Safety manual for Fisher™ FIELDVUE™ DLC3100 SIS Digital Level Controller

This supplement applies to

Instrument Level	SIS
Device Type	130D
Device Revision	1
Hardware Revision	1
Firmware Revision	1.0.9

1. Purpose

This safety manual provides information necessary to design, install, verify, and maintain a Safety Instrumented Function (SIF) utilizing the Fisher DLC3100 SIS digital level controller. It describes the conditions of use for the DLC3100 SIS in safety applications. This document must be thoroughly reviewed and implemented as part of the safety lifecycle. This information is necessary for meeting the IEC61508 or IEC61511 functional safety standards.

⚠ WARNING

This instruction manual supplement is not intended to be used as a stand-alone document. It must be used in conjunction with the following documents:
Fisher DLC3100 Quick Start Guide (D104214X012)
Fisher DLC3100 Instruction Manual (D104213X012)

Failure to use this instruction manual supplement in conjunction with the above referenced documents could result in personal injury or property damage. If you have any questions regarding these instructions or need assistance in obtaining any of these documents, contact your Emerson sales office or Local Business Partner.

Other related documents include:

- **Fisher 249 Caged Displacer Sensors Instruction Manual (D200099X012)**
- **Fisher 249 Cageless Displacer Sensors Instruction Manual (D200100X012)**
- **Fisher 249VS Cageless Displacer Sensor Instruction Manual (D103288X012)**
- **Fisher 249W Cageless Wafer Style Level Sensor Instruction Manual (D102803X012)**

2. Description of the Device

The Fisher DLC3100 SIS is a microprocessor-based digital level controller that measures and transmits change in liquid level, or level of an interface between two liquids. Changes in the buoyancy of a displacer suspended in a vessel vary the load on a torque tube assembly (249 sensors). The displacer with torque tube assembly and lever assembly constitute the primary mechanical sensors. The angular rotational deflection of the torque tube is measured by the instrument transducer, which consists of a magnet system moving over a Hall Effect sensor. In level measurement mode, it is the proportion of displacer covered by liquid that produces the measured buoyancy.

DLC3100 SIS Default Settings

Application	Level Interface	Level
Alarm Switch	Low Alarm High Alarm	High Alarm
Safety Recovery	Auto Manual	Manual
Trip Alarm Current Settings	Device Malfunction	Enable
	Reference Voltage Failed	Enable
	PV Analog Output Readback Limit Failed	Enable
	Instrument Temperature Sensor Alert	Enable
	Hall Sensor Alert	Enable
	RTD Sensor Alert	Enable
	Hall Diagnostic Alert	Enable
	RTD Diagnostic Alert	Enable
	Program Memory Failed	Enable
	NVM Error	Enable
	RAM Test Error Alert	Enable
	Watchdog Reset Executed	Enable
	PV HiHi Alert	Disable
	PV LoLo Alert	Disable

3. Terms, Abbreviations, and Acronyms

249	Fisher caged and cageless displacer level sensors.
Device Response TIme	Time required for the digital level controller to carry out its part of the safety function, includes time taken to sense a change in input (lever assembly) and transmit a corresponding output signal.
Diagnostic test interval	Time taken to detect internal faults.
DLC3100 SIS	Digital level controller, product model designation for Safety Instrumented System applications.
Fault Reaction Time	Time taken to respond once a fault is detected.
FIT	Failure In Time ($1x10^{-9}$ failures per hour)
FMEDA	Failure Mode Effect and Diagnostic Analysis
HART	Highway Addressable Remote Transducer, open protocol for digital communication superimposed over a direct current.
HFT	Hardware Fault Tolerance
λ	Failure rate. λ_{DD}: dangerous detected; λ_{DU}: dangerous undetected; λ_{SD}: safe detected; λ_{SU}: safe undetected.
Low Demand Mode	Mode of operation of a safety instrumented function where the demands to activate the SIF are less than once every two proof test intervals.
PFD_{AVG}	Average Probability of Failure on Demand
Process Safety Time	Period of time between a failure occurring in the system (with the potential to give rise to a hazardous event) and the occurrence of the hazardous event if the safety function is not performed
Safety	Freedom from unacceptable risk of harm.
Safety Function	Function of a device or combination of devices intended to be used within a Safety Instrumented System to reduce the probability of a specific hazardous event to an acceptable level.
SFF	Safe Failure Fraction
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SIS	Safety Instrumented System
Type B Element	“Complex” element (using complex components such as micro controllers or programmable logic); for details see 7.4.4.1.3 of IEC 61508-2.

4. Safety Requirements

Average Probability of Failure on Demand (PFD_{AVG})

Table 1 shows the achievable Safety Integrity Level (SIL) in Low Demand Mode of operation, depending on the average probability of failure.

Table 1. Achievable Safety Integrity Level (SIL) in Low Demand Mode

Safety Integrity Level (SIL)	PFD_{AVG} with Low Demand Mode
4	$\geq 10^{-5}$ to $< 10^{-4}$
3	$\geq 10^{-4}$ to $< 10^{-3}$
2	$\geq 10^{-3}$ to $< 10^{-2}$
1	$\geq 10^{-2}$ to $< 10^{-1}$

Safety Integrity of the hardware

Table 2 shows the achievable Safety Integrity Level (SIL) depending on the Safe Failure Fraction (SFF) and the Hardware Fault Tolerance (HFT) for safety related Type-B subsystems.

Table 2. Achievable Safety Integrity Level depending on the Safe Failure Fraction and Hardware Fault Tolerance

Safe Failure Fraction	Hardware Fault Tolerance (HFT) A hardware fault tolerance of N means that N+1 faults could cause a loss of the safety function		
	0	1	2
< 60%	Not Permitted	SIL 1	SIL 2
60% - < 90%	SIL 1	SIL 2	SIL 3
90% - < 99%	SIL 2	SIL 3	SIL 4
≥ 99%	SIL 3	SIL 4	SIL 4

5. Safety Characteristics

The specified characteristics are applicable under the following assumptions that have been made during the FMEDA.

- The mean time to restoration after a device has failed is 24 hours.
- The architectural constraint type for the DLC3100 SIS digital level controller is Low Demand mode.
- The hardware fault tolerance of the device is 0 (HFT = 0).
- To avoid unwanted or unauthorized modification, the set parameters must be protected.
- Proof test interval: ≤ 1 year.
- Safety accuracy: 2% of full span.
- Only a single component failure will fail the entire DLC3100 SIS digital level controller.
- Failure rates are constant, wear out mechanism is not included.
- Propagation of failures is not relevant.
- All components that are not part of the safety function and cannot influence the safety function (feedback immune) are excluded.

- Stress levels are average for an industrial environment and can be compared to the exida profile 2 with temperature limits within manufacturer's rating (see table 3 and 4 below). Other environmental characteristics are assumed to be within manufacturer's rating.
- A practical fault injection test can demonstrate the correctness of the failure effects assumed during the FMEDA and the diagnostic coverage provided by the automatic diagnostics.
- The HART®protocol is only used for setup, calibration and diagnostics purposes, not for safety critical operation.
- The application program in the logic solver is constructed in such a way that Fail High and Fail Low failures are detected regardless of the effect, safe or dangerous, on the safety function.
- Materials are compatible with process conditions.
- The device is installed, calibrated, and maintained per manufacturer's instructions.
- External power supply failure rates are not included.
- DLC3100 MTBF = 155 years
- Diagnostic Test Interval: Range from 500 milliseconds to 7 minutes

Table 3. exida Profiles, Electronic

exida Electronic Database				
Profile	According to IEC60654-1	Ambient Temperature (°C)		Temperature Cycle (°C/365 days)
		Average (External)	Mean (Inside box)	
1	B2	30	60	5
2	C3	25	30	25
3	C3	25	45	25

Profile 1: Cabinet mounted equipment typically has significant temperature rise due to power dissipation but is subjected to only minimal daily temperature swings.
Profile 2: Low power electrical (two-wire) field products have minimal self heating and are subjected to daily temperature swings.
Profile 3: General (four-wire) field products may have moderate self heating and are subjected to daily temperature swings.

Table 4. exida Profiles, Mechanical

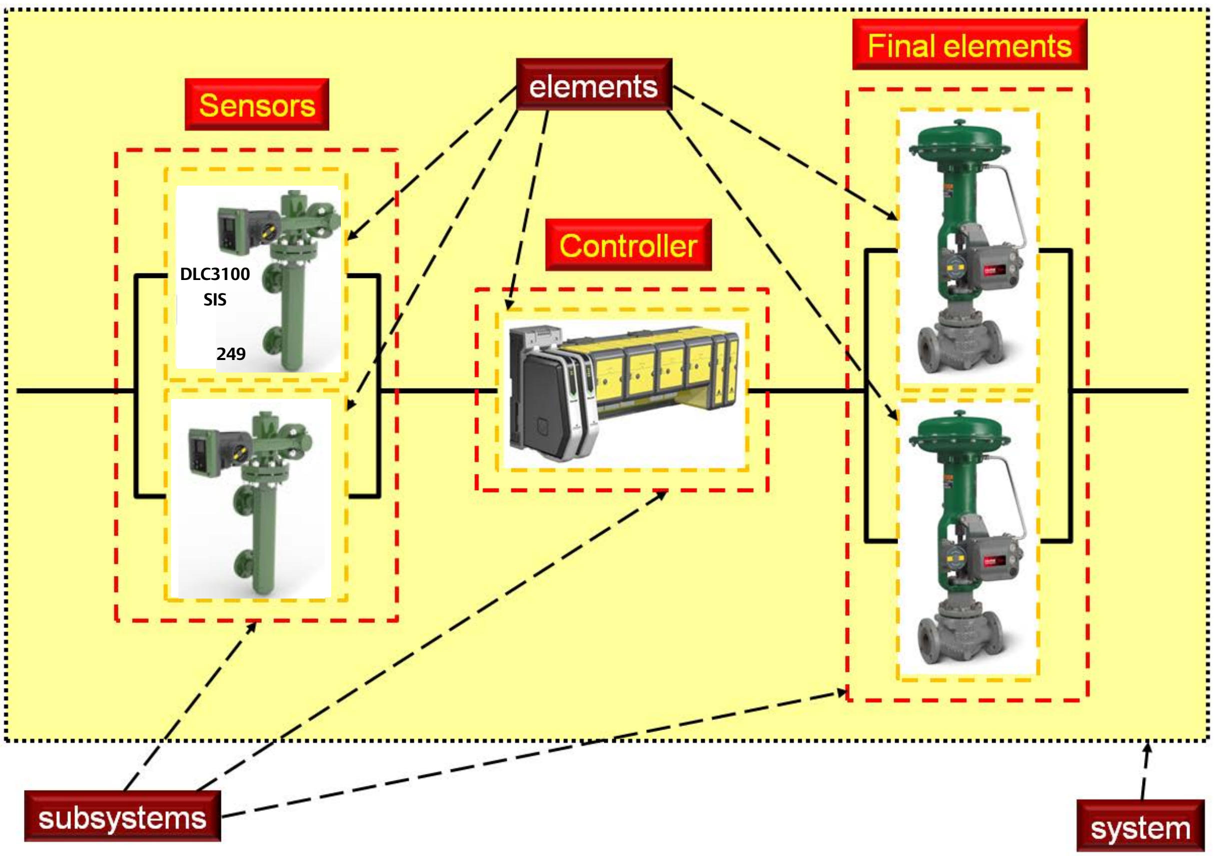
exida Mechanical Database				
Profile	According to IEC60654-1	Ambient Temperature (°C)		Temperature Cycle (°C/365 days)
		Average (External)	Mean (Inside box)	
1	B2	30	60	5
2	C3	25	30	25
3	C3	25	45	25
4	D1	25	30	35

Profile 1: Cabinet mounted equipment typically has significant temperature rise due to power dissipation but is subjected to only minimal daily temperature swings.
Profile 2: Mechanical field products have minimal self heating and are subjected to daily temperature swings.
Profile 3: Mechanical field products may have moderate self heating and are subjected to daily temperature swings.
Profile 4: Unprotected mechanical field products with minimal self heating, are subject to daily temperature swings and rain or condensation.

6. Safety Instrumented System Design

Safety Instrumented System (SIS) is an implementation of one or more Safety Instrumented Functions. A SIS is composed of any combination of sensor(s), logic solver(s), and final element(s), as shown in figure 1.

Figure 1. Example of Safety Instrumented System Components



When using the DLC3100 SIS in a safety instrumented system, the following items must be reviewed and considered.

- SIL Capability
- Safety Function
- Failure Rates
- Application Limits
- Environment Limits

SIL Capability

- Systematic Integrity

  SIL 2 Capable – The DLC3100 SIS digital level controller has met manufacturer design process requirements of IEC61508 Safety Integrity Level 2.

- Random Integrity

  The DLC3100 SIS digital level controller is classified as a Type B device according to IEC61508. The complete element subsystem will need to be evaluated to determine the SFF. If the SFF of the subsystem is > 90% and the $PFD_{avg} < 10^{-2}$, the design can meet SIL2 @ HFT = 0. If the SFF of the subsystem is between 60% and 90%, and the $PFD_{avg} < 10^{-1}$, the design can meet SIL1 @ HFT = 0.

Safety Function

The safety function of DLC3100 SIS digital level controller is to measure level or interface of fluids and transmit a 4-20 mA analog signal within the safety accuracy (measurement accuracy ±2%). It includes the whole hardware and software measurement chain from the displacer through the torque tube and the electronic board to the primary analog output signal.

Table 5. Normal and Alarm States for FIELDVUE DLC3100 SIS Digital Level Controller

Output Function	Normal State	Safety Accuracy	Alarm State[1]
4-20 mA Level transmitter	Actual fluid level	±2%	>21.0 mA or <3.6 mA

1. Configurable high or low. Values are per NAMUR NE43.

Failure Rates

The failure rate data listed in table 6 and 7 is valid for the 15-year useful lifetime of the DLC3100 SIS digital level controller. Its useful lifetime is highly dependent on the subsystem itself and its operating conditions. The failure rate will increase after this time period. Reliability calculations based on the data listed in the FMEDA report for mission times beyond the useful lifetime may yield results that are too optimistic.

Table 6. Failure Rates for FIELDVUE DLC3100 SIS Digital Level Controller

Failure Category	Failure Rate (FIT)
Fail Safe Detected, λ_{SD}	0
Fail Safe Undetected, λ_{SU}	0
Fail Dangerous Detected, λ_{DD}	463
Fail Detected (detected by internal diagnostics)	230
Fail High (detected by logic solver)	83
Fail Low (detected by logic solver)	150
Fail Dangerous Undetected, λ_{DU}	39
No Effect	186
Annunciation Detected	33
Annunciation Undetected	14
SFF	92.2%

Table 7. Failure Rates for Fisher 249 Displacer Sensors with DLC3100 Digital Level Controller

Failure Category	High Trip Failure Rate (FIT)	Low Trip Failure Rate (FIT)
Fail Safe Detected, λ_{SD}	38	39
Fail Safe Undetected, λ_{SU}	10	8
Fail Dangerous Detected, λ_{DD}	570	568
Fail Detected (detected by internal diagnostics)	342	340
Fail High (detected by logic solver)	77	77
Fail Low (detected by logic solver)	151	151
Fail Dangerous Undetected, λ_{DU}	61	63
No Effect	205	205
Annunciation Detected	34	34
SFF	91.0%	90.7%

Application Limits

- Safety Instrumented Function design verification must be done for the entire collection of equipment used in the Safety Instrumented Function including the DLC3100 SIS digital level controller. The SIS must fulfill the requirements according to the Safety Integrity Level, especially the limitation of average Probability of Failure on Demand (PFDavg).
- The DLC3100 SIS digital level controller can only be used for Level or Interface applications.
- The system response time is dependent on the entire final element subsystem. The user must verify the system response time is less than the process safety time for each final element. The DLC3100 SIS digital level controller safety function has a fault reaction time upon fault detection of < 1 second plus the mean time to repair.
- Measurement signal used by logic solver must be the analog 4-20 mA signal proportional to the fluid level.
- The logic solver must recognize both high/low alarms. If the logic solver loop uses IS barriers, caution must be taken to ensure the loop continues to operate properly under the low alarm condition.
- Safe failure in which 4-20 mA current is driven out of range (<3.6 mA or > 21 mA).
- Device Response Time: less than 1 second
- When using the DLC3100 SIS in redundant applications, the owner-operator of the facility should institute common causes training and more detailed maintenance procedures specifically oriented toward common cause defense.

Environmental Limits

- Operating ambient temperature: -40°C to 80°C (-40°F to 176°F)
- Humidity: tested per IEC61298-3 Section 6
- Electromagnetic Compatibility: tested per IEC61326-3-2
- Vibration: tested per ISA 75.13 and FTEP 3B1

7. Installation and Commissioning Guidelines

1. Verify that the DLC3100 SIS is suitable for use in Safety Instrumented Function
2. Verify nameplate markings are suitable for the hazardous location (if required)
3. Verify appropriate connections to the logic solver are made by referring to the instruction and safety manual of the logic solver
4. For maximum availability and benefit of digital level controller features, the unit must be properly configured and calibrated, the Instrument Mode set to In Service, and the protection enabled. With protection set, calibration and other protected parameters cannot be changed, including Instrument Mode.
5. The sensor safety function of the DLC3100 SIS along with the SIS safety function must be tested after installation to ensure that it meets safety demand and applicable process safety time requirements.

8. General Requirements

Refer to Fisher DLC3100 quick start guide and instruction manual for mounting to a 249 sensor, starting up, and configuring and calibrating the DLC3100 SIS.

DLC3100 SIS digital level controllers shall be mounted so that they are easily accessible for service, configuration, and monitoring. Exposure to corrosive atmosphere, excessive vibration, shock, or physical damage shall be prevented.

9. Operation, Periodic Inspection, Test, and Repair

Periodic testing, consisting of proof test, is an effective way to reduce the PFDavg of the DLC3100 SIS instrument as well as the 249 sensors connected to it. The SIL for the DLC3100 SIS is based on the assumption that the end user will carry out these tests and inspection at least once per year. The system check must be carried out to prove that the safety functions meet the IEC specification and result in the desired response of the safety system as a whole. Results of periodic inspections and tests should be recorded and reviewed periodically.

Maintenance

- The effective time to restore the DLC3100 SIS is approximately 24 hours. This comprises of disassembly, repair, reassembly, and recalibration.
- Digital level controller preventive maintenance consists, at a minimum, of replacing all critical elastomeric seals and a visual inspection of moving components to verify satisfactory condition. The SIS Preventive Maintenance Kit includes all elastomeric seals and is available through your local Emerson sales office. Following maintenance, the digital level controller must be calibrated per the calibration menu. After calibration, the digital level controller functional safety must be validated.
- A conservative approach is taken in estimating the service interval for the digital level controller in Safety Instrumented Systems. For SIS applications, preventive maintenance must be performed on the digital level controller at eight to ten year intervals from the date of shipment. If the instrument is exposed to the upper or lower extremes of the environmental limits, the interval for preventive maintenance may need to be reduced.

Protection

When protection is enabled, setup and calibration of the DLC3100 SIS are not permitted by local user interface or by remote HART communication. Only reading data is allowed. The LCD display will show a lock icon (🔒) to indicate that the DLC3100 SIS is currently protected.

Decommissioning Guidelines

When decommissioning a DLC3100 SIS instrument, proper procedures must be followed. Decommissioning includes the following steps:

1. Avoid personal injury or property damage from sudden release of process pressure or bursting of parts. Before proceeding with any decommissioning procedures:
   - Always wear protective clothing, gloves, and eyewear to prevent personal injury or property damage.
   - Do not remove the sensor from the process while the vessel is still pressurized.
2. Bypass the sensor subsystem or take appropriate action to avoid a false trip
3. Bypass the safety function of the level measurement or take appropriate action to avoid a false trip.
4. Disconnect the electrical wiring to and from the DLC3100 SIS instrument.
5. Remove the DLC3100 SIS instrument, mounting parts from the sensor assembly.

Application

The DLC3100 SIS digital level controller can be applied to most process or storage vessels, bypass chambers, and interfaces up to the unit pressure and temperature ratings. The DLC3100 SIS with 249 sensor can be used for liquids, clean or dirty, light hydrocarbons to heavy acids to meet the safety system requirements of IEC61508.

Benefits

The DLC3100 SIS provides the following benefits to operation:

- Suitable for use in environments up to SIL 2 (Safe Failure Fraction = 92.2%) as independently assessed (full assessment) by exida.com as per IEC61508/61511-1.
- Continuous self-test with > 21 mA or < 3.6 mA fault indication fully compliant with NAMUR NE-43.
- Intrinsic Safe, Explosion-proof approvals.
- Two-wire, loop-powered transmitter for level, interface measurement.

Proof testing

According to section 7.4.5.2f of IEC61508-2, proof tests must be undertaken regularly to reveal dangerous faults which are undetected by diagnostic tests. Proof test coverage is a measure of how many undetected dangerous failures are detected by the proof test. It is a testing of safety system components to detect any failures not detected by automatic online diagnostics followed by repair of those failures to an equivalent as-new state. A proof test is a test that is manually initiated. It is an effective way to reduce the PFDavg of the DLC3100 SIS instrument. As part of the test, the capability of the SIF to achieve the defined safe state must be verified. The Safety Function must be verified. The proof test interval must be established for the SIF based on the failure rates of all the elements within the function and the risk reduction requirements. This determination is a critical part of the design of the SIS. A proof test will detect 95% of possible dangerous failures undetected in the DLC3100 SIS digital level controller with Fisher 249 displacer sensors. Proof testing is a vital part of the safety lifecycle and is critical to ensuring that a system achieves its required safety integrity level throughout the safety lifecycle.

Note

Any time the SIF needs to be disabled, such as to perform a proof test or to take corrective action, appropriate measures must be taken to ensure the safety of the process.

Note

To ensure corrective action, continuous improvement, and accurate reliability prediction, the user must also work with their local Emerson Automation Solutions service representative to see that all failures are reported.

Test steps for the Fisher DLC3100 SIS

Following are the steps to detect Dangerous Undetected (DU) failure. The procedure will detect approximately 95% of possible DU failures in the DLC3100 SIS digital level controller with Fisher 249 displacer sensors.

Proof Test Procedure:

1. Bypass the safety function and take appropriate action to avoid a false trip and any safe actions against dangerous atmospheres.
2. Inspect the instrument for dirty or clogging parts, adequate wiring, correct mounting of end connections and other physical damage.
3. Observe the tightening torques for the nuts and studs.
4. Use HART communications to retrieve Alarm High / Low setting, any diagnostics alerts and take appropriate action. Alarm High / Low setting should be checked against the plant safety requirement for that particular application. If setting is High, go to step 5. If setting is Low, go to step 6.
5. Retrieve PV HiHi alert setting. Send a HART command (Enable Trip Alarm Current and set PV HiHi alert threshold to activate the PV HiHi alert) to the transmitter to go to the high alarm current output and verify that the analog current reaches that value. This will test for compliance voltage problems such as a low loop power supply voltage or increased wiring resistance. Continue to step 7.
6. Retrieve PV LoLo alert setting. Send a HART command (Enable Trip Alarm Current and set PV LoLo alert threshold to activate the PV LoLo alert) to the transmitter to go to the low alarm current output and verify that the analog current reaches that value. This will test for possible quiescent current related failures.
7. Perform a two-point calibration of the displacer and digital level controller over the full working range using process fluids. If the calibration is performed by any means other than fluids acting on the displacer, Trim Zero calibration has to be done when it is put back to actual process fluids.
8. Perform a five-point calibration check. If the calibration check is correct, the proof test is complete. Proceed to step 10. If the calibration check is incorrect, remove the displacer and digital level controller from the process. Inspect for damage, buildup or clogging. Clean it if necessary. Examine the torque tube and the displacer to detect corrosion or leaks (replace if necessary). Observe the tightening torques for the nuts and studs. Perform a two-point calibration of the displacer and digital level controller over the full working range using process fluids.
9. If the calibration check is off by more than 2%, contact the factory for assistance. If the calibration check is correct, the proof test is complete.
10. Reinstall the displacer and digital level controller if the assembly was removed previously. Ensure the Alarm setting is correct and reinstate the PV HiHi/LoLo Alert settings.
11. Lock the settings by write protection.
12. Remove the bypass and otherwise restore normal operation.

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