nRF24Ex in a wireless keyboard design

GENERAL

With the nRF24E1 and nRF24E2, in this document called nRF24Ex, from Nordic VLSI ASA is it now possible to design a wireless keyboard for the 2.4GHz ISM band. The nRF24Ex series has an embedded 8051 microcontroller, a 9 channel ADC and the same RF part as the popular nRF2401/nRF2402. The nRF24Ex series can run at voltages from 1.9V to 3.6V making it especially suited for battery applications. This white paper will show how a keyboard scan matrix can be realized by using the nRF24Ex.

THE DESIGN

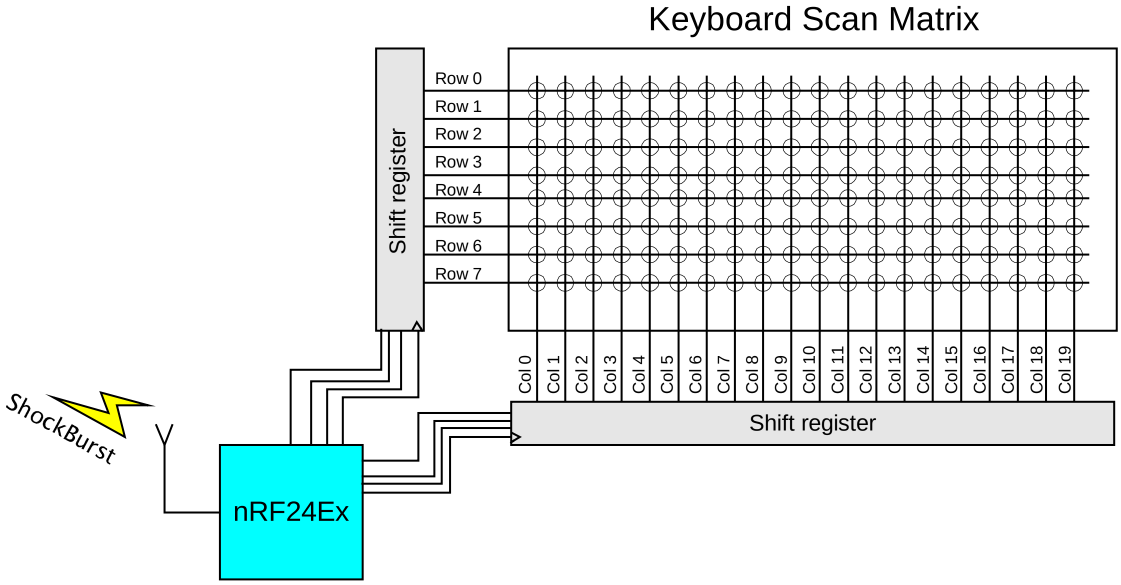

Figure 1 nRF24Ex in a wireless keyboard design

The RF part

As shown in the schematics, Figure 4, the RF part is based on the nRF24Ex reference design that can be downloaded from www.nvlsi.no. The design has a 16MHz crystal and an external EPROM for firmware storage. The firmware will use the ShockBurst™ technology to transmit the packets from the keyboard. The ShockBurst™ technology is designed to minimize the current consumption per transmitted bit in order to extend the battery lifetime. Read more about the ShockBurst™ technology in the nRF24Ex datasheet and in a white paper that can be downloaded from www.nvlsi.no.

Wireless keyboard basics

Wireless keyboards are using RF to communicate with the PC. They are mostly powered by batteries, and as a consequence of this, some power saving techniques are used. The LEDs that indicate “Num Lock”, “Caps Lock” and “Scroll Lock” on wired keyboards are not present on wireless keyboards. This is one of the power saving actions that has been taken on wireless keyboards.

Careful use of the RF module is another power saving technique. A RF data packet from the keyboard to the PC can contain up to 8 key strokes. The scan matrix is scanned about 500 times pr second. Normally not more than one keystroke is detected during one scan period. Humans will not detect delays that are shorter than 150ms, so if the keyboard detects a keystroke, it can wait up to 150ms to collect even more keystrokes before transmitting a packet to the PC. This will ensure as little use of the RF module as possible.

A keyboard using the nRF24E2 will only be able to send data to the PC. This will give enough features for most keyboard vendors. If a two-way link is required, the nRF24E1 should be used. The keyboard will then be able to receive data from the PC. This opens for features like link encryption, retransmission protocol and even more power saving features like detection of system power off.

Keyboard scan matrix

A keyboard can have as many as 104 keys that are organized in a scan matrix. The scan matrix can have 8 rows and up to 20 columns. This enables a maximum of 160 unique keys to be placed on a keyboard. Each key is connected to an intersection between a row and a column, as shown in Figure 2. When pressed, the key will connect the row with the column in that intersection.

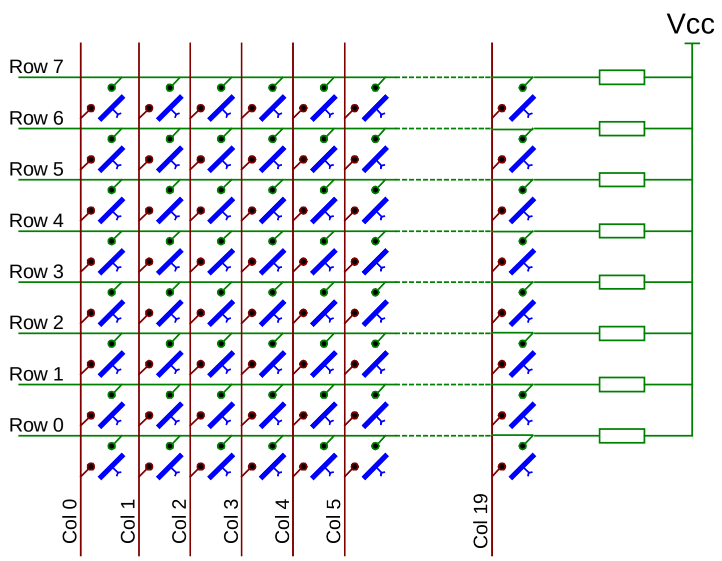

Figure 2 Key connection

To scan the matrix, the nRF24Ex will clock a bit pattern into the column shift register (see Figure 4 for details.) This bit pattern consists of one 0 and nineteen 1s. The 0 is shifted trough the shift register. For each time the 0 is shifted one position, the rows are read. If a key has been pressed on the column being set to 0 at that point, a 0 will come out on the intersecting row. See Figure 3 for details.

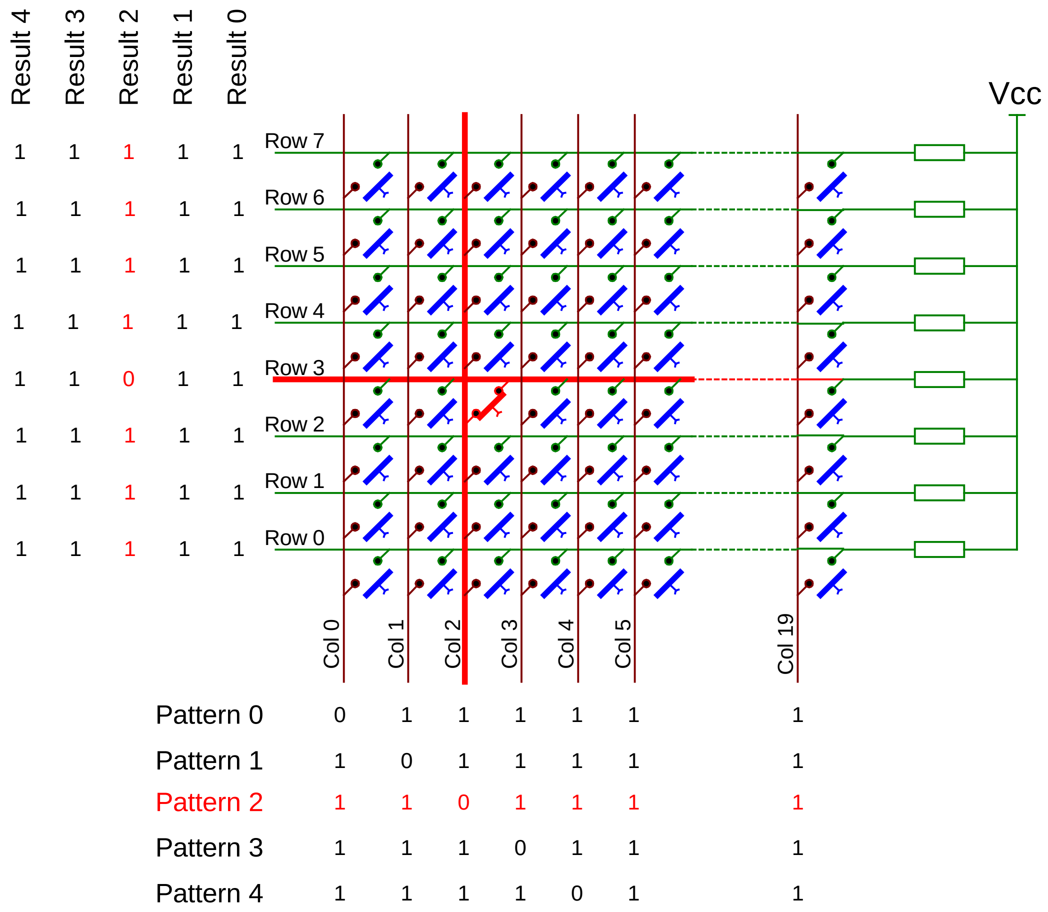

Figure 3 Key press detection

Keys that are pressed may bounce and cause misdetection of real key events. To solve this problem, once a key press has been detected the system should ignore changes in status for this key for 30-50ms.

Schematics

Figure 4 shows how the 74HC595 and 74HC597 shift registers together with the standard nRF24Ex layout with an EPROM, can be interfaced to a keyboard scan matrix.

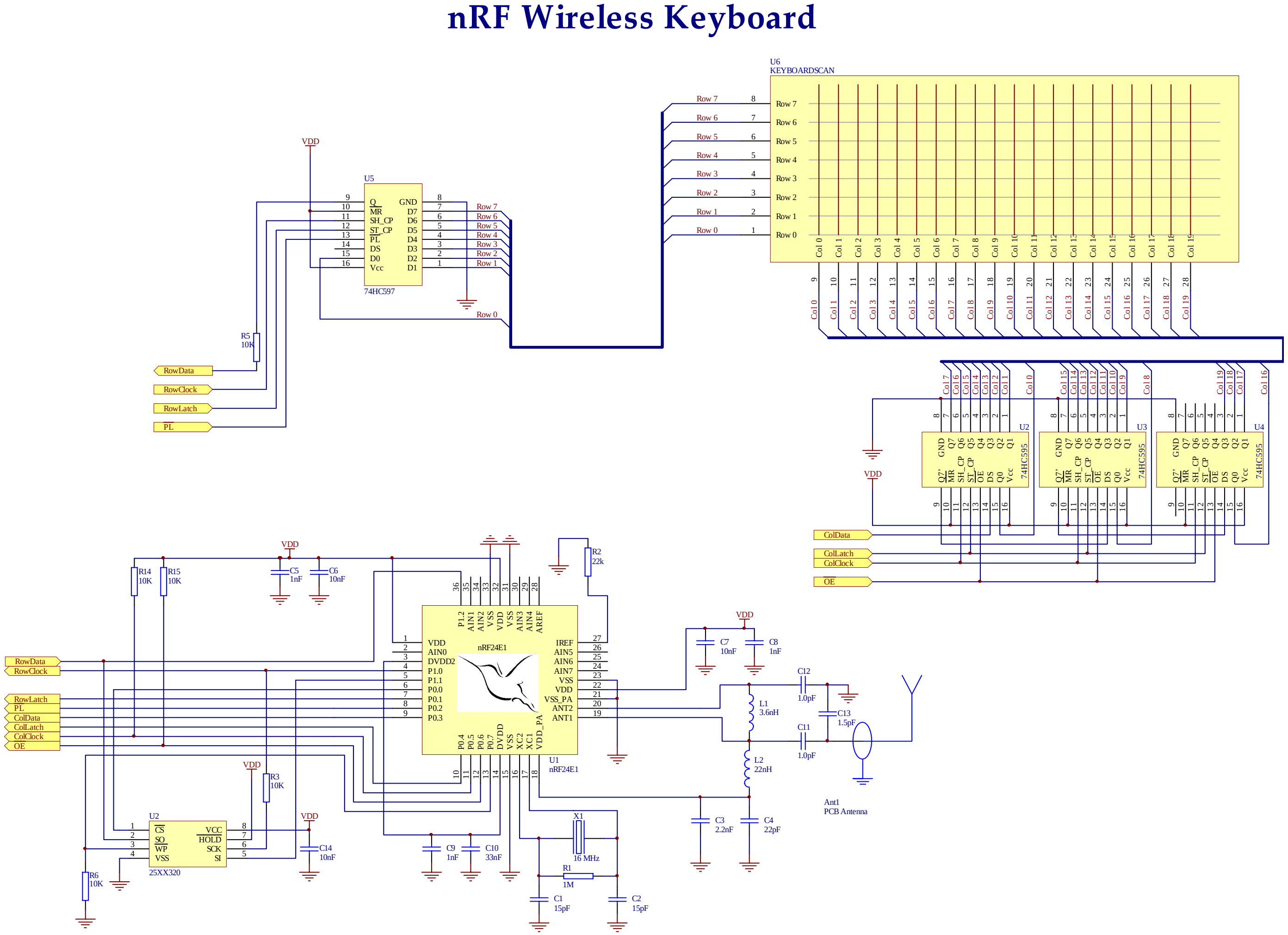

Figure 4 Schematics of the nRF24EX Wireless Keyboard

SYSTEM FIRMWARE

The nRF24Ex has 4K of internal RAM used for firmware storage. It is more than enough space for the keyboard firmware.

The firmware should perform the following tasks:
- Load scan shift registers with scan patterns
- Read scan rows
- Detect and de-bounce key presses
- Send the key press scan codes to the PC
- Power duty cycling

As mentioned earlier in this document the wireless keyboard should use power saving techniques to extend battery lifetime. Low power consumption when operating the radio is given by the ShockBurst™ technology, so the system firmware designer does not have to worry about that. But the average system standby current can be further reduced by implementing power duty-cycling techniques.

The nRF24Ex drains 3mA when the 8051 core is running. Since the use of a keyboard is periodically with long delays between use, a lot of current can be saved by putting the 8051 core in power down when the keyboard is not used. The current consumption in power down mode is 2uA.

A typical power duty cycling algorithm can have two operating modes; Idle and Active mode.
Idle mode:
- Perform a complete keyboard scan. (takes 0.5 ms)
- If a key has been pressed, go to active mode.
- Set 8051 in power down with RTC wakeup enabled on 20 ms.
- Loop idle mode.

Active mode:
- Scan the keyboard 500 times/second.
- Send any key pressed scan codes to the PC.
- If no key pressed in 10 seconds, go to idle mode.
- Loop active mode.

This power duty cycling will reduce the average stand-by current consumption from 3mA to (0.5ms*3mA+2uA*20ms)/20.5ms = 75uA. This will cause the batteries to last 40 times longer!

LIABILITY DISCLAIMER

Nordic VLSI ASA reserves the right to make changes without further notice to the product to improve reliability, function or design. Nordic VLSI does not assume any liability arising out of the application or use of any product or circuits described herein.

LIFE SUPPORT APPLICATIONS

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Nordic VLSI ASA customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Nordic VLSI ASA for any damages resulting from such improper use or sale.

White paper. Revision Date : 28.10.2003.

YOUR NOTES

Nordic VLSI - World Wide Distributor

For Your nearest dealer, please see http://www.nvlsi.no

Nordic VLSI ASA

Main Office:
Vestre Rosten 81, N-7075 Tiller, Norway
Phone: +47 72 89 89 00, Fax: +47 72 89 89 89

Visit the Nordic VLSI ASA website at http://www.nvlsi.no

NORWEGIAN ACCREDITATION No. S03
NS-EN ISO 9001 CERTIFICATED FIRM