FD3.1 (A), (E), (R), (D), (G)
FD3.2 (S), (E), (R), (G), (C), (B)

Full digital microstep stepper motor driver
Hardware manual

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06/10/2016 update	13/05/2019 update "B"vers.
02/02/2017 update	14/02/2020 Err open

1. DESCRIPTION

Fig. 1 - FD3.2RS

FD3.1 and FD3.2 belong to full-digital microstep stepper motor driver family. 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.

It can be controlled by digital I/O's such as the traditional step/dir signals or start/stop of selected movements and by fieldbuses (Modbus RTU and CANopen).

Many hardware versions are available, tailor-made for the most of application needs.
FD3.1 is the hardware code of the models equipped with field-busses, which, in addition to 6 opto-insulated inputs, 2 digital outputs and 1 analogic input, implement Modbus RTU on RS-232 and on opto-insulated RS-485 (model FD3.1).
Models with the suffix A, i.e. FD3.1A, implements also opto-insulated CANopen.
Models with the suffix E implements incremental encoder input and 5 V output power supply for the encoder itself.

FD3.2S is equipped with I/O and RS-232 (this model is conceived for working in step/dir or by cycles and sequences, i.e. movements that can be programmed in flash from RS-232 and selected, started and stopped using I/O).
FD3.2 is the hardware code for the model working only in step/dir.

All the models can be equipped with motor phases short circuit relays, suffix R, which works as a brake in case of loss of power supply.
All the FD3.1 models can be equipped with an optional DC/DC opto-insulated, which can keep the communication and the position active in case of main power supply loss, suffix D.
Normally IN5 is programmed as "disable current". It is also available the version with IN5 programmed as "enable current", suffix C.
Suffix G identifies the models equipped with DIN rail mounting hook.

Model	Power supply voltage	Digital I/O	RS-232	RS-485	Analog IN
FD3.1	24 – 115 V_{AC}	✓	✓	✓	✓
FD3.2	30 – 165 V_{DC}	✓	"S" only		"B" only
A = CANopen	R = relays	E = external encoder input		C = IN5 Enable Current	
D = DC/DC	S = RS-232	G = DIN rail mounting hook		B = Analog IN	

Tab. 1 – Hardware codes and suffix

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 FD3.x are basic drive module, BDM (EN 61800-3), which 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. Electrocution: because of 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. Cabling connections and current set-up using DIP switches shall be made when the drive is off.

i. IP20 protection implies that the drive shall be installed inside enclosures in compliance with the rules and regulations specific for the application.

j. The equipment which mounts FD3 shall be equipped with external protective systems, which are not based on the correct functioning of the device.

a. 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.

b. 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 safety.

k. Digital inputs, outputs, RS-485 and CAN are optically insulated from the power circuit.

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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:

- The drive shall be installed inside a cabinet or enclosure with EMC shielding walls.
- The connection drive-motor shall be made using shielded cable. The shield shall be connected on both sides, the motor PE and the drive pin J2.5, using as short as possible path.
- Install an electronic filter (FINMOTOR: FIN 40.005.F or equivalent) nearby the drive. The solution of a single filter at the entrance of machine power input is also possible. In this case, the machine cabling shall be made to avoid coupling between power and low signals.
- Transformer shall be double insulated type. Connect transformer shield to PE.
- Earthing (PE) connections shall be made as short as possible, with a line having a low high-frequencies impedance.
- 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.

FD3 drives are BDM, 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.

4. ELECTRICAL CHARACTERISTICS

Parameter	Range			Unit
	Min	Typ	Max	
Power supply voltage	24		115	V_{AC}
	30		165	V_{DC}
	Note: the maximum rectified voltage is 180 V_{DC}			
Power supply current			6	Amp
	Note: depends upon power supply voltage, configured motor current, speed and load			
Peak motor current	500		12 000	mA_P/phase
	Note: it can be configured via DIP switches. On FD3.1 and FD3.2S it can also be programmed via field-bus.			
Mode (position resolution)	400	12 800	204 800	step/rev
	Note: it can be configured via DIP switches. On FD3.1 and FD3.2S it can also be programmed via field-bus using numerator and denominator.			
Compatible stepper motor inductance	0.5		15	mH
	Note: bi-phase motors 4, 6 and 8 wires			
Dimension		150h x 44l x 99d		[mm]
Ambient temperature	5		45	°C
	Note: over-temperature alarm at 100 °C			
International Protection	IP 20			

Tab. 2 – Electrical characteristics

5. INTERFACES

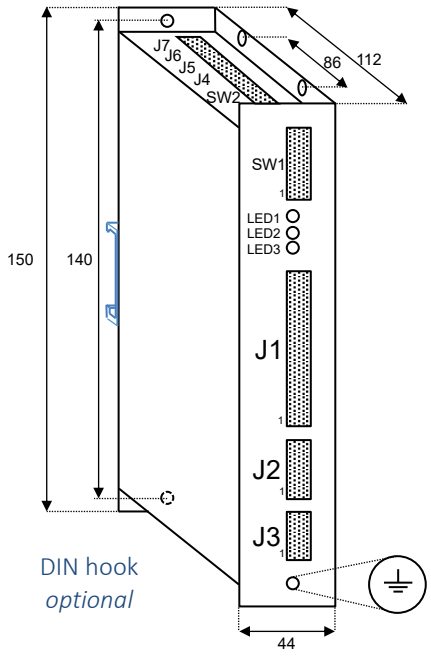

Fig. 2 – Intefaces

1	IN1/2 *Step*	3 – 24 V_{STEP}
2		0 V_{STEP}
3	IN3/4 *Dir*	3 – 24 V_{DIR}
4		0 V_{DIR}
5	IN5 *Dis. curr.*	24 V_{EXT}
6	IN6 *Dis. freq.*	24 V_{EXT}
7	IN7	24 V_{EXT}
8	IN8	24 V_{EXT}
9	OUT9 *Drive ok*	0- V_{EXT}
10	OUT10 *Running*	0- V_{EXT}
11	V_{EXT}	5 – 35 V_{DC} (24 V_{DC} typ.)
12	0 V_{EXT}	0 V di IN5, IN6, IN7, IN8, OUT9 e OUT10

J1
I/O

Input configuration valid for FD3.2 (step/dir). All other model versions have configurable inputs: refer to firmware description.

1	A
2	A*
3	B
4	B*
5	GND (shield)

J2
Motor output

1	24- 115 V_{AC}
2	24- 115 V_{AC}
3	Power 0 V

J3
Power input

"Power 0 V" is the 0 V of the rectified AC input voltage. When more drives are connected in parallel on the same AC line, connect "Power 0 V" of only one drive to PE.

1	TxD232
2	Power 0V
3	RxD232

J4
RS-232

Not mounted on FD3.2 (step/dir). Mounted on all FD3.1 models and FD3.2S.

1	A
2	A*
3	B
4	B*
5	5 V_{EXT}
6	0 V_{EXT}

J5
Encoder

Mounted on E models

1	CAN H
2	CAN L
3	0 V_{EXT}
4	RS-485 +
5	RS-485-

J6
RS-485 / CAN

RS-485 and CAN not mounted on FD3.2 models. RS-485 mounted on all FD3.1 models. CAN mounted only on FD3.1A model.

1	12 V_{POWER} (2.2 kΩ out)
2	In analogic
3	Power 0V

J7
Analogic input

Refer to firmware description

Note:
V_{EXT} is the power supply of IN5,…, IN8, OUT9, OUT10, RS-485 and CANopen buses. Its ground is separated from power circuitry, V_{POW}. Since the microprocessor is powered from the power circuitry, in case of loss of V_{POW} the communication stops. If it is necessary to keep alive the communication when V_{POW} is off, the model FD3.1D is equipped with insulated DC/DC converter, which powers the microprocessor from external V_{EXT}. This allows also the multi-turn position retention in case of loss of power.

DIP switch 2.2 is used for User Flash Program mode (bolt symbol button on DwLoader), i.e. when active during drive power-on it allows the drive to enter in booting mode and being reprogrammed via RS-232. No DIP switch activation is needed when in-application-programming (IAP) method is used. IAP can be performed over RS-232, RS-485 and CANopen.

6. INPUTS / OUTPUTS ELECTRICAL CHARACTERISTICS

Inputs and outputs are opto-insulated PNP type.

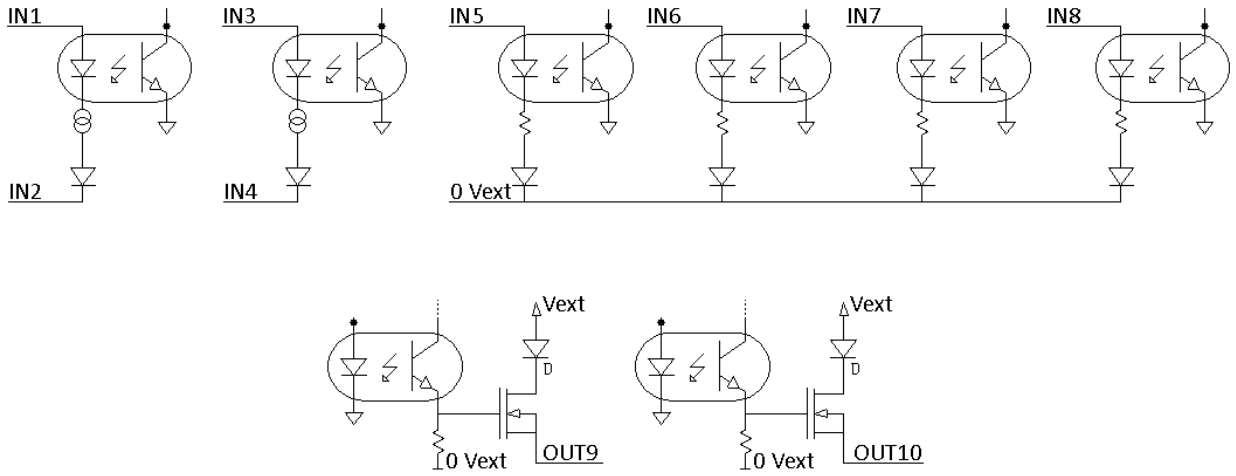

Fig. 3 I/O simplified circuit

IN1/2 step and IN3/4 direction are fast differential inputs (10 Mbps opto-insulator), equipped with current limiter (maximum 3.5 mA) to be suitable for low level signals (5 V) as well as per high level signals (12 – 24 V).
Threshold is at 2 V. Being so fast inputs it is necessary to implement precautions to avoid disturbances, e.g. shielded cable. When IN1/2 is used as step input, it is digitally filtered (8 samples at 9 MHz). When IN1/2 and IN3/4 are configured for other functions such as start, stop or cycle selection a software filtering is implemented.

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	

Tab. 3 – IN1/2 and IN3/4 characteristics

The other four inputs are 24 V type, software filtered. Their 0 V is the 0V of V_{EXT} and their threshold is about 5 V.

Outputs, PNP type, are powered from V_{EXT}. Typically V_{EXT} is 24 V, but if necessary, the outputs work also with V_{EXT} = 5 V.

Parameter	Symbol	Rating
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 VND5160J datasheet.	
Output mosfet resistance	$R_{DS-ON-OUT}$	160 mΩ
Maximum commutation energy		33 mJ
	Note: ref. to datasheet VND5160J.	

Tab. 4 – OUT9 and OUT10 characteristics

7. MOTOR CURRENT SETTINGS

On FD3.2 models, use DIP switches 1.2, 1.3 and 1.4 to set the "maximum motor current". 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.

To avoid unwanted heat dissipation motor current is automatically reduced at the value "minimum motor current" when motor is stopped. On FD3.2 models, use DIP switch 1.1 to set "minimum motor current" at 50 % or 25 % of "maximum motor current".

1	Reduction current
off	I_{MIN} = 50 % I_{MAX}
on	I_{MIN} = 25 % I_{MAX}

Tab. 5 – Automatic current reduction

2	3	4	Current [A]
off	off	off	3
off	off	on	4
off	on	off	5
off	on	on	6
on	off	off	7.5
on	off	on	9
on	on	off	10.5
on	on	on	12

Tab. 6 – Maximum motor current

On FD3.1 models, minimum and maximum current are programmable on the flash memory and modifiable via field-bus. DIP switches 1.x are used to set the network address of the node.

Note:
Heating transfer from the drive to the ambient takes place via natural convection. The heat generation depends upon current settings, duty cycle and power supply. If high currents are used and cabinet temperature reaches high values, it is recommended to verify the temperature of FD3 aluminium cover on working conditions. Its value shall not exceed 80 °C. If the temperature exceeds such limit, it is recommended to increase the heat transfer surface or to adopt fans inside the enclosure to circulate the air. All the drives are internally over-temperature protected. The on-line temperature value can be monitored via fieldbuses.

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8. MODE – POSITION RESOLUTION (STEP/REV)

5	6	7	8	step/rev
off	off	off	off	400
off	off	off	on	500
off	off	on	off	800
off	off	on	on	1000
off	on	off	off	1600
off	on	off	on	2000
off	on	on	off	3200
off	on	on	on	4000
on	off	off	off	6400
on	off	off	on	8000
on	off	on	off	10000
on	off	on	on	12800
on	on	off	off	Quad. 800
on	on	off	on	Quad. 1600
on	on	on	off	Quad. 3200
on	on	on	on	Quad. 12800

Tab. 7 – Mode Settings

Use DIP switches 1.5, 1.6, 1.7 and 1,8 to set the ordered steps per revolution (when 1.8° motors are used).
The first twelve switch combinations of table 7 configures IN1/2 and IN3/4 as step and direction respectively.
Last four combinations configures IN1/2 and IN3/4 to receive quadrature steps input, like for instance when the drive shall follow an incremental encoder signal type. The drive evaluate all the signal edges (x4), i.e. for a 400 step/rev encoder Mode = Quad. 1600 step/rev.
FD3.1 and FD3.2S have programmable resolution via two parameters: resolution numerator and resolution denominator. The resulting step/rev is given from the formula:

$$\text{Resolution} = \frac{50 \cdot \text{Res}_{NUM}}{\text{Res}_{DEN}} \left[\frac{\text{step}}{\text{rev}}\right]$$

Higher resolution values allows smoother motor motion at low speeds.

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9. DIAGNOSTIC

FD3 is equipped with three inline LEDs on the front view: two greens- LED1 on top, LED2 in the middle- and one red- LED3 in the bottom.

Meaning	LED's	Registers
Drive ok	Green LED1 blinking: - 5 Hz communication ON - 0.5 Hz communication OFF Green LED2: - OFF, motor stopped - blinking, motor running towards increasing position - steady ON, motor running towards decreasing positions Red LED3 OFF	ERR_FAT = 0
User flash program (DIP switch 2.2 ON)	All LEDs are OFF	
In application programming (entered into programming mode)	Green LED1 and Red LED3 blinking alternatively: - 5 Hz communication ON - 0.5 Hz communication OFF	ERR_FAT = 0 Status Word, bit 18 high
Step loss (applicable to E models only)	Green LED1 as drive ok Green LED2 OFF Red LED3 steady lit	ERR_FAT = 1
Over temperature (100 °C)	Green LED1 as drive ok Green LED2 OFF Red LED3 blinking at 5 Hz	ERR_FAT = 2
Short circuit	Green LED1 as drive ok Green LED2 OFF Red LED3 blinking at 0,5 Hz	ERR_FAT = 3
Over voltage	Green LED1 steady lit Green LED2 OFF Red LED3 steady lit	ERR_FAT = 4
Programmed data error	Green LED1 and red LED3 blinking together at 5 Hz Green LED2 OFF	ERR_FAT = 5
Open motor cable	Green LED1 and red LED3 blinking together at 0,5 Hz	ERR_FAT = 6
Under voltage	Green LED1 as drive ok Green LED2 off Red LED3 blinking at 0,33 Hz (33% ON, 67% OFF)	ERR_FAT = 7

Tab. 8 – Front panel LEDs diagnostic

Note:
When programming the drive by DIP switch 2.2, user flash program method, when restarting the drive after reprogramming, wait one minute, in order to discharge the internal capacitor, before powering back on.