Fuji Electric
Innovating Energy Technology

APPLICATION NOTE	AN-Lift2-0001v140EN
Use of FRENIC-Lift STO inputs in elevator applications	

Inverter type	FRENIC-Lift (LM2A)
Software version	L2S1_01010570 (or later)
Required options	Not needed
Related documentation	EN 81-20:2014 EN 81-1:1998+A3:2009 EN ISO 13849-1:2008+AC:2009 EN 61800-5-2 IEC 61508-1 to -7:2010 EN 61810-1
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Languages	English

1. Introduction.

This document describes the use of STO functional safety function of FRENIC-Lift inverter in lift applications.

2. Foreword.

The standard EN 81-20:2014 (before EN 81-1:1998+A3:2009) requires that two independent contacts are used for the interruption of power to the motor in lift applications. When an inverter is used, these contacts are installed between the inverter and the motor. If these contacts are opened/closed with the inverter active (enabled), i.e., when the inverter is giving voltage (current) at the output, electrical arcing can arise in the contacts, therefore reducing their life and the inverter output stage (transistors) life.

Another important point is the verification of the status of the contacts. According to EN 81-20:2014, the elevator system must verify that the contacts are really open each time the lift changes travelling direction. This verification will be done by the lift controller (Safety PLC) or by a dedicated safety system (if a normal PLC is used for the lift control), but not by the inverter.

The use of two contactors at the output of the inverter is a very simple solution with an easy understanding of the failure modes, but has the following weak points:

- Requires a proper sequence to avoid damaging either the contactors or the inverter's IGBTs.
- The life of the contacts (contactors) is limited. The number of open/close operations is limited.

- It produces acoustic noise at every start and stop due to closing/opening of the contactors.
- The open/close status of the contacts must be checked by the elevator system -at latest- at every change of travelling direction of the elevator.

EN 81-20:2014 allows as well replacing the two contacts by an adjustable speed electrical power drive system according to clause 5.9.2.5.4 d) and 5.9.3.4.2 d). FRENIC-Lift STO functional safety function satisfies the above mentioned clauses of EN 81-20:2014 and, therefore, can be used instead of the two contacts that interrupt the power to the motor, complying with the requirements of clauses 5.9.2.5.4 a) and 5.9.3.4.2 a).

3. Use of FRENIC-Lift STO FS function in elevator applications.

FRENIC-Lift has built-in as standard STO functional safety function. STO FS function is able to interrupt safely the current to the motor and therefore ensures that no torque can be applied to the motor. STO FS function of FRENIC-Lift complies with the following safety requirements specification:

- SIL 3 HFT=1 according to EN/IEC 61800-5-2 and IEC 61508-X.
- PL e according to EN ISO 13849-1.
- Can replace the two contactors between the inverter and the motor, as required by clauses 5.9.2.5.4 d) and 5.9.3.4.2 d) of EN 81-20:2014 standard.

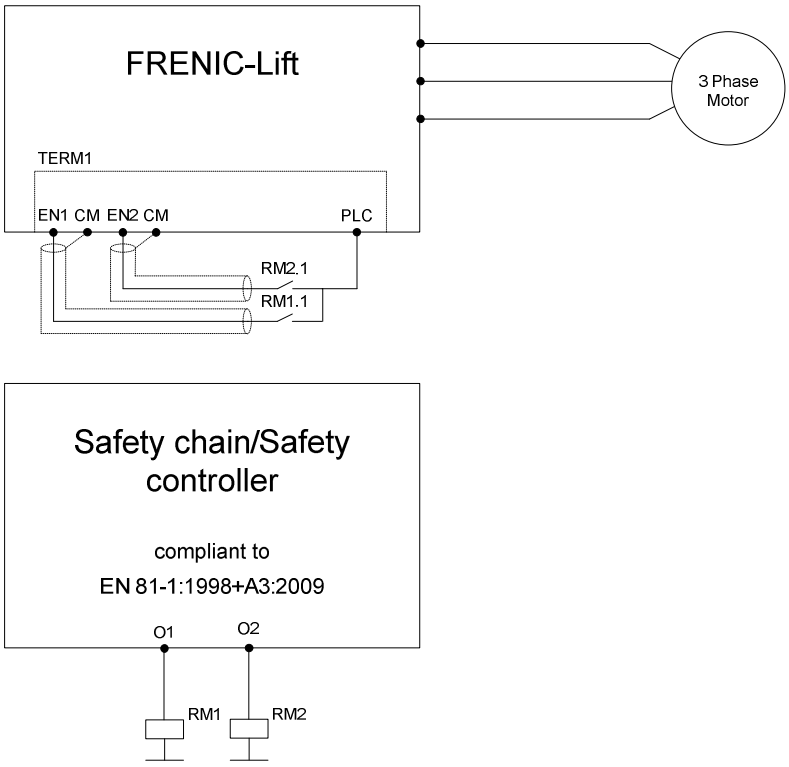
It is important to consider:

- STO function does not provide galvanic isolation. Therefore the inverter must be disconnected from the AC mains before manipulating the electrical connections between the inverter and the motor.
- STO function does not provide a controlled deceleration nor controlled stop. Therefore, in elevator applications (in vertical conveyance applications in general), ensure that the mechanical brake is applied (closed) before or -at latest- simultaneously when STO FS function becomes active.

The STO function becomes inactive (inverter can provide current to the motor) if both EN1 and EN2 digital inputs are active (+24 VDC is applied). If any of the two EN1/EN2 digital inputs becomes inactive, the inverter will interrupt the current to the motor. If there is a discrepancy in the state of EN1/EN2 digital inputs during a time longer than 50 ms the inverter will judge that there is a problem in the safety circuit and will trip by an alarm. This alarm can only be reset by powering OFF the power supply of the inverter (both control and main circuit supply).

Figure 1 shows the connection of the inverter with the elevator system. Two independent signals must be connected to the EN1/EN2 digital inputs in order to keep the required safety integrity level (required hardware fault tolerance). These signals must be segregated in different electrical conductors installed

inside different conduits, otherwise the use of independent shielded cables is a must. The armour of the conduit or the shield must be connected to a functional earth (0 V). The EN1/EN2 signals are either provided by the safety chain or a safety controller. Either solution must comply with the relevant requirements of EN 81-20:2014 which are not in the scope of this document. Optionally, a feedback signal can be connected to the elevator controller to indicate that the STO circuit is active and/or it is working properly (no failure has been detected). The connection of the feedback is optional because FRENIC-Lift makes by itself the diagnostics of the STO FS function related circuits in order to fulfil the requirements of clause 5.11.2.3 of EN 81-20:2014.



EN1: STO FS function digital input 1 of the inverter
EN2: STO FS function digital input 2 of the inverter
PLC: Common (+24 VDC) of the digital inputs/outputs of the inverter
CM: Common (+0 VDC) of the digital inputs/outputs of the inverter
RM1: Relay 1 for the activation of EN1 digital input.
RM2: Relay 2 for the activation of EN2 digital input.
RM1.1: NO Contact 1 of relay RM1
RM2.1: NO Contact 1 of relay RM2
O1: Signal 1 from safety chain (or safety controller) compliant to EN 81-20:2014
O2: Signal 2 from safety chain (or safety controller) compliant to EN 81-20:2014

Figure 1. Connection of FRENIC-Lift STO inputs.

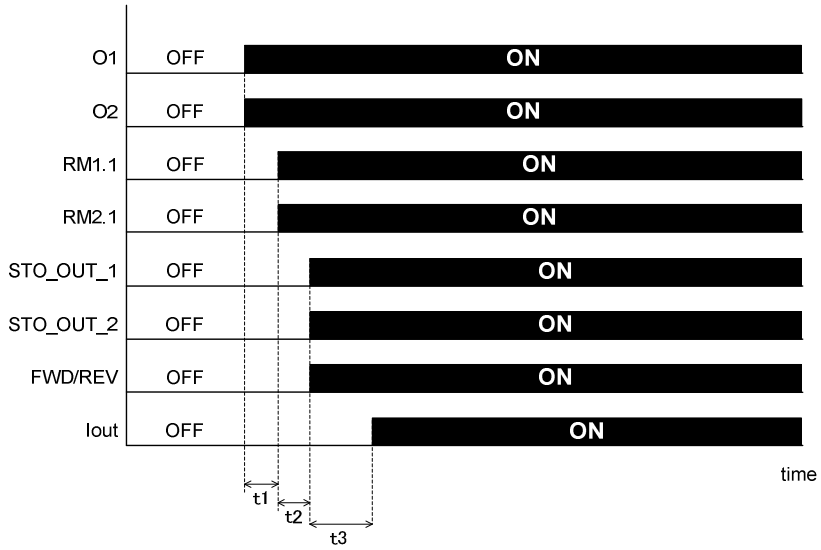
In figure 1, an example by using relays is shown. The only requirement as far as functional safety is concerned is that the selected relays comply with the relevant product standard for relays (EN 61810-1).

Figure 2 shows an example of EN1 and EN2 digital inputs activation sequence (deactivation of STO function). First of all, the outputs compliant to EN 81-

20:2014 on the lift controller are activated. When these outputs are activated, associated relays are closing NO contacts. These contacts close the circuit between terminal PLC and EN1 and EN2 digital inputs on inverter side, deactivating STO FS function (STO_OUT_1/2). At this moment IGBT's gate drivers become active.

Additionally, because at same time RUN command (FWD or REV) is activated, L85 timer starts to count; after this timer is elapsed inverter starts to apply voltage (current) at the output circuit. L85 is a delay timer used to make sure voltage (current) is active after main contactors are closed. In case of using STO FS function, because no contactors are installed, L85 can be set to 0.00 s.

On the other hand, if SCC function is used, in other words, a power relay or mini contactor is installed to short circuit motor phases in stand-by condition, additional delay timer L121 has to be considered. This delay ensures that the power relay or mini contactor is completely open before applying voltage (current) on the output circuit. t3 will finish when L121 or L85 timers are elapsed, in case that both timers are different than zero, t3 will finish after longest time set.

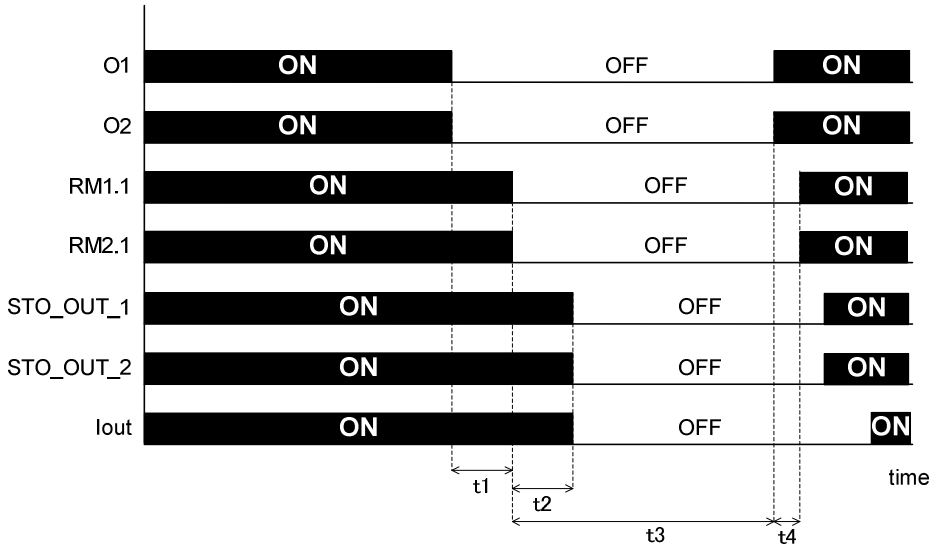


O1: Signal 1 from safety chain (or safety controller) compliant to EN 81-20:2014
O2: Signal 2 from safety chain (or safety controller) compliant to EN 81-20:2014
RM1.1: NO Contact 1 of relay RM1
RM2.1: NO Contact 1 of relay RM2
STO_OUT_1: Activation signal 1 of IGBT's gate drivers (STO FS function)
STO_OUT_2: Activation signal 2 of IGBT's gate drivers (STO FS function)
FWD/REV: RUN command by means of FWD or REV terminal
Iout: Indication that inverter is giving voltage (current) at the output

t1: Reaction time of RM1 and RM2 relay contacts
t2: Reaction time of STO FS function (20 ms)
t3: L85 or L121 delay timer depending on the use

Figure 2. Time diagram for the activation sequence of EN1 and EN2 digital inputs.

Figure 3 shows an example of STO FS function activation sequence. First of all, the outputs compliant to EN 81-20:2014 on the lift controller are disabled (for example because lift safety chain is opened). When these outputs are disabled, associated relays are opening NO contacts. These contacts open the circuit between PLC terminal and EN1 and EN2 digital inputs on inverter side, activating STO FS function (STO_OUT_1/2). At this moment IGBT's gate drivers become inactive.



O1: Signal 1 from safety chain (or safety controller) compliant to EN 81-20:2014
O2: Signal 2 from safety chain (or safety controller) compliant to EN 81-20:2014
RM1.1: NO Contact 1 of relay RM1
RM2.1: NO Contact 1 of relay RM2
STO_OUT_1: Activation signal 1 of IGBT's gate drivers (STO FS function)
STO_OUT_2: Activation signal 2 of IGBT's gate drivers (STO FS function)
Iout: Indication that inverter is giving voltage (current) at the output

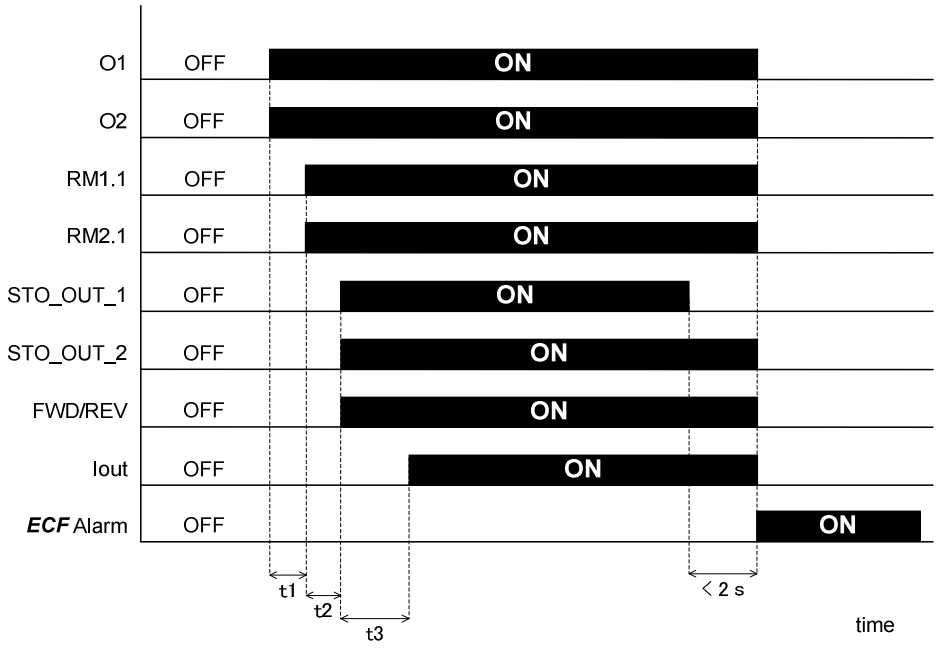
t1: Reaction time of RM1 and RM2 relays
t2: Reaction time of STO FS function (50 ms)
t3: Minimum time STO ON (condition: t3+t4 > 2 s)*1
t4: Reaction time of RM1 and RM2 relay contacts

NOTE *1: Minimum time of 2 seconds has to be ensured only one time per hour. For additional information please refer to Chapter 4.

Figure 3. Time diagram when safety circuit is interrupted.

Figure 4 shows an example when there is a mismatch between EN1 and EN2 digital inputs signal. Starting sequence is same as described in figure 2. During operation, EN1 signal is switched OFF for any reason (for example an internal circuit failure). Because this mismatch between EN1 and EN2 signal state is kept for more than 50 ms (safety reaction time), STO function switches OFF IGBT's gate drivers (interrupting motor current) and *ECF* alarm is issued.

On the other hand, because inverter trips *ECF* alarm, safety chain (or safety controller) switches OFF O1 and O2 output signals and consequently, lift controller switches OFF RUN command (FWD or REV) consequently.



O1: Signal 1 from safety chain (or safety controller) compliant to EN 81-20:2014
O2: Signal 2 from safety chain (or safety controller) compliant to EN 81-20:2014
RM1.1: NO Contact 1 of relay RM1
RM2.1: NO Contact 1 of relay RM2
STO_OUT_1: Activation signal 1 of IGBT's gate drivers (STO FS function)
STO_OUT_2: Activation signal 2 of IGBT's gate drivers (STO FS function)
FWD/REV: RUN command by means of FWD or REV terminal
Iout: Indication that inverter is giving voltage (current) at the output

t1: Reaction time of RM1 and RM2 relays
t2: Reaction time of STO FS function (20 ms)
t3: L85 or L121 delay timer depending on the use.

Figure 4. Time diagram when there is a mismatch between EN1 and EN2 digital inputs.

4. Operation requirements.

The STO circuit of FRENIC-Lift requires a self-diagnostic at least 1 time per hour. In order to make the diagnostic, the STO function must be activated. Therefore it is required to activate the STO function (turn OFF both EN1/EN2 signals for two seconds or longer) at least one time per hour. When EN1/EN2 signals are OFF, the diagnostic is continuously performed. Therefore it is recommended to keep EN1/EN2 signals OFF when the elevator is in standstill.

In case of using stand-by mode S2 (complete power OFF), the self-diagnostic of the STO function will be performed at power ON. In this case the only point that needs to be considered is that both EN1 and EN2 inputs need to be OFF for two seconds or longer.

A diagnostic of the main (power) circuit of the inverter must be executed at least 1 time per year. In order to make the diagnostic, the power supply of this circuit

must be completely disconnected. In other words, L1, L2 and L3 phases (or L and N phases in case of single phase power supply) have to be disconnected. The auxiliary power supply of the control circuit can be kept ON during this procedure.

5. Installation requirements.

FRENIC-Lift electrical and electronic circuits have been designed according to Pollution degree 2 overvoltage category III requirements. Therefore, in order to keep the required safety requirements (electrical and functional), it must be installed inside an area of Pollution Degree 2.

EN/IEC 61800-5-1 for example, defines Pollution degree 2 as the micro-environmental condition when normally, only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation is to be expected, when the PDS (Power Drive System) is out of operation.

The signals that activate EN1 and EN2 inputs must be segregated in different electrical conductors installed inside different conduits; otherwise the use of independent shielded cables is a must. The armour of the conduit or the shield must be connected to a functional earth (0 V).

6. Conclusion.

The main ideas of this document are:

- EN 81-20:2014 requires the interruption of the power between the inverter and the motor by using two independent contacts, as stated in clauses 5.9.2.5.4 a) and 5.9.3.4.2 a).
- The contactors at the output of the inverter is a simple solution whose failure modes are easy to understand, but has the following weak points:
    - The start-stop timing sequence must be done properly in order to avoid damage to either the contacts (contactors) or the inverter IGBT's.
    - The life of the contactors is limited (number of open/close operations).
    - They produce acoustic noise when closing/opening at every start/stop.
    - The open status of the contacts must be checked by the elevator controller –at latest- at every change of travelling direction of the elevator.

- FRENIC-Lift STO functional safety function satisfies the clauses 5.9.2.5.4 d) and 5.9.3.4.2 d) of EN 81-20:2014 and, therefore, can be used instead of the two contacts that interrupt the power to the motor, complying with the requirements of clauses 5.9.2.5.4 a) and 5.9.3.4.2 a).

7. References.

[1] EN 81-1:1998+A3:2009. Safety rules for the construction and installation of lifts. Part 1: Electric lifts.

[2] EN 81-20:2014. Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. Passenger and goods passenger lifts.

[3] EN ISO 13849-1:2008+AC:2009. Safety of machinery - Safety-related parts of control systems – Part 1: General principles for design.

[4] EN 61800-5-2. Adjustable speed electrical power drive systems – Safety requirements – Functional

[5] IEC 61508-1 to -7:2010. Functional safety of electrical/electronic/programmable electronic safety-related systems – Parts 1 to 7

[6] EN 61810-1. Electromechanical elementary relays - Part 1: General requirements

8. Document history.

Version	Changes applied	Date	Written	Checked	Approved
1.0.0	First version	07/04/2014	D. Bedford		
1.1.0	Figures from 1 to 4 are added. Additional explanations about sequence are added. Small mistakes are corrected	23/04/2014	J. Alonso		
1.2.0	Figure 1 is modified	25/04/2014	J. Alonso		
1.2.1	Added chapter Operation requirements. Small changes.	26/04/2014	D. Bedford		
1.3.0	Figures 2, 3 and 4 are modified. Some text is added on chapter 4.	05/05/2014	J. Alonso	D. Bedford	J. Català
1.3.1	Some text is modified.	14/08/2014	J. Alonso	D. Bedford	J. Català
1.3.2	Modifications after checking by Y. Nakato	18/11/2014	D. Bedford		
1.3.3	Modifications and small corrections	23/12/2014	J. Alonso	D.Bedford	
1.3.4	Figure 1 is modified (new terminals distribution). Some text is added in Chapter 4. Small corrections.	22/01/2015	J. Alonso	D.Bedford	J. Català
1.4.0	Standards updated with EN81-20:2014. Installation requirements are modified. Pollution degree 2 description is added.	26/06/2015	J. Alonso	D. Bedford	J. Català