

Automated Steering Kit Installation Guide

Kit: EDX-C2388, P/N 911-2030-000


Fits CaseIH Combine Models:

2166	2366	
2377	2577	
2188	2388	2588

Note: There are two possible rear axle/drive variations for the models listed above—Rear Wheel Assist and 2WD. This guide provides instructions for two wheel angle sensor (WAS) installations (WAS 1 and WAS 2) and the guide makes it clear which instructions apply to which variant. The parts required for both installations are supplied. Models with Rear Wheel Assist can be distinguished by the hoses connected to the hydraulic drive motors at the rear wheels - see Figure 2a on page 13.



Read and Follow Safety Messages

- In these instructions, you will see the heading **WARNING** and the safety alert symbol . They indicate a hazardous situation that, if not avoided, could result in death or serious injury. The safety messages provide information to identify a hazard associated with potential injury.
- Before installing, operating, or performing maintenance or service on any part of the system:
 - Read and understand this installation guide and all of the safety information.
 - Read and understand the Automated Steering System User Guide.
- Do not allow anyone to operate without instruction.
- Keep these instructions and all related safety information with the manual for your machine and other implements.

If you have any questions or need assistance, contact your local dealer or distributor.

Overview

A series of equipment specific kits has been developed to work in conjunction with your automated steering system. For the machine models listed above, these kits contain the components for:

- the steering hydraulics
- the wheel angle sensor (WAS)
- the steering wheel switch (SWS - for steering override)

The items in each kit are detailed in the tables that follow the safety warnings beginning below. After the kit tables, there are four step-by-step installation sections, one for each of the kits.

Please read this manual thoroughly before beginning the installation.

WARNING:

To avoid serious injury or death during machine operation, install the appropriate kits for your machine make and model.

Machine Preparation

⚠ WARNING:

Inspect the machine and perform any needed maintenance (for example, contaminated hydraulic fluid) before installing the automated steering kit. This kit cannot perform as intended on a machine that is not maintained properly. Errors in performance increase the risk of operator and bystander injury or death.

Failure to maintain clean hydraulic fluid and operational hydraulic components can cause loss of directional control resulting in serious injury or death.

To avoid serious injury, wear hand and eye protection and use wood or cardboard when checking for leaks.

Turn off the machine and power off the automated steering controller when installing or performing maintenance.

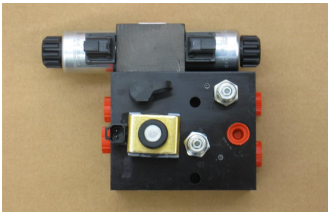



Before attempting to install any of the components, park the machine on a clean level floor with adequate clearance to work all around.

Before you perform any drilling, cutting or fastening, ensure that no other machine components, such as hydraulic hoses or electrical wiring, will be damaged. Failure to follow this warning may cause physical injury and/or damage to the machine.






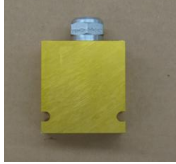



To prevent hydraulic system contamination, it is essential to thoroughly clean hydraulic system fittings and hose connections prior to disconnecting or removing. Use a degreasing solvent spray cleaner such as a brake cleaner to prevent hydraulic system contamination. Note that o-rings used on ORB and ORFF type fittings, referred to in the Kit Contents section, may be damaged by degreasing solvent cleaners. If a fitting is to be cleaned internally, you should first remove and clean the o-ring with a fiberless cloth.

Kit Contents - Steering Hydraulics

Unpack the hydraulics installation kit and identify the required parts as shown. Kit items are A, B, C etc. with an H (Hydraulic) prefix.

REF	PART NUMBER	QTY	DESCRIPTION	PHOTOGRAPH
HA	760-0020-000	1	Assembly, hyd valve block - 15L\proportional (Hydraulic steering block)	
Bag H1 contains HB and HC				
HB	760-2061-000	4	Adapter, hyd 90 elbow - #6maleJIC x #8maleORB (P [pressure], T [tank] and A and B [steering] ports on hydraulic steering block)	
HC	760-2058-000	1	Adapter, hyd 90 elbow - #6maleJIC x #6maleORB (LS port on hydraulic steering block)	
HD	640-0027	1	Hydraulic steering block mounting bracket	

Kit Contents - Steering Hydraulics (*continued*)

REF	PART NUMBER	QTY	DESCRIPTION	PHOTOGRAPH
Bag H2 contains HE				
HE	675-2006	2	Bolt, 3/8NC x 3-3/4" Gr5, ZP	
	678-1054	2	Washer, narrow flat, 3/4"OD x 13/32"ID x 1/16" thk ZP	
	676-1035	2	Nut, nylock - 3/8NC ZP	
(Mount hydraulic steering block HA on HD)				
Bag H4 contains HI, HJ, HK and HL				
HI	760-2046	2	Adapter, hyd run-tee - #6ORFF (Pressure line and steering line)	
HJ	760-2047	1	Adapter, hyd 90 elbow - #6maleORFF x #6femORFF swivel (Use with HI in steering line)	
HK	760-2069	2	Adapter, hyd run-tee - #8ORFF (Tank line and steering line)	
HL	760-2070	1	Adapter, hyd 90 elbow - #8maleORFF x #8femORFF swivel (Use with HK in steering line)	
HM	760-0009	1	Assembly, hyd dynamic load sense valve	
Bag H5 contains HN, HO, HP and HQ				
HN	760-2033	1	Adapter, hyd 90 elbow - #4maleORFF x #6maleORB (Use in HM - LS function port)	
HO	760-2082	1	Adapter, hyd 90 elbow - #6maleJIC x #4maleORB (Use in HM - to steering block LS port)	
HP	760-2090	1	Adapter, hyd - #6maleORB x #4femORB (Use in HM - source port)	

Kit Contents - Steering Hydraulics *(continued)*

HQ	760-2089	1	Adapter, hyd 90 elbow - #4maleORB x #4femORFF (Use with HP in HM)	
HR	760-1292-000	1	Hose, hyd - 3/8" x 46", #6femJIC swivel x #6femORFF 90 swivel (Pressure hose)	
HS	760-1018	1	Hose, hyd - 3/8" x 45", #6femJIC swivel x #8femORFF 90 swivel (Tank hose)	
HT	760-1097	1	Hose, hyd - 1/4" x 62", #6femJIC swivel #6femJIC 90 swivel (Load sense hose)	
HU	760-1107	1	Hose, hyd - 3/8" x 102", #6femJIC swivel x #8femORFF 90 swivel (Steering hose)	
HV	760-1111	1	Hose, hyd - 3/8" x 102", #6femJIC swivel x #6femORFF 90 swivel (Steering hose)	
HW	677-2001	20	Tie strap, 11" heavy duty	

Kit Contents - Wheel Angle Sensor

Unpack the wheel angle sensor kit and identify the required parts as shown. Kit items are A, B, C etc. with a W (Wheel) prefix.

REF	PART NUMBER	QTY	DESCRIPTION	PHOTOGRAPH
Bag 710-0099-000 contains WA to WJ				
WA	720-0045-000#	1	WAS assembly	
WB	750-5002-000	1	Sensor, dual output, BEI	
WC	602-1087-000	1	Connector arm, steering	
WD	675-1191-000	2	Screw, mach, 8-32 x 3", PPH ZP	
WE	676-1054-000	4	Nut, nylock 8-32NC, ZP	
WF	675-1150-000	2	Screw, 8-32 x 1", Allen socket cap, ZP	
WG	675-2031-000	1	Threaded rod, 5/16-24 x 12"	
WH	676-1053-000	4	Nut, 5/16-24 standard ZP	
WI	760-0018-000	2	Rod end swivel with stud, 5/16-24	
WJ	675-2010-000	2	Bolt, 5/16NC x 3/4" Gr5 ZP	  (Attach WAS assembly to WK)
	678-1077-000	2	Washer, lock 5/16, ZP	

Kit Contents - Wheel Angle Sensor (continued)

REF	PART NUMBER	QTY	DESCRIPTION	PHOTOGRAPH
WK	640-0127-000	1	WAS assembly mounting bracket (Rear wheel assist machines)	
WL	640-0128-000	1	WAS rod link bracket (Rear wheel assist machines)	
WM	640-0136-000	1	WAS assembly mounting bracket (2WD machines)	
WN	640-0138-000	1	WAS rod link bracket (2WD machines)	
Bag W3 contains WO, WP, WQ and WR				
WO	675-1139-000	2	Screw, 1/4-20 x 1/2", hex, cap, SS	
	676-1040-000	2	Nut, 1/4NC Gr5 ZP (Rear wheel assist machines)	
WP	675-0156-000	1	Clamp, 2.19" - 2.50" TBOLT, SS (Rear wheel assist machines)	
WQ	678-1053	1	Washer, flat - 1/4" ZP (Rear wheel assist machines - use with WL)	
WR	682-1053-222	2	Hose clamp, 2-1/4" max, embossed (2WD machines)	
Bag W4 contains WS				
WS	675-2062-000	1	Bolt, 3/4" - 10 x 5", Gr5, ZP	
	676-1077-000	1	Nut, hex, 3/4" - 10, Gr5 ZP (Mount WK or WM if required)	

Kit Contents - Steering Wheel Switch

Unpack the steering wheel switch kit and identify the required parts as shown. Kit items are A, B, C etc. with an S (Switch) prefix.

REF	PART NUMBER	QTY	DESCRIPTION	PHOTOGRAPH
SA	478-0008	2	Magnet, flex - 1/2" W x 1" L x 1/8"thk, plain 1	
SB	675-0077	1	Epoxy, Hardman 04001 - single double bub	
SC	602-1062	1	Bracket, steering wheel switch mounting	
SD	726-1054 or 051-0443-10	1	Assembly, steering wheel switch/cable	
SE	677-2002	4	Tie strap, 7" releasable	
Bag S1 contains SF				
SF	676-1059-000	1	Nut, nylock - 3.8NF ZP (Mount SC)	

Installation - Automated Hydraulic Steering Kit

⚠ WARNING:

Before installing, disconnecting or repairing the hydraulic hoses and components, turn off the machine and relieve all pressure from the hydraulic system by turning the steering wheel left and right. Failure to remove the pressure can result in serious injury or death from unexpected machine movement.

To avoid burn injury when installing, disconnecting or repairing the hydraulic hoses and components, turn off the machine and allow the system to cool down prior to touching the parts of the machine that are heated.

See Appendix for a schematic of the hydraulic circuits.

1. Prepare the hydraulic steering block.

NOTE: Make sure the hydraulic steering block **HA** is clean and dust free.

Remove the plastic plugs from hydraulic steering block **HA** and install adapter fittings **HB** in the **P**, **T**, **A** and **B** ports and adapter plug **HC** in the **LS** port (Figure 1).

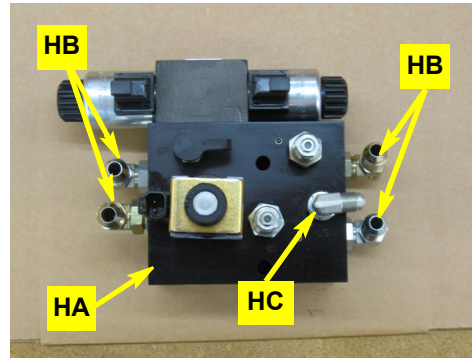


Figure 1: Prepared hydraulic block

2. Install the steering block mounting bracket.

Install the steering block mounting bracket **HD** on the first and second bolts (from the left, or outside) in the leading edge of the ladder support channel under the left side of the cab (Figure 2 with inset).

Mount **HD** with its bend forward so that its long side is not against the channel.

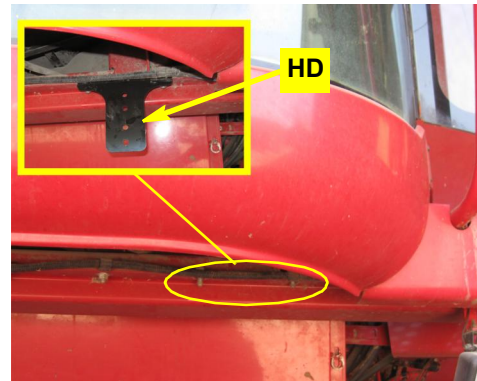


Figure 2 with inset: Installed steering block mounting bracket

3. Install the hydraulic steering block.

Using hardware **HE**, mount hydraulic steering block **HA** on bracket **HD** as follows (Figure 3):

- Mount **HA** with its solenoids downward (with the **P** and **T** ports to the left).

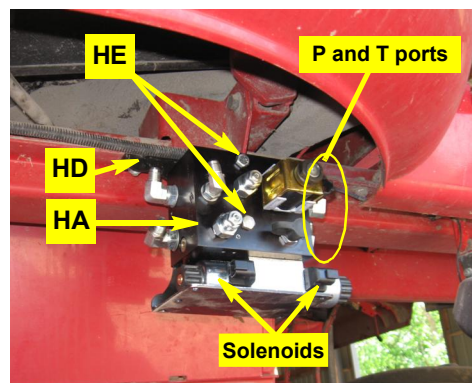


Figure 3: Installed steering block

4. **Install the pressure fitting.**

Locate the pressure port on the front face of the priority valve on the left side of the compartment behind the cab (Figure 4 and left inset). Disconnect the machine's pressure hose and install run-tee **HI** in the pressure port. Reconnect the machine's pressure hose to the open 'T' end of the run-tee (Figure 4 - right inset).

NOTE:

Leave run-tees loose to allow for alignment when attaching hoses. Plastic caps placed on the open ends of the fittings will prevent excessive leakage prior to hose installation.

5. **Install the tank fitting.**

Locate the return oil manifold on the left side of the machine (Figure 5 and left inset). Locate the machine's tank hose to the left of the existing run-tee in the manifold. Disconnect the machine's tank hose, install run-tee **HK** then reconnect the machine's tank hose to the open 'T' end of the run-tee (Figure 5 - right inset).

6. **Prepare and install the load sense valve.**

a. Prepare dynamic load sense valve **HM** as follows (Figure 6a):

- Install adapter **HN** in the valve's function port
- Install adapter **HO** in the valve's **LS** port (to hydraulic steering block)
- Install adapter **HP** in the valve's source port and then adapter **HQ** in **HP**.

b. Locate the machine's load sense line at the top of the priority valve (Figure 6b) and disconnect it. Connect load sense valve adapter **HQ** to the load sense port then reconnect the machine's load sense line to load sense valve adapter **HN** (Figure 6b inset).

NOTE:

*In the following hose installation steps, route hoses with other machine plumbing and clear of moving parts. Secure hoses with heavy duty tie straps **HW**. Tighten all hoses, run-tees and steering block fittings when installation is complete.*

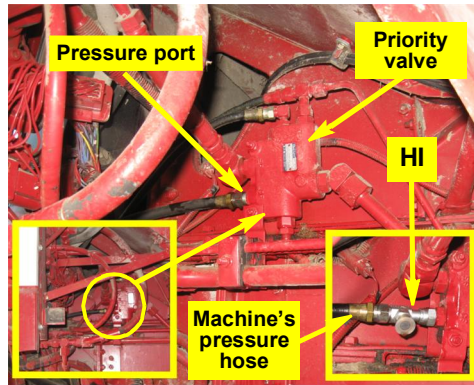


Figure 4 with insets: Run-tee at pressure port, machine's pressure hose reconnected

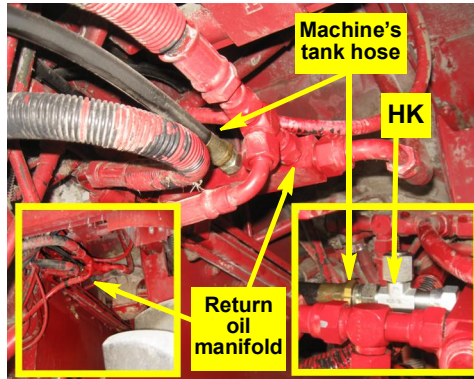


Figure 5 with insets: Run-tee at tank port, machine's tank hose reconnected

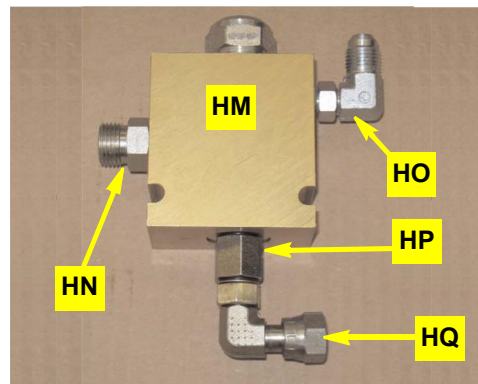


Figure 6a: Prepared load sense valve

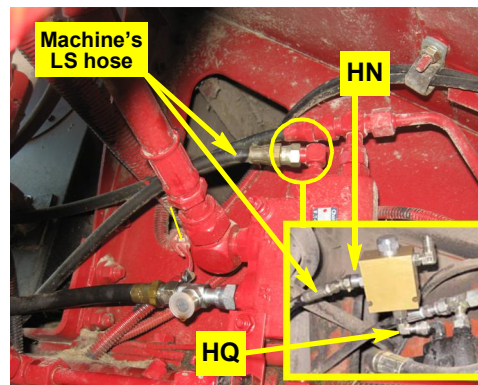


Figure 6b with inset: Load sense valve installed, machine's load sense hose reconnected

7. **Install the pressure, tank and load sense hoses.**

a. Install pressure hose **HR** between adapter **HB** in the **P** port of the hydraulic steering block (Figure 7a) and the open stem of run-tee **HI** installed at step 4 (Figure 7a inset).

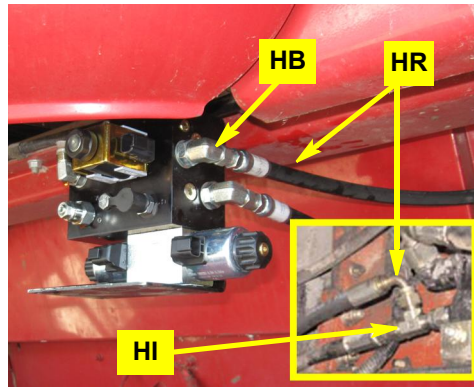


Figure 7a with inset: Pressure hose installed at steering block and (inset) at priority valve

b. Install tank hose **HS** between adapter **HB** in the **T** port of the hydraulic steering block (Figure 7b) and the open stem of run-tee **HK** installed at step 5 (Figure 7b inset)

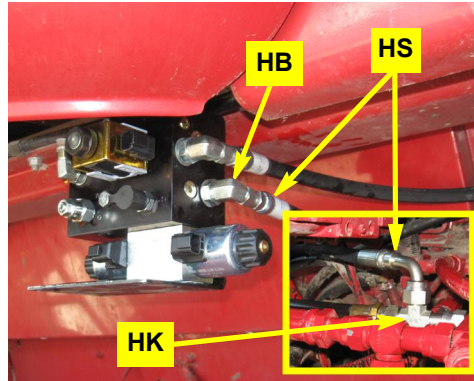


Figure 7b with inset: Tank hose installed at steering block and (inset) at return oil manifold

c. Install load sense hose **HT** between adapter **HC** in the **LS** port of the hydraulic steering block (Figure 7c) and adapter **HO** in the load sense valve installed in step 6 (Figure 7c inset).

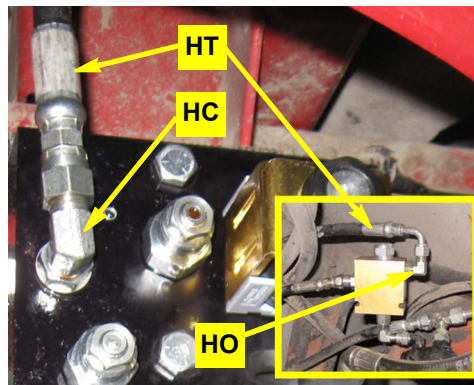


Figure 7c with inset: Load sense hose installed at steering block and (inset) at load sense valve

8. **Install the steering fittings.**

Locate the steering hose/steel line connections behind the front axle on the left side of the machine, near the left drive shaft. Disconnect the hoses from the supported fittings and install adapter elbow fittings **HL** and **HJ**. Install run-tees **HK** and **HI** on **HL** and **HJ** respectively (Figure 8). Reconnect the machine's steering hoses to the stems of the run-tees.

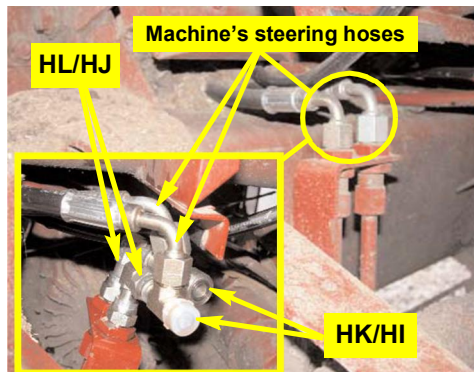


Figure 8 with inset: Run-tees installed at steering hose/steering line connections

9. **Install the steering hoses.**

Install steering hoses **HU** and **HV** between the open 'T' ends of run-tees **HK** and **HI** respectively and adapters **HB** in the **A** and **B** ports of the hydraulic steering block (Figure 9 inset). Route the hoses from the run-tees along the side of the machine to, then behind the hydraulic steering block to the **A** and **B** ports.

10. **Verify operation.**

⚠ WARNING: *During tests of the hydraulic system, the machine may move unexpectedly. Be prepared for machine movement to avoid injury.*

Keep others away and stay clear of mechanical steering linkages to prevent serious injury or death from pinch point hazards while manually operating the hydraulic steering circuit.

- a. Tighten all connections and clean up the installation area around the machine and make certain that it is safe to operate.
- b. Start the machine and check hydraulic connections for any leaks.
- c. Rotate the steering wheel from one extreme to the other and back.

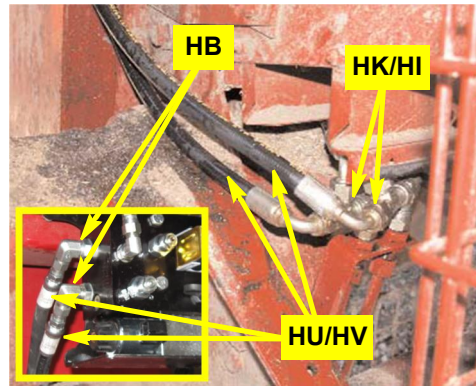


Figure 9 with inset: Steering hoses installed

Installation - Wheel Angle Sensor (WAS 1)

This WAS installation section—WAS 1—is applicable to machines with Rear Wheel Assist (see Figure 2a on page 13).

⚠ WARNING:

Switch off the machine's engine while installing or adjusting the WAS. Keep others away and stay clear of mechanical steering linkages to prevent serious injury or death from pinch point hazards while manually operating the hydraulic steering circuit.

1. Prepare the wheel angle sensor.

- a. Using the provided hardware **WE** (nuts) and **WD** (bolts - not visible), attach the WAS wire connector **WB** to the WAS housing **WA**. Install the bolts up through the bottom of the housing. The WAS wire connector **WB** can be mounted 90° to any of the WAS housing **WA** sides (Figure 1a).

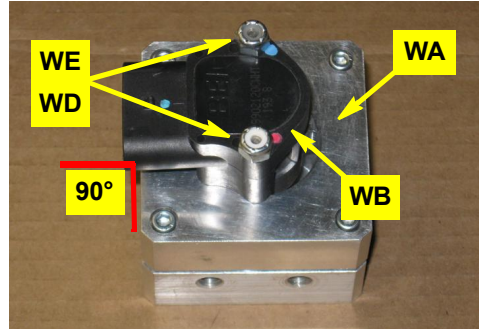


Figure 1a: Prepared WAS housing/connector

- b. Cut four holes off WAS arm **WC** at the opposite end from the WAS shaft mounting hole (Figure 1b).

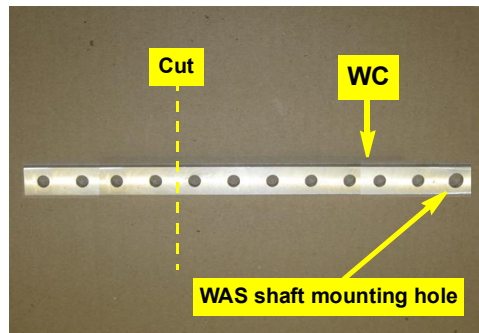


Figure 1b: WAS arm preparation

- c. Using hardware **WF** (screw) and **WE** (nut), attach the WAS arm **WC** to the WAS assembly. Mount the arm in the same direction to the WAS wire connector **WB** (Figure 1c with inset).

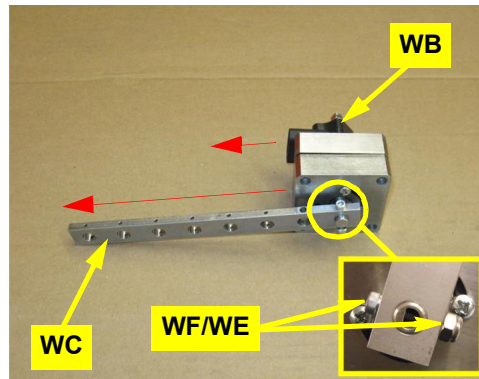


Figure 1c with inset: WAS arm installed

- d. Screw nuts **WH** and swivel rod ends **WI** onto rod **WG** to achieve a center-to-center stud measurement of 13¼" (Figure 1d). Leave **WH** loose until you complete linkage adjustment at step 2f.

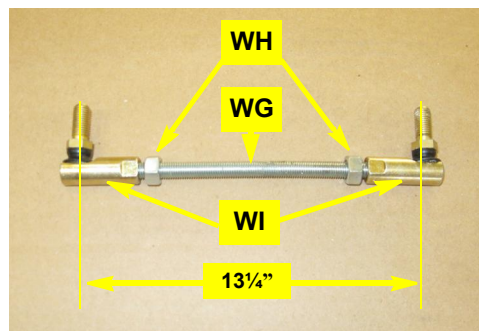


Figure 1d: Assembled threaded link rod

2. **Mount the wheel angle sensor.**

NOTE: Figures in this section show prototype brackets. Install your brackets as described.

- a. On the front face of the right side rear axle, locate and loosen the two outer axle track adjustment nuts (next to the clevis pin at the end of the axle adjustment sleeve) and install WAS mounting bracket **WK** (Figure 2a and inset - but see **Note** following). Use the length of **WK**'s slot to mount the WAS assembly (at the next step) high enough for WAS arm **WC** to clear hoses or any other equipment on top of the axle.

NOTE: Depending on the track width you are using, you may want to mount the WAS bracket on a different bolt. This includes either of the two existing center row bolts in the axle sleeve or any unused center row holes in the axle sleeve (see alternative **WK** mount locations in Figure 2a). Use hardware **WS** (not shown) to mount the WAS bracket if using one of the previously unused holes.

- b. Using hardware **WJ** (not visible), install the WAS assembly from step 1 on the axle side of bracket **WK**. Have the wire connector **WB** on top, pointing toward the center of the machine. Connector arm **WC**'s working arc will be toward the rear of the machine (Figure 2b). Use the slot in **WK**, as required, to raise **WC** clear of anything on the axle.
- c. With the machine's wheels set straight ahead, use hardware **WO** with clamp **WP** (its flanges rearward - Figure 2c inset) to mount rod link bracket **WL** at the back of the tie rod. Mount **WL** with its short arm upward and pointing forward and its center line 13½" from **WK**'s bracket center line (Figure 2c).

- d. Using hardware **WH**, install the rod link assembly from step 1 between the last hole in connector arm **WC** and bracket **WL**. Set the swivel studs downward at both ends (Figure 2d). Leave swivel nuts **WH** loose.
- e. With all hardware **WH** loose, slowly turn the wheels full left lock then full right lock. Check that the linkage moves freely without binding and adjust the linkage as necessary.
- f. When the linkage does move freely and without binding, tighten hardware **WH** on the rod and the swivels.

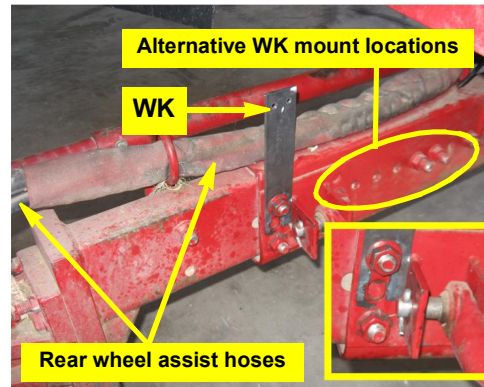


Figure 2a with insets: WAS assembly mounting bracket installed - rear wheel assist models

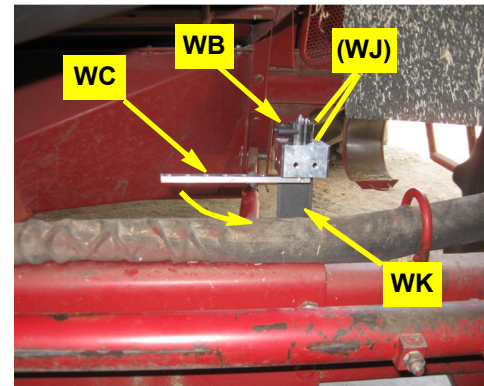


Figure 2b: WAS assembly installed

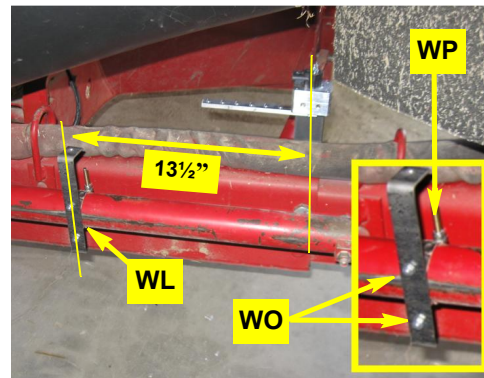


Figure 2c: WAS rod link mounting bracket installed

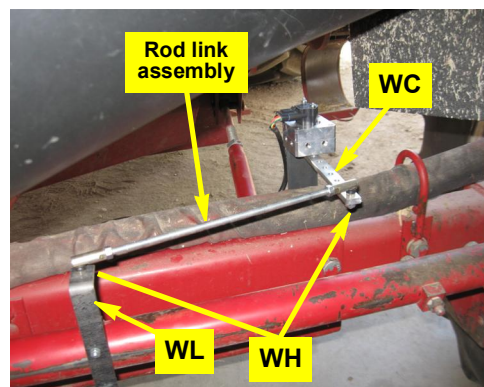


Figure 2d: WAS link rod assembly installed

Installation - Wheel Angle Sensor (WAS 2)

This WAS installation section—WAS 2—is applicable to 2WD machines, that is, machines without Rear Wheel Assist (see WAS 1's Figure 2a on page 13).

⚠ WARNING:

Switch off the machine's engine while installing or adjusting the WAS. Keep others away and stay clear of mechanical steering linkages to prevent serious injury or death from pinch point hazards while manually operating the hydraulic steering circuit.

1. Prepare the wheel angle sensor.

- a. Using the provided hardware **WE** (nuts) and **WD** (bolts - not visible), attach the WAS wire connector **WB** to the WAS housing **WA**. Install the bolts up through the bottom of the housing. The WAS wire connector **WB** can be mounted 90° to any of the WAS housing **WA** sides (Figure 1a).

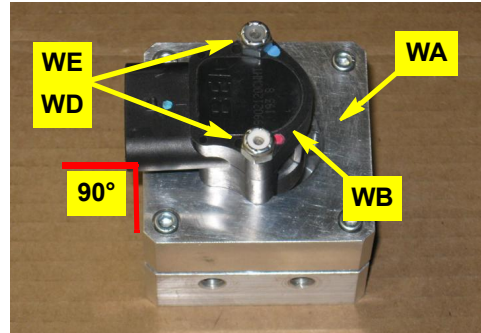


Figure 1a: Prepared WAS housing/connector

- b. Cut five holes off WAS arm **WC** at the opposite end from the WAS shaft mounting hole (Figure 1b).

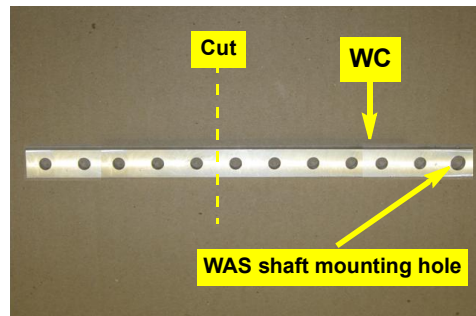


Figure 1b: WAS arm preparation

- c. Using hardware **WF** (screw) and **WE** (nut), attach the WAS arm **WC** to the WAS assembly. Mount the arm in the same direction to the WAS wire connector **WB** (Figure 1c with inset).

NOTE:

Before you cut the rod at step d, screw the provided nuts **WH** onto the threaded rod **WG** so that they are inside the cut you will make. After you have cut the rod, the nuts can help clean the threads.

- d. Cut threaded rod **WG** to 7¾" long (Figure 1d-i) then screw swivel rod ends **WI** onto the cut rod to achieve a center-to-center stud measurement of 9" (Figure 1d-ii). Leave **WH** loose until you complete linkage adjustment at step 2f.

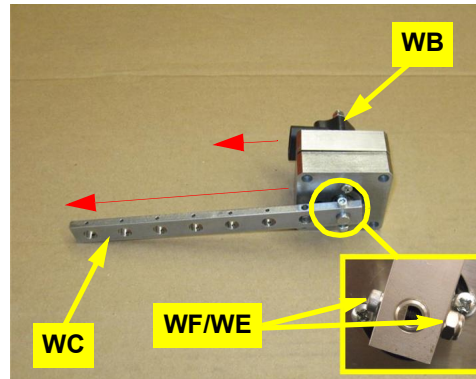


Figure 1c with inset: WAS arm installed

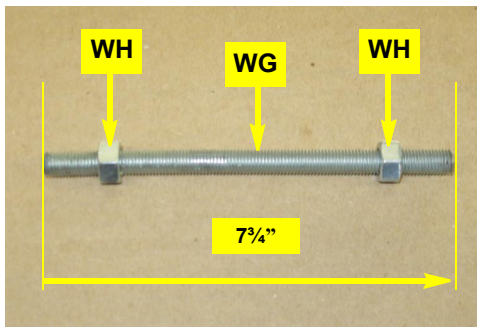


Figure 1d-i: Threaded link rod preparation

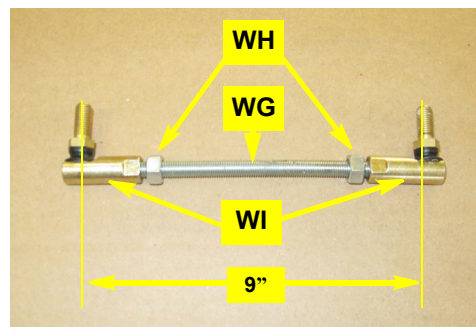


Figure 1d-ii: Assembled threaded link rod

2. Mount the wheel angle sensor.

NOTE: Figures in this section show prototype brackets. Install your brackets as described.

- a. Using hardware **WJ** (not visible), install the WAS assembly from step 1 on bracket **WM**. Have the wire connector **WB** on top and mount the assembly so that the bends in **WM** hold the assembly away from the axle when installed at step b (Figure 2a with inset).

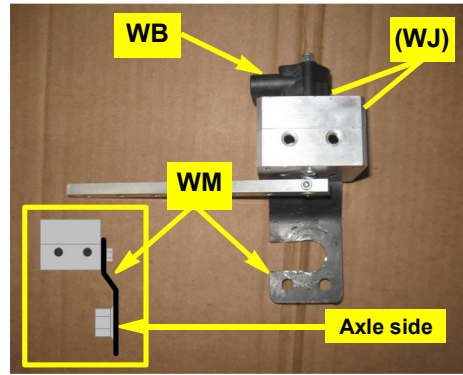


Figure 2a with inset: WAS assembly on its mounting bracket installed - 2WD models

- b. On the rear face of the right side rear axle, locate and loosen the inner of the two center row track adjustment bolts and install bracket **WM** (Figure 2b - but see **Note** following). Mount **WM** so that its bends hold the WAS assembly away from the axle.

NOTE: Depending on the track width you are using, you may want to mount the WAS bracket on a different bolt. This includes the other center row bolt in the axle sleeve or any unused center row holes in the axle sleeve (see alternative **WM** mount locations in Figure 2b). Use hardware **WS** to mount the WAS bracket if using one of the previously unused holes.

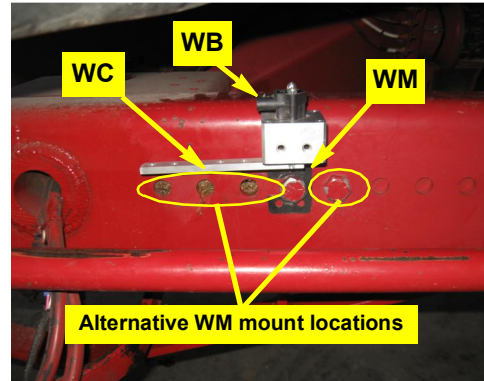


Figure 2b: WAS assembly installed

- c. With the machine's wheels in the straight ahead position, use hose clamps **WR** to mount rod link bracket **WN** on the tie rod. Mount **WN** with its long arm upward and inward. Set **WN** with its right (outer) edge 10" from the center line of bracket **WM** (Figure 2c with inset - you will install the rod link in the next step and connect the ECU's WAS cable in the ECU installation section).

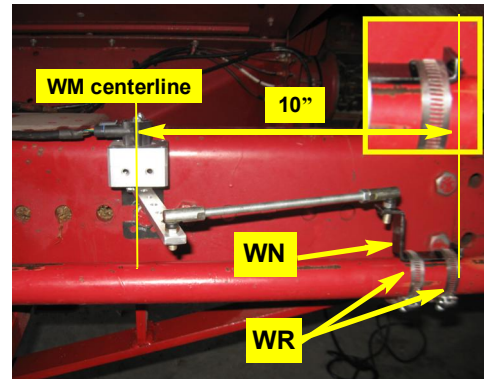


Figure 2c with inset: WAS rod link mounting bracket installed

- d. Using hardware **WH**, install the rod link assembly from step 1 between the last hole in connector arm **WC** and bracket **WN**. Set the swivel studs downward at both ends (Figure 2d). Leave swivel nuts **WH** loose.

- e. With all hardware **WH** loose, slowly turn the wheels full left lock then full right lock. Check that the linkage moves freely without binding and adjust the linkage as necessary.

- f. When the linkage does move freely and without binding, tighten hardware **WH** on the rod and the swivels.

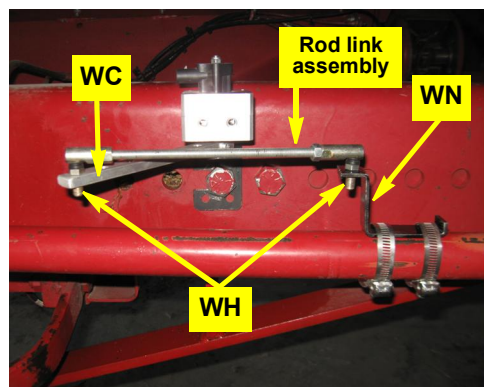


Figure 2d: WAS link rod assembly installed

Installation - Steering Wheel Switch (SWS)

1. Prepare the switch bracket.

Prepare switch bracket **SC** as detailed (Figures 1 and 3a and 3b). Note that the position of bends and twists are approximate - rework them as required once you have installed the bracket):

- Drill a 3/8" hole in the opposite end from the pre-drilled end
- Put an upward bend (about 80°) approximately 2 3/4" from the newly drilled end
- Put a slight 'forward' twist 1" from the newly drilled end
- Put a slight 'backward' twist (opposite to the first twist) 1/2" from the pre-drilled end

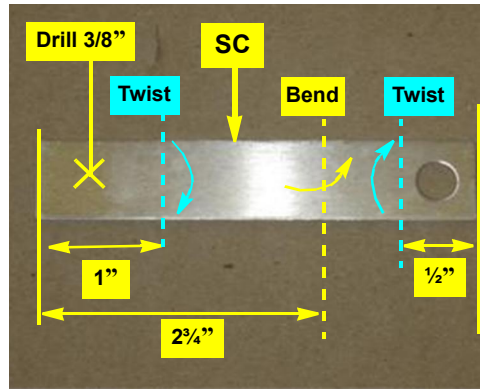


Figure 1: Switch bracket preparation (not to scale). See finished bracket in Figures 3a/b.

2. Install the magnets.

Retracting the floor mat as required, access the bottom of the steering shaft inside the steering column. Using the two-part epoxy **SB**, install magnets **SA**, 180° apart, on the shaft immediately above its narrow section (Figure 2).

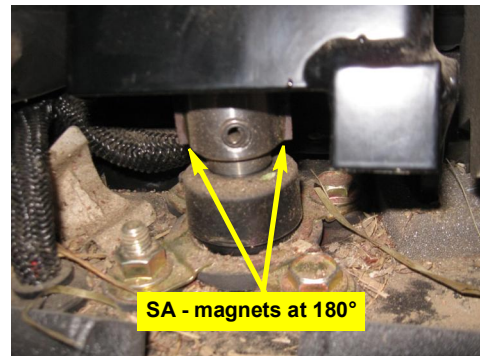


Figure 2: Installed magnets

3. Install the switch bracket and switch.

- a. Using hardware **SF** install switch bracket **SC** on the front right stud of the lower steering shaft support. Rework the bend and twists in bracket **SC** as required to align the switch hole with the center of one of the magnets (Figure 3a).

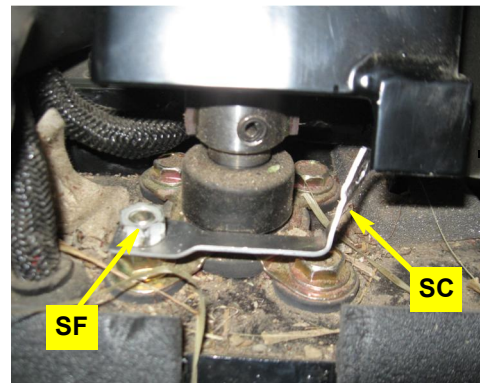


Figure 3a: Installed switch bracket

- b. Install switch **SD** in bracket **SC** and use the switch nuts to set the sensor face to 1/8" to 1/4" from the magnets (Figure 3b). Drop **SD**'s cable down the ledge at the front of the floor and refit the floor mat.

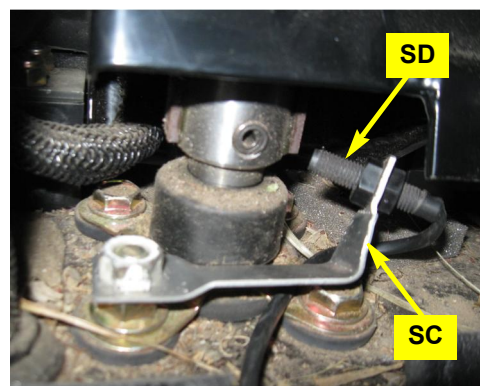


Figure 3b: Installed switch bracket and switch

© Outback Guidance (2020). All rights reserved.

Appendix - Hydraulic Circuits

