maxon motor

maxon motor control 4-Q-EC Servoamplifier DES 50/5

Order number 205679

Operating Instructions April 2002 edition

The DES (**D**igital **E**C **S**ervoamplifier) is a very efficient digital servoamplifier with sinusoidal current commutation for the perfect control of EC (**E**lectronic **C**ommutation) motors.
The EC motors must be equipped with Hall sensors and a digital encoder with line driver. The controller, the monitoring and the complete control algorithms are implemented in a very fast digital signal processor. As with classical, conventional automatic controllers, easy trimming and adjustment of the servoamplifier is possible, with just a few potentiometers.
As an alternative, configuration and commanding also is possible over the PC (RS232 or CAN). This is particularly favourable with series application, as all adjustments and parameters can be quickly reproducibly and numerically set.
The set value specification can be made conventionally with an analogue input (0 ... 5 V or ±10 V), RS232 or CAN bus interface.
The sinusoidal commutation causes minimal torque ripple and low motor noise. The motor chokes integrated in the DES extend the operating range of the DES up to motors with very low inductance.

Table of Contents

The latest edition of these operating instructions, additional documentation and software to the DES 50/5 may also be found in the internet under http://www.maxonmotor.com category «Service», subdirectory «Downloads», Order number 205679.

1 Safety Instructions

Skilled Personnel
Installation and starting of the equipment shall only be performed by experienced, skilled personnel.

Statutory Regulations
The user must ensure that the servoamplifier and the components belonging to it are assembled and connected according to local statutory regulations.

Load Disconnected
For primary operation the motor should be free running, i.e. with the load disconnected.

Additional Safety Equipment
An electronic apparatus is, in principle, not fail-safe. Machines and apparatus must therefore be fitted with independent monitoring and safety equipment. If the equipment breaks down, if it is operated incorrectly, if the control unit breaks down or if the cables break, etc., it must be ensured that the drive or the complete apparatus is kept in a safe operating mode.

Repairs
Repairs may be made by authorised personnel only or by the manufacturer. It is dangerous for the user to open the unit or make repairs to it.

Danger
Do ensure that during the installation of the DES 50/5 no apparatus is connected to the electrical supply. After switching on, do not touch any live parts!

Max. Supply Voltage
Make sure that the supply voltage is between 12 and 50 VDC. Voltages higher than 50 VDC or of wrong polarity will destroy the unit.

Electrostatic Sensitive Device (ESD)

2 Performance Data

2.1 Electrical data

Supply voltage Vcc (Ripple < 5%)	12 - 50 VDC
Max. output voltage	0.9 • Vcc
Max. output current I_{max}	15 A
Continuous output current I_{cont}	5 A
Switching frequency	50 kHz
Max. efficiency	92 %
Band width current controller	1 kHz
Max. speed (motors with 2 poles)	25 000 rpm
Built-in motor choke per phase	160 µH / 5 A

2.2 Inputs

"Set value"	configurable by DIP Switch 8: -10 ... +10 V (R_i = 80 kΩ)
	0 ... +5 V (R_i = 10 kΩ)
"Enable"	+2.4 ... +50 VDC (R_i = 22 kΩ)
"Digital 1" (Switch "Monitor n" / "Monitor I")	+2.4 ... +50 VDC (R_i = 22 kΩ)
"Digital 2" (Switch speed- / current controller)	+2.4 ... +50 VDC (R_i = 22 kΩ)
"STOP"	+2.4 ... +50 VDC (R_i = 22 kΩ)
Encoder signals	A, A\, B, B\, I, I\ max. 1 MHz
Hall sensor signals	Hall sensor 1, Hall sensor 2, Hall sensor 3
CAN ID (CAN identification)	configured by DIP Switch 1...7
	ID = 1 ... 127 (binary coded)

2.3 Outputs

Monitor "Monitor n" or "Monitor I", configurable	0 ... 5 VDC (R_o = 10 kΩ, f_g = 340 Hz)
Status reading "Ready"	open collector max. 30 VDC (I_L < 20 mA)

2.4 Voltage outputs

Encoder supply voltage	+5 VDC, max. 100 mA
Hall sensors supply voltage	+5 VDC, max. 50 mA

2.5 Interfaces

RS232	RxD; TxD (max. 115 200 bit/s)
CAN	CAN_H (high); CAN_L (low) (max.1 Mbit/s)

2.6 Trim potentiometers

n_{max}, Offset, $I_{max,}$ gain

2.7 LED indicator

2 colours LED	READY / ERROR
	green = READY, red = ERROR

2.8 Ambient temperature- / Humidity range

Operating	-10 ... +45°C
Storage	-40 ... +85°C
non condensating	20 ... 80 %

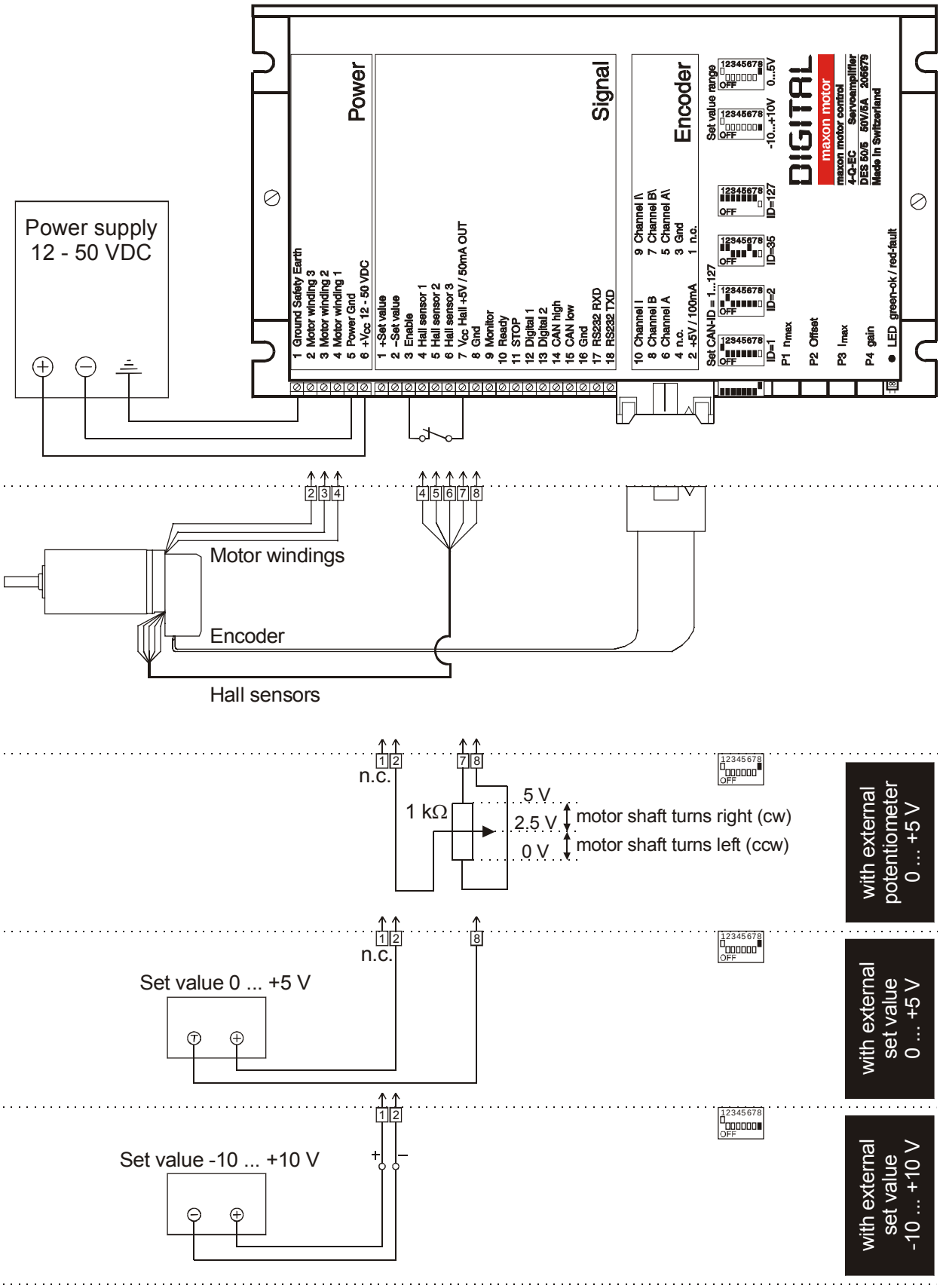
2.9 Mechanical data

Weight	approx. 410 g
Dimensions	see dimension drawing

2.10 Connections

PCB clamps	Power (6 poles), Signal (18 poles)
Pitch	3.5 mm
suitable for wire cross section	0.14 ... 1 mm^2 multiple-stranded
	or 0.14 ... 1.5 mm^2 single wire
Encoder	Plug DIN41651 (10 poles)
	for flat band cable, pitch 1.27 mm, AWG28

3 Minimum External Wiring for Different Modes of Operation



4 Operating Instructions

4.1 Power supply layout

Any available power supply can be used, as long as it meets the minimal requirements set out below.
During set up and adjustment phases, we recommend separating the motor mechanically from the machine to prevent damage due to uncontrolled motion.

Power supply requirements	
Output voltage	V_{cc} min. 12 VDC; max. 50 VDC
Ripple	< 5 %
Maximum output current	5 A continuous (15 A max.)

The required voltage can be calculated as follows:
Known values:
- Operating torque M_B [mNm]
- Operating speed n_B [rpm]
- Nominal motor voltage U_N [Volt]
- Motor no-load speed at U_N, n_0 [rpm]
- Speed/torque gradient of the motor $\Delta n / \Delta M$ [rpm / mNm]

Sought values:
- Supply voltage V_{cc} [Volt]

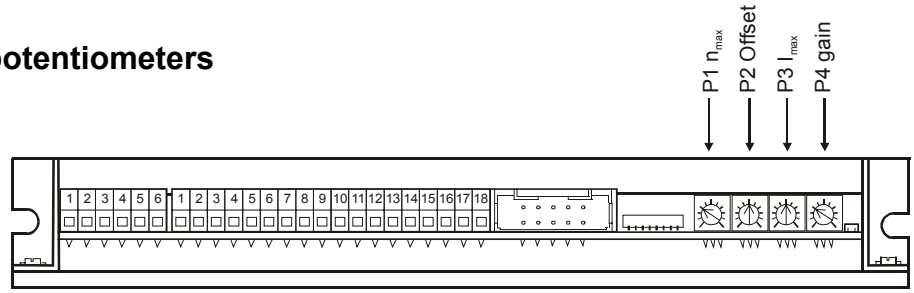
Solution:

$$V_{CC} = \frac{U_N}{n_0} \cdot (n_B + \frac{\Delta n}{\Delta M} \cdot M_B) \cdot \frac{1}{0{,}9} + 2\,[V]$$

Choose a power supply capable of supplying this calculated voltage under load. The formula takes a max. PWM cycle of 90 % and a 2 volts max. voltage drop at DES 50/5 into account.

Consider:
The power supply must be able to buffer the back-fed energy from brake operation e.g. in a condenser. With electronically stabilized power supply units it is to ensure, that the overcurrent protection responds in no operating condition.

4.2 Function of the potentiometers



Potentiometer		Function	Turn to the left ↺	Turn to the right ↻
P1	n_{max}	max. speed at max. set value (e.g. external potentiometer fully clockwise; 5 V; 10 V)	slower min. 0 rpm	faster max. 25000 rpm
P2	Offset	Adjustment: n = 0 rpm (set value e.g. ext. pot. in centre pos.)	motor turns CCW	motor turns CW
P3	I_{max}	current limit	lower ≈ 0 A	higher ≈ 15 A
	I_{cont}		lower ≈ 0 A	higher ≈ 5 A
P4	gain	amplification	lower	higher

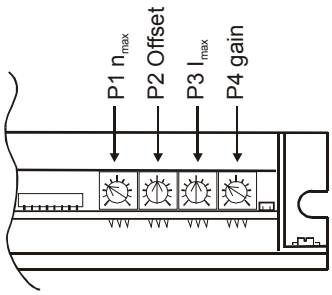
4.3 Adjustment of the Potentiometers

4.3.1 Pre-adjustment

With the pre-adjustment, the potentiometers are set in a preferred position.

DES units in the original packing are preset.

Pre-adjustment potentiometers		
P1	n_{max}	30 % [1]
P2	Offset	50 %
P3	I_{max}	50 % [2]
P4	gain	30 %



1) 30 % are equivalent to n_{max} = approx. 7500 rpm
2) 50 % are equivalent to I_{cont} = approx. 2,5 A; I_{max} = approx. 7,5 A

4.3.2 Adjustment

Digital speed control
(see also 5.1.6)

1. Give the max. set value (e.g. 10 V) and turn potentiometer **P1 n_{max}** so far that the required speed is achieved.
2. Set potentiometer **P3 I_{max}** at the limiting value desired.
   Important: The limiting value I_{cont} ($=^1/_3\, I_{max}$) should be below the max. continuous current as shown on the motor data sheet.
3. Increase potentiometer **P4 gain** slowly until the amplification is set large enough.
   Caution: If the motor vibrates or becomes loud, the amplification is adjusted too high and the potentiometer must be readjusted until the instability of the closed loop of the drive under all loads ceases.
4. Adjust set value to zero, e.g. by short circuiting the set value. Then, with the potentiometer **P2 Offset**, set the motor speed to zero.
   Note: Step 4 is not necessary with external set value potentiometer.

Digital current control
(see also 5.1.6)

1. Set potentiometer **P3 I_{max}** at the limiting value desired.
   Important: The limiting value I_{cont} ($=^1/_3\, I_{max}$) should be below the max. continuous current as shown in the motor data sheet.
2. Adjust set value to zero, e.g. by short circuiting the set value. Then, with the potentiometer **P2 Offset,** set the motor speed to zero

   Note:
   Configured as a current controller, P1 n_{max} and P4 gain are not activated.

5 Functions

5.1 Inputs

5.1.1 “Set value“

Two different versions can be selected to give an analogue set value.
Versions are selected by setting the DIP-Switch 8 "Set value range".
The "Set value" input is protected against overvoltage.

Set value range -10 ... +10 V	Input voltage range	-10 ... +10 V
	Input circuit	differential
	Input resistance	80 kΩ
	Positive set value	(+Set Value) > (-Set Value)
	Negative set value	(+Set Value) < (-Set Value)
	DIP-Switch 8	OFF 

Set value range 0 ... +5 V is selected, if the set value is given from an external potentiometer.

Set value range 0 ... +5 V	Input voltage range	0 ... +5 V
	Input circuit	against Gnd
	Input resistance	10 kΩ
	Positive set value	(-Set Value) < 2.5 VDC
	Negative set value	(-Set Value) > 2.5 VDC
	DIP-Switch 8	ON 
	Required external potentiometer	1 kΩ

Note on set value range 0 ... +5 V:
If using a set value range 0 ... +5 V, do not connect "+Set Value" (Signal clamp pin 1).

5.1.2 “Enable“

If a voltage is given at “Enable”, the servoamplifier switches the motor voltage to the winding connections. If the “Enable” input is not switched on or is connected to Gnd, the power stage will be high-impedance (floating) and will be disabled.
The “Enable“ input is protected against overvoltage.

“Enable“	Minimum input voltage	+2.4 VDC
	Maximum input voltage	+50.0 VDC
	Input resistance	22 kΩ
	Switching time	nominal 3 ms (at 5 V)
“Disable“	Minimum input voltage	0 VDC
	Maximum input voltage	+0.8 VDC
	Input resistance	22 kΩ
	Switching time	nominal 4 ms (at 0 V)

5.1.3 “Hall sensor 1“ “Hall sensor 2“ “Hall sensor 3“

Hall sensors are needed for detecting rotor position during start up.
The “Hall sensor“ inputs are protected against overvoltage.

Voltage value “low“	max. 0.8 V
Voltage value “high“	min. 2.4 V
Internal pull-up resistor	2.7 kΩ (against +5 VDC)

Suitable for hall effect sensors IC using Schmitt trigger with open collector output.

5.1.4 “STOP“

If a voltage is given at “STOP”, the motor speed will be stopped with maximum deceleration (adjusted value at potentiometer P3 I_{max}) until motor shaft stands still.
If the “STOP” input is not switched on (floating) or is connected to Gnd the motor speed is not influenced.
The “STOP“ input is protected against overvoltage.

“STOP“ disabled	Minimum input voltage	0 VDC
	Maximum input voltage	+0.8 VDC
	Input resistance	22 kΩ
“STOP“ enabled	Minimum input voltage	+2.4 VDC
	Maximum input voltage	+50.0 VDC
	Input resistance	22 kΩ

5.1.5 Toggle monitor signal “Digital 1“

If the “Digital 1” input is not switched on (floating) or is connected to Gnd the actual motor speed is given to the “Monitor” output.
If a voltage is given at “Digital 1”, the actual motor current is given to the “Monitor” output.
The “Digital 1“ input is protected against overvoltage.

“Monitor n“ enabled	Minimum input voltage	0 VDC
	Maximum input voltage	+0.8 VDC
	Input resistance	22 kΩ
“Monitor I“ enabled	Minimum input voltage	+2.4 VDC
	Maximum input voltage	+50.0 VDC
	Input resistance	22 kΩ

5.1.6 Toggle controller mode (speed- / current control) “Digital 2“

If the “Digital 2” input is not switched on (floating) or is connected to a voltage higher than 2.4 VDC the servoamplifier is configured to speed controller mode.
If the “Digital 2” input is connected to Gnd the servoamplifier is configured to current (torque) mode.
The “Digital 2“ input is protected against overvoltage.

Speed control enabled	Minimum input voltage	+2.4 VDC
	Maximum input voltage	+50 VDC
	Input resistance	22 kΩ
Current control enabled	Minimum input voltage	+0 VDC
	Maximum input voltage	+0.8 VDC
	Input resistance	22 kΩ

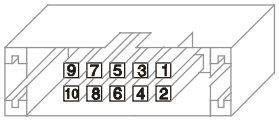
Note:
If the controller mode has been changed, a Disable-Enable process (refer to 5.1.2) must be carried out for the activation of the new mode.

5.1.7 Encoder

Encoder supply voltage	+5 VDC max. 100 mA	
Maximum encoder frequency	1 MHz	
Voltage value	TTL	
	Low	max. 0.8 V
	High	min. 2.0 V
Line receiver (internal)	EIA standard RS-422	

Use an encoder with built-in line driver.

Male connector (front view)



Pin configuration at “Encoder” input:

1	n.c.	Not connected
2	+5 V	+5 VDC max. 100 mA
3	Gnd	Ground
4	n.c.	Not connected
5	A\	Inverted channel A
6	A	Channel A
7	B\	Inverted Channel B
8	B	Channel B
9	I\	Inverted Channel I
10	I	Channel I

This pin configuration is compatible with the flat cable plugs of the HEDL 55xx encoder (with line driver)

Note:
The standard encoder adjustment (original packing) refers to a 500-counts per turn encoder. For other encoders the adjustment must be modified with the software (GUI).

5.2 Outputs

5.2.1 Auxiliary voltage "V_{cc} Hall +5 V / 50 mA OUT"

An internal auxiliary voltage of +5 V is provided:
- powering the hall sensors
- gating the signals: Enable, Digital 1 and Digital 2
- reference voltage for external set value potentiometer (1 kΩ)

The output is fuse-protected against overload.

Output voltage	+5 VDC
Max. output current	< 50 mA

5.2.2 "Monitor"

Speed monitor "Monitor n"

"Digital 1" input	0 ... 0.8 VDC (or not connected)

The speed monitor is primarily intended for the qualitative estimation of the dynamics. The absolute speed is determined by the properties of the speed sensors and by the setting of the n_{max} potentiometer. The signal is proportional to the speed. The output voltage of the speed monitor is 5 V when the maximum number of revolutions set by the n_{max} potentiometer has been reached.

Output voltage range	0 ... +5 VDC
Ripple	max. 0.055 V
Resolution	approx. 0.025 V (5 V / 200 Bit)
Output resistance R_O	10 kΩ
Cutoff frequency f_g	340 Hz

Example:

0 V	corresponding speed	$-n_{max}$
2.5 V	corresponding speed	0 rpm
5.0 V	corresponding speed	$+n_{max}$

Current monitor "Monitor I"

"Digital 1" input	2.4...+50 VDC

The servoamplifier makes a current actual value available for monitoring purposes. The signal is proportional to the mean value of the motor current.

Output voltage range	0...+5 VDC
Ripple	max. 0.055 V (= 0.33 A)
Resolution	approx. 0.025 V (5 V / 200 Bit) (= 0.15 A)
Output resistance R_O	10 kΩ
Cutoff frequency f_g	340 Hz
Gradient	≈ 6 A/V

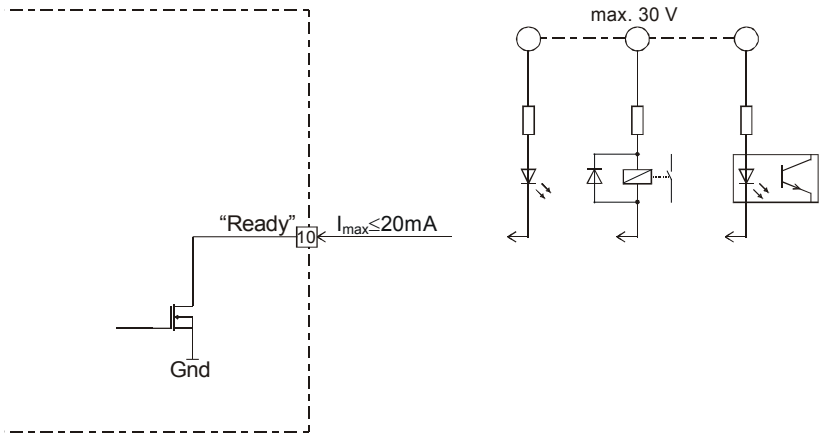
Example:

0 V	corresponding	-15 A	negative torque
2.5 V	corresponding	0 A	
5.0 V	corresponding	+15 A	positive torque

The "Monitor" output is protected against overload.

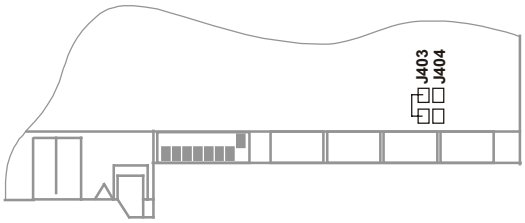
5.2.3 Status reading „Ready“

The “Ready“ signal can be used to report the state of operational readiness or a fault condition on a master control unit. The fault condition is stored. In order to reset the fault condition, the servoamplifier must be re-released (Enable).
If the cause of the fault situation cannot be eliminated, the error will occur again immediately.



An external additional voltage is required:

Input voltage range	max. 30 VDC
Load current	< 20 mA



Version 1
Standard (pre-adjusted)

Error output	J403 short-circuited (0 Ω) J404 not mounted (open)

The open collector output is, in normal cases, i.e. no faults, switched to Gnd.
In case of a fault with excess voltage or excess current, the error output is not conducting (high resistance).

Version 2
Special (customized)

Inverted error output	J403 not mounted (open) J404 short-circuited (0 Ω)

The open collector output is, in normal cases, i.e. no faults, not conducting (high resistance).
In case of a fault with excess voltage or excess current, the error output is switched to Gnd.

Note on variation 1 and variation 2:
Under voltage is displayed but not stored!

5.3 Interfaces

5.3.1 Serial Interface “RS232 RX“, “RS232 TX“

Maximum input voltage	± 30 V
Maximum output voltage	± 30 V
Maximum bit rate	115 200 bit/s
Data line protection	ESD protected
Internal RS232 driver/receiver	EIA RS232 standard
Baud rate (configurable)	Up to max. 115 200 bit/s

Notes
- Please bear in mind your PC’s serial port maximal baud rate.
- The standard baud rate setting (original packing) is 38 400 bauds. If a different rate is required, the setting must be changed using the software (GUI).

Data bits	8
Parity	none
Stop bit	1
Protocol	none

Connection DES - PC

Servoamplifier DES 50/5	➡	**PC Interface (RS232), DIN41652**
Signal clamp pin 16 Gnd	➡	Pin 5 Gnd
Signal clamp pin 17 RS232 RxD	➡	Pin 3 TxD
Signal clamp pin 18 RS232 TxD	➡	Pin 2 RxD

5.3.2 CAN Interface “CAN high“, “CAN low“

Standard type	CAN high-speed
	ISO 11898 compatible
Maximum bit rate	1 Mbit/s
Max. number of CAN nodes (fan out)	110
Protocol	CAN 2.0B
CAN frame type	Standard (11 bit identifier)
Identifier setting	by software over CAN or RS232

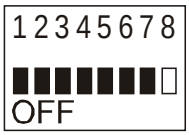
Connection DES – CAN bus line CiA DS-102

Servoamplifier DES 50/5	➡	**CAN 9-pin D-Sub (DIN41652)**
Signal clamp pin 14 CAN high	➡	Pin 7 CAN_H
Signal clamp pin 15 CAN low	➡	Pin 2 CAN_L
Signal clamp pin 16 Gnd	➡	Pin 3 CAN_GND

5.3.3 CAN ID (CAN Identification)

The CAN-ID (node address) is set at DIP-switch 1 ... 7.
All addresses can be coded from 1 ... 127 using the binary code.

Switch	Binary code	Valence
1	2^0	1
2	2^1	2
3	2^2	4
4	2^3	8
5	2^4	16
6	2^5	32
7	2^6	64



If the valences of all switches set at "ON" are added together, this gives the set CAN-ID (node address).

Examples:
The following table can be used as a guide, but is not comprehensive

	Switch	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
	Valence	**1**	**2**	**4**	**8**	**16**	**32**	**64**	
CAN-ID	**Switch setting**								**Calculation**
1		**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
2		**0**	**1**	**0**	**0**	**0**	**0**	**0**	**2**
32		**0**	**0**	**0**	**0**	**0**	**1**	**0**	**32**
35		**1**	**1**	**0**	**0**	**0**	**1**	**0**	**1 + 2 + 32**
127		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1 + 2 + 4 + 8 + 16 + 32 + 64**

Notes:
- CAN-ID = 0 is invalid and overwritten with CAN-ID = 1.
- DIP-Switch 8 only affects the set value range and has no impact on the CAN-ID.

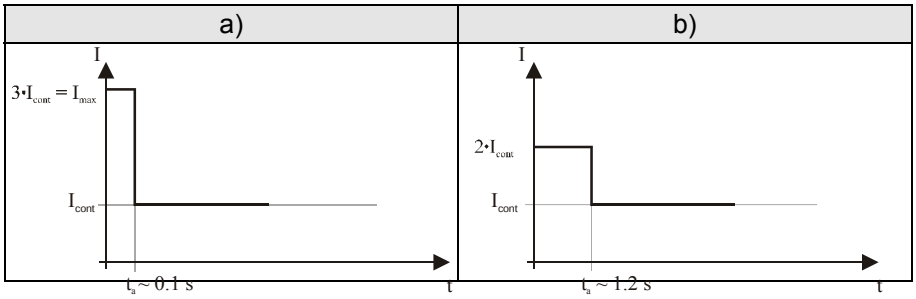
5.4 Current limit

Brushless maxon EC motors are exceptionally suitable the application in servo-drives. Very fast acceleration times and in addition, thermal overload protection are required.
The digital servoamplifier DES 50/5 operates with an I_{max} and an I_{cont} - current limiting, which satisfies both requirements.

Maximum output current I_{max}	< 15 A
Continuous output current I_{cont}	< 5 A
Ratio I_{max} : I_{cont}	3:1

The continuous output current I_{cont} (0 ... 5 A), adjusted with the potentiometer, is available for unlimited time.
A higher current is also permitted for a short time ($I_{max} = 3 \cdot I_{cont}$), whereby the length of time is dependent on the prehistory of the current process.

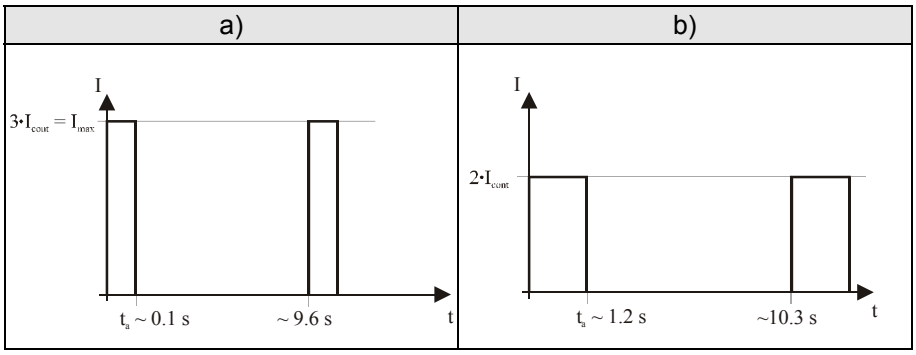
Example 1:



During the time t_a[1] a higher current is permitted for the acceleration of the motor. Afterwards the current is limited to the continuous output current I_{cont}.

If the motor is operated long term with the continuous output current I_{cont}, no higher current is permitted (thus t_a = 0 s).

Example 2: (cyclical mode)



In cyclic operation the max. output current I_{max} is available after a break time of approx. 10 s. On condition that the current between the acceleration processes is zero. Otherwise the time t_a is reduced.

[1]The length of time depends on the current value and the past current load of the motor.

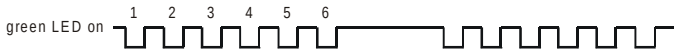
6 Error Messages

6.1 Faultless condition

The green LED shows the operating status ("Enable" or "Disable") of DES.
DES in "Disable" status (DES ready): green LED flashes (flash frequency approx. 1 Hz), red LED does not shine.
DES in "Enable" status (power stage of DES is enabled): green LED shines continually, red LED does not shine.

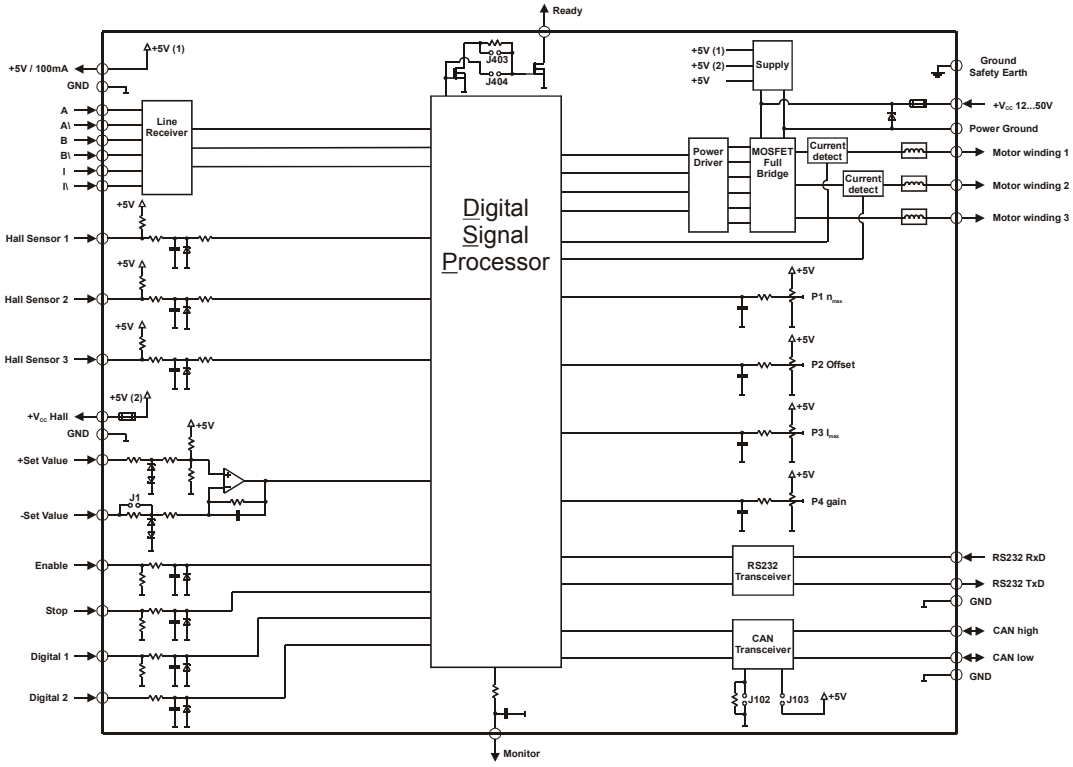
6.2 Faulty condition

Error conditions are detected by DES.
The red LED shines continually in the event of error condition.
Depending on error, the green LED flashes at varying intervals.

Example: Error 5 

Number of flashing pulses of green LED	possible errors
1	*Error 0 => Hall sensor error* • Hall sensors incorrectly wired • Hall sensor supply voltage incorrectly wired • damaged Hall sensor in the motor
2	*Error 1 => Index processing error* • encoder without working index channel • system parameter "Encoder Resolution" set too low • input frequency of encoder signal too high
3	*Error 2 => Wrong setting of encoder resolution* • system parameter ("encoder resolution") set incorrectly
4	*Error 3 => Hall sensor 3 not found* • Hall sensor 3 incorrectly wired • damaged Hall sensor 3 in the motor • system parameter "Encoder Resolution" set too low
5	*Error 4 => Over current error* • short circuit in the motor winding • power supply cannot supply enough acceleration current • gain regulation loop is too high; speed regulation gains must be reduced • system parameter ‘’acceleration’’ too high • damaged power stage
6	*Error 5 => Over voltage error* • power supply voltage too high • voltage in generation mode too high
7	*Error 6 => Over speed error* • speed too high (> 30 000 rpm)
8	*Error 7 => Supply voltage too low for operation* • supply voltage is too low for operation
14	*Error 13 => Parameter out of range* • system parameter "Encoder Resolution" outside the permissible range
15	*Error 14 => Flash code error* • check-total check failed => Firmware must be reloaded in the DES

7 Block Diagram



8 Dimension Drawing

Dimensions in [mm]