TI Designs
Low-Voltage Battery Buck-Boost Haptic Driver

TI Designs

TI Designs provide the foundation that you need including methodology, testing and design files to quickly evaluate and customize the system. TI Designs help *you* accelerate your time to market.

Design Resources

TIDA-00407	Tool Folder Containing Design Files
DRV2605L	Product Folder
TPS63030	Product Folder
DRV-ACC16-EVM	Product Folder

TI E2E™ Community

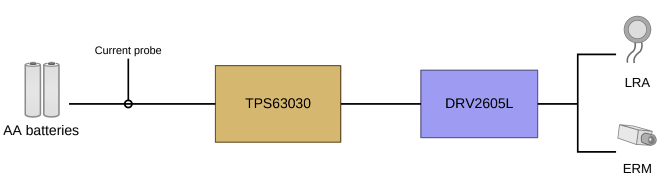
ASK Our E2E Haptics Experts
WEBENCH® Calculator Tools

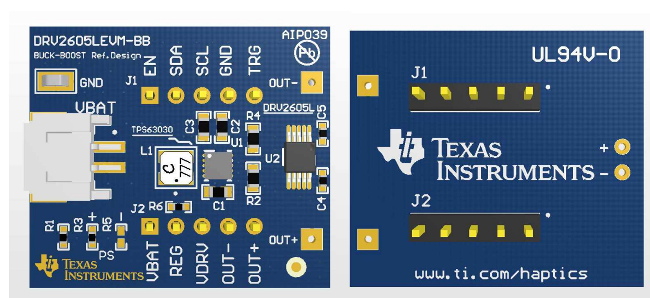
Design Features

- Achieves Constant Vibration Strength Over Battery Voltage
- Buck-Boost Topology Provides Constant Output Voltage for Haptic Feedback
- Haptic Driver With Embedded Waveform Library
- Wide Battery-Operating Range (1.8 V to 5.5 V)
- Supports 2x AA and Lithium Batteries

Featured Applications

- TV Remotes
- PC Accessories
- Mice
- Trackpads
- Portable Electronics
- Battery-Operated Personal Hygiene Products
- Other Accessories





An IMPORTANT NOTICE at the end of this TI reference design addresses authorized use, intellectual property matters and other important disclaimers and information.

Coilcraft is a registered trademark of Coilcraft Inc.
TouchSense is a registered trademark of Immersion Corporation.
All other trademarks are the property of their respective owners.

1 Introduction

Haptics is a new interface that has been adopted in many new portable devices. Many devices use tactile vibrations to communicate with the user. Traditionally, haptic technology is used in many gaming devices and smart phones to immerse the user in the game content or to provide "button feel" to a phone user. Many wearable devices, like TV remotes and mice, are using haptics to provide notifications, tactile feedback, render a virtual scroll wheel, and more. One common feature in all these devices is that they are operated by AA, AAA, or lithium/lithium polymer batteries,where the voltages could range anywhere from 2 V to 4.5 V. This design provides a preconfigured voltage level to the DRV2605L haptic driver by either lowering or boosting the output voltage as required by the system and defined by the hardware. Because the DRV2605L can work anywhere from 2 V to 5.2 V, this design is applicable to systems with battery voltage swings below the drive voltages of the motor.

2 Board Description

The DRV2605L haptic driver is powered by the TPS63030 Buck-Boost DC-DC converter in this design. The input voltage of the TPS63030 ranges from 1.8 V to 5.5 V. The reference design is configured for a default output voltage of 5 V. For different voltage configurations, refer to Equation 1. A buck-boost topology has been chosen to adjust to any higher or lower variations in the battery voltage. The current capability of this DC-DC converter is significantly high to drive powerful motors. Standard 100-mil headers are used to be compatible with breadboards and other external connectors.

3 System Description

3.1 *TPS63030 High-Efficiency Single Inductor Buck-Boost Converter*

The design uses a TPS63030 Buck-Boost converter with 1-A switches that power the DRV2605LMSOP.

The VBAT can be supplied from a battery source (AA, AAA, Lithium, and others). A JST connector is used in this design to be compatible with many battery kits already available on the market. The EN pin is connected to VBAT to have the chip ready to output as soon as a valid VBAT within the operating range is applied.

The PS/SYNC pin can disable or enable the power save feature. This feature may be helpful for loads lighter than 10 mA, like a micro-controller connected to the same rail. The power save is disabled on this board and can be enabled by removing resistor R3 and connecting resistor R5, which pulls the pin high or low. The feedback resistors R4 and R2 provide a steady output voltage of 5 VDC. Based on the maximum overdrive voltage of the motor, the feedback resistors can be configured to obtain a lower voltage. Refer to Equation 1 from the datasheet to get other voltages by changing R2 from the design. The inductor L1 is a 2.2-µH inductor from Coilcraft®. Refer to the *Design Calculations for Buck-Boost Converters Application Report* (SLVA535) for more information on selecting an inductor. The net REG is the output of the TPS63030 and is connected to the DRV2605L.

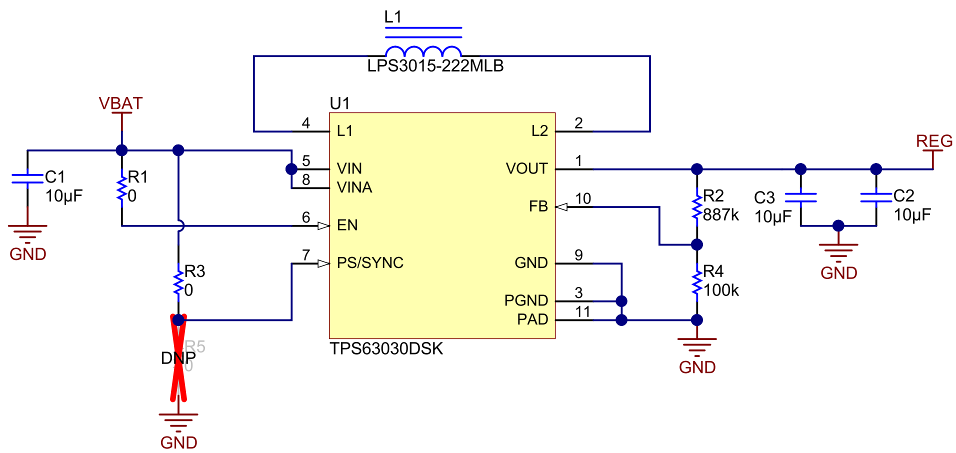


Figure 1. TPS63030 Buck Boost (1.8–5 V)

3.1.1 Equations

From the datasheet of the device, the following equations are the calculations to configure the output voltage of the TPS63030 (net REG).

$$R_2 = R_4 \times \left(\frac{Vout}{Vfb} - 1 \right) \quad (1)$$

If R4 = 100 kΩ, Vfb = 500 mV, then

For V_{OUT} = 5 V,

$$\Rightarrow R_2 = 100 \times \left(\frac{5}{0.5} - 1 \right) \quad (2)$$

R_2 = 887 kΩ

Similarly for V_{OUT} = 3 V, R2 ≈ 540 kΩ.

3.2 DRV2605L Haptic ERM/LRA Driver with Integrated Effect Library and Smart Loop

The DRV2605L is a low-voltage haptic driver with a built-in licensed Immersion TouchSense® 2200 waveform library. The DRV2605L is compatible with ERM and LRA motors and can be controlled over I²C from an external microcontroller. The connections to a motor are on nets OUT+ and OUT–.

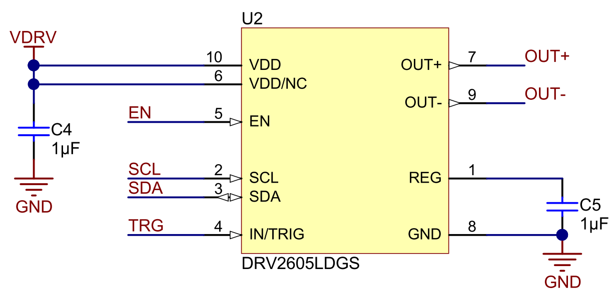


Figure 2. DRV2605L Haptic Driver

3.2.1 Motor Voltages

When designing a system for haptic effects, consider these two voltage levels:

- **Rated Voltage**: This is the voltage at which the actuator is driven. The datasheet usually has this parameter.
- **Overdrive**: This is the voltage higher than the rated voltage applied during startup of the actuator to give an initial push to the actuator. During startup and braking phases, overdrive makes the effect very crisp and sharp. During the braking phase, the voltage is on opposite polarity for ERMs and in the same phase as the previous pulse for LRAs. Some datasheets specify the duration and the overdrive voltage, which is usually 1.5× to 2× the rated voltage for approximately under 50 ms. The DRV2605L also calculates the absolute number of overdrive pulses for LRA using the back-emf, which mitigates excessive overdrive or braking scenarios.

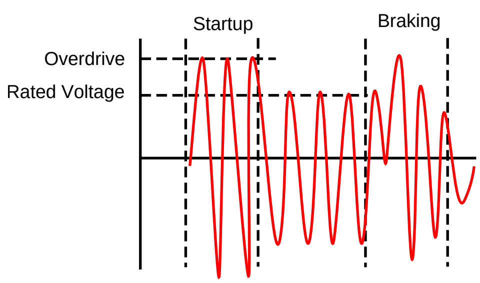


Figure 3. Overdrive and Rated Voltage LRA

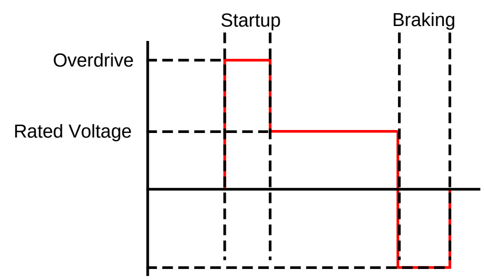


Figure 4. Overdrive and Rated Voltage ERM

4 Test Data

4.1 Tools Used

- A DRV2605LEVM-BB AA Battery Buck-Boost reference design board
- A DRV-ACC16-EVM Haptic Accelerometer Measurement Tool
- A DRV-USBCOM-EVM Haptics Communication Board
- A Lecroy AP015 Current Probe
- Silicone Gel Blocks

4.2 Scope Capture Reference

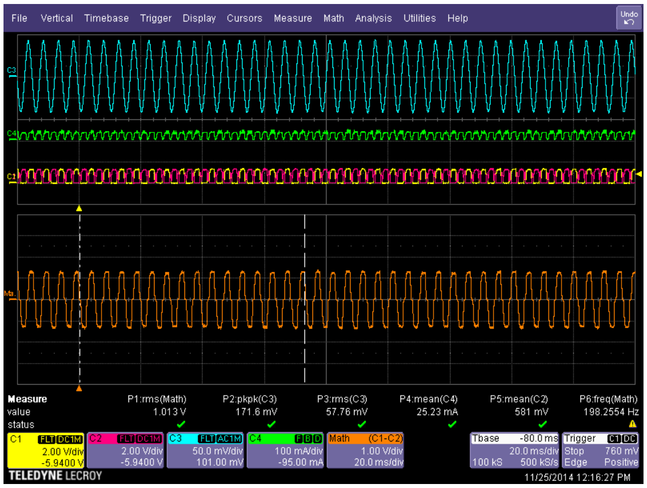


Figure 5. Sample Scope Capture

- Channel 1 (C1) = OUT+ of DRV2605L
- Channel 2 (C2) = OUT– of DRV2605L
- Channel 3 (C2) = Acceleration on the dominant motor vibration axis
- Channel 4 = Current probe on net VBAT
- Math = Difference of OUT+ and OUT– (C1-C2)

The current measurement window is denoted by the two dotted marker lines on the waveform. The size of the window is based on the duration of the effect and will calculate time-based measurements, such as energy per click.

4.2.1 Acceleration Conversion

The peak-to-peak value of C3 can calculate the acceleration.

$$\text{Acceleration} = \frac{\text{Value of C3}_{\text{peak to peak}}}{\left(\frac{57}{2}\right)} \tag{3}$$

4.3 Effects Preview

Different motors were connected to the outputs of the DRV2605LMSOP. Table 1 lists the three motors used in this study:

Table 1. List of Motors Used in this Study

MOTOR	MOTOR TYPE	PROGRAMMED RATED VOLTAGE	PROGRAMMED OVERDRIVE CLAMP	ACCELERATION (G)
SEMCO 1030	LRA	1 VRMS	3.3 V	1.5
NRS2574i	ERM	1.7 V	2 V	1
Johnson Electric	ERM	4 V	5 V	6.7

List of effects: The following is a list of the effects that were captured.

- Infinite Buzz
- Strong Click
- Sharp Click
- Double Click
- Triple Click
- Buzz 100
- Pulsing

NOTE: These effects were captured with the a configuration of 5 V applied to the DRV. The resistors R2 and R4 were unchanged.

4.4 SEMCO 1030 Linear Resonant Actuator

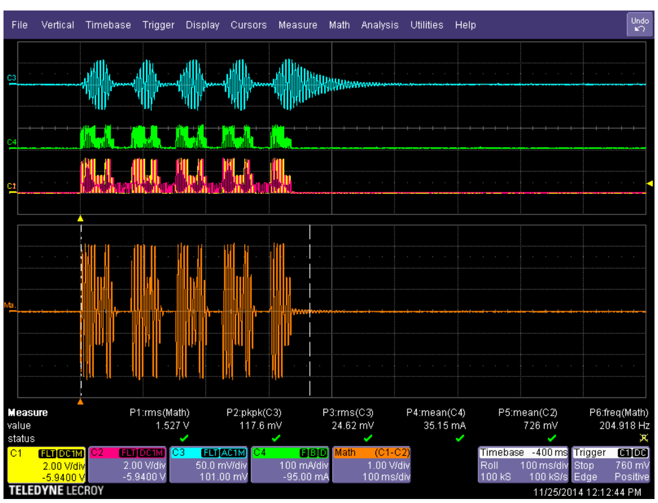


Figure 6. Pulsing Strong

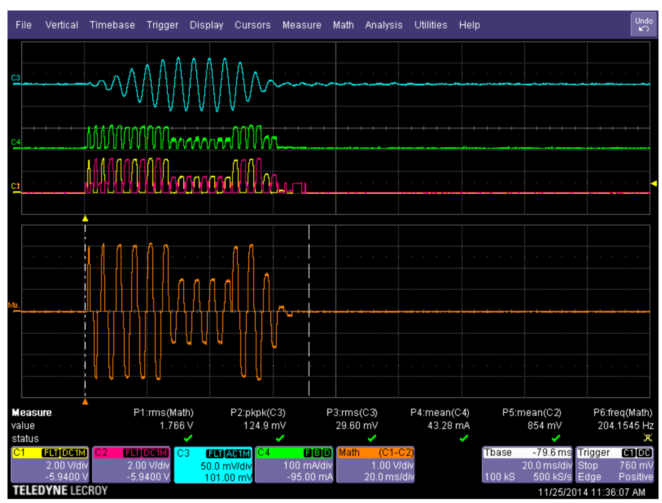


Figure 7. Strong Click

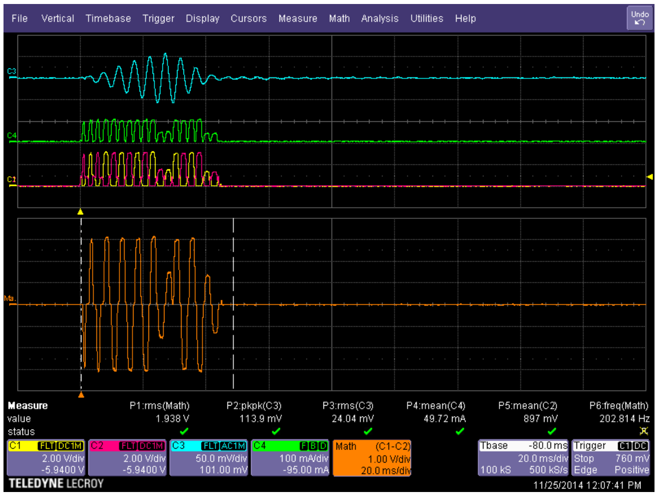


Figure 8. Sharp Click 100

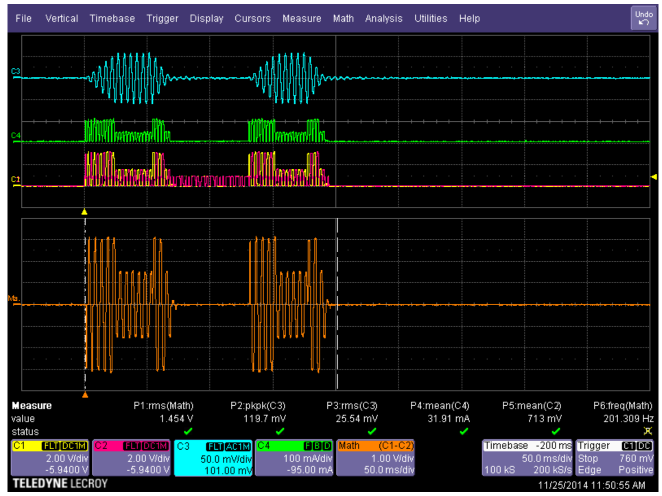


Figure 9. Double Click

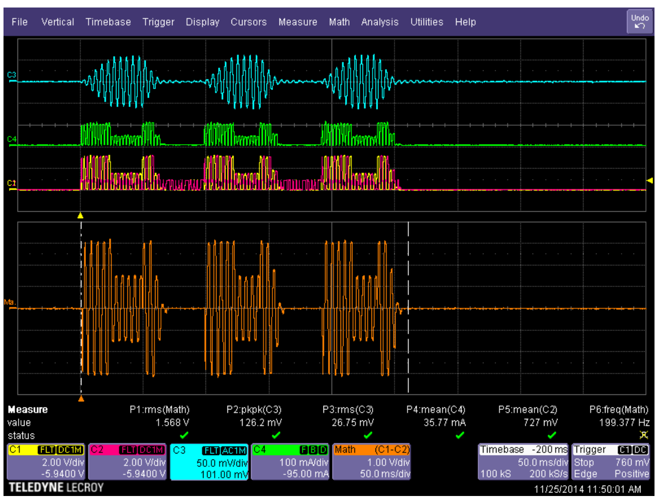


Figure 10. Triple Click

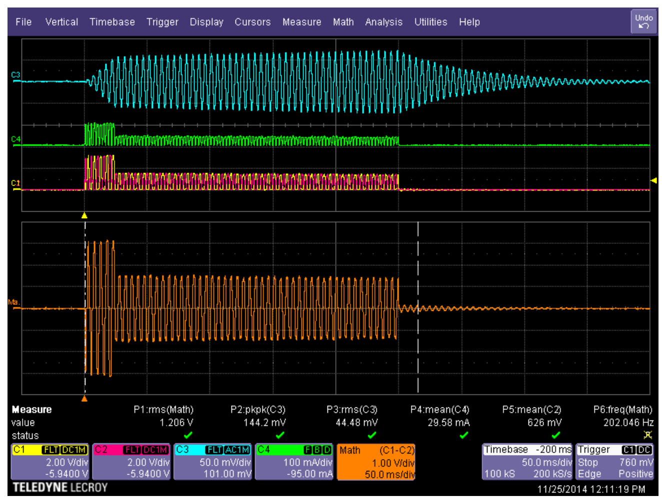


Figure 11. Buzz1-100

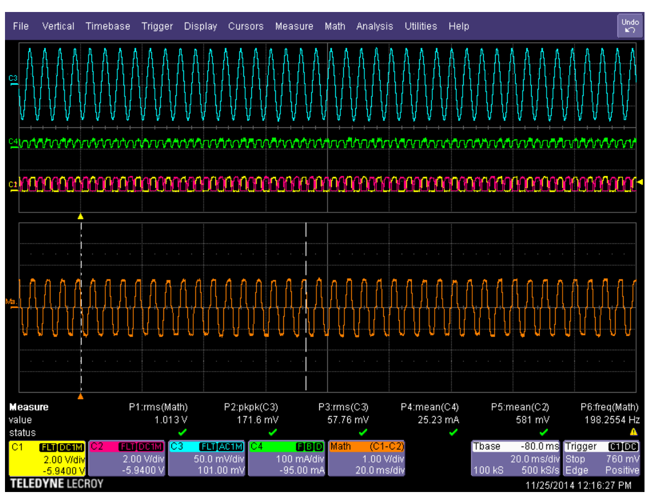


Figure 12. Infinite Alert

4.5 Johnson Electric

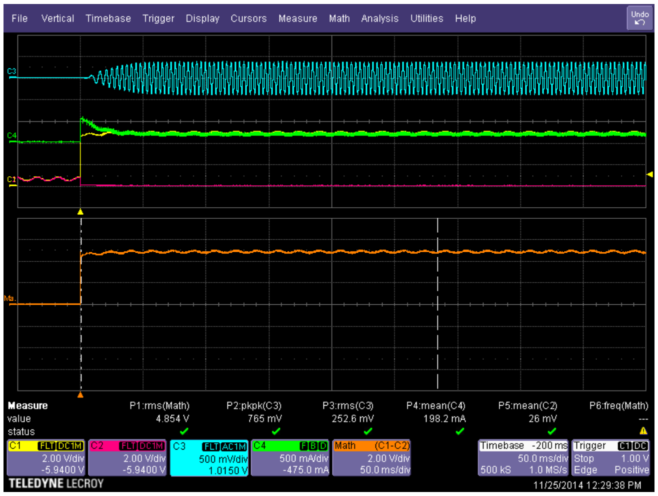


Figure 13. Infinite Alert

Figure 14. Strong Click

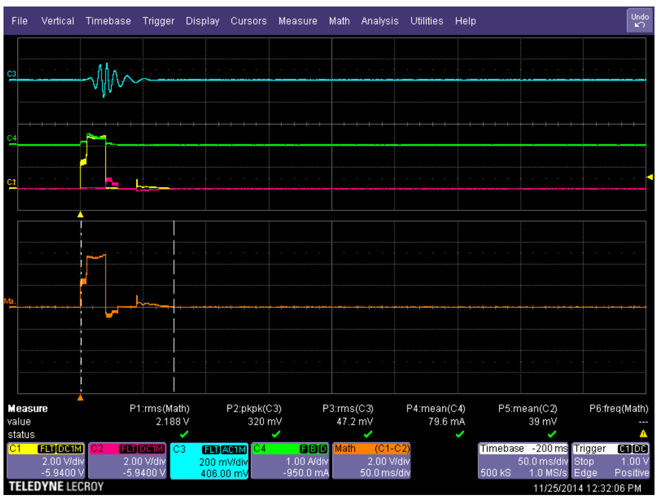


Figure 15. Sharp Click 100

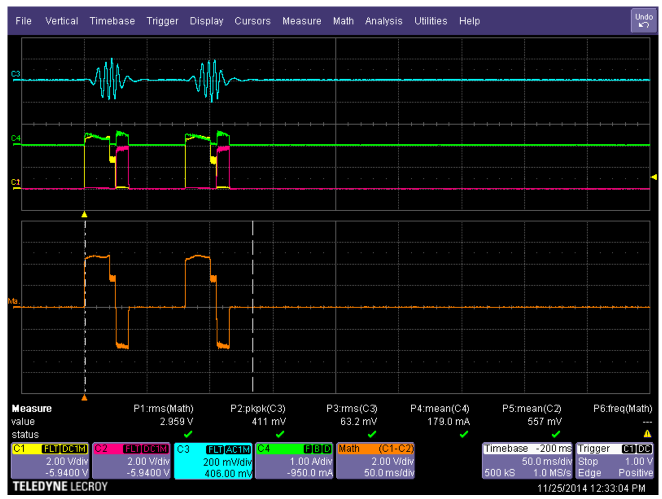


Figure 16. Double Click

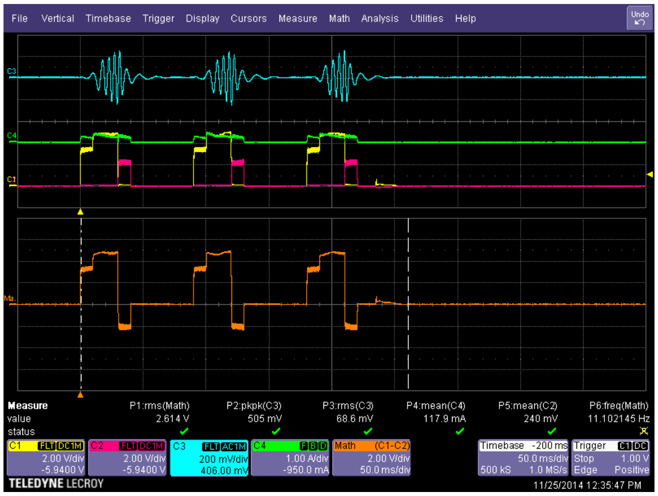


Figure 17. Triple Click

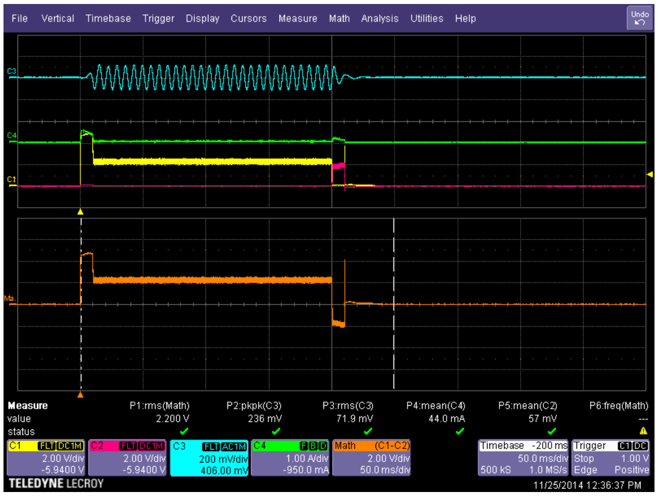


Figure 18. Buzz 100

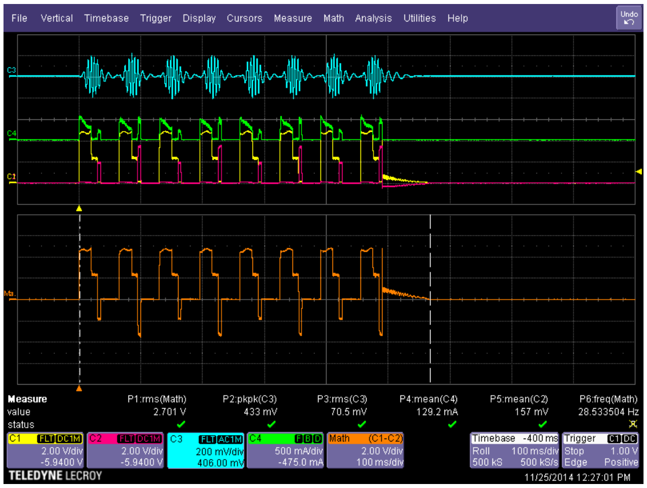


Figure 19. Pulsing Strong

4.6 NRS2574i

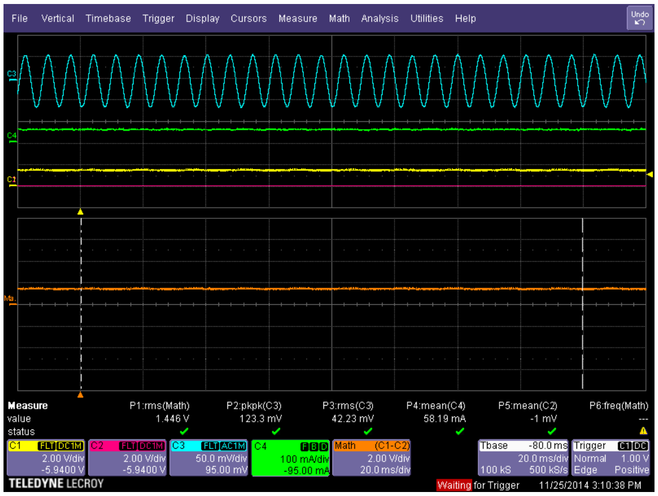


Figure 20. RTP Buzz

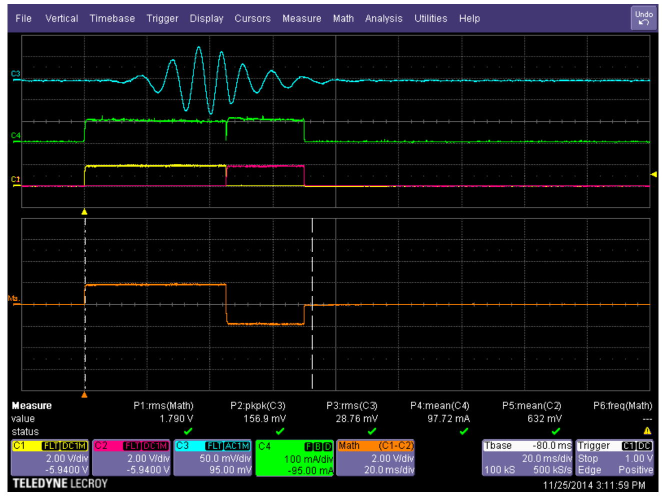


Figure 21. Strong Click

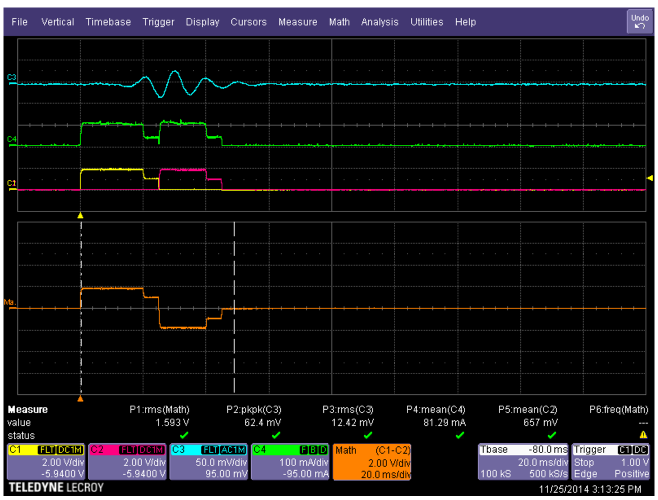


Figure 22. Sharp Click 100

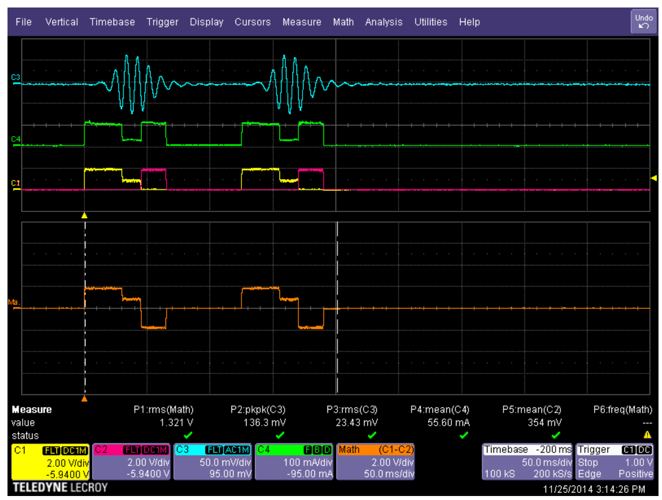


Figure 23. Double Click

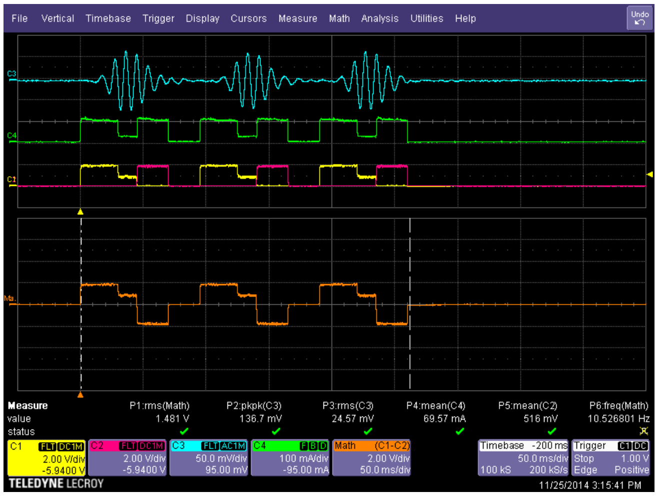


Figure 24. Triple Click

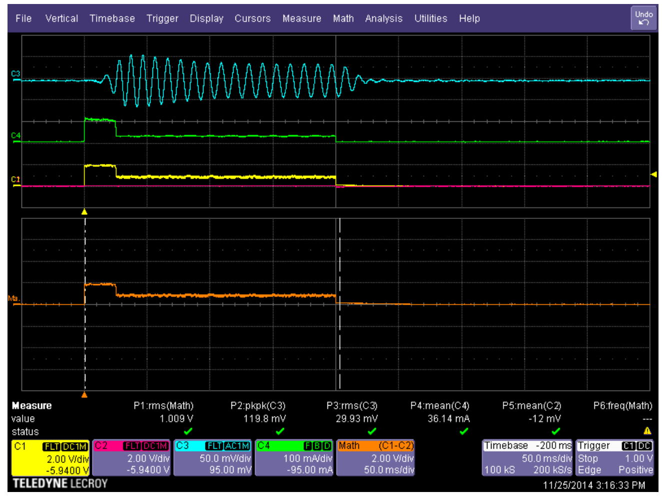


Figure 25. Buzz 100

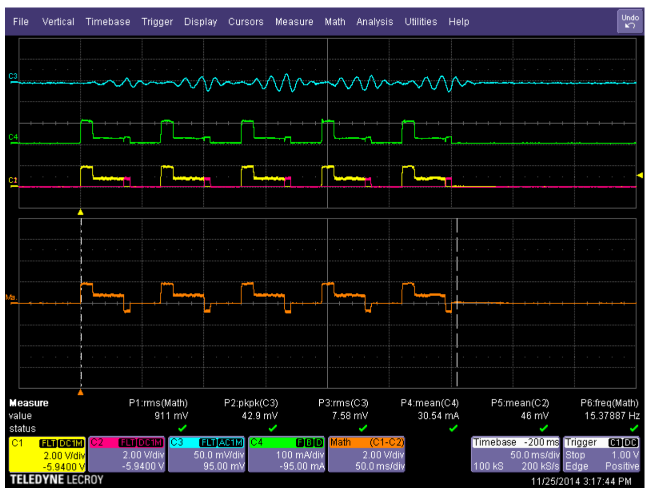


Figure 26. Pulsing Strong

4.7 Choice of Output Voltage vs Optimizing for Efficiency

From Equation 1, one can obtain different voltages on the output of the TPS63030, which is powering the DRV2605L. Two different configurations of V_{OUT} were obtained with resistor R2 = 887 kohm and 537 kohm, which corresponds to V_{OUT} = 5 V and 3.3 V, respectively.

This voltage is important as it is the maximum to which the overdrive clamp can be set. Table 2 shows that it is optimal to have the difference between the output voltage closer to the overdrive voltage. Based on the application and in an example of a 3-V overdrive on an LRA, a 5-V output configuration for the same acceleration is unnecessary.

4.8 Resistor R2 = 887 kohm (V_{OUT} = 5 V)

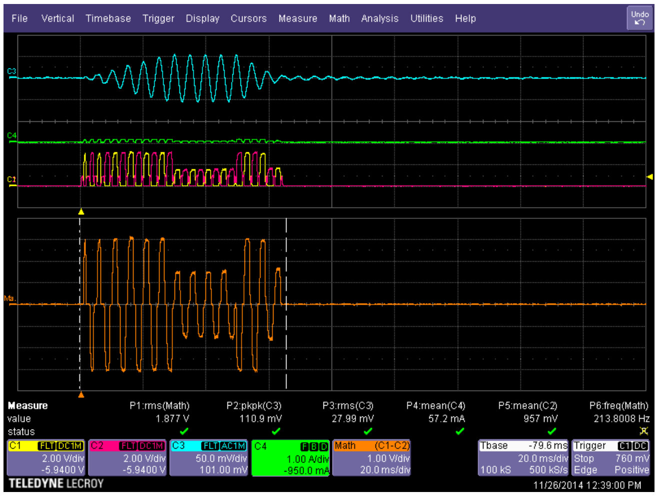


Figure 27. VBAT = 5 V

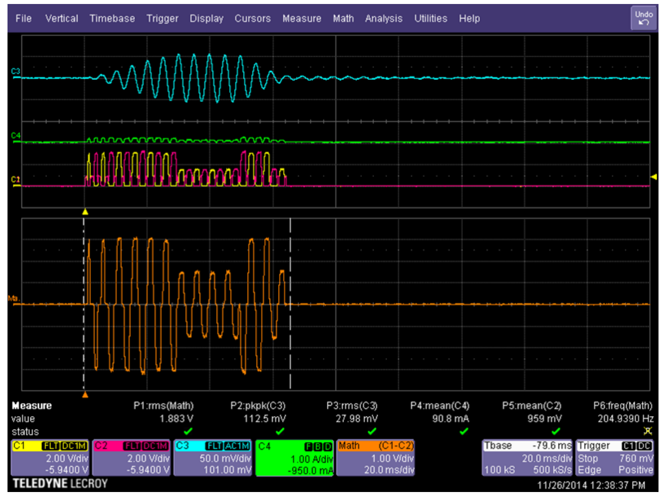


Figure 28. VBAT = 4 V

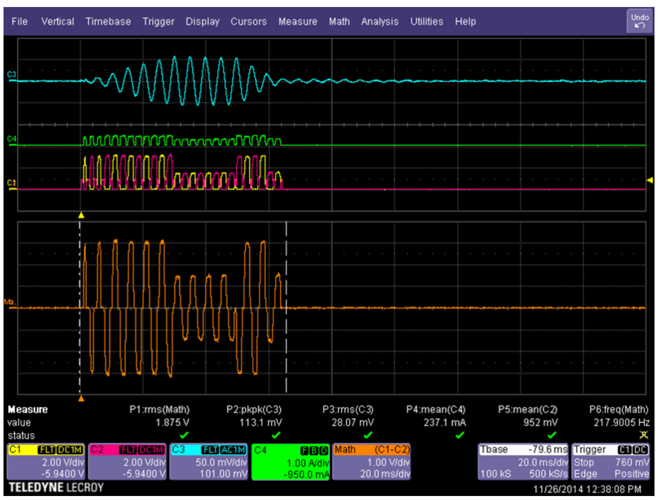


Figure 29. VBAT = 3 V

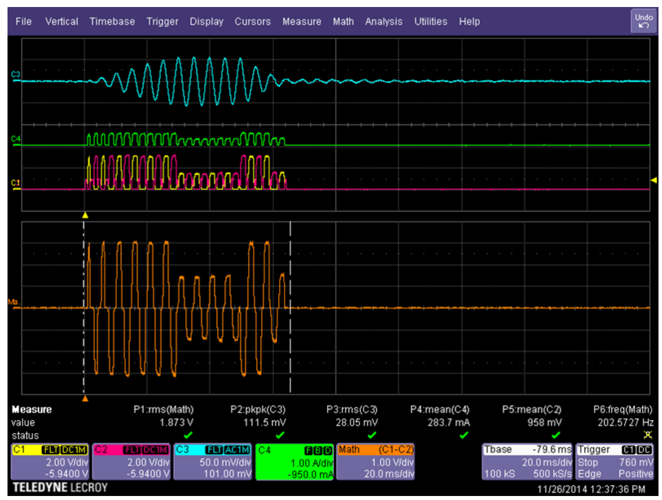


Figure 30. VBAT = 2 V

4.9 Resistor R2 = 530 kΩ (V_{OUT} ≈ 3 V)

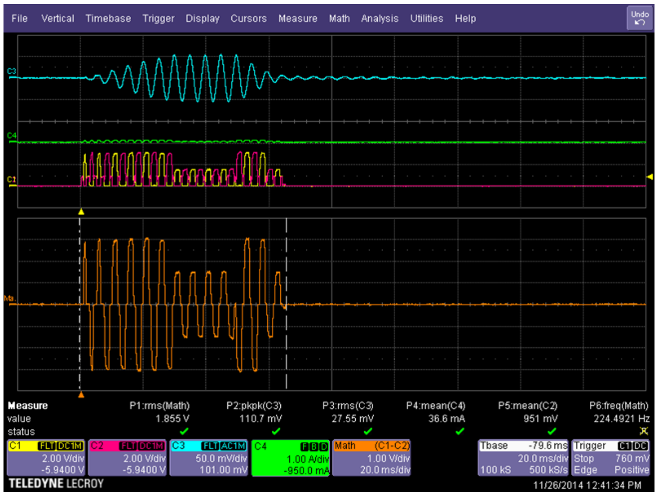


Figure 31. VBAT = 5 V

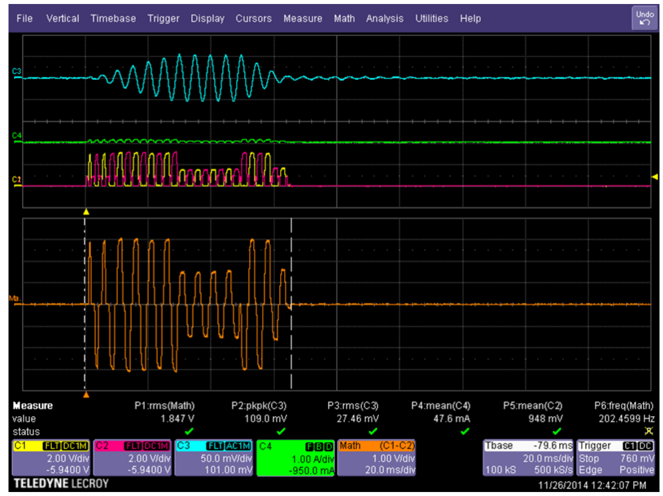


Figure 32. VBAT = 4 V

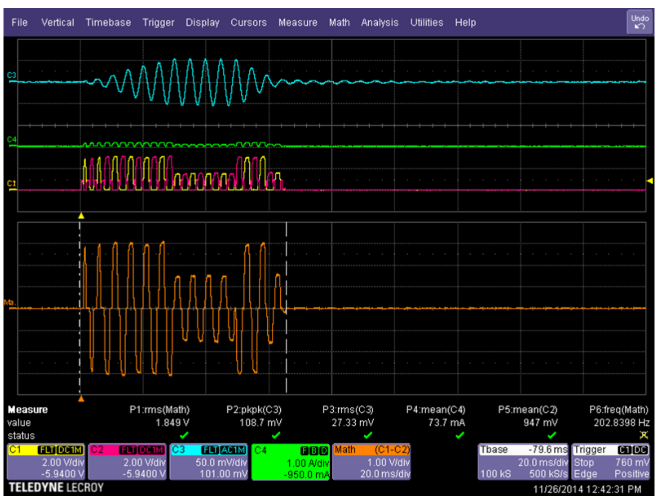


Figure 33. VBAT = 3 V

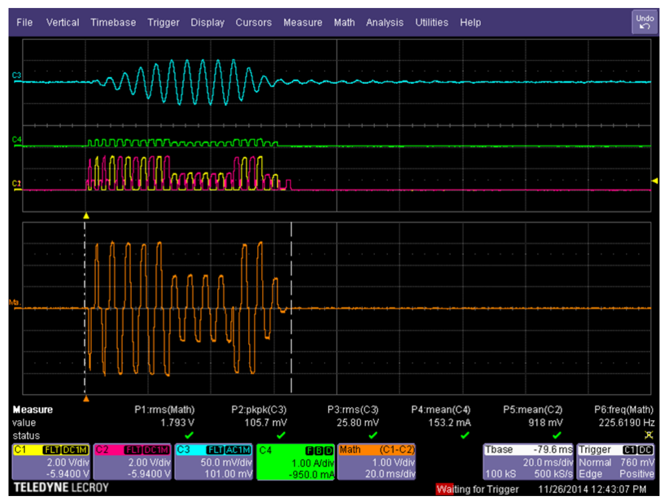


Figure 34. VBAT = 2 V

Table 2. Current Consumption Summary

CONDITION	MEAN CURRENT (mA)	VBAT (V)	REG (V)	DURATION (ms)	ENERGY PER CLICK (µAh)	APPROXIMATE NUMBER OF CLICKS FROM A 1500-mAh BATTERY
R2 = 887 k	57.2	5	5	65	1.03	1,452,394
R2 = 887 k	90.8	4	5	65	1.64	914,944
R2 = 887 k	237.1	3	5	65	4.30	350,388
R2 = 887 k	283.7	2	5	65	5.12	292,834
R2 = 530 k	36.6	5	3	65	0.66	2,269,861
R2 = 530 k	47.6	4	3	65	0.86	1,745,314
R2 = 530 k	73.7	3	3	65	1.33	1,127,231
R2 = 530 k	153.2	2	3	65	2.77	542,278

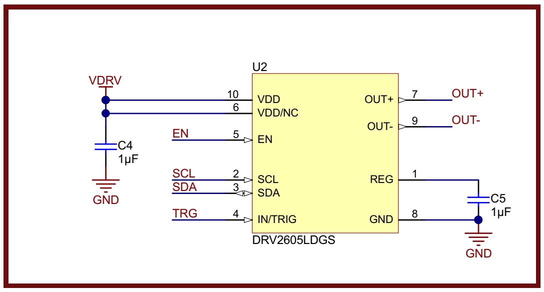
NOTE: Always configure the output voltage of the Buck-Boost converter to be greater than or equal to the overdrive voltage of the motor.

Table 2 shows that for best results, the output voltage of the Buck-Boost converter must be set as high as the lowest value required for the overdrive clamp voltage of the motor.

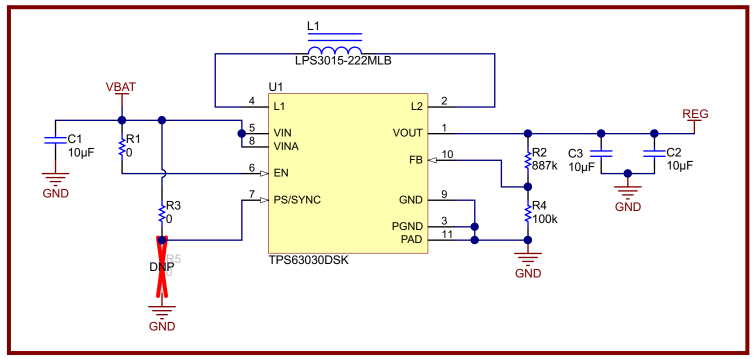
5 Design Files

5.1 Schematics

To download the schematics, see the design files at TIDA-00407.



DRV2605L Haptic Driver



TPS63030 Buck Boost (1.8-5V)

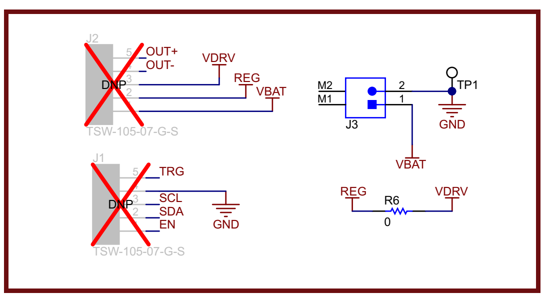


Figure 35. Schematics Page 1

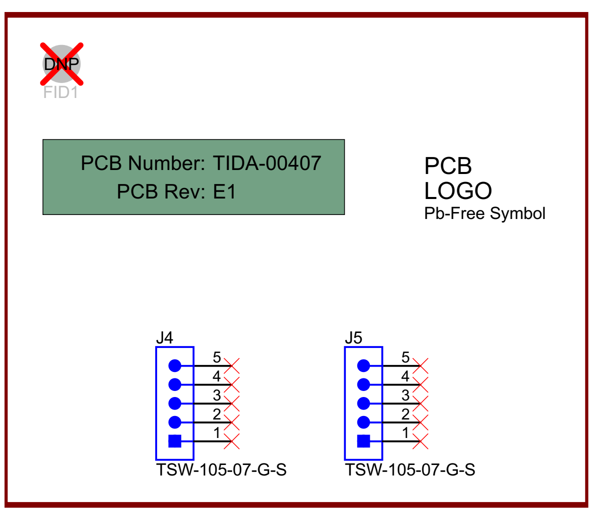


Figure 36. Schematics Page 2

5.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-00407.

Table 3. Bill of Materials

ITEM #	DESIGNATOR	QUANTITY	VALUE	PART NUMBER	MANUFACTURER	DESCRIPTION	PACKAGE REFERENCE
1	!PCB1	1		TIDA-00407	Any	Printed Circuit Board	
2	C1, C2, C3	3	10 µF	C0603C106M9PACTU	Kemet	CAP, CERM, 10 µF, 6.3 V, ± 20%, X5R, 0603	603
3	C4, C5	2	1 µF	C1005X5R1C105K050BC	TDK	CAP, CERM, 1 µF, 16 V, ± 10%, X5R, 0402	402
4	J3	1		S2B-PH-SM4-TB(LF)(SN)	JST Manufacturing	Header (shrouded), 2 mm, 2x1, R/A, SMT	Header, 2x1, 2 mm, R/A
5	J4, J5	2		TSW-105-07-G-S	Samtec	Header, 100 mil, 5x1, Gold, TH	5x1 Header
6	L1	1	2.2 µH	LPS3015-222MLB	Coilcraft	Inductor, Shielded Drum Core, Ferrite, 2.2 µH, 1.4 A, 0.11 Ω, SMD	LPS3015
7	R1, R3, R6	3	0	CRCW04020000Z0ED	Vishay-Dale	RES, 0, 5%, 0.063 W, 0402	402
8	R2	1	887 k	RC0603FR-07887KL	Yageo America	RES, 887 k, 1%, 0.1 W, 0603	603
9	R4	1	100 k	RC0603FR-07100KL	Yageo America	RES, 100 k, 1%, 0.1 W, 0603	603
10	TP1	1	SMT	5015	Keystone	Test Point, Miniature, SMT	Testpoint_Keystone_Miniature
11	U1	1		TPS63030DSK	TI	High-Efficiency Single Inductor Buck-boost Converter with 1-A Switches, DSK0010A	DSK0010A
12	U2	1		DRV2605LDGS	TI	Haptic Driver for LRA and ERM With Built-In Library and Smart Loop Architecture, DGS0010A	DGS0010A
13	FID1	0		N/A	N/A	Fiducial mark. There is nothing to buy or mount.	Fiducial
14	J1, J2	0		TSW-105-07-G-S	Samtec	Header, 100mil, 5x1, Gold, TH	5x1 Header
15	R5	0	0	CRCW04020000Z0ED	Vishay-Dale	RES, 0, 5%, 0.063 W, 0402	402

5.3 Layer Plots

To download the layer plots, see the design files at TIDA-00407.

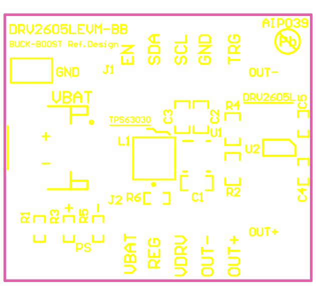


Figure 37. Top Overlay

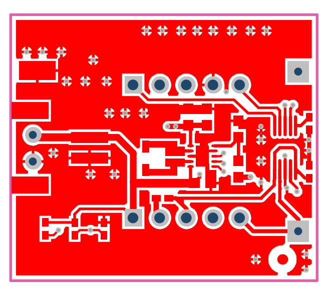


Figure 38. Top Layer

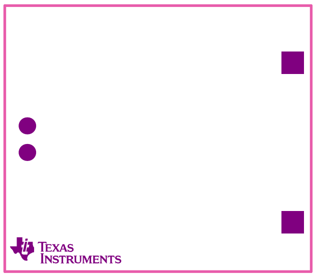


Figure 39. Top Solder

Figure 40. Bottom Overlay

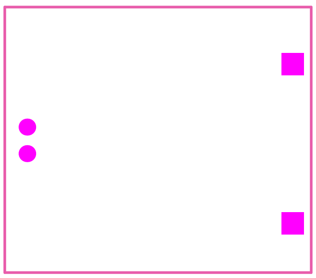


Figure 41. Bottom Solder

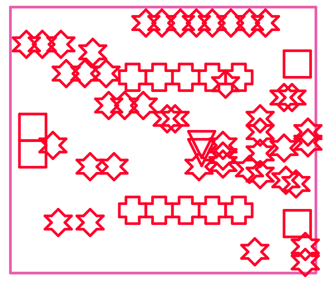


Figure 42. Drill Drawing

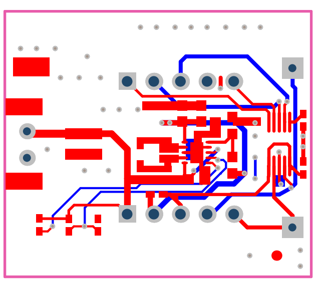


Figure 43. Composite Layer

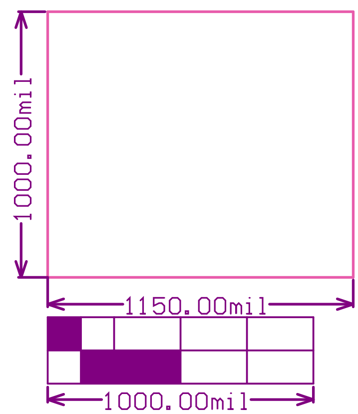


Figure 44. Board Dimensions

5.4 Altium Project

To download the Altium project files, see the design files at TIDA-00407.

5.5 Layout Guidelines

To download the layout guidelines, see the design files at TIDA-00407.

5.6 Gerber Files

To download the Gerber files, see the design files at TIDA-00407.

6 References

1. *Choosing Inductors and Capacitors for DC/DC Converters* (SLVA157)
2. *DRV2605 Setup Guide* (SLOA189)

7 About the Author

GAUTHAM RAMACHANDRAN is an Applications Engineer at TI, where he currently works on Haptic technology. He develops hardware, evaluation modules, and reference designs along with collateral and system-level debug on various consumer electronic platforms. Gautham received his Masters of Electrical Engineering from Texas Tech University researching Micro Electro Mechanical Systems (MEMS). He has also worked on touch-screen controllers and has built automated test setups for touch panels in his previous role at TI.

IMPORTANT NOTICE FOR TI REFERENCE DESIGNS

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265