

Vibration Diagnosis and Correction

Specifications

Tire and Wheel Runout Specifications

Application	Specification	
	Metric	English
Aluminum Wheel		
Lateral	0.762 mm	0.030 in
Radial	0.762 mm	0.030 in
Steel Wheel		
Lateral	1.143 mm	0.045 in
Radial	1.015 mm	0.040 in
Tire and Wheel (Radial and Lateral)		
Off-Vehicle	1.27 mm	0.05 in
On-Vehicle	1.52 mm	0.06 in
Wheel Stud	0.25 mm	0.01 in
Wheel Hub	0.132 mm	0.0052 in

Propeller Shaft Runout Specifications

Application	Metric	English
One-Piece Propeller Shaft Runout		
• Front	1.016 mm	0.040 in
• Center	1.27 mm	0.050 in
• Rear	1.40 mm	0.055 in
Two-Piece Propeller Shaft Runout		
• Front	0.762 mm	0.030 in
• Center	0.762 mm	0.030 in
• Rear	0.889 mm	0.035 in
Pinion Runout	0.076 mm	0.003 in

Propeller Shaft Balancing Weight Amounts

Correction, Total Weight	Clamp Spread, Degrees
0.0	180
0.1	174
0.2	169
0.3	163
0.4	157
0.5	151
0.6	145
0.7	139
0.8	133
0.9	127
1.0	120
1.1	113
1.2	106
1.3	99
1.4	91
1.5	83
1.6	74
1.7	64
1.8	52
1.9	36
2.0	0

Diagnostic Information and Procedures

Systematic Approach

During the last 10–15 years, vehicle design and engineering have dramatically changed due to the following factors:

- Increased fuel costs
- Decreased fuel supplies
- Corporate Average Fuel Economy requirements
- Clean air legislation
- Foreign competition
- Ability to withstand collision
- Rising customer expectations

Vehicle designs have evolved from full-frame construction to lighter unibody designs. These designs transfer noise and vibration much more readily.

General Motors has greatly reduced the use of heavier and smoother running V8 engines, replacing these engines with lighter, more fuel-efficient 4-cylinder and 6-cylinder engines. During this same time period, the following options have become increasingly popular:

- Air conditioning
- Power steering
- All-wheel drive

Such options increase engine load and can also generate unwanted noise and vibration.

Customer perception of quality can be directly linked to the presence or absence of unwanted noise and vibration. The technician's ability to quickly diagnose and repair a noise or vibration concern directly affects that customer's loyalty to the dealership. The technician who is capable of satisfying this need will be highly regarded and in great demand.

The intentions of this section of the service manual are to provide systematic approaches to vehicle vibration diagnosis and correction. By using the Strategy Based Diagnosis and the troubleshooting philosophies covered in this section, the technician will be able to provide effective and timely repairs.

Diagnostic Information and Procedures

This section describes the techniques and procedures for correcting the following types of vibrations:

- Tire and wheel shake
- Steering/suspension shimmy and shake
- Launch shudder
- Exhaust moan
- Engine firing frequency

Identifying the Complaint

The first step in diagnosing a vibration complaint is to identify the exact vibration that concerns the customer.

Sometimes the vibration can be duplicated at a given speed. Other vibrations may not be as evident and may require questioning the customer carefully. Perform a road test with the customer in the vehicle in order to determine the specific vibration complaint.

Ask the following questions when attempting to identify a vibration complaint:

- At what speed is the vibration the worst?
- Can the customer feel the vibration? If so, where?

- Can the customer hear the vibration?
- Does the engine or the vehicle load affect the vibration?
- Does the vibration occur in more than one gear range?
- When did the vibration first appear?

The answers to these questions will help in duplicating and diagnosing the vibration.

If you suspect that the vibration is normal, compare the vibration with a vehicle that is equipped in the same way, including the following factors:

- Body style
- Engine option
- Engine driven accessories
- Transmission type
- Tire size
- Suspension performance type
- Axle ratio

Important: Do NOT attempt to repair a normal condition, or the customer will probably be convinced that the vehicle has a problem. Customer satisfaction becomes extremely difficult after this point.

If necessary, ride with the customer. Make the comparison with the customer present and explain the situation.

Duplicate the Condition

All vehicles produce vibrations. Some vibrations are normal, while others are not. Some vibrations can be repaired, some cannot. Duplicate or experience the customer's complaint. Evaluate the vibration and the cause of the vibration under changing conditions. Otherwise, you cannot know for certain that you are fixing what the customer would like fixed.

The symptoms and characteristics of a noise or vibration are also important information. Ask yourself the following questions before you begin:

- What does the vibration feel like?
- Does the vibration make noise? If so, what does the vibration sound like?

Different types of noise and vibration have particular characteristics. These characteristics will help determine the cause of the condition, and the best way to correct the condition.

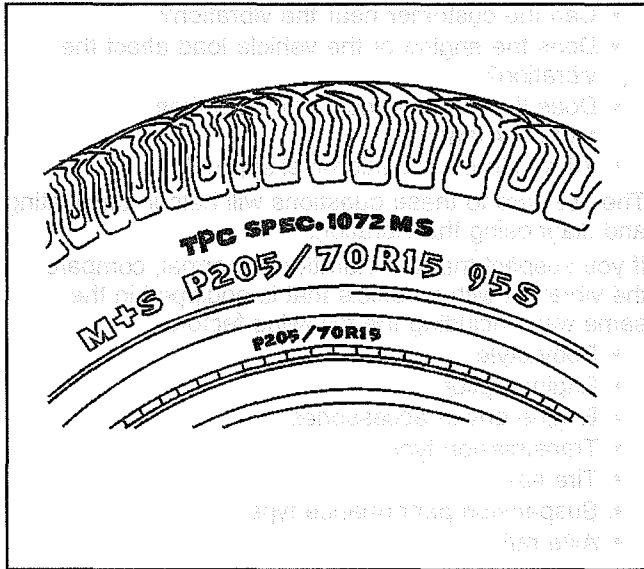
A Process of Elimination

You must understand a few basic concepts before attempting to diagnose a vibration. As in any diagnostic process, you must perform the following steps:

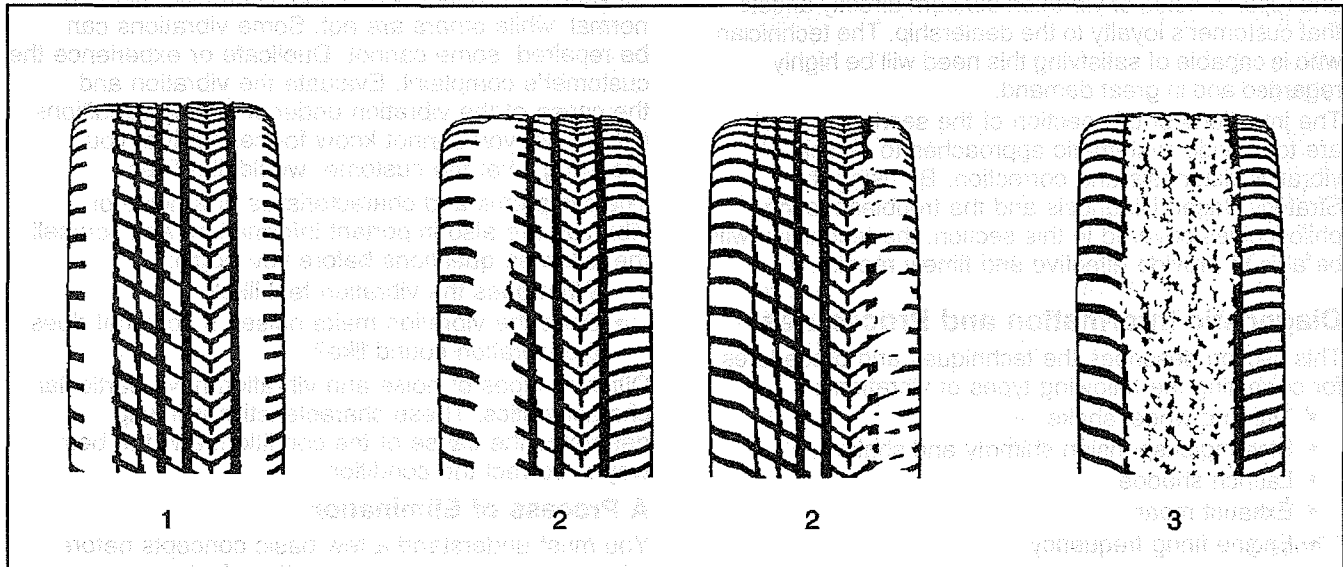
- Gather the information
- Decipher the information
- Make your correction based on the results

Road test the vehicle and inspect the vehicle in a manner which systematically eliminates different components. This process supplements the information which you have received from the customer concerning the complaint. Concentrating efforts on the areas that have not been eliminated will make repairs faster and more effective.

Tire and Wheel Inspection



The tires on all new GM models have a tire performance criteria (TPC) rating number molded on the sidewall. The TPC rating will appear as a 4-digit number preceded by the letters TPC SPEC on the tire wall near the tire size. A replacement tire should have the same TPC rating.



Legend

- (1) Hard Cornering, Under Inflation
- (2) Excessive Toe on Non-Drive Axle

- (3) Heavy Acceleration on Drive Axle, Excessive Toe on Drive Axle, Over Inflation

Inspect the tire and wheel assemblies for the following conditions:

- Unusual wear such as cupping, flat spots, and heel-and-toe wear
(These conditions can cause tire growl, howl, slapping noises, and vibrations throughout the vehicle.)
- Proper inflation
- Bulges in the sidewalls
(Do not confuse bulges with normal ply splices, commonly seen as indentations in the sidewall).
- Bent rim flanges

By inspecting these characteristics of the tire and wheel assemblies, you may discover the cause of the vibration. The inspection will also provide assurance that the vehicle is safe for road testing.

Road Test

Purpose of Road Testing

The purpose of road testing is to duplicate the vibration complaint and to find any operating conditions that change or eliminate the vibration. Most importantly, road testing will determine whether the vibration is related to the engine speed or to the road speed.

In order to complete a quick and accurate road test, install an engine tachometer (such as a scan tool) and the EVA in the vehicle. Place the EVA vibration sensor in a location where the customer's concern can be felt.

Which Component Group is Causing the Vibration

After you have related a vibration to either the engine or to the vehicle-speed, break the vibration down further in order to fit into one of the following groups of rotating components:

- The engine, the clutch disc (manual transmission), the propeller shaft (within the driveline support assembly), the transmission flexplate (automatic transmission), and the transmission torque converter
- The transmission output shaft and the rear axle differential pinion (mounted in the rear of the differential)
- The tires, the wheels, the hubs, and the rotors

These 3 groups represent the major areas that can produce vibration complaints. The components in each group are related to each other because the components are either bolted or splined together. This means that each group of components rotates at the exact same speed.

These categories can be broken down further in order to identify the exact component responsible for the disturbance. The emphasis is on testing (and more testing) in order to pinpoint the source and to eliminate unnecessary parts replacement.

Perform a road test for ALL vibration complaints unless the disturbance occurs only with the vehicle at a standstill.

Types of Road Test Procedures

Caution: Refer to *Road Test Caution in Cautions and Notices*.

Important: Before performing any road test, inspect the tires and wheels. Refer to *Tire and Wheel Inspection*.

The following road test procedures are the most informative and the most used:

- Slow acceleration test
- Neutral coast-down test
- Downshift test
- Neutral run-up test
- Brake torque test
- Steering input test
- Standing start acceleration test (launch shudder)

These tests will help to pinpoint the vibration. Perform all of the tests on a smooth and level road.

Slow Acceleration Test

This test will identify those conditions which are related to the engine-speed or to the vehicle-speed. Additional tests may be necessary in order to determine the exact cause of the vibration.

Caution: Refer to *Road Test Caution in Cautions and Notices*.

1. On a smooth, level road, slowly accelerate up to highway speed.
2. Look for disturbances that match the customer's description.
3. Observe the following readings where the disturbance occurs:
 - The vehicle speed, km/h (mph)
 - The engine speed (RPM)
 - The frequency (if possible)

Now perform the neutral coast-down test and the downshift test.

Neutral Coast-Down Test

Caution: Refer to *Road Test Caution in Cautions and Notices*.

1. On a smooth level road, accelerate to a speed slightly higher than the speed at which the vibration occurs.
2. Shift the vehicle into NEUTRAL gear and coast down through the vibration range.

Observe whether the vibration is present in NEUTRAL gear.

If the vibration still occurs in NEUTRAL gear, then the vibration is definitely sensitive to vehicle-speed. At this point, the following components have been eliminated as a cause of the vibration:

- The engine
- The clutch disc (manual transmission)
- The transmission flywheel (automatic transmission)
- The torque converter

Depending on the symptoms or the frequency, the repair will concentrate on one of the following components:

- The tire and wheel assemblies
- The transmission output shaft
- The propeller shaft
- The rear axle differential pinion
- The rear drive axle or the rear drive axle shafts

Downshift Test

Caution: Refer to Road Test Caution in Cautions and Notices.

1. On a smooth, level road, accelerate to the speed at which the concern vibration occurs.
Observe the engine RPM.
2. Decelerate and safely downshift to the next lower gear.
3. Operate the vehicle at the previous engine RPM.

If the vibration returns at the same engine RPM, the following conditions are the most probable causes of the vibration:

- The engine
- The clutch disc (manual transmission)
- The propeller shaft
- The transmission flywheel (automatic transmission)
- The torque converter

Repeat this test in lower gears, and in NEUTRAL, in order to confirm the results.

In some cases, a vibration may also be sensitive to torque or engine load, as well as being related to a specific engine speed or vehicle speed. These vibrations can be most difficult to diagnose, and require additional testing. A systematic approach usually leads to isolating the problem.

Neutral Run-Up Test

This test is designed to identify vibrations which are related to the speed of the engine. Use this test when the customer has a concern with vibration at idle, or as a follow-up to the downshift test. This test probably doesn't apply when the complaint is related to vehicle speed only (appearing at the same vehicle speed regardless of the engine speed).

Caution: Refer to Road Test Caution in Cautions and Notices.

1. Slowly increase the engine speed while looking for disturbances that match the customer's complaint.
2. Observe the engine speed (RPM) and the frequency (if possible) where the vibration occurs.

Brake Torque Test

This test is designed to identify engine-related vibrations that were not uncovered with the neutral run-up test. This test also works for vibrations that are sensitive to the engine load or to the torque. This test will probably not apply to vibrations which are related only to the speed of the vehicle.

Caution: Refer to Road Test Caution in Cautions and Notices.

1. Apply the park brake.
2. Block the front wheels.
3. Step firmly on the brake pedal.
4. Place the vehicle in DRIVE.
5. Slowly increase the engine speed while looking for vibrations that match the customer's description.
6. Observe the engine speed (RPM) and the frequency (if possible) at which the disturbance occurs.
7. If necessary, place the vehicle in REVERSE gear and repeat steps 5 and 6.

Steering Input Test

This test is intended to determine how much the wheel bearings and other suspension components contribute to the vibration, especially a vibration relating to noise, such as growl, grinding, and roaring.

Caution: Refer to Road Test Caution in Cautions and Notices.

1. With the vehicle at the vibration speed (mph), drive through slow sweeping turns, first in one direction and then in the other direction.
2. If the vibration gets worse or if the vibration goes away, inspect the following components as possible causes of the vibration:
 - The wheel bearings
 - The hubs
 - The tire tread
3. The CV joint angle increases when the vehicle is turning. On front wheel drive (FWD) and four wheel drive (4WD) vehicles, CV joint condition systems may appear when the angle increases. Putting a load on the CV joint may increase the vibration amplitude. The third order, tire speed related amplitude would remain the same.

Standing Start Acceleration (Launch Shudder) Test

The purpose of this test is to duplicate a vibration called launch shudder. In some cases, a powertrain mount or an exhaust ground-out may also be the cause of the vibration, depending on the symptoms.

Caution: Refer to Road Test Caution in Cautions and Notices.

1. With the vehicle at a complete stop and in gear, remove your foot from the brake pedal.
2. Accelerate to 48–64 km/h (30–40 mph) while looking for vibrations that match the customer's description.

Other possible causes of launch shudder include the following conditions:

- Incorrect trim height. Refer to *Trim Height Specifications* in Suspension General Diagnosis.
- A worn or damaged drive axle CV joint
- A ground-out through the engine or transmission mounts
- Faulty exhaust hangers and mounts

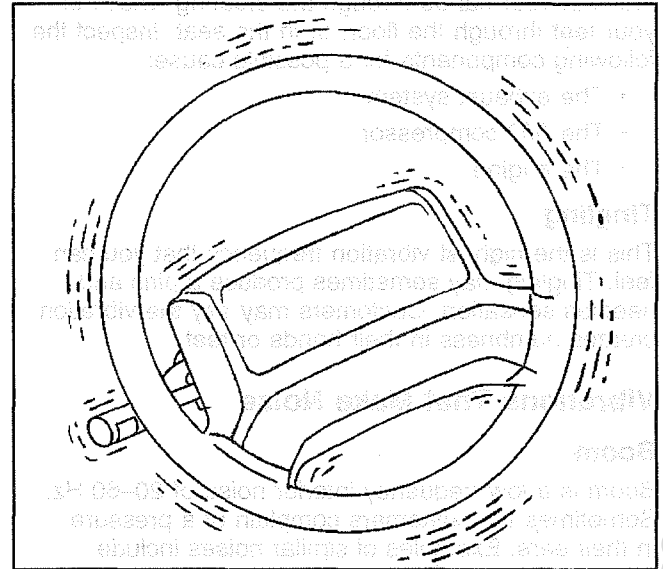
Classifying the Vibration

The next step after road testing the vehicle is to identify the frequency of the duplicated and abnormal vibration. Use the EVA in order to measure the frequency. If the EVA is not available, observe how the vibration feels or sounds. The majority of vibrations will fit into one of the following categories.

- Vibrations that can be felt:
 - Shake
 - Roughness
 - Buzz
 - Tingling
- Vibrations that make noise:
 - Boom
 - Moan and groan
 - Howl
 - Whine

Vibrations That Can Be Felt

Shake



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The shake is a low frequency vibration, typically 5–20 Hz. The shake is sometimes seen in the steering wheel, the seat, or the console. The best description is the feeling from an out-of-round or unbalanced tire.

Customers may refer to a shake in one of the following terms:

- Shimmy
- Wobble
- Shudder
- Waddle
- Hop

In most cases, shake is caused by damage or wear to the following components:

- The tires
- The wheels
 - The brake rotors (vehicle-speed sensitive)
 - The steering tie rod ends
 - The suspension ball joints
 - The engine (engine-speed sensitive)

Roughness

Roughness is a vibration with a slightly higher frequency than the shake, usually 20–50 Hz. Roughness is similar to the feeling you get from holding a jigsaw.

Buzz

Buzz is slightly higher in frequency: 50–100 Hz. A buzz is similar to the feel of an electric razor. You may feel it in your hands through the steering wheel, in your feet through the floor, or in the seat. Inspect the following components for a possible cause:

- The exhaust system
- The A/C compressor
- The engine

Tingling

This is the highest vibration frequency that you can feel. Tingling may sometimes produce a pins and needles sensation. Customers may say the vibration creates numbness in their hands or feet.

Vibrations That Make Noise**Boom**

Boom is a low frequency interior noise of 20–60 Hz. Sometimes the customers complain of a pressure in their ears. Examples of similar noises include a bowling ball rolling down an alley, deep thunder, or a bass drum.

A customer may use the following words to describe boom:

- Droning
- Growling
- Moaning
- Roaring
- Rumbling
- Humming

Boom may be accompanied by a perceptible vibration (roughness).

Moan or Drone

Moan or drone is a sustained tone at a low frequency of 60–120 Hz, somewhat higher than boom.

Examples of similar noises include a bumble bee or blowing air across the top of a soda bottle. A customer may use the following words to describe moan or drone:

- Humming
- Buzzing
- Resonance

Moan or drone may be accompanied by a perceptible buzzing vibration. Inspect the following systems:

- The powertrain mounts
- The exhaust system

Howl

Howl is a noise at mid-range frequency of 120–300 Hz. This sounds like the wind howling.

Whine

Whine is a prolonged, high-pitched sound in the 300–500 Hz range. Whine is usually related to the meshing gears or gear noise. Similar sounds include mosquitoes, turbine engines, and vacuum cleaners.

Matching Frequency to Component RPM

At this point in the diagnosis, the vibration has gone through the following analysis:

- The vibration has been duplicated.
- The vibration has been designated as abnormal.
- The vibration has been related either to engine speed or to vehicle speed.
- The vibration has been assigned a frequency from the EVA or identified based on its feel or its sound.

Automotive vibrations are usually related to the rotating speed of a component. Calculate the speed of these components using either an engine speed method or a vehicle speed method. Use the engine RPM readings taken during the road test in order to diagnose the vibrations that are sensitive to engine speed.

If the vibration is sensitive to vehicle speed, determine the rotational speed of the tires. As long as you operate the vehicle at a constant speed, the tires will operate at a constant speed. This speed is measured in rotations, or cycles per second. The reading is then compared to the frequency of the vibration, which is also measured in cycles per second.

Calculating Tire Rotation

TIRE/WHEEL AND PROPSHAFT ROTATION			
Vehicle Information			
Complaint Speed: _____	km/h (mph)	Year: _____	Model: _____
Symptom: _____		VIN: _____	
Frequency: _____		Engine: _____	Trans: _____
Engine Speed: _____	rpm	Tire Size: _____	Axle Ratio: _____
Gear: _____		TPC Spec: _____	
Tire/Wheel Speed			
Vibration Occurs at: _____	km/h $\div$ 8 (km/h) mph $\div$ 5 (mph)	= _____	Increments of 8 km/h (5mph)
8 km/h (5mph) increments _____	x _____	= _____	Tire/Wheel Speed, RPS (Hz) 1st order
1st order _____	x 2	= _____	2nd order
1st order _____	x 3	= _____	3rd order
Propeller Shaft Speed			
1st order tire _____	x _____ (axle ratio)	= _____	Propeller Shaft Speed 1st order
1st order propshaft _____	x 2	= _____	2nd order
*RPS=revolutions per second; equates to cycles per second (Hz).			

Determine the rotational speed of the tires in revolutions per second, or Hertz (Hz), based on the vehicle speed at which the vibration occurs. In order to determine the rotational speed, use the following procedure:

1. Determine the speed at which the vibration occurs.
2. Determine the number of 8 km/h (5 mph) increments:
 - Divide the complaint speed by eight when using kilometers.
 - Divide the complaint speed by five when using miles.

3. Determine the vehicle tire size.
4. Locate on the table below, the Hertz value at 8 km/h (5 mph) for that tire size.
5. Multiply the Hertz value by the number of 8 km/h (5 mph) increments.
6. The result is the rotational speed of the tires in Hertz at the complaint speed. If this figure matches the vibration frequency, a first-order vibration is present in the tire and wheel assembly.

For example, if the complaint speed is 60 mph, the number of increments is 12. According to the following table, a tire with size of P235/75R15 has a value of 1.00 Hz. You can calculate the rotational speed at 60 mph:

$$12 \text{ increments} \times 1 \text{ Hz} = 12 \text{ Hz}$$

Tire/Speed

Tire Size	Tread	Revs/Sec (Hz) at 5 MPH
P235/55R16	AL2	1.11
P215/60R16	AL2	1.10
P275/40ZR17	HW4	1.12
P245/50ZR16	AL3	1.13
P215/60R16	AL3	1.10
P245/50ZR16	HW4	1.13
Tread Types: AL2: Touring AL3: Export HW4: Performance Tire		

Sometimes, the tire/wheel vibration may be of a higher-order. In order to compute possible higher-order vibrations, multiply the rotational speed of the tires, in Hertz, at the complaint speed by the order number. If any of these matches the vibration frequency, a vibration of that particular order is present in one of the tire/wheel assemblies.

Steering and Suspension Assembly Vibrations

Steering and suspension assembly vibrations are the first level of testing for low-frequency vibrations that are sensitive to vehicle speed. The symptoms of a steering/suspension first-order vibration are a shimmy or a shake. This is usually felt in the steering wheel or in the seat. Inspect the following components for wear or damage:

- The steering tie rod ends
- The suspension ball joints

Calculating Propeller Shaft Rotation

The propeller shaft drives the tires through the rear axle. Knowing the rotational speed of the tires enables you to easily calculate the speed of the propeller shaft. Therefore, you can determine the rotational speed of the propeller shaft by multiplying the rotational speed of the tires by the ratio of the rear axle.

RPO	Description	Ratio
GU2	Ratio, Rear Axle	2.73
GU4	Ratio, Rear Axle	3.08
GU5	Ratio, Rear Axle	3.23
GU6	Ratio, Rear Axle	3.42

1. Obtain the tire speed by performing the tire speed calculation, described earlier in this section.
2. Determine the axle ratio using one of the following methods:
 - Cross reference the axle information from the service information part label to the parts book.
 - Cross reference the axle identification code that is stamped on the axle to the parts book.

- Perform the following calculation:

- 2.1. Make a mark on the tires and the propeller shaft.
- 2.2. Rotate the tires for one complete revolution, counting the number of propeller shaft rotations.

For example, the propeller shaft rotates approximately $3\frac{1}{2}$ times for every tire revolution. The axle ratio is 3.5:1

3. In order to find the propeller shaft rotation speed, multiply the tire speed by the rear axle ratio.

In the earlier example, at a 60 mph complaint speed:

$$12 \text{ Hz} \times 3.5 = 42 \text{ Hz}$$

Match the frequency of the vibration from the EVA with the rotational speed of a component (either a tire or a wheel). If none of the frequencies match, do one of the following actions:

- Recheck the data.
- Attempt to match the figures again, allowing for 1–5 mph of speedometer error.

When you have matched the speed of the component with the frequency of the vibration, refer to the service information that outlines the repair procedures for that particular component.

Rotor/Drum Imbalance

Rotors and drums do not have a set tolerance. However, rotors or drums with more than 21 g (0.75 ounce) imbalance have the potential to cause vibration. Inspect the rotors and the drums for imbalance using either the on-vehicle or the off-vehicle method.

Checking Rotor/Drum Imbalance (On-Vehicle)

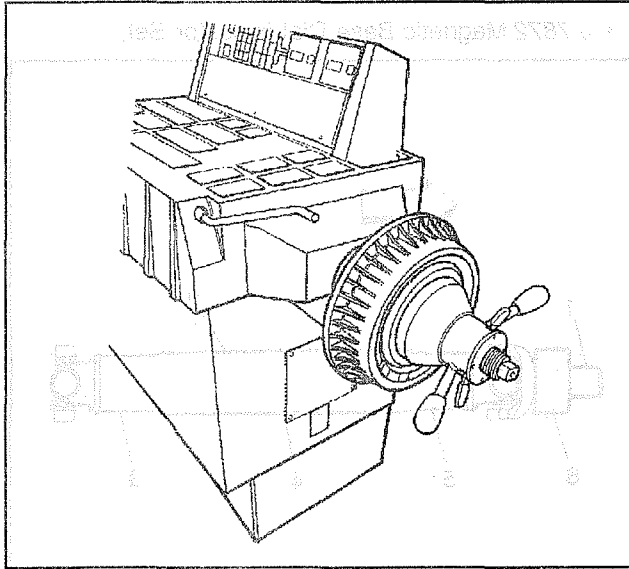
1. Raise and suitably support the vehicle. Refer to *Lifting and Jacking the Vehicle* in General Information.
2. Remove the rear tire and wheel. Refer to *Tire and Wheel Removal and Installation* in Tires and Wheels.

Caution: Refer to Work Stall Test Caution in Cautions and Notices.

3. Reinstall the wheel nuts in order to retain the rotors/drums.
4. Run the vehicle at the complaint speed while inspecting for the vibration.
5. If the vibration still exists, perform the following steps:
 - 5.1. Remove the rotors/drums.
 - 5.2. Run the vehicle back to speed.
6. If the vibration is eliminated, perform the following steps:
 - 6.1. Remove the rotors/drums one at a time.
 - 6.2. Perform the vibration test for each rotor/drum.
 - 6.3. Replace the rotor/drum that is causing the imbalance.
 - 6.4. Inspect the balance of the new rotor/drum.

Checking Rotor/Drum Imbalance (Off-Vehicle)

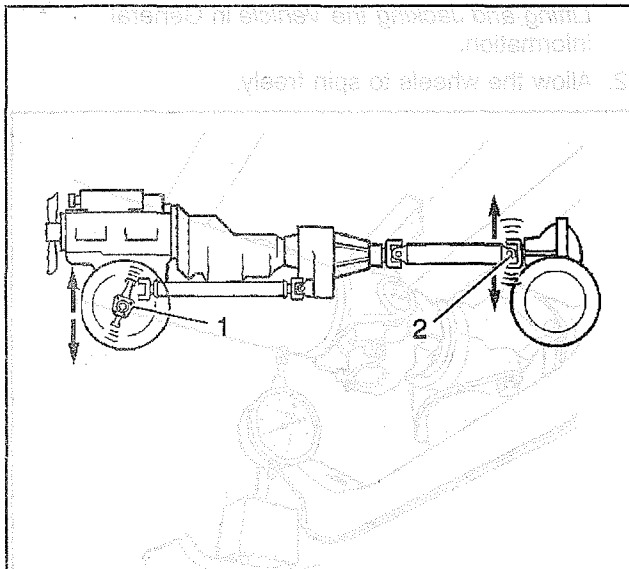
1. Measure the diameter and the width of the rotor/drum.



2. Mount the rotor/drum on a balancer in the same manner as a wheel.

Important: You can only inspect the rotors/drums for static imbalance. Ignore the dynamic imbalance reading.

3. Inspect for static imbalance.
4. If the rotor/drum shows imbalance, replace the rotor/drum.
5. Inspect the balance of the new rotor/drum before you install the rotor/drum on the vehicle.

Driveline Vibration Analysis

The following components are possible sources of driveline vibration:

- The transmission output shaft
- The propeller shaft(s)/driveshaft(s)
- The pinion yoke/flange (2)
- The pinion gear

The above components are either bolted or splined together. Therefore, all of the components rotate at the same speed, vibrate at the same frequency, and have the same symptoms.

Driveline vibrations may relate either to the first order or to the second order of driveline rotation. Driveline vibrations are always related to the speed of the vehicle. The vibration is often related to torque. If the vibration is worse or only noticeable when accelerating, decelerating, or crowding the throttle, the vibration is related to the torque. In this case, the vibration will always occur at the same speed. If a vibration is sensitive both to torque and to speed, the driveline is the probable cause. Tire/wheel vibrations are speed-sensitive, but not torque-sensitive.

First-Order Driveline Vibration Symptoms

The following symptoms may indicate first-order driveline vibration:

- The vibration is related to vehicle speed.
- The vibration is torque sensitive.
- A boom or moan noise is present.
- The vibration occurs commonly above 72 km/h (45 mph), but possibly at speeds as low as 48 km/h (30 mph).
- The roughness or buzz vibration is felt in the seat, the floor or the steering wheel.
- The corresponding frequency on the EVA equals first-order driveline rotation (25–60 Hz), depending on the speed of the vehicle and the ratio of the axle. Refer to *Matching Frequency to Component RPM* in order to obtain the rotation speed of the propeller shaft.

Diagnosing First-Order Driveline Vibration

Diagnosis will be much easier once you have identified a vibration as first-order of driveline rotation during the road test. Next identify the exact area of the vibration and take proper action.

In most cases, vibration may be reproduced in the stall. In the stall the vibration may be better or worse than that experienced during the road test.

The objective is to reduce the vibration to the lowest point possible in the stall, then evaluate the results during a road test. Many times, a vibration you were only able to reduce drastically in the stall will be completely eliminated on the road.

The cause of first-order driveline vibration is usually excessive runout or an imbalanced component.

The following procedure offers a systematic process of elimination in order to determine which component is at fault:

1. Raise the vehicle to curb height. Support the vehicle on a hoist or heavy stands. Refer to *Lifting and Jacking the Vehicle* in General Information.
2. Remove the rear tires/wheels. Refer to *Tire and Wheel Removal and Installation* in Tires and Wheels.
3. Inspect the propeller shaft. The propeller shaft should be free of undercoating before continuing.

4. Inspect the propeller shaft and the U-joint for any obvious dents or damage. Dents or damage will contribute to first-order driveline vibrations.
5. Start the engine.
6. Place the transmission in gear.
7. Run the vehicle up to the speed at which the vibration was most severe.
8. Record whether the vibration was present, and at what speed.
9. If the vibration is not present do a complete road test.
10. If the vibration is present, determine which end of the driveshaft is vibrating the most. Hold your hand against the pinion nose and the transmission tailshaft, or hold an EVA vibration sensor up to each component.
11. If the vehicle is equipped with a two-piece propeller shaft, inspect the center support bearing for vibration.
12. If the transmission tail is vibrating, touch the transmission crossmember under the transmission mount. If there is no vibration on the crossmember, then the transmission mount is working properly.
13. Remember which end of the driveshaft is the worst, and how severe the vibration is. The inspection will be a reference by which to judge future progress.

Do not fill the propeller shaft with foam, oil, or any other substance in order to correct a vibration. Filling the propeller shaft is only effective in reducing an unrelated condition called Torsional Rattle. Filling the propeller shaft should only be done in strict adherence to the procedure outlined in corporate bulletins that address Torsional Rattle. Failure to follow the correct procedure will induce a vibration and/or affect the structural integrity of the propeller shaft. The propeller shaft will then have to be replaced.

Propeller Shaft Runout

A propeller shaft or pinion (companion) flange with excessive runout causes first-order driveline vibrations. Use the following procedure in order to measure the runout of the propeller shaft:

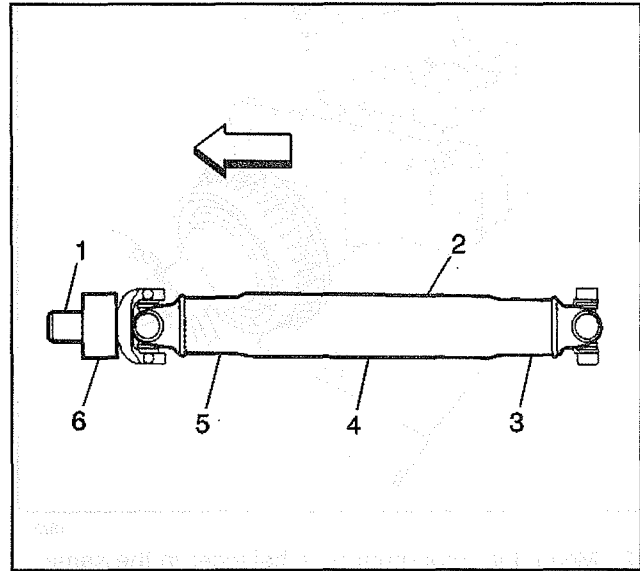
- Remove excess corrosion of the propeller shaft surface before inspecting the runout.
- Inspect for damage and dents.
- Replace dented propeller shafts.
- Remove any undercoating from the propeller shaft before proceeding.
- Refer to Measuring Propeller Shaft Runout, below, for the measurement procedure that applies to the following shaft assemblies:
 - One-piece
 - Two-piece

The splined end of a propeller shaft is critical to the smooth operation of a two-piece propeller shaft. When inspecting stub-shaft runout, ensure that the dial indicator readings are accurate.

Measuring Propeller Shaft Runout

Tools Required

- J 8001 Dial Indicator Set
- J 7872 Magnetic Base Dial Indicator Set

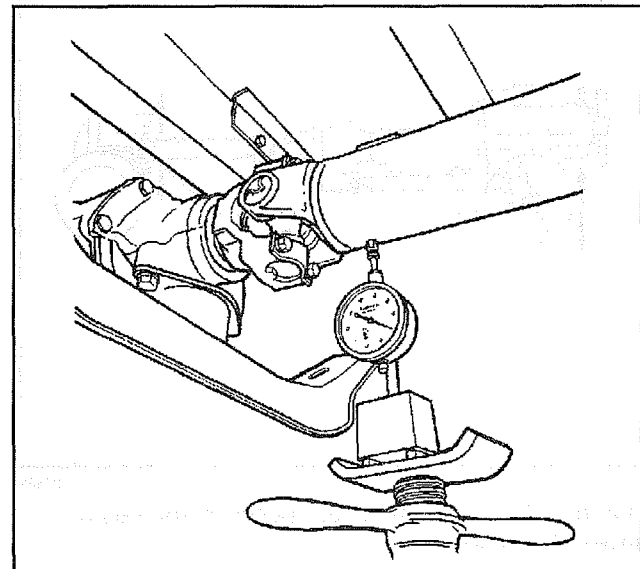


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Legend

- (1) Slip Yoke
- (2) Tube
- (3) Rear Runout Check
- (4) Center Runout Check
- (5) Front Runout Check
- (6) Damper

1. Raise the vehicle on a suitable hoist. Refer to *Lifting and Jacking the Vehicle* in General Information.
2. Allow the wheels to spin freely.



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3. Attach a J 8001 and a J 7872.
4. Place the transmission in NEUTRAL.

5. Rotate the pinion flange or the transmission yoke by hand while taking the measurements for the runout.

Important: The propeller shaft turns easier in one direction than in the other. Removing the wheels will also help. Do not include fluctuations on the dial indicator due to welds or surface irregularities.

6. Perform the following steps for one-piece propeller shafts if the runout exceeds the tolerances at one or more points:
 - 6.1. Rotate the propeller shaft 180 degrees in the pinion flange.
 - 6.2. Reinstall the propeller shaft.
 - 6.3. Measure the propeller shaft runout.
 - 6.4. If the runout still exceeds the tolerance, inspect the pinion flange runout before replacing the propeller shaft.
7. Perform the following steps for two-piece propeller shafts if the runout exceeds the tolerances at one or more points:

Important: The runout of the rear splines on the front propeller shaft affects the runout of the front measurement on the rear propeller shaft.

- 7.1. Measure the rear propeller shaft.
- 7.2. Mark the position of the rear shaft in the pinion flange.
- 7.3. Remove the rear shaft.
- 7.4. Measure the front propeller shaft runout on the tube and the stub shaft.
- 7.5. Replace the propeller shaft if either measurement is out of tolerance. Refer to *Propeller Shaft Runout Specifications*.

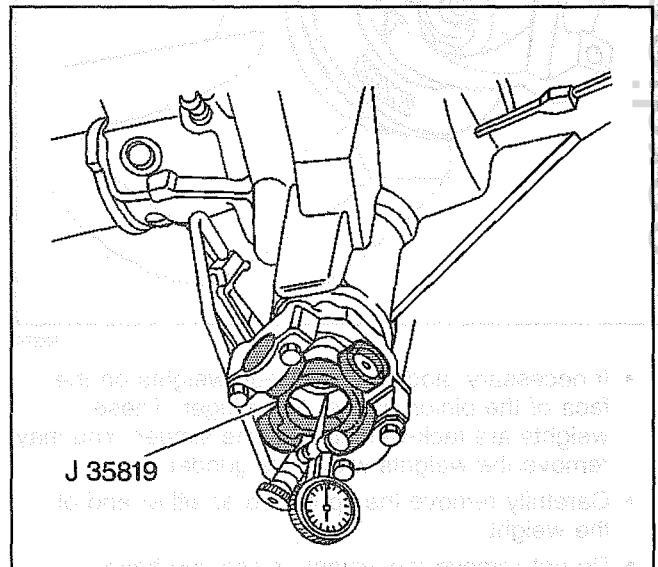
Important: When you replace a propeller shaft, inspect the new shaft for runout. Inspect the pinion flange runout if the replacement shaft runout is also out of tolerance.

Propeller Shaft Measurement Points				
Propshaft	Front Runout	Center Runout	Rear Runout	Stub Shaft Runout
One-Piece	Measure	Measure	Measure	—
Aluminum Graphite	Measure	—	Measure	—
Two-Piece Front Slip Yoke	Measure	—	—	Measure

Measuring Pinion Flange Runout

Tools Required

- J 8001 Dial Indicator Set
 - J 23409 Dial Indicator Extension
 - J 35819 Flange Runout Gauge
1. Place the vehicle on a suitable hoist. Refer to *Lifting and Jacking the Vehicle* in General Information.
 2. Allow the wheels to rotate freely.
 3. Remove the propeller shaft from the pinion flange.



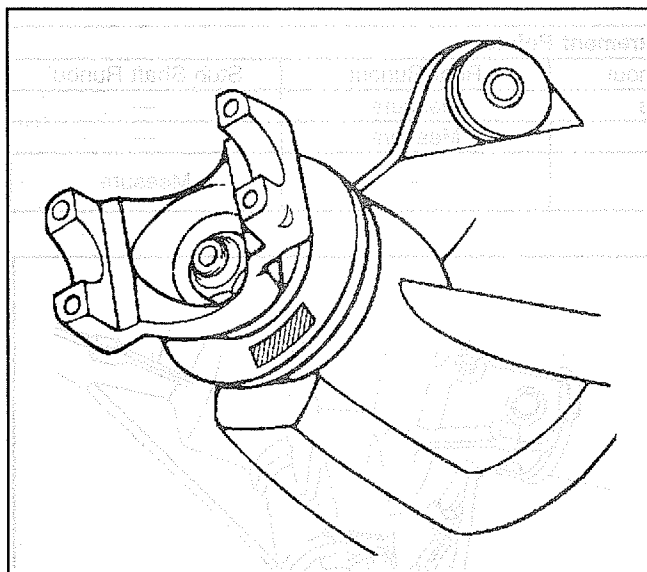
4. Install the J 35819.

If a J 35819 is not available, measure the pinion runout as close as possible to the pinion flange.

Important: The dial indicator will have inverted readings. You are measuring the inside diameter of the flange; you are not measuring the outside diameter. The highest reading on the dial indicator is the low spot. The lowest reading is the high spot.

5. Rotate the pinion shaft 360 degrees and zero the dial indicator on the low spot.

6. Rotate the pinion flange again and record the total runout.
7. If the pinion flange runout is 0.15 mm (0.006 in) or less, remove the pinion flange balance weight.
8. If the pinion flange runout is greater than 0.15 mm (0.006 in) but not less than 0.28 mm (0.011 in), and the runout compensation weight is at or near the low spot, no further action is necessary. If the runout compensation weight is not at or near the low spot, remove the weight.
9. If the pinion flange runout is greater than 0.28 mm (0.011 in) but not greater than 0.38 mm (0.015 in), and the balance weight is at or near the low point, no further action is necessary. If the runout compensation weight is not at or near the low spot, remove the weight and re-index the pinion flange until the runout is 0.25 mm (0.010 in) or less.
10. Replace the pinion flange/yolk when the runout cannot be reduced to 0.25 mm (0.010 in) or less. Then, recheck the runout. Service replacement flanges do not have balance weights.



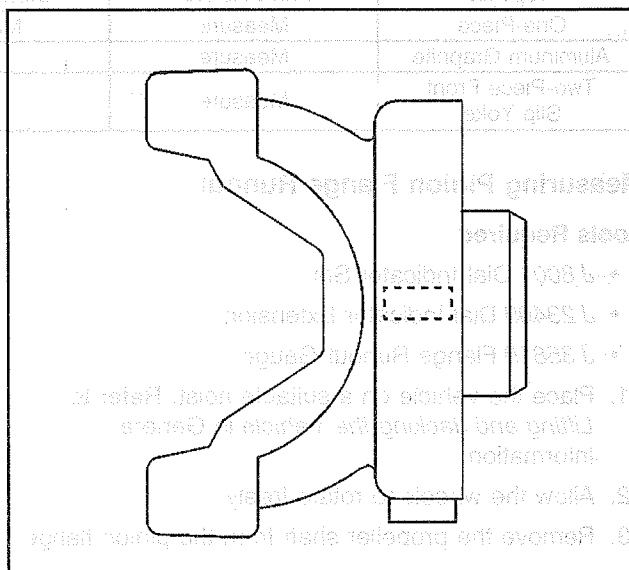
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- If necessary, add compensation weights on the face of the pinion flange dust slinger. These weights are tack-welded onto the slinger. You may remove the weights with a die-grinder.
- Carefully remove the spot weld at either end of the weight.
- Do not remove the weight unless you have inspected the pinion flange runout and the procedure requires weight removal.

- Do not remove any weights on the outboard edge of the dust slinger. These weights are present in order to balance internal axle components. The weights are not related to the pinion flange runout.
- If a J 35819 is not available, inspect the propeller shaft runout as near as possible to the flange. Rotate the shaft 180 degrees in the pinion flange. Reinstall the shaft. Inspect the measurement at the same location.
A large difference in the runout, greater than 0.38 mm (0.015 in), may indicate that the flange is out of tolerance. If the runout does not change at all, the flange is OK.

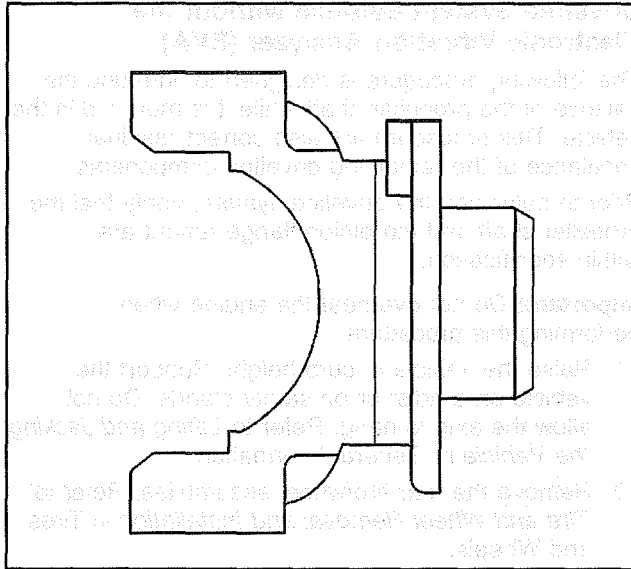
Balanced Axles

Beginning in the early 1990's, the manufacturer began system balancing rear axles. During the build process, these axle assemblies were spun with a slave fixture. A balance weight was attached to the outboard edge of the companion flange dust slinger. A system-balanced rear axle companion flange differs from a non-balanced flange. You must diagnose and service this flange in a unique way.



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Some pinion flange assemblies have a U-shaped deflector designed to hold a system balance weight on the outside diameter.



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Other pinion flange assemblies have a runout compensation weight on the face of the deflector. The pinion flange assemblies that are system balanced do not use runout compensation weights.

Measuring the runout on a system-balanced companion flange is very straight-forward. A balanced flange that is good will have a measured runout between 0.00–0.38 mm (0.00–0.015 in). If a balanced flange has more than 0.38 mm (0.015 in) runout, replace the flange or reindex the flange 180 degrees on the pinion. If you replace or reindex a balanced flange, you must system balance the rear axle again.

Correcting Vibration at the Pinion Nose

Most first-order driveline vibrations originate at the pinion nose end of the driveshaft. Ensure that the vibrations are at a minimum at this location in order to achieve acceptable results. Reduce the runout of the components to a minimum. Balance the driveline as a system when necessary.

1. Measure the runout of the propeller shaft and inspect the tolerance.
2. If the tolerance is excessive, mark the position of the shaft for future reference and rotate the shaft 180 degrees.
3. Reinstall the shaft and reinspect the runout. Inspect the level of vibration in order to determine if the vibration is lower or corrected.
4. If the runout is still excessive, or if the vibration is still present, refer to Measuring Pinion Flange Runout. Replace the pinion flange or re-index the flange 180 degrees if the pinion flange runout exceeds the tolerance.

Remove and reinstall the pinion flange only once on axles utilizing a crush type sleeve. Replace the sleeve with a new sleeve if the sleeve is crushed. Removing the sleeve requires removal of the ring and pinion set. Replace flanges with excessive runout. Regardless of the method used, measure the pinion flange runout in order to ensure that the flange is within tolerance.

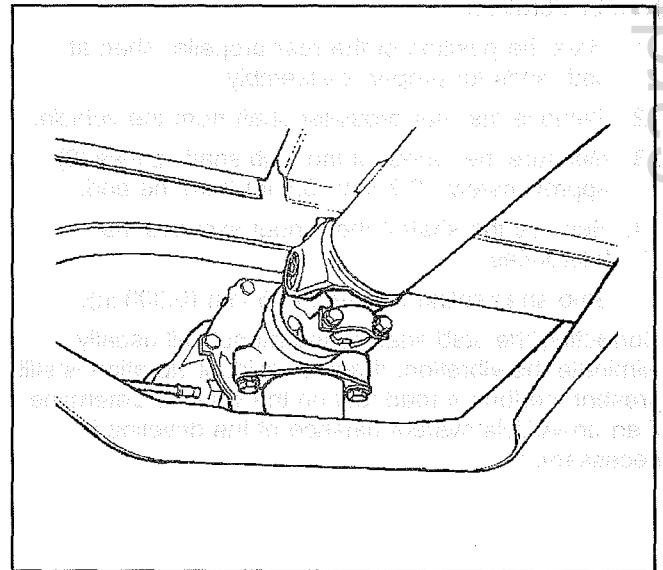
5. Reinspect the propeller shaft runout if the vibration is present after the pinion flange runout is corrected. If the propeller shaft runout is still excessive, correct the runout before doing a driveline system balance. Either replace the shaft with a shaft that is within tolerance or sublet the shaft to a reputable independent for straightening and re-balance. Ensure that the new or rebuilt shaft is within runout tolerance before continuing.
6. Once the propeller shaft and pinion flange are within runout tolerances, inspect to see if the vibration is still present. If the level of the vibration is still unacceptable, perform a driveline system balance procedure.

Correcting Vibration at the Transmission Tailshaft

First-order driveline vibrations that originate at the transmission end of the propeller shaft are rare. If the tailshaft of the transmission is vibrating, inspect the tailshaft housing bushing for wear or damage. A leaky transmission tailshaft oil seal indicates bushing problems.

Feel for vibration at the crossmember underneath the transmission mount. If there is no vibration, the transmission mount is functioning properly by isolating the vibration from the structure of the vehicle. The transmission mount is therefore probably not the cause of the vibration.

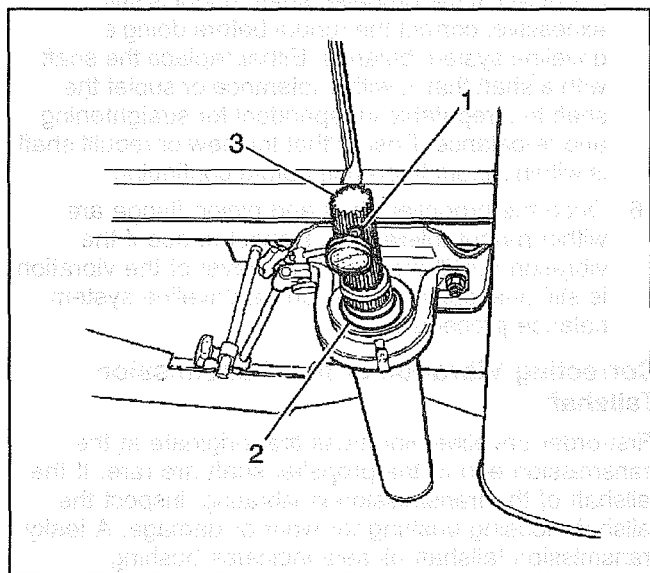
Use the following procedure if you can feel vibration on the crossmember and the tailshaft bushing, and if the transmission output is normal:



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1. Measure the propeller shaft runout. If the runout is excessive, replace the shaft with one that has acceptable runout. Alternatively, sublet the shaft to a reputable independent service shop in order to have the shaft rebalanced and the runout corrected.
2. Test drive the vehicle. If the vibration is still unacceptable, balance the shaft on the vehicle. Refer to Rear Driveline System Balance.

Correcting Vibration at the Center Support Bearing



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These guidelines apply to the two-piece propeller shaft only. First-order driveline vibrations that occur mainly at the center support bearing are usually the result of excessive runout at the stub (splined) shaft.

Unlike other first-order driveline vibrations, these vibrations can appear at unusually low speeds of 40 km/h (25 mph) and up.

Perform the following procedure in order to correct this type of vibration:

1. Mark the position of the rear propeller shaft at both ends for proper reassembly.
2. Remove the rear propeller shaft from the vehicle.
3. Measure the runout of the stub shaft splines (3) approximately 12.7 mm (0.5 in) from the end.
4. Replace the shaft if the runout exceeds the tolerances.

Stub shaft/spline runout 0.076 mm (0.003 in).

Correcting the stub shaft/spline runout will usually eliminate the vibration. If some residual vibration is still present, perform a road test on the vehicle. Determine if an on-vehicle system balance of the driveline is necessary.

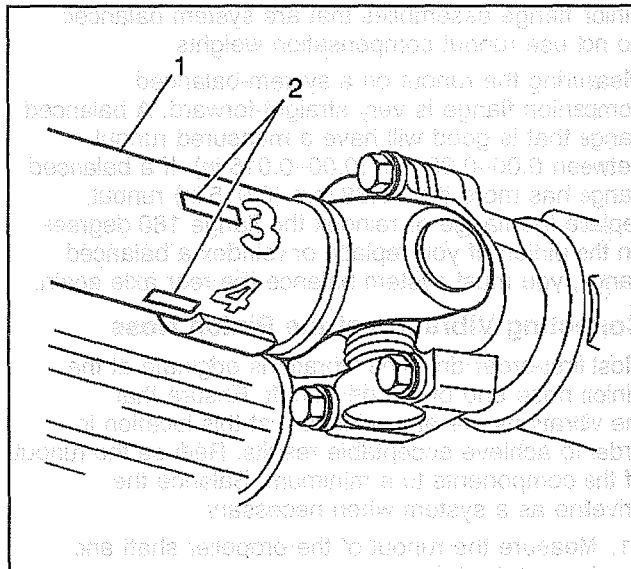
Driveline System Balance without the Electronic Vibration Analyzer (EVA)

The following procedure is designed to fine-tune the balance of the propeller shaft while it is mounted in the vehicle. This procedure will also correct residual imbalance of the remaining driveline components.

Prior to balancing the driveline system, verify that the propeller shaft and the pinion flange runout are within specification.

Important: Do not overheat the engine when performing this procedure.

1. Raise the vehicle to curb height. Support the vehicle on a hoist or on safety stands. Do not allow the axle to hang. Refer to *Lifting and Jacking the Vehicle* in General Information.
2. Remove the rear tire/wheel assemblies. Refer to *Tire and Wheel Removal and Installation* in Tires and Wheels.
3. Determine which end of the propeller shaft has the most vibration in order to identify where to begin installing the hose clamps.



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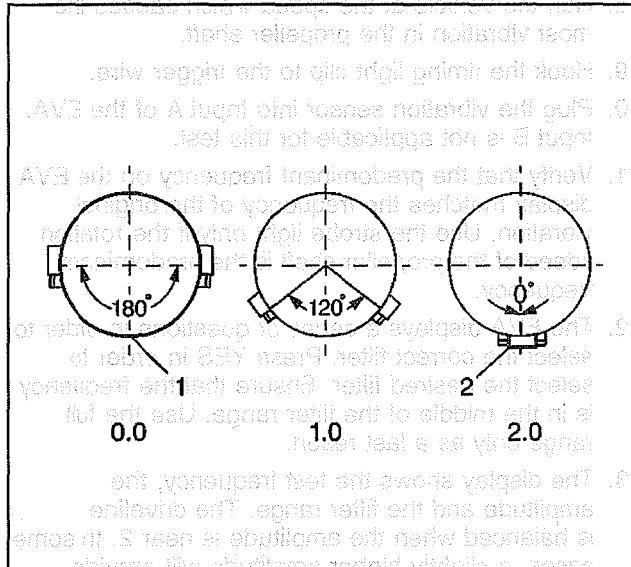
4. Mark the end of the propeller shaft (1) which has the most vibration at four points (2), 90 degrees apart. Number the marks 1 through 4.

The following procedure uses a trial and error method of determining where to place the hose clamps on the shaft. Use the following tips in order to help locate the clamps:

1. Because the imbalance may be related to propeller shaft runout, begin installing the clamps at the low point of the propeller shaft runout.
2. When the plant workers balance the propeller shaft, they use weights in graduated increments: 2 g (1/16 oz), 4 g (1/8 oz), etc. If the stock weight is too light or too heavy, place the hose clamp either directly in line with or opposite to the stock weight.

The last method involves running the vehicle at a speed which the vibration is felt.

1. Carefully hold a piece of chalk up to the very end of the propeller shaft. Barely touch the chalk to the shaft.
2. Shut the engine OFF in order to stop the propeller shaft from rotating. Do not step on the brake pedal. Do not put the transmission in PARK.
3. Inspect the chalk mark.



If you performed the above procedure correctly, the chalk mark will indicate the heavy spot on the shaft. The heavy spot will deflect downward and touch the chalk. If the chalk mark circles the entire shaft, touch the chalk more gently to the shaft. Ensure that the chalk touches only the heavy spot. Once the heavy spot is located, place the hose clamp 180 degrees opposite to the chalk mark (1). Perform the following steps:

1. Place the hose clamp at the light spot, or at any of the 4 points marked previously.
2. Test drive the vehicle at the speed at which the vibration occurred. Record any changes in the vibration.
3. Move the clamp to the other positions.
4. Test drive the vehicle each time you move the clamp. Record any changes in vibration. Remember which position gives the best balance.
 - If the vibration did not change at all or if the vibration becomes worse, then one clamp is either too light or too heavy. Repeat the procedure using the two clamps together (2).
 - If the previous step did not correct the problem, repeat the procedure using the two clamps separated in order to reduce the spinning weight.

Continue the trial and error procedure using different weights in different locations until you achieve the best balance. If more than three clamps aligned in the same position are required, replace the propeller shaft.

If you are able to reduce the vibration in the stall, but are unable to eliminate the vibration completely, perform a road test on the vehicle. A slight vibration noticeable in the stall may not be noticeable on the road.

Driveline System Balance with Electronic Vibration Analyzer (EVA)

In order to pinpoint the source, you must reproduce the vibration in the service stall. Determine which component is vibrating the most using the EVA.

Perform the following steps:

1. Support the vehicle on a suitable hoist or on safety stands. Ensure that the rear of the rear axle is at curb height. Do not allow the axle to hang. Refer to *Lifting and Jacking the Vehicle* in General Information.
2. Remove the rear tire/wheel assemblies. Refer to *Tire and Wheel Removal and Installation* in Tires and Wheels.
3. Ensure that the propeller shaft is free of undercoating. Inspect for dents or damage to the propeller shaft or the U-joint.
4. Start the engine.
5. Place the transmission in gear.
6. Run the engine at the vehicle speed at which the vibration is occurring.

Caution: Do not run the vehicle higher than 89 km/h (55 mph). Stay clear of the universal joints and the balance weight area in order to avoid personal injury. Do not run the vehicle on the hoist for extended periods of time. Running the vehicle on the hoist for extended periods of time may cause the engine or the transmission to overheat.

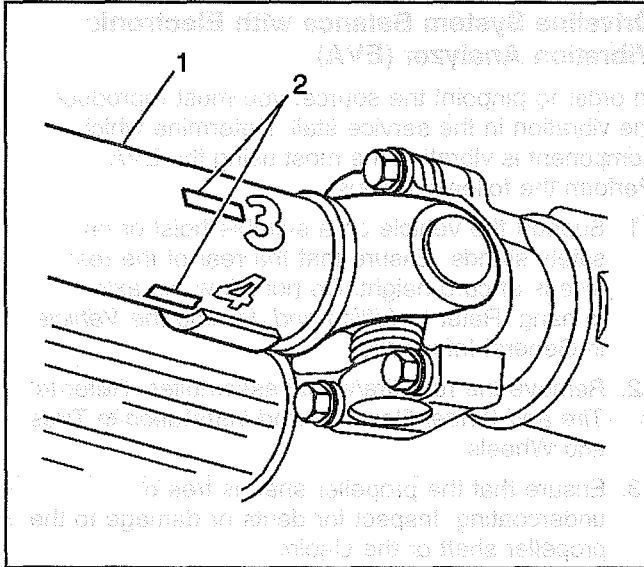
Determine which end of the propeller shaft is vibrating the most. Hold the EVA's sensor against the pinion nose and the transmission tailshaft assembly. The higher the amplitude reading, the greater the vibration.

- If the vehicle has a two-piece propeller shaft, inspect the center support bearing.
- If the transmission tailshaft vibrates, inspect the transmission crossmember under the transmission mount. The vibration should not be present if the mount is functioning correctly.

Strobe Balance Testing with the Electronic Vibration Analyzer (EVA)

Ensure that the runout of the various driveline components are within specifications. If the runouts are within specifications, strobe balance the driveline. The EVA is able to simplify the balancing process, using the following procedure:

1. Use the EVA in order to determine which end of the propeller shaft has the most vibration.



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2. Mark the end of the propeller shaft (1) that has the most vibration at four points (2), 90 degrees apart. Number the marks 1 through 4.

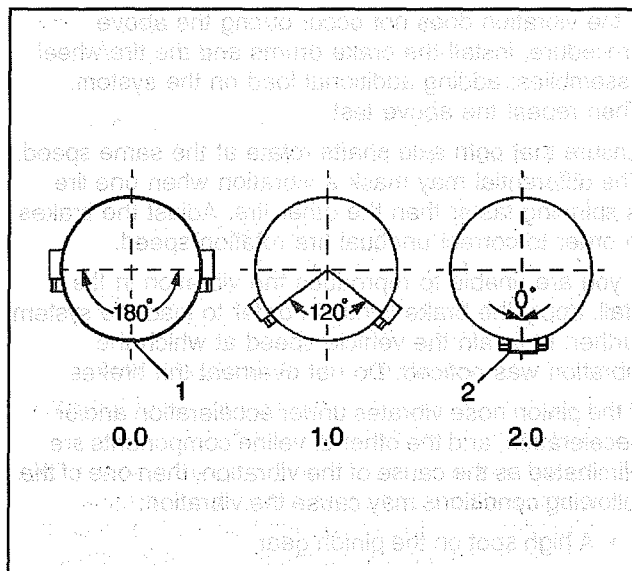
3. Mount the EVA sensor onto the bottom of the following components:

- The differential housing
- The center bearing support (for 2-piece propeller shafts that use a center bearing support)
- The transmission tailshaft assembly

4. Position the sensor as close to the propeller shaft as possible. Verify that the following conditions exist:

- The UP side of the sensor faces upward.
- The sensor is horizontal.

5. Start the engine.
6. Turn OFF all of the engine accessories.
7. Place the transmission in gear.
8. Run the vehicle at the speed which causes the most vibration in the propeller shaft.
9. Hook the timing light clip to the trigger wire.
10. Plug the vibration sensor into Input A of the EVA. Input B is not applicable for this test.
11. Verify that the predominant frequency on the EVA display matches the frequency of the original vibration. Use the strobe light only if the rotation speed of the propeller shaft is the predominant frequency.
12. The EVA displays a series of questions in order to select the correct filter. Press YES in order to select the desired filter. Ensure that the frequency is in the middle of the filter range. Use the full range only as a last resort.
13. The display shows the test frequency, the amplitude and the filter range. The driveline is balanced when the amplitude is near 2. In some cases, a slightly higher amplitude will provide adequate balance.
14. Point the timing light at the propeller shaft. The strobe effect will appear to freeze the propeller shaft. Remember which of the numbered marks is at the bottom of the propeller shaft, or the six o'clock position. This position is the light spot.
15. Turn the engine OFF.
16. Install a weight directly on the light spot.
17. Start the engine.
18. Run the vehicle at peak vibration speed.



19. Strobe the propeller shaft again.

- The propeller shaft is balanced if the strobe image is erratic and the amplitude is near two.
- The propeller shaft is not balanced if one of the following conditions exist:
 - The weight and the original light spot are at the six o'clock position (1).

The above condition means that there is not enough weight on the propeller shaft. In order to correct the balance, add a second weight next to the first weight. Inspect the balance again using the strobe light.

If the weights are now 90–180 degrees off (between the nine o'clock and the three o'clock positions) too much weight exists. In order to correct the balance, split the two weights equally on either side of the original light spot (1) in order to produce a total weight between 1–2 weights (between 0–120 degrees apart). Inspect the balance again using the strobe light. Adjust the weights as needed.

- The weight and original light spot are 90–180 degrees off (between the nine o'clock and the three o'clock positions).

The above condition means that one weight is too much. In order to correct the balance, split the two weights equally on either side of the original light spot in order to produce a total weight less than one (120–180 degrees apart). Inspect the balance again using the strobe light. Adjust the weights as needed.

- The weight and the original light spot are within 180 degrees of the six o'clock position.

Move the weight towards the six o'clock position. Inspect the balance again using the strobe light. Adjust the weight as necessary. Refer to the previous two conditions.

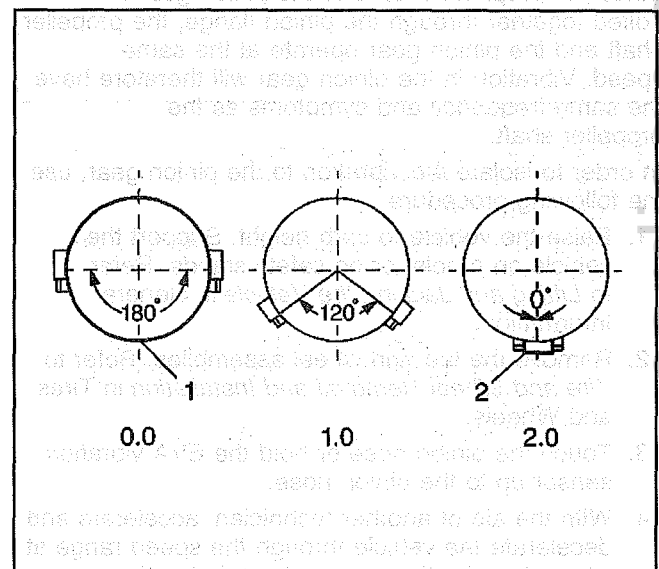
If the shaft will not balance using two weights, place a third weight on the light spot. Split the first two weights in order to produce a total weight between two and three weights.

If three weights fail to balance the driveline, replace the propeller shaft.

When the propeller shaft balances, road test the vehicle in order to verify that the vibration is eliminated.

Propeller Shaft Balance Weights

When using clamps in order to balance a propeller shaft with the total weight method, the correction weight required will often be a fraction or a multiple of one hose clamp. Use the following phasing procedure with two hose clamps in order to accurately place any required amount (0.0–2.0 total weights).



1. Ensure that the clamps are located with even spaces on either side of the light spot, or 180 degrees opposite the heavy spot (1).
The table containing the weight amounts in terms of the total weight and the included angle (spread) between the clamps is in specifications. Refer to *Propeller Shaft Balancing Weight Amounts*.
2. If the vibration does not change at all or gets worse, then one clamp is too light or too heavy. Repeat the procedure using the two clamps together.
3. If the previous step did not correct the problem, repeat the procedure using the two clamps separated in order to reduce the spinning weight.

4. Continue the trial and error procedure using different weights in different locations until you achieve the best balance.
5. If more than three clamps aligned in the same position are required, replace the propeller shaft.
6. If you are able to reduce the vibration in the stall, but are unable to eliminate the vibration completely, road test the vehicle. A slight vibration that is noticeable in the stall may not be noticeable on the road.

First-Order Driveline Vibration Analysis (Torque Sensitive)

If the following conditions are true, the internal rear axle components are the probable cause of the vibration:

- The vehicle has a vibration that is equal to first-order driveline rotation, and the vibration is not present you test the vehicle in the stall.
- You were able to correct the vibration in the stall, but the vibration returned during the road test.

Internal rear axle vibrations may be aggravated by the load of the vehicle working against the ring and pinion gear seat.

Since the propeller shaft and the pinion gear are bolted together through the pinion flange, the propeller shaft and the pinion gear operate at the same speed. Vibration in the pinion gear will therefore have the same frequency and symptoms as the propeller shaft.

In order to isolate the vibration to the pinion gear, use the following procedure:

1. Raise the vehicle to curb height. Support the vehicle on a hoist or on safety stands. Refer to *Lifting and Jacking the Vehicle* in General Information.
2. Remove the tire and wheel assemblies. Refer to *Tire and Wheel Removal and Installation* in Tires and Wheels.
3. Touch the pinion nose or hold the EVA vibration sensor up to the pinion nose.
4. With the aid of another technician, accelerate and decelerate the vehicle through the speed range at which the vibration was noticed during the road test.

Example

- If the vibration was originally noticed at 88 km/h (55 mph), accelerate from 72 km/h (45 mph) to 107 km/h (65 mph). Then decelerate from 107 km/h (65 mph) back to 72 km/h (45 mph).
- Repeat the above step and remember whether or not the pinion nose vibrates under load during acceleration and/or deceleration.

If the vibration does not occur during the above procedure, install the brake drums and the tire/wheel assemblies, adding additional load on the system. Then repeat the above test.

Ensure that both axle shafts rotate at the same speed. The differential may mask a vibration when one tire is spinning faster than the other tire. Adjust the brakes in order to correct unequal tire rotation speed.

If you are unable to reproduce the vibration in the stall, apply the brake lightly in order to load the system further. Maintain the vehicle speed at which the vibration was noticed. Do not overheat the brakes.

If the pinion nose vibrates under acceleration and/or deceleration, and the other driveline components are eliminated as the cause of the vibration, then one of the following conditions may cause the vibration:

- A high spot on the pinion gear
- A bent pinion stem
- A cocked pinion bearing
- An improper axle housing bore

Anything that effects the pinion gear and how the pinion gear contacts the rotating ring gear may contribute to a first-order, torque-sensitive driveline vibration. The only way to correct the condition is to replace the faulty components. In most cases, you must replace the ring and pinion gear set and the related bearings. In some cases, you must replace the axle housing. Complete a close-up visual inspection for damage or unusual wear in order to measure or identify the specific faulty component.

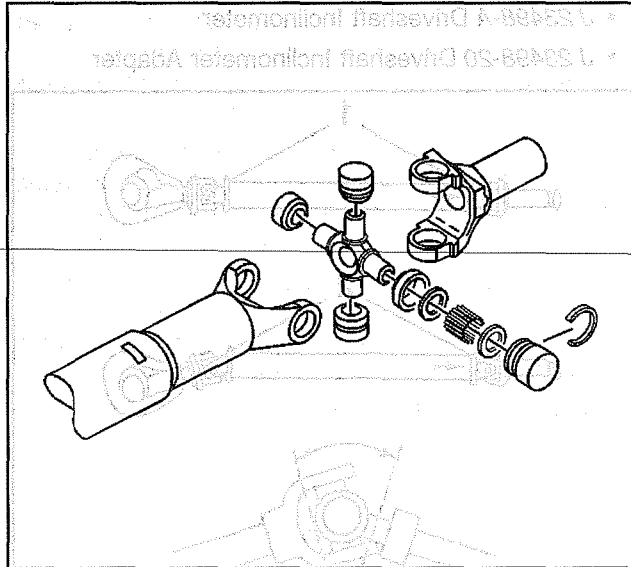
It is possible to isolate an internal axle vibration. Install a known good axle assembly from a stock unit. Verify that the known good axle assembly does not have a vibration problem.

Once you correct the internal axle problem, road test the vehicle. Inspect the vehicle for vibration.

Balance the driveline, as necessary, in order to eliminate any remaining vibration.

Diagnosing Second-Order Driveline Vibration

Second-Order Driveline Vibration Theory



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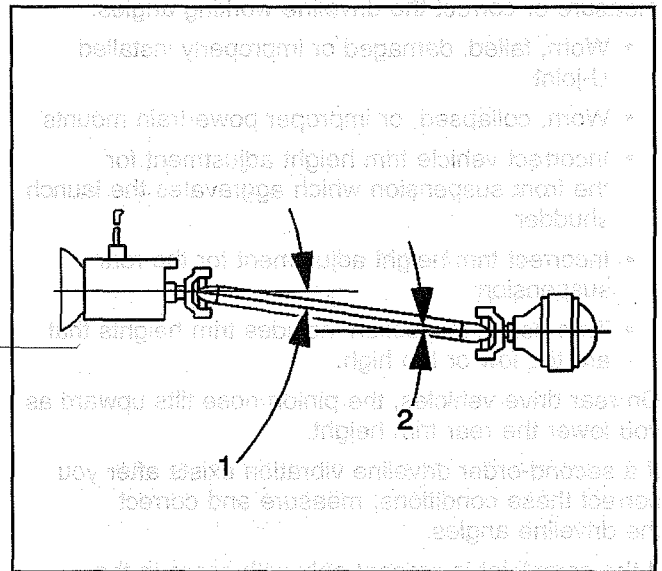
A faulty universal joint (U-joint) may cause a vibration that occurs twice for each rotation of the propeller shaft. This type of vibration is called a second-order vibration.

Second-order driveline vibrations are independent of runout or balance of a driveline component.

The following description of basic U-joint theory will help you to understand where second-order driveline vibrations originate and why they occur.

- As the propeller shaft rotates, the U-joint speeds up and slows down twice for each rotation of the propeller shaft.
- The acceleration and deceleration of the U-joint is not visible. If there is vibration in the U-joint, the acceleration and deceleration will be audible and tactile.
- Compare the U-joint in a vehicle to a universal-type socket. When a universal-type socket is used to tighten a bolt, the socket will bind and release as the socket turns toward 90 degrees. The bind and release occurs twice for each revolution of the socket.
- The U-joint in a vehicle works in the same way as the universal-type socket. The bind and release effect is directly proportional to the angle that the U-joint operates: the greater the angle, the greater the effect.
- Because the transmission output speed is constant, the binding and releasing of the U-joint is better described as an acceleration and deceleration which occurs twice for each revolution of the propeller shaft.
- If the propeller shaft is running slowly, the accelerating and decelerating effect is visible. The acceleration and deceleration may create a vibration due to the fluctuations in force that are generated at high speeds.

Canceled Out Driveline Angles



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Legend

- (1) Front Working Angle
- (2) Rear Working Angle

Engineers design drivelines in order to compensate for the accelerations and decelerations in order to produce a smooth, constant flow of power, as listed below:

- The transmission drives the front yoke of the propeller shaft at a smooth and constant speed.
- The first U-joint causes the power to fluctuate twice for each revolution of the propeller shaft.
- The second U-joint, oriented 90 degrees from the first U-joint, causes the power to fluctuate opposite that of the first U-joint.
- As the first U-joint slows down, the second U-joint speeds up.

This design causes one U-joint to cancel out the effect of the other U-joint. The cancelled effects result in a smooth, constant power flow from the output yoke of the propeller shaft.

Second-order driveline vibrations occur when the cancellation becomes unequal between the front U-joint and the rear U-joint.

The main objective of this section is to correct the conditions that interfere with the proper cancellation effect of the U-joint. The most common condition, especially where the launch shudder is concerned, is incorrect driveline working angles (1,2). Other factors may aggravate the condition.

Address the following factors before you attempt to measure or correct the driveline working angles:

- Worn, failed, damaged or improperly installed U-joint
- Worn, collapsed, or improper powertrain mounts
- Incorrect vehicle trim height adjustment for the front suspension which aggravates the launch shudder
- Incorrect trim height adjustment for the rear suspension
- Trim height inspection includes trim heights that are too low or too high.

On rear drive vehicles, the pinion nose tilts upward as you lower the rear trim height.

If a second-order driveline vibration exists after you correct these conditions, measure and correct the driveline angles.

If the complaint is present only with cargo in the vehicle, perform the measurements with the vehicle fully loaded. Once you correct a second-order driveline vibration with the vehicle loaded, the vibration may reappear with the vehicle unloaded. The reverse of this condition is also true. You may have to reach a compromise with the customer in this case.

Second-Order Driveline Vibration Symptoms

Second-Order driveline vibration has the following signs and symptoms:

- The vibration is always related to vehicle speed.
- The vibration is usually torque-sensitive.
- The vibration is worse under a torque load.

Launch shudder is the most common complaint of a second-order driveline vibration.

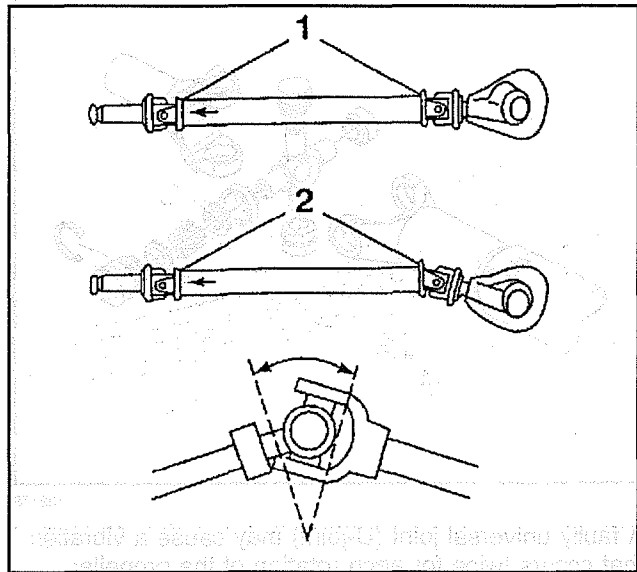
Launch shudder occurs during acceleration from 0–40 km/h (0–25 mph). Launch shudder appears as a low frequency shake, wobble, or shudder. The driver may feel the vibrations in the seat or steering wheel at low speeds of 0–24 km/h (0–15 mph). The vibrations will increase in frequency as the vehicle speed increases. Launch shudder feels more like driveline roughness at higher speeds of 24–40 km/h (15–25 mph). At speeds greater than 40 km/h (25 mph) the vibration usually disappears.

Launch shudder vibration is equal to a second-order vibration of the driveline. The EVA will not perceive frequency information due to the transitory nature of launch shudder.

Driveline Working Angles

Tools Required

- J 38460 Digital Inclinometer
- J 23498-A Driveshaft Inclinometer
- J 23498-20 Driveshaft Inclinometer Adapter



6498

Driveline working angle does not refer to the angle of any one shaft, but to the angle that is formed by the intersection of two shafts.

The procedure for measuring and correcting driveline working angles depends on whether the vehicle is equipped with a propeller shaft consisting of one piece, two pieces, or three pieces.

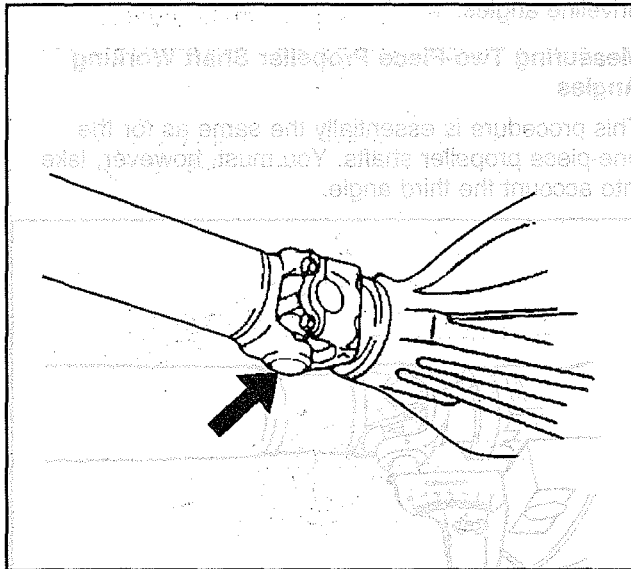
In order to verify the accuracy of the adapter, inspect the angle of an accessible joint with the inclinometer prior to assigning the adapter on an inaccessible joint.

One-Piece Propeller Shaft System

Raise the vehicle on a suitable hoist or on safety stands. Ensure that the rear axle is supported at curb height and that the wheels are free to spin. Refer to *Lifting and Jacking the Vehicle* in General Information. Place the transmission in NEUTRAL. Ensure that the vehicle has a full tank of fuel or the equivalent amount of weight in the rear to simulate a full tank. The weight of 3.8 liters of gasoline (1 gallon) is approximately 2.8 kg (6.2 lb).

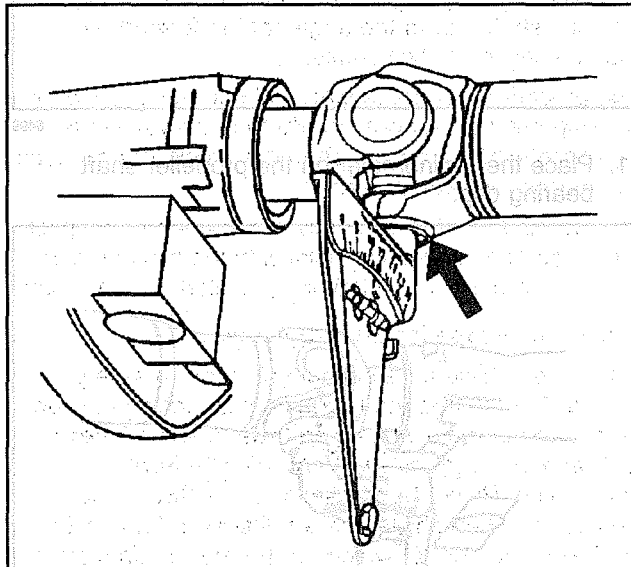
Checking Phasing of U-joint

Inspect the propeller shaft for correct phasing. Correct phasing means that the front and the rear U-joint are directly in line or parallel with each other so that proper cancellation takes place.



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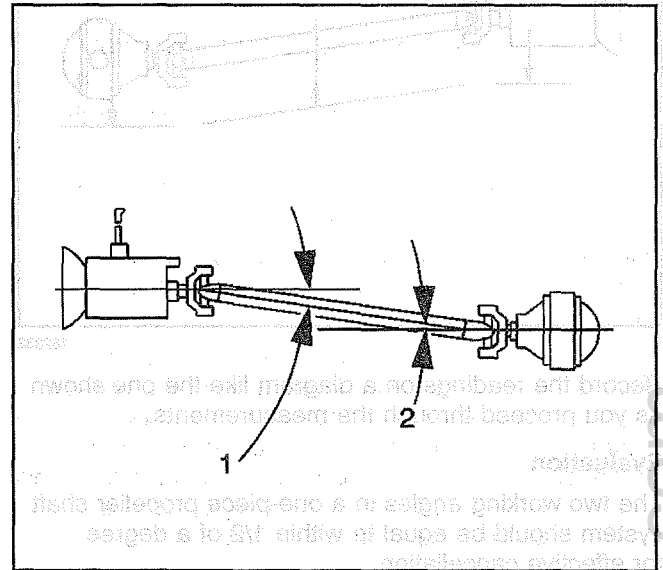
1. Rotate the propeller shaft so that the propeller shaft rear U-joint bearing cap is vertical.



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2. Ensure that the front bearing cap is also vertical.
3. Place the inclinometer on the propeller shaft rear U-joint bearing cap in order to ensure that both U-joints are vertical.
4. Set the indicator line above the sight glass on 15 (the horizontal reference). Rotate the propeller shaft until the bubble centers in the sight glass. This action brings the rear U-joint to vertical.
5. Remove the inclinometer without disturbing the setting. Leave the setting on 15.
6. Install the inclinometer on the front U-joint. The bubble should remain centered plus or minus 3 degrees if the shaft is properly phased.

The out of phasing of the single-piece propeller shaft is very unusual. If the shaft is visibly out of place, the end yokes are welded on in the wrong position or the shaft is damaged due to twisting. In either case, replace the propeller shaft before continuing with this procedure.

Measuring the Working Angles

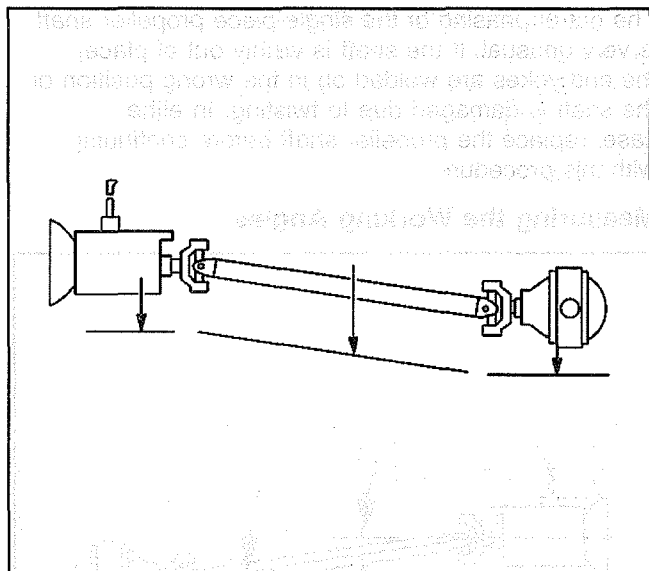
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The working angle of a U-joint is the difference between the angles formed when two shafts intersect. One piece propeller shaft systems have two working angles, the front (1) and the rear (2).

- The two working angles should be equal within $\frac{1}{2}$ of a degree.
- The working angles should not exceed 4 degrees.
- The working angles should not be equal to ZERO because a ZERO working angle will cause premature U-joint wear due to lack of rotation of the U-joint.
- The angle formed by the propeller shaft and the rear axle pinion from the rear working angle (2)
- The angle formed by the propeller shaft and the transmission output shaft form the front working angle (1)

The angles of these components are most accurately measured from the U-joint bearing caps. Verify that the bearing caps are free of corrosion or foreign material in order to ensure accurate readings. Remove any snap rings that may interfere with the correct placement of the inclinometer. Reinstall the snap rings after you take the measurements.

Take the measurements from the same side of the propeller shaft in order to maintain consistent angle measurements (either on the driver side or on the passenger side).



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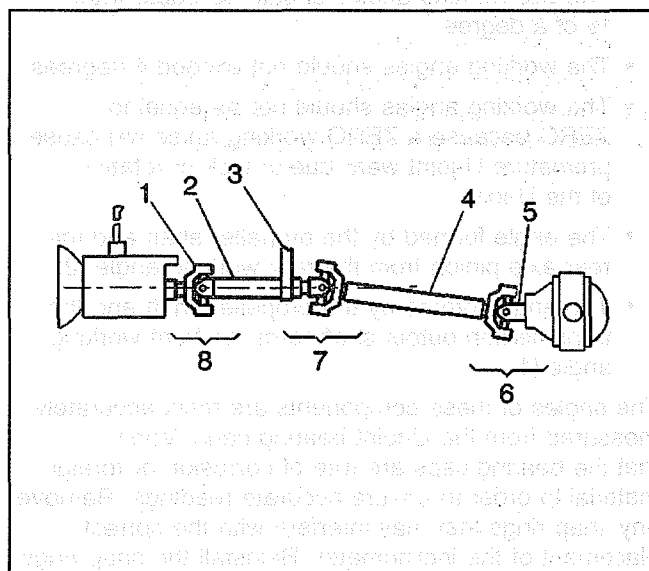
Record the readings on a diagram like the one shown as you proceed through the measurements.

Evaluation

The two working angles in a one-piece propeller shaft system should be equal to within $1/2$ of a degree for effective cancellation.

Measuring Two-Piece Propeller Shaft System Working Angles

Two-piece propeller shaft systems have three working angles instead of two working angles as in the one-piece systems.



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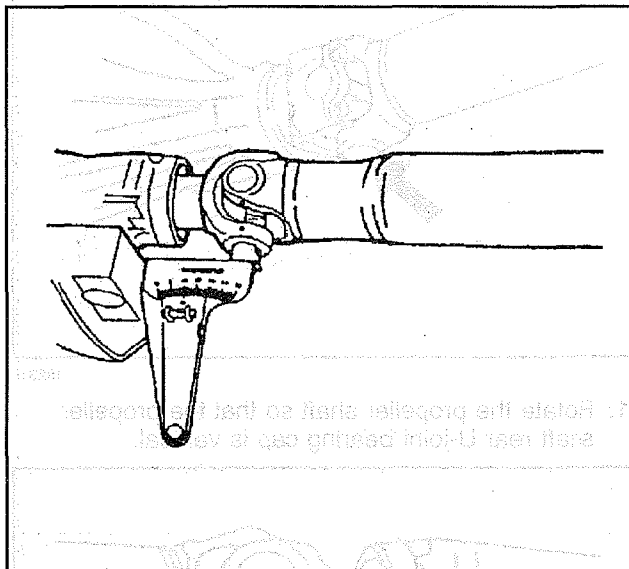
- The first angle is the front working angle (8). It is formed by the angle of the output shaft of the transmission and the angle of the front propeller shaft.
- The second angle (7) is the middle working angle. It is formed by the angle of the front propeller shaft and the angle of the rear propeller shaft.

- The third angle (6) is the rear working angle. It is formed by the angle of the rear propeller shaft and the angle of the pinion yoke of the rear axle.

If the launch shudder or the second-order driveline vibration is still present, measure and correct the driveline angles.

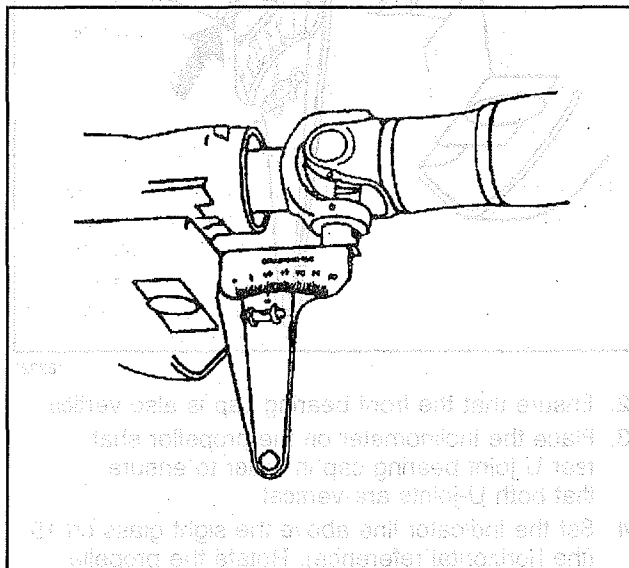
Measuring Two-Piece Propeller Shaft Working Angles

This procedure is essentially the same as for the one-piece propeller shafts. You must, however, take into account the third angle.



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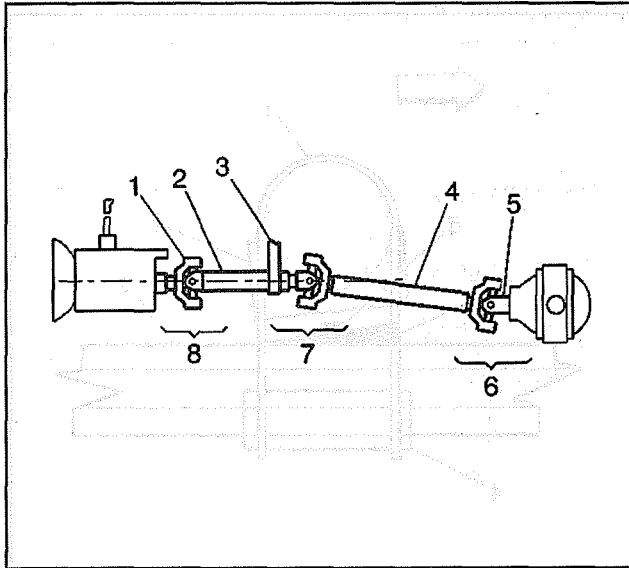
1. Place the inclinometer on the propeller shaft bearing cap.



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2. Center the bubble in the sight glass.
3. Record the measurement. The bearing cap must be straight up and down in order to obtain an accurate measurement.
4. Enter the measurements on your diagram.

5. Rotate the propeller shaft 90 degrees and place the inclinometer on the transmission output yoke bearing cap. The bearing cap must be straight up and down in order to obtain an accurate measurement.
6. Center the bubble in the sight glass.
7. Record the measurement.
8. Subtract the smaller reading from the larger reading in order to obtain the front U-joint working angle.



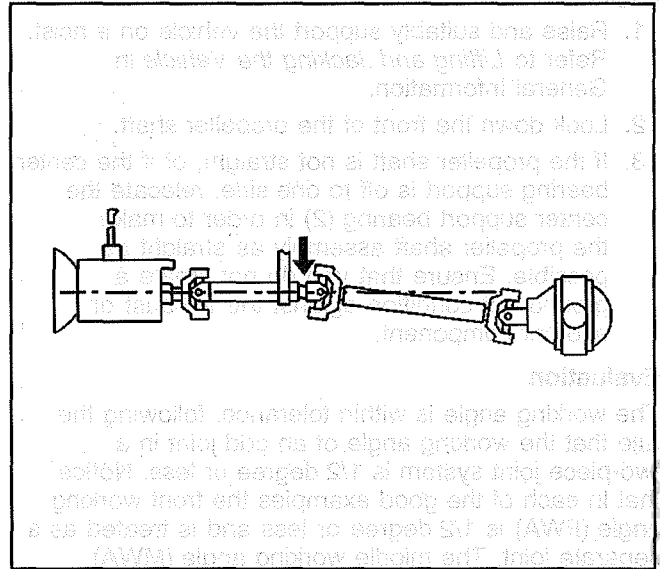
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The front angle is considered the odd U-joint because this angle does not have another joint to provide cancellation. The rear working angle (6) and the middle working angle (7) act as a pair of U-joints in order to cancel each other out, as in the one-piece propeller shaft systems. Because of this condition, keep the working angle of the odd U-joint (8) at or under 1/2 of a degree.

Keep the working angle of this odd joint to a minimum so that there are not any great fluctuations in speed that need to be canceled out. The front joint is used as the odd joint because the front joint angle does not change with suspension bounce, rebound, or axle windup. For this reason, think of the front propeller shaft of a two-piece system as an extension of the transmission output shaft.

Two-Piece Propeller Shaft Phasing

The setup and measurement techniques are identical to that of a the one-piece propeller shaft system. First, test for proper phasing, using the following procedure:



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1. Turn the rear propeller shaft so that the rear U-joint is straight up and down. Verify that the front U-joint of the rear propeller shaft is also straight up and down.
2. Rotate the shafts 90 degrees so that the front propeller shaft front U-joint is straight up and down. Ensure that the front propeller shaft is also straight up and down (actually part of the slip yoke on the rear shaft).

If the two U-joint of the front propeller shaft are not in this phase, the two halves of the propeller shaft may have been assembled incorrectly.

Two-Piece Propeller Shaft Lateral Alignment

The procedure for lateral alignment of a two-piece propeller shaft is used for launch shudder or any second-order driveline vibrations. Adjust the lateral alignment before you measure and adjust the driveline angles.

1. Raise and suitably support the vehicle on a hoist. Refer to *Lifting and Jacking the Vehicle* in General Information.
2. Look down the front of the propeller shaft.
3. If the propeller shaft is not straight, or if the center bearing support is off to one side, relocate the center support bearing (2) in order to make the propeller shaft assembly as straight as possible. Ensure that you do not create a ground-out condition against the exhaust or another component.

Evaluation

The working angle is within tolerance, following the rule that the working angle of an odd joint in a two-piece joint system is 1/2 degree or less. Notice that in each of the good examples the front working angle (FWA) is 1/2 degree or less and is treated as a separate joint. The middle working angle (MWA) and the rear working angle (RWA) are subtracted. The difference (DIFF) is 1/2 degree or less. The middle and the rear joints may cancel each other.

Correcting Working Angles

In order to change the working angles, shim the components up or down. Look closely at the existing angles. Use the existing angles and the shims in order to achieve the correct working angles.

Compared to horizontal or true level, the components located at the rear of the vehicle are usually lower than the components located at the front of the vehicle. This condition is called down in the rear. If a component with a down in the rear angle is shimmed up at the rear, the shim will bring the component closer to the horizontal (zero). Alternately, if a component with a down in the rear angle is shimmed down, the component will move farther from the horizontal (zero).

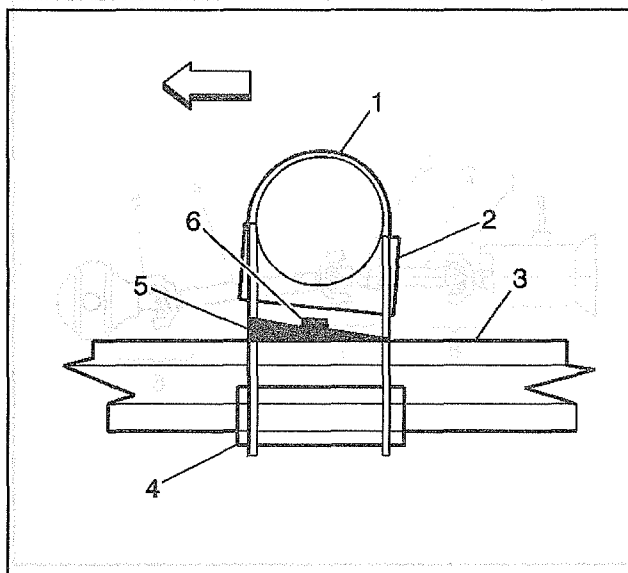
Rear Axle Wind-Up

Rear axle wind-up may cause launch shudder even when all of the working angles are within specifications. Rear axle wind-up occurs when heavy torque during acceleration causes the pinion nose to point upward. In order to compensate for axle wind-up, tip the pinion nose downward. Install the axle shims incrementally, performing a road test after each shim. Add shims until the road test indicates that the shudder is eliminated.

Rear Axle Shims

Wedge shims of different sizes are available through the parts' system and independent suppliers for the purpose of shimming the rear axle angle. Wedge shims are available in 2, 3, and 4 degrees.

Caution: Never attempt to shim a rear axle using anything except shims that are designed for this purpose. Failure to do so will result in the shims falling out and a loss of vehicle control and that could cause personal injury.



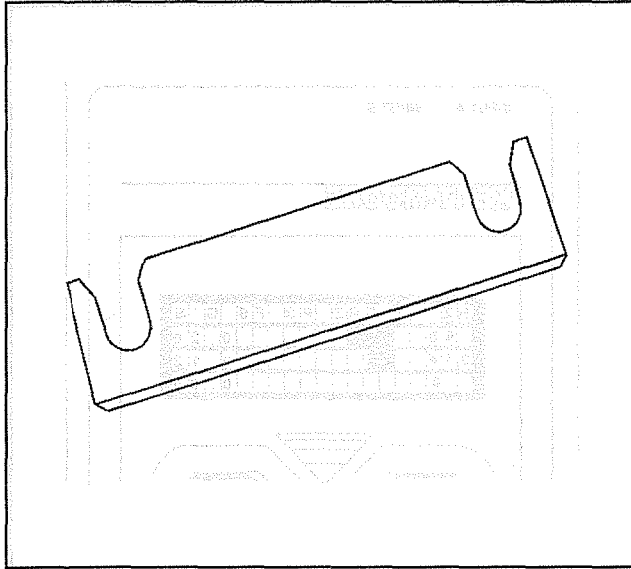
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Install the shims (5) in order to increase or decrease the angle of the rear axle pinion. Install the shims between the leaf spring (3) and the spring seat (2). Depending on the design of the suspension [leaf spring on top or underneath the axle (1)], and the direction of the desired change, install the shims with either the thick side toward the front of the vehicle or toward the rear of the vehicle.

Important: After installing the shims, ensure that the U-bolt has two or three threads above the nut.

Ensure also that the center bolt, located in the spring seat, is long enough to seat in the locator hole. If these two conditions do not exist, use longer U-bolts and center bolts. Longer U-bolts and center bolts are available through local spring shops.

Transmission Shims



If a transmission requires shims, order the shims through the parts distribution system.

Installing most shims will change the transmission angle approximately 1/2 degree.

When shimming transmissions, use a shim made from steel stock at the necessary thickness. Ensure that the shim contacts the full width of the area to be shimmed. Do not use washers.

Engine Related Vibration

Engine vibration is usually due to one or more of the following conditions:

- First-order engine imbalance
- Inherent engine firing sequence
- Inherent engine shaking forces
- Engine-driven accessories

Because these vibrations are engine-speed related, they are also usually torque sensitive. These vibrations may appear and disappear at different vehicle or road speeds, but will always appear at the same engine speed.

For example, if a customer states that a vibration is present at 40 km/h (25 mph), 64 km/h (40 mph), and again at 104 km/h (65 mph), and that the symptoms of the vibration are similar at each of these speeds, the vibration is probably engine-speed related. Any disturbance or vibration that is present during the following road tests would be considered engine-speed related:

- The neutral run-up test
- The downshift test
- The brake torque test

Any vibration that is present during the neutral coast-down test is not engine-speed related. The engine-related vibrations covered in this diagnosis are engine-speed sensitive only.

First-Order Engine Imbalance

Notice: Proper flywheel installation requires carefully WALKING the flywheel onto the crankshaft and stagger-tightening the bolts. Proper torque converter to flywheel installation then requires gradually WALKING the torque converter to be flush with the flywheel, prior to installing the bolts. Do not draw the torque converter to the flywheel with the bolts. If these precautions are not followed, warping or bending of the flywheel and/or damage to the transmission torque converter may result.

Engine imbalance is a condition that exists when a component that rotates at crankshaft speed is either unbalanced or has excessive runout. In rare cases, the crankshaft may be unbalanced. In any case, balancing the component or correcting the runout may reduce the disturbance to an acceptable level.

Symptoms

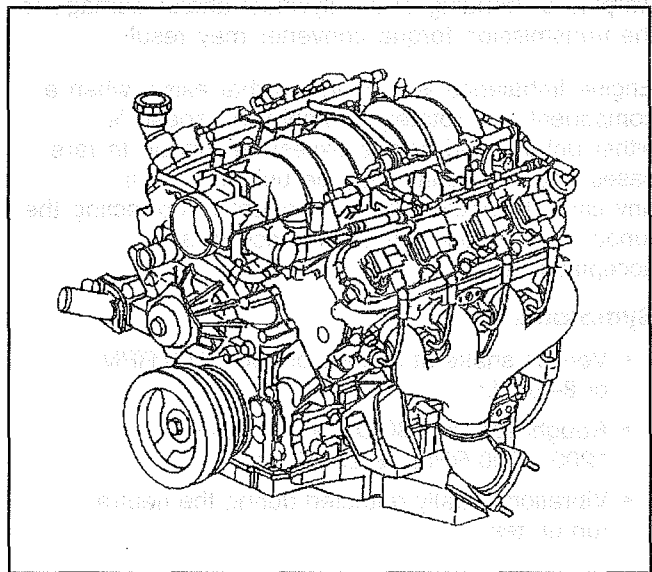
- Vehicle shake at speeds of 500–1200 RPM, or 8–20 Hz
- Roughness and BOOM at speeds of 1200–3000 RPM, or 20–50 Hz
- Vibration usually detected during the neutral run-up test

Isolating the Components

1. Perform the neutral run-up test, noting the RPM at which the vibration is the worst, and the severity. Refer to *Road Test*.
2. Inspect all powertrain mounts. Repair or replace as needed.
3. Inspect for any bindings or ground-outs in the exhaust system.
4. Matchmark the torque converter and the flywheel.
5. Disconnect the torque converter from the flywheel.
6. Tie up the converter, away from the flywheel.
7. Perform the neutral run-up test again.
 - If the flywheel shows any wobble or lateral runout, replace the flywheel. Refer to *Engine Flywheel Replacement* in Engine Mechanical-3.8 L or *Engine Flywheel Replacement* in Engine Mechanical-5.7 L.
 - Re-index the torque converter in three different positions. If the disturbance still exists, replace the torque converter.

8. If the vibration still exists, inspect the propeller shaft runout.
9. If the vibration still exists, inspect the harmonic balancer.
10. If the vibration still exists, the problem is related to residual engine imbalance. Refer to the procedure below.

Excessive Inherent Engine Firing Frequency



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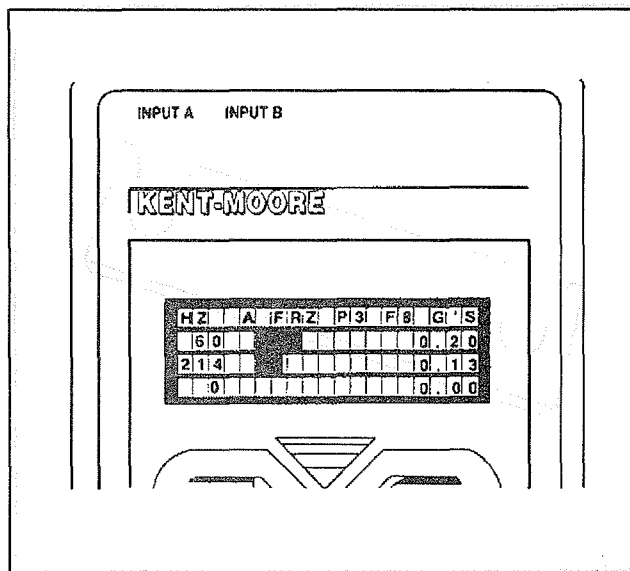
Firing frequency is a term used to describe the pulses created as the engine fires in each cylinder. All engines have a firing frequency. The intention here is to keep these disturbances from entering the passenger compartment. Initially, inspect for the following conditions:

- The engine and the exhaust system are mounted in the correct position.
- All of the mounts and hangers are in good condition and are correct for the application.
- No components, hoses, or lines are grounding to the frame or to the body.

The frequency of these disturbances will depend on the number of cylinders. The engine order will always be equal to one-half the number of cylinders. This is because a four-stroke engine requires two complete revolutions of the crankshaft in order to fire all of the cylinders.

For example, a V6 engine will fire cylinders 1, 3, and 5 on the first revolution. Cylinders 2, 4, and 6 will fire on the second revolution. This results in three firing pulses per revolution of the crankshaft.

Engine Vibration Diagnosis with the EVA



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1. Place the EVA vibration sensor on the seat track rail with the UP label facing upward.
2. Plug the EVA into a 12 volt power supply.
3. Prepare the EVA for data recording:
 - 3.1. Press RECORD
 - 3.2. Select a snapshot tag number
 - 3.3. Press ENTER in order to begin recording
4. Slowly accelerate until the vibration occurs.
5. Note the vehicle speed and the engine RPM where the disturbance occurs.
6. Press ENTER on the EVA in order to record the vibration data.
7. Perform the road test diagnoses in order to determine engine-speed or vehicle-speed sensitivity. Refer to *Road Test*.

Engine Firing Frequency Symptoms

- The vibration may be torque sensitive.
- The vibration is engine-speed related.
- The vibration is heard as a boom or a moan.
- The vibration is felt as a shake, roughness or buzz (depending on the number of cylinders).
- The vibration affects the resonance of a system or a component, causing the system or the component to have a narrow RPM range.

The key to correcting these types of complaints is to isolate the vibration from the passenger compartment or the body.

Diagnosis and Repair of Engine Firing Frequency-Related Vibrations

1. Raise and suitably support the vehicle. Refer to *Lifting and Jacking the Vehicle* in General Information.

Caution: Refer to *Work Stall Test Caution in Cautions and Notices*.

2. Attempt to duplicate the vibration.
3. While the vibration is present, find the area of the vehicle affected by the vibration.
4. Inspect for witness marks caused by rubbing components.
5. Isolate the component and re-evaluate the vibration.
6. Inspect for proper torque on the affected component. Tighten as needed.
7. If the vibration still exists, follow the procedure below.

Engine Firing-Frequency Related Vibration Causing Components

1. Inspect for collapsed engine mounts.
Replace as needed. Refer to *Engine Mount Replacement* in Engine Mechanical - 3.8 L or, refer to *Engine Mount Replacement (Left)* or *Engine Mount Replacement (Right)* in Engine Mechanical - 5.7 L.
2. Inspect for a collapsed or broken transmission mount. Replace as needed. Refer to *Transmission Support and Mount Assembly* in Manual Transmission - M49, *Transmission Support and Mount Assembly* in Manual Transmission - MM6 or *Transmission Support Replacement* in Frame and Underbody.
3. Inspect the exhaust hangers.
 - Exhaust systems can expand one to two inches when hot.
 - Remove the hangers one at a time.
 - Adjust or replace the exhaust hangers as needed.

4. Inspect the A/C and P/S lines.
 - Isolate the hoses from the body.
 - Install the retainers.
5. Inspect the drive belt for the proper tension.
6. Inspect the accessory unit fasteners for damage or looseness.
7. Inspect the body panels for missing or loose welds.
8. Remove any aftermarket equipment that may complete a transfer path into the passenger compartment.
9. Inspect the exhaust system and powertrain mounts. Re-bed the engine and align the exhaust system as follows if needed:
 - Loosen the mounts and hangers.
 - Tighten all fasteners with the powertrain in the relaxed position.

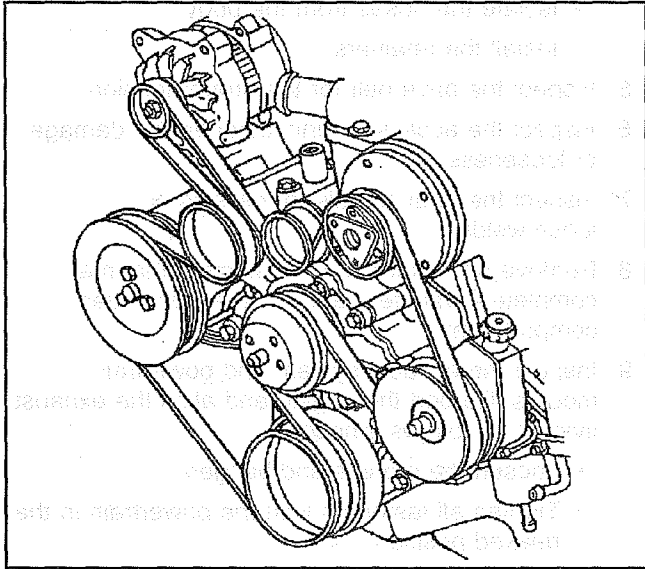
Some residual vibrations may be normal. Compare the vibrations with a similar vehicle to get a feel for what is commercially acceptable, preferably with the customer present. Also, refer to bulletins for updates on the use of mass damper weights for specific applications.

Inherent Engine Shaking Forces

Just as with firing frequency, some engine disturbances are the result of normal operation. Some engines can have additional inherent vibration due to the cylinder arrangement, the design, or the firing order.

Before attempting to repair a disturbance, compare the disturbance to another, known good, vehicle. Some vibrations could be normal though they may not be pleasing to the customer.

The key to resolving an inherent engine disturbance is to isolate the vibration from the passenger compartment. Follow the same procedures as outlined for the engine firing-frequency related vibrations.

Engine-Driven Accessories

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Engine driven accessories that exhibit vibration pose some special challenges. For example, the drive belts can no longer be removed one at a time in order to isolate the condition. If removing the belt eliminates the vibration, reinstall the belt and operate each accessory individually in order to determine which has the most effect on the vibration. However, one component may affect another because the drive belt drives all of the accessories.

Verify that the accessory load is not affecting the engine firing frequency.

Diagnosis

1. Compare the vibrations to a known good vehicle in order to ensure they are abnormal.
2. Remove the drive belt.
3. If the vibration stops, perform the following steps:
 - 3.1. Install the drive belt.

Important: The drive belt drives all of the engine accessories. Therefore, one component may affect another.

- 3.2. Operate each accessory individually in order to determine which has the most effect on the vibration.
4. Test for the accessory load affecting the engine firing frequency.
5. Inspect the pulleys for misalignment or lateral runout. Repair or replace as needed.

6. Inspect the A/C system for overcharging. Evacuate and recharge as needed. Refer to *Refrigerant Recovery and Recharging* in Heating, Ventilation and Air Conditioning.
7. Inspect the engine oil level. Add or drain oil as needed.

Tire and Wheel Vibration

Tire and wheel assembly vibrations are the next level of testing for low-frequency vibrations that are vehicle speed sensitive. The tires, wheels, brake rotors and wheel hubs should be systematically tested, according to the symptoms.

First-Order Tire and Wheel Assembly Vibration

The following are symptoms of first-order vibrations caused by tire and wheel assemblies:

- The vibration is always vehicle-speed related.
If the vibration is affected by the speed of the engine, or is eliminated by placing the transmission in NEUTRAL, then the vibration is not related to the tire and wheel assemblies.
- The vibration will feel like a SHAKE, usually in the steering wheel or the seat:
 - Tire and wheel vibrations that are felt in the steering wheel are most likely related to the front tire and wheel assemblies.
 - Tire and wheel vibrations that are felt in the seat or the floor are most likely related to the rear tire and wheel assemblies.

This may not always hold true, but is a general rule that may serve to initially isolate a problem to the front or the rear of the vehicle.

- The customer may complain of a WADDLE at low speeds of 8 to 56 km/h (5 to 35 mph).
- The frequency on the EVA will correspond to the first-order of tire rotation. This frequency will usually be in the 10 to 20 Hz range, depending on the speed of the complaint and the size of the tire. The smaller the tire, the faster it will rotate at any given speed.
- The range of the human ear begins at 20 Hz. For this reason, first-order tire vibrations are rarely produce noise. The exception to this would be if the tires display an irregular tread pattern or flat spots, causing a GROWLING or SLAPPING noise.

Repair Instructions

Balancing Tires and Wheels

Tire Balancer Calibration Test

Caution: Failure to adhere to the following precautions before tire balancing can result in personal injury or damage to components:

- Clean away any dirt or deposits from the inside of the wheels.
- Remove any stones from the tread.
- Wear eye protection.
- Use coated weights on aluminum wheels.

Important: Tires may be balanced either on-vehicle or off-vehicle, but the off-vehicle balancing procedures are recommended. Off-vehicle methods are better because tire rotation will not affect the balancing. The off-vehicle balancers are also more accurate than the on-vehicle balancers. Off-vehicle balancers can perform dynamic balancing as well as static balancing. Tire and wheel balancers can drift out of calibration without warning or become inaccurate as a result of abuse. The balancer calibration should be inspected every two weeks or whenever the readings become questionable.

1. Spin the balancer without a wheel or any of the adapters on the shaft.

2. Inspect the balancer readings.

Specification

0.00–0.25 oz.

3. Balance a tire and wheel that is within radial and lateral tolerances to ZERO.

4. Add a 3-ounce test weight to the wheel at any location.

5. Spin the tire and wheel again. Observe the readings.

- In the static and dynamic modes, the balancer should call for 3 ounces of weight, 180 degrees opposite the test weight.
- In the dynamic mode only, the weight should be called for on the flange of the wheel opposite the last weight.

6. With the wheel unbalanced to 3 ounces, cycle the balancer five times.

7. Take the balancer readings:

Specification

Variation: 0.25 oz or less.

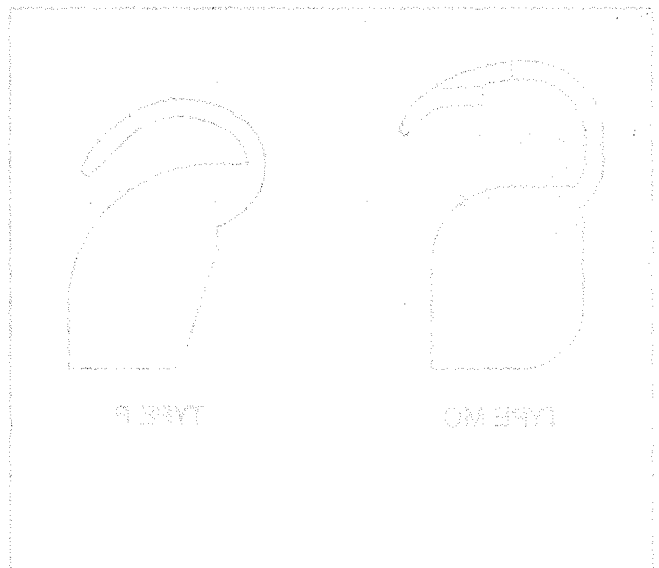
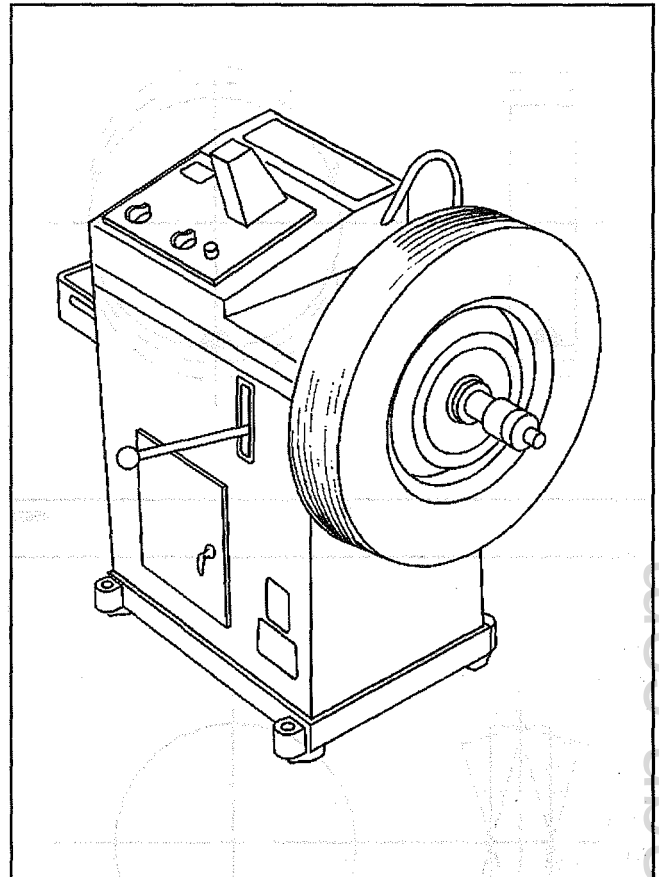
8. Index the tire and wheel at four separate locations on the balancer shaft, 90 degrees apart.

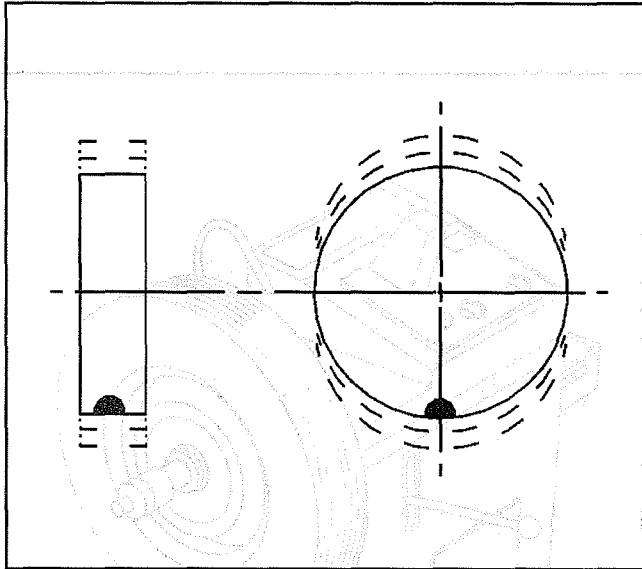
9. Cycle the balancer with the weights at each location.

10. Take the balancer readings:

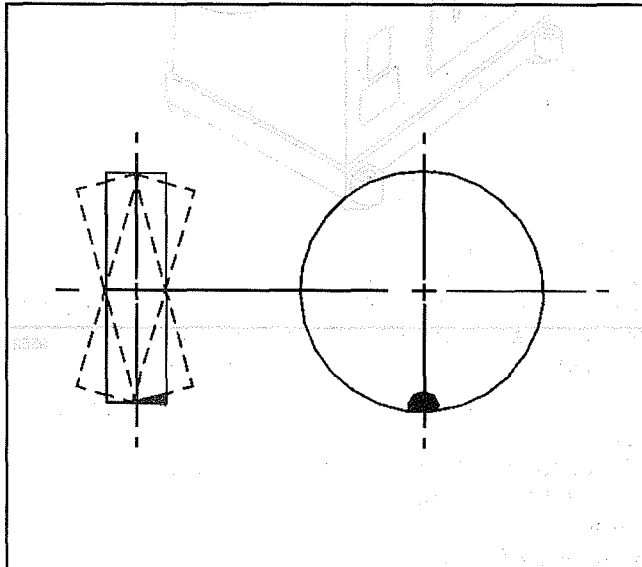
Specification

Variation: 0.25 oz or less.

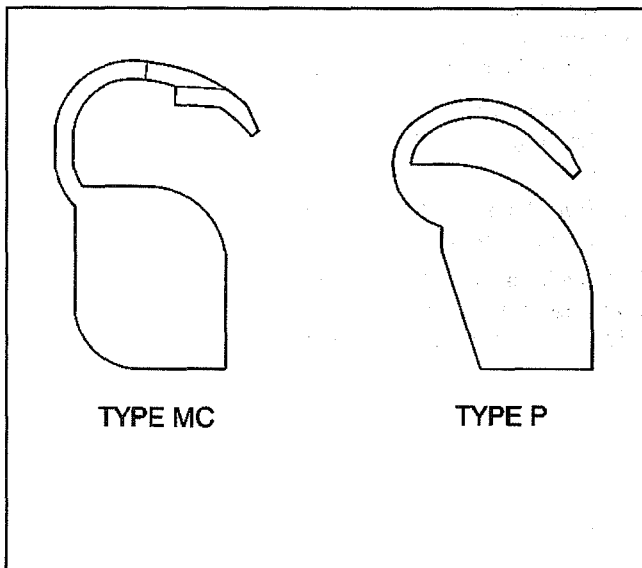




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Tire Balancing Guidelines

Static and dynamic balance are two kinds of tire/wheel balancing:

1. Static balance, also called single plane balance, affects the distribution of weights around the wheel circumference.
2. Dynamic balance, or two-plane balance, affects the distribution of weight on each side of the tire/wheel centerline.
3. Most off-vehicle balancers can check both types of balance simultaneously.
4. As a general rule, most balancers are most sensitive to static imbalance that to dynamic imbalance. As little as 0.50 – 0.75 oz may induce a vibration in some vehicles. Vibration induced by static imbalance will cause a vertical, or bouncing motion of the tire. Dynamic imbalance results in a side-to-side motion of the tire, or shimmy.
5. Balance all four tires/wheels as close to ZERO as possible.
6. Carefully follow the wheel balancer manufacturers instructions for proper mounting techniques for different types of wheels.
7. Aftermarket wheels, especially those incorporating universal lug patterns, are potential sources of runout and mounting problems.
8. Use the correct coated weights on aluminum wheels.
9. Retest the tire and wheel for excessive runout after correction and installation.
10. Evaluate the vehicle at the complaint speed and note if the vibration has been corrected.
11. If the vibration is still present, or is reduced but still unacceptable, consider these possibilities:
 - On-vehicle imbalance
 - Radial or lateral force variation

Wheel Weight Usage (Aluminum Wheels)

1. Locate the wheel weights on the inboard rim flange. If during static balancing more than 28 grams (1 ounce) is needed, split the weights as equally as possible between the inboard and outboard flanges.
2. Use special polyester-coated clip-on wheel weights in order to balance factory aluminum wheels. These weights are designated MC or P, and must be used on aluminum wheels having a wide 7.6 mm (19/64 in) flange. Use a plastic tipped hammer in order to prevent damage to the weight's coating during installation.

3. Adhesive wheel weights are also available. Use the following procedure in order to install adhesive wheel weights.
 - 3.1. Determine where the wheel weigh is to be located on the inboard side of the wheel.
 - 3.2. Clean that area by sanding to bare aluminum. Do NOT sand the outboard side of the wheel as this will damage the clear coat finish.
 - 3.3. Wipe the sanded area with a mixture of half isopropyl alcohol and half water. Use a clean cloth or paper towel.
 - 3.4. Dry the area with hot air until the wheel surface is warm to the touch.
 - 3.5. Warm the adhesive backing on the wheel balance weight to room temperature.
 - 3.6. Remove the tape from the back of the weight. Do not touch the adhesive tape.
 - 3.7. Apply the wheel weight and press on with hand pressure.
 - 3.8. Secure the wheel weight with a 70–110 N·m (16–25 lb ft) force applied with a roller.

Description and Operation

Basic Terms

The following are the two primary components of vibration diagnosis:

- The physical properties of objects
- The object's properties of conducting mechanical energy

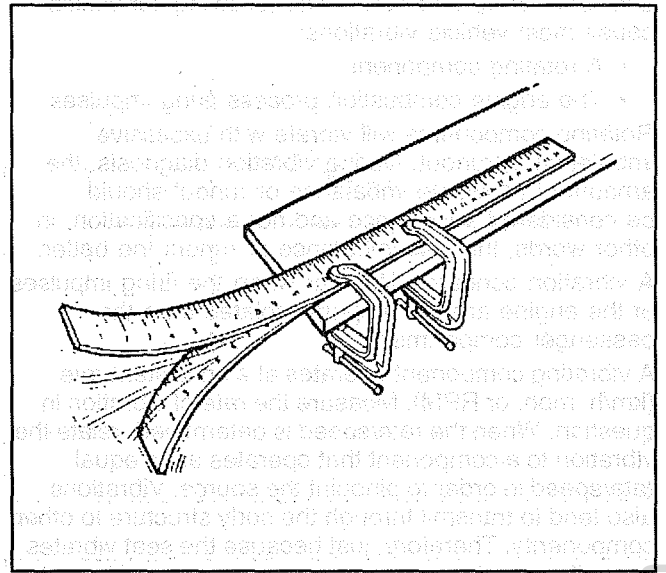
The repetitive up/down or back/forth movement of a component causes most customer vibration complaints. The following are the components that often vibrate:

- The steering wheel
- The seat cushion
- The frame
- The instrument panel

Vibration diagnosis involves the following steps:

1. Measure the repetitive motion and assign a value to the measurement in cycles per second or cycles per minute.
2. Relate the frequency to the rotational speed of a component that is operating at the same rate or speed.
3. Inspect and test the components for conditions that cause vibration.

For example, performing the following steps will help demonstrate the vibration theory:



1. Clamp a yardstick to the edge of a table, leaving about 50 cm (20 in) hanging over the edge of the table.
2. Pull down on the edge of the stick and release while observing the movement of the stick.

The motion of the stick occurs in repetitive cycles. The cycle begins at midpoint, continues through the lowest extreme of travel, then back past the midpoint, through the upper extreme of travel, and back to the midpoint where the cycle begins again.

The cycle occurs over and over again at the same rate, or frequency. In this case, the frequency is about 10 cycles per second. If we measure the frequency to reflect the number of complete cycles that the yardstick made in one minute, the measure would be 10 cycles x 60 seconds = 600 cycles per minute (cpm).

We could have also found a specific amount of motion, or amplitude, in the total travel of the yardstick from the very top of the cycle to the very bottom of the cycle. Redo the experiment as follows:

1. Reclamp the yardstick to the edge of a table, leaving about 25 cm (10 in) hanging over the edge of the table.
2. Pull down on the edge of the stick and release while observing the movement of the stick.

The stick vibrates at a much faster frequency: 30 cycles per second (1800 cycles per minute). The total travel, or amplitude, is less.

Vibration

Vibration is the repetitive motion of an object, back and forth, or up and down. The following conditions cause most vehicle vibrations:

- A rotating component
- The engine combustion process firing impulses

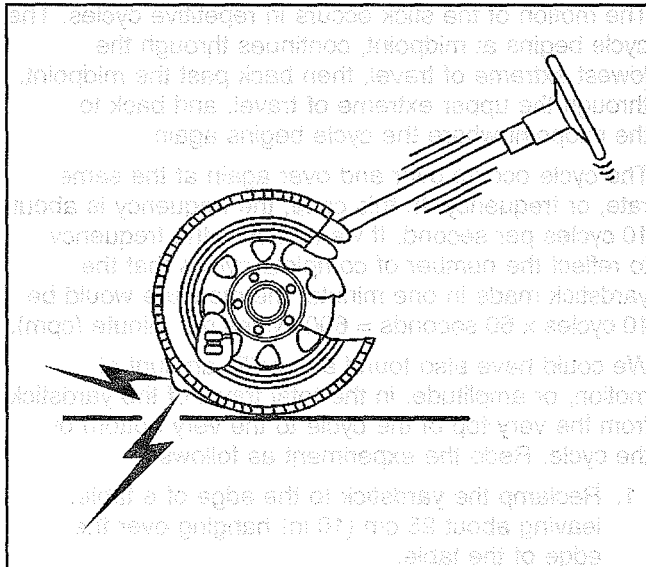
Rotating components will vibrate with excessive imbalance or runout. During vibration diagnosis, the amount of allowable imbalance or runout should be considered a tolerance and not a specification. In other words, the less imbalance or runout the better.

A vibration concern will occur when the firing impulses of the engine are not properly isolated from the passenger compartment.

A vibrating component operates at a consistent rate (km/h, mph, or RPM). Measure the rate of vibration in question. When the rate/speed is determined, relate the vibration to a component that operates at an equal rate/speed in order to pinpoint the source. Vibrations also tend to transmit through the body structure to other components. Therefore, just because the seat vibrates doesn't mean the source of the vibration is in the seat.

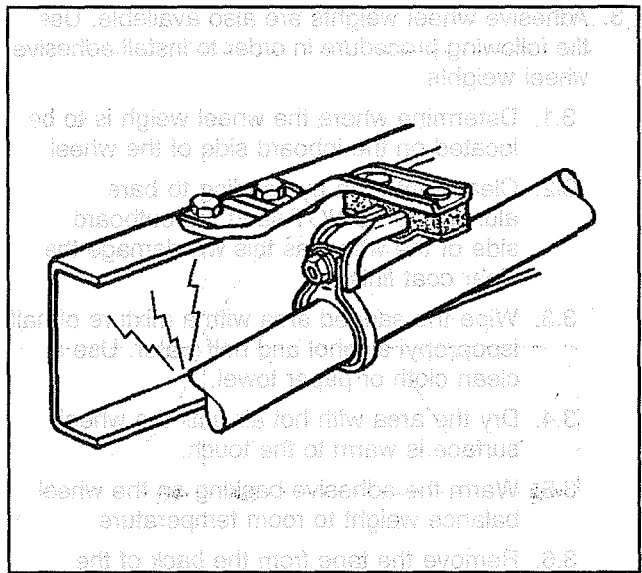
Vibrations consist of the following three elements:

- The source — the cause of the vibration
- The transfer path — the path the vibration travels through the vehicle
- The responder — the component where the vibration is felt



95585

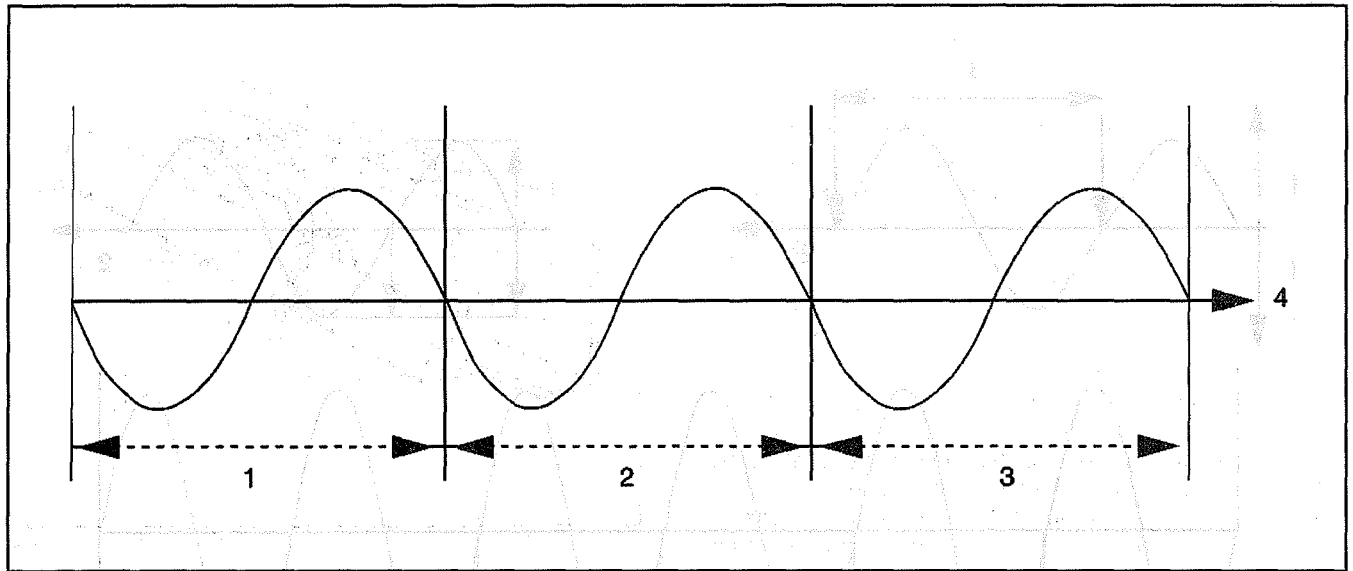
In the preceding figure, the source of the vibration is the unbalanced tire. The transfer path is the route the vibrations travels through the vehicle's suspension system into the steering column. The responder is the steering wheel, which the customer reports as vibrating. Eliminating any one of these three elements will usually correct the condition. Decide, from the gathered information, which element makes the most sense to repair. Adding a brace to the steering column may keep the steering wheel from vibrating, but adding a brace is not a practical solution. The most direct and effective repair would be to properly balance the tire.



95586

Vibration can also produce noise. As an example, consider a vehicle that has an exhaust pipe which is grounded to the frame. The source of the vibration is the engine firing impulses traveling through the exhaust. The transfer path is a grounded or bound-up exhaust hanger. The responder is the frame. The floor panel vibrates, acting as a large speaker, which produces noise. The best repair would be to eliminate the transfer path. Aligning the exhaust system and correcting the grounded condition at the frame would eliminate the transfer path.

Cycle

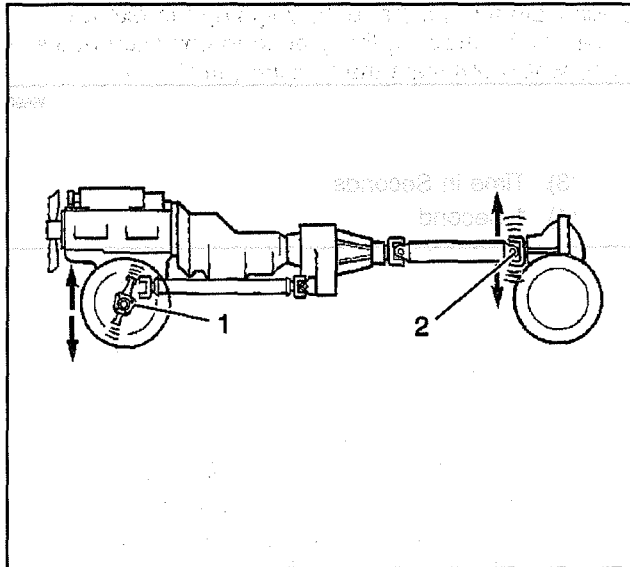


Legend

- (1) 1st Cycle
- (2) 2nd Cycle

- (3) 3rd Cycle
- (4) Time

Vibration Cycles in Powertrain Components

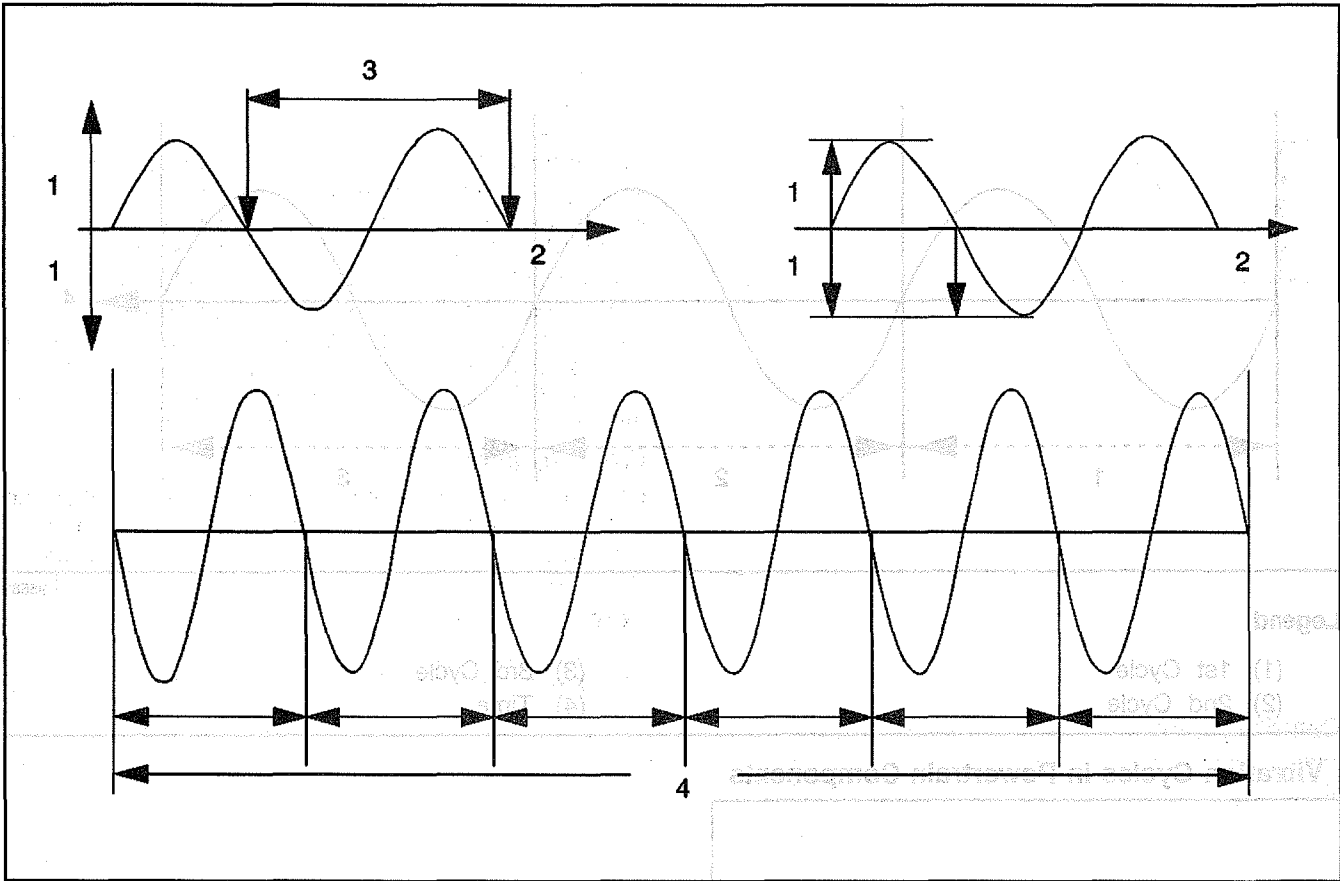


Legend

- (1) Spindle
- (2) Pinion Nose

The word "cycle" comes from the same root as the word "circle." A circle begins and ends at the same point, and so does a cycle. All vibrations consist of repetitive cycles.

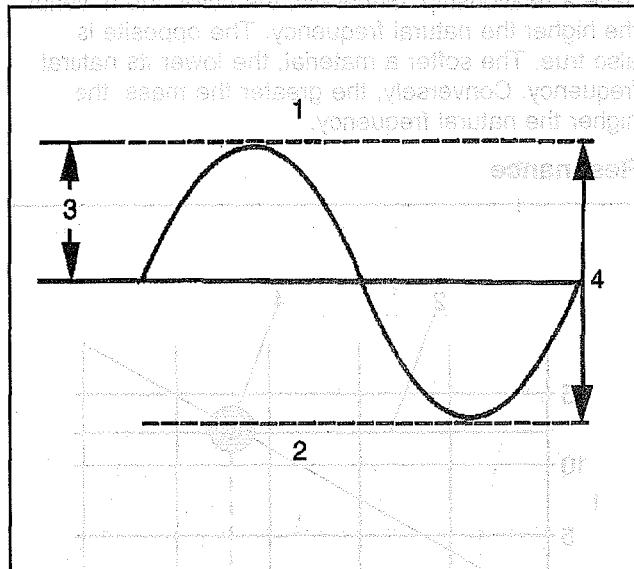
Frequency



Legend

- (1) Amplitude
- (2) Reference
- (3) Time in Seconds
- (4) 1 Second

Frequency is defined as the rate at which an event occurs during a given period of time. With a vibration, the event is a cycle, and the period of time is one second. Thus, frequency is expressed in cycles per second, or Hertz (Hz). Multiply the Hertz by 60 to get the cycles, or revolutions, per minute (RPM).

Amplitude

95593

Legend

- (1) Maximum
- (2) Minimum
- (3) Zero-to-Peak Amplitude
- (4) Peak-to-Peak Amplitude

Amplitude is the maximum value of a periodically varying quantity. Used in vibration diagnostics, amplitude is the magnitude of the disturbance. A severe disturbance would have a high amplitude; a minor disturbance would have a low amplitude.

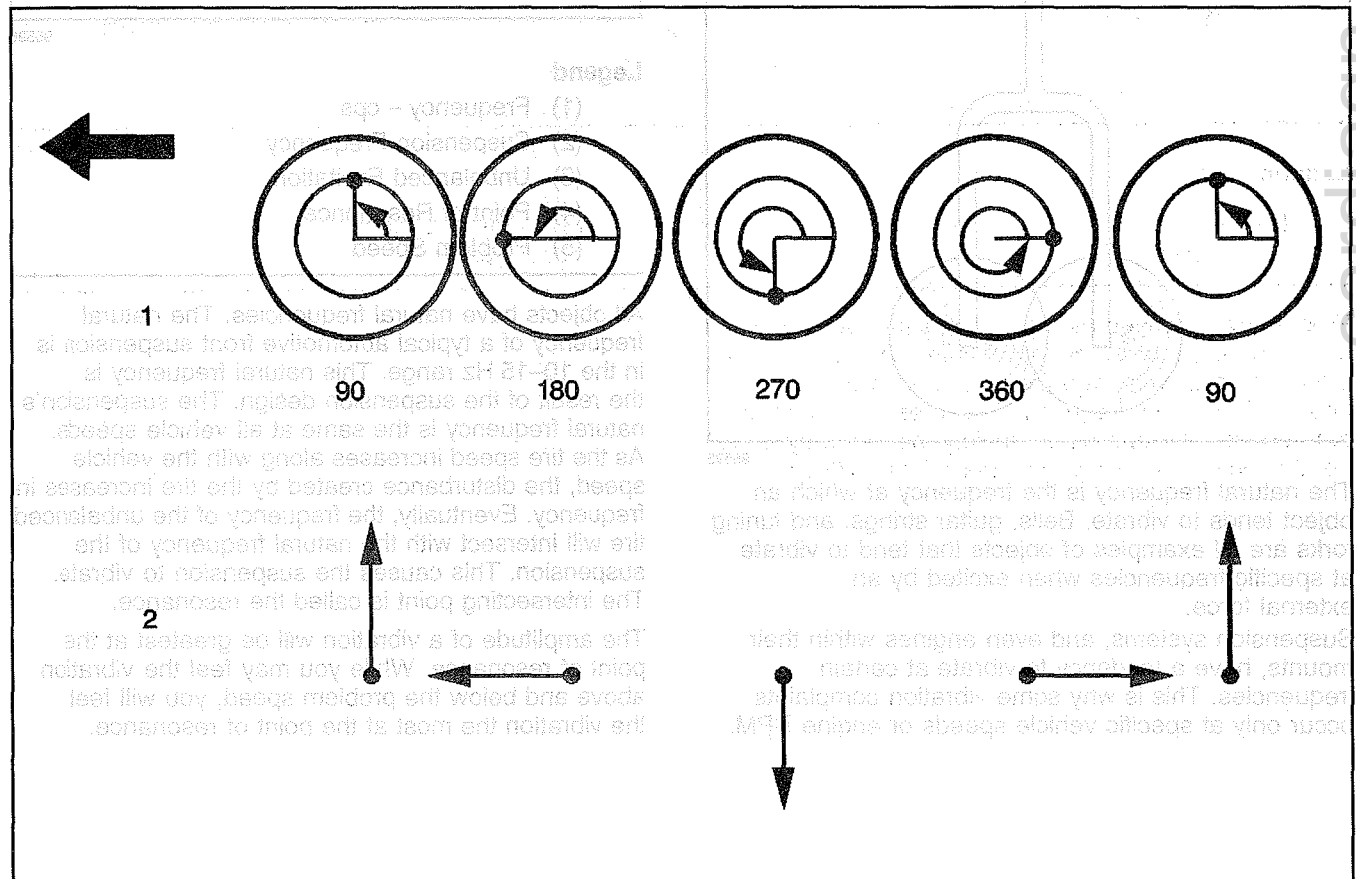
Amplitude is measured by the amount of actual movement, or the displacement. For example, consider the vibration caused by an out-of-balance wheel at 80 km/h (50 mph) as opposed to 40 km/h (25 mph). As the speed increases, the amplitude increases.

Free Vibration

Free vibration is the continued vibration in the absence of any outside force. In the yardstick example, the yardstick continued to vibrate even after the end was released.

Forced Vibration

Forced vibration is when an object is vibrating continuously as a result of an outside force.

Centrifugal Force Due to an Imbalance

95594

Legend

(1) Location of Imbalance (Degrees)

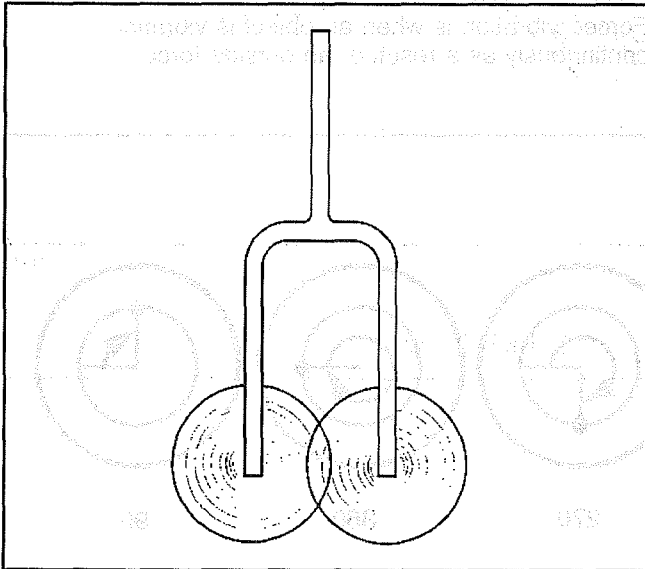
(2) Centrifugal Force Acting on Spindle

A spinning object with an imbalance generates a centrifugal force. Performing the following steps will help to demonstrate centrifugal force:

1. Tie a nut to a string.
2. Hold the string. The nut hangs vertically due to gravity.
3. Spin the string. The nut will spin in a circle.

Centrifugal force is trying to make the nut fly outward, causing the pull you feel on your hand. An unbalanced tire follows the same example. The nut represents the imbalance in the tire. The string represents the tire/wheel/suspension assembly. As the vehicle speed increases, you can feel the disturbing force of the unbalanced tire in the steering wheel, the seat, and the floor. This disturbance will be repetitive (Hz) and the amplitude will increase. At higher speeds, both the frequency and the amplitude will increase. As the tire revolves, the imbalance, or the centrifugal force, will alternately lift the tire up and force the tire downward, along with the spindle, once for each revolution of the tire.

Natural or Resonant Frequency



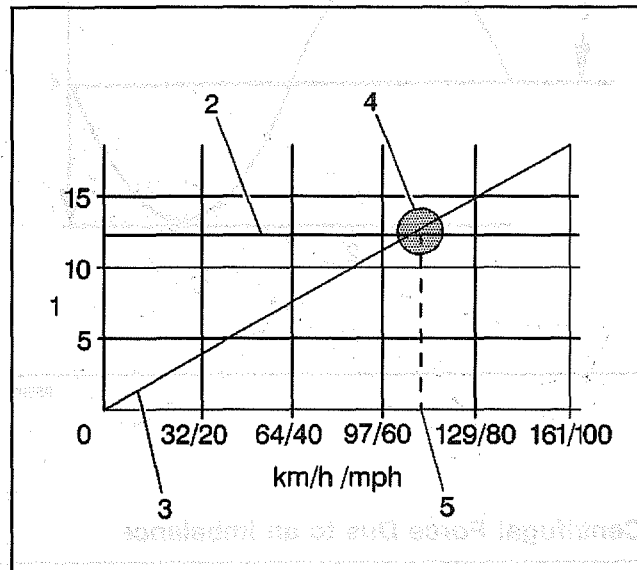
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The natural frequency is the frequency at which an object tends to vibrate. Bells, guitar strings, and tuning forks are all examples of objects that tend to vibrate at specific frequencies when excited by an external force.

Suspension systems, and even engines within their mounts, have a tendency to vibrate at certain frequencies. This is why some vibration complaints occur only at specific vehicle speeds or engine RPM.

The stiffness and the natural frequency of a material have a relationship. Generally, the stiffer the material, the higher the natural frequency. The opposite is also true. The softer a material, the lower its natural frequency. Conversely, the greater the mass, the higher the natural frequency.

Resonance



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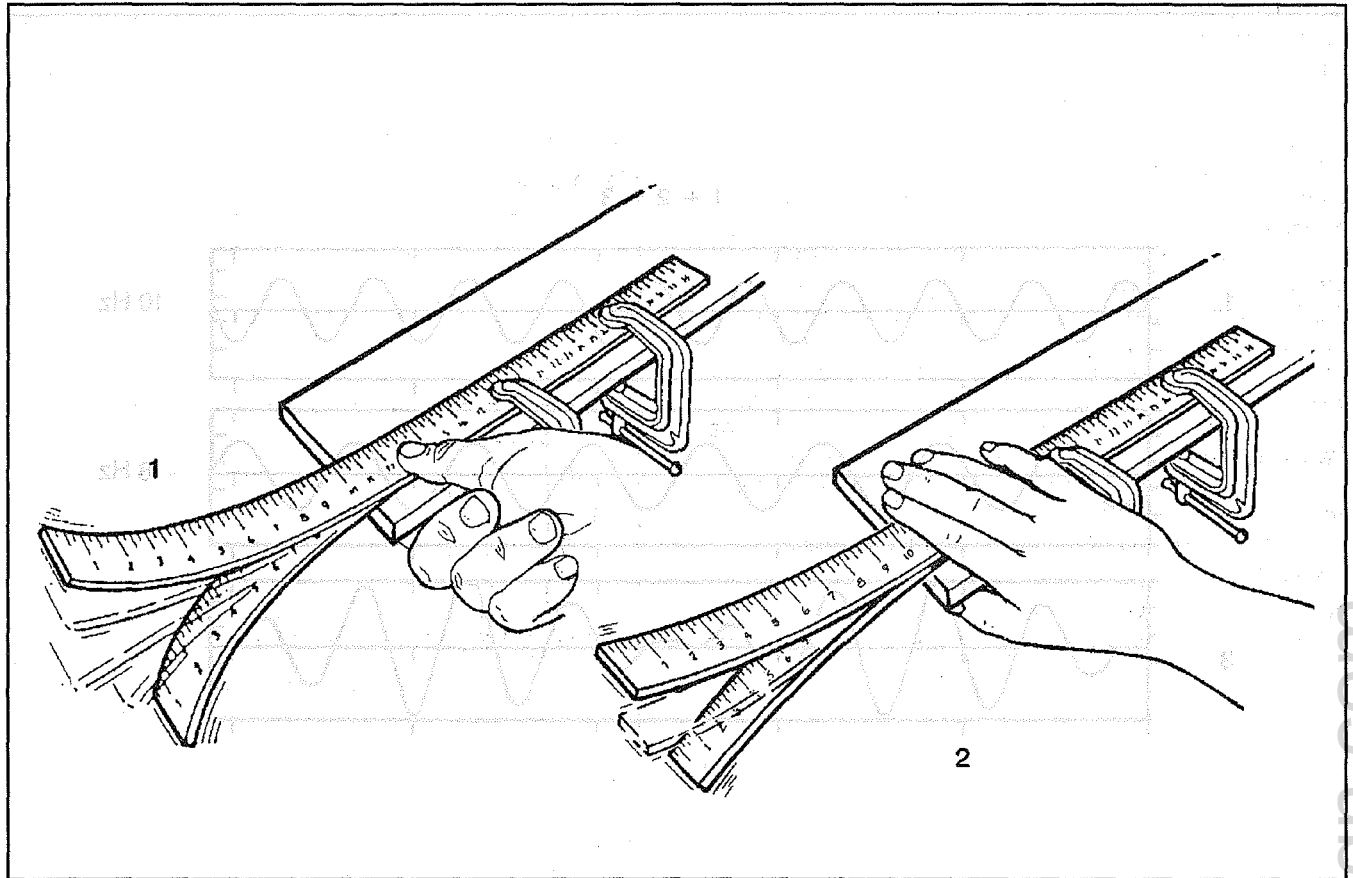
Legend

- (1) Frequency – cps
- (2) Suspension Frequency
- (3) Unbalanced Excitation
- (4) Point of Resonance
- (5) Problem Speed

All objects have natural frequencies. The natural frequency of a typical automotive front suspension is in the 10–15 Hz range. This natural frequency is the result of the suspension design. The suspension's natural frequency is the same at all vehicle speeds. As the tire speed increases along with the vehicle speed, the disturbance created by the tire increases in frequency. Eventually, the frequency of the unbalanced tire will intersect with the natural frequency of the suspension. This causes the suspension to vibrate. The intersecting point is called the resonance.

The amplitude of a vibration will be greatest at the point of resonance. While you may feel the vibration above and below the problem speed, you will feel the vibration the most at the point of resonance.

Damping



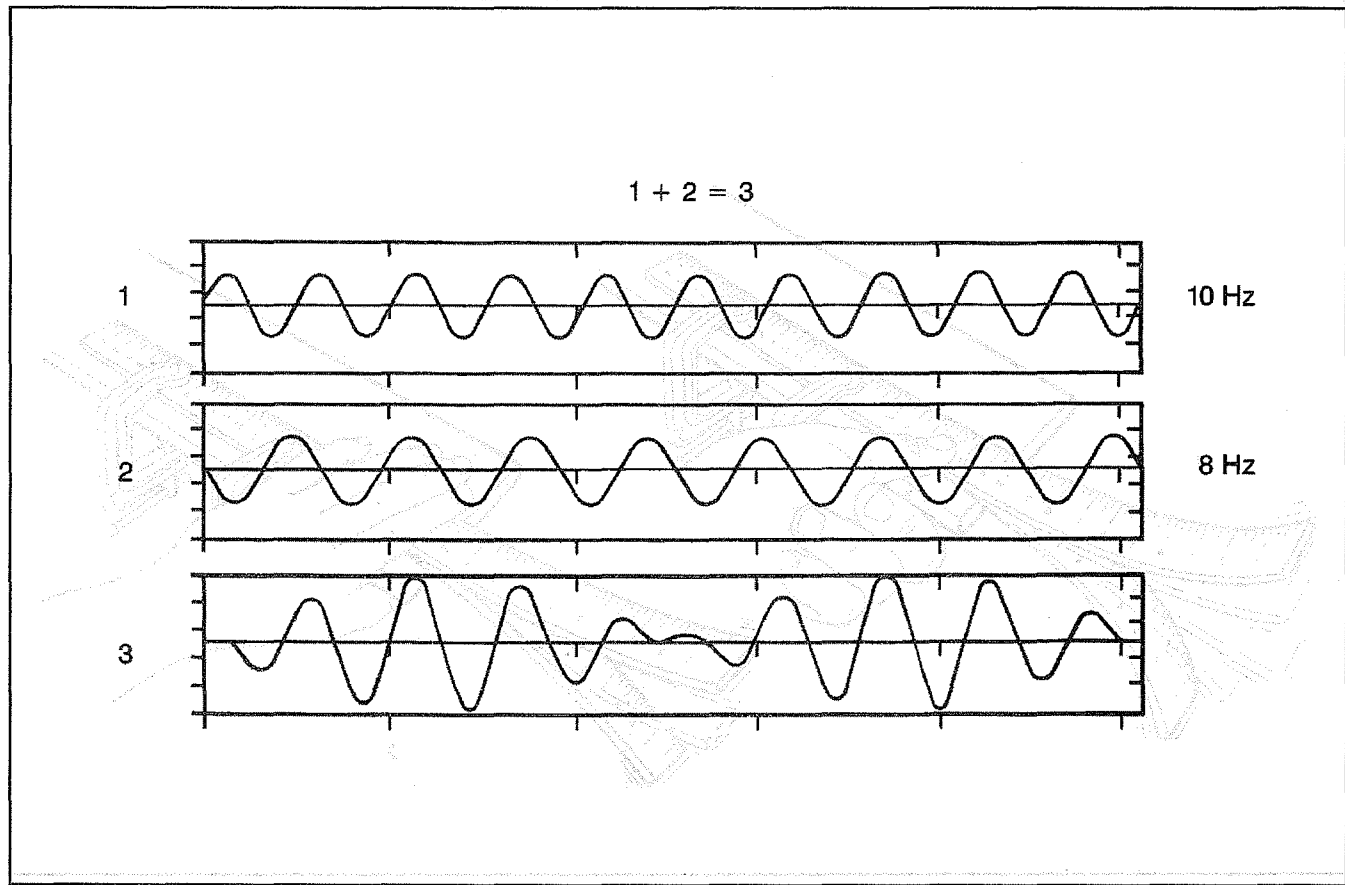
Legend

(1) Low Damping

Damping is the ability of an object or material to dissipate or absorb vibration. The automotive shock absorber is a good example. The function of the shock absorber is to absorb or dampen the oscillations of the suspension system.

(2) High Damping

Beating (Phasing)



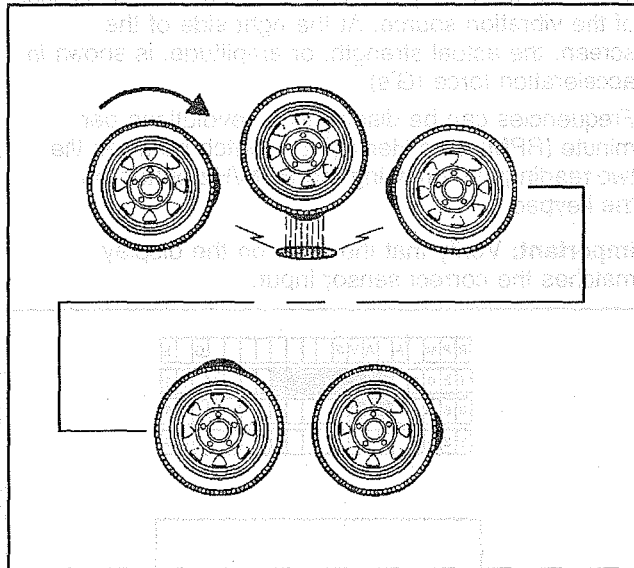
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Two separate disturbances that are relatively close together in frequency will lead to a condition called beating, or phasing. A beating vibration condition will increase in intensity or amplitude in a repetitive fashion as the vehicle travels at a steady speed. This beating vibration can produce the familiar droning noise heard in some vehicles.

Beating occurs when two vibrating forces are adding to each other's amplitude. However, two vibrating forces can also subtract from each other's amplitude. The adding and subtracting of amplitudes in similar frequencies is called beating. In many cases, eliminating either one of the disturbances can correct the condition.

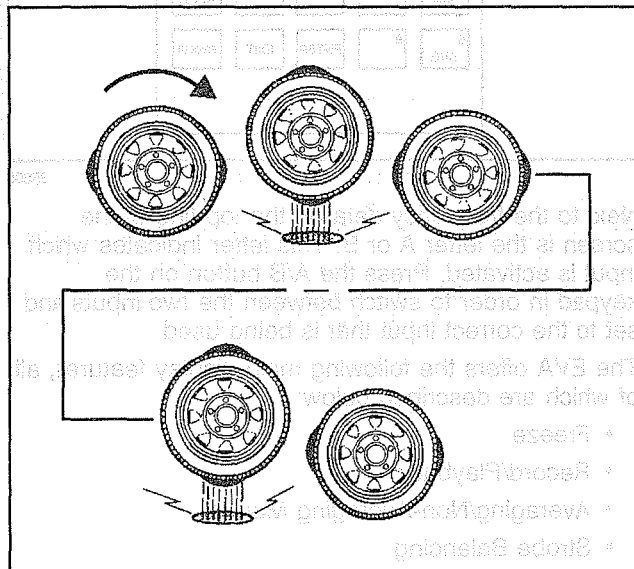
Order

Order refers to how many times an event occurs during one revolution of a rotating component.



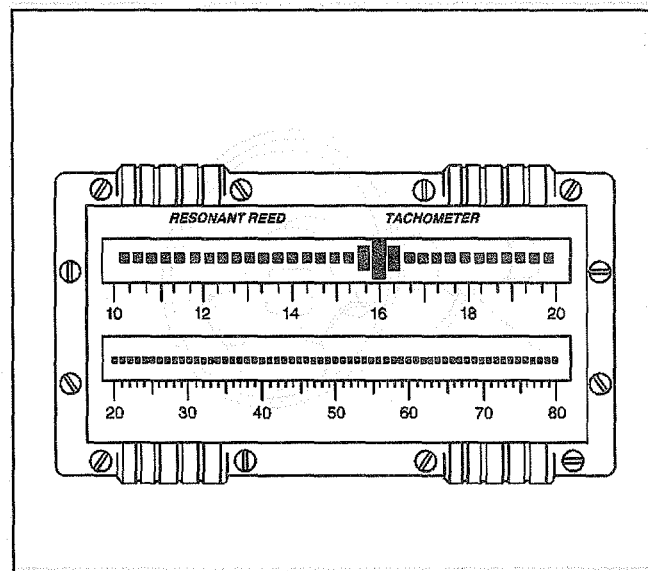
95600

For example, a tire with one high spot would create a disturbance once for every revolution of the tire. This is called first-order vibration.



95601

An oval-shaped tire with two high spots would create a disturbance twice for every revolution. This is called second-order vibration. Three high spots would be third-order, and so forth. Two first-order vibrations may add or subtract from the overall amplitude of the disturbance, but that is all. Two first-order vibrations do not equal a second-order vibration. Due to centrifugal force, an unbalanced component will always create at least a first-order vibration.

Reed Tachometer

386790

The reed tachometer consists of two rows of reeds arranged side-by-side. Each reed vibrates when excited by a specific frequency. The reeds are tuned to vibrate at increasing frequencies from left to right. This allows for a visual display of the frequency range from 10–80 Hz.

Due to increasing costs, limited availability and limited diagnostic capability, the reed tachometer is no longer recommended as the primary tool in diagnosing vibration.

Electronic Vibration Analyzer (EVA)

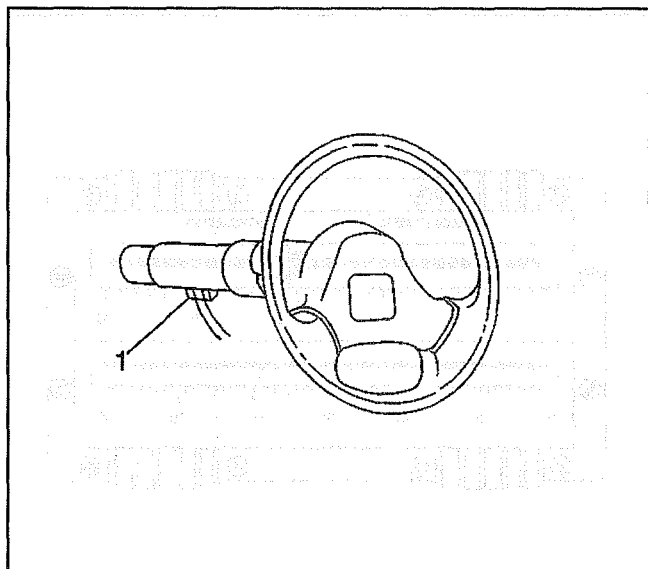
The J 38792 Electronic Vibration Analyzer (EVA), with the J 38792-60 Electronic Vibration Analyzer Cartridge, is specifically designed to diagnose vibrations. This hand-held device is similar to a scan tool. A standard 12-volt power feed supplies the power. The vibration sensor, or the accelerometer, is at the end of a 6 mm (20 ft) cord. The vibration sensor can be mounted virtually anywhere on the vehicle where a vibration is felt.

EVA Basic Hookup

1. Verify that the software cartridge is correctly inserted at the bottom of the unit. (The cartridge usually remains there at all times.)
2. Connect the vibration sensor cord into either Input A or B.
3. Line up the sensor connector so that the release button is at the bottom.
4. Push the sensor connector into the input until the connector clicks and locks into place.
5. Plug the power cord into a 12-volt power feed in order to turn the EVA on. (The EVA is not equipped with an ON-OFF switch.)

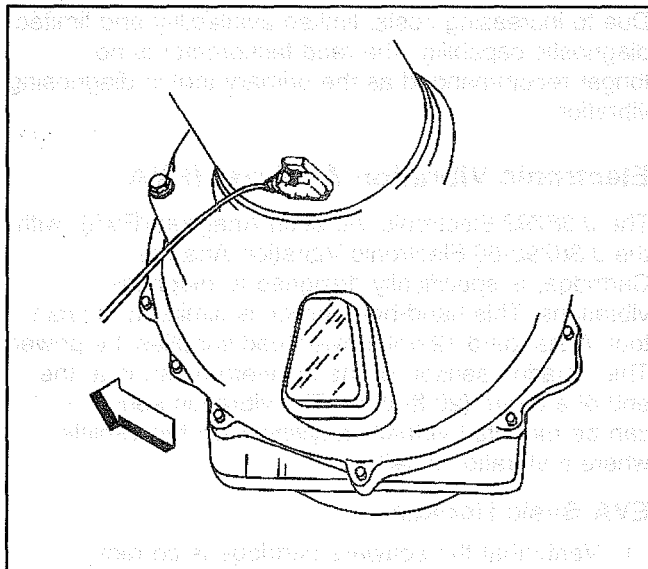
To disconnect the sensor connector, press the release button and gently pull the connector straight out.

EVA Sensor Placement



95603

Proper EVA sensor placement is critical in order to take proper vibration readings. You can place the sensor anywhere on the vehicle where vibrations are felt (1). Use putty or a hook and loop fastener in order to hold the sensor in place on non-ferrous surfaces, such as the surface of the steering column.



95604

A magnet holds the sensor to ferrous surfaces.

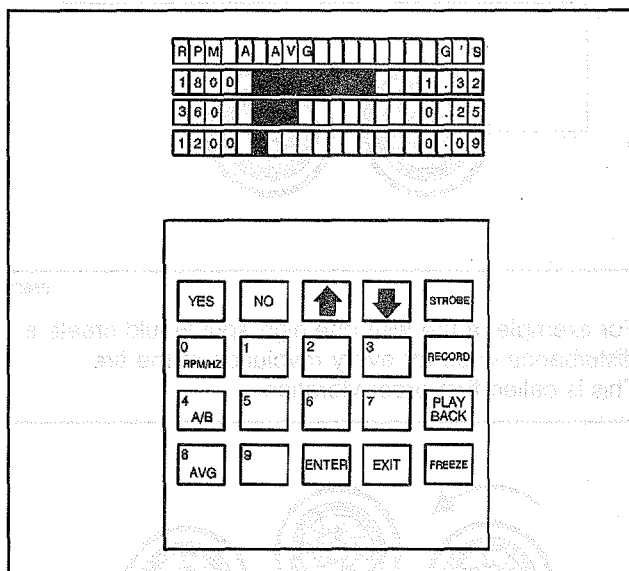
Vibrations are typically felt in an up-and-down direction. The sensor is directionally sensitive. Therefore, place the sensor as flat as possible with the side marked UP facing upward. Place the UP side of the sensor in the exact position every time for consistent results when repeating the tests or making a comparison.

EVA Display

Up to three dominant vibration frequencies are displayed on the EVA's liquid crystal screen. On the left is the frequency reading, followed by a description of the vibration source. At the right side of the screen, the actual strength, or amplitude, is shown in acceleration force (G's).

Frequencies can be displayed in revolutions per minute (RPM) or in Hertz (Hz). Switch between the two readings by pressing the RPM/Hz button on the keypad.

Important: Verify that the letter on the display matches the correct sensor input.



95605

Next to the frequency data on the top line of the screen is the letter A or B. This letter indicates which input is activated. Press the A/B button on the keypad in order to switch between the two inputs and set to the correct input that is being used.

The EVA offers the following main display features, all of which are described below:

- Freeze
- Record/Playback
- Averaging/Non-Averaging Modes
- Strobe Balancing
- Smart Strobe
- Auto Mode

Freeze

Pressing the FREEZE button on the keypad activates the freeze function, which locks the display of data. The display changes to Hz FR V = XX G and a caret symbol points to a vibration source. Additional diagnostic information or that vibration source can be viewed by pressing ENTER. The freeze function is useful when conducting an acceleration/deceleration test in which the significant amount of vibration registers only for a very short time. Pressing EXIT or the FREEZE button again deactivates the freeze function.

Record/Playback

The displayed vibration information can be recorded for later playback. The EVA retains stored data for approximately 70 hours after the unit has been unplugged from a power source. Data is recorded as snapshots of vibration information. Each snapshot consists of 10 different frames. Up to 10 snapshots can be recorded.

Press the RECORD button in order to record a snapshot. The screen will display R? in order to request a tag number between 0 and 9. These tag numbers are the individual frames of the snapshot recording. Then press ENTER to begin recording. New data will replace the existing data when a number is chosen that has already been used in order to tag a snapshot.

Pressing the PLAYBACK button plays back the recorded data. The screen shows P? in order to request the tag number for the wanted snapshot. Once the number is entered, the snapshot data displays the letter P followed by the tag number then press ENTER to play back the data. Then the screen displays the letter F followed by a number between 0 and 9 in order to indicate which frame of the snapshot is being displayed.

Use the freeze function in order to freeze the display at any point in the sequence during playback. You can view individual frames in a forward or backward sequence using the UP and DOWN arrow keys.

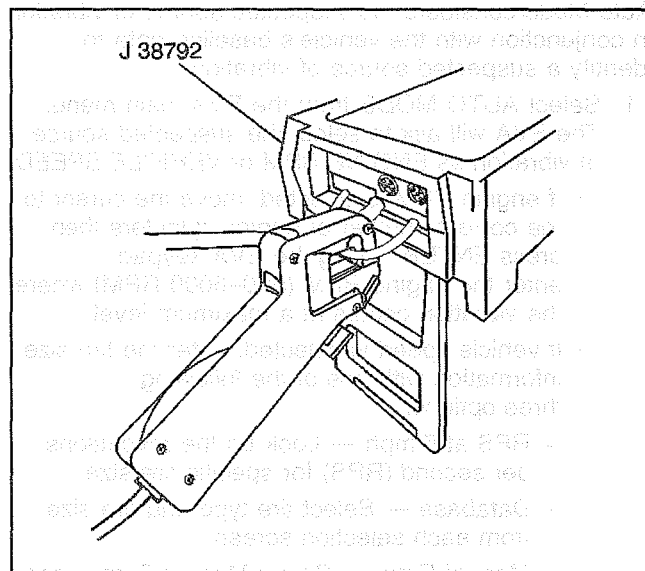
The display returns to the active screen when the recording or playback of a snapshot is finished, or when EXIT is pressed.

Averaging/Non-Averaging Modes

The EVA normally operates in an averaging mode that averages multiple vibration samples over a period of time. The averaging mode minimizes the effects of a sudden vibration that is not related to the problem (such as from potholes or from uneven road surfaces). Most tests use the averaging mode.

The EVA is more sensitive to vibrations in the non-averaging mode. The display is more instantaneous and not averaged over a period of time. The non-averaging mode is used when measuring a vibration that exists for only a short period of time, and during acceleration/deceleration tests.

Pressing the AVG button switches between the averaging and non-averaging modes. During the averaging mode, the screen will display AA. During the instantaneous mode the top of the screen will display IA.

Strobe Balancing

95606

The J 38792 can strobe balance a rotating component. A trigger wire is located on the top of the EVA, which is used with an inductive pick-up strobe light (timing light). The EVA triggers the strobe light at the same frequency as the most predominant vibration. The timing light clips on to the trigger wire. The vibration sensor must be attached to input A. Input B does not provide the strobe function.

Pressing the STROBE button starts the strobe balancing function. The EVA will ask a series of questions in order to determine the correct filter range: low, medium or high.

The low, medium and high ranges prevent other vibrations from interfering with the operation of the strobe light. Press YES in order to select a range. Press NO in order to go on to the next range. The vibration/strobe frequency must fall within the selected range.

The EVA will display the signal frequency, signal level (amplitude), and filter range. The EVA is now ready to begin the strobe balance procedure.

1. Run the engine at the RPM at which the vibration is the greatest and trigger the strobe.
2. Enter an initial test point strobe frequency between 10-200 Hz (600-1200 RPM).
3. As you start the strobe light at the rotating object, press the strobe light trigger.
4. From the Main Menu, select Strobe Balance.
5. With the engine off, mark and adjust your sensor to causing vibration. A job is more precise with correction fluid works well.
6. Enter an initial test point strobe frequency between 10-200 Hz (600-1200 RPM).
7. Connect to a 15-volt power source.
8. If a timing light with an advance feature is used, set advance to 0 degrees.
9. If a timing light with an advance feature is used, set advance to 0 degrees.

Auto Mode

Auto Mode considers the suspected source of vibration in conjunction with the vehicle's baseline data to identify a suspected source of vibration.

1. Select AUTO MODE from the EVA main menu. The EVA will ask to select the suspected source of vibration as ENGINE RPM or VEHICLE SPEED.
 - If engine RPM is selected, move the cursor to the correct number of engine cylinders then press ENTER. Using the EVA keypad, enter the engine RPM (500–6000 RPM) where the vibration occurs at a maximum level.
 - If vehicle speed is selected, enter the tire size information with one of the following three options:
 - RPS at 5 mph — Look up the revolutions per second (RPS) for specific tire size.
 - Database — Select tire type and tire size from each selection screen.
 - Manual Entry — Select Manual Entry when the vehicle is fitted with specialty tires.
2. Enter one of the following driveshaft configurations:
 - FWD (Front Wheel Drive)
 - RWD (Rear Wheel Drive)
 - AWD (All Wheel Drive)
 - 4WD (Four Wheel Drive)
3. Enter the axle ratio only if FWD is not selected.
4. Select the vehicle speed units in mph (miles-per-hour) or km/h (kilometers-per-hour).

Smart Strobe

The Smart Strobe mode enables complete control of the frequency at which the strobe light will flash. Smart Strobe is well suited for identifying the speed at which objects are rotating at. This is helpful for identifying the source of a vibration. The pulley RPM can be converted to a frequency by pressing the RPM/Hz key.

1. To use the Smart Strobe function, begin by clipping the inductive pickup of the timing light to the "wiring loop" of the EVA.
2. Connect to a 12-volt power source.
3. If a timing light with an advance feature is used, set advance to 0 degrees.
4. From the Main Menu, select Smart Strobe.
5. With the engine off, mark the object you suspect is causing vibration. A dab of white paint or correction fluid works well.
6. Enter an initial test point strobe frequency between 10–200 Hz (600–12000 RPM).
7. Run the engine at the RPM at which the vibration is the greatest and trigger the strobe.
8. As you point the strobe light at the spinning object, press the Strobe Light trigger.

9. Press the EVA up or down keys to manually adjust the RPM until only one mark is seen and the mark on the object appears stationary.
10. As the test is run, the strobe speed must be manually adjusted to match the actual object RPM.

EVA Calibration

The EVA features the following two built-in calibration procedures:

- Sensor calibration
- Phase shift calibration

Calibrate a replaced or an added sensor in order to function properly with the EVA unit. The phase shift calibration is performed at the factory. Do NOT repeat this calibration under normal use.

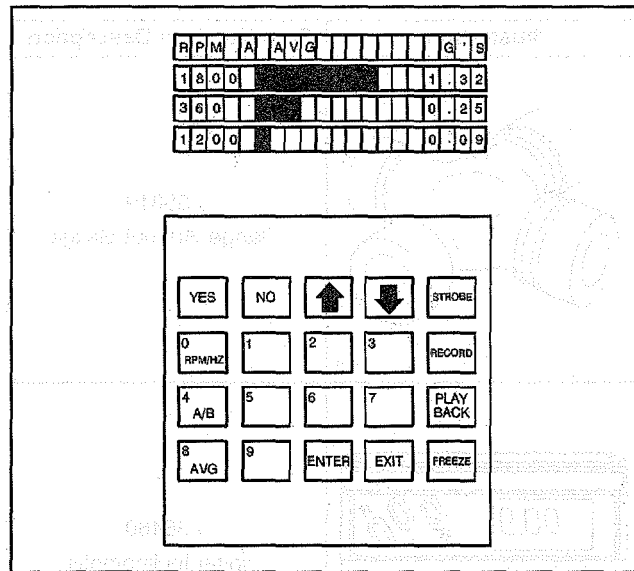
Sensor Calibration

1. Lay the sensor on a flat stationary surface with the UP side facing upward.
2. Plug the sensor into either input A or B.
3. Plug the EVA into a 12-volt power supply.
4. After the display initializes, select the proper input.
5. Press the number 1 to initiate sensor calibration.
6. Press the number 2 three times on the keypad. The message BURNING will appear, followed by a request to turn the sensor over.
7. Turn the sensor over.
8. Press any key in order to commence calibration:
 - Calibration will take approximately 20 seconds.
 - The display will return to the active mode when calibration is complete.

Phase Shift Calibration

1. Plug the EVA into a 12-volt power supply.
2. Press the number 5 to initiate phase shift calibration.
3. Press the number 2 on the keypad three times in order to begin calibration:
 - Do not press any key until the message ANY KEY TO CONTINUE appears. Pressing a key will cancel the calibration process.
 - The display will flash numbers for 5–6 minutes. (If the numbers flash for more than 10 minutes, the EVA is defective.)
 - The message BURNING PHASE SHIFT CONSTANTS will appear for one minute.
 - The BURNING CENTER FREQUENCIES LOW=40, MEDIUM=50, HIGH=60 message will appear.
 - The ANY KEY TO CONTINUE message should appear.
4. Press any key in order to return to the active mode.

Keypad Reference



95605

A/B: Switches the display between the A Input and the B Input. You must use Input A when strobe balancing.

AVG: Switches the display between the non-averaging mode and the averaging mode. The non-averaging mode is more sensitive to sudden vibration variations. When in the averaging mode, the word AVG appears at the top of the display.

RPM/HZ: Switches the frequency display between RPM and Hz.

FREEZE: Locks the display data at that moment and displays the word FRZ at the top of the screen. This key operates in the active display or during playback. Pressing the FREEZE key again or pressing the EXIT key unlocks the display.

RECORD: Places the EVA in the record mode. Pressing the EXIT key will return the screen to the active display.

PLAYBACK: Places the EVA in the playback mode in order to view vibration information that was previously recorded. Pressing the EXIT key will return the key screen to the active display.

Numeric Keys (0-9): The numbered keys are used in order to select one of ten snapshot tag numbers between 0 and 9 when recording or playing back information.

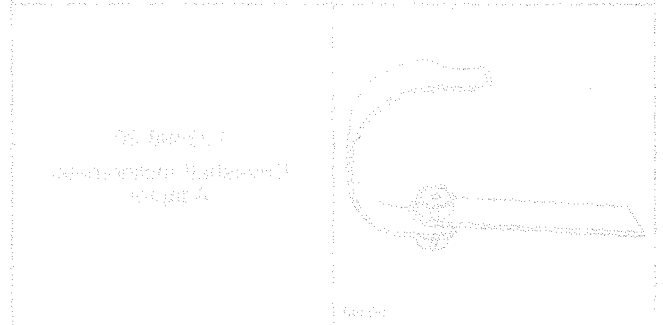
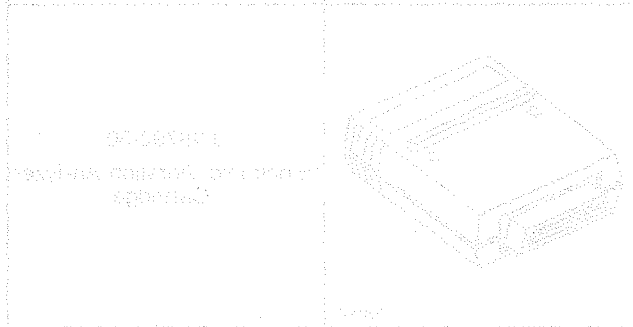
Arrow Keys: The arrow keys are used in order to move through the individual frames of a snapshot during a freeze in the playback mode. Pressing the UP arrow moves forward one frame and pressing the DOWN arrow moves backward one frame.

ENTER: Once the EVA is in the record mode and you have selected a snapshot tag number, press ENTER in order to start recording.

STROBE: Places the EVA in the strobe mode for driveshaft balancing and diagnosis. Pressing the EXIT key will return the screen to the active display.

YES and NO: Used in order to select a filter range when in the strobe balancing mode.

EXIT: Returns the screen to the active display when the EVA is in the freeze mode, the record mode, the playback mode, or the strobe mode.



Special Tools and Equipment

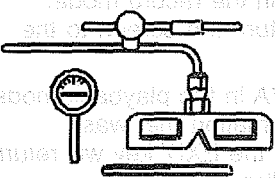
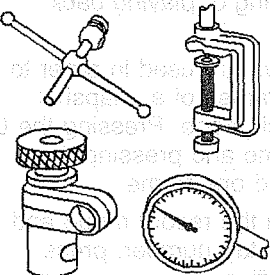
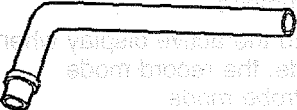
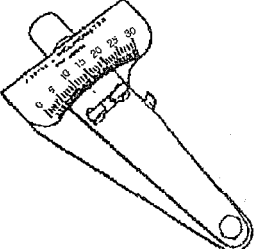
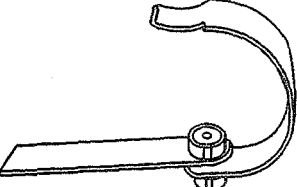
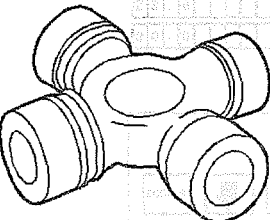
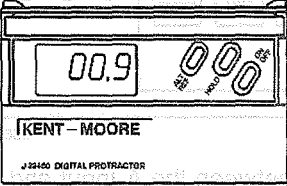
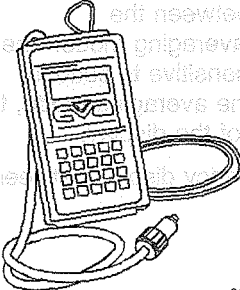
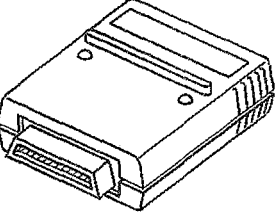
Illustration	Tool Number/ Description
 35463	J 7872 Magnetic Base Dial Indicator Set
 2014	J 8001 Dial Indicator Set
 1517	J 23409 Dial Indicator Extension
 8224	J 23498-A Driveshaft Inclinator
 180348	J 23498-20 Driveshaft Inclinator Adapter

Illustration	Tool Number/ Description
 1512	J 35819 Flange Runout Gauge
 198883	J 38460 Digital Inclinator
 6826	J 38792 Electronic Vibration Analyzer (EVA)
 580649	J 38792-50 Electronic Vibration Analyzer Cartridge