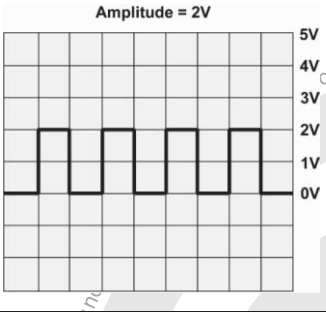
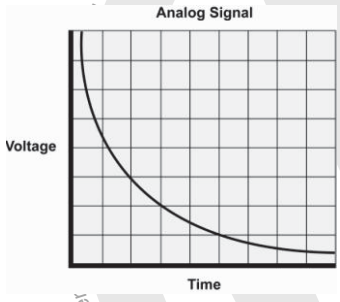
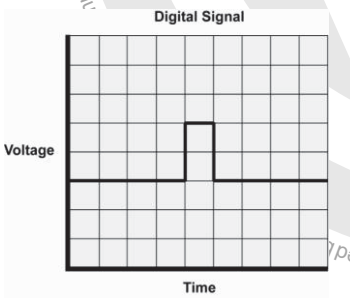
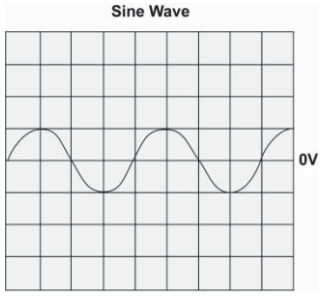
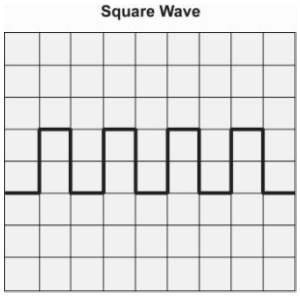
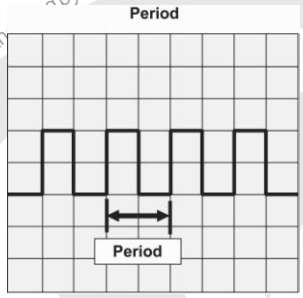
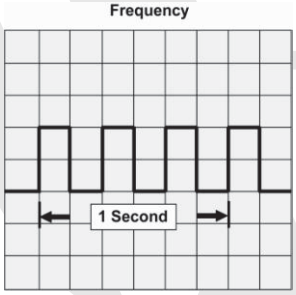
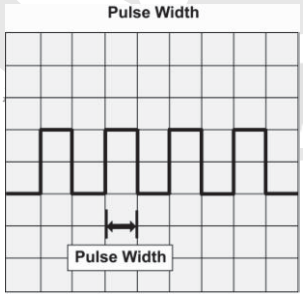
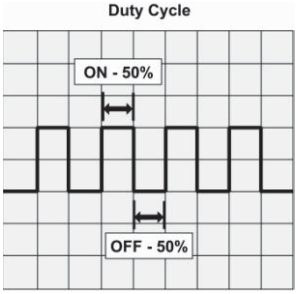
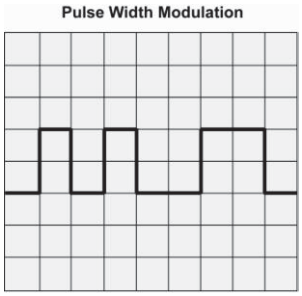
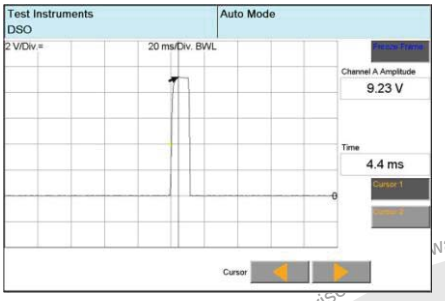
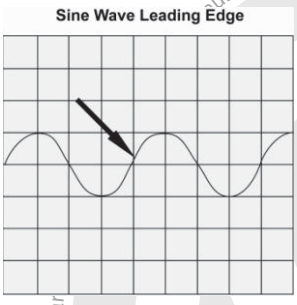
Automotive Electrical Signals Glossary

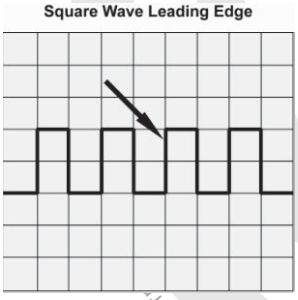
	**Amplitude:** The voltage level of a signal above or below zero volts. The signal in the example at left has an amplitude of 2V.
	**Analog Signal:** An electrical signal whose amplitude can be measured at an infinite number of positions along the waveform.
	**Digital Signal:** An electrical signal with an instantaneous change in amplitude (called a pulse) from low to high and high to low. Since the change in state is instantaneous, the amplitude can only be measured in two positions, high or low. The pulse shown at left is a positive pulse, because the normal state of the waveform is low and the pulse goes high. However, with a negative pulse, the normal state of the waveform is high and the pulse goes low.
	**Sine Wave:** An analog signal where the current reverses direction at regular intervals, also called alternating current (AC). In automotive applications, sine waves are produced by either the alternator (unrectified) or inductive sensors (such as the RPM sensor).
	**Square Wave:** A digital signal that continuously alternates between on and off. A true square wave is on and off for an equal length of time. A variation of the square wave is the rectangular wave, which is on and off for an unequal length of time, but is usually still called a square wave.

	**Period:** The time required for a signal to complete one cycle. It can be measured in seconds (s), milliseconds (ms) or microseconds (µs).
	**Frequency:** The number of times a signal repeats in one second (cycles per second), measured in Hertz (Hz). The example at left has a frequency of 3Hz. The frequency of a signal can be fixed or variable. Any sensor that measures a rotating component (such as the camshaft position sensor) generates a variable frequency signal.
	**Pulse Width:** The time that a signal remains on during one period. It can be measured in seconds (s), milliseconds (ms) or microseconds (µs). Pulse width is similar to duty cycle, except duty cycle is measured in percent (%) instead of time, see duty cycle.
	**Duty Cycle:** The percentage (%) of time a signal remains on during one period. Duty cycle is similar to pulse width, except pulse width is measured in time instead of percent, see pulse width. Duty cycle is calculated by dividing the pulse width (s, ms or µs) by the period (s, ms or µs), and then multiplying the result by 100. For example, a signal with a 50 ms pulse width and a 100 ms period has a 50% duty cycle. $\% \text{ Duty Cycle} = \frac{\text{Pulse Width}}{\text{Period}} \text{ X } 100$
	**Pulse Width Modulation (PWM):** A signal that varies the pulse width of a signal. It is also called variable duty cycle.

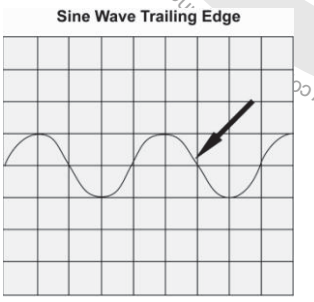


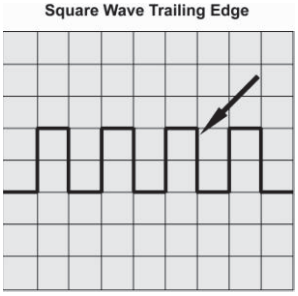
Waveform: The graphic representation of an electrical signal as displayed on an oscilloscope screen. While waveform is the preferred name, it is also called a trace or a pattern.



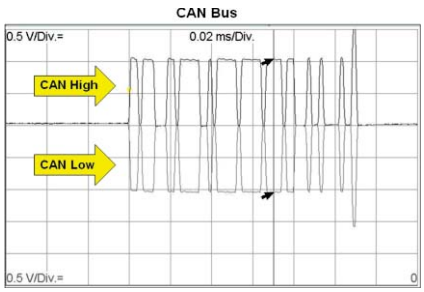
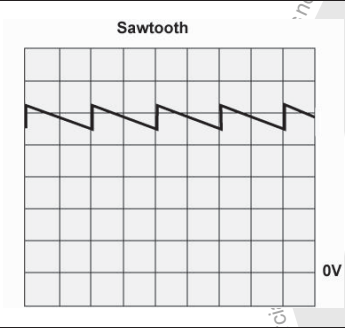


Leading Edge: When viewing a waveform, the change in vertical height at the beginning of the signal. It is also called the rising edge or positive edge.





Trailing Edge: When viewing a waveform, the decrease in vertical height at the end of a signal. It is also called the falling edge or negative edge.

 	**Networked Signals:** A signal that consists of a sequence of coded pulses (sequence of event signals) used to broadcast data between a network of control modules. The CAN and LIN busses use networked signals.
	**Sawtooth Wave:** A signal in which the amplitude instantaneously rises and then ramps down, giving the appearance of a sawtooth. Sawtooth signals are used in the hood switch circuit in late model Volkswagens.

Note: The following lists provide general information on sensors, actuators and their signals. They are not intended to account for every sensor and actuator in the vehicle, and applications include, but are not limited to, those listed.

Analyzing Automotive Electrical Signals

Three factors affect automotive signals:

- Amplitude
- Frequency
- Sequence of Events

Amplitude: On/Off, analog, pulse width modulated and duty cycle signals are characterized by the rate of change in amplitude or the time the signal remains in the high or low state. When used in sensor applications, the amplitude or pulse width (duty cycle) of a signal is varied to supply data to a control module. Thermistors, potentiometers, Hall switches and pressure sensors are commonly used in this way.

Frequency: Square and sine wave signals are examples of signals that are characterized by changes in frequency (the number of times they repeat themselves per second). In sensor applications, Hall and inductive sensors are used to provide rotational data such as RPM, CMP and wheel speed sensors.

Sequence of Events: Sequence of event signals are characterized by a series of pulses that can be compared to messages sent by Morse code. By altering the sequence of the pulses, an almost infinite number of coded messages can be quickly and accurately transmitted between different control modules. Networked signals that are used by the CAN and LIN buses are examples of sequence of event signals.

Automotive Electrical Sensors and Actuators

Analog Sensors

Thermistor: A two wire sensor that utilizes a resistor whose resistance varies with temperature. The thermistors used in most automotive applications have a Negative Temperature Coefficient (NTC), where the resistance of the thermistor decreases as the temperature increases. In a Positive Temperature Coefficient (PTC) thermistor, the resistance of the thermistor increases as the temperature increases. NTC thermistors are commonly used as temperature sensors. The temperature value is not obtained by reading the sensor resistance directly, but instead by placing a reference voltage (usually 5 volts) and ground across the sensor and then reading the resulting voltage drop.

Potentiometer: A three wire variable resistor that is used as a voltage divider. A reference voltage (usually 5 volts or battery voltage) and ground are placed across a resistance element. A wiper is moved across the element to produce an infinitely variable voltage signal from zero up to the reference voltage, which is measured on the third wire. In automotive applications, potentiometers are commonly used as position sensors for motors or measuring throttle plate position.

Inductive Sensor: A two wire sensor that measures the rotation of a shaft. Unlike other sensors, this sensor does not have an external power supply. Instead, it contains a permanent magnet that creates a magnetic field which collapses and expands when a sensor wheel is rotated through it, generating an AC sine wave signal. The frequency of the signal varies with changes in the RPM of the sensor wheel. Many crankshaft position (RPM) sensors and older ABS wheel speed sensors are inductive sensors.

Knock Sensor: A two wire sensor that is used to measure spark knock in an engine. This sensor uses a crystal material that generates an AC voltage when mechanical stress is applied to it (piezoelectric effect) when spark knock occurs. During installation, a knock sensor must be properly torqued to read spark knock correctly.

Digital Sensors

Hall Sensors and Switches: A two or three wire electronic sensor that produces a variable frequency square wave signal. Power and ground are supplied to a Hall Effect Transistor which is located in a magnetic field generated by a permanent magnet. As the magnet field is altered by moving the magnet in relation to the transistor or by moving a shutter wheel through the magnetic field, the reference voltage is alternately pulled high or low resulting in a square wave signal. Hall Sensors are often used to measure the position of rotating components such as camshaft position sensors.

Pressure Sensor: A three wire electronic sensor that converts pressure measurements into an electrical signal. Power and ground are supplied to a pressure sensing device, which then produces a PWM or analog signal relative to the measured pressure. The third wire transmits the PWM signal to the control module. While majority of automotive pressure sensors fall into this category, there are a small number of pressure sensors that use potentiometers to read pressure (such as in the Routan HVAC system).

Actuators

Solenoid: A two wire electromechanical device used to control the flow of liquids, gasses or the operation of mechanical components. To operate the solenoid, an on/off, PWM or variable frequency signal (commonly a switched ground) is supplied to a winding inside the solenoid, which in turn generates a magnetic field that moves a plunger. Depending on the design of the solenoid, the plunger may be normally open or normally closed in its rest state. A fuel injector is an example of a solenoid.

When the signal to the solenoid is switched off and the magnetic field around the winding collapses, the winding produces a phenomenon called “inductive kick”. Inductive kick is a high voltage pulse that is injected back into the control circuit and is similar in principal to the pulse produced by an ignition coil, although the voltage is much lower (generally around 30 to 60 volts).

Relay: An electromechanical switch that uses a low current input signal to control a high current output signal. It contains a winding that is used to magnetically move a set of points (switch), similar to the operation of a solenoid. When an on/off signal is supplied to the winding, a magnetic field is generated which changes the position of the switch. Depending on the design of the relay, the switch may be normally open or normally closed in its rest state. The most common type of relay is a four wire relay, which uses two wires for the control circuit and two wires for the switched circuit. Relays that use more than four wires are usually variations of this design, usually containing multiple control and switched circuits. If a relay contains logic circuits, it is generally considered a control unit although it may still be called a relay.

Like solenoids, relays also produce an inductive kick. Volkswagen relays have a built in suppression circuit consisting of a resistor placed parallel to the winding.

Motor: A device that converts electrical energy into rotational motion. On late model vehicles, the speed of most motors is controlled using PWM circuits. If a motor has low output, checking the motor amperage can determine if the problem is electrical or mechanical. Increasing the electrical resistance in a motor circuit will decrease the amperage in the circuit, while increasing the mechanical load on the motor shaft will increase the amperage in the circuit.

The direction of motor rotation can be changed by reversing the polarity of the signals to the motor.

Cautions & Warnings

Please read these WARNINGS and CAUTIONS before proceeding with maintenance and repair work. You must answer that you have read and you understand these WARNINGS and CAUTIONS before you will be allowed to view this information.

- If you lack the skills, tools and equipment, or a suitable workshop for any procedure described in this manual, we suggest you leave such repairs to an authorized Volkswagen retailer or other qualified shop. We especially urge you to consult an authorized Volkswagen retailer before beginning repairs on any vehicle that may still be covered wholly or in part by any of the extensive warranties issued by Volkswagen.

- Disconnect the battery negative terminal (ground strap) whenever you work on the fuel system or the electrical system. Do not smoke or work near heaters or other fire hazards. Keep an approved fire extinguisher handy.

- Volkswagen is constantly improving its vehicles and sometimes these changes, both in parts and specifications, are made applicable to earlier models. Therefore, part numbers listed in this manual are for reference only. Always check with your authorized Volkswagen retailer parts department for the latest information.

- Any time the battery has been disconnected on an automatic transmission vehicle, it will be necessary to reestablish Transmission Control Module (TCM) basic settings using the VAG 1551 Scan Tool (ST).

- Never work under a lifted vehicle unless it is solidly supported on stands designed for the purpose. Do not support a vehicle on cinder blocks, hollow tiles or other props that may crumble under continuous load. Never work under a vehicle that is supported solely by a jack. Never work under the vehicle while the engine is running.

- For vehicles equipped with an anti-theft radio, be sure of the correct radio activation code before disconnecting the battery or removing the radio. If the wrong code is entered when the power is restored, the radio may lock up and become inoperable, even if the correct code is used in a later attempt.

- If you are going to work under a vehicle on the ground, make sure that the ground is level. Block the wheels to keep the vehicle from rolling. Disconnect the battery negative terminal (ground strap) to prevent others from starting the vehicle while you are under it.

- Do not attempt to work on your vehicle if you do not feel well. You increase the danger of injury to yourself and others if you are tired, upset or have taken medicine or any other substances that may impair you or keep you from being fully alert.

- Never run the engine unless the work area is well ventilated. Carbon monoxide (CO) kills.

- Always observe good workshop practices. Wear goggles when you operate machine tools or work with acid. Wear goggles, gloves and other protective clothing whenever the job requires working with harmful substances.

- Tie long hair behind your head. Do not wear a necktie, a scarf, loose clothing, or a necklace when you work near machine tools or running engines. If your hair, clothing, or jewelry were to get caught in the machinery, severe injury could result.

- Do not re-use any fasteners that are worn or deformed in normal use. Some fasteners are designed to be used only once and are unreliable and may fail if used a second time. This includes, but is not limited to, nuts, bolts, washers, circlips and cotter pins. Always follow the recommendations in this manual - replace these fasteners with new parts where indicated, and any other time it is deemed necessary by inspection.

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Cautions & Warnings

- Illuminate the work area adequately but safely. Use a portable safety light for working inside or under the vehicle. Make sure the bulb is enclosed by a wire cage. The hot filament of an accidentally broken bulb can ignite spilled fuel or oil.

- Friction materials such as brake pads and clutch discs may contain asbestos fibers. Do not create dust by grinding, sanding, or by cleaning with compressed air. Avoid breathing asbestos fibers and asbestos dust. Breathing asbestos can cause serious diseases such as asbestosis or cancer, and may result in death.

- Finger rings should be removed so that they cannot cause electrical shorts, get caught in running machinery, or be crushed by heavy parts.

- Before starting a job, make certain that you have all the necessary tools and parts on hand. Read all the instructions thoroughly; do not attempt shortcuts. Use tools that are appropriate to the work and use only replacement parts meeting Volkswagen specifications. Makeshift tools, parts and procedures will not make good repairs.

- Catch draining fuel, oil or brake fluid in suitable containers. Do not use empty food or beverage containers that might mislead someone into drinking from them. Store flammable fluids away from fire hazards. Wipe up spills at once, but do not store the oily rags, which can ignite and burn spontaneously.

- Use pneumatic and electric tools only to loosen threaded parts and fasteners. Never use these tools to tighten fasteners, especially on light alloy parts. Always use a torque wrench to tighten fasteners to the tightening torque listed.

- Keep sparks, lighted matches, and open flame away from the top of the battery. If escaping hydrogen gas is ignited, it will ignite gas trapped in the cells and cause the battery to explode.

- Be mindful of the environment and ecology. Before you drain the crankcase, find out the proper way to dispose of the oil. Do not pour oil onto the ground, down a drain, or into a stream, pond, or lake. Consult local ordinances that govern the disposal of wastes.

- The air-conditioning (A/C) system is filled with a chemical refrigerant that is hazardous. The A/C system should be serviced only by trained automotive service technicians using approved refrigerant recovery/recycling equipment, trained in related safety precautions, and familiar with regulations governing the discharging and disposal of automotive chemical refrigerants.

- Before doing any electrical welding on vehicles equipped with anti-lock brakes (ABS), disconnect the battery negative terminal (ground strap) and the ABS control module connector.

- Do not expose any part of the A/C system to high temperatures such as open flame. Excessive heat will increase system pressure and may cause the system to burst.

- When boost-charging the battery, first remove the fuses for the Engine Control Module (ECM), the Transmission Control Module (TCM), the ABS control module, and the trip computer. In cases where one or more of these components is not separately fused, disconnect the control module connector(s).

- Some of the vehicles covered by this manual are equipped with a supplemental restraint system (SRS), that automatically deploys an airbag in the event of a frontal impact. The airbag is operated by an explosive device. Handled improperly or without adequate safeguards, it can be accidentally activated and cause serious personal injury. To guard against personal injury or airbag system failure, only trained Volkswagen Service technicians should test, disassemble or service the airbag system.

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Cautions & Warnings

- Do not quick-charge the battery (for boost starting) for longer than one minute, and do not exceed 16.5 volts at the battery with the boosting cables attached. Wait at least one minute before boosting the battery a second time.

- Never use a test light to conduct electrical tests of the airbag system. The system must only be tested by trained Volkswagen Service technicians using the VAG 1551 Scan Tool (ST) or an approved equivalent. The airbag unit must never be electrically tested while it is not installed in the vehicle.

- Some aerosol tire inflators are highly flammable. Be extremely cautious when repairing a tire that may have been inflated using an aerosol tire inflator. Keep sparks, open flame or other sources of ignition away from the tire repair area. Inflate and deflate the tire at least four times before breaking the bead from the rim. Completely remove the tire from the rim before attempting any repair.

- When driving or riding in an airbag-equipped vehicle, never hold test equipment in your hands or lap while the vehicle is in motion. Objects between you and the airbag can increase the risk of injury in an accident.

I have read and I understand these Cautions and Warnings.

back OK