Technical support – Driving & control

There are three general methods for actuator drive/control that are most commonly employed:

1. DC drive (static operation)
2. AC drive (dynamic operation)
3. Pulse drive (switched operation)

1.1 DC drive (static operation)

Piezoelectric elements are essentially capacitors. Power is only required to change the voltage on the PZT element. The relationship of current and voltage for a piezoelectric actuator is the following:

$I = dQ/dt = C \times dU/dt$

Where:
I=Current
Q=Charge
C=Capacitance
U=voltage
t=time

To maintain a piezoelectric actuator in its state of activation, only the leakage current has to be supplied. At temperatures well below the Curie temperature the internal resistance of piezoelectric actuator is in the order of 10^{10} Ohms. Consequently, under static operation virtually no current is drawn nor power consumed to maintain a state of activation (the high internal resistance reduces leakage current to micro-amp or sub-micro-amp range).

1.2 AC drive (dynamic operation)

<u>Electrical consideration</u>

Piezoelectric actuators can provide accelerations of thousands of g's and are well suited for dynamic applications. Piezo actuators require electrical power/current only during dynamic operations. The amplifier output current and rise time determine the maximum operating frequency of the piezoelectric system. The following equations describe the relationship between amplifier output current, voltage and operating frequency. They help determine the minimum specifications of a PZT amplifier for dynamic operation:

Average current required for sinusoidal operation:
$I_{avg} = f \times C \times U_{p\text{-}p}$

Peak current required for sinusoidal operation at maximum frequency:
$I_{max} = \pi \times f_{max} \times C \times U_{p\text{-}p}$

Where:
I_{avg}= average amplifier source/sink current
I_{max} = peak amplifier source/sink current
f_{max} = maximum operating frequency
C = PZT actuator capacitance
$U_{p\text{-}p}$ = peak-peak drive voltage
f = operating frequency

Noliac A/S • Hejreskovvej 18 • DK-3490 Kvistgaard • Denmark • Phone: +45 4912 5030 • Fax:+ 45 4912 5031 • Web: www.noliac.com

Self-heating

An important aspect of dynamically operating piezoelectric actuators is self-heating. Piezoelectric ceramics dissipate energy in the form of heat proportional to the dissipation factor (tan δ), the tangent of the loss angle for the material. The mechanism is similar to that by which any elastic material such as a rubber band becomes hot when stretched repeatedly. For comparison between the materials, the dissipation factors is usually specified for low electrical fields and at 1000Hz. Soft PZT materials have large dissipation factors in the order of 2% to 4% and hard PZT materials have dissipation factors on the order of 0.5%.

The power dissipated by a piezoelectric element with a capacitance C, driven at a voltage V and frequency f can be estimated from the following equation:

$$P = 2 \times \Pi \times f \times C \times \tan(\delta) \times U_{p\text{-}p}^{\ 2}$$

The resultant temperature rise will depend on a factor such as the heat capacity of the device and what means exist for transferring that heat to the surroundings by convection, conduction and radiation. With soft PZT materials, the capacitance may increase rapidly with temperature due to increase in the dielectric constant approaching the Curie temperature. Consequently caution is necessary when running at high frequency to avoid thermal runaway by self-heating that might damage the actuator. A temperature sensor mounted on the piezoelectric actuator is suggested for monitoring purposes.

1.3 Pulse drive (switched operation)

An important feature of piezoelectric actuators is their capability to produce extreme forces and acceleration rates, which can be used for fast switching of valves or to produce mechanical shocks. In such cases, the actuator should switch in as short time as possible between two distinct levels, whereas the exact motion profile between these levels is not important. The minimum rising time of an actuator can be derived from its elastic properties. A short electrical pulse excites the resonant oscillation of the actuator and the minimum rising time t_p can be estimated by the following equation:

$$t_p = t_r/3$$

Where:
t_r = period time of actuator's resonance
t_p= minimum rising time in pulsed operation

Pulse drive actuators are typically operated in open-loop mode, but special care must be taken to suppress overshoot and mechanical ringing that frequently occur after the pulse voltage is applied (if the voltage rises fast enough to excite a resonant oscillation in the piezoelectric actuator). Quick and precise positioning is difficult to achieve, and moreover can lead to the destruction of the actuator due to large tensile stress associated with overshoot. In such cases, compressive bias stress should be employed on the device through clamping mechanisms such as a helical spring or a plate spring.

Another solution to suppress this problem is to reduce significantly the mechanical vibration overshoot and ringing by choosing a suitable rising time. Indeed, when a piezoelectric actuator is driven by trapezoidal pulse, the mechanical ringing is significantly reduced when the rise time is adjusted exactly to the resonance period of the piezoelectric actuator.

Pulse operation may require peak powers up to the kilowatt range with currents of 10 to 100 Amperes. In these cases it is reasonable not to use analogue amplifiers but electronic pulse switches.

Noliac A/S • Hejreskovvej 18 • DK-3490 Kvistgaard • Denmark • Phone: +45 4912 5030 • Fax:+ 45 4912 5031 • Web: www.noliac.com