Comparison Between A Proposed Dual-Cell Power Amplifier

And A Conventional Single-Cell Converter

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Abstract

This paper compares a proposed dual-cell power amplifier with extended small-signal control bandwidth to a conventional half-bridge power amplifier for driving actuators in precision positioning systems. The dual-cell converter was first introduced in [1], and a control strategy is provided in [2] to improve the bandwidth and thereby reduce the power amplifier's error contribution in a high-precision positioning system. This paper compares the proposed dual-cell converter with the conventional solution, considering the effects of input and output disturbances.

Figure 1 shows the single-phase half-bridge representation of the conventional power amplifier and the proposed dual-cell topology. The proposed dual-cell converter contains two cells: 1) a Low-Frequency High-Voltage (LF-HV) cell that provides the main power to the load and is equivalent to the conventional power amplifier's switching cell, and 2) a High-Frequency Low-Voltage (HF-LV) cell that improves the controller's bandwidth. The HF-LV cell is not in the main power path and thus has a negligible effect on the converter's efficiency. Additionally, a simple unipolar voltage source is sufficient to supply this cell. However, a more complex dual-input single-output controller is required to control the dual-cell power amplifier.

Figure 2. illustrates the traditional controller of the conventional power amplifier and the proposed control strategy for the dual-cell converter. To ensure a fair comparison, the LF-HV cell of the dual-cell power amplifier is exactly the same as that of the conventional power amplifier, and both are switched at $f_{sw,single} = f_{sw,LF} = 100\ \mathrm{kHz}$. The HF-LV cell operates at $f_{sw,HF} = 10\ \mathrm{MHz}$.

As Figure 3 (a) shows, the dual-cell converter's control bandwidth is considerably improved thanks to the inclusion of a high-frequency cell. Figure 3 (b) shows the sensitivity of both converters to their control inputs. The dual-cell converter has two control inputs, $v_{m,LF}$ and $v_{m,HF}$ while the single-cell converter has only one control input v_m. The peak sensitivity of the proposed dual-cell converter is reduced compared with the single-cell converter. However, this converter is more sensitive to high-frequency input disturbances. Figure 3 (c) and (d) show the sensitivity of the power amplifiers to

output current and voltage perturbations. Again, while the overall peak sensitivity is considerably reduced for the dual-cell converter, it is more sensitive to high-frequency perturbations.

The experimental results will be included in the final presentation.

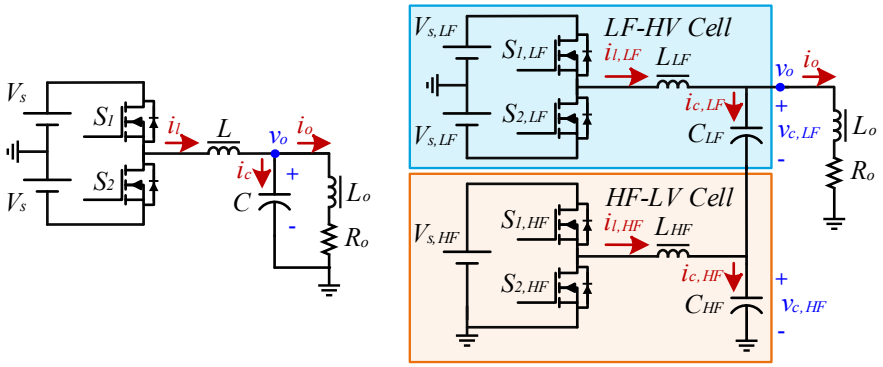

Figure 1: Single-phase half-bridge representation of (a) conventional power amplifier, and (b) dual-cell power amplifier.

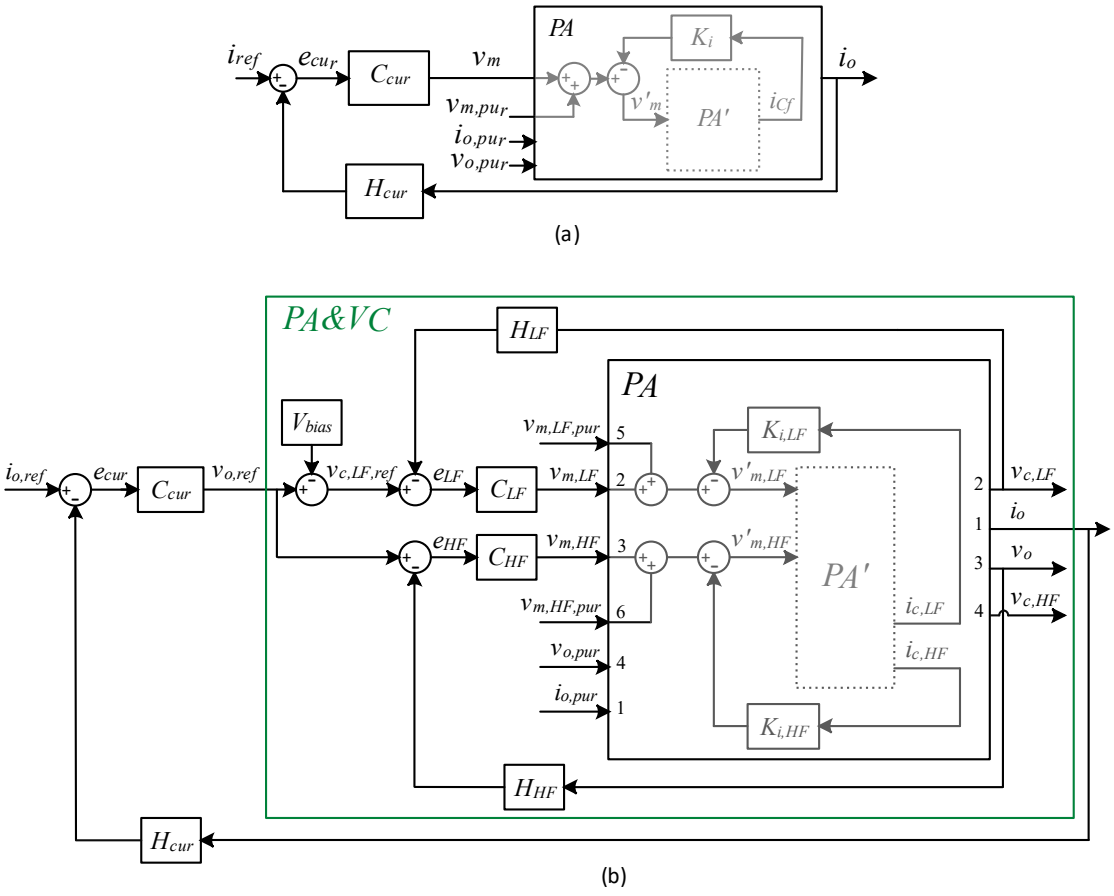

Figure 2: Controller system of (a) conventional power amplifier, and (b) dual-cell power amplifier.

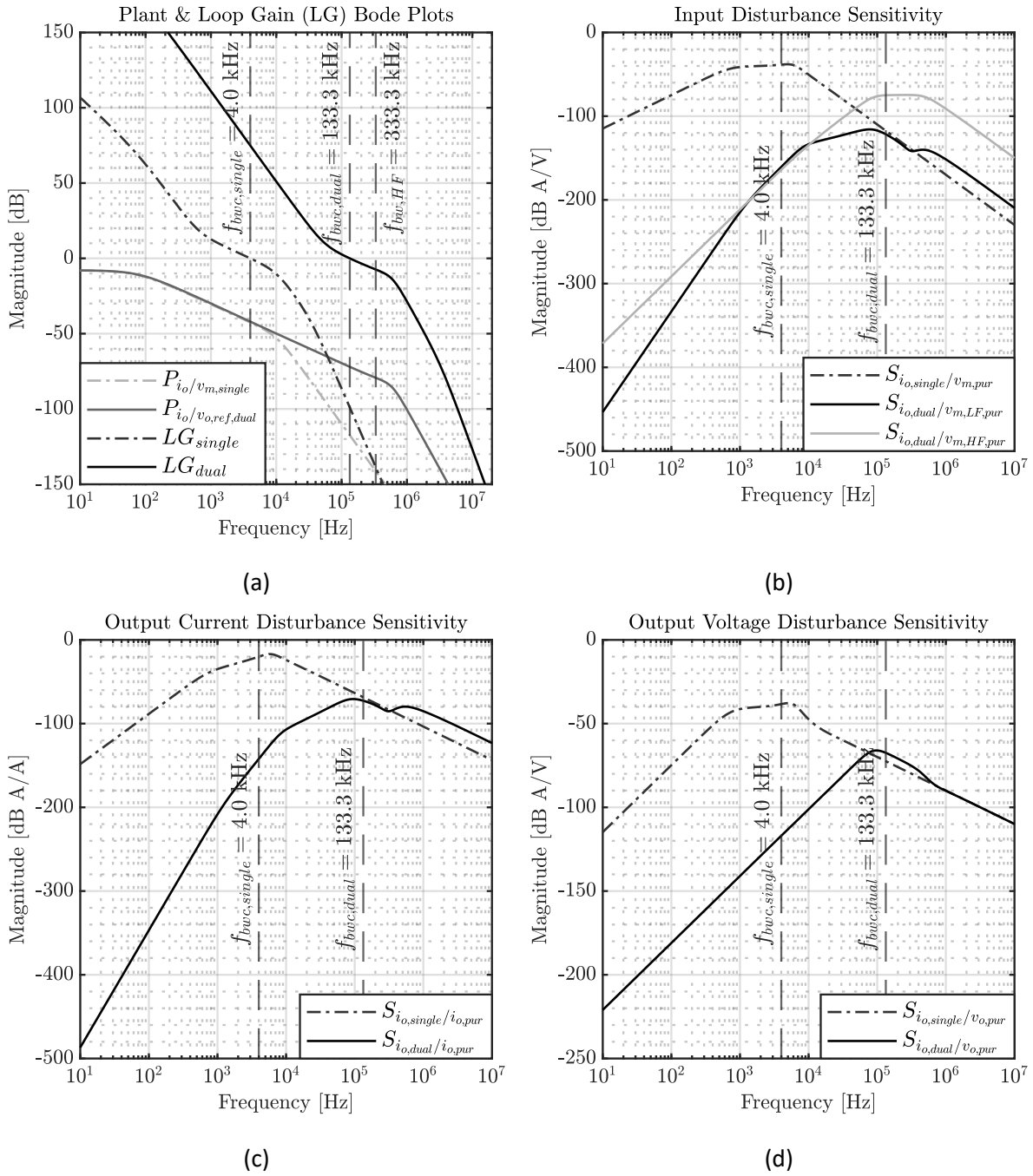

Figure 3: (a) Proposed dual-cell converter controller open-loop gain compared with single-cell converter controller open-loop gain, (b) comparison between the sensitivity of the dual-cell converter to input disturbances and that of the single-cell converter, (c)-(d) comparison between the sensitivity of the dual-cell converter to output disturbances and that of the single-cell converter.

References:

[1] M. Mauerer, “Low-Noise and Low-Distortion Switch-Mode Power Amplifiers for Nano-Positioning Applications,” Ph.D. dissertation, Dept. Elect. Eng., ETH Univ., Zurich, 2018.

[2] M. Hajiheidari, B. Vermulst, J. van Duivenbode and H. Huisman, "High Bandwidth Power Amplifier with A Shunt Correction Cell," 2023 11th International Conference on Power Electronics and ECCE Asia (ICPE 2023 - ECCE Asia), Jeju Island, Korea, Republic of, 2023, pp. 2105-2111, doi: 10.23919/ICPE2023-ECCEAsia54778.2023.10213825.