ENGINEERING TOMORROW

Functional Safety Application Guide

Encoder-less Safety Functions SLS, SSR using DOLD Frequency Monitor

VACON® and VLT® FC-series

vlt-drives.danfoss.com

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1 Introduction

1.1 Purpose

This manual describes how to implement the safety functions Safely Limited Speed (SLS) or Safe Speed Range (SSR) using DOLD UH 6937 frequency monitor without encoder.

The DOLD module can be used with the following products:

- VLT® HVAC Drive FC 102
- VLT® Refrigeration Drive FC 103
- VLT® AQUA Drive FC 202
- VLT® Midi Drive FC 280
- VLT® AutomationDrive FC 301
- VLT® AutomationDrive FC 302
- VACON® 100 Industrial
- VACON® 100 Flow
- VACON® NXP Liquid Cooled
- VACON® NXP System Drive
- VACON® NXP Air Cooled
- VACON® NXP Common DC Bus
- VACON® NXP Liquid Cooled Enclosed Drive
- VACON® NXP Liquid Cooled Common DC Bus

1.2 Scope

This manual is intended for application designers, for realizing safe speed functions of frequency converters without encoder feedback, using an external frequency monitor.

1.3 Abbreviations

PL	Performance Level
SIL	Safety Integrity Level
SLS	Safely Limited Speed
SSR	Safe Speed Range
STO	Safe Torque Off

Table 1.1 List of Abbreviations

2 Safety Functions SLS and SSR

The Safely Limited Speed (SLS) function monitors the speed to a set limit value without any encoder feedback, see *Illustration 2.1*. The frequency of the motor is measured and compared to the limit value. If the measured value is more than the set value, then the safety output relay is deactivated to trigger the STO function.

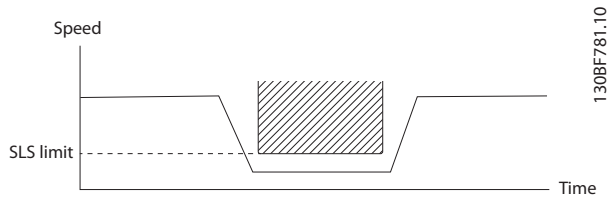

Illustration 2.1 SLS Function

The Safe Speed Range (SSR) function monitors the speed within a given range or outside a given range. See *Illustration 2.2*.

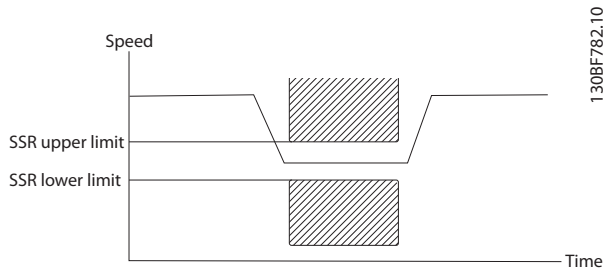

Illustration 2.2 SSR Function

Monitoring within the given range:
If the frequency is within the given speed range, the STO signal is not active. If the measured frequency is outside the given speed range, the relay output triggers the STO function of the frequency converter.

Monitoring outside the given range:
If the frequency is outside the defined speed range, the STO signal is not active. If the measured frequency lies inside the limits, the relay output triggers the STO function of the frequency converter.

In the standard module variant 0, 1 of the following monitoring functions is selected:

- Over frequency
- Under frequency
- Inside range
- Outside range

The variant 1 module has extra selection inputs for selecting 4 frequency modes during the operation.

NOTICE

If the frequency converter does not have an integrated STO function, the relay outputs can be used to activate the motor contactors to cut off the power to the motor.

3 SLS and SSR Implementation

The SLS safety function implementation is based on the STO function and the following safety-related components:

- **Frequency monitor (3rd party DOLD UH 6937)**
  The UH 6937 frequency module does not have safe inputs to activate and deactivate the safety functions. In variant 0, the module always monitors the frequency. The monitoring can only be muted by selecting the parameter in the display. In variant 1, there are 4 digital safe inputs available to select different frequency modes, and 1 of the combinations is the muting function.
- **Noise suppression filter for measuring relays (3rd party DOLD LG 5130), optional**
  These filters are only required if there is measurement errors after complete installation.
- **Third-party functional safety system or fail-safe PLC (≤ SIL2), optional**
  A fail-safe PLC is required to implement the safety logic based on the status of the relay outputs of a frequency module. One of the use cases is, that the relay output status is ignored as long as the safety door is locked for SLS speed. Once the door is opened, the safety relay output is used to activate the STO of the frequency converter for speed limit violations.

The circuit example in *chapter 3.1 Circuit Diagram* shows the DOLD UH 6937 used with a Danfoss frequency converter FC-series or VACON® series.

The auxiliary voltage 24 V is connected to terminals A1–A2. Any 24 V PELV or SELV supply can be used. If no additional devices are supplied via terminal 12 or 13 (+24 V), A1 can be connected to terminal 12 or 13. A2 can be connected to terminal 20 (0 V).

Terminals E1a, E1b, E2L, E2H, E3L, and E3H form the measuring input. For low voltages (AC 8–280 V), the measuring voltage is connected to E1a–E2L and E1b–E3L. For higher voltages (AC 16–600 V), the measuring voltage is connected to E1a–E2H and E1b–E3H.

When monitoring single-phase AC voltage, the terminals E1a–E2L or E1a–E2H should be connected directly to the frequency converter. The terminals E1b–E3L or E1b–E3H should be connected directly to the motor connection terminals.

NOTICE

Separate wires in separate cables with spacing in between have to be used for each of the frequency inputs. When monitoring 3-phase AC voltages, these terminals have to be wired directly to the motor connection terminals.

⚠WARNING

RISK OF DEATH AND SERIOUS INJURY

If external forces act on the motor, for example in case of vertical axis (suspended loads) the motor must be equipped with extra measures for fall protection. For example, install extra mechanical brakes.

The noise filter (LG 5130) has 4 inductances connected in series in each path for the 3 phases (input L1/L2/L3). This provides broad band filtering up to high frequencies. If the PE is connected, a Y-capacitor connected to PE is activated and provides increased filtering (T-filter).

The noise filter is connected via its input terminals L1/L2/L3 to the frequency converter output and the frequency monitor device to the filter outputs L1′/L2′/L3′.

By connecting the noise filter between the frequency converter and the measuring frequency monitor device, the current flowing via the coupling capacitances is reduced. The reduction happens because the filter elements create a rising impedance with a rising frequency. This prevents disturbance or damage on the connected device. Protection as shown in *Illustration 3.5*.

It is not mandatory to connect the PE to the frequency monitor device terminals, but it increases the filter effect.

Chapter 3.2 Safety Function Operation and Timing includes the SLS operation and timing.

3.1 Circuit Diagram

Illustration 3.1 shows the UH 6937 Circuit diagram. The relay contacts 13–14 and 23–24 can be used as STO input to the frequency converter.

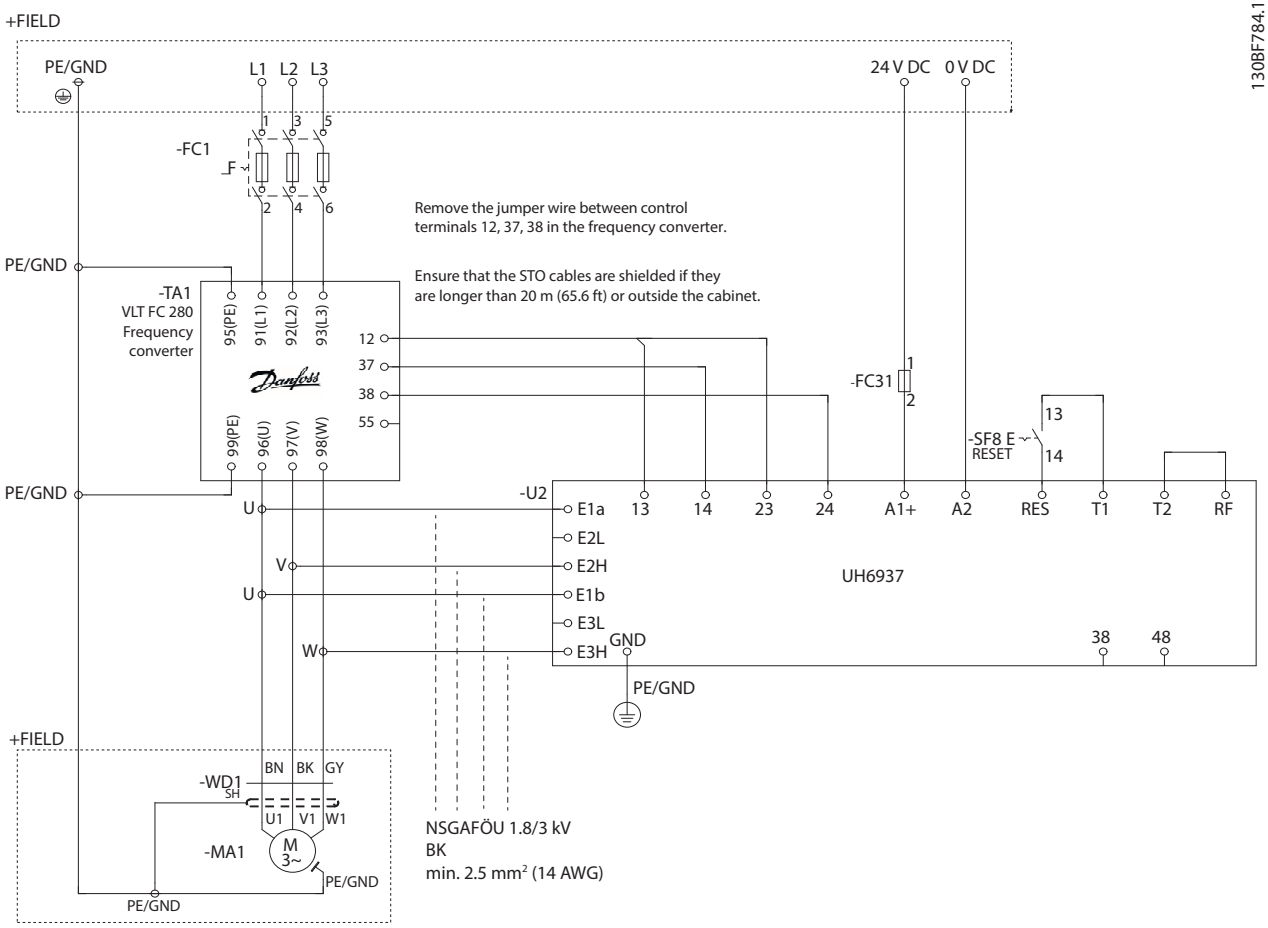

Illustration 3.1 FC 280 and UH 6937 Wiring Diagram

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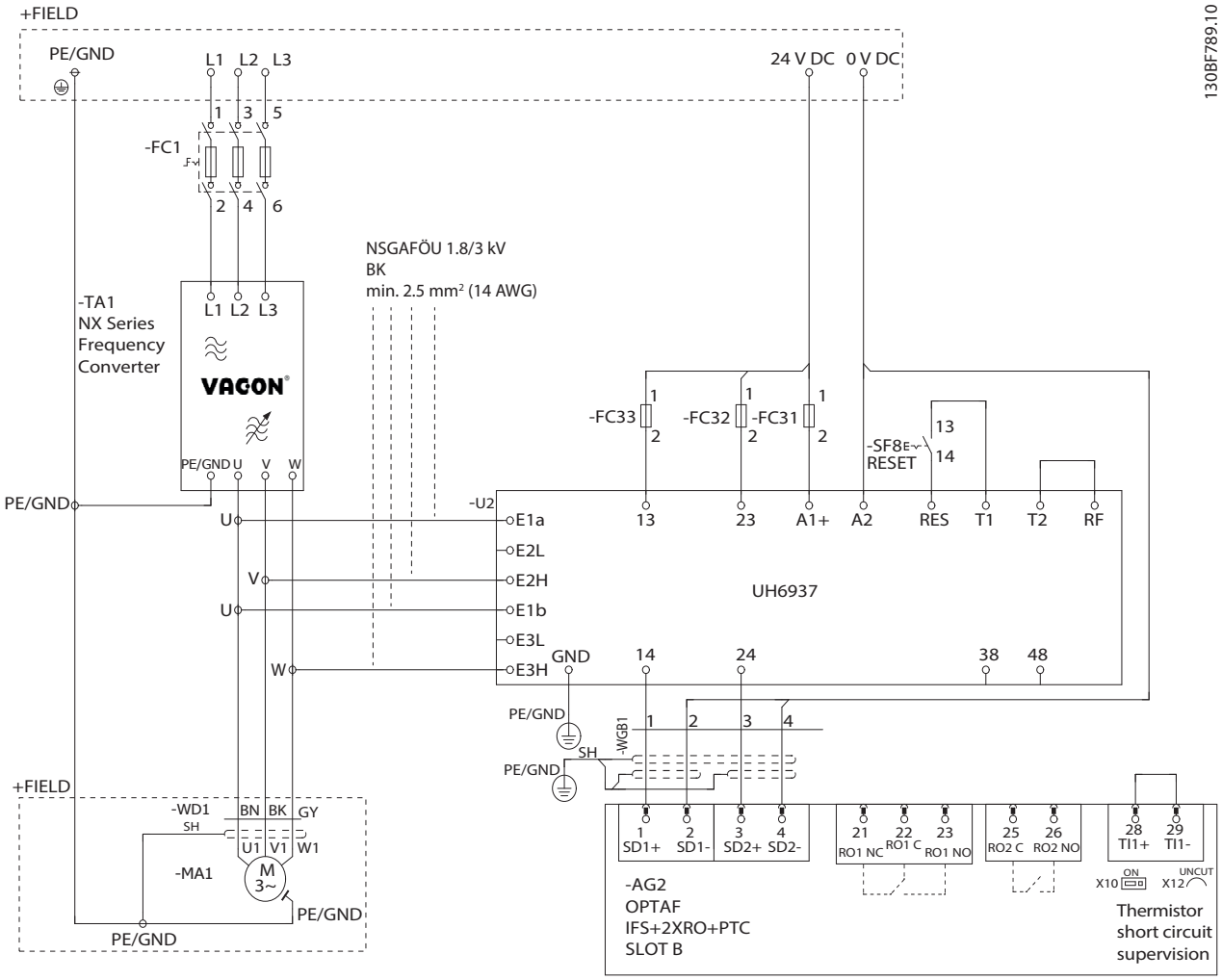

Illustration 3.2 NX Drive, OPT-AF, and UH 6937 Wiring Diagram

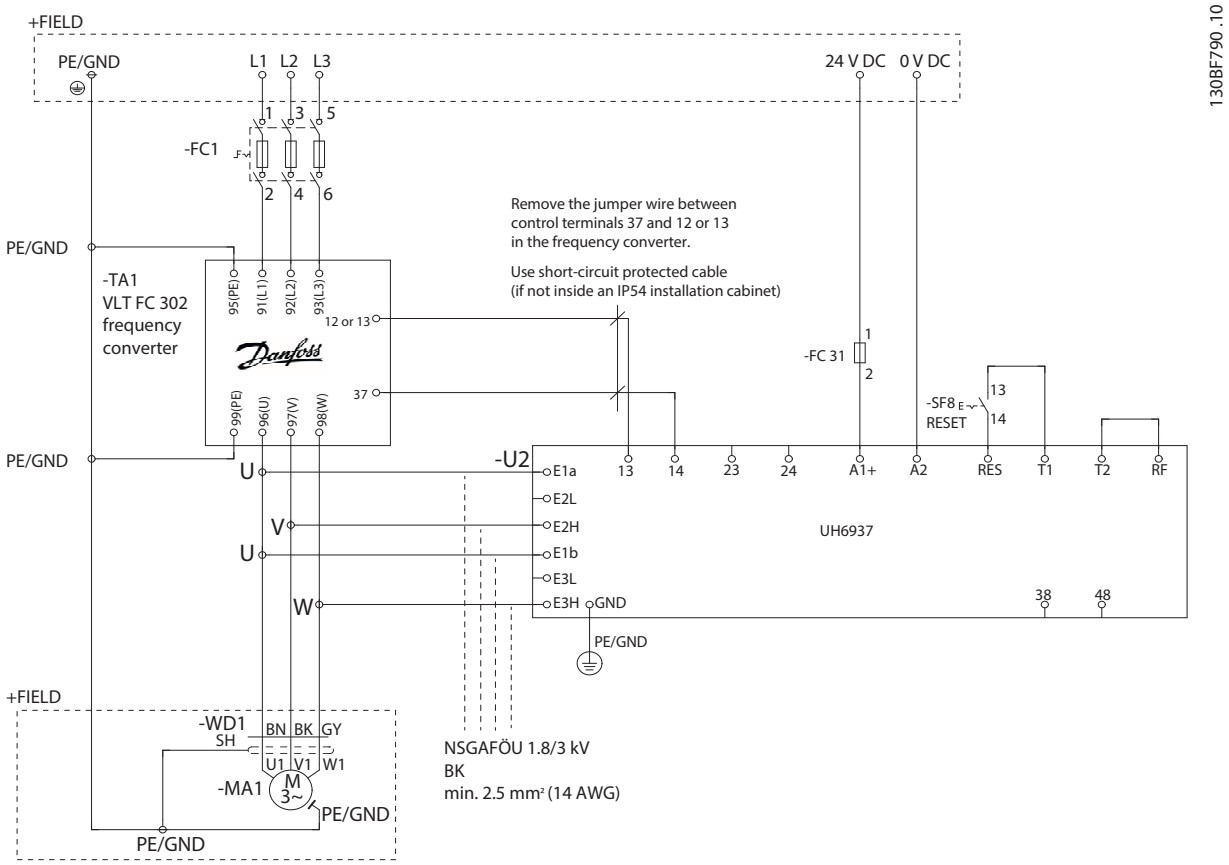

Illustration 3.3 FC 302 and UH 6937 Wiring Diagram

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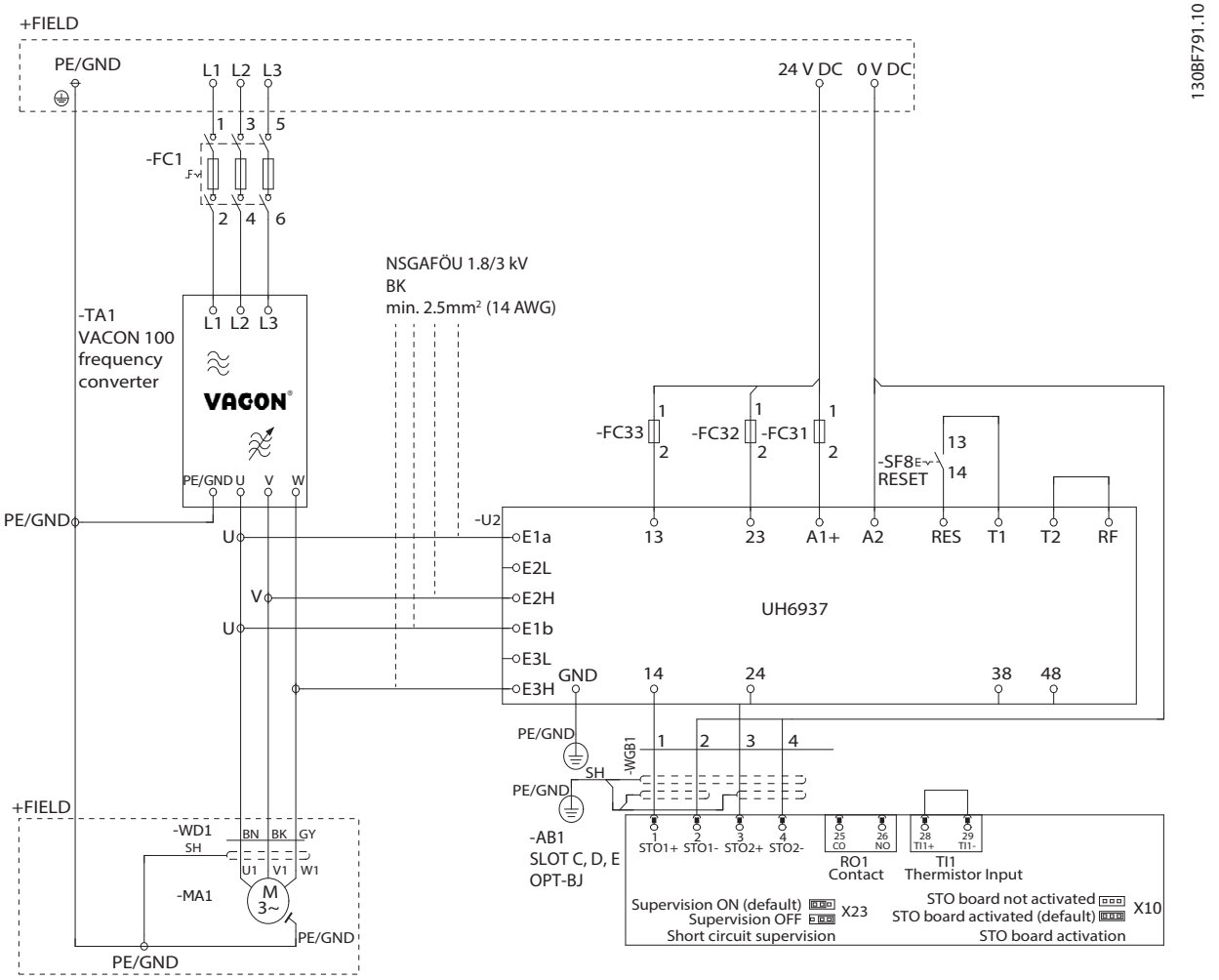

Illustration 3.4 VACON® 100, OPT-BJ, and UH 6937 Wiring Diagram

Illustration 3.5 shows the LG 5130 Circuit Diagram with noise filtering between the 3 phases of the frequency converter and the frequency monitor UH 6937.

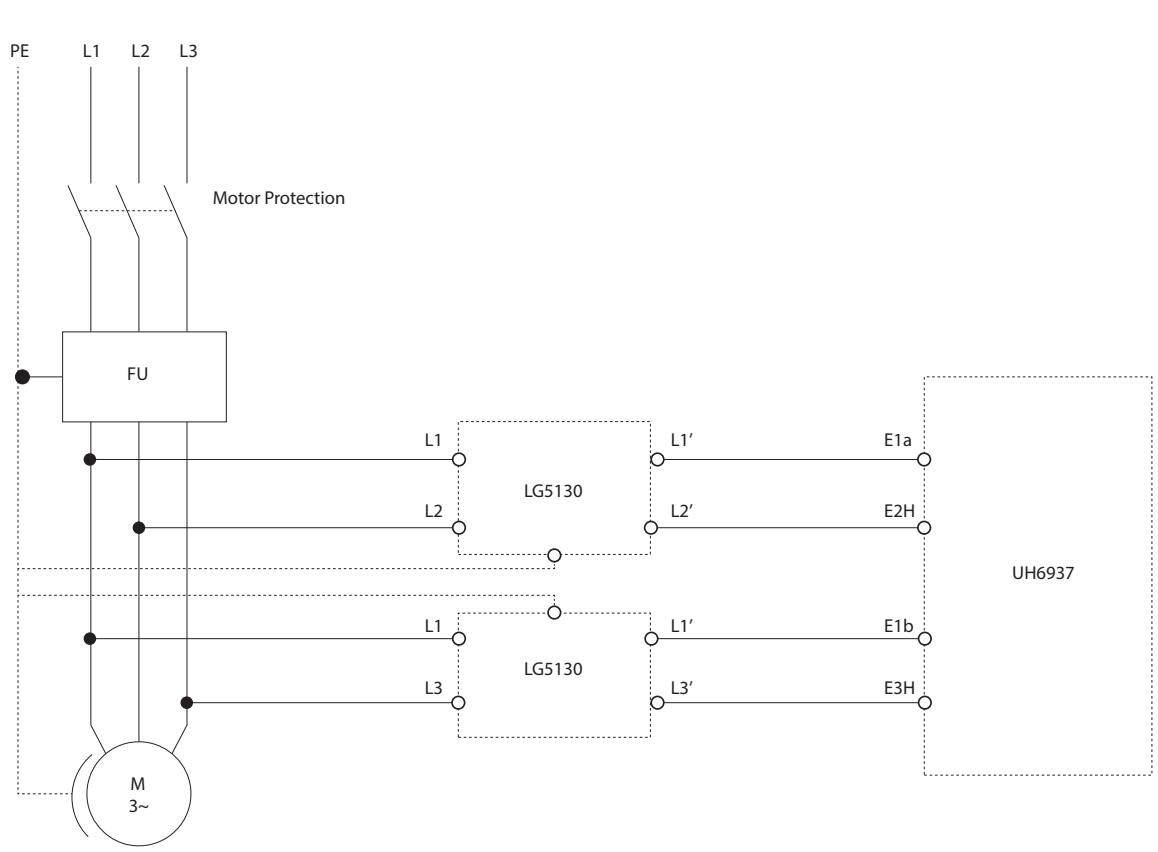

Illustration 3.5 LG 5130 Circuit Diagram

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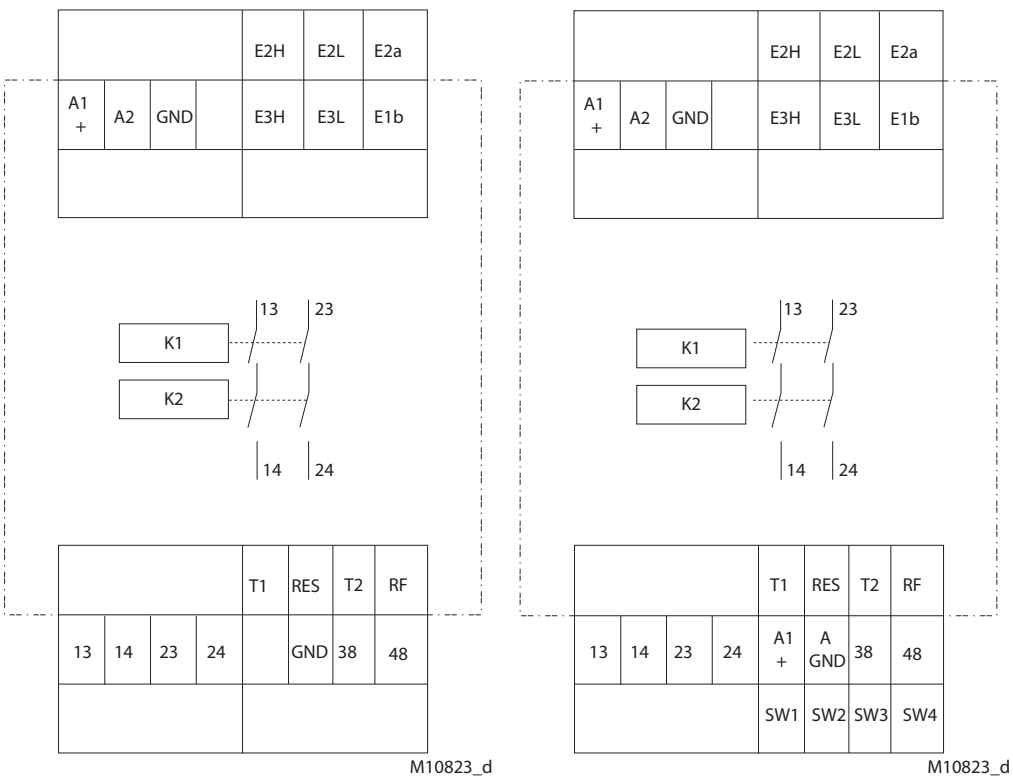

UH6937 UH6937/__1

Terminal designation	Signal designation
A1+	24 V DC
A2	0 V
E1a, E1b, E2L, E2H, E3L, E3H	Frequency measuring inputs
GND	Reference potential for semiconductor monitoring output and control outputs
13, 14, 23, 24	Forcibly guided NO contacts for release circuit
38, 48	Semiconductor-monitoring output
T1, T2	Control output
RES, RF, SW1, SW2, SW3, SW4	Control input
A+, A GND	Analog output

Illustration 3.6 Terminals Description

3.2 Safety Function Operation and Timing

The safe speed monitoring has to be configured for the speed limits in the frequency converters applications. The customer is responsible for defining the speed limits on the risk assessment. The commissioning test report is made available for the final assessment and for future references.

3.2.1 Initial Conditions

If the safe speed limit monitor is configured without the start-up delay and the RF feedback circuit is closed, it is active immediately after the power-on.

3.2.2 Fault Handling

When faults are detected on or in the device, they are indicated with a message in the display. If the fault requires a reset of the device, the alarm and the associated diagnostic message has to be acknowledged first. Press the left key for approximately 3 s to initiate a reset of the device.

NOTICE

If a system failure is detected again after restart, the device must be replaced and sent back to the manufacturer.

3.2.3 SLS Operation

Typically, the SLS safety function is used for safe speed monitoring according to a defined speed limit. In this case, the SLS function defines the speed limit where it is considered safe for personal interaction with the machine. As long as the frequency of the frequency converter is within the defined limit, the STO function is not active. When the output frequency goes beyond the limit value, STO is immediately activated so the motor coasts and comes to a standstill. This coasting time must be considered before allowing the access to the dangerous zone.

The safe output on the frequency monitor UH 6937 is active and the output relays remain closed, as long as the actual speed is lower than the safe speed limit parameter (SLS limit).

If the actual speed exceeds the safe speed limit parameter (SLS limit), speed output relays are opened, and the safe output signal is removed.

If an internal fault occurs, the SLS safety function can be configured for automatic reset. If the function is configured for a manual reset, the RESET input should be provided for normal operation after removing the limit violations.

The module UH 6937 always monitors the configured frequency limits. The frequency module does not have its own safe inputs, therefore a third-party functional safety system, for example a fail-safe PLC system, is used. It activates the safe function when a safe function is demanded. This means that more safety logic can be prepared based on the status of the frequency module relays in the PLC. For example, the PLC logic controls the access to the dangerous zone via its output signal (door control). The SLS output (relays) is connected to the fail-safe PLC's safety input. The access is allowed as long as the frequency is below the SLS limit. If the speed limit is exceeded, the STO of the frequency converter is immediately activated via the fail-safe PLC output to bring the system to a safe state.

The input frequency is compared to the setting value. As the device measures the cycle duration, the fastest frequency measurement is possible. Should the overfrequency function be set, the output relay switches to the alarm mode when the set response parameter value exceeds the defined value in the alarm-delay function (tV). Should the frequency decrease to a value below the response parameter, minus the set hysteresis, the output relay is activated after the expiry of the reset delay time period(tF). It then returns to its preset allowed supervisory state. The underfrequency function means that the output relay switches to the alarm mode when the set response parameter value drops below the set alarm-delay function(tV) time period. When the frequency returns to the range governed by the response parameter, plus the set hysteresis, the output relay returns to the preset allowed state after the expiry of the reset-delay time period(tF).

3.2.4 SSR operation

The SSR function is used for speed monitoring within or outside of a defined speed range.

In the *internal window function mode*, the output relay switches to the alarm setting when the frequency exceeds the preset allowed range of both the upper and lower response parameters, minus and/or plus the preset hysteresis values (upper response parameter minus and/or the lower response parameter plus the relative hysteresis values). The output relay again switches back to the preset allowed range after the expiry of the reset-delay time period (tF).

In the *external window function mode*, the monitoring function acts inversely to the *internal window function*.

Should the manual reset function be activated, the output relay remains in alarm mode when the frequency returns to the preset allowed range. A reset of the saved

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parameter is possible when the reset input is activated or the auxiliary voltage is shut down.

When a start-up delay time period (tA) is set, the set start-up delay time period expires initially when the auxiliary voltage of the equipment is switched on and the "RF" feedback circuit is closed. The start-up delay time period also expires after a reset of the manual reset mode. During this time period, a frequency evaluation is disabled and the output relays remain at the preset allowed setting. The start-up delay function can, for example, override an alarm message during the start-up stage of a generator or electric motor. Should the feedback circuit not be closed after a reset (in the manual reset mode), the equipment goes into a safe error state.

The frequency monitoring operation is shown in *Illustration 3.7*.

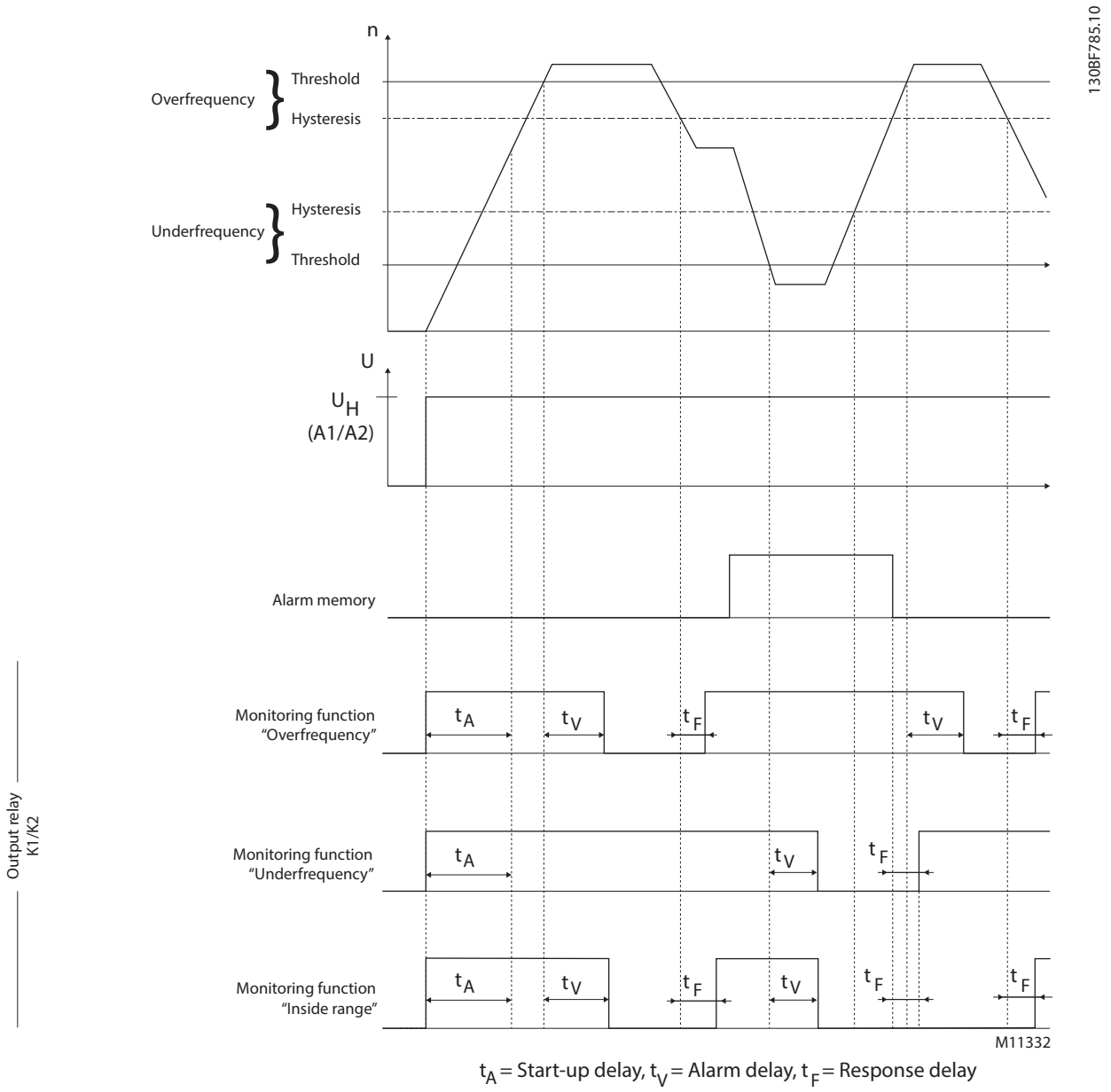


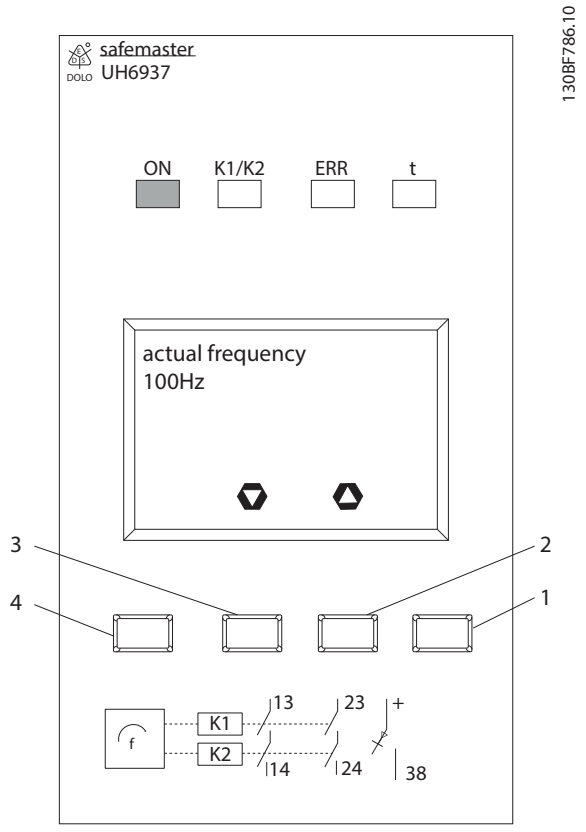
Illustration 3.7 Frequency Monitor Timing

3.3 Parameters and Configuration

The equipment can be configured via the display and the setting keys on the display. See *Illustration 3.8*.

To enter the parameterization-mode on the device, follow these steps:

1. Press and hold the [OK] key.
2. Press the [Reset] key.
3. A display test follows and has to be acknowledged using the [OK] key, when it was successful.
4. It is now possible to change the parameterization. Before the device adopts changed parameters, they must be confirmed once more for safety reasons.



1	OK
2	▲
3	▼
4	Reset

Illustration 3.8 Frequency Monitor Device Display

Follow the installation guide from the manufacturer for a detailed description. *Table 3.1* shows a default configuration of the frequency monitor.

The safe speed limit parameter (SLS limit) is configured to the upper limit parameter of frequency mode 1. The lower limit is configured to 0.0 Hz.

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1.	**Parameterization**			
	1.1	**Monitoring function**		
			Overfrequency	X
			Underfrequency	–
			Inside range	–
			Outside range	–
	1.2	**Limits**		
			Frequency mode 1	
			Upper limit	400.0 Hz
			Lower limit	200.0 Hz
			Frequency mode 2	
			Upper limit	400.0 Hz
			Lower limit	200.0 Hz
			Frequency mode 3	
			Upper limit	400.0 Hz
			Lower limit	200.0 Hz
			Frequency mode 4	
			Upper limit	400.0 Hz
			Lower limit	200.0 Hz
	1.3	**Hysteresis**		
			5%	
	1.4	**Time Delay**		
			Start-up delay	0.0 s
			Response Delay	0.0 s
			Alarm delay	0.1 s
			Changeover bridging	0.0 s
	1.5	**Alarm memory**		
			Alarm memory	X
			Automatic reset	–
	1.6	**Muting function**		
			Activate	–
			Deactivate	X
2.	**Display settings**			
	2.1	**Languages**		
			English	X
			Deutsch	–
			Francais	–
	2.2	**Contrast**		
			50	%
	2.3	**Backlight**		
			OFF	–
			10 s	X
			1 min	–
			5 min	–
	2.4	**Status indicator**		
			Manual	X
			10 s	–
			1 min	–
			5 min	–

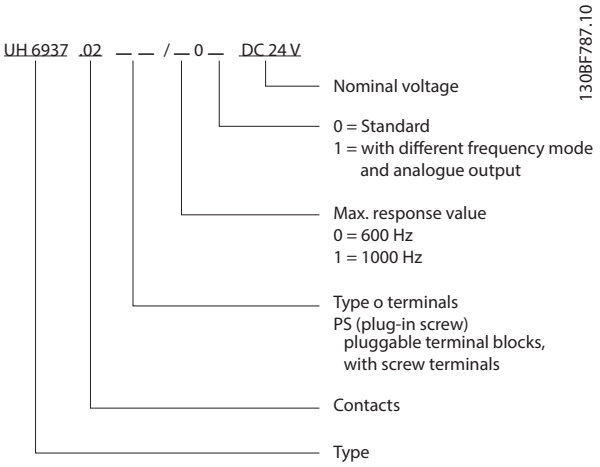
3.	**Factory settings**	
		Parameters
		Display settings
		Parameter + display settings
4.	**Change tracking**	
		Activate
5.	**About UH 6937**	

Table 3.1 Frequency Monitor Configuration

4 Ordering Data for DOLD Components

4.1 Frequency Monitor

The ordering information for the DOLD frequency monitor is shown in *Illustration 4.1*.



Description	Type	Order number	Pcs. / Pkt.
Safe frequency monitor	UH6937.02PS DC24V	0066820	1
Noise suppression filter[1)]	LG5130	0065015	2

Illustration 4.1 Ordering Example

1) *Even though the UH6937 has enough EMC immunity for normal conditions, the suppression filter for each channel of measurement is needed only when the frequency monitor module does not function correctly due to high EMC or high frequency noise.*

5 Functional Safety-related Data

5.1 SIL Calculation

The SLS safety function consists of 3 subsystems:

- Frequency converter
- Frequency monitor
- Functional safety system, such as fail-safe PLC

These have different safety-related data.

The values for the fail-safe PLC must be at least the shown values in *Table 5.3*.

IEC 61508	SIL2
EN 62061	SILCL 2
EN/ISO 13849: 2006	PL d Category 3
EN 61800-5-2	SIL2
PFH	$1x10^{-10}$/h

Table 5.1 Subsystem VLT® AutomationDrive FC 302

IEC 61508	SIL3
EN 62061	SILCL 3
EN/ISO 13849: 2006	PL e Category 4
PFH	$4.43x10^{-10}$/h

Table 5.2 Subsystem Frequency Monitor

IEC 61508	≥SIL2
EN 62061	≥SILCL 2
EN/ISO 13849: 2006	≥PL d ≥Category 3
EN 61800-5-2	≥SIL2
PFH	$<9.1x10^{-8}$/h

Table 5.3 Subsystem Fail-safe PLC

IEC 61508	SIL2
EN 62061	SILCL 2
EN/ISO 13849: 2006	PL d Category 3
EN 61800-5-2	SIL2
PFH	$< 1x10^{-7}$/h

Table 5.4 SLS Safety Function

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