

DRV2624 ERM, LRA haptic driver evaluation kit

The DRV2624 is a haptic driver designed for Linear Resonant Actuators (LRA) and Eccentric Rotating Mass (ERM) motors. It provides many features which help eliminate the design complexities of haptic motor control including reduced solution size, high efficiency output drive, closed-loop motor control, quick device startup, memory for waveform storage, and auto-resonance frequency tracking.

The DRV2624EVM-CT Evaluation Module (EVM) is a complete demo and evaluation platform for the DRV2624. The kit includes a microcontroller, linear actuator, eccentric rotating mass motor, and capacitive touch buttons which can be used to completely demonstrate and evaluate the DRV2624.

This document contains instructions to setup and operate the DRV2624EVM-CT in demo and evaluation mode.



Figure 1. DRV2624EVM-CT Board

Evaluation Kit Contents:

- DRV2624EVM-CT demo and evaluation board
- Micro-USB cable
- Demonstration Firmware

Required for programming and advanced configuration:

- Code Composer Studio™ (CCS) or IAR Embedded Workbench IDE for MSP430
- MSP430 LaunchPad (MSP-EXP430G2), or MSP430-FET430UIF hardware programming tool
- DRV2624EVM-CT firmware available on ti.com

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1 Getting Started

The DRV2624 can be used as a demonstration or evaluation tool. When the DRV2624EVM-CT evaluation module is powered on for the first time, a demo application automatically starts. To power the board, connect the DRV2624EVM-CT to an available USB port on your computer using the included micro-USB cable. The demo begins with a board power-up sequence and then enters the demo effects mode. The four larger buttons on the wheel (1–4) can be used to sample haptic effects using both the ERM and LRA motor in the top right corner.

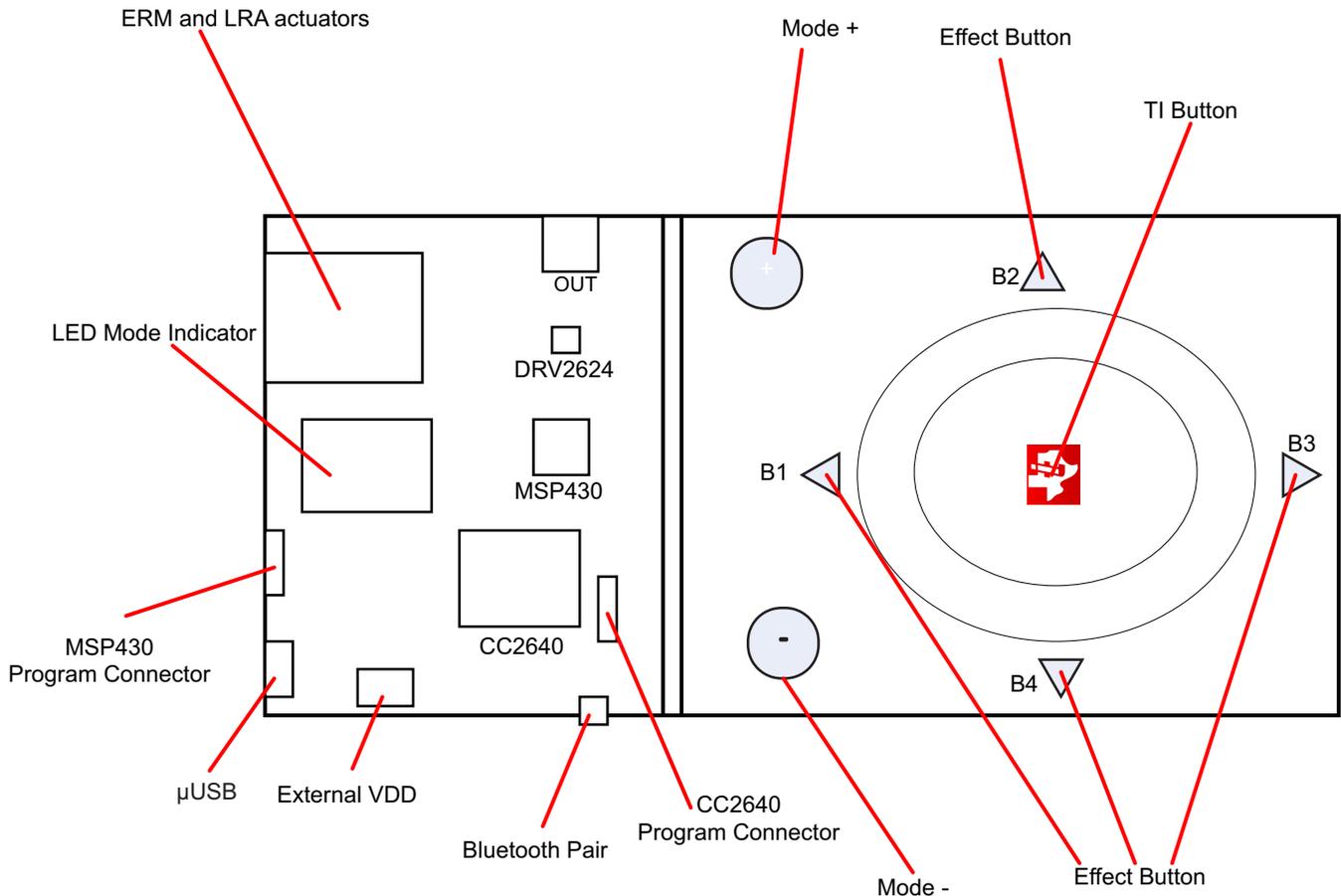


Figure 2. Board Diagram

1.1 Evaluation Module Operating Parameters

The following table lists the operating conditions for the DRV2624 on the evaluation module.

Parameter	Specification
Supply voltage range	2.7 V to 5.5 V
Power-supply current rating	400 mA

1.2 Quick Start Board Setup

The DRV2624EVM-CT firmware contains haptic waveforms which showcase the features and benefits of the DRV2624. Follow the instructions below to begin the demo:

1. Out of the box, the jumpers are set to begin demo mode using USB power. The default jumper settings are found in the table below.

Jumper	Default Position	Description
J3	Short pin 2-3	Powers using USB
J2	Short pin 2-3	USB power to DVDD
J5	Shorted	Level translator
J17	Open	Trigger/NRST for DRV2624
J7	Shorted	Bypass the I-Sense
J8	Shorted	Motor+ terminal
J9	Shorted	Motor- terminal
J4	Open	SDA/SCL connections to debug/Monitor advanced operations

2. Connect the included micro-USB cable to the USB connector on the DRV2624EVM-CT board.
3. Connect the other end of the USB cable to an available USB port on a computer, USB charger, or USB battery pack.
4. If the board is powered correctly, the LEDs will blink and the LRA and the ERM actuator will spin and stop at the start up.

2 DRV2624 Demonstration Program

The sections below provide a detailed description of the demo modes and effects.

2.1 Modes and Effects Table

The effects preloaded on the DRV2624EVM-CT are listed in [Table 1](#). The modes are selected using the + and – mode buttons in the center of the board. The current mode is identified by the white LEDs directly above the mode buttons. Buttons B1–B4 trigger the effects listed in the description column and change based on the selected mode.

Table 1. Mode and Effects Table

Mode	Button	Description	Actuator	Waveform Location	Interface
Mode 0 LEDs Off	B1	Sharp Click	ERM	RAM	Internal Trigger (I ² C)
	B2	Sharp Click	LRA		
	B3	PulsingSharp	ERM		
	B4	PulsingSharp	LRA		
Mode 1 LED M1 On	B1	Soft Bump	ERM	RAM	Internal Trigger (I ² C)
	B2	Soft Bump	LRA		
	B3	Double Click	ERM		
	B4	Double Click	LRA		
Mode 2 LED M2 On	B1	Heartbeat x 3	ERM	RAM	Internal Trigger (I ² C)
	B2	Heartbeat x 3	LRA		
	B3	Buzz Alert 750mS	LRM		
	B4	Buzz Alert 750mS	ERA		
Mode 3 LED M3 On	B1	Closed Loop RTP 7F Buzz	LRA	RAM	RTP (I ² C)
	B2	Open Loop Pulsing with Auto Brake	LRA		RTP (I ² C)
	B3	Sine Wave Buzz RTP 7F	LRA		RTP (I ² C)
	B4	Open Loop Pulsing with no Auto Brake	LRA		RTP (I ² C)
Mode 4 LED M1 On	B1	RTP Strength change on position of the wheel	ERM and LRA	RAM	RTP (I ² C)
	B2				
	B3				
	B4				
	T1 Button	Toggle ERM/LRA			Trigger One wire

2.2 Description of the Demo Modes

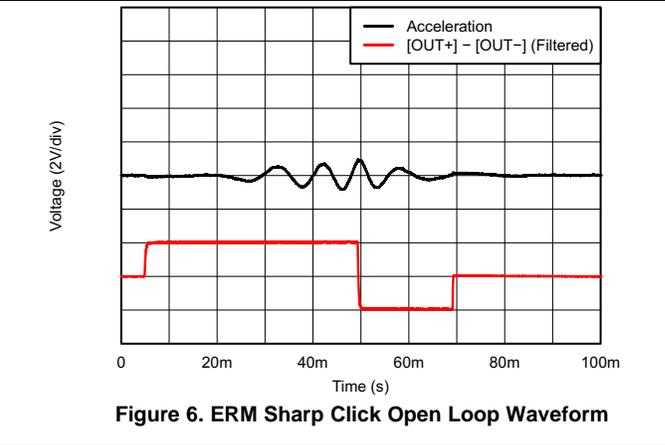
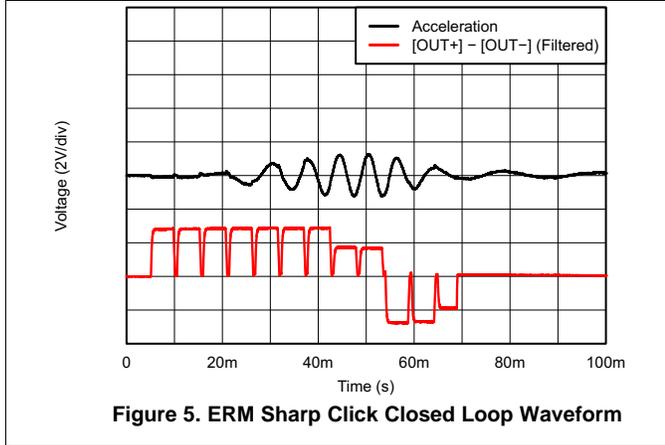
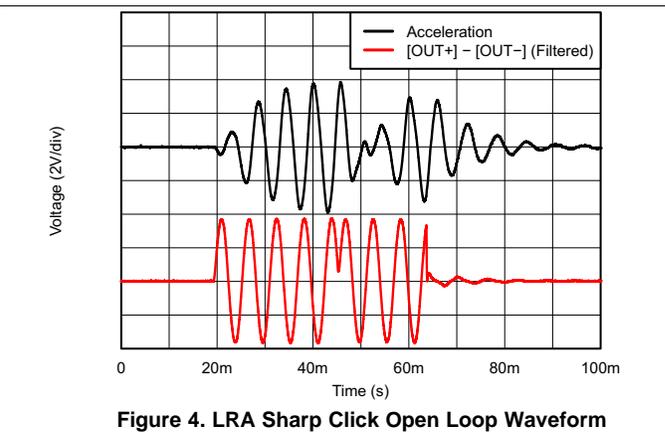
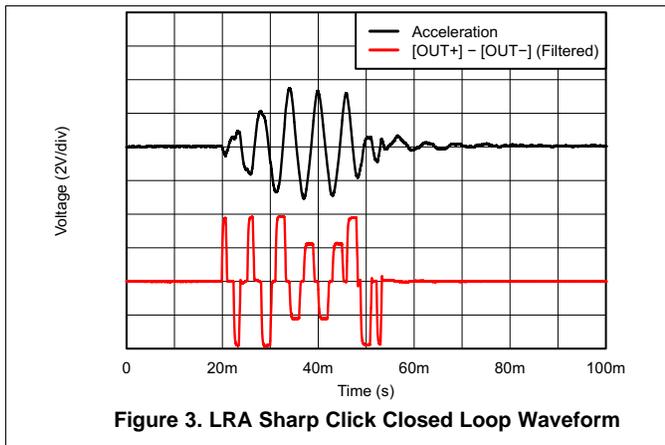
The following section highlights different features and benefits of using the DRV2624.

2.2.1 Mode Off – Haptics Effect Sequences

Below are a set of ERM and LRA Sharp Click waveforms. The four effects below show the difference between closed and open loop operation for both ERM and LRA.

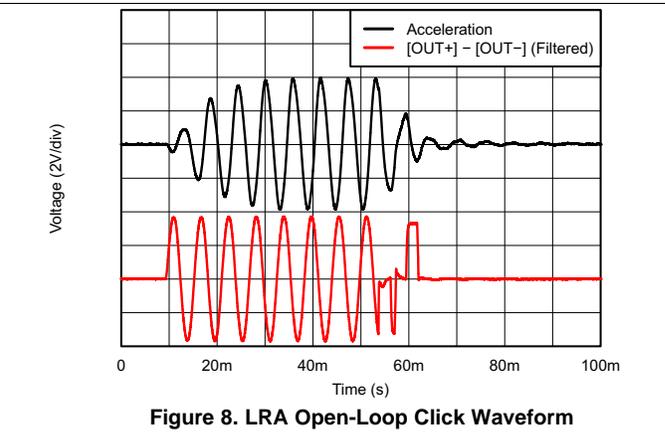
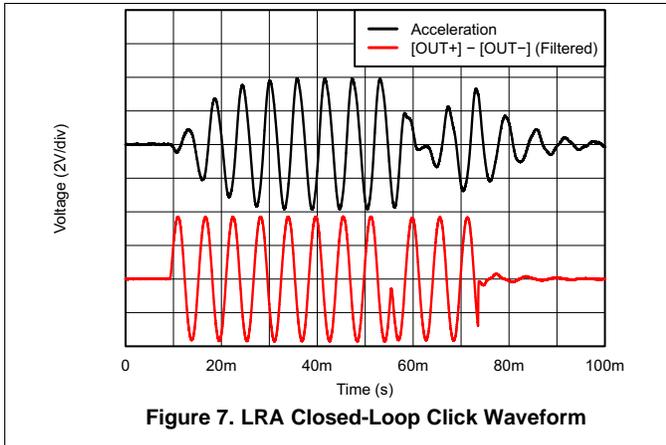
In closed-loop operation for ERM's, the driver automatically overdrives and brakes the actuator. In open-loop, the waveform must be predefined with overdrive and braking.

For LRA's in closed-loop, the driver automatically tracks the resonant frequency, and overdrives and brakes the actuator. In open-loop, the waveform must be predefined with a static drive frequency, and overdrive and braking times.



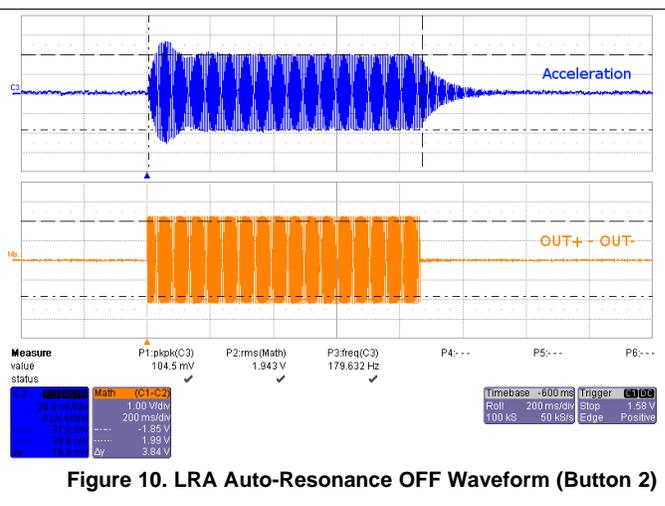
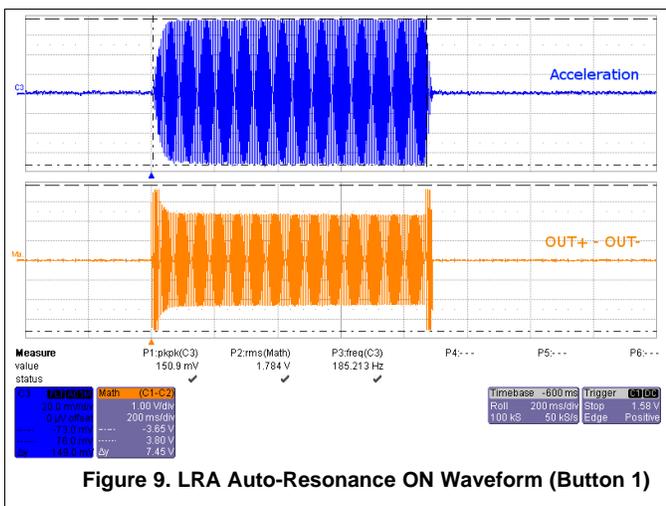
2.2.2 Automatic Braking in Open Loop

The DRV2624 offers automatic braking in open-loop operation for both ERM and LRA. See [Figure 7](#) and [Figure 8](#) below for two separate LRA waveforms that show the advantage of using closed-loop breaking out of open loop operation. Notice that the settling time of the waveform with automatic braking is 15 ms, significantly faster than the 40-ms time achieved without automatic braking enabled.



2.2.3 Auto-Resonance Tracking

Figure 9 and Figure 10 below showcase the advantages of the Smart Loop Architecture which includes auto-resonance tracking, automatic overdrive, and automatic braking. The two images below show the difference in acceleration between LRA auto-resonance ON and LRA auto-resonance OFF. Notice that the acceleration is higher when driven at the resonant frequency. The auto-resonance ON waveform has 1.32 G of acceleration and the auto-resonance OFF waveform has 0.92 G of acceleration. The auto-resonance ON waveform has 43% more acceleration.



The reason for higher acceleration can be seen in the acceleration versus frequency graph below. The LRA has a very narrow operating frequency range due to the properties of a spring-mass system. Furthermore, the resonance frequency drifts over various conditions such as temperature and drive voltage. With the Smart Loop auto-resonance feature, the DRV2624 dynamically tracks the exact resonant frequency to maximize the vibration force.

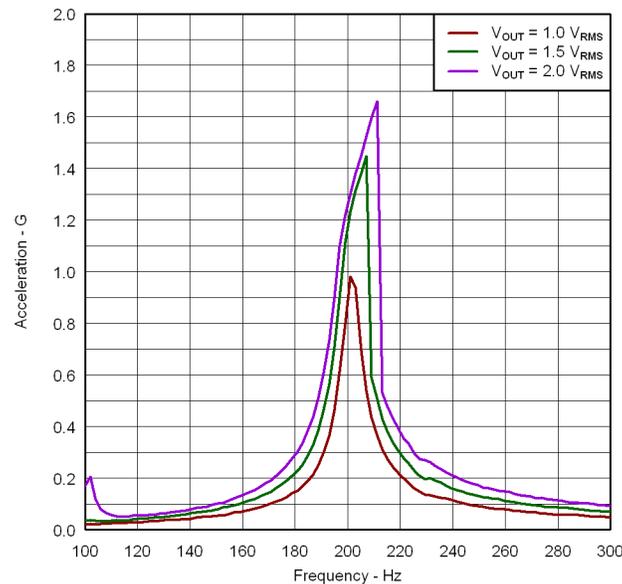


Figure 11. Acceleration Versus Frequency

3 Additional Hardware Modes

Additional modes are available on the DRV2624EVM-CT providing increased board control and functionality.

3.1 Accessing GUI Mode

The DRV2624EVM-CT has the ability to be controlled via Haptics Control Console. In order to place the EVM into 'GUI Mode', hold down the (+) for approximately 3 seconds. The LED indicators blink, and the right half of the LEDs remain on, indicating that the EVM is in GUI Mode.

3.2 Haptics Control Console GUI

Haptics Control Console (HCC) allows the user to have control over the DRV2624 driver through a number of controls and features.

To control the DRV2624EVM-CT via HCC, connect the EVM to an available port on a computer using the included micro USB cable. Once the EVM is powered on, access GUI Mode by holding down the (+) for approximately 3 seconds as described in [Section 3.1](#).

Open up the latest version of Haptics Control Console, and on the tool bar the USB tab will read out '2.Haptics DRV2624 EVM [version]'. Once the GUI has recognized the DRV2624EVM-CT, press 'Connect' to access the device Console.

Once connected the HCC provides the user flexibility to control the EVM functions through a GUI 'Console', and the ability to read and write to and from the DRV2624 through the 'Register Map' window as seen below in [Figure 12](#) below.

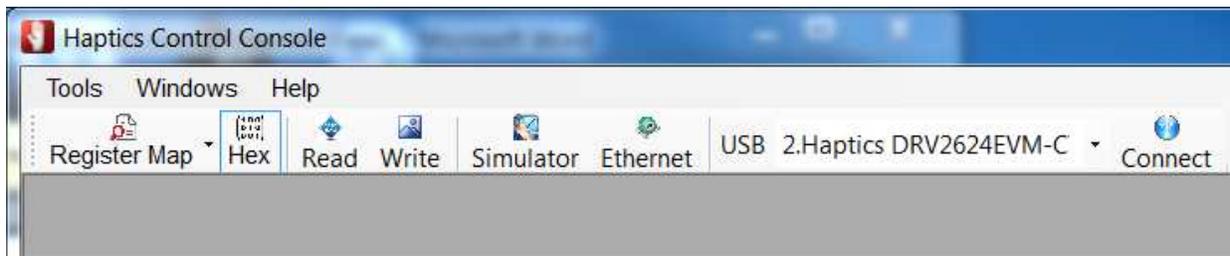


Figure 12. Haptics Control Console

3.2.1 DRV2624 Console

The DRV2624 Console is divided into three sections Initialization, Work Mode, and Board Status, as seen below in Figure 13. Each section allows the user to control the device on the EVM through I2C writes and communication.

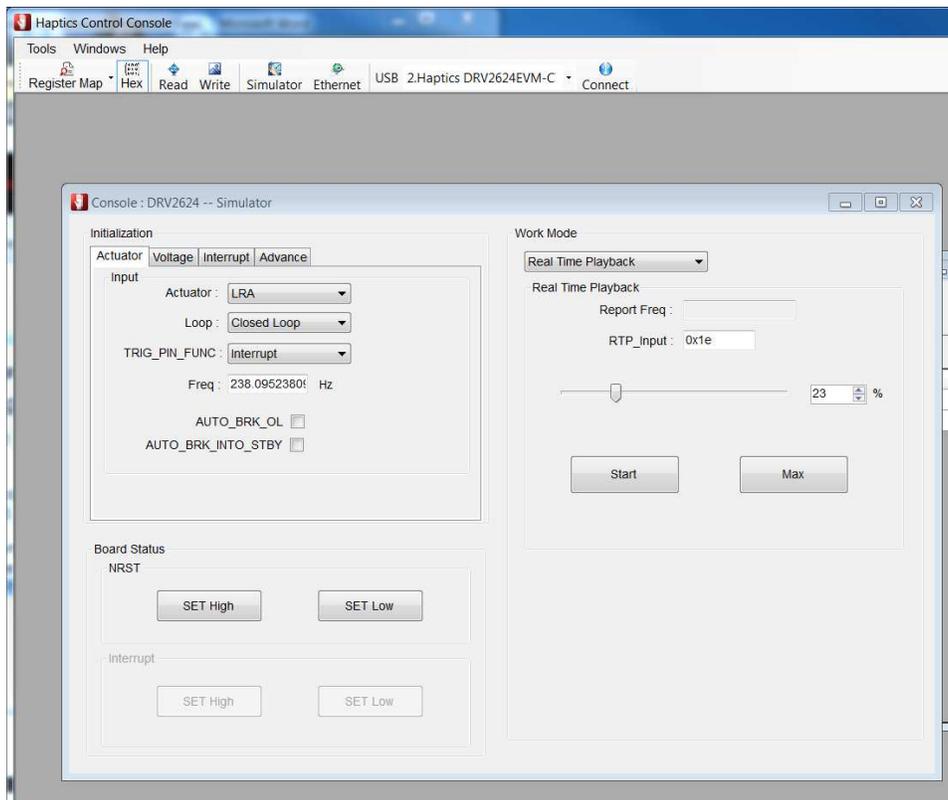


Figure 13. HCC DRV2624 Console

Please refer to the Haptics Control Console Users Guide for more detailed information on the device management features accessible through Haptics Control Console. The user's guide can be found on www.ti.com.

4 Hardware Configuration

The DRV2624EVM-CT is very flexible and can be used to completely evaluate the DRV2624. The following sections list the various hardware configurations.

4.1 Input and Output Overview

The DRV2624EVM-CT allows complete evaluation of the DRV2624 through test points, jacks, and connectors. [Table 2](#) gives a brief description of the hardware.

Table 2. Hardware Overview

Signal	Description	I/O
DRV TRIG	External input or monitor to DRV2624 IN/TRIG pin	Input/Output
NRST	External DRV2624 shutdown control	Input
OUT+/OUT-	Filtered output test points for observation, connect to oscilloscope or measurement equipment	Output
USB	USB power (5 V)	Input
VBAT	External Supply Power (2.5 V – 5.5 V)	Input
SBW	MSP430 programming header	Input/Output
I ² C	DRV2624 and MSP430 I ² C bus	Input/Output

Hardware configuration details can be found in the following sections.

4.2 Power Supply Selection

The DRV2624EVM-CT can be powered by USB and an external power supply (VBAT). Jumpers J3 is used to select USB or VBAT for the DRV2624 and MSP430G2553, respectively. See [Table 3](#) for possible configurations.

Table 3. Power Supply Configurations

Supply Configuration	DRV	MSP	DRV2624 Supply Voltage ⁽¹⁾
USB – Both	USB	USB	5 V
DRV2624 external supply, MSP430 USB	VBAT	USB	VBAT

⁽¹⁾ The DRV2624 supply must be on before operating the MSP430.

4.3 Using an External Actuator

The DRV2624EVM-CT can be used with an external actuator. Follow the instructions below to attach an actuator to the *OUT* terminal block.

1. Remove jumpers J8 and J9 to disconnect the on-board actuators from the DRV2624.
2. Attach the positive and negative leads of the actuator to the green *OUT* terminal block keeping in mind polarity.
3. Screw down the terminal block to secure the actuator leads.

Use the green terminal block when connecting an external actuator. The *OUT+* and *OUT-* test points have low-pass filters and should only be used for oscilloscope and bench measurements.

5 Measurement and Analysis

The DRV2624 uses PWM modulation to create the output signal for both ERM and LRA actuators. To measure and observe the DRV2624 output waveform, connect an oscilloscope or other measurement equipment to the filtered output test points, *OUT+* and *OUT-*.

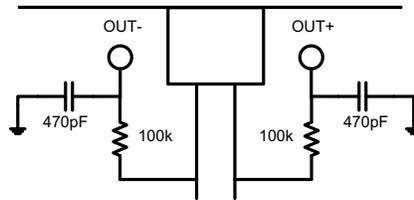


Figure 14. Terminal Block and Test Points

The DRV2624 drives LRA and ERM actuators using a 20-kHz PWM modulated waveform, but only the frequencies around the LRA resonant frequency or the ERM DC drive voltage are relevant to the haptic actuator vibration. The higher frequency switching content does not contribute to the vibration strength of the actuator and can make it difficult to interpret the modulated output waveform on an oscilloscope. The oscilloscope image on the left shows the DRV2624 unfiltered waveform and the image on the right shows a filtered version used for observation and measurement.

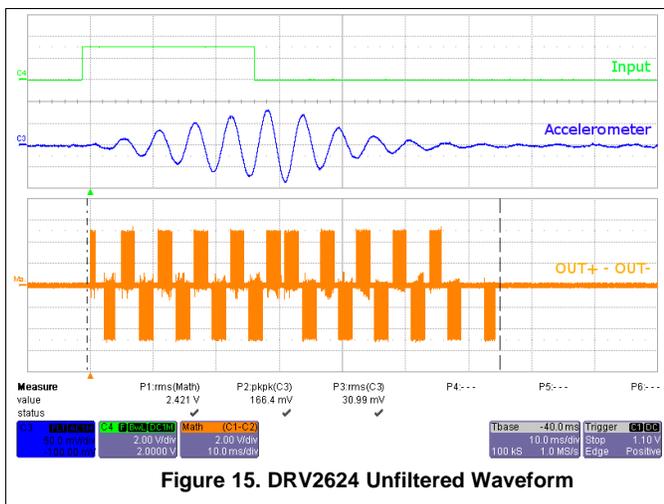


Figure 15. DRV2624 Unfiltered Waveform

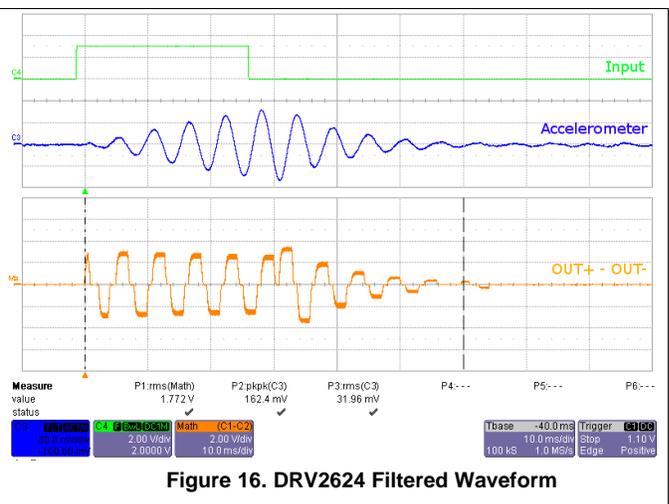


Figure 16. DRV2624 Filtered Waveform

6 Modifying or Reprogramming the Firmware

The MSP430 firmware on the DRV2624EVM-CT can be modified or reprogrammed to create new haptic effects or behaviors. Find the latest firmware source code and binaries on ti.com. Follow the instructions below to modify or reprogram the DRV2624EVM-CT.

1. Purchase one of the following MSP430F5510 compatible programmers:
 - MSP430 64-pin Target Development Board and MSP-FET(MSP-FETU64USB)
 - MSP-FET MCU Programmer and Debugger
2. Download and install Code Composer Studio (CCS) or IAR Embedded Workbench IDE.
3. Download the DRV2624EVM-CT source code and binaries from ti.com.
4. Connect the programmer to an available USB port.
5. Connect the programmer to the J6 header on the DRV2624EVM-CT.
6. In CCS,
 - a. Open the project file by selecting Project→Import Existing CCS Project.
 - b. Select **Browse** and navigate to the DRV2624EVM-CT project folder, then press **OK**.
 - c. Select the checkbox next to the DRV2624EVM-CT project in the *Discovered projects* window and then press **Finish**.
 - d. Before compiling, navigate to Project→Properties→Build→MSP430 Compiler→Advanced Options→Language Options and make sure the checkbox for *Enable support for GCC extensions (-gcc)* is checked.
7. In IAR,
 - a. Create a new MSP430 project in IAR,
 - b. Select the MSP430F5510 device,
 - c. Copy the files in the project folder downloaded from ti.com to the new project directory.

Figure 17 shows the connection between the MSP430 Programmer and Debugger (MSP-FET) and the DRV2624EVM-CT.

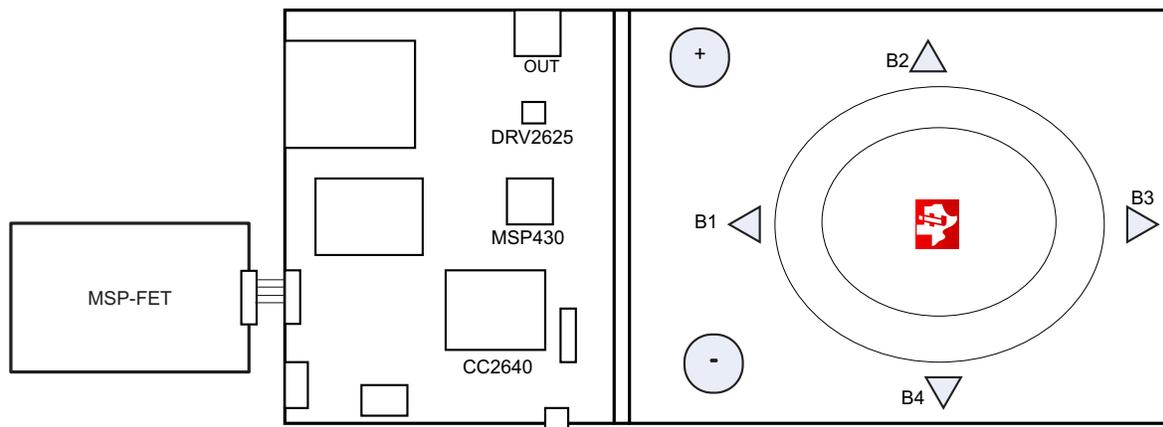


Figure 17. FET Programmer Connection

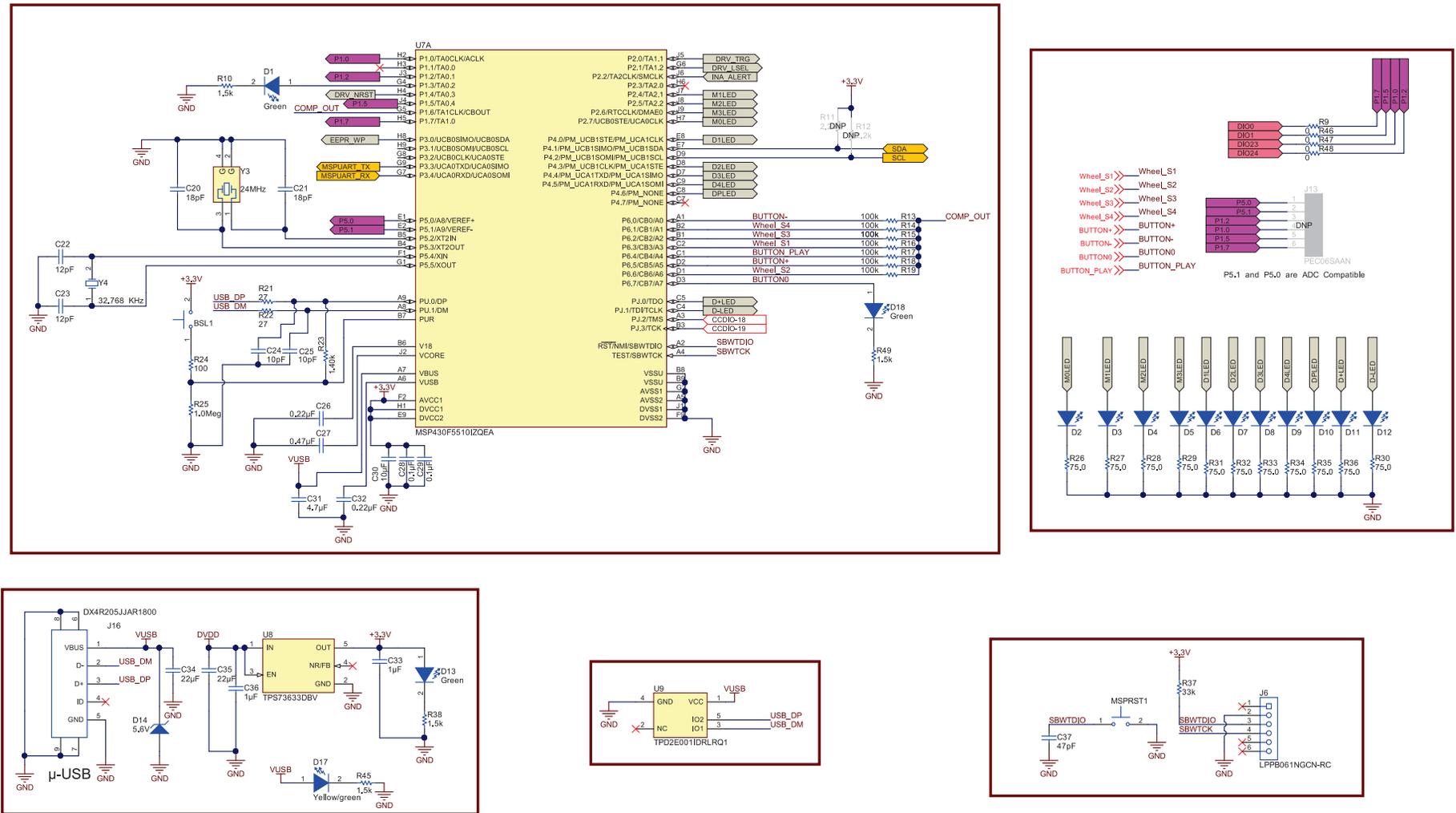


Figure 19. DRV2624EVM-CT Schematic Page 2

8 Layout

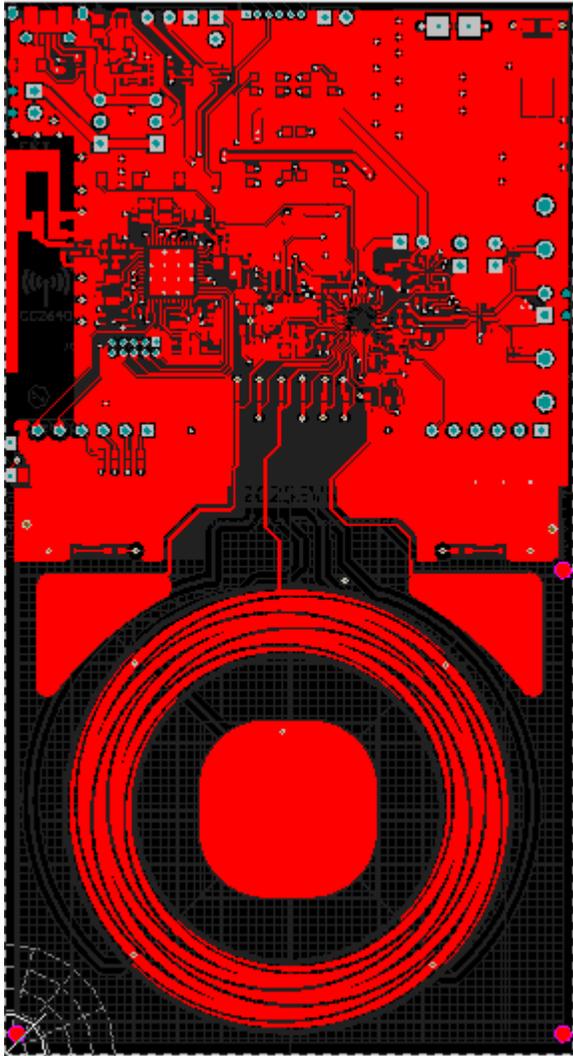


Figure 20. Top Layer

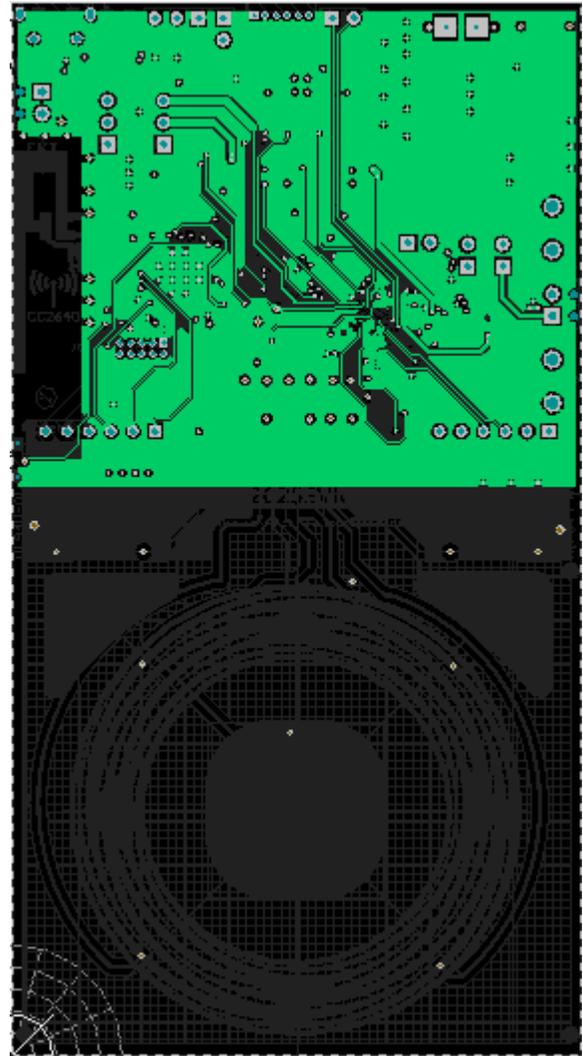


Figure 21. Layout Layer 2

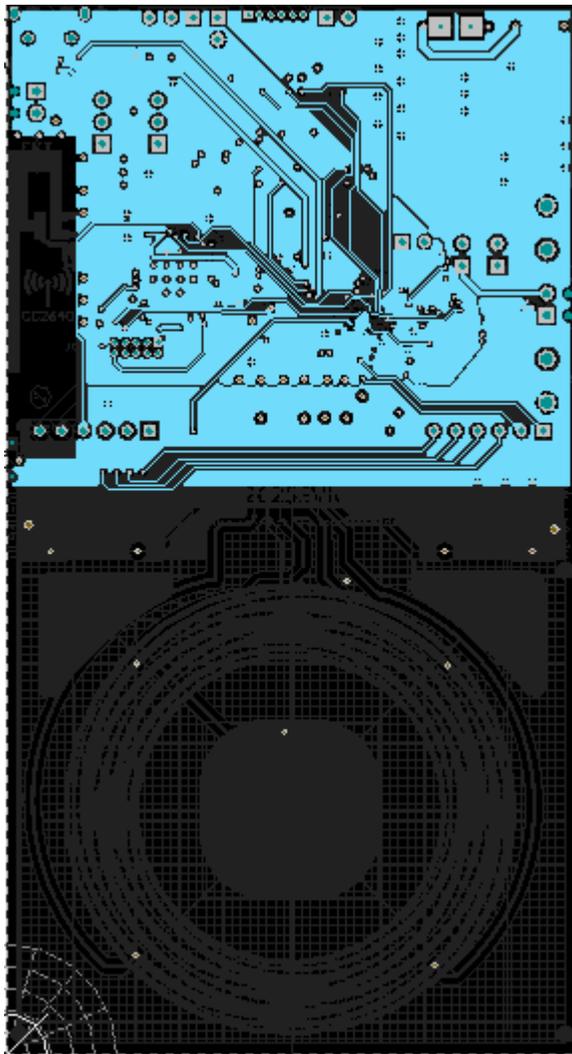


Figure 22. Layout Layer 3

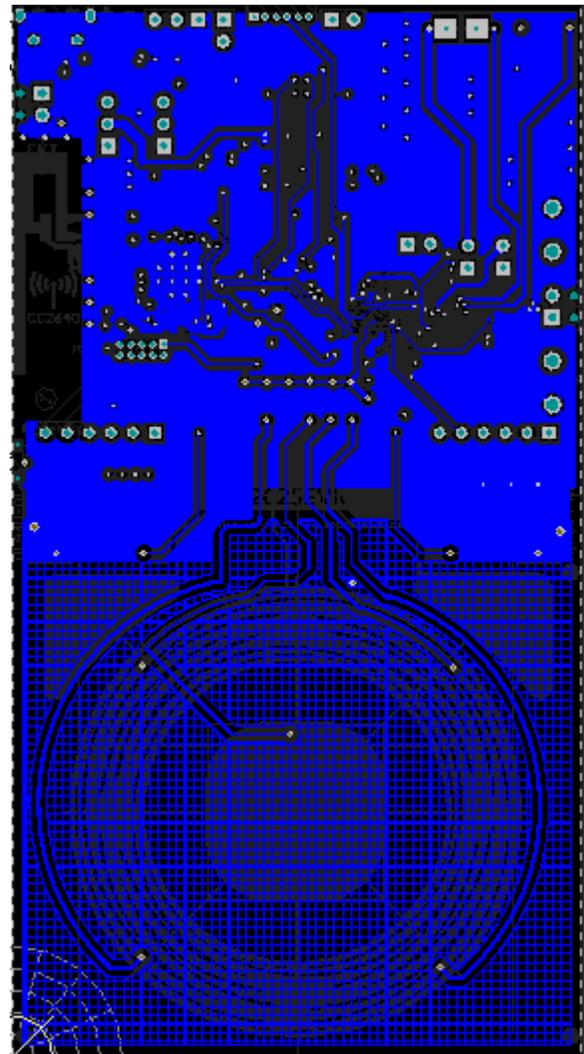


Figure 23. Layout Layer 4

9 Bill of Materials

Item #	Designator	Quantity	Value	Part Number	Manufacturer	Description	Package Reference
1	IPC B1	1		AIP044	Any	Printed Circuit Board	
2	ANT1, ANT4, L2, L3	4	2.4nH	LQG15HS2N4S02D	MuRata	Inductor, Multilayer, Air Core, 2.4 nH, 0.3 A, 0.15 ohm, SMD	0402 polarized
3	ANT3, C15, C18	3	1pF	GRM1555C1H1R0CA01D	MuRata	CAP, CERM, 1 pF, 50 V, +/- 5%, C0G/NP0, 0402	0402
4	ANT5, R3, R4, R6, R7, R9, R39, R40, R46, R47, R48	11	0	CRCW04020000Z0ED	Vishay-Dale	RES, 0, 5%, 0.063 W, 0402	0402
5	ANT6	1	0.5pF	GRM1555C1HR50BA01D	MuRata	CAP, CERM, 0.5 pF, 50 V, +/- 20%, C0G, 0402	0402
6	BSL1, MSPRST1	2		TL1015AF160QG	E-Switch	Switch, Tactile, SPST-NO, 0.05A, 12V, SMT	Switch, 4.4x2x2.9 mm
7	C1, C2	2	470pF	C1005C0G1H471J	TDK	CAP, CERM, 470 pF, 50 V, +/- 5%, C0G/NP0, 0402	0402
8	C3, C4, C19, C38, C39, C40, C41, C42, C43, C44, C45	11	0.1uF	GRM155R71C104KA88D	MuRata	CAP, CERM, 0.1 uF, 16 V, +/- 10%, X7R, 0402	0402
9	C5	1	0.27uF	GRM155R61A274KE15D	MuRata	CAP, CERM, 0.27 uF, 10 V, +/- 10%, X5R, 0402	0402
10	C6, C7, C8, C28, C29	5	0.1uF	GRM155R61C104KA88D	MuRata	CAP, CERM, 0.1uF, 16V, +/-10%, X5R, 0402	0402
11	C9, C30	2	10uF	GRM155R61A106ME44	MuRata	CAP, CERM, 10 uF, 10 V, +/- 20%, X5R, 0402	0402
12	C10, C33, C36	3	1uF	GRM155R61A105KE15D	MuRata	CAP, CERM, 1 uF, 10 V, +/- 10%, X5R, 0402, CAP, CERM, 1uF, 10V, +/-10%, X5R, 0402, CAP, CERM, 1 uF, 10 V, +/- 10%, X5R, 0402	0402
13	C11, C12, C13, C14, C22, C23	6	12pF	GRM1555C1H120JA01D	MuRata	CAP, CERM, 12 pF, 50 V, +/- 5%, C0G/NP0, 0402, CAP, CERM, 12 pF, 50 V, +/- 5%, C0G/NP0, 0402, CAP, CERM, 12 pF, 50 V, +/- 5%, C0G/NP0, 0402, CAP, CERM, 12pF, 50V, +/-5%, C0G/NP0, 0402, CAP, CERM, 12pF, 50V, +/-5%, C0G/NP0, 0402	0402
14	C16, C17	2	15pF	GRM1555C1H150JA01D	MuRata	CAP, CERM, 15 pF, 50 V, +/- 5%, C0G/NP0, 0402	0402
15	C20, C21	2	18pF	GRM1555C1H180JA01D	MuRata	CAP, CERM, 18pF, 50V, +/-5%, C0G/NP0, 0402	0402
16	C24, C25	2	10pF	GRM1555C1H100JA01D	MuRata	CAP, CERM, 10pF, 50V, +/-5%, C0G/NP0, 0402	0402
17	C26, C32	2	0.22uF	GRM155R71C224KA12D	MuRata	CAP, CERM, 0.22uF, 16V, +/-10%, X7R, 0402	0402
18	C27	1	0.47uF	GRM155R61C474KE01	MuRata	CAP, CERM, 0.47uF, 16V, +/-10%, X5R, 0402	0402
19	C31	1	4.7uF	GRM155R61A475M	MuRata	CAP, CERM, 4.7uF, 10V, +/-20%, X5R, 0402	0402
20	C34, C35	2	22uF	GRM21BR61C226ME44	MuRata	CAP, CERM, 22 uF, 16 V, +/- 20%, X5R, 0805	0805
21	C37	1	47pF	GRM1555C1E470JA01D	MuRata	CAP, CERM, 47pF, 25V, +/-5%, C0G/NP0, 0402	0402
22	C46	1	10uF	GRM155R61A106ME21D	MuRata	CAP, CERM, 10 uF, 10 V, +/- 20%, X5R, 0402	0402
23	D1, D13, D18	3	Green	LTST-C190GKT	Lite-On	LED, Green, SMD	1.6x0.8x0.8mm
24	D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12	11		SML312WBCW1	Rohm	LED, White, SMD	LED, 0603
25	D14	1	5.6V	MMSZ5232B-7-F	Diodes Inc.	Diode, Zener, 5.6V, 500 mW, SOD-123	SOD-123
26	D15	1	Green	150060VS75000	Würth Elektronik eiSos	LED, Green, SMD	LED_0603
27	D16	1	Blue	LB Q39G-L2N2-35-1	OSRAM	LED, Blue, SMD	BLUE 0603 LED
28	D17	1	Yellow/green	SML-P12MTT86	Rohm	LED, Yellow/green, SMD	0402 LED
29	H1	1		ELV1036A	AAC	AAC1036 LRA Actuator	Used in PnP output
30	H2	1		TI-EVACASE-BLACK	Royal Case	TI Black EVA Case	Used in PnP output
31	H3	1		3-5-468MP	3M	TAPE TRANSFER ADHESIVE 3" X 5YD	Used in PnP output
32	H4	1		2-5-4466W	3M	TAPE POLY FOAM 2" x 5YD	Used in PnP output

Item #	Designator	Quantity	Value	Part Number	Manufacturer	Description	Package Reference
65	U5	1		TS5A12301EYFP	Texas Instruments	IEC LEVEL 4 ESD-PROTECTED 0.75-O SPDT ANALOG SWITCH WITH 1.8-V COMPATIBLE INPUT LOGIC, YFP0006AAAA	YFP0006AAAA
66	U6	1		TXS0102DCT	Texas Instruments	2-BIT BIDIRECTIONAL VOLTAGE-LEVEL TRANSLATOR FOR OPEN-DRAIN AND PUSH-PULL APPLICATIONS, DCT0008A	DCT0008A
67	U7	1		MSP430F5510IZQEA	Texas Instruments	25 MHz Mixed Signal Microcontroller with 32 KB Flash, 4096 B SRAM and 47 GPIOs, -40 to 85 degC, 80-pin BGA (ZQE), Green (RoHS & no Sb/Br)	ZQE0080A
68	U8	1		TPS73633DBV	Texas Instruments	Cap-Free, NMOS, 400mA Low-Dropout Regulator with Reverse Current Protection, DBV0005A	DBV0005A
69	U9	1		TPD2E001IDRLRQ1	Texas Instruments	Automotive Catalog Low-Capacitance + / - 15 kV ESD-Protection Array for High-Speed Data Inter, 2 Channels, -40 to +85 degC, 5-pin SOT (DRL), Green (RoHS & no Sb/Br)	DRL0005A
70	Y1	1		FC-135 32.7680KA-A3	Epson	Crystal, 32.768 KHz, 12.5 pF, SMD	SMD, 2-Leads, Body 3.2x1.5mm
71	Y2	1		TSX-3225 24.0000MF20G-AC3	Epson	Crystal, 24 MHz, 9 pF, SMD	SMD, 4-Leads, Body 2.65x3.35mm, Height 0.6mm
72	Y3	1		ABM8-24.000MHZ-B2-T	Abracon Corporation	Crystal, 24.000MHz, 18pF, SMD	3.2x0.8x2.5mm
73	Y4	1		FC-12M 32.7680KD-A3	Epson	Crystal, 32.768kHz, 12.5pF, SMD	Crystal 2.05x.6x1.2mm
74	FID1, FID2, FID3	0		N/A	N/A	Fiducial mark. There is nothing to buy or mount.	Fiducial
75	J12, J13	0		PEC06SAAN	Sullins Connector Solutions	Header, 100mil, 6x1, Tin, TH	TH, 6-Leads, Body 608x100mil, Pitch 100mil
76	R8	0	0	CRCW04020000Z0ED	Vishay-Dale	RES, 0, 5%, 0.063 W, 0402	0402
77	R11, R12	0	2.2k	CRCW04022K20JNED	Vishay-Dale	RES, 2.2k ohm, 5%, 0.063W, 0402	0402

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (December 2016) to A Revision	Page
• Changed 'ROM' to 'RAM' in Waveform Location column in the Table 1 table.....	5
• Deleted 'ROM Library Mode' and 'Waveform Library Effects List' sections	8

Changes from A Revision (March 2017) to B Revision	Page
• Deleted section: <i>Accessing Bluetooth Mode</i>	8

1 Trademarks

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 - 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:*
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 - 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 DEGRADATION 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/lstds/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/lstds/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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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.

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- 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.
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