power integrations™

BridgeSwitch™ Integrated Half-Bridge (IHB) for High Voltage Motor Drives

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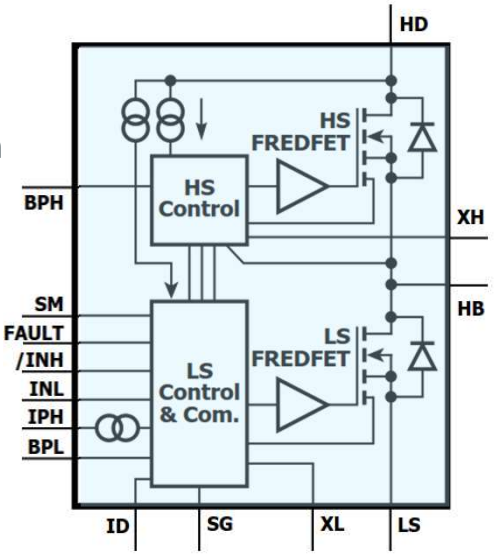
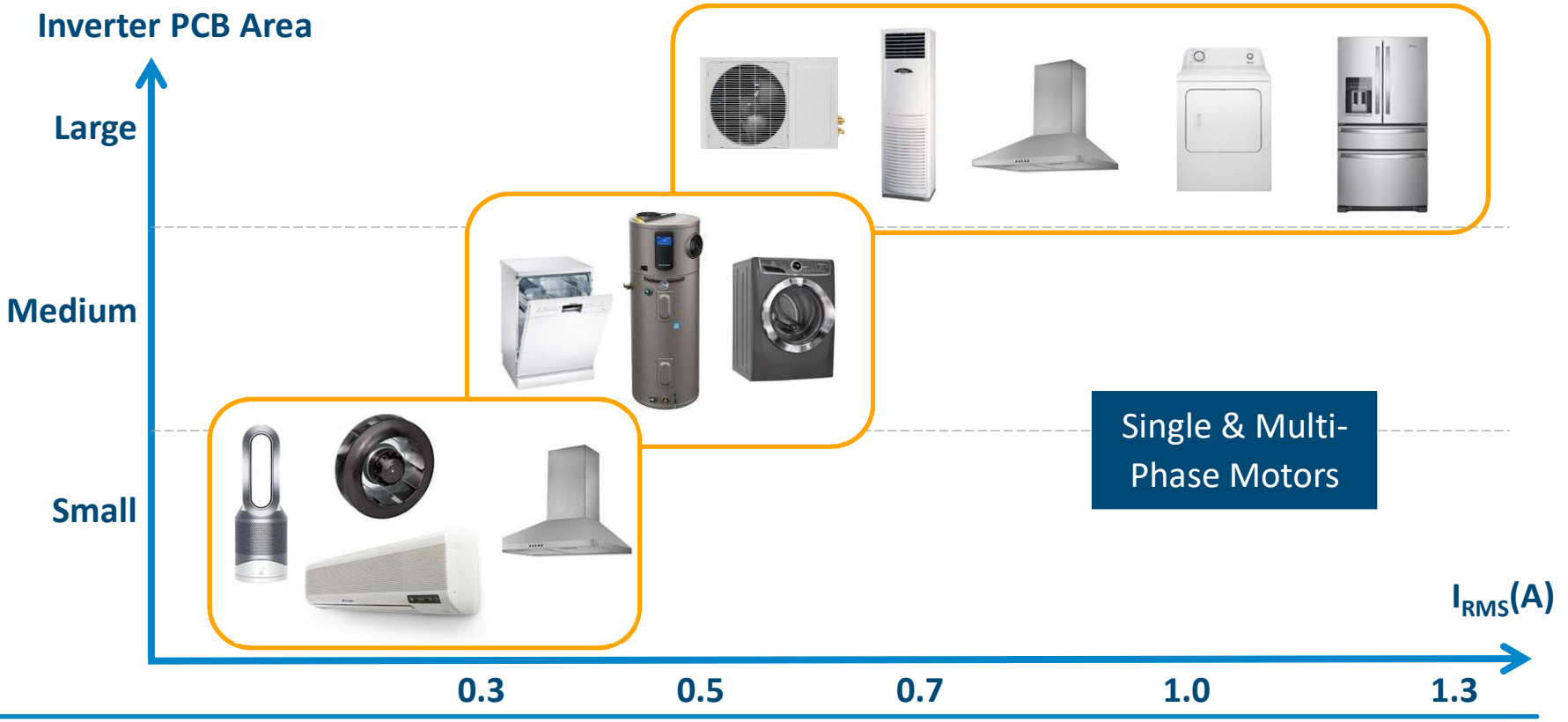
ac-dc converters led drivers gate drivers motor drivers

BridgeSwitch: Smart Integrated Motor Driver IC

- **Up to 400 W inverter output power**
- **600 V power FREDFETs, low $R_{DS(ON)}$**
  - Unique lossless current sense simplifies motor control and system protection
  - Optimized body diode for low loss, reduced EMI
- **Current trimmed gate drivers deliver consistent performance**
  - Minimizes losses and reduces EMI
- **Self-biased – simplifies system power requirements**
- **HW device and system protection – IEC 60730-1 Class A ready**
- **Single-wire predictive maintenance interface**
  - Supports any control algorithm
- **Thermally optimized SMD package**
  - No heatsinks



Ideal for Fans, Pumps and Compressors



The BridgeSwitch Family Provides a Platform Solution

Product Family		
Product[3]	**FREDFET DC Output Current**[1]	**Continuous Phase RMS Current**[2]
BRD1160C / BRD1260C	1.0 A	0.22 A
BRD1161C / BRD1261C	1.7 A	0.50 A
BRD1163C / BRD1263C	3.0 A	0.75 A
BRD1165C / BRD1265C	5.5 A	1.00 A
BRD1167C / BRD1267C	11.5 A	1.33 A

Table 1. *Product Family.*

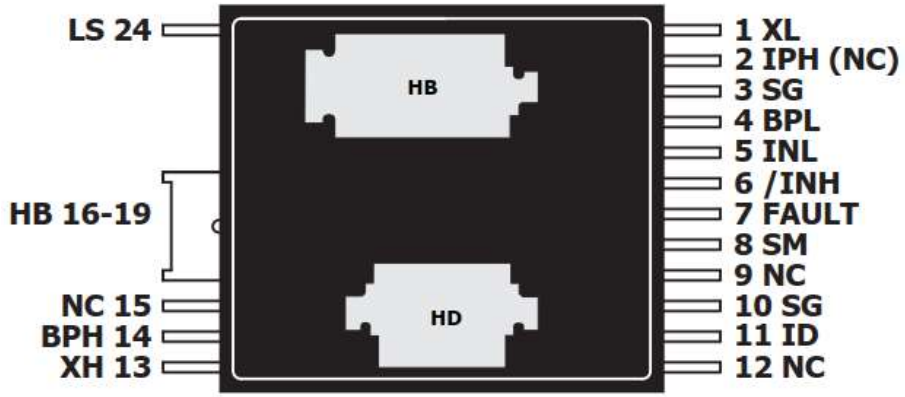
Notes:

1. Continuous DC output current per FREDFET, calculated at 25 °C case and 125 °C junction temperature. Normally limited by internal circuitry
2. Continuous phase RMS current, internal self-supply, 340 V bus, trapezoidal commutation with 12 kHz high-side PWM, PCB heat sinking with 50 °C case temperature rise.
3. Package: InSOP-24C.

Feature	BRD116X	BRD126X
Market leading FREDFET diode characteristic	✓	✓
No heatsink required Compact surface mount package	✓	✓
Self-supplied operation	✓	✓
HS/LS cycle-by-cycle current limit protection	✓	✓
Device dual level thermal protection	✓	✓
DC link UV/OV monitoring	✓	✓
System level over-temperature monitoring	✓	✓
Single wire FAULT-bus communication	✓	✓
Positive low-side phase current output	-	✓

Thermally Optimized Package

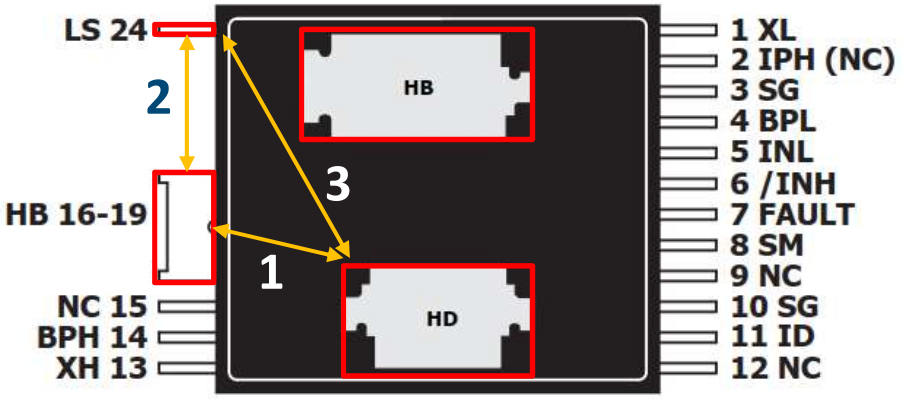
- **InSOP-24C package with two exposed pads**
  - Low profile: 1.35 mm
- **Small PCB footprint: 13.6 x 9.4 mm**
- **Pinout (bottom view):**



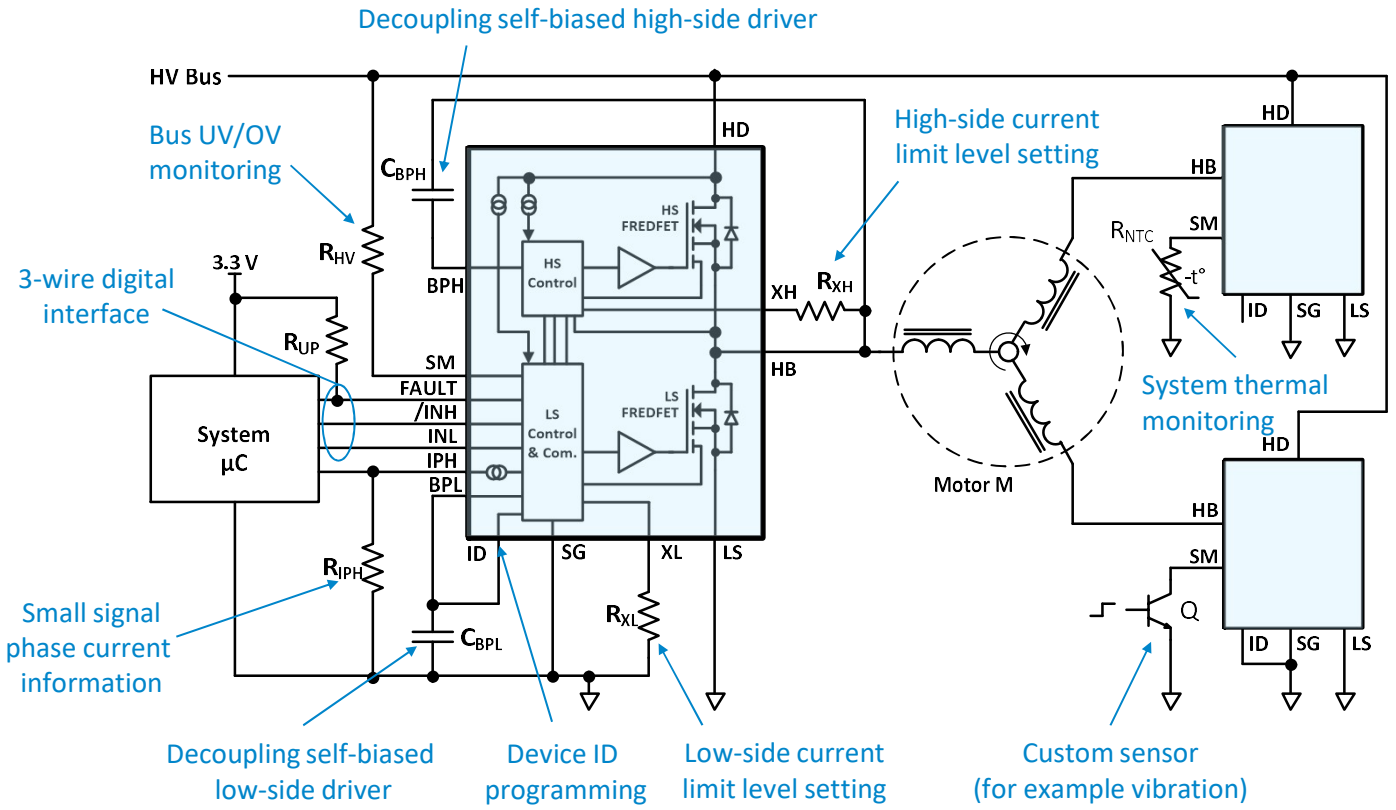
Pin	Function
LS	Low-side SOURCE
HB	Half-bridge center-point
BPH	Bypass (high-side)
XH	Sets high-side current limit
ID	Device ID
SG	Signal ground
SM	System monitor
FAULT	Fault communication
/INH	Driver control input (high-side)
INL	Driver control input (low-side)
BPL	Bypass (low-side)
XL	Sets low-side current limit
IPH (NC)	Phase current output (BRD126X) / NC: (BRD116X)
HD	High-side DRAIN (exposed pad)

Extended Creepage and Clearance

Potential			Creepage
1.	High-side drain	Half Bridge center-point	>2.2 mm
2.	Half Bridge center-point	Low-side source	>2.2 mm
3.	High-side drain	Low-side source	> 3.2 mm



Typical 3-Phase Inverter Architecture

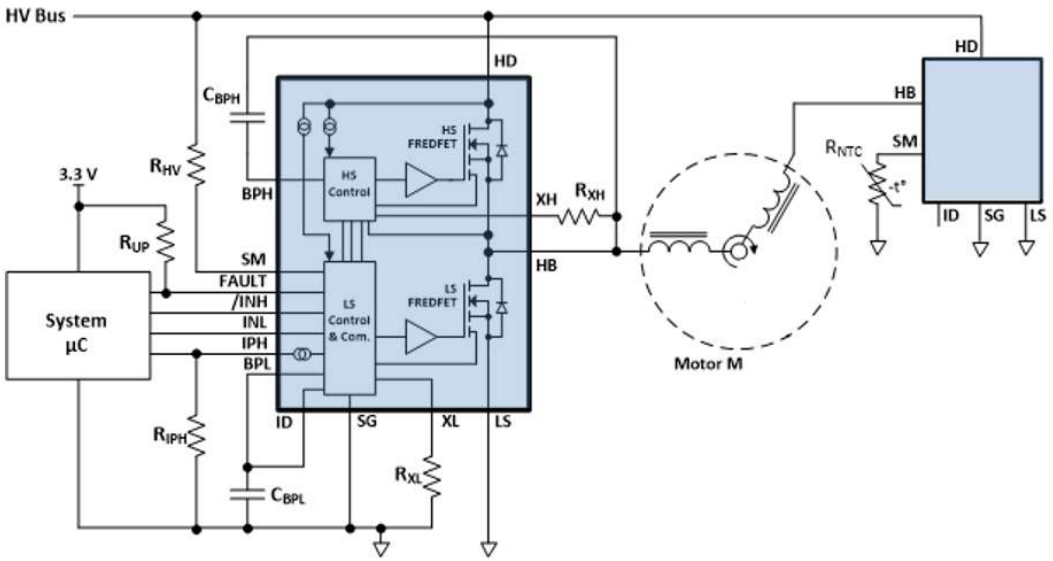


1-Phase BLDC is More Cost Effective Than 3-Phase BLDC

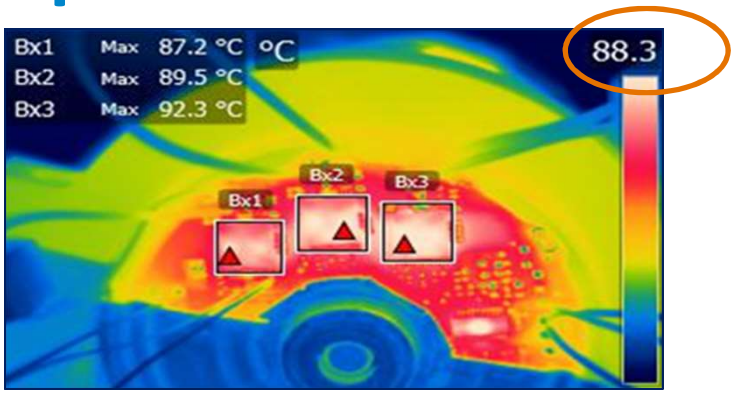
	1-Phase BLDC	3-Phase BLDC
Speed Control	Yes	Yes
Motor Size	Smaller	Smallest
Efficiency	High	High
Noise	Low	Lowest
Drive Algorithm	Average/Complex	Complex
Protection	Yes	Yes

BridgeSwitch Advantage for 1-Phase Applications

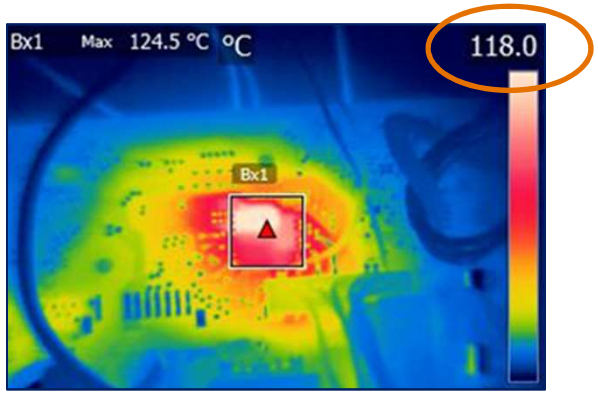
- Saves BOM and PCB space
- No heatsink
- Self biased
- Enables HW-based protection
- SMD for easy assembly
- Scalable solution can be easily adapted to 3-phase designs



Integrated Half-Bridge (IHB) Structure Eliminates Hot Spots

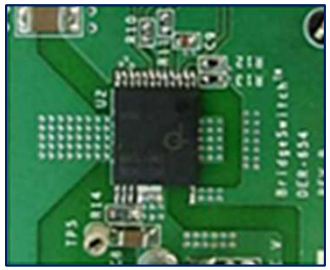


IHB allows distributed thermal architecture



IPM creates hot spots

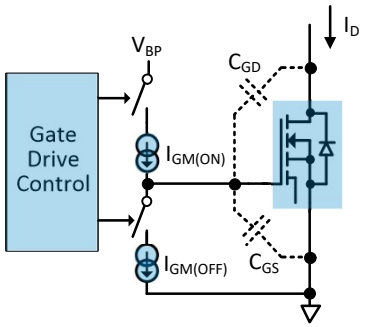
- **Separating Half-Bridge switches efficiently spreads heat**
  - Permits use of PCB for cooling
    - Reduces system cost by eliminating heatsink
    - Eliminates assembly cost for mounting heatsink
  - Reduces size of power stage



PI FREDFETs are Ideal for Motor Drives

- **Low gate charge**
  - Reduces switching losses
- **Trimmed current-source for gate-drive controls slew rate**
  - 2.5 V/ns V_DS turn-on slew rate
    - Reduces stress on commutating diode in half-bridge leg
  - 3 V/ns V_{DS} turn-off slew rate
    - Reduces cross-over loss
- **Ultra-soft, fast recovery diode**
  - Low Q_{RR} increases efficiency
  - Reverse Recovery Softness Factor (RRSF) > 1 for reduced EMI

$$RRSF = \frac{di/dt_{FWD}}{di/dt_{REC}}$$



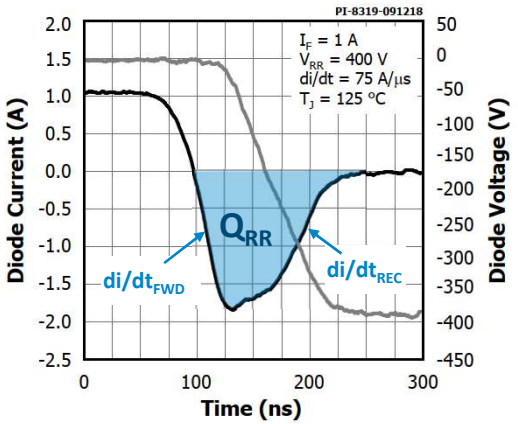
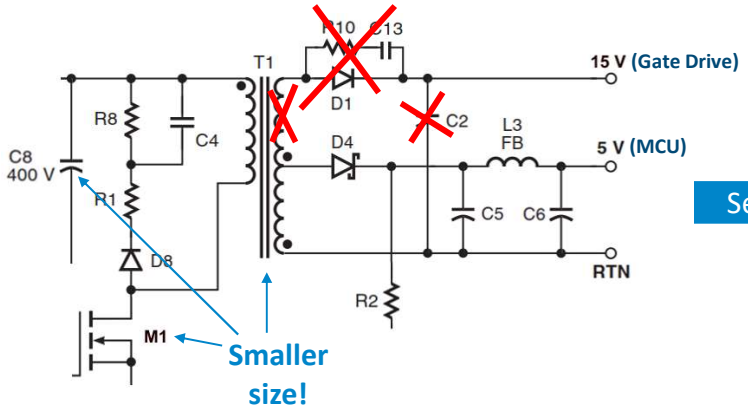


Figure 30. Typical Diode Reverse Recovery (BRD1X65).

Self-supply Reduces Auxiliary Power Requirements

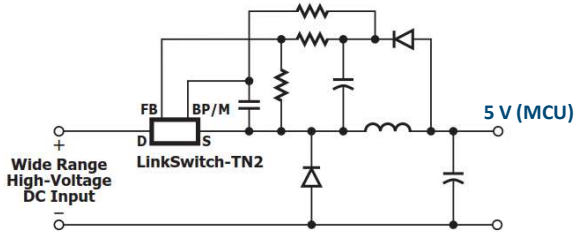
- **BridgeSwitch supplies itself from high-voltage bus**
- **Eliminates Gate drive power requirement from auxiliary power supply**
  - Single output permits use of simpler auxiliary power topology

Flyback Power Supply for Multi-Output Auxiliary Power



Self-Supply

Simple Buck Converter drives System µC

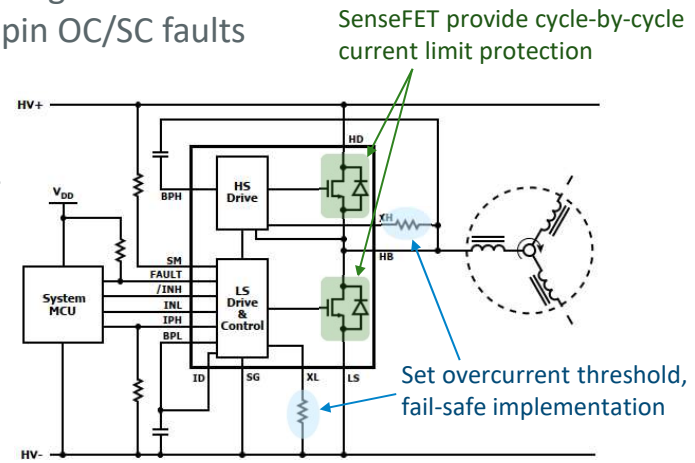


BridgeSwitch Monitors and Protects the Entire System

- **High-side and low-side lossless cycle-by-cycle current limit**
  - Provides hardware based motor and inverter fault protection
- **High-voltage DC bus UV/OV monitor**
  - Four distinct UV thresholds and one OV threshold
- **Two level low-side FREDFET over-temperature monitoring and protection**
  - Sense-input (SM) pin on each BridgeSwitch IC allows monitoring of PCB and/or motor-winding temperature
- **Detects low-side and high-side driver faults**
  - Includes supply voltage and pin-connection faults
- **Additional monitoring node**
  - System level thermal monitor
  - Motor vibration sensor etc.
- **Prevents simultaneous FREDFET conduction**
  - Extra layer of protection
- **FAULT output (single wire bus) provides status updates**
  - Informs system micro-controller about abnormal operation or BridgeSwitch protection actions

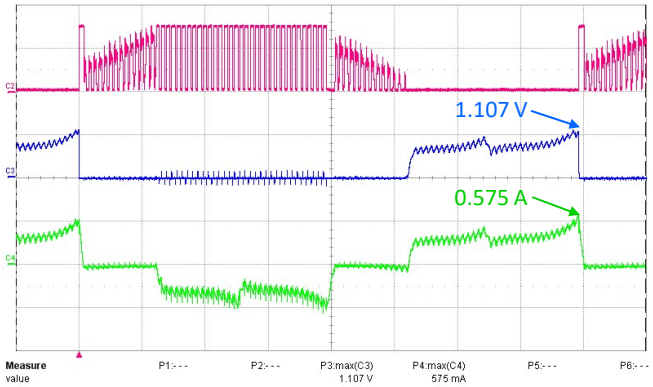
Hardware Based Motor Fault Protection Saves Certification Time and Cost

- **Low-side and high-side cycle-by-cycle current limit protects inverter & motor**
  - Independent high-side and low side programming with 43-100% range
  - Fail-safe implementation – BridgeSwitch also monitors for XL/XH pin OC/SC faults
- **Hardware protection against motor fault conditions**
  - Stalled motor, disconnected motor-phase, running over load
  - Inherent redundancy – two BridgeSwitch ICs in series with motor
- **No software interaction required to trigger protection**
  - Simplifies system level safety certification
  - Means that Class A rated control software can be used
- **IEC 60335-1 & 60730-1 compliance confirmed**
  - UL Report 4788685352
- **FAULT interface reports over-current faults**
  - Informs MCU that BridgeSwitch hardware based motor protection is engaged



Phase Current Output Simplifies Motor Control

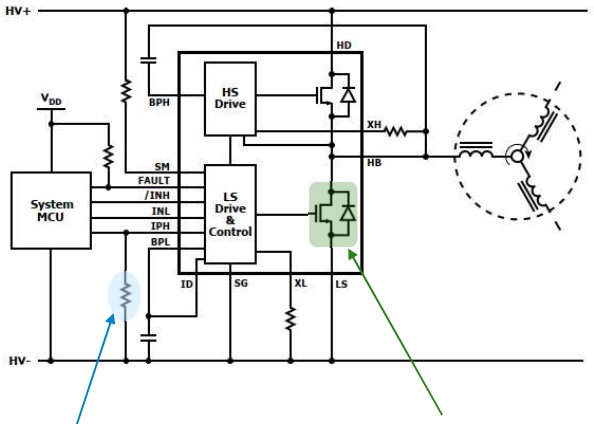
- **IPH output mirrors instantaneous low-side FREDFET Drain current (BRD126X devices)**
- **Eliminates current shunt resistors and associated circuitry**
- **Driven by small signal current source with fixed gain**
  - R_{IPH} sets desired signal amplitude
  - No external signal amplification needed
- **Supports individual sensing or composite signal sensing**



Half-bridge voltage (200 V/Div)

IPH output voltage (1 V/Div)

Motor winding current (500 mA/Div)

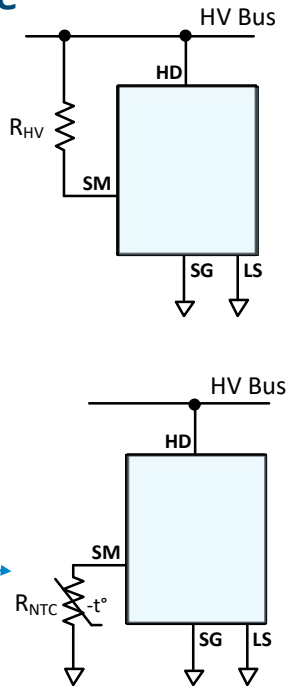


Resistor voltage represents LS FREDFET Drain current

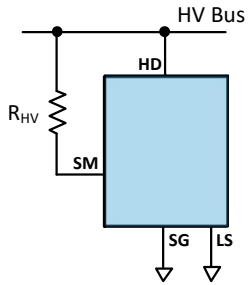
SenseFET provides instantaneous Drain current information

System Monitor Pin Provides Inverter Telemetry Information

- **SM-pin serves as HV bus voltage or as system temperature sense**
- **Self-configuration uses programming resistor**
  - Presence of R_{HV} is ascertained during start-up
- **With R_{HV} present: High-voltage bus voltage monitor**
  - Four line UV thresholds
  - One line OV threshold
  - Current based sensing reduces noise sensitivity
  - Low power consumption (15 mW with 7 MΩ at 320 VDC bus)
- **With thermistor R_{NTC} present: System thermal monitor**
  - Also supports other external sensors (e.g. door closure)
- **FAULT output sends SM status updates to MCU**



High Voltage Bus Monitoring



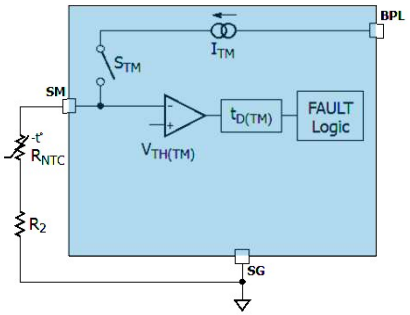
- **SM-pin configured as bus voltage sense input**
- **Four bus UV thresholds – one bus OV threshold**
  - Resistor R_{HV} determines bus OV and UV thresholds
  - Increase resolution by using the SM pin on multiple devices (for example 8 thresholds with 2 BridgeSwitch devices)
  - FAULT bus sends bus UV or OV status change updates
- **FREDFET turn-on signals are ignored if bus over-voltage exceeds threshold**
  - Provides hard-wired protection
- **FAULT output reports OV fault to system µC – enables entire inverter shutdown through µC**
  - Switching is re-enabled after HB bus drops below OV threshold hysteresis (7%)

Sensing Resistor R_{HV1}	6 MΩ	7 MΩ	8 MΩ
	Bus Voltage UV or OV Threshold		
I_{OV} (typ. 60 µA)	362 V	422 V	482 V
I_{UV100} (typ. 35 µA)	212 V	247 V	282 V
I_{UV85} (typ. 30 µA)	182 V	212 V	242 V
I_{UV70} (typ. 25 µA)	152 V	177 V	202 V
I_{UV55} (typ. 20 µA)	122 V	142 V	162 V

Device and System Temperature Monitoring

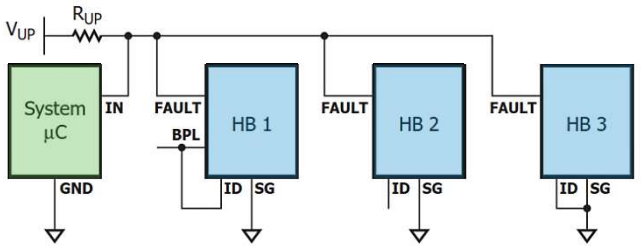
- **BridgeSwitch monitors low-side FREDFET temperature and provides two thresholds**
  - +125 °C **warning** threshold (OTW) allows system MCU to react
    - Enables monitoring of PCB temperature (junction temperature correlates to PCB)
  - +150 °C **protection** threshold (OTP) inhibits switching (latch-off)
    - System MCU can re-enable switching by sending latch-reset command via the FAULT bus
  - FAULT output reports reaching-and-clearing of OTW or OTP thresholds

- **External NTC allows temperature monitoring of system devices**
  - To reduce power consumption I_{TM} is pulsed with a 1% duty ratio
  - R_2 allows fine-tuning of desired shutdown temperature T_{SD}
  - FAULT output pin reports exceeding set-temperature-threshold
    - Also reports clearing of system temperature fault



FAULT Bus Reports Device & Inverter Status

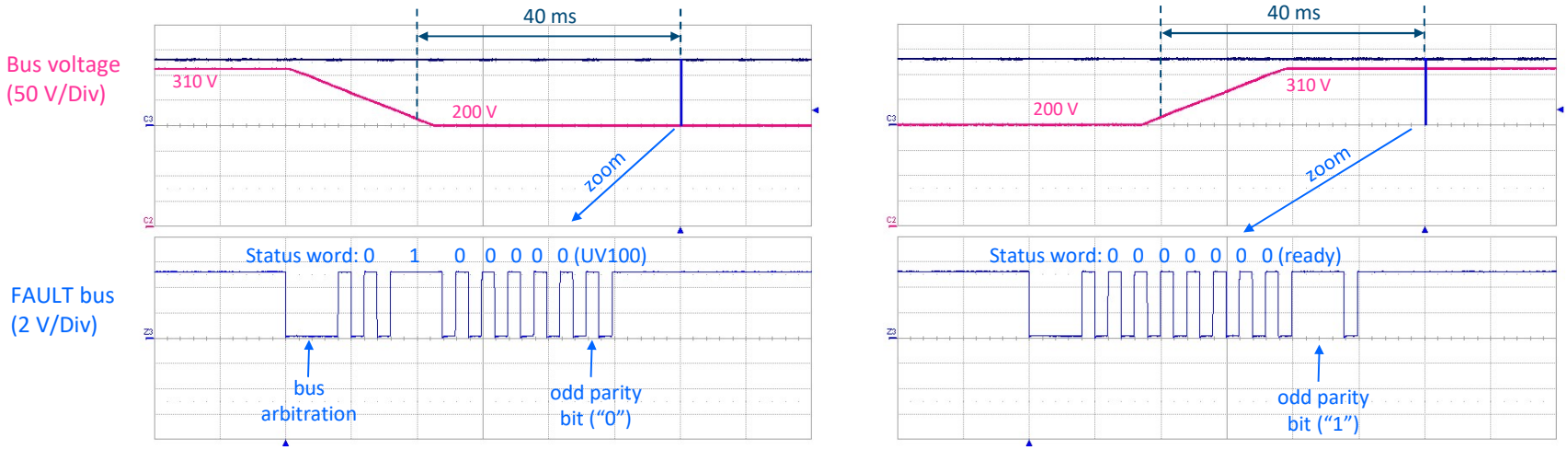
- **Single wire bus using open Drain outputs**
  - Reduces resources requirement for system micro-controller
  - 3.3 V and 5 V compatible
- **Bus architecture allows instantaneous fault reporting**
  - No master and slave operation
  - Reports any status update only once – reduces activity on bus



- **Enables system µC to react to abnormal conditions**
  - For example reduce inverter output power during AC brownout or elevated temperatures
- **ID-pin sets device ID – enables system µC to locate physical location of a fault**
- **Bidirectional communication**
  - BridgeSwitch transmits status updates with a 7-bit word followed by an odd parity bit
  - System µC can query status updates or reset over-temperature fault latch

Example: Bus UV Condition Status Update

- **BridgeSwitch detects bus voltage drop <212 V and sends a status update**
  - 6 MΩ bus sense resistance – sets UV100 threshold to 212 V
  - Clearing UV condition also triggers status update
  - 40 ms UV fault deglitch filter prevents false reporting due to noise



Support Material

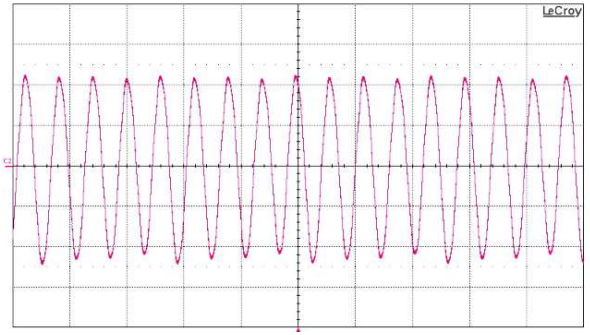
Wide Range of Inverter Reference Designs

(1) Available March 2020

Example Design	Motor	PI Part Number	DC Current	Control	Full Load Efficiency	Microcontroller
DER-653	3-Phase	BRD1165C	5.5 A	Sensorless FOC	98%	Toshiba TMP375FS
DER-654	3-Phase	BRD1265C	5.5 A	Any	98.3%	Wide selection of Microcontroller
DER-749	3-Phase	BRD1260C	1 A	Sinusoidal with Hall Sensor	94%	Princeton PT2505
RDR-851[1]	3-Phase	BRD1260C	1 A	Trapezoidal or Sinusoidal	95%	Wide selection of Microcontroller
RDR-852[1]	3-Phase	BRD1263C	3 A	Sensorless FOC	97.5%	Wide selection of Microcontroller
RDR-853[1]	3-Phase	BRD1265C	5.5 A	Sensorless FOC	98.2%	Wide selection of Microcontroller
DER-870[1]	3-Phase	BRD1267C	11.5 A	Sensorless FOC	99.2%	Wide selection of Microcontroller
DER-872[1]	1-Phase	BRD1260C	1 A	Block commutation	94%	Wide selection of Microcontroller
DER-873[1]	1-Phase	BRD1260C	1 A	Sinusoidal	98.2%	Wide selection of Microcontroller

DER-749: 40 W AC Fan Drive

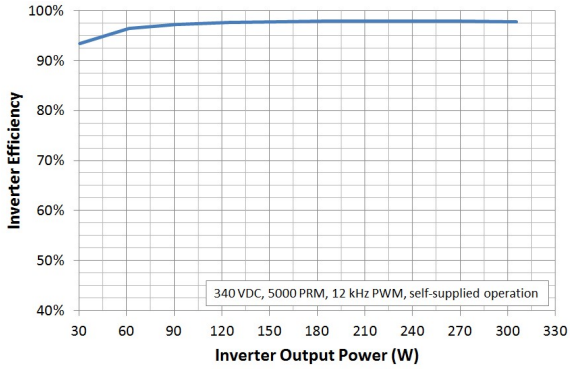
- **3-phase inverter using BRD1160C**
  - Inverter >94% efficient at 40 W motor output
  - Self-supplied operation
  - 20 kHz commutation frequency
  - No heatsinks
- **Motor stall protection via composite IPH signal**
- **Employs Princeton Technology PT2505**
  - Stand-alone sinusoidal BLDC motor controller
- **High-voltage buck converter with LinkSwitch-TN2 LNK3202D**
  - Supplies microcontroller and associated circuitry

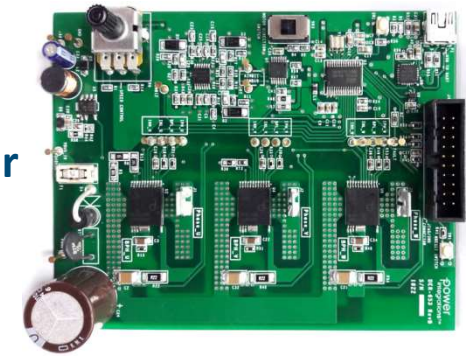


Phase current at 40 W motor load

DER-653: Sensorless FOC Development Platform

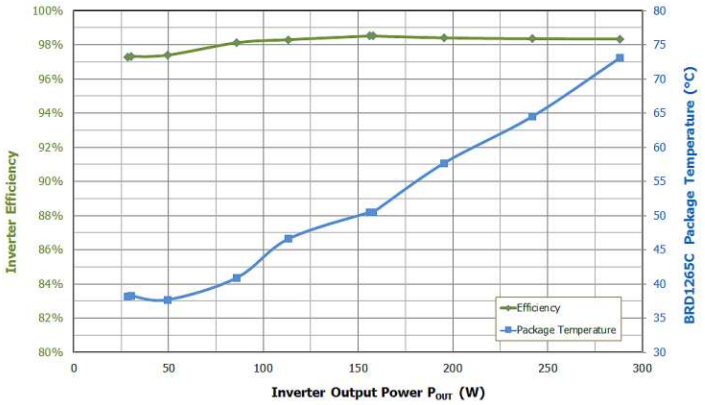
- **3-phase 0.9 A_{RMS} inverter example using BRD1165C**
  - >97% efficient at 305 W output
  - Self-supplied operation
  - No heatsinks
- **Sensorless field-oriented control (FOC)**
- **Employs Toshiba TMPM375 vector engine**
- **Fully implemented FAULT interface**
  - Control algorithm uses device and system level telemetry data
- **Provide microcontroller and associated circuitry with power**
  - High-voltage buck converter using LinkSwitch™-TN2 IC (LNK3204D)
- **Passes motor-abnormal-operation tests per IEC 60335-1**
  - No software interaction required





DER-654: 300 Watt Inverter

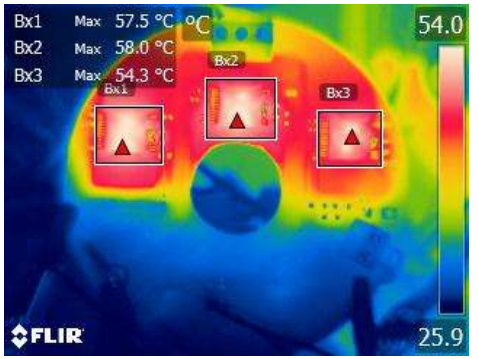
- **3-phase design example using BRD1265C**
  - >98% efficient at 300 W output
  - 0.37 W no-load input power
  - Self-powered – no auxiliary power supply needed
- **Instantaneous phase-current output**
- **System monitoring – HV bus and temperature**
- **Single-wire status communication bus**
- **Supports trapezoidal or sinusoidal control**
- **Small size: 140 x 42 mm**
- **No heatsinks**
- **Passes motor abnormal operation tests per IEC 60335-1 w/o software action**



Efficiency & Temperature Over Load

RDK-851: 50 W DC Fan Drive

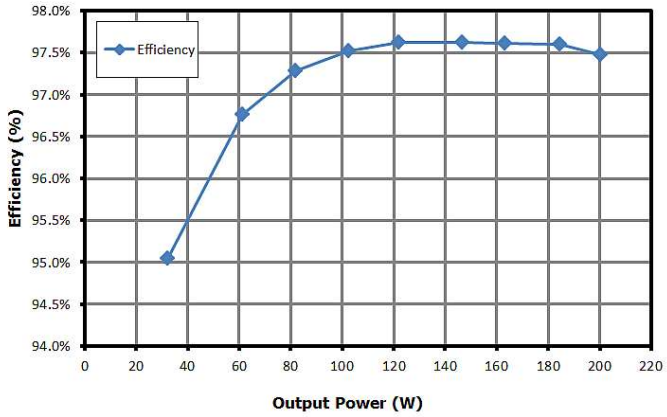
- **3-phase inverter example using BRD1260C**
  - 270-365 VDC input
  - 96.2% efficient at 50 W (0.22 A_{RMS}) output using external supply
    - 95% efficient using internal supply
  - Supports self-supplied or external-power operation
  - Up to 20 kHz commutation frequency
  - No-load input power <50 mW (with external supply)
- **Less than 35° C temperature rise without heatsink**
  - 0.22 A_{RMS} continuous phase current
  - Self-supplied or external supply
- **Single wire status communication interface**
- **Supports any microcontroller via single header connector**

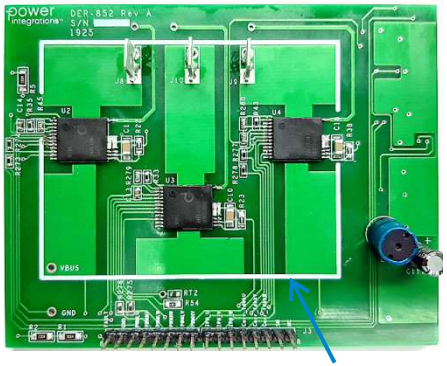


88 mm outer diameter

RDK-852: 200 W Pump Motor Drive

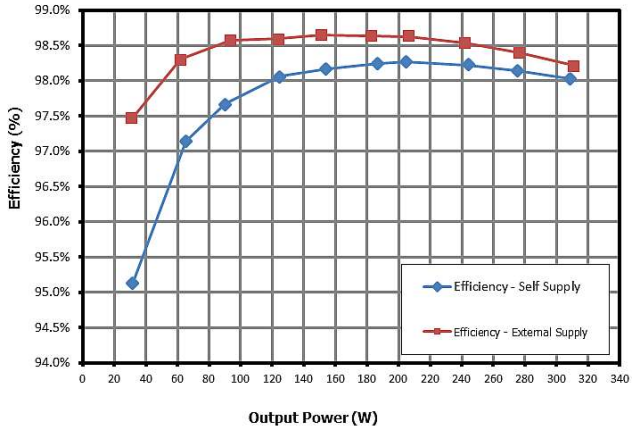
- **3-phase inverter example using BRD1263C**
  - 270-365 VDC input
  - 97.5% efficient at 200 W (0.6 A_{RMS}) output
  - Supports either self-supplied or external power
  - 40 °C rise above ambient (self-supplied) without heatsinks
- **Passes motor abnormal operation tests per IEC 60335-1**
  - No software interaction required, Class A ready
- **Aux. power for current sensing amplifiers and BridgeSwitch**
  - High-voltage buck converter using LinkSwitch-TN2 IC (LNK3204D)
- **Single wire Status communication interface**
- **Supports any microcontroller via single header connector**

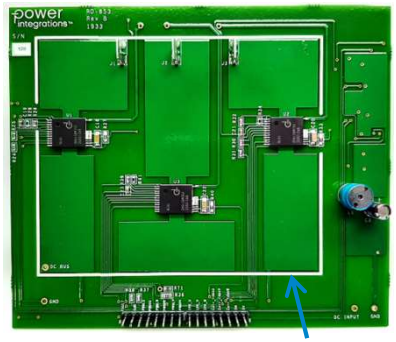




RDK-853: 300 W Compressor Drive

- **3-phase inverter example using BRD1265C**
  - 270-365 VDC input
  - 98.2% efficient at 310 W output (12 kHz PWM)
    - 98.3% efficient at 62 W output (12 kHz PWM)
  - Support self-supplied or external-supply operation
  - 43 °C temperature rise (12 kHz, external supply) without heatsink
  - 50 mW no-load input power (external supply)
- **Passes motor abnormal operation tests per IEC 60335-1**
  - No software interaction required
- **Aux. power for current sensing amplifiers and BridgeSwitch**
  - High-voltage buck converter using LinkSwitch-TN2 IC (LNK3204D)
- **Single wire status communication interface**
- **Supports any microcontroller via single header connector**

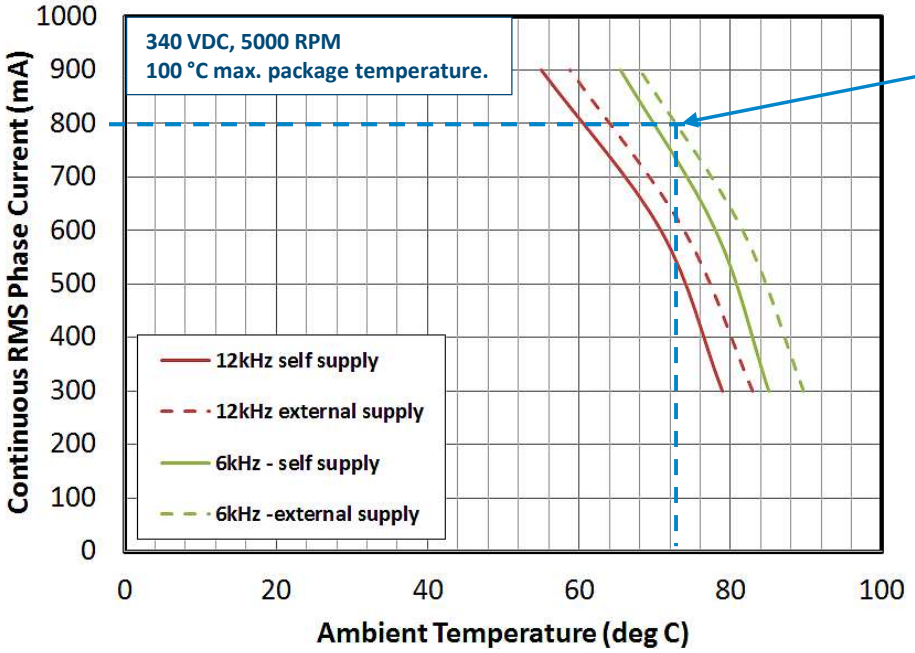




95 x 75 copper area mm

RDK-853 Current Capability

- **Governed by ambient temperature, PWM frequency, and device supply**
  - Curves represent BridgeSwitch case temperature of 100 °C



Example:
0.8 A_{RMS} @ 75 °C ambient temperature & 100 °C package temperature with 6 kHz PWM and external supply and no heat sinks

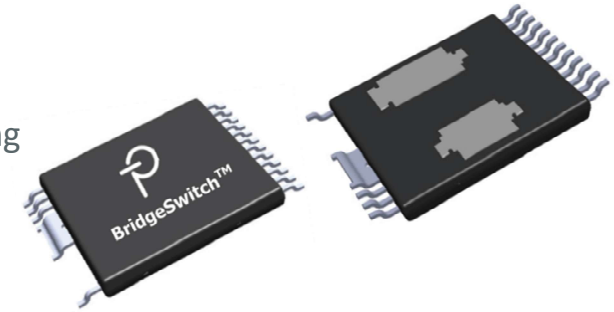
Support Documentation

- **AN-80 describes the BridgeSwitch FAULT Status Communication Interface**
  - Includes sample code-library
- **AN-83 BridgeSwitch Design Tips, Techniques and Troubleshooting Guide**
- **UL Informative Report (IEC 60335-1 and IEC 60370-1 Compliance)**
  - Includes AN-76 failure mode and effect analysis for the BridgeSwitch Family
- **Whitepapers**
  - Impact of PCB Layout on Device Temperature in 3-Phase Inverters using BridgeSwitch ICs
  - Direct Use of BridgeSwitch Current Sense Signal Output in Field Oriented Control of Brushless DC Motors
  - Simplified Product Safety Certification through Hardware based Motor fault Protection
- **Design Example Engineering Reports**
- **Available at https://bit.ly/BridgeSwitch**

BridgeSwitch Summary

motor drivers

- **Integrated, flexible half-bridge – drives up to 400 W without heatsinks**
  - Drives single-phase or three-phase motors
- **Highest efficiency**
  - Integrated FREDFETs with fast, ultra-soft diode and lossless current sensing
- **Hardwired protection and monitoring of entire inverter**
  - Simple single-wire interface communicates with system MCU
- **Simplifies auxiliary power requirements**
  - Internal self-supply removes need for gate drive power and level shifting
- **Supports all common motor control schemes**
  - Trapezoidal (6-step), sinusoidal, and field oriented (FOC)
- **Small low-profile surface mount package**
  - No heatsink due to high efficiency and heat distributed across multiple BridgeSwitch parts



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