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Signal generator based on a chaotic circuit

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Abstract This paper describes a signal generator based on Chua's circuit in order to obtain some know wave forms: chaotic, sine, square and triangle signals, with the possibility to generate other types of waves in others forms. The results are tested experimentally. The hardware implementation of the signal generator is very simple.
keywords: Chua circuit, signal generator, analog circuit.

1 Introduction

Though many signals are obtained from transducers, in most cases it is desirable to generate these for any application. Some of the most common examples are the clock pulses generation for timing and control, the carrier signal for transmission of information, test signals for measurement and audio signals for the synthesis of music and voice.

Sinusoidal oscillators for example uses the system theory principles to create a fair conjugate pole pair on the imaginary axis to get sustained sinusoidal oscillation, thus exploiting the instability of the circuit to achieve predictable oscillations. Some of these basic circuits are the Wien bridge oscillator and quadrature oscillators [1,2].

There are also relaxation oscillators that use bistable devices such as switches, Schmitt triggers, logic gates and flip-flops, to repeatedly load and unload a capacitor. The waveforms that are usually obtained there are the triangular wave, sawtooth, square and exponential pulse [3].

There is also another type of signals called chaotic arising from nonlinear oscillators. For example, Chua's circuit is a nonlinear oscillator that has been advantageously used in various applications [4]. In this manner the challenge is how to develop a multifunction signal generator that for one side provided chaotic signals and by other conventional signals (sine, triangle and square).

The purpose of this paper is to design the nonlinear Chua's circuit which naturally will produce chaotic signals, but by changing conveniently the parameters will generate the sinusoidal, square and triangle waveforms. The paper is organized as follows: Sec. 2 presents the mathematical model, the electronic diagram and gives the parameters of Chua's circuit for self oscillating mode. Sec. 3 shows how common type signals are obtained and at end conclusions are drawn.

2 Chua's oscillator

For the generation of signals, we use the Chua's circuit shown in Fig. 1. It contains four linear elements (two capacitors, one inductor and one resistor) and a nonlinear resistance called Chua diode. The set of differential equations describing the dynamic state of the circuit are:

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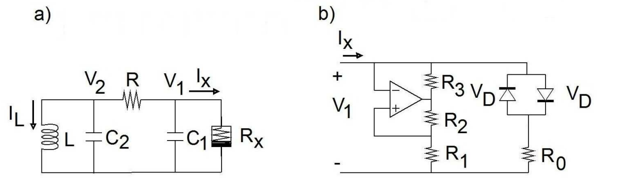

Fig. 1 Diagram for: a) Chuas circuit and b) Chua diode.

$$\begin{aligned}\dot{V}_1 &= \tfrac{1}{RC_1}V_2 - \tfrac{1}{RC_1}V_1 - \tfrac{1}{C_1}I_x \\ \dot{V}_2 &= \tfrac{1}{RC_2}V_1 - \tfrac{1}{RC_2}V_2 - \tfrac{1}{C_2}I_L \\ \dot{I}_L &= \tfrac{1}{L}V_2\end{aligned} \quad (1)$$

Where the dot means time derivatives, and the current in the Chua diode is governed by:

$$I_x = m_1 V_1 - \frac{1}{2}(m_0 - m_1)(|V_1 + V_D| - |V_1 - V_D|)$$

with $m_0 = -\frac{R_2}{R_1 R_3}$ and $m_1 = -\frac{R_2}{R_1 R_3} + \frac{1}{R_0}$.

If the circuit parameters are chosen as shown in column two of Table 1 the circuit will oscillate in a chaotic way. The output of generator will be the potential in the states V_1 and V_2 as shown in Fig. 2.

parameter	Chaos	Periodic
L	$18mH$	$18mH$
C_1	$10nF$	$10nF$
C_2	$100nF$	$100nF$
R	$1.6k\Omega$	$1.54k\Omega$
R_0	$1.2k\Omega$	$1.2k\Omega$
R_1	750Ω	750Ω
R_2	220Ω	220Ω
R_3	220Ω	220Ω

Table 1 Parameter values for the circuits of Fig. 1

3 Sine, square and triangle waveforms

The Chua's circuit must oscillate periodically in order to generate the sinusoidal, square and triangle signals. The circuit parameters are tuned according to the values given in column three of Table 1. With these values the Chua's circuit exhibits the behavior of a point center in the subspace $V_1 - V_2$ Fig.3a, resulting that the state V_2 is a function of time like that of an oscillator circuit, i.e. the Wien bridge, which are stable sine waves (see Fig. 3b). In the oscillatory mode, we use the V_2 potential as a comparator input, producing a square

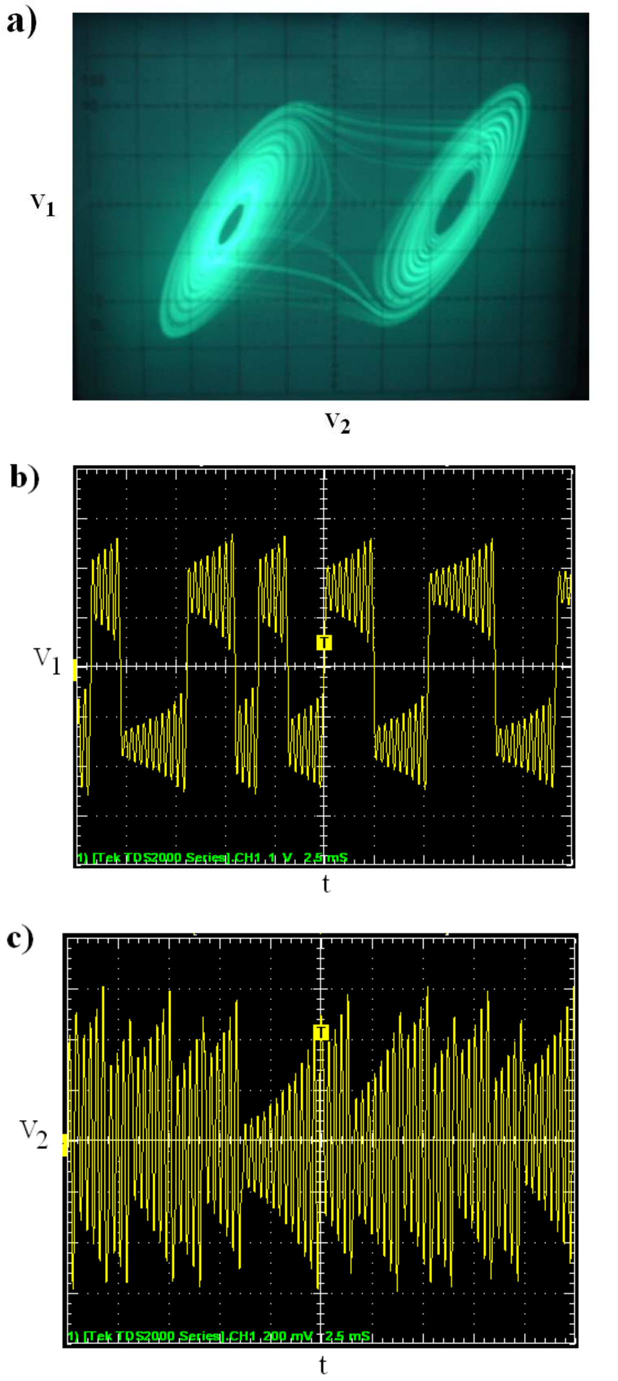

Fig. 2 Node voltages V_1 and V_2 of Chua's circuit as chaotic signal generator.

wave at the output (Fig. 3c). Finally, feeding this output to an integrator we become a ramp signal, since the constant levels of the square wave are transformed to uniformly increasing (negative constant) or decreasing (positive constant) functions of time (Fig. 3d).

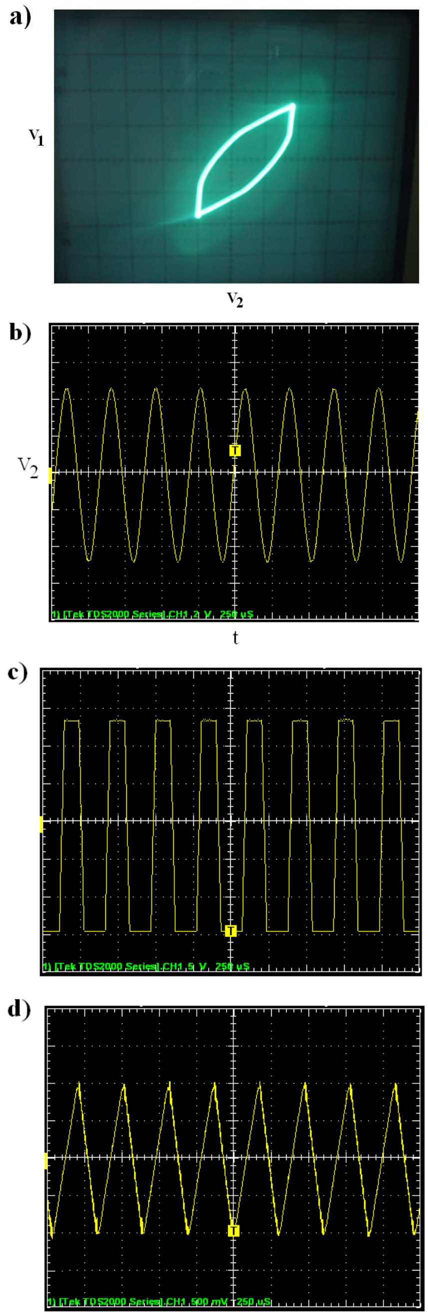

Fig. 3 a) $V_1 - V_2$; b) sine wave generated at node V_2 of Chua circuit (Fig. 1) whit components given in the third column of Table 1; c) square wave generated at the output of A_2 in Fig. 4; d) triangle wave generated at the output of A_3 in Fig. 4.

The complete electronic circuit for generating sine, square and triangle waveforms with its parameters is shown in Fig. 4. The circuit was built with three operational amplifiers (A_1, A_2 and A_3), a resistor and a capacitor, where the output of A_1, A_2 and A_3 are the sine, square and triangle waveforms.

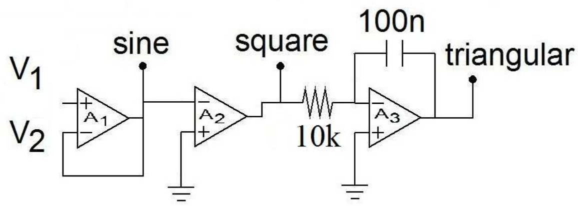

Fig. 4 Circuit for generating sine, square and triangle waveforms.

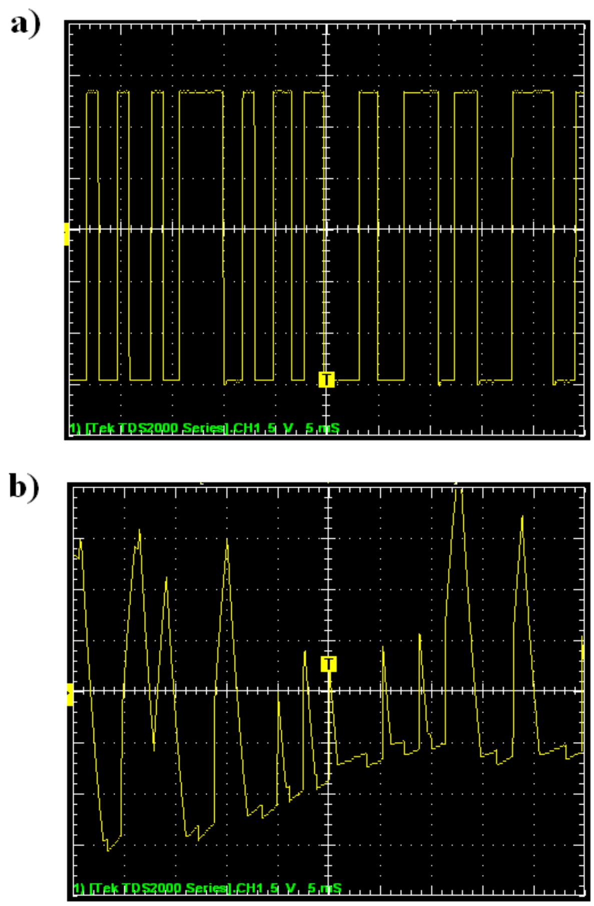

Fig. 5 Non periodic signals: a) square wave; b) triangle signal.

Returning to the chaotic mode Chua's circuit and taking the potential V_1 for feeding the auxiliary circuit the outputs in A_2 and A_3 are non periodic signals, whose square wave and triangle wave are of different pulse width, i.e. pulse width modulation (PWM) as shown in Fig. 5. This kind of signals could be applied to circuits in the field of power electronics, i.e. dc-dc converters, dc-ac, and so on.

On the other hand, the Chua's circuit can change its oscillation frequency by modifying the parameters L, C and R. Fig. 6 shows a new frequency just as you

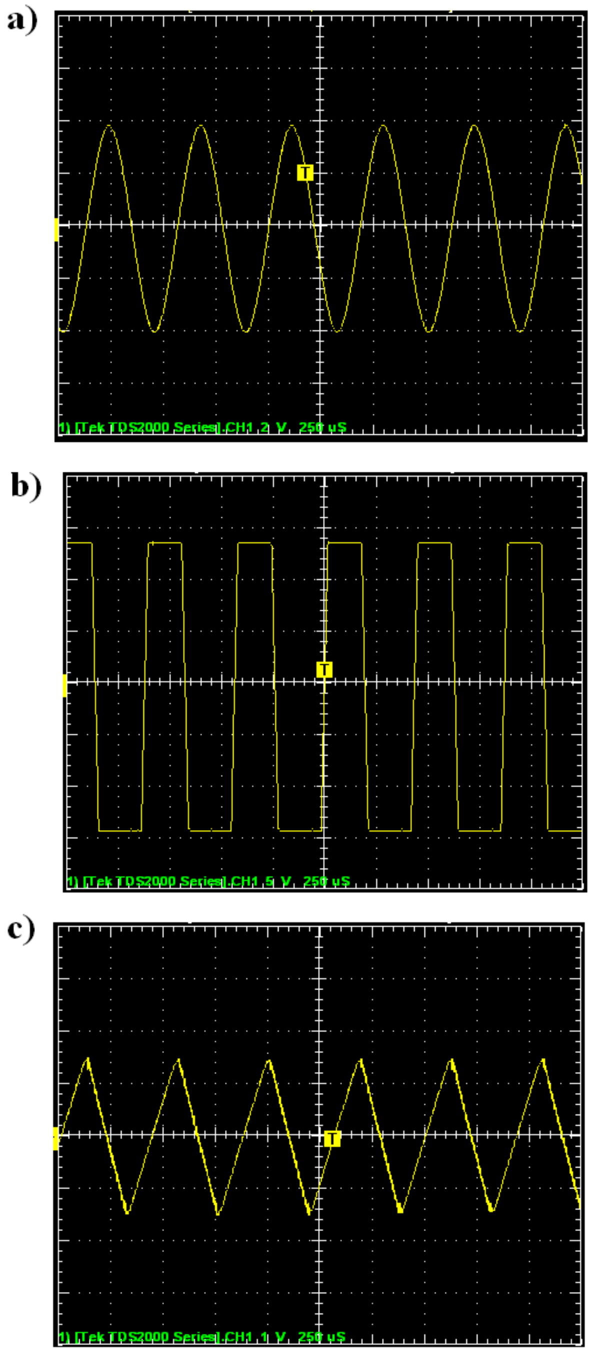

Fig. 6 Frequency change with $C_2 = 220nF$: a) sine wave; b) square wave; c) triangle signal.

would hold a conventional wave generator, for example if you take C_2 as $220nF$.

4 Conclusions

It has been shown that Chua's circuit with an auxiliary circuit is capable to generate chaotic, conventional periodic and non periodic signals. So by modifying the parameters of Chua's circuit one is able to generate signals of different types, for example by tuning the resistance value R. This is easily accomplished at the hardware level if R is a potentiometer instead of a fixed resistor. In the other hand, the output of the auxiliary circuit who is shown in Fig. 4, has a noisy behavior, when the chua's circuit are oscillating chaotically. Also there is the possibility of varying the oscillation frequency by changing the value of C_2. Finally this new class of multifunctional generators can provide support in engineering applications and future research.

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