FD1E

Integrated stepper motor driver
Hardware manual

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1. DESCRIPTION

FD1E belongs to FD family drives, which are designed in a compact solution to be mounted directly on motor end-shield.

FD drives are all controlled by ARM-based microcontroller. They are equipped with very low $R_{DS\text{-}on}$ MOSFETs and Hall-effect current sensors to optimize power efficiency.

The drive mounts a 12-bit magnetic encoder, which can be used to verify the correct execution of the ordered steps, to modulate the motor current with the load and other functions, which are described in detail on firmware manuals.

FD1E is equipped with configurable I/O's (2 digital inputs and 1 digital output), which can be used as step, direction, quadrature steps, homing sensor, alarm, start, stop, torque-off, etc.
It can communicate in EtherCAT using CoE protocol (CAN over EtherCAT), by 2 industrial M8 circular connectors.
A RS-232 port, accessible opening drive enclosure, (from 4 800 up to 115 200 bps) is used for firmware and parameters programming.

The drive logic is supplied from external 24 V_{DC}, which allows to keep communication and multiturn position counting active in case of loss of power.

Fig. 1 – FD1.1E applied to IP65 NEMA 24 stepper motor.

2. RISK AND PRECAUTION

Products described in this manual are marked CE and comply with the following directives:

- EMC Directive 2014/30/EU,
- LV Directive 2015/35/EU.

a. Stepper drives FD1 are basic drive modules, BDM (EN 61800-3) integrated with the motor. This means they are components to be integrated in higher complexity industrial equipment by qualified personnel, expert in the field of motor drive and in their related problems. Direct use of this product by final user is not allowed, only a professional assembler can install and put in service this component. They are addressed to limited distribution. Not qualified personnel use is forbidden. It is exclusive responsibility of the designer of the complete machine or installation, in which this component is used to take care of the safety and reliability of his project.

b. Use for safety related functions is forbidden. It is also forbidden any application arrangement in which a drive fault or failure could generate a hazardous condition.

c. The use is prohibited in presence of gas or any other flammable material.

d. Capacitor discharge: depending on supply type and application conditions (external capacitor, discharging resistor and supply voltage value), it is necessary to wait sufficient time after switching off before opening the enclosure.

e. Hot surface: wait 10 minutes after switching off, before touching the equipment.

f. The drive cannot be connected directly to the mains. It has to be supplied by a power supply equipped with transformer mains insulation.

g. Drive could generate electromagnetic interference if instruction about installation directions are not respected. The compliance with 2014/30/UE directive has to be tested on whole machine in normal working condition and in accordance with specific standards covering the application.

h. The equipment which mounts FD1 shall be equipped with external protective systems, which are not based on the correct functioning of the device.

i. The drive cannot be altered, dismounted from the motor or repaired by un-authorized personnel. Dismounting the drive from the motor can induce improper functioning.

j. Disable current input signal and internal electronic protections switch off the drive output power, but they cannot be used as emergency stop or any other function involving personnel safety.

k. Digital inputs, outputs and EtherCAT are galvanically insulated from power circuit.

l. Several motor shafts are pulled out by a spring mounted on the rear bearing seat. When tightening the front flange's screws, pay attention not to pull-back the shaft inside the motor. Improper mounting can cause shaft blocking and damages to the magnetic encoder.

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3. ELECTROMAGNETIC COMPATIBILITY (EMC)

The drive, the connections and the motor are electromagnetic interference source (EMI) conducted and radiated.

In order to comply with EC Electromagnetic Compatibility Directive 2014/30/CE and the relevant standard EN 61800-3, it is necessary to abide by installation scheme and following indications:

Use only shielded cable. Cable shield needs to be earthed on both sides.

Connection made to Protective Earth terminal (PE) must be short and have the lowest possible inductance.

Interpose a filter near the AC main supply entrance, on transformer primary side.

Use a supply transformer with a metal shield between primary and secondary winding and connect this shield to PE.

Use varistors on transformer primary side and use TVS on the rectified DC voltage to protect the drives from over-voltages.

FD1 drives are BDM integrated with the motor, conceived for restricted distribution. This means that Auxind has the responsibility to verify the product compatibility in the typical way of use in order to give correct installation directions. In any case, it is responsibility of the professional assembler, who installs this product, to verify the compatibility of the EMC of the complete system.

Theoretically the drive could work without any earth connection in a complete floating system, but, in this case, some possible internal insulation failures will not be detected by protection system, causing potentially hazardous situation like dangerous voltage present on drive or I/O, moreover there could be much more problems in satisfying EMI requirements. The recommended solution is the connection of GND (the V- of rectified voltage) terminal to PE.

Connect GND terminals to earth and to enclosure metal chassis with a line having a low high-frequencies impedance.

Take care to ensure a good earth connection among different parts of chassis where the motor is installed.

When cable length exceeds 5 meters use buffer type driving signals instead of open collector type.

Verify logic compatibility when interfacing drive with control system.

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4. ELECTRICAL CHARACTERISTICS

Measurement	Range			Unit
	Min	Typ	Max	
Supply voltage	24		60	V_{DC}
	Note: minimum power supply output capacitor 1000 µF			
Supply current			4	A
	Note: depends upon power supply voltage, configured motor current, speed and load			
Motor current	500		7 000	mA_P/phase
	Note: Maximum and minimum current are configurable (limited to internal predefined value)			
Angular resolution	400	12 800	204 800	µstep / revolution
Stepper motors	Bi-phase; 4, 6 and 8 wires; from 0.5 to 15 mH inductance			
Size	100 x 65 x 20 mm + motor			
Ambient temperature	0		45	°C
IP	65			
	Note: overall IP rating depends on selected motor applied to the drive			

Tab. 1 - Electrical characteristics

5. CODING

The product code is given in below format:

FD1.1 E - 5L45

Full Digital

Hardware version	
E	EtherCAT

Motor code	
5L45	Moons Nema24 MS24HS5L455A-01 (IP65)
AL45	Moons Nema23 ML23HSAL4500-12 (IP40)

Hardware versions, identified by suffixes, are characterized as per following table:

Type	Rated input voltage	Integrated absolute encoder	Digital inputs	Digital outputs	RS-232	EtherCAT
FD1.1E	24 – 60 V_{DC}	✓	2	1	✓	✓
FD1.2E		✓	2		✓	✓

Tab. 2 – Hardware versions

6. INTERFACES

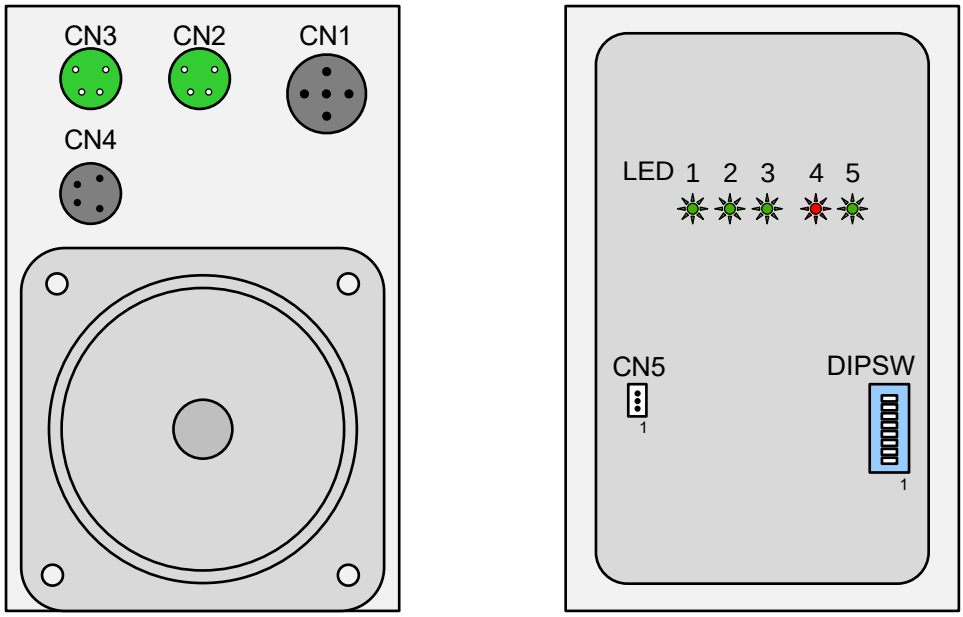
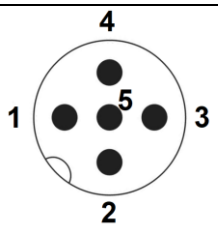
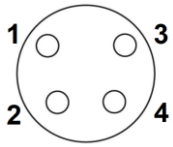
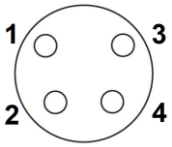
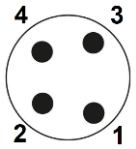
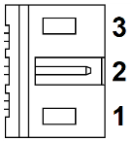


Fig. 2 – FD1.1E applied to NEMA 24 stepper motor

CN1		CN2		CN3		CN4		CN5	
Power supplies		EtherCAT IN		EtherCAT OUT		Digital I/O		RS-232	
M12, male, 5p, A-coded		M8, female, 4p, A-coded		M8, female, 4p, A-coded		M8, male, 4p		JST, PHR-3, SPH-002T-P0.5S	
									
1	GND	1	Tx+	1	Tx+	1	$0\ V_{IN}$	1	Tx 232
2	GND	2	Rx+	2	Rx+	2	IN1	2	GND
3	V_{POW}	3	Rx-	3	Rx-	3	IN2	3	Rx 232
4	V_{POW}	4	Tx-	4	Tx-	4	OUT1		
5	$24\ V_{EXT}$								

Tab. 3 - Connectors pinout

Notes:
It is recommended to install an external capacitor in parallel to V_{POW} to store the reactive energy of the motor. The capacitance depends upon motor, voltage and application. Typically 1 000 µF are considered sufficient.
Maximum current for CN1 pins is 4 A. It is suggested to use two pins of CN1 in parallel and bear attention on the choice of female connector.

The microprocessor is powered from V_{EXT} and V_{POW}. When V_{EXT} is present, in case of loss of V_{POW} because of emergency shut down the logic and communication remain active. This allows also the multi-turn position retention.

Use shielded Ethernet copper cabling (twisted pair) according to BS EN 50173 class D. Connector shall meet the standard EN61076-2-101, type D.

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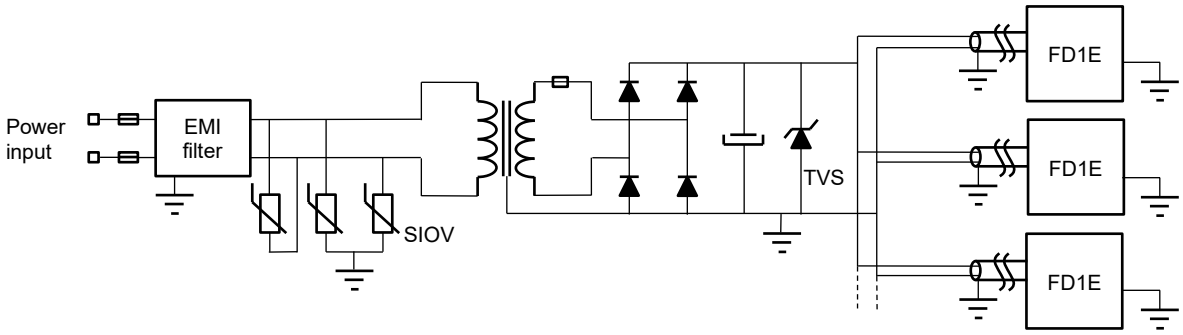
7. POWER SUPPLY

FD1 needs to be powered with DC voltage in the range 24- 60 V_{DC}.

Careful attention should be paid when using switching power supply to feed a DC-bus for the machine drives.

The converter shall provide sufficient EMC protection and it shall be able to withstand back-feed power from the motor to the power supply, generated during fast decelerations and inertial loads, i.e. the converter output shall be characterized by a sufficient output capacitance to avoid over-voltages.
As a rule of thumb, it can be considered 1000 µF for each drive, but the optimal value depends upon the motor selection, the inertia of the load and the duty-cycle of the motors.
Several AC/DC converters on the market are equipped with an output diode for parallel use. Such diode does not allow to back-feed the power from the motor to the output capacitor, leading to dangerous over-voltages during motor deceleration. Although the drive is equipped with over-voltage protection, which stops the motor from regenerating, preventing dangerous voltages to occur, it is highly recommended to add an external capacitor on the DC bus.

When the transformer with rectifier solution is adopted, following connection scheme is recommended.



EMI filter:
FN2080, Shaffner or any other equivalent.

SIOV:
Recommended B72214S0251K101 for 230 V_{AC} incoming line.

Transformer:
The transformer shall be equipped with an electrostatic shield between the primary and the secondary winding, connected to earth, thus avoiding transfer of surge or impulse voltages passing through inter-winding capacitance. It is also important that the primary wiring to and secondary wiring from the isolation transformer are routed through separate trays or conduits.

Rectifier bridge:
Connect GND (the V- of DC voltage) to earth with a line having low high-frequencies impedance.

Capacitor:
Capacitor should be located at a distance not greater than 3 m from the drive. The purposes of the capacitor are:

- Reduce the ripple on the DC voltage due to AC incoming lines rectification,
- Absorbs the energy regenerated by the motor during the deceleration.

In case of high capacitance value, a discharging resistor in parallel is recommended.
Capacitor size depends on load, deceleration ramps, on the simultaneity factor, motor, etc. As a rule of thumb a value of 1000 µF per drive is recommended.

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TVS:

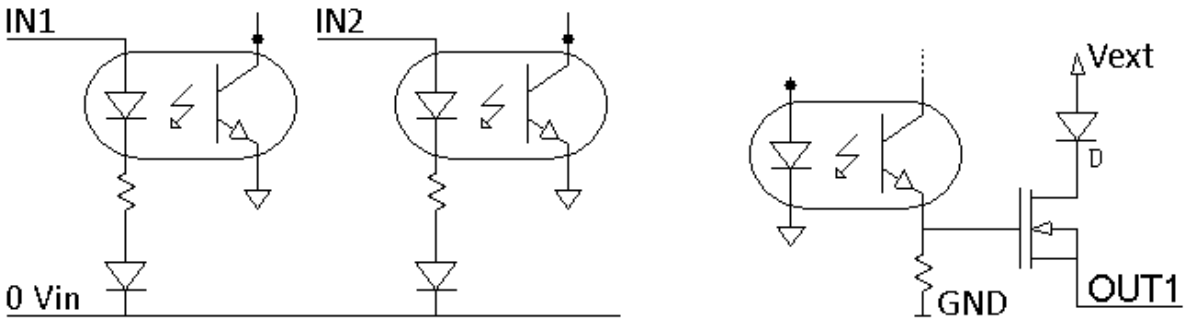
Using unidirectional TVS as additional protective measure on the DC voltage increases the system reliability.
The model needs to be chosen based on the DC voltage applied and on the power of the over-voltage that needs to be sustained. Using many TVS in parallel increases their protective capabilities. E.g. working with 48 V_{DC} power supply, model 1.5KE56A can be used.

Connections:

Do not place any fuse on GND lines to drives. Fuses can be installed only on V+ wires.
Do not place any fuse between the capacitor and the drives.
Cable shields need to be earthed on both sides. As low as possible high frequency impedance connection need to be used.
Ensure the motor is connected to earth (if earth connection is done via chassis, avoid painting between the motor and the chassis and ensure a good earth connection among the parts of chassis).

8. INPUTS / OUTPUTS ELECTRICAL CHARACTERISTICS

Inputs and outputs are opto-insulated PNP type, refer to following block diagram.



IN1 and IN2 are single-ended digital inputs, working at 0-24 V and software filtered. Their 0 V is on pin 1 of CN4 and their threshold is approximately at 5 V.

OUT1 is PNP type digital output, powered from V_{EXT}. Typically, V_{EXT} is 24 V, but if necessary, the outputs can work also with V_{EXT} = 5 V. OUT1 is not available in FD1.2E.

Parameter	Symbol	Rating
Maximum output voltage	$V_{EXT-MAX}$	30 V (40 V peak)
Maximum output current	$I_{OUT-MAX}$	1 A *Note: output is short circuit protected, ref. to datasheet VND5160J.*
Output MOSFET resistance	$R_{DS-ON-OUT}$	160 mΩ
Maximum commutation energy		33 mJ *Note: ref. to datasheet VND5160J.*

Tab. 4 – OUT1 characteristics

9. MOTOR CURRENT SETTINGS

It is recommended to keep sufficient torque margins when configuring the motor current specific for the application, taking into account that too high currents unnecessarily heat up drive and motor and may induce resonances.
Current setting is limited to the factory programmed value in order to protect the motor and the drive from misconfiguration.

To avoid unwanted heat dissipation V6 firmware version implements motor torque control, which reduces the current in absence of resistant torque and increase it proportionally with the load till the maximum value configured.
Torque control is active all the times, also at zero speed, which means that if a load is applied when the motor is stopped, the drive will counteract the load, increasing motor current.

V6 firmware regulates motor current in a configurable range of current (programmable minimum and maximum current) and it implements the step accumulation function. This feature gives great benefits to the application: it allows to accumulate the steps which cannot be executed because of a sudden resistant torque above the maximum motor torque. In such condition, FD1 maintains the maximum motor torque and, when the load decreases, it recovers the steps accumulated, accelerating and reaching the reference position. The engage, which is the change from chasing mode to synchronous mode, takes place through bump-less speed adjustment, without vibrations.

In those applications characterized by high acceleration and inertial load traditional stepper drives need to have sufficient torque margins, so that in case of an increment of the load the motor does not lose the synchronism with consequent step loss (or even stop if the frequency is above the start/stop frequency). In other words, with the traditional stepper driver, it is necessary to oversize motor and drive.
Thanks to V6 control firmware, instead, the drive increases current and torque until the maximum set value. In case of higher resistant torque the resulting speed and acceleration reduction is managed through the accumulation of the input steps not been executed. As soon as the resistant torque decreases the driver executes the accumulated steps without position loss. A configurable alarm limit of input steps accumulation is implemented.

This control firmware combines together the benefits of stepper systems: low cost, simplicity (no PID tuning), very low position overshoot, high torque/motor size ratio and the benefits of brushless systems: high efficiency (current adjustment with the load, working at maximum torque) and position retention.

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10. LED DIAGNOSTIC

FD1E is equipped with six LEDs, visible from the rear part of the motor removing the cover, which allow the following diagnostic:

LED1 EtherCAT IN link / activity

LED2 EtherCAT OUT link / activity

LED3 EtherCAT AL status

LED4 Alarm

LED5 Power on

LED	Color	LED status	Meaning
LED1, LED2 EtherCAT link / activity	Green	Off	No link detected
		On	Link without activity
		Blinking	Link and activity
LED3 EtherCAT AL status	Green	Off	Init
		Blinking slowly	Pre-op
		Single flash with long pause	Safe-op
		On	Op
LED4 Alarm	Red	Off	Drive Ok
		Blinking	N blinks, 2 seconds off. The number of blinks, N, identify the alarm code: 1: step accumulation limit 2: over temperature 3: motor short circuit 4: over voltage 5: programmed data error 7: under voltage
LED5 Power on	Green	Off	Microprocessor is not running. Following action shall be taken: verify that the drive is not in boot mode (DIP switch 8 on), verify the presence of V_{EXT}, contact Auxind.
		Blinking	Firmware is running. When RS-232 Modbus communication is active, blinking frequency increases
		Flash	Short flash every 4 sec indicates a magnetic encoder warning: verify that the shaft is not pulled back inside the motor, caused by improper mounting.

Tab. 5 - LED diagnostic