Distribution Training
„Going for a Greener World with Infineon’s Innovative High Performance Solutions“

Solutions Power steering, fans and pumps
Automotive Gate Driver ICs

2011
Benno Köppl
Agenda

- Low voltage MOS drivers
- Application

- Electric Power Steering
  - Application requirements
  - TLE7183 / 89
  - TLE 7185
  - TLE7181 / 82

- HVAC and Engine cooling fan
  - Application requirements
  - TLE7184

- Fuel pump
  - Application requirements
  - TLE7185
Power on Demand
Electric Power Steering

- Demand oriented torque controlled electric motor
- Reduced Average Power Consumption down to 50W
- Technologies available

Total Equivalent Electric Power Saving ~ 250 W

CO$_2$-reduction ~ 5.9 g/km
Application requirements Power Steering

- Basic requirements to power stage
  - 3-phase motor drive
  - Field oriented control
  - up to 200A phase current
  - mostly 12V application

- Trends
  - has to work at lower supply voltages
  - only one shunt for current measurement
  - increasing accuracy of current measurement
  - highest efficient usage of motor (0...100% duty cycle)
  - fulfill ASIL D safety requirement in application
Application requirements Power Steering

- **160A B6-Bridge -> Diver Requirements**
  - Powerful output stage up to 1.5A
  - Robust to positive and negative spikes
  - Separate Source connections: 4
  - Floating output stages: 4

TLE7183 / 89 / 85
Application requirements Power Steering

- **Current measurement**
  - Only one shunt for cost reasons
  - Very short time to measure current
  - Increasing accuracy requirements
  - High current in application lead to negative spikes at shunt

- **OpAmp requirements**
  - Input range +/-5V spikes
  - High bandwidth typ. 20 MHz UGBW
  - Low input offset down to +/- 1.5mV
  - High CMRR > 60db minimum

**TLE7183 / 89**

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TLE7183F 3-Phase Driver IC for 12V

- Voltage Supply 14V + 100%DC
- Current Sense Over current
- Low quiesc. current
- Fix dead time
- Diagnosis 2 bit

Charge pump 1
Charge pump 2

Driver

3x Vx_fb

Vbat

Driver

Charge pump 1
Charge pump 2

Voltage check
Shoot through Protect.

Charge pump 1
Charge pump 2

Voltage check

Charge pump 1
Charge pump 2

Driver

Voltage check
Shoot through Protect.

Charge pump 1
Charge pump 2

Driver

Voltage check
Shoot through Protect.

Charge pump 1
Charge pump 2

Driver

Voltage check
Shoot through Protect.

Charge pump 1
Charge pump 2

Driver

Voltage check
Shoot through Protect.
Charge pump 1
pumps VS to ~13V = chip and lowside supply
similar to TLE6280

Charge pump 2
adds VCB1 to VS = highside supply new

Vreg 10V Driver

Full 10V VGS down to 6.5V supply !!!

0 – 100% without limits
Conditions:

\[ V_S = 5.5 \ldots 12 \text{ V} \]
\[ Q_G = 130 \text{ nC} \]
\[ f = 20 \text{ kHz} \]

(Max. UV limit on CB1: 8.3 V)

0...100% duty cycle

full supply voltage reaches motor

highest efficient usage of motor (costs + space)
TLE7189F
3-Phase Driver IC for 12V

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Package VQFN48

- **Voltage Supply 14V + 100%DC**
- **Current - Sense Over current**
- **Low quiesc. current**
- **Dead time fix**
- **Diagnosis 2 bit**

Charge pump 1
- **Voltage check**
- **Shoot through Protect.**

Charge pump 2
- **Short Circuit Protection adj**

Driver

- **Driver**

- **3 x OpAmp !**

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I sense: Bi-directional

Bias reference buffer allows bi-directional current sensing

2.4 Mhz Bandwidth @ gain 15
CMRR>80db
Input offset voltage <+/-1.5mV
Max rating Input +/-5V

Over current warning with adjust. Current level
Philosophy

Add ProSIL features to existing product: “sleeping bug is excluded by repeated testing”

- VCC check (monitors the uC supply)
- Test function for VCC check

- SC-Detection (monitors short circuit of MOSFET)
- Test function for SC-Detection at 0A

- High voltage inputs (18V)

- “Common mode failure analysis” (FTA) available, tailored to the FMEA and the FTA of the target system
TLE7185
Simplified 3-phase driver IC

- Features
  - B6 MOS Bridge driver
    - ~10 Ohm output stages for MOSFETs up to 100A
    - 0-95% duty cycle (bootstrap principle)
    - Adj. Short circuit detection level 0.3-2V
    - Adj. Dead time
    - Low quiescent current mode 20uA
    - 2 bit diagnostic
    - Separate Source pin for each MOSFET
    - Functional range 5.5 to 33V
  - Charge pump to boost the supply voltage
  - P-DSO36-Exposed pad allows TA up to 140°C

Optimized for applications running at 5.5V supply

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## Bridge Driver ICs - Electric Power Steering

### Features overview

<table>
<thead>
<tr>
<th>features</th>
<th>TLE6280GP</th>
<th>TLE 7183F</th>
<th>TLE 7189F</th>
<th>TLE 7185E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage (operation)</td>
<td>8...30V</td>
<td>5.5 ... 28V (CP)</td>
<td>5.5 ... 28V (CP)</td>
<td>5.5 ... 32V (CP)</td>
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<td>Duty cycle</td>
<td>0...95% (bootstrap)</td>
<td>0...100% (CP)</td>
<td>0...100% (CP)</td>
<td>0...95% (bootstrap)</td>
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<tr>
<td>Low quiescent mode</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>OpAmps</td>
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<td>3</td>
<td>-</td>
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<tr>
<td>Adjustable Dead time</td>
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<td>yes</td>
<td>fix</td>
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<tr>
<td>Adjustable short circuit detection level</td>
<td>yes</td>
<td>5 fixed options</td>
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</tr>
<tr>
<td>SIL 3 features</td>
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<tr>
<td>Used in SIL3 applic.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Package</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Electric Power Steering – DC brush
Typical ECU Block diagram

+12V from Battery

Belt Pre-Tensioner ECU

Supply ICs
TLE 4266-2

Wake-up

16-bit MCU
XC2300

CAN Transceiver
TLE 6250G
TLE8250

H-Bridge Driver IC
TLE 78182EM

Current Sense

OptiMOS™-T 40V
5x IPD90N04S3-H4
or
5x IPD80N04S3-06

CAN-Bus / LIN-Bus

: all products available at ATV
TLE7182EM
H-Bridge Driver IC for 12V

Package SSOP24-EP

Voltage-Supply + 100%DC
Current - Sense Over current
Low quiesc. current
Dead time adj.
Diagnosis bit

Reverse Polarity
Short Circuit Protection adj

ERR1 DT SCDL PWM DIR ENA INH lout GND1-4

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Output stages of TLE7182EM

- ~10 Ohm output stages for N-channel MOSFETs
  - Highside stage 0..95%(@20kHz) & 100%
  - Lowside stage 0..100%
- 4 independent inputs – high flexibility
- Dead time adjustable
- Low quiescent current mode 8µA $T_J = 25^\circ C$
- Supply voltage range: 7.0..34V
- Fast and accurate integrated OPAMP
- Control for reverse polarity MOSFET
- Adj. Short circuit protection
- PG SSOP 24 with exposed pad allows $T_{ambient}$ up to 140°C
Agenda

- Low voltage MOS drivers
- Application
  - Electric Power Steering
    - Application requirements
    - TLE7183 / 89
    - TLE 7185
    - TLE7181 / 82
- HVAC and Engine cooling fan
  - Application requirements
  - TLE7184
- Fuel pump
  - Application requirements
  - TLE7185
HVAC System has Huge Saving Potential
PWM Controlled Blower Fan

- Blower Control via PWM
- Drastically Reduced Power Losses
- Technologies available

Total Power Saving ~ 80 W

\[ \text{CO}_2\text{-reduction} \sim 1.9 \text{ g/km} \]

Comparison against linear controlled motor with huge power losses

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Power on Demand
PWM Regulated Water Pump

- Electric motor driven and demand controlled by PWM
- Reduced Average Power Consumption down to 15W
- Technologies available

Total Equivalent Electric Power Saving ~ 300 W

$\text{CO}_2\text{-reduction} \sim 7.1. \text{ g/km}$
HVAC
General statements

- **Main Solution**
  - DC Brush motor with linear control -> (Planar MOSFETs)
  - or
  - DC Brush motor with PWM control -> Trench MOSFETs

- **Main trend**
  - Main trend DC Brush with PWM
  - Trend to BLDC
    - In use 250W….450W for high end cars
    - Silence drives in luxury cars
    - High maintenance costs (>8h workshop)
    - Reduced EMC
HVAC fan and Engine Cooling Fan
General block diagram BLDC

- Variations
  - Current sense: 1 phase or none
  - Rotor position: 1-3 Hall or BEMF
  - Interface: PWM (Majority) or LIN or CAN
  - Supply: Dependent on uC – mostly 5V
BLDC Drive for Fans and pumps
TLE7184

5V LDO
PWM interface

TLE 7184

8 or 16 bit μC

B6-Driver IC
1 OPAMPs
Protection
Diagnosis

40V MOSFET 6x
1 shunts

BLDC Motor

BEMF
Application requirements HVAC / Engine cooling fan

- **50A B6-Bridge ->Diver Requirements**
  - less powerful output stage 10 Ohm
  - Robust to positive and negative spikes +/-7V at SL
  - Floating output stages 4
  - Moderate Price 4

  ![Diagram of 6xN MOSFETs and PMSM](image)

  **TLE7184**
Application requirements HVAC / Engine cooling fan

- **Current measurement**
  - Only one shunt for cost reasons
  - Very short time to measure current
  - Medium current + low cost power bridge lead to negative spikes at shunt

- **OpAmp requirements**
  - Input range +/-5V spikes 4
  - High bandwidth typ. 20 MHz UGBW
  - Low input offset down to +/- 2mV
  - High CMRR > 60db minimum

**TLE7183 / 84 / 85**
Application requirements HVAC / Engine cooling fan

- **Low cost approach / less space**
  - Integration of VREG for uC
  - relatively high accuracy for current / temperature measurement

- **VDD regulator**
  - Low drop regulator 4
  - support of 8 and 16 uC up to 70mA
  - 5V 4
  - Sufficient accuracy 2% 5...25mA 3% 5...70mA

**TLE7184**
Application requirements HVAC / Engine cooling fan

**Interface**
- Low cost interface 400Hz PWM
- Capability of 19.2 kbaud flash mode

Switch T2 for bi-directional communication not integrated because
- bi-directional mode not always needed
- GND shift requirement of -6V makes external solution cheaper
Application requirements HVAC / Engine cooling fan

**Temperature Measurement**

- Very important in these applications for
  - Control strategy of cooling fan
  - Protection of MOSFETs

**Integration of two sensors**

- Analog temperature sense (single point calibration recommended) 4
- Digital over-temp warning 4
Application requirements HVAC / Engine cooling fan

- **Optimized logic**
  - Allows operation in application controlled by
    - only interface (wake up on bus)
    - only KL15 (wake up on key)
    - mixed operation

- Secures IC against thermal cycling even without interference of any uC
  - Dead lock mode

- Allows uC controlled after-run
Features
- B6 MOS Bridge driver
  - ~10 Ohm output stages for MOSFETs up to 100A
  - Works down to 7V
  - OpAmp (UGBW 20Mhz / <1.5mV)
  - 0-94% duty cycle (bootstrap principle)
  - Protection functions
- 5V 70mA LDO to support 8 and 16bit uCs
- PWM interface
- Precise analog and digital temperature sense
- Specific Logic
- VDH switch (disconnects circuit from battery – sleep mode)

Simplified ECU for BLDC Motors
Features optimized for HVAC and cooling fan applications
Features
- same as TLE7186
- U V W voltage feedback additional

Simplified Single shunt current sensing
Helpful for BEMF Detection
## Features overview

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<tr>
<td>5V LDO for uC</td>
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- Fuel pump
  - Application requirements
  - TLE7185
Power on Demand
PWM Regulated Fuel Pump

- Electric motor driven and demand controlled by PWM
- Reduced Average Power Consumption up to 40%
- Technologies available

Total Power Saving ~ 80 W

CO₂-reduction ~ 1.9 g/km
Power on Demand
PWM Regulated Fuel Pump

- Has to run at low battery voltages 5.5V and below
- 100 to 250W
- Mainly DC-brush
- Small trend to BLDC

Source: Continental
Typical halfbridge - Application Circuit

Microcontroller

Voltage Regulator

PI Filter

Reverse Polarity Protection

Fuel Pump

BTN7960B
BTN797xB

High Current Half Bridge
Integrated protected Half Bridge – NovalithIC Concept

BTN797xB

Current Limitation ~70A typ. / 50A min. (low side)

25 kHz PWM w. Active Freewheeling
No Charge Pump

7 mΩ typ.
9 mΩ typ.

Chip-On-Chip
Chip-By-Chip

Current Sense
**Enhanced NovalithIC™ family**

- 40% reduced switching losses
  - Enhanced switching speed for reduced switching losses (rise/fall times down to typ. 600ns)
- Extended operating voltage range down to 4.5 V
- Optimized for half-bridge applications
  - "Smart clamping" in overvoltage

**BTN7933B**
- $R_{ds(on)} = 28 \text{ m}\Omega$ (path)
- $I_d = 32$ A (current limitation)

**BTN7963B**
- $R_{ds(on)} = 16 \text{ m}\Omega$ (path)
- $I_d = 47$ A (current limitation)

**BTN7973B**
- $R_{ds(on)} = 16 \text{ m}\Omega$ (path)
- $I_d = 70$ A (current limitation)

_all values typ. @ 25°C_
Features

- B6 MOS Bridge driver
  - ~10 Ohm output stages for MOSFETs up to 100A
  - 0-95% duty cycle (bootstrap principle)
  - Adj. Short circuit detection level 0.3-2V
  - Adj. Dead time
  - Low quiescent current mode 20uA
  - 2 bit diagnostic
  - Separate Source pin for each MOSFET
  - Functional range 5.5 to 33V
- Charge pump to boost the supply voltage
- P-DSO36-Exposed pad allows TA up to 140°C

Optimized for applications running at 5.5V supply
ENERGY EFFICIENCY
COMMUNICATIONS
SECURITY

Innovative semiconductor solutions for energy efficiency, communications and security.