

INTRODUCING NEW SPI CONTROLLED BRUSHED DC MOTOR DRIVERS FEATURING FUNCTIONAL SAFETY AND HIGHER TORQUE

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PUBLIC



SECURE CONNECTIONS
FOR A SMARTER WORLD

AGENDA

- H-Bridge Motor Drivers introduction
- Applications
- HB2000 / 2001 block diagram and key features
- Live demonstration of current limit
- Roadmap
- Enablement tools

H-BRIDGE MOTOR DRIVERS INTRODUCTION



Motor Basics – H-Bridge / Brushed DC

Basic Motor Operation

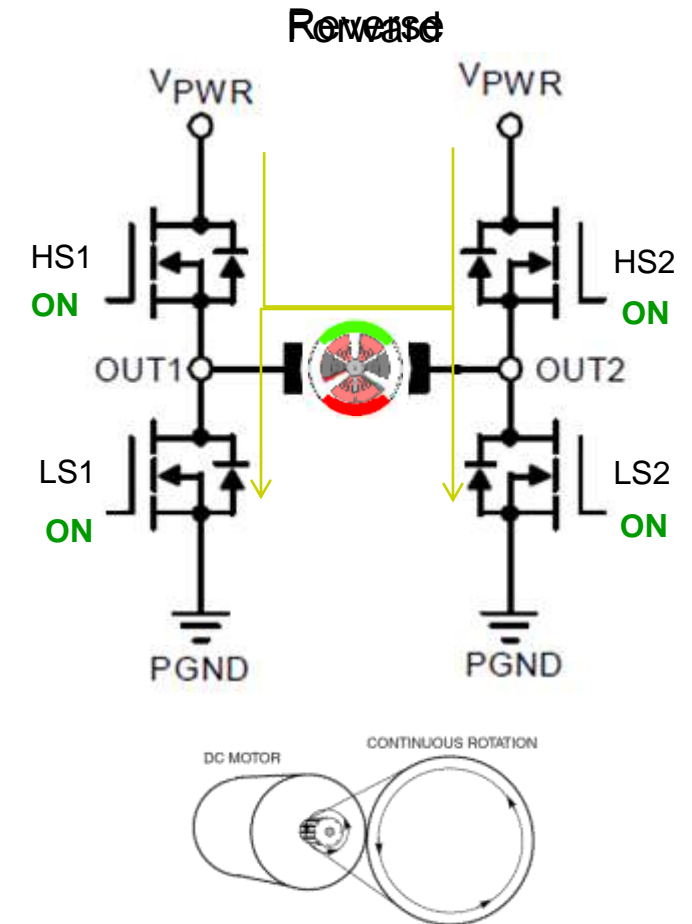
Main focus of our portfolio

- Brushed DC, Brushless DC, some Stepper
- Today we are focused on brushed, H-Bridge for direction and speed

Important considerations for motor drivers

- Voltage & current operation range; will vary depending on load (motor)
- Number of outputs
- Switching frequency; trade-off between noise and efficiency

NXP offers integrated solution combining analog, digital and power MOSFETs into a turnkey solution



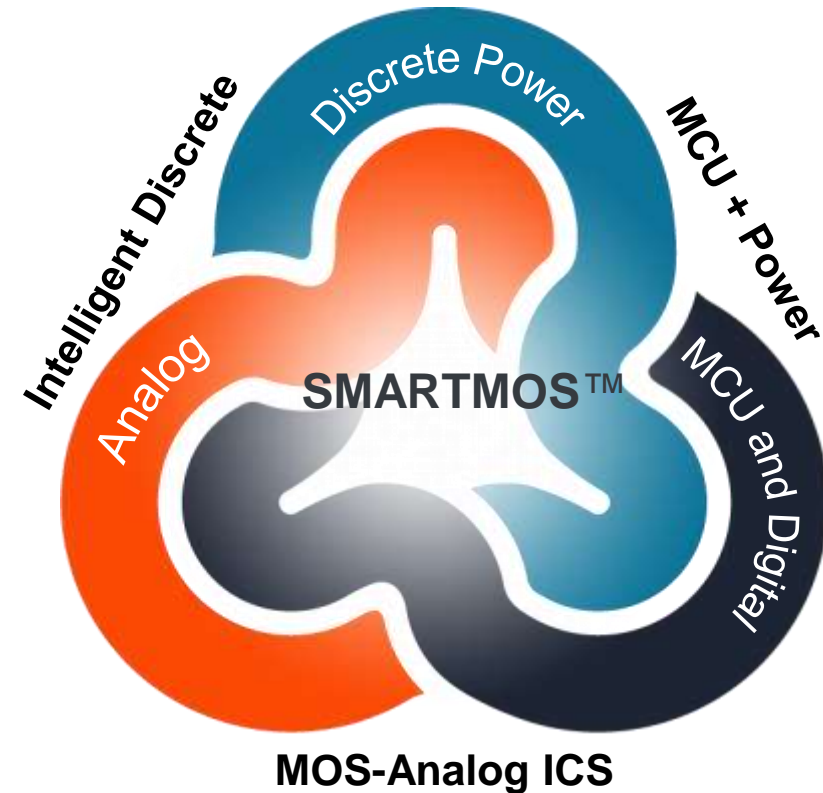
An H-bridge is an electronic circuit that enables a voltage to be applied across a load in either direction.




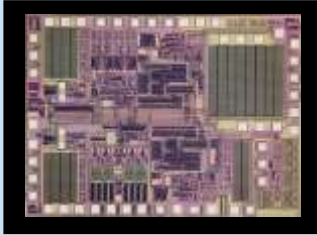
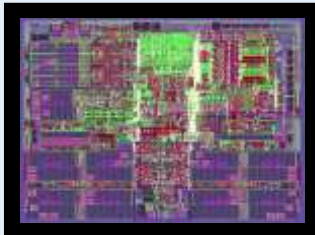
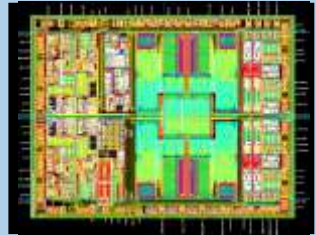
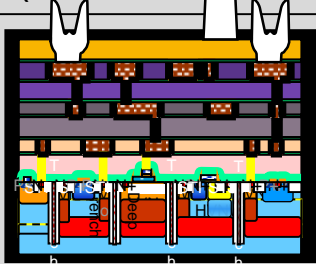
SMARTMOS™ Technology Integration

More than driving loads







- Cost effective high voltage (110 V) power analog embedded system process platform
- Low $RDS_{(ON)} \cdot A$ (30 m Ω -mm²) for thermal efficiency in high current applications
- High precision for sensor interface integrated with power applications
- Advanced isolation capability (-40 V) and robust system transient ESD/EMC immunity
- Low power devices to reduce overall system power consumption
- Extreme temperature operation for harsh application environments (-40 to +175°C)



SMARTMOS Evolution

| | | | | |
|--|---|--|--|--|
| Logic Density | 1.1 K | 2.0 K | 25.0 K | 90.0 K |
| Voltage Capability | 65 V | 105 V | 45 V | 105 V |
| 45V Power Rdson*A | 90 mΩ·mm ² | 67 mΩ·mm ² | 40 mΩ·mm ² | 30 mΩ·mm ² |
| Isolation Voltage | 65 V (Junction) | 105 V (Junction) | 80 V (Trench) | 105 V (Trench + SOI) |
|  |  |  |  |  |
| | SMOS5AP 1996 (0.8 μm) | SMOS5HVP 2002 (0.7 μm) | SMOS8MV 2006 (0.25 μm) | SMOS10HV 2013 (0.13 μm) |

Medium Voltage Motor Driver Feature Products

| Base Part # | Out | Op Volt (V) | RDS(ON) MAX(mΩ) | Peak Current (A) | SPI | Sleep (μA) | Freq (kHz) | Temp Range °C | Package (mm) | Samples/ Release |
|--------------|-----|-------------|-----------------|------------------|-----|------------|---------------|---------------|-------------------|---|
| MC33926PNB | 2 | 5-28 | 235 | 5 | - | 50 | 11/20 | -40 to 125 | PQFN 32 (8x8) | Now |
| MC33931EK | 2 | 5-28 | 235 | 5 | - | 50 | 11 | -40 to 125 | SOIC 32 (11x10.3) | Now |
| MC33932EK | 4 | 5-28 | 235 | 5 | - | 50 | 11 | -40 to 125 | SOIC 54 (18x10.3) | Now |
| MC34931SEK | 2 | 5-36 | 235 | 5 | - | 18 | 20 | -40 to 85 | SOIC 32 (11x10.3) | Now  |
| MC34932SEK | 4 | 5-36 | 235 | 5 | - | 18 | 20 | -40 to 85 | SOIC 54 (18x10.3) | Now  |
| MC33926ES | 2 | 5-28 | 235 | 5 | - | 50 | 11/20 | -40 to 125 | QFN 28 (6X6) | Now / Q4'16  |
| MC33HB2000ES | 2 | 5-36 | 235 | 5/7/9/11 | Y | 50 | 2-50 8 div | -40 to 125 | QFN 28 (6X6) | Now / Q4'16  |
| MC33HB2000EK | 2 | 5-36 | 235 | 5/7/9/11 | Y | 50 | 2-50 8 div | -40 to 125 | SOIC 32 (11x10.3) | Now / Q2'16  |
| MC33HB2001EK | 2 | 5-36 | 125 | 5/7/9/11 | Y | 50 | 2-50 8 div | -40 to 125 | SOIC 32 (11x10.3) | Now  |
| MC33HB2000FK | 2 | 5-36 | 235 | 5/7/9/11 | Y | 50 | 2-50 8 div | -40 to 125 | PQFN 32 (8x8) | Now / Q2'16  |
| MC33HB2001FK | 2 | 5-36 | 125 | 5/7/9/11 | Y | 50 | 2-50 8 div | -40 to 125 | PQFN 32 (8x8) | Now / Q2'16  |

APPLICATIONS



Driver Segment – Standard ICE Powertrain Electrification

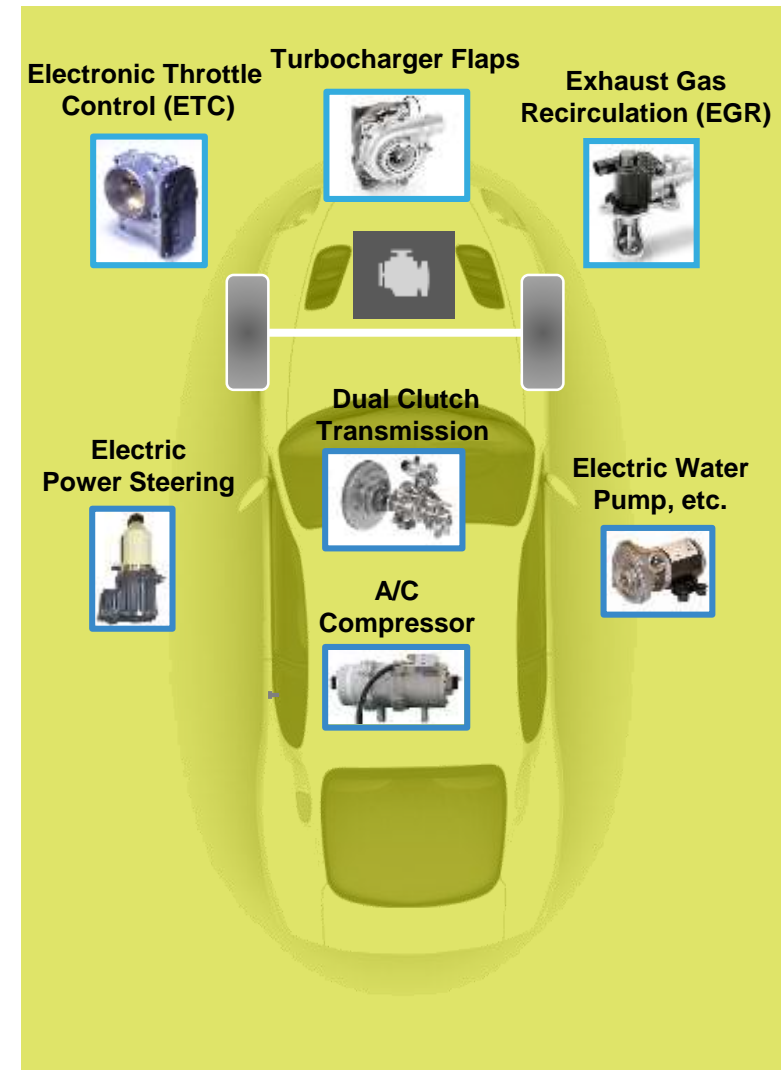
Key Applications and Products

Brushed DC Motor Control

- Key H-Bridges Drivers Applications
 - MC33926, MC33931, MC33932
 - MC33HB2000, MC33HB2001 (Q1'16 release)

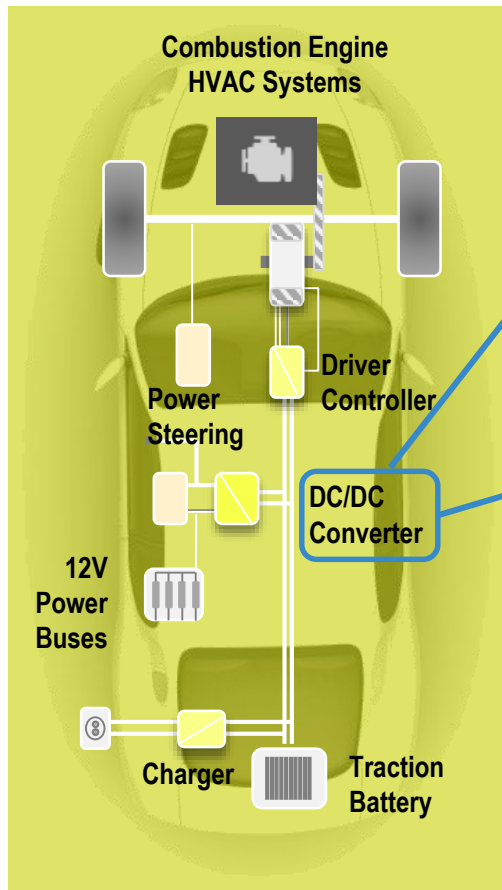
Brushless DC Motor Control

- These applications are primarily 3-Phase Gate Driver, but can be H-Bridge
 - MC33937
 - MC33GD3000 (Q4'15 release)
 - MC33GD3601 (TBD)



Driver Segment – Products for Powertrain Electrification

Key Application for 48 V HEV MOSFET GDIC and HV IGBT GDIC



48 V Mild-Hybrid (HEV) & Torque-Assist Systems Permanent Magnetic Synchronous Motors (PMSM) & Switched Reluctance Motors (SRM)



- MC33GD3200 (NPI for PMSM)
- MC33GD3201 (NPI for SRM)

Electric Vehicle (EV) High-Power Inverters & Plug-In Hybrid HV IGBT Gate Driver



- MC33GD3100 (NPI)

MC33HB2000 & 2001 Target Applications

Target Applications: Robust, Remote, Critical



Automotive Throttle

Product Function

- Electronic Throttle Control (ETC)
- Bi-directional control of butterfly valve to regulate Air Flow in drive by wire systems



Other Auto

Product Function

- Cruise Control
- Electronic Gas Recirculation (EGR)
- Multi-Port Injection (MPI) Flaps Control
- Gasoline Direct Injection (GDI) Swirl and Whirl Flaps

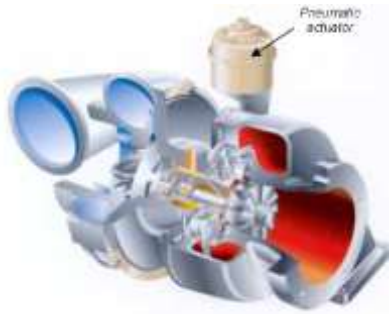


Industrial

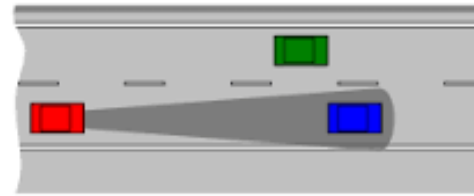
Product Function

- Medical
- Down hole / Avionics
- Robotics
- Home Automation
- Rolling Doors
- Where voltage and current matches the application

MC33HB2000 & HB2001 Automotive Applications



Electronic Gas Recirculation



Cruise Control



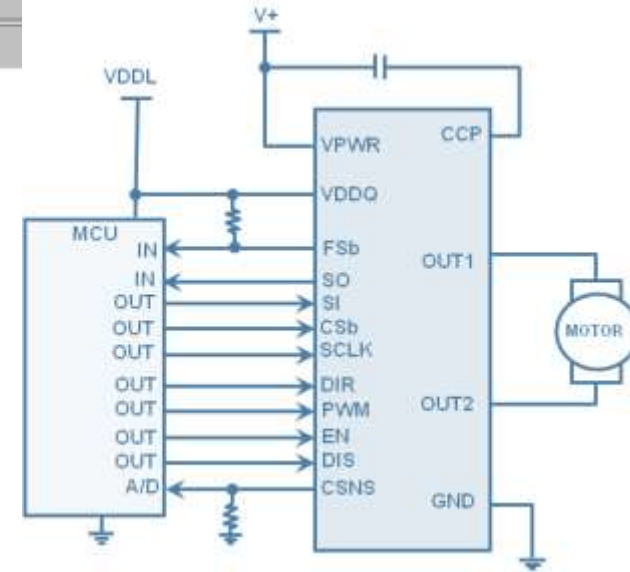
Turbocharger Flaps



Throttle Control



Rear Window Wiper



- Brushed DC motor
- Robust Operation

BLOCK DIAGRAM AND KEY FEATURES



MC33931 Monolithic Single H-Bridge Motor Driver

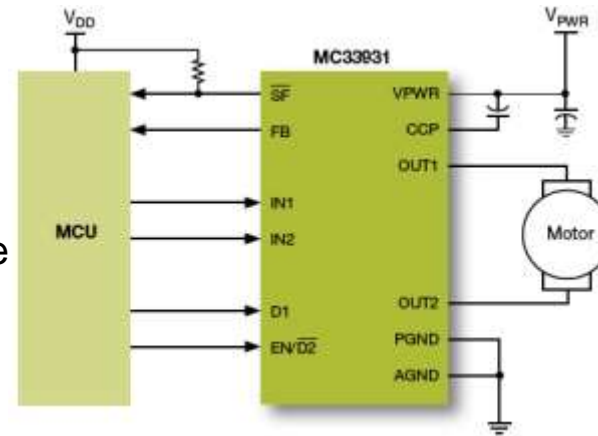
Thermally efficient 28V/5A H-Bridge DC motor driver featuring real-time load current monitoring and automatic thermal back-off ensures high availability operation in demanding high current, harsh environment applications

• Differentiating Points

- Ultra-low theta JC < 1°C/Watt for superior heat dissipation
- Current Mirror – 1/400 out from current flowing in MOSFET
- Over current limiting (regulation) via internal constant-off-time PWM
- Over temperature protection – current fold back at 165°C
- Temperature dependent shut down at 185°C
- Short to PWR, Short to GND, UVLO, Open Load Detect

• Product Features

- H-Bridge configuration for bi-directional motors
- 5 to 28 Volt continuous; to 40 V transient operation
- 5 Amp peak output current
- 235 mΩ maximum @ T_j=150°C, 120 mΩ typical RDS(ON) @ T_j=25°C (for each H-Bridge MOSFET)
- 3 and 5V TTL/CMOS logic compatible inputs
- Sleep mode current typical < 50 μA



32-Pin, SOIC-EP
10x11 mm

Availability

Samples: Now
Production: Now

Typical Applications

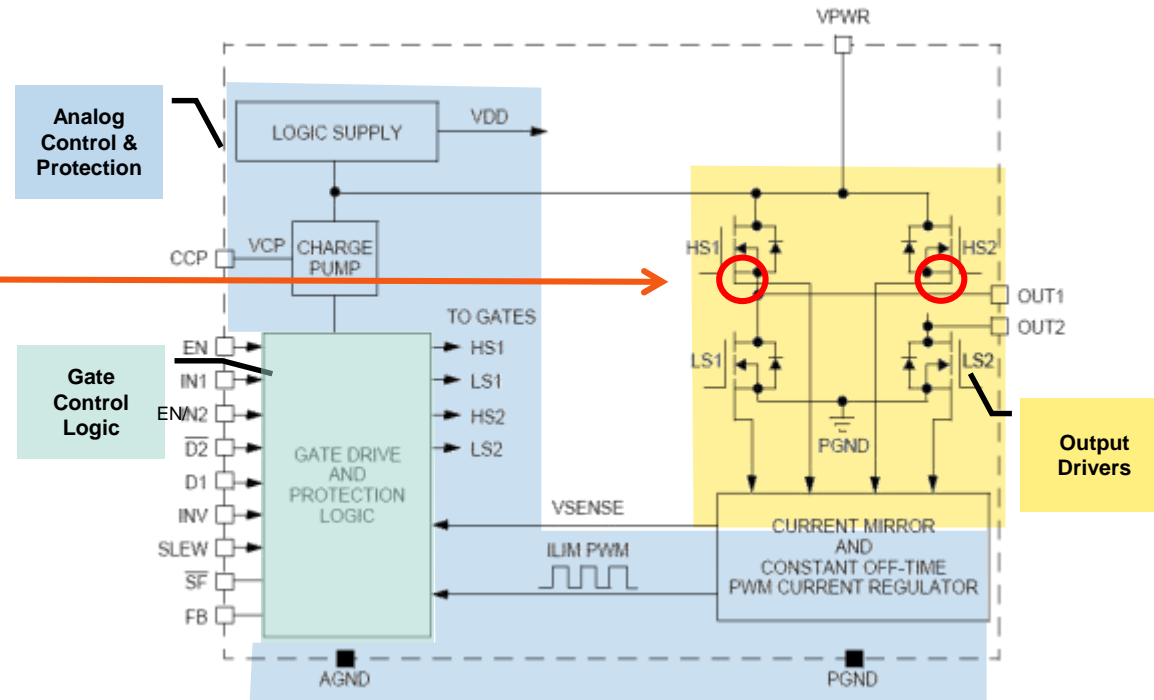
- Electronic Throttle Control
- Electronic Gas Recirculation
- Turbo Flap Control

33931 H-Bridge Block Diagram

33926PNB (PQFN) Single
33931EK & 931SEK (SOIC) Single
33932EK & 33932SEK (SOIC) Dual

Driver protects against thermal damage when motor is binding or under heavy loads

- Package offers lowest thermal resistance $< 1^{\circ}\text{C/W}$
- Current & temperature of MOSFETs monitored using real time current mirror
- When at ILIM device will start to switch (PWM) MOSFETs
- At 165°C device will thermal fold back to 4.2 A or less
- At 185°C device will shut down when temperature exceeds safe operation range



Thermal Management – For Motor and Device Protection)

PWM switching to 6.5 A at < 165°C

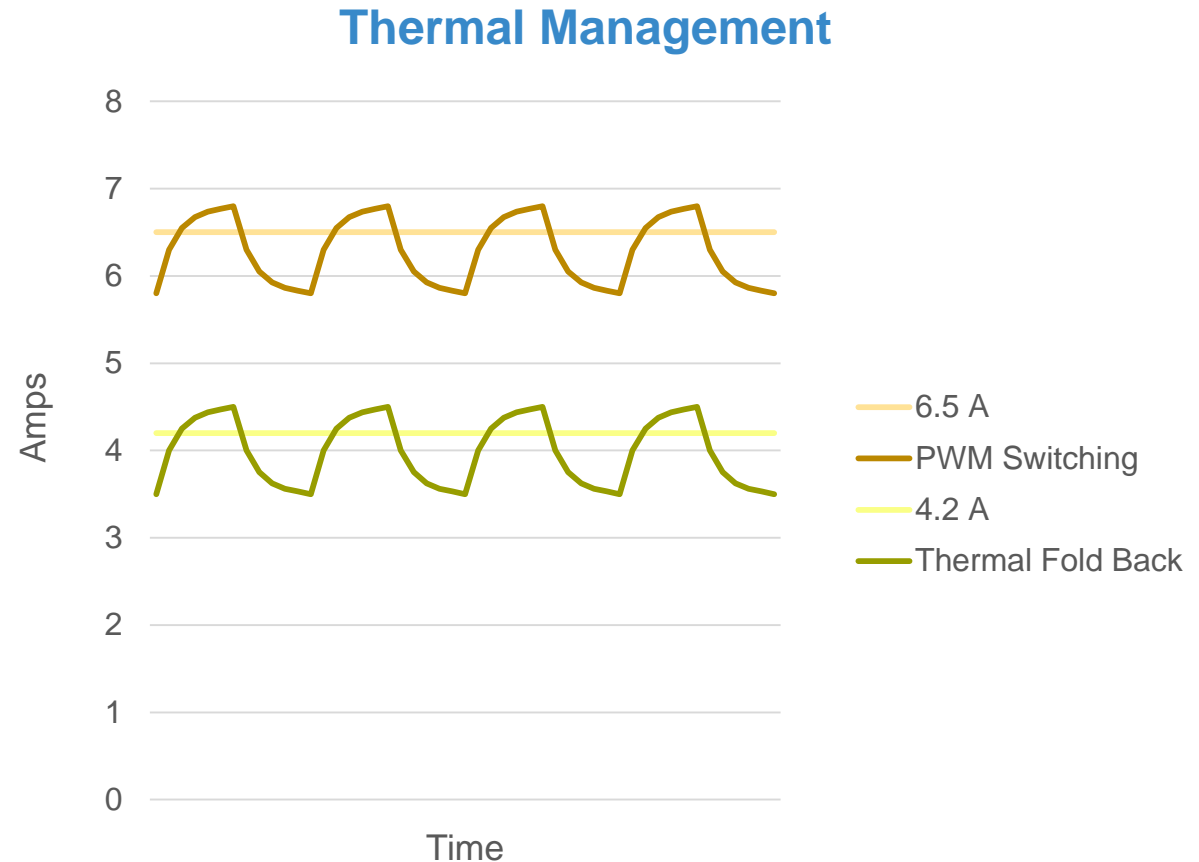
- Below 165°C, the device PWMs the outputs, averaging under 6.5 A to reduce thermals while continuing operation

Thermal fold back to 4.2 A or less at > 165°C

- Above 165°C, the device goes into thermal fold back, averaging under 4.2 A or lower to reduce thermals while continuing operation

Thermal shutdown at 185°C

- Above 185°C, the device shuts down



HB2000/HB2001 Key Features

The HB2000/1 are advanced H-Bridge Motor Driver designed to provide enhanced safety features for high-safety integrity, SPI control for improved flexibility, and thermal management for continuous operation

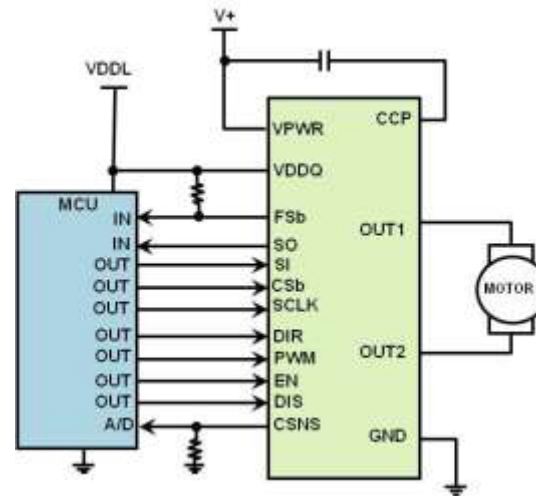


Differentiating Points

- First part designed to support ISO26262 ASIL D
- 4X more accurate real time current feedback ($\pm 5\%$)
- 53% lower RDS(ON)
- 50% lower thermal resistance $< 1^\circ\text{C/W}$
- 42% smaller package
- Widest slew rate selection for continuous operation
- Patented thermal protected current limit
- Pin for Pin drop-in replacement for flexibility

Product Features

- 4.5 – 28 V supply, 40 V transient
- MB33HB2000: 120 m Ω typical
- MB33HB2001: 65 m Ω typical (best in industry)
- SPI selectable current limits: 5.4 / 7.0 / 8.8 / 10.7 A
- SPI selectable slew rates: 0.25, 0.5, 1, 2, 4, 8, 16 V/ μs & by-pass
- Two packages: 8 x8x1.2 mm PQFN and
 - 10x11x1.2 mm SOIC-EP Package



| PART # | PKG | RELEASE |
|--------------|---------|---------|
| MC33HB2000EK | SOIC 32 | NOW |
| MC33HB2000FK | PQFN 32 | Q3'16 |
| MC33HB2001EK | SOIC 32 | NOW |
| MC33HB2000FK | PQFN 32 | Q3'16 |

Typical Applications

- Electronic Throttle Control
- Electronic Gas Recirculation
- Turbo Flap Control

HB2000 & HB2001 H-Bridge Circuit Block Diagram

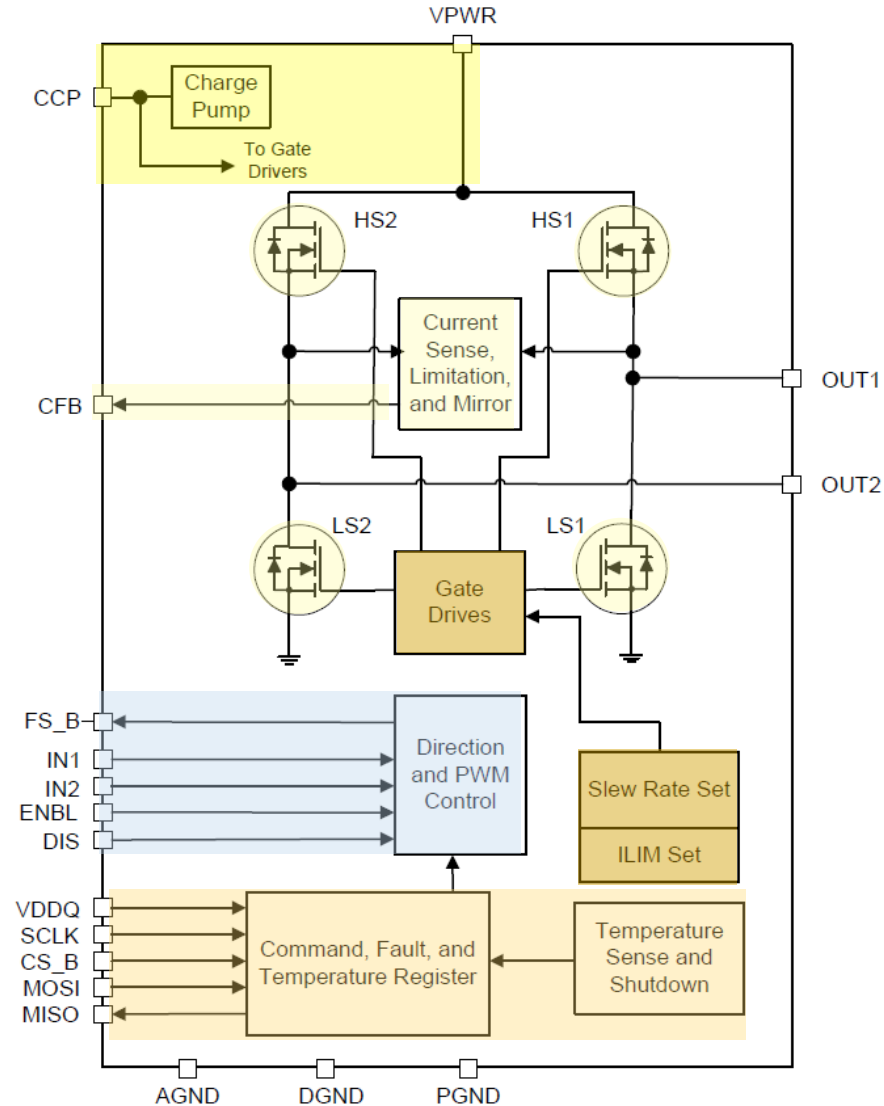
VPWR (Power Supply Input)
 $5\text{ V} < \text{VPWR} < 28\text{ V}$ ($\text{UVLO} < \text{VPWR} < 40\text{ V}$)

CCP (Charge Pump Capacitor connect pin) CCP
 $\text{Clamp} = \text{VPWR} + 12\text{V}$

CFB (Current Mirror Output)
 $\pm 5\%$ current accuracy @ $2\text{ A} < \text{Iload} < 10\text{ A}$

FS_B (Fault output, open drain)
IN1, IN2 (Output Control)
 Two control modes support by SPI
H Bridge Mode (Default)
 IN1=Direction control, IN2=PWM input
Half Bridge Mode
 IN1=OUT1 control, IN2=OUT2 control
ENBL (IC Enable)
DIS (Output Disable)

VDDQ (P/S for SPI_MISO output)
SCLK, CS_B, MOSI, MISO (SPI Communication I/O)
 Supports configuration, check fault status and daisy chain connection.



Rdson @ $8\text{ V} < \text{VPWR} < 28\text{ V}$,
 $T_J = 150^\circ\text{C}$, $\text{Iload} = 3\text{ A}$

125 mΩ (33HB2001)
 235 mΩ (33HB2000)

Programmable Slew Rate
 Bypass / 16 / 8 / 4 / 2 / 1 / 0.5 / 0.25 V/us

Programmable Current Limit
 5.4 / 7.0 / 8.8 / 10.7 Amps

Full Diagnostics

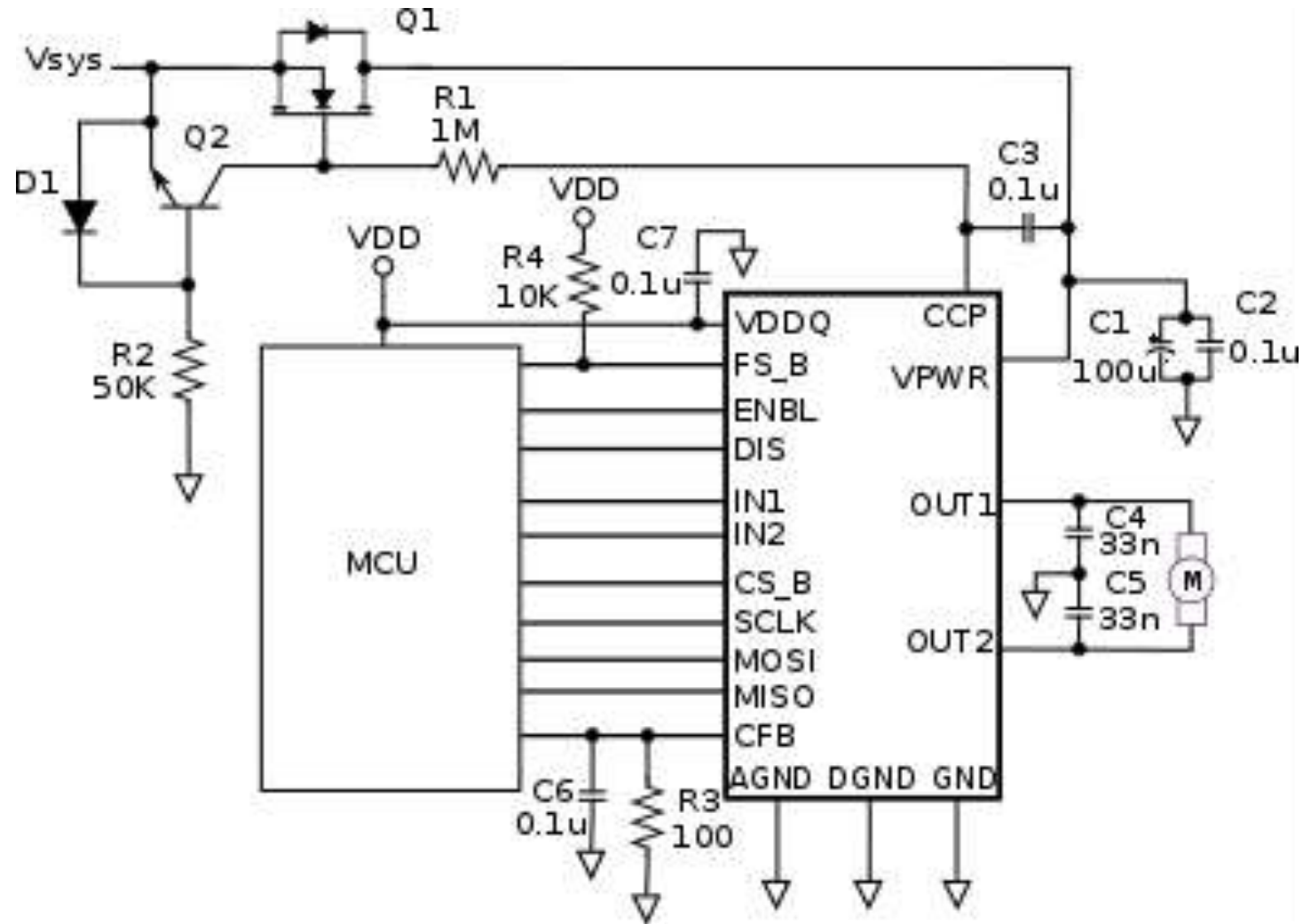
HB2000 & HB2001 Performance Enhancements

- High speed daisy chainable 10 MHz SPI
- Any status bit can be programmed to feedback via status pin for full configurability
- Selectable Overvoltage Protection
 - May be disabled to extend voltage range
 - Available as warning only in half-bridge control mode
 - Full bridge mode protection goes to HS recirculation
- Functional 4.0V to 40V (UV during crank to max rating)
- HB2000 and HB2001 are 100% pin and function compatible
- Thermal impedance $R_{\theta JC_bottom} < 0.8 \text{ } ^\circ\text{C/W}$
- I/O withstands 36V
- Safety: Supports ISO26262 safety feature in full bridge mode

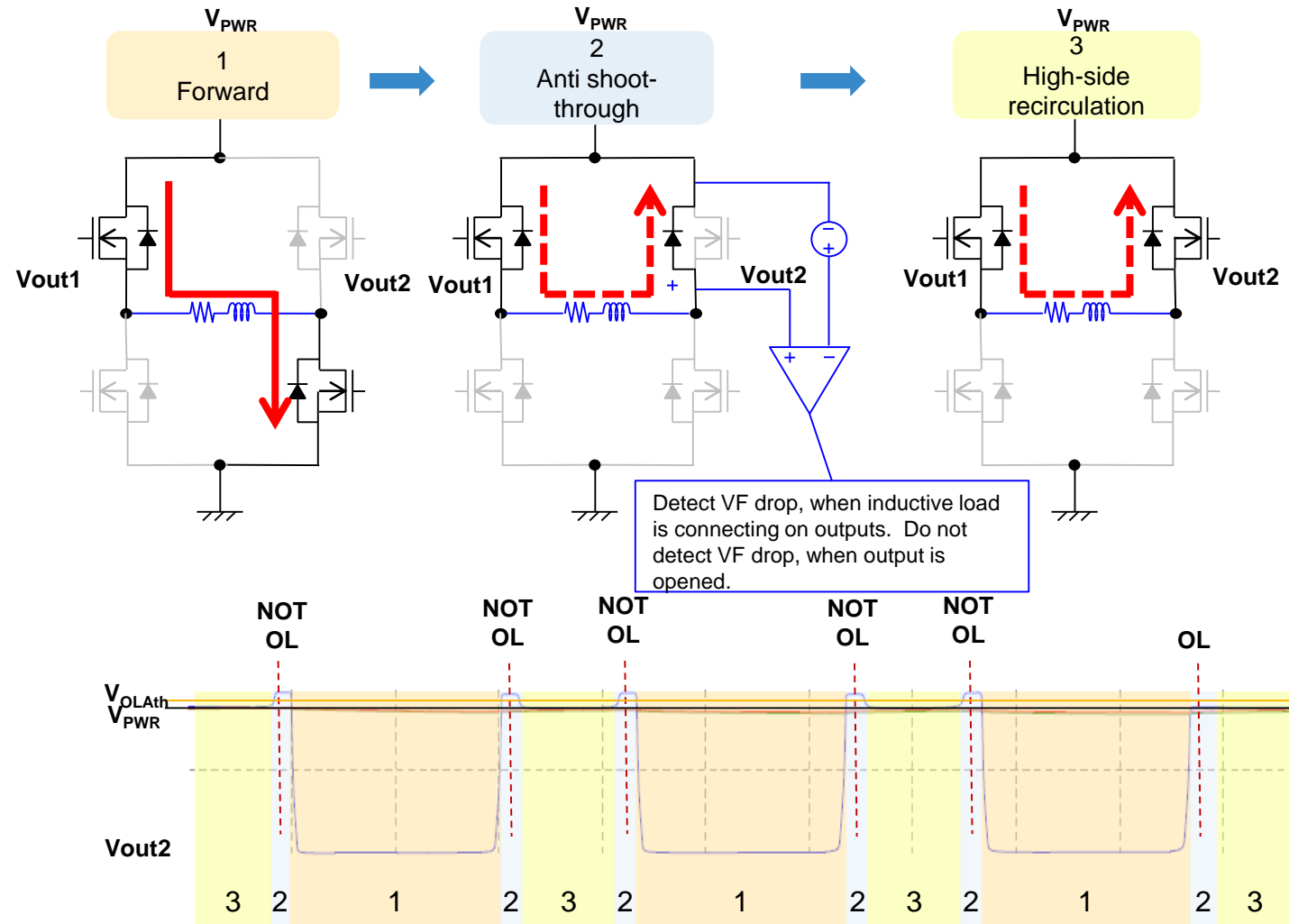
HB2000 & HB2001 Enhanced Diagnostics

- SPI register always provides detailed status bits
 - Over Temperature Shutdown
 - Thermal Warning
 - Over Current
 - Open Load (in standby mode and in normal full H-bridge operating mode)
 - Short Circuit to Ground Output 1
 - Short Circuit to Ground Output 2
 - Short Circuit to Power Output 1
 - Short Circuit to Power Output 2
 - Vpwr Over Voltage
 - Vpwr Under Voltage
 - Charge Pump Under Voltage
 - SPI Framing Error

HB2000 & HB2001 Supports external N-Channel MOSFET for reverse battery protection

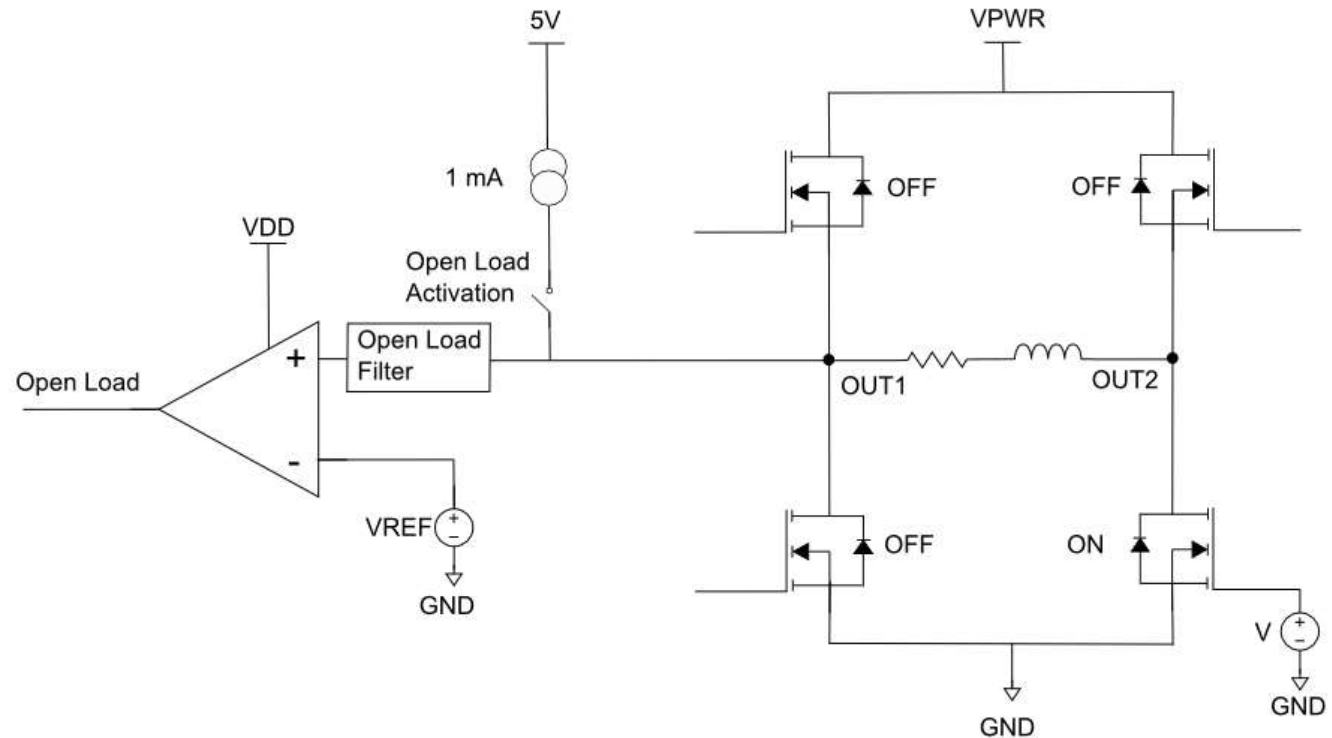


HB2000 & HB2001 Active-mode Open Load Detection Diagram



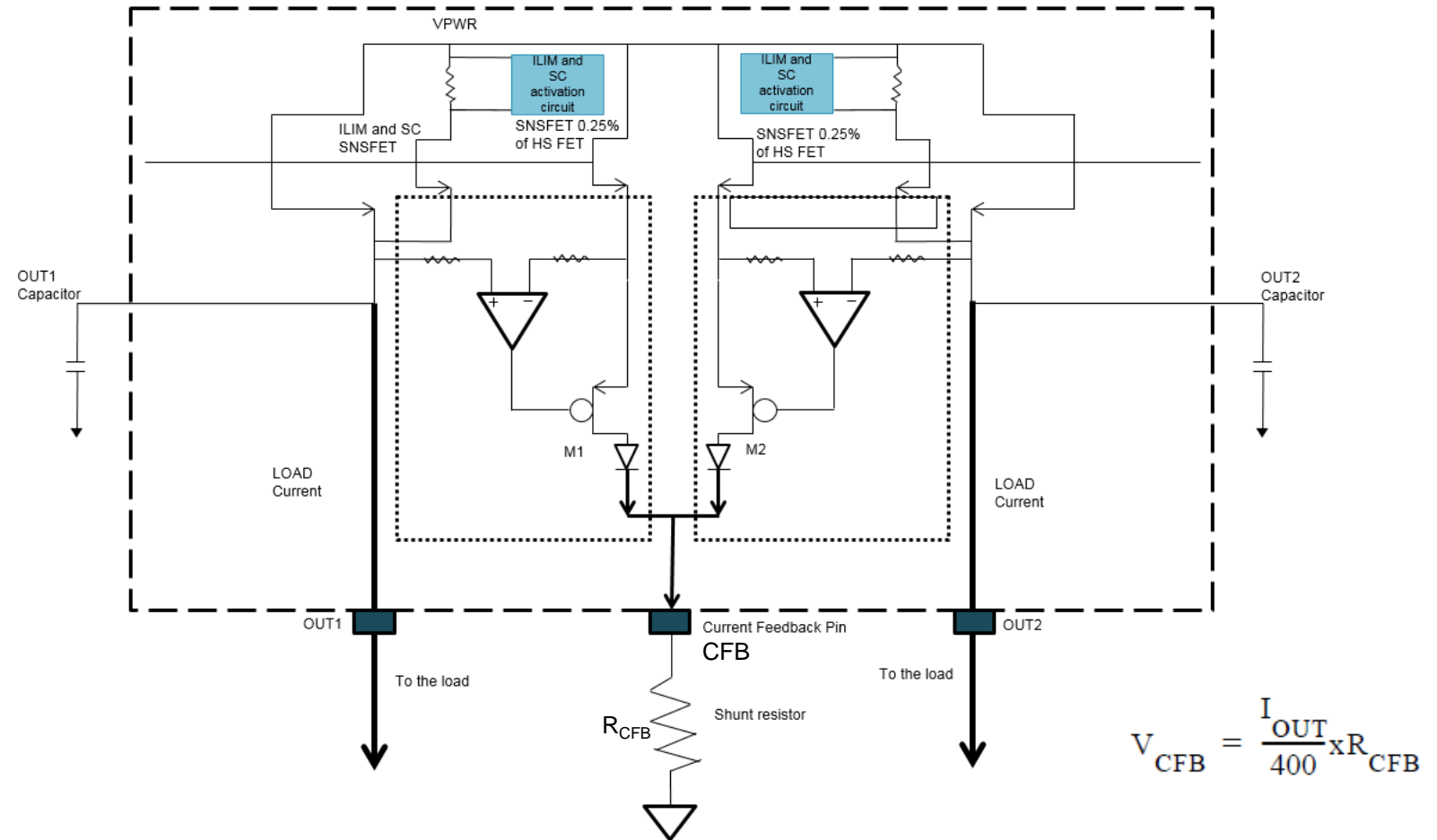
HB2000 & HB2001 Stand-by Mode Open Load Detection

- Operates in Standby mode in H-Bridge mode
- Designed for applications having less than 50 nF from OUT1 and OUT2 to GND
- Load inductance < 15 mH, and an equivalent load resistance of 600 Ω (typical)



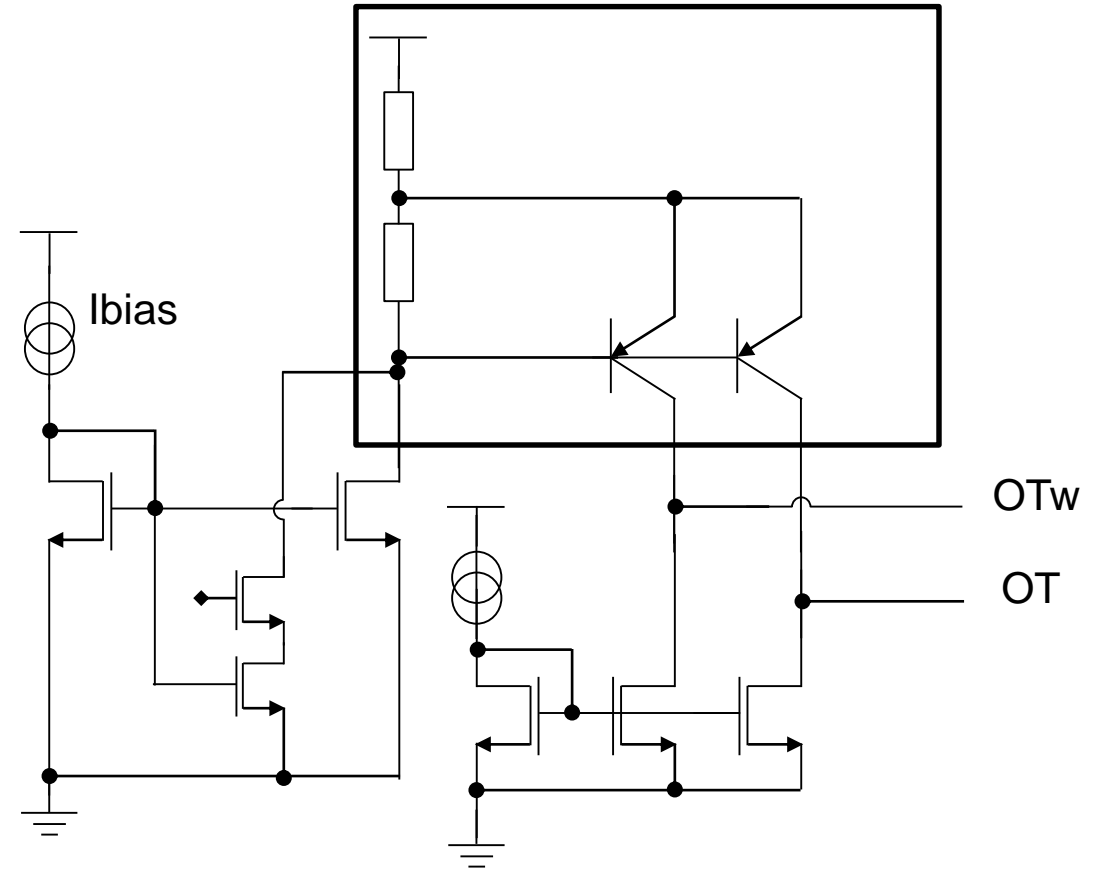
High Accuracy Current Feedback Via CFB Pin

- Current feedback with less than $\pm 5\%$ tolerance between 2 to 10 A load current
- An external resistor connected to the CFB pin to set current to voltage gain



Real Time Temperature Monitoring for Power FETs

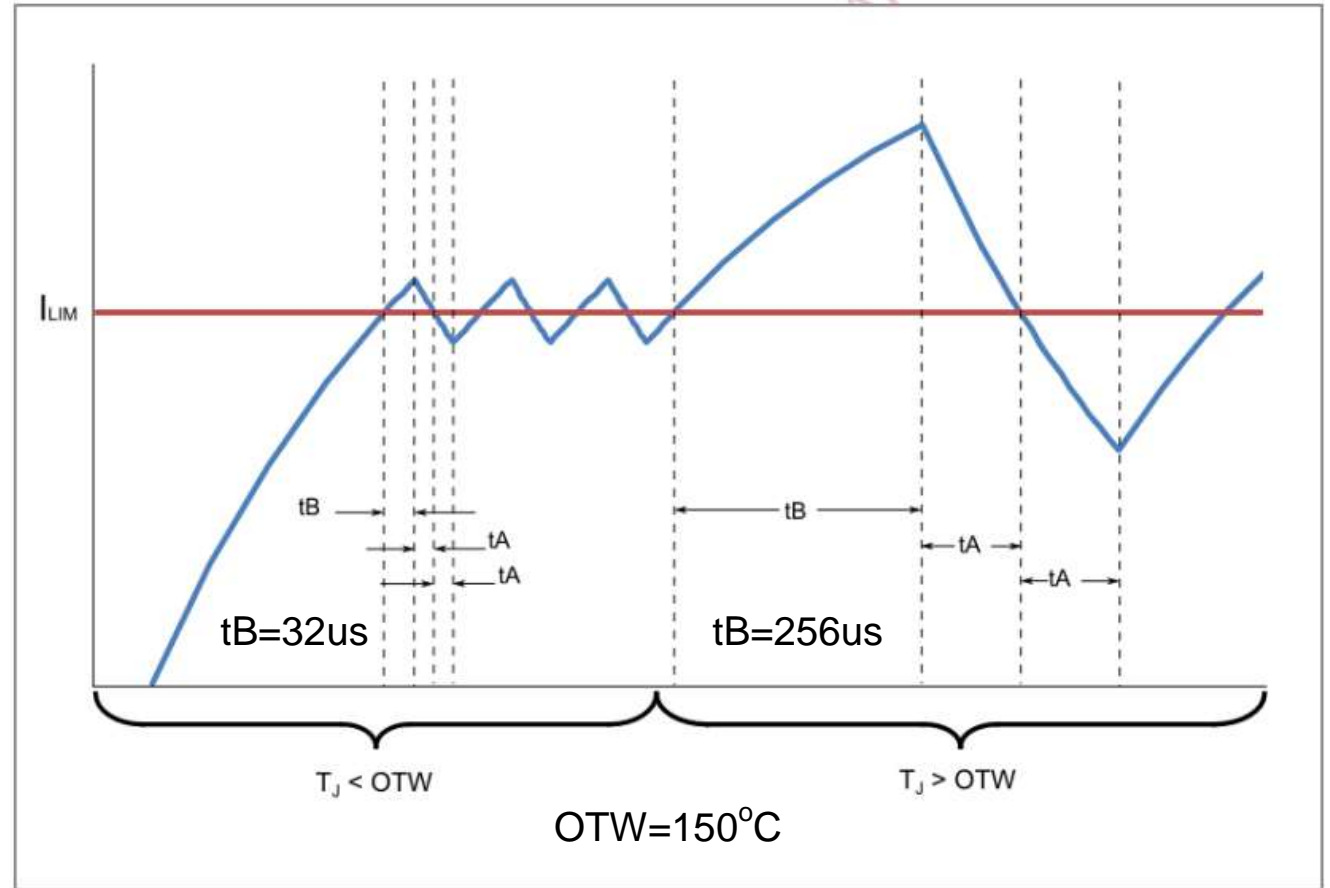
- Continuously monitors the temperature of each of the 4 power FETs for Over-temperature warning (Otw) and Over-temperature shutdown (OT).
- Enables patented temperature dependent current limiting circuit to cool down the part without compromising on current drive capability at elevated device temperature.



HB2000 & HB2001 Active Current Limit

- Programmable Current Limit
 - 4 settings from nominal 5.4 A to 10.7 A average
 - Short Circuit threshold scales up/down as per the current limit selected
 - Patented thermal management does not compromise the current set point; delivers more torque

| Setting | I_{LIM} | Short Circuit HS | Short Circuit LS | Units |
|---------|-----------|------------------|------------------|-------|
| 00 | 5.4 | 11.9 | 10.9 | A |
| 01 | 7.0 | 13.5 | 12.5 | A |
| 10 | 8.8 | 15.3 | 14.3 | A |
| 11 | 10.7 | 17.2 | 16.2 | A |



Ilim Timing and Thermal response

LIVE CURRENT LIMIT DEMONSTRATION



ROADMAP



MC33926ES New Package Proposal

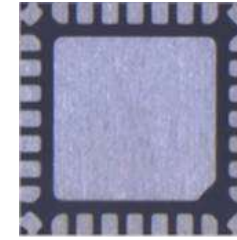
Thermally efficient 28 V/5 A H-Bridge DC motor driver featuring real-time load current monitoring and automatic thermal back-off ensures high availability operation in demanding high current, harsh environment applications

Differentiating Points

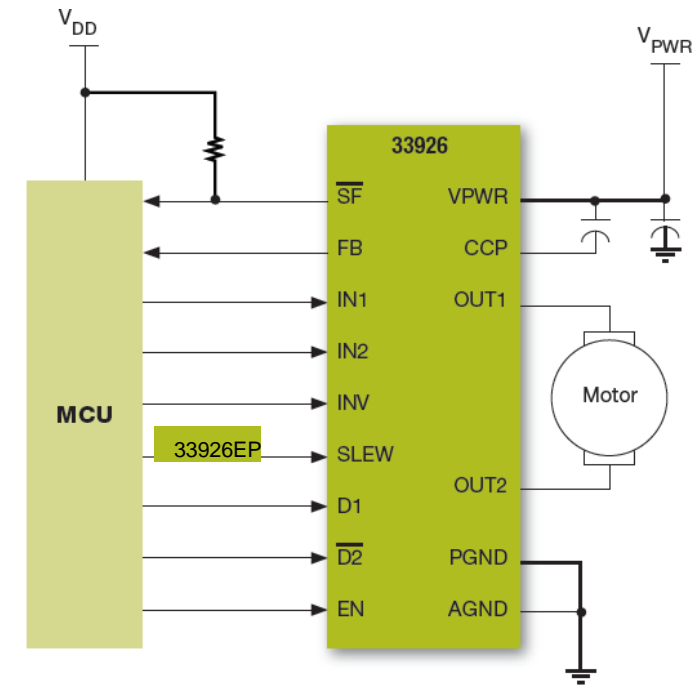
- Current mirror – 1/400 out from current flowing in MOSFET
- Over current limit – via internal constant-off-time PWM
- Over temperature protection – current fold back at 165°C
- Temperature dependent shut down – at 185°C
- Short to PWR, Short to GND, UVLO, Open Load Detect
- Selectable Slew Rate Control (11 or 20kHz)

Product Features

- H-Bridge configuration for bi-directional motors
- 5 to 28 Volt continuous; to 40 V transient operation
- 5 Amp peak output current
- 235 mΩ maximum @ T_j=150°C, 120 mΩ typical RDS(ON) @ T_j=25°C (for each H-Bridge MOSFET)
- 3 and 5 V TTL/CMOS logic compatible inputs
- Protected against common failure conditions
- Available with and without inspectable fillets
- Theta JC - tbd



28-Pin, QFN
6x6 mm
(proposal)



| PART # | PKG | SAMPLES | RELEASE |
|-----------|-------|---------|---------|
| MC33926ES | QFN28 | NOW | Q4'16 |

Typical Applications

- Electronic Throttle Control
- Electronic Gas Recirculation
- Turbo & Swirl Flap Control



MC33HB2000 & MC33HB2001 New Package

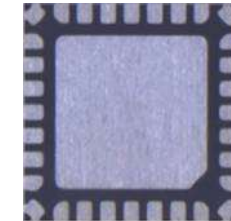
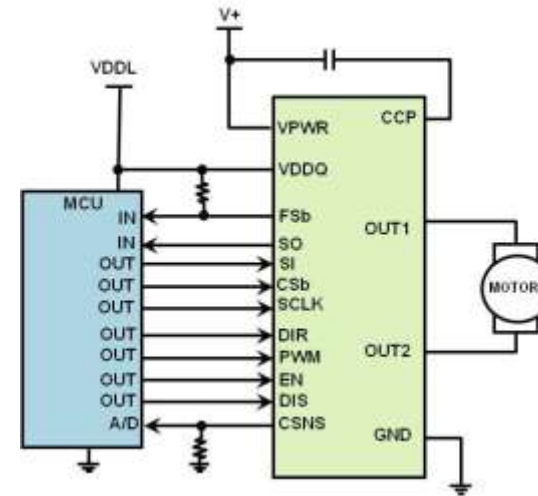
The MC33HB2000/1 are advanced H-Bridge Motor Driver designed to provide enhanced safety features for high safety integrity, SPI control for improved flexibility, and thermal management for continuous operation

Differentiating Points

- First ISO26262 Qualified
- Most accurate real time current feed back (5%)
- Lowest RDS(ON)
- Smallest package
- Widest slew rate selection for continuous operation
- Patented thermal protected current limit
- Pin for Pin drop-in replacement for flexibility

Product Features

- 4.5 – 28 V supply, 40 V transient
- MB33HB2000EJ: 120 mΩ typical
- MB33HB2001EJ: 65 mΩ typical (best in industry)
- SPI selectable current limits: 5.4 / 7.0 / 8.8 / 10.7 A
- SPI selectable slew rates: 0.25, 0.5, 1, 2, 4, 8, 16 V/μs & by-pass
- New package: 6x6 mm, 28ld, thermal resistance target < 1°C/W



28-Pin, QFN
6x6mm
(proposal)

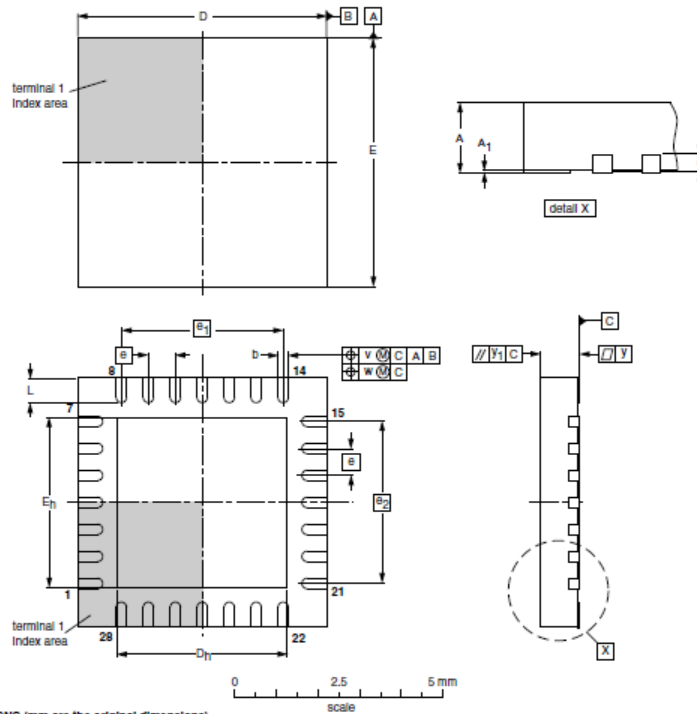
Typical Applications

- Electronic Throttle Control
- Electronic Gas Recirculation
- Turbo Flap Control

| PART # | PKG | SAMPLES | RELEASE |
|--------------|-------|---------|---------|
| MC33HB2000ES | QFN28 | NOW | Q4'16 |
| MC33HB2001ES | QFN28 | TBD | TBD |

HVQFN28

Plastic Thermal Enhanced Very Thin Quad Flat Package; No Leads; 28 Terminals; Body 6 x 6 x 0.85 mm With Inspectable Fillets



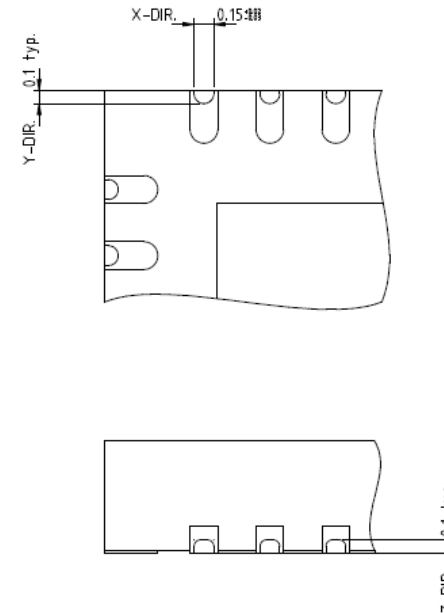
DIMENSIONS (mm are the original dimensions)

| UNIT | A ⁽¹⁾ max. | A ₁ | b | c | D ⁽¹⁾ | D _{tr} | E ⁽¹⁾ | E _{tr} | e | e ₁ | e ₂ | L | v | w | y | y ₁ |
|------|--------------------------|----------------|--------------|-----|------------------|-----------------|------------------|-----------------|------|----------------|----------------|--------------|-----|------|------|----------------|
| mm | 1 | 0.05 0.00 | 0.35 0.25 | 0.2 | 6.1 5.9 | 4.25 3.95 | 6.1 5.9 | 4.25 3.95 | 0.65 | 3.9 | 3.9 | 0.75 0.50 | 0.1 | 0.05 | 0.05 | 0.1 |

Note

1. Plastic or metal protrusions of 0.075 mm maximum per side are not included.

| OUTLINE VERSION | REFERENCES | | | EUROPEAN PROJECTION | ISSUE DATE |
|--------------------|------------|--------|-------|------------------------|------------|
| | IEC | JEDEC | JEITA | | |
| SOT798-1 | --- | MO-220 | --- | | 02-10-22 |



BURR SPECIFICATION:

- MAX. ALLOWABLE BURRS: X-DIRECTION = 0.05
Y-DIRECTION = 0.075
Z-DIRECTION = 0.04
- SHARP CAVITY EDGE VISIBLE ON BOTTOM SIDE.

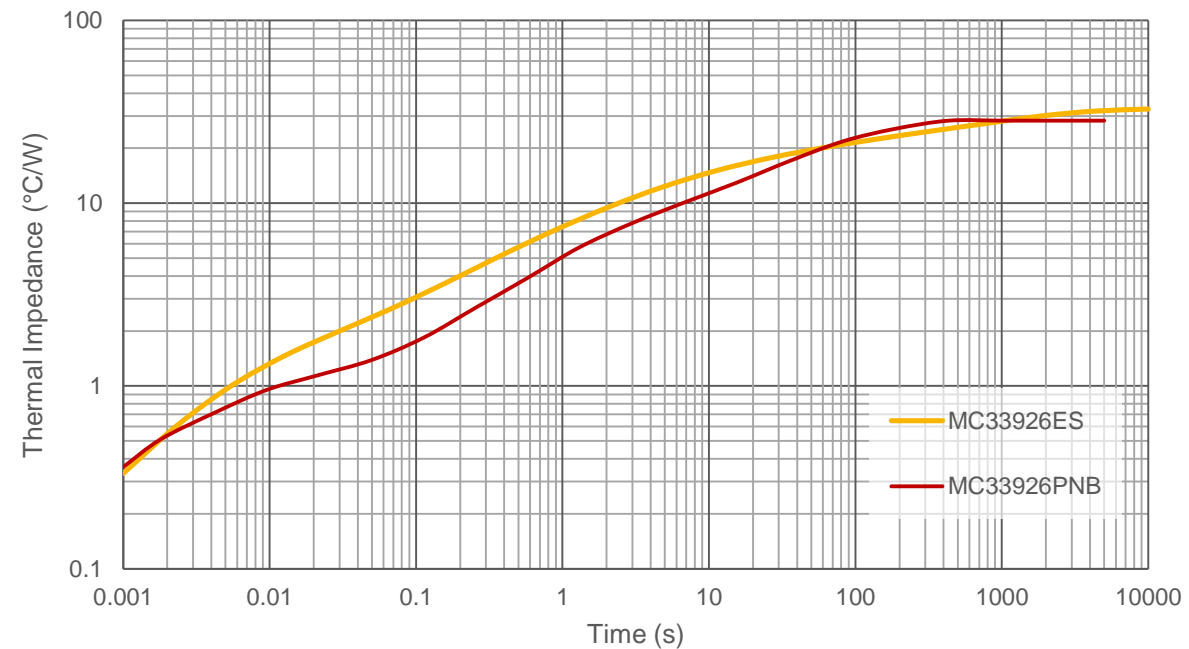


HVQFN28 6x6 Thermal comparison to PQFN32 8x8

Table of Thermal Resistance Data for MC33926 (°C/W)

| Rating | | | QFN | PQFN | Unit |
|---|-------------------------|-----------------|------|------|------|
| Junction to Ambient Natural Convection | Single Layer board (1s) | R_{qJA} | 90.2 | 80 | °C/W |
| Junction to Ambient Natural Convection | Four layer board (2s2p) | R_{qJA} | 32.8 | 28 | °C/W |
| Junction to Board | | R_{qJB} | 12.7 | 12 | °C/W |
| Junction to Case (Bottom) | | $R_{qJCBottom}$ | 1.54 | 1.0 | °C/W |
| Junction to Package Top | Natural Convection | Y_{JT} | 1.87 | | °C/W |

Transient Thermal Response on JEDEC 2s2p

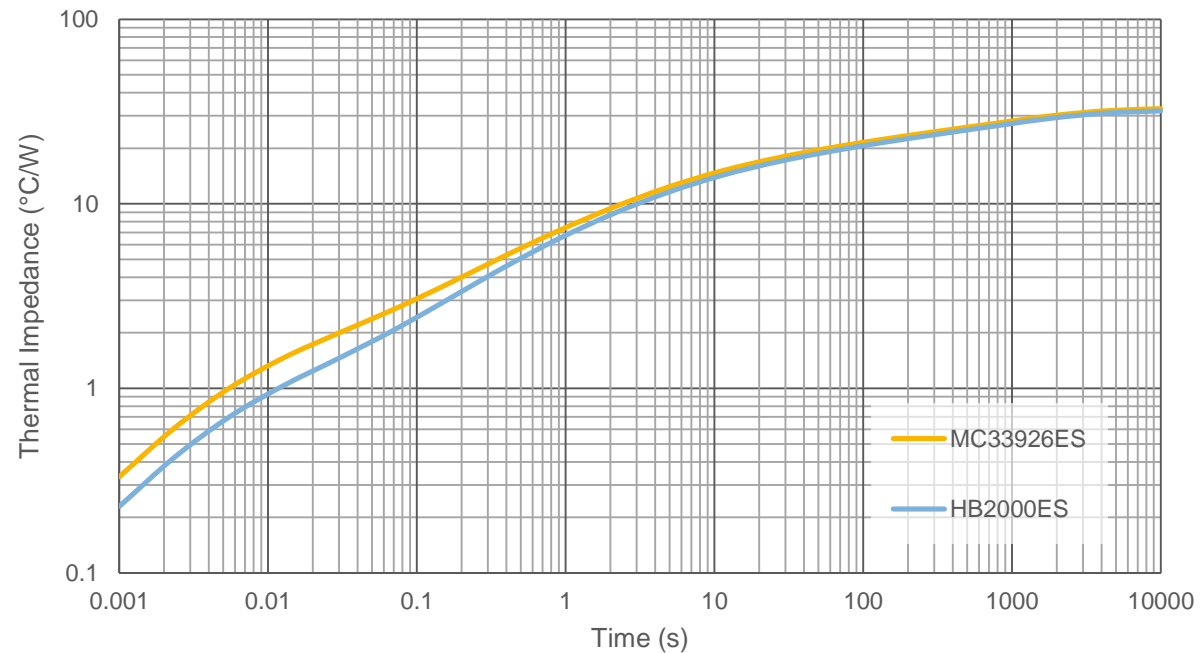


QFN Thermal Comparison MC33926PNB to HB2000ES

Table of Thermal Resistance Data for (°C/W)

| Rating | | | MC33926 | HB2000 | Unit |
|---|----------------------------|-----------------|---------|--------|------|
| Junction to Ambient Natural Convection | Single Layer board (1s) | R_{qJA} | 90.2 | 88.9 | °C/W |
| Junction to Ambient Natural Convection | Four layer board (2s2p) | R_{qJA} | 32.8 | 31.9 | °C/W |
| Junction to Board | | R_{qJB} | 12.7 | 11.9 | °C/W |
| Junction to Case (Bottom) | | $R_{qJCBottom}$ | 1.54 | 1.07 | °C/W |
| Junction to Package Top | Natural Convection | Y_{JT} | 1.87 | 1.45 | °C/W |

Transient Thermal Response on JEDEC 2s2p



ENABLEMENT TOOLS



H-Bridge DC Motor Drivers

HB2000 & HB2001 Ecosystems

- Freedom kits include:
 - Development board
 - Users Guide
 - Schematic and bill of material
 - Software
 - Pre-programmed FRDM-KL25Z
- Development tools:
 - [SPIGen](#) GUI software available on NXP website
 - Attach to FRDM-KL25Z and others
 - PE and new AML for production ready enablement



| NXP Part # | Kit Name | Associated Boards |
|--------------|-----------------|---|
| MC33HB2000EK | FRDM-HB2000-EVM | FRDM-KL25Z / others |
| MC33HB2000FK | FRDM-HB2000FEVM | FRDM-KL25Z / others |
| MC33HB2001EK | FRDM-HB2001-EVM | FRDM-KL25Z / others |
| MC33HB2001FK | FRDM-HB2001FEVM | FRDM-KL25Z / others |

Availability

Live expect the AML

HB2000 & HB2001 SPIGen GUI

The screenshot displays the SPIGen GUI interface. At the top, there is a menu bar with 'File', 'Edit', 'View', 'Configuration', 'USB to SPI Dongle', and 'Help'. Below the menu bar is a toolbar with various icons. The main window is divided into several sections:

- SPI Words:** Two 16-bit registers for 'SPI Word Sent' and 'SPI Word Received', each with bit positions 15 to 0. Below them are checkboxes for '=' and '= 1'.
- Device View:** A tree view on the left showing a hierarchy of devices including 'Generic', 'MC33813', 'MC33814', 'MC33816', 'MC33909', 'MC33978', 'MC33HB2001', and 'MC33PT2000'. Each device has sub-items for 'Single Command', 'Batch Commands', 'Commands', 'Configuration', 'Tristate', and 'Registers'.
- Device Identification:** A 'Read' button and a 16-bit register with bits 0-9 and RV3-RV0.
- Status:** 'Read', 'Write', and 'Clear Bits' buttons, followed by a 16-bit register with bits TEST, FRM, CP_UV, UV, OV, SCP2, SCP1, SCG2, SCG1, OL, OC, TW, OT.
- Fault Status Mask:** 'Read', 'Write', and 'Clear Bits' buttons, followed by a 16-bit register with bits 0, FRM, CP_UV, UV, OV, SCP2, SCP1, SCG2, SCG1, OL, OC, TW, OT.
- Configuration and Control:** 'Read', 'Write', and 'Clear Bits' buttons, followed by a 16-bit register with bits CL, TM, AL, ILIM1, ILIM0, SR2, SR1, SR0, EN, MODE, INPUT, VIN2, VIN1.
- SPI Control:** 'Direction' dropdown (Forward), 'Input Control Selection' dropdown (Parallel), 'Current Limit' dropdown (6.7), 'Input Control Mode' dropdown (H-Bridge), and 'Slew Rate' dropdown (2.0).
- Open Load Test:** 'Activate' dropdown (No).
- Parallel Control:** 'Enable' (Yes/No), 'Direction' (Forward/Reverse), 'Disable' (No/Yes), and 'Recirculation' (High-Side) options. 'Start' and 'Stop' buttons are also present.
- PWM Freq:** Input field set to 5000.
- Duty Cycle (%):** A slider ranging from 10 to 90.
- Current Feedback:** A digital display showing '0.00', 'Read Current' and 'Read Current Continuously' buttons, and a 'Status Fault' indicator (green dot).





SECURE CONNECTIONS
FOR A SMARTER WORLD