DC Motor Control Shield with TLE94112EL

For Arduino

About this document

Scope and purpose

This user manual describes the DC motor control shield for Arduino equipped with the TLE94112EL, a twelve-fold half-bridge driver with integrated power stages. This document provides detailed information on the board’s content, layout and use. It should be used in conjunction with the TLE94112EL datasheet, which contains full technical details on the device specification and operation.

Intended audience

Engineers, hobbyists and students who want to add a powerful motor control to Arduino projects.

Related information

Table 1 Supplementary links and document references

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<th>Description</th>
</tr>
</thead>
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<td>Product page which contains reference information for the multiple half-bridge driver TLE94112EL</td>
</tr>
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<td>TLE941xy SPI interface</td>
<td>Application note for the SPI interface of the multiple half-bridge driver family TLE941xy</td>
</tr>
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<td>Information page for the XMC1100 Boot Kit</td>
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<tr>
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<td>Download page for Arduino Integrated Development Environment</td>
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1 Introduction

1.1 DC Motor Control Shield overview

The DC Motor Control Shield with TLE94112EL for Arduino Uno makes it easy to control up to six independent or eleven cascaded bidirectional DC motors.

The shield can be controlled by a microcontroller via an SPI interface. For example, either an Arduino Uno R3 or the XMC1100 Boot Kit from Infineon can be used as master.

The board features an Infineon TLE94112EL, a twelve-fold half-bridge driver with integrated MOSFETs. Each half-bridge can drive peak currents up to 0.9 A and DC current in the range of 200 mA to 500 mA, depending on the application conditions and the number of activated outputs.

The DC Motor Control Shield has an active reverse polarity protection with the p-channel MOSFET IPD50P04P4L-11.

The DC Motor Control Shield can be easily connected e.g. to any Arduino board or to the XMC1100 Boot Kit via headers.

Figure 1 DC Motor Shield with TLE94112EL
1.2 Key features

The DC Motor Control Shield has the following features:

- An Arduino Uno R3, XMC1100 Boot Kit, or similar board connected to the shield can control twelve half-bridges via the SPI interface
- Brushed DC Motor Control up to 0.9 A peak
  - 5.5 – 18 V normal operating input voltage
  - 18 – 20 V extended operating input voltage
  - Maximum input voltage up to 40V (absolute max. rating)
- Control of:
  - Six independent bidirectional DC motors
  - Eleven cascaded bidirectional DC motors
- SPI interface for high configurability and detailed diagnosis
- Protections:
  - Overtemperature
  - Overcurrent
  - Undervoltage
  - Overvoltage
- Detailed diagnosis per MOSFET:
  - Individual open load detection
  - Individual overcurrent detection
- Paralleling outputs for higher current capability
- Motor speed control by PWM
  - Three independent PWM generators
  - PWM frequency: 80 Hz, 100 Hz or 200 Hz
  - 8-bit resolution, 0.5% duty cycle steps
  - Active freewheeling for lower power dissipation
- Two shields can be stacked to control an increased number of motors
- Reverse polarity protection with IPD50P04P4L-11
1.3 Application diagram for bi-directional DC motor applications

Figure 2 Simplified application diagram with TLE94112EL driving DC motors

Refer to the TLE94112EL datasheet for more information.
2 DC Motor Control Shield description

For a safe and optimized motor control design, some discrete components are needed. Some of them are dedicated to the motor application and some to the TLE94112EL.

Figure 4, Figure 5 and Figure 6 show the schematics and the corresponding layout of the DC Motor Control Shield with TLE94112EL.

2.1 Overview

![DC Motor Control Shield]

Figure 3 DC Motor Control Shield connectors
2.2 Schematics

Figure 1  Figure 4 Schematics Motor Control Shield for Arduino with TLE94112EL

2.3 Layout

Figure 5 and Figure 6 show the layout of the DC Motor Shield with TLE94112EL.

Figure 2  Figure 5 DC Motor Control Shield – Bottom and top layers
Figure 3  Figure 6 DC Motor Control Shield for Arduino with TLE94112EL – Layout
2.4 Bill of Material of the DC Motor Shield

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<thead>
<tr>
<th>Part</th>
<th>Part number</th>
<th>Manufacturer</th>
<th>Description</th>
<th>Qty</th>
<th>Distributor</th>
<th>Order Number</th>
<th>Comment</th>
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<tr>
<td>C1, C2, C3</td>
<td>C085010E01N00</td>
<td>Kemet</td>
<td>Capacitor 100n/50V</td>
<td>3</td>
<td>Farnell</td>
<td>2070045</td>
<td></td>
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<tr>
<td>C4</td>
<td>EE2 FT1470AP</td>
<td>Panasonic</td>
<td>Capacitor 4.7µF/50V</td>
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<td>D21</td>
<td>MM53Z12T16</td>
<td>ON Semiconductor</td>
<td>Zener 12V</td>
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<td>Farnell</td>
<td>1431191</td>
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<tr>
<td>D22</td>
<td>SM6693A</td>
<td>STMicroelectronics</td>
<td>Transient suppressor diode</td>
<td>1</td>
<td>Farnell</td>
<td>9802703</td>
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<td>IC1</td>
<td>TLE94112EL</td>
<td>Infineon</td>
<td>12-fold half-bridge driver</td>
<td>1</td>
<td>Mouser</td>
<td>726-TLE94112ELXUMA1</td>
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<td>JP1</td>
<td>JT254F-D180-850-100-0</td>
<td>MTCQNN</td>
<td>Stacking header - 10 pins</td>
<td>1</td>
<td>Mouser</td>
<td>726-TLE94112ELXUMA1</td>
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<tr>
<td>JP2, JP4</td>
<td>JT254F-D180-850-100-0</td>
<td>MTCQNN</td>
<td>Stacking header - 8 pins</td>
<td>2</td>
<td>Mouser</td>
<td>726-TLE94112ELXUMA1</td>
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<tr>
<td>JP5</td>
<td>JT254F-D180-850-100-0</td>
<td>MTCQNN</td>
<td>Stacking header - 6 pins</td>
<td>1</td>
<td>Mouser</td>
<td>726-TLE94112ELXUMA1</td>
<td></td>
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<tr>
<td>Q1</td>
<td>IPD50SP04F4L-11</td>
<td>Infineon</td>
<td>40V p-channel MOSFET</td>
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<td>Farnell</td>
<td>2443434</td>
<td></td>
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<td>R1, R2, R3, R4, R6</td>
<td>WR08X4700PTL</td>
<td>Walsin</td>
<td>Resistor</td>
<td>5</td>
<td>Farnell</td>
<td>2502730</td>
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<td>R5</td>
<td>CRC2W12064X70F00A</td>
<td>Vishay</td>
<td>Resistor</td>
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<td>Farnell</td>
<td>1470013</td>
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<td>R7</td>
<td>WR08X0100</td>
<td>Walsin</td>
<td>Resistor</td>
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<td>2502664</td>
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<tr>
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<td>Walsin</td>
<td>Resistor</td>
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<td>Farnell</td>
<td>2502664</td>
<td>Not mounted</td>
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<td>X2</td>
<td>31090106</td>
<td>Metz Connect</td>
<td>6-Position terminal block, 3.5mm</td>
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<td>Farnell</td>
<td>2434247</td>
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<td>X4</td>
<td>OSTS0E090104</td>
<td>On Shore Technology</td>
<td>9-Position terminal block, 3.5mm</td>
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<td>Digkey</td>
<td>ED2747</td>
<td></td>
</tr>
</tbody>
</table>

Figure 7 DC Motor Control Shield with TLE94112EL – Bill of Material (BOM)

2.5 CSN1 and CSN2 Selection

The Pin 10 of the Arduino Uno is used by default to control CSN (Negated Chip Select) input of the TLE94112EL (Figure 8).

Alternatively, the pin 9 of the Arduino Uno can be used instead to stack two shields (refer to section 2.6). In this case, the resistor R7 (0 Ω, case 0805) must be desoldered (Figure 9) and a 0 Ω resistor (case 0805) must be soldered on the footprint of R8 (Figure 9)

Figure 8 Control of CSN of TLE94112EL by Pin 10 (CSN1)
2.6 Stacking two DC Motor Shields

It is possible to stack two DC Motor Shields to double the number of controlled motors.

In this configuration, the CSN input of each TLE94112EL must be controlled individually by different microcontroller GPIOs:

- The TLE94112EL of one DC Motor shield is controlled by the pin 10 (default setting, Figure 8).
- The TLE94112EL of the other DC Motor shield is controlled by the pin 9 (Figure 9).

2.7 Pin assignment

To use the DC Motor Control Shield, the necessary control signals can be applied directly at the Arduino™ connectors with an Arduino, an XMC 1100 Boot Kit or any other microcontroller.

Figure 10 shows the pinout/ connectors of the DC Motor Shield with TLE94112EL.
Figure 10 Connectors of DC Motor Shield
## 2.8 Pin definitions and functions

<table>
<thead>
<tr>
<th>Pin</th>
<th>I/O ¹</th>
<th>Function</th>
</tr>
</thead>
</table>
| SGND | -     | Signal GND  
Connect to the signal GND of the microcontroller |
| PGND | -     | Power GND  
Connect one of the connector to the power GND the application |
| VBAT | -     | Battery supply (5.5 – 20 V operating, 40V absolute max. rating)  
Connect to the battery voltage of the application |
| VDD  | -     | Logic supply (5V for Arduino Uno) |
| SCLK | I     | Serial Clock Input ² |
| SDI  | I     | Serial Data Input ² |
| SDO  | O     | Serial Data Output ² |
| CSN1 | I     | Negated Chip Select 1 ², ³ |
| CSN2 | I     | Negated Chip Select 2 ², ³ |
| EN   | I     | Enable Input  
Connect to a GPIO of the microcontroller. When set to low device goes in sleep mode with low current consumption. |
| OUT1-12 | O | Connectors for outputs of the half-bridges 1-12 |

¹ With respect to the TLE94112EL

² Connect these signals to an SPI interface of the microcontroller

³ Refer to chapters CSN1 and CSN2 Selection and 2.6
3 TLE94112EL overview

The TLE94112EL is a protected twelve-fold half-bridge driver designed especially for automotive motion control applications such as heating, ventilation and air conditioning (HVAC) flap DC motor control. It is part of a larger family offering half-bridge drivers from three outputs to twelve outputs with direct interface or SPI interface.

The half bridge drivers are designed to drive DC motor loads in sequential or parallel operation. Operation modes forward, reverse, brake and high impedance are controlled from a 16-bit SPI interface. It offers diagnosis features such as short circuit, open load, power supply failure and overtemperature detection.

In combination with its low quiescent current, this device is attractive among others for automotive applications. The small fine pitch exposed pad package, PG-SSOP-24, provides a good thermal performance and reduces PCB-board space and costs.

3.1 Key features of the TLE94112EL

- Twelve half-bridge power outputs
- Optimized EMC behavior
- Very low power consumption in sleep mode
- 3.3V / 5V compatible inputs with hysteresis
- All outputs with overload and short circuit protection
- Independently diagnosable outputs (overcurrent, open load)
- Open load diagnostics in ON-state for all high-side and low-side
- Outputs with selectable open load thresholds (HS1, HS2)
- 16-bit Standard SPI interface with daisy chain and in-frame response capability for control and diagnosis
- Fast diagnosis with the global error flag
- PWM capable outputs for frequencies 80Hz, 100Hz and 200Hz with 8-bit duty cycle resolution
- Overtemperature pre-warning and protection
- Over- and Undervoltage lockout
- Cross-current protection
- AEC-100 Qualified

Figure 11 PG-SSOP-24 Package
3.2 Block diagram

Figure 12 Block diagram TLE94112EL
### 3.3 Pin assignment

| Pin  | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  | 20  | 21  | 22  | 23  | 24  |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| GND  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | GND |
| OUT 1|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | OUT 2|
| OUT 5|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | OUT 8|
| OUT 7|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | VS2 |
| SDI  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | SCLK|
| VDD  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | CSN |
| SDO  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | OUT 12|
| EN   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | OUT 11|
| OUT 9|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | VS1 |
| OUT 6|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | OUT 10|
| OUT 4|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | OUT 3 |
| GND  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | GND |

*Figure 13 Pin assignment TLE94112EL (top view)*
### 3.4 Pin definitions and functions

<table>
<thead>
<tr>
<th>Pin</th>
<th>Symbol</th>
<th>Function</th>
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<tr>
<td>1</td>
<td>GND</td>
<td>Ground. All ground pins should be externally connected together.</td>
</tr>
<tr>
<td>2</td>
<td>OUT 1</td>
<td>Power half-bridge 1</td>
</tr>
<tr>
<td>3</td>
<td>OUT 5</td>
<td>Power half-bridge 5</td>
</tr>
<tr>
<td>4</td>
<td>OUT 7</td>
<td>Power half-bridge 7</td>
</tr>
<tr>
<td>5</td>
<td>SDI</td>
<td>Serial data input with internal pull down</td>
</tr>
<tr>
<td>6</td>
<td>VDD</td>
<td>Logic supply voltage</td>
</tr>
<tr>
<td>7</td>
<td>SDO</td>
<td>Serial data output</td>
</tr>
<tr>
<td>8</td>
<td>EN</td>
<td>Enable with internal pull-down; Places device in standby mode by pulling the EN line Low</td>
</tr>
<tr>
<td>9</td>
<td>OUT 9</td>
<td>Power half-bridge 9</td>
</tr>
<tr>
<td>10</td>
<td>OUT 6</td>
<td>Power half-bridge 6</td>
</tr>
<tr>
<td>11</td>
<td>OUT 4</td>
<td>Power half-bridge 4</td>
</tr>
<tr>
<td>12</td>
<td>GND</td>
<td>Ground. All ground pins should be externally connected together.</td>
</tr>
<tr>
<td>13</td>
<td>GND</td>
<td>Ground. All ground pins should be externally connected together.</td>
</tr>
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<td>14</td>
<td>OUT 3</td>
<td>Power half-bridge 3</td>
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<td>15</td>
<td>OUT 10</td>
<td>Power half-bridge 10</td>
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<td>16</td>
<td>VS1</td>
<td>Main supply voltage for power half bridges. VS1 should be externally connected to VS2.</td>
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<td>17</td>
<td>OUT11</td>
<td>Power half-bridge 11</td>
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<td>18</td>
<td>OUT12</td>
<td>Power half-bridge 12</td>
</tr>
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<td>19</td>
<td>CSN</td>
<td>Chip select Not input with internal pull up</td>
</tr>
<tr>
<td>20</td>
<td>SCLK</td>
<td>Serial clock input with internal pull down</td>
</tr>
<tr>
<td>21</td>
<td>VS2</td>
<td>Main supply voltage for power half bridges. VS1 should be externally connected to VS1.</td>
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<td>22</td>
<td>OUT 8</td>
<td>Power half-bridge 8</td>
</tr>
<tr>
<td>23</td>
<td>OUT 2</td>
<td>Power half-bridge 2</td>
</tr>
<tr>
<td>24</td>
<td>GND</td>
<td>Ground. All ground pins should be externally connected together.</td>
</tr>
<tr>
<td>EDP</td>
<td>-</td>
<td>Exposed Die Pad; For cooling purpose only - not usable as electrical ground. Electrical ground must be provided by pins 1, 12, 13, 24</td>
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</tbody>
</table>
4 Getting started

4.1 Target applications

The main application targeted by the TLE94112EL is brushed DC motor control with peak currents below 0.9A. Several outputs can be connected in parallel to increase the current capability.

Besides motor control, the TLE94112EL can drive any other inductive, capacitive and resistive loads within the device electrical characteristics such as monostable relays, bistable relays and LEDs.

4.2 Getting started: Shield

- Connect the brushed DC motors to the corresponding output connectors (OUTx, x=1…12). Refer to Figure 14.
- Choose a DC adapter
  - The extended operating input range of the shield (VBAT) is 5.5 V – 20 V DC.
  - The absolute maximum rating is 40 V.
- Connect the DC Motor Shield to e.g. an Arduino Uno R3 or an XMC 1100 Boot Kit. The control signals between the TLE94112EL and the Arduino Uno R3 or XMC1100 are linked to each other (Figure 15).
- Connect the USB cable to e.g. the Arduino Uno R3 (Figure 16) or the micro USB to the XMC 1100 Boot Kit.
  - Once the software is flashed to the microcontroller a, a standard mobile phone charger can be used to supply the XMC 1100 Boot Kit
- Program the controller board with the motor control software with the corresponding IDE.
- Connect the DC adapter to the Power Shield (VBAT and GND, see Figure 16).
- Turn on the power.
DC Motor Shield with TLE94112EL
For Arduino

Figure 14 Motor Control Shield connectors

Figure 15 Control signals between DC motor shield and Arduino Uno
4.3 Getting started: Software

Download the sketch example for the DC Motor Shield with TLE94112 for Arduino (TLE94112EL_Shield_Arduino_Example_Sketch Link).

Connect the Arduino Uno with a USB cable to the USB port of your PC.

- Download and install the Arduino IDE: free Development Platform for Code Generation from Arduino. Link: Arduino IDE
- Start the Arduino IDE and import the project file: TLE94112EL_Shield_Arduino_Example_Sketch (Link).
- Upload the sketch to the Arduino Uno
4.4 Sketch example for DC motor shield

The TLE94112EL-Sketch example (Link) is intended to operate with shields configured as shown in Figure 4: The CSN input of the TLE94112EL is controlled by the Pin 10 of the Arduino Uno board.

Sketch content:

- Declarations of register addresses
- Functions to read / write and clear registers of the TLE94112EL
- Function to display the SPI frames sent/received by the TLE94112EL on the IDE Serial Monitor
- Motors activation in loop:
  1. The motor connected between OUT1/OUT2 operates in PWM mode / 100 Hz
     - During 2 seconds: Low-Side 2 (LS2) ON, High-Side 1 (HS1) ON with 90 % duty cycle / 100 Hz
     - During 2 seconds: LS2 ON, HS1 ON with 20 % duty cycle / 100 Hz
     - Brake to GND for 300 ms: LS1 and LS2 ON
  2. Activation of six motors (connected to OUT1/2, OUT3/4, OUT5/6, OUT7/8, OUT9/10 and OUT11/12)
     - During 1 second:
       - LS1, LS3, LS5, LS7, LS9, LS11 ON
       - HS2, HS4, HS6, HS8, HS10, HS12 ON
     - Brake to GND for 300 ms:
       - LS1-12 ON
     - During 1 second:
       - HS1, HS3, HS5, HS7, HS9, HS11 ON
       - LS2, LS4, LS6, LS8, LS10, LS12 ON
     - Brake to GND for 300 ms:
       - LS1-12 ON
# Revision History

Major changes since the last revision

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<tr>
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<th>Description of change</th>
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<tr>
<td>V1.0, 2017-02-13</td>
<td>First release</td>
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