AN453
Application note

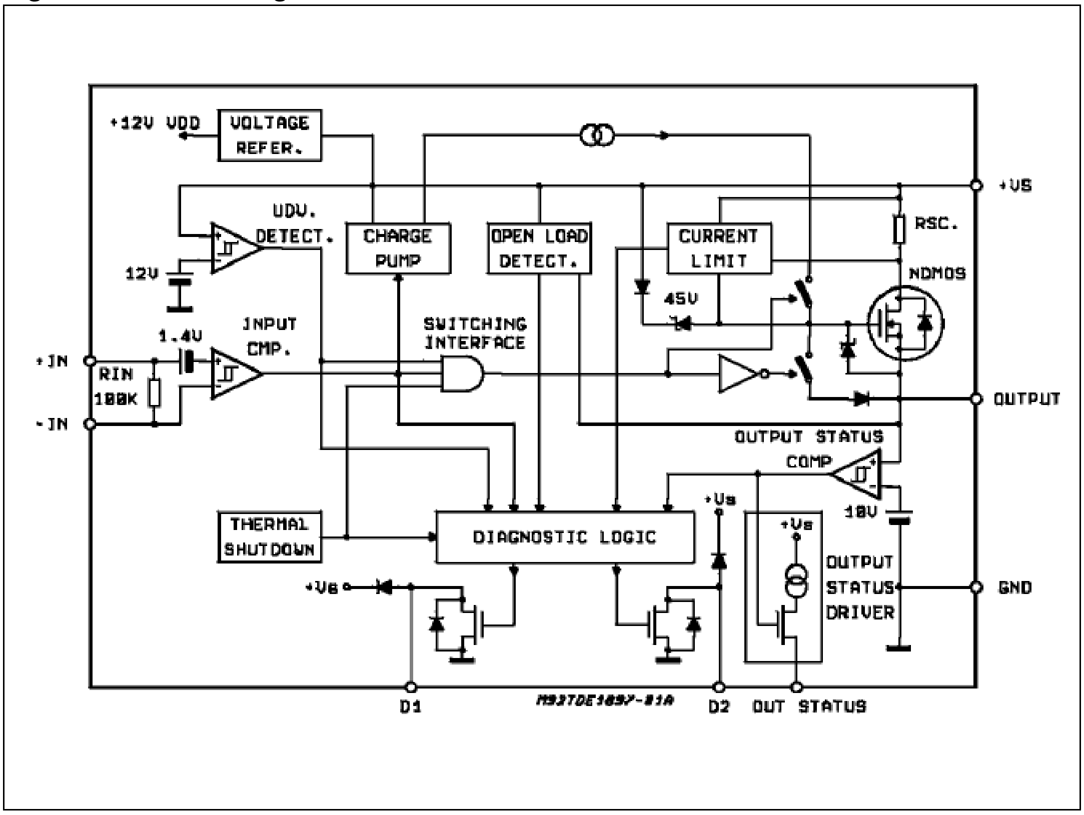
TDE1897C, TDE1897R, TDE1898C and TDE1898R in extreme overload conditions

Introduction

The purpose of this document is to provide the circuit designer with some insight into how the TDE1897C, TDE1897R, TDE1898C and TDE1898R devices behave in extreme overload conditions. Although the conditions may range outside the limits of the guaranteed performances described in the device datasheet, erroneous connections during the installation phase may occur and momentarily create such conditions. The performed tests confirm the extreme ruggedness of this device and its ability to overcome the accidental overload.

The TDE1897C, TDE1897R, TDE1898C and TDE1898R are monolithic intelligent power switch (IPS) in high-side configuration made in BCD technology (see *Figure 1*). They can drive resistive and inductive loads such as lamps, relays, electrovalves and so on. An internal voltage clamping diode to $+V_S$ creates, in inductive loads, a fast demagnetization path with no external components. Suitable for industrial applications, the device operates in the 18- to 35 V supply range, delivering output currents up to 500 mA. In typical applications, it can drive up to 1 or 1.5 H load coils (48 to 60 Ω typical associated resistance).

Figure 1. Block diagram



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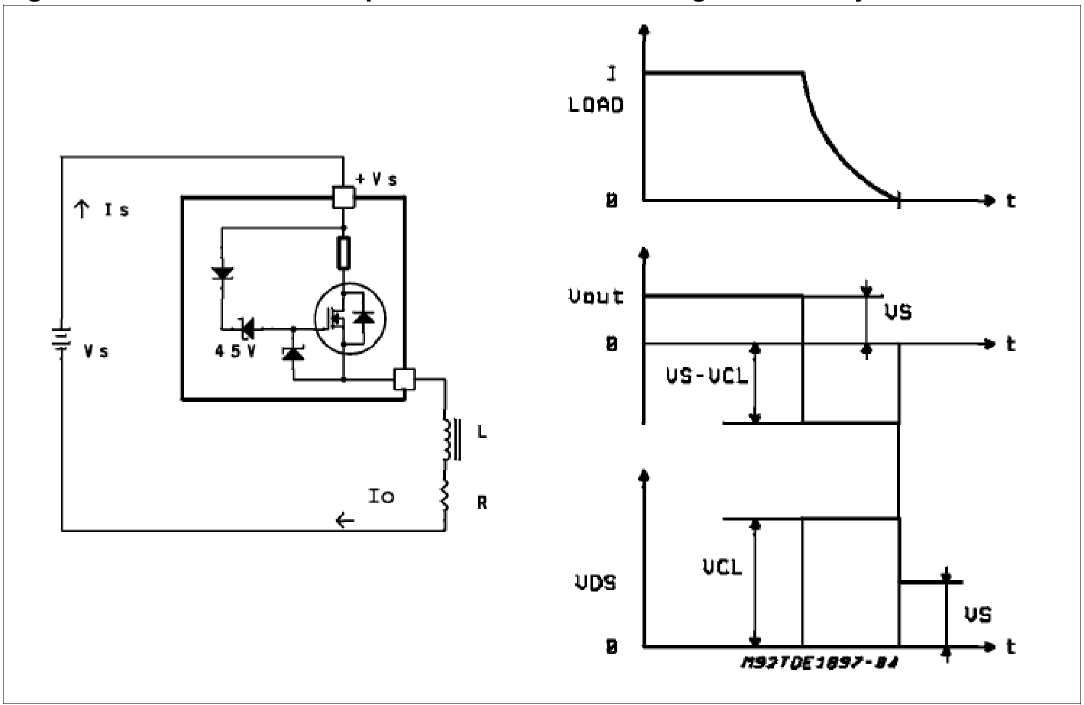
1 Overload conditions

To investigate how the TDE1897C, TDE1897R, TDE1898C and TDE1898R behave in extreme inductive overload conditions, which can occur when too big a load is connected to the device output, tests have been performed in bias conditions that lead the device to function out of the operatives and rated limits specified in the datasheet.

The test conditions (depicted in *Figure 2*) are the following: V_S = +24 V, I_O = internal limited, T_{amb} = 25 °C, L = 1.4 H (non saturating), R_L = 12 Ω, Vi = 2 V (V_{ih})[a], T_j = from Θ Lim-T_H to Θ Lim and above[b].

Figure 2. Inductive load equivalent circuit and demagnetization cycle waveforms



a. The input signal asks for a permanent "on" state.

b. Θ Lim and TH = thresholds of intervention and hysteresis of the internal thermal protection circuit.

2 Overload operation

Due to the internal limitation (I_{SC}), the output current (I_O) is not limited by the load (V_S/R_l = 2 A, $I_{SC} \leq 1.5$ A) but by the device itself. As soon as the current reaches I_{SC}, the IPS goes out of the minimum resistance state and increases its voltage drop so that $I_O = I_{CS}$. The silicon temperature of the DUT increases rapidly up to the thermal protection threshold value (Θ Lim) and such protection tries to cut-off the output DMOS. The output's turn-off forces the demagnetization cycle, which discharges the energy of the inductive load (to V_S) through the device.

Because of the higher energy in the magnetic load and the higher peak power (see *Note 1*), the higher-clamped current value (I_{SC}) produces, during demagnetization, more stress conditions.

During the "on" state, the power (P_{don}) on the DUT (see the 225 msec. interval in *Figure 3*) is defined by the I_O (I_{SC}) and R_l values. The chip temperature rapidly increases and reaches the upper thermal protection threshold value (Θ Lim).

At that moment the protection is triggered on, inducing a switch-off of the output channel. Due to the inductive component in the load, you must wait for the associated demagnetization phase (some 50 msec. after the 225 msec. interval) to see the actual switch-off.

The DUT then starts to cool down staying in the *off* state until the chip temperature goes down to a lower thermal threshold value (Θ Lim-T_H). When this lower limit is attained, the thermal protection circuit withdraws itself and the chip resumes its normal functions and restarts another cycle. In fact, its input will have been connected permanently to a voltage level of more than 2 V, meaning a continuous request for conduction. A new overload cycle begins and a periodic repetition of the following:

- Load charging
- Current limitation
- Over-temperature and demagnetization
- Cooling down in the off state.

It can be noted that, for given thermal parameters (Z_{th}, thermal protection levels and hysteresis), differences in P_{don} affect only the "T_{ON}" and "T_{OFF}" duration and ratio of such periodic repetitions.

Note: 1 During the demagnetization phase, the power dissipated inside the IPS chip is: $I_O(t) * V_{CL}$. I_O (t) decays to zero from I_{SC}, V_{CL} is set by the IPS itself to approximately 50 V.

3 Measurements and calculations

For a typical TDE1897C or TDE1897R sample in Minidip package (see *Figure 3*) in "thermal" periodic repetition, the current (self-limited region) is limited to 1.1 A and the voltage across the DUT is equal to 10.8 V for 225 msecs of "on" time.

The energy dissipated on the DUT in the demagnetization cycle is equal to 1.28 J.

- The repetition cycle rate is equal to 0.27 Hz (t = 3.7 seconds)
- P_{don} (average) = 1.1 A × 10.8 V × 0.225 sec/3.7s = 0.72 W
- P_{dem} (average) = 1.28 J × 0.27 cycles/s = 0.346 W.

Adding the small power dissipated to operate the quiescent current and for $I_O(t)^{2*}R_{ON}$ in the load charging region, the total power P(tot) of 1.1 W is considered a realistic value.

Minidip (on the test-socket) $R_{thj\text{-}amb}$ is approximately 85 °C/W, which leads the average temperature in the hot region of the chip to 115/120 °C (the chip is not homogeneous in temperature; higher temperatures are reached, during dissipation, in the area of the output DMOS).

Figure 3. TDE1897R or TDE1897C in Minidip package output voltage (CH2) and output current (CH1) vs. time in thermal periodic repetition

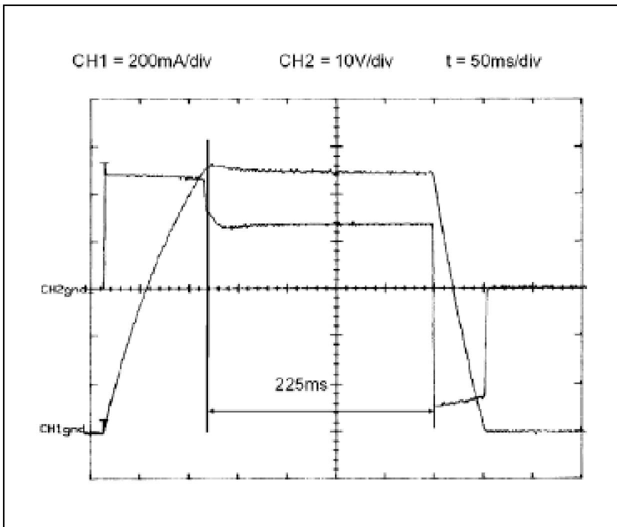
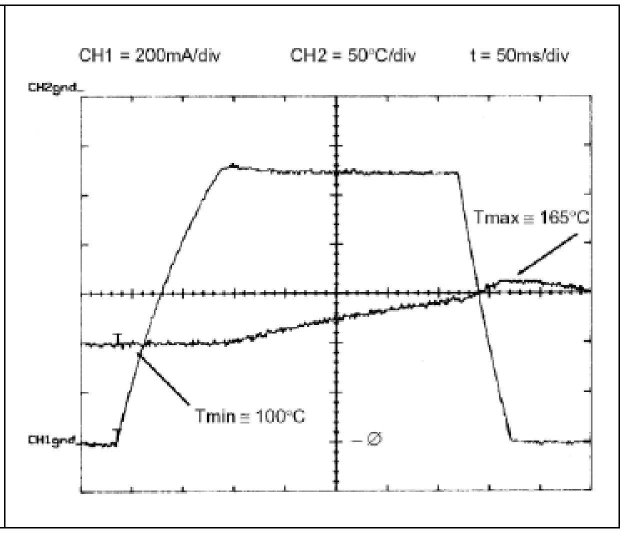


Figure 4. TDE1897R or TDE1897C in Minidip package output current and temperature in the test point vs. time



4 Conclusion

The complex protection system of the TDE1897C, TDE1897R, TDE1898C and TDE1898R also prove effective in extreme overload conditions. Although the behavior of such devices in these conditions cannot be guaranteed due to the high temperatures that accelerate the intrinsic ageing mechanism, the tests performed show that there is a lot of margin beyond the limits guaranteed in the device datasheet.

These tests also show that it is quite likely that such devices will survive non-permanent overloads like the ones that can occur in practice during the installation or modification of an industrial control system.

5 Revision history

Table 1. Document revision history

Date	Revision	Changes
December 2003	1	Initial release
July 2005	2	– Updated the layout look & feel. – Changed title
10-Dec-2008	3	– Document reformatted. No content change. – Obsoleted SIP9 package reference