

Low-Power Hex Keypad Using MSP430™ MCUs



Introduction

Keypads are used in many applications but implementations often struggle to achieve a design that is simple, low cost, and low power. The [MSP430FR2000](#) microcontroller (MCU) is an ultra-low-power device that provides a cost-effective solution using only 512 bytes of nonvolatile ferroelectric random access memory (FRAM). The device's extensive low-power modes enable extended battery life. A keypad design utilizing this MCU can implement a completely interrupt-driven approach that requires no polling and uses minimal external components. While waiting for a keypress, this design consumes only 0.58 μA , and it draws a maximum of only 2.6 μA at 3 V if all keys are pressed simultaneously. The design also takes advantage of the eUSCI peripheral within the MSP430™ MCU to provide a 4800-baud UART interface that reports the button pressed to any connected device. To get started, [download project files and a code example](#) demonstrating this functionality. Additionally, the [infrared BoosterPack™ plug-in module](#) was used to develop and test this example code with added external pulldown resistors.

Implementation

This keypad design uses the strategy outlined in [Implementing An Ultralow-Power Keypad Interface with MSP430 MCUs](#). This approach takes advantage of port 1's interrupt capability to wake the device from a low-power mode. The columns of the keypad are connected to P2.0, P2.1, P2.6, and P2.7, and the rows are connected to port pins P1.0 to P1.3. [Figure 1](#) shows these keypad connections to the MSP430 MCU and the associated key numbers.

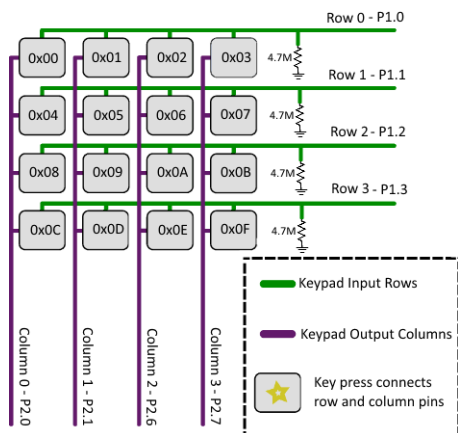


Figure 1. Keypad MSP430 MCU Connections

While the MSP430 device is waiting for a key press, it enters a wait-for-press mode where the keypad columns are driven high. Simultaneously the P1.x rows are configured as inputs and pulled low using 4.7-M Ω external pulldown resistors. The device is then put into low-power mode 4, where the current consumption is approximately 0.58 μA , and remains there until a key is pressed.

When a key is pressed, a physical connection is made between a column and one of the P1.x pins. This causes the P1.x pin to interrupt on a rising edge and wake the CPU from low-power mode 4 to continue program execution. First, the key is debounced using the watchdog timer (WDT) for an interval of approximately 15 ms. During this time, the device enters low-power mode 3 to conserve as much energy as possible.

Upon WDT expiration, the device once again wakes from low-power mode and performs a key-scanning algorithm to determine which key is pressed. If a key is pressed, the MSP430 MCU reports the key number using the UART interface.

The device then enters a wait-for-release mode where only one column is driven high. Simultaneously the P1.x rows are reconfigured to interrupt on a falling edge associated with the key being released. This allows the MCU to enter low-power mode 4 while the key is being held and also limits the maximum current consumption to the condition in which all 4 keys on a single column are held down.

When the key is released, it is first debounced using the WDT, and then the key scanning algorithm is executed to ensure no keys are being held. If any keys remain held, the wait-for-release mode continues and the device enters low-power mode 4. Finally, when all keys are released, the MSP430 MCU returns to wait-for-press mode.

The software flow described above can also be viewed graphically in [Figure 2](#). It should be noted that the key scanning algorithm and pin configurations have been optimized for this specific application. If pins are changed, the key scanning algorithm must be changed accordingly.

Performance

The firmware written for this application was highly optimized for the keypad connections detailed in [Figure 1](#). This was done to ensure it could fit inside a 512 byte memory space while allowing room for slight user modification. It also maintains a high focus on low power, achieving 0.58- μ A standby current and a maximum of 2.6 μ A when all keys are pressed. This makes the implementation ideal for low-cost battery-powered applications.

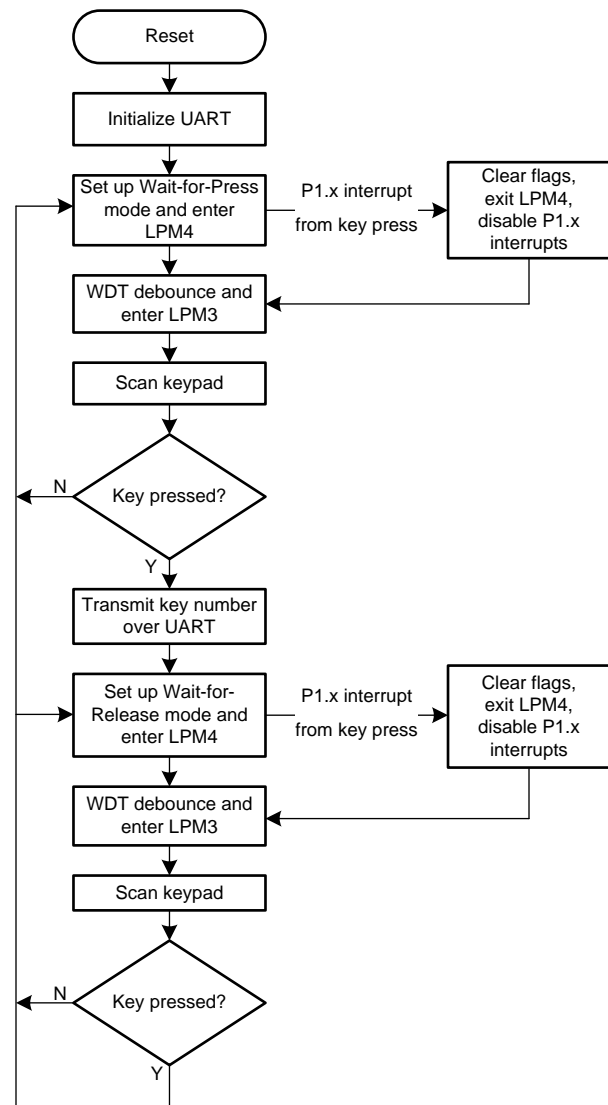
While it may seem like some key presses can be missed using this procedure, the 15-ms debounce interval and interrupt driven approach allow for any button push to be detected. However, this implementation does not take into account ghosting in a keypad matrix, which can only occur when multiple buttons are pressed at the same time. The user can attempt to add a ghost key detection algorithm using the remaining code space available or substitute a larger device if necessary.

Device Recommendations

The device used in this example is part of the MSP430 Value Line Sensing portfolio of low-cost MCUs, designed for sensing and measurement applications. This example can be used with the devices shown in [Table 1](#) with minimal code changes. For more information on the entire Value Line Sensing MCU portfolio, visit www.ti.com/MSP430ValueLine.

Table 1. Device Recommendations

Part Number	Key Features
MSP430FR2000	0.5KB FRAM, 0.5KB RAM, eComp
MSP430FR2100	1KB FRAM, 0.5KB RAM, 10-bit ADC, eComp
MSP430FR2110	2KB FRAM, 1KB of RAM, 10-bit ADC, eComp
MSP430FR2111	3.75KB FRAM, 1KB RAM, 10-bit ADC, eComp



Note: P1.x input must have interrupt capability

Figure 2. Software Flow

IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ("TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products (<http://www.ti.com/sc/docs/stdterms.htm>), [evaluation modules](#), and [samples](http://www.ti.com/sc/docs/sampterm.htm) (<http://www.ti.com/sc/docs/sampterm.htm>).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2017, Texas Instruments Incorporated