Analysis of Frequency Domain Data Generated by a Quartz Crystal

Fabian N. Murrieta-Rico
https://orcid.org/0000-0001-9829-3013
Universidad Politécnica de Baja California, Mexico

Moisés Rivas-López
https://orcid.org/0000-0001-8751-4693
Universidad Politécnica de Baja California, Mexico

Oleg Sergiyenko
https://orcid.org/0000-0003-4270-6872
Universidad Autónoma de Baja California, Mexico

Vitalii Petranovskii
Universidad Nacional Autónoma de México, Mexico

Joel Antúnez-García
https://orcid.org/0000-0003-3668-1701
Universidad Nacional Autónoma de México, Mexico

Julio C. Rodríguez-Quiñonez
Universidad Autónoma de Baja California, Mexico

Wendy Flores-Fuentes
https://orcid.org/0000-0002-1477-7449
Universidad Autónoma de Baja California, Mexico

Abelardo Mercado Herrera
Universidad Politécnica de Baja California, Mexico

Araceli Gárate García
Universidad Politécnica de Baja California, Mexico

INTRODUCTION

Quartz crystals are versatile devices with plenty of applications. Their primary application is in the development of time-keeping devices, but also, they are used as actuators or sensors. After some electrical connections with other devices, an electrical signal is generated, and its frequency is defined by the proper frequency of crystal. Some popular circuits used for a building resonating circuit are Colpitts oscillator or gate oscillator (Frerking, 1978). As any other device, the functioning of the resonating circuit is affected by quite diverse effects, such as: crystal aging, different forms of jitter, frequency drift, thermal

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variations, etc. Most of these effects have an influence in the signal that is generated, for this reason an analysis of such data is desired. In case when the resonating circuit is connected to a frequency counter, the measured frequency is obtained over time, and analysis of data is possible. In this sense, the frequency counter plays an important role, because the measurement characteristics define how the data is obtained.

BACKGROUND

There are different methods for frequency counting that include conventional counters, reciprocal counting, interpolating reciprocal counting, time-stamping counting, method for measurement of absolute values, method for measurement of relative values, and universal method of dependent count (Johansson, 2005; Kalisz, 2004; Kirianaki et al., 2001). In the recent years, the principle of rational approximations has been proposed for measuring the frequency of a desired signal. This method requires to compare a signal to measure with other whose frequency is known. Both signals are required to go through a signal conditioning process, where the signals are converted into streams of pulses with a rectangular shape, which appear at regular intervals defined by the frequency of original signals (Hernández Balbuena et al., 2009). These conditioned signals are compared using an AND condition, and a third signal is generated: the signal of coincident pulses. As a result, a coincidence appears where a pulse of the desired signal overlaps in time with a pulse of the reference signal. After the first coincidence, the counting of pulses in three signals starts; when there is another coincidence, an approximation to the desired frequency is obtained. As any other time-frequency measurement technique, when the measurement time increases, the accuracy of measurement increases and uncertainty decreases. The principle of rational approximations has plenty of advantages over other measurement techniques, namely: continuous measurement without dead time, uncertainty limited by the accuracy of reference frequency, approximations to desired frequency are obtained in very short time, and ease of implementation (Avalos-Gonzalez, Sergiyenko, et al., 2018; Murrieta-Rico, Sergiyenko, et al., 2016; Murrieta-Rico et al., 2017, 2018; Murrieta-Rico, Petranovskii, Galván, et al., 2021).

A continuous measurement generates a vast amount of information, and in most cases, these datasets are difficult to interpret. Among the tools available for data analysis, the principal component analysis (PCA) is a method that is widely spread, and it allows to obtain information regarding the relationship of measured variables. In the PCA, the dimensionality of input datasets is reduced, the interpretability is increased and loss of information is avoided; this is done after the creation of new and uncorrelated variables, which successively maximize variance (Jolliffe & Cadima, 2016). Although PCA has been widely developed from statistics point of view, it finds quite diverse applications. Some of them include, dimension reduction on non-Euclidean manifolds with PCA (Mardia et al., 2022), diagnosis of dental pathologies (Nouir et al., 2022), geographically and temporally weighted analysis (Han et al., 2022), etc.

In this work, a quartz crystal and a resonator circuit are used for generating an electrical signal. Then, a frequency counter is used for measuring the generated frequency. The frequency counter uses the principle of rational approximations, and measurement over long time is available. Consequently, a vast amount of data is generated. Then, the generated information is analyzed using PCA. At the same time, the measurement process is simulated using the experimental conditions. The experimental results are compared with the theoretical outcome, and conclusions regarding the effects that define the measured frequency are drawn. The methodology here proposed aims to work as basis for future applications, where different applications of quartz crystals will be explored.

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