HIWIN®
Motion Control and System Technology

D1 Servo Drive

Technical Information

HIWIN®
Motion Control and System Technology

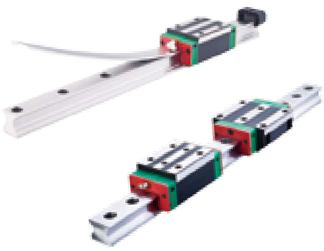
INDUSTRIE 4.0 Best Partner

Multi Axis Robot
Pick-and-place / Assembly / Grinding and Polishing / Semiconductor / Light Industry / Automotive industry / Food industry
- Articulated Robot
- Delta Robot
- Movable Delta Robot
- SCARA Robot
- Wafer Robot
- Electric Gripper

Single Axis Robot
Precision / Semiconductor / Medical / FPD
- KK, SK
- KS, KA
- KU, KE, KC

Medical Equipment
Hospital / Rehabilitation centers / Nursing homes
- Robotic Gait Training System
- Hygiene System
- Robotic Endoscope Holder

Ballscrew
Precision Ground / Rolled
- Super S series
- Super T series
- Mini Roller
- Ecological & Economical lubrication Module E2
- Rotating Nut (R1)
- Energy-Saving & Thermal-Controlling (C1)
- Heavy Load Series (RD)



Linear Guideway
Automation / Semiconductor / Medical
- Ball Type--HG, EG, WE, MG, CG
- Quiet Roller Type--QH, QE, QW, QR
- Other--RG, E2, PG, SE, RC

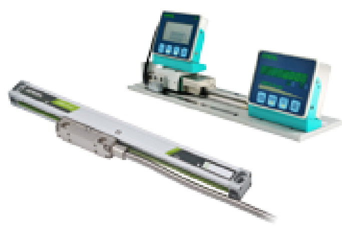
Direct Drive Rotary Table
Aerospace / Medical / Auto industry
- RAB Series
- RAS Series
- RCV Series
- RCH Series

Bearing
Machine tools / Robot
- Crossed Roller Bearings
- Ball Screw Bearings
- Linear Bearing
- Support Unit

AC Servo Motor & Drive
Semiconductor / Packaging machine / SMT / Food industry / LCD
- Drives-D1, D1-N, D2
- Motors-50W~2000W

Torque Motor (Direct Drive Motor)
Inspection / Testing equipment / Machine tools/ Robot
- Rotary Tables-TMS,TMY,TMN
- TMRW Series

Linear Motor
Automated transport / AOI application / Precision / Semiconductor
- With Iron-core
- Coreless Type
- Linear Turbo LMT
- Planar Servo Motor
- Air Bearing Platform
- X-Y Stage
- Gantry Systems



Positioning Measurement System
Cutting machines / Traditional gantry milling machines / Programmable drilling machines
- High Resolution
- Signal Translator
- High-precision Enclosed
- High Efficiency Counter

Contents

1. Features

■ Excellent Performance

The D1 drive attains high positioning performance to compliment the motion control technology of the semiconductor industry. The D1 drive achieves very good following characteristics and effectively shortens the positioning time.

■ Simple Operation

Human-machine interface provides very simple settings. All standard types of motors and encoders are built inside. Setup can be completed with just one-click.

■ Complete Tool Sets

There are test interfaces for speed and acceleration protection settings, gain settings, and an I/O test. Plus the D1 drive has a complete filter, frequency analysis, Bode plot, Lissajous figures and other functions which provide a complete drive control program.

■ Easy Integration

HIWIN provides positioning modules, motors, and the best servo drive solution from mega-fabs. According to customer's requirements we can integrate all that are required for user's easiness of application.

■ Services

Through HIWIN's complete global presence, we can provide immediate technical services at any time.

■ EtherCAT

The D1 series delivers the high performance amplifier with EtherCAT interface

EtherCAT®

2. Application international Safety Standard

		Drive	Motor
EC Directives	EMC Directives	EN55011 EN61000-6-2 EN61000-6-4 EN61800-3	EN55011 EN61000-6-2 EN61000-6-4
	Low-Voltage Directives	EN61800-5-1	EN60034-1 EN60034-5
UL		UL508C CSA C22.2 NO.14-13	UL1004-1 UL1004-6

3. Order Code

Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Example	D	1	-	3	6	-	S	2	-	2	-	0	-	0	0

Product
D1 .... =D1

Peak Current
9A .... =09
18A .... =18
36A .... =36

Interface
Standard/without communication interface............ =S
EtherCAT(CoE).. =E
EtherCAT(mega-ulink) .... =F

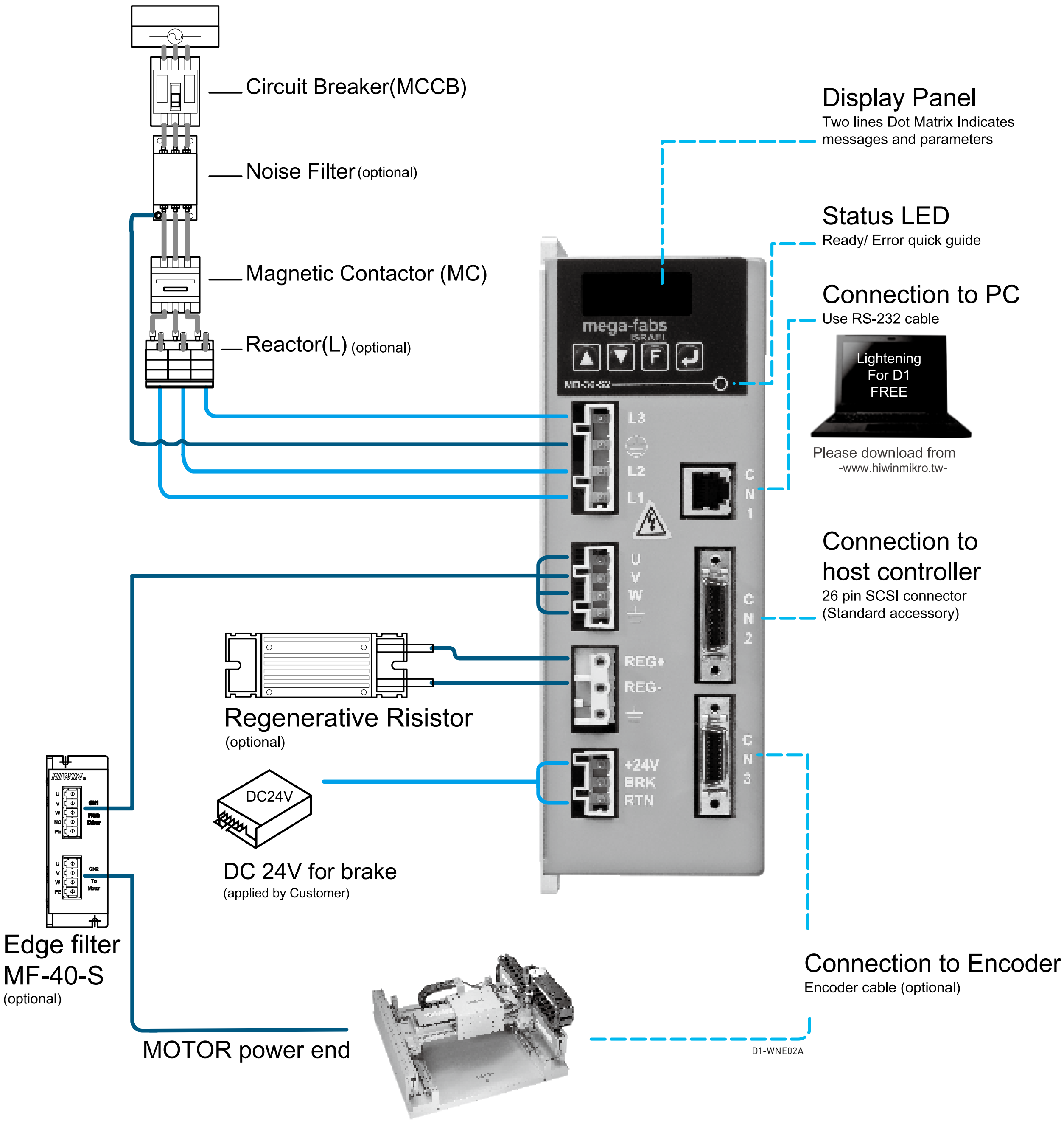
Encorder Type
Standard(Analog) .... =2
Standard(Digital) .... =3
Resolver.. =4

Voltage range
1Φ/3Φ 220V .... =2

Heat sink type
Without external heat sink.. =0
High profile(H1) .... =1
Low profile(H2) .... =2

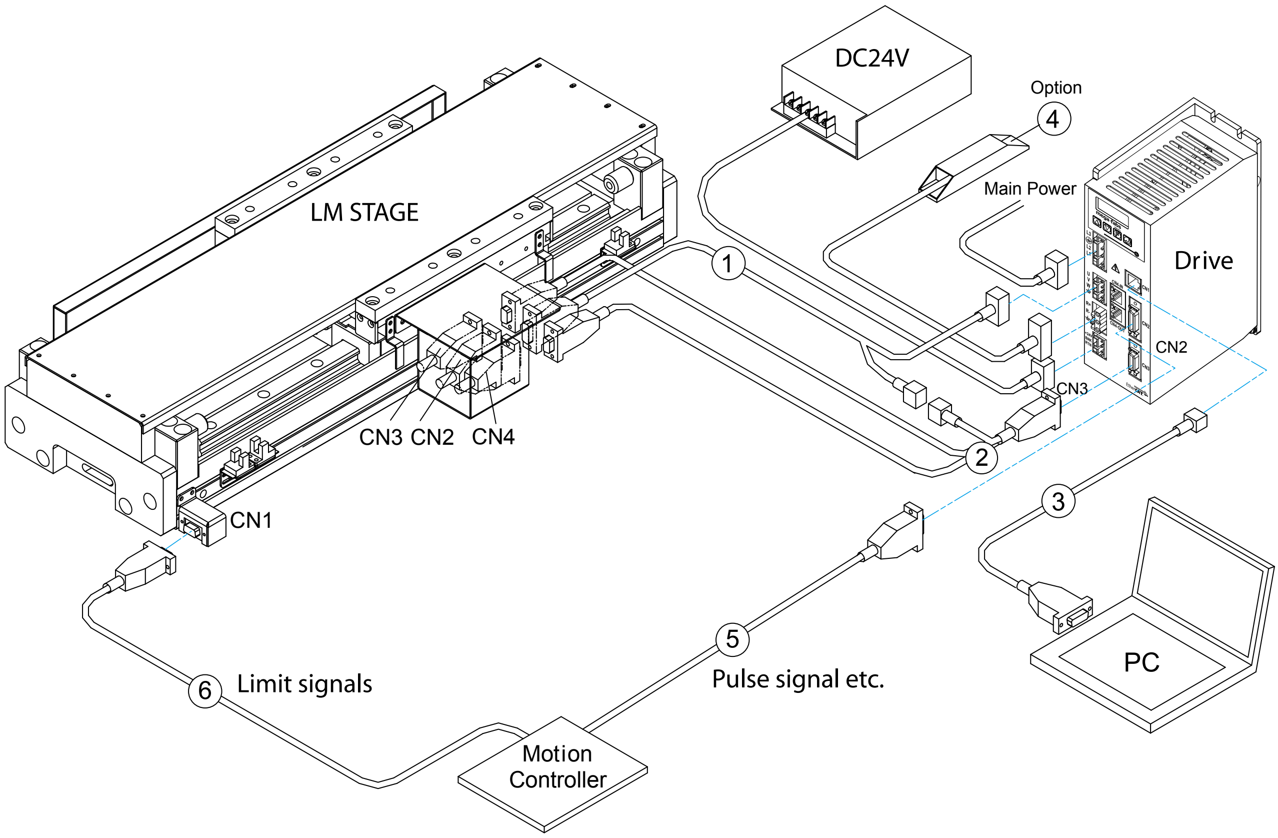
Reserved
Standard .... =00

4. Overall Wiring



mega-fabs D1 Servo Drive

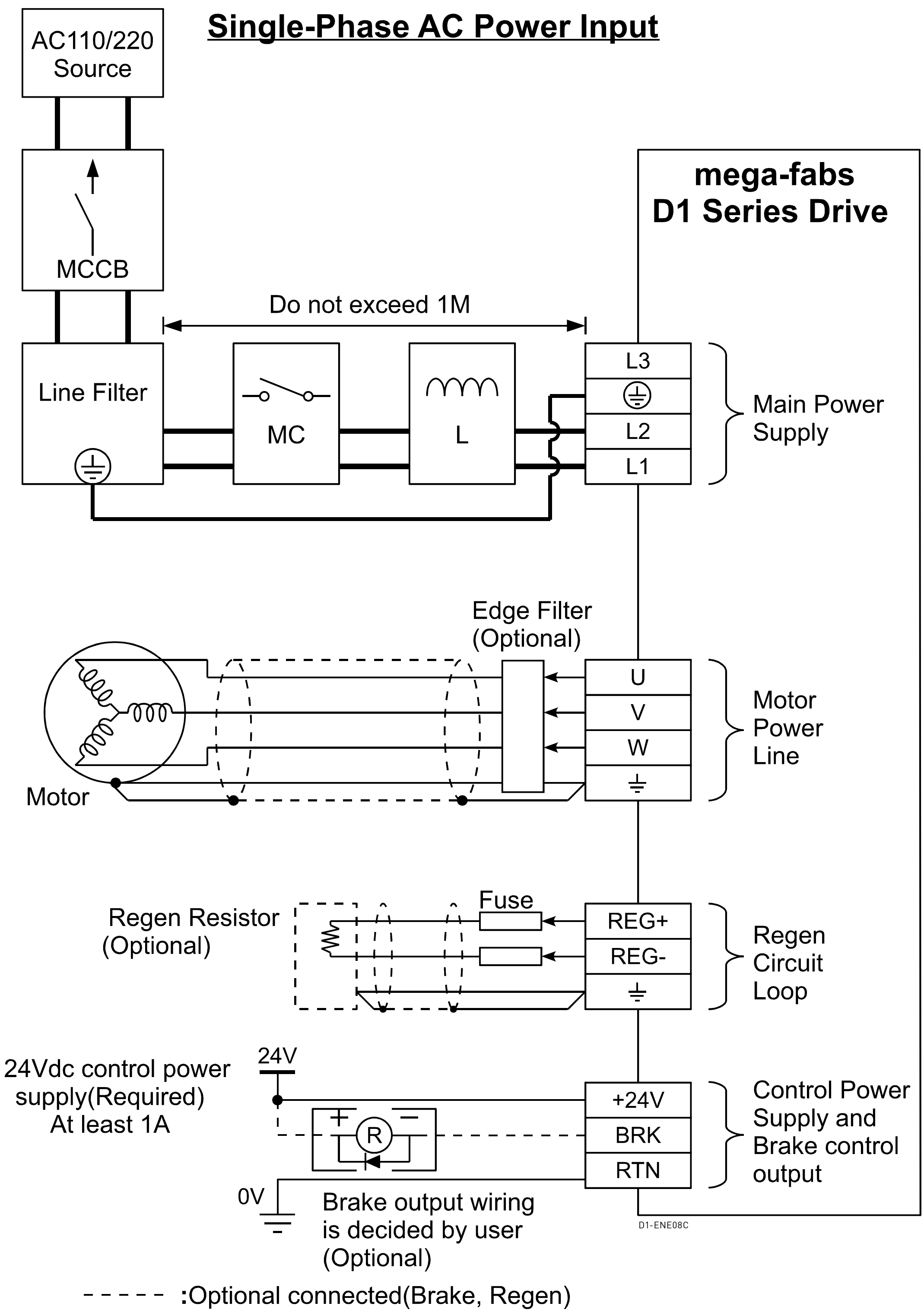
- Digital amplifier
- Field oriented control
- Intuitive Lightening interface
- 100-240VAC input power
- Supports Step/Direction, CW/CCW and A/B phase pulse format
- Supports analog and digital encoder



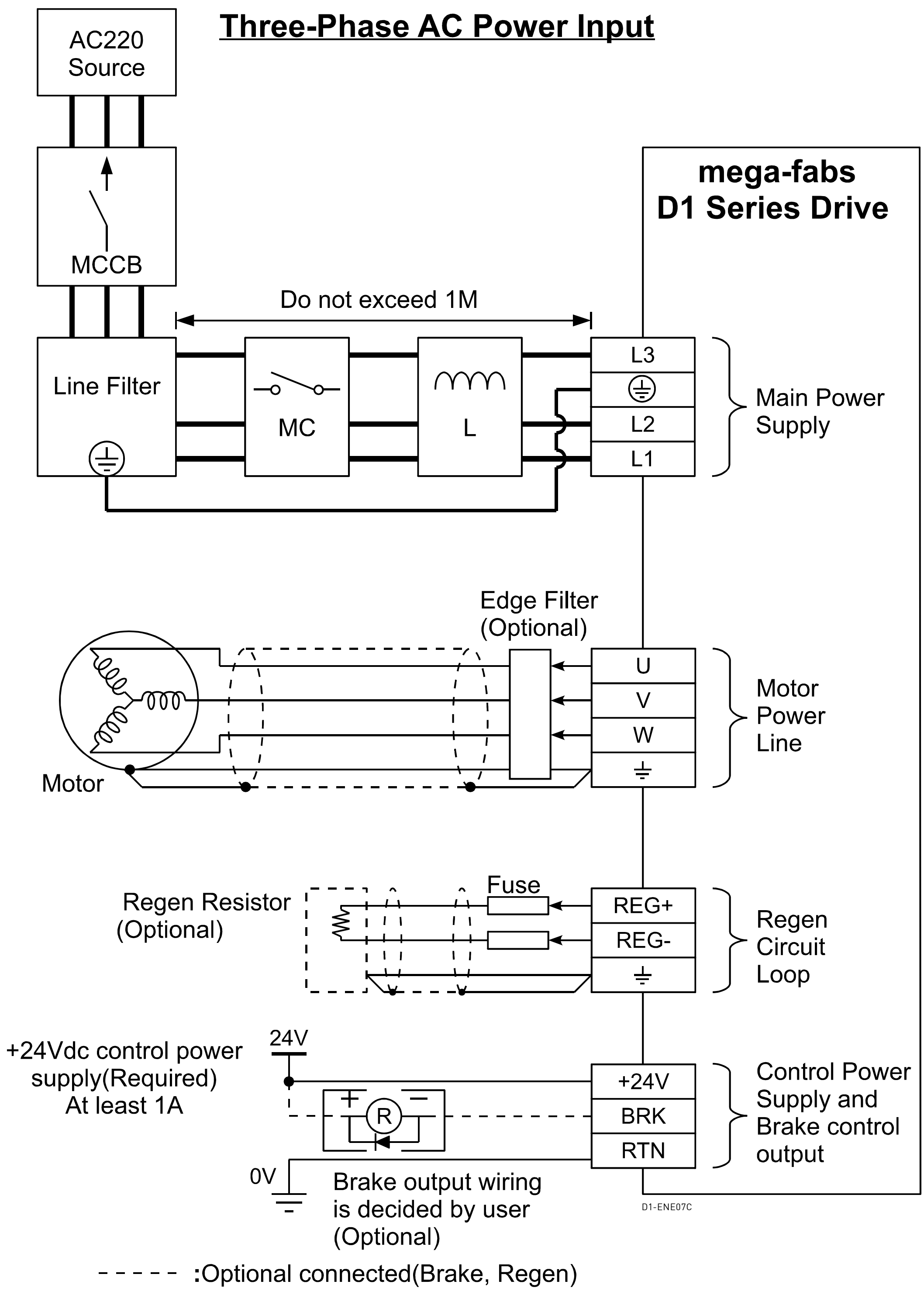
① Motor Cable
② Encoder Cable
③ RS-232 Cable
④ Regenerative Resistor
⑤ Controller Pulse Cable

4.1 Wiring Diagram

■ Single-phase power (Brake without relay, using HIWIN motor)



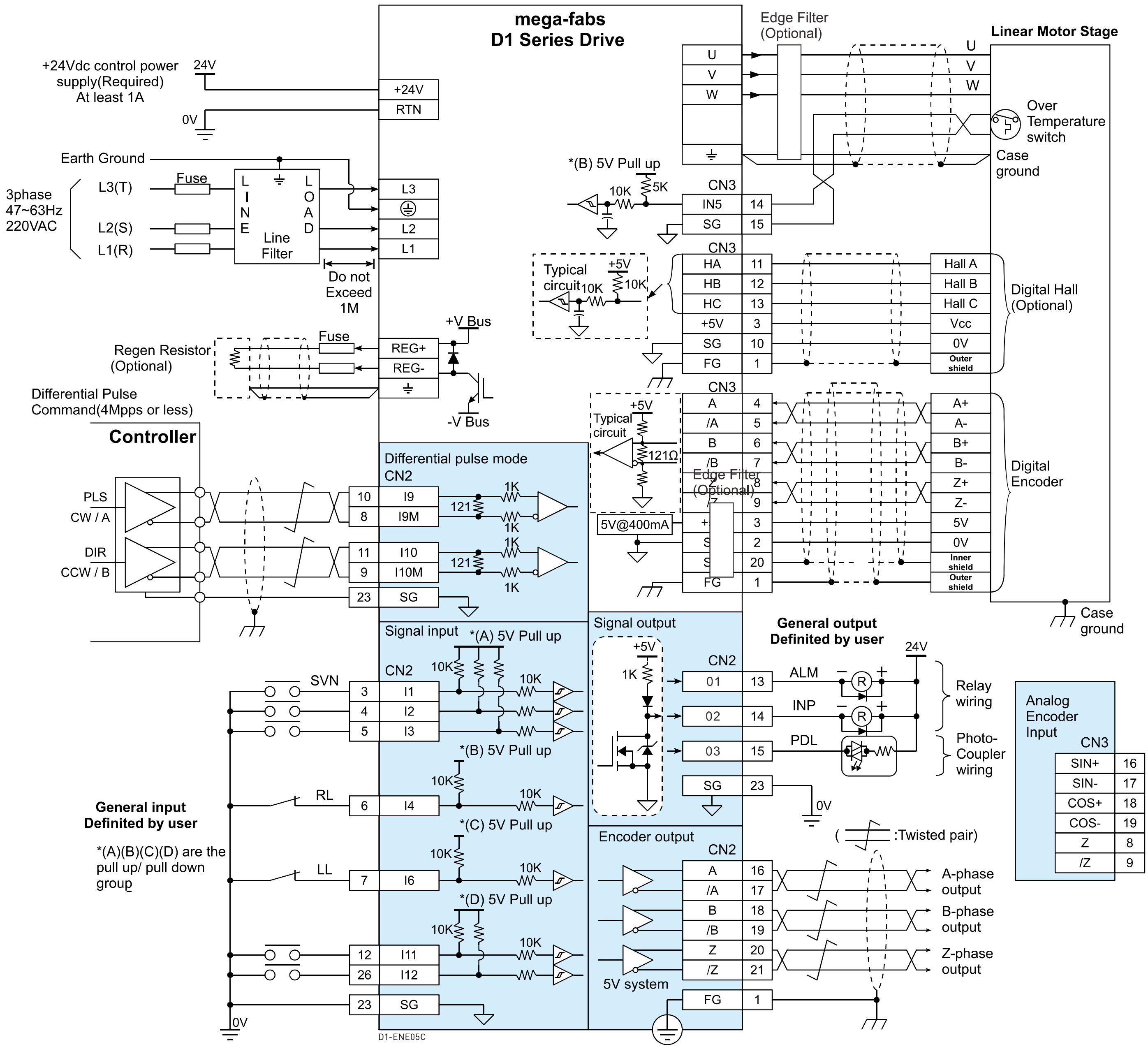
■ Three-phase power (Brake without relay, using HIWIN motor)



4.2 Control Circuit

Wiring Example of Position Control Mode

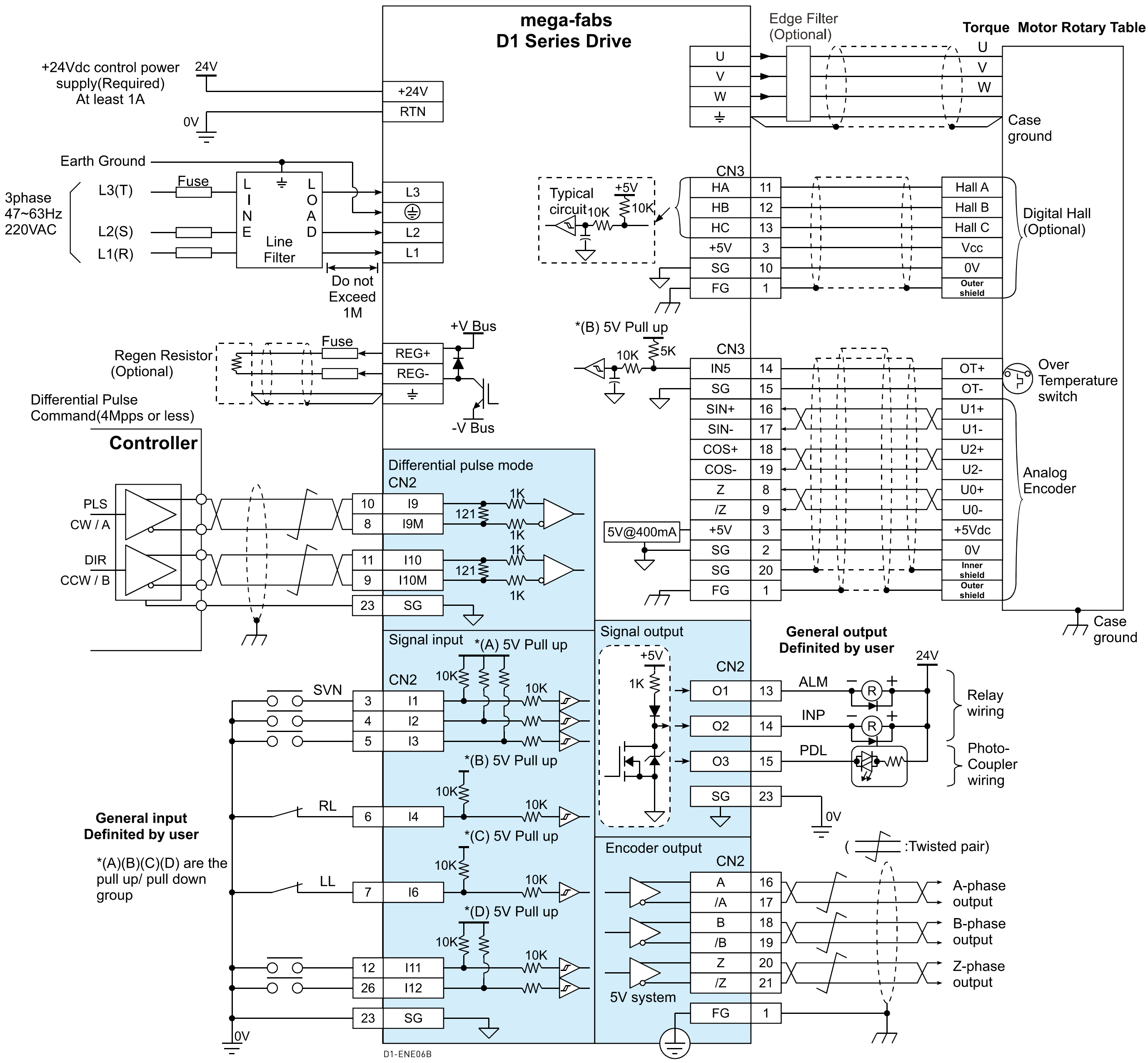
- Linear Motor Stage



Descriptpion:

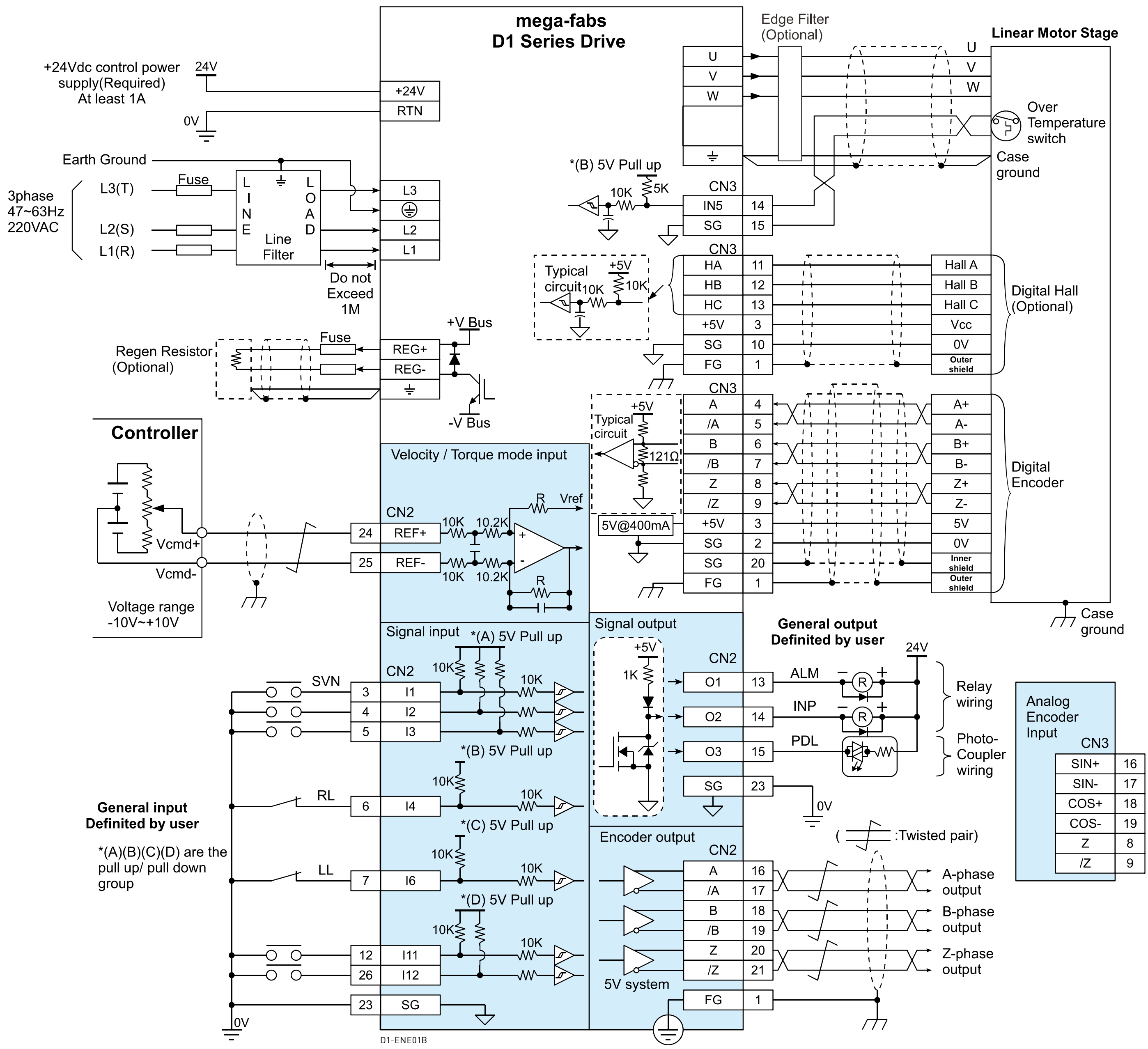
Wiring example of Position Mode with liner motor. Pulse command input is differential signal.

- Direct Drive Motor



Descriptpion:
Wiring example of Position Mode with liner motor. Pulse command input is differential signal.

- Velocity/Torque



Descriptpion:

Wiring example of Velocity/Torque Mode with liner motor.

5. Drives

5.1 Basic Specifications

<table>
<tr><td colspan="4">Type: D1 series</td><td>D1-09-XX ; D1-18-XX ; D1-36-XX</td></tr>
<tr><td rowspan="5">Power Input</td><td colspan="3">Voltage</td><td>100 - 240 VAC ±10%</td></tr>
<tr><td colspan="3">Frequency</td><td>50/60 Hz</td></tr>
<tr><td colspan="3">Phase</td><td>1 Ø or 3 Ø</td></tr>
<tr><td colspan="3">Control voltage</td><td>+24 Vdc ±10%</td></tr>
<tr><td colspan="3">Control current</td><td>1A minimum</td></tr>
<tr><td rowspan="4">Power Output</td><td colspan="3" rowspan="2">Continuous current</td><td>D1-09:3Apk[2.12Arms]
D1-18:6Apk[4.24Arms]
D1-36:12Apk[8.5Arms]</td></tr>
<tr><td>(Note: External heat sink installed by depending on application)</td></tr>
<tr><td colspan="3">Peak current</td><td>D1-09:9Apk[6.36Arms]
D1-18:18Apk[12.7Arms]
D1-36:36Apk[25.4Arms]</td></tr>
<tr><td colspan="3">Continuous time of peak current</td><td>1 second</td></tr>
<tr><td colspan="4">Main loop control</td><td>IGBT PWM space vector control</td></tr>
<tr><td colspan="4">Type of motor</td><td>AC servo motor, linear motor and torque motor</td></tr>
<tr><td colspan="2" rowspan="2">Status LED</td><td colspan="2">Non EtherCAT drive</td><td>Red: Error; Green: Servo Ready</td></tr>
<tr><td colspan="2">EtherCAT drive</td><td>Red: Error; Green: RUN</td></tr>
<tr><td rowspan="13">*Control</td><td rowspan="6">Position mode</td><td colspan="2">input port</td><td>[I9,I9M][I10,I10M] Differential or
I9, I10 single end input</td></tr>
<tr><td colspan="2">Pulse command mode</td><td>Pulse/Direction; CW/CCW ; AqB</td></tr>
<tr><td rowspan="2">Maximum input frequency</td><td>differential</td><td>Pulse (2M Pulses/s max.);
Quad A/B(8M counts/s max.)</td></tr>
<tr><td>Single end</td><td>Pulse:(500K Pulses/s max.);
Quad A/B(2M counts/s max.)</td></tr>
<tr><td colspan="2">Command generator</td><td>Pulse from host controller</td></tr>
<tr><td colspan="2">Electrical gear ratio</td><td>Gear ratio: pulses / counts
pulses:1~2147483647, counts:1~2147483647</td></tr>
<tr><td rowspan="7">Velocity mode</td><td rowspan="2">Analog</td><td>Input resistance</td><td>10KΩ</td></tr>
<tr><td>Voltage</td><td>±10 Vdc</td></tr>
<tr><td rowspan="4">Digital</td><td>Dual wire type</td><td>I9 :PWM = 0% - 100%
I10 : Direction= 1/0</td></tr>
<tr><td>Single wire type</td><td>I9 :PWM = 50% ± 50%
I10: Nonfunctional</td></tr>
<tr><td>Operation range</td><td>36.5KHz minimum, 100KHz maximum</td></tr>
<tr><td>Pulse width limit</td><td>220 ns minimum</td></tr>
<tr><td colspan="2">Command generator</td><td>Voltage or PWM from host controller</td></tr>
</table>

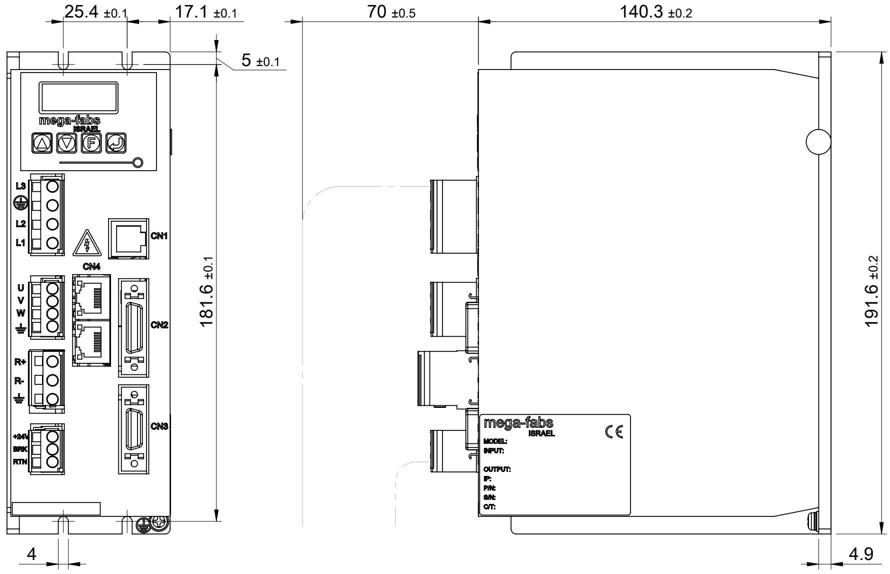
Torque mode	Analog Input Command		Same as velocity mode
	Digital command format		Same as velocity mode
	Command generator		Voltage or PWM from host controller
Encoder Type	Operation voltage		+5Vdc±5% @400mA
	Digital	Input signal	A, /A, B, /B, Z, /Z, RS422 differential signal
		Bandwidth	5MHz line frequency, for AqB 20M Count/s
	Analog	Input amplitude	1Vp-p (Sin/Cos), different signal
		Bandwidth	1MHz maximum line (cycle) frequency
		Resolution	Maximum 65528 Counts/cycle
Resolver	Resolution		12 bits(equivalent to a 1024 line quadrature encoder)
	Reference frequency		5KHz
	Reference voltage		6Vp-p
	Reference maximum current		100mA
*Output of Feedback pulse			Maximum 18M Count/s, RS422 differential signal output, Scaling adjustment
Hall signal			Single end signals with 120° phase difference: HA, HB, HC
Communication		Interface	RS232 to PC
		Protocol	Full duplex, Baud rate: 115,200bps, Binary format
Programmable I/O interface	10 digital inputs		Inputs [I1~I6, I11, I12][I9,I10] -74HC14 Schmitt trigger input Note:[I9, I10] not for general purpose I/O under pulse mode
	3 digital outputs		0.3Adc max, +40Vdc max (Open Drain) [O1], [O2], [O3]
	Brake output		BRAKE [O4], 1Adc max
PDL	Maximum code size		32K Bytes
	Variable storage capacity		800 Bytes
	Support variable type		Floating: 32 bits Integer:16 and 32 bits; array and point
	Execution cycle		66.67us
	Multitasking features		Execute 4Task at the same time
	instructions		if, else, while loop, for loop, goto and till
	Operators		Contains the basic arithmetic operators, logical operators, comparison operators
	Character length limitations		variable : 17, label : 24, proc : 24

Regen Circuit	Resistor	External	
	Turn on voltage	+HV > 390 Vdc	
	Turn off voltage	+HV < 380 Vdc	
	DC Bus capacitance	940uF/9A.18A	1880uF/36A
Protection		Short, Over voltage(> 400Vdc), Position error too big, Encoder error, Motor cable lost connection, Drive over-temperature(IGBT > 80°C ± 3°C), Motor over-temperature, Under voltage(< 60Vdc)	
Error Mapping	Applies to	Linear motor	
	Method	Established compensation table to compensate encoder error by linear interpolation	
	Samples	Maximum 5,000 points	
	Storage	Flash ROM, Disc file	
	Unit	um, count	
	Activation	Activated internally by home complete, or activated externally by input signal	
functional frequency range of VSF		0.1Hz~200Hz	
Environment	Operation Temperature	0~50°C (if over 55°C , air circulation is needed)	
	Storage Temperature	-20°C ~65°C	
	Humidity	0 to 90%RH	
	Elevation	Under 1000 Meters	
	Vibration	1G (10 to 500Hz)	
	IP Code	IP20	
Cooling System		Natural circulation and to install two types of heat sink	
Weight		1,250 g(min)	
Dimension		191.6mm X 139.8 mm X 64.8 mm	
Chassis		Compliance with U.L. Spec 94 V-0 Flammability Rating	

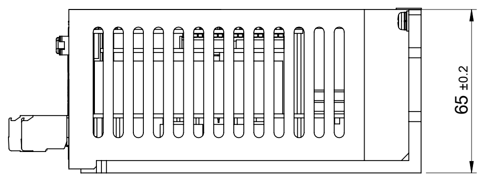
Note * - Only for non EtherCAT drive

5.2 Dimensions of drive

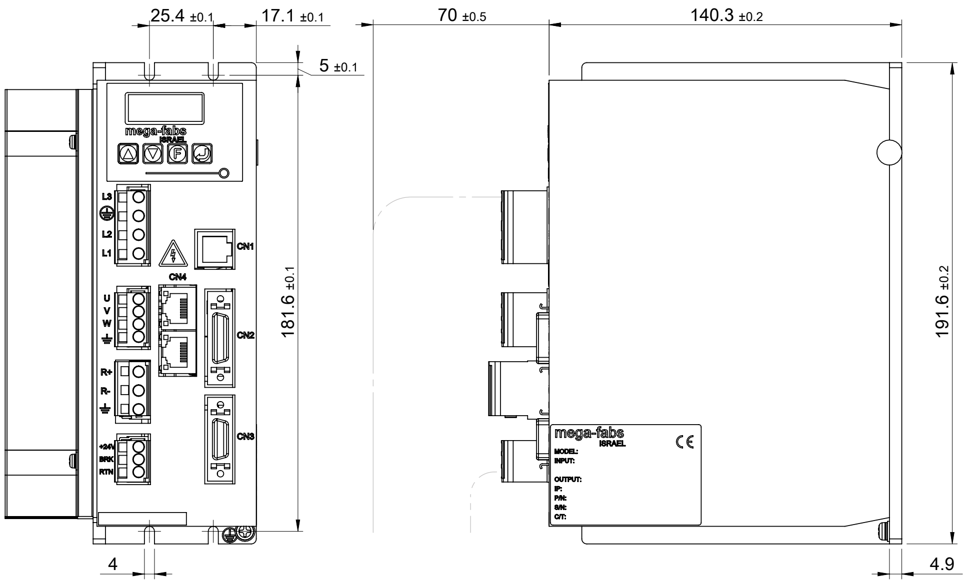
(D1-xx-xx-x-0-xx)



D1-DNE06A



(D1-xx-xx-x-1-xx)



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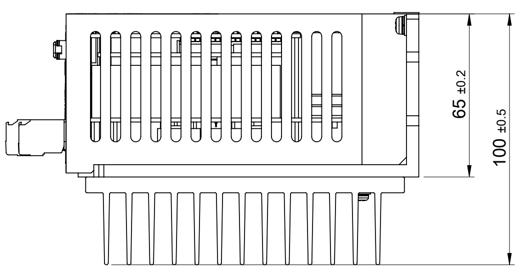
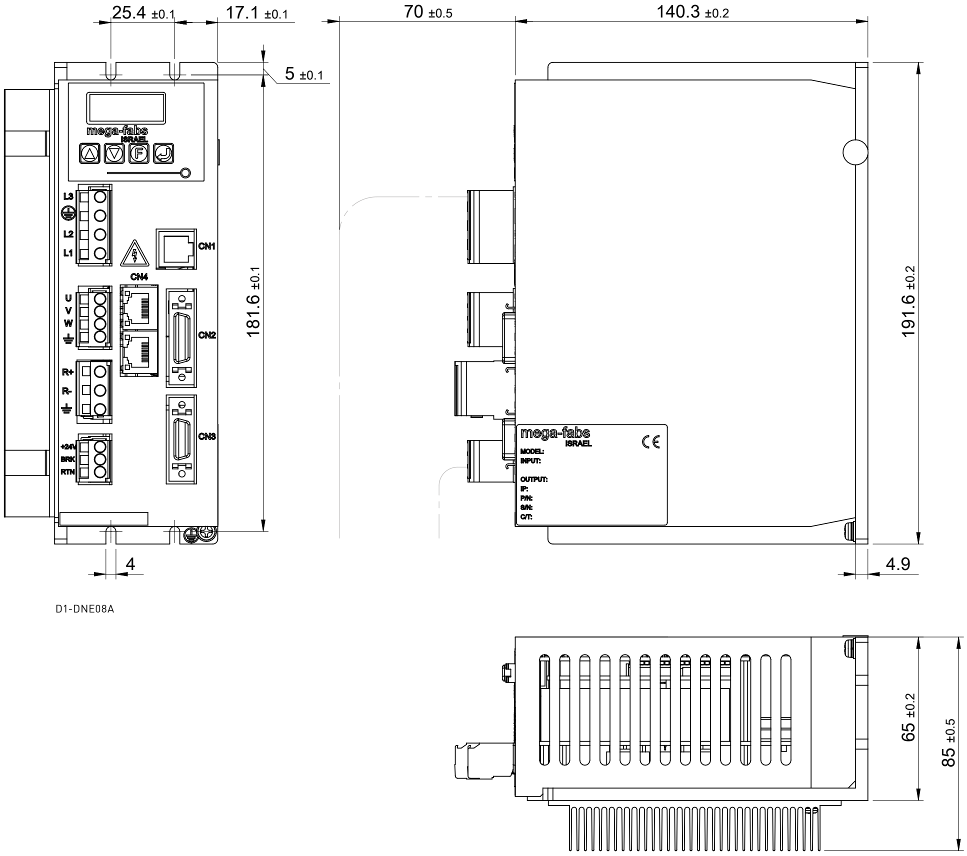


(D1-xx-xx-x-2-xx)



D1-DNE08A

6. Accessories

6.1 Motor Power Cable

Part name	Type	Model	Description
Motor cable	Linear	LMACS □□ D	For LMS series linear motor and motor OT cable included
		LMACS □□ K	For LMCA~LMCD,LMT series linear motor and motor OT cable included
		LMACS □□ L	For LMCF series linear motor and motor OT cable included
		LMACS □□ H	For LMSA series linear motor and motor OT cable included
		LMACS □□ J	For LMF series linear motor and motor OT cable included
	Torque	LMACS □□ F	For TMS, TMN, TMY series torque motor

□□ Represents cable length as the following:

□□	03	04	05	06	07	08	09	10
Cable length(m)	3	4	5	6	7	8	9	10

6.2 Feedback Signal Cables

Part name	Type	Model	Description
Encoder Cable	Linear	LMACE □□ Y	For Renishaw Digital Encoder, motor OT
		LMACE □□ Z	For Renishaw Digital Encoder, motor OT, and digital hall sensors
		LMACE □□ C	For Renishaw Analog Encoder, motor OT
		LMACE □□ J	For Renishaw Analog Encoder, motor OT, and digital hall sensors
		LMACE □□ AW	For Renishaw Digital Encoder, motor OT, with Encoder alarm, with Encoder alarm
		LMACE □□ AV	For Renishaw Digital Encoder, motor OT, and digital hall sensors, with Encoder alarm
	Rotary	LMACE □□ AA	For Jena Analog Encoder , motor OT. For TMS
		LMACE □□ AM	For Jena Analog Encoder , motor OT. For TMS, and digital hall sensors
		LMACE □□ AU	For Dual Resolver

□□ Represents cable length as the following:

□□	03	04	05	06	07	08	09	10
Cable length(m)	3	4	5	6	7	8	9	10

6.3 Control Signal Cables

Part name	Model	Description
Control Cable	LMACK30R	For motion controller (about 3m long)
	LMACK □□ A	For ACS SPiiPlus SA motion controller

□□ Represents cable length as the following:

□□	03	04	05	06	07	08	09	10
Cable length(m)	3	4	5	6	7	8	9	10

6.4 RS232 Communication Cable

Part name	Model	Description
RS232 communication cable	LMACR21D	Cable length is 2 meters long and connector type RJ11 at the drive side
Ethercat communication cable	HE00834D8400	Cable length is 0.2 meters long and connector type RJ45 at the drive side(For Ethercat communication between the drive)
Ethercat communication cable	HE00834D8500	Cable length is 3 meters long and connector type RJ45 at the drive side(For Ethercat communication between the drive)

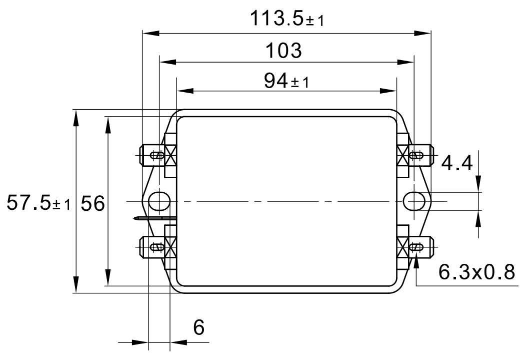
6.5 Accessory Pack of Connector

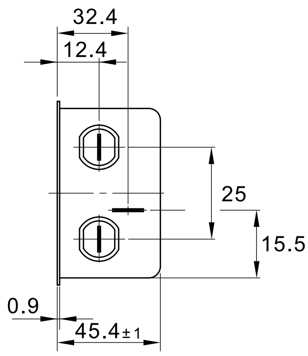
Part name	Model	Description	Qty
Accessory Pack (without CN3)	D1-CK1	AC main power connector: 4 pins and pitch 7.5mm	1
		Motor cable connector: 4 pins and pitch 5mm	1
		Regenerative resister connector: 3 Pin and pitch 7.5mm	1
		24V dc power and brake connector: 3 pins and pitch 5mm	1
		CN2 control signal connector: MDR 26P	1
		Connecter tool	2
Accessory Pack (CN3 connector included)	D1-CK2	AC main power connector: 4 pins and pitch 7.5mm	1
		Motor cable connector: 4 pins and pitch 5mm	1
		Regenerative resister connector: 3 pins and pitch 7.5mm	1
		24V dc power and brake connector: 3 pins and pitch 5mm	1
		Connecter tool	2

6.6 EMC Accessory Pack

Part name	Model	Description	Qty
EMC accessory for EMI core	EMI Core (050300400026)	EMI core KCF-130-B (EMI core can use for drive power input/output cables and signal cables to decrease noise)	1
EMC accessory Pack for single phase	D1-EMC1 (051800200063)	Single phase filter FN2090-10-06 (051800200044) (Rated current:6A, leakage current: 0.67mA)	1
		EMI core KCF-130-B (0503004000026)	2
EMC accessory pack for three phase	D1-EMC2 (051800200062)	Three phase filter FN3258-7-45 (051800200060)	1
		EMI core KCF-130-B (050300400026)	2
	D1-EMC3 (051800200083)	Single phase filter FNFN3025HL-20-71 (Low leakage current) (051800200071)	1
		EMI core KCF-130-B (050300400026)	2
EMC accessory for edge filter	MF-40-S (FF000MF11001)	Edge filter MF-40-S (Used to minimize the differential and common mode noise on the output of any D1 drive)	1

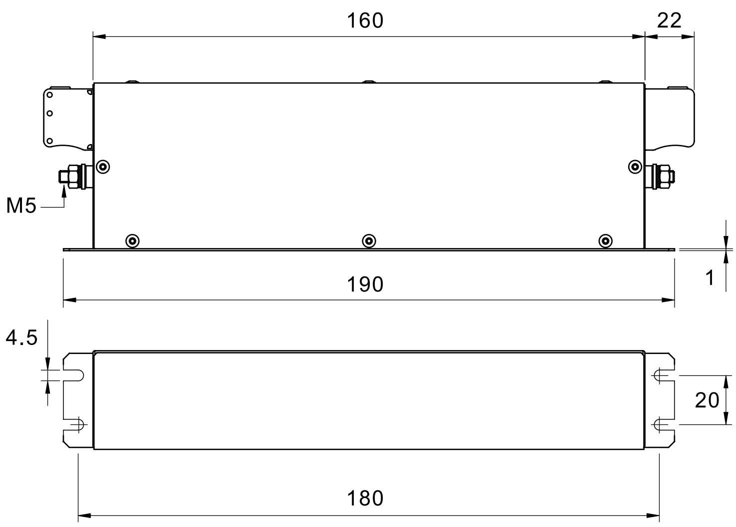
■ Single phase filter (D1-EMC1)

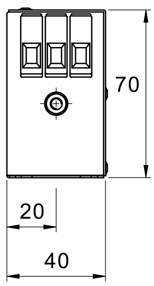




(Unit:mm)
D1-DNE05B
D1-DNE05B

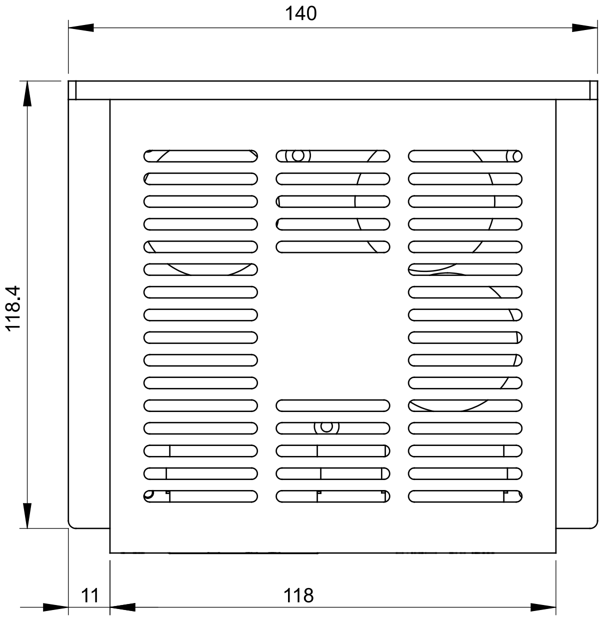
■ Three phase filter (D1-EMC2)

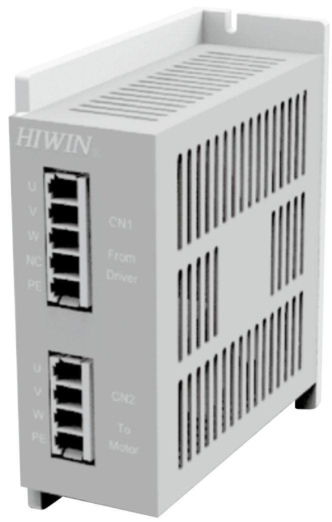


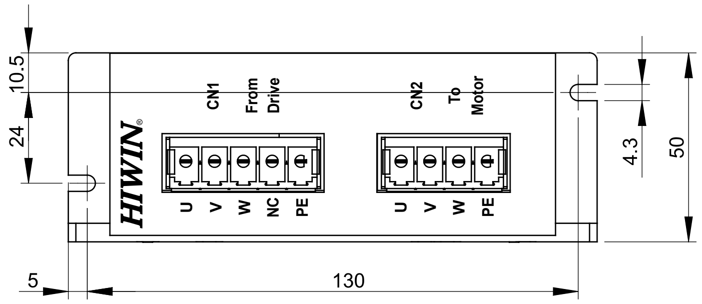


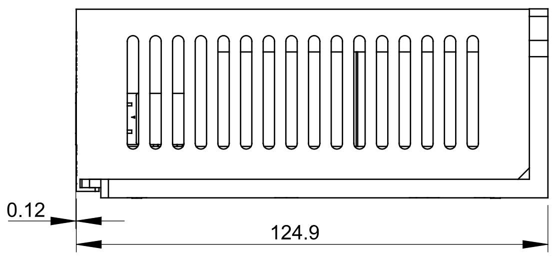
(Unit:mm)
D1-DNE01B

Edge filter (MF-40-S)



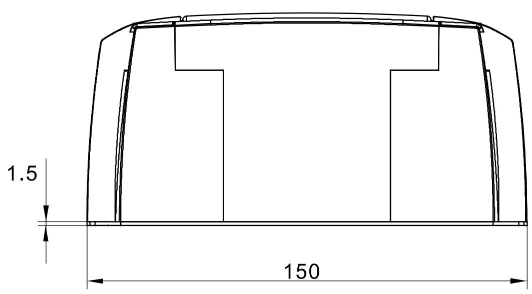


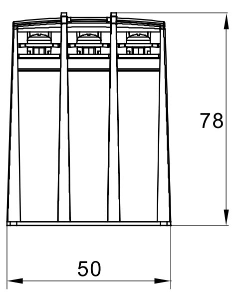


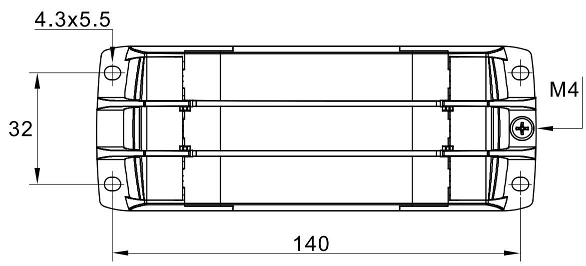


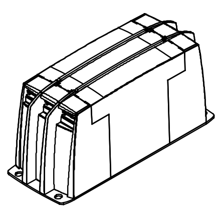
(Unit:mm)
D1-DNE11A

Three phase filter (D1-EMC3)









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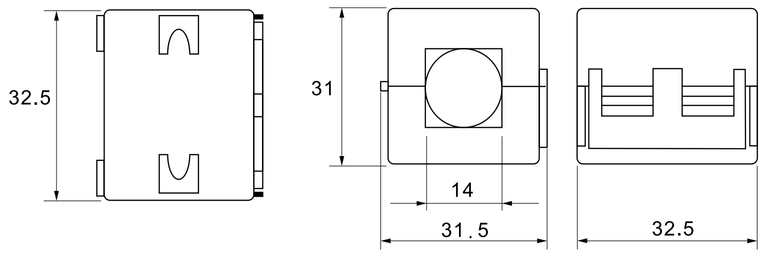
D1-DNE04A

■ EMI core

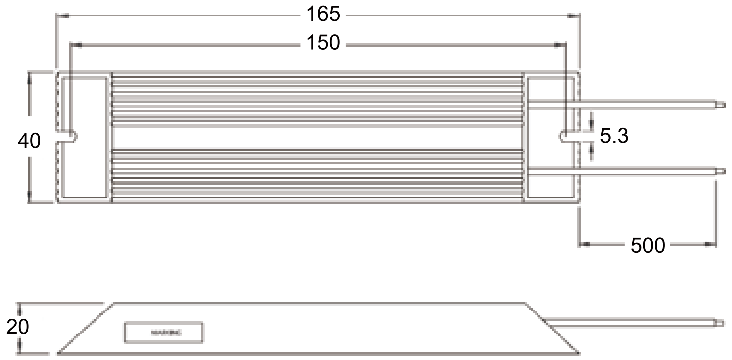


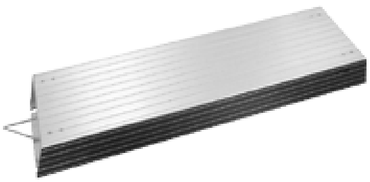
(Unit:mm)
D1-DNE02B

6.7 Other Accessories

Part name	Model	Description
Regenerative	RG1	68Ω, Rated power100W and peak 500W
Heat sink	D1-H1	High profile
	D1-H2	Low profile

■ Regenerative resistor

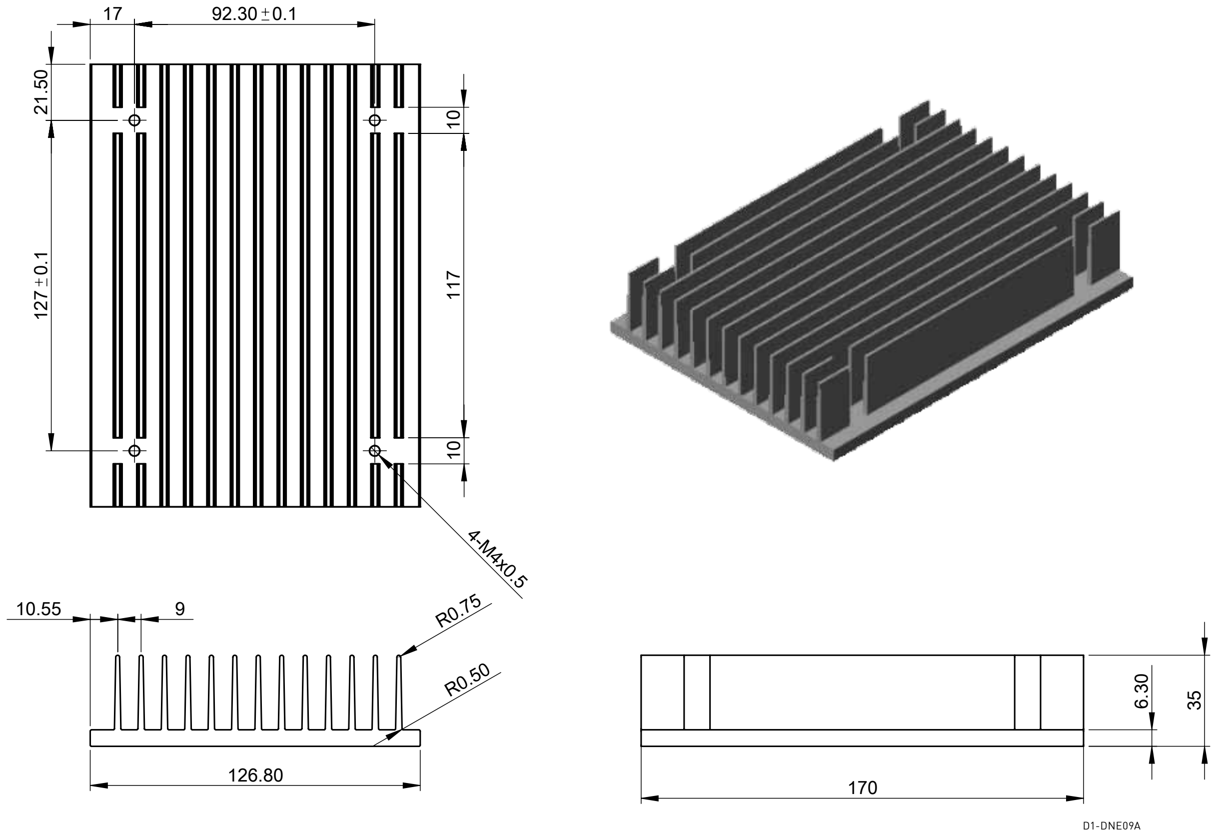




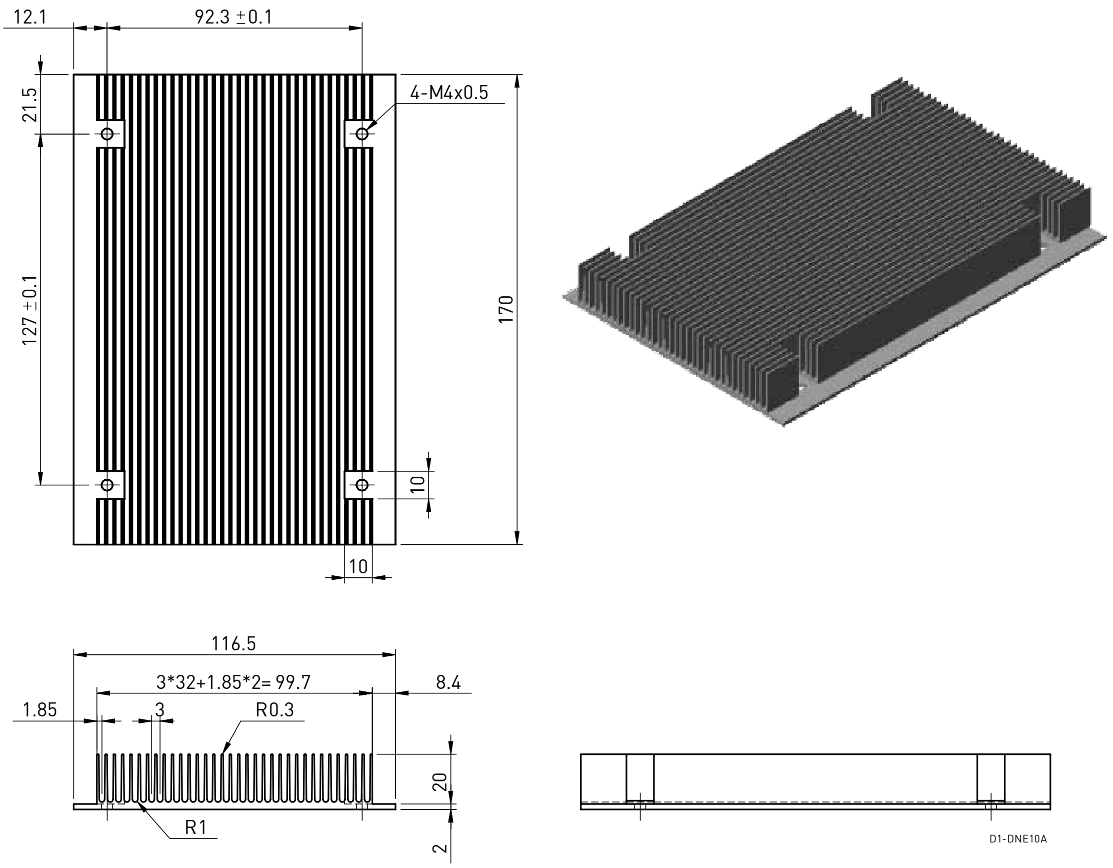
(Unit:mm)
D1-DNE03A

■ Heat sink

-D1-H1



- D1-H2



7. Motor Line-up

Motor Line-up

D1-XX-X2 or D1-XX-X3 for Linear motors

LMC :

LMC-EFC1, LMC-EFC2, LMC-EFC3, LMC-EFC4, LMC-EFE6, LMCA2, LMCA3, LMCA4, LMCA5, LMCA6, LMCB2, LMCB3, LMCB4, LMCB5, LMCB6, LMCB7, LMCB8, LMCBA, LMCC7, LMCC8, LMCD4, LMCD6, LMCD8, LMCDA, LMCE4, LMCE6, LMCE8, LMCEA, LMCEC, LMCF4, LMCF6

LMS :

LMSC7, LMSC7(WC)

LMFA :

LMFA0x, LMFA1x, LMFA2x, LMFA3x, LMFA4x, LMFA5x, LMFA6x

LMSA :

LMSA1x, LMSA2x, LMSA3x, LMSACx

LMT :

LMT2D, LMT2Q, LMT2T, LMTA2, LMTA3, LMTA4, LMTB2, LMTB3, LMTB4, LMTC2, LMTC3, LMTC4, LMTD2, LMTD3, LMTD4

D1-XX-X2 for Torque motors

TMS :

TMS0x, TMS1x, TMS3x, TMS7x

TMN :

TMNxxE

D1-XX-X4 for Absolute Resolver Torque motors

TMY :

TMY4x, TMY6x, TMYAx

TMN:

TMNxxA

Note Please contact with Sales Represent

8. Selecting motor capacity guide

8.1 Motor Sizing

■ Start Motor Sizing

The following contents describe how to choose proper motor according to speed, moving distance, and loading inertia. The basic process for sizing a motor is:

- Decide motion profile and required parameters
- Calculate peak and continuous force
- Select motor

■ Symbols

X : move distance (mm)
T : move time (sec)
a : acceleration (mm/s^2)
V : velocity (mm/s)
M_L: loading (kg)
g : gravitation acceleration (mm/s^2)
F_p : peak force (N)
F_c : continuous force (N)
F_a : attraction force between stator and forcer (applicable for LMS, LMF series) (N)
F_i : inertia force (N)
K_p : force constant (N/Arms)
I_p : peak current (Arms)
I_e : effective current (Arms)
I_c : continuous current (Arms)
V_0 : starting velocity (mm/s)

■ STEP 1 Decide motion velocity profile and required parameters

In order to determine the correct motor for a particular application it is necessary to be familiar with the motion equation.

■ Motion equation

Basic kinematics equations are described as follows:

$$V = V_0 + aT$$

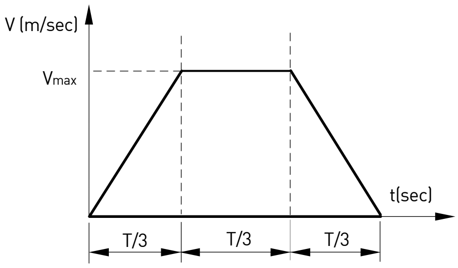
$$X = V_0T + \frac{1}{2}aT^2$$

Where V is velocity, a is acceleration, T is move time and X is move distance.
You can choose two of the four parameters (V, a, T and X) as your designed parameters, then the last two parameters can be calculated by above equations.

Motion velocity profile

1. 1/3-1/3-1/3 trapezoid profile

If the distance (X) and move time (T) have been given, the most common and efficient velocity profile for point-to-point motion is the "1/3-1/3-1/3" trapezoid curve because it provides the optimal move by minimizing the power required to complete the move. It breaks the time of the acceleration, traveling, and deceleration into three segments as shown below.



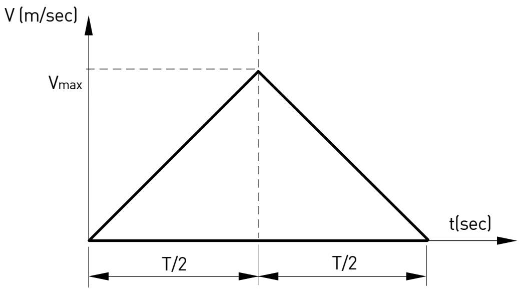
$$V_{max} = 1.5 \times \frac{X}{T} \quad (\text{Because } X = \frac{V}{2} \times \frac{T}{3} + V \times \frac{T}{3} + \frac{V}{2} \times \frac{T}{3})$$

$$a_{max} = \frac{V_{max}}{T/3} = \frac{4.5X}{T^2}$$

Herein the parameters are described as motion equation.

2. 1/2-1/2 triangle profile

If X and T are given, another common motion profile is the 1/2-1/2 triangle profile. The motion is divided into two parts, namely acceleration and deceleration. The second motion velocity profile is shown as follows.

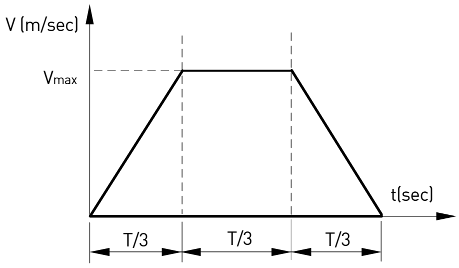
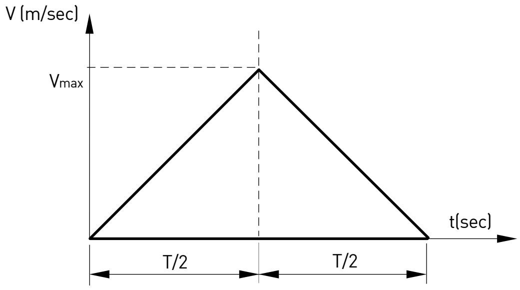


$$V_{max} = 2 \times \frac{X}{T}$$

$$a_{max} = \frac{4X}{T^2}$$

The acceleration required in the first motion velocity profile is bigger than that in the second motion velocity profile; therefore, the required motor size is bigger. When choosing second motion velocity profile, the chosen motor size is smaller, however, we need to verify the DC bus of drive is bigger enough, due to the higher velocity (V_{max}).

3. Some useful equations

	1/3 -1/3-1/3 Trapezoid profile 	Triangle profile 
V	$1.5 \times \frac{X}{T}$	$2 \times \frac{X}{T}$, or $\sqrt{a \times X}$
a	$\frac{4.5X}{T^2}$	$\frac{4X}{T^2}$
t	$\frac{X}{V_{max}} + \frac{V_{max}}{a}$ (if $\frac{X}{V_{max}} \geq \frac{V_{max}}{a}$)	

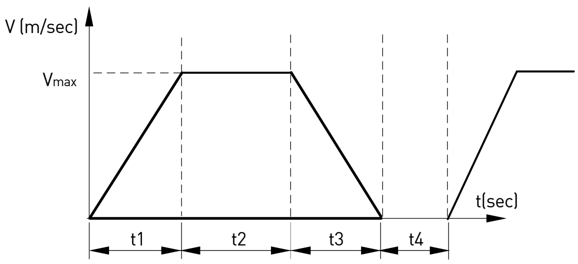
■ STEP 2 Determine peak force and effective force

The peak force can be calculated by the follow equation

$$F_p = M_L \times a_{max} + (M_L \times g + F_a) \times \mu = F_i + F_f$$

Where F_i is inertia force while F_f is friction force, and μ is friction factor.
In most cases, motions are cyclic point-to-point movements. Assuming a cyclic motion shown in the following profile with a pause time of t_4 second, the effective force can be calculated as following formula:

$$F_e = \sqrt{\frac{(F_i + F_f)^2 t_1 + F_f^2 t_2 + (F_i - F_f)^2 t_3}{t_1 + t_2 + t_3 + t_4}}$$



The peak current I_p and effective current I_e can be calculated by using motor force constant K_f.

$$I_p = \frac{F_p}{K_f}$$

$$I_e = \frac{F_e}{K_f}$$

STEP 3 Select motor by peak force and verify the current supply of motor

From the catalog of HIWIN, you can check the specifications of motor and choose an applicable motor by peak force, and then you can verify the current supply if it is fitted the specification as follows.

$$I_p = \frac{F_p}{K_f} < I_p \text{ (from specification of chosen motor)}$$

$$I_e = \frac{F_e}{K_f} < I_c \text{ (from specification of chosen motor)}$$

Regarding effective and continuous current, the ratio of I_e/I_c had better be less than 0.7 to attain some margin.

Linear motor sizing example

For example, if load is 5 kg (moving mass of mechanism is 1 kg and payload is 4 kg), friction factor μ is 0.01 ,distance is 500 mm, move time is 400 ms and dwell time is 350 ms.
At first, we can calculate the V_{max}, a_{max}, F_p and F_e by the formulas described above (choose the first motion velocity profile and LMC series)

$$V_{max} = 1.5 \times \frac{X}{T} = 1.5 \times \frac{0.5}{0.4} = 1.875 \text{ (m/sec)}$$

$$a_{max} = \frac{4.5 \times X}{T^2} = \frac{4.5 \times 0.5}{(0.4)^2} = 14.06 \text{ (m/sec}^2\text{)}$$

$$F_p = M_L \times a_{max} + (M_L \times g + F_a) \times \mu$$

$$= 5 \times 14.06 + 5 \times 9.81 \times 0.01 = 70.3 + 0.49 = 70.79 \text{ (N)}$$

$$F_e = \sqrt{\frac{\left[(70.3 + 0.49)^2 + 0.49^2 + (70.3 - 0.49)^2\right] \times 0.1333}{0.4 + 0.35}}$$

$$= 41.92 \text{ (N)}$$

In this case, we can choose motor of type LMCA6 (p.48) which can provide up to 187(N)of peak force and continuous force 62(N), and the force constant is 33.8 N/A(rms). Then the current supply of motor can be determined as follows

$$I_p = \frac{F_p}{K_f} = \frac{70.79}{33.8} = 2.09 \text{(Arms)} < 5.4 \text{(Arms)}$$

$$I_p = \frac{F_e}{K_f} = \frac{41.92}{33.8} = 1.24 \text{(Arms)} < 1.8 \text{(Arms)}$$

$$I_e / I_c = \frac{1.24}{1.8} \times 100\% = 68.89\% < 70\%$$

8.2 Sizing a Regenerative Resistor

■ Gather required information

To calculate the power and resistance of the regen resistor requires information about the amplifier and the motor. For all applications, gather the following information:

- Detail of motion profile, including acceleration and velocity
- Amplifier model number
- Applied line voltage to amplifier
- Toque/force constant of the motor
- Resistance (line-to-line) of the motor windings

For rotary motor applications, gather additional information
- Load inertia seen by the motor
- Inertia of the motor

For linear motor applications, gather additional information
- Moving mass

■ Observe the properties of each deceleration during a complete cycle of operation

For each deceleration during the motion cycle, determine:
- Speed at the start of the deceleration
- Speed at the end of the deceleration
- Time over which the deceleration takes place

■ Calculate energy returned for each deceleration

The energy returned during each deceleration can be calculated by the following formulas.
Rotary motor:

$$E_{dec} = \frac{1}{2} J_t (\omega_1^2 - \omega_2^2)$$

E_{dec} (joules): Energy returned by the deceleration
J_t (kg m^2): Load inertia on the motor shaft plus the motor inertia
ω_1 (radians /sec): Shaft speed at the start of deceleration
ω_2 (radians /sec): Shaft speed at the end of deceleration
I_e : effective current (Arms)

Linear motor:

$$E_{dec} = \frac{1}{2} M_t (V_1^2 - V_2^2)$$

E_{dec} (joules): Energy returned by the deceleration
M_t (kg): Moving mass
V_1 (meters /sec): Velocity at the start of deceleration
V_2 (meters /sec): Velocity at the end of deceleration

■ Determine the amount of energy dissipated by the motor

Calculate the amount of energy dissipated by the motor due to current flow through the motor winding resistance using the following formula.

$$P_{motor} = \frac{3}{4} R_{winding} (\frac{F}{K_t})^2$$

P_{power} (watts): Power dissipated in the motor

$R_{winding}$ (ohm): Line to Line resistance of the motor coil
F : Force need to decelerate the motor
Nm for rotary applications
N for linear applications
K_t: Torque constant for the motor
Nm/Amp for rotary applications
N/Amp for linear applications
$E_{motor} = P_{motor} T_{decel}$
E_{motor} (joules): Energy dissipated in the motor
T_{decel} (seconds): Time of deceleration

Determine the amount of energy returned to the amplifier

Calculate the amount of energy that will be returned to the amplifier for each deceleration using the following formula
$E_{returned} = E_{dec} - E_{motor}$
$E_{returned}$ (joules): Energy returned to the amplifier
E_{dec} (joules): Energy returned by the deceleration
E_{motor} (joules): Energy dissipated by the motor

Determine if energy returned exceeds amplifier capacity

Compare the amount of energy returned to the amplifier in each deceleration with the amplifier's absorption capacity. The following formula is used to determine the energy that can be absorbed by the amplifier.

$$W_{capacity} = \frac{1}{2} C (V_{regen}^2 - (1.414 V_{mains})^2)$$

$W_{capacity}$ (joules): The energy that can be absorbed by the bus capacitor
C (farads): Bus capacitance
V_{regen}(volts): Voltage at which the regen circuit turns on
V_{mains}(volts): Mains voltage (AC) applied to the amplifier

Calculated energy to be dissipated for each deceleration

For each deceleration where the energy exceeds the amplifier's capacity, using the following formula to calculate the energy that must be dissipated by the regen resistor.
$E_{regen} = E_{returned} - E_{amp}$
E_{regen} (joules): Energy that must be dissipated in the regen resistor
$E_{returned}$ (joules): Energy delivered back to the amplifier from the motor
E_{amp} (joules): Energy that the amplifier will absorb

Calculate pulse power of each deceleration that exceeds amplifier capacity

For each deceleration where energy must be dissipated by the regen resistor, use the following formula to calculate the pulse power that will be dissipated by the regen resistor
$P_{pulse} = E_{regen} / T_{decel}$
P_{pulse} (watts): Pulse power
E_{regen} (joules): Energy that must be dissipated in the regen resistor
T_{decel} (seconds): Time of deceleration

Calculate resistance needed to dissipate the pulse power

Using the maximum pulse power from the previous calculation, calculate the resistance value of the regen resistor required to dissipate the maximum pulse power.
$R = V^2_{regen} / P_{pulse\ max}$

R(ohms):Resistance

$P_{pulse\ max}$:The maximum pulse power

V_{regen} :The voltage at which the regen circuit turns on

Choose a standard value of resistance less than the calculated value. The value must also be greater than the minimum regen resistor value specified by the amplifier supplier.

Regenerative resistor sizing example

Gather required information

LM ROBOTS type: LMXL1L-S37L-1200-G200

Amplifier: mega-fabs D1

DC bus capacitance: 1880uF

Regen circuit turn on voltage: 390V

Minimum resistance: 15Ω

Moving mass: 86Kg (include payload 74 Kg)

V_{max}: 2 m/s

Acceleration, deceleration: 5 m/s^2

Power supply (AC) of drive: 220VAC

Motor type: LMS37L

Force constant (Kf): 68N/A(rms)

$R_{winding}$: 2 ohms(line-to-line)

Calculate regen resistor as following step:

$$F = ma = 86 \times 5 = 430\,(N)$$

$$E_{dec} = \frac{1}{2} m_t V^2 = \frac{1}{2} \times 86 \times 2^2 = 172(\text{joule})$$

$$P_{motor} = \frac{3}{4} \times R_{winding} \times \left(\frac{F}{K_f} \times \sqrt{2}\right)^2 = \frac{3}{4} \times 2 \times \left(\frac{430}{68} \times \sqrt{2}\right)^2$$

$$= 120\ (\text{Watt})$$

$$E_{motor} = P_{motor} \times T_{decel} = 120 \times \left(\frac{2}{5}\right) = 48\,(\text{joule})$$

$$E_{returned} = E_{dec} - E_{motor} = 172 - 48 = 124\ (\text{joule})$$

$$W_{capacity} = \frac{1}{2} \times C \times (V_{regen}^2 - (1.414 V_{mains})^2)$$

$$= \frac{1}{2} \times 1880 \times 10^{-6} \times (390^2 - (1.414 \times 220)^2)$$

$$= 51.98\ (\text{joule})$$

$$\because E_{returned} > W_{capacity}$$

$$E_{regen} = E_{returned} - E_{amp} = 124 - 51.98 = 72.02(\text{joule})$$

$$P_{pulse} = E_{regen} / T_{decel} = 72.02/0.4 = 180.05(\text{Watt})$$

$$R = \frac{V_{regen}^2}{P_{pulse}} = \frac{390^2}{180.05} = 844.77(\text{ohms})$$

Because the total value of selected resistance must be less than 844.77 ohms and the power capacity must be more than 180.05 watts, we choose two resistors and connect them in series, in each resistor the resistance is 68 ohms and power capacity is 100W. The total resistance value is 136 ohms and power capacity is 200W. The resistance order number is 050100700001.

9. Linear Motor Requirements List

Date :

Company name : Email Tel : Fax :		Contact person : Title :
Industrial		Notes :
Environment	☐Normal environment ☐Clean room,class ☐Other _____	
Stage type	☐Single axis ☐XY axis ☐Bridge type ☐Gantry(Single drive) ☐Gantry (Dual drive) ☐Other _____	
Load(kg)or Moment of inertia(kg-m2)		
Max. Velocity(m/s) or (rad/s)		
Max. Acceleration(m/s^2)or(rad/s^2)		
Stroke(mm)		
Repeatability(μm)or(deg)		
Accuracy(μm)or(deg)		
Encoder type	☐Analog ☐Pitch _____ μm ☐Digital ☐resolution ____ μm	
Orientation of Stage	☐Horizontal ☐Vertical ☐Laterally ☐Upside-down	
Multiple forcer	☐Yes, Number : _____ ☐No	
Dust-proof device	☐No ☐Cover ☐Bellow	
Cable Chain	☐No ☐Horizontal ☐Vertical	
Drive voltage	☐110V ☐220V ☐Other _____ V	
Pulse format	☐CW/CCW ☐A/B ☐STEP/DIR	
Application	☐Point to point ☐Scan	
Special measurement requirement		

The information below is to be filled out by our authorized agents.
Recommended specification :

Manager : Engineer : Salesperson :

MEMO

D1 Servo Drive Technical Information

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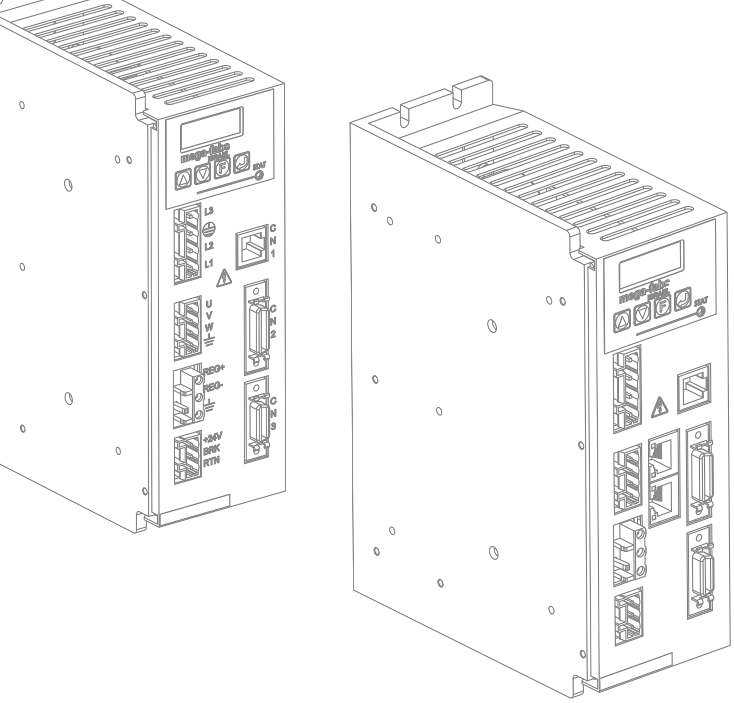

HIWIN®

Motion Control and System Technology

HIWIN MIKROSYSTEM CORP.
No.6, Jingke Central Rd.,
Taichung Precision Machinery Park,
Taichung 40852, Taiwan
Tel: +886-4-23550110
Fax: +886-4-23550123
www.hiwinmikro.tw
business@hiwinmikro.tw

Subsidiaries & R&D Centers

HIWIN GmbH
OFFENBURG, GERMANY
www.hiwin.de
www.hiwin.eu
info@hiwin.de

HIWIN JAPAN
KOBE · TOKYO · NAGOYA · NAGANO ·
TOHOKU · HOKURIKU · HIROSHIMA ·
KUMAMOTO · FUKUOKA, JAPAN
www.hiwin.co.jp
info@hiwin.co.jp

HIWIN USA
CHICAGO · SILICON VALLEY, U.S.A.
www.hiwin.com
info@hiwin.com

HIWIN Srl
BRUGHERIO, ITALY
www.hiwin.it
info@hiwin.it

HIWIN Schweiz GmbH
JONA, SWITZERLAND
www.hiwin.ch
info@hiwin.ch

HIWIN s.r.o.
BRNO, CZECH REPUBLIC
www.hiwin.cz
info@hiwin.cz

HIWIN SINGAPORE
SINGAPORE
www.hiwin.sg
info@hiwin.sg

HIWIN KOREA
SUWON, KOREA
www.hiwin.kr
info@hiwin.kr

HIWIN CHINA
SUZHOU, CHINA
www.hiwin.cn
info@hiwin.cn

Mega-Fabs Motion System, Ltd.
HAIFA, ISRAEL
www.mega-fabs.com
info@mega-fabs.com

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