



FTF 2016
TECHNOLOGY FORUM

INTRODUCING NEW SPI CONTROLLED BRUSHED DC MOTOR

FTF-AUT-N1823

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Segment Line Manager

FTF-AUT-N1823

May 16, 2016

PUBLIC USE



AGENDA

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

H-BRIDGE MOTOR DRIVERS INTRODUCTION



Motor Basics – H-Bridge / Brushed DC

Basic Motor Operation

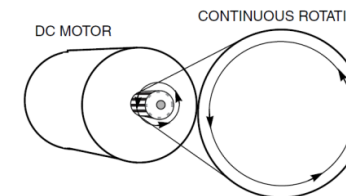
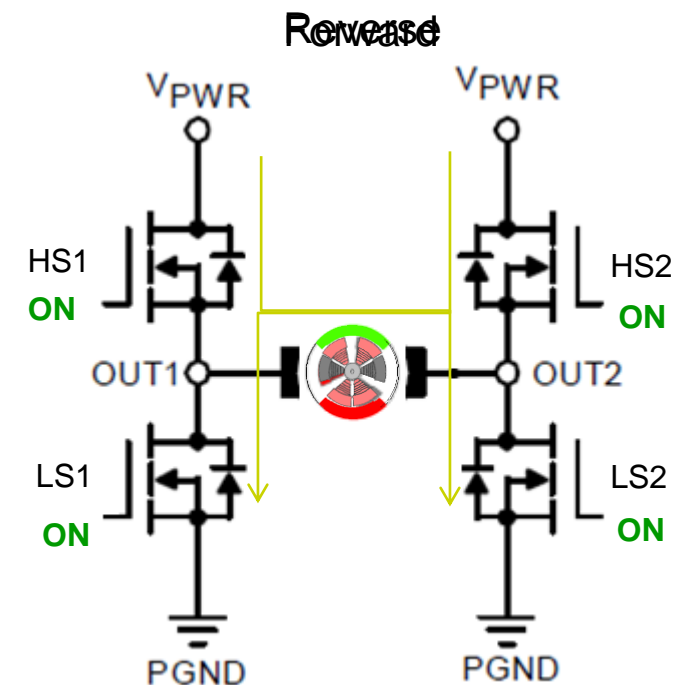
Main focus of our portfolio

- Brushed DC, Brushless DC, some Stepper

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



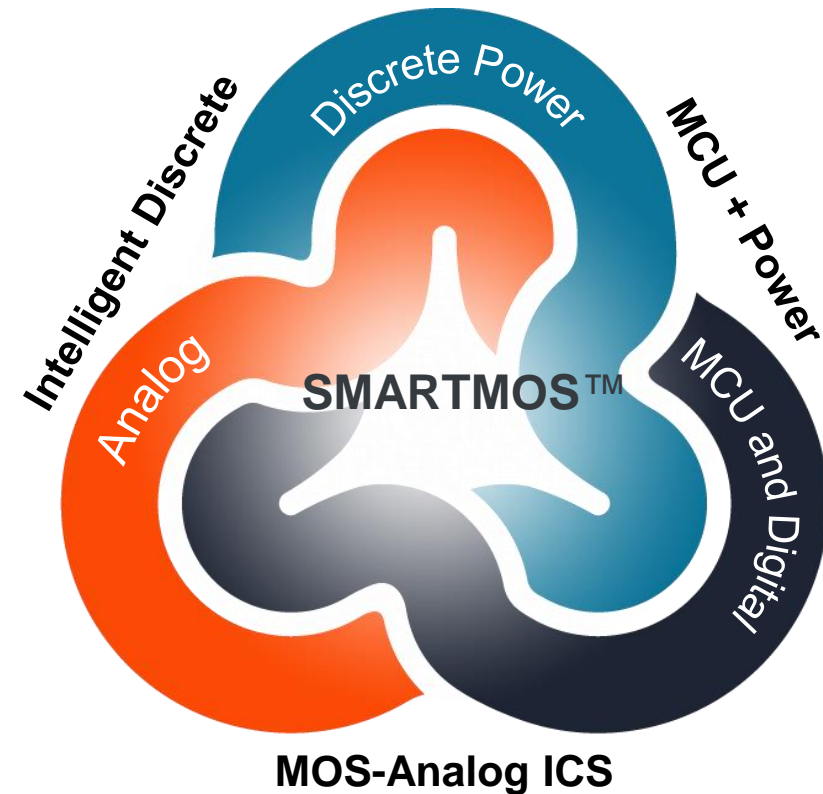
An H-bridge is an electronic circuit that enables a voltage to be applied across a load in either direction.




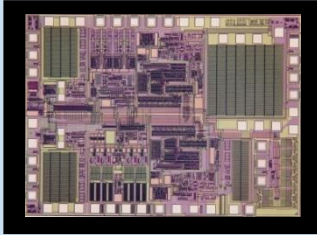
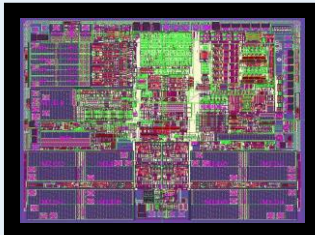
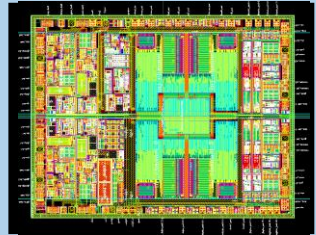
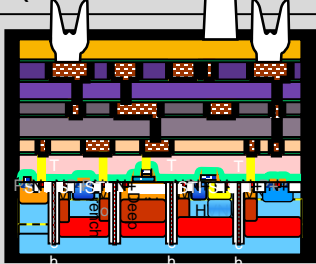
SMARTMOS™ Technology Integration

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 R _{dson} *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

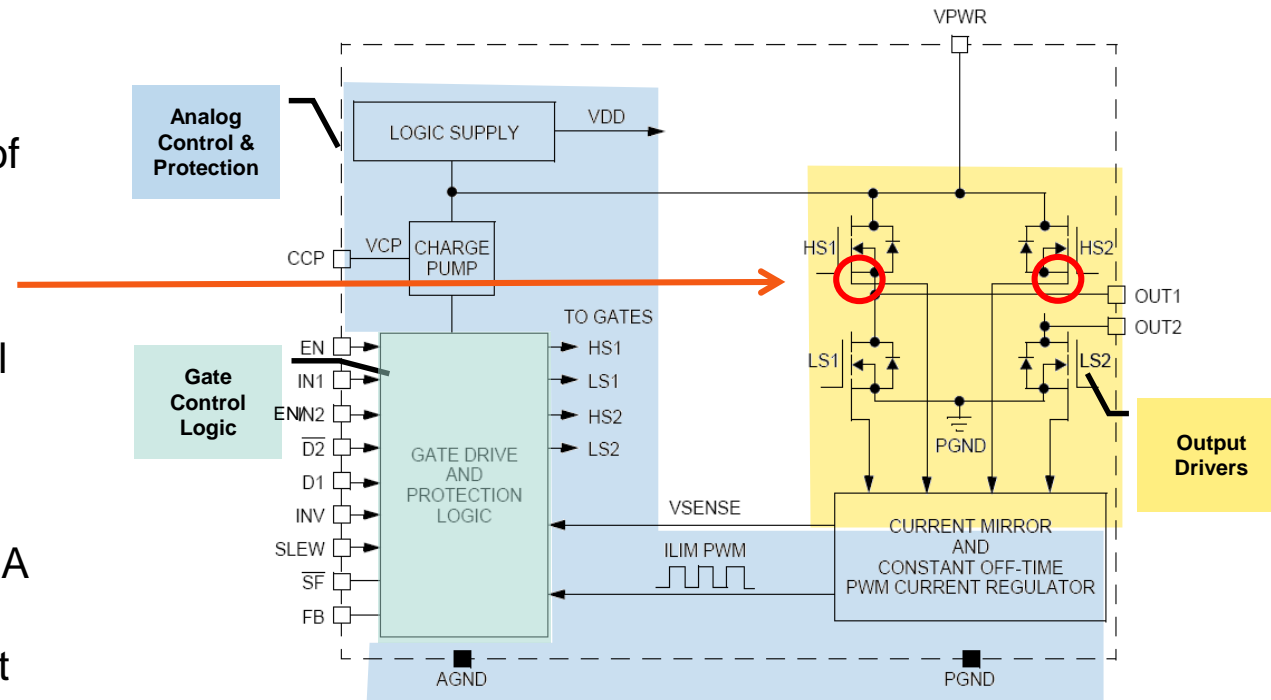
Base Part #	Out	Op Volt (V)	RDS(ON) MAX(mΩ)	Peak Current (A)	SPI	Sleep (μA)	Freq (kHz)	Temp Range °C	Package (mm)	Samples/ Release
MC33926PNB	2	5-28	235	5	-	50	11/20	-40 to 125	PQFN 32 (8x8)	Now
MC33931EK	2	5-28	235	5	-	50	11	-40 to 125	SOIC 32 (11x10.3)	Now
MC33932EK	4	5-28	235	5	-	50	11	-40 to 125	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 
MC33926EP	2	5-28	235	5	-	50	11/20	-40 to 125	QFN 28 (6X6)	Q1'16/ Q3'16 
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 / Q1'16 
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 

Customer Challenge

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 < $1^{\circ}\text{C}/\text{W}$
- 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

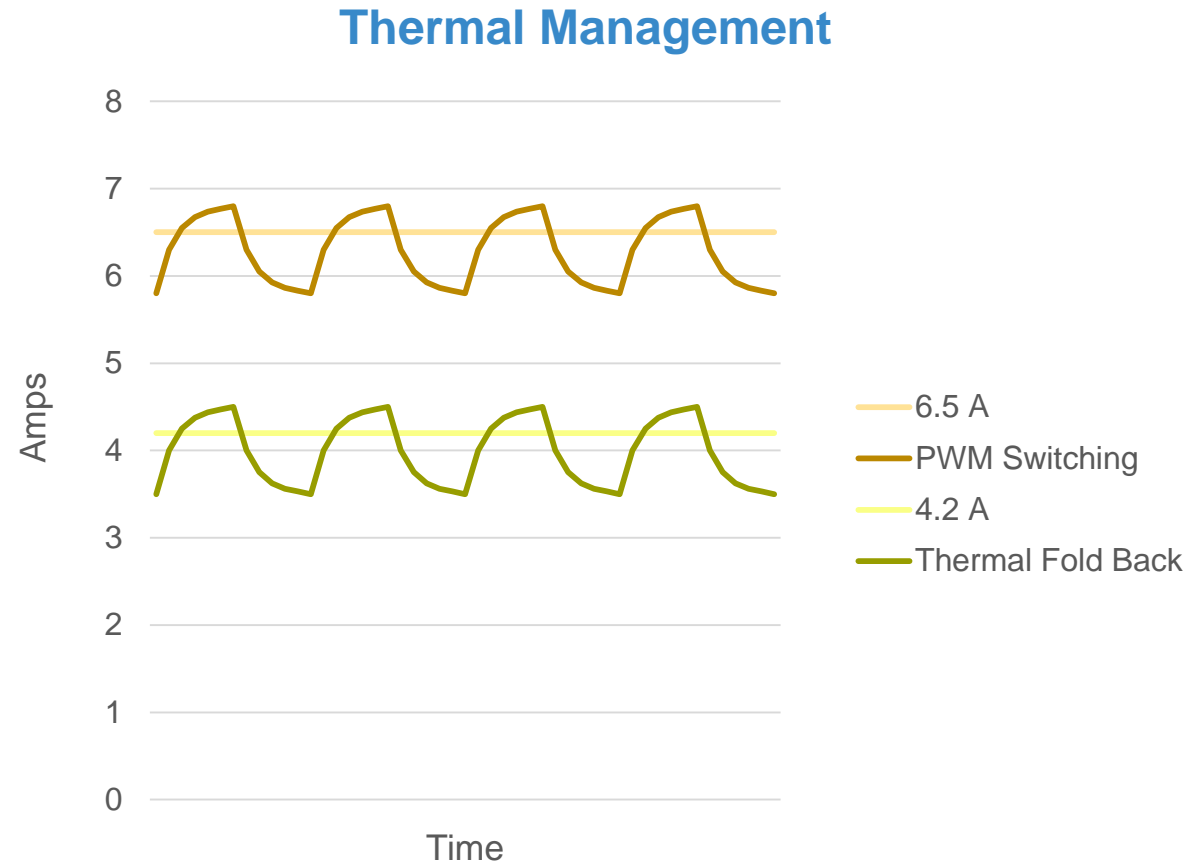
- Below 165°C, the device PWMs the outputs, averaging under 6.5 A to reduce thermals while continuing operation

Thermal fold back to 4.2 A 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



Applications

MC33HB2000 and MC33HB2001

-  Automotive
-  Industrial
-  Key applications

Driver Segment – Standard ICE Powertrain Electrification

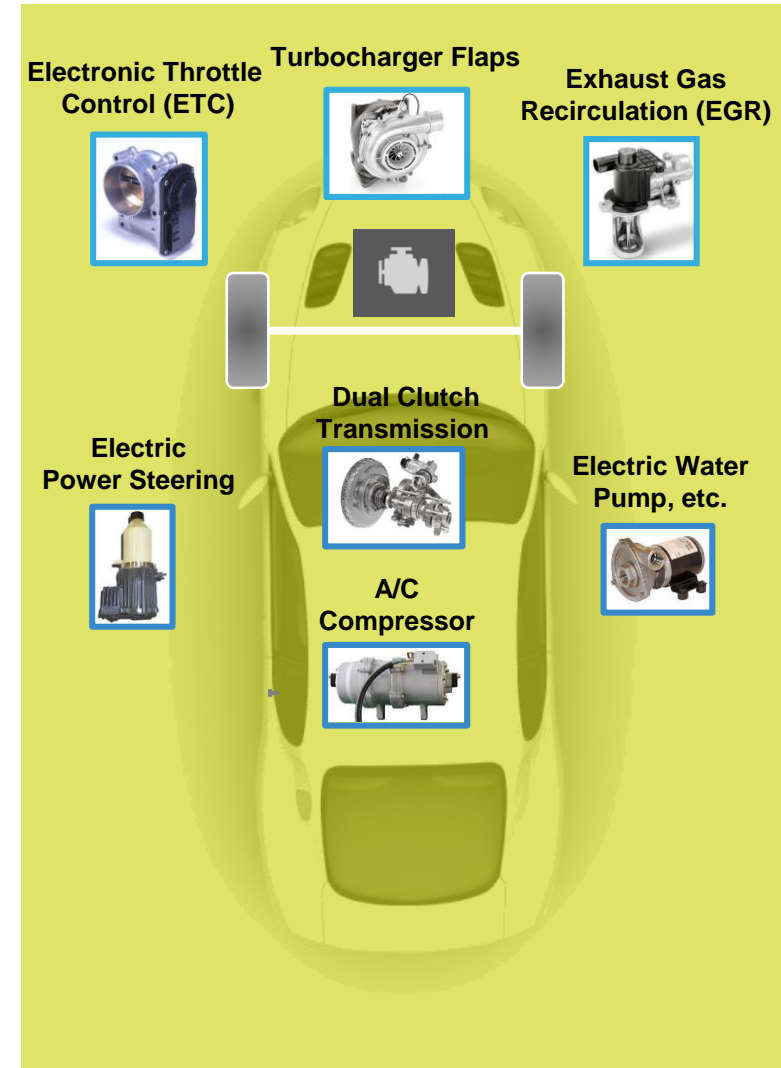
Key Applications and Products

Brushed DC Motor Control

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

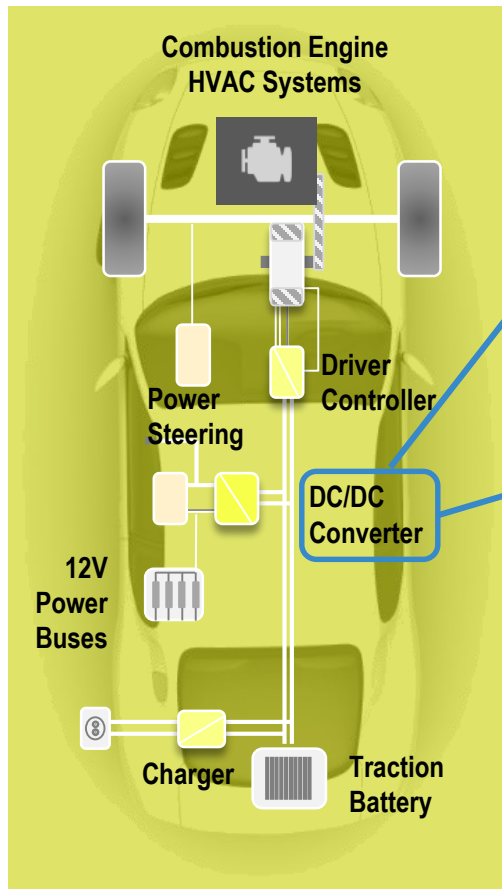
Brushless DC Motor Control

- 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)
- MC33GD3601 (NPI)

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

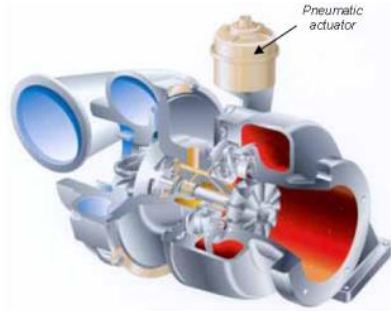


Industrial

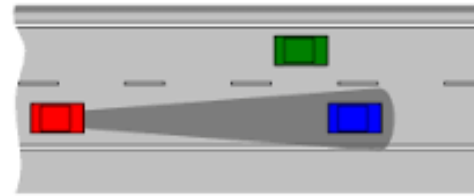
Product Function

- 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



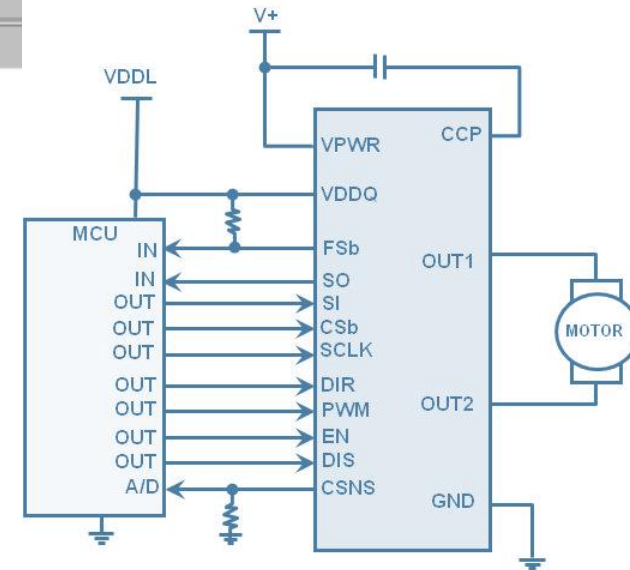
Turbocharger Flaps



Throttle Control



Rear Window Wiper



- Brushed DC motor
- Robust Operation

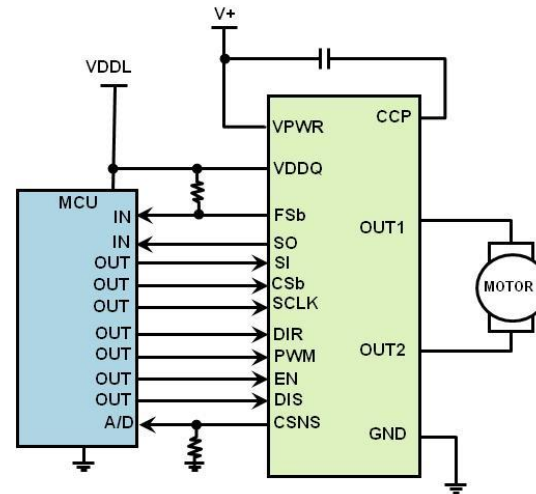
SYSTEM BLOCK DIAGRAM AND KEY FEATURES

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 & bypass
 - Two packages: 8 x8x1.2 mm PQFN and
 - 10x11x1.2 mm SOIC-EP Package



PART #	PKG	RELEASE
MC33HB2000EK	SOIC 32	Q1'16
MC33HB2000FK	PQFN 32	Q2'16
MC33HB2001EK	SOIC 32	NOW
MC33HB2000FK	PQFN 32	Q2'16

Typical Applications

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

HB2000 & HB2001 H-Bridge Circuit Block Diagram

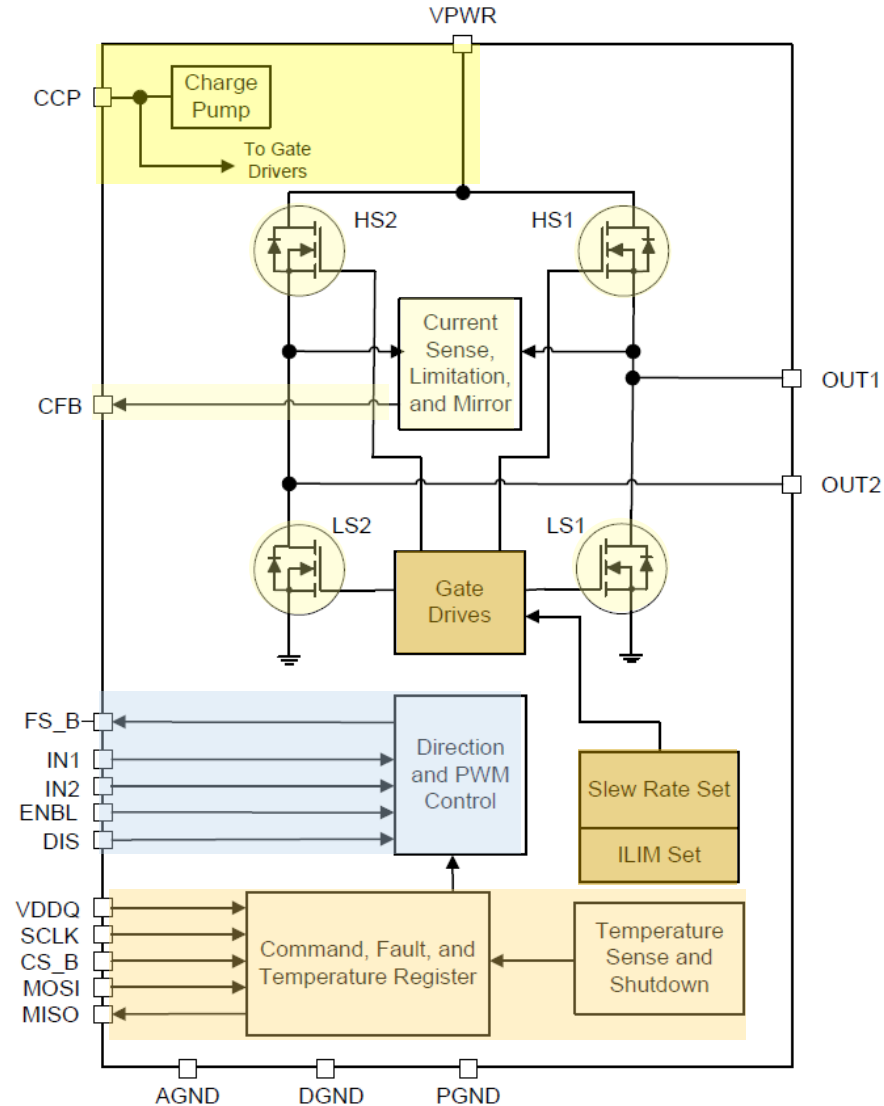
VPWR (Power Supply Input)
 $5\text{ V} < \text{VPWR} < 28\text{ V}$ ($\text{UVLO} < \text{VPWR} < 40\text{ V}$)

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

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 4.0 V to 40 V (UV during crank to max rating)
- HB2000 and HB2001 are 100% pin and function compatible
- Thermal impedance $q_{JC_bottom} < 0.8 \text{ } ^\circ\text{C/W}$
- I/O withstands 36V
- Safety: Supports ISO26262 safety feature in full bridge mode

HB2000 & HB2001 Enhanced Diagnostics

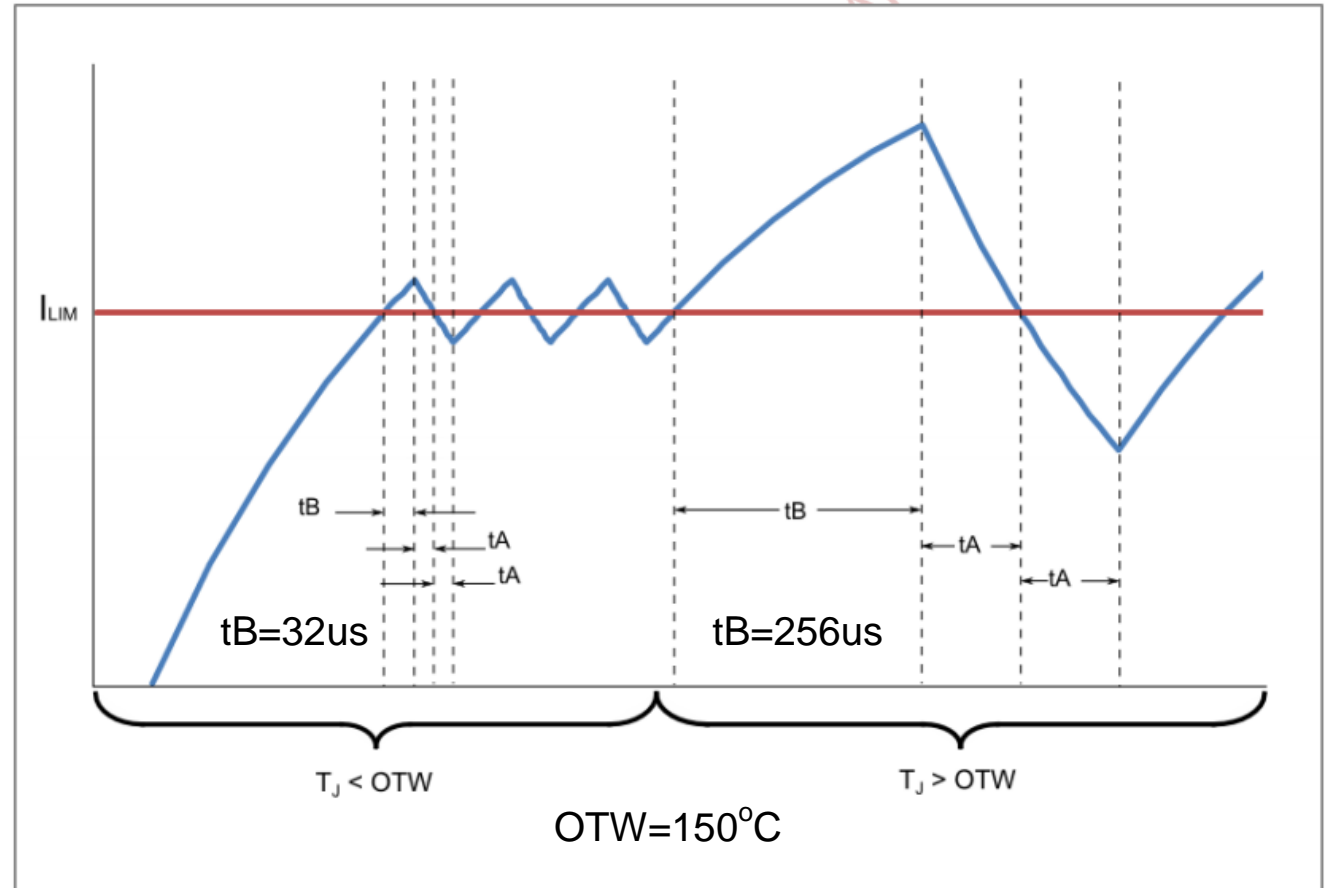
- SPI register always provides detailed status bits
 - Over Temperature Shutdown
 - Thermal Warning
 - Over Current
 - Open Load (in standby mode and in normal full H-bridge operating mode)
 - Short Circuit to Ground Output 1
 - Short Circuit to Ground Output 2
 - Short Circuit to Power Output 1
 - Short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

HB2000 & HB2001 Active Current Limit

Programmable Current Limit

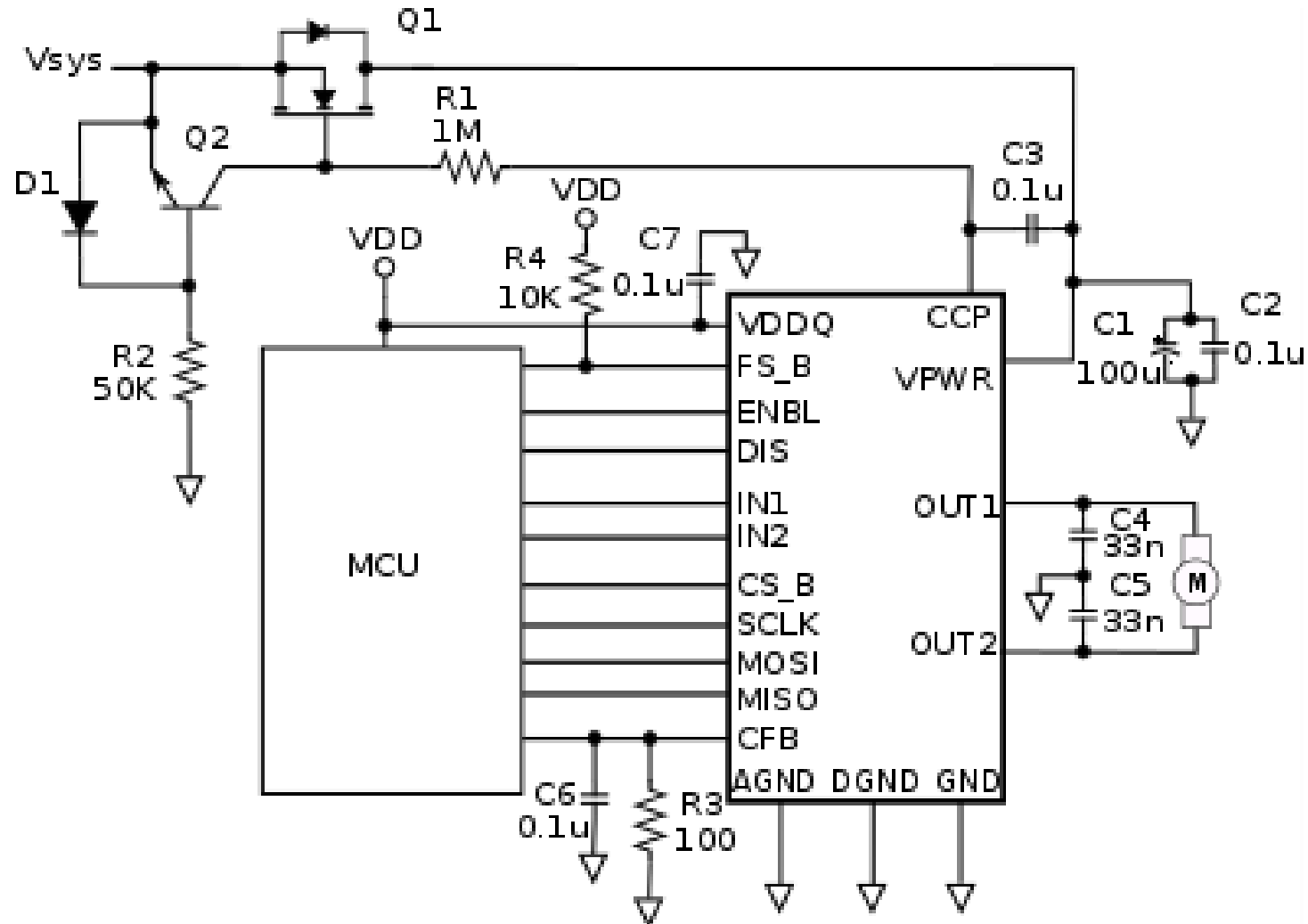
- 4 settings from nominal 5.4 A to 10.7 A average
- Short Circuit threshold scales up/down as per the current limit selected
- Patented thermal management does not compromise the current set point

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

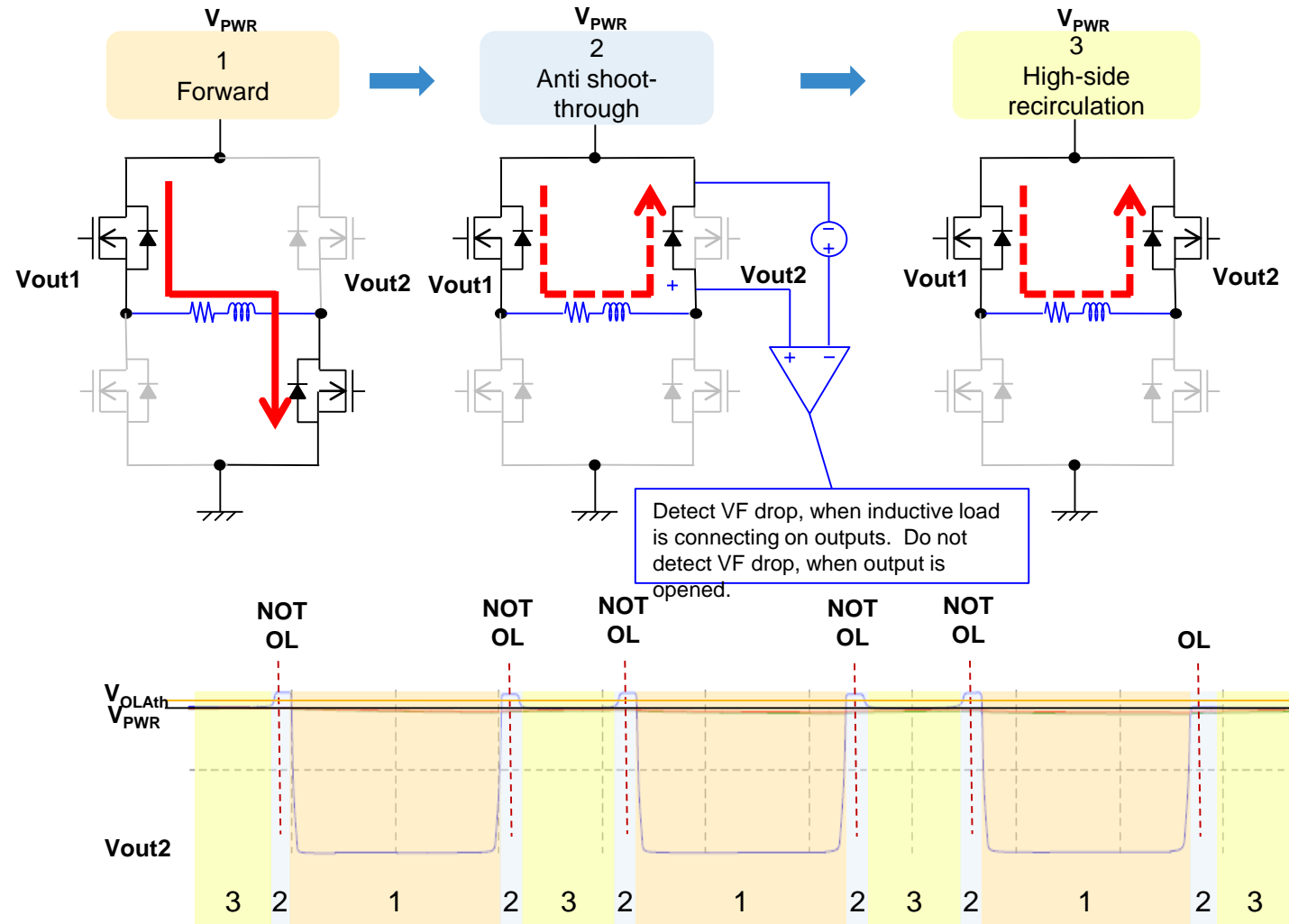


I_{lim} Timing and Thermal response

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

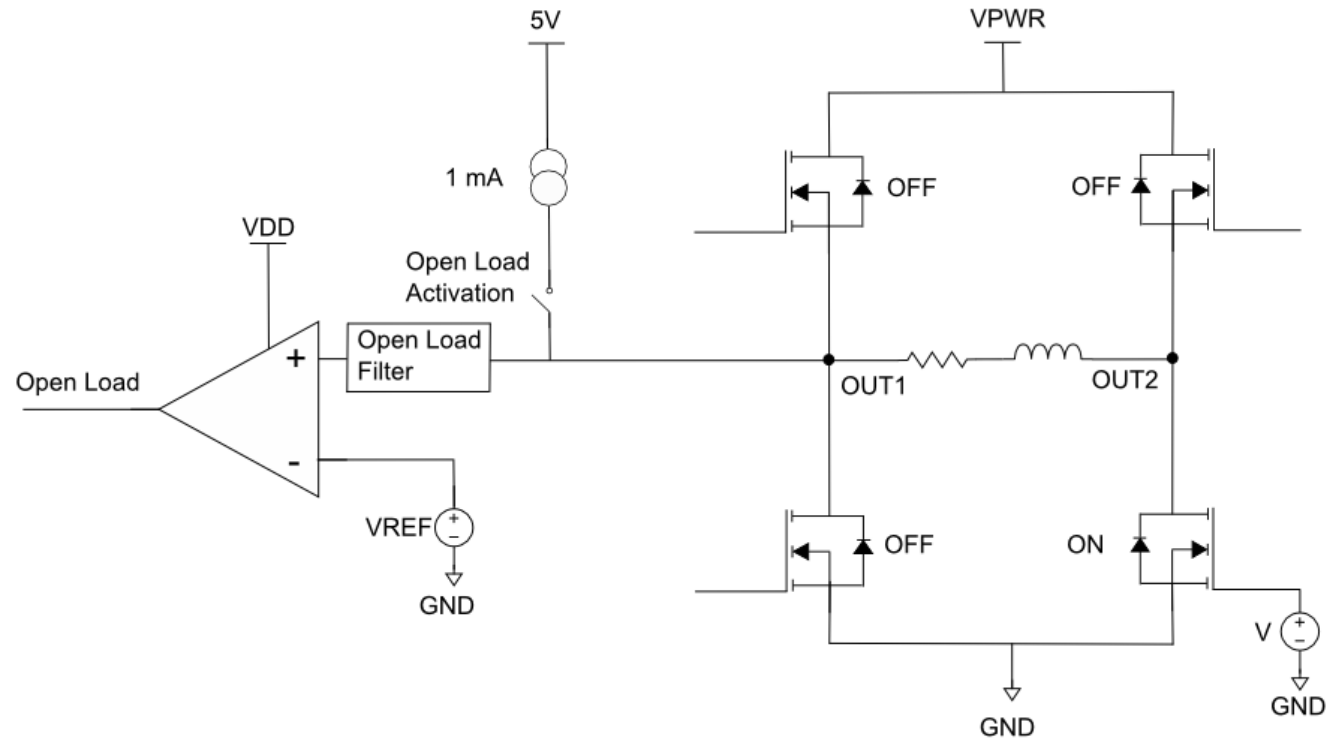


HB2000 & HB2001 Active-mode Open Load Detection Diagram



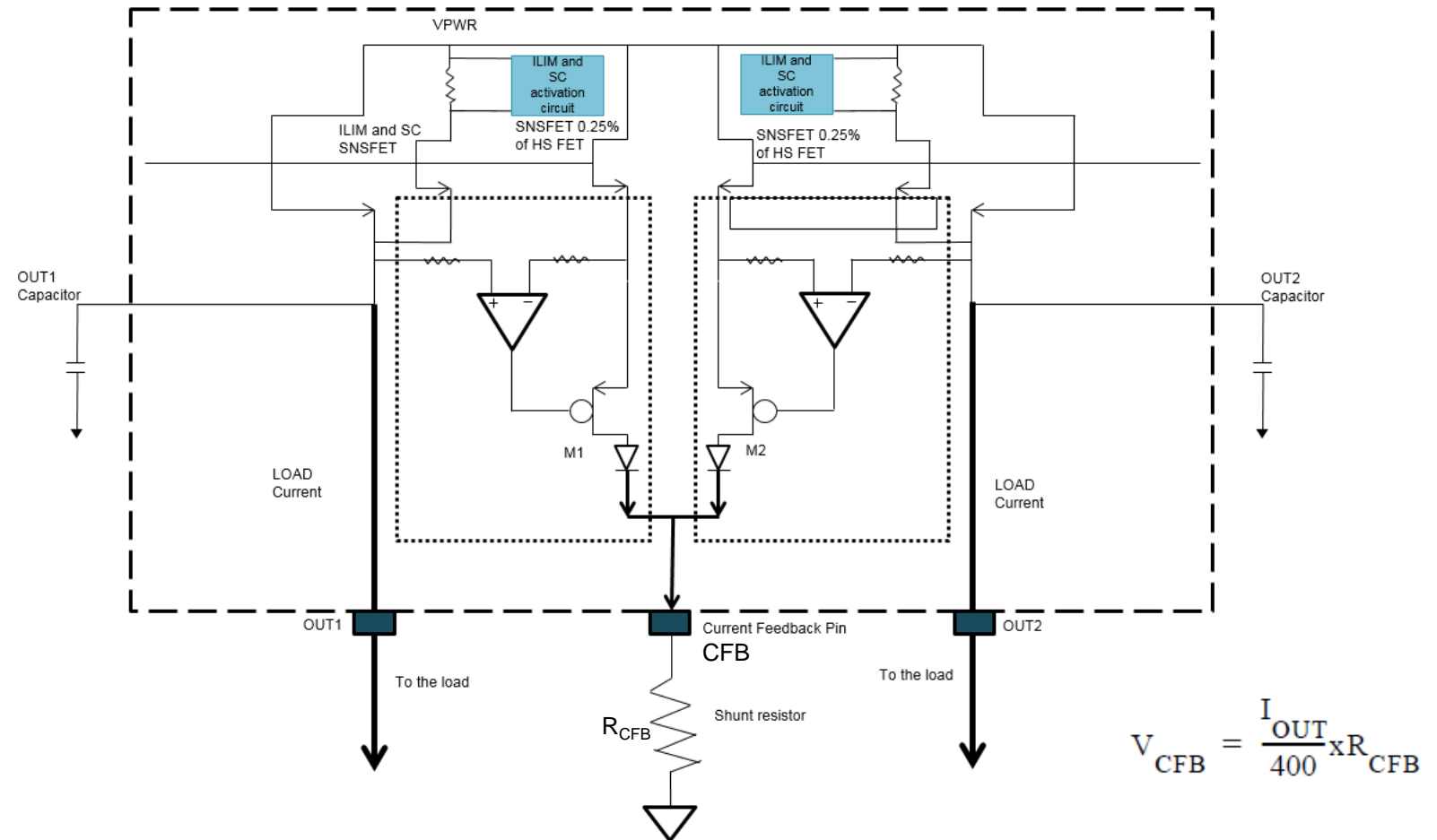
HB2000 & HB2001 Stand-by Mode Open Load Detection

- 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)



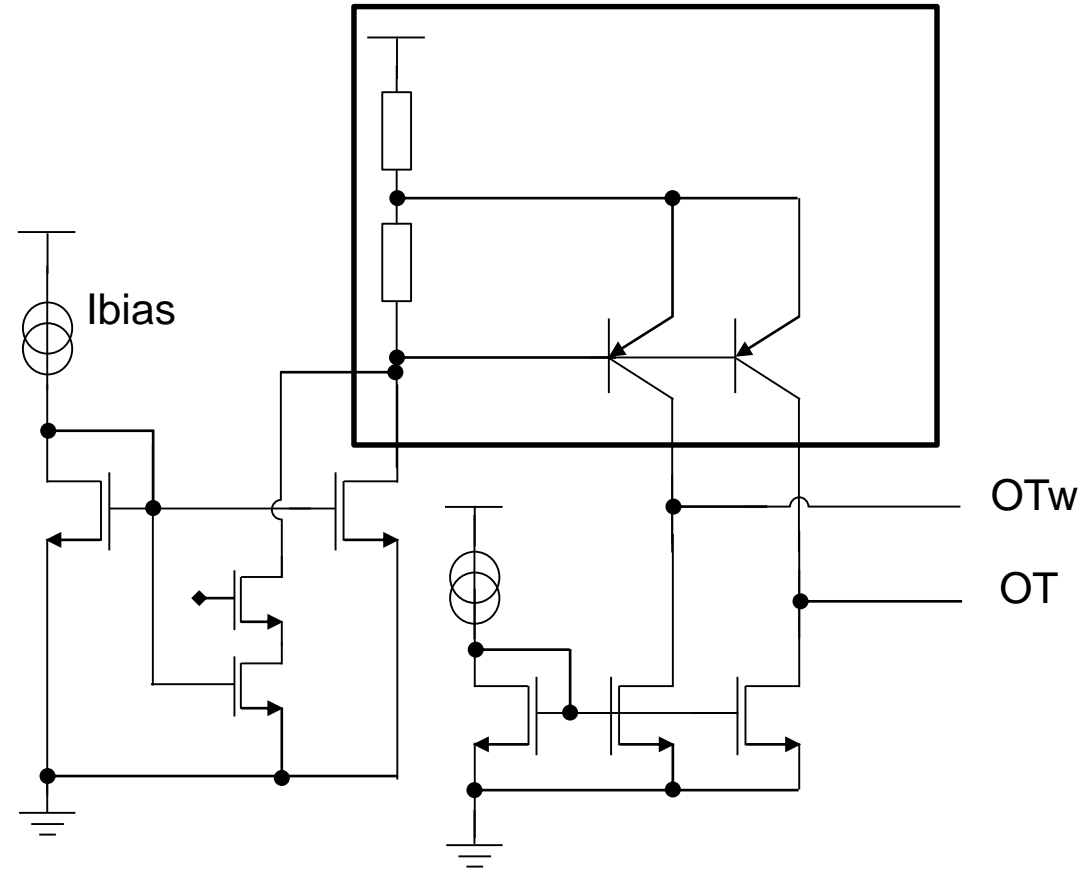
High Accuracy Current Feedback Via CFB Pin

- 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.



LIVE CURRENT LIMIT DEMONSTRATION



ROADMAP



MC33926ES New Package Proposal

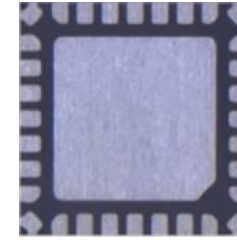
Thermally efficient 28 V/5 A H-Bridge DC motor driver featuring real-time load current monitoring and automatic thermal back-off ensures high availability operation in demanding high current, harsh environment applications

Differentiating Points

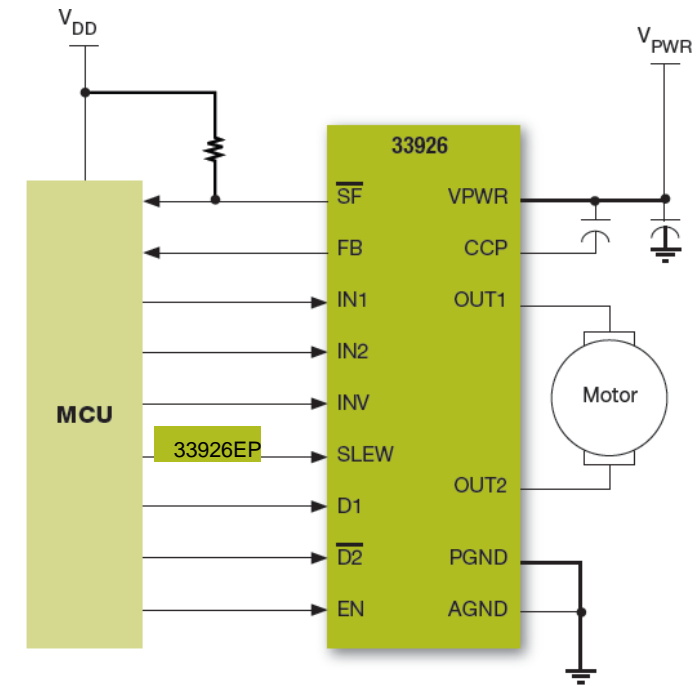
- Current mirror – 1/400 out from current flowing in MOSFET
- Over current limit – via internal constant-off-time PWM
- Over temperature protection – current fold back at 165°C
- Temperature dependent shut down – at 185°C
- Short to PWR, Short to GND, UVLO, Open Load Detect
- Selectable Slew Rate Control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

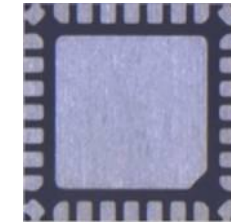
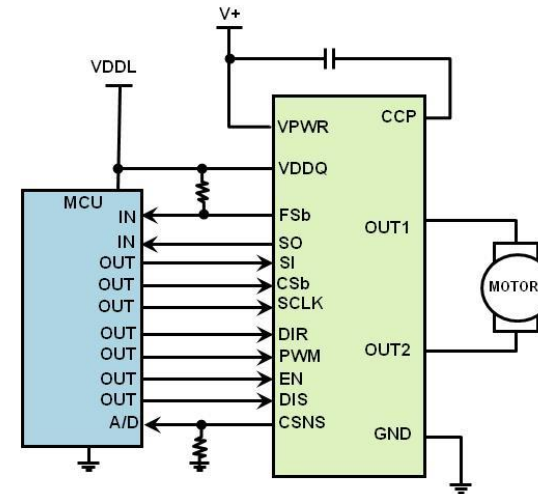
The MC33HB2000/1 are advanced H-Bridge Motor Driver designed to provide enhanced safety features for high safety integrity, SPI control for improved flexibility, and thermal management for continuous operation

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)

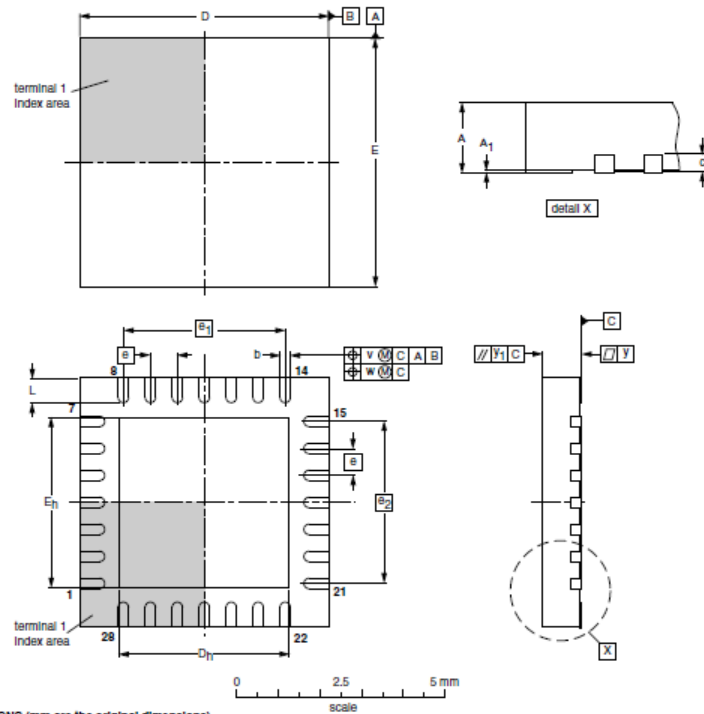
Typical Applications

- 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



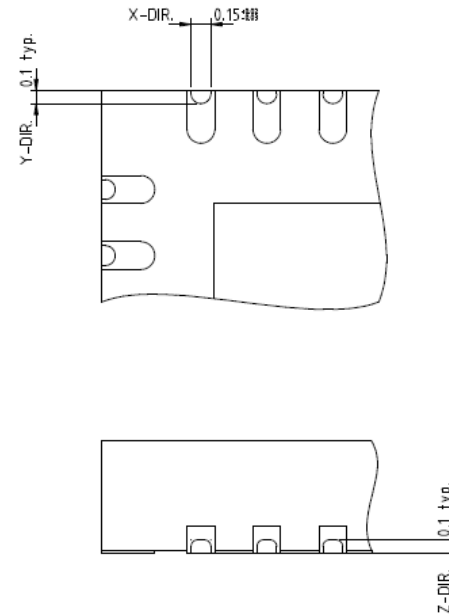
DIMENSIONS (mm are the original dimensions)

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

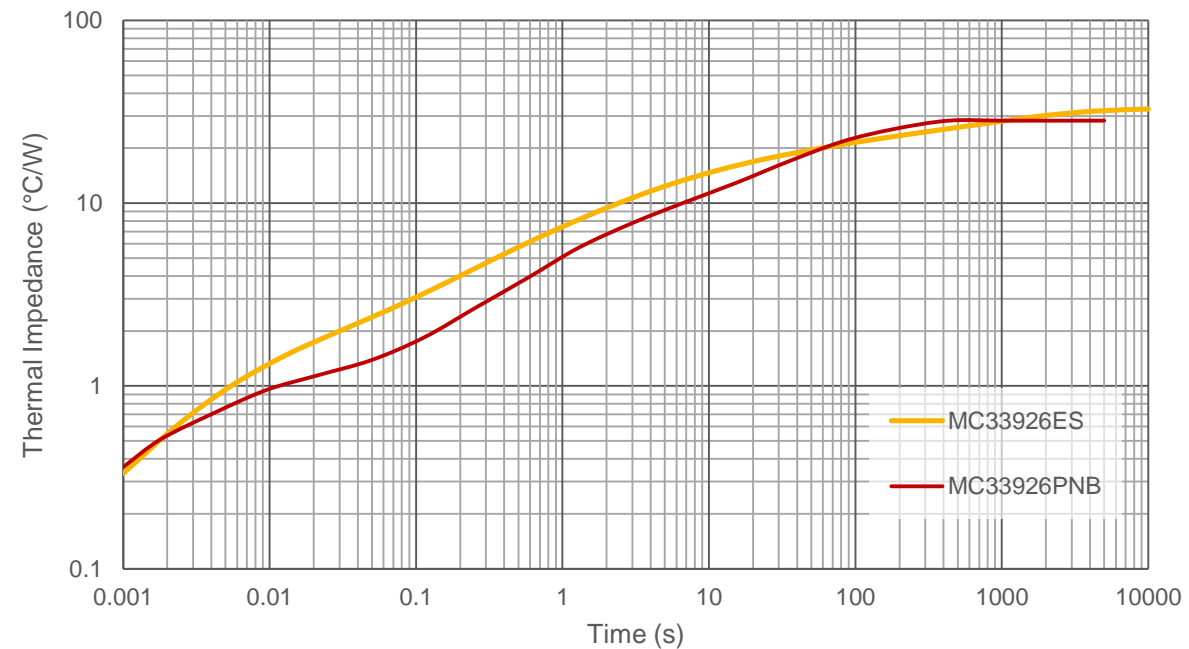
2. SHARP CAVITY EDGE VISIBLE ON BOTTOM SIDE.

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

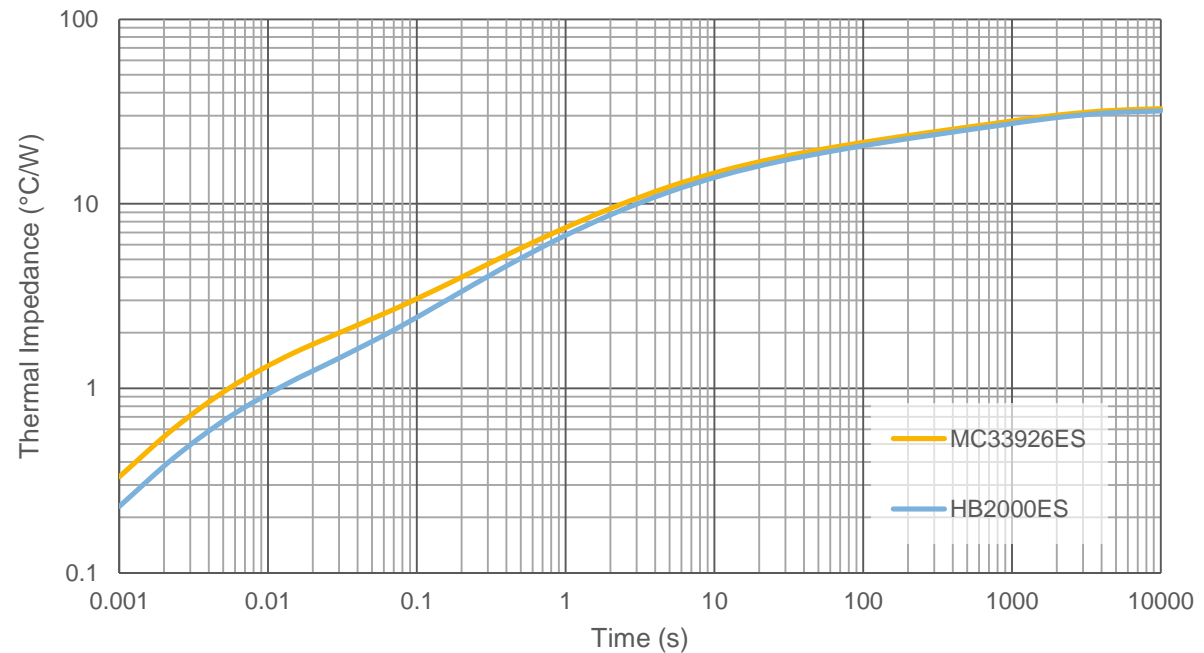


QFN Thermal Comparison MC33926 to HB2000

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

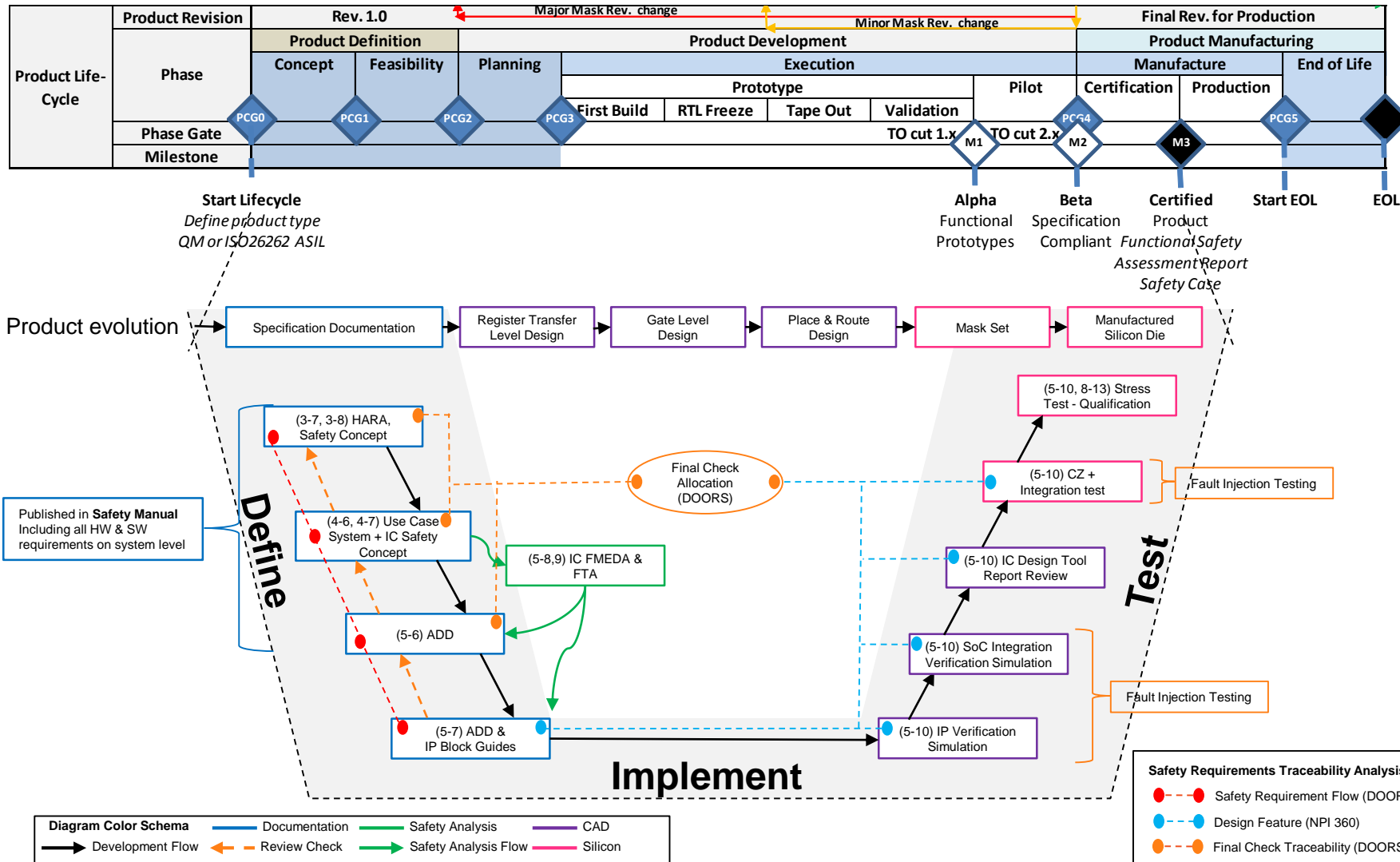
Rating			MC33926	HB2000	Unit
Junction to Ambient Natural Convection	Single Layer board (1s)	R_{qJA}	90.2	88.9	°C/W
Junction to Ambient Natural Convection	Four layer board (2s2p)	R_{qJA}	32.8	31.9	°C/W
Junction to Board		R_{qJB}	12.7	11.9	°C/W
Junction to Case (Bottom)		$R_{qJCBottom}$	1.54	1.07	°C/W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

Transient Thermal Response on JEDEC 2s2p

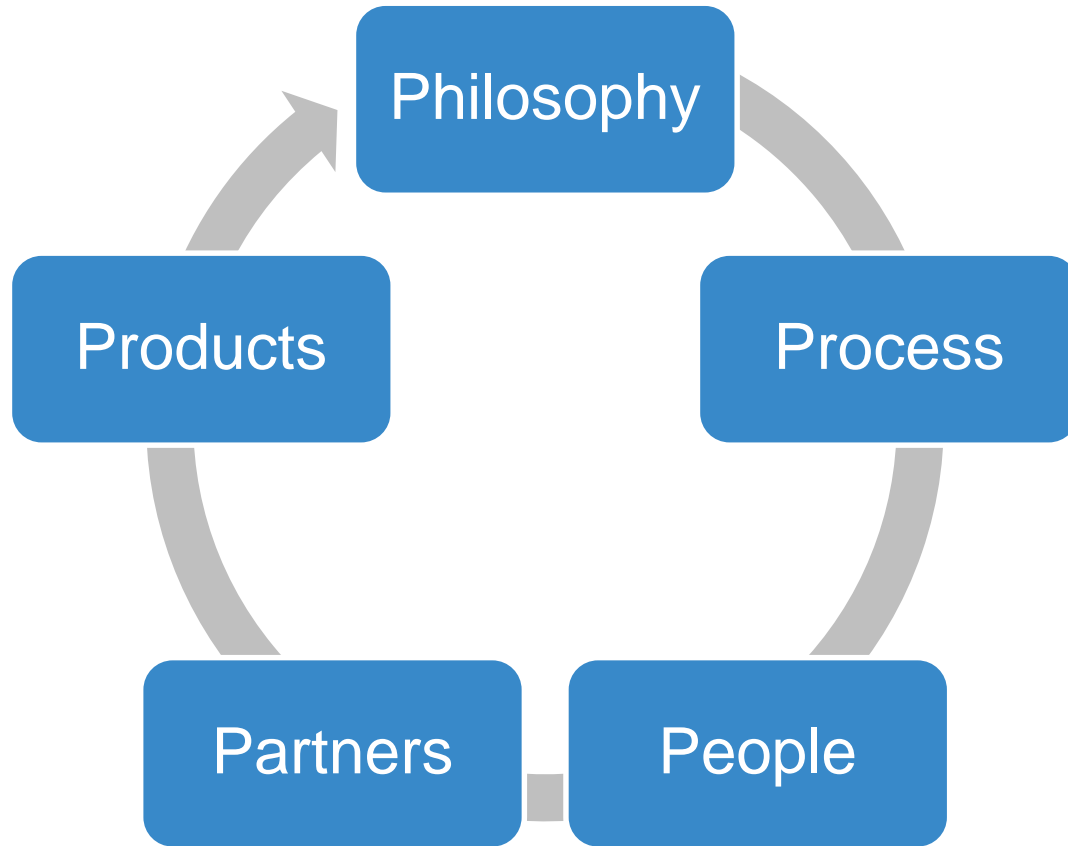


FUNCTIONAL SAFETY

Functional Safety Process – Definition to Test



5P's Functional Safety Pillars



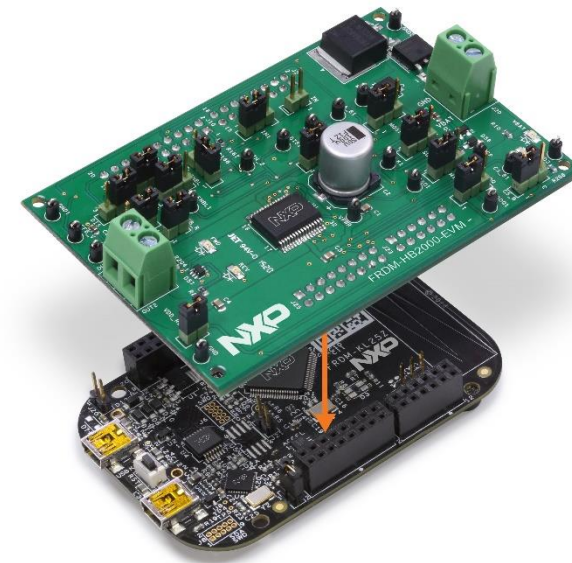
ENABLEMENT TOOLS



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 options: File, Edit, View, Configuration, USB to SPI Dongle, and Help. Below the menu bar is a toolbar with various icons. The main area 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 bit values, with a legend showing a white box for 0 and a blue box for 1.
- Device View:** A tree view on the left showing a hierarchy of device folders and commands. The selected device is MC33978.
- Device Identification:** A section with a 'Read' button and a 14-bit register (bits 0-9, RV3, RV2, RV1, RV0).
- Status:** A section with 'Read', 'Write', and 'Clear Bits' buttons and a 14-bit register (TEST, FRM, CP_UV, UV, OV, SCP2, SCP1, SCG2, SCG1, OL, OC, TW, OT).
- Fault Status Mask:** A section with 'Read', 'Write', and 'Clear Bits' buttons and a 14-bit register (0, FRM, CP_UV, UV, OV, SCP2, SCP1, SCG2, SCG1, OL, OC, TW, OT).
- Configuration and Control:** A section with 'Read', 'Write', and 'Clear Bits' buttons and a 14-bit register (CL, TM, AL, ILIM1, ILIM0, SR2, SR1, SR0, EN, MODE, INPUT, VIN2, VIN1).
- SPI Control:** A section with 'Direction' (Forward), 'Input Control Selection' (Parallel), 'Current Limit' (6.7), 'Input Control Mode' (H-Bridge), and 'Slew Rate' (2.0) settings.
- Open Load Test:** A section with an 'Activate' dropdown set to 'No'.
- Parallel Control:** A section with 'Enable' (Yes/No), 'Direction' (Forward/Reverse), 'Disable' (No/Yes), and 'Recirculation' (High-Side) settings. It includes 'Start' and 'Stop' buttons.
- PWM Freq:** A text input field set to 5000.
- Duty Cycle (%):** A slider control ranging from 10 to 90, currently set at 50.
- Current Feedback:** A digital display showing 0.00, with 'Read Current' and 'Read Current Continuously' buttons.
- Status Fault:** A green indicator light and the text 'Status Fault'.



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