FD2.1
FD2.2

Integrated stepper motor driver
Hardware manual

23/03/2015 mod	09/01/2017 Power supply added	19/12/2018 FD2.1Z
19/06/2015 mod	26/05/2017 Scheme updated	
21/05/2016 mod	10/07/2017 Diagnostic	
01/09/2016 CN3/9 changed with CN3/10.	18/12/2017 Temp, I/O scheme	

1. DESCRIPTION

FD2.1 and FD2.2 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 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.

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.

All FD2 models are equipped with configurable I/O's (6 inputs and 2 outputs), which can be used as step, direction, quadrature steps, homing sensor, alarm, start, stop, etc. plus transceiver RS-232 (from 4 800 up to 115 200 bps).
FD2.1 and FD2.1A are equipped also with transceiver RS-485 for Modbus communication (from 4 800 up to 921 600 bps), while only FD2.1A is equipped with CAN transceiver. CANopen protocol is implemented (from 10 kHz up to 1 MHz).
RS-485 and CAN are opto-insulated from the power circuitry, supplied from external 24 V_{DC}.

Fig. 1 - FD2.1 applied on NEMA 34 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 FD2 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 FD2 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, 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:

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.

FD2 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		130	V_{DC}
	Note: minimum power supply output capacitor 1000 µF			
Supply current			6	A
	Note: depends upon power supply voltage, configured motor current, speed and load			
Motor current	500		10 000	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	86 x 99 x 25 mm + motor			
Ambient temperature	0		45	°C
IP	40			

5. CODING

The product code is given in below format:

FD2.1 — **Full Digital**

A

Hardware version	
A	CANopen
D	DC/DC
Z	Under-mounted

-

1404

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

+

KA

Cable
KA
KB
KC
...

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	Analog I/O
FD2.1	24 – 130 V_{DC}	✓	✓	✓	✓	✓
FD2.2		✓	✓	✓		✓
FD2.1Z		✓	IN5, IN6	✓		
A = CANopen (only applicable to FD2.1) D = DC/DC to supply the logic from V_{EXT} when V_{POW} is off Z = under-mounted version with CANopen, RS-232, DC/DC and 2 digital inputs only						

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

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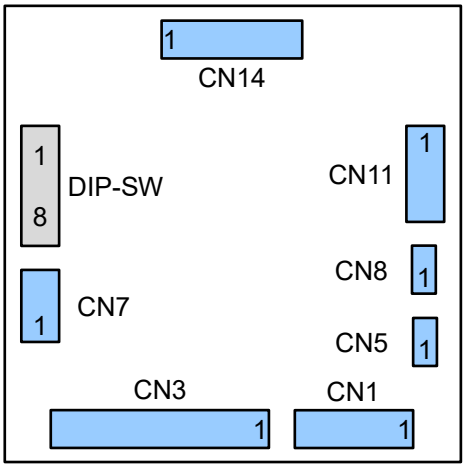
6. INTERFACES



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

CN1
CAN, RS-485

HW versions:
FD2.2 is not equipped with RS-485 and CAN transceivers.
Only FD2.1A is equipped with CAN transceiver.

Phoenix
PT1,5/5-PH-3,5

1	TxD232
2	GND
3	RxD232

CN7
RS-232

Phoenix
PT1,5/3-PH-3,5

1	12 V_{OUT} 2K2Ω out
2	INA
3	GND

CN8
Analogic input

JST
B3B-PH

1	0V V_{EXT}
2	V_{EXT}

CN5
Fan power supply
optional

1	IN1/2 (Step, ...)	3 – 24 V
2	0 V IN1/2	
3	IN3/4 (Dir, ...)	3 – 24 V
4	0 V IN3/4	
5	IN5	24 V
6	IN6	24 V
7	IN7	24 V
8	IN8	24 V
9	OUT9 (Drive ok)	
10	OUT10	
11	V_{EXT}	5 – 35 V (24V typ.)
12	0 V V_{EXT}	0 V IN5 ... IN8

CN3
I/O

Phoenix
PT1,5/12-PH-3,5

1	V_{POW}
2	V_{POW}
3	GND
4	GND

CN11
Power input

Connect in parallel V_{SUPPLY} and GND

Phoenix
PT1,5/4-PH-3,5

1	A
2	A*
3	B
4	B*

CN14
Motor output
optional

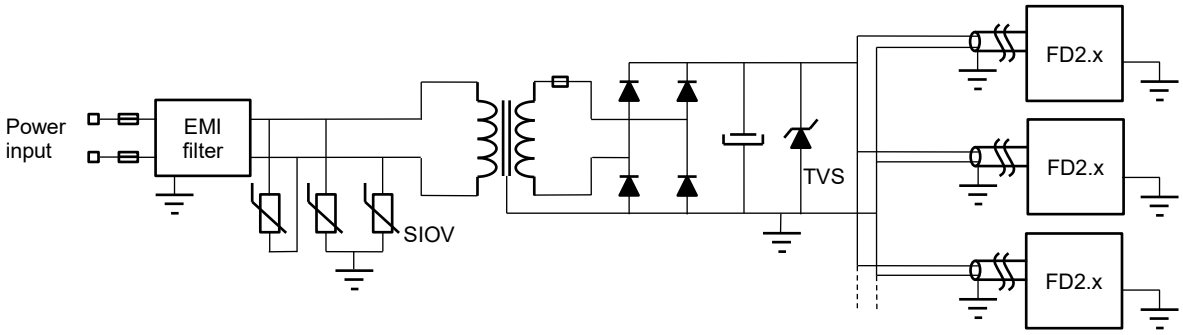
Notes:
It is recommended to install an external capacitor in parallel to V_{POW} to accumulate the reactive energy of the motor. The size depends upon motor, voltage and application. Typically 1 000 µF are considered sufficient. Maximum current for pin is 8 A (5 A @ 90 °C). It is suggested to use two pins of CN11 for the capacitor, only if the current absorption is less than 5 A, in other words if the power supply voltage is high enough and required power is limited.

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 FD2.1AD 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.

7. POWER SUPPLY

FD2 needs to be powered with DC voltage in the range 24 - 130 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 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.

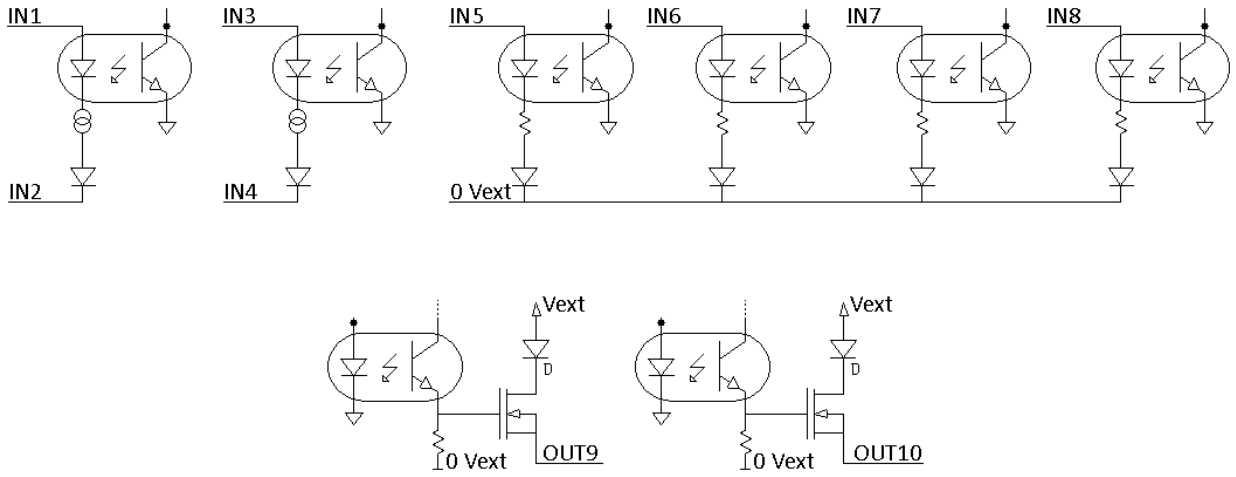
TVS:
Using unidirectional TVS as additional protective measure on the DC voltage increases the system reliability. The model needs to be chosen based on the DC voltage applied and on the power of the over-voltage that needs to be sustained. Using many TVS in parallel increases their protective capabilities. E.g. working with 78 V_{DC} power supply, model 1.5KE82A 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).

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.

8. INPUTS / OUTPUTS ELECTRICAL CHARACTERISTICS

Inputs and outputs are opto-insulated PNP type.



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 these inputs 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. 1 – 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.

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

Tab. 2 – OUT9 and OUT10 characteristics

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 FD2 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

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