TLE4729G

2-Phase Stepper-Motor Driver
Application Note
Error Detection Method

Automotive Power

Never stop thinking

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1 Abstract

Note: The following information is given as a hint for the implementation of the device only and shall not be regarded as a description or warranty of a certain functionality, condition or quality of the device.

This Application Note is intended to provide detailed technical information about the error detection method that is used within the Infineon stepper-motor driver TLE4729G. Special attention is paid on influence of external components and parasitics.

2 Introduction

The TLE4729G stepper-motor driver is intended to be used for bipolar, two-phase, current-controlled stepper motors (see **Figure 1**).

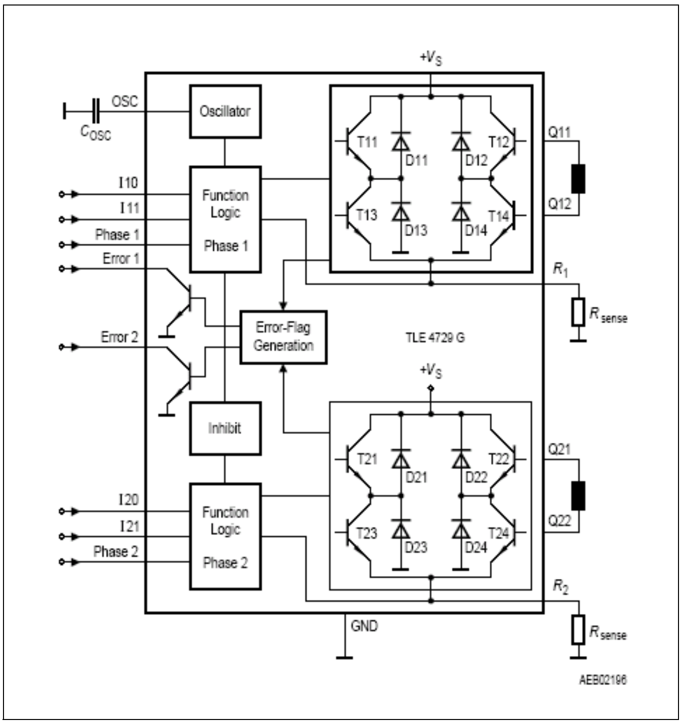

Figure 1 TLE4729G Block diagram

3 Error Detection Method

There are two dedicated pins used for signaling device errors:

- Error 1 on pin 21, which signals open load or short-circuit to V_s of one or more outputs or short-circuit of the load or overtemperature
- Error 2 on pin 14, which signals short-circuit to ground of one or more outputs or overtemperature.

Error flag 1 as well as error flag 2 both signal the malfunction with a “low” signal. The different error output signals are described in the logic table (see **Table 1**).

The Error Pins have open collector outputs which require an external pull-up resistor. 10kOhm is recommended.

Table 1 Logic Table

Kind of Error		Error Output	
		Error 1	Error 2
a)	No error	H	H
b)	Short circuit to GND	H	L
c)	Open load[1)]	L	H
d)	b) and c) simultaneously	H	L
e)	Temperature prealarm	L	L

1) Also possible: short circuit to + V_S or short circuit of the load.

3.1 Over-temperature

Detection of overtemperature is implemented as a pre-alarm. Both error pins signal over-temperature approximately 20°C before thermal shut down.

If the temperature begins decreasing again, then typically 20°C (hysteresis) below the pre-alarm temperature the error flags will be reset.

3.2 Open Load

The recirculation of the inductive load is used for detecting an open load.

Generally at each phase change-over an internal error flip-flop is set (see fig.2). The output of this flip-flop is connected to the error flag 1, but with a filtertime of typ. 15us (t_{PEol}), synchronized with phase changeover.

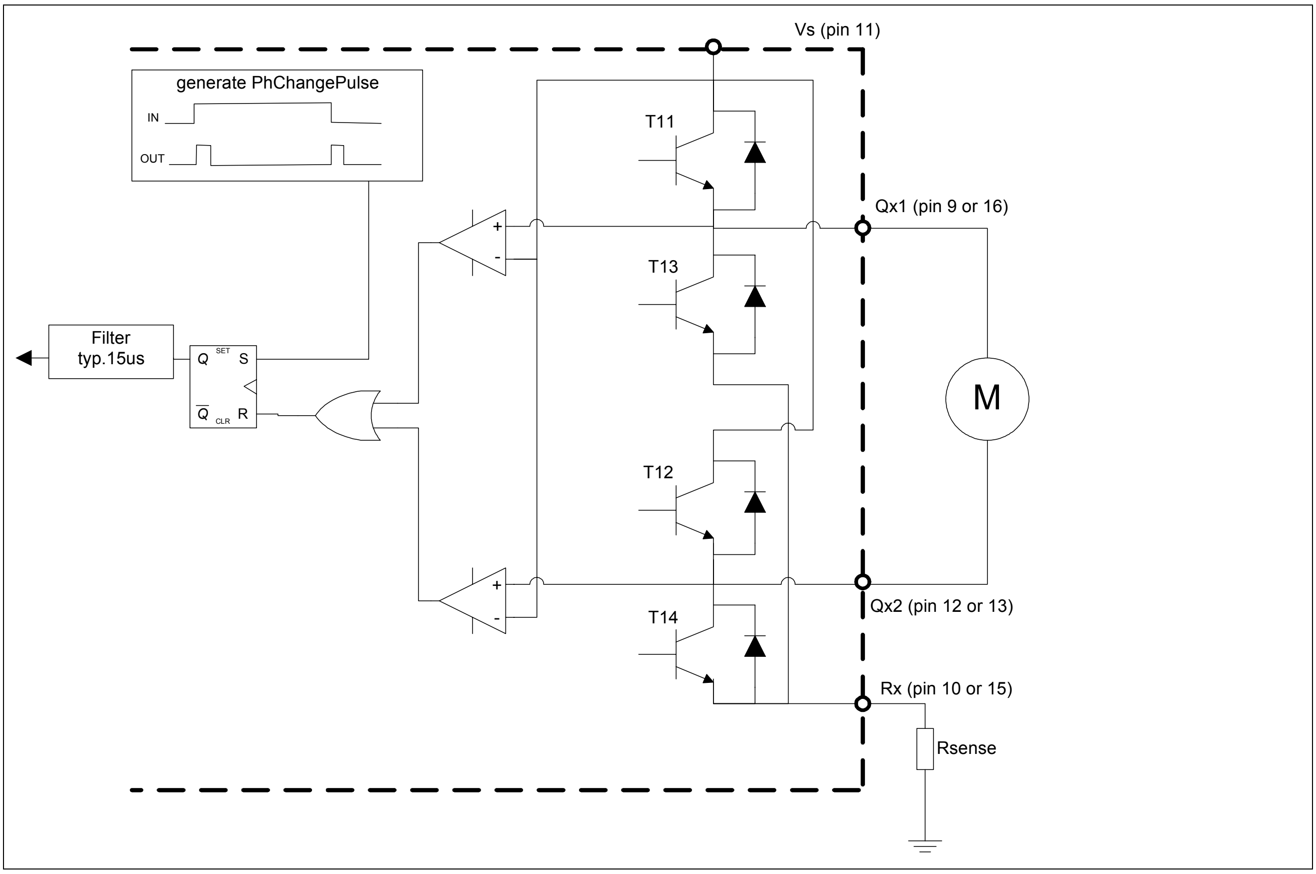

Figure 2 Simplified schematic of Open Load detection (valid for Short to Vs and Short across the load as well)

If an inductive load is connected, one of the outputs will rise to a voltage V_S+V_{FU} (V_{FU} being the forward voltage of the source-transistor freewheeling diode). This voltage is detected by a comparator which resets the flip-flop. As this happens much faster than the 15us filtertime, the error flag is not set under normal operation (**Figure 3**). If, however, the inductive fly-back is missing due to open load and the voltage does not rise above V_S, the flip-flop remains set and the error flag 1 is set after 15us (**Figure 4**, **Figure 5**).

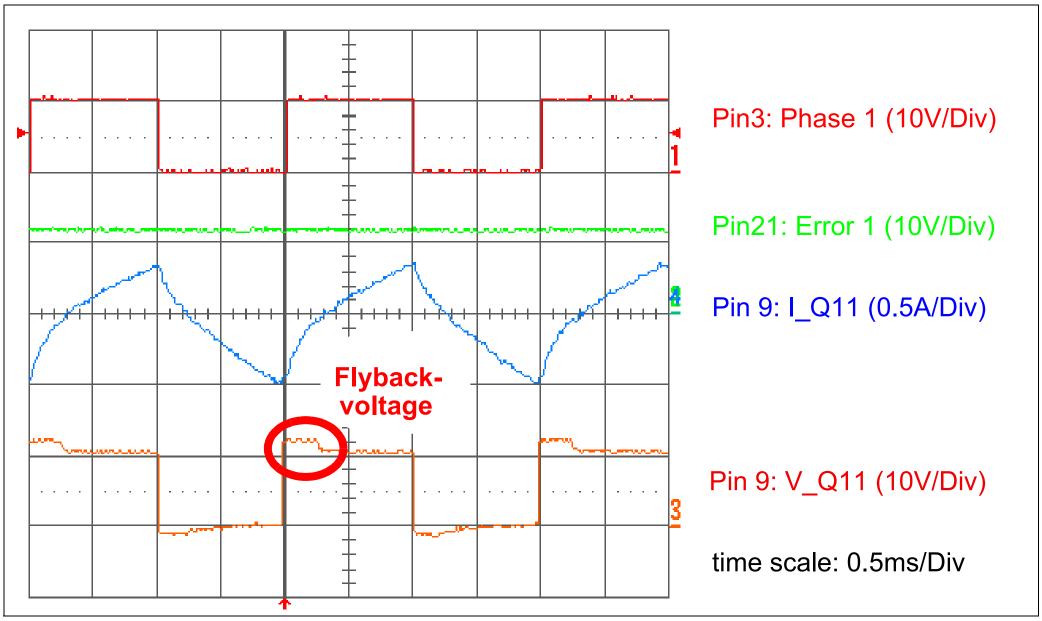

Figure 3 Normal mode, no error

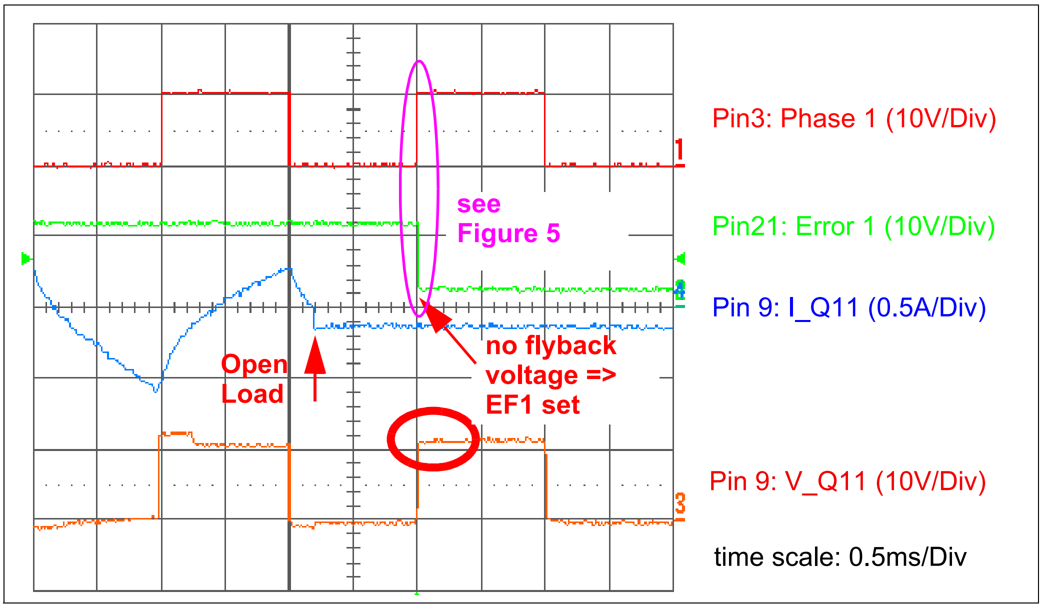

Figure 4 Normal mode, open load detected

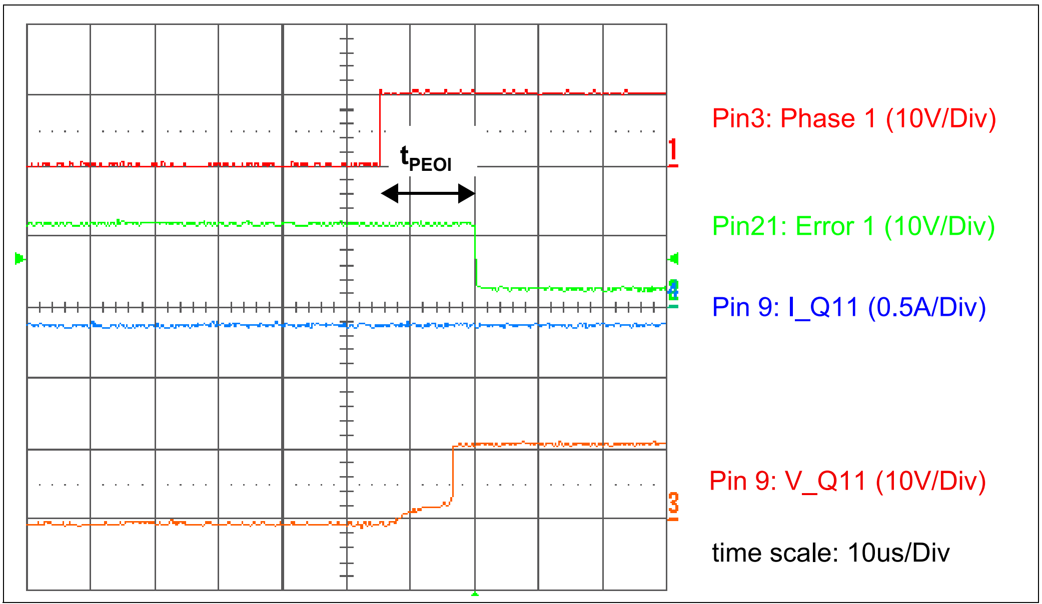

Figure 5 Normal mode, open load detection (section of Figure 4)

3.3 Short to Ground (Safe Operating Area) protection

Every output power transistor is protected against short circuit by a SOA. This SOA circuit switches off the power transistors, if the current becomes too high (>1.5A). The SOA circuitry consists of a metal shunt resistor for the current measurement and a comparator (**Figure 6**).

If the threshold of the comparator is reached, the power transistor is switched off. The output current decreases and, under a certain threshold of the current, the power transistor is switching on again. This moment is depending on the oscillator frequency. As result an oscillation of the output current of several 100kHz can be observed (**Figure 8**).

For the highside switch this SOA signal is connected to the diagnosis block. If this overload state lasts longer than typ.40us, a flip-flop is set, which switches off the power stages and sets the output EF2 to “low”. The high-frequency oscillation of the output current may create EMC disturbances, therefore the power transistors are switched off after this delay time.

The flip-flop is reset by a phase change or turning off/on the supply or setting the inhibit mode.

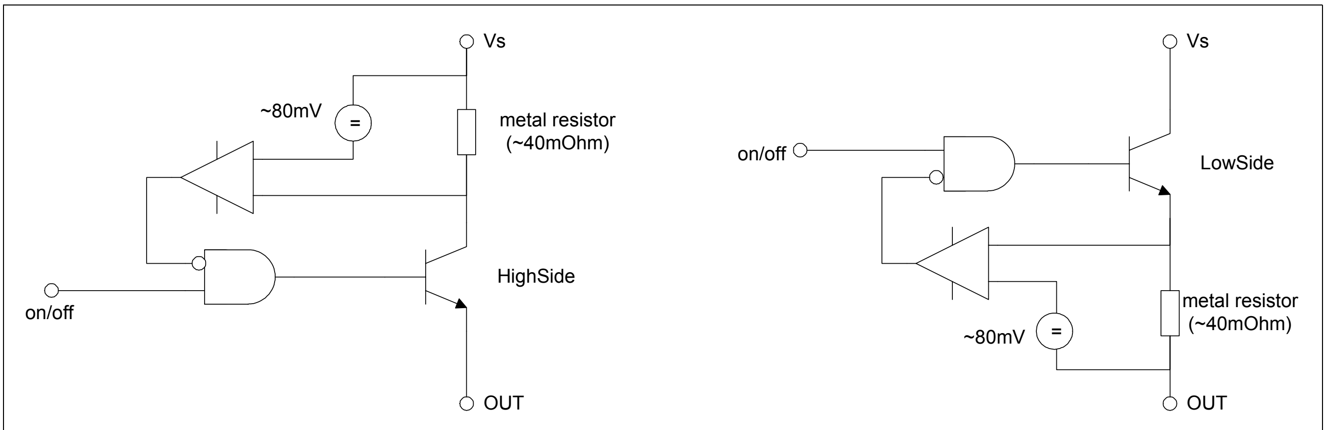

Figure 6 SOA circuitry

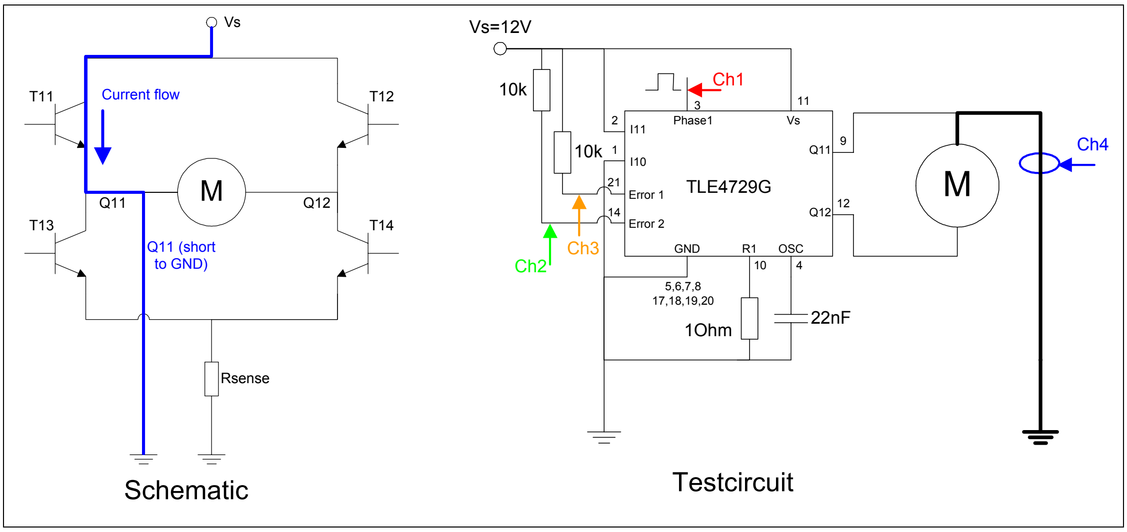

Figure 7 Short circuit of Q11 to GND (Phase 1 = High)

Figure 7 is showing the test circuit for short circuit of output Q11 to GND and the corresponding current flow for a High-Signal at Phase 1.

The error signal behavior can be explained as follows: If Phase 1 is changing from “L” to “H”, the device is detecting OpenLoad. There was no current through the motor because all 4 transistors were switched off. Thus there is no recirculation, therefore EF1 will be set (see **Figure 8**). The upper power transistor T11 is turned on and is working against the short circuit. The SOA protection circuit of T11 will shut down all 4 transistors after typ.40us and EF2 is set (at time t1).

EF1 is reset at t1 (changing from “L” to “H”) because error flag 2 has priority. These conditions continue until Phase 1 toggles to low.

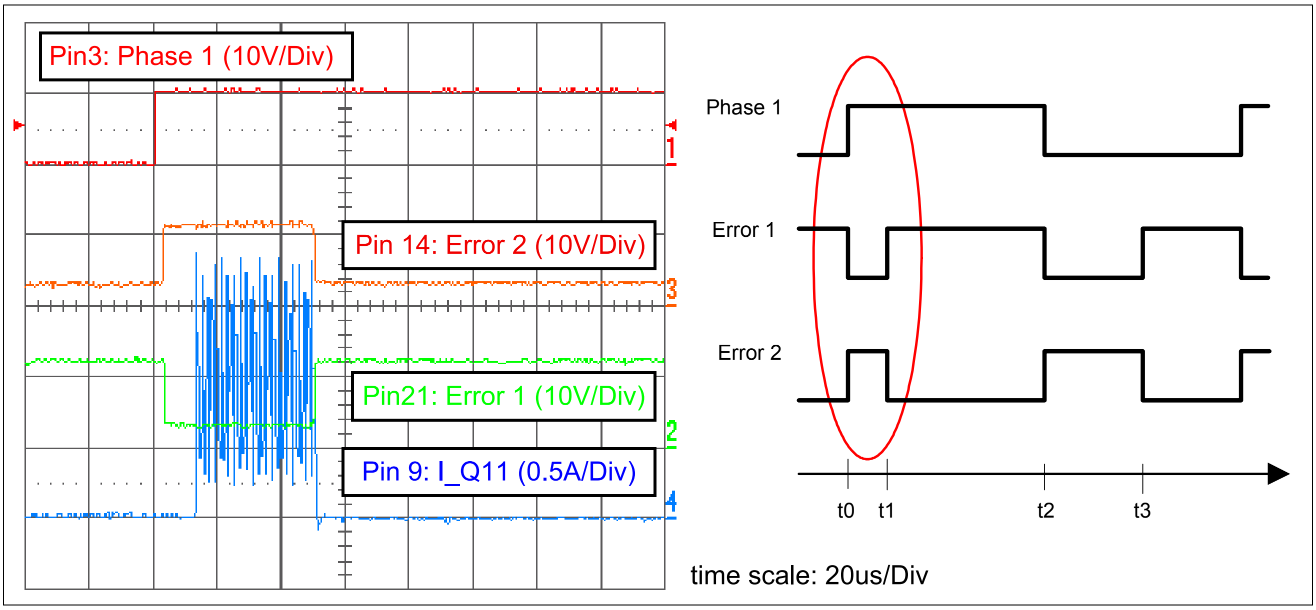

Figure 8 Behavior for short circuit of Q11 to GND (if Phase 1 is changing from “L” to “H”)

Figure 9 is showing the test circuit for short circuit of output Q11 to GND and the corresponding current flow for a Low-Signal at Phase 1.

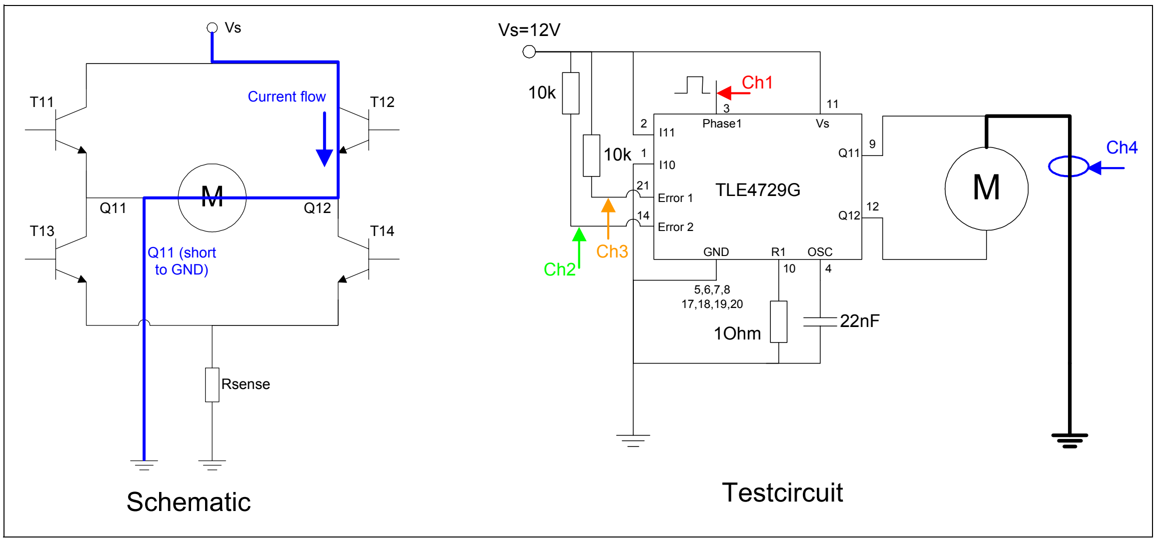

Figure 9 Short circuit of Q11 to GND (Phase 1 = Low)

If Phase 1 is changing from "High" to "Low", EF2 will be reset and EF1 will be set again (because there is no recirculation). The short circuit is now in parallel to the lower active transistor T13, the load current doesn't flow through Rsense and so no current limitation is reached. Therefore the SOA circuit of the upper transistor T12 limits the current. Because the current is flowing through the motor inductivity, the delay due to the current ramp (caused by the inductivity) has to be considered. As result it takes longer until all 4 power transistors are switched off. Depending on the motor inductivity, the time between t2 and t3 might reach several 100us (**Figure 10**).

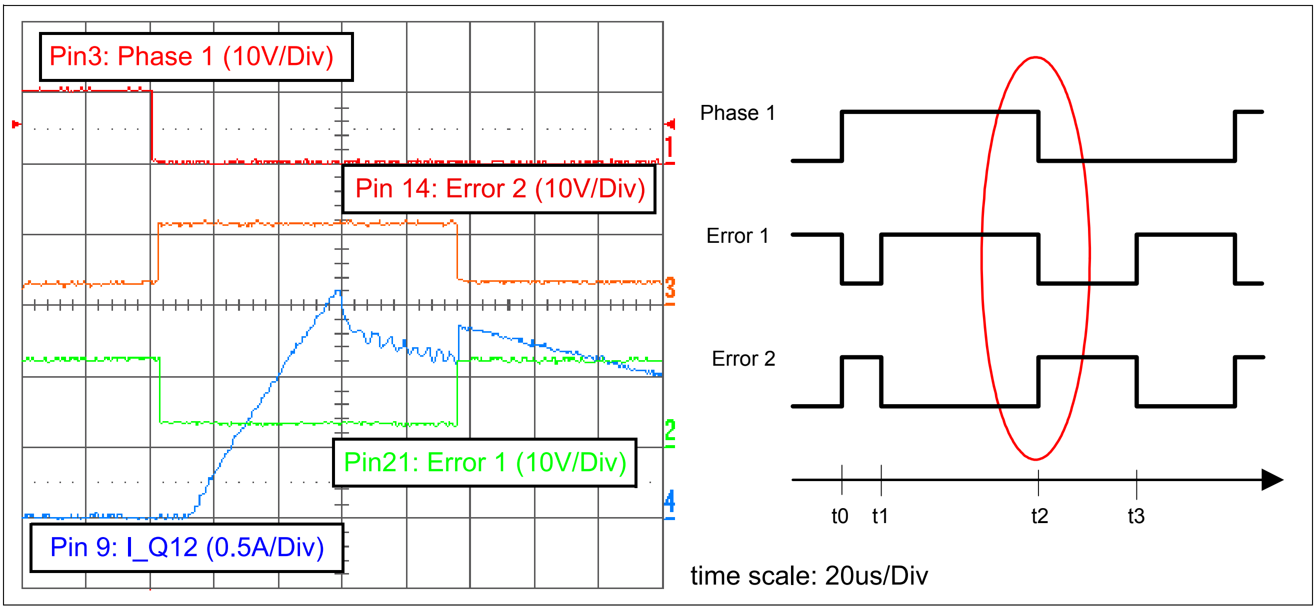

Figure 10 Behavior for short circuit of Q11 to GND (if Phase 1 is changing from "H" to "L")

3.4 Short to V_s / Short across the load

There is no special circuit implemented for short to V_s or short across the load. As mentioned in **Chapter 3.3**, the filter time of the SOA circuitry for the highside switch is typical 40us. Much faster than this filter time is the chopper regulation of the device.[1] The set-up for short to Vs / short across the load will be described in **Section 3.4.2**.

3.4.1 Chopper Regulation

This circuit provides a nearly constant current through the inductive load. It only works with an external sense resistor.

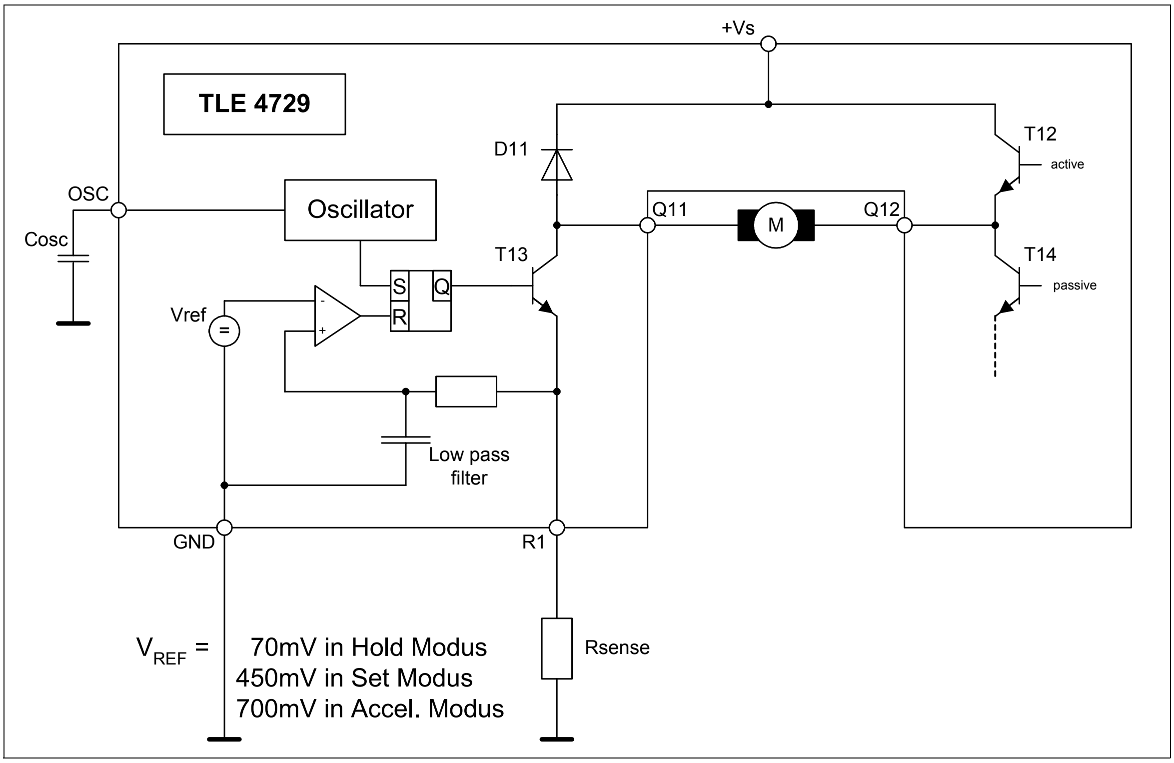

Figure 11 Chop Principle

At time t_0 the Phase 1 input is at low and the current control pin I_{11} is switched to high (= set mode). T_{12} and T_{13} are activated, the current is flowing from Q_{12} to Q_{11}. The current through the motor increases until it reaches at t_1 the threshold i_{set} (respectively the threshold voltage of 450mV in set mode at the sense resistor Rsense). The current ramp between t_0 and t_1 depends on the motor inductivity.

At t_1 the flip-flop is reset and T_{13} turns off. The inductive current recirculates over D_{11} back to V_s and decreases with a slight slope. At time t_2 the oscillator (25kHz with C_{osc}=2.2nF) sets the flip-flop, T_{13} turns on and the load current increases again until it reaches the threshold at t_3 and so on. The time delay by the low pass filer is little bit greater than 1us.

When Phase is changed from low to high, T_{12} and T_{13} both turn off, current recirculates in D_{11} and D_{14} (not shown here, but antiparallel to T14). T_{11} and T_{14} are switched on, the current is flowing in opposite direction (from Q_{11} to Q_{12}) and is limited on the same way as described above.

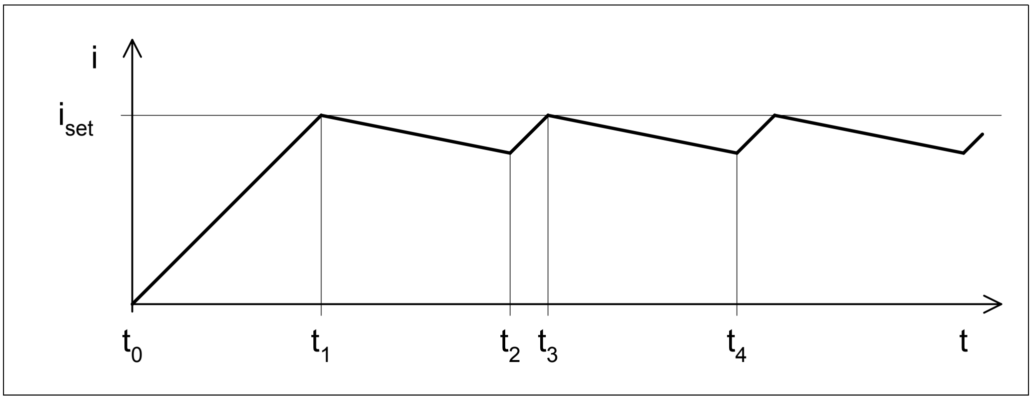

Figure 12 Current Characteristic

Note: This is a very simplified example of an application circuit. The function must be verified in the real application.

3.4.2 Behavior at short to Vs / short across the load

If there is a short to Vs or from Output to Output (**Figure 13**), the current chopper comparator (see **Chapter 3.4.1**) detects the short circuit current as a normal current which has reached the threshold and switches off the lowside transistor. Because there is no recirculation, the current drops immediately to zero. After 40us (oscillator frequency 25kHz with C_{osc}=2.2nF) the lowside transistor switches on again, reaches very fast the threshold and the flip-flop switches the lowside transistor off and so on. As result small spikes can be seen every 40us.

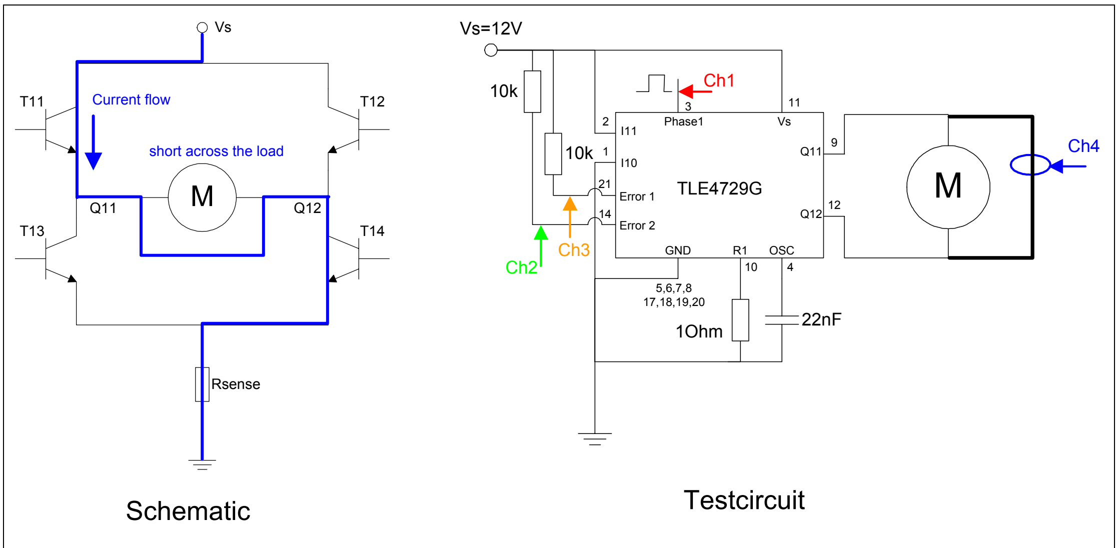

Figure 13 Short across the load (Phase 1 = High)

If phase 1 is changing from “High” to “Low”, Error 1 will be set because there was no load current and therefore no recirculation (**Figure 14**). Depending on the wire harness and temperature, error flag 1 might be sometimes reset. Such behaviour will be discussed in **Chapter 4.2**.

For short to V_s the signal behaviour looks different, compared to short across the load. If one output is shorted to V_s, the current is flowing through the motor load in one direction only, as shown in **Figure 15**. As result, error flag 1 is not set if Phase 1 is changing from “High” to “Low”.

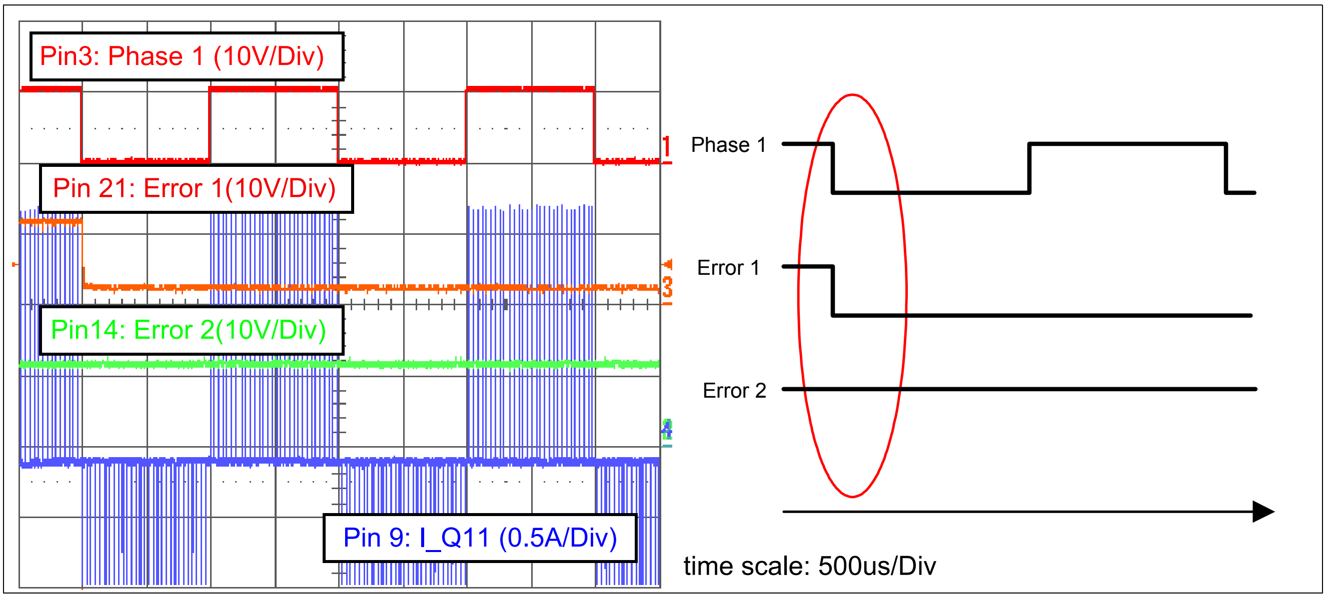

Figure 14 Behavior for short across the load (if Phase 1 is changing from “H” to “L”)

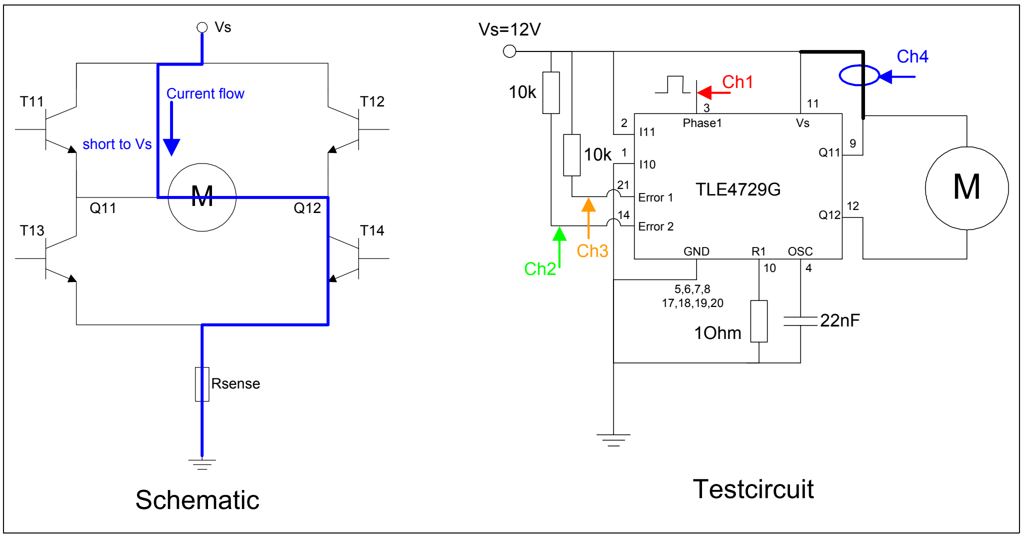

Figure 15 Short to Vs (Phase 1 = High)

Let’s have a closer look to **Figure 16**: Phase 1 is low, error flag 1 and 2 both are high. There is no open load error and no short to GND error. The current is flowing from Vs due to the short direct to Q11 and over T13 and Rsense to GND. There is no current through the motor load. If now phase 1 is changing from Low to High, error flag 1 will be set because there was no recirculation.

The load current increases until it reaches the threshold i_{set} (see **Figure 12**), resulting in switching off the lower power transistor T14. The current now recirculates and resets error flag 1, the lower transistor is switched on again by the oscillator and normal chop mode continues (as described in **Chapter 3.4.1**).

The time t_{set}, until i_{set} is reached, depends on the load inductivity and resistance. If the load resistance is too high and the current threshold will never be reached, then error flag 1 will keep “low” status until the next phase change.

Then phase 1 toggles to Low again, the current recirculates (error flag 1 will be not set) and now the lower transistor T13 is switched on in serial to the short to Vs. The current increases very fast, but the lower transistor is switched off by the current comparator, which resets the flip-flop (**Figure 11**). This results in current spikes every 40us (oscillator frequency 25kHz), which do not shut down all four power transistors. Therefore error flag 2 is not set.

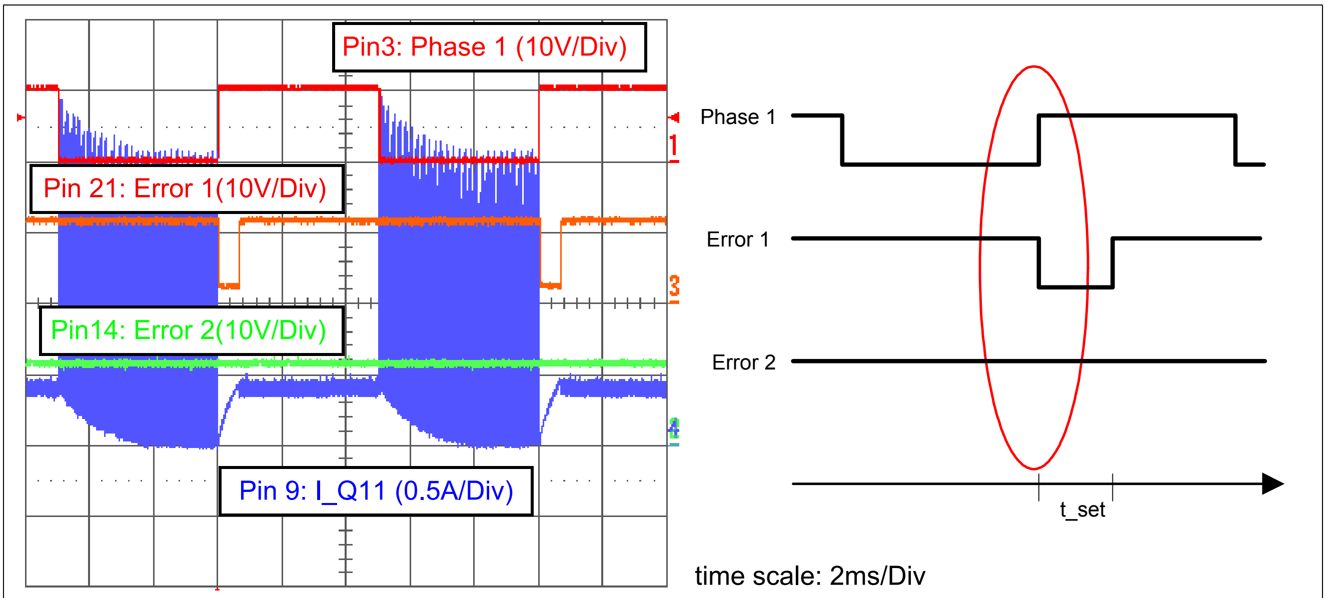

Figure 16 Behavior for short to Vs (if Phase 1 is changing from "L" to "H")

4 Parasitic Considerations

TLE4729G is using the flyback voltage of the inductive load for error detection. This flyback voltage depends on the used motor/inductivity, wire harness and temperature. There is a risk of misdetection, either detecting an error which is not true or overlooking a real existing failure. This chapter describes the known cases and how to reduce the risk of failures in error detection.

4.1 Misdetection of Open Load

If both digital input pins are set to "Low", the device is in "no current" mode. No current in both bridges inhibits the circuit and current consumption will sink below 50uA (as described in datasheet [2]). The device is now in the inhibit-mode.

If the device starts to operate again (that mean, at least one of the digital input pins has high potential), the error flag 1 signals an open load error if the corresponding phase input is high (**Figure 17**). There are two possibilities for resetting error flag 1:

- at the next phase change due to the flyback voltage
- as result of the chop mode (**Chapter 3.4.1**). The chop mode is generating a flyback voltage as well and should reset error flag 1 much faster than the next phase change.

There are two reasons, why the chop mode might be not active in a real application:

- there is no sense resistor used in the application circuit (chopper regulation only works with an external sense resistor)
- the load is high-ohmic and the threshold for activation of the chop mode will never be reached.

If the corresponding phase input is low when starting operation again (after inhibit mode) (**Figure 18**), then error flag 1 will not be activated.

In the application there is no way to avoid the Open Load signal when activating the device after inhibit mode. It is recommended to ignore the first open load detection signal after deactivating the inhibit mode by using a software solution.

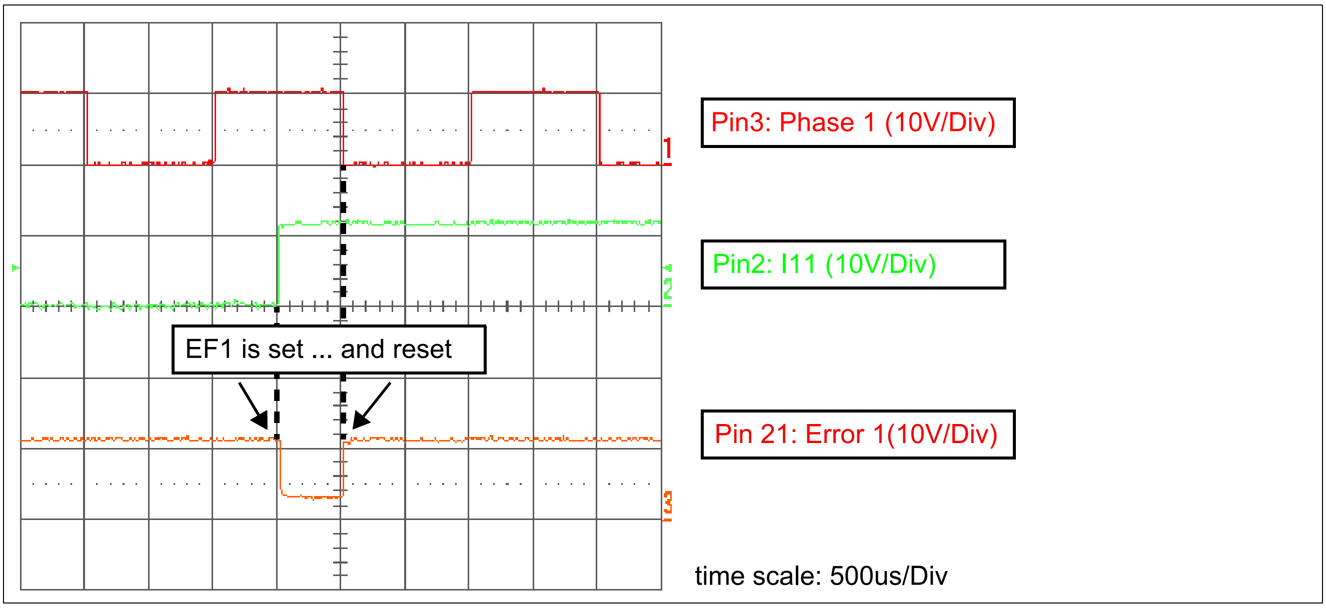

Figure 17 Signal behavior after inhibit mode (corresponding phase is “High”)

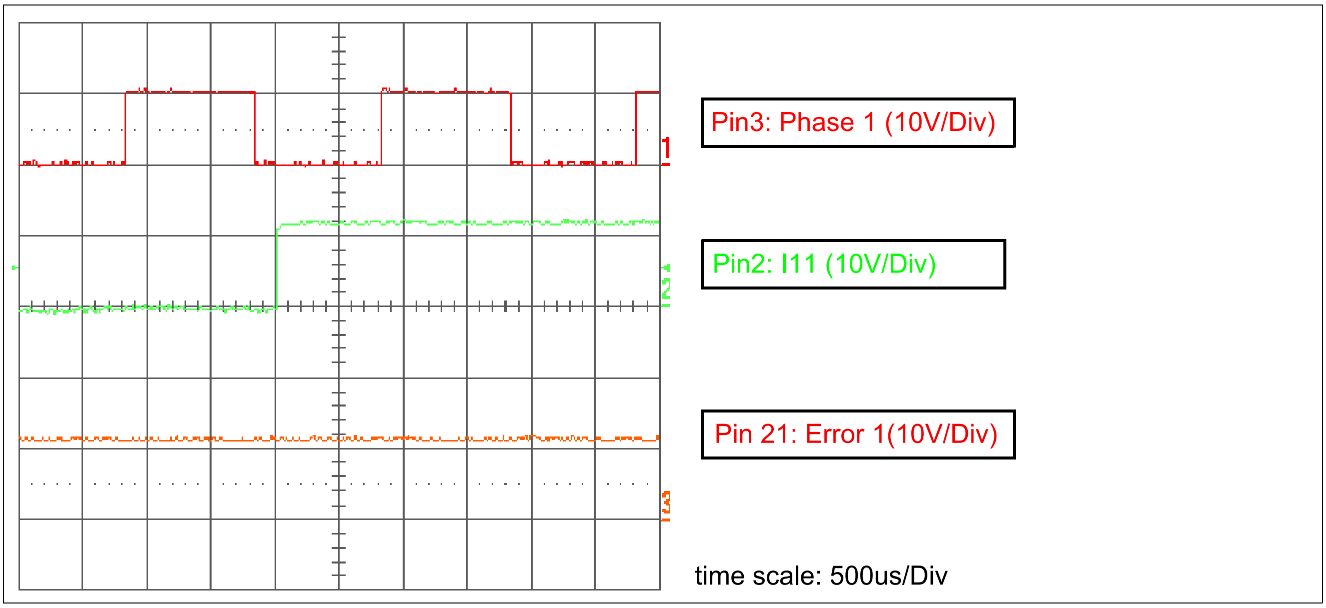

Figure 18 Signal behavior after inhibit mode (corresponding phase is “Low”)

4.2 Misdetection of Short to V_s / Short across the load

As shown in **Figure 14**, in ideal case the error flag 1 is set and remains low all the time. In an real application it may be different.

In reality a short always has some resistance and inductance, causing a flyback voltage as well. **Figure 19** is showing different scenarios for setting / re-setting error flag 1, depending on the timing and parasitic wire harness of the short:

Case 1: Ideal case, as described in **Figure 14**; no parasitic inductivity, no flyback voltage; error flag 1 is set at phase change and remains set.

Case 2: Error flag 1 will be resetted due to the flyback voltage, caused by the current peaks. The current spikes are caused by the current comparator, switching of the lower power transistor (as described in **Chapter 3.4.2**). The time between the spikes depends on the external capacity C_{osc}. For C_{osc}=2.2nF the spikes occur every 40us.

Depending on the timing between error flag setting and oscillator frequency, the length of the error flag 1 may vary (**Figure 20**, **Figure 21**).

Case 3: There might be some rare cases that error flag 1 is not set at the phase change even if a short across the load happen (but probably will be set at the next phase change). If at the moment of phase change or within t_{PEol} a flyback voltage occur (e.g. due to current spikes), the short circuit will be ignored and error flag 1 will be not set.

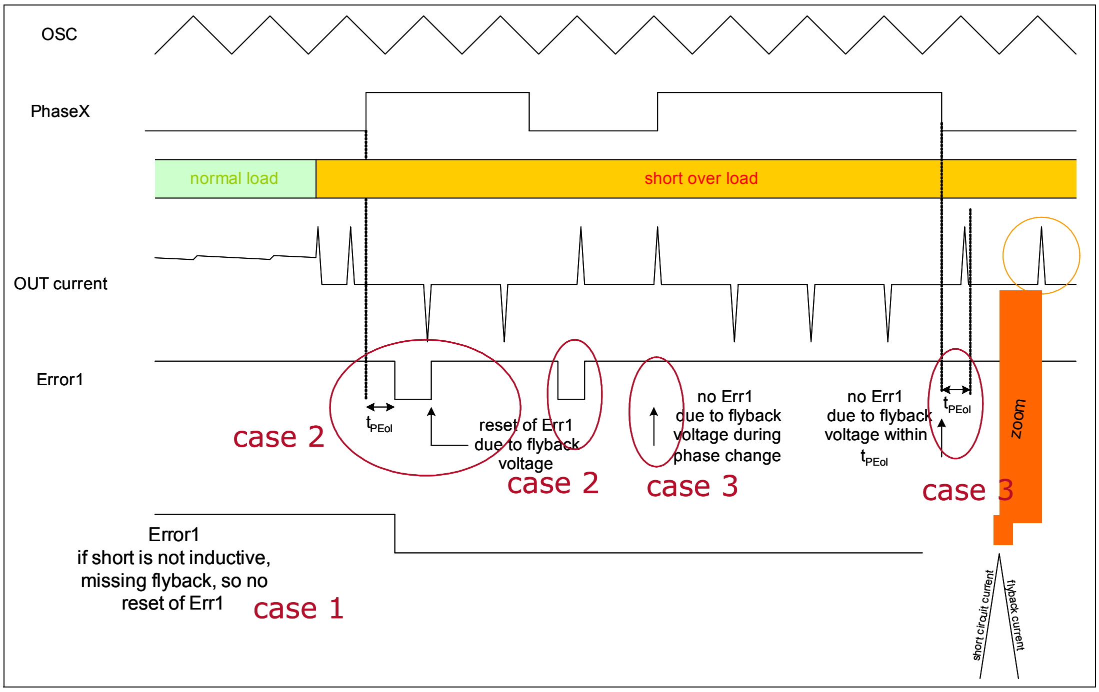

Figure 19 Signal behavior for short across the load

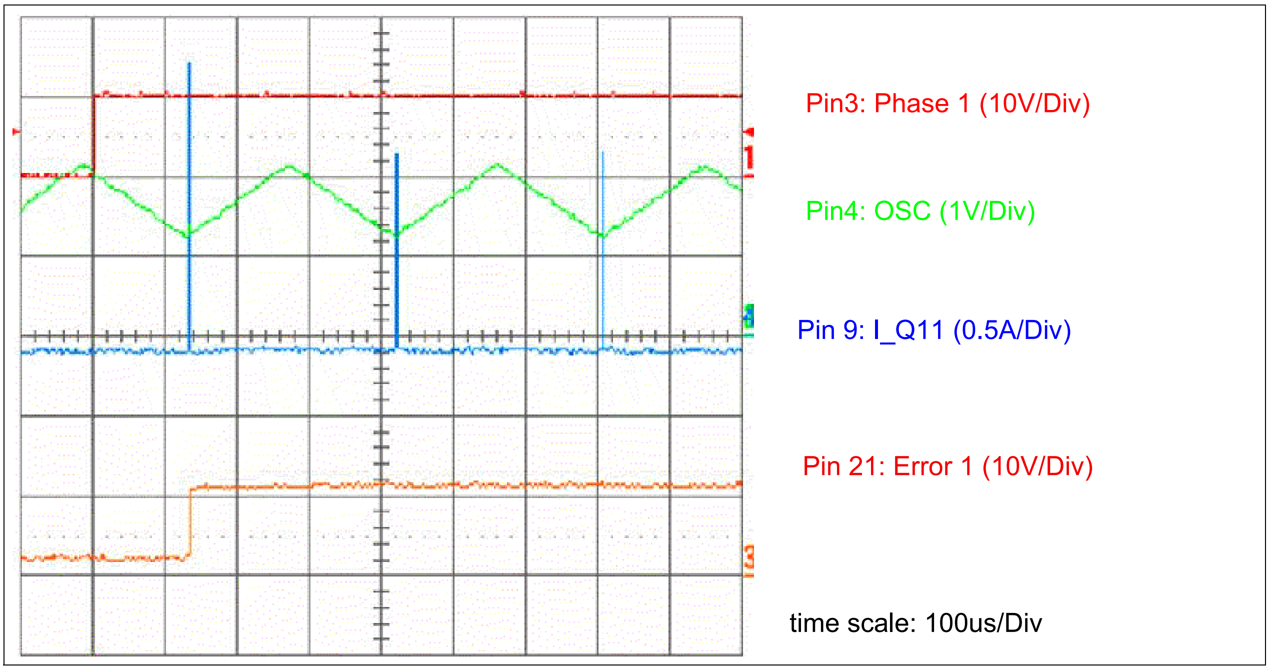

Figure 20 Current spikes inline with the oscillator frequency create flyback voltage => EF1 reset (short circuit close to the load, cable length 50cm)

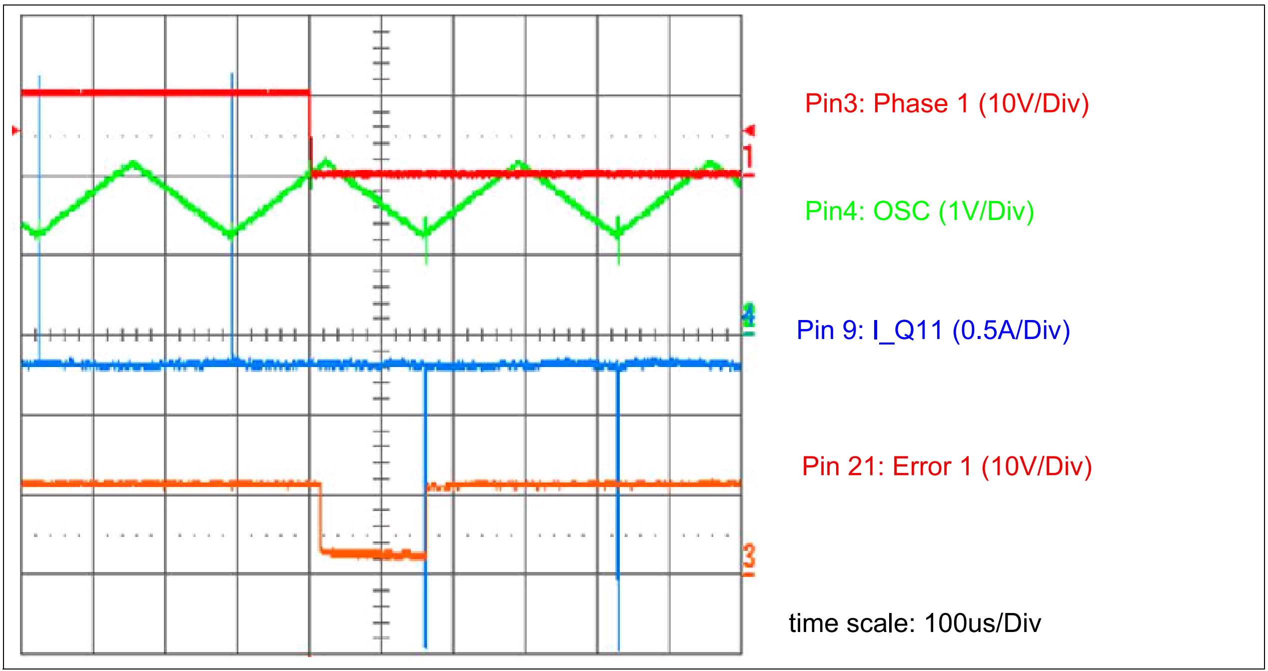

Figure 21 Error Flag 1 is set after t_{PEol}(typ.15us)... and reset due to current spike (short circuit close to the load, cable length 50cm)

5 Conclusion

This application note described the error signal behavior for TLE4729G in case of Open Load, Short circuit to GND, Short circuit to V_s and Short circuit across the load. Special attentation were paid on the influence of parasitic wire harness in case of short circuit as well as some specific device behavior due to inhibit mode.

6 Additional Information

Literature:

[1] Application Note ANPS063E, "TLE472X Family Stepper Motor Drivers - Current Control Method and Accuracy", V1.0, August 2001

[2] Datasheet TLE4729G, 2005-01-17

Abbreviations:

V_S	supply voltage
tP_{EoI}	Error Output Timing: Delay Phase X to Error 1
EF X	error flag X
V_{FU}	forward voltage of freewheeling diode
SOA	Safe Operating Area
C_{OSC}	external capacitor on pin 4 (usally 2.2nF for f=25kHz)

- For further information you may contact **http://www.infineon.com/**

7 Revision History

TLE4729G

Revision History:	**2008-01-21**	1.1
Previous Version:	1.0	
Page	Subjects (major changes since last revision)	
4	Fig.2 Schematic changed (logic OR instead of logic AND for Reset the Flip Flop)	

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