Single-Axis Motor Control and PFC Kit Hardware

Reference Guide

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The Single-Axis Digital Motor Control (DMC) and Power Factor Correction (PFC) kit (TIDM-1AXISMTR-PFC-5X) provides an excellent way to learn and experiment with integrated analog and digital control of high-voltage motor inverter and PFC stage. This document includes the kit contents and hardware details and explains the functions and locations of jumpers and connectors on the board.

WARNING

This EVM is meant to be operated in a lab environment only and is not considered by TI to be a finished end-product fit for general consumer use.

This EVM must be used only by qualified engineers and technicians familiar with risks associated with handling high-voltage electrical and mechanical components, systems, and subsystems.

This equipment operates at voltages and currents that can cause in electrical shock, fire hazard, and/or injure you if not properly handled or applied. You must use the equipment with necessary caution and appropriate safeguards employed to avoid injuring yourself or your property.

You must confirm that the voltages and isolation requirements are identified and understood, before energizing the board and/or simulation. When energized, do not touch the EVM or components connected to the EVM.

You must use isolation transformers when connecting grounded equipment to the EVM.

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1 Getting Familiar With the Kit

1.1 Contents

A complete test bench kit consists of the following:

- High-voltage F2805x: Digital Motor + PFC control [R2.1]
- AC power cord (configured for your local country mains connection)
- Banana plug cords
- USB-B to A cable

The kit is available from the TI eStore.You can find the schematic and Gerber files for this PCB at the following path:

C:\TI\controlSUITE\development_kits\TIDM-1AXISMTR-PFC-5X_v1.0\1AxisMtrPfc5x_HWdevPkg\1AxisMtrPfc5x_R2.1

A single common flat heat sink is mounted underneath the board to dissipate heat from the inverter and PFC switches and provide structural robustness. The heat sink is isolated from power devices and is tied to the Earth pin of the AC receptacle onboard. When the AC receptacle is disconnected and powered from an external DC source, induced voltages can exist on the heat sink.

> **CAUTION**
>
> Do not touch the heat sink or other parts of the kit while operating.
>
> This equipment operates at voltages and currents that can cause in electrical shock, fire hazard, and/or injure you if not properly handled or applied.

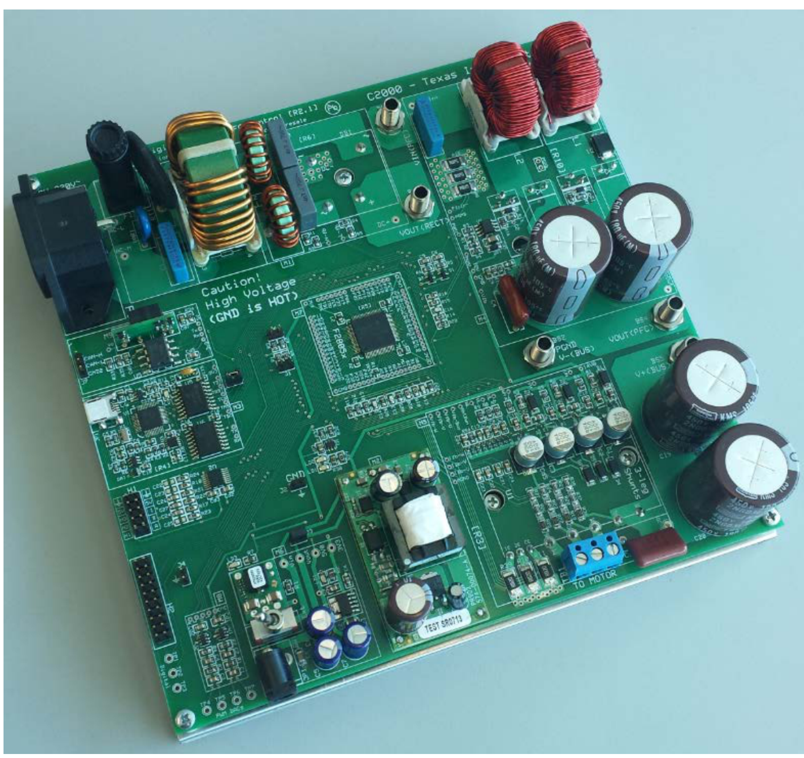

Figure 1. Kit Assembly

1.2 Features

The kit has the following features:

- A **3-phase inverter stage** to control high-voltage motors:
  - 350-V DC maximum input voltage
  - 1-KW maximum load
  - Sensorless and sensored field oriented control of ACI motor
  - Sensorless and sensored field oriented control of PMSM motor
  - Sensorless and sensored trapezoidal control of BLDC motor
  - QEP and CAP inputs available for speed and position measurement
  - Low-side current sensing using on-chip programmable gain amplifier (PGA) with F2805x
- **Power factor correction** stage, rated for 600 W [(1)], to improve the power factor of the input AC current and regulating the DC bus for the inverter:
  - Two-phase interleaved topology
  - 100 V to 132 V AC / 170 V to 250 V AC rectified input
  - 400-V DC maximum output voltage
  - 600-W maximum power rating
  - Up to 96% efficiency
  - 100-kHz switching frequency
  - Up to 100-kHz PFC control loop frequency
  - Uses the TI UCC27524, high-speed, dual-MOSFET drivers
- An **AC rectifier** stage, rated to deliver up to 750 W, to generate the DC bus voltage for the inverter directly or provide input for the PFC stage on the board:
  - 100 V to 132 V AC / 170 V to 250 V AC input
  - 750-W maximum power rating
- An **auxiliary power supply module** (400 V to 15 V, and 5-V module) that can generate 15 V and 5 V DC from the DC link voltage to the inverter (input maximum voltage 400 V).
- An **isolated CAN interface** to communicate over the CAN bus. The CAN interface is isolated from the high voltages using a TI ISO1050 isolated CAN transceiver with 4000-V Vpeak isolation and a TI DCH01 series, miniature 1-W, 3-kV isolated, DC-DC converter.
- **Onboard isolated JTAG emulation**
- An **isolated UART** through the SCI peripheral and the FTDI chip
- **Four PWM DACs** generated by low-pass filtering the PWM signals to help you observe the system variables on an oscilloscope and easily debug control algorithms.
- **Overcurrent protection** for the inverter stage and PWM trip zone protection for IPM faults
- **Overvoltage protection** for the PFC output voltage
- A **hardware developer’s package** that includes schematics and bill of materials is available through controlSUITE™

(1) The power rating tests for the power stages were performed at room temperature.

2 Hardware Overview

Figure 2 shows an overview of a typical motor drive system running from AC power. The PFC stage enables wave shaping of the input AC current. The TIDM-1AXISMTR-PFC-5X kit has the power and control blocks of a typical motor drive system (see Figure 4).

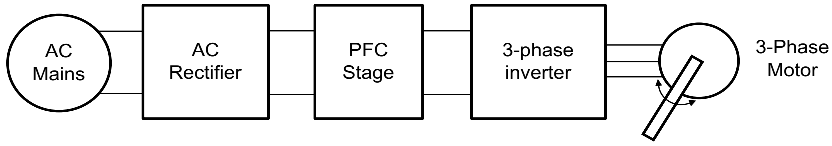

Figure 2. Block Diagram for a Typical Motor Drive System Using PFC

2.1 Macro Blocks

The motor control board has functional groups that enable a complete motor drive system. These groups are macro blocks.

Nomenclature: The following list refers to each component on the board with a macro number in the brackets followed by a dash and a reference number. [M3]-J1 refers to the jumper J1 in the macro M3. [Main]-J1 refers to the J1 on the board outside of the defined macro blocks.

The following is a list of the macro blocks on the board and their functions:

- [Main] – This block includes jumpers, communications (isoCAN), instrumentation (DACs), QEP and CAP connections, and voltage translation.
- [M1] – This block is an AC power entry that takes AC power from the wall/mains power supply and rectifies it. This power can be an input of the PFC stage or can generate the DC bus for the inverter directly.
- [M2] – This block is the auxiliary power supply, a 400 V to 15 V and 5-V module, that generates 15 V and 5 V for the board from the DC bus connected to inverter.
- [M3] – This block includes Isolated USB emulation that provides a isolated JTAG connection to the controller and can be an isolated SCI when JTAG is unneeded.
- [M4] – This block is a two-phase interleaved PFC stage.
- [M5] – This block is a three-phase inverter that enables control of high voltage three-phase motors.
- [M6] - This DC-power entry generates 15 V, 5 V, and 3.3 V for the board from DC power through the DC-jack using the power supply shipped with the board.
- [M7] – This block is a F2805x CPU.
- [M8] – This block contains the PWMDACs.

Figure 3 shows the position of these macro blocks on the board. The macro block approach for different power stages lets you easily debug and test one stage at a time. You can use banana jack connectors to connect the power line of these power stages and blocks to construct a complete system. The PWMs and ADC signals, which are the actuation and sense signals, have test points on the board that make it easy to try out algorithms and strategies.

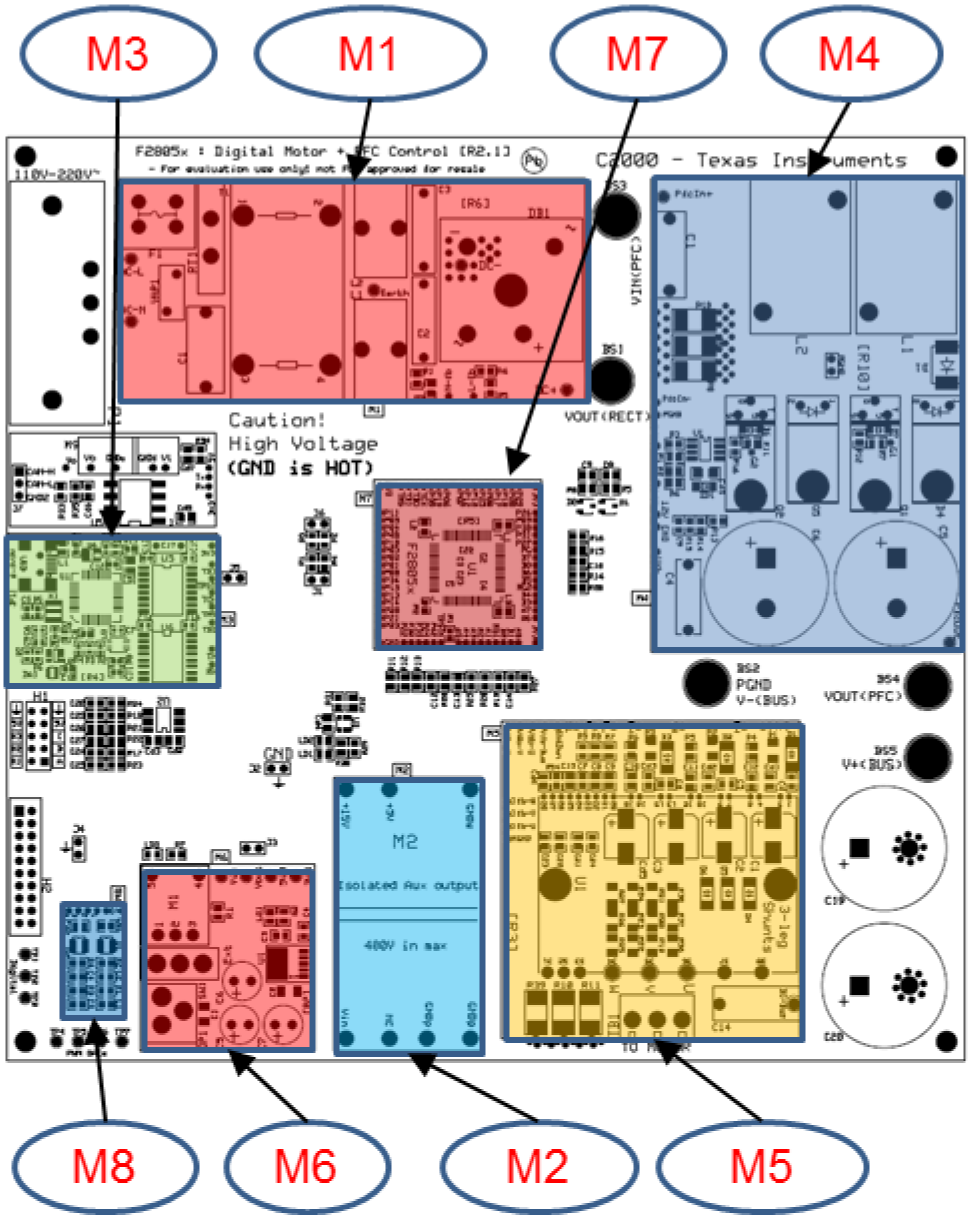

Figure 3. The Layout of 1AXISMTR-PFC-5X Board

- [Main] – The controlCARD connection, jumper configurations, and trip zones
- [M1] – The AC power entry
- [M2] – The auxiliary power supply, 400 V to 5 V and 15 V
- [M3] – The isolated USB emulation
- [M4] – The 2-phase interleaved PFC stage
- [M5] – The 3-phase inverter
- [M6] – The DC-power entry
- [M7] – The CPU F2805x
- [M8] – The PWMDACs

2.2 Powering the Board

The board has the following power domains [2]:

- The low-voltage controller power domain powers the microcontroller and the logic circuit on the board.
- The high-voltage domain that contains the DC bus connecting the PFC and inverter.

WARNING

Use caution to avoid electrocuting yourself when using EVM electronics with high voltages.

The controller power supply creates the 15 V, 5 V, and 3.3 V that powers the MCU, logic, and sensing circuits on the board.

The following sources provide power to the power supply:

- An external isolated 15-V / 1-A DC-power supply can be connected to the DC-power entry macro [M6] through the DC jack ([M6]-JP1)
- The auxiliary power supply module [M2] can generate 15-V and 5-V DC from the DC-link voltage that supplies the inverter.

The DC bus power is the high-voltage line that supplies voltage to the inverter stage to generate 3-phase AC to control the motor. [Main]-BS5 and [Main]-BS2 are the power and ground connectors, respectively, for this inverter bus.

Use one of the following sources to power the power supply

- An external isolated variable DC power supply that TI recommends for all experiments (maximum 350 V)
- An isolated variable AC-power supply
- AC Main ([Mains]-P1, 110-V or 220-V AC power supply) (TI recommends using a variac [variable AC transformer] and isolator with this power source.)

For more information, see the hardware configuration section of the *Single-Axis Motor Control and PFC Kit User's Guide* (SPRUI27).

NOTE: Because the 3-phase induction motors are typically rated at 220-V AC, the 320-V DC-bus voltage is needed. When using 110-V AC power source to generate the DC bus for the inverter, the motor can run as intended only under half the speed range without saturating the PI regulators in the control loop.

You can run the PFC as boost converter to increase the DC bus voltage or connect an external DC-power supply.

2.3 Ground Levels and Safety

TI recommends taking the following precautions when using the board:

- Do not touch any part of the board or components connected to the board when the board is energized.
- Use the AC Mains/wall power supply to power the kit.
- Use caution when connecting scopes and other test equipment to the board because the AC rectifier generates the DC-output voltage, which has a HOT ground floating from the protective earth ground.
- Do not touch any part of the board, the kit or its assembly when energized. (Though the IPM heat sink is isolated from the board, high-voltage switching generates some capacitive coupled voltages over the heat sink body. If the earth line breaks, the heat sink may be hot.)

[2] The ground planes of the power domains are the same.

- Ensure you understand and comply with the individual ratings of the power stages on the board (for example, the voltage, current, and power levels) before you connect these power blocks together and energize the board and/or simulation.

3 Hardware Resource Mapping

The Figure 4 shows the various stages of the board in a block diagram format and illustrates the major connections and feedback values being mapped to F2805x MCU. Table 1 lists these resources.

Table 1. PWM and ADC Resource Allocation

Macro Name	Macro Signal Name	PWM Channel/ADC Channel No Mapping	Function
Three-Phase Inverter	PWM-1L	PWM-1A	Inverter drive PWM
	PWM1-H	PWM-1B	Inverter drive PWM
	PWM2-L	PWM-2A	Inverter drive PWM
	PWM2-H	PWM-2B	Inverter drive PWM
	PWM3-L	PWM-3A	Inverter drive PWM
	PWM3-H	PWM-3B	Inverter drive PWM
	Ifb-U	ADC-B1	Low-side U-phase current sense
	Ifb-V	ADC-A1	Low-side V-phase current sense
	Ifb-W	ADC-A3	Low-side W-phase current sense
	Vfb-Bus	ADC-A7	DC-bus voltage sense
	Vfb-U	ADC-A2	U-phase voltage sense
	Vfb-V	ADC-A4	V-phase voltage sense
	Vfb-W	ADC-A5	W-phase voltage sense
Two-Phase PFC	PWM-1	PWM-5A	PFC phase 1 drive PWM
	PWM-2	PWM-5B	PFC phase 2 drive PWM
	Ipfc	ADC-B7	Return current sense
	Vpfc	ADC-A7	PFC output voltage sense
	L-fb	ADC-B5	Line voltage sense
	N-fb	ADC-B0	Neutral voltage sense
Main Board	DAC-1	PWM-6A	Driving DAC signal
	DAC-2	PWM-6B	Driving DAC signal
	DAC-3	PWM-4A	Driving DAC signal
	DAC-4	PWM-4B	Driving DAC signal

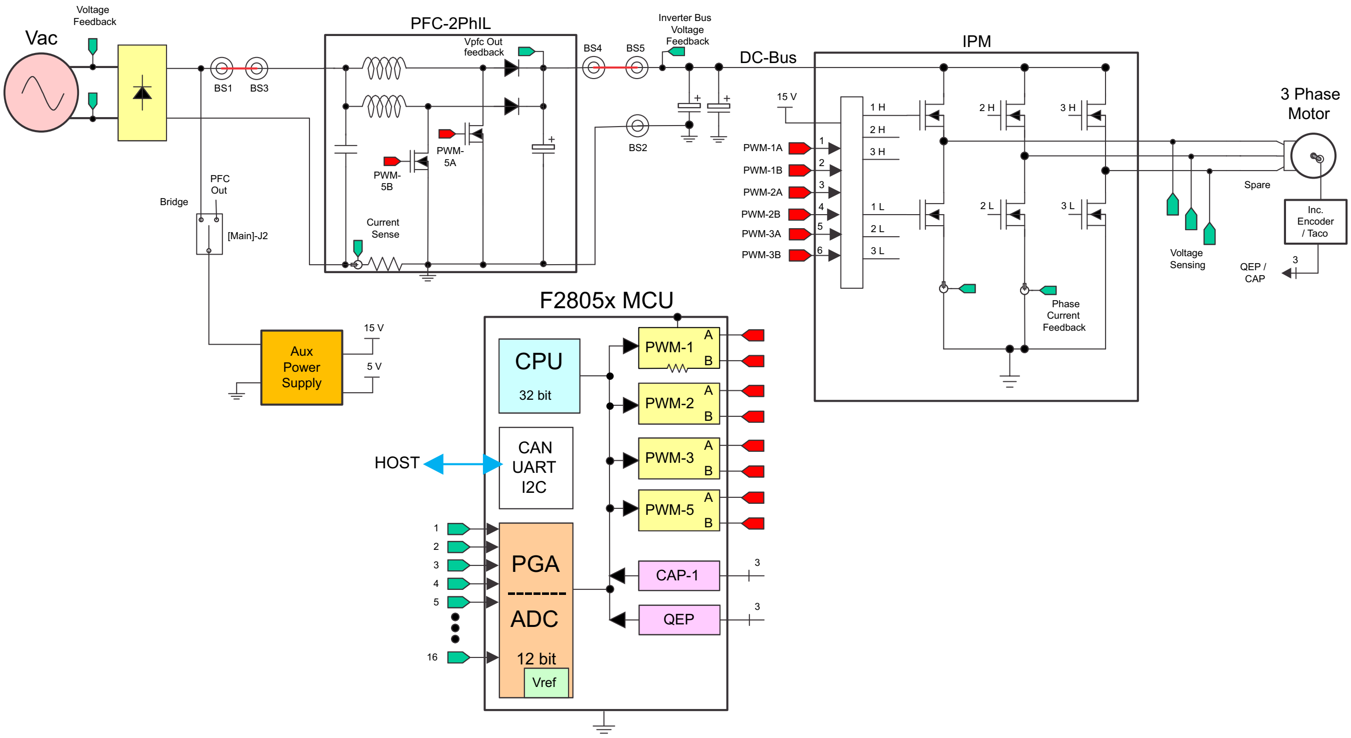

Figure 4. Single Axis Motor + PFC Board Diagram With F2805x

3.1 Jumpers and Connectors

Table 2 lists the connections available on the board and ordered by the macro. Figure 5 shows these connections on the board.

Table 2. Jumpers and Connectors

[Main] P1	AC input connector (110-V to 220-V AC)
[Main]-TB1	Terminal block to connect motor
[Main]-BS1	Banana jack for output from AC rectifier
[Main]-BS2	Banana jack for GND connection
[Main]-BS3	Banana jack for connecting an input voltage for the PFC stage; this would typically be rectified AC voltage from the [Main]-BS1 connector.
[Main]-BS4	Banana jack for connecting a load to the output from the PFC stage. When using PFC+Motor project, the PFC output feeds the inverter input. ([Main]-BS5)
[Main]-BS5	Banana jack for input of DC bus voltage for the inverter
[Main] J3	Jumper J3 sources 15 V to the DC power entry macro M6 from the auxiliary power supply macro M2.
[Main] J5	This jumper connects and disconnects JTAG TRSTn. When populated, this jumper enables JTAG connection to MCU. If no JTAG connection is required, leave the jumper unpopulated like when booting from flash.
[Main]- TP1-TP3	General-purpose digital input or output for debug purposes
[Main]- TP4-TP7	General-purpose analog outputs (PWMDAC) for debugging that give voltage outputs from a PWM attached to a first-order, low-pass filter. Pins 1, 2, 3, and 4 are attached to low-pass filtered PWM-4A, PWM-4B, PWM-6A, and PWM-6B, respectively. These pins observe system variables on an oscilloscope with the PWMDAC DMC library components.
[Main]-J7	An isolated CAN bus connector
[Main]-H1	A QEP connector that connects with a 0-V to 5-V QEP sensor to gather information on a speed and position of the motor.
	CAP/Hall effect sensor connector: connects with a 0-V to 5-V sensor to gather information on the speed and position of a motor.
[Main]-H2	General-purpose 20-pin header with SPI and I2C signals for extension
[M1]-F1	Fuse for the AC input
[M3]-JP1	USB connection for onboard emulation

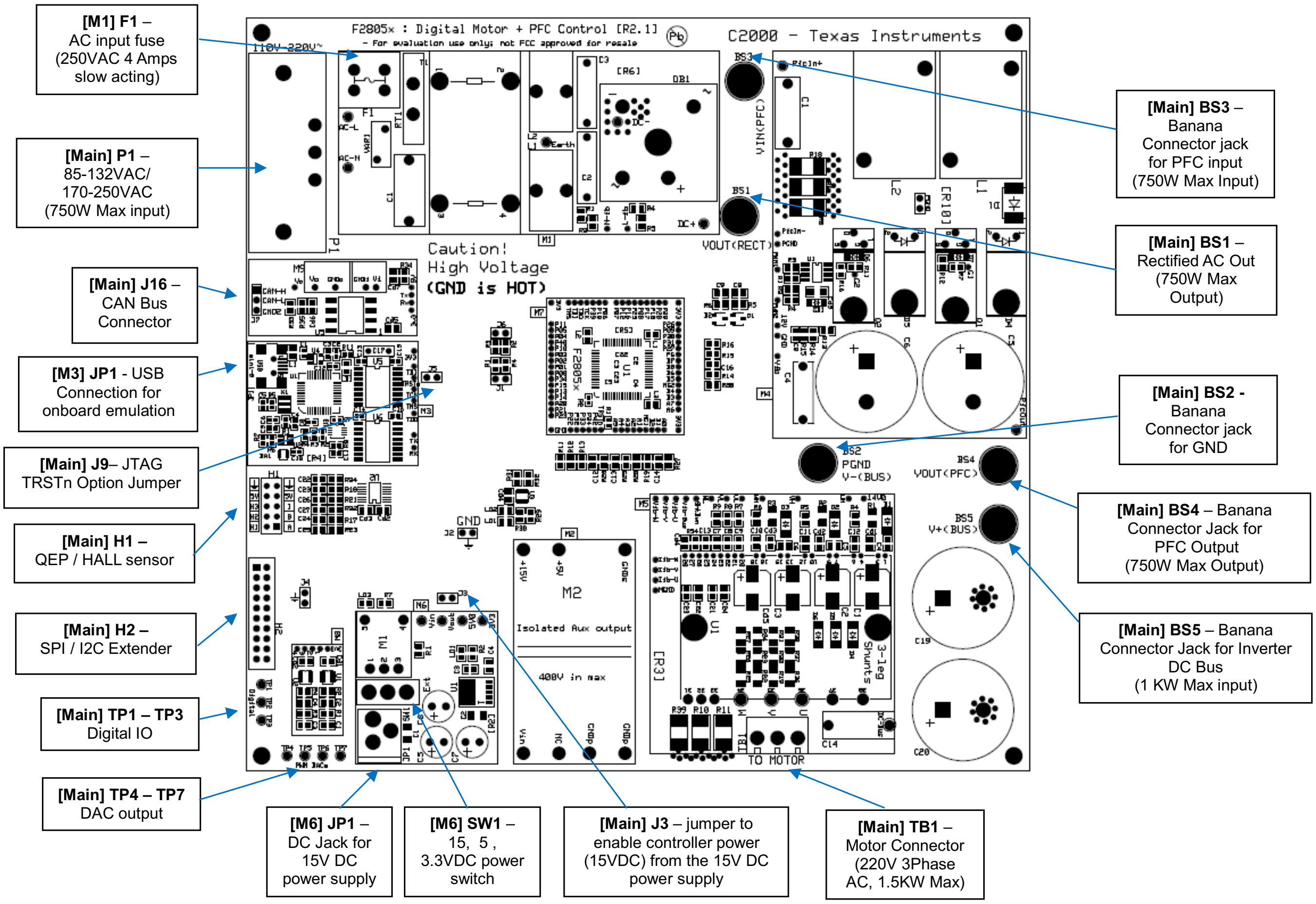

Figure 5. PCB Layout Diagram of the 1AXISMTR-PFC-5X Board

WARNING

TI provides the high-voltage DMC and PFC kit schematic drawings to help users develop C2000 based reference design products. Application safety, safety of the high-voltage DMC and PFC kit and design integrity of such reference designs are solely responsibility of the user. Any reference designs generated off these schematics must take into account necessary product safety design requirements, including interface components and load motors in order to avoid user risks including potential for fire hazard, electrical shock hazard and personal injury, including considerations for anticipated agency certification compliance requirements.

Such product safety design criteria shall include, but not be limited to, critical circuit creepages and clearances, component selection, ratings compatibility of controlled motor loads, and required protective means (that is, output fusing) depending on the specific loads being controlled.

TI accepts no responsibility for design integrity of any reference designs based on supplied schematic drawings and the schematics are strictly for development purposes.

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