Flexible, High Speed Amplifiers Fit Many Roles

by John Morris and Glen Brisebois

Introduction

Selecting the best operational amplifier for a particular application can be difficult. Fast amplifiers rarely have enough input or output range. Many can't handle difficult capacitive loads, or if they can, they're usually too slow or use too much supply current for the application at hand. But now there is a simple solution: the LT6210 (single) and LT6211 (dual) are flexible enough to satisfy the needs of many applications by solving all of these problems.

These devices couple a high-speed, current-feedback topology with a C-Load™ stable, high current drive, rail-to-rail output stage. They have programmable supply current with a nearly constant speed to power ratio, from 10MHz at 300µA up to 200MHz at 6mA. The LT6210 and LT6211 can fit into such a wide variety of different applications—ranging from power-sensitive, battery-powered applications to high-bandwidth video drivers—that it may be possible to stock just one amplifier for every use.

The single-amplifier LT6210 is available in the SOT-23 6-pin package, while the dual-amplifier LT6211 is available in both an MSOP-10 package and a tiny 3mm × 4mm DFN-10 package. The LT6211 allows independent switching of each amplifier from a high speed to a low power mode.

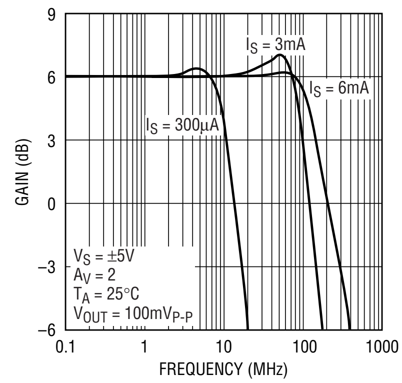

Figure 1. Small signal response vs supply current (per amplifier)

Performance

Table 1 summarizes the performance of the LT6210 and LT6211 at three selected quiescent current levels. The majority of AC specifications improve linearly with supply current. Table 2 shows the resistor values used to achieve these performance values. The frequency response with a 100mV$_{P-P}$ signal at the three selected supply currents is shown in Figure 1. Transient response of a 3.5V$_{P-P}$ signal at the three selected supply currents is shown in Figures 2, 3 and 4.

Circuit Operation

Figure 5 shows the simplified schematic of a single amplifier. Transistors Q1 and Q2 mirror a current from the

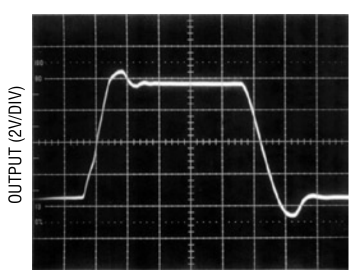

Figure 2. Large signal transient response (I_S = 6mA per amplifier)

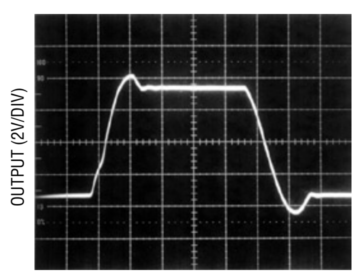

Figure 3. Large signal transient response (I_S = 3mA per amplifier)

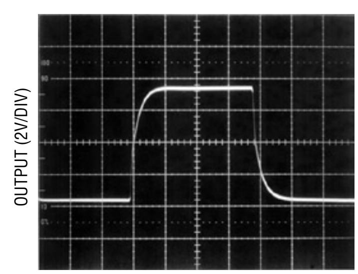

Figure 4. Large signal transient response (I_S = 300µA per amplifier)

Table 1. LT6210 performance at three quiescent current levels on ±5 supplies

Parameter	Conditions	I_S = 6mA	I_S = 3mA	I_S = 300µA	Units
–3dB Bandwidth	A_V = 2, V_{OUT} = 200mV$_{P–P}$	200	100	10	MHz
Slew Rate	A_V = 2, V_{OUT} = 7V$_{P–P}$	700	600	170	V/µs
2nd Harmonic Distortion	A_V = 2, V_{OUT} = 2V$_{P–P}$, f = 1MHz	–70	–65	–40	dBc
3rd Harmonic Distortion	A_V = 2, V_{OUT} = 2V$_{P–P}$, f = 1MHz	–75	–65	–45	dBc
Maximum Output Current	V_{IN+} = 0V, $V_{IN–}$ = ±50mV, R_L = 0Ω	±75	±70	±30	mA

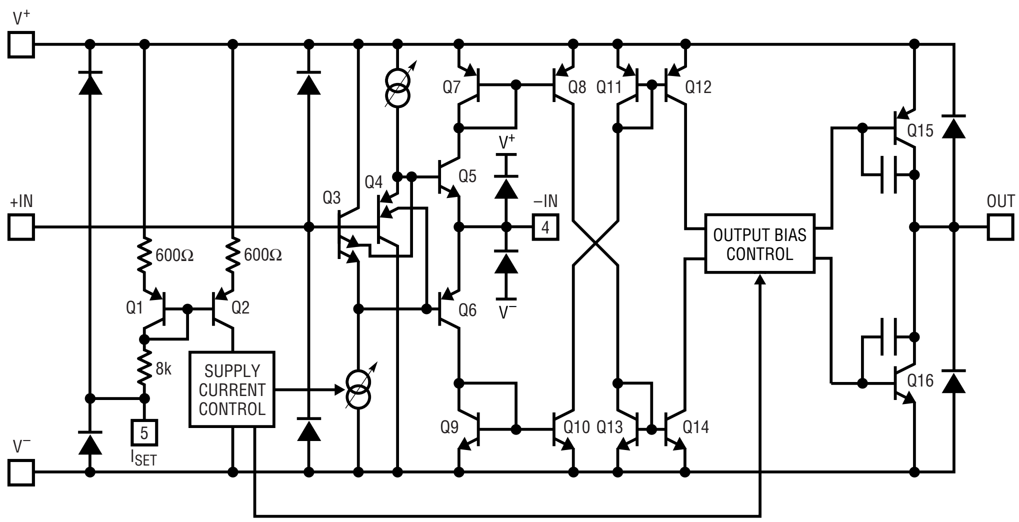

Figure 5. Simplified schematic of single amplifier

I_{SET} pin to a bias distribution network feeding the input stage. The internal 8k resistor sets the bias current when the I_{SET} pin is directly shorted to ground, and internal clamping circuitry within the supply current control ensures that the current is never high enough to damage the device.

The input stage uses a current-feedback diamond topology with two complementary pairs of emitter followers (Q3–Q6) between the noninverting and inverting inputs. Q3 and Q4 each have additional emitters that diode-clamp to the opposing positive input devices to prevent damage in case of large differential input voltages. The current outputs of the diamond circuit at the collectors of Q5 and Q6 are fed into current mirrors (Q7/Q8 and Q9/Q10) that would feed a high-impedance node in a typical current feedback amplifier. In the rail-to-rail topology of the LT6210 and LT6211, though, the signal currents are inverted by a second set of current mirrors (Q11/Q12 and Q13/Q14) and then directed into output transistors Q15 and Q16 along with an output bias current, derived from the variable supply current control. The primary frequency compensation is at the output, enhancing the amplifier's ability to drive capacitive loads.

Table 2. LT6210 configuration for A_V = +2 at various current levels

I_S	R_{SET}	R_{FB}, R_{GAIN}	R_{LOAD}
6mA	20k	887Ω	150Ω
3mA	56k	1.1k	150Ω
300μA	1M	11k	1k

Applications

Optimizing the Response of a Differential Cable Driver

Using a differential twisted pair instead of coaxial cable to transmit signals over longer distances can reduce both cost and bulk. In addition, transmitting signals differentially eliminates common mode noise pickup that can occur in longer routings. The LT6211 is ideal for these applications since the amplifier's bandwidth can be altered without changing the gain both by scaling the feedback and gain resistors and by tweaking the quiescent current of the amplifier. Therefore, the response can be optimized for a specific application, and the inverting and noninverting amplifiers can be programmed to have nearly identical frequency responses.

The C-Load stability of the LT6211 provides an additional benefit in twisted pair applications. If the differential cables are disconnected or not properly terminated the LT6211 remains stable (of course, if the line is left unterminated, signal fidelity will suffer).

The following explains how to obtain a desired response for a specific twisted pair application, in this case, for a flat response with approximately 100MHz of –3dB bandwidth. The circuit with its final values is shown in Figure 6.

Since the inverting gain amplifier gain of –2 is not shown in the Typical AC Performance table of the LT6210/LT6211 data sheet, an educated guess for the starting resistor values is required. A 1k feedback resistor is a good starting point, roughly halfway between the 1200Ω resistor suggested for a gain of –1 at the 3mA, 80MHz level and the 698Ω resistor suggested at 6mA and 140MHz. This fixes the gain resistor value at 499Ω for a gain of –2. With the gain network complete, the potentiometer at the I_{SET} pin can be tweaked while viewing the small signal frequency response on a network analyzer until the desired, flat response is achieved. With an R_{SET} value of 40.7k, the frequency response is entirely first order, with a –3dB bandwidth of 97MHz and a ±0.05dB bandwidth of 39MHz.

The approach for setting the resistor values on the noninverting channel is similar. 1k resistors are initially selected to get the desired response, but after adjusting the quiescent current to achieve a flat response, the –3dB bandwidth is significantly higher than the inverting channel. Therefore, 1.21k feedback and gain resistors are swapped in and the R_{SET} potentiometer tweaked again. This makes sense since the A_V = 2, I_S = 3mA in the "Typical AC Performance" section shows a 100MHz bandwidth with R_{FB}, R_G = 1.1k. The

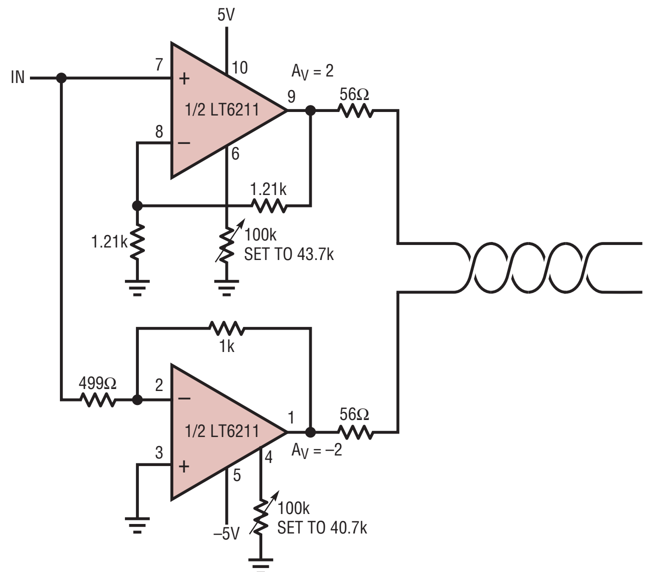

Figure 6. Differential cable driver application using LT6211

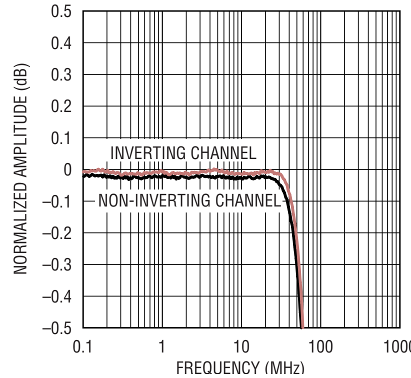

Figure 7. LT6211 differential cable driver has 0.02db gain flatness

slightly larger feedback resistor and higher quiescent current flatten the AC response from the 1dB peaking shown in the data sheet curves.

With the 1.21k resistors, bandwidth and response of the noninverting channel closely matches the inverting channel with a ±0.05dB bandwidth of 35MHz and a –3dB bandwidth of 101MHz. The final R_{SET} resistance for the noninverting amplifier is 43.7k, setting the total supply current for both amplifiers to 7.8mA. Figure 7 shows the gain flatness and ±0.1dB response of the two channels.

3V Cable Driver with Active Termination

Driving back-terminated cables on single supplies usually results in very limited signal amplitude at the receiving end of the cable. While the rail-to-rail output of the LT6210 and LT6211 already provides a larger swing than typical current feedback amplifiers, positive feedback can be used to further improve swing at the load by reducing the size of the series back termination resistor, decreasing the attenuation between the series and load termination resistors. The positive feedback also maintains controlled output impedance from the line-driving amplifier, allowing the amplifier to drive long cables without signal degradation.

Figure 8 shows the LT6210 using this "active termination" scheme on a single 3V supply. The amplifier is AC-coupled and in an inverting gain configuration to maximize the input signal range. The gain from V_{IN} to the receiving end of the cable, V_{OUT}, is set to –1. The effective impedance looking back into the amplifier circuit from the cable is 50Ω throughout the usable bandwidth.

The response of the cable driver with a 1MHz sinusoid is shown in Figure 9. The circuit is capable of transmitting a $1.5V_{P-P}$ undistorted sinusoid to the 50Ω termination resistor and has a full power ($1V_{P-P}$) bandwidth of 50MHz. Small signal –3dB bandwidth extends from 1kHz to 56MHz with the selected coupling capacitors.

Line Driver with Low Power Mode

In applications where low distortion or high slew rate are desirable but not necessary at all times, the LT6210 or LT6211's quiescent current can be decreased when the higher power performance is not required. Figure 10 illustrates a method of setting quiescent current with a FET switch. In the 5V dual supply case pictured, shorting the I_{SET} pin through an effective 20k to ground sets the supply current to 6mA, while the 240k resistor at the I_{SET} pin with the FET turned off sets the supply current to approximately 1mA. The feedback resistor of 4.02k is selected to minimize peaking in low power mode. The bandwidth of the LT6210 in this circuit increases from just over 40MHz in low power mode to over 200MHz in full speed mode, as illustrated in Figure 11. Other AC

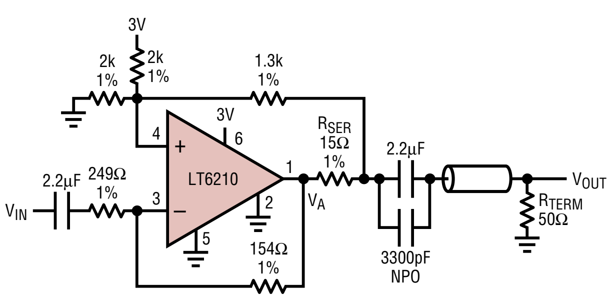

Figure 8. 3V cable driver with active termination

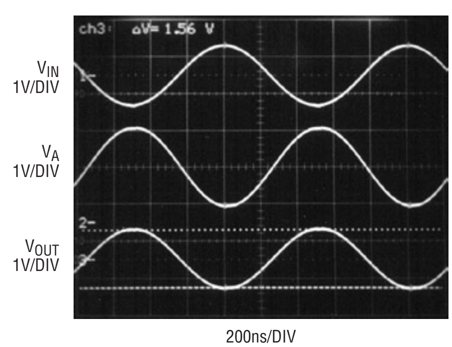

Figure 9. Response of 3V cable driver circuit at 1MHz

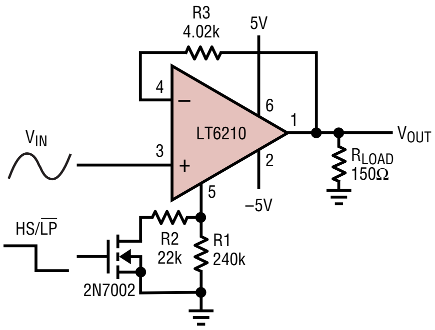

Figure 10. LT6210 line driver with low power mode

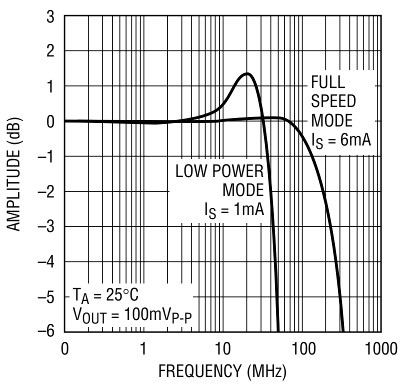

Figure 11. Frequency response of line driver for full speed and low power modes

performance also improves significantly at the higher current setting. Table 3 shows harmonic distortion at 1MHz with a $2V_{P-P}$ sinusoid at the two selected current levels.

In a system with multiple LT6211's, it is possible to use a single FET to change the supply current of all the amplifiers in parallel, as shown in Figure 12. While a single FET can be used to control numerous I_{SET} pins due to its connection to ground, individual resistors from the FET to each amplifier's I_{SET} pin are recommended to ensure consistent current programming.

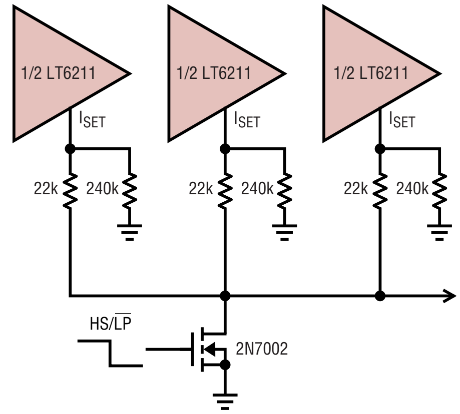

Figure 12. Using a single FET to switch multiple LT6211 quiescent currents

Conclusion

The LT6210 / LT6211 family offers impressive, high speed versatility. With a rail-to-rail, C-Load stable output stage and programmable speed and supply current, the part can be tuned to fit most applications. Whether the application is supply current sensitive or requires high speed with high output drive, the LT6210 and LT6211 are suited to the task.

Table 3. Harmonic distortion of line driver with low power mode

Low Power		Full Speed	
HD2	–53dBc	HD2	–68dBc
HD3	–46dBc	HD3	–77dBc

LTC2921/LTC2922, continued from page 5

are short-lived, do not trip the monitors. Thus momentary load transients and electronic noise do not affect the continuous monitoring operation, but a supply voltage consistently outside of the designed range, even a small amount, does. Allowing time to factor into the threshold comparison affords glitch tolerance without degrading monitoring accuracy.

Bonus Functionality: Sequencing

Whereas tracking satisfies the requirements for many multiple-supply systems, sequencing is sometimes necessary. The LTC2921 and LTC2922 offer a single-chip solution to simple sequencing via the power good output. The PG pin has a weak pull-up current to the same voltage rail that allows the GATE pin to pull well above V_{CC}. By connecting one or more external FET gates and a capacitor to the PG output, it functions as an auxiliary gate driver with an independently selectable ramp rate. The time period set by the capacitor at TIMER provides the sequencing delay between the ramps. It is important to note that because the automatic remote sense switches activate before the power good signal activates, sources ramped by PG cannot take advantage of remote sense switching. Figure 6 shows a schematic of an application that takes advantage of the sequencing capability of the LTC2921 and LTC2922 to create early-on and late-on supplies.

Conclusion

The LTC2921 and LTC2922 monitor up to five supply sources and ramps their loads up together. When any source fails its monitoring threshold, all loads are disconnected. Once all monitors are again satisfied, the turn-on sequence is attempted again. The LTC2921 and LTC2922 combine a guaranteed threshold accuracy of ±1.5% over temperature (which facilitates tight monitoring limits) with input glitch filtering (which allows the customer to take full advantage of the threshold accuracy). The low 0.5V monitor threshold allows even sub-1V supplies to be tracked. The parts feature remote sense switching that automatically connects the loads to the Kelvin sense inputs of the supply sources after the loads have fully ramped. The integrated switches and control circuitry allow the supply sources to compensate the load levels for any voltage drops due to currents through the external tracking FETs.