Application Report

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10-cm Capacitive Proximity Detection With MSP430™ Microcontrollers

Travis Hwang *MCU*

ABSTRACT

The PinOsc feature of the MSP430 microcontroller value line family provides a simple and straight forward mechanism to measure capacitance. The PinOsc feature not only allows for touch detection but also provides enough sensitivity to support proximity applications. This application report demonstrates a 10+-cm proximity detection BoosterPack design solution. The software uses the PinOsc feature and the Fast RO method for a portable (battery powered) consumer product.

Project collateral and a code example for a BoosterPack solution discussed in this document can be downloaded from the following URL: http://www.ti.com/lit/zip/slaa521.

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1 Introduction

Capacitive proximity sensing is an extension of the capacitive touch solution. The extension is an increase in sensitivity to detect the small changes in capacitance associated with objects at a certain distance from, instead of coming in contact with, the electrode. The sensitivity is a function of the electrode size, ground coupling, and the measurement mechanism. The housing and application (battery powered) limit the size of the electrode and the ground coupling, so the performance is enhanced with a 32-bit software solution to provide the detection distance required.

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This application report walks through a proximity application with a 10-cm detection requirement. A BoosterPack solution using the MSP430 LaunchPad™ is presented. The purpose of the BoosterPack is to easily develop and verify the operation of the proximity sensor. However, using the BoosterPack does create some challenges to get proper sensitivity. This document describes how to overcome these challenges to achieve 10-cm proximity distance. This document includes the application level implementation and a performance summary of the firmware implementation is presented. For more information about Fast RO method to get proximity sensing counts, see the *Capacitive Touch Software Library* (SLAA490).

Figure 1 and Figure 2 show how the BoosterPack can be used to measure the capacitance of a proximity vent.

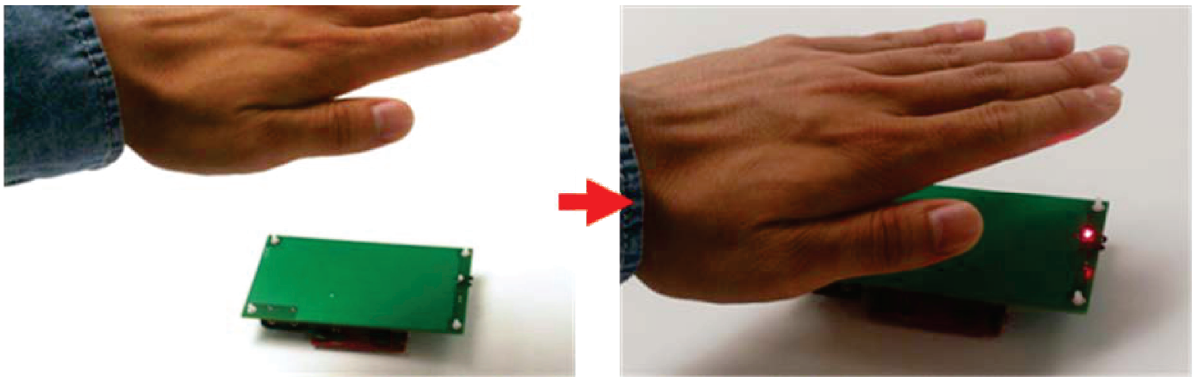

Figure 1. Operation of BoosterPack With LaunchPad

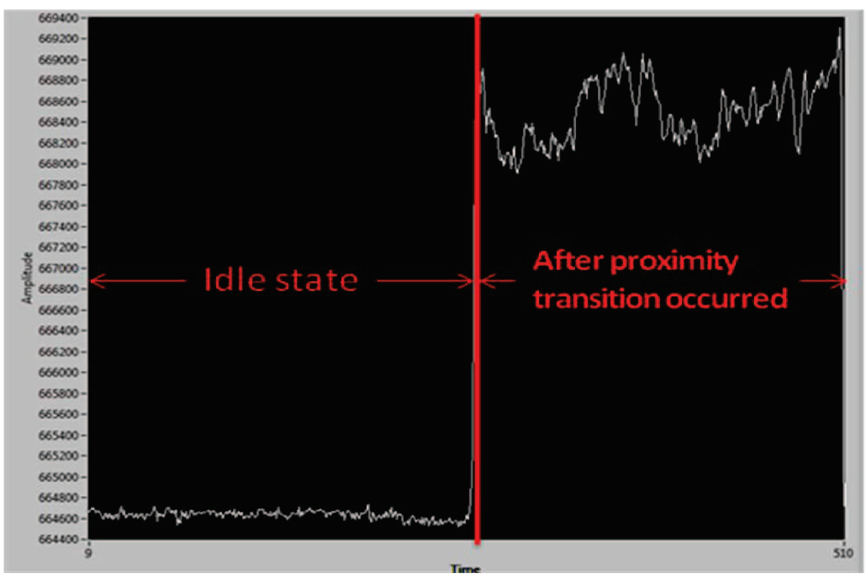

Figure 2. Proximity Counts

2 Hardware Description

The hardware description includes both the PCB and the enclosure.

2.1 Hardware Description of BoosterPack

With the MSP430 LaunchPad and the BoosterPack, proximity sensing is able to be built easily. The BoosterPack includes two connectors for the LaunchPad: a battery pack and some LEDs to check the operation of the sensor. Pin P1.4 is used for connection with the proximity electrode of the BoosterPack. Pins P1.6 and P1.7 are connected with two LEDs. Figure 3, Figure 4, and Figure 5 show the shape, schematic and layout for the BoosterPack. The gerber files are also included in the download package http://www.ti.com/lit/zip.slaa521.

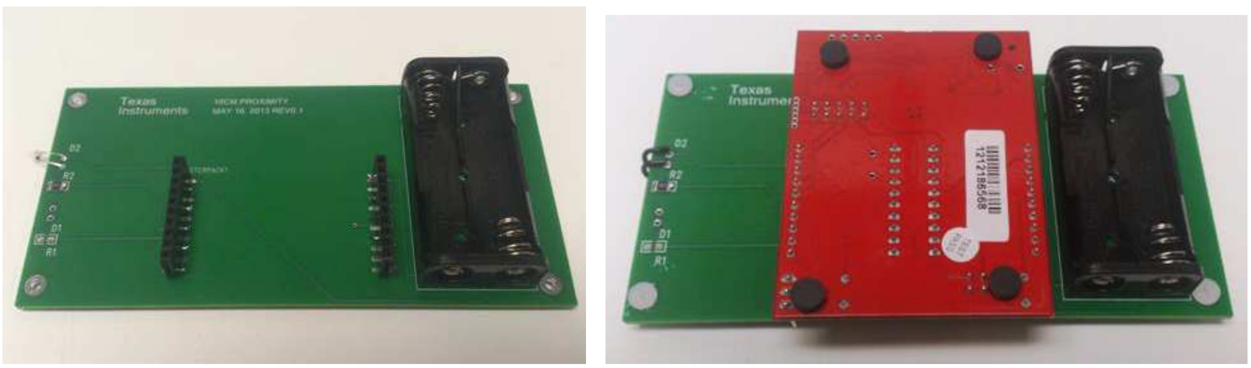

Figure 3. Shape of BoosterPack

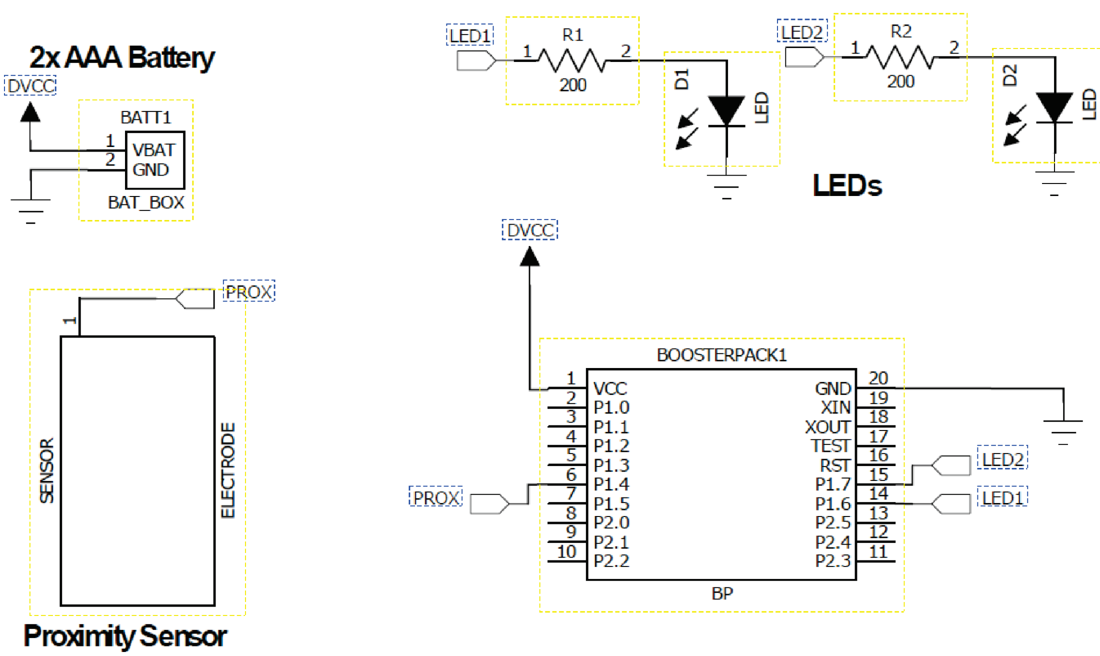

Figure 4. Schematic of BoosterPack

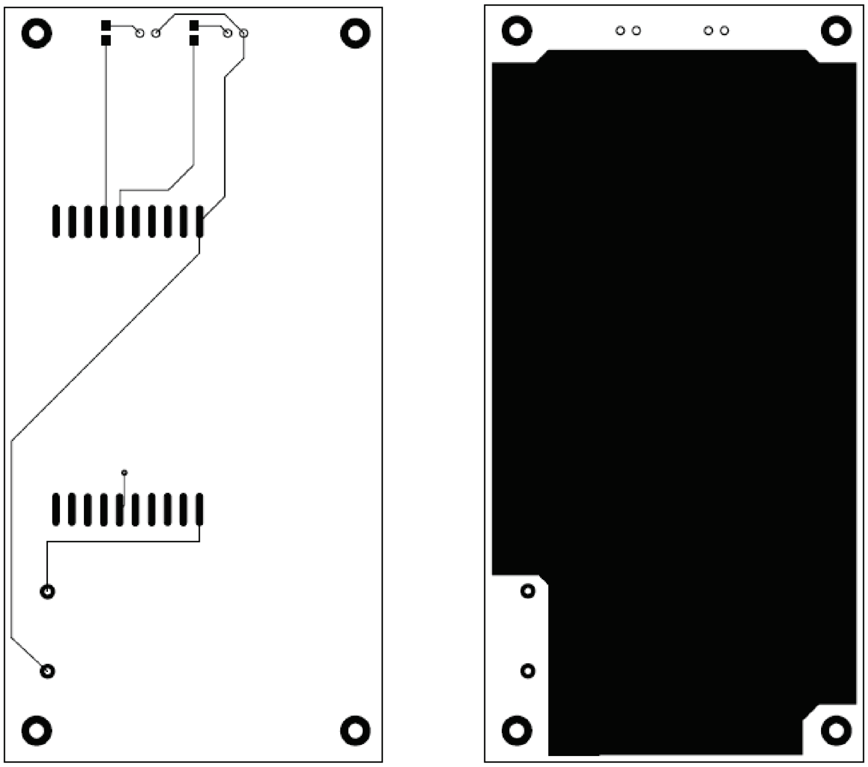

Figure 5. Layout of BoosterPack

2.1.1 Easy Solution to Build a BoosterPack

Building a new BoosterPack is easy [2]. For the proximity sensing, the BoosterPack just needs a GPIO Pin, V_{CC} and GND. Using the 10-cm proximity code example with a few modifications, a simple BoosterPack can easily be built. Connect the GPIO Pin to the electrode. The bigger the size of the electrode, the better the performance. The designer building the BoosterPack can decide the size of the electrode.

2.1.2 Design Challenges

Since the solution implements the proximity sensor and the proximity is affected by environments much more than a touch sensor, the BoosterPack designer should remember all conductive elements can introduce noise into the system. The noise is coupled due to the parasitic capacitance created between an electrode and conductive elements. In the case of the BoosterPack, the batteries affect the sensitivity because they are conductive elements. This was addressed by extending the size of the electrode. In addition, some LEDs or a Bluetooth (BT) module can be added to check the operation of BoosterPack. To avoid influencing the electrode, the position of the BT module has to be separated from the position of the electrode as much as possible. Also, LEDs can influence the electrode.

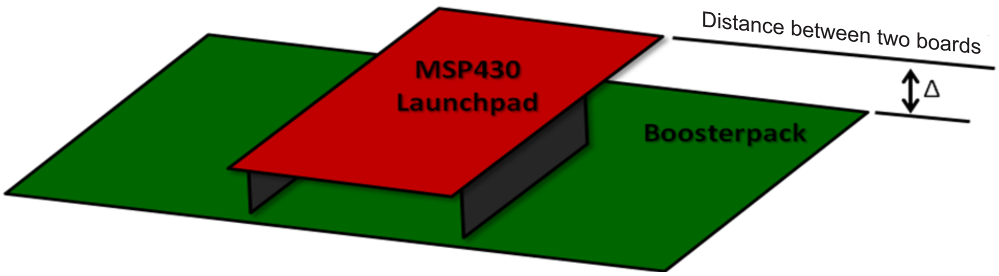

Figure 6. Connection of MSP430 LaunchPad and BoosterPack

2.2 Plastic Enclosure

A plastic enclosure (Part number: Polycase©, SL-53P) was used for this application. The mounting hole of the BoosterPack aligns perfectly with the enclosure, which has 4 PCB mounting bosses inside it. The dimensions of the enclosure are 5.63 x 3.285 x 1.15 inch (L x W x H).

Figure 7. Plastic Enclosure

To confirm the operation of the LED, one small hole has to be drilled near the position of the LED. Another hole has to be put at the side of the enclosure to connect LaunchPad with the PC USB if you want to use the BoosterPack with the USB power source.

3 Firmware Description

3.1 Relationship to TI Capsense Library

3.1.1 Description of LaunchPad Setting

GPIO Pin P1.4 is used to connect with an electrode of the BoosterPack and set as PinOsc function of MSP430G2553 device. With the setting, pin oscillation count is collected and used for the proximity detection. Two LEDs are connected to the Pin 1.6 and Pin 1.7 of the device. You can set the LEDs to confirm the operation of the proximity sensor or any purpose you want. The code example uses Pin 1.7 to check the operation by blinking LED.

3.1.2 Reuse of Function

The 10-cm proximity detection BoosterPack code example is using TI_CAPT_Raw function from the TI Capsense Library. TI_CAPT_Raw function obtains the counts of the Timer. In the code example, this function is executed periodically while looping. In the meanwhile, 32 bits conversion algorithm convert measured 16 bits count to 32 bits count.

3.1.3 32 Bits Conversion

To get a better performance, this application converts 16 bits measured count to 32 bits value using the previously collected count. The ‘count’ value is always increasing while Timer 1 is working and being saved to the ‘counts’ value continually. The current ‘count’ value and saved previous ‘counts’ value are converted to one 32 bits counts using the following formula.

$$counts = counts + (65535 \times count)$$

3.2 Block Diagram

The code example for a BoosterPack is created by 32-bit proximity value counting. Updating the baseline is implemented in a main loop of the code to reduce the size of the code. The flowchart of the firmware for BoosterPack is shown in Figure 8.

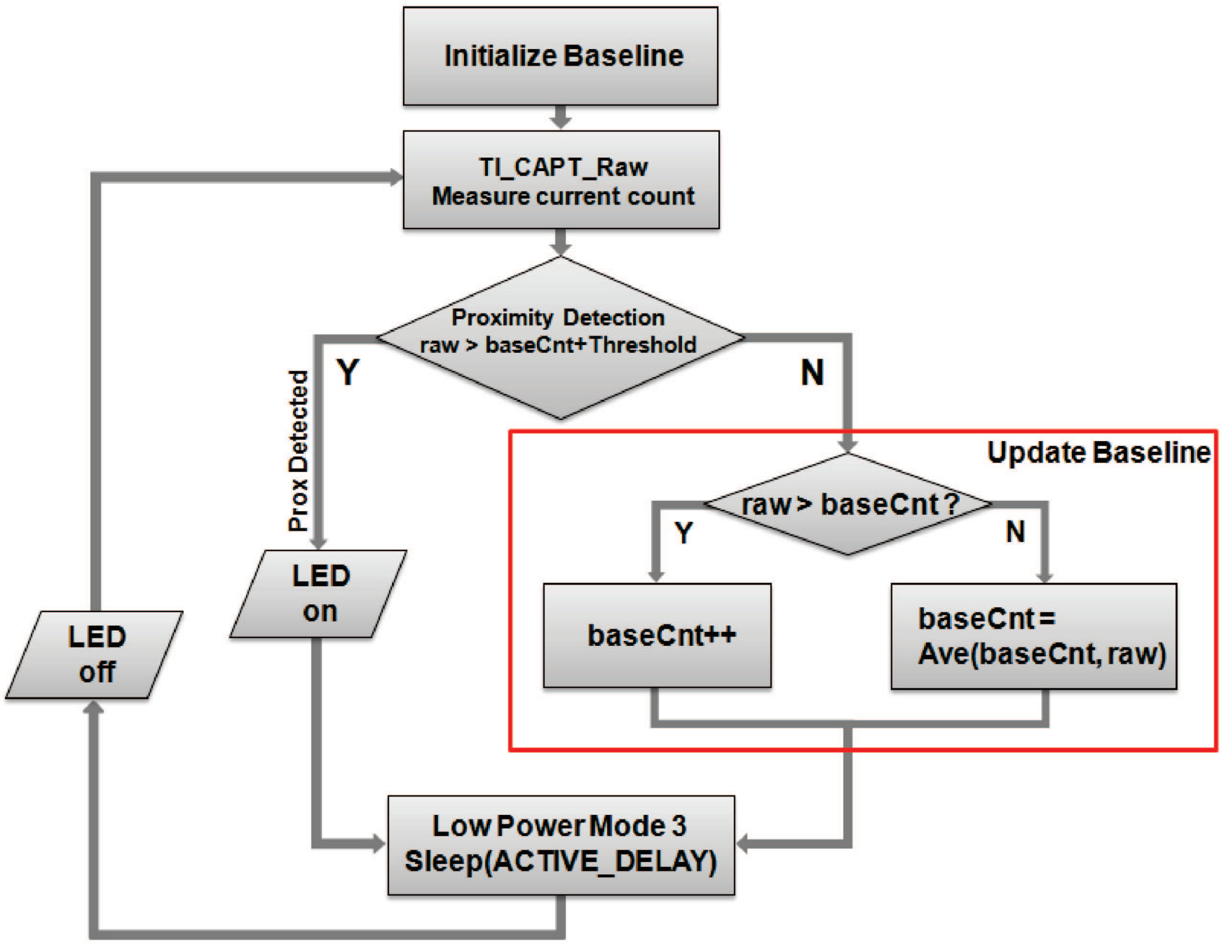

Figure 8. Flowchart of BoosterPack Code Example

With this flow, the proximity distance can be reached 10cm using battery power source as well as USB power source. And, changing the threshold and accumulation cycle will affect to the proximity distance and sensitivity.

4 Performance

Since the PinOsc frequency is around 856 kHz with the electrode, the gate time is calculated as 29.178 ms. The clock frequency of the code example is set as 12 MHz and VLO is used for low power mode 3. Figure 9 is the estimated power consumption using the TI Capacitive Touch Power Designer. To estimate the current consumption with the Power Designer, some values have to be set. The PinOsc frequency can vary for your MSP430G2553 device. You should get the PinOsc frequency of your device to get the sensor gate time. To get the sensor gate time for the Power Designer, see the following equations:

$$PinOsc\ Frequency = accumulation\ Cycle \times \frac{Timer\ Source\ Frequency}{Actual\ counts\ for\ 1\ scanning\ time} \tag{1}$$

$$\begin{aligned} Sensor\ Gate\ Time &= \frac{1}{PinOsc\ Frequency} \times accumulation\ Cycle \\ &= \frac{Actual\ counts\ for\ 1\ scanning\ time}{Timer\ Source\ Frequency} \end{aligned} \tag{2}$$

For this application:

$$Sensor\ Gate\ Time = \frac{350142}{12000000} \cong 0.0291785s \quad (3)$$

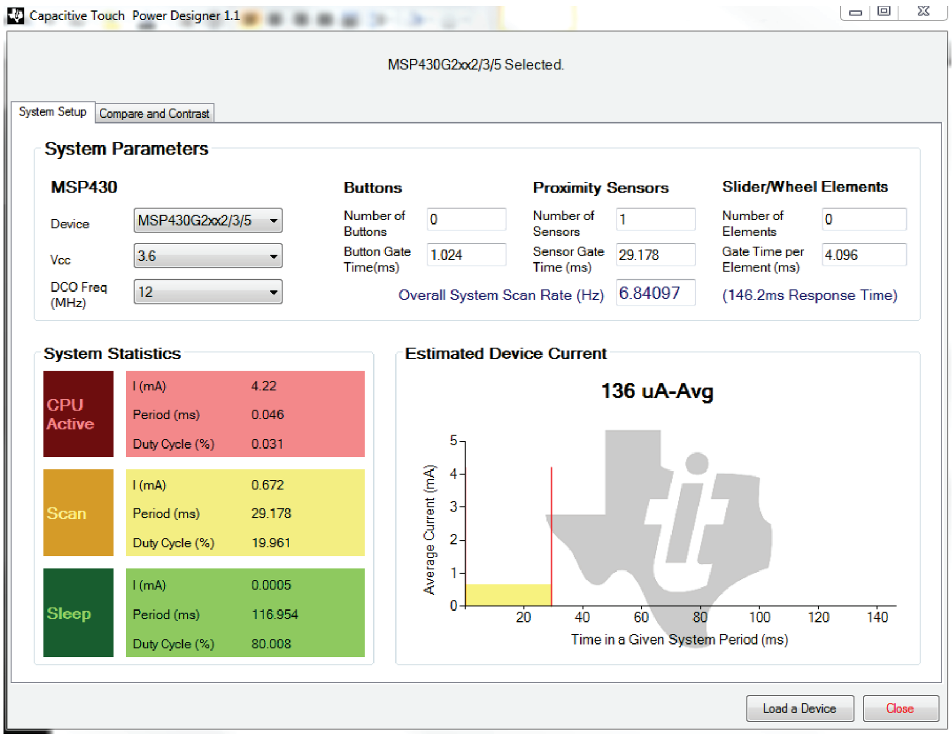

Figure 9. Estimated Power Consumption

The performance of the BoosterPack and some information is shown in Table 1. The Δ in the table means the distance between the LaunchPad and the BoosterPack, as shown in Figure 7. The bigger Δ, the farther distance of the proximity sensor we can get. The reason of better performance with the USB power is the GND. With the USB connection, the PC provides certain GND to the boards and it makes better performance than GND from the AAA battery. It is the reason of the various proximity distances, which is occurred from the distance between two boards.

Table 1. Performance: Distance, Power, Flash Size

Solution	V_{CC} Source	Average current	Distance
32-bit ; 29-ms measurement (12 MHz, LPM0), 117-ms idle time (VLO, LPM3) 4-in x 2-in electrode	USB Power	145.838 µA	13cm
Flash size; 968 bytes (no optimization)	2x AAA Battery	117.917µA	10cm

5 Conclusion

The pin oscillator is a simple and effective feature in the MSP430 microcontroller family for making capacitive measurements for both touch and proximity applications. The target range for this application was 10 cm for the given dimensions of the design, but it is possible with larger applications (and larger electrodes) to achieve greater distances.

6 References

1. *Capacitive Touch Library* (SLAA490)
2. *Build Your Own BoosterPack*: http://processors.wiki.ti.com/index.php/BYOB
3. *Capacitive Touch Power Designer*: http://www.ti.com/tool/MSPTOUCHPOWERDESIGNERGUI
4. *1-µA Capacitive Grip Detection Based on the MSP430 Microcontrollers* (SLAA515)

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