

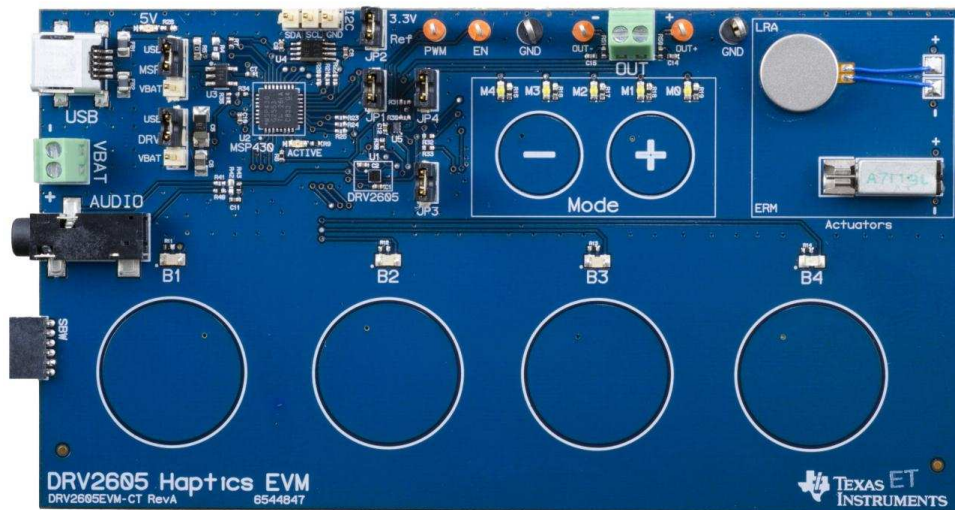
DRV2605EVM-CT ERM and LRA Haptic Driver Evaluation Kit

The DRV2605 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
- Embedded waveform library
- Auto-resonance frequency tracking

The DRV2605EVM-CT evaluation module (EVM) is a complete demo and evaluation platform for the DRV2605. The kit includes a microcontroller, linear actuator, eccentric rotating mass motor, sample waveforms, and capacitive touch buttons, which can completely demonstrate and evaluate the DRV2605.

This user's guide contains instructions to setup and operate the DRV2605EVM-CT in demonstration and evaluation mode.



Evaluation Kit Contents:

- DRV2605EVM-CT demo and evaluation board
- Mini-USB cable
- Demonstration mode firmware

Needed 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
- DRV2605EVM-CT firmware available on www.ti.com

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1 Getting Started

The DRV2605 can be used as a demonstration or evaluation tool. When the DRV2605EVM-CT is powered on for the first time, a demo application automatically starts. To power the board, connect the DRV2605EVM-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 to 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 (“-” and “+”) are used to change between the different banks of effects. See the [DRV2605 Demonstration Program](#) section for a more detailed description of the demo application.

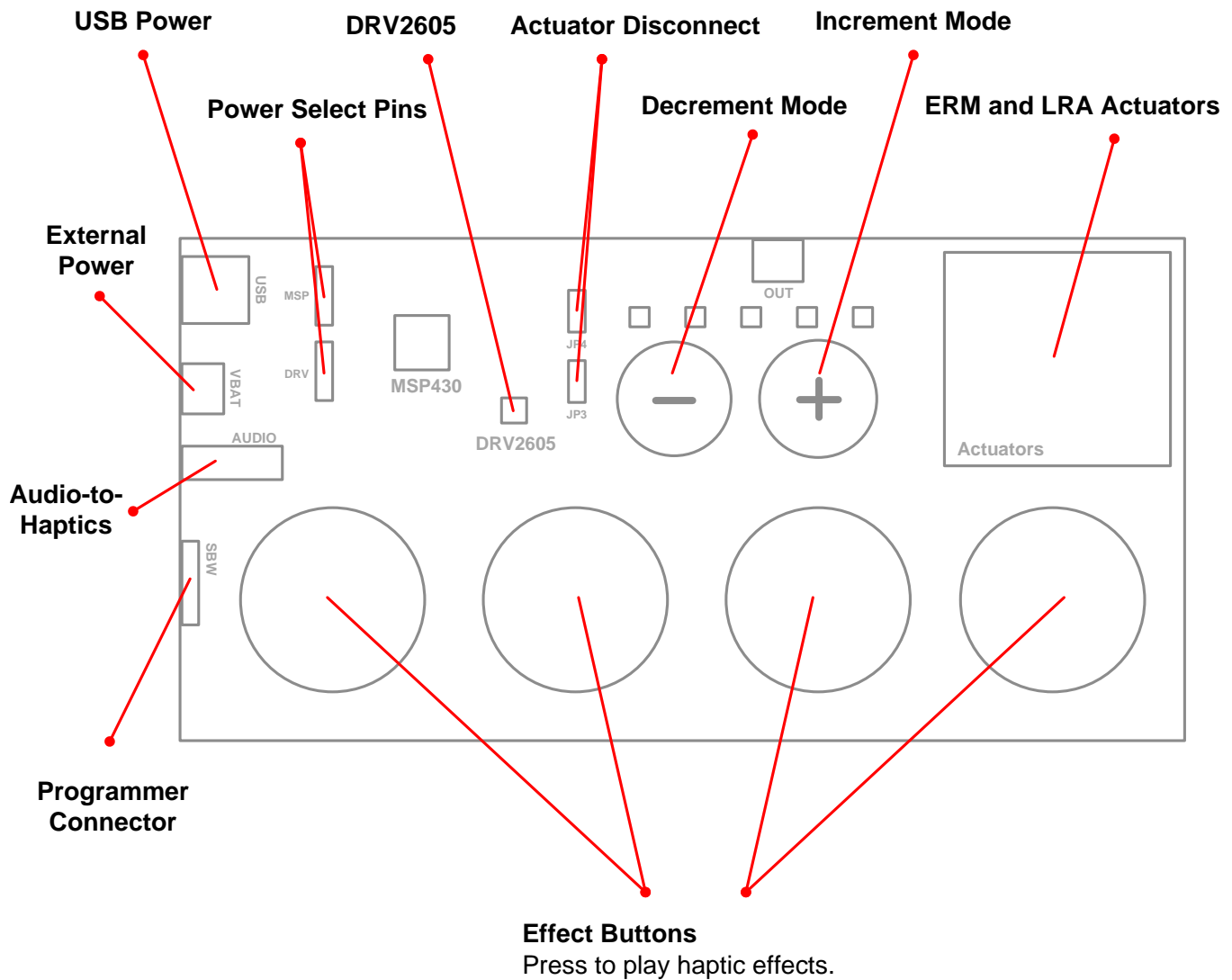


Figure 1. Board Diagram

1.1 Evaluation Module Operating Parameters

The following table lists the operating conditions for the DRV2605 on the evaluation module.

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

1.2 Quick Start Board Setup

The DRV2605EVM-CT firmware contains haptic waveforms which showcase the features and benefits of the DRV2605. 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 can be found in [Table 1](#).

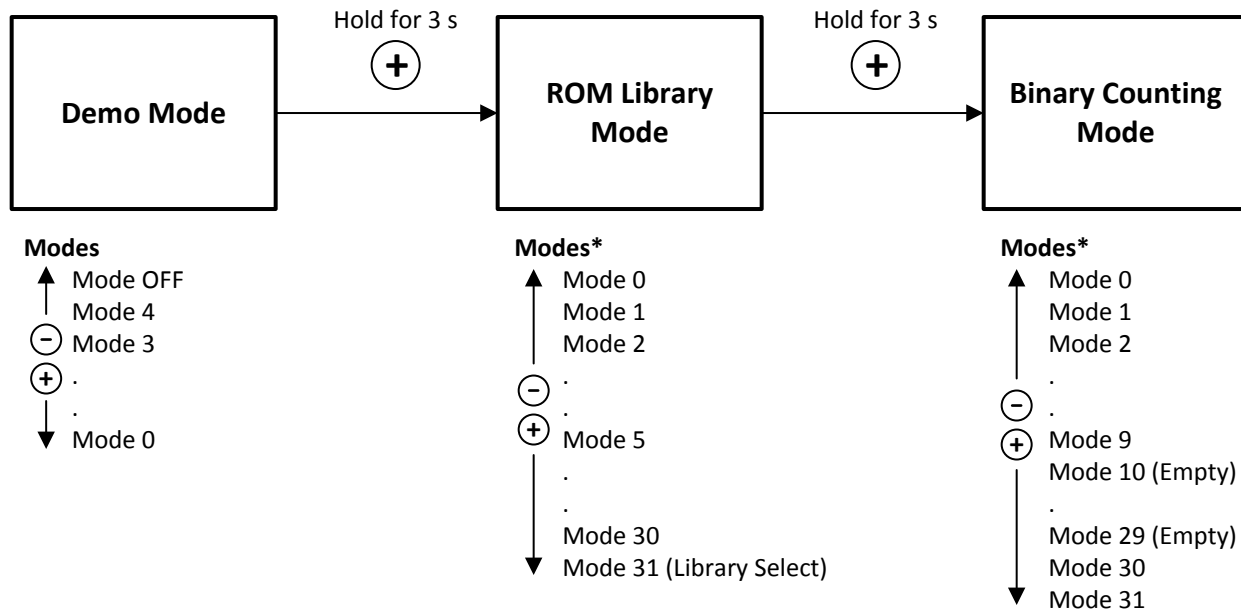
Table 1. Jumper Descriptions

| Jumper | Default Position | Description |
|----------|------------------|--|
| JP1 | Shorted | Connect MSP430 GPIO or PWM output to DRV2605 IN/TRIG |
| JP2 | Shorted | 3.3-V reference for I ² C |
| JP3, JP4 | Shorted | Connect on-board actuators to DRV2605 |
| 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 DRV2605 |

2. Connect the included mini-USB cable to the USB connector on the DRV2605EVM-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 turn on, four mode LEDs flash, and the LRA and ERM perform auto-calibration, indicating the board has been successfully initialized.

2 DRV2605 Demonstration Program

The DRV2605EVM-CT contains a microcontroller and embedded software to control the DRV2605. There are three sets of modes accessible by pressing and holding the “+” button. Follow the instructions in the following sections to access the effects in each set.



* Displayed in Binary

Figure 2. DRV2605EVM-CT Mode Sets

2.1 Demo Mode

Table 2 lists the effects preloaded on the DRV2605EVM-CT. The modes are selected using the “+” and “-” mode buttons in the center of the board. The current mode can be identified by the white LEDs directly above the mode buttons. Buttons B1 to B4 trigger the effects listed in the description column and change based on the selected mode.

Table 2. Mode and Effects Table

| Mode | Button | Description | Actuator | Waveform Location | Interface |
|----------------------|--------|---|-------------|------------------------|-------------------------------------|
| Mode Off LEDs Off | B1 | Click + Ramp Down | ERM | ROM | Internal trigger (I ² C) |
| | B2 | Ramp Up + Pulsing | | | |
| | B3 | Click + Ramp Down | LRA | | |
| | B4 | Ramp Up + Pulsing | | | |
| Mode 4 LED M4 On | B1 | SharpClick_100 | ERM | ROM | Internal trigger |
| | B2 | StrongClick_60 + Release | | | External edge trigger |
| | B3 | SoftBump_100 | | | Internal trigger |
| | B4 | DoubleClick_100 | | | External level trigger |
| Mode 3 LED M3 On | B1 | SharpTick2_80 | LRA | ROM | Internal trigger |
| | B2 | StrongClick_100 + Release | | | External edge trigger |
| | B3 | SoftBump_100 | | | Internal trigger |
| | B4 | DoubleClick_100 | | | External level trigger |
| Mode 2 LED M2 On | B1 | LRA auto-resonance on | LRA | μController | RTP |
| | B2 | LRA auto-resonance off | | | PWM |
| | B3 | ERM buzz alert (closed loop) | ERM | ROM | RTP |
| | B4 | ERM buzz alert (open loop) | | | Internal trigger |
| Mode 1 LED M1 On | B1 | Concentration game The board displays a pattern using the effect buttons. See how many times you can repeat the pattern as it increases by one effect each time. | ERM and LRA | ROM | Internal trigger (I ² C) |
| | B2 | | | | |
| | B3 | | | | |
| | B4 | | | | |
| Mode 0 LED M0 On | B1 | Audio-to-haptics enable | ERM | External analog source | Audio-to-haptics |
| | B2 | Audio-to-haptics enable | LRA | | |
| | B3 | Exit A2H, click, return to A2H | ERM and LRA | ROM | Internal trigger (I ² C) |
| | B4 | Exit A2H, buzz, return to A2H | | | |

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 contains a set of haptic sequences that combine a series of haptic effects. The two following effects show combinations of clicks, ramps, and pulses.

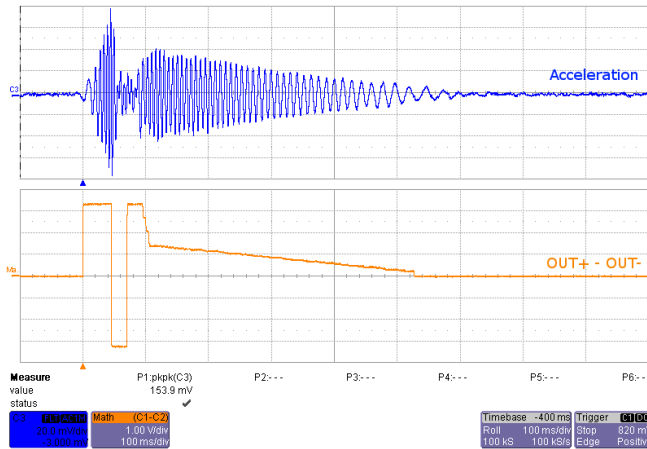


Figure 3. ERM Click and Ramp-Down Waveform (Button 1)

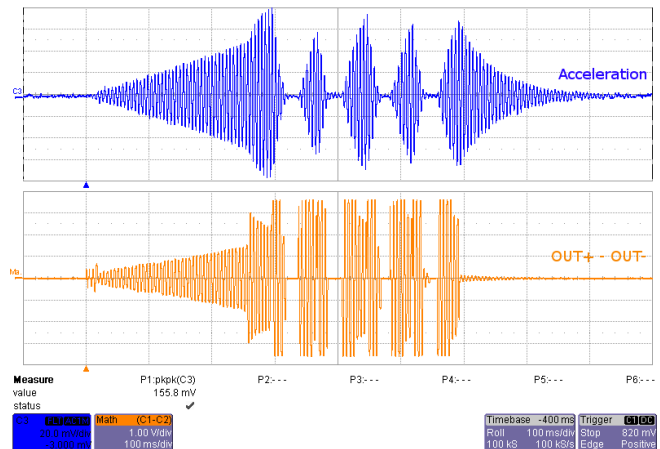


Figure 4. LRA Ramp-Up and Pulsing Waveform (Button 4)

2.2.2 Mode 4 – ERM Clicks

Mode 4 shows two different ERM click styles. Button 1 shows a single sharp click. Button 2 shows a click and release effect. The click and release effect provides a haptic waveform on both the button press and the button release.

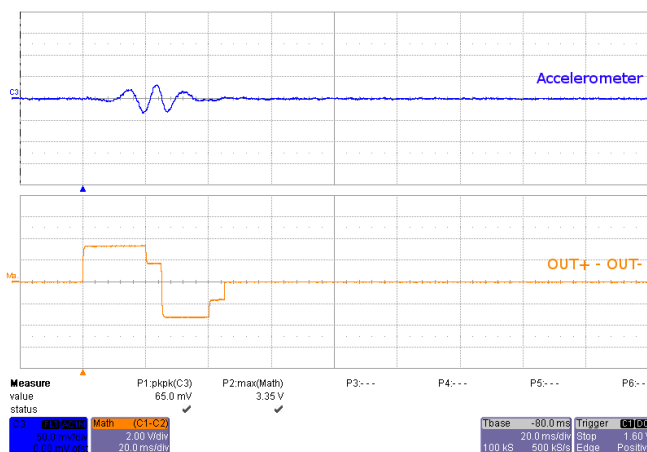


Figure 5. ERM SharpClick_100 (Button 1)

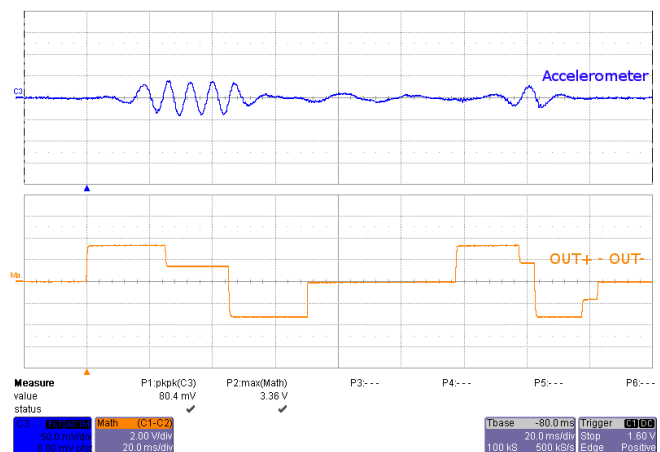


Figure 6. ERM StrongClick_60 and Release SharpClick_100 (Button 2)

2.2.3 Mode 3 – LRA Clicks

Mode 3 shows two different LRA click styles. Button 1 shows a single sharp click and Button 2 shows a click and release effect. The click and release effect provides a haptic waveform on both the button press and the button release.

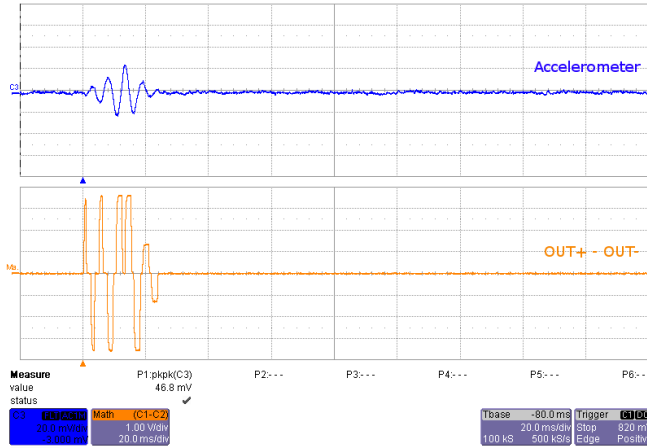


Figure 7. LRA SharpTick2_80 (Button 1)

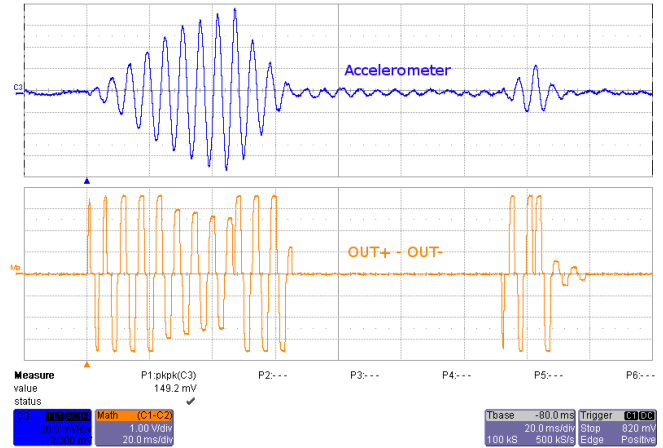


Figure 8. LRA StrongClick 100 and Release SharpTick2_80 (Button 2)

2.2.4 Mode 2 – Alerts

Mode 2 showcases the advantages of the smart loop architecture, which includes auto-resonance tracking, automatic overdrive, and automatic braking.

Figure 9 and Figure 10 show the difference in acceleration when using LRA auto-resonance on and LRA auto-resonance off. Notice that the acceleration is higher when driven at the resonant frequency. Also, notice the start and stop time of the acceleration are much quicker when using the overdrive and braking feature of the DRV2605.

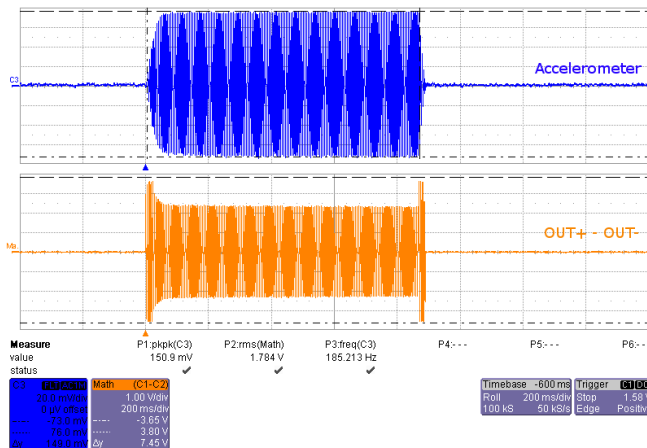


Figure 9. LRA Auto-Resonance On (Button 1)

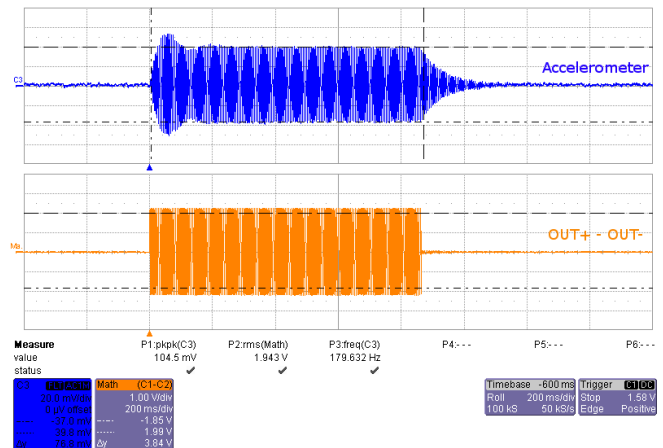


Figure 10. LRA Auto-Resonance Off (Button 2)

The reason for higher acceleration can be seen in **Figure 11**. 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 (the effects shown in **Figure 11**). With the smart loop auto-resonance feature, the DRV2605 dynamically tracks the exact resonant frequency to maximize the vibration force.

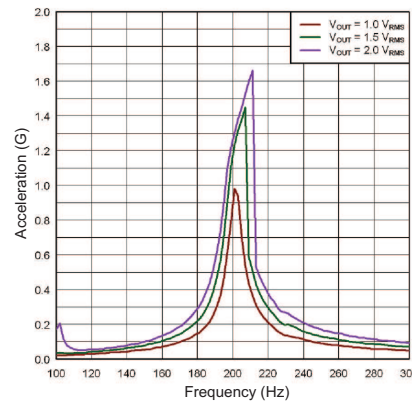


Figure 11. LRA Acceleration versus Frequency over Output Voltage

Figure 12 and **Figure 13** show the difference between an ERM with automatic closed-loop overdrive and braking, and the open-loop library waveform with a predefined overdrive period. The closed-loop version starts and stops the actuator perfectly and does not drive too long or too short. Automatic overdrive and braking simplify the design of haptic effects by eliminating the tuning time for actuator startup and stop.

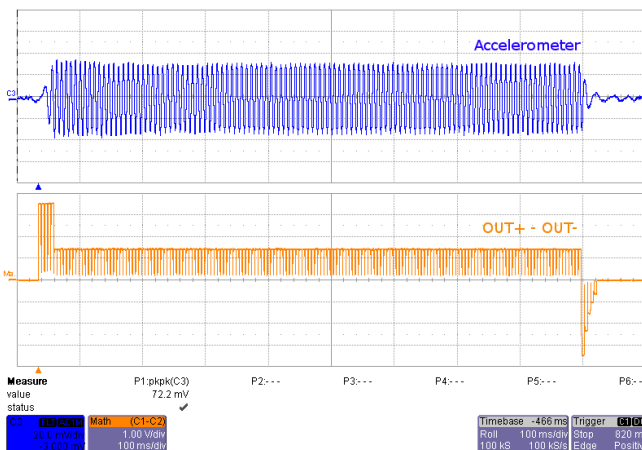


Figure 12. ERM Closed Loop (Button 3)

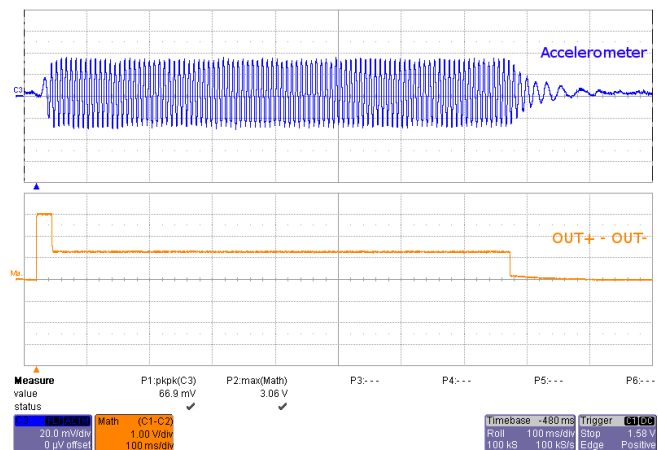


Figure 13. ERM Open Loop (Button 4)

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 buttons.
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 – Audio-to-Haptics

Audio-to-haptics is a unique feature that converts an audio signal to haptics. Take audio from music, games, or movies and automatically create haptic effects.

Buttons B1 to B4 perform the following actions:

- Button 1 – Audio-to-haptics using ERM
- Button 2 – Audio-to-haptics using LRA
- Button 3 – Switch to internal trigger and play library click effect
- Button 4 – Switch to internal trigger and play library buzz effect

To use this mode:

1. Connect an audio source to the audio jack on the left side of the board. The tip of the audio connector is applied to the input of the DRV2605.
2. Press button 1 which enables audio-to-haptics using the on-board ERM
3. Decrease the volume of the audio source, if the ERM is constantly vibrating, or increase the volume, if the ERM is not vibrating at all.
4. Feel the haptic vibrations as the audio plays.
5. Press button 2 which enables audio-to-haptics using the on-board LRA.
6. Decrease the volume of the audio source if the LRA is constantly vibrating or increase the volume if the LRA is not vibrating at all.
7. Feel the haptic vibrations as the audio plays.
8. Press button 3 or 4 to trigger a click or buzz during audio-to-haptics playback.

Figure 14 and Figure 15 show the conversion process from audio to haptics for both ERM and LRA.

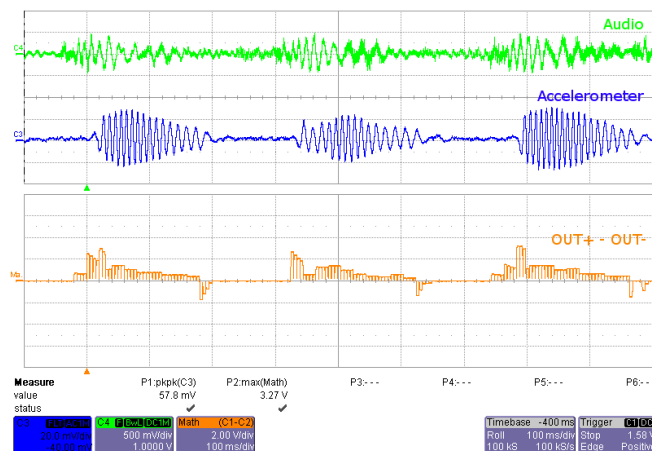


Figure 14. ERM Audio-to-Haptics Conversion (Button 1)

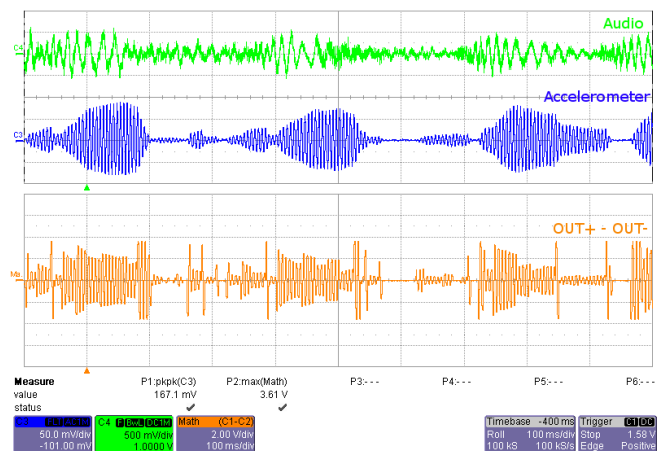


Figure 15. LRA Audio-to-Haptics Conversion (Button 2)

2.3 ROM Library Mode

ROM library effects can be accessed by holding the "+" button until the mode LEDs flash and colored LEDs flash once.

Once in "Library Mode," the DRV2605 embedded ROM 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:

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

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

% - is the modulo operator

To change between the 5 ERM libraries and 1 LRA library:

1. Select mode 31 (11111'b) using the "+" or "-" buttons.
 - B1 – Press repeatedly to access ROM libraries 1 through 5. The current library flashes on the mode LEDs
 - B2 – Press to select the LRA ROM library
2. Then use the ROM effects as described previously

Each ERM library was designed for specific actuator behavior. [Table 3](#) describes the actuator properties that are best suited for each library. Note that the rated and overdrive voltages can be changed using the rated and overdrive clamp registers in the DRV2605. The most important parameters to characterize with your actuator are the rise and brake times.

Table 3. DRV2605 Library Table

| Number | Library | Actuator Properties | | | |
|--------|-----------|---------------------|-----------------------|----------------|-----------------|
| | | Rated Voltage (V) | Overdrive Voltage (V) | Rise Time (ms) | Brake Time (ms) |
| 1 | Library A | 1.3 | 3 | 40 – 60 | 20 – 40 |
| 2 | Library B | 3 | 3 | 40 – 60 | 5 – 15 |
| 3 | Library C | 3 | 3 | 60 – 80 | 10 – 20 |
| 4 | Library D | 3 | 3 | 100 – 140 | 15 – 25 |
| 5 | Library E | 3 | 3 | >140 | >30 |

2.4 ROM Library Effects List

Below is a description of the 123 waveforms embedded in the DRV2605.

| Effect ID# | Waveform Name | Effect ID# | Waveform Name | Effect ID# | Waveform Name |
|------------|---|------------|--|------------|---|
| 1 | Strong click – 100% | 42 | Long double sharp click medium 2 – 80% | 83 | Transition ramp up long smooth 2 – 0 to 100% |
| 2 | Strong click – 60% | 43 | Long double sharp click medium 3 – 60% | 84 | Transition ramp up medium smooth 1 – 0 to 100% |
| 3 | Strong click – 30% | 44 | Long double sharp tick 1 – 100% | 85 | Transition ramp up medium smooth 2 – 0 to 100% |
| 4 | Sharp click – 100% | 45 | Long double sharp tick 2 – 80% | 86 | Transition ramp up short smooth 1 – 0 to 100% |
| 5 | Sharp click – 60% | 46 | Long double sharp tick 3 – 60% | 87 | Transition ramp up short smooth 2 – 0 to 100% |
| 6 | Sharp click – 30% | 47 | Buzz 1 – 100% | 88 | Transition ramp up long sharp 1 – 0 to 100% |
| 7 | Soft bump – 100% | 48 | Buzz 2 – 80% | 89 | Transition ramp up long sharp 2 – 0 to 100% |
| 8 | Soft bump – 60% | 49 | Buzz 3 – 60% | 90 | Transition ramp up medium sharp 1 – 0 to 100% |
| 9 | Soft bump – 30% | 50 | Buzz 4 – 40% | 91 | Transition ramp up medium sharp 2 – 0 to 100% |
| 10 | Double click – 100% | 51 | Buzz 5 – 20% | 92 | Transition ramp up short sharp 1 – 0 to 100% |
| 11 | Double click – 60% | 52 | Pulsing strong 1 – 100% | 93 | Transition ramp up short sharp 2 – 0 to 100% |
| 12 | Triple click – 100% | 53 | Pulsing strong 2 – 60% | 94 | Transition ramp down long smooth 1 – 50 to 0% |
| 13 | Soft fuzz – 60% | 54 | Pulsing medium 1 – 100% | 95 | Transition ramp down long smooth 2 – 50 to 0% |
| 14 | Strong buzz – 100% | 55 | Pulsing medium 2 – 60% | 96 | Transition ramp down medium smooth 1 – 50 to 0% |
| 15 | 750-ms alert 100% | 56 | Pulsing sharp 1 – 100% | 97 | Transition ramp down medium smooth 2 – 50 to 0% |
| 16 | 1000-ms alert 100% | 57 | Pulsing sharp 2 – 60% | 98 | Transition ramp down short smooth 1 – 50 to 0% |
| 17 | Strong click 1 – 100% | 58 | Transition click 1 – 100% | 99 | Transition ramp down short smooth 2 – 50 to 0% |
| 18 | Strong click 2 – 80% | 59 | Transition click 2 – 80% | 100 | Transition ramp down long sharp 1 – 50 to 0% |
| 19 | Strong click 3 – 60% | 60 | Transition click 3 – 60% | 101 | Transition ramp down long sharp 2 – 50 to 0% |
| 20 | Strong click 4 – 30% | 61 | Transition click 4 – 40% | 102 | Transition ramp down medium sharp 1 – 50 to 0% |
| 21 | Medium click 1 – 100% | 62 | Transition click 5 – 20% | 103 | Transition ramp down medium sharp 2 – 50 to 0% |
| 22 | Medium click 2 – 80% | 63 | Transition click 6 – 10% | 104 | Transition ramp down short sharp 1 – 50 to 0% |
| 23 | Medium click 3 – 60% | 64 | Transition hum 1 – 100% | 105 | Transition ramp down short sharp 2 – 50 to 0% |
| 24 | Sharp tick 1 – 100% | 65 | Transition hum 2 – 80% | 106 | Transition ramp up long smooth 1 – 0 to 50% |
| 25 | Sharp tick 2 – 80% | 66 | Transition hum 3 – 60% | 107 | Transition ramp up long smooth 2 – 0 to 50% |
| 26 | Sharp tick 3 – 60% | 67 | Transition hum 4 – 40% | 108 | Transition ramp up medium smooth 1 – 0 to 50% |
| 27 | Short double click strong 1 – 100% | 68 | Transition hum 5 – 20% | 109 | Transition ramp up medium smooth 2 – 0 to 50% |
| 28 | Short double click strong 2 – 80% | 69 | Transition hum 6 – 10% | 110 | Transition ramp up short smooth 1 – 0 to 50% |
| 29 | Short double click strong 3 – 60% | 70 | Transition ramp down long smooth 1 – 100 to 0% | 111 | Transition ramp up short smooth 2 – 0 to 50% |
| 30 | Short double click strong 4 – 30% | 71 | Transition ramp down long smooth 2 – 100 to 0% | 112 | Transition ramp up long sharp 1 – 0 to 50% |
| 31 | Short double click medium 1 – 100% | 72 | Transition ramp down medium smooth 1 – 100 to 0% | 113 | Transition ramp up long sharp 2 – 0 to 50% |
| 32 | Short double click medium 2 – 80% | 73 | Transition ramp down medium smooth 2 – 100 to 0% | 114 | Transition ramp up medium sharp 1 – 0 to 50% |
| 33 | Short double click medium 3 – 60% | 74 | Transition ramp down short smooth 1 – 100 to 0% | 115 | Transition ramp up medium sharp 2 – 0 to 50% |
| 34 | Short double sharp tick 1 – 100% | 75 | Transition ramp down short smooth 2 – 100 to 0% | 116 | Transition ramp up short sharp 1 – 0 to 50% |
| 35 | Short double sharp tick 2 – 80% | 76 | Transition ramp down long sharp 1 – 100 to 0% | 117 | Transition ramp up short sharp 2 – 0 to 50% |
| 36 | Short double sharp tick 3 – 60% | 77 | Transition ramp down long sharp 2 – 100 to 0% | 118 | Long buzz for programmatic stopping – 100% |
| 37 | Long double sharp click strong 1 – 100% | 78 | Transition ramp down medium sharp 1 – 100 to 0% | 119 | Smooth hum 1 (No kick or brake pulse) – 50% |
| 38 | Long double sharp click strong 2 – 80% | 79 | Transition ramp down medium sharp 2 – 100 to 0% | 120 | Smooth hum 2 (No kick or brake pulse) – 40% |
| 39 | Long double sharp click strong 3 – 60% | 80 | Transition ramp down short sharp 1 – 100 to 0% | 121 | Smooth hum 3 (No kick or brake pulse) – 30% |
| 40 | Long double sharp click strong 4 – 30% | 81 | Transition ramp down short sharp 2 – 100 to 0% | 122 | Smooth hum 4 (No kick or brake pulse) – 20% |
| 41 | Long double sharp click medium 1 – 100% | 82 | Transition ramp up long smooth 1 – 0 to 100% | 123 | Smooth hum 5 (No kick or brake pulse) – 10% |

3 Additional Hardware Modes

Additional modes are available on the DRV2605EVM-CT that provide 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 six 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 modes” 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 4 lists the modes available in “binary counting mode”.

Table 4. Binary Counting Modes

| Mode | Button | Description | Notes |
|--|--------|------------------------------|---|
| Mode 0 External I ² C mode LEDs: 00000 | B1 | Set ERM output | Use this mode to control the DRV2605 using an external I ² C Master. Press B1 or B2 to choose between the ERM or LRA. Press B3 to choose the trigger type. (1 - Internal, 2 - External edge, 3 - External level). Press B4 to trigger the waveform sequencer. |
| | B2 | Set LRA output | |
| | B3 | Choose trigger | |
| | B4 | Trigger button | |
| Mode 1 Auto-calibration and 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 | |
| Mode 2 External PWM LEDs: 00010 | B1 | Disable PWM mode | External PWM - disconnect MSP430 PWM using JP1. Connect external PWM signal to the "PWM" test point at the top of the board. Select actuator using buttons B2 and B3. |
| | B2 | Set ERM output | |
| | B3 | Set LRA output | |
| | B4 | – | |
| Mode 3 External PWM and enable LEDs: 00011 | B1 | Return to typical mode | External PWM and enable - disconnect MSP430 PWM using JP1. Connect external PWM signal to the "PWM" test point at the top of the board. Connect an external enable signal to the "EN" test point. Select actuator using buttons B2 and B3. Press B1 before switching modes. |
| | B2 | Set ERM output | |
| | B3 | Set LRA output | |
| | B4 | – | |
| Mode 4 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" test point. |
| | B2 | DC coupling - ERM | |
| | B3 | AC coupling - LRA | |
| | B4 | DC coupling - LRA | |
| Mode 5 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 | |
| Mode 6 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 or 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) | |
| Mode 7 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 or 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 and mode 1. |
| | B2 | Test buzz | |
| | B3 | Decrease output voltage (–1) | |
| | B4 | Increase output voltage (+1) | |
| Mode 8 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 or 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) | |
| Mode 9 Recorder LEDs: 01001 | B1 | Start or 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 effect | |
| | B3 | Start or stop play back | |
| | B4 | – | |
| Mode 30 Actuator break-in LEDs: 11110 | B1 | Begin actuator break-in | Actuator break-in - used to break in new actuators |
| | B2 | | |
| | B3 | | |
| | B4 | | |
| Mode 31 About the board LEDs: 11111 | B1 | Device ID | About the board - the value appears on the mode LEDs in binary. DRV2605 Device ID = 00011 |
| | B2 | Silicon revision | |
| | B3 | Code revision | |
| | B4 | | |

4 Hardware Configuration

The DRV2605EVM-CT is flexible and can be used to completely evaluate the DRV2605. The following sections list the various hardware configurations.

4.1 Input and Output Overview

The DRV2605EVM-CT allows complete evaluation of the DRV2605 through test points, jacks, and connectors. Table 5 gives a brief description of the hardware.

Table 5. Hardware Overview

| Signal | Description | I/O |
|------------------|---|-----------------|
| PWM | External input to DRV2605 IN/TRIG pin | Input / Observe |
| EN | External DRV2605 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 to 5.5 V) | Input |
| SBW | MSP430 programming header | Input / Output |
| I ² C | DRV2605 and MSP430 I ² C bus | Input / Output |
| Audio | The audio jack is connected to the IN/TRIG pin of the DRV2605. When the DRV2605 is in audio-to-haptics mode, audio from this jack is converted to haptics | Input |

Hardware configuration details can be found in the following sections.

4.2 Power Supply Selection

The DRV2605EVM-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 DRV2605 and MSP430G2553, respectively. See the following table for possible configurations.

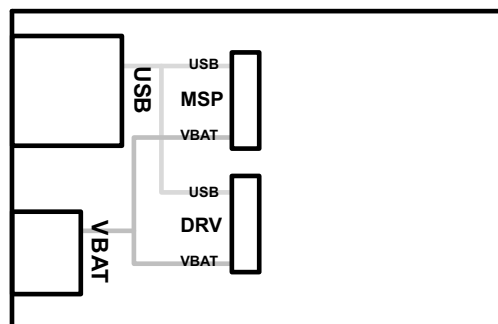


Figure 16. Power Jumper Selection

| Supply Configuration | DRV | MSP | DRV2605 Supply Voltage ⁽¹⁾ |
|--|------|------|---------------------------------------|
| USB – both | USB | USB | 5 V |
| DRV2605 external supply, MSP430 USB | VBAT | USB | VBAT |
| External Supply – both | VBAT | VBAT | VBAT |
| USB with 3.3-V LDO ⁽²⁾ – Both | USB | USB | 3.3 V (R4 = Short, R5 = Open) |

⁽¹⁾ The DRV2605 supply must be on before operating the MSP430.

⁽²⁾ If a 3.3-V DRV2605 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

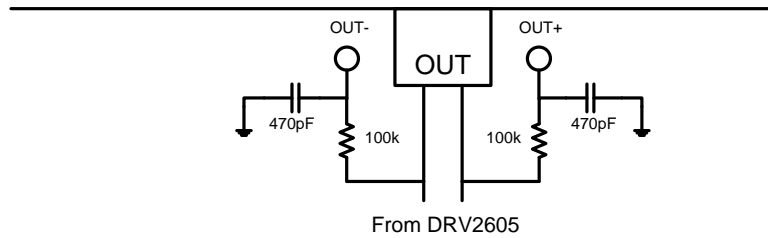


Figure 17. Terminal Block and Test Points

The DRV2605EVM-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 DRV2605.
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.

NOTE: It is important to 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.

4.4 PWM Input

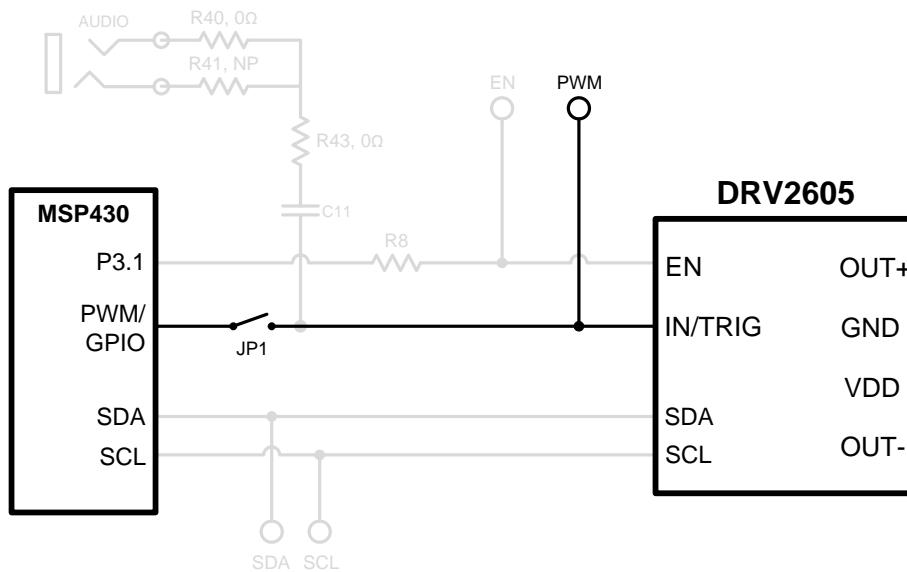


Figure 18. External PWM Input

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

To control the DRV2605 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 button B1 or B2.
 4. Apply the PWM signal to the PWM test point at the top of the board.

4.5 External Trigger Control

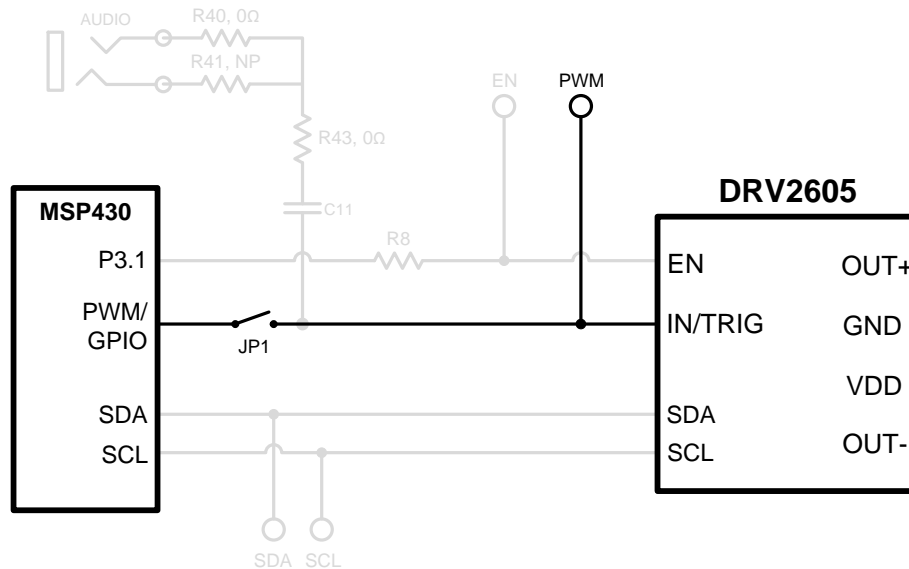


Figure 19. External Trigger Control

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

The DRV2605 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 [datasheet](#) for more information on these input trigger modes.

In mode 0 in the [Additional Hardware Modes](#) section, the DRV2605 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 = External edge, 3 = External level)
 - B4 - Trigger the waveform sequence using the MSP430
3. Fill the waveform sequencer with waveforms using the external I²C 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 button B3. The trigger type appears in binary on the mode LEDs.
6. Apply the trigger signal to the IN/TRIG pin by pressing button B4.

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 = External edge, and 3 = External level)
 - B4 - Trigger the waveform sequence using the MSP430
4. Fill the waveform sequencer with waveforms using the external I²C 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 button B3. 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 I²C Input

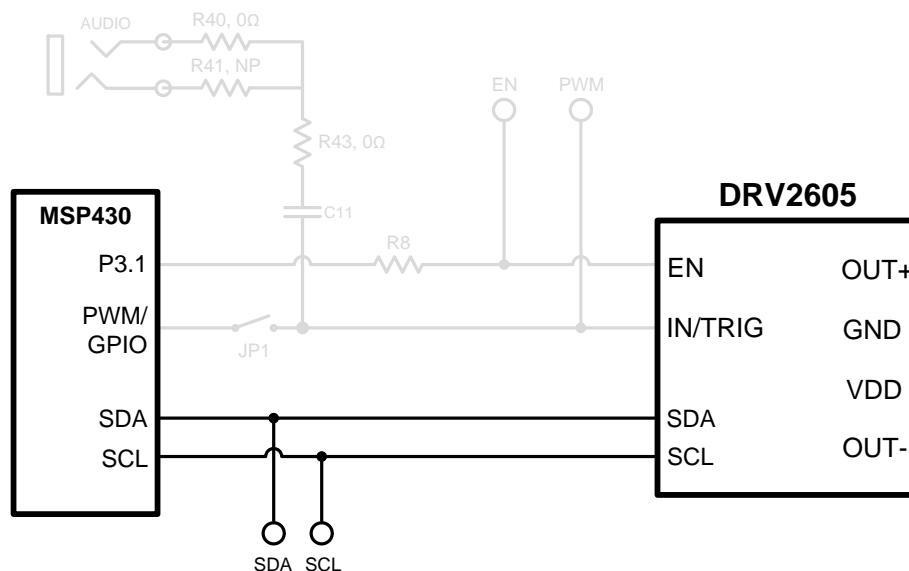


Figure 20. External I²C Input

The DRV2605 can be controlled by an external I²C source. Attach the external controller to the I²C header at the top of the board; be sure to connect SDA, SCL, and GND from the external source.

I²C communication is possible only when the EN pin is set high. To enable the DRV2605 and allow external I²C control, follow these instructions:

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 = External edge, 3 = External 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 DRV2605 using the external I²C source.

4.7 Audio-to-Haptics Input

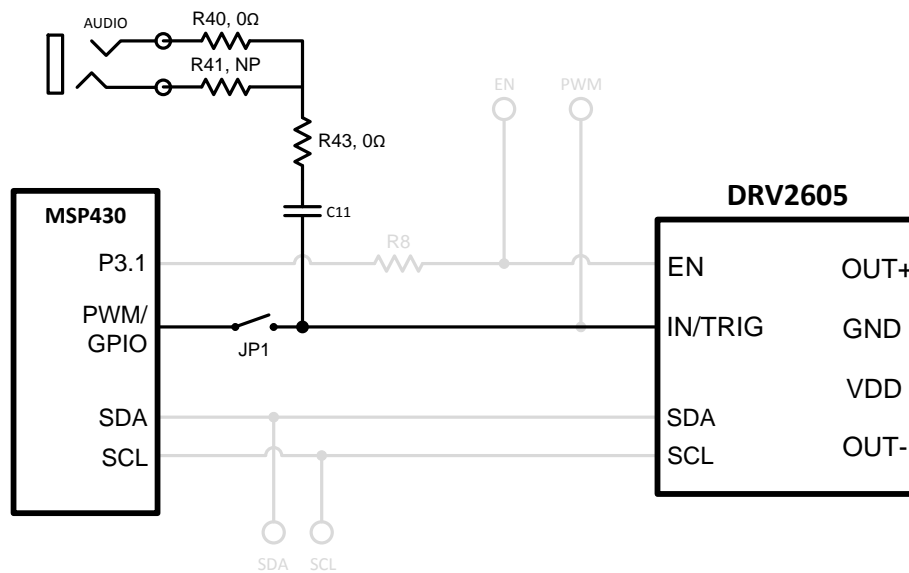


Figure 21. Audio-to-Haptics Input

The DRV2605 audio-to-haptics feature converts an audio signal to a corresponding haptics waveform. This can be used to simulate bass in music, or use the audio track of a game to produce haptic effects.

To use audio-to-haptics:

1. Apply an analog line-out audio signal (not PWM) to the AUDIO jack on the left side of the board. The tip of the inserted male audio plug is applied to the IN/TRIG pin of the DRV2605. See [Figure 21](#).

NOTE: To get the best performance using a headphone out, the user may need to adjust the volume, so that the input signal is near, but does not exceed $1.8 V_{peak}$.

2. In demo mode, select mode 0 (00001'b) using the increment mode button ("+").
3. In mode 0, press either button B1 or B2 to enable the DRV2605 audio-to-haptics. Buttons B3 and B4 switch to internal trigger mode, play a ROM library effect, and then switch back to audio-to-haptics mode.
 - B1 – Audio-to-haptics using ERM
 - B2 – Audio-to-haptics using LRA
 - B3 – Switch to internal trigger and play library click effect
 - B4 – Switch to internal trigger and play library buzz effect
4. Play music and feel the vibrations of the actuator.

NOTE: Some audio signals are too large or too small and the volume must be adjusted. Adjust appropriately so that the maximum input voltage is 1.8 V and the bass of the input signal can be felt on the actuator. The audio input minimum and maximum thresholds can be adjusted using I²C. See the [datasheet](#) for more details.

5 Measurement and Analysis

The DRV2605 uses PWM modulation to create the output signal for both ERM and LRA actuators. To measure and observe the DRV2605 output waveform, connect an oscilloscope or other measurement equipment to the filtered output test points, “OUT+” and “OUT-”.

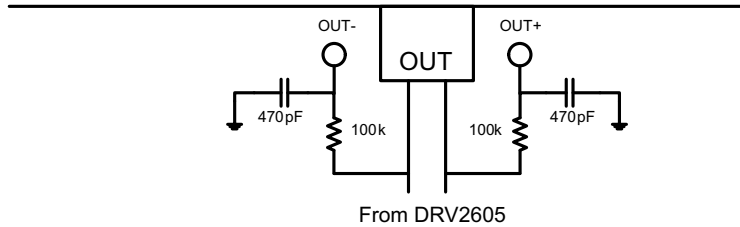


Figure 22. Terminal Block and Test Points

The DRV2605 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 Figure 23 shows the DRV2605 unfiltered waveform and Figure 24 shows a filtered version used for observation and measurement.

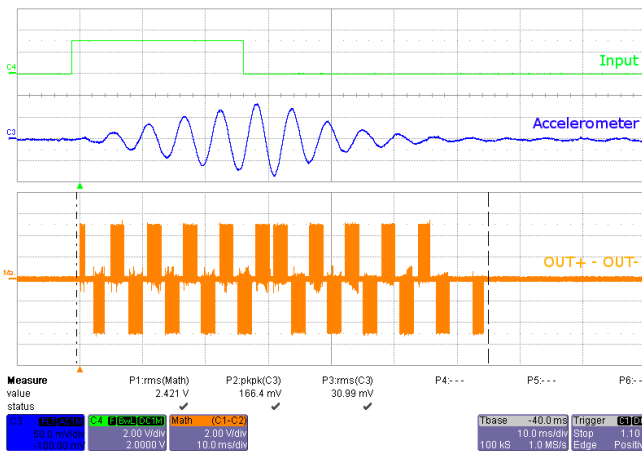


Figure 23. DRV2605 Unfiltered Waveform

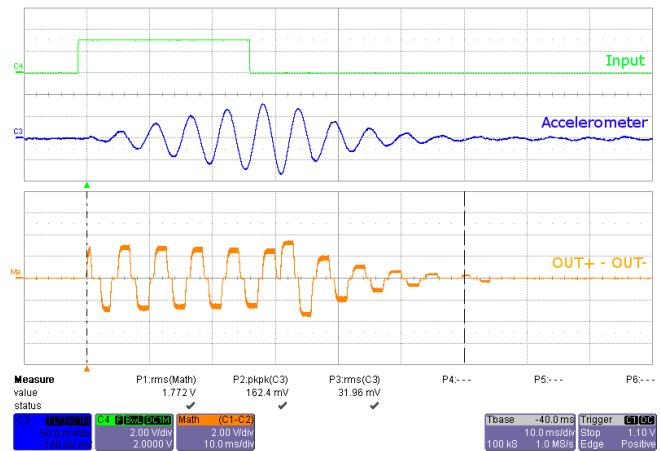


Figure 24. DRV2605 Filtered Waveform

If the DRV2605EVM-CT filter is not used, TI recommends using a first-order, low-pass filter with a cutoff between 1 and 3.5 kHz. Figure 25 shows a recommended output filter for use while measuring and characterizing the DRV2605 in the lab.

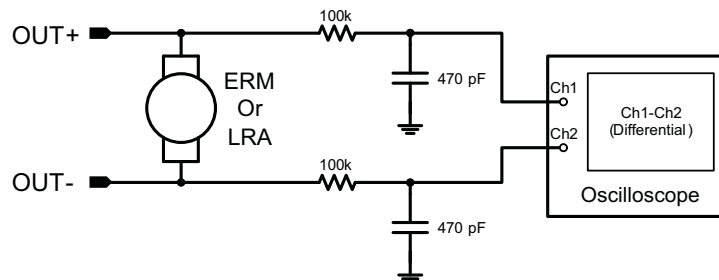


Figure 25. Measuring the DRV2605 Output Signal With an Analog Low-Pass Filter

6 MSP430 Firmware

The MSP430 firmware on the DRV2605EVM-CT can be modified or reprogrammed to create new haptic effects or behaviors. Find the latest firmware source code and binaries on www.ti.com. Follow these instructions to modify or reprogram the DRV2605EVM-CT:

1. Purchase one of the following MSP430G2553 compatible programmers:
 - MSP430 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 DRV2605EVM-CT source code and binaries from www.ti.com.
4. Connect the programmer to an available USB port.
5. Connect the programmer to the “SBW” header on the DRV2605EVM-CT.
6. In CCS,
 - (a) Open the project file by selecting Project → Import Existing CCS Project.
 - (b) Select Browse and navigate to the DRV2605EVM-CT project folder, then press OK.
 - (c) Select the checkbox next to the DRV2605EVM-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 www.ti.com to the new project directory

Figure 26 shows the connection between the MSP430 LaunchPad (MSP-EXP430G2) and the DRV2605EVM-CT.

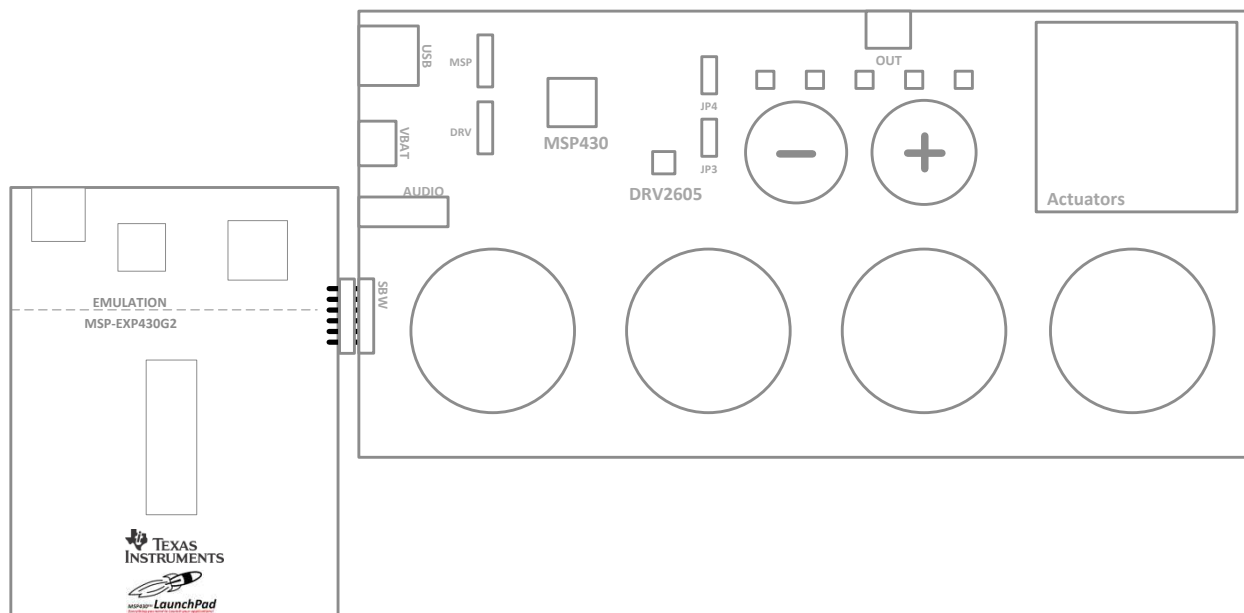


Figure 26. LaunchPad Programmer Connection

6.1 MSP430 Pinout

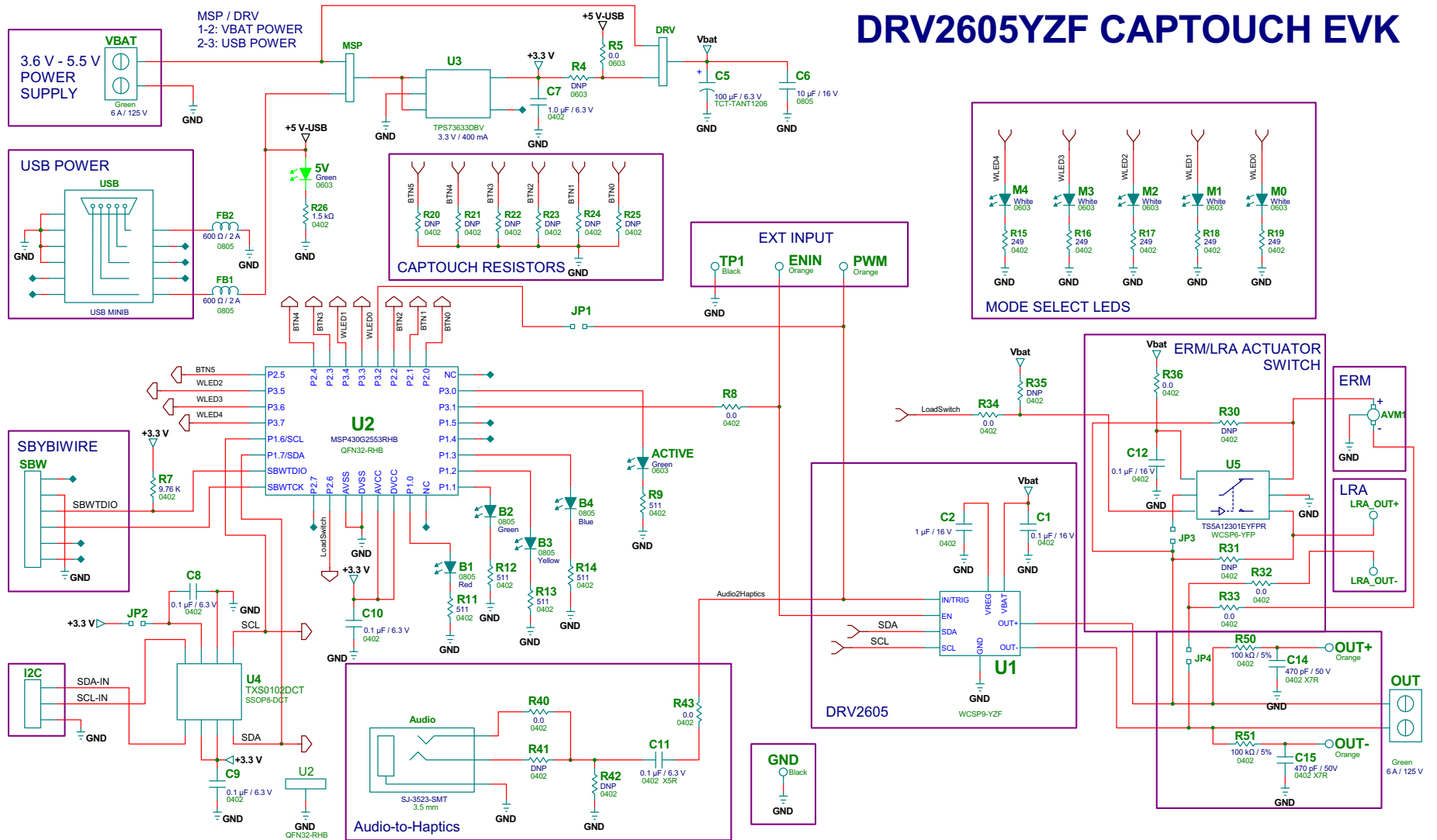
The DRV2605EVM-CT contains a MSP430G2553 low-cost microcontroller, which controls the board and contains sample haptic effects. The pinout for the microcontroller can be found in [Table 6](#).

Table 6. MSP430 Pinout

| NO. | NAME | 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 ² C Clock |
| 22 | P1.7/SDA | I ² 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

DRV2605YZF CAPTOUCH EVK



8 Layout

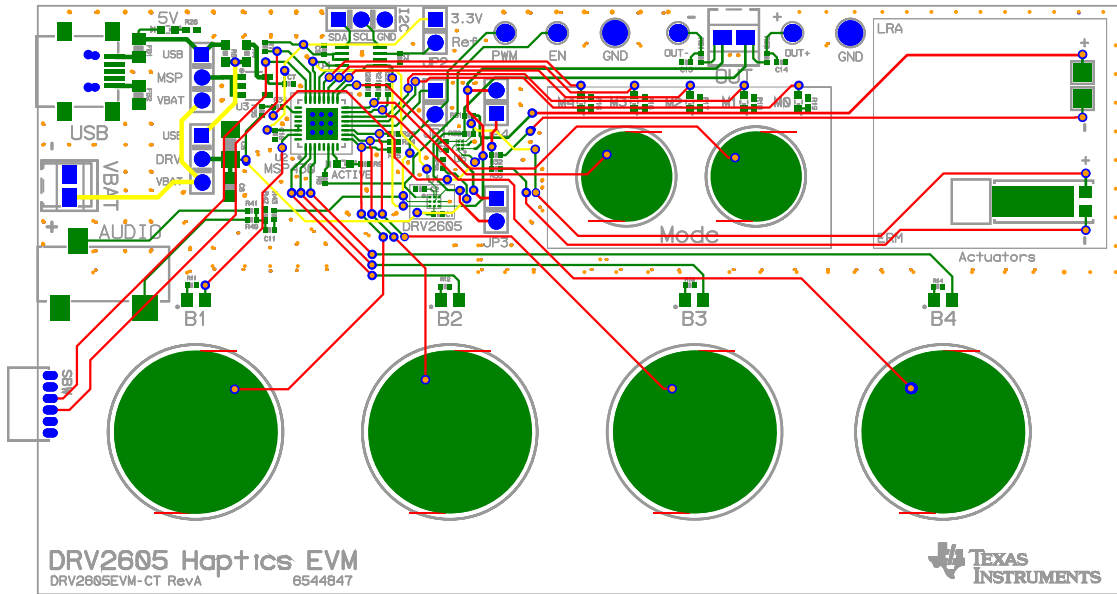


Figure 27. X-Ray Top View

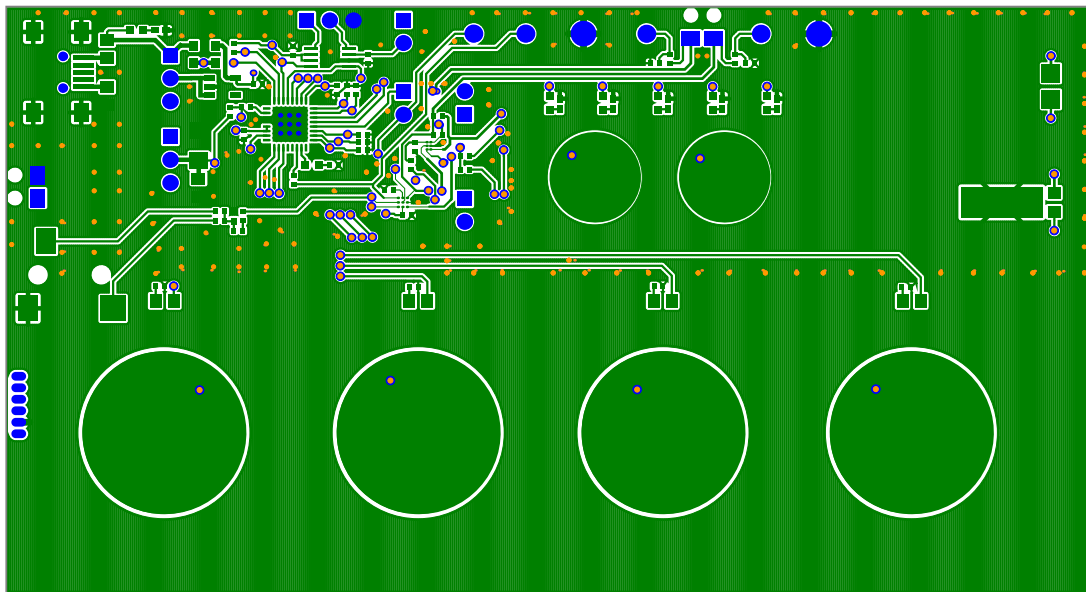


Figure 28. Top Copper

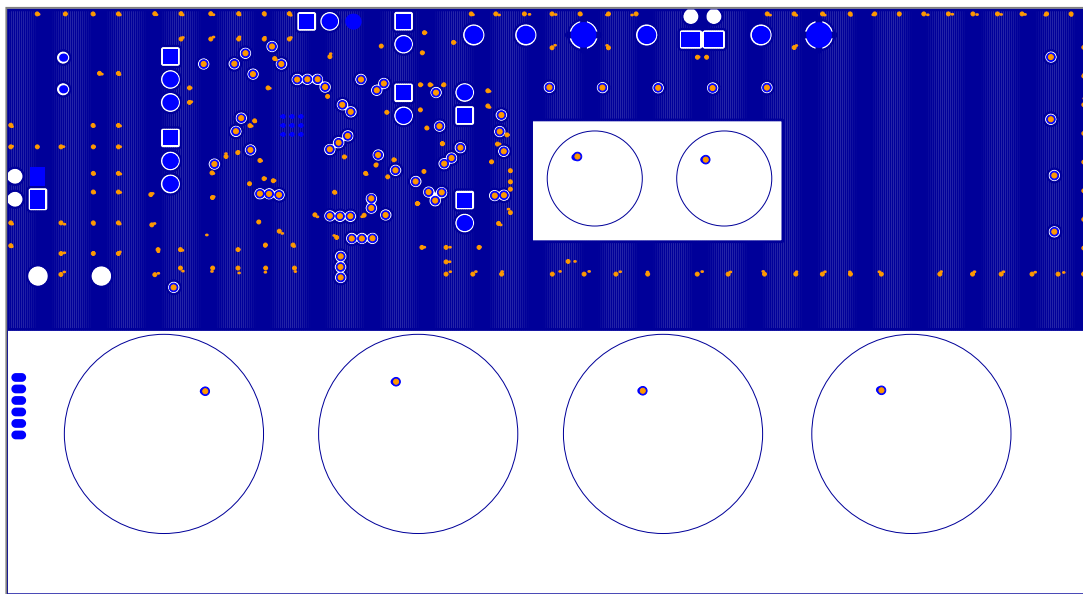


Figure 29. Layer 2 Copper

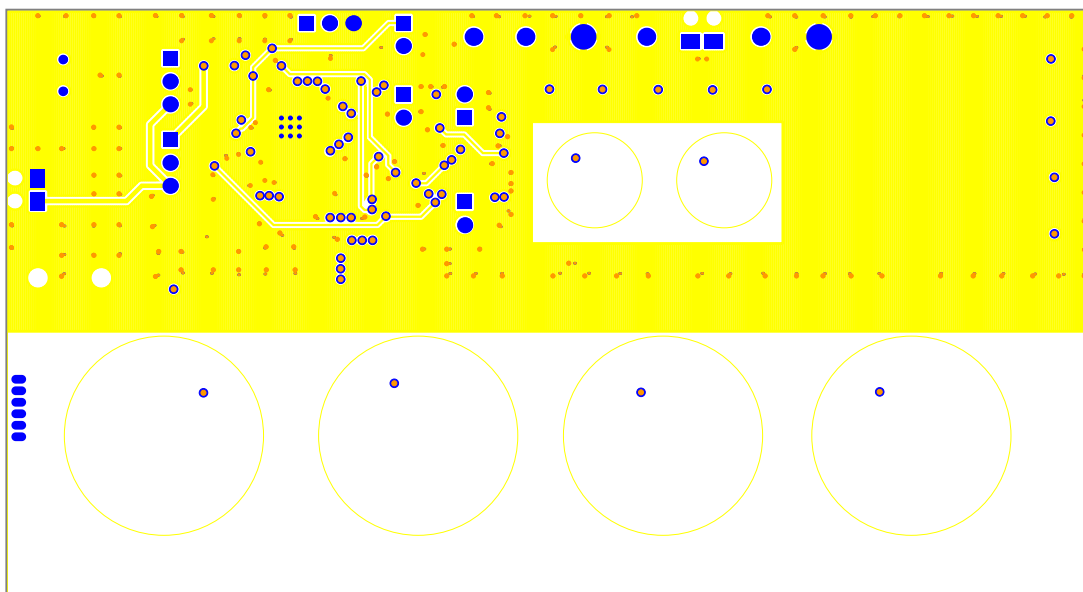


Figure 30. Layer 3 Copper

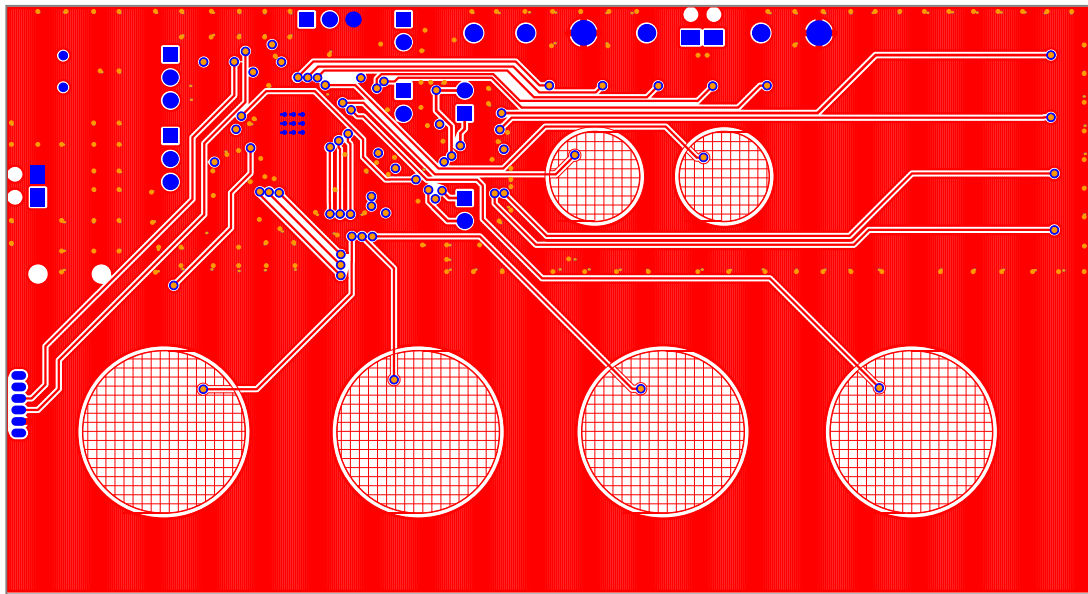


Figure 31. Bottom Copper

9 Bill of Materials

| ITEM | MANU PART NUMBER | QTY | REF DESIGNATORS | VENDOR PART NUMBER | DESCRIPTION | MANUFACTURER |
|-----------------------|---------------------|-----|--------------------|----------------------|---|-------------------|
| SEMICONDUCTORS | | | | | | |
| 1 | DRV2605YZF | 1 | U1 | DRV2605YZF | 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. |
| CAPACITORS | | | | | | |
| 12 | GRM155R71C104KA88D | 2 | C1, C12 | 490-3261-1-ND | CAP SMD0402 CERM 0.1UFD 16V X7R 10% ROHS | MURATA |
| 13 | C1005X5R1C105K050BC | 1 | C2 | 445-4978-1-ND | CAP SMD0402 CERM 1.0UFD 16V 10% X5R ROHS | TDK CORP |
| 14 | C1005X5R0J104K | 3 | C8, C9, C10 | 445-1266-1 | CAP SMD0402 CERM 0.1UFD 6.3V 10% X5R ROHS | TDK CORP |
| 15 | 0805YD106KAT2A | 1 | C6 | 478-5165-1 | CAP SMD0805 CERM 10UFD 16V X5R 10% ROHS | AVX |
| 16 | GRM155R60J105KE19D | 1 | C7 | 490-1320-1 | CAP SMD0402 CERM 1.0UFD 6.3V X5R 10% ROHS | MURATA |
| 17 | C1005X5R0J104K | 1 | C11 | 445-1266-1 | CAP SMD0402 CERM 0.1UFD 6.3V 10% X5R ROHS | TDK CORP |
| 18 | C0402C471K5RACTU | 2 | C14, C15 | 399-1025-1 | CAP SMD0402 CERM 470PFD 50V 10% X7R ROHS | KEMET |
| 19 | TCTAL0J107M8R | 1 | C5 | 511-1498-1-ND | CAP TANT1206 100UFD 6.3V 20% TCT SERIES ROHS | ROHM |
| RESISTORS | | | | | | |
| 20 | ERJ-2RKF9761X | 1 | R7 | P9.76KLCT-ND | RESISTOR SMD0402 THICK FILM 9.76K OHMS 1/10W 1% ROHS | PANASONIC |

| ITEM | MANU PART NUMBER | QTY | REF DESIGNATORS | VENDOR PART NUMBER | DESCRIPTION | MANUFACTURER |
|-----------------------------------|------------------|-----|--|---------------------|--|-----------------------|
| 21 | RMCF0402ZT0R00 | 5 | R8, R32, R33, R34, R36 | RMCF0402ZT0R00CT | ZERO OHM JUMPER SMT 0402 0 OHM 1/16W,5% ROHS | STACKPOLE ELECTRONICS |
| 22 | RC0402FR-07511RL | 5 | R9, R11, R12, R13, R14 | 311-511LRCT-ND | RESISTOR SMD0402 THICK FILM 511 OHMS 1% 1/16W ROHS | YAGEO |
| 23 | ERJ-2GEJ152 | 1 | R26 | | RESISTOR,SMT,0402,THICK FILM,5%,1/16W,1.5K | Panasonic |
| 24 | RMCF0603ZT0R00 | 1 | R5 | RMCF0603ZT0R00CT-ND | RESISTOR SMD0603 ZERO OHMS 1/10W ROHS | STACKPOLE ELECTRONICS |
| 25 | ERJ-2RKF2490X | 5 | R15, R16, R17, R18, R19 | P249LTR-ND | RESISTOR,SMT,0402,249 OHM,1%,1/16W | Panasonic |
| 26 | CRCW04020000Z0ED | 2 | R40, R43 | 541-0.0JCT | ZERO OHM JUMPER SMT 0402 0 OHM 1/16W,5% ROHS | VISHAY |
| 27 | ERJ-2GEJ104 | 2 | R50, R51 | P100KJCT | RESISTOR SMD0402 THICK FILM 100K OHMS 1/16W 5% ROHS | PANASONIC |
| FERRITE BEADS | | | | | | |
| 28 | MPZ2012S601A | 2 | FB1, FB2 | 445-2206-1 | FERRITE BEAD SMD0805 600 Ohms 2A ROHS | TDK |
| HEADERS, JACKS, AND SHUNTS | | | | | | |
| 29 | LPPB061NGCN-RC | 1 | SBW | S9010E-06 | HEADER THRU FEMALE 1X6-RA 50LS GOLD ROHS | SULLINS |
| 30 | PBC03SAAN | 3 | DRV, I2C, MSP | S1011E-03-ND | HEADER THRU MALE 3 PIN 100LS GOLD ROHS | SULLINS |
| 31 | PBC02SAAN | 1 | JP2 | S1011E-02 | HEADER THRU MALE 2 PIN 100LS GOLD ROHS | SULLINS |
| 32 | PBC02SAAN | 3 | JP1, JP3, JP4 | | HEADER THRU MALE 2 PIN 100LS GOLD ROHS | SULLINS |
| 33 | UX60-MB-5ST | 1 | USB | H2959CT | JACK USB MINIB SMT-RA 5PIN ROHS | HIROSE |
| 34 | SJ-3523-SMT | 1 | Audio | CP-3523SJCT-ND | JACK AUDIO-STEREO MINI(3.5MM ,3-COND SMT-RA ROHS | CUI STACK |
| 35 | SPC02SYAN | 6 | MSP (2-3), DRV (2-3), JP1, JP2, JP3, JP4 | S9001-ND | SHUNT BLACK AU FLASH 0.100LS CLOSED TOP ROHS | SULLINS |
| 36 | 1725656 | 2 | OUT, VBAT | 277-1273 | TERMINAL BLOCK MPT COMBICON 2PIN 6A/125V GREEN 100LS ROHS | PHOENIX CONTACT |
| TEST POINTS AND SWITCHES | | | | | | |
| 37 | 5011 | 2 | GND, TP1 (Solder so that color ring is secured) | 5011K | PC TESTPOINT BLACK 063 HOLE ROHS | KEYSTONE ELECTRONICS |
| 38 | 5003 | 4 | PWM, ENIN, OUT+, OUT- (Solder so that color ring is secured) | 5003K | PC TESTPOINT, ORANGE, ROHS | KEYSTONE ELECTRONICS |
| 39 | NRS-2574 | 1 | AVM1 | NRS-2574 | ACUTATOR VIBRATION MOTOR 1,3V 9000 RPM ROHS | SANYO |
| 40 | SEMCO1030 | 1 | - | - | ACTUATOR - LINEAR VIBRATOR, 2VRMS | SAMSUNG |

Bill of Materials
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| ITEM | MANU PART NUMBER | QTY | REF DESIGNATORS | VENDOR PART NUMBER | DESCRIPTION | MANUFACTURER |
|---------------------------------|----------------------------|-----|---|---------------------|---|-----------------------|
| 40 ⁽¹⁾ | ELV1036 | - | - | - | Alternate ACTUATOR – LINEAR VIBRATOR, 2VRMS | AAC |
| 42 | 3-5-468MP | 1 | - | 3M9724-ND | TAPE TRANSFER ADHESIVE 3" X 5YD | 3M |
| 43 | 2-5-4466W | 1 | - | 3M9962-ND | TAPE POLY FOAM 2" x 5YD | 3M |
| COMPONENTS NOT ASSEMBLED | | | | | | |
| 44 | TestPoint_SMD-Square_2.0mm | 2 | LRA_OUT+,LRA_OUT- | | TESTPOINT SMD SQUARE 2.0mm | |
| 45 | R0402_DNP | 9 | R20, R21, R22, R23, R24, R25, R30, R31, R35 | | R0402_DNP | |
| 46 | R0603_DNP | 1 | R4 | RMCF0603ZT0R00CT-ND | R0603_DNP | STACKPOLE ELECTRONICS |
| 47 | R0402_DNP | 1 | R41 | P4.99KLCT-ND | R0402_DNP | PANASONIC |
| 48 | R0402_DNP | 1 | R42 | 541-0.0JCT | R0402_DNP | VISHAY |

⁽¹⁾ This is an alternate actuator used on the EVM.

Revision History

| Changes from Original (January 2013) to A Revision | Page |
|---|------|
| • Added a diagram of the different modes of the DRV2605EVM | 6 |
| • Changed the capacitance of C2 to 1 μ F / 16 V | 24 |
| • Added more information for ref designator C2 entry in Bill of Materials | 28 |

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

Revision History

| Changes from A Revision (October 2013) to B Revision | Page |
|--|------|
| • Changed title of document | 1 |
| • Added title to first table in section 1.2, <i>Jumper Descriptions</i> | 5 |
| • Changed item 40 to SEMCO1030 and added 40 (with note) as alternate actuator in BOM. | 28 |

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

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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 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 its 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.

Industry Canada Compliance (English)

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.

Canada Industry Canada Compliance (French)

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.

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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.

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If user uses EVMs in Japan, user is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

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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