

# TLE7183F

Automotive Power



Never stop thinking

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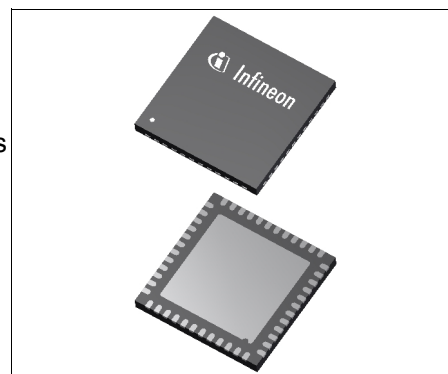
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## 1 Overview

### Features

- Compatible to very low ohmic normal level input N-Channel MOSFETs
- Separate input for each MOSFET
- PWM frequency up to 30kHz
- Fulfills specification down to 5.5V supply voltage
- Low EMC sensitivity and emission
- VQFN-48 package with exposed heat slug
- Control inputs with TTL characteristics
- Separate source connection for each MOSFET
- Integrated minimum dead time
- Shoot through protection
- Short circuit protection with 5 fixed detection level available
- Disable function and sleep mode
- Detailed diagnosis
- Thermal overload warning for driver IC
- integrated overcurrent warning
- Integrated current sense amplifier
- 0 to 100% duty cycle
- Green Product (RoHS compliant)
- AEC Qualified



**PG-VQFN-48**

### Description

The TLE7183F is a driver IC dedicated to control the 6 to 12 external MOSFETs forming the converter for high current 3 phase motor drives in the automotive sector. It incorporates features like short circuit detection, diagnosis and high output performance and combines it with typical automotive specific requirements like full functionality even at low battery voltages. Its 3 high side and 3 low side output stages are powerful enough to drive MOSFETs with 400nC gate charge with approx. 150 ns fall and rise times.

The TLE7183F can be ordered with 5 different options for a fixed short circuit detection level. Please see [Table 2](#) for detailed information.

Typical applications are cooling fan, water pump, electro-hydraulic and electric power steering. The TLE7183F is designed for 12 Vpower net.

Type	Options	Package	Marking
TLE7183F	SCD1	PG-VQFN-48	TLE7183SCD1
TLE7183F	SCD2	PG-VQFN-48	TLE7183SCD2
TLE7183F	SCD3	PG-VQFN-48	TLE7183SCD3
TLE7183F	SCD4	PG-VQFN-48	TLE7183SCD4
TLE7183F	SCD5	PG-VQFN-48	TLE7183SCD5

## 2 Block Diagram

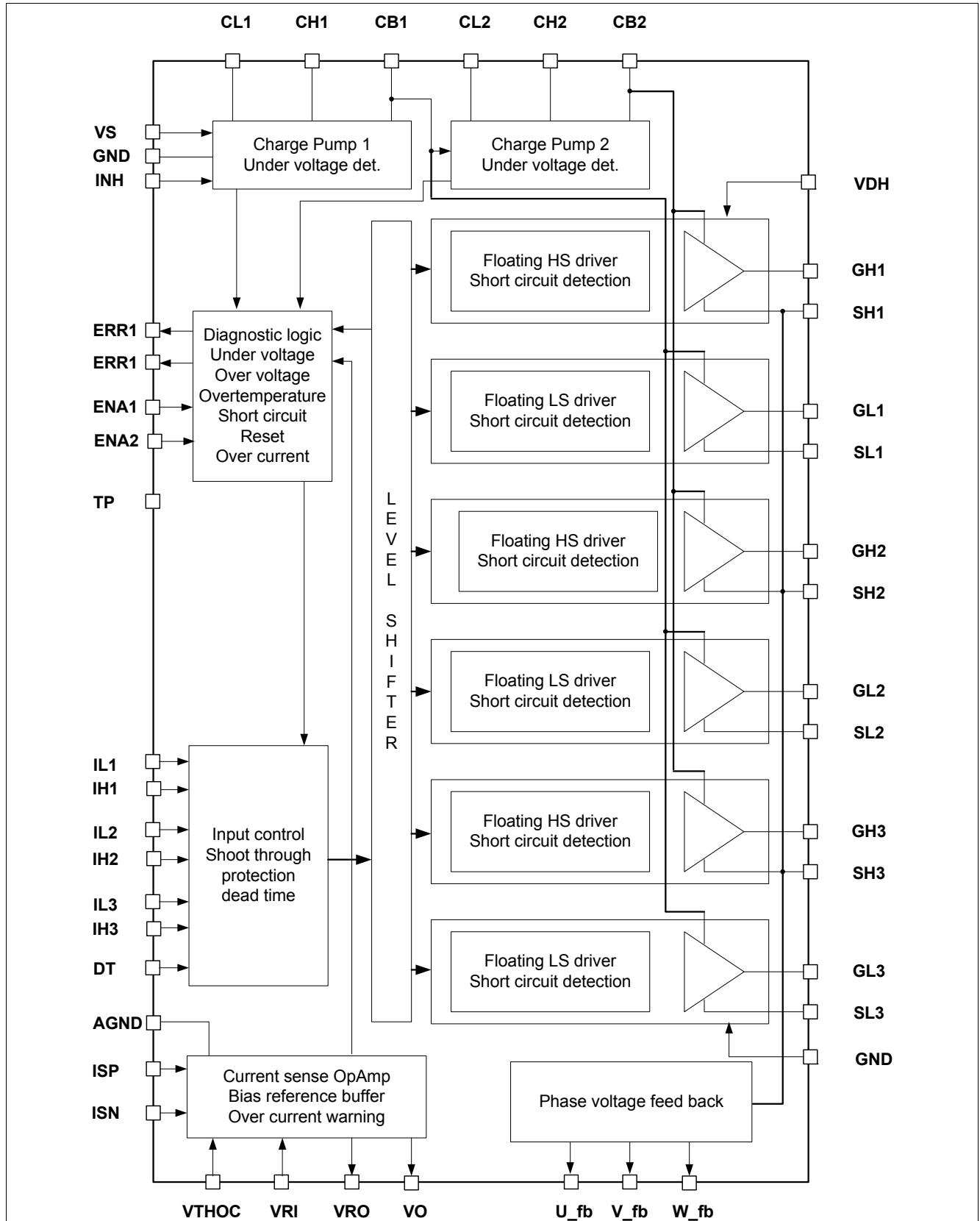
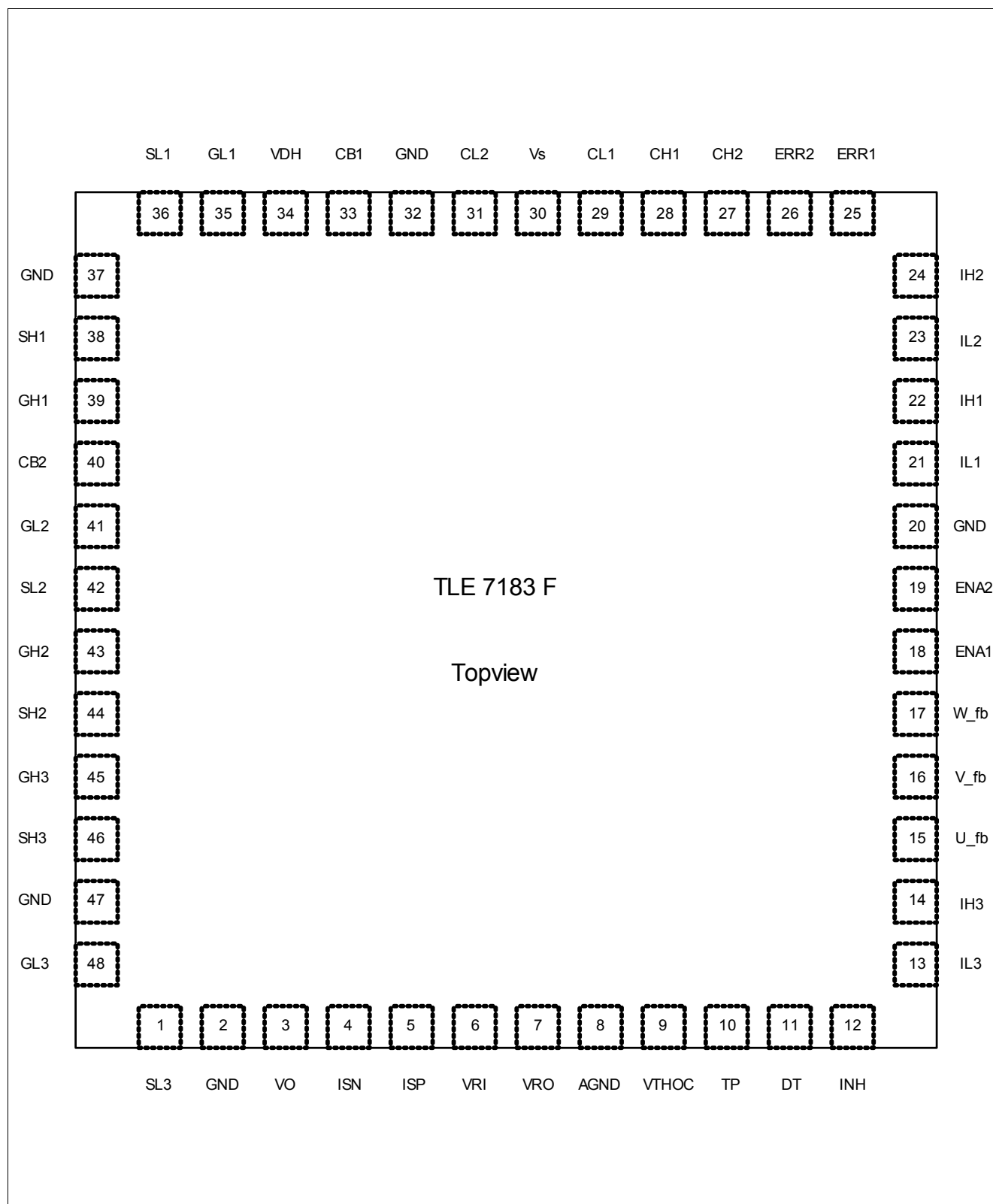


Figure 1 Block Diagram

### 3 Pin Configuration

#### 3.1 Pin Assignment TLE7183F



**Figure 2 Pin Configuration**

### 3.2 Pin Definitions and Functions

Pin	Symbol	Function
1	SL3	Connection to source low side switch 3
2	GND	Logic and power ground
3	VO	Output of OpAmp for shunt signal amplification
4	ISN	- Input of OpAmp for shunt signal amplification
5	ISP	+ Input of OpAmp for shunt signal amplification
6	VRI	Input of bias reference amplifier
7	VRO	Output of bias reference amplifier
8	AGND	Analog ground especially for the current sense OpAmp
9	VTHOC	Threshold voltage for overcurrent detection
10	TP	test pin, connect to GND of driver IC
11	DT	Dead time program pin
12	INH	Inhibit pin (active low)
13	IL3	Input for low side switch 3 (active high)
14	IH3	Input for high side switch 3 (active low)
15	U_fb	Digital logic representation of the voltage phase U; positive logic
16	V_fb	Digital logic representation of the voltage phase V; positive logic
17	W_fb	Digital logic representation of the voltage phase W; positive logic
18	ENA1	Enable pin (active high)
19	ENA2	Enable pin (active high)
20	GND	Logic and power ground
21	IL1	Input for low side switch 1 (active high)
22	IH1	Input for high side switch 1 (active low)
23	IL2	Input for low side switch 2 (active high)
24	IH2	Input for high side switch 2 (active low)
25	ERR1	Error signal 1
26	ERR2	Error signal 2
27	CH2	+ terminal for pump capacitor of charge pump 2
28	CH1	+ terminal for pump capacitor of charge pump 1
29	CL1	- terminal for pump capacitor of charge pump 1
30	VS	Voltage supply
31	CL2	- terminal for pump capacitor of charge pump 2
32	GND	Logic and power ground
33	CB1	Buffer capacitor for charge pump 1
34	VDH	Connection to drain of high side switches for short circuit detection
35	GL1	Output to gate low side switch 1
36	SL1	Connection to source low side switch 1
37	GND	Logic and power ground
38	SH1	Connection to source high side switch 1
39	GH1	Output to gate high side switch 1
40	CB2	Buffer capacitor for charge pump 2

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**Pin Configuration**

<b>Pin</b>	<b>Symbol</b>	<b>Function</b>
41	GL2	Output to gate low side switch 2
42	SL2	Connection to source low side switch 2
43	GH2	Output to gate high side switch 2
44	SH2	Connection to source high side switch 2
45	GH3	Output to gate high side switch 3
46	SH3	Connection to source high side switch 3
47	GND	Logic and power ground
48	GL3	Output to gate low side switch 3

## 4 General Product Characteristics

### 4.1 Absolute Maximum Ratings

#### Absolute Maximum Ratings <sup>1)</sup>

40 °C ≤  $T_j$  ≤ 150 °C; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Pos.	Parameter	Symbol	Limit Values		Unit	Conditions
			Min.	Max.		
Voltages						
4.1.1	Supply voltage	$V_S$	-4.0	45	V	with 10Ohm and 1μF
4.1.2	Supply voltage	$V_S$	-0.3	45	V	–
4.1.3	Supply voltage	$V_S$	-0.3	47	V	$t_p$ <200ms
4.1.4	Voltage range at IHx,ILx,ERRx, VO, DT, VTHOC, ENAx, VRI, VRO	$V_{DP}$	-0.3	6.0	V	–
4.1.5	Voltage range at INH	$V_{INH}$	-0.3	18.0	V	–
4.1.6	Voltage range at TP	$V_{TP}$	-0.3	2	V	
4.1.7	Voltage range at SLx	$V_{SL}$	-7	7	V	–
4.1.8	Voltage range at SHx	$V_{SH}$	-7	45	V	–
4.1.9	Voltage range at GLx	$V_{GL}$	-7	18	V	–
4.1.10	Voltage range at GHx	$V_{GH}$	-7	55	V	–
4.1.11	Voltage difference Gxx-Sxx	$V_{GS}$	-0.3	15	V	–
4.1.12	Voltage range at VDH	$V_{VDH}$	-0.3	55	V	INH=high
4.1.13	Voltage range at VDH	$V_{VDH}$	-4.0	55	V	INH=high; with $R_{VDH} > 70\Omega$ ; 200ms, 5x
4.1.14	Voltage range at VDH	$V_{VDH}$	-0.3	28	V	INH=low
4.1.15	Voltage range at VDH	$V_{VDH}$	-4.0	28	V	INH=low; with $R_{VDH} > 70\Omega$ ; 200ms, 5x
4.1.16	Voltage range at CL1	$V_{CL1}$	-0.3	25	V	–
4.1.17	Voltage range at CH1, CB1	$V_{CH1}$	-0.3	25	V	–
4.1.18	Voltage difference CH1-CL1	$V_{DC1}$	-0.3	25	V	–
4.1.19	Voltage range at CL2	$V_{CL2}$	-0.3	25	V	–
4.1.20	Voltage range at CH2, CB2	$V_{CH2}$	-0.3	45	V	–
4.1.21	Voltage difference CH2-CL2	$V_{CP2}$	-0.3	25	V	–
4.1.22	Voltage range at ISP, ISN	$V_{ISI}$	-5	5	V	–
4.1.23	Output current range at VO	$I_{VO}$	-20	20	mA	–
4.1.24	Gate resistor	$R_{Gate}$	2	–	Ω	–
Temperatures						
4.1.25	Junction temperature	$T_j$	-40	150	°C	–
4.1.26	Storage temperature	$T_{stg}$	-55	150	°C	–
4.1.27	Lead soldering temperature (1/16” from body)	$T_{sol}$	–	260	°C	–



## General Product Characteristics

**Absolute Maximum Ratings** (cont'd)<sup>1)</sup>

40 °C ≤ T<sub>j</sub> ≤ 150 °C; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Pos.	Parameter	Symbol	Limit Values		Unit	Conditions
			Min.	Max.		
4.1.28	Peak reflow soldering temperature <sup>2)</sup>	T <sub>ref</sub>	–	260	°C	–

**Thermal Resistance**

4.1.29	Junction to case	R <sub>thjC</sub>	–	5	K/W	–
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**Power Dissipation**

4.1.30	Power Dissipation (DC) @ TCASE=125°C	P <sub>tot</sub>	–	2	W	–
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**ESD Susceptibility**

4.1.31	ESD Resistivity <sup>3)</sup>	V <sub>ESD</sub>	–	2	kV	
4.1.32	ESD Resistivity (charge device model) <sup>4)</sup>	V <sub>ESD</sub>	–	750	V	

1) Not subject to production test, specified by design.

2) Reflow profile IPC/JEDEC J-STD-020C

3) ESD susceptibility HBM according to EIA/JESD 22-A 114B

4) ESD susceptibility CDM according to EIA/JESD 22-C 101

**Attention: Stresses above the ones listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.**

**Attention: Integrated protection functions are designed to prevent IC destruction under fault conditions described in the data sheet. Fault conditions are considered as “outside” normal operating range. Protection functions are not designed for continuous repetitive operation.**

## 4.2 Functional Range

Pos.	Parameter	Symbol	Limit Values		Unit	Conditions
			Min.	Max.		
4.2.1	Supply voltage <sup>1)2)</sup>	V <sub>S</sub>	5.5 5.5	20 28	V	DC t<1s
4.2.2	Duty cycle <sup>3)</sup>	D	0	100	%	–
4.2.3	PWM frequency	F <sub>PWM</sub>	0	25	kHz	Total gate charge 400nC
4.2.4	Quiescent current <sup>4)</sup>	I <sub>Q</sub>	–	30	µA	V <sub>S</sub> , V <sub>DH</sub> <20 V
4.2.5	Quiescent current into VDH	I <sub>Q_VDH</sub>	–	30	µA	V <sub>DH</sub> <20V; V <sub>S</sub> pin open
4.2.6	Supply current at Vs	I <sub>Vs</sub>	– –	175 175 110 110	mA	F <sub>PWM</sub> =25kHz Q <sub>G</sub> =250nC: V <sub>S</sub> = 5.5V V <sub>S</sub> = 14V V <sub>S</sub> = 17V V <sub>S</sub> = 20V
4.2.7	Supply current at Vs(device disabled by ENA)	I <sub>Vs(o)</sub>	–	60 50	mA	Vs=5.5V..17V Vs=17V..20V
4.2.8	Current into VDH (device not in sleep mode)	I <sub>VDH</sub>		1.5	mA	V <sub>VDH</sub> =5.5..20V INH=high

## General Product Characteristics

Pos.	Parameter	Symbol	Limit Values		Unit	Conditions
			Min.	Max.		
4.2.9	Voltage difference CB2-VDH	$V_{CB2}$	-0.3	25	V	Operation mode
4.2.10	Junction temperature	$T_j$	-40	150	°C	

- 1) max ratings for  $T_j$  has to be considered as well
- 2) For proper start up minimum  $V_s=6.5V$  is required
- 3) Duty cycle is referred to the high side input command (IHx); The duty cycles can be driven continuously and fully operational
- 4) total current consumption from power net ( $V_s$  and VDH)

*Note: Within the functional range the IC operates as described in the circuit description. The electrical characteristics are specified within the conditions given in the related electrical characteristics table.*

### 4.3 Default State of Inputs

**Table 1 Default State of Inputs**

Characteristic	State	Remark
Default state of ILx (if ILx left open)	Low	Low side MOSFETs off
Default state of IHx (if IHx left open)	High	High side MOSFETs off
Default state of ENA (if ENA1 left open)	Low	Device outputs disabled
Default state of ENA (if ENA2 left open)	Low	Device outputs disabled
Default state of INH (if INH left open)	Low	Sleep mode, $I_Q < 30 \mu A$
Default State of sense amplifier output $V_O$ (ISP=ISN=0V)	Zero ampere equivalent	–
Status of the device and the outputs when ENA1=ENA2=INH='1'	Device active and outputs functional	$V_s=5.5..28V$
Pull up or pull down integrated resistors Ixx, ENA	$30k\Omega \pm 40\%$	–
Pull down integrated resistor INH	$45k\Omega \pm 40\%$	–

*Note: The load condition " $C=22nF$ ;  $R_{Load}=1\Omega$ " in the paragraph "Electrical characteristics / Dynamic charactersitic" means that  $R_{Load}$  is connected between the output Gxx and the positive terminal of the C. The negative terminal of the C is connected to GND and the corresponding Sxx. The voltage is measured at the positive terminal of the C.*

## 5 Description and Electrical Characteristics

### 5.1 MOSFET Driver

#### 5.1.1 Output Stages

The 3 low side and 3 high side powerful push-pull output stages of the TLE7183F are all floating blocks, each with its own source pin. This allows the direct connection of the output stage to the source of each single MOSFET, allowing a perfect control of each gate-source voltage even when 200A are driven in the bridge with rise and fall times clearly below 1 $\mu$ s.

All 6 output stages have the same output power and thanks to the used charge pump principle they can be switched all up to 30kHz.

Its output stages are powerful enough to drive MOSFETs with 400nC gate charge with approx. 150ns fall and rise times or even to run 12 MOSFETs with 200nC each with fall and rise times of approx. 150ns.

Maximum allowed power dissipation, max. junction temperature and the limited current capabilities of the charge pump limit the use for higher frequencies.

Each output stage has its own short circuit detection block. For more details about short circuit detection see [Chapter 5.2.1](#).

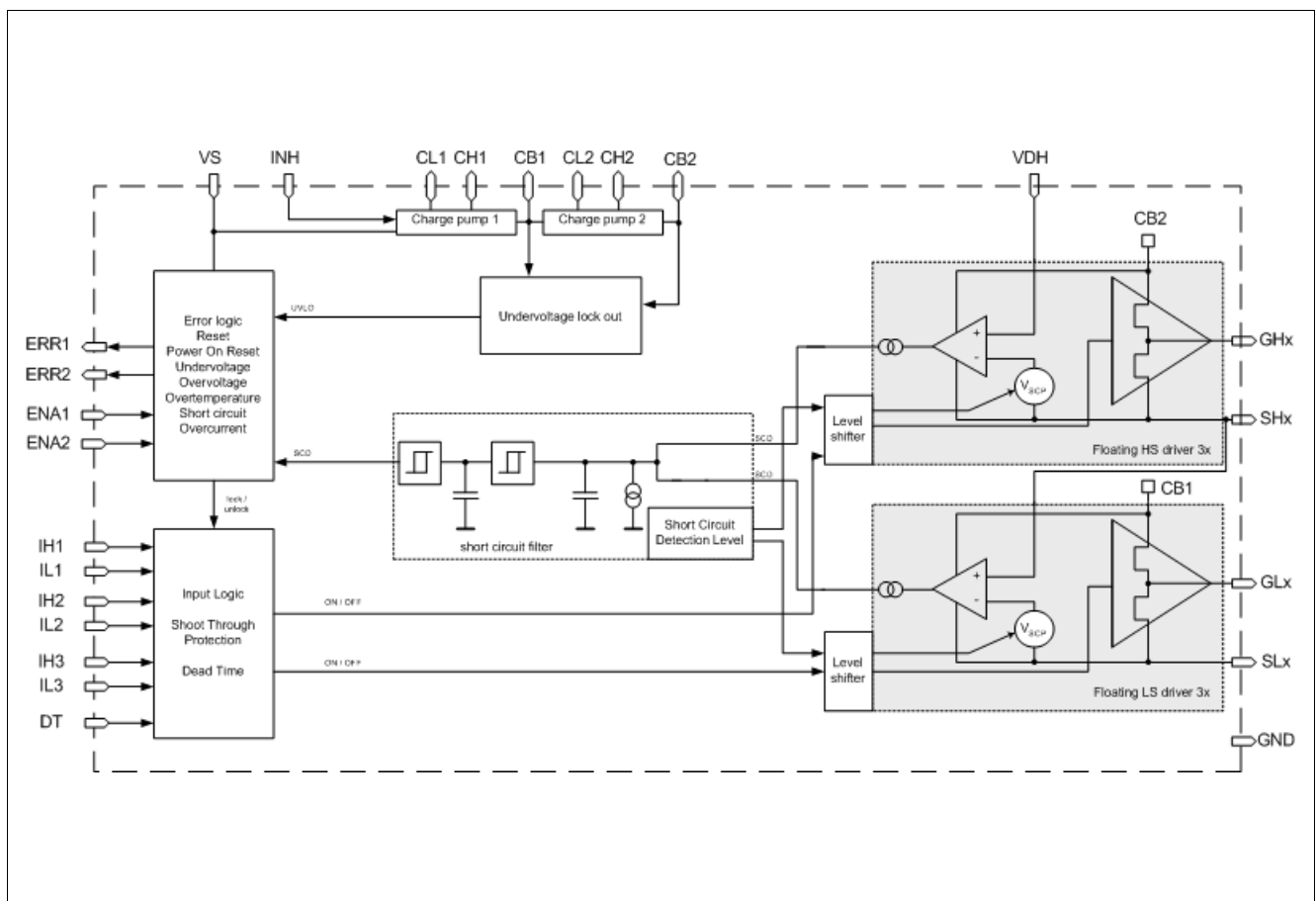


Figure 3 Block Diagram of Driver Stages including Short Circuit Detection

### 5.1.2 Operation at $V_s < 12V$ - Integrated Charge Pumps

The TLE7183F provides a feature tailored to the requirements in 12V automotive applications. Often the operation of an application has to be assured even at 9V supply voltage or lower. Normally bridge driver ICs provide in such conditions clearly less than 9V to the gate of the external MOSFETs, increasing their  $R_{DSon}$  and the associated power dissipation.

The TLE7183F has two charge pump circuitries for external capacitors.

The operation of the charge pumps is independent upon the pulse pattern of the MOSFETs.

The output of the charge pumps are regulated. The first charge pump doubles the supply voltage as long as it is below 8V. At 8V supply voltage and above, charge pump 1 regulates its output to 15V typically. Above 15V supply voltage, the output voltage of charge pump 1 will increase linearly. Yet, the output will not exceed 25V.

Charge pump 2 is regulated as well but it is pumped to the voltage on  $V_s$ . Normally  $VDH$  and  $V_s$  are in the same voltage range. The driver is not designed to have significant higher voltages at  $VDH$  compared to  $V_s$ . This would lead to reduced supply voltages for the high side output stages.

Charge pump 1 supplies the low side MOSFETs and output stages for the low side MOSFETs with sufficient voltage to assure 10V at the MOSFETs' gate even if the supply voltage is below 10V. Charge pump 2 supplies the output stages for the high side MOSFETs with sufficient voltage to assure 10V at the MOSFETs' gate. In addition, the charge pump 1 supplies most of the internal circuits of the driver IC, including charge pump 2. Output of charge pump 1 is the buffer capacitor CB1 which is referenced to GND.

Charge pump 2 supplies the high side MOSFETs and the output stages for the high side MOSFETs with sufficient voltage to assure 10V at the high side MOSFET gate. Output of charge pump 2 is buffer capacitor CB2 which is referenced to  $VDH$ .

This concept allows to drive all external MOSFETs in the complete duty cycle range of 0 to 100% without taking care about recharging of any bootstrap capacitors.

This simplifies the use in all applications especially in motor drives with block wise commutation.

The charge pumps are only deactivated when the device is put into sleep mode via INH.

During Start Up of the device it is not allowed to have any PWM patterns at the  $ILx$  and  $IHx$  pins until the charge pumps have ramped up to their final values or it is recommended to keep one  $ENAx$  pin low. So for proper Wake Up at  $V_{sWU}$  the output stages of the driver IC have to be switched off or one  $ENAx$  pin has to be kept low.

The size of the charge pump capacitors (pump capacitors  $CPx$  as well as buffer capacitors  $CBx$ ) can be varied between 1  $\mu F$  and 4.7  $\mu F$ . Yet, larger capacitor values result in higher charge pump voltages and less voltage ripple on the charge pump buffer capacitors  $CBx$  (which supply the internal circuits as well as the external MOSFETs, pls. see above). Besides the capacitance values the ESR of the buffer capacitors  $CBx$  determines the voltage ripple as well. It is recommended to use buffer capacitors  $CBx$  that have small ESR.

Pls. see also [Chapter 5.1.3](#) for capacitor selection.

### 5.1.3 Sleep Mode

When the INH pin is set to low, the driver will be set to sleep mode. The INH pin switches off the complete supply structure of the device and leads finally to an undervoltage shut down of the complete driver. Enabling the device with the INH pin means to switch on the supply structure. The device will run through power on reset during wake up. It is recommended to perform a Reset by  $ENA$  after Wake up to remove possible ERR signals; Reset is performed by keeping one or more  $ENA$  pins low until the charge pump voltages have ramped up.

Enabling and disabling with the INH pin is not very fast. For fast enable / disable the  $ENA$  pin is recommended.

When the TLE 7183 F is in INH mode (INH is low) or when the supply voltage is not available on the  $V_s$  pin, then the driver IC is not supplied, the charge pumps are inactive and the charge pump capacitors are discharged. Pin CB2 (+ terminal of buffer capacitor 2) will decay to GND. When the battery voltage is still applied to  $VDH$  (- terminal of buffer capacitor 2) the buffer capacitor 2 will slowly charged to battery voltage, yet with reversed polarity compared to the polarity during regular operation. Hence, it is important to use a buffer capacitor 2 (CB2) that can

## Description and Electrical Characteristics

withstand both, +25 V during operation mode and  $-V_{BAT}$  during INH mode, e.g. a ceramic capacitor. In case of load dump during INH mode, the negative voltage across CB2 will be clamped to -31 V (CB2 referenced to VDH).

### 5.1.4 Electrical Characteristics

#### Electrical Characteristics MOSFET drivers - DC Characteristics

$V_S = 5.5$  to  $20V$ ,  $T_j = -40$  to  $+150^\circ C$ ,  $F_{PWM} < 25kHz$ , all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Pos.	Parameter	Symbol	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
5.1.1	Low level output voltage	$V_{G\_LL}$	—	—	0.2	V	$I=30mA$
5.1.2	High level output voltage, Low Side	$V_{G\_HL}$	7.5	—	13	V	$I=-2mA$ ; $V_S=5.5..8V$
5.1.3	High level output voltage, High Side	$V_{G\_HL}$	6.5	—	13	V	$I=-2mA$ ; $V_S=5.5..8V$
5.1.4	High level output voltage	$V_{G\_HL}$	9	—	13	V	$I=-2mA$ ; $V_S=8..20V$
5.1.5	High level output voltage difference	$dV_{G\_H}$	—	—	1.0	V	$I=-100mA$ ; $V_S=20V$
5.1.6	Gate drive output voltage (device disabled via ENAx)	$V_{G(DIS)}$	—	—	0.2	V	Disabled; $V_S=5.5..20V$ ; $I=10mA$
5.1.7	Gate drive output voltage $T_j=-40^\circ C$ $T_j=25^\circ C$ $T_j=150^\circ C$	$V_{G\_5}$	—	—	1.4 1.2 1.0	V	UVLO; $V_S \leq 5.5V$
5.1.8	Gate drive output voltage high side $T_j=-40^\circ C$ $T_j=25^\circ C$ $T_j=150^\circ C$	$V_{G\_HS}$	—	—	1.4 1.2 1.0	V	Overvoltage
5.1.9	Gate drive output voltage low side	$V_{G\_LS}$	—	—	0.2	V	Overvoltage
5.1.10	Low level input voltage of Ixx, ENAx	$V_{I\_LL}$	—	—	1.0	V	—
5.1.11	High level input voltage of Ixx, ENAx	$V_{I\_HL}$	2.0	—	—	V	—
5.1.12	Low level input voltage of INH	$V_{I\_LL}$	—	—	0.75	V	—
5.1.13	High level input voltage of INH	$V_{I\_HL}$	2.1	—	—	V	—
5.1.14	Input hysteresis of IHx, ILx, ENAx	$dV_I$	50	—	—	mV	$V_S=5.5..8V$
5.1.15	Input hysteresis of IHx, ILx, ENAx	$dV_I$	100	200	—	mV	$V_S=8..20V$
5.1.16	Output bias current SHx	$I_{SHx}$	0.3	1.0	1.6	mA	$V_{SHx}=0..(V_S+1)$ ; $I_{Lx}=low$ ; $I_{Hx}=high$
5.1.17	Output bias current SLx	$I_{SLx}$	0.3	1.0	1.6	mA	$V_{SLx}=0..7V$ ; $I_{Lx}=low$ ; $I_{Hx}=high$

## Description and Electrical Characteristics

## Electrical Characteristics MOSFET drivers - Dynamic Characteristics

$V_S = 5.5$  to  $20V$ ,  $T_j = -40$  to  $+150^\circ C$ ,  $F_{PWM} < 25kHz$ , all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Pos.	Parameter	Symbol	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
5.1.18	Min. internal dead time	$t_{DT\_MIN}$	50	–	200	ns	DT pin to GND ( $R_{DT}=0\Omega$ )
5.1.19	Programmable internal dead time	$t_{DT}$	0.26 0.64 1.07 2.02	0.41 1.05 1.85 3.82	0.56 1.45 2.63 5.62	$\mu s$	$R_{DT}=10\text{ k}\Omega$ $R_{DT}=47\text{ k}\Omega$ $R_{DT}=100\text{ k}\Omega$ $R_{DT}=1000\text{ k}\Omega$
5.1.20	Max. internal dead time	$t_{DT\_MAX}$	2.33	–	6.35	$\mu s$	DT pin open
5.1.21	Turn on current, peak	$I_{G(on)}$	–	0.8	–	A	$V_{Gxx}-V_{Sxx}=0V$ ; $V_S=5.5..8V$ ; $C=22nF$ ; $R_{Load}=1\Omega$
5.1.22	Turn on current, peak	$I_{G(on)}$	–	1.5	–	A	$V_{Gxx}-V_{Sxx}=0V$ ; $V_S=8..20V$ $C=22nF$ ; $R_{Load}=1\Omega$
5.1.23	Turn off current, peak	$I_{G(off)}$	–	1.5	–	A	$V_{Gxx}-V_{Sxx}=10V$ ; $V_S=8..20V$ $C=22nF$ ; $R_{Load}=1\Omega$
5.1.24	Rise time (20-80%) $T_j = -40^\circ C$ $T_j = 25^\circ C$ $T_j = 150^\circ C$	$t_{G\_rise}$	–	150	400 400 700	ns	$C=22nF$ ; $R_{Load}=1\Omega$
5.1.25	Fall time (20-80%) $T_j = -40^\circ C$ $T_j = 25^\circ C$ $T_j = 150^\circ C$	$t_{G\_fall}$	–	150	230 230 500	ns	$C=22nF$ ; $R_{Load}=1\Omega$
5.1.26	Input propagation time (low on)	$t_{P(ILN)}$	90	190	290	ns	$C=22nF$ ; $R_{Load}=1\Omega$
5.1.27	Input propagation time (low off)	$t_{P(ILF)}$	0	100	200	ns	$C=22nF$ ; $R_{Load}=1\Omega$
5.1.28	Input propagation time (high on)	$t_{P(IHN)}$	90	190	290	ns	$C=22nF$ ; $R_{Load}=1\Omega$
5.1.29	Input propagation time (high off)	$t_{P(IHF)}$	0	100	200	ns	$C=22nF$ ; $R_{Load}=1\Omega$
5.1.30	Absolute input propagation time difference (all channels turn on)	$t_{P(an)}$	–	–	70	ns	$C=22nF$ ; $R_{Load}=1\Omega$
5.1.31	Absolute input propagation time difference (all channels turn off)	$t_{P(af)}$	–	–	50	ns	$C=22nF$ ; $R_{Load}=1\Omega$
5.1.32	Absolute input propagation time difference (1channel high off - low on)	$t_{P(1hfin)}$	–	–	150	ns	$C=22nF$ ; $R_{Load}=1\Omega$
5.1.33	Absolute input propagation time difference (1channel low off - high on)	$t_{P(1hfn)}$	–	–	150	ns	$C=22nF$ ; $R_{Load}=1\Omega$

## Description and Electrical Characteristics

## Electrical Characteristics MOSFET drivers - Dynamic Characteristics

$V_S = 5.5$  to  $20V$ ,  $T_J = -40$  to  $+150^\circ C$ ,  $F_{PWM} < 25kHz$ , all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Pos.	Parameter	Symbol	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
5.1.34	Absolute input propagation time difference (all channel high off - low on)	$t_{P(ahfln)}$	–	–	150	ns	$C=22nF$ ; $R_{Load}=1\Omega$
5.1.35	Absolute input propagation time difference (all channel low off - high on)	$t_{P(alhfn)}$	–	–	150	ns	$C=22nF$ ; $R_{Load}=1\Omega$
5.1.36	Wake up time; INH low to high	$t_{INH\_Pen}$	–	–	20	ms	Driver fully functional; $V_S=6.5...8V$ ; $ENAx=low$ ; $CPx=CBx=4.7\mu F$
5.1.37	Wake up time; INH low to high	$t_{INH\_Pen}$	–	–	10	ms	Driver fully functional; $V_S=8...20V$ ; $ENAx=low$ ; $CPx=CBx=4.7\mu F$ ;
5.1.38	Wake up time logic functions; INH low to high	$t_{INH\_log}$	–	–	10	ms	diagnostic, OpAmp working; $V_S=6.5...8V$ ; $ENAx=low$ ; $CPx=CBx=4.7\mu F$
5.1.39	Wake up time logic functions; INH low to high	$t_{INH\_log}$	–	–	5	ms	diagnostic, OpAmp working; $V_S=8...20V$ ; $ENAx=low$ ; $CPx=CBx=4.7\mu F$
5.1.40	INH propagation time to disable the output stages	$t_{INH\_P(O)}$	–	–	10	$\mu s$	$V_S=5.5...8V$
5.1.41	INH propagation time to disable the output stages	$t_{INH\_P(O)}$	–	–	8	$\mu s$	$V_S=8...20V$
5.1.42	INH propagation time to disable the entire driver IC	$t_{INH\_P(IC)}$	–	–	300	$\mu s$	–
5.1.43	Supply voltage $V_S$ for Wake up	$V_{VSWU}$	6.5	–	–	V	diagnostic, OpAmp working;
5.1.44	Charge pump frequency	$f_{CP}$	38	55	72	kHz	–

## 5.2 Protection and Diagnostic Functions

### 5.2.1 Short Circuit Protection

The TLE7183F provides a short circuit protection for the external MOSFETs. It is a monitoring of the drain-source voltage of the external MOSFETs. As soon as this voltage is higher than the short circuit detection limit, a timer will start to run.

The short circuit detection level is programmed fix in the chip. 5 different short circuit level options are available:

**Table 2** Short circuit detection level options

TLE7183	typ. short circuit detection level
SCD1	0.5V
SCD2	0.75V
SCD3	1.0V
SCD4	1.5V
SCD5	2.0V

After a delay of about 6  $\mu$ s all external MOSFETs will be switched off until the driver is reset by the ENAx pin. The error flag is set.

The drain-source voltage monitoring of the short circuit detection for a certain external MOSFET is active as soon as the corresponding input is set to "on" and the dead time is expired.

### 5.2.2 Overcurrent Warning

The TLE7183F offers the possibility to shut down the output stages if a current threshold is reached. (see [Figure 4](#)). The output of the current sense OpAmp is connected to an integrated comparator, comparing the amplified current sense signal with an external adjustable threshold value. After the comparator a blanking time (1.5  $\mu$ s typ.) is implemented to avoid false triggering caused by overswing of the current sense signal.

If the overcurrent situation is detected, only an error signal is given. During overcurrent the driver IC works normally. The error signal disappears as soon as the current decreases below the overcurrent limit set on the VTHOC pin. The error signal disappears as well when the current commutates from the low side MOSFET to the associated high side MOSFET (no current through the shunt resistor).

It is the decision of the user to react on the over current signal by modifying the Ixx patterns to lower the current.

### 5.2.3 Dead Time and Shoot Through Protection

In bridge applications it has to be assured that the external high side and low side Mosfet are not "on" at the same time, connecting directly the battery voltage to GND. The dead time generated in the TLE7183F is fixed to a minimum value of 50..200ns if the DT pin is connected to GND. This function assures a minimum dead time if the input signals coming from the  $\mu$ C are faulty.

The dead time can be increased beyond the internal fixed dead time by connecting the DT pin via a dead time resistor  $R_{DT}$  to GND - the larger the dead time resistor the larger the dead time (for details pls. see the "Dynamic Characteristic" table in the MOSFET driver section).

The exact dead time of the bridge is usually controlled by the PWM generation unit of the  $\mu$ C.

In addition to this dead time, the TLE7183F provides a locking mechanism, avoiding that both external MOSFETs of one half bridge can be switched on at the same time. This functionality is called shoot through protection.

If the command to switch on both high and low side switches in the same half bridge is given at the input pins, the command will be ignored.



### 5.2.4 Undervoltage Shut Down

The TLE7183F has an integrated undervoltage shut down, to assure that the behavior of the device is predictable in all supply voltage ranges.

If the voltage of a charge pump buffer capacitors CBx reaches the undervoltage shut down level for a minimum specified filter time, the gate-source voltage of all external MOSFETs will be actively pulled to low. In this situation the short circuit detection of this output stage is deactivated to avoid a latching shut down of the driver.

As soon as the charge pump buffer voltage recovers, the output stage condition will be aligned to the input patterns automatically. This allows to continue operation of the motor in case of undervoltage shut down without a reset by the  $\mu\text{C}$ .

Undervoltage shut down will not occur when  $V_S > 6\text{ V}$ ,  $Q_G < 250\text{ nC}$ ,  $F_{\text{PWM}} < 25\text{ kHz}$ , and the charge pump capacitors  $C_{xx} = 4.7\text{ }\mu\text{F}$ .

### 5.2.5 Overvoltage Shut Down

The TLE7183F has an integrated overvoltage shut down to avoid destruction of the IC at high supply voltages. The voltage is observed at the Vs and the VDH pin. When one of them or all of them exceed the overvoltage shut down level for more than the specified filter time then the external MOSFETs are switched off. In addition, overvoltage will shut down the charge pumps and will discharge the charge pump capacitors. This results in an undervoltage condition which will be indicated on the ERRx pins. During overvoltage shut down the external MOSFETs and the charge pumps remain off until a reset is performed.

### 5.2.6 Overtemperature Warning

If the junction temperature is exceeding  $t_{\text{yp. } 170^\circ\text{C}}$  an error signal is given as warning. The driver IC will continue to operate in order not to disturb the application.

The warning is removed automatically when the junction temperature is cooling down. It is in the responsibility of the user to protect the device against overtemperature destruction.

### 5.2.7 ERR Pins

The TLE7183F has two status pins to provide diagnostic feedback to the  $\mu\text{C}$ . The outputs of these pins are 5V push pull stages, they are either high or low.

**Table 3 Overview of error conditions**

ERR1	ERR2	Driver conditions
Low	Low	no errors
High	Low	Overtemperature or overvoltage
High	High	Undervoltage
Low	High	Short circuit detection or overcurrent

**Table 4 Behaviour at different error conditions**

Error condition	restart behavior	Shuts down...
Short circuit detection	Latch, reset must be performed at ENAx pin	All external Power -MOSFETs
Overcurrent warning	Self clearing	Nothing
Undervoltage	Auto restart	All external Power -MOSFETs
Overvoltage	Latch, reset must be performed at ENAx pin	All external Power -MOSFETs
Overtemperature warning	Self clearing	Nothing

*Note: All errors do NOT lead to sleep mode. Sleep mode is only initiated with the INH pin. The latch and restart behaviour allows to distinguish between the different error types combined at the ERR signals.*

**Table 5 Priorisation of Errors**

Priority	Error
1	Short circuit detection
2	Undervoltage detection
3	Overvoltage detection
4	Overtemperature Overcurrent

#### Reset of ERROR registers and Disable

The TLE7183F can be reseted by the enable pins ENAx. If one or two ENAx pins is pulled to low for a specified minimum time, the error registers are cleared and the external MOSFETs are switched off actively.

During disable only the errors undervoltage shut down and overtemperature warning are shown. Other errors are not displayed.

## 5.2.8 Electrical Characteristics

#### Electrical Characteristics - Protection and diagnostic functions

$V_S = 5.5$  to  $20V$ ,  $T_j = -40$  to  $+150^{\circ}C$ , all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Pos.	Parameter	Symbol	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
Overtemperature							
5.2.1	Overtemperature warning	$T_{j(OW)}$	150	170	190	°C	–
5.2.2	Hysteresis for overtemperature warning	$dT_{j(OW)}$	–	20	–	°C	–
Overcurrent warning							
5.2.3	Overcurrent threshold	$V_{THOC}$	2	–	4.5	V	Vs=5.5..8V
5.2.4	Overcurrent threshold	$V_{THOC}$	2	–	4.8	V	Vs=8..20V
5.2.5	Input offset voltage of OC Comp	$V_{OCOF}$	-50	–	50	mV	–
5.2.6	Input offset voltage temperature drift of OC Comp <sup>1)</sup>	$V_{IO}$	-5	–	5	mV	–
5.2.7	Over current protection threshold hysteresis	$dV_{THOC}$	25		–	mV	Vs=5.5..8V
5.2.8	Over current protection threshold hysteresis	$dV_{THOC}$	50	80	–	mV	Vs=8..20V
5.2.9	Filter time of over current protection	$t_{OC}$	1.0	1.5	3.0	µs	
Short circuit protection							
5.2.10	Filter time of short circuit protection	$t_{SCP(off)}$	4.5	6.8	9	µs	default
5.2.11	Maximum duty cycle for no SCD <sup>2)</sup>	$D_{ySCDmax}$	–	–	6	%	fPWM=20kHz at IHx or ILx and at static applied SC
5.2.12	minimum duty cycle for periodic SCD <sup>2)</sup>	$D_{ySCDmin}$	13	–	–	%	fPWM=20kHz at IHx or ILx and at static applied SC

### Electrical Characteristics - Protection and diagnostic functions (cont'd)

$V_S = 5.5$  to  $20V$ ,  $T_j = -40$  to  $+150^\circ C$ , all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Pos.	Parameter	Symbol	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
5.2.13	Short circuit protection detection level SCD1	$V_{SCP1(off)}$	0.3	0.5	0.65	V	
5.2.14	Short circuit protection detection level SCD2	$V_{SCP2(off)}$	0.6	0.75	0.9	V	
5.2.15	Short circuit protection detection level SCD3	$V_{SCP3(off)}$	0.85	1.0	1.15	V	
5.2.16	Short circuit protection detection level SCD4	$V_{SCP4(off)}$	1.35	1.5	1.65	V	
5.2.17	Short circuit protection detection level SCD5	$V_{SCP5(off)}$	1.8	2.0	2.2	V	

### ERR pins

5.2.18	High level output voltage of ERRx	$V_{OHERR}$	4.0	–	5.2	V	$I = -0.2mA$
5.2.19	Low level output voltage of ERRx	$V_{OLERR}$	-0.1	–	0.4	V	$I = 0.2mA$
5.2.20	Propagation time difference ERR1 to ERR2	$t_{PD(ERR)}$		–	200	ns	–
5.2.21	Rise time ERRx (20 - 80 %)	$t_{r(ERR)}$	50	–	600	ns	$C_{LOAD} = 100pF$
5.2.22	Fall time ERRx (80 - 20 %)	$t_{f(ERR)}$	50	–	400	ns	$C_{LOAD} = 100pF$

### Over- and undervoltage

5.2.23	Overvoltage shut down	$V_{OV(off)}$	28	–	33	V	on $V_S$ and/or $VDH$
5.2.24	Overvoltage filter time	$t_{OV}$	30	–	65	$\mu s$	–
5.2.25	Undervoltage shut down CB1	$V_{UV1}$	6.75	–	8.25	V	CB1 to GND
5.2.26	Undervoltage shut down CB2	$V_{UV2}$	3.9	–	5.7	V	CB2 to $VDH$
5.2.27	Undervoltage shut down hysteresis of CB1 and CB2	$V_{DUV}$	–	1.0	–	V	–
5.2.28	Undervoltage filter time	$t_{UV}$	1	–	3	$\mu s$	–

### Reset and Enable

5.2.29	Reset time to clear ERR registers	$t_{Res1}$	2.0	–	–	$\mu s$	–
5.2.30	Low time of ENAx signal without reset	$t_{Res0}$	–	–	0.5	$\mu s$	–
5.2.31	ENAx propagation time (High --> Low)	$t_{PENA\_H-L}$	–	–	2.0	$\mu s$	–
5.2.32	ENAx propagation time (Low --> High)	$t_{PENA\_L-H}$	–	–	0.5	$\mu s$	–
5.2.33	Return time to normal operation at auto-restart	$t_{AR}$	–	–	1.0	$\mu s$	–

1) Not subject to production test; specified by design

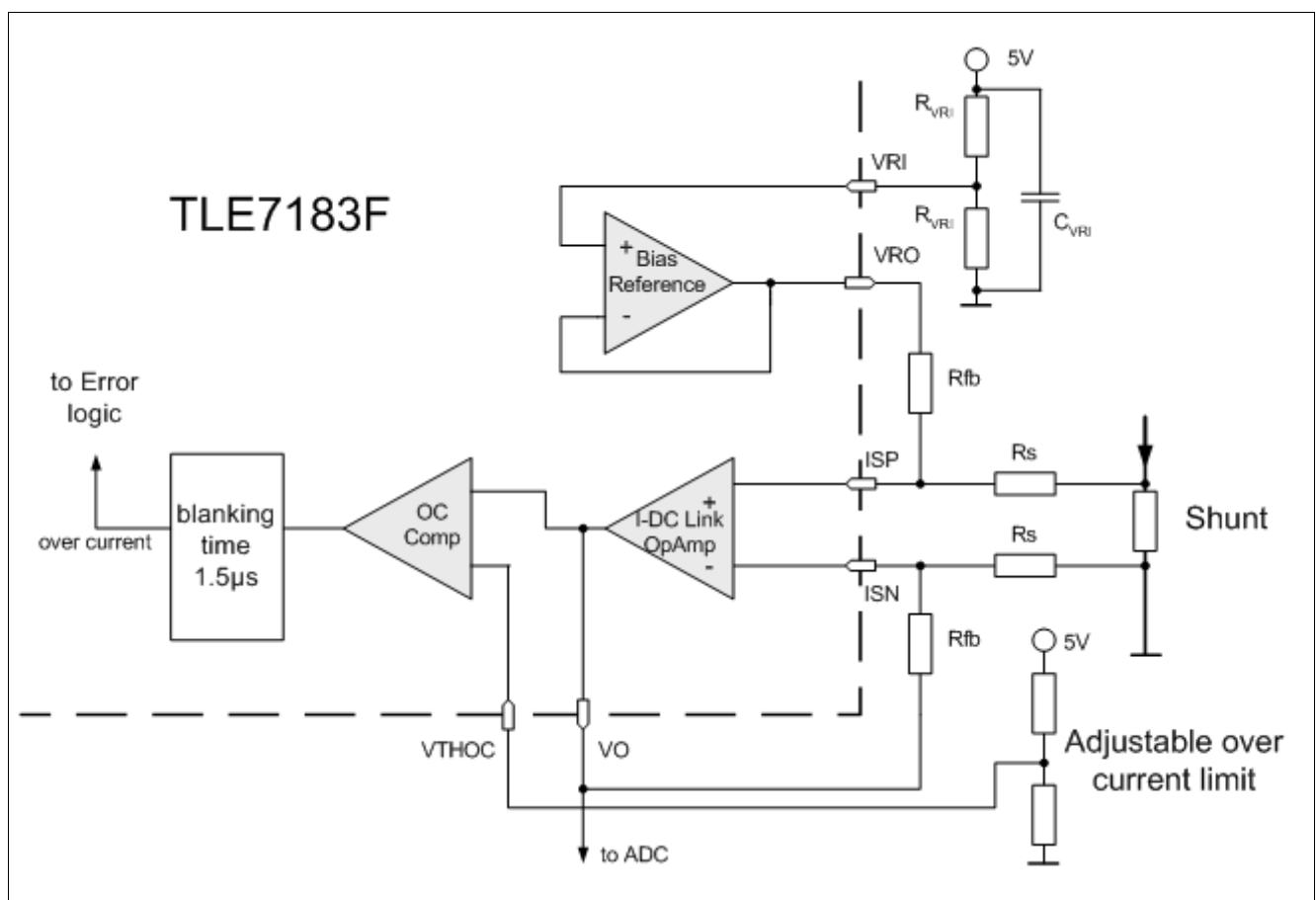
2) Parameters describe the behaviour of the internal SCD circuit. Therefore only internal delay times are considered. In application dead-/ delay times determined by application circuit (switching times of MOSFETs, adjusted dead time) have to be considered as well.

### 5.3 Shunt Signal Conditioning

The TLE7183F incorporates a fast and precise operational amplifier for conditioning and amplification of the current sense shunt signal. Additionally, one reference bias buffer is integrated to provide an adjustable bias reference for the three OpAmps. The voltage divider on the VRI pin should be less than 50 kOhm, the filtering capacitor less than 1.2  $\mu$ F - if needed at all. The gain of the OpAmp is adjustable by external resistors within a range of 5 to 15.

When  $V(ISP) = V(ISN)$ , VO provides the reference voltage VRO. VRO is normally half of the regulated voltage provided from an external voltage regulator for the ADC used to read the current sense signal. The additional buffer allows bi-directional current sensing and permits the adaptation of the reference bias to different  $\mu$ C I/O voltages. The reference buffer assures a stable reference voltage even in the high frequency range.

The output of the I-DC link Opamp Vo is not short-circuit proof.



**Figure 4 Shunt Signal Conditioning Block Diagram and Over Current Limitation**

Over current warning see [Chapter 5.2.2](#).

### 5.3.1 Electrical Characteristics

#### Electrical Characteristics - Current sense signal conditioning

$V_S = 5.5$  to  $20V$ ,  $T_j = -40$  to  $+150^\circ C$ ,  $F_{PWM} < 25kHz$ , all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Pos.	Parameter	Symbol	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
5.3.1	Series resistors	$R_S$	100	500	1000	$\Omega$	–
5.3.2	Feedback resistor Limited by the output voltage dynamic range	$R_{fb}$	2000	7500	–	$\Omega$	–
5.3.3	Resistor ratio (gain ratio)	$R_{fb}/R_S$	5	–	15	–	–
5.3.4	Steady state differential input voltage range across VIN <sup>1)</sup>	$V_{IN(ss)}$	-400	–	400	mV	–
5.3.5	Transient differential input voltage range across VIN	$V_{IN(tr)}$	-800	–	800	mV	–
5.3.6	Input differential voltage (ISP - ISN)	$V_{IDR}$	-800	–	800	mV	–
5.3.7	Input voltage (Both Inputs - GND) (ISP - GND) or (ISN - GND)	$V_{LL}$	-800	–	1500	mV	$V_S=5.5..8V$
5.3.8	Input voltage (Both Inputs - GND) (ISP - GND) or (ISN - GND)	$V_{LL}$	-800	–	2000	mV	$V_S=8..20V$
5.3.9	Input offset voltage of the I-DC link OpAmp	$V_{IO}$	–	1	+/-5	mV	$R_S=500\Omega$ ; $V_{CM}=0V$ ; $V_O=1.65V$ ; $V_{RI}=1.65V$
5.3.10	Input offset voltage temperature drift of the I-DC link OpAmp <sup>2)</sup>	$V_{IO}$	–	1	2	mV	$R_S=500\Omega$ ; $V_{CM}=0V$ ; $V_O=1.65V$ ; $V_{RI}=1.65V$
5.3.11	Input offset voltage of the reference buffer	$V_{IO}$		1	+/-5	mV	–
5.3.12	Input offset voltage temperature drift of the reference buffer <sup>2)</sup>	$V_{IO}$		1	2	mV	–
5.3.13	Input range at VRI	$V_{IO}$	1.2	–	2.8	V	–
5.3.14	Input bias current (ISx to GND)	$I_{IB}$	–	–	300	$\mu A$	$V_{CM}=0V$ ; $V_O=open$
5.3.15	High level output voltage of VO	$V_{OH}$	4.8	–	5.2	V	$V_{RI}=1.65V/2.5V$ ; $I_{OH}=-3mA$
5.3.16	Low level output voltage of VO	$V_{OL}$	-0.1	–	0.2	V	$V_{RI}=1.65V/2.5V$ ; $I_{OH}=3mA$
5.3.17	Output voltage of VO <sup>3)</sup> $V_{RI}=2.5V$ , $V_{RI}=1.65V$	$V_{OR}$	2.42 1.58	2.50 1.65	2.58 1.73	V	$V_{IN(ss)}=0V$ ; Gain=15;
5.3.18	Temperature drift of output voltage of VO <sup>3)</sup>	$V_O$	0	–	32	mV	$V_{IN(ss)}=0V$ ; Gain=15
5.3.19	Output short circuit current	$I_{SC}$	5	–	–	mA	–
5.3.20	Differential input resistance <sup>2)</sup>	$R_I$	100	–	–	k $\Omega$	–
5.3.21	Common mode input capacitance <sup>2)</sup>	$C_{CM}$	–	–	10	pF	10kHz

### Electrical Characteristics - Current sense signal conditioning (cont'd)

$V_S = 5.5$  to  $20V$ ,  $T_j = -40$  to  $+150^\circ C$ ,  $F_{PWM} < 25kHz$ , all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Pos.	Parameter	Symbol	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
5.3.22	Common mode rejection ratio at DC CMRR = $20 \cdot \log((V_{out\_diff}/V_{in\_diff}) \cdot (V_{in\_CM}/V_{out\_CM}))$	CMRR	80	100	–	db	–
5.3.23	Common mode suppression <sup>4)</sup> with CMS = $20 \cdot \log(V_{out\_CM}/V_{in\_CM})$ Freq = 100kHz Freq = 1MHz Freq = 10MHz	CMS	–	62 43 33	–	db	VIN=360mV* $\sin(2 \cdot \pi \cdot freq \cdot t)$ ; Rs=500Ω; Rfb=7500Ω; VRI=1.65/2.5V
5.3.24	Slew rate	$dV/dt$	3	10	–	V/μs	Gain ≥ 5; RL=1.0kΩ; CL=500pF
5.3.25	Large signal open loop voltage gain (DC)	$A_{OL}$	80	100	–	dB	–
5.3.26	Unity gain bandwidth	GBW	10	20	–	MHz	RL=1kΩ; CL=100pF
5.3.27	Phase margin <sup>2)</sup>	$\phi_M$	–	50	–	°	Gain ≥ 5; RL=1kΩ; CL=100pF
5.3.28	Gain margin <sup>2)</sup>	$A_M$	–	12	–	db	RL=1kΩ; CL=100pF
5.3.29	Bandwidth	BWG	1.6	–	–	MHz	Gain=15; RL=1kΩ; CL=500pF; Rs=500Ω
5.3.30	Output settle time to 98% <sup>1)</sup>	$t_{set}$	–	1	1.8	μs	Gain=15; RL=1kΩ; CL=500pF; 0.3<VO< 4.8V; Rs=500Ω
5.3.31	Output rise time 10% to 90% <sup>1)</sup>	$t_{rise}$	–	–	1	μs	Gain=15; RL=1kΩ; CL=500pF; 0.3<VO< 4.8V; Rs=500Ω
5.3.32	Output fall time 90% to 10% <sup>1)</sup>	$t_{fall}$	–	–	1	μs	Gain=15; RL=1kΩ; CL=500pF; 0.3<VO< 4.8V; Rs=500Ω;

1) Input current and output amplifier characteristics:

"Output signal must be amplified and available at 2μs after input signal change (Gain 5...15)

2) Not subject to production test; specified by design

3) calculated out of [5.3.9](#), [5.3.10](#), [5.3.11](#) and [5.3.12](#)

4) Without considering any offsets such as input offset voltage, internal miss match and assuming no tolerance error in external resistors.

## 5.4 Phase voltage feedback

The TLE7183F incorporates an fast conversion of the phase voltages into logic signals. The threshold values are proportional to  $V_{DH}$ . The outputs are 5V push pull stages. When they are not used they can be left open.

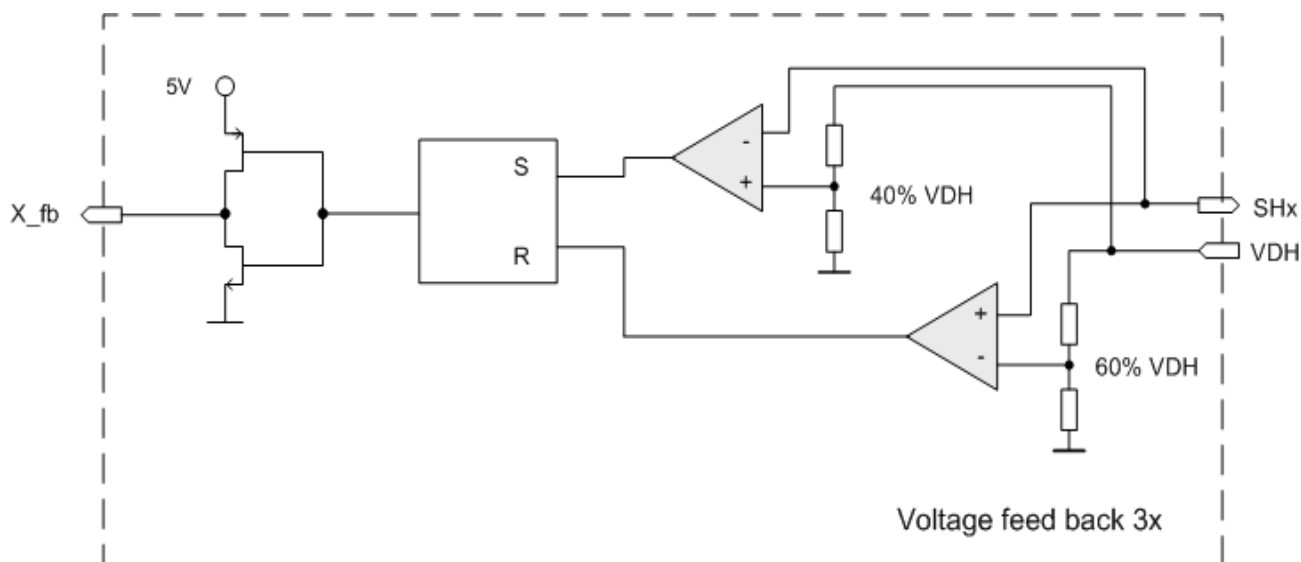


Figure 5 Block diagram phase voltage feedback

### 5.4.1 Electrical Characteristics

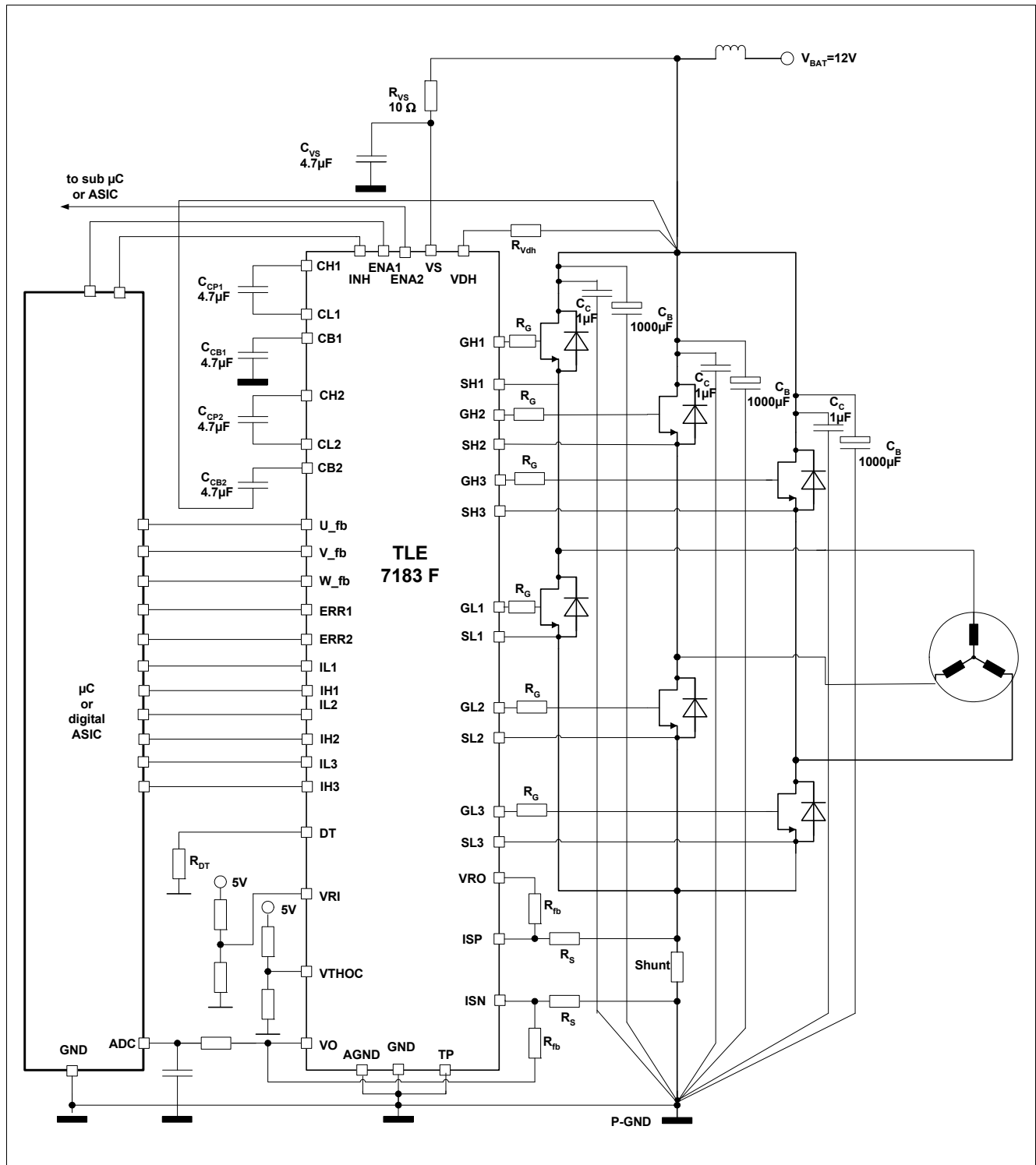
#### Electrical Characteristics - Phase Voltage Feedback

$V_S = 5.5$  to  $20V$ ,  $T_j = -40$  to  $+150^\circ C$ ,  $F_{PWM} < 25kHz$ , all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Pos.	Parameter	Symbol	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
5.4.1	Low level threshold	$V_{ILfb}$	35	40	45	% of VDH	VDH>5.5V $V_{SHX}$ decreasing
5.4.2	High level threshold	$V_{IHfb}$	55	60	65	% of VDH	VDH>5.5V $V_{SHX}$ decreasing
5.4.3	High level output voltage of x_fb	$V_{OHfb}$	4.0		5.2	V	$I = -0.5mA$
5.4.4	Low level output voltage of x_f	$V_{OLfb}$	-0.1		0.2	V	$I = 0.5mA$
5.4.5	Propagation delay time incl. rise or fall time	$t_{PDfb}$			110	ns	$C_{LOAD} < 100pF$
5.4.6	Matching of propagation delay time	$t_{dPDfb}$			30	ns	

## 6 Application Description

In the automotive sector there are more and more applications requiring high performance motor drives, such as electro-hydraulic or electric power steering. In these applications 3 phase motors, synchronous and asynchronous, are used, combining high output performance, low space requirements and high reliability.



**Figure 6 Application Circuit - TLE 7183 F**

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



## 6.1 Layout Guide Lines

Please refer also to the simplified application example.

- Three separated bulk capacitors  $C_B$  should be used - one per half bridge
- Three separated ceramic capacitors  $C_C$  should be used - one per half bridge
- Each of the 3 bulk capacitors  $C_B$  and each of the 3 ceramic capacitors  $C_C$  should be assigned to one of the half bridges and should be placed very close to it
- The components within one half bridge should be placed close to each other: high side MOSFET, low side MOSFET, bulk capacitor  $C_B$  and ceramic capacitor  $C_C$  ( $C_B$  and  $C_C$  are in parallel) and the shunt resistor form a loop that should be as small and tight as possible. The traces should be short and wide
- The three half bridges can be separated; yet, when there is one common GND referenced shunt resistor for the three half bridges the sources of the three low side MOSFETs should be close to each other and close to the common shunt resistor
- VDH is the sense pin used for short circuit detection; VDH should be routed (via Rvdh) to the common point of the drains of the high side MOSFETs to sense the voltage present on drain high side
- CB2 is the buffer capacitor of charge pump 2; its negative terminal should be routed to the common point of the drains of the high side MOSFETs as well - this connection should be low inductive / resistive
- Additional R-C snubber circuits (R and C in series) can be placed to attenuate/suppress oscillations during switching of the MOSFETs, there may be one or two snubber circuits per half bridge, R (several Ohm) and C (several nF) must be low inductive in terms of routing and packaging (ceramic capacitors)
- the exposed pad on the backside of the VQFN should be connected to GND

## 6.2 Further Application Information

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

## 7 Package Outlines

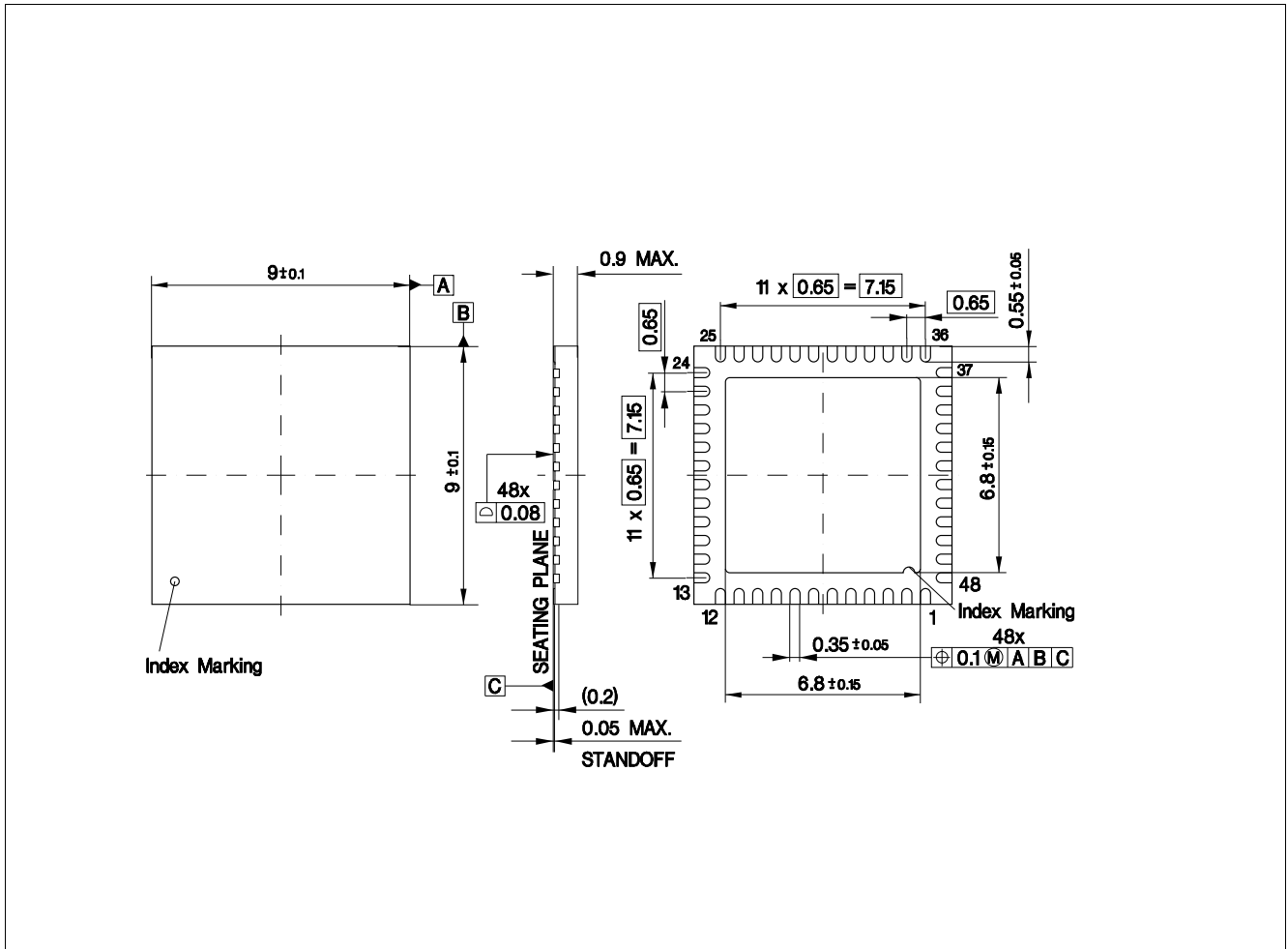


Figure 7 PG-VQFN-48

### Green Product

To meet the world-wide customer requirements for environmentally friendly products and to be compliant with government regulations the device is available as a green product. Green products are RoHS-Compliant (i.e Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020).

You can find all of our packages, sorts of packing and others in our Infineon Internet Page "Products": <http://www.infineon.com/products>.

Dimensions in mm

## 8 Revision History

Version	Date	Changes
V2.2	2016-01-27	package adjustments
V2.1	2007-08-08	<p><b>Chapter 1</b>: title overview added</p> <p><b>Chapter 1</b>: description paragraph 2 added</p> <p><b>Chapter 1</b>: edit table overview</p> <p><b>Chapter 4.1</b>: parameter 4.1.26 ambient temperature deleted</p> <p><b>Chapter 5.2.1</b>: table 2: Short circuit detection level options added</p> <p><b>Chapter 5.2.8</b>: parameter 5.2.13-5.2.17 min. max values defined; comment on request deleted</p>
V2.0	2006-10-18	<p>change of specified supply voltage range from <math>V_s=8..20V</math> to <math>V_s=5.5..20V</math> incl. adjustment of values</p> <p>Final datasheet</p>

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