## L99DZ200G driving three motors with two H-bridges: configuration and use cases

### Introduction

The L99DZ200G integrates two H-bridge drivers that can be used to control up to three DC motors; the purpose of this Technical Note is to describe how the L99DZ200G can be configured to make its two embedded H-bridge drivers control three DC motors.

This three DC motor control can be used in the so called Power Trunk application to automatically open and close the Power Trunk of the car. In the Power Trunk application, two DC motors run in parallel and in the same direction (spindle motors) in order to move up and down the Trunk Door, while the third motor (here called Power Cinch Motor) is activated once the movement of the Trunk is completed in order to lock/unlock the Trunk Door.

The technical note has been organized in two main sections. The first section describes in detail the L99DZ200G H-bridge control, starting from the truth table reported in the datasheet (see References) to detail how the DC motor is driven in all the supported configurations (single and dual modes). In the second section a possible configuration of the two H-bridges to control three DC motors is proposed.

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# 1 H-bridge control

The two H-bridges driven by the L99DZ200G are composed by four external MOSFETs and they have been named A and B; the half bridges (or legs) composing each H-bridge have been named 1 and 2. In this way we have:

- 1A is the first leg (half bridge) of H-bridge A
- 2A is the second leg (half bridge) of H-bridge A
- 1B is the first leg (half bridge) of H-bridge B
- 2B is the second leg (half bridge) of H-bridge B

In the following sections the configuration and the behavior of the H-bridge in both single and dual modes is reported. How the current recirculate (active or passive freewheeling) when using PWM is detailed too.

## 1.1 Single mode

The L99DZ200G single mode is directly inherited from L99DZ100G and kept unchanged.

For DIRHy, SDxy and SDSxy in single mode (DMy = 0), control signals polarity is like the one in L99DZ100G:

- DIRHy = 0 => "direct" motor rotation
- DIRHy = 1 => "reverse" motor rotation
- SDSxy = 0 => active freewheeling
- SDSxy = 1 => passive freewheeling
- SDxy = 0 => freewheeling on LS
- SDxy = 1 => freewheeling on HS

Table 1 shows all combinations of control signals and the effect on the H-bridge without any fault condition:

**Table 1. H-bridge y (y = A, B) control truth table: single mode**

| Nr. | Control pins | | Control bits | | | | | | | Output pins | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PWMH1y | PWMH2y | DIRHy | HENy | DMy | SD1y | SDS1y | SD2y | SDS2y | GH1y | GL1y | GH2y | GL2y | |
| 1 | x | x | x | 0 | x | x | x | x | x | RL | RL | RL | RL | H-bridge y disabled |
| 6 | 1 | x | 0 | 1 | 0 | 0 | 0 | x | x | L | H | H | L | Bridge y HS2 and LS1 on |
| 6_1 | 1 | x | 0 | 1 | 0 | 0 | 1 | x | x | L | H | H | L | Bridge y HS2 and LS1 on |
| 6_2 | 1 | x | 0 | 1 | 0 | 1 | 0 | x | x | L | H | H | L | Bridge y HS2 and LS1 on |
| 6_3 | 1 | x | 0 | 1 | 0 | 1 | 1 | x | x | L | H | H | L | Bridge y HS2 and LS1 on |
| 7 | 0 | x | 0 | 1 | 0 | 0 | 0 | x | x | L | H | L | H | Active freewheeling LS1 and LS2 on |
| 7_1 | 0 | x | 1 | 1 | 0 | 0 | 0 | x | x | L | H | L | H | Active freewheeling LS1 and LS2 on |
| 8 | 0 | x | 0 | 1 | 0 | 0 | 1 | x | x | L | H | L | L | Passive freewheeling through LS2 diode |
| 9 | 0 | x | 1 | 1 | 0 | 0 | 1 | x | x | L | L | L | H | Passive freewheeling through LS1 diode |
| 10 | 1 | x | 1 | 1 | 0 | 0 | 0 | x | x | H | L | L | H | Bridge y HS1 and LS2 on |
| 10_1 | 1 | x | 1 | 1 | 0 | 0 | 1 | x | x | H | L | L | H | Bridge y HS1 and LS2 on |
| 10_2 | 1 | x | 1 | 1 | 0 | 1 | 0 | x | x | H | L | L | H | Bridge y HS1 and LS2 on |
| 10_3 | 1 | x | 1 | 1 | 0 | 1 | 1 | x | x | H | L | L | H | Bridge y HS1 and LS2 on |

| Nr. | Control pins | | Control bits | | | | | | | Output pins | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 0 | x | 0 | 1 | 0 | 1 | 0 | x | x | H | L | H | L | Active freewheeling HS1 and HS2 on |
| 11_1 | 0 | x | 1 | 1 | 0 | 1 | 0 | x | x | H | L | H | L | Active freewheeling HS1 and HS2 on |
| 12 | 0 | x | 0 | 1 | 0 | 1 | 1 | x | x | L | L | H | L | Passive freewheeling through HS1 diode |
| 13 | 0 | x | 1 | 1 | 0 | 1 | 1 | x | x | H | L | L | L | Passive freewheeling through HS2 diode |

### 1.1.1 Two possible motor rotation directions (SDy = x, SDSy = x)

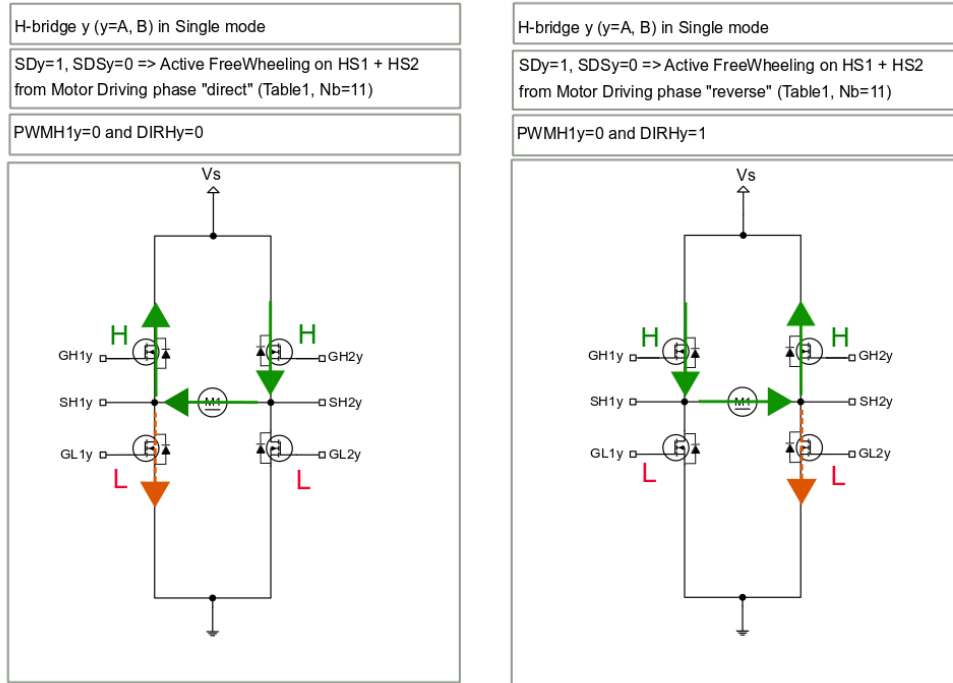**Figure 1. Two possible motor rotation directions (SDy = any, SDSy = any)**
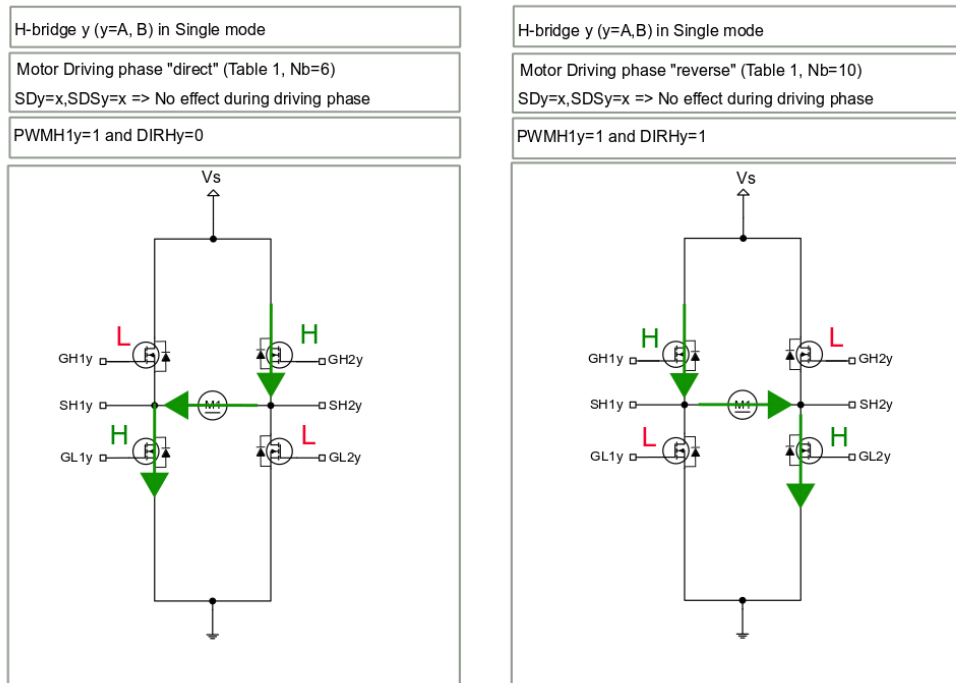
## 1.1.2 SDy = 0, SDSy = 0 => Active freewheeling on LS1 + LS2

**Figure 2.** SDy = 0, SDSy = 0 => Active freewheeling on LS1 + LS2
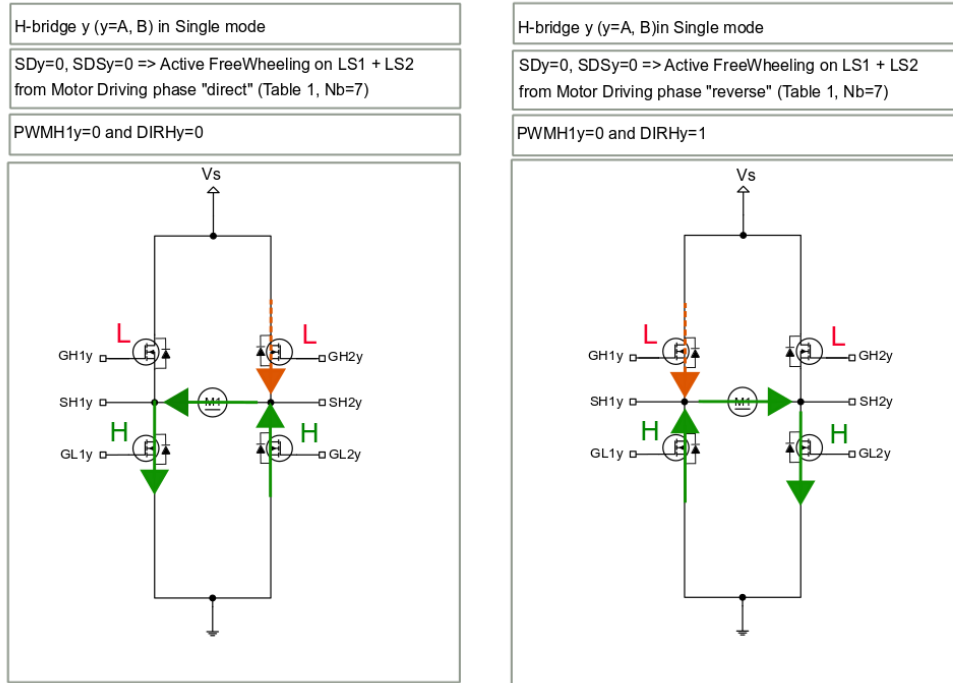
### 1.1.3 SDy = 1, SDSy = 0 => Active Freewheeling on HS1 + HS2

**Figure 3. SDy = 1, SDSy = 0 => Active freewheeling on HS1 + HS2**

| H-bridge y (y=A, B) in Single mode |
|---|
| SDy=1, SDSy=0 => Active FreeWheeling on HS1 + HS2 from Motor Driving phase "direct" (Table1, Nb=11) |
| PWMH1y=0 and DIRHy=0 |

| H-bridge y (y=A, B) in Single mode |
|---|
| SDy=1, SDSy=0 => Active FreeWheeling on HS1 + HS2 from Motor Driving phase "reverse" (Table1, Nb=11) |
| PWMH1y=0 and DIRHy=1 |

## 1.1.4 SDy = 0, SDSy = 1 => Passive freewheeling on LS

**Figure 4.** SDy = 0 SDSy = 1 => Passive freewheeling on LS
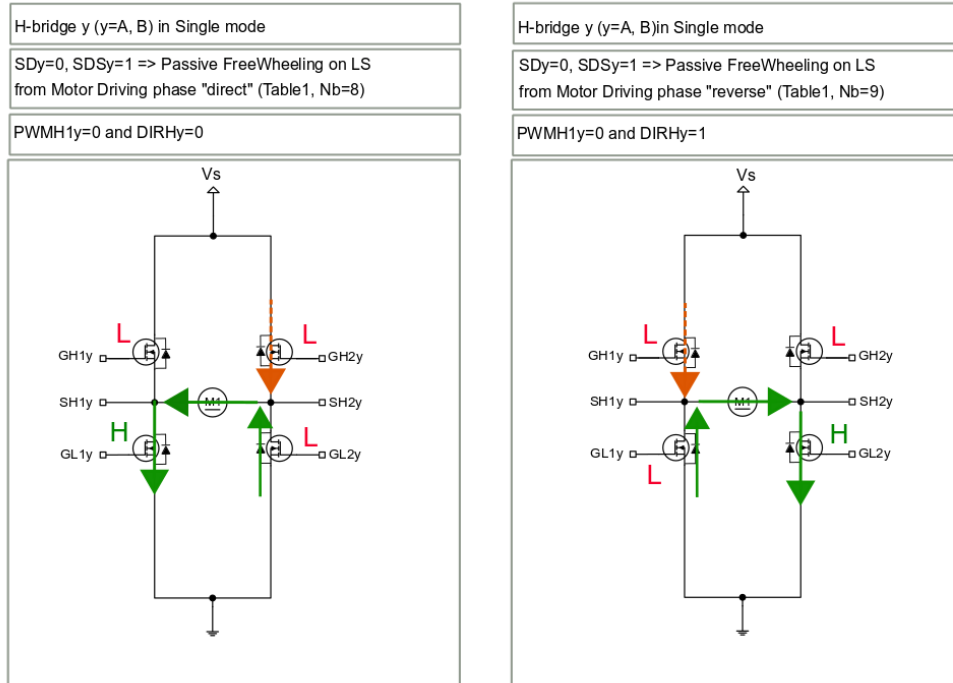
### 1.1.5 SDy = 1, SDSy = 1 => Passive freewheeling on HS1 + HS2

**Figure 5. SDy = 1, SDSy = 1 => Passive freewheeling on HS1 + HS2**
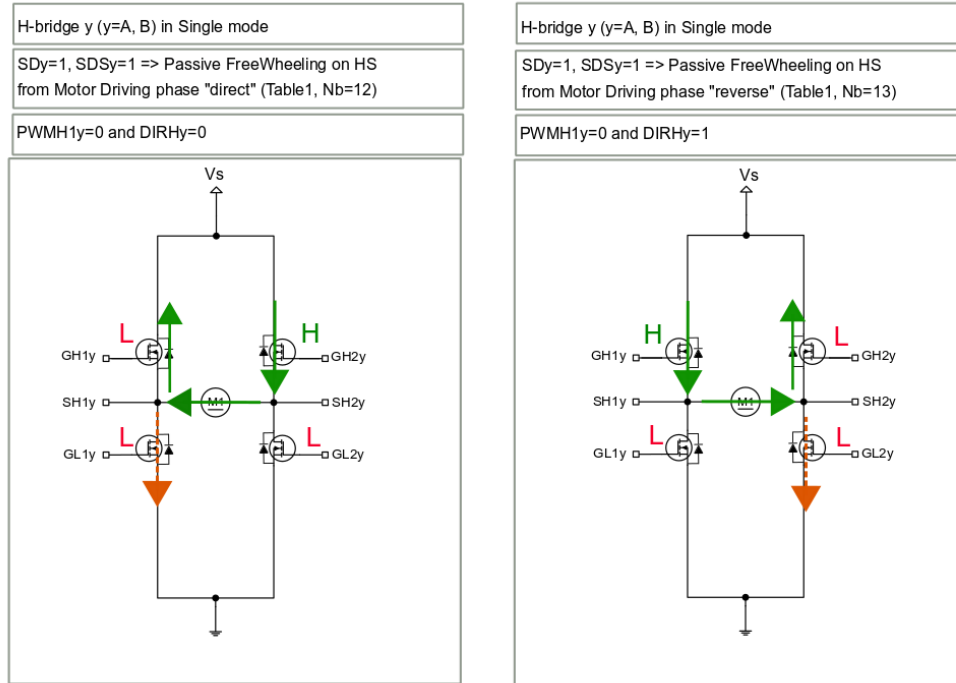


## 1.2 Dual mode

The dual mode is a feature of the L99DZ200G which allows to independently use the two half bridges composing each of the two external H-bridges. Thanks to this feature, in dual mode the two H-bridges embedded in the L99DZ200G can be seen as four independent half-bridges. By combining the usage of the two H-bridges in single and dual mode as reported in Section 2 , three DC motors can be driven.

Hereafter the letter 'y' identifies the H-bridge in use; the letter 'x' identifies the half bridge (or leg) inside a given H-bridge. It can take the following values: 1A, 1B, 2A or 2B.

In the following section, half-bridge operates in dual mode without any fault condition.

In dual mode (DMy = 1) for a single half-bridge 'xy' (x = 1, 2; y = A, B), we need the following command signals:

- PWMHxy (pin): power command (ON/OFF) adjusted by changing PWM duty cycle
- SDxy (spi): direction choice. Drive Low-Side (LS) or High-Side (HS)
- SDSxy (spi): passive or active freewheeling choice

For SDxy and SDSxy in dual mode (DMy = 1), the following signals polarity is chosen to be consistent with single mode:

- SDSxy = 0 => active freewheeling
- SDSxy = 1 => passive freewheeling
- SDxy = 0 => PWM drives HS
- SDxy = 1 => PWM drives LS

Truth table for a half-bridge when DMy = 1 (HENy = 1 and no fault) is reported in Table 2

**Table 2. H-bridge y (y = A, B) control truth table: Dual mode**

| Nr. | Control pin | Control bits | | | | | Output pins | | Comment |
|-----|-------------|--------------|---|---|---|---|-------------|---|---------|
| | PWMHxy | HENy | DMy | DIRHy | SDxy | SDSxy | GHxy | GLxy | |
| 1 | 0 | 1 | 1 | X | 0 | 0 | L | H | Active freewheeling LS |
| 2 | 1 | 1 | 1 | X | 0 | 0 | H | L | DRIVE HS |
| 3 | 0 | 1 | 1 | X | 1 | 0 | H | L | Active freewheeling HS |
| 4 | 1 | 1 | 1 | X | 1 | 0 | L | H | DRIVE LS |
| 5 | 0 | 1 | 1 | X | 0 | 1 | L | L | Passive freewheeling |
| 6 | 1 | 1 | 1 | X | 0 | 1 | H | L | DRIVE HS |
| 7 | 0 | 1 | 1 | X | 1 | 1 | L | L | Passive freewheeling |
| 8 | 1 | 1 | 1 | X | 1 | 1 | L | H | DRIVE LS |

## 1.2.1 Dual mode example: drive one motor

**Figure 6. HS and LS driving**
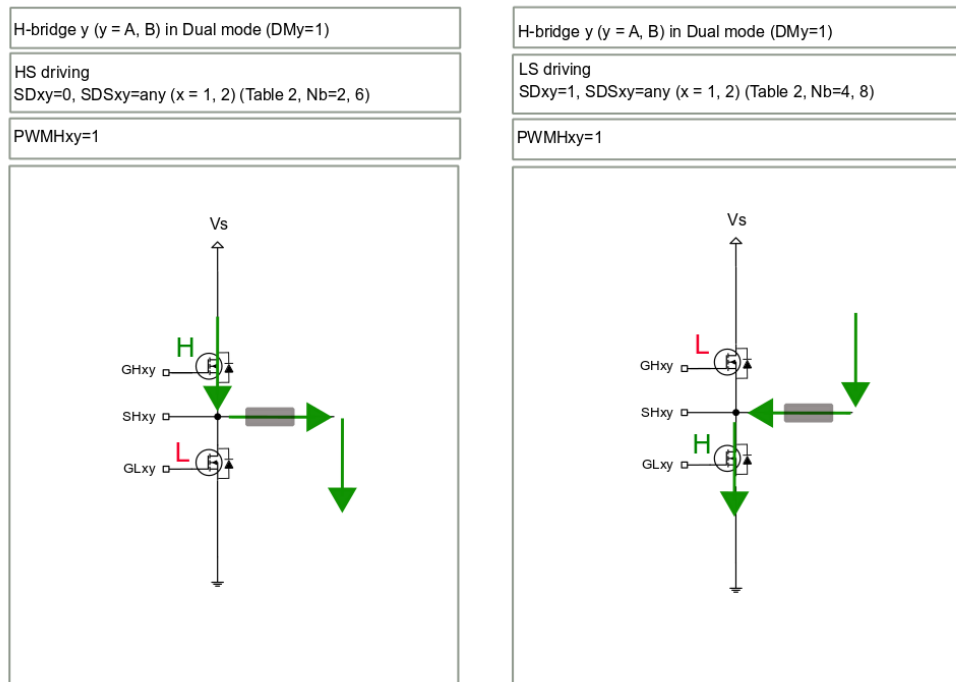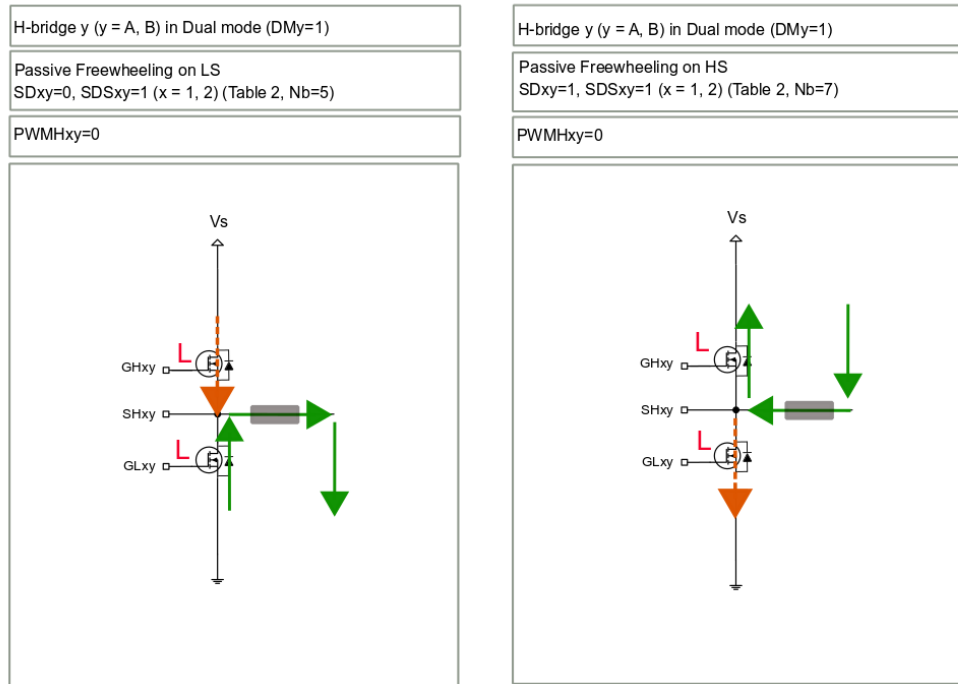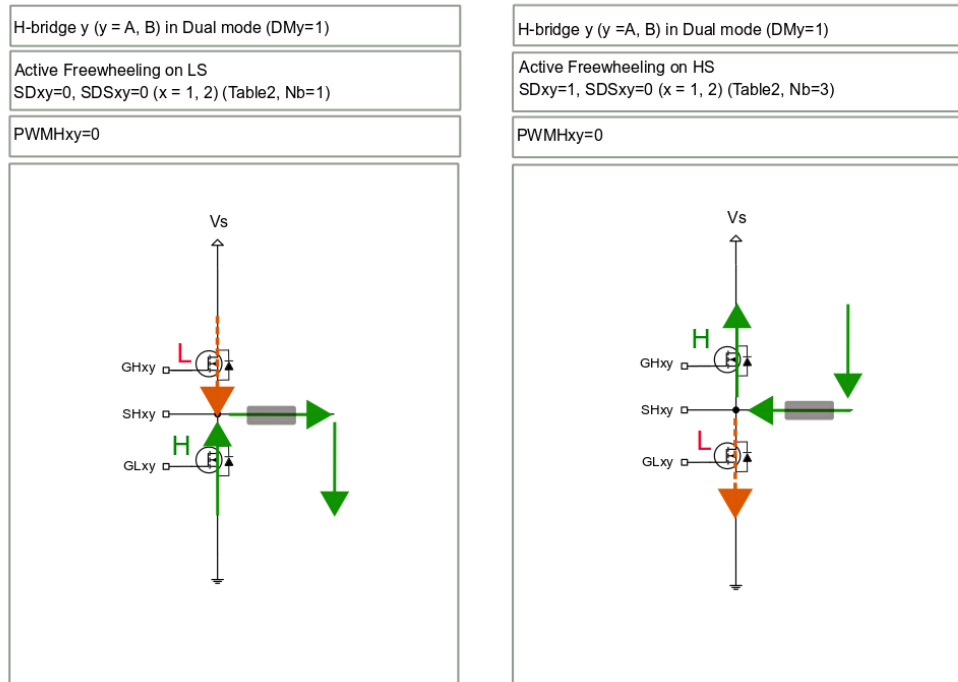
**Figure 7. Passive freewheeling on LS and on HS**

**Figure 8. Active freewheeling on LS and on HS**

| H-bridge y (y = A, B) in Dual mode (DMy=1) |
| --- |
| Active Freewheeling on LS<br>SDxy=0, SDSxy=0 (x = 1, 2) (Table2, Nb=1) |
| PWMHxy=0 |

| H-bridge y (y =A, B) in Dual mode (DMy=1) |
| --- |
| Active Freewheeling on HS<br>SDxy=1, SDSxy=0 (x = 1, 2) (Table2, Nb=3) |
| PWMHxy=0 |

# 2 Three DC motors control example

In this section the two steps actuation of the 3 DC motors is described.

Usually in Trunk application two Spindle Motors (here referred as M1 and M2) and a Power Cinch Motor (here referred as M3) are used.

During the first step both the motors M1 and M2 can run in the same direction (direct or reverse) to open or close the Trunk Door. In the second step, the two spindle motors are switched OFF and the Power Cinch Motor can be activated in Direct or Reverse direction, in order to lock or unlock the trunk cinch (or latch).

In step 1, two configurations can be identified to close and open the trunk.

In step 1, configuration 1 (see Section 2.1 ) the two spindle motors (M1 and M2) are activated at the same time and in the same "reverse" direction, while the cinch motor (M3) is switched OFF (Figure 9 and Figure 13).

In step 1, configuration 2 (see Section 2.2 ) the two spindle motors (M1 and M2) are activated at the same time, but in the "direct" direction; the cinch motor (M3) is switched OFF (Figure 9 and Figure 13).

In step 2, configuration 3, the two spindle motors are switched OFF and the cinch motors is activated (Figure 11 and Figure 14); in this case, both the H-bridges A and B are configured in Dual Mode.

In Table 3 the configuration of the implemented example is reported:

**Table 3. Test example configuration**

| VBAT | PWMH1A | PWMH1B | Phase shift | Current recirculation |
|---|---|---|---|---|
| 13.5 V | 1 kHz Frequency<br>40 % Duty Cycle | 1 kHz Frequency<br>60 % Duty Cycle | 180 ° | Active freewheeling |

## 2.1 Step 1, configuration 1: spindle motors "reverse" and cinch motor OFF

**Table 4. H-bridge A configuration 1**

| PWMH1A | HENA | DIRHA | DMA | SD1A | SDS1A | SD2A | SDS2A | GH1A | GL1A | GH2A | GL2A | Nr. (Table 1) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 | 0 | any | any | H | L | L | H | 10 |
| 0 | 1 | 1 | 0 | 0 | 0 | any | any | L | H | L | H | 7 |

**Table 5. H-bridge B configuration 1**

| PWMH2B | PWMH1B | HENB | DIRHB | DMB | SD1B | SDS1B | SD2B | SDS2B | GH1B | GL1B | GH2B | GL2B | Nr. (Table 2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | any | 1 | any | 1 | 0 | 0 | L | L | H | L | 2 |
| 0 | 0 | 1 | any | 1 | any | 1 | 0 | 0 | L | L | L | H | 1 |

**Figure 9. Step 1, configuration 1: M1, M2 are ON ("reverse"), M3 is OFF**
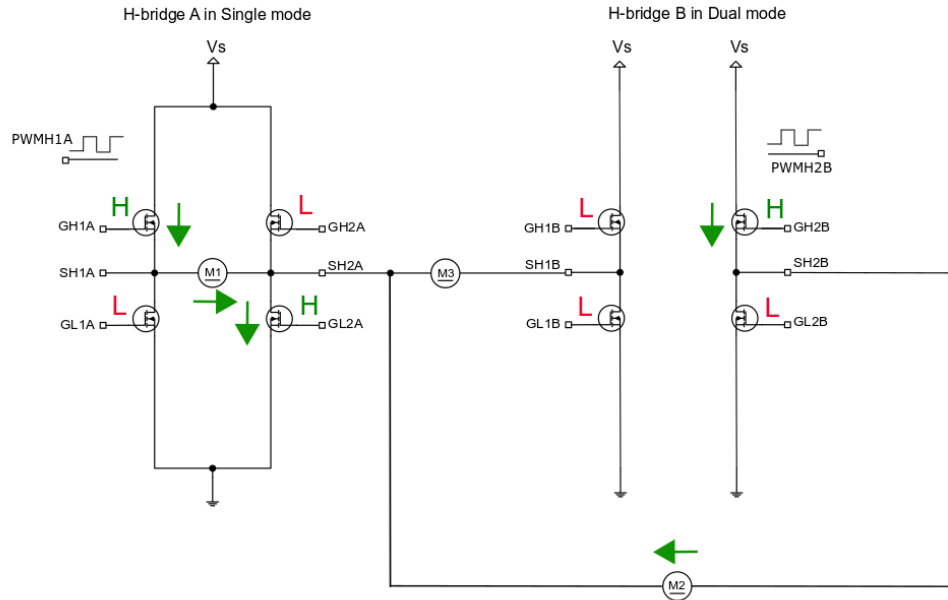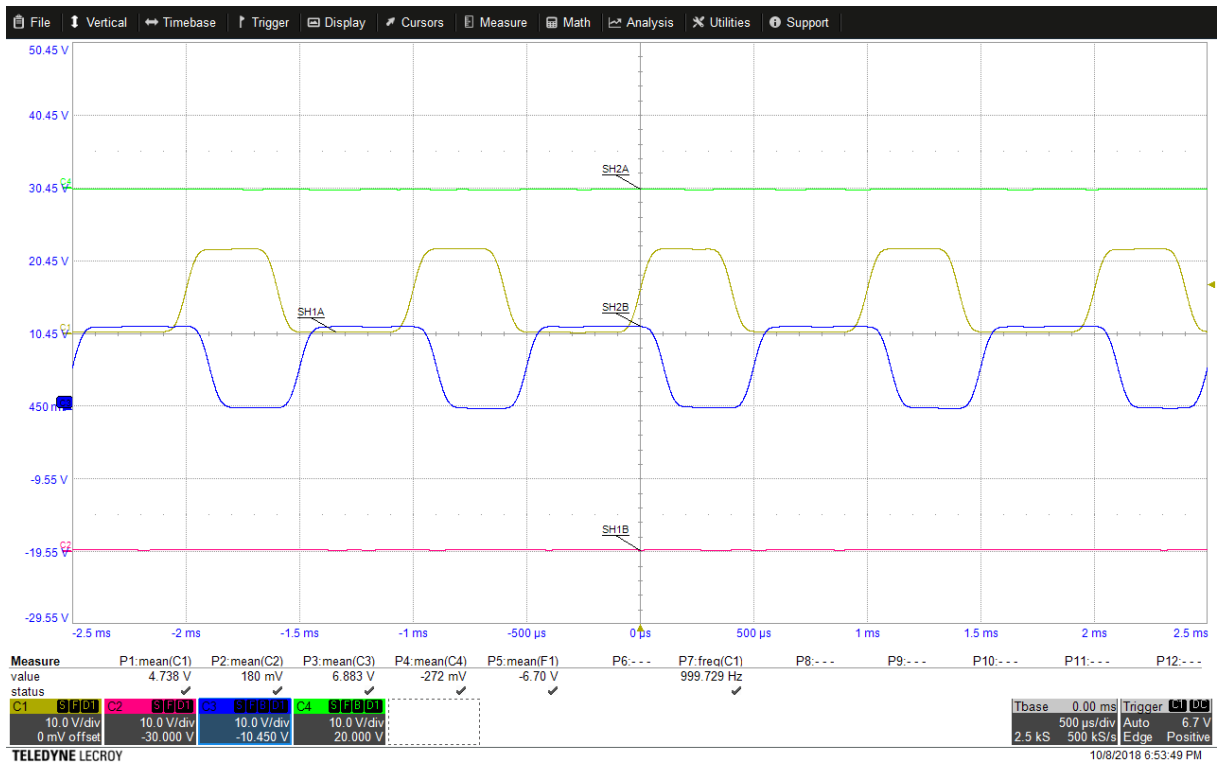


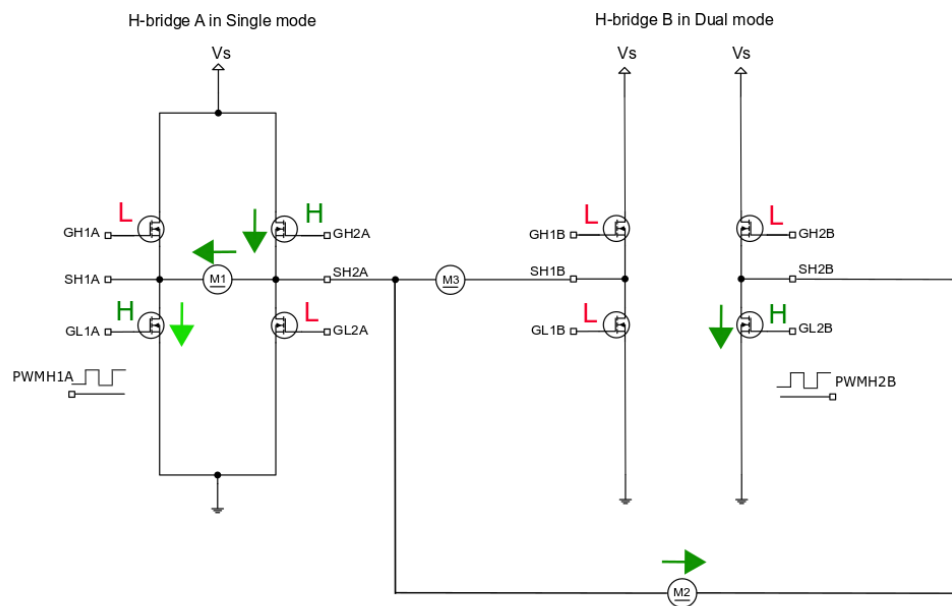**Figure 10. Step 1, configuration 1: SHxy behavior**

## 2.2 Step 1, configuration 2: spindle motors "direct" and cinch OFF

**Table 6. H-bridge A step 1, configuration 2**
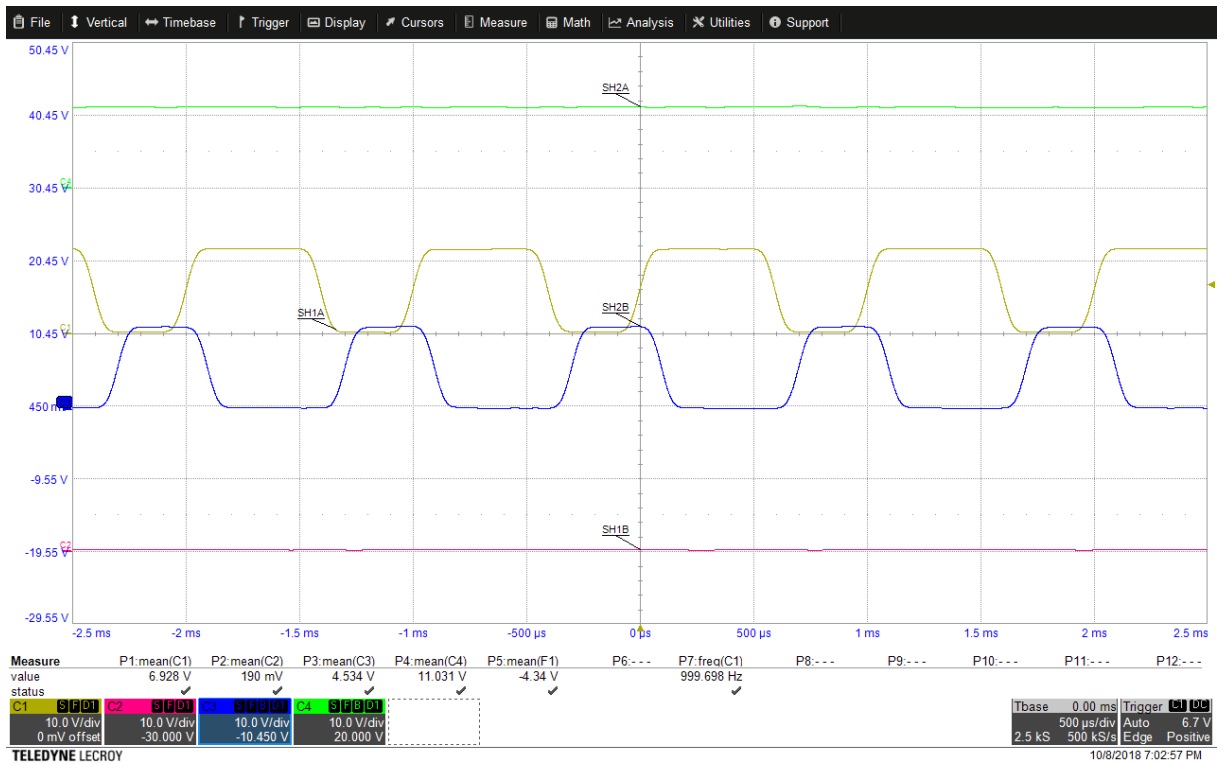
| PWMH1A | HENA | DIRHA | DMA | SD1A | SDS1A | SD2A | SDS2A | GH1A | GL1A | GH2A | GL2A | Nr. (Table 1) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 1 | 0 | any | any | L | H | H | L | 6 |
| 0 | 1 | 0 | 0 | 1 | 0 | any | any | H | L | H | L | 11 |

**Table 7. H-bridge B step 1, configuration 2**

| PWMH2B | PWMH1B | HENB | DIRHB | DMB | SD1B | SDS1B | SD2B | SDS2B | GH1B | GL1B | GH2B | GL2B | Nr. (Table 2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | any | 1 | any | 1 | 1 | 0 | L | L | L | H | 4 |
| 0 | 0 | 1 | any | 1 | any | 1 | 1 | 0 | L | L | H | L | 3 |

**Figure 11. Step 1, configuration 2: M1, M2 are ON ("direct"), M3 is OFF**

**Figure 12. Step 1, configuration 2: SHxy behavior**



## 2.3 Step 2, configuration 3: spindle motors OFF and cinch motor direct

**Table 8. H-bridge A step 2, configuration 3**

| PWMH2A | PWMH1A | HENA | DIRHA | DMA | SD1A | SDS1A | SD2A | SDS2A | GH1A | GL1A | GH2A | GL2A | Nr. (Table 2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | any | 1 | any | 1 | 0 | 0 | L | L | L | H | 1A: 5 or 7 2A: 1 |

**Table 9. H-bridge B step 2, configuration 3**

| PWMH1B | PWMH2B | HENB | DIRHB | DMB | SD1B | SDS1B | SD2B | SDS2B | GH1B | GL1B | GH2B | GL2B | Nr. (Table 1) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | any | 1 | 0 | 0 | any | 1 | H | L | L | L | 1B: 2 2B: 5 or 7 |
| 0 | 0 | 1 | any | 1 | 0 | 0 | any | 1 | L | H | L | L | 1B: 1 2B: 5 or 7 |

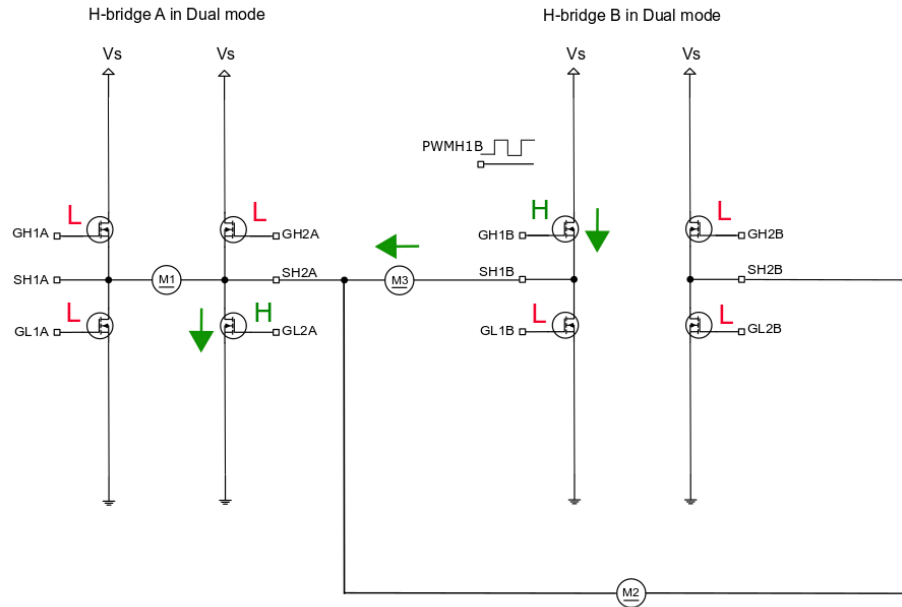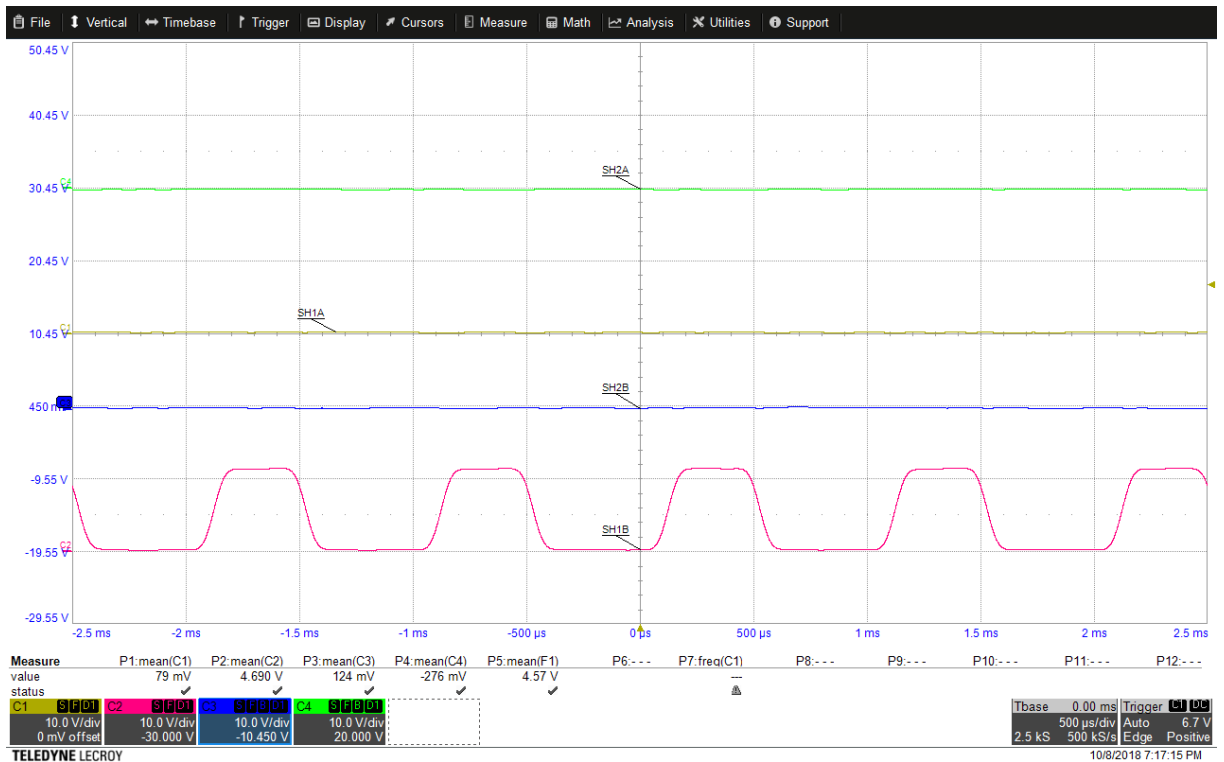**Figure 13. Step 2 configuration 3: M1, M2 are OFF; M3 is ON**



**Figure 14. Step 2, configuration 3: SHxy behavior**

# 3 Conclusion

The Technical Note describes how the L99DZ200G is able to drive three DC motors by using its two integrated H-bridge drivers and 2x4 external MOSFETS. A detailed description of the single and dual modes is given detailing the current recirculation when using the PWM feature.

In the end a possible configuration of the three DC motors is given; the feasibility of this solution has been evaluated and here detailed.

# Appendix A  Other information

## A.1    Reference documents

**Table 10.** **Reference documents**

| Doc Name | Title |
|---|---|
| DS13220 | Automotive Front Door device with LIN and CAN providing Dual H-bridge driving |

# Revision history

**Table 11.** Document revision history

| Date | Version | Changes |
|:---:|:---:|:---|
| 21-Dec-2020 | 1 | Initial release. |

# Contents

**1**     **H-bridge control** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**2**

  **1.1**     Single mode. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2

       **1.1.1**     Two possible motor rotation directions (SDy = x, SDSy = x) . . . . . . . . . . . . . . . . . . . . . . . 3

       **1.1.2**     SDy = 0, SDSy = 0 => Active freewheeling on LS1 + LS2. . . . . . . . . . . . . . . . . . . . . . . . 4

       **1.1.3**     SDy = 1, SDSy = 0 => Active Freewheeling on HS1 + HS2 . . . . . . . . . . . . . . . . . . . . . . . 5

       **1.1.4**     SDy = 0, SDSy = 1 => Passive freewheeling on LS . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 6

       **1.1.5**     SDy = 1, SDSy = 1 => Passive freewheeling on HS1 + HS2. . . . . . . . . . . . . . . . . . . . . . . 7

  **1.2**     Dual mode . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 7

       **1.2.1**     Dual mode example: drive one motor . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 8

**2**     **Three DC motors control example.** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**11**

  **2.1**     Step 1, configuration 1: spindle motors "reverse" and cinch motor OFF . . . . . . . . . . . . . . . 11

  **2.2**     Step 1, configuration 2: spindle motors "direct" and cinch OFF. . . . . . . . . . . . . . . . . . . . . . . 13

  **2.3**     Step 2, configuration 3: spindle motors OFF and cinch motor direct . . . . . . . . . . . . . . . . . . 14

**3**     **Conclusion** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**16**

**Appendix A**   **Other information** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**17**

  **A.1**     Reference documents. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 17

**Revision history** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**18**

# List of tables

# List of figures

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