Design Engineering Report

Title	***1-Phase Inverter Using BridgeSwitch™ BRD1160C***
Specification	• 185 V_{AC}- 265 V_{AC} • 0.220 A_{RMS} Motor Phase Current • 1ph BLDC motor with Hall sensor • 10kHz PWM
Application	1ph High-Voltage BLDC sensored Motor Drive
Author	SA
Date	Nov 5, 2019
Revision	1.0

Summary and Features

- BridgeSwitch – High-voltage half-bridge motor driver
- Integrated 600 V FREDFETs with ultra-soft, fast recovery diodes
- No heat sink
- Fully self-biased operation – simplifies auxiliary power supply
- High-side and low-side cycle-by-cycle current limit
- Two level device over-temperature protection
- Single wire status update communication bus

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Table of Contents

1 Introduction

This document describes a 0.220A_{rms}, inverter for sensored 1ph BLDC motor application using BridgeSwitch BRD1160C device.

This document also contains the inverter specification, schematic, bill of materials, printed circuit board (PCB) layout, performance data.

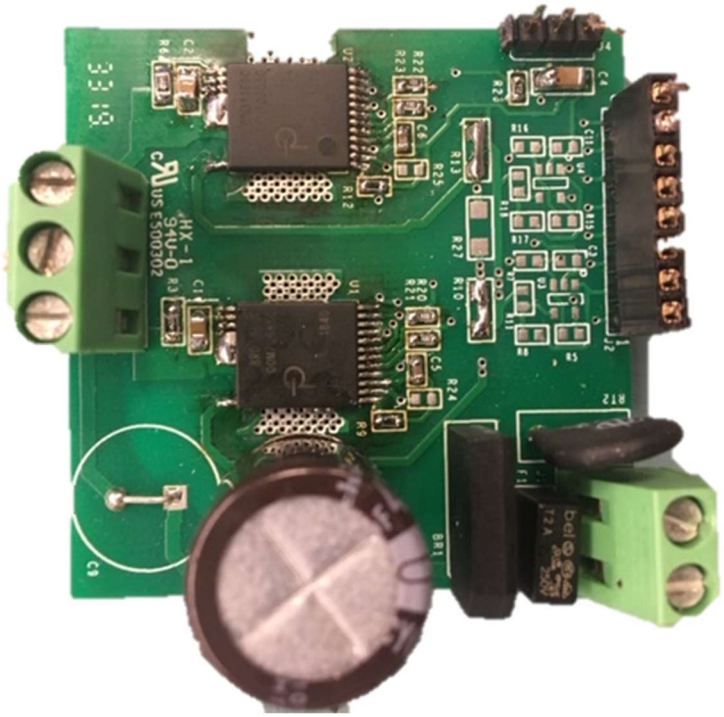

Figure 1 – Populated Circuit - Top View.

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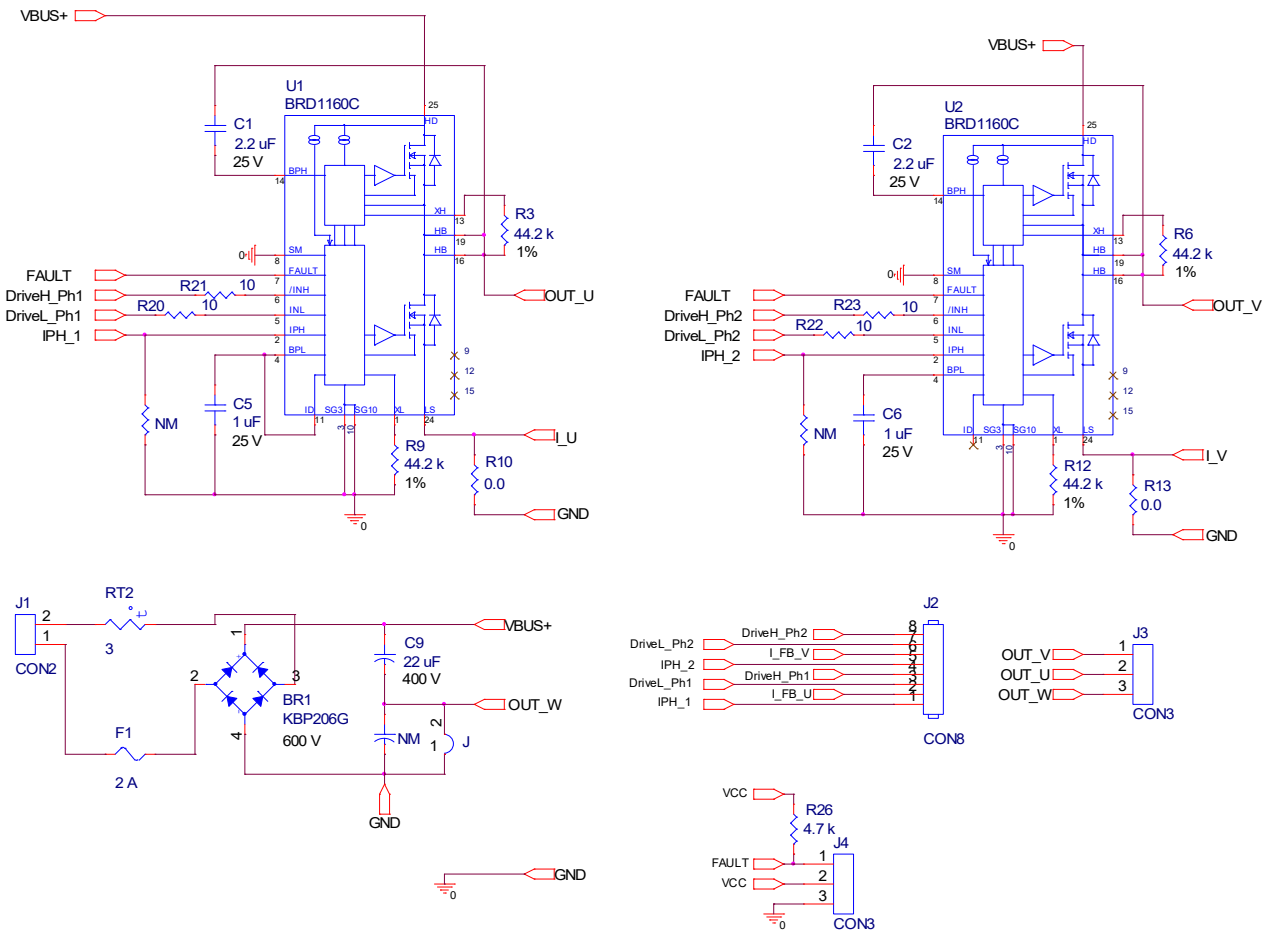
2 Inverter Specification

The table below provides the electrical specification of the 3-phase inverter design. The result section provides actual performance data.

Description	Symbol	Min	Typ	Max	Unit	Comment
Input Voltage	V_{IN}	185	230	265	V	2-wire AC input
Output						
Motor Phase Current	I_{MOTOR}		0.220		A_{RMS}	RMS phase current
PWM Carrier Frequency[1]	f_{PWM}		10		kHz	
Efficiency	n		86		%	At full load
Environmental Ambient Temperature	T_{AMB}	0		60	°C	

3 Schematic



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4 Circuit Description

The schematic shows a 1-phase inverter utilizing two BridgeSwitch devices. The circuit design drives a high-voltage, 1-phase, brushless DC (BLDC) motor with Hall sensor. BridgeSwitch combines two 600V, N-channel power FREDFETs with its corresponding gate drivers into a low profile surface mount package. The BridgeSwitch power FREDFET features ultra-soft, fast recovery diode ideally suited for inverter drives. Both drivers are fully self-supplied eliminating the need for the system power supply to provide gate drive power.

In addition, BridgeSwitch incorporates internal fault protection and system level monitoring. Internal fault protection includes cycle-by-cycle current limit for both FREDFETs and a two level thermal overload protection. On the other hand, system level monitoring includes high-voltage DC bus sensing with multi-level under-voltage thresholds and one over-voltage threshold. BridgeSwitch can also be configured using external sensors such as a thermistor for system temperature monitoring. A single wire open Drain bus communicates all detected fault or change of status to the system micro-controller.

4.1 *Single phase BridgeSwitch Inverter*

The two BridgeSwitch devices U1, U2 form the 1-phase inverter with the output of the inverter connects to the 1-phase BLDC motor through connectors J3 (OUT_U, OUT_V).

4.2 *Input stage*

The input stage consist of fuse F1, BRIDGE diode BR1, inrush thermistor RT2, and input capacitor C9. Fuse F1 provides protection when there is an excessive input current. Bridge Diode BR1 is use for input rectification and circuit protection in case the polarity of the input bus voltage is reverse. Thermistor RT2 is a negative temperature coefficient (NTC) device that initially presents high resistance, which prevents large currents from flowing at turn-on therefore limiting inrush-current. A bulk capacitor C9 is used for high input bus voltage. A second bulk capacitor in series with C9 is short circuited. It can be used to configure the inverter as dual bulk capacitor.

4.3 *Bias supply*

Capacitors C5 and C6, provide self-supply decoupling for the integrated low-side controller and gate driver. Internal high-voltage current source recharges such capacitors as soon as the voltage level starts to dip. On the other hand, capacitors C1 and C2 provide self-supply decoupling for the integrated high-side controller and gate driver. Internal high-voltage current sources recharge these capacitors whenever the half-bridge point of the respective device drops to the low-side source voltage level (i.e. the low-side FREDFET turns on).

4.4 *PWM input*

Input PWM signals DriveH_Phx, DriveL_Phx control the switching state of the integrated high side and low side power FREDFETs. The system microcontroller provides the required PWM signal and desired switching frequency.

4.5 *Cycle by cycle current limit*

Resistors R9, R3, R12, R6 set the cycle-by-cycle current limit level for the integrated low side and high-side power FREDFETs. A selected value of 44.2 kΩ set the current limit to 100% of the default level.

4.6 *Fault communication*

The BridgeSwitch device (U1, U2) reports any detected internal and system status change through the communication bus connected to pin 1 of J4.

The microcontroller takes action in accordance to the status update reported by the device. Such action could be for instance inverter shutdown, latch, restart, warning, etc.

4.7 *Device ID*

Each BridgeSwitch assigns itself a unique device ID through the connection of pin 11 (ID pin). The pin connection can either be floating, connected to the SG pin or BPL pin. Device ID enables communicating the actual device flagging a fault to the system microcontroller.

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5 Printed Circuit Board Layout

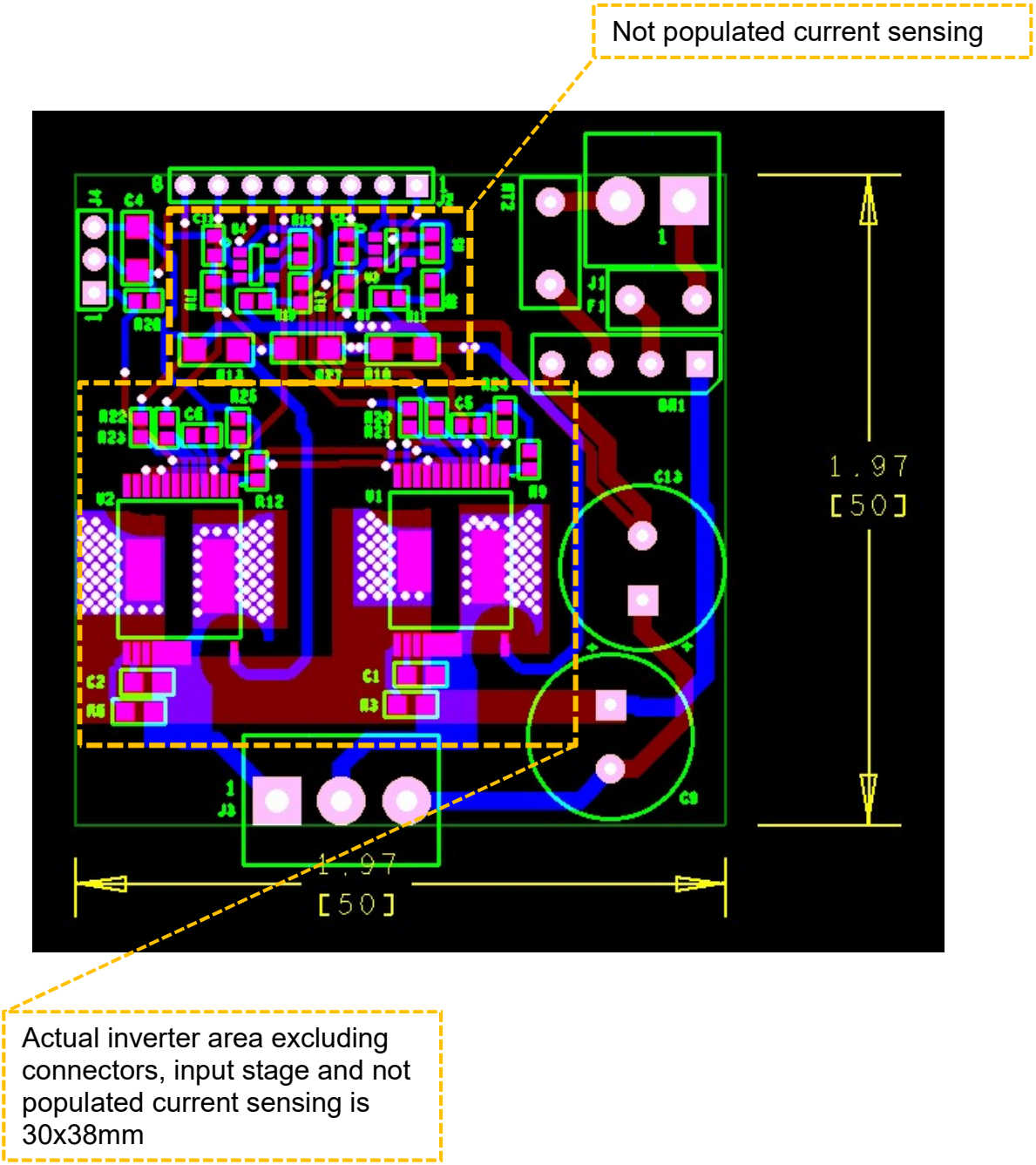

Figure 2 – Printed Circuit Board Layout

6 Bill of Materials

Item Num	Part Ref	Quan	Value	Description	Mfg	Mfg Part Number
1	BR1	1	KBP206G	600 V, 2 A, Bridge Rectifier, Glass Passivated	Diodes	KBP206G
2	C1 C2	2	2.2 uF	2.2 uF, 25 V, Ceramic, X7R, 0805	TDK Corp	C2012X7R1E225M
4	C4	1	4.7uF	4.7 uF, 35 V, Ceramic, X5R, 1206	TDK Corp	C3216X5R1V475M085AB
5	C5 C6	2	1 uF	1 uf, ±10%, 25 V, Ceramic, X7R, 0603 (1608 Metric)	TDK Corp	CGA3E1X7R1E105K080AE
6	C9	2	22 uF	CAP ALUM 22UF 20% 400V T/H	Rubycon	400AX22MEFC12.5X16
7	F1	1	2 A	2 A, 250V, Slow, Long Time Lag,RST	Belfuse	RST 2
8	J1	1	CON2	2 Position (1 x 2) header, 5 mm (0.196) pitch, Vertical, Screw - Rising Cage Clamp	Phoenix Contact	1715022
9	J2	1	CON8	CONN HEADER VERT 8POS 2.54MM	Molex	0022284080
10	J3	1	CON3	3 Position (1 x 3) header, 5 mm (0.196) pitch, Vertical, Screw - Rising Cage Clamp	Phoenix Contact	1715035
11	J4	1	CON3	CONN HEADER VERT 3POS 2.54MM	Molex	0022284036
12	R3 R6	2	44.2 k	RES, 44.2 k, 1%, 1/8 W, Thick Film, 0805	Panasonic	ERJ-6ENF4422V
16	R9 R12	2	44.2 k	RES, 44.2 k, 1%, 1/16 W, Thick Film, 0603	Panasonic	ERJ-3EKF4422V
19	R20 R21 R22 R23	4	10	RES, 10 R, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ100V
20	R26	1	4.7 k	RES, 4.7 k, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ472V
22	RT2	1	3	ICL 3 OHM 20% 5A 13MM	Cantherm	MF72-003D11
23	U1 U2	2	BRD1160C	BridgeSwitch, Max. BLDC Motor Current 1.0A (DC)	Power Integrations	BRD1160C

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7 Performance Data

This section presents waveform plots and performance data of the BridgeSwitch inverter. The input voltage is 230Vac unless stated otherwise. Full load operation describes the inverter operating 0.220Arms output phase current, 2500rpm, 10kHz PWM. All measurements performed at room ambient temperature.

7.1 *Start-up Operation*

7.1.1 BPL and BPH Startup Waveforms

Figure 3 – BPL startup (self-supply)
CH1: V_{INL}, 5 V/div
CH2: V_{BPL}, 10 V/div
CH4: V_{BPH}, 10 V/div
Time scale: 200ms/div

7.2 ***Steady-State Operation***

7.2.1 Phase Voltages (HB to LS) and Current during Steady State

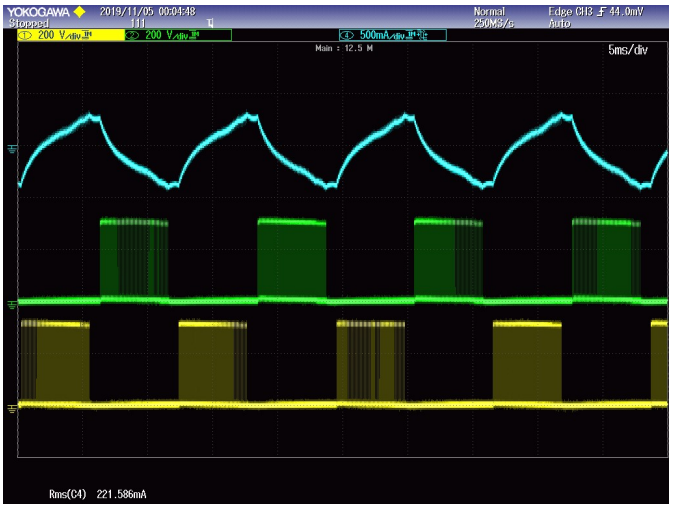

Figure 6 – Phase current and HB voltage
CH1: V_{HB_PHASEU}, 200V/div
CH2: V_{HB_PHASEV}, 200V/div
CH4: I_{PHASE}, 500mA/div
Time scale: 5msec/div

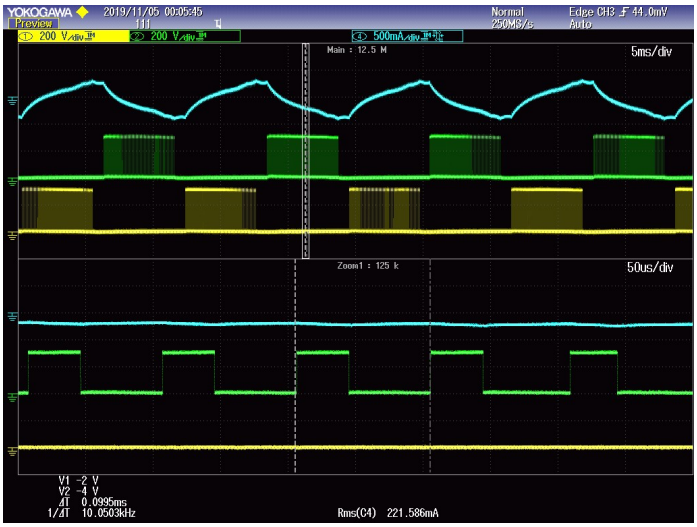

Figure 6 – Phase current and HB voltage
CH1: V_{HB_PHASEU}, 200V/div
CH2: V_{HB_PHASEV}, 200V/div
CH4: I_{PHASE}, 500mA/div
Time scale: zoom 50usec/div

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7.3 *Thermal Performance*

The thermal measurements below show on-board BRD1160C thermal performance after 60 minutes of operation with $220A_{rms}$ inverter phase current running at a constant speed of 2500 RPM, 10 kHz PWM switching frequency, 230Vac input, 27°C room ambient temperature, with self-supply

Figure 8 - BRD1160C - self-supply

7.4 *Efficiency*

The graphs below show the BridgeSwitch inverter efficiency at 230Vac, 10kHz PWM switching frequency, constant motor speed of 2500 RPM, self-supply at different rms phase current

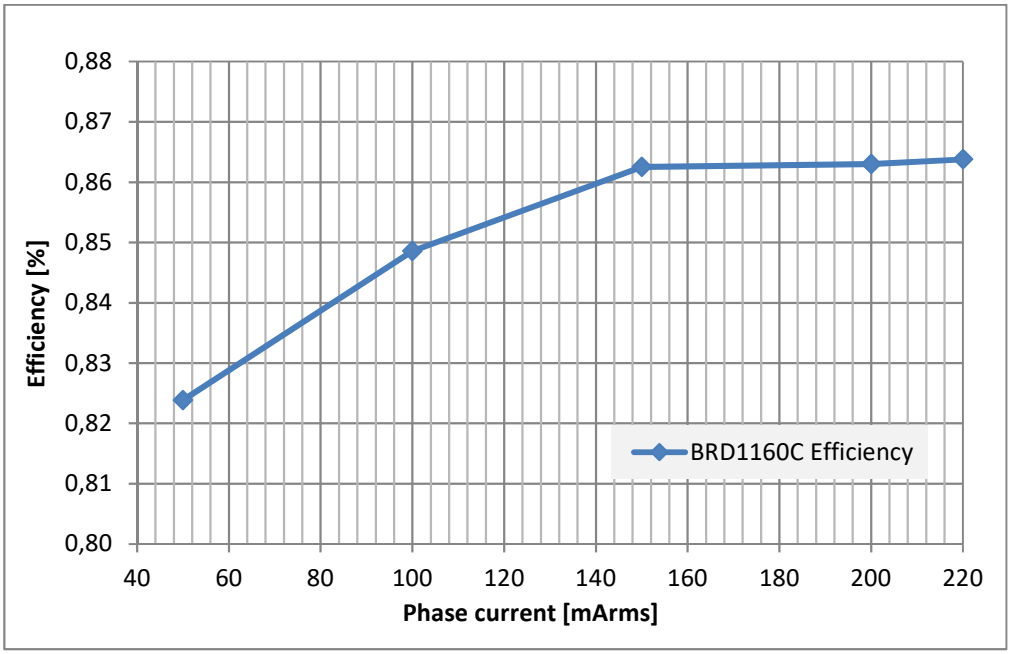

Figure 12 – BRD1160C Inverter Efficiency

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8 Revision History

Date	Author	Rev.	Description & Changes
5-November-19	SA	1.0	First release

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