Texas Instruments Inc.

High Performance Analog

High Speed Products

High Speed Amplifiers

Design Guide

Low power fully differential PGA using OPA2683

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Abstract

The objective of this reference design was to create a Low Power Fully Differential Programmable Amplifier. To accomplish this goal, the High Speed Current Feedback Amplifier OPA2683 was selected to provide a low power solution. The design is to provide a quick evaluation solution that provides the benefits of a PGA performance without the penalty on power consumption; within reason considering board design limitations.

A low power current feedback amplifier was selected to provide the drive capabilities required of a PGA with high dynamic range, high slew rate, and reduced bandwidth changes versus gain; gain and bandwidth are independent of each other, and the bandwidth is relatively constant with the Rf feedback resistor. With the OPA2683 we add the benefit of low power operation to the list of benefits. The OPA2683 provides many of the advantages of an ideal CFB with low power operation, there is also a closed-loop input stage buffer to provide low and linearized impedance at the inverting input. A deeper explanation of voltage feedback and current feedback amplifiers may prove useful, but is beyond the scope of this paper; a good resource would be the Texas Instruments Application note SLVA051[*].

Programmable gain amplifiers provide the benefit of adjustable gain without need to change external feedback resistors. These amplifiers are excellent for data acquisition systems, providing wide dynamic range based on input signal amplitude, allowing full use of the ADC input range.

Fully differential amplifiers provide excellent ADC drive performance with improved even order distortion performance, and increased dynamic range. So the combination of the two should prove to be a useful device.

Typically PGAs provide the relatively flat bandwidth across all gain settings, low distortion, and wide dynamic range versus gain. In PGAs that accomplish this, the power consumption is the cost for the performance. The increased power is due to the gain switching circuitry built into the amplifier, and the architecture requirements to provide flat response throughout gain settings. With this low power fully differential programmable reference design you have programmable gain control via analog circuitry and wide bandwidth at high gains with relatively low power consumption compared to current PGAs on the market.

** Voltage Feedback vs. Current Feedback Op Amps Application Note*

Reference Design: Schematic

The OPA2683 Dual Low Power amplifier was used in the following Programmable Gain Amplifier reference design. A low power switch may be utilized and is included in the reference design schematic, but for the purposes of this paper jumpers were used to switch between gain configurations. The schematic below has a switch in place, however it has been removed for testing as peaking was significantly detrimental to performance. A lower capacitance switch may be selected for use, or jumpers may be used between gain settings.

In selecting a switch for this type of configuration, the following should be considered. The switch should provide an isolated path when OFF and low resistance when ON. The other key to a stable design would be low capacitance in both states. For the OPA2683 it is recommended to have low parasitic capacitance <2pF on the inverting input. External capacitance in excess of 2pF will start to peak the frequency response, in excess of 5pF on the inverting node, input stage oscillation that cannot be filtered by a feedback element adjustment will be present.

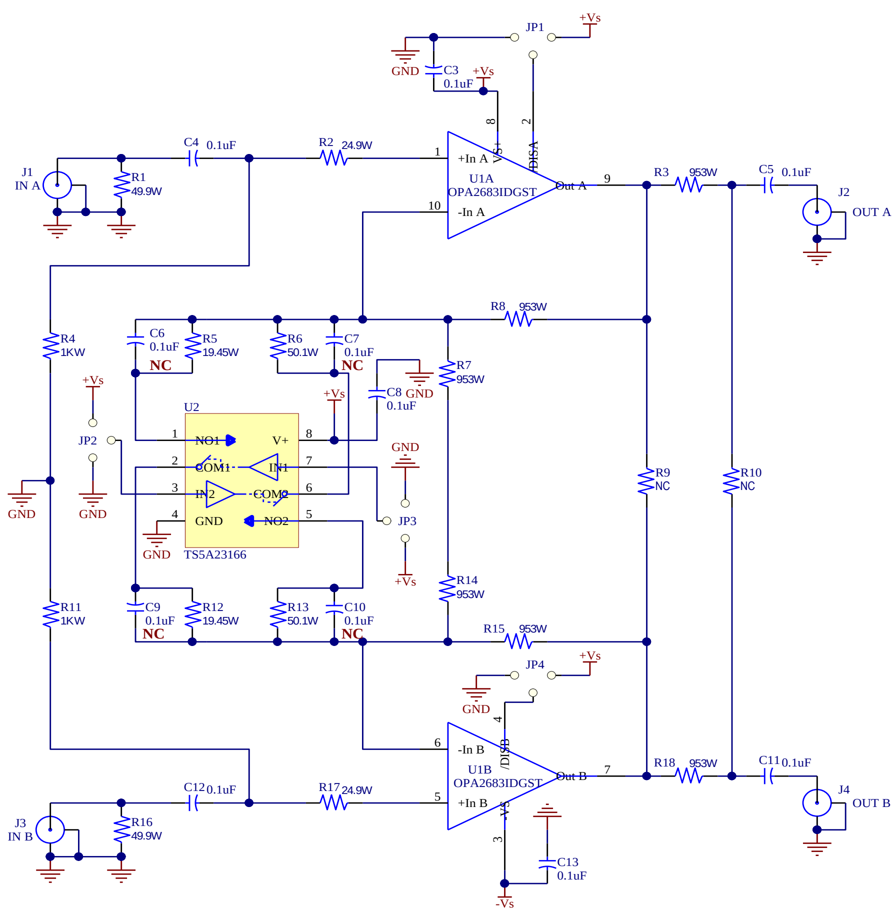

Figure 1: (Reference Design Schematic)

Reference Design: Test Circuit

The reference design was evaluated with the following test conditions:

Voltage Supply = +/-5V

G = 2, 21, 50, and70 V/V

Load = 1kohm

Output Voltage = 2Vpp for Frequency Response and Harmonic Distortion measurements.

A THS4509 Fully Differential Amplifier in Single-ended to Differential conversion configuration was used to provide a single-end to differential conversion for the input signal. EVMs for this are available on the TI eStore.

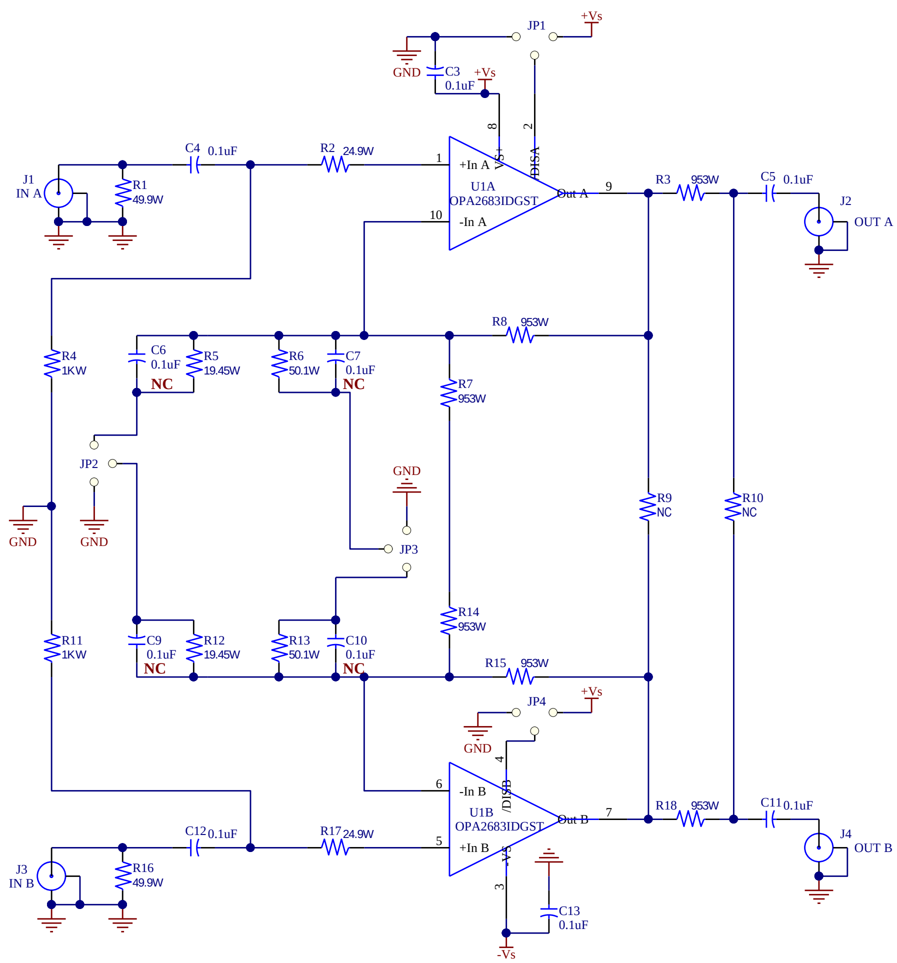

Figure 2: (Test Circuit)

Performance: Frequency Response

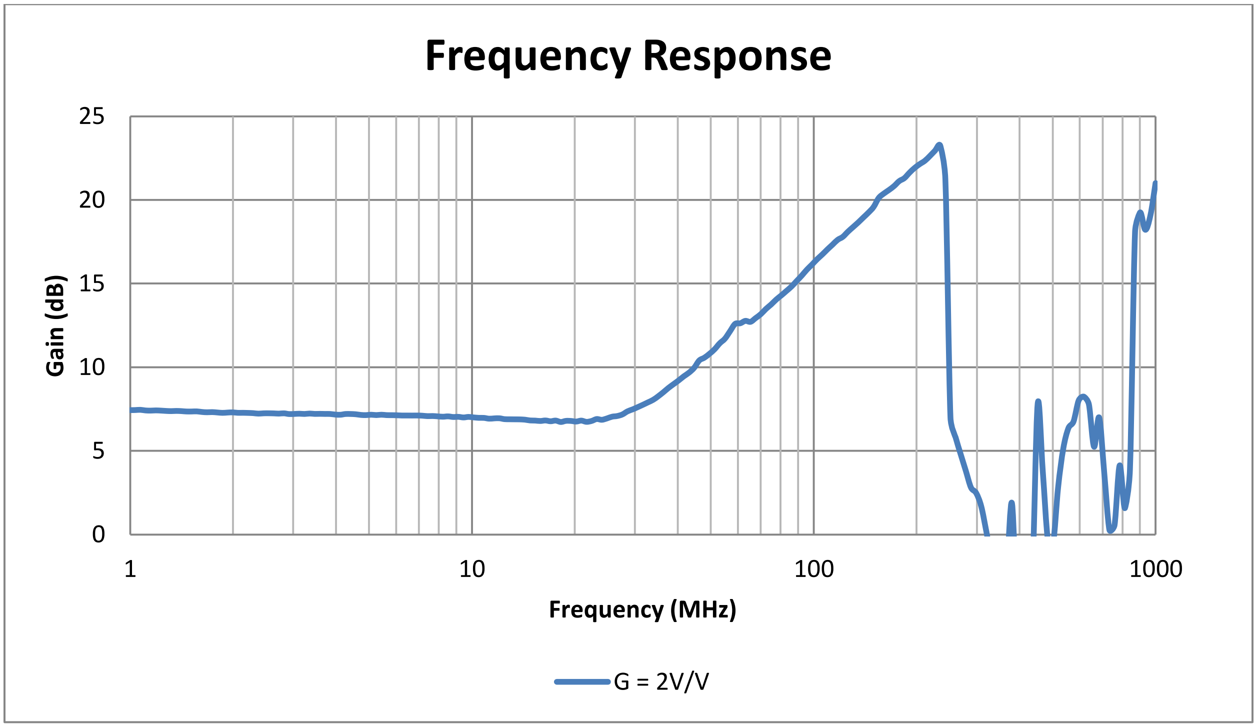

Figure 3: (G = 2V/V -3dB BW = 278MHz)

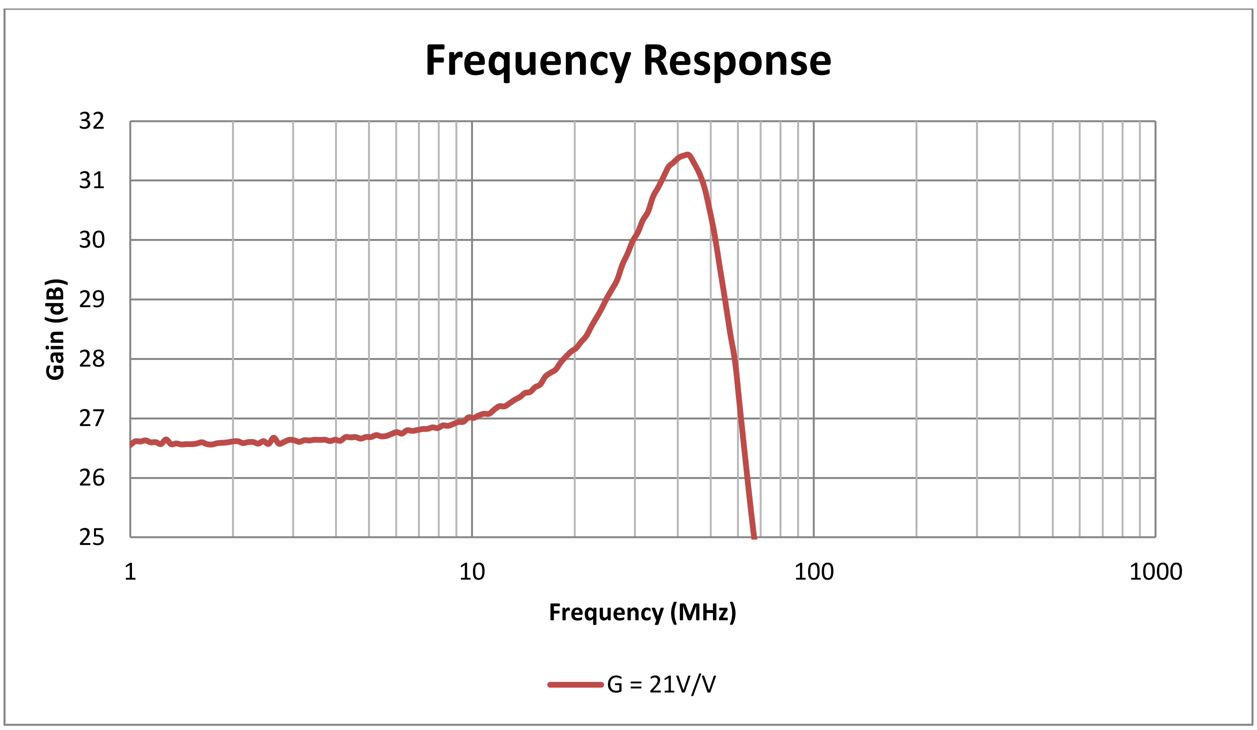

Figure 4: (G= 21V/V -3dB BW = 72MHz

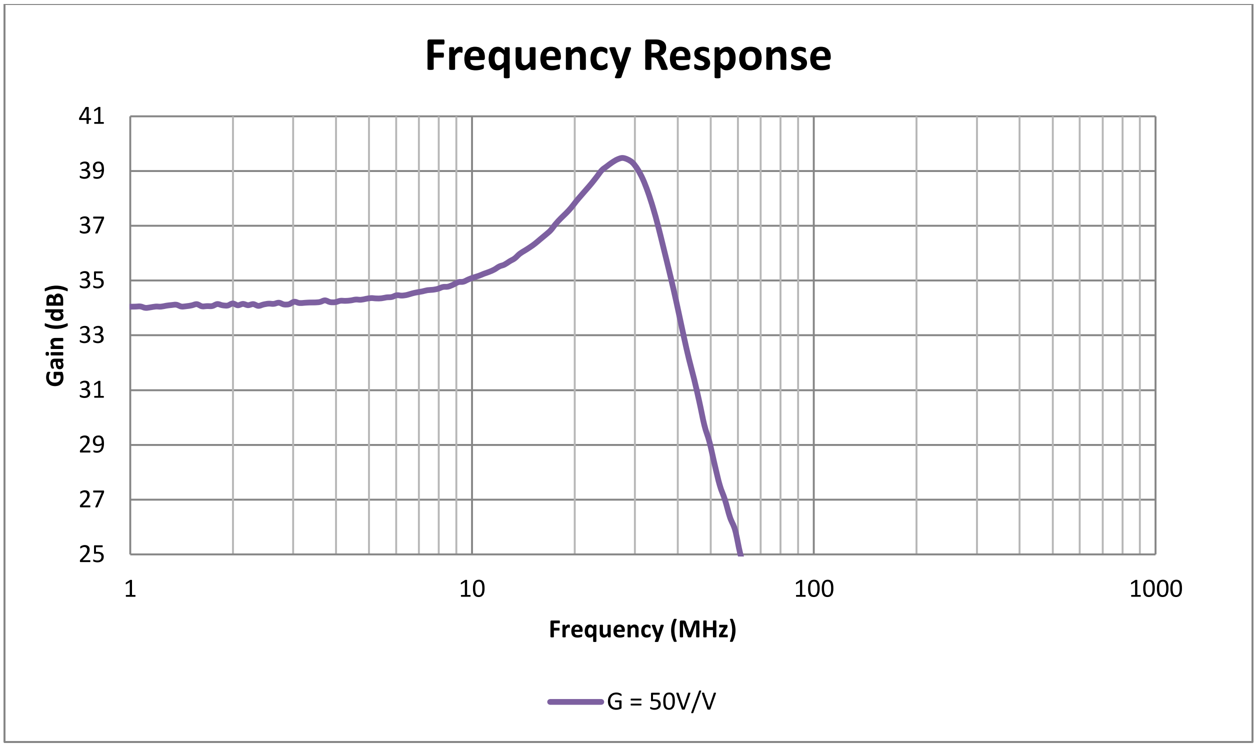

Figure 5: (G = 50V/V -3dB BW = 45MHz)

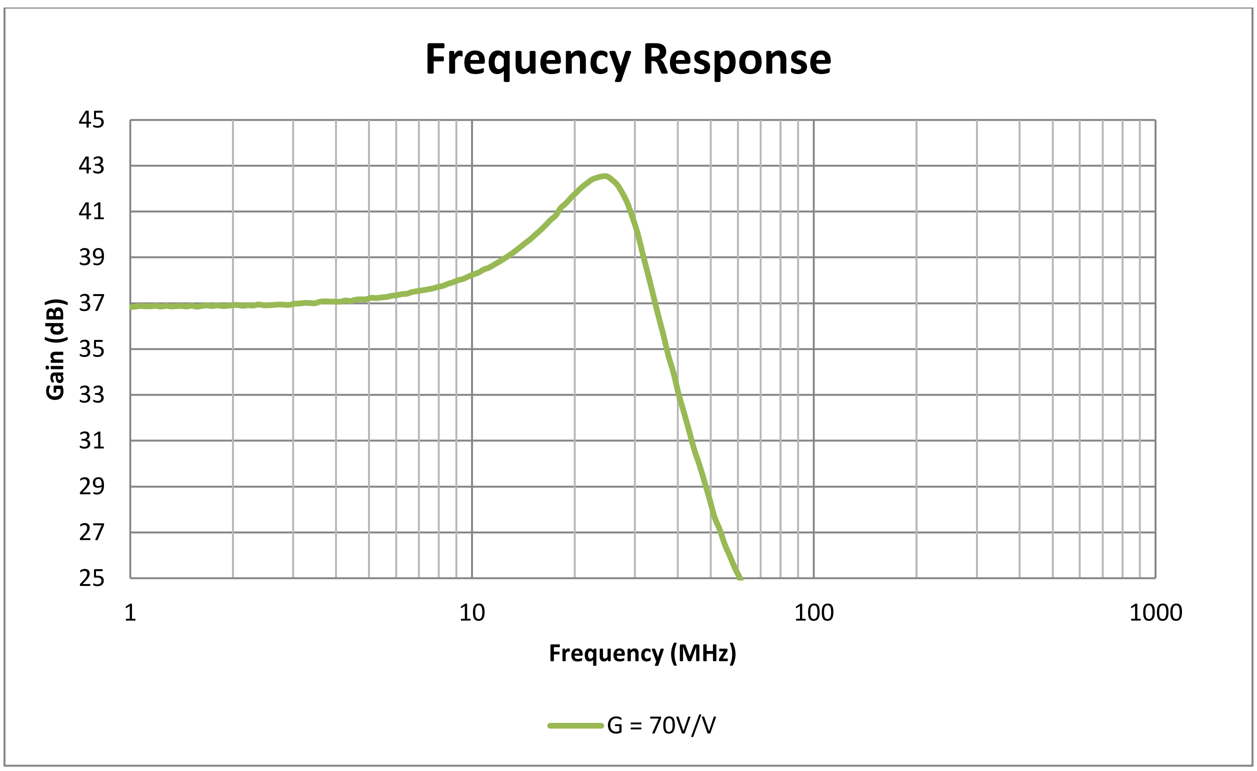

Figure 6: (G =70V/V -3dB BW = 40MHz)

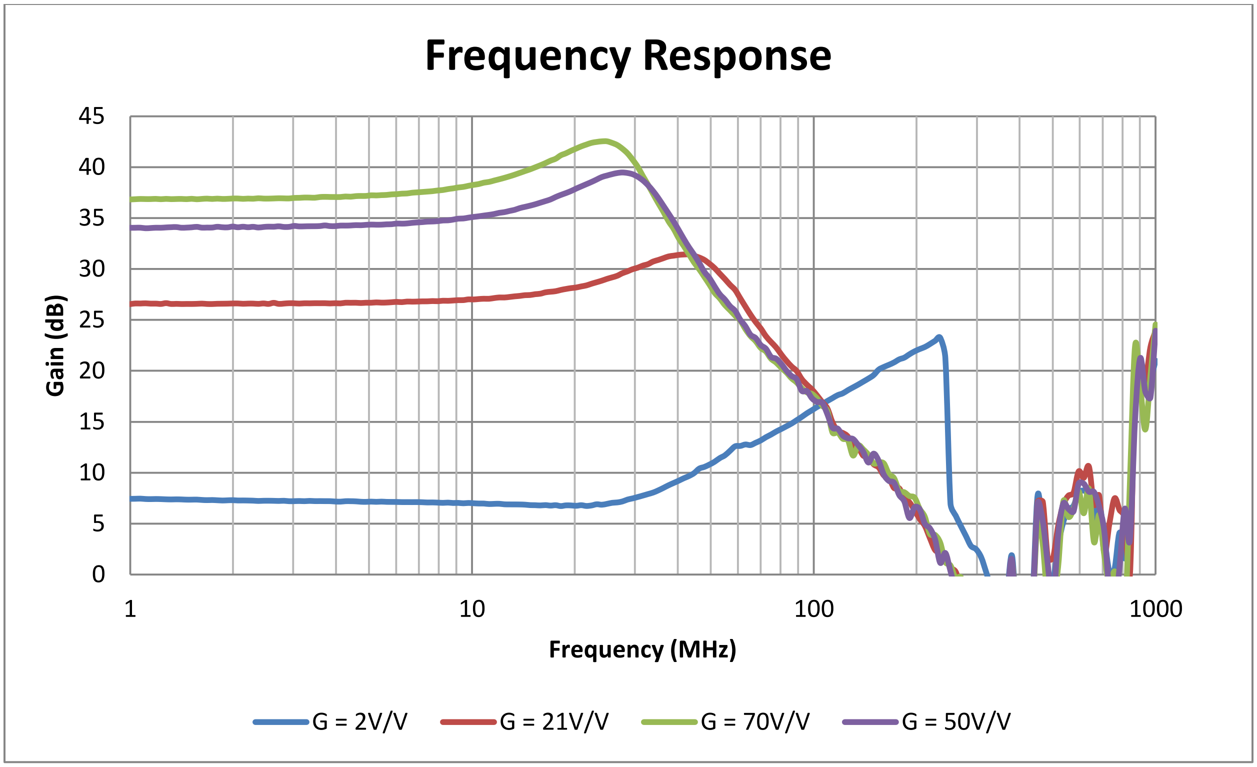

Figure 7: (All Gain Settings)

Performance: Harmonic Distortion

f = 300kHz	
600kHz	900kHz
HD2 (dBc)	HD3 (dBc)
-58.65	-31.15
-49.88	-28.55
-41.41	-28.41
-38.42	-28.20

f = 5MHz	
10MHz	15MHz
HD2 (dBc)	HD3 (dBc)
-58.56	-30.85
21.33	49.88
13.00	41.41
10.22	38.42

Figure 8: Harmonic Distortion f = 300kHz & f = 5MHz

Performance: Power Consumption vs. Gain

The power consumption was tested with a 5MHz Sine wave with varying amplitude.

Load = 1kohms

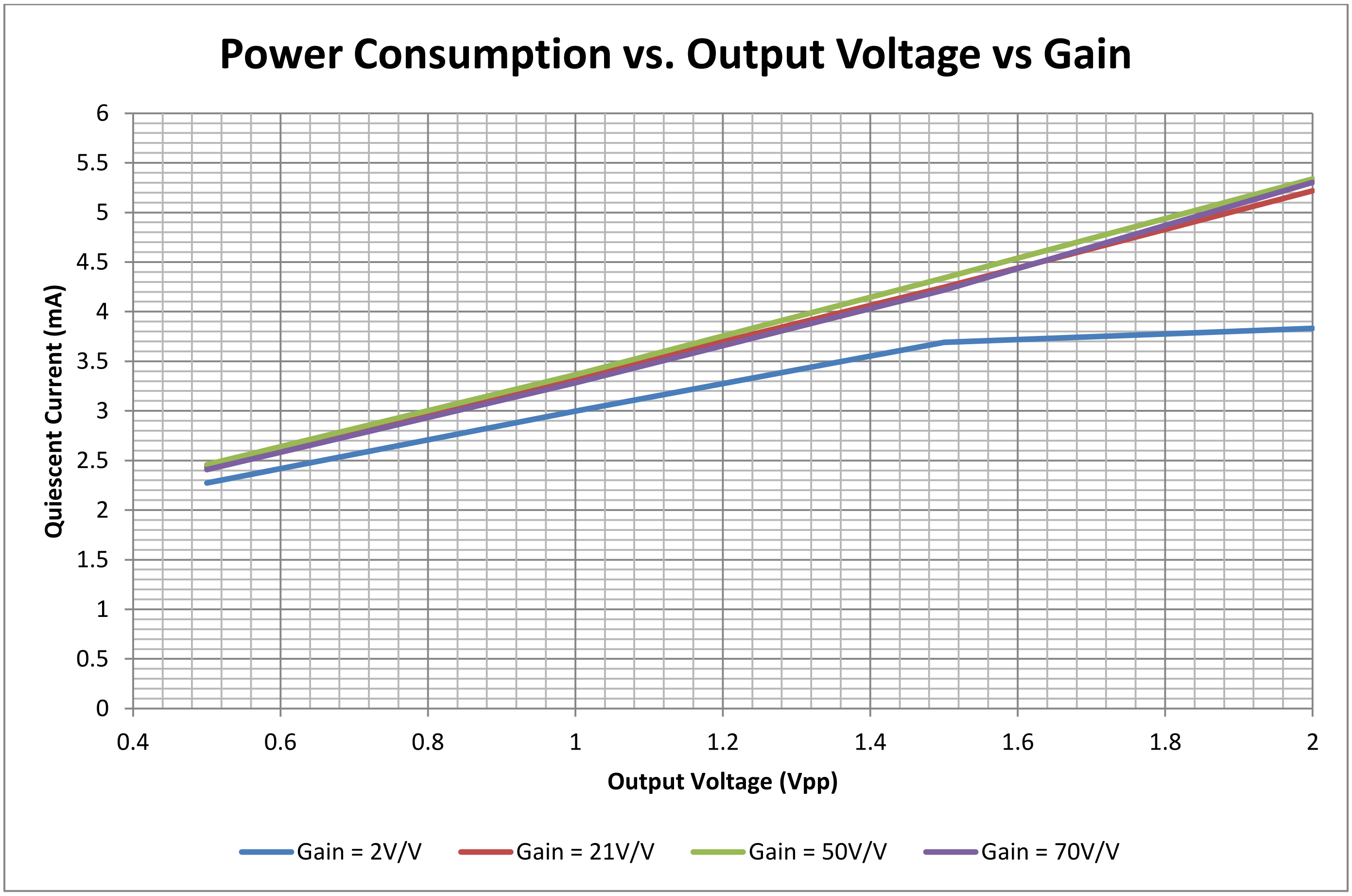

Figure 9: Power Consumption vs. Output Voltage vs. Gain

The plot shows the quiescent current of the reference design with varying output voltage at each gain setting. Gain of 2V/V shows the most differentiated change versus output voltage, with the higher gains being nearly negligible for power consumption difference.

Results

From the above frequency response plots we see significant peaking in the Gain of 2V/V. This is due to the excess capacitance on the inverting input from the board and from the jumpers used for the test circuit. With decreased capacitance this peaking will diminish. The peaking is also noticeable in the higher gain settings, but this is reduced since the series resistance of Rg eliminates some of the stray capacitance on the inverting input when the jumper is closed.

Overall the bandwidth is reduced; as you would expect in higher gain configurations. Considering this is a low power part used in this configuration, the tradeoff is warranted by the goal. As with most amplifiers and overall analog designs, higher performance for flat wide bandwidth and low distortion comes at the price of consuming more power.

The distortion performance is also reduced for the configuration used in this reference design. This further proves the challenge in creating a programmable differential amplifier with the switchable gain done externally. Careful consideration must be taken to reduce stray capacitance one the sensitive feedback path as mentioned in an earlier section of this paper.

Another device which accomplishes the goal of this reference design is the LMH688x which is The World's First Programmable Differential Amplifier. The aforementioned device has excellent performance with higher power consumption, but for 2.4GHz bandwidth, this part does a superior job with low distortion, low noise and high bandwidth.

Conclusion

The OPA2683 provides the performance metrics necessary to accomplish the goal of a fully differential low power PGA solution. The OPA2683 demonstrates peaking at throughout gain settings; however this is to be expected, due to stray capacitance. The limitation of a low power solution for a fully differential programmable has been mitigated with this reference design. Performance and distortion are comparable relative to the power consumption for such a device configuration. For better performance higher power consumption is to be expected.

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