

# DESIGN NOTES

## A Low Power, High Output Current Dual CFA Makes xDSL Line Driving Clean and Easy – Design Note 187

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### Introduction

Driving the balanced lines of high speed modems has become a very popular application for high speed, high output current, dual operational amplifiers. High amplifier speed is required to faithfully process signal passbands of at least 1MHz bandwidth, and high output currents are required to meet peak drive levels into 100Ω or 135Ω termination. Taking into account peak-to-average signal ratios in these applications, Table 1 summarizes peak voltage/current drive levels required by current xDSL systems. The peak voltage and current drive values shown are for ADSL systems with 100Ω termination and HDSL/HDSL2 systems with 135Ω termination.

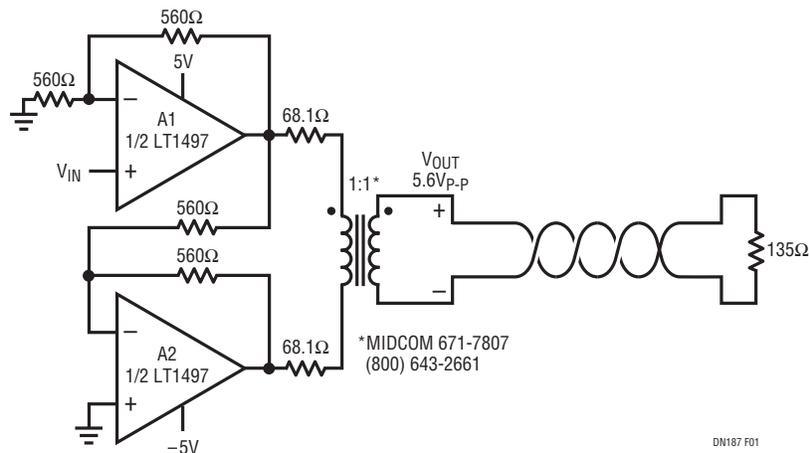
There are amplifier products available today that can address at least one, but not all, of the xDSL applications listed in Table 1. These products are single application specific and suffer from one or more of the following shortcomings: limited supply voltage operation, excessive zero-load power dissipation, large packaging/heat sinking and/or limited dynamic performance (thermal and intermodulation crosstalk).

The LT<sup>®</sup>1497, a 50MHz, 125mA dual CFA from Linear Technology, is the fourth product in our family of high speed, high current dual current feedback amplifiers, capable of addressing any one or all five of the xDSL applications in Table 1. It operates from ±2.5V to ±15V supplies, consumes less than 7mA per amplifier and is available in both SO-8 and thermally enhanced S16 packages. With its 125mA output stage and available voltage swing to within 2V of either rail, the LT1497 is a good, economical choice because it allows the use of smaller turns-ratio (1:1 and 1:2) transformers to deliver power into the line. These transformers are less expensive

**Table 1. Peak Drive Levels for Popular xDSL Systems**

xDSL	Nominal Transmit Power	Peak Voltage	Peak Current
HDSL	13.5dBm	5.6V <sub>p-p</sub>	42mA <sub>p-p</sub>
ADSL DMT Upstream	13dBm	15V <sub>p-p</sub>	150mA <sub>p-p</sub>
ADSL CAP Upstream	13dBm	8.5V <sub>p-p</sub>	86mA <sub>p-p</sub>
ADSL CAP Downstream	20dBm	18.9V <sub>p-p</sub>	190mA <sub>p-p</sub>
HDSL2	16.5dBm	19.6V <sub>p-p</sub>	146mA <sub>p-p</sub>

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**Figure 1. A Low Distortion, LT1497-Based Differential Transmitter Circuit for xDSL Applications**

than the high turns-ratio transformers required by some amplifiers that operate on a single supply voltage rail. In addition, its low quiescent supply current allows more modem lines per card because less PC board area is required for the device and heat sinking. Its low input offset voltage match ( $\pm 3.5\text{mV}$ ) and low  $\text{TCV}_{\text{OS}}$  ( $10\mu\text{V}/^\circ\text{C}$ )—not specified for other amplifiers—combine to eliminate output coupling capacitors used to block DC current flow through the transformer's primary windings.

### A Low Distortion HDSL Line Driver

Figure 1 shows an HDSL differential line driver circuit that transmits signals over a  $135\Omega$  twisted pair through a 1:1 transformer. The driver amplifiers are configured for gains of two (A1) and minus one (A2) to compensate for the attenuation inherent in the back termination of the line and to provide differential drive to the transformer.

Even though the input circuit configuration is single ended, the circuit configuration can be very easily manipulated to accommodate differential output analog front ends (AFEs) and/or single supply rail operation for the line driver circuit. For HDSL applications, the LT1497's high output current and voltage swing drive the  $135\Omega$  line at the required distortion level of  $-72\text{dBc}$ . For an HDSL data rate of  $1.544\text{Mbps}$ , the fundamental frequency of operation is  $392\text{kHz}$ .

### Performance

The circuit of Figure 1 was evaluated for harmonic distortion with a  $400\text{kHz}$  sine wave and an output level of  $5.6\text{V}_{\text{p-p}}$  into  $135\Omega$ , representing peak drive operation into the HDSL termination. Figure 2 shows that the second harmonic is  $-72.3\text{dB}$  relative to the fundamental for the  $135\Omega$  load. Third harmonic distortion is not critical, because received signals are heavily filtered before being digitized by an A/D converter.

With multicarrier applications, such as discrete multitone modulation (DMT), becoming as prevalent as single-carrier applications, another important measure of amplifier dynamic performance is 2-tone intermodulation distortion. This evaluation is a valuable tool for evaluating amplifier linearity when processing more than one tone at a time. For this test, two sine waves at  $300\text{kHz}$  and  $400\text{kHz}$  were used, with levels set to obtain  $5.6\text{V}_{\text{p-p}}$  across the  $135\Omega$  load. Figure 3 shows that the third-order intermodulation products are well below  $-72\text{dB}$ .

### Conclusion

The new LT1497 offers outstanding distortion performance in an SO-8 package with remarkably low power dissipation and very attractive high speed modem system economics. It is ideally suited for single-pair digital subscriber line systems, specifically DMT remote terminal, CAP central office/remote terminal, HDSL or HDSL2 line-driver applications.

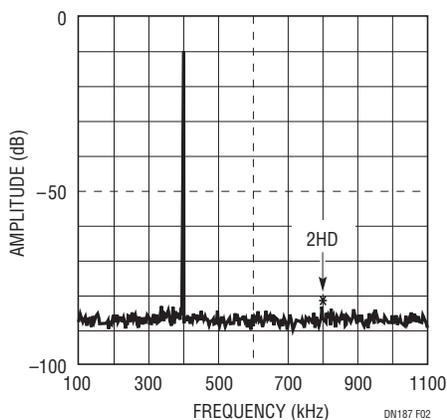


Figure 2. Harmonic Distortion Performance of Figure 1's Circuit with a  $400\text{kHz}$  Sine Wave at  $5.6\text{V}_{\text{p-p}}$  into  $135\Omega$

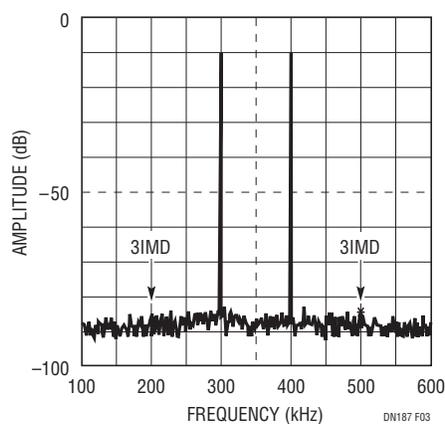


Figure 3. 2-Tone Intermodulation Distortion Performance of Figure 1's Circuit. Two Sine Waves at  $300\text{kHz}$  and  $400\text{kHz}$  Are Used to Obtain  $5.6\text{V}_{\text{p-p}}$  into  $135\Omega$

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