

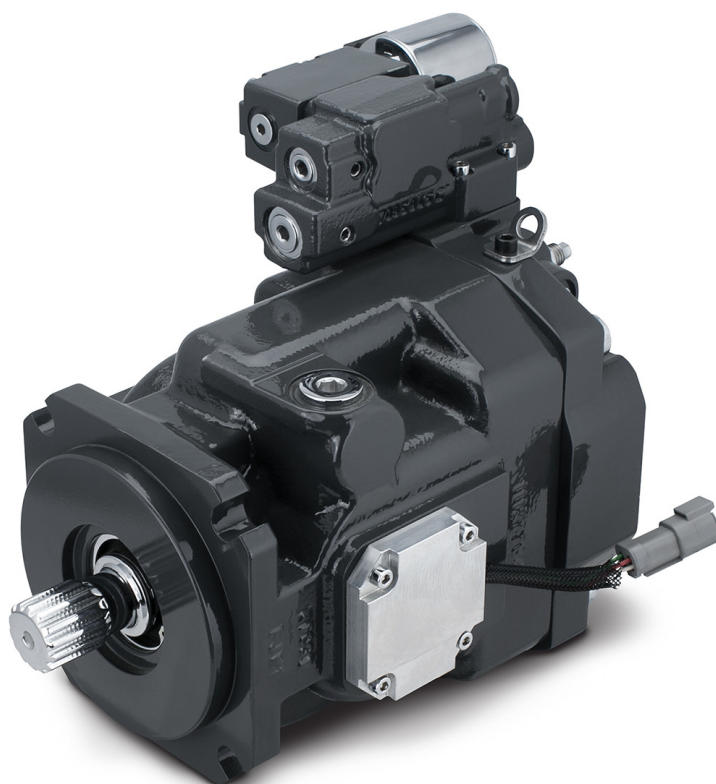
ENGINEERING  
TOMORROW



User Manual

# Electronic Torque Limiting Control

## Series 45





Revision history

Table of revisions

Date	Changed	Rev
March 2024	Changed document number from 'AQ00000167' and 'L1519202' to 'AQ157786482866' and replaced cover image	0203
March 2015	First edition	0101

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## Overview

### Purpose of this Manual

This manual is intended to be a reference for customers using Danfoss S45 Open Circuit Axial Piston Electronic Torque Limiting (ETL) pumps in conjunction with the keyed ETL MC012 and PLUS+1® Guide Subsystem Application Block. The setup and operation of the PLUS+1® ETL software will be illustrated with S45 ETL pumps by utilizing the ETL PLUS+1® service screens.

### Before You Start

Users setting up an ETL system with both PLUS+1® software and S45 Open Circuit ETL pumps should have a working knowledge of basic hydraulic systems, principles, and PLUS+1® Service Tools.

Users should also have access to PLUS+1® and S45 technical literature.

### Literature References

Useful technical information on pump displacements, controls specifications, software, and operating condition requirements can be found in the following literature.

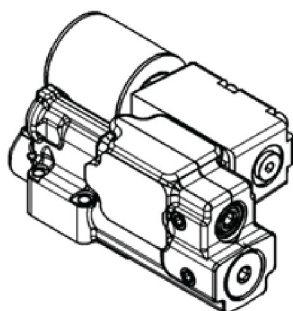
#### Literature references

Literature type	Literature title	Literature number
Technical Information	<i>Series 45 Axial Piston Open Circuit Pumps</i>	BC152886483703
Service Manual	<i>Series 45 Frame J Open Circuit</i>	AX152886481532
	<i>Series 45 Frame F Open Circuit</i>	AX152886481225
	<i>Series 45 Frame E Open Circuit</i>	AX152886482455
Parts Manuals	<i>Series 45 Frame J</i>	AX152886482331
	<i>Series 45 Frame F</i>	AX152886481988
	<i>Series 45 Frame E</i>	AX152886481846
Repair Instructions	<i>Series 45 Frame J Open Circuit</i>	520L0610
	<i>Series 45 Frame F Open Circuit</i>	520L0821
	<i>Series 45 Frame E Open Circuit</i>	520L0609
User Guide	<i>PLUS+1® Service Tool User Manual</i>	AQ152986484649 (Also found under <b>Help</b> on toolbar)
Data Sheet	<i>PLUS+1® Controllers MC012-110 and MC012-112</i>	AI152986480902
Product Electrical Installation	<i>MBS1250 Heavy Duty Pressure Transmitter</i>	11062087

## General Electronic Torque Control Information

### PLUS+1 Compliance

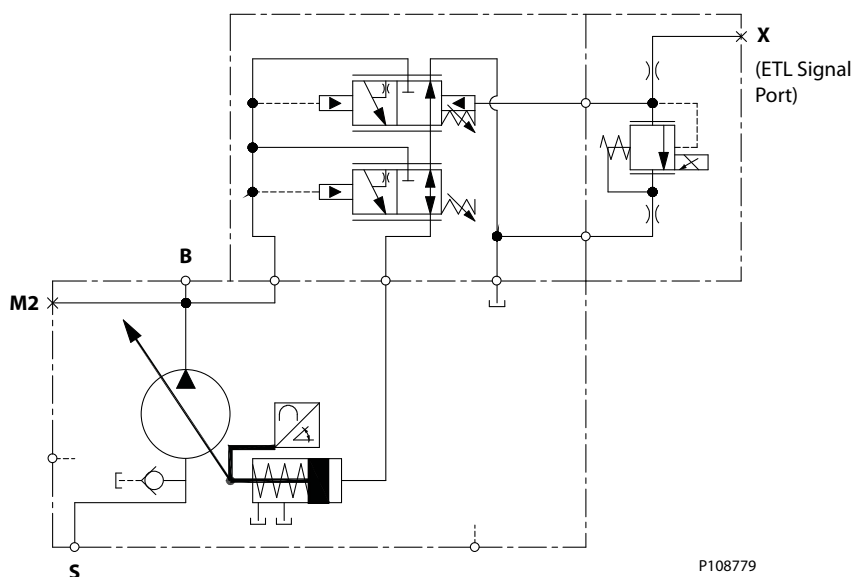
All Series 45 Electric controls have met and passed the Danfoss PLUS+1 compliance standard testing, and as such, this Series 45 control is PLUS+1 compliant. PLUS+1 compliance blocks are available on the Danfoss website, within the PLUS+1 Guide section.



### Electric Torque Limiting Control Principle

The Electronic Torque Limiting control consists of a normally closed proportional relief valve (PRV) integrated into a Pressure Compensated/Load Sensing control. This control operates as a PC/LS control, with the additional ability to limit load sense pressure using the integrated PRV by varying the current to the solenoid. When combined with an angle sensor, this control allows for a PC/LS control with electronic torque limiting.

*J-frame pump with integrated ETL control*



Pump torque consumption is a function of pump outlet pressure, pump displacement, and pump mechanical efficiency. When pump mechanical efficiency is considered constant, the pump torque can be limited when pump displacement is known and pump pressure is controlled. As pump displacement increases, the pump outlet pressure can be limited using the PRV to result in a constant torque limit.

## General Electronic Torque Control Information

Pump outlet pressure is equal to the load sense pressure, which is limited with the PRV, plus the margin pressure setting of the pump.

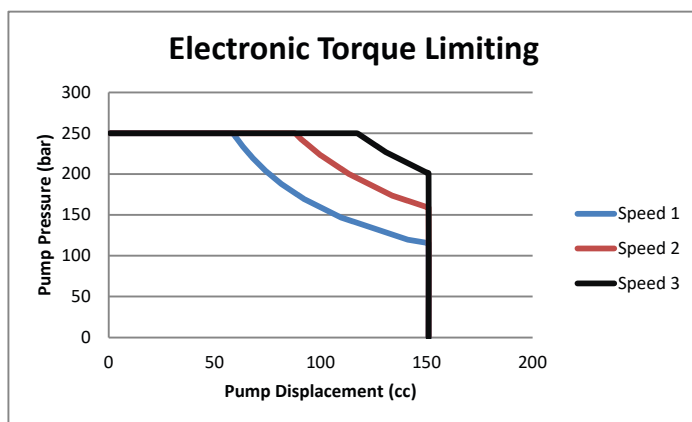
$$\text{Torque} = \frac{\text{Pump Outlet Pressure (bar)} * \text{Pump Displacement} \left(\frac{\text{cc}}{\text{rev}}\right)}{62.8 * \text{Pump Mechanical Efficiency (\%)}}$$

### LS Signal Line Orifice

S45 Electronic Torque Limiting Controls require the use of an LS signal line orifice. The LS signal line orifice is used to enhance system stability, as well as allow the limiting of torque throughout the full range of pump pressure and flow. The standard 0.8 mm orifice is best suited for use in a wide variety of applications. Please contact your Danfoss representative for further information on the availability of additional LS signal line orifice sizes.

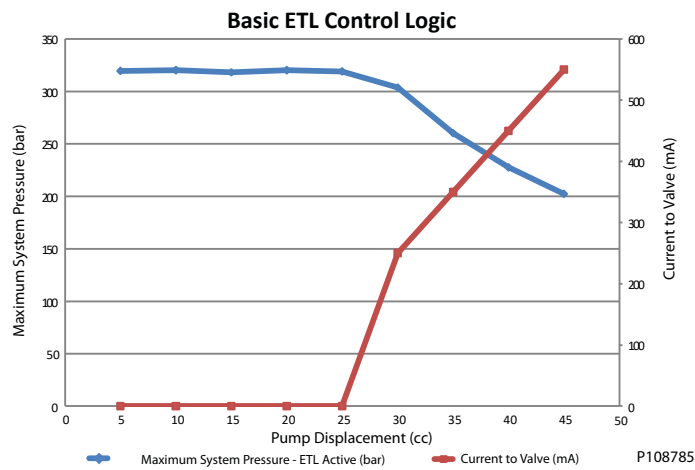
## Electronic Torque Limiting Control Characteristic

The Electronic Torque Limiting control allows users to limit pump torque consumption electronically by combining a pressure limiting PRV and angle sensor. This torque limit can be changed with varying engine speeds (as shown in the Electronic Torque Limiting graph below), allowing the use of full engine torque at all engine speeds and increasing machine productivity. A microcontroller is required to store engine torque vs speed, receive the pump angle sensor signal, and then calculate and output the pump outlet pressure limit. The basic torque limiting control logic for a single engine speed is shown below. Danfoss offers a PLUS+1 subsystem application block for the Electronic Torque Limiting control option in combination with keyed MC012-112 microcontroller hardware. The part number for the keyed MC012-112 microcontroller is 11157484. Refer to graph [Figure 1](#) for pressure vs. current information.



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**General Electronic Torque Control Information**





## **System Considerations when Implementing ETL**

When setting up an ETL system to function properly, you must account for LS signal line orificing and margin erosion.

### **Electronic Torque Limiting and Load Sense Signals**

Danfoss PVG valves, as well as many competitor valves, are manufactured with LS signal line orifices installed in the pump inlet (PVP) module. These orifices enhance system stability by dampening the highest load pressure signal before it is relayed to the open circuit pump. They also help limit the amount of flow over the load sense relief valve inside the PVP.

It is important to ensure that when using these LS line orifices the highest resolved load sense pressure is communicated to the pump or loss of some flow sharing functionality may occur. If you experience symptoms of loss of flow sharing, some troubleshooting steps may include removing the LS line orifice in the valve stack, or ensuring that the LS pressure rails are connected to each other when using two or more different valve stacks. In this way, the highest load from the system is communicated to the pump.

### **Electronic Torque Limiting and Margin Erosion**

A potential flow sharing problem may arise when several functions are actuated at the same time and require a high flow demand from the pump. This problem may include a loss of movement in the highest pressure function when many functions are actuated at the same time. This problem is margin erosion.

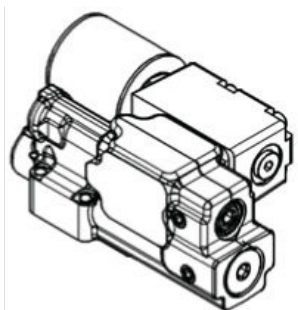
Margin erosion is caused when margin pressure is shifted from the operator-controlled valves to the LS signal line orifice in the S45 pump. When this margin shifts too much, the valve cannot flow share correctly. Danfoss PVG valve groups reduce this problem with compensator valves which remain open at a very low margin pressure. This allows more aggressive torque limiting, particularly at low engine idle speeds where torque limiting is most critical.

In addition to using valves with superior low pressure flow sharing characteristics, it is possible to use calculations to identify problem areas where margin erosion can become a concern. Please contact your Danfoss representative for more information on calculating and planning for margin erosion.

## General Angle Sensor Information

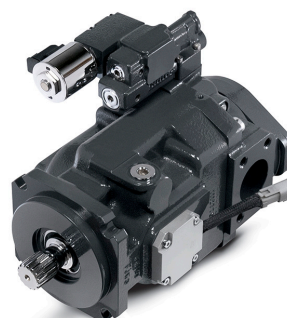
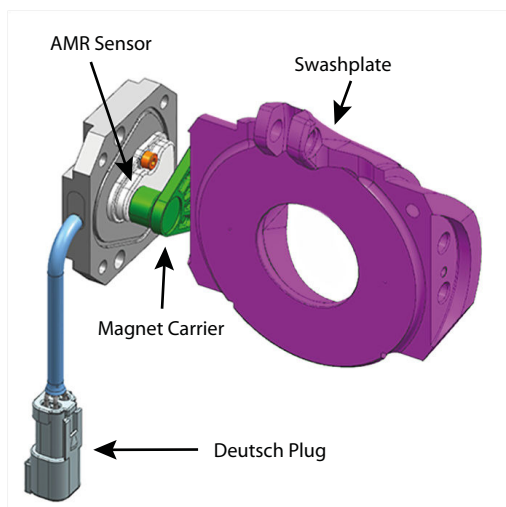
### PLUS+1 Compliance

The Electric Angle Sensor has met and passed the Danfoss PLUS+1 compliance standard testing, and as such, this Angle Sensor is PLUS+1 compliant. PLUS+1 compliance blocks are available on the Danfoss website, within the PLUS+1 Guide section.



### Angle Sensor Principle

The Series 45 Angle Sensor option allows users to measure the angle of pump displacement. The angle sensor is an electronic sensor mounted to the housing of the pump, which reads the pump stroke angle based on the swashplate position. Interfacing with the angle sensor is achieved through a 4-pin Deutsch DTM04-4P receptacle attached to a flexible connection cable (for a mating connector, use Deutsch® plug DTM06-4S). The sensor is mounted to the pump within an aluminum housing to prevent magnetic interference.



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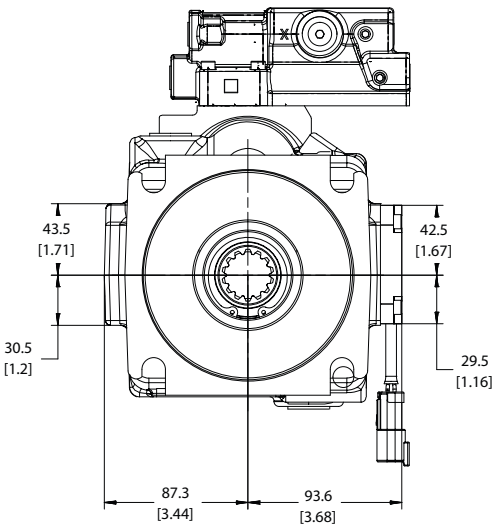
### Angle Sensor Characteristics

The angle sensor package incorporates two sensor signals (primary & secondary), within a single sensor housing. This allows for improved accuracy and troubleshooting. For the 'Angle Sensor – Right' order code in the K module, the sensor is positioned according to the following conventions.

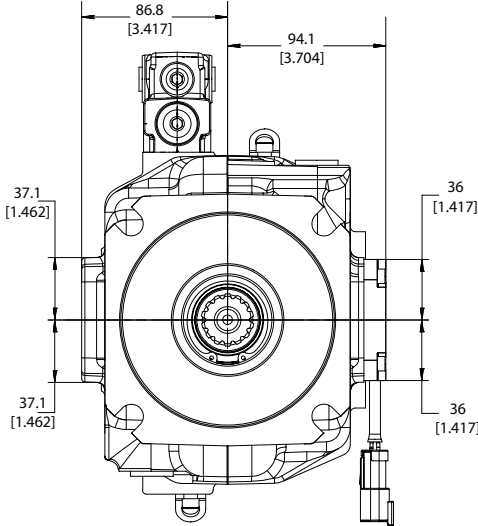
## General Angle Sensor Information

### J & F-Frame (45-90cc) Angle Sensor Identification Convention:

When looking at the input shaft with the control on the 'top' side, the angle sensor will be viewed on the right hand side. This convention is true for both Clockwise and Counter-clockwise rotation J & F-Frames.



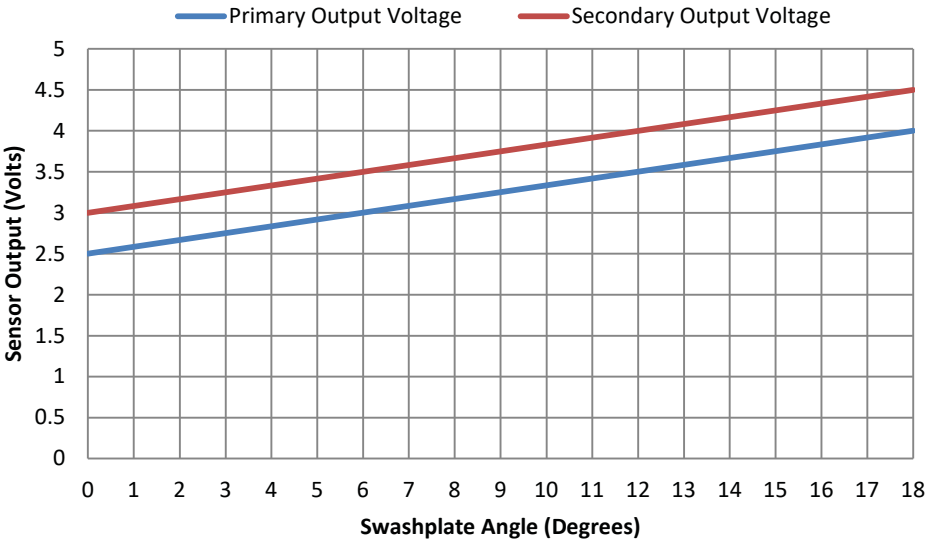
J Frame Angle Sensor Position



F Frame Angle Sensor Position

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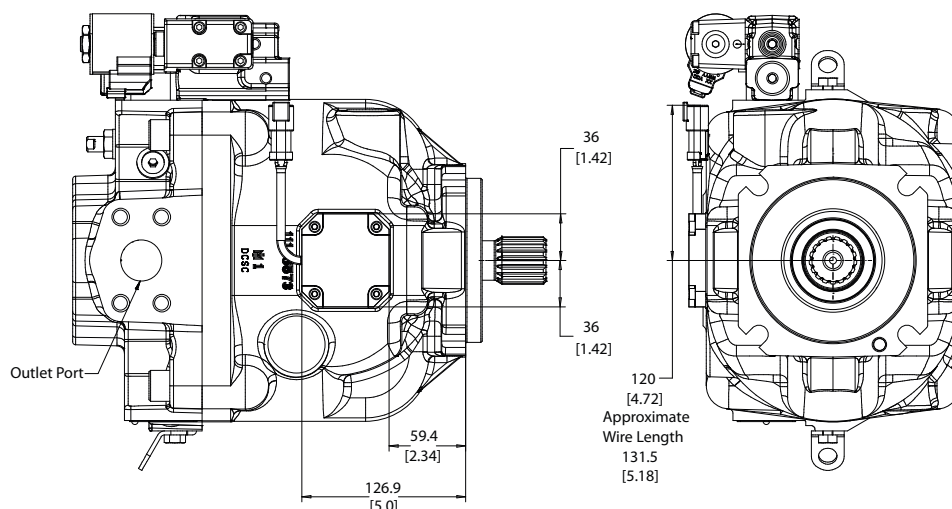
This sensor location yields a unique voltage versus swashplate angle characteristic curve which is the same for both Clockwise and Counter-clockwise rotation J & F-frames. Although each pair of curves will be unique for individual pumps, a general example of what to expect is provided below for J & F units with the 'Right' angle sensor position.



### E-Frame (100-147cc) Angle Sensor Identification Convention:

The location convention for the E-Frame angle sensor is different from that of the J & F-Frame due to a difference in design of the endcap and servo systems. When looking at the input shaft, the angle sensor will be positioned on the same side as the outlet port of the endcap. The outlet port of the endcap is always the smaller of the inlet and outlet ports, indicated below. This is the 'right side' order code location, even though it appears on the left hand side from a frontal view.

## General Angle Sensor Information



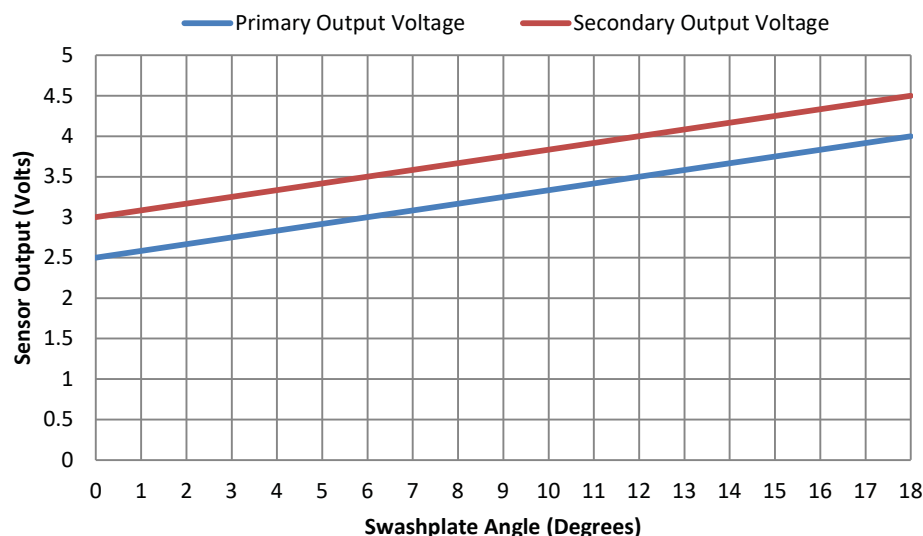
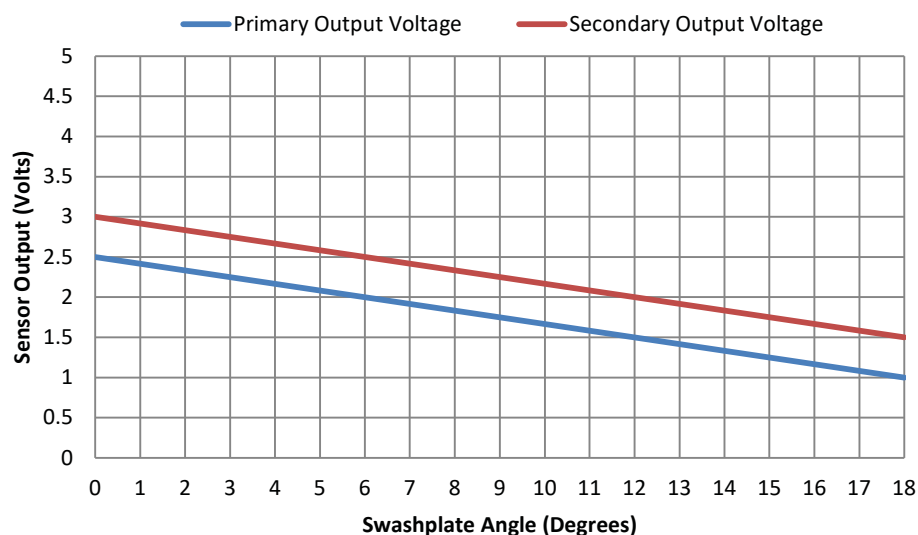
**E Frame Angle Sensor Position**

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Clockwise rotation E-frames appear with the control on the top side in this view. Counter-clockwise rotation E-Frames appear with the control on the bottom side in this view.

This sensor location yields a unique voltage versus swashplate angle characteristic curve which is different for Clockwise and Counter-clockwise rotation E-frames. Although each pair of curves will be unique for individual pumps, a general example of what to expect is provided below for both Clockwise and Counter-clockwise rotation units with the **Right** angle sensor position.

## General Angle Sensor Information



## Angle sensor electrical specifications

### Electrical specifications

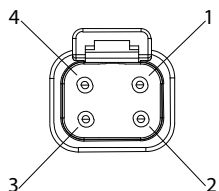
Description	Minimum	Typical	Maximum	Unit	Note
Supply (V+)	4.75	5	5.25	Vdc	Sensor is ratiometric in the voltage range
Supply protection	—	—	28	Vdc	Sensor will switch off above 5.5 V
Supply current drawn	—	22	25	mA	Sensor supply at 5 V
Output short circuit current (VDD to SIG 1/2 and GND to SIG 1/2)	—	—	7.5	mA	Additional 7.5 mA for each sensor signal, total sensor 7.5x2+22=37 mA typical for FSO
Resolution	—	0.03	—	degree	11 bit output channel
Hysteresis	—	—	—	—	Design of sensor eliminates any mechanical hysteresis
Environment temperature range	-40 (-40)	80 (176)	104 (220)	°C (°F)	If temperature limits are exceeded, the sensor will function at a reduced level of performance
Operating temperature range	20 (68)	50 (122)	95 (203)	°C (°F)	Temperature of oil
Storage temperature	-40 (-40)	—	125 (257)	°C (°F)	—
Refresh rate of the sensor	—	—	100	µs	Internal ADC refresh rate

## General Angle Sensor Information

### Sensor Connector and MC012 Microcontroller Pin Assignments

#### Angle sensor DTM04-4P connector pin assignments

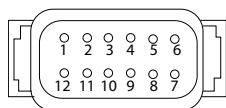
For a mating connector, use Deutsch® plug DTM06-4S.



Pin	Assignment
1	Ground (GND)
2	Output signal 2 (SIG2) - Secondary signal
3	Output signal 1 (SIG1) - Primary signal
4	Supply (V+)

#### Pre-compiled MC012 Pin Assignments

12-pin connector



#### Pre-compiled MC012 Pin Assignments

Pin callout	Pin assignment type	ETL function assigned
C1-P1	Power ground (–)	Generic/sensor ground
C1-P2	Power supply (+)	Machine power
C1-P3	CAN (+)	CAN/J1939 High
C1-P4	CAN (–)	CAN/J1939 Low
C1-P5	AIN/CAN shield	Pressure transducer signal (optional)
C1-P6	5Vdc sensor power (+)	Angle sensor power (mandatory)
		Pressure transducer power (optional)
		Torque potentiometer power (optional)
C1-P7	Sensor power ground (–)	Generic/sensor ground
C1-P8	DIN/AIN/FreqIN	Angle sensor signal 1 (mandatory)
C1-P9	DIN/AIN/FreqIN	Angle sensor signal 2 (optional)
		RPM speed ring pickup
		Boost mode switch functionality
C1-P10	DIN/AIN/FreqIN	Potentiometer wiper (optional)
C1-P11	PWMOUT/DOUT/PVGOUT	User function
C1-P12	PWMOUT/DOUT/PVGOUT	Control coil current supply

## Potentiometers, Pressure Transducers, and the PumpTorqCalc Function Block

### Potentiometer

It is possible to use a potentiometer to control the torque limiting signal for ETL setup purposes. Use a 1k-ohm potentiometer with a 120-ohm resistor on the +V and –V ends.

## General Angle Sensor Information

### Pressure transducer

Using a pressure transducer allows the ETL service tool to report actual torque and power consumed by the S45 pump via the PumpTorqCalc Function Block. The PumpTorqCalc function block is an optional part of the ETL system, and it allows the user to report real-time data on a graphical display terminal to help equipment operators understand and improve operating efficiencies or share data between subsystems to coordinate power sharing.

For more detailed information on the PumpTorqCalc Function Block, see *Work Function Control Blocks Library* (**AQ152986482242**).

Danfoss recommends using the MBS1250 Heavy Duty Pressure Transducer with a measuring range of 0 to 400 bar [5800 psi]. For information on this transducer, see *MBS1250 Heavy Duty Pressure Transmitter Product Electrical Installation* (**11062087**).

## General PLUS+1 ETL Service Tool Information

The Electronic Torque Limiting (ETL) Service Tool is used to set up the torque limiting functionality on a machine. See [ETL Service Tool Setup](#) on page 19 for the steps required to set up an ETL system.

[Typical ETL Service Tool Screen](#) shows a typical ETL Service Tool screen. You can navigate the Service Tool screens in two ways.

- Diagnostic Navigator Panel (1), which allows you to view the hierarchy of all screens
- Navigation buttons (2), which give you quick access to related screens

ETL functionality is listed under **Diagnostic Navigator > Parameter Functions** (3).

- System Overview
  - Torque Limit Setpoint
    - Torque Potentiometer Calibration
    - Torque Limit Profile Setup
    - Torque Setpoint
    - CAN Torque Setpoint Setup
  - Command Filter Setup
  - Angle Sensor Calibration
  - Boost Setup
  - RPM Input Setup
  - Pump Setup
  - Pressure Sensor Setup
  - Pressure Setpoint Faults
  - Electrical Interface

User-defined toggle inputs (4) appear with a blue background.

Parameter faults (5) are shown as green, if no fault is present, and red, if a fault is present.

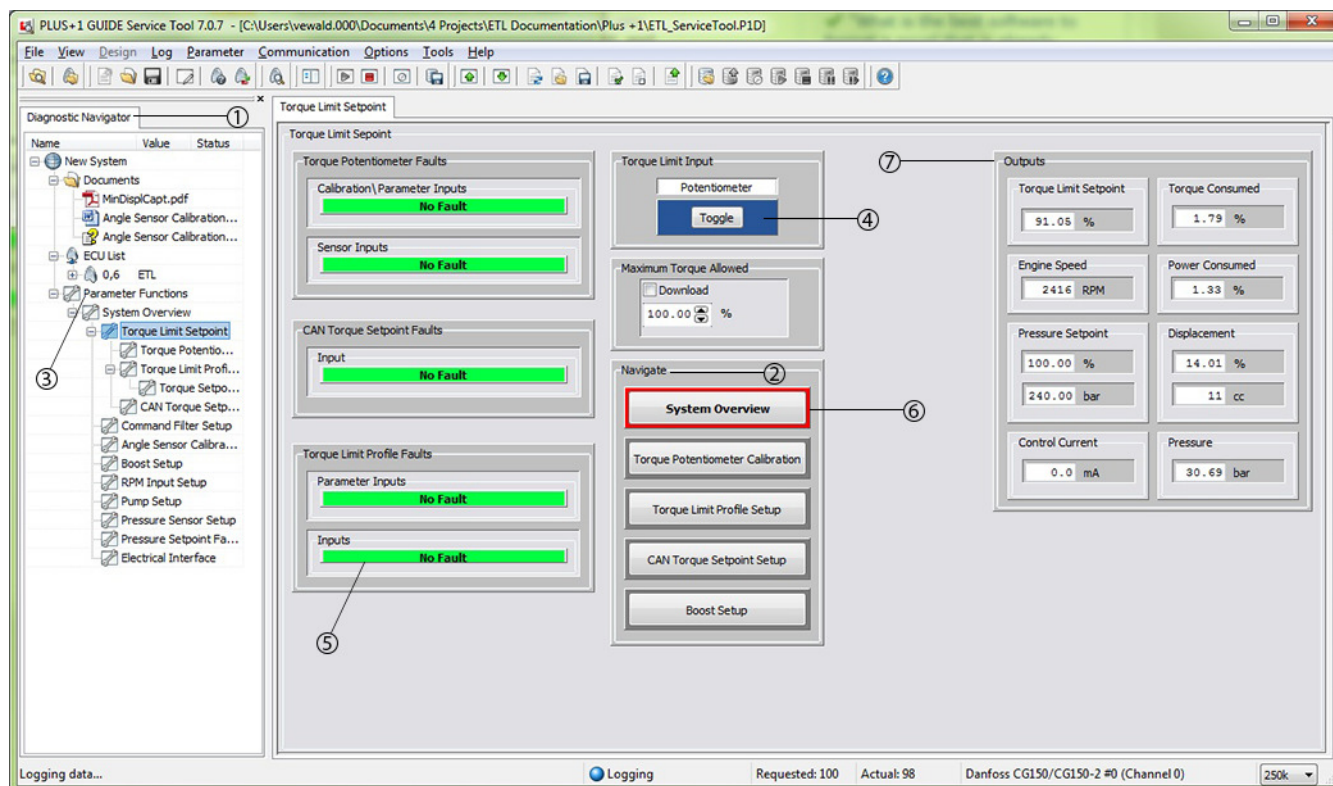
Each screen includes navigation links back to the System Overview (6), bounded by red.

Outputs (7) appear on all ETL Service Tool screens.



## General PLUS+1 ETL Service Tool Information

### Typical ETL Service Tool Screen



### Typical ETL Service Tool Outputs

Output	Description
Torque Limit Setpoint	Displays the real-time calculated torque limit for the real-time engine speed as a percentage of maximum torque consumable by the pump. It is calculated based on the curve fitted from the torque limit profile (discussed on torque limit profile page) or as an input of the voltage from the Torque Potentiometer.
Engine Speed	Shows the real-time engine speed fed back from the machine. Engine speed feedback must be wired to the microcontroller by the user using either the CAN High and CAN Low pins (C1-P3 and C1-P4), or the RPM speed ring pickup pin (C1-P9) (see <a href="#">RPM Input Setup</a> on page 24).
Pressure Setpoint	Displays the real-time system pressure currently allowed by the ETL control system. Displayed both as a percentage of Max Pump Pressure and in bar. It is calculated by referencing current pump displacement and engine speed (torque available at engine).
Control Current	Displays real-time current in milliamps (mA) being sent to the pump's control solenoid from the PLUS+1 <sup>®</sup> microcontroller. A current of zero or near-zero mA indicates that the solenoid is not being activated to limit torque.
Torque Consumed	Displays the real-time torque consumed by the pump as a calculated percentage of pump maximum torque based on the Max Pump Displacement and Max Pump Pressure inputs.
Power Consumed	Displays the real-time power consumed by the pump as a calculated percentage of pump maximum power based on the Max Pump Displacement, Max Pump Pressure, and Max Pump Speed.
Displacement	Displays the real time pump displacement in both percent of maximum displacement and cm <sup>3</sup> /rev. This displacement depends directly on the minimum and maximum displacement calibration points.
Pressure	Indicates real-time system pressure based on a pressure transducer. Note that a pressure transducer must be added to the system by the user for this optional functionality.

## General PLUS+1 ETL Service Tool Information

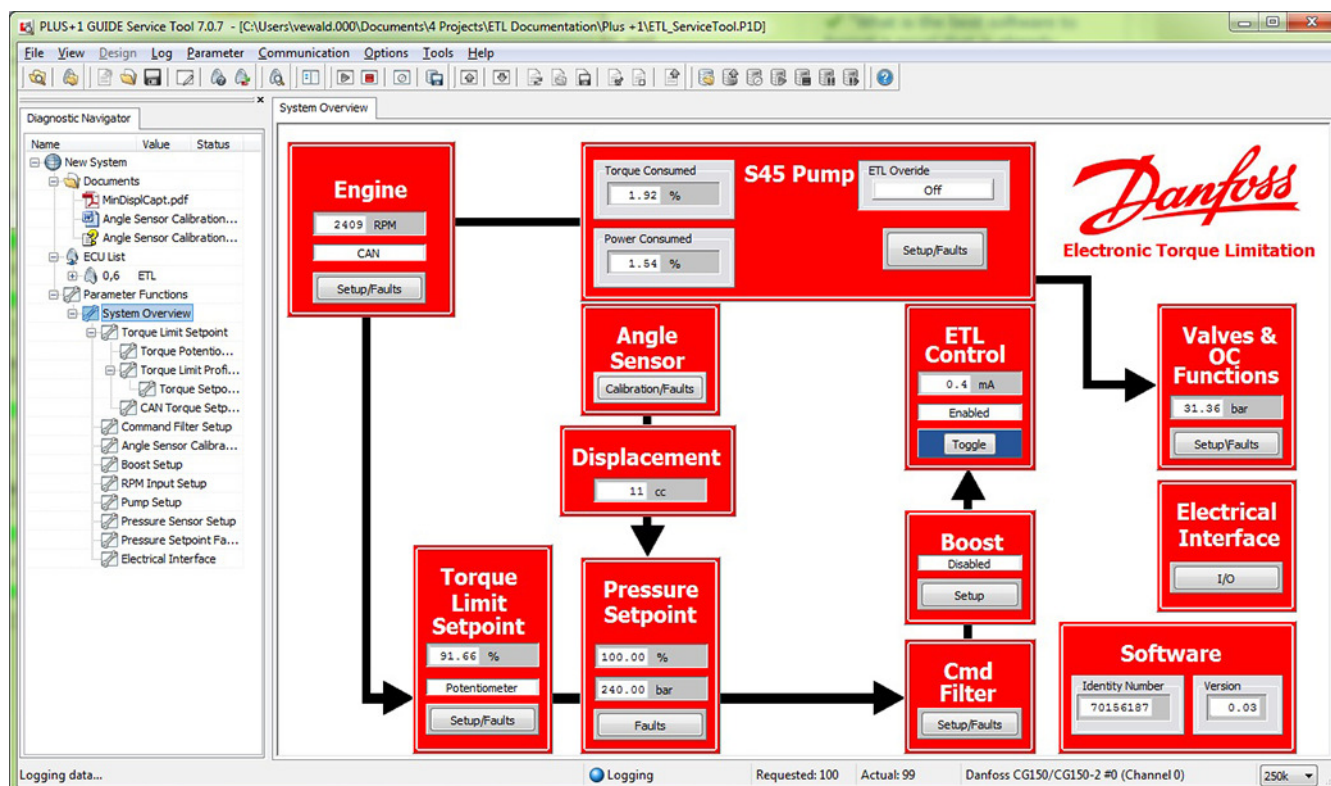
### System Overview

The System Overview screen is the home screen for the ETL Service Tool. This screen shows a high-level overview of how the S45 ETL software ties into the machine's engine and hydraulic systems by reporting real-time parameters.

You can also use the System Overview to do the following actions.

- Navigate to each ETL functionality to tune changes or conduct diagnostics after the general setup
- Enable or disable **ETL Control** using the **Toggle** button

### ETL System Overview Screen



### Torque Limit Setpoint

The **Torque Limit Setpoint** screen is important because it allows the user to select between two torque limit input options (Torque Limit Profile or Torque Potentiometer).

This screen also provides quick navigation to the most frequently used setup screens.

### Torque Limit Setpoint Parameters

#### Torque Limit Setpoint Parameters

Inputs	Torque Limit Input	Allows the user to select between two different forms of torque limitation controls, Torque Profile and Potentiometer. The Torque Profile is used when the seven limiting setpoints are finalized, and the Potentiometer is used when first setting up ETL or conducting diagnostics. These are discussed in detail in <a href="#">Torque Limit Profile Setup</a> on page 27.
	Maximum Torque Allowed	Allows the user to de-rate the whole Torque Limit Profile by a common factor. The software sets the default value to 100%.

## ETL Service Tool Setup

This section describes the ETL functions that are required for the ETL system to operate, including how to set up each ETL function.

To set up each ETL function, you will make changes to each function's respective ETL Service Tool screen, similar to the screen shown in [Typical ETL Service Tool Screen](#).

The following steps are required in order for the ETL system to operate.

1. Calibrate Angle Sensor
  - a. [Establish the Minimum Pump Displacement](#) on page 20
  - b. [Establish the Maximum Pump Displacement with Engine Off](#) on page 21

or

[Establish the Maximum Pump Displacement with Engine Running](#) on page 21
2. [Define Pump Displacement](#) on page 23
3. [Perform RPM Input Setup](#) on page 24
4. [Calibrate Torque Potentiometer](#) on page 25
5. [Select Pressure Sensor Setup](#) on page 26
6. Establish Torque Limit Profile
  - [Establish Torque Limit Profile with Torque Curve](#) on page 28

or

[Establish Torque Limit Profile without Torque Curve](#) on page 28

## Angle Sensor Calibration

A fundamental step in setting up ETL is to calibrate your angle sensor. The calibration will ensure accurate angle sensor voltage readings based on maximum and minimum pump displacements (swashplate angles).

Calibration does not inform the software what the physical maximum displacement of the pump is in terms of engineering units. This is done in the **Pump Setup Parameters** screen, and the correct calibration of the angle sensor is independent of the **Max Pump Displacement** input.

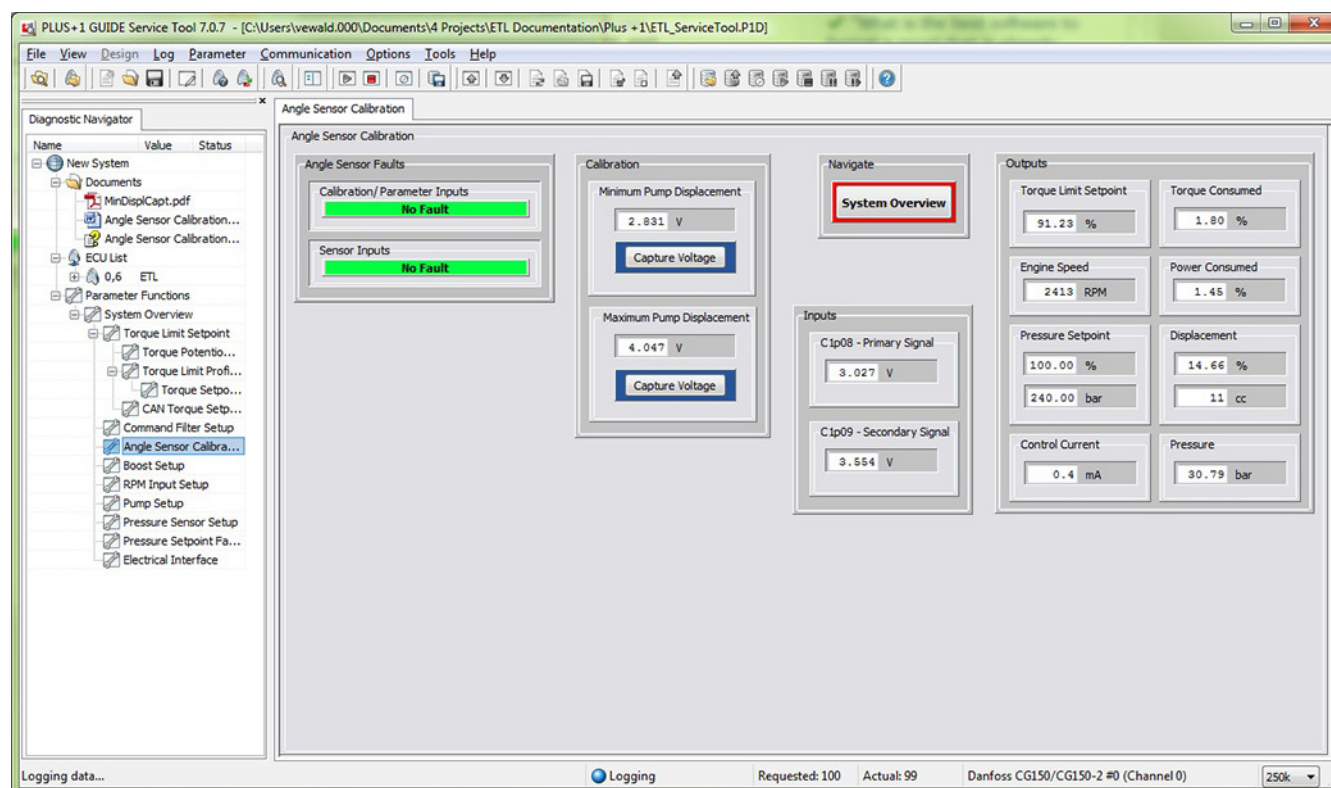
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It is possible when calibrating the angle sensor that the Minimum Displacement Voltage is greater than the Maximum Displacement Voltage. This is due to the different relationships between swashplate angle and voltage for J and F-frames versus E-frame pumps. For more information, see the [Angle Sensor Characteristics](#) on page 10.

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## ETL Service Tool Setup

### Angle Sensor Calibration Screen



### Angle Sensor Calibration Parameters

#### Angle Sensor Calibration Parameters

Calibration	Minimum Pump Displacement	Records the angle sensor signal voltage that corresponds to the pump's lowest displacement condition
	Maximum Pump Displacement	Records the angle sensor signal voltage that corresponds to the pump's highest displacement condition
Inputs	C1p08-Primary Signal	Displays the real-time voltage signal from the primary sensor pickup
	C1p09-Secondary Signal	Displays the real-time voltage signal from the secondary sensor pickup, if enabled (optional)
Faults	Calibration/Parameter Faults	Minimum/Maximum displacement not calibrated
		Invalid setup/calibration
		Parameter out of range
	Sensor Input Faults	Signal 1 input too low/high
		Signal 1 input at Sensor Power/Ground
		Redundant signal indicates error

### Establish the Minimum Pump Displacement

To establish the minimum displacement of the pump, you must operate the pump at either the Low Pressure Standby Condition (LPSB) or the High Pressure Standby Condition (HPSB).

For the best results, calibrate and compare using both LPSB and HPSB to achieve the lowest (or highest, for CW E-frame units) captured voltages.

## ETL Service Tool Setup

It is important to compare the minimum displacement voltage readings at both LPSB and HPSB. Generally, the swashplate angle is lower at LPSB because there are lower leakages at lower pressures, so lower displacements are required to make up the leakages. This is not true when some flow is allowed past the main valve block at LPSB. Then, HPSB conditions become preferred. Although the leakages are higher at higher pressures, the increase in flow due to leakages is lower than the flow allowed by the main valve.

1. Set the engine at full operating speed.

The engine must be operated at full speed to prevent an inaccurate displacement reading.

2. If the ETL is not disabled in the **System Overview** screen, toggle **ETL Control** to **Disabled**.

The control current should approximate 0 mA.

3. Operate the pump at one or both of the following conditions.

Condition	When to use
Low Pressure Standby Condition (LPSB)	Use when the machine's main valve block completely shuts off flow to any downstream components (zero flow needed by machine functions/valves from pump)
High Pressure Standby Condition (HPSB)	Use when the machine's main valve block does not completely shut off flow to all downstream components (some small flow needed by machine functions/valves from pump at all times, even with no operator command)

- a) If using LPSB, let the machine stand at full engine speed without operating any functions.

This allows the pump to de-stroke naturally because no flow is commanded from the pump, and system pressures will be only slightly higher than the pump's LS setting.

- b) If using HPSB, operate a machine function over a hard-stop and reach full pressure compensator (PC) setting with system pressure.

This allows the pump to de-stroke by porting high pressure oil to servo.

From the **Angle Sensor Calibration** screen while maintaining either LPSB or HPSB:

4. Click **Minimum Pump Displacement > Capture Voltage**.

### Establish the Maximum Pump Displacement with Engine Off

1. Turn off the machine.
2. Momentarily jog the starter to turn the pump shaft a few revolutions, without actually running the engine.

This allows the pump's swashplate to return to its naturally spring biased full-stroke position by overcoming residual pressure and friction in the swashplate and servo system.

From the **Angle Sensor Calibration** screen:

3. Click **Maximum Pump Displacement > Capture Voltage**.

### Establish the Maximum Pump Displacement with Engine Running

The engine must be operated at full speed to prevent an inaccurate displacement reading.

1. Operate the pump in a full displacement, full flow, and low load machine condition.
  - a) Operate engine at full operating speed.
  - b) Command a single high flow function or multiple machine functions simultaneously while remaining below the pump's pressure compensator setting (low system pressure).

Do not reach or exceed the pressure compensator setting or the pump will begin to de-stroke and reduce its displacement and render a bad maximum displacement reading.

From the **Angle Sensor Calibration** screen:

2. Click **Maximum Pump Displacement > Capture Voltage**.



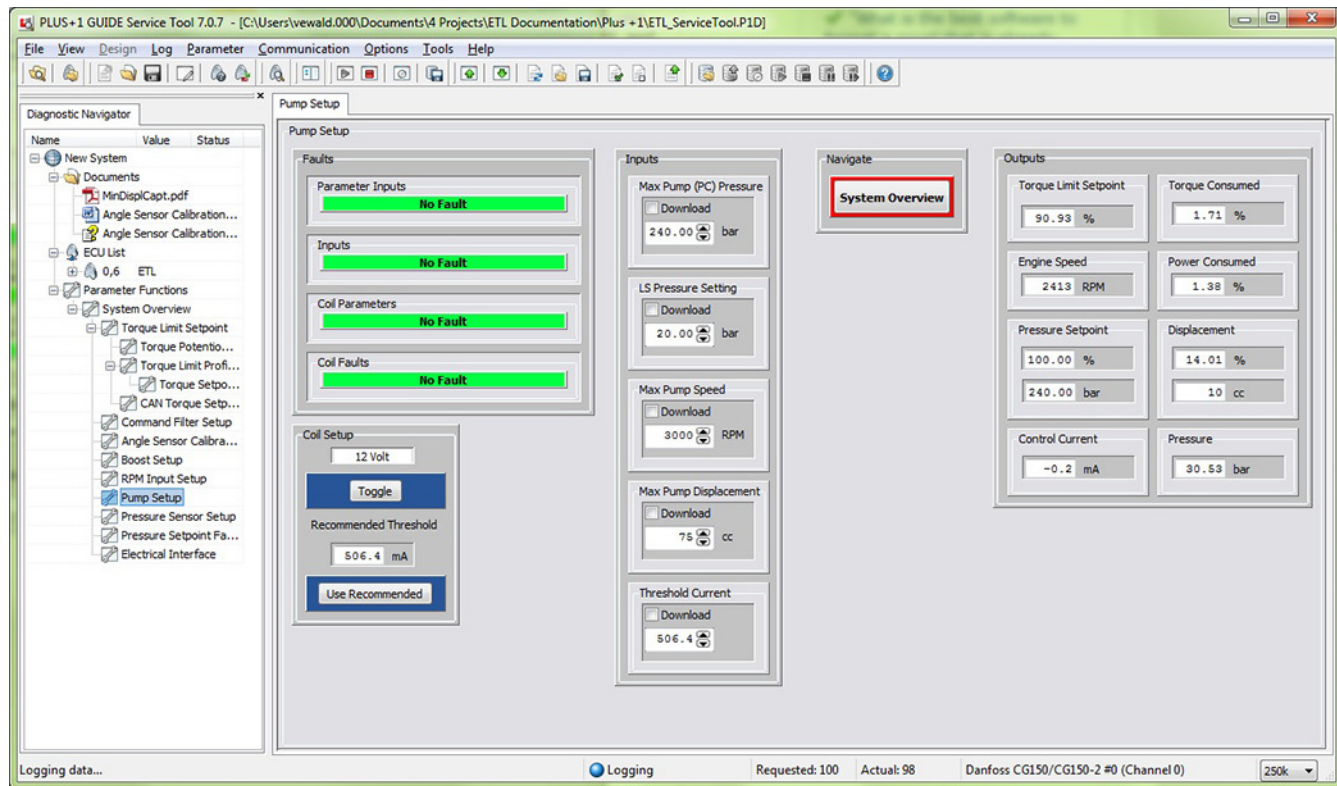
## ETL Service Tool Setup

### Pump Setup

The pump setup function defines the pump displacement in PLUS+1® software. It also sets the maximum system pressure and maximum pump speed to calculate the maximum pump torque and power.

Coil current thresholds are also set up based on the user's inputs.

#### Pump Setup Screen



## ETL Service Tool Setup

### Pump Setup Parameters

#### Pump Setup Parameters

Inputs	Max Pump Pressure	Defines the maximum desired system pressure created by the pump, in bar. This must be less than or equal to the Pressure Compensator (PC) setting. This software setting DOES NOT override the pump's factory set mechanical Pressure Compensator setting. If the <b>Max Pump Pressure</b> is higher than the PC setting, the pump will default to the physical PC pressure of the pump and the ETL system will not function correctly.
	Max Pump Speed	Calculates power consumed by the pump. Generally, the highest engine operation speed of the machine should be used. See <i>Series 45 Pumps Technical Information (BC152886483703)</i> for allowed pump operating speeds in order to ensure conformance to recommended continuous operation speeds. This input does not limit physical pump speed in any way.
	Max Pump Displacement	Defines the true maximum displacement of the pump in terms of cm <sup>3</sup> /rev and correlates it to the Maximum Captured Voltage. Also known as nominal pump displacement, it can be determined by the pump's model code.
	LS pressure setting	Defines the margin setting of the pump, in bar. This must be equal to the LS pressure setting as defined from the factory. This may be found on the pump's identification tag.
	Threshold current	Defines the minimum current required for active torque limiting in the control. It is based on the <b>Max Pump (PC) Pressure</b> , <b>LS Pressure Setting</b> , and 12- vs. 24-volt coil characteristics. This is an interpolated value that references control pressure vs. current curves.
Faults	Parameter input faults	<b>Max Pump Pressure</b> out of range
		<b>Max Pump Speed</b> out of range
		<b>Max Pump Displacement</b> out of range
	Input faults	Displacement value too high or low
		Speed value too high or low
		Pressure value too high or low

### Define Pump Displacement

From the **Pump Setup** screen:

1. Set **Pump Max Pressure** to the desired maximum operating pressure.

The **Pump Max Pressure** setting must not exceed the Pressure Compensator (PC) setting of the pump. It should be equal to or less than the PC setting, or else the system will lose power because the pump will need to relieve pressure in a constant manner.

2. Set **LS Pressure Setting** to the pump's factory LS margin pressure.

3. Set **Max Pump Speed** to the maximum operating speed at which the pump will operate.

In general, you should use the highest engine operation speed of the machine. See *Series 45 Pumps Technical Information (BC152886483703)* for allowed pump operating speeds to conform to the recommended continuous operation speeds.

4. Set **Max Pump Displacement** to the physical maximum displacement of the pump in units of cm<sup>3</sup>/rev.

5. Set **Threshold Current**.

a) Toggle **Coil Setup** to the correct coil voltage.

b) Set **Max Pump (PC) Pressure** and **LS Pressure Setting**.

The **Recommended Threshold** field will display the recommended threshold.

c) Select **Use Recommended**.

The recommended current threshold will transfer to the **Threshold Current** field.

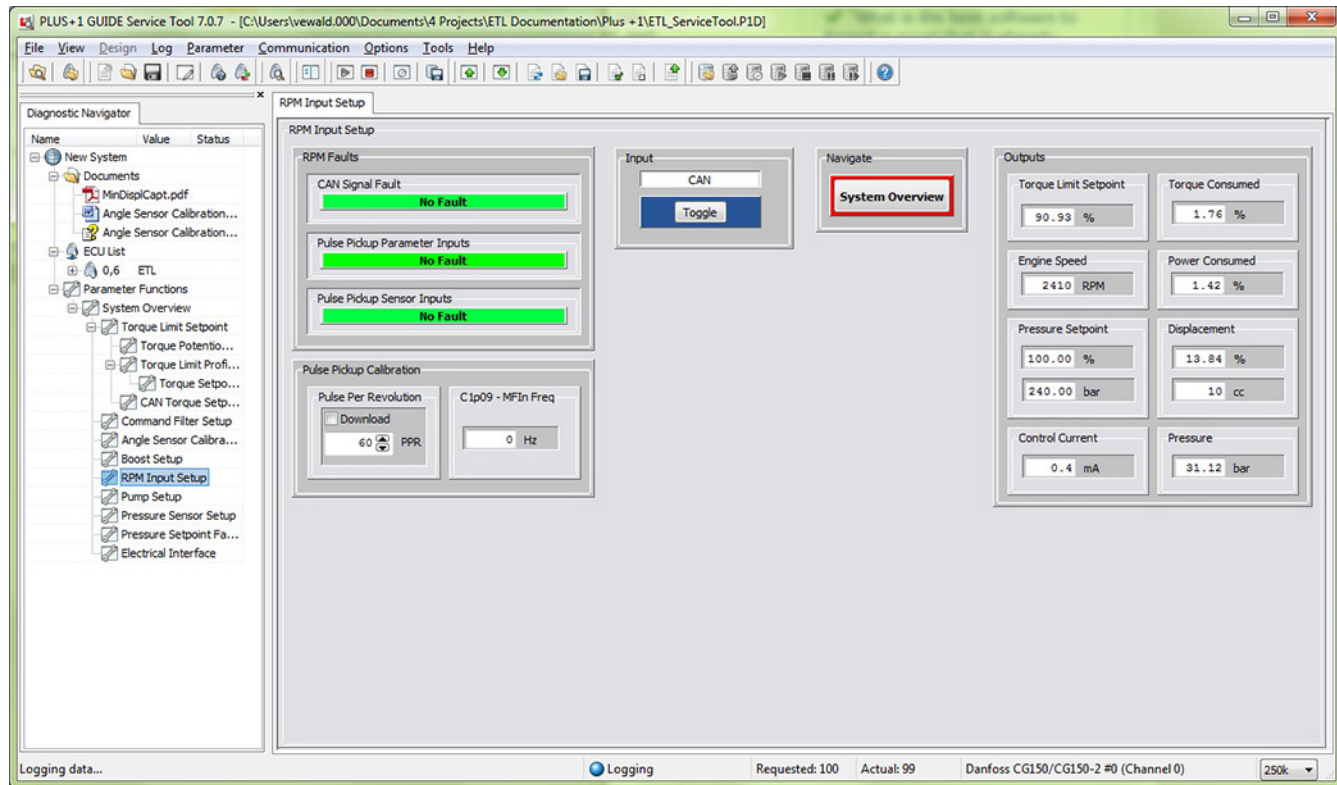
Advanced users may reference a control pressure vs. current curve and enter their own threshold to create a custom offset for the threshold setting.

## ETL Service Tool Setup

### RPM Input Setup

The RPM input limits the torque throughout an engine's usable speed range. To set up this limit, you must select the proper speed input, either CAN bus speed pickup or speed ring pulse pickup.

#### RPM Input Setup Screen



### RPM Input Parameters

#### RPM Input Parameters

Inputs	Speed Input	Toggle switches between two different inputs: CAN bus and Speed ring pulse pickup
	Pulse Per Revolution	Sets the number of pulses per revolution of the Hall Effect Sensor when Speed Ring is selected
	C1p09 - MFIn Freq	Displays the frequency at which the speed ring sensor is sensing pulses
Faults	Parameter input faults	PPR parameter is out of range (>10,000)
		Frequency is too high (>50,000)
		Frequency is too low (=0)

### Perform RPM Input Setup

From the **RPM Input Setup** screen:

1. Toggle your desired input to use for the engine speed pickup.
  - Speed ring
  - CAN bus
2. If a hall effect/speed ring type is used, indicate the number of pulses per revolution in **Pulse Pickup Calibration > Pulse Per Revolution**.  
The engine speed output will read the real-time speed when set up.



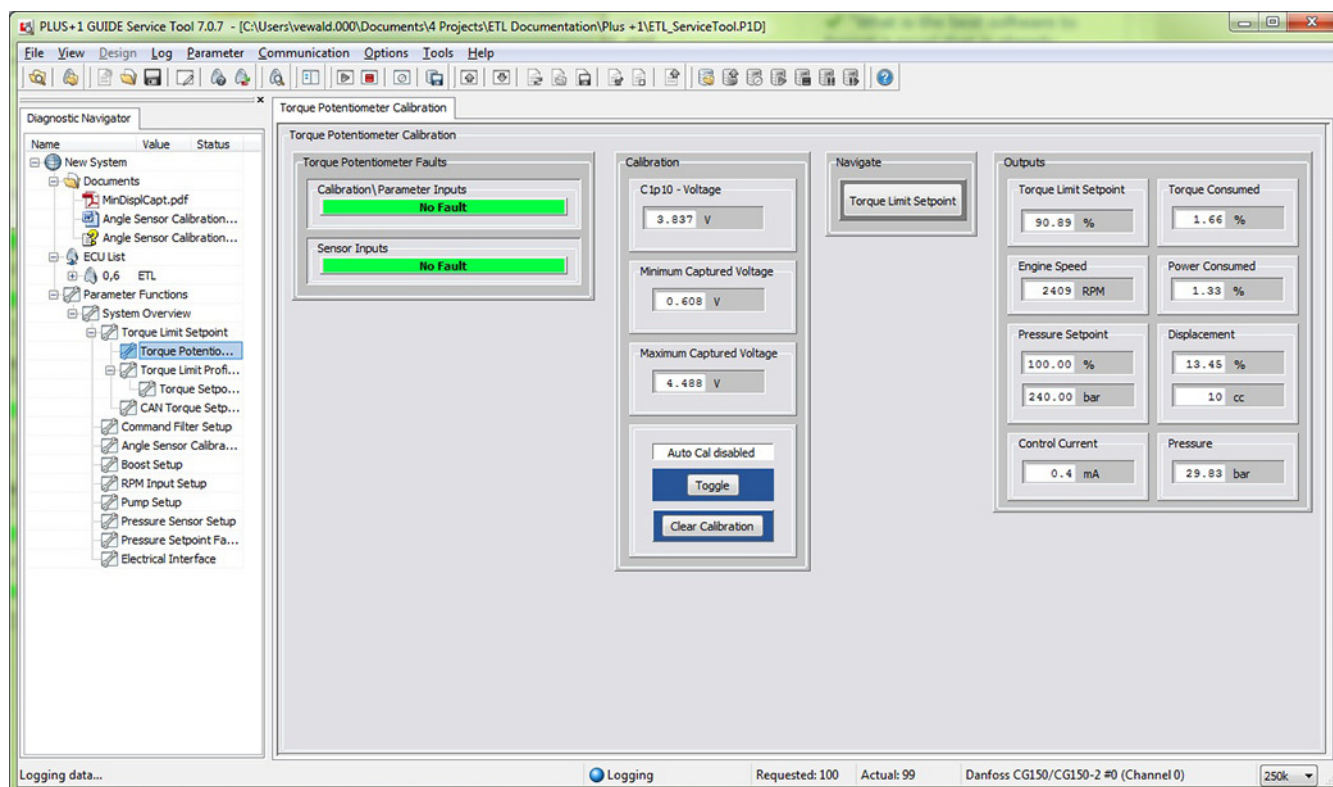
## ETL Service Tool Setup

### Torque Potentiometer Calibration

This section applies only if a potentiometer is used for ETL setup.

A potentiometer greatly reduces the Torque Limit Profile setup time by allowing quick adjustments to the actual torque limit at any engine speed condition. In order for a potentiometer to be used for this functionality, it must first be calibrated.

#### Torque Potentiometer Calibration Screen



### Torque Potentiometer Calibration Parameters

#### Torque Potentiometer Calibration Parameters

Calibration	C1p10 - Voltage	Indicates the real-time signal voltage being input from the Torque Potentiometer
	Minimum Captured Voltage	Displays the minimum captured voltage created by the potentiometer
	Maximum Captured Voltage	Displays the maximum captured voltage created by the potentiometer
	Auto Calibration Toggle	Enables or disables the auto calibration feature
	Clear Calibration	Clears the minimum and maximum captured voltages from the previous calibration to establish a new calibration

### Calibrate Torque Potentiometer

1. Connect a potentiometer to the indicated pins in the MC012 pin out.

From the **Torque Potentiometer Calibration** screen:

2. Toggle the auto calibration to **Auto Cal Enabled**.

This calibrates the potentiometer.

## ETL Service Tool Setup

3. Turn the potentiometer from lock to lock in a steady manner.

The auto calibration feature will automatically capture the minimum and maximum allowable voltages registered while the Auto Cal is enabled. The proper voltage range will be attained when using a 1k-ohm potentiometer with 120-ohm resistors on both the +V and -V ends.

4. After the minimum and maximum voltages are captured, toggle the auto calibration to **Auto Cal Disabled**.
5. If the calibration did not cover the full range of the potentiometer, or if you need to use a new potentiometer, click **Clear Calibration**.

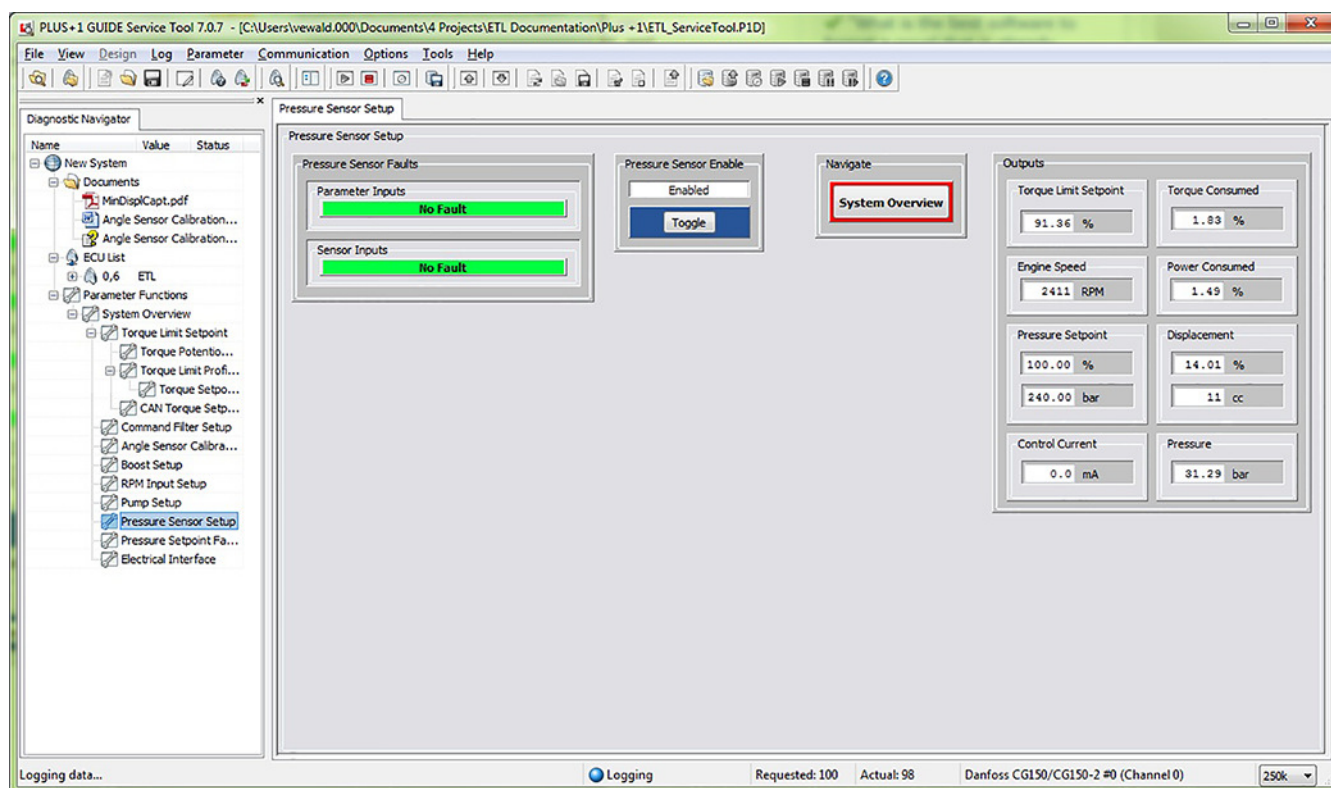
This deletes the previously captured voltages to capture a new calibration.

The minimum and maximum voltages of the potentiometer will not be 0V or 5V. This is not allowed for fault monitoring purposes.

## Pressure Sensor Setup

The **Pressure Sensor Setup** screen allows the user to enable the use of a system pressure transducer. A pressure transducer is helpful to diagnose the system and calculate power consumed by the pump.

### Pressure Sensor Setup Screen



## Pressure Sensor Setup Parameters

### Pressure Sensor Setup Parameters

Inputs	Pressure Sensor Enable	Enables or disables in-line pressure transducer functionality
Faults	Parameter input faults	Pin value too high (at sensor power)
		Pin value too low (at sensor ground)

## Select Pressure Sensor Setup

## ETL Service Tool Setup

1. After system pressure functionality is desired, hook up the recommended pressure transducer to the recommended pins.

For pinout, see [Pre-compiled MC012 Pin Assignments](#) on page 14.

From the **Pressure Sensor Setup** screen:

2. Toggle **Pressure Sensor Enable** to **Enabled**.

## Torque Limit Profile Setup

The Torque Limit Profile is the heart of an ETL system. It is what defines how a machine reacts to torque loads, and it has an infinite number of tuning possibilities. It allows you to define how the system limits torque consumed by the open circuit hydraulic system.

The most basic torque profile will reference a graph of engine torque available vs. engine speed from the engine manufacturer. However, this basic profile may not always be the best profile, and such detailed engine information might be difficult to obtain.

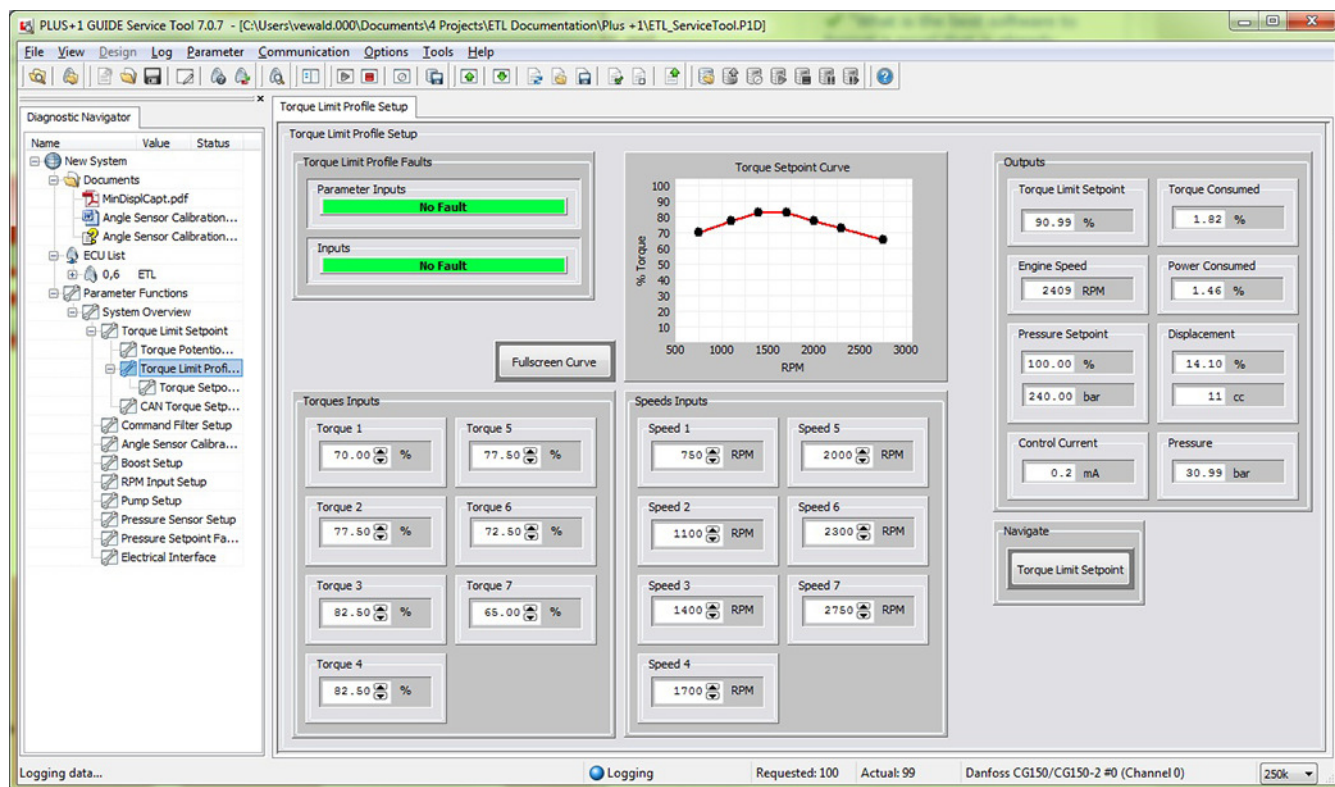
It is important to realize that the user can tune the reactivity of the ETL system by how closely the 7 input points match the actual torque available from the engine. Torque values which exactly match the available torque from the engine may yield a system which allows for noticeable engine speed reactions (engine bog or droop) as torque limiting takes over. This generally occurs because the pump's input torque requirements may increase much more rapidly than the engine's torque output.

However, torque values which are set slightly lower than the actual available engine torque provide some margin between the limited torque and the actual torque. This combats any reactivity from the engine at all, and gives the operator the setup with the lowest potential for noticeable engine speed changes.

The desired amount of engine reaction is subjective and can vary for different applications.

You can create a Torque Limit Profile with or without a torque curve. A torque curve is highly recommended for best optimization, but it is not necessary.

### Torque Limit Profile Setup Screen



## ETL Service Tool Setup

### Torque Limit Profile Setup Parameters

#### Torque Limit Profile Setup Parameters

Inputs	Speed Inputs 1–7	These speed inputs correspond to 7 engine speed points on a torque curve for which torque is to be limited
	Torque Inputs 1–7	These torque inputs correspond to the 7 engine speed points on a torque curve for which torque is to be limited
Faults	Parameter inputs	Speed [N] is less than or equal to Speed [N-1]
		Speed [N], out of range
		Torque [N], out of range
	Inputs	Actual engine input speed value too low or high

### Establish Torque Limit Profile with Torque Curve

The following steps establish a torque limit profile if a known engine torque curve is available.

From the **Torque Limit Profile Setup** screen:

1. Set the engine **Speed Inputs** (Speed 1–7) at which you wish to limit torque.  
For example, set the lowest engine idle speed, highest engine idle speed, and five equally spaced points between the two.
2. Set the **Torque Inputs** (Torque 1–7).  
To do this, normalize the engine's torque values to reflect the pump's maximum consumable torque. That is, divide the available engine torque by the pump's maximum consumable torque to get a Pump Torque Setpoint percentage.

$$\text{Pump Torque Setpoint}_{n \text{ speed}} [\%] = \frac{\text{Engine Available Torque}_{n \text{ speed}}}{\text{Pump Torque Consumed}_{\text{Max Pump Pressure, Displacement}}}$$

For example, if your engine's available torque at 950 rpm is 196 N-m, and a 75cc J-frame pump operating at a pressure limit of 240 bar will consume 302 N-m of torque, then  $196 / 302 = 65\%$ . This is the Pump Torque Setpoint required at 950 rpm. Continue using this method for all 7 torque setpoints.

After establishing a torque limit profile, the torque setpoints may still require adjustment to achieve the desired engine/machine reactivity. See [Adjust Torque Setpoints](#) on page 28.

### Establish Torque Limit Profile without Torque Curve

The following steps establish a torque limit profile if an engine torque curve is not available. It uses a guess-and-check method.

From the **Torque Limit Profile Setup** screen:

1. Set the engine **Speed Inputs** (Speed 1–7) at speeds which you wish to limit torque.  
For example, set the lowest engine idle speed, highest engine idle speed, and five equally spaced points between the two.
2. Set the **Torque Inputs** (Torque 1–7) .  
The following steps are one suggestion.
  - a) Pick the lowest engine speed and set the machine at this condition.
  - b) Operate the machine through various high-torque consumption cycles.
  - c) Adjust the torque limit setpoint to achieve the desired level of torque limiting (some, or virtually none, engine reaction/bog).

The reactivity is affected by how close the pump's allowed torque is relative to the engine's available torque.

After establishing a torque limit profile, the torque setpoints may still require adjustment to achieve the desired engine/machine reactivity. See [Adjust Torque Setpoints](#) on page 28.

### Adjust Torque Setpoints

After establishing a torque limit profile, the torque setpoints may still require adjustment to achieve the desired engine/machine reactivity.

## ETL Service Tool Setup

Adjust the torque setpoints using one of the following options.

Option	Steps
Torque Inputs	<ol style="list-style-type: none"> <li>Set the <b>Torque Inputs</b> (Torque 1–7).</li> <li>Download and check.</li> </ol>
Torque Setpoint Curve	<ol style="list-style-type: none"> <li>Click and drag the points in <b>Torque Setpoint Curve</b>.</li> <li>Download and check.</li> </ol>
Torque Potentiometer	<ol style="list-style-type: none"> <li>Use a torque potentiometer to adjust the torque setpoints while operating the machine.</li> <li>Enter the setpoints into the Torque Limit Profile.</li> <li>Download and check.</li> </ol>

---

The torque potentiometer has been shown to greatly reduce the process time to adjust torque setpoints and fine tune the torque profile.

---

### Considerations for Establishing the Torque Limit Profile

- The amount of torque limiting required may be objective or subjective
  - Objective examples
    - Killing the machine vs. not killing the machine
    - Not allowing the engine to droop more than 'XXXX' rpm below desired idle speed
    - Not allowing the engine to droop to a certain sound criteria
    - Allowing the engine to droop to a certain sound criteria
    - Not allowing the pump to drop below a certain flow requirement based on a pressure criteria (necessary function speed under no load)
  - Subjective examples
    - Operator must be able to experience some engine reactivity to perceive machine work
    - Operator skill allows for smaller margin between available engine torque and pump torque consumed
    - Operator does not want machine to slow down too much
- The amount of torque consumed by the open circuit pump system does not account for the torque consumed by the closed circuit pump system
  - Propel vs. work functions
- A specific machine function may require more or less torque depending on environmental conditions
  - Cold weather vs. hot weather oil viscosity

For questions on setting up the Torque Limit Profile for your machine, consult your Danfoss representative.



## Additional Setup

The features in this section are not required for an ETL system to function. These features enhance or adjust system performance and functionality.

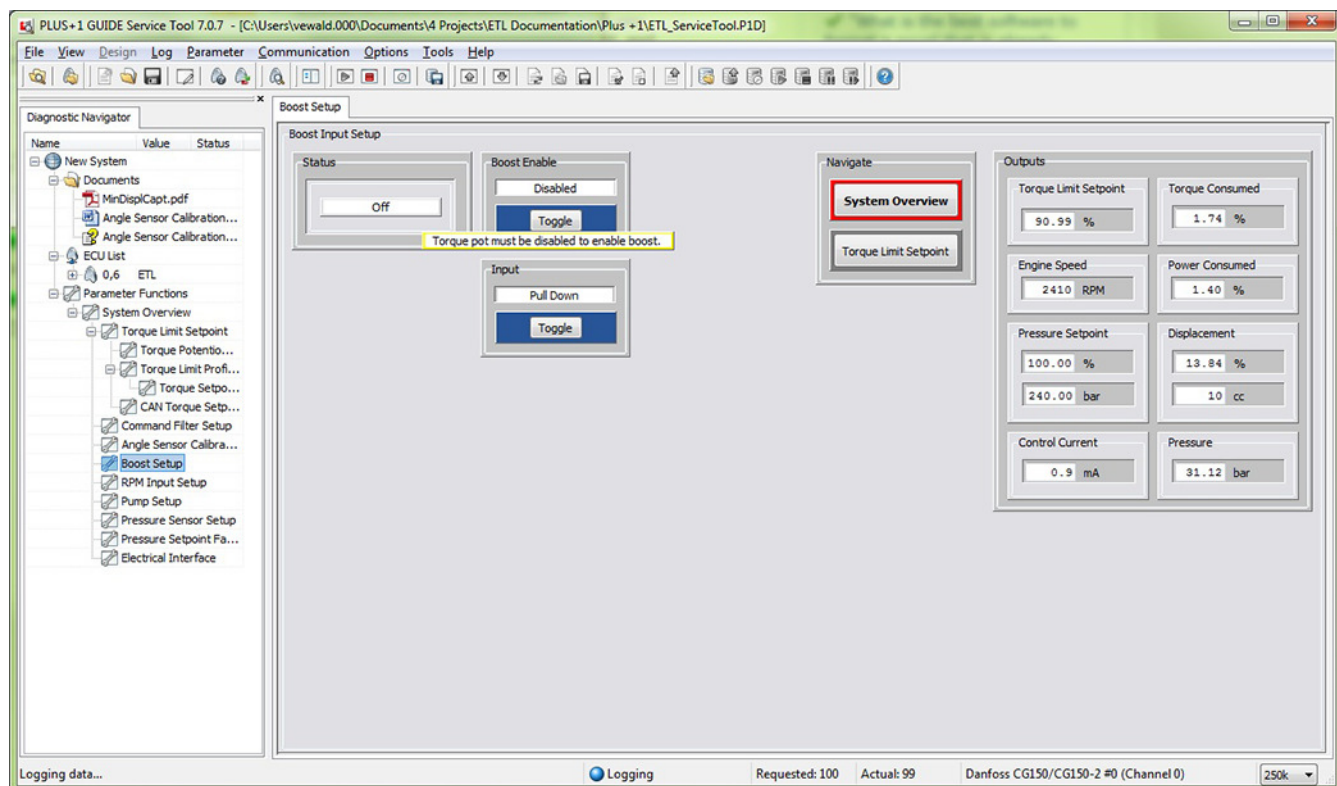
### Boost Mode

Boost mode, or ETL override, allows the user to configure an operator interface to enable or disable ETL. One example is a momentary switch incorporated into an interface such as a joystick.

The pre-keyed MC012 does not allow both the torque potentiometer and the boost mode functionality to be used at the same time. To use boost mode, the potentiometer functionality must be disabled, and vice versa. The engine will not be protected from stalling while boost mode is enabled.

One benefit of boost mode includes artificially creating a pressure setting that is lower than the pump's physical pressure compensator setting. As a result, you can achieve extra pressure capability on command by enabling or disabling ETL and creating an extra power level.

#### Boost Setup Screen



### Boost Mode Parameters

#### Boost Mode Parameters

Boost Enable	Allows or prevents the use of Boost Mode. When Disabled, Boost Mode cannot be used even if an operator interface is present. If Enabled, Boost Mode can be used when not using the Torque Potentiometer functionality.
Input	Boost mode can be configured with a switch that is either Pull Up or Pull Down in the electrical schematic. This toggle switches the logic between the two options.
Status	Indicates whether Boost Mode is Off (ETL enabled) or Boost Enabled (ETL disabled).

### CAN Torque Setpoint Setup

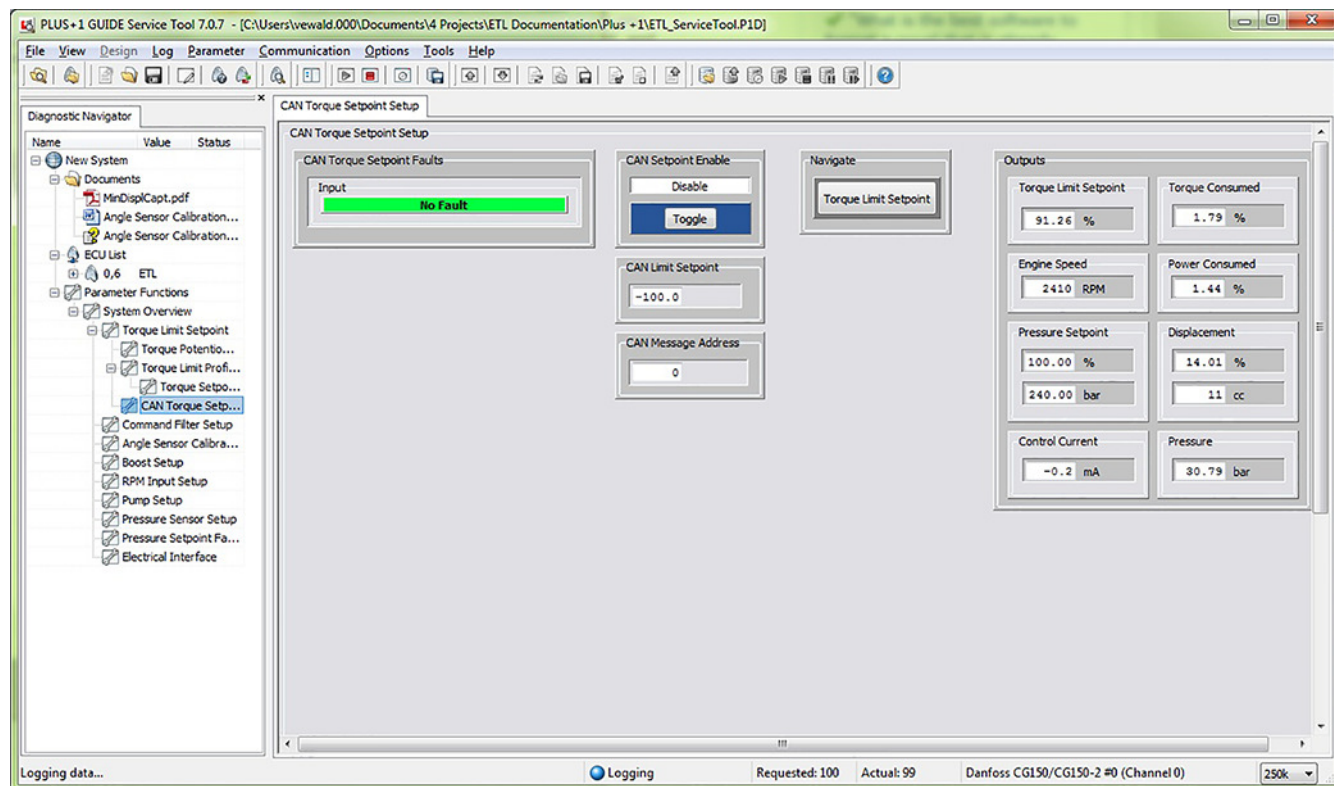
In CAN setpoint enable mode, the S45 pump responds to auxiliary command messages.

## Additional Setup

When the CAN setpoint is enabled, you can remotely send a torque setpoint to the pump by identifying an address on the CAN.

Please consult with your Danfoss representative for more information on setting up torque setpoints with CAN messaging.

### CAN Torque Setpoint Setup Screen



## Command Filter Setup

The **Command Filter Setup** screen allows for possible filtering of control current signals if there are pressure oscillations. The ETL system, by default, sets the command control filter to zero, which means it is disabled.

If the command control filter is used, the filter values can be increased until the unwanted oscillations reach an acceptable level.

Command filter setup is only necessary if unwanted instability or oscillations occur when ETL is active. The time constant sets the cutoff frequency for a first order low pass exponential filter.

Determining the frequency of oscillations can help give you a starting point for the time constant:  $f_c = 1 / (2 * \pi * t)$ .

## Additional Setup



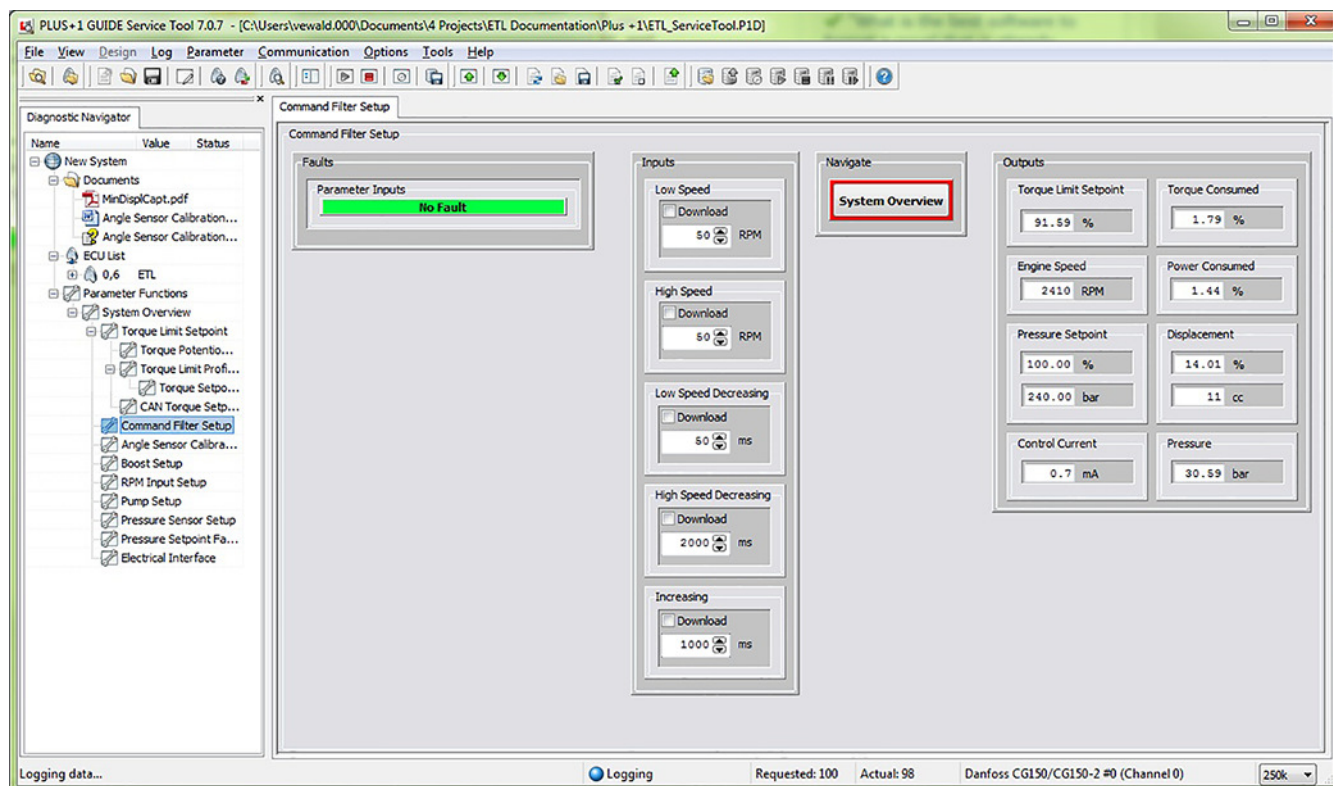
If the ETL control produces unwanted oscillations, and all time constant values are set to zero, use the following table and the **Command Filter Setup** screen to reduce oscillations.

Are oscillations occurring when the load is increasing?	Yes	Increase the <b>Increasing</b> input.
	No	Leave the <b>Increasing</b> input at zero.
Are oscillations only occurring when the load is decreasing at high engine speed?	Yes	<ul style="list-style-type: none"> <li>Set the <b>High Speed</b> input to the affected engine speed.</li> <li>Increase the <b>High Speed Decreasing</b> input.</li> </ul>
	No, there is no oscillation when the load is decreasing at high engine speed	<ul style="list-style-type: none"> <li>Leave the <b>High Speed Decreasing</b> input at zero.</li> <li>Set the <b>High Speed</b> input to the high engine speed.</li> </ul>
	No, oscillations occur when the load is decreasing at both high and low speeds	<ul style="list-style-type: none"> <li>Ensure the <b>High Speed</b> and <b>Low Speed</b> inputs match the engine tuning speeds before adjusting filter inputs.</li> <li>Set the <b>High Speed Decreasing</b> and <b>Low Speed Decreasing</b> inputs to the high and low engine setpoints.</li> </ul>



## Additional Setup

### Command Filter Setup Screen



For questions on system stability and tuning with Command Filter time constants, consult your Danfoss representative.

### Command Filter Setup Parameters

#### Command Filter Setup Parameters

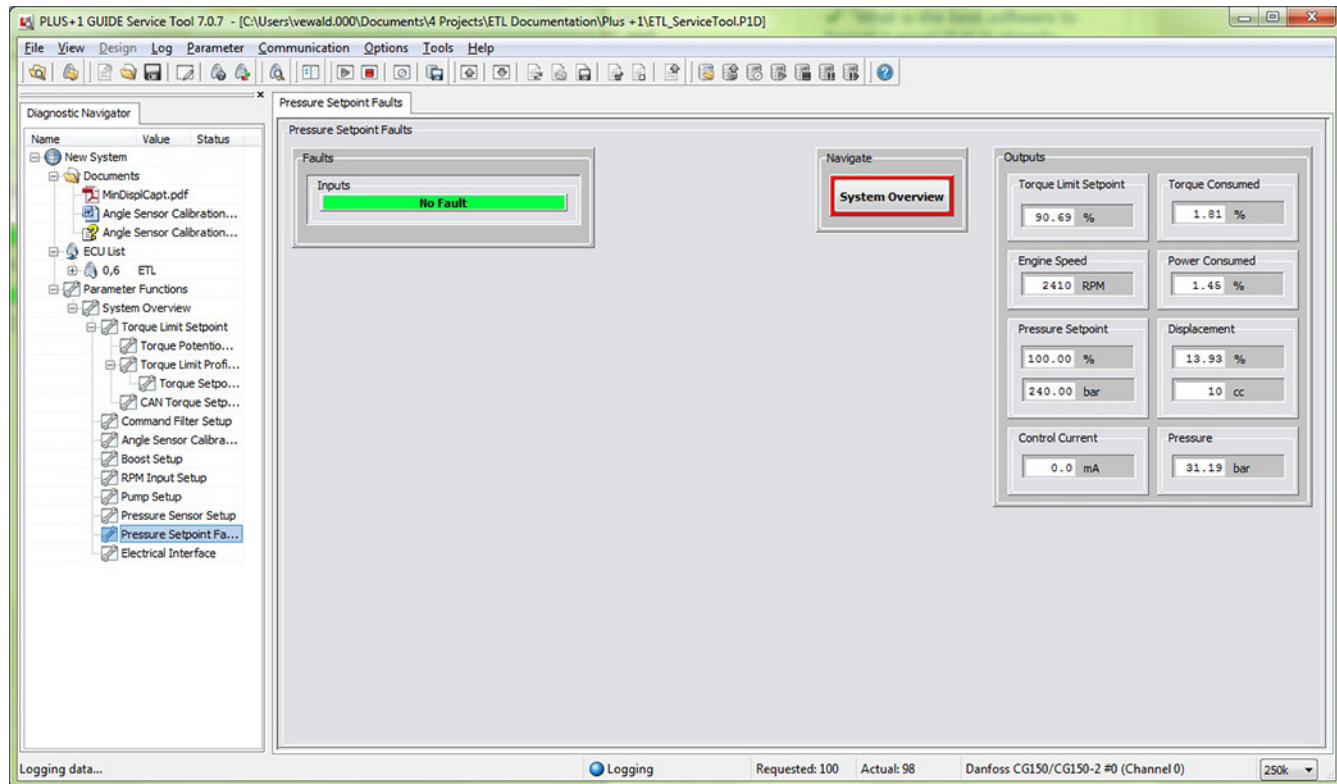
Inputs	Low Speed	Speed at which Low Speed Decreasing time constant is used for filtering the torque setpoint output
	High Speed	Speed at which High Speed Decreasing time constant is used for filtering the torque setpoint output
	Low Speed Decreasing	Low pass filter time constant to limit decrease in pressure setpoint. The actual used filter value is a scaled between High Speed Decreasing and Low Speed Decreasing, depending on speed. Associated with Low Speed.
	High Speed Decreasing	Low pass filter time constant to limit decrease in pressure setpoint. The actual used filter value is a scaled between High Speed Decreasing and Low Speed Decreasing, depending on speed. Associated with High Speed.
	Increasing	Low pass filter time constant to limit increase in pressure setpoint.
Faults	Parameter Fault	High Speed out of range
		Low Speed out of range
	Input Fault	Displacement too low/high
		Speed to low/high
		Torque Demand too low/high

## Troubleshooting

### Pressure Setpoint Faults

The **Pressure Setpoint Faults** screen is used for troubleshooting.

#### Pressure Setpoint Faults Screen

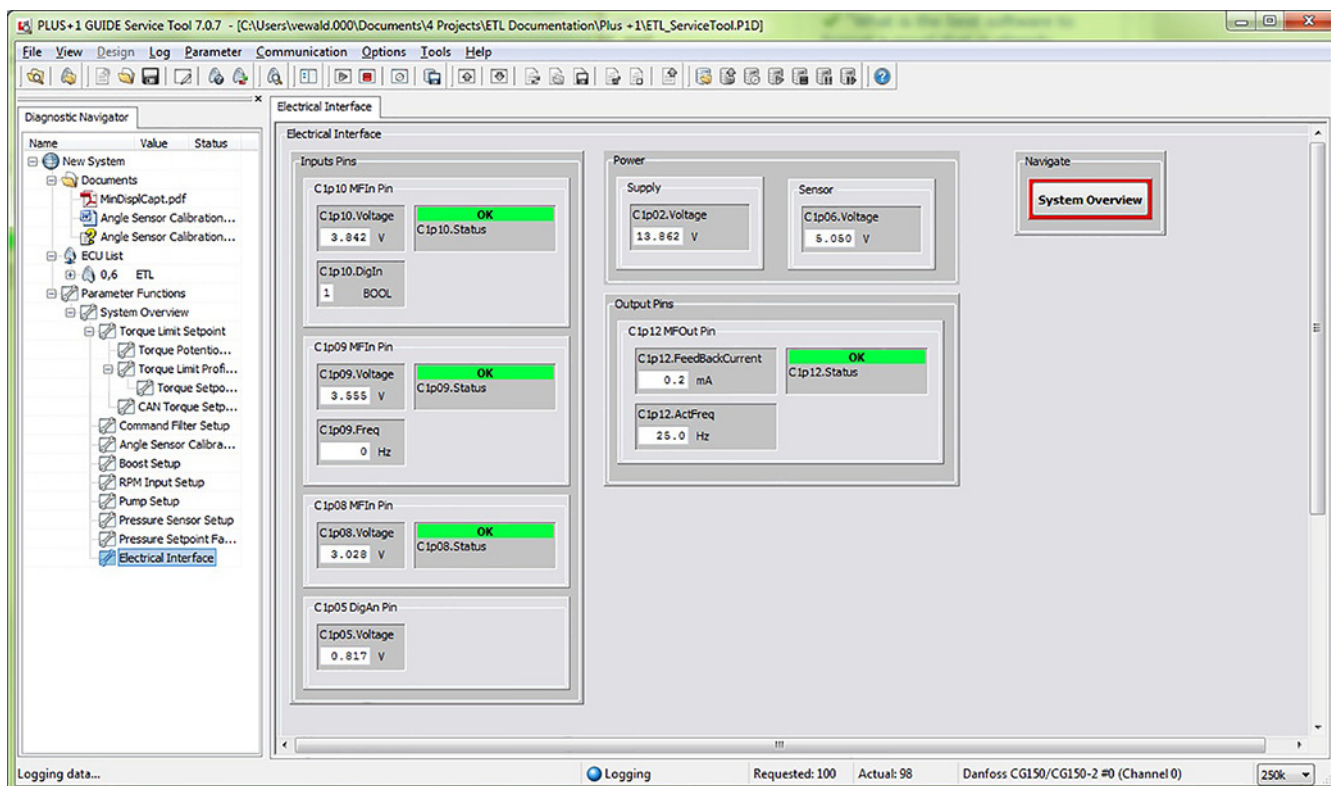


### Electrical Interface

The **Electrical Interface** screen allows you to troubleshoot the electrical interface, including the status of the input pins, output pins, and supply/sensor power.

## Troubleshooting

### ETL Electrical Interface Screen



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

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

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

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