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Review of Piezoelectric Shapes and Piezo Controller.

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ABSTRACT: In today's world nanotechnology is helping to considerably improve, even revolutionize, many technology and industry sectors. Since nanotechnology is based on the size factor the movements in these applications will also be relatively small. There are many applications in the industry which require movement in microscale such as fine adjustment of lenses and mirror in telescope as well as in high power atomic microscope. Thus, the proposed system uses a piezo disc which is a material with low hysterics and have a property of bending when given a consistent voltage due to inverse piezo-electric effect. Implementing this idea can be a change and cost-efficient method as it requires only few pennies to buy a piezo disc replacing the conventional method to get the required displacement in micro scale.

Keywords:DRV2700 HV500 piezo controller board,piezo actuators, piezo disc, piezo stack, piezo tube, X7R dielectric MLCC capacitors.

I. INTRODUCTION

This paper is introduced to review the piezo controller design and application of piezoelectric materials with the use of a DRV2700 HV500 piezo controller board which is used to drive the various piezo materials and to observe the displacement caused by them using a plunger type Dial indicator which is capable of measuring displacement in micrometre scale. The main piezoelectric shapes used here to review are the piezo actuators, piezo disc, piezo stack, piezo tube and the X7R dielectric MLCC capacitors.

The DRV2700 Industrial Piezo Driver with Integrated Boost Converter is a single-chip piezo driver with an integrated 105V boost switch, integrated power diode, and integrated fully differential amplifier. This is capable of driving both high-voltage and low-voltage piezoelectric loads. A typical start-up time of 1.5ms makes the DRV2700 device an ideal piezo driver for coming out of sleep quickly. Thermal overload protection prevents the device from damage when overdriven.

This paper also reviews the displacement obtained through various piezo materials and comparing it with each other. For this we use an analogue device which is known as the plunger type dial indicator. It is a simple analogue device with a simple design it consists of a pin which faces vertically downward and placed on the test object to determine the displacement as the pin presses inwards the corresponding reading is taken and displayed on the dial.

[1]. The study, shows a comparison between the piezo disc, piezo tube and the piezo stack when given the voltage of -10V to +10V a displacement of up to -6μm to +6μm on giving the corresponding voltages of alternate polarity. Similarly, when voltage of -30V to +150V it correspondingly showed the displacement from -6μm to +6μm alternately. On moving further when a voltage ranging from -200V to +200V the same displacement was observed as earlier in the above two cases. After comparison the three cases it is observed the piezo disc are best suited to generate such micro displacement due to low hysteresis.

[2].The piezoelectric actuators are used inhigh force and large displacement in compact sizes, high resolution within the nanometre range, very short response time below 1ms, life time greater than 10^{10} cycles, low voltage supply below 150V DC, no backlash and no play, low power consumption when static, severe environment compatibility. Actuator applications of piezoelectric started,aiming at consumer applications such as precision positioners with high-strain materials, multilayer device designs and mass fabrication processes for portable electronic devices, ultrasonic motors for micro robotics and smart structures.

[3].The industrial-grade X7R type multilayer ceramic capacitor is as an actuator.At a DC bias voltage, the ceramic capacitors exhibit a large converse piezoelectric effect which can be

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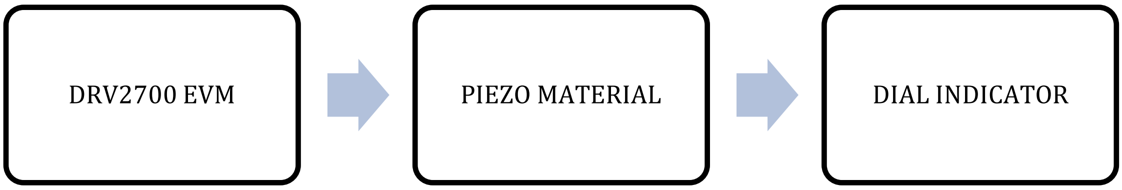
used for actuating applications. Here, in this study it has shown the comparison between three X7R dielectric capacitors of capacitance 10,47 and 100µF respectively. These piezoelectric actuators are widelyin many applications such as micro-positioning systems which desire features of nominal temperature stability, effective infinite resolution, high stiffness, compact size and fast frequency response.

[4].The high-voltage DC-DC converter used here is based on the Texas Instruments DRV2700 piezo driver.This integrated circuit can be operated as a boost converter to drive an on-chip differential amplifier up to 100 V, or as a flyback converter up to 1 kV or more.The boost voltage is set using two external resistors. The boost current-limit is programmable through the $R(R_{ext})$ resistor. The boost converter architecture does not allow the demand on the supply current to exceed the limit set by the $R(R_{ext})$resistor; therefore, allowing the user to optimize the DRV2700 circuit for a given inductor based on the desired performance requirements. Additionally, this boost converter is based on a hysteretic architecture to minimize switching losses and therefore increase efficiency.

[5].The setup of a dial indicator consists of a comparator which is a well-arranged mechanism of gears train and spindle (Analog dial indicators).It is based on the principle of rack and pinion. It provides relative measurement rather than of absolute one. In this comparator there are two needles with different radii and graduation or marking from 0 to 9. The needle with the larger radius rotates and after making the one complete rotation of the needle while measuring the component, it rotates the needle of lower radius through one divisionin the direction of clockwise or anti-clockwise which depends on the nature of the help of arrangement of gear trains which are placed inside the base plate. After observing the movement or location of the needles the tolerance between the two faces or surfaces are determines with the a quite simple calculation.

II. METHODOLOGY AND IMPLEMENTATION



The DRV2700 EVM kit is a single chip high-voltage driver which consists of an integrated 105-V boost switch, integrated power diode, and integrated fully differential amplifier. It utilizes the high-voltage switch into a flyback configuration that is able to achieve up to 500 V. There is a flyback configuration on thus EVM which uses a low -pass filtered PWM waveform from the microcontroller. The most commonly used microcontroller is the MS340 PWM input mode. The evaluation kit is capable of varying voltage up to 0V to 500V by varying the boost output voltage.

The output provided from the evaluation kit can be used to drive the piezo material, this process is called the inverse piezo-electric effect. This is due to the high strain, permittivity and coupling constants of the piezo material. The piezo material has low mechanical quality factor and high curie temperatureextends its temperature range and thermal stability. The high charge output is really useful for sensing devices and generate elements. The high strain output useful for large displacements at modest voltages. The piezo material has a property of bending at consistent voltage which utilized in many applications

This bending is measured with help of the dial indicator which has a resolution of 1µm or can be more precise. The dial indicator shows the exact bending through the analogue circular scale. By giving the controlled voltages we can use and measure the displacement in many applications such as atomic spectroscopy to move the sample under the lenses and in various industrial applications.

The basic methodology and implementation are explained in the block-diagram which gives the idea of the method used.

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III. COMPARISON OF PIEZO SHAPES

A. Based on the operating voltage and corresponding displacement.

Piezo Shapes	Operating Voltage (triangular wave)	Displacement (in µm)
Piezo actuators	Up to 130V	-6 to +6
Piezo disc	-10V to 10V	-6 to +6
Piezostack	-30V to +150V	-6 to +6
Piezo Tube	-200V to +200V	-6 to +6

The above table consists of different piezo shapes based on their operating voltages which are calculated to obtain the displacement.The third column shows the displacement which is obtained after giving the various operating voltage to the different shapes and the corresponding displacement is obtained. As clearly shown in the table that at different voltages given to the piezo shapes it gives same displacement of 6 micro meter. If we look at the piezo actuator it is observed that when a voltage up to 130V is given it produces a displacement of 6µm in positive as well as negative direction. On comparison to that if we look at the piezo stack is almost similar to the piezo actuator as it has an operating voltage of almost equal to the piezo stack i.e., 150V and causes a displacement of 6µm.

On the other hand, the piezo stack is high voltage piezo material which has an operating voltage of 200V which is pretty much higher which gives the same displacement of 6µm in either positive or negative direction based on the polarity of the voltage. Last piezo shape is the piezo disc which are mostly used in the sound buzzers and has a low hysteresis. The biggest advantage of lower hysteresis is the coercivity and the retentivity of the material. Ferroelectric materials with the highest piezoelectric properties are usually the ones with the strongest electromechanical hysteresis. The piezo disc has the operating voltage of +10V to -10V at this range it gives a displacement of ±6µm which is great property of piezo disc. Hence in the earlier discussed methodology we have used the piezo disc with a piezo driver i.e., the DRV2700 evaluation board and obtained the displacement in micrometre.

B. Based on application and its advantages.

Piezo Shapes	Advantages	Applications
Piezo actuators	Unlimited and position resolution, stiffness, load capacity and force generation.	Cryogenic, Non-magnetic, High stiffness, and Ultra-high vacuum specific applications.
Piezo disc	Low current consumption, larger footprint and higher sound pressure level.	Pest deterrents, Computer devices, Telephones, Toys / Games.
Piezo stack	Low stroke and high blocking force.	Used to control Hydraulic valves, Act as a small-volume motor and in other applications requiring movement or force.
Piezo Tube	Fibre stretching and Beam scanning.	Micromanipulation, Fibre stretcher and Scanning Microscopy (AFM and STM).

The fore table mentioned gives a brief idea of the different piezo shapes and its applications and advantages. There are no limitations to the applications of these materials they can be used in many industrial areas where there is requirement of micro displacement. Not only in micro displacement but also in many well-known applications which is mentioned in the table.

IV. EXPERIMENTATION.

The piezoelectric actuator was tested using a DC power supply at a range of voltages from 10V to 80V and the corresponding displacement was measured using the dial indicator. The following voltage vs. displacement table was observed:

Voltage(V)	Displacement(µm)
10	2
20.005	6
29.98	8
39.95	12
49.99	16
60.01	18
70.5	21
80	23

V. CONCLUSION.

In this study, we analysed the methodology and the implementation of the piezo-controller board DRV2700 HV-500 EVM and its design to obtain the micro displacement which can be used in many industrial applications. Parallelly, we conducted the review of different shapes of the piezo materials and their operating voltages at which we can obtain the corresponding displacement. The main advantages and applications of the different piezo shapes were also compared and discussed in the table.

Finally, an experiment was conducted with the piezo actuators in order to measure the micro displacement with respect to the voltage provided to it. The study really helped in understanding the different properties of the piezo material and the behaviour towards the different range of voltages.

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