

BOOST-DAC8730-HART Evaluation Module

This user's guide describes the characteristics, operation, and use of the BOOST-DAC8730-HART evaluation board. This user's guide also discusses the proper setup and configuration of both software and hardware, and reviews various aspects of program operation. A complete circuit description, schematic diagram, and bill of materials (BOM) are also included in this document.

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1 Overview

The DAC8730 integrates several components in creating a smart-loop-powered sensor transmitter with included *Highway Addressable Remote Transducer* (HART), *FOUNDATION Fieldbus* (FF), and Profibus PA (PA) modems. The key components of the device include a 16-bit PWM DAC, loop-control operation amplifier, HART or FF/PA modem, internal reference and power tree.

1.1 BOOST-DAC8730-HART Kit Contents

Table 1 details the contents of the kit. Contact the TI Product Information Center or visit the Texas Instruments E2E Community (<http://E2E.ti.com>) if any component is missing.

Table 1. Contents of BOOST-DAC8730-HART Kit

Item	Quantity
BOOST-DAC8730-HART PCB evaluation board	1

1.2 Related Documentation From Texas Instruments

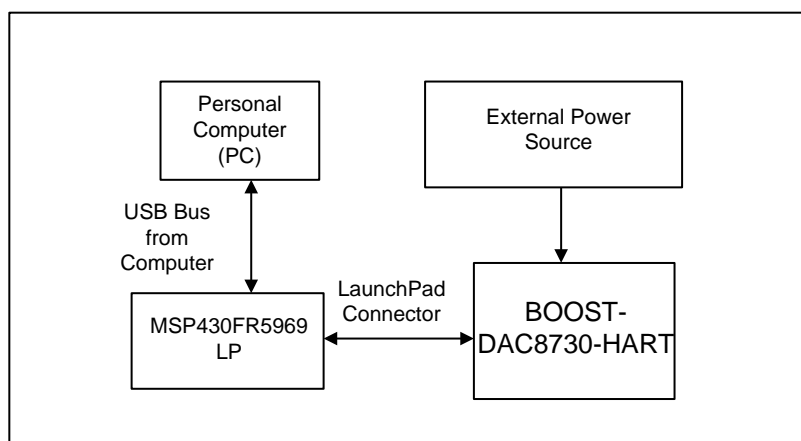
The following document provides information regarding Texas Instruments integrated circuits used in the assembly of the BOOST-DAC8730-HART. This user's guide is available from the TI web site under literature number SLAU699. Any letter appended to the literature number corresponds to the document revision that is current at the time of the writing of this document. Newer revisions may be available from the TI web site at <http://www.ti.com/>, or call the Texas Instruments Literature Response Center at (800) 477-8924 or the Product Information Center at (972) 644-5580. When ordering, identify the document by both title and literature number.

Table 2. Related Documentation

Document	Literature Number
BOOST-DAC8730-HART Product Data Sheet	SLASEH8

2 BOOST-DAC8730-HART Hardware Setup

This section provides the overall system setup for the BOOST-DAC8730-HART Booster Pack. The Booster Pack can be evaluated standalone – with any SPI- or UART-capable microcontroller – or with the MSP430FR5969 LaunchPad™. The software provides installation steps to install the necessary LaunchPad drivers, and MSP430FR5969 firmware. Additionally, the Graphical User Interface (GUI) provides an interactive interface that syncs communication between the MSP430FR5969 LaunchPad and DAC8730 device. The hardware (BOOST-DAC8730-HART and MSP430FR5969LP) is powered externally via the loop connections of the BOOST-DAC8730-HART J2 terminal block. [Figure 1](#) displays the system setup for the BOOST-DAC8730-HART.

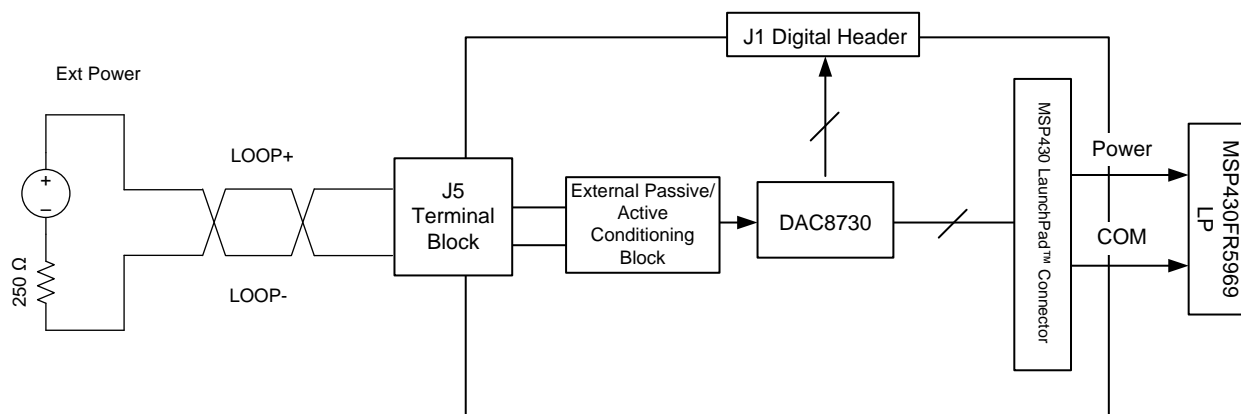


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Figure 1. BOOST-DAC8730-HART Hardware Setup

2.1 Theory of Operation for BOOST-DAC8730-HART Hardware

A block diagram of the BOOST-DAC8730-HART board is displayed in [Figure 2](#). The board provides an external terminal block (J2) for the supplies, and a digital header connection (J1) that enables connection to the DAC8730 digital pins. Once powered, the DAC8730 outputs a voltage that powers the MSP430FR5969 LaunchPad. The BOOST-DAC8730-HART includes a diode bridge and protection circuit that is tied to the J2 terminal block. This protection allows any polarity of power into the J2 terminal block.



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Figure 2. BOOST-DAC8730-HART Test Board Block Diagram

2.2 MSP430FR5969 LaunchPad™ Connections

Before connecting the LaunchPad to the BOOST-DAC8730-HART board, the following MSP430FR5969 LaunchPad (J13) jumpers must be set to the configuration shown in [Table 3](#).

WARNING

If the jumper connections are not configured as in [Table 3](#), the BOOST-DAC8730-HART and MSP430FR5969 will receive damage from the USB supply connection.

Table 3. MSP430FR5969 LaunchPad™ Header

PIN on J13	Signal	Shunt position
20	GND	Connected
18	5 V	Open
16	V+	Open
14	RTS	Open
12	CTS	Open
10	RXD	Connected
8	TXD	Connected
6	RST	Connected
4	TST	Connected

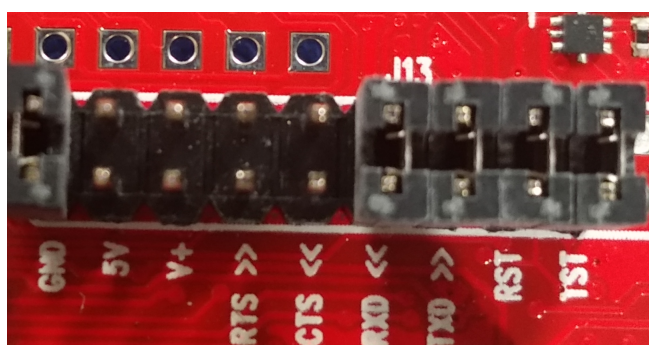


Figure 3. MSP430FR5969 LaunchPad™ Header

3 BOOST-DAC8730-HART Software Setup

This section provides the procedures for software installation.

3.1 Operating Systems for BOOST-DAC8730-HART Software

The software has been tested on the Microsoft® Windows® XP and Windows 7 operating systems with the United States and European regional settings. The software should also be compatible with other Windows operating systems.

3.2 BOOST-DAC8730-HART Software Installation

The software is available through the product folder on the TI website. Once the software is downloaded onto the PC, navigate to the BOOST-DAC8730-HART folder, and run the Setup.exe file, as shown in [Figure 4](#). When the software is launched, an installation dialog will open, and prompt the user to select an installation directory. If left unchanged, the software location defaults to C:\Program Files (x86)\Texas Instruments\BOOST-DAC8730-HART, as shown in [Figure 5](#).

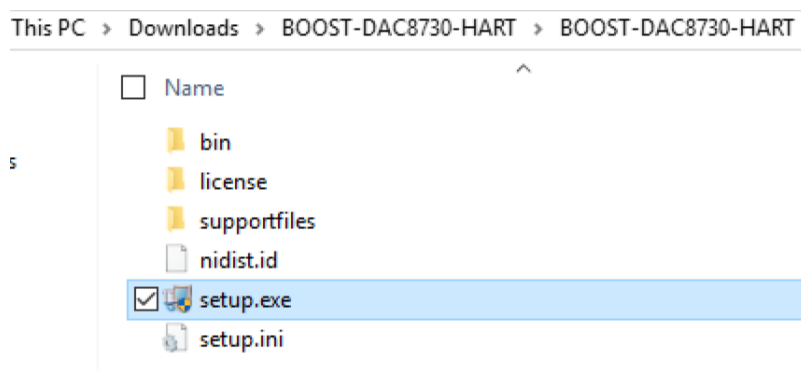


Figure 4. BOOST-DAC8730-HART Installer Directory

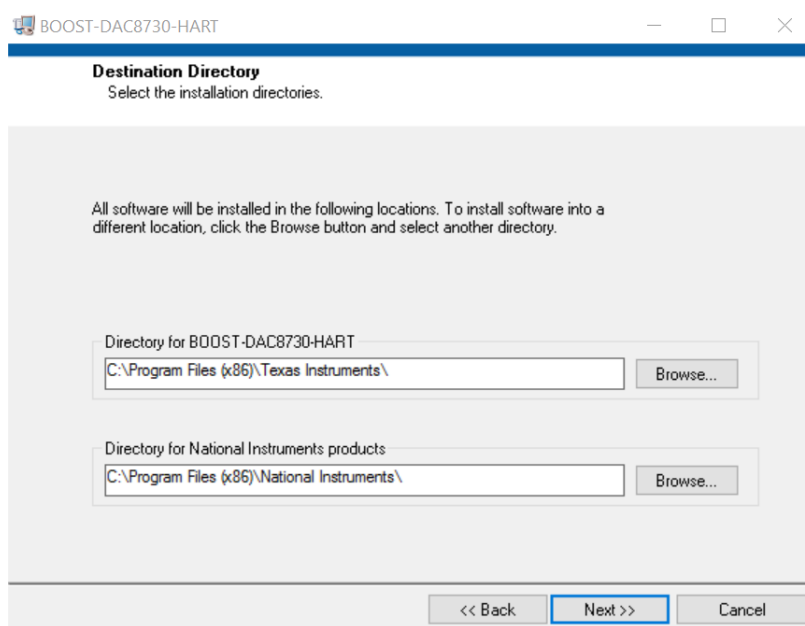


Figure 5. BOOST-DAC8730-HART Install Path

3.3 Installing Drivers and MSP430FR5969 LaunchPad™ Firmware

Before connecting the BOOST-DAC8730-HART board to the MSP430FR5969 LaunchPad, the user must ensure that the MSP430 device drivers are installed on the PC, and that the firmware is flashed on the MSP430FR5969 LaunchPad.

Driver installation is accomplished by invoking the GUI before any hardware is connected to the PC. In this step, ensure that no hardware is connected to the PC. To invoke the GUI, click the “BOOST-DAC8730-HART” icon found in the programs or apps section of the start menu. The GUI will display a splash screen and a pop-up displaying “No MSP LaunchPad Found”. Press the **OK** button, and the GUI will start in DEMO mode. Navigate to the DAC8730 page by pressing the “DAC8730” tab under the *Pages* field and press the **Install MSP430 Drivers** button, as shown in Figure 6.

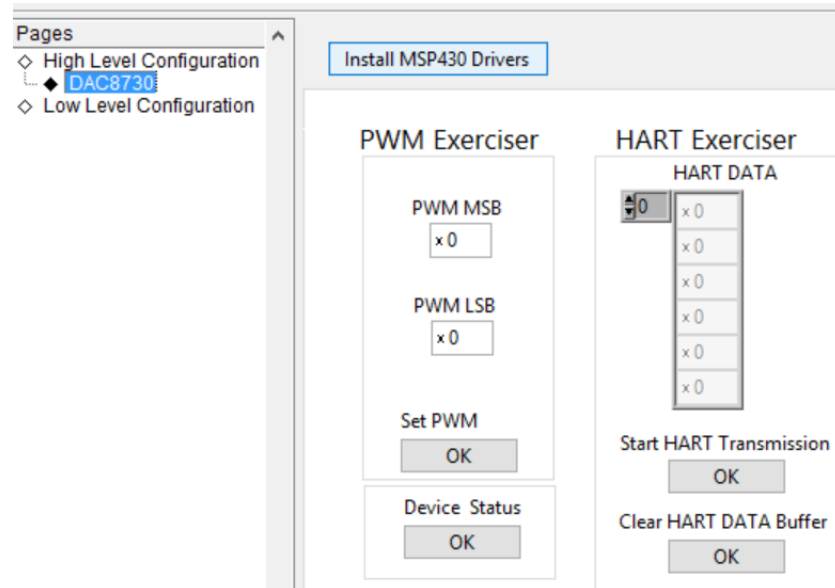


Figure 6. Install MSP430 Drivers Button

Once pressed, a batch file will execute from the software and install the necessary files. Several prompts may appear that query the user to accept software changes made by the application. Press the **Continue** button to proceed with the installation. The next step is to connect the MSP430FR5969 LaunchPad to the PC (without BOOST-DAC8730-HART) via the micro USB cable. Now press the **Install MSP430 Firmware** button of the GUI to flash custom firmware to the MSP430FR5969 LaunchPad. The LEDs of the LaunchPad will begin to flash, and a black window may appear during the firmware installation. Additionally, the text field next to the **Install MSP430 Firmware** should read as “UPLOADING”. When flashing is complete, the cmd prompt will exit, and the text field will update to display “COMPLETE”. The MSP430FR5969 LaunchPad has now been successfully flashed.

Now close the GUI by pressing the exit **X** button located on the top right of the GUI page, and disconnect the LaunchPad USB cable from the PC.

4 BOOST-DAC8730-HART Hardware Overview

The subsequent sections provide detailed information on the hardware, and jumper configuration settings. [Table 4](#) displays the default configurations of all jumper connections on the BOOST-DAC8730-HART.

Table 4. Default Jumper Settings

Jumper	Default Position	Description
JP1	Shunt on 1-2	Configures the VCCIO output voltage 00 = 1.8 V, 01 = 2.5 V, 10 = 3.0 V, 11 = 3.15 V (Default setting: 3.15 V)
JP2	Shunt on 1-2	
JP3	Shunt on 2-3	Connect to GND for operation with crystal, connect to VINL for operation with resonator (Default setting: GND)

4.1 Electrostatic Discharge Warning

Many of the components on the BOOST-DAC8730-HART are susceptible to damage by electrostatic discharge (ESD). Customers are advised to observe proper ESD handling precautions when unpacking and handling the board, including the use of a grounded wrist strap at an approved ESD workstation.

4.2 Connecting the BOOST-DAC8730-HART

To connect the BOOST-DAC8730-HART to the MSP430FR5969 LaunchPad, align and firmly connect the LaunchPad connectors to the BOOST-DAC8730-HART J3 and J4 female headers. The booster pack connects to the pins on the outermost column of the MSP430FR5969 LaunchPad connectors, and care must be taken to align J3 and J4 of the DAC8730 board to the MSP430FR5969 LaunchPad. The alignment of the connection is shown in [Figure 7](#), with green boxes surrounding the electrical points of contact.

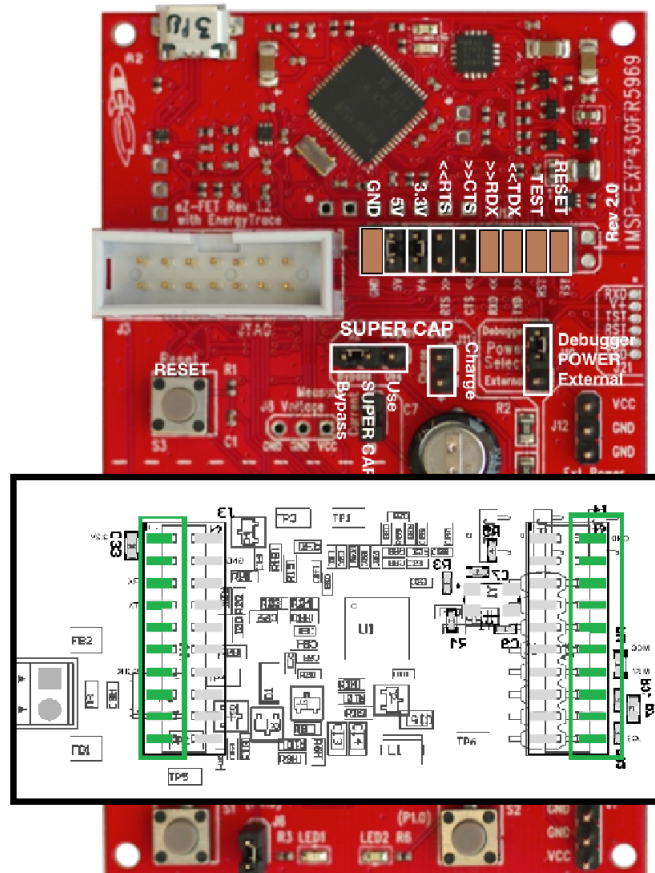


Figure 7. Typical Hardware Connections on the BOOST-DAC8730-HART

4.3 BOOST-DAC8730-HART Power Configurations

The BOOST-DAC8730-HART provides a terminal block (J2) to connect to the external loop-supply. A typical two-wire connection has a sense resistor tied to either the negative or positive node of the external supply. A minimum loop resistance value of 250 ohms is commonly required for HART communication. The minimum voltage for DAC8730 device operation and other parameter requirements are listed in the DAC8730 data sheet ([SLASEH8](#)). For correct loop operation, please be aware that the loop-supply voltage must exceed the sum of both the minimum voltage requirement of the DAC8730 device, and the IR drop across the sense resistor.

Table 5. BOOST-DAC8730-HART Power Supply Configuration

Connector	Connection Type	Description
J2	Terminal block	External loop-supply connection

A loop-supply voltage of 24 V is the nominal supply voltage for most 4- to 20-mA two-wire transmitters.

4.4 SPI Communication Signals and Digital Inputs/Outputs

The SPI signals are located on the J2 header and are described in [Table 6](#), along with the digital input signals of the BOOST-DAC8730-HART device.

Table 6. Digital Block Signal Definition

Name	Connector	Description
GND	J2-1	Local GND
DS1	J2-2	Power transformer driver (driven from the REG_IN pins)
DS2	J2-3	
VCCIO	J2-4	External supply output
CLKOUT	J2-5	Clock output
RESET	J2-6	Hardware reset
\overline{CS}	J2-7	SPI chip select
MOSI	J2-8	SPI data input
MISO	J2-9	SPI data output
SCLK	J2-10	SPI clock input
RX	J2-11	UART RX input
TX	J2-12	UART TX output
IRQ	J2-13	Interrupt request output (active low)
GND	J2-14	Local GND
VSHUNT	J2-15	Internal DC/DC voltage FB_SUPPLY
VINL	J2-16	Synchronous DAC load control input

5 BOOST-DAC8730-HART Software Overview

This section discusses how to use the BOOST-DAC8730-HART software.

5.1 Starting the BOOST-DAC8730-HART Software

Once the hardware connections are established and jumper settings configured, power on the BOOST-DAC8730-HART with the loop-supply voltage. Next, launch the software located in the *Texas Instruments* folder of the *Start All Programs* menu, and select the BOOST-DAC8730-HART icon.

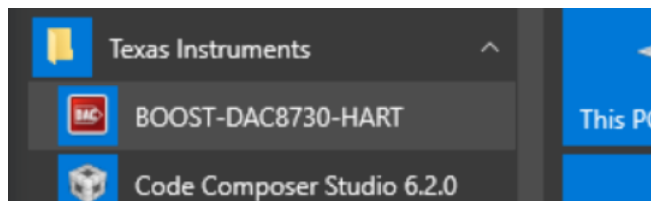


Figure 8. BOOST-DAC8730-HART GUI Location

If the LaunchPad is properly connected to the BOOST-DAC8730-HART, the GUI should automatically display "HARDWARE CONNECTED" on the lower left of the GUI, as seen in [Figure 9](#).



Figure 9. BOOST-DAC8730-HART GUI – Power On

If the LaunchPad has a faulty connection, or is not connected at all, the GUI will launch in DEMO mode. If this text appears while the LaunchPad device is connected, then power off the loop-supply voltage, unplug the LaunchPad, and close the GUI. Reconnect the LaunchPad and ensure that the connectors are correctly aligned. After this, verify the USB extender cable is properly connected to both the LaunchPad and PC. Reapply the loop-supply voltage and re-launch the GUI. This issue can also occur if the MSP430 driver is installed incorrectly, and so the BOOST-DAC8730-HART software may need to be reinstalled.

5.2 BOOST-DAC8730-HART Software Features

The following subsections describe the functionality of each page of the BOOST-DAC8730-HART GUI.

5.2.1 BOOST-DAC8730-HART Low Level Configuration Page

The BOOST-DAC8730-HART features a *Register Map* page that allows access to low-level communication by directly writing to and reading from the registers of the BOOST-DAC8730-HART. Selecting a register on the *Register Map* list will present a description of the values in that register, and also display register information such as the address, default value, size, and current value. The register values can be modified by either writing directly to the value column or selecting the bit individually. This is shown in [Figure 10](#).

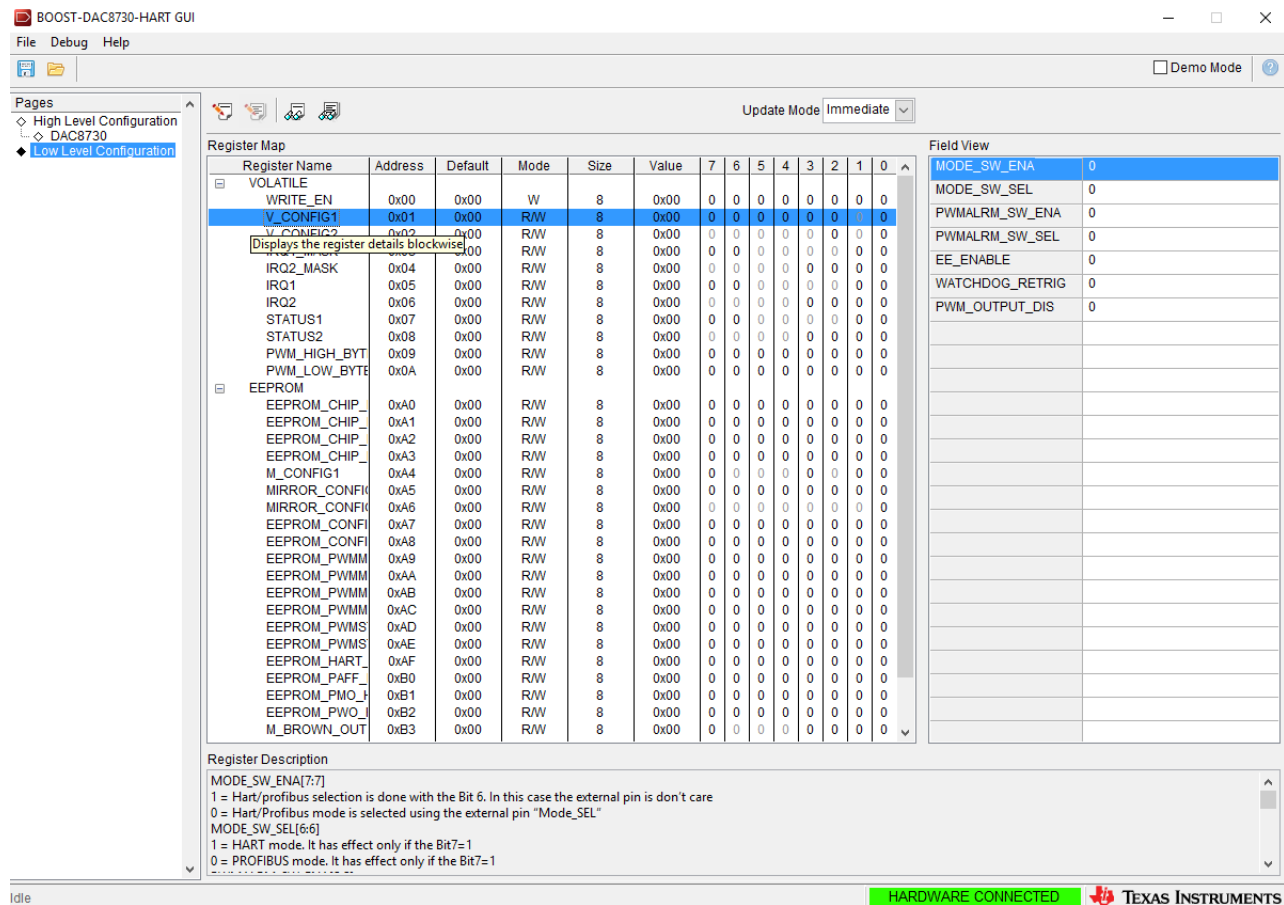


Figure 10. Low Level Configuration Page

The values of the register map can also be saved by pressing the **Save Configuration** button under the *File* menu option. Additionally, the configuration files can be accessed through the **Load Configuration** button.

Other options selectable by the user are the *Update Mode*, *Write Selected* (red box), *Read Selected* (orange box), *Write Modified* (gray box) and *Read All* (yellow box) icons. All icons are displayed in Figure 11.



Figure 11. Low Level Configuration Page Available Options

If *Update Mode* is selected to "Immediate", all changes to register values will update immediately, while "Deferred" allows the user to modify the value of a register without taking effect until the *Write Selected*, or *Write Modified* icon is pressed.

The *Read Selected* icon allows individual register reads, while the *Read All* icon reads the status of all registers located in the register map.

5.2.2 BOOST-DAC8730-HART High Level Configuration Page

The *High Level Configuration* page provides an interface to observe and control the different data registers, modes, and configurations available for the BOOST-DAC8730-HART device. This page is displayed in Figure 12.

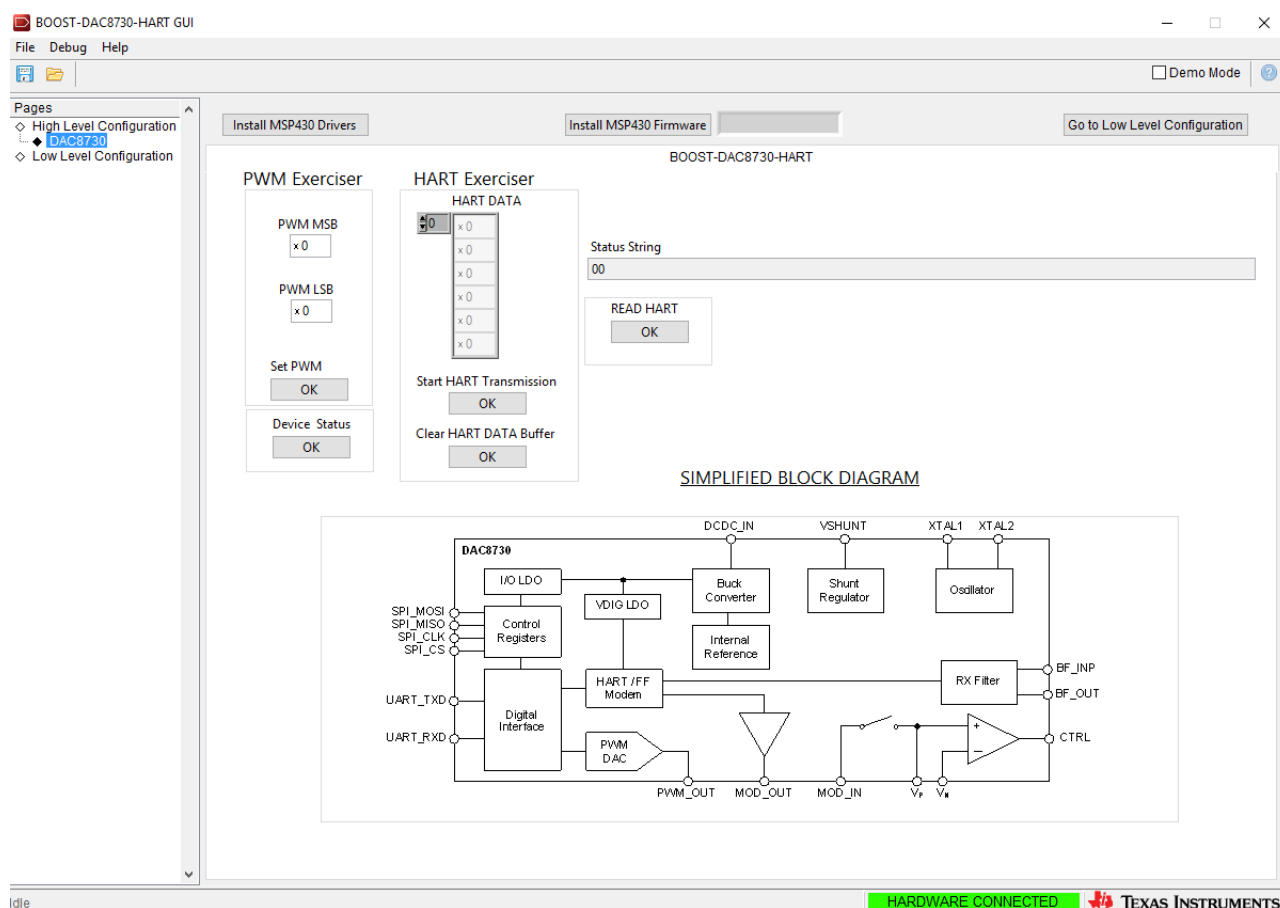


Figure 12. High Level Configuration Page

The main page primarily has 3 functions – the *PWM Exerciser*, the *HART Exerciser* (transmit and read), and the **Device Status** button.

The 16-bit PWM DAC can be exercised by writing to the MSL and LSB fields and pressing the **OK** button for *Set PWM* – the appropriate code range is 0x1000 - 0xEFFF.

The HART interface is controlled via UART, which is controlled in the firmware of the MSP430FR5969 device. To create a transmit packet type the data, in hexadecimal format, to the *HART DATA* array and press the **OK** button located under *Start HART Transmission*. The resulting HART waveform can be captured by monitoring the differential voltage across the loop-supply pins or the shunt resistor. To clear this array, press the **OK** button located under *Clear HART DATA Buffer*.

NOTE: The DAC8730 device creates a local ground from the loop-supply voltage. In the case that a desktop machine is used, the USB connection will share an earth ground connection with the local ground that is generated from the DAC8730 device. Therefore, to avoid any potential shorting between earth ground and probed nets, the user will require a differential probe when inspecting the HART waveform.

The DAC8730 device notifies the microcontroller of a valid HART transaction, and will send this information to the microcontroller, which in turn will store to a buffer. Pressing the **OK** button located under *READ HART* reads the byte information from the buffer. This information is displayed in the *Status String* indicator field in hexadecimal format.

Pressing the **OK** button located under *Device Status* will read the *Status Nibble* of the DAC8730 device, which will notify of any errors or flags. This information is displayed in the *Status String* indicator field in hexadecimal format and is detailed in [Table 7](#).

Table 7. UART Command Byte

Code Nibble				Status Nibble			
DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
See the following table				ILOOP_LOW	VSHUNT_LOW	Don't Care	HL_PWM

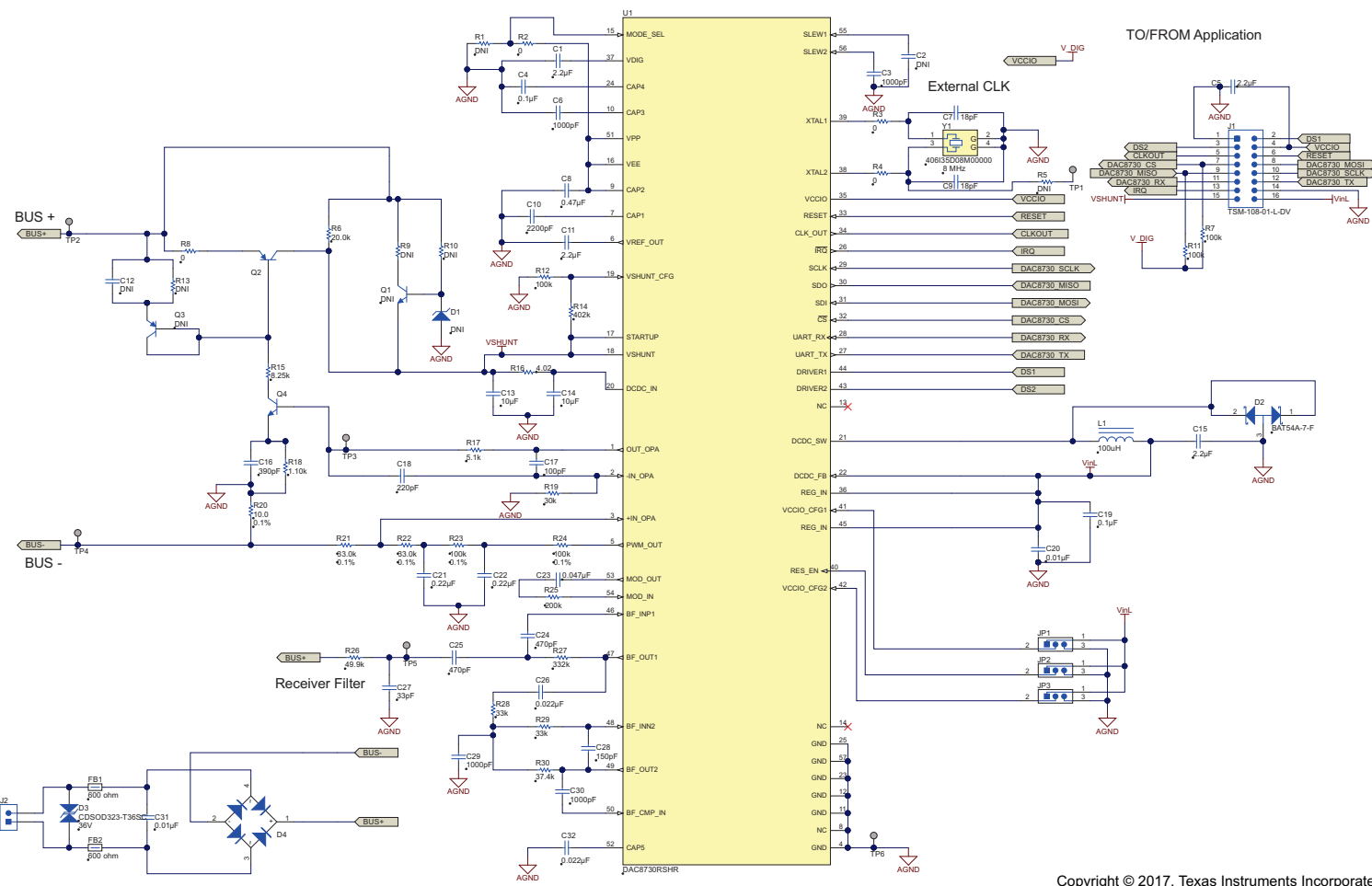
Command	Code Nibble	Reply	2 nd Byte	Description
RESET	0000	PWM		A 25-ms timeout has occurred and an updated DAC data is required. After 10 consecutive RESET commands, a resynchronization occurs.
IDLE	0010	PWM	TX-HART (optional)	Request for DAC data, no transmitted or received HART data is required for the bus
START_RX	0100	-	-	A carrier has been detected, and there is activity on the HART bus
RX	0101	PWM	RX-HART	Correct HART data has been received and will be transmitted in the next byte
RX_PE	1101	PWM	RX-HART	A parity error has been detected in the HART data. The received byte will still be transmitted in the next byte.
RX_FE	1110	PWM	RX-HART	A framing error has been detected in the HART data. The received byte will still be transmitted in the next byte.
END_RX	0110	PWM	-	The received HART packet is complete and the bus is no longer occupied
START_TX	1000	PWM	TX-HART (optional)	HART transmission started and HART data is ready to be transmitted
TX	1001	PWM	TX-HART (optional)	HART data is still available and the HART packet is still transmitting
END_TX	1010	PWM	-	No more HART data is available and the packet is terminated
EXCEPTION	1111	-	-	Internal state machine error

6 BOOST-DAC8730-HART Documentation

This section contains the complete bill of materials and schematic diagram for the BOOST-DAC8730-HART. Documentation information for the SDM-USB-DIG platform is found in the *SDM-USB-DIG Platform User's Guide* (SBOU136), available from the TI web site at <http://www.ti.com>.

6.1 BOOST-DAC8730-HART Board Schematic

Figure 13 illustrates the BOOST-DAC8730-HART schematic.



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Figure 13. BOOST-DAC8730-HART Board Schematic

6.2 BOOST-DAC8730-HART PCB Components Layout

Figure 14 shows the layout of the components for the BOOST-DAC8730-HART board.

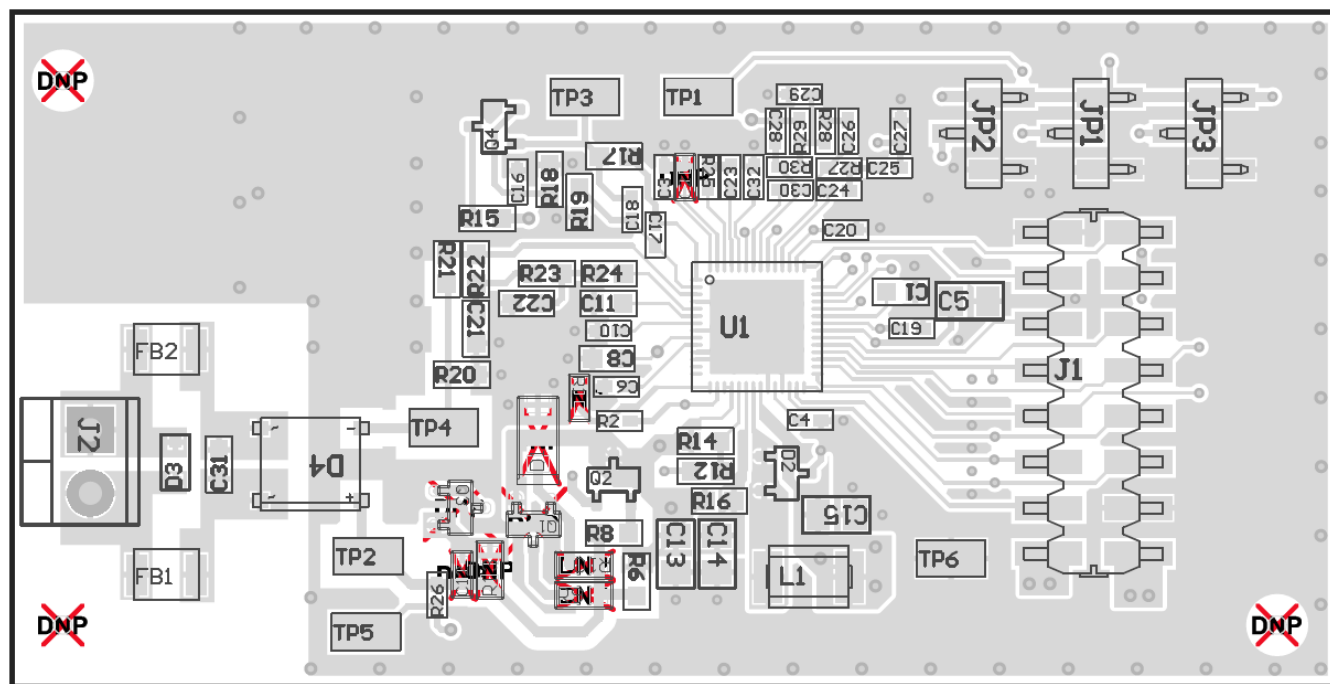


Figure 14. BOOST-DAC8730-HART PCB Components Layout

6.3 BOOST-DAC8730-HART Test Board Bill of Materials

Table 8 lists the BOOST-DAC8730-HART test board BOM.

Table 8. BOOST-DAC8730-HART Test Board Bill of Materials

Item #	Designator	Qty	Value	Part Number	Manufacturer	Description	Package Reference
1	!PCB1	1		PA022	Any	Printed Circuit Board	
2	C1, C11	2	2.2uF	GRM188Z71C225KE43	Murata	CAP, CERM, 2.2 μ F, 16 V, \pm 10%, X7R, 0603	0603
3	C2, D1, Q1, Q3, R1, R5, R10, R31	8	DNI	DNI	DNI	DNI, Diode, Zener, 6.8 V, 500 mW, SOD-123, Transistor, NPN, 65 V, 0.1 A, SOT-23, Transistor, PNP, 60 V, 0.8 A, SOT-23, RES, 0, 5%, 0.063 W, 0402, DNI, RES, 1.10 k, 1%, 0.1 W, 0603, RES, 0, 5%, 0.063 W, 0402	DNI
4	C3, C6, C29, C30	4	1000pF	GRM1555C1H102JA01D	Murata	CAP, CERM, 1000 pF, 50 V, \pm 5%, C0G/NP0, 0402	0402
5	C4, C19	2	0.1uF	GCM155R71H104KE02D	Murata	CAP, CERM, 0.1 μ F, 50 V, \pm 10%, X7R, AEC-Q200 Grade 1, 0402	0402
6	C5, C15	2	2.2uF	C0805C225K4RACTU	Kemet	CAP, CERM, 2.2 μ F, 16 V, \pm 10%, X7R, 0805	0805
7	C7, C9	2	18pF	GRM1555C1H180JA01D	Murata	CAP, CERM, 18 pF, 50 V, \pm 5%, C0G/NP0, 0402	0402
8	C8	1	0.47uF	GRM188R71E474KA12D	Murata	CAP, CERM, 0.47 μ F, 25 V, \pm 10%, X7R, 0603	0603
9	C10	1	2200pF	GRM155R71H222KA01D	Murata	CAP, CERM, 2200 pF, 50 V, \pm 10%, X7R, 0402	0402
10	C12	1	1000pF	DNI	DNI	DNI	0402
11	C13, C14	2	10uF	GRM21BZ71E106KE15L	Murata	CAP, CERM, 10 μ F, 25 V, \pm 10%, X7R, 0805	0805
12	C16	1	390pF	GRM1555C1H391JA01D	Murata	CAP, CERM, 390 pF, 50 V, \pm 5%, C0G/NP0, 0402	0402
13	C17	1	100pF	GRM1555C1H101JA01D	Murata	CAP, CERM, 100 pF, 50 V, \pm 5%, C0G/NP0, 0402	0402
14	C18	1	220pF	GRM1555C1H221JA01D	Murata	CAP, CERM, 220 pF, 50 V, \pm 5%, C0G/NP0, 0402	0402
15	C20	1	0.01uF	GCM155R71H103KA55D	Murata	CAP, CERM, 0.01 μ F, 50 V, \pm 10%, C0G/NP0, 0402	0402
16	C21, C22	2	0.22uF	885012206048	Würth Elektronik	CAP, CERM, 0.22 μ F, 16 V, \pm 10%, X7R, 0603	0603
17	C23	1	0.047uF	C1005X7R1H473K050BB	TDK	CAP, CERM, 0.047 μ F, 50 V, \pm 10%, X7R, 0402	0402
18	C24, C25	2	470pF	GRM1555C1H471JA01D	Murata	CAP, CERM, 470 pF, 50 V, \pm 5%, C0G/NP0, 0402	0402
19	C26, C32	2	0.022uF	GCM155R71H223KA55D	Murata	CAP, CERM, 0.022 μ F, 50 V, \pm 10%, C0G/NP0, 0402	0402
20	C27	1	33pF	GRM1555C1H330JA01D	Murata	CAP, CERM, 33 pF, 50 V, \pm 5%, C0G/NP0, 0402	0402
21	C28	1	150pF	GRM1555C1H151JA01D	Murata	CAP, CERM, 150 pF, 50 V, \pm 5%, C0G/NP0, 0402	0402
22	C31	1	0.01uF	C0603C103K5RACTU	Kemet	CAP, CERM, 0.01 μ F, 50 V, \pm 10%, X7R, 0603	0603
23	C33	1	1uF	GCM188R71E105KA64D	Murata	CAP, CERM, 1 μ F, 25 V, \pm 10%, X7R, AEC-Q200 Grade 1, 0603	0603
24	D2	1	30V	BAT54A-7-F	Diodes Inc.	Diode, Schottky, 30 V, 0.2 A, SOT-23	SOT-23
25	D3	1	36V	CDSOD323-T36SC	Bourns	Diode, TVS, Bi, 36 V, SOD323, 2-Leads, Body 1.9x1.45mm, No Polarity Mark	SOD323, 2-Leads, Body 1.9x1.45mm, No Polarity Mark
26	D4	1	1000V	DSRHD10-13	Diodes Inc.	Diode, Switching-Bridge, 1000V, 1A, 5.0x1.21x6.2mm	5.0x1.21x6.2mm
27	FB1, FB2	2	600 ohm	FBMH3225HM601NT	Taiyo Yuden	Ferrite Bead, 600 ohm @ 100 MHz, 3 A, 1210	1210
28	FID1, FID2, FID3	3		N/A	N/A	Fiducial mark. There is nothing to buy or mount.	Fiducial

Table 8. BOOST-DAC8730-HART Test Board Bill of Materials (continued)

Item #	Designator	Qty	Value	Part Number	Manufacturer	Description	Package Reference
29	J1	1		TSM-108-01-L-DV	Samtec	Header, 2.54mm, 8x2, Gold, SMT	Header, 2.54mm, 8x2, SMT
30	J2	1		ED555/2DS	On-Shore Technology	Terminal Block, 6A, 3.5mm Pitch, 2-Pos, TH	7.0x8.2x6.5mm
31	J3, J4	2		SSW-110-22-F-D-VS-K	Samtec	Connector, Receptacle, 100mil, 10x2, Gold plated, SMD	10x2 Receptacle
32	JP1, JP2, JP3	3		TMM-103-01-G-S-SM	Samtec	Header, 2mm, 3x1, Gold, SMT	Header, 2mm, 3x1, SMT
33	L1	1	1mH	74476630	Würth Elektronik	Inductor, Wirewound, 1 mH, 0.03 A, 50 ohm, SMD	1812
34	Q2	1	60 V	MMBT2907A	Fairchild Semiconductor	Transistor, PNP, 60 V, 0.8 A, SOT-23	SOT-23
35	Q4	1	65 V	BC846BLT1G	ON Semiconductor	Transistor, NPN, 65 V, 0.1 A, SOT-23	SOT-23
36	R2, R3, R4, R32	4	0	RC0402JR-070RL	Yageo America	RES, 0, 5%, 0.063 W, 0402	0402
37	R6	1	20.0k	RC0603FR-0720KL	Yageo America	RES, 20.0 k, 1%, 0.1 W, 0603	0603
38	R7, R11	2	100k	RC0603FR-07100KL	Yageo America	RES, 100 k, 1%, 0.1 W, 0603	0603
39	R8	1	0	RC0603JR-070RL	Yageo America	RES, 0, 5%, 0.1 W, 0603	0603
40	R9, R13	2	DNI	DNI	DNI	RES, 5.62 k, 1%, 0.1 W, 0603, RES, 1.10 k, 1%, 0.1 W, 0603	0603
41	R12	1	100k	CRCW0603100KFKEA	Vishay-Dale	RES, 100 k, 1%, 0.1 W, 0603	0603
42	R14	1	402k	CRCW0603402KFKEA	Vishay-Dale	RES, 402 k, 1%, 0.1 W, 0603	0603
43	R15	1	8.25k	CRCW06038K25FKEA	Vishay-Dale	RES, 8.25 k, 1%, 0.1 W, 0603	0603
44	R16	1	4.02	CRCW06034R02FKEA	Vishay-Dale	RES, 4.02, 1%, 0.1 W, 0603	0603
45	R17	1	5.1k	CRCW06035K10JNEA	Vishay-Dale	RES, 5.1 k, 5%, 0.1 W, 0603	0603
46	R18	1	1.10k	CRCW06031K10FKEA	Vishay-Dale	RES, 1.10 k, 1%, 0.1 W, 0603	0603
47	R19	1	30k	CRCW060330K0JNEA	Vishay-Dale	RES, 30 k, 5%, 0.1 W, 0603	0603
48	R20	1	10.0	RT0603BRD0710RL	Yageo America	RES, 10.0, 0.1%, 0.1 W, 0603	0603
49	R21, R22	2	33.0k	RG1608P-333-B-T5	Susumu Co Ltd	RES, 33.0 k, 0.1%, 0.1 W, 0603	0603
50	R23, R24	2	100k	RT0603BRD07100KL	Yageo America	RES, 100 k, 0.1%, 0.1 W, 0603	0603
51	R25	1	200k	CRCW0402200KFKEA	Vishay-Dale	RES, 200 k, 1%, 0.063 W, 0402	0402
52	R26	1	49.9k	CRCW040249K9FKED	Vishay-Dale	RES, 49.9 k, 1%, 0.063 W, 0402	0402
53	R27	1	332k	CRCW0402332KFKEA	Vishay-Dale	RES, 332 k, 1%, 0.063 W, 0402	0402
54	R28, R29	2	33k	CRCW040233K0JNEA	Vishay-Dale	RES, 33 k, 5%, 0.063 W, 0402	0402
55	R30	1	37.4k	CRCW040237K4FKED	Vishay-Dale	RES, 37.4 k, 1%, 0.063 W, 0402	0402
56	SH-J1, SH-J2, SH-J3	3	1x2	2SN-BK-G	Samtec	Shunt, 2mm, Gold plated, Black	2mm Shunt, Closed Top
57	TP1, TP2, TP3, TP4, TP5, TP6	6		5019	Keystone	Test Point, Miniature, SMT	Test Point, Miniature, SMT
58	U1	1		DAC8730RSHR	Texas Instruments	Loop Powered DAC with HART / FOUNDATION Fieldbus / Profibus PA Modems, RSH0056A (VQFN-56)	RSH0056A
59	Y1	1		406I35D08M00000	CTS Electrocomponents	Crystal, 8 MHz, 18 pF, SMD	SMD, 4-Leads, Body 6.2x3.7mm

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

- 1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductor products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software
- 1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

- 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.

- 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。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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.

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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。

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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 liability 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.

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, INDEMNITY 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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