Modular Test Equipment for Analysis and Operation of Ultrasonic Motors

Introduction
The movement of ultrasonic motors is based on the transfer of vibration energy from a mechanical resonator to a suitably guided surface over frictional contact, Fig. 1.

Driving Ultrasonic Motors
Requirements for the excitation of single and multiple phase piezoelectric resonators cannot be met with standard equipment. The availability of amplifiers to drive piezoelectric loads is limited and only a few manufacturers are able to deliver appropriate devices to drive high power ultrasonic resonators. However, these amplifiers usually operate from a source signal generated with function generators. As these standalone devices in most cases have GPIB connectors some basic functional tests using LABVIEW are possible but this is about the limit of performance evaluation that can be implemented. A really flexible workstation must be faster in order to implement feedback control and must be capable to drive single and multiple phase resonators, especially as the latter offer distinct advantages with respect to their controllability. For laboratory use DSP based prototype controller boards like those offered from DSPACE which interface Matlab/Simulink as a powerful tool for control system design are an attractive approach for different applications. However due to the high excitation frequencies direct excitation signal generation is not feasible. The analogue outputs of a fast DS1103 prototype board can be operated only up to 20 kHz with sufficient signal quality, but this is just where ultrasonic motors start to operate. Another major drawback of this controller board based signal generation is, that computing power is consumed for low level tasks. Thus it is necessary to design circuits that can perform the signal generation and free computing power of the DSP board upon which the prototype control system will be based.

Control System Design
Fast excitation signal generation is crucial to realize a prototype control system. Fig. 2 shows the structure of a device built on direct digital synthesis (DDS) based numerical controlled oscillators (NCO) that allow programming of sine wave and triangle wave output signals at any desired phase shift to drive multiple phase ultrasonic resonators.

Sine Wave Generator
The sine wave output of the used DDS IC (AD9833) is unipolar with only 0.6 V and is not suited to drive the four quadrant amplifiers that need a 10 V p-p input signal for full output swing. The signal level needs to be amplified, level shifted and of course amplitude control needs to be implemented. Fig. 3 shows a schematic circuit diagram.

Square Wave Generator
Square wave inverters with output filters are the industrial standard excitation devices for ultrasonic motors. They are built as full bridge or half bridge push-pull inverter circuits that can be controlled using pulse width modulation. Unlike conventional amplifiers switched inverters can be miniaturized easily and are less expensive to produce. Fig. 5 shows the schematic diagram of the developed dual phase inverter with +/-90 degrees phase shift.

Conclusion
Using the presented circuits a DS1103 controller board can be used to control a variety of single and multiple phase ultrasonic motors. Two different circuits have been demonstrated that can be operated with four quadrant amplifiers or a switched inverter and drive motors at frequencies up to 300 kHz.

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