Piezo Amplifier

Piezo amplifier is ideal for driving high-capacitance and high-frequency piezoelectric devices. Piezo actuators and transducers are usually capacitive. Due to their high-capacitance, their impedance is low at high frequencies. A high-current amplifier is needed to drive them at ultrasonic frequencies. The amount of current required is calculated by Ohm's law and it is proportional to voltage, frequency, and capacitance as shown in Equation 1. In Equation 1, I is the current, V is the voltage, C is the piezo capacitance, and ω is the angular frequency.

$$I=V/Z=V/|1/j\omega C| =V\omega C \qquad \text{Equation-1}$$

For example, if the high-frequency piezo actuator capacitance is 3.3uF, the peak voltage required is 20V, and the frequency is 10kHz, the required peak current is 4.14A. A very high-current piezo driver is needed to be able to drive that much current. Higher frequency often requires an even higher current.

Piezoelectric Amplifier Connection

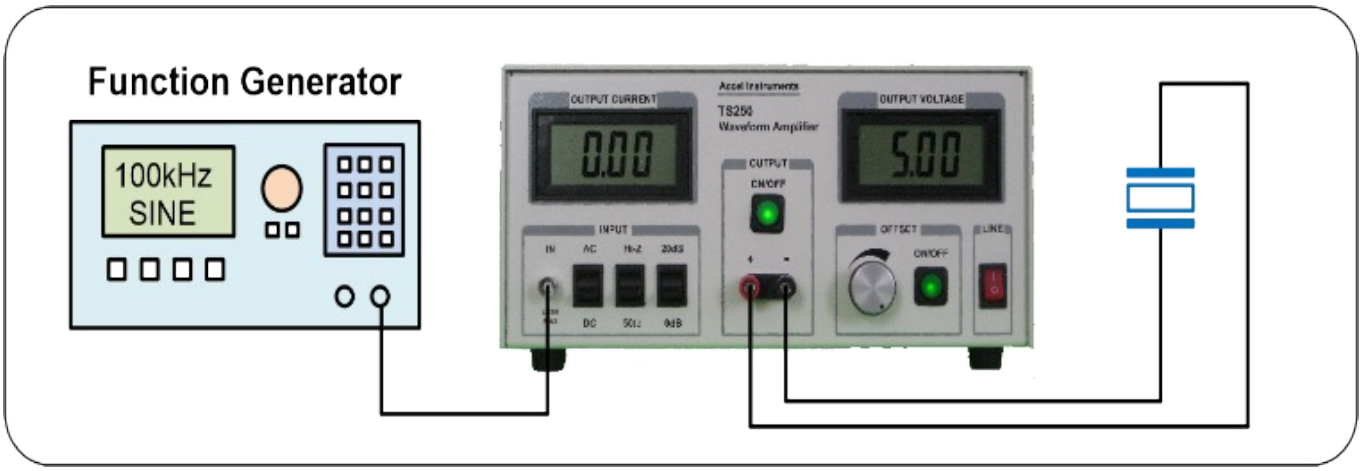

Figure 1. The TS250 piezo driver amplified signal and drives a piezo transducer.

High-Voltage Piezo Driver

Other than high current, piezoelectric actuators also require high voltage. Their operating voltage range is generally greater than 10V and can go up to 100V or more. Most signal generator such as those waveform generators are less than 5V, but piezo elements require higher voltage. Therefore a high-voltage and high-current piezoelectric amplifier is needed for driving them. For instance, a piezo motor requires an 40Vpp waveform, but a function generator output is only 5V. As shown in Figure 1, the TS250 to amplifies the waveform generator signal and outputs high-current and high-voltage sine-wave that drives the piezoelectric sensor. Basically, the TS250 high current amplifier functions perfectly as a piezoelectric amplifier and driver.

Piezo Amplifier Output Waveform Examples

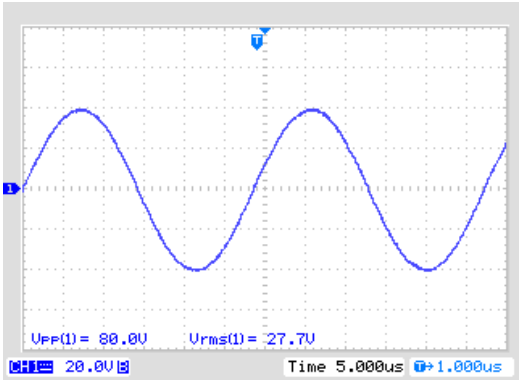

Figure 2. TS250-3 generates 80Vpp 35kHz ultrasonic sine wave into 15 ohm load which is +/-2.7A current

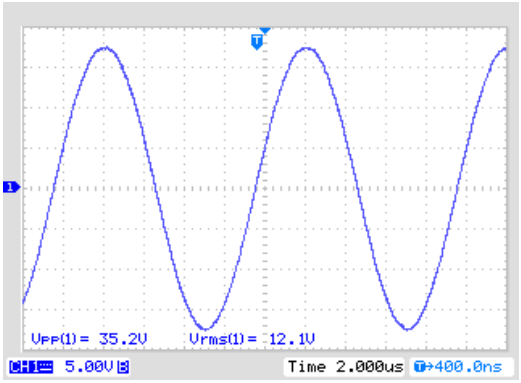

Figure 3. TS250-1 drives 100kHz 35Vpp into 3.9 ohm load (+/-4.4A).

Figure 2 and 3 illustrates two examples of TS250 piezo amplifier high-frequency output voltage waveform. It can drive up to 80Vpp sine wave at 2.7A or 40Vpp at 4.4A.

Piezo Driver Selection

The TS250 and the TS200 are both high-current and high-voltage piezoelectric driver. Unlike other amplifier instruments available today, the TS250 and TS200 are capable of output very high current at ultrasonic frequencies. Table 1 details the TS250/TS200 piezo driver output voltage and current ranges.

Table 1. Piezoelectric Driver Selection Guide

Model	Voltage Range	Peak Reactive Current (Note 1)	Peak Resistive Current (Note 2)
TS200-0A/B	-10V to + 10V	0 – 4.0A	0 – 5.0A
TS200-1B	-20V to + 20V	0 – 2.8A	0 – 3.8A
TS200-2B	-20V to + 45V	0 – 1.4A	0 – 2.0A
TS200-3B	-10V to + 70V	0 – 1.4A	0 – 2.0A
TS200-4A/B	0V to + 15V	0 – 3.5A	0 – 4.5A
TS200-5B	-40V to + 40V	0 – 1.4A	0 – 2.0A
TS250-0	-10V to + 10V	0 – 5.0A	0 – 6.0A
TS250-1	-20V to + 20V	0 – 3.1A	0 – 4.4A
TS250-2	-30V to + 30V	0 – 2.1A	0 – 3.0A
TS250-3	-40V to + 40V	0 – 1.7A	0 – 2.5A
TS250-4	-6V to + 15V	0 – 4.0A	0 – 5.0A
TS250-5	-6V to + 30V	0 – 2.1A	0 – 3.0A
TS250-6	-6V to + 45V	0 – 1.7A	0 – 2.5A
TS250-7	-6V to + 65V	0 – 2.1A	0 – 2.5A

Note 1. Piezo element is capacitive which means their power is reactive. The TS250 output current is adjusted for reactive power.

Note 2. Peak resistive current is specified at maximum voltage minus 1V. For ex maple 19V for the TS250-1.

High-Frequency Piezo Amplifier Impedance Matching

Reactive Power vs. Real Power

As discussed above, high-frequency piezo transducers and sensors are highly capacitive. Its impedance is nearly all reactive without real resistance. Such piezo devices does not dissipate real power. This means all power are dissipated inside the piezo amplifier driver instead. The result is in excess heating of the piezoelectric driver amplifier. The TS200/TS250 can dissipate about 45 watt RMS power.

Increase Resistive Impedance

One simple technique to increase piezo driver output current is to make the high-frequency pzt device more resistive. It can be done by just adding a resistor in series with the transducer as shown in Figure 4. The resistance should be chosen between 0.5Z to Z. Z is equal to the piezo transducer's impedance. For example, if the transducer impedance is 20j ohm at 10kHz, chose the series resistor between 10 ohm and 20 ohm. The total impedance is now equal to Equation 2 below. The power dissipated in the matching resistor is given in Equation 3. The dissipating power can be very high and the resistor may be hot. Be sure to select the impedance matching resistor that handles the power.

$$Z_{Total} = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$ Equation-2

$$P_{Dissipate} = (I_{RMS})^2 R$$ Equation-3

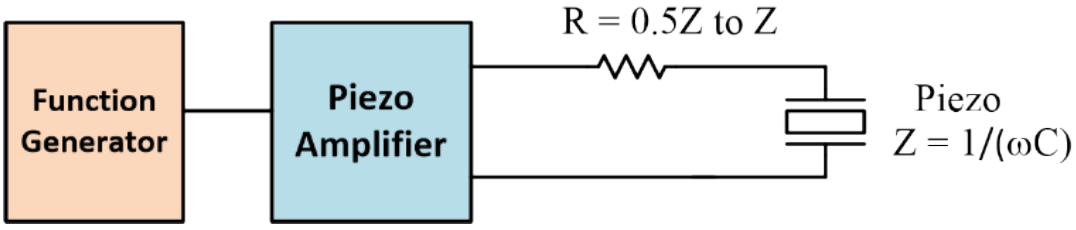

Figure 2. Simple resistive impedance matching increases the piezoelectric driver output

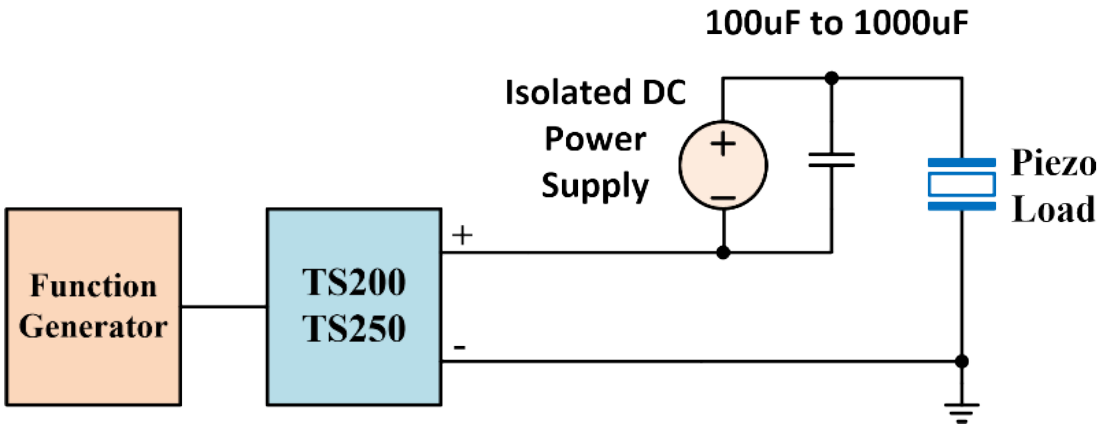

Figure 5. Using a piezo amplifier and a DC power supply for high-voltage testing.

Driving Resonant Piezo Devices

Some piezoelectric devices are operating only at resonant frequency. An example of these devices is Langevin Ultrasonic Transducers for ultrasonic washing and cleaning applications. At the piezo resonant frequency, these devices' impedance are actually resistive as opposed to capacitive. These resonant pzt devices often specified operating power rather than voltage. For example, a resonant piezo transducer specified 16 ohm resistance at resonant frequency and the maximum operating power is 32 watts. The TS200 or TS250 ultrasonic amplifier can output up to ~70 watt.

To chose a piezoelectric amplifier, select the TS250/TS200 model that outputs the highest current using Table 1 above. The highest current is calculated by the piezo amp's maximum voltage divided by the resonant resistance, or the peak resistive output current in Table 1, whichever is the lowest. For example, for a 16 ohm high-frequency piezo transducer, chose the TS250-2 (+/-30V). The maximum current is 30V/16ohm = 1.875A. The peak power is 56.25 watts (1.875A*30V = 56.25W). The RMS power is 28.1W. It is calculated by the RMS current times the RMS voltage (Equation 5). The RMS current is the RMS voltage divided by piezoelectric resonant resistance.

$$P_{Peak} = I_{Peak}V_{Peak}$$ Equation-4

$$P_{RMS} = I_{RMS}V_{RMS}$$ Equation-5

$$I_{RMS} = \frac{V_{RMS}}{R}$$ Equation-6

Table 2. Piezoelectric Transducer Amplifier Selection Guide

Model	Voltage Range	Polarity
TS200-0A/B	-10V to + 10V	Bipolar
TS200-1B	-20V to + 20V	Bipolar
TS200-2B	-20V to + 45V	Unipolar
TS200-3B	-10V to + 70V	Unipolar
TS200-4A/B	0V to + 15V	Unipolar
TS200-5B	-40V to + 40V	Bipolar

Model	Voltage Range	Polarity
TS250-0	-10V to + 10V	Bipolar
TS250-1	-20V to + 20V	Bipolar
TS250-2	-30V to + 30V	Bipolar
TS250-3	-40V to + 40V	Bipolar
TS250-4	-6V to + 15V	Unipolar
TS250-5	-6V to + 30V	Unipolar
TS250-6	-6V to + 45V	Unipolar
TS250-7	-6V to + 65V	Unipolar

High-Voltage Piezo Driver

The TS250 outputs up to 65V. If higher voltage is required, an isolated DC power supply can be used to boost the voltage higher. For example a unipolar piezoelectric actuator needs a DC bias voltage of 100V and a 80Vpp sine wave. The operating swing voltage range is from 60V to 140V. Using an isolated DC power supply in conjunction with the TS250 piezo driver can generate extremely high power (reactive or real) and high current.

As shown in Figure 5, the piezoelectric amplifier driver is connected in series with the DC power supply. Make sure the TS250 driver negative output terminal is connected to ground. The ground connection is common with the function generator ground and the piezo load. Most DC power supplies already have capacitors internal. It is still recommended to add external bypass capacitors, especially for high frequency piezo. You may use multiple capacitors connected in parallel. It is recommend to use low ESR and ESL ceramic capacitors, but a mix of electrolytic, tantalum, and ceramic caps are acceptable. The total capacitance should be large enough such that their impedance is much lower than the pzt load impedance.

Parallel Piezoelectric Drivers For Higher Current

The TS250-1 is able to output 3.1A peak current for driving piezoelectric device. To increase the piezo driver output current, two or three TS250/TS200 may be connected in parallel. As shown in Figure 4, each ultrasonic piezo amplifier driver is isolated with a small series resistor. The resistance is typically between 0.25 ohm to 1 ohm. Contact factory for more information on parallel connection and high output current driver.

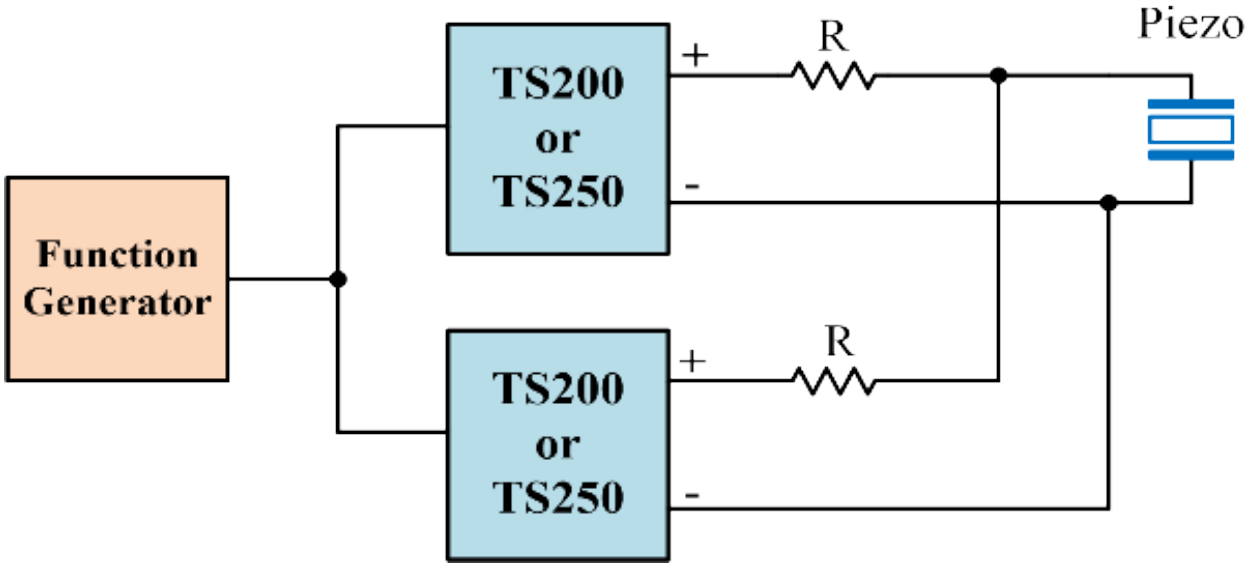

Figure 4. Connect two TS250 in parallel to increase the output current by 2x.

Bipolar vs. Unipolar

Some high-frequency piezo actuators and transducers required bipolar voltage. This means that the applied voltage swing between negative and positive. For example, the voltage across the actuator is a sine wave with an amplitude -20V to +20V. On the other hand, some piezo devices only need unipolar voltage or only positive voltage. An example would be a sine wave swinging from 0V to +40V. Table 2 shows voltage ranges of the TS200 and TS250 piezo amplifiers.