LB-14

Speed Up the LM108 Feedforward Compensation

National Semiconductor
Linear Brief 14

Feedforward frequency compensation of operational amplifiers can provide a significant increase in slew rate and bandwidth over standard lag compensation. When feedforward compensation is applied to the LM101A operational amplifier,[1] an order of magnitude increase in bandwidth results. A simple feedforward network has also been developed for use with the LM108 micropower amplifier to give a factor of five improvement in speed. It uses no active components and does not degrade the excellent dc characteristics of the LM108.

Figure 1 shows a schematic of an LM108 using the new compensation. The signal from the inverting input is fed forward around the input stage by a 500 pF capacitor, C_1. At high frequencies it provides a phase lead. With this lead,

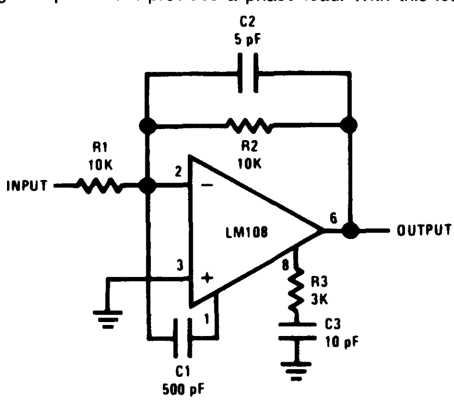

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FIGURE 1. LM108 with Feedforward Compensation

overall phase shift is reduced and less compensation is needed to keep the amplifier stable. The C_2–R_1 network provides lag compensation, insuring that the open loop gain is below unity before 180°C phase shift occurs. The open loop gain and phase as a function of frequency is compared with standard compensation in *Figure 2*.

The slew rate is increased from 0.3V/μs to about 1.3V/μs and the 1 kHz gain is increased from 500 to 10,000. Small signal bandwidth is extended to 3 MHz. The bandwidth must be limited to 3 MHz because the phase shift through the lateral PNP transistors used in the second stage becomes excessive at higher frequencies. With the LM101A, 10 MHz bandwidth was possible since the signal was bypassed around the low frequency lateral PNP's. Nonetheless, 3 MHz is very respectable for a micropower amplifier drawing only 300 μA quiescent current.

When the LM108 is used with feedforward compensation, it is less tolerant of capacitive loading and stray capacitance. Precautions must be taken to insure stability. If load capaci-

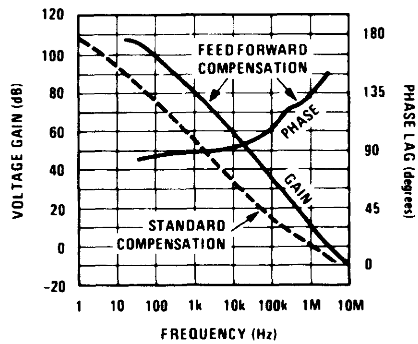

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FIGURE 2. Open Loop Voltage Gain

tance is greater than about 75 to 100 pF, it must be isolated as shown in *Figure 3*. A small capacitor is always needed to provide a lead across the feedback resistor to compensate for strays at the input. About 3 to 5 pF is the minimum value capacitor. Care must be taken to minimize stray capacitance at Pins 1, 2 and 8 when feedforward compensation is used. Additionally, when the source resistance on the noninverting input is greater than 10k, it should be bypassed with a 0.1 μF capacitor.

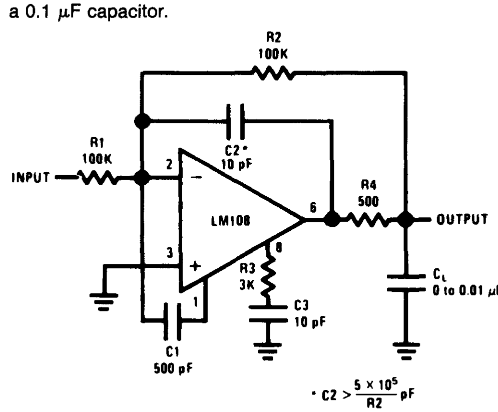

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FIGURE 3. Decoupling Load Capacitance

As with any externally compensated amplifier, increasing the compensation of the LM108 increases the stability at the expense of slew and bandwidth. The circuit shown is for the fastest response. Increasing the size of C_2 to 20 or 30 pF will provide 2 or 3 times greater stability and capacitive load tolerance. Therefore, the size of the compensation capacitor should be optimized for the bandwidth of the particular application.

The stability of the LM108 with feedforward compensation is indicated by the small signal transient responses shown in *Figure 4*. It is quite stable since there is little overshoot and ringing even though the amplifier is loaded with a 50 pF capacitor. Large signal transient response for a 20V square wave is shown in *Figure 5*. The small positive overshoot is not severe and usually causes no problems.

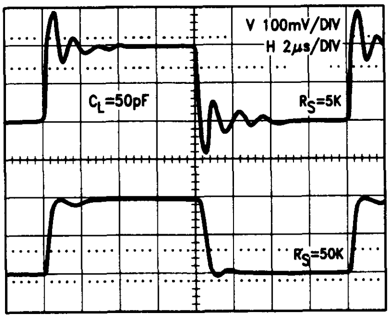

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FIGURE 4. Small Signal Transient Response of LM108 with Feedforward Compensation

The LM108 is unusually insensitive to power supply bypassing with the new compensation. Even with several feet of wire between the device and power supply, it does not become unstable. However, it is still wise to bypass the supplies for drill since noise on the V+ line can be injected to the summing junction by the 500 pF feedforward capacitor.

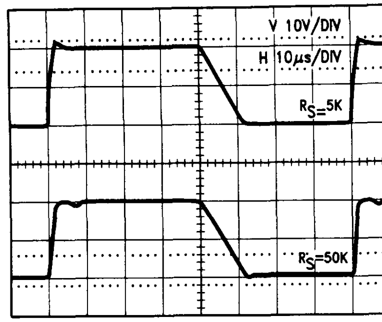

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FIGURE 5. Large Signal Transient Response of LM108 with Feedforward Compensation

The new feedforward compensation is easy to use and offers a factor of five improvement over standard compensation. Slew rate is increased to 1.3V/μs and power bandwidth extended to 20 kHz. Also, gain error at high frequencies is reduced. This makes the LM108 more useful in precision applications where low dc error as well as low ac error is desired.

REFERENCE

1. Robert C. Dobkin, "Feedforward Compensation Speeds Op Amp," *National Semiconductor LB-2*, March, 1969.