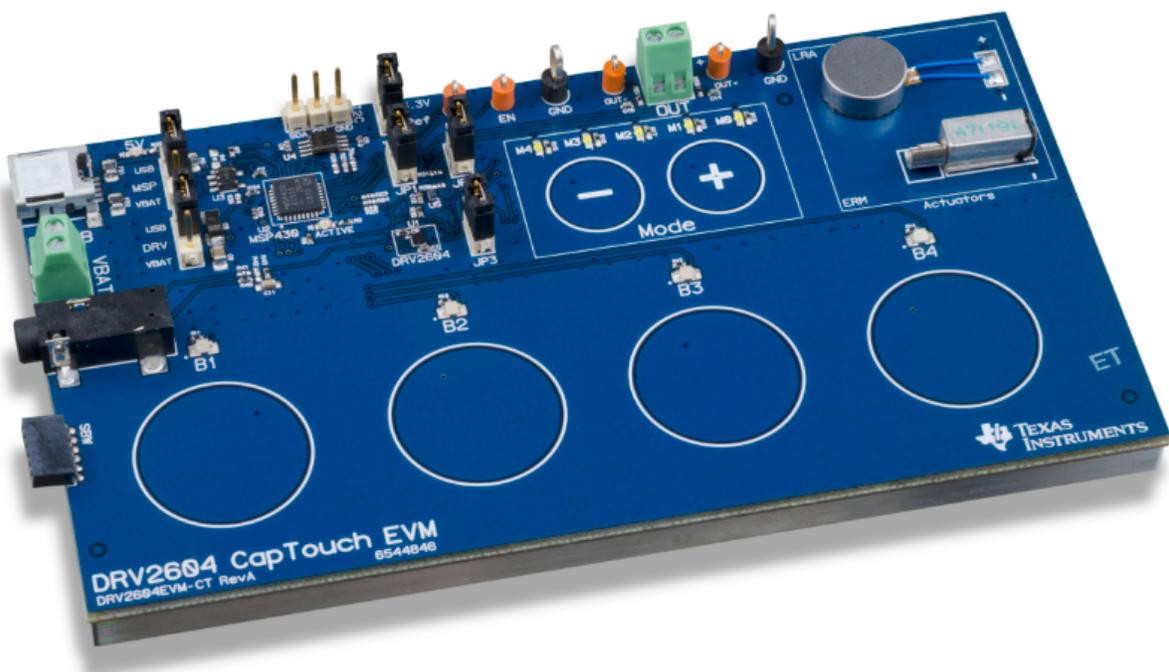


## ***DRV2604 ERM, LRA Haptic Driver Evaluation Kit***

The DRV2604 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 DRV2604EVM-CT Evaluation Module (EVM) is a complete demo and evaluation platform for the DRV2604. 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 DRV2604.

This document contains instructions to setup and operate the DRV2604EVM-CT in demo and evaluation mode.



**Figure 1. DRV2604EVM-CT Board**

### **Evaluation Kit Contents:**

- DRV2604EVM-CT demo and evaluation board
- Mini-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
- DRV2604EVM-CT firmware available on [ti.com](http://ti.com)

Code Composer Studio is a trademark of Texas Instruments.  
I<sup>2</sup>C is a trademark of NXP.

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## 1 Getting Started

The DRV2604 can be used as a demonstration or evaluation tool. When the DRV2604EVM-CT evaluation module is powered on for the first time, a demo application automatically starts. To power the board, connect the DRV2604EVM-CT to an available USB port on your computer using the included mini-USB cable. The demo begins with a board power-up sequence and then enters the demo effects mode. The four larger buttons (B1–B4) can be used to sample haptic effects using both the ERM and LRA motor in the top right corner. The two smaller mode buttons (–, +) are used to change between the different banks of effects. See the [DRV2604 Demonstration Program](#) section for a more detailed description of the demo application.

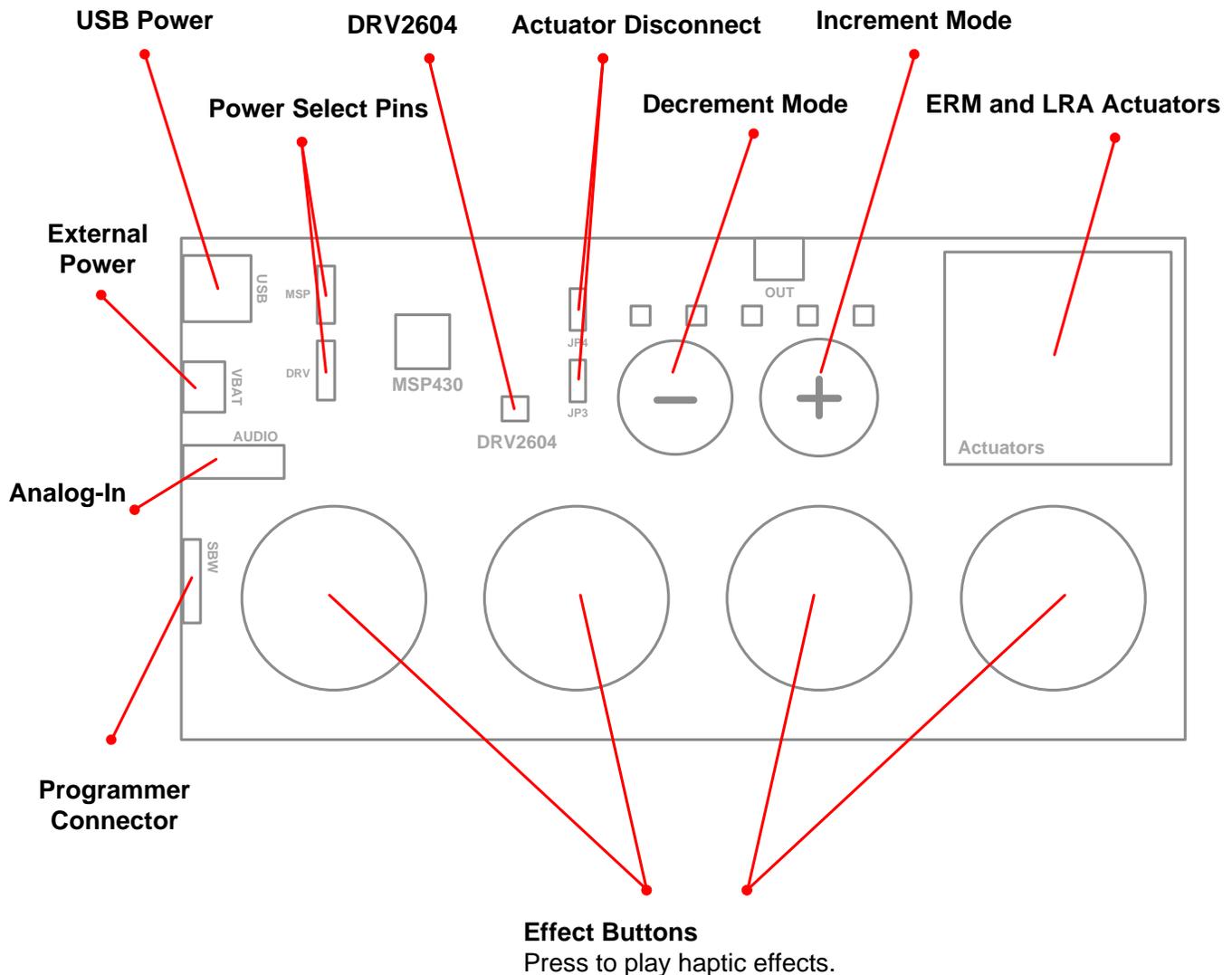


Figure 2. Board Diagram

## 1.1 Evaluation Module Operating Parameters

The following table lists the operating conditions for the DRV2604 on the evaluation module.

Parameter	Specification
Supply voltage range	2.5 V to 5.5 V
Power-supply current rating	400 mA

## 1.2 Quick Start Board Setup

The DRV2604EVM-CT firmware contains haptic waveforms which showcase the features and benefits of the DRV2604. 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
JP1	Shorted	Connect MSP430 GPIO/PWM output to DRV2604 IN/TRIG
JP2	Shorted	3.3 V reference for I <sup>2</sup> C™
JP3, JP4	Shorted	Connect on-board actuators to DRV2604
MSP	USB to MSP	Select USB (5 V) or VBAT power for the MSP430
DRV	USB to DRV	Select USB (5 V) or VBAT power for the DRV2604

2. Connect the included mini-USB cable to the USB connector on the DRV2604EVM-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 four colored LEDs will turn on, the four mode LEDs will flash, and the LRA and ERM will perform auto-calibration, indicating the board has been successfully initialized.

## 2 DRV2604 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 DRV2604EVM-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
<b>Mode Off</b> LEDs Off	B1	Click + Bounce	ERM	RAM	Internal Trigger (I <sup>2</sup> C)
	B2	Ramp Up + Click	LRA		
	B3	Gallop Alert	ERM		
	B4	Pulsing Alert	LRA		
<b>Mode 4</b> LED M4 On	B1	Strong Click	ERM	RAM	Ext. Level Trig.
	B2	Bump + Release			Internal Trigger
	B3	Double Strong Click			Ext. Edge Trig.
	B4	Click (Open Loop)		μController	PWM
<b>Mode 3</b> LED M3 On	B1	Strong Click	LRA	RAM	Ext. Level Trig.
	B2	Bump + Release			Internal Trigger
	B3	Double Strong Click			Ext. Level Trig.
	B4	Click (Open Loop)		μController	PWM
<b>Mode 2</b> LED M2 On	B1	Buzz Auto-Resonance ON	LRA	μController	RTP (I <sup>2</sup> C)
	B2	Buzz Auto-Resonance OFF			PWM
	B3	Buzz Alert	ERM		RTP (I <sup>2</sup> C)
	B4	Scroll Wheel	LRA		
<b>Mode 1</b> LED M1 On	B1	Concentration Game	ERM and LRA	RAM	Internal Trigger (I <sup>2</sup> C)
	B2	The board will display a pattern using the effect buttons. See how many times you can repeat the pattern as it increases by one effect each time.			
	B3				
	B4				
<b>Mode 0</b> LED M0 On	B1		Auto-Calibration	ERM	Internal Routine
	B2	Auto-Calibration	LRA		
	B3	Click	ERM/LRA	RAM	
	B4	Buzz			

## 2.2 Description of the Demo Modes

The following sections describe each demo mode in more detail.

### 2.2.1 Mode Off – Haptics Effect Sequences

Mode Off is a set of haptic sequences that combine a series of haptic effects. The two effects below show combinations of clicks and ramps.

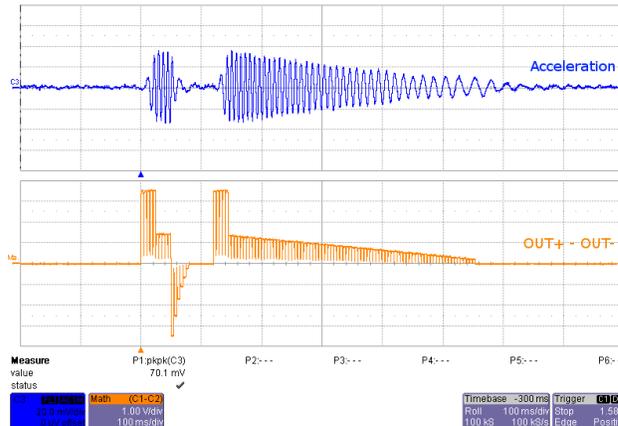


Figure 3. ERM Click and Bounce Waveform (Button 1)

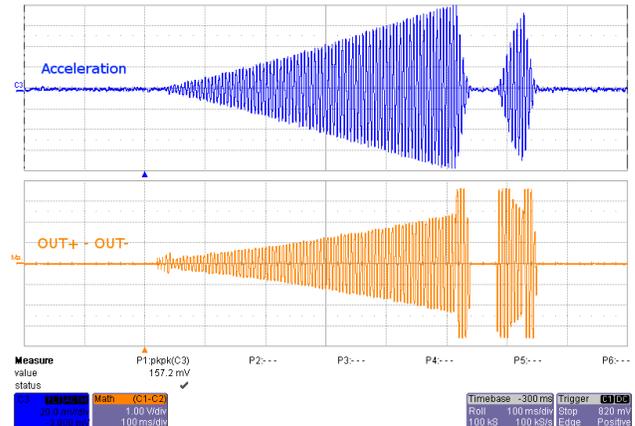


Figure 4. LRA Ramp-Up and Click Waveform (Button 2)

### 2.2.2 Mode 4 – ERM Clicks

Mode 4 shows the difference in open-loop and closed-loop ERM clicks. In closed-loop the driver automatically overdrives and brakes the actuator. In open-loop, the waveform must be predefined with overdrive and braking. The image on the left shows a closed-loop waveform and the image on the right shows the same input waveform without closed-loop feedback enabled.

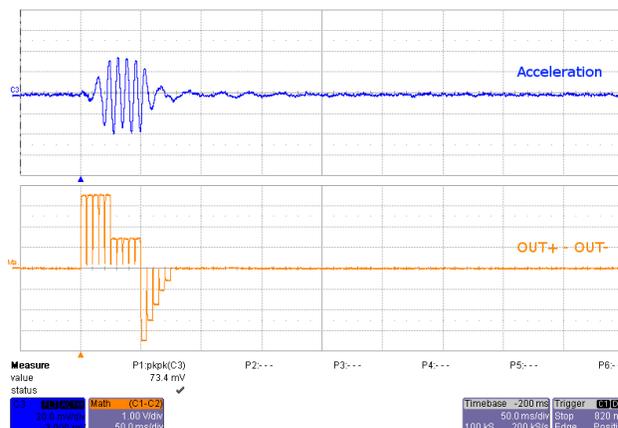


Figure 5. ERM Closed-Loop Click Waveform (Button 1)

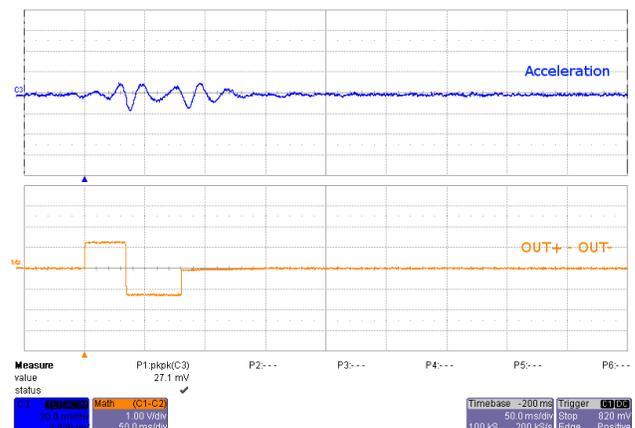


Figure 6. ERM Open-Loop Click Waveform (Button 4)

### 2.2.3 Mode 3 – LRA Clicks

Mode 3 shows the difference in open-loop and closed-loop LRA clicks. 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. The image on the left shows a closed-loop waveform and the image on the right shows a waveform with auto-resonance off and no overdrive or braking.

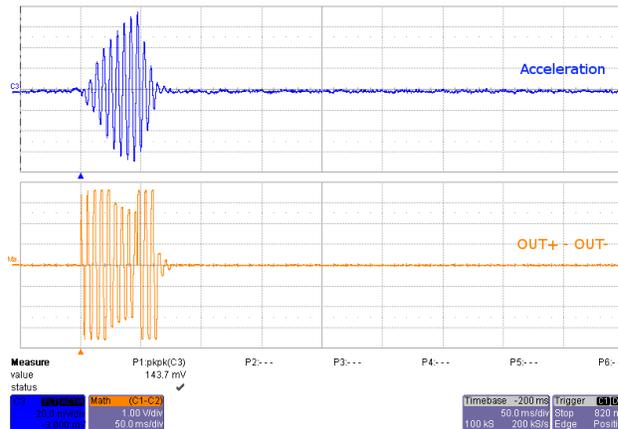


Figure 7. LRA Closed-Loop Click Waveform (Button 1)

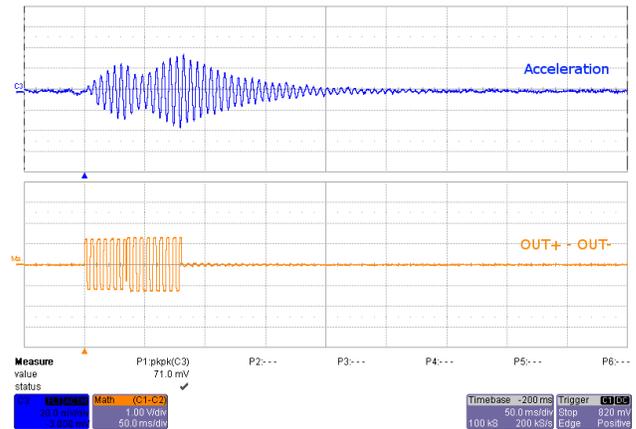


Figure 8. LRA Open-Loop Click Waveform (Button 4)

### 2.2.4 Mode 2 – Alerts and Scroll Wheel

Mode 2 showcases 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.

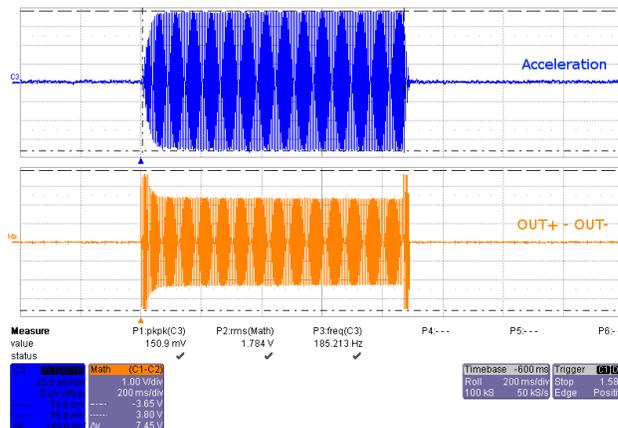


Figure 9. LRA Auto-Resonance ON Waveform (Button 1)

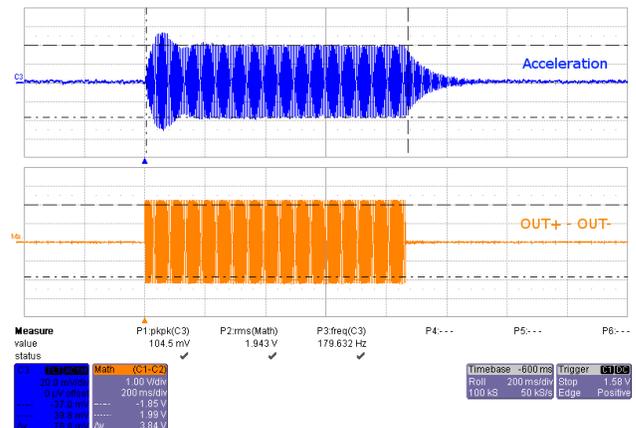


Figure 10. LRA Auto-Resonance OFF Waveform (Button 2)

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 DRV2604 dynamically tracks the exact resonant frequency to maximize the vibration force.

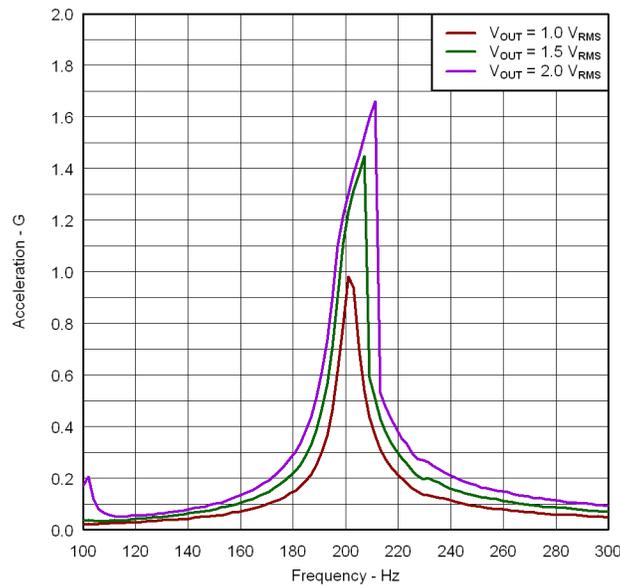


Figure 11. Acceleration Versus Frequency

Button 4 uses a series of clicks to create a scroll wheel effect. See the oscilloscope capture in Figure 12.

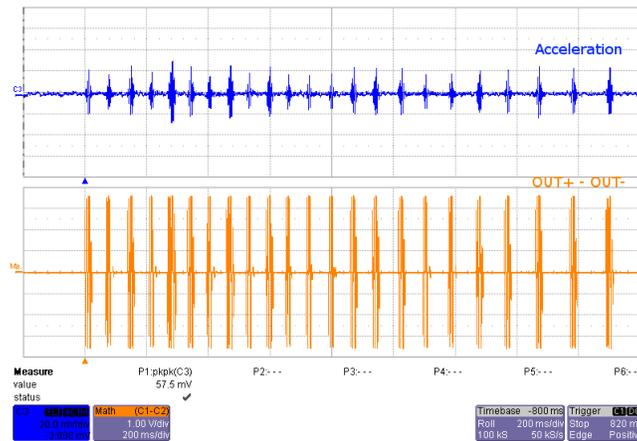


Figure 12. LRA Scroll Wheel Effect Waveform (Button 4)

### 2.2.5 Mode 1 – Concentration Game

Mode 1 is a game that incorporates the various LRA and ERM effects. This can be used to demonstrate haptics in a real application.

To begin playing Concentration:

1. Press any of the large effect buttons.
2. The game then counts down.
3. Once the countdown completes, a button lights and an effect plays.
4. Repeat the pattern by pressing the same button.
5. After each successfully repeated pattern, the board repeats the same pattern and adds one additional button effect to the sequence.

### 2.2.6 Mode 0 – Auto-Calibration

Auto-calibration is a DRV2604-embedded routine that detects the characteristics and behavior of an actuator and adjusts the drive waveform automatically.

Perform auto-calibration using the following steps:

1. Connect an actuator to the green output terminal (OUT) or use the on-board actuators
2. For an ERM actuator, run the ERM auto-calibration by pressing button B1
3. For an LRA actuator, run the LRA auto-calibration by pressing button B2
4. Read the auto-calibration register values using I<sup>2</sup>C
5. Test using buttons B3 and B4

### 2.3 RAM Library Mode

Access the RAM library effects by holding the + button until the mode LEDs flash and the colored LEDs flash ONCE.

Once in *Library Mode* the DRV2604 loaded RAM effects can be accessed in sequential order. For example, with all Mode LEDs off, B1 is waveform 1, B2 is waveform 2, and so on. Then when Mode LED M0 is on, B1 is waveform 5, B2 is waveform 6, and so on.

The equations for calculating the Mode and Button of an effect are:

$$\text{Mode} = \text{RoundDown}(\text{Effect No.} / 4)$$

$$\text{Button} = (\text{Effect No.} - 1) \% 4 + 1$$

% - modulo operator

To change between ERM and LRA:

1. Select mode 31 (11111'b) using the + or – buttons.
  - B1 – Press to select ERM
  - B2 – Press to select LRA
2. Then use the RAM effects as described above.

### 2.4 Waveform Library Effects List

Below is a description of the waveforms embedded in the DRV2604.

Effect ID	Waveform Name
1	Strong Click
2	Medium Click
3	Light Click
4	Tick
5	Bump
6	Strong Double Click
7	Medium Double Click
8	Light Double Click
9	Strong Triple Click
10	Buzz
11	Ramp Up
12	Ramp Down
13	Click + Bounce
14	Ramp Up + Click
15	Gallop Alert
16	Pulsing Alert

### 3 Additional Hardware Modes

Additional modes are available on the DRV2604EVM-CT providing increased board control and functionality. The additional modes are not available in *demo* mode, but can be accessed by switching to *binary counting mode*. In *binary counting mode* the mode LEDs count in binary (32 modes) rather than in *demo* mode format (only 6 modes including off).

#### 3.1 Enter Binary Counting Mode

To enter *binary counting mode* and access the additional modes:

1. Press and hold the increment mode button (+) for approximately 3 seconds until the mode LEDs flash and the colored LEDs flash once.
2. Press and hold the increment mode button (+) one more time until the mode LEDs flash and the colored LEDs flash twice.
3. Select from the *binary counting mode* using the + and – buttons.

#### 3.2 Exit Binary Counting Mode

To exit *binary counting mode* and return to *demo* mode:

1. Press and hold the decrement mode button (–) for approximately 3 seconds.
2. Release the button when the actuator buzzes and mode LEDs flash.
3. Select from the *demo* modes using the + and – buttons.

### 3.3 Binary Counting Modes

Table 2 lists the modes available in *binary counting mode*.

**Table 2. Binary Counting Modes**

Mode	Button	Description	Notes
<b>Mode 0</b> External I <sup>2</sup> C Mode LEDs: 00000	B1	Set ERM Output	Use this mode to control the DRV2604 using an external I2C Master. Press B1 or B2 to choose between the ERM or LRA. Press B3 to choose the trigger type. (1 - Internal, 2 - Ext. Edge, 3 - Ext. Level). Press B4 to trigger the waveform sequencer.
	B2	Set LRA Output	
	B3	Choose Trigger	
	B4	Trigger Button	
<b>Mode 1</b> Auto-Calibration & Diagnostics LEDs: 00001	B1	ERM Auto-Calibration	Run the auto-calibration. The new auto-calibration results are used for all board effects. 1 flash = successful, 3 flashes = error.
	B2	LRA Auto-Calibration	
	B3	ERM Diagnostics	Run diagnostics. 1 flash = successful, 3 flashes = error. The status register bits [3:0] are displayed on the mode LEDs [3:0] when complete.
	B4	LRA Diagnostics	
<b>Mode 2</b> External PWM LEDs: 00010	B1	Disable PWM Mode	External PWM - disconnect MSP430 PWM using JP1. Connect external PWM signal to the "PWM" testpoint at the top of the board. Select actuator using buttons B2 and B3.
	B2	Set ERM Output	
	B3	Set LRA Output	
	B4	-	
<b>Mode 3</b> External PWM and Enable LEDs: 00011	B1	Return to normal mode	External PWM and Enable - disconnect MSP430 PWM using JP1. Connect external PWM signal to the "PWM" testpoint at the top of the board. Connect an external enable signal to the "EN" testpoint. Select actuator using buttons B2 and B3. Press B1 before switching modes.
	B2	Set ERM Output	
	B3	Set LRA Output	
	B4	-	
<b>Mode 4</b> Analog Input LEDs: 00100	B1	AC Coupling - ERM	Analog Input - apply an external analog signal for AC coupling on the "Audio" jack. Apply a DC coupled signal to the "PWM" testpoint.
	B2	DC Coupling - ERM	
	B3	AC Coupling - LRA	
	B4	DC Coupling - LRA	
<b>Mode 5</b> Auto-resonance OFF frequency adjust LEDs: 00101	B1	Alert (Auto-resonance On)	Vary the auto-resonance OFF (open-loop) output frequency and see the change in vibration force over frequency. Hold B3 or B4 for quick frequency adjustment. Compare B2 (auto-resonance off) with B1 (auto-resonance on).
	B2	Alert (Auto-resonance Off)	
	B3	Decrease output frequency	
	B4	Increase output frequency	
<b>Mode 6</b> Life Test (RTP) 2s ON, 1s OFF LEDs: 00110	B1	Begin Life Test	Life Test using RTP (2 seconds on, 1 second off) - life test repeats infinite times and board must be powered down to stop. Increment / Decrement amplitude using B3 and B4. Test new amplitude using B2. Choose actuator using buttons B1 and B2 in Mode 0 or Mode 1.
	B2	Test Buzz	
	B3	Decrease output voltage (-1)	
	B4	Increase output voltage (+1)	
<b>Mode 7</b> Life Test (RTP) Infinite Buzz LEDs: 00111	B1	Begin Life Test	Life Test using RTP (Infinite Buzz) - board must be powered down to stop buzz. Increment / Decrement amplitude using B3 and B4. Test new amplitude using B2 before beginning life test. Choose actuator using buttons B1 and B2 in Mode 0 or Mode 1.
	B2	Test Buzz	
	B3	Decrease output voltage (-1)	
	B4	Increase output voltage (+1)	
<b>Mode 8</b> Life Test (PWM) 2s ON, 1s OFF LEDs: 01000	B1	Begin Life Test	Life Test using PWM (2 seconds on, 1 second off) - life test repeats infinite times and board must be powered down to stop. Increment / Decrement amplitude using B3 and B4. Test new amplitude using B2. Choose actuator using buttons B1 and B2 in Mode 0 or Mode 1.
	B2	Test Buzz	
	B3	Decrease output voltage (-1)	
	B4	Increase output voltage (+1)	
<b>Mode 9</b> Recorder LEDs: 01001	B1	Start/Stop Recording	Recorder - use this mode to create a single amplitude pattern. Start by pressing the record button (B1). Then use B2 to create the pattern by tapping the button. When finished press the play back button (B3).
	B2	Create Pattern	
	B3	Start/Stop Play Back	
	B4	-	
<b>Mode 10</b> Life Test (RAM) Infinite Buzz LEDs: 01010	B1	Life Test Infinite Buzz	Life Test (RAM Mode) - Increment / Decrement amplitude using B3 and B4. B1 - Start/Stop Infinite Buzz Life Test. B2 - Start/Stop 2s ON, 1s OFF life test. Choose actuator using buttons B1 and B2 in Mode 0 or Mode 1.
	B2	Life Test 2s ON, 1s OFF	
	B3	Decrease output voltage (-1)	
	B4	Increase output voltage (+1)	
<b>Mode 30</b> Actuator Break-in LEDs: 11110	B1	Begin Actuator Break-in	Actuator Break-in - used to break in new actuators
	B2		
	B3		
	B4		
<b>Mode 31</b> About the Board LEDs: 11111	B1	Device ID	About the Board - the value will appear on the mode LEDs in binary. DRV2604 Device ID = 00100
	B2	Silicon Revision	
	B3	Code Revision	
	B4		

## 4 Hardware Configuration

The DRV2604EVM-CT is very flexible and can be used to completely evaluate the DRV2604. The following sections list the various hardware configurations.

### 4.1 Input and Output Overview

The DRV2604EVM-CT allows complete evaluation of the DRV2604 through test points, jacks, and connectors. [Table 3](#) gives a brief description of the hardware.

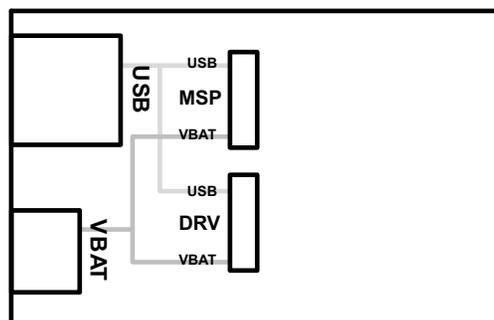
**Table 3. Hardware Overview**

Signal	Description	I/O
PWM	External input to DRV2604 IN/TRIG pin	Input/Observe
EN	External DRV2604 enable control	Input/Observe
OUT+/OUT-	Filtered output test points for observation, connect to oscilloscope or measurement equipment	Output
OUT	Unfiltered output terminal block, connect to actuator	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 <sup>2</sup> C	DRV2604 and MSP430 I <sup>2</sup> C bus	Input/Output
Audio	The audio jack is connected to the IN/TRIG pin of the DRV2604. When the DRV2604 is in analog input mode, an analog signal from this jack controls the amplitude envelope of the output waveform.	Input

Hardware configuration details can be found in the following sections.

### 4.2 Power Supply Selection

The DRV2604EVM-CT can be powered by USB or an external power supply (VBAT). Jumpers DRV and MSP are used to select USB or VBAT for the DRV2604 and MSP430G2553, respectively. See the following table for possible configurations.



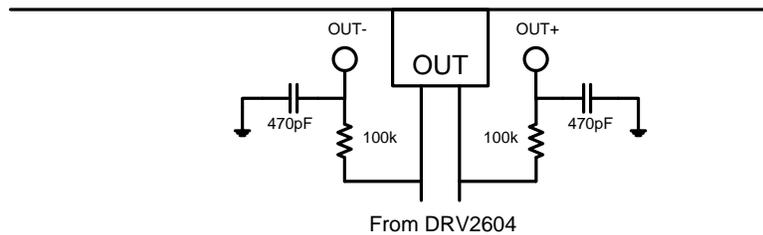
**Figure 13. Power Jumper Selection**

Supply Configuration	DRV	MSP	DRV2604 Supply Voltage <sup>(1)</sup>
USB – Both	USB	USB	5 V
DRV2604 external supply, MSP430 USB	VBAT	USB	VBAT
External supply – both	VBAT	VBAT	VBAT
USB with 3.3-V LDO <sup>(2)</sup> – both	USB	USB	3.3 V (R4 = Short, R5 = Open)

<sup>(1)</sup> The DRV2604 supply must be on before operating the MSP430.

<sup>(2)</sup> If a 3.3-V DRV2604 supply voltage is preferred while using the USB as the power source, remove R5 and add a 0-Ω resistor across R4.

### 4.3 Using an External Actuator



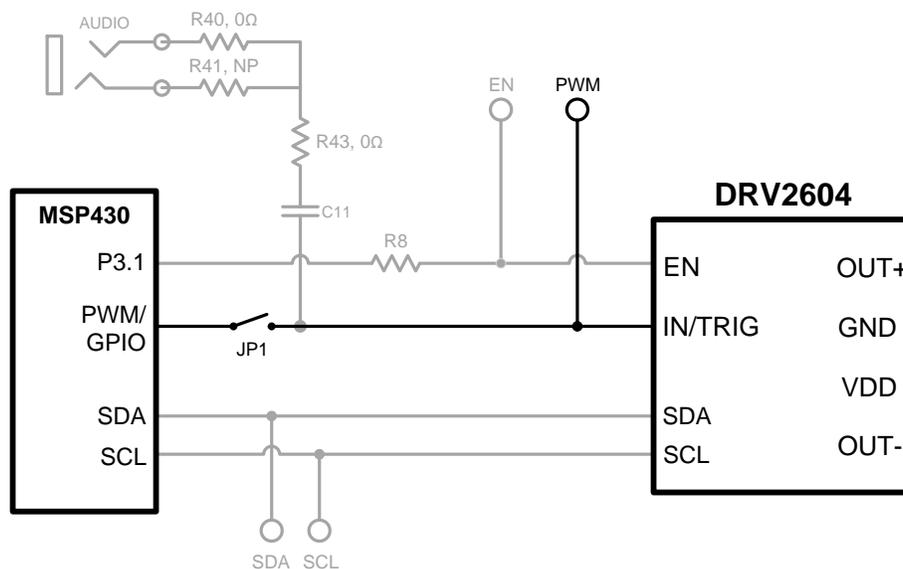
**Figure 14. Terminal Block and Test Points**

The DRV2604EVM-CT can be used with an external actuator. Follow the instructions below to attach an actuator to the *OUT* terminal block.

1. Remove jumpers JP3 and JP4, which disconnects the on-board actuators from the DRV2604.
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.

It is important to use the green terminal block when connecting an external actuator. The *OUT+* and *OUT-* testpoints have low-pass filters and should only be used for oscilloscope and bench measurements.

### 4.4 PWM Input



**Figure 15. External PWM Input**

JP1	PWM Source
Shorted	MSP430
Open	External PWM using PWM test point

To control the DRV2604 using PWM, follow the instructions below:

1. Enter [Additional Hardware Modes](#).
2. Select Mode 2 (00010'b) using the increment mode button (+).
  - B1 – Disable Amplifier
  - B2 – ERM Mode
  - B3 – LRA Mode

- B4 – No function
3. Choose either the on-board ERM or LRA using buttons B1 or B2.
  4. Apply the PWM signal to the PWM test point at the top of the board.

#### 4.5 External Trigger Control

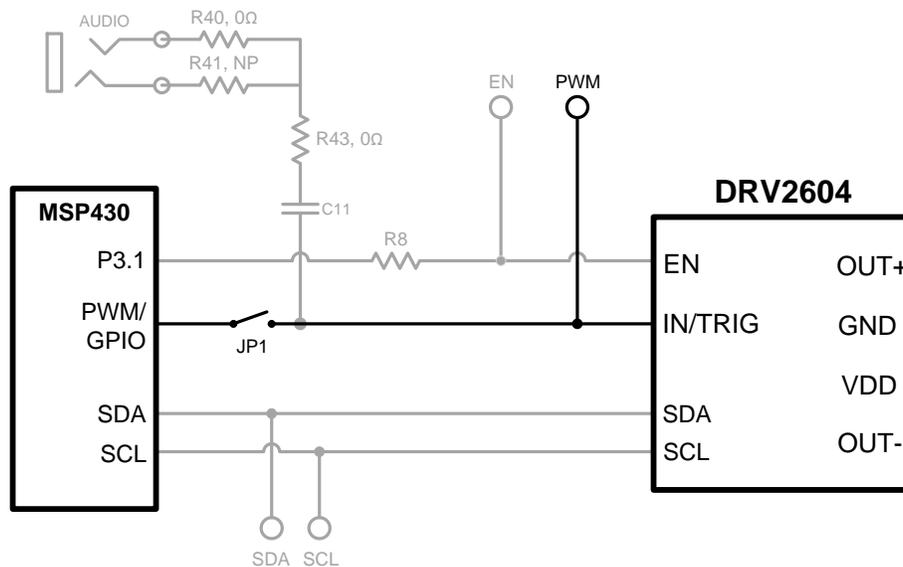


Figure 16. External Trigger Control

JP1	PWM Source
Shorted	MSP430
Open	External GPIO using PWM test point

The DRV2604 internal waveform sequencer can be triggered by controlling the IN/TRIG pin. There are two external trigger options: edge trigger and level trigger. See the data sheet for more information on these Input Trigger Modes.

In Mode 0 in the [Additional Hardware Modes](#) section, the DRV2604 can be set in external trigger mode and then triggered by using the trigger button control on button B4 or alternatively by applying an external trigger signal to the PWM test point.

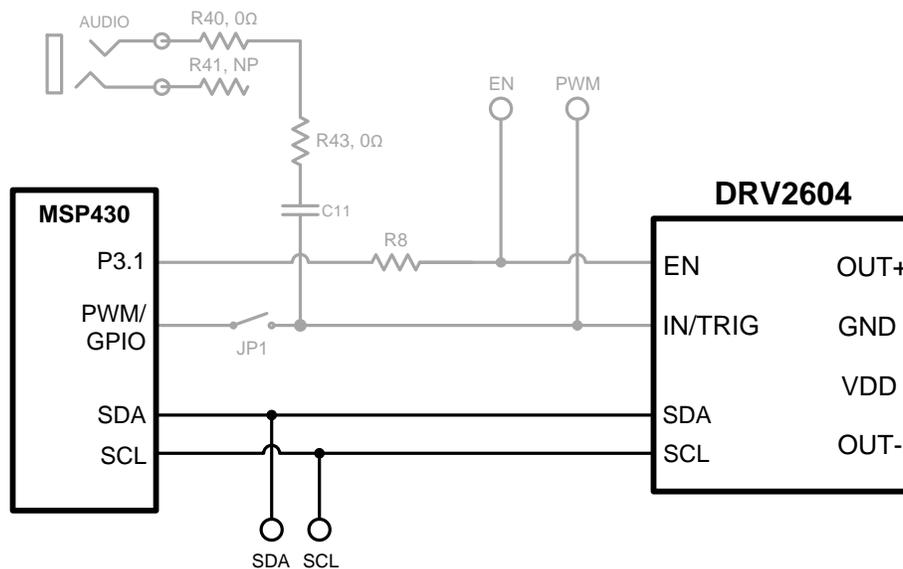
##### 4.5.1 MSP430 Trigger Control

1. Enter [Additional Hardware Modes](#).
2. Select Mode 0 (00000'b) using the increment mode button (+).
  - B1 – Select the on-board ERM
  - B2 – Select the on-board LRA
  - B3 – Trigger Select (1 = Internal Trigger, 2 = Ext. Edge, 3 = Ext. Level)
  - B4 – Trigger the waveform sequence using the MSP430.
3. Fill the waveform sequencer with waveforms using the external I<sup>2</sup>C port.
4. Choose either the on-board ERM or LRA using buttons B1 or B2.
5. Select either External Edge (2) or External Level (3) trigger using the B3 button. The trigger type appears in binary on the mode LEDs.
6. Apply the trigger signal to the IN/TRIG pin by pressing the B4 button.

#### 4.5.2 External Source Trigger Control

1. Remove jumper JP1.
2. Enter [Additional Hardware Modes](#).
3. Select Mode 0 (00000'b) using the increment mode button (+).
  - B1 – Select the on-board ERM
  - B2 – Select the on-board LRA
  - B3 – Trigger Select (1 = Internal Trigger, 2 = Ext. Edge, 3 = Ext. Level)
  - B4 – Trigger the waveform sequence using the MSP430.
4. Fill the waveform sequencer with waveforms using the external I<sup>2</sup>C port.
5. Choose either the on-board ERM or LRA using buttons B1 or B2.
6. Select either External Edge (2) or External Level (3) trigger using the B3 button. The trigger type appears in binary on the mode LEDs.
7. Apply the external logic signal to the PWM test point to trigger the waveform.

#### 4.6 External I<sup>2</sup>C Input



**Figure 17. External I<sup>2</sup>C Input**

The DV2604 can be controlled by an external I<sup>2</sup>C source. Attach the external controller to the I<sup>2</sup>C header at the top of the board; be sure to connect SDA, SCL and GND from the external source.

I<sup>2</sup>C communication is possible only when the EN pin is set high. To enable the DRV2604 and allow external I<sup>2</sup>C control, follow the instructions below.

1. Enter [Additional Hardware Modes](#).
2. Select Mode 0 (00000'b) using the increment mode button (+).
  - B1 – Select the on-board ERM
  - B2 – Select the on-board LRA
  - B3 – Trigger Select (1 = Internal Trigger, 2 = Ext. Edge, 3 = Ext. Level)
  - B4 – Trigger the waveform sequence using the MSP430.
3. Choose either the on-board ERM or LRA using buttons B1 or B2. Either button sets the EN pin high and turns on the *Active* LED.
4. Begin controlling the DRV2604 using the external I<sup>2</sup>C source.

## 4.7 Analog Input

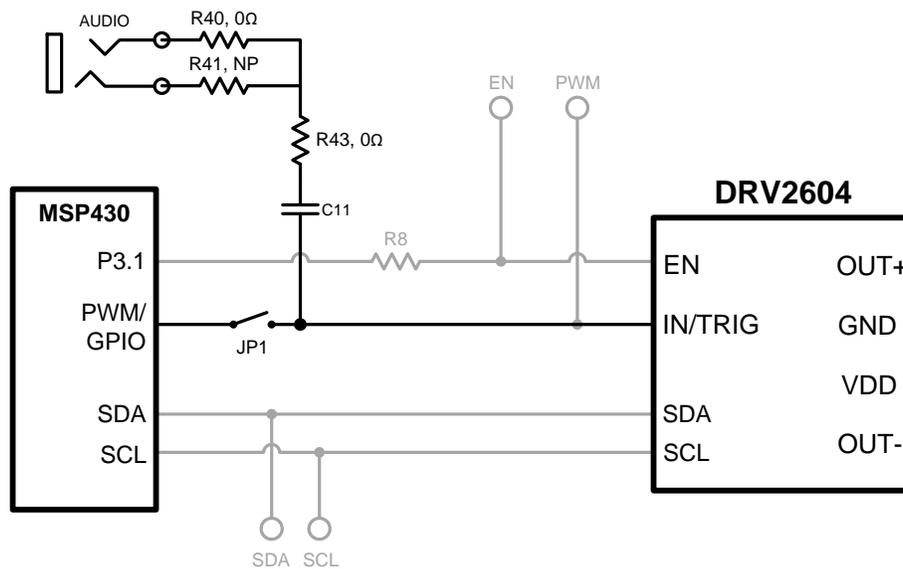


Figure 18. Analog Input

The analog input accepts an analog signal to control the envelope of the output waveform.

Use the following steps to use analog input mode:

1. Apply an analog signal (not PWM) to the AUDIO jack on the left side of the board. The tip of the inserted male 3.5 mm jack is applied to the IN/TRIG pin of the DRV2604. See [Figure 18](#).
2. Enter [Additional Hardware Modes](#).
3. Select Mode 5 (00101'b) using the increment mode button (+).
4. In Mode 5, choose button B1–B4, depending on the actuator and input coupling.
  - B1 – AC Coupling – ERM
  - B2 – DC Coupling – ERM
  - B3 – AC Coupling – LRA
  - B4 – DC Coupling – LRA
5. Enable the analog input signal.

## 5 Measurement and Analysis

The DRV2604 uses PWM modulation to create the output signal for both ERM and LRA actuators. To measure and observe the DRV2604 output waveform, connect an oscilloscope or other measurement equipment to the filtered output test points, *OUT+* and *OUT-*.

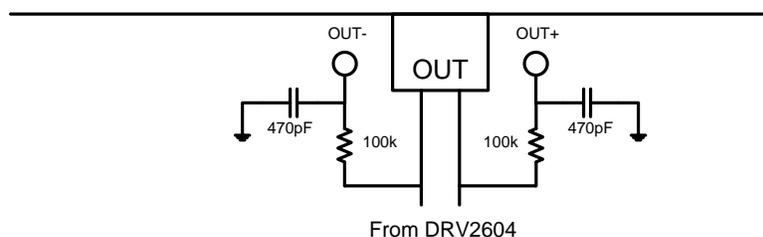


Figure 19. Terminal Block and Test Points

The DRV2604 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 DRV2604 unfiltered waveform and the image on the right shows a filtered version used for observation and measurement.

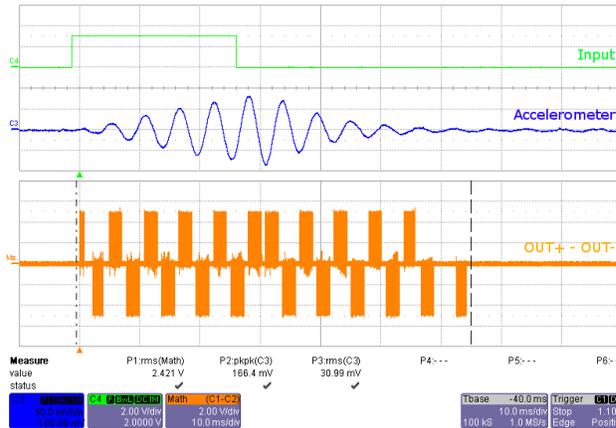


Figure 20. DRV2604 Unfiltered Waveform

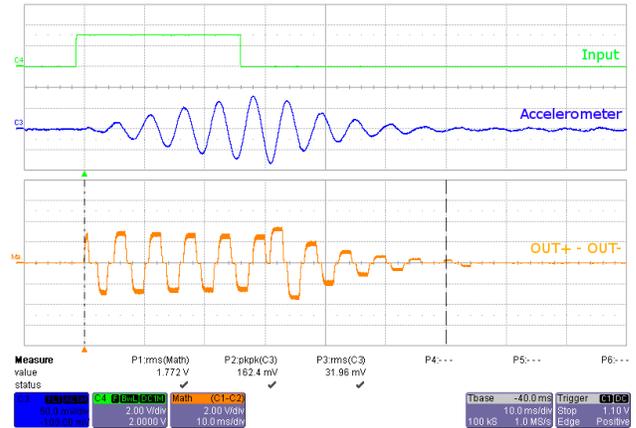


Figure 21. DRV2604 Filtered Waveform

If the DRV2604EVM-CT filter is not used, TI recommends using a 1st-order, low-pass filter with a cutoff between 1kHz and 3.5kHz . Below is a recommended output filter for use while measuring and characterizing the DRV2604 in the lab.

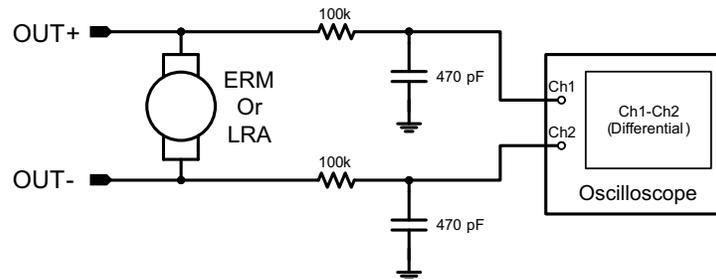


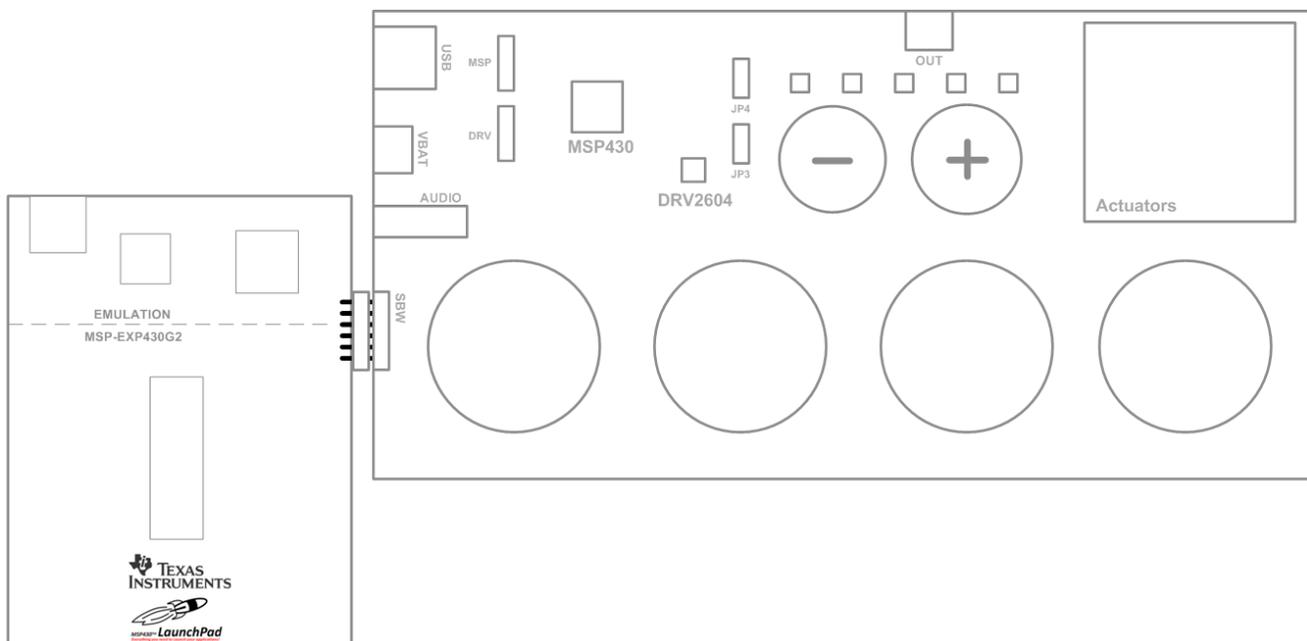
Figure 22. Measuring the DRV2604 Output Signal with an Analog Low-Pass Filter

## 6 Modifying or Reprogramming the Firmware

The MSP430 firmware on the DRV2604EVM-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 DRV2604EVM-CT.

1. Purchase one of the following MSP430G2553 compatible programmers:
  - LaunchPad (MSP-EXP430G2) – requires the additional purchase of a header for J4 (recommended)
    - Digi-Key: ED8650-ND
    - Mouser: 575-500201
  - MSP430-FET430UIF – requires a JTAG to Spy-Bi-Wire adapter (MSP-JTAGSBW if available)
2. Download and install Code Composer Studio (CCS) or IAR Embedded Workbench IDE.
3. Download the DRV2604EVM-CT source code and binaries from ti.com.
4. Connect the programmer to an available USB port.
5. Connect the programmer to the SBW header on the DRV2604EVM-CT.
6. In CCS,
  - (a) Open the project file by selecting Project→Import Existing CCS Project.
  - (b) Select **Browse** and navigate to the DRV2604EVM-CT project folder, then press **OK**.
  - (c) Select the checkbox next to the DRV2604EVM-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 MSP430G2553 device,
  - (c) Copy the files in the project folder downloaded from [ti.com](http://ti.com) to the new project directory.

The figure below shows the connection between the MSP430 LaunchPad (MSP-EXP430G2) and the DRV2604EVM-CT.



**Figure 23. LaunchPad Programmer Connection**

## 6.1 MSP430 Pin-Out

The DRV2604EVM-CT contains a MSP430G2553 low-cost microcontroller which controls the board and contains sample haptic effects. The pin-out for the microcontroller is found in [Table 4](#).

**Table 4. MSP430 Pin-Out**

#	Label	Description
1	P1.1	Green LED
2	P1.2	Yellow LED
3	P1.3	Blue LED
4	P1.4	VREF+
5	P1.5	Audio-to-Haptics
6	P3.1	Enable
7	P3.0	Actuator Mode Selection
8	NC	
9	P2.0	Button 1
10	P2.1	Button 2
11	P2.2	Button 3
12	P3.2	PWM
13	P3.3	WLED 0
14	P3.4	WLED 1
15	P2.3	Button 4
16	P2.4	+ Button
17	P2.5	– Button
18	P3.5	WLED 2
19	P3.6	WLED 3
20	P3.7	WLED 4
21	P1.6/SCL	I <sup>2</sup> C Clock
22	P1.7/SDA	I <sup>2</sup> C Data
23	SBWTDIO	Spy-Bi-Wire Data
24	SBWTCK	Spy-Bi-Wire Clock
25	P2.7	
26	P2.6	LRA/ERM Load Switch
27	AVSS	Analog Ground
28	DVSS	Digital Ground
29	AVCC	Analog Supply
30	DVCC	Digital Supply
31	P1.0	Red LED
32	NC	

7 Schematic

DRV2604YZF CAPTOUCH EVM

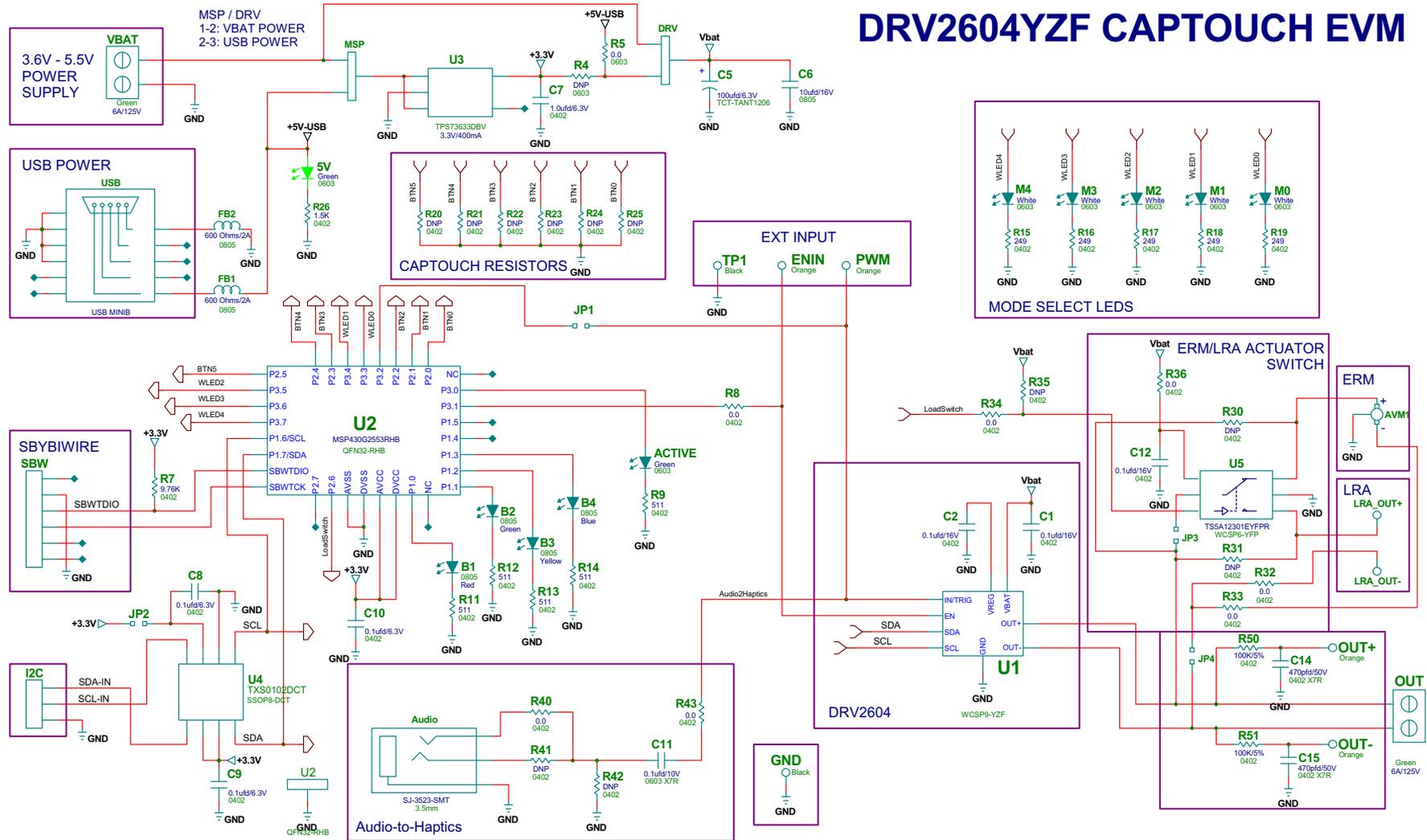


Figure 24. DRV2604EVM-CT Schematic

8 Layout

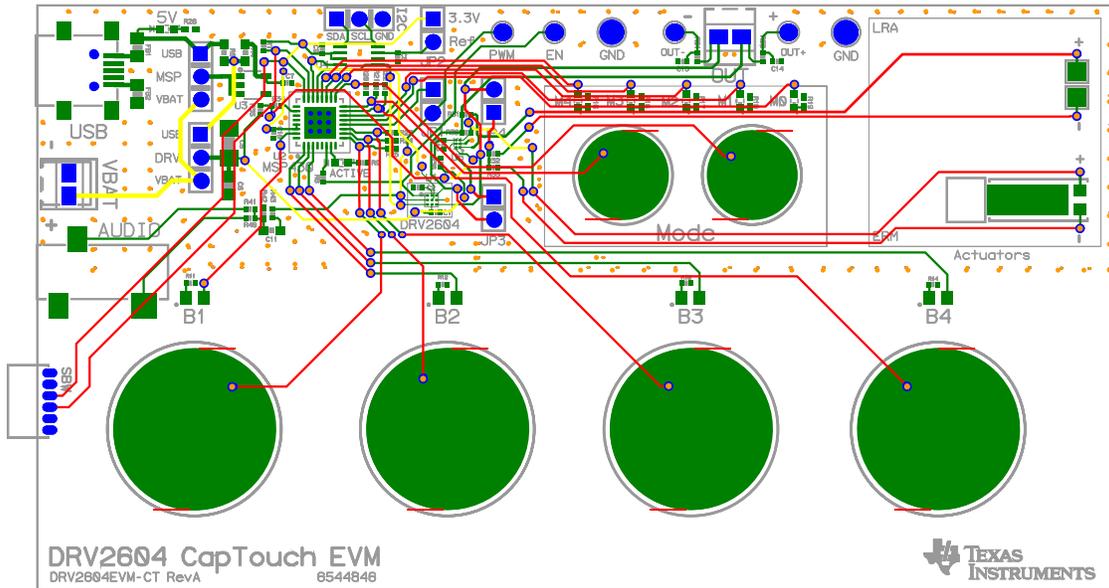


Figure 25. X-Ray Top View

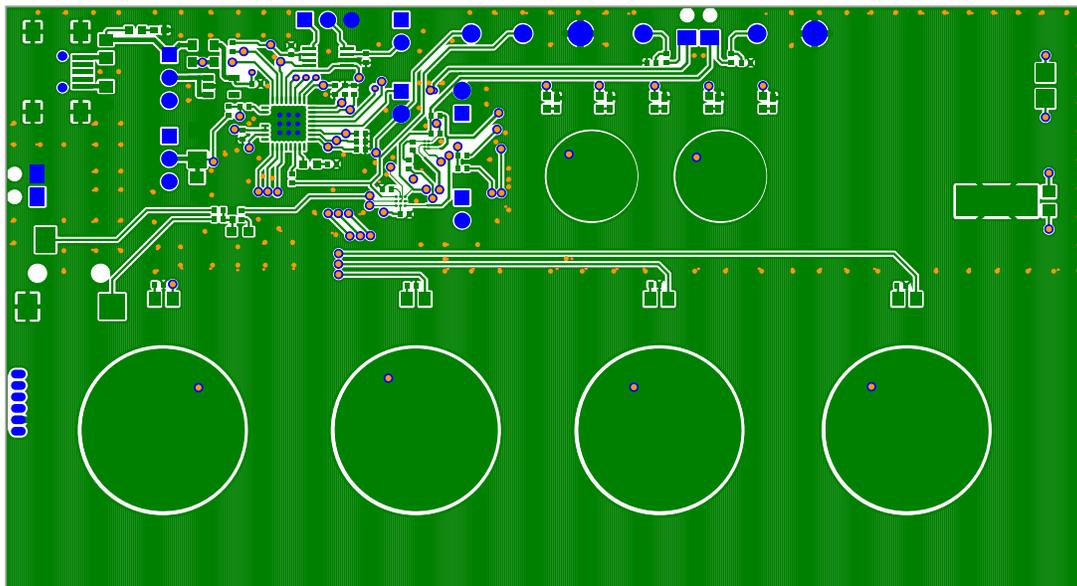


Figure 26. Top Copper

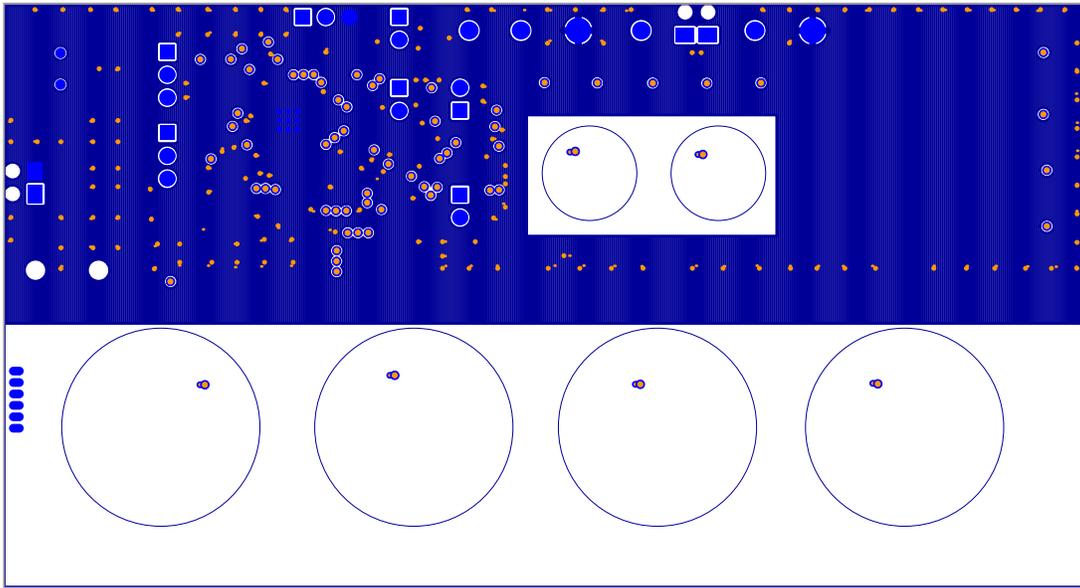


Figure 27. Layer 2 Copper

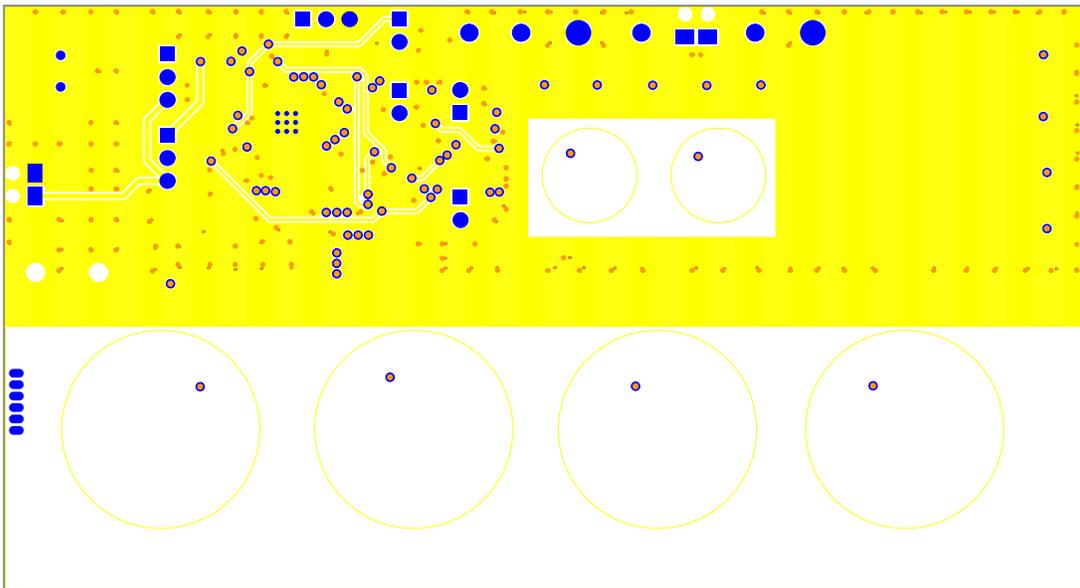
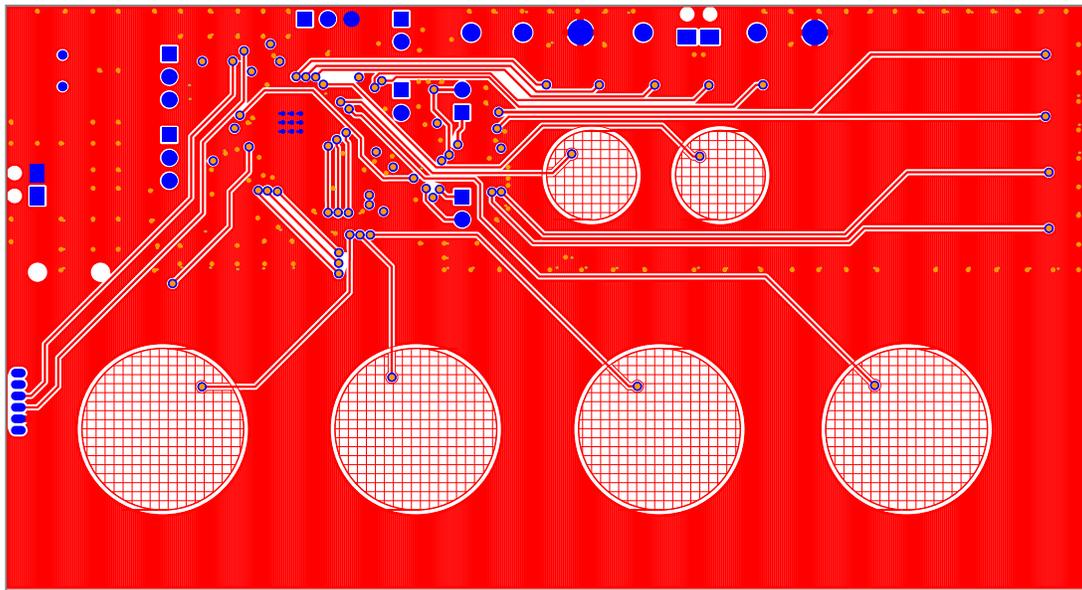


Figure 28. Layer 3 Copper



**Figure 29. Bottom Copper**

## 9 Bill of Materials

ITEM	MANU PARTNUM	QTY	REF DESIGNATORS	VENDOR PARTNUM	DESCRIPTION	MANUFACTURER
<b>SEMICONDUCTORS</b>						
1	DRV2604YZF	1	U1	DRV2604YZF	HAPTIC DRIVER AUTO DETECT FOR LRA AND ERM WCSP9-YZF ROHS	TEXAS INSTRUMENTS
2	TXS0102DCTR	1	U4	296-21978-1	2-BIT BIDIR LEVEL TRANSLATOR SSOP8-DCT ROHS	TEXAS INSTRUMENTS
3	MSP430G2553IRHB32T	1	U2	595-P430G2553IRHB32T	MIXED SIGNAL MICRO 16KB FLASH 512B RAM QFN32-RHB ROHS	TEXAS INSTRUMENTS
4	TPS73633MDBVREP	1	U3	296-21283-1	VOLT REG 3.3V 400MA LDO CAP FREE NMOS SOT23-DBV5 ROHS	TEXAS INSTRUMENTS
5	TS5A12301EYFPR	1	U5	296-23757-1-ND	IEC LEVEL 4 ESD-PROTECTED 0.75-OHM ANALOG SWITCH WCSP6-YFP ROHS	TEXAS INSTRUMENTS
6	LTST-C190KGKT	2	5V,ACTIVE	160-1435-1-ND	LED, GREEN, 2.0V, SMD0603, ROHS	LITE-ON INC.
7	LNJ037X8ARA	5	M0,M1,M2,M3,M4	LNJ037X8ARACT-ND	LED, WHITE 2.9V SMD0805 ROHS	PANASONIC
8	SML-LXT0805SRW-TR	1	B1	67-1555-1	LED, RED 2.0V SMD0805 ROHS	LUMEX OPTO
9	SML-LXT0805GW-TR	1	B2	67-1553-1	LED, GREEN 2.0V SMD0805 ROHS	LUMEX OPTO
10	SML-LXT0805YW-TR	1	B3	67-1554-1	LED, YELLOW 2.0V SMD0805 ROHS	LUMEX OPTO
11	LTST-C171TBKT	1	B4	160-1645-1-ND	LED, BLUE 3.3V SMD0805 ROHS	LITE-ON INC.
<b>CAPACITORS</b>						
12	GRM155R71C104KA88D	3	C1,C2,C12	490-3261-1-ND	CAP SMD0402 CERM 0.1UFD 16V X7R 10% ROHS	MURATA
13	C1005X5R0J104K	3	C8,C9,C10	445-1266-1	CAP SMD0402 CERM 0.1UFD 6.3V 10% X5R ROHS	TDK CORP
14	0805YD106KAT2A	1	C6	478-5165-1	CAP SMD0805 CERM 10UFD 16V X5R 10% ROHS	AVX
15	GRM155R60J105KE19D	1	C7	490-1320-1	CAP SMD0402 CERM 1.0UFD 6.3V X5R 10% ROHS	MURATA
16	C1005X5R0J104K	1	C11	445-1266-1	CAP SMD0402 CERM 0.1UFD 6.3V 10% X5R ROHS	TDK CORP
17	C0402C471K5RACTU	2	C14,C15	399-1025-1	CAP SMD0402 CERM 470PFD 50V 10% X7R ROHS	KEMET
18	TCTAL0J107M8R	1	C5	511-1498-1-ND	CAP TANT1206 100UFD 6.3V 20% TCT SERIES ROHS	ROHM
<b>RESISTORS</b>						
19	ERJ-2RKF9761X	1	R7	P9.76KLCT-ND	RESISTOR SMD0402 THICK FILM 9.76K OHMS 1/10W 1% ROHS	PANASONIC
20	RMCF0402ZT0R00	5	R8,R32,R33,R34,R36	RMCF0402ZT0R00CT	ZERO OHM JUMPER SMT 0402 0 OHM 1/16W,5% ROHS	STACKPOLE ELECTRONICS

ITEM	MANU PARTNUM	QTY	REF DESIGNATORS	VENDOR PARTNUM	DESCRIPTION	MANUFACTURER
21	RC0402FR-07511RL	5	R9,R11,R12,R13,R14	311-511LRCT-ND	RESISTOR SMD0402 THICK FILM 511 OHMS 1% 1/16W ROHS	YAGEO
22	ERJ-2GEJ152	1	R26		RESISTOR,SMT,0402,THICK FILM,5%,1/16W,1.5K	Panasonic
23	RMCF0603ZT0R00	1	R5	RMCF0603ZT0R00CT- ND	RESISTOR SMD0603 ZERO OHMS 1/10W ROHS	STACKPOLE ELECTRONICS
24	ERJ-2RKF2490X	5	R15,R16,R17,R18,R19	P249LTR-ND	RESISTOR,SMT,0402,249 OHM,1%,1/16W	Panasonic
25	CRCW04020000Z0ED	2	R40,R43	541-0.0JCT	ZERO OHM JUMPER SMT 0402 0 OHM 1/16W,5% ROHS	VISHAY
26	ERJ-2GEJ104	2	R50,R51	P100KJCT	RESISTOR SMD0402 THICK FILM 100K OHMS 1/16W 5% ROHS	PANASONIC
<b>FERRITE BEADS</b>						
27	MPZ2012S601A	2	FB1,FB2	445-2206-1	FERRITE BEAD SMD0805 600 Ohms 2A ROHS	TDK
<b>HEADERS, JACKS, AND SHUNTS</b>						
28	LPPB061NGCN-RC	1	SBW	S9010E-06	HEADER THRU FEMALE 1X6-RA 50LS GOLD ROHS	SULLINS
29	PBC03SAAN	3	DRV,I2C,MSP	S1011E-03-ND	HEADER THRU MALE 3 PIN 100LS GOLD ROHS	SULLINS
30	PBC02SAAN	1	JP2	S1011E-02	HEADER THRU MALE 2 PIN 100LS GOLD ROHS	SULLINS
31	PBC02SAAN	3	JP1,JP3,JP4		HEADER THRU MALE 2 PIN 100LS GOLD ROHS	SULLINS
32	UX60-MB-5ST	1	USB	H2959CT	JACK USB MINIB SMT-RA 5PIN ROHS	HIROSE
33	SJ-3523-SMT	1	Audio	CP-3523SJCT-ND	JACK AUDIO-STEREO MINI(3.5MM ,3-COND SMT-RA ROHS	CUI STACK
34	SPC02SYAN	6	MSP (2-3), DRV (2-3), JP1, JP2, JP3, JP4	S9001-ND	SHUNT BLACK AU FLASH 0.100LS CLOSED TOP ROHS	SULLINS
35	1725656	2	OUT,VBAT	277-1273	TERMINAL BLOCK MPT COMBICON 2PIN 6A/125V GREEN 100LS ROHS	PHOENIX CONTACT
<b>TESTPOINTS AND SWITCHES</b>						
36	5011	2	GND,TP1 ((Solder so that color ring is secured)	5011K	PC TESTPOINT BLACK 063 HOLE ROHS	KEYSTONE ELECTRONICS
37	5003	4	PWM,ENIN, OUT+, OUT- (Solder so that color ring is secured)	5003K	PC TESTPOINT, ORANGE, ROHS	KEYSTONE ELECTRONICS

ITEM	MANU PARTNUM	QTY	REF DESIGNATORS	VENDOR PARTNUM	DESCRIPTION	MANUFACTURER
38	NRS-2574	1	AVM1	NRS-2574	ACTUATOR VIBRATION MOTOR 1,3V 9000 RPM ROHS	SANYO
39	ELV1036A	1	-	-	ACTUATOR - LINEAR VIBRATOR, 2VRMS	AAC
40	-	1	-	-	Metal Block (Custom Block, Heavy Metal, See metal block spec)	Heavy Metal
41	3-5-468MP	1	-	3M9724-ND	TAPE TRANSFER ADHESIVE 3" X 5YD	3M
42	2-5-4466W	1	-	3M9962-ND	TAPE POLY FOAM 2" x 5YD	3M
<b>COMPONENTS NOT ASSEMBLED</b>						
43	TestPoint_SMD- Square_2.0mm	2	LRA_OUT+, LRA_OUT-		TESTPOINT SMD SQUARE 2.0mm	
44	R0402_DNP	9	R20,R21,R22,R23,R24,R 25,R30,R31,R35		R0402_DNP	
45	R0603_DNP	1	R4	RMCF0603ZT0R00CT- ND	R0603_DNP	STACKPOLE ELECTRONICS
46	R0402_DNP	1	R41	P4.99KLCT-ND	R0402_DNP	PANASONIC
47	R0402_DNP	1	R42	541-0.0JCT	R0402_DNP	VISHAY

## EVALUATION BOARD/KIT/MODULE (EVM) ADDITIONAL TERMS

Texas Instruments (TI) provides the enclosed Evaluation Board/Kit/Module (EVM) under the following conditions:

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING LIMITED WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

Please read the User's Guide and, specifically, the Warnings and Restrictions notice in the User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI's environmental and/or safety programs, please visit [www.ti.com/esh](http://www.ti.com/esh) or contact TI.

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## REGULATORY COMPLIANCE INFORMATION

As noted in the EVM User's Guide and/or EVM itself, this EVM and/or accompanying hardware may or may not be subject to the Federal Communications Commission (FCC) and Industry Canada (IC) rules.

For EVMs **not** subject to the above rules, this evaluation board/kit/module is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

### General Statement for EVMs including a radio

*User Power/Frequency Use Obligations:* This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

### 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

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**

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.

### **For EVMs annotated as IC – INDUSTRY CANADA Compliant**

This Class A or B digital apparatus complies with Canadian ICES-003.

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

### **Concerning EVMs including radio transmitters**

This device complies with Industry Canada licence-exempt RSS standard(s). 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.

### **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.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

### **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.

### **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.

## **【Important Notice for Users of this Product in Japan】**

### **This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan**

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product 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 this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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## **EVALUATION BOARD/KIT/MODULE (EVM) WARNINGS, RESTRICTIONS AND DISCLAIMERS**

**For Feasibility Evaluation Only, in Laboratory/Development Environments.** Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure 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.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

**Certain Instructions.** It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please 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 result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's 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, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

**Agreement to Defend, Indemnify and Hold Harmless.** You agree to 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 use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

**Safety-Critical or Life-Critical Applications.** If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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