# HITFETs: Smart, Protected MOSFETs

Application Note

Automotive Power

Never stop thinking

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# 1 Abstract

This short application note aims at shining some light on HITFET devices from historical beginnings to today's most complex applications. A decription of its operating mode, fault mode and protection is also given. Additonally, details on all existing products, packages, availability, trends and contact information are also provided. We will continue to improve the content and update the information as necessary.

# 2 Introduction

Ever increasing demand for highly integrated protected switches will continue to drive the use, acceptance and development of HITFET® (High-Integrated Temperature protected FET) long into the future.

Fault detection and protection are safety features required and widely used today in numerous automotive and industrial applications. In particular for these high power applications where voltage transients or high inductance loads are present, circuit protection is critical.

HITFET low-side switches are versatile power transistors ideally designed for automotive and industrial applications. Their built-in intelligence and protective features offer not only significant cost and PCB reduction, shorter time to market, but also improved performance & reliability over conventional, discrete solutions.

# 3 Functional Description. Portfolio Overview.

HITFET low-side power switches from Infineon Automotive Power represent a unique, new generation of smart transistors distinguished by all round protection against:

- short circuits and overloads
- voltage surges (or open circuit)
- excess temperature, and
- electrostatic discharge (ESD)

over a wide, almost unlimited range of automotive and industrial applications. Additionally, IFX HITFETs provide fault detection and diagnostic via a feedback loop system.

Basically, one can think of HITFETs as improved, evolved MOSFET devices. At one end there is the typical MOSFET (with no protection), followed by TEMPFET/SPEEDTEMPFET, Clamped MOSFET, and the self-protected HITFETs as illustrated below.

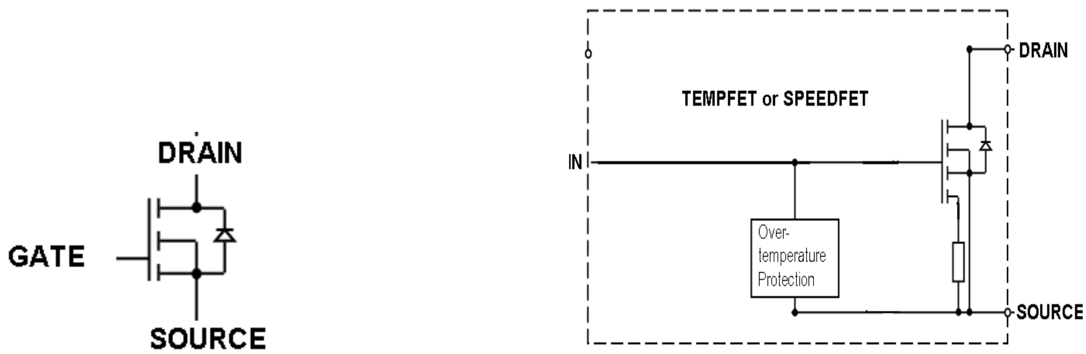


Figure 3.1. HITFET evolution: MOSFET and TEMPFET - block diagram

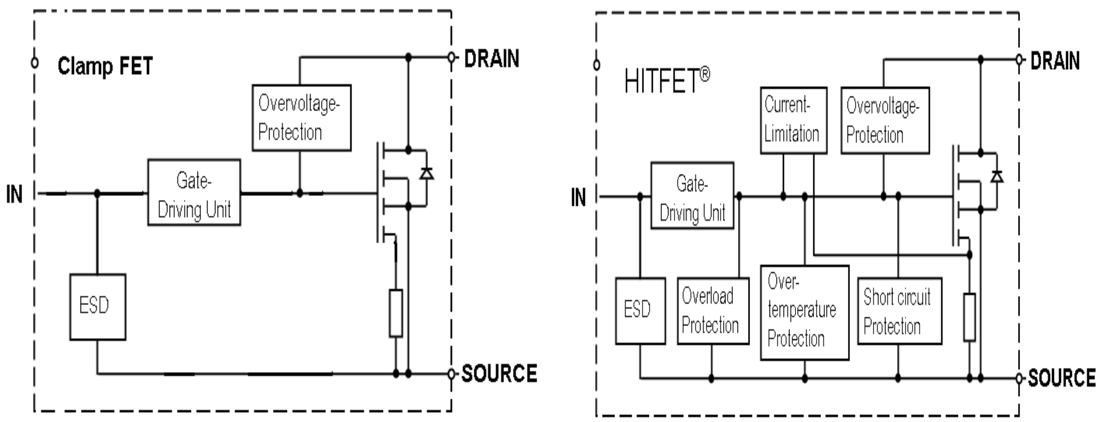


Figure 3.2. HITFET evolution: Clamped MOSFET and HITFET block diagram

A typical MOSFET has no intrinsic current, voltage or temperature protection. Simple, low cost, allowing quick designs are clearly their benefits in non-protected applications. However they are not suitable for applications requiring any level of protection, hence limiting its applicability as a stand alone device.

TempFETs and, the faster (to1MHz), SPEEDFETs are basically MOSFETs with added temperature protection/sensor. They are used in applications requiring minimum level of protection and, although new designs on protected MOSFETs do not focus on TempFETs anymore, there are still numerous niche applications that use them, especially when reliability, robustness and long life are essential.

The ClampFET is a protected MOSFET device that offers ESD and overvoltage protection. The datasheet curves and parameters of MOSFETs are almost identical to the ClampFET devices. They are relatively cheap, fast, reliable and are suitable for applications requiring simple, medium level of protection especially for inductive loads.

Lastly, over the past years, the HITFETs have established themselves as power protected MOSFETs of choice for low side applications requiring not only ESD, overvoltage protection and temperature protection, but also current, open circuit and other diagnostic functions. They are extremely robust and reliable, well suited for automotive/truck and industrial applications. HITFETs are suitable for driving all kind of resistive, capacitive and inductive loads and the load current is only limited by the current limitation of each device. Additionally, HITFETs are suitable in numerous fast, high frequency PWM applications.

Generally there are two HITFET versions available: restart and latch. For restart HITFETs, the device 'restarts' once the temperature drops/cools down under a certain limit. For latch devices, the microcontroller controls the timing of the restart.

Infineon's available TEMPFETs and HITFETs are summarized in the table below.

| **Device** | **Package** | **Protection type** | **Qualification** (A-automotive, I-industrial) | **Available** | **Type, target applic.** |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| **TEMFETs SPEEDFET** | | | | | |
| BTS244 | TO220 | Temperature | A, I, all | Gray & GREEN | High Voltage Applications , Trucks |
| BTS247 | TO220 | Temperature | A, I, all | Gray & GREEN | High Voltage Applications ,Trucks |
| BTS282 | TO220 | Temperature | A, I, all | Gray & GREEN | High Voltage Applications ,Trucks |
| www.infineon.com/hitfets | | | | | |
| | | | | | |
| **HITFETs** | | | | | |
| | | | | | |
| BSP75N | SOT223 | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Restart, High Voltage Applications , 60V+, Industrial & |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | Automotive, Trucks |
| BSP76 | SOT223 | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Restart |
| BSP77 | SOT223 | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Restart |
| BSP78 | SOT223 | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Restart |
| BTS117 | D2PAK | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Latch, High Voltage Applications , 60V+, Industrial & Automotive, Trucks |
| BTS118D | DPAK | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Restart |
| BTS133 | D2PAK | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Latch, High Voltage Applications , 60V+, Industrial & Automotive, Trucks |
| BTS134D | DPAK | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Restart |
| BTS141 | D2PAK | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Latch, High Voltage Applications , 60V+, Industrial & Automotive, Trucks |
| BTS142D | DPAK | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Restart |
| BTS149 | D2PAK | ESD, Temp, V, I, diagnostic | A, I, all | Gray | Latch, High Voltage Applications , 60V+, Industrial & Automotive, Trucks |
| BTS3110 | SOT223 | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Latch |
| BTS3118 | DPAK, SOT223 | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Latch |
| BTS3134 | DPAK, SOT223 | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Latch |
| BTS3142 | DPAK | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Latch |
| BTS3160 | DPAK | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Latch |
| BTS3205 | DS08, DPAK | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Restart |
| BTS3207 | SOT223 | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Restart |
| BTS3405 | DS08 | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Restart, 2ch |
| BTS3408 | DS08 | ESD, Temp, V, I, | A, I, all | Gray & | Restart, |

| | | | | | |
|---|---|---|---|---|---|
| | | diagnostic | | GREEN | 2ch, High Voltage Applications , 60V+, Industrial & Automotive, Trucks |
| BTS3410 | DS08 | ESD, Temp, V, I, diagnostic | A, I, all | Gray & GREEN | Restart, 2ch |
| www.infineon.com/hitfet | | | | | |

Table1. Infineon portfolio. Protected power MOSFET switches

For more information, datasheets, order, contact information please check our homepage out: www.infineon.com/hitfet

Generally when selecting a protected switch for a certain application, the following parameters should be considered: RDSon, nominal current, break down voltage, load dump voltage, latch/restart type, clamping energy, number of channels, package type, dissipated power, and PWM requirements.
Additionally, depending of the specific application and cooling conditions, other parameters (ex. operating temperature, thermo-resistance) may also be important.

## 4 Circuit fault. Operation Mode description

HITFETs can be driven in a similar manner to standard MOSFETs and operated in both analog and digital circuits as well. The three-pin version is 1:1 compatible with the standard MOSFET (but draws a small gate current), whereas the five-pin power HITFETS version has a digital control input and battery supply pin that allows the user to program and control the maximum current (min RDSon), or/and PWM/slew rate.

### A. Typical circuit conditions and faults

Overload and short circuit are clearly the most damaging conditions in an application and it can take a few forms, depending on the input and load conditions: I.e. the short could be across the load (Vbb and Drain), or device (Drain-Source) for different input conditions (Vgs= LOW or Vgs= HIGH).

Additionally, the short could be intermittent, significantly worsening the situation especially when the circuit contains inductive loads. In this case the self induced (fly-back) voltage and/or the clamped energy could be significantly higher than specified values for the device, thus irreversibly damaging the device.

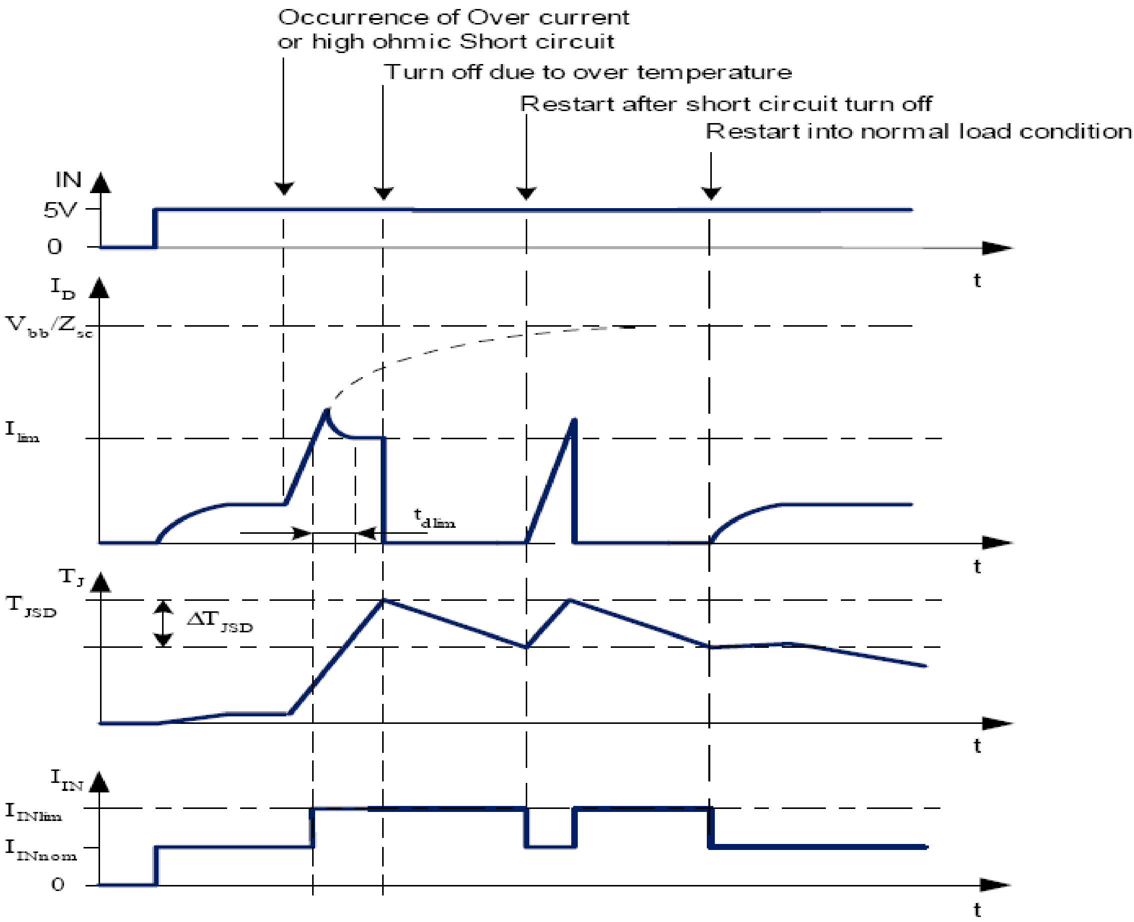


Figure 4.1. Short-circuit behaviour of a restart HITFET

In case of a short circuit or overload condition, the current reaches Ilim then starts limiting it at that value, however it could briefly go over that value. As the device heats up, it eventually reach thermal showdown temperature when it turns off.

There are numerous load type, however the ones that pose most risks to the device are inductive and capacitive loads.

In case of an electrical motor, i.e. an inductive load, there are relatively high currents passing through the motor coils at start-up time or, in case of friction/stalling of the rotor or its moving parts. In these cases the device limits the maximum current to a maximum value that is preset by the manufacturer. In case of more severe conditions, such as rotation stalling or shorted winding, the device switches the load off to prevent any electrical damage to the motor or to its driver circuitry.

When switching capacitive loads or bulbs with high in-rush currents the device limits the maximum current to a preset limit, as with inductive loads described above. The in-rush current for capacitive loads could be 8 -10 times larger than the steady state current. The nominal and maximum current must be known before choosing a certain device for an application.

In addition to high start-up currents in inductive or capacitive loads, there are self inducted voltages that appear during the turn-off process, voltage and inductive energy that may easily exceed the rated voltage and clamping energy of the switching component. IFX devices are actively protected above 60V, and clamping energy to 3J depending of the package and technology used.

During device storage, handling or soldering the input ESD voltage can reach critical levels that could easily damage the device. All Infineon TEMPFET and HITFET devices are protected against voltages at the input pins of the device. (more details below)

Overall, the internal control circuitry of the HITFET products can detect and control the device operation during many of these external failure modes. This is done by operating in safe mode while the device returns to normal function (when fault condition is removed).

## B. Operation Mode

Older HITFET used Smart and SPT Technologies, whereas the new power HITFET have a SFET base chip and a SPT Top chip. The base chip, representing the larger area of the chip, contains the power MOSFET transistor, and the Top chip contains the protection circuitry. The internal block diagram is illustrated below.

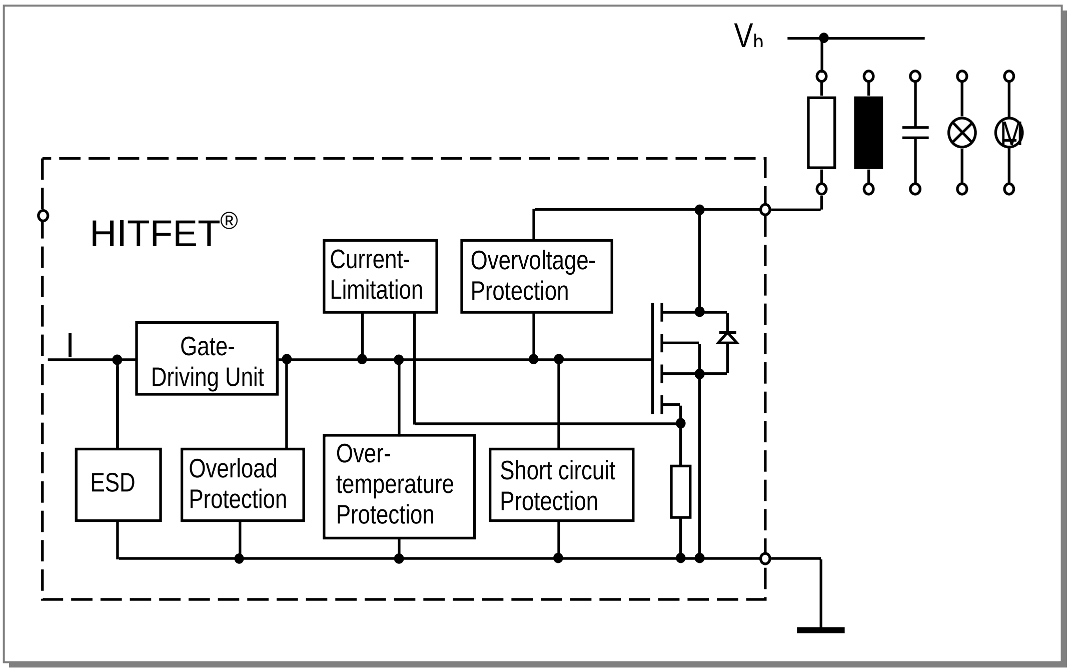


Figure 4.2. HITFET internal block diagram

In brief:

- during normal operation the device work similarly to a standard power MOSFET, with one difference: it draws a small current, approx. 50-100uA, that powers the internal circuitry. This current varies very little from device to device.

- the ESD block provides up to 4kV ESD protection to the input pin(s) and it is usually implemented with a EDS Zener diode. More complex configurations include multiple Zeners, or a Zener and a transistor.

- the GATE Driving unit, works as a current source providing about 0.2mA to the input of the MOSFET and other protection circuit. Linked to the input pin it sources the current needed for the fault detection. In case of a fault the input current increases to 6x-10x (or more) of the normal operation current.

- Current Limitation unit protects the MOSFET when in protect mode, via a feedback to the input of the device

- OVERVOLTAGE protection is internally set to about 70V for truck (24V) devices and to 42V for automotive (12V) devices, providing ruggedness and energy handling capability especially for inductive load driving

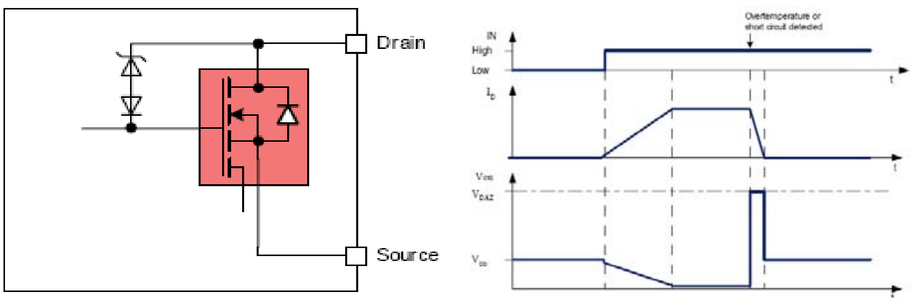


Figure 4.3. Overvoltage protection - clamping mechanism

Infineon HITFET devices are equipped with a voltage clamping mechanism that keeps and protects the Drain-Voltage under a certain limit, as illustrated below.

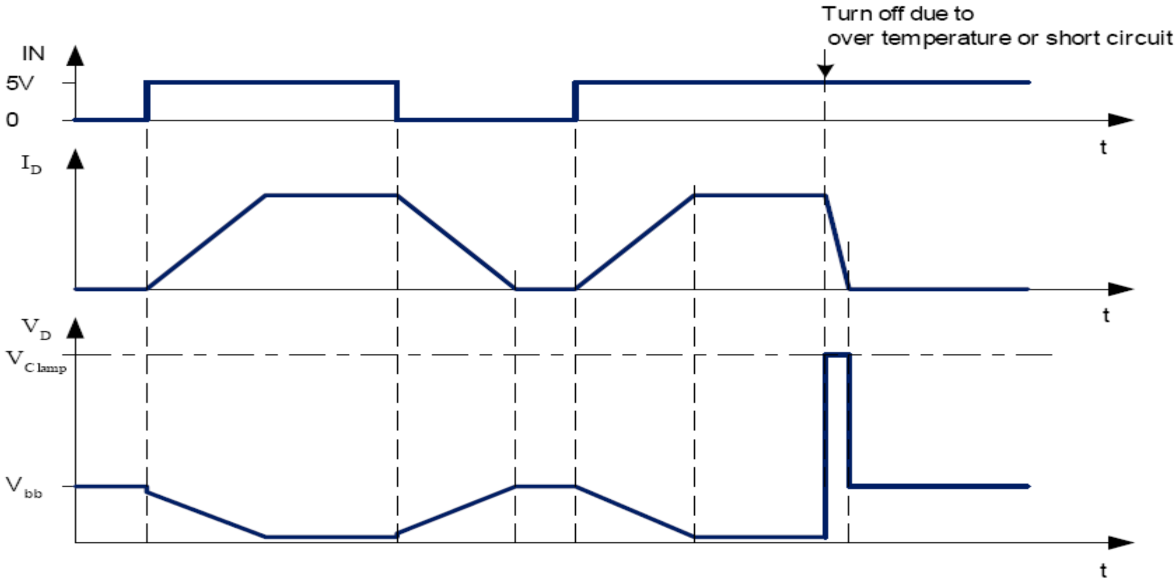


Figure 4.4. Overvoltage switching: inductive loads

- the other internal block, as their name is self explanatory, provide OVER-LOAD, OVER TEMPERATURE and SHORT CIRCUIT protection, and are based on sensing the chip temperature and it is independent of the input voltage. The position of the temperature sensor allows fast, accurate detection of the junction temperature.

The timing and characteristics of the thermo-shutdown process is shown below.

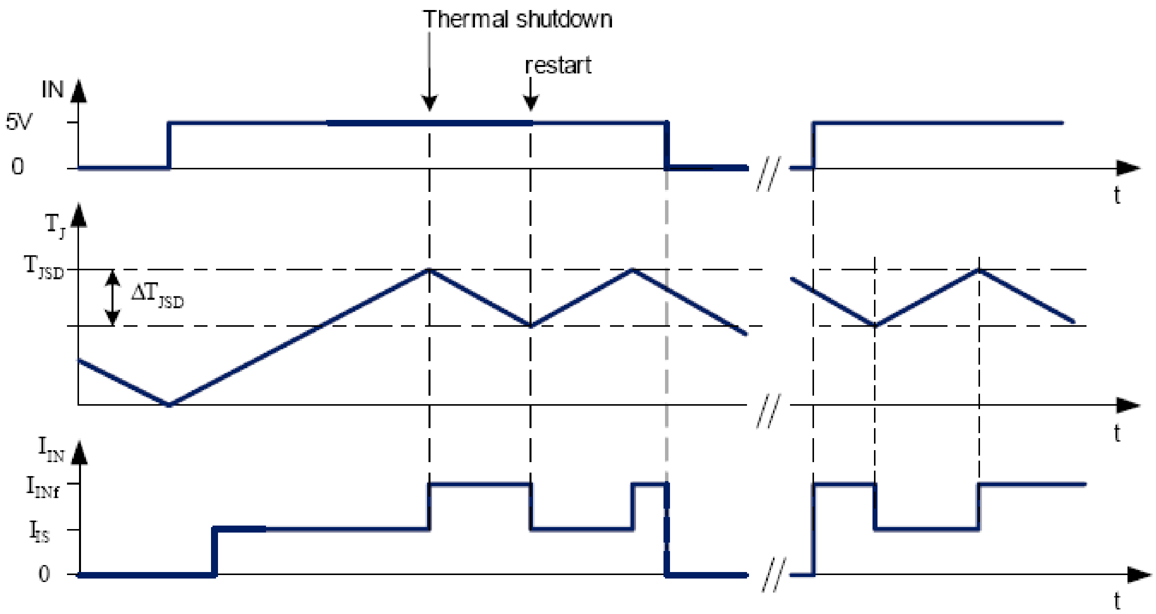


Figure 4.5. Thermal shutdown timing for a restart device

For Infineon devices the over-temperature limits are set to minimum 150C and 175C typical. The device restarts automatically when the temperature drops under 165C/typical, 140C/minimum. In case of a latch device, the microcontroller has to reset the voltage on the input pin, restarting the device.

Despite the very low surface resistance, the MOSFET power transistor function takes up the greater part, about 70 to 90%, of the total chip area, depending on the drain-source on resistance (RDSon).

The way the HITFET is connected in a circuit and the corresponding voltages are shown below.

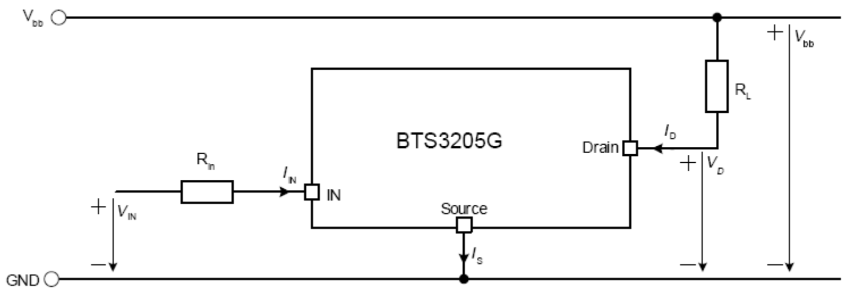


Figure 4.6. Typical circuit diagram of a HITFET

For latch and restart HITFETs the devices are connected and controlled by a microcontroller as shown below.

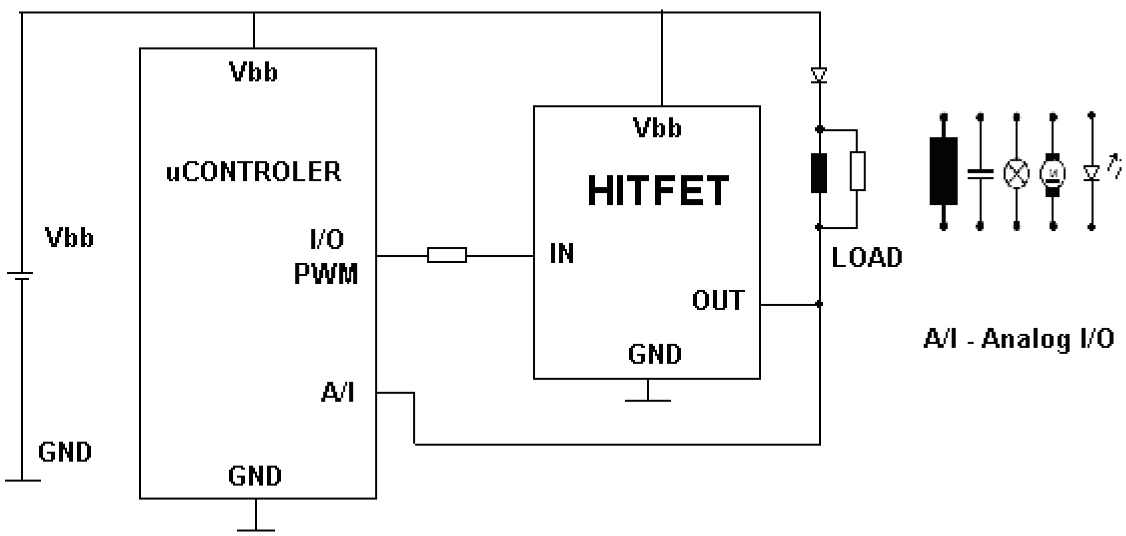


Figure 4.7. HITFET circuit configurations: LATCH type

In case of latch devices the microcontroller controls the HITFETs restart time.

For restart devices, the HITFETs restart when the temperature drops under a certain limit, and this can be controlled either by a microcontroller, or by the HITFET itself.

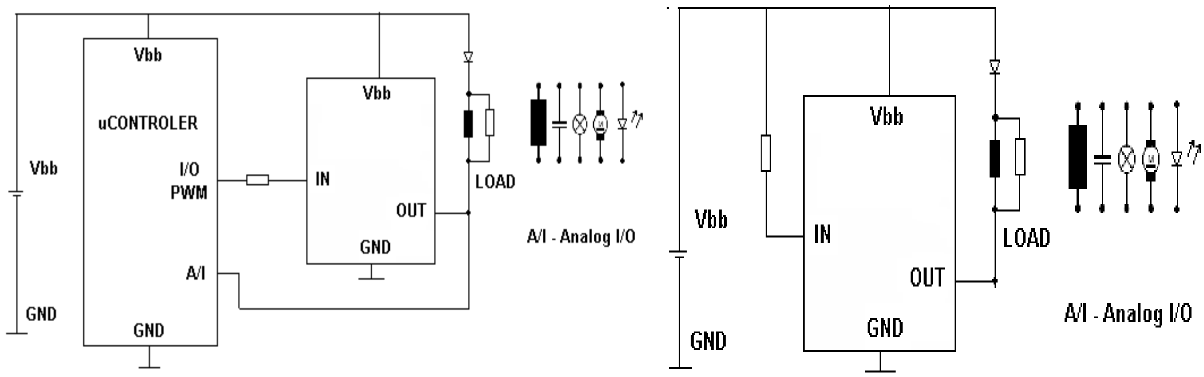


Figure 4.8. HITFET circuit configurations: RESTART type

In case of a short circuit as on a Power HITFET (i.e. BTS3160), as the current and the device temperature increases to its limiting value as the HITFET continues to be switched on. Once this current limit is reached the device switches off automatically.

If the overload or short circuit condition lasts for only a few milliseconds, the HITFET returns automatically to its original operating state. This is illustrated in the diagrams below:

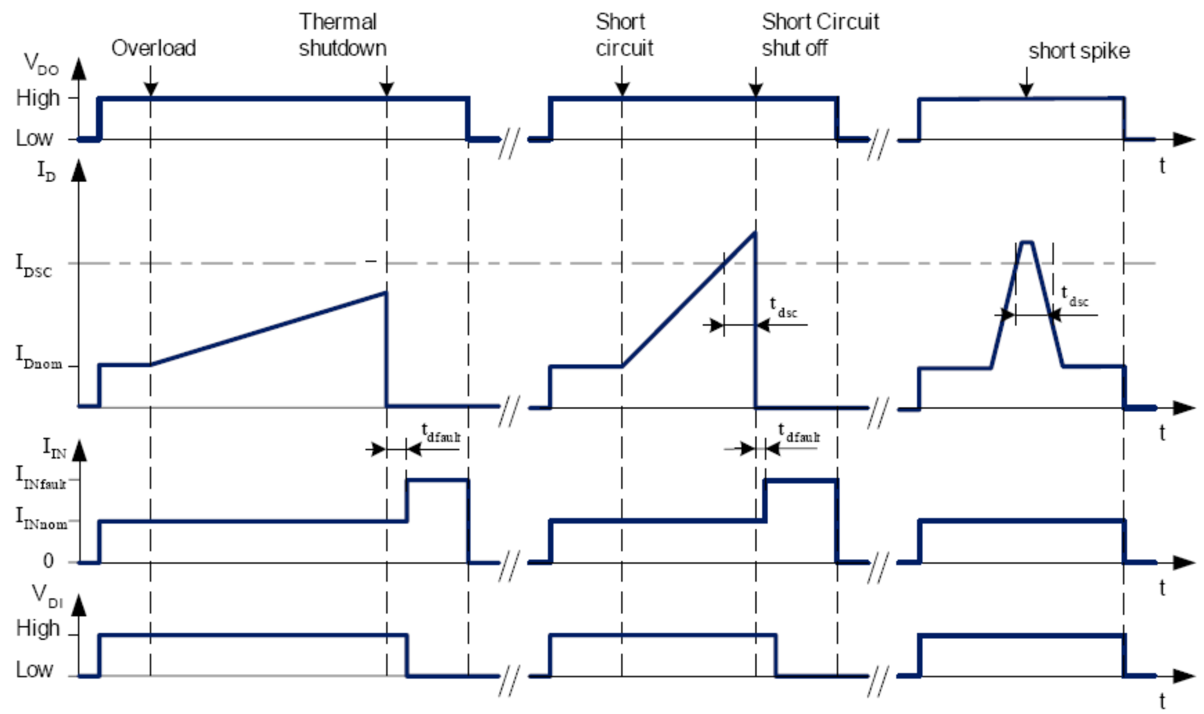


Figure 4.9. Short circuit, ON state condition. Resistive/Ohmic load.

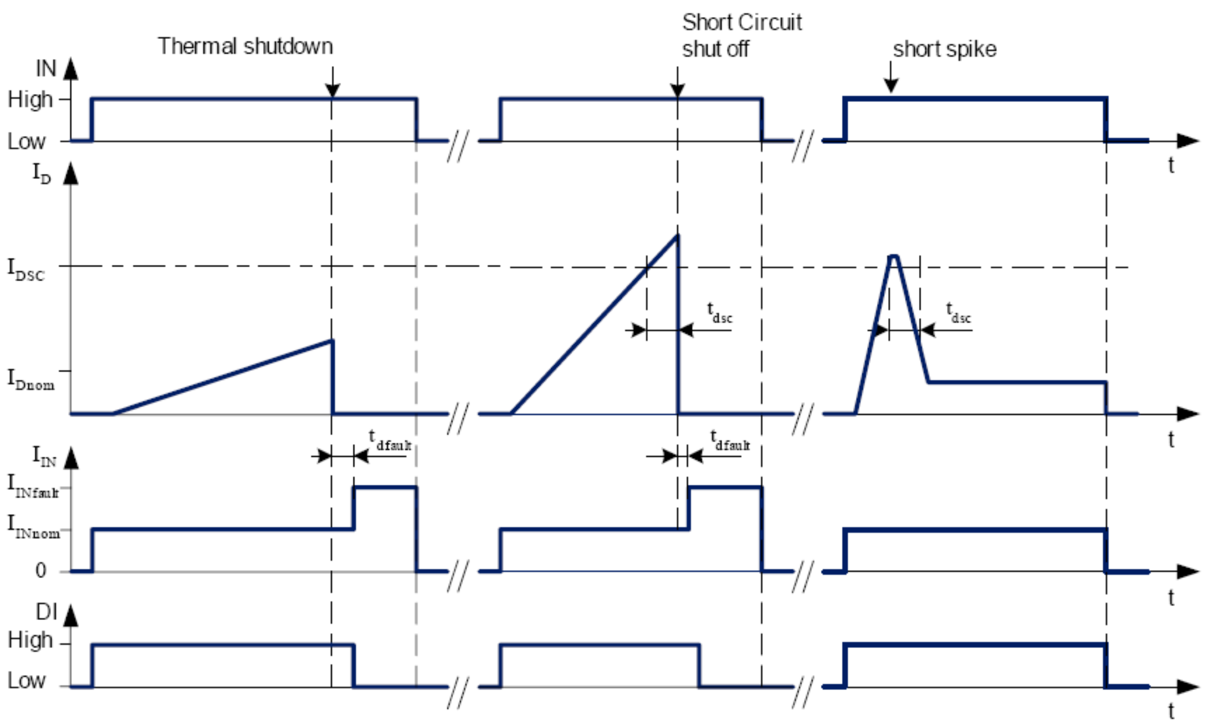


Figure 4.10. Turn ON into existing short circuit. Resistive/Ohmic load.

However, in case the overload condition persists, the temperature sensor comes on switching the HITFET off. The device will try to restart on its own, or wait for a reset signal from the microcontroller, depending of restart or latch configuration.

Afterwards, once the device temperature drops under a certain limit, and depending whether the device is a restart or a latch device, the HITFET turns on automatically or it is turned on by the microcontroller.

Load dump voltage is another circuit condition that HITFETs must withstand repeatably without any loss in performance. IFX devices are rated to 65V-100V, depending of the class and technology used.

The user could choose between devices with a fast turn-on/off time with no current limiting or a moderate turn-on time with current limiting. The latter mode extends the service life of the lamp without increasing the turn-on time noticeably.

Proper operation of the HITFET logic function is almost independent of the input signal level at normal Vbb. Generally HITFETs have a typical operating voltage of 1.5-1.7V, and could be turned-on even at an input voltage of 4-5V making them ideal for low voltage applications, or low level output microcontrollers in analog applications.

More details on the operation mode are given in any of the datasheets posted online. (www.infineon.com/hitfet)

## C. Parameter Variation

For temperature variation, input or/and output conditions, some of the parameters exhibit some changes. Some of the most important ones are shown below. (graphs taken from BTS3205 and BTS3160 datasheets)

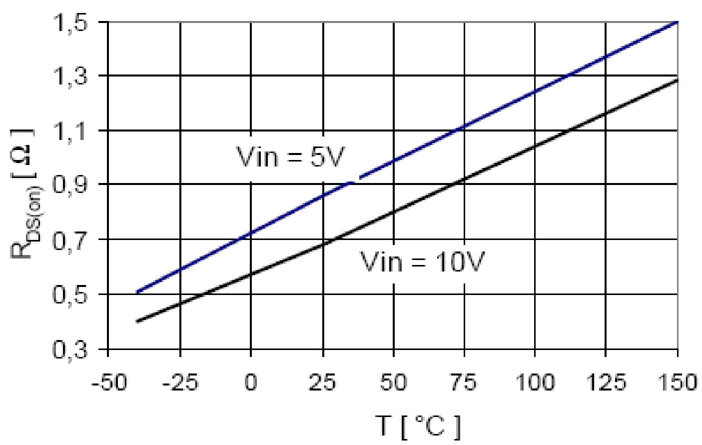


Figure 4.11. Variation of RDSon over temperature and input voltage

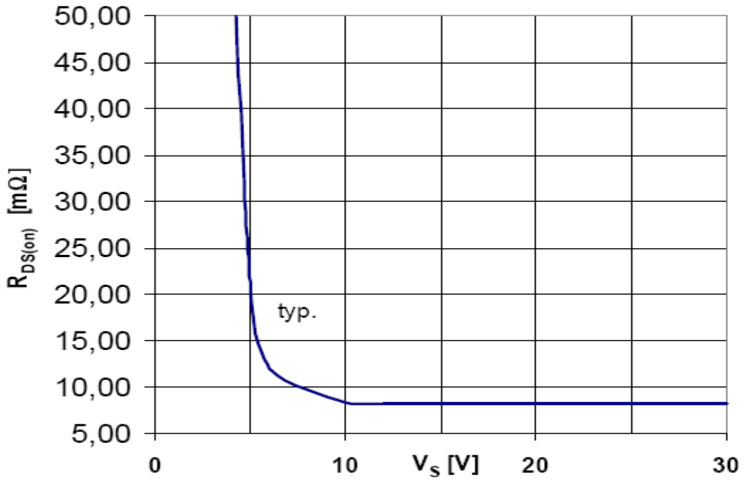


Figure 4.12. RDSon variation with Vs

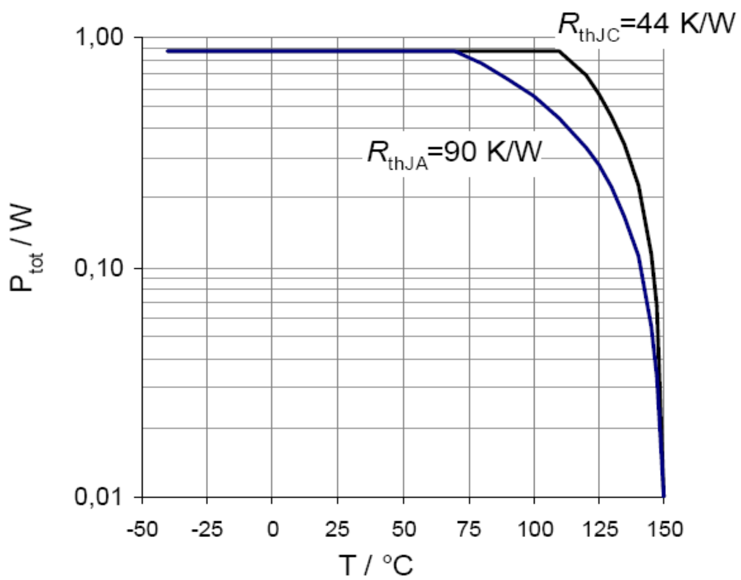


Figure 4.13. Allowable power dissipation in the device

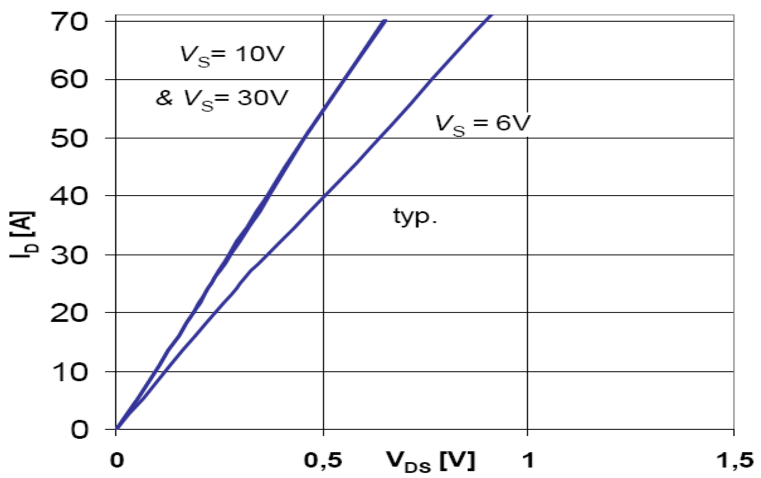


Figure 4.14. Input/Output characteristics, room temperature

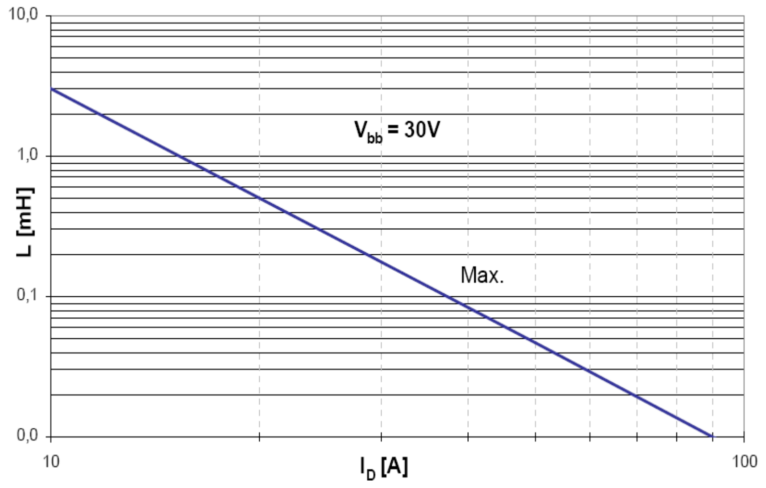


Figure 4.15. Maximum load inductance for single pulse

## 5 Summary: Characteristics, Benefits, Selling Points, Applications

Simple, fast design, low cost, reliable and robust are qualities that make HITFETs present in a wide range of applications in automotive and industrial electronics. A summary of their characteristics, benefits, selling points and applications is given below.

- IFX HITFETs power, protected switches are used everywhere protection is needed:
  - Current (overload and short circuit)
  - Voltage (overload and open)
  - Temperature
  - ESD
  - Provide fault diagnostic

- Benefits:
  - Cost - replaces discrete switching circuits, relays and fuses
  - PCB Space – small, integrated, save PCB area
  - Design Cost and TTM (time to market) - fast, simple design

- IFX Unique Selling Points:
  - broad product portfolio
    - ☐ Rdson/Inom, (10mohm to 700mohm; 350mA to 8A)
    - ☐ Single and dual channels
    - ☐ Vds (62Vmin, suitable for truck applications). To 100V load dump
    - ☐ High Clamping Energy (to 6J)

- ☐ Wide product packages (five)
- ☐ Green & Robust
- ☐ Automotive and Industrial qualified

- reputation for quality, reliability and robustness
- well established relationships among all top players
- wide knowledge of customer applications

- Automotive and Industrial applications:
  - Transportation
  - Lighting
  - Agriculture
  - Medical
  - Monitoring
  - Test and Measurement.
  - Other

- Automotive and Industrial **specific** applications. Switching and control of:
  - AC, DC Motors
  - Fans
  - Relay drivers
  - Pumps
  - Voltage regulators
  - Battery chargers
  - LEDs and bulbs
  - AC and Heating
  - Other

# 6 Contact and Ordering Information

For more product information, order, contact information please check our homepage: www.infineon.com/hitfet

You can also send us an email at:

http://www.infineon.com/cms/en/product/channel.html?channel=ff80808112ab681d0112ab69ddae0347&tab=contacts

Or call us:

International Toll Free: 0(0) 800 951 951 951

Direct Access: +49 89 234 65555

**AP Number**
**Revision History:**

| | |
|---|---|
| Previous Version: | 1.1 |
| D.B. ver1.1. June08 | Format change, updated figures, added restart/latch circuit configuration |
| D.B  ver1.2. Sept08 | Updates table applications,  figures, improved wording, added explanations |
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