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One shot bipolar saw tooth-like waveform converter as piezoelectric driver of stick-slip motion

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Abstract: A novel one shot bipolar saw tooth- like waveform converter that can be used as a piezoelectric (PZT) driver of stick-slip motion is presented. It can provide accurate displacement of a PZT actuator with a single-step adjustment.

Index Terms- **waveform, converter, piezoelectric, stick-slip.**

I. INTRODUCTION

Since the invention of scanning probe microscopy in 1982, it has been an important tool for the study of surface science because it mainly involves the use of tiny probes to detect features of a sample surface on the nanometer or even atomic scaleand shows three-dimensional features of the sample surface and the second surface [1]. To date, dozens of types of probe microscopy have been developed, and these scanning probe microscopes have a common requirement:scanning should be conducted using different types of PZT platforms. The main reason for using piezoelectric devices is that they can facilitate displacements on the order of micrometers or nanometers. Over the past 40 years, many studies related to the piezoelectric element driver have been published [2]-[9].But, the use of the stick-slip friction movement concept for the piezoelectric actuator has rarely been discussed; it was discussed by Eng et al.[5] and Mariotto et al.[7] in 1996 and 1999, respectively. These authors only mentioned the use of unidirectional saw tooth and unipolar quarter sine waves for driving a PZT tube. The aforementioned studies did not provide any information about the use of one-shot motion for achieving a single micro step adjustment and obtaining accurate positions. In this article, the overall design of a one shot bipolar saw tooth- like waveform converter is discussed; the waveform converter was constructed and used in the current study. A detailed schematic of each component is presented. Our major objective was to use the one-shot bipolar saw tooth-like waveform converter as a PZT driver capable of stick-slip motion.

II. THE CONCEPT

The concept and detailed circuit of the one shot bipolar saw tooth- like waveform converter is shown in Fig. 1. IC1 (TL494) acts as the ramp waveform generator and produces a ramp with period 2*w*on the basis of the value of the variable resistor (VR2) and capacitor (C2). The operational amplifier integrated circuit (TL084) provides four operational amplifiers (OP1a–OP1d) in the same package. The AC coupler involves resistor R7 and capacitor C3, and it can produce a bipolar ramp wave signal. The operational amplifiers (OP1a, OP1b, and OP1d) act as buffers and provide impendence matching to guarantee the absence of the load effect. The operational amplifier OP1c has high gain feedback and it acts as a zero-crossing function to convert the bipolar ramp wave into a bipolar square wave. The diode (D1) clamps the bipolar square wave, producing a unipolar square wave that is provided to the input of the divided-by-two circuit. The divided-by-two circuit is constructed using D flip-flops, named as IC2 (CD4013), and its output wave is a square wave with a fifty-fifty duty ratio. Its period is twice the ramp wave period.

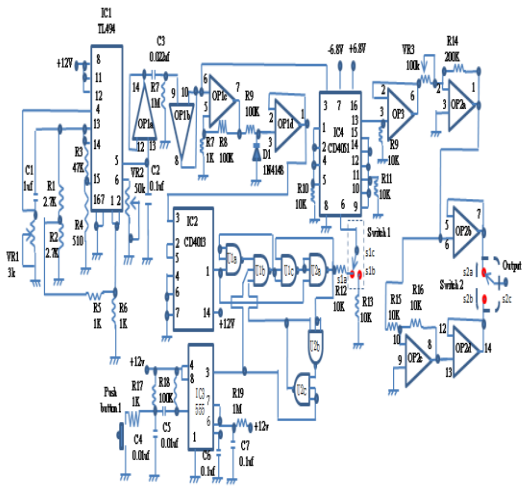

Fig. 1. The detail schematic of one shot bipolar saw tooth-like waveform converter.

The sync-gate-controlled circuit has a simple structure and consists of six three-input NAND gates (CD 4023), which are labeled U1a–U1c and U2a–U2c. The circuit has two inputs and one output. IC3 (CA555) acts as a monostable circuit and can provide a one-shot signal. The one-shot signal is provided when Button 1 is pressed. The time width of the one-shot signal is determined by resistor R19 and capacitor C7. Pin 3 of IC3 (CA555) provides a one-shot signal to input U2c of the sync-gate-controlled circuit. Basically, the time width of the one-shot signal must be larger than that of the waveform generated by the ramp wave generator. IC4 is an analog switch with a power supply of ±6.8 V. It requires a bipolar power supply because the ramp wave provided to its input is bipolar. The output of the analog switch has a wave shape and bipolarity identical to those of its input. The single-pole double-throw (SPDT) switch (Switch 1) has three connect points—s1a, s1b, and s1c. Point s1c is connected to Pin 6 of IC4. When both s1c point and s1b point of Switch 1 are connected, the analog switch is always turned on. When both the s1c point and s1a point are connected and there is a high-level signal at output U2a of the sync-gate-controlled circuit, the analog switch of IC4 is turned off. The operational amplifier (OP2) acts as a buffer between the output of the analog switch and the inverter amplifier and prevents the load effect of the resistor network of the operational amplifier (OP3a). The operational amplifier OP3-TL084 has four operational amplifiers in the package (OP3a–OP3d). OP3a is an inverter amplifier, and its gain can be adjusted to obtain a bipolar ramp wave with the required amplitude. The operational amplifier (OP3c) is also an inverter amplifier and its gain is one; it is used to obtain the inverse phase of the bipolar ramp wave of the output of OP3a. The SPDT switch (Switch 2) also has three connect points, s2a, s2b, and s2c. The s2c point is the output of the one shot bipolar saw tooth- like waveform converter. The output ramp wave has a positive slope when both s2b and s2c points of Switch 2 are closed. By contrast, the output ramp wave has a negative slope when both s2a and s2c points of Switch 2 are closed.The forward direction of the bipolar saw tooth-like waveform is a signal voltage with a constant slope from the zero voltage point to the positive maximum voltage and a sharp decrease to the minimum negative voltage; the signal voltage subsequently shows a constant slope from the negative minimum voltage point to the zero voltage point. By contrast, the backward direction of the bipolar saw tooth-like waveform is a signal voltage with a constant slope from the zero voltage point to the minimum negative voltage and a sharp increase to the maximum positive voltage; subsequently, the signal voltage shows a constant slope from the maximum positive voltage to the zero voltage point. Figure 2 shows two one-shot bipolar saw tooth-like waveforms obtained experimentally; the upper trace represents the backward direction for a stick-slip motion PZT driver and the lower trace indicates the forward direction for a stick-slip motion PZT driver.

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Fig 2 the upper trace represents the backward direction and the lower trace indicates the forward direction for a stick-slip motion PZT driver

III.CONCLUSION

The bipolar saw tooth-like waveform converter can also provide a continuous bipolar saw tooth-like waveform that can be used for continuously driving PZT elements. The waveform converter is connected to a linear high-voltage amplifier (PA94) that its instantly transfer time of the output of PA94approximately 18 μs for the range ±400 V. A digital ramp generator is better than an analog ramp generator because its instantly transfer time easily affects the discharge time of the capacitor in the analog circuit. A sine wave generator is positioned of a ramp generator in a oneshot bipolarsinewaveform converter. However, the concept of one-shot bipolar saw tooth-like waveform converter can be modifiedto obtain any one-shot arbitrarily bipolar waveformconverter.

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