

DRV2625 ERM, LRA Haptic Driver Evaluation Kit

The DRV2625 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 DRV2625EVM-CT Evaluation Module (EVM) is a complete demo and evaluation platform for the DRV2625. 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 DRV2625.

This document contains instructions to setup and operate the DRV2625EVM-CT in demo and evaluation mode.



Figure 1. DRV2625EVM-CT Board

Evaluation Kit Contents:

- DRV2625EVM-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
- DRV2625EVM-CT firmware available on ti.com

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1 Getting Started

The DRV2625 can be used as a demonstration or evaluation tool. When the DRV2625EVM-CT evaluation module is powered on for the first time, a demo application automatically starts. To power the board, connect the DRV2625EVM-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.

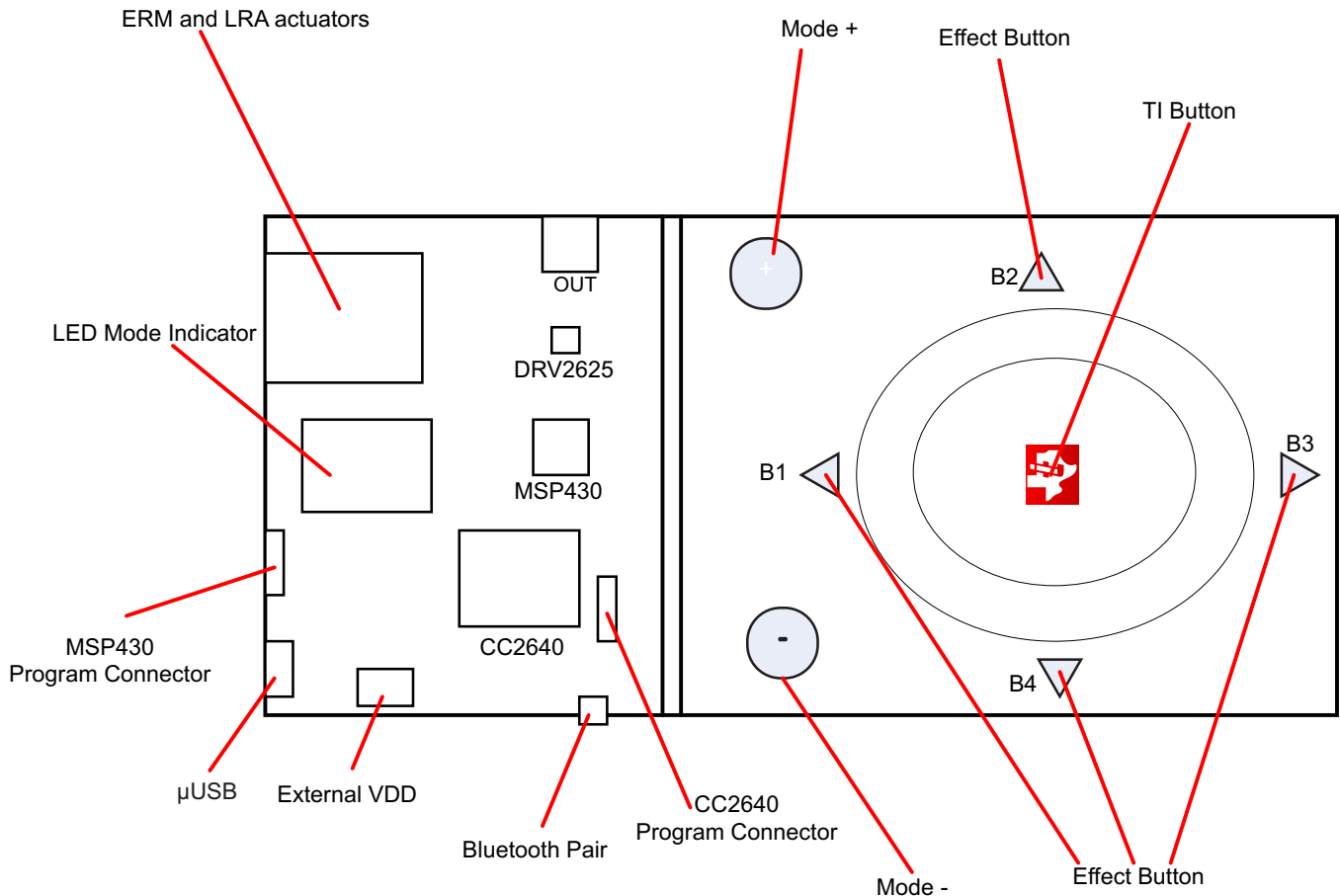


Figure 2. Board Diagram

1.1 Evaluation Module Operating Parameters

The following table lists the operating conditions for the DRV2625 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 DRV2625EVM-CT firmware contains haptic waveforms which showcase the features and benefits of the DRV2625. 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 DRV2625
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 DRV2625EVM-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 DRV2625 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 DRV2625EVM-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	ROM	Internal Trigger (I ² C)
	B2	Sharp Click	LRA		
	B3	PulsingSharp	ERM		
	B4	PulsingSharp	LRA		
Mode 1 LED M1 On	B1	Soft Bump	ERM	ROM	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	ROM	Internal Trigger (I ² C)
	B2	Heartbeat x 3	LRA		
	B3	Buzz Alert 750 mS	LRA		
	B4	Buzz Alert 750 mS	ERM		
Mode 3 LED M3 On	B1	Closed Loop RTP 7F Buzz	LRA	ROM	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	ROM	RTP (I ² C)
	B2				
	B3				
	B4				
	T1 Button	Toggle ERM/LRA			Trigger One wire

2.2 Description of the Demo Modes

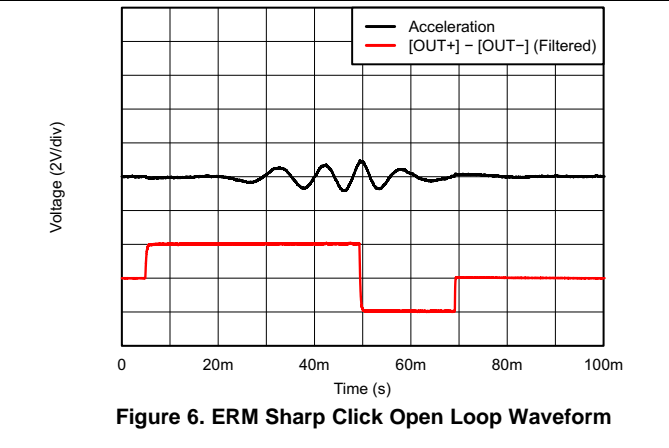
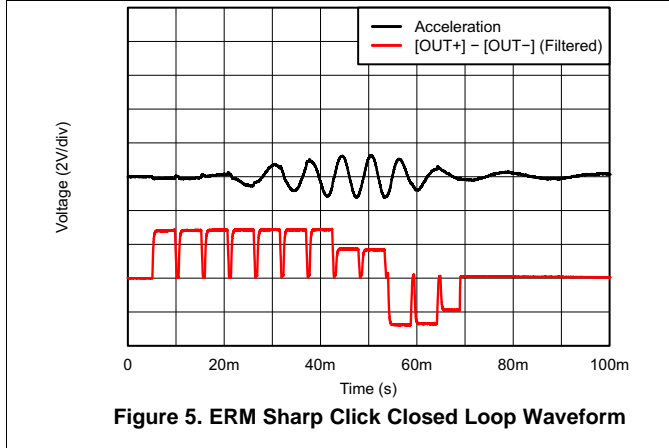
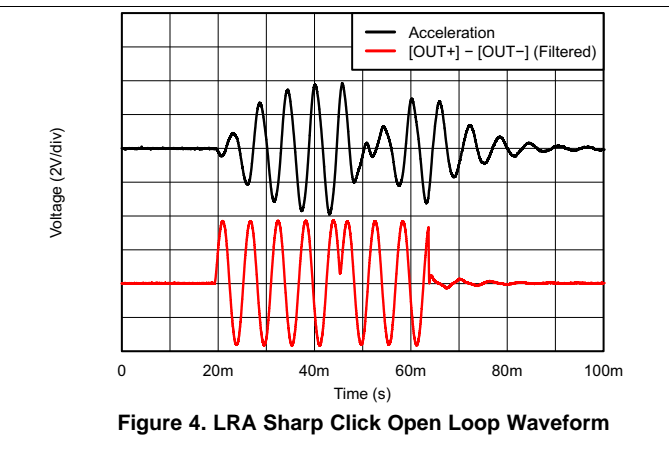
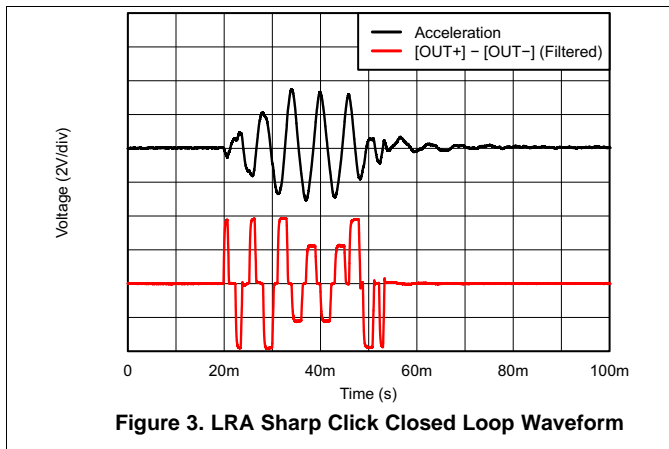
The following section highlights different features and benefits of using the DRV2625.

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.

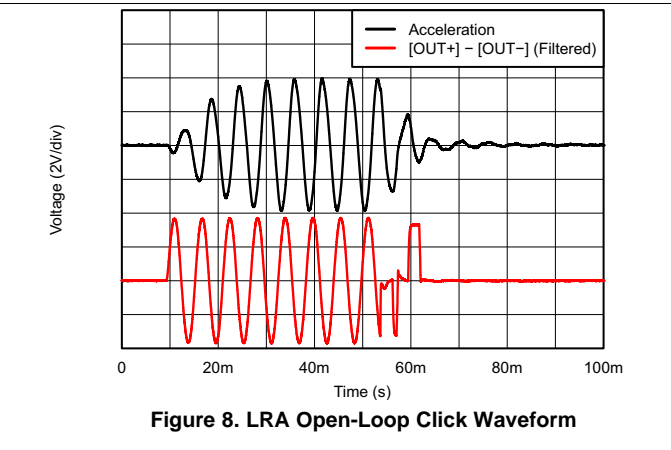
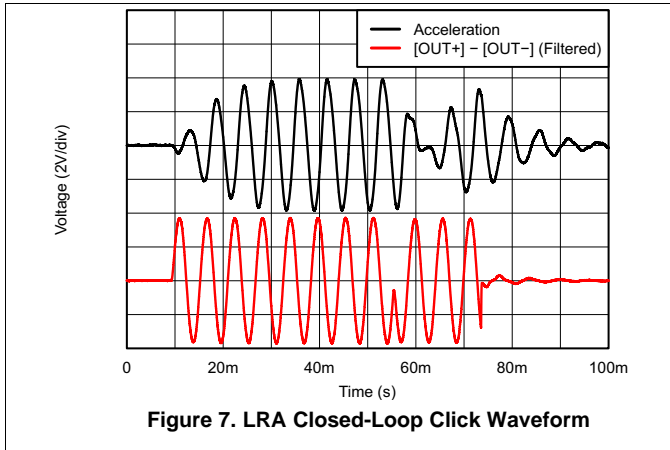
In closed-loop operation for ERM's, the driver automatically overdrives and brakes the actuator. In open-loop, the waveform must be predefined with overdrive and braking.

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.



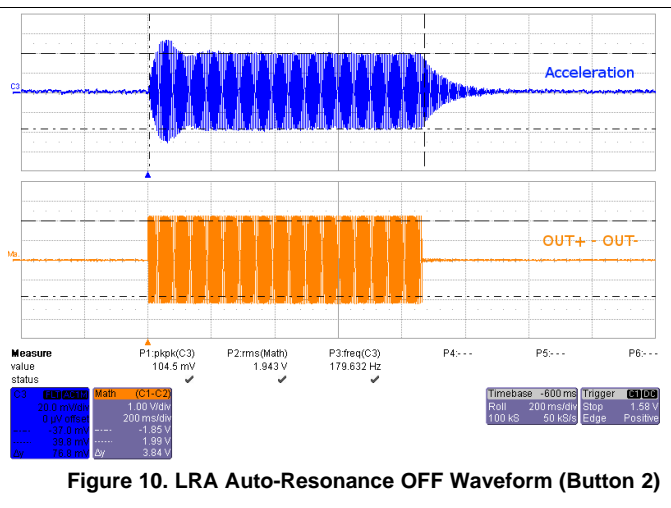
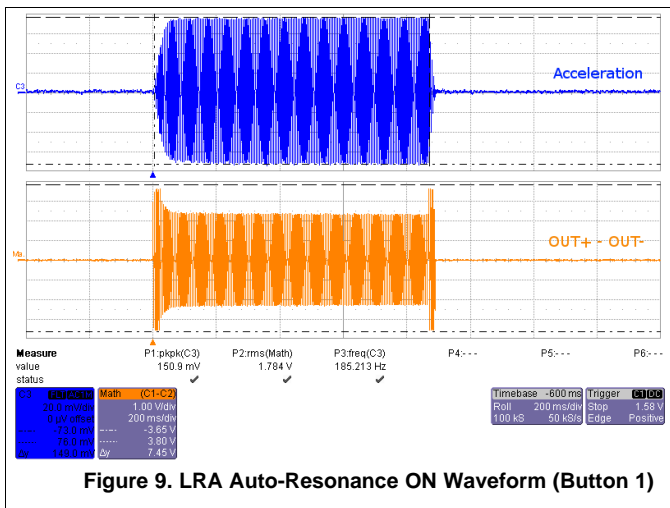
2.2.2 Automatic Braking in Open Loop

The DRV2625 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 DRV2625 dynamically tracks the exact resonant frequency to maximize the vibration force.

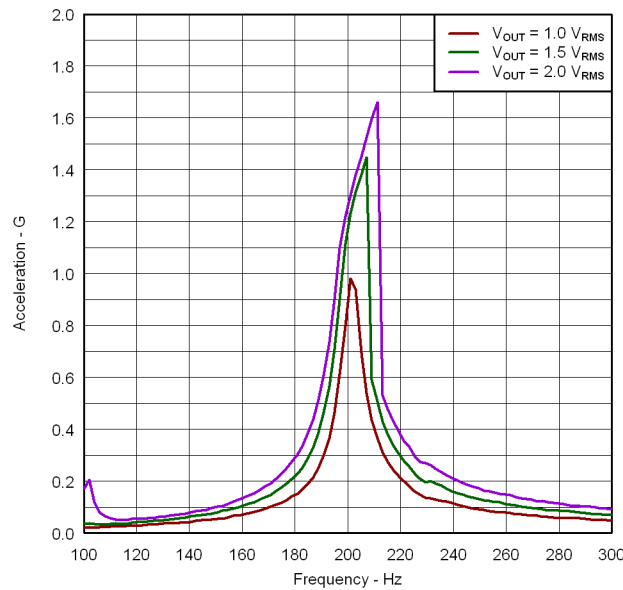


Figure 11. Acceleration Versus Frequency

3 Additional Hardware Modes

Additional modes are available on the DRV2625EVM-CT providing increased board control and functionality.

3.1 Accessing GUI Mode

The DRV2625EVM-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 will blink, and the right half of the LED's will remain on, indicating that the EVM is in GUI Mode.

3.2 Accessing Bluetooth Mode

The DRV2625EVM-CT Evaluation Module also features a mobile app for control over Bluetooth from an iOS app. In order to control the evaluation module via the mobile app, hold down the (-) for approximately 3 seconds. The LED indicators will blink, and the left half of the LED's will remain on, indicating that the EVM is in 'Bluetooth Mode'.

3.3 Haptics Control Console GUI

Haptics Control Console (HCC) allows the user to have control over the DRV2625 driver through a number of controls and features.

To control the DRV2625EVM-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 DRV2625 EVM [version]'. Once the GUI has recognized the DRV2625EVM-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 DRV2625 through the 'Register Map' window as seen below in [Figure 12](#) below.

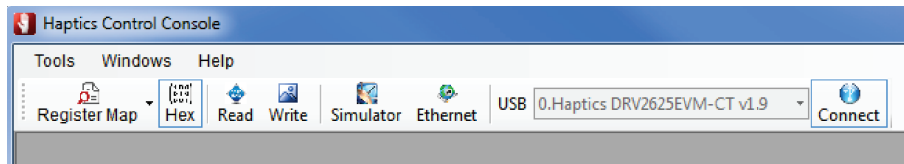


Figure 12. Haptics Control Console

3.3.1 DRV2625 Console

The DRV2625 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.

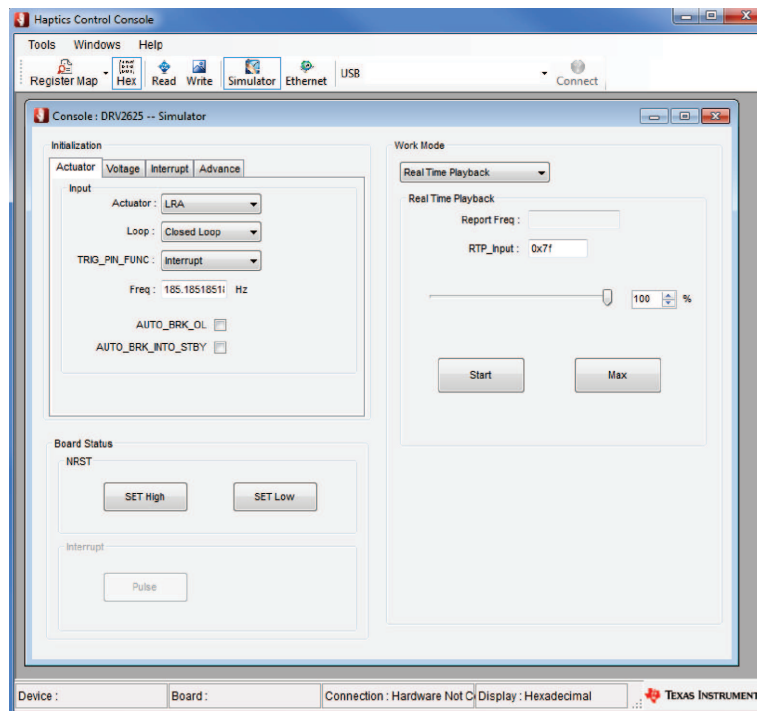


Figure 13. HCC DRV2625 Console

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 DRV2625EVM-CT is very flexible and can be used to completely evaluate the DRV2625. The following sections list the various hardware configurations.

4.1 Input and Output Overview

The DRV2625EVM-CT allows complete evaluation of the DRV2625 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 for DRV2625 IN/TRIG pin	Input/Output
NRST	External DRV2625 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	DRV2625 and MSP430 I ² C bus	Input/Output

Hardware configuration details can be found in the following sections.

4.2 Power Supply Selection

The DRV2625EVM-CT can be powered by USB and an external power supply (VBAT). Jumpers J3 is used to select USB or VBAT for the DRV2625 and MSP430G2553, respectively. See Table 3 for possible configurations.

Table 3. Power Supply Configurations

Supply Configuration	DRV	MSP	DRV2625 Supply Voltage ⁽¹⁾
USB – Both	USB	USB	5 V
DRV2625 external supply, MSP430 USB	VBAT	USB	VBAT

⁽¹⁾ The DRV2625 supply must be on before operating the MSP430.

4.3 Using an External Actuator

The DRV2625EVM-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 which disconnects the on-board actuators from the DRV2625.
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 DRV2625 uses PWM modulation to create the output signal for both ERM and LRA actuators. To measure and observe the DRV2625 output waveform, connect an oscilloscope or other measurement equipment to the filtered output test points, *OUT+* and *OUT-*.

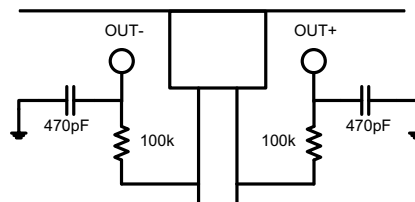


Figure 14. Terminal Block and Test Points

The DRV2625 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 DRV2625 unfiltered waveform and the image on the right shows a filtered version used for observation and measurement.

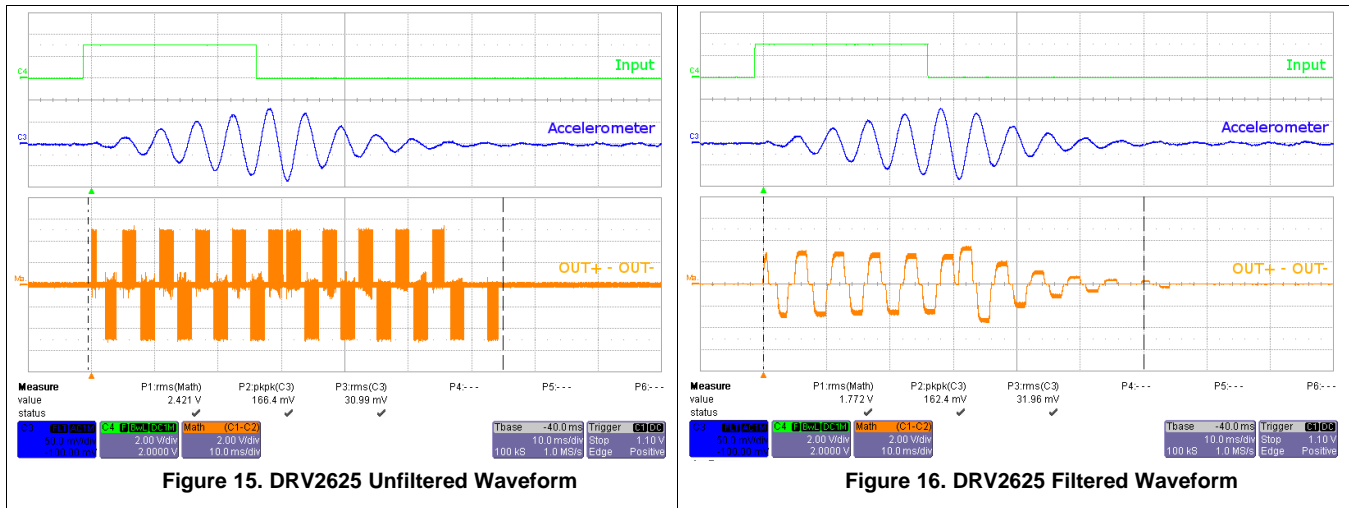


Figure 15. DRV2625 Unfiltered Waveform

Figure 16. DRV2625 Filtered Waveform

6 Modifying or Reprogramming the Firmware

The MSP430 firmware on the DRV2625EVM-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 DRV2625EVM-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 DRV2625EVM-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 DRV2625EVM-CT.
6. In CCS,
 - (a) Open the project file by selecting Project→Import Existing CCS Project.
 - (b) Select **Browse** and navigate to the DRV2625EVM-CT project folder, then press **OK**.
 - (c) Select the checkbox next to the DRV2625EVM-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 below shows the connection between the MSP430 Programmer and Debugger (MSP-FET) and the DRV2625EVM-CT.

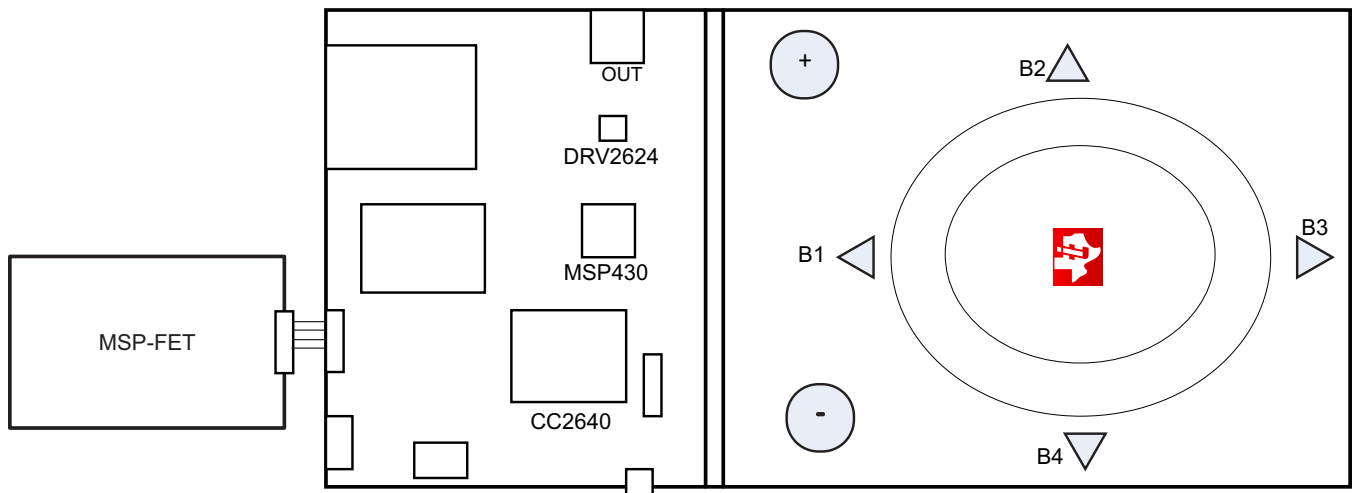


Figure 17. FET Programmer Connection

7 Schematic

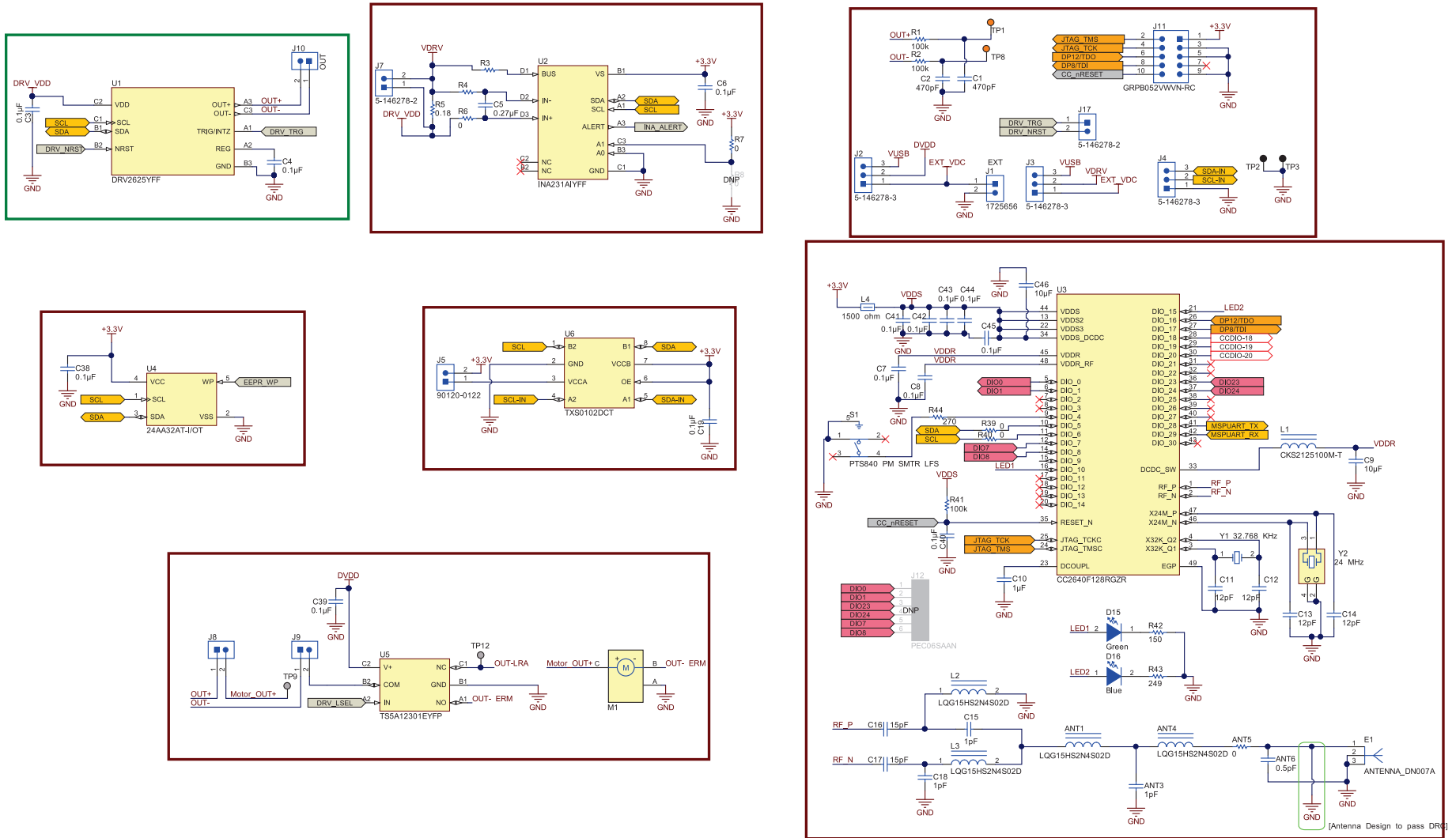


Figure 18. DRV2625EVM-CT Schematic Page 1

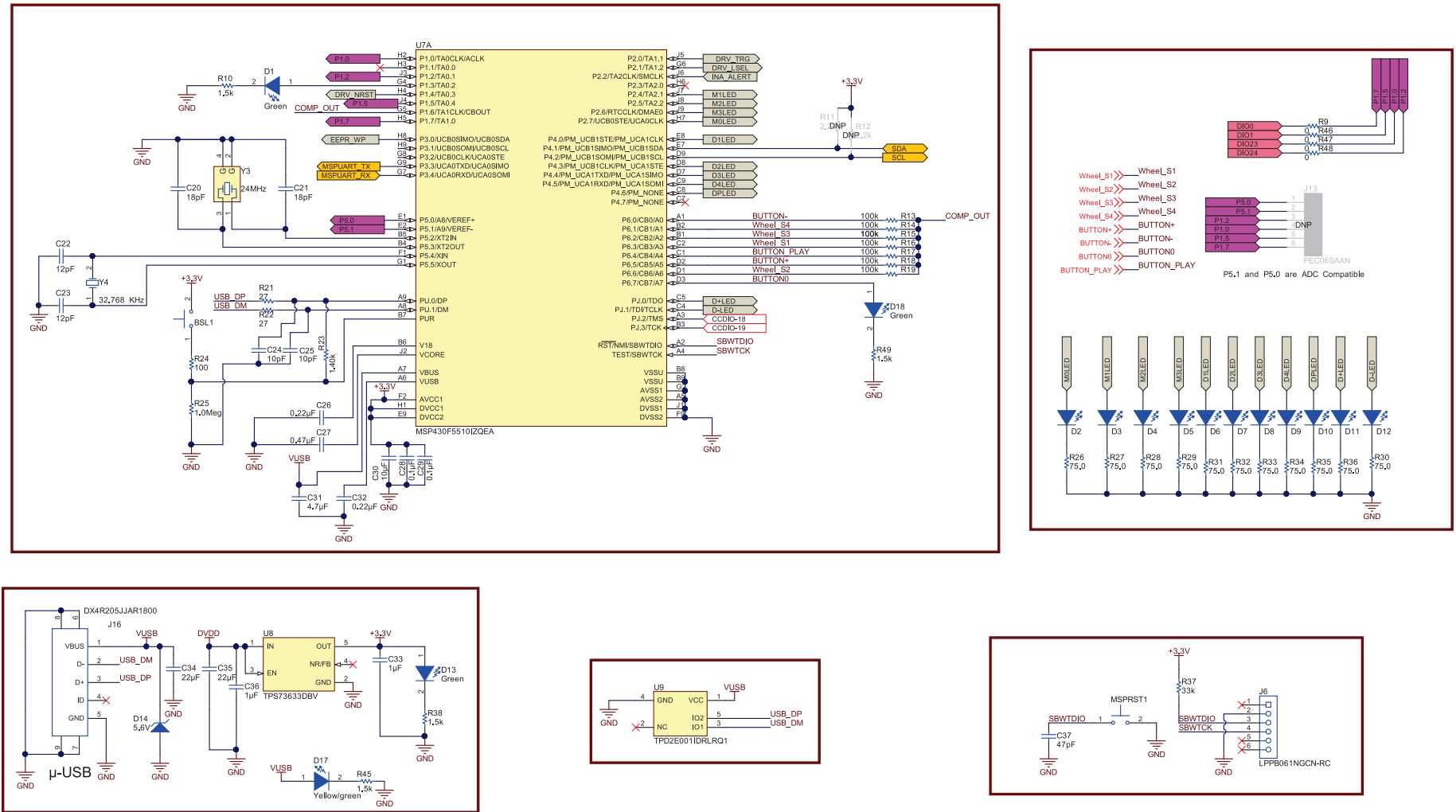


Figure 19. DRV2625EVM-CT Schematic Page 2

8 Layout

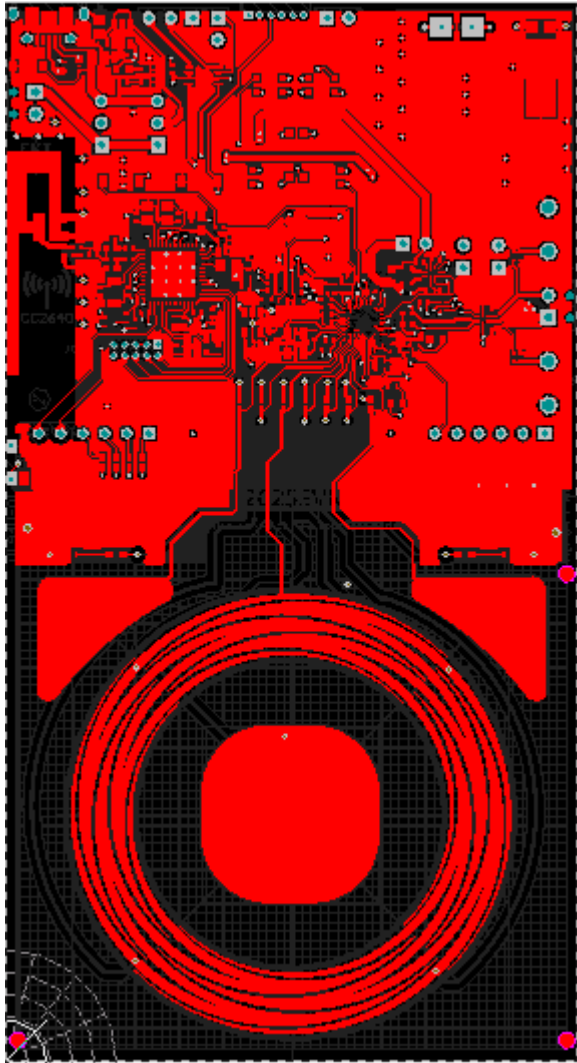


Figure 20. Top Layer

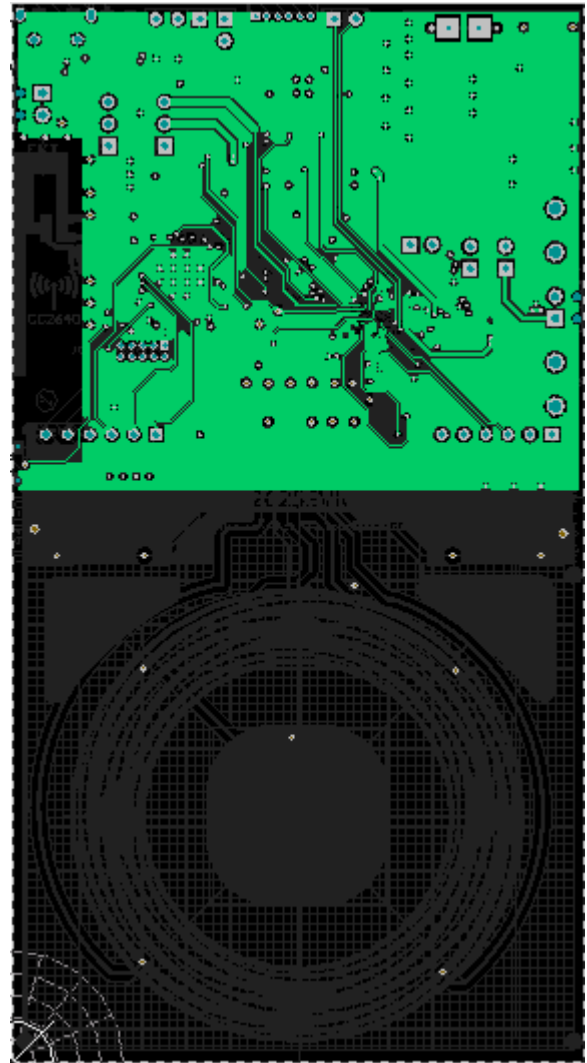


Figure 21. Layout Layer 2

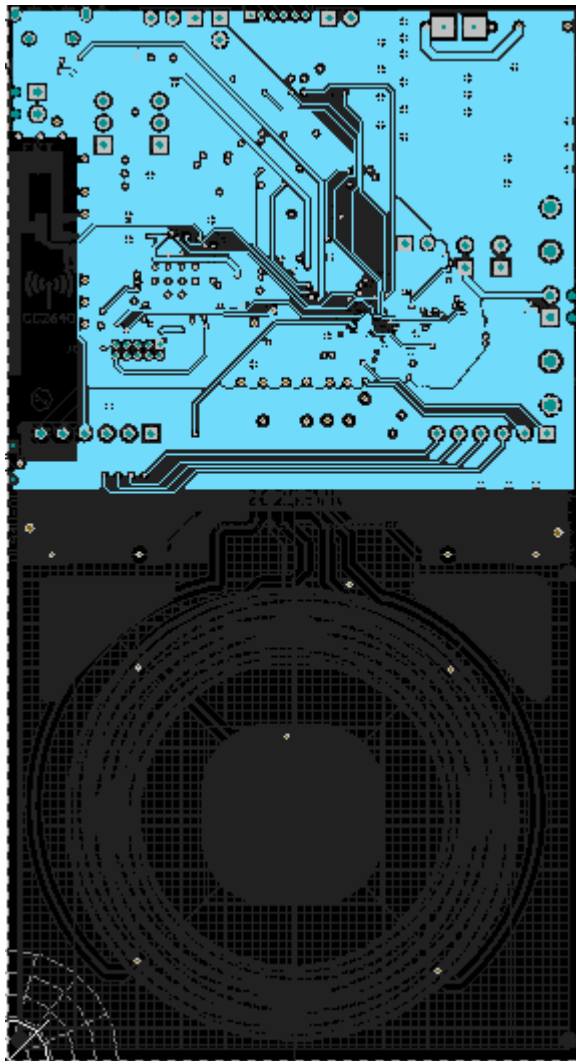


Figure 22. Layout Layer 3

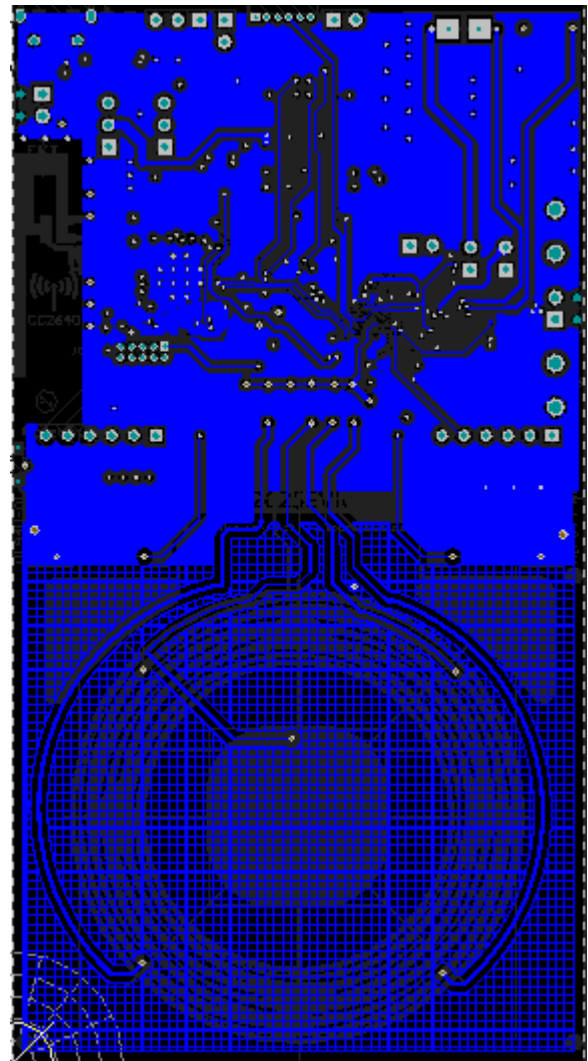


Figure 23. Layout Layer 4

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		TPD2E001DRLRQ1	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 'LRM' to 'LRA' in Actuator column of Mode 2 – B3 row in Table 1	5
• Changed 'ERA' to 'ERM' in Actuator column of Mode 2 – B4 in Table 1	5
• Deleted 'ROM Library Mode' and 'Waveform Library Effects List' sections	8

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