Fuji Electric
e-Front runners

APPLICATION NOTE	AN-Lift-0020v112EN
Use of FRENIC-Lift EN1 and EN2 inputs in lift applications	

Inverter type	FRENIC-Lift
Software version	-
Required options	Not needed
Related documentation	
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Use	Public, web
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Version	1.1.2
Languages	English

1. Introduction.

This document describes the recommended connection/use of EN1 and EN2 inputs of FRENIC-Lift inverters in lift applications.

2. Foreword.

The standard 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. On the other hand, the inverter will deliver voltage (current) at the output only if EN1 and EN2 inputs are active.

The status of these contacts must be controlled by the lift controller (Safety PLC) and -if any safety condition is not fulfilled- these contacts must be interrupted (opened). The inverter can be also used for the operation of the contacts by providing an additional enable signal to the contacts.

Another important point is the verification of the status of the contacts. According to EN 81-1:1998+A3:2009, the 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.

One contact can be replaced with a control circuit that is able to interrupt the power to the motor safely. The enable inputs (circuits) of the FRENIC-Lift inverter –when not active- interrupt the output current as a functional safety function classified as category 3 and with a Performance Level d (PLd), according to EN ISO 13849-1:2008+AC:2009; therefore can be used as such a control circuit. In that case **only one contactor** is required at the output of the inverter. The contact, EN1 and EN2 inverter inputs must be controlled by the lift

controller (Safety PLC). Additionally, the status of the contact and the enable inputs safety circuit must be verified by the lift controller (Safety PLC). The inverter can again be used for the operation of the contact by providing an additional enable signal to the contact. Because the inverter enable inputs are approved according to EN ISO 13849-1:2008+AC:2009 Cat. 3 PL d, they are one fault tolerant (safe only in case of one failure). If the inverter detects a failure in the enable inputs circuit, it will trip (go to alarm status), PWM modulation will stop and therefore no voltage (current) will be generated at the output.

3. Explanation of EN1 and EN2 inputs connection.

There are two complete different solutions for EN1 and EN2 inputs connection, depending on whether the main contactors are operated by the lift controller (Safety PLC) or operated by the inverter. This chapter does not pretend to describe all possible solutions but tries to highlight the important concepts to keep the required functional safety and the electrical safety.

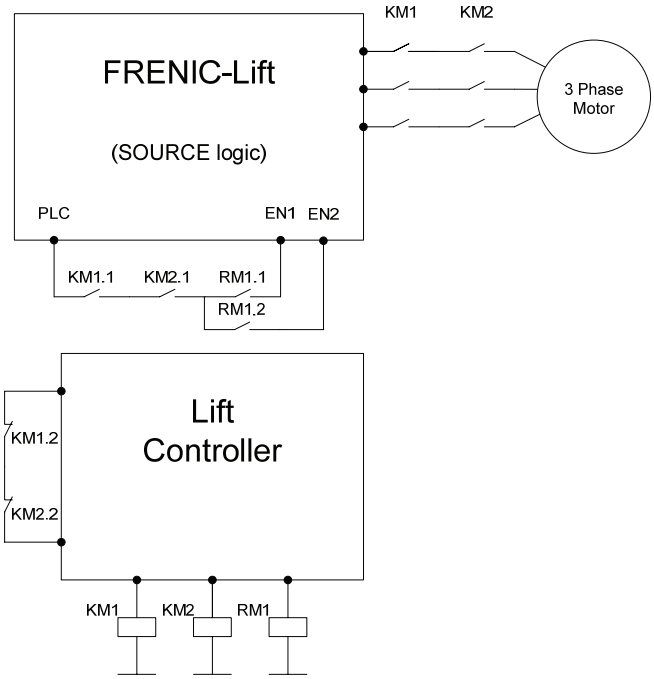
In case of subchapters 3.1 and 3.2 the contactors are operated by the Lift controller (Safety PLC), whereas in subchapter 3.3 the contactors are operated by the inverter (FRENIC-Lift). For simplicity of the connection diagrams below the safety circuit is represented inside the lift controller (Safety PLC) in all cases.

3.1 Case that EN1 and EN2 inputs are not used as functional safety function.

In the case that EN1 and EN2 inputs of FRENIC-Lift are not used as a functional safety function then two contactors are needed at the output of the inverter (figure 1).

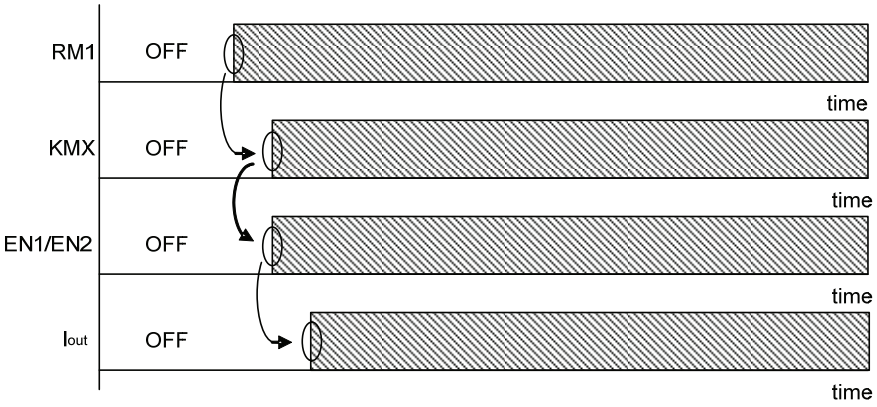
Another important point -already mentioned in the foreword- is that EN1 and EN2 inputs must be active (enabled) only when the main contactors at the output of the inverter are already closed. This avoids that the inverter delivers voltage at the output before the contactors are closed. On the other hand -when the contactors open- the inverter output must be already (before) inactive (disabled), avoiding arcing in the contactors, and therefore enlarging their life and also avoiding problems on the inverter output stage (transistors).

To ensure that EN1 and EN2 inputs must be active only when the main contactors are closed, we must use one **normally open** (NO) auxiliary contact of each main contactor (KM1.1, KM2.1) and connect these contacts in series, as depicted in figure 1. Figure 2 shows the time diagram with the signal sequence at the start (when EN1 and EN2 inputs are activated). We can observe in this time diagram that EN1 and EN2 signals will be active only after KM1 and KM2 are closed. A short time after EN1 and EN2 are active, the inverter will start delivering voltage (current) at the output.



EN1: Safety enable digital input 1 of the inverter
EN2: Safety enable digital input 2 of the inverter
PLC: Common (+24 VDC) of the digital inputs/outputs of the inverter
KM1: Main contactor 1
KM2: Main contactor 2
KM1.1: Auxiliary contact (NO) of main contactor 1
KM1.2: Auxiliary contact (NC) of main contactor 1
KM2.1: Auxiliary contact (NO) of main contactor 2
KM2.2: Auxiliary contact (NC) of main contactor 2
RM1: Relay for the activation of enable circuit
RM1.1: Contact 1 of relay RM1
RM1.2: Contact 2 of relay RM1

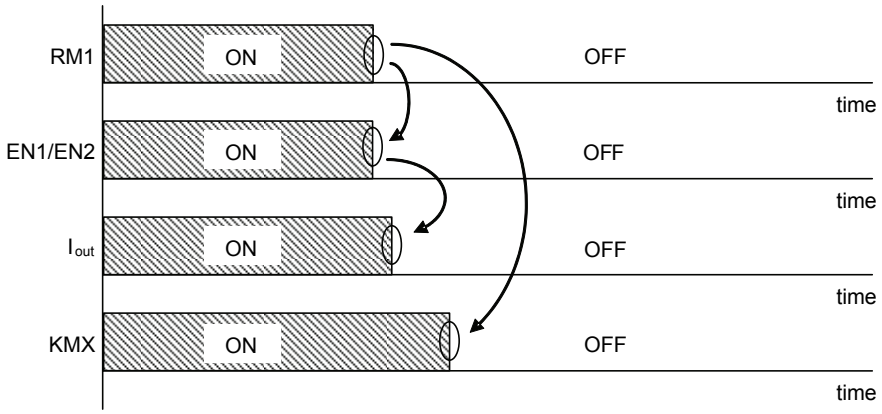
Figure 1. Connection diagram of EN1 and EN2 inputs when not used as a safety function.



RM1: Relay for the activation of main contactors and EN1 and EN2 inputs state
KMX: Main contactor X (1 or 2) state
EN1/EN2: Enable input signals 1 and 2 state
I_{out}: Indication that inverter is giving voltage (current) at the output

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

To assure that the inverter is already disabled when the main contactors are opened there are different alternatives (solutions). One solution is to add a third **normally open** contact (one for each enable terminal) in series with the auxiliary contacts of the contactors (RM1.1 and RM2.2 in figure 1). We **must ensure** that these contacts are opened a few milliseconds before the main contactors are opened.



RM1: Relay for the activation of main contactors and EN input state
EN1/EN2: Enable input signals 1 and 2 state
I_{out}: Indication that inverter is giving voltage (current) at the output
KMX: Main contactor X (1 or 2) state

Figure 3. Time diagram when safety circuit is interrupted.

The ideal time sequence in case safety circuit is interrupted is shown in figure 3. In this time diagram we can observe that when RM1 is opened EN1 and EN2 inputs are deactivated almost at the same time. After a short time (11.8 ms) the inverter does not give current to the motor, and this happens a few milliseconds before the main contactors (KM1, KM2) are opened. This is due to the fact that the RM1 is switched OFF before and the time response of the enable circuit is faster than the time response of the coils of the main contactors (KM1 and KM2).

3.2 Case that EN1 and EN2 inputs are used as safety function.

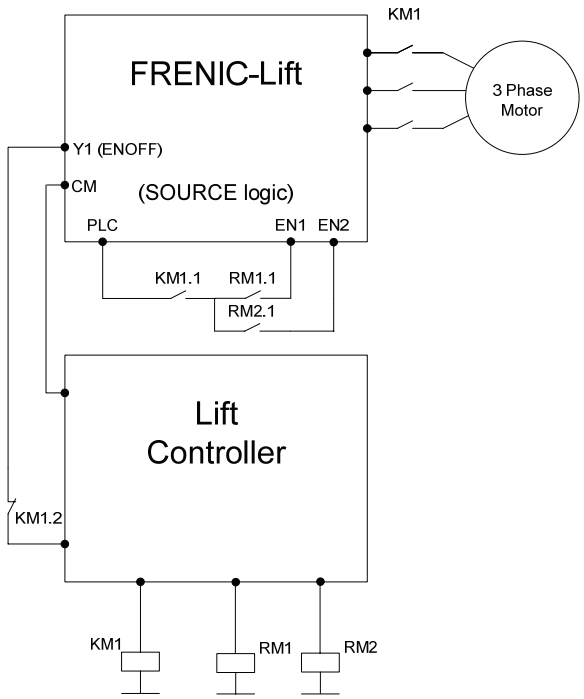
In the case that EN1 and EN2 inputs of FRENIC-Lift are used as a safety function (because they have the approval according to EN ISO 13849-1:2008+AC:2009 and EN 81-1:1998+A3:2009) then only one contactor is needed at the output of the inverter (figure 4).

To fulfil the required safety integrity level for the application, the following important condition must be fulfilled:

- An output signal from the inverter must be connected to the Lift controller to indicate (feedback) the status of the enable input. This is equivalent to the normally closed auxiliary contact of a main contactor. This signal can be connected in series with the normally closed auxiliary contact of the remaining main contactor.

- Lift controller output signal/s which controls enable signals (EN1 and EN2) has to be designed according to safety standards. In this case, it has to fulfil with Category 3 and PLd according to EN ISO 13849-1:2008+AC:2009.

Additionally, it is required that the signals that activate RM1/RM2 are turned OFF a few milliseconds before the signal that activates KM1. This ensures that the inverter stops giving output current before the main contactor between the inverter and the motor (KM1) is opened, avoiding the arcing on the contactors (may damage the contactors and/or the inverter output transistors). In this case the same time diagrams as described in subchapter 3.1 apply for the switch ON and switch OFF sequences.



EN1: Safety enable digital input 1 of the inverter
EN2: Safety enable digital input 2 of the inverter
PLC: Common (+24 VDC) of the digital inputs/outputs of the inverter
CM: Common (0 V) of the digital inputs/outputs of the inverter
Y1: Transistor digital output 1 of the inverter (programmed to ENOFF function)
KM1: Main contactor 1
KM1.1: Auxiliary contact (NO) of main contactor 1
KM1.2: Auxiliary contact (NC) of main contactor 1
RM1: Relay for the activation of EN1 input
RM2: Relay for the activation of EN2 input
RM1.1: Contact 1 of relay RM1
RM2.1: Contact 1 of relay RM2

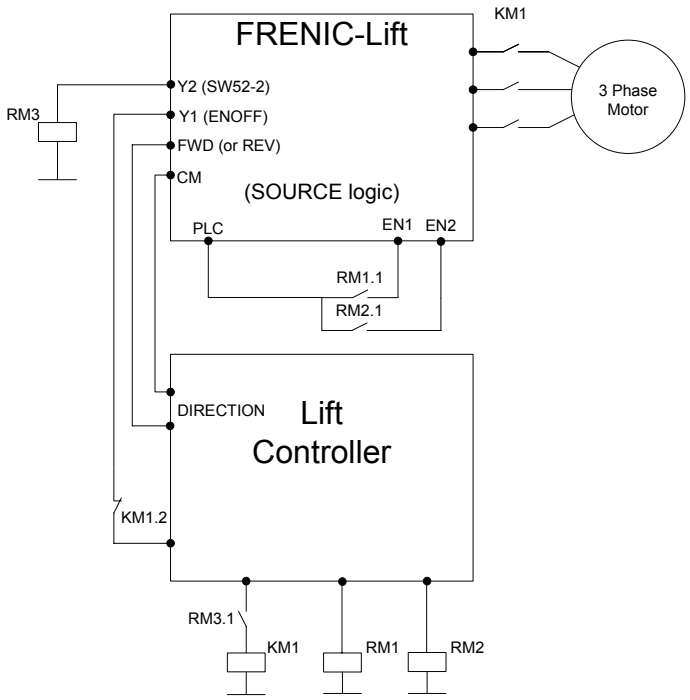
Figure 4. Connection diagram of EN1 and EN2 inputs when used as a safety function.

3.3 Case that EN1 and EN2 inputs are used as safety function and the main contactor is operated by the inverter.

There are two possible alternative functions to operate the main contactor: SW52-2 and SW52-3. By using both alternatives the safety integrity level achieved is the same.

3.3.1 Using function SW52-2 to operate the main contactor.

Figure 5 shows the connection diagram when EN1 and EN2 inputs of FRENIC-Lift are used as a safety function and the inverter operates the remaining main contactor using function SW52-2.

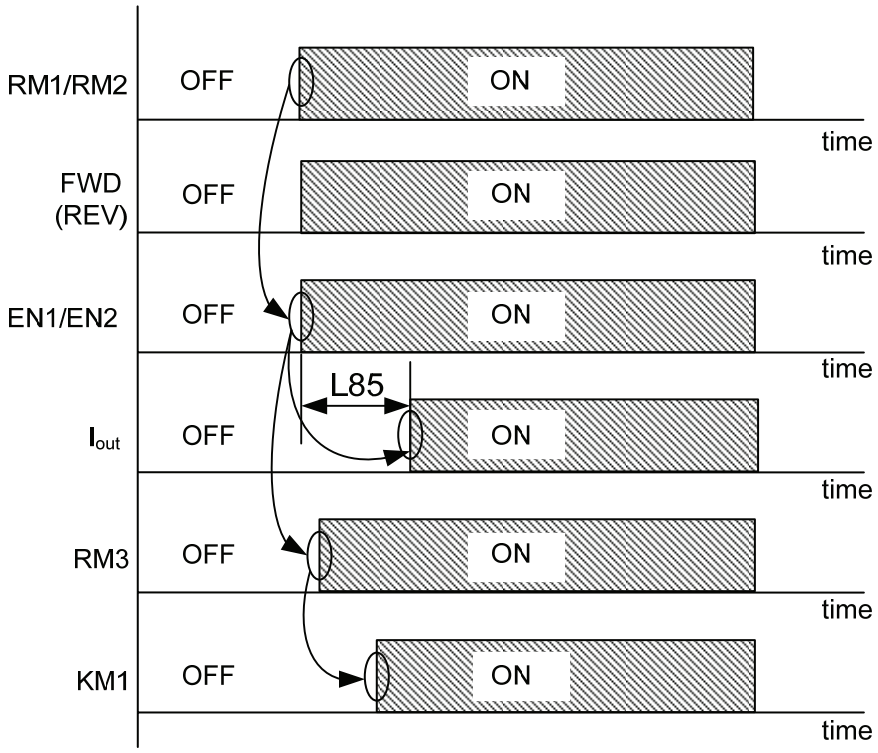


EN1: Safety enable digital input 1 of the inverter
EN2: Safety enable digital input 2 of the inverter
PLC: Common (+24 VDC) of the digital inputs/outputs of the inverter
CM: Common (0 V) of the digital inputs/outputs of the inverter
Y1: Transistor digital output 1 of the inverter (programmed to ENOFF function)
Y2: Transistor digital output 2 of the inverter (programmed to SW52-2 function)
KM1: Main contactor 1
KM1.2: Auxiliary contact (NC) of main contactor 1
RM1: Relay for the activation of EN1 input
RM2: Relay for the activation of EN2 input
RM3: Relay for the activation of main contactor 1 controlled by the inverter
RM1.1: Contact 1 of relay RM1
RM2.1: Contact 1 of relay RM2
RM3.1: Contact 1 of relay RM3

Figure 5. Connection diagram in case the main contactor is operated by the inverter using function SW52-2.

To fulfil the required safety integrity level for the application, the important condition described in subchapter 3.2 must be also fulfilled (feedback of the inverter enable status and lift controller output/s signals to control RM1/RM2 designed according to safety standards).

Also in this solution the EN input will be activated from the Lift controller. In this case L85 parameter of the inverter (delay time of inverter current output after being enabled) must be set up in order to ensure that the inverter does not apply current to the motor before the contactor KM1 is completely closed (Figure 6).



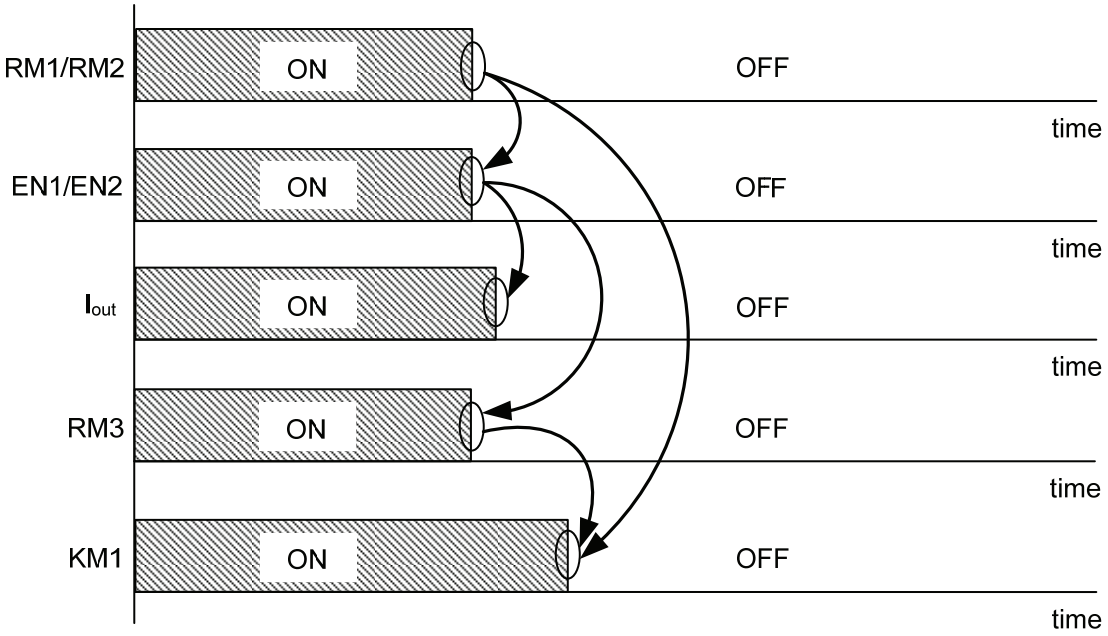
RM1/RM2: Relay for the activation of enable inputs state
RM3: Relay for the activation of main contactor state
EN1/EN2: Enable input signals state
I_{out}: Indication that inverter is giving voltage (current) at the output
KM1: Main contactor 1 state

Figure 6. Time diagram for the activation sequence of EN1 and EN2 inputs in case the main contactor is operated by the inverter using function SW52-2.

One important point to remark is that, for safety reasons, the status of the main contactor KM1 and the ON/OFF status of EN1 and EN2 inputs are controlled by the Lift Controller (or the safety system if it is not integrated in the Lift Controller), using two different signals. In this way, in the case the safety circuit of the lift is interrupted, EN1 and EN2 inputs will be deactivated a few milliseconds before the main contactors are opened.

Figure 7 shows the time diagram of the signals when the safety circuit is interrupted. In this diagram it can be seen that when the signals RM1/RM2 are deactivated, almost at the same time, EN1 and EN2 signals become inactive. After a short time (11.8 ms), the inverter does not give current to the motor, and this happen a few milliseconds before RM3 is opened and the main contactor is opened.

This is due to the fact that the signals that activate RM1/RM2 are turned OFF a few milliseconds before the signal that activates KM1 and the time response of the enable circuit is faster than the time response of relay RM3 and the coil of the main contactor KM1.



RM1: Relay for the deactivation of EN1 input state
RM2: Relay for the deactivation of EN2 input state
EN1: EN1 input signal state
EN2: EN2 input signal state
I_{out}: Indication that inverter is giving voltage (current) at the output
RM3: Relay for the deactivation of main contactor state
KM1: Main contactor 1 state

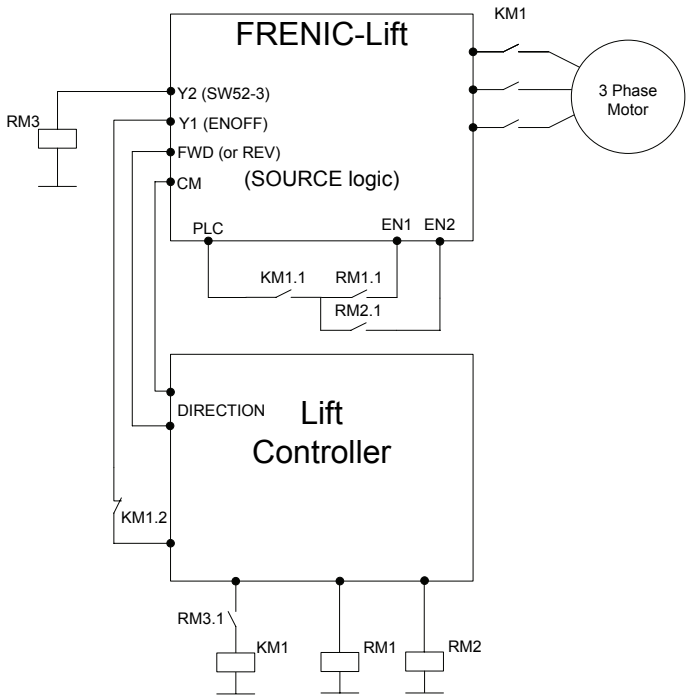
Figure 7. Time diagram when safety circuit is interrupted in case main contactor is operated by the inverter using function SW52-2.

3.3.2 Using function SW52-3 to operate the main contactor.

Figure 8 shows another variant where the function used in the inverter to operate the main contactors is SW52-3. The main difference of SW52-3 compared to SW52-2 function, is that the sequence is triggered only by RUN command (FWD or REV). In other words, the inverter activates the output programmed with SW52-3 function (to give permission to close the main contactor) without having EN1 and EN2 inputs active.

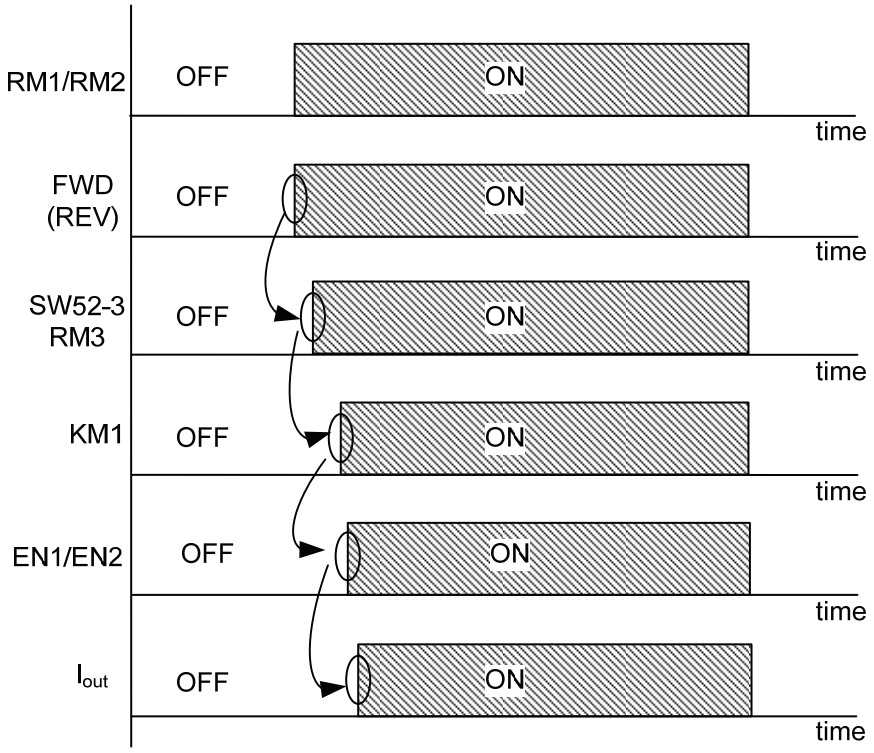
To fulfil the required safety integrity level for the application, the important condition described in subchapter 3.2 must be also fulfilled (feedback of the inverter enable status and lift controller output/s signals to control RM1/RM2 designed according to safety standards).

To ensure that EN1 and EN2 inputs must be active only when the remaining main contactor KM1 is closed, we must use one **normally open** (NO) auxiliary contact of this contactor (KM1.1) and connect this contact in series, as depicted in figure 8. Figure 9 shows the time diagram with the signal sequence at the start (when EN1 and EN2 inputs are activated). We can observe in this time diagram that enable signal will be active only after KM1 is closed. A short time after enable is active, the inverter will start delivering voltage (current) at the output.



EN1: Safety enable digital input 1 of the inverter
EN2: Safety enable digital input 2 of the inverter
PLC: Common (+24 VDC) of the digital inputs/outputs of the inverter
CM: Common (0 V) of the digital inputs/outputs of the inverter
Y1: Transistor digital output 1 of the inverter (programmed to ENOFF function)
Y2: Transistor digital output 2 of the inverter (programmed to SW52-3 function)
KM1: Main contactor 1
KM1.1: Auxiliary contact (NO) of main contactor 1
KM1.2: Auxiliary contact (NC) of main contactor 1
RM1: Relay for the activation of EN1 input
RM2: Relay for the activation of EN2 input
RM3: Relay for the activation of main contactor 1 controlled by the inverter(operated by SW52-3)
RM1.1: Contact 1 of relay RM1
RM2.1: Contact 1 of relay RM2
RM3.1: Contact 1 of relay RM3

Figure 8. Connection diagram in case the main contactor is operated by the inverter using function SW52-3.

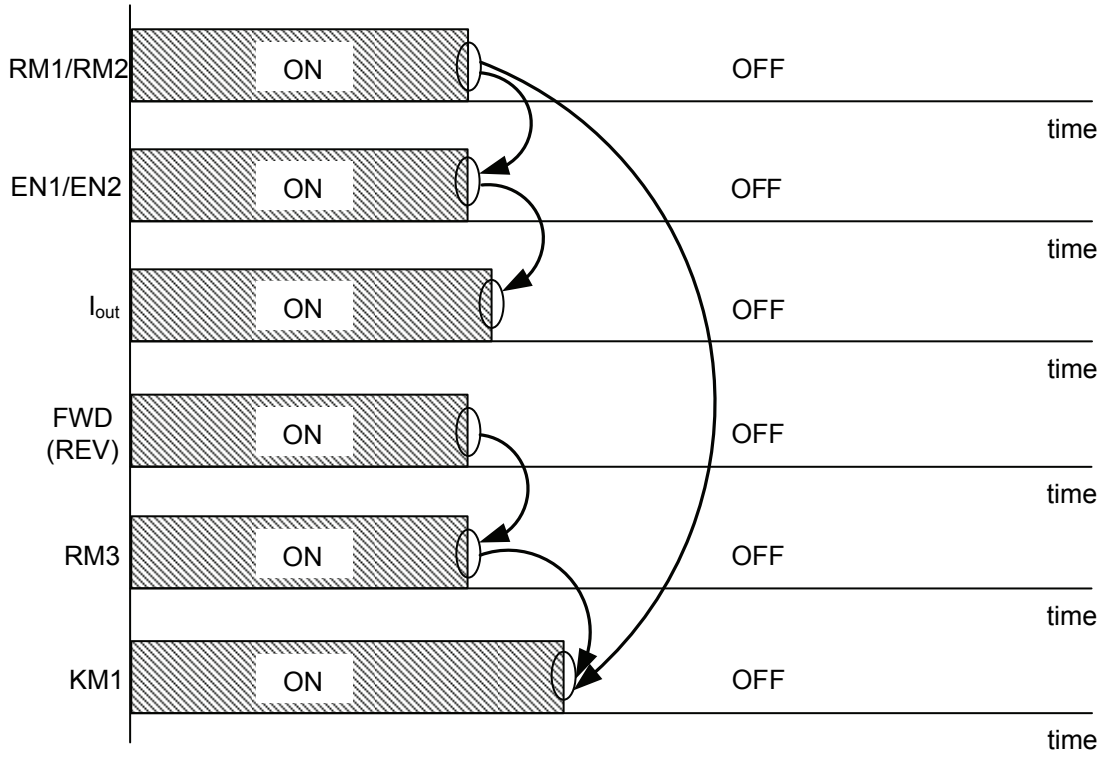


RM1/RM2: Relay for the activation of enable inputs state
RM3: Relay for the activation of KM1 (operated by SW52-3) state
FWD (or REV): RUN command (DIRECTION) of the inverter state
KM1: Main contactor 1 state
EN1/EN2: Enable input signals state
I_{out}: Indication that inverter is giving voltage (current) at the output

Figure 9. Time diagram for the activation sequence of EN1 and EN2 inputs in case main contactor is operated by the inverter using function SW52-3.

It is important to remark that, also in this case in order to keep the safety integrity level, the status of the main contactor KM1 and the ON/OFF status of EN1 and EN2 inputs are controlled by the Lift Controller (or the safety system if is not integrated in the Lift Controller), using two different signals. In this way, in the case the safety circuit of the lift is interrupted, the enable inputs will be deactivated a few milliseconds before the main contactors are opened. The safety level of this solution and the solution proposed in 3.3.1 are exactly equivalent.

Figure 10 shows the time diagram of the signals when the safety circuit is interrupted. In this diagram it can be seen that when the signals RM1/RM2 are deactivated, almost at the same time, EN1 and EN2 signals become inactive. After a short time (11.8 ms), the inverter does not give current to the motor, and this happen a few milliseconds before the main contactor is opened. This is due to the fact that, the signals that activate RM1/RM2 are turned OFF a few milliseconds before the signal that activates KM1 and the time response of the EN circuit is faster than the time response of the main contactor KM1.



RM1: Relay for the deactivation of EN1 input state
RM2: Relay for the deactivation of EN2 input state
EN1: EN1 input signal state
EN2: EN2 input signal state
I_{out}: Indication that inverter is giving voltage (current) at the output
RM3: Relay for the deactivation of KM1 (operated by SW52-3) state
KM1: Main contactor 1 state

Figure 10. Time diagram when safety circuit is interrupted in case main contactor is operated by the inverter using function SW52-3.

4. Conclusion.

The main ideas of this document are:

- The inverter can deliver (generate) voltage (current) only if EN1 and EN2 inputs are active. These inputs are approved -when not active- to interrupt the current as a functional safety function classified as category 3 or with a Performance Level d (PLd), as described in EN ISO 13849-1:2008+AC:2009.
- EN 81-1:1998+A3:2009 requires for safety reasons the interruption of the power to the motor with two contacts in series.
- According also to EN 81-1:1998+A3:2009, it is possible to use only one contact at the output of the inverter if the enable inputs of this inverter (when inactive) interrupt the output current as a functional safety function classified as category 3, or with Performance Level d (PLd), as described in EN ISO 13849-1:2008+AC:2009.

- There is a compromise between functional safety and electrical safety. Functional safety must be the priority, but without causing any damage to the electrical components (main contactors at the output and inverter transistors).
- To avoid any damage to the electrical components, the connection and sequence of the signals must be done in a way that the contacts at the output of the inverter are the first to close (before the inverter is enabled) and the last to open (after the inverter is disabled).
- There are two different strategies to control the main contactors of the inverter: contactors operated by the inverter or contactors operated by the lift controller (safety PLC). In any case, the safety circuit must also control the ON/OFF status of the contactors.
- There are different solutions to ensure that enable inputs are activated after the output contactors are closed, and that enable inputs are deactivated before the output contactors are opened.
- In order to ensure that enable inputs are the first signals to become inactive we recommend the use of a fast relay to switch ON/OFF these signals. A recommended type is Schneider/Telemecanique Zelio Relay type RSB (example of item code is RSB 2A 080 P7: 2 contacts and 220 VAC coil).
- If a failure is detected in the EN1 and/or EN2 inputs circuit, the inverter will trip with alarm ECF (keypad will display this alarm code) and disables PWM, stopping delivering current to the motor (safe state).

5. References.

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

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

6. Document history.

Version	Changes applied	Date	Written	Checked	Approved
1.0.0	First version following TÜV advice.	15/12/2008	D. Bedford		
1.0.1	Corrections following TÜV advice.	13/01/2009	D. Bedford	P. Kocybik	
1.0.2	Additional corrections following TÜV advice.	16/01/2009	D. Bedford	P. Kocybik	
1.0.3	Correction of small errors	16/01/2009	D. Bedford	P. Kocybik	P. Kocybik
1.0.4	Emphasize EN activation sequence. Correction of small errors.	30/07/2009	D. Bedford	J. Català	D. Bedford
1.0.5	Control of contactors by inverter using SW52-3 added The text and text box in figure 5 have been modified. The text in figures 6 and 7 have been modified. Fuji Electric logo changed.	8/01/2010	D. Bedford		
1.0.6	Figures 5, 6 and 7 have been modified	27/01/2010	D. Bedford	J.Alonso	D. Bedford
1.0.7	Recommendation of fast relay added	09/03/2010	D. Bedford		
1.0.8	ECF alarm description is added	11/03/2010	D. Bedford		
1.1.0	EN1 and EN2 inputs are added. Safety standards updated to EN ISO 13849-1. Layout has been changed.	04/01/2012	J. Alonso	D. Bedford	
1.1.1	Response time of EN inputs has been corrected.	11/01/2012	J. Alonso	D. Bedford	
1.1.2	Safety of machinery and lift standard versions updated according to TÜV advice. Figure 4, 5, 6, 7, 8, 9 and 10 modified according to TÜV advice. Some text is added.	23/01/2012	J. Alonso	D. Bedford	P. Robben