24V, 35W Sensorless FOC BLDC reference design with 85 —265VAC, 0.92pF single stage PFC

TEXAS INSTRUMENTS

Description

For achieving energy efficiency, ceiling fans and ventilation fans are moving from simple AC induction motors to brushless DC (BLDC) motors. This reference design meets these challenges of higher efficiency and power factor in a simple way by using a universal main power supply input from 85—265VAC with a single stage power factor corrected isolated flyback to convert offline voltages, and can reach up to 0.92pF in 24VDC. The design also combines a fully integrated and well protected single-chip for sensorless field-oriented control FOC brushless motor control.

Resources

TIDA-010951	Design Folder
MCF8315C	Product Folder
MCF8316A	Product Folder
MSPM0L1105	Product Folder
MSPM0C1104	Product Folder
UCC28810	Product Folder

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Features

- 24V, 35W Sensorless FOC drive capable of driving brushless DC (BLDC) motors
- Highly-integrated and protected single-chip, brushless FOC motor controller reduces external parts count and audible noise
- Integrated FOC algorithm with windmilling support, fast start-up, and quiet operation
- Support closed-loop speed control maintains high accuracy of expected motor speed
- Reliable start-up and fully-protected system with short circuit, overcurrent, and blocked rotor protection
- Single stage PFC to Achieve High Input Power Factor (> 0.92),universal input capability (85V to 265V AC) with minimum variation in efficiency
- Cost-optimized MCUs MSPM0C or MSPM0L offer high-performance analog peripheral integration
- Optimized small-form factor (SFF) fits for motor integration

Applications

- Air purifier and humidifier
- Residential and living fan
- Dishwasher
- Washer and dryer
- Appliances pumps and fans
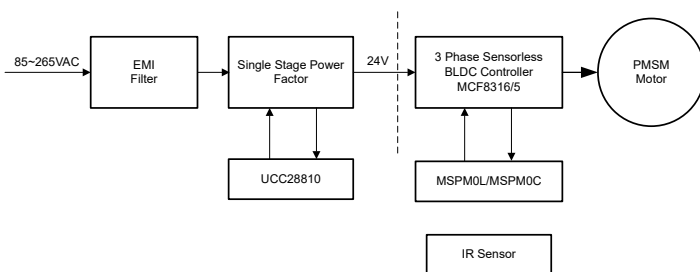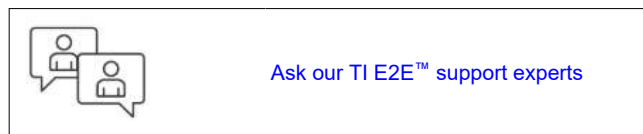
1 System Description

The use of brushless DC (BLDC) motors has been steadily increasing in applications where a wide range of speed variation is required and BLDC motors are highly efficient as compared to induction motors. For very low power applications, using low voltage motors offers several advantages, such as operation over universal voltage input conditions, cost savings on motors and passives, and a compact printed circuit board (PCB). Additionally, highly integrated and protected low voltage motor driver integrated circuits (ICs) make the motor easier to control and more efficient. However, the use of a low voltage motor does require an efficient and low-cost AC-DC conversion stage. The TIDA-10951 design addresses this application requirement in a simple and efficient manner. The PCB also integrates an efficient and feature rich motor controller stage, which enables customers to use this platform for applications such as ceiling fans, exhaust fans, ventilation fans, oven fans, and other low-power BLDC drives used in home and industrial appliances.

As Figure 1-1 shows, a buck power factor correction (PFC) power stage converts the 85V to 265V, AC input to a regulated 24V DC output. This design utilizes a UCC28810 PFC IC to control this power stage. The 24V DC generated by the power stage is used to power the three-phase sensorless FOC BLDC motor controller MCF8315/MCF8316. This drives the motor to control the speed. The MCF8315/MCF8316 controller also generates a 3.3V supply, which powers the microcontroller (MCU). The MSPM0L/MSPM0C MCU transmits the speed reference to the MCF8315/MCF8316 controller in the form of a pulse-width modulation (PWM) signal producing a duty cycle proportional to the desired speed. This PWM signal is based on the signal received from the infrared (IR) sensor, which in turn is activated by a general-purpose IR remote control. Customizing the firmware of the MCU is easy for any given remote-control data format.
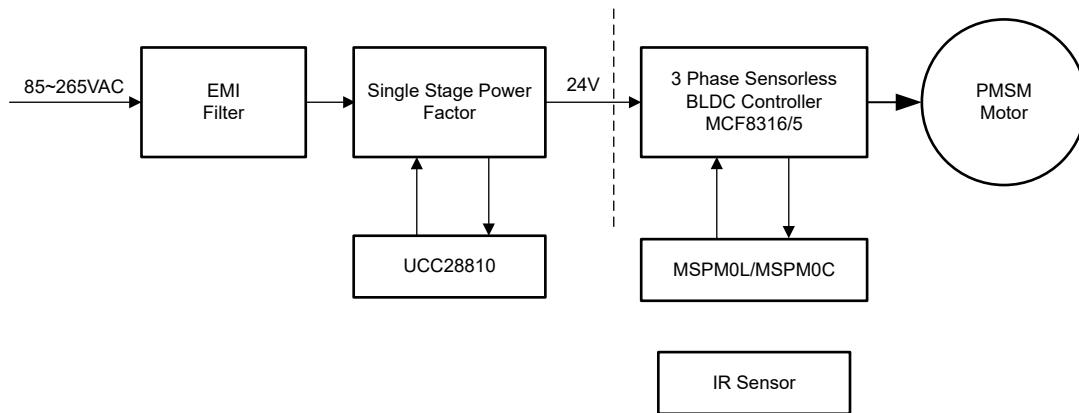
Figure 1-1. TIDA-010951 Block Diagram

The MCF8315/MCF8316 is a highly integrated and protected single-chip FOC motor controller with integrated sensorless FOC algorithm, gate driver, and FETs, capable of delivering constant torque under varying load conditions. The MSPM0L/MSPM0C is a general-purpose microcontroller from TI's portfolio of highly integrated, low-cost Arm® Cortex®-M0+ MCUs allowing this system to receive IR signal, control motor speed and direction, and get motor status via I2C. The total design is optimized with high efficiency and a small PCB form factor to easily fit into the motor.

1.1 Key System Specifications

Parameter	Value	Comment
1-phase AC input voltage (RMS)	85-265V, 230V(typ.)	Designed for 230V RMS, 50Hz 1pH AC input systems
Max. output power from 24V	50W	
Input current THD (at 230V, 35W fly-back output power)	<10%	
Power factor (at 230V, 35W fly-back output power)	0.95	
Input current THD at (140-265V), 35W fly-back output power)	<12.5%	THD across operating input voltage range at full load

Parameter	Value	Comment
Power factor at (140-265V), 35W fly-back output power)	> 0.92	Power factor across operating input voltage range at full load
PCB layer stack	2-Layer	
PCB size	Ø85mm	
Non-isolated MCU (MSPM0L) interface to host processor	3.3V I/O	

WARNING

TI intends this reference design to be operated in a lab environment only and does not consider the device to be a finished product for general consumer use.

TI Intends this reference design to be used only by qualified engineers and technicians familiar with risks associated with handling high-voltage electrical and mechanical components, systems, and subsystems.

High voltage! There are accessible high voltages present on the board. The board operates at voltages and currents that can cause shock, fire, or injury if not properly handled or applied. Use the equipment with necessary caution and appropriate safeguards to avoid injuring yourself or damaging property.

Hot surface! Contact can cause burns. **Do not touch!** Some components can reach high temperatures > 55°C when the board is powered on. The user must not touch the board at any point during operation or immediately after operating, as high temperatures can be present.
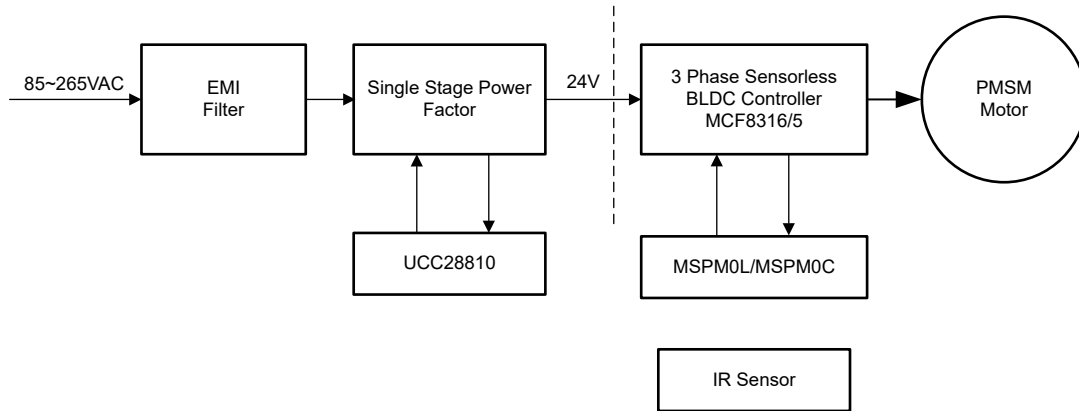

CAUTION

Do not leave the design powered when unattended.

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2 System Overview

2.1 Block Diagram

Figure 2-1 shows the system block diagram of TIDA-010951 design.

Figure 2-1. TIDA-010951 Block Diagram

2.2 Design Considerations

The reference design has the following sub-blocks:

- 85-265VAC input and EMI filter
- High performance single stage PFC using UCC28810, provides 24VDC for motor control
- High integrated MOSFET and algorithm sensorless BLDC controller using MCF8315/MCF8316 for motor control
- Cost-optimized MCU MSPM0L/MSPM0C device for MCF8315/ MCF8316 control and support IR Sensor control.

2.3 Highlighted Products

2.3.1 UCC28810

The UCC28810 are general lighting power controllers for low to medium power lumens applications requiring power factor correction and EMC compliance. UCC28810 is designed for controlling a flyback, buck or boost converter operating in critical conduction mode. UCC28810 features a trans-conductance voltage amplifier for feedback error processing, a simple current reference generator for generating a current command proportional to the input voltage, a current-sense (PWM) comparator, PWM logic and a totem-pole driver for driving an external FET.

In the critical conduction mode operation, the PWM circuit is self-oscillating with the turn-on being governed by a transformer zero energy detector (TZE pin) and the turn-off being governed by the current sense comparator. Additionally, the controller provides features such as peak current limit, restart timer, over-voltage protection (OVP), and enable.

2.3.2 MCF8315

The MCF8315 is part of TI's latest generation of BLDC motor drivers with integrated code-free, sensorless FOC along with 40V, 240mΩ (HS+LS) FETs based 3-phase inverter power stage to provide a compact, efficient, "all-in-one" design for applications like residential fans, appliance pumps/fans, seat cooling blowers, projector fan etc.,

Key highlights include,

- 40V, 240mΩ (HS+LS) FETs with integrated gate driver with configurable slew rate control to mitigate EMI
- Integrated 3-phase current sensing to reduce BOM costs
- Integrated sensorless FOC for low acoustic, high efficiency BLDC motor operation

- Integrated power management features including configurable output voltage buck (3.3/4/5/5.7V) capable of delivering up to 170mA in addition to a 3.3V LDO capable of delivering up to 20mA
- Configurable features like PWM switching frequency, PWM modulation schemes, minimum on time to improve efficiency
- TI proprietary features like dead time compensation, reverse drive, active deceleration, DC bus current limit to enable differentiated end application performance
- Compact 7x5mm, 40-pin QFN package: p2p with MCF8316 (40V, 95mΩ FETs) for higher power applications
- Operating junction temperature absolute maximum ratings: -40°C to 150°C.
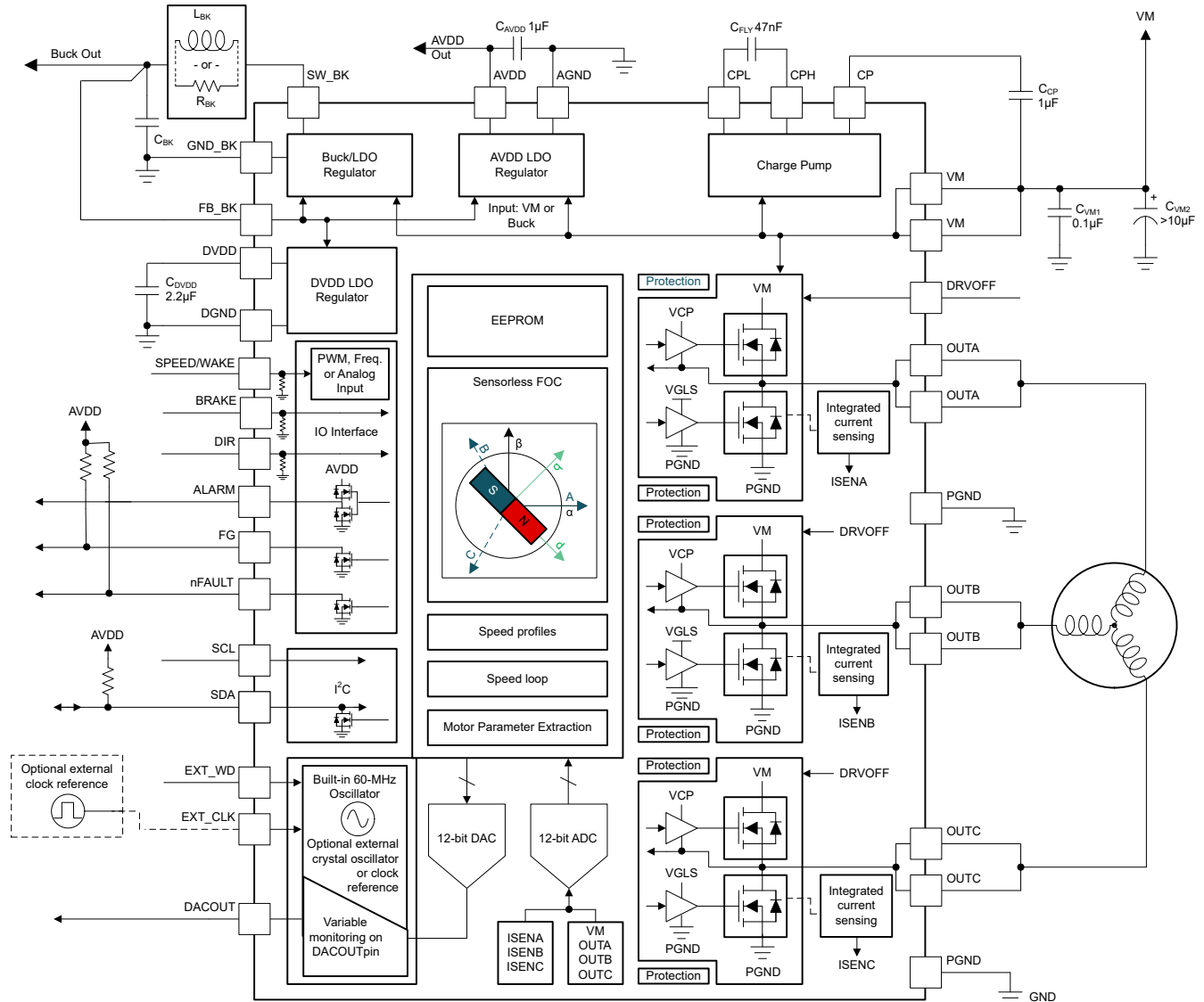
Figure 2-2. MCF8315C Block Diagram

2.3.3 MSPM0L

MSPM0L110x microcontrollers (MCUs) are part of the MSP highly-integrated ultra-low-power 32-bit MSPM0 MCU family based on the enhanced Arm Cortex-M0+ core platform operating at up to 32MHz frequency. These cost-optimized MCUs offer high-performance analog peripheral integration, support extended temperature ranges from -40°C to 105°C, and operate with supply voltages from 1.62V to 3.6V.

The MSPM0L110x devices provide up to 64KB embedded flash program memory with 4KB SRAM. These MCUs incorporate a high-speed on-chip oscillator with an accuracy up to ±1.2%, eliminating the need for an external crystal. Additional features include a 3-channel DMA, 16 and 32-bit CRC accelerator, and a variety of high-performance analog peripherals such as one 12-bit 1.68-Msps ADC with configurable internal

voltage reference, one general-purpose amplifier, and an on-chip temperature sensor. These devices also offer intelligent digital peripherals such as four 16-bit general purpose timers, one windowed watchdog timer, and a variety of communication peripherals including two UARTs, one SPI, and one I2C. These communication peripherals offer protocol support for LIN, IrDA, DALI, Manchester, Smart Card, SMBus, and PMBus.

The TI MSPM0 family of low-power MCUs consists of devices with varying degrees of analog and digital integration let customers find the MCU that meets project needs. The architecture combined with extensive low-power modes is optimized to achieve extended battery life in portable measurement applications.

2.3.4 MSPM0C

MSPM0C110x microcontrollers (MCUs) are part of the MSP highly-integrated ultra-low-power 32-bit MCU family based on the enhanced Arm Cortex-M0+ core platform operating at up to 24MHz frequency. These cost-optimized MCUs offer high-performance analog peripheral integration, support extended temperature ranges from -40°C to 125°C, and operate with supply voltages from 1.62V to 3.6V.

The MSPM0C110x devices provide up to 16KB embedded flash program memory with 1KB SRAM. These MCUs incorporate a high-speed on-chip oscillator with an accuracy from -2% to +1.2%, eliminating the need for an external crystal. Additional features include a 1-channel DMA, CRC-16 accelerator, and a variety of high-performance analog peripherals such as one 12-bit 1.5Msps ADC with VDD as the voltage reference, and an on-chip temperature sensor. These devices also offer intelligent digital peripherals such as one 16-bit advanced timer, two 16-bit general purpose timer, one windowed watchdog timer, and a variety of communication peripherals including one UART, one SPI, and one I2C. These communication peripherals offer protocol support for LIN, IrDA, DALI, Manchester, smart card, SMBus, and PMBus.

The TI MSPM0 family of low-power MCUs consists of devices with varying degrees of analog and digital integration let customers find the MCU that meets project needs. The architecture combined with extensive low-power modes is optimized to achieve extended battery life in portable measurement applications.

3 System Design Theory

3.1 MCF8315 Design

MCF8315 is a 40V, 240mΩ, sensorless FOC based BLDC driver that operates from a single DC input (VM) ranging from 4.5-35V. MCF8315 has integrated power management circuits including a buck converter (3.3/4/5/5.7V,170mA) and an LDO (3.3V/20mA). The motor driver also has a host of GPIOs for a variety of functionalities like speed input (SPEED), motor speed output (FG), fault indicator (nFAULT), direction control (DIR), DAC outputs (DACOUT1/2), I2C communication (SCL/SDA) and more.

3.1.1 Power section

The power section of MCF8315/MCF8316 needs the following passive components for proper operation as shown in Figure 3-1.

1. **VM:** Bulk capacitor (≥10µF, 2x VM) to reduce the input voltage ripple depending on the PWM switching frequency, peak phase currents etc., Additionally a 100nf, 2x VM capacitor can be added as an option to filter the high frequency noise on VM, if needed
2. **Charge pump:** MCF8315/MCF8316 uses an integrated charge pump to generate the gate drive for high-side FETs. The charge pumps needs two caps – one rated at (47nF, 2x VM) between CPH and CPL pins and one rated (at 1µF, ≥16V) between CP and VM
3. **Buck:** Buck converter can be operated in inductor mode (higher efficiency and cost) or resistor mode (lower efficiency and cost). In TIDA-010951, the buck converter is designed to operate in inductor mode and can deliver up to 170mA for external loads. The inductor is rated at 47µH, 1.5A saturation current and the capacitor is rated at 22µF, 10V. Refer to MCF8315 data sheet for more information on resistor mode.
4. **AVDD:** This 3.3V LDO needs a decoupling cap rated at 1µF, 10V and can deliver up to 20mA for external loads. The minimum capacitance at AVDD is more than 600nF across operating conditions for rated 3.3V regulation.
5. **DVDD:** This 1.5V LDO needs a decoupling cap rated at 1µF, 10V. The minimum capacitance at DVDD is more than 600nF across operating conditions for rated 1.5V regulation.
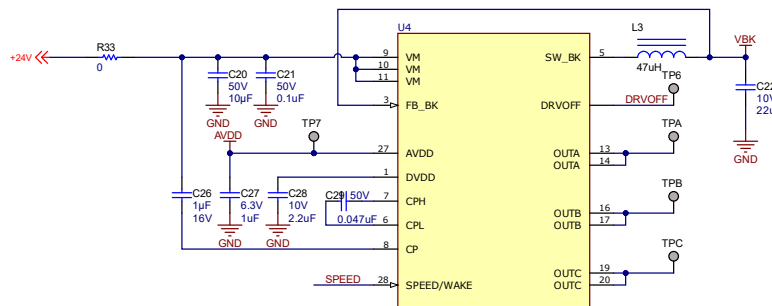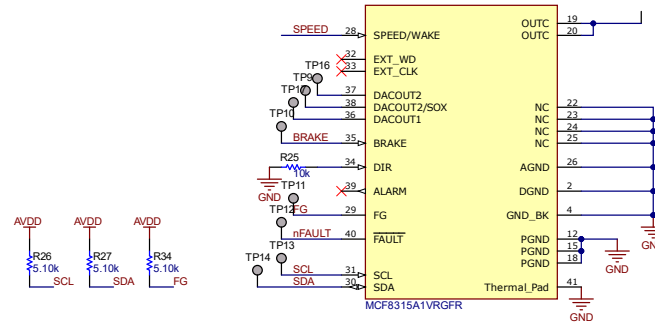

Figure 3-1. MCF8315/MCF8316 Power Section

3.1.2 GPIO section

The GPIOs of MCF8315 are connected as shown in Figure 3-2.

1. **SPEED** pin is connected to MSPM0L1306 for speed control. This pin can instead be directly connected to a (0-3)V input for speed control using analog speed control mode.
2. **SCL, SDA** pins are connected to MSPM0L1306 with pull-up resistors to AVDD for I2C communication.
3. **FG** pin is connected to MSPM0L1306 with external pull-up resistor to AVDD. FG indicates the motor speed. The external pull-up resistor can be removed when internal pull-up resistor is enabled through EEPROM.
4. **DIR** pin is connected to AGND (through an optional pull-down resistor) since the pin is unused. In this case, direction of rotation can set using EEPROM.
5. **BRAKE** pin is connected to MSPM0L1306 for brake operation. This is an active high signal and when BRAKE pin is set high, MCF8315 decelerates the motor to user configured speed threshold and then applies low side brake to quickly bring the motor to a stop.
6. **DACOUT1, DACOUT2, DACOUT2/SOX** are output pins that are connected to test points for monitoring signals.

7. **EXT_WD, EXT_CLK** pins are unused and hence left floating. EXT_WD, EXT_CLK can also be connected to AGND directly when unused.

8. **nFAULT** pin is connected to MSPM0L1306. This is an active low, open drain fault indicator output and needs internal pull-up resistor to AVDD to be enabled through EEPROM for fault indication.

9. **DRVOFF** pin is an active high input signal that is connected to MSPM0L1306 and can be used to immediately disconnect power to the motor.

10. **ALARM** pin is left floating since the pin is unused.

11. **NC** pins are connected to AGND along with thermal pad and all other ground pins (DGND, GND_BK, PGND, AGND) for better thermal performance.

Figure 3-2. MCF8315/MCF8316 GPIO Section

3.2 ACDC Design: Single Stage PFC

This single-stage power factor corrected converter is an isolated flyback AC/DC topology that rectifies the AC input line to a DC output with an input sinusoidal current. The single-stage flyback topology is widely used as an isolated LED driver design and some applications need PFC and flyback AC/DC, to achieve high power factor with low component count, high reliability, and low cost without a large size 450VDC bulk capacitor.

The basic principle of the circuit are as follows:

From the input side, a 3.15A fuse is placed to protect overcurrent, an MOV is placed to protect overvoltage, and an NTC is placed to suppress the start-up inrush current. L1, L2, C3, C1 are input EMI filters, and D1 is a bridge rectifier. D2, D3, R1, R2, R3 form an input voltage detection circuit, R4, R5, C10, D13 form a high-voltage start-up circuit, and enter VSENSE through R13, R14 voltage division. Q1 is the primary power switch, and R16, D14, R17 help control the switching speed. R23 connected in series on the source is the primary current sensing resistor, and the T1 bias winding also provides a transformer zero energy (TZE) detection signal (transmitted to the TZE pin of U1 via R21, R20, C12). R11, D10, and D9 connected in parallel on the primary winding of the transformer form a clamping circuit on the drain of Q2.

D6, C5, C6, and C7 form a secondary rectifier filter circuit. The TL431 circuit formed by U3 feeds back the signal to EAOUT through an optocoupler. In this design, we set the feedback voltage to 24.18V .U1 detects the AC input voltage through the pin VINS, which can force the peak switch current to track the change of the input voltage, thereby improving the system power factor. C16,R18,D11,R20,Q3,R22,Q2 as a leading edge blanking circuit, for the detail information you can check the description of "Leading Edge Blanking Circuit on the TZE Pin" in the UCC28810 data sheet.
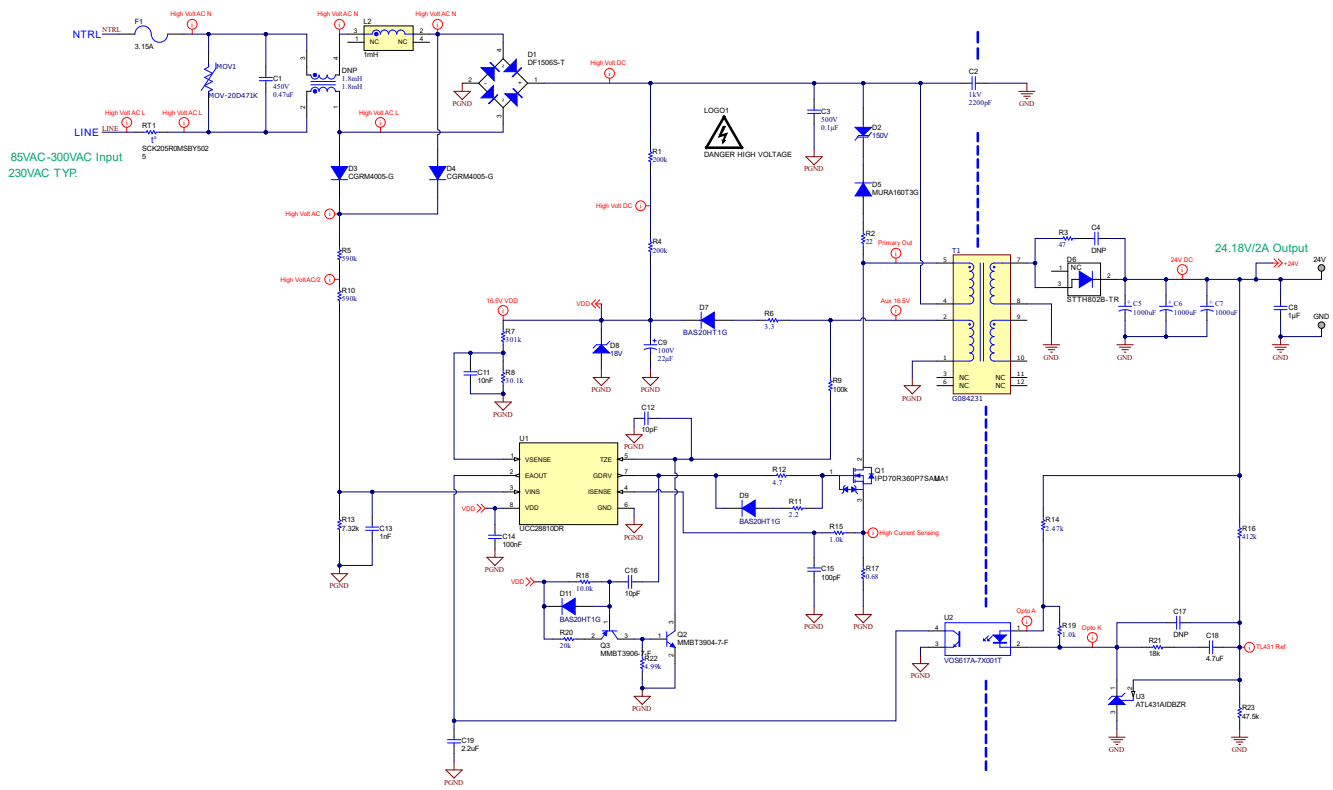
Figure 3-3. Single Stage PFC Design

3.3 Host MCU Design

The 20-pin MSPM0L1306 is used in this TIDA-010951 design. Customers can use MSPM0C110X and MSPM0L110X according to needs. MSPM0L130X Pin to Pin with MSPM0L110X(VSSOP) and MSPM0C110X(VSSOP). The MSPM0L1306 is a 32MHz device with 64kB flash and 4kB RAM. In this design, we use I2C (PA0 and PA11) to communicate with the MCF831x device, and the MCF831x device can be configured or controlled through I2C. BRAKE, FG, SPEEP, DRVOFF are brake, speed feedback, speed input, and drive off pins, respectively, which can be obtained or controlled through the MCU GPIO. The IR receiver out pin is connected to PA11 as the input pin of the IR signal. In this design, PA18 is pulled down to prevent the initial power-on from entering the BSL mode. At the same time, the design also reserves UART communication TX, RX (PA22, PA23)
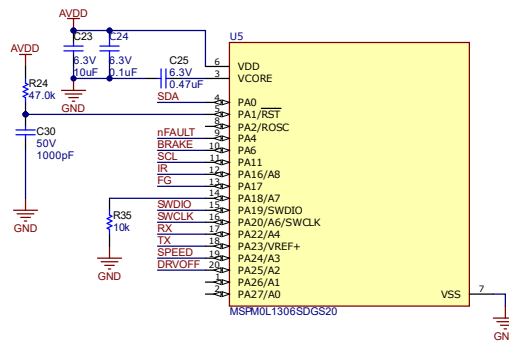
Figure 3-4. Host MCU Design

4 Hardware, Software, Testing Requirements, and Test Results

4.1 Hardware Requirements

4.1.1 Hardware Overview

This section details the hardware and explains the different sections on the board and how to set them up for the experiments as outlined in this design guide.
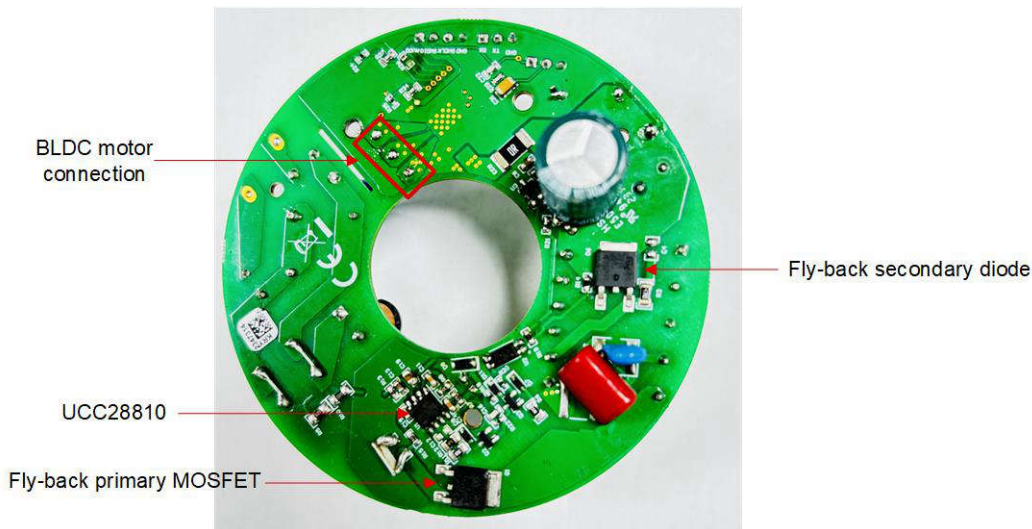
4.1.2 TIDA-010951 PCB

The TIDA-010951 requires only one power input: a 1-phase, 85-265VAC RMS source capable of delivering up to 50W. The input terminals for the AC power supply are on the top side of the PCB (highlighted in a box) in the top right quadrant of Figure 4-1. The diode rectifier, fly-back transformer and the 24V rail bus capacitors are also on the top side of the PCB. The BLDC motor driver MCF8315C is powered off the 24V rail and drives the BLDC motor based on the speed command received over I2C from an MCU (MSPM0L1306) shown in Figure 4-1. The IR receiver to receive the speed command is also on the top side of the PCB. In addition, the two connectors for communication with the MSPM0L1306 (SWD and UART) are also placed on the top side of the PCB as marked in Figure 4-1.
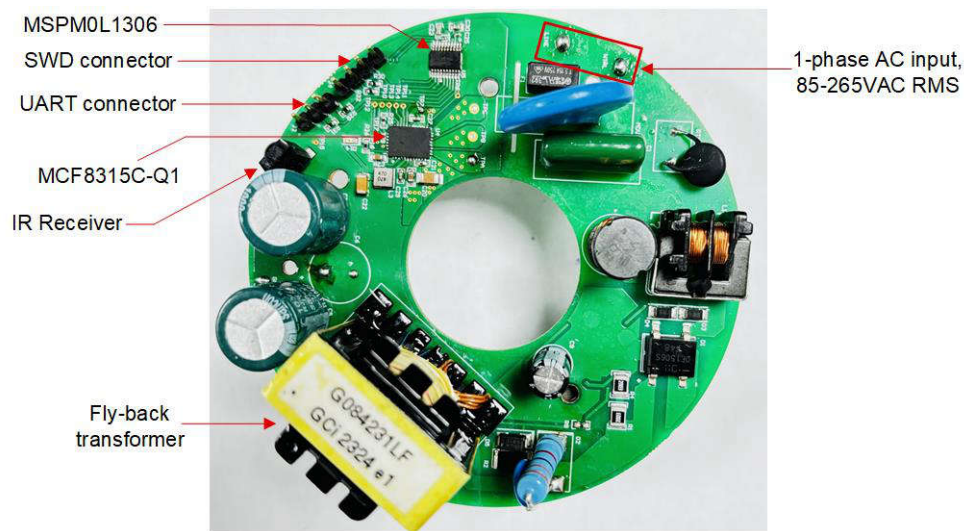
Figure 4-1. TIDA-010951 PCB Top View

The PCB bottom side shows the fly-back converter components including the controller, UCC28810, primary MOSFET and secondary diode. In addition, the three phase outputs for the BLDC motor are also available on the bottom side of the PCB as marked in Figure 4-2.

Figure 4-2. TIDA-010951 PCB Bottom View

4.2 Software Requirements

To download the software files, contact your TI sales representative.

4.3 Testing requirements

The table below lists the key test equipment. Description and pictures of the test setup for specific tests are provided in the section of the corresponding test results.

Table 4-1. TIDA-010951 Test Equipment

Description	Part number
Reference design	TIDA-010951
Pedestal fan	24V, 3-phase BLDC motor, 350RPM
1ph AC power source	Gwinstek APS-7100
Oscilloscope	Rohde and Schwarz MXO44
High voltage isolated probe	Agilent N2790A
Low voltage non-isolated probe	Tektronix TPP0101
Power Analyzer	Tektronix PA4000
Current probe	Keysight N2783B
Thermal camera	Fluke Ti480

4.4 Test Setup

- Make familiar with the TIDA-010951 PCB, schematic and layer plots. Remember that the TIDA-010951 PCB and related interfaces can be exposed to high voltages
- Test and validate the TIDA-010951 PCB only in a proper lab. Verify the TIDA-010951 PCB is de-energized and not connected to any power supply before handling the PCB, making any power or signal connections for measurement and more.
- Place the TIDA-010951 in a protective box with emergency stop button to turn off the input power quickly in case of emergency.
- Use fans with appropriate guards to protect from spinning fan blades.
- Use properly rated connectors to connect the 1-phase AC power input to TIDA-010951.
- Fan speed control can be achieved by two methods – using 'Analog' speed control mode and a (0-3)V input to SPEED pin of MCF8315C or using 'I2C' speed control mode and sending speed command through MSPM0L1306.
- Speed control through IR remote can also be achieved using the IR receiver and proper IR protocol implementation on MSPM0L1306.
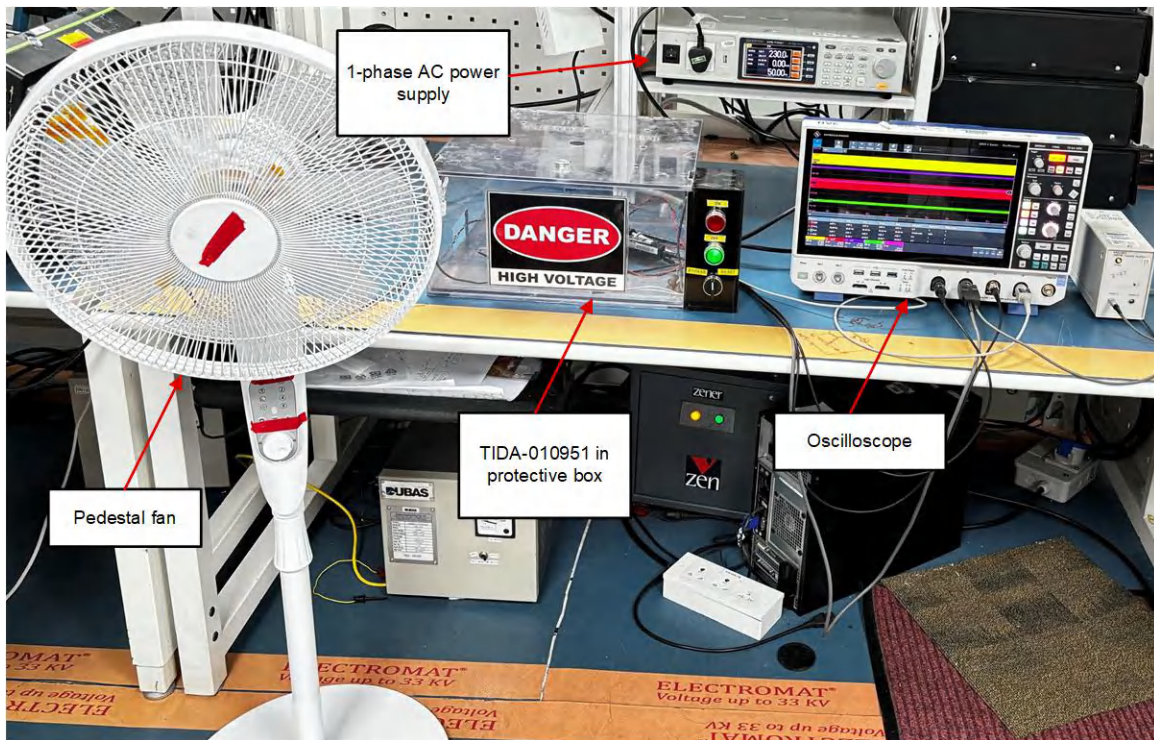
Figure 4-3. Picture of Test Setup

4.5 Test Results

4.5.1 Power Management in TIDA-010951

A 1-phase, 230VAC RMS input is connected to the reference design PCB. The UCC28810 based fly-back converter on TIDA-010951 uses the rectified AC to generate an isolated 24V rail for powering the BLDC motor driver, MCF8315C-Q1. MCF8315C-Q1 generates a 5V (VBK) from an integrated buck converter and 3.3V (AVDD) from an integrated LDO. AVDD powers the MSPM0L1306 which is used to receive the speed command over Infrared (IR) and send the command to MCF8315C-Q1 over I2C. MSPM0L1306 can also be used for monitoring the status of the BLDC fan operation using I2C communication. VBK is used to power the IR received TSOP32238

4.5.2 UCC28810 Based Single Stage PFC

TIDA-010951 provides a UCC288210 based secondary side regulated single stage PFC that generates an isolated 24V rail capable of delivering up to 2A. This fly-back converter can operate across (140-265) VAC RMS and provide a tightly regulated 24V while maintaining an input power factor (PF) > 0.92 and input current THD < 12.5% at 35W load (from 24V). The line, load regulation, efficiency, input PF and THD of the single stage PFC is as shown in Table 4-2.

Table 4-2. Single Stage PFC Test result in 140-265VAC

Vin (AC RMS)	PIN (W)	POUT (W)	VOUT (V)	Efficiency (%)	Input PF	Input current THD (%)
	8.49	6	24.15	70.68	0.867	26.5
	14.38	11	24.16	76.5	0.964	10.51
140	21.19	17	24.15	80.23	0.978	9.65
	30.35	25	24.16	82.38	0.985	10.1
	42	35	24.15	83.34	0.988	11.5

Table 4-2. Single Stage PFC Test result in 140-265VAC (continued)

Vin (AC RMS)	PIN (W)	POUT (W)	VOUT (V)	Efficiency (%)	Input PF	Input current THD (%)
230	8.49	6	24.15	70.68	0.51	45.43
	14.34	11	24.15	76.71	0.682	36
	21.25	17	24.15	80	0.826	22.5
	30.48	25	24.16	82.03	0.93	10.4
	42	35	24.15	83.34	0.95	9.6
265	8.6	6	24.15	69.77	0.426	45.1
	14.45	11	24.15	76.13	0.579	40.4
	21.32	17	24.15	79.74	0.709	32.67
	30.47	25	24.15	82.05	0.828	20.9
	42.04	35	24.16	83.26	0.92	12.2

If you want to use TIDA-010951 at 85VAC-140VAC, we need to make some modifications to the PCB to achieve good PF and iTHD.

Please check following changes and test results in Table 4-2.

R14=6.8Kohm, R19=DNP, R17=0.22ohm, R18=2.2Kohm, C16=47pF, R20=18Kohm.

Table 4-3. Single Stage PFC Test result in 85-140VAC

Vin (AC RMS)	PIN (W)	POUT (W)	VOUT (V)	Efficiency (%)	Input PF	Input current THD (%)
85	8.49	6	24.11	78.9	0.968	8.5
	14.38	11	24.11	83.9	0.977	9.4
	21.19	17	24.11	84.8	0.961	9.4
	30.35	25	24.11	85.5	0.949	11.9
	42	35	24.11	85.2	0.948	12.0
110	8.49	6	24.11	78.9	0.94	14.9
	14.34	11	24.11	84.0	0.964	9.3
	21.25	17	24.11	88.6	0.965	9.6
	30.48	25	24.11	87.1	0.955	10.8
	42	35	24.11	87.0	0.951	11.6
140	8.6	6	24.11	77.9	0.86	21.1
	14.45	11	24.1	83.0	0.941	10.6
	21.32	17	24.11	84.8	0.952	9.6
	30.47	25	24.11	87.0	0.961	10.0
	42.04	35	24.11	87.3	0.956	10.5

Figure 4-4 shows the input phase current while delivering 35W (drawn from 24V rail) at 230V RMS. The input power factor is 0.95 and input current THD is 9.6%.
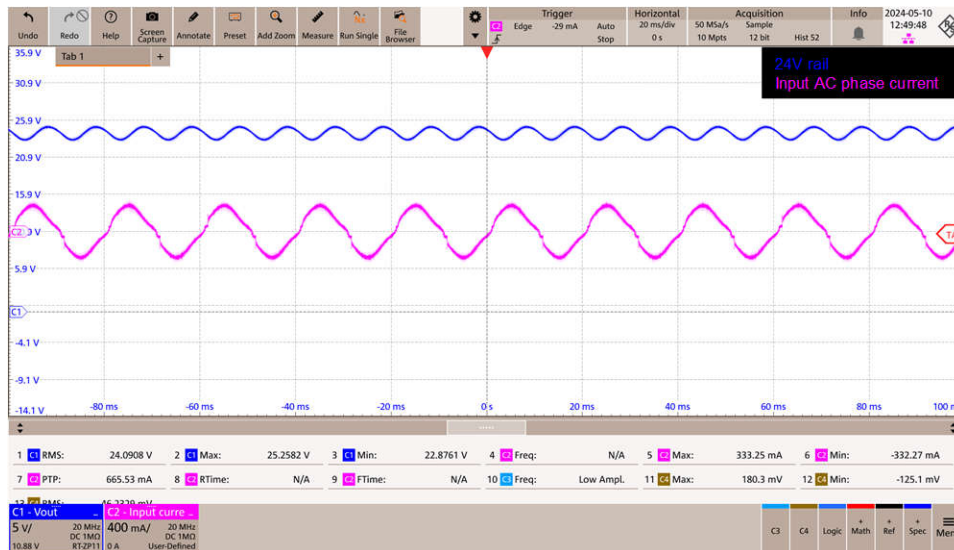
Figure 4-4. Input Phase Current at 230V RMS, 35W Load (Drawn From 24V Rail)

4.5.3 BLDC Residential Fan Operation Using MCF8315C

4.5.3.1 Power-Up Sequence

Figure 4-5 shows the power-up sequence and time taken for the fan to reach full speed after the 1-phase power supply is turned on. In this test, SPEED pin was tied to AVDD to set 100% speed command by default on power-up.
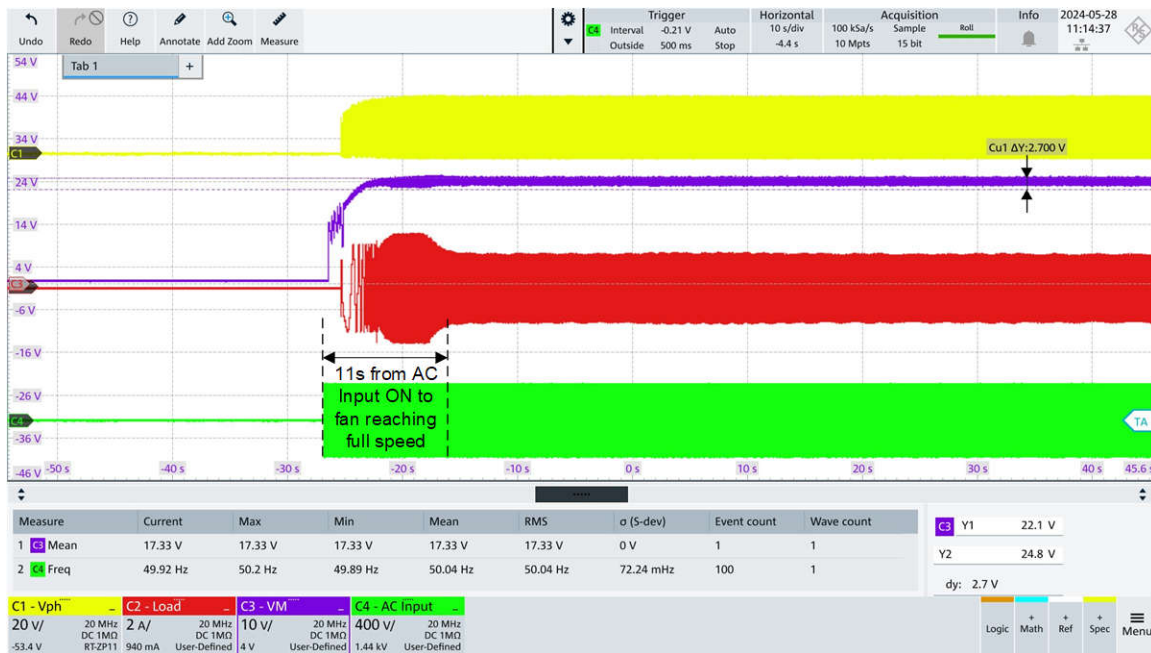

Figure 4-5. Power-Up Sequence

4.5.3.2 Forward Windmilling (ISD Forward Resync)

Figure 4-6 shows the forward windmilling (ISD forward resync) feature of MCF8315C-Q1 at high (about 90%) and low fan (about 10%) speeds. This is a critical use-case for residential fans wherein the motor driver has to resync at fan coasting speed and drive to set speed command within shortest possible time.

Figure 4-6. Forward Windmilling (High Speed ISD Forward Resync)

Figure 4-7. Forward Windmilling (Low Speed ISD Forward Resync)

4.5.3.3 Reverse Windmilling (ISD Reverse Resync)

Figure 4-8 shows the reverse windmilling (ISD reverse resync) capability of MCF8315C-Q1. In this test case, the fan is coasting in the reverse direction (due to cross winds) when a speed command is received. MCF8315C-Q1 resyncs in the reverse direction, decelerates the fan to zero speed in a smooth, controlled manner and then accelerates in the forward direction to set speed.
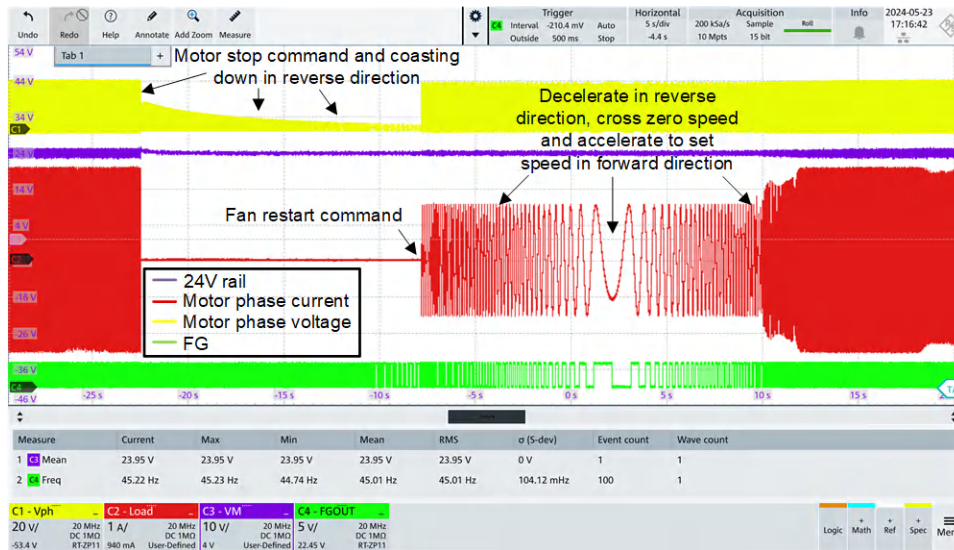
Figure 4-8. Reverse Windmilling (ISD Reverse Resync)

4.5.3.4 Direction Reversal

MCF8315C-Q1 can reverse the direction of fan rotation without applying brake or relying on motor inertia to coast down. This is a useful feature to smoothly change the fan direction as seen in Figure 4-9. The fan is decelerated at a controlled slew rate to prevent voltage spike on 24V rail (using the AVS feature) and upon reaching zero speed is accelerated to set speed in the forward direction.

Figure 4-9. Direction Reversal

4.5.3.5 Fan Acceleration/Deceleration

Figure 4-10 and Figure 4-11 show the acceleration and deceleration performance of MCF8315C-Q1 when changing fan speed from 100->30% and 30->100%. The acceleration rate is as set in the EEPROM while the deceleration rate is lower of the following two values - determined by AVS (to prevent voltage spike on 24V rail) and EEPROM configured value. During acceleration/deceleration, the maximum current limit is set by EEPROM configured value to prevent over current condition.
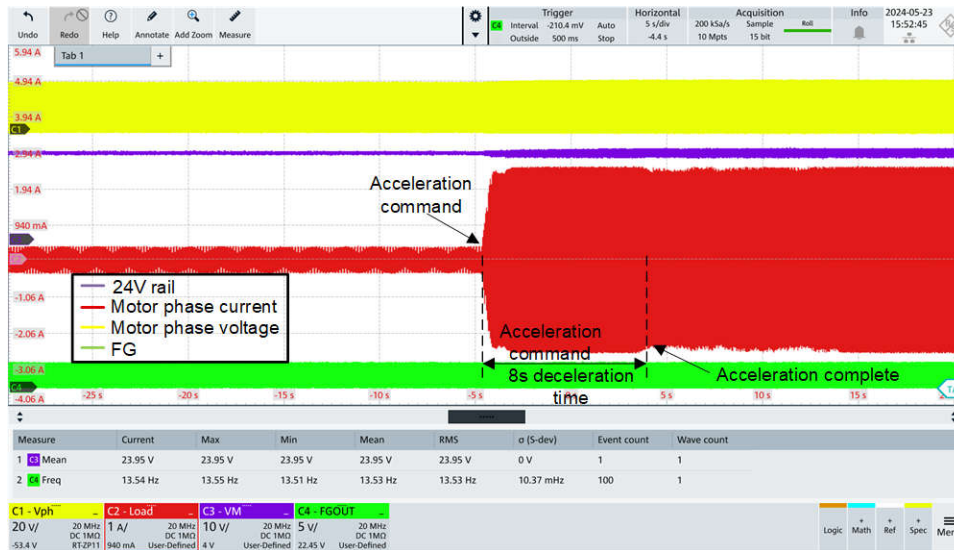
Figure 4-10. Acceleration
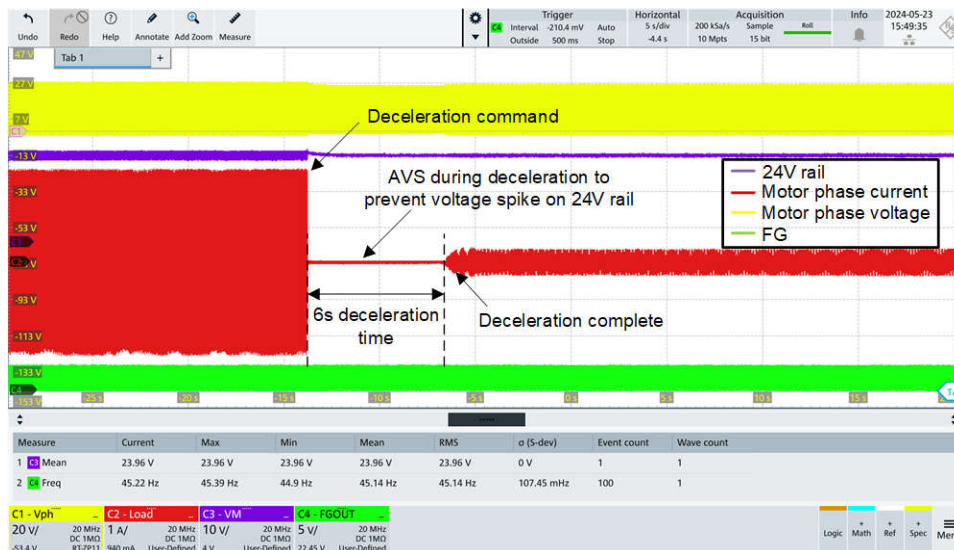
Figure 4-11. Deceleration

4.5.4 Thermal Performance

Figure 4-12 and Figure 4-13 shows the maximum case temperature of the key power dissipating components on TIDA-010951. The test conditions are – 25°C ambient, passive cooling, 230VAC RMS input, 1A motor phase currents. The thermal images were captured after 30 minutes of continuous operation at the aforementioned test conditions.
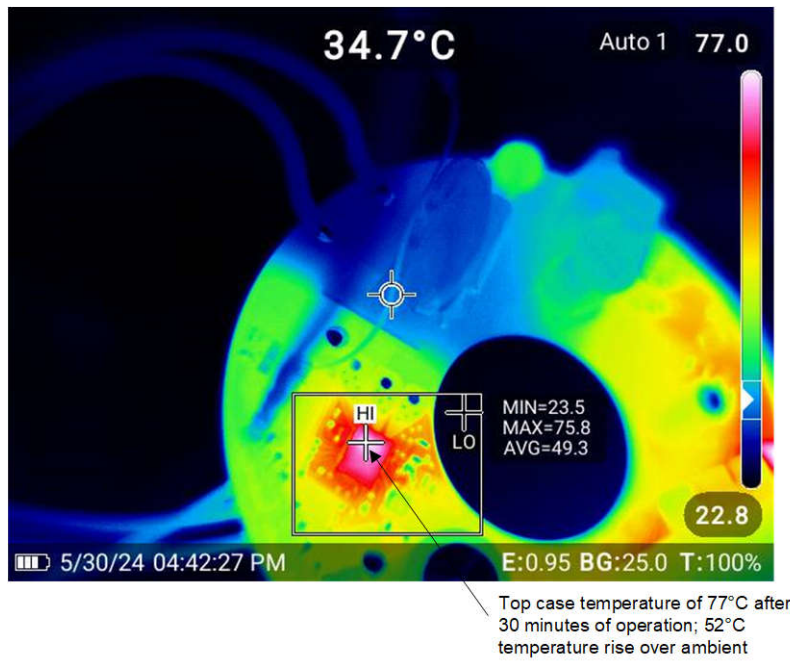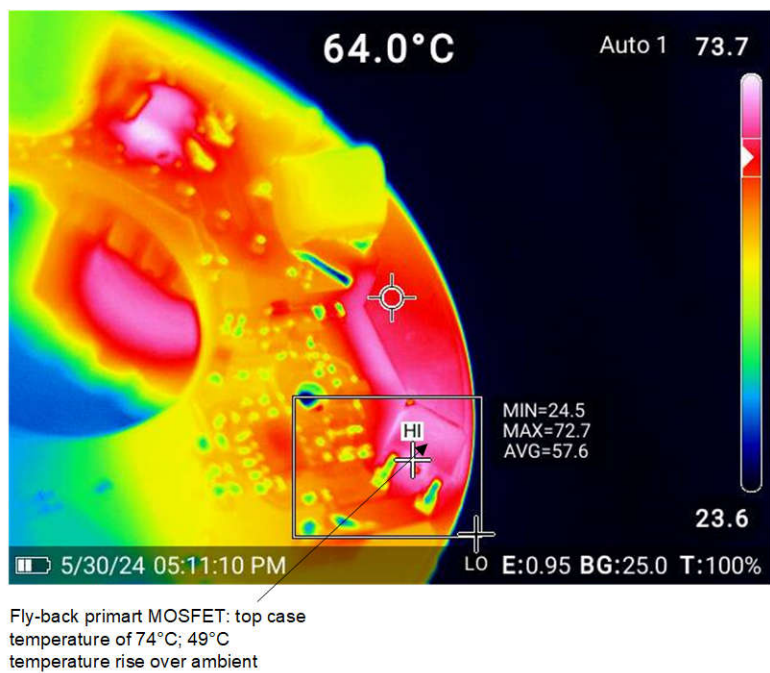
Figure 4-12. Thermal Performance of MCF8315C

Figure 4-13. Thermal Performance of Power Supply

5 Design and Documentation Support

5.1 Design Files

5.1.1 Schematics

To download the schematics, see the design files at TIDA-010951.

5.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDA-010951.

5.2 Tools and Software

Tools

MOTORSTUDIO	Motor Studio is an easy-to-use graphical user interface (GUI) that simplifies the tuning process of our brushless DC (BLDC) motor drivers to reduce device evaluation and product development time. The GUI allows users to quickly spin up their motors and optimize various stages of motor operation to achieve highest motor performance, stable motor start-up and minimal noise.
CCSTUDIO	Code Composer Studio is an integrated development environment (IDE) for TI's microcontrollers and processors. The IDE comprises a suite of tools used to develop and debug embedded applications. Code Composer Studio is available for download across Microsoft® Windows®, Linux® and macOS® desktops. The software can also be used in the cloud by visiting the TI developer zone.

5.3 Documentation Support

1. Texas Instruments, *MCF8315C 40V max, 4A peak, sensorless field-oriented control (FOC) three-phase BLDC motor driver* data sheet
2. Texas Instruments, UCC28810 *LED Lighting Power Controller* data sheet
3. Texas Instruments, *MSPM0C110x 24MHz Arm® Cortex®-M0+ MCU with 16KB flash, 1KB SRAM, 12-bit ADC* data sheet
4. Texas Instruments, *MSPM0L110x Mixed-Signal Microcontrollers* data sheet

5.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

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6 About the Author

JENSON FANG is a System Engineer in Texas Instruments where he is responsible for developing appliance systems related to Motor control and BMS design, and other appliances-related systems.

JOYCE GAO is a Field Application Engineer in China,support this hardware design while rotating in SEM Appliances team.

7 Recognition

The author recognizes the excellent contribution from **Roberto Scibilia** to the TIDA-010951 reference design for ACDC design. And also recognize **Robert Wedan**, **Sivabalan Mohan**, **Jinesh Todawat** support for this design test and prepare the guide.