Servo Amplifier
4-Quadrant PWM for Brushless DC-Servomotors

Series BLD 5603

Series BLD 5606

FAULHABER GROUP
We create motion

Operating Instructions
Surf to the following Internet address and you will find the latest edition of the instruction manual on-line: www.minimotor.ch/uk/pr/

For direct Download:
# Index

## General Information
1. Description
2. Application diagram
3. Combination possibilities

## Technical Data
4. Dimensions and weight
5. Maximum ratings
6. Specific characteristics

## General Characteristics
7.1 Speed regulator, type PI
7.2 Overheating protection
7.3 Current limiter, type I<sup>T</sup>
7.4 Enable
7.5 Motor-Speed Monitor
7.6 High PWM frequency

## Servo Amplifiers BLD 5603-CC4P and BLD 5606-CC4P for Current Control
8. Basic circuit diagram
9. Dimensional drawing
10. Connection diagram

## Servo Amplifiers BLD 5603-SH4P and BLD 5606-SH4P for Speed Control
11. Basic circuit diagram
12. Dimensional drawing
13. Connection diagram

## Servo Amplifiers BLD 5603-SE4P and BLD 5606-SE4P for Speed Control
14. Basic circuit diagram
15. Dimensional drawing
16. Connection diagram

## Notice of Use
17. Special considerations
17.1 Signal command
17.2 Power supply
17.3 Wiring

## Start-Up Procedure
18.1 Servo amplifiers BLD 5603-CC4P and BLD 5606-CC4P for current control
18.2 Servo amplifiers BLD 5603-SH4P and BLD 5606-SH4P for speed control
18.3 Servo amplifiers BLD 5603-SE4P and BLD 5606-SE4P for speed control with encoder
18.4 Offset adjustment
18.5 Selection of R7 for servo amplifiers BLD 5603-SH4P and BLD 5606-SH4P
18.6 Selection of R7 for servo amplifiers BLD 5603-SE4P and BLD 5606-SE4P
18.7 Current limiter
18.8 Optimizing the speed regulator
18.8.1 Optimizing procedure
18.8.2 Optimizing R7
18.8.3 Load influence
18.8.4 Function of R1, C1 and C2
General Information

1. Description

The BLD 5603 and the BLD 5606 are 4-quadrant PWM servo amplifiers suitable for the three-phase brushless DC-servomotors, type 2036, 2444, 3056 and 3564. The Servo Amplifiers use a combination of SMD (Surface Mounted Device), MOSFET power stage and PWM (Pulse-Width Modulation) technologies to achieve both, compact design and high power efficiency. The basic board of the servo amplifiers is a single level PCB structure, which performs all the commutation and protective functions and contains the power stage mounted on the heat sink plate.

The amplifiers are available in two different function modes: Current control and Speed control.

Current control (basic boards)

- BLD 5603-CC4P or BLD 5606-CC4P
  In the amplifiers the current flowing in the active phases of the motor is regulated by the analog current command. The amplifiers are designed for use with a position controller or in constant torque applications.

Speed control (two amplifier configurations are available)

- BLD 5603-SH4P or BLD 5606-SH4P > the type SH4P uses the Hall sensor signals of the brushless DC-servomotor to allow precise regulation at speed above 1000 rpm.
- BLD 5603-SE4P or BLD 5606-SE4P > the type SE4P is able to regulate at much lower speeds, depending on the encoder resolution. Typical speed with 500 line encoder down to 20 rpm.

These two servo amplifiers consist of the basic board with optional modules. These modules have a special frequency-to-voltage converter, allowing accurate motor speed control and are provided with a current limiter function, type I\(^2\)t.

The maximum continuous output power without additional heat sink is 220 W. For ease of installation a loose female terminal block is supplied together with the main board connector.
2. Application diagram

Servo Amplifiers BLD 5603 and 5606

Current control

The Servo Amplifiers type BLD 5603-CC4P and BLD 5606-CC4P are the basic board suitable for the current control (torque control) of brushless DC-Servomotors.

Speed control

The Servo Amplifiers type BLD 5603-SE4P and BLD 5606-SE4P are the basic board with an additional module for speed control of brushless DC-Servomotors with an additional encoder.

The Servo Amplifiers type BLD 5603-SH4P and BLD 5606-SH4P are the basic board with an additional module for speed control of brushless DC-Servomotors.

3. Combination possibilities

<table>
<thead>
<tr>
<th>Servo Amplifiers Type</th>
<th>Brushless DC-Servomotors Type</th>
<th>Encoders Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLD 5603-CC4P</td>
<td>2036 U ... B, 2444 S ... B</td>
<td></td>
</tr>
<tr>
<td>BLD 5606-CC4P</td>
<td>3056 K ... B, 3564 K ... B</td>
<td></td>
</tr>
<tr>
<td>BLD 5603-SH4P</td>
<td>2036 U ... B, 2444 S ... B</td>
<td></td>
</tr>
<tr>
<td>BLD 5606-SH4P</td>
<td>3056 K ... B, 3564 K ... B</td>
<td></td>
</tr>
<tr>
<td>BLD 5603-SE4P</td>
<td>2036 U ... B, 2444 S ... B</td>
<td>5500</td>
</tr>
<tr>
<td>BLD 5606-SE4P</td>
<td>3056 K ... B, 3564 K ... B</td>
<td>5500</td>
</tr>
</tbody>
</table>

Specifications subject to change without notice
## Technical data

### 4. Dimensions and weight

<table>
<thead>
<tr>
<th>Format (L x W x H)</th>
<th>CC4P (L x W x H)</th>
<th>SH4P (L x W x H)</th>
<th>SE4P (L x W x H)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>119.3 x 90.5 x 29</td>
<td>119.3 x 90.5 x 37</td>
<td>119.3 x 90.5 x 37</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td>195</td>
<td>225</td>
<td>225</td>
<td>g</td>
</tr>
</tbody>
</table>
# Technical data

## 5. Maximum ratings

<table>
<thead>
<tr>
<th></th>
<th>Power stage</th>
<th>Analog and logic inputs</th>
<th>Continuous output current @(T_A = 25^\circ)C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power supply</td>
<td>56 V DC</td>
<td>–6 to +6 V DC</td>
<td>4 A</td>
</tr>
<tr>
<td>Analog and logic inputs</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>150 kHz</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Transconductance gain (BLD 5603/BLD 5606)</td>
<td>0,6 / 1,2 A/V</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Current limit (BLD 5603/BLD 5606)</td>
<td>4 / 8 A</td>
<td>4 / 8 A</td>
<td>4 / 8 A</td>
</tr>
</tbody>
</table>

## 6. Specific characteristics

<table>
<thead>
<tr>
<th></th>
<th>CC4P</th>
<th>SH4P</th>
<th>SE4P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power stage:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– Power supply</td>
<td>14 ÷ 56 V DC</td>
<td>14 ÷ 56 V DC</td>
<td>14 ÷ 56 V DC</td>
</tr>
<tr>
<td>– Total output voltage drop ((I_{\text{motor}} = 4)A)</td>
<td>2,0 V DC</td>
<td>2,0 V DC</td>
<td>2,0 V DC</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>150 kHz</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Transconductance gain (BLD 5603/BLD 5606)</td>
<td>0,6 / 1,2 A/V</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Current limit (BLD 5603/BLD 5606)</td>
<td>4 / 8 A</td>
<td>4 / 8 A</td>
<td>4 / 8 A</td>
</tr>
</tbody>
</table>

*Analog input command:*

|                  | ±5 V DC | ±5 V DC | ±5 V DC |
| – Voltage range   | ±5 V DC | ±5 V DC | ±5 V DC |
| – Input resistance | 20 kΩ  | 220 kΩ  | 150 kΩ  |
| – Frequency bandwidth | 0.1 kHz | 1 kHz   | –       |

*Logical input*

|                  | TTL | TTL | TTL |
| – Power supply   |     |     |     |
| – Total output voltage drop (\(I_{\text{motor}} = 4\)A) |     |     |     |
| – Voltage range | ±5 ±5 ±5 | ±5 ±5 ±5 | ±5 ±5 ±5 |
| – Frequency bandwidth | 0.1 kHz | 0.1 kHz | 0.1 kHz |
| – Input resistance | 20 kΩ  | 220 kΩ  | 150 kΩ  |

*Output voltage for external use:*

|                  | Positive (50 mA max. load) | Negative (5 mA max. load) |
| – Positive (50 mA max. load) | +5 +5 +5 | V DC | +5 V DC |
| – Negative (5 mA max. load) | –5 –5 –5 | V DC | –5 V DC |

*Total stand-by current, typical (Hall sensors included)*

|                  | 60 mA | 140 mA | 140 mA |
| – Speed range \(^3\) | to 40 000 | 1000 ÷ 40 000 | to 40 000 |
| – Dynamic range \(^4\) | – | 40 | 40 |

*Temperature range:*

|                  | – Operating temperature | – Storage temperature |
| – Operating temperature | 0 ÷ +70 | 0 ÷ +70 | 0 ÷ +70 |
| – Storage temperature | –20 ÷ +80 | –20 ÷ +80 | –20 ÷ +80 |

---

\(^1\) Cycle by cycle current limiting.  
\(^2\) Analog input command (positive voltage = CW – negative voltage = CCW) may be set by an external potentiometer or an external voltage.  
\(^3\) Depending on the motor type and/or encoder characteristics.  
\(^4\) Maximum to minimum controllable speed ratio: \(n_{\text{max}}/n_{\text{min}}\).
7. General characteristics

7.1 Speed regulator, type PI
A Speed Regulator type Proportional Integrator (PI) controls a brushless DC-servomotor with no steady-state error (step input command).

7.2 Overheating protection
The servo amplifier automatically shuts off if the heat sink temperature exceeds +75 °C. A temperature below +70 °C will restart the servo amplifier.

7.3 Current limiter, type I²t
A brushless DC-servomotor tolerates peak currents much higher than the maximum continuous current admissible, though only for a limited period of time. A current limiter, type I²t, takes these characteristics into account and, in addition, provides excellent protection against a possible overload.
To illustrate the operation of this current limiter, the following figure provides an example of a brushless DC-servomotor operating in an Acceleration-Constant Speed-Deceleration cycle.

n = motor speed [rpm]
l = motor current [A]
t = time [s]
General characteristics

The continuous current limit, $I_{\text{lim}}$, is set according to the specific application. From the above figure one can deduce that for $t < t_1$, the motor is fed by a current less than the current limit. In the deceleration phase (interval $t_1$, $t_2$), the current assumes the value $I_{p1} > I_{\text{lim}}$. The presence of the limiter allows the power rating to be exceeded without any risk to the motor. The maximum overload period of the motor $T[s]$ depends directly on the peak current value and on the actual current before the overload:

$$T[s] = 10.34 \ [s] \ \log_e \frac{I_p[A] - I_c[A]}{I_p[A] - I_{\text{lim}}[A]}$$

where:
- $I_p = \text{peak current}$
- $I_c = \text{continuous current}$
- $I_{\text{lim}} = \text{max. continuous admissible current}$

In the event of an overload period longer than the maximum $T$ period, the servo amplifier will impose the current $I_{\text{lim}}$ which will continue for the duration of the overload (e.g.: interval $[t_4, t_5]$).

**N.B.:** When the limiter is active, the servo amplifier has no control on the motor speed.

7.4 Enable
The servo amplifier is disabled when contacts 7 and 11 are connected (high level). Opening this connection (low level) enables the power stage. This input is for contact closures only (e.g.: relay contacts).

7.5 Motor-Speed Monitor
The Motor-Speed Monitor (contact 15 of the connector), generates a voltage proportional to the actual motor speed.

7.6 High PWM frequency
The high PWM frequency of 150 kHz allows the servo amplifier to exploit the technical characteristics of brushless DC-servomotors to the utmost.
Servo Amplifiers for current control  BLD 5603-CC4P
BLD 5606-CC4P

For combination with:
Brushless DC-Servomotors: 2036, 2444, 3056, 3564

8. Basic circuit diagram

Current command

Current amplifier

Controller

Power stage

Brushless DC-Servomotor

Enable

+5V  -5V

GND logical

9. Dimensional drawing

Scale reduced

Female terminal block, type: MSTB 2,5/15-ST
(Phoenix contact)

Pot. 1: Offset trimmer adjustment

Male terminal block, type: MSTBA 2,5/15-G
(Phoenix contact)

Specifications subject to change without notice
Servo Amplifiers for current control  BLD 5603-CC4P
BLD 5606-CC4P

For combination with:
Brushless DC-Servomotors: 2036, 2444, 3056, 3564

10. Connection diagram

Before connecting it is recommended to read chapter 17, Special considerations.
Servo Amplifiers for speed control  BLD 5603-SH4P  
BLD 5606-SH4P

For combination with:  
Brushless DC-Servomotors: 2036, 2444, 3056, 3564

11. Basic circuit diagram

12. Dimensional drawing

Specifications subject to change without notice
Before connecting it is recommended to read chapter 17, Special considerations.
Servo Amplifiers for speed control BLD 5603-SE4P
BLD 5606-SE4P

For combination with:
Brushless DC-Servomotors: 2036, 2444, 3056, 3564
Encoders: 5500

14. Basic circuit diagram

15. Dimensional drawing

Female terminal block, type: MC 1,5/4-G-3,81 (Phoenix contact)
Male terminal block, type: MC 1,5/4-ST 3,81 (Phoenix contact)

Female terminal block, type: MSTB 2,5/15-ST (Phoenix contact)

Pot. 1: Offset trimmer adjustment
Pot. 2: Current Limiter

Specifications subject to change without notice
Servo Amplifiers for speed control  BLD 5603-SE4P
BLD 5606-SE4P

For combination with:
Brushless DC-Servomotors: 2036, 2444, 3056, 3564
Encoders: 5500

16. Connection diagram

Before connecting it is recommended to read chapter 17, Special considerations.
17. Special considerations

17.1 Signal command

The signal command is given by an external voltage of ± 5 Volts or by a potentiometer connected directly to the servo amplifier. The total potentiometer resistance must be between 10 kΩ and 47 kΩ. Before connecting it is recommended to read this chapter to obtain a good operation of the brushless DC-Servomotor.

17.2 Power supply

Any unstabilized DC power supply voltage within the servo amplifier range (14V ≤ Vm ≤ 56V) may be used, although it is advisable to keep this voltage as low as possible in order to minimize the EMI noise. Thus the optimum power supply is given by the following relation:

\[
V_m [V] \approx 5 [V] + R [\Omega] \cdot I_{\text{max}} [A] + k_E [V/rpm] \cdot n_{\text{max}} [rpm]
\]

with:
- \( R, k_E \) = Terminal resistance (phase to phase) and Back-EMF constant of the motor
- \( I_{\text{max}}, n_{\text{max}} \) = Maximum current and speed reached by the motor in your specific application.

17.3 Wiring

A well known disadvantage of Pulse Width Modulation, PWM, is the large amount of interferences generated. This has two consequences, namely perturbations to the environment and self-perturbations. The EMI is generated in the motor power leads and induced in the Hall sensor wires. The smooth running of the motor is therefore perturbated and even in some cases, the motor will not run at all.

In order to reduce the effect of these perturbations, there are some basic rules to follow:

- Use wires as short as possible;
- Avoid to run signal wires (logical and analog commands, Hall sensor and encoder signals) in close proximity to power lead wires (power supply and servomotor phases);
- Connect shielded wires to ground at one end only to avoid ground loops.
Notice of Use

Special care should be given to the motor connection. The following table summarize the different solutions:

<table>
<thead>
<tr>
<th>Action</th>
<th>To</th>
<th>From</th>
<th>Self</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No special care</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>0,3 m</td>
</tr>
<tr>
<td>2. Twisted wires (see figure 1)</td>
<td>slightly</td>
<td>slightly</td>
<td>slightly</td>
<td>1,0 m</td>
</tr>
<tr>
<td>3. Shielded Hall sensor wires (see figure 2)</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>5,0 m</td>
</tr>
<tr>
<td>4. Shielded Hall sensor and phases wires</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>5,0 m</td>
</tr>
</tbody>
</table>

(see figure 3)

To: perturbations To environment reduced
From: perturbations From environment reduced
Self: self-perturbations reduced
Length: maximum cable length

In case of wires longer than the standard product (0,3 m), it is recommended to use the following cable sections:

Phase, brushless DC servomotors type, 2036 ... B, 2444 ... B: 1,0 mm² / AWG 18;
Phase, brushless DC servomotors type, 3056 ... B, 3564 ... B: 1,5 mm² / AWG 16;
Hall sensors, brushless DC servomotors 2036, 2444, 3056 and 3564: 0,5 mm² / AWG 20;

Note: If wires longer than 5 m please consult us.
Notice of Use

Twisted wires

Figure 1

<table>
<thead>
<tr>
<th>Connector</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brushless DC-Servomotor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase A</td>
<td>Brown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase B</td>
<td>Orange</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase C</td>
<td>Yellow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GND logical</td>
<td>Black</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logical supply +5V</td>
<td>Red</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hall sensor C</td>
<td>Grey</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hall sensor B</td>
<td>Blue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hall sensor A</td>
<td>Green</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Shielded Hall sensor wires

Figure 2

<table>
<thead>
<tr>
<th>Connector</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brushless DC-Servomotor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase A</td>
<td>Brown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase B</td>
<td>Orange</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase C</td>
<td>Yellow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GND logical</td>
<td>Black</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logical supply +5V</td>
<td>Red</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hall sensor C</td>
<td>Grey</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hall sensor B</td>
<td>Blue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hall sensor A</td>
<td>Green</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Shielded phase and Hall sensor wires

Figure 3

<table>
<thead>
<tr>
<th>Connector</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brushless DC-Servomotor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase A</td>
<td>Brown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase B</td>
<td>Orange</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase C</td>
<td>Yellow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GND logical</td>
<td>Black</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logical supply +5V</td>
<td>Red</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hall sensor C</td>
<td>Grey</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hall sensor B</td>
<td>Blue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hall sensor A</td>
<td>Green</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Specifications subject to change without notice
### Start-up Procedure

**18.1 Servo Amplifiers BLD 5603/06-CC4P for current control**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Connect the servo amplifier</td>
<td>10. Connection diagram</td>
</tr>
<tr>
<td>- Power the servo amplifier</td>
<td>18.4 Offset adjustment</td>
</tr>
<tr>
<td>- Adjust offset</td>
<td></td>
</tr>
</tbody>
</table>

**18.2 Servo Amplifiers BLD 5603/06-SH4P for speed control**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Connect the servo amplifier</td>
<td>13. Connection diagram</td>
</tr>
<tr>
<td>- Adjust offset</td>
<td>18.4 Offset adjustment</td>
</tr>
<tr>
<td>- Select R7, R1, C1 and C2</td>
<td>18.5 Selection of R7</td>
</tr>
<tr>
<td>- Set current limit</td>
<td>for servo amplifier BLD 5603/06-SH4P</td>
</tr>
</tbody>
</table>

**18.3 Servo Amplifiers BLD 5603/06-SE4P for speed control with encoder**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Connect the servo amplifier</td>
<td>16. Connection diagram</td>
</tr>
<tr>
<td>- Adjust offset</td>
<td>18.4 Offset adjustment</td>
</tr>
<tr>
<td>- Connect SE4P module to encoder</td>
<td>18.6 Selection of R7</td>
</tr>
<tr>
<td>- Select R7, R1, C1 and C2</td>
<td>for servo amplifier BLD 5603/06-SE4P</td>
</tr>
<tr>
<td>- Set current limit</td>
<td>7.3 and 18.7 Current limiter</td>
</tr>
</tbody>
</table>

**18.4 Offset adjustment**

The offset is adjusted changing potentiometer Pot. 1, (the position is indicated in chapters 9, 12 and 15 "Dimensional drawing").

**Important:** This setting is made by Minimotor (potentiometer Pot. 1 sealed), hence no other intervention is required.
Start-up Procedure

18.5 Selection of R7 for Servo Amplifiers BLD 5603/06-SH4P

Select resistor R7 adapted to the specific application considering also the motor characteristics (see data sheets):

<table>
<thead>
<tr>
<th>( n_{\text{max}} ) [rpm]</th>
<th>R7 [kΩ]</th>
<th>Gain [rpm/V]</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 000</td>
<td>8,2</td>
<td>8 140</td>
</tr>
<tr>
<td>30 000</td>
<td>11</td>
<td>6 090</td>
</tr>
<tr>
<td>20 000</td>
<td>16</td>
<td>4 180</td>
</tr>
<tr>
<td>15 000</td>
<td>22</td>
<td>3 040</td>
</tr>
<tr>
<td>10 000</td>
<td>33</td>
<td>2 040</td>
</tr>
</tbody>
</table>

\( n_{\text{max}} \) [rpm] – max. controllable speed;
Gain [rpm/V] – gain factor of servo amplifier; corresponds to ratio between motor speed and speed command.

Resistor R7 mounted originally: 11KΩ / 0.6W / 1%.

Table 1: Values of components R1, C1 and C2 recommended for different speed ranges (R7)

<table>
<thead>
<tr>
<th>R7 [kΩ]</th>
<th>R1 [kΩ]</th>
<th>C1 [µF]</th>
<th>C2 [nF]</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.2</td>
<td>240</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>11</td>
<td>240</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>16</td>
<td>150</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>22</td>
<td>150</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>33</td>
<td>120</td>
<td>1</td>
<td>33</td>
</tr>
</tbody>
</table>

For detailed description of components R7, R1, C1 and C2 see chapter: 18.8. “Optimizing the speed controller”.

Application 1:

Brushless DC servomotor 3564 K 024 B; max. speed of motor in this application \( n_{\text{max}} = 8 \text{ 000 rpm} \).

1. Selection of resistor R7:
   \( R7 = 33 \text{ kΩ} \), resulting in a max. speed of 10 000 rpm, values slightly above 8 000 rpm allows to operate in a broad speed range.

2. Knowing the dynamic range ( = 40) of the amplifier allows to calculate the min. controllable speed for this application, i.e.: 10 000 rpm / 40 = 250 rpm. However this min. speed of 250 rpm is not reachable, the min. speed reachable with the SH4P module is approx. 700 rpm and depends on a large extent of the specific application. In general, for applications for a speed below 1 000 rpm, the use of servo amplifier BLD 5606-SE4P or BLD 5603-SE4P is recommended.
Start-up Procedure

18.6 Selection of R7 for Servo Amplifiers BLD 5603/06-SE4P

Select resistor R7 adapted to the specific application considering both the motor and encoder characteristics (see data sheets):

**Note:** The formulae to determine the speed and gain depending on the encoder (CPR) used, are represented with values with six zeros in the denominator; this was chosen intentionally since the CPR value normally exceeds 100 and in such a way the max. speed and the gain are obtained by a simple calculation.

**N.B.:** The max. motor speed must not exceed the encoder speed range, i.e.:

\[
\text{n}_{\text{max}} \,[\text{rpm}] \leq \frac{f_{\text{max}} \,[\text{Hz}] \cdot 60}{\text{CPR} \, [-]}
\]

<table>
<thead>
<tr>
<th>n\text{max} ,[\text{rpm}]</th>
<th>R7 ,[k\Omega]</th>
<th>\text{Gain} ,[\text{rpm/V}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 000 000 / CPR</td>
<td>5,1</td>
<td>1 680 000 / CPR</td>
</tr>
<tr>
<td>4 000 000 / CPR</td>
<td>16</td>
<td>800 000 / CPR</td>
</tr>
<tr>
<td>2 000 000 / CPR</td>
<td>33</td>
<td>400 000 / CPR</td>
</tr>
<tr>
<td>1 000 000 / CPR</td>
<td>75</td>
<td>200 000 / CPR</td>
</tr>
</tbody>
</table>

f\text{max} \,[\text{Hz}] – max. encoder frequency response;

n\text{max} \,[\text{rpm}] – max. controllable speed;

CPR [-] – number of encoder pulses per revolution;

Gain [rpm/V] – gain factor of servo amplifier; corresponds to ratio between motor speed and speed command.

Resistor R7 mounted originally: 16 kΩ / 0.6W / 1%.

<table>
<thead>
<tr>
<th>R7 ,[k\Omega]</th>
<th>R1 ,[k\Omega]</th>
<th>C1 ,[\mu F]</th>
<th>C2 ,[nF]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,1</td>
<td>1000</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>1000</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>33</td>
<td>510</td>
<td>1</td>
<td>2,2</td>
</tr>
<tr>
<td>75</td>
<td>360</td>
<td>1</td>
<td>2,2</td>
</tr>
</tbody>
</table>

**Table 2:** Values of components R1, C1 and C2 recommended for different speed ranges (R7)

For detailed description of components R7, R1, C1 and C2 see chapter:

18.8. “Optimizing the speed controller”.
**Application 2:**

Brushless DC servomotor 2444 S 024 B mounted with an optical encoder HEDS 5500 with 512 pulses per revolution; max. encoder frequency response: 100 kHz; operating range of system for this application: 340 to 4 500 rpm.

1. The recommended max. speed is calculated as follows: \( n_{\text{max}} = \frac{100 \times 000 \times 60}{512} = 11 \; 719 \; \text{rpm} \). There are no problems since this value is higher than the max. speed of the application (4 500 rpm).

2. Selection of resistor \( R7 \): \( R7 = 16 \; \text{k} \); resulting in a max. speed of approx. 7800 rpm \((4000000 / 512)\).

   **Note:** A resistance value selected between 16 \( k \) and 33 \( k \) (max. speed 3 900 rpm) would allow a better use of the speed range (see chapter 18.8.2. Optimizing \( R7 \)).

3. The dynamic range of the servo amplifier allows to calculate the min. controllable speed, i.e.: \( 7 \; 800 \; \text{rpm} / 40 = 195 \; \text{rpm} \); there are no problems since the value is below 340 rpm.

4. The gain value allows to calculate the analog input command for a given speed (speed command = speed/gain).

   Example: For 3 500 rpm the speed command is approx 2.2V (speed command = 3 500 / (800 000 / 512)).

---

**18.7 Current limiter**

The current limiter is a protection if the motor stalls or if it is overloaded. Allows also to set up your specific system without the risk to damage the motor.

1. Remove load from motor or disconnect motor phases;

   **Note:** At this point of the procedure the current limit is not known, hence to avoid motor damages during adjustment proceed as described above;

2. Determine the voltage value \( V_{TP} \).

   **Table 3:** Recommended values

   **Note:** The positions of TP and Pot. 2 are indicated in chapters 12. and 15. “Dimensional drawing”.

   3. Power the servo amplifier;

   4. Using a voltmeter, measure voltage at point TP (pretinned point) and set Pot. 2 until the value \( V_{TP} \) is obtained.

---

### Specifications subject to change without notice
Start-up Procedure

18.8 Optimizing the speed controller

This chapter contains all necessary detail information to optimize the system.

Important: Before optimizing be sure that the current limiter is set.

18.8.1 Optimizing procedure

This procedure refers to the servo amplifiers BLD 5603-SH4P, BLD 5606-SH4P, BLD 5603-SE4P and BLD 5606-SE4P.
Purpose of the first part is to make our system operative and prepared for measurements, whilst the second part comprises optimizing.

Part 1

1. Select R7 depending of the desired speed range (chapters 18.5 or 18.6).

2. Use the R1, C1 and C2 values of the table as a function of the selected R7 value (table 1 or 2, chapters 18.5 or 18.6).

3. For the servo amplifier and brushless DC servomotor system, select supply voltage, inertia and load friction jointly so that these characteristics are identical with those of the type of application to be optimized.

4. Apply rectangular low-frequency signal (e.g.: 0.2 Hz, ±2V).

5. Display the output signal Motor-Speed Monitor (contact 15) on an oscilloscope.

Part 2

<table>
<thead>
<tr>
<th>Procedure</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Optimizing R7</td>
<td>18.8.2. Optimizing R7</td>
</tr>
<tr>
<td>7. Optimizing response</td>
<td>18.8.3. Load influence</td>
</tr>
<tr>
<td>8. Check good operation over whole speed range</td>
<td>18.8.4. Function of R1, C1 and C2</td>
</tr>
<tr>
<td></td>
<td>(if not optimum return to step 7).</td>
</tr>
</tbody>
</table>

N.B.: - During any exchange of components, disconnect power supply from servo amplifier;
- Use a set of resistors and capacitors to facilitate optimizing;
- Use only ceramic capacitors;
- Once the optimization is finished, solder the components.
18.8.2 Optimizing R7

In the following application a servo amplifier BLD 5603-SH4P was considered, naturally this optimizing procedure also applies both for the servo amplifier BLD 5606-SH4P and for the servo amplifiers BLD 5603-SE4P and BLD 5606-SE4P.

Application 3:

In an application with a servo amplifier BLD 5603-SH4P e.g. a max. speed of \( n_{\text{max}} = 35 \, 000 \text{ rpm} \) and a min. speed of \( n_{\text{min}} = 875 \text{ rpm} \) are desired making maximum use of the dynamic range (\( = \frac{n_{\text{max}}}{n_{\text{min}}} = 40 \)) of the system.

1. Select value of R7 (chapter 18.5) corresponding to a max. speed slightly higher than that of the application (in this case \( R7 = 8.2 \, k\Omega \rightarrow n_{\text{max}} = 40 \, 000 \text{ rpm} \)).

2. Verify value of R7 (chapter 18.5) corresponding to a max. speed slightly lower than that of the application (in this case \( R7 = 11 \, k\Omega \rightarrow n_{\text{max}} = 30 \, 000 \text{ rpm} \)).

3. The selected value of R7 to obtain a max. speed of 35 000 rpm is between 8.2 k\( \Omega \) and 11 k\( \Omega \).

4. Determine by way of experiment the value of R7 corresponding to a max. speed of 35 000 rpm choosing a resistance value between those as determined above.

18.8.3 Load influence

Before beginning note that this optimizing procedure is necessary only if a faster response of the system is required.

This chapter shows by means of an extremely practical application how to intervene to adapt the response, whilst the following chapter illustrates the function of the components R1, C1 and C2 and their influence on the system response.

Response too slow

The considered values of table 1 and 2 (chapters 18.5 and 18.6) were determined without load to assure a safe stability at each load condition; hence for such applications, in particular with high load, the system response will become slow. If a fast system response should become necessary, increasing resistance R1 and decreasing capacitor C1 will be sufficient, see Application 4.
Start-up Procedure

**Application 4:** Brushless DC servomotor 3564 K 024 B without load controlled by servo amplifier BLD 5606-SH4P; max. speed 8 000 rpm.

Starting values of servo amplifier components:
- \( R_7 = 33 \ \text{k}\Omega \)
- \( R_1 = 120 \ \text{k}\Omega \)
- \( C_1 = 1 \ \mu\text{F} \)
- \( C_2 = 33 \ \text{nF} \)

**Comment** - The speed command is applied to contact 14 of the connector.

**Measurement 1** (input signal)

**Motor without load**

**Comment** - The output signal corresponds to the speed of the motor, it is measured on contact 15 of the connector (Motor-Speed Monitor).
Start-up Procedure

**Diagram 3**

**Motor with load**

**Measurement 3**
(output signal)

**Time [sec]**

**Motor-Speed Monitor [V]**

**Comment** - This measurement shows the influence of the motor load on the response of the system; compared with measurement 2 the information obtained is as follows:

- The load dampens the response and thus it increases the system stability, positive effect;
- The load slows down the response, negative effect.

**Values of servo amplifier components after optimization:**

- \( R_7 = 33 \, \text{k}\Omega \)
- \( R_1 = 1 \, \text{M}\Omega \)
- \( C_1 = 220 \, \text{nF} \)
- \( C_2 = 33 \, \text{nF} \)

**Diagram 4**

**Motor with load and optimization**

**Measurement 4**
(output signal)

**Comment** - This measurement shows the result of an optimization, varying the components \( R_1 \) and \( C_1 \) of the regulator; the influence of the load is compensated and the response accelerated.
Start-up Procedure

18.8.4 Function of R1, C1 and C2

The purpose of this chapter is the detailed explanation of the function of the regulator components R1, C1 and C2 in such a way to allow an intervention in the stability of the system. Starting data are identical to those in Application 4. The speed command corresponds to Measurement 1 while the output signal corresponds to Measurement 2.

Comparing Measurements 5 to 8 vs. Measurement 2, the influence of each single component is evidenced on the system response.

Important:
- For Measurements 5 to 8, one component value at the time has been modified in relation to the starting values;
- Measurements made without load.

Application 5: See initial data and values of Application 4, Measurements 1 and 2.

Diagram 5

Note: This measurement shows an acceleration better than the acceleration as obtained with the recommended values (Measurement 2). The reason for it is the fact that the choice of the values of the table was made to meet the requirements of a very broad range of applications; this was examined for brushless DC servomotors and their combinations with Minimotor encoders for which reason these values were indicated as recommended values and not as ideal values.

Comment (compare against Measurement 2):
- Increasing resistance R1 the time required for the system to stabilize is reduced.
Start-up Procedure

**Decrease of R1 (R1 = 56 kΩ)**

![Diagram 6](image)

**Comment** (compare against Measurement 2):
- Reducing resistance R1 the time required for the system to stabilize is increased.

**Increase of C1 (C1 = 4.7 µF)**

![Diagram 7](image)

**Comment** (compare against Measurement 2):
- Increasing capacity C1 increases the damping (reduction of oscillations before achieving stability).

Specifications subject to change without notice
Start-up Procedure

Comment (compare against Measurement 2):
- Reducing capacity C1 reduces the damping (increase of oscillations before achieving stability).

Function of capacitor C2

Capacitor C2 allows, together with C1, the optimization of the system at low speed. It is important to understand that the three components R1, C1 and C2 are closely interlinked. If e.g. there are problems when setting up the system at low speed varying only the capacity C2, it is also necessary to change the values of the components R1 and C1.
The FAULHABER Group:

DR. FRITZ FAULHABER
GMBH & CO. KG
Daimlerstraße 23
71101 Schönaich · Germany
Tel.: +49 (0)7031/638-0
Fax: +49 (0)7031/638-100
Email: info@faulhaber.de
www.faulhaber.de

MINIMOTOR SA
6980 Croglio · Switzerland
Tel.: +41 (0)91 611 31 00
Fax: +41 (0)91 611 31 10
Email: info@minimotor.ch
www.minimotor.ch

MicroMo Electronics, Inc.
14881 Evergreen Avenue
Clearwater · FL 33762-3008 · USA
Phone: +1 (727) 572-0131
Fax: +1 (727) 573-5918
Toll-Free: (800) 807-9166
Email: info@micromo.com
www.micromo.com