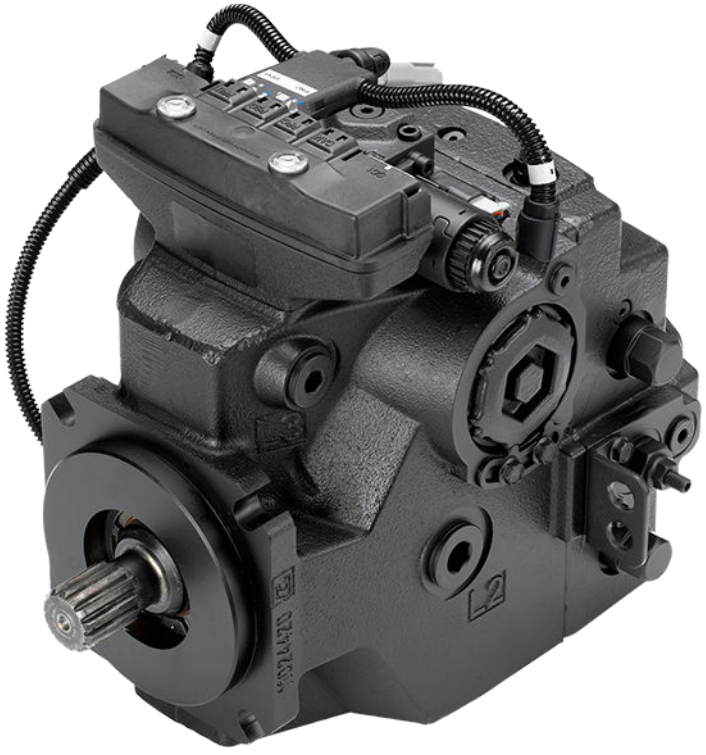
ENGINEERING
TOMORROW

Technical Information

Automotive Controls for H1 Single Pumps
AC–1 and AC–2



Revision history

Table of revisions

Date	Changed	Rev
May 2017	Major update.	0501
May 2014	Size 165 added	DA
Feb 2014	Layout in DITA CMS	CA
Oct 2013	Converted to Danfoss layout	BA
Jan 2013	All frame sizes into one document	AA

Contents

General description

Automotive Control system description

The Automotive Control is designed to control a single-path hydrostatic transmission system consisting of one pump and one motor. The hydrostatic pump is equipped with 2 proportional valves.

The Automotive Control is divided into 2 systems, AC-1 and AC-2. AC-2 is an extension of AC-1 that features an integrated pump swash plate angle sensor and software enabled functions such as Swash Plate Control and Flow Limiter.

The AC is optimized for use with a hydrostatic motor equipped with Pressure Control Override (PCOR) or Proportional (PROP) valve to control pressure or motor displacement. Additionally a Brake Pressure Defeat (BPD) digital control valve can override the hydraulic pressure control during vehicle decelerating.

Parking brake valve, Reverse motion buzzer, Forward/Reverse Lamp Indicator, a Retarder valve and a Stabilizer valve can be controlled by additional digital outputs. All functions may not be available simultaneously.

The H1 AC can read several analog, digital, and frequency signals representing operator input, system demands, and machine status inputs.

The CAN Comunication Interface is used for diagnosis purposes and for information exchanging with other controllers such as engines, other Danfoss Power Solutions or customer controllers.

Automotive Control advanced functions

The Automotive Control commands the basic vehicle driving behavior and performance (i.e. acceleration, deceleration, and vehicle speed). The operator selects the driving mode, driving direction, and basic transmission set point command via throttle or Creep/Drive pedal. An additional input, the inch pedal command, can be used to override the basic transmission command.

A number of advanced features can be independantly activated and configured depending on the installed Application Software package. Below is a list of the primary advanced functions:

- Engine and motor over-speed protection
- Engine anti-stall
- Constant speed control
- ECO fuel saving mode
- Vehicle speed limitation and flow limiter
- Intelligent operator presence detection
- Electronic swash plate control
- Temperature compensation and overheat-protection
- Maximum motor torque at vehicle start
- Engine speed dependend retarder control
- Cruise Control in Work mode

Automotive Control hydrostatic propel methods

The application software provides three different hydrostatic propel methods, defined as mode types, which can be used individually.

Automotive	Load dependent (torque controlled) driving behaviour. Setpoint for the drive curve is the engine rpm. Primarily intended for wheel loader and telescopic handler applications.
Non-Automotive	Load independent (speed controlled) driving mode. The setpoint for the drive curve is a Joystick or pedal signal, independent of the engine rpm. The best performance can be achieved with a AC-2 Swash Plate Angle Sensor.

General description

	Primarily intended for sweeper, forestry, and forklift applications.
Creep-Automotive	Load dependent (torque controlled) driving behaviour. Setpoint for the drive curve is the engine rpm. The setpoint can be reduced by the creep potentiometer if a high engine rpm in combination with low vehicle speed is needed. Primarily intended for wheel loader and telescopic handler applications.

All mode types are available as part of the basic application (hardware and software) and can be independently configured for performance utilizing advanced software and hardware settings. Each selectable system mode can be configured as one of the 3 mode types (hydrostatic propel methods):

- Automotive Mode
- Non-Automotive Mode
- Creep-Automotive Mode; (combination of Automotive and Non-Automotive)

General description

System modes and selection

The application simultaneously supports up to 4 system modes. The system modes define the basic characteristic of the transmission and are operator selectable via 2 digital inputs: Mode Switch A and Mode Switch B. Each of the four system modes can be optimized for driving behavior through independent drive curves with individual pump and motor ramping.

Each of the four system modes can be configured as any one of the mode types (propel methods).

The following table describes the relationship between the digital input mode switches and the resulting system modes.

Modes and selection

		System mode			
		Mode 1	**Mode 2**	**Mode 3**	**Mode 4**
Mode Switch A		Low	Low	High	High
Mode Switch B	Nominal	Low	High	Low	High
	Redundant	High	Low	High	Low

Functional option packages

AC functional option packages available for all H1 pumps

Option package	AC1	AC2	Functional basis	CAN J1939	ECO fuel saving	SIL 2 additional features	Cruise control
E	●	—	●	in/out	●	—	—
F	●	●	●	in/out	—	—	—
H	●	●	●	out	—	●	—
J	—	●	●	in/out	●	—	●

Functions

Basic Functions

Inching

The inch function allows the operator to reduce the vehicle speed, stop the machine or keep the vehicle speed low while raising the engine speed to meet auxiliary flow demands.

Drive/Creep Pedal

The drive pedal allows the operator to command the vehicle speed through pump and motor displacement setpoint. In addition a CAN controlled engine can be commanded.

The Creep potentiometer function will keep the vehicle speed low while raising the engine speed to meet auxiliary flow demands.

Joystick or Rocker Pedal

A Joystick or Rocker Pedal will combine the function of the drive pedal with FNR direction switch.

Not available in special settings: D3E, D4E, D5J or D6J.

Four Selectable System Modes

The application supports 4 configurable System Modes which are selectable with digital inputs Mode Switch A and Mode Switch B. Each System Mode can be individually configured through Mode Type (Automotive, Creep-Automotive, Non-Automotive) and all advanced functions (e.g. CSD, Antistall, Overspeed Protection, etc.).

Independent Pump/Motor Profiling & Ramping

The pump and motor curves can both be independently configured for the forward and reverse driving direction in each of the four modes. The software application facilitates individual command profiles.

Configurable System Mode and Direction Change

This function allows configuration of an application specific System Mode transition. The System Mode change conditions can be dependent on multiple factors including actual FNR Direction, Drive Pedal Input, and Ground Speed. The vehicle driving direction change can be configured on vehicle speed and/or measured pump swashplate angle dependency.

Pump Speed Sensor

The pre-installed pump speed sensor is connected to calculate the pump/engine rpm. The calculated engine rpm is the setpoint for the automotive drive curve.

Hydro-Motor Speed Sensor

A hydro-motor speed sensor can be connected to calculate the vehicle speed utilizing the configured final drive ratio & wheel diameter. The calculated vehicle speed enables advanced functions such as constant speed drive and vehicle speed limitation.

Proportional Pump Displacement Control

The proportional pump displacement is directly controlled by the measured engine rpm. (Automotive Mode = NFPE). For each of the four System Modes two independent profile curves for forward & reverse are available.

Load Independent Pump Displacement Control (Option AC2)

The load independent pump displacement control maintains commanded swash plate position independent of load (Non-Automotive, similar to EDC behavior) using electronic feedback from the

Functions

pump swash plate angle sensor. The function can be enabled individually for each of the four System Modes. Two independent profile curves for forward & reverse are available.

Caution

Required control: P8 or P9 / R4 or R5.

Engine Anti-Stall Protection

The Engine Anti-Stall prevents the engine from being stalled due to overload through the transmission system. If the engine is drooped, the engine anti-stall function will reduce the pump command to reduce the engine load and prevent the engine from stalling. The engine anti-stall can be individually enabled for each system mode and is configurable at:

- A fixed engine rpm setpoint or
- A variable engine rpm, commanded by the drive pedal (needs a CAN controlled engine)

Hydro-Motor Displacement Control

Variable displacement and 2-Position motors can be controlled directly. The hydro-motor command can be defined by a constant value or a profile curve output, individually for each of the four System Modes and driving direction.

Hydro-Motor Brake Pressure Defeat (BPD) Control

The Motor BPD Control is used in combination with a pressure controlled (PCOR) hydro-motor control. It prevents the activation of the internal motor control pressure compensator (PCOR) during deceleration events. The Motor BPD Control is activated by the pump command (System State Change) or the measured vehicle driving direction (needs a hydro-motor speed and direction sensor)

Caution

Requirement: hydro-motor speed and direction sensor.

Maximum Hydro-Motor Torque at Low Vehicle Speed

This function will command the hydro-motor to max displacement during low vehicle speed to provide the maximum available torque. If the defined vehicle speed is reached, the hydro-motor will follow the original drive curve. A hydro-motor or vehicle speed sensor is required to detect the actual vehicle speed.

Caution

Requirement: hydro-motor and speed sensor.

Functions

Performance Functions

Vehicle Constant Speed Drive (CSD)

The CSD function will allow driving the vehicle with a constant speed, independent of the load. If the actual vehicle speed differs from the commanded speed, the CSD function will adjust the pump command to compensate the speed difference. The speed set-point can be generated either:

- By an electric drive pedal or
- Calculated by the pump rpm and pump command

For the feedback a hydro-motor or vehicle speed sensor is required.

Caution

Requirement: hydro-motor speed sensor.

Vehicle Speed Limitation

The Vehicle Speed Limitation prevents the machine from over-speeding and can be used e.g. for export machines to different countries. The vehicle speed limitation can be configured separately for each System Mode and driving direction. The feedback signal comes from:

- A hydro-motor or vehicle speed sensor
- The measured pump swash angle/displacement (only option AC2)

Caution

Requirement: hydro-motor speed sensor or control P8 or P9 / R4 or R5.

Park Brake Control

The Park Brake Control digitally activates (apply/release) a park brake. Park brake activation can be by CAN signal or vehicle speed dependent with additional dependency on:

- Software machine state in STOP mode
- Actual pump valve current below user defined value
- Actual inch pedal command exceeds user defined value.

Delay times for park brake application and release are individually configurable

Park Brake Test Mode

For Roller applications the Park Brake must be checked in intervals. The Park Brake Test Mode according SAE J1472 / EN500-4 allows the hydrostatic transmission system to drive against the applied park brake and can be individually configured for each System Mode.

Dynamic Brake Light Control

The dynamic Brake Light control uses the inch signal to trigger a digital output for the brake light.

Forward and Reverse Direction Output

The Forward and Reverse Direction Output function digitally drives lamps or LED's to indicate the selected driving direction from the FNR.

Reverse Driving Direction Buzzer Output

The Reverse Driving Direction Buzzer Output controls a buzzer that indicates reverse driving direction. The output logic can be directly controlled by FNR status or by actual propel movement

Functions

Vehicle Speed Dependent Output Signal

The Vehicle Speed Dependent Output Signal toggles a digital output when the actual vehicle speed exceeds a user defined speed. It can be used e.g. for a speed dependent load stabilizer valve.

Retarder Control

The engine Speed Dependent Retarder Control toggles a digital output when the actual engine rpm exceeds a user defined level. The Retarder can activate a valve of the work hydraulic to give load to engine and prevent an over speeding.

Status Output (Red LED)

In case of an Error, the status LED shows a blink code. The LED is continuously on, if the Start Protection is activated.

Pump Hysteresis Compensation

The pump hysteresis incurred while stroking or de-stroking the swash plate is measured in the factory. The hysteresis value is stored in the controller and will used to correct pump command.

Temperature Compensation

An integrated sensor will measure the temperature to compensate the oil viscosity influence. Parameter for high and cold temperature will adjust the pump command.

J1939 CAN Subsystem Data Interface

The AC Control can exchange information with the vehicle system via the CAN bus. The following standard messages are supported: TSC1 (Torque/speed control), EEC1 (pump/engine rpm), EEC2 (drive pedal), EBC1 (Inch pedal), ETC5 (FNR), VH (vehicle hours), RCI (brake remote control), OPS (operator presence), CC VS (vehicle speed), VEP1 (battery voltage), TRF1 (oil temperature).

Additional Danfoss Power Solutions specific (proprietary) messages are available to share information about Mode switches, Hydro motor rpm, Transmission state and error messages. All messages can be individually activated and designated for usage.

J1939 CAN Pedal Calibration

The calibration of the inch and drive pedal may be started via an external CAN interface (e.g. dash-board).

ECO Fuel Saving Mode

The ECO Mode will reduce the diesel engine rpm to save fuel during transport. The function can be enabled in each of the four driving modes. The activation of the ECO Mode will be automatically when the vehicle speed reaches the defined ECO speed.

Caution

Requirements: Control P6 or P7 / P5 or R3 and Special Setting D3E or D4E.

Cruise Control

The Cruise Control function is designed for a work mode with fixed engine speed. The driver can "store" the vehicle speed and release the driver pedal. The Cruise Control function will keep the vehicle speed constant by using different feedback signals like: vehicle speed, pump swash angle and system pressure.

Caution

Requirements: Control P8 or P9 / R4 or R5. and Special Setting D5J or D6J.

Functions

Protection and Safety Functions

Safety Controlled Vehicle Start-Protection

The Safety Controlled Vehicle Start Protection prevents uncommanded, unexpected, or otherwise dangerous machine propel movement after initial power on of the AC system. The Start Protection is monitoring the following signals:

- Engine rpm
- Battery voltage
- Error status
- Inch calibration
- FNR in Neutral

If all conditions are fulfilled the Start Protection will switch OFF and the vehicle can drive.

Operator Presence Detection

The Operation Presence Detection monitors the presence of the operator in the seat (seat switch) and an optional current activity (Throttle, Drive Pedal, Inch Pedal). It will stop the machine under predefined circumstances.

Hydraulic System Overheat Protection and Low Temperature Protection

An integrated sensor will measure the temperature. The function protects the complete hydrostatic system by reducing the pump flow (by pump command) at extreme high or low temperatures according to user defined temperature curve.

Hydromotor Over Speed Protection

The Hydromotor Over Speed Protection prevents the hydrostatic motor from over speeding by either decreasing pump displacement or increasing motor displacement. The hydromotor rpm speed limit, is user defined and valid in all four System Modes when activated.

SIL 2 Certification/Compliance

The H1 AC fulfills the requirements of the guidelines accordant to IEC 61508, SIL 2 (Functional safety of electrical / electronic / programmable electronic safety-related systems (1998-2000)). The specified documents have been presented to the certification body TÜV NORD, Hamburg.

The electronic hardware and the hardware development process comply with the requirements of IEC 61508-1 (version 1998-12), subset for hardware, and IEC 61508-2 (version 2000-05), SIL 2.

The software and the system development process comply with the requirements of IEC 61508-1 (version 1998-12), subset for software and system, and IEC 61508-3 (version 2000-05), SIL 2.

The SIL 2 compliance will support and accelerate the certification process on vehicle system level at the customer. The H1-AC can be used in safety-related systems with a max. Performance Level (PL) d (ISO13849-1) or SILCL2 (IEC62061). All wires, sensors or actuators that are connected to the H1-AC have to verified and validated against the safety requirements on machine level by the customer.

Caution

Special setting requirements: D3H, D4H, D5H or D6H.

Quick Stop

To move the vehicle in Transport Mode (Automotive or Creep-Automotive), the AC Control will use the engine rpm as the setpoint. The electric drive pedal position (out of the deadband) is used as an enable signal.

Functions

The driver must press the drive pedal and the engine rpm must rise to move the vehicle. If the driver release the drive pedal fully (drive pedal return into the deadband), the pump current will decrease with an adjustable ramp to a defined value and the vehicle will stop.

Engine control and protection

J1939-CAN Engine Interface

The AC control can exchange information with the engine via the CAN J1939 protocol. All CAN messages can be individually activated and designated for usage. The following functions and standard messages are provided:

- Engine speed control (TSC1) via redundant drive pedal
- Engine Anti-Stall protection
- Engine Overspeed protection during inching
- Engine Overspeed protection with Retarder function
- Cold start protection

Engine Speed Control

An electric drive pedal with redundant input can be connected to the AC Control. The Engine Speed setpoint is transmitted via CAN TSC1 to the engine controller.

Engine Anti-Stall Protection

The Engine Anti-Stall prevents the engine from being stalled due to overload through the transmission system. If the engine is drooped, the engine anti-stall function will reduce the pump command to reduce the engine load and prevent the engine from stalling.

Engine Over Speed Protection During Inching

To decelerate the vehicle, the inch command will decrease the pump command. The pump displacement is reduced and the engine rpm will rise due to high oil flow. The engine overspeed protection will reduce the inch command proportional if the engine rpm is above the configured level. When the pump displacement increases, the engine rpm will be reduced.

Engine Over Speed Protection with Retarder

The engine rpm dependent Retarder Control toggles a digital output when the actual engine rpm exceeds a user defined level. The Retarder can activate a valve of the work hydraulic to give load to engine and prevent an over speeding.

Caution

Special setting D3E, D4E, D5J or D6J.

Cold Start Protection

An integrated sensor will measure the system temperature. When the temperature is lower than a user defined level, the engine rpm command (TSC1) is limited till the system is warmed up to protect the engine and the hydraulic system..

J1939 CAN Engine rpm Monitoring

The AC control commands the CAN engine via (TSC1) message and monitors the engine/pump rpm by the integrated rpm sensor. The engine rpm command can be modified by an external controller, but only if the vehicle is in Stop mode. If the engine rpm command is modified by an external controller while driving, the AC control handle it as an error and ramp down into Safe mode to stop the vehicle.

Requirements

SIL 2 requirements

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To ensure the SIL 2 compliant to the IEC 61508, it is mandatory to use the certified PLUS+1® Service Tool, Version 7.2.10 for any parameter settings, changes, up- and downloads of parameter or application software.

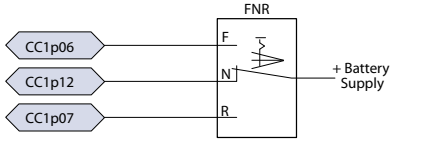
PLUS+1® Service Tool (IEC 61508 SIL 2 Certified), Version: 7.2.10

Caution

CAN Input options are not certifiable according SIL 2 of IEC 61508. Danfoss is not responsible for the function and safety third-party sensors and actuators which are connected to the AC.

General customer sensor requirements

FNR



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To become SIL 2 compliant, the following settings are required:

- Switch to be supplied by battery voltage
- Switch to be compliant to the input resistance of the digital input
- Gold-plated contacts are recommended
- 3-layer switch with continuous signal
- Separate output signals for **FORWARD**, **NEUTRAL** and **REVERSE** indication as input signals of the AC connector pins for CC1: p06, p07 and p12
- Input selector configuration:
  - **FNR source:** FNR signal from digital inputs
  - **FNR signal (continuous) interpretation:** F or R or N held

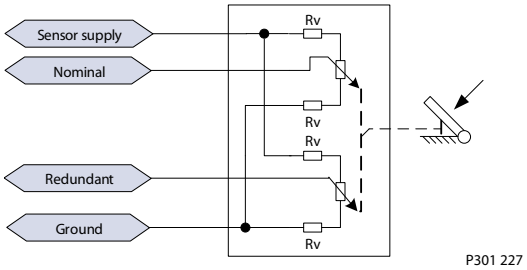
If no SIL 2 compliance is required, the following settings are possible:

- 2-layer switch for **FORWARD** and **REVERSE** minimum
- Input selector configuration:

Requirements

- **FNR source:** FNR signal from digital inputs on via CAN bus
- **FNR signal interpretation:** held or momentary

Drive / Creep / Joystick / Rocker and Inch Pedal



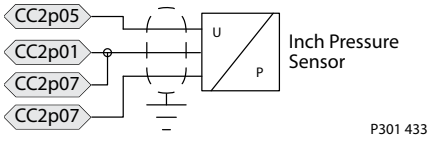
To become SIL 2 compliant, the following settings are required:

- Sensor must be supplied with AC sensor supply voltage and must not exceed the maximum output current (overload).
- This sensor must produce two electrically independent output signals that are in direct correlation with each other. The difference of the two input signals should be 500 mV. The redundant tolerance should be set to ± 200 mV.
- In case of an internal detected error, the sensor output signal has to be clamped by the sensor itself to sensor supply voltage. This feature enables the software application to recognize this failure.
- The first output signal is used as the source of pedal position signal. It must rise when the pedal is pressed. The second output signal is used for diagnostic purposes.
- The voltage range of the output signals must not be lower than 5% and not higher than 95% of sensor voltage. Upper and lower voltage limits to sensor supply are requested for wire-fault detection.

If no SIL 2 compliance is required a single output (not redundant) is possible.
Joystick or Rocker Pedal function is not SIL 2 compliant.

Pressure inch sensor

Pressure inch sensor schematic



To become SIL 2 compliant, the following settings are required:

- Sensor must be supplied with AC sensor supply voltage and must not exceed the maximum output current (overload).
- The signal must rise when the pedal is pressed.
- The voltage range of the output signals must not be lower than 5% and not higher than 95% of sensor voltage. Upper and lower voltage limits to sensor supply are requested for wire-fault detection.
- In case of an internal detected error, the sensor output signal has to be clamped by the sensor itself to sensor supply voltage. This feature enables the software application to recognize this failure.

When using an inch pedal without mechanic brake function:

Requirements

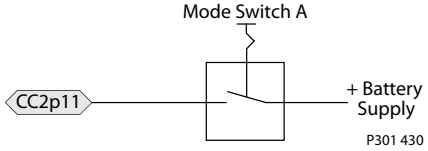
- This sensor must produce two electrically independent output signals that are in direct correlation with each other. The difference of the two input signals should be 500 mV. The redundant tolerance should be set to ± 200 mV.

When using a hydraulic brake function with brake pressure sensor:

- A redundant signal is not needed. A single output signal is sufficient, because the redundancy is here given by the hydraulic brake system and the direct measurement of the braking pressure. The inch function is only supporting the vehicle brake system to prevent driving against the brakes.
- Recommended pressure sensors MBS 1250 Nr.: **11044562**

Mode switch A

Mode switch A schematic

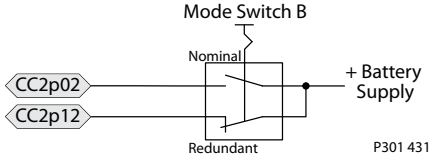


To become SIL 2 compliant, the following settings are required:

- Switch to be supplied by battery voltage
- Switch to be compliant to the input resistance of the digital input
- Gold-plated contacts are recommended
- No loads (e.g. valve) in parallel

Mode switch B

Mode switch B schematic

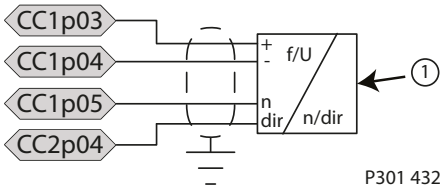


To become SIL 2 compliant, the following settings are required:

- Switch to be supplied by battery voltage
- Switch to be compliant to the input resistance of the digital input
- Gold-plated contacts are recommended
- No loads (e.g. valve) in parallel
- Switching logic to be diverse redundant (opening and closing in parallel)
- Input selector configuration (Software Parameter settings):
  - for all system mode changes from **Automotive** and **Creep-Automotive** to **Non-Automotive** and vice versa. The parameter Mode Switch B Redundant must be configured as Redundant
  - for **Automotive** to **Creep-Automotive** mode and vice versa. This is not mandatory.

Requirements

HST motor speed sensor with optional direction indication



Legend: 1 – HST motor speed sensor with optional direction indication

- Sensor must be supplied with AC sensor supply voltage and must not exceed the maximum output current (overload).
- The voltage range of the output signals must not be lower than 5% and not higher than 95% of sensor voltage. Upper and lower voltage limits to sensor supply are requested for wire-fault detection.
- PPU must comply with input resistance of the RPM and analog input
- Recommended speed and direction sensor Nr.: **11046759**

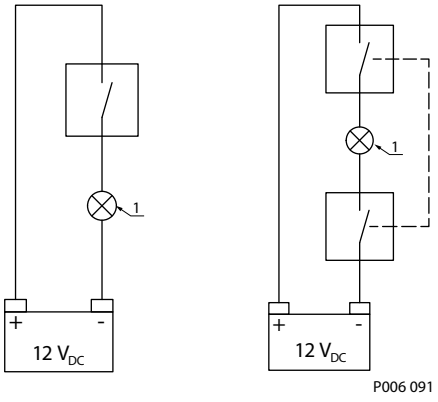
Motor displacement and Brake Pressure Defeat (BPD)

The digital and PWM outputs are supplied with battery voltage and must not exceed the max. output current (overload).

General Customer Actuator Requirements

In general there are two different circuit designs available:

Open loop (left) and Closed loop (right)



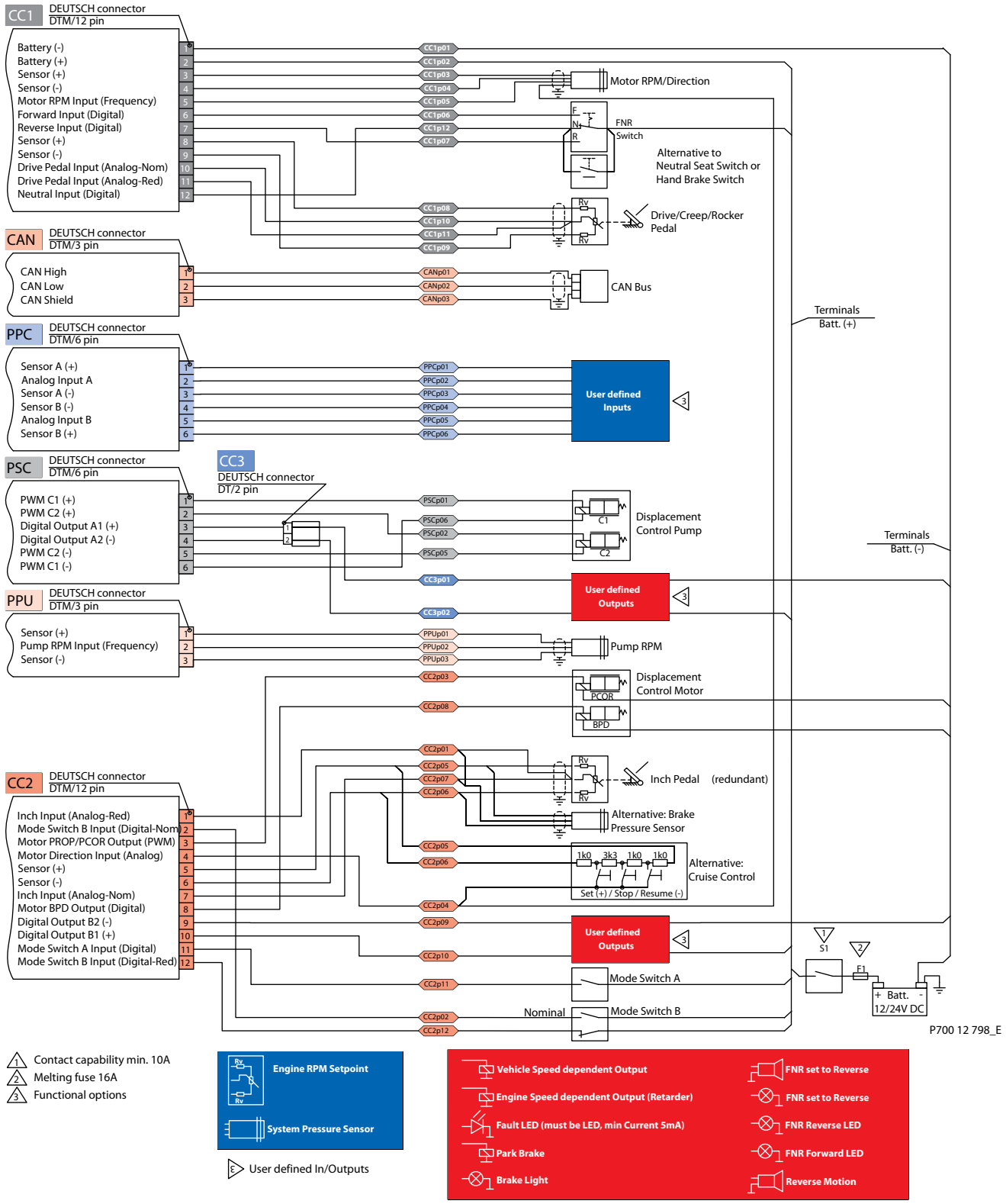
Legend: 1 – Lamp

Digital outputs A1/A2 and B1/B2

- Safety relevant functions (like **Brake Light Control, Park Brake Control, Reverse Motion Signal**, etc.) must be connected in closed loop.
- The current feedback A2 (-) and B2 (-) are actively monitored, a detected fault will result in **SAFE** mode operation
- The digital outputs are supplied with battery voltage and must not exceed the max output current (overload)
- Open-loop options are not compliant of SIL 2 according to IEC 61508

Technical specification

Automotive Control connection diagram



Technical specification

Power Supply [Battery (+) and Battery (-)]

The AC can be supplied with 12 or 24 V_{DC} system.

CC1: 01 Battery (-) Power supply input from battery

CC1: 02 Battery (+) Power supply input from battery

The 5 V sensor supply is internally generated. The sensor supply is protected against overload and reverse polarity connection.

For more information about a pinout description, see *Customer connectors (CC1, CC2 and CC3)* on page 26.

Supply characteristics

Parameter	Minimum	Maximum
Battery supply current	—	12 A
Recommended fuse size	—	16 A
Permanent supply voltage range	9 V_{DC}	36 V_{DC}
Rated 12 V range	9 V_{DC}	16 V_{DC}
Rated 24 V range	18 V_{DC}	32 V_{DC}
Permanent reverse voltage protection	—	-36 V_{DC}
Sensor supply voltage range (internal)	4.825 V_{DC}	5.075 V_{DC}
Sensor supply current	—	1 A*

* Maximum 1 A for all sensors together.

Forward-Neutral-Reverse (FNR) switch

The FNR switch selects the driving direction, switched to battery supply (12/24 V_{DC}). To be SIL 2 compliant a 3-pin switch with continuous signal is required and only one digital input may be applied at a time.

CC1:06 Forward Input Digital Input for driving direction FORWARD

CC1:07 Reverse Input Digital Input for driving direction REVERSE

CC1:12 Neutral Input Digital Input for driving direction NEUTRAL. This input can also be used for a seat switch or hand brake fucntion.

For more information about a pinout description, see *Customer connectors (CC1, CC2 and CC3)* on page 26.

Parameter	Minimum	Maximum
Rising voltage threshold[1)]	—	7.0 V_{DC}
Falling voltage threshold[2)]	1.66 V_{DC}	—
Input impedance	13.4 kΩ	13.8 kΩ

[1)] A digital input is guaranteed to be read as high if the voltage is > 7 V.

[2)] A digital input is guaranteed to be read as low if the voltage is < 1.66 V.

Technical specification

Mode switch A and B

The Mode switches are switched to battery supply (12/24 V_{DC}) and select the 4 possible System Modes according to the table below:

Modes and selection

Mode Switch		System mode			
		Mode 1	Mode 2	Mode 3	Mode 4
A		Low	Low	High	High
B	Nominal	Low	High	Low	High
	Redundant	High	Low	High	Low

To be SIL 2 compliant the Mode switch B must provide a nominal and a redundant signal.

CC2:11 Mode Switch A Input — Digital Input for mode switch A

CC2:02 Mode Switch B Input (Nominal) — Digital Input for mode switch B (nominal)

CC2:12 Mode switch B Input (Redundant) — Digital Input for mode switch B (redundant). This input can also be used for a seat switch or hand brake fucntion.

For more information about a pinout description, see *Customer connectors (CC1, CC2 and CC3)* on page 26.

Parameter	Minimum	Maximum
Rising voltage threshold[1)]	—	7.0 V_{DC}
Falling voltage threshold[2)]	1.66 V_{DC}	—
Input impedance	13.4 kΩ	13.8 kΩ

[1)] A digital input is guaranteed to be read as high if the voltage is > 7 V.

[2)] A digital input is guaranteed to be read as low if the voltage is < 1.66 V.

Inch Pedal

The inch pedal allows the operator to reduce the vehicle speed, stop the machine or keep the vehicle speed low while raising the engine speed to meet auxiliary flow demands.

An increasing inch pedal signal will reduce the pump displacement, thus reducing vehicle speed. Additionally, the motor can be increased to maximum displacment at the same time. The vehicle will come to a complete stop at 100 % inch signal.

CC2:01 Inch Input (Analog-Red) — Redundant Analog Input for the Inch Signal

CC2:05 Sensor (+) — Sensor supply (+)

- Supply for sensors within 4.825 to 5.075 V_{DC}
- Max. output current is 200 mA

CC2:06 Sensor (-) — Sensor supply (-) – direct GROUND connection

CC2:07 Inch Input (Analog-Nominal) — Nominal Analog Input for the Inch Signal

For more information about a pinout description, see *Customer connectors (CC1, CC2 and CC3)* on page 26.

Technical specification

Analog inputs

Parameter	Minimum	Maximum
Input voltage range	0.08 V_{DC}	5.26 V_{DC}
Resolution (4096 steps)	—	12 Bit
Input impedance	230 kΩ	236 kΩ

Drive/Creep Pedal, Joystick and Rocker Pedal

The Drive/Creep and the Rocker Pedals allow the operator to command the vehicle speed through pump and motor displacement setpoint. The displacement setpoint is defined by the configured profile and ramp for the 2 mode types:

1. **Non-Automotive:**
   - Pump displacement controlled directly
   - Motor displacement
     - Controlled directly for two-position and proportional controls
     - Controlled indirectly through pressure control for PCOR controls
2. **Automotive and Creep-Automotive:**
   - Pump displacement controlled directly only

All advanced functions, for example: Anti stall, CSD, Over speed protection can override this command. The Drive/Creep Pedal, Joystick provides a driving command only.

The driving direction is selected by the FNR input. The Rocker Pedal provides a driving command and the driving direction signal. Whether a Drive/Creep Pedal, Joystick or a Rocker Pedal is used will be configured by parameters.

The drive pedal signal can be configured and sent by the AC as **CAN Engine Speed Command** for the J1939-CAN message TSC1.

CC1:08 Sensor (+)	Sensor supply (+) • Supply for sensors within 4.825 to 5.075 V_{DC} • Max. output current is 200 mA
CC1:09 Sensor (-)	Sensor supply (-) – direct GROUND connection
CC1:10 Drive Pedal Input (Analog-Nom)	Nominal Analog-Input for Creep/Drive Pedal, Joystick or Rocker Pedal
CC1:11 Drive Pedal Input (Analog-Red)	Redundant Analog-Input for Creep/Drive/Joystick or Rocker Pedal

For more information about a pinout description, see *Customer connectors (CC1, CC2 and CC3)* on page 26.

Analog inputs

Parameter	Minimum	Maximum
Input voltage range	0.08 V_{DC}	5.26 V_{DC}
Resolution (4096 steps)	—	12 Bit
Input impedance	230 kΩ	236 kΩ

Technical specification

Motor Speed Sensor

A motor speed sensor signal can be read by the AC and used to calculate vehicle speed utilizing the configured final drive ratio. The calculated vehicle speed enables advanced functions such as constant speed operation and maximum vehicle speed limitation.

The optional motor direction signal can used to control the motor Brake Pressure Defeat (BPD) or the Reverse Motion signal (buzzer).

Depending on the Application Software Version (Special settings) this input is used for one of the following functions:

- Motor Direction (not available with Special settings: **D5J** and **D6J**)
- Cruise Control

CC1:03 Sensor (+)	Sensor supply (+) • Supply for sensors within 4.825 to 5.075 V_{DC} • Max. output current is 200 mA
CC1:04 Sensor (-)	Sensor supply (-) – direct GROUND connection
CC1:05 Motor RPM Input (Frequency)	Frequency input for HST motor PPU sensor
CC2:04 Input (Analog)	• Analog Input for HST motor direction • Analog Input for Cruise Control

For more information about a pinout description, see *Customer connectors (CC1, CC2 and CC3)* on page 26.

Frequency Input (Motor RPM)

Parameter	Minimum	Maximum
Rising voltage threshold (middle range)[1)]	2.0 V_{DC}	3.5 V_{DC}
Falling voltage threshold (middle range)[2)]	0.74 V_{DC}	—
Input impedance[3)]	7.0 kΩ	7.21 kΩ
Frequency range (in steps of 1 Hz)	0 Hz	10 000 Hz

[1)] The frequency input is guaranteed to be read as high if the voltage is > 3.5 V

[2)] The frequency input is guaranteed to be read as low if the voltage is < 0.74 V.

[3)] 15 kΩ to sensor supply, 13.5 kΩ to GND

Analog Input (Motor Direction or Cruise Control)

Parameter	Minimum	Maximum
Input voltage range	0.08 V_{DC}	5.26 V_{DC}
Resolution (4096 steps)	—	12 Bit
Input impedance [*]	—	—

[*] 15 kΩ to sensor supply, 14.1 kΩ to Ground

Technical specification

Analog Inputs

Two analog inputs can be read by the AC. The function differs, depending of the used application software version.

PPC:01 Sensor A (+)	Sensor supply (+) • Supply for sensors within 4.825 to 5.075 V_{DC} • Max. output current is 200 mA
PPC:02 Analog Input A	Analog Input
PPC:03 Sensor A (-)	Sensor supply (-) – direct GROUND connection
PPC:04 Sensor B (-)	Sensor supply (-) – direct GROUND connection
PPC:05 Analog Input B	Analog Input
PPC:06 Sensor B (+)	Sensor supply (+) • Supply for sensors within 4.825 to 5.075 V_{DC} • Max. output current is 200 mA

For more details see *PPC connector* on page 27.

Analog inputs

Parameter	Minimum	Maximum
Input voltage range	0.08 V_{DC}	5.26 V_{DC}
Resolution (4096 steps)	—	12 Bit
Input impedance	230 kΩ	236 kΩ

Mating connectors are available from Danfoss.

Motor Displacement and Brake Pressure Defeat (BPD) Control

Variable displacement and 2-Position motors can be controlled direcly. The output signal may be controlled by pump (engine) speed or drive pedal position.

For vehicle braking conditions a Brake Pressure Defeat (BPD) valve can be controlled dependent on the driving direction.

CC2:03 Motor PROP/ PCOR Driver	Proportional output (+) for the Pressure Control Override or proportional motor valve. PWM signal from battery Supply (12/24V).
CCC2:08 Motor BPD Driver	Digital output for the Brake-Pressure-Defeat (BPD) valve. Switched to battery (+) supply (12/24 V_{DC}) .

For more information about pinning description, see *Customer connectors (CC1, CC2 and CC3)* on page 26.

PWM and digital output

Parameter	Minimum	Maximum
Proportional current	0 A	3.0 A
Output voltage	—	Supply
PWM frequency	33 Hz	200 Hz

Technical specification

Digital Output A1 and A2

The digital outputs can be used as single outputs (open loop - switch to battery supply or GND) or in closed loop. Only the closed loop variant is compliant according SIL 2. The outputs can be configured individually to operate as:

- Brake Light Control
- Status Signal (Error LED)
- Reverse Motion Signal
- Engine speed dependent Retarder Control
- FNR in Reverse Signal
- Vehicle Speed Dependent signal
- Cruise Control on

CC3:01 A1 (+)	Digital output – switched to battery (+) supply
CC3:02 A2 (-)	Digital output – switched to GND (-)

For more information about a pinout description, see *Customer connectors (CC1, CC2 and CC3)* on page 26.

Parameter	Minimum	Maximum
Output current	0 A	3.0 A
Output voltage A1(+) / B1(+)	—	Supply
Output voltage A2(-) / B2(-)	—	Ground

Digital Output B1 and B2

The digital outputs can be used as single outputs (open loop - switch to battery supply or GND) or in closed loop. Only the closed loop variant is compliant according SIL 2. The outputs can be configured individually to operate as:

- Brake Light Control
- Status Signal (Error LED)
- Reverse Motion Signal
- Engine speed dependent Retarder Control
- FNR in Reverse Signal
- FNR in Forward Signal
- Park Brake Control

CC2:09 Digital Output B2 (-)	Digital output – switched to GND (-)
CC2:10-Digital Output B1 (+)	Digital output – switched to battery (+) supply

For more information about a pinout description, see *Customer connectors (CC1, CC2 and CC3)* on page 26.

Parameter	Minimum	Maximum
Output current	0 A	3.0 A
Output voltage A1(+) / B1(+)	—	Supply
Output voltage A2(-) / B2(-)	—	Ground

Technical specification

CAN communication

The AC Control can exchange information with the vehicle system via CAN bus. CAN communication baudrate is max. 250 kBaud. The physical (hardware) layer operates using the CAN 2.0B specification according to ISO 11898-2, high speed. The CAN interface is used for application software downloads and parameter settings.

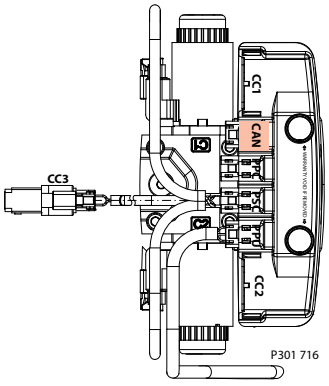
CAN:01 CAN High	Communication connection for CAN – High line
CAN:02 CAN Low	Communication connection for CAN – Low line
CAN:03 CAN Shield	Communication connection for CAN – Shield

For more details see *CAN connector* on page 24.

Mating connectors are available from Danfoss.

CAN connector

CAN connector DEUTSCH DTM, 3-pin



3-pin description:
1. CAN – High line
2. CAN – Low line
3. CAN – Shield

CAN connector kit information

There are 2 available kits, differentiated by customer wire diameter, containing both a CAN mating connector.

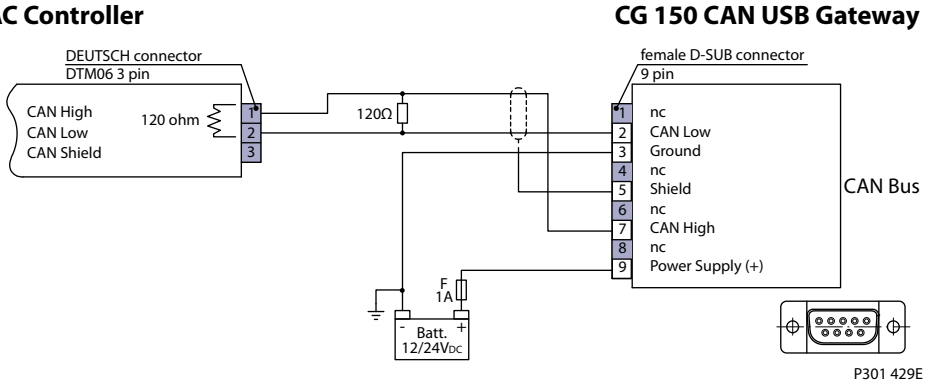
Kit Name	Lead wire diameter	Material No.
Grey and gold plated pins	0.5-2.0 mm² (14-20 AWG)	**11072736**
	0.2-0.5 mm² (20-24 AWG) {recommended}	**11033864**

Mating connectors are available from Danfoss.

Technical specification

CAN bus adapter

H1 AC controller / CG 150 CAN USB Gateway diagram



The additional adapter cable is required to connect the CG150 CAN USB Gateway with the Automotive Control (AC). The pigtail cable transitions from DEUTSCH to DSUB connector and contains terminating resistors to enable CAN communication.

Bill of material

Material description	Ordering No.
Adapter Cable H1P AC CAN Guide	**11153051**
Assembly bag with 1 DEUTSCH connector DTM06 3-SOCKET	**11033864**
9 pin female D-SUB connector with housing	
120 Ω resistor ¼ W ± 5% or better	
1 m cable 3 wire, Lead wire diameter 0.2 to 1.0 mm² (0.5 mm² recommended)	

If using a cable longer than 1 m, a shielded cable is required. For further information see the J1939 specification.

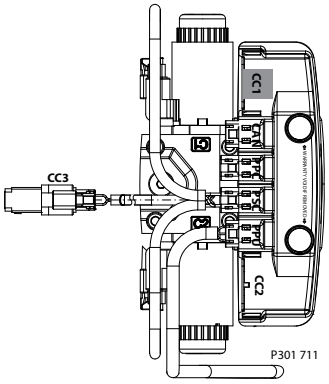
Technical specification

Mating Connectors

Customer connectors (CC1, CC2 and CC3)

CC1 connector

CC1 connector DEUTSCH DTM, 12-pin

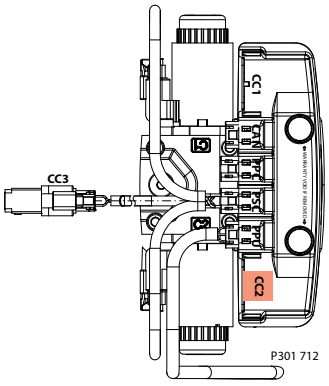


12-pin description:

1. Battery (-)
2. Battery (+)
3. Sensor (+)
4. Sensor (-)
5. Motor RPM Input (Frequency)
6. Forward Input (Digital)
7. Reverse Input (Digital)
8. Sensor (+)
9. Sensor (-)
10. Drive Pedal Input (Analog-Nom)
11. Drive Pedal Input (Analog-Red)
12. Neutral Input (Digital)

CC2 connector

CC2 connector DEUTSCH DTM, 12-pin



12-pin description:

1. Inch Input (Analog Red)
2. Mode Switch B Input (Digital Nom)
3. Motor PROP/PCOR Output (PWM)
4. Motor Direction Input (Analog)
5. Sensor (+)
6. Sensor (–)
7. Inch Input (Analog Nom)
8. Motor BPD Output (Digital)
9. Digital Output B2 (–)
10. Digital Output B1 (+)
11. Mode Switch A Input (Digital)
12. Mode Switch B Input (Digital Red)

There are 2 available kits, differentiated by customer wire diameter, containing both CC1 and CC2 mating connectors.

CC1 and CC2 connectors kits information

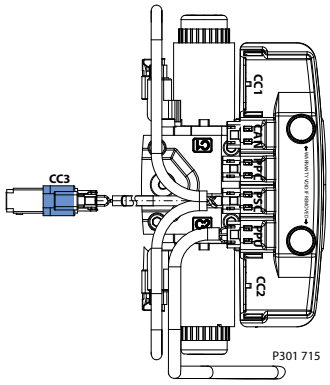
Kit Name	Lead wire diameter	Material No.
Assembly bag with 2 DEUTSCH connectors DTM06 12-SOCKET Black/Grey and gold plated pins	0.5-1.0 mm² (16-20 AWG)	**10102023**
	0.2-0.5 mm² (20-24 AWG) {recommended}	**10100945**

Mating connectors are available from Danfoss.

Technical specification

CC3 connector

CC3 connector DEUTSCH DT, 2-pin



2-pin description:
1. Digital Output A1 (+)
2. Digital Output A2 (–)

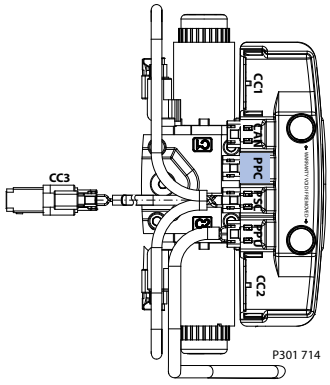
CC3 connector DEUTSCH kit information

Kit Name	Lead wire diameter	Material No.
Assembly bag with 1 DEUTSCH connector DT04 2-SOCKET Grey and gold plated pins	0.5-2.0 mm² (14-20 AWG)	**11070531**

Mating connectors are available from Danfoss.

PPC connector

PPC connector DEUTSCH DTM, 6-pin



6-pin description:
1. Sensor A (+)
2. Analog Input A
3. Sensor A (-)
4. Sensor B (-)
5. Analog Input B
6. Sensor B (+)

PPC connector DEUTSCH DTM kits information

Kit Name	Lead wire diameter	Material No.
Assembly bag with 1 DEUTSCH connector DT06 6-SOCKET Grey	0.5-1.0 mm² (16-20 AWG)	**11033863**
Assembly bag with 1 DEUTSCH connector DT06 6-SOCKET Black	0.2-0.5 mm² (20-24 AWG) {recommended}	**11033865**

Mating connectors are available from Danfoss.

Technical specification

AC electrical data & characteristics

Supply characteristics

Supply characteristics

Parameter	Minimum	Maximum
Battery supply current	—	12 A
Recommended fuse size	—	16 A
Permanent supply voltage range	9 V_{DC}	36 V_{DC}
Rated 12 V range	9 V_{DC}	16 V_{DC}
Rated 24 V range	18 V_{DC}	32 V_{DC}
Permanent reverse voltage protection	—	-36 V_{DC}
Sensor supply voltage range (internal)	4.825 V_{DC}	5.075 V_{DC}
Sensor supply current	—	1 A*

* Maximum 1 A for all sensors together.

I/O characteristics

Parameter	Minimum	Maximum
Rising voltage threshold[1)]	—	7.0 V_{DC}
Falling voltage threshold[2)]	1.66 V_{DC}	—
Input impedance	13.4 kΩ	13.8 kΩ

1) A digital input is guaranteed to be read as high if the voltage is > 7 V.

2) A digital input is guaranteed to be read as low if the voltage is < 1.66 V.

Analog inputs

Parameter	Minimum	Maximum
Input voltage range	0.08 V_{DC}	5.26 V_{DC}
Resolution (4096 steps)	—	12 Bit
Input impedance	230 kΩ	236 kΩ

Analog Input (Motor Direction or Cruise Control)

Parameter	Minimum	Maximum
Input voltage range	0.08 V_{DC}	5.26 V_{DC}
Resolution (4096 steps)	—	12 Bit
Input impedance *	—	—

* 15 kΩ to sensor supply, 14.1 kΩ to Ground

Frequency Input (Motor RPM)

Parameter	Minimum	Maximum
Rising voltage threshold (middle range)[1)]	2.0 V_{DC}	3.5 V_{DC}
Falling voltage threshold (middle range)[2)]	0.74 V_{DC}	—
Input impedance[3)]	7.0 kΩ	7.21 kΩ
Frequency range (in steps of 1 Hz)	0 Hz	10 000 Hz

1) The frequency input is guaranteed to be read as high if the voltage is > 3.5 V

2) The frequency input is guaranteed to be read as low if the voltage is < 0.74 V.

3) 15 kΩ to sensor supply, 13.5 kΩ to GND

Technical specification

Parameter	Minimum	Maximum
Output current	0 A	3.0 A
Output voltage A1(+) / B1(+)	—	Supply
Output voltage A2(-) / B2(-)	—	Ground

Operating characteristics

- CAN communication baudrate is max. 250 kBaud.
- Physical Layer as per ISO11898-2, high speed.
- Temperature range for parameter download: from min. -40 °C up to max. 104 °C

The number of speed (target) ring teeth

Size	045/053	060/068	069/078	089/100	115/130	147/165	210/250
Teeth	79	92	86	86	102	108	90

Environmental and protection characteristics

Parameter	Standard description
Short circuit	All inputs and outputs will withstand continuous short circuit to all other leads. When the short circuit is removed the unit returns to normal function.
EMC-Immunity (EMI)	EN 61000-6-2 EMC generic standard for immunity, industrial environment - incl. 1 kHz w/AM 80%
EMC-Emission (RFI)	EN 61000-6-3 EMC generic standard for emission, residential and industrial enviroments EN 12895 for industrial trucks
ESD	EN 61000-4-2 Electrostatic discharge immunity test Level 4 Direct contact discharge to connector pins
Automotive transients	ISO 7637 / 1-3
Temp/Volt/Humidity	IEC 60068-2-38
Cold test	IEC 60068-2-1 AD
Dry heat	IEC 60068-2-2 BD
Ice water shock	ISO 16750-4
Salt mist	IEC 60068-2-11 test Ka
IP67 and IPX9K*	IEC 60529 and DIN 40050 part 9 (valid for control only)

* with installed plug

Technical specification

Automotive Control (AC) Options

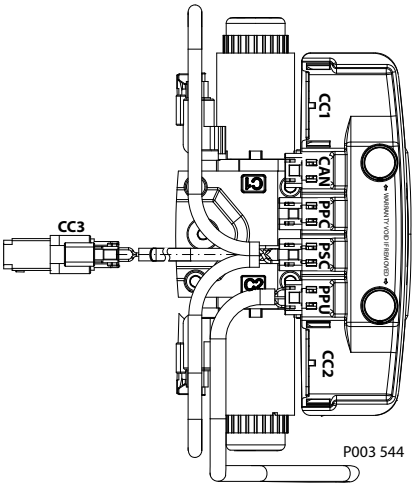
The AC-1 and AC-2 propel transmission system consists of an H1 variable pump, embedded electronic controller, and service tool configurable PLUS+1 software that allows the customer to completely optimize vehicle performance.

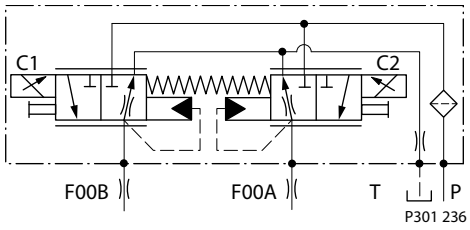
The embedded electronic controller provides an electric input signal activating one of two solenoids that port charge pressure to either side of the pump servo cylinder. The AC has no mechanical feedback mechanism but AC-2 is available with an electronic feedback signal for the swash plate position.

Automotive Control (AC) options overview

AC-1 options		AC-2 options	
P6 or P5	**P7 or R3**	**P8 or R4**	**P9 or R5**
12 V_{DC}	24 V_{DC}	12 V_{DC}	24 V_{DC}

Automotive Control (AC) and schematic

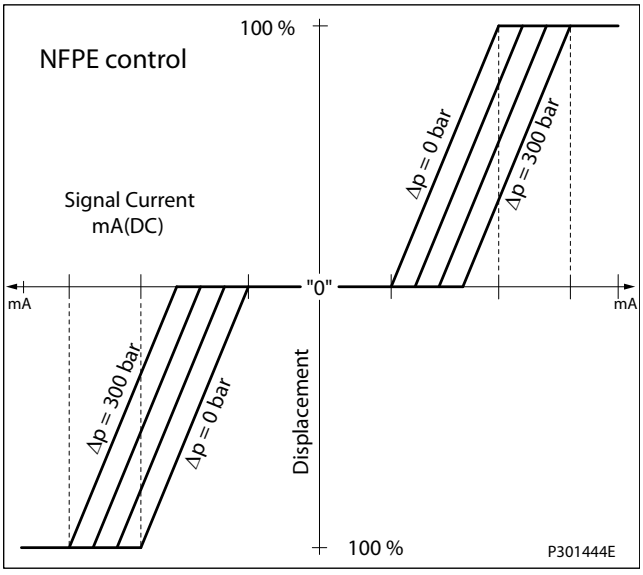




The pump displacement is proportional to the solenoid signal current, but it also depends upon pump input speed and system pressure. This characteristic also provides a power limiting function by reducing the pump swash plate angle as system pressure increases. A typical response characteristic is shown in the accompanying graph.

Technical specification

Pump displacement vs. input signal



Under some circumstances, such as contamination, the control spool could stick and cause the pump to stay at some displacement.

A serviceable 170 µm screen is located in the supply line immediately before the control porting spool.

Solenoid data

Description		**12 V**	**24 V**
Maximum current		1800 mA	920 mA
Nominal coil resistance	**@ 20 °C [68 °F]**	3.66 Ω	14.20 Ω
	@ 80 °C [176 °F]	4.52 Ω	17.52 Ω
Inductance		33 mH	140 mH
PWM	**Range**	70-200 Hz	
	Frequency (preferred)*	100 Hz	
	Frequency for NFPE, AC	200 Hz	
IP Rating	**IEC 60 529**	IP 67	
	DIN 40 050, part 9	IP 69K with mating connector	
Connector color		Black	

* PWM signal required for optimum control performance.

Pump output flow direction vs. control signal

Shaft rotation	**CW**		**CCW**	
Coil energized*	**C1**	**C2**	**C1**	**C2**
Port A	in	out	out	in
Port B	out	in	in	out
Servo port pressurized	M5	M4	M5	M4

* For coil location see Installation drawings.

Technical specification

Manual Over Ride (MOR)

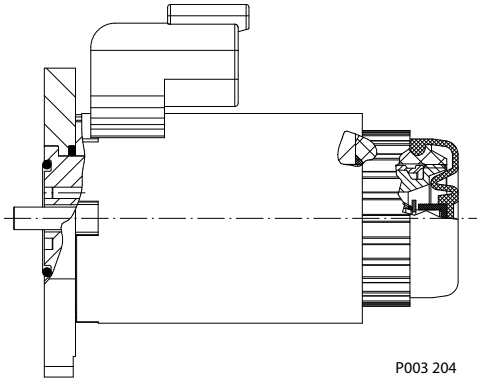
All Automotive AC-1 and AC-2 controls feature a Manual Over Ride (MOR) for temporary actuation of the control to aid in diagnostics.

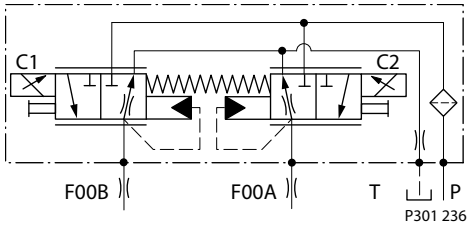
Initial actuation of the o-ring seal MOR plunger will require a force of 45 N. Additional actuations typically require less force to engage the MOR plunger. Proportional control of the pump via the MOR is not intended. The MOR plunger has a 4 mm diameter and must be manually depressed to be engaged. Depressing the plunger mechanically moves the control spool which allows the pump to go on stroke.

Unintended MOR operation can cause the pump to go into stroke.
The vehicle or device must always be in a safe condition (example: vehicle lifted off the ground) when using the MOR function. The MOR should be engaged anticipating a full stroke response from the pump.

Refer to control flow table for the relationship of solenoid to direction of flow.

MOR and schematic (AC shown)

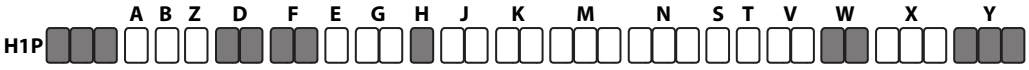

P003 204



P301 236

Model code

Automotive Control code part in the H1P model code



045	053	060	068	069	078	089	100	115	130	147	165	210	250
45.0 [2.75]	53.8 [3.28]	60.4 [3.69]	68.0 [4.15]	69.0 [4.22]	78.0 [4.76]	89.2 [5.44]	101.7 [6.21]	115.8 [7.07]	130.8 [7.98]	147.0 [8.97]	165.0 [10.07]	211.5 [12.91]	251.7 [15.36]

D – Controls — Automotive Control (AC)

Code	AC type	Voltage	MOR	Speed sensor	Wire harness	Angle sensor	DEUTSCH Connector
P6	**AC–1**	12 V	●	●	●	—	●
P7	**AC–1**	24 V	●	●	●	—	●
P8	**AC–2**	12 V	●	●	●	●	●
P9	**AC–2**	24 V	●	●	●	●	●
P5	**AC–1**	12 V	●	—	—	—	●
R3	**AC–1**	24 V	●	—	—	—	●
R4	**AC–2**	12 V	●	—	—	●	●
R5	**AC–2**	24 V	●	—	—	●	●

● – To be used for the control; — Not to be used for the control

F — Orifices

C3	No orifice.	Recommended for non-propel applications.
C1	Orifices 0.8 mm in servo supply 1 and 2	Recommended for propel applications, available options depend on the pump size.
C2	Orifices 1.3 mm in servo supply 1 and 2	
C4	Orifices 1.8 mm in servo supply 1 and 2	
D7	Orifices 3.0 mm in servo supply 1 and 2	
D8	Orifices 2.7 mm in servo supply 1 and 2	

H — Mounting flange (speed sensor)

J	45-53 cm^3 SAE B 2 Bolt	Option with pump speed sensor and with cable harness
K	60-100 cm^3 SAE C 4 Bolt	
L	115-165 cm^3 SAE D 4 Bolt	
E	210-250 cm^3 SAE E 4 Bolt	
F	45-53 cm^3 SAE B 2 Bolt	Option without pump speed sensor and without cable harness. EEC1 speed signal from the CAN engine is needed.
H	60-100 cm^3 SAE C 4 Bolt	
G	115-165 cm^3 SAE D 4 Bolt	
C	210-250 cm^3 SAE E 4 Bolt	

W — Special hardware

P2	AC valve plate with speed sensor *(Align with options: **D** Control selection and **E** Displacement limiter)*

Model code

Y – Special settings (SIL–2 non-certifiable, without customer files)

Code	CAN J1939	ECO fuel saving mode	Functional option	Cruise control	Control	AC type
D3E	in/out	●	E	–	N1 (12 V_{DC})	AC–1
D3F	in/out	–	F	–		
D4E	in/out	●	E	–	N2 (24 V_{DC})	
D4F	in/out	–	F	–		
D5F	in/out	–	F	–	P8 (12 V_{DC})	AC–2 with Swash Plate Angle Sensor
D5J	in/out	●	J	●		
D6F	in/out	–	F	–	P9 (24 V_{DC})	
D6J	in/out	●	J	●		

● = available option
– = not available option

For a complete Master model code, please refer to the Technical Informations H1 Axial Piston Pumps, Size 045 – 250.

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Comatrol
www.comatrol.com

Turolla
www.turollaocg.com

Hydro-Gear
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