

Application Guide

PVED-CLS

Closed loop joystick steering



Revision history

Table of revisions

Date	Changed	Rev
January 2019	Replaced all graphics	0103
December 2018	Corrected document title for consistency	0102
October 2018	First edition	0101

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Introduction

Closed loop joystick overview

This application guide provides information on how to set up a closed loop joystick subsystem when using a PVED-CLS steering actuator in a fluid power system. This information applies to all valve subsystems. The information below details functionality, prerequisites and literature references necessary to successfully and safely set up a closed loop joystick subsystem and tune the steering performance.

Literature references

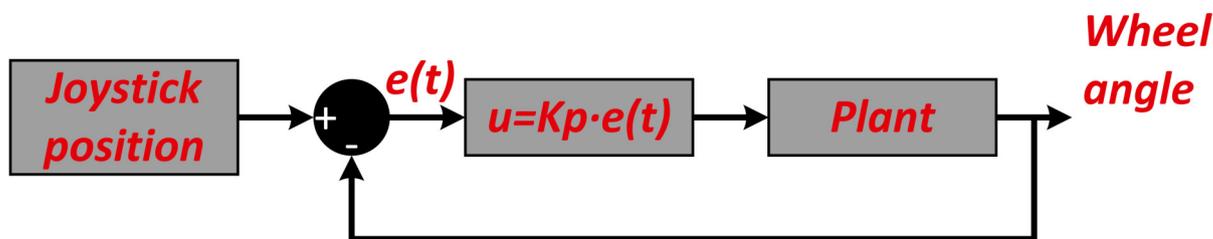
- PVED-CLS user manual (included in firmware release package /technical manuals folder)
- Communication protocol (included in firmware release package /technical manuals folder)
- PLUS+1® Service Tool user guide (found in firmware release package /Service tool folder)
- PVED-CLS safety manual (must be requested from local eSteering Product Application Engineer or sales representative)

Additional resources

- PLUS+1® Service Tool

Closed loop joystick function

The closed loop joystick steering algorithm performs closed loop control of the wheel angle, for two-wheel steered vehicles, or the articulation angle for articulated vehicles. A simple proportional controller is used.



The joystick position corresponds to a wheel angle set-point. The closed loop controller works to minimize the error, thereby the wheel angle will follow the joystick position.

For a closer look at the algorithm, see Control algorithm and steering performance.

Closed loop joystick prerequisites

To successfully setup a closed loop joystick subsystem, the following components must have been installed.

- Man-Machine-Interface subsystem
- Vehicle speed sensor subsystem
- Wheel angle sensor subsystem which has been calibrated
- CAN based joystick¹
- CG-150 CAN gateway
- Spool calibration

¹ The CAN based joystick must follow the protocol described in the section **AUX sensor as a joystick** in *PVED-CLS Controller for Electrohydraulic Steering Communication Protocol Version 3.44*

Introduction

Downloading the required software

1. Download the desired or latest firmware release package on the [PVED-CLS web page](#)
2. Optional: Request and download the [PLUS+1® Service Tool](#) under **Service Tool: Request** heading.

Preparing the PVED-CLS for configuration

The following steps detail how to load service pages and diagnostic data files onto the PVED-CLS as well as how to set your Parameter Sector Access Code.

1. Connect the CG-150 to the PC and the CAN bus.
2. Open the PVED-CLS service pages (.PID file) found in the `\Service tool` folder found in the release package.

The document *PLUS+1 Service tool user guide.pdf* describes how to load the service pages into the PLUS+1® Service Tool and how to install Diagnostic data files. The Diagnostic data files folder in the release package.

3. Download the PVED-CLS bootloader and application software into the PVED-CLS if the firmware version installed on the PVED-CLS does not match the version being used.
4. On the info page, select your Parameter Sector Access Code Level using the drop-down list.
5. Press **Edit PASC** and enter the Parameter Sector Access Code.
6. Click OK.

The closed loop joystick subsystem is now ready to be configured in the PVED-CLS.

Configuring the closed loop joystick subsystem

Closed loop joystick interface selection

The auxiliary interface must be activated and set to a closed loop joystick.

1. In the PLUS+1® Service Tool, navigate to **Peripherals Config > AUX Config**.
2. Set an auxiliary device to be present in the system by setting parameter **P3239: AUX present** to "Present."
3. Select the auxiliary type to be a closed loop joystick by setting parameter **P3240: AUX type** to "Closed Loop Joystick."
4. Press **Download parameters** and once the download is done validate that the read back parameters of the entire page are correct and press **Approve parameters**.

The PVED-CLS is now setup to utilize the closed loop joystick sub-system.

The MMI message includes a flag to set if auxiliary steering is allowed or prohibited. If the flag is set to "AUX steering prohibited", it will not be possible to activate the closed loop joystick steering. For further information see *PVED-CLS Controller For Electrohydraulic Steering Communication Protocol Version 3.44*.

Closed loop joystick engaging settings

Closed loop joystick steering mode will be engaged when the following conditions are met.

- **AUX steering device lockout** flag in operation status message is shown as **AUX steering allowed**.
- **Joystick enable signal** flag in the AUX messages is shown as **active**.
- The absolute error (wheel angle – wheel angle set-point), is less than the value specified by parameter **P3732: AUX joystick - Max closed loop error for engaging closed loop joystick steering**.

Changing parameter P3732

If the absolute error (wheel angle – wheel angle set-point) is less than the value found in parameter **P3732: AUX joystick - Max closed loop error for engaging closed loop joystick steering**, then the wheels can move to the corresponding position of the joystick. If **P3732** is set too high, the wheels can very quickly change angles, potentially causing a tipping hazard while moving at high speed. If the parameter is set too low, it may be hard to match the joystick angle to the current position of the wheels. In either case the setting needs to be changed.

The following steps detail how to set the absolute error value.

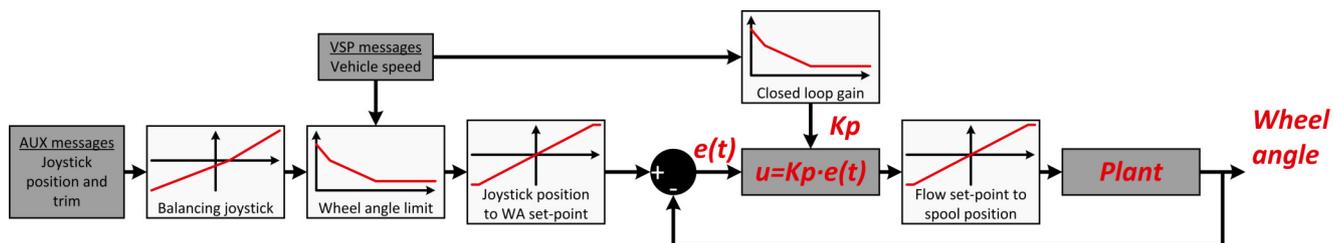
1. Navigate to **AUX Config > AUX-Closed loop joystick** in the PLUS+1® Service Tool.
2. Change the value of **P3732: AUX joystick - Max closed loop error for engaging closed loop joystick steering** either by using the up/down arrows or entering a value using the keyboard.
3. Press **Download parameters**.
4. After the download is complete, verify that the parameters on the entire page are correct and press **Approve parameters**.

Control algorithm and steering performance

Closed loop joystick algorithm

The diagram below shows the closed loop joystick algorithm.

Closed loop joystick algorithm representation



The algorithm can be broken down and explained in five parts:

- Balancing joystick
- Vehicle speed dependent wheel angle limit
- Joystick position to wheel angle set-point scaling
- Vehicle speed dependent closed loop gain
- Closed loop controller, flow set-point and spool set-point

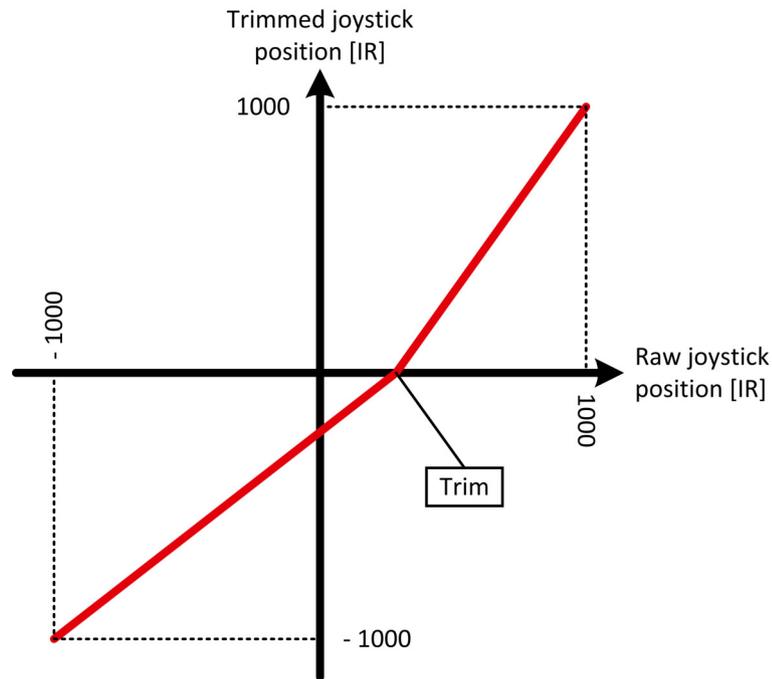
Control algorithm and steering performance

Balancing joystick

The vehicle will drive in a circle (instead of straight ahead) if there is a misalignment between the neutral position of the joystick and the neutral position of the wheels. To avoid this misalignment, the AUX message includes a trim signal.

The trim signal will offset the neutral position with a piecewise linear function, which converts the joystick position to a scaled joystick position that will be used by the control algorithm.

Example of joystick trim



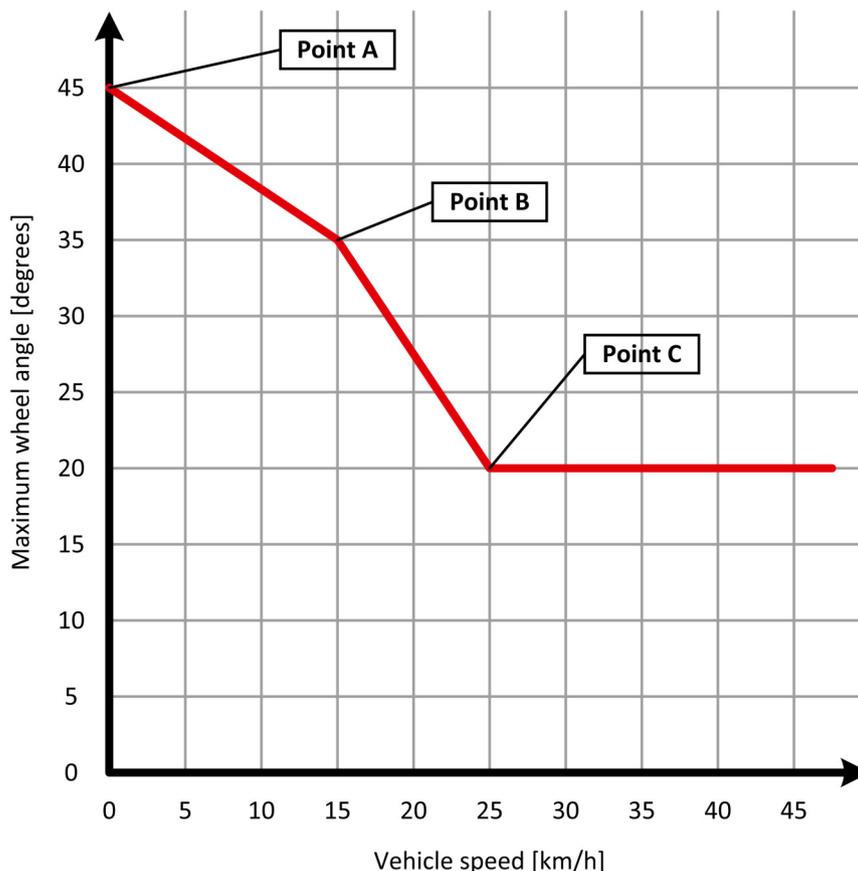
The example above shows a situation where the joystick neutral position has been trimmed to the right.

[For more information on the joystick neutral trim, see *PVED-CLS Controller for Electrohydraulic Steering Communication Protocol Version 3.44*.](#)

Control algorithm and steering performance

Vehicle speed dependent wheel angle limitation

The maximum wheel angle commanded by the closed loop joystick algorithm can be configured to be dependent on vehicle speed. A piecewise linear function configured by three points will be used to calculate the maximum wheel angle for a given vehicle speed.



The following parameters are used to configure the piecewise linear function shown above:

- Point A** P3720: AUX joystick - Max wheel angle @ Point A
- Point B** P3721: AUX joystick - Max wheel angle @ Point B
 P3723: AUX joystick - Vehicle speed limiting wheel angle @ Point B
- Point C** P3722: AUX joystick - Max wheel angle @ Point C
 P3724: AUX joystick - Vehicle speed limiting wheel angle @ Point C

Changing the parameters

To change the setting for the above parameters, follow these steps.

1. Navigate to **AUX Config > AUX-Closed loop joystick** in the PLUS+1® Service Tool.
2. Set parameters to the desired values.
3. Press **Download parameters**.
4. After the download is complete, verify the parameters on the entire page are correct and press **Approve parameters**.

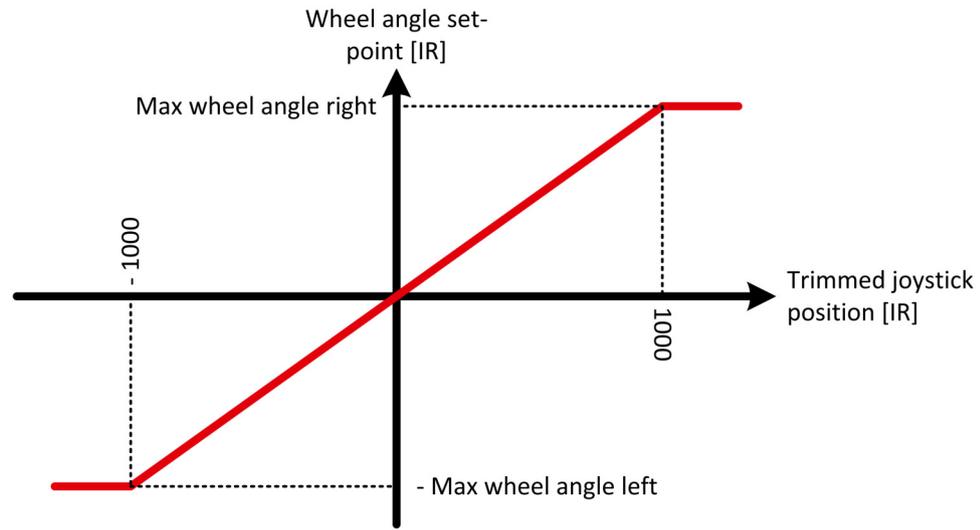
Control algorithm and steering performance

Joystick position to wheel angle set-point scaling

The wheel angle set-point is found by scaling the trimmed joystick position to a wheel angle set-point, using a piece-wise linear function.

The function uses the joystick position range (X axis on below figure) and the max wheel angle found by the vehicle speed dependent wheel angle limitation function (Y axis).

Example of scaling from joystick to wheel angle set-point



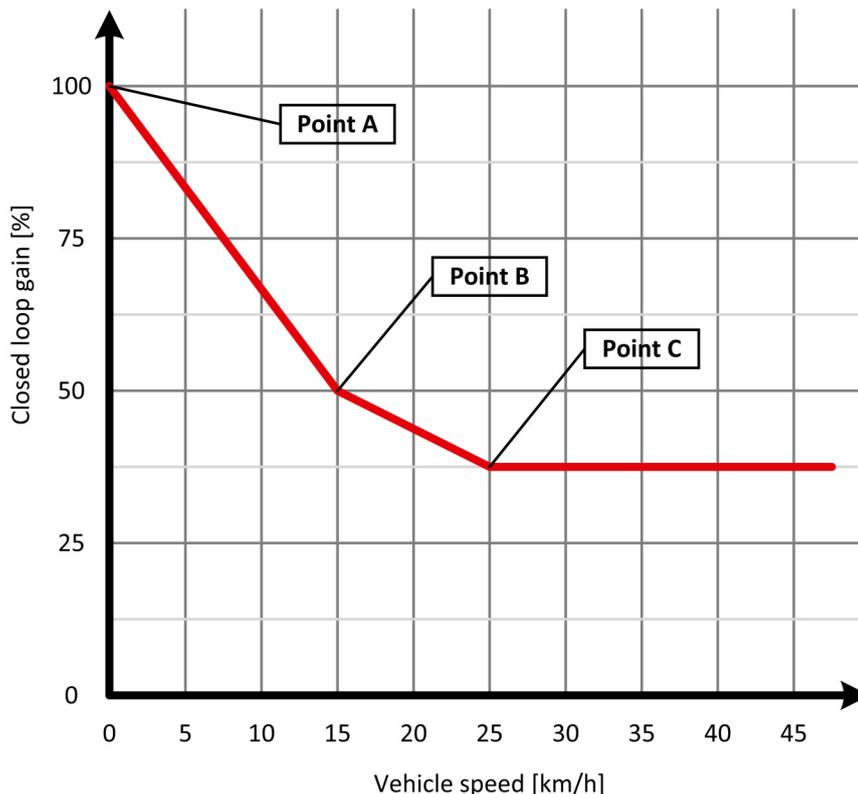
The wheel angle set-point and the measured wheel angle will be used to calculate the closed loop error.

Control algorithm and steering performance

Vehicle speed dependent closed loop gain

The closed loop gain used by the closed loop joystick control algorithm can be configured to be dependent on vehicle speed. A piecewise linear function configured by three points will be used to calculate the closed loop gain for a given vehicle speed.

Vehicle speed dependent closed loop gain example



The following parameters are used to configure the piecewise linear function shown above.

Point A	P3725: AUX joystick - CL gain @ Point A
Point B	P3726: AUX joystick - CL gain @ Point B P3728: AUX joystick - Vehicle speed @ Point B
Point C	P3727: AUX joystick - CL gain @ Point C P3728: AUX joystick - Vehicle speed @ Point C

Changing the parameters

To change the setting for the above parameters, follow these steps.

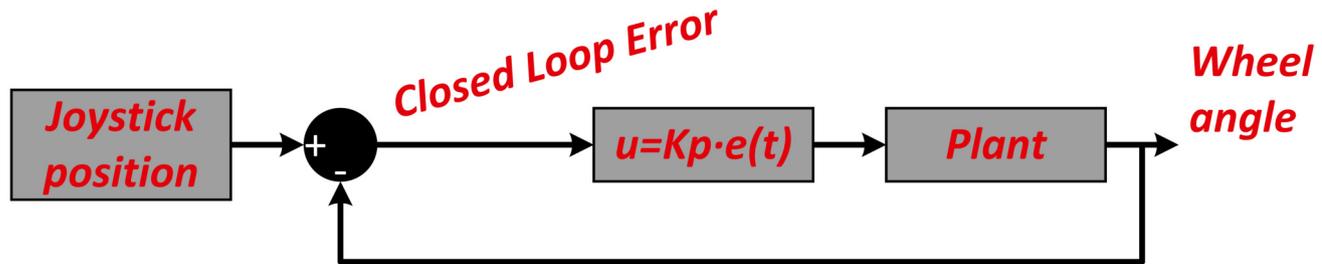
1. Navigate to **AUX Config > AUX-Closed loop joystick** in the PLUS+1® Service Tool.
2. Set parameters to the desired values.
3. Press **Download parameters**.
4. After the download is complete, verify the parameters on the entire page are correct and press **Approve parameters**.

Control algorithm and steering performance

Closed loop controller, flow and spool set-points

The input for the closed loop controller is the error between wheel angle set-point and the measured wheel angle.

Example of wheel angle controlled by joystick input

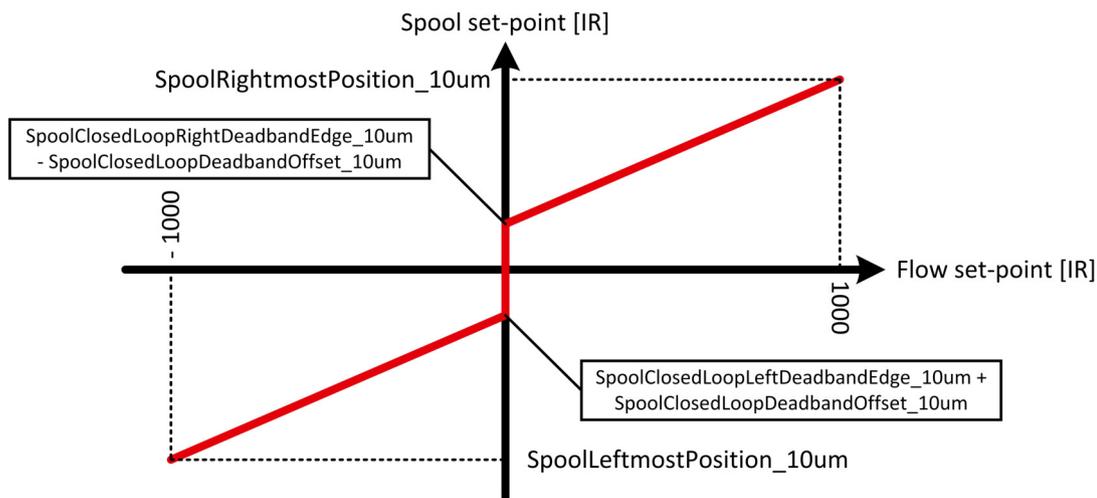


The output of the control loop is a flow set-point. Since a P-controller is used, the controller is represented by the following equation:

$$\text{FlowSetpoint_IR} = (\text{AUX_ClosedLoopGain} * \text{AUX_ClosedLoopError}) / 10$$

The flow set-point is scaled to spool set-point by a piece-wise linear function defined by the EEPROM parameters found during the spool calibration.

Scaling from flow set-point to Spool set-point



For optimal closed loop joystick steering performance, it is important that the spool calibration parameters are correct.

Closed loop joystick safety functions

The PVED-CLS includes several safety functions for closed loop joystick steering. These safety functions can be used for risk mitigation on the system level.

These safety functions are:

- Closed loop Auxiliary steering device sensor subsystem SSM_064
- Safe Closed loop joystick engage SSM_063
- Vehicle speed dependent wheel angle limitation - closed loop joystick SSM_062
- Auto-guidance disengage by AUX steering device - closed loop joystick SSM_065

[For more information, see the latest version of the *PVED-CLS Safety Manual*.](#)

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Local address:

**Danfoss
Power Solutions (US) Company**
2800 East 13th Street
Ames, IA 50010, USA
Phone: +1 515 239 6000

**Danfoss
Power Solutions GmbH & Co. OHG**
Krokamp 35
D-24539 Neumünster, Germany
Phone: +49 4321 871 0

**Danfoss
Power Solutions ApS**
Nordborgvej 81
DK-6430 Nordborg, Denmark
Phone: +45 7488 2222

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