

APPLICATION NOTE	AN-LM2A-0005v120EN
Vector control with peripheral PG (Synchronous motor)	

Inverter type	FRENIC-Lift (LM2A)
Software version	Any
Required options	OPC-PG3 OPC-PMPG OPC-G1-PG OPC-G1-PG2
Related documentation	INR-SI47-1909-E
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Use	Public, web
Date	20/05/2016
Version	1.2.0
Languages	English

1. Introduction

In case of Permanent Magnet Synchronous Motors (PMSM) encoder normally is placed in the middle of motor shaft. This allows in a simple way the following:

- Easy detection of magnet position.
- Easy detection of motor speed.

However, other motor manufacturers have chosen another strategy. This strategy is to install an incremental encoder on the rotor diameter (pulley). The disadvantages of this method are:

- Slip between motor pulley and encoder sheave.
- Loss of magnet position.
- None fixed relationship between motor speed and encoder speed.

Due to disadvantages mentioned above, a specific control method is needed for this motor configuration. In case of FRENIC-Lift (LM2A), this control method is called "Vector control with peripheral PG".

2. Related parameters

FRENIC-Lift has macros which preset the inverter depending on the motor type. Macros can be set by means of parameter H03. As in this case a PMSM is used, H03 recommended setting is 2.

The parameters and functions related to “Vector control with peripheral PG” control are listed in table 1:

Table 1. Function codes related to “Vector control with peripheral PG” control.

Function codes	Name	Setting range	Units	Recommended Setting
C21	Speed units selection	0 to 3	-	2: Hz
P01	Motor (n ^o of poles)	2 to 100	<i>poles</i>	Depending on the motor
P02	Motor (Rated capacity)	0.01 to 220.0	<i>kW</i>	Depending on the motor
P03	Motor (Rated current)	0.00 to 500.0	<i>A</i>	Depending on the motor
P07	Motor (%R1)	0.00 to 50.00	<i>%</i>	20
P60	Motor (Armature resistance – Rs)	0.000 to 50.00	<i>ohm</i>	Depending on the motor
P62* ¹	Motor (Armature q-axis reactance – Xs)	0.000 to 50.00	<i>ohm</i>	Depending on the motor
P63* ¹	Motor (Interphase inductive voltage – E)	0 to 500	<i>V</i>	Depending on the motor
P65* ¹	Motor (q-axis inductance magnetic saturation correction)	0 to 100	<i>%</i>	65 %
F03	Motor rated speed	30.00 to 6000.0	<i>rpm</i>	Depending on the motor
F04	Motor rated frequency	30.00 to 6000.0	<i>Hz</i>	Depending on the motor
F05	Motor rated voltage	160 to 500	<i>V</i>	Depending on the motor
F42	Motor control mode selection	0 to 2	-	1: Vector control with PG (Sync)
L01	Pulse encoder (selection)	0 to 8	-	1: AB+Z
L02	Pulse encoder resolution	360 to 60000	<i>P/R</i>	Depending on the encoder
L07	Automatic pole tuning selection	0 to 4	-	4
L130	Sheave diameter (Ds)	0.0 to 6553.5	<i>mm</i>	Depending on the motor
L131	Encoder diameter (De)	0.0 to 6553.5	<i>mm</i>	37.2
L132	Theta compensation band	1 to 90	<i>deg</i>	45
L133	Theta compensation gain lower limit	0.0 to 1.0	-	0.2
L198	Operation setting switch 1	0000 0000 to 1111 1111	-	0010 0000

*¹ Please check the description of this parameter. The setting on this function code depends on ROM version.

The function codes related to “Vector control with peripheral PG” are explained in more detail below:

- Speed units selection
(Function code **C21**)

Speed units can be selected between m/min, rpm, Hz and mm/s. It is recommended to work with Hz.

For additional information refer to chapter 3. Motor function codes.

- Motor (n° of poles)
(Function code **P01**)

On this function code, total number of motor poles has to be set. Number of poles depends on motor type. Normally this value has to be calculated as it doesn't appear on motor's name plate.

For additional information refer to chapter 3. Motor function codes.

- Motor (Rated capacity)
(Function code **P02**)

On this function code, motor's rated power has to be set.

For additional information refer to chapter 3. Motor function codes.

- Motor (Rated current)
(Function code **P03**)

On this function code, motor's rated power has to be set.

For additional information refer to chapter 3. Motor function codes.

- Motor (%R1)
(Function code **P07**)

Set this function code to 20 %. Please do not use any other setting than the recommended.

- Motor (Armature resistance - Rs)
(Function code **P60**)

On this function code rotor's resistance value is set.

For additional information refer to chapter 3. Motor function codes.

- Motor (Armature q-axis reactance - Xs)
(Function code **P62**)

On this function code rotor's reactance value is set.

If inverter's ROM version (Main) is 0600 or below, please uses the formula below:

$$P63 = \text{Rotor's reactance value} \times 0.6$$

For additional information refer to chapter 3. Motor function codes.

- Motor (Interphase inductive voltage-E)
(Function code **P63**)

On this function code inductive voltage value is set.

If inverter's ROM version (Main) is 0600 or below, please uses the formula below:

$$P63 = \text{Interphase inductive voltage} \times 0.58$$

For additional information refer to chapter 3. Motor function codes.

- Motor (q-axis inductance magnetic saturation correction)
(Function code **P65**)

Set this function code to 65 %. Please do not use any other setting than the recommended.

If inverter's ROM version (Main) is 0600 or below, this parameter doesn't exist.

- Motor rated speed
(Function code **F03**)

On this function code motor's rated speed (in rpm) is set.
For additional information refer to chapter 3. Motor function codes.

- Motor rated frequency
(Function code **F04**)

On this function code motor's rated frequency (in Hz) is set. This function code unit depends on **C21** setting; therefore, if **C21** is set to a different value than recommended, **F04** has to be adapted to the new unit selected.

For additional information refer to chapter 3. Motor function codes.

- Motor rated voltage
(Function code **F05**)

On this function code motor's rated voltage (in V) is set.
For additional information refer to chapter 3. Motor function codes.

- Motor control mode selection
(Function code **F42**)

This control mode is based in PMSM as explained above; therefore F42 has to be set to 1: Vector control with PG (synchronous). Please do not use any other setting than the recommended.

- Pulse encoder (selection)
(Function code **L01**)

On this function code type of encoder is selected. For this control mode type 1 is used, therefore please set L01 to 1: With ABS signal (12 /15 V Complementary / Open collector / 5 V line driver / Z phase). Please do not use any other setting than the recommended.

On the other hand, Z phase of the encoder (PZ, or PZ+ and PZ-) doesn't need to be connected.

- Pulse encoder resolution
(Function code **L02**)

On this function code number of encoder pulses per revolution is set. It is recommended to use encoder with 1024 p/r or higher resolution. As higher is the resolution, easier will be to control the rollback.

- Automatic pole tuning selection
(Function code **L07**)

This parameter is used to select if pole tuning will be performed automatically or not. Please do not use any other setting than the recommended.

- Sheave diameter (Ds)
(Function code **L130**)
- Encoder diameter (De)
(Function code **L131**)

These function codes are used to set the motor's sheave diameter and encoder's diameter respectively. Figure 1 shows which diameter has to be taken in consideration.

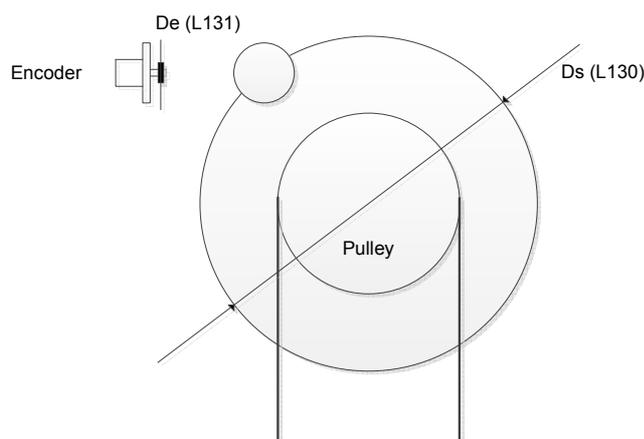


Figure 1. L130 and L131 diameters on the application

Figure 1 shows a basic diagram of a motor and an encoder. As it can be observed, the diameter that has to be measured on the motor side (**L130**) is the external one, please do not confuse with pulley (the one which holds the ropes). Sheave diameter depends on the motor type. Diameter that has to be measured on the encoder is the one corresponding to the rubber wheel (**L131**). This diameter is normally 37.2 mm; therefore do not modify the recommended setting.

Rubber wheel tends to wear out over time. Make sure that rubber wheel diameter is kept at 37.2 mm; otherwise inverter may lose motor's control. For additional information refer to chapter 3. Motor function codes.

- Theta compensation band
(Function code **L132**)
- Theta compensation gain lower limit
(Function code **L133**)

Please do not use any other setting than the recommended.

- Operation setting switch 1
(Function code **L198**)

Bit 5 of **L198** function code defines whether pole tuning is performed only at first RUN command after Power ON or after every RUN command.

L198(Bit 5)= 0: Automatic pole tuning under certain conditions.
L198(Bit 5)= 1: Automatic pole tuning every RUN command.

In case of selecting automatic pole tuning under certain conditions (Bit5= 0), inverter will perform an automatic pole tuning in following cases:

ROM version 600 and below:

- During first RUN command after Power ON

ROM version 800 and above:

- During first RUN command after Power ON
- Inverter alarm (Only: OCx, OS, PG)
- Motor moves (pulses are detected) if inverter is in STOP mode

3. Motor function codes

Some motors have been already tested with success. Table 2 shows the right parameters that have to be set in each motor type case.

Table 2. Recommended setting depending on motor type.

Motor type	MX05	MX05/10	MX05/10	MX06	MX06/10
Manufacturer	KONE	KONE	KONE	KONE	KONE
P01	20	14	14	24	16
P02	2,8 kW	2,8 kW	2,8 kW	3,7 kW	3,7 kW
P03	8 A	9 A	9 A	11 A	11 A
P07	20 %	20 %	20 %	20 %	20 %
P60	3,5 Ω	3,5 Ω	3,5 Ω	2,2 Ω	2,2 Ω
P62 ^{*1}	6,3 / 10,5 Ω	6 / 10 Ω	5,3 / 8,8 Ω	4,8 / 8,0 Ω	4,8 / 8,0 Ω
P63 ^{*1}	69 / 120 V	69 / 120 V	120 / 208 V	69 / 120 V	69 / 120 V
F03	112 rpm	112 rpm	112 rpm	95 rpm	95 rpm
F04	19 Hz	13 Hz	13,1 Hz	19 Hz	12,7 Hz
F05	280 V	280 V	305 V	280 V	280 V
L130	530 mm	530 mm	530 mm	630 mm	630 mm

*1 This value depends on ROM version. First number corresponds to ROM version 0600 or below and second to 0800 and above. Second number corresponds to the value that can be found in motor's name plate.

Figure 2 shows where information is placed in motor's name plate.

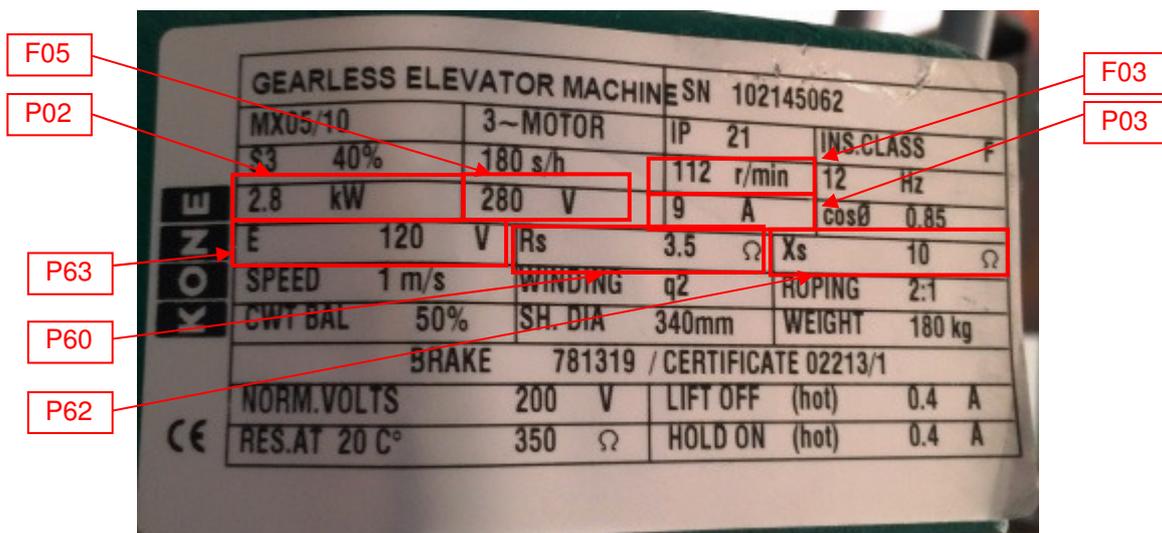


Figure 2. MX05/10 name plate

If the motor that has to be controlled is not on the list, and some setting is not clear, please contact your Fuji Electric representative.

4. Encoder option board

Four option cards are available depending on the encoder type (open collector or line driver). These option boards are called OPC-G1-PG or OPC-PG3 and OPC-G1-PG2 or OPC-PMPG respectively. Encoder board can be only connected to port C as is shown in figure 3.

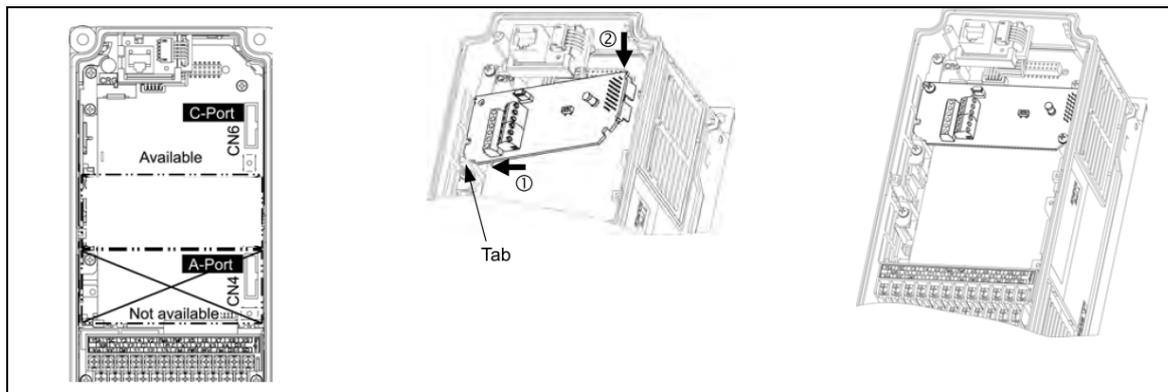


Figure 3. Available port and option board installation

4.1 Option board OPC-PG3/OPC-G1-PG

Option board OPC-PG3 (or OPC-G1-PG) is the specific board for connecting a HTL standard encoder (standard power supply voltage range between 10~30 VDC). The encoder connected must fulfil the technical requirements specified in table 3.

Table 3. HTL encoder technical requirements

Property	Specification	
Encoder's required supply	+12 VDC $\pm 10\%$, 120 mA (SW1=12 V) +15 VDC $\pm 10\%$, 120 mA (SW1=15 V)	
Option board input pulses threshold	High level ≥ 8 VDC, Low level ≤ 3 VDC (SW1=12 V) High level ≥ 10 VDC, Low level ≤ 3 VDC (SW1=15 V)	
Output signal	Open Collector	Push pull (complementary)
Maximum input frequency	30 kHz	100 kHz
Maximum cable length	20 m	100 m

For wiring this encoder type to OPC-PG3, see figure 4 and table 4 below.

Table 4. Option terminals and encoder signals

Signal	Option terminal	Meaning
+ VDC	PO	Power supply
A phase	PA	Pulses phase A
B phase	PB	Pulses phase B 90° shifted
0 VDC	CM	Common 0 V

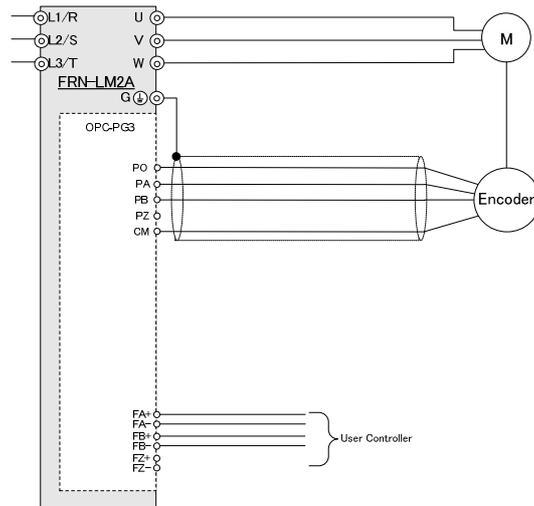


Figure 4. Encoder's connection

Note 1: OPC-G1-PG doesn't include Fxx terminals (encoder repetition for controller)

Note 2: OPC-G1-PG terminals for A phase and B phase are called YA and YB respectively.

Note 3: In case of using OPC-PG3 inverter's ROM version must be 0600 or above.

4.2 Option board OPC-PMPG/OPC-G1-PG2

Option board OPC-PMPG (or OPC-G1-PG2) is the specific board for connecting a Line Driver standard encoder (differential signal +5 VDC). The encoder connected must fulfil the technical requirements specified in table 5.

Table 5. Line Driver encoder technical requirements

Property	Specification
Encoder's required supply	+5 VDC $\pm 10\%$, 200 mA
Output signal	Line Driver
Maximum input frequency	100 kHz
Maximum cable length	100 m

For wiring this encoder type to OPC-PMPG, see figure 5 and table 6 below.

Table 6. Option terminals and encoder signals

Signal	Option terminal	Meaning
+ VDC	PO	Power supply
A phase	PA+	Pulses phase A
/A phase	PA-	Pulses phase A inverted
B phase	PB+	Pulses phase B 90° shifted
/B phase	PB-	Pulses phase B inverted 90° shifted
0 VDC	CM	Common 0 V

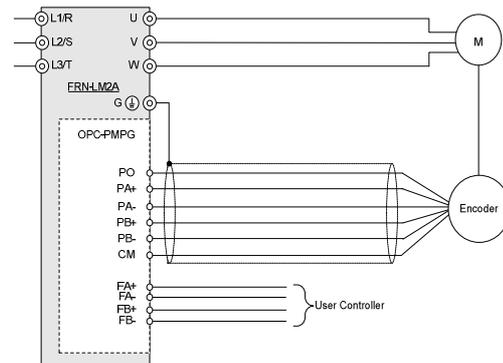


Figure 5. Encoder's connection

Note 1: OPC-G1-PG2 doesn't include Fxx terminals (encoder repetition for controller)

Note 2: OPC-G1-PG2 terminals for A phase and B phase are called YA and YB respectively (Same for inverter phases).

Note 3: In case of using OPC-PMPG inverter's ROM version must be 0600 or above.

5. Pole tuning procedure

Before RUN the motor a pole tuning has to be performed in order to detect the magnets position inside motor's rotor, to do so please follow below procedure.

Pole tuning procedure in 6 steps:

1. Check that the motor and the encoder are properly wired to the inverter.
2. Power ON the lift power supply.
3. Make sure that the setting described on chapters 2 and 3 is properly set.
4. Check that the inverter receives the encoder pulses as following: in the keypad go to Menu **3. INV Info / 2. I/O Check** and press the down arrow key until you reach the page [6/6] that shows P1, Z1, P2 and Z2. If the motor is not moving, the display shows **0 kP/s** after P2. Open (release) the brake and turn a little bit the motor. In this moment the display should show a number different than 0 (positive or negative depending on the rotation direction). If the display shows **----p/s** (or **+0 p/s** meanwhile the motor is turning) means that no signal is coming from the encoder. In this case please check the encoder cable, the connection of the signals or option card installation.
5. Give RUN command to the inverter from the lift controller (normally in INSPECTION mode). The main contactors will be closed and current will flow through the motor producing some acoustic noise. This procedure will take some seconds. After the procedure is finished, the lift should move normally in inspection speed in up or down direction (depending on RUN command given).
6. RUN the inverter in INSPECTION mode from top to bottom of the shaft and other way around. During constant speed check that output current has a constant and logic value. Logic value normally means an output current below rated current. Output current can be monitored on Menu **3. INV Information / 1. Op Monitor** at page [2/8] as lout.

If during step 5 or 6 the inverter is directly tripping OCx, OLU or Ere or OS just after giving RUN command set H190= 0 and repeat the procedure starting from step 1.

If pole tuning is not performed automatically in step 5, switch OFF inverter power supply, and make sure keypad is completely OFF before turning power supply ON.

6. Troubleshooting

Alarm message Displayed	Description	Possible causes
OLU	Inverter overloaded	<ul style="list-style-type: none"> a. If OLU alarm appears during constant speed at full torque (car empty going down) please repeat Pole tuning process starting from Step 1. b. If pole tuning is correct check the setting of L133 to 0.8 c. If OLU appears randomly independently of the load make sure encoder is correctly fixed, rubber wheel is touching motors sheave and rubber wheel diameter is correct.
OS	Overspeed	If OS appears during creep speed, increase it. Recommended value of creep speed is 1 Hz. If inverter is tripping with recommended creep speed, increase it to 2 Hz.

7. Rescue operation

Some elevators have a rescue operation system which consist in opening manually the brake and move car by gravity. If this rescue operation is performed make sure to switch completely power OFF and switch it ON again before doing any standard travel. Otherwise inverter may loss motor's control.

If automatic pole tuning is set as recommended on this application note (L198(Bit 5)= 1: Automatic pole tuning every RUN command) power supply doesn't need to be removed before doing any travel after rescue operation.

If the setting of L198(Bit 5) is 0, but ROM version is 0800 or above, inverter will perform automatic pole tuning as well, in other words, no need to remove power supply of the inverter.

8. Conclusions

This application note explains how to control a PMSM with the encoder installed in the periphery of the rotor.

9. Document history

Version	Changes applied	Date	Written	Checked	Approved
1.0.0	First version (Draft)	29/07/2015	J. Alonso		
1.1.0	Recommended setting and explanation of P62, P63 and L133 is modified on chapter 2 and 3. Note 1 is added in table 2.	16/12/2015	J. Alonso	S. Ureña	J. Català
1.2.0	Explanation of L198, P62 and P63 modified/updated. P65 is included. Information about different software versions is included. Table 1, 2, 4 and 6 updated. Figure 2, 4 and 5 updated. Chapter 6 updated. Information about OPC-PG3 and OPC-PMPG is included.	20/05/2016	J. Alonso	S. Ureña	J. Català