Section 6

Introduction to Electronic Signals

Oscilloscope

An oscilloscope displays voltage changes over time. Use an oscilloscope to view analog and digital signals when required during circuit diagnosis.

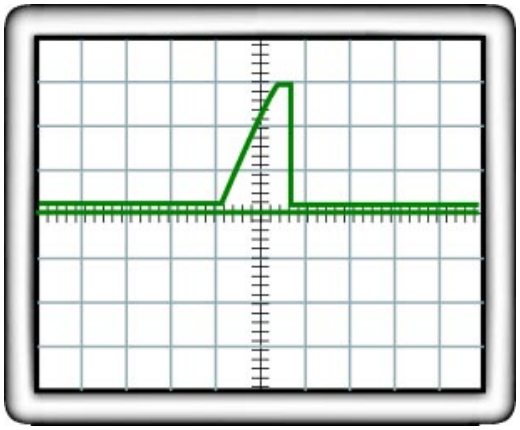

Fig. 6-01
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Input and Output Signals

An understanding of digital and analog signals will help you choose appropriate test equipment and troubleshoot effectively. Automotive circuits use two types of signals:

- INPUT - provides information about operating conditions (switches, sensors)
- OUTPUT - causes an electrical or electronic device to operate (lamps, LEDs, relays, motors)

Input and output signals can be either digital or analog, depending on the application. Electronic Control Units (ECUs) typically receive, process, and generate both analog and digital signals.

Analog Signals

A signal that represents a continuously variable voltage is an analog signal.

Variable resistors - A throttle position sensor incorporates a continuously variable resistor to generate an analog signal.

- Variable resistor changes the sensor's internal resistance with the position of the throttle.
- The voltage produced by the sensor is also continuously variable; it is an analog signal.
- The signal can be any value from 0 through battery voltage.

A fuel gauge sender is another device that uses variable resistance to send an analog signal.

Oscilloscope Display of Analog and Digital Signals

Input and output signals can be either analog or digital.

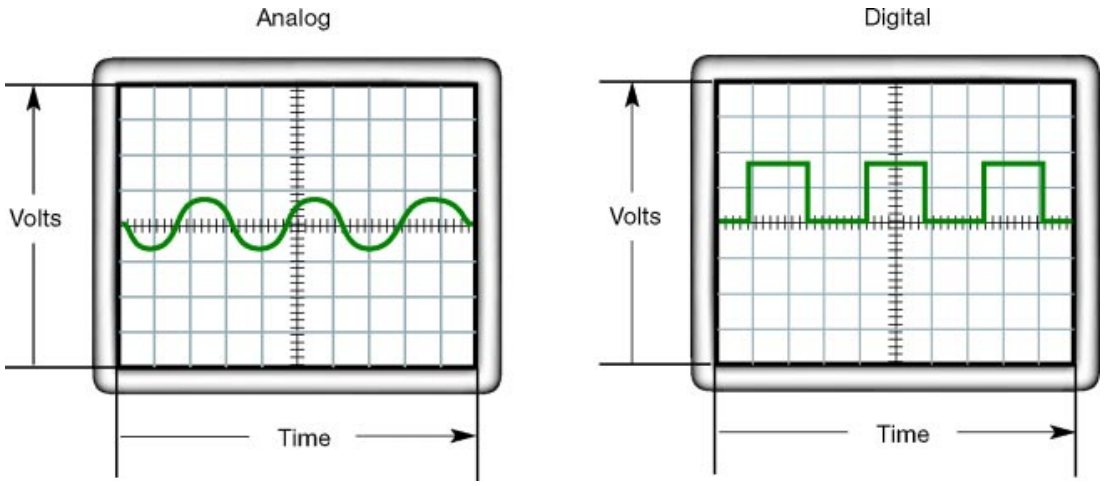

Fig. 6-02
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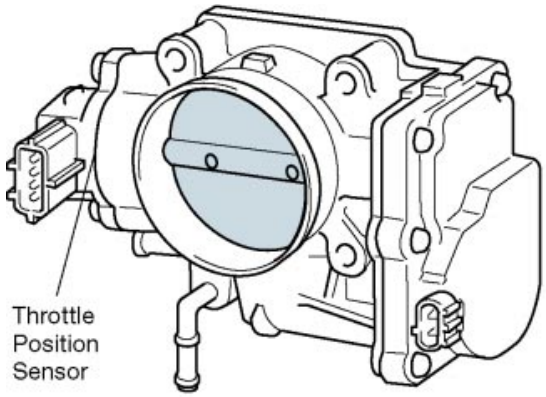
Temperature and position sensors - These sensors vary internal resistance in response to temperature or position. The signal is a varying voltage analog type.

Analog Signals

This sensor is a variable resistor that generates an analog signal.



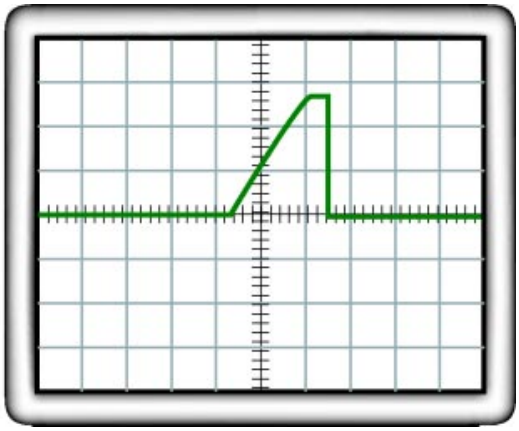


Fig. 6-03
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Digital Signals

A signal that represents just two voltage levels is a digital signal. A digital signal has only two states. The signal is not continuously variable. The two states can be expressed in various ways:

- High/Low
- ON/OFF
- 1/0

In a typical automotive electronic circuit, a digital signal is either 0 volts or + 5 volts.

Example 1 - A switch is a simple device that generates a digital signal:

- Switch open = 0 volts (also Low or OFF)
- Switch closed = 5 volts (also High or ON)

Electronic Control Units - ECUs can derive or provide information through these characteristics of a digital signal:

- Signal state (ON or OFF)
- Signal frequency (how many times per second the signal state change from high to low)
- Signal duration (how long a signal stays ON or OFF)
- Duty cycle (the percentage of time ON versus time OFF)

Digital Signal - Power Steering Pressure Switch

A switch is an example of a digital signal producing device. The output is either on or off and produces either a high or low voltage.

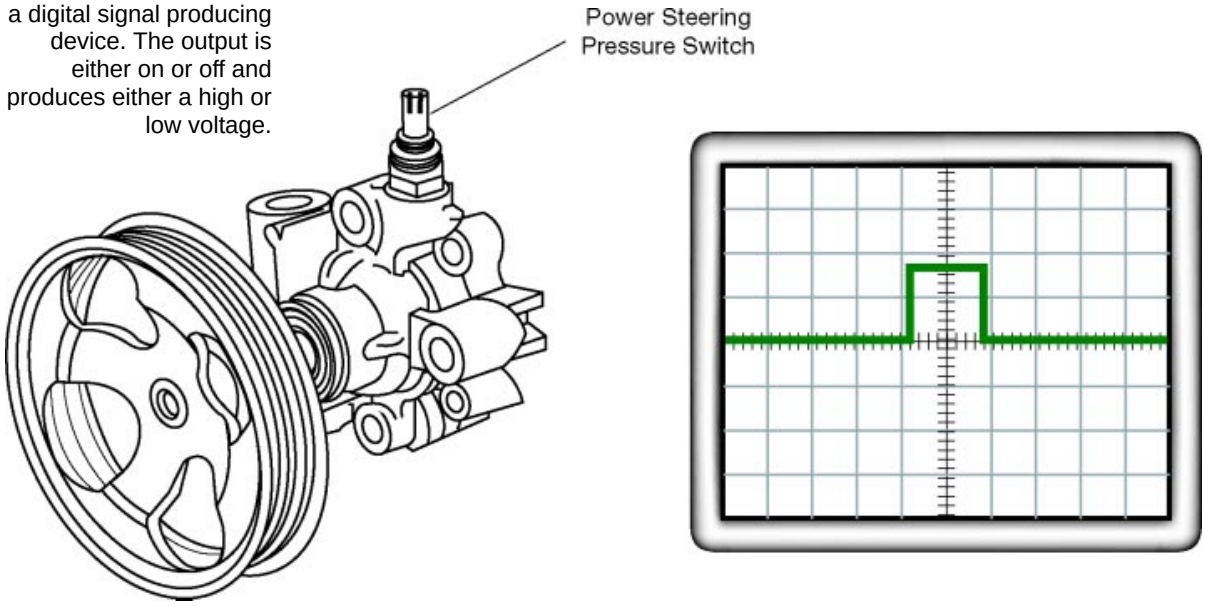

Fig. 6-04
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Electronic Control Units

Electronic Control Units monitor inputs, process input signals, and generate output signals.

Inputs - Switches and sensors send input signals to ECUs.

- These signals tell the ECU what is happening in the systems it is controlling.
- Input signals provide the ECU with information about operating conditions and driver commands.

Outputs - ECUs are used to control various systems in the vehicle:

- Engine
- Automatic transmission
- Climate control
- Cruise control
- Anti-lock braking, traction control, and VSC
- Accessory systems

One type of ECU is an Engine Control Module (ECM). A typical ECM has these input signals:

- Water temperature
- Air/fuel ratio (oxygen sensor)
- Crankshaft position
- Camshaft position
- Throttle position
- Mass air flow

An ECM processes the information from the sensors and generates output commands to devices and systems that control engine operation:

- Ignition
- Fuel

Engine Control System

An ECM processes information from sensors and generates output commands to control engine operation.

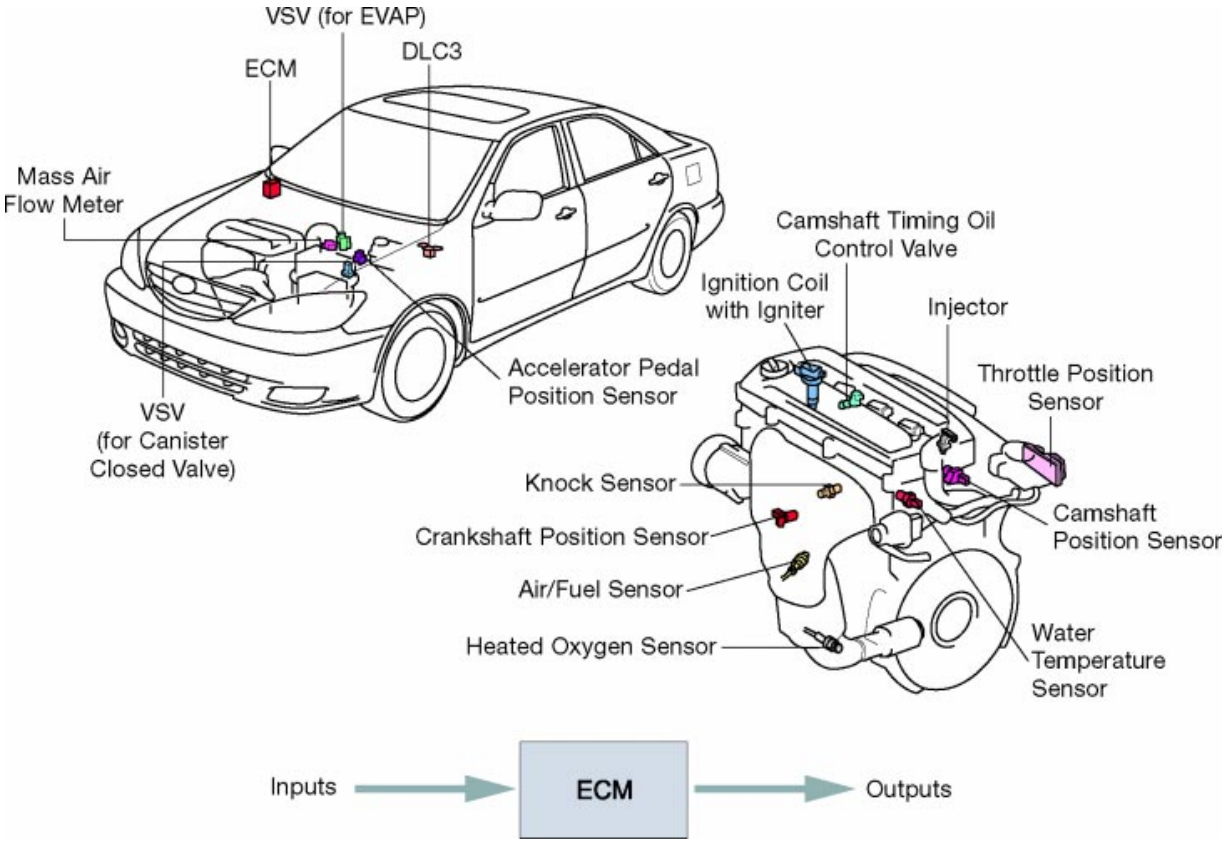

Fig. 6-05
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ECU Input - Voltage Divider

Divider Electronic Control Units monitor some sensors using a voltage divider circuit.

A voltage divider circuit is typically used to generate a voltage that is different from the supply (battery) voltage.

ECU Input - Voltage

ECU's monitor some sensors with voltage divider circuits.

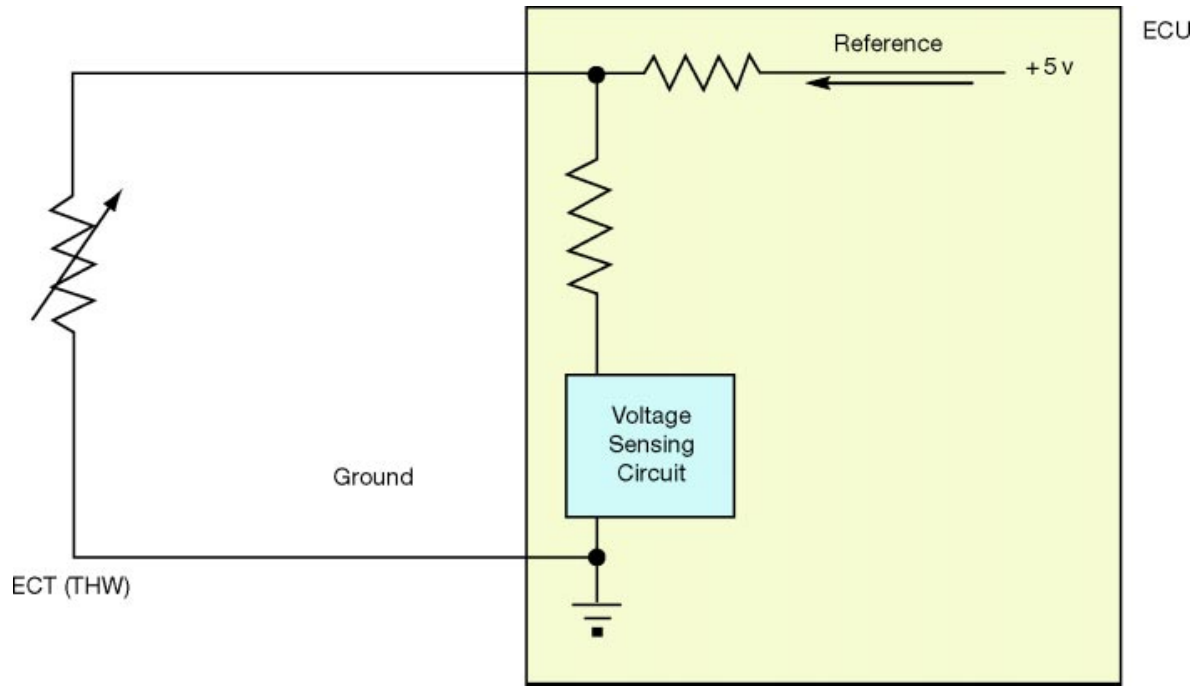

Fig. 6-06
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ECU Data Processing

How an Electronic Control Unit processes an input depends on the signal type.

Digital signals - Digital signals are in a form that ECUs can process directly.

Analog signals - ECUs typically convert an analog signal to a digital signal before processing the information. For example, an analog wheel speed sensor signal is converted to ON and OFF pulses for processing by the ABS ECU.

Look-up tables - ECUs process most input signals using look-up tables. A look-up table is a set of instructions, one for each possible condition the ECU may see. For example, if an ECM senses 200°F coolant temperature, the instruction in the look-up table may tell it to turn on the cooling fan. For 125°F coolant temperature, the instruction may be to turn off the cooling fan.

ECU Data Processing

Analog signals are converted to digital signals before being processed by an ECU.

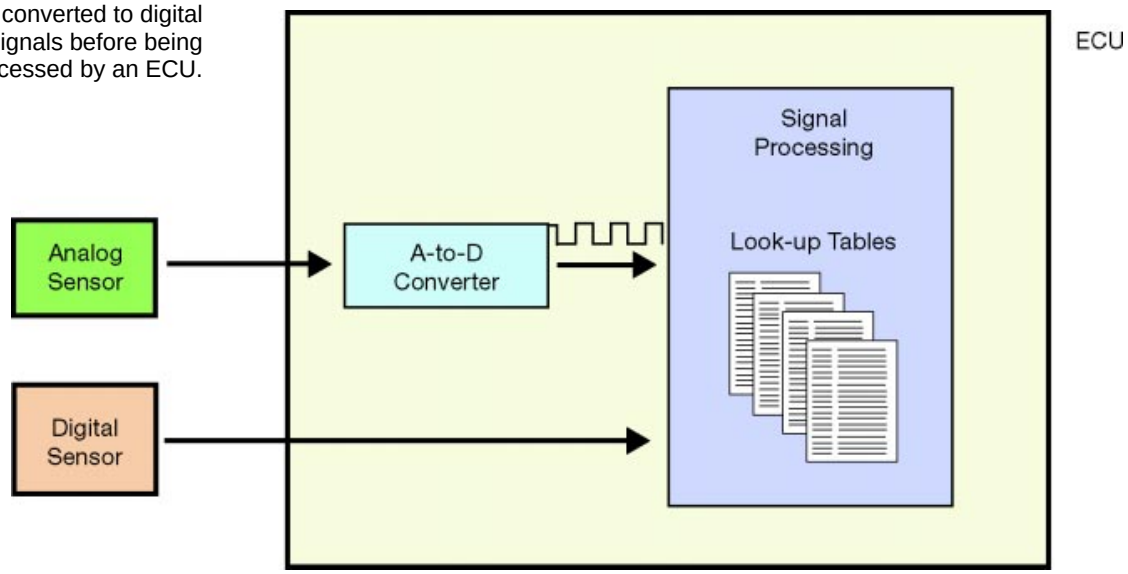

Fig. 6-07
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ECU Output Signals

ECUs operate a variety of output devices including:

- Door lock actuators
- Actuators to operate air redirection doors in climate control systems
- Indicator lamps (Check Engine, etc.)
- Ignition coil(s)

ECU Output Signals

After processing input signals, ECU's output commands to various actuator devices.

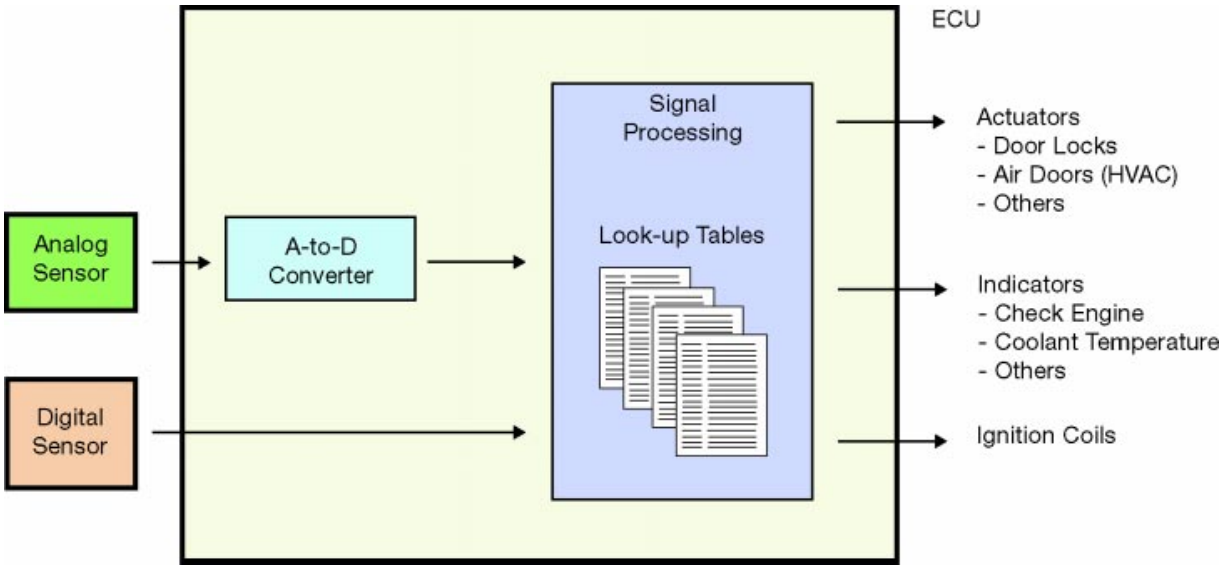

Fig. 6-08
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Troubleshooting with an Oscilloscope

Troubleshooting electronic control units consists of confirming three elements:

- Input device (sensor, switch) produces the required signals at the time they are needed;
- ECU processes input signals and produces the required output signals at the time they are needed;
- Output device responds to ECU's signals and operates correctly.

An oscilloscope, also called a "scope," constructs a visual image of an electronic signal. This image takes the form of a graph. Like any graph, an oscilloscope image shows two values:

- ON THE HORIZONTAL AXIS - The scope shows the passage of time along the horizontal axis (moving from left to right). The units of time are set by a control on the oscilloscope.
- ON THE VERTICAL AXIS - The image on the scope display shows voltage along the vertical axis. The higher the signal is from the bottom of the graph, the higher is the voltage being represented.

Oscilloscope Display

An oscilloscope displays a visual representation of an electronic signal.

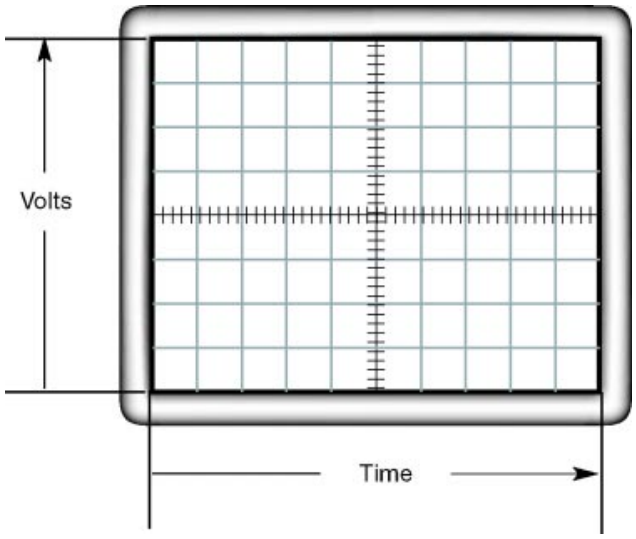

Fig. 6-09
TL623f609

An oscilloscope display provides a record of voltage over time.

Example 1 - Connect the oscilloscope leads to an automotive battery:

- Scope displays a constant horizontal line at about 12.6 volts.
- The horizontal line is constant because the voltage is not changing over time.

Oscilloscope Display - Battery Voltage

This is what battery voltage looks like on an oscilloscope display.

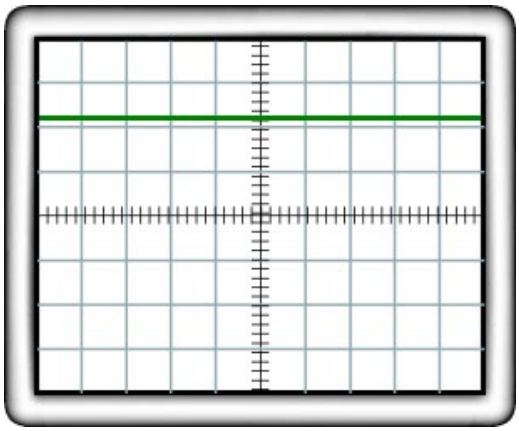

Fig. 6-10
TL623f610c

An oscilloscope display provides a record of voltage over time.

Example 2 - Connect the oscilloscope to the output of a throttle position sensor:

- Hold the throttle stationary, and the scope displays a constant horizontal line (voltage unchanging over time).
- Move the throttle from fully closed to fully open, and the scope displays a sloping horizontal line (voltage increases over time).

Oscilloscope Display - TPS Signal

This is a TPS signal on an oscilloscope display.

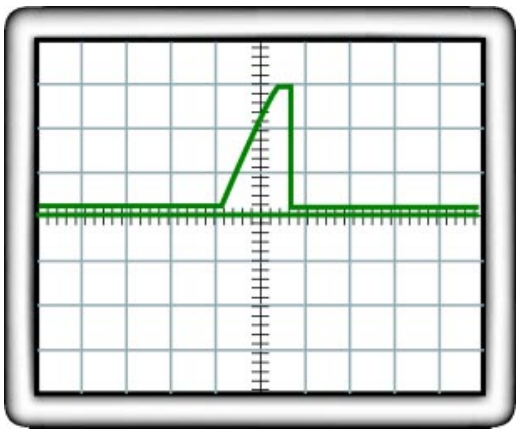

Fig. 6-11
TL623f600c

An oscilloscope display provides a record of voltage over time.

Example 3 - Connect the oscilloscope to the ground side of the cylinder # 1 fuel injector:

- Source voltage is supplied to the injector when the ignition is ON.
- The ECM controls the ground side of the circuit.
- The ECM varies the injector ON time to adjust the amount of fuel delivery.
- The ON time is viewed as the duration of time when there is 0 volts on the ground.
- The duration will vary as injector ON time changes due to fuel requirements of the engine.
- You can adjust the time setting on the scope to represent this value in a scale that is best for interpretation.

Digital signal characteristics - An oscilloscope display can represent all the characteristics of a digital signal:

- Voltage
- Frequency and pulse width (time)
- Duty cycle (time ON versus time OFF)

Oscilloscope Display - Fuel Injector Signal

This is the signal from a fuel injector.

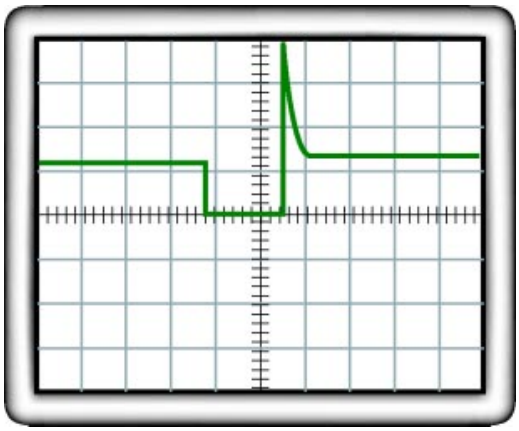

Fig. 6-12
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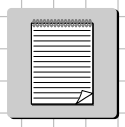

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