Mazda 4 Wheel Steering

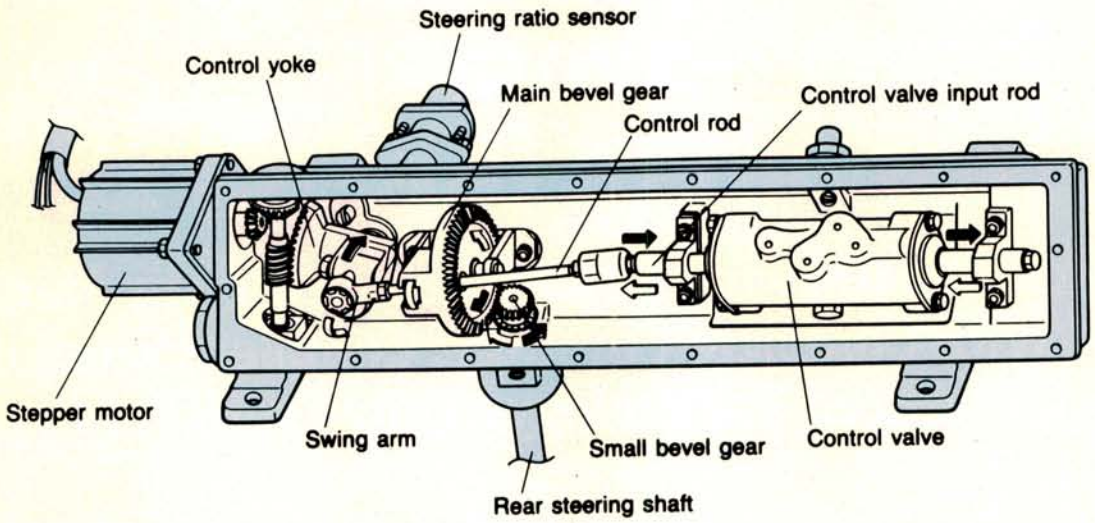
In an earlier **New Car Technology** column, we covered the Four Wheel Steering system offered on Honda's Prelude. As we noted, the all-mechanical planetary gear system utilized by Honda runs contrary to the high tech trend. Mazda has developed a completely different solution to the Four Wheel Steering (4WS) question. Mazda describes their system as electronically controlled with hydraulic assist, and it relies heavily on microprocessors for its operation. We'll take you through the basic operation of this "steer by wire" system.

WHAT ARE THE ADVANTAGES?

You might well question the need for added complexity in today's cars. What are the real benefits of 4WS? Mazda engineers claim that steering improvements over 2WS are made in five areas. You don't need to be a hook and ladder operator to appreciate them.

• **Improved straight ahead stability at high speeds.** Minor steering corrections necessary to main-

Phase Control Unit

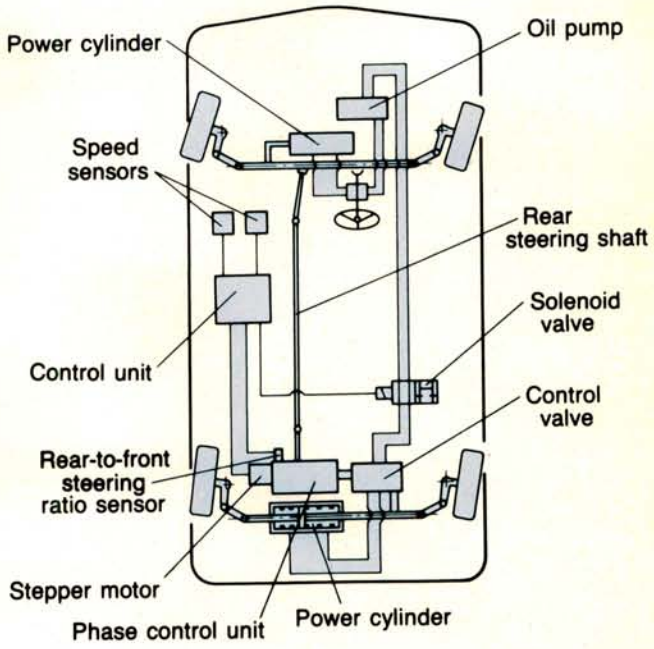


tain a straight path take less driver effort. Corrections for road imperfections or cross winds are two examples.

- **Greater control during lane changes.** Because the rear wheels follow the fronts, there is less rear end yawing during lane changes.
- **Better balance during cornering.** Centrifugal force exerted on the car's body increases as cornering speed increases. Greater steering force is necessary to make the car begin to turn. Tire slip angles also increase as the car tries to continue in a straight line. With 4WS, steering force is distributed to all four wheels. This greatly reduces yawing of the rear end and returns the car to a balanced condition more quickly.
- **Greater responsiveness and precision of steering operation.** The first thing that you might notice about a car with 4WS is that it seems to get the job done with less input at the steering wheel. The steering seems "quicker." This allows for more precise vehicle control.
- **Improved parking ability.** By turning the rear wheels opposite the fronts at slow speeds, vehicle turning radius is reduced. Parking spaces that you might have passed up before are now easier to get into.

HOW DOES IT WORK?

We've included a diagram to show you the major components and their locations in the Mazda system. By the use of speed sensors, rear steering angle is determined by vehicle speed as well as front steering angle. As an added safety feature, a self-centering spring located in the rear steering gear assembly returns the rear wheels to the straight ahead position in the event of either electrical or hydraulic failures.



The real heart of this system is called the Phase Control Unit. Decisions made by the Control Unit are translated into movement of the rear wheels by this unit. Once you understand how the Phase Control Unit functions, the rest is easy. The *phase* in Phase Control refers to the front and rear wheels' relationship to one another. Front and rear wheels turning in the same direction are said to be in the same phase, and opposite phase if they are turning opposite one another.

On the Mazda system, rear wheel phase is determined by vehicle speed. At speeds below 22 mph, the phase control unit steers the rear wheels in opposite phase. At exactly 22 mph, there is no rear wheel steer-

ing and the wheels are said to be in neutral phase. As speed exceeds 22 mph, the Phase Control Unit steers the rear wheels in the same phase as the fronts.

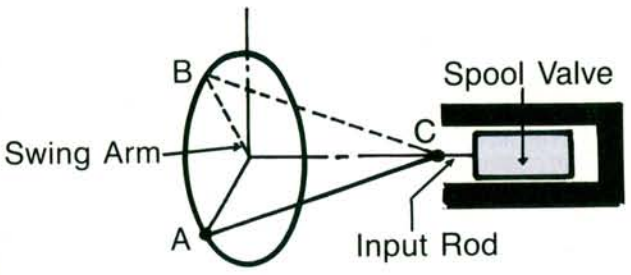
Below is a cutaway drawing of the Phase Control Unit. This may end up sounding a little like "the thigh bone is connected to the knee bone," but here's a basic description of how the Phase Control Unit works.

- Electrical instructions are sent from the Control Unit to the Stepper Motor where they are translated into movement of the motor.
- The Stepper Motor is connected through a set of gears to the Swing Arm.
- Movement of the Swing Arm is transferred through the Control Rod to the Control Valve Input Rod.
- As the Input Rod moves, it opens the Control Valve and allows hydraulic pressure to move the rear wheels.
- Steering input from the front steering unit is provided by the Steering Angle Input Shaft. The shaft is connected to a small bevel gear which acts on the Main Bevel Gear.
- The Control Rod must pass directly through the Main Bevel Gear on its way to the Control Valve. This provides a linkage between the front and rear steering units which helps the Control Unit to determine its instructions to the Stepper Motor.

All of this motion must be coordinated to provide just the right amount of rear steering in the correct phase and at the correct time. Following are three drawings showing how the system responds to front steering changes and adjusts the rear steering in the three speed ranges mentioned earlier.

Diagram A

A: At 35 km/h (22 mph)

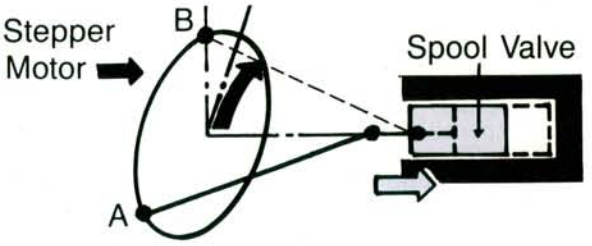


Moved By Bevel Gear
(Steering Wheel Turned Left)

Think of the swing arm as a disc. The point where the input and control rod meet (c) is at the disc's center line. At this point the vehicle speed is exactly 22 mph. As the steering wheel is turned from left to right, the control rod moves from (a) to (b). Because our disc (the swing arm) has remained in an upright position, no movement of the spool valve takes place. No hydraulic pressure is released and the rear wheels stay in neutral phase.

Diagram B

B: At more than 35 km/h (22 mph)

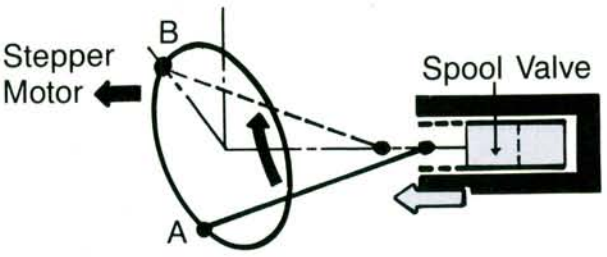


Steering Wheel Turned Left

Our speed has now exceeded 22 mph. As you can see, the stepper motor has tilted the disc off of its axis to the right. Now as the steering wheel is turned to the left, the control rod must follow a path that will force the spool valve into the control valve. This allows the release of hydraulic pressure which forces the rear wheels to the left in the same phase as the fronts. The process is simply reversed if the steering wheel is turned to the right.

Diagram C

C: At less than 35 km/H (22 mph)



Steering Wheel Turned Left

At speeds below 22 mph, the stepper motor pulls the disc off axis to the left. This forces the control rod to follow a path which takes it further away from the control valve as the steering wheel is turned to the left. The spool valve now applies hydraulic pressure in the opposite direction and the rear wheels are allowed to turn in opposite phase. Everything's perfectly clear now, right?

WHAT IF IT BREAKS?

Mazda was considerate enough to build a self-diagnostic system into their 4WS. In the unlikely event of a system failure, diagnosis is possible through the use of trouble codes flashed at the dash warning light. No additional special tools are required to access these codes. If a fault is detected, the warning light will flash the appropriate code for one minute and then remain on constantly. To repeat the codes, turn the ignition off and then on again. After repairs have been made, repeat the procedure to make sure that the trouble codes have been erased. If there has been more than one failure, trouble codes will be displayed in order, starting with the lowest number.

We've included a list of the failure codes for your information. As a safety feature, the system will revert to 2WS if a failure is detected. The self-centering spring in the power cylinder keeps the rear wheels in the straight ahead position until repairs are made.

Item		Check timing		Warning light	Reaction to failure
		Ign ON	Driving		
Speed sensor	Speed sensor in speedometer	—	*	Flashes 1 time (2 sec. period between cycles)	2WS
	Speed sensor on transaxle	—	*		
	Difference between above sensors	—	*		
Phase control system	Mis-stepping (out of phase)	—	*	Flashes 2 times	
Solenoid valve	Wiring circuit	*	*	Flashes 3 times	
Stepper motor	Wiring Circuit	*	*	Flashes 4 times	
	Operation	—	*		
Rear-to-front steering ratio sensor	Output	*	*	Flashes 5 times	
	Standard position	*	*	Flashes 6 times	
Power steering fluid	Level	*	*	Flashes 7 times	
Control unit	Program	*	*	Flashes 8 times	
	Memory	*	*		
	Conversion from analogue to digital values	*	—		
	Computer error	*	*	OFF	4WS after computer reset
Power supply	Battery voltage	—	*	Stays ON	2WS

Note: After repairing a failure, turn off the ignition switch to cancel the warning operation.

SPECIAL CAUTIONS

You may get one of these cars in your shop one day for a four-wheel alignment. Assuming that there are no trouble codes flashing on the dash, would you feel confident enough to align it? The following is a simple test that you can use to quickly determine if the 4WS is out of adjustment. The adjustment procedure itself is pretty involved and your best bet would be to consult the manual if you intend to attempt it. Remember, we're talking vehicle safety here.

4WS PERFORMANCE INSPECTION

1. Put a strip of masking tape between the steering wheel and column cover. Cut the tape at a 90 degree angle at the gap between the two.

2. Drive the vehicle on a straight, flat road for at least 20 feet.

3. Stop and mark the straight ahead position with a straight line on the tape between the steering wheel and column cover.

4. Return to the shop and realign your marks with the front wheels straight ahead.

5. Have an assistant start the engine while you watch one of the rear wheels. If the rear wheel moves off center, it's because the Control Unit thinks the car is turning and is allowing hydraulic pressure to be applied to the Power Cylinder. The 4WS is out of adjustment and must be corrected before an alignment can be performed.

—By Karl Seyfert