Form 1571T-VoTech, 10/11
PRICE $25.00

Vehicle Alignment Seminar

Training Supplement
Technician Reference Guide

HUNTER Engineering Company

Table of Contents

Wheel Alignment

Definition: The process of measuring and positioning all wheels attached to a common chassis.

The most common reasons for wheel alignment to change are:

- Spring sag
- Weight added or removed
- Steering / suspension component wear and/or damage

The most common symptoms related to incorrect wheel alignment are:

- Crooked steering wheel
- A vehicle that drifts or pulls to one side
- Accelerated and abnormal tire wear

The process begins with the customer interview.

Date: ___/___/___ Customer name: _____

Year _____ Make _____ Model _____

	Yes	No		Yes	No	
1.	☐	☐	Does car pull? left ☐ right ☐	10. ☐	☐	Does vehicle tow a trailer? How often?_____
2.	☐	☐	Does it pull while braking?	11. ☐	☐	Have the struts or shocks been replaced recently?
3.	☐	☐	Does it pull when accelerating?	12. ☐	☐	Has the engine or transmission been removed or replaced?
4.	☐	☐	Does pull get worse after driving a while?	13. ☐	☐	Have the tires been replaced in the last 2 years?
5.	☐	☐	Is the steering wheel straight?	14. ☐	☐	Have the wheels been replaced?
6.	☐	☐	Have you noticed any abnormal tire wear? LF ☐ RF ☐ LR ☐ RR ☐	15.		When was the vehicle's last alignment performed?_____
7.	☐	☐	Have you hit any potholes?	16.		How often have the tires been rotated?_____
8.	☐	☐	Are multiple drivers involved?			
9.	☐	☐	How often is cargo carried?			

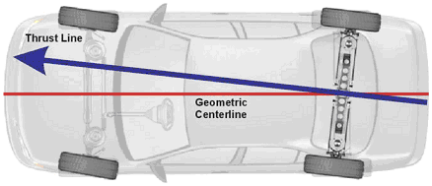
Road Testing the Vehicle

A road test is needed to:

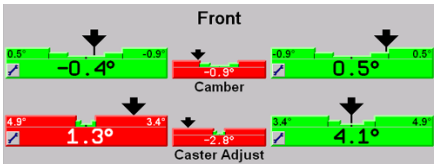
1. Evaluate the vehicle's operation under normal driving conditions
2. Confirm the customer's concerns
3. Create a base-line for the post-alignment test drive

The test drive should include these areas and observations:

Straight, level road surface

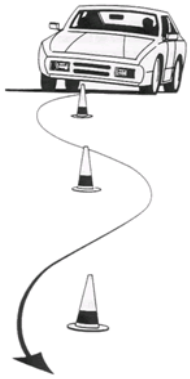


1. Is the steering wheel position level?
    a. Front individual toe is incorrect
    b. Rear individual toe is incorrect



2. Does the vehicle pull or drift in one direction?
    a. Vehicle pulls at speeds below 20 mph.
        i. Tire conicity or ply-steer
        ii. Brake drag
        iii. Power steering imbalance
    b. Vehicle pulls at speeds of 20 mph and more:
        i. Front cross camber exceeds manufacturer's specification
        ii. Front cross caster exceeds manufacturer's specification
        iii. Road crown
        iv. Uneven side-to-side load

An area to stop and start



1. Does the vehicle pull during braking?
    a. Vehicle pulls with slight brake pedal application:
        i. Contaminated friction material
        ii. binding caliper piston
        iii. binding caliper slides
        iv. master cylinder by-pass
        v. Restricted brake hose
    b. Vehicle only pulls during hard brake applications
        i. Control arm bushings
        ii. Radius arm bushings
        iii. Strut rod bushings

2. Does the vehicle pull when accelerating or decelerating?
    a. Worn engine or transaxle mounts
    b. Worn suspension components, i.e. control arm or strut rod bushings,
    c. Tire conicity or tread pattern differences
    d. Tire circumference differences

3. Do any unusual noises or component shifts occur?
    a. Sub-frame mounting bolts
    b. Control arm bushings
    c. Strut rod bushings
    d. Shocks and struts
    e. Strike-out bumpers

Left and right turns

1. Does the steering wheel return straight properly?
    a. Binding ball joint or strut bearing
    b. Steering gear box adjustment
    c. Caster angles

2. Does the vehicle have tendency to drift in the direction of the last turn?
    a. Binding ball joint or strut bearing
    b. Steering gear box adjustment
    c. Improper torque of steering or suspension component

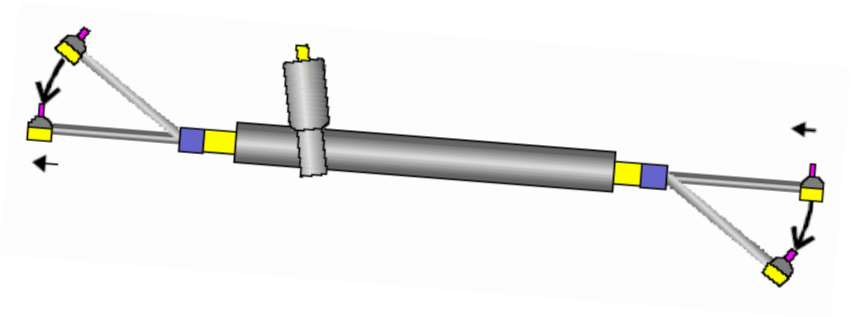
3. Do any unusual noises or component shifts occur?
    a. A clicking noise while turning may indicate worn outer (fixed) CV joints.
    b. A grinding sound while turning hard and over a bump may indicate steering stops may be worn or require lubrication.
    c. Noise or vibration when turning may indicate worn or binding outer u-joints on 4-wheel drive vehicles
    d. Strut bearing or ball joint binding
    e. Gear box adjustment

A dip or bump

1. Does the vehicle change direction?
    a. Outer tie rods have different angles
    b. Steering linkage attachment or gear box mounting

2. Do any unusual noises or component shifts occur?
    a. Shock or strut attachment or internal failure
    b. Suspension bottoming out

3. Does the vehicle bounce excessively?
    a. Worn shocks or struts
    b. Spring condition



Inspection of tires and wheels

1. Check the air pressure in each tire and inspect for wear patterns.
2. Adjust the air pressure to factory specifications.
3. The type and size of the tire and wheel should be uniform for a given axle.
4. Wheel rim dimensions should be the same for any given axle.

Normal
Slight front to back feathering

Lack of Rotation
Deep front to back feathering on non-drive tires

Excessive Camber
Wear is isolated to the shoulder and smooth

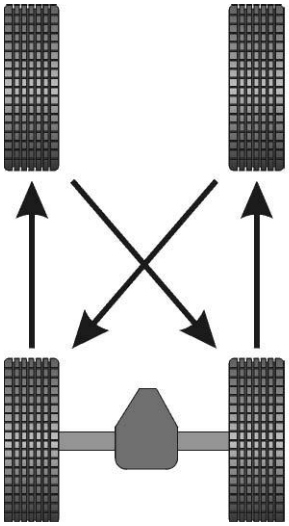
Excessive Toe
Wear starts on shoulder, moves inward and feels rough

Weak Shocks or Wheel Imbalance
Spotty cupping

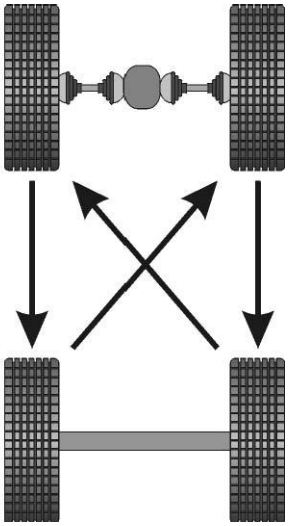
Unequal Rear Toe
Diagonal wipe

Tire rotation patterns

Modified X rotation

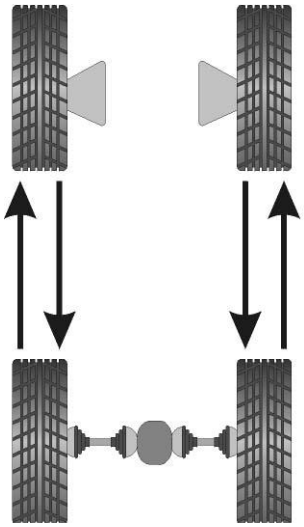


Rear-wheel drive

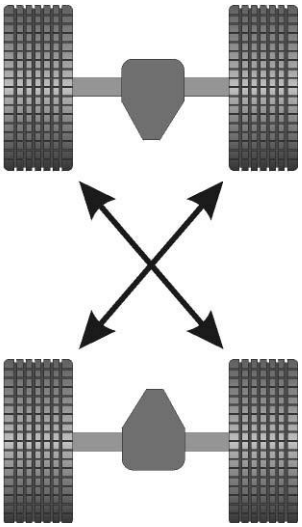


Front-wheel drive

Exceptions



Directional tires



Sport Utility Vehicle

WARNING:

Always refer to the vehicle manufacturer's guidelines for tire rotation. Systems using wheel speed information, such as electronic stability control, may be adversely affected by tire rotation. Some vehicles use different size tires or wheels front-to-rear.

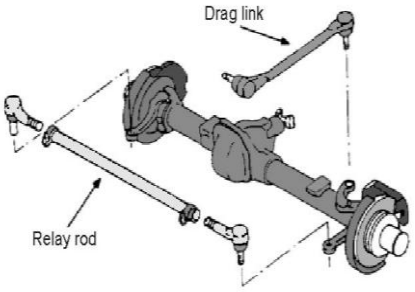
Steering Systems

Four steering systems are commonly used:

- Relay rod steering system
- Haltenberger steering system
- Parallelogram (conventional) steering system
- Rack and Pinion steering system

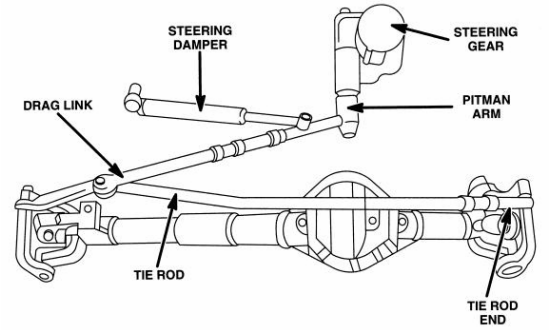
Relay Rod Steering System

Trucks and sport utility vehicles with a non-independent front suspension typically use a relay rod steering system.



Standard linkage components:

⇒ Drag link
⇒ Relay rod
⇒ Outer tie rods



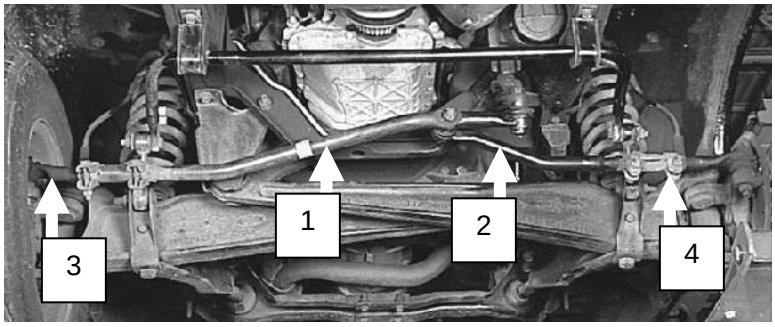
Total toe is adjusted using the relay rod.

Steering wheel position is corrected by adjusting the drag link, if adjustable.

Those without an adjustable drag link will require the steering wheel to be removed to correct a crooked position.

Haltenberger Steering System

Ford and Mazda light trucks and sport utility vehicles, with twin I-beam suspensions, use a Haltenberger steering system.



Standard linkage components:

⇒ Drag link (1)
⇒ Inner tie rod (2)
⇒ Outer tie rods (3)
⇒ Adjustment sleeves (4)

Individual front toe is set by:

1. Start the engine
2. Level the steering wheel
3. Install the steering wheel holder, if required
4. Turn the engine off
5. Adjust each tie rod until individual toe is 1/2 the total toe specification

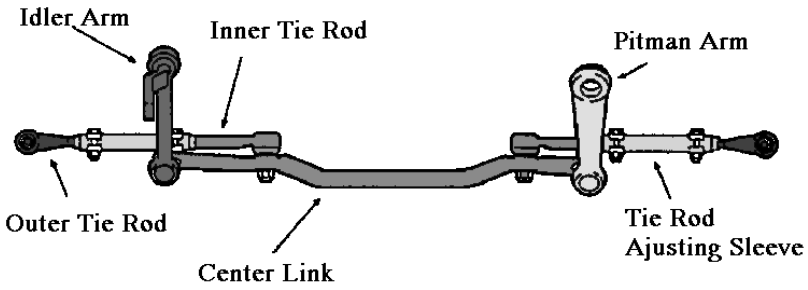
NOTE: Some older models may be equipped with only one tie rod adjuster. In this case, set front total toe using the adjuster. The steering wheel will have to be removed and repositioned manually.

Parallelogram system

A “parallelogram” steering system, also known as a “conventional” steering system, is common on many cars and light trucks.

Standard linkage components:

- ⇒ Pitman arm
- ⇒ Center link
- ⇒ Idler arm
- ⇒ Inner tie rods
- ⇒ Adjustment sleeves
- ⇒ Outer tie rods



Each tie rod assembly has an “individual toe” adjustment sleeve.

Individual front toe is set by:

1. Start the engine
2. Level the steering wheel
3. Install the steering wheel holder, if required
4. Turn the engine off
5. Adjust each tie rod until individual toe is 1/2 the total toe specification

Rack and Pinion Steering System

The “rack and pinion” steering system incorporates the steering gear and the steering linkage as one assembly.

Standard linkage components:

- ⇒ Inner tie rods
- ⇒ Outer tie rods
- ⇒ Jam nuts

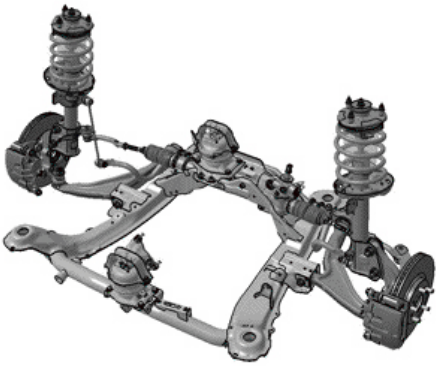
Each tie rod assembly has an “individual toe” adjustment sleeve.

Individual front toe is set by:

1. Start the engine
2. Level the steering wheel
3. Install the steering wheel holder, if required
4. Turn the engine off
5. Adjust each tie rod until individual toe is 1/2 the total toe specification

NOTE: Ensure the bellows boot does not twist when adjusting the inner tie rod.

Suspension Systems



A suspension system is necessary to:

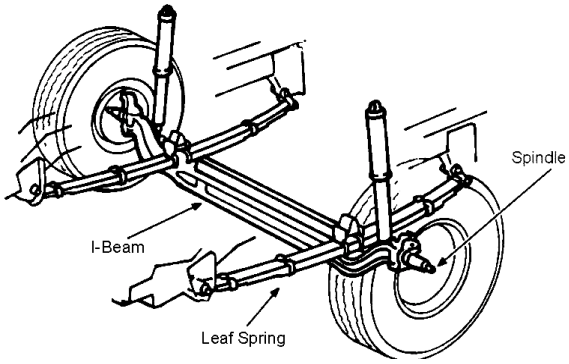
- Provide comfort
- Provide driver control
- Support weight
- Absorb and dampen shock
- Maintain tire contact with the road
- Provide wheel to wheel alignment.

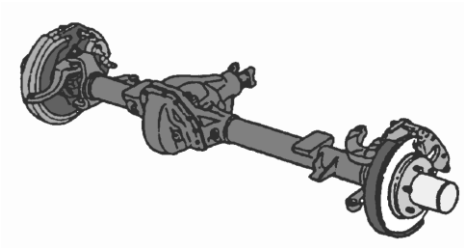
There are two major categories of design:

1. Non-independent
2. Independent

Non-independent Front Suspension

The solid I-beam axle is an example of a non-independent suspension.





The axle is an I-beam construction and usually made of steel or aluminum.

Leaf springs provide support and attachment and kingpins are commonly used to attach the steering knuckle to the axle.

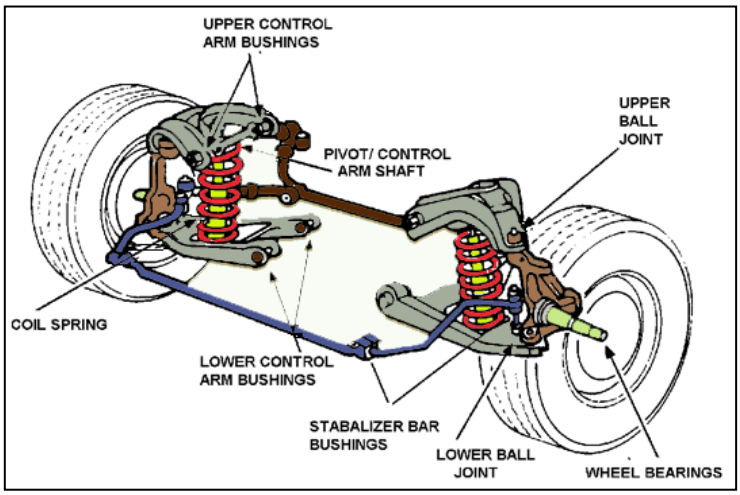
This system is still used on trucks, busses, and off-road equipment because of its great load carrying capacity.

The non-independent front drive axle shares the same qualities as the beam axle, but may use ball joints instead of a kingpin.

Independent Suspension

Independent suspensions improve ride, handling and tire life by providing an isolated mounting for each wheel.

SLA (Short / Long Arm)

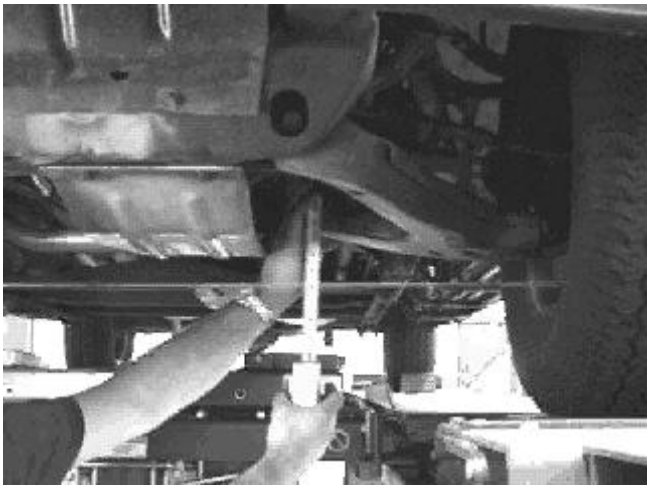


The "Short-Long Arm" (SLA) suspension uses upper and lower control arms to position the steering knuckle.

The numerous pivot points and bushings help supply one of the best ride quality levels of any suspension.

SLA suspensions may use coil springs, torsion bars or air bag springs.

The longitudinal torsion bar design is found on many domestic and import 4x4 pickup trucks and sport utility vehicles.



Measuring and adjusting ride height is a very important step in the alignment process. Vehicle ride height affects all alignment angles.

Adjustments for camber and caster are typically made using the upper control arms. Some vehicles use the lower control arm to adjust camber and caster.

Wishbone / Hybrid Strut

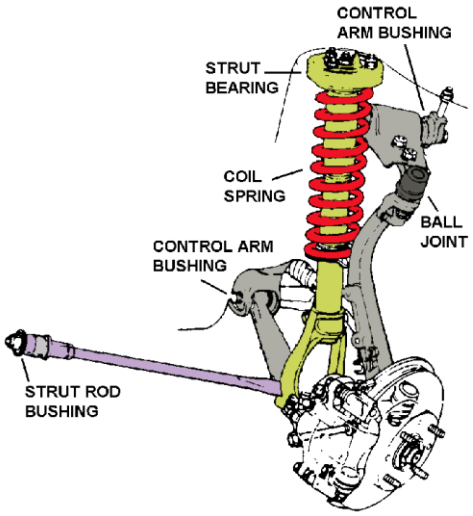
A coil-over-strut using upper and lower control arms is commonly referred to as a “wishbone” “Hybrid” suspension.

This suspension is common on many of today’s cars and light trucks.

The coil springs should be inspected carefully, especially near the base of the spring. Broken coil springs are not uncommon on this suspension.

Adjustments for camber and caster may be at one of the following locations:

- Upper ball joint
- Lower control arm
- Upper strut mounting plate
- Strut rod



or

Front four-link suspension and sub-frame

Late model Audi’s, VW Passat and VW Phaeton use an advanced four-link front suspension.

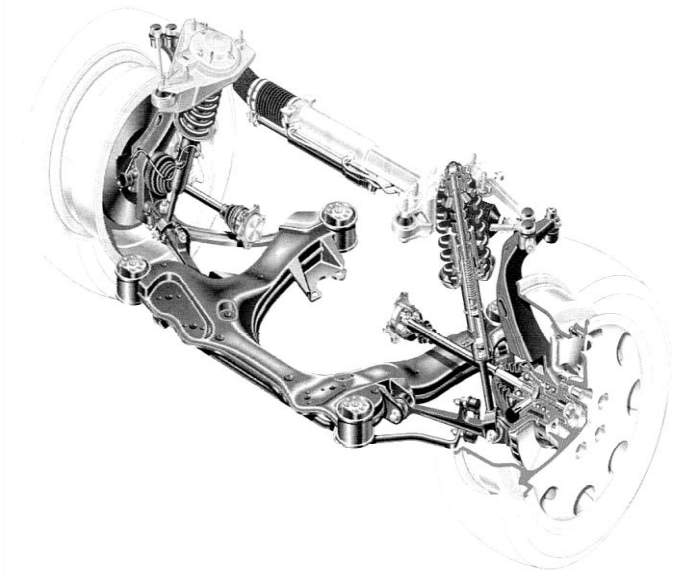
The “four-link” suspension is unique using two upper and two lower ball joints for each front knuckle assembly.

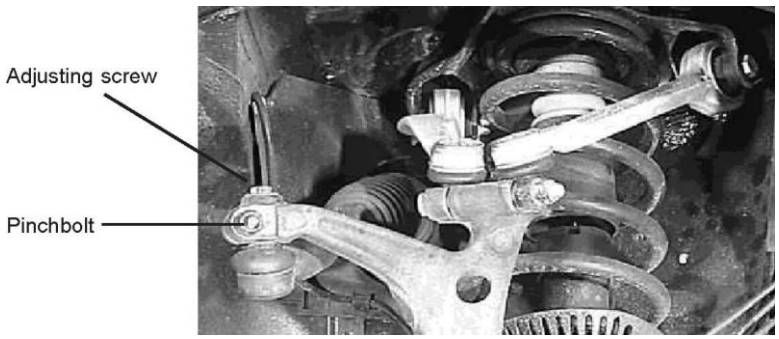
Front camber may be adjusted by shifting the front sub-frame side-to-side.

Caster adjustment is typically not specified.

Special tools, procedures and alignment software may be required to properly adjust the outer tie rod angles.

Proper tie rod angles prevent a condition known as “Bump Steer”.





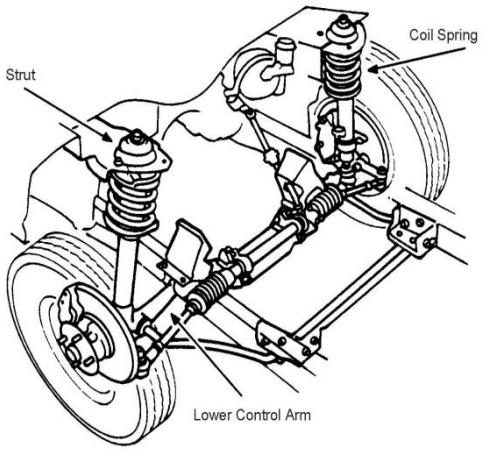
“Bump Steer” is a term used to describe a change in vehicle direction when traveling through dips or over bumps in the road.

The outer tie rod angles are adjustable using the bolt opposing the tie rod stud.

The following conditions will require tie rod angle adjustment:

1. Suspension or steering components have been replaced
2. The vehicle has been repaired following a collision
3. The owner complains of a “Bump Steer” condition

MacPherson strut (old version)



The original MacPherson strut suspension was used extensively on down-sized FWD and RWD vehicles because it is:

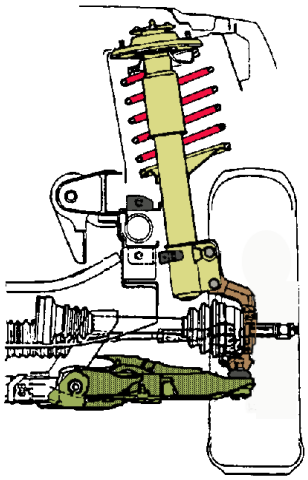
- Lighter
- Less costly to manufacture
- Consumes less space

Typically, front camber and caster are not adjustable using factory adjustments.

Check ride height when one or more camber angles are incorrect. Front-to-rear level will affect the caster angle.

Aftermarket camber/caster strut bearing plates may be available.

MacPherson strut (new style)



The newer style MacPherson strut design, sometimes referred to as an Iso strut, offers better ride quality and supports a larger vehicle.

⇒ Larger lower control arm
⇒ Larger coil spring
⇒ Larger strut

These struts are easily identified by the offset larger coil spring.

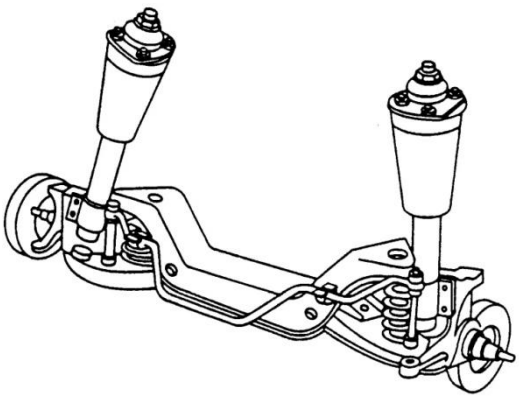
Adjustments to camber and caster may be available at the following locations:

- Strut to knuckle bolts
- Upper strut mounting plate

Aftermarket camber and/or caster adjustment kits are usually available.

Modified strut

The Modified strut suspension has been offered on some RWD vehicles such as the Ford Mustang, Chevrolet Camaro, Pontiac Firebird and some import models.



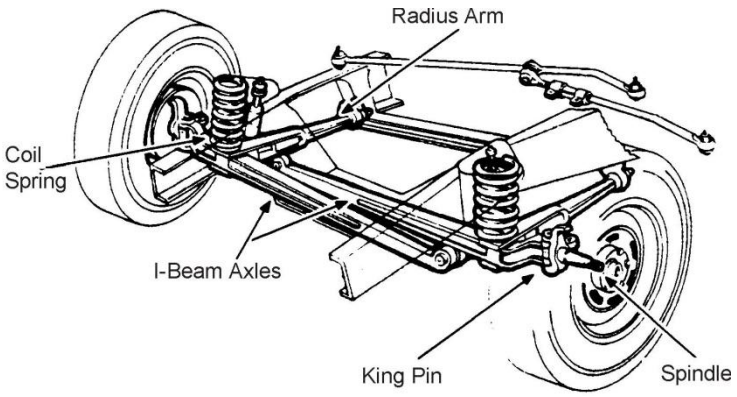
This suspension keeps the spring on the lower control arm, which makes it impractical for a FWD vehicle.

Typically, camber and/or caster adjustments are available using the upper strut mounting plate.

Aftermarket manufacturers offer camber kits, which supply more adjustment using the strut-to-knuckle bolts.

Twin I-beam

The Twin-I-beam suspension is a unique independent design found on Ford and some Mazda light trucks and vans. The original design used king pins.



The Twin-I-beam suspension is popular because it provides the load capacity of an I-Beam axle with the ride quality of an independent suspension.

The original configuration included stamped, cast or forged I-beam axles connected to the steering knuckle with king pins. Camber adjustments could be made on the forged axle by using hydraulic bending equipment.

A newer design was introduced in the late 1980's. King pins were replaced with ball joints. This change introduced the camber/caster adjustment bushing on the upper ball joint stud.

This suspension is very sensitive to changes in ride height. The front camber angles will decrease as the ride height decreases.

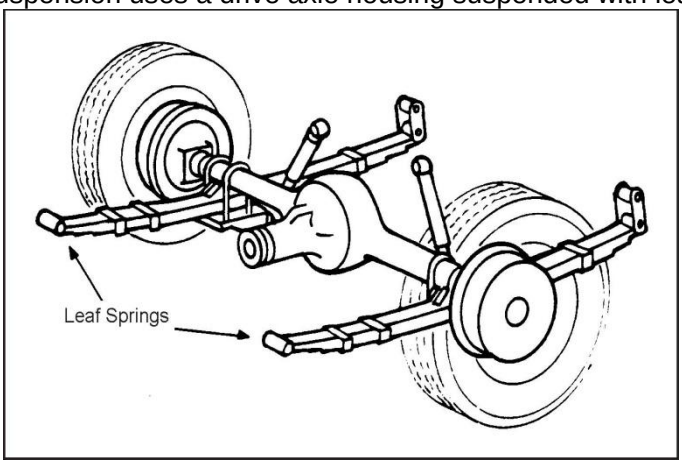
Radius arm bushings should be inspected carefully for signs of wear or looseness. The caster angle may be affected by worn radius arm bushings.

Rear Suspensions

Rear suspensions affect the ride quality, handling, load capacity, cornering and tracking of the vehicle.

Rear Non-Independent Suspensions

A common RWD suspension uses a drive axle housing suspended with leaf springs.

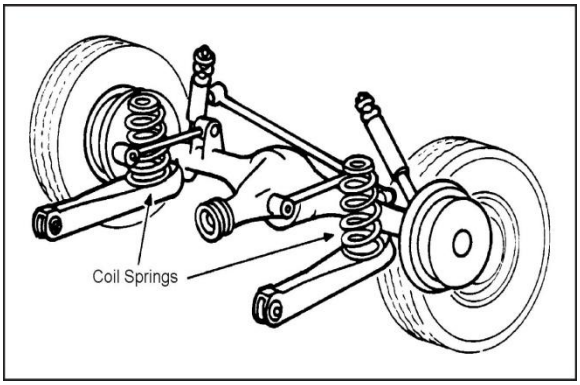


The benefits of this design include:

- ⇒ increased load carrying capacity
- ⇒ durability

Excessive rear camber and total toe angles are generally signs of damage to the rear axle housing or axle flange.

Excessive thrust angle conditions may be the result of broken centering pins, loose u-bolts or damaged spring hangers. Alignment adjustments are limited to aftermarket parts.



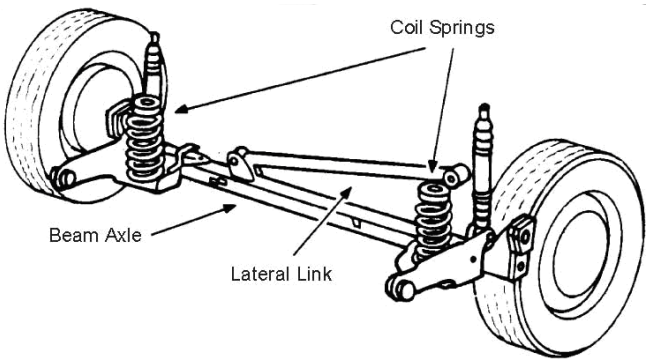
The non-independent rear coil spring suspension is a variation of the same design.

The leaf springs are replaced with coil springs and control arms.

This design offers improved ride quality, but factory alignment adjustments are still unavailable.

Beam Axle

The “beam axle” is a commonly used rear suspension used on front-wheel-drive cars and mini-vans.

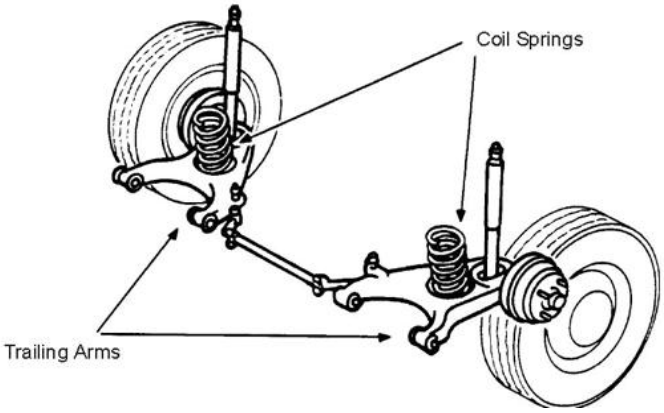


Alignment adjustments may be available using slots at the trailing arms or with aftermarket full contact shims installed between the hub and axle flange.

Rear independent suspension

Rear independent suspensions have become more widely used because of improved ride quality and performance. A “trailing arm” is a typical design.

Independent rear trailing arm and lateral arm designs generally offer rear alignment adjustments for rear camber and/or rear toe.



Note!

Install rear slip plates or pull the pins from rear slip plates to ensure an accurate alignment!

Primary Wheel Alignment Angles

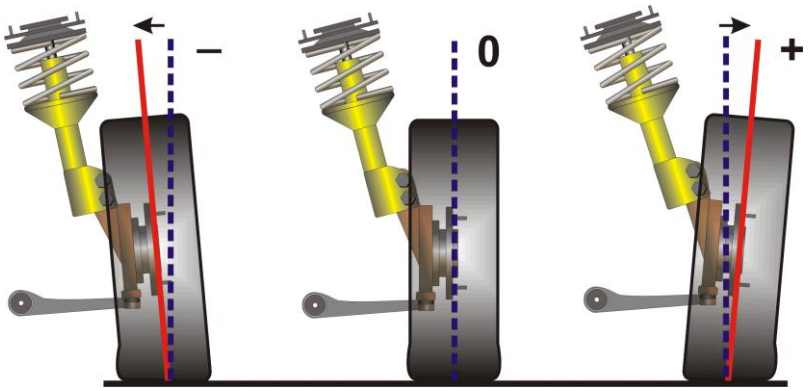
Characteristics of Wheel Alignment

- **Directional Stability**
  - The ability of a vehicle to maintain a straight path
- **Tire Life**
  - Maximizing the usable life of tires
- **Cornering**
  - Enhancing the cornering performance
- **Returnability**
  - The ability of the front wheels to return to center without assistance from the driver
- **Predictability**
  - Maintain a consistent behavior
- **Tracking**
  - The position of all wheels relative to centerline
- **Road Isolation / Feedback**
  - Desired ride quality based on performance ability
- **Centered Steering wheel**
  - A level steering wheel when traveling a straight path

Camber

Camber is the angle formed by the inward or outward tilt of the wheel referenced to a vertical line originating from the center base of the tire.

Camber angles affect ride quality, directional stability, cornering and tire life. Spring sag is the primary reason for camber angles to change.



Positive camber – an outward tilt of the wheel at the top

Negative camber – an inward tilt of the wheel at the top

Zero camber – the wheel is vertical

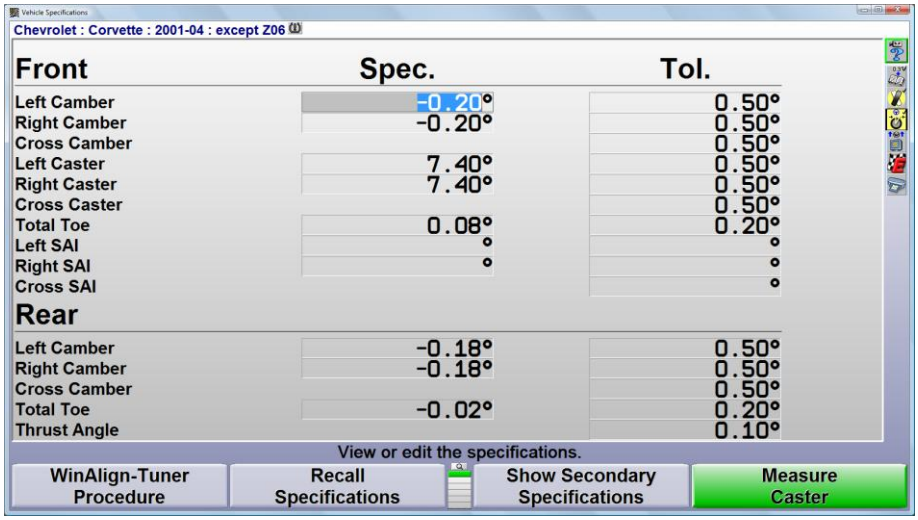
Camber is measured and displayed in degrees

Camber specifications are given as a preferred measurement and an allowable tolerance.

The preferred front camber specification for the 2001-04 Corvette is -0.20°.

A tolerance of .50° (1/2°) is given for each front wheel. This permits a decrease or increase of the preferred camber angle (-0.20°) by 0.50°.

-0.70° ⟵ -0.20° ⟶ +0.30°



Excessive camber may cause shoulder wear on the tire's tread

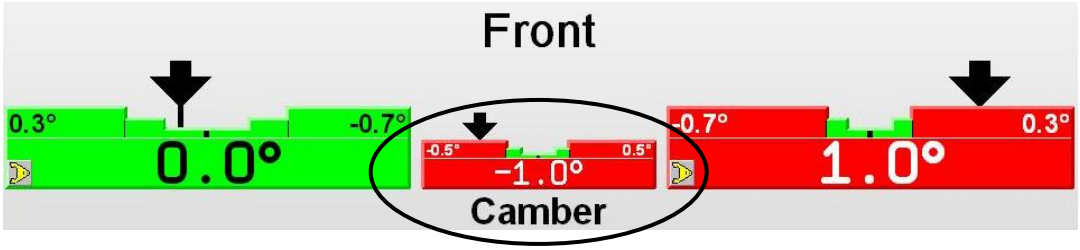
Excessive positive camber wears the outer shoulder of the tread surface.

Excessive negative camber wears the inner shoulder of the tread surface.

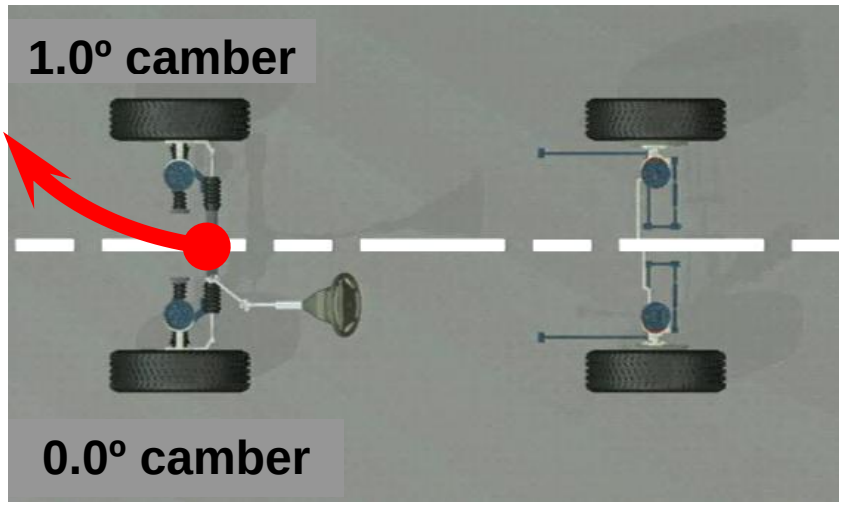
The wear pattern should be smooth to the touch and isolated to the shoulder of the tire.

Cross camber is the difference between left and right front camber measurements.

The cross camber measurement may be displayed between the left and right front camber measurements when viewing the bar graph adjustment screen.



Front cross camber greater than 0.5° may cause a pull or drift to the side with the most positive camber setting.



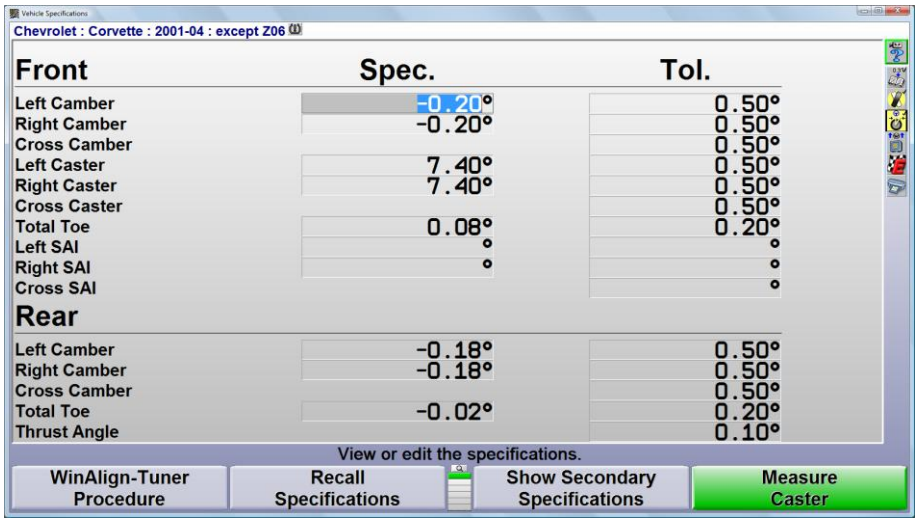
Rear cross camber is not known to be a pulling factor.

Rear camber will exhibit the same tire wear patterns as front camber if excessive.

In this example, each rear wheel is specified -0.18° negative camber.

A tolerance of .50° (1/2°) is given for each rear wheel. This permits a decrease or increase of the preferred camber angle by 0.50°.

-0.68° ⟵ -0.18° ⟶ +0.28°

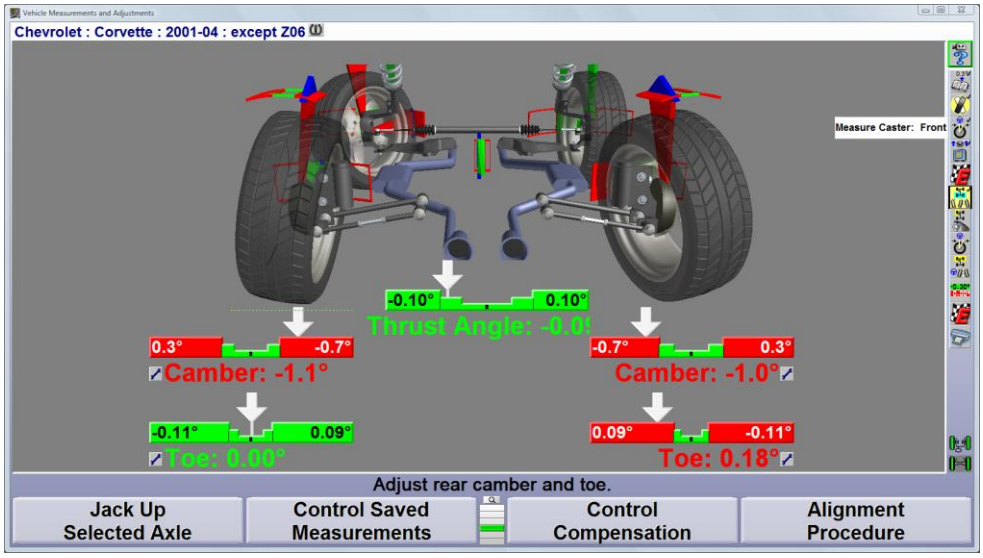


Rear camber is the first angle to be adjusted in the rear because rear toe changes as rear camber is adjusted.

Camber adjustments may be viewed on the following displays:

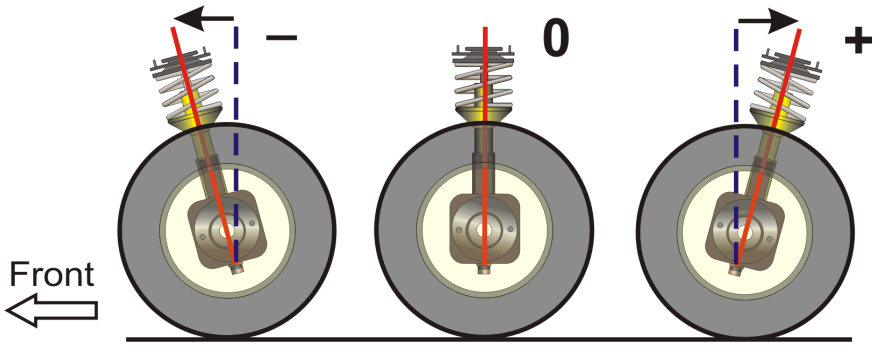
- Primary measurement display
- Virtual View™
- Front or rear bar graphs
- Zero adjust
- CAMM®

Camber adjustments may be easier to accomplish by using the “Jack Up Selected Axle” feature offered by the WinAlign® software.



Caster

Caster is the angle formed by the forward or rearward tilt of the steering axis in reference to a vertical line drawn from the center base of the wheel and viewed from the side.



Positive caster – the rearward tilt of the steering axis at the top viewed from the side

Negative caster – the forward tilt of the steering axis at the top viewed from the side

Zero caster – the steering axis is vertical when viewed from the side

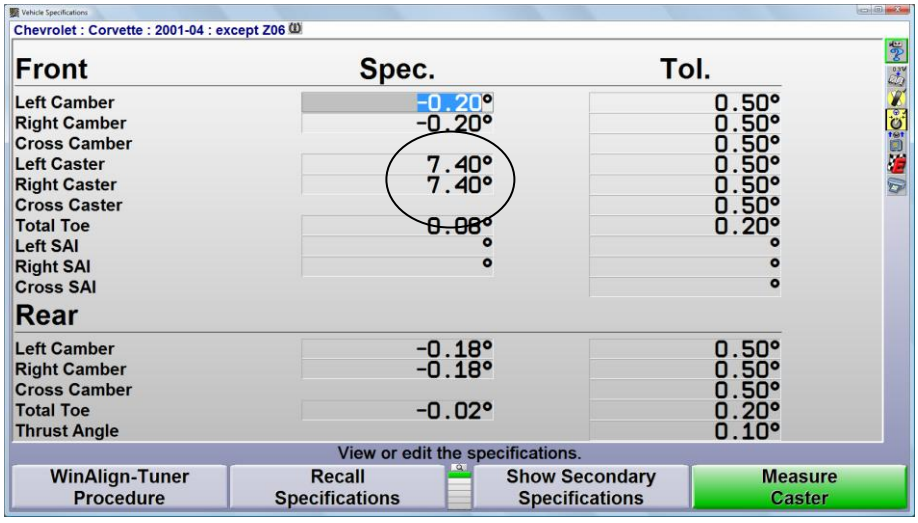
Caster is a suspension angle measured and displayed in degrees. Caster angles are responsible for directional stability, returnability and cornering.

Caster specifications are given as a preferred measurement and an allowable tolerance.

The preferred front caster specification for the 2001-04 Corvette is 7.40°.

A tolerance of .50° (1/2°) is given for each front wheel. This permits a decrease or increase of the preferred camber angle (7.40°) by 0.50°.

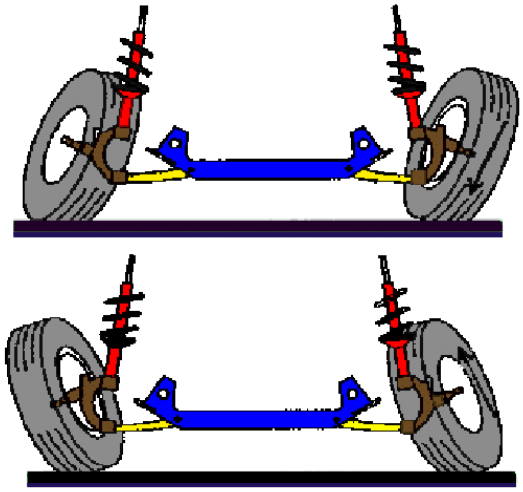
6.90° ⟵ 7.40° ⟶ 7.90°



Rear caster may be specified on vehicles equipped with a rear independent suspension. Although rear caster is uncommon, it will require additional measurement devices specified by the vehicle's manufacturer.

Caster is not a direct tire wear angle.

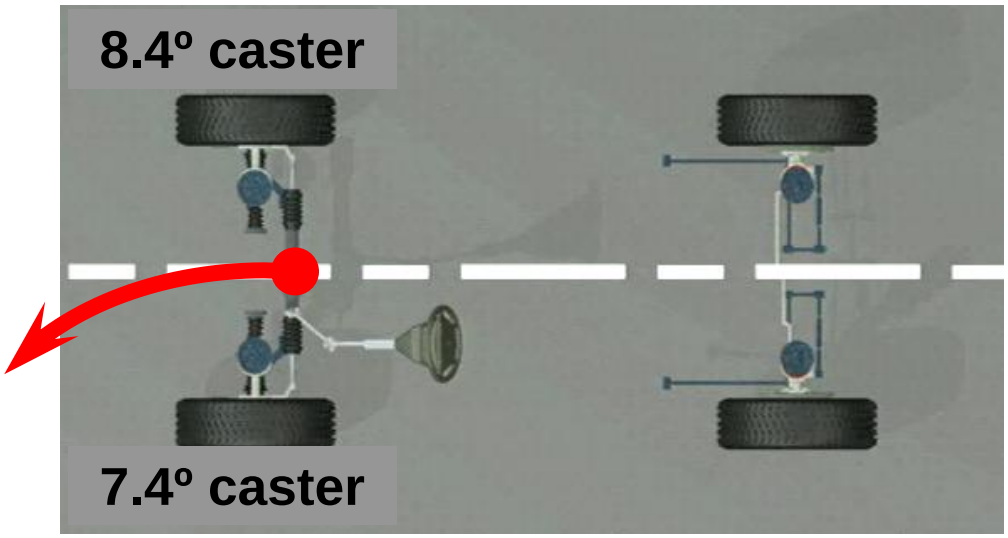
Caster has an **indirect** influence on tire wear when the front wheels steer away from straight ahead because it causes front camber angles to change.



Camber Roll - the change in front camber when front wheels are steered

If severe, the tires may develop wear on the inner and outer shoulders.

Cross caster is the difference in the left and right front caster measurements.



Cross caster greater than 0.5° may cause a pull or drift to the side with the least positive caster setting.

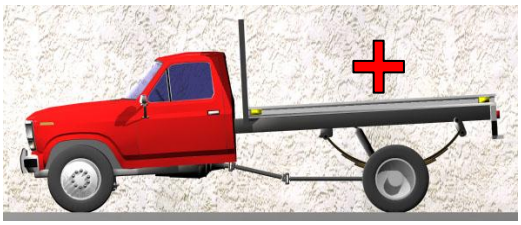
The example above shows a vehicle with a 1° caster cross caster. The left side is low making the cross caster measurement -1.0°. The vehicle should pull left.

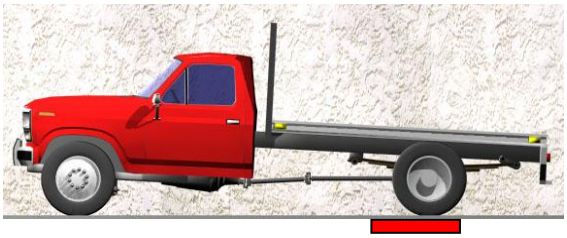
Frame Angle

Frame angle is the slope of a vehicle's frame rail from front-to-rear.

A positive frame angle exists when rear of the vehicle's frame is higher than the front of the vehicle's frame.

A negative frame angle exists when rear of the vehicle's frame is lower than the front of the vehicle's frame.

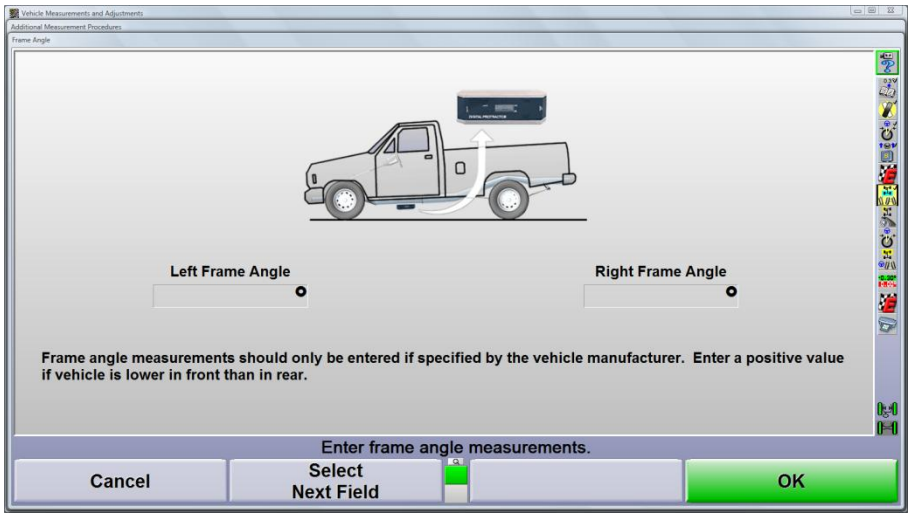




A magnetic or digital protractor may be used to measure frame angle.

Typically, there is a 1:1 relationship between frame angle and caster. Caster will change 1° for each 1° of frame angle.

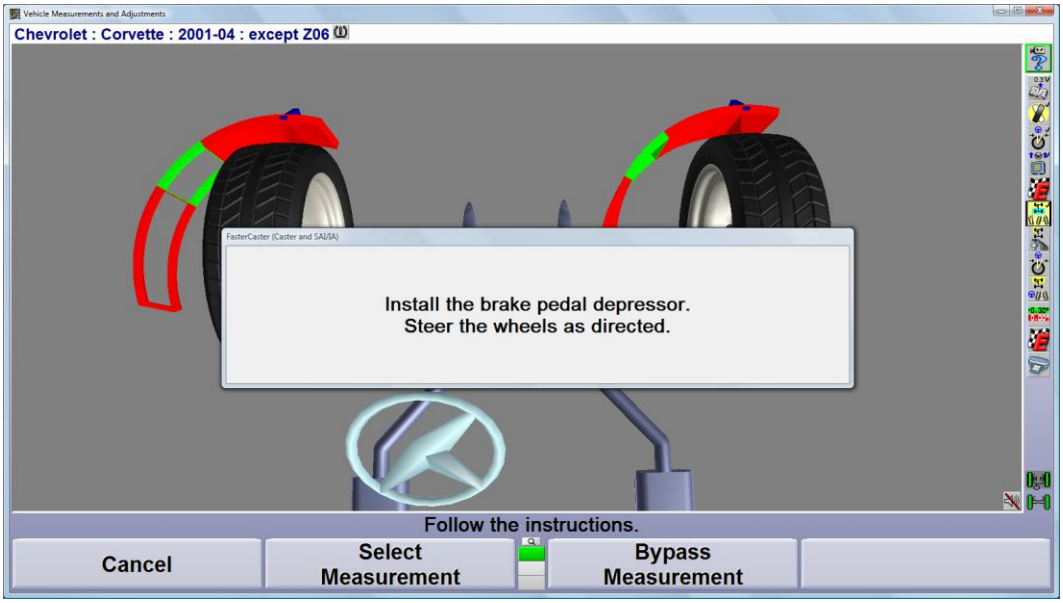
Entering the current frame angle on the WinAlign screen will adjust the current caster measurement to frame corrected caster.



Frame corrected caster anticipates the change in frame angle and adjusts the current caster measurement to allow for caster changes when the vehicle is loaded.

Caster Measurement

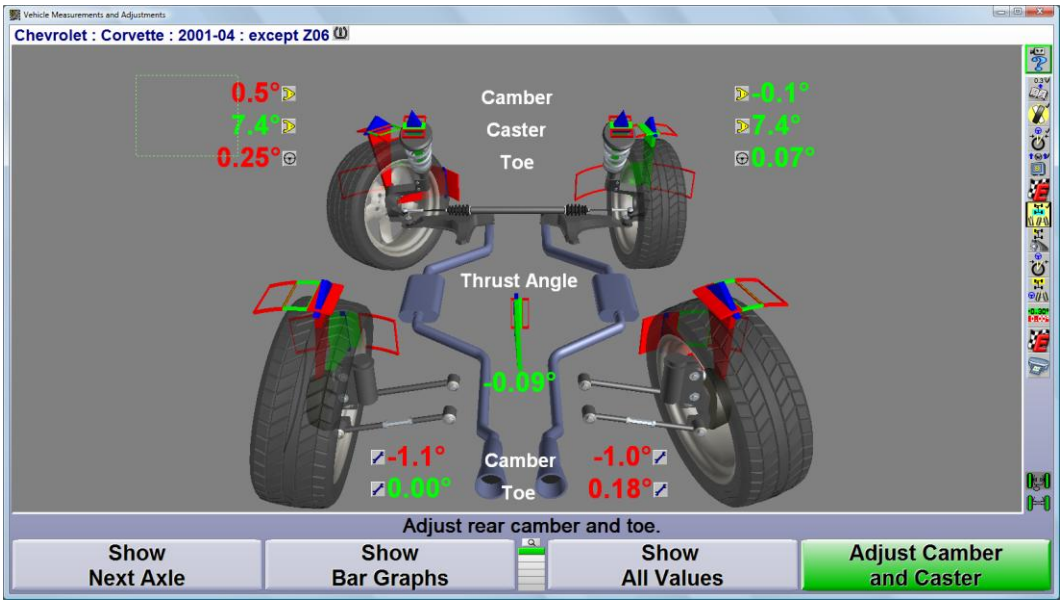
A caster measurement is needed to determine the values of left and right front caster. Follow the instructions on the “Caster Measurement” display.



Caster is calculated by steering the front wheels to the left and right of straight ahead.

Steer the wheels to place the arrow in the center portion of the bar graph.
The arrow does not need to be perfectly centered, but must be within the green area of the bar graphs or graphic and perfectly still for the process to continue.
.
The caster measurements are posted on the “Vehicle Measurement and Adjustment” display.

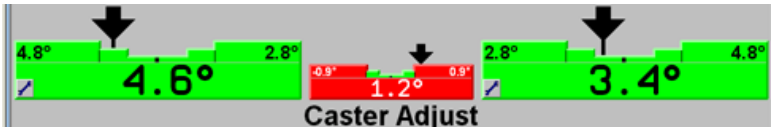
<u>Caster measurements on the screen below are posted after a caster measurement and will not change until another caster measurement is performed!</u>



Caster Adjust

The following displays may be used to watch caster adjustments:

- Virtual View™
- Front bar graphs
- Zero Adjust
- CAMM®



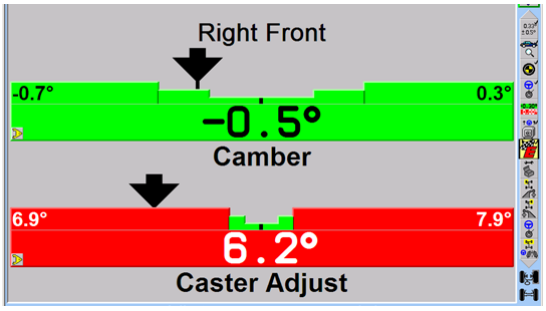
<u>The primary measurement display cannot be used to watch caster adjustments.</u>

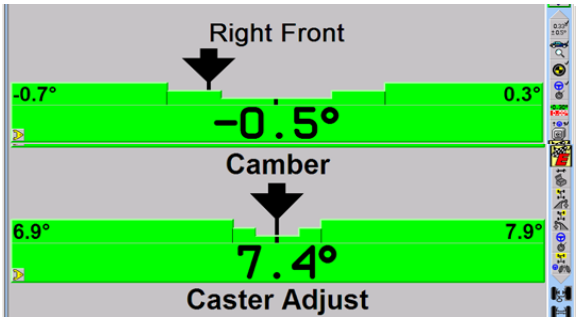
To adjust caster using conventional sensors:

- Lock the service brake with the pedal depressor.
- If using conventional sensors, level and lock the front sensors
- Adjust caster angles
- Re-measure caster

To adjust caster using Image system and targets:

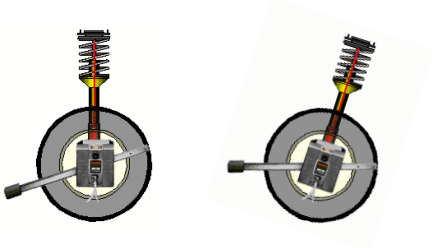
- Lock the service brake with the pedal depressor.
- **<u>Do not</u>** adjust sensor level
- Adjust caster angles
- Re-measure caster





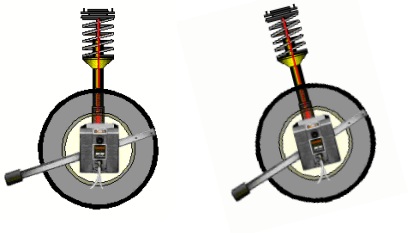
As caster is adjusted in a positive direction, the sensor will tilt upward.

- The bar graph will display the positive caster change.



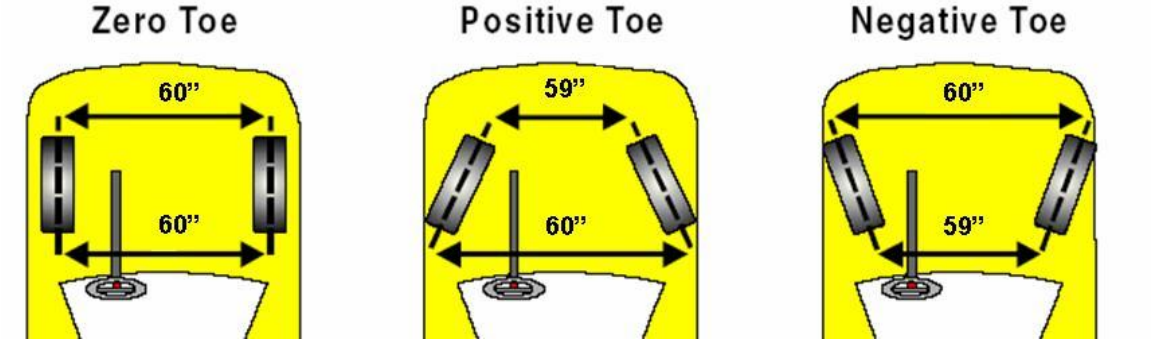
As caster is adjusted in a negative direction, the sensor will tilt downward.

- The bar graph will display the negative caster change.



Toe Angles

Total toe is the difference in measurements taken across the front of the tires versus a measurement taken across the rear of the same tires.

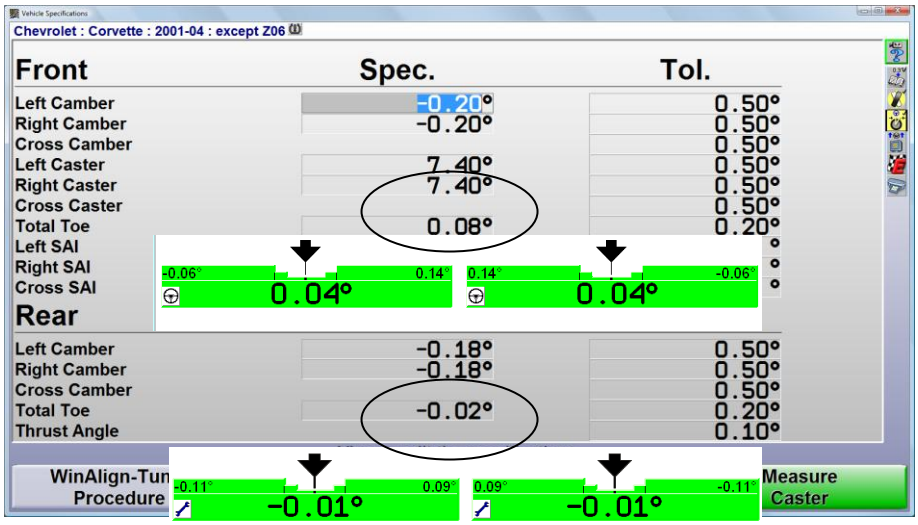


Total toe is measured and displayed in degrees

Total toe specifications are given as a preferred measurement and an allowable tolerance.

The preferred front total toe specification for the 2001-04 Corvette is 0.08°.

The individual toe specification is ½ the total toe specification.



Incorrect total toe will wear tires extremely fast.

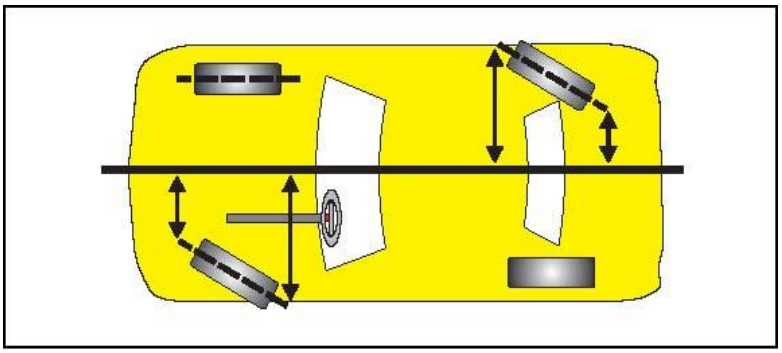
<u>Excessive positive front total toe wear begins on the outer shoulder of both front tires.</u>

<u>Excessive negative total toe wear begins on the inner shoulder of both front tires.</u>

<u>The toe wear pattern should be similar on both front tires</u>.

The wear pattern should feel rough to the touch and wear the tire tread from the shoulder toward the center of the tire.

Individual toe is the difference in distance between the front center and the rear center of the same tire using a common reference line.



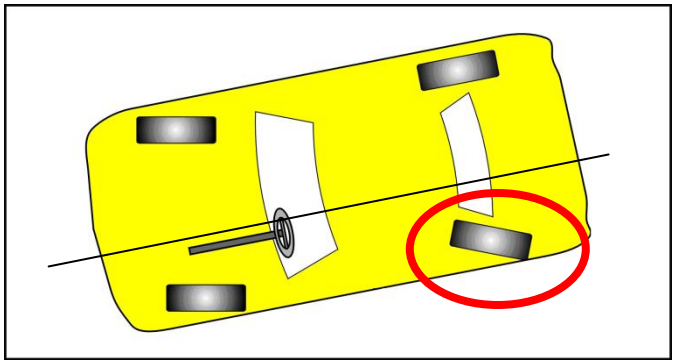
The steering wheel position (level or not level) is determined by front individual toe.

The front tires will travel down a straight path with equal toe numbers unless an outside force interferes. A deep rut in the road surface may cause the wheel to steer.

This outside force could be a mechanical interference from a ball joint or strut bearing, which binds and refuses to allow front toe to equalize. This is known as “Memory Steer”.

Unequal rear individual toe causes “**dog tracking**” and may cause tire wear.

Unequal individual toe on the rear axle may cause the rear tires’ tread to squirm as the vehicle goes down the road.



This squirming may cause the rear tires to develop a diagonal cupping pattern on the tread surface.

Diagonal cupping is also known as “**Diagonal Wipe**” and is a wear condition seen on the rear wheels of FWD vehicles. Excessive individual toe is typically the cause of this wear pattern.

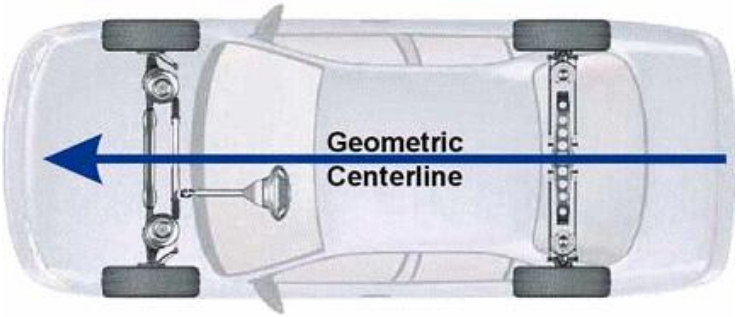
Rear individual toe measurements are used as a reference for front toe measurements. Rear toe should be adjusted before the front alignment angles are adjusted.

Adjustment sequence:

1. adjust rear camber
2. adjust rear toe
3. Adjust front camber and caster
4. Adjust front toe

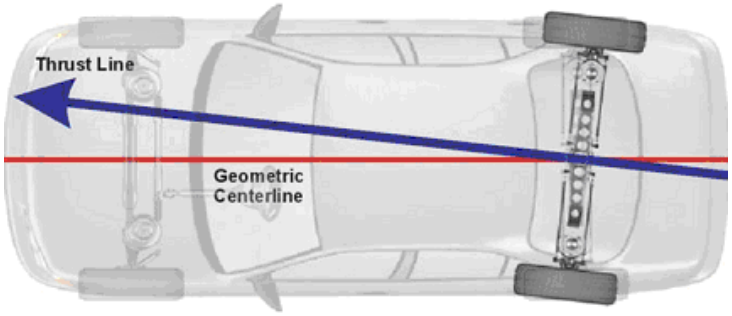
Toe Related Geometry

Geometric centerline is a line drawn though the midpoints of both front wheels and both rear wheels. Frame centerline is the middle of the frame rails.

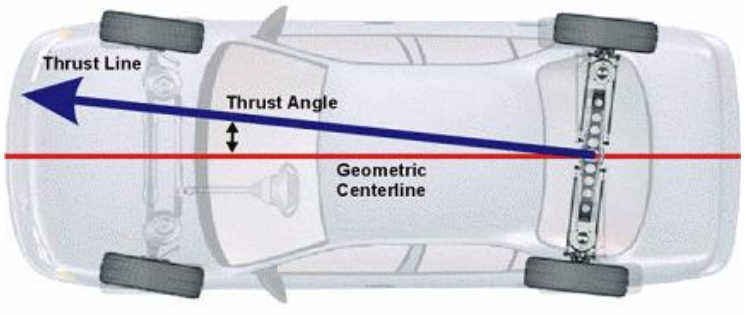


Make sure the wheel adapters are mounted using the same method for each axle. Using different mounting methods on the same axle will move centerline.

Thrustline is simply the direction the rear wheels are pointed.

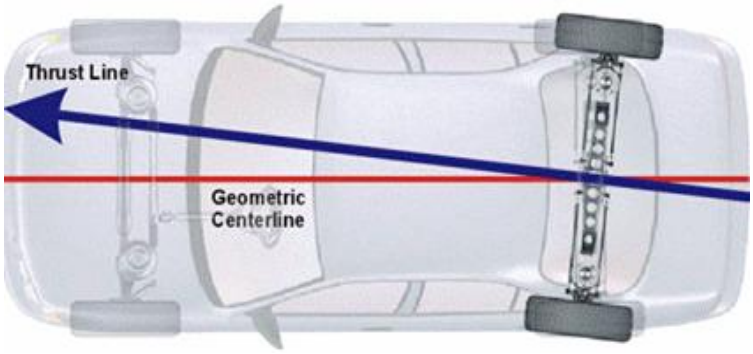


Thrustline dictates the straight-ahead position of the front wheels; therefore, it is the most accurate reference when measuring or adjusting the front wheels.

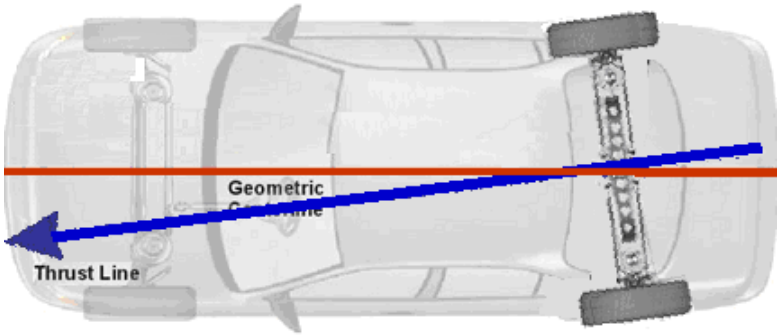


Thrust Angle is the angle formed by the intersection of the geometric centerline and the thrustline.

Positive thrust angle is when the rear wheels point to the right of the geometric centerline.



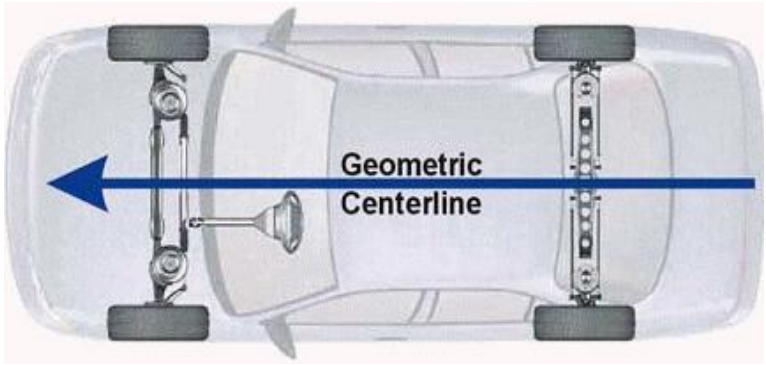
Negative thrust angle is when the rear wheels point to the left of the geometric centerline.



Knowing the amount and direction of the thrust angle may be helpful when making rear wheel alignment adjustments.

Adjust rear toe on vehicles where adjustments are possible and reasonable.

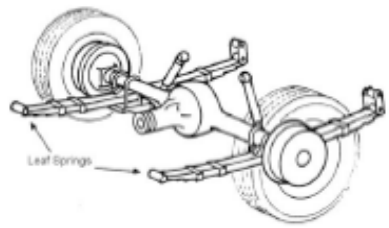
After adjusting rear toe to preferred specification, thrustline will be parallel with the geometric centerline and the thrust angle is reduced to zero. This should eliminate any dog tracking.



Don't ignore thrust angle on vehicles with non-adjustable rear suspensions.

The major problems associated with excessive thrust are:

- Dog-tracking
- Crooked steering wheels
- Damaged components

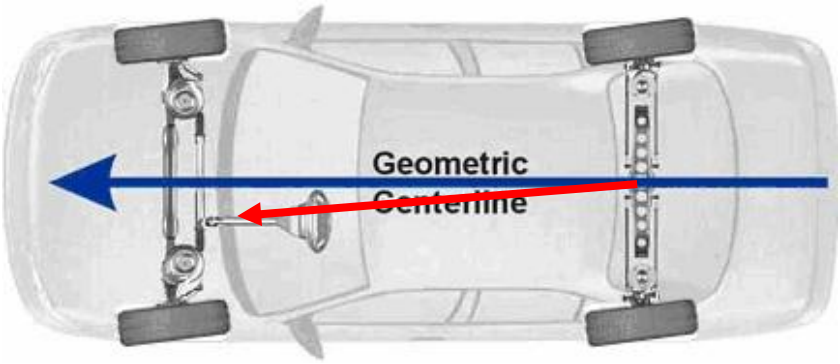


Alignment Procedures

4-Wheel Thrustline alignment

A thrustline alignment aligns the front wheels to the position of the rear wheels.

Mount all four sensors …. compensate all four sensors. All primary measurements will be displayed.



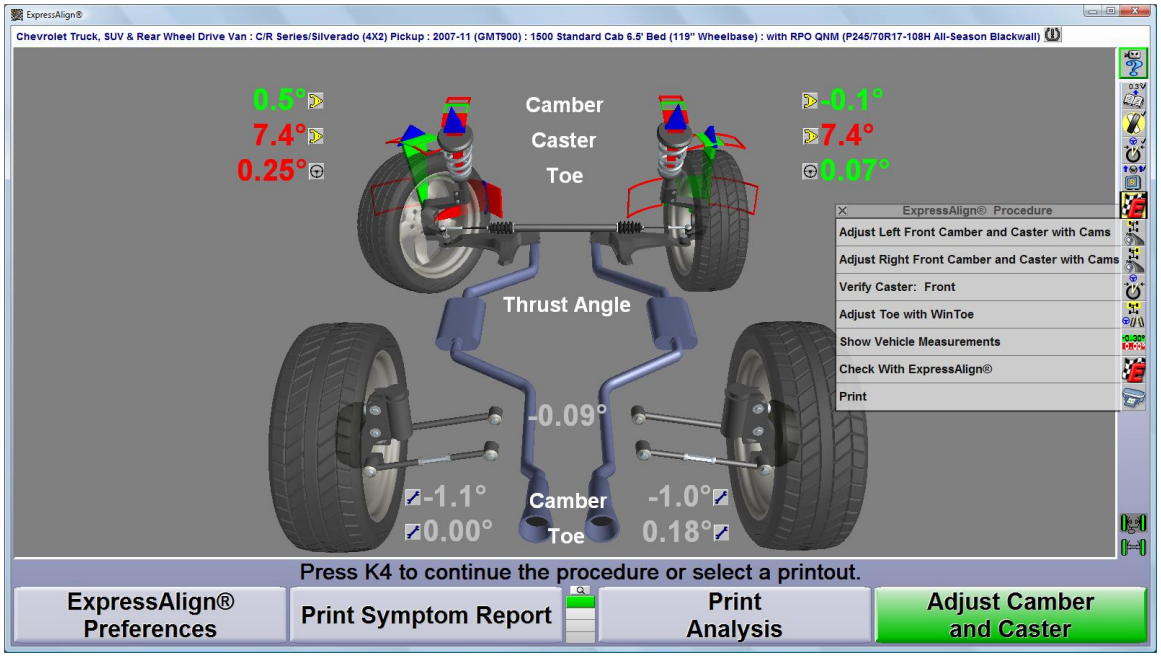
The adjustment sequence will be as follows:

1. Adjust front camber and caster
2. Adjust front individual toe and total toe

If a thrust angle is present, the result will be:

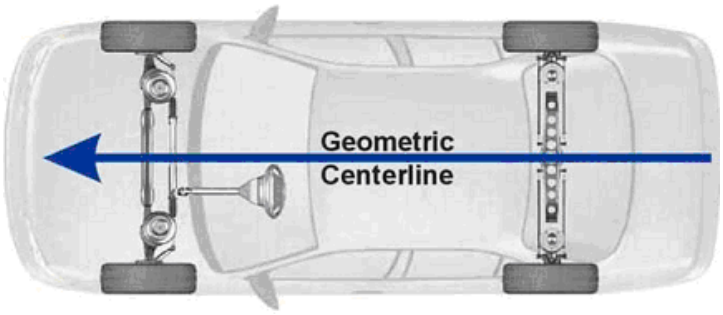
⇒ The vehicle may dog track going down the road

⇒ <u>The steering wheel will be centered</u>.



Total 4-wheel Alignment

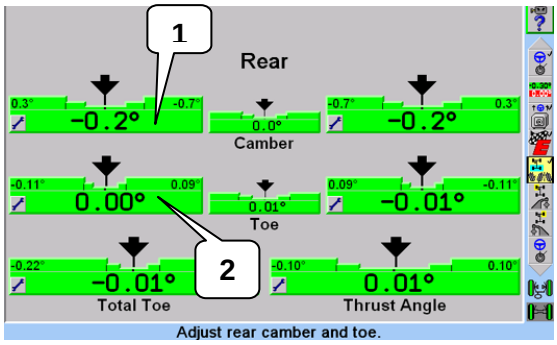
A total 4-wheel alignment aligns the rear wheels to the geometric centerline and the front wheels to the thrustline.

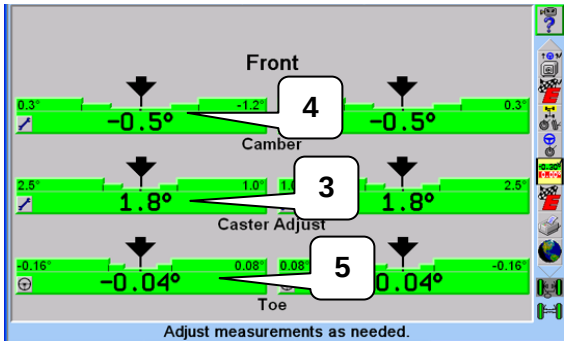


Mount all four sensors …. compensate all four sensors. All primary measurements will be displayed.

The adjustment sequence will be as follows:

1. Adjust rear camber (if available)
2. Adjust rear individual, total toe and thrust angle
3. Adjust front caster
4. Adjust front camber
5. Adjust front individual toe and total toe



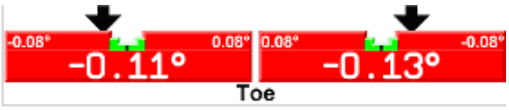


Front	Left		Right
Camber	-0.2°		-0.2°
Cross Camber		0.0°	
Caster	7.4°		7.4°
Cross Caster		0.0°	
SAI	0.0°		0.0°
Toe	0.05°		0.04°
Total Toe		0.08°	
Rear	**Left**		**Right**
Camber	-0.2°		-0.2°
Toe	0.00°		-0.01°
Total Toe		-0.01°	
Thrust Angle		0.01°	

Front Toe Adjustment

The two primary reasons to adjust front toe are:

⇒ Minimize tire scuff
⇒ Level the steering wheel



The toe angle is displayed in 1/100th of a degree. This example shows front total toe as 0.32°, which is slightly over 1/8".

Because the toe angles are so small, attention must be paid to details.

Front turn plates must be free to move front-to-rear and side-to-side.

The vehicle's front wheels should be centered on the turnplates.

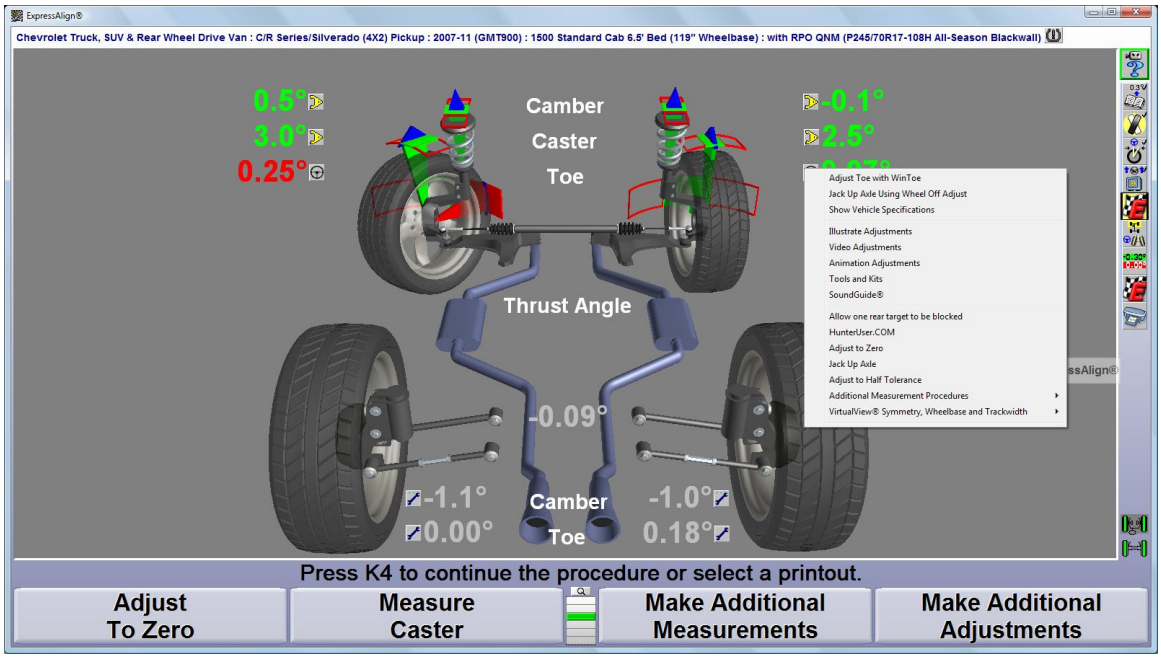
The vehicle should be jounced after the adjustment to ensure the wheels are relaxed.

Adjusting Individual toe with WINTOE®

WinToe® is a software feature designed to make adjusting toe easier and faster, without the use of a steering wheel hold-down tool.

Using WinToe® will make it easier to achieve the desired toe settings for each wheel and ensure a level steering wheel position.

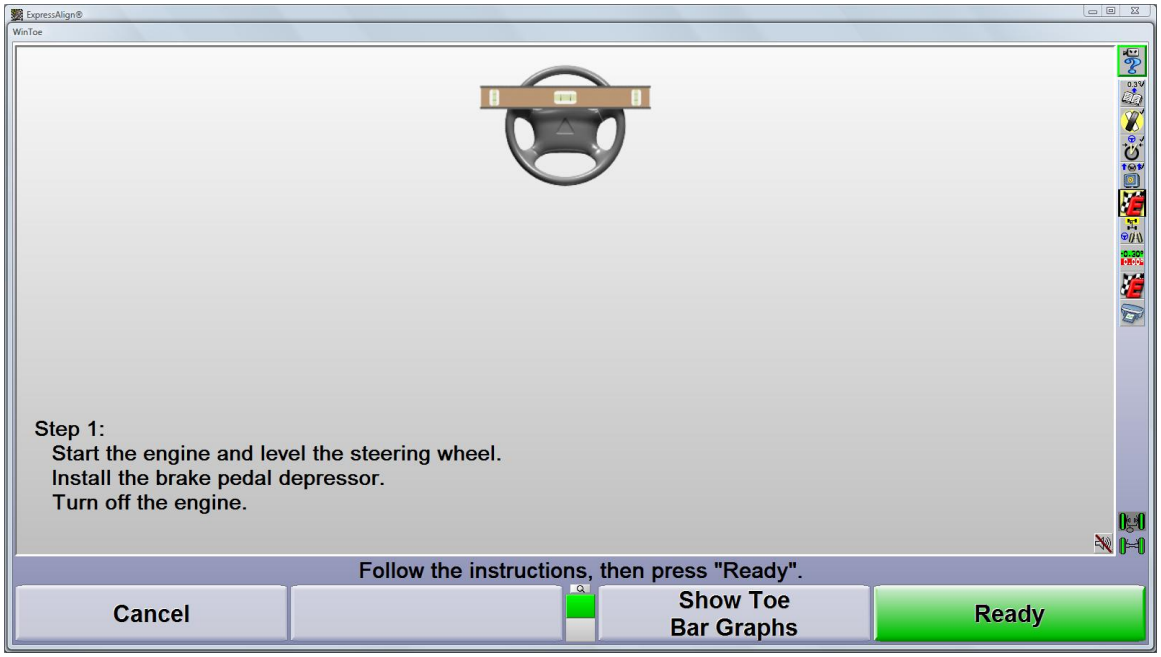
Select "Adjust toe with WinToe" using the "Make Additional Adjustments" soft key label, or from the menu generated by clicking on the small steering wheel icon.



Step 1

"WinToe®" will ask for the steering wheel to be level in the straight ahead position, with the engine running. Level the wheel and turn the engine off.

WARNING: Follow the manufacturer's instructions when aligning hybrid vehicles. It is not necessary or advised to start the engine if the vehicle is equipped with electronic power steering.



A steering holder is not needed or wanted during this procedure.

Level and lock the front sensors if required. (Conventional toe-arm style sensors)

NOTE:
Steering wheel leveling is important and should be performed as follows:

1) For vehicles with power steering, place the transmission in park or neutral, lock the brakes, and ensure the wheels are chocked. Start the engine and level the steering wheel. A steering holder is not needed during this procedure.
2) While sitting in the driver's seat, gently rock the steering wheel back and forth. The arcing motion should start out with larger arcs and gradually become smaller arcs.
3) Level the steering
4) Use chalk to mark the leveled steering wheel position with the side of the steering column. This reference mark will save time in final adjustment verification.
5) With the steering wheel centered, turn the engine off and exit the vehicle being careful to not touch or bump the wheel position.

Follow the on-screen instructions and press "Ready."

The WinToe® program "memorizes" each front wheel's position relative to the desired steering wheel position. WinToe® will track the needed adjustments for each wheel, even if the steering moves or gets jarred during the adjustment process.

Step 2

The screen will change to display a bar graph prompting to adjust the right toe.

Adjust the right tie rod until the bar graph is green and the value is near zero.

Jounce the vehicle to release any binding between the tires and turn plate. Adjust the tie rod again, if needed. Jounce the vehicle after any adjustment.

Adjust and lock the right tie rod assembly

Select “Ready”, if the bar graph remains green with the adjustment locked. The value does not have to read zero.

Step 3

After the right side adjustment is completed and locked, select “Ready”

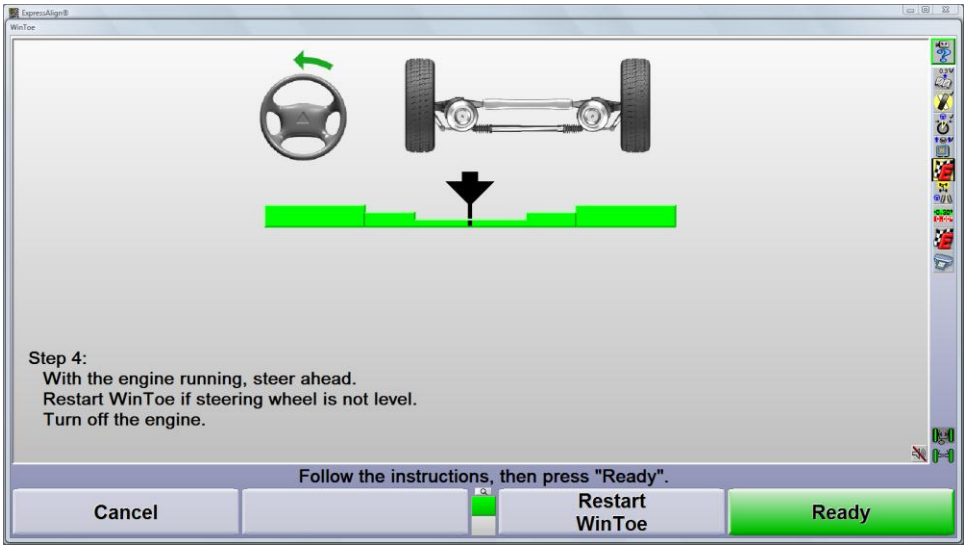
Adjust the left side tie rod until the bar graph is green and the value is near zero.
Before locking the adjustment, lightly jounce the front end.

Lock the adjustment and lightly jounce the suspension again to verify the adjustment. The adjustment is complete if the bar graph remains green, with the adjustment locked. The value does not have to read zero, however, the bar graph must be green.

Select “Ready.” The screen will change to display the final step in the process.

Step 4

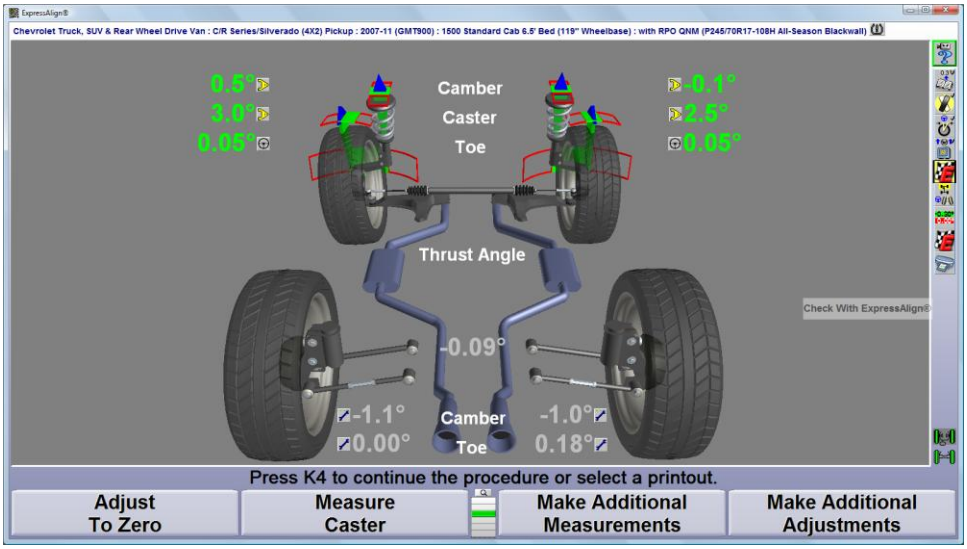
The final step is to verify steering wheel position.



1) With the vehicle in park or neutral, wheels blocked and engine running, steer ahead until the arrow is centered on the bar graph.
2) Check the steering wheel position with the arrow in the center of the bar graph. The reference chalk marks will also indicate if the steering wheel is positioned correctly.
3) Turn the engine off. Select “Ready”, if the steering wheel position is acceptable.
4) Press “Restart WinToe”, if the steering wheel position is unacceptable.
5) Pressing K-4 “Ready” will finish the WinToe® procedure.

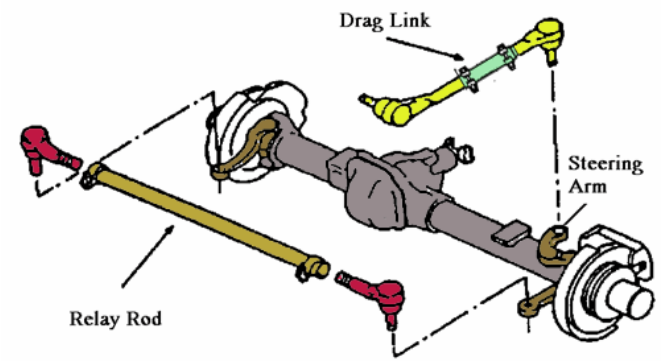
NOTE:

Looking at the steering wheel from outside the vehicle may be misleading and result in a slightly crooked steering wheel during the final test drive.

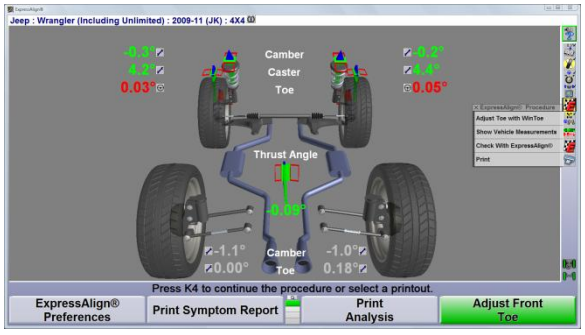


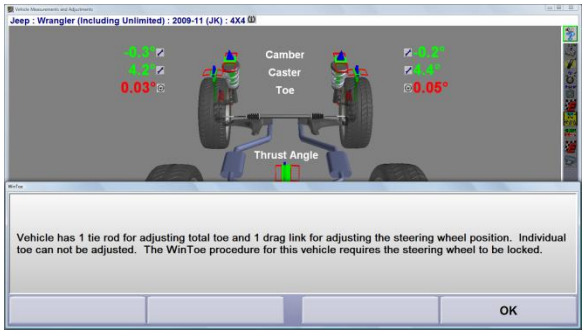
Adjusting Total Toe / Steer Ahead using WinToe®

Solid front axle 4x4 light trucks and sport utility vehicles often use the relay rod steering system. **This system does not offer individual toe adjustment.**

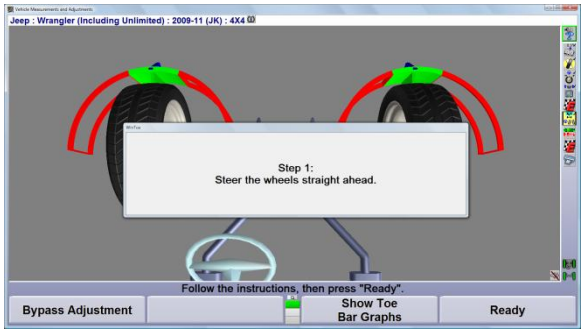


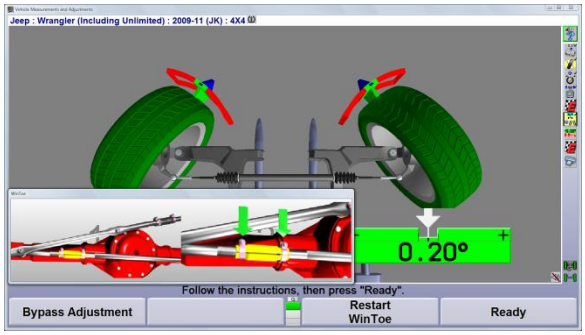
Select “Adjust toe with WinToe” using the “Make Additional Adjustments” soft key label, or select it off the menu activated from the front toe bar graph.





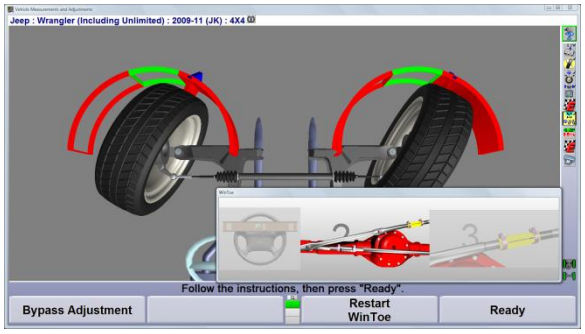
Select WinToe® and confirm the vehicle has 1 tie rod and 1 drag link adjuster.

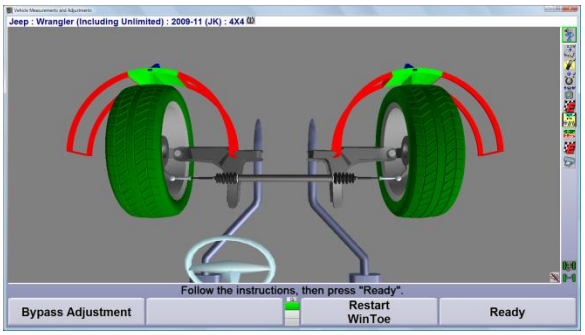




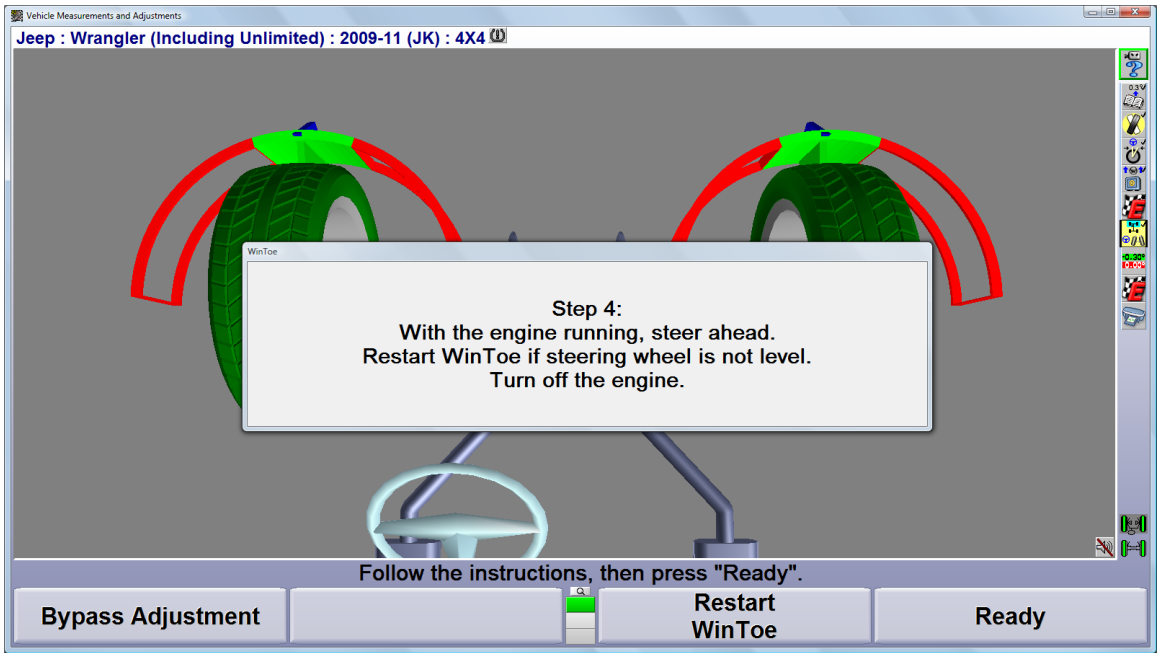
Steer the front wheels straight ahead using the bar graph … Adjust total toe.

Secure clamp bolts … Select “Ready” …. Level and lock the steering wheel.





Adjust drag link until arrow is centered and secure clamps … Select Ready … Check steering wheel position



1) With the vehicle in park or neutral, wheels blocked and engine running, steer ahead until the arrow is centered on the bar graph.

2) Check the steering wheel position with the arrow in the center of the bar graph. The reference chock marks will also indicate if the steering wheel is positioned correctly.

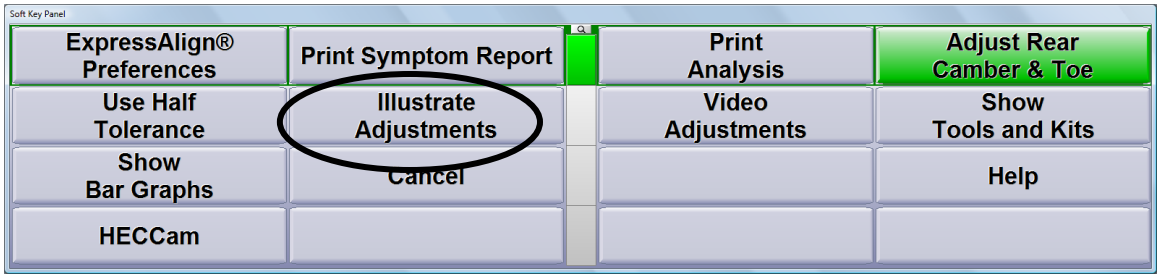
3) Turn the engine off. Press “Ready” if the steering wheel position is acceptable.

4) Press “Restart WinToe” if the steering wheel position is unacceptable.

5) Pressing K-4 “Ready” and the WinToe® procedure is complete.

Common Adjustments

A soft key label called “Illustrate Adjustments” displays pictures of the factory approved adjustments for camber, caster and toe for the vehicle selected from spec memory.



This will be very useful in identifying the location and type of adjustments.
Many of the following photos screens are from Illustrate Adjustment.

Camber and/or caster adjustments may be located in the following areas:

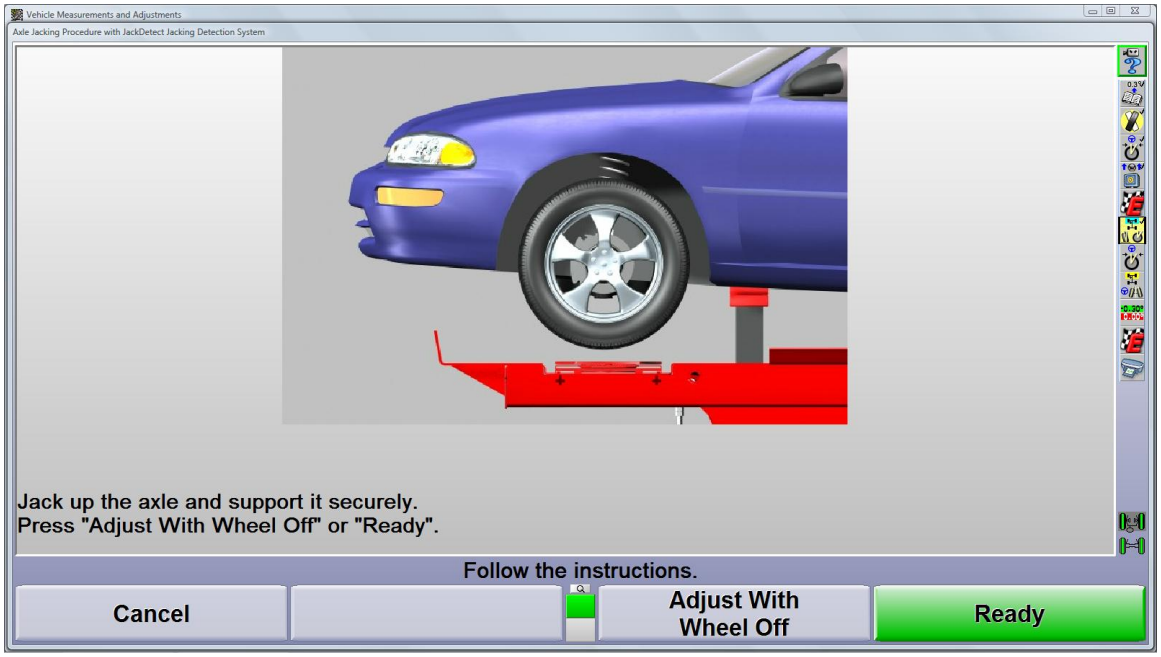
1) Strut to knuckle
2) Upper strut plate
3) Lower control arm
4) Upper control arm

Strut to knuckle

Camber may be adjusted by loosening two bolts holding the strut to the steering knuckle. If the strut casing is slotted, the knuckle will tilt inward or outward.

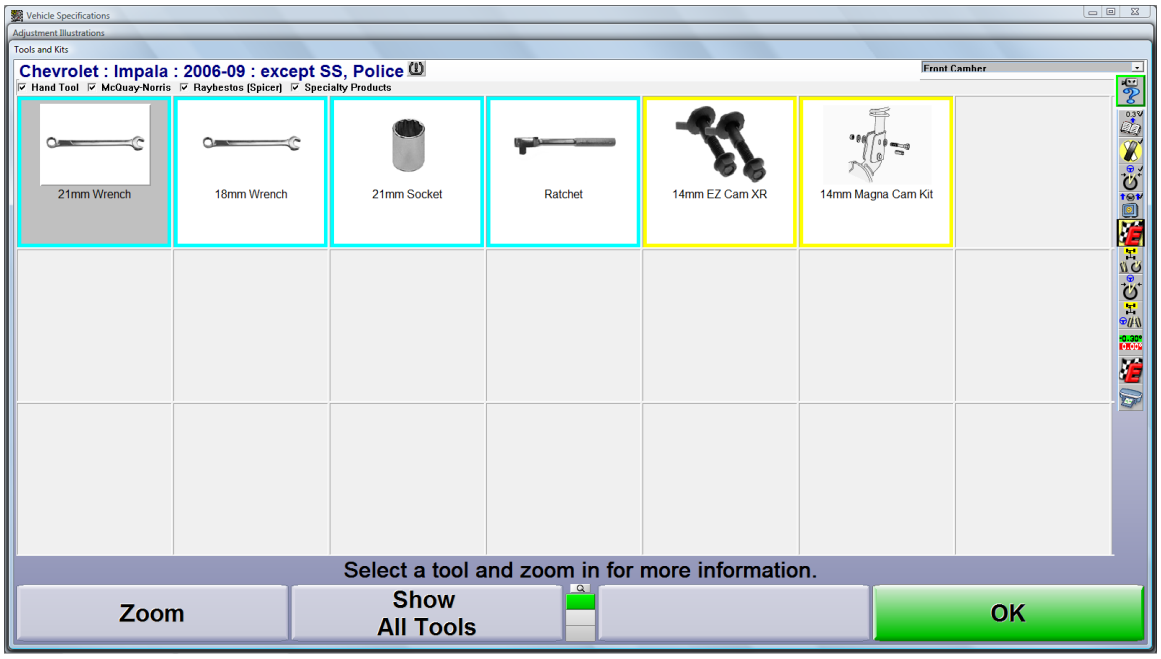
As the bolts are loosened, the weight of the vehicle will cause the knuckle to slip further inward changing camber in a negative direction.

The “Raise Selected Axle” feature of the alignment software will make the job easier by allowing the vehicle weight to be lifted off the knuckle.



The strut casing may not be slotted. If this is the case, the OE might permit the strut casing to be modified. This modification would be to elongate one of the strut bolt holes.

An under-sized bolt may be available from the aftermarket parts manufacturers. One of the strut-to-knuckle bolts is replaced by the smaller diameter bolt giving the knuckle room to move inward and outward.

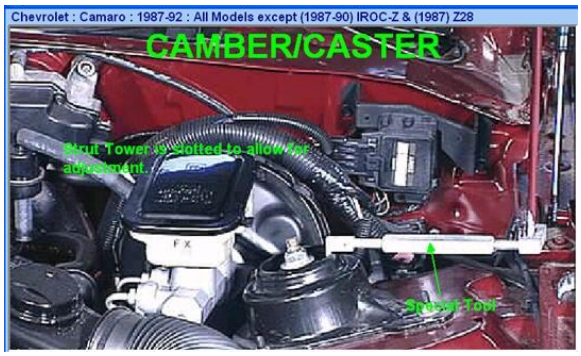


The “Tools and Kits” feature will display tools and aftermarket kits available for the vehicle being aligned. Most cam kits will not require any modification to the strut casing.

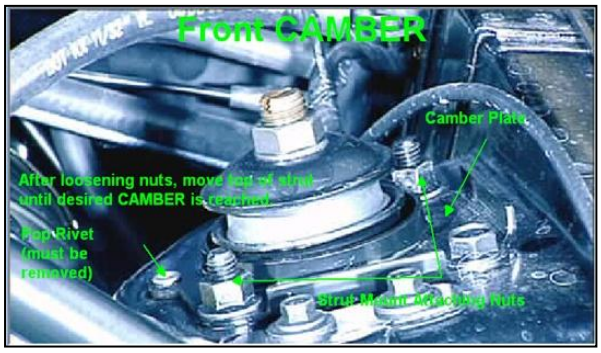
Upper Strut Plate

Front camber and/or caster may be adjustable using the upper strut plate.

The modified strut is used extensively by Ford and GM permitting adjustments at the upper strut plate.



GM Camaro / Firebird



Ford Mustang

The GM Camaro / Firebird offered both camber and caster adjustment. The upper strut plate would slide side-to-side for camber adjustment and front-to-rear for caster adjustment. The tool shown in the photo is used to maintain camber as the upper plate is being moved forward or rearward for caster.

The Ford Mustang has a camber adjustment only. A special tool is available to assist in the camber adjustment.

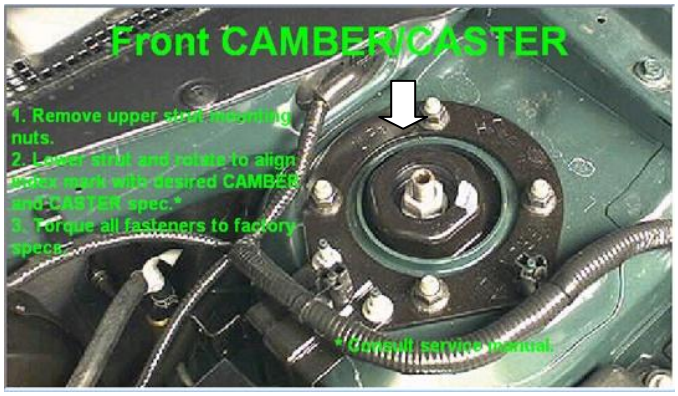
Mustang Camber Tool

The strut plate may be offset, which permits camber and caster adjustments.

This style of adjustment requires the strut plate to be rotated to one of four possible positions.

1) +0.5° camber & +0.5° caster
2) +0.5° camber & -0.5° caster
3) -0.5° camber & +0.5° caster
4) -0.5° camber & -0.5° caster

The strut is positioned rearward and out in this picture. This means camber and caster are as far positive as they will go.



Lower Control Arm

Front camber and/or caster may be adjustable using the lower control arm.

The Camaro lower control arm is considered asymmetric because the two slotted adjustment points are unequal distances from the lower ball joint. Adjustment point “A” is closest to the ball joint and will primarily affect camber. Adjustment point “B” is furthest from the ball joint and will primarily affect caster. Adjust point “B” before point “A” for best results. A special tool is shown called the “Camaro tool” or “F-Body tool”, which makes the adjustment easier.

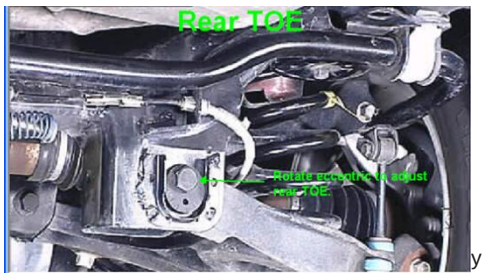
The GM Colorado 4x2 truck lower control arm is considered symmetrical. Both slotted adjustment points are equal distance from the lower ball joint. Adjusting cams are provided to make the adjustment easier. Each of the adjustment points will affect camber and caster. Refer to the control arm section of this manual for additional adjustment information.

The Ford Thunderbird front lower control arm adjusts camber only.

An eccentric cam bolt makes the adjustment simple. Loosen the nut and turn the bolt head. The offset washer will force the control arm inward or outward changing front camber.

A lower control arm may also be used to adjust rear toe.

- ⇒ Pulling the control arm inward will cause a toe-out change.
- ⇒ Pushing the control arm outward will cause a toe-in change



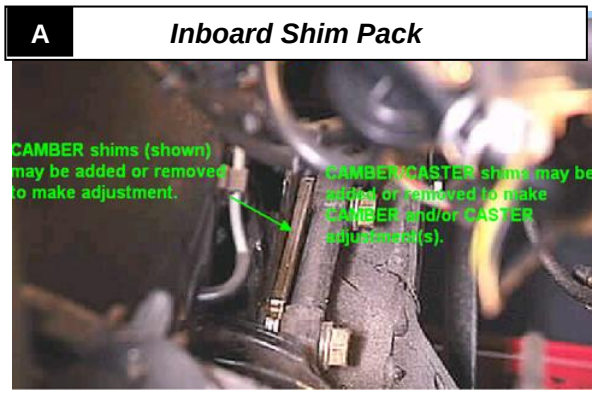
Upper Control Arm

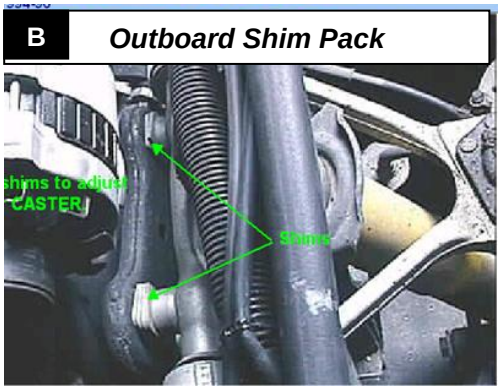
Front camber and/or caster may be adjustable using the upper control arm.

The Durango upper control arm is considered asymmetric because the two slotted adjustment points are unequal distances from the upper ball joint. Point “A” is closest to the ball joint and will primarily affect camber. Point “B” is furthest from the ball joint and will primarily affect caster. Adjust point “B” before point “A”.

The GM K1500 truck upper control arm is considered symmetrical. Both slotted adjustment points are equal distance from the lower ball joint.

Adjusting cams are provided to make the adjustment easier. Each of the adjustment points will affect camber and caster. Refer to the control arm section of this manual.

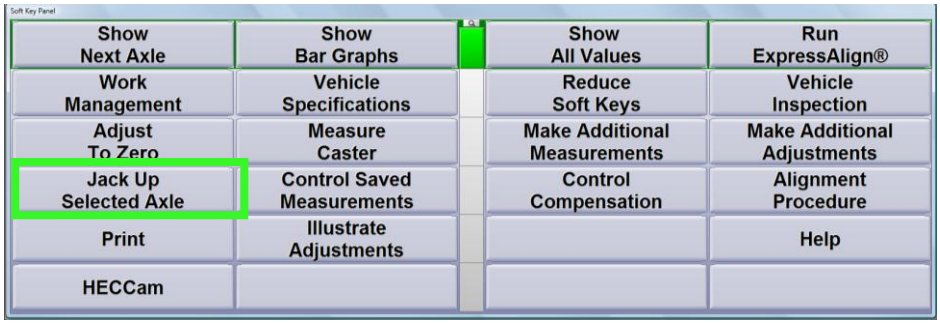




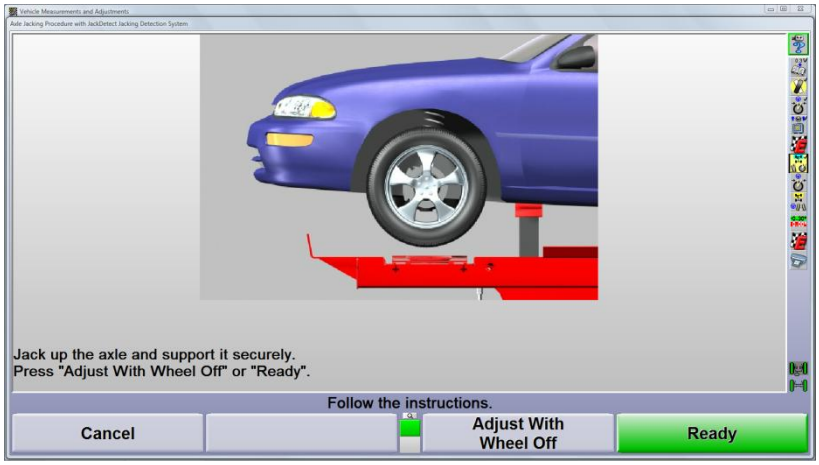
“Jack Up Selected Axle” Procedure

Jacking up the wheels off the rack may make adjusting rear camber, front camber or front caster easier on some vehicles. If the instructions are followed, the software compensates for the movement of the sensors to allow accurate adjustment.

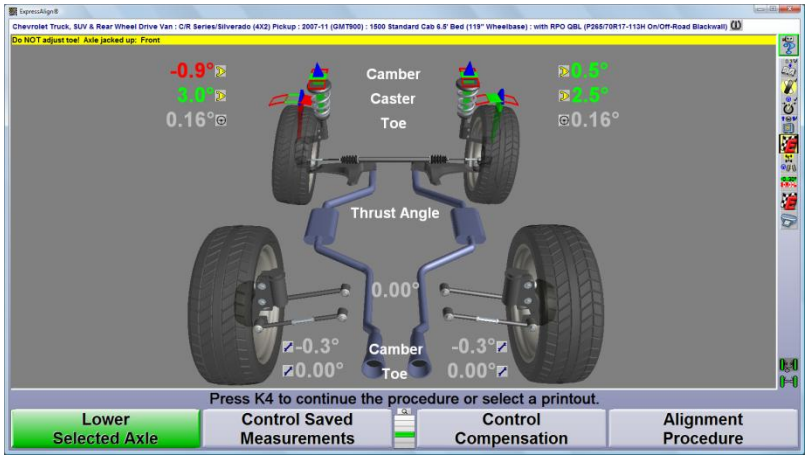
1. Find and press the “Jack Up Selected Axle” soft key label.



The “Jack up Selected Axle” popup screen will appear.



2. Follow the screen instructions, which may include:
3. Make the necessary adjustments while observing the bar graphs.

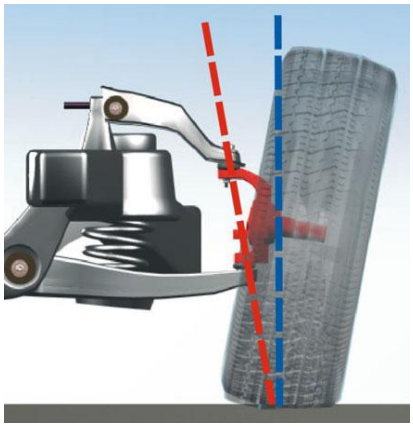


4. Select “Lower Selected Axle”.

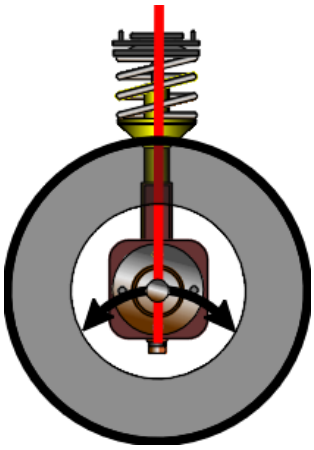
<u>The caster measurements will not be updated on the “Measurements and Adjustments” primary display until the caster angle is verified.</u>

Steering Axis Inclination and Included Angle

Steering Axis Inclination or **SAI** for short is the angle formed by a line drawn through the upper and lower pivot points of the spindle and a vertical line from the lower pivot point.



Steering Axis Inclination (SAI)

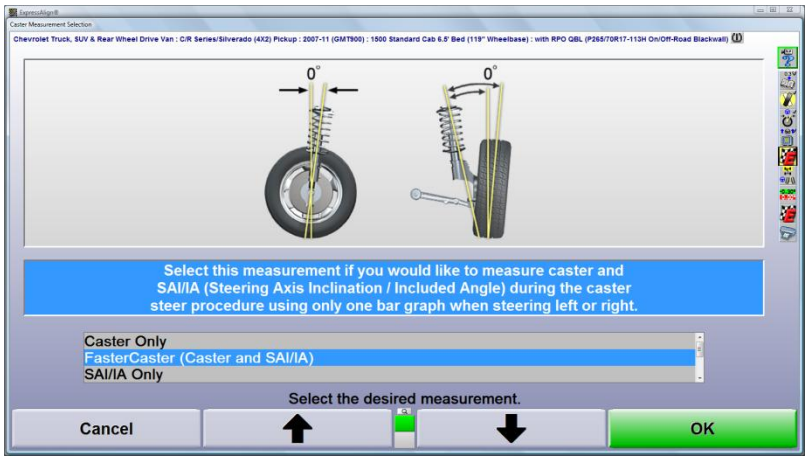


S.A.I. Spindle Arc

S.A.I. and caster combine to supply high speed directional stability and returnability of the front wheels back to equal front toe. S.A.I. and I.A. measurements are useful diagnostics tools.

Measuring S.A.I. and Included Angle

Press “Measure Caster” on the “Vehicle Measurements and Adjustments” primary screen.



Press “Select Measurement,” to access “Measurement Selection”.

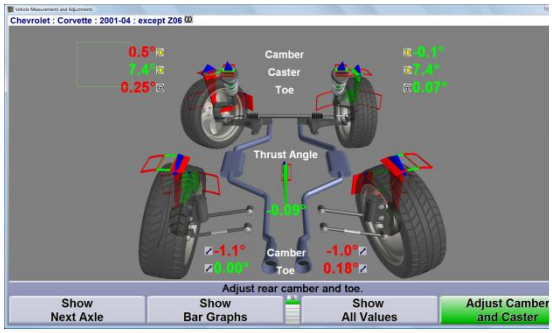
Measuring “SAI / IA Only”

This selection asks for the front wheels to be lifted, sensors to be locked and the brakes to be locked. The measurement is complete once the vehicle is lowered.

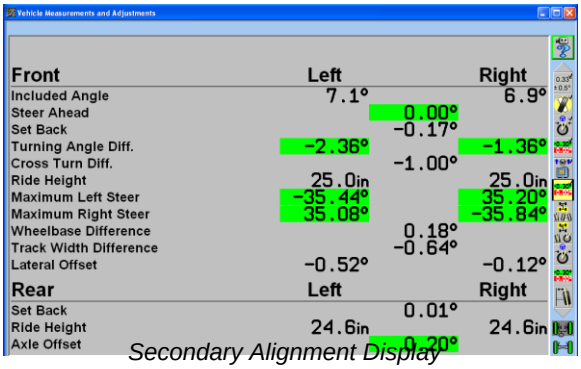
Measuring Faster Caster (Caster and SAI/IA)

This selection asks for the front wheels to stay on the turn plates. Lock the front brakes using a brake pedal depressor and level and lock sensors.

The SAI/IA measurement relies on the front brakes holding the wheel from rotating as they are steered. Should the front brakes slip, the measurement will be falsified.



Primary Alignment Display

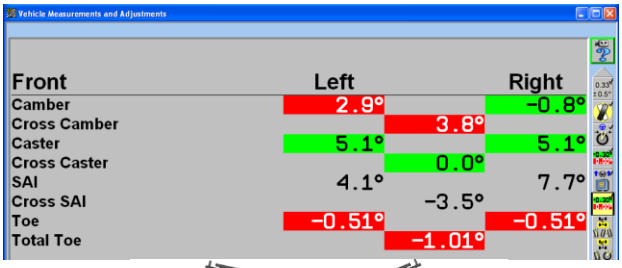


Secondary Alignment Display

S.A.I. measurements are displayed on the “Primary Measurement” display.

Included Angle is displayed on the “Secondary Measurement” display.

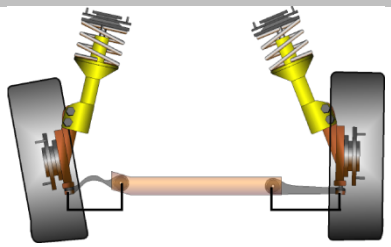
S.A.I. Diagnosis



Use when severe front camber differences are present.

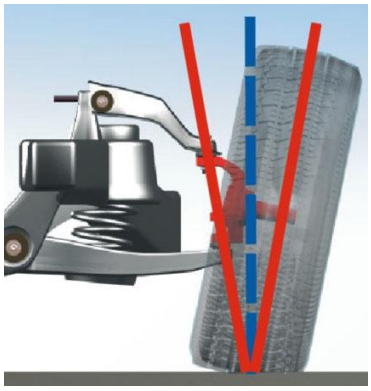
Cross S.A.I. equal to or greater than 1.5º may indicate a:

- Bent control arm
- Damaged strut tower
- Damaged frame or sub-frame
- Bent axle



Included Angle

Included angle, or I..A**.** for short, is the combination of S.A.I and camber.



Included Angle

Cross Included Angle = Left IA – Right IA

Included Angle diagnosis

Cross Included Angle equal to or greater than 1.5º generally may indicate a:

- Bent spindle
- Bent knuckle
- Bent ball joint stud

Glossary

Alignment:	The process of measuring and positioning all wheels attached to a common chassis.
Angle:	Two intersecting lines.
Ball joint:	A connector consisting of a ball and socket. This component allows for simultaneous angular and rotational motion.
Bump steer:	A directional change in steering during jounce and rebound due to unequal tie rod lengths or angles.
Camber roll:	The changes of camber that occur in a turn due to caster.
Camber:	The inward or outward tilt of the top of the wheel as viewed from the front.
Caster:	The forward or rearward tilt of the steering axis as viewed from the side.
Centerline steering:	A centered steering wheel with the vehicle tracking a “straight ahead” course.
Conicity:	A tire condition caused by an off-center belt, which creates lateral forces
Conventional steering:	See definition for parallelogram steering
Cornering:	The ease which a vehicle travels a curved path.
Degree:	A unit of measurement used to describe an angle.
Directional stability:	The tendency for a vehicle to maintain a directed path.
Direct tire wear:	Tire wear which occurs when traveling a straight path
Dog tracking:	The appearance given when the thrustline is not parallel with the centerline of the vehicle.
Drift (lead):	The tendency of a vehicle to steer away from a directed course. Less severe than a pull, constant pressure at the steering wheel is not needed to maintain straight ahead.
Frame angle:	The angle of a non-level frame.
Geometric centerline:	A line drawn through the midpoint of both front wheels and both rear wheels.
Included angle:	S.A.I. plus camber
Indirect tire wear:	Tire wear which only occurs when the vehicle is steered
Independent	A suspension which provides an isolated mounting for

suspension:	each wheel to the chassis.
Individual toe:	The angle formed by the intersection of an individual line drawn through the plane of one wheel and the centerline.
Jounce:	A suspension moving upward in its travel.
Lead:	A slight tendency for a vehicle to move away from a given path. The term drift also describes this condition.
Memory steer:	A condition where the front wheels seek a position other than straight ahead after being steered.
O.E.M.	An acronym used instead of Original Equipment Manufacturer.
Parallel:	Two lines that stay at the same distance apart and never meet.
Parallelogram steering:	A linkage design where, if all pivot points are connected by lines, the lines are parallel. This system includes a pitman arm, idler arm, centerlink, and tie rod assemblies.
Pivot point:	A component used to permit the steering knuckle to turn i.e. ball joint, strut bearing, king pin
Pull:	The tendency of a vehicle to steer away from a directed course. A constant pressure is maintained by the driver at the steering wheel to travel straight ahead.
Rack and pinion steering:	A steering system design that utilizes a pinion gear meshed with a rack gear to transmit steering forces to the spindle.
Radial force variation:	A change in force exerted on the axle by the tire/wheel assembly while rotating under load.
Rebound:	A suspension moving downward in its travel.
Relay rod steering:	A steering design that has a direct bar connection between the tie rods.
Returnability:	The tendency of the front wheels to return to the straight ahead position from a steered position.
Road crown:	The slope of the lane surface.
Road isolation:	The ability of the vehicle to absorb or dissipate road vibrations.
Road shock:	The transmission of road forces to the passenger compartment.
Setback:	The angle formed by the geometric centerline and a line drawn perpendicular to the front axle.
Shimmy:	A violent side-to-side motion of an object.
SLA suspension:	An independent suspension design where the upper and lower control arms are not equal in length.

Solid axle suspension:	A suspension design using an I-beam axle or tubular axle housing extending the width of the vehicle.
Static balance:	An even distribution of weight around the wheel circumference.
Steering axis:	A line drawn between the upper and lower pivot points of the spindle.
Steering arm:	A steering component that connects the outer tie rod to the spindle. The angle of the steering arm to the wheel's axis determines turning angle.
Steering Axis Inclination: (S.A.I.)	An angle formed by a line drawn through the upper and lower pivot points of the steering knuckle and a vertical line drawn through the lower pivot point, as viewed from the front.
Suspension:	An assembly used to support weight, dampen shock, and maintain tire contact and proper wheel to chassis position.
Thrust angle:	The angle formed between the thrustline and the geometric centerline.
Thrust line:	The bisector of rear toe, also described as a line drawn in the direction the rear wheels are pointed.
Torque steer:	A pull during acceleration or deceleration caused by driveline components.
Torsion bar:	A longitudinal wrapped steel spring used primarily with SLA suspensions and designed to maintain specified ride height.
Total toe (angular):	The angle formed by the intersection of lines drawn through both wheels of a given axle.
Total toe (linear):	The difference in measurements taken across the front of the tires versus a measurement taken across the rear of the same tires.
Tracking:	The interrelated paths taken by the front and rear wheels.
Turning angle:	The angle of a wheel during a turn.
Vertical:	Something upright or straight up and down.
Vibration:	The repetitive motion of an object up and down or back and forth.
Wander:	The tendency of a vehicle to drift to either side of a directed course.