LINEAR TECHNOLOGY

DESIGN NOTES

C-Load™ Op Amps Tame Instabilities – Design Note 83

Richard Markell, George Feliz and William Jett

Introduction

By taking advantage of advances in process technology and innovative circuit design, Linear Technology Corporation has developed a series of C-Load op amps which are tolerant of capacitive loading, including the ultimate, amplifiers which are stable with any capacitive load. These amplifiers span a range of bandwidths from 1MHz to 140MHz. They are suited for a wide range of applications from coaxial cable drivers to capacitive transducer exciters.

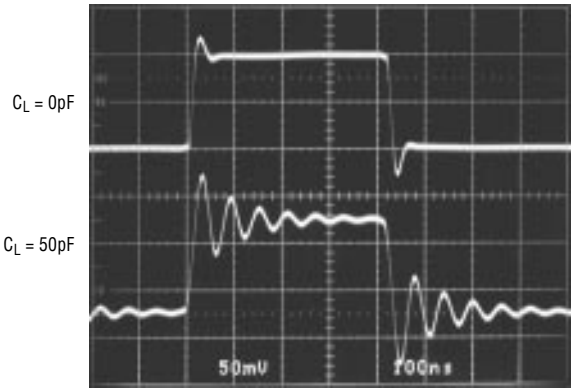
The Problem

The cause of the capacitive load stability problem in most amplifiers is the pole formed by the load capacitance and the open-loop output impedance of the amplifier. This output pole increases the phase lag around the loop which reduces the phase margin of the amplifier. If the phase lag is great enough the amplifier will oscillate.

External networks can be used to improve the amplifier's stability with a capacitive load but have serious drawbacks. For instance, most designers are familiar with the use of a series resistor R_S between the load and the amplifier output. The optimum value of R_S depends on the load capacitance, so this approach isn't useful for ill-defined loads. Further disadvantages of the external approach include reduced output swing and drive current, and increased component count.

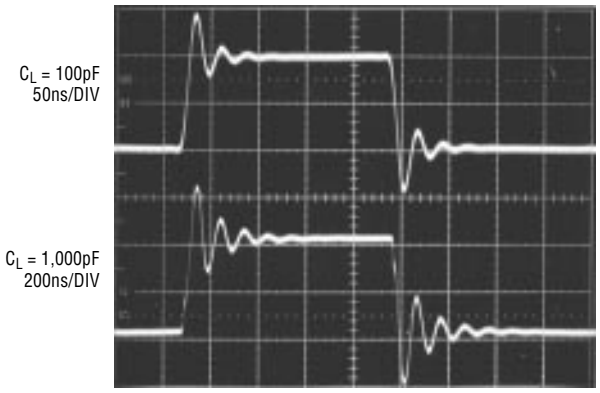
An Example

Figure 1 shows an example of a competitor's medium speed device which is sensitive to capacitive loading. When 50pF is paralleled with a 5kΩ load, the response exhibits considerable ringing. With a 75pF load the device oscillates. By comparison, the transient responses of the 50MHz LT1360 voltage feedback amplifier (Figure 2) shows the improvement in stability achieved in the latest generation of C-Load op amps. In fact the LT1360 maintains a stable transient response for any capacitive load.



V_S = ±15V R_L = 5k
A_V = 1

Figure 1. Medium Speed Non-LTC Op Amps



V_{IN} = 100mV_{P-P} A_V = 1
V_S = ±15V R_L = 5k

Figure 2. LT1360

The Solution

LTC's new family of voltage feedback amplifiers adjusts the frequency response of the op amp to maintain adequate phase margin regardless of the capacitive load thus, the amplifiers cannot oscillate. These C-Load amplifiers are great in systems where the load is not fixed or is ill-defined. Examples include driving coaxial cables that

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may or may not be terminated, driving twisted-pair transmission lines, and buffering the inputs of sampling A/D converters that present time varying impedances.

Table 1 lists LTC's *unconditionally stable* voltage feedback C-Load amplifiers. Table 2 lists other voltage feedback C-Load amplifiers that are stable with loads up to 10,000pF. Figure 3 shows overshoot as a function of capacitive load being driven for a wide variety of LTC op amps. Note that the unconditionally stable amplifiers (LT1355, LT1358 and LT1363) have the greatest overshoot for C_L = 10nF. Overshoot actually declines as C_L is increased beyond 10nF.

Table 1. Unity-Gain Stable C-Load Amplifiers Stable with All Capacitive Loads

Singles	Duals	Quads	GBW (MHz)	I_S/Amp (mA)
LT1200	LT1201	LT1202	11	1
LT1220	—	—	45	8
LT1224	LT1208	LT1209	45	7
LT1354	LT1355	LT1356	12	1
LT1357	LT1358	LT1359	25	2
LT1360	LT1361	LT1362	50	4
LT1363	LT1364	LT1365	70	6

Table 2. Unity-Gain Stable C-Load Amplifiers Stable with $C_L \leq$ 10,000pF

Singles	Duals	Quads	GBW (MHz)	I_S/Amp (mA)
LT1012	—	—	0.6	0.4
—	LT1112	LT1114	0.65	0.32
LT1097	—	—	0.7	0.35
—	LT1457	—	2	1.6

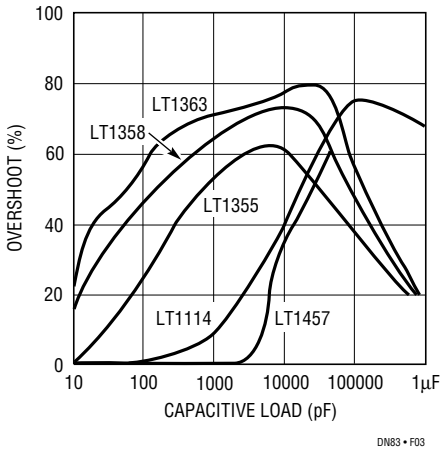

Figure 3. Overshoot vs Capacitive Load

All LTC op amps with adjustable bandwidth can be stabilized for a range of capacitive loads. The bandwidth of current feedback amplifiers is set by the external feedback resistor. Graphs which allow selection of the proper feedback resistor for C_L values to 10,000pF appear in the data sheets of most LTC current feedback amplifiers. As an example, Figure 4 shows the LT1206, a 60MHz current feedback amplifier with 250mA output current, driving loads of 1000pF and 10,000pF while remaining stable.

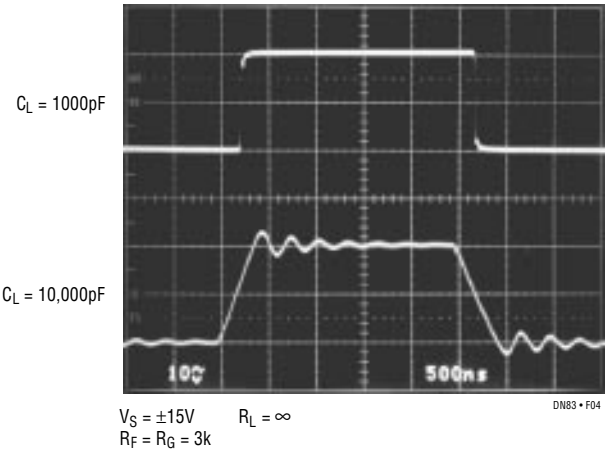

Figure 4. LT1206

Conclusions

Linear Technology has developed families of medium and high speed amplifiers which are much easier to apply than their predecessors. Stable operation with capacitive loads can be achieved without critical external components or loss of output drive. Amplifiers which are stable with any capacitive load are ideal for applications where the load is not well defined. These amplifiers can simplify even low frequency designs by insuring stability under all conditions of loading. For more information on C-Load op amps see the February 1994 issue of *Linear Technology* Magazine.

For literature on our Operational Amplifiers, call **1-800-4-LINEAR**. For applications help, call (408) 432-1900, Ext. 456

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7487
(408) 432-1900 • FAX: (408) 434-0507 • TELEX: 499-3977

LT/GP 0694 190K • PRINTED IN THE USA

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