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Studies on the operation of trap filters and oscillators systems based on ceramic resonators at the cryogenic temperatures

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ABSTRACT

We investigated the temperature dependence of the applications of piezo PZT ceramic resonators down to 93 K in oscillators and filters circuits inside a frequency range of 400 kHz–4.0 MHz. For both systems, their waveforms were plotted at different temperature values ranging from room level (293 K) down to (93 K). From which, it is clearly shown that, cryogenic temperature effect on the operation of the trap filter system was shown to increase the voltage value at stop-band from 1.40 V, measured at 293 K, up to 4.40 V. The rise and fall times of the square wave oscillator were shown to increase slightly with temperature decreasing. Initial values of 92.3 ns, and 85.8 ns, measured at 293 K, were observed to increase up to 106 ns and 107 ns, measured at 93 K, respectively, while the signal output was kept constant. But for the sine-wave oscillator, its frequency, and output voltage were shown decrease as the temperature decreases

1. Introduction

The ceramic resonator is mostly principally used as filters and oscillators circuits in different applications. The ceramic resonator is often used instead of a quartz crystal because of its lower price. The frequency accuracy is not as good as a quartz crystal but in many applications the accuracy is not critical. The ceramic resonator uses the mechanical resonance of piezoelectric ceramics, generally Lead Zirconium Titanate, PZT. The ceramics are made of high stability piezoelectric ceramics that functions as a mechanical resonator. The frequency is primary adjusted by the size and thickness of the ceramic element. Typical application includes TVs, VCRs, telephones, communications, remote controls and radios. Finally, the uses of ceramic resonators and novel circuit techniques have led to a line of low-cost ceramic resonator oscillators with low phase noise over a wide temperature range. This of course is of great importance in space applications, where, the environmental temperature on many NASA missions, such as deep space probes and outer planetary exploration, is significantly below the range for which conventional commercial–of-the-shelf electronics is designed [1–3]. Presently, spacecraft operating in the cold environment of such deep space missions carry a large number of radioisotopes or other heating units in order to maintain the surrounding temperature of the on-board electronics at approximately 20 °C. So, electronic devices and circuits capable of operation at cryogenic temperature levels will not only tolerate the harsh environment of deep space but also will reduce system size and weight by eliminating or reducing the heating units and their associate structures [4–6]. So, the present paper will focus on how extreme low temperature can affect space craft electronics. In this concern, the ceramic resonators were chosen to be subjected to such very low temperature level environments in order to determine the tolerance degree on their characteristics.

During the present work, the authors concentrated their interest on studying the cryogenic temperature effects on the electrical parameters of the ceramic devices, simulating their applications in outer space.

1.1. Ceramic trap filter

In the field of electric signals filtration, the circuit shown in Fig. 1 can be used as ceramic trap filter system, where a dual terminal ceramic resonator is inserted in parallel with function generator, with 1.0 V sine-wave signal amplitude, and resistors R_1 and R_3 having values 9.0 kΩ and 1.0 kΩ, respectively. Also, R_2 connected in series with the resonator having value equals 75 Ω. The circuit has wide applications on sound trap for TV sets and video signal in picture amplitude circuits.

1.2. Ceramic oscillators

Ceramic resonators are generally operated in the parallel resonance mode. This allows the use of an inverting amplifier or logic

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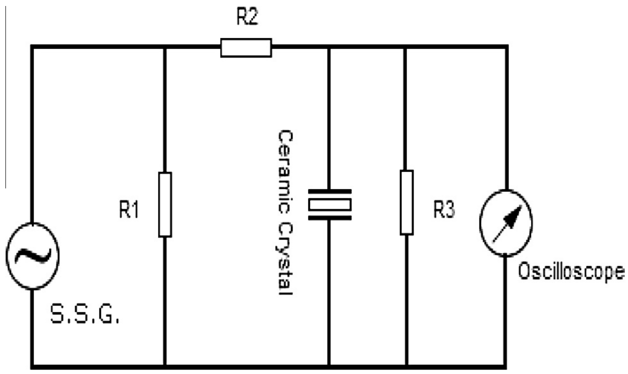

Fig. 1. Trap ceramic filter circuit.

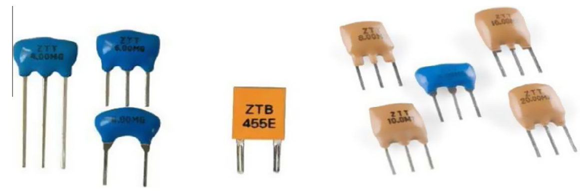

Fig. 3. Some of the investigated ceramic resonator samples.

Table 1
Passive element values of the square wave oscillator circuit.

Frequency range	V_{DD}	Circuit constants			
375–0429 kHz	+5.0 V	C_1 (pF)	C_2 (pF)	R_f (MΩ)	R_d (kΩ)
		120	470	1.0	0
430–0699 kHz		100	100	1.0	0
700–1250 kHz		100	100	1.0	5.6
3.40–10.00 MHz		15.0	15.0	1.0	0

inverter which provides 180° of phase shift. The combination of the resonator in the inductive portion of its response curve, and the load capacitors provide the balance of the 360° of phase shift around the oscillator loop needed to maintain oscillation. In addition, the gain of the amplifying device must be sufficient to maintain a loop gain greater than or equal to unity to sustain oscillation [7–9]. The oscillation frequency specified for a particular resonator is the frequency at which the device will operate when used with a specific integrated circuit and with appropriate load capacitors. Fig. 2a shows the configuration of a basic square wave oscillation circuit (Pierce circuit) with a typical two CMOS inverters in which, a ceramic resonator is simply put across the input and the output of CMOS inverter.

On the other hand, Fig. 2b shows the configuration of Colpitts sine wave type oscillation circuit with a transistor, in which the amplifier is an emitter–follower. As a consequence, this circuit is used as sine wave oscillator in which the used values of resistors and capacitors are to be R_1 = 1.0 kΩ, R_2 = 30 kΩ, C_1 = 1.0 nF, and C_2 = 4.68 nF. In this configuration, the ceramic crystal operates in a parallel mode. When running in this mode, the resonator should be presented with a load capacitance to operate on its correct frequency. So, Feedback is provided via a tapped capacitor voltage divider (C_1 and C_2) which form a capacitive voltage divider that couples some of the energy from the emitter to the base. On the other hand, R_1 is the emitter resistor and R_2 is the bias resistor. So, together with the loading capacitors (C_1, C_2) and transistor, this

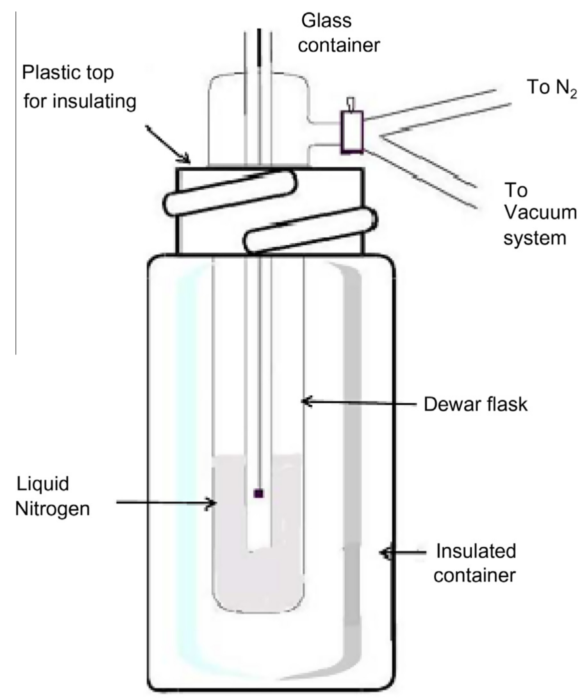

Fig. 4. Cooling system used for controlling the samples low temperature levels.

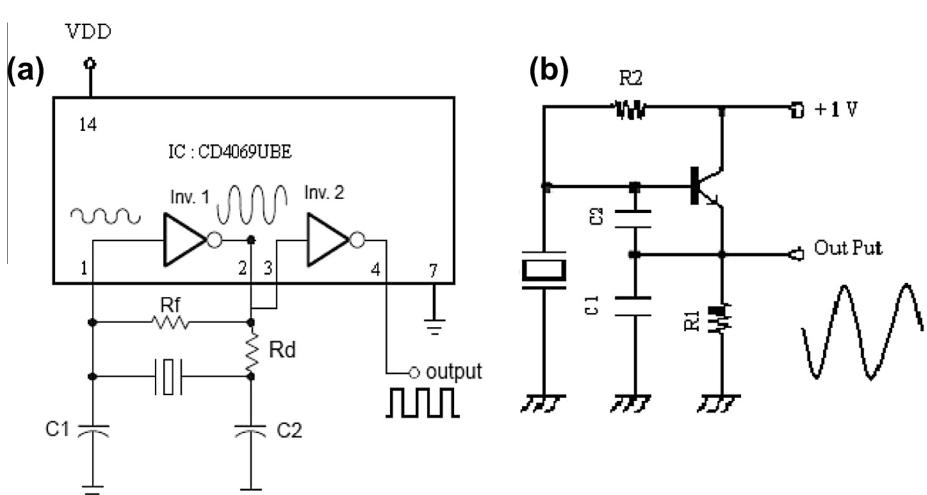

Fig. 2. PZT ceramic (a) square wave oscillator – and (b) Colpitts sine wave oscillator – circuits.