PROFET™+2 12V

Frequently asked questions

About this document

Scope and purpose

This document is intended to answer some of the most frequently asked customer questions related to the PROFET™+2 12V product family of Infineon smart high-side switches.

Intended audience

Engineers, hobbyists and students who want to add powerful protected high-side switches for heating or power distribution projects.

Table of contents

Table of contents

1 What is a PROFET™?

A PROFET™ (“PROtected high-side MOSFET”) is a smart high-side switch switching a positive supply line in a 12 V, 24 V or 48 V system. Other common names are “intelligent power device” (IPD) or “high-side driver” (HSD). They are widely used in automotive applications. Mounted on a printed circuit board (PCB), they are part of many electronic control units (ECU) in car, driving bulbs (body controller), heaters (seat module), DC brush motors (washer pump), or powering up entire electronic systems (smart junction box).

A PROFET™ consists of a MOSFET (DMOS), a gate driver with charge pump, and multiple protection and diagnosis features. The power component of a PROFET™ is an n-channel MOSFET. A PROFET™ amplifies the digital output signal (push) of a microcontroller (3.3 V or 5 V) to a 12 V domain, with the capability to drive a high output current. In case of overload, a PROFET™ automatically switches off, avoiding severe damage to the device. Many PROFET™ include the capability to provide information about the system state (broken wire, overload, short circuit, analog load current measurement).

Other smart products are low-side switches and half-bridges. HITFET™ is a low-side switch, see the website ***Infineon HITFET™***. NovalithIC™ is a smart half bridge, see the website ***Infineon Novalithic™***.

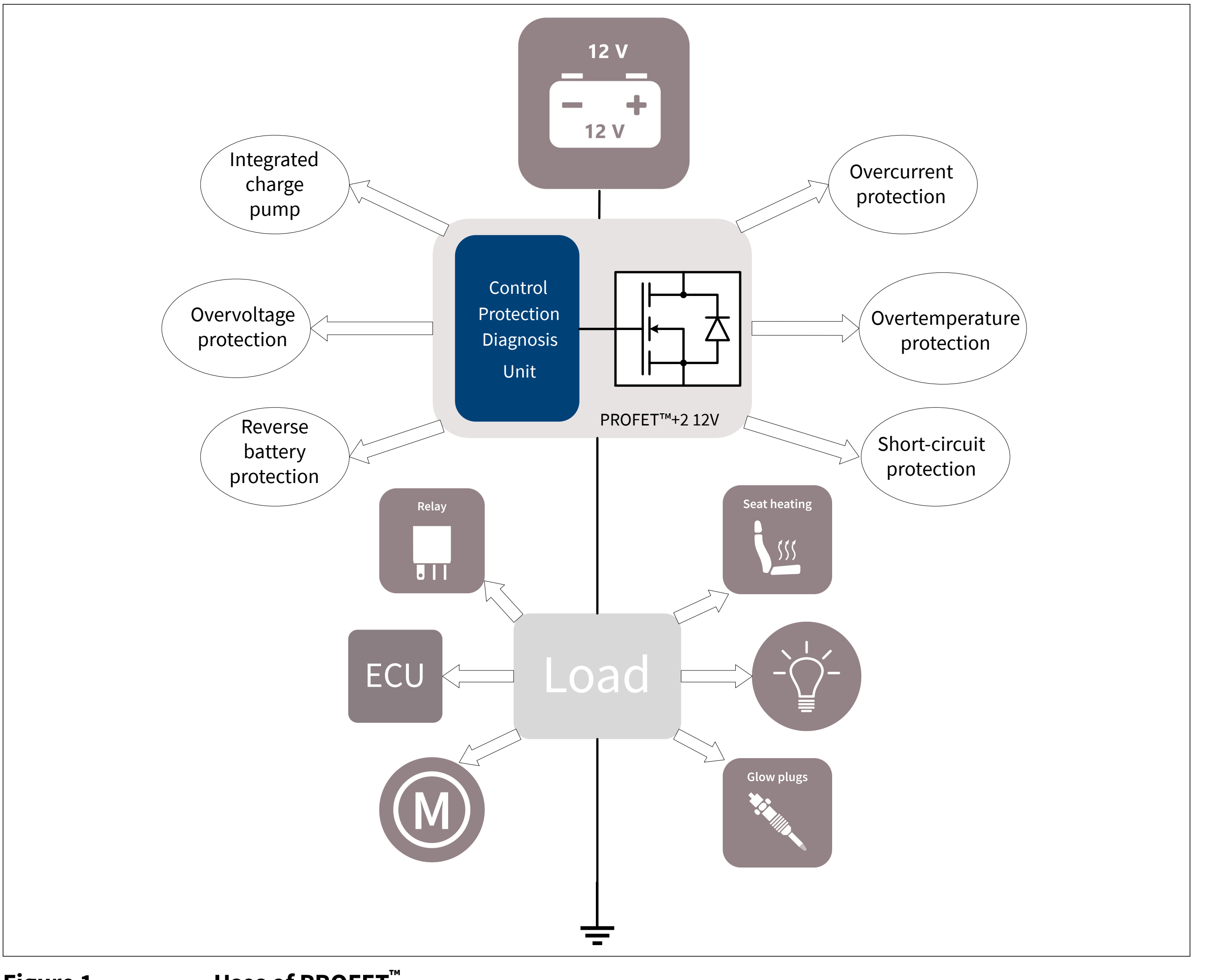


Figure 1 **Uses of PROFET™**

2 Which problems can be solved by a PROFET™+2 12V?

2.1 PROFET™+2 12V at a glance

PROFET™+2 12V

- can switch on a load – continuously or with low frequency PWM – in a 12 V DC system, for example a headlamp of a car
- is designed for the 12 V automotive board net, with as little input filtering as possible:
  - 1 transient voltage suppressor (TVS) per battery feed
  - 1 ceramic capacitor for VS and 1 for each output (0805 or 0603)
  - 1 GND resistor and 1 for each digital input
- is usually operated at 6 V up to 18 V supply voltage, supporting cranking down to 3.1 V (2.7 V for BTS7200-2EPC) and jump start up to 24 V. It is not designed for a nominal supply voltage of 3.3 V, 5.5 V or 24 V
- is operated at ambient temperatures from -40°C to 125°C, allowing the junction temperature to go up as high as 150°C
- switches off in case of overload, overtemperature or short circuit, to protect itself, and provides a "fault" signal as a feedback to a microcontroller
- stores a "fault" signal and stays off until a dedicated "reset" signal is provided or after $t_{DELAY(CR)}$ (as specified in the datasheet) has passed
- enables simple load current measurement with a microcontroller. An analog signal (proportional to the load current) interfaces with an analog-digital-converter (ADC) of a microcontroller – at nominal current
- is optimized for driving heating resistors (seat heating, glow plugs, mirror heating, window heating)
- is optimized for driving bulbs (head lamp, stop lamp, indicator lamp, fog lamp, interior lamps)
- is optimized for driving standard automotive relays

2.2 PROFET™+2 12V behavior in failure mode

- **Loss-of-GND:** without a proper ground connection, it is not guaranteed that the PROFET™+2 12V stays off. The PROFET™+2 12V could stay on because of the presence of a parasitic ground path between the device itself and the external circuitry
- **GND shift:** the device is robust against a voltage shift between device GND and ground connection of the load. If the GND shift exceeds ± 1 V, switching losses and RF emission may be affected
- **Undervoltage / loss-of-V_S:** without a proper supply connection, PROFET™+2 12V switches off / stays off. The devices switch on again at maximum 4.1 V with a 5 ms delay if IN = "high"
- **Overtemperature:** in case the junction temperature (T_J) of a PROFET™+2 12V typically reaches 175°C, PROFET™+2 12V switches off, putting the application into a safe state, providing a "fault" signal. The device can switch on again if the junction has cooled down sufficiently and a "reset" command is provided. Overtemperature may be caused for example by an overload condition, by a weak solder connection between a PROFET™+2 and a PCB, or by an excessive ambient temperature
- **Overload:** in case of overload, excessive power losses cause the PROFET™+2 12V to heat up until absolute or dynamic overtemperature protection is triggered and the device is shut down, providing a "fault" signal. The device can switch on again if the junction has cooled down sufficiently and a reset command is provided
- **Short to GND (STG):** in case the output is shorted to ground while the device is on or switching on (for example: broken load, damaged wire), very high load currents may appear. If the current exceeds the overload detection current, the PROFET™+2 12V immediately switches off, shutting down within less than

20 µs, providing a fault signal. The device can switch on again after a reset command is provided. Some of the devices may retry 7 times according a fixed scheme before staying off, see ***Chapter 4*** “What are the main differences between EPP and EPA PROFET™+2?” for details.

If a short to GND appears while the PROFET™+2 12V is off, this has no influence on the device and cannot be detected by the device, until the PROFET™+2 12V is commanded to switch on. Usually, a short to GND in off-state is no stressful condition to the device or the system

- **Short to battery (STB):** in case the output is connected to positive supply line, the load will be activated independent of the state of the PROFET™+2 12V. The devices provide features helping to detect STB condition. See ***Chapter 11*** “How to do short to battery detection with PROFET™+2 12V?” for details.
- **Missing load connection / broken wire / broken load:** A broken bulb, a missing connection or a cable torn apart are common failures in a car. Detecting them helps a lot to fulfill safety goals, speed up the repair, and are sometimes even legally required. PROFET™+2 12V product family provides features to detect such failures. Check ***Chapter 12*** “Application diagram with open load detection circuitry for multiple outputs and devices” for more details, and see application note ***Sense Accuracy and Calibration of the PROFET™+2 12V family***.
- **Short to another output:** If the output of a PROFET™+2 is shorted to another output or another load, the load current is higher compared to normal condition. In case of overload, the devices will switch off.
- **Reversed cable connection at the battery / power supply:** If the cables for + and – are mixed up, voltage at the load and at the PROFET™ will be inverted, causing a negative current to flow through the body diode of a PROFET™. The PROFET™+2 12V family incorporates ReverSave™ functionality (except BTS7120/200-2EPA/C), making the output stage almost as low ohmic as during normal "on" condition, reducing the power losses and helping the application to survive during this failure case.

These are the most prominent failure cases of an electronic module in a car.

3 What is unique about PROFET™+2 12V family?

3.1 Smallest footprint

Entire family in PG-TSDSO-14 package is 50% smaller than a DPAK (TO252). On the right hand side of ***Figure 2*** the package of PROFET™+2 12V, compared to SMART6 technology.

- Less PCB space
- Higher integration

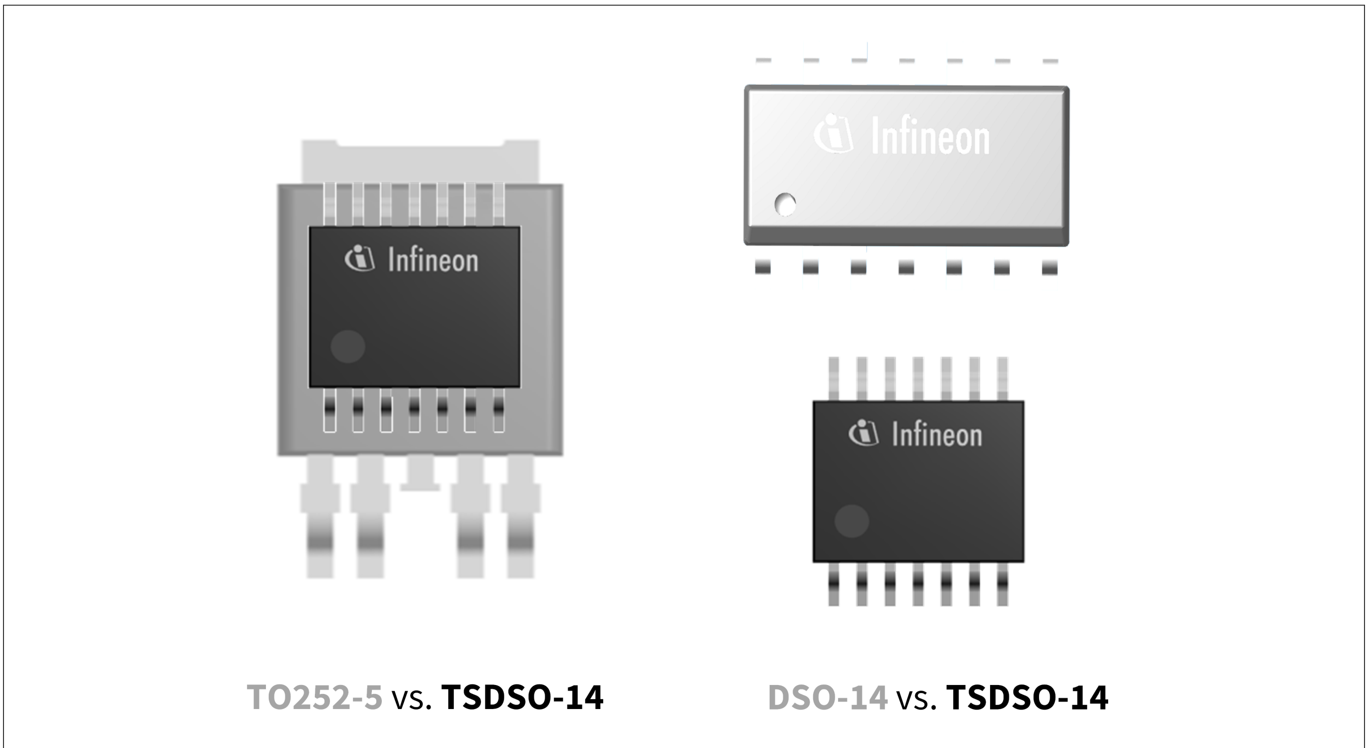


Figure 2 Package size comparison

3.2 Biggest family

- with 18 different products released, PROFET™+2 12V is the biggest family of smart high-side switches on the market
- all in PG-TSDSO-14 package
- including products with 1 and 2 independent outputs
- for applications with as little power as relay driver or single LED, up to high current loads with as much as 20 A DC current
- with a minimum of changes in the feature set, offering the optimum for each target load. For details, see ***Chapter 4*** "What are the main differences between EPP and EPA PROFET™+2 12V?"

Table 1 PROFET™+2 12V product portfolio

Load current	Single channel	Load current	Dual channel	Quad channel
21 A	BTS7002-1EPP	–	–	–
15 A	BTS7004-1EPP	–	–	–
	BTS7004-1EPZ	–	–	–
13 A	BTS7006-1EPP	–	–	–
	BTS7006-1EPZ	–	–	–
10 to 11 A	BTS7008-1EPP	7 to 7.5 A	–	–
	BTS7008-1EPA		BTS7008-2EPA	–
	BTS7008-1EPZ		BTS7008-2EPZ	–
8 to 9 A	BTS7010-1EPA	6 to 6.5 A	BTS7010-2EPA	–
	BTS7012-1EPA	6 to 6.5 A	BTS7012-2EPA	–
–	–	5 to 5.5 A	BTS7020-2EPA	–
–	–	4 to 4.5 A	BTS7030-2EPA	–
4 to 4.5 A	BTS7040-1EPA	3 to 3.5 A	BTS7040-2EPA	–
	BTS7040-1EPZ	–	–	–
–	–	3 to 3.5 A	BTS7080-2EPA	–
			BTS7080-2EPZ	–
–	–	2 to 2.5 A	BTS7120-2EPA	–
–	–	1 to 1.5 A	BTS7200-2EPA	BTS7200-4EPA
–	–		BTS7200-2EPC	–

Key applications of EPZ products: Powertrain and "under the hood"

- Based on EPA or EPP variant
- Same characteristic as the base variant
- With extended junction temperature range up to 175°C

k_{ILIS} optimized for power distribution applications

4 What are the main differences between EPP and EPA PROFET™+2 12V?

Within PROFET™+2 12V product family, small changes in the feature set are indicated by the last letter of the product name. While the EPA devices are optimized for bulb driving, EPP devices are tuned for the vast range of heating applications.

Table 2 PROFET™+2 12V EPA compared with PROFET™+2 12V EPP

	EPA	EPP
Example	BTS7008-2EPA	BTS7008-1EPP
Target	Lighting and body applications	Heating and power distribution
Nominal load current range	1 A…. 10 A	10 A…..20 A
Switching speed (typical slew rate)	Faster (0.6 V/µsec)	Slower (0.27 V/µsec)
Latch after short circuit or overtemperature	Fault flag is latched until "reset" signal is sent, but output toggles 7 times before staying off	Fault flag is latched and output stays off until "reset" signal is sent
Diagnosis focus	Open load @ "on" k_{ILIS}	Power distribution k_{ILIS}
Output pins per channel	3	6
Nominal load current	7.5 A	11 A
Current measurement range	Saturation at 2x $I_{L(NOM)}$ Overlap inrush current vs. fault signal	Full load current range Distinguish inrush current vs. fault signal

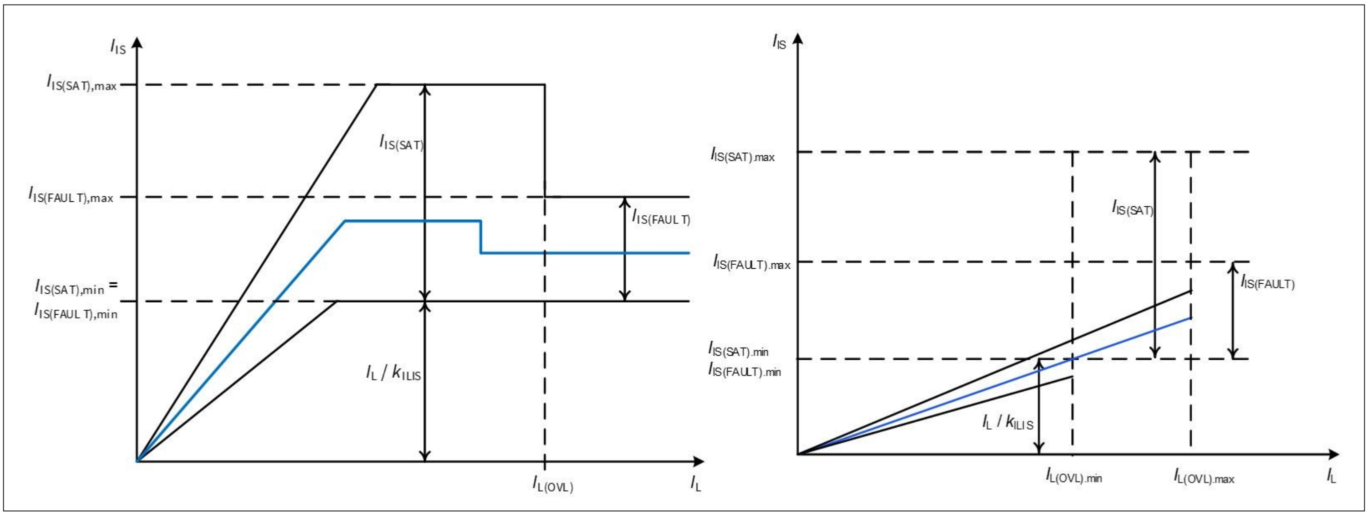


Figure 3 Relationship between I_{IS} and I_L in PROFET™+2 12V EPA (l.h.s) compared with PROFET™+2 12V EPP (r.h.s)

5 What is the inrush current capability of PROFET™+2 12V?

Inrush current may need consideration when selecting the right device within the Infineon PROFET™+2 12V product portfolio.

Activating a load, a peak current may occur, for example by charging up a filter capacitor or from bringing an electric motor up to speed. These peak currents are transient load conditions. If the inrush current is too high, it may trigger the overload detection threshold $I_{L(OVL)}$, stopping the activation of the load. If the inrush current takes too long, it may trigger overtemperature shutdown. Also switching an inrush current on or off may trigger overtemperature shutdown because of the high switching losses.

Unless Infineon provides special guidance for a dedicated load, check the minimum $I_{L(OVL)}$ specified in the datasheet. The minimum $I_{L(OVL)}$ shall be higher than the maximum inrush current occurring in your application. This means that, by looking at ***Figure 4*** below, I_{INRUSH} must be lower than $I_{L(OVL)}$.

The inrush current may be 10 times the static DC current. PROFET™+2 12V with lower $R_{DS(on)}$ have a higher $I_{L(OVL)}$.

Transient temperature increase in on-state can be calculated using a Z_{thja} diagram. PROFET™ datasheet provides an example of a Z_{thja} diagram, assuming a standardized PCB and a typical ambient condition.

Refer to Power PROFET™ and Classic PROFET™ product families. With their bigger packages and higher energy capability, these product families may offer solutions.

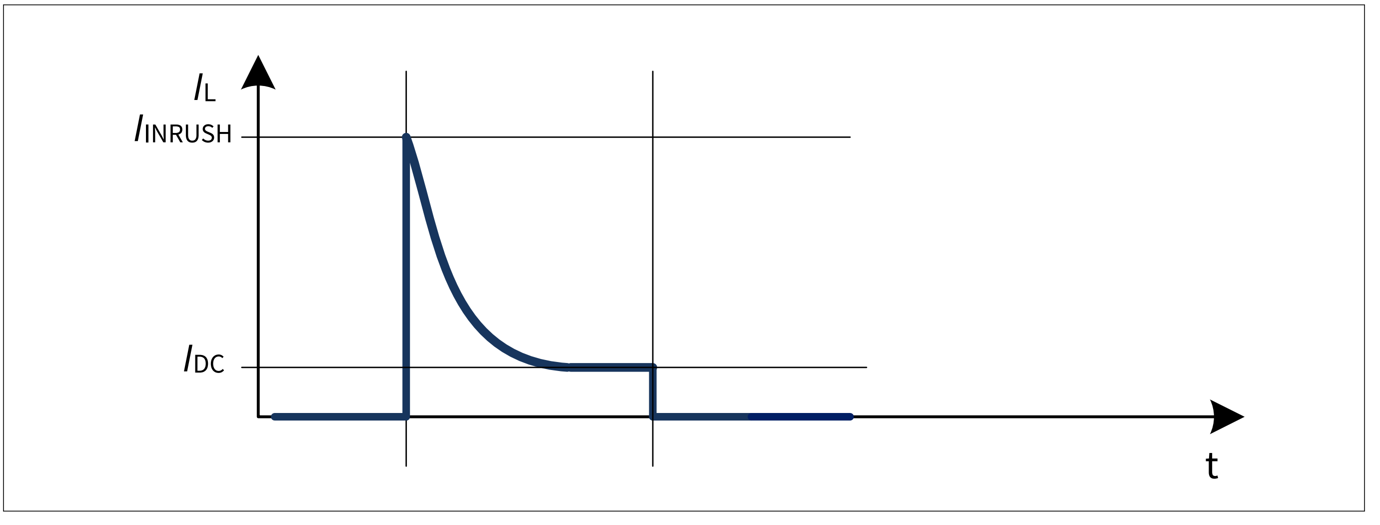


Figure 4 **Inrush current capability**

6 How to drive an inductive load with PROFET™+2 12V?

Compared to heating resistors or bulbs, inductive loads (for example: motors, valves, relays, filter coils) come with some well-known additional effects and properties, which need to be considered for choosing the right PROFET™, such as flyback energy, higher switching losses, different behavior at transient disturbances. When it is switched off, this load could generate a huge negative voltage which could damage the driving circuit.

In order to avoid any damage, the magnetic energy has to be stored in a clamping circuit: every PROFET™+2 12V has such a circuitry to clamp the voltage over the device to a typical value of 38 V at temperatures equal or higher than 25 °C.

Recommended circuitry includes a freewheeling diode to avoid inductive clamping of the PROFET™+2 12V and a MOSFET for reverse battery protection.

The most common solution to discharge an inductive load is a freewheeling diode. When the PROFET™+2 12V is ON, the diode is reverse-biased and does not conduct any current. When the PROFET™+2 12V turns OFF, the diode become forward biased and helps the inductor to discharge. For many applications, the freewheeling diode is often physically quite large and adds significant extra costs lengthening the decay of current through the inductor. If a freewheeling diode is not applicable for these reasons, and the flyback energy has to be dissipated in the PROFET™, please have a look at the Infineon POWER and Classic PROFET™ families.

Usage of one TVS diode (D_{Z2}) per battery feed and R_{GND} = 47 Ω / 125 mW are recommended.

Switching off, the PROFET™ may see high switching losses (at least, E_{OFF} = 0.5 x (V_{BAT}+0.7 V) x I_{LOAD} x t_{OFF}). The switching losses may cause dynamic temperature increases of more than 80°C, triggering the dynamic temperature limitation of the device. It is recommended to keep the temperature increase significantly below 80°C and not to switch off during normal startup / inrush current.

Inductive loads such as motors or valves, being deactivated, may induce a voltage ("back EMF") on the output. If this voltage is high enough to cause V_{DS} < $V_{DS(OLOFF)}$, the open load signal ($I_{IS(OLOFF)}$) will be triggered if DEN ="high".

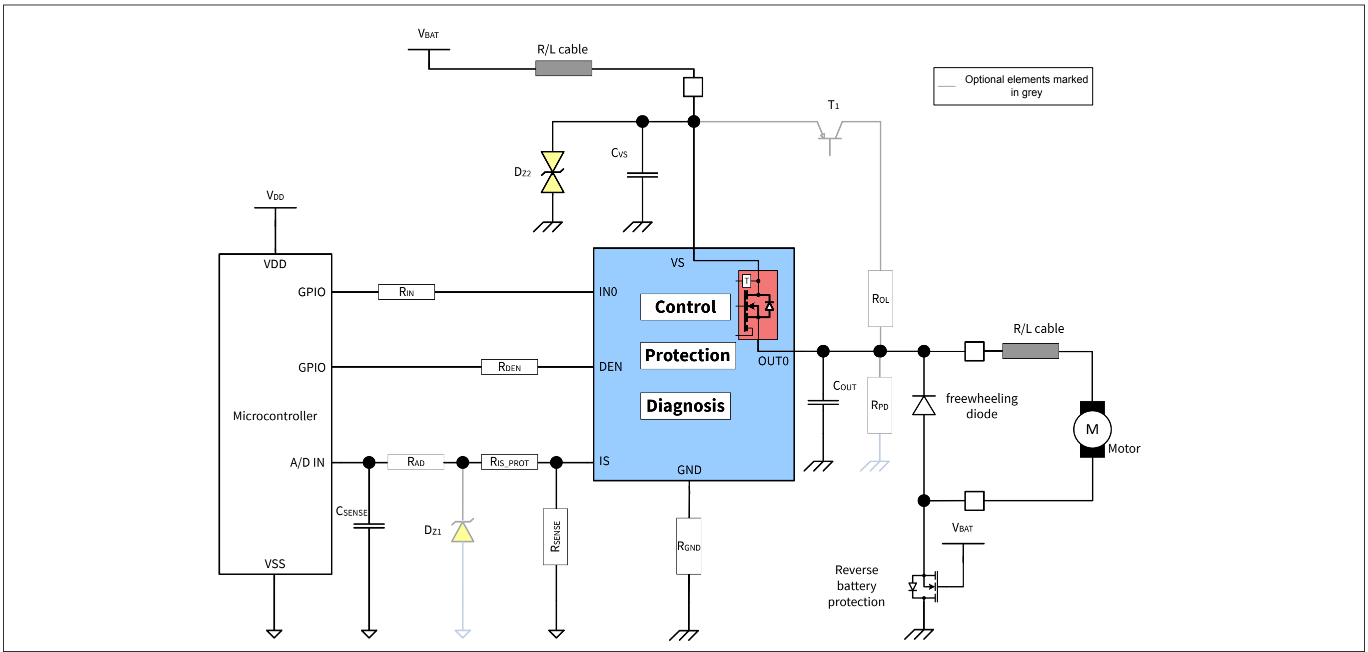


Figure 5 Application diagram for inductive loads

Note: This is a very simplified example of an application circuit. The function must be verified in the real application.

7 What to consider for layout when using a PROFET™+2 12V?

Using a printed circuit board (PCB) with 4 copper layers or more has become a standard for using PROFET™+2 12V products. For electromagnetic compatibility as well as for thermal considerations, using one inner layer as a GND plane, and another inner layer as a supply (+) plane, while using the outer layers for component placing, small signal routing and OUT connection did show good results.

For more detail on thermal considerations, see application note "***Thermal behavior of PROFET™+2 12V in PG-TSDSO-14***."

Below, some practical hints for achieving best system performance. Check ***Figure 6*** for a practical example and ***Figure 8*** for the application diagram of a low ohmic single channel PROFET™+2 12V.

- Minimize parasitic capacitance associated with the digital input pins (IN, DEN, DSEL), by placing R_{IN}, R_{DEN} and R_{DSEL} as close as possible to the pin; add openings in supply and GND layers
- Place R_{GND} as close as possible to the device
- Place C_{VS} and C_{OUT} as close as possible to the device
- Place R_{SENSE} and R_{IS_PROT} as close as possible to the IS pin, while placing C_{SENSE} and $R_{A/D}$ as close as possible to the A/D pin of the microcontroller, to minimize coupling to the IS signal
- Place at least 2 vias for GND connection of C_{VS} and C_{OUT} as close as possible to the capacitors, to minimize parasitic L
- Put thermal vias around exposed pad, for cooling + current from inner layers - mind the current density
- Check if thermal vias under exposed pad are applicable
- n.c. pins are internally not connected for PROFET™+2 12V product family. There is no conductive connection inside the device. For mechanical stability reasons, they must be soldered to the PCB (true for any pin). Electrically, they may be left unconnected or may be connected to OUT, VS, IS, or IN0. Even connecting n.c. pins to different signals is possible. Especially when using high current single channel devices (such as BTS7002-1EPP), connecting pin 11 to OUT may help to reduce failure modes. For dual channel devices, pin 11 may be left unconnected to reduce risk of short between OUT0 and OUT1. Pin 6 and 7 of BTS7002-1EPP may be connected to VS for a slight improvement of transient thermal behavior
- When planning to build variants of a PCB by mounting single or dual channel devices, use the pin out of the dual channel device. If planning to mount dual channel devices and high current single channel devices on the same footprint (1EPP devices, for example BTS7002-1EPP), please note all output pins of the high current devices have to be shorted on the PCB to ensure equal current distribution. For example, put a solder bridge close to pin 10 and 12, which is closed when mounting BTS7002-1EPP and open when mounting BTS7008-2EPA.
- See ***Chapter 8*** and ***Chapter 10*** on how to handle DEN pin and IS when not using them.

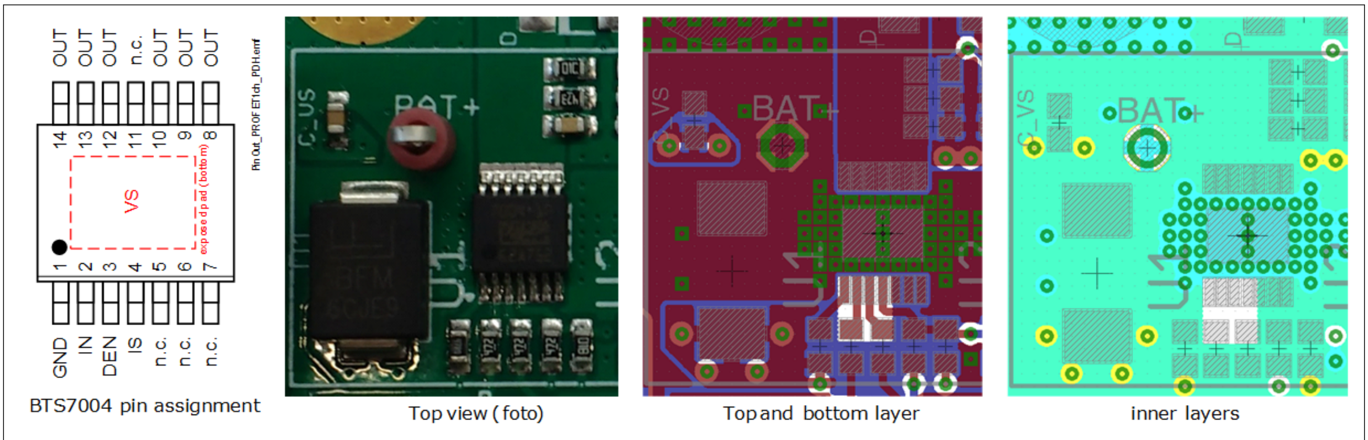


Figure 6 **Example layout (PROFET™+2 12V)**

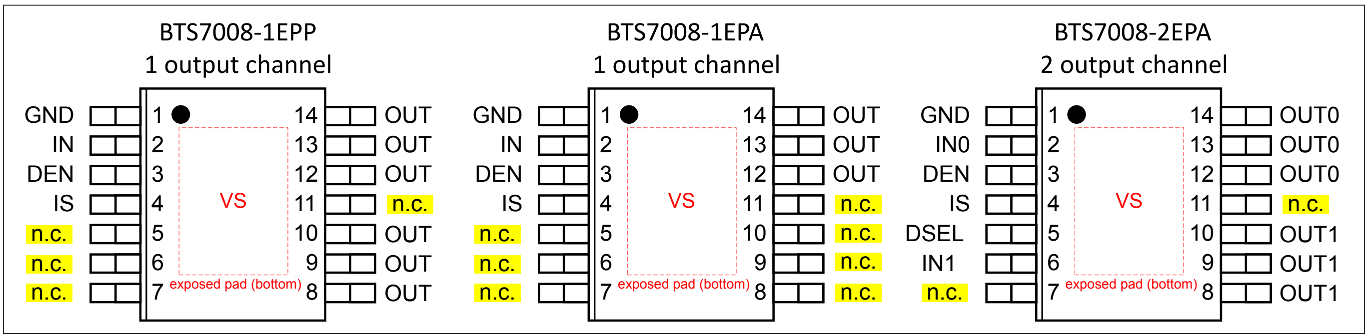


Figure 7 **Pin-out of single channel EPP, single channel EPA and dual channel EPA PROFET™+2 12V**

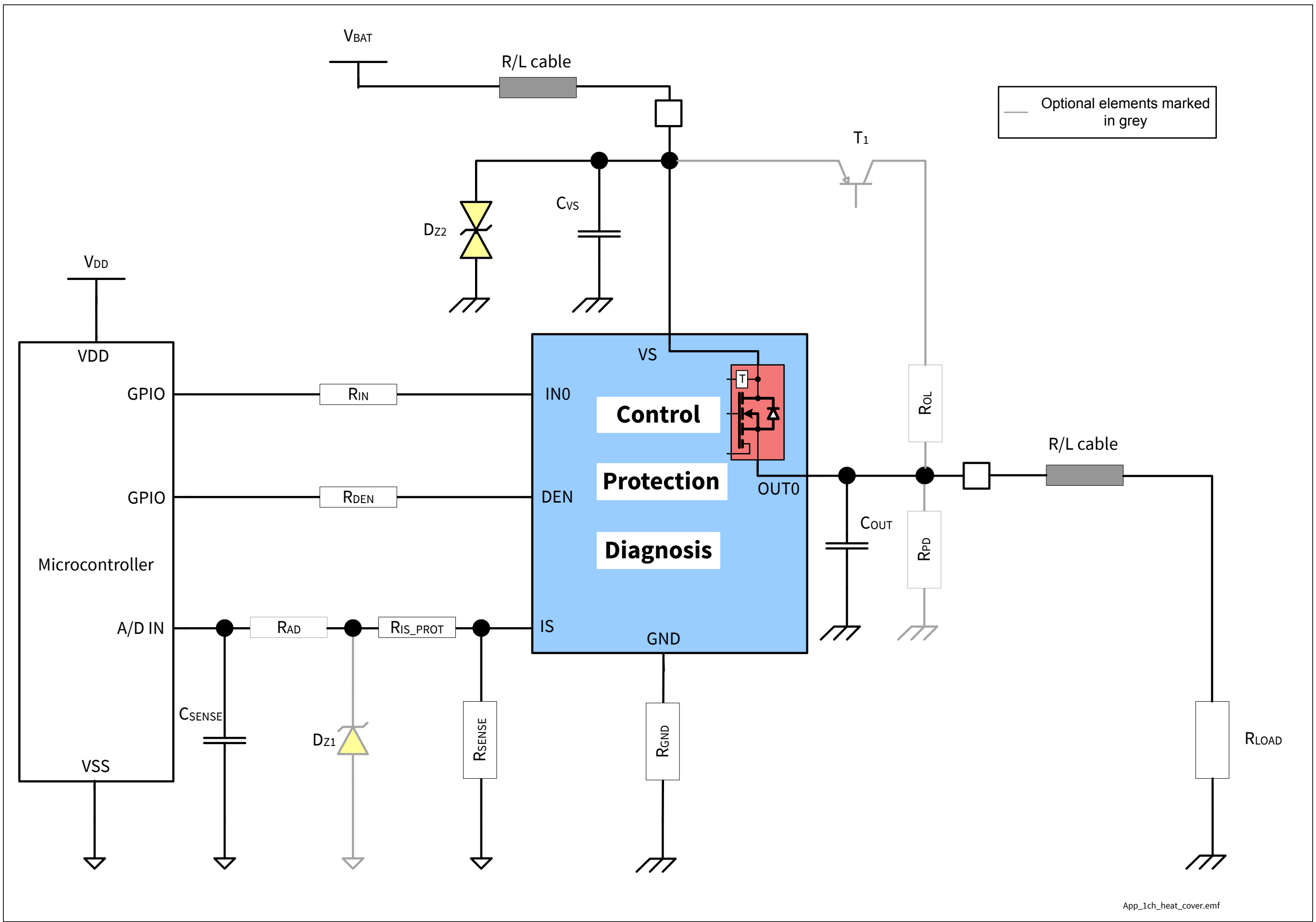


Figure 8 **Application diagram of a PROFET™+2 12V (BTS7002-1EPP)**

Note: This is a very simplified example of an application circuit. The function must be verified in the real application.

8 How to connect DEN pin when not multiplexing the IS signal?

In some applications, it is not necessary to multiplex IS signal. To save microcontroller I/O pins, DEN may be connected to different signals available on the module:

Option A (standard): connect R_{DEN} to an microcontroller GPIO (see datasheet Figure 1)

Option B: connect R_{DEN} to existing 3.3 V or 5 V supply (V_{DD})

- Device goes to SLEEP when V_{DD} is deactivated (module stand-by)
- Open load detection in OFF state can not be deactivated while V_{DD} is active → add R_{PD} at OUT if OLOFF signal needs to be avoided
- RESET of FAULT signal possible only by IN = "low" for t> $t_{DELAY(CR)}$

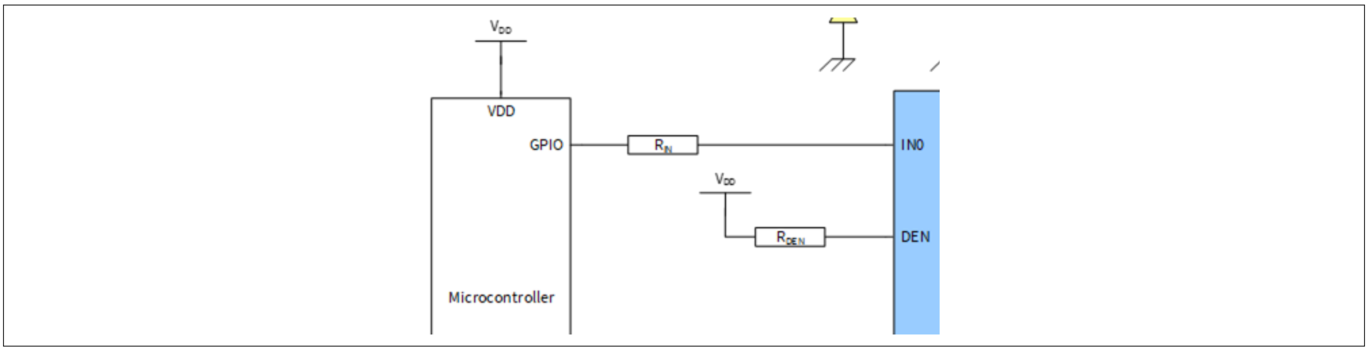


Figure 9 OPTION B for connecting DEN – extract of application diagram

Option C: connect R_{DEN} to IN

- Lowest design effort (always keep R_{DEN}!)
- Device goes to SLEEP whenever IN = DEN = "low" → higher RF emission at PWM operation for less than 0.5 MHz
- Open load detection in OFF state cannot be activated
- RESET of FAULT signal possible only by IN = "low" for t > $t_{DELAY(CR)}$

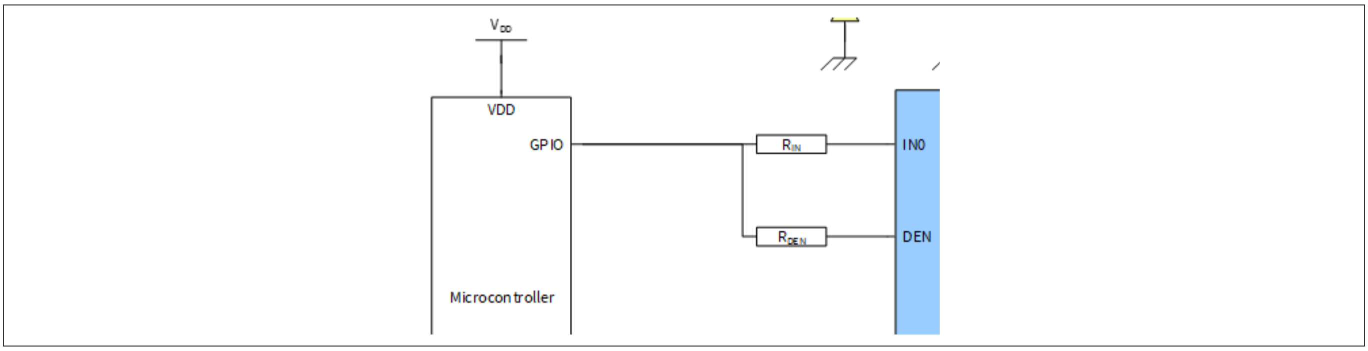


Figure 10 OPTION C for connecting DEN – extract of application diagram

9 How to measure load current using PROFET™+2 12V?

See application note ***Sense Accuracy and Calibration of the PROFET™+2 12V***

10 What to do with IS pin when not measuring the load current?

Leave unconnected, but keep the solder pad for this pin in the layout.

11 How to do short-to-battery detection with PROFET™+2 12V?

In case the output is shorted to positive supply line (short-to-battery, STB), the load will be activated independent of the state of the PROFET™+2 12V. For example, this may be a result of a damaged wire harness, a squeezed board connector or a mistake during soldering.

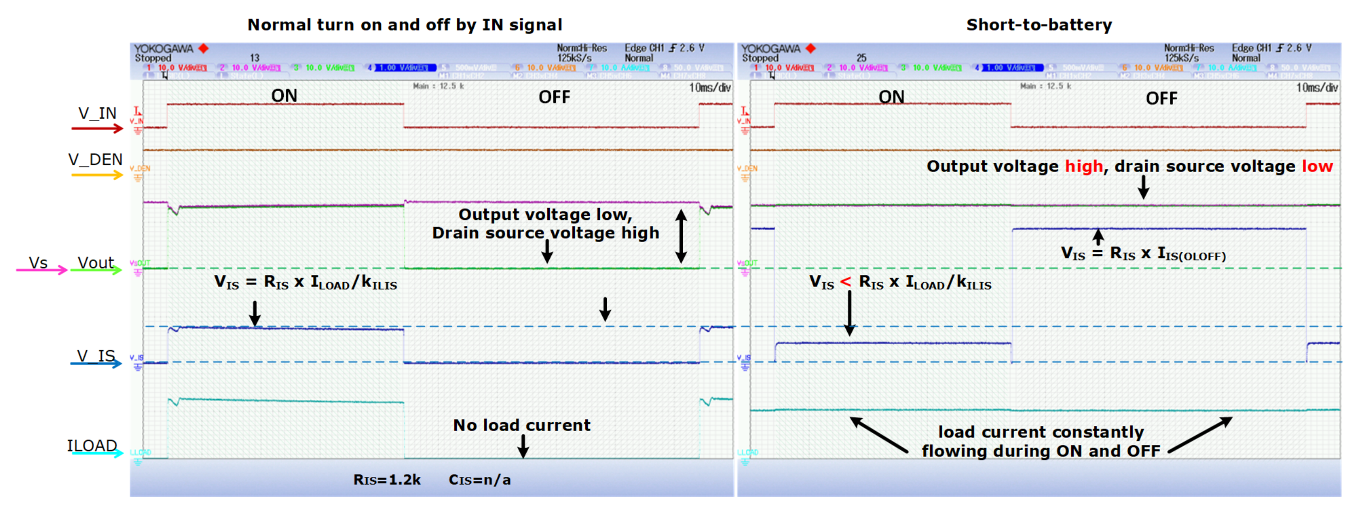


Figure 11 Electrical signals in normal load and short-to-battery condition

During STB, in on-state, the load current is shared between the PROFET™+2 12V and the contact shorting OUT-to-battery. If STB is low ohmic enough, STB can be detected by analog load current sense signal (it will be less compared to normal condition). In off-state, because of STB, output voltage remains high. A PROFET™+2 12V will provide a dedicated signal ($I_{IS(OLOFF)}$), if diagnosis is enabled (DEN = "high"). This signal has a different level than the FAULT signal ($I_{IS(FAULT)}$) and can be distinguished.

Note: *When connecting a capacitor to the output of a PROFET™+2 12V, the output voltage is buffered. Because of this, the $I_{IS(OLOFF)}$ may be triggered even without an STB or open load condition, depending on the discharging speed of the capacitor. To avoid $I_{IS(OLOFF)}$ during normal switch-off of a resistive load, after falling edge on the input signal, $I_{IS(OLOFF)}$ is blanked for a fixed duration ($t_{IS(OLOFF)\_D}$).*

12 How to do "open load in off-state" detection with PROFET™ +2 12V?

For some loads, it may be necessary to check their availability without powering them up. For example, it may be necessary to check if bulbs or LEDs (or the cable they are connected to) are intact or broken, without creating a flash light by switching them on.

Examples of the open load detection at "off" for a single output and for multiple device or outputs are shown in *Figure 12* and *Figure 13*

Note: *These are very simplified examples of an application circuit. The function must be verified in the real application.*

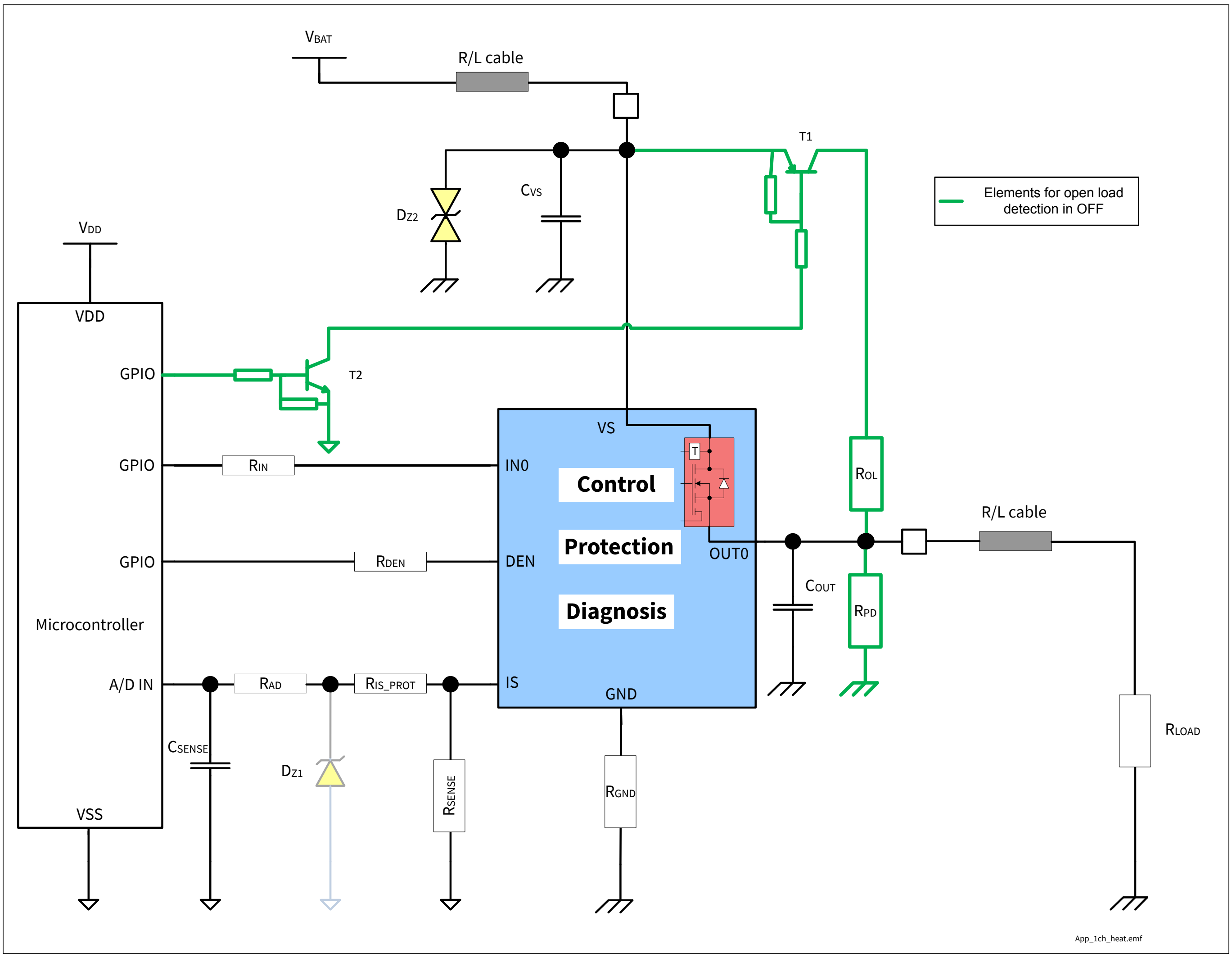


Figure 12 **Application diagram with open load detection circuitry**

12 How to do "open load in off-state" detection with PROFET™+2 12V?

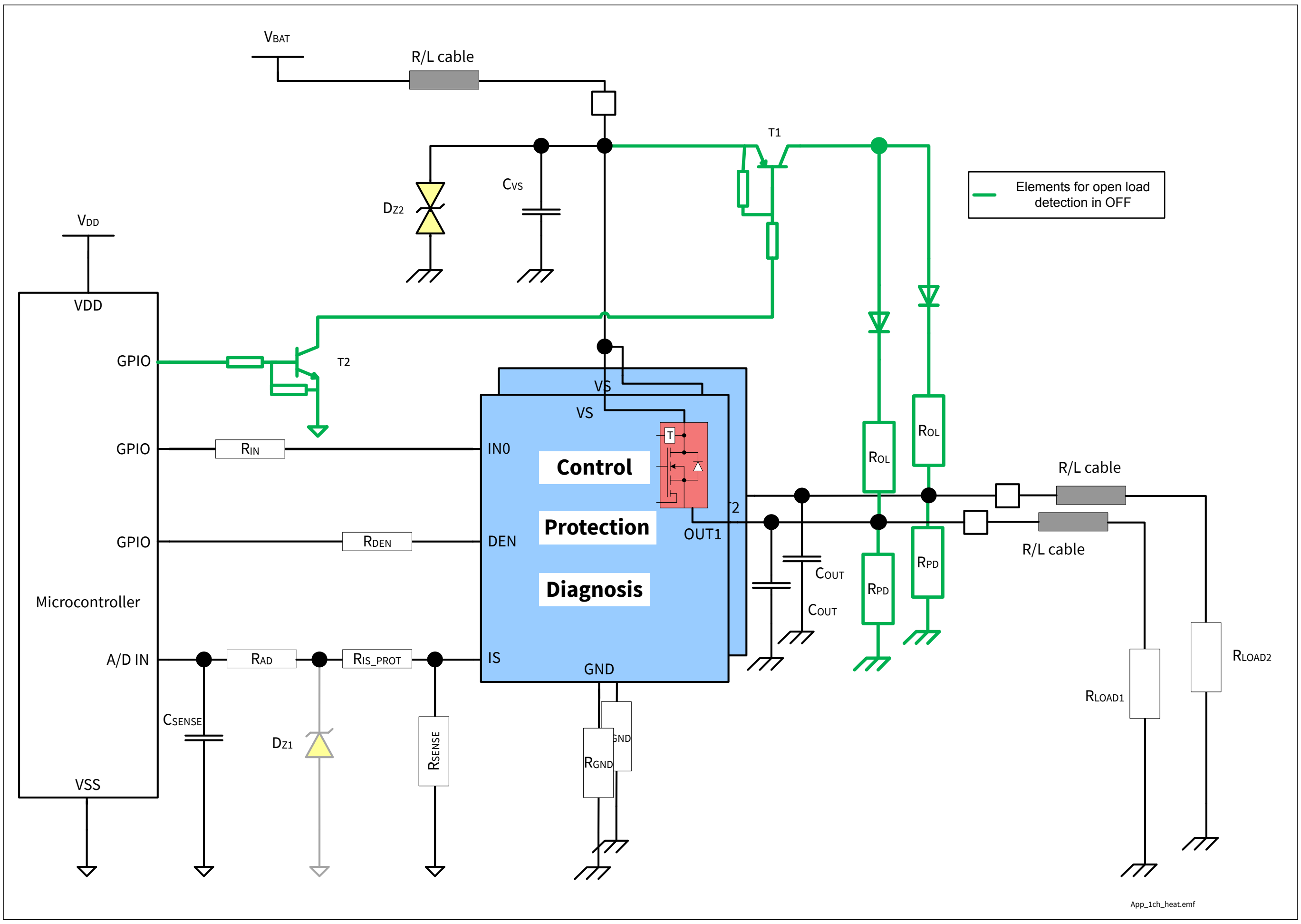


Figure 13 **Application diagram with open load detection circuitry for multiple outputs and devices**

In the example circuitry in ***Figure 12***, a small current (few milliamperes) is injected into the output, powerful enough to pull up the output if there is no load connected, but not powerful enough to activate the load in a disturbing manner. If the output voltage of a PROFET™+2 12V becomes too high, drain-source voltage will be lower than $V_{DS(OLOFF)}$, and the PROFET™+2 12V will provide an open load signal $I_{IS(OLOFF)}$, if DEN = "high" while IN = "low". To avoid continuous power losses in "off" state in open load condition, and to be able to distinguish open load from short-to-battery in "off" state, the pull-up circuitry must be deactivated.

12 How to do "open load in off-state" detection with PROFET™+2 12V?

Begin

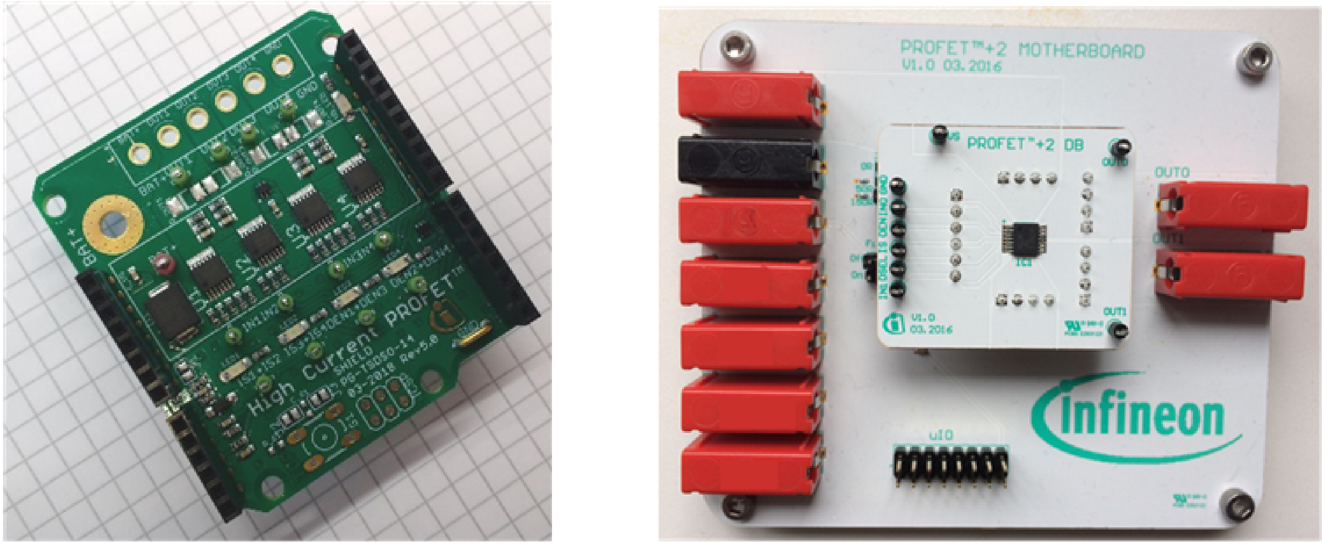
```
IN=low; DEN=high;
activate pull-up;
read IS;
If IS=IIS(OLOFF)
De-activate pull-up;
Read IS;
If IS=IIS(OLOFF)
Short-to-battery detected;
Else open load detected;
Else
if IS=IIS(fault)
short-to-ground or overtemperature detected;
else
normal load condition detected;
de-activate pull-up;
end;
```

The limits of the pull-up currents have to reflect maximum allowed load current, which does not activate the load. That depends strongly on the load, and has to be adapted accordingly.

As leakage currents battery-to-output (for example, output leakage current $I_{L(OFF)}$) and output-to-GND may occur in a system, resistors for pull-up and pull-down may be needed.

13 How to do a quick laboratory evaluation?

The easiest way to do a laboratory evaluation is to order an Infineon evaluation board. See the website ***Evaluation boards*** or contact your Infineon Sales person for more details.



PROFET™ shield,
compatible with ARDUINO

PROFET+2 evalboard sandwich
(motherboard + daughterboard)

Figure 14 Evaluation boards for PROFET™+2 12V product family

14 Why does a PROFET™+2 12V toggle with 200 Hz during short circuit test? Is it not supposed to latch off?

During short-to-GND condition, if the supply line is too weak, supply voltage may break down causing undervoltage shutdown (typically 2.3 V) before reaching overload detection threshold. If IN = "high", PROFET™+2 12V devices will restart within approximately 5 ms. Switching on will take little time, allowing high currents to flow, causing again a breakdown of the supply voltage. This will be repeated every 5 ms (1/5 ms = 200 Hz) until the device reaches overtemperature, IN = "low" or a sufficient change of the boundary conditions.

15 My application does not switch on - how to debug?

Based on practical experience, here is a checklist to find most common bugs in a test setup for PROFET™+2 12V:

- Power supply is switched on and activated, with output voltage 6 V…18 V? Power supply is powerful enough?
- For lab power supplies: current limit is sufficiently high?
- Power supply cable ok?
- Ground cable ok?
- Output cable ok?
- Output cable connected to the correct output?
- Ground connection of the load ok?
- Load ok?
- Does the device switch on after a reset? (switch IN = "low" for more than 100 ms, then high again)
- Measuring with a multimeter or oscilloscope:
  - Voltage at OUT is low (<< 1 V)?
  - Voltage at pin IN (or INx) higher than 2 V?
  - Supply voltage at the device higher than 4.1 V?
  - Activate DEN (2-channel: set DSEL accordingly). Voltage at pin IS is low? If no, protective switch-off is triggered, by a peak current (e.g. inrush) exceeding $I_{L(OVL)}$ or by overtemperature shutdown

If no trouble was found up until this point, remove all connections of the board.

- Are all pins soldered correctly?
  - Start with visible inspection. All pins have solder? All SMD resistors mounted?
  - No short between pin IN and GND? No short between IN and DEN (IN and DSEL)?
  - No short between OUT and GND?
  - Connection between the board's supply connector and the PROFET™+2 12V ok?
  - Exposed pad (backside of the package) soldered to supply line on the board? Check if connection of the power stages' body diode is measureable on the board (most multimeter can measure a diode forward voltage)
  - Connection between the board's GND connector and the PROFET™+2 12V ok?
  - R_{GND} ok? R_{IN} ok?

Repeat the test with a different board or sample of PROFET™+2 12V. Does it switch on?

16 What is the step in the $I_{IS(fault)}$ signal after short circuit shutdown?

When shutting down at overcurrent or overtemperature condition, the PROFET™+2 12V devices provide a fault signal $I_{IS(fault)}$ at the IS pin. While $I_{IS(fault)}$ is the same for overcurrent (OCSD), absolute overtemperature (aOTSD), dynamic overtemperature shutdown (dOTSD), small differences in the dynamic behavior of the IS signal may be observed:

- Absolute overtemperature shutdown: I_{IS} is constant after aOTSD
- Dynamic overtemperature shutdown: I_{IS} is typically 2 mA higher as long as $T_{J(DYN)}$ is exceeded
- Overcurrent shutdown: For typically 40 µs after OCSD, I_{IS} is typically 3.5 mA higher

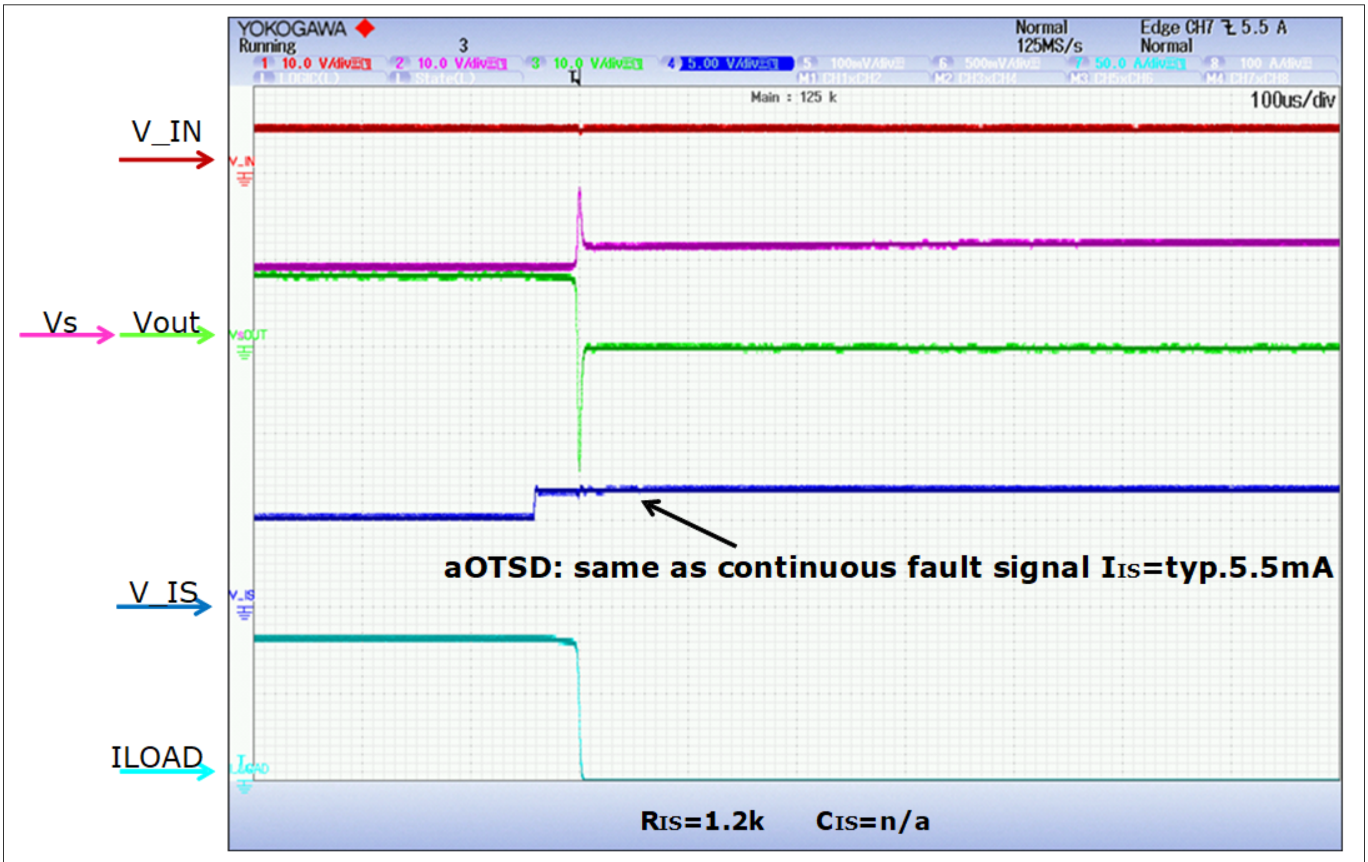


Figure 15 **Fault signal after absolute overtemperature shutdown**

16 What is the step in the $I_{IS(fault)}$ signal after short circuit shutdown?

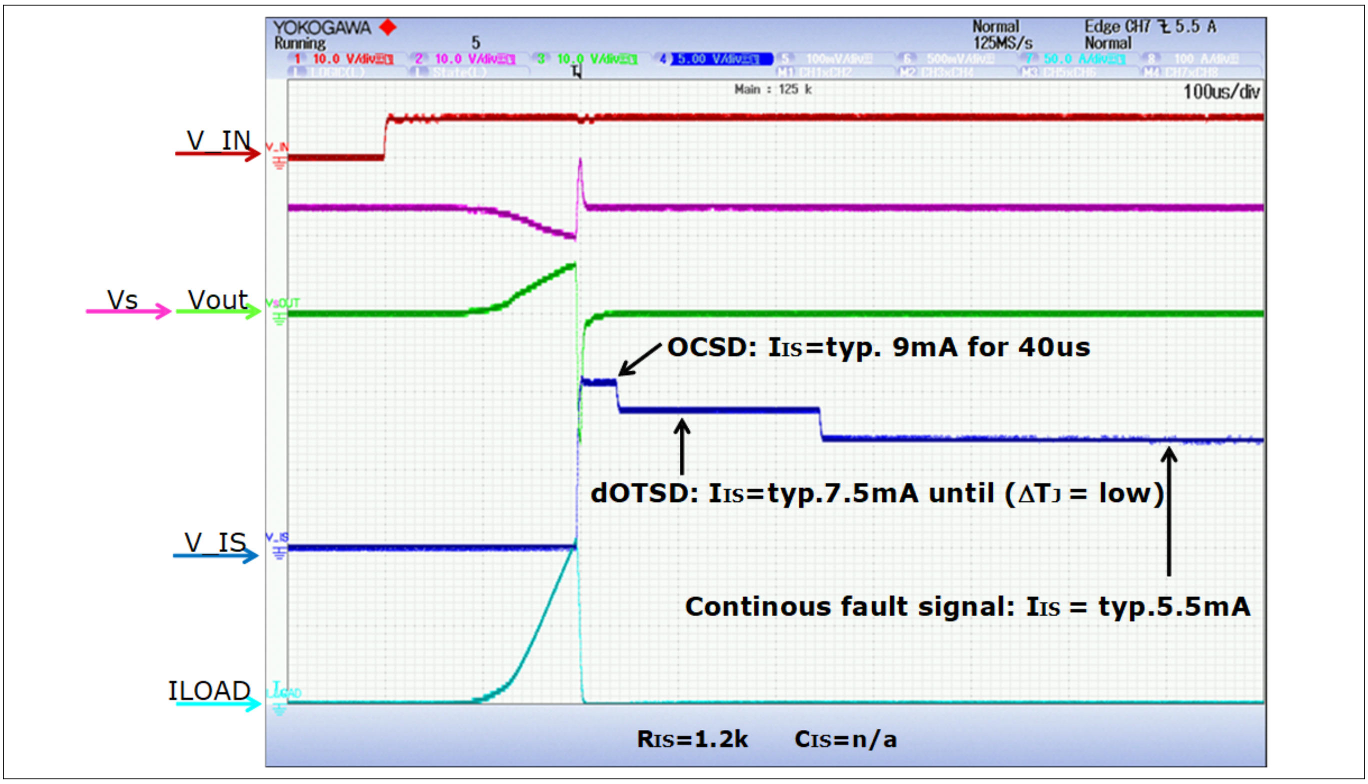


Figure 16 Fault signal after overcurrent shutdown, additionally triggering dynamic overtemperature shutdown

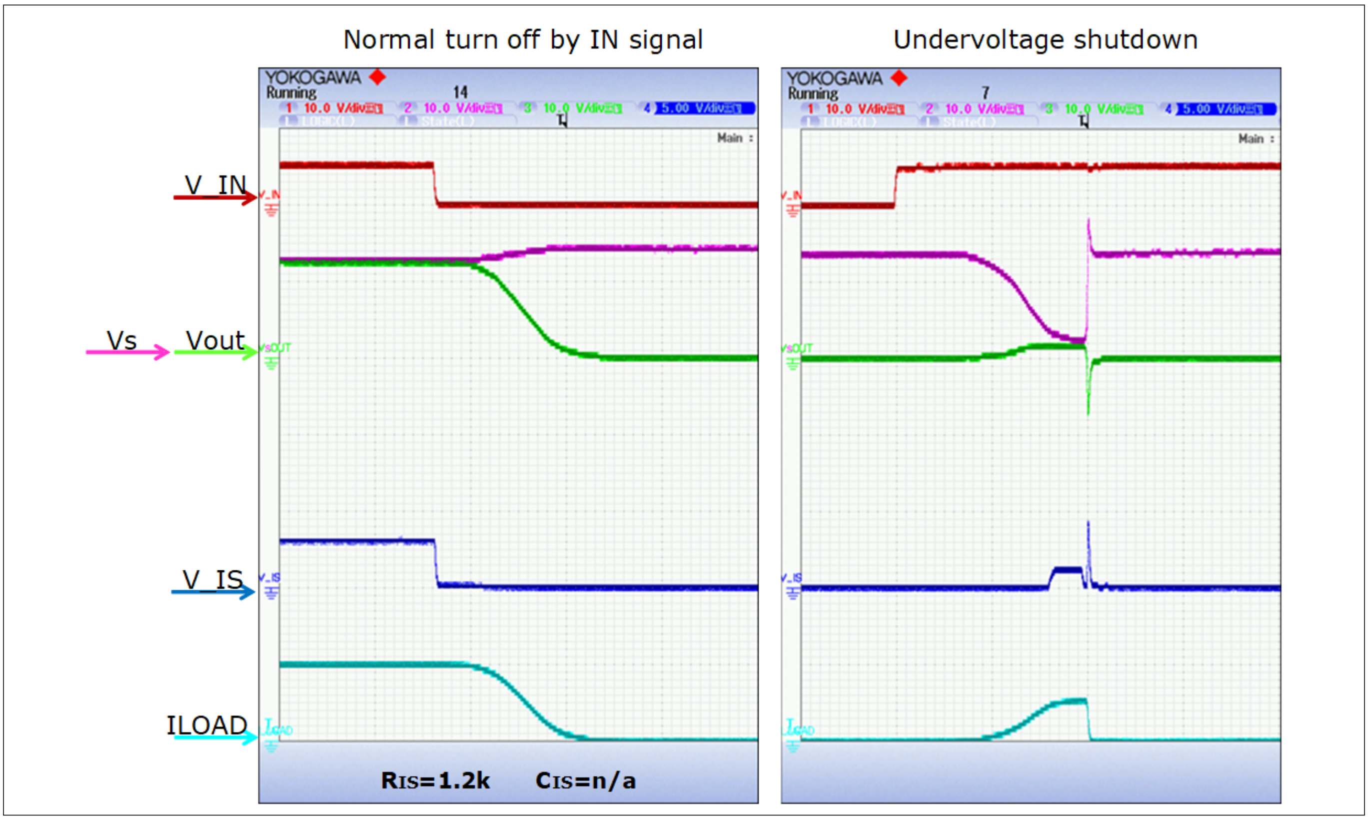


Figure 17 Normal switch-OFF (BTS7004-1EPP) and undervoltage shutdown

17 How to read the datasheet of PROFET™+2 12V? Some practical hints ...

Compared to other PROFET™ datasheets, PROFET™+2 12V datasheets have many pages, a high number of electrical characteristics tables, and (almost) no diagrams with electrical characteristics. For a characterization report, please contact your Infineon sales person for more details.

Here some hints how to read the datasheet more efficiently.

When looking for a parameter…

- If you know the parameter symbol (for example "$R_{DS(on)}$"), try the search function of your pdf viewer (already tried "CTRL+F"?). Type "rds(on)" in the search field of your pdf viewer, and usually you'll find the parameter in the description, in the figures and in the electrical characteristics table.
- If you don't know the parameter symbol, think of which type of parameter you are looking for.
- For electrical parameters, datasheet distinguishes absolute maximum ratings (=what may damage the device), functional range (=parameters limiting the function of the device), electrical characteristics (describing the functions of the device) and application information (=suggested external components).
- "Absolute maximum ratings" and "functional range" will be found at "General product characteristics". "Electrical characteristics" are stored in the chapter of the dedicated functional block (for example, the input current of the digital pins are found at "logic pins", the k_{ILIS} is found at "Diagnosis" chapter, ...)
- For electrical characteristics, there are 2 tables per chapter:
  - First "electrical characteristics" chapter contains the generic parameters which are the same for various members of the product family (for example $V_{DS(CLAMP)}$, $T_{J(ABS)}$)
  - Second "electrical characteristics" chapter contains the parameters which depend on the different $R_{DS(on)}$ of the members of the PROFET™+2 12V family (for example $R_{DS(ON)\_25}$, $I_{L(OVL)}$)
- For navigation, use the bookmarks, which are included in the pdf file. Just scrolling down the file would take too long before you reach your target.

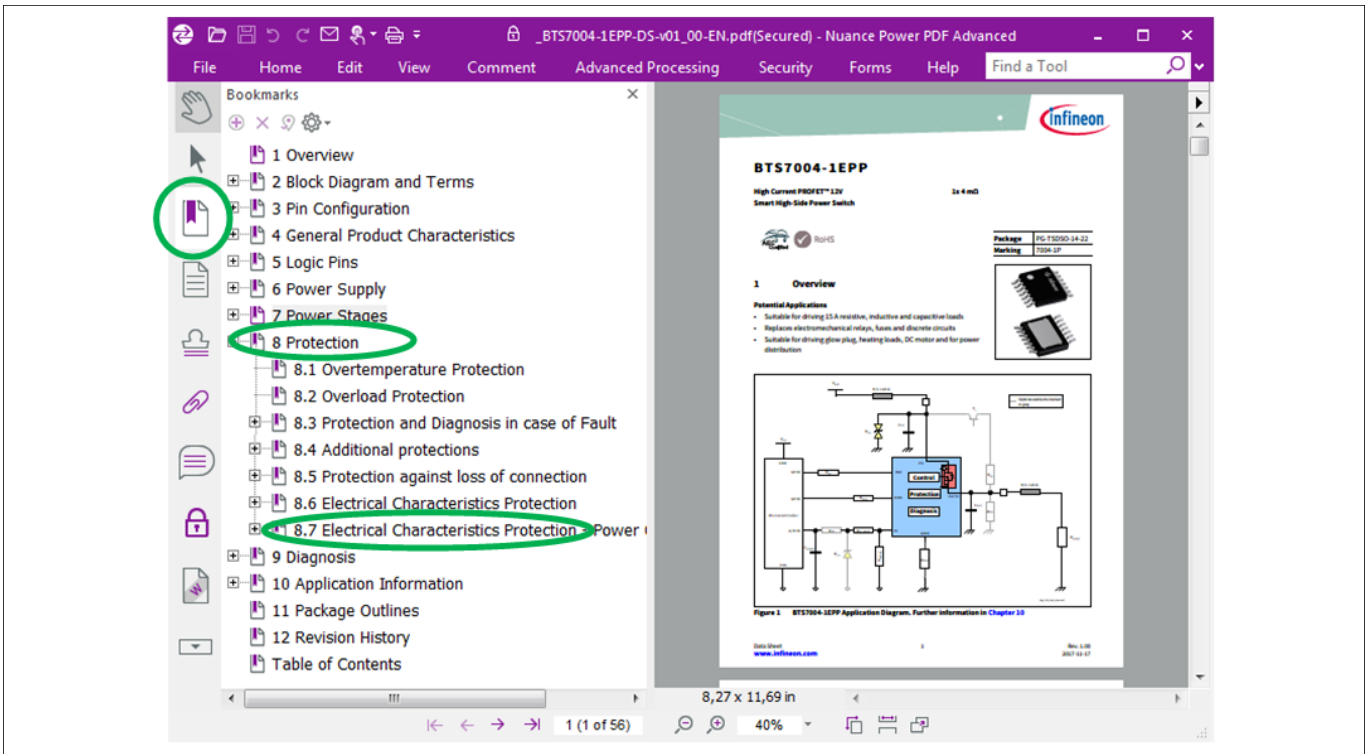


Figure 18 Bookmarks included in PROFET™+2 12V datasheet

18 What does the PROFET™+2 12V product naming stand for?

Example of BTS7004-1EPP

Table 3 Naming key

Naming	Meaning
BTS	12 V protected high-side switch for bulbs, heating, power distribution
7	SMART7 technology
004	Class of on-state resistance: 4 mΩ (for accurate value check the datasheet!)
-1	Number of independent outputs: 1 output
EP	Package: PG-TSDSO-14
P	Feature set: power (see ***Chapter 4*** “What are the main difference between EPP and EPA PROFET™+2 12V?"

19 What is the difference between input voltage and supply voltage?

In the datasheets of PROFET™+2 12V family, input voltage refers to digital input pins, enabling and disabling the devices. Digital input pins are compatible with 3.3 V or 5 V logic. Supply voltage refers to the voltage domain from which the products are supplied. The normal supply voltage range of PROFET™+2 12V product family is 6 V…18 V.

20 Revision history

Document version	Date of release	Description of changes
Rev.1.20	2020-03-31	• Updated ***Table 1*** and added text • Updated text in ***Chapter 9*** • Corrected typos
Rev. 1.10	2020-03-16	• Modification of diagrams • Name update from High Current PROFET™ to PROFET™+2 12V • Updated and refined text throughout
Rev. 1.00	2018-08-02	• Initial Application Note

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