Selecting the Right Power Op-Amp for Piezoelectric Transducers

Over the last few decades, the use of piezoelectric transducers has seen quite an increase in popularity. This is due to the many advantages these devices offer. To name a few: as modern piezoelectric materials are initially fluid, the eventual transducer can be made into virtually any shape. Driving these transducers does not involve magnetic fields, so they are impervious to these forces. There are no moving parts that can wear out, meaning they are low maintenance. Piezoelectric transducers can work in a vacuum and at cryogenic temperatures. All good reasons why piezoelectric transducers have made their way into a wide array of applications, as diverse as (but certainly not limited to) sonar, inkjet printing, precision microscopy, aerospace and satellite instrumentation, vibration cancellation, mirror and lens deformation, etc.

Electrically, piezoelectric transducers behave like capacitors. This has consequences for the stability, output current capability, and internal power dissipation of the driving amplifier. One must also consider that a piezoelectric transducer can reverse functionality; rather than changing shape by applying a voltage across it (creating an electric field within it), it can generate high voltage transients when mechanically manipulated. Apex power operational amplifiers are very well suited to drive piezo transducers as they are available in a wide range of voltage, current, frequency, and power dissipation capabilities; moreover, their circuits can be tweaked externally to support the requirements of specific transducers.

If one has a piezoelectric transducer to drive and a cursory knowledge of Apex's broad portfolio of power op-amps, the question quickly becomes: which op-amp is most suitable?

First, one will note that piezoelectric transducers are commonly driven with higher voltages, typically >50V. For this Apex offers power op-amps from 50V up to 2.5kV. Next, the output current capability of the amplifier must be considered. It is important to realize that the drive signal waveform plays an important role here:

- If the signal is pulse-shaped, the current needed to (dis)charge the capacitive load, that a piezoelectric transducer represents, is:

$$i = C \cdot \frac{dV}{dt} \text{ [A].}$$

- If the drive signal is sinusoidal, the current can be found by first calculating the transducers impedance at the drive signal's frequency, and then used with the drive signal's voltage:

$$Z = \frac{1}{2\pi \cdot f \cdot C}\,[\Omega],\; I_{PK} = \frac{U_{PK}}{Z}\,[\text{A}].$$

The next step in the process is to identify an initial selection of op-amps which meet our basic output voltage and current requirements, for this Apex offers an excellent software tool called **Power Design**. It is frequently the case that many of Apex's power op-amps appear to fit when taking only these two requirements into consideration.

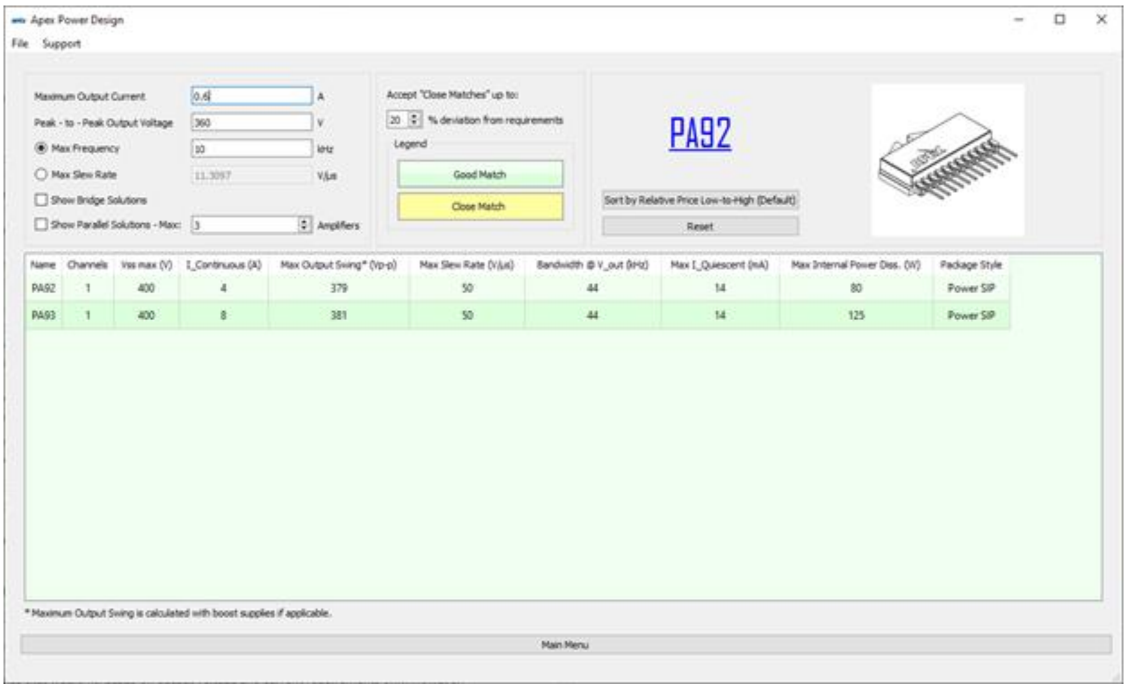

Figure 1: Power Design: Selecting a power op-amp to drive a 50nF piezoelectric transducer 360V_{P_P} at 10kHz.

However, power dissipation and stability are also critical aspects of the selection process when driving a piezo element. Again, Power Design offers the piezoelectric driver amplifier designer the means to evaluate these two aspects to come to a final, well-supported choice.

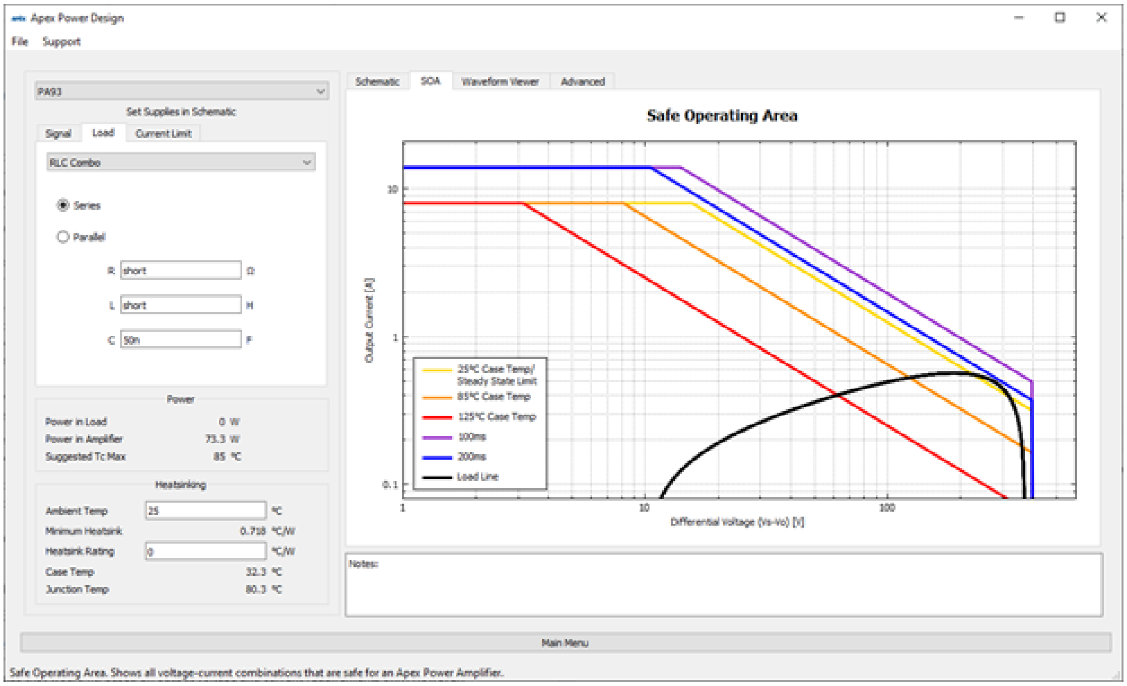

Figure 2: Power Design: Evaluating power dissipation.

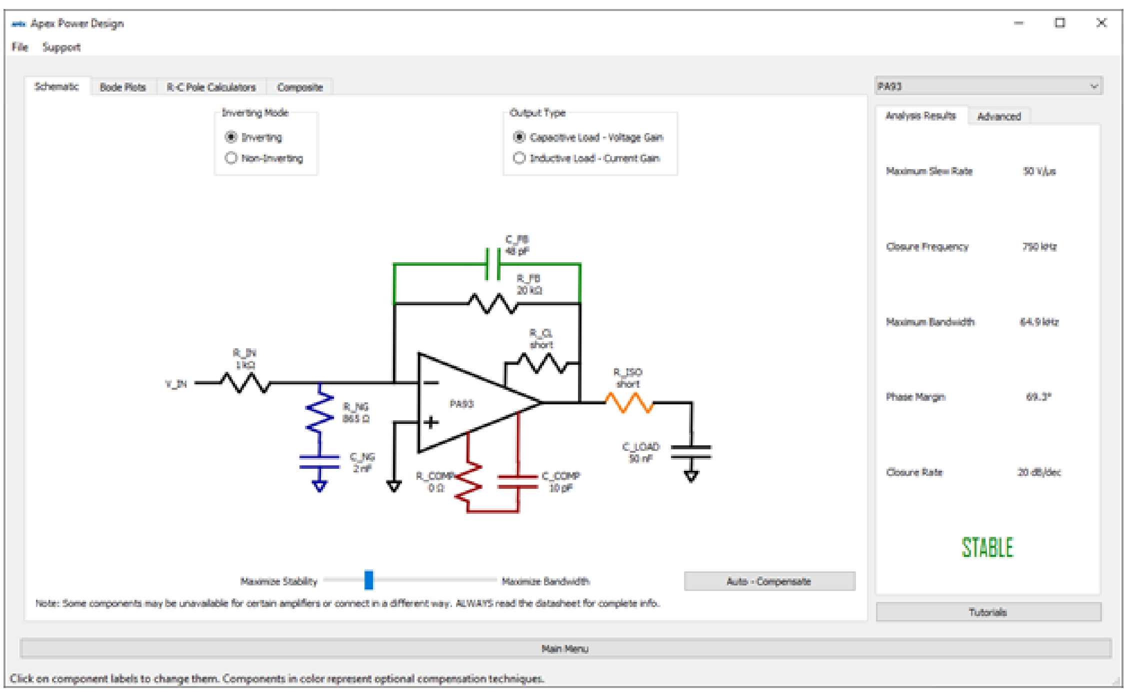

Figure 3: Power Design: Evaluating stability

Finally, it is important to protect the output of the amplifier against any potential high voltage transients generated by the transducer. This can be done by clamping the op-amp's output to the supply rails through fast reverse recovery (T_{RR} < 100ns) rectifier diodes. The (reverse) voltage rating of these diodes needs to be equal to or larger than the total supply voltage across the op-amp. Additionally, it is also recommended to protect the op-amp against voltage transients on the supply rails, this can be achieved by connecting the supply pins to ground through unidirectional transient voltage suppressor diodes having a reverse stand-off voltage greater than the supply voltage.

For driving piezoelectric applications, Apex offers high-performance power operational amplifiers ranging from 50 V to 2500 V, such as the PA98 and the PA85. Both parts achieve 450 V and 200mA with an impressive 1,000V/µs slew rate targeted for high voltage applications including piezoelectric transducers, electrostatic transducers, and deflection. The PA98 is a hybrid product design housed in a space saving, electrically isolated 12-pin PowerSIP package which lends itself to high-density circuit board layouts. The PA85 is housed in an 8-pin TO-3 isolated metal package and comes in both standard and A grade variants. To view the PA98 and PA85 in addition to Apex Microtechnology's full product portfolio, visit: apexanalog.com

PA98

Power Amplifier in PowerSIP

- High Voltage – 450 V
- High Slew Rate – 1000V/µs
- High Output Current – 200mA

https://www.mouser.com/new/apex-microtechnology/apex-pa98-amplifiers/

PA85

Power Amplifier with High Power Bandwidth

- High Voltage – 450V
- High Slew Rate - 1000V/µs
- High Output Current – 200mA
- High Power Bandwidth – 300kHz

https://www.mouser.com/new/apex-microtechnology/apex-microtechnology-pa85-amplifiers/