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Analogical versus Logical Keypad Interfaces for Microcontrollers Ports

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Abstract* – Interfacing keypads with microcontrollers' port lines is classicaly represented by the wellknown matrix structure, but many other solution are available. Since new generations of microcontrollers are bringing new facilities, alternative solutions were proposed in order to obtain the maximum number of interface keys with minimum costs. Some of these solutions consist in using analog-to-digital interfaces instead of the logical I/O ports. Coding the keys with analog voltages involve A/D converters for decoding. Since analogue coding is usualy based on cheap resistive dividers connected with the keypads, reading the keys voltage values could be done with comparators or A/D converters if included with the system. With appropiate sofware algorithm, low cost interface could be designed. The paper is sugesting some optimal solutions to do that.

***Keywords:* analog ports, digital design, microcontrollers, interfacing, keypad, optimization**

I. INTRODUCTION

Studying the use of analog facilities of the microcontrollers to interface with keypads is part of a larger demarche of the author started from classical matrix keypad connection and optimized alternatives based on unidirectional I/O ports, passing through optimised solution using microcontrollers bidirectional lines and arriving to the use of analogical ports [1] [2]. Even usual switches are two states devices and they are classically delivering logical levels, further extensions could be achieved if multilevel logic is used instead of binary logic [2]. For these propose analog lines (A-to-D inputs, comparator inputs, PWM outputs) has to be used as shown in this paper.

II. USING ANALOG PORTS I/O LINES FOR KEYPAD INTERFACING

A. A/D inputs interface principle

Since today many cheap microcontrollers have analogue or mixed signal ports, new interfacing techniques could be developed [6]. The principle of using analog inputs line for keypad interfacing can be explained based on figure 1. The idea is to activate one column at the time by logical "1" and to read, with the aid of an A/D input, the voltage value given by the resistive dividers. Any other pressed key from non-active columns will supply zero voltage. Any non-zero voltage will be associated with the corresponding key from the active column.

For n lines and equal resistors the line number k will be identified as part of the logical "1" voltage output:

$$V_k = \frac{\sum_{i=1}^{k} R_i}{\sum_{j=1}^{n} R_j} \cdot V_{"1"} = \frac{k}{n} \cdot V_{"1"} \qquad (1)$$

The only ambiguities are when two keys are pressed in the same time because a different voltage will be generated. If the two keys are on the same line, including series switch diodes on each column end or using the port three-state outputs if available, the problem can be solved. Pressing two keys from the same column is not manageable.

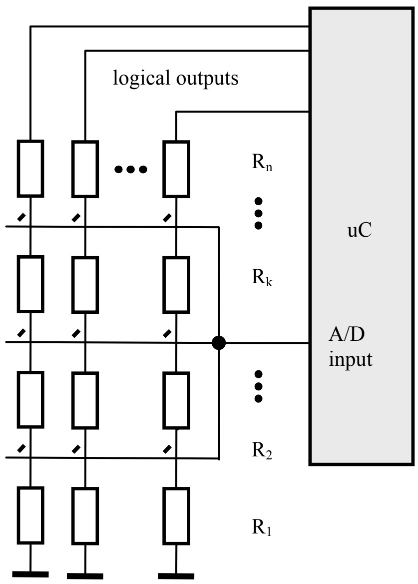

Fig. 1. Keypad interface based on analogical inputs

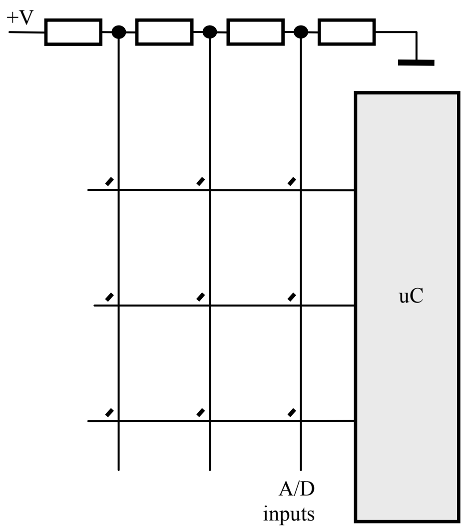

Fig. 2. Keypad interface based on analogical inputs

For n logical output lines and m significant bits resulting from the A/D conversion, the keys number is

$$B_{A1} = n \cdot 2^m \qquad (2)$$

The value of m is basically limited by the A/D converter resolution but usually the number of keypad lines (and the number of resistors), the noise and the software filtering possibilities are the real limitation reasons. By software generating binary masks, 4 to 6 most significant bits could easily be used like direct code with no excessive filtering.

An equivalent solution can be used if more than one A/D inputs are available, as in figure 2. Only one divider serves to all columns, line being identified by the selection of A/D input channel. Simultaneously pressed keys are accepted but only on the same column.

Some improvements are also possible if each line can be driven to high-impedance state (figure 3). This way, if buttons from different columns are pressed in the same time, only the one from active columns will determine the voltage. The diode from each line is driven between the logical output and its inverted value and it will be open only when the corresponding line is activated with logical "1". Not used output lines have to be in high-impedance state to avoid interfering with active one. More, if a multiplexer with high impedance outputs (analogical type) is employed, a larger number of columns could be driven with few output lines. The solution is also suggested on figure 3. The manageable number of keys is

$$B_{A2} = 2^n \cdot 2^m \qquad (3)$$

If separate anological inputs (or external multiplexers) are used than two pressed key problems are also handled.

For 3 logical lines (n = 3) and with 4 bits for A/D conversion B_{A2} = 128. The needed number of dividers resistors is

$$N_R = (2^m + 1) \cdot n \qquad (4)$$

B. Single line interface

If special type of key buttons are available than only one A/D input line could be used "to read" a certain key (figure 4). Now, every key is encoded with a unique voltage, if the line and column resistive divider has appropriate values to generate for V_{Li} and V_{Cj} non-confusing values. A simple rule could be the next one: generating for lines voltages 1V, 2V … 5V and for columns 0.1V, 0.2V … 0.9V. The voltage at the A/D input will be the corresponding sum of V_{Li} and V_{Cj}. This manner values like 1.1, 1.2, 1.3 … 2.1, 2.2, 2.3 etc. are possible.

Supposing that the A/D input has the input impedance R by pressing the buttons from the cross point between line i and column j, the generated voltage is:

$$V_{A/D\,i,j} = V_{Li}\frac{R}{R_L + R} + V_{Cj}\frac{R}{R_C + R} \qquad (5)$$

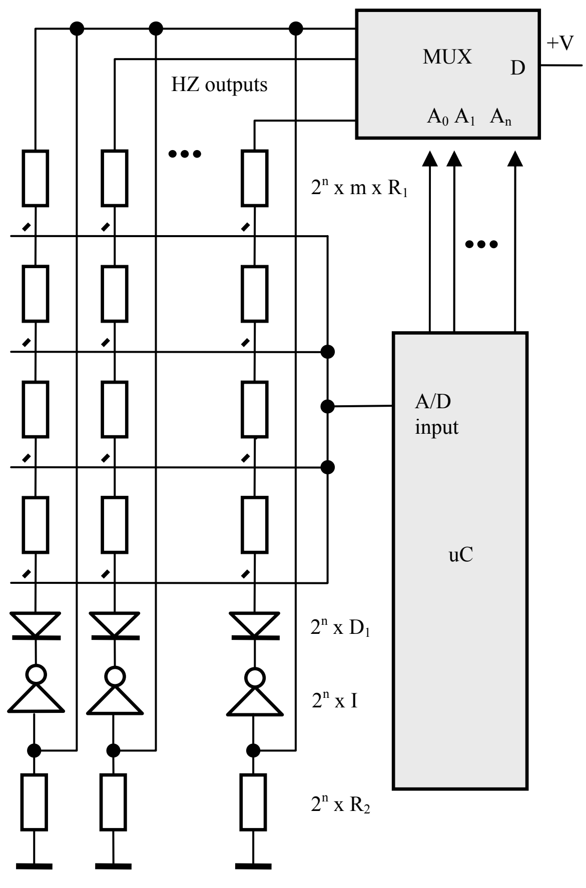

Fig. 3. Enhanced keypad interface based on analogical inputs

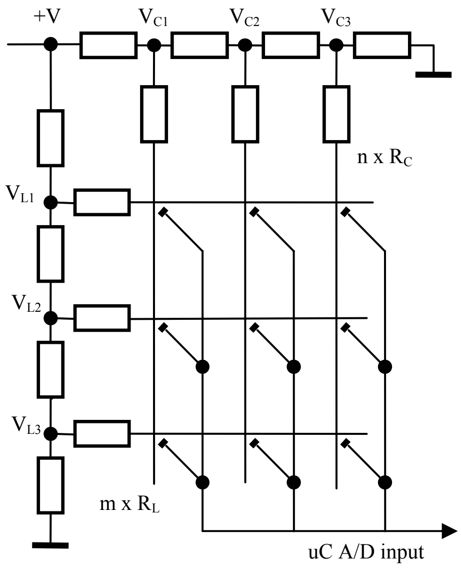

Fig. 4. One A/D input keypad interface

If R_L+R_C and R>>R_L, R_C (R is usually very high) than, with a good approximation, the A/D input voltage is

$$V_{A/D\,i,j} \approx V_{Li} + V_{Cj} \qquad (6)$$

If the resulting voltages are too close one from another a rigorous software filtering is necessary in processing input values.

The method is known like “2 from 7” code (if m+n=7) and the principle is used at phone keypads to generate dual tones by mixing two frequencies (DTMF signals) [7]. So, some specialized phone keypads can be also used like microcontroller interfaces.

Coding the keys with analog voltages like above could be also implemented as in figure 5 using a autoruning shift register, serial in parallel out, configurated as ring self counter [5] [1]. This device will move a logical “1” successively on its output, driven by an independent clock oscillator having the appropiate frequecncy to allow a complete conversion during a period. It can be impemented using logical ports of a microcontroller. Each “1” register output connects a different ratio divider as the output voltage is different for every pressed keys and 0 if none.

The principle diagram and some possible ratio values are suggested in figure 5. If V is output voltage associate with logical “1”, the generated analog voltages will be

$$\frac{1}{n+1}\cdot V,\ \ \ldots\ \ ,\frac{1}{4}\cdot V,\ \frac{1}{3}\cdot V,\ \frac{1}{2}\cdot V,$$
$$\frac{2}{3}\cdot V,\ \frac{3}{4}\cdot V,\ \ \ldots\ \ ,\frac{n}{n+1}\cdot V; \qquad (7)$$

Using these values the voltage interval is symmetrically shared and, going from the middle of the scale to the extremes, the differences between two neighbor voltages are continuously decreasing. So, we have to pay attention at the A/D converter resolution related with the accepted noise for a simple software filtering engagemnet. Anyway, 2n-1 keys can be used. The solution needs only one input port line, is a very low cost one but pressing to keys at the time is not possible.

C. Interfacing scheme with analogue inputs and outputs

In figure 6 is shown an interesting idea consisting in using both, a D-to-A output (usually a PWM output) and a A-to-D input line. The analogical voltage generated by the microcontroller is used to toggle successively a cascade of comparators. Each line of the keypad matrix is connected between two comparators successive outputs so that only one line is active at the time. The active line will be that one which correspond with the last “1” outputs followed by a “0” , starting from L_1 to L_3 in figure 6, because like that a current will flow from positive voltage from the left, associated with logical “1”, to the ground voltage from the right, associated with logical “0”. All other possible situation means that the line is connected between “1” and “1” or between “0” and ”0” and no current will be driven through. Any pressed key will generate 0V, if $V_{D/A\ output}$ is less than $V_{R\ j}$ reference, or will generate “1” if $V_{D/A\ output}$ is above $V_{R\ j+1}$. Only for $V_{D/A\ output}$ being between $V_{R\ j}$ and $V_{R\ j+1}$ intermediary voltages will be possible. Reading algorithm will consider that for 0 and V+ on the A/D line no key is pressed and for any other voltage a key will be identified on the corresponding line. No two key pressed at the time is possible, but using separation diodes (dashed lines, figure 6) the keys from the same column can be pressed in the same time (but not from the same line).

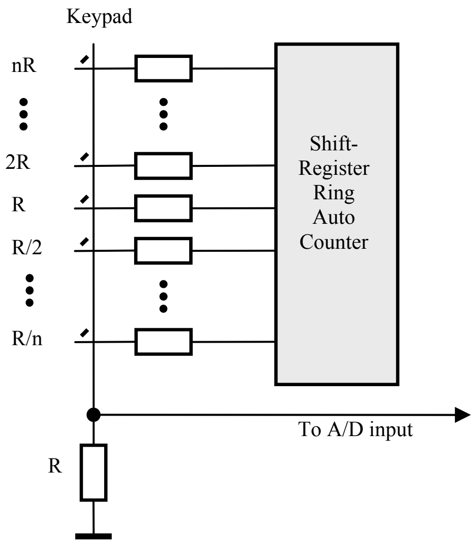

Fig. 5. Keypad interface with shift register and one A/D port line

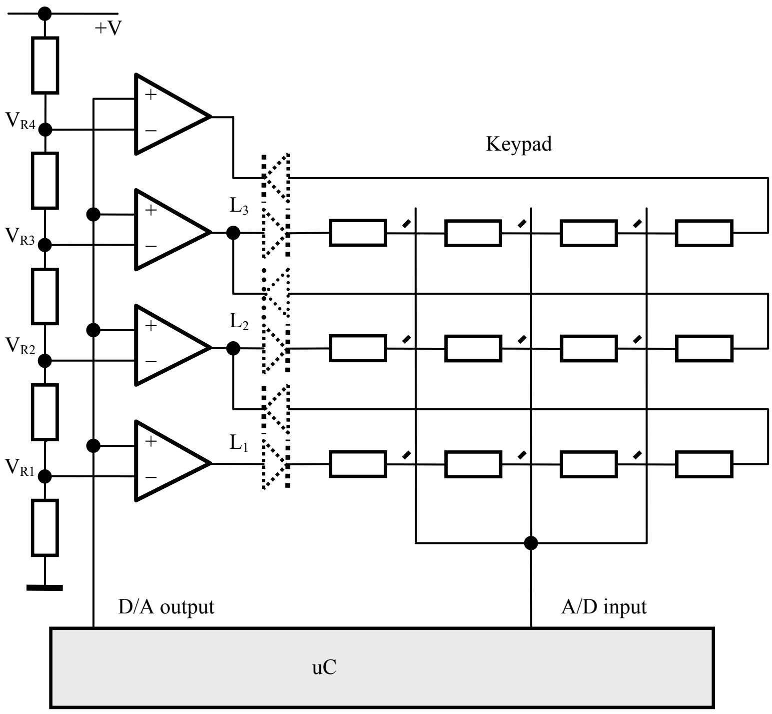

Fig. 6. Keypad interface using one D/A output and one A/D input

Starting from figure 6 structure another mixed signal solution comes ahead. The same multilevel comparator (stand alone or based on microcontroller integrated comparators if available) driven by a PWM output could generate alternatively active lines for a matrix keypad. The lines has to be powered as in figure 6 but one resistor has to be kept on every line (to avoid directly connection of output "high" and output "low") and the microcontrolller inputs, logical like, has to be connected one to each column. These way only one D/A output is managing all the lines, the columns are logical inputs but few comparators are engaged.

III. CONCLUSIONS

Using the best solution to interface the microprocessor systems with human operators via keypads is a permanent challenge. Starting with classical matrix keypad interface some improvements were proposed in order to obtain a better efficiency at the level of the compromise costs – available number of interface keys. Even based on usual unidirectional port lines interface the possible keys number could be increase by adding cheap additional devices like coders/decoders instead of using powerful and more expensive microcontrollers [2]. More, if bidirectional port lines are available than a much better efficiency can be obtained by exploiting the programmable two ways of data directions [4] [1]. As shown in the paper, using analogue facilities of a microcontroller, low cost keypads with large number of keys can be easily designed. As the hardware solution is simpler as the software algorithm goes complicated.

The most important advantage is related with the posibility of using a very low number of port lines, even one line, if the solution is an approapriate one, to control a quite large number of keys face to the involved number of port lines. For a larger number of keys the most efficient solution is still based on bidirectional logical port lines as former studies of the author revealed.

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