HL Application Note

Temperature sense concept – Speed Tempfet®

Principle of the temperature sense concept of the Speed-TEMPFET family

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Introduction

The well-known classic TEMPFET products from Siemens are a cost-effective solution for a protected MOSFET and meet with a good response in the marketplace. Overtemperature, overload and even short-circuit protection can be realized using only one external gate resistor.
The need for this gate resistor leads to relatively high switching times, thus limiting the usage of classic TEMPFETs in PWM applications.

The new Speed TEMPFET family was designed to provide a low-cost protected MOSFET solution for applications with a requirement for fast switching times.

This application note describes the principle underlying the protection system for the classic TEMPFET and the new Speed-TEMPFET family.

1 Classic TEMPFET architecture

The classic TEMPFET is a Chip on Chip device. Using Chip on Chip technology, Siemens is able to combine different semiconductor technologies by gluing a top chip onto a base chip.
In the case of the TEMPFET family, the base chip is a standard MOSFET. A temperature sensor is mounted on top of the base chip. This temperature sensor can be described as a special thyristor, designed to sense the temperature of the base chip.
This special thyristor switches on if its temperature exceeds its thermal trip temperature of 160˚C. To reset the thyristor, the current through the device has to fall below a minimum holding current. As long as this current is higher than a maximum holding current, the thyristor remains in the on state.

This thyristor characteristic is used in the TEMPFET to implement a latching temperature protection.

In the classic TEMPFET, the anode of the thyristor is internally connected to the gate of the MOSFET, and the cathode to its source.
Figure 1 shows a typical circuit with a classic TEMPFET.

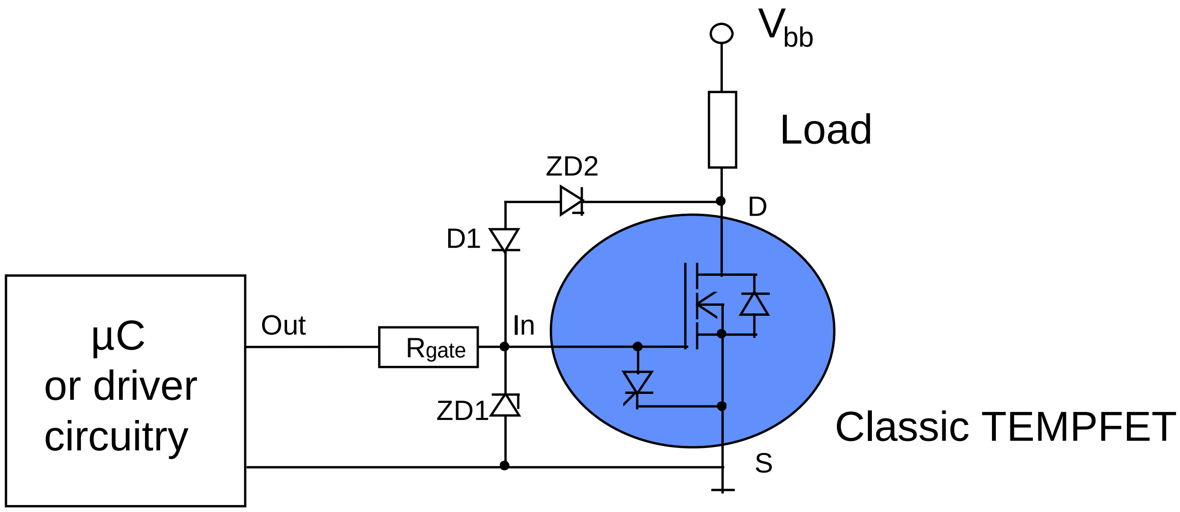

Figure 1: Typical classic TEMPFET circuit

As long as the temperature of the top chip (thyristor) stays below the minimum thermal trip temperature, the connection between gate and source is blocked and the TEMPFET works like a standard MOSFET.
When the thyristor switches on because its temperature exceeds the trip temperature, the thyristor connects the gate and the source and tries to reduce the gate-source voltage. In this case a current flows from the driver circuitry across the gate resistor into the input pin of the TEMPFET and across the thyristor to the source pin. To limit this current and to create a voltage drop at the input pin, a gate resistor is needed.

1.1 **Dimensioning the gate resistor** (Example for logic level TEMPFET)

For the dimensioning of the gate resistor, the following rules have to be taken into account:

- To protect the temperature sensor (=thyristor) against overload, the current through the sensor has to be limited to the specified max. forward current
- To guarantee that the temperature sensor stays latched, the current through the sensor has to be above the maximum holding current
- For the dimensioning of the gate resistor, the maximum forward voltage of the sensor has to be taken into account

Dimensioning example:

Max. forward voltage	1.4V
Min. forward voltage	0.5V (Thyristor in on mode)
Max. forward current	5mA
Max. holding current	0.5mA

Max. $V_{Out\text{-}Source}$ 5.5V
Min. $V_{Out\text{-}Source}$ 4.5V

Max. R_{Gate} :

$$R_{Gate} \leq \frac{4.5V - 1.4V}{0.5mA} = 6.2k\Omega$$

Min. R_{Gate} :

$$R_{Gate} \geq \frac{5.5V - 0.5V}{5mA} = 1.0k\Omega$$

Of course, the size of this resistor influences the switching time of the TEMPFET. Therefore the minimum R_{Gate} means a minimum switching time and restricts the usability of the classic TEMPFET to slow switching applications.

2 Speed TEMPFET architecture

The limitation of the classic TEMPFET architecture to slow switching applications caused Siemens to develop the new Speed TEMPFET family shown in Figure 2.

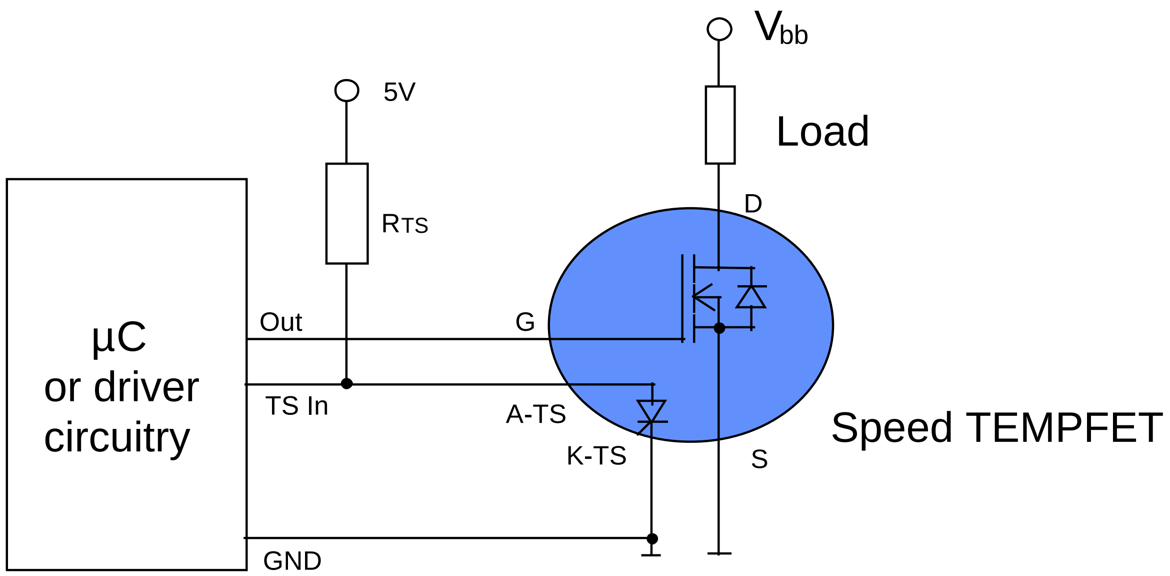

Figure 2: Typical Speed TEMPFET circuit

The difference compared to the classic TEMPFET is that the temperature sensor is not internally connected to the gate and source of the MOSFET, but is available as external pins A-TS and K-TS.

This concept allows the gate of the MOSFET to be driven with or without low ohmic gate resistors, resulting in very fast switching capability.
In consequence, the temperature signal has to be read out externally and the reaction to that signal also has to be defined externally. System control is usually implemented using a microcontroller, but a driver IC or discrete circuitry can also be used.

The new Speed-TEMPFET family can of course also be used as classic TEMPFETs simply by connecting the A-TS pin to the gate and the K-TS pin to the source.

ESD protection and active Zener clamping can be realized in similar fashion to the classic TEMPFET. The improved avalanche rating of the Speed TEMPFETs allows their use in repetitive avalanche mode, too.

2.1 Reading the temperature signal

The temperature sensor is the same as in the classic TEMPFET. If the anode of the sensor is connected to 5V with a resistor R_{TS}, the signal at the temperature sense input TS In of the µC will be 5V (= high) as long as the thyristor is in the off state.
When the temperature exceeds the thermal trip temperature, the thyristor switches on and the current is limited by R_{TS}. The voltage at TS In of the µC goes down below the maximum forward voltage of the sensor and creates a low signal in the µC. The forward voltage level is dependent on the forward current and the temperature of the sensor.
At temperatures above 150˚C and 1.5mA forward current, the forward voltage is below 0.9V. At 5mA forward current and over the whole temperature range the forward voltage is below 1.4V.
The designer of the system can now decide whether the TEMPFET switches off or goes into a working mode which reduces the thermal load on the TEMPFET.

2.2 Resetting the temperature signal

To reset the temperature sensor, the current through the sensor has to be reduced to below the minimum holding current.
This can be realized by means of an extra reset output and a small MOSFET inserted in the path K-TS and GND to switch off the current.
A more cost-efficient solution would be to switch the µC input from input mode to output mode and use the push-pull stage of this output to reset the temperature signal.
In this case the current across the R_{TS} resistor flows mainly over the pull transistor T_L of the µC. If the voltage at A-TS falls below 0.5V, the temperature sensor will reset.

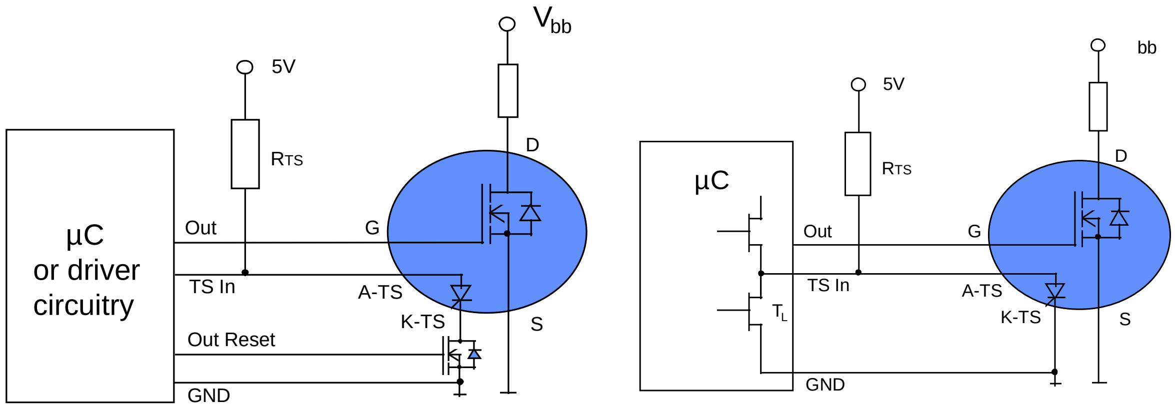

Figure 3: Two ways to reset the temperature sensor

2.3 Dimensioning tips

In principle the same rules have to be considered for the dimensioning of the gate resistor as for the classic TEMPFETs:

- To protect the temperature sensor (=thyristor) against overload, the current through the sensor has to be limited to the specified forward current
- To guarantee that the temperature sensor stays latched, the current through the sensor has to be above the maximum holding current
- For the dimensioning of the gate resistor, the maximum forward voltage of the sensor has to be taken into account

To avoid the need for extra components to reset the temperature sensor, the following aspect also has to be considered:

- To reset the temperature sensor with the aid of the µC without an extra transistor, the current across the R_{TS} has to be sufficiently low so that the µC output can handle it. As mentioned above, the voltage across the thyristor has to fall below 0.5V to reset the device.

Dimensioning example:

Max. forward voltage	1.4V
Min. forward voltage	0.5V (Thyristor in on mode)
Max. forward current	5mA
Max. holding current	0.5mA
Max. V_{5V}	5.5V
Min. V_{5V}	4.5V
Output specification of µC: (e.g. Siemens C504)	0.45V @ 1.6mA

The aim of this dimensioning example is to minimize the current across the µC and at the same time guarantee the minimum holding current for the thyristor.

Max. R_{Gate} :

$$R_{TS} \leq \frac{4.5V - 1.4V}{0.5mA} = 6.2k\Omega$$

➪ Use a 5.6kΩ resistor with a tolerance of +/- 10%.

Min. R_{TS} :

$$R_{TS} \geq 5.6k\Omega \times 0.9 = 5.0k\Omega$$

Max. I_{RTS} :

$$I_{RTS} \geq \frac{5.5V}{5k\Omega} = 1.1mA$$

This maximum current, together with the output specification of the µC, guarantees that the µC is able to pull the A-TS voltage clearly below 0.45V.
This means that the µC is able to reset the sensor without extra components such as an additional MOSFET.

2.4 Test circuitry proposals

To test the Speed TEMPFET without a µC, a discrete solution is usually dependent on the application and the test objective.

Nevertheless, a possible test circuit is shown here.

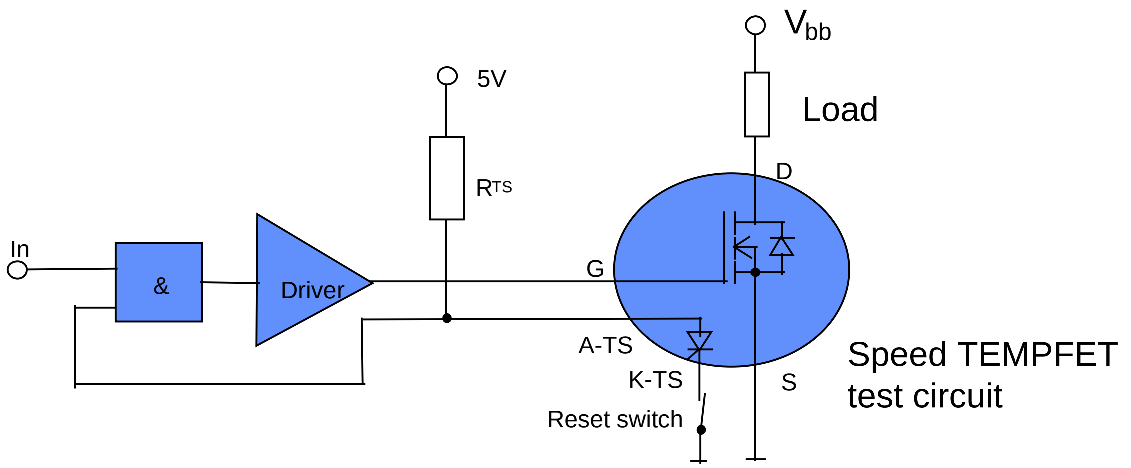

Figure 4: A possible test circuit

Under normal conditions the reset switch is on. When the overtemperature signal occurs, the driver stage will be switched off as long as the reset switch is not opened.

3 Summary

The new Speed-TEMPFET family combines the possibility of driving fast PWM applications with temperature protection.
The ease with which it is possible to read the precise over temperature signal and to reset the device makes the Speed-Tempfet a perfect device for these applications.

Remark:

This information describes the type of component and shall not be considered as assured charcteristics