ENGINEERING
TOMORROW

Danfoss

Technical Information

Steering
SASA Sensor

Revision history

Table of revisions

Date	Changed	Rev
March 2016	First edition	0101

Contents

Sensor type SASA general

The SASA sensor detects the absolute position and speed of the steering wheel. The sensor can be used in electro-hydraulic steering systems using Danfoss OSPE, EHI, or EHPS steering valves with programmable controller or in any other steering system where the rotation of the steering wheel must be detected as an electronic signal.

There are two versions available of SASA sensors:

SASAIIC used for PVED-CL actuator. SASAIIC has single CAN output signal and "fail silent" concept

SASAIID used for PVED-CLS actuator and general usage. SASAIID has dual CAN output signal.

The use of SASA sensor is relevant e.g. for variable steering ratio and closed loop set-ups where steering wheel position and steering angle have to match.

The SASA sensor also can be used for "kick out" of Auto-steering. When the steering valve is in auto-guidance mode, and the driver wants to swap to manual steering, a signal from the SASA sensor will deactivate the Auto-steering and the steering wheel movement has priority.

SASA is based on a non-contact inductive principle giving a very high resolution.

The sensor features a robust design and resists e.g. electro-magnetic radiation.

The output is a CAN signal, which makes it easy to interface to advanced vehicle controllers and to Danfoss PVED-CLS actuators for steering valves.

The steering wheel shaft turns the rotor of the SASA sensor, and the sensor is simply mounted between steering unit and steering column. The shaft of the steering column must be 15 mm longer when using SASA sensor.

In cases where customers want to use the same steering column in applications with and without SASA sensors, Danfoss offers an adapter kit type SAK to built in between column and sensor.

The SASA sensor offers the following features:

*   High resolution < 0.1°
*   Output CAN signal
*   High safety
    *   SASAIIC: "fail silent" concept
    *   SASAIID: two output messages concept
*   SASAIID is *PLUS+1° Compliant*
*   Flanged in between steering unit and column
*   Compact design

Versions, code numbers and weights for SASA sensor

Code number	Type	Supply voltage	Termination resistor	Cable length	Connector	Weight	
						kg	[lb]
11088656	SASAIIC, CAN	9 - 32 V_{DC}	No	500 mm	AMP code no. 2-967059-1	0.25	[0.55]
11099289	SASAIIC, CAN	9 - 32 V_{DC}	No	500 mm	DEUTSCH DT04-4P-CE02	0.25	[0.55]
11116505	SASAIID, CAN	6 - 36 V_{DC}	No	500 mm	DEUTSCH DT04-4P-CE02	0.25	[0.55]

SASAIIC

SASAIIC CAN message protocol

Interface: CAN 2.0 B

Baud rate: 125 kBaud, 250 kBaud (default), 500 kBaud

SASA returns cyclic the following CAN message every 5, 10 (default) or 20 ms.

301 h	Data							
	0 Low byte	1 High byte	2	3 Low byte	4 High byte	5	6 Low byte	7 High byte
ID	Steering angle		Count	Steering angle change		Status	CRC-16	

Identifier	301h (11 bit)
Steering angle	12 bit word (0 – 4095) relative to a 0-index point. 0 = 0 degrees 4095 = 359,912 degrees Overflow at 4095 for CW activation shall increment 0 Underflow at 0 for CCW activation shall decrement 4095
Count	Byte (0-255) Increments 1 for each message
Steering angle change	Difference between 2 transmitted position values in succession. 16 bit integer with 2's complementary encoding for negative values (-32768 to 32767). -4095 = -359,912 degrees 0 = 0 degrees 4095 = 359,912 degrees

Status

7	6	5	4	3	2	1	0
-	-	-	-	-	-	-	Progamming mode

Programming mode	Normal state is 1 Response with a 0 when starting the programming sequence (See the programming sequence described below under setup message)
CRC-16	The standard CRC16 polynomial is used ($x^{16}+x^{15}+x^2+1$)

SASAIIC

SASAIIC parameter setup

Setup message: sensor can be programmed as shown in the CAN setup message below.

0C0h	Data							
	0	1	2	3	4	5	6 Low byte	7 High byte
ID	Baud rate	Data rate	Set 0-index		Programming sequence		CRC-16	

Identifier	0C0h (11 bit)
Baud rate	During the programming sequence, byte 0 is set to: • 02h for 125 kBaud • 03h for 250 kBaud (default) • 04h for 500 kBaud
Data rate	During the programming sequence, byte 1 is set to: • 02h for 5 ms • 03h for 10 ms (default) • 04h for 20 ms
Set 0-index	If byte 2 is set to AAh during the programming sequence, the actual angle will be stored as a reference value (0 degree) in persistent memory.
Programming sequence	The following sequence is used when programming the sensor. 1. The controller unit sends a setup message where byte 4 is set to AAh and byte 5 is set to 55h. 2. The sensor answers with a 0 on the status byte (bit 0). 3. The control unit then sends a setup message where byte 4 is set to 0Fh and byte 5 is set to F0h. The first and second message shall match. 4. After receiving the last message the programming takes place in the sensor if the parameters are in the defined range, the timeout period has not been exceeded and the CRC-16 check is correct in both messages. 5. After programming the status bit in the output message changes back from 0 to 1. 6. If the controller's second message does not come within 1 second after the controller's first message, the programming sequence will be aborted.
CRC-16	The standard CRC16 polynomial is used ($x^{16}+x^{15}+x^2+1$)

SASAIIC

SASAIIC technical data

Mechanical

Input range:	Continuous 360° rotation
Rotor torque:	≤ 0.2 N•m
Expected life:	> 10 million cycles

Electrical

Supply voltage:	9 - 32 V_{DC}
Power consumption:	<1 W

Output

CAN V2.0B, (compatible to J1939)

Termination resistor:	120 ohm (optional)
Baud rate:	125, 250 or 500 kb/s
Angle:	12-bit word (0 - 4095) relative to a programmable 0-index point.
Resolution:	< 0.1°
Linearity:	1% of full scale
Angle change:	16 bit integer with 2's complementary encoding for negative values (-32768 to 32767).

Safety function

If a failure occurs, the SASA CAN transceiver will be disabled.

Environmental

Operating temperature:	-30° to 85°C [-22 to 185°F]
Storage temperature:	-40° to 105°C
Sealing:	IP65
EMI/RFI Rating:	100 V/m
Vibration:	Meets IEC 60068-2-64
Shock:	Meets IEC 60068-2-27 test Ea

SASAIID

SASAIID CAN message protocol

Dual CAN output

The PVED-CLS (valve controller) can interface to a SASA with redundant output. A safety function that compares the two output messages from SASA is implemented in the PVED-CLS. There is a 180-degree phase shift between the two angles transmitted in the messages. Steering angle 1 and steering angle 2 are sampled with a delay < 2ms. The ID1 and ID2 messages are transmitted with a delay < 5ms. It is possible to configure the sensor to transmit cyclic 1 or 2 messages.

Interface: CAN 2.0 B

Baud rate: 250 kBaud

Transmit rate: 10, 20, 50 (default), 100, 200 ms (cyclic message transmission, 1 or 2 messages, tolerance: ± 10%)

Proprietary B 29-bit	Data							
	0	1	2	3	4	5	6	7
ID1	Steering angle 1		Steering angle velocity 1		Reserved	Status	CRC-16	

Identifier	J1939 proprietary B. Programmable 29 bit message id.
	ID1 = $0CFFYYXX
	PGN-offset1 YY is programmable, default value is $10
	Source Address XX is programmable, default value is $4D
Steering angle 1	Data byte 0-1: Value measured by angle sensor 1 relative to the 0-index point.
	16-bit integer
	0 corresponds to 0 degrees
	4095 corresponds to 359.912 degrees
	Overflow at 4095 for CW activation shall increment 0
	Underflow at 0 for CCW activation shall decrement 4095
	4096 – 65534: Not available
	65535 : Sensor failure
Steering angle velocity 1	Data byte 2-3: Velocity of the rotor measured by sensor 1.
	16-bit integer
	0 corresponds to -300 RPM (CCW)
	20480 corresponds to 0 RPM
	40960 corresponds to 300 RPM (CW)
	40961 – 65534: Not available
	65535: Sensor failure
Reserved	Data byte 4: $FF
Status	Data byte 5

SASAIID

7	6	5	4	3	2	1	0
Error Code				Sequence number			

Error Code	Bit 4-7
	$0 - Reserved
	$1 - Sensor Chip Error
	$2 - Steering angle failure
	$3 - CAN input message failure
	$4 - Power failure
	$5 - CPU failure
	$6 - Memory failure
	$7-$D - Reserved
	$E - Temperature warning
	$F - No error
Sequence number	Bit 0-3
	Increments 1 for each message.
	Valid range is $0 - $F

CRC-16	Data byte 6-7: The CRC16 polynomial 0xC86C is used to calculate a checksum for byte 0-5.
	Width - 16
	Init - 0x0000
	Ref-In - False
	Ref-Out - False
	Xor-Out - 0x000
	Check - 0x6774

'Check' is the CRC result for UTF-8 string "123456789".
The above parameters conform to the Rocksoft™ Model CRC Algorithm.

Proprietary B 29-bit	**Data**							
	0	1	2	3	4	5	6	7
ID2	Steering angle 2		Steering angle velocity 2		Reserved	Status	CRC-16	

Identifier 2 (Optional)	J1939 proprietary B. Programmable 29 bit message id.
	ID2 = $0CFFZZXX
	PGN-offset2 ZZ is programmable, default value is $11
	Source Address XX is programmable, default value is $4D

SASAIID

Steering angle 2	Data byte 0-1: Value measured by angle sensor 2 (with a 180 degree offset to Steering angle 1).	
	16-bit integer	
	0 corresponds to 180 degrees	
	4095 corresponds to 179.912 degrees	
	Overflow at 4095 for CW activation shall increment 0	
	Underflow at 0 for CCW activation shall decrement 4095	
	4096 – 65534: Not available	
	65535 : Sensor failure	
Steering angle velocity 2	Data byte 2-3: Velocity of the rotor measured by sensor 2.	
	16-bit integer	
	0 corresponds to -300 RPM (CCW)	
	20480 corresponds to 0 RPM	
	40960 corresponds to 300 RPM (CW)	
	40961 – 65534: Not available	
	65535: Sensor failure	
Reserved	Data byte 4: $FF	
Status	Data byte 5	

7	6	5	4	3	2	1	0
Error Code				Sequence number			

Error Code	Bit 4-7	
	$0 - Reserved	
	$1 - Sensor Chip Error	
	$2 - Steering angle failure	
	$3 - CAN input message failure	
	$4 - Power failure	
	$5 - CPU failure	
	$6 - Memory failure	
	$7-$D - Reserved	
	$E - Temperature warning	
	$F - No error	
Sequence number	Bit 0-3	
	Increments 1 for each message.	
	Valid range is $0 - $F	

CRC-16   Data byte 6-7: The CRC16 polynomial 0xC86C is used to calculate a checksum for byte 0-5.

SASAIID

Width - 16

Init - 0x0000

Ref-In - False

Ref-Out - False

Xor-Out - 0x000

Check - 0x6774

'Check' is the CRC result for UTF-8 string "123456789".
The above parameters conform to the Rocksoft™ Model CRC Algorithm.

SASAIID configuration protocol

The sensor complies with the PLUS+1® Lite Diagnostic Communication Protocol – UDS.

The services to configure the sensor are:
-
-

Read data by identifier

This service is used for retrieving the value of a given parameter.

29 bit CAN identifier	PCI and Frame data bytes			
	Byte #0	Byte #1	Byte #2	Byte #3
CAN ID	PCI	Service ID	ID – Sub function (MSB first)	

CAN ID ID = $1BC788XX (The sensor node address XX is configurable, default value is $4D, and the Danfoss diagnostic tester node address is $F1)

ID = $1BC78FFF (Used for broadcast requests, i.e. when the Danfoss diagnostic tester is requesting the configuration address format)

29 bit CAN identifier										
Priority			Extended data page	Data page	Type of service (TOS)		Source address		Destination address	
							net	node	net	node
28	27	26	25	24	23	22	21 19	18 11	10 8	7 0
1	1	0	1	1	1	1	000	11110001	000	01001101
$1BC7884D										

29 bit CAN identifier										
Priority			Extended data page	Data page	Type of service (TOS)		Source address		Destination address	
							net	node	net	node
28	27	26	25	24	23	22	21 19	18 11	10 8	7 0
1	1	0	1	1	1	1	000	11110001	111	11111111
$1BC78FFF										

SASAIID

PCI	PCI = $03 (PCI type = 0, SF Data Length = 3)
Service ID	SID = $22 –Read Data by Identifier
ID - Sub function	See *SASAIID configuration data list* on page 17

Positive response

This message is used as positive response to a Read Data by Identifier request.

29 bit CAN identifier	PCI and Frame data bytes							
	Byte #0	Byte #1	Byte #2	Byte #3	Byte #4	Byte #5	Byte #6	Byte #7
CAN ID	PCI	Service ID	ID – Sub function (MSB first)		Value			

CAN ID ID = $1BC268F1 (Here shown with the default sensor node address $4D, and the Danfoss diagnostic tester node address $F1)

29 bit CAN identifier										
Priority			**Extended data page**	**Data page**	**Type of service (TOS)**		**Source address**		**Destination address**	
							net	node	net	node
28	**27**	**26**	**25**	**24**	**23**	**22**	**21 19**	**18 11**	**10 8**	**7 0**
1	1	0	1	1	1	1	000	01001101	000	11110001
$1BC268F1										

PCI	PCI = $0X (PCI type = 0, SF Data Length = X)
Service ID	SID = $62 –Positive response ID to a Read Data by Identifier request.
ID - Sub function	See *SASAIID configuration data list* on page 17
Value	See *SASAIID configuration data list* on page 17

Negative response

This message is used as negative response to a Read Data by Identifier request.

29 bit CAN identifier	PCI and Frame data bytes			
	Byte #0	Byte #1	Byte #2	Byte #3
CAN ID	PCI	Service ID	ID – Sub function (MSB first)	

CAN ID ID = $1BC268F1 (Here shown with the default sensor node address $4D, and the Danfoss diagnostic tester node address $F1)

SASAIID

29 bit CAN identifier									
Priority			Extended data page	Data page	Type of service (TOS)		Source address		Destination address	
							net	node	net	node
28	27	26	25	24	23	22	21 19	18 11	10 8	7 0
1	1	0	1	1	1	1	000	01001101	000	11110001
$1BC268F1										

PCI   PCI = $03 (PCI type = 0, SF Data Length = 3)

Service ID   SID = $7F –Negative response ID

ID - Sub function $22XX (For XX, see the following table)

Byte 2	Error message	Error cause	Service Tool response
$13	Incorrect Message Length Or Invalid Format	The length of the message is wrong	Resend correct command
$22	Conditions Not Correct	This code shall be returned if operating conditions of the server for performing the required action are not met.	Resend command later
$31	Request Out Of Range	This code shall be sent if: **1.** none of the requested data identifier values are supported by the device **2.** the client exceeded the maximum number of data identifiers allowed to be requested at a time	Resend with correct/fewer IDs
$33	Security Access Denied	This code shall be sent if at least one of the data identifiers is secured and the server is not in an unlocked state	Perform security access routine
$78	Response pending	Routine needs more time	Extend P2_CAN_Server_max to P2*_CAN_Server_max

Write data by identifier

This service is used for writing configuration data.

29 bit CAN identifier	PCI and Frame data bytes							
	Byte #0	Byte #1	Byte #2	Byte #3	Byte #4	Byte #5	Byte #6	Byte #7
CAN ID	PCI	Service ID	ID – Sub function (MSB first)		Value			

CAN ID   ID = $1BC788XX (The sensor node address XX is configurable, default value is $4D, and the Danfoss diagnostic tester node address is $F1)

SASAIID

29 bit CAN identifier										
Priority			Extended data page	Data page	Type of service (TOS)		Source address		Destination address	
							net	node	net	node
28	27	26	25	24	23	22	21 19	18 11	10 8	7 0
1	1	0	1	1	1	1	000	11110001	000	01001101
$1BC7884D										

PCI	PCI = $0X (PCI type = 0, SF Data Length = X)
Service ID	SID = $2E –Write Data by Identifier
ID - Sub function	See *SASAIID configuration data list* on page 17
Value	See *SASAIID configuration data list* on page 17

Positive response

This message is used as positive response to a Write Data by Identifier request.

29 bit CAN identifier	PCI and Frame data bytes			
	Byte #0	Byte #1	Byte #2	Byte #3
CAN ID	PCI	Service ID	ID – Sub function (MSB first)	

CAN ID	ID = $1BC268F1 (Here shown with the default sensor node address $4D, and the Danfoss diagnostic tester node address $F1)

29 bit CAN identifier										
Priority			Extended data page	Data page	Type of service (TOS)		Source address		Destination address	
							net	node	net	node
28	27	26	25	24	23	22	21 19	18 11	10 8	7 0
1	1	0	1	1	1	1	000	01001101	000	11110001
$1BC268F1										

PCI	PCI = $03 (PCI type = 0, SF Data Length = 3)
Service ID	SID = $6E –Positive response ID to a Write Data by Identifier request.
ID - Sub function	See *SASAIID configuration data list* on page 17

Negative response

This message is used as negative response to a Write Data by Identifier request.

29 bit CAN identifier	PCI and Frame data bytes			
	Byte #0	Byte #1	Byte #2	Byte #3
CAN ID	PCI	Service ID	ID – Sub function (MSB first)	

SASAIID

CAN ID ID = $1BC268F1 (Here shown with the default sensor node address $4D, and the Danfoss diagnostic tester node address $F1)

29 bit CAN identifier										
Priority			Extended data page	Data page	Type of service (TOS)		Source address		Destination address	
							net	node	net	node
28	27	26	25	24	23	22	21 19	18 11	10 8	7 0
1	1	0	1	1	1	1	000	01001101	000	11110001
$1BC268F1										

PCI PCI = $03 (PCI type = 0, SF Data Length = 3)

Service ID SID = $7F –Negative response ID

ID - Sub function $2EXX (For XX, see the following table)

Byte 2	Error message	Error cause	Service Tool response
$13	Incorrect Message Length Or Invalid Format	The length of the message is wrong	Resend correct command
$22	Conditions Not Correct	This code shall be returned if operating conditions of the server for performing the required action are not met.	Resend command later
$31	Request Out Of Range	This code shall be sent if: **1.** none of the requested data identifier values are supported by the device **2.** the client exceeded the maximum number of data identifiers allowed to be requested at a time	Resend with correct ID / data
$33	Security Access Denied	This code shall be sent if at least one of the data identifiers is secured and the server is not in an unlocked state	Perform security access routine
$72	General Programming Failure	This return code shall be sent if the server detects an error when writing to a memory location	Resend command
$78	Response pending	Routine needs more time	Extend P2_CAN_Server_max to P2*_CAN_Server_max

SASAIID

SASAIID configuration data list

This is a list of all configurable parameters.

Identifier	Name	Access	Value/Range	Default
$0101	Node Address	R/W	$01 – $FD	$4D
$0102	Output mode	R/W	$01 (Single message) $02 (Dual message)	$02
$0103	Message transmission rate (CAN mode)	R/W	$03 (10 ms) $04 (20 ms) $05 (50 ms) $06 (100 ms) $07 (200 ms)	$05
$0104	Zero-index	W	$AA – just a trigger value	$00
$0109	Temperature	R	$XX (8 bit integer),[°C]	
$010A	PGN-offset1	R/W	$01 – $FF	$10
$010B	PGN-offset2	R/W	$01 – $FF	$11
$0201 - $021F	Reserved for supplier			
$F010	Address Format	R	$A5	
$F1FA	Diagnostic File ID Part A	R	$350A706F (MSB first)	
$F1FB	Diagnostic File ID Part B	R	$0D164B57 (MSB first)	
$F1FC	Diagnostic File ID Part C	R	$BC59E069 (MSB first)	
$F1FD	Diagnostic File ID Part D	R	$4ACFFEE7 (MSB first)	
$F193	Hardware version	R	XXXXXXXX (4 characters)	
$F195	Software version	R	XXXXXXXX (4 characters)	
$F18C	Serial Number	R	$XXXXXXXX (32 bit integer, MSB first)	
$F18B	Manufacturing date	R	YY,MM,DD in BCD	

SASAIID

SASAIID technical data

Mechanical

Input range:	Continuous 360° rotation
Rotor torque:	≤ 0.2 N•m
Expected life:	> 10 million cycles

Electrical

Supply voltage:	6 - 36 V_{DC}
Power consumption:	<2 W

Output

CAN V2.0B, (compatible to J1939)

Termination resistor:	120 ohm (optional)
Baud rate:	250 kb/s
Angle:	12-bit word (0 - 4095) relative to a programmable 0-index point.
Resolution:	< 0.1°
Linearity:	<1% of full scale
Angle change:	16 bit integer. Values: primary message from 0–40960. Redundant message: the same but with 20480 offset.

Safety function

Dual CAN output signal (the CAN signals are supervised by the PVED-CLS actuator or alternative external safety controller).

However, the SASAIID has built in these safety and monitoring functions:
- Sensor chip diagnostics
- Steering angle cross-check
- MCU heartbeat check: the two microcontrollers check each other's aliveness
- Power-on memory check

Environmental

|	
Operating temperature:	-40° to 105°C [-40° to 221°F]
Storage temperature:	-55° to 105°C [-67° to 221°F]
Sealing:	IP65
EMI/RFI Rating:	150 V/m
Vibration:	Meets IEC 60068-2-64
Shock:	Meets IEC 60068-2-27 test Ea

Dimensions SASA sensor

P301 221
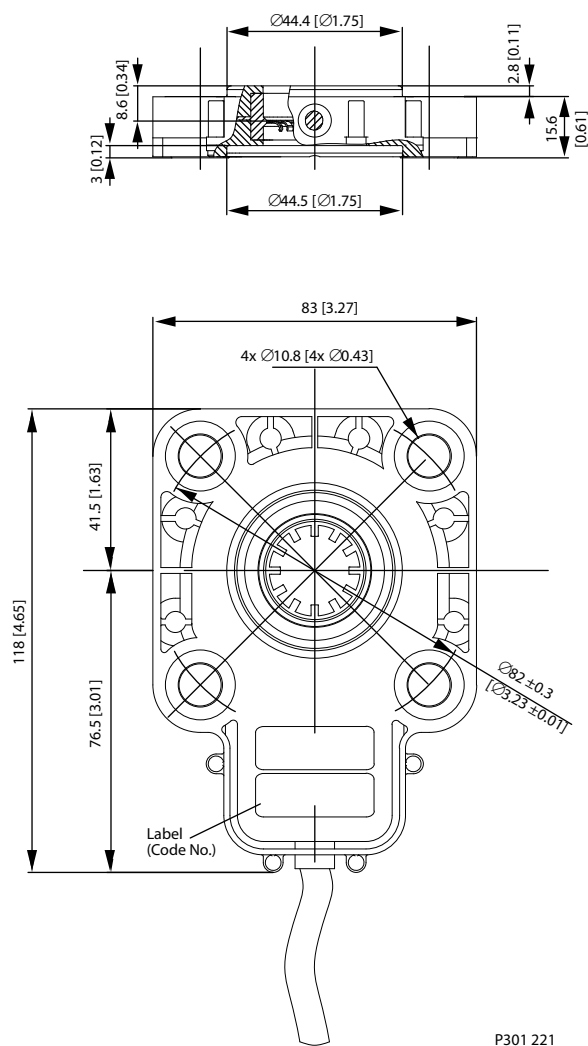
SAK

Code number and weight, SAK adapter kit

Code number	Weight	
	kg	[lb]
150Z6000	0.8	[1.76]

SAK adapter kit

1. Flexible teeth, 12 pieces to interact with splines on steering column

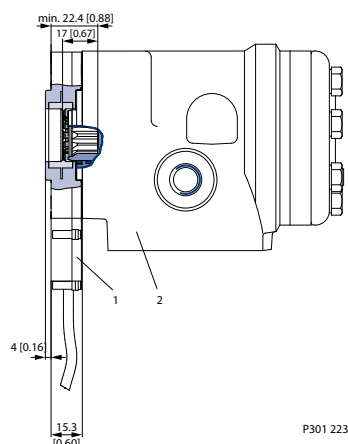**2.** Cable, 500 mm with connector. See "Code numbers" for type of connector
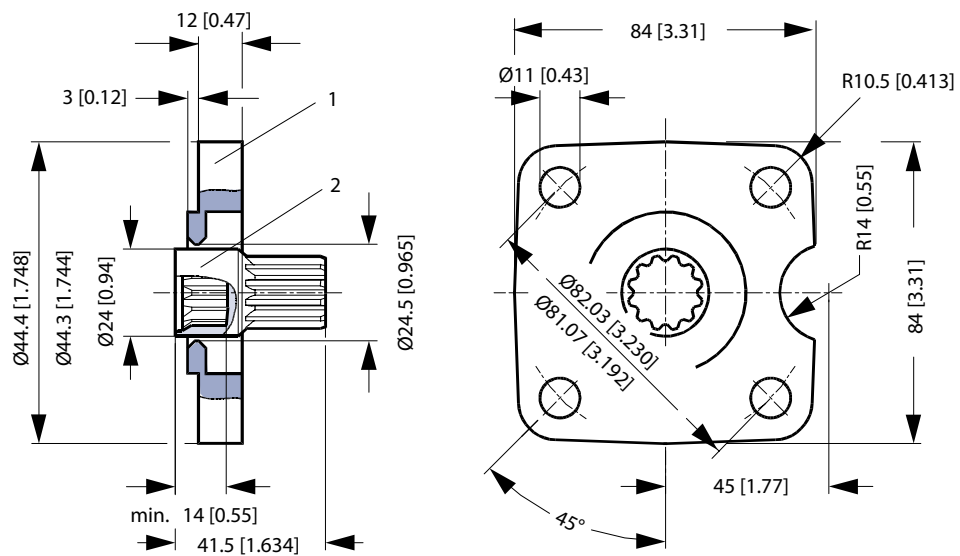
150Z05.10

1. Distance plate

2. Shaft

Installation

SASA has to be mounted between steering column and steering unit (OSP) with 4 bolts max 30 N•m [265.5 lbf•in]. Shaft in column must be 15 mm [0.59 in] longer when using SASA.

Assembly: SASA sensor and OSP steering unit

1. SASA sensor
2. OSP steering unit

⚠ **Caution**

Make sure that the spline profile of the SASA sensor is aligned to the spline profile of the steering column shaft. A safe method of assembly is to place SASA sensor on the steering column spline shaft first – and not opposite! In case of using force, there is a risk of bending the spline profile of SASA sensor.

For use of original steering column, use adapter kit type SAK, see sketch below.

Assembly: SAK adapter kit, SASA sensor and OSP steering unit
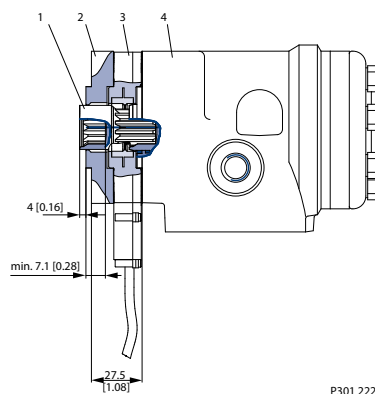
1. Shaft of SAK adapter kit
2. Distance plate of SAK adapter kit
3. SASA sensor
4. OSP steering unit

Installation

Wiring guidelines

- Protect wires from mechanical abuse, run wires in flexible metal or plastic conduits.
- Use 85˚ C (185˚ F) wire with abrasion resistant insulation and 105˚ C (221˚ F) wire should be considered near hot surfaces.
- Use a wire size that is appropriate for the module connector.
- Separate high current wires such as solenoids, lights, alternators or fuel pumps from sensor and other noise-sensitive input wires.
- Run wires along the inside of, or close to, metal machine surfaces where possible, this simulates a shield which will minimize the effects of EMI/RFI radiation.
- Do not run wires near sharp metal corners, consider running wires through a grommet when rounding a corner.
- Do not run wires near hot machine members.
- Provide strain relief for all wires.
- Avoid running wires near moving or vibrating components.
- Avoid long, unsupported wire spans.
- Ground electronic modules to a dedicated conductor of sufficient size that is connected to the battery (-).
- Power the sensors and valve drive circuits by their dedicated wired power sources and ground returns.
- Twist sensor lines about one turn every 10 cm (4 in).
- Use wire harness anchors that will allow wires to float with respect to the machine rather than rigid anchors.

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