Bridge driver IC / TLE7184F

Power dissipation calculation

Application Note

Rev. 1.0, 2010-09-30

Automotive Power

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 a description of the power dissipation within the bridge driver IC TLE7184F.

It should help the user to investigate the thermal conditions within the bridge driver and allows to judge if the chip temperature stays below the maximum rating provided in the datasheet.

It is assumed that the user knows the data sheet of the driver IC TLE7184F and its functions.

The application note is not meant to explain the functions of the driver IC.

2 Introduction

Typical applications for the bridge driver IC TLE7184F are automotive 3-phase motor drives such as engine cooling fan, HVAC fan or pump applications or any other 3-phase motor application in the 12V power net.

Please study the datasheet of the device before you read this application note.

Many automotive applications have a quite high ambient temperature, so that the customer has to be carefully cooling his PCB. A detailed power dissipation calculation is necessary for:

- the judgement if the chip temperature stays below the maximum rating provided in the datasheet
- the design of the cooling features of the PCB.

This application note should help the designer using the TLE7184F within his application, to calculate the power dissipation within the device.

In addition to this application note, an Excel-sheet can be downloaded, to calculate the power dissipation. This application note describes the Excel-sheet and provides back ground information to the formulas used in this sheet.

3 The calculation of power dissipation

To determine the power dissipation within the TLE7184F starts first with the identification of the features within the device contributing to the power dissipation.

3.1 Features contributing to the power dissipation

There are mainly two features contributing to the power dissipation of the TLE7184F:

- The linear voltage regulator VDD providing a 5V supply for external components like the µC
- The bridge driver functionality

Beside these two main contributors, other features can be considered in the power dissipation calculation, like

- Current drawn at the ERR pin
- Current drawn at the ISO pin
- Current at the VDHS pin
- Current at the DT pin
- Current drawn at the IFuC, the INHD and the TEMP pin

First the two main contributors will be investigated.

3.2 The linear voltage regulator VDD

The integrated voltage regulator VDD is providing a 5V supply for external components like an µC or voltage dividers or other loads.

The current consumption out of this pin is application specific and will determine the power dissipation, described by the following formula:

$$P_{DIS} = (V_{VS} - 5V) * I_{VDD}$$

with

P_{DIS} is the power dissipation inside the TLE7184F

V_{VS} is the voltage at the supply pin VS

$5V$ is the output voltage of the regulator

I_{VVD} is the load current drawn out of the regulator

Beside the VDD regulator the bridge driver is responsible for the main power dissipation.

3.3 The bridge driver function

To determine the power dissipation caused by the bridge driver function, the gate current has to be calculated, which flows to the gates of the MOSFETs.

The following equation can be used:

$$I_{Gate} = n * Q_{gtot} * f_{PWM}$$

with

I_{Gate} is the current flowing to the MOSFET gate

n is the number of MOSFETs switched with f_{PWM}

Q_{gtot} is the total gate charge of the MOSFET

f_{PWM} is the switching frequency

The total gate charge can be found in every MOSFET datasheet. It is dependent to which voltage level the gate of the MOSFETs is charged. The TLE7184F is charging the MOSFET gates normally to voltages between 10 and 11V.

If a space vector modulation is chosen to drive the motor, normally all 6 MOSFETs of the B6 bridge are switching with the same frequency.

This is different when a BLDC motor is driven with a classical block commutation. In this case normally 4 MOSFETs are switching at a lower frequency determined by the rotor speed. Only 2 MOSFETs are switching fast to limit the motor current. In this case the formula has to be adapted slightly to:

$$I_{Gate} = n_1 * Q_{gtot} * f_{PWM1} + n_2 * Q_{gtot} * f_{PWM2}$$

with

I_{Gate} is the current flowing to the MOSFET gate

n_1 is the number of MOSFETs switched with f_{PWM1}

Q_{gtot} is the total gate charge of the MOSFET

f_{PWM1} is the lower switching frequency

n_2 is the number of MOSFETs switched with f_{PWM2}

f_{PWM2} is the higher switching frequency

In addition to the current which is flowing directly to the MOSFET gates, the TLE7184F consumes internally current for its own operation.

This current is specified in the datasheet with the parameter $I_{VS(0)}$:

4.2.3	Supply current at VS (device enabled)	$I_{VS(0)}$	–	19	mA	V_s=8...18V; no load[3]; f_{PWM}=25kHz;

This is the current consumption of the TLE7184F in normal operation without any loads like external MOSFETs and other loads at the following pins: VDD, ERR, ISO, IFµC, VDHS, GXX, TEMP DT. This current $I_{VS(0)}$ has to be added to the gate current calculated above.

The power dissipation for the gate driver functionality is therefore:

$$P_{DIS} = \left[I_{VS(0)} + \left(n_1 * Q_{gtot} * f_{PWM1} + n_2 * Q_{gtot} * f_{PWM2}\right)\right] * V_{VS}$$

In the following chapters, it is shown how additional loads have to be considered

3.4 The ERR pin

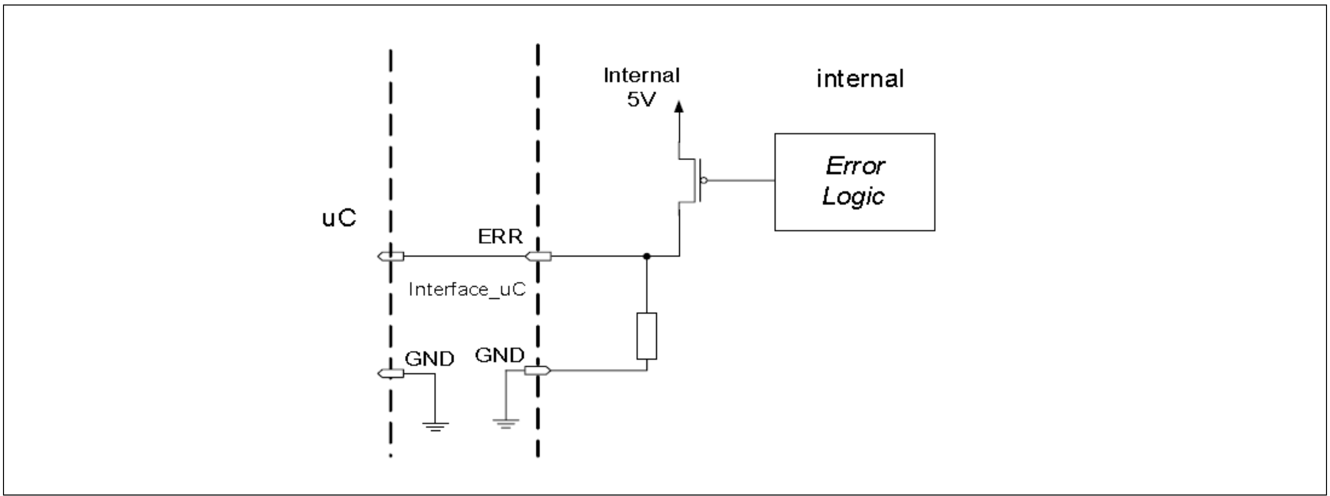

Figure 1 Normal ERR pin configuration

Under normal conditions the ERR pin is set to 5V to indicate that no error condition is given.

Figure 1 shows the internal structure of the ERR pin. It can be seen that the internal pull down resistor will consume current when the ERR pin is set to high. This current is already included in the $I_{VS(0)}$ current. Only current caused by additional external loads have to be considered as additional power dissipation in the driver.

Such an additional load could be for example an external pull down resistor.

If such an external load is given, the equation for the additional power dissipation would be:

$$P_{DIS} = I_{ERR} * V_{VS}$$

with

P_{DIS} is the additional power dissipation

I_{ERR} is the additional current drawn by an external load from the ERR pin.

V_{VS} is the supply voltage at the VS pin

In **Figure 1** there is no external load present, because the µC input would have a high impedance.

3.5 The ISO pin

If the OpAmp of the TLE7184F is used, the ISO pin, which is the output pin of the OpAmp, is loaded with an additional current I_{ISO}. This current is normally flowing via R_{fb1} and R_{S2} to GND. Please compare with **Figure 2**. This current will vary with the output voltage at the ISO pin. In addition current will flow to charge external capacitors at the ISO pin, if the ISO voltage rises. Both currents are coming from the VS pin and contribute to the power dissipation.

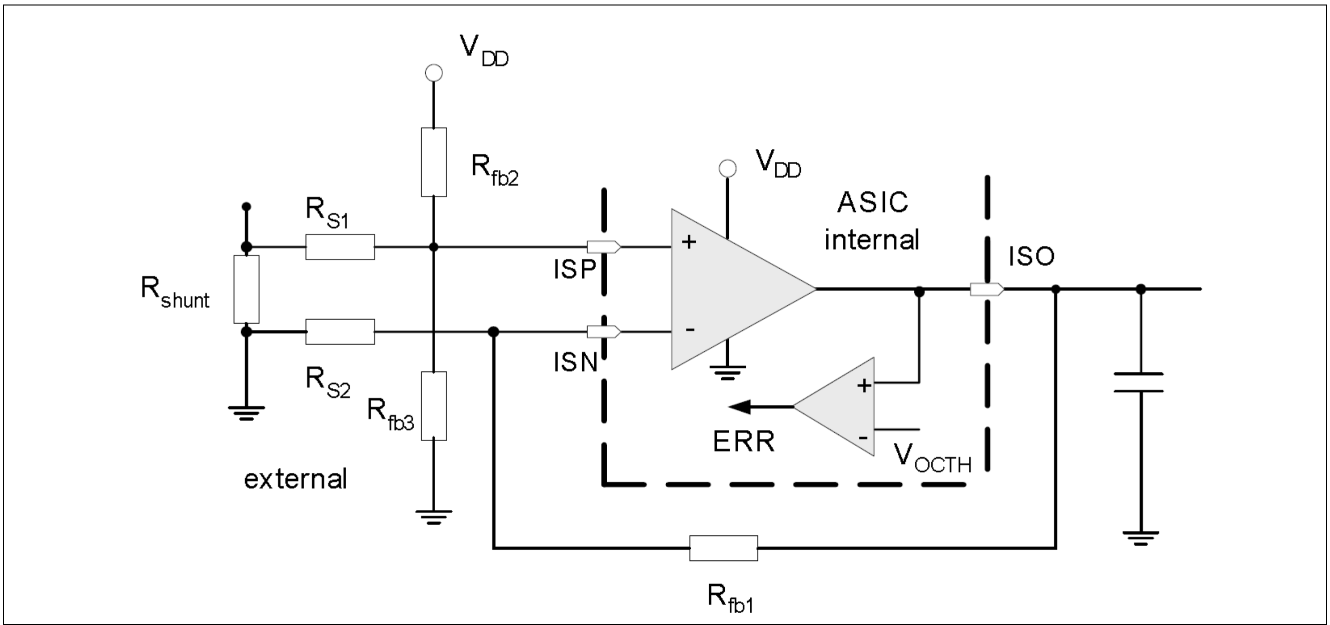

Figure 2 The usual OpAmp configuration

In reality it might be difficult to determine these currents. One approach could be to use the worst case static current which can be calculated with:

$$I_{ISO} = \frac{5V}{\left(R_{fb1} + R_{S2}\right)}$$

The power dissipation would be:

$$P_{DIS} = I_{ISO} * V_{VS}$$

with

P_{DIS} is the additional power dissipation

I_{ISO} is average current drawn from the ISO pin.

V_{VS} is the supply voltage at the VS pin

3.6 The DT pin

The DT pin is used to program the dead time of the driver. At this pin normally a dead time resistor is placed and connected to GND. If the dead time resistor is higher than 10kΩ, the DT pin is internally regulated to about 1.6V. This allows to calculate the current flowing over the dead time resistor R_{DT}.

The additional power dissipation can be calculated:

$$P_{DIS} = \frac{1.6V}{R_{DT}} * V_{VS}$$

with

P_{DIS} is the additional power dissipation

R_{DT} is the dead time resistor placed between the DT pin and GND

V_{VS} is the supply voltage at the VS pin

The use of dead time resistors with lower resistance as 10kΩ is not recommended, because the dead time will not be significantly shorter, but the current consumption will increase.

3.7 The pin VDHS

Between the pins VS and VDHS there is a high side switch. This switch allows to drive external voltage dividers. If the driver IC goes into the sleep mode, the high side switch is switched off and allows to disconnect the voltage dividers from the battery to reach low quiescent targets.

This switch is a MOSFET and therefore the power dissipation in the switch can be calculated with

$$P_{DIS} = R_{DSon} * I_{VDHS}^2$$

with

P_{DIS} is the additional power dissipation

R_{DSon} is the on-resistance of the integrated MOSFET (max 150 Ω)

I_{VDHS} is the current drawn by external components from VDHS

As the current I_{VDHS} is normally not very high, it is acceptable to calculate with the worst case R_{DSon}.

3.8 The pins IFuC, INHD and TEMP

The IFuC is the output pin of the interface to the µC. Normally there is no significant external load to be driven as the µC port has an high impedance.

The power dissipation can be calculated with:

$$P_{DIS} = I_{IFuC} * V_{VS}$$

with

P_{DIS} is the additional power dissipation

I_{IFuC} is external current drawn from the IFuC pin.

V_{VS} is the supply voltage at the VS pin

The INHD output is a weak digital output. It is not designed for higher load currents. Normally it is directly connected to a µC input.

The TEMP pin is an analog output which is quite weak. It is not recommended to place additional pull down resistors or similar loads to the pin. A capacitor can be placed at this output.

Therefore it is not necessary to take these pins into account for the power dissipation calculation.

4 Summary

The formula shown in **Chapter 3** are used to create an Excel sheet which allows to calculate the power dissipation of the TLE7184F easily.

The total power dissipation is the sum of all components shown in **Chapter 3**.

The maximum chip temperature can be determined by a measurement of the PCB temperature below the VQFN package of the driver. Normally the PCB below the driver has thermal vias. Therefore the backside of the PCB has nearly the same temperature as the case (= pad) of the VQFN exposed pad package.

The R_{th} of the package is lower than 5K/W. The chip temperature is than:

$$T_J = T_{PCB} + R_{thJC} * P_{DIStot}$$

with

T_{J} is the chip temperature

T_{PCB} is the temperature of the PCB below the exposed pad of the package

R_{thJC} is the R_{th} between the chip and the case of the TLE7184F

P_{DIStot} is the total power dissipation in the TLE7184F

If you have additional questions, please contact your Infineon sales channel.

5 Revision History

TLE7184F

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Previous Version(s):
Rev. none

Page	Subjects (major changes since last revision)

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