FD1.6C(W)
FD1.6AC(W)

Integrated stepper motor driver
Hardware manual

06/09/2023 First edition

1. DESCRIPTION

FD1.6C and FD1.6AC belongs to FD family drives, which are designed in a compact solution to be mounted directly on motor end-shield.

The FD drives are controlled by a 72 MHz ARM microcontroller, equipped with very low RDS-on MOSFETs and Hall effect current sensors to optimize energy efficiency.

They differ from model FD1.6 for the interface thought of M12 connectors, instead of cable glands.

As described in detail in firmware manual, FD1.6C and FD1.6AC, can operate in four modes:

- Step/dir o quadrature steps A/B
- Cycle selection – or sequence of cycles – by digital combination of logic inputs and start/stop commands
- Parametrization and control by Modbus RTU over RS-485
- CANopen (profile position mode, homing mode, profile velocity mode, interpolated position mode)

FD1.6C identifies the hardware code of the Modbus RTU model (from 4˙800 to 921˙600 bps), FD1.6AC identifies the CANopen model (from 10 kHz to 1 MHz). The appearance of the two models is identical, they differ only in the functionality of the two fieldbus connectors. The presence of two connectors allows daisy-chain connection.

Fig. 1 – FD1.6CW applied to NEMA 24 motor

Both drives are equipped with 12-bit absolute single turn magnetic encoder, to verify the correct execution of the ordered steps and to modulate the motor current with the applied load, as well as other functions described in detail in the firmware manual.

FD1.6C and FD1.6AC are equipped with configurable I/O (4 inputs and 2 outputs), which can be configured as step, direction, quadrature step, limit switch, homing sensor, disable current, start, stop, cycle selection, etc.
They are also equipped with RS-232 serial port (from 4˙800 to 115˙200 bps) for PC connection (via DwLoader software tool).

Standard versions are protected IP50, while “W” versions are protected IP65. Obviously to obtain an IP65 drive motor assembly, an IP65 motor must be selected

2. RISKS AND PRECAUTIONS

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 power 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 instructions 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 are insulated from the rest of the circuit (opto-insulator is approved IEC/EN/DIN EN 60747-5-2, *reinforced insulation* approved).
Output terminals and serial lines are NOT electrically separated from internal power voltage. Those terminals 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.

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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 double insulated 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 it could be difficult to satisfy 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 the drive with control system.

4. ELECTRICAL CHARACTERISTICS

Properties		Range			Unit
		Min	Typ	Max	
Power supply voltage V_{POW}		20		80	V_{DC}
		Note: minimum power supply output capacitor 1000 µF			
Power supply current I_{POW}				4	A
		Note: depends upon power supply voltage, configured motor current, speed and load			
Motor current I_{MOT}		500		7 000	mA / phase
		Note: minimum and maximum motor current can be configured			
Angular resolution		400	12˙800	204˙800	µstep / revolution
Stepper motors		Bi-phase; 4, 6 and 8 wires; inductance from 0.5 to 15 mH			
Ingress Protection	FD1.6(A)C	IP50			
	FD1.6(A)CW	IP65			
Ambient temperature		0		45	°C
Dimensions		67 x 67 x 45 + motor length			mm

5. HARDWARE CODES

Complete hardware code is given in below format

FD1.6 ACW - 5L455

Full Digital

Suffix – hardware	
	Modbus RTU
A	CANopen
	IP50
W	IP65
C	Connettori M12

Motore code		
5L455	Moons Nema 24	(IP65)
2231	Ametek Nema23	(IP40)
3426	Ametek Nema34	(IP40)
1404	Moons Nema34	(IP40)
2431	Moons Nema34	(IP40)

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

Model	Rated input voltage	Integrated absolute encoder	Digital I/O	RS-232	RS-485	CANopen
FD1.6C	20 – 80 V_{DC}	✓	✓	✓	✓	
FD1.6AC		✓	✓	✓		✓

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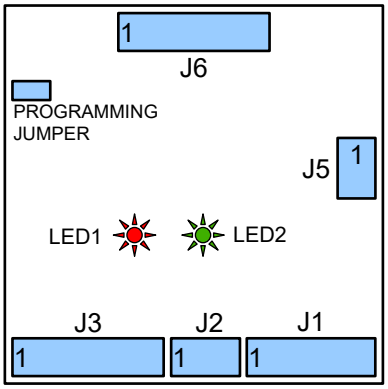
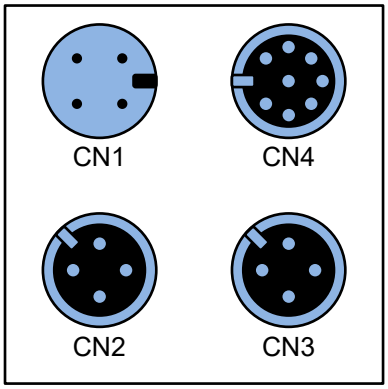
6. INTERFACES



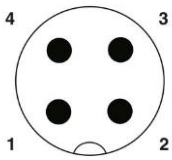
PCB connectors



M12 field connectors

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

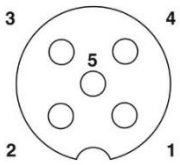
CN1
Power supply



M12, 4 poles, male, A-coded

1	GND
2	V_{EXT}
3	GND
4	485+
5	485-

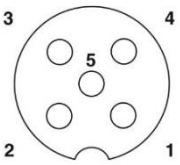
CN2 e CN3
Modbus
FD1.6C



M12, 5 poles, female, A-coded

1	GND
2	V_{EXT}
3	GND
4	CAN H
5	CAN L

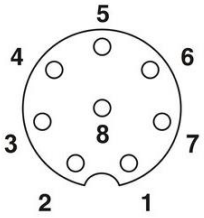
CN2 e CN3
CANopen
FD1.6AC



M12, 5 poles, female, A-coded

1	COM
2	IN1
3	IN2
4	IN3
5	IN4
6	OUT1
7	OUT2
8	V_{EXT}

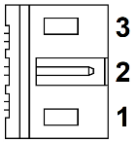
CN4
I/O



M12, 8 poles, female, A-coded

1	TxD232
2	GND
3	RxD232

J2
RS-232

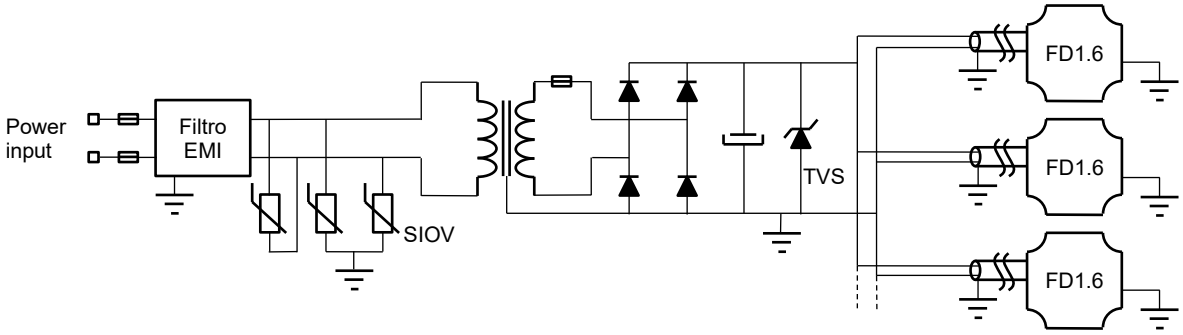


JST-PHR3 (contact SPH-002T-P0.5S)

7. POWER SUPPLIES

7.1. DC bus – V_{POW}

FD1.6(A)C(W) shall 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}

V_{EXT}, in addition to powering the fieldbus and the outputs, also powers the microprocessor and the encoder, in the event of a power supply failure. Therefore, in case of emergency, the power can be removed, while the logic remains powered, with the benefit of maintaining the multi-turn position and communication active (refer to the firmware manual).

V_{EXT} can be connected to pin 8 of CN3 or to pin 2 of CN3 or CN4, i.e., via the fieldbus cable.
If V_{EXT} is connected through CN3:8 it is necessary to

CONNECT EXTERNALLY V_{EXT} GND TO V_{POW} GND.

If powered via fieldbus, connect V_{EXT} to pin 2 and V_{EXT} GND to pin 1 (connected internally to V_{POW} GND).

	Range			Unit
	Min	**Typ**	**Max**	
Logic power supply voltage V_{EXT}	11	24	30 *(40 V peak)*	V_{DC}
Current I_{EXT} (outputs and fieldbuses disabled)		22 (V_{EXT} = 24 V_{DC})		mA

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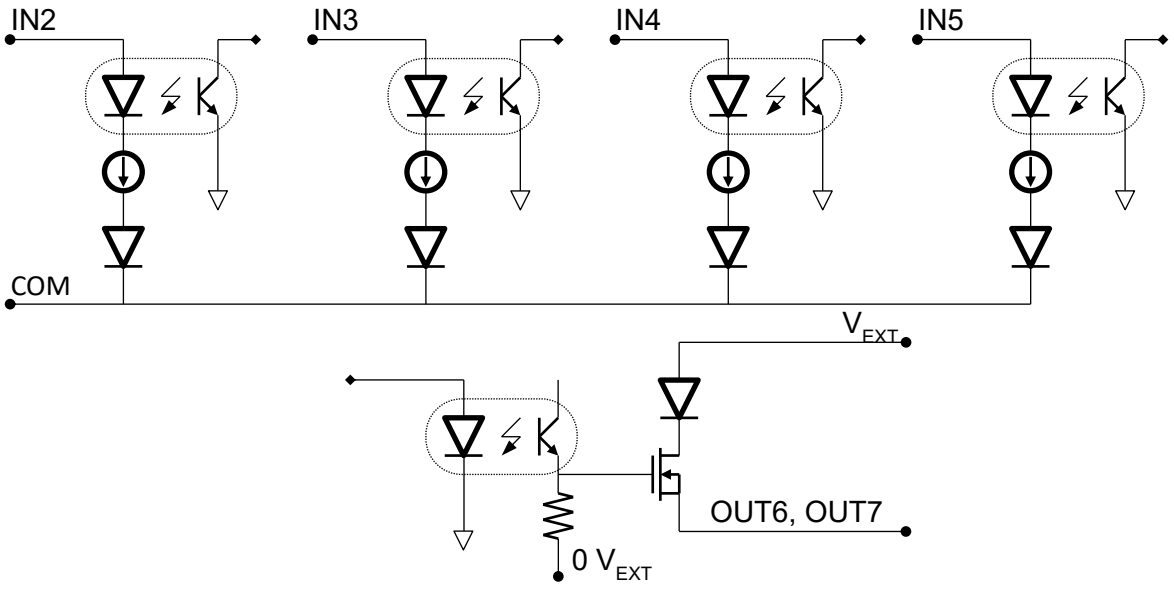
8. I/O ELECTRICAL CHARACTERISTICS

Inputs are opto-isolated PNP type. Transmitter GND shall be connected to COM (CN4:1). COM is the 0 V of the inputs, not to be confused with GND.
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: 2 V.

Because of high speed opto-isolator (10 Mbit) with input hardware filter of 0.5 µs, precaution to avoid disturbances are needed, especially when inputs are configured as step / direction or quadrature steps. Use of shielded cable is highly recommended. The other input configurations, such as Start, stop, etc., are also software filtered.

The PNP type outputs are not opto-isolated.
It is therefore necessary to connect the V_{EXT} GND (the PLC zero volt) to V_{POW} GND (the 0 V of the motor power supply).

Parameter	Symbol	Rating
Maximum input voltage	V_{MAX}	30 V (40 V peak)
Maximum input current	I_{MAX}	3.5 mA
Maximum voltage for low logic level	V_{IL-MAX}	1.5 V_{DC}
Minimum voltage for high logic level	V_{IH-MIN}	2.5 V_{DC}
Maximum current for low logic level	I_{L-MAX}	0.5 mA
Minimum current for high logic level	I_{H-MIN}	1.5 mA
Minimum time width of step signal	T_{MIN}	2.5 µsec
Minimum set-up time of direction input signal	$T_{DIR-SETUP}$	100 µsec *Note: the inversion of direction signal shall take place 100 µs before the first edge of step signal*
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.*
MOSFET resistance	$R_{DS-ON-OUT}$	160 mΩ
Maximum commutation energy		33 mJ *Note: ref. to VND5160J datasheet.*



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 I2t 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 implement the step accumulation function.
This feature provides significant 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 and green LED's 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 same as drive ok	ERR_FAT = 1
Over temperature *V1 modellata come I^2t* *V3, V5, V8 oltre i 100 °C*	Red LED blinking at 5 Hz Green LED same as drive ok	ERR_FAT = 2
Short circuit	Red LED blinking at 0.5 Hz Green LED same 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
Mancanza alimentazione di potenza (V_{EXT} presente)	Short red LED blink every 3 seconds (0.33 Hz, 33% on, 67% off) Green LED same as drive ok	ERR_FAT = 7
Encoder warning	Red LED off Short green LED blink every 4 seconds (0.25 Hz)	ERR_FAT = 0 ENC_STATUS != 0

11. FLASH PROGRAM

As described in the firmware manual, the user can program firmware and/or parameters (such as acceleration, type, speed and memory space of cycles/sequences) from a PC, through the DwLoader. From DwLoader user can also monitor the real-time data while the motor is moving.

In order to connect the PC to the drive a USB to RS-232 converter and a cable with PHR-3 connector are needed.

Opening the rear cover, connect to connector J2, select firmware and/or parameters and click IAP (In Application Programming over Modbus).

If you wish to modify few parameters, it is advisable to perform an upload of the parameters first, then modify the specific parameters. By selecting the checkbox parameters and by clicking IAP, parameters will be transferred to the drive and saved into flash.
It is also possible to connect the PC to one of the two connectors CN2 or CN3.
With FD1C a USB to RS-485 converter (half duplex setting) is needed.
With FD1AC a USB to CAN converter by IXXAT is required (USB-to-CAN V2 with VCI drivers).
In both cases, the node address and baud rate of the device on the DwLoader (the address is not needed with RS-232).

If the communication program on board the drive has been mis-programmed (power off during programming or other possible faults), it is always possible to bring it back to factory conditions from RS-232 by clicking on User Flash Program (bolt symbol push button on DwLoader). The procedure is as follows:

1. Turn off both the V_{POW} and V_{EXT}
2. Insert the programming jumper
3. Turn on power and/or V_{EXT} (green LED is off in programming mode)
4. Click the bolt push button on DwLoader (this overwrites both the firmware and the parameters)
5. Turn off, remove the programming jumper and turn on again (the green LED must flash).

By clicking on Modbus a second window opens from which it is possible to monitor operation, give commands and program parameters, cycles, sequences in RAM.