AUXIND

FD1.6

Integrated stepper motor driver
Hardware manual

28/06/17 First version
13/12/17 Ambient temp
22/12/17 Coding
18/12/2018 Cabling

1. DESCRIPTION

FD1.6 belongs to FD family drives, which are designed in a compact solution to be mounted directly on motor end-shield. It differs from model FD1.5 for the possibility of supplying the logic in case of loss of main power supply.

FD drives are all controlled by 72 MHz ARM-based microcontroller. They are equipped with very low $R_{DS\text{-}on}$ MOSFETs and Hall effect current sensors to optimize power efficiency.

FD1.6 is the hardware code of the open type, while the suffix B (e.g. FD1.6B) identifies the model protected by a cover. The aluminium cover works also as heat sink allowing higher motor currents.

The drive is equipped with 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.

FD1.6 is equipped with configurable I/O's (4 inputs and 2 outputs), which can be used as step, direction, quadrature steps, homing sensor, alarm, start, stop, etc. plus transceivers RS-232 (from 4 800 up to 115 200 bps) and RS-485 (from 4 800 up to 921 600 bps) for Modbus communication.

The suffix A identifies the model equipped with CAN transceiver, i.e. FD1.6AB. CANopen protocol is implemented (from 10 kHz up to 1 MHz).

Other under-mounted versions, characterized by hardware features tailor made for the specific application and identified with different suffixes are also available.

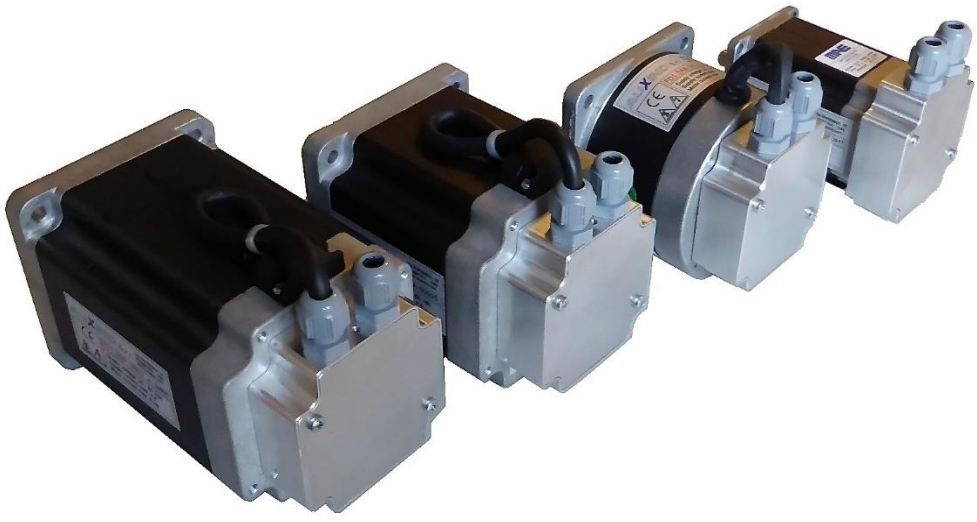


Fig. 1 FD1.6B applied on NEMA 34 and NEMA23 stepper motors.

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. FD1 open type (without the suffix B) must be installed in closed electrical operating area only, i.e. room or location for electrical equipment to which access is restricted to skilled or instructed persons by the opening of a door or the removal of a barrier by the use of a key or tool and which is clearly marked by appropriate warning signs.

c. FD1 open type (without the suffix B) has protection degree IP00, it means that the drive is to be installed inside protective enclosure under user responsibility, in compliance with specific application rules to avoid electric shock hazard. The enclosure must provide a local environment suitable to the drives and meet the requirements for electromagnetic compatibility.

d. FD1 close type (with the suffix B) has protection degree IP40.

e. 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.

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

g. 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.

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

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

j. 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.

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

l. 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.

m. 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.

n. Digital inputs are insulated from the rest of the circuit (opto-insulator is approved IEC/EN/DIN EN 60747-5-2).
Output terminals and serial lines are NOT electrically separated from internal power voltage. Those terminal are not impedance protected. Thereby, in case of drive failure and power supply with dangerous voltages, such voltages could appear on logic output connections and serial lines. For this reason measures for the evaluation of machine safety during a single fault condition, the external control system, connected to these terminals, has to be considered potentially subject to high voltage, unless an external separation is provided.

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.

4. ELECTRICAL CHARACTERISTICS

Measurement		Range			Unit
		Min	Typ	Max	
Supply voltage		20		80	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	FD1.6	500		5 000	mA_P/phase
	FD1.6B	500		7 000	
		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	FD1.6	60 x 60 x 15 + motor			mm
	FD1.6B	67 x 67 x 23 + motor			
Ambient temperature		0		45	°C
IP	FD1.6	IP 00			
	FD1.6B	IP 40			

5. CODING

The product code is given in below format:

FD1.6 **Full Digital** — AB — - — 1404 — + — K1

Hardware version	
A	CANopen
B	Aluminium box
Z	Under-mounted

Motor code	
5A	Only el. board (no encoder)
2231	Ametek Nema23
3426	Ametek Nema34
1404	Moons Nema34
2431	Moons Nema34
...	...

Cable
K2
K14
K18
K19

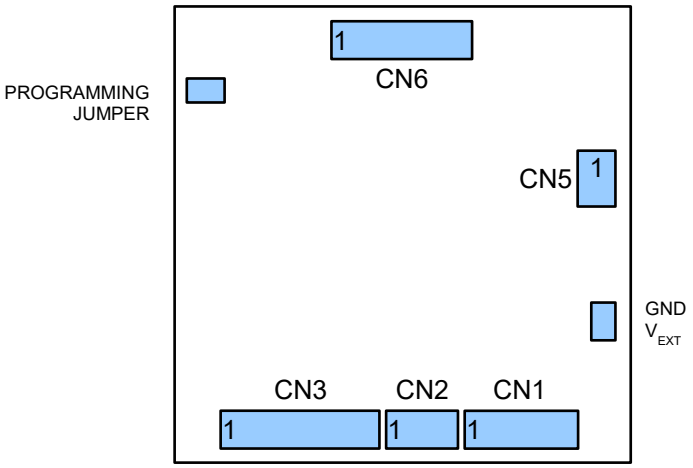
The drive is also available not integrated with the motor, with the electronic board alone without the encoder. In such case the motor code is 5A and the maximum output drive current is limited to 5 A_{Pk}.

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

Type	Rated input voltage	Integrated absolute encoder	Digital I/O	RS-232	RS-485	CANopen
FD1.6	20 – 80 V_{DC}	✓	✓	✓	✓	
FD1.6A		✓	✓	✓	✓	✓
FD1.6Z		✓	IN3 only	✓		✓
B = aluminum cover (included in FD1.6Z)						

Several cables, Kxx, are available depending on selected interface. Refer to cable datasheet.

6. INTERFACES



1	CAN H
2	CAN L
3	GND
4	RS-485 +
5	RS-485 -

1	TxD232
2	GND
3	RxD232

1	COM
2	IN2
3	IN3
4	IN4
5	IN5
6	OUT6
7	OUT7
8	V_{EXT}

1	V_{POW}
2	GND

1	A
2	A*
3	B
4	B*

CN1 **CAN, RS-485**	CN2 **RS-232**	CN3 **I/O**	CN5 **Power input**	CN6 **Motor output**
JST connectors			Phoenix PCB connector	JST connectors
PHR-5	PHR-3	PHR-8		EHR-4
JST crimp contacts			PT 1,5/ 2-PH-3,5	JST crimp contacts
SPH-002T-P0.5S	SPH-002T-P0.5S	SPH-002T-P0.5S		SEH-001T-P0.6

Note:
FD1.6 logic and the fieldbus communications can be supplied from V_{EXT} when V_{POW} is off, e.g. in case of emergency shut down. In this way the multi-turn absolute encoder position is not lost.

Both V_{EXT} and V_{POW} are internally referred to the same GND (CN5.2), for this reason the two GND of V_{EXT} and V_{POW} supplies shall be externally connected together.

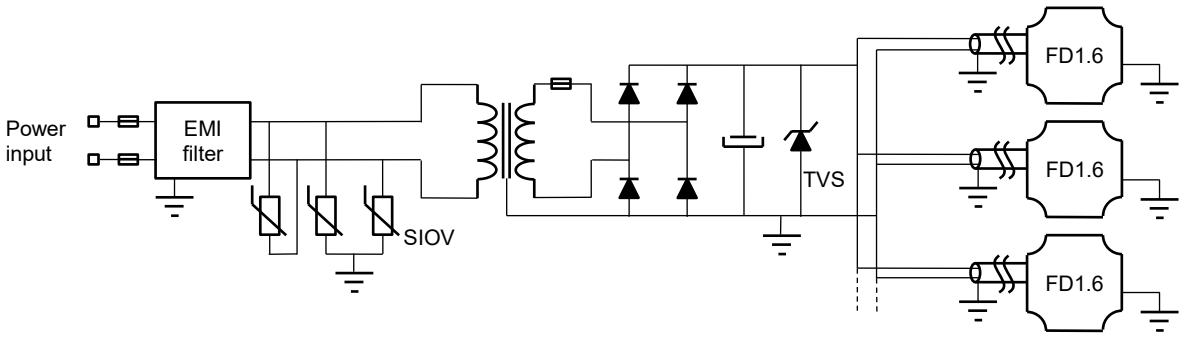
CN6 connector is used only in version 5A.

7. POWER SUPPLIES

7.1. Power DC Bus – V_{POW}

FD1.6 needs to be powered with DC voltage in the range 20 - 80 V_{DC}.

When the transformer / 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 V_{POW}) 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.

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 in the range of 470 – 1000 µF per drive is recommended.

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 70 V_{DC} maximum power supply, model 1.5KE75A can be used.

Connections:
Do not place any fuse on GND lines to drives. Fuses can be installed only on V+ wires or on AC lines.
Do not place any fuse between the capacitor and the drives.
Cable shields need to be earthed on both sides (it is already connected to the case inside the FD1.6B). 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).

It is possible to use a switching power supply instead of transformer / rectifier power supply, provided that sufficient capacitance is installed on the output line and that the device provides sufficient EMC protection.

7.2. Logic power supply – V_{EXT}

On FD1.5 drive version V_{EXT} supplies the two outputs only, while on FD1.6 V_{EXT} can supply also the microprocessor, the encoder and field bus in case of loss of DC bus power supply, V_{POW}. For this reason, in case of emergency shut-down, it is possible to keep the logic supplied, with the benefit of maintaining the multi-turn position and communication active.

Parameter	Range			Unit
	Min	Tip	Max	
Logic voltage, V_{EXT}	11	24	30	V_{DC}
	(40 V peak)			
Current absorption (outputs and fieldbus off)		22 (V_{EXT} = 24 V)		mA

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8. I/O ELECTRICAL CHARACTERISTICS

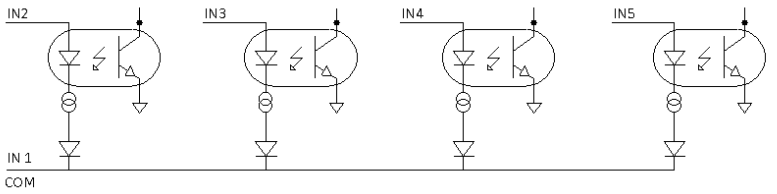
Inputs are opto-isolated PNP type. Transmitter GND shall be connected to COM (CN3.1).

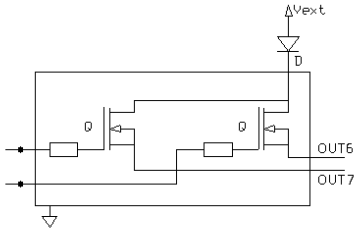
Inputs are equipped with current limiter (max 3.5 mA), they are suitable for low level (5 V) and high level (12-24 V) signals. Commutation threshold is at 2 V.

Because of high speed opto-isolator (10 Mbit) with output filter of 0.5 µsec, precaution to avoid disturbances are needed, especially when inputs are configured as step / direction or quadrature steps. Use of shielded cable is highly recommended. Other configuration of inputs are software filtered.

Outputs are PNP type not opto-isolated. It is necessary to connect receiver GND to FD1 GND on receiver side (do not use the same GND of input signals to avoid disturbances).

Parameter	**Symbol**	**Rating**
Maximum input voltage	V_{MAX}	30 V (40 V peak)
Maximum input current	I_{MAX}	3.5 mA
Low level max input volt.	V_{IL-MAX}	1.5 V
High level min input volt.	V_{IH-MIN}	2.5 V
Low level max input curr.	I_{L-MAX}	0.5 mA
High level min input curr.	I_{H-MIN}	1.5 mA
Minimum duration of step input frequency	T_{MIN}	2.5 µsec
Direction input set-up duration	$T_{DIR-SETUP}$	100 µsec *Note: anticipate the change of direction of 100 µsec in respect to the first clock*
Maximum output voltage	$V_{EXT-MAX}$	30 V (40 V peak)
Maximum output current	$I_{OUT-MAX}$	1 A *Note: outputs are 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.*





9. MOTOR CURRENT SETTINGS

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

To avoid unwanted heat dissipation some firmware versions (V1, V5 and V8) implement motor torque control, which reduce 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.

V1 control firmware implements a current regulation from 50% till 150% of the maximum current configured.
To protect the drive and the motor an I^2t protection (thermal model of the motor) is implemented, which disables the drive when the motor heats up over safety conditions.
The drive is also disabled if the load torque is so high that the 150% of current is not sufficient to execute the ordered steps (step-loss alarm).

V3 control firmware implements just current reduction when the motor is stopped and step loss detection.

V5 and V8 regulates motor current in a configurable range of current (programmable minimum and maximum current) and they 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 this case 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 V5 and V8 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.

10. DIAGNOSTIC

Meaning	LED's	Registers
Drive ok	Red LED off Green LED blinking 5 Hz communication ON 0.5 Hz communication OFF	ERR_FAT = 0
In application programming	Red LED and green led blinking alternatively 5 Hz communication ON 0.5 Hz communication OFF	ERR_FAT = 0 Status Word, bit 18 high
Step loss Step accumulation limit	Red LED steady lit Green LED as drive ok	ERR_FAT = 1
Over temperature *V1 modelled as I^2t* *V3, V5, V8 over 100 °C*	Red LED blinking at 5 Hz Green LED as drive ok	ERR_FAT = 2
Short circuit	Red LED blinking at 0,5 Hz Green LED as drive ok	ERR_FAT = 3
Over voltage	Red LED steady lit Green LED steady lit	ERR_FAT = 4
Programmed data error	Red LED and green led blinking together at 5 Hz	ERR_FAT = 5
Under voltage	Red LED blinking at 0,33 Hz (33% on, 67% off) Green LED as drive ok	ERR_FAT = 7
Encoder warning	Red LED off Green LED blinking at 0,25 Hz	ERR_FAT = 0 ENC_STATUS != 0