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On design and realization of digitally programmable square-wave generator

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Abstract: *This paper presents a simple and low-cost digitally tuned square-wave generator using few components. The behavior of proposed circuit was tested in hardware implementation. The results obtained are satisfactory to its theoretical calculations.*

Key words: **Square wave generator, operational amplifier, binary weighted resistors, analog switches.**

1. INTRODUCTION

Square wave signals find application in various electronic systems. Digitally tuning the output frequency of square-wave generators, offer flexibility when used with digital machines. Circuits of this type have not been popularly discussed in literature. Abuelma'atti et al in [1], proposed a circuit employing various active devices thus making output frequency more sensitive to temperature variations. Another circuit was proposed by Ali et al in 1994 [2], where in the the effect of temperature can be compensated by using an analog to digital (A/D) converter and microcontroller. Both the circuits, proposed in [1] and [2], show hardware complexiy but have an advantage of monolithic fabrication. There are situations where accuracy, high speed and monolithic fabrication are not the only considerations but simplicity and low cost of circuits are demanded. In view of lack of significant work carried out in this direction, a very simple and low-cost circuit is presented.

2. PROPOSED CIRCUIT

The conventional non-programmable, operational amplifier based, circuit for square wave generator is shown in Fig.1. The frequency of oscillation is given by [3]

$$f_o=1/\{2R_fC\log_e[(2R_1+R_2)/R_2]\} \quad (1)$$

and if $R_2=1.16R_1$, then

$$f_o=1/2R_fC \quad (2)$$

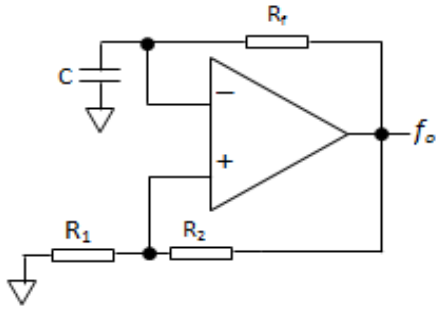


Fig.1: Non- programmable square wave generator

In the proposed circuit the resistor R_f is replaced with binary weighted resistor network. Any one of the feedback resistors (R, 2R, 4R) can be connected by turning on analog switches by the application of the binary code at b_2 b_1 b_0.

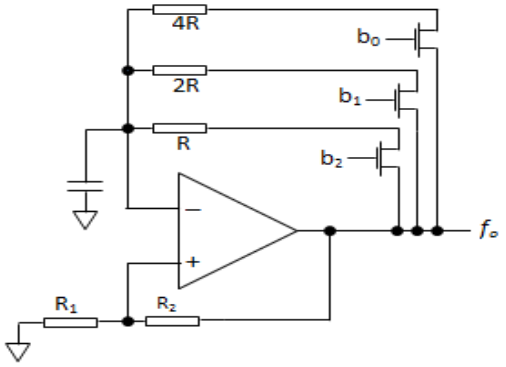


Fig.2: Proposed programmable square wave circuit

For example, when 001 is applied, only one switch is closed and therefore only one resistor i.e. 4R is connected and hence a particular frequency is generated. Similarly for every different code, except 000, a different frequency values can be achieved. At 000 all the switches are open and therefore the feedback path is not closed. If n is the code length, the number of frequencies (N) is equal to

$$N = 2^n - 1 \quad (3)$$

Now choosing $R_2=1.16R_1$, the frequency of oscillation is given by

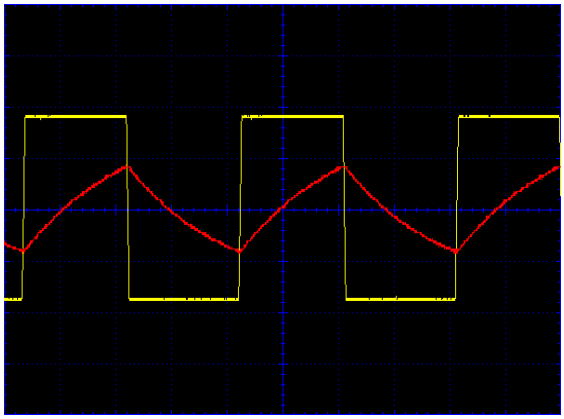
$$f_o = 1/2R_{eq}C \quad (4)$$

where R_{eq} is calculated as follows

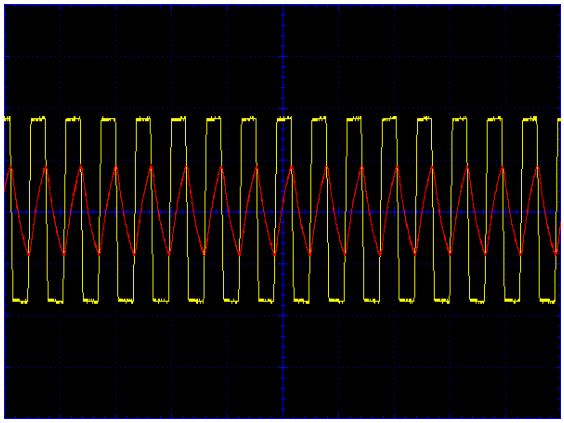
$$1/R_{eq} = [(b_0/4R)+(b_1/2R)+(b_2/R)] \quad (5)$$

3. EXPERIMENTAL RESULTS

The workability of the circuit was tested in hardware using off the shelf components. General purpose operational amplifier IC741 was used within ±10V power supply and CD4066 as analog switches. The capacitor value chosen was 0.047µf and the binary weighted network was implemented using three preset resistors, tuned to 20K, 10K and 5K ohms. The *on* resistance (~125Ω) of switches was not taken into account. The circuit was implemented only for 3-bit code word and seven different frequencies were obtained at different code words from 001 to 111 as shown in Fig.3. The frequencies obtained against the resistances corresponding to binary values are given in table and in Fig. 4(a).



(a) $b_2 = 0 b_1 = 0 b_0 = 1$ (f_o=.515 KHz)



(b) $b_2 = 1 b_1 = 1 b_0 = 1$ (f_o=3.573 KHz)

Fig. 3: Waveforms generated by proposed circuit

Oscilloscope time scale=500µs

Table

Binary *b2 b1 b0*	Resistance (KΩ)	Calculated Frequency f_o (KHz)	Measured Frequency f_o (KHz)
0 0 1	20	.532	.515
0 1 0	10	1.064	1.033
0 1 1	6.6	1.612	1.567
1 0 0	5	2.128	2.057
1 0 1	4	2.660	2.562
1 1 0	3.33	3.195	3.065
1 1 1	2.85	3.733	3.573

Capacitor value=47nf=0.047microfarad

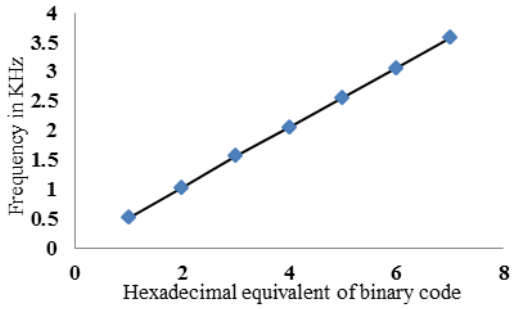


Fig. 4(a)

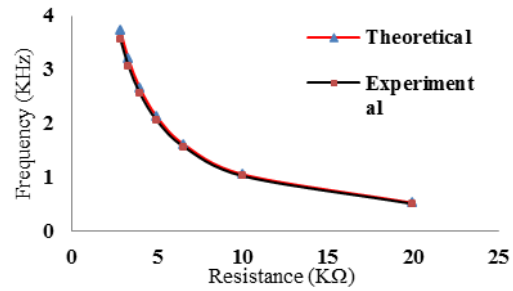


Fig. 4(b)

As depicted from Fig 4(b), the percentage of error increases between the theoretically and practically obtained frequencies, as the resistance decreases. This can be kept small by choosing high slew rate operational amplifier and taking into account the *on* resistance of the analog switches while theoretical calculation.

4. CONCLUSION

A simple square wave generator with digital tuning is presented in this paper. The circuit uses only one operational amplifier, and few active and passive components, which makes it economical for low cost systems.

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BIOGRAPHY

Faroze Ahmad received M.Sc. and Ph.D in Electronics in 2000 and 2007 respectively from University of Kashmir, Srinagar, India. He is presently serving as Assistant Professor in E&C Engineering at Islamic University of Science and Technology (IUST) Awantipora, J&K India. The major areas of research include Message Encryption and Spread Spectrum Communication System.