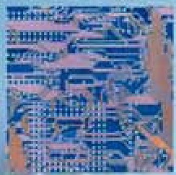

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The Environmental Challenge

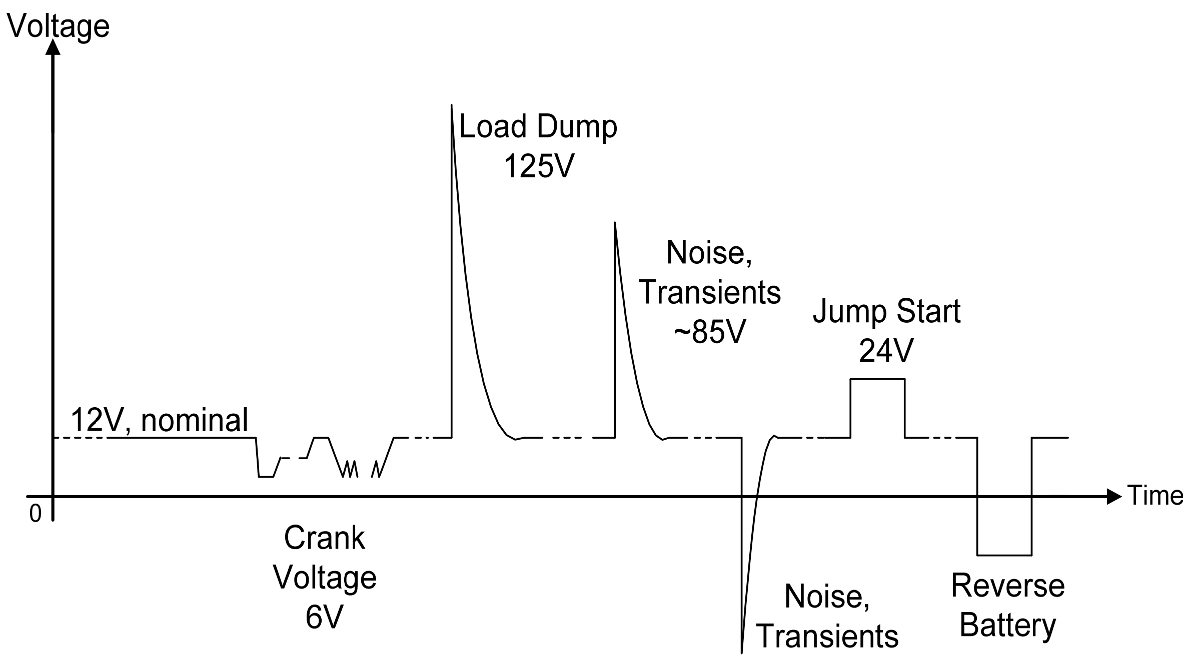


Figure 1 – Typical DC Battery Voltage

The DC voltage of a motor vehicle can deviate from the nominal 12V DC due to:

- **Crank voltage (Engine starting): 6V**
- **Load dump and transient: can be up to +/-125V.**
- **Jump start and reverse battery: 24V / -24V**

The need for self protected MOSFETs

When solid state electronics was first deployed in automotive applications designers relied on:

- The inherent ruggedness of large MOSFETs
- OR , utilised discrete clamp circuits.

To absorb energy from transient load dumps.

Self Protected MOSFET's – adding intelligence

Self-protected MOSFET's add intelligence to the standard MOSFET by incorporating :

- ❑ Over-voltage Protection
- ❑ Over-current Protection
- ❑ Over-temperature Protection
- ❑ Human Body ESD Protection
- ❑ Additional features such as status flags

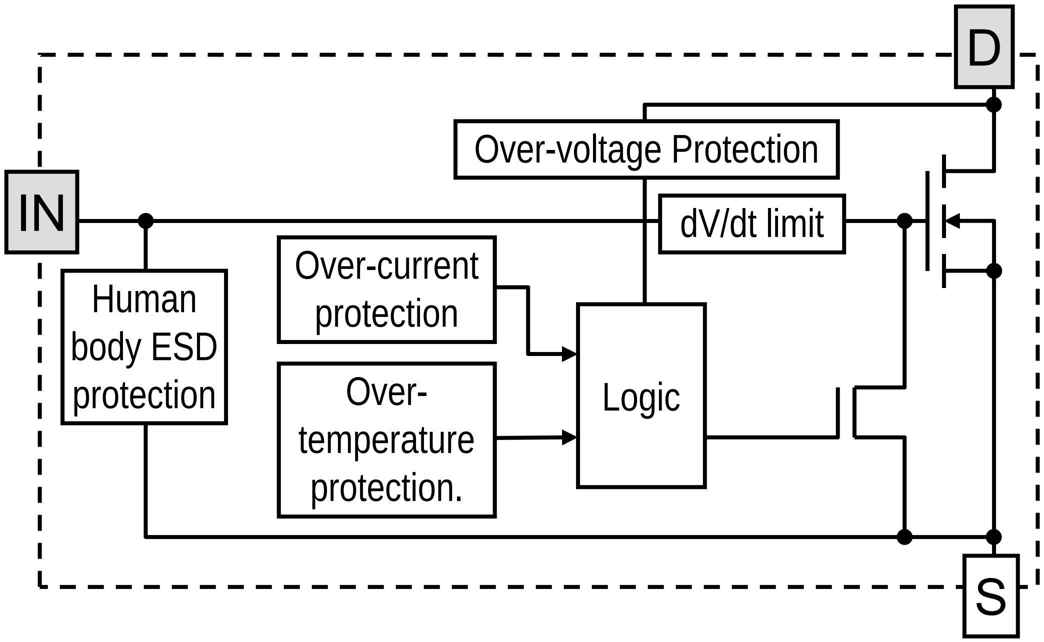
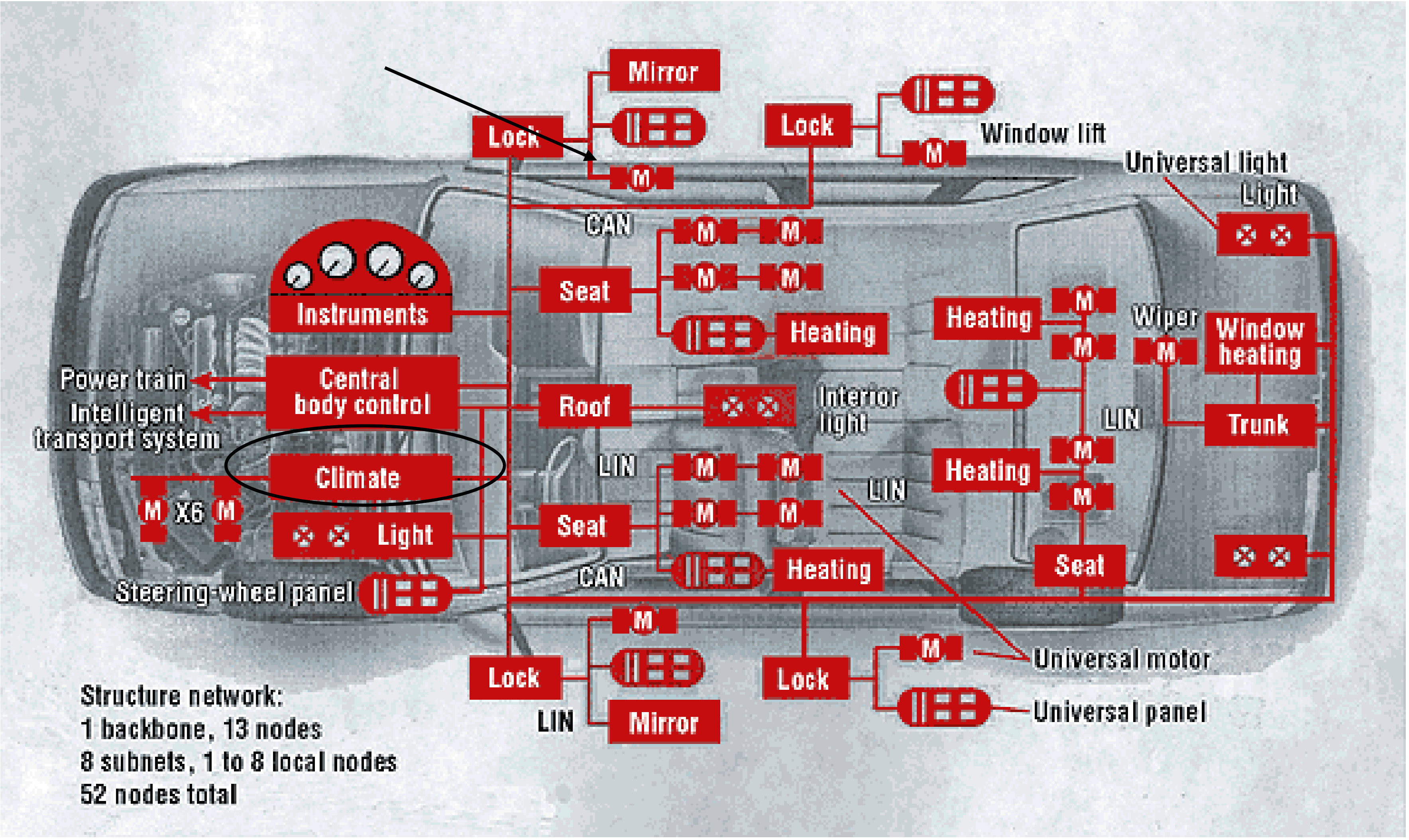


Figure 2 – typical self protected MOSFET block diagram

Use and Application of self-protected MOSFETs in Automotive



Use and Application of Self Protected MOSFETs in Industrial applications

Self protected MOSFETs are ideally suited to use in harsh industrial environments where there is a a need for immunity from radiated and conducted emissions. Self protected MOSFETs have proliferated into a number of non Automotive applications that include:

- Remote I/O controller outputs (Programmable Logic Controllers)
- Distributed I/O Modules
- Relay driving
- Lamp driving
- Proximity switches
- Alarm system
- GPS system
- Relay driving in HVAC applications

The theory and operation of self protected MOSFETs

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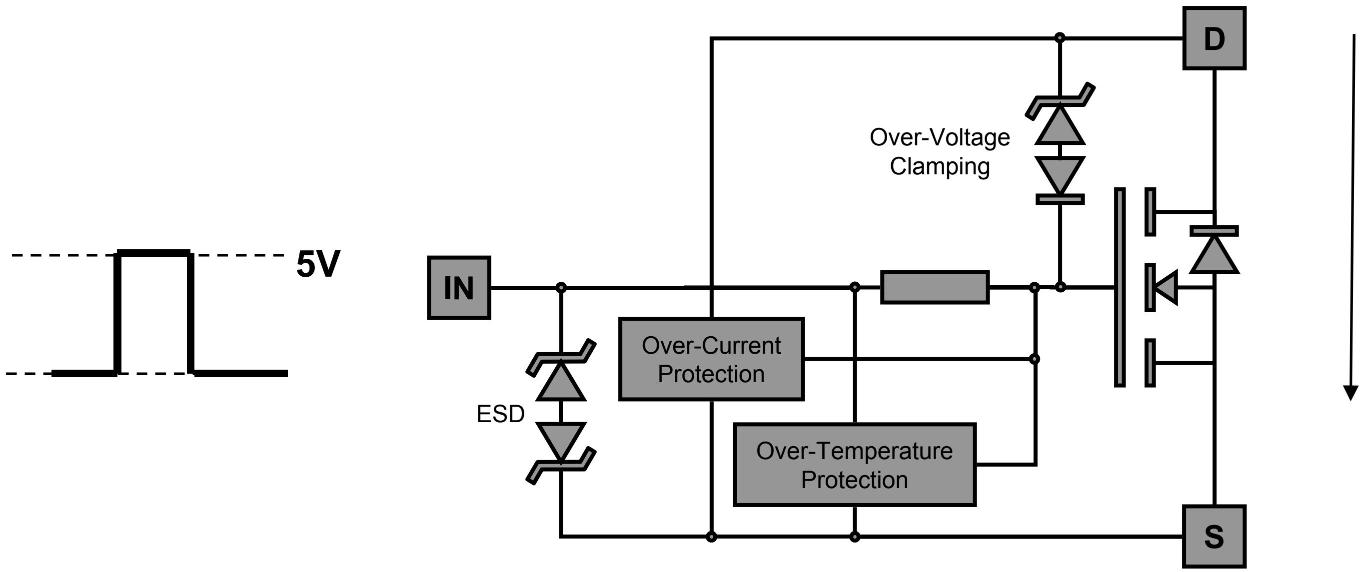
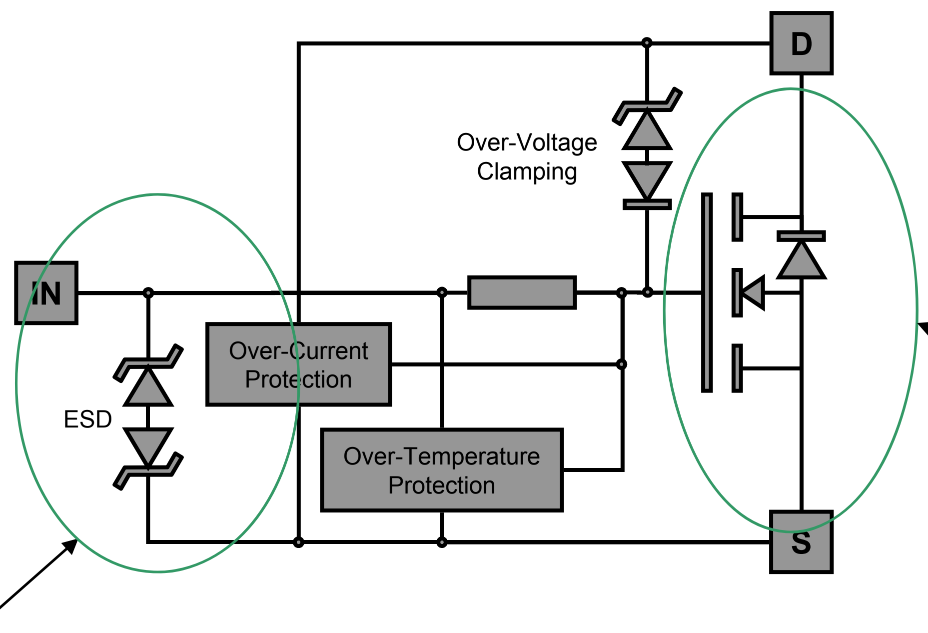
Self protected MOSFETs – normal operation



Self protected MOSFETs – ESD protection

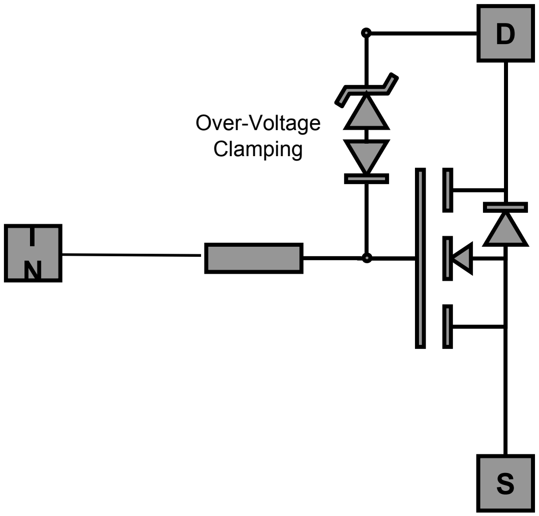


Body diode and miller capacitance protect the drain source

ESD diodes protect

the input to xx

Overvoltage protection – active clamping



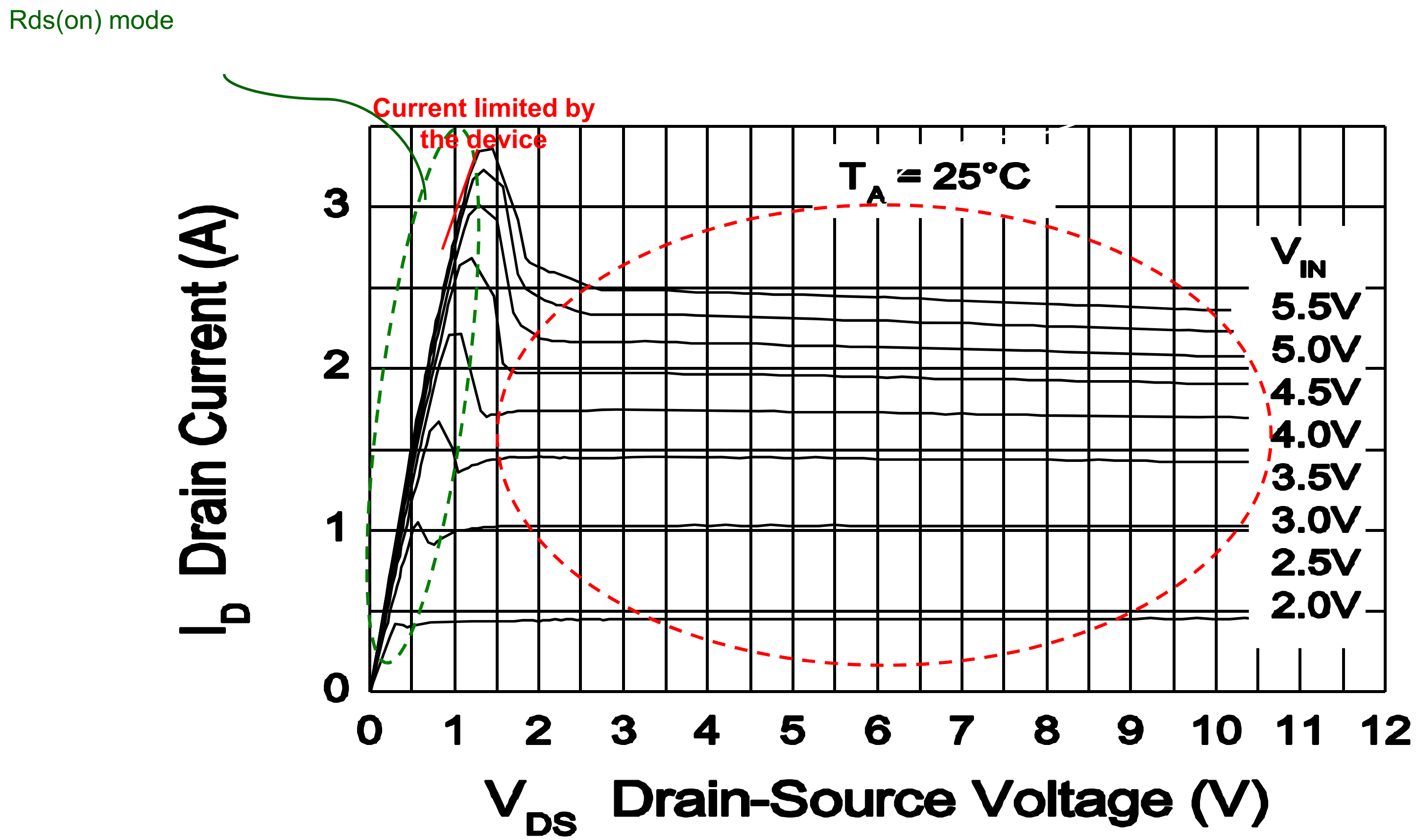
Internal active clamp circuit protects the MOSFET and load for voltages >65V (typ.)

Over current protection – current limiting with a negative temperature coefficient

The over-current protection operates by reducing the internal gate drive when the Drain-Source voltage is high enough that a large current would cause excessive dissipation.

In normal operation the full Input voltage is delivered to the internal gate as long as the Drain-Source voltage is small, typically less than 1.5V, and low dissipation is assured. However, if the load current rises sufficiently to generate a substantial Drain-Source voltage, then the device reacts by reducing the internal gate drive and restricting the Drain-Source current.

Over current protection – current limiting with a negative temperature coefficient



Typical Output Characteristic

Over-temperature protection – thermal shutdown with hysteresis

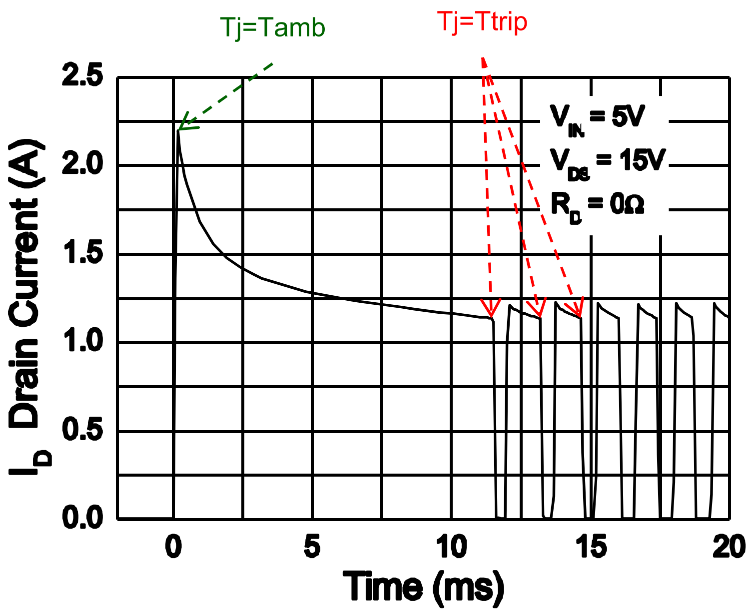
If the over-current conditions persist, then eventually the device temperature reaches a point where the device has to turned off to protect itself.

The over-temperature circuit comprises of a temperature sensor and hysteresis circuit. This over-temperature thermal shutdown circuit is active for Input voltages of 3V or more and constantly monitors the junction temperature. It does this completely independently of over-current, clamping etc. Once the temperature of the power device reaches the threshold temperature the thermal shutdown circuit turns the internal gate off and interrupts the dissipation. The hysteresis of this circuit ensures that the output of the device will turn back on again when the power device has cooled by around 10°C.

Over-temperature protection – thermal shutdown with hysteresis

This behaviour can be seen in the data sheet chart opposite. Note that during over-temperature hysteresis cycling, on the right of the chart, the over-current protection levels never return to the initial (25°C) values.

The auto-restart frequency will depend on the overload conditions (supply voltage, load resistance) and the thermal environment (PCB design etc).



Typical Short Circuit Protection

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Over-current and Over-temperature are independent but work together

The over-current and over-temperature protections are completely independent functions. In a cool ambient environment the over-current regulation may operate for substantial periods before temperatures approach the threshold of the over-temperature thermal shutdown circuit. The only requirement for over-current protection to occur is that the applied V_{DS} is sufficiently high enough (nominally 1.5V but this is dependent on input voltage and temperature).

In a hot enough ambient environment the over-temperature will turn-off the output even if there is little or no dissipation in the device. The only requirement for over-temperature shutdown is a high enough Input voltage (3 V or more).

Normally though, the two functions work together. The normal protection sequence is that an excessive load condition causes the over-current circuit to reduce the gate drive and self-regulate the current. Then, if the condition persists for long enough, the device temperature rises until over-temperature cycling begins. Over-temperature cycling will continue until the Input voltage or overload conditions are removed.

Self-protected MOSFET (IntelliFET)portfolio

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Part number	Features	TAB	BV_{DSS} V	I_D V_{IN}=5V A	P_D @25 C W	$R_{DS(ON)}$max @ V_{IN}=3V mΩ	V_{IN}=5V mΩ	V_{IN}=10V mΩ	$V_{DS(SC)}$ (1) V	E_{AS} (2) mJ	T_{JT} (3) °C	Package	Status
BSP75G	Improved power dissipation	D	60	1.4	2.5	-	675	550	36	550	150	SOT223	Released
BSP75N	BSP75N pin out	S	60	1.4	2.5	-	675	550	36	550	150	SOT223	Released
ZXMS6001G	500µA input current	S	60	1.1	2.5	-	675	550	36	550	150	SOT223	Released Jan 2008
ZXMS6002G	with status flag	D	60	1.4	2.5	-	675	550	36	550	150	SOT223	Released
ZXMS6003G	with status flag and programmable current limit	D	60	1.4	2.5	-	675	550	36	550	150	SOT223	Released

Features

- Thermal shutdown
- Short circuit protection
- Over voltage protection
- ESD Protection

Benefits

- Self protecting
- Protects both itself and the load from current surges
- Protects against overvoltlage breakdown
- No need for external ESD protection

1st Generation Low Side - IntelliFET Portfolio

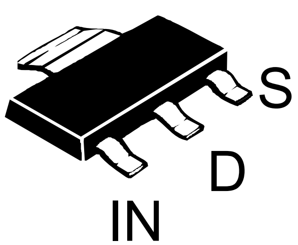
Features

- Over-voltage Protection
- Over-current Protection
- Over-temperature Protection
- Human Body ESD Protection

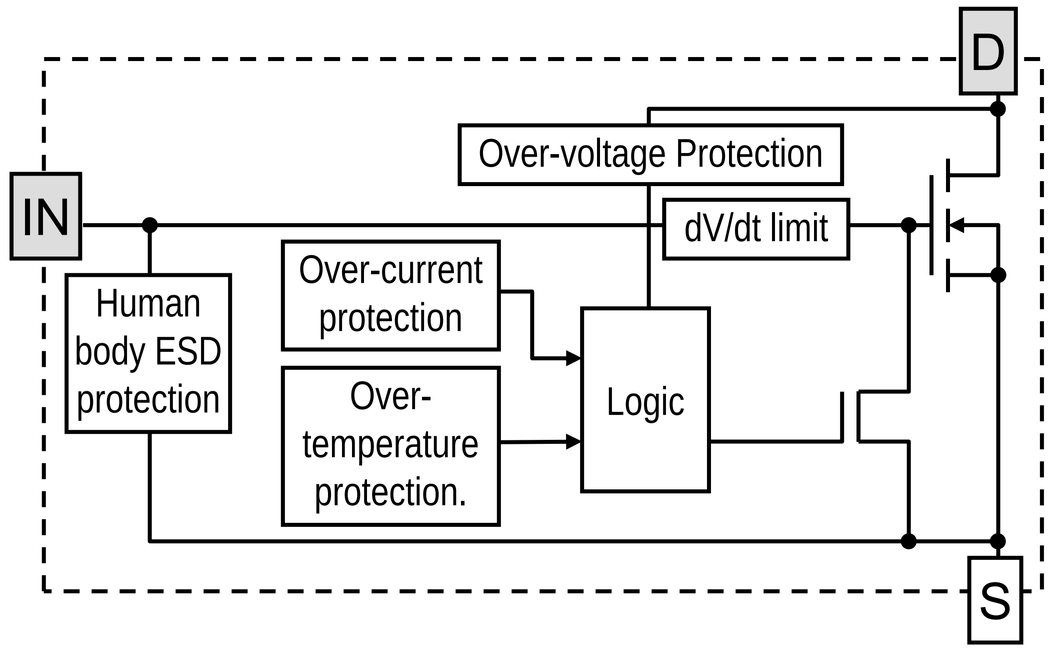
Matches most Infineon BSP75 specs

- **Better P_{DIS}**
- **Better I_{CONT}**
- Higher I_{IN}
- Different tab connection

Spec	Infineon BSP75N	BSP75G
$I_{IN(MAX)}$ (V_{IN}=5V)	200μA	1200μA
I_D	0.7	1.4A
P_{DIS}	1.8W	2.5W
$V_{IN\text{-}TH(TYP)}$	1.8	2.1



BSP75G



BSP75G 60V, 0.55Ω Self Protected NMOSFET

Features

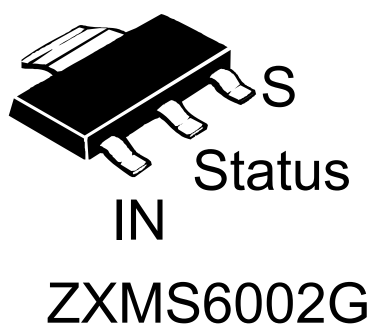
Status pin gives analog feedback to uC

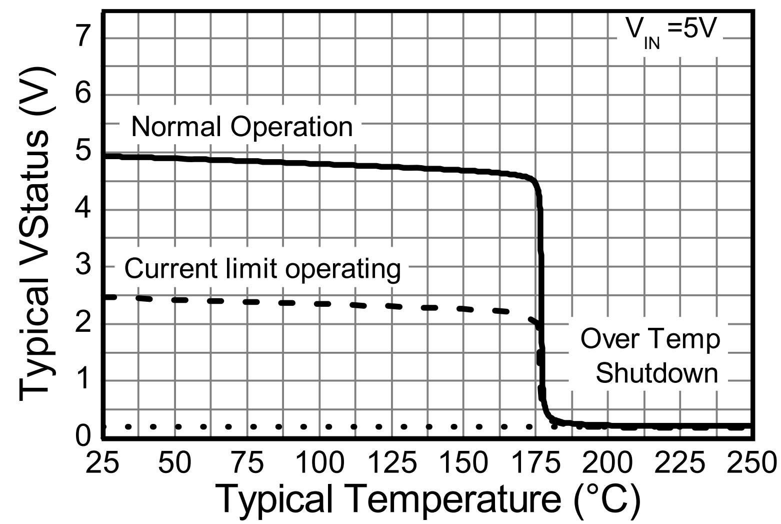
Status pin voltage changes with condition of MOSFET

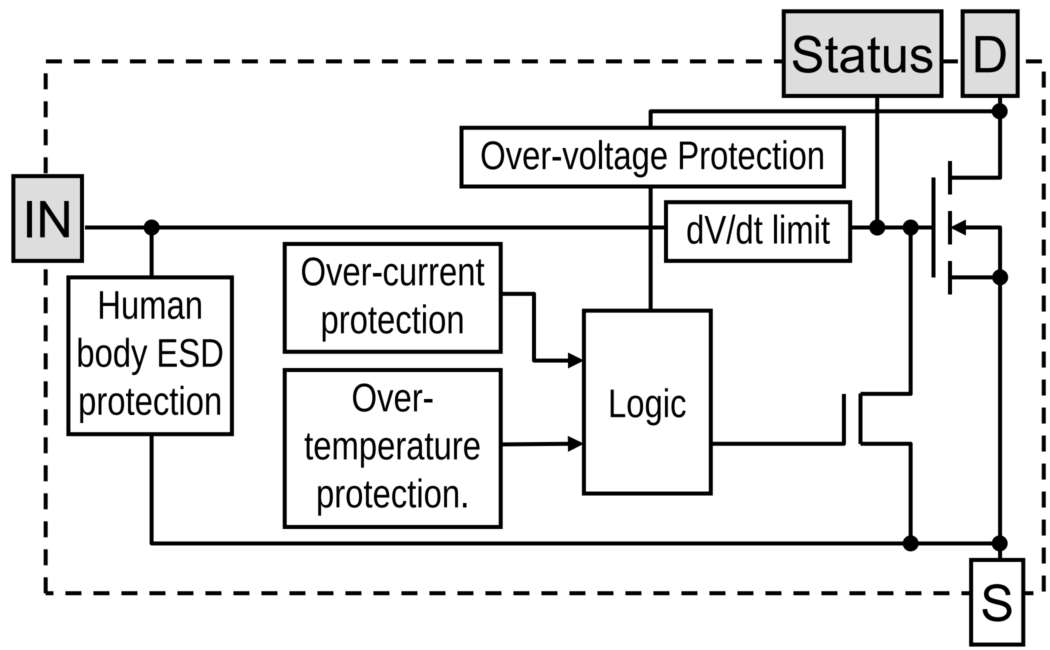
- Normal operation > 4V
- Current limit >2V
- Over temperature shutdown <1V

Status pin voltage varies with

- Input voltage
- Temperature







ZXMS6002G 60V, 0.5Ω Self Protected N Channel MOSFET with status flag

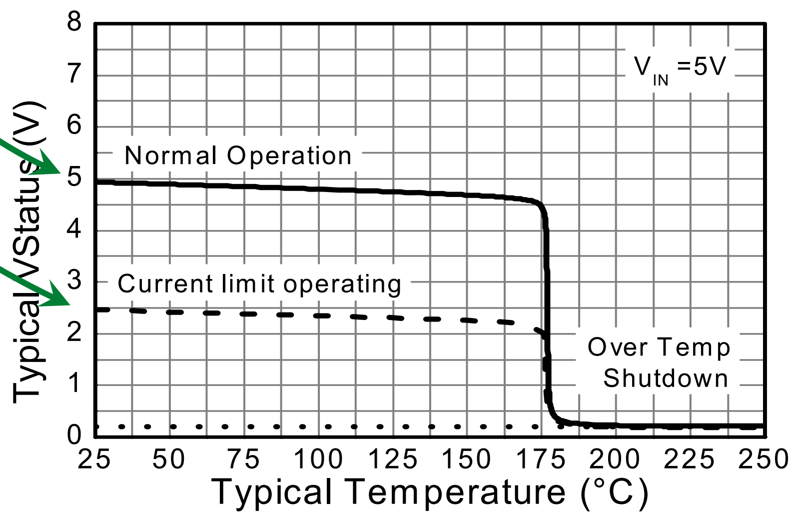
status pin gives analog output equal to internal gate drive

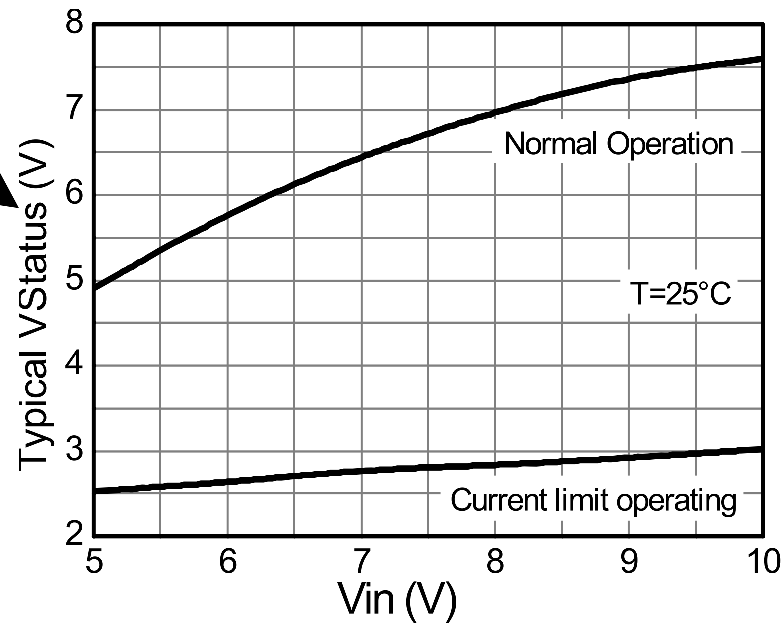
Status pin voltage changes with

- Operating condition of MOSFET
  - Normal operation > 4V
  - Current limit >2V
  - Over temperature shutdown <1V

Status pin voltage varies with

- Input voltage
- Temperature





VStatus vs Vin

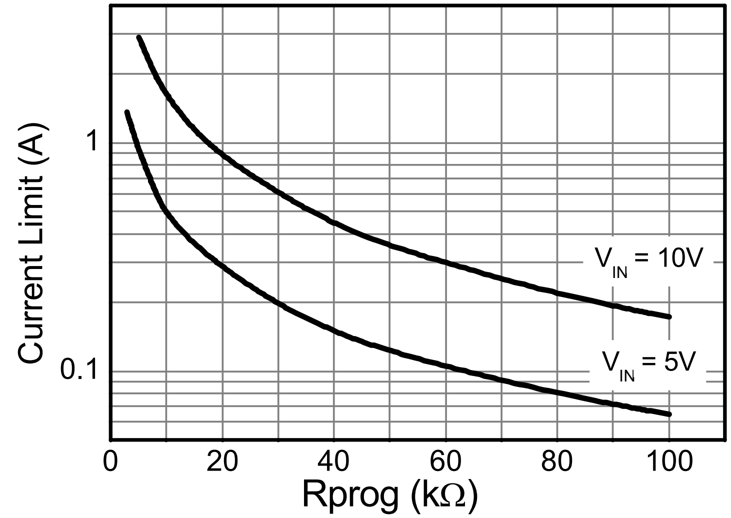
Features

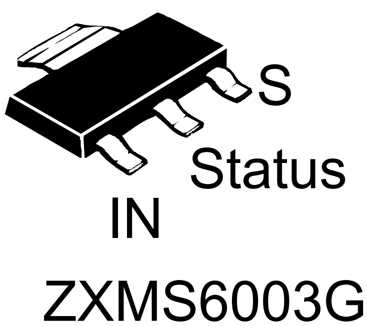
Status pin used for setting over-current limit

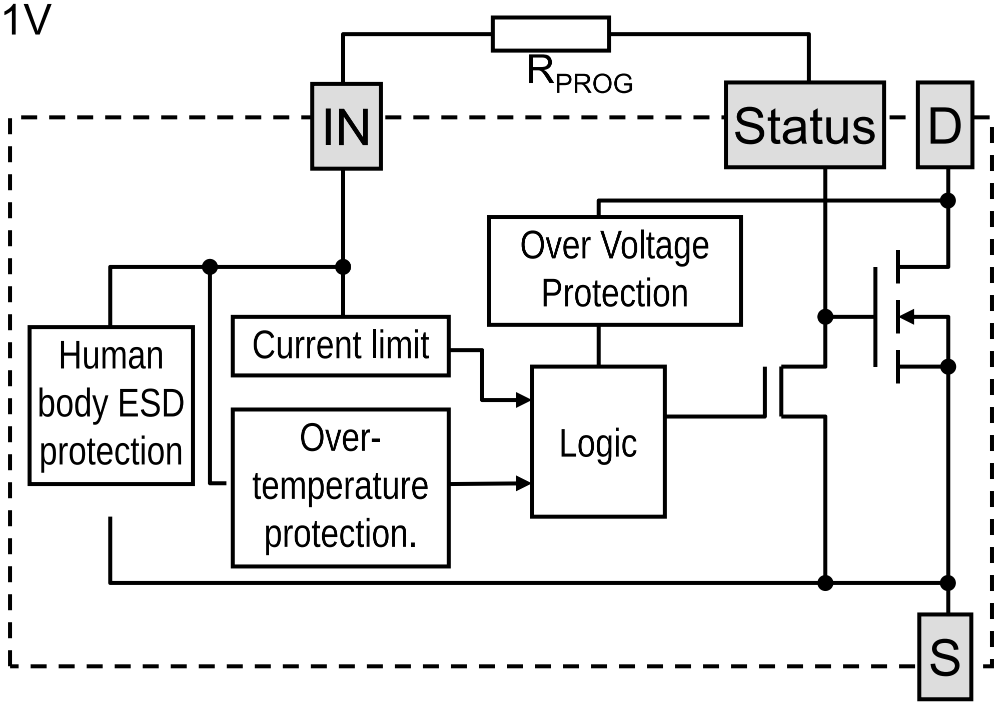
- Set by external resistor

Device status pin voltage changes with condition of MOSFET

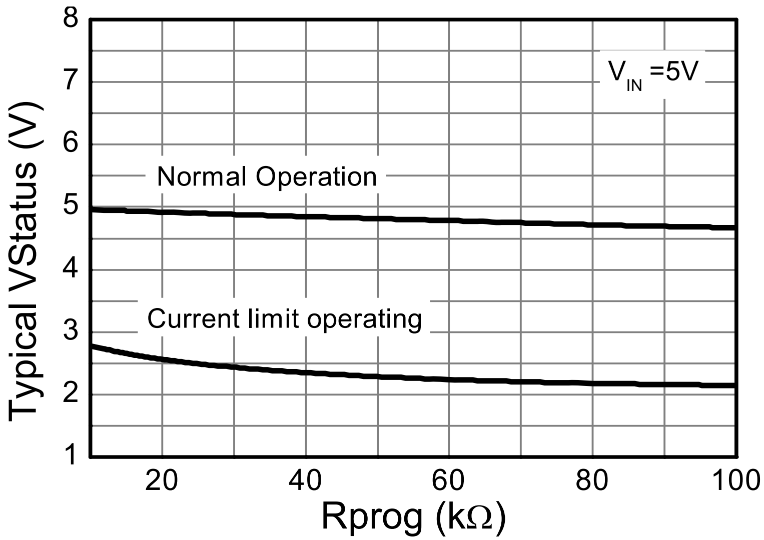
- Normal operation > 4V
- Current limit >2V
- Over temperature shutdown <1V



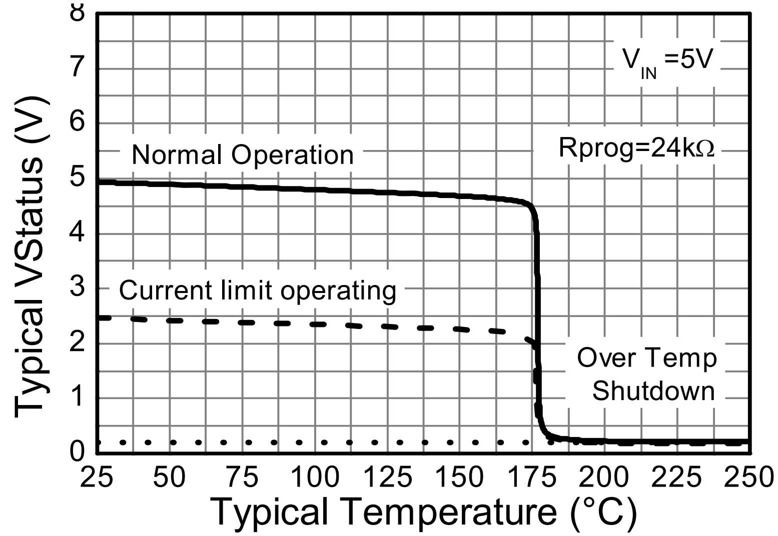




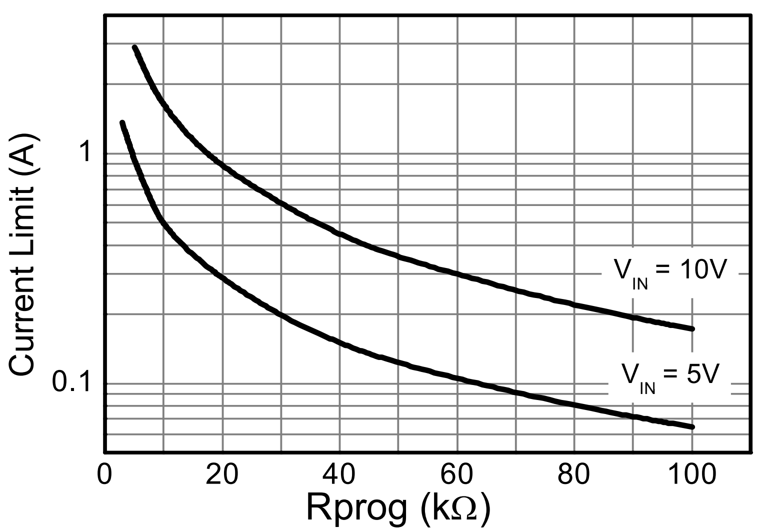
ZXMS6003G 60V, 0.5Ω Self Protected NMOSFET with external over-current programming



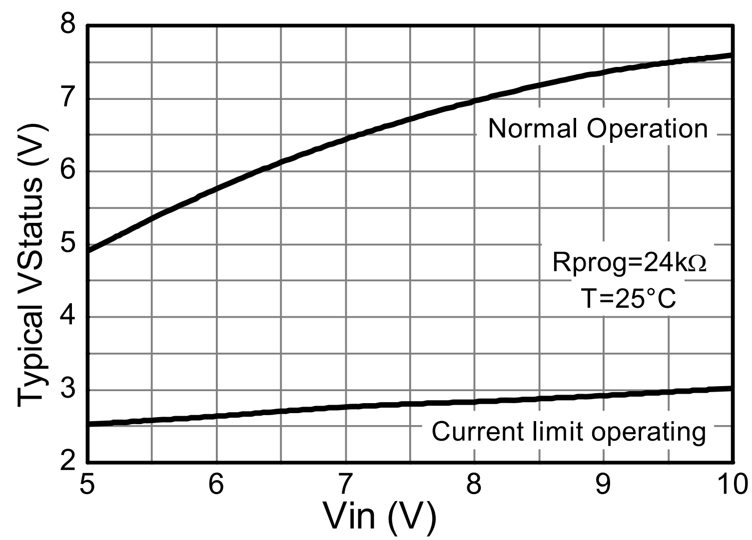
VStatus vs Rprog @ Vin=5V



V_{STATUS} vs T_J @ V_{IN} = 5V



Current Limit vs Rprog

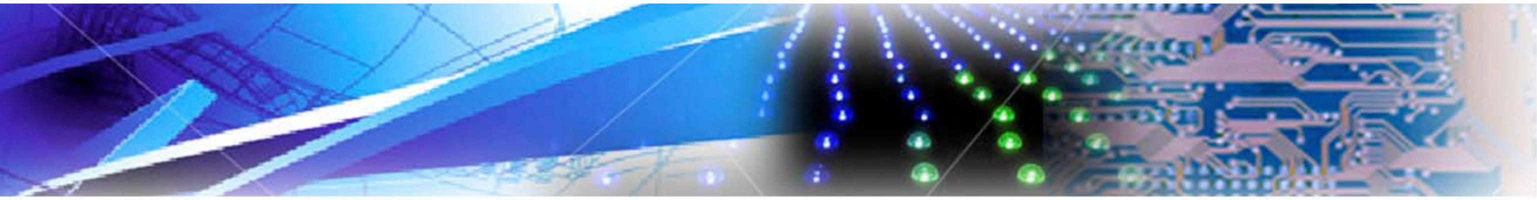


VStatus vs Vin

ZXMS6003G Status/Current Limit Characteristics

The SOT23 Flat package occupies 85% less board space than SOT223 solutions
Placement flexibility and potential cost saving from reduced PCB area
Incorporates over-voltage, over-current, over-temperature and ESD protection
Provides the same functionality as larger SOT223 solutions
Thermally efficient small form factor SOT23F (Flat) package
Provides a power density three times that of SOT223 solutions
3.3V to 5V input range
Can interface directly with microcontroller outputs
Fully meets the stringent requirement of AECQ101
Ideally suited to operation in harsh environments

Industry’s smallest self-protected MOSFET – ZXMS6004FFTA



First releases off 2^{nd} Generation Platform

Part number	Features	TAB	BV_{DSS}	I_D	P_D	$R_{DS(ON)}$max @			$V_{DS(SC)}$[1]	E_{AS}[2]	T_{JT}[3]	Package	Status
				V_{IN}=5V	@25 C	V_{IN}=3V	V_{IN}=5V	V_{IN}=10V					
			V	A	W	mΩ	mΩ	mΩ	V	mJ	°C		
ZXMS6004FF	High power SOT23	-	60	1.3	0.9	600	500	-	36	550	150	SOT23F	Released
ZXMS6004DG	Tab connected to source	S	60	1.3	1.3	600	500	-	36	490	150	SOT223	Released
ZXMS6004SG	Tab connected to drain	D	60	1.3	1.3	600	500	0	36	490	150	SOT223	Released

Part Number	Status	Configuration	TAB	BV_{DSS} (V)	ID(A) VIN =	PD (W)	RDS (on) Max(Ω) @VIN =			VDS(S/C)	EAS (mJ)	T_j (°C)	Package Outlines
							3V	5V	10V	VIN = 5V			
ZXMS6004DT8	Full Production	Dual		60	1.2	2.3	0.6	0.5	-	36	210	150	SM8
ZXMS6005DG	Full Production	Single	Drain	60	2	1.6	0.25	0.2	-	36	490	150	SOT223
ZXMS6005SG	Full Production	Single	Source	60	2	1.6	0.25	0.2	-	36	490	150	SOT223
ZXMS6005DT8	Full Production	Single		60	1.8	1.6	0.25	0.2	-	36	210	150	SM8

Support Materials

- New Product Announcement
- Know How Guide

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