DRV2605EVM-BT User's Guide

The DRV2605EVM-BT is an evaluation kit for the DRV2605 ERM and LRA Haptic Driver. The kit connects the DRV2605 to an iOS App. wirelessly over Bluetooth Low Energy to allow control, creation, and customization of haptic effects. Use the included app to demonstrate the use of haptics in smart watches, fitness trackers, wearable devices, or to "haptify" any application without having to connect wires externally to a micro-controller. The app. includes notification demos, waveform playback, and DRV2605 register control.

The DRV2605 contains an embedded waveform library licensed from Immersion that supports driving eccentric rotating mass motors (ERM) or linear resonant actuators (LRA). With the included LRA, mount it and immediately begin using the DRV2605 library through the iOS App. The DRV2605EVM-BT can also be powered either by a 5V USB power supply using the included micro-USB cable or by 3xAAA batteries using the included battery pack with JST connector.

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1 Introduction

The DRV2605 offers the integrated Immersion TS2200 waveform library, which consists of 123 patterns for eccentric rotating mass (ERM) and linear resonant actuator (LRA) that can be selected, sequenced, and streamed from the iOS application on to the DRV2605EVM-BT. Other novel features of the DRV2605 are:

- Automatic resonance tracking for LRAs
- High-efficiency output drive stages
- Very-low shutdown current
- Reduced solution size
- Compatible with many ERM and LRA
- Capable of driving very high loads.

2 Evaluation Kit Contents

- DRV2605EVM-BT
- Micro-USB cable
- 3x AAA battery pack with keyed connector (batteries not included)
- LRA

NOTE: The DRV2605EVM-BT is also referred as DRV2605EVM in the document. EVM refers to evaluation module. App refers to the iOS application. PCB refers to Printed Circuit Board. Board refers to the DRV2605EVM-BT PCB.

3 Getting Started

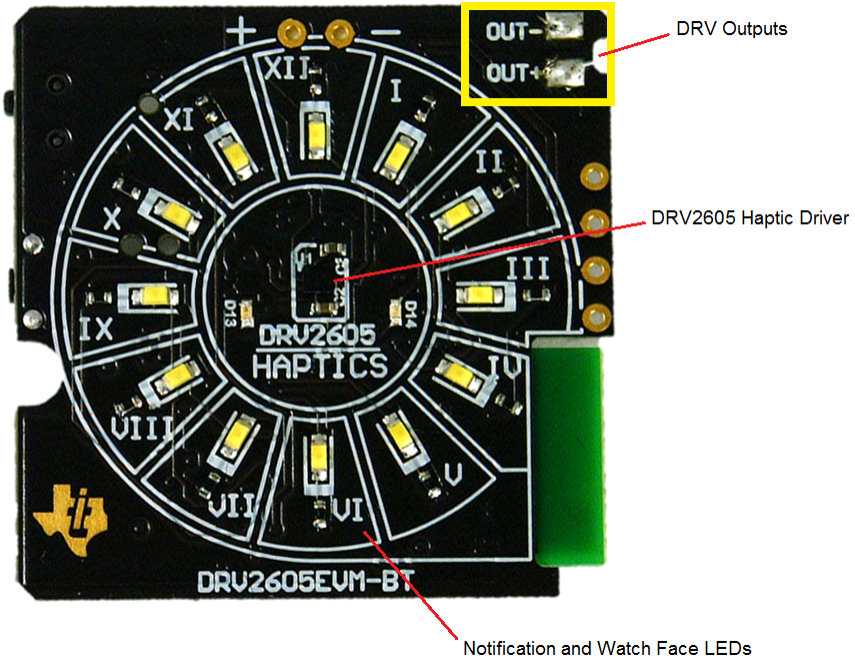


Figure 1. Top View of DRV2605EVM-BT

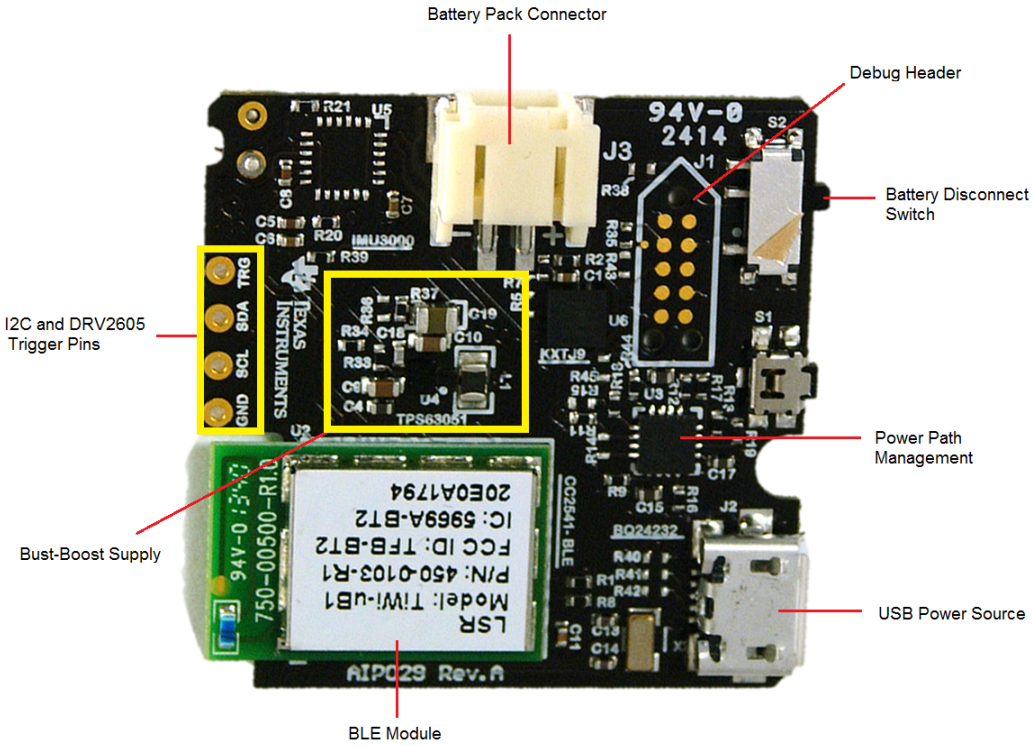


Figure 2. Bottom View of DRV2605EVM-BT

4 Steps to Connect to the App

The iOS app is available in the Apple® App Store℠ as “TI Haptic Bluetooth Kit” by Texas Instruments. It is compatible with iPod touch® and iPhone® with iOS7 operating system or later. Download and install the app.

1. Connect a valid power source to the DRV2605EVM-BT. If connected to the battery pack, turn the switch S2 and the battery pack switch to ON position. If connected using the included micro-USB cable, there is no need to configure the switches as the board will choose the best power source automatically.
2. The LEDs play the advertising pattern analagous to a refresh swipe of an internet browser.
3. Open the iOS app.
4. The DRV2605EVM-BT will appear on the iOS device color coded based on the RSSI strength. If the board was previously connected to the iOS device, a "Previously Connected" tag will appear. This helps to identify a particular board when multiple boards are advertising simultaneously. You will get a pop-up asking to check Bluetooth settings if Bluetooth is not turned ON on the iOS device.
5. Click on the board of interest and a connection is made automatically.
6. When the board has successfully connected, it will display the Stock Waveforms menu.
7. Use the buttons to fire individual effects or swipe left to right to access inner menus. Refer to Section 6 for more information.

5 Hardware Overview

5.1 DRV2605 Haptic Driver

The DRV2605EVM-BT's DRV2605 haptic driver is powered by onboard bq24232 battery management chip. The DRV2605 is capable of driving ERM and LRA actuators. The BLE microcontroller's I2C, EN and trigger pins are connected to the DRV2605. There are 123 library effects embedded inside the DRV2605. The DRV2605 is configured to play LRA actuator waveforms on statup which can be configured differently if needed. The DRV2605EVM-BT has optional pad to set into an external trigger mode to play a particular pattern on an external microcontroller output trigger. An example of this is described in Section 5.11. There are two capacitors: one for decoupling and the other for the internal regulator of the chip. The rectangular bounding silkscreen around the DRV2605 on the DRV2605EVM-BT highlights the solution size.

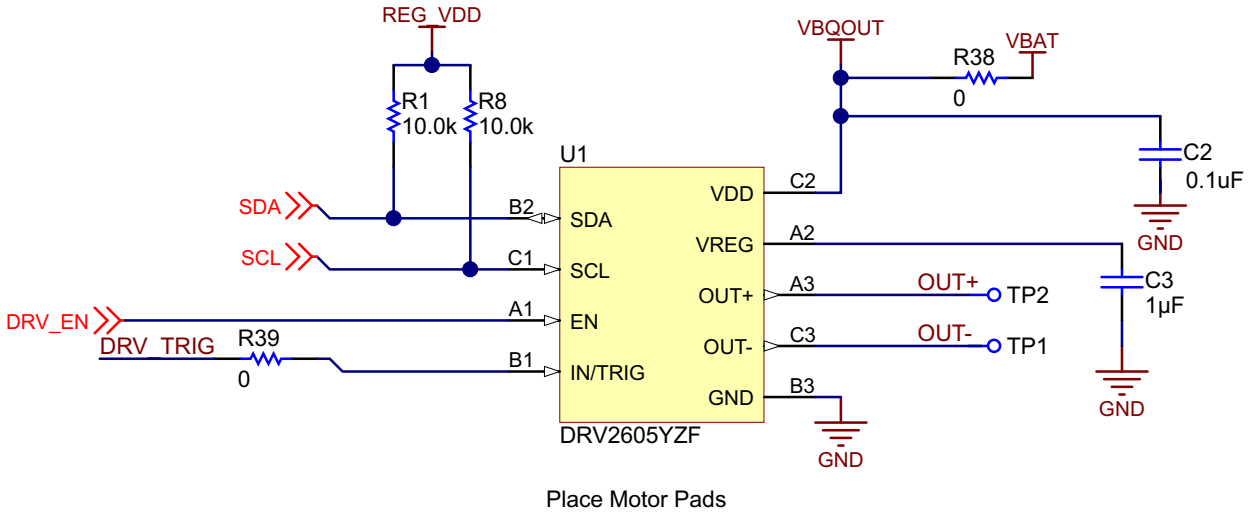
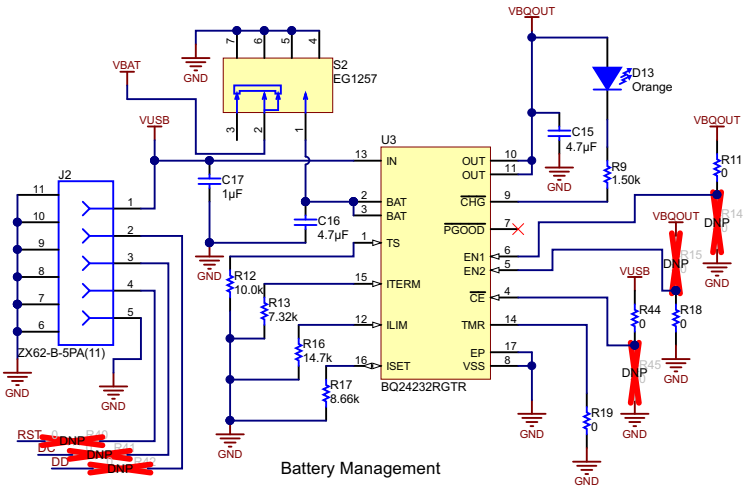


Figure 3. Smart Haptic Driver

5.2 BQ24232 Battery Management IC

The bq24232 is a USB-capable lithium-ion battery charger with dynamic power path management. This chip is purely used in this application to manage the selection of the power supply between a battery pack or a USB source. The battery management chip delivers power directly to the DRV2605 haptic driver and the TPS63051 DC-DC buck-boost converter. Net VBQOUT is the output of the battery management chip.



CAUTION

TI does not recommend any changes to the circuitry around the BQ24232.

Figure 4. Battery / Power Source Management

5.3 TPS63051 Buck-Boost Converter

The onboard TPS63051 DC-DC converter is used to power the board including the Bluetooth radio and LEDs. The TPS63051 is a fixed-voltage part meaning that the output voltage is steady at 3.3 V even for any changes in the battery voltage within the operating conditions. An automatic buck boost switching converter is desirable in this application to provide a steady output in cases where the battery voltage is unsteady analogous to the typical voltage drain of a battery. The PGOOD LED D14 indicates that the board is powered-up and the DC-DC converter is operational. The board is configured in PFM mode through a resistor R37 which pulls the PFM/PWM pin to low. The REGVDD is the fixed 3.3-V rail for the board.

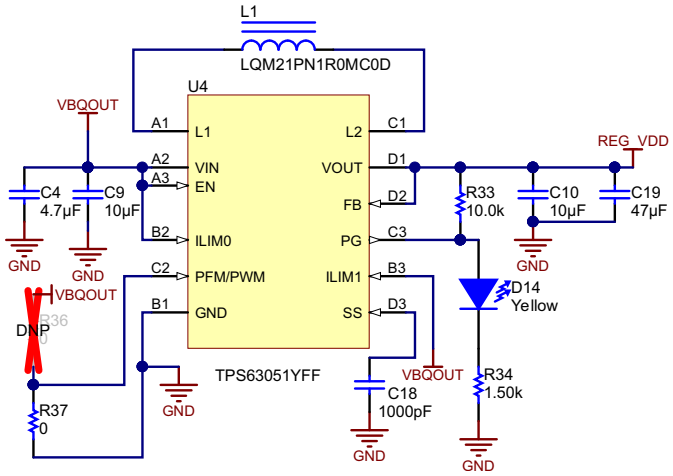


Figure 5. Buck-Boost Converter for Board Supply

5.4 LSR Bluetooth Module (CC2541 Inside)

The TiWi-uB1 module with the TI-CC2541 chip inside it, handles the communication link between the DRV2605EVM-BT and the iOS device. The module is used to talk to the onboard devices (primarily over I^2C), change LED settings, and maintain a steady communication channel. The module is FCC certified (ID: TFB-BT2). Complete documentation on the certification is available at: http://www.lsr.com/wireless-products/tiwi-ub1.

Table 1. Port Mapping LSR-CC2541 BLE Module

Port Name	Description
P0 0	Push switch (optional GPIO/pairing switch)
P0 1	—
P0 2	Accelerometer interrupt (optional)
P0 3	LED 1-o-Clock
P0 4	LED 2-o-Clock
P0 5	LED 3-o-Clock
P0 6	Haptic Driver Enable
P0 7	LED 4-o-Clock
P1 0	LED 12-o-Clock
P1 1	—
P1 2	LED 5-o-Clock
P1 3	LED 6-o-Clock
P1 4	LED 7-o-Clock
P1 5	LED 8-o-Clock
P1 6	LED 9-o-Clock
P1 7	LED 10-o-Clock
P2 0	LED 11-o-Clock
P2 1	DD
P2 2	DC
P2 4	Crystal Oscillator
P2 3	Crystal Oscillator

5.5 Debug Header

A new firmware download is possible by connecting a CC Debugger to the on-board header, J1. The pinout for the debug header is listed on the schematic. Although not all ten pins are required to flash the CC2541 module, they are available on the board to maintain compatibility with the CC Debugger. More information is available in *Section 7* .

5.6 USB Connector

The USB connector is installed on the DRV2605EVM-BT for an additional power supply than a battery source. There is no communication enabled over the USB.

5.7 Testpoints

The testpoints give exclusive access to the I^2C lines compatible with user friendly 100-mil spacing headers. They can be used to connect external microcontrollers. The TRG testpoint can be used to provide PWM input to the DRV2605. See *Section 5.11* to learn more about converting the audio signal to haptic effects.

5.8 Switches S1 and S2

S1 is connected to P0.0 on the CC2541. Switch S1 closes the connection between GND and P0.0 when it is pressed. Even though disabled on the DRV2605EVM-BT, the switch is available to maintain compatibility with other versions of the firmware where this port is used for pairing.

S2 is a load switch which connects and disconnects the battery. Turn S2 to ON position if using an external battery to power the board.

5.9 OUT– and OUT+

These pads are the output of the DRV2605. A vibration motor like an ERM or LRA can be connected to these pads.

5.10 LEDs

LEDs I to XII: These white LEDs arranged in a clock-like orientation, can display time synced from the iOS device and demonstrate visible alerts from notification menu. Custom LED patterns can be created from the LED Playground mode.

Status LEDS: D14 indicates that the DRV2605EVM-BT is powered by a valid source and ready to talk over Bluetooth. D14 is intentionally made dim as it ON at all times.

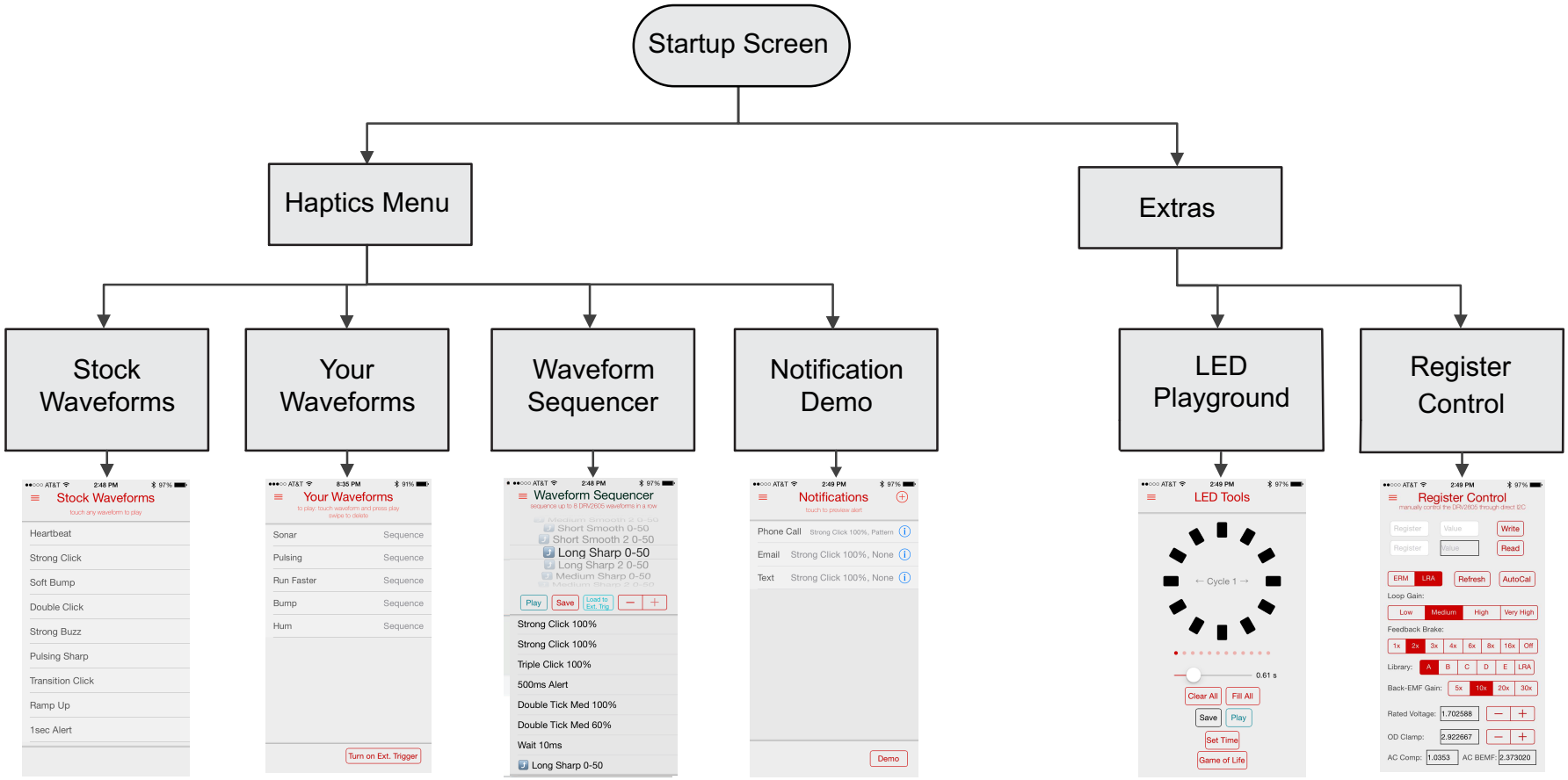
5.11 Audio-to-Haptics and Trigger Mode

The DRV2605 features an audio to haptics mode that converts an audio input signal into meaningful haptic effects using the Immersion "BOOMbox" technology. The audio signal can be connected to the TRG pin. For the TRG pin to function as the analog audio input to the haptic driver for audio-to-haptics mode, the resistor R39 has to be replaced with an 0402 size 0.1-µF DC blocking capacitor. Later the driver has to be set to the audio-to-haptics mode on the I^2C register setting. For more details on this configuration, refer to the DRV2605 data sheet.

The trigger pin can be connected to an external microcontroller's GPIO or an interrupt line of a different IC to fire effects on an event. The DRV2605 has to be configured to External Trigger Mode through Register Control tab or more easily through the "Turn ON Ext. Trigger" button available at different sections of the iOS app. for this function to be executed. An example of this function is when a Touch-IC generates an interrupt and a haptic effect is generated to mimic a "keyboard click".

6 IOS App Overview

iOS APP Map



Lets the user play a select few waveforms from the ROM library of the DRV2605.

See *Section 6.2.1*

Your patterns customized in the waveform sequencer are located here.

See *Section 6.2.2*

Lets the user create and save customizable alerts for different use cases.

See *Section 6.2.3*

Demonstrates the real world application of haptics in a system.

See *Section 6.2.4*

Lets the user create a frame by frame LED Movie.

See *Section 6.3.1*

Gives the user lower level access to the DRV2605 registers to change modes/ behavior of the smart driver.

See *Section 6.3.2*

6.1 Startup

Figure 6 shows the startup screen of the iOS application. The application checks for any advertising DRV2605EVM-BTs, and if any are found, displays them on the screen as shown in Figure 6. The devices are color coded based on the signal strength to the Bluetooth device. The application identifies whether the application was previously connected to the DRV2605EVM-BT that is advertising currently. A single-touch event on the appropriate display box connects to that particular DRV2605EVM-BT and a connection overlay appears during the process as shown in Figure 7 before showing the next screen.

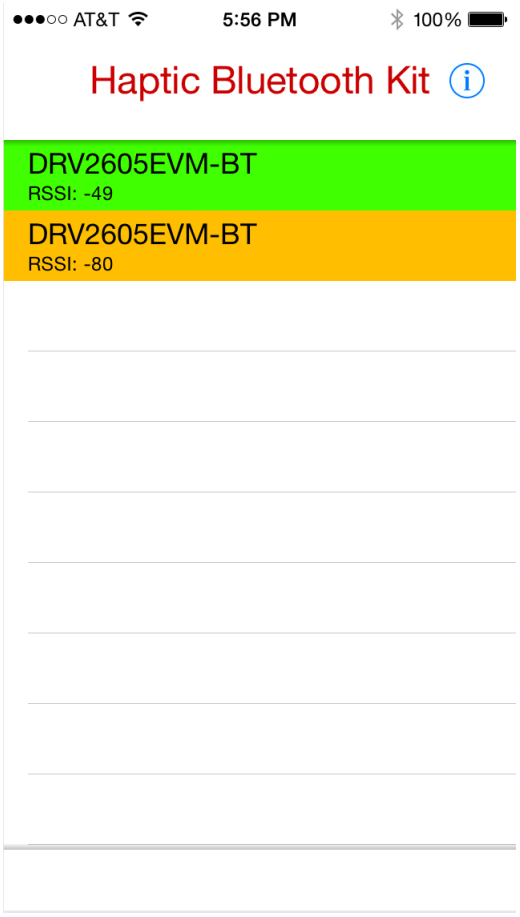


Figure 6. Startup Screen

Figure 7. Connection Overlay

6.2 Haptics Menu

6.2.1 Stock Waveforms

The stock waveforms submenu consists of a select few waveforms from the ROM libraries of the DRV2605. The list shows nine waveforms. These haptic patterns can be triggered by touch-selecting the respective pattern.

The user can navigate between screens either by swiping from left to right (as shown in Figure 8) or by clicking the list icon at the top of the screen.

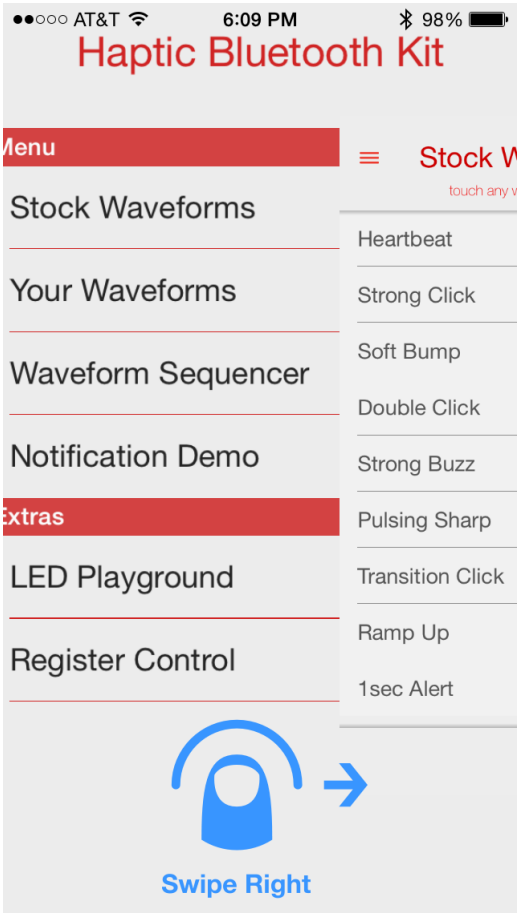


Figure 8. iOS App Menu

6.2.2 Your Waveforms

The Your Waveforms menu hosts the patterns created by the user and sample patterns. The app. has some default preloaded patterns which shows an example of creating effects like "Sonar", "Run-Faster" or "Pulsing". The user can click the Turn on Ext. Trigger button to automatically play a waveform on a trigger source. Connect your trigger line to the TRG pin shown in *Section 5.7* . Any patterns created in the *Section 6.2.3* appear in the Your Waveforms screen as well. All these patterns are combinations of the DRV2605 library waveforms and showcase how a user can combine unique sequences for different scenarios by mixing the waveforms from the ROM libraries.

6.2.3 Waveform Sequencer

The Waveform Sequencer submenu allows you to load up to eight sequences on the sequencer of the DRV2605. The list shown in Figure 9 is scrollable and contains 123 patterns from the effects library. Click on the + and – buttons to add or remove a waveform. As an option, the user can click the Play All button to immediately feel the sequence, or the user can save it to be used in different sections of the application or play the sequence using the external trigger

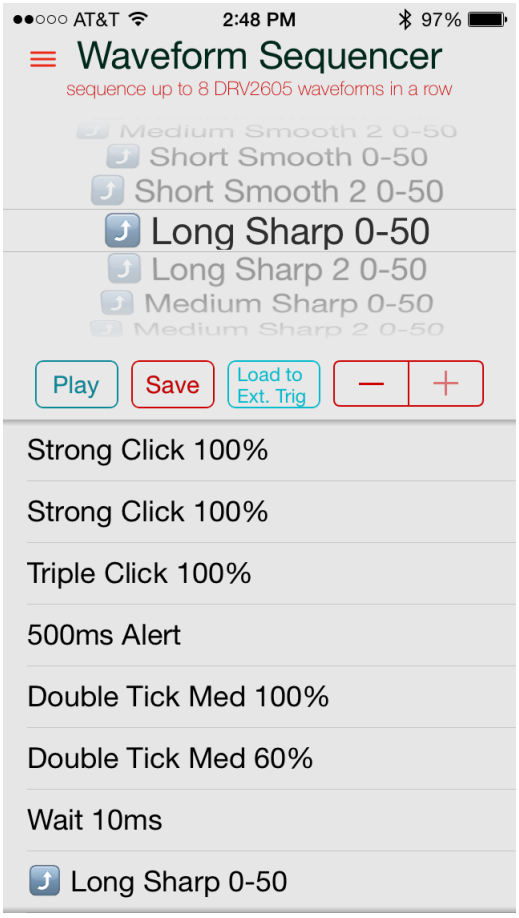


Figure 9. Waveform Sequencer

6.2.4 Notification Demo

The notifications demo menu demonstrates the use of haptics in a real application such as a body wearable device like a smart-watch or a fitness tracker. Haptics can be used to convey messages or statues to a user non-intrusively. The user can select a different pattern for a phone call, message, or text. Click on the buttons to begin simulating the notification. Depending on the scenario (text, email, or phone call), the appropriate overlays will appear during the sequence. To stop the phone call notification, click on the Decline button.

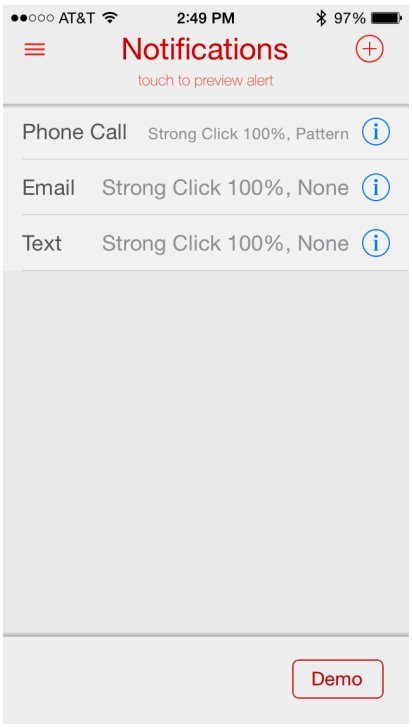


Figure 10. Notifications Screen

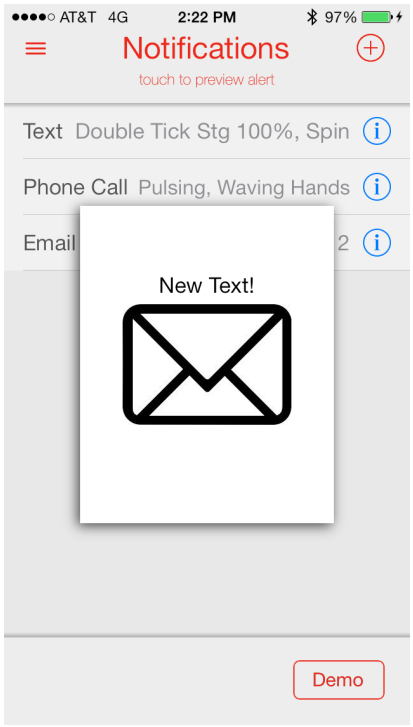


Figure 11. Text Message Notification

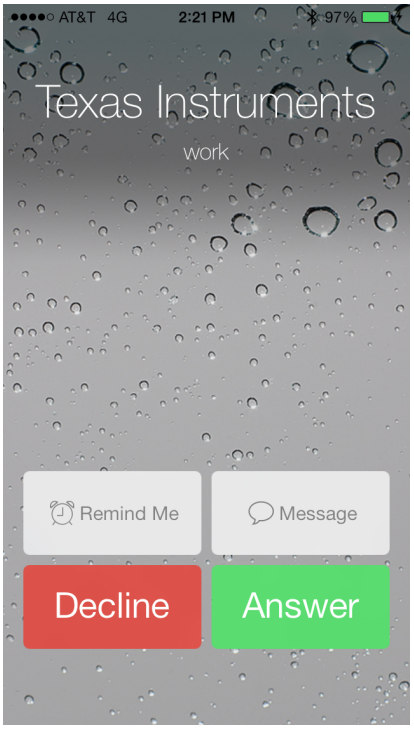


Figure 12. Phone Call Notification

Creating a new notification: Click on the "+" arrow on the top right corner of the notification demo page.

Customizing alerts for a notification: Click on the "i" button next to the notification to access the inner menu which allows the user to customize both vibration and visual alerts for the scenario. The top half is the LED menu for customizing the visible alert. The application comes with preloaded LED patterns and the ability to add more patterns as described in *Section 6.3* . This list is scrollable. Slide the selection window over the pattern to play it. The table on the bottom half of the screen is the haptic notification. The user can either choose the waveforms from the Your Waveforms list or select a pattern from the 123 DRV2605 ROM libraries.

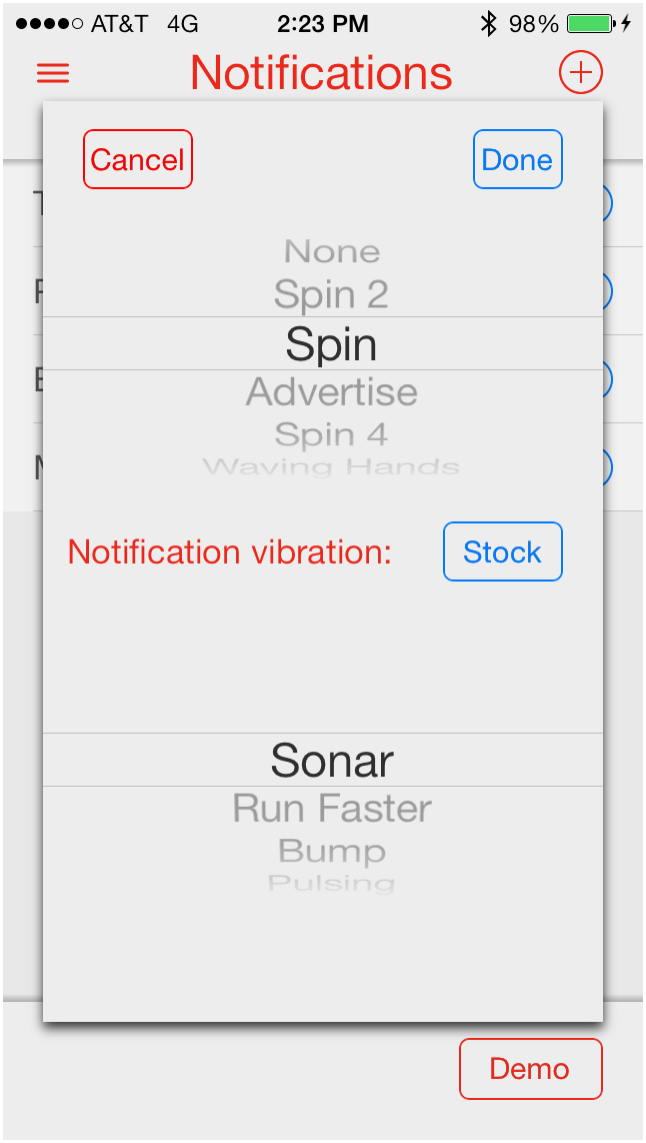


Figure 13. Notification Haptic and LED Effect Selection Screen

6.3 Extras

6.3.1 LED Playground

The LED Playground is a custom frame-by-frame LED movie creation tool. By default, the LEDs are grayed out indicating OFF on a frame. The user can select LEDs by touching them on the application, and the LED turns on when the frame is played. Flick from left to right or right to left in order to jump to a different frame. When the user creates a movie, they can click the Play button to relay it back on the board. As a shortcut, there are Clear All and Fill All buttons, which turn all LEDs ON or OFF on the frame. The slider shown in Figure 14 adjusts the play rate of the movie. This is analogous to frames per second (fps) in a video. Less time on the slider results in more frames per second of the LED movie. The application also has a Game of Life sequence embedded.

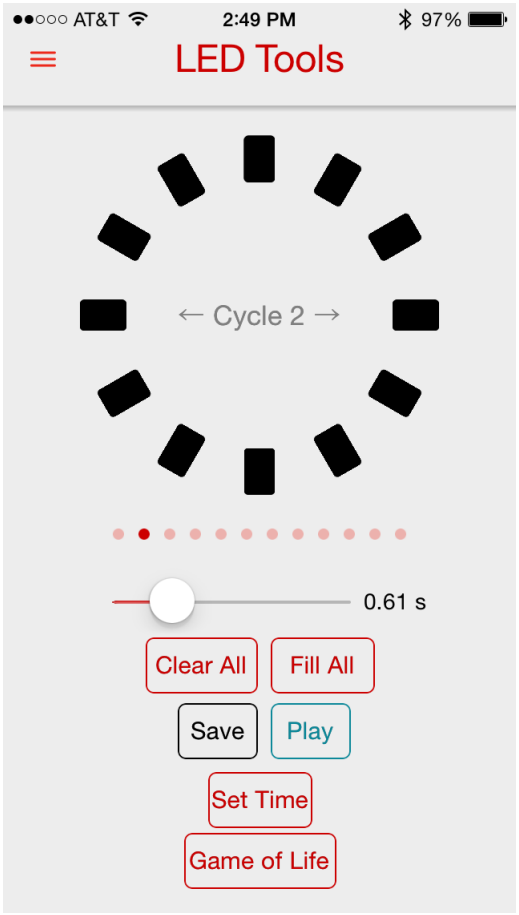


Figure 14. LED Playground

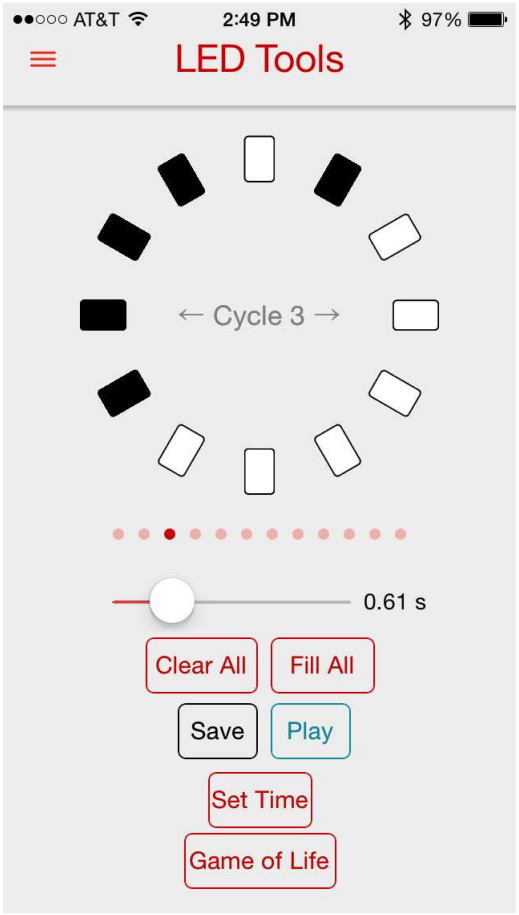


Figure 15. LED Playground with Sample LEDs Selected

6.3.2 Register Control

The Register Control menu gives the user access to the registers of the DRV2605 over BLE by performing I^2C Write and I^2C Read . Some sample registers the user could read or set are Autocal, brake factor, Audio2Haptics, Overdrive, LRA resonant frequency read register, and DRV input voltage monitoring registers. To change a register, place the cursor in the textbox and a hex-keypad will appear. Note that the inputs are in hex format from this tool. Type in the appropriate values and perform a read or write operation.

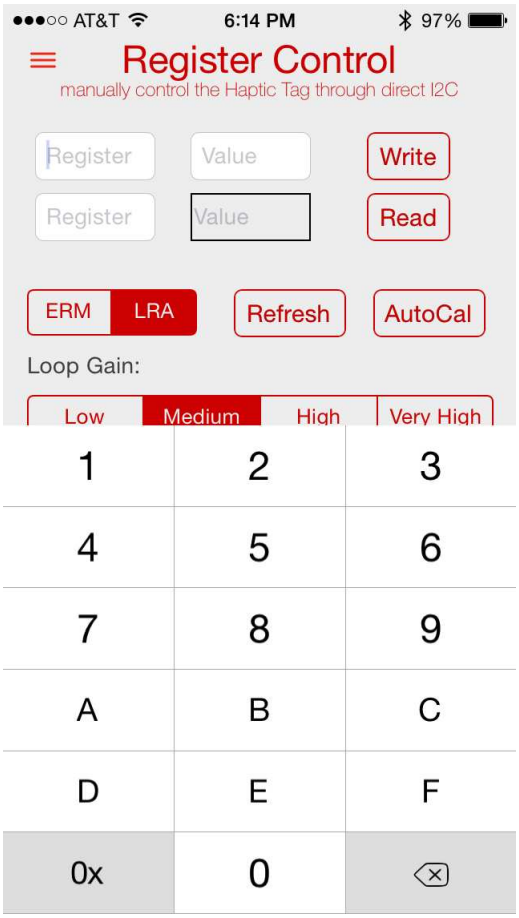


Figure 16. I^2C Keypad – Register Control Screen

In addition to the I^2C read and write access, quick switches allow the user to control settings applicable to different vibration motors. For example, the ERM/LRA switch toggles between the type of the output waveform that is played.

The rated voltage is the drive voltage to the actuator. It can be adjusted by touch, or touch and hold, to increment or decrement the value on the indicator.

The overdrive clamp controls how much of a startup push is given to the motor. The overdrive feature of the DRV2605 makes the effects crisp. It is usually 1.5× to 2x higher than the rated voltage, but check the actuator data sheet for more information.

7 Updating Firmware on DRV2605EVM-BT

The DRV2605EVM-BT ships with a factory-programmed image ready to connect with an iOS device on a valid power source. To change the firmware on the CC2541, follow the steps mentioned in *Section 7.2* .

CAUTION

Beware of flashing the firmware on the DRV2605EVM-BT because an incorrect firmware image could cause issues with getting the board to work properly.

The firmware files are available for download on the EVM product page at www.ti.com.

7.1 Tools Needed

- CC Debugger
- Tag-Connect TC2050-IDC-NL 10-pin no-legs cable with ribbon connector
- SmartRF Flash Programmer utility
- Firmware file ('.hex'- extension)

7.2 Steps

1. Download and install the SmartRF Flash Programmer available at: http://www.ti.com/tool/flash-programmer. Make sure the user installing the software has administrator privileges on the target machine. The user may have to right click on the installer and select Run as Administrator.
2. Connect the TC2050 cable to the CC Debugger as shown in Figure 17.
3. Connect the USB cable to the target machine running the programmer utility
4. Press the connector against the board firmly as shown in Figure 18.
5. Press the Reset button on the CC Debugger. The status LED changes to green indicating a valid CC2541 chip is detected.
6. The CC Debugger displays on the System-on-Chip submenu.
7. Locate the flash image (a .hex file) on the hard disk.
8. Under the Actions groupbox, select Erase, program, and verify.
9. Click Perform Actions and wait until the process is complete.
10. After a success message, the board is ready with the new firmware image.

Figure 17. CC – Debugger

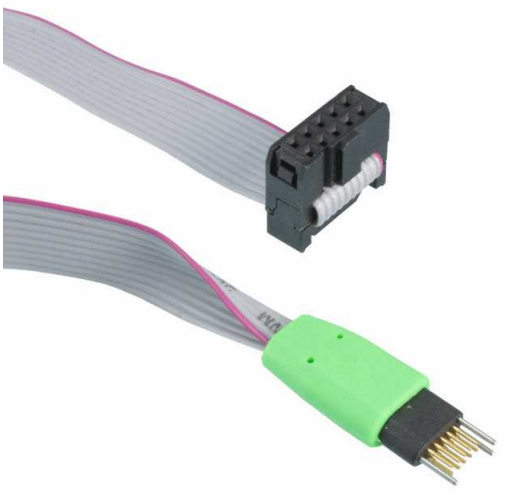
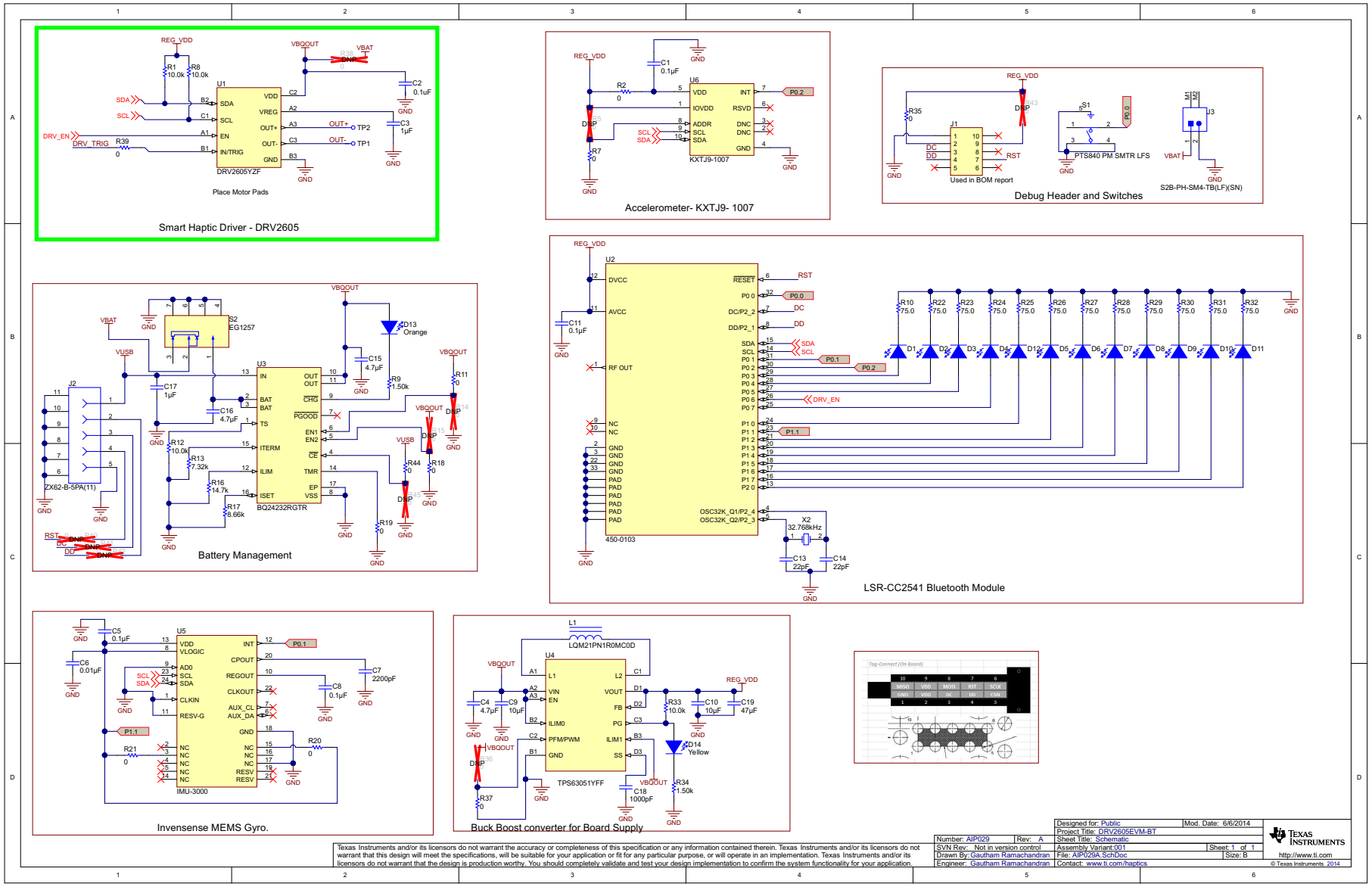
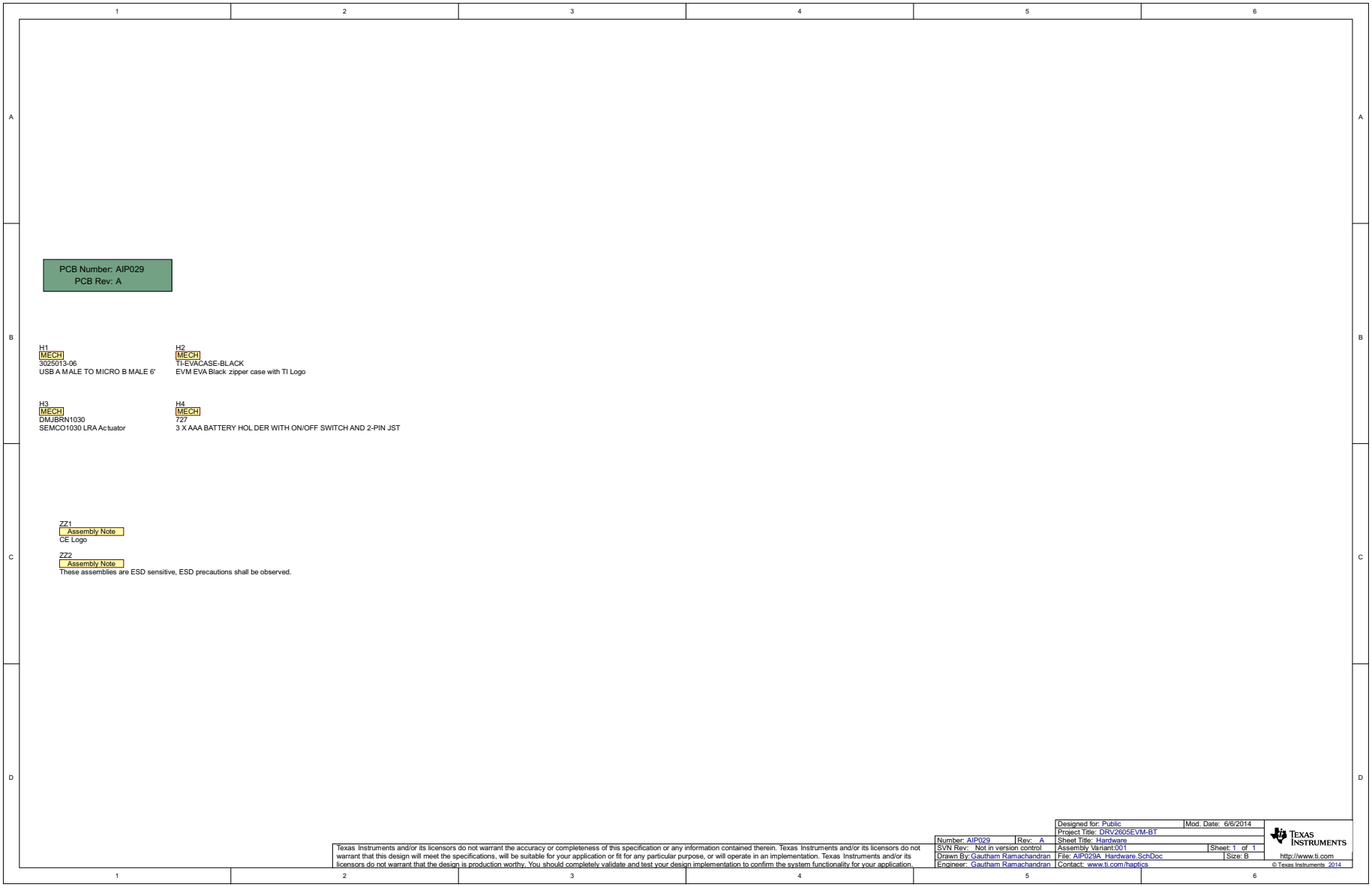


Figure 18. Tag-Connect TC2050-IDC-NL 10-Pin No-legs Cable with Ribbon Connector

8 Schematics, PCB Layers, and Bill of Materials

8.1 Schematics





8.2 PCB Layers

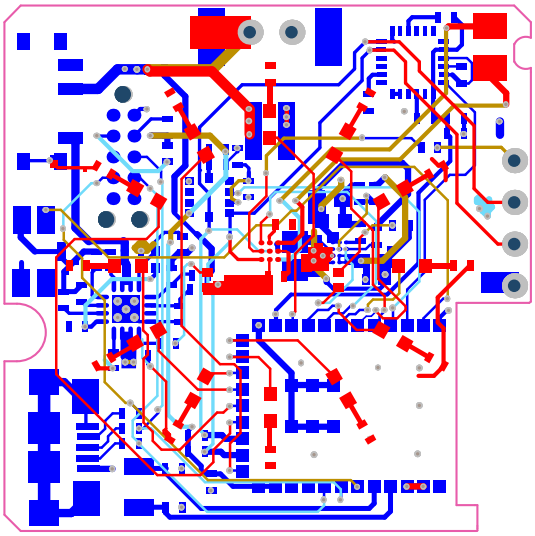


Figure 19. X-Ray Top View

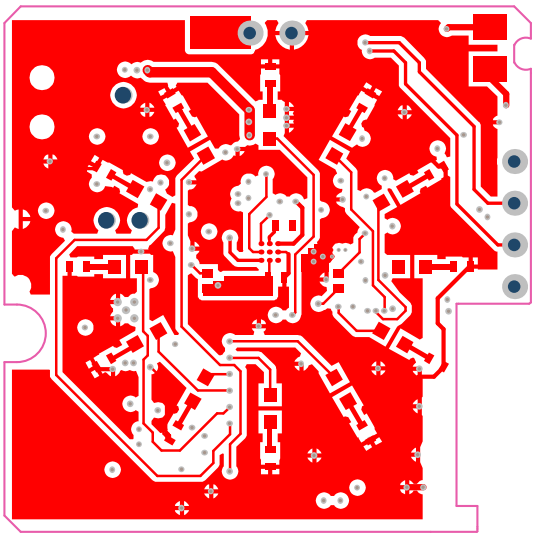


Figure 20. Top Layer

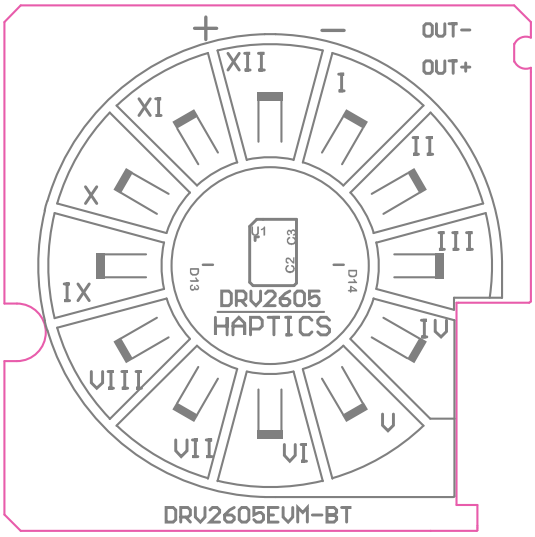


Figure 21. Top Overlay

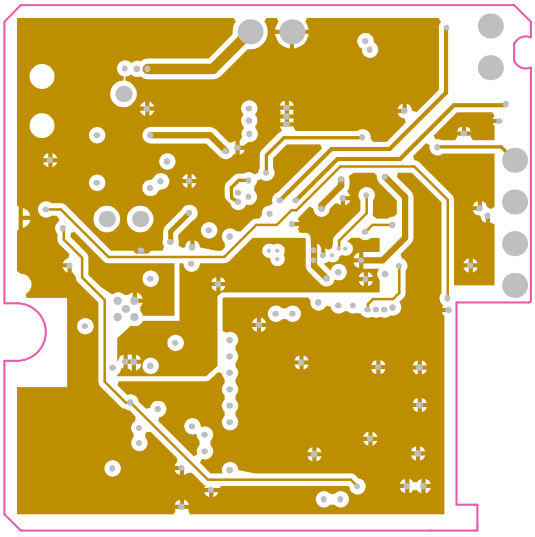


Figure 22. Mid-Layer 1

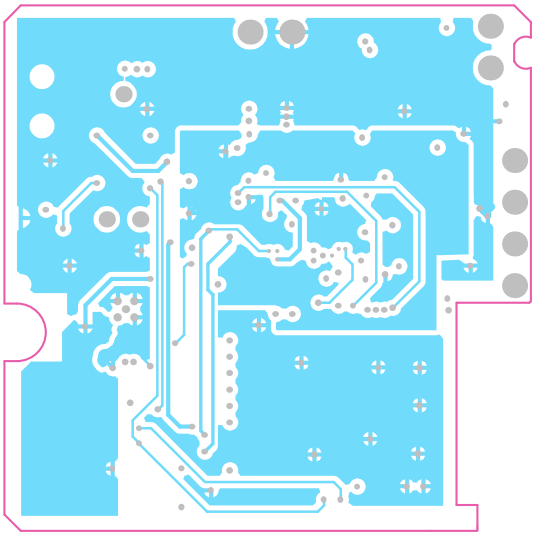


Figure 23. Mid-Layer 2

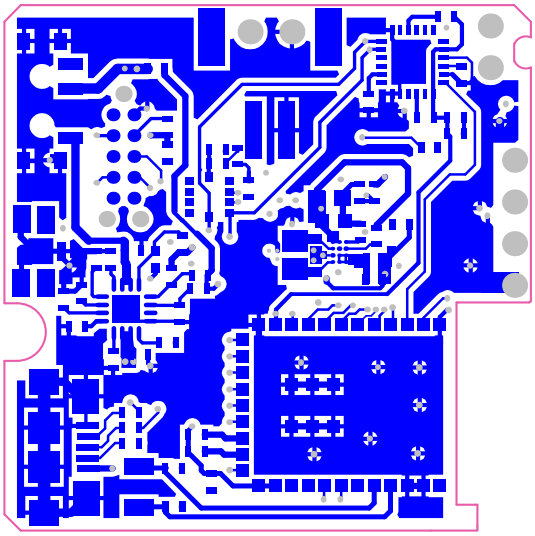


Figure 24. Bottom Layer

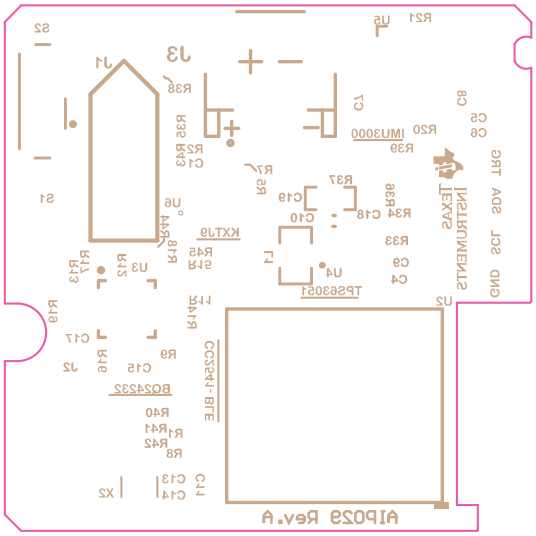


Figure 25. Bottom Overlay

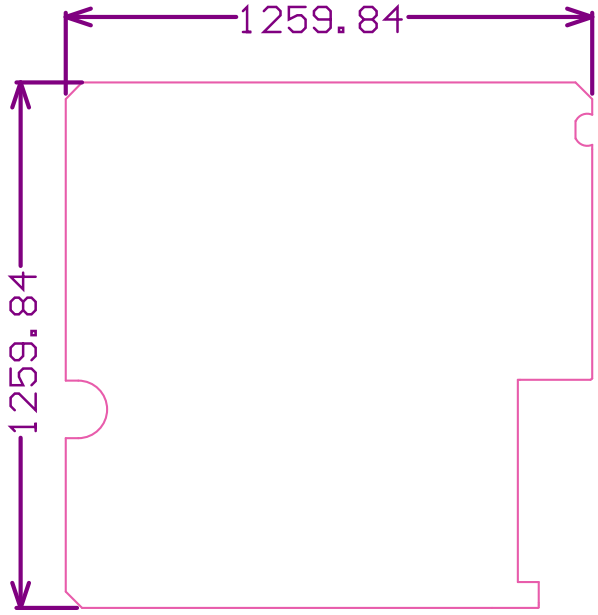


Figure 26. Board Dimensions

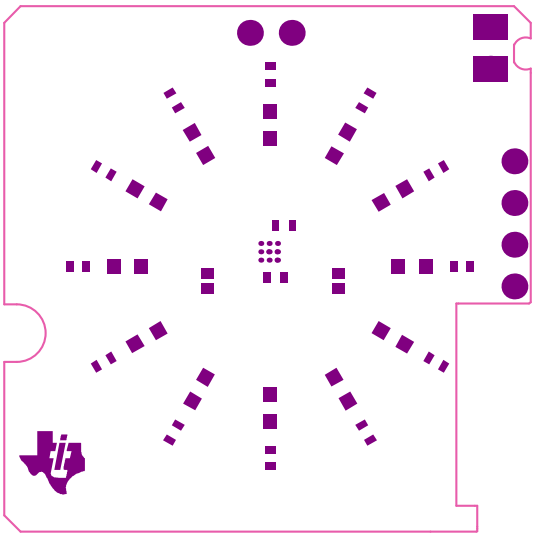


Figure 27. Top Solder

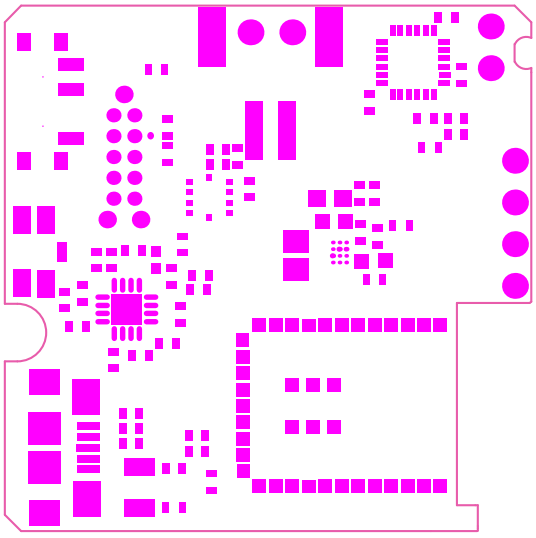


Figure 28. Bottom Solder

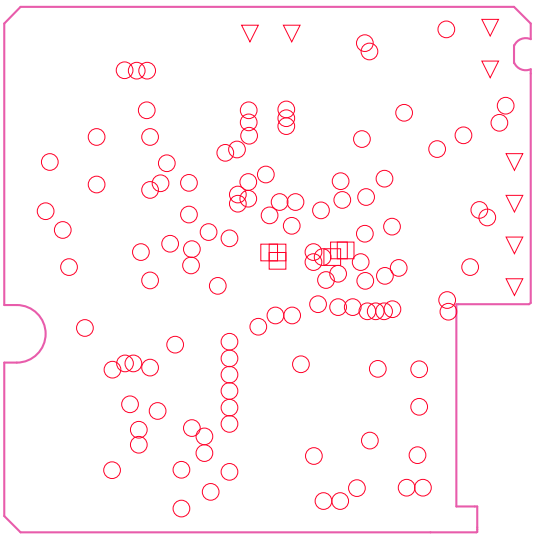


Figure 29. Drill Drawing

□	6	6mil (0.152mm)	PTH	Round
○	117	8mil (0.203mm)	PTH	Round
▽	8	30mil (0.762mm)	PTH	Round
	131 Total			

Drill Table

Figure 30. Drill Table

8.3 Bill of Materials

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
!PCB	1		Printed Circuit Board		AIP029	Any
C1, C2	2	0.1 uF	CAP, CERM, 0.1uF, 16V, ±10%, X7R, 0402	0402	GRM155R71C104KA88D	MuRata
C3, C17	2	1 uF	CAP, CERM, 1uF, 10V, ±10%, X5R, 0402	0402	GRM155R61A105KE15D	MuRata
C4	1	4.7 uF	CAP, CERM, 4.7uF, 6.3V, ±20%, X5R, 0402	0402	C1005X5R0J475M050BC	TDK
C5, C8	2	0.1 uF	CAP, CERM, 0.1uF, 10V, ±10%, X7R, 0402	0402	GRM155R71A104KA01D	MuRata
C6	1	0.01 uF	CAP, CERM, 0.01uF, 25V, ±10%, X7R, 0402	0402	GRM155R71E103KA01D	MuRata
C7	1	2200 pF	CAP, CERM, 2200pF, 50V, ±10%, X7R, 0402	0402	GRM155R71H222KA01D	MuRata
C9, C10	2	10 uF	CAP, CERM, 10uF, 10V, ±20%, X5R, 0603	0603	C1608X5R1A106M	TDK
C11	1	0.1 uF	CAP, CERM, 0.1uF, 50V, ±10%, C0G/NP0, 0402	0402	C1005X7R1H104K	TDK
C13, C14	2	22 pF	CAP, CERM, 22pF, 50V, ±5%, C0G/NP0, 0402	0402	GRM1555C1H220JA01D	MuRata
C15, C16	2	4.7 uF	CAP, CERM, 4.7uF, 10V, ±20%, X5R, 0402	0402	GRM155R61A475M	MuRata
C18	1	1000 pF	CAP, CERM, 1000pF, 25V, ±5%, C0G/NP0, 0402	0402	C1005C0G1E102J	TDK
C19	1	47 uF	CAP, CERM, 47uF, 6.3V, ±20%, X5R, 0603	0603	GRM188R60J476M	MuRata
D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12	12		LED, White, SMD	LED, 0603	SML312WBCW1	Rohm
D13	1	Orange	LED, Orange, SMD	Orange LED	SML-P12DTT86	Rohm
D14	1	Yellow	LED, Yellow, SMD	Yellow LED	SML-P12YTT86	Rohm
H1	1		USB A MALE TO MICRO B MALE 6'	Used in PnP output	3025013-06	Qualtek
H2	1		EVM EVA Black zipper case with TI Logo	Used in PnP output	TI-EVACASE-BLACK	Royal Case
H3	1		SEMCO1030 LRA Actuator	Used in PnP output	DMJBRN1030	Samsung Electro-Mechanics
H4	1		3 X AAA BATTERY HOLDER WITH ON/OFF SWITCH AND 2-PIN JST	Used in PnP output	727	Adafruit
J2	1		Connector, micro USB Type B, Receptacle, R/A, SMD	Micro USB-B receptacle	ZX62-B-5PA(11)	Hirose Electric Co. Ltd.
J3	1		Header, 2x1,2mm, R/A, SMT	Header, 2x1, 2mm, R/A	S2B-PH-SM4-TB(LF)(SN)	JST Manufacturing
L1	1	1 uH	Inductor, Multilayer, Ferrite, 1uH, 0.8A, 0.19 ohm, SMD	0805	LQM21PN1R0MC0D	MuRata
R1, R8, R12, R33	4	10.0k	RES, 10.0k ohm, 1%, 0.063W, 0402	0402	CRCW040210K0FKED	Vishay-Dale

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
R2, R7, R11, R18, R19, R20, R21, R35, R37, R39, R44	11	0	RES, 0 ohm, 5%, 0.063W, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R9, R34	2	1.50k	RES, 1.50k ohm, 1%, 0.063W, 0402	0402	CRCW04021K50FKED	Vishay-Dale
R10, R22, R23, R24, R25, R26, R27, R28, R29, R30, R31, R32	12	75.0	RES, 75.0 ohm, 1%, 0.063W, 0402	0402	CRCW040275R0FKED	Vishay-Dale
R13	1	7.32k	RES, 7.32k ohm, 1%, 0.063W, 0402	0402	CRCW04027K32FKED	Vishay-Dale
R16	1	14.7k	RES, 14.7k ohm, 1%, 0.063W, 0402	0402	CRCW040214K7FKED	Vishay-Dale
R17	1	8.66k	RES, 8.66k ohm, 1%, 0.063W, 0402	0402	CRCW04028K66FKED	Vishay-Dale
S1	1		SWITCH TACTILE SPST-NO 0.05A 12V, SMT	3.5 x 1.35 x 3.55 mm	PTS840 PM SMTR LFS	C&K Components
S2	1		Switch, Slide, SPDT, 0.3A, SMT	6.7 x 1.4 x 2.6 mm	EG1257	E-Switch
TP1, TP2	2	STD	PAD, 5X5 mm		STD	STD
U1	1		Haptic Driver for ERM and LRA with Built-In Library and Smart Loop Architecture, YZF0009ADAD	YZF0009ADAD	DRV2605YZF	Texas Instruments(1)
U2	1		BLUETOOTH SMART (BLE) MODULE	17.9 x 2.2 x 11.6 mm	TiWi-uB1	LS RESEARCH
U3	1		USB Friendly 0.5 A Li+ Charger with Dynamic Power Management, 10.5 V OVP, 4.3 V, -40 to 85 degC, 16-pin QFN (RGT), Green (RoHS & no Sb/Br)	RGT0016C	BQ24232RGTR	Texas Instruments(2)
U4	1		SINGLE INDUCTOR BUCK-BOOST WITH 1A SWITCHES AND ADJUSTABLE SOFT START, YFF0012AFAF	YFF0012AFAF	TPS63051YFF	Texas Instruments(2)
U6	1		± 2g / 4g / 8g Tri-axis Digital Accelerometer, SMT	LGA, 3X0.9x3-0.65 mm pitch	KXTJ9-1007	Kionix
X2	1		Crystal, 32.768kHz, 12.5pF, SMD	2-SMD	NX3215SA-32.768K-STD-MUS-2	NDK
J1	1			eg: 0603, used in PnP report	Used in BOM report	Used in BOM report
R5, R14, R15, R36, R38, R40, R41, R42, R43, R45	0	0	RES, 0 ohm, 5%, 0.063W, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
U5	1		Motion Processing Unit, QFN-24	QFN, 4 x 0.95 x 4 mm	IMU-3000	InvenSense

(1) Alternate manufacturer not available.
(2) Alternate manufacturer not available.

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