AVR240: 4 x 4 Keypad - Wake-up on Keypress

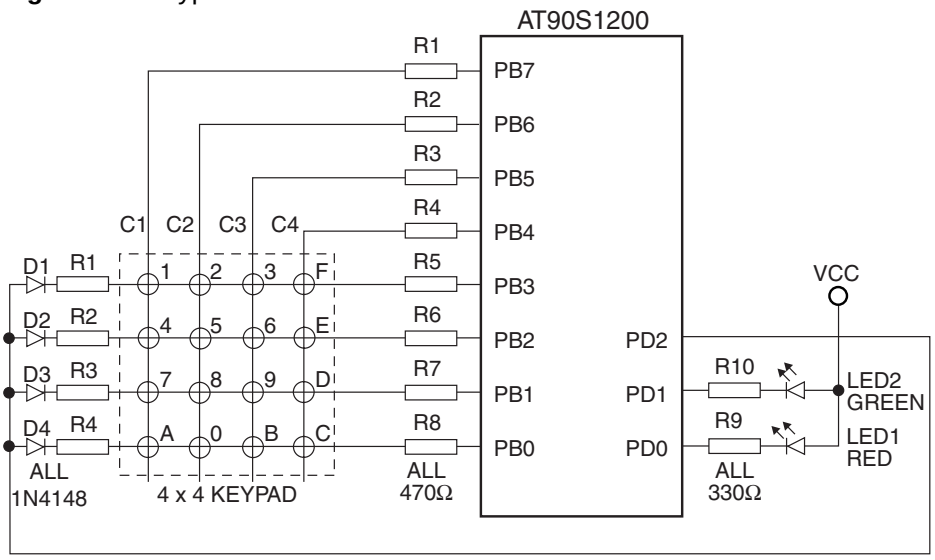
Features

- 16 Key Pushbutton Pad in 4 x 4 Matrix
- Very Low Power Consumption
- AVR in Sleep Mode and Wakes Up on Keypress
- Minimum External Components
- ESD Protection Included if Necessary
- Efficient Code
- Complete Program Included for AT90S1200
- Suitable for Any AVR MCU

1 Introduction

This application note describes a simple interface to a 4 x 4 keypad designed for low power battery operation. The AVR spends most of its time in Power-down mode, waking up when a key is pressed to instigate a simple test program that flashes one of two LEDs according to the key pressed. If “0” (zero) is pressed the RED LED flashes 10 times. All other keys flash the GREEN LED the number of times marked on the key (e.g., if “C” is pressed the GREEN LED flashes twelve times).

Figure 1-1. Keypad and LED Connections



8-bit AVR® Microcontrollers

Application Note

PRELIMINARY

Rev. 1232D-AVR-06/06

2 Theory of Operation

The keypad columns are connected to the high nibble of port B. The keypad rows are connected to the low nibble. Resistors R1 to R8 (this is shown in Figure 1-1) serve to limit input current to a safe level in the event of ESD from the keypad. They can be omitted in most applications.

In the steady state condition the high nibble is configured as outputs and are in the low state. The low nibble is configured as inputs and has the internal pull-ups enabled, removing the need for external pull-up resistors. After initialization the AVR is put to sleep. When a key is pressed one of the diodes D1 - D4 pull down the external interrupt line PD2, which also has internal pull-ups enabled. This wakes up the AVR and causes it to run the interrupt service routine, which scans the keypad and calculates which key is pressed.

It then returns to the main program and drives the LEDs according to the key pressed, putting the AVR back to sleep when it has finished.

Resistors R9 and R10 are the traditional current limit resistors for the LEDs and can be any suitable value for the supply rail. This application note was tested using 330Ω on a 5V supply. The LEDs are driven in current sink mode (“0” = ON) and provide about 10 mA of forward current with the values specified.

3 Implementation

The firmware consists of three sections, the reset routine, the test program and the interrupt service routine sets up the ports, sleep mode, power saving and the interrupts. The test program flashes the LED on wake-up and the interrupt service routine responds to the keypress.

3.1 Reset Routine

The flowchart for the Reset Routine is shown in Figure 3-1. On reset the ports are initialized with their starting directions. These are fixed on port D, with all bits as outputs except PD2, which must be an input for the external interrupt. This bit has its pull-up enabled by setting bit 2 of Port D. The unused bits are configured as outputs to avoid noise pickup or excessive power consumption, which could otherwise occur if left floating. Port B starts with the high nibble as outputs sending out zeroes, and the low nibble set as inputs with the pull-ups enabled.

Since we are using a minimum of external components, we must ensure that internal pull-ups are turned on for all those bits set up as inputs. This is achieved by configuring the Data Direction Register with “1”s for outputs, “0”s for inputs, and then writing “1”s to the input bits in the PORT Register. The inputs can then be read or tested from the PIN register. This program looks for “0”s and uses the SBIS instruction to skip over the keypress action if not a “0”.

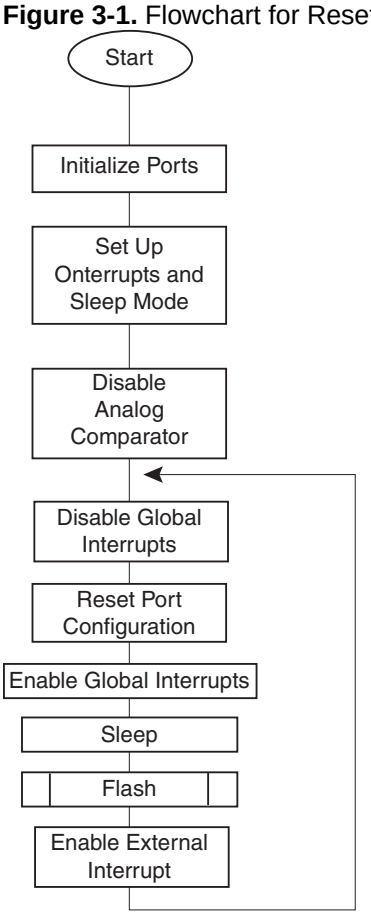
Power-down mode is selected by setting the SE and SM bits of the MCUCR. At the same time the external interrupt configured by writing “0”s into the ISC00/01 bits. This will set the external interrupt INT0 to trigger on a LOW level. When using “Power-down” mode the AVR can only be woken up by LOW LEVEL trigger.

Turning off the Analog Comparator reduces power consumption further. This is done by setting the ACD bit in the ACSR Register. This must be done with care; otherwise an unwanted interrupt can be generated. This program disables global interrupts until

the program is ready to be interrupted, solving this problem. If you wish to use the Analog Comparator this code can be removed, but you will need to change ports for the keypad since port B is used for this.

The AVR then enters sleep mode. This is placed in the main loop to ensure that it goes back to sleep after it has finished its interrupt function and carried out the “Flash” test routine. When the AVR wakes up after a keypress, the “Flash” routine is called after the interrupt routine is finished. When the “Flash” routine is done, the external interrupt is enabled, so that another interrupt can occur.

Figure 3-1. Flowchart for Reset and Main Routine



3.2 Flash Test Function

The flow chart is shown in Figure 3-2.

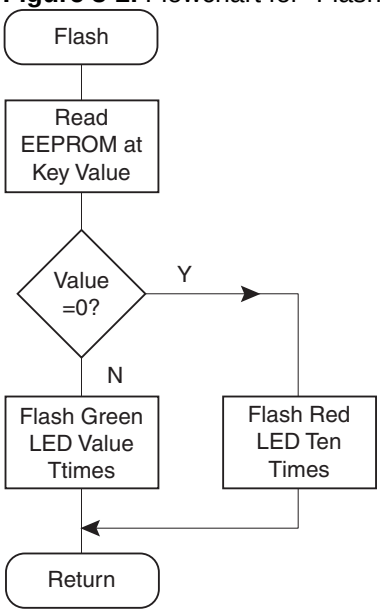
This function can be replaced by your own application to be executed out of “Power-down” mode. It serves to demonstrate that the key scan routine is working correctly. The value of the key pressed is taken from the “key” variable and used as a pointer to access a 16-byte look-up table stored in EEPROM. The look-up table contains the number of the key pressed.

The table has been used for two reasons, it makes the program much shorter, and it allows easy extension to provide full ASCII coding for the key press. For the larger AVRs it would make sense to store this table in program memory and access it using the LPM instruction.

The key value derived from the EEPROM is then used as a countdown variable inside an ON/OFF loop for the LED outputs. If the value is “0” the RED LED is flashed 10 times. If the value is non-zero the GREEN LED is flashed that number of times. For example, three times for the “3” key, fifteen times for the “F” key etc. The AVR then repeats the loop and falls asleep.

The LED flashing routine is easily modified for your own application, replacing the “Flash” function by your routine. The main consideration is the timing. Because the test program spends some time flashing the LEDs, no extra debounce arrangements are necessary. If your code is very fast you might need to put a short delay in to allow time for contact bounce. Wake-up from sleep mode typically takes 16 ms or so, although this is being reduced on the newer devices. This also provides some debouncing.

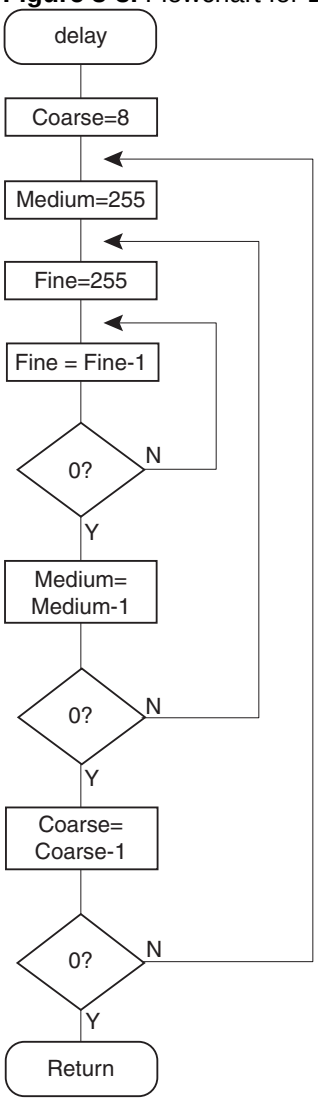
Figure 3-2. Flowchart for “Flash” Function



3.3 Long Time Delay Subroutine (delay)

To see the LEDs flash requires a delay of at least 0.25 second. This is achieved using a conventional FOR loop to keep the Timer/Counter free for other work. To achieve over 0.25 seconds delay with a 4 MHz clock requires three nested loops. Three local variables contained in registers “fine”, “medium” and “coarse” are used for the loop. The fine and medium counters run the maximum of 255 times with the coarse Counter set to 5, giving about 0.25 second delay. The flowchart is shown in Figure 3-3.

Figure 3-3. Flowchart for Delay Subroutine



3.4 Interrupt Service Routine

On entry the Status Register is preserved to avoid corrupting any work the main program was doing. In this application it may be left out for optimization if you wish. The flowchart is shown in Figure 3-4 and Figure 3-5.

The key row is first detected by testing each row input in turn looking for “0”. A base number 0, 4, 8, or 12 is then assigned to the variable “key”. The ports are then reinitialized with Port B I/O swapped over so that the key rows are tested.

A short time delay “settle” is used to allow the pins time to discharge. This takes the form of a conventional time waste loop using a FOR loop arrangement.

The key column is then detected and a number assigned in a temporary variable “temp” of 0, 1, 2, or 3. The final keypress is then computed by adding “key” and “temp”, placing the result in “key” ready for use by the “Flash” function. This method is easier to code than the conventional single bit scan in this application.

The Port B configuration is the swapped back prior to restoring the Status Register. This saves using the settling delay again.

At the end, the external interrupt is disabled. This is done to avoid the interrupt routine being triggered again immediately upon exit.

3.5 Short Time Delay Subroutine

This short delay is required when changing the Port B I/O configuration to allow time for the pin values to settle. The routine uses the Global Scratch Register “temp” as a single loop counter for the FOR loop, set at maximum 255 passes. This provides a delay of 0.192 ms at 4 MHz. This value could be shortened by experimentation if time is of the essence or the pins are set high prior to reconfiguration to speed things up. This might remove the need for this delay completely.

Figure 3-4. Flowchart for Interrupt Service Routine

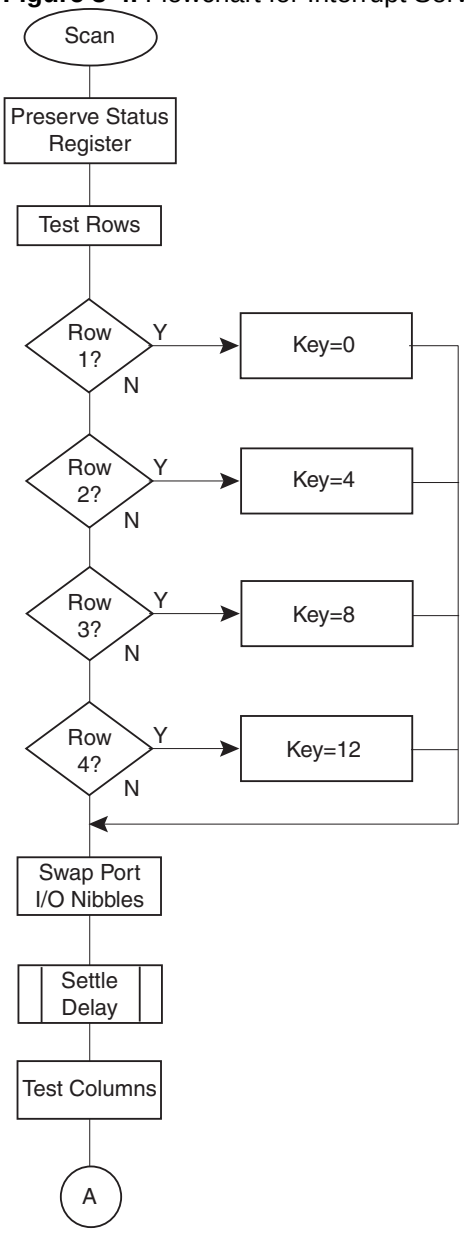
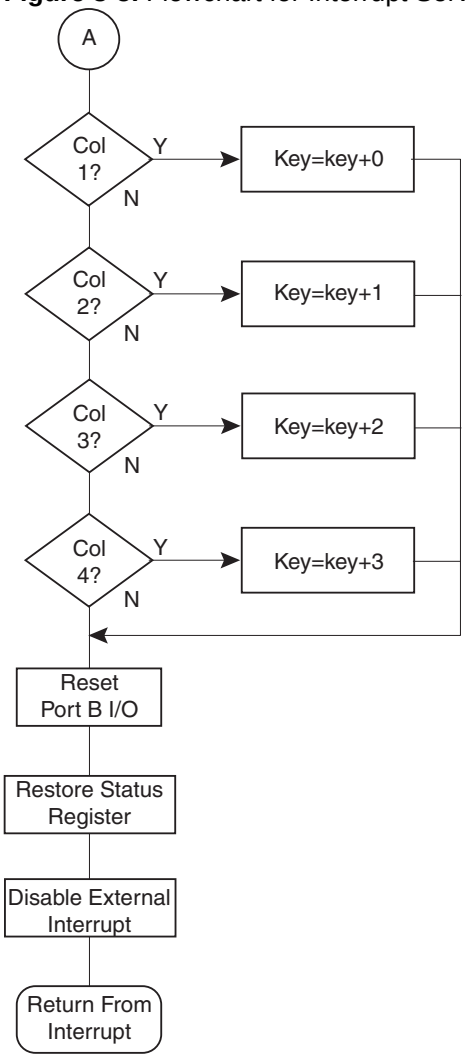


Figure 3-5. Flowchart for Interrupt Service Routine Continued



3.6 Resources

Table 3-1. Main CPU and Memory Usage

Function	Code Size	Cycles	Register Usage	Interrupt	Description
Main	24 words	19	R16	–	Initialization
Flash	20 words	-	R16	–	Example program
Scan	31 words	47 typical	R16, R17, R21	INTO	Scans 4x4 keypad
Delay	10 words	1,000,000	R18, R19, R20	–	0.25 second delay used in example program only
Settle	4 words	764	R16	–	Pin settling time delay used in scan
Total	87 words	-	R16, R17, R18, R19, R20, R21	–	

Table 3-2. Peripheral Usage

Peripheral	Description	Interrupts
External Interrupt 0 (INT0)	Key pressed wake up signal	External Interrupt 0 (Low Level triggered)
16 bytes EEPROM	Key to value mapping	–
8 I/O pins	4 x 4 keypad connections	–
2 I/O pins	Flashing LEDs for example only	–

```
;**** A P P L I C A T I O N   N O T E   A V R 2 4 0 **********************
;*
;* Title:  4x4 keypad, wake-up on keypress
;* Version:   1.2
;* Last Updated:  2004.11.11
;* Target:   All AVR Devices
;*
;* Support E-mail: avr@atmel.com
;*
;* DESCRIPTION
;* This Application note scans a 4 x 4 keypad and uses sleep mode
;* causing the AVR to wake up on keypress.  The design uses a minimum of
;* external components. Included is a test program that wakes up the AVR
;* and performs a scan when a key is pressed and flashes one of two LEDs
;* the number of the key pressed.  The external interrupt line is used for
;* wake-up.  The example runs on the AT90S1200 but can be any AVR with
;* suitable changes in vectors, EEPROM and stack pointer. The timing
;* assumes a 4 MHz clock. A look up table is used in EEPROM to enable the
;* same structure to be used with more advanced programs e.g ASCII output
;* to displays.
;*******************************************************************************

;***** Register used by all programs
;******Global variable used by all routines

.def     temp =r16 ;general scratch space

;Port B pins

.equ     ROW1 =3  ;keypad input rows
.equ     ROW2 =2
.equ     ROW3 =1
.equ     ROW4 =0
.equ     COL1 =7  ;keypad output columns
.equ     COL2 =6
.equ     COL3 =5
.equ     COL4 =4

;Port D pins

.equ     GREEN=0  ;green LED
.equ     RED=1  ;red LED
.equ     INTR =2  ;interrupt input

.include "1200def.inc"
```

```
;***** Registers used by interrupt service routine

.def     key=r17 ;key pointer for EEPROM
.def     status=r21 ;preserve sreg here

;***** Registers used by delay subroutine
;***** as local variables

.def     fine =r18 ;loop delay counters
.def     medium =r19
.def     coarse =r20

;*****Look up table for key conversion*****************************
.eseg           ;EEPROM segment
.org 0

        .db 1,2,3,15,4,5,6,14,7,8,9,13,10,0,11,12
;****Source code***************************************************
.cseg           ;CODE segment
.org 0
          rjmp reset  ;Reset handler
          rjmp scan   ;interrupt service routine
          reti    ;unused timer interrupt
          reti    ;unused analogue interrupt

;*** Reset handler ************************************************
reset:

          ldi temp,0xFB  ;initialise port D as O/I
          out DDRD,temp  ;all OUT except PD2 ext.int.
          ldi temp,0x30  ;turn on sleep mode and power
          out MCUCR,temp   ;down plus interrupt on low level.
          ldi temp,0x40  ;enable external interrupts
          out GIMSK,temp
          sbi ACSR,ACD   ;shut down comparator to save power
main:     cli    ;disable global interrupts
          ldi temp,0xF0  ;initialise port B as I/O
          out DDRB,temp  ; 4 OUT  4 IN
          ldi temp,0x0F  ;key columns all low and
          out PORTB,temp   ;active pull ups on rows enabled
          ldi temp,0x07  ;enable pull up on PD2 and
          out PORTD,temp   ;turn off LEDs
          sei    ;enable global interrupts ready
          sleep   ;fall asleep
          rcall flash  ;flash LEDs for example usage
          ldi temp,0x40
```

```
            out GIMSK,temp   ;enable external interrupt
            rjmp main   ;go back to sleep after keyscan

;****Interrupt service routine**************************************
scan:
            in status,SREG   ;preserve status register
            sbis PINB,ROW1   ;find row of keypress
            ldi key,0   ;and set ROW pointer
            sbis PINB,ROW2
            ldi key,4
            sbis PINB,ROW3
            ldi key,8
            sbis PINB,ROW4
            ldi key,12
            ldi temp,0x0F  ;change port B I/O to
            out DDRB,temp  ;find column press
            ldi temp,0xF0  ;enable pull ups and
            out PORTB,temp   ;write 0s to rows
            rcall settle   ;allow time for port to settle
            sbis PINB,COL1   ;find column of keypress
            ldi temp,0  ;and set COL pointer
            sbis PINB,COL2
            ldi temp,1
            sbis PINB,COL3
            ldi temp,2
            sbis PINB,COL4
            ldi temp,3
            add key,temp   ;merge ROW and COL for pointer
            ldi temp,0xF0  ;reinitialise port B as I/O
            out DDRB,temp  ; 4 OUT  4 IN
            ldi temp,0x0F  ;key columns all low and
            out PORTB,temp   ;active pull ups on rows enabled
            out SREG,status  ;restore status register

            ldi temp,0x00
            out GIMSK,temp   ;disable external interrupt
                 ;have to do this, because we're
                 ;using a level-triggered interrupt

            reti    ;go back to main for example program

;***Example test program to flash LEDs using key press data***********

flash:      out EEAR,key   ;address EEPROM
            sbi EECR,EERE  ;strobe EEPROM
            in temp,EEDR   ;set number of flashes
```

```
            tst temp  ;is it zero?
            breq zero   ;do RED LED
green_flash:
              cbi PORTD,GREEN;flash green LED 'temp' times
              rcall delay
              sbi PORTD,GREEN
              rcall delay
              dec temp
              brne green_flash
exit:       ret
zero:       ldi temp,10
flash_again:  cbi PORTD,RED;flash red LED ten times
              rcall delay
              sbi PORTD,RED
              rcall delay
              dec temp
              brne flash_again
            rjmp exit


;****Time Delay Subroutine for LED flash*********************************
delay:
          ldi coarse,5      ;triple nested FOR loop
cagain:     ldi medium,255   ;giving about 1/4 second
magain:       ldi fine,255   ;delay on 4 MHz clock
fagain:       dec fine
              brne fagain
            dec medium
            brne magain
          dec coarse
          brne cagain
          ret

;***Settling time delay for port to stabilise****************************

settle:
          ldi temp,255
tagain:     dec temp
            brne tagain
          ret
```

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