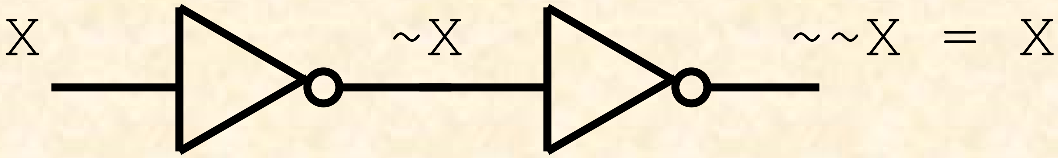
Y = ~X

X	Y
0	1
1	0

NOT

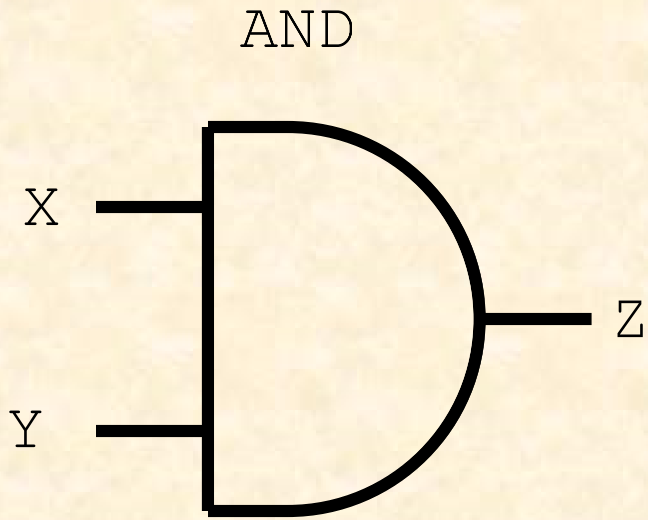
- `Y = ~X` (Verilog)
- `Y = !X` (ABEL)
- `Y =` **`not`** `X` (VHDL)
- `Y = X'`
- $Y = \neg X$
- $Y = \overline{X}$ (textook)
- **`not`**`(Y,X)` (Verilog)

NOT



X	~X	~~X
0	1	0
1	0	1

AND Gate



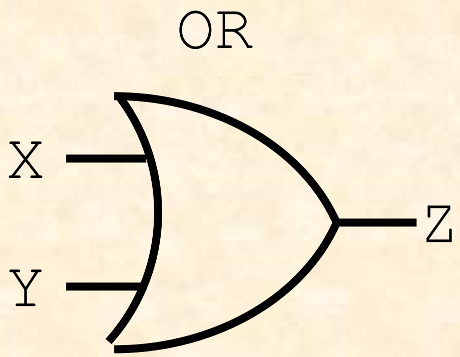
Z = X & Y

X	Y	Z
0	0	0
0	1	0
1	0	0
1	1	1

AND

- X & Y (Verilog and ABEL)
- X **and** Y (VHDL)
- X $\wedge$ Y
- X $\cap$ Y
- X * Y
- XY (textbook)
- **and**(Z,X,Y) (Verilog)

OR Gate



Z = X | Y

X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	1

OR

- X | Y (Verilog)
- X # Y (ABEL)
- X **or** Y (VHDL)
- X + Y (textbook)
- X **V** Y
- X **U** Y
- **or**(Z,X,Y) (Verilog)

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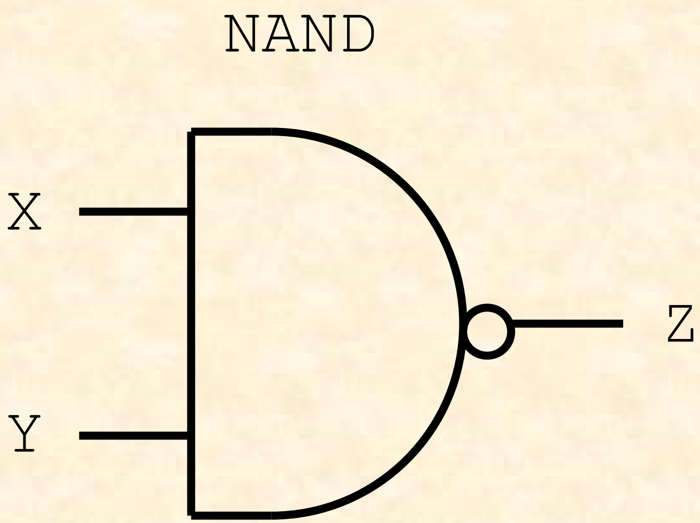
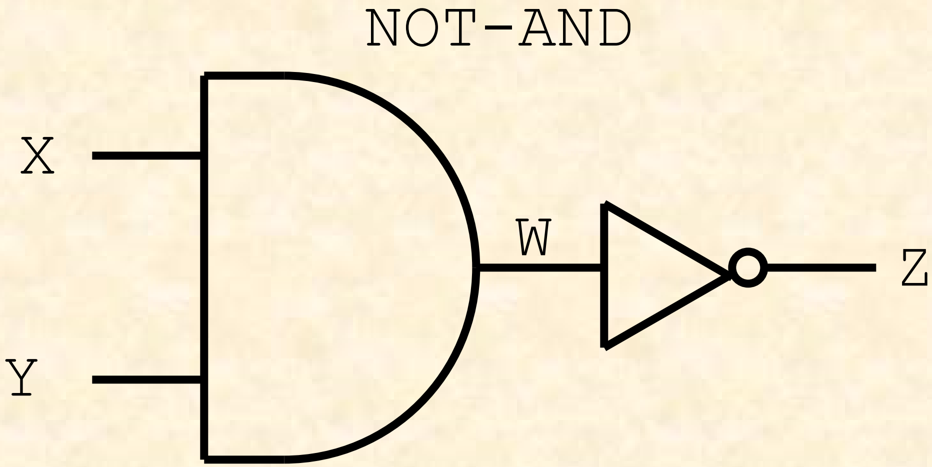
NAND Gate



X	Y	Z
0	0	1
0	1	1
1	0	1
1	1	0

```
Z = ~(X & Y)
nand(Z,X,Y)
```

NAND Gate

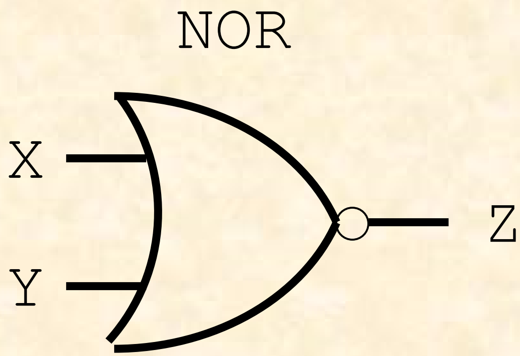


X	Y	W	Z
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

W = X & Y

Z = ~W = ~(X & Y)

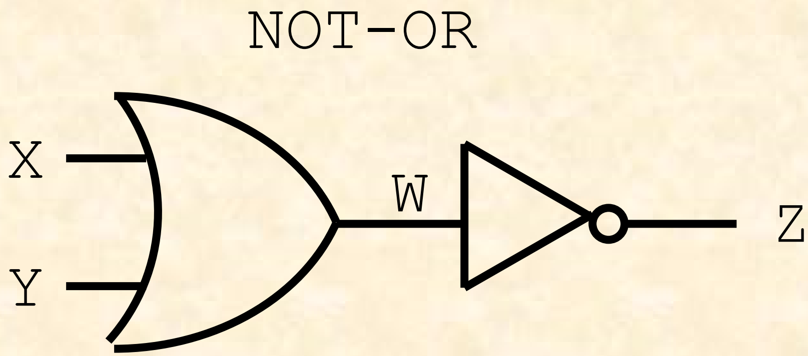
NOR Gate



X	Y	Z
0	0	1
0	1	0
1	0	0
1	1	0

```
Z = ~(X | Y)
nor(Z,X,Y)
```

NOR Gate



X	Y	W	Z
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

W = X | Y

Z = ~W = ~(X | Y)

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and Basic Digital Design

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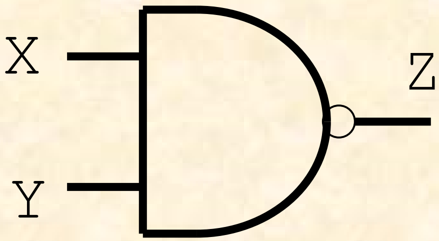
NAND Gate



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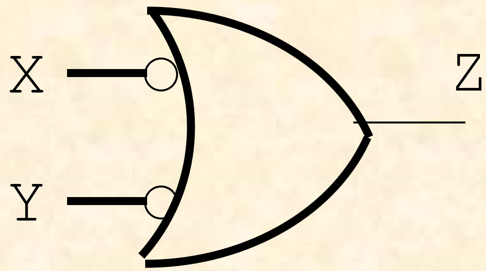


Z = ~(X & Y)

Z = ~X | ~Y

X	Y	W	Z
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

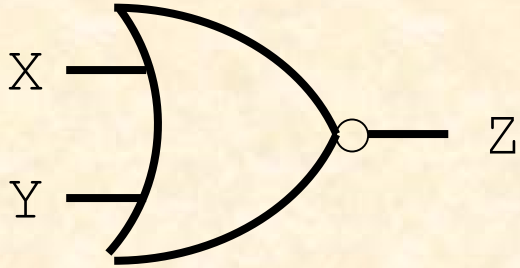
X	Y	~X	~Y	Z
0	0	1	1	1
0	1	1	0	1
1	0	0	1	1
1	1	0	0	0

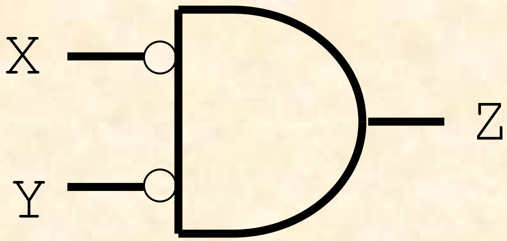
De Morgan’s Theorem-1

```
~(X & Y) = ~X | ~Y
```

- NOT all variables
- Change & to | and | to &
- NOT the result

NOR Gate





Z = ~(X | Y)

X	Y	Z
0	0	1
0	1	0
1	0	0
1	1	0

Z = ~X & ~Y

X	Y	~X	~Y	Z
0	0	1	1	1
0	1	1	0	0
1	0	0	1	0
1	1	0	0	0

De Morgan's Theorem-2

```
~(X | Y) = ~X & ~Y
```

- NOT all variables
- Change & to | and | to &
- NOT the result

De Morgan’s Theorem

- NOT all variables
- Change & to | and | to &
- NOT the result
- --
- ~X | ~Y = ~(~~X & ~~Y) = ~(X & Y)
- ~(X & Y) = ~~(~X | ~Y) = ~X | ~Y
- ~X & !Y = ~(~~X | ~~Y) = ~(X | Y)
- ~(X | Y) = ~~(~X & ~Y) = ~X & ~Y

Basic Logic Gates and Basic Digital Design

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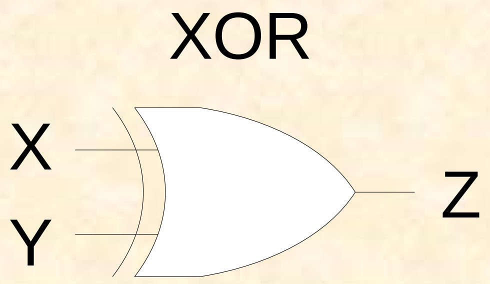
- **Exclusive-OR (XOR) Gate**
- Multiple-input Gates

Exclusive-OR Gate



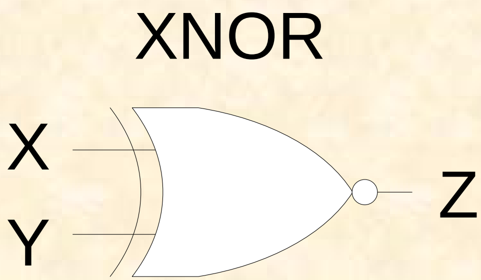

```
Z = X ^ Y
xor(Z,X,Y)
```

X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	0

XOR

- `X ^ Y` (Verilog)
- `X $ Y` (ABEL)
- `X @ Y`
- **X ⊕ Y** (textbook)
- **`xor`**`(Z,X,Y)` (Verilog)

Exclusive-NOR Gate




```
Z = ~(X ^ Y)
Z = X ~^ Y
xnor(Z,X,Y)
```

X	Y	Z
0	0	1
0	1	0
1	0	0
1	1	1

XNOR

- `X ~^ Y` (Verilog)
- `!(X $ Y)` (ABEL)
- `X @ Y`

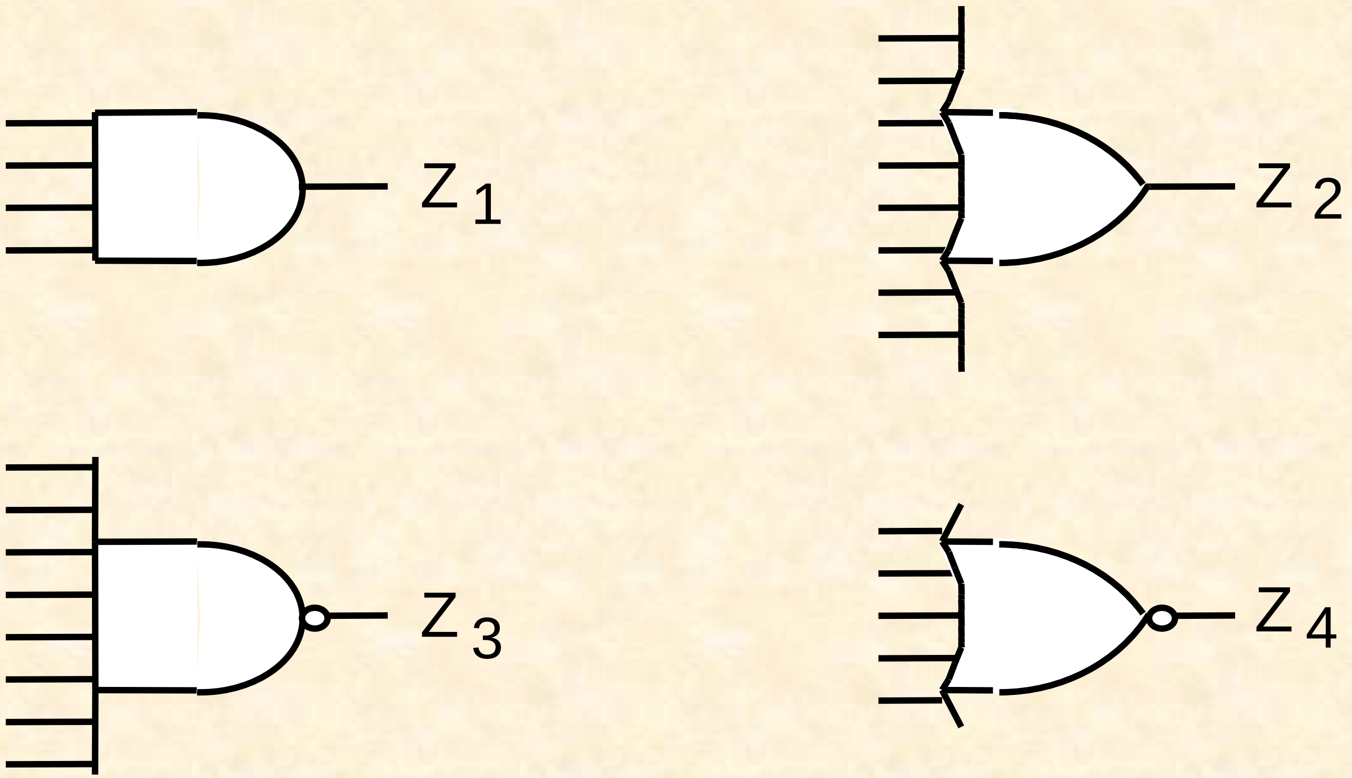
□**X** □ **Y**

- **`xnor`**`(Z,X,Y)` (Verilog)

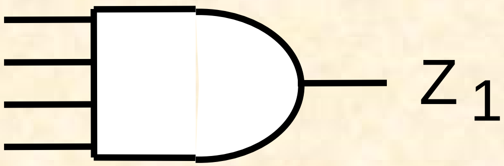
Basic Logic Gates and Basic Digital Design

- NOT, AND, and OR Gates
- NAND and NOR Gates
- DeMorgan's Theorem
- Exclusive-OR (XOR) Gate
- **Multiple-input Gates**

Multiple-input Gates



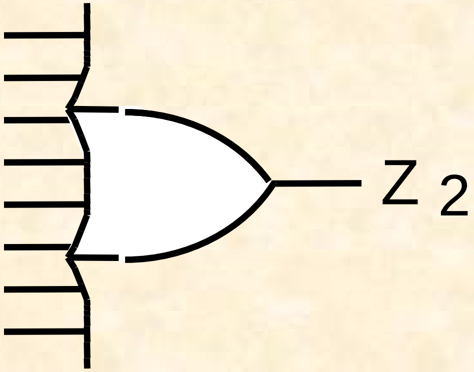
Multiple-input AND Gate



Output Z_1 is HIGH only if all inputs are HIGH

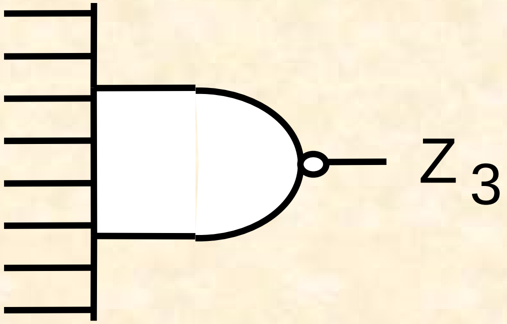
An open input will float HIGH

Multiple-input OR Gate



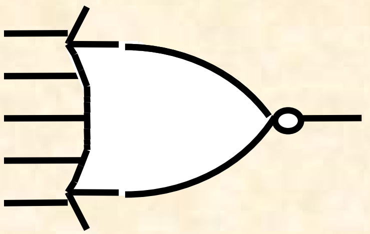
Output Z_2 is LOW only if all inputs are LOW

Multiple-input NAND Gate



Output Z_3 is LOW only if all inputs are HIGH

Multiple-input NOR Gate



Output Z_4 is HIGH only if all inputs are LOW

ANTI LOCK BRAKING

Introduction

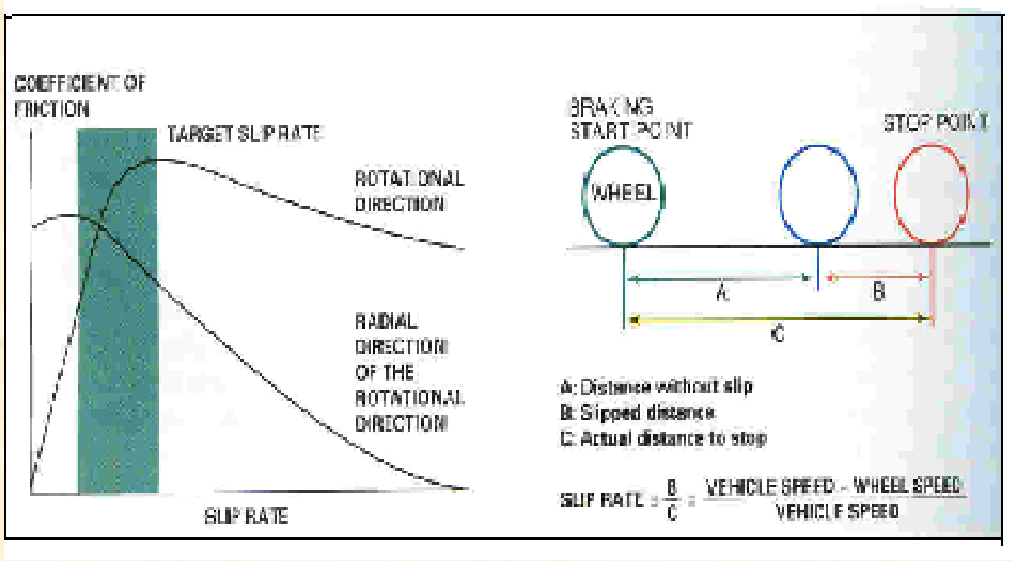
- Wheel lockup during braking causes skidding which in turn cause a loss of traction and vehicle control
- This reduces the steering ability to change direction. So the car slides out of control
- With ABS system, the driver can brake hard, take the evasive action and still be in control of the vehicle in any road condition at any speed and under any load.

Concept of ABS

- A **skidding wheel** (where the tire contact patch is sliding relative to the road) has less **traction** than a non-skidding wheel
- By keeping the wheels from skidding while you slow down, anti-lock brakes benefit you in two ways:
- You'll stop faster, and you'll be able to steer while you stop

Slip rate

- During ABS operation, the target slip rate can be from 10 to 30%.
- 0% slip means the wheel is rolling freely, while 100 % means the wheel is fully locked.
- A slip rate of 25 % means the velocity of a wheel is 25 % less than that of a freely rolling wheel at the same vehicle speed



ABS components

- <u>**Hydraulic components**</u>

1. **Accumulator**

   An accumulator is used to store hydraulic fluid to maintain high pressure in the brake system and provide the residual pressure for power assisted braking

2. **Antilock hydraulic control valve assembly**

   This assembly controls the release and application of the brake system pressure to the wheel brake assemblies .

   It may be of integral type and non integral type

3. **Booster pump**

The booster pump is an assembly of an electric motor and pump. The booster pump is used to provide pressurized hydraulic fluid ABS

4. **Booster/Master cylinder assembly**

It is referred as the hydraulic unit, contains the valves and pistons needed to modulate hydraulic pressure in the wheel circuit during the ABS operations

5. **Fluid accumulator**

accumulator temporarily stored brake fluid that is removed from the wheel brake unit during ABS cycle. This fluid is then used by pump to build pressure for the brake hydraulic system.

6. Hydraulic control unit

This assembly contains solenoid valve, fluid accumulator, pump and electric motor. The unit may have one pump and one motor or it have one motor and two pumps.

7. **Main Valve**

   This is a two position valve and is also controlled by ABS control module and is open only in the ABS mode.

8. **Modulator unit**

   The modulator unit controls the flow of pressurized brake fluid to the individual wheel circuits. Normally the modulator is made up of solenoid that open and close valves

9. **Solenoid valves**

   The solenoid valves are located in the modulator unit and are electrically operated by signals from the control module

ESP – Electronic Stability Program

What are the components of ESP?

- Sensors for monitoring vehicle-state and driver-inputs
- ESP-ECU with micro processor
- Hydraulic unit for stabilizing brake-application

ESP – Electronic Stability Program

What are the components of ESP? (2)

- The yaw sensor
  - measures the vehicle's rotation around
    its vertical axis (yaw rate)
  - uses the effect of the coriolis acceleration
  - is a micromechanical sensor

ESP – Electronic Stability Program

What are the components of ESP? (3)

- Wheel speed sensors
  - individually monitor each wheel's speed without physical contact
  - recognize wheel speeds from close
    to zero r.p.m.
  - detect the direction of

ESP – Electronic Stability Program

How does ESP work? (1)

- ESP analyzes: What is the driver‘s intention?

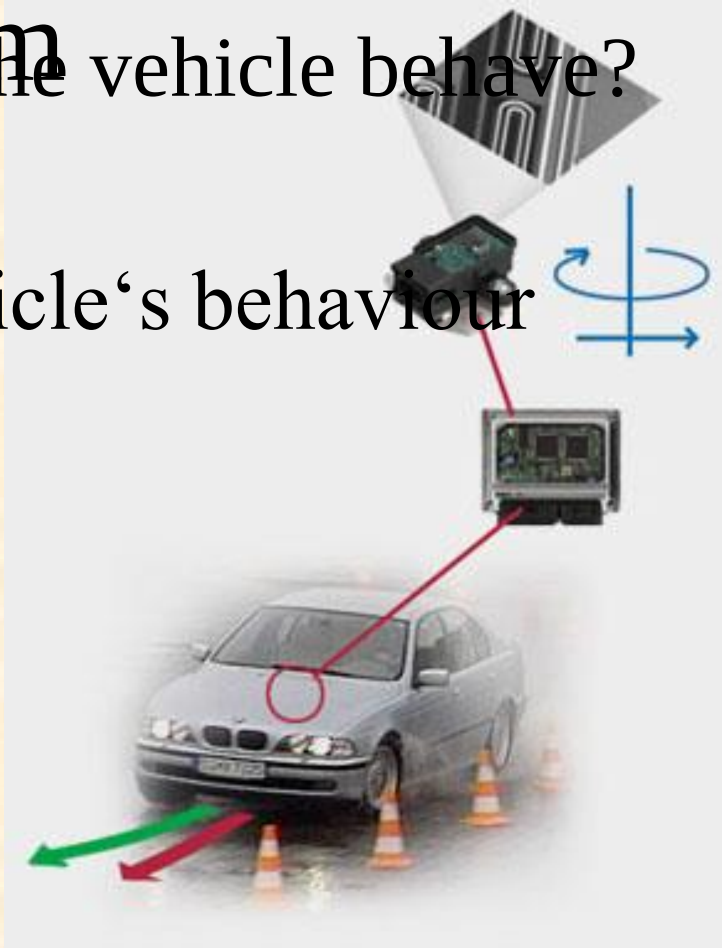
Position of the steering wheel
+ wheel speed
+ position of the accelerator
+ brake pressure

= ECU recognizes driver’s intention

ESP – Electronic Stability Program

How does ESP work? (2)

- ESP examines: How does the vehicle behave?
  Yaw speed
  + Lateral forces
  = ECU calculates the vehicle's behaviour



ESP – Electronic Stability Program

How does ESP work? (3)

- ESP acts: It ”steers“ through brake-application
- The ECU calculates the required measures
- The hydraulic unit quickly and individually supplies the brake pressure for each wheel
- In addition, ESP can reduce the engine torque via connection to the motor management

ESP – Electronic Stability Program

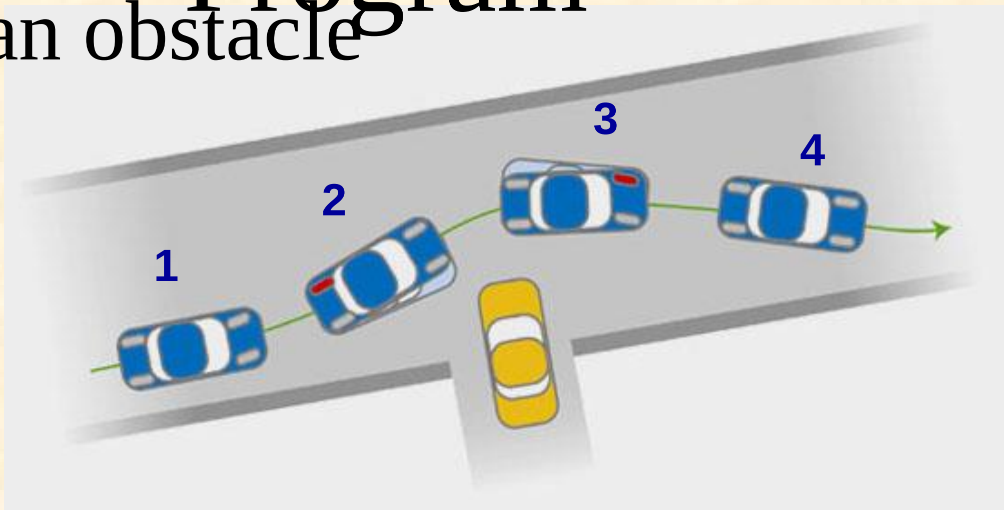
In what situations is ESP needed? (1)

- Examples:
  - Avoiding an obstacle
  - Sudden wrenching of the steering wheel
  - Driving on varying road surfaces (Longitudinal and/or lateral changes)

ESP – Electronic Stability Program

In what situations is ESP needed? (2)

- Avoiding an obstacle



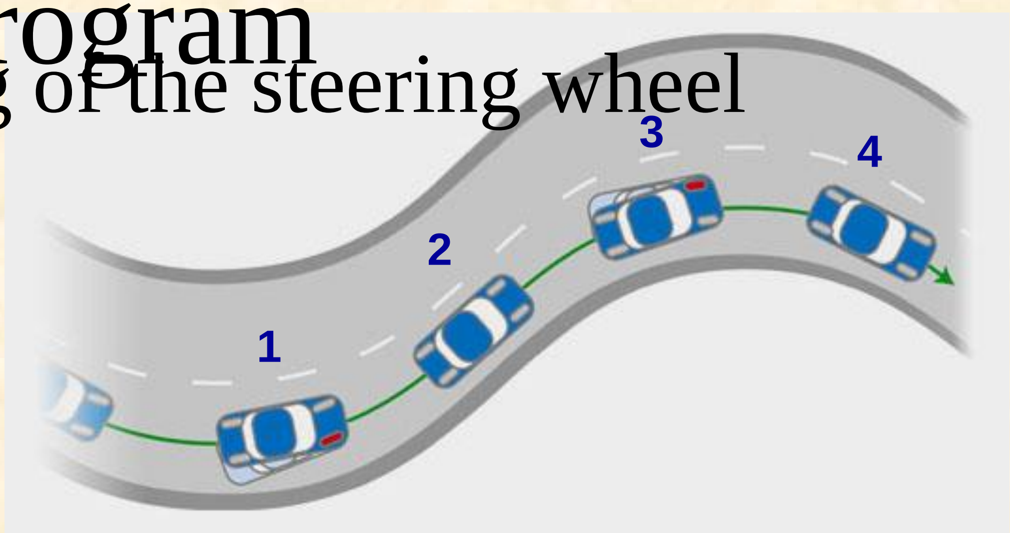
1) Hit the brakes, wrench the steering wheel: Vehicle tends to understeer

2) ESP brakes the left rear wheel, vehicle obeys steering-wheel input

ESP – Electronic Stability Program

In what situations is ESP needed? (3)

- Sudden wrenching of the steering wheel



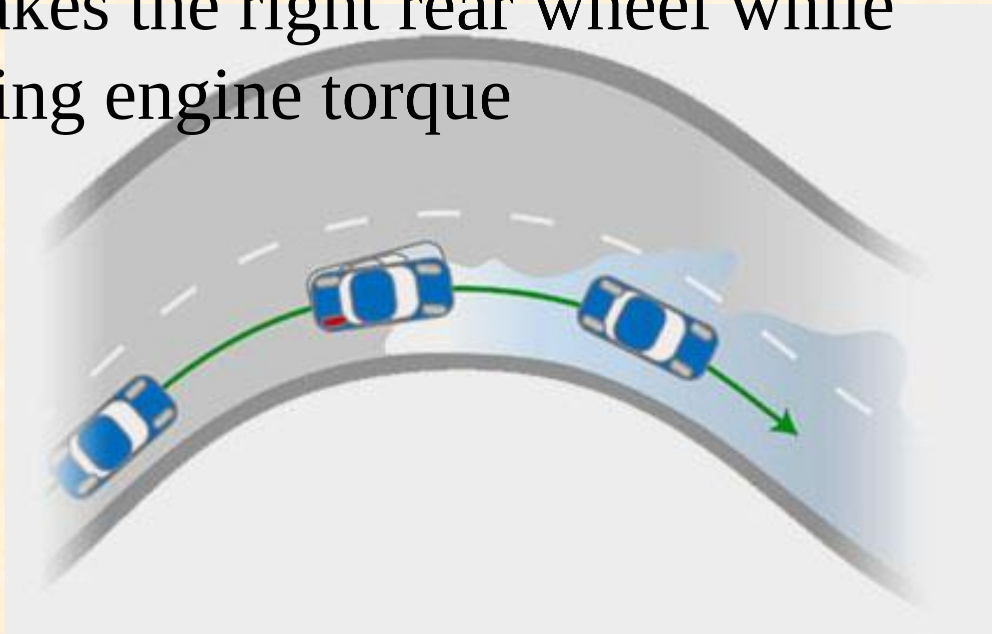
1) Vehicle tends to break away.
   Automatic breaking-pressure rise at the front right wheel
2) Vehicle is stable
3) Vehicle tends to break away.
   Automatic breaking-pressure rise at the front left

ESP – Electronic Stability Program

In what situations is ESP needed? (4)

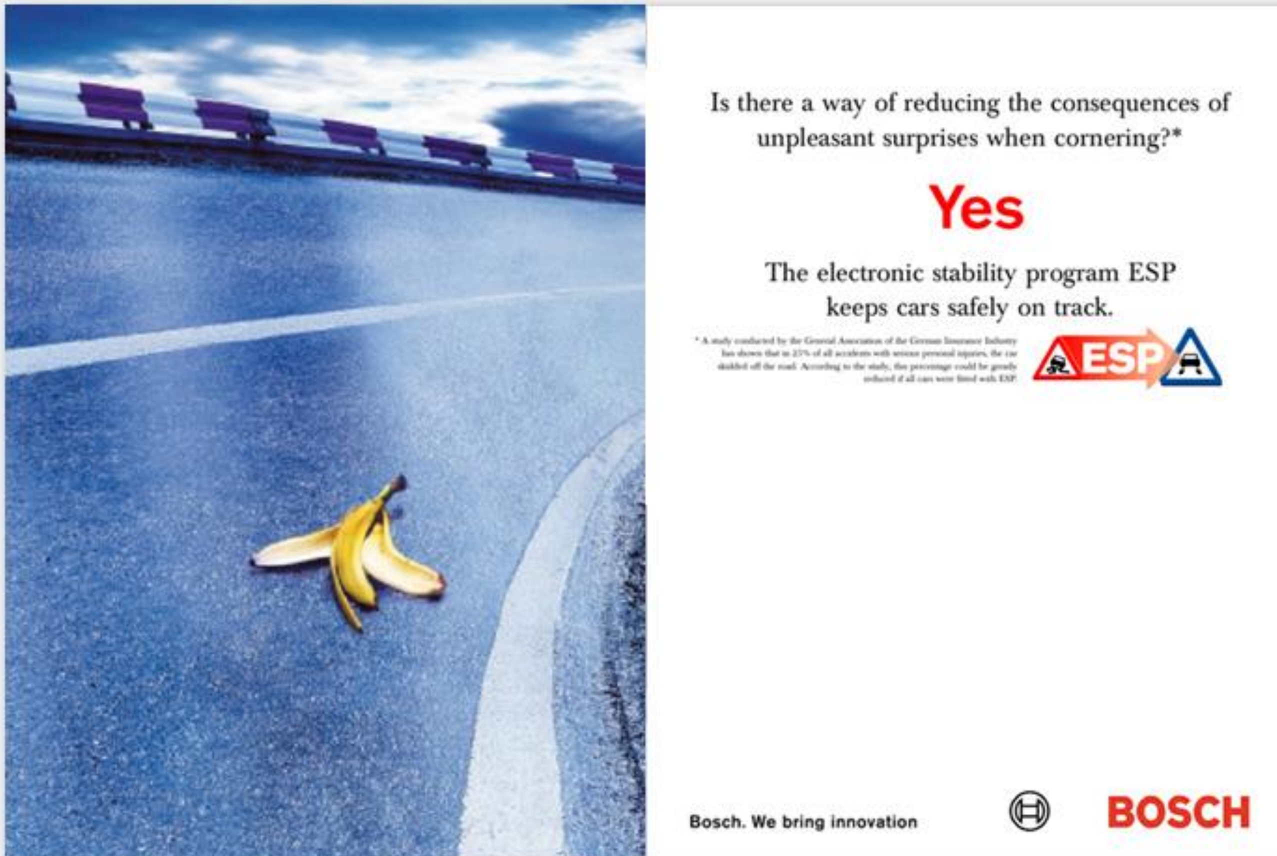
Driving on varying road surfaces

- Vehicle tends to break away (understeer):
- ESP intervenes and brakes the right rear wheel while at the same time reducing engine torque



ESP – Electronic Stability

Do you drive more safely with ESP?



FUEL INJECTION IN THE SPARK IGNITION ENGINE

Merits of Fuel Injection in the SI Engine

- **Absence of Venturi – No Restriction in Air Flow/Higher Vol. Eff./Torque/Power**
- **Hot Spots for Preheating cold air eliminated/Denser air enters**
- **Manifold Branch Pipes Not concerned with Mixture Preparation (MPI)**
- **Better Acceleration Response (MPI)**
- **Fuel Atomization Generally Improved**

Merits (Continued)

- Use of Greater Valve Overlap
- Use of Sensors to Monitor Operating Parameters/Gives Accurate Matching of Air/fuel Requirements: Improves Power, Reduces fuel consumption and Emissions
- Precise in Metering Fuel in Ports
- Precise Fuel Distribution Between Cylinders (MPI)

Merits (Continued)

- **Fuel Transportation in Manifold not required (MPI) so no Wall Wetting**
- **Fuel Surge During Fast Cornering or Heavy Braking Eliminated**
- **Adaptable and Suitable For Supercharging (SPI and MPI)**

Limitations of Petrol Injection

- High Initial Cost/High Replacement Cost
- Increased Care and Attention/More Servicing Problems
- Requires Special Servicing Equipment to Diagnose Faults and Failures
- Special Knowledge of Mechanical and Electrical Systems Needed to Diagnose and Rectify Faults

Limitations of Petrol Injection (Continued)

- **Injection Equipment Complicated, Delicate to Handle and Impossible to Service by Roadside Service Units**
- **Contain More Mechanical and Electrical Components Which May Go Wrong**
- **Increased Hydraulic and Mechanical Noise Due to Pumping and Metering of Fuel**

Limitations of Petrol Injection (Continued)

- **Very Careful Filtration Needed Due to Fine Tolerances of Metering and Discharging Components**
- **More Electrical/Mechanical Power Needed to Drive Fuel Pump and/or Injection Devices**
- **More Fuel Pumping/Injection Equip-ment and Pipe Plumbing Required- May be Awkwardly Placed and Bulky**

Indirect Injection

- Also Called Manifold Injection or Single Point Injection (SPI) or Throttle Body Injection (TBI)
- Injector Usually Upstream From Throttle (Air Intake Side) or In Some Cases Placed on the Opposite Side
- Pressures are Low – 2 to 6 Bar. Maybe Injected Irrespective of Intake Process
- Cost Would be Low

Indirect Injection (Continued)

- **Has Same Air and Fuel Mixing and Distribution Problems as Carburetor but Without Venturi Restriction so Gives Higher Engine Volumetric Efficiency**
- **Higher Injection Pressures Compared to Carburetion – Speeds up Atomization of Liquid Fuel**

Semi-direct Injection

- Also Called Port Injection or Indirect Multipoint Injection (IMPI) or Simply Multi-point Injection (MPI)
- Injectors Positioned in Each Induction Manifold Branch Just in Front of Inlet Port
- Injection at Low Pressure (2-6 Bar)
- Need Not Be Synchronized With Engine Induction Cycle

Semi-direct Injection (Continued)

- **Fuel Can Be Discharged Simultaneously to Each Induction Pipe Where it is Mixed and Stored Until IVO**

- **Need Not Be Timed – Requires Low Discharge Pressures – Injectors Not Exposed to Combustion Products so Complexity Reduced – Less Cost**

Semi-direct Injection (Continued)

- **No Fuel Distribution Difficulties Since Each Injector Discharges Directly Into Its Own Port and Mixture Moves a Short Distance Before Entering Cylinder**
- **Induction Manifold Deals Mainly With Only Inducted Air – So Branch Pipes Can Be Enlarged and Extended to Maximize Ram Effect**

Direct Cylinder Injection

- Also Called Direct Multi-point Injection (DMPI) or Gasoline Direct Injection (GDI)
- Injection May be During Intake or Compression Process
- Increased Turbulence Required
- To Compensate For Shorter Permitted Time For Injection/Atomization/Mixing Injection Pressure Must Be Higher

Direct Cylinder Injection (Continued)

- **More Valve Overlap Possible So Fresh Air Can Be Utilized For Scavenging**
- **Injector Nozzle Must Be Designed For Higher Pressure and Temperature So Must Be More Robust and Will Be Costlier Than Other Types**
- **Position and Direction of Injection Are Important – No One Position Will Be Ideal For All Operating Conditions**

Direct Cylinder Injection (Continued)

- **Air and Fuel Mixing Is More Thorough in Large Cylinders Than In Small Cylinders Because Droplet Size is the Same**
- **Condensation and Wall Wetting in Intake Manifold Eliminated But Condensation On Piston Crown and Cylinder Walls**

Major Features With Petrol Injection

- There is Separate Air and Fuel Metering

- Fuel Metering is Precise Under All Engine Operating Conditions

Methods of Discharging Fuel Into Air

1. **CONTINUOUS INJECTION**

   Injector Nozzle and Valve are Permanently Open While Engine is Operating

   Amount of Fuel Discharged as a Spray is Controlled by

a. **Varying Metering Orifice, or**
b. **Varying Fuel Discharge Pressure, or**
c. **Both**

Methods of Discharging Fuel Into Air (Continued)

2. INTERMITTENT OR PULSED INJECTION

Fuel is Sprayed at Regular Intervals With Constant Fuel Discharge Pressure

Amount of Fuel Discharged is Controlled By the Time Period the Injector Nozzle Valve is Open

Comparing Pulsed and Continuous Injection

Assume Engine Operates Between 750 (Idling) and 7500 rev/min (Max. Speed)

(1:10 ratio)

In Continuous Fuel Injection:

- **Fuel Flow has to vary by a Factor of 1:50 by Volume using Variable Area Orifice**
- **Injection Pressure has to Vary by a**

Factor of 1:2500 using Fixed Orifice

Or a Combination of Both Variables

Comparing Pulsed and Continuous Injection (Continued)

In Pulsed Fuel Injection:

- **Nozzle Valve is Opened For a Short Time When Fuel Has to Be Sprayed**
- **Fuel Flow Has to Vary by a Factor of 1:5 (Between Idle and Maximum Speed)**
- **This Range is Increased Significantly For Cold Starting Where Control Accuracy Requirement is Much Reduced**

Types of Injection For MPI

1. <u>Timed Injection</u>

Start of Fuel Delivery For Each Cylinder Occurs at the Same Angular Point in Engine Cycle – Could be 60 or 90 Deg. ATDC of Induction Stroke of Each Cyl.

2. <u>Non-timed Injection</u>

All Injectors Programmed to Discharge Fuel at Same Time. Each Piston Will be on a Different Part of the Cycle

Operation

- Injection System Must Sense Changes to Influencing Parameters
- Pass Information to a Coordinating System (Microprocessor or Computer)
- Which In Turn Integrates Individual Signals and Interprets Fuel Requirements
- Then Signals Injector to Open and Close

Operation (Continued)

- **Needs are Transmitted by Mechanical, Hydraulic or Electrical Means to Pumping and Metering Devices Which Supply Correct Quantity of Fuel to the Appropriate Injector**

Controlling Parameters to Sense

(Some of the Parameters)

1. Engine Speed
2. Amount of Inlet Air (Engine Load)
3. Throttle Position
4. Air Temperature
5. Coolant Temperature
6. Altitude
7. Cranking Speed
8. Exhaust Oxygen Concentration
9. Battery Voltage

Gasoline Fuel Injection System Components

1. Electric Fuel Pump
2. Fuel Accumulator – Maintains Fuel Line Pressure When Engine is Shut Off and Quietens the Noise Created by the Roller Cell Pump
3. Fuel Filter - A Pleated Paper or Lint-of-fluff Type Plus Strainer
4. Primary Pressure Regulator – Maintains Output Delivery Pressure to be About 5 Bar

Gasoline Fuel Injection System Components (Continued)

5 **Push Up Valve – Prevents Control Pressure Circuit Leakage.**

It is a Non-return Valve Placed at Opposite End of Pressure Regulator

6. **Fuel Injection Valve – Valves are Insulated in Holders to Prevent Fuel Vapor Bubbles Forming in the Fuel Lines Due to Engine Heat.**

Valves Open at about 3.3 Bar and Spray Fuel.

Valve Oscillates About 1500 cycles per second and so Helps in Atomization

K-Jetronic Fuel Injection System (F.I.S.) (Bosch)

This is a Driverless Mechanical F.I.S.

Fuel is Continuously Metered in Proportion to Quantity of Air Induced into Engine Cylinders

“K” Stands for the German Word for “Continuously”

K-Jetronic Fuel Injection System (F.I.S.) (Bosch) (Continued)

Considered in 3 Parts

1. **Air Flow Measurement**

2. **Fuel Supply**

3. **Metering and Injection of Fuel**

Ignition Coils

- The coil creates a high-voltage spark by electromagnetic induction.
- Many ignition coils contain two separate but electrically connected windings of copper wire.

- Other coils are true transformers in which the primary and secondary windings are not electrically connected
- The center of an ignition coil contains a core of laminated soft iron (thin strips of soft iron).

Ignition Coils (continued)

- This core increases the magnetic strength of the coil.
- Surrounding the laminated core are approximately 20,000 turns of fine wire (approximately 42 gauge).
- These windings are called the **secondary** coil windings.
- Surrounding the secondary windings are approximately 150 turns of heavy wire (approximately 21 gauge).
- These windings are called the **primary** coil windings.

Ignition Coils (continued)

- The secondary winding has about 100 times the number of turns of the primary winding, referred to as the turn ratio (approximately 100:1).
- The primary windings of the coil extend through the case of the coil and are labeled as positive and negative.
- The positive terminal of the coil attaches to the ignition switch, which supplies current from the positive battery terminal.
- The negative terminal is attached to an **electronic ignition module (or igniter)**, which opens and closes the primary ignition circuit by opening or closing the ground return path of the circuit.

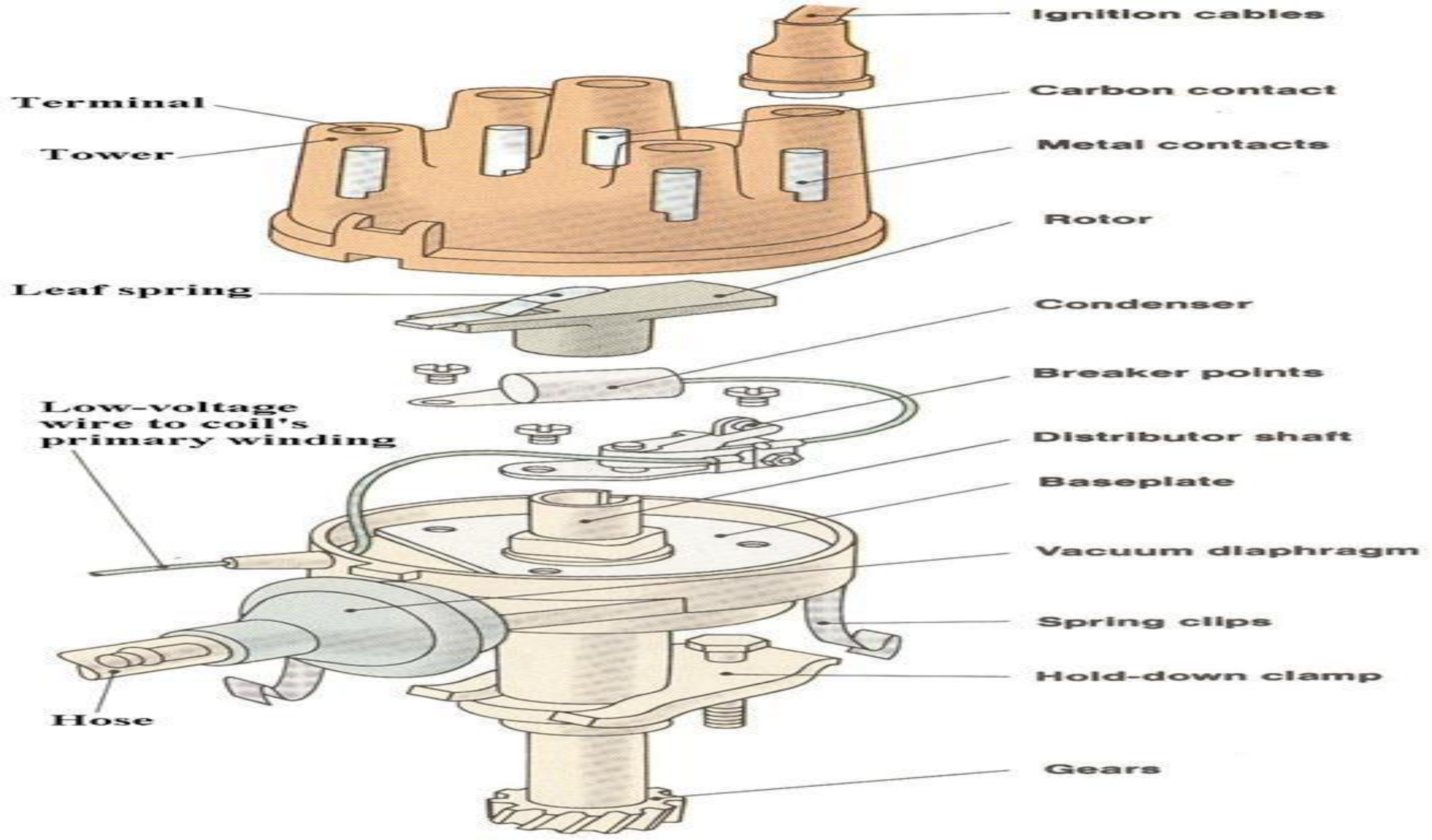
How Ignition Coils Create 40,000 Volts

- If the primary circuit is completed, current (approximately 2 to 6 A) can flow through the primary coil windings.
- This flow creates a strong magnetic field inside the coil.
- When the primary coil winding ground return path connection is opened, the magnetic field collapses and induces a voltage of from 250 to 400 volts in the primary winding of the coil and a high-voltage (20,000 to 40,000 volts) low-amperage (20 to 80 am) current in the secondary coil windings.
- This high-voltage pulse flows through the coil wire (if the vehicle is so equipped), distributor cap, rotor, and spark plug wires to the spark plugs

DISTRIBUTORLESS IGNITION

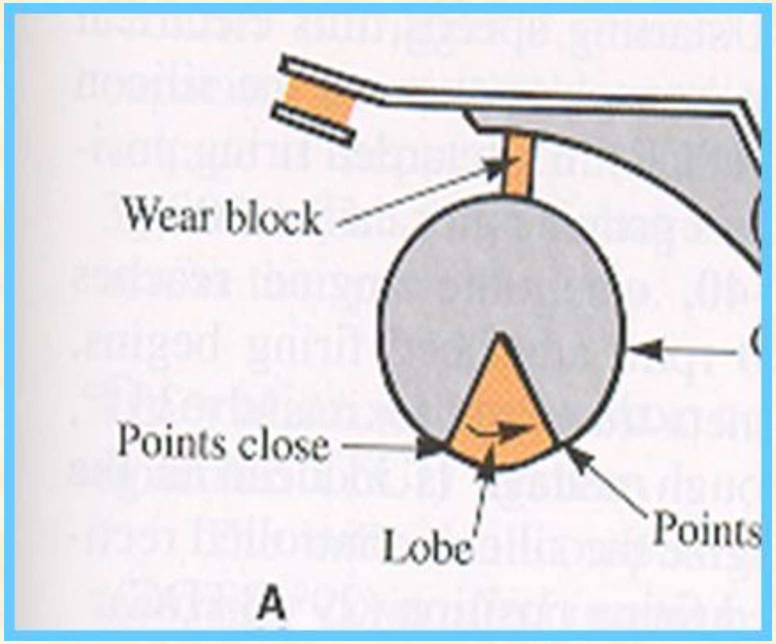
- Timing is very precise
- No mechanical parts to wear out
- Requires less maintenance
- Ignition timing is USUALLY not adjustable
- Computer relies on ignition sensors
- On-board computer controls ignition timing usually through a ignition module

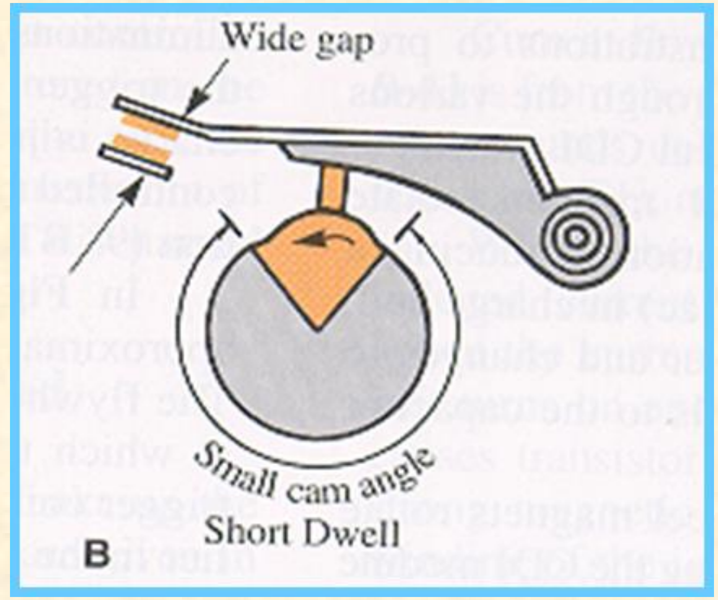
The component

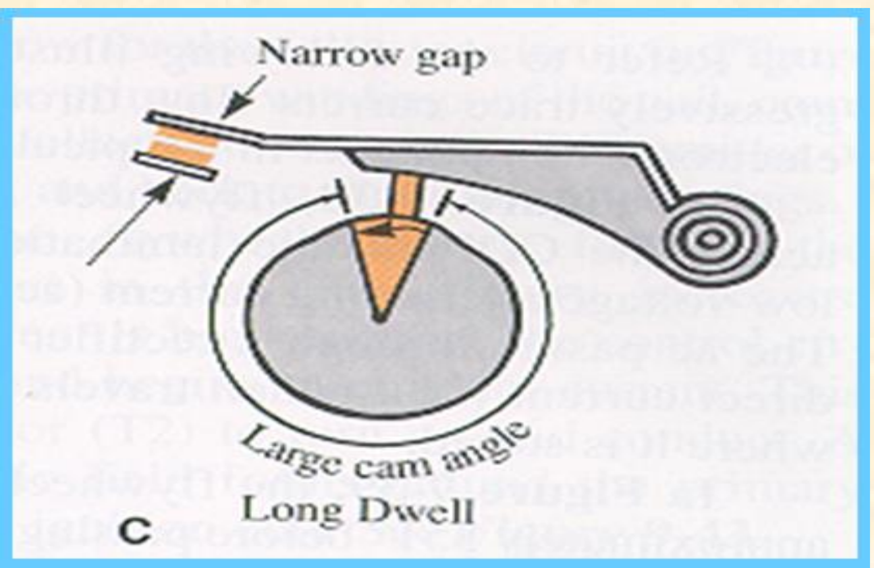


The **distributor** handles several jobs. Its first job is to distribute the high voltage from the coil to the correct cylinder. This is done by the **cap** and **rotor**. The coil is connected to the rotor, which spins inside the cap. The rotor spins past a series of contacts, one contact per cylinder. As the tip of the rotor passes each contact, a high-voltage pulse comes from the coil. The pulse arcs across the small gap between the rotor and the contact (they don't actually touch) and then continues down the spark-plug wire to the spark plug on the appropriate cylinder. When you do a tune-up, one of the things you replace on your engine is the cap and rotor -- these eventually wear out because of the arcing. Also, the spark-plug wires eventually wear out and lose some of their electrical insulation. This can be the cause of some very mysterious engine problems.

A cam in the center of the distributor pushes a lever connected to one of the points. Whenever the cam pushes the lever, it opens the points. This causes the coil to suddenly lose its ground, generating a high-voltage pulse.
The points also control the timing of the spark. They may have a **vacuum advance** or a **centrifugal advance**. These mechanisms advance the timing in proportion to engine load or engine speed.
Spark timing is so critical to an engine's performance that most cars don't use points. Instead, they use a sensor that tells the engine control unit (ECU) the exact position of the pistons. The engine computer then controls a transistor that opens and closes the current to the coil.

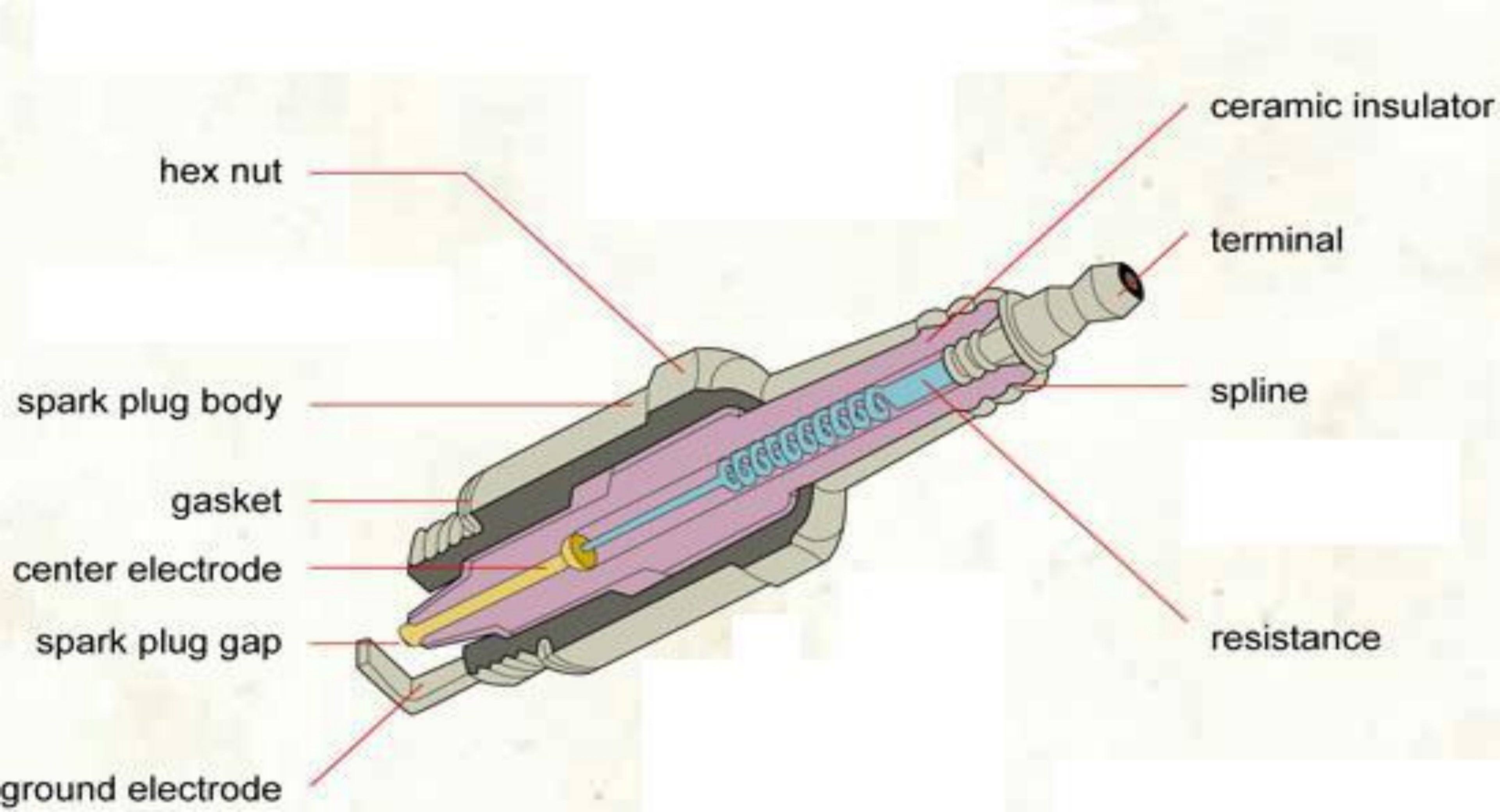






Point gap effects spark timing and Voltage Magnitude

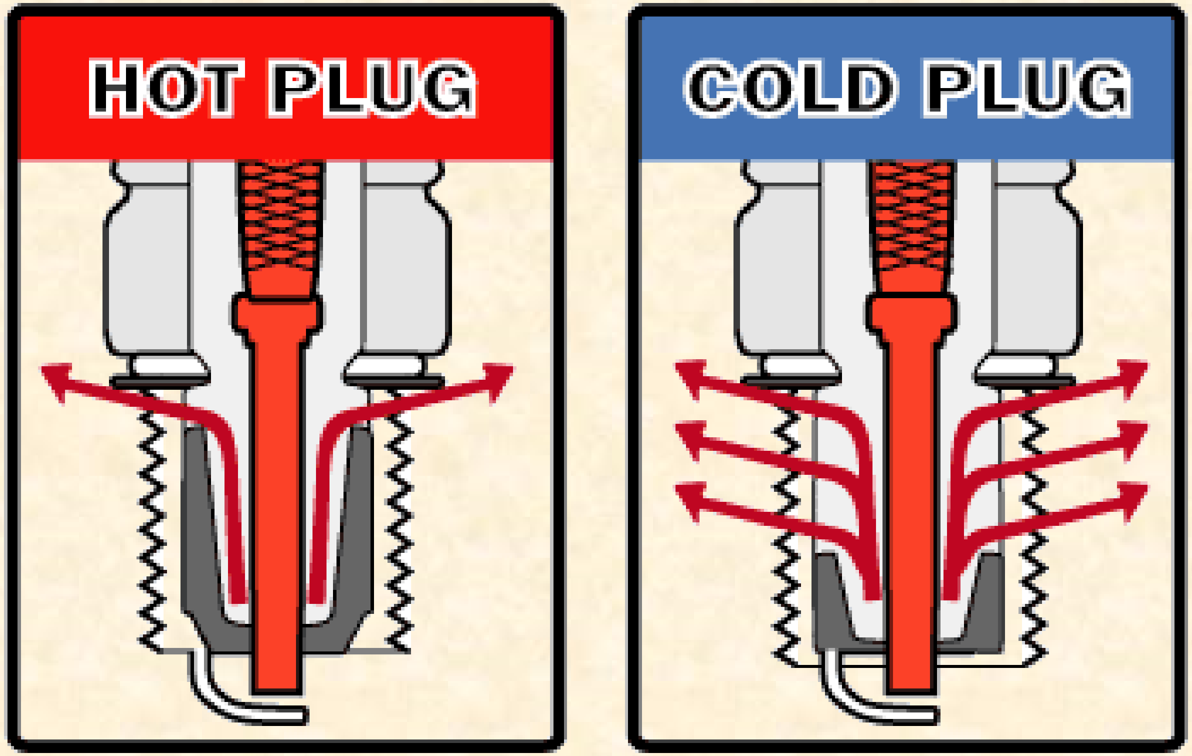
Spark Plug



ceramic insulator
hex nut
terminal
spark plug body
spline
gasket
center electrode
spark plug gap
resistance
ground electrode

Heat Ranges of Plugs

The difference between a "hot" and a "cold" spark plug is in the shape of the ceramic tip.



The difference between a "hot" and a "cold" spark plug is in the shape of the ceramtip.

The carmaker will select the right-temperature plug for each car. Some cars with high-performance engines naturally generate more heat, so they need colder plugs. If the spark plug gets too hot, it could ignite the fuel before the spark fires; so it is important to stick with the right type of plug for your car.

Spark plug construction

- **Terminal**
- The top of the spark plug contains a terminal to connect to the ignition system. The exact terminal construction varies depending on the use of the spark plug. Most passenger car spark plug wires snap onto the terminal of the plug, but some wires have spade connectors which are fastened onto the plug under a nut. Plugs which are used for these applications often have the end of the terminal serve a double purpose as the nut on a thin threaded shaft so that they can be used for either type of connection. These are a necessary part of the spark plug.

Insulator

The main part of the insulator is made from porcelain. Its major function is to provide mechanical support for the centre electrode, whilst insulating the high voltage. It has a secondary role, particularly in modern engines with deeply inaccessible plugs, in extending the terminal above the cylinder head so as to make it more readily accessible.

Ribs

By lengthening the surface between the high voltage terminal and the grounded metal case of the spark plug, the physical shape of the ribs functions to improve the electrical insulation and prevent electrical energy from leaking along the insulator surface from the terminal to the metal case. The disrupted and longer path makes the electricity encounter more resistance along the surface of the spark plug even in the presence of dirt and moisture. A few spark plugs have insulators that aren't ribbed, but this is rare

Seals

Because the spark plug also seals the combustion chamber or the engine when installed, the seals ensure there is no leakage from the combustion chamber. The seal is typically made by the use of a multi-layer braze because there are no braze compositions that will wet both the ceramic and metal case and therefore intermediary alloys are required.

Metal case

The metal case (or the "jacket" as many people call it) of the spark plug bears the torque of tightening the plug, serves to remove heat from the insulator and pass it on to the cylinder head, and acts as the ground for the sparks passing through the center electrode to the side electrode. As it acts as the ground, it can be harmful if touched while igniting.

Center electrode

The center electrode is connected to the terminal through an internal wire and commonly a ceramic series resistance to reduce emission of radio noise from the sparking. The tip can be made of a combination of copper. nicle. iron , or precious metal. In the late seventies, the development of engines reached a stage where the 'heat range' of conventional spark plugs with solid nickel alloy centre electrodes was unable to cope with their demands. A plug that was 'cold' enough to cope with the demands of high speed driving would not be able to burn off the carbon deposits caused by stop-start urban conditions, and would foul in these conditions, making the engine misfire. Similarly, a plug that was 'hot' enough to run smoothly in town, could actually melt when called upon to cope with extended high speed running on motorways, causing serious damage to the engine.

The answer to this problem, devised by the spark plug manufacturers, was a centre electrode that carried the heat of combustion away from the tip more effectively than was possible with a solid nickel alloy. Copper was the material chosen for the task and a method for manufacturing the Copper cored center electrode was created by Floform

The center electrode is usually the one designed to eject the electrons (the cathode) because it is the hottest (normally) part of the plug; it is easier to emit electrons from a hot surface, because of the same physical laws that increase emissions of vapor from hot surfaces (see thermionic emission). In addition, electrons are emitted where the electrical field strength is greatest; this is from wherever the radius of curvature of the surface is smallest, *i.e.* from a sharp point or edge rather than a flat surface (see corona discharge). It would be easiest to pull electrons from a pointed electrode but a pointed electrode would erode after only a few seconds. Instead, the electrons emit from the sharp edges of the end of the electrode; as these edges erode, the spark becomes weaker and less reliable

Side electrode, or ground electrode

The side electrode is made from high nickel steel and is welded to the side of the metal case. The side electrode also runs very hot, especially on projected nose plugs. Some designs have provided a copper core to this electrode, so as to increase heat conduction. Multiple side electrodes may also be used, so that they don't overlap the center electrode.

Spark plug gap

Spark plugs are typically designed to have a spark gap which can be adjusted by the technician installing the spark plug, by the simple method of bending the ground electrode slightly to bring it closer to or further from the center electrode. The belief that plugs are properly gapped as delivered in their box from the factory is only partially true, as proven by the fact that the same plug may be specified for several different engines, requiring a different gap for each. Spark plugs in automobiles generally have a gap between 0.045"-0.070" (1.2-1.8mm). But it can depend on the engine: new spark plugs might be pre-gapped for a V-8 engine, installing all 8 plugs unchanged; however if installed in a 6-cylinder engine, all (6) plugs would require re-gapping

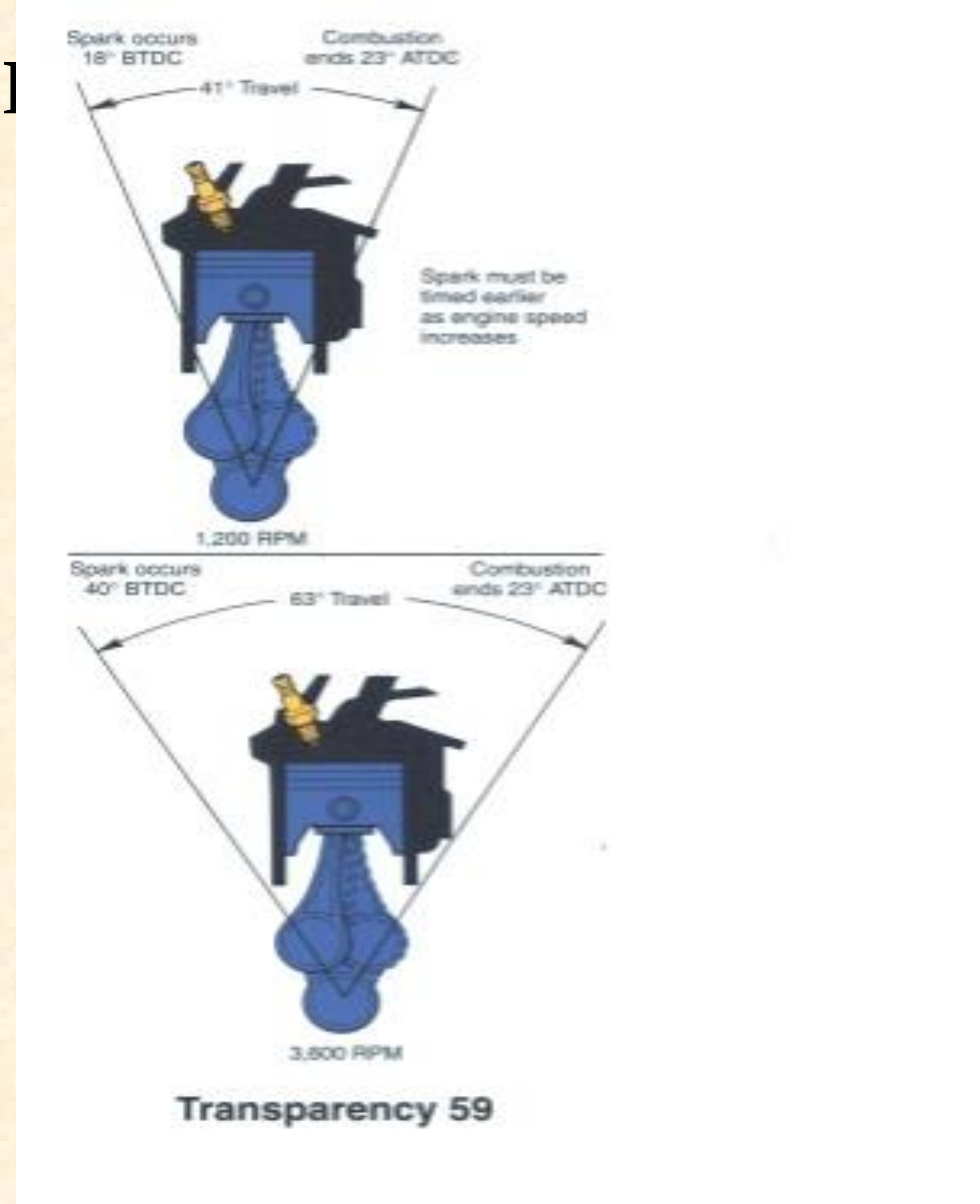
- ***Narrow-gap risk:*** spark might be too weak/small to ignite fuel;
- ***Narrow-gap benefit:*** plug always fires on each cycle;
- ***Wide-gap risk:*** plug might not fire, or miss at high speeds;
- ***Wide-gap benefit:*** spark is strong for a clean burn.

Gap gauge: A disk with sloping edge; the edge is thicker going counter-clockwise, and a spark plug will be hooked along the edge to check the gap

A *spark plug gap gauge* is a disc with a sloping edge, or with round wires of precise diameters, and is used to measure the gap; use of a feeler gauge with flat blades instead of round wires, as is used on distributor points or valve lash, will give erroneous results, due to the shape of spark plug electrodes. The simplest gauges are a collection of keys of various thicknesses which match the desired gaps and the gap is adjusted until the key fits snugly. With current engine technology, universally incorporating solid state ignitions and computerized fuel injection, the gaps used are much larger than in the era of carburetors and breaker point distributors, to the extent that spark plug gauges from that era are much too small for measuring the gaps of current cars.

Ti

- Engine Warm
- At Idle
- Defeat Advance
- #1 Plug wire



Ignition Timing

- Ignition timing refers to when the spark plug fires in relation to piston position.
- The ignition in the cylinder takes a certain amount of time usually 30 ms (3/1000 of a second).
- For maximum efficiency from the expanding gases inside the combustion chamber, the burning of the air-fuel mixture should end by about 10° after top dead center.

Engine manufacturers include timing marks on their engines, so that the technician can check and adjust the engine timing if some conditions have changed.

Ignition Timing (continued)

- If the burning of the mixture is still occurring after that point, the expanding gases do not exert much force on the piston because it is moving away from the gases.
- Therefore, to achieve the goal of having the air-fuel mixture by completely burned by the time the piston reaches 10° after top dead center (ATDC), the spark must be advanced (occur sooner) as the engine speed increases.

Checking For Spark

- If the engine is equipped with a separate ignition coil, remove the coil wire from the center of the distributor cap, install a **spark tester**, and crank the engine.
- A good coil and ignition system should produce a blue spark at the spark tester.

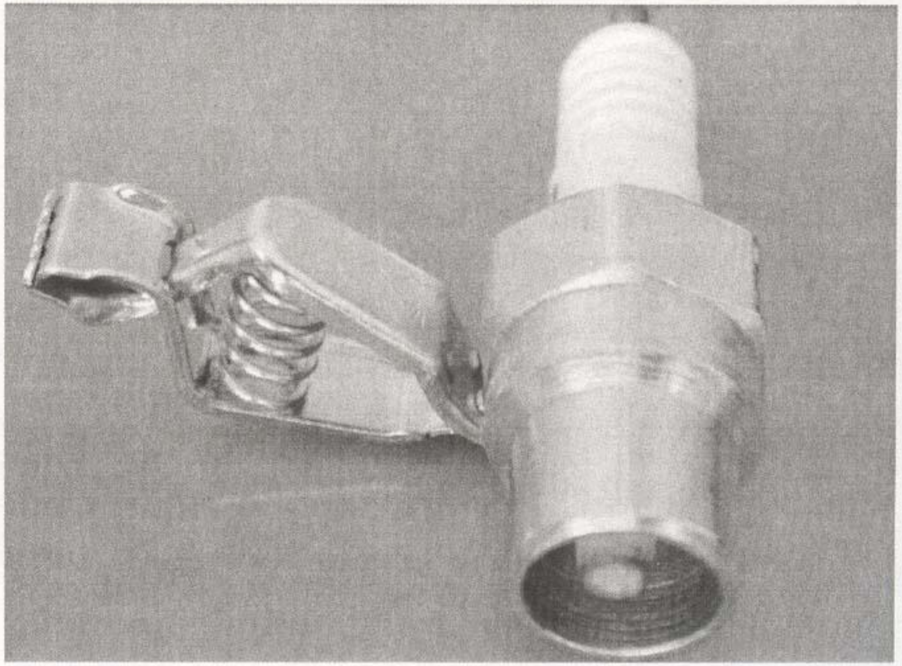


FIGURE 20-1 A spark tester looks like a regular spark plug with an alligator clip attached to the shell. This tester has a specified gap that requires at least 25,000 volts (25 kV) to fire.

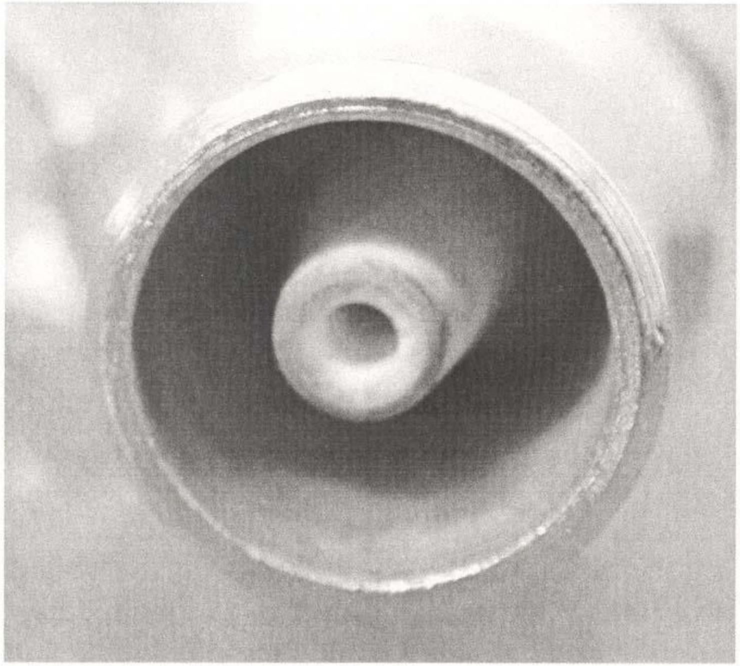


FIGURE 20-2 A close-up showing the recessed center electrode on a spark tester. It is recessed 3/8 in. into the shell and the spark must then jump another 3/8 in. to the shell for a total gap of 3/4 in.

Checking For Spark (continued)

- Typical causes of a no-spark (intermittent spark) condition include the following:
  1. Weak ignition coil
  2. Low or no voltage to the primary (positive) side of the coil
  3. High resistance or open coil wire, or spark plug wire
  4. Negative side of the coil not being pulsed by the ignition module
  5. Defective pickup coil
  6. Defective module

Automotive starter batteries (usually of lead acid type) provide a nominal 12-V by connecting six galvanic cell in series. Each cell provides 2.1 volts for a total of 12.6 volt at full charge. Lead-acid batteries are made up of plates of lead and separate plates of lead dioxide which are submerged into an electrolyte solution of about 35% sulfuric acid and 65% water This causes a chemical reaction that releases electrons , allowing them to flow through conductors to produce electricity . As the battery discharge, the acid of the electrolyte reacts with the materials of the plates, changing their surface to lead sulfate . When the battery is recharged , the chemical reaction is reversed: the lead sulfate reforms into lead oxide and lead. With the plates restored to their original condition, the process may now be repeated.

Hydraulic actuators

- Economic
- Reliable
- Able to support heavy loads
- Resistant to overloads

- Low working speed
- Hydraulic group noisy in operation
- Possible oil leakage