FD1.1EC
FD1.2EC

Integrated stepper motor driver
Hardware manual

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25/06/2024 CN2, CN3 pinout
19/09/2024 FD1.2EC

1. DESCRIPTION

FD1.1EC and FD1.2EC, part of the FD family of drives, boast a compact design tailored for direct mounting on motor end-shields. These drives are powered by ARM-based microcontrollers, utilizing ultra-low $R_{DS\text{-}on}$ MOSFETs and Hall-effect current sensors to enhance power efficiency significantly.

FD1.1EC and FD1.2EC are equipped with a 12-bit single-turn magnetic encoder to serve multiple functions: it verifies the execution of ordered steps, it modulates motor current with the load, it allows the accumulation of steps that cannot be executed because of load torque, and more, detailed comprehensively in the firmware manual.

They feature configurable I/Os, offering 4 digital inputs and 2 digital outputs. These ports can serve as step, direction, quadrature steps, homing sensor, alarm, start, stop, torque-off, etc.
Communication occurs via EtherCAT using CoE (CAN over EtherCAT) and FoE protocols through industrial M12 circular connectors. Additionally, a RS-232 port, accessible through one of the screw caps, facilitates firmware programming, parameter adjustment, and real-time monitoring during operation.

Compared to its predecessor, FD1.1E, FD1.1EC and FD1.2EC introduce several enhancements. Its redesigned enclosure accommodates NEMA 34 motors, alongside NEMA 23 and 24. The M12 type connectors, located at the rear, offer additional I/O options. Notably, there's galvanic insulation between power GND and logic GND, ensuring robust electrical separation.

The drive logic is supplied only from external V_{EXT} 24 V_{DC}, which allows to keep communication and multiturn position counting active in case of loss of power. FD1.1EC drive's logic relies solely on an external V_{EXT} 24 V_{DC} supply, while FD1.2EC logic can be supplied by V_{EXT} and by main power supply V_{POW}. This setup guarantees active communication and multiturn position counting even in the event of power loss, enhancing the drive's reliability and operational continuity

Fig. 1 – FD1.1EC applied to 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. **Professional installation:** stepper drives FD1 are basic drive modules, BDM (EN 61800-3), integrated with motors, meant for incorporation into complex industrial equipment by qualified experts. Direct user handling is prohibited. Only skilled assemblers can install and commission these units. They are addressed to limited distribution, and unqualified usage is strictly 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. **Safety functions:** usage for safety-related functions is strictly prohibited. Any configuration where a drive malfunction could create hazardous conditions is not allowed.

c. **Flammable material:** operation in the presence of gas or other flammable substances is strictly prohibited.

d. **Capacitor discharge:** depending on supply type and application specifics (external capacitor, discharging resistor and supply voltage value), sufficient time must elapse after switching off before opening the enclosure. This ensures safe discharge if external capacitors and discharging resistors are present.

e. **Hot surface warning:** allow a cooling-off period of 10 minutes after switching off before touching the equipment to avoid burns.

f. **Power supply:** the drive must not be directly connected to the mains. It should be powered by a supply equipped with transformer mains insulation.

g. **Electromagnetic interference:** improper installation might result in electromagnetic interference. Compliance with the 2014/30/UE directive must be tested on the entire machine under normal working conditions, adhering to specific standards.

h. **External protective systems:** equipment incorporating FD1 must include external protective systems independent of the device's correct functioning.

i. **Unauthorized alteration:** the drive must not be altered, disassembled, or repaired by unauthorized personnel. Dismounting the drive from the motor may lead to malfunction.

j. **Emergency stop:** disable current input signals and internal electronic protections only switch off the drive output power. They cannot substitute for emergency stop functions or other safety measures for personnel.

k. **Galvanic isolation:** digital inputs, outputs, and EtherCAT interfaces are galvanically insulated from the power circuit for enhanced safety.

l. **Motor shaft handling:** exercise caution when tightening front flange screws, as some motor shafts are pulled out by a spring mounted on the rear bearing seat. Make sure the shaft is free to move inside the hub before tightening the flange screws. Improper mounting can cause shaft blocking and damage to the magnetic encoder.

These guidelines are crucial for the safe and effective operation of stepper drives FD1. Adhering to these instructions is essential to prevent accidents and ensure the longevity of the equipment.

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3. ELECTROMAGNETIC COMPATIBILITY (EMC)

The drive, connections, and motor emit electromagnetic interference (EMI) both conducted and radiated. To comply with the EC Electromagnetic Compatibility Directive 2014/30/CE and the standard EN 61800-3, it's essential to follow specific installation guidelines:

- Use shielded cables: utilize only shielded cables and ensure that the cable shield is grounded on both ends.
- Protective earth terminal: connections to the Protective Earth terminal (PE) must be short and have minimal inductance.
- AC main supply entrance filter: place a filter near the AC main supply entrance, i.e., on the transformer's primary side.
- Shielded supply transformer: implement a supply transformer with a metal shield between the primary and secondary winding, connecting this shield to PE.
- Voltage protection: incorporate varistors on the transformer's primary side and transient voltage suppressors (TVS) on the rectified DC voltage to safeguard the drives from over-voltages.

FD1 drives are Basic Drive Module (BDM) integrated with the motor, designed for restricted distribution. Auxind ensures product compatibility in typical usage, providing correct installation guidelines. However, the professional assembler responsible for installation must verify the complete system's EMC compatibility.

While theoretically the drive could function in a floating system without an earth connection, this setup might not detect internal insulation failures, leading to hazardous situations. To prevent this, it's advisable to connect the GND terminal (the V- of rectified voltage) to PE.

Additionally:

- Grounding connections: connect GND terminals to earth and the enclosure metal chassis using low high-frequency impedance lines.
- Chassis earth connection: ensure a robust earth connection among different parts of the chassis where the motor is installed.
- Signal driving: when cable length exceeds 5 meters, opt for buffer type driving signals instead of open collector types.
- Logic compatibility: verify logic compatibility when interfacing the drive with the control system to maintain seamless operation.

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4. ELECTRICAL CHARACTERISTICS

Measurement	Range			Unit
	Min	Typ	Max	
Power supply voltage	24		80	V_{DC}
	Note: minimum power supply output capacitor 470 µF			
Power 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 allowed	Bi-phase; 4, 6 and 8 wires; from 0.5 to 15 mH inductance			
Size	69 x 69 x 45 mm + motor + connectors			
Ambient temperature	0		45	°C
IP	65			
	Note: overall IP depends upon motor selection			

Tab. 1 - Electrical characteristics

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5. CODING

The product code is given in below format:

FD1.1		EC		-	5L45	
Full Digital		**Hardware version**			**Motor code**	
.1	Logic powered from VEXT	E	EtherCAT		5L455	Moons NEMA24 MS24HS5L455A-01
.2	Logic powered from VEXT and VPOW	C	M12 connectors		AL45	Moons NEMA23 ML23HSAL4500-12
					0L46	Moons NEMA34 MS34HD0L4600
						Etc.

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

Type	Rated voltage	Integrated absolute encoder	Digital I/O	RS-232	EtherCAT
FD1.1EC FD1.2EC	24 – 80 V_{DC}	✓	4 DIN, 2 DOUT	✓	✓

Tab. 2 – Hardware versions

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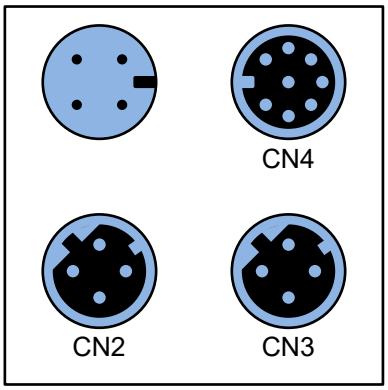
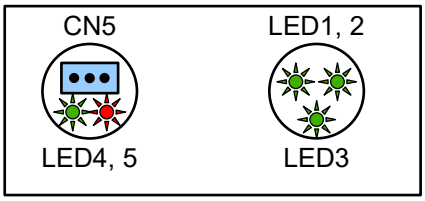
6. INTERFACES

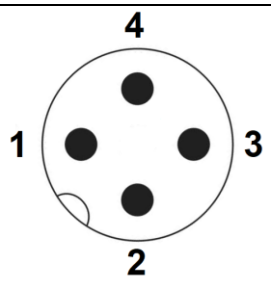
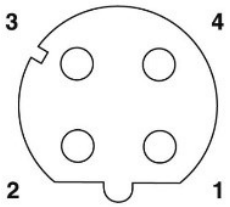
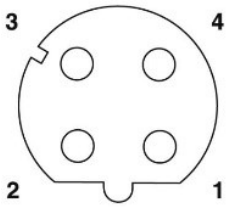
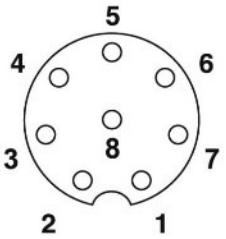
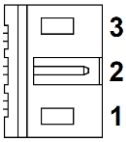


M12 field connectors



LEDs and CN5 connector are installed below screw caps

Fig. 2 – Connectors and LEDs

CN1		CN2		CN3		CN4		CN5	
Power supplies		EtherCAT IN		EtherCAT OUT		Digital I/O		RS-232	
M12, male, 4p A-coded		M12, female, 4p D-coded		M12, female, 4p D-coded		M12, female, 8p A-coded		JST, PHR-3, SPH-002T-P0.5S	
									
1	GND_{POW}	1	Tx+	1	Tx+	1	GND_{EXT}	1	Tx 232
2	GND_{POW}	2	Rx+	2	Rx+	2	IN1	2	GND_{POW}
3	V_{POW}	3	Tx-	3	Tx-	3	IN2	3	Rx 232
4	V_{POW}	4	Rx-	4	Rx-	4	IN3		
						5	IN4		
						6	OUT1		
						7	OUT2		
						8	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, 470 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 only from V_{EXT}. 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.

LED	Meaning
LED1	EtherCAT IN link / activity
LED2	EtherCAT OUT link / activity
LED3	EtherCAT AL status
LED4	Alarm
LED5	Power on

Tab. 4 – LED's meaning

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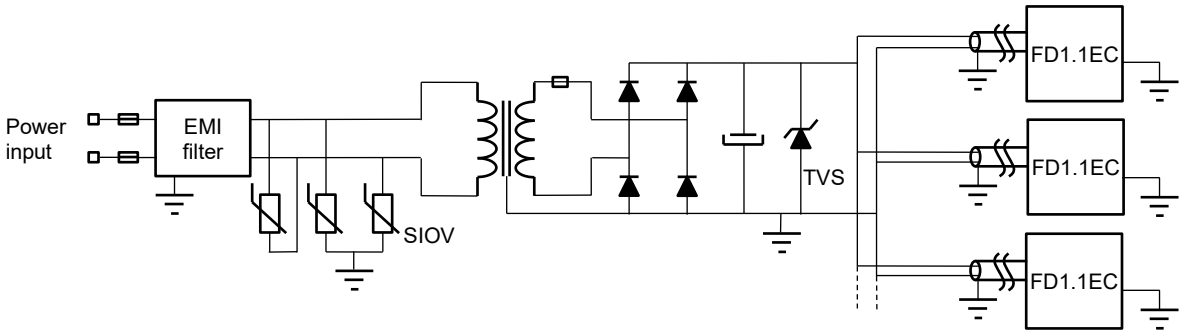
7. POWER SUPPLY

FD1.1EC requires a power supply within the range of 24 to 80 V_{DC}, with an additional 24 V_{DC} needed for logic, bus, and output supply. FD1.2EC logic can be powered by the 24 V_{DC} and by the main power supply 24 to 80 V_{DC}.

Special attention is crucial when employing a switching power supply to energize the DC-bus for the machine drives. The chosen converter must offer robust EMC protection and be capable of handling back-feed power from the motor to the power supply, particularly during rapid decelerations and inertial loads. To prevent over-voltages, the converter's output capacitance should be sufficient. A general guideline is 470 µF for each drive, but the ideal value varies based on motor selection, load inertia, and motor duty-cycle.

Some AC/DC converters available in the market come equipped with an output diode for parallel usage. However, this diode prevents power from flowing back from the motor to the output capacitor, potentially causing hazardous over-voltages during motor deceleration. Despite the drive having over-voltage protection, which halts motor regeneration to prevent dangerous voltage spikes, it is highly recommended to incorporate an external capacitor into the DC bus for added safety.

When opting for a transformer with a rectifier solution, the recommended connection scheme is as follows.

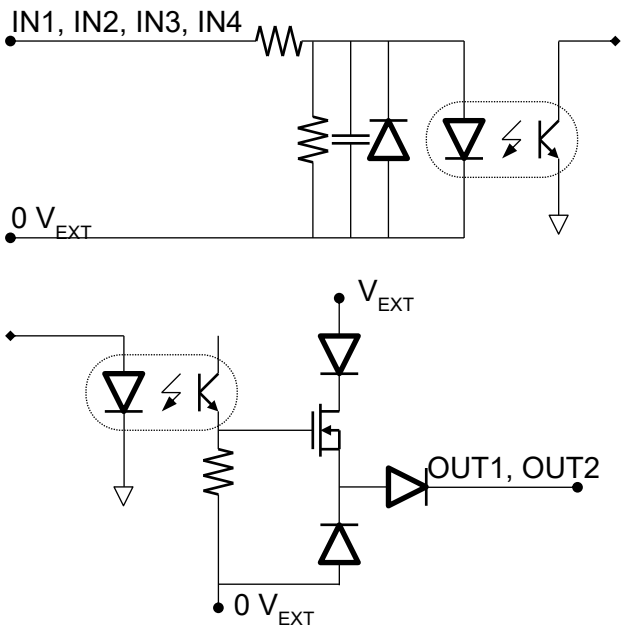


- **EMI filter**: FN2080, Shaffner or any other equivalent.
- **SIOV**: for the 230 V_{AC} incoming line, the recommended choice is B72214S0251K101.
- **Transformer:** the double-insulated transformer must feature an electrostatic shield between the primary and secondary windings, grounded to prevent the transfer of surge or impulse voltages. Primary and secondary wiring should be routed separately, using dedicated trays or conduits.
- **Rectifier bridge:** connect the GND (0V of DC voltage) to earth with a low high-frequency impedance line to ensure proper grounding.
- **Capacitor:** place capacitors within 3 meters from the drive to achieve the following:
  - reduce ripple on the DC voltage due to AC incoming lines rectification.
  - absorb energy regenerated by the motor during deceleration. Consider a discharging resistor in parallel for high capacitance values. A rule of thumb suggests 470 µF per drive; however, the specific value depends on load, deceleration ramps, simultaneity factor, motor specifications, etc.
- **TVS:** integrate unidirectional TVS components as an additional protective measure for the DC voltage system. Choose a model based on the applied DC voltage and the power of over-voltage that needs to be sustained. Enhance protection by using multiple TVS units in parallel. For instance, with a 48 VDC power supply, model 1.5KE56A can be suitable.
- **Connections:**
  - avoid placing fuses on GND lines to the drives. Fuses should only be installed on V+ wires.
  - do not insert fuses between the capacitor and the drives.
  - ensure cable shields are grounded on both ends. Use connections with minimal high-frequency impedance.
  - properly ground the motor. If grounding is done via the chassis, prevent paint between the motor and the chassis and ensure secure connections among chassis components.

Adhering to these guidelines will enhance the reliability and safety of the system.

8. LOGIC SUPPLY AND I/O ELECTRICAL CHARACTERISTICS

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



IN1, IN2, IN3, IN4 are single-ended isolated digital pnp inputs, working at 0-24 V, hardware and software filtered. Their 0 V is on pin 1 of CN4 and their threshold is approximately 5 V.

OUT1 and OUT2 are PNP type, isolated, digital output, powered from V_{EXT}.

Parameter	Symbol	Rating
Logic supply voltage	V_{EXT}	24 V_{DC} ± 10 % (40 V peak)
Logic supply current	I_{EXT}	100 mA + outputs currents
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. 5 – Logic supply and OUT1, OUT2 characteristics

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9. MOTOR CURRENT SETTINGS

When configuring motor current for specific applications, it is crucial to maintain adequate torque margins. Excessive currents not only cause unnecessary heating in both the drive and motor but also have the potential to induce resonances. To safeguard the motor and drive against misconfigurations with too high values, the current setting is limited to the factory-programmed value.

To mitigate unwanted heat dissipation, the V6 firmware version implements motor torque control. This feature dynamically adjusts the current based on the load encountered. When there is no resistant torque, the current is reduced. As the load increases, the firmware proportionally boosts the current until it reaches the maximum configured value. Notably, torque control remains active even at zero speed. If a load is applied while the motor is stationary, the drive counteracts the load by increasing motor current.

The V6 firmware regulates motor current within a customizable range (programmable minimum and maximum values) and employs the step accumulation function. This function offers significant advantages to applications. It enables the accumulation of steps that cannot be executed due to sudden resistant torque exceeding the maximum motor torque. In such scenarios, FD1.xEC maintains the maximum motor torque. When the load decreases, the accumulated steps are recovered, facilitating swift acceleration to reach the reference position. The transition from chasing mode to synchronous mode, known as engage, occurs seamlessly through bump-less speed adjustments, eliminating vibrations.

In applications characterized by high acceleration and inertial loads, traditional stepper drives require substantial torque margins. This ensures that the motor maintains synchronicity and prevents step loss or even complete stoppage when the load increases beyond the start/stop frequency. In essence, traditional stepper drivers necessitate oversized motors and drives.

The V6 control firmware, on the other hand, dynamically increases current and torque until the maximum set value is achieved. In cases of higher resistant torque beyond motor possibilities, the resulting reduction in speed and acceleration is managed by accumulating the input steps that were not executed. Once the resistant torque diminishes, the driver executes the accumulated steps without any position loss. Additionally, a configurable alarm limit for input steps accumulation is implemented to enhance control and safety.

This advanced control firmware seamlessly integrates the advantages of stepper systems, such as cost-effectiveness, simplicity (eliminating the need for PID tuning), minimal position overshoot, and a high torque-to-motor size ratio, with the benefits of brushless systems, including high efficiency (current adjustment based on the load, operating at maximum torque) and precise position retention.

10. ADDRESS SETTINGS

Configuring the address of your converter is a straightforward process. The address can be easily set using the DIP switch located inside the drive (to access untight the 4 screws on the cover). Bits 1-7 of the DIP switch determine the address, while bit 8 (BOOT) is designated for programming purposes.
When the drives leave the factory, the address is set to zero (Bits 1-7 are turned off). This allows you the convenience of assigning the positional address, without having to remove the cover. However, if you prefer to set the address using the DIP switch, you will need to remove the cover by carefully disconnecting the internal connectors between the two cards. Be sure to turn off the power before proceeding.

If you find the gasket glued in place, gently insert a screwdriver at the corresponding spot without causing any damage. Once the address is configured, putting the cover back is a simple process. The PCB itself guides the insertion. All you need to do is maintain the PCB perpendicular and ensure that the gasket isn't "pinched". To achieve this, it's advisable to insert the four screws into the gasket before securing the cover in place.

This method guarantees a hassle-free address configuration while ensuring the integrity of your equipment. Always exercise caution and care during this process to avoid any damage.

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11. PROGRAM DRIVE FIRMWARE AND PARAMETERS

There are three methods available to program the drive firmware and parameters.

If the programming fails for any reason (loosing connection, etc.) perform a power cycle and after try again.

1. Filetransfer over EtherCAT (FoE)

To initiate Filetransfer over EtherCAT, the Master must request the EtherCAT state machine transition to BOOT mode. In BOOT mode, the drive's green LED (4) and red LED (5) will alternate blinking. Using TwinCAT or any equivalent EtherCAT automation software, it is possible to download binary files of firmware and parameters via FoE protocol. To create these binary files, use DwLoader with the following commands:

File -> Create Parameters binary file

File -> Create Firmware binary file

Ensure to name the files with the prefix *Firmware_Bin* and *Parameters_Bin*, such as *Firmware_Bin_V6_22.bin* and *Parameters_Bin_elevator1.bin*.

The password to program is 0.

2. In Application Programming

To connect to the drive for in-application programming, use a USB to RS-232 converter and a cable with PHR-3 connector. Connect to the CN5 connector after removing one of the screw caps. On DwLoader main window, select firmware and/or parameters, and click IAP push-button with microcontroller symbol (In Application Programming over Modbus). For modifying specific parameters, it's recommended to upload the parameters first, make the necessary changes, select "parameters" only, and then click IAP (which writes the changes to the FLASH memory).

3. User Flash Program:

If the drive's communication program has degraded, programming via RS-232 is necessary. Follow these steps:

- Turn off V_{POW} and V_{EXT}.
- Remove the cover and turn on switch 8.
- Reinstall the cover and turn on V_{EXT} (ensure the green LED4 near CN5 is off).
- Click the "lightning" button on DwLoader (this overwrites both the firmware and parameters). A command prompt window will appear.
- Turn off, remove the cover, set switch 8 to OFF, replace the cover, and turn on again (the green LED should flash).
- Tighten the four screws.

Note: Please ensure that DwLoader is saved in a folder path that does not contain any blank spaces.

12. LED DIAGNOSTIC

FD1EC is equipped with five LEDs, visible by removing the two screw caps. LD4 and LD5 are integrated into a single LED (dual LED). They allow the following diagnostics:

LED1	EtherCAT IN link / activity	LED4	Alarm
LED2	EtherCAT OUT link / activity	LED5	Power on
LED3	EtherCAT AL status		Note: LD4 and LD5 = dual LED

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
		Flickering	Boot
		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 LED4 and LED 5 blink alternatively when in boot mode.
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. LED4 and LED 5 blink alternatively when in boot mode.
		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. 6 - LED diagnostic