Technical Information

Automotive Controls for H1 Single Pumps
AC–1 and AC–2
**Revision history**

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Technical Information

Automotive Control for H1 Single Pumps (Size 045–250 cm³)

Contents

General description

Automotive Control system description.................................................................4
Automotive Control advanced functions...............................................................4
Automotive Control hydrostatic propel methods..................................................4
System modes and selection..................................................................................6
Functional option packages..................................................................................6

Functions

Basic Functions......................................................................................................7
Performance Functions..........................................................................................9
Protection and Safety Functions.............................................................................11
Engine control and protection..............................................................................12

Requirements

SIL 2 requirements...............................................................................................13
General customer sensor requirements...............................................................13
Drive / Creep / Joystick / Rocker and Inch Pedal....................................................14
Pressure inch sensor............................................................................................14
Mode switch A.......................................................................................................15
Mode switch B.......................................................................................................15
HST motor speed sensor with optional direction indication.................................16
Motor displacement and Brake Pressure Defeat (BPD).........................................16
General Customer Actuator Requirements........................................................16
Digital outputs A1/A2 and B1/B2........................................................................16

Technical specification

Automotive Control connection diagram............................................................17
Power Supply [Battery (+) and Battery (-)]..........................................................18
Forward-Neutral-Reverse (FNR) switch...............................................................18
Mode switch A and B............................................................................................19
Inch Pedal............................................................................................................19
Drive/Creep Pedal, Joystick and Rocker Pedal......................................................20
Motor Speed Sensor...........................................................................................21
Analog Inputs........................................................................................................22
Motor Displacement and Brake Pressure Defeat (BPD) Control...........................22
Digital Output A1 and A2.....................................................................................23
Digital Output B1 and B2.....................................................................................23
CAN communication...........................................................................................24
CAN connector.....................................................................................................24
CAN bus adapter.................................................................................................25
Mating Connectors...............................................................................................26
Customer connectors (CC1, CC2 and CC3).........................................................26
PPC connector....................................................................................................27
AC electrical data & characteristics.................................................................28
Supply characteristics........................................................................................28
I/O characteristics.............................................................................................28
Operating characteristics..................................................................................29
Environmental and protection characteristics...................................................29
Automotive Control (AC) Options.......................................................................30
Manual Over Ride (MOR)....................................................................................32

Model code

Automotive Control code part in the H1P model code.......................................33
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

<table>
<thead>
<tr>
<th>System mode</th>
<th>Mode 1</th>
<th>Mode 2</th>
<th>Mode 3</th>
<th>Mode 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode Switch A</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Mode Switch B</td>
<td>Nominal</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Redundant</td>
<td>High</td>
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</tbody>
</table>

Functional option packages

AC functional option packages available for all H1 pumps

<table>
<thead>
<tr>
<th>Option package</th>
<th>AC1</th>
<th>AC2</th>
<th>Functional basis</th>
<th>CAN J1939</th>
<th>ECO fuel saving</th>
<th>SIL 2 additional features</th>
<th>Cruise control</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>●</td>
<td>—</td>
<td>●</td>
<td>in/out</td>
<td>●</td>
<td>—</td>
<td>—</td>
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<tr>
<td>F</td>
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<td>●</td>
<td>in/out</td>
<td>●</td>
<td>—</td>
<td>●</td>
</tr>
</tbody>
</table>
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
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.
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 the 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 be used to correct pump command.

Temperature Compensation
An integrated sensor will measure the temperature to compensate the oil viscosity influence. Parameters 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 (FNRI), 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., dashboard).

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.
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.
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 ©2003-2008,Danfoss. All Rights Reserved.

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

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**

![Diagram of sensor supply and redundant signal lines]

**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**

![Diagram of 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

Contact capability min. 10A
Melting fuse 16A
Functional options

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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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
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<td>Battery supply current</td>
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<td>12 A</td>
</tr>
<tr>
<td>Recommended fuse size</td>
<td>—</td>
<td>16 A</td>
</tr>
<tr>
<td>Permanent supply voltage range</td>
<td>9 VDC</td>
<td>36 VDC</td>
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<tr>
<td>Rated 12 V range</td>
<td>9 VDC</td>
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<tr>
<td>Rated 24 V range</td>
<td>18 VDC</td>
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</tr>
<tr>
<td>Permanent reverse voltage protection</td>
<td>—</td>
<td>-36 VDC</td>
</tr>
<tr>
<td>Sensor supply voltage range (internal)</td>
<td>4.825 VDC</td>
<td>5.075 VDC</td>
</tr>
<tr>
<td>Sensor supply current</td>
<td>—</td>
<td>1 A*</td>
</tr>
</tbody>
</table>

* 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 function.

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising voltage threshold(^1)</td>
<td>—</td>
<td>7.0 VDC</td>
</tr>
<tr>
<td>Falling voltage threshold(^2)</td>
<td>1.66 VDC</td>
<td>—</td>
</tr>
<tr>
<td>Input impedance</td>
<td>13.4 kΩ</td>
<td>13.8 kΩ</td>
</tr>
</tbody>
</table>

\(^1\) 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\textsubscript{DC}) and select the 4 possible System Modes according to the table below:


text

<table>
<thead>
<tr>
<th>Mode Switch</th>
<th>System mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mode 1</td>
</tr>
<tr>
<td>A</td>
<td>Low</td>
</tr>
<tr>
<td>B</td>
<td>Nominal</td>
</tr>
<tr>
<td></td>
<td>Redundant</td>
</tr>
</tbody>
</table>

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**
Digital Input for mode switch B (nominal)

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

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising voltage threshold(^1)</td>
<td>—</td>
<td>7.0 V\textsubscript{DC}</td>
</tr>
<tr>
<td>Falling voltage threshold(^2)</td>
<td>1.66 V\textsubscript{DC}</td>
<td>—</td>
</tr>
<tr>
<td>Input impedance</td>
<td>13.4 kΩ</td>
<td>13.8 kΩ</td>
</tr>
</tbody>
</table>

\(^1\) 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 displacement 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\textsubscript{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**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage range</td>
<td>0.08 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>5.26 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Resolution (4096 steps)</td>
<td>—</td>
<td>12 Bit</td>
</tr>
<tr>
<td>Input impedance</td>
<td>230 kΩ</td>
<td>236 kΩ</td>
</tr>
</tbody>
</table>

**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<sub>DC</sub>
- 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**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage range</td>
<td>0.08 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>5.26 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Resolution (4096 steps)</td>
<td>—</td>
<td>12 Bit</td>
</tr>
<tr>
<td>Input impedance</td>
<td>230 kΩ</td>
<td>236 kΩ</td>
</tr>
</tbody>
</table>
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 be 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<sub>DC</sub>
- 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)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising voltage threshold (middle range)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>2.0 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>3.5 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Falling voltage threshold (middle range)&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.74 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>—</td>
</tr>
<tr>
<td>Input impedance&lt;sup&gt;3&lt;/sup&gt;</td>
<td>7.0 kΩ</td>
<td>7.21 kΩ</td>
</tr>
<tr>
<td>Frequency range (in steps of 1 Hz)</td>
<td>0 Hz</td>
<td>10 000 Hz</td>
</tr>
</tbody>
</table>

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

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

<sup>3</sup> 15 kΩ to sensor supply, 13.5 kΩ to GND

**Analog Input (Motor Direction or Cruise Control)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage range</td>
<td>0.08 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>5.26 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Resolution (4096 steps)</td>
<td>—</td>
<td>12 Bit</td>
</tr>
<tr>
<td>Input impedance *</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

* 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<sub>DC</sub>
- 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<sub>DC</sub>
- Max. output current is 200 mA

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

**Analog inputs**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage range</td>
<td>0.08 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>5.26 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Resolution (4096 steps)</td>
<td>—</td>
<td>12 Bit</td>
</tr>
<tr>
<td>Input impedance</td>
<td>230 kΩ</td>
<td>236 kΩ</td>
</tr>
</tbody>
</table>

Mating connectors are available from Danfoss.

Motor Displacement and Brake Pressure Defeat (BPD) Control

Variable displacement and 2-Position motors can be controlled directly. 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<sub>DC</sub>)

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

**PWM and digital output**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportional current</td>
<td>0 A</td>
<td>3.0 A</td>
</tr>
<tr>
<td>Output voltage</td>
<td>—</td>
<td>Supply</td>
</tr>
<tr>
<td>PWM frequency</td>
<td>33 Hz</td>
<td>200 Hz</td>
</tr>
</tbody>
</table>
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

**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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output current</td>
<td>0 A</td>
<td>3.0 A</td>
</tr>
<tr>
<td>Output voltage A1(+) / B1(+)</td>
<td>—</td>
<td>Supply</td>
</tr>
<tr>
<td>Output voltage A2(-) / B2(-)</td>
<td>—</td>
<td>Ground</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output current</td>
<td>0 A</td>
<td>3.0 A</td>
</tr>
<tr>
<td>Output voltage A1(+) / B1(+)</td>
<td>—</td>
<td>Supply</td>
</tr>
<tr>
<td>Output voltage A2(-) / B2(-)</td>
<td>—</td>
<td>Ground</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Kit Name</th>
<th>Lead wire diameter</th>
<th>Material No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grey and gold plated pins</td>
<td>0.5-2.0 mm² (14-20 AWG)</td>
<td>11072736</td>
</tr>
<tr>
<td></td>
<td>0.2-0.5 mm² (20-24 AWG)</td>
<td>11033864</td>
</tr>
</tbody>
</table>

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

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

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

Customer connectors (CC1, CC2 and CC3)

**CC1 connector**

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**

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)
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**

<table>
<thead>
<tr>
<th>Kit Name</th>
<th>Lead wire diameter</th>
<th>Material No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly bag with 2 DEUTSCH connectors DTM06 12-_SOCKET Black/Grey and gold plated pins</td>
<td>0.5-1.0 mm² (16-20 AWG)</td>
<td>10102023</td>
</tr>
<tr>
<td></td>
<td>0.2-0.5 mm² (20-24 AWG) (recommended)</td>
<td>10100945</td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Kit Name</th>
<th>Lead wire diameter</th>
<th>Material No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly bag with 1 DEUTSCH connector DT04 2- SOCKET Grey and gold plated pins</td>
<td>0.5-2.0 mm² (14-20 AWG)</td>
<td>11070531</td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Kit Name</th>
<th>Lead wire diameter</th>
<th>Material No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly bag with 1 DEUTSCH connector DT06 6- SOCKET Grey</td>
<td>0.5-1.0 mm² (16-20 AWG)</td>
<td>11033863</td>
</tr>
<tr>
<td>Assembly bag with 1 DEUTSCH connector DT06 6- SOCKET Black</td>
<td>0.2-0.5 mm² (20-24 AWG) [recommended]</td>
<td>11033865</td>
</tr>
</tbody>
</table>

Mating connectors are available from Danfoss.
Technical specification

AC electrical data & characteristics

**Supply characteristics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery supply current</td>
<td>—</td>
<td>12 A</td>
</tr>
<tr>
<td>Recommended fuse size</td>
<td>—</td>
<td>16 A</td>
</tr>
<tr>
<td>Permanent supply voltage range</td>
<td>9 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>36 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Rated 12 V range</td>
<td>9 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>16 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Rated 24 V range</td>
<td>18 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>32 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Permanent reverse voltage protection</td>
<td>—</td>
<td>-36 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Sensor supply voltage range (internal)</td>
<td>4.825 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>5.075 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Sensor supply current</td>
<td>—</td>
<td>1 A*</td>
</tr>
</tbody>
</table>

* Maximum 1 A for all sensors together.

**I/O characteristics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising voltage threshold&lt;sup&gt;1&lt;/sup&gt;</td>
<td>—</td>
<td>7.0 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Falling voltage threshold&lt;sup&gt;2&lt;/sup&gt;</td>
<td>1.66 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>—</td>
</tr>
<tr>
<td>Input impedance</td>
<td>13.4 kΩ</td>
<td>13.8 kΩ</td>
</tr>
</tbody>
</table>

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

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

**Analog inputs**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage range</td>
<td>0.08 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>5.26 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Resolution (4096 steps)</td>
<td>—</td>
<td>12 Bit</td>
</tr>
<tr>
<td>Input impedance</td>
<td>230 kΩ</td>
<td>236 kΩ</td>
</tr>
</tbody>
</table>

**Analog Input (Motor Direction or Cruise Control)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage range</td>
<td>0.08 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>5.26 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Resolution (4096 steps)</td>
<td>—</td>
<td>12 Bit</td>
</tr>
<tr>
<td>Input impedance</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

* 15 kΩ to sensor supply, 14.1 kΩ to Ground

**Frequency Input (Motor RPM)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising voltage threshold (middle range)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>2.0 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>3.5 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Falling voltage threshold (middle range)&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.74 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td>—</td>
</tr>
<tr>
<td>Input impedance&lt;sup&gt;3&lt;/sup&gt;</td>
<td>7.0 kΩ</td>
<td>7.21 kΩ</td>
</tr>
<tr>
<td>Frequency range (in steps of 1 Hz)</td>
<td>0 Hz</td>
<td>10 000 Hz</td>
</tr>
</tbody>
</table>

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

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

<sup>3</sup> 15 kΩ to sensor supply, 13.5 kΩ to GND
Technical specification

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output current</td>
<td>0 A</td>
<td>3.0 A</td>
</tr>
<tr>
<td>Output voltage A1(+) / B1(+)</td>
<td>—</td>
<td>Supply</td>
</tr>
<tr>
<td>Output voltage A2(+) / B2(+)</td>
<td>—</td>
<td>Ground</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Size</th>
<th>045/053</th>
<th>060/068</th>
<th>069/078</th>
<th>089/100</th>
<th>115/130</th>
<th>147/165</th>
<th>210/250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teeth</td>
<td>79</td>
<td>92</td>
<td>86</td>
<td>86</td>
<td>102</td>
<td>108</td>
<td>90</td>
</tr>
</tbody>
</table>

Environmental and protection characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short circuit</td>
<td>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.</td>
</tr>
<tr>
<td>EMC-Immunity (EMI)</td>
<td>EN 61000-6-2 EMC generic standard for immunity, industrial environment - incl. 1 kHz w/AM 80%</td>
</tr>
<tr>
<td>EMC-Emission (RFI)</td>
<td>EN 61000-6-3 EMC generic standard for emission, residential and industrial environments EN 12895 for industrial trucks</td>
</tr>
<tr>
<td>ESD</td>
<td>EN 61000-4-2 Electrostatic discharge immunity test Level 4 Direct contact discharge to connector pins</td>
</tr>
<tr>
<td>Automotive transients</td>
<td>ISO 7637 / 1-3</td>
</tr>
<tr>
<td>Temp/Volt/Humidity</td>
<td>IEC 60068-2-38</td>
</tr>
<tr>
<td>Cold test</td>
<td>IEC 60068-2-1 AD</td>
</tr>
<tr>
<td>Dry heat</td>
<td>IEC 60068-2-2 BD</td>
</tr>
<tr>
<td>Ice water shock</td>
<td>ISO 16750-4</td>
</tr>
<tr>
<td>Salt mist</td>
<td>IEC 60068-2-11 test Ka</td>
</tr>
<tr>
<td>IP67 and IPX9K⁺</td>
<td>IEC 60529 and DIN 40050 part 9 (valid for control only)</td>
</tr>
</tbody>
</table>

⁺ with installed plug
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

<table>
<thead>
<tr>
<th>AC-1 options</th>
<th>AC-2 options</th>
</tr>
</thead>
<tbody>
<tr>
<td>P6 or P5</td>
<td>P7 or R3</td>
</tr>
<tr>
<td>12 VDC</td>
<td>24 VDC</td>
</tr>
<tr>
<td>12 VDC</td>
<td>24 VDC</td>
</tr>
<tr>
<td>12 VDC</td>
<td>24 VDC</td>
</tr>
</tbody>
</table>

### 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.
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

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

*PWM signal required for optimum control performance.

### Pump output flow direction vs. control signal

<table>
<thead>
<tr>
<th>Shaft rotation</th>
<th>CW</th>
<th>CCW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coil energized*</td>
<td>C1</td>
<td>C2</td>
</tr>
<tr>
<td>Port A</td>
<td>in</td>
<td>out</td>
</tr>
<tr>
<td>Port B</td>
<td>out</td>
<td>in</td>
</tr>
<tr>
<td>Servo port pressurized</td>
<td>MS</td>
<td>M4</td>
</tr>
</tbody>
</table>

*For coil location see Installation drawings.
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)*
Model code

Automotive Control code part in the H1P model code

| H1P Model Code | A | B | Z | D | F | E | G | H | J | K | M | N | S | T | V | W | X | Y |
|----------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 045            | 053| 060| 068| 069| 078| 089| 100| 115| 130| 147| 165| 175| 210| 250|

D – Controls — Automotive Control (AC)

<table>
<thead>
<tr>
<th>Code</th>
<th>AC type</th>
<th>Voltage</th>
<th>MOR</th>
<th>Speed sensor</th>
<th>Wire harness</th>
<th>Angle sensor</th>
<th>DEUTSCH Connector</th>
</tr>
</thead>
<tbody>
<tr>
<td>P6</td>
<td>AC–1</td>
<td>12 V</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>—</td>
<td>●</td>
</tr>
<tr>
<td>P7</td>
<td>AC–1</td>
<td>24 V</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>—</td>
<td>●</td>
</tr>
<tr>
<td>P8</td>
<td>AC–2</td>
<td>12 V</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>P9</td>
<td>AC–2</td>
<td>24 V</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>P5</td>
<td>AC–1</td>
<td>12 V</td>
<td>●</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>●</td>
</tr>
<tr>
<td>R3</td>
<td>AC–1</td>
<td>24 V</td>
<td>●</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>●</td>
</tr>
<tr>
<td>R4</td>
<td>AC–2</td>
<td>12 V</td>
<td>●</td>
<td>—</td>
<td>—</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>R5</td>
<td>AC–2</td>
<td>24 V</td>
<td>●</td>
<td>—</td>
<td>—</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

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

F — Orifices

<table>
<thead>
<tr>
<th>C3</th>
<th>No orifice.</th>
<th>Recommended for non-propel applications.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Orifices 0.8 mm in servo supply 1 and 2</td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>Orifices 1.3 mm in servo supply 1 and 2</td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td>Orifices 1.8 mm in servo supply 1 and 2</td>
<td></td>
</tr>
<tr>
<td>D7</td>
<td>Orifices 3.0 mm in servo supply 1 and 2</td>
<td></td>
</tr>
<tr>
<td>D8</td>
<td>Orifices 2.7 mm in servo supply 1 and 2</td>
<td></td>
</tr>
</tbody>
</table>

H — Mounting flange (speed sensor)

<table>
<thead>
<tr>
<th>J</th>
<th>45-53 cm³ SAE B 2 Bolt</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>60-100 cm³ SAE C 4 Bolt</td>
</tr>
<tr>
<td>L</td>
<td>115-165 cm³ SAE D 4 Bolt</td>
</tr>
<tr>
<td>E</td>
<td>210-250 cm³ SAE E 4 Bolt</td>
</tr>
<tr>
<td>F</td>
<td>45-53 cm³ SAE B 2 Bolt</td>
</tr>
<tr>
<td>H</td>
<td>60-100 cm³ SAE C 4 Bolt</td>
</tr>
<tr>
<td>G</td>
<td>115-165 cm³ SAE D 4 Bolt</td>
</tr>
<tr>
<td>C</td>
<td>210-250 cm³ SAE E 4 Bolt</td>
</tr>
</tbody>
</table>

Option with pump speed sensor and with cable harness
Option without pump speed sensor and without cable harness. EEC1 speed signal from the CAN engine is needed.

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)*

<table>
<thead>
<tr>
<th>Code</th>
<th>CAN J1939</th>
<th>ECO fuel saving mode</th>
<th>Functional option</th>
<th>Cruise control</th>
<th>Control</th>
<th>AC type</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3E</td>
<td>in/out</td>
<td>●</td>
<td>E</td>
<td>–</td>
<td>N1</td>
<td>AC–1</td>
</tr>
<tr>
<td>D3F</td>
<td>in/out</td>
<td>–</td>
<td>F</td>
<td>–</td>
<td>(12 VDC)</td>
<td></td>
</tr>
<tr>
<td>D4E</td>
<td>in/out</td>
<td>●</td>
<td>E</td>
<td>–</td>
<td>N2</td>
<td>AC–1</td>
</tr>
<tr>
<td>D4F</td>
<td>in/out</td>
<td>–</td>
<td>F</td>
<td>–</td>
<td>(24 VDC)</td>
<td></td>
</tr>
<tr>
<td>D5F</td>
<td>in/out</td>
<td>–</td>
<td>F</td>
<td>–</td>
<td>P8</td>
<td>AC–2</td>
</tr>
<tr>
<td>D5J</td>
<td>in/out</td>
<td>●</td>
<td>J</td>
<td>●</td>
<td>(12 VDC)</td>
<td></td>
</tr>
<tr>
<td>D6F</td>
<td>in/out</td>
<td>–</td>
<td>F</td>
<td>–</td>
<td>P9</td>
<td></td>
</tr>
<tr>
<td>D6J</td>
<td>in/out</td>
<td>●</td>
<td>J</td>
<td>●</td>
<td>(24 VDC)</td>
<td></td>
</tr>
</tbody>
</table>

● = 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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