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

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 µA while waiting for a key press, is interrupt driven, requires no polling, and consumes a maximum of only 2 µA 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-µA 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-MΩ pulldown 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.

![Diagram of Keypad Schematic Diagram](image-url)
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 µA. Any other key press does not result in increased current consumption, because the corresponding row is not driven high.

In this 3×4 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.

![Software Flow Diagram]

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
clr.b Error_Flags ; Clear error flags

ret

;------------------------------------------------------------------------------

Debounce ; Debounce Delay Routine
;------------------------------------------------------------------------------
SetupTA mov #TASSEL1+TACLRCR, &TACTL ; SMCLK, Clear TA
mov #CCIE, &TACCTL0 ; Enable CCR0 interrupt
mov #512, &TACCR0 ; Value for typ delay of ~40mS
bis #MC0, &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
bic.b #07h, &P1OUT ; Clear column bits in P1OUT reg
Scan_1 bic.b #0F, &P3OUT ; Stop driving rows
bic.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 ;
rla.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 #0F, &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 further 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

mov.b #1,R11 ; row counter
L$1 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
bic.b #07h,&P1IES ; H-L Interrupts
clr.b &P1IFG ; Clear any pending flags
bic.b #07h, &P1IE ; Enable Interrupts
bic #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 further P1 interrupts
ret

;------------------------------------------------------------------------------
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.
**Revision History**

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

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