LDC0851EVM

The Texas Instruments LDC0851 evaluation module (EVM) helps designers evaluate the operation and performance of the LDC0851 Inductive Switch. The EVM contains one LDC0851 soldered onto the EVM PCB and options to operate with battery or USB power. A 50-kΩ trim pot is also included to change the switching distance threshold making it easy to evaluate for a wide variety of use cases.

Table 1. Device and Package Configurations

DEVICE	IC	PACKAGE
U1	LDC0851	WSON-8

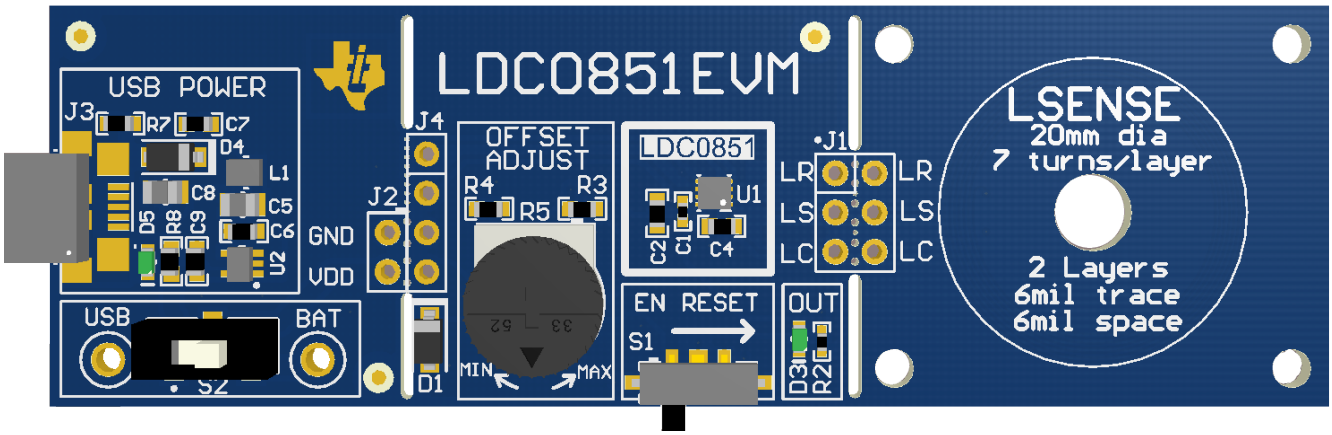

Figure 1. LDC0851EVM

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1 EVM Features and Connections

This section describes the connectors on the LDC0851EVM and how to properly connect, set up and use the LDC0851.

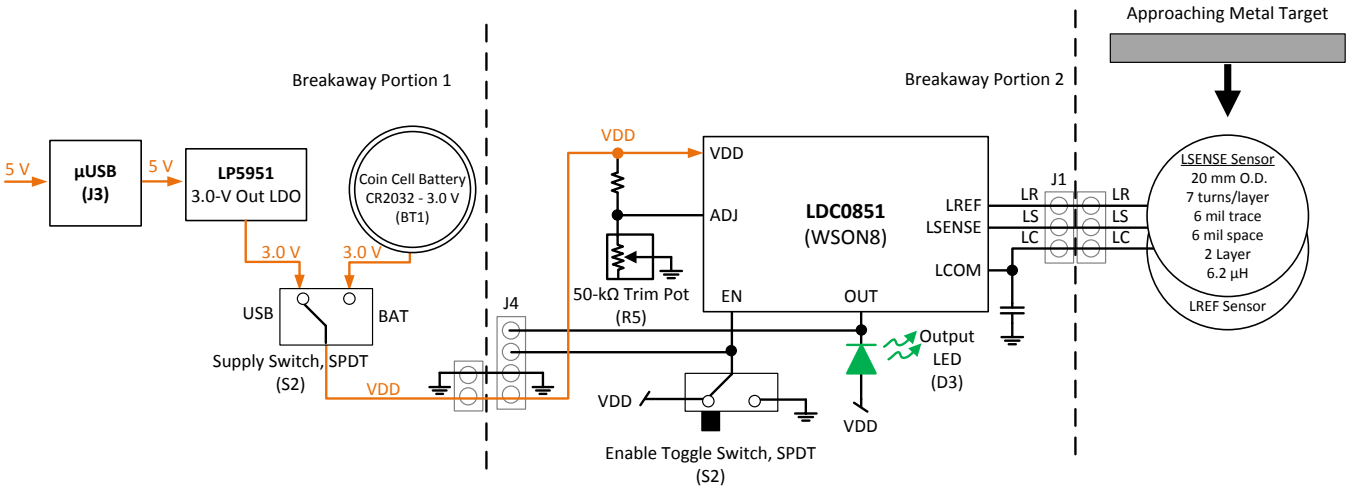

Figure 2. EVM Block Diagram

1.1 Connector Description

Table 2. EVM Connections

CONNECTOR	TYPE	FUNCTIONALITY
J1	6 pin, 100 mil header (not stuffed)	Provides connections for LREF, LSENSE, and LCOM if sensor portion is detached.
J2	2 pin, 100 mil header (not stuffed)	Provides connections for GND and VDD if the power section is detached.
J3	Micro-USB connector	Provides 3.0-V power to the DUT when connected to 5 V.
BT1 – CR2032	CR2032 Battery Holder	Provides 3.0-V power to the DUT when CR2032 battery is inserted into the battery slot.
J4	4 pin, 100 mil header (not stuffed)	Provides optional connections for DUT Supply, Ground, OUT, and EN.
S1 – EN RESET	SPDT Switch	Spring loaded switch (default on) to toggle EN low. This resamples the voltage on the ADJ pin.
S2	SPDT Switch	Toggle between 3.0-V USB Power (USB position) and 3.0-V battery power (BAT position).
D3 – OUT	Green LED	Indicates when the output of the LDC0851 switches. Note that LED will be off in the absence of a metal target.
D5	Green LED (not stuffed)	Indicates 3.0 V is present at output of the 3.0-V LDO (LP5951).
R5 – OFFSET ADJUST	50k Trim Pot	Provides adjustable resistance to create a voltage divider between 0 V and VDD/2 on the ADJ pin. If the voltage is changed during operation, the EN pin must be toggled low then high with switch S1.
Breakaway Perforation 1	Perforation	The EVM can be separated at this point to use a different supply rail or to directly access VDD, GND, OUT, and EN.
Breakaway Perforation 2	Perforation	The EVM can be separated at this point to use different LSENSE and LREF sensors.
USB	Test Point	Test point for 3.0-V output of LP5951.
BAT	Test Point	Test point for 3.0-V output of Battery

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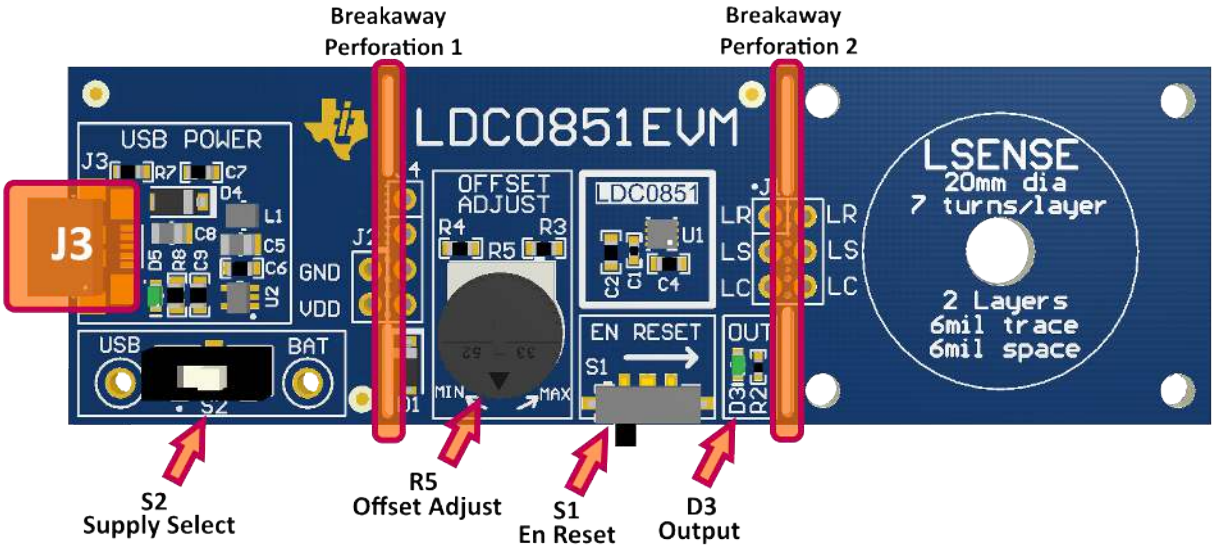

Figure 3. Connector and Feature Locations (Top)

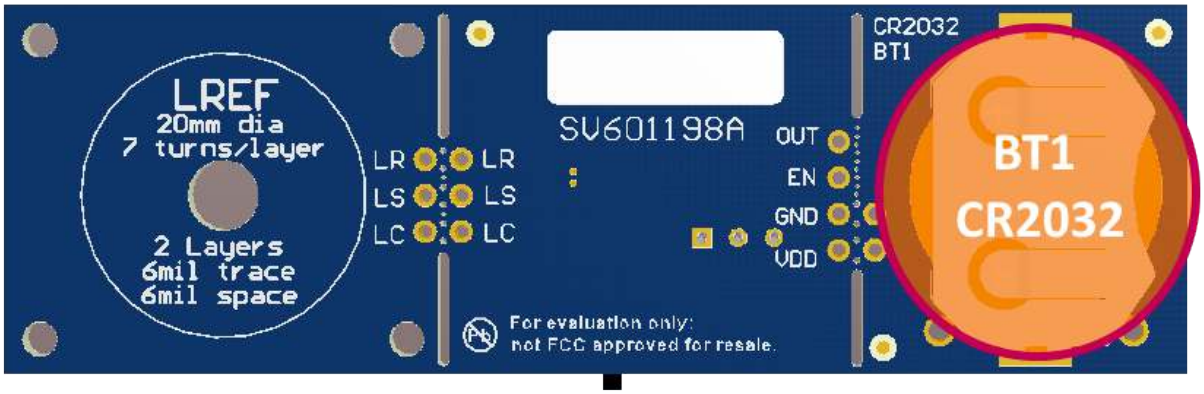

Figure 4. Connector and Feature Locations (Bottom)

1.2 EVM Interface

The LDC0851EVM can be powered with 5 V via the micro-USB connection (J3) on the top side of the EVM. Alternatively, a 3-V battery via the battery connection (BT1) on the backside of the EVM may be used to directly supply the LDC0851 with 3 V. Use Supply Switch (S2) to select the desired power source.

The voltage on the ADJ pin of the LDC0851 at startup will determine the distance at which a metal target will be detected. The voltage can be easily controlled through the 50-kΩ trim pot (R5). Note, the ADJ value is only sampled once on startup or after EN has toggled low to high with switch S1.

Table 3. LED Indicator Behavior with GUI

LED	COLOR	FUNCTIONALITY
D3	Green	Indicates when the output of the LDC0851 switches.

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1.3 Break-Away Sections

Figure 5. EVM Break-Away Sections

The LDC0851 EVM can be broken into 3 discrete sections: a 5-V to 3-V section which includes the USB interface section, an LDC0851 section, and a sensor section which contains the LREF and LSENSE sensors.

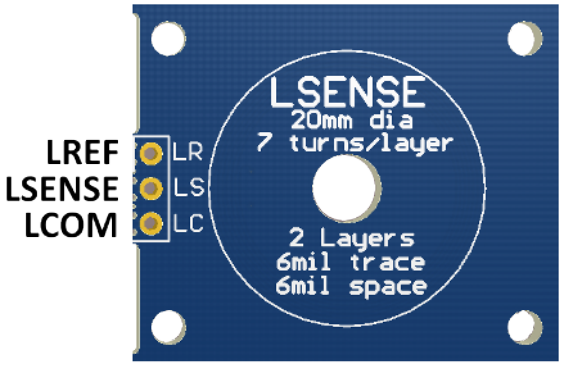

Figure 6. Break-Away Sensor (Top)

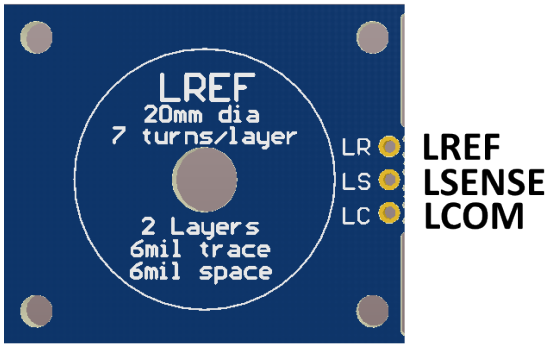

Figure 7. Break-Away Sensor (Bottom)

Break-Away Sensor Section: The Sensor section of the LDC0851EVM can be broken along the indicated line to separate the sensor from the LDC0851 IC. A three pin header is available on the LDC0851 section to connect to different sensors or for remote location. If the cable connection between the sensor and the LDC0851EVM is longer than 2 cm, use twisted pair or coaxial to connect back to the LDC0851 section.

The EVM sensor is a 4 layer stacked coil design, with the top 2 layers used for the sensing coil, and the bottom 2 layers used for the reference coil.

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Table 4. LDC0851EVM Sensor Parameters

PARAMETER	LSENSE SENSOR VALUE	LREF SENSOR VALUE
Outer Diameter	787.4 mils (20.0 mm)	787.4 mils (20.0 mm)
Inner Diameter	619.4 mils (15.7 mm)	619.4 mils (15.7 mm)
Number of turns	7	7
Trace Width	6 mils (0.152 mm)	6 mils (0.152 mm)
Trace Spacing	6 mils (0.152 mm)	6 mils (0.152 mm)
Number of layers	2	2
Trace Thickness	1 oz-cu (35 µm)	1 oz-cu (35 µm)
Inductance at 9.5 MHz	8.65 µH	8.65 µH
C_{SENSOR} (C4)	68 pF	68 pF
f_{SENSOR} (no target)	9.5 MHz	9.5 MHz

2 Theory of Operation

The LDC0851 is an inductance based switch for contactless and robust applications such as presence detection, event counting, and coarse position detection. The device is connected to a reference coil (LREF) and a sensing coil (LSENSE). The output of the LDC0851 switches when the inductance of LSENSE drops below LREF which is caused by an approaching metal target. The LDC0851 EVM employs a stacked coil arrangement, in which the LSENSE sensor coil is closer to the metal target than the LREF reference coil when approached from the top side (LSENSE side). The user can take advantage of the Offset Adjust feature to change the switching distance (dswitch). The offset is added to LREF so that increasing the ADJ code causes the LDC0851 to switch at a closer distance. The ADJ code is determined by the voltage level on the ADJ pin at device power on and by toggling the Enable pin low then high.

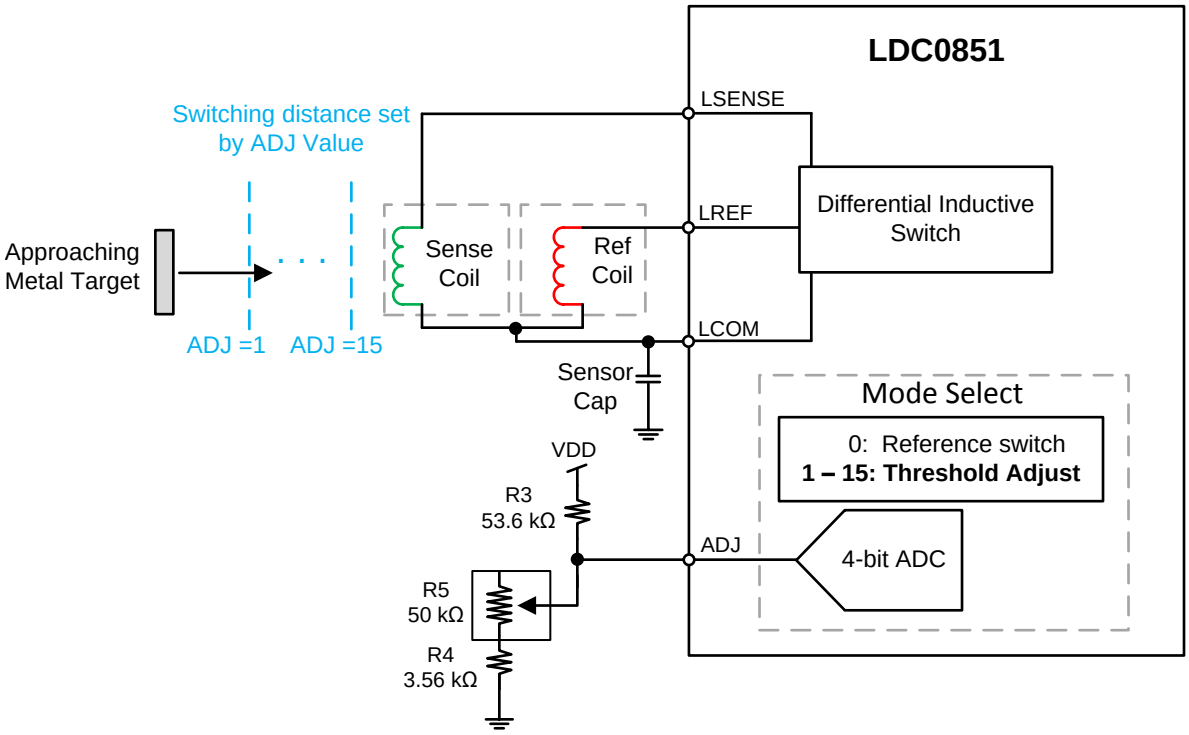

Figure 8. Simplified Block Diagram for Stacked Coils

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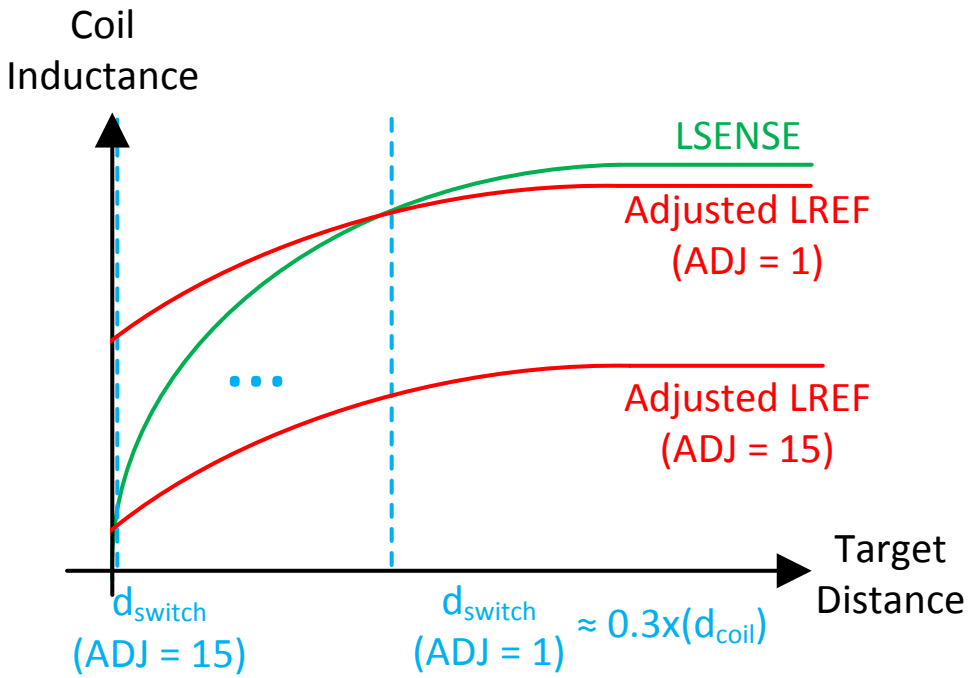

Figure 9. Switch Distance with Offset

A potentiometer (R5) has been included to make adjusting the threshold easier for prototyping. Note that rotating the potentiometer clockwise towards the *MIN* direction decreases the ADJ value and results in a longer switching threshold. Similarly, rotating R5 counter clockwise towards the *MAX* position increases the ADJ value and decreases the switching distance. The Enable pin should be toggled low then high to set a new switching threshold.

Figure 10. Adjust the Offset

The ADJ value can be achieved by setting the combination of R4 + R5 to the values in Table 5.

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Table 5. Resistor Values for ADJ Code

ADJ Level (code)	R4+R5 (kΩ)
1	3.57
2	5.54
3	7.66
4	9.93
5	12.37
6	15.01
7	17.87
8	20.97
9	24.36
10	28.08
11	32.16
12	36.67
13	41.69
14	47.29
15	53.60

The switching distance for stacked coils can be approximated with Equation 1.

$$d_{switch} = d_{coil} \times 0.3x\left(1 - \frac{ADJ_{Code}}{16}\right) \quad (1)$$

where

- d_{switch} is the approximated switching distance for a stacked coil sensor with good separation between LSENSE coil layers and LREF coil layers. Note that for side-by-side coils, the switching distance uses a factor of 0.4.
- d_{coil} is the coil diameter
- ADJ_{Code} is the desired value from Table 5

For example, consider a coil with a diameter of 20 mm. An ADJ code of 1 yields a switching distance of 5.6 mm, and an ADJ code of 15 yields a switching distance of 0.375 mm. This method helps approximate the switching distance, but the actual response of the coils may vary slightly which is why it is important to prototype the coil as can be seen in Figure 11 below.

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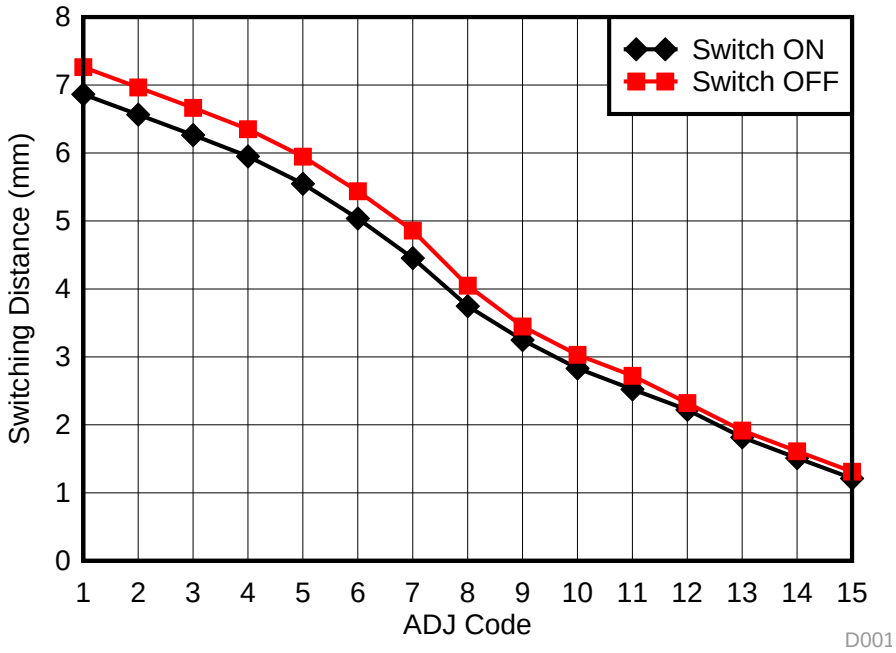

Figure 11. Switching Distance of 20mm Stacked Coil

It should be noted that the sensing distance is determined by the diameter of the coils, inductance matching, and the spacing or PCB thickness between the LSENSE coil and LREF coil layers. To achieve the maximum sensing range for stacked coils, the spacing (h) between the LSENSE and LREF coils should be as thick as possible. Refer to Figure 12 below.

Figure 12. Stacked Coil Separation

It is also recommended to use a target of equal or larger size to the coil diameter to get the longest sensing range.

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3 Quick Start Guide

3.1 Supply Power to the LDC0851EVM

Power can be supplied either through the 5-V micro-USB connection (J3) or through the 3.0-V battery slot (BT1) on the backside of the EVM.

3.1.1 5-V Micro-USB to 3-V Device Power

Connect a USB cable between the 5-V source and the micro-USB connector (J3) on EVM. An onboard LDO will convert the 5-V source into 3.0 V which can be measured at the USB test point shown below.

Figure 13. Insert 5-V Micro-USB

Verify that SUPPLY Switch (S2) is in the USB position.

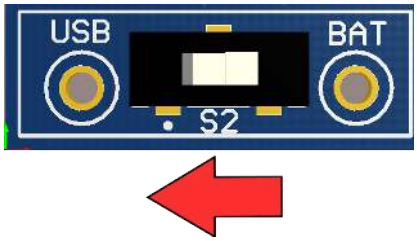

Figure 14. Set SUPPLY Switch (S2) to USB

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3.1.2 3-V Battery Power

Alternatively, the LDC0851 may be operated from battery power. The list of battery requirements is provided below:

Table 6. Battery Requirements

Parameter	Specification
Battery Model	CR2032 UL Certified Battery
Voltage	3.0 V
Min Capacity	225 mAh
Min Discharge Rate	200 µA
Manufacturer and Model Number	Panasonic - BSG CR2032 (or equivalent)

When the EVM is powered by the battery, it is not necessary to have a micro-USB cable connected to J3. Insert CR2032 battery in the slot (BT1) on the back of the board. A voltage of 3.0 V can be measured at the BAT test point shown below.

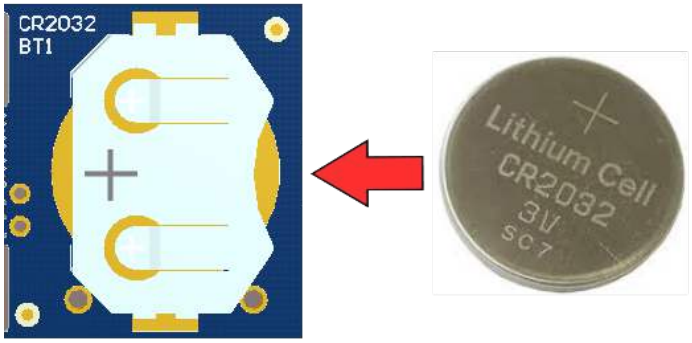

Figure 15. Insert CR2032 Battery into BT1

Slide SUPPLY switch (S2) to the BAT position.

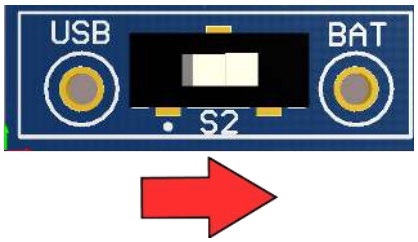

Figure 16. Change SUPPLY Switch (S2) to BAT

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3.2 Adjust the Threshold

The EVM has a potentiometer (R5) which can be used to control the voltage level on the ADJ pin. Rotate the pot clockwise towards “MIN” so that ADJ value is in the minimum offset position, which has the longest sensing range.

Figure 17. Adjust the Offset

To set a new threshold, toggle the EN RESET switch (S1) to re-sample the ADJ pin. This must be done every time a new threshold is set.

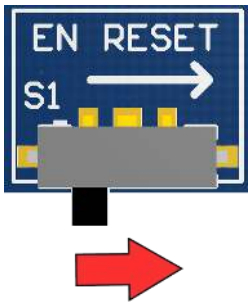

Figure 18. Toggle Enable to Set New Threshold

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3.3 Detecting presence of Metal Targets

With no target is present the OUTPUT LED (D3) should be off. If D3 is on or remains on, increase the offset with R5 and toggle EN with S1 as shown in the previous step.

Figure 19. Observe Status of OUT LED

Bring a conductive target close to the LSENSE coil. The OUT LED (D3) should turn on when the target is 1 to 8 mm above the EVM sensing coil depending on the ADJ value.

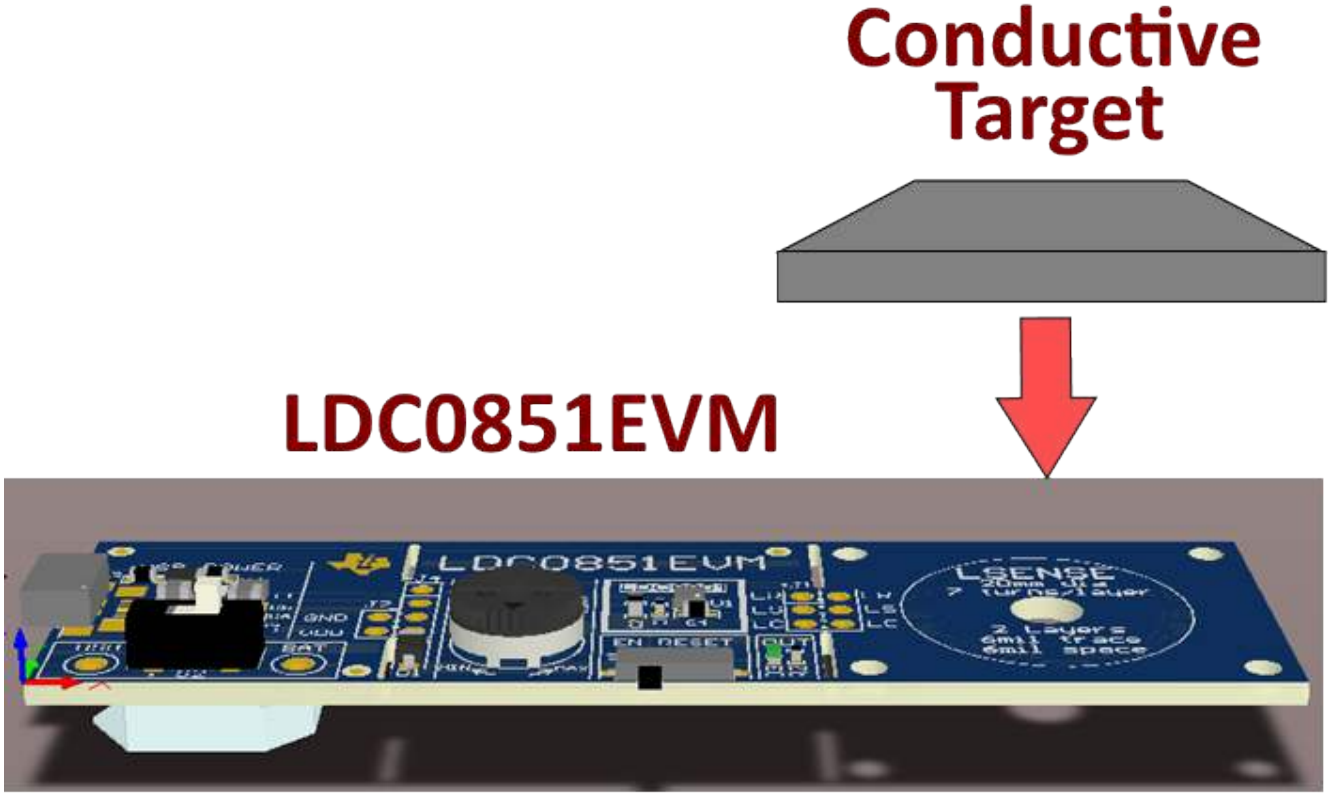

Figure 20. Bring Metal Target Close to LSENSE

To change the switching threshold simply adjust the value of R5, toggle EN with S1 and retest. Note that during active operation the ADJ pin draws ~10 µA of current will alter the resistance reading if using a multi meter to check the value. In order to properly set or check the ADJ resistance when using a multi meter, turn off the device, remove the battery, and set S2 to BAT. The resistance measured across R4 + R5 should be set according to Table 5 for a desired ADJ setting.

This process can be repeated and fine-tuned for a variety of applications including open/close proximity switches, white goods, home security and tamper detection, e-meters, and printers.

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3.4 PCB Breakoff Sections and Compliance

The different sections of the EVM may be broken apart for ease of prototyping and development. Please note that breaking apart the sections voids the warranty. In addition, the stated performance and compliance specifications of the EVM cannot be guaranteed when sections have been broken apart.

The LDC0851EVM has the ability to be powered by either connecting a USB cable or by a 3 V battery as mentioned in Section 3.1. Compliance was evaluated with both Battery powered and USB powered options. Note that if a USB cable is used for powering the EVM, ferrites need to be added to each end of the cable. Fair-rite, Model #0431164951 (or equivalent) are to be installed with one turn each at each end when a USB cable is used for powering the EVM. If provided, the shielded USB cable is less than 3m in length. If not, and one is to be purchased for use with this EVM, it is required to be no longer than 3m to retain the stated performance and compliance.

Figure 21. ESD Compliance

CAUTION

The EVM contains components that can potentially be damaged by electrostatic discharge. Always transport and store the EVM in the supplied ESD bag when not in use. Handle using an antistatic wristband. Operate on an antistatic work surface. For more information on proper handling, refer to Electrostatic Discharge (ESD)[SSYA010].

4 EVM Design – Board Layout

Table 7. Layer Usage

LAYER	FUNCTIONALITY
Top	Signals, Components, Sense coil, and ground-fill
Mid-layer 1	Sense coil, and section transition routing
Mid-layer 2	Reference coil, and section transition routing
Bottom	Signals, Components, Reference coil, and ground-fill

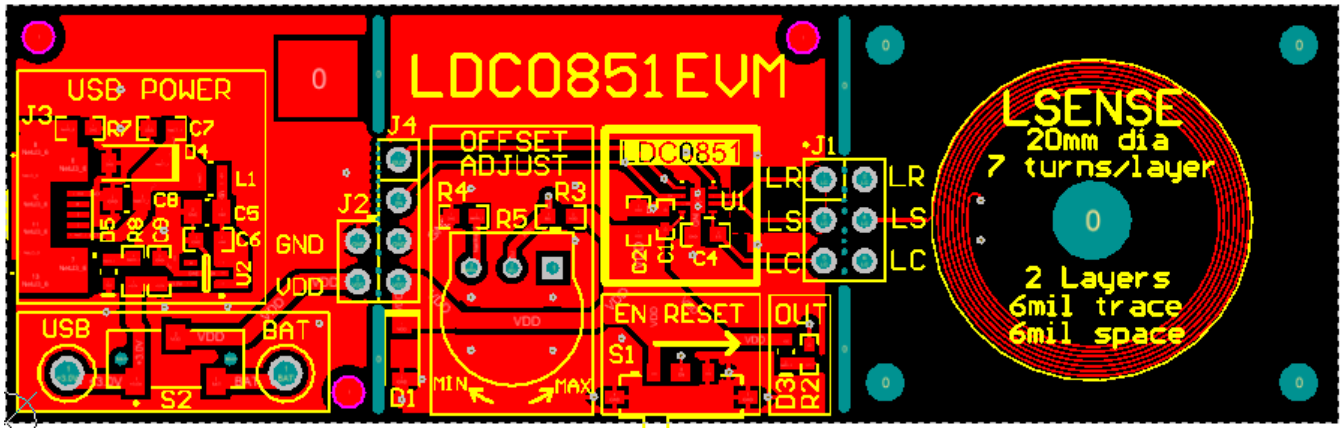

Figure 22. Top Layer Routing

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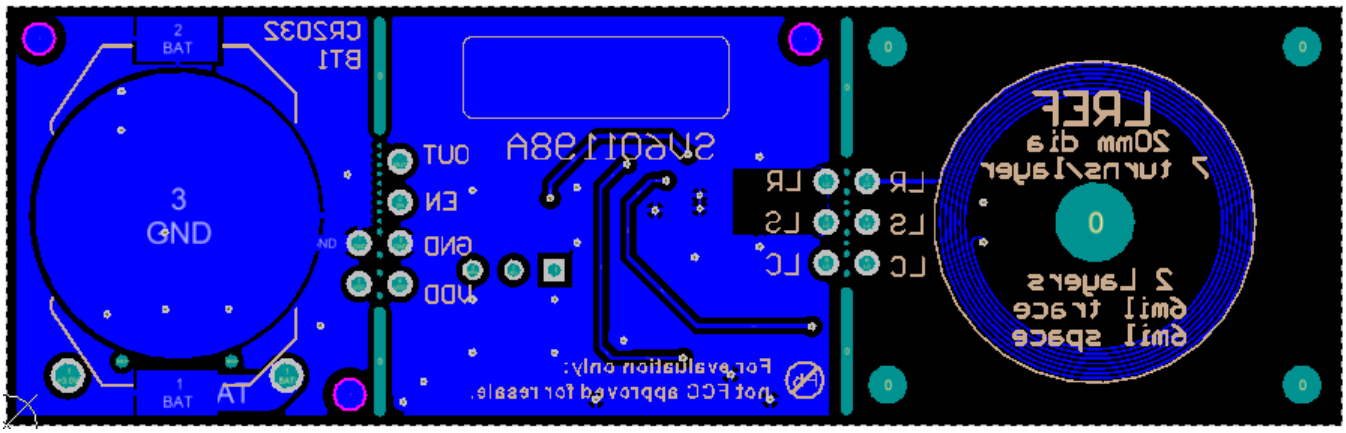

Figure 23. Bottom Layer Routing

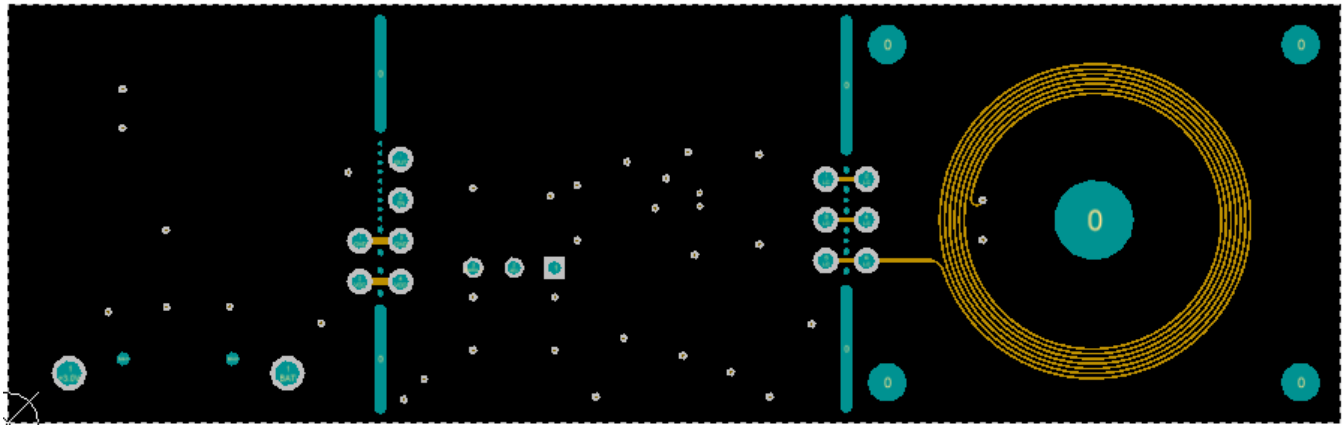

Figure 24. Mid-Layer 1 Routing

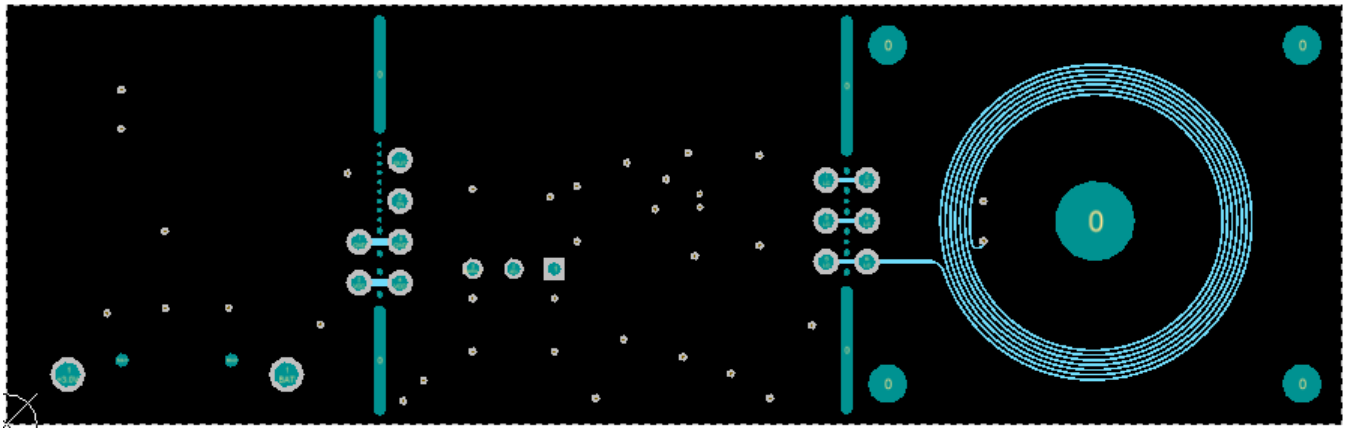

Figure 25. Mid-Layer 2 Routing

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5 EVM Design - Schematic

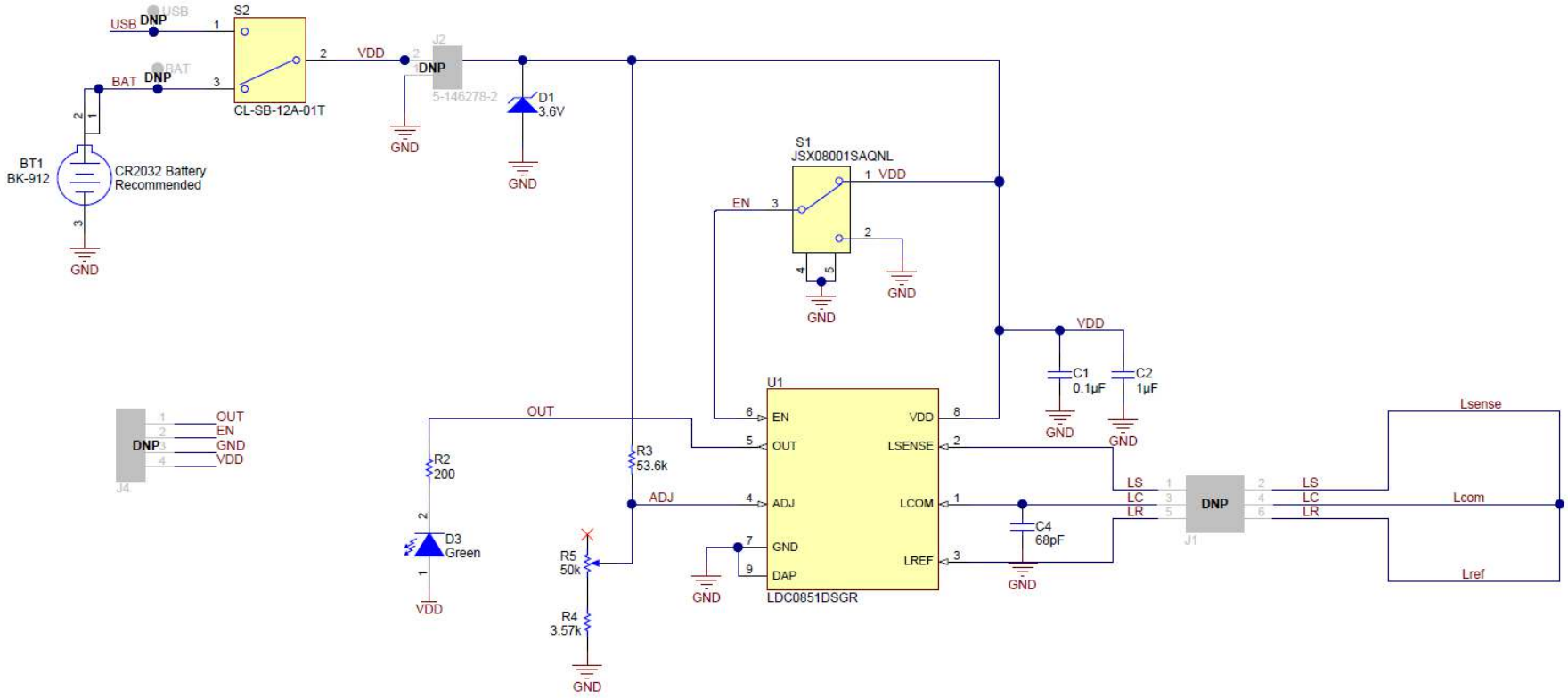

Figure 26. Battery, LDC0851, and Sensor

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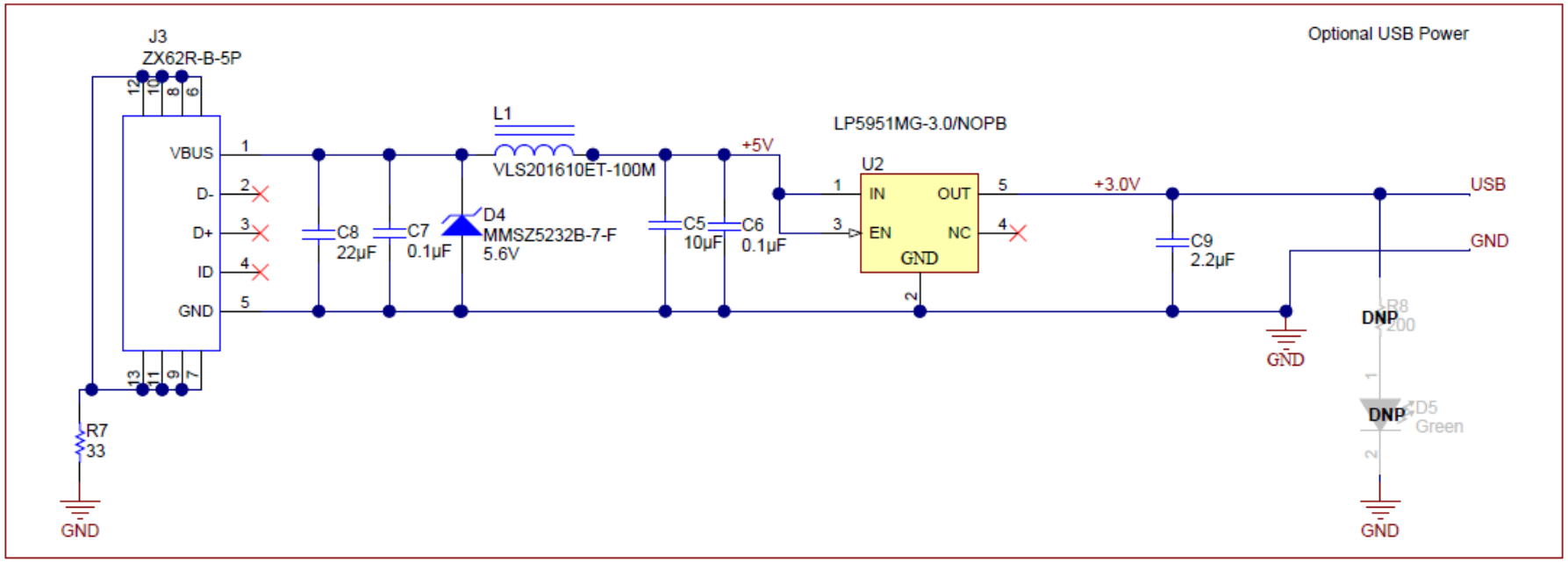

Figure 27. Optional 5-V Micro-USB to 3.0 V

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6 EVM Bill of Materials

Table 8. Bill of Materials

ITEM #	DESIGNATOR	PART NUMBER	MANUFACTURER	DESCRIPTION
1	!PCB1	SV601198	Any	Printed Circuit Board
2	BT1	BK-912	Memory Protection Devices	Battery Holder for CR2032, SMT
3	C1	C1005X7R1H104K	TDK	CAP, CERM, 0.1 µF, 50 V, +/- 10%, X7R, 0402
4	C2	C0603C105K4PACTU	Kemet	CAP, CERM, 1 µF, 16 V, +/- 10%, X5R, 0603
5	C4	C1608C0G1H680J	TDK	CAP, CERM, 68 pF, 50 V, +/- 5%, C0G/NP0, 0603
6	C5	EMK212BB7106MG-T	Taiyo Yuden	CAP, CERM, 10 µF, 16 V, +/- 20%, X7R, 0805
7	C6, C7	C0603C104J3RAC	Kemet	CAP, CERM, 0.1 µF, 25 V, +/- 5%, X7R, 0603
8	C8	C2012X7S1A226M125AC	TDK	CAP, CERM, 22 µF, 10 V, +/- 20%, X7S, 0805
9	C9	GRM188R71A225KE15D	MuRata	CAP, CERM, 2.2 µF, 10 V, +/- 10%, X7R, 0603
10	D1	MMSZ4685-V	Vishay-Semiconductor	Diode, Zener, 3.6 V, 500 mW, SOD-123
11	D3	LG L29K-G2J1-24-Z	OSRAM	LED, Green, SMD
12	D4	MMSZ5232B-7-F	Diodes Inc.	Diode, Zener, 5.6 V, 500 mW, SOD-123
13	FID6	N/A	N/A	Fiducial mark. There is nothing to buy or mount.
14	J3	ZX62R-B-5P	Hirose Electric Co. Ltd.	Connector, Receptacle, Micro-USB Type B, SMT
15	L1	VLS201610ET-100M	TDK	Inductor, Shielded, Ferrite, 10 µH, 0.4 A, 1.38 ohm, SMD
16	LBL1	THT-14-423-10	Brady	Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll
17	R2	CRCW0402200RFKED	Vishay-Dale	RES, 200, 1%, 0.063 W, 0402
18	R3	RC0603FR-0753K6L	Yageo America	RES, 53.6 k, 1%, 0.1 W, 0603
19	R4	CRCW06033K57FKEA	Vishay-Dale	RES, 3.57 k, 1%, 0.1 W, 0603
20	R5	3352T-1-503LF	Bourns	Trimming Potentiometer, 50K, 0.5W, TH
21	R7	CRCW060333R0JNEA	Vishay-Dale	RES, 33, 5%, 0.1 W, 0603
22	S1	JSX08001SAQNL	C&K Components	Switch, SPDT, On-Mom, 1 Pos, 0.01A, 5 VDC, SMD
23	S2	CL-SB-12A-01T	Copal Electronics	Switch, Slide, SPDT, 0.2A, J Lead, SMD
24	U1	LDC0851DSGR	Texas Instruments	1.8-3.3V Inductive Switch, DSG0008A
25	U2	LP5951MG-3.0/NOPB	Texas Instruments	Micropower, 150mA Low-Dropout CMOS Voltage Regulator, 5-pin SC-70, Pb-Free

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Revision History

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

Changes from Original (November 2015) to A Revision	Page
• Changed to new ug layout	3
• Added PCB Breakoff Sections and Compliance section	14

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