Low Side Switch Shield

with BTF3050TE for Arduino

About this document

Scope and purpose

This document describes how to use the Low Side Switch Shield with BTF3050TE for Arduino.

Intended audience

Engineers, hobbyists and students who want to add powerful Low Side Switches to Arduino projects.

Related information

Table 1   Supplementary links and document references

Reference	Description
BTF3050TE Data Sheet	Product page which contains reference information for the BTF3050TE
Arduino Home Page	All information on Arduino
Arduino Uno Product Page	Arduino Uno R3 description
DAVE™ Development Platform	All details on DAVE™ IDE
XMC1100 Boot Kit	Product page which contains reference information for the XMC1100 Boot Kit
Shields for Arduino by Infineon	All details on Infineon's shields for Arduino
XMC Homepage	All information about the XMC^{TM} microcontroller family

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1 Low Side Switch Shield Introduction

This chapter will provide a brief introduction of the Low Side Switch Shield.

1.1 Low Side Switch Shield overview

The Low Side Switch Shield adds powerful Low Side Switches to Arduino projects. The shield can be controlled with the general logic IO-Ports of a microcontroller. For example either an Arduino Uno R3 or the XMC1100 Boot Kit from Infineon can be used as the master. Note: When using an Arduino the Switch SI cannot be used anymore.

On board of the Low Side Switch Shield are three self-protected BTF3050TE. Each is featuring one N-channel low side MOSFET with an integrated driver IC in one package. In addition to the driver, several security features have been integrated, like over-temperature-, short circuit- and over voltage protection. With the multi functional pin *SRP* it is possible to give a fault feedback after an overtemperature shut down. For more information please see the datasheet of the BTF3050TE.

The BTF3050TE is easy to control by applying logic level signals to the IN pin. For example when applying a PWM to the IN pin, a motor can be controlled with the duty cycle of the PWM.
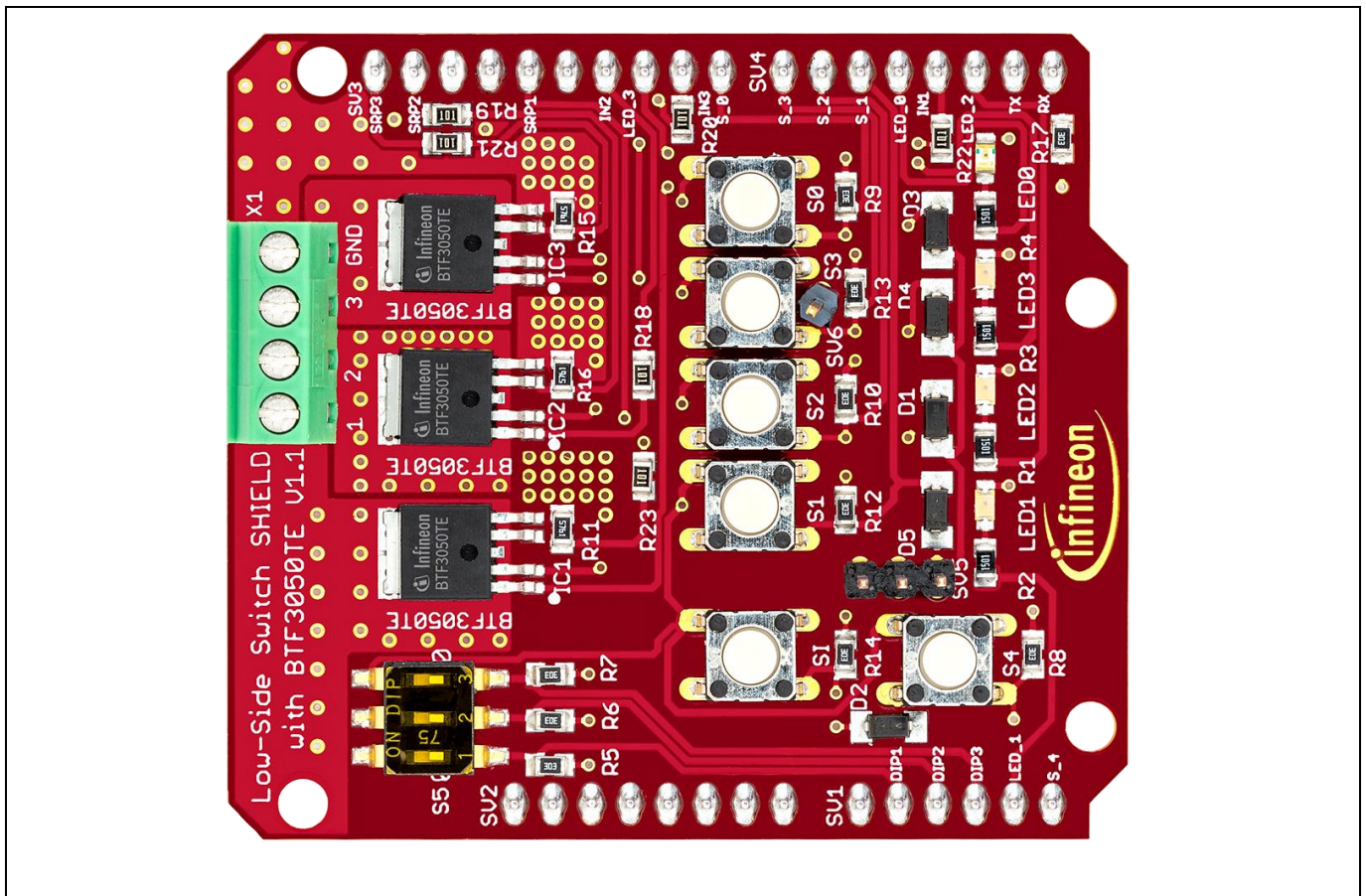
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Figure 1   Low Side Switch Shield photo

1.2 Key features

The Low Side Switch Shield has the following features:

- An Arduino Uno R3, XMC1100 Boot Kit, or similar board connected to the shield can control the three Low Side Switches via general IO pins.
- Able to switch all kind of loads like resistive, inductive and capacitive, limited by clamping energy
- Three Low Side Switches BTF3050TE
    - Input voltage : 3 to 5.5V
    - Supply voltage: 3 to 5.5V
    - Nominal battery voltage: 8 to 18V
    - Extended battery voltage: 3 to 28V
    - Nominal load current: 3 A
    - Minimum current limitation: 30 A
- Over temperature shutdown with auto-resart
- Active clamp over voltage protection of the output (min. 40 V)
- Enhanced short circuit protection
- Capable of PWM up to14 kHz (at 10% duty cycle)
- Driver circuit with logic level inputs
- Diagnosis function
- Protection e.g. against overtemperature, overcurrent and overvoltage
- Communication with the environment via four LEDs, one DIP-switch and up to 6 push buttons
- Easy handling of push buttons: The pin connected to switch SI is always activated; when any button is pushed. This characteristic provides the option to handle easily push button inputs via interrupt.
- Further comments:
    - In order to use the board with an Arduino Uno R3, the pin headers SV5 must be removed. This results in the loss of the usage of the push button SI. Any other feature remains.

1.3 Application diagram of the BTF3050TE

In Figure 2 an application example of the BTF3050TE is shown. This gives the clear information how to use the BTF3050TE with a microcontroller. More details to the BTF3050TE are given in chapter 3 or in the data sheet.
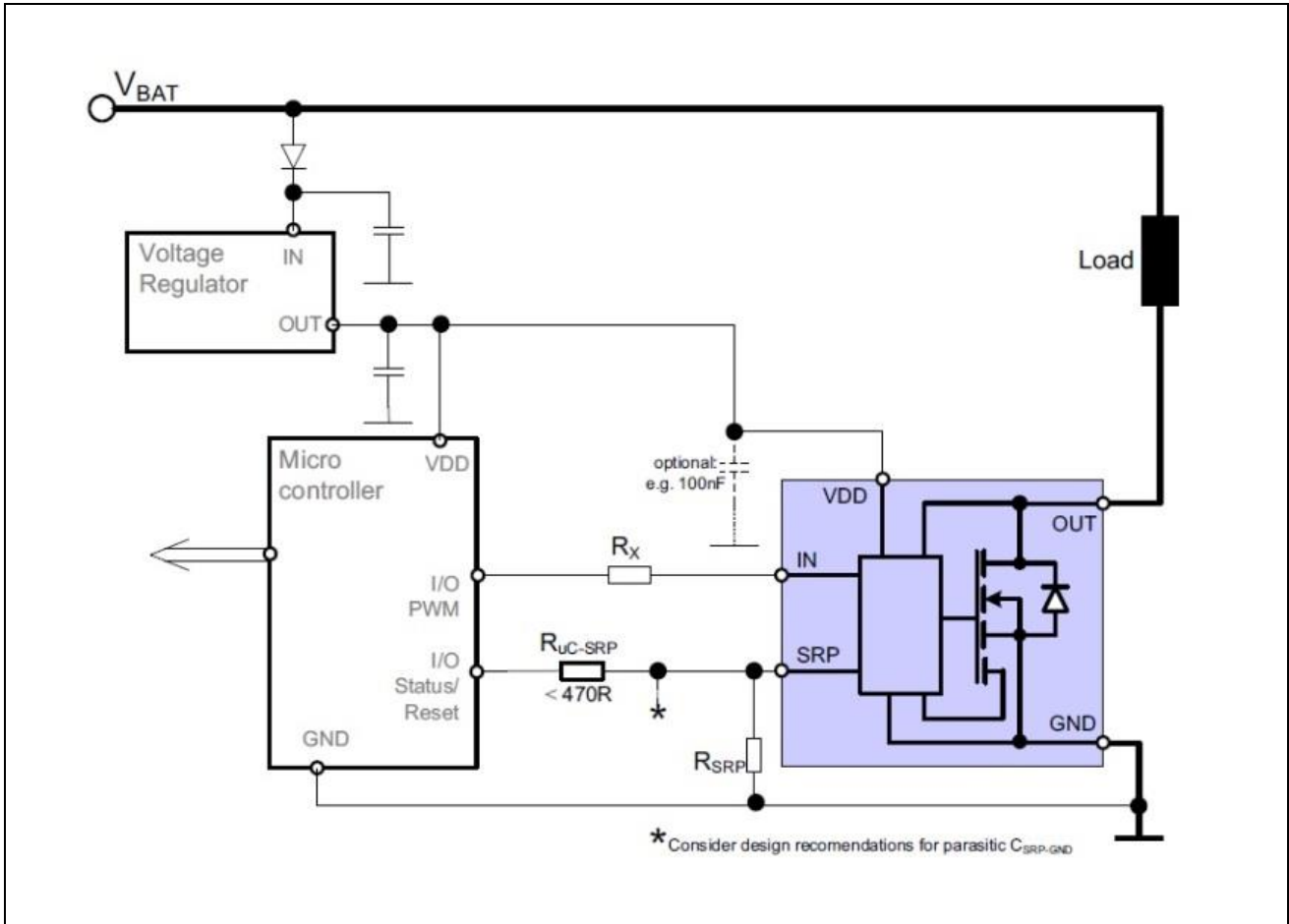
Figure 2   Application circuit for BTF3050TE

2 Low Side Switch Shield board description

For a safe and sufficient Low Side Switch design, discrete components are needed. Some of them must be dedicated to the application and some to the BTF3050TE.

Figure 3, Figure 4 and Figure 5 show the schematics plus the corresponding layout of the Low Side Switch Shield.

2.1 Schematics

In Figure 3 show the schematics and their corresponding layout of the Low Side Switch Shield. The schematics are based on the application circuit in the BTF3050TE Data Sheet.
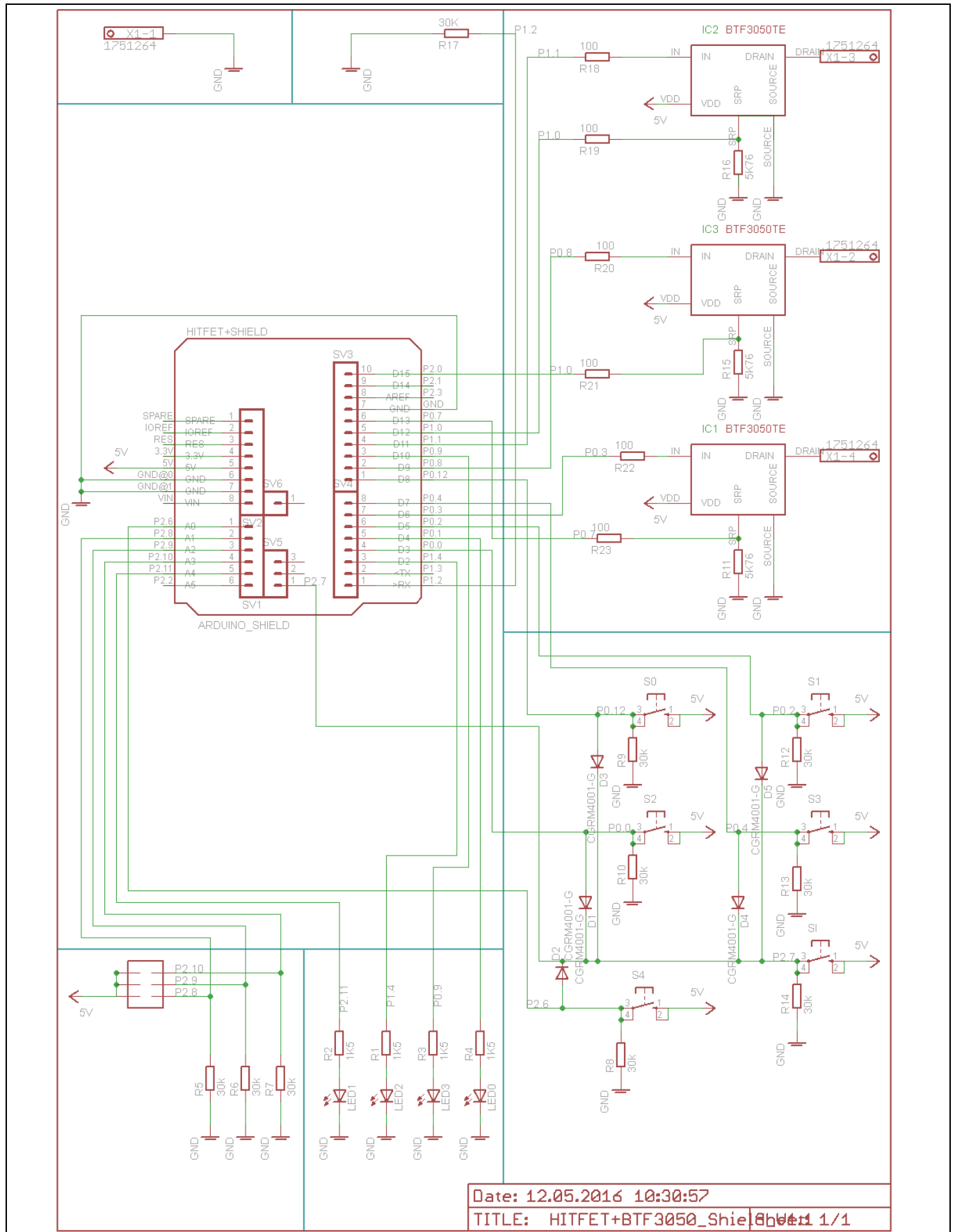
Figure 3   Schematics Low Side Switch Shield for Arduino with BTF3050TE

2.2 Layout
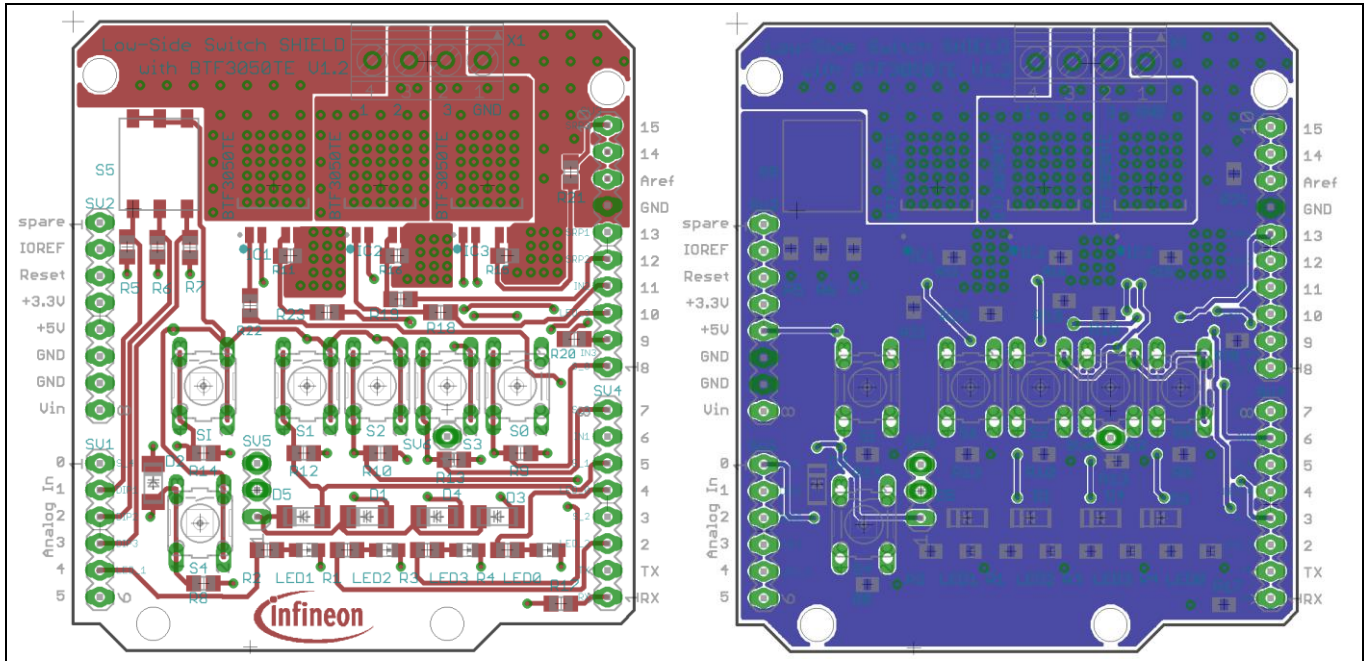
Figure 4   Low Side Switch Shield – Bottom and top layers
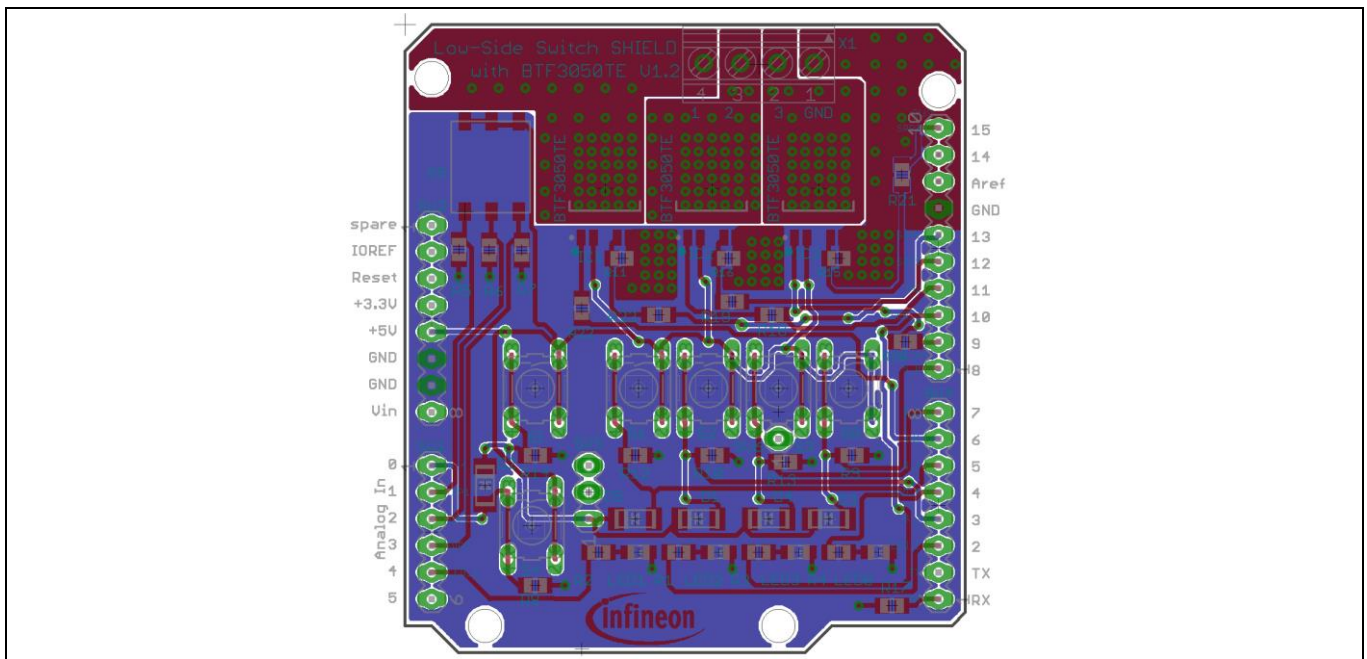

Figure 5   Low Side Switch Shield – Complete layout

Table 2   Bill of Material

Part	Value	Device	Package	Description	Qty in total
IC1, IC2, IC3		BTF3050TE	PG-TO252-5	HIFTET+	3
R11, R15, R16	5k76 Ohm		SMD-0805	Resistor	3
R1, R2 ,R3, R4	1k5 Ohm		SMD-0805	Resistor	4
R5, R6, R7, R8, R9, R10, R12, R13, R14, R17	30k Ohm		SMD-0805	Resistor	10
R18, R19, R20, R21, R22, R23	100 Ohm		SMD-0805	Resistor	6
LED1, LED2, LED3	RED		CHIPLED-0805	LED	3
LED0	GREEN		CHIPLED-0805	LED	1
S5				DIP-switch	1
S0, S1, S2, S3, S4, S5, SI			B3F-10XX	Tactile switch	6
D1, D2, D3, D4, D5		MMSD4148T1G	SOD-123	Diode	5
X1			1751264	Screw terminal	1
SV3			2.54mm	Pinheader	1
SV4, SV2			2.54mm	Pinheader	2
SV5			2.54mm	Pinheader	1
SV6			2.54mm	Pinheader	1
SV1			2.54mm	Pinheader	1

2.3 Important design and layout rules

Following components are implemented in the shield.

- R5, R6, R7, R8, R9, R10, R12, R13, R14: These resistors are needed to make use of the push buttons and the DIP-Switch. They are used as pull-down resistors. The resistance is pulling down the voltage, if the push buttons or the switch is not activated.
- R11, R15, R16: These resistors are needed to adjust the switching speed. The tranistors are driven in fast mode, while still providing the diagnosis function. Check the data sheet of the BTF3050TE to get a detailed description of this functionality.
- R1, R2, R3, R4: These resistors are used to provide the LEDs with the desired current.
- D1, D2, D3, D4 ,D5: The diodes are placed to make an implementation of interrupts to handle inputs via push buttons easily. In this way there will always be a high input signal at SI pin as soon as another button gets pushed. It is advantageous to trigger the interrupt when the desired input signal at SI is measured.
- R17: This resistor filters noise to make UART more reliable.
- R18, R19, R20, R21, R22, R23: The resistors are used to protect the microcontroller. Input currents get reduced.
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2.4 Pin assignment

To use the Low Side Switch Shield the necessary control signals can be applied directly at the Arduino^{TM} connectors. The control pins are logic level inputs which can be driven by any other microcontroller or with logic level signals. Besides the supply voltage V_{BAT} has to be provided to the V_{BAT} connector. Figure 6 shows the pinout/connectors of the Low Side Switch Shield.
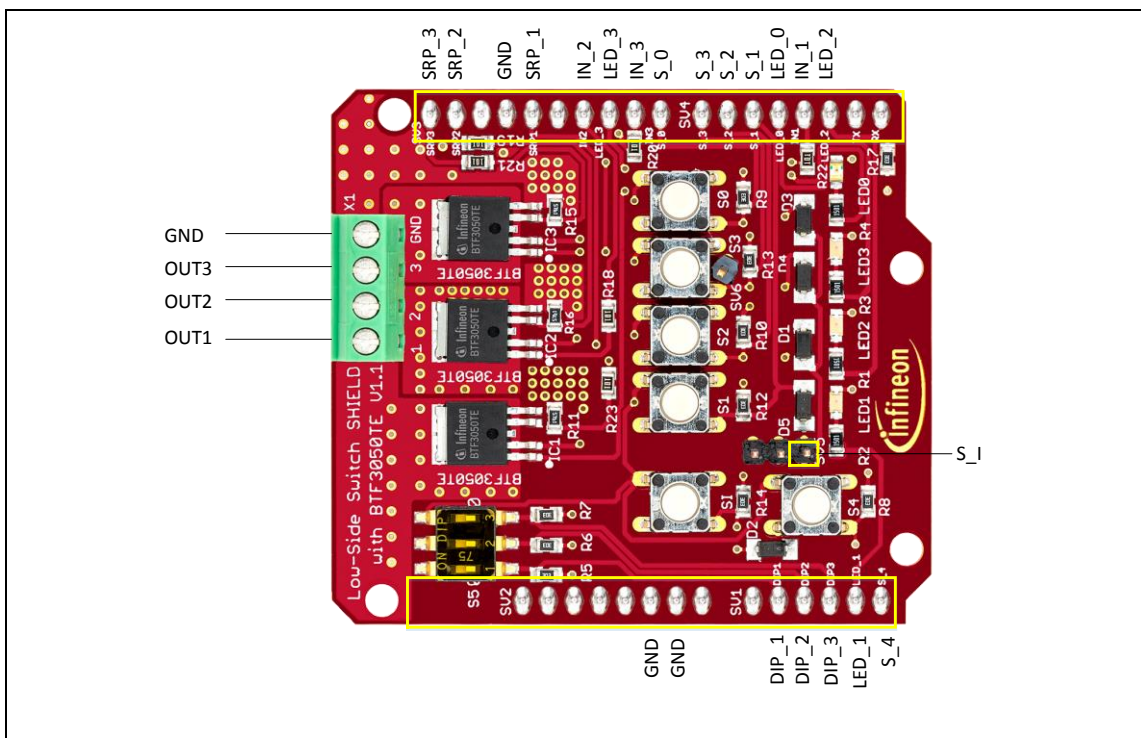

Figure 6   Low Side Switch Shield connectors

2.5 Pin definitions and functions

The pin headers are connected as described in table 3.

Table 3   **Pin defintion**

PIN	Symbol	Input / Output	Function
GND	GND	-	Ground
P0.1	LED_0	O	Visualization of output signals When set to high, LED emits light
P2.11	LED_1	O	Visualization of output signals When set to high, LED emits light
P1.4	LED_2	O	Visualization of output signals When set to high, LED emits light
P0.9	LED_3	O	Visualization of output signals When set to high, LED emits light
P2.8	DIP_1	I	Handling of user input
P2.9	DIP_2	I	Handling of user input
P2.10	DIP_3	I	Handling of user input
P0.12	S_0	I	Handling of user input
P0.2	S_1	I	Handling of user input
P0.0	S_2	I	Handling of user input
P0.4	S_3	I	Handling of user input
P2.6	S_4	I	Handling of user input
P2.7	S_I	I	Handling of user input (note: This pin can not be used with the Arduino Uno R3)
P0.3	IN_1	I	Control of the BTF3050TE When set to high, BTF3050TE is conducting (OUT1)

PIN	Symbol	Input / Output	Function
P1.1	IN_2	I	Control of the BTF3050TE When set to high, BTF3050TE is conducting (OUT2)
P0.8	IN_3	I	Control of the BTF3050TE When set to high, BTF3050TE is conducting (OUT2)
P0.7	SRP_1	I/O	Handling of the fault feedback of BTF3050TE When fault feedback is present, BTF3050TE will pull up internally the voltage at SRP_1 to high In order to reset the fault feedback, SRP_1 needs to be pulled down externally by the microcontroller to ground
P1.0	SRP_2	I/O	Handling of the fault feedback of BTF3050TE. When fault feedback is present, BTF3050TE will pull up internally the voltage at SRP_2 to high. In order to reset the fault feedback, SRP_2 needs to be pulled down externally by the microcontroller to ground.
P2.0	SRP_3	I/O	Handling of the fault feedback of BTF3050TE When fault feedback is present, BTF3050TE will pull up internally the voltage at SRP_3 to high In order to reset the fault feedback, SRP_3 needs to be pulled down externally by the microcontroller to ground

3 BTF3050TE overview

The BTF3050TE used in the Low Side Switch Shield is a 50 mΩ high integrated single channel Low Side switch which can be used in many applications. The power transistor itself is a built in N-channel power MOSFET. The whole device is monolithically integrated. This means that the power MOSFET, the driver and protection blocks are integrated in one package. Interfacing to a microcontroller is made easy by the integrated driver IC, which features logic level inputs, diagnosis, slew rate adjustment and protection against overtemperature, undervoltage, overcurrent and short circuit.

The BTF3050TE is automotive qualified and is optimized for 12V automotive and industrial applications.

3.1 Key features of the BTF3050TE

- Single channel device
- Very low power DMOS leachage current in OFF state
- Drain-Source Resistance ($R_{DS(ON)}$) of max. 100 mΩ @ 150 °C (typ. 40 mΩ @ 25 °C)
- Capable of PWM up to 14KHz (at 10% duty cycle)
- 3.3V and 5V compatible logic inputs
- Low quiescent current of typ. 6 µA @ 25 °C
- Current limitation level of 30 A min.
- Diagnosis function (Short circuit to battery, over temperature)
- Overtemperature shut down with autorestart behavior
- Undervoltage shut down
- Enhanced short circuit protection
- Driver circuit with logic level inputs
- Adjustable slew rates and switching speed for optimized EMI
- Operation up to 28 V
- Green Product (RoHS compliant)
- AEC Qualified in PG-TO252-5 package

Figure 7   PG-TO252-5

3.2 Block diagram

- The BTF3050TE is able to switch resistive, inductive and capacitive loads. The limiting factors are the clamping energy (E_{AS}) and the maximum current and voltage capabilities
- The device offers dedicated ESD protection on the IN, VDD and SRP pin, which refer to the Ground
- An over voltage clamping protection is implemented between the output (OUT) and the Source/ GND
- The over voltage protection gets activated during inductive turn offconditions or other over voltage events (e.g. load dump). The power MOSFET is limiting the Drain-Source voltage if it rises above the $V_{OUT(CLAMP)}$
- To prevent the device from over heating due to overload and/or bad cooling conditions a temperature protection unit is built in
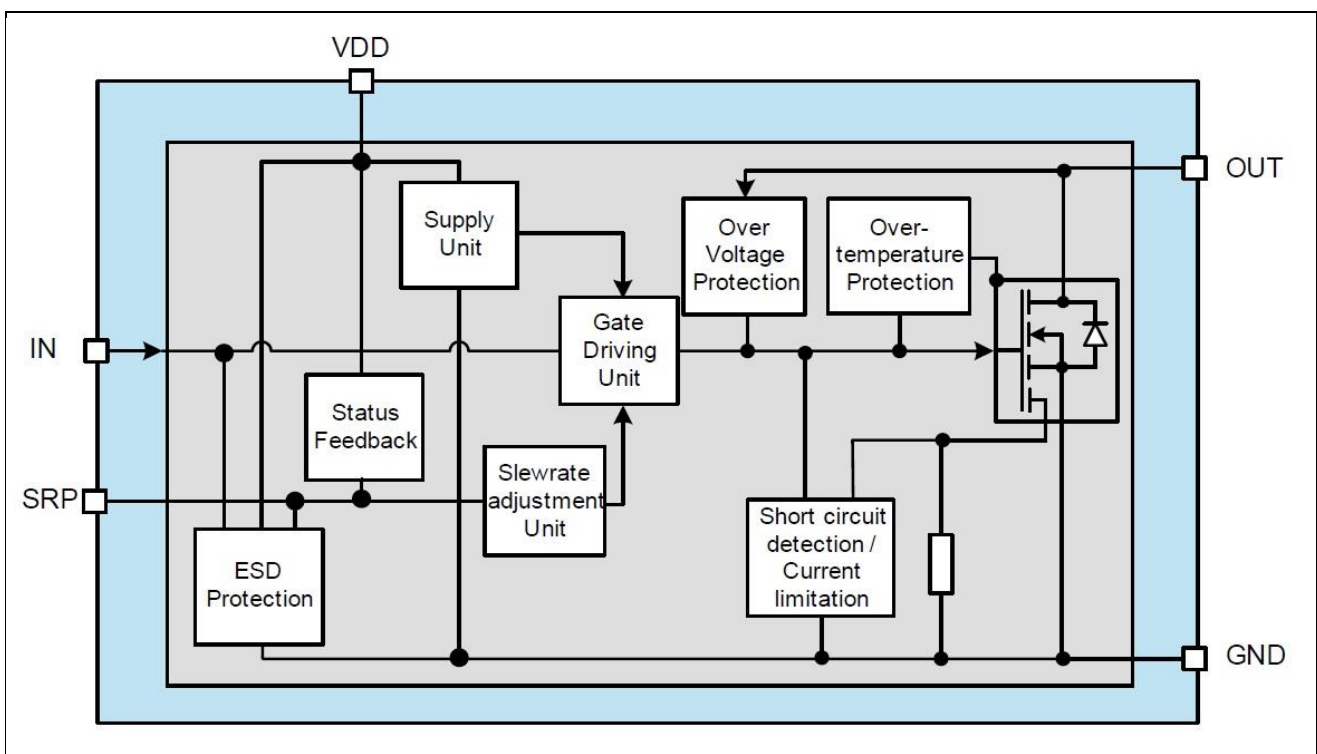

Figure 8   Block diagram BTF3050TE

If the temperature reaches a certain value $T_{J(SD)}$, the device switches off. The temperature is decresing and if the value dropped below $T_{J(SW)}$ and the input (IN) is still high, the device switches on again. This is the so called "**Restart function**". In case of detected over-temperature the fault signal is set and the SRP pin will be internally pulled up to V_{DD}. This state is independent in relation to the input (IN) and providing a stable fault signal, which can be read out for example through an microcontroller and correspondingly processes can be started. This latched fault signal needs to be reset by an low signal at the SRP pin ($V_{SRP} < V_{SRP(RESET\_MIN)}$). The length of this RESET needs to be at least t_{RESET} (100µs).

The short circuit behavior of the BTF3050TE works slightly different. If the load current I_L (from OUT to GND) reaches the current limitation trigger level $I_{L(LIM)\_TRIGGER}$ the internal current limitation will be activated and the device limits the current to a lower value level $I_{L(LIM)}$. The device starts heating up and will reach $T_{J(SD)}$. At this point we will see the behavior from the temperature protection and the SRP pin will be set to high. The current

limitation trigger is also a latched signal. It will be only reset by input (IN) pin = low <u>and</u> SRP pin = low at the same time! For more detailed information please see the data sheet.
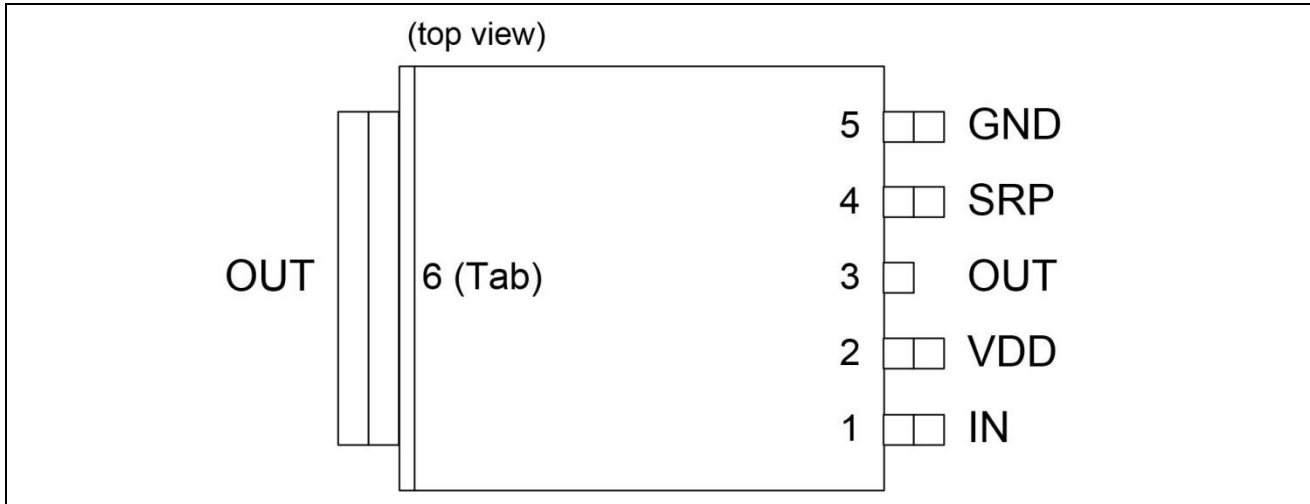
3.3   Pin assignment

Figure 9   Pin assignment BTF3050TE (top view)

3.4   Pin definitions and functions BTF3050TE

Table 4

Pin	Symbol	I/O	Function
1	IN	I	Input pin
2	VDD	I	5V supply pin
3, 6	OUT	I	Drain, load connection for power DMOS
4	SRP	I/O	Slew rate adjustment and digital status feedback
5	GND	O	Ground, source of power DMOS

4 Getting started

4.1 Target applications

The applications targeted by the Low Side Switch Shield are resistive, inductive and capacitive loads in DC or up to 14 kHz in PWM at 10 % duty cycle. Since three BTF3050TE are used on the shield, three channels are provided. Each of the channels is capable of driving a nominal load current of 3 A (typ.) DC.

4.2 Typical target application

Common resistive loads can be heating elements, such as PTC auxiliary heater or lambda sensor (heating element of the O_2 sensor).

Inductive loads are typically solenoids, valves, flaps and safety locks among others. These loads typically are driven with PWM between 4-5 kHz.

The shield can also be used to charge capacitors or drive loads that behave in a similar way such as bulbs. For these loads the device is able to handle the high inrush current.

4.2.1 Getting started: Shield

- Choose up to three appropriate loads, for example a valve

- Connect the Low Side Switch Shield for example to the Arduino Uno R3 or the XMC 1100 Boot Kit

- To supply the Arduino/XMC1100 Boot Kit, connect the board with the proper USB cable. The logic of the shield is directly supplied by the Arduino/ XMC1100 Boot Kit

- Program the controller board with the Low Side Switch software (see 4.2.2)

- Connect the GND of shield's screw terminal with the ground of your power supply. Connect the three outputs of the screw terminal with your loads and the loads to your power supply. Your power supply should not exceed 18V for nominal operation

- Turn on the power

4.2.2 Getting started: Software for the XMC1100 Boot Kit

In order to use the Low Side Switch Shield in combination with the XMC1100 Boot Kit following steps have to be taken first:

- Download the latest version of DAVE™ from www.infineon.com/dave

- Get the sample application software at www.infineon.com/shields-for-arduino

- Open DAVE™ and navigate via the toolbar to File > Import > Infineon > DAVE projects and pick the sample application as an archive file

- After the project was imported successfully, adjust the values for the PWM in the main.c file to match your setup

- Afterwards generate the code and build the projects with the corresponding buttons in the toolbar of DAVE™

- Conntect the XMC1100 Boot Kit with your computer via USB

- To run the software click on the debug button and than on the run button

4.2.3 Getting started: Software for Arduino Uno

To use the Low Side Switch Shield with an Arduino Uno following steps need to be done first:

- Download the latest Arduino IDE from https://www.arduino.cc/en/Main/Software

- Get the sample application software at www.infineon.com/shields-for-arduino

- Open the sample application software

- Adjust the parameters for the PWM in the software code

- Connect your Arduino Uno with the computer via USB

- To run the software on the Arduino, upload the software with the corresponding button in the toolbar of the IDE

4.2.4 Software functionality

The installed example software provides following functionality.

The DIP-Switch turns the corresponding BTF3050TE on or off.

The push buttons S_1, S_2 and S_3 increase or decrease the duty cycle of the associated BTF3050TE depending on LED_0. If LED_0 emits light, the duty cycle will be increased once S_1, S_2 or S_3 is pressed. If LED_0 does not emit light, the duty cycle will be decreased. Once S_0 is pushed, LED_0 toggles.

If a fault feedback is present, LED_1, LED_2 or LED_3 will shine to show a fault feedback on the corresponding BTF3050TE. S_4 resets all fault feedbacks at once.

NOTE: For use with Arduino Uno, SI cannot be used anymore.

Table 5   Software functionality

DIP_1	Turns the left BTF3050TE on or off (OUT1)
DIP_2	Turns the middle BTF3050TE on or off (OUT2)
DIP_3	Turns the right BTF3050TE on or off (OUT3)
S_I	No functionality
S_0	Toggles LED0. LED0 indicates wether the duty cycle of the PWM will increase or decrease while pressing the corresponding button. If the Led emits light the duty cycle will increase, elsewise it will decrease
S_1	Increase/decrease duty cycle of left BTF3050TE (OUT1)
S_2	Increase/decrease duty cycle of middle BTF3050TE (OUT2)

DIP_1	Turns the left BTF3050TE on or off (OUT1)
S_3	Increase/decrease duty cycle of right BTF3050TE (OUT3)
S_4	Reset fault feedback. The fault feedback is indicated by LED1, LED2 and LED3. For further information about the fault feedback, please refer to the datasheet of BTF3050TE

Revision History

Major changes since the last revision

Revision	Description of change
V1.0 2016-08-01	Initial release