Load Size Selection and Limiting Factors of the SLICE-DHV's Modulation Output

Vescent Photonics

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1 Introduction

The SLICE-DHV dual-channel high-voltage amplifier is a powerful tool for driving PZTs and other capacitive loads in the lab. However, it is important to understand the capabilities, and intended use cases of the SLICE-DHV before employing it in your system. Specifically, some care must be given to ensuring that the SLICE-DHV can drive its load at the desired bandwidth. This application note will discuss choosing an appropriate load for the SLICE-DHV given some bandwidth constraint, as well as how to pick the correct Modulation and Output settings to fit your system.

2 Setup

The data used in this application note were collected using a Stanford Research Systems Model DS345 function generator, which supplied a 1 V_{pp} sine wave modulation to the SLICE-DHV's front panel input. A capacitive load was connected to the HV Ouput on the back panel of the SLICE-DHV, and the voltage across the capacitor was measured as a function of time on an Agilent InfiniiVision DSO-X 2004A Oscilloscope with a Rigol PVP2150 scope probe. The amplitude of the modulated voltage across the capacitor was then compared to that of the input signal, which was split off with a BNC tee and connected to the same Oscilloscope. The modulation was said to have rolled-off if the power gain (G_P) of the voltage across the capacitor dipped below -3dB as given by

$$G_P = 20 * log_{10}\left(\frac{V_{out}}{V_{in} * G_{out}}\right). \tag{1}$$

This yields 3dB down cutoff amplitudes of 0.71 V_{pp} for the G=1 output mode (small signal regime, <20 V_{pp}), and 14.2 V_{pp} for the G=20 output mode (large signal regime, $\geq$20 V_{pp}). Multiple loads were tested, both within and outside of the range specified for the SLICE-DHV. A block diagram of the setup is shown in Figure 1.

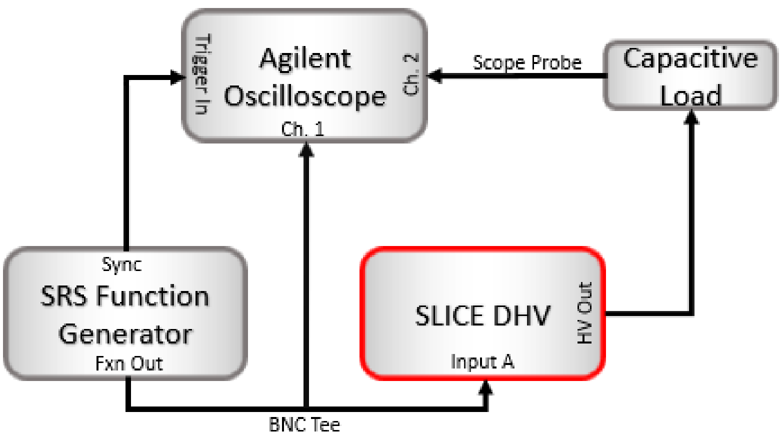


Figure 1: Block diagram of the test setup. The SRS Function Generator was manually kept at 1 V_{pp} throughout.

3 Maximum Bandwidths and Limitations

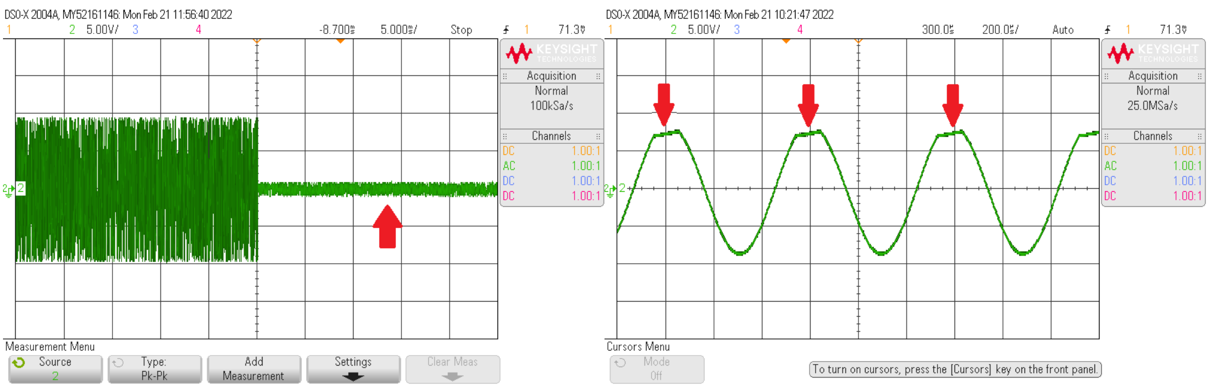
The maximum load specification for the SLICE-DHV listed on the Vescent website is 1000nF. However, the bandwidth performance of the SLICE-DHV is not flat up to this specification, and it is not necessarily zero above it. In reality, smaller capacitive loads will always have higher bandwitdhs than large ones, and the SLICE-DHV settings will also have an effect on modulation bandwidth.

Figure 2 gives a table of maximum bandwidth values for tested loads. Given some bandwidth requirement, the approximate maximum capacitance of a load can be extrapolated from these data with a simple ratio. Capacitance values much higher than those tested may be limited by factors outside the scope of this application note, however. While it is possible, it is not strictly recommended to use values higher the specification of 1000nF.

	Current Limited		Full Bandwidth	
Capacitance (nF)	Max BW Small Signal (Hz)	Max BW Large Signal (Hz)	Max BW Small Signal (Hz)	Max BW Large Signal (Hz)
10	360000	358000	1650000	327000
20	180000	176000	961000	178000
50	72000	70000	384000	76000
95	36000	35500	160700	890
237	14600	25	66700	25
475	7400	11	34100	11
950	3700	--	17200	--
1425	2470	--	11400	--
2375	1480	--	6800	--
4750	--	--	3740	--

Figure 2: Table of data showing maximum bandwidths of different capacitive loads. Maximum bandwidth for capacitors between these values can be extrapolated with a simple ratio.

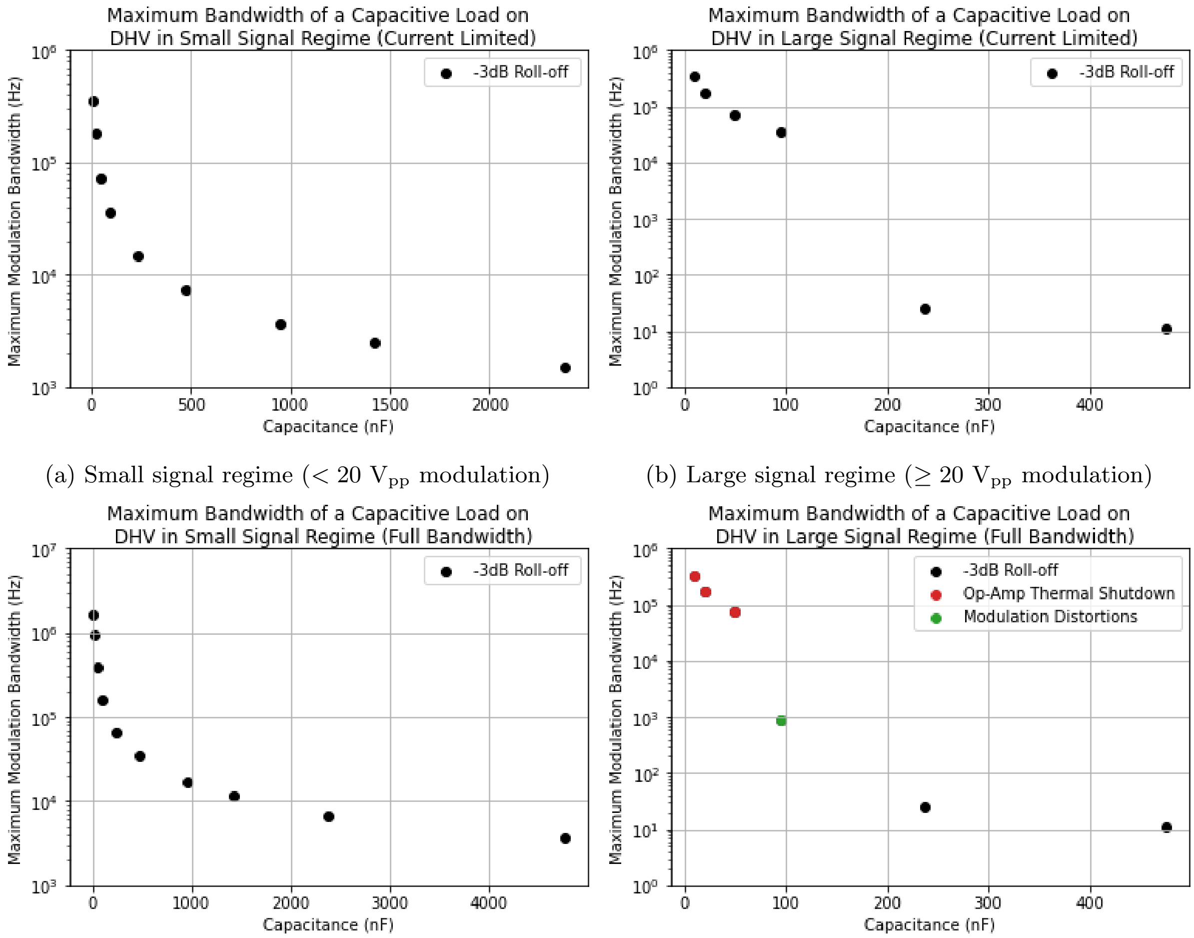
In general, the bandwidth of the SLICE-DHV follows a $f_B \propto 1/C$ relationship. This means that a doubling of capacitance in the load will result in a roughly halving of the maximum bandwidth available. This relationship breaks down slightly in the large signal regime, since the circuitry is not designed to be able to modulate large loads quickly at high amplitude. Because of this, it is not advised to modulate at more than 20 V_{pp} any faster than 20Hz unless you are using a very small load. Aside from power gain roll-off, discussed in the Setup section, modulation distortions and the thermal shutdown of the output op-amp can also limit the bandwidth of the SLICE-DHV. A method for avoiding these can be found in Section 4: Choosing Output and Modulation Modes, and a picture of each can be found in Figure 3. If planning on modulating small loads in this regime at higher frequencies, it is best to do so in the "Current Limited" modulation mode to avoid thermal shutdown of the output op-amp.



(a) Thermal Shutdown of the output op-amp. (b) Modulation distortions on an over-driven load

Figure 3: Thermal shutdown and modulation distortions can be viewed on an oscilloscope. Thermal shutdown presents as a flickering of the modulation, which when viewed on a long time scale can be seen as the op-amp shutting off periodically due to overheating. Modulation distortions appear either as clipping, or as waves on the output signal. These will typically get worse as modulation frequency increases, and occur most often on high capacitance loads being driven in the large signal regime ($\geq$ 20 V_{pp}).

Figure 4 shows plots of the data in Figure 3, separated by small and large signal regime, and modulation mode. Data plotted in black were limited by their 3dB down power gain roll-off, while those plotted in red, and green were limited by thermal shutdown and modulation distortions respectively.



(a) Small signal regime (< 20 V_{pp} modulation)

(b) Large signal regime (≥ 20 V_{pp} modulation)

(c) Small signal regime (< 20 V_{pp} modulation)

(d) Large signal regime (≥ 20 V_{pp} modulation)

Figure 4: Small and Large signal regime plots of the maximum bandwidth available to different capacitive loads driven by the SLICE-DHV in its "Current Limited" (a and b), and "Full Bandwidth" (c and d) modulation modes. Note that the Y axis is on a log scale to increase visibility.

4 Choosing Output and Modulation Modes

Thermal shutdown almost always occurs while the SLICE-DHV is in Full Bandwidth mode in the large signal regime, and is caused by the output op-amp overheating. Current Limited mode prevents this by dramatically limiting the current supplied to the op-amp, keeping it cooler. This slightly reduces system bandwidth when used, but is not generally necessary outside of the large signal regime. Modulation distortions occur when large loads are over-driven, and can be especially problematic when the SLICE-DHV is being used to drive sensitive components such as locking PZTs. These can generally be avoided by operating in the small signal regime, or below 20 Hz in the large signal regime. Smaller loads can be modulated at a higher frequency in the large signal regime, but it is still advised to operate them at lower frequencies to avoid potential distortions.

When choosing output and modulation modes for the SLICE-DHV, it is generally recommended to use the Full Bandwidth modulation mode if in the small signal regime (G=1 output mode), and to switch the SLICE-DHV into its Current Limited modulation mode if larger modulations (G=20 output mode) are required. This will help to prevent thermal shutdown. Certain systems may require different settings than this, though, and factors outside the scope of this application note might also have an effect.

5 Summary

The SLICE-DHV is a powerful tool for driving PZTs and other capacitive loads in the lab. However, some care must be given to ensuring that the SLICE-DHV can drive its load at the desired bandwidth. It is possible to approximate the maximum bandwidth of a load using the formula $f_B \propto 1/C$, even for loads outside of the range specified for the SLICE-DHV (with some exceptions). While using the G=1 output mode, it is best to operate the SLICE-DHV using the Full Bandwidth modulation mode, but if using the G=20 output mode, it is often necessary to switch to the Current Limited modulation mode to prevent thermal shutdown of the output op-amp. Occasionally, while using the G=20 output mode, modulation distortions may appear at high modulation frequencies. These can affect the ability of your system to modulate properly, and can be avoided by limiting operation of the SLICE-DHV in G=20 mode to frequencies under 20Hz. Smaller loads can be modulated at higher frequencies without distortion, but it is always best to check your load before use.

For more information, contact Vescent at:+1 (303) 296-6766, info@vescent.com, or visit our website at https://www.vescent.com