

PERFECTION IN AUTOMATION www.br-automation.com

# 리니어 모터 시운전 방법

### -Linear Motor Commissioning-

Date:

2016.11.24

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### I Versions

| Version | Date         | Comment       | Edited by  |
|---------|--------------|---------------|------------|
| 1.0     | Nov 24, 2016 | First Edition | Dongsu Kim |
|         |              |               |            |
|         |              |               |            |
|         |              |               |            |

Table 1: Versions

#### **II** Distribution

| Name | Company, Department | Amount | Remarks |
|------|---------------------|--------|---------|
|      |                     |        |         |
|      |                     |        |         |
|      |                     |        |         |
|      |                     |        |         |

Table 2: Distribution

### **III Safety Notices**

Safety notices in this document are organized as follows:

| Safety notice | Description  |
|---------------|--|
| Danger!       | Disregarding the safety regulations and guidelines can be life-threatening.                                      |
| Warning!      | Disregarding the safety regulations and guidelines can result in severe injury or heavy damage to mate-<br>rial. |
| Caution!      | Disregarding the safety regulations and guidelines can result in injury or damage to material.                   |
| Information:  | Important information used to prevent errors.  |

Table 3: Safety notices

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### 1 소개

리니어 모터 사용시 필요한 절차에 대해 나열한 문서입니다.

### 2 하드웨어 구성

#### 2.1 요약

| List           | Specification (Model name) | Reference   |
|----------------|----------------------------|-------------|
| Linear motor   | I-force 410                | PAKER       |
| Encoder        | Lida487                    | HEIDENHAIN  |
| CPU            | 5AP1120.121                | 5PPC2100    |
| Servo Drive    | 8V1090.00-2                | ACOPOS 1090 |
| Interface card | 8AC114.60-2 (2ea)          |             |
|                | 8AC120.60-1 (2ea)          |             |

#### 2.2 모터



## I-Force Ironless 410 Series

#### Performance

| Units  | 410-2                               | 410-3   | 410-4   | 410-6  | 410-8   |
|--------|-------------------------------------|---|---|--|---|
| N (lb) | 1041.4<br>(234.1)                   | 1523.6<br>(342.5)   | 2006.3<br>(451.0)   | 2967.2<br>(667.0)  | 3928.1<br>(883.0)   |
| N (lb) | 233.1<br>(52.4)                     | 340.8<br>(76.6)   | 448.9<br>(100.9)  | 663.7<br>(149.2)   | 878.6<br>(197.5)  |
| W      | 2835                                | 4050  | 5265  | 7695   | 10125   |
| W      | 142                                 | 203   | 263   | 385  | 506   |
|        | Units<br>N (lb)<br>N (lb)<br>W<br>W | Units        410-2          N (lb)        1041.4<br>(234.1)          N (lb)        233.1<br>(52.4)          W        2835          W        142 | Units        410-2        410-3          N (lb)        1041.4        1523.6          (234.1)        (342.5)          N (lb)        233.1        340.8          (52.4)        (76.6)          W        2835        4050          W        142        203 | Units        410-2        410-3        410-4          N (lb)        1041.4        1523.6        2006.3          (234.1)        (342.5)        (451.0)          N (lb)        233.1        340.8        448.9          (52.4)        (76.6)        (100.9)          W        2835        4050        5265          W        142        203        263 | Units        410-2        410-3        410-4        410-6          N (lb)        1041.4        1523.6        2006.3        2967.2          (234.1)        (342.5)        (451.0)        (667.0)          N (lb)        233.1        340.8        448.9        663.7          (52.4)        (76.6)        (100.9)        (149.2)          W        2835        4050        5265        7695          W        142        203        263        385 |

Peak force and current based on 5% duty cycle and one second duration.
 Continuous force and current based on coil winding temperature maintained at 100 °C.

#### Electrical

| Model                        | Units                            |               | 410-2         | 2             |               | 410-3         | 3             |               | 410-4         | 4             |               | 410-6         | 6             |               | 410-8         | 3             |
|------------------------------|----------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Winding                      | Series/Parallel/Triple           | S             | Р             | т             | S             | Ρ             | т             | S             | Ρ             | т             | s             | Ρ             | т             | S             | Р             | т             |
| Peak Current                 | A <sup>pk sine</sup><br>RMS      | 19.1<br>13.5  | 38.2<br>27.0  | 57.3<br>40.5  | 18.6<br>13.2  | 37.2<br>23.6  | 55.8<br>39.5  | 18.4<br>13.0  | 36.8<br>26.0  | 55.2<br>39.0  | 18.1<br>12.8  | 36.2<br>25.6  | 54.3<br>38.4  | 18.0<br>12.7  | 36.0<br>25.5  | 54.0<br>38.2  |
| Continuous Current           | A <sup>pk sine</sup><br>RMS      | 4.3<br>3.0    | 8.6<br>6.1    | 12.9<br>9.1   | 4.2<br>3.0    | 8.4<br>5.9    | 12.6<br>8.9   | 4.1<br>2.9    | 8.2<br>5.8    | 12.3<br>8.7   | 4.1<br>2.9    | 8.2<br>5.8    | 12.3<br>8.7   | 4.0<br>2.8    | 8.0<br>5.7    | 12.0<br>8.5   |
| Force Constant <sup>1)</sup> | N/A peak<br>Ib/A peak            | 54.5<br>12.3  | 27.3<br>6.1   | 18.2<br>4.1   | 81.8<br>18.4  | 40.9<br>9.2   | 27.3<br>6.1   | 109.0<br>24.5 | 54.5<br>12.3  | 36.3<br>8.2   | 163.7<br>36.8 | 81.8<br>18.4  | 54.6<br>12.3  | 218.4<br>49.1 | 109.2<br>24.6 | 72.8<br>16.4  |
| Back EMF <sup>2)</sup>       | V/m/s<br>V/in/s                  | 63.0<br>1.60  | 31.5<br>0.80  | 21.0<br>0.53  | 94.5<br>2.40  | 47.2<br>1.20  | 31.5<br>0.80  | 126.0<br>3.20 | 63.0<br>1.60  | 42.0<br>1.07  | 189.0<br>4.80 | 94.5<br>2.40  | 63.0<br>1.60  | 252.0<br>6.40 | 126.0<br>3.20 | 84.0<br>2.13  |
| Resistance @ 25°C (ph        | ase-to-phase) <sup>3)</sup> ohms | 8.0           | 2.0           | 0.9           | 12.0          | 3.0           | 1.3           | 16.0          | 4.0           | 1.8           | 24.0          | 6.0           | 2.7           | 32.0          | 8.0           | 3.6           |
| Inductance (phase-to         | o-phase) <sup>4)</sup> mH        | 10.0          | 2.5           | 1.1           | 15.0          | 3.8           | 1.7           | 20.0          | 5.0           | 2.2           | 30.0          | 7.5           | 3.3           | 40.0          | 10.0          | 4.4           |
| Electrical Time Cons         | stant <sup>6)</sup> ms           | 1.3           | 1.3           | 1.3           | 1.3           | 1.3           | 1.3           | 1.3           | 1.3           | 1.3           | 1.3           | 1.3           | 1.3           | 1.3           | 1.3           | 1.3           |
| Motor Constant <sup>6)</sup> | N/W<br>Ib/W                      | 19.57<br>4.40 | 19.57<br>4.40 | 19.57<br>4.40 | 23.98<br>5.39 | 23.98<br>5.39 | 23.98<br>5.39 | 27.67<br>6.22 | 27.67<br>6.22 | 27.67<br>6.22 | 33.90<br>7.62 | 33.90<br>7.62 | 33.90<br>7.62 | 39.14<br>8.80 | 39.14<br>8.80 | 39.14<br>8.80 |
| Terminal Voltage (ma         | ax.) 7) VDC                      | 330           | 330           | 330           | 330           | 330           | 330           | 330           | 330           | 330           | 330           | 330           | 330           | 330           | 330           | 330           |

 Terminal Voltage (max), \*/
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### 2.3 엔코더(Encoder)



Montageanleitung Mounting Instructions Instructions de montage Istruzioni di montaggio Instrucciones de montaje



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### 3 튜닝 방법(Tuning)과 결과

#### 3.1 Servo Drive, Encoder interface card 배선 체크

멀티미터기로 각 장치들의 정격 전압이 출력되는지 확인합니다.

#### 3.2 ACOPOS Parameter Table 입력

Linear motor 의 경우 Parameter table 에 Motor Parameter 값을 입력해주어야 합니다. Parameter table 에 값을 넣어주기 위해 Motor 의 데이터시트를 참고하여 자사의 엑셀 시트에 작성을 합니다. (Help 에 양식 있음. GUID: c472ed70-2413-4cf1-930b-efb9f9729000)



Motion > Reference manual > ACOPOS drive functions > Motor > Synchronous Linear Motor > Parameter conversion from linear motor to synchronous motor

#### 1) 엑셀시트 작성

### Parameter conversion from linear motor to synchronous motor



is provided to help with the parameter conversion:

| Name                          | Value  | Unit       |           | Name                           | Value     | Unit              |
|-------------------------------|--------|------------|-----------|--------------------------------|-----------|-------------------|
| MOTOR POLEPAR WIDTH           | 0,0281 | m          |           | s Reference length = sa*Za [m] | 0,281     | m                 |
|                               |        |            |           | MOTOR_POLEPAIRS                | 10        |                   |
| MOTOR LINEAR SPEED NOMINAL    | 5      | m/s        | 1         | MOTOR SPEED RATED              | 1068      | min <sup>-1</sup> |
| MOTOR LINEAR SPEED MAX        | 5      | m/s        |           | MOTOR SPEED MAX                | 1068      | min <sup>-1</sup> |
| MOTOR FORCE STALL             | 10,5   | N          | 2.00      | MOTOR TORQ STALL               | 0,47      | Nm                |
| MOTOR FORCE RATED             | 10,5   | N          | $\mapsto$ | MOTOR TORQ RATED               | 0,47      | Nm                |
| NOTOR FORCE MAX               | 21     | N          |           | MOTOR TORQ MAX                 | 0,94      | Nm                |
| MOTOR LINEAR VOLTAGE CONSTANT | 4,00   | Vana/(m/s) |           | MOTOR VOLTAGE_CONST            | 18,73     | m∨min             |
| MOTOR FORCE CONST             | 60     | NG         |           | MOTOR_TORQ_CONST               | 2,683     | Nm/Amu            |
| MOTOR MASS                    | 4,7    | kg         |           | MOTOR INERTIA                  | 0,0094005 | kigm <sup>2</sup> |
| ENCODER: Line length          | 1000   | µm/Line    |           | SCALE ENCOD_INCR               | 4603904   | inc/pe            |
| MOTOR_BRAKE_FORCE_RATED       | 860    | N          |           | MOTOR BRAKE TORO RATED         | 38,46     | Nm                |
| nput fields: Enter values     |        |            |           |                                |           |                   |
| Dutput fields                 |        |            |           |                                |           |                   |

#### 2) Encoder Setting

- 작성된 엑셀 시트의 Motor reference length 의 결과 값을 이용합니다.
- Units = Motor reference length(m)
- Rev = 1
- 단위 변경시에는 Motor reference length 의 단위를 um, mm 혹은 nm 로 변경후에 입력합니다.

#### 3) Parameter table 작성

- 엑셀시트의 Output field 에 있는 값들을 Automation studio 의 Parameter table 에 기입합니다. (Unit 확인 필요)
- 하기 의 파란색 표시된 MOTOR\_COMMUT\_OFFSET 값을 제외한 모든 Parameter 값들을 입력합니다.

<Linear motor calculation 엑셀시트>



#### LinearMotor\_Calculati

| OTTAIS  |         |           |        |   |
|---|---------|-----------|--------|---|
| 🔋 gAxis01a::gAxis01a.apt [ACOPOS Parameter Table Ed | itor] × |           |        |   |
| r 😤 📮   |         |           |        |   |
| ame   | ID      | Value     | Unit   | Description   |
| - Parameters  |         | · alao    | 0      | Description   |
|   | 390     | 220       | v      | CTRL DC bus: Nominal voltage  |
| SGEN SW END IGNORE                                  | 128     | 1         | -      | Limit values: Ignore SW end positions   |
| - ALC6000 - Gantry Linear Motor (X Axis)            |         |           |        |   |
| General parameters                                  |         |           |        |   |
| Brake parameters                                    |         |           |        |   |
| Thermo sensor parameters                            |         |           |        |   |
| 🖨 🦉 Motor parameters                                |         |           |        |   |
| MOTOR_VOLTAGE_RATED                                 | 48      | 220       | V      | Motor: Rated voltage  |
| MOTOR_VOLTAGE_CONST                                 | 49      | 56.70     | mV*min | Motor: Voltage constant   |
| -  MOTOR SPEED RATED                                | 50      | 352       | 1/min  | Motor: Rated speed  |
| - WOTOR_SPEED_MAX                                   | 51      | 703       | 1/min  | Motor: Maximum speed  |
| MOTOR_TORQ_STALL                                    | 52      | 9.90      | Nm     | Motor: Stall torque   |
| MOTOR_TORQ_RATED                                    | 53      | 9.01      | Nm     | Motor: Rated torque   |
| MOTOR_TORQ_MAX                                      | 54      | 40.30     | Nm     | Motor: Peak torque  |
| MOTOR_TORQ_CONST                                    | 55      | 1.111     | Nm/A   | Motor: Torque constant  |
| MOTOR_CURR_STALL                                    | 56      | 5.8       | A      | Motor: Stall current  |
| MOTOR_CURR_RATED                                    | 57      | 5.8       | A      | Motor: Rated current  |
| MOTOR_CURR_MAX                                      | 58      | 25.6      | A      | Motor: Peak current   |
| MOTOR_WIND_CROSS_SECT                               | 59      | 0         | mm     | Motor: Line cross section   |
| MOTOR_STATOR_RESISTANCE                             | 60      | 6.0       | Ohm    | Motor: Stator resistance  |
| MOTOR_STATOR_INDUCTANCE                             | 61      | 0.0075    | Henry  | Motor: Stator inductance  |
| -  MOTOR_INERTIA                                    | 62      | 0.0007969 | kgm    | Motor: Moment of inertia  |
| MOTOR_COMMUT_OFFSET                                 | 63      | 1.89407   | rad    | Motor: Commutation offset 4.3317637   |
| MOTOR_TAU_THERM                                     | 849     | 0.251     | s      | Motor: Thermal time constant  |
| 🖨 🔚 Isolation parameters                            |         |           |        |   |
| MOTOR_WIND_TEMP_MAX                                 | 74      | 130       | ?      | Temperature sensor: Limit temperature   |
| 🖮 🎽 SS2   |         |           |        | 8AC120.00   |
| ENCOD_TYPE  | 97      | ncINC     |        | Encoder1: Type  |
| SCALE_ENCOD_INCR                                    | 109     | 69910528  |        | Encoder1: Encoder scaling: increments per SCALE_ENCOD_MOTOR_REV motor revolutions |
| ENCOD_LINE_CHK_IGNORE                               | 727     | 0         |        | Encoder1: Ignore check  |
| MOTOR_CURR_ROT_DIR                                  | 872     | 255       |        | Motor: Rotational direction of current  |
| PHASING_MODE  | 276     | 2         |        | Motor: Phasing: Mode  |

- MOTOR\_COMMUT\_OFFSET 값은 NC Test Window 를 이용하여 Motor Phasing 을 실시해서 값을 찾을 수 있습니다.
- Mode 를 Stepper 를 선택하여 Phasing 을 실시하여 Commute Offset 값을 기입합니다. (Motor 가 약 70cm 정도 움직이므로 주의 필요)
- Phasing 시에 Temperature, Lag error 에 의하여 실패할경우 MOTOR\_CURR\_ROT\_DIR(872)의 로터 디렉션 (0, 255)을 변경하여 Phasing 을 재 실시 합니다.

| gAxis01.mdc* 🗙 📓 gAxis01a::gAxis01a.apt [ACOPOS Parameter Table | e Editor] 👫 5PPC2100_BY44_000a:   | :Cpu.per [Permanent Varial | oles] | Acp10map.ncm [Mapping Editor] | • |  |  |  |  |
|---|---|----------------------------|-------|-------------------------------|---|--|--|--|--|
| 🕸 🗃 🏶 🏔 🛸 🛛 🗃 🎯 🖉 🖉 🏕 🔼 🐴 🕕                                     |   |                            |       |                               |   |  |  |  |  |
| Use ncaction  | Structure   |                            |       |                               |   |  |  |  |  |
| Trace enabled   | Name  | Description                | *     |                               |   |  |  |  |  |
|   | encoder_if  |                            |       | Encoder Interface             |   |  |  |  |  |
| Basis Movement  | 🛊 🖉 limit   |                            |       | Limit value                   |   |  |  |  |  |
| E-•: Limits   | controller  |                            |       | Controller                    |   |  |  |  |  |
|   | move  |                            |       | Movement                      |   |  |  |  |  |
| Det Motor Simulation  | i p. ✓ 🊰 setup  |                            |       | Setup                         |   |  |  |  |  |
| E-¶: Setup  | 🛁 🖗 status  | ncOFF                      |       | Status                        |   |  |  |  |  |
| 🕂 📲 Induction Motor   | 🛶 🖗 detail  | ncOFF                      |       | Detail                        |   |  |  |  |  |
| Determine parameters  | 📄 👘 🚰 datobj  |                            |       | Data object                   |   |  |  |  |  |
| L → Save parameters   | 🖶 🚰 motor_induction   |                            |       | Induction motor               |   |  |  |  |  |
| Synchronous Motor   | 🖶 🚰 motor_synchron  |                            |       | Synchronous motor             |   |  |  |  |  |
| Determine parameters  |   |                            |       | Motor phasing                 |   |  |  |  |  |
| L → Save parameters   | 🕀 🚰 status  |                            |       | Status                        |   |  |  |  |  |
| 🗇 📬 Motor phasing   | i interest in the interest in |                            |       | Parameters                    |   |  |  |  |  |
| Determine parameters  | 🐓 mode  | ncMOTPH_STEPPER            |       | Mode                          |   |  |  |  |  |
| Save parameters   | 🔰 🚽 🙀 i   | 0                          | A     | Current                       | Ξ |  |  |  |  |
| E- Controller Autotuning  | 🖉 👘 🛊 t   | 0                          | s     | Time                          |   |  |  |  |  |
| F Start tuning  | 🕂 🚰 controller  |                            |       | Controller                    |   |  |  |  |  |
| Save parameters   | 🖶 🚰 isq_ripple  |                            |       | ISQ-Ripple                    |   |  |  |  |  |
|   | 🗊 🥂 monitor   |                            |       | Monitor                       |   |  |  |  |  |
| Determine parameters  | message   |                            |       | Messages (errors, warnings)   |   |  |  |  |  |
| Stop  | nc_test   |                            |       | NC Test                       |   |  |  |  |  |
|   |   |                            |       |                               | - |  |  |  |  |

- ParID 48~63 값이 기입이 다 되었으면 Identification 을 실시하여 Parameter Quality 를 확인합니다.
- 입력한 Parameter 값이 올바르지 않을 경우에 Quality 값이 낮게 나올 수 있기 때문에 Parameter 값을 재확인 후 다시 Identification 을 실시합니다. (Quality 는 엔지니어 판단 하에 진행)

| gAxis01.mdc* × 📓 gAxis01a::gAxis01a.apt [ACOPOS Parameter] | Table Ed  | ditor] | 😤 Acp  | o10map    | .ncm [Mappin | ig Editor]       |       |                                     | -     |
|--|-----------|--------|--|-----------|--------------|------------------|-------|-------------------------------------|-------|
| 🗞 🗃 🍪 🔛 👘 🍞 ङ 🖉 🏄 🔼 🍕 🕕                                    |           |        |  |           |              |                  |       |                                     |       |
| Use ncaction   | Structure |        |  |           |              |                  |       |                                     | 🗕 🔶 🛧 |
| Trace enabled  | N         | ame    |  |           |              | Value            | Unit  | Description                         | •     |
|  |           |        |  | ····      | error        | ncFALSE          |       | Error                               |       |
| Thomas Hovement  |           |        |  |           | quality      | 0                | %     | Quality of parameter identification |       |
|  |           |        | ė-   | 🚰 pa      | rameter      |                  |       | Parameters                          |       |
| B. Service Interface                                       |           |        |  | × 📦       | mode         | ncIDENTIFICATION |       | Mode                                |       |
| Motor Simulation   |           |        |  | 📦         | z_p          | 0                |       | Number of polepairs                 |       |
| ⊡•(° Setup   |           |        |  | 📦         | u_n          | 0                | V     | Rated voltage                       |       |
|  |           |        |  | 🃦         | i_n          | 0                | Α     | Rated current                       |       |
| Determine parameters                                       |           |        |  | 📦         | v_n          | 0                | 1/min | Rated speed                         |       |
| Save parameters  |           |        |  | 🤪         | trq_n        | 0                | Nm    | Rated torque                        |       |
| 🔤 📲 Synchronous Motor                                      |           |        |  |           | trq_max      | 0                | Nm    | Peak torque                         |       |
| Determine parameters                                       |           |        |  | 📦         | i_max        | 0                | А     | Peak current                        |       |
| └  Save parameters   |           |        |  | 📦         | t_tripping_t | 0                | s     | Tripping time at thermal overload   |       |
| 中 📬 Motor phasing  | =         |        |  | ÷ 1       | optional     |                  |       | Optional parameters                 |       |
| Determine parameters                                       |           |        | <b>⊢</b> ∕ <u></u>   | motor     | phasing      |                  |       | Motor phasing                       |       |
| └ ◆ Save parameters  |           |        | The second secon | 🚰 sta     | atus         |                  |       | Status                              |       |
| English Controller Autotuning                              |           |        | Ē.   | 🖉 ра      | rameter      |                  |       | Parameters                          | =     |
| - Start tuning   |           |        | _  |           | mode         | ncMOTPH STEPPER  |       | Mode                                | -     |
| Save parameters  |           |        |  | 🍙         | 1            | 0                | А     | Current                             |       |
| E Ta ISQ-Ripple  |           |        |  | · · · · · | t            | 0                | S     | Time                                |       |
| Determine parameters                                       |           |        | j. 🥂   | control   | ler          | -                | -     | Controller                          |       |
| Save parameters  |           |        | TL   | Sta       | atus         |                  |       | Status                              |       |
| - 🗸 Бюр  | -         |        | I L  |           | rameter      |                  |       | Parameters                          | -     |

#### 4) 모터 튜닝

- Speed, Position 에 대한 Auto tuning 을 실시합니다.
- Motor movement 를 통해 튜닝에 대한 평가를 진행합니다.

- 평가 항목 : Lag error, 모터 전류, 온도, Set&Actual Position 에 대한 데이타를 Trace 로 . 평가합니다.
- 추가적으로 Fine tuning 을 하기 위해 Servo Loop Optimizer 를 실행하여 Gain 값 조정 또는 Filter(BIQUAD, NOTCH 등) 를 사용해 볼 수 있습니다.

\* 참고사항: 항상 동일 지점에서 Lag error 가 크게 발생할 시, Parameter 오입력을 가능성이 큼

<sup>5)</sup> 결과

| Target speed<br>Target acc , de | Target<br>: 20 mm/s<br>c : 100 mm/s <sup>2</sup> |                                      |
|---------------------------------|--|--------------------------------------|
| Distance                        | : 1 m<br>- Result                                |                                      |
| velocity ripple                 | · 56 µm/c  | (Velocity Max Min Zt)                |
| velocity ripple                 | . 5.0 um/s                                       |                                      |
| tracking error                  | :250 nm  | (Master 대비 Slave Actual position 차이) |
|                                 |  |                                      |



X LinearMotorTestResul t.csv

LinearMotorTestResult.mch