# LT1815: 220MHz, 1500V/μs Amplifier Saves Space and Power

by Kris Lokere

## Introduction

The LT1815 is a low power, low distortion single op amp with a 220MHz gain bandwidth product and a 1500V/μs slew rate. The device operates with supplies from ±2V to ±6V and draws a typical supply current of only 6.5mA. The LT1815 can drive 100Ω loads with low distortion; typically the distortion products are –67dBc relative to a 5MHz, $2V_{P-P}$ carrier. The LT1815 is available in the space saving SOT-23-5 and SOT-23-6 packages and the SO-8 package. The 6-lead SOT-23 package features a current programming pin that allows the user to lower the supply current for even more power savings while the device

remains active with reduced frequency performance. This combination of high speed and low power, and the flexibility to trade off one for the other "on-the-fly," makes the LT1815 a useful component in many high speed communication systems where power consumption has to be minimized.

## Performance

Table 1 summarizes the performance of the LT1815. Note that the LT1815, a voltage feedback amplifier, slews at a rate of 1500V/μs or 670ps per volt. A high slew rate not only reduces the settling time (15ns for a 5V step to settle to within ±50mV), it also extends the effective frequency range of the amplifier. The full-power bandwidth can be calculated from the slew rate by the formula:

$$f_{FPBW} = SR/2\pi V_P$$

For a slew rate of 1500V/μs and output amplitude of ±3V ($V_P$ = 3V), this amounts to a full-power bandwidth of 80MHz. Although this is still short of the 220MHz small signal–gain bandwidth product, it extends well into the range of many broadband communications and digital video systems.

A high slew rates also ensures that slew limiting does not contribute to

distortion over a wide frequency range. The 220MHz gain bandwidth product, in turn, ensures a high loop gain at the frequency of interest. At a carrier frequency of 5MHz, the open loop gain equals 44, which further reduces distortion. Figure 1 (bottom two curves) shows distortion vs frequency of the LT1815 amplifier in a gain-of-2 configuration.

## Programmable Current Option

The discussion so far has centered on the LT1815 specifications in the full speed mode. In the SO-8 and 5-lead SOT-23 packages, this is the only mode offered. The 6-lead SOT-23 package, however, features a current programming pin labeled $\overline{EN}$, which is referenced to the negative supply rail and has an active low polarity.

In order to operate the amplifier at full speed (and full supply current), pull the $\overline{EN}$ pin down to the negative supply through a resistance of 75Ω or less. This is the enabled mode, hence the name of the pin. When the $\overline{EN}$ pin is left unconnected or is forced to at least 2V above the negative supply voltage, the amplifier is in shutdown mode and draws only 150μA of standby current.

To adjust or program the supply current and speed of the LT1815, connect an external resistor ($R_{\overline{EN}}$) between the $\overline{EN}$ pin and the negative

**Table 1. LT1815 key performance characteristics**

| Parameter | Value |
|---|---|
| Supply Current | 6.5mA |
| Gain Bandwidth Product | 220MHz |
| Slew Rate | 1500V/μs |
| Full-Power Bandwidth, $V_{OUT} = 6V_{P-P}$ | 80MHz |
| Harmonic Distortion, $f_C$ = 5MHz, $A_V$ = 2, $V_{OUT} = 2V_{P-P}$, $R_L = 100\Omega$ | –67dBc |
| Input Noise Voltage | 6nV/√Hz |
| Input Offset Voltage (Max) | 1.5mV |
| Input Noise Current | 1.3pA/√Hz |
| Input Bias Current (Max) | ±8μA |
| Output Current, $V_{OUT} = ±3V$ | ±75mA |
| Input Common Mode Range | ±4.2V |
| CMRR | 85dB |
| PSRR | 97dB |
| All specifications are typical at ±5V, 25° C unless otherwise noted. ||
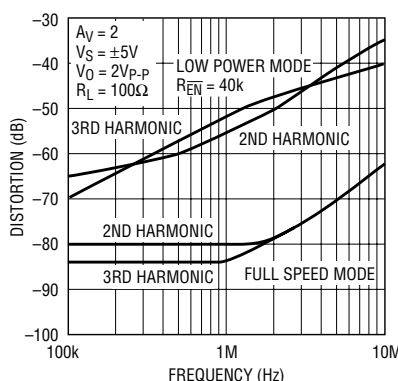


Figure 1. LT1815 distortion vs frequency
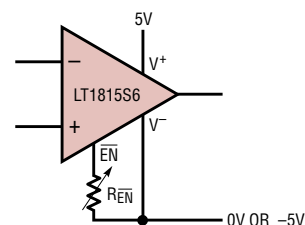


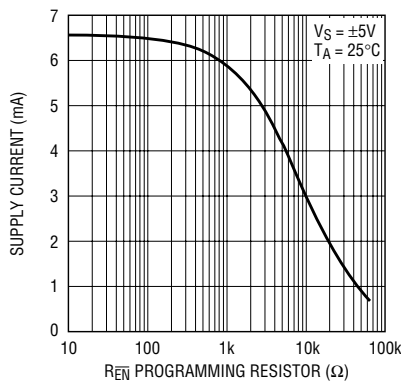Figure 2. Programming resistor between $\overline{EN}$ and $V^-$

**Figure 3. Supply current vs R$_{\overline{EN}}$ programming resistor**



**Figure 4. Gain bandwidth product vs R$_{\overline{EN}}$ programming resistor**

supply as shown in Figure 2. The higher the value of the programming resistor, the lower the supply current. The gain bandwidth product also decreases, though at a slower rate than does the supply current. Hence, the ratio of gain bandwidth product to supply current (one key figure of merit of an op amp) actually increases from 33MHz/mA to approximately 50MHz/mA for a 40k programming resistor. Figures 3 and 4 show supply current and gain bandwidth product vs programming resistor value, allowing the user to choose the optimal trade-off for the application. The top two curves in Figure 1 show distortion vs frequency with a 40k programming resistor (1.2mA supply current).

In a sense, the programmable current option transforms the LT1815 amplifier into a family of amplifiers, each at a different point in the performance vs supply current trade-off. Figure 5 shows distortion vs supply current, one of these trade-off curves. The dots represent data points for
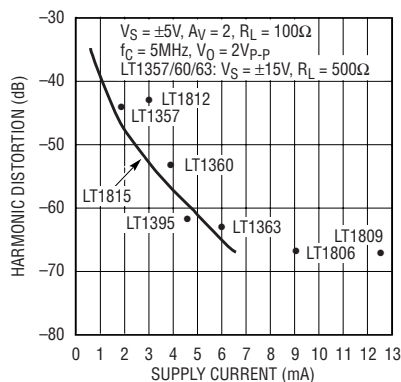
some other Linear Technology amplifiers, while the curve represents the continuous set of data points that the LT1815 and a well-chosen programming resistor can offer. While keeping in mind that every op amp is different, offering its own unique set of advantages, the LT1815 does in fact offer lower distortion for a given supply current than many other op amps.

When desired, the user can dynamically switch between full speed, shutdown and one or more low power modes using various combinations of open-drain logic, as shown in Figure 6. For example, a communication system employing the LT1815 can adjust its dynamic range depending on the noise and distortion in the receiving or transmitting channel and, in the process, never consume more current than necessary.

## Circuit Design

A simplified schematic of the LT1815 is shown in Figure 7. Both inputs are high impedance, classifying the amplifier as a voltage feedback topology. Complementary NPN and PNP emitter followers Q1–Q8 buffer each input and present the differential input signal across the internal resistor R1. The input common mode range extends to typically 0.8V from either supply, and is limited by a V$_{BE}$ of Q10/Q14 plus a V$_{SAT}$ of Q5/Q6. NPN and PNP current mirrors Q10–Q11 and Q14–Q15 mirror the current generated through R1 into the high impedance node. Cascode devices Q9 and Q13 improve the output impedance of the mirror.

Resistor R1, the transconductances of Q5–Q8 and compensation capacitor C1 set the 220MHz gain bandwidth product of the amplifier. The R$_C$, C$_C$ network between the high impedance node and the output provides extra compensation when the output drives a capacitive load. The current generated across R1, divided by the capacitor C1, determines the slew rate. Note that this current, and hence the slew rate, is proportional to the magnitude of the input step. The input step equals the output step divided by the closed loop gain. The highest
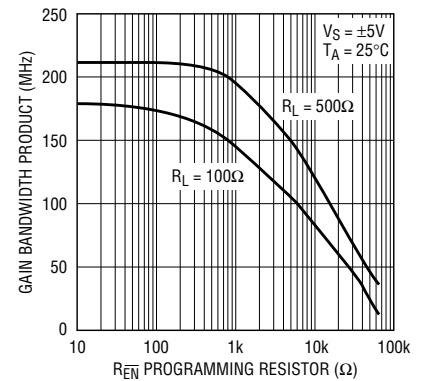
slew rates are therefore obtained in the lowest gain configurations. The LT1815 data sheet specifies the 1500V/μs slew rate in an inverting gain of –1, which is equivalent to a noninverting gain of 2. The slew rate is even higher in a noninverting, unity-gain configuration.

The internal current generated across the input resistor can be much higher than the quiescent supply current (up to 80mA). In normal transient, closed-loop operation this does not present a problem, since after a few nanoseconds the feedback brings the differential input signal back to zero. However, sustained (that is, open loop) differential input voltages may result in excessive power dissipation; therefore this amplifier should not be used as a comparator.

The output stage buffers the high impedance node from the load by providing current gain. Emitter followers Q17–Q20 provide a current gain equal to Beta$_{NPN}$ × Beta$_{PNP}$, but
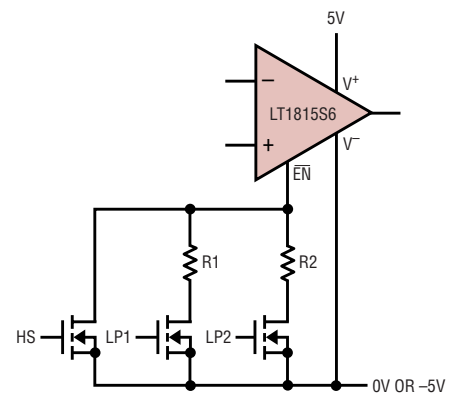


**Figure 5. Distortion vs supply current**



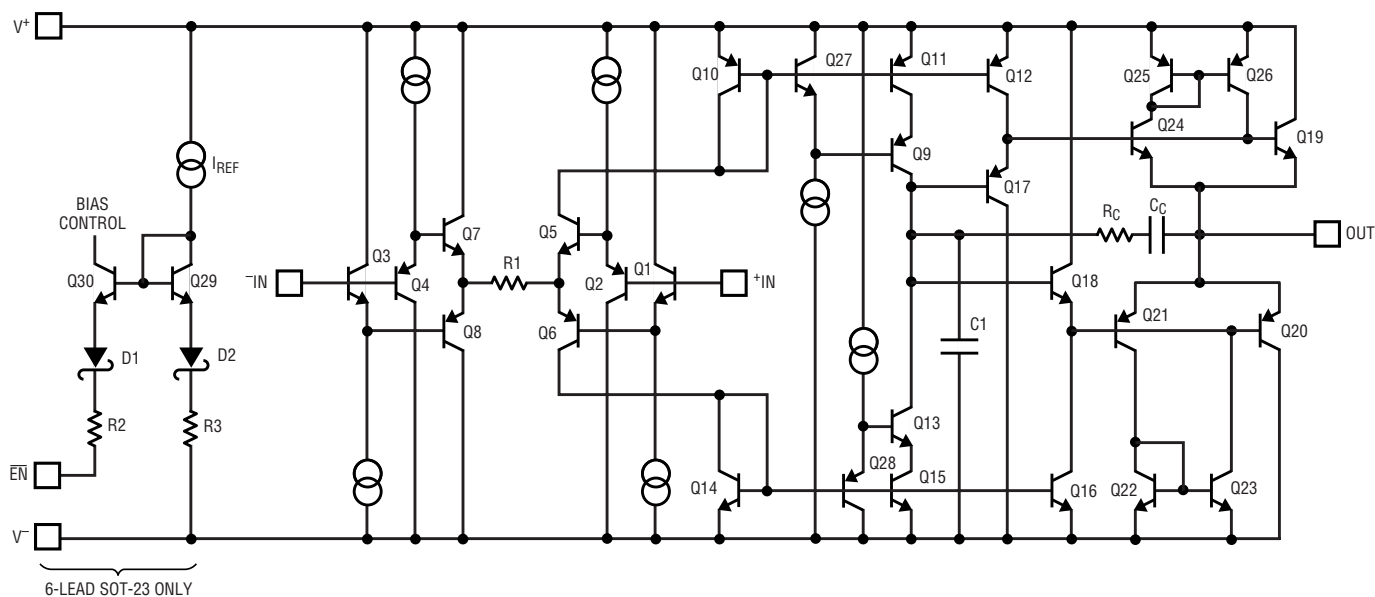**Figure 6. Switching the LT1815 between high speed mode and multiple low power modes**

Figure 7. LT1815 simplified schematic

the effective current gain is greatly enhanced by the dynamic base current compensation provided by Q24–Q26 and Q21–Q23. Q24 measures a fraction of the output current that flows through Q19; mirror Q25–Q26 injects the appropriate current back into the base of Q19. This signal-dependent boost improves the linearity of the amplifier by reducing the amount of differential input signal required for a given output current. An additional advantage is that the output devices can be smaller, which requires less quiescent current for a given amplifier speed.

The internal reference current, $I_{REF}$, flows into the current mirror formed by Q29, Q30, Schottky diodes D1 and D2 and resistors R2 and R3. When $\overline{EN}$ is shorted to $V^-$, the mirror ratio is one and all bias currents in the amplifier are nominal. Any external resistor connected between $\overline{EN}$ and the negative supply reduces the mirror ratio and thus the total supply current of the amplifier. When $\overline{EN}$ is left unconnected or pulled high, the bias to the amplifier is shut off and only the 150µA of standby current remains.

## Conclusion

The LT1815 amplifier provides an excellent combination of low supply current and high bandwidth for both small and large signals. The amplifier's low distortion at high frequencies is a big plus for signal conditioning applications. The programmable current option offers further flexibility to dynamically optimize performance in low power systems.