

# **Implementing An Ultra-Low-Power Keypad Interface With MSP430™ MCUs**

*MSP430 Applications*

## **ABSTRACT**

In applications with keypads, a key can be held or stuck down, which causes excess current consumption and reduces the battery life of a battery-operated product. This application report describes a solution. The keypad interface in this report, based on the MSP430F123 microcontroller (MCU), draws 0.1  $\mu\text{A}$  while waiting for a key press, is interrupt driven, requires no polling, and consumes a maximum of only 2  $\mu\text{A}$  at 3 V if all keys are pressed and held simultaneously.

The source code described in this application report can be downloaded from <http://www.ti.com/lit/zip/slaa139>.

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## **1 Introduction**

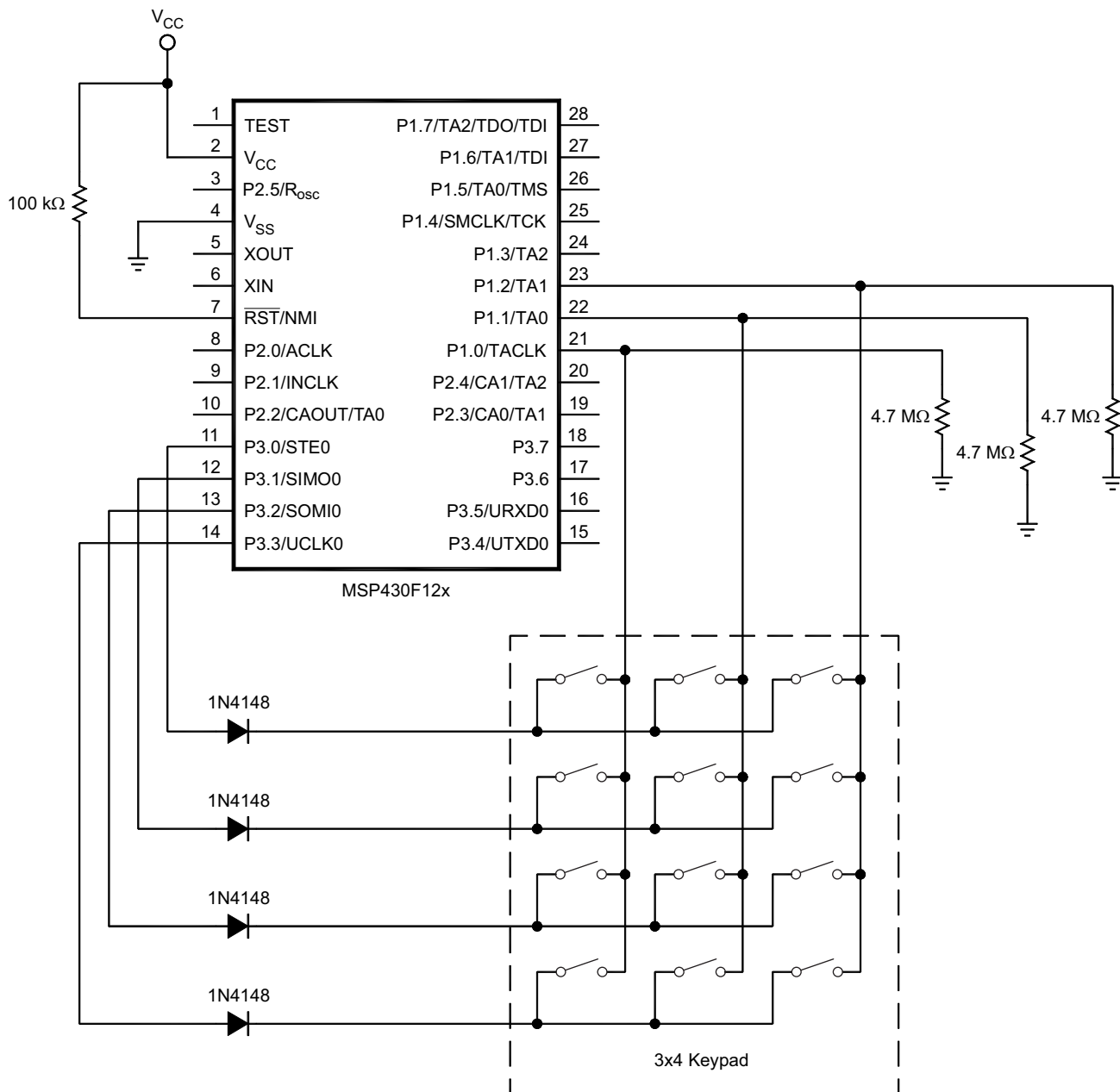
The keypad interface described in this report (see [Figure 1](#)) is based on the [MSP430F123 MCU](#). Features of this design include:

- 100-nA typical current consumption while waiting for key press
- 2- $\mu\text{A}$  maximum current consumption if all keys are held simultaneously
- No polling required
- No crystal required
- Minimum external components
- Suitable for any MSP430™ MCU

## 2 Implementation

The rows of the keypad are connected to port pins P3.0 to P3.3. The columns are connected to pins P1.0 to P1.2. Connecting the rows to port 3 pins, instead of port 1 pins, leaves the other port 1 pins for other interrupt sources, because the P1 pins have interrupt capability, but the P3 pins do not.

In normal mode, while the circuit is awaiting a key press (wait-for-press mode), the rows are driven high, and the P1.x column pins are configured as inputs, with interrupts enabled and set to interrupt on a rising edge. The 4.7-M $\Omega$  pull-down resistors hold the inputs low in this state. The MCU then enters low-power mode 4 (LPM4), in which the MCU current consumption is approximately 100 nA. This state is maintained indefinitely until a key is pressed. The circuit is interrupt-driven with no need for polling.



**Figure 1. Keypad Schematic Diagram**

When a key is pressed, the column associated with that key receives a rising edge, waking the MSP430 MCU. At that time, Timer\_A is configured to perform a debounce delay of approximately 40 ms. The timer for the delay uses the internal digitally controlled oscillator (DCO) of the MSP430 MCU, which is an RC-type oscillator. The DCO is subject to tolerances, so a debounce delay was chosen to give a worst-case-minimum delay of 25 ms. That translates to a worst-case maximum delay of approximately 86 ms and a typical delay of approximately 40 ms. This is a useable range for keypad debounce.

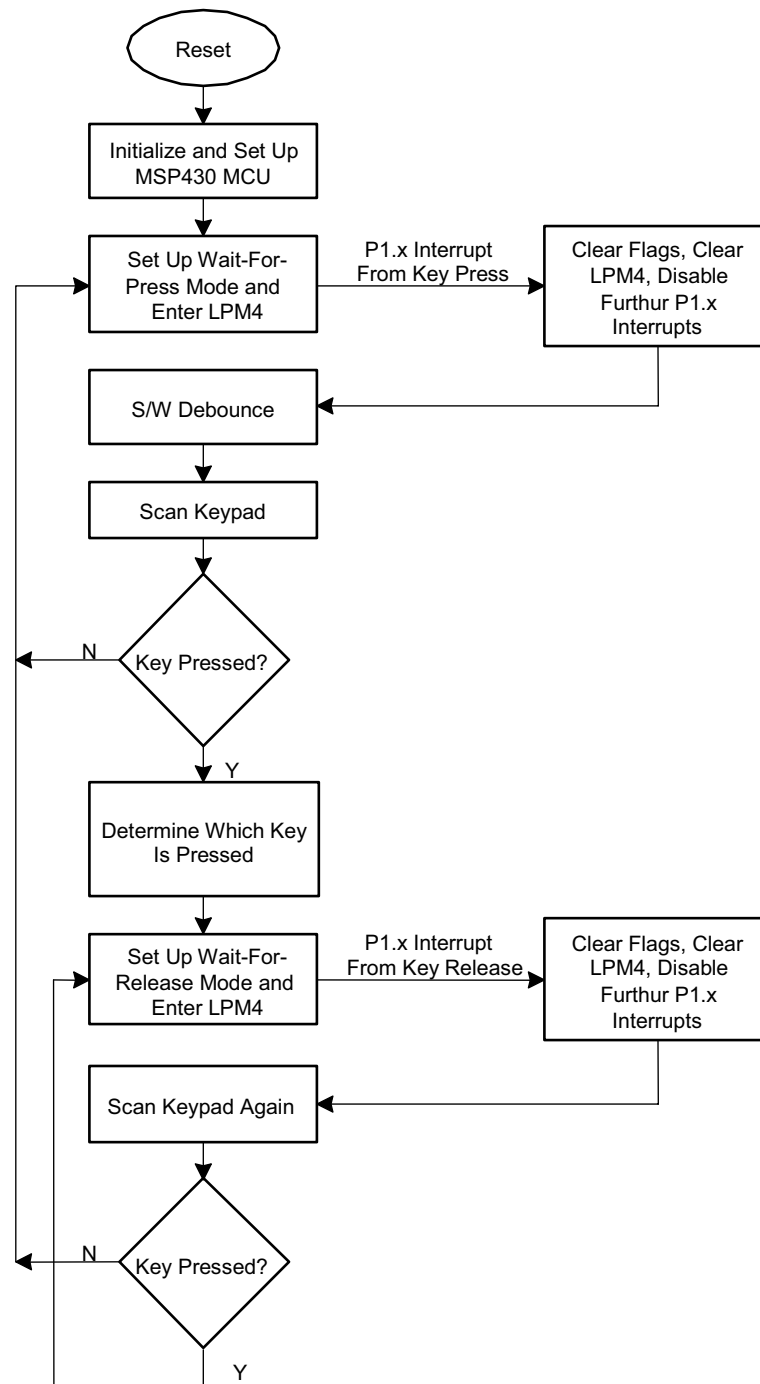
After a key has been pressed, the MCU enters a wait-for-release mode in which it drives high only the necessary row for the key being pressed (other rows are driven low). The software reconfigures the P1.x I/O lines to interrupt on a falling edge, and the MCU returns to LPM4, waiting for the release of the key. Again, there is no polling necessary. The detection of the key release is interrupt driven, which allows the microcontroller to stay in LPM4 while the key is held, thus reducing current consumption. When the key is released, the debounce delay is again executed. After the debounce delay, the keypad is scanned again to determine if any other keys are being held. If so, the wait-for-release mode continues, waiting for all keys to be released. When all keys are released, the MSP430 MCU returns to the wait-for-press mode.

During the wait-for-release mode, only one row of the keypad is driven high, therefore limiting the maximum amount of current consumption to the condition where all three keys on a single row are pressed and held. For a 3-V system, that equates to approximately 2  $\mu$ A. Any other key press does not result in increased current consumption, because the corresponding row is not driven high.

In this 3 $\times$ 4 keypad example, the rows are driven rather than the columns to limit the maximum current consumption by the circuit when all keys are pressed and held simultaneously. If the columns were driven instead, the rows would have had the pulldown resistors, therefore increasing the number of paths to ground when all the keys are held and increasing the possible current consumption.

### 3 Software

Figure 2 shows the software flow. The complete code listing follows and is can be downloaded from <http://www.ti.com/lit/zip/slaa139>.



**Figure 2. Software Flow**

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#include "msp430x12x.h"

;*****
; Ultralow-Power Keypad Interface
;
; Description: This program implements and ultralow-power keypad interface
; on the MSP430F12x. The circuit consumes .1uA in normal mode while waiting
; for a key press. After a key press, a s/w debounce is performed and the
; uC then waits for the key to be released. The circuit consumes a maximum

```

```

; of 2uA in the even the keys are accidentally pressed and held. The circuit
; is completely interrupt driven, requires no polling, and requires no
; external crystal.
;
;
; Mike Mitchell
; MSP430 Applications
; Texas Instruments, Inc
; January, 2002
;
;*****
                RSEG    CSTACK                ; System stack
                DS      0

;*****

                RSEG    UDATA0              ; RAM Locations
;*****

NoKey           EQU    01h
NoMatch        EQU    02h
Error_Flags    DS      1                ; Error Flags
                ;      xxxx xxxx
                ;      ||
                ;      |-- No Key being depressed
                ;      |----- No key match found

;*****

                RSEG    CODE                ; Program code
;*****

Reset          mov     #SFE(CSTACK),SP      ; Initialize stackpointer
SetupWDT       mov     #WDTPW+WDTHOLD,&WDTCTL ; Stop WDT
SetupPorts     mov.b   #0F8h,&P1DIR         ; Unused P1.x as Outputs
               mov.b   #0FFh,&P2DIR         ; Unused P2.x as outputs
               mov.b   #0FFh,&P3DIR         ; All P3.x as outputs

               eint                    ; Enable Interrupts

SetupDCO       mov.b   #0,&BCSCTL1         ; Set Rsel=0, leave DCO=3
               ; This gives nom MCLK of
               ; 130KHz at 3V, 25C.

Mainloop       call    #Set_For_Press     ; Setup to wait for key press
               bis     #LPM4,SR           ; Wait for key press
               call    #Debounce          ; Call debounce delay
               call    #KeyScan           ; Scan Keypad
               bit.b   #NoKey,Error_Flags ; Test if no key was depressed
               jnz     Mainloop           ; False interrupt, no key pressed
               call    #KeyLookup         ; Lookup Key value
               call    #Wait_For_Release  ; Wait for key(s) to be released
               jmp     Mainloop           ;

;-----
Set_For_Press  ; Setup to wait for key press
;-----
               bis.b   #BIT0+BIT1+BIT2+BIT3,&P3OUT ; Enable keypad
               bic.b   #BIT0+BIT1+BIT2,&P1IES  ; L-to-H interrupts
               clr.b   &P1IFG             ; Clear any pending flags
               mov.b   #BIT0+BIT1+BIT2,&P1IE  ; Enable interrupts

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        clr.b   Error_Flags           ; Clear error flags

        ret

;-----
Debounce ; Debounce Delay Routine
;-----
SetupTA  mov     #TASSEL1+TACLR,&TACTL ; SMCLK, Clear TA
        mov     #CCIE,&TACCTL0       ; Enable CCR0 interrupt
        mov     #5125,&TACCR0       ; Value for typ delay of ~40ms
        bis     #MCO,&TACTL         ; Start TA in up mode
        bis     #LPM0,SR            ; Sleep during debounce delay

        ret                           ; Return

;-----
KeyScan  ; Keypad Routine
;-----
#define   KeyMask      R15
#define   LoopCount    R14
#define   KeyHex       R13
#define   KeyVal       R5

        mov     #1,KeyMask           ; Initialize scan mask
        mov     #4,LoopCount         ; Initialize loop counter
        clr     KeyHex               ; Clear register
Scan_1   bic.b   #07h,&P1OUT         ; Clear column bits in P1OUT reg
        bic.b   #0Fh,&P3OUT         ; Stop driving rows
        bis.b   #07h,&P1DIR         ; Set column pins to output and low
        bic.b   #07h,&P1OUT         ; To bleed off charge and avoid
        ;                                     ; erroneous reads
        bic.b   #07H,&P1DIR         ; Set column pins back to input
        Mov.b   KeyMask,&P3OUT      ; Drive row
        bit.b   #7h,&P1IN           ; Test if any key pressed
        jz     Scan_2               ; No key pressed
        bis.b   KeyMask,KeyHex      ; If yes, set bit for row
        mov.b   &P1IN,R12           ; Read column inputs
        and.b   #07h,R12           ; Clear unused bits
        rla.b   R12                 ;
        rla.b   R12                 ; Rotate column bit
        rla.b   R12                 ;
        rla.b   R12                 ;
        bis.b   R12,KeyHex          ; Set column bit in KeyHex
Scan_2   rla.b   KeyMask            ; Rotate mask
        dec     LoopCount           ; Decrement counter
        jnz    Scan_1               ; Continue scanning if not done

; Check to see if any key is being pressed.  If not, set flag and return.
        tst.b   KeyHex              ; Test KeyHex
        jnz    EndScan              ; If not 0 return
        bis.b   #NoKey,Error_Flags ; Set flag

EndScan  bis.b   #0Fh,&P3OUT         ; Drive rows again
        ret

;-----
KeyLookup ; Table look-up to determine what key was pressed.
;-----
        mov     #10,KeyVal          ; Initial key value
LookLoop cmp.b   Key_Tab(R5),KeyHex ; Compare
        jeq    EndLU               ; If equal end look-up

```

```

        dec        KeyVal          ; decrement pointer/counter
        jnz        LookLoop        ; Continue until find key or
                                   ; count to zero.

EndError ; If get here, Did not find match, so more than one key is pressed.
        ; return error condition
        bis.b     #NoMatch,Error_Flags ; Set Error Flag
        ret                               ; Return

EndLU   ; Done with Key look-up - found key successfully.
        dec        KeyVal          ; Adjust because using same
                                   ; register for key counter
                                   ; and table pointer
        ; --> The key that was pressed is now in R5. The applicaion
        ; can now move it for furthur handling, display, etc.
        ; This example doesn't actually do anything with the key information.

        ret

;-----
Wait_For_Release ; Setup to wait for key release
;-----
; Isolate one row that is in use

L$1      mov.b     #1,R11          ; row counter
        and.b     #0Fh,KeyHex     ; And off column info in KeyHex
        rrc       KeyHex          ; Rotate row info through C
        jc        proceed         ; Looking for a '1'
        rla       R11             ; Shift to next bit and
        jmp       L$1             ; continue looking

proceed  inv.b     R11             ; Invert
        and       #0Fh,R11        ; Clear upper bits
        bic.b     R11,&P3OUT       ; Turn off all but one row

; Setup for interrupt on key release
        bis.b     #07h,&P1DIR      ; Set column pins to output and low
        bic.b     #07h,&P1OUT      ; To bleed off charge and avoid
                                   ; erroneous reads
        bic.b     #07H,&P1DIR      ; Set column pins back to input
        bis.b     #07h,&P1IES      ; H-L Interrupts
        clr.b     &P1IFG          ; Clear any pending flags
        bis.b     #07h,&P1IE       ; Enable Interrupts
        bis       #LPM4,SR        ; Sleep waiting for release
        Call      #Debounce        ; Debounce release of key
        call      #KeyScan         ; Scan keypad again
        bit.b     #NoKey,Error_Flags ; Test if any key pressed
        jz        Wait_For_Release ; If so, repeat

End_Wait bic.b     #NoKey,Error_Flags ; Clear flag
        ret                               ; Return

;-----
P1ISR ; P1.x Interrupt service Routine
;-----
        bic       #LPM4,0(SP)      ; Return active
        clr.b     &P1IFG          ; Clear interrupt flag
        clr.b     &P1IE          ; Disable furthur P1 interrupts
        reti

;-----
CCR0_ISR ; CCR0 Interrupt Service Routine
;-----

```



```

        bic    #LPM0,0(SP)          ; Return Active
        mov    #TACLR,&TACTL       ; Stop and clear TA
        clr    &TACCTL0           ; Clear CCTL0 register
        reti

;-----
Key_Tab ; Key look-up table
;-----
        DB    00h ; Dummy value. Allows use of same register for
                ; both table pointer and key counter
        DB    028h ; '0' key
        DB    011h ; '1' key
        DB    021h ; '2' key
        DB    041h ; '3' key
        DB    012h ; '4' key
        DB    022h ; '5' key
        DB    042h ; '6' key
        DB    014h ; '7' key
        DB    024h ; '8' key
        DB    044h ; '9' key

;-----
        COMMON INTVEC                ; Interrupt vectors
;-----

        ORG    RESET_VECTOR
        DW    Reset
        ORG    TIMERA0_VECTOR
        DW    CCR0_ISR
        ORG    PORT1_VECTOR
        DW    P1ISR

;-----
        END

```

#### 4 Low-Power Implementation on MSP430 FRAM MCUs

These resources give additional information about keypad applications based on the MSP430 FRAM-based microcontrollers:

[Low-Power Hex Keypad Using MSP430 MCUs](#) implements a completely interrupt-driven approach with minimal use of external components.

[Infrared \(IR\) BoosterPack Plug-In Module](#) includes a low-power hex keypad implementation.

[MSP430 Capacitive Sensing Microcontrollers](#) enable capacitive-touch keypad implementations.

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## Revision History

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

### Changes from February 5, 2002 to May 22, 2018

**Page**

- 
- Editorial changes throughout document..... 1
  - Added [Section 4, Low-Power Implementation on MSP430 FRAM MCUs](#) ..... 10
-

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