

TI Designs Bluetooth Low Energy Keyboard Reference Design



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[MSP430G2444](#) Product Folder
[CC2541](#) Product Folder



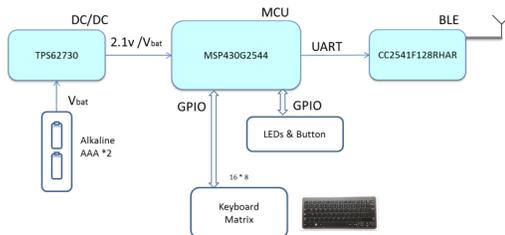
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Design Features

- Low power, 3 mW average when typing at 300 characters per minute speed
- Designed with TI Bluetooth Low Energy (BLE) protocol stack, including HOGP implementation
- Full feature keyboard support of up to 128 keys (16 x 8 matrix) without PCB modification
- Turnkey solution for BLE keyboard applications

Featured Applications

- Keyboard for tablet PC and Smart Phone



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1 System Description

This solution uses the MSP430G2444 and CC2541 to implement a Bluetooth Low Energy keyboard.

1.1 MSP430G2444

The Texas Instruments MSP430 family of ultra-low power microcontrollers consists of several devices, featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally-controlled oscillator (DCO) allows a wake-up from low-power mode to active mode in less than 1 μ s.

The MSP430G2x44 series are ultra-low power mixed signal microcontrollers with built-in 16-bit timers, up to 32 GPIO, and a built-in communication capability using the universal serial communication interface. In addition, the MSP430G2x44 family members have a 10-bit A/D converter. Typical applications include low-cost sensor systems that capture analog signals, convert them to digital values, and then process the data for display or for transmission to a host system.

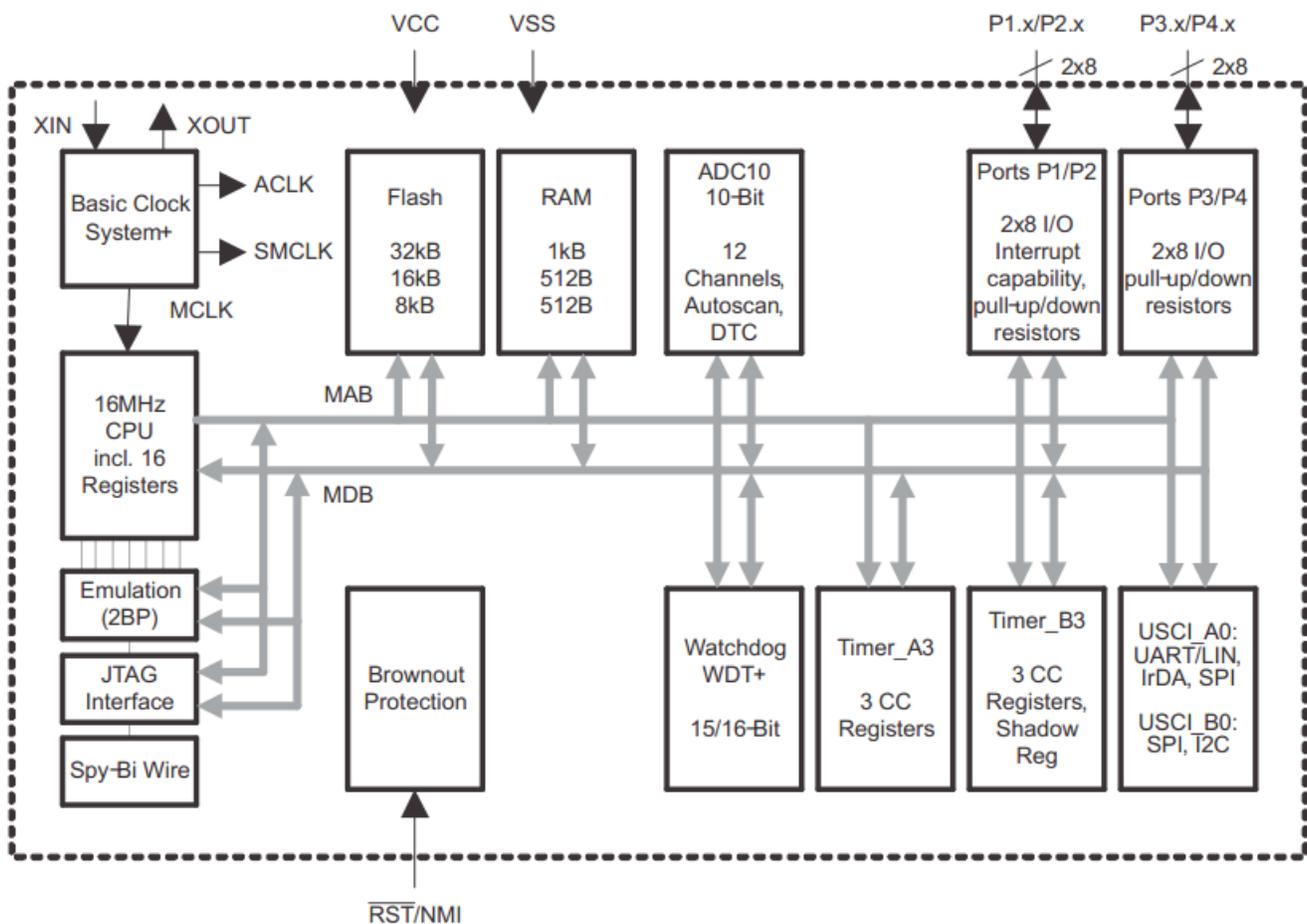


Figure 1. Functional Block Diagram, MSP430G2x44

1.2 CC2541

The CC2541 is a power-optimized, true system-on-chip (SoC) solution for both Bluetooth Low Energy and proprietary 2.4 GHz applications. The CC2541 enables network nodes to be built with low total bill-of-material costs. The CC2541 combines the performance of a leading RF transceiver with an industry standard-enhanced 8051 MCU, in-system programmable flash memory, 8-KB RAM, and other powerful supporting features and peripherals. The CC2541 is highly suited for systems requiring ultralow power consumption. This is specified by various operating modes. Short transition times between operating modes enable low power consumption.

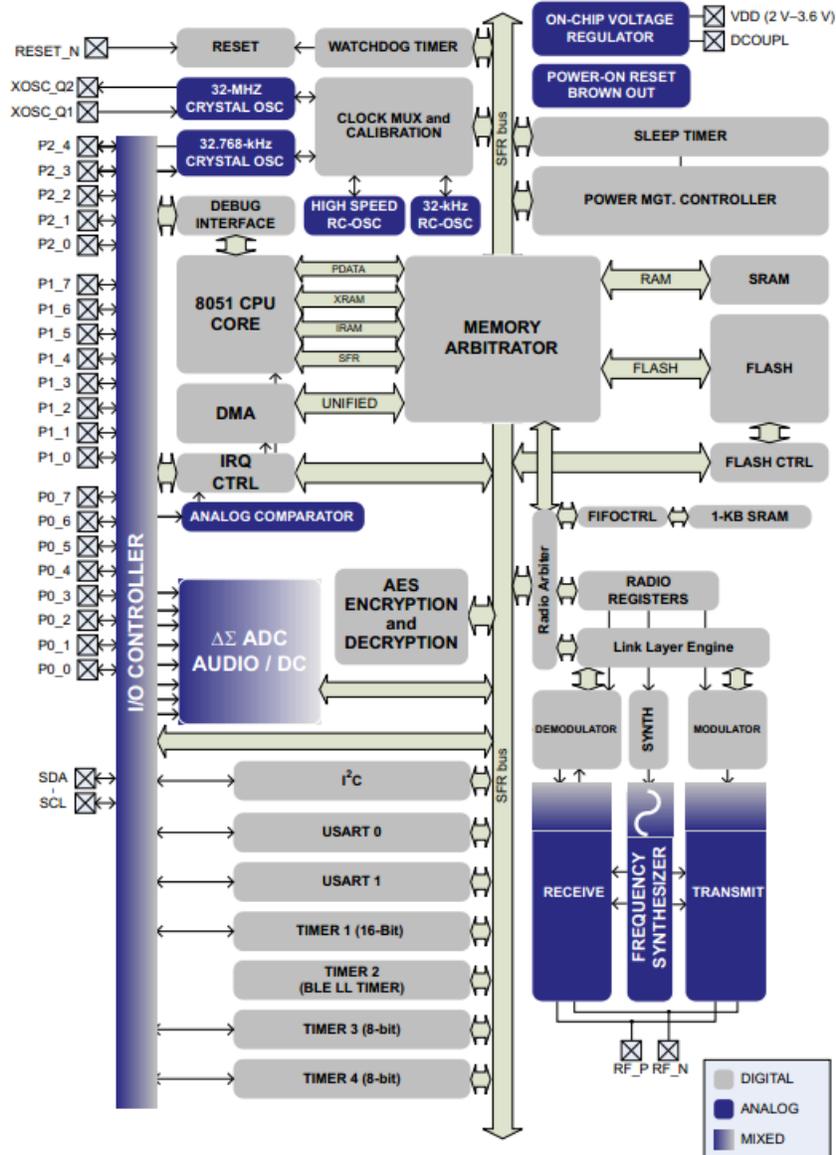


Figure 2. CC2541 Simplified Block Diagram

2 Block Diagram

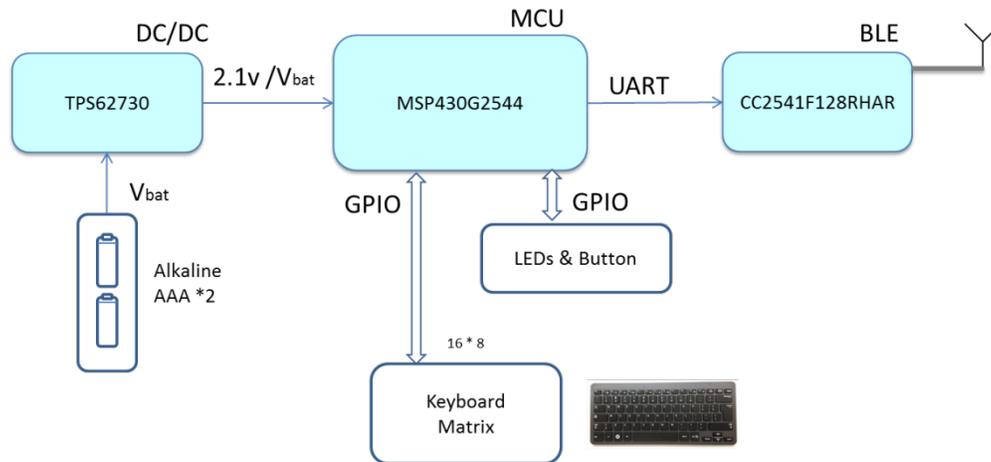


Figure 3. Hardware Block Diagram

3 System Design Theory

For this keyboard to work properly, the host operating system must support a BLE-enabled keyboard. Windows 8.1 can be used as the host, as it already supports BLE keyboards through a HID over GATT profile. The HID over GATT profile defines the procedures and features used by Bluetooth Low Energy HID Devices using GATT, and Bluetooth HID hosts using GATT. As shown in Figure 4, the keyboard is the device and Windows 8.1 is the host in this solution.

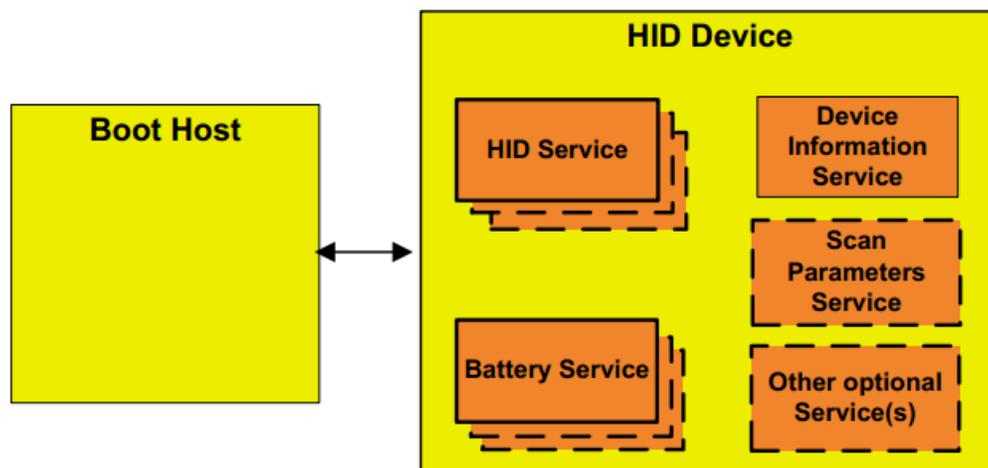


Figure 4. Host and HID device Roles in HOGP

4 Getting Started Hardware

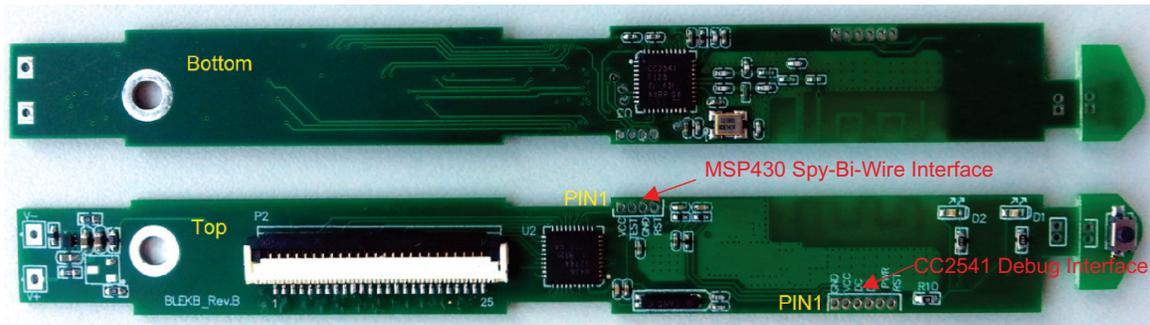


Figure 5. Debug and Programming Interface

4.1 MSP430G2444 JTAG (SPY-BI-WIRE) Connection

To download the program into flash for the MSP430, use the connections between the PCBA and the JTAG tool shown in [Table 1](#):

Table 1. PCBA and JTAG Connections

PCBA PIN	JTAG
1	VCC
2	TEST
3	GND
4	RESET

4.2 CC2541 Debug Interface Connection

To download the program into flash for the CC2541, use the connections between the PCBA and the debug or programming tool shown in [Table 2](#):

Table 2. PCBA and Debug Tool Connections

PCBA PIN	Debug I/F
1	GND
2	VCC
3	DC
4	DD
5	PWR
6	RESET

5 Getting Started with Firmware

5.1 Keyboard Work Mode State Machine

Figure 6 depicts the working mode of the keyboard: this assumes that the keyboard is already paired and bounded with the host.

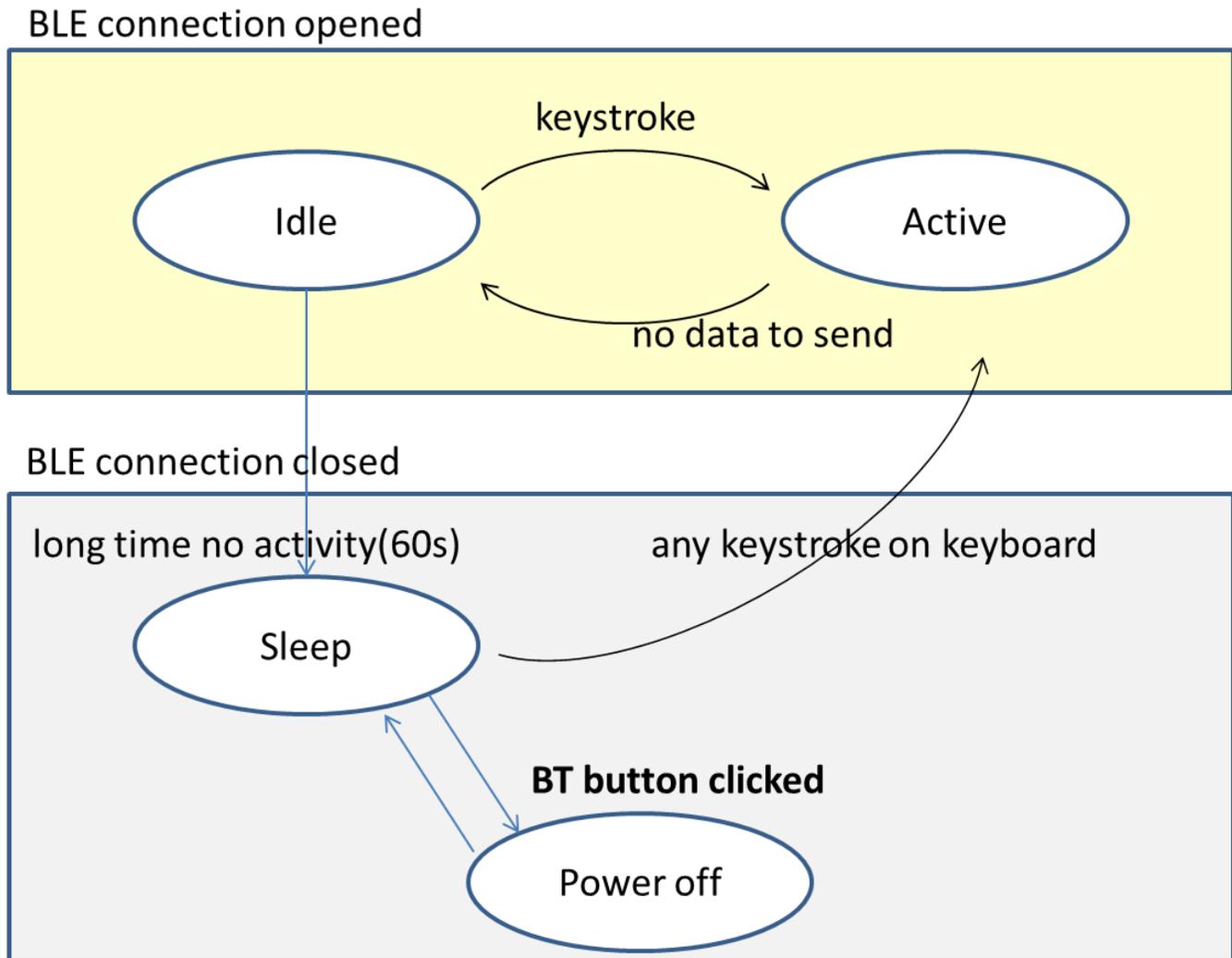


Figure 6. Working Mode State Machine

5.1.1 Idle Mode

After a successful pairing progress, the keyboard enters idle mode. In idle mode, the BLE connection is established with the host. No data is sent by the BLE radio, but the keyboard waits for any keystroke and the BLE radio works periodically to keep the BLE connection.

5.1.2 Active Mode

When the user types any key on the keyboard when in idle mode, it enters active mode. In active mode, the keystroke data is sent out to the host. The keyboard returns to idle state when no data remains. The BLE radio in this mode is on full duty.

5.1.3 Sleep Mode

When there is no user input for 60 seconds, the keyboard enters sleep mode. In sleep mode, the BLE connection closes to save power. If the user strikes any key on the keyboard, the keyboard tries to build a BLE connection and rolls into active mode if successful. In sleep mode, the BLE radio is shut off.

5.1.4 Power Off Mode

The power off mode is similar to sleep mode, other than that when in this mode, a keystroke cannot wake up the entire system. The BT button on the bottom-right side of the keyboard is the only key able to power on the keyboard. This mode avoids accidentally triggering the keyboard, to save power consumption.

5.2 Keyboard User's Guide

To make the keyboard work, see [Figure 7](#) and follow the steps:



Figure 7. BT Button and LED

1. Insert 2 AAA alkaline batteries by unlocking the battery case, as illustrated in [Figure 7](#). The BT LED will blink two times and enter sleep mode.
2. Prepare the BLE host, which in this example is a Windows 8.1 tablet PC. Go to the Device Manager – Bluetooth and enable the BT device. The keyboard should appear in the list in the next step.

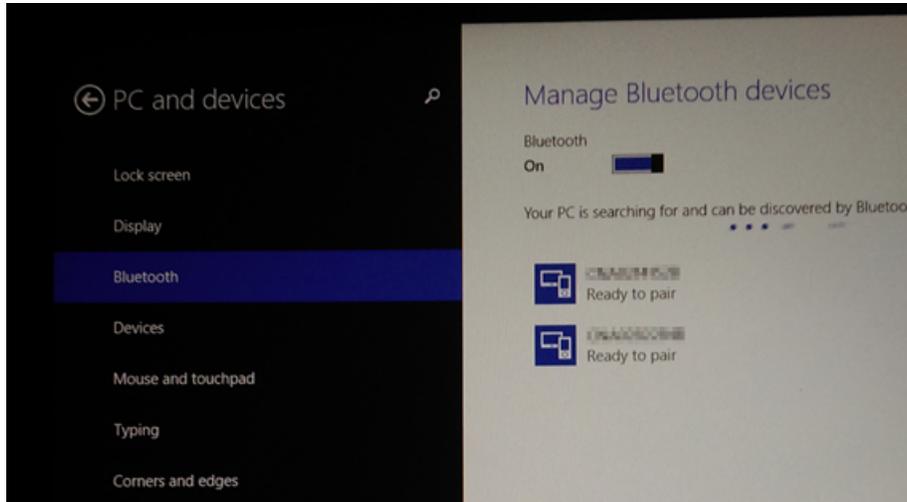


Figure 8. Enable Bluetooth Device in Windows 8.1

3. Hold the BT button until the BT LED starts blinking quickly. The keyboard should now be listed as BLE Keyboard; click on it and select Pair to pair and bind the keyboard with the tablet. The user will be prompted to input a 6 digit number. Wait until the operation is successful. The keyboard only needs to be bound one time with the tablet; to bound the keyboard to another tablet, remove the binding from this tablet first.
4. After the keyboard is paired and bound to the host, any keystroke on the keyboard will cause the keyboard to try and connect with the host (except in power off mode). If the host is ready, the BLE connection is established automatically.
5. The keyboard automatically goes into sleep mode if there is no user input for around 60 seconds, to save power. Press the BT button to toggle Power On/ Power Off mode for the keyboard. See [Figure 6](#) for more details.

6 Test

This section describes how to measure the power consumption of the keyboard.

6.1 Test Environment

Test instrument: FLUKE 287C, mA/uA

Voltage for 2 AAA alkaline batteries: 3.2 V no load

6.2 Test Mode

1. Active mode
2. Idle mode
3. Sleep mode and power off mode

6.3 Test Data

Keyboard Work Mode	Average Current	Comments
Active	1.0 mA	Typing rate is around 300 characters per minute
Idle	165 uA	
Sleep and power off	<1 uA	

7 Design Files

7.1 Schematics

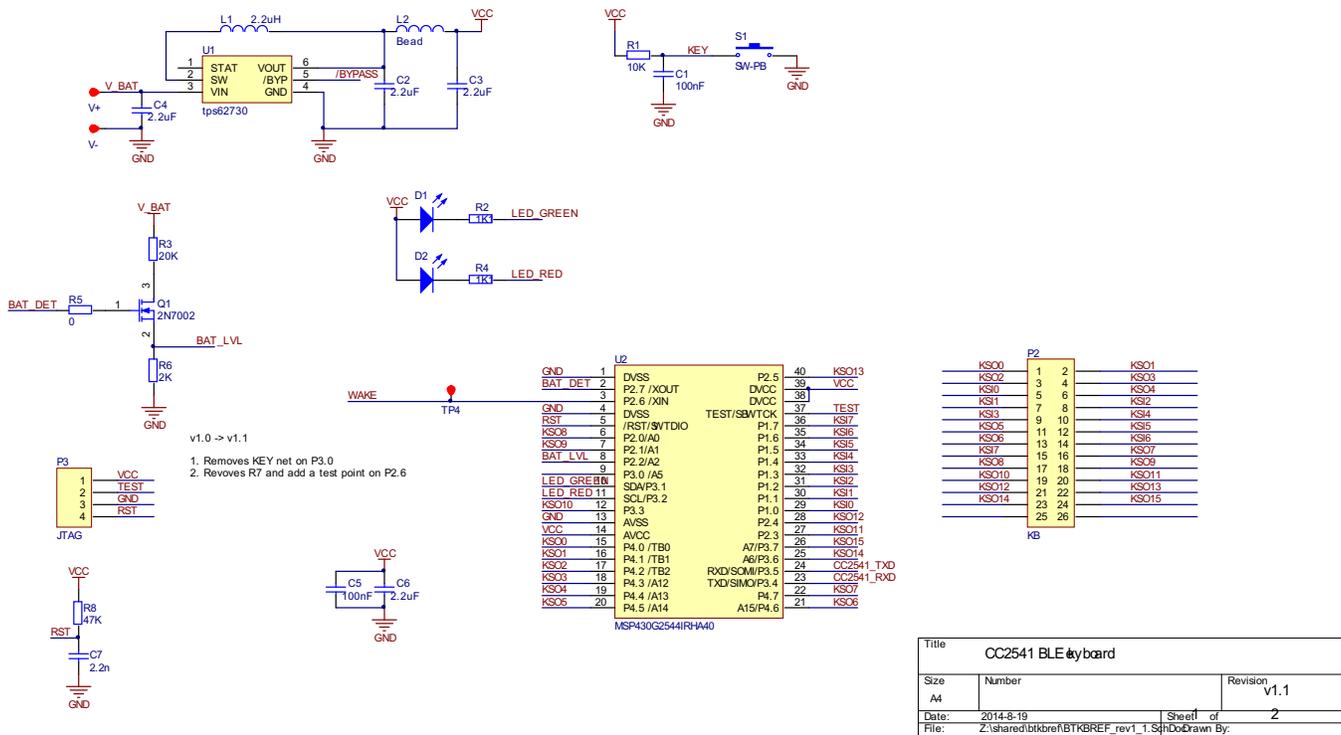


Figure 9. Schematic 1

Title		
CC2541 BLE keyboard		
Size	Number	Revision
A4		v1.1
Date:	2014-8-19	Sheet of 2
File:	Z:\shared\lbt\ref\BTKBREF_rev1.1.SchDoc	

7.2 Bill of Materials

Table 3. BOM

Item	Qty	Reference	Value	Part Description	Manufacturer	Manufacturer Part Number	PCB Footprint
1	3	C1, C5, C18	100 nF	CAP CER 100 nF 6 V 10% 0402			0402
2	1	C6	2.2 uF	CAP CER 2.2 uF 6 V 10% 0402			0402
3	1	C7	2.2 nF	CAP CER 2.2 uF 6 V 10% 0402			0402
4	2	C8, C9	1 uF	CAP CER 1 uF 6 V 10% 0402			0402
5	1	C25	1 nF	CAP CER 0.1 UF 6 V 10% 0603			0402
6	2	C21, C22	12 pF	Capacitor, 12p, 0402, NP0, 5%, 50 V	Murata	GRM1555C1H120JA01D	0402
7	2	C23, C24	15 pF	Capacitor, 15p, 0402, NP0, 5%, 50 V	Murata	GRM1555C1H150JA01D	0402
8	2	C15, C16	18 pF	Capacitor, 18p, 0402, NP0, 5% 25 V	Murata	GRM1555C1H180JZ01D	0402
9	3	C13, C14, C17	1 pF	Capacitor, 1p, 0402, NP0, +/-0.25 pF 50 V	Murata	GRM1555C1H1R0CZ01D	0402
10	1	C12	220 pF	Capacitor, 220p, 0402, N,P0, 5%, 50 V	Murata	GRM1555C1H221JA01D	0402
11	4	C10, C11, C19, C20	100 nF	Capacitor, 100n, 0402, X5R, 10%, 10 V	Murata	GRM1555R71A104KA01D	0402
12	3	C2, C3, C4	2.2 uF	CAP CER 2.2 uF 6 V 10% 0402	Murata	GRM155R60J225ME15D	0603
13	2	D1, D2		RED LED 0603			0603
14	1	R1	10K	Resistor, 10K, 0402, 5%			0402
15	1	R8	47K	Resistor, 47K, 0402, 5%			0402
16	1	R9	56K	Resistor, 56K, 0402, 1%			0402
17	1	R11	2.7K	Resistor, 2.7K, 0402, 5%			0402
18	1	R5	0	Resistor, 0, 0402, 5%			0603
19	2	R2, R4	1.1K	Resistor, 1.1K, 0402, 5%			0603
20	1	R6	2K	Resistor, 2K, 0402, 5%			0603
21	1	R3	20K	Resistor, 20K, 0402, 5%			0603
22	1	R10	0	Resistor, 0, 0402, 5%			0603
23	1	Q1	2N7002	N-Channel MOSFET			SOT23-3P
24	1	L2	Bead	EMI filter bead, 0402 1k ohms tape GHz Band	Murata	BLM15HG102SN1D	0603
25	1	L3	1 nH	Inductor, 1n0, 0402, Monolithic +/-0.3 nH	Murata	LQG15HS1N0S02D	0402
26	2	L5, L6	2 nH	Inductor, 3n0, 0402, Monolithic +/-0.3 nH	Murata	LQG15HS2N0S02D	0402
27	1	L4	3 nH	Inductor, 2n0, 0402, +/-0.3 nH	Murata	LQG15HS3N0S02D	0402
28	1	L1	2.2 uH	Inductor, 2.2 uH, 0603,500 mA 30%	Murata	LQM21PN2R2NGC	0603
29	1	U2	MSP430G2444	MCU	Texas Instruments	MSP430G2444IRHA40R	IC-QFN40-RHA-RTB
30	1	U1	tps62730	DC-DC	Texas Instruments	TPS62730DRYR	DRY0006A
31	1	U3	CC2541F128	BLE SOC	Texas Instruments	CC2541F128RHAR	IC-QFN40-RHA-RTB
32	1	X2	XTAL32K	CRYSTAL, OSCILATOR, 32.768 KHZ, -20PPM/ + 20PPM, -40DEGC/ +85DEGC, 12.5 pF, SMD	Epson Toyocom	12-00422	SSP-T-32768
33	1	X1	XTAL32M	CRYSTAL, OSCILATOR, 32 MHz, 10 pF, -10PPM/+10PPM, -40DEGC/+85DEGC, SMD	Epson Toyocom	12-00430	XIAL4P-SMT3*2X5
34	1	SW1	Button switch	Button switch			SW-PB-SMT3*4*2
35	1	P3	JTAG connector	JTAG connector for MSP430			MHDR1X4
36	1	P2	Keyboard connector	25-pin connector			FFC-25-P1.0
37	2	S1, S2	Connector	2-pin connector			MHDR1X2
38	1	P4	CCDEBUG	debug connector for CC2541			MHDR1X6

7.3 PCB Layouts

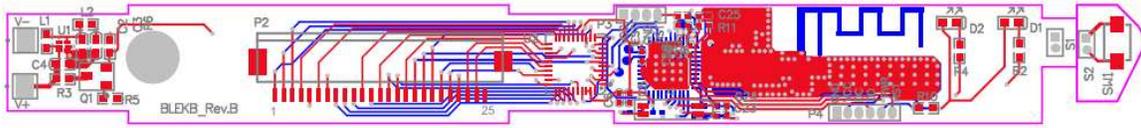


Figure 11. PCB Layouts

8 Software Files

9 References

1. MSP430G2x44 - Mixed Signal Microcontroller ([SLAS892B](#))
2. CC2541 -2.4-GHz Bluetooth low energy and Proprietary System-On-Chip ([SWRS110D](#))
3. HID OVER GATT PROFILE SPECIFICATION v10r00

10 About the Author

NAN JIANG is an MCU Systems Application Engineer at Texas Instruments, responsible for developing system solutions for IoT (Internet of Things) and industrial applications.

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