LOW VOLTAGE CHAOTIC OSCILLATOR

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Abstract: -In this paper a low voltage Colpitts chaotic oscillator is proposed, based on an Electrically Programmable Analog Device matched Pair Mosfet Array (EPAD). The Oscillator is capable of producing chaotic carriers in very low supply voltages, this feature is very useful in mobile and low power consumption utilities.

Key-Words: - Chaos, Colpitts Oscillator, Low Voltage, EPAD.

1 Introduction

In the last few years, dynamical chaos has enjoyed a tremendous attention, and it is considered today a major candidate for future secure communications. Chaotic oscillators, capable of generating chaotic oscillations from audio frequencies up to the optical band, are used as sources of chaotic carriers in a variety of applications including signal masking [1], chaos modulation [2], [3], and spectrum spreading. These chaotic oscillators differ form each other in both structure and element set used. Among them is the classical Colpitts oscillator which, although commonly used to generate sinusoidal signals, with special settings of the circuit parameters it may exhibit chaotic behaviour.

Chaos in the Colpitts Oscillator, first reported in [4], has attracted a lot of interest due to its applications in encryption and modulation methods applied to communication systems. The main premise in these studies is that broad-band signals generated by simple deterministic systems with chaotic dynamics can replace pseudo-random carrier signals widely used in spread spectrum communication systems.

The use of classical Colpitts oscillator with Bipolar Junction Transistor (B.J.T.) requires voltage supply of at least 7 volts. This voltage power it’s quite difficult to be found in mobile low voltage device that they are being using batteries to be supplied. On the other hand it’s possible to produce a higher voltage supply value than the required voltage supply value, but this would be increasing the complicity of the circuit design and implementation. Also the power consumption will be increased and this is something undesirable for mobile devices.

In this paper, a low voltage of a chaotic Colpitts oscillator is proposed. The proposed implementation of EPAD MOSFETs technology [5] adds functionality to the classical Chaos Colpitts Oscillator idea that operated in very low supply voltages. The second benefit from the EPAD MOSFETs is the employment of a floating gate structure, which can be precise, trimmed to produce tightly controlled transistor electrical characteristics. This is a very important feature, because a basic disadvantage of the analogue chaotic systems is the tolerance to the electrical characteristics that the analogue components, especially the active ones (transistors), appear. As a result of this, is the output difference of identical systems and the impossibility of synchronisation.

The outline of this paper is as follows. Section 2 describes the circuit design, which is at first based on a classical chaotic Colpitts Oscillator. Section 3 presents the operational results and section 4 concludes the paper.
2 Circuit Design

Colpitts oscillator is a single-transistor implementation of a sinusoidal oscillator which is widely used in electronic devices and communication systems. The single ended Colpitts oscillator is shown in Fig. 1. It is a combination of a transistor amplifier consisting of a single bipolar junction transistor (BJT), and an LC circuit used to feedback the output signal as it is depicted in Fig. 1. The fundamental oscillation frequency is given by:

\[ f = \frac{1}{2\pi \sqrt{L_1 \frac{C_2}{C_1 + C_2}}} \tag{1} \]

The intrinsic nonlinearity of Colpitts oscillator, which depends by the exponential characteristic of the active device, easily leads to obvious indications of chaotic behavior such as positive values of Lyapunov exponents. For a specific set of parameters values, the oscillator exhibits a complex dynamic behavior which is described by the system’s attractor (Fig.2).

The output buffer is powered by \( V_L \) with pull up resistor \( R_{OUT} \), which can be selected to optimize the output voltage swing levels as well as providing adequate output drive currents. \( V_L \) is an output voltage level that can be equal to, higher than or lower than \( V_+ \), depending on desired output voltage swing levels. \( R_{OUT} \) must be selected for a selected \( V_L \) and at the same time minimize current drain. The output buffer performance data:

\[ V_+ = 0.5V, \ I_+ = 25 \mu A, \ P_D = 12.5 \mu W, \]
\[ f_{\text{fundamental}} = 1MHz \]
\[ V_+ = 5.0V, \ I_+ = 250 \mu A, \ P_D = 1250 \mu W, \]
\[ f_{\text{fundamental}} = 1MHz \]

The oscillator circuit performance data [5]:

- \( V_+, I_+, P_D \) values
- \( f_{\text{fundamental}} \) values

In figure 3 is the low-voltage LC (Colpitts) oscillator circuit using EPAD MOSFETs that operates on a single supply ranging from 0.5V to 5V. A dual EPAD MOSFETs is connected in parallel to provide more low voltage drive current at lower supply voltages.
The fundamental frequency of the circuit in Fig. 3 can be calculated by equation (1). The system in Fig. 3 can describe by the set of differential equations (3) if we take account of all the following suggestions.

- The resistance $R_L$ has a very low value. Because of the extremely low value of the drain current ($<100\mu A$), the voltage drop is also extremely low.
- The bias current of the gates and the two MOSFETs is in the range of 10pA Therefore it can be considered as negligible in terms of the drain current.
- The resistance $R_F$ has a very high value and the current goes through can be considered as negligible.
- The capacitor $C_i$ represents the capacitance that in fact can be appeared in a coil. The capacitance value has a very low value and therefore it can be considered as negligible.

$$C_{L_2} \frac{dV_{DS}}{dt} = I_{R_D} - I_D - I_{L_1}$$

$$C_{L_1} \frac{dV_{GS}}{dt} = I_{C_1}$$

$$L_1 \frac{dl_1}{dt} = V_+ - R_D I_{R_D} - V_{DG}$$

(2)

The drain current is equal to source current:

$$I_D = I_S$$

(3)

The non-linear voltage-current forward transfer characteristics of the gate-source junction can be shown in figure 4 and 5 and can be approximated by a piecewise linear function.

Figure 4. Forward Transfer Characteristics of ALD110800.

Figure 5. Gate Source Voltage vs. Drain Source ON Current of ALD110800.

3 Simulation and Experimental Results

Figure 6 shows the chaotic attractor portrait of the low voltage chaotic oscillator that has been produced from the simulator program dynamic solver, which is appropriate for dynamic systems simulations. The attractor form shows clearly that the system is being in a multi-harmonic chaotic operation.
The experimental device was implemented on a printing circuit board using quad N-channel zero threshold EPAD matched pair MOSFETs array ALD110800. The values of the peripheral circuit elements were those of Table 1.

In order to obtain as much as possible stable and recurrent results, the bias of the active elements was achieved using resistors and capacitors of small tolerance (1%) and very stable voltage sources. The chaotic attractor from the experiment circuit is depicted in figure 5. Also, it’s obtained that the two attractor diagrams (fig. 6 and fig. 7), the first one from the simulation and second one from the experiment, are interrelated.

### Table 1. Circuit Parameters Values used in Simulation and in Experiments

<table>
<thead>
<tr>
<th>Circuit Elements</th>
<th>$V_i$</th>
<th>$I_i$</th>
<th>$P_{DI}$</th>
<th>$V_L$</th>
<th>$I_L$</th>
<th>$P_{DL}$</th>
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<td>2.5 V</td>
<td>125 $\mu$A</td>
<td>625 $\mu$W</td>
<td>2.5 V</td>
<td>67 $\mu$A</td>
<td>167 $\mu$W</td>
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<td>$R_{DC}$</td>
<td>$R_F$</td>
<td>$R_L$</td>
<td>$C_{L1}$</td>
<td>$C_{L2}$</td>
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<tr>
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<td>2.2 $\Omega$</td>
<td>5.35 $\Omega$</td>
<td>4.7</td>
<td>10 $pF$</td>
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<tr>
<td>Circuit Elements</td>
<td>$L_i$</td>
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<tr>
<td>Elements' Values</td>
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### 4 Conclusion

The proposed chaotic oscillator uses an Electrically Programmable Analog Device matched Pair MOSFET Array (EPAD) as an active component, for the accomplishment of the required amplification from the Colpitts circuit, needed for the oscillation maintenance. Both the simulation and the experimental procedures have been generated chaos under certain conditions that have been created by the use of the appropriate settings and components use.

The use of the EPAD MOSFET, adds to the standard Oscillator circuit two more very important features:

1. The ability to operate with very low voltage values, which is very useful for applications that...
require low voltage operation, like remote battery-operated sensors with low power consumption.

2. Due to the similar MOSFET manufacturing and settings, they produce much related operation characteristics and thus an almost identical output.

References:


