HL Application Note

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Intelligent power semiconductors for valve actuation in automobiles (ABS, engine, gearbox)

In automotive applications, magnetic valves are often used as the actuators in complex control loops and, because these applications are safety-related, they are controlled by power semiconductors with integral protection and diagnostic functions. A typical example of this is the hydraulic valves in anti-lock braking systems (ABS). The TLE Smart Power Switch family has been specially developed for such applications, and is described here with respect an ABS application. Further areas in which they can be used are in engine and gearbox controllers.

For a long time now, automobile manufacturers have been striving to increase the active safety aspects of vehicles. The introduction of ABS was a huge step in this direction. It is nowadays standard equipment in many vehicles, including the compacts. Slip-control systems are a further development, where ABS is enhanced by various additional elements.

By taking into account loss of grip in the vehicle's lengthwise direction, anti-slip control (ASC) helps to increase traction and ensure vehicle stability (steering accuracy). The best-developed system for increasing drive stability is the forward dynamics regulator **(Fig. 1).** By taking into account lateral dynamic factors (yawing moment) and by also noting the driver's intentions (steering angle sensor), it is possible to

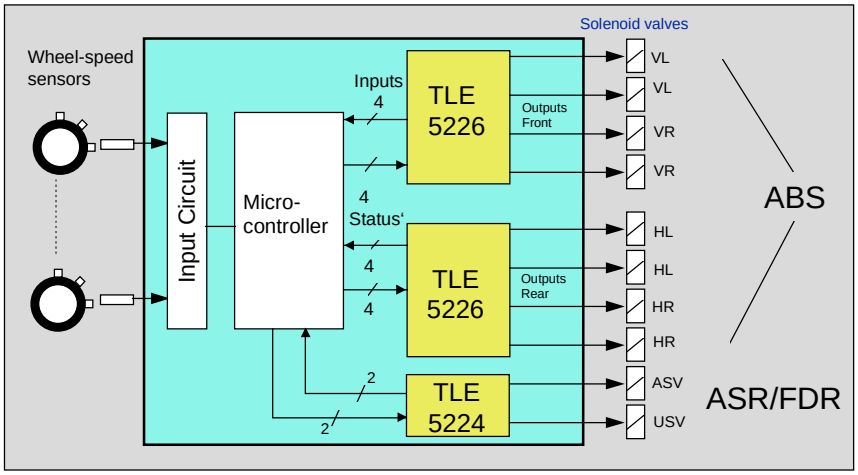


Fig. 1 Block diagram of an ABS/ASC control device

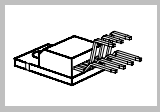
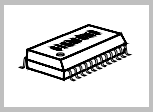
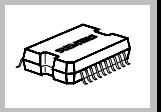
Features	TLE 4224-2	TLE 5224 G2	TLE 5226 G
Channels	1	2	4
R_{ON} (typical at 25°C)	0.25 Ω	2 x 0.25 Ω	2 x 0.25 Ω 2 x 0.35 Ω
I_{max}	4 A	2 x 4 A	2 x 5 A 2 x 3 A
V_S	6.5 - 45 V	4.8 - 45 V	4.8 - 32 V
Reversal supply protection	●	–	–
Load: inductive/lamp	● / –	● / –	● / –
Open load current detection	●	●	●
Open load voltage detection	●	●	●
Open load compare voltage	●	●	●
Overload current flip flop	●	●	●
Overtemperature switch off	●	–	●
Overtemperature monitoring	–	●	–
Parallel input / status	●	●	●
Z-clamping 50 V internal	●	●	●
Package	P-TO220-7-1 	P-DSO 24 	P-DSO 20-10 
Technology	SPT 75	SPT 75	SPT 75

Table 1 Features of the 1, 2 and 4 channel switch

exercise better control of fear and panic reactions, and also to drastically reduce the risk of skids.

This is achieved by specific regulation of the brake pressure for each wheel independently, supplemented by overrides on the throttle valve setting and ignition system.
Modulation of the hydraulic pressure is effected by one inlet and one relief valve (2/2 magnetic valves) per wheel.
Intelligent power semiconductors are used to actuate these valves. In order for them to meet to the stringent automobile safety requirements in this particular area, these switches must provide extensive protective and diagnostic functions. The TLE Low-Side Switch family was developed specially for these requirements, and consists of a one-channel, two-channel and four-channel type **(Table 1)**.

These switches have been developed using modern Smart Power Technology (SPT), which allows precise analog functions to be realized in bipolar technology, logic functions in CMOS technology and power functions in low-loss DMOS technology.
This combined technology enables building various switching and protective functions on the same chip as indicated in Fig. 2. In order to protect the load circuit against various malfunctions, the current and voltage of each output is monitored both when switched on and when switched off.

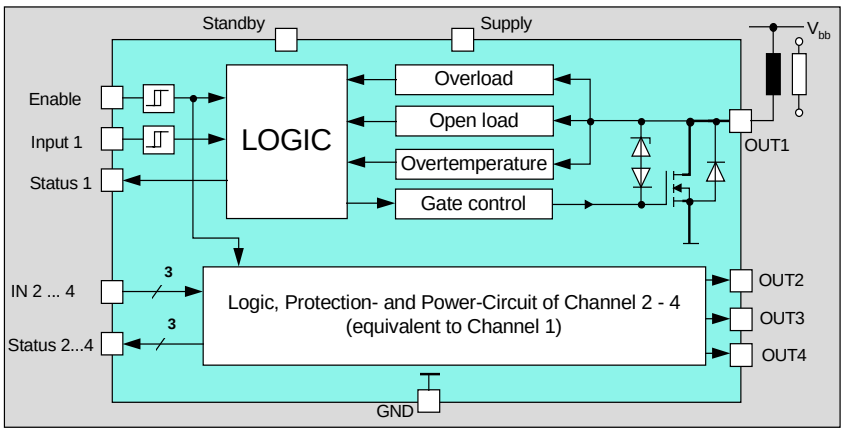


Fig. 2 Block diagram of the TLE 5226 G

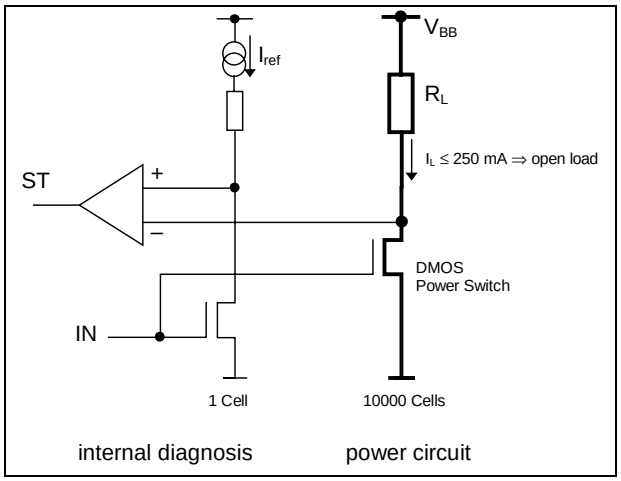


Fig. 3 On mode open-load identification

Diagnosis in the on state

In the switched-on state, the load current is measured and compared with an internal reference current. The minimum load current is (typically) 250 mA. If the actual value falls below this, then "open load" is reported at the corresponding status output **(Fig. 3)**.

In the switched-on state, the output voltage is monitored on the load circuit for overload and short-circuit by comparison against the battery voltage. If a specific limiting value is exceeded, the corresponding status message will be generated.

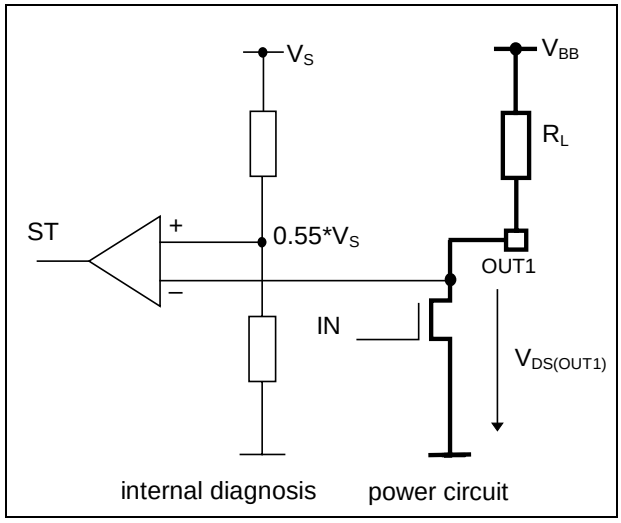


Fig. 4 Off mode open load identification

Diagnosis in the off state

In the switched-off state, each output is compared with a fraction of the supply voltage V_S. Load drop-out (or short-circuit to ground) is identified if the output voltage V_{DS} drops below 55% of the supply voltage **(Fig. 4)**.

In addition, the TLE power switch includes an even more sensitive, precisely specified, load drop-out identification mechanism. It compares two output voltages V_{DS} with each other (for a one-channel switch the test is against an adjustable comparison voltage V_C). If a fixed offset of ΔV = 1.25 V (typical) is exceeded, then "open load" is reported **(Fig. 5)**.

This makes the detection of an external interference suppression capacitor connected in parallel with the load (or at the output without a load) just as reliable as detection of the load going „high resistance“.

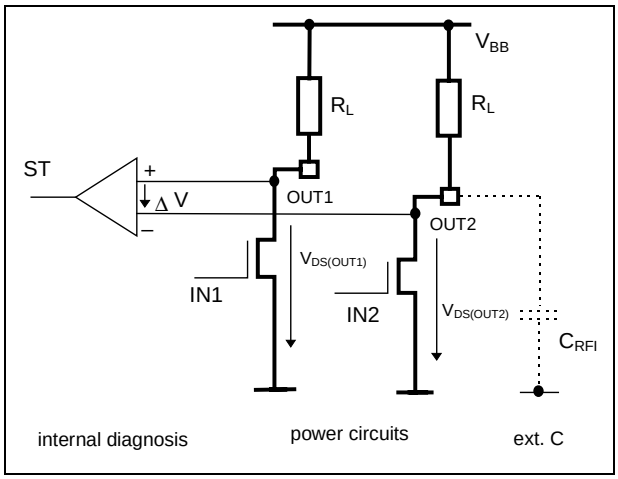


Fig. 5 Compare voltage for open load identification

Overtemperature protection

For protection against an overload or too high an ambient temperature, the chip is equipped with a temperature sensor which switches off the affected channel concerned and stores the fault in a flip-flop, which can only be reset by switching the channel off. This inhibits operation of the module at temperatures which could be detrimental to its reliability.

Application circuit

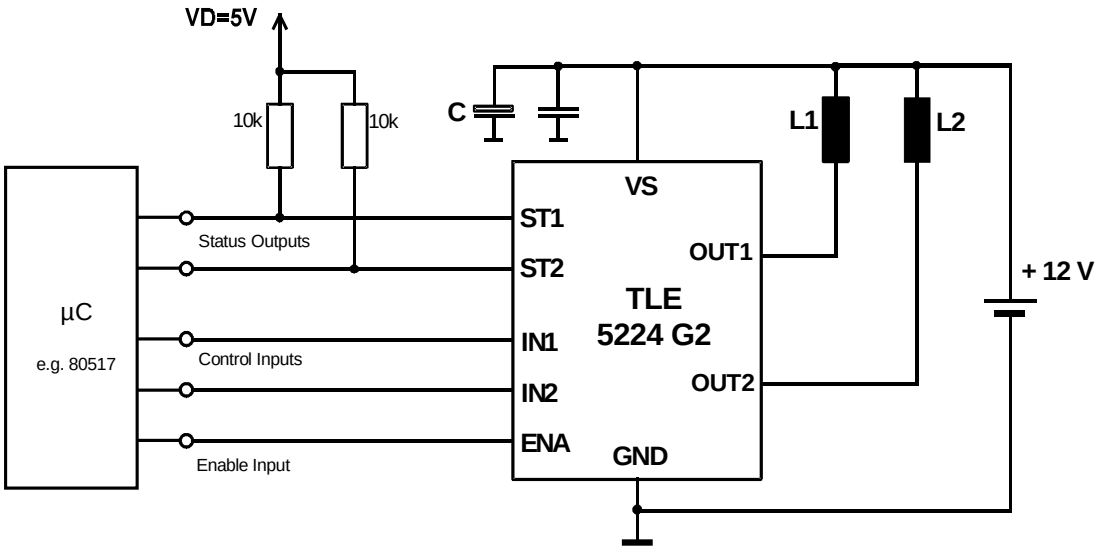


Fig. 6 Control and diagnosis by microcontroller

The TLE power switch provides TTL-compatible inputs, which enable direct control to be exercised by a microcontroller **(Fig. 6)**. All the inputs have pull-down resistors, which effect a defined switch-off for the input circuit if no control signal is applied or if there is a malfunction.
All faults which are detected are reported via status outputs to the microcontroller, which uses a warning light to inform the driver, and stores the fault in an EPROM. This enables the fault to be identified and located during workshop diagnosis, and to be eliminated.

The use of a Zener clamp (typically 55 V), enables inductances to be rapidly demagnetized, so that highly accurate dynamic control of the hydraulic pressure is possible.

Thermal behavior

The use of power packaging ensures good heat dissipation. For switched-mode applications, (e.g. current control for a coil), the use of an external heat sink enables a significant temperature reduction to be achieved. With SO packaging this is even more clearly evident, because of the greater thermal resistance. **Fig. 7** shows the depletion layer tem-

perature of a TLE 5226 G when operated with 4 ABS valves at a clock frequency of 50 Hz, and at different duty cycles, for both active zenering and external freewheeling.

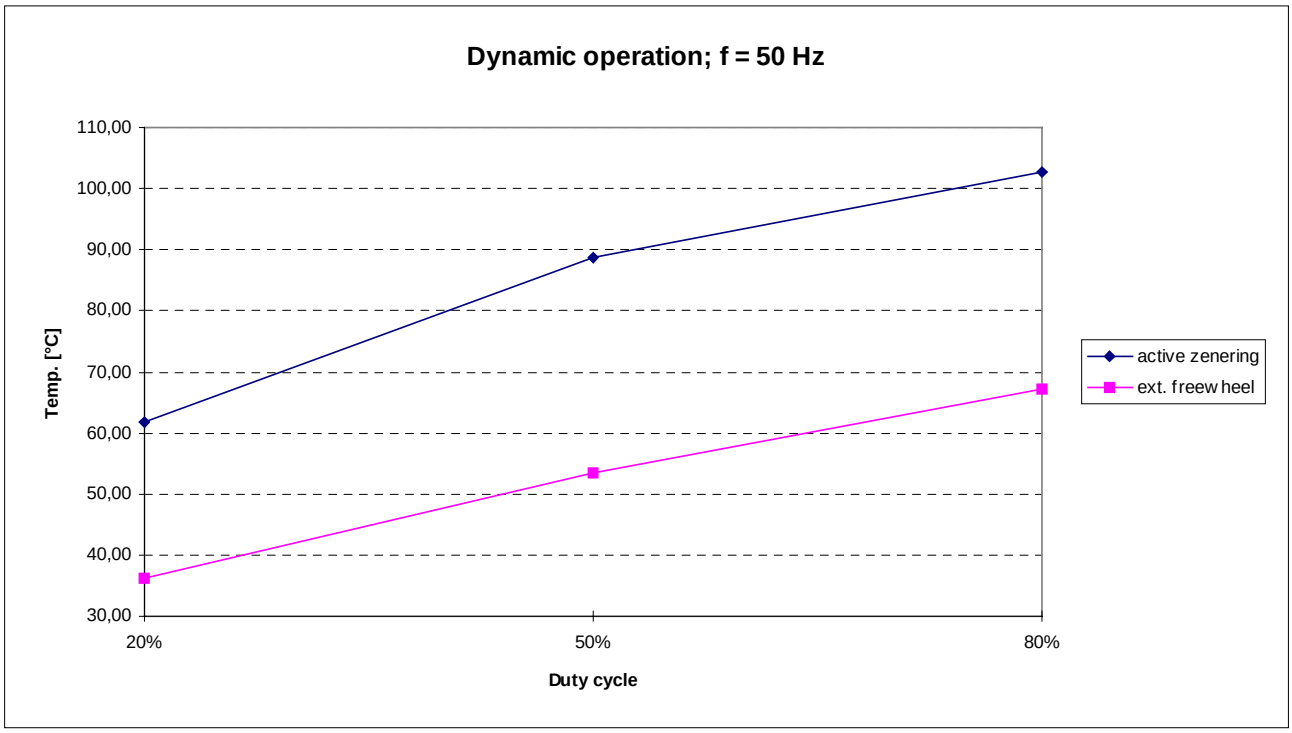


Fig. 7 Depletion layer temperature of a TLE 5226 G as a function of the duty cycle, for active zenering and for external freewheeling (ambient temperature T_A = 25 °C)

These comprehensive protection and diagnostic functions predestine the TLE power switches for use in the harsh automotive environment. Apart from ABS, other safety-related applications are also possible in this field:

- gearbox control,
- engine management,
- air conditioning/heating.

Outlook

Further well-planned technological development will enable the performance of the device system to be raised while reducing power losses. Thus, the next generation of SPT technology (ready for use in 1997) will bring a virtual doubling of the analog and digital cell densities, with a reduction of approximately 20% in the switch-on resistance. In the ABS area, for example, this will permit signal conditioning, the voltage supply and the power elements to be integrated onto one chip, thus further improving the safety of the system.