# EVM User's Guide: BP-AM2BLDCSERVO AM2x BLDC Servo Motor BoosterPack (BP-AM2BLDCSERVO)

### Description

The AM2x BLDC Servo Motor BoosterPack (BP-AM2BLDCSERVO) is an add-on for the Sitara AM2x MCU LaunchPad development boards which provides a networked, industrial BLDC servo development platform. Compatible with the AM243x (LP-AM243) and the (AM263x) LP-AM263 LaunchPad development boards, this BoosterPack provides up to two axes BLDC 3-phase motor drive, in-phase current feedback, Sigma-Delta current feedback, industrial absolute encoder, and a single axis of resolver feedback.

The attached AM2x LaunchPad natively provide an array of industrial Ethernet, CAN, UART, LIN and other connectivity and control peripherals of the AM2x MCU. Together this LaunchPad and BoosterPack system provide a complete platform for prototyping networked, industrial BLDC servo drives.

### **Get Started**

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features easy-to-use training modules that range from the basics of getting started to advanced development

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### Features

topics.

- BOOST-XL TI BoosterPack Design 80 digital/ analog I/O compatible with AM2x LaunchPad Development Kits
- Two axes of 3-phase BLDC motor drive with the DRV8316R 24 V/8A monolithic gate drive and amplifier bridges
- Two axes (6 channels) of 3-phase current feedback through AMC1035D Sigma-Delta modulator and INA241A current sense path
- Two axes of RS-485 based absolute encoder feedback supporting multiple industrial encoder standards
- Single-axis of resolver feedback

### Applications

- Servo drive communication module
- Servo drive control module
- Servo drive position feedback
- Servo drive position sensor
- Servo drive power stage module



LP-AM243 LaunchPad Attached to BP-AM2BLDCSERVO BoosterPack

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## **1 Evaluation Module Overview**

### **1.1 Introduction**

The BP-AM2BLDCSERVO BoosterPack kit, when attached to a compatible AM2x MCU LaunchPad MCU board, provides an industrial BLDC servo drive development platform.

A reference software/hardware solution based on the AM243x (ALX) 2-axis servo reference system is shown in the figure below. Together the BP-AM2BLDCSERVO and the LP-AM243 LaunchPad can be used to experiment with this and similar networked industrial servo drive architectures.



Figure 1-1. AM243x Based BLDC Motor Drive - 2-Axis BLDC Servo Scenario

By using the AM2x dual-R5F cores along with the Programmable Real-time Unit (PRU) cores, the AM2x MCU are able to create a flexible hardware and software architecture. This supports a wide range of industrial real-time Ethernet standards and industrial absolute encoder standards while also taking care of the core control loop and monitoring tasks.

### 1.2 Kit Contents

The only item that comes with this kit is the BP-AM2BLDCSERVO PCB assembly itself.

Additional required components, per motor axis (not included in this kit):

- 24 V (nominal), 8A (max) bench DC supply
- 3-Phase, BLDC motors maximum 8A (RMS) current draw
- Absolute position encoders running on EnDat22, HDSL, or Tamagawa protocols

If you have any feedback or questions, support for the Sitara MCU and this BP-AM2BLDCSERVO kit is provided by the TI Product Information Center (PIC) and the TI E2E<sup>™</sup> Forum. Contact information for the PIC can be found on the TI website. Additional device-specific information can be found in the Section 5.

### **1.3 Specification**

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The BP-AM2BLDCSERVO is divided up into axis-1 and axis-2 component channels with a few common system components. All motor control I/O from the attached MCU are passed through the BoosterPack headers. Screw terminals are used to provide a quick attachment point for bench DC power and attaching BLDC motor drive output.

Axis-1 and axis-2 channels both include a DRV8316 BLDC 3-phase motor driver, RS-485 transceiver set for 2-wire and 4-wire absolute encoder communication, and AMC1035D based Sigma-Delta current feedback channels for each 3-phase motor driver output.

Additionally, axis-1 includes direct INA241A current sense amplifier feedback channels for MCU ADC sampling and a resolver excitation and receiver amplifier network.

The encoder RS-485 transceivers and resolver amplifier I/O are routed to Dsub15 female connectors and optional 100-mil pitch headers that are routed in line with minimal distance between them. This gives a standard connector interface as well as the flexible prototyping headers to account for different encoder and resolver pinouts.



Figure 1-2. BP-AM2BLDCSERVO System Block Diagram

### **1.4 Device Information**

This BoosterPack is part of the LaunchPad development kit ecosysem for Sitara<sup>™</sup> Microcontrollers Family of Arm<sup>®</sup> Cortex<sup>®</sup>-R based high performance microcontrollers. With advanced networking, real-time control, and signal processing accelerators these MCU meet the emerging and dynamic requirements for industrial and automotive applications.

This BoosterPack is intended to operate with the Sitara Microcontrollers - LaunchPad Evaluation Modules. TI provides device-specific Evaluation Module (EVM) designs to help kick-start product development. See the AM263x LaunchPad and AM243x LaunchPad for more information.

The following list highlights the primary devices used in the design of this BoosterPack evaluation kit.

- DRV8316: 40-V max 8-A peak 3-phase motor driver with integrated current sensing. This device is used to provide the MCU with a motor drive bridge network to drive the attached 3-phase BLDC motors.
- INA241A: -5-V to 110-V bidirectional ultraprecise current sense amplifier with enhanced PWM rejection. An
  array of INA241A are used as the shunt current sense amplifier to provide 3-phase current feedback from the
  DRV8316 motor driver.



- AMC1035: Precision delta-sigma modulator with ±1-V bipolar input and 2.5-V reference output. An array of AMC1035 are used to provide a Sigma-Delta digital modulation for the current sense feedback.
- LMK1C1108: 8-channel output LVCMOS 1.8-V buffer. Used to distribute Sigma-Delta clocks from the attached MCU to the array of AMC1035 modulators.
- THVD1450D: 3.3-V to 5-V RS-485 transceiver with ±18-kV IEC ESD protection. Multiple THVD1450 are used to provide RS-485 transceiver and line-driver capability for the 3.3V MCU absolute encoder interfaces.
- LM74502: 3.2-V to 65-V industrial RPP controller with load disconnect and OVP. These devices are used to provide over-voltage and reverse-polarity protection to the motor and encoder distribution network.

Many other devices were used in the construction of this evaluation kit as well. Please see the BP-AM2BLDCSERVO Board Design Files for details.

### 1.5 Important Usage Notes

#### Thermal Warning

Note

The BP-AM2BLDCSERVO includes two motor driver amplifier devices, U6 and U7 (Texas Instruments Part Number DRV8316RRGFR) which can exceed 55 C case temperature during normal operation. The following additional PCB silkscreen and this user's guide statement has been added to alert users to these higher temperature components.



#### Mechanical Warning

Note

This kit assembly does not include any mechanical components. However, normal usage of this assembly requires attaching motors, encoders and resolvers to compatible terminals and connectors of the board.



TI has not performed specific safety assessments on motor, encoder or resolver components that is used with this kit. Users of this kit are advised to follow all usage, maintenance and safety recommendations provided by the selected accessory component manufacturers. Caution must observed in the usage of all accessory components.

#### Power Supply Usage

**Note** The BP-AM2BLDCSERVO requires up to two external power supplies to function. No power supplies, cables or adapters are included in this kit.



#### Note

**External Power Supply Requirements:** 

- J5 and J6 terminal blocks (Phoenix Contact Part Number 1711725) are used as power input
- J5 and J6 terminal blocks accept 12-30 AWG wire. Multistranded 16 AWG, or larger diameter, recommended.
- Input voltage: 9-24 Volts (nominal), 36 Volts (max)
- Max input current: 8 Amps

#### Note

TI recommends using an external power supply or accessory which complies with applicable regional safety standards such as (by example) UL, CSA, VDE, CCC, PSE.



## 2 Hardware

### 2.1 Assembly Instructions

The following assembly steps must be followed when starting with a new BP-AM2BLDCSERVO BoosterPack and a new LP-AM2x LaunchPad.

- 1. BP-AM2BLDCSERVO and LP-AM2x LaunchPad are both powered down.
- 2. BP-AM2BLDCSERVO and LP-AM2x LaunchPad can be attached through their LaunchPad connectors.
- 3. Attach LP-AM2x LaunchPad power and debugging cable (if necessary) and keep LaunchPad unpowered.
- 4. Attach 24 V DC supply (current limit to 8A) to the BoosterPack screw terminals and keep supply powered off.
- 5. Attach motor drive output to the BoosterPack screw terminals.
- 6. Attach encoder power/data cable/wires to the BoosterPack Dsub15 connectors or 100-mil pitch headers.
- 7. Attach resolver power/data cable/wires to the BoosterPack Dsub15 connectors or 100-mil pitch headers.
- 8. Verify that all motor and encoder shafts are free and clear of obstructions prior to powering on and testing system.



Figure 2-1. LP-AM243 mated to BP-AM2BLDCSERVO

### 2.2 Power Requirements

After assembly, the following power-on and power-off sequence must be followed when working with the BP-AM2BLDCSERVO kit.

The LP-AM2x 5.0V and 3.3V BoosterPack pins provide system-level 5.0V and 3.3V power for the attached BP-AM2BLDCSERVO kit, including indicator LED power and various logic-default pull-up resistor voltages.

### **Power-On Sequence**

Follow the steps below to power on the device:

- 1. Power on the LP-AM2x LaunchPad.
- 2. Power on the 24 V DC supply for the BoosterPack.
- 3. Load and run LP-AM2x LaunchPad application over attached XDS110 debugger and Code-Composer Studio debug session.

### **Power-Off Sequence**

Follow the steps below to power off the device:

- 1. Power-off the 24V DC supply for the BoosterPack.
- 2. Power-off the LP-AM2x LaunchPad.



### 2.3 Interfaces

#### **Major Components and Location**

The below figures show the location of major connectors, components and circuit functions used on this design. BP-AM2BLDCSERVO Top View, Major Component Areas and Connectors Highlighted



Figure 2-2. BP-AM2BLDCSERVO Top View, Major Component Areas and Connectors Highlighted

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Figure 2-3. BP-AM2BLDCSERVO Bottom View, Major Component Areas and Connectors Highlighted



Figure 2-4. BP-AM2BLDCSERVO Top View - Connectors and Cables Overview

### **Typical Usage**

A typical setup for an axis-1, BLDC motor control scenario is shown below. The bench power, motor drive output and absolute encoder cables are shown attached. The attached LP-AM243 is shown with USB-C power and XDS110 debugger cable also attached.





# Figure 2-5. BP-AM2BLDCSERVO and LP-AM243 LaunchPad - Axis-1 Power, Motor and Encoder cables attached

### 2.4 LaunchPad Specific Features

Based on available LaunchPad I/O pinout, and specific MCU peripheral availability, each AM2x LaunchPad supports a subset of the overall available features made available by this BP-AM2BLDCSERVO BoosterPack.

Additionally, only a subset of available hardware features have been fully incorporated into the AM243 and AM263 MCU SDK or made available through demo application through dev.ti.com. These supported, unsupported and future features are outlined in the tables below. These tables are updated a new features are tested and made available.

Feature	AM243x LaunchPad LP-AM243 Rev E3	AM243x LaunchPad LP-AM243 Rev A
Axis-1 BLDC Driver	Yes	Yes
Axis-2 BLDC Driver	No	Yes
Axis-1 SDFM Current Feedback	Yes	Yes
Axis-2 SDFM Current Feedback	No	Yes
Axis-1 Current Feedback	No	No
Axis-2 Current Feedback	No	No
Axis-1 Absolute Position Encoder	Yes	Yes
Axis-2 Absolute Position Encoder	No	Yes
Axis-1 Resolver Position	No	No

#### Table 2-1. Currently Supported Features

The below table captures the planned features as testing, MCU SDK development and demo application work continue with this kit.

#### Table 2-2. Planned/Future Features

Feature	AM263x LaunchPad LP-AM263 Rev E2	AM263x LaunchPad LP-AM263 Rev A
Axis-1 BLDC Driver	Yes	Yes
Axis-2 BLDC Driver	No	Yes
Axis-1 SDFM Current Feedback	Yes	Yes
Axis-2 SDFM Current Feedback	No	Yes
Axis-1 Current Feedback	No	No
Axis-2 Current Feedback	No	No
Axis-1 Absolute Position Encoder	Yes	Yes



Table 2-2. Planned/Future Features (continued)

Feature	AM263x LaunchPad LP-AM263 Rev E2	AM263x LaunchPad LP-AM263 Rev A
Axis-2 Absolute Position Encoder	No	Yes
Axis-1 Resolver Position	No	No

### 2.5 Jumper Information

This section describes the jumper selectable options on this board. See table and figures below for list of available jumper options, details and configuration defaults. Additional jumper details are located in each the major

### Note

These static jumper configurations must be checked and set prior to running different motor control scenarios.



Figure 2-6. Layout Top View - Jumper Locations

Axis	Jumper	Function	Default LP-AM243x Configuration	Default LP-AM263x Configuration
Both	J11	VSENSE/ISENSE Select Jumper pins 1-2 shorted: Select Axis-1, Phase-A INA241 current sense output routed to BoosterPack J15.24 Jumper pins 2-3 shorted: Select Axis-2 DRV8316 VSENSE Phase-A Output routed to BoosterPack J15.24	Jumper installed across pins 2-3 Routes optional motor VSENSE into GPADC input	Jumper installed across pins 1-2 Routes required motor ISENSE into SAR ADC input
	J13	VSENSE/ISENSE Select Jumper pins 1-2 shorted: Select Axis-1, Phase-B INA241 current sense output routed to BoosterPack J15.24 Jumper pins 2-3 shorted: Select Axis-2 DRV8316 VSENSE Phase-B Output routed to BoosterPack J15.24	Jumper installed across pins 2-3 Routes optional motor VSENSE into GPADC input	Jumper installed across pins 1-2 Routes required motor ISENSE into SAR ADC input
	J26	VSENSE/ISENSE Select Jumper pins 1-2 shorted: Select Axis-1, Phase-C INA241 current sense output routed to BoosterPack J15.24 Jumper pins 2-3 shorted: Select Axis-2 DRV8316 VSENSE Phase-C Output routed to BoosterPack J15.24	Jumper installed across pins 2-3 Routes optional motor VSENSE into GPADC input	Jumper installed across pins 1-2 Routes required motor ISENSE into SAR ADC input
	J17	SDFM Clock Feedback Select Jumper pins 1-2 shorted: Jumper pins 2-3 shorted: asdad		Jumper Uninstalled Function not used
	J27/J28	Encoder/SDFM MUX Select J27/J28 uninstalled: selects AM243x SDFM and Encoder Paths J27/J28 installed: selects AM263x SDFM and Encoder Paths	J27 uninstalled	J27 Installed
Axis-1	J18/J19	Encoder/Resolver Voltage Select J18 installed: sets VSENSOR1 to 12 V J19 installed: sets VSENSOR1 to 5.0V Note: only one jumper must be installed at a time during operation.	J19 Installed This defaults VSENSOR1 to 5.0V compatible with most absolute encoders.	J19 Installed This defaults VSENSOR1 to 5.0V compatible with most absolute encoders.
	J22	SDFM Manchester Encoding Select Uninstalled: Manchester encoding disabled Installed: Manchester encoding enabled	J22 uninstalled	J22 uninstalled
	J24	RS485 Absolute Encoder 2-Wire/4-Wire MUX Select Uninstalled: RS-484 4-Wire Path Selected Installed: RS-485 2-Wire Path Selected	J24 uninstalled Compatible with Heidenhain EnDat22 Encoders	J24 uninstalled Compatible with Heidenhain EnDat22 Encoders

#### Table 2-3. Jumper Configuration Options



Table 2-0: Vamper Configuration Options (continued)				
Axis	Jumper	Function	Default LP-AM243x	Default LP-AM263x
			Configuration	Configuration
Axis-2	J20/J21	Encoder/Resolver Voltage Select	J21 Installed	J21 Installed
		J20 installed: sets VSENSOR2 to 12	This defaults VSENSOR2 to	This defaults VSENSOR2 to
		V	5.0V compatible with most	5.0V compatible with most
		J21 installed: sets VSENSOR2 to	absolute encoders.	absolute encoders.
		5.0V		
		Note: only one jumper must be		
		installed at a time during operation.		

#### Table 2-3. Jumper Configuration Options (continued)

#### AM243x/AM263x ISENSE/VSENSE Select

The below diagrams describe the select path used to choose between Axis-1 in-phase current sense and Axis-2 voltage sense into a set of LaunchPad ADC channels. The Axis-1 in-phase current sense path is only usable with the AM263x LaunchPad SAR ADC channels.



Figure 2-7. Axis-1 ISENSE/VSENSE Select - Jumper J11, J13, and J26 Configuration











### **VSENSE/ISENSE Select**

### Figure 2-8. Axis-1 ISENSE/VSENSE Select - Layout/Schematic Excerpt for Jumper J11, J13, and J26

### AM243x/AM263x PRU Encoder/Sigma-Delta MUX

The below diagrams describe the MUX path used to de-MUX and MUX a set of overlapping but conflicting pins to the AM2x MCU AM243x and AM263x LaunchPad. Select lines for these MUX paths are either jumper selectable.





#### **PRU Sigma-Delta Modulator Clock Path Select**

The below diagrams describe the select path used to choose between the different PRU Sigma-Delta Modulator (SDFM) feedback clocks. The SYNC0 and SYNC1 paths from the PRU are used to generate two different clocks that can be used for both clocking data out of the attached SDFM AM1035 transceivers as well as clocking data into the AM2x MCU.



Figure 2-10. PRU Sigma-Delta Modulator Clock Path Select – J17



Pins 1-2 Shorted





Figure 2-11. BP-AM2BLDCSERVO Layout - Layout/Schematic Excerpt for PRU SDFM Clock Path Select – J17

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### 2.6 Mechanical

The following tables and figures present the overall mechanical dimensions, BoosterPack connector relative placement and mounting hole dimensions and locations. For further mechanical detail please refer to the board design file package where STEP 3D model files have been provided. This STEP model was exported from the source Altium Designer CAD package.

Table 2-4. BP-AM2BLDCSERVO PCB Assembly Dimensions				
Dimension	Value	Unit		
Overall Width	8000	Mils		
Overall Depth	4300	Mils		
Overall Height	1190.90	Mils		
Mount Hole Diameter	144.0	Mils		



Figure 2-12. BP-AM2BLDCSERVO PCB Assembly – Top View





Figure 2-13. BP-AM2BLDCSERVO PCB Assembly – Bottom View





### **Mounting Holes**

The board includes 4x 144 mil diameter corner mounting holes. An additional 8x 144 mil diameter holes match the LP-AM243 and the LP-AM263 LaunchPad to allow the LaunchPad boards to be secured through standoffs. For basic usage, the LaunchPad 80-pin connectors provide a strong retention force.



### 2.7 System Power

The BP-AM2BLDCSERVO power tree is divided between motor axis-1, motor axis-2 and common digital and analog supplies. 24 V DC power is provided through the J5 and J6 screw-terminals. After passing through over-voltage/reverse-polarity protections, this supply is used to directly power the BLDC motor drivers and encoder/resolver on-board regulators.

When motor bench power is applied to the J5 and J6 terminal blocks, the U2/U3 over-voltage and reverse polarity circuits are powered. J5 and J6 can be powered from the same bench source or different bench sources, allowing for different motor voltages to be used on each axis.

In normal condition, the J5/J6 bench power will power the BLDC motor drivers and the Encoder/Resolver regulators. In an over-voltage or reverse polarity state, the LM74502 NFET switch path remains in a high impedance state, protecting the downstream devices. Over-voltage protection disables the power to the system if J5/J6 exceeded. Reverse polarity protection disables the power to the system if the J5/J6 negative voltage terminal exceeds the positive voltage terminal.

### Motor and Encoder Bench Power

After bench supply power-on through J5/J6, the encoder/resolver connectors are initially disconnected from their regulator by way of the U5/U40 load switches. This prevents typical high inrush currents from attached encoders/ resolvers from effecting regulator power-on and feedback loop stabilization. GPIO control from the attached LaunchPad is required to enable the U5/U40 load switches and power on the attached encoders/resolves.

**Note** Encoder output power through U4 and U39 buck-converter is selected through a jumper selector. See <u>Section 2.5</u> for a description of all jumper configuration option descriptions.



Figure 2-16. Motor Axis-2 Power Distribution

### System Digital/Analog Power

The LaunchPad 3.3V/1A supply is used to power all of the BP-AM2BLDCSERVO 3.3V logic and analog loads. See the below diagram of the 3.3V derived power tree. VSYS\_3V3 power is applied from the attached LaunchPad pins as soon as the LaunchPad is powered on.

This powers on all of the 3.3V powered digital loads such as the AMC1035 Sigma-Delta modulators, the sigma-delta clock distribution components. Through an LC filter, **the also** power on the onboard VREF sources, and current sense paths making all of these components ready to send SDFM/current sense data back to the attached MCU.



Figure 2-17. Common 3.3V Digital and Analog Power Tree



### 2.8 BLDC Motor Drive

The BP-AM2BLDCSERVO provides up to two axes of 3-phase, 24 Volt, 8 Amp (peak) BLDC motor drive. Each axis utilizes a DRV8316 monolithic gate-driver and 3-phase half-bridge to provide phase power to the attached BLDC motors. The AM2x MCU control the DRV8316 through a set of GPIO enable and fault lines and a SPI management bus. AM2x EPWM are used as gate-driver inputs.



#### Figure 2-18. Axis-1 DRV8316 Motor Drive







DRV8316 SPI management is through a single SPI BUS from the AM2x MCU LaunchPad is MUX'd between both Axis-1 and Axis-2. The SPI MUX select line is controlled through an MCU GPIO.

#### Note

The BP-AM2BLDCSERVO design is primarily focused on providing evaluation of the MCU control, feedback and networked peripherals. The DRV8316 driver is lower-current industrial driver used to provide a minimum gate-driver and motor drive platform. This may not be a good choice for higher current, or higher voltage BLDC servo applications.

Multiple current sense feedback are designed around these motor drivers. See Section 2.9 for a full description of all of these paths.

See the DRV8316 data sheet for more information on this particular motor driver.

### 2.9 Motor Current Feedback

The BP-AM2BLDCSERVO supports multiple current feedback paths for current feedback control. Direct current sense paths route current sense amplifier output directly to the AM263x SAR ADC LaunchPad channels. The other path utilizes a set of onboard AMC1035 Sigma-Delta Modulator ADC and then routes the digital samples to the PRU peripheral inputs of the AM2x device. Each path is designed to support the different current sense capabilities of the attached AM2x MCU.

- The INA241A sense amplifiers provide the voltage proportional to the current through in-line resistors on each motor output phase. This path is routed to AM263x SAR ADC pinout of the Launchpad connectors.
- The DRV8316 provides an internal sense and amplifier path for current through the low-side FET of each half-bridge. See the for a full description of the different feedback paths. This path is routed to the AM263x SAR ADC pinout of the LaunchPad connectors.
- The AMC1035 path provides sampled current feedback in a bitstream modulated format. This is intended to be used with the AM2x PRU SDFM demodulation firmware.



Figure 2-20. Axis-1 Motor Current Feedback Paths





Figure 2-21. Axis-2 Motor Current Feedback Paths

#### INA241 ADC Current Feedback

As shown in the above axis-1 motor current feedback figure, INA241A is used to amplify the small shunt voltage. The INA241A provides a fixed 10x gain and common-mode voltage set by the REF1 and REF2 inputs.

This output gain and common-mode setup are intended to provide good usage of the available AMC1035D linear range and be compatible with the AM263x SAR ADC input range.



Figure 2-22. Motor Current Feedback – Current Sense Path

See the INA241A data sheet for more information on this device.

#### Programmable Realtime Unit (PRU) Sigma-Delta Modulator (SDFM) Current Feedback

An onboard array of AMC1035 Sigma-Delta modulators provides digital current feedback for the AM2x PRU SDFM peripheral. The data path from each AMC1035 is directly routed to a PRU SD Data pin on the LaunchPad pinout. The AMC1035 clocking is provided through an onboard, LMK1C1108, low-jitter clock distributor. The input to this clock distribution comes from the PRU SYNC0 source output.

A jumper selector **(J17)** is used to select which clock distribution tap point is used to provide the PRU SD peripheral input clock. Either the SYNC1 (alternate clock output) can be selected or one of the SDFM clock distribution channels can be selected. The PRU peripheral provides for internal clock routing to each of the individual PRU SD Data channels.

Hardware





Figure 2-23. PRU SDFM Motor Current Feedback – Data/Clock Paths

The AMC1035 data clock is generated by the PRU SYNC0 output present on PRU\_SD5\_CLK. This is fanned out to each of the individual AMC1035 devices through an LMK1C1108 1:8 clock distribution IC (U37). For clocking data back into the PRU from the AMC1035, either one of the LMK1C1108 output channels can be used or a separate PRU generated SYNC1 signal (present on present on PRU\_SD5\_DATA) can be selected. Clock feedback is selected through the (J17) jumper.





See the AMC1035D and INA241Ax data sheets for a full description of these two components operations.



### 2.10 Motor Position Encoder Feedback

The AM2x MCU PRU provide a flexible 2-wire and 4-wire absolute encoder feedback path for interfacing to high performance industrial and safety critical absolute encoders and protocols.

A set of THVD1450 RS-485 transceivers is used to convert the 3.3V logic level transmit, receive, clock and transmit-enable signals from the AM2x MCU to the expected RS-485 line-levels with proper termination. A 4-channel 1:2 MUX (U35, and U24) are used to select between the 2-Wire RS-485 path option (TX/RX on a single differential pair) vs. the 4-Wire RS-485 path option (TX/RX differential pair and a separate clock differential pair). 2-Wire/4-Wire mode selection is done through the J24 and J25 jumpers.



Figure 2-25. PRU Absolute Encoder Feedback – PRU Mapping

With this combination of RS-485 transceivers and configurable 2-wire/4-wire peripheral support, the AM2x MCU can support a wide range of RS-485 based absolute encoders such as Heidenhain EnDat22, SICK HIPERFACE DSL, Tamagawa, Nikon and others. See the AM243x MCU SDK and the AM263x MCU SDK for an array of encoder interface software examples.

### Axis-1 Absolute Encoder Feedback

The axis-1 encoder PRU path implementation is multiplexed between the compatible LP-AM243 and LP-AM263 pins which utilize different parts of the LaunchPad pinout. Jumper J28 selects between the LP-AM243 and LP-AM263 paths. Jumper J24 is used to select between 2-wire and 4-wire RS-485 options.



Figure 2-26. Axis-1 - PRU Absolute Encoder Feedback

#### Axis-2 Absolute Encoder Feedback

The axis-2 path is direct from the BoosterPack headers to the U24 MUX and on to the RS-485 transceivers. This axis-2 path is only compatible with the LP-AM243 LaunchPad pinout. Jumper J25 is used to select between 2-wire and 4-wire RS-485 options.



Figure 2-27. Axis-2 - PRU Absolute Encoder Feedback



### **3 Hardware Design Files**

### 3.1 Schematics

The full Altium Designer CAD project, and manufacturing outputs can be found in the BP-AM2BLDCSERVO Board Design Files package.

### 3.2 PCB Layouts

To download the PCB guidelines and example layouts from Altium, see BP-AM2BLDCSERVO Board Design Files page.

### 3.3 Bill of Materials (BOM)

To download the bill of materials (BOM), see BP-AM2BLDCSERVO Board Design Files page.

### **4** Additional Information

### 4.1 Trademarks

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#### 4.2 Terminology

### **5** References

Please see the following references for devices and other kits used with this BoosterPack

#### AM2x LaunchPad Kits

AM243x LaunchPad Development Kit AM263x LaunchPad Development Kit

#### AM2x MCU Software Development Kits

AM243x MCU-PLUS SDK AM263x MCU-PLUS SDK

#### STANDARD TERMS FOR EVALUATION MODULES

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- 2 Limited Warranty and Related Remedies/Disclaimers:
  - 2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.
  - 2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.
  - 2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

### WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 Regulatory Notices:

3.1 United States

3.1.1 Notice applicable to EVMs not FCC-Approved:

**FCC NOTICE:** This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:

#### CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

#### FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

#### FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.
- 3.2 Canada

3.2.1 For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247

#### Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

#### Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

#### **Concerning EVMs Including Detachable Antennas:**

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

#### Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

- 3.3 Japan
  - 3.3.1 Notice for EVMs delivered in Japan: Please see http://www.tij.co.jp/lsds/ti\_ja/general/eStore/notice\_01.page 日本国内に 輸入される評価用キット、ボードについては、次のところをご覧ください。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

3.3.2 Notice for Users of EVMs Considered "Radio Frequency Products" in Japan: EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

- 1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
- 2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
- 3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けて

いないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの 措置を取っていただく必要がありますのでご注意ください。

- 1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用 いただく。
- 2. 実験局の免許を取得後ご使用いただく。
- 3. 技術基準適合証明を取得後ご使用いただく。
- なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。 上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・イ

ンスツルメンツ株式会社

#### 東京都新宿区西新宿6丁目24番1号

西新宿三井ビル

- 3.3.3 Notice for EVMs for Power Line Communication: Please see http://www.tij.co.jp/lsds/ti\_ja/general/eStore/notice\_02.page 電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧くださ い。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html
- 3.4 European Union
  - 3.4.1 For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive):

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

#### 4 EVM Use Restrictions and Warnings:

- 4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.
- 4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.
- 4.3 Safety-Related Warnings and Restrictions:
  - 4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.
  - 4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and inability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.
- 4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.
- 5. Accuracy of Information: To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.
- 6. Disclaimers:
  - 6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.
  - 6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.
- 7. USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS. USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

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- 8. Limitations on Damages and Liability:
  - 8.1 General Limitations. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS, REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.
  - 8.2 Specific Limitations. IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.
- 9. Return Policy. Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.
- 10. Governing Law: These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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