Noise, Vibration, and Harshness

Self Study Program

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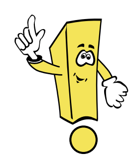

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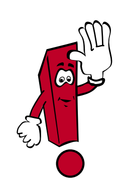

The Self-Study Program provides you with information regarding designs and functions.

The Self-Study Program is not a repair manual.

For maintenance and repair work, always refer to the current technical literature.

Course Goals

This course will enable you to:

- Identify the terminology used in diagnosing Noise, Vibration, and Harshness (NVH) concerns
- Identify the different types of NVH
- Identify the steps of the NVH systematic diagnostic approach
- Identify the road test procedures necessary to isolate a noise or vibration
- Calculate NVH frequencies necessary for component classification
- Identify test equipment and tools used in diagnosing and correcting NVH concerns
- Identify, diagnose, and specify the component causing the NVH concern

Introduction

This Self-Study Program focuses on vehicle Noise, Vibration, and Harshness (NVH), their causes and diagnostic and service procedures to locate and correct NVH concerns.

Modern cars and trucks use a combination of systems to provide the driver with the safest, most responsive, and comfortable vehicle ever built. Today's driver has come to expect a smooth and quiet ride in all operating environments. When vehicle noise, vibration, or ride harshness exceeds the driver's expectations, it is up to the technician to correct the cause of the customer's concern.

Vehicle components are being manufactured using lighter weight metals. Lighter weight metals reduce the overall vehicle weight that reduce emissions and improve fuel economy. As technologies develop stronger and more lightweight metals this trend will continue. Lighter vehicle components do not absorb noises and vibrations as well as heavier components. This leads to an increase in NVH concerns.

Diagnosing NVH concerns has been developed into a logical and almost scientific procedure. This course will provide the Volkswagen technician with concepts to help understand and diagnose NVH concerns.

Characteristics of Noise, Vibration, Harshness

Noise is defined as any unpleasant or unexpected sound created by a vibrating object.

Vibration is defined as any objectionable repetitive motion of an object, back-and-forth or up-and-down.

Harshness is defined as an aggressive suspension feel or lack of "give" in response to a single input.

Generation of Noise and Vibration

A vibrating object normally produces sound, and that sound may be an annoying noise. In the case where a vibrating body is the direct source of noise (such as combustion causing the engine to vibrate), the vibrating body or source is easy to find. In other cases, the vibrating body may generate a small vibration only.

This small vibration may cause a larger vibration or noise due to the vibrating body's contact with other parts. When this happens, attention focuses on where the large vibration or noise occurs while the real source often escapes notice.

An understanding of noise and vibration generation assists with the troubleshooting process. The development of a small noise into a larger noise begins when a vibration source (compelling force) generates a vibration. Resonance amplifies the vibration with other vehicle parts. The vibrating body (sound generating body) then receives transmission of the amplified vibration.

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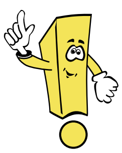
Sounds and Sound Waves

A sound wave's cycle, period, frequency, and amplitude determine the physical qualities of the sound wave. The physical qualities of sound are:

- Audible range of sound
- Pitch
- Intensity

All people have different capabilities for hearing sound. Some people may not hear sounds that other people can hear. Keep these facts in mind while diagnosing noise concerns. Most customers become tuned into a noise after hearing it repetitively.



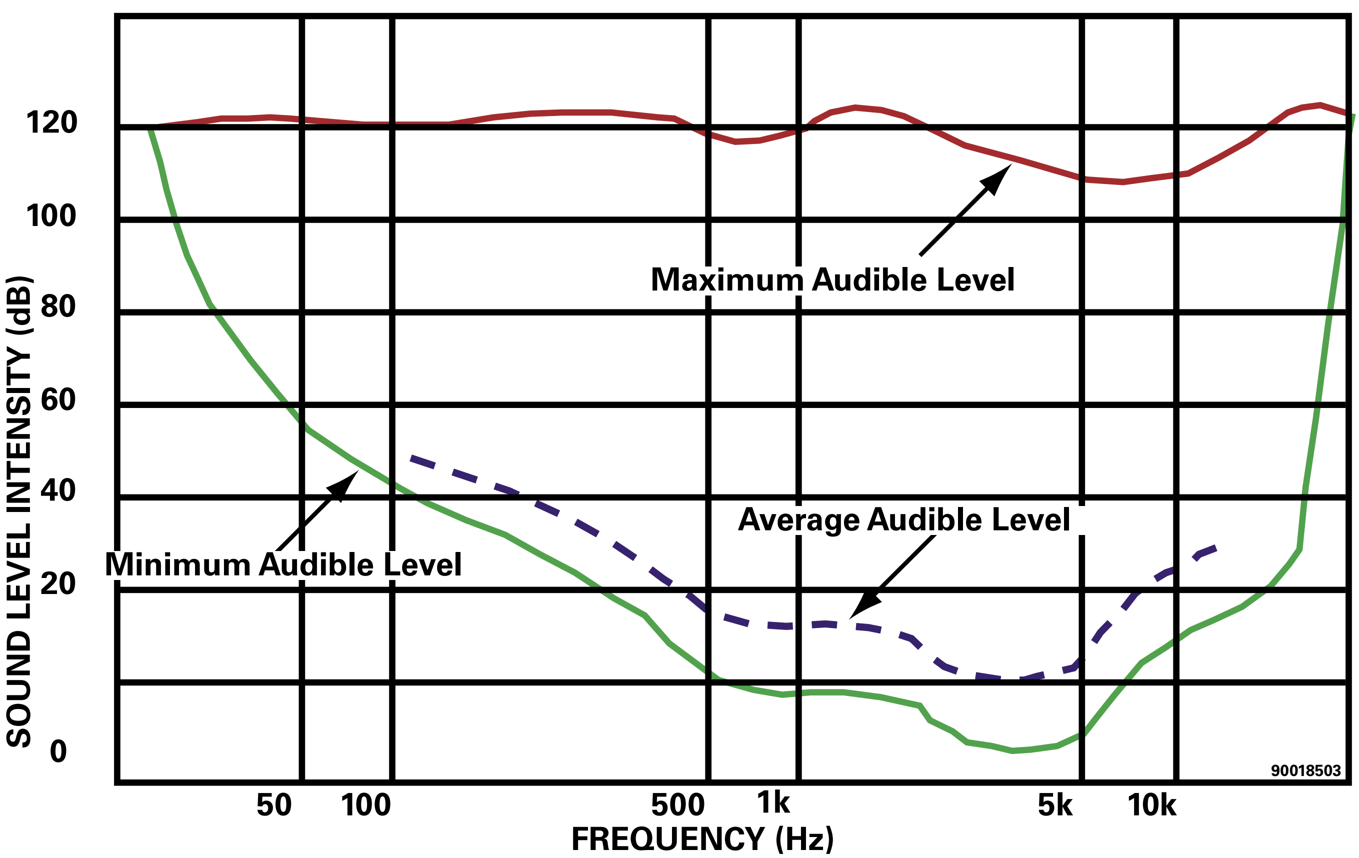
When diagnosing a vehicle, it may be beneficial to have the customer reproduce the noise during a road test.

Audible Range of Sound

For sound to be heard, the resulting acoustic wave must have a range of 20 to 20,000 Hz, which is the audible range of sound for humans. While many vehicle noises are capable of being heard, some NVH noises are not in the audible range.

Low-speed droning is an example of a low frequency NVH concern that may have components not in the audible range. This condition exerts pressure on the driver's eardrum and can be extremely uncomfortable.

On the other end of the audible range of vehicle noises are wind noise and brake squeaking. The high frequencies of these NVH concerns produce a high-pitched noise that can be extremely annoying. The figure below illustrates the audible range of automotive noises.



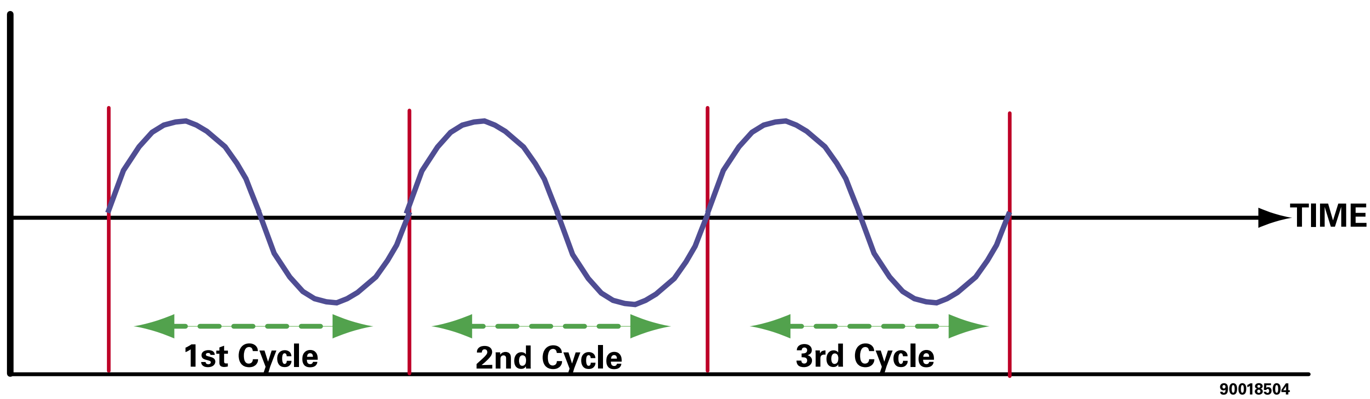
NVH Terminology

There are common terms used when discussing an NVH concern. The following terms and graphics will help when discussing NVH with other people with a technical background.

Cycle

Cycle is the path a wave travels before the wave begins to repeat the path again. If an Alternating Current (AC) sine wave begins a path at zero volts, the wave completes one cycle when it returns to zero volts from a positive voltage.

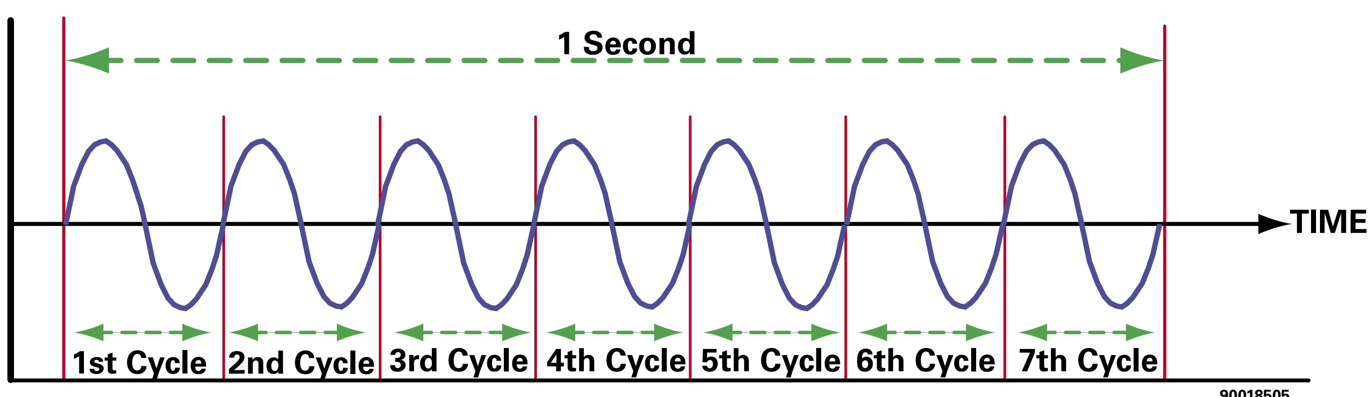
In other words, the wave completes one cycle by traveling the path from a negative voltage to zero volts, then to a positive voltage, and then back to zero volts.



Frequency

Frequency is the number of complete cycles that occur in one second. Sound and vibration waves are measured in Hz, or Cycles Per Second (CPS). One Hz is equal to one CPS.

The sound wave in the figure below has a frequency of 7 Hz because it completes seven CPS. The frequency of a sound or vibration can aid in troubleshooting an NVH concern.



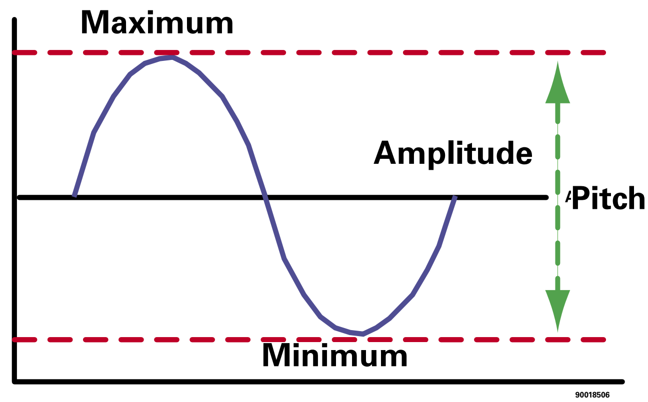
Frequency Equals 7 Cycles Per Second or 7 Hz

Pitch

Pitch is the physical quality of sound that relates to the frequency of the wave. Increasing the frequency of a sound increases the pitch of the sound. If frequency decreases, pitch also decreases.

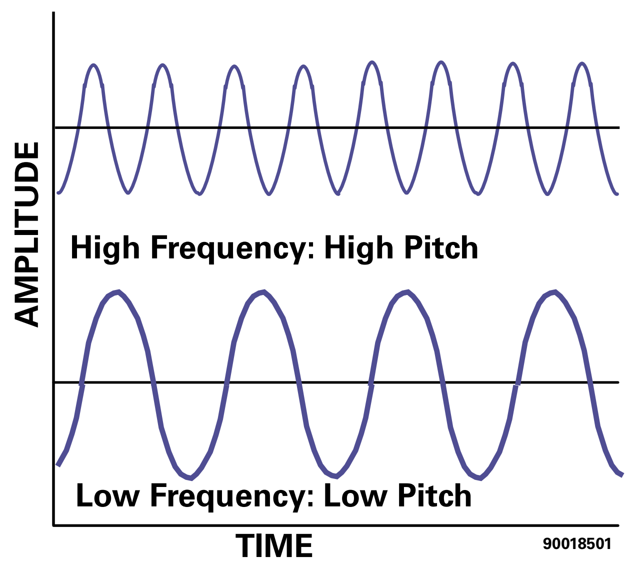
Listening to an accessory drive belt squeaking is an example of a high pitched, high frequency type of noise. A high pitched, high frequency noise is irritating to most people.

A roller bearing that makes noise is an example of a low pitched, low frequency type of noise.



Amplitude

Amplitude refers to the vertical measurement between the top and the bottom of a wave. Two waves can have the same frequency, but differ in amplitude. Amplitude is the quantity or amount of energy produced by a vibrating component.

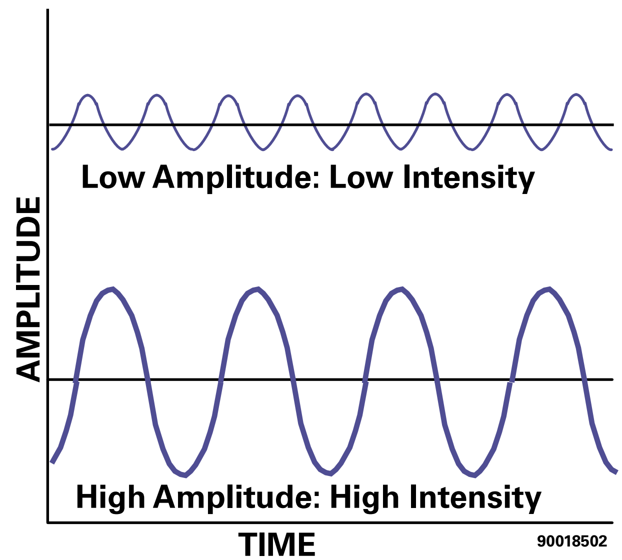


Sound Intensity

Sound intensity is the physical quality of sound that relates to the amount and direction of the flow of acoustic energy at a given position. The figure illustrates two sound waves with the same frequency but different amplitudes (different intensity levels).

Sound intensity is measured in decibels. A decibel is a unit for expressing relative difference in power between acoustic signals. Sounds greater than 160 decibels are dangerous to human hearing.

Differences in pitch, the source of each sound, or the person who hears the sound can create the perception that two sounds of the same intensity have different levels of loudness.



Resonance

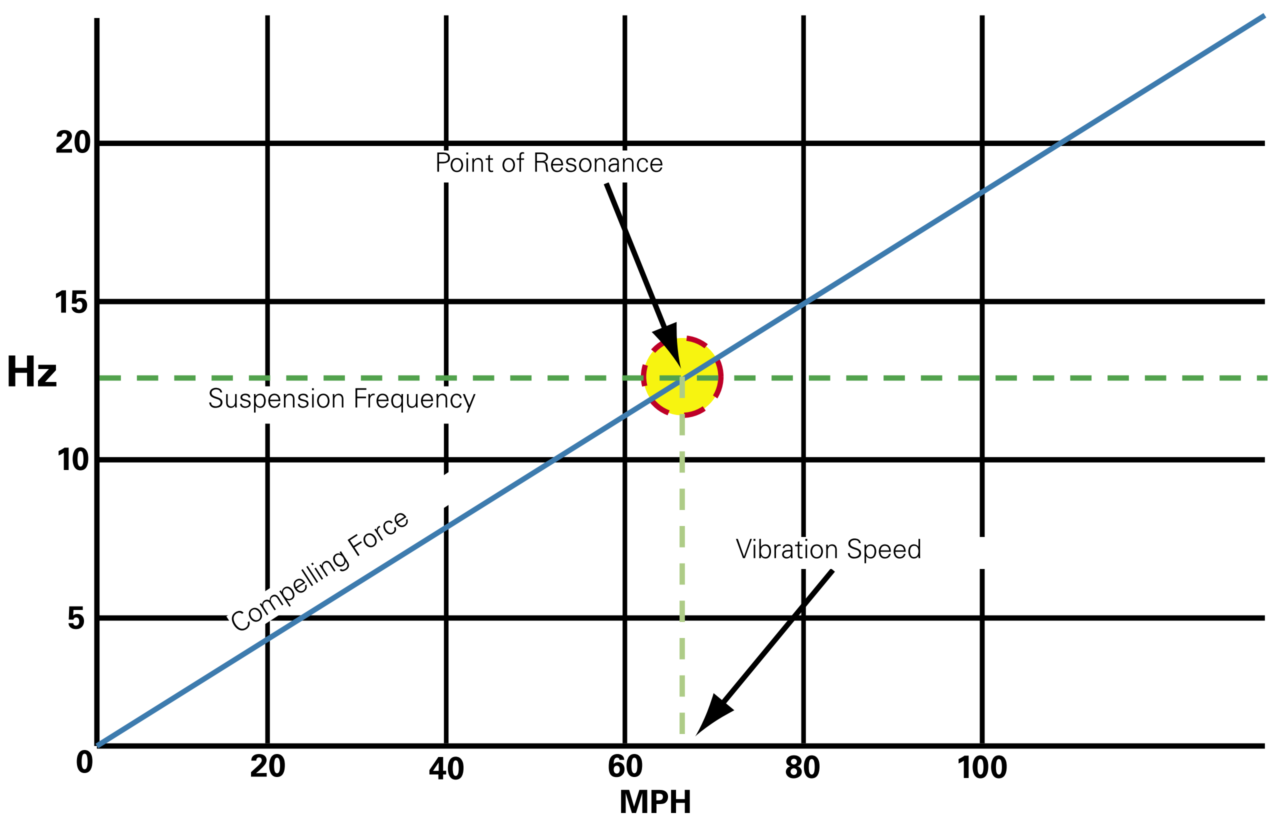
Resonance is the tendency of a system to respond to a compelling force oscillating at, or near, the natural frequency of the system. All objects have natural frequencies and experience maximum response at the point of resonance.

The natural frequency of a typical automotive front suspension is in the 10 to 15 Hz range. This is designed for ride and handling considerations.

As seen in the figure, the suspension's natural frequency is the same no matter what the vehicle speed. As the tire speed increases, along with the vehicle speed, the disturbance created by the unbalanced tire increases in frequency. Eventually, the frequency of the unbalanced tire intersects with the natural frequency of the suspension, causing the suspension to vibrate. This intersection point is called the resonance.

The amplitude of a vibration is greatest at the point of resonance. Although the vibration can be felt above and below the problem speed, it is most prominent at the point of resonance.

Resonance explains why a tire vibration occurs at certain vehicle speeds. If the vehicle's suspension has a natural frequency of 13 Hz, the suspension will transmit, or resonate the vibration at speeds in the 13 Hz range. The vehicle will vibrate at 39 mph, 52 mph and 65 mph because these speeds cause a tire vibration to resonate through the suspension into the vehicle.



Types of Noise

There can be many types of noise concerns on a vehicle. The classification of noises assists the technician in troubleshooting and repairing the customer's vehicle.

Noise is an unpleasant or unexpected sound created by a vibrating object. Interpretation plays a large role in defining noise characteristics. Terms used to describe noise include:

- Droning
- Beat
- Road noise
- Brake squeal

The frequency of noise vibrations is much higher than that which can only be felt, often ranging between 20 and 500 Hz. Certain noises can be associated with the component systems of a vehicle such as the engine, driveline, axle, brakes, or body components.

In other situations, a noise can telegraph through the body of a vehicle. For example, a chirping noise may be heard in the area of the instrument panel when, in fact, it is being produced by the rear brakes. The sound has traveled, or telegraphed through the parking brake cables. Following a systematic approach when troubleshooting an NVH concern helps to locate the cause and correct the condition.

Noise can be annoying to some people, while others find it acceptable. Automotive noises can be audible at certain speeds or under certain driving conditions. A gear-driven unit, such as an automotive drive axle, produces a certain amount of noise. In dealing with these concerns, it is important to know what a normal condition is and explain it to the customer in terms they can understand.

Trying to repair a normal vehicle condition can be frustrating. Despite good intentions, an attempted repair can also become a liability if legal action is initiated.

Droning

The sensation people experience when driving into a tunnel at high speed, or climbing to a high altitude, is a feeling of ear discomfort. The ear drums feel as if they are being forced in or out due to sudden changes in atmospheric pressure. An unpleasant droning causes a similar sensation due to large fluctuations of air pressure in the car.

A customer may refer to unpleasant droning noises as humming noises. There are three types of unpleasant droning:

- Low-speed
- Middle-speed
- High-speed

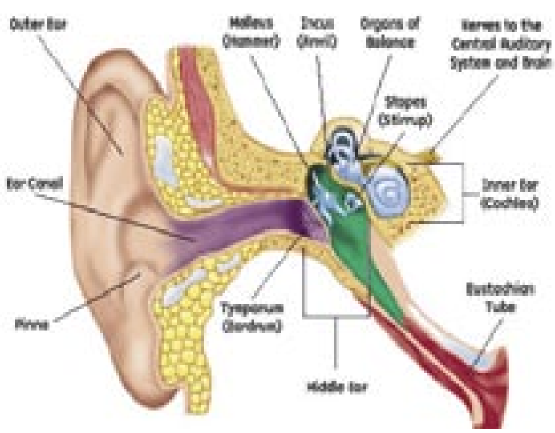
Unpleasant droning at low and middle-speed driving is a long duration, low-pitched noise that is non-directional. It is hard to hear and feels like pressure in the ears.

Feeling a small amplitude vibration is common with low and middle-speed droning. Low-speed droning has a range of up to 30 mph (50 kph) and has a frequency of 30 to 60 Hz. Middle-speed droning has a range of 30 to 50 mph (50 to 80 kph) with a frequency of 60 to 100 Hz.

Unpleasant droning at high-speed driving is a long duration, non-directional humming noise that is uncomfortable to the ears. High-speed droning has a range of 50 mph (80 kph) and up with a frequency of 100 to 200 Hz.

The three classifications of droning are speed and frequency related. A low-speed droning sound has a lower pitch than a high-speed droning sound.

The table summarizes the speed and frequency ranges for the three types of droning.



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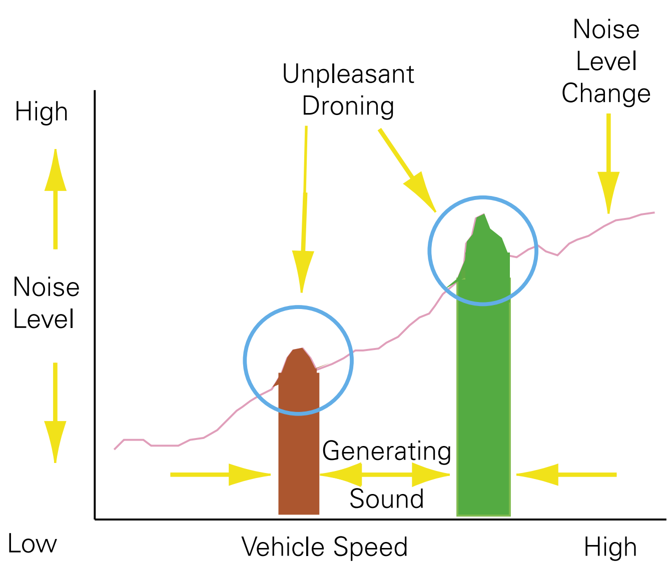
Speed and Frequency Ranges of Droning

	SPEED RANGE	FREQUENCY RANGE
Low-Speed Droning	Up to 30 mph (50 kph)	30 to 60 Hz
Middle-Speed Droning	30 to 50 mph (50 to 80 kph)	60 to 100 Hz
High-Speed Droning	50 mph (80 kph and up)	100 to 200 Hz

Droning can occur when accelerating, decelerating, or driving at a constant speed, but most often occurs when accelerating. Droning usually is apparent at a specific engine rpm or vehicle speed. For example, the figure illustrates how the noise level of a vehicle increases with vehicle speed. As vehicle speed reaches a certain range (the solid colored areas of the figure), a large increase in the noise level occurs.



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The speed or rpm range at which unpleasant droning occurs is relatively narrow. When droning occurs at a specific vehicle speed, the range is generally within 3 mph (5 kph) of that speed. When droning occurs at a specific engine rpm, the technician should change vehicle speed very slowly. Changing vehicle speed quickly will make it difficult to check the droning because rpm will pass through the specific range too quickly.

Droning is usually generated by more than one component. In most cases, it is necessary to eliminate all the causes in order to remove the droning noise. For example, unpleasant droning can occur when engine and driveline vibrations are transmitted to the body panels causing them to resonate. Air cleaner, air intake, and exhaust noises can combine and cause droning in the passenger compartment.

Other items that are sometimes responsible for unpleasant droning include:

- Bending resonance of exhaust pipes
- Resonance of auxiliary equipment
- Bending resonance of propeller shaft
- Resonance of suspension links
- Transmission of engine vibration
- Transmission of exhaust noise
- Transmission of intake air noise

The bending resonance is a normal occurrence for straight tubes and pipes, and exhaust and drive shafts. These components deform (resonate) at known frequencies. Engineers design components so that the bending resonance will not occur during the normal operation of the vehicle.

Beat

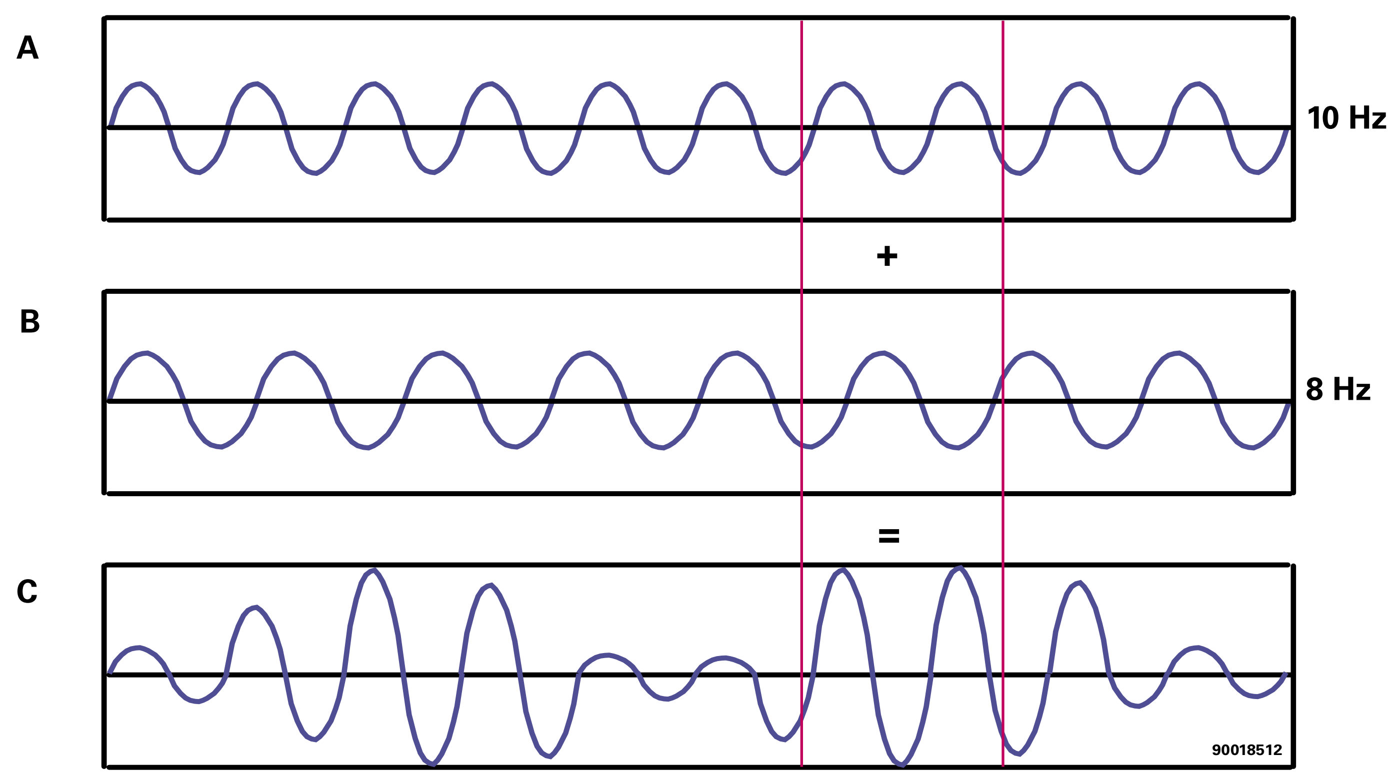
For beat sounds to develop, there must be two sound sources. For example, striking a tuning fork produces a pure tone of a certain frequency (pitch). If a second tuning fork with a very different pitch is struck, each tone is distinguishable from one another. However, if the pitches of the tuning forks are similar, the two tones produce a beat sound with a pitch that occurs in cycles at the difference of the two frequencies. If the pitches of the two sounds are the same or only slightly different, they are indistinguishable and are perceived as one sound.

The figure illustrates two tuning forks producing sound waves with troughs and peaks. The two waves have slightly different frequencies. The sound level becomes higher when their peaks occur at the same time. The sound level drops when a peak of one wave occurs at the same time as the trough of the other wave. When the two waves combine, they produce a beat sound in which loudness changes periodically.

The sensation of a beat sound is most noticeable when the frequency difference is 1 to 6 Hz. If the two frequencies are closer, their tones are indistinguishable and are sensed as the same sound. If the two frequencies are greater than 6 Hz apart, each tone is distinguishable from one another.

Beat sounds can result from a combination of many types of vibrations. Common combinations that result in beat sounds include:

- Engine and air-conditioning compressor
- Engine and power steering hydraulic pump or other accessories
- Engine and vibrations of the drive shaft
- Tire non-uniformity
- Tire and drive shaft vibrations



Sound Waves C are the sum of Sound Waves A and B
(The fluctuation in Magnitude is Phasing or Beating)

Road Noise

The sounds that occur while driving on gravel or roughly paved roads is an example of road noise. This type of noise is continuous and has a constant character. Road noise can occur at all vehicle speeds, or when the vehicle is coasting, and has a frequency range of 30 to 500 Hz. A very fine vibration also may be noticeable.

Road roughness and tires are major sources of noise and vibration that occur during driving. Since the source of road noise is irregular road surfaces, different types of tires can influence the amount of road noise. The impact force from road surfaces transmits to the tires causing them to vibrate. This vibration, in turn, transmits to the suspension and body. The resonance characteristic of the passenger compartment amplifies the vibration and generates annoying road noise.

Brake Squeal

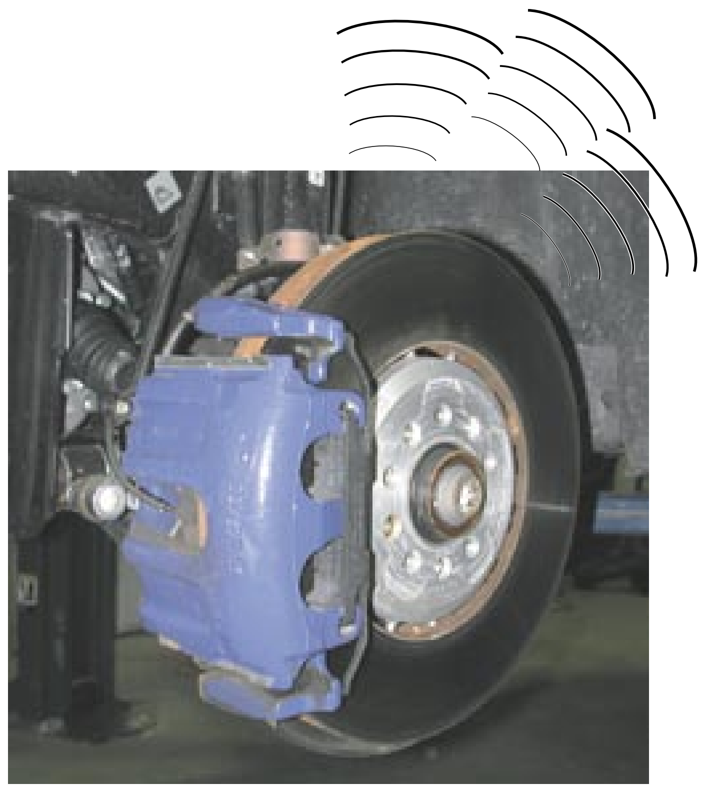
The most common brake system NVH concern is brake squeal. Brake squeal is a high-pitched noise. If brake squeal only appears when the vehicle is first put into operation, it may be due to moisture on the brake linings.

Brake squeal also can occur when friction is created between brake components during braking. Worn or damaged brake components can produce a vibration resulting in brake squeal. This high frequency noise can occur under different brake pedal pressures, vehicle speeds, and brake temperatures.

Drum brakes usually emit a lower pitch noise that gets louder with increased brake pedal pressure. Disc brake noise is generally a high-pitched squeal that occurs under light pedal pressure.

The major vibration sources of brake squeal are:

- Worn brake shoes
- Non-uniform thickness of brake disc or drums
- Excessive runout
- Damage or contamination of friction surfaces



Because of the complex nature of brakes and the many different parts found in them, the best way to correct brake squeal is to follow service procedures. During brake service, always thoroughly clean any friction surface before reassembling the brake. A wide variety of coating materials used on brake backing surfaces and the installation of shims and clips can help eliminate brake squeal NVH concerns.

Compelling Force and Vibrating Body

Vibrations occur when there is a compelling force (or exciting force) acting upon an object that causes the body to vibrate. Locating the compelling force (the source of the vibration) can assist in eliminating an NVH concern.

The major component groups that produce compelling forces are:

- Tire and wheel
- Driveline
- Engine and torque converter

Vibration

Vibration is the repetitive motion of an object (back-and-forth or up-and-down). This motion is a function of time and is measurable in Hz. Vibration can be described in many ways, which include:

- Shake
- Shimmy
- Shudder

Vibrations can be constant or variable, and occur during a portion of the total operating speed range. Vibrations usually are caused by some rotating component or components, or sometimes by the combustion of the air/fuel mixture in the individual engine cylinders.

Under normal circumstances, a rotating component does not produce a noticeable vibration. However, if the component has improper weight distribution (imbalance), or is rotating in an eccentric pattern (out-of-round or bent), then a noticeable vibration may be produced. If the characteristics of the vibration can be measured, the information about the vibration can be used to match it with components that are the likely cause.

There are many types of vibration problems on a vehicle. The classification of vibrations assists the technician in troubleshooting and repairing the customer concern.

Vibration Transfer Path

Vibrations travel through a vehicle's structure similar to the way radio waves travel through air. Vibrations are often noticed in a component far removed from where they are generated. Transmission of a vibration to other components is called "telegraphing." For example, an out-of-balance front tire and wheel assembly may result in a noticeable steering wheel shake. In this case, the wheel and tire assembly is the originator of the vibration, the suspension is the conductor, and the steering wheel is the reactor.

Vibration Order

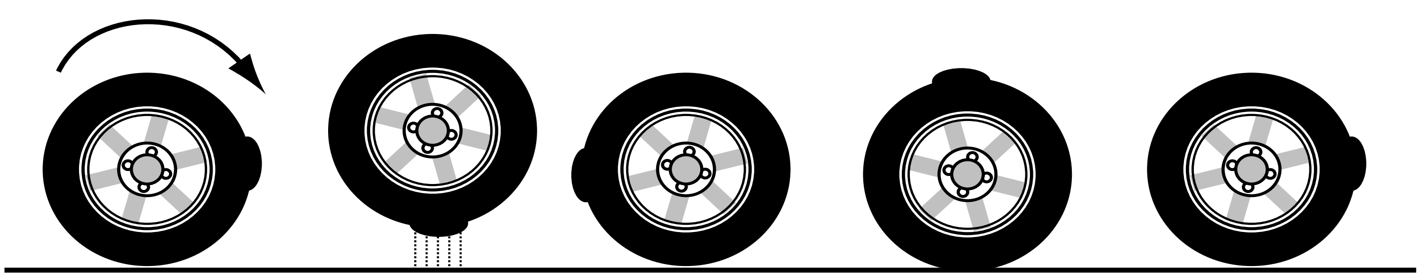
Order is the number of disturbances created in one revolution of a component. A single high spot on a tire causes one disturbance per revolution and is called a first-order disturbance. If the wheel rotates 10 times per second, there are 10 disturbances per second. This creates a first-order disturbance of 10 Hz.

If the tire developed a second high spot, a second-order disturbance would result. The wheel rotating 10 times per second produces 20 disturbances per second. This creates a second-order disturbance of 20 Hz. Three high spots create a third-order disturbance and four high spots create a fourth order disturbance. Higher order disturbances continue to progress in this way.

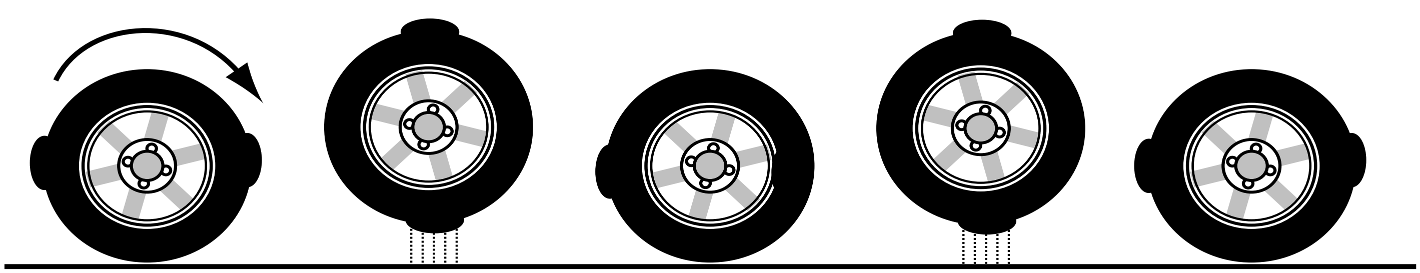
The vibration order can aid the technician while troubleshooting. For example: a vehicle has an NVH concern that is producing a vibration at 68 Hz. After calculating drive shaft frequency, it is determined the drive shaft has a frequency of 34 Hz. The second-order frequency of the drive shaft is 68 Hz. This matches the frequency of the NVH concern.

By determining that the NVH concern is a possible second-order vibration, you would look at components that could cause a vibration of this type. Universal joints would be a good component to check because it is possible they could produce two disturbances with each revolution of the drive shaft. A missing drive shaft weight could be eliminated from the list of possibilities because this situation would produce a vibration of the first-order.

First-order Vibration



Second-order Vibration



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Vibration Order Examples

Half-order vibration

Half-order vibration is created when any component that rotates at half the crankshaft speed is out-of-balance or has excessive runout. An example of this is camshaft imbalance. Balancing the component or correcting the runout may bring the vibration to an acceptable level.

First-order vibration

First-order vibration is created when any component that rotates at crankshaft speed is out of balance or has excessive runout. Examples are flywheel or torque converter imbalance and cylinder-to-cylinder mass differences. In rare cases, the crankshaft itself may be imbalanced. Balancing the component or correcting the runout may bring the vibration to an acceptable level.

Second-order vibration

Second-order vibration is caused by the up-and-down motion of the pistons. This reversal of mass and motion creates a natural vibration.

Symptoms of engine imbalance include:

- A low-speed shake felt between 480 and 1,200 Revolutions Per Minute (rpm) that has a frequency of 8 to 20 Hz
- A roughness sometimes felt and heard between 1,200 to 3,000 rpm at a frequency of 20 to 50 Hz

First and second-order engine vibrations usually are detected during the neutral run-up test.

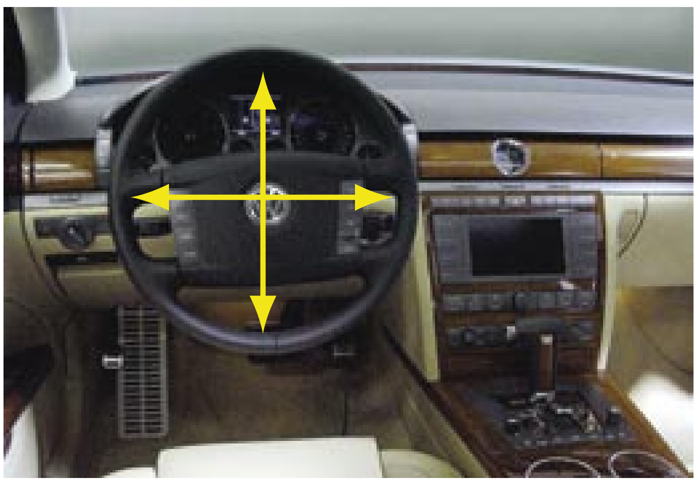
Third-order vibration

A third-order vibration is caused by any component that has three heavy spots.

Types of Vibration

Vibrations in a vehicle can be any one of the following types:

- Shake
- Shimmy
- Brake Vibration/Shudder



Shake

Vibrations at the steering wheel or seat, or an annoying vibration at the floor, are indicators of "shake." Shake generally has a frequency of 10 to 30 Hz. There are two types of shake:

- Vertical (up-and-down)
- Lateral (side-to-side)

Vertical shake is severe vertical vibration of the body, seats, and steering wheel. A trembling engine hood or rearview mirror also can be a vertical shake symptom.

Lateral shake is side-to-side vibration of the body, seats, and steering wheel. A trembling vibration in the driver's waist or hips may be a symptom of a lateral shake.

The major vibration sources of vertical and lateral shake are:

- Roughness of road
- Tire imbalance
- Non-uniform tires
- Bent or out-of-round wheels
- Driveline
- Engine

Shimmy

Vibration that causes the steering wheel to oscillate is known as "shimmy." The body of the vehicle also may vibrate laterally. Shimmy generally has a frequency of 5 to 15 Hz. There are two types of shimmy:

- High-speed shimmy
- Low-speed shimmy

High-speed shimmy occurs when driving on smooth roads at high speeds. High-speed shimmy typically has a limited speed range in which symptoms are noticeable.

Low-speed shimmy occurs when the steering wheel begins to vibrate as the vehicle is driven across a bump at low speeds.

The major vibration sources of high-speed and low-speed shimmy are:

- Roughness of road
- Tire imbalance
- Non-uniform tires
- Bent or out-of-round wheels

For example, a tire with excessive runout, out-of-balance, or out-of-round may cause high or low-speed shimmy. This is because the tire fault generates a vibration at a particular frequency. When the vibration of the tire reaches the natural frequency of the vehicle's front unsprung components (such as the front axle, tires, and wheels), they start to vibrate. When the frequency of the front unsprung components matches the natural frequency of the steering system, resonance occurs. This resonance causes the steering wheel to vibrate heavily in the turning direction.

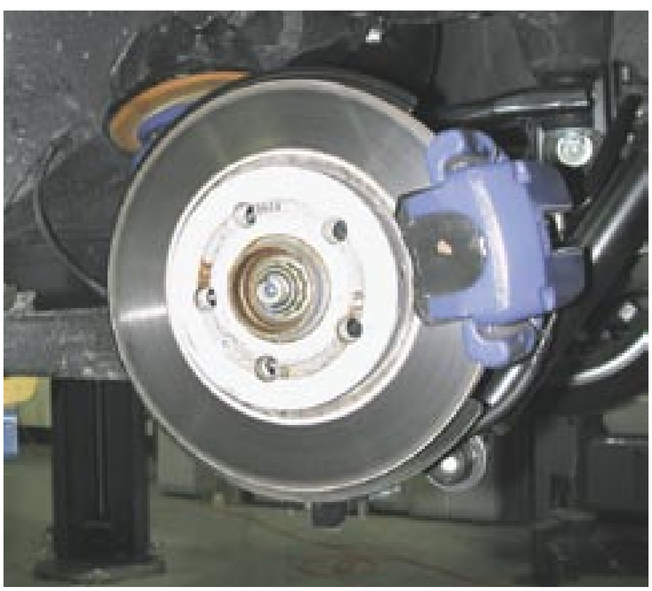
Brake Vibration/Shudder

Brake vibration/shudder is transmitted through the brake hydraulic lines to the suspension system, steering system, and the brake pedal. Brake pedal pulsation is generated when applying a brake with a non-uniform diameter drum or a disc brake with non-uniform brake disc thickness.

Brake shudder causes the instrument panel, steering wheel, and sometimes the entire body to vibrate vertically and back-and-forth during braking. It also may result in brake pedal pulsation related to wheel rotation and can occur during any braking condition or vehicle speed. Normally, brake shudder has a peak at 40 to 50 mph (60 to 80 kph) and has a frequency of 5 to 30 Hz.

Certain operating conditions can affect the cause of these vibrations. These include:

- Extended periods where the vehicle is not in operation
- Brake disc surface irregularities due to foreign agents (oil or grease, antifreeze, etc.)
- Deformation of brake disc or drum due to poor installation

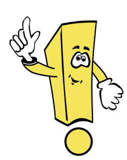


If the disc rotor has excessive thickness variation, friction force on the braking surface varies during brake application. The change in the braking force generates a vibration at a certain frequency. This vibration is transmitted to the suspension, steering, and brake pedal. The vibration can also transmit to the body, causing it to resonate.

The root cause of disc brake vibration/shudder concerns is thickness variation. Thickness variation can be caused by a rotor that has lateral runout. Lateral runout can be caused by improper wheel tightening procedures and torque values as well as hub runout. As the rotor wobbles (lateral runout), contact is made with the brake pads. As sections of the rotor make contact with the pads, small amounts of metal wear from the rotor surface. This continues until enough metal is worn in sections to cause thickness variation. This is why improper wheel tightening procedures often take weeks or months to produce brake vibrations.

The same is true for hub runout. Resurfacing or replacing rotors when the hub has lateral runout is usually a short-term repair. Always follow service information for proper wheel tightening procedures and torque values. Check the hub for lateral runout when resurfacing or replacing rotors for a brake vibration.

If the vibration or noise is caused by the brake system, refer to service manual information for the vehicle. Procedures to check drums and rotors for out-of-round, thickness variation and lateral runout are covered in the service information.



Overtightening wheel bolts, such as with an impact wrench, often causes rotor warpage.
Be sure wheel nuts are correctly torqued.

Ride Comfort

Ride comfort plays a large part in a customer's satisfaction with their vehicle. Avoiding abnormal vibrations ensures a quality ride comfort level.

Normal vehicle vibrations are a result of road roughness. During normal operation, the vehicle experiences vibration between the sprung components (body and suspension) and the unsprung components (axles, tires, and wheels). This is an acceptable condition unless the sprung or unsprung components become defective, worn, or damaged.

When unsprung components resonate with the sprung components, the result is poor ride comfort. Ride comfort vibrations may cause the vehicle to roll, pitch, and bounce, which may cause a customer concern. Poor ride comfort can be minimized by ensuring suspension and steering components are not damaged or worn.

Harshness

Harshness results when the vehicle is unable to absorb vibrations produced by road conditions. The causes may be due to deterioration of vehicle components, damage, or modification of the original equipment. In most cases, harshness is related to chassis components.

When diagnosing a harshness concern, pay close attention to interior noise levels in the vehicle. Many harshness conditions are due to a component that is not allowed to move within its normal travel, or one that has lost its isolating grommets or bushings. This makes engine mounts, subframe mounts, bushings and suspension components prime suspects in the diagnostic procedure.

Oversized tires, heavy-duty springs and shocks, or other vehicle modifications also must be considered. Some aftermarket tires, even when they are the correct size, may produce changes in the vehicle that will generate owner concerns.

Many customers use the word "harshness" to describe ride comfort concerns. Harshness has become a universal term when dealing with NVH concerns on a vehicle. For the purpose of this course, harshness is an aggressive suspension feel or lack of "give" in response to a single input. It can be associated with an abrupt thumping noise, as well as an aggressive feel.

Harshness occurs when a vehicle vibrates from moving across road joints, projections, stepped differences, or depressions on paved roads. Driving on the expressway increases the pitch of the thumping sound. The impact force from the road surface causes the tires to vibrate. The tires transmit the vibration through the suspension system to the car body. Harshness has a frequency of 30 to 60 Hz.

Vibrations

Vibrations are noticeable at the steering wheel, seats, and floor. The level and intensity of the vibration changes with the suspension type and the bushings used.

Longitudinal impact forces are transmitted to the lower arms where suspension bushings dampen the vibration. The dampened vibration then transmits through the suspension crossmember and strut insulators to the body.

The rigidity of the bushings and insulators in the vibration transmission path has a large influence on harshness. The use of low-rigidity bushings and insulators to provide greater fore-aft suspension compliance softens the impact force effectively, but results in less responsive steering.

Along with suspension system designs, tire characteristics influence the amount of harshness. When tires experience an impact force from a pavement joint, they deform to cushion the rest of the vehicle. The tires absorb the force to some extent and are an important factor when dealing with harshness. At the same time, the deformation transmits vibration to other portions of the tires. This causes the tires to undergo complicated resilient vibrations. A tire that can absorb vibrations from impact is efficient in controlling the problem of harshness.

It is extremely difficult for a tire to absorb harshness vibrations completely. These vibrations involve not only tire type, but also inflation pressure. The technician should always ensure proper tire inflation pressure when troubleshooting a harshness concern.

Generally, a soft tire with enveloping characteristics performs well in preventing harshness. Radial tires have rigid treads and are low in enveloping characteristics. They tend to cause harshness, particularly at 19 to 25 mph (30 to 40 kph).

Getting Good Information from Service Advisors

To properly diagnose and repair an NVH concern, the concern will need to be duplicated during a road test. The service advisors are a good source for the symptoms and facts surrounding the concern. Proper questioning of the customer will usually provide the information necessary to duplicate the concern.

If the customer is leaving the vehicle and will be unavailable for a road test later in the day, then it is advisable that the service advisor or technician road test with the customer beforehand to experience the symptoms and facts of the NVH concern.

The Four Steps

1. Focus the discussion with the customer on the symptom description.

2. Ask questions that clarify what, when, where and how often.

3. Summarize your understanding and get agreement from the customer. Use open-ended questions to prompt for specifics.

4. Explain what you will do to proceed and get acknowledgement from the customer.

Diagnosing and Solving Customer Concerns

1. Describe the concern.
    - List known symptoms
    - Avoid opinions or disguised solutions
2. Verify and analyze.
    - Try to duplicate the concern
    - List possible causes
3. Locate the concern.
    - Select the probable causes
    - Prioritize tasks
    - Identify the concern
4. Repair the concern.
    - Determine the specific cause
    - Perform the repair
5. Conduct a quality check.
    - Recheck for proper operation and reassembly
    - Check for cleanliness and appearance

Other Information Sources:

- Volkswagen Electronic Service Information System (VESIS)
    - Technical Bulletins
- Other technicians
- Helpline
- Known good vehicle
- This training manual
- The GSP9700 Vibration Control System Operation Instructions

Pre-Road Test Inspection

Begin checking the vehicle with a visual inspection. Be sure to carefully inspect the tires, unless the NVH concern only occurs at a standstill. Prior to the road test, inspect the following:

- Tires:
  - Pressure – Inflated to specification
  - Wear – Cupping, flat spots, feathering and shoulder wear
  - Tread grooves – Correct depth over entire surface
  - Type – The tire is the proper application
  - Foreign debris – Stones, mud, etc.
- Wheels:
  - Not deformed or bent
  - Weights – Properly installed/correct size
  - Wheel bolts – Torqued to specification
  - Tire bead – Uniform
- Driveline:
  - Not damaged or bent
  - Properly mounted and supported
  - Properly aligned
- Engine:
  - Belts and accessories for damage
  - Properly aligned
  - Mounts
- Exhaust:
  - Not damaged or bent
  - Properly aligned
  - Properly mounted and supported

Road Test Tips

Observe the following guidelines when preparing for the road test:

- Check the customer repair order before beginning the road test. It is important to know which specific concern the customer has with his/her vehicle. This prevents correcting the wrong concern and increasing the cost of the repair. If possible, road test with the customer.
- Don't be misled by the reported location of the noise or vibration. The cause actually may be some distance away.
- Remember that the vibrating body may generate a small vibration only. This small vibration in turn may cause a larger vibration or noise due to the vibrating body's contact with other components.
- Conduct the road test on a quiet street where safely duplicating the noise or vibration is possible. It must be possible to operate the vehicle at the speed in which the condition occurs. It is best to conduct the road test on a route that has been previously driven with known good vehicles. This allows for any road imperfections; i.e. road surfaces and joints, from being the source of NVH concerns.
- Turn off the radio and the blower for the heater and air conditioner unless the noise or vibration only occurs with the air conditioning or radio on.
- Determine which test equipment is needed for the road test. If utilizing test equipment during a road test, it is best practice to have an assistant drive while the equipment is being monitored and the results recorded.
- For cold weather climates, be aware that snow and ice can be the cause of NVH concerns.

Road Testing

The following road test procedure assists in classifying an NVH concern into:

- Engine speed
- Vehicle speed
- Wheel speed

Each of the following procedures helps to eliminate possible components. Depending upon the cause of the NVH concern, certain procedures may or may not be necessary.

- Slow Acceleration Test
- Neutral Coast-Down Speed Test
- Downshift Speed Test
- Torque Converter Test
- Steering Input Test 1
- Steering Input Test 2
- Neutral Run-Up Test
- Engine Loaded Test
- Engine Accessory Test

Slow Acceleration Test

The first vehicle check to determine a related symptom of an NVH concern is the slow acceleration test. This test is used to identify the noise or vibration if a road test with the customer was not possible. The steps of the slow acceleration test are:

1. Slowly accelerate the vehicle to the speed in which the problem occurs.
2. Note the vehicle speed and the engine rpm.
3. If possible, determine the frequency of the noise or vibration.
4. Classify the noise or vibration.

Neutral Coast-Down Speed Test

The next vehicle check when performing the road test is the neutral coast-down speed test. This test divides the possible causes of the noise or vibration into two categories:

- Vehicle speed-related
- Engine speed-related
- Wheel speed-related

The steps of the neutral coast-down speed test are:

1. Drive the vehicle at a speed higher than the speed in which the noise or vibration was obvious in the slow acceleration test.
2. Place the vehicle in Neutral and coast down through the speed where the concern occurs.
3. Classify the NVH concern as either vehicle speed-related or engine speed-related.
   - If the noise or vibration exists, then the concern is vehicle or wheel speed-related. This eliminates the engine and torque converter as possible causes
   - If the NVH concern did not occur during the neutral coast-down speed test, perform a downshift speed test to confirm the concern as engine speed-related

Downshift Speed Test

This vehicle check helps to confirm the NVH concern as engine speed-related. The steps of the downshift speed test are:

1. Stop the vehicle and place the transmission in a lower gear.
2. Drive the vehicle at the engine rpm in which the noise or vibration occurs.
   - If the noise or vibration exists, then the concern is engine speed-related. This eliminates tires, wheels, brakes, and suspension components
   - If necessary, repeat the test using other gears and Neutral to confirm the results

Torque Converter Test

This vehicle check determines how the torque converter contributes to an engine speed-related condition. The steps of the torque converter test are:

1. Drive the vehicle at the speed in which the NVH concern exists.
2. Operate the torque converter by taking it in and out of lock-up by lightly depressing the brake pedal, while maintaining vehicle speed.
3. Check for noise when the torque converter is not locked up.

Steering Input Test 1

The next road test steps are the two steering input tests. These tests determine if the wheel bearings and other suspension components are contributing to a speed-related condition.

The steps of the Steering Input Test 1 are:

1. Drive the vehicle at the speed in which the NVH concern exists.
2. Make wide sweeping turns in both directions.
    - If the concern goes away or gets worse, wheel bearings, hubs, Universal Joints (U-joints), drive axles, constant velocity joints and tire tread wear may be the components causing the concern

Steering Input Test 2

Perform the Steering Input Test 2 if the NVH condition occurs when turning only. The steps of Steering Input Test 2 are:

1. Drive the vehicle at a speed higher than the speed at which the noise or vibration occurs.
2. Place the vehicle in Neutral and coast down through the speed where the NVH concern is obvious, while making wide sweeping turns in both directions.
    - If the concern exists, check for worn wheel bearings, suspension bushings, constant velocity joints and U-joints (contained in the axles of AWD applications)
    - If the vibration does not occur, stop the vehicle and engage the transmission/transaxle. Alternately accelerate and decelerate through the speed at which the NVH concern appears, while making wide sweeping turns in both directions
    - If the concern returns, then the cause is dependent upon engine load. The probable causes are constant velocity joints or U-joints (contained in the axles of AWD applications) and loose or missing wheel nuts
    - If the noise is a “clunking sound,” engine and transaxle mounts, suspension bushings and U-joints are probable causes

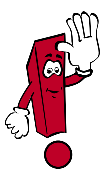
Neutral Run-Up Test

Perform the Neutral Run-Up Test if the NVH concern is engine speed-related. Use the test as a follow-up to the downshift test or when the NVH concern occurs at idle. The steps are:

1. Increase the engine rpm while in Park or Neutral.
2. If necessary, make note of the rpm and frequency of the NVH concern.

Engine Loaded Test

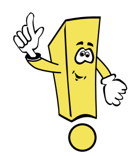
Perform the Engine Loaded Test if the NVH concern is engine speed-related. This test may help reproduce engine speed-related concerns not evident with the neutral run-up or neutral coast-down speed tests. The engine loaded test also identifies noise and vibration sensitive to engine load or torque. These NVH concerns often appear during heavy acceleration or when climbing a hill.



Warning: Block the front and back wheels or injury to personnel may result. Do not exceed five seconds when performing the engine loaded test or damage to the transmission/ transaxle may result.

The steps of the Engine Loaded Test are:

1. Block the front and back wheels.
2. Apply the parking and service brakes.
3. Put the transmission in Drive while keeping the brakes applied.
4. Increase the engine rpm to the rpm at which the NVH concern occurred. If necessary, make note of the rpm and frequency of the NVH concern.
5. Return engine to idle.
6. Put the transmission in Reverse while keeping the brakes applied.
7. Increase the engine rpm to the rpm at which the NVH concern occurred. If necessary, make note of the rpm and frequency of the NVH concern.



Immediately after engine loaded test, run in neutral for 3 minutes at a slightly elevated rpm to cool the transmission.

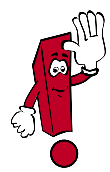
If the concern is definitely engine speed-related, perform the Engine Accessory Test to narrow down the possible source of the concern

Engine Accessory Test

Perform the Engine Accessory Test if the NVH concern is engine speed-related. This test helps locate faulty belts and accessories that are causing engine speed-related NVH concerns.

The steps are:

1. Block the front and back wheels.
2. Apply the parking and service brakes.
3. Remove the accessory drive belt(s).
4. Increase engine rpm to the rpm at which the NVH concern occurred.
   - If the vibration occurs, the belts and accessories are not the source of the concern
   - If the belts and accessories are the source of the NVH concern, continue to add or remove specific accessory belts to locate the concern



Caution: With the accessory belt removed:
- Do not drive the vehicle
- Do not operate the engine for extended periods
  - Water-cooled alternators can fail
  - Engines can overheat

Engine Speed-Related Vibrations

During the initial vehicle road test, using the road test procedure, the vibration causing the concern will be classified into either engine speed-related or vehicle speed-related. This section will be used when the vibration is found to be engine speed-related.

Engine speed-related vibrations are caused by a component that is driven by the engine. These components may be part of the engine assembly or an engine accessory.

Using the frequency of the vibration and mathematical formulas, the engine speed-related vibration can be classified into these categories:

- Engine Components
- Engine Accessories
- Engine Cylinders (Firing Frequency)

Types of Engine Vibrations

Many NVH concerns are related to the engine systems. The operation of the engine creates a natural vibration. If any one component is slightly out-of-balance, the natural vibration of the engine is compounded. Engine vibration is generally caused by any of the following:

- First and second-order engine imbalance
- Engine firing frequency
- Engine mounts
- Engine accessories

First and Second-Order Engine Imbalance

A first-order engine imbalance is created when any component that rotates at crankshaft speed is out-of-balance or has excessive runout. Examples are harmonic balancer, flywheel or torque converter imbalance and cylinder-to-cylinder mass differences. In rare cases, the crankshaft itself may be imbalanced. Balancing the component or correcting the runout may bring the vibration to an acceptable level. First-order engine vibrations can be offset by proper arrangement of crankshaft counterweights.

Second-order engine imbalance is caused by the up-and-down motion of the pistons. This reversal of mass and motion creates a natural vibration.

Symptoms of engine imbalance include:

- A low-speed shake felt between 480 and 1,200 rpm that has a frequency of 8 to 20 Hz
- A roughness sometimes felt and heard between 1,200 to 3,000 rpm at a frequency of 20 to 50 Hz

First and second-order engine imbalances are usually detected during the Neutral Run-Up Test.

Half-Order Engine Vibration

A half-order vibration is created when any component that rotates at half the crankshaft speed is out-of-balance or has excessive runout. An example of this is camshaft imbalance. Balancing the component or correcting the runout may bring the vibration to an acceptable level.

Torque Converter

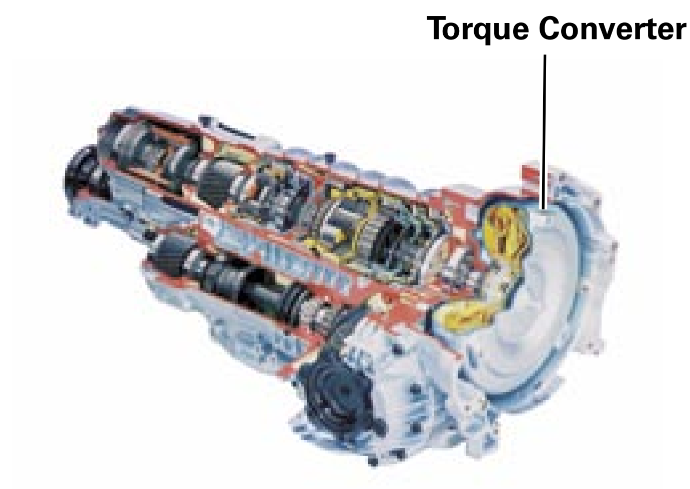
Although not actually an engine component, the torque converter rotates at engine speed and its vibration frequencies are often the same as the engine. The torque converter is a fluid coupling that uses transmission fluid to transfer and multiply engine torque to the input shaft of an automatic transmission.

The movement of the fluid between the impeller, which is connected to the engine, and the turbine, which connects to the transmission, can sometimes generate a beat sound. If this is the case, however, the sound disappears when the torque converter clutch engages, mechanically locking the impeller and turbine together.

Another NVH concern that may be caused by the torque converter is vibration during clutch engagement. If the converter clutch does not apply smoothly, it might result in a jerking or shaking vibration that can be felt throughout the vehicle. This vibration disappears when the clutch finally engages completely.

Converter clutch vibrations also can occur during downshifts and coasting if the clutch fails to release correctly. If a converter clutch malfunction is the suspected cause of an NVH concern, refer to the appropriate service publications for transmission diagnostic procedures.

Torque converter imbalance is also a possibility when dealing with an engine-dependent NVH concern. Although rare on new vehicles, this type of vibration may appear if the torque converter had been replaced or installed incorrectly during transmission service. Also, inspect the flexplate for damage, as this could cause noise or vibration.



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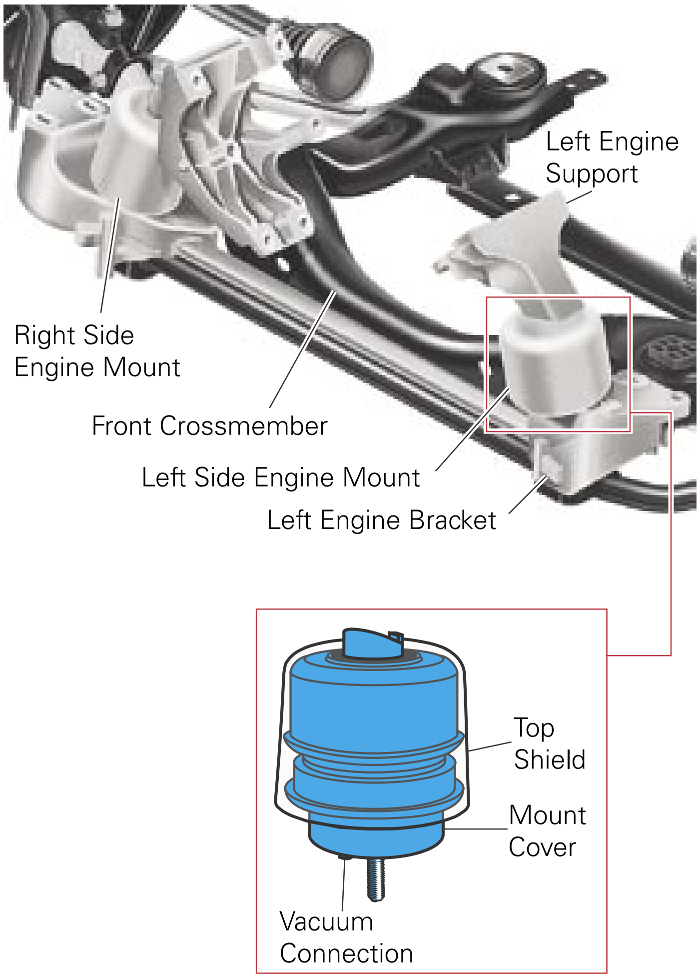

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Engine Mounts

The first components that isolate vibration from the engine to the passenger compartment are engine mounts. Engine and transmission mounting consists of a number of relatively small parts and are sometimes ignored when troubleshooting. However, these parts are extremely important in preventing noise and vibration produced by the engine.

Torque reaction force of the engine acts directly on the transmission, causing engine mounts to be subjected to a large force. Therefore, engine mounts must be rigid to stabilize the engine. On the other hand, to minimize inherent engine vibrations and noise during all engine speeds, the engine mounts also must be soft. Any fault in the engine mounting system can lead directly to noise and vibration.

Inspect engine mounts for cracks or damage to the insulator and the bracket. Grounded, the engine mounted bracket contacting the frame-mounted bracket, or strained engine mounts may not isolate engine vibrations.

Engine mounts must be installed correctly. If the mounts are installed incorrectly or incorrect parts are used, they cannot absorb engine vibration. Service information details the procedure to remove and install the engine mounting bolts and locator pins.

Several Volkswagen models use Electro-Hydraulic Engine Mount Solenoid Valves. These valves soften or stiffen the engine mounts depending upon engine operating characteristics. The system may be the source of an engine vibration at idle if not operating properly. Consult with Volkswagen Service information for system information.

Accessory Vibration

Engine accessories can be a source of engine vibration. For example, air conditioning compressors are susceptible to overcharging, which can result in an NVH condition. Accessory pulley misalignment or faulty components also can cause vibrations.

With the advent of serpentine belts, it is no longer possible to remove belts one at a time to isolate the source component. Because the serpentine belt drives all components, one component may affect another through resonance. If removing the serpentine belt eliminates the vibration, reinstall the belt and operate each component separately. By turning the air conditioning ON and OFF, or by turning the steering wheel, some components can be eliminated or isolated as NVH sources.

When diagnosing accessory vibration, make sure the source of the vibration is not caused by the engine or engine firing frequencies. Engine firing frequencies can cause components to resonate and vibrate. The vibration amplitude may increase with the accessories loaded. The most effective repair may be isolating the disturbance by interrupting its transfer path rather than attempting to eliminate the source.

Engine Vibration Formula

For purposes of vibration diagnosis, the engine also includes the torque converter and exhaust system. When an NVH problem is torque sensitive, the vibration may appear or disappear at different vehicle speeds (mph/kph), but is present at the same engine rpm. For example, if a vehicle has some vibration at 25 mph (40 kph), 40 mph (64 kph) and 65 mph (104.6 kph), but is worse at a particular speed, the NVH concern is probably torque sensitive since the condition occurs at the same engine rpm but at a different load.

Use the engine rpm at which the NVH symptom occurs to determine engine frequency. Calculate engine frequency as follows:

Divide the engine rpm by 60 (the number of seconds in a minute).

rpm ÷ 60 =
Hz (engine frequency)

For example, if the corresponding engine rpm of an NVH problem on a vehicle is 2400 rpm, the resulting engine frequency is 40 Hz.

2400 ÷ 60 = 40 Hz

To get the second and third-order frequency, multiply the first-order frequency by 2 for second-order, 3 for third-order, etc.

First-order x 2 = Second-order

First-order x 3 = Third-order

Engine vibrations also may have half-order frequencies; half-order frequencies are calculated by dividing the first-order by 2.

First-order ÷ 2 = Half-order

Engine Accessory Formula

Belt-driven engine accessories produce vibrations at different frequencies than the engine itself. This is because the drive ratio created by the different size pulleys causes them to rotate at different speeds. Determining engine accessory frequency is comparable to calculating driveline frequency.

Calculate engine accessory frequency by performing the following steps:

1. Determine the size ratio between the accessory pulley and the crankshaft pulley by dividing the crankshaft pulley diameter by the accessory pulley diameter.

Crankshaft pulley diameter ÷ Accessory pulley diameter = Pulley ratio

For example, if the diameter of the crankshaft pulley is 152.4 mm (6 inches) and the accessory pulley diameter is 50.8 mm (2 inches), divide 6 by 2. The accessory pulley rotates three times for every crankshaft rotation.

6 ÷ 2 = 3 Accessory Hz

2. Multiply the engine rpm in which the NVH condition occurs by the pulley ratio.

Engine rpm x Pulley ratio = Accessory rpm

For example, if the engine rpm is 2,400 rpm (engine speed), multiply 2,400 by 3. The accessory is rotating at 7,200 rpm

2400 x 3 = 7200 rpm

3. Divide the accessory rpm by 60 (the number of seconds in a minute) to obtain the accessory Hz.

Accessory rpm ÷ 60 = Accessory Hz

For example, the engine accessory rpm is 7,200, divide 7,200 by 60. The engine accessory frequency is 120 Hz.

7200 ÷ 60 = 120 Hz

Engine Vibrations

Types of Engine Noises

When engine components deviate from the precise specifications in which they were engineered, the engine creates excessive or intolerable noises.

Reciprocating motion of the pistons and the rotating motion of other engine components create inherent noises. Causes of engine noises include:

- Combustion – Noises are produced when the air/fuel mixture is ignited
- Friction
- Moving parts and the impact between reciprocating parts
- Tolerance “slap” – Pistons move up-and-down, and the tolerance between parts is repeatedly pulled in alternating directions

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Abnormal Combustion

Any abnormalities in the combustion process can lead to audible engine vibrations. Abnormal combustion can include any of the following:

- Spark knock (pinging)
- Backfiring

Detonation (Pinging)

Pinging is generally distinguished by a high-pitched striking noise generated when the throttle is fully open or during hard acceleration. If operation is continued in this state, the pistons and valves are adversely affected, resulting in a damaged engine.

Causes of engine spark knock (pinging) include the following:

- Inadequate fuel
- Incorrect timing
- Carbon deposits in the combustion chamber

Backfiring

One type of backfire, known as pop-back, occurs when the cylinder is fired before the intake valve closes. When the intake valve opens, the air/fuel mixture in the intake manifold is ignited and burns. This situation is sometimes violent enough to cause an explosive report within the manifold. Pop-back can be caused by the following:

- Excessively lean fuel mixture
- Incorrect valve timing

If the mixture is too lean, flame speed becomes slower, taking longer to complete the combustion process. If timing has been disturbed, a pop-back can occur and possibly the engine will not start.

Another type of backfire is afterfire. Afterfire is combustion in the exhaust system producing a loud report or flames at the tail pipe. Conditions that can produce afterfire are:

- Driving for periods of time with the engine braked
- The throttle valve closing rapidly

Afterfire occurs when unburned fuel is released from the combustion chamber and is reheated by components in the exhaust system. When the fuel is reheated past its self-ignition point, afterfire occurs. In some cases, afterfire can cause damage to the muffler, catalytic converter, or other components of the exhaust system. Main causes of afterfire include:

- Rich fuel mixture
- Incorrect ignition or valve timing
- Faulty ignition components

Exhaust Noise

The exhaust system can be a source of noise. Exhaust noises include:

- Exhaust gas sounds
- Muffler and pipe

Exhaust gas sounds are further subdivided into three categories:

- Pulsating
- Air column resonance
- Air stream sounds

Exhaust gases are discharged each time the exhaust valves open, creating a pulsating sound. The sound is cyclic and is associated with engine speed and the number of cylinders. The sound is relatively low-pitched, consisting mainly of this basic frequency.

Air-column resonance consists of sounds produced in exhaust pipes and mufflers. Pipe length and the cross-sectional area of the pipe determine the frequency. Air stream sounds can be produced by high-speed exhaust. An example of this is turbulence caused by air going through the muffler, or jet noise when exhaust is discharged from the tailpipe.

Muffler and exhaust noises can be caused by exhaust system misalignment, incorrectly installed or damaged mounting brackets, or failed hangers. This can cause a variety of annoying noises that can be located with a thorough visual inspection.

Any of these sounds in the exhaust system can be carried, or transmitted, throughout many of the exhaust system components and into the passenger compartment.

Engine Vibrations

Compelling Force of Exhaust

The compelling force of exhaust exiting each cylinder creates a pulsation on the exhaust manifold. The pulsating pressure at the exhaust manifold produces acoustic energy, which is transmitted to the exhaust pipe. The pulsating sound waves traveling through the exhaust pipe are a source of vibration for the exhaust system. Exhaust vibrations can become amplified by resonating with engine firing frequencies and vibrations caused by the reciprocal motion of the pistons. The combination of these vibrations can produce unwanted NVH concerns.

Exhaust Flap

The Volkswagen R32 has an exhaust flap that is controlled by the Engine Control Module (ECM). This flap will open or close depending on either engine speed or other vehicle conditions. When diagnosing an exhaust noise or other NVH concern, be sure this flap is operating correctly and is not the cause of abnormal noises.

Exhaust Hangers

The combination of engine, exhaust, and acoustic vibrations within the exhaust system must be dampened. In order to dampen these vibrations and prevent them from acting on the body of the vehicle, exhaust hangers must be specially designed. Exhaust hangers are designed to suspend the exhaust pipe from the body and to prevent transmission of vibration to the body. Exhaust hangers usually consist of rigid metal to support the system separated by rubber to dampen the vibration.

Ideally, hangers should be located for support at points where they bear the weight of the exhaust uniformly. They are also located at points of inherent minimum vibration. The location and tension of the hanger rubber affects the passenger compartment noise level.

Main muffler hangers are double vibration proof. The body side of the mount is installed with a rubber bracket, and the muffler is then supported by a hanger.

Exhaust System Symptoms and Corrections

Exhaust system vibrations, symptoms, and possible corrections are listed in the table.

Exhaust System NVH Concerns

CONDITION	SYMPTOM	CORRECTION
Unpleasant droning	Generated when exhaust system vibration is transmitted through exhaust pipe hangers, and engine mounts to the body. Causes body panels and frames to vibrate.	Inspect exhaust pipe hangers and engine mounts for damage. Tighten or replace as necessary.
Outside passenger compartment radiating noise	Noise produced by vibration of exhaust system pipes, muffler shell, end plate, separator, exhaust pipe, or shield plate. Engine racing can reproduce this noise.	Identify exhaust component(s) responsible for the noise, and check for looseness, damage, or interference. Adjust or replace as necessary.
Idling vibration	Heavy deformation of exhaust pipes or flexible tubes (collapsed flexible tubes) can change vibration characteristics of the exhaust system, inducing idling vibration.	Replace damaged or deformed exhaust component.

Engine Firing Frequency

All engines have inherent first-order vibrations. Engines also have vibrations created by firing frequency. Firing frequency refers to the force created by the engine each time a cylinder fires. The force of the combustion creates one pulse, and with the cylinders firing in order, a natural vibration is created. The higher the load an engine is under, the more prominent the firing frequency becomes. Vibrations also increase when the engine has a problem that interferes with the normal combustion cycle.

Symptoms of firing frequency NVH concerns include:

- Engine rpm sensitivity
- Torque sensitivity
- Low frequency noise
- Shake or buzz
- Loaded engine

If an NVH concern is firing frequency sensitive, it may be causing resonance of another component when a specific rpm is reached. Firing frequency concerns usually have a narrow rpm range. To prevent the vibrations created by firing pulses from becoming an NVH concern, the vibration must be isolated. Motor mounts are designed to minimize the amount of vibrations that reach the passenger compartment.

Engine Firing Frequency Formula

Engine firing frequency is a term used to describe the pulses an engine creates from the firing of the cylinders. Engine firing frequency depends upon how many cylinders an engine has. The number of times an engine fires a cylinder with each crankshaft revolution is equal to one-half the number of cylinders. A four-cylinder engine fires two cylinders with each crankshaft revolution. Two revolutions of the crankshaft fires all four cylinders. A six-cylinder engine fires three cylinders with each crankshaft revolution. An eight-cylinder engine fires four cylinders for each crankshaft revolution.

Calculate the engine firing frequency by performing the following steps:

Divide the engine rpm at which the vibration occurs by 60.

rpm ÷ 60 = Engine Hz

For example,

2,400 rpm ÷ 60 = 40 Hz

Multiply engine frequency by half of the number of cylinders in the engine. (For a four-stroke engine.)

Engine Hz x Half the number of cylinders = Engine firing Hz

For example,

40 x 3 (six cylinder engine) = 120 Engine Firing Hz

Vehicle Speed-Related Vibrations

During the initial vehicle road test, using the road test procedures, the vibration causing the concern will be classified into either engine speed-related or vehicle speed-related. This section will be used when the vibration is found to be vehicle speed-related.

Vehicle speed-related vibrations are caused by a component that is rotating at vehicle speed. These components may be part of the tire and wheel assemblies or a drive train component transmitting power to the wheels. There are drive train components that rotate at tire and wheel frequencies, i.e. axle shafts or brake components. The vibration can be diagnosed to another component rotating at tire frequencies by substituting tires and wheels of the same type from a known good vehicle. These components will need to be diagnosed after a tire frequency vibration cannot be corrected by servicing the tire and wheel assemblies.

Using the frequency of the vibration and mathematical formulas, the vehicle speed-related vibration can be classified into these categories:

- Tire and Wheel Assembly
- Drive Train Component

Tires and Wheels

Noise and vibration that occur during driving have various sources. The major sources are the following:

- Rough or irregular road surfaces
- Condition of the tires and wheels

Impact force caused by rough and irregular road surfaces is first transmitted to the tires causing them to vibrate. This characteristic represents the close relationship that exists between the tire and road surface.

Tires, just like the suspension, body, and other components, are designed to minimize noise and vibration. However, they wear faster than other components. This is a contributing factor to tire and wheel noise and vibration.

Tires and wheels can cause vehicle vibrations for one or more of the following reasons:

- Imbalance
- Excessive radial force variation
- Excessive radial runout
- Excessive lateral runout
- Improperly mounted wheel on the vehicle's hub

One or more of the following tire properties can cause tire noise:

- Natural frequency and vibration transfer characteristics
- Tread patterns

Imbalance

When the tire and wheel assembly are rotating at normal highway speeds, imbalance conditions are most likely to be noticed by the driver and the occupants of the passenger compartment. The first step in correcting a tire and wheel vibration is to balance the tire and wheel assembly. There are two methods for balancing tire and wheel assemblies. They are:

- Static Balancing
- Dynamic Balancing

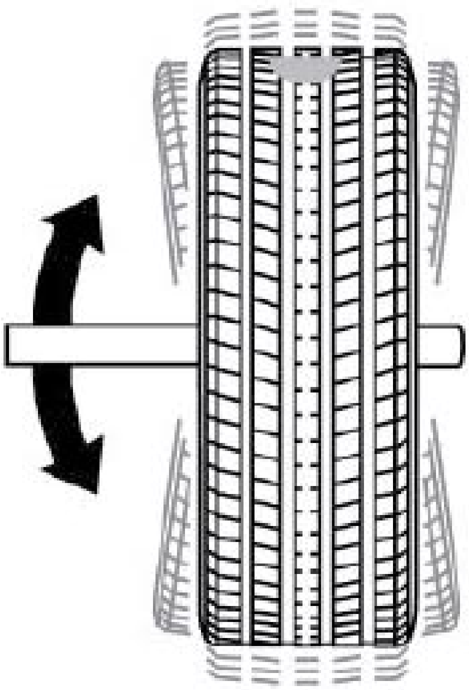
Static Balancing

As the word static implies, the tire will be balanced when at rest. For example, if an unmoving assembly was centered on a cone and was balanced, it would be statically balanced. A "bubble balancer" is designed to statically balance a tire and wheel assembly.

Static imbalance is where there is one amount of weight located in the center of the tire and wheel assembly causing an imbalance. As the weight rotates, centrifugal forces are created causing the wheel to lift as the weight reaches top dead center. This lifting motion causes the tire and wheel assembly to move "up and down" creating a bounce to be felt.

The static imbalance condition is evident by a "jiggle" or up-down movement of the steering wheel. These vibrations may also be apparent in the body, with or without steering wheel shake. A statically imbalanced tire driven for an extended period may cause "cupping" in the tire's tread, create vibration, and adversely affect handling. Static balancing alone is a seldom-recommended procedure that balances the assembly using only a single weight plane.

For example, a single weight is commonly placed on the inner clip weight position for cosmetic purposes. This is not a recommended practice and usually results in an assembly that is not dynamically balanced. The assembly may then experience side-to-side imbalance while in motion, causing a shimmy condition and objectionable vibration.



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Dynamic Balancing

Dynamic imbalance is defined where one or more locations of the tire and wheel assembly are heavier causing an imbalance force or an imbalance wobble.

The example shown is a tire and wheel assembly with two heavy spots of equal weight which are located 180 degrees across from each other on opposite sides. As this assembly rotates, centrifugal forces cause a large imbalance wobble to be created, but the imbalance force (as well as the static imbalance) will be zero. A wheel with this condition will cause a wobble or shimmy to be felt in the steering wheel. Excessive dynamic imbalance of this type creates a shimmy that transfers through the suspension components to the occupants of the vehicle, especially at higher speeds.

Dynamic balancers spin the wheel in order to measure both the up and down imbalance force and the wobble or shimmy related imbalance (side-to-side). Dynamic balancers direct the operator to place correction weights on the inside and outside correction locations of the rim so that both imbalance force and imbalance wobble will be eliminated.

Mechanical Unloaded Runout

Runout of a tire and wheel assembly directly affects the amount of imbalance and radial force variation and should be corrected first. The smaller the amount of runout, the less imbalance and force variation. Radial and lateral runout can be corrected at the same time. There are two methods to measure runout of the tire and wheel assembly:

- On-vehicle
- Off-vehicle

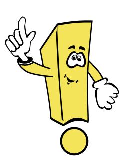
Prior to performing a runout measurement, ensure that the beads are seated equally around the circumference of the tire.

On-vehicle measurements require the wheel to be mounted onto the hub and that the wheel bearing is in good condition.

Once the on-vehicle runout has been checked, then on off-vehicle check should be taken.

If there is a large difference between runout measurements on the vehicle and off the vehicle, then runout is due to one of the following:

- Stud circle runout
- Hub flange runout
- Some other mounting condition between the wheel and the vehicle



When diagnosing a tire and wheel concern on a vehicle, consult the service information for correct specifications.

Mechanical Unloaded Radial Runout

Radial runout of the tire and wheel assembly should be started at the tire while mounted to the vehicle. If the tire radial runout measurements are within specifications, no further radial measurements of the assembly need to be measured.

If the radial runout measurements exceed specifications while mounted on the vehicle, perform the measurements off-vehicle. The tire and wheel assembly radial runout can be measured off-vehicle when mounted on a balancing machine.

If the off-vehicle runout exceeds specifications, radial runout of the stud circle and hub flange needs to be measured. The wheel-to-hub mounting should be checked to ensure there are no faults causing the runout.

If the off-vehicle measurement exceeds specifications, the radial runout of the wheel assembly should be taken. If the wheel assembly exceeds specifications, it will need to be replaced. If the wheel assembly meets specifications, the tire is at fault and will need to be replaced.

Mechanical Unloaded Lateral Runout

Lateral runout of the tire and wheel assembly should be started at the tire while mounted to the vehicle. If the tire lateral runout measurements are within specifications, no further lateral measurements of the assembly are needed.

If the lateral runout measurements exceed specifications while mounted on the vehicle, perform measurements off-vehicle. The tire and wheel assembly lateral runout can be measured off-vehicle when mounted on a balancing machine.

If the off-vehicle runout exceeds specifications, lateral runout of the stud circle and hub flange needs to be measured. The wheel to hub mounting should be checked to ensure there are no faults causing the runout.

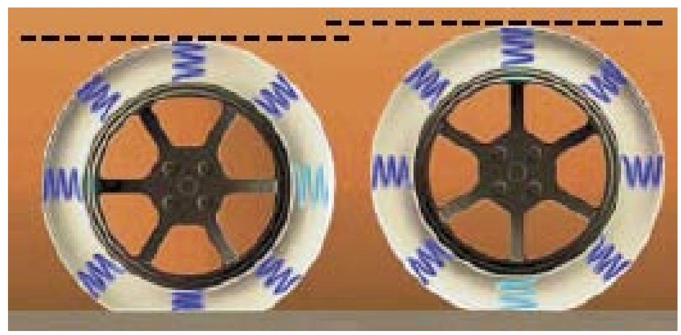
If the off-vehicle measurement exceeds specifications, the lateral runout of the wheel assembly should be taken. If the wheel assembly exceeds specifications, it will need to be replaced. If the wheel assembly meets specifications, the tire is at fault and will need to be replaced.

Radial Force Variation (RFV)

The RFV is an industrial measurement term describing the tire uniformity under load, measuring the variation (up and down) of the load acting on the vehicle spindle. All tires have some non-uniformity in the sidewall and/or footprint due to variables in the manufacturing process.

Tire uniformity measurement values can be affected by rim width, rim condition and many diverse tire mounting variables. Unlike balancing, there is often a small amount of RFV remaining in the tire and wheel assembly after assembly and this is generally acceptable.

To understand the effects of radial force variation on vibration, a model of a tire can be used. The sidewall and footprint can be understood as a collection of springs between the rim and the tire contact patch. If the “springs” are not of uniform stiffness, a varied force is exerted on the axle and causes it to move up and down as the tire rotates and flexes. This movement creates a vibration in the vehicle unrelated to balance.



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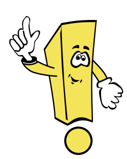
A tire with noticeable RFV will produce a vibration even though it is perfectly balanced and is within the radial and lateral runout limits. Manufacturers attempt to minimize the RFV during tire and wheel assembly.

The RFV can be measured by a load roller pressing against a rotating tire and wheel assembly to evaluate the magnitude of existing assembly harmonics. The Hunter GSP9700 Series Vibration Control System is one method of determining and possibly correcting for RFV.



Paint marks or tape strips on the tire and wheel, or valve stem location in the wheel vary in purpose. Manufacturers use these markings for heavy spot, RFV, runout, inventory control and similar purposes. Without specific manufacturer information, they are of little use to the technician.

Natural Frequency and Vibration Transfer Characteristics

When a tire is subjected to a compelling force at one point, it only vibrates there as long as the frequency of the compelling force is low (below 30 Hz). When the frequency is high, the whole tire starts to vibrate. Similar vibrations are caused when tires are excited by road surface irregularities. These vibrations have a large effect on unwanted harshness and road noise.

The relationship between vibration transmissibility and excitation frequency is called the "vibration transfer characteristic." This is a measure of a tire's overall vibration characteristic. Radial and bias tires have a natural frequency between 90 and 140 Hz, respectively. The poor harshness characteristics of a radial tire are due to high transmission of vibrations at low natural frequencies of about 90 Hz. On the other hand, the poor road noise characteristics of a bias tire are due to high vibration transmissibility at natural frequencies near 140 Hz.

Tire and wheel NVH concerns are low frequency (usually around 10 to 20 Hz). Knowing the natural frequency and vibration transfer characteristics of different tires can help determine if an NVH concern is due to the tire type or if the tire is in need of service because of a runout or imbalance condition.

Tread Patterns

Tire noise associated with tread patterns has two causes:

- Repeated deformation of the tread pattern grooves that occurs as the tire rolls on the road combined with the resultant flow of air in the grooves
- Continuous striking of the tread pattern against the road surface

A smooth tread having no pattern on the surface is the most silent. The noise levels of the tire tread increases in the order of:

1. Straight rib with grooves running around the circumference
2. General purpose rib with the zigzag grooves

Tire noise associated with tread patterns will change pitches when driven on different road surfaces. Diagnosing tire noise is accomplished by driving the vehicle on different types of road surfaces, i.e. asphalt and concrete. The tire noise will still be present, however it will sound different on the different road surfaces. Similar vehicles with the same type tires will also exhibit the same noise characteristics.

Tire Vibration Formulas

To determine if a vehicle speed-related vibration is being caused by a tire and wheel assembly, use the tire vibration formulas. Tire and wheel calculations are performed in 5 mph (8 kph) increments.

Begin by calculating the number of tire and wheel rotations in 5 mph (8 kph) increments. The next step is to calculate the RPS per every 5 mph (8 kph). Then, calculate the vehicle speed where the vibration occurs in 5 mph (8 kph) increments and calculate the tire and wheel assembly Hz rate at the vibration speed.

Tire Revolutions per 5 mph (8 kph) Formula

Use the following formula to determine the RPS per 5 mph (8 kph).

1. Verify the tire size on the vehicle.
2. Determine tire diameter by using the following formula:
   1. Multiply the tire aspect ratio by the tire width.
   2. Divide the above answer by 2540.
   3. Multiply the above answer by 2.
   4. Add the above answer to the wheel diameter.

$$\text{Tire Diameter} = 2\left(\frac{\text{Aspect Ratio x Tire Width}}{2540}\right) + \text{Wheel Diameter}$$

Example: P195/70R15

Aspect ratio x Tire width
70 x 195 = 13650

Answer above ÷ 2540
13650 ÷ 2540 = 5.38

Answer above x 2
5.38 x 2 = 10.76

Answer above + Wheel diameter
10.76 + 15 =
25.76” (654.3 mm) Tire diameter

3. Determine RPS in 5 mph (8 kph) increments using the following formula:
   1. Divide 20800 by the tire diameter.
   2. Multiply the above answer by 5.
   3. Divide the above answer by 3600.

$$\text{Tire rps per 5 mph} = \frac{5\left(\frac{20800}{\text{Tire Diameter}}\right)}{3600}$$

Example: P195/70R15

20800 ÷ Tire diameter
20800 ÷ 25.76 = 807.45

Answer above x 5
807.45 x 5 = 4037.25

Answer above ÷ 3600
4037.25 ÷ 3600 =
1.12 RPS at 5 mph (8 kph)

This formula has determined that a P195/70R15 tire revolves 1.12 times per second for every 5 mph (8 kph) increment. Using the 1.12 RPS per 5 mph (8 kph), the Hz rate of the tire and wheel assembly at a given vehicle speed can now be determined. Use the Tire and Wheel HZ Formula to calculate the Hz rate at a given vehicle speed.

Tire and Wheel Hz Formula

Use the tire and wheel Hz formula to calculate a tire and wheel Hz rate at a given vehicle speed.

Remember, all tire and wheel calculations are determined in 5 mph (8 kph) increments.

Begin to calculate tire and wheel frequency in 5 mph (8 kph) increments by performing the following steps:

1. Divide vehicle speed mph by 5 (kph by 8).

   This step is necessary due to all calculations being done in 5 mph (8 kph) increments.

Vehicle speed ÷ 5 =
5 mph increment

   For example, if the corresponding speed of an NVH problem on a vehicle is 45 mph (72.4 kph), the resulting 5 mph (8 kph) increment is nine.

45 ÷ 5 =
9 (5 mph increments)

2. Use the Tire Revolutions at 5 MPH (8 KPH) Formula (previous page) to determine the tire and wheel RPS per 5 mph (8 kph).

   Example from previous page: If the tire size on the vehicle is P195/70R15, then the RPS per 5 mph (8 kph) is 1.12.

3. Multiply the vehicle 5 mph (8 kph) increment by the tire and wheel RPS per 5 mph (8 kph).

   This determines how many times the tire and wheel assembly revolves per second at the vehicle speed where the vibration occurs.

5 mph increment x Tire RPS/5 mph
=
tire and wheel RPS at vibration speed

   Example: P195/70R15 at 45 mph

9 x 1.12 =
10.08 RPS at 45 mph

The tire and wheel assembly revolves 10.08 times per second (or 10 Hz)at the vehicle speed of 45 mph (72.4 kph).

The calculated frequency of 10 Hz is the first-order tire and wheel frequency.

The second-order frequency of the tire and wheel assemblies is twice this number, or 20 Hz.

10 x 2 = 20 Hz

The third-order frequency is three times this number, or 33 Hz.

10 x 3 = 30 Hz

Drive Shaft Frequency Formula

Knowing the tire and wheel frequency allows for easy calculation of drive shaft frequency. The drive shaft drives the tires through the rear axle. Therefore, to determine drive shaft frequency, multiply tire and wheel frequency by the ratio of the ring and pinion. Calculate drive shaft frequency by performing the following steps:

1. Obtain the axle ratio
2. Multiply the tire and wheel frequency at vibration speed by the axle ratio

Tire Hz x Axle ratio = Drive shaft frequency

For example, a P195/70R15 equipped vehicle with a vibration at 45 mph (72.4 kph) and an axle ratio of 3.90:1.

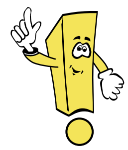
Using this information, multiply 10 Hz (the tire and wheel frequency at 5 mph, calculated by using the Tire and Wheel Frequency Formula) by the axle ratio of 3.90.

This results in a drive shaft frequency of 39 Hz at the vehicle speed of 45 mph (72.4 kph).

The calculated frequency of 39 Hz is the first-order drive shaft frequency.

The second-order frequency of the drive shaft is twice this number, or 78 Hz.

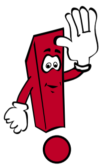
35 x 2 = 78



It is important to remember the difference between drive shaft and axle shaft frequencies. The frequency of drive shaft concerns are high since they rotate approximately three to four times that of the tire and wheel assemblies. Axle shaft concerns are lower frequency because they rotate at tire and wheel speed.

Drive Shafts

The function of a drive shaft is to transmit power from one point to another in a smooth action. The shafts are designed to send torque through an angle from the transmission (transfer case on AWD vehicles), to the axle.



Use exact replacement parts for attaching the drive shafts. This ensures safe operation. The specified torque always must be applied when tightening the fasteners. Often, Volkswagen vehicles will have special procedures to align the engine and transmission in the vehicle. There are special procedures to align the drive shafts as well.

Drive shaft vibrations can be classified into three different orders: first-order, second-order, and fourth-order. A first-order vibration may be caused by a bent or out-of-balance drive shaft condition. A second-order vibration may be caused by drive shaft angle, U-joint cancellation, and worn CV-joints or U-joints. A fourth-order vibration may be caused by a worn CV-joint or U-joint.

Driveline Vibration

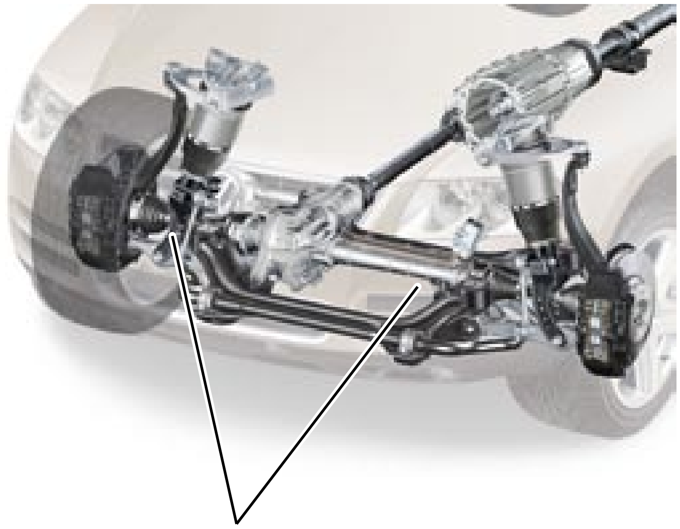
Driveline vibrations can be caused by:

- Damaged drive shafts
- Missing shaft balance weights
- Worn or out-of-balance wheels
- Loose wheel bolts
- Worn U-joints or constant velocity joints
- Loose or broken springs
- Loose pinion gear nut
- Excessive pinion yoke runout

In addition, check for loose or damaged front-end components or engine/transmission mounts. These components can contribute to what appears to be a rear-end vibration. Do not overlook engine accessories, brackets, and drive belts. All driveline components should be examined before attempting any repair.

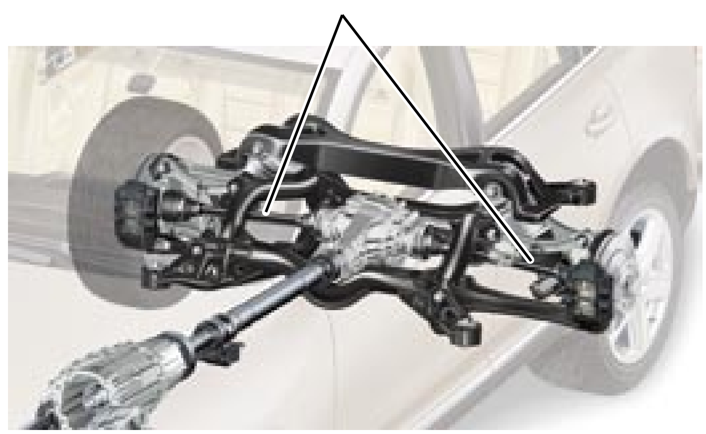
Bent Drive Shafts

A bent drive shaft can cause a vibration in the vehicle. If a bent drive shaft is suspected, perform a runout check on the drive shaft. The dial indicator must be placed at a 90 degree angle from the drive shaft for accurate readings. First, measure the runout close to each yoke weld and verify it is within the specifications in the service information. The second measurement is done in the center of the drive shaft to verify it is within specifications. If the runout is not within the specifications, the drive shaft must be replaced.



Front Drive Shafts

Rear Drive Shafts



Transmission Noise and Vibrations

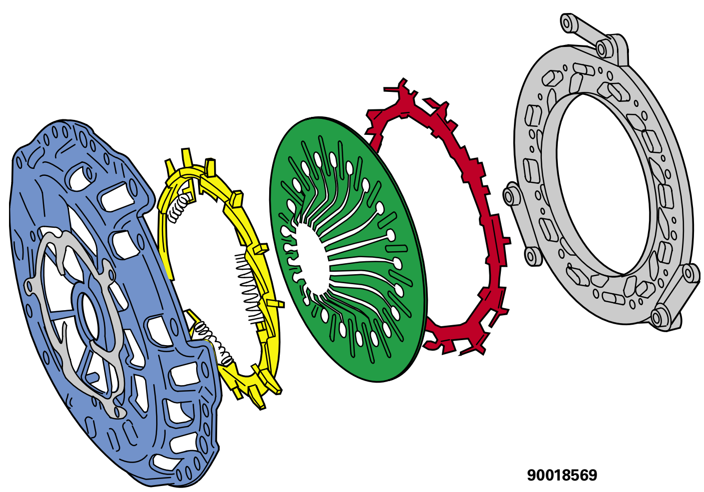
Transmission related concerns can cause noise or vibrations. The purpose of the transmission is to provide several different gear ranges to improve vehicle torque and acceleration qualities. The different gear ranges rotate at different speeds from the tire and wheel and shafts.

If the transmission is causing the noise and vibration it will usually change characteristics when the different gear ranges are selected. Most transmission noises and vibration will not be present when the transmission is placed in neutral during the road test.

Manual transmissions utilize a clutch assembly between the engine and transmission. The clutch assembly can cause noise and vibration. If it is suspected that the manual transmission is causing noise and vibration, refer to the transmission section of the service information for diagnostic procedures.

Automatic transmissions utilize a torque converter between the engine and transmission. The torque converter is driven at engine speed. Torque converter frequency will match engine frequency.

A locking torque converter improves fuel mileage and reduces engine emissions. This component can cause noise and vibration concerns. The torque converter operation can be monitored with a scan tool. Refer to service information to diagnose torque converter concerns.



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Differential Operation

The differential gear system divides the torque between the axle shafts. It allows the axle shafts to rotate at different speeds when turning corners. Most differentials consist of a pair of side gears and a pair of pinion gears. Each differential side gear is splined to an output shaft. The pinion gears are mounted on a pinion shaft and are free to rotate on the shaft. The pinion gear is fitted in a bore in the differential case and is positioned at a right angle to the axle shafts.

In operation, power flow occurs as follows:

- The pinion gear rotates the ring gear
- The ring gear (bolted to the differential case) rotates the case
- In straight ahead driving, the differential case rotates as one complete unit, no differential gears (pinion or side gears) rotate, and transmit power to the output shafts
- When cornering, the differential pinion gears (mounted on the pinion shaft in the case) rotate the side gears at a difference in speed allowing the tires to rotate smoothly
- The side gears (splined to the output shafts) rotate the shafts, during straight-ahead driving or cornering

Straight-Ahead Driving

During straight-ahead driving, the differential pinion gears do not rotate on the differential pinion shaft, because input torque applied to the gears is divided and distributed equally between the two side gears. As a result, the pinion gears revolve with the differential pinion shaft, but do not rotate around it.

Turning Corners

The outside wheel must travel a greater distance than the inside wheel in order to complete a turn. The difference must be compensated for to prevent the tires from scuffing and skidding through turns.

The differential allows the axle shafts to turn at unequal speeds. In this instance, the input torque applied to the pinion gears is not divided equally. The pinion gears now rotate around the pinion mate shaft in opposite directions. This allows the side gear and axle shaft attached to the outside wheel to rotate at a faster speed.

If a noise or vibration is being caused by the differential, the concern will usually change characteristics during straight-ahead driving and when turning corners. This is due to the different operation of the differential when turning. Differential noises are often torque sensitive resulting in characteristic changes when changing torque input.

During a road test, drive in a figure 8 pattern, in a safe and open area, and determine if the NVH concern is more pronounced while loading the differential gears.

Consult the axle section of service information if it is suspected the differential is causing a noise or vibration concern.

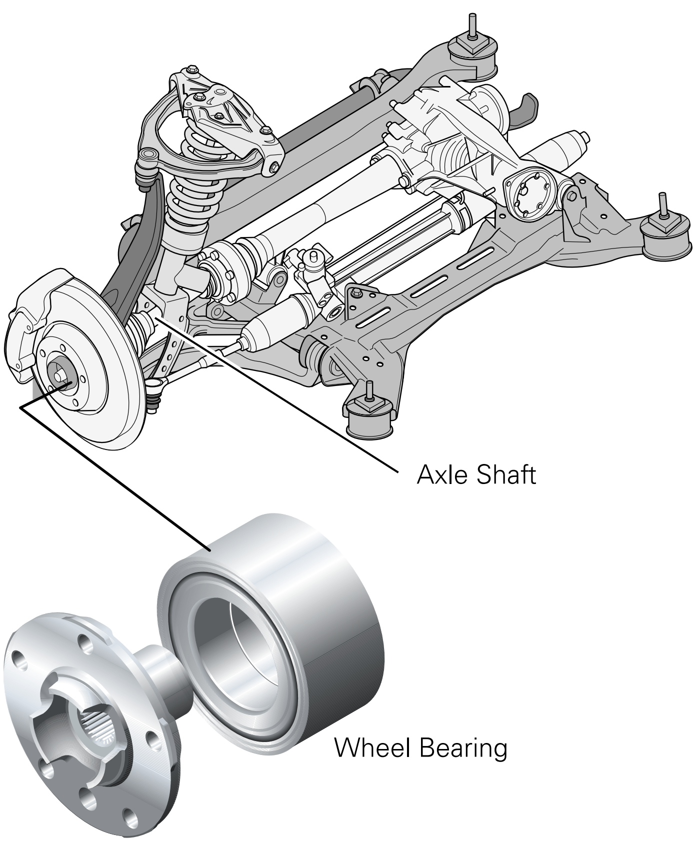
Vehicle Speed Vibrations

Bearing Noise

Wheel bearings and pinion and differential gear bearings can produce noise when worn or damaged. Bearing noise can be either a whining or a growling sound.

Faulty wheel bearings produce noise that generally changes when the bearings are loaded. When road testing the vehicle, turn the vehicle sharply to the left and right. This loads the bearings and changes the noise level. When wheel bearing damage is slight, the noise is usually not noticeable at speeds above 30 mph (48 kph).

Pinion bearings usually change noise characteristics when torque input is changed, i.e. coasting or hard accelerations



Gear Noise

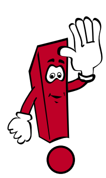
Gear noise usually occurs at specific speed ranges, usually between 30 and 40 mph (48 and 64 kph) or above 50 mph (80.5 kph). Gear noise can also occur during specific driving conditions such as acceleration, deceleration, coast, or constant load. Gear noises usually disappear if the vehicle is allowed to coast without any acceleration or deceleration torque applied to the gears.

Driveline Snap

A snap or clunk noise when the vehicle is shifted into gear (or the clutch is engaged) can be caused by:

- High engine idle speed
- Loose engine/transmission/transfer case mounts
- Worn U-joints
- Loose axle mounts
- Loose pinion gear nut and yoke
- Excessive ring gear backlash
- Excessive side gear/case clearance

The source of a snap or clunking noise can be determined by raising the vehicle on a hoist with the wheels free to rotate. Have another technician shift the transmission into gear and listen for the noise. A stethoscope, either manual or electronic, is helpful in isolating the source of the noise.



Use caution when working around rotating components.

Suspension Components

The suspension system plays a large role in the effects of NVH on a vehicle. Similar to the steering system components, the suspension of a vehicle can easily act as the medium through which vibration can be transferred. When the source of an NVH concern is determined, you usually can find the cause by performing a thorough visual inspection.

Passengers of a vehicle are sensitive to the effects of a harsh riding suspension. For this reason, various measures are taken in the design and development phase of a vehicle's suspension. For example, springs and bushings are carefully selected to provide a smooth ride and also to reduce the impact of steering forces.

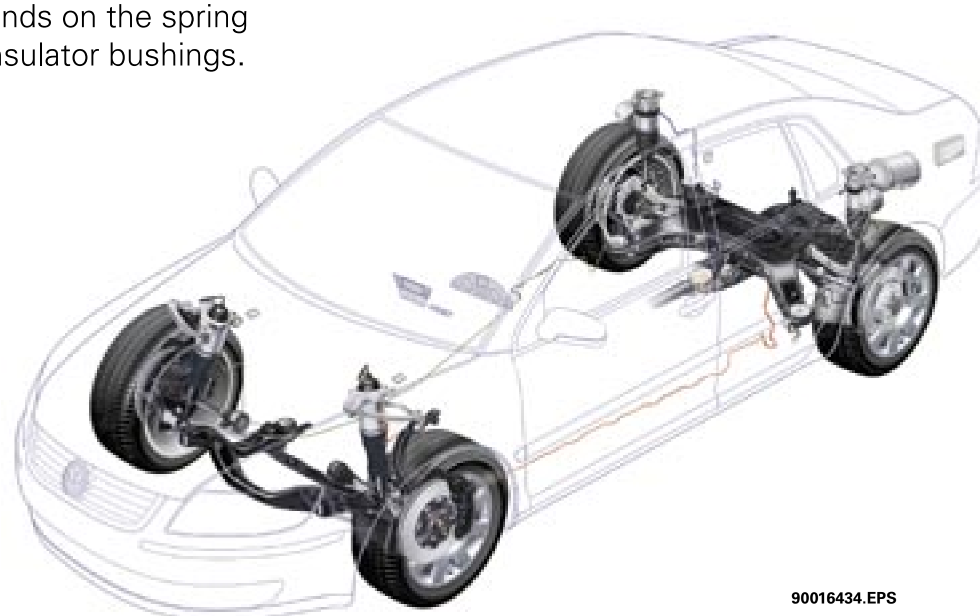
The vibration of a vehicle's suspension system consists of vertical and longitudinal forces. The vertical forces are controlled by well-proportioned sprung and unsprung weights, shocks, and coil springs.

Longitudinal forces are controlled by careful selection of suspension bushings. The suspension of a particular vehicle is designed so that the lower control arms absorb longitudinal impacts from the tires. Tire impact is further dampened by bushings before being transmitted through the crossmember to the body. This longitudinal compliance depends on the spring constant rate of the rubber insulator bushings.

Bushings are designed so they are softer in one area than in another. Bushings are made softer in the longitudinal direction so the effects of tire impact, or road shock, are reduced. Bushings are made stiffer in the lateral direction so steering the vehicle does not have as much of an adverse effect. It is important that bushings and insulators are in good condition, and they are of the specified type in order to avoid NVH concerns in the suspension.

Noise from the suspension is typically caused by one of the following:

- Loose components
- Worn bushings
- Poor lubrication



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Steering Components

Many customer concerns regarding NVH are related to the steering system. This is because the driver is holding the steering wheel at all times while driving, and any vibrations from the tires or suspension are transferred to the steering components. Noise-related concerns are usually generated within the steering system itself. Vibration-related concerns can be caused by many different components, including components in the suspension, tires, and wheels.

Noise

Some steering system sounds are normal and should not be of concern. There are some inherent noises in all power steering systems. However, other sounds may indicate a problem within the steering system. Many normal steering system sounds are related to the power steering pump. Hissing and rattling are two steering system related noises that may occur.

Hiss

A hissing noise usually originates in the steering gearbox and power steering pump. With the vehicle stationary, a hissing sound may be heard when the steering wheel is turned, which results from fluid pressure pulsation in the pump.

When diagnosing a hissing noise concern, first inspect all steering hoses to ensure they are not touching other parts of the vehicle.

Check service information and technical service bulletins for possible updated hoses or hose routings when diagnosing a hissing concern.

Rattle

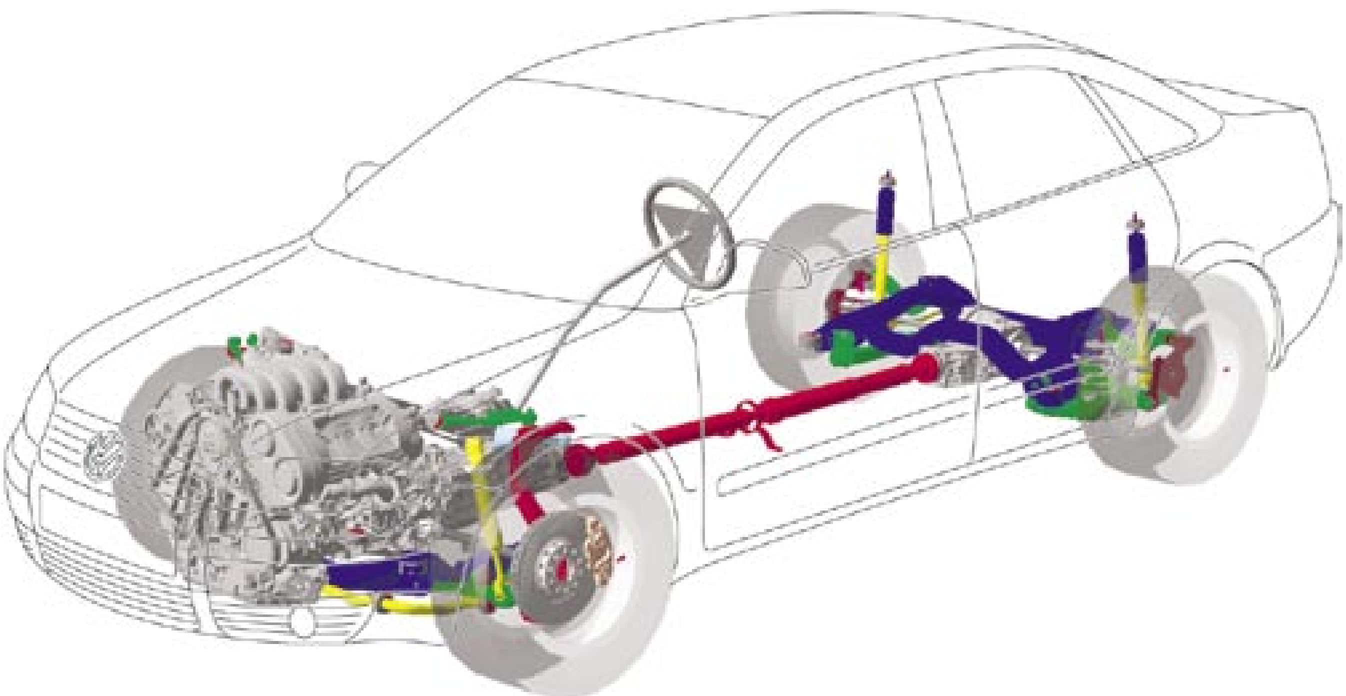
Rattle usually originates in the steering gear. The possible causes for this condition are:

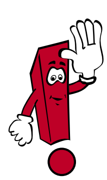
- Worn steering or suspension components
- Worn or damaged rack-and-pinion retainers and bushings
- Pressure hoses touching other vehicle components

All-Wheel Drive Systems

Because all-wheel drive vehicles have more moving parts than their 2-wheel drive counterparts, there is more opportunity for vibrations to occur. Knowing the construction and operation of these systems can help in diagnosis of NVH concerns.

The next few pages contain excerpts from several SSPs. Refer to the original SSP for more information.





Refer to SSP 822203, The Passat W8, for more information.

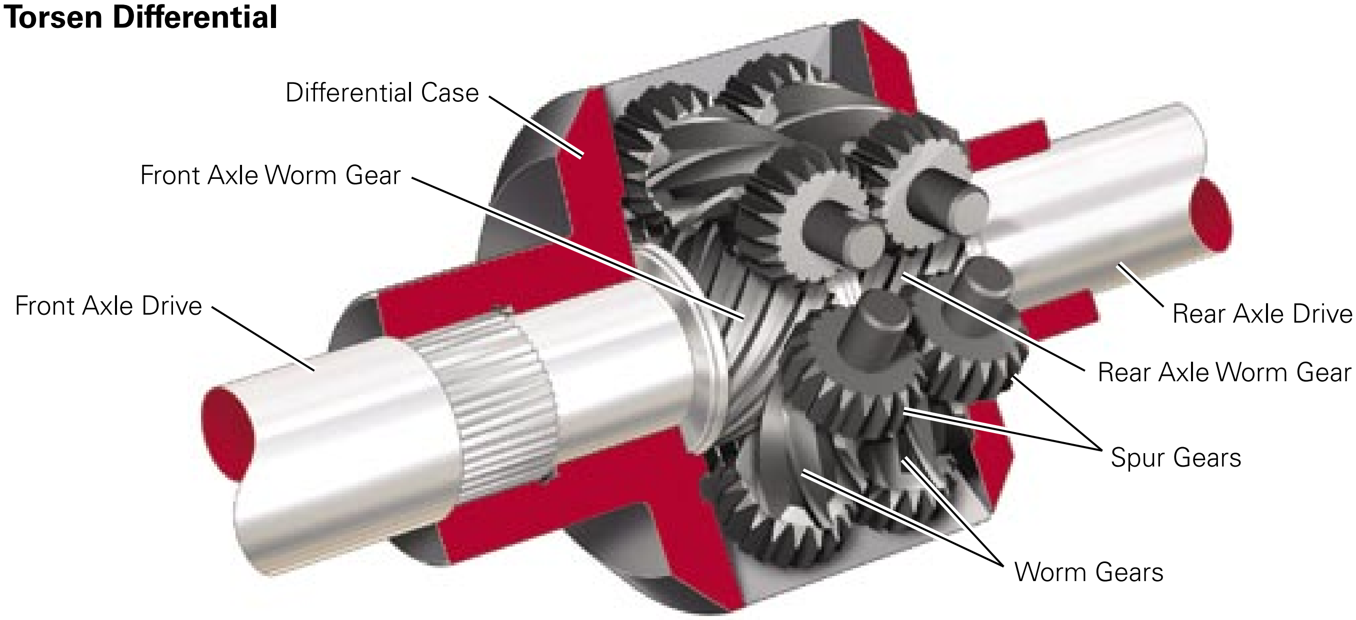
4Motion All-Wheel Drive

The 4Motion all-wheel drive system is designed to distribute the drive forces between the front and rear axles to maintain positive engagement at the wheels with traction.

The Torsen® differential detects wheel slip in one axle and distributes the drive power to the wheels of an axle with better wheel grip.

The Torsen® differential permits limited differences in speed between the front and rear axles to allow for ABS control processes. It operates automatically and reacts independently of driver input.

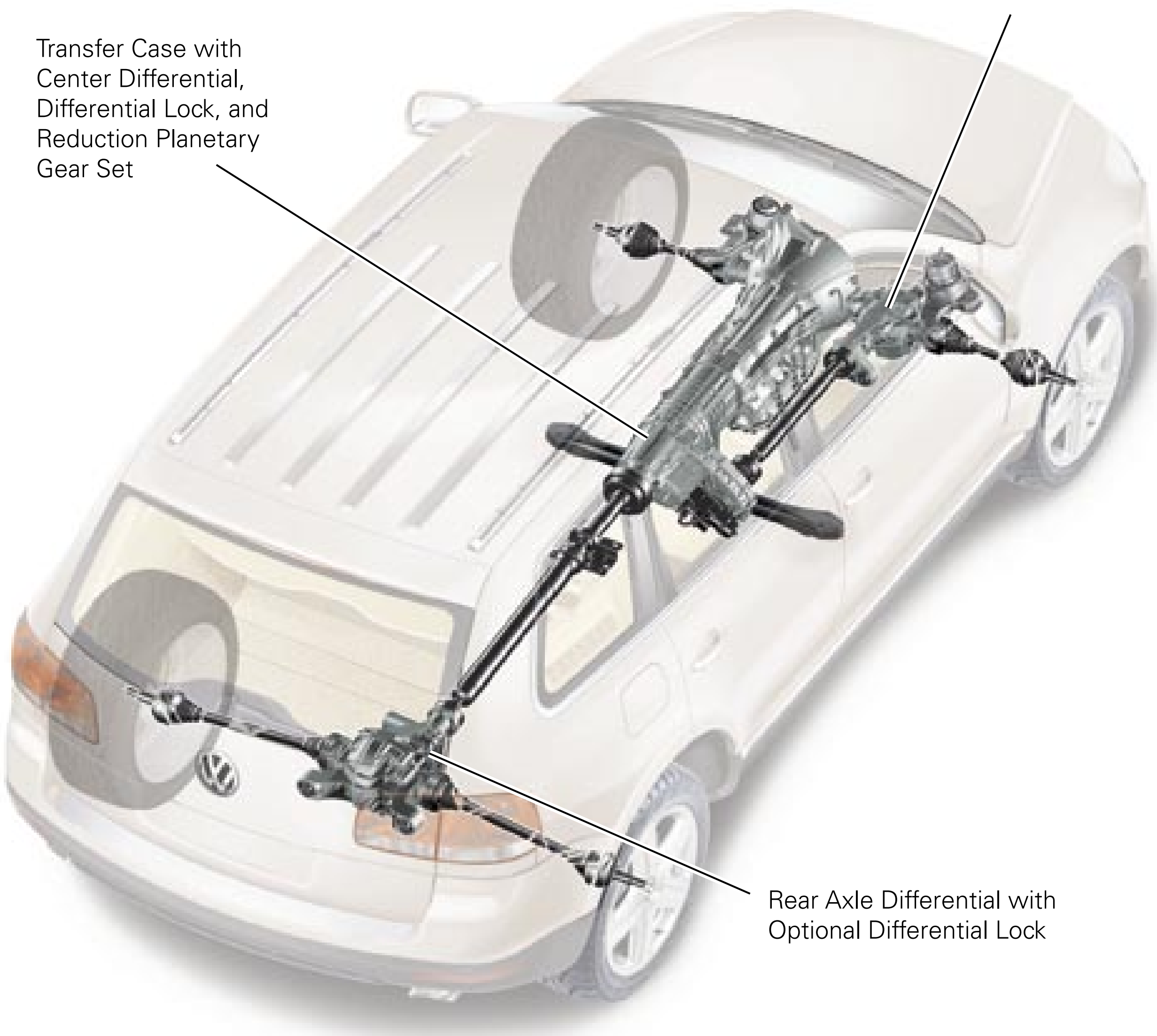
The Torsen Differential



4XMOTION

The power of the Touareg engine is transmitted to the wheels via the full-time 4 wheel drive, 4XMOTION system.

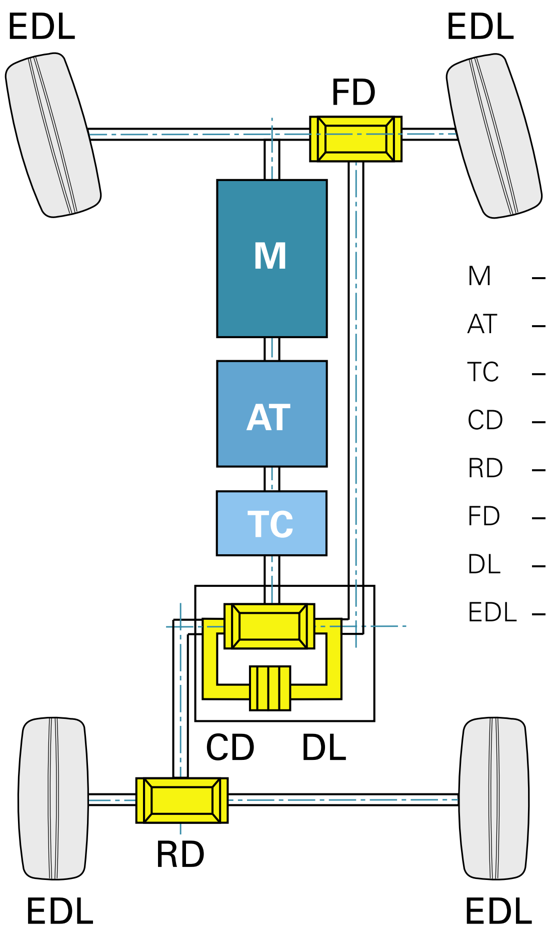
The front axle differential is a separate component from the engine/transmission assembly and is flexibly mounted to the sub-frame. In addition to being acoustically beneficial, this also makes it possible to mount the front wheels further forward.



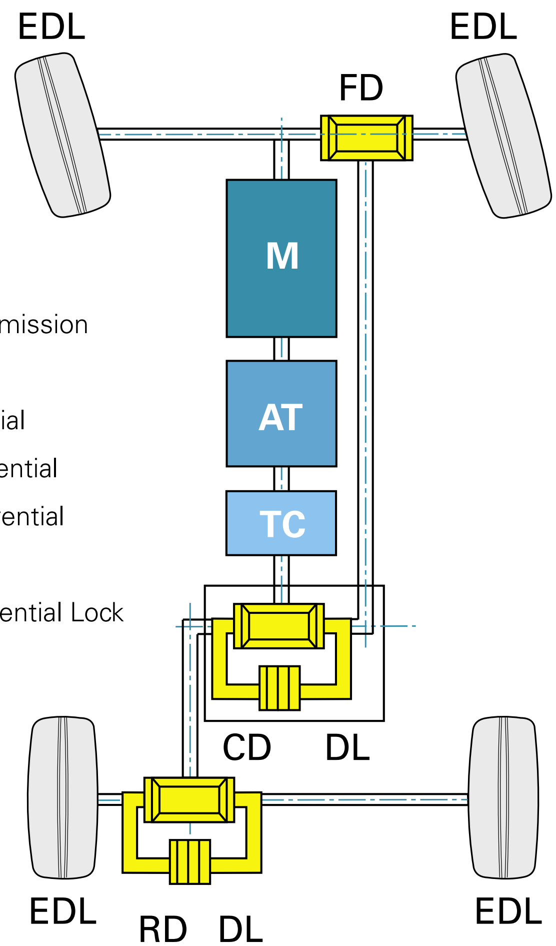
Refer to SSP 89H303, The Touareg Suspension and 4XMOTION Systems, for more information.

There are two drive equipment options for the 4XMOTION system. The open rear differential is standard equipment while a locking rear differential is available as an option.

Open Rear Differential



Optional Locking Rear Differential



M	–	Motor
AT	–	Automatic Transmission
TC	–	Transfer Case
CD	–	Center Differential
RD	–	Rear Axle Differential
FD	–	Front Axle Differential
DL	–	Differential Lock
EDL	–	Electronic Differential Lock

The adjustable multi-plate clutch of the center differential is automatically controlled by the Differential Control Module J646.

Torque is distributed from the engine to the front and rear axles via the automatic transmission and transfer case.

During normal operation, torque is divided equally between the front and rear axles.

The multi-plate center differential is allowed to disengage whenever the Differential Control Module determines a power differential between the front and rear axles is required, for example, during cornering.

The driving force between the wheels of an individual axle is distributed through the operation of the Electronic Differential Lock function of the ABS.

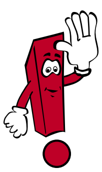
The driver also has the option of locking the center differential (and optional rear differential) by using a rotary switch in the center console.

Locking the center differential with the switch overrides automatic control and forces the front and rear axles to operate at the same speed.

Haldex Coupling

The development of the Haldex coupling is a giant step forward in modern all-wheel drive technology. This coupling is controllable, based on the inputs the Haldex control module receives from the vehicle.

Slip is no longer the only decisive factor in the distribution of drive forces — the car's dynamic state is also a factor. The Haldex control module monitors the ABS wheel speed sensors and the engine control module (accelerator pedal signal) via the CAN-bus. This data provides the engine control module with all the information it needs on road speed, cornering, coasting or traction mode, and can respond optimally to any driving situation.



Refer to SSP 89C303, Volkswagen R32, for more information.

Characteristics of the Haldex coupling:

- Permanent all-wheel drive with electronically controlled multi-plate clutch
- Front drive characteristic
- Quick response
- No strain on clutch when parking and maneuvering vehicle
- Compatible with different tires (e.g., emergency wheel)
- No restrictions on towing with the rear axle on the ground
- Fully integrates with systems such as the Anti-Lock Brake System (ABS), Electronic Differential Lock (EDL), Anti-Slip Regulation (ASR), Electronic Brake Distribution system (EBD), and Electronic Stabilization Program (ESP)

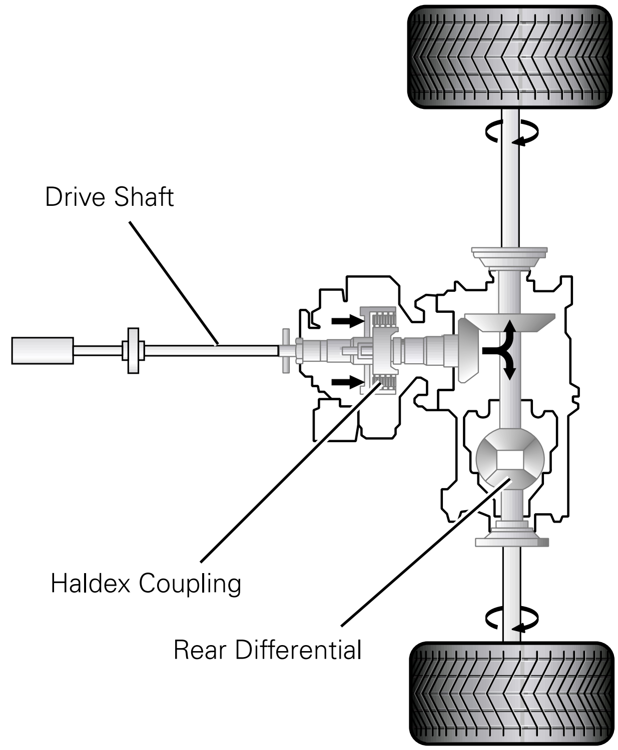
Haldex Coupling

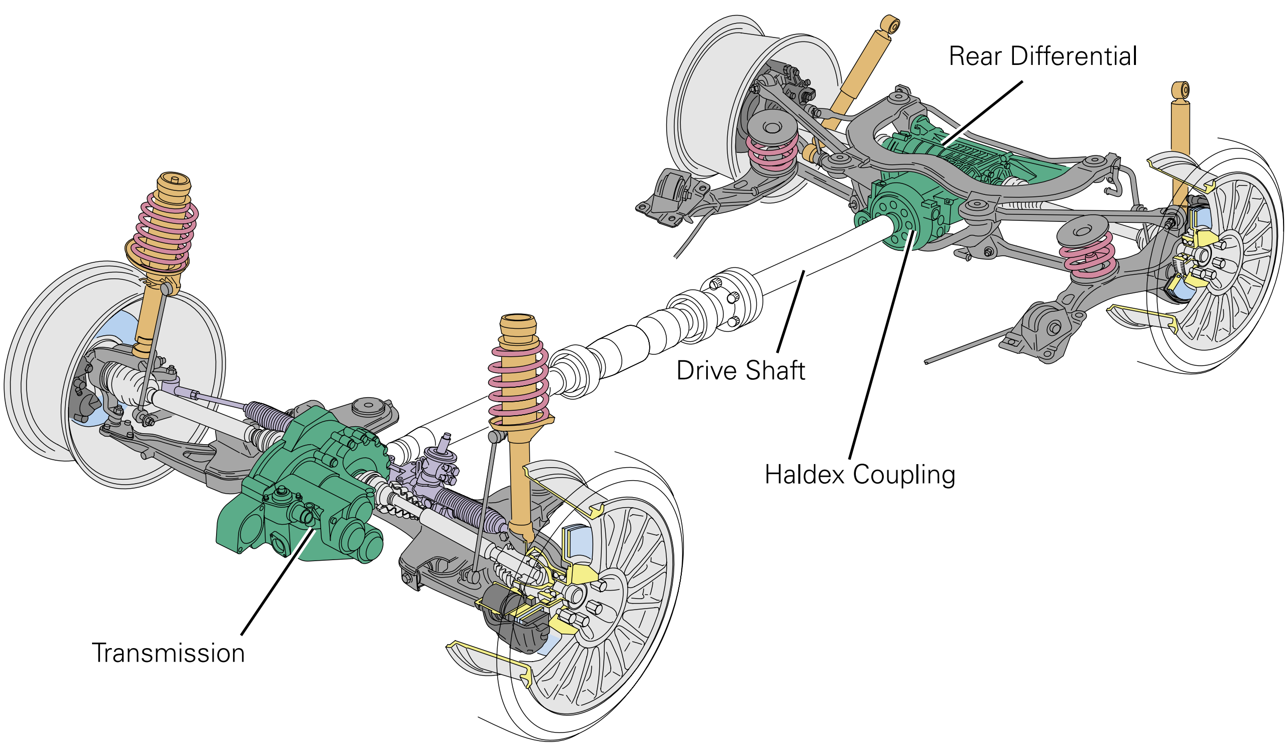
The Haldex coupling is mounted on the rear axle differential and is driven by the drive shaft.

Engine torque is transmitted to the drive shaft through the gearbox, the front axle differential, and the front axle drive.

The drive shaft is connected to the input shaft of the Haldex coupling. In the Haldex coupling, the input shaft is separated from the output shaft to the rear axle differential.

Torque can only be transmitted to the rear axle differential when the Haldex coupling clutch plates are engaged.





Sirometer (Vibratach)

The sirometer is a tool that is useful when diagnosing NVH concerns. Originally used for reading small engine rpm, this inexpensive tool is highly accurate for measuring vibration frequencies. The sirometer has enough range to measure the majority, if not all, of an automobile's vibration frequencies. The tool can be purchased at most full service small engine repair and parts centers.

The sirometer has a wire that, when adjusted to the proper length, resonates to the vibration frequency. To use the sirometer, hold it against a vibrating component. Rotate the dial to extend the wire and change the wire's resonant frequency until the wire vibrates at its widest arc. Then read the frequency on the tool's face, labeled Cycles Per Second – Hertz.

Always adjust the length of the wire from its smallest length to its longest length to ensure all frequencies are being recorded. It is possible to have more than one vibration present in a vehicle.

EVA II™

The EVA II allows for a systematic collection of information that is necessary to accurately diagnose and repair NVH problems. The proper use of the EVA II can significantly reduce vehicle service time. The tool uses an electronic pick-up that measures vibration frequency and amplitude. An additional pick-up can be added and two sources of vibrations can be compared. The pick-ups can be placed anywhere on the vehicle. By placing the pick-up on different areas of the vehicle and comparing the vibration's amplitude, as displayed on the screen, the source of the vibration can be located by the highest amplitude. If the steering wheel or passenger's seat is vibrating, the pick-up can be placed there to measure the vibration.

The EVA II contains a software database that contains most tire sizes and axle gear ratios. When the correct vehicle information is entered into the EVA II, the tool will determine and display the source(s) of the vibration. This feature eliminates most of the mathematical formulas and calculates the known frequencies of rotating components.

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The EVA II can record snapshots during a road test and the data replayed to determine the vibration frequency. This is useful for intermittent or short duration vibrations.

The EVA II has feature to use an inductive pick-up timing light to visually flash a vibration frequency. The operation manual for the tool describes how to use this feature to help in diagnosing the location of a vibration's source. The flashing timing light can be used to balance propeller shafts.

Contact Equipment Solutions for more information on the EVA II.

ChassisEAR™

The ChassisEAR is a versatile electronic listening tool that allows the user to listen to amplified sounds through a professional set of headphones. The proper use of the ChassisEAR can reduce the time in diagnosing NVH concerns on a vehicle. The tool has multiple microphone inputs that can be placed in different sections of the vehicle. Attachment of the six microphones and clamps helps to locate many difficult-to-diagnose vehicle parts. During a road test, these parts do not make the same sounds as when the car is on a hoist. To accurately diagnose an under-vehicle problem, operate the vehicle so all parts and bearings are under full load. The different inputs allow the loudest area to be determined and thus determine the possible source. Place the microphones on parts or areas suspected as being the possible source. Some of these vehicle parts and areas include:

- Wheel bearings
- Brake calipers
- CV joints
- Leaf and coil springs
- Differential
- Transmission
- Body squeaks and rattles
- Under dash
- Fuel injectors
- Generator
- Water pump
- Smog pump
- Power steering pump
- Air conditioning compressors

Remember that noises can be caused from a vibration that resonates through another component causing it to vibrate. Always check for a vibration frequency when beginning to diagnose a noise concern.

Contact Equipment Solutions for more information on the ChassisEAR.

Hunter's GSP9700 Service Vibration Control System™

The Hunter GSP9700 Series Vibration Control System is an electronic dynamic balancer. The GSP9700 measures tire and wheel assembly balance, runout, and radial force variation measurement (road force variation (RFV) measurement).

Other Tools

Several automotive tool manufacturers have developed electronic tools for measuring and recording noises and vibrations. Some of these tools have multiple vibration and noise inputs, recording and graphing capabilities. Not all of the tools available have been covered.

Please contact automotive tool manufacturers to request information.

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NVH Terminology

Audible Range of Sound – Sounds that are in the range of 20 to 20,000 Hertz (Hz).

Amplitude – The vertical measurement between the top and bottom of a wave. Also see magnitude.

Beat – An NVH concern produced by two sounds that is most noticeable when the frequency difference is 1 to 6 Hz.

Bead Seating – The process of seating the tire to the rim. If properly lubricated the bead seating occurs when the tire and wheel are assembled.

Compelling Force – A vibrating object acting upon another object that causes the other object to vibrate.

Cycle – The path a wave travels before the wave begins to repeat the path again.

Dampen – To reduce the magnitude of a noise or vibration.

Dampers – A component used to dampen a noise or vibration. Foam and rubber are commonly used to dampen vibrations.

Dynamic Balance – A procedure that balances a tire and wheel assembly in two planes. Dynamic balance removes radial and lateral vibrations.

Droning, High-Speed – A long duration, non-directional humming noise that is uncomfortable to the ears and has a range of 50 mph (80.5 kph) and up.

Droning, Low-Speed – A long duration, low-pitched noise that is non-directional and has a range of up to 30 mph (48 kph).

Droning, Middle-Speed – A long duration, low-pitched noise that is non-directional and has a range of 30 to 50 mph (48 to 80.5 kph).

Electronic Vibration Analyzer II (EVA II) – An electronic NVH diagnostic tool that measures frequency and amplitude.

Frequency – The number of complete cycles that occurs in a given period of time.

Harshness – An aggressive suspension feel or lack of give in response to a single input.

Hertz – The unit of frequency measurement in seconds (a vibration occurring 8 times per second would be an 8 Hz vibration).

Intensity – The physical quality of sound that relates to the amount and direction of the flow of acoustic energy at a given speed.

Lateral Runout – A condition where a rotating component does not rotate in a true plane. The component moves side-to-side (wobbles) on its rotational axis.

Magnitude (Amplitude) – The amount of force or the intensity of the vibration. The magnitude or strength of a vibration is always greatest at the point of resonance.

Medium – Provides a path for sound waves to travel through.

Natural Frequency – The frequency that a component will vibrate the easiest. Normally, the larger the mass, the lower its natural frequency.

- Engine block (2-4 Hz)
- Tire and wheel assemblies (1-15 Hz) – proportional to vehicle speed
- Suspension (10-15 Hz
- Driveline (20-60 Hz)
- Differential components (120-300 Hz)

Noise – The unpleasant or unexpected sound created by a vibrating object.

Order – The number of disturbances created in one revolution of a component.

Phase – The position of a vibration cycle relative to another vibration cycle in the same hertz rate (time frame).

Phase – The cycle pattern of two or more vibrations that overlap and combine to increase or decrease the overall magnitude.

Pitch – The physical quality of sound that relates to the frequency of the wave.

Radial Force Variation (RFV) – A measurement of the tire's uniformity, under load, in regards to the variation of the load acting towards the center of the tire; commonly referred to as the tire's sidewall variation.

Radial Runout – A condition where a rotating component does not rotate in a true plane. The component moves up and down on its rotational axis.

Resonance – The tendency of a system to respond increasingly to a compelling force oscillating at, or near, the natural frequency of the system. This causes a sudden and large vibration.

Road Noise – A noise that occurs while driving on gravel or roughly paved roads at all vehicle speeds, or when a vehicle is coasting.

Shake, Lateral – A side-to-side vibration of the body, seats, and steering wheel.

Shake, Vertical – An up and down vibration of the body, seats, and steering wheel.

Shimmy, High-Speed – A vibration that causes the steering wheel to oscillate when driving on smooth roads at high speeds.

Shimmy, Low-Speed – A vibration that causes the steering wheel to oscillate when driving across a bump at low speeds.

Source Component – The component that is diagnosed as being the root cause of a vibration or noise concern.

Sound – The result of a vibrating disturbance of an object, which produces waves that transmit out from the source.

Static Balance – The method of balancing a tire and wheel assembly in a single plane. Static balancing removes only the lateral (side to side, wobble) imbalance and the tire and wheel assembly could possibly have a radial (up and down) vibration.

Torque Sensitive Vibration or Noise – A vibration or noise that is sensitive to different loads and torque, applied to the drive train of a vehicle. The vibration or noise changes when the throttle position or transmission gearing is used, during a road test, to change the torque applied to the drive train.

Vibration – The repetitive motion of an object, back and forth or up and down, which may be felt or heard.

Wheel Diameter – The dimension of a wheel measured on the inside of the wheel at the bead seat area.

Check vehicle history prior to diagnosis and use NVH SSP for in-depth diagnosis.

Road test to verify concern

- Is it felt through the steering wheel? – Start with **front** axle
- Is it felt through seat/vehicle floor pan? – Start with **rear** axle

Diagnose according to conditions listed below

Felt while braking

Check:
- Brake components
- Steering components
- Suspension components
- Relevant Technical Bulletins

Concern disappears or is diminished after the car has been driven awhile

Check tires for Temporary Flat-Spotting:
Tires can become temporary flat-spotted when a vehicle has been driven and then parked on a cold surface. This may happen in cold climates as well as warm climates. Vehicles parked for long periods of time and/or stored with low air pressure are also susceptible to flat spotting.

Vibration is felt at a certain vehicle speed

Check wheels for:
- Dirt, mud, snow, or ice build-up
- Damage
- Missing or excessive wheel weights
- Loose wheel bolts
- Proper wheel torque
- Excessive runout

Check tires for:
- High Radial Force Variation (RFV)
- Imbalance
- Irregular wear
- Abnormal pressure

Check drive train for:
- Prop shaft misalignment
- Damaged axle shafts/CV joints
- Worn wheel bearings
- Rear differential performance

Vibration is felt at a certain engine speed

Check drive train for:
- Prop shaft misalignment
- Damaged axle shafts
- Damaged CV joints
- Rear differential performance
- Proper torque converter performance

Check Engine for:
- Misfires
- Accessory vibrations
- Camshaft, crankshaft and intermediate shaft imbalance

Check Chassis for:
- Damaged or misaligned engine and transmission mounts
- Proper Electro-Hydraulic mount operation
- Damaged or misaligned exhaust system and components

An online Knowledge Assessment (exam) is available for this Self-Study Program.
The Knowledge Assessment may or may not be required for Certification.
You can find this Knowledge Assessment at:

www.vwwebsource.com

From the vwwebsource.com Homepage, do the following:

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– Type the course number in the Search box

– Click "Go!" and wait until the screen refreshes

– Click "Start" to begin the Assessment

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Or, E-mail:

Comments@VWCertification.com

Notes

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