Innovative Features Integrated in Hall Switches

Increase System Quality, Safety and Control

Application Note

TLE4961-x/TLE4964-x/TLE4968-x

Application Note

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Revision History	
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1 Introduction

1.1 Overview

The TLE4961-x/TLE4964-x/TLE4968-x are parts of the new generation of high precision hall effect unipolar and bipolar switches and latches. They are equipped with highly accurate switching thresholds and an operating range form -40°C up to 170°C. To improve the reading of this document these various devices with different magnetic behaviors will be referred to as **Hall Effect Switches** or **Hall Switches**.

Compared to the previous products some new features like the defined start-up behavior, start-up reset, shutdown reset and the overtemperature and overcurrent protection, were implemented.

The functionality of these features are explained in this application note.

1.2 Overall Product Features

- 3.0 V to 32 V operating supply voltage
- Operation from unregulated power supply
- Reduced current consumption (1.6 mA)
- Overvoltage capability up to 42 V without external resistor
- Reverse polarity protection (-18 V)
- Output overcurrent & overtemperature protection
- Active error compensation
- High stability of magnetic thresholds
- High ESD performance (7 kV)
- SOT23 like SMD package PG-SC59-3-5 (TLE496x-yK)
- Leaded package PG-SSO-3-2 (TLE496x-yL)
- Small SMD package PG-SOT23-3-15 (TLE496x-yM)

Figure 1-1 TLE496x-yK in the PG-SC59-3-5, TLE496x-yM in the PG-SOT23-3-15 and TLE496x-yL in the PG-SSO-3-2 Package

1.3 Target Applications

Target applications for the TLE4961-x/TLE4964-x/TLE4968-x Hall switch family are all applications which require a high precision Hall switch with a operating temperature range from -40°C to 170°C. Its superior supply voltage range from 3.0 V to 32 V with overvoltage capability (e.g. load-dump) up to 42 V without external resistor makes it ideally suited for automotive and industrial applications.

- The TLE4964-x family are unipolar switches with various different operating points. They are ideally suited for various position detection applications like in gear sticks, seats or HVAC.
- The TLE4961-x family are latches and suited for BLDC rotor position measurement or pole wheel applications, for index counting and or speed measurement. Index counting is often used in power closing applications like window lifters or sunroofs.
- The TLE4968-x has very low magnetic thresholds (very sensitive) and a bipolar switching behavior. It is therefore especially suited for applications which require a high sensitivity sensor. Applications are BLDC rotor position measurement or speed and position measurements in camshaft or transmission applications.

2 Start-up Reset and Power-on Time t_{PON}

Start-up reset and start-up sequence

When V_{DD} is powered up it has to cross 2V to get the voltage regulator to start. Then the internal supply voltage V_{DDA} is following V_{DD}. With V_{DD} reaching the specified minimal level of 3V an active start-up sequence is triggered. The device and the output transistor are set to a defined state by V_{DDA} crossing the internal reset voltage level. Two different start-up sequences of the device are illustrated with exemplary slopes shown in **Figure 2-2** and **Figure 2-1**.

Depending on the ramp of the applied supply voltage t_{PON} can vary between 55µs and smaller. Going to extremes, a minimum value in the range of the internal signal delay time t_d, (15µs to 20µs) could be reached.

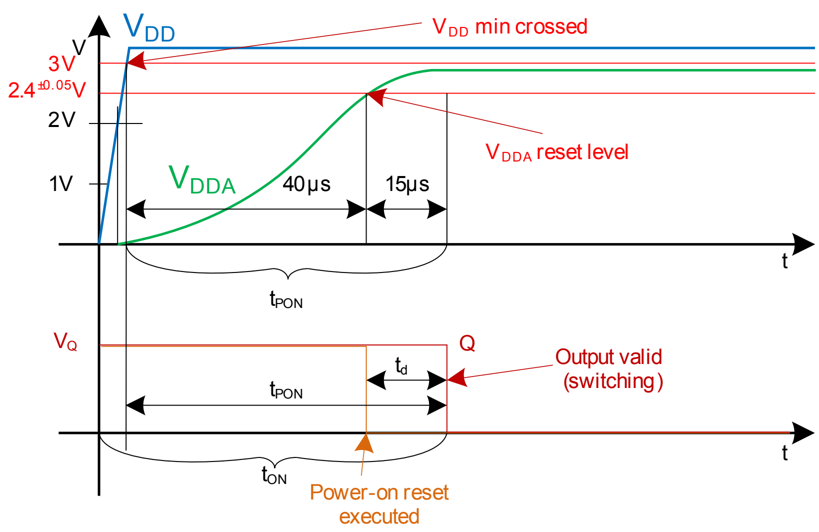

Figure 2-1 Power-on With a Fast V_{DD} Ramp

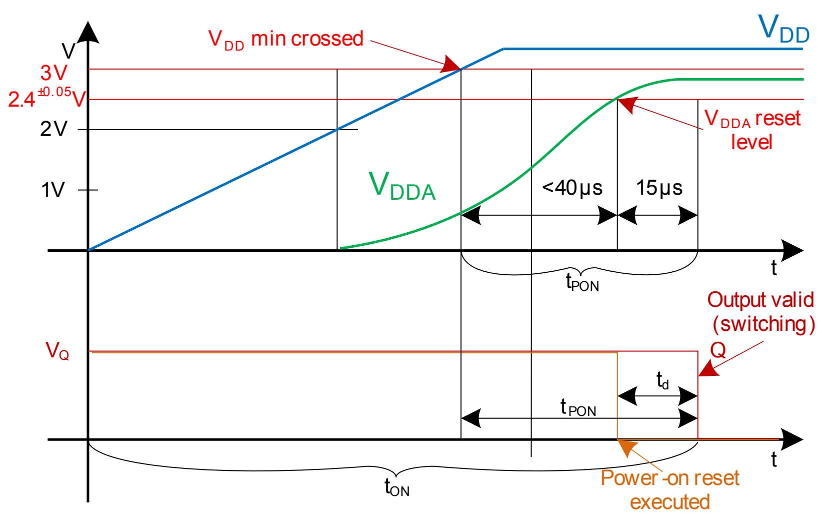

Figure 2-2 Power-on With a Slow V_{DD} Ramp

These startup mechanisms ensure a safe and predictable power-on behavior of the new Hall Switches family, providing a big advantage for the customers system design.

Power on time T_{PON} definition

The power-on time t_{PON} is defined as follows:

Time from applying the external supply voltage V_{DD} = 3.0 V to the sensor until the output is valid in respect to the magnetic input.

To specify t_{PON} the following conditions: V_{DD} = 3 V, $B \leq B_{RP}$ - 0.5 mT or $B \geq B_{OP}$ + 0.5 mT have to be fulfilled.

The power-on time is a combination of the time frame for the internal circuitry powering up and the additional internal signal delay time t_d as explained on page 9.

3 Default Start-up Behavior

The start-up behavior is one very important operating condition for sensors like hall effect switches. Not only the power on time (t_{PON}) is of importance but as well the behavior of the output signal.

Compared to other integrated circuits for sensors the behavior is always effected by a stimulus, the input signal which is intended to be sensed. For Hall Switches there are three different conditions of importance (see **Figure 3-1**).

- The magnetic field is above the Operating Points (B_{OP}) threshold $B > B_{OP}$
- The magnetic field is below the Release Points (B_{RP}) threshold $B < B_{RP}$
- The magnetic field is in between the Operating Points (B_{OP}) and the Release Points (B_{RP}) thresholds within hysteresis $B_{OP} > B > B_{RP}$

To avoid the uncertainty of the random startup in previous devices, a so called “default power on” state was defined.

This means the device is, independent from the stimulus (actual magnet field applied), starting up in the logical “ZERO” state, which means the V_Q pin is at the pull up voltage level. After a certain startup time the device is reacting according to the applied magnetic field. If the B_{OP} threshold is exceeded, the logical “ONE” state, which means the V_Q pin is at the low voltage level is applied.

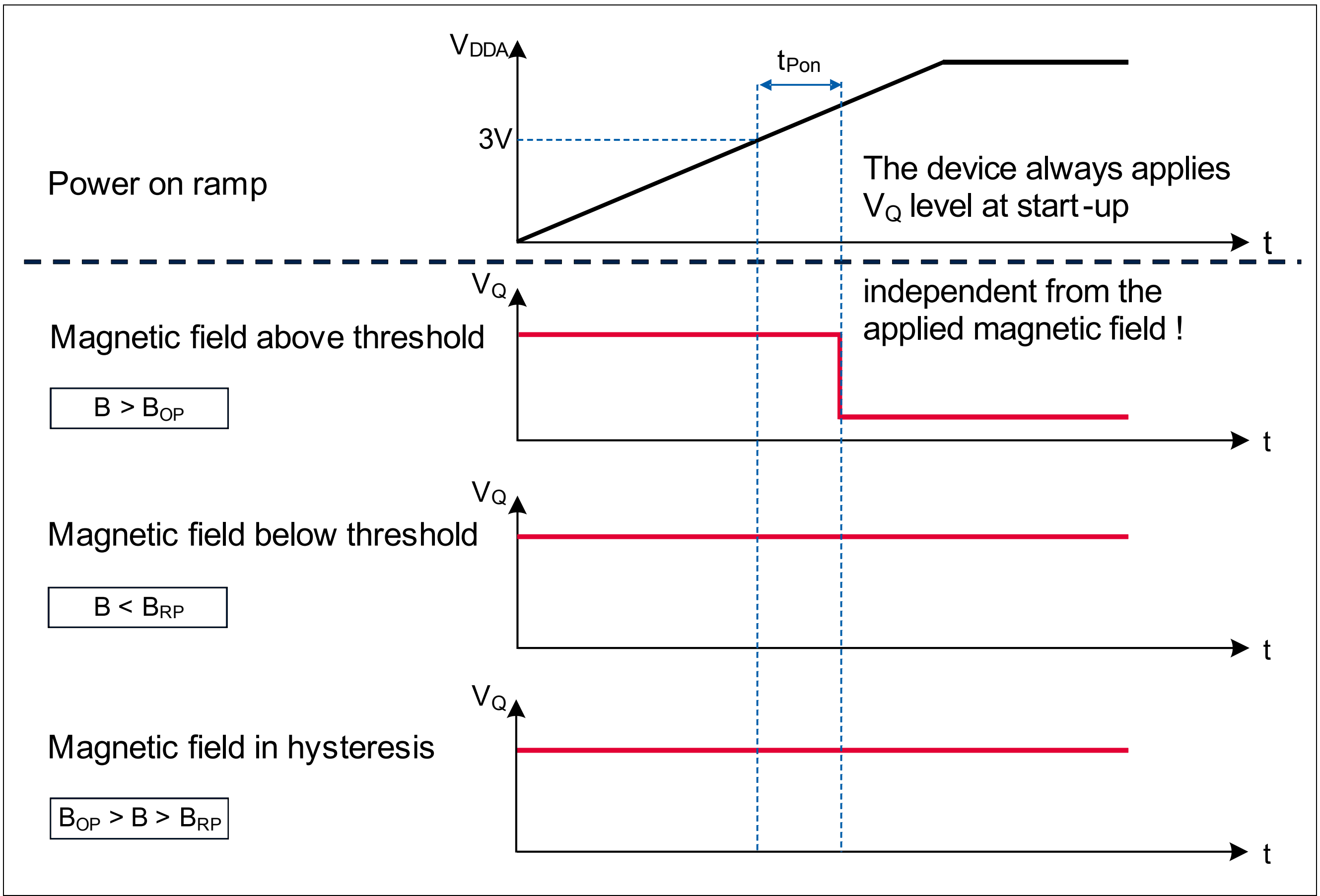

Figure 3-1 Exemplary Illustration of the Default Start-up of the TLE4961-x/TLE4964-x/TLE4968-x

4 Shutdown Reset and Defined Output Shutdown Behavior

Complementary to the defined start-up behavior and start-up reset a defined shutdown and shutdown reset was implemented in the new generation Hall Switches.

The advantage of this feature is to have the fast discharge of the output transistor and the option for a better test functionality.

Compared to existing devices which show some capacitive discharging behavior at the output pin (see **Figure 4-1**),

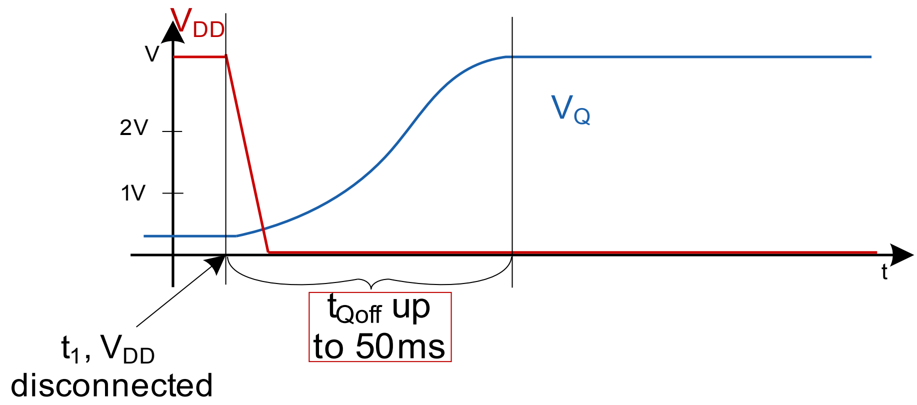

Figure 4-1 Slow Output Shutdown Behavior at Existing Devices

the new generation Hall Switches have a second internal reset functionality implemented. Once the shutdown reset level of $2.1^{\pm 0.05}$ V (different to the power-on reset level of $2.4^{\pm 0.05}$ V) is crossed, a fast discharge of the output transistor is triggered (see **Figure 4-2**).

This enables to have the V_Q level reached at the output pin in around 5µs, compared to the tens of milliseconds of other devices.

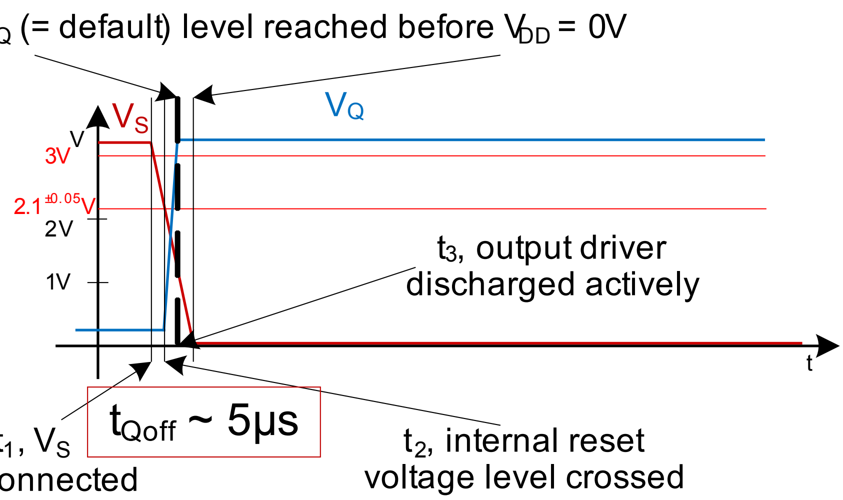

Figure 4-2 Fast Output Shutdown Behavior and Shutdown Reset for the New Generation Hall Switches

In system functionality test example

To use this shutdown behavior for functionality tests in the system, one could think of following scenario.

It's necessary to have a magnetic flux applied.

- Then V_{DD} has to be disconnected.
- The output will be at V_Q level within 5 µs.
- Powering V_{DD} up, the Output will go back to the 0 V level after the power on time (t_{PON}, see **Chapter 2**).

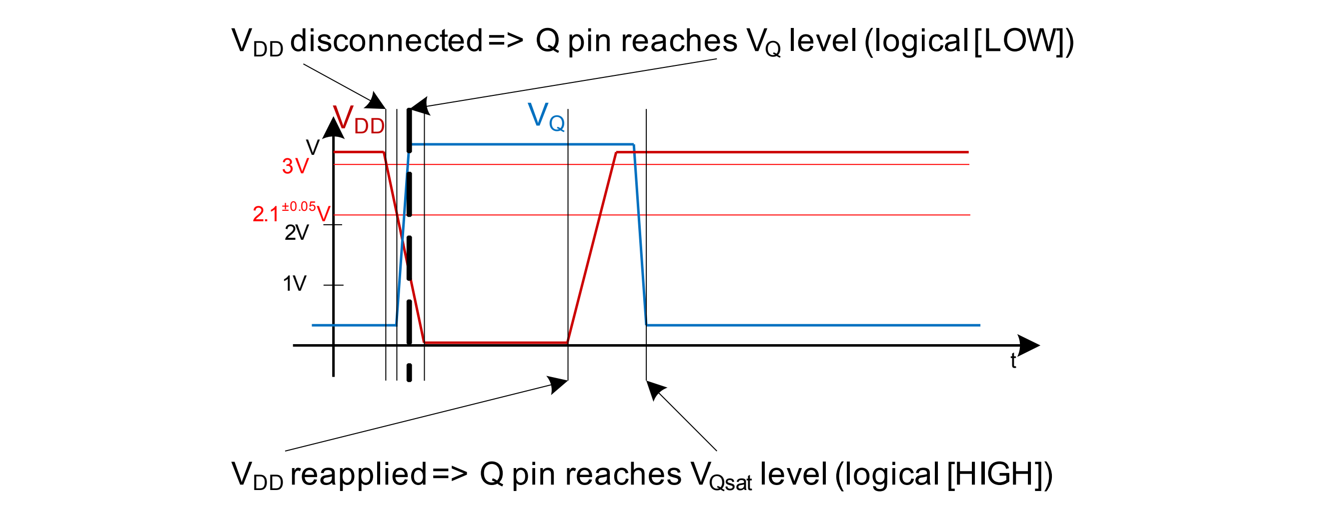

Figure 4-3 Example of a Functionality Test Timing Diagram

5 Overtemperature and Overcurrent Protection

This feature was implemented to prevent a fast destruction of the sensor and to increase the robustness of the device. In combination of the improved high voltage capability and ESD robustness this was an essential addition for the targeted high quality standard.

As shown in the Maximum Ratings Table in the Data Sheets, here **Table 5-1**, the junction temperature has a big influence regarding the lifetime.

Table 5-1 Absolute Maximum Rating Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Supply voltage	V_{DD}	-18		32 42	V	 10h, no external resistor required
Output voltage	V_Q	0		32	V	
Reverse output current	I_Q	-70			mA	
Junction temperature[1)]	T_J	-40		155 165 175 195	°C	for 2000h (not additive) for 1000h (not additive) for 168h (not additive) for 3 x 1h (additive)
Storage temperature	T_S	-40		150	°C	
Thermal resistance Junction ambient	R_{thJA}			300 200 300	K/W	for PG-SC59-3-5 (2s2p) for PG-SSO-3-2 (2s2p) for PG-SOT23-3-15 (2s2p)
Thermal resistance Junction lead	R_{thJL}			100 150 100	K/W	for PG-SC59-3-5 for PG-SSO-3-2 for PG-SOT23-3-15

1) This lifetime statement is an anticipation based on an extrapolation of Infineon's qualification test results. The actual lifetime of a component depends on its form of application and type of use etc. and may deviate from such statement. The lifetime statement shall in no event extend the agreed warranty period.

Calculation of the dissipated power P_{DIS} and junction temperature T_J of the chip (SC59 example):

e.g for: V_{DD} = 12 V, I_S = 2.5mA, V_{QSAT} = 0.5 V, I_Q = 20mA
Power dissipation: P_{DIS} = 12 V x 2.5mA + 0.5 V x 20mA = 30mW + 10mW = 40mW
Temperature $\Delta T = R_{thJA} \times P_{DIS}$ = 300K/W x 40mW = 12K
For T_A = 150°C: $T_J = T_A + \Delta T$ = 150°C + 12K = 162°C

The case temperature (T_{case}) reaches a maximum after some tens of seconds in the short circuit condition. But in fact the junction temperature (T_J) crossed the internal shutdown temperature of 192°C after some hundred milliseconds. The further increasing case temperature reflects the device starting to toggle between the shutdown T_J of 192°C and the cut-in T_J of 180°C at around 120Hz at 25°C ambient temperature.

Note: Following plots show measurements of T_{case} of the PG-SC59-3-5 and the PG-SSO-3-2 package. A remarkable difference between T_{case} and T_J should be kept in mind. Although the chip is already in thermal shutdowm, the T_{case} is relatively slowly increasing to a maximum level much lower then the T_J shutdown value.

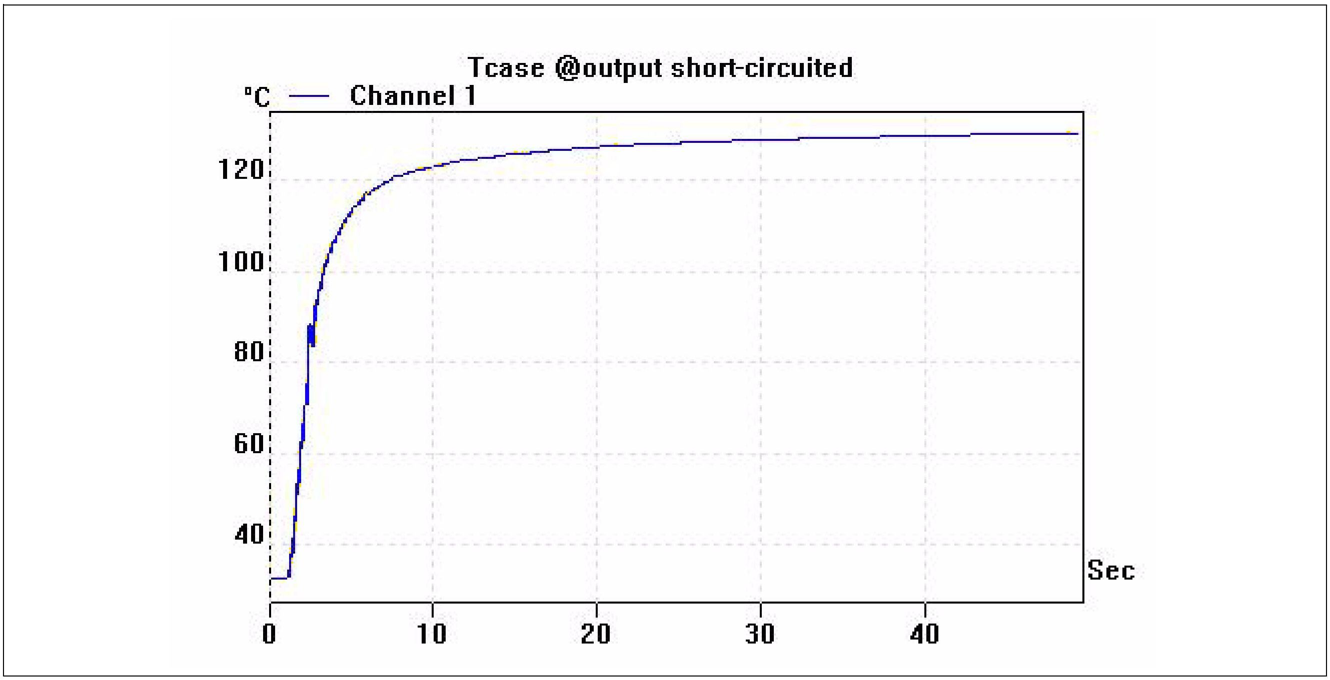

Figure 5-1 Case Temperature for a TLE496x-yK in the PG-SC59-3-5 and Short-circuited Output

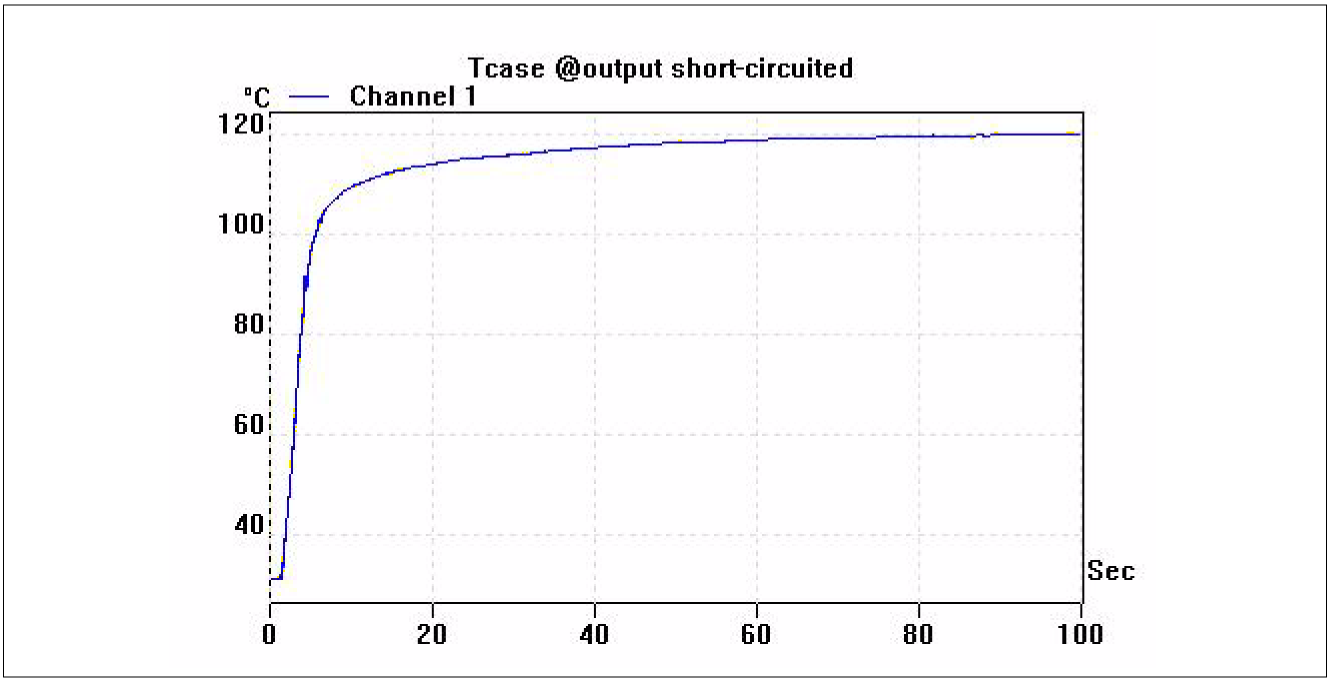

Figure 5-2 Case Temperature for a TLE496x-yL in the PG-SSO-3-2 and Short-circuited Output

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