MICROCONTROLLER BASED AUDIO SIGNAL GENERATOR

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Abstract: *This paper describes a signal generator build around a single microcontroller, which is used as test equipment in audio domain. Due to architectural elements, microcontrollers can be used in applications requiring repetitive operations such as signals generation.*
Key-words: *microcontroller, audio waveform, embedded, DDS, LFSR*

1. INTRODUCTION

In this paper we present our approach regarding a possible solution for an embedded audio signal generator (tester), very useful in many electronic warfare applications or for the maintenance of military voice communications systems in the modern battlefield [1], [2]. The requirements for this type of audio system are very challenging: reliable, dynamically reconfigurable, low power consumption, small size, light weight, easy to operate. All these lead us towards a microcontroller-based system design approach.

This software programmable signals generator provides four waveform shapes: sine, triangle, square and white noise. For the generation of the first three signals, modern DDS (Direct Digital Synthesis) technique it is adopted, and for the generation of the white noise signal it is implemented the classical Linear Feedback Shift Register (LFSR) technique.

2. SINE, TRIANGLE, SQUARE WAVES GENERATION TECHNIQUE

The generation of analog signals like sine, triangle or square with DDS technique requires two main steps, first one for the creation of an appropriate pattern in digital form and second one for the conversion from digital to analog form [3]. A standard DDS architecture (see Fig.1) consists of phase accumulator, ROM lookup table (phase-to-amplitude conversion), DAC (digital-to-analog conversion) and LPF (low pass filter). DDS module has two inputs "clock" and "FCW" and one output. The frequency of sine wave at the output depends on two parameters: the reference-clock frequency (f_{clk}) and the frequency control word (FCW – *M* bits):

$$f_{out} = \frac{f_{clk}}{2^M} \cdot FCW. \tag{1}$$

For each clock cycle, the phase accumulator is incremented with a constant value provided by binary tuning word, FCW. A high-frequency signal is generated, if the incrementing step is large and low frequency waveform in case of using small phase accumulator increment [3].

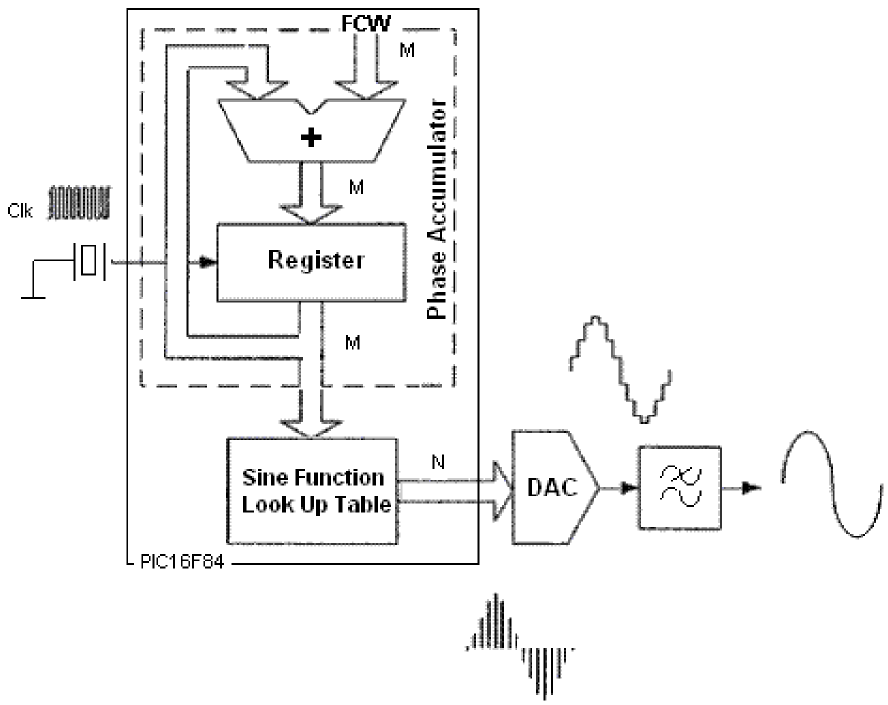

Figure 1. Standard DDS block-diagram

In our approach, DDS based on PIC16F84 microcontroller is designed in simplest form: a quartz crystal reference clock, a program counter for LUT address, a programmable flash memory for storing binary samples, and an external DAC (see Fig.2).

To improve power consumption efficiency of the audio tester it is necessary to optimize the software required by the microcontroller, thus the assembly code has been adopted for the implementation of sine wave LUT [4]. In a special software subroutine the value of POINTER register is moved to the program counter register PCL. Then it will jump to certain address of flash LUT memory and returns with literal value stored in the Working register (W). The content of W is moved to PORTB connected to DAC08.

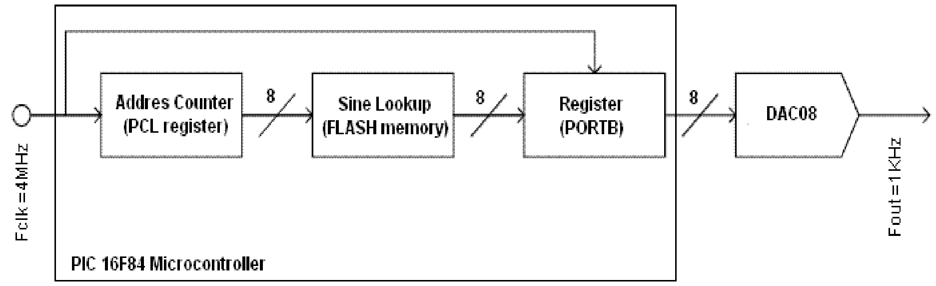

Figure 2. PIC16F84 simple DDS

```
Loop    movf    POINTER,W
        call    LUT             ; call Look Up Table subroutine for sine function
        movwf   PORTB   ; binary value of one sample of sine
        call    Delay           ; time between samples for  Fout =1 KHz
        …
        goto    Loop
        ...
LUT     addwf   PCL,F
        retlw   b'00001000'     ;       8
        retlw   b'00001100'     ;           12
        retlw   b'00001110'     ;             14
        retlw   b'00010000'     ;               16
        retlw   b'00010000'     ;               16
        retlw   b'00001110'     ;             14
        retlw   b'00001100'     ;           12
        retlw   b'00001000'     ;        8
        retlw   b'00000100'     ;     4
        retlw   b'00000010'     ;    2
        retlw   b'00000000'          ;    0
        retlw   b'00000000'     ;  0
        retlw   b'00000010'     ;    2
        retlw   b'00000100'     ;     4
...
```

The method is not restrictive to sine waves. For triangle and square waves only the content of LUT must be changed in the appropriate form.

3. WHITE NOISE GENERATION TECHNIQUE

White noise is a random signal and it is totally non-deterministic [5]. Microcontrollers are digital logic and deterministic devices and thus are not considered a good choice for true random numbers. Thus, random number generation on a microcontroller is only pseudo-random number generation. The most common way to implement a pseudo-random sequence is a Linear Feedback Shift Register (LFSR) technique. The Fibonacci implementation of LSFR consists of a shift register whose input bit is replaced with the result of a modulo-2 sum of some taps [6], [7].

A general *n*-stage LFSR (b_{n-1}, …, b_0) is shown in Figure 3, where c_0, c_1,…, c_n are called the feedback tap coefficients . For any given tap, there are two possibilities, connected or not to the feedback path, according to the binary value of c_i.

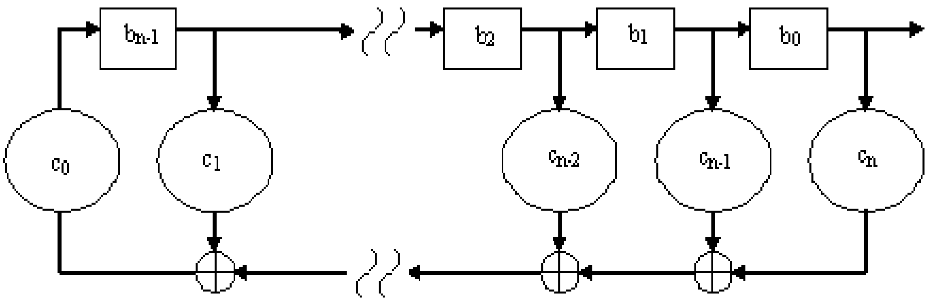

Figure 3. General n-stage LSFR

The generator polynomial for the n-stage LFSR is:

$$P(x) = x^n + c_1 x^{n-1} + c_2 x^{n-2} + ... + c_{n-1} + 1 \qquad (2)$$

and if this is a primitive polynomial will produce a maximal length sequence, 2^n-1 etc.

In our approach the primitive polynomial used is $x^8 + x^6 + x^5 + x^3 + 1$. The process begins by setting up an 8 bit shift register RAND with the initial value 11010010 (seed). The register is right shifted, and the lowest bit is transferred to the output pin RB0. The lowest, the 3rd, the 5th, the 6th bits are XOR-ed and the result shifted into the highest bit position (see Fig.4). The cycle is repeated, with each cycle producing a bit in a pseudo-random bit sequence. The pseudo-random bit sequence described repeats each 255 cycles. The frequency of the pseudo-random noise generator depends on using different delays to the program loop, using an external clock, or using the internal clock/counter/prescaler of the PIC16F84 [8].

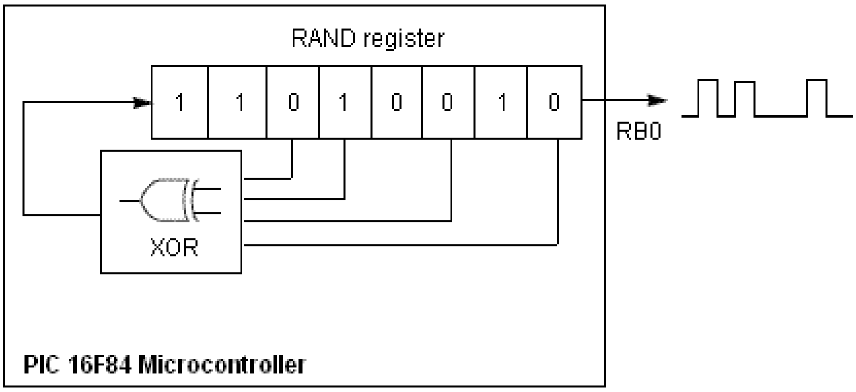

Figure 4. PIC16F84 pseudo-random bit sequence

At RB0 output pin, LFSR generates a uniformly distributed pseudo-random sequence. To obtain white Gaussian-distributed noise, a number of identical PIC controllers can be connected in parallel in a true realization of the central-limit theorem. The central-limit theorem states that the sum of an infinite number of noise sources has Gaussian distribution, regardless of the individual noise distribution of each generator. Using an infinite number of noise generators is impractical, but 10 to 16 are sufficient in most cases [8], [9].

4. CONCLUSIONS

In this paper are shown two of the most widely used techniques, DDS and LSFR, for software generation of standard audio waveforms, using a general purpose microcontroller. Software offers flexibility to change easily frequencies and levels of output waveforms.

Because operations within a microcontroller are digital, it can offer fast switching between output frequencies, fine frequency resolution, an accurate signal whose frequency and phase can be precisely controlled in real-time.

Also, the microcontroller can be programmed to automatically and repetitively sweep the frequency of the output waveform between two determined limits. This capability makes it very easy to evaluate the frequency response of a given electronic circuit.

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