An ultra-low noise, high-voltage piezo driver

N.C. Pisenti,[1, a)] B.J. Reschovsky,[1] D.S. Barker,[1] A. Restelli,[1] and G.K. Campbell[1]

Joint Quantum Institute, University of Maryland and National Institute of Standards and Technology

(Dated: 19 December 2015)

We present an ultra-low noise, high voltage driver suited for use with piezoelectric actuators and other low-current applications. The architecture leverages a commercially available, small-form-factor integrated circuit (IC) for generating high voltage outputs. The IC uses a flyback configuration switching regulator to generate up to 250V in our design (but up to 1kV or more with small modification), and a high slew-rate op-amp capacitively coupled to the output compensates for the switching noise. A low-voltage (± 10 V), high bandwidth modulation input is capable of summing small voltage corrections onto the output, making the driver well suited for use in closed-loop feedback applications.

I. INTRODUCTION

Many instrumentation applications in the modern laboratory require agile, low-noise voltage sources that can supply hundreds of volts or more. Such high-voltage amplifiers are useful for micro-positioning applications, driving piezo-actuated mirrors (e.g., in a scanning Fabry-Peròt cavity) or diffraction gratings (such as in extended-cavity diode lasers). Precision high voltage sources can also be used to bias low-noise, high-bandwidth photodiodes [details?], Other applications...? biophysics? medical devices? Often, these applications are operated in a closed feedback loop, where small voltage changes on top of a large DC voltage are necessary to correct for some disturbance to the system.

Traditionally, laboratory electronics capable of supplying high voltages fall under one of two architectural umbrellas: switching converters, and "linear" amplifiers. DC-DC converters are efficient and can work at very high voltages, but suffer from switching noise and limited control bandwidths. Linear-type devices are typically constructed from a high-voltage operational amplifier (op-amp), powered either from a high voltage linear regulator or more typically from a secondary switching converter. While the op-amp provides 100 dB or more of power-supply noise rejection, a high-voltage op-amp require substantially more power than an equivalent switching circuit. In either case, the output voltage $V_{\rm out}$ is typically given by

$$V_{\rm out} = G_p(V_{\rm DC} + V_{\rm mod})\,, \tag{1}$$

where G_p is the piezo amplifier gain (typically $G_p \approx 10 - 20$ or more), $V_{\rm DC}$ is a DC setpoint, and $V_{\rm mod}$ is a modulation input used for closed-loop control.

It is often the case, however, that in closed-loop feedback applications we do not need and often do not want the modulation control to have a high gain. Because the closed loop gain cannot be increased without limit, $G_pV_{\rm mod} \gg 1$ means the servo gain G must be proportionally smaller to keep the lock stable. Because noise added by the servo is suppressed by $1/|G|$ in the large gain limit, if G is limited to achieve a stable lock it is no longer as effective at servoing its own noise.

To avoid this problem, we desire a high voltage amplifier which separates the "setpoint" gain G_p from the modulation gain, G_m. That is,

$$V_{\rm out} = G_pV_{\rm DC} + G_mV_{\rm mod}\,, \tag{2}$$

where now we can make $G_m \approx 1$.

II. CIRCUIT DESIGN

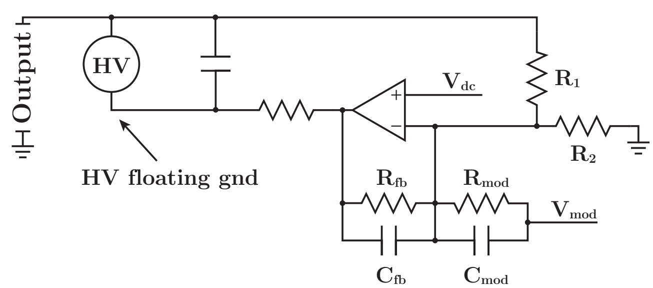

FIG. 1. Schematic of the high voltage stabilization. The voltage HV is generated using a Texas Instruments DRV2700 high voltage driver in flyback configuration (see Fig. ??). A fast, very high slew-rate op-amp senses the output voltage across R_1 and R_2, and servos it by modulating the node at "HV floating gnd". The $V_{\rm DC}$ gain is set by $(1 + R_1/R_2)$, while the modulation gain is set by $-R_{\rm mod}/R_{\rm fb}$. The capacitor linking the floating ground node to the output allows the op-amp to remove residual switching noise and stabilize the DC output according to the transfer function given in Eq. (2).

Discussion of individual circuit components

III. RESULTS

Noise analysis, bandwidth, (DC) stability, etc.

IV. CONCLUSION

[a] npisenti@umd.edu