Performance of an Oscillator with Bipolar Junction Transistors Operating at Ultralow Voltage

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1. Abstract

An oscillator using inductive coupling of the bases with bipolar junction transistors is proposed, able to operate with ultralow voltages. The topology needs a bias voltage at the bases, and we present a circuit called starting block that generates this voltage from the supply. The circuit was capable of starting with a minimum supply of 69 mV and delivers up to 173 µW from 100 mV.

2. Introduction

Autonomous systems like implanted devices, wireless sensor networks and embedded systems require an energy source, usually in the form of a battery or supercapacitor. The miniaturization and reduction of power consumption in modern electronic devices enables using alternative energy sources as a way of extending the lifespan of these systems. The energy can be supplied by the environment, as sunlight, vibration, heat or RF waves. The process of extracting and suiting this energy is called usually as energy harvesting.

The development of energy harvesting systems presents challenges. The search is for highly efficient and very low consuming circuits. The energy rate is usually not constant and the system must be able to work even at absence of it.

Additional constraints are the current and/or voltages levels: some sources can supply only dozens of milivolts or nanoamps. The system must be able to scavenge the energy in such low levels.

One approach to harvesting energy of low voltage sources is designing oscillators that can operate in these conditions.

A simple solution of an ultralow voltage oscillator with moderate volume and power capacity is proposed in [1]. However, the performance of this circuit is related to the behavior of the MOS transistors as controlled resistors. In order the circuit reaches high efficiency, they should present a low resistance when conducting. This implies in a large overvoltage in the gates and/or transistors with large area. A large overvoltage is obtained with high turns ratio in the transformer.

Bipolar junction transistors (BJT's), although have exponential relationships between currents and voltages. This suggests that, for a given current, the transistors might have a smaller area or the circuit might need a transformer with a lower turns ratio.

Preliminary results of a version with BJT's of the circuit proposed in [1] were already presented [2]. In that short brief the circuit was evaluated using an external bias voltage at the bases. However the need of this bias voltage limits the application of the oscillator to the systems where it is available.

In this paper a circuit, called starting block, which generates the base voltage from the power supply is introduced, turning the oscillator independent of a preexistent voltage. In Section 3 the oscillator is reviewed for clarity. In Section 4 the starting block is presented. Section 5 brings experimental results with a prototype using commercial BJT's and a starting block. Analysis of the results is made in Section 6.

3. The Proposed Oscillator

The proposed circuit is a variation of the oscillator with inductive coupling of the bases (Fig. 1). This kind of oscillator is described in the literature of RF circuits [3], where it is used as harmonic oscillator.

The operation of the proposed circuit is initially as astable multivibrator. The simple idea is constructing the base inductors with a high turns ratio, enabling that a voltage variation in the collectors induces a higher enough voltage at the bases that can sustain the oscillation.

The voltage excursion of the circuit is controlled by the bias voltage V_B. This node has low current consumption that can be supplied by the internal battery or supercapacitor of the autonomous system.

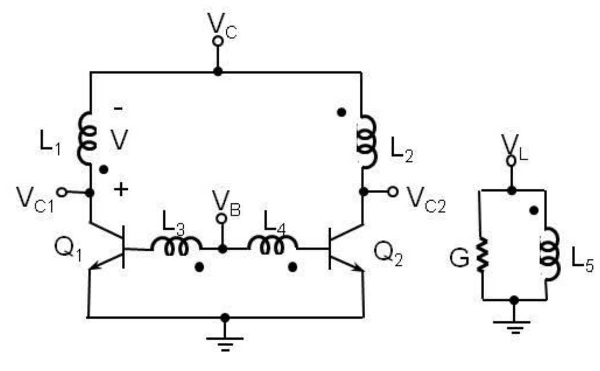

Fig.1. *Proposed oscillator.*

4. The Starting Block

We propose here a block, illustrated in Fig. 2, that can derive V_B from V_C, enabling that the circuit operates with only one power supply. Basically the transformer T_1 generates a voltage pulse that starts the oscillation. L_6 and L_7 form feedback loops that stabilize the voltage after the action of the pulse from the transformer. More details of its working principle can be found in [4]. Although a second feedback loop is not essential, its advantage will be apparent in next section.

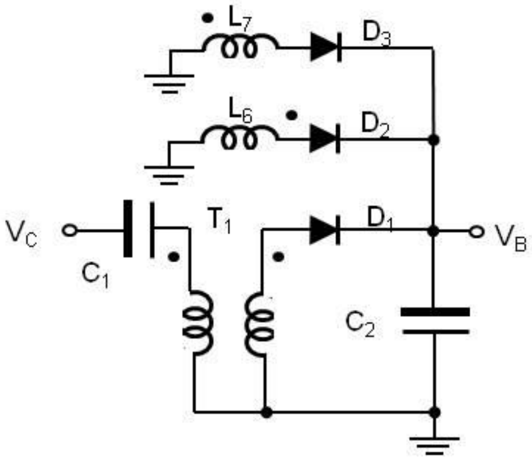

Fig. 2. *Starting block.*

5. Experimental Results

A prototype of the circuit was assembled using discrete transistors from NXP BC868 family, due to their high β_R's (30.57). It can be shown [4] that this parameter defines the output excursion.

A magnetic circuit was manufactured including the turns aimed to be used as feedback to the starting block. Table I shows the values of this circuit.

Schottky diodes BAT754C were used in the circuit, in order to take advantage of their low voltage drop. The components of the starting block are listed in Table II.

Table I. *Parameters of the magnetic circuit.*

Parameter	L_1 & L_2	L_3 & L_4	L_5
Value	165 µH (4 turns)	611 µH (8 turns)	165 µH (4 turns)

Table II. *Parameters of the starting block.*

Parameter	L_6 & L_7	T_1 prim.	T_1 second.	C_1
Value	19.4mH (45 turns)	11.2 µH (2 turns)	2.08 mH (40 turns)	10 µF

The prototype was evaluated with one and two feedback loops. Its minimum starting voltage without load was 69 mV for both conditions (Figs. 3 and 4). Average voltages at V_B were 460 mV and 510 mV for one and two feedback loops respectively.

The circuit started delivering 69 µW and 173 µW with one and two feedback loops respectively, from a power supply of 100 mV.

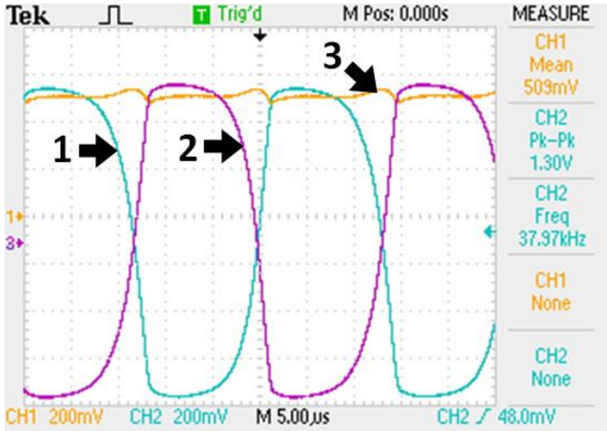

Fig. 3. *Voltage waveforms for the circuit with two feedback loops: L_6 (1), L_7 (2), V_B (3).*

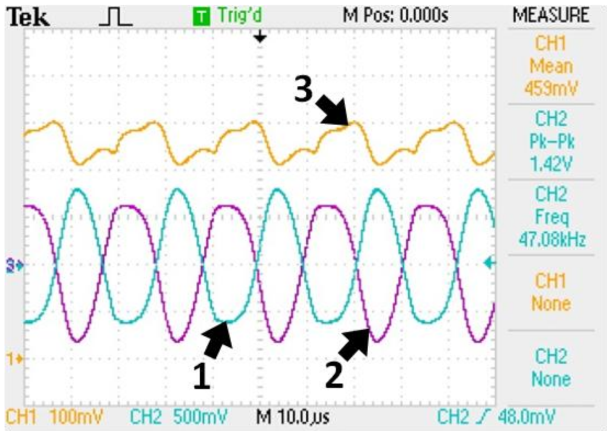

Fig. 4. *Voltage waveforms for the circuit with one feedback loop: L_6 (1), L_7 (2), V_B (3).*

6. Conclusions

An oscillator, able to operate with voltages as low as 69 mV, was proposed. The circuit uses a block that generates the bias voltage at the bases from the power supply, making it independent of a preexistent voltage.

The performance of the circuit is best when using two feedback loops. This is due to higher and more stable bias voltage at the bases, obtained with the full-wave rectification of the oscillating waveform in this condition.

References

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