June 1996, Rev A FN7065

Triple 130MHz Current Feedback Amplifier

élantec

The EL2360 is a triple current-feedback operational amplifier which achieves a -3dB bandwidth of 130MHz at a gain of +2. Built using the Elantec proprietary monolithic complementary bipolar process, these amplifiers use current mode feedback to achieve more bandwidth at a given gain than a conventional voltage feedback amplifier.

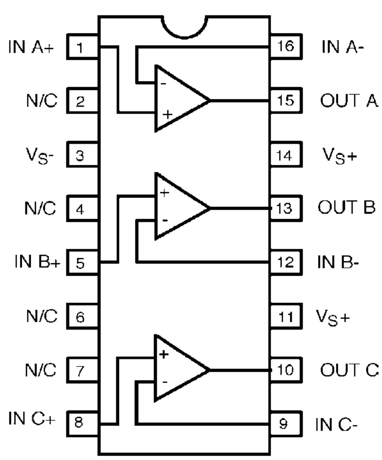
The EL2360 is designed to drive a double terminated 75Ω coax cable to video levels. It's fast slew rate of 1500V/µs, combined with the triple amplifier topology, makes its ideal for RGB video applications.

This amplifier can operate on any supply voltage from 4V (±2V) to 33V (±16.5V), yet consume only 8mA per amplifier at any supply voltage. The EL2360 is available in 16-pin PDIP and SOIC packages.

For Single, Dual, or Quad applications, consider the EL2160, EL2260, or EL2460 all in industry standard pin outs. For Single applications with a power down feature, consider the EL2166.

Pinout

EL2360
(16-PIN SO, PDIP)
TOP VIEW



Features

- Triple amplifier topology
- 130MHz -3dB bandwidth (A_V=+2)
- 180MHz -3dB bandwidth (A_V=+1)
- Wide supply range, ±2V to ±15V
- 80mA output current (peak)
- Low cost
- 1500V/µs slew rate
- Input common mode range to within 1.5V of supplies
- 35ns settling time to 0.1%
- Available in single (EL2160), dual (EL2260), and quad (EL2460) form

Applications

- RGB amplifiers
- Video amplifiers
- Cable driver
- Test equipment amplifiers
- Current to voltage converters
- Video broadcast equipment

Ordering Information

PART NUMBER	TEMP. RANGE	PACKAGE	PKG. NO.
EL2360CN	-40°C to +85°C	16-Pin PDIP	MDP0031
EL2360CS	-40°C to +85°C	16-Pin SOIC	MDP0027

Absolute Maximum Ratings (T_A = 25°C)

Voltage between V_S+ and V_S- . . . .+33V
Common-Mode Input Voltage . . . . V_S- to V_S+
Differential Input Voltage . . . .±6V
Current into +IN or -IN . . . . ±10mA
Internal Power Dissipation . . . . See Curves
Output Current (continuous) . . . . ±50mA
Operating Ambient Temperature Range . . . .-40°C to +85°C
Operating Junction Temperature . . . . 150°C
Storage Temperature Range . . . .-65°C to +150°C

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

IMPORTANT NOTE: All parameters having Min/Max specifications are guaranteed. Typical values are for information purposes only. Unless otherwise noted, all tests are at the specified temperature and are pulsed tests, therefore: $T_J = T_C = T_A$

DC Electrical Specifications

V_S = ±15V, R_L=150Ω, T_A=25°C unless otherwise specified.

PARAMETER	DESCRIPTION	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	V_S = ±5V, ±15V		2	10	mV
TCV_{OS}	Average Input Offset Voltage Drift (Note 1)			10		µV/°C
$+I_{IN}$	+Input Current	V_S = ±5V, ±15V		0.5	3	µA
$-I_{IN}$	-Input Current	V_S = ±5V, ±15V		5	25	µA
CMRR	Common Mode Rejection Ratio (Note 2)	V_S = ±5V, ±15V	50	55		dB
-ICMR	-Input Current Common Mode Rejection (Note 2)	V_S = ±5V, ±15V		0.2	5	µA/V
PSRR	Power Supply Rejection Ratio (Note 3)		75	95		dB
-IPSR	-Input Current Power Supply Rejection (Note 3)			0.2	5	µA/V
R_{OL}	Transimpedance (Note 4)	V_S = ±15V, R_L = 400Ω	500	2000		kΩ
		V_S = ±15V, R_L = 150Ω	500	1800		kΩ
$+R_{IN}$	+ Input Resistance		1.5	3		MΩ
$+C_{IN}$	+ Input Capacitance	PDIP package		1.5		pF
		SOIC package		1		pF
CMIR	Common Mode Input Range	V_S = ±15V		±13.5		V
		V_S = ±5V		±3.5		V
V_O	Output Voltage Swing	V_S = ±15V, R_L = 400Ω	±12	±13.5		V
		V_S = ±15V, R_L = 150Ω		±12		V
		V_S = ±5V, R_L = 150Ω	±3.0	±3.7		V
I_{SC}	Output Short Circuit Current (Note 5)	V_S = ±5V, ±15V	60	100	150	mA
I_S	Supply Current (per amplifier)	V_S = ±15V		8.0	11.3	mA
		V_S = ±5V		5.7	8.8	mA

NOTES:

1. Measured from T_{MIN} to T_{MAX}.
2. V_{CM} = ±10V for V_S = ±15V, V_{CM} = ±3V for V_S = ±5V.
3. The supplies are moved from ±2.5V to ±15V.
4. V_{OUT} = ±7V for V_S = ±15V, V_{OUT} = ±2V for V_S = ±5V.
5. A heat sink is required to keep junction temperature below absolute maximum when an output is shorted.

AC Electrical Specifications

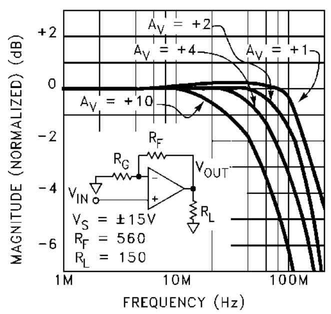
V_S = ±15V, A_V = +2, R_F=R_G=560Ω, R_L=150Ω, T_A=25°C unless otherwise specified. (Note 1)

PARAMETER	DESCRIPTION	CONDITIONS	MIN	TYP	MAX	UNITS
BW	-3dB Bandwidth	V_S = ±15V, A_V = +2		130		MHz
		V_S = ±15V, A_V = +1		180		MHz
		V_S = ±5V, A_V = +2		100		MHz
		V_S = ±5V, A_V = +1		110		MHz
SR	Slew Rate (Note 2)	R_L= 400Ω	1000	1500		V/µs
		R_F = 1 kΩ, R_G = 110Ω, R_L= 400Ω		1500		V/µs
t_R, t_F	Rise Time, Fall Time	V_{OUT} = ±500mV		2.7		ns
t_{PD}	Propagation Delay	V_{OUT} = ±500mV		3.2		ns
OS	Overshoot	V_{OUT} = ±500mV		0		%
t_S	0.1% Settling Time	V_{OUT} = ±2.5V, A_V = -1		35		ns
dG	Differential Gain (Note 3)	R_L = 150Ω		0.025		%
		R_L = 500Ω		0.006		%
dP	Differential Phase (Note 3)	R_L = 150Ω		0.1		°
		R_L = 500Ω		0.005		°

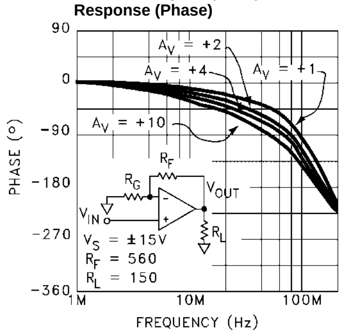
NOTES:

1. All AC tests are performed on a “warmed up” part, except Slew Rate, which is pulse tested.
2. Slew Rate is with V_{OUT} from +10V to -10V and measured at +5V and -5V.
3. DC offset from -0.714V to +0.714V, AC amplitude 286mV_{P-P}, f = 3.58MHz.

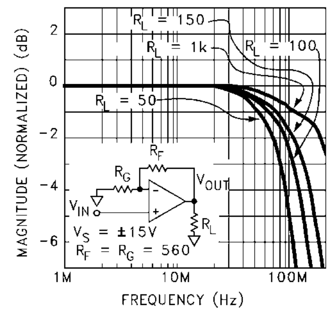
Typical Performance Curves



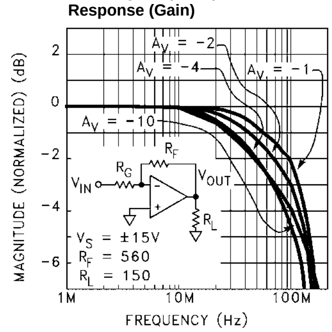
Non-Inverting Frequency Response (Gain)



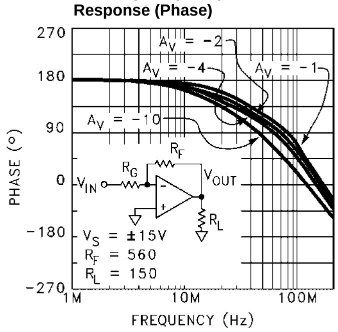
Non-Inverting Frequency Response (Phase)



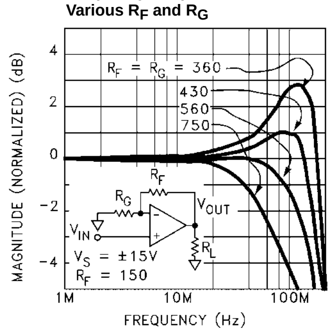
Frequency Response for Various R_L



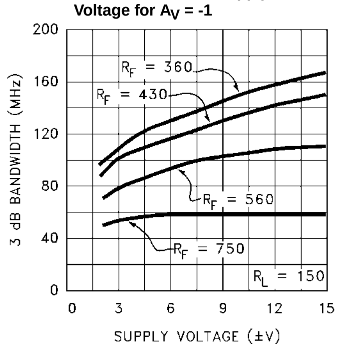
Inverting Frequency Response (Gain)



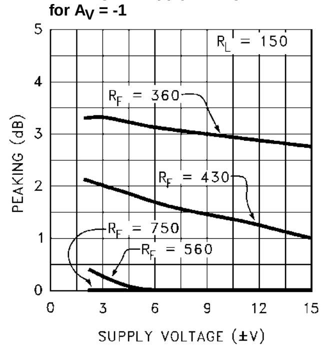
Inverting Frequency Response (Phase)



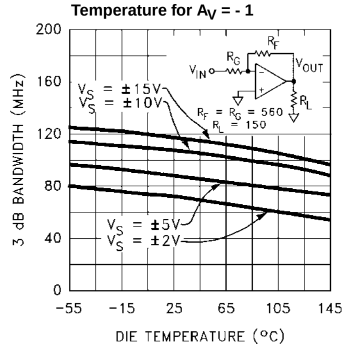
Frequency Response for Various R_F and R_G



3dB Bandwidth vs Supply Voltage for A_V = -1



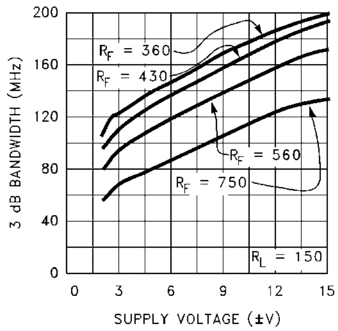
Peaking vs Supply Voltage for A_V = -1



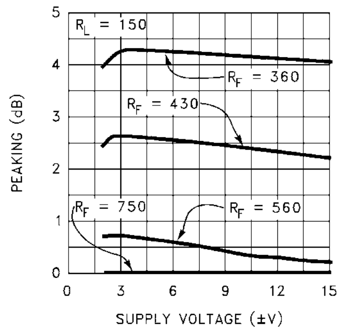
3dB Bandwidth vs Temperature for A_V = - 1

Typical Performance Curves (Continued)

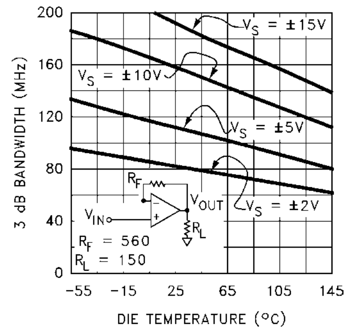
3dB Bandwidth vs Supply Voltage for A_V = +1



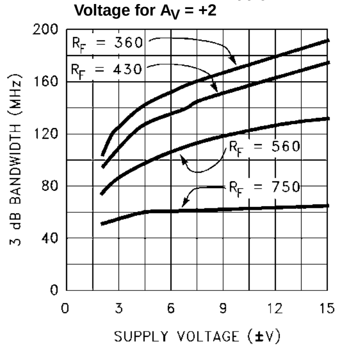
Peaking vs Supply Voltage for A_V = +1



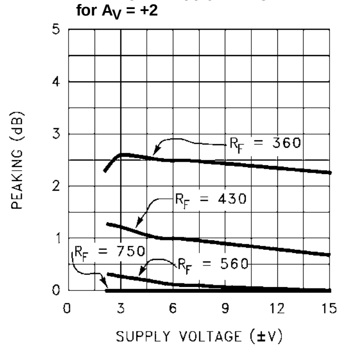
3dB Bandwidth vs Temperature for A_V = +1



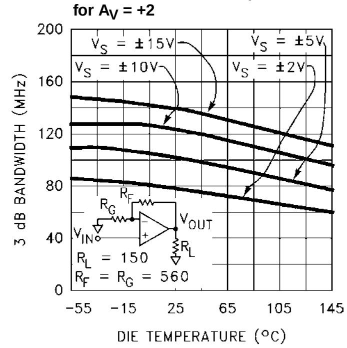
3dB Bandwidth vs Supply Voltage for A_V = +2



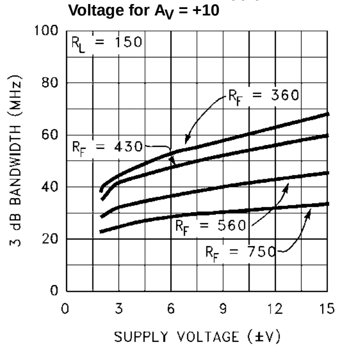
Peaking vs Supply Voltage for A_V = +2



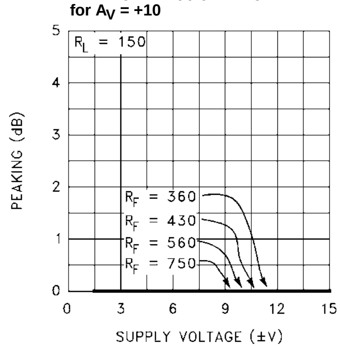
3dB Bandwidth vs Temperature for A_V = +2



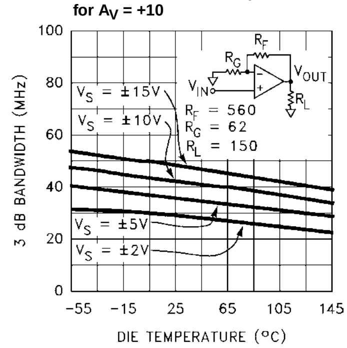
3dB Bandwidth vs Supply Voltage for A_V = +10



Peaking vs Supply Voltage for A_V = +10

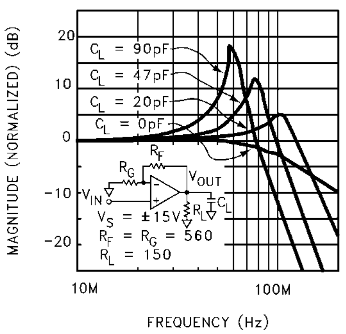


3dB Bandwidth vs Temperature for A_V = +10

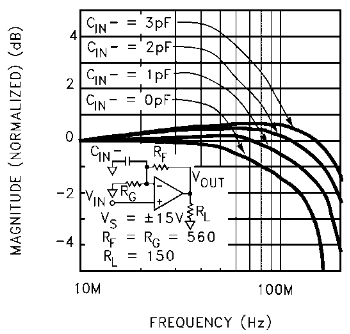


Typical Performance Curves (Continued)

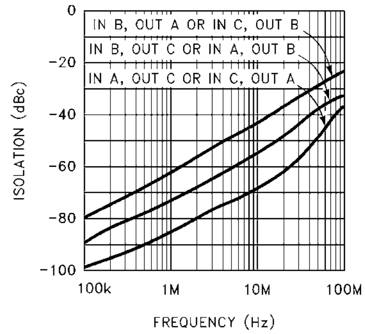
Frequency Response for Various C_L



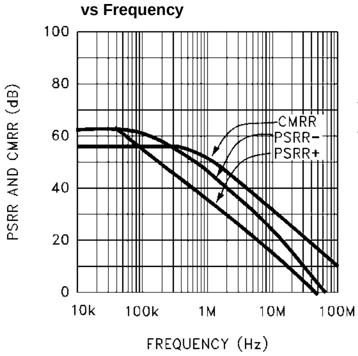
Frequency Response for Various C_{IN-}



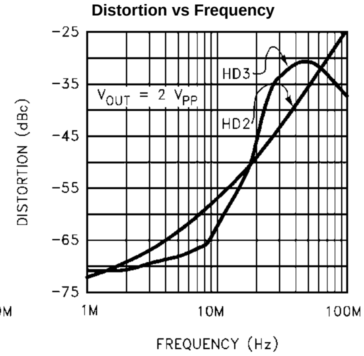
Channel to Channel Isolation vs Frequency



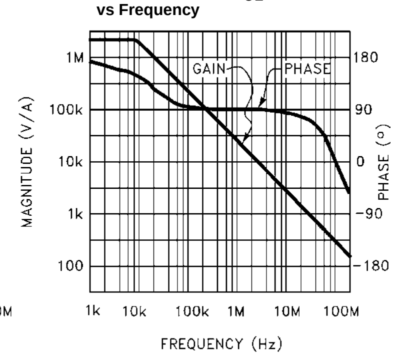
PSRR and CMRR vs Frequency



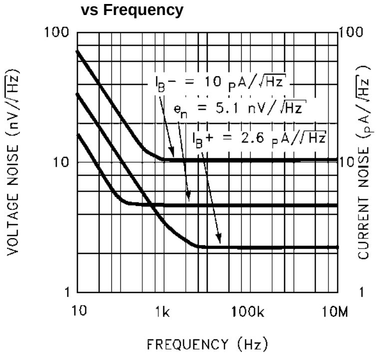
2nd and 3rd Harmonic Distortion vs Frequency



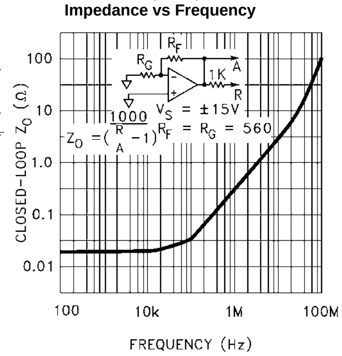
Transimpedance (R_{OL}) vs Frequency



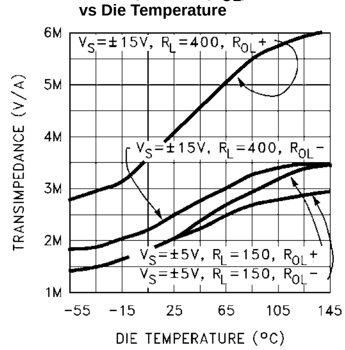
Voltage and Current Noise vs Frequency



Closed-Loop Output Impedance vs Frequency

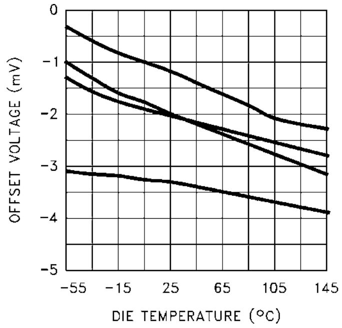


Transimpedance (R_{OL}) vs Die Temperature

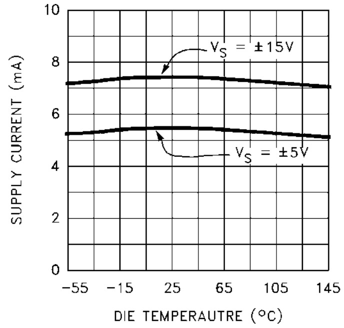


Typical Performance Curves (Continued)

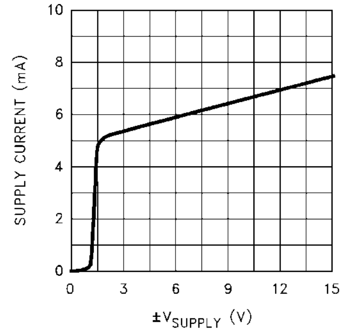
Offset Voltage vs Die Temperature (4 Samples)



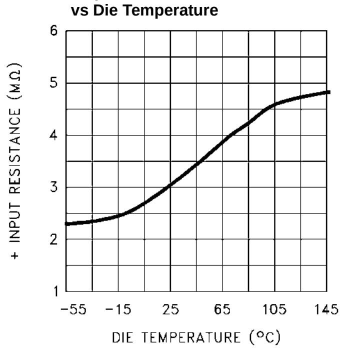
Supply Current vs Die Temperature (Per Amplifier)



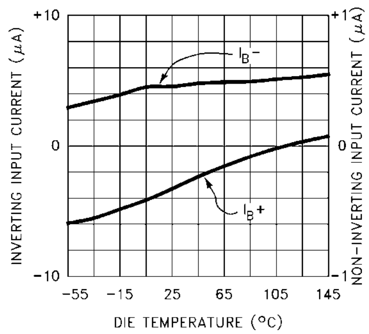
Supply Current vs Supply Voltage (Per Amplifier)



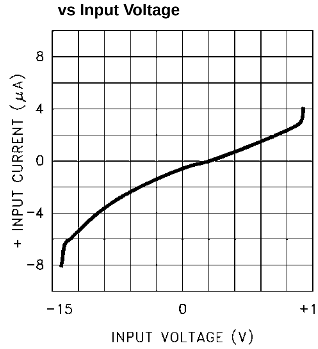
+Input Resistance vs Die Temperature



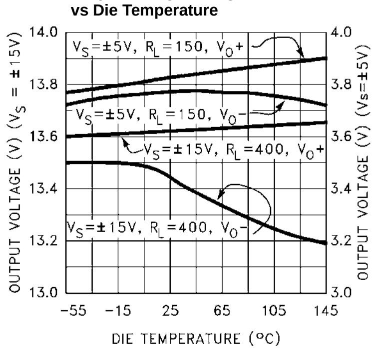
Input Current vs Die Temperature



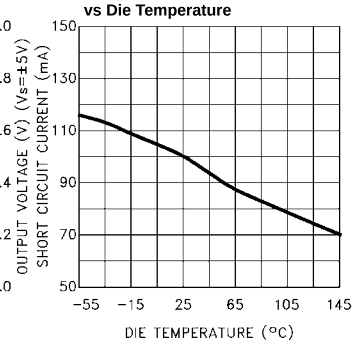
+Input Bias Current vs Input Voltage



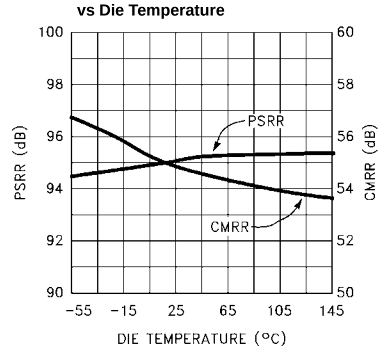
Output Voltage Swing vs Die Temperature



Short Circuit Current vs Die Temperature

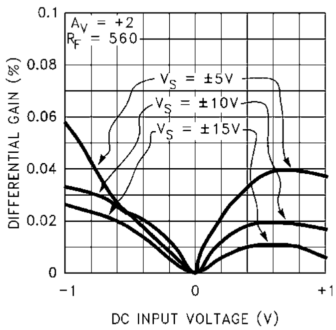


PSRR & CMRR vs Die Temperature

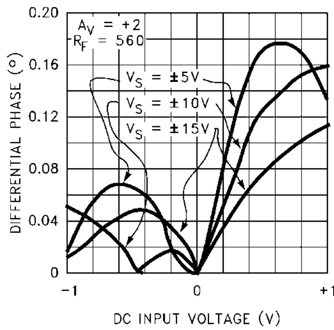


Typical Performance Curves (Continued)

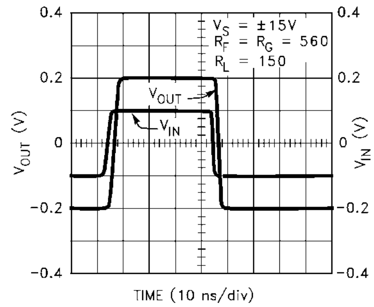
Differential Gain vs DC Input Voltage, R_L = 150



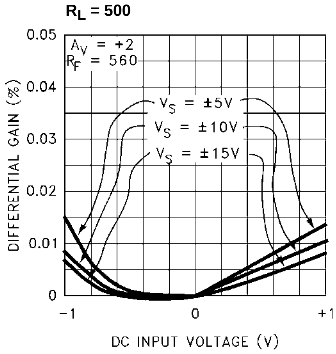
Differential Phase vs DC Input Voltage, R_L = 150



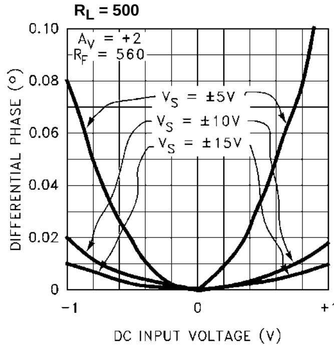
Small Signal Pulse Response



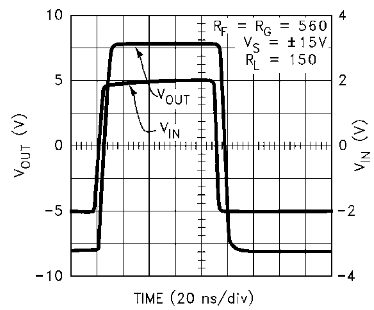
Differential Gain vs DC Input Voltage, R_L = 500



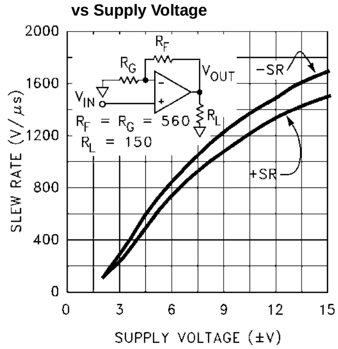
Differential Phase vs DC Input Voltage, R_L = 500



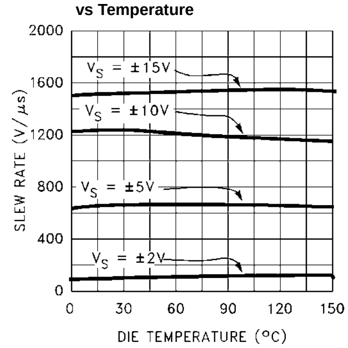
Large Signal Pulse Response



Slew Rate vs Supply Voltage

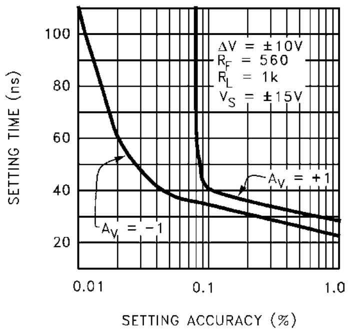


Slew Rate vs Temperature

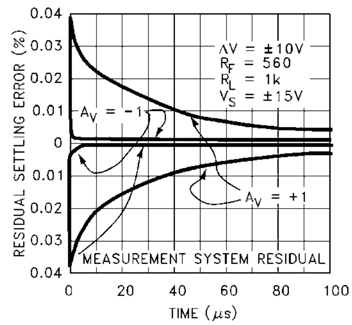


Typical Performance Curves (Continued)

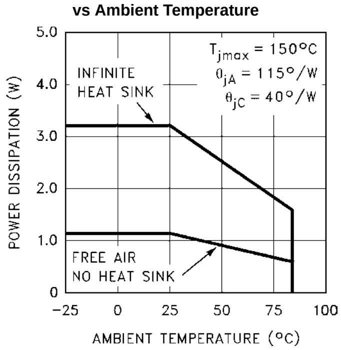
Settling Time vs Settling Accuracy



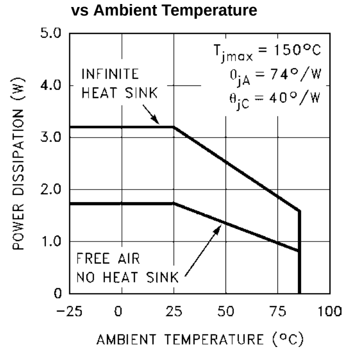
Long Term Settling Error



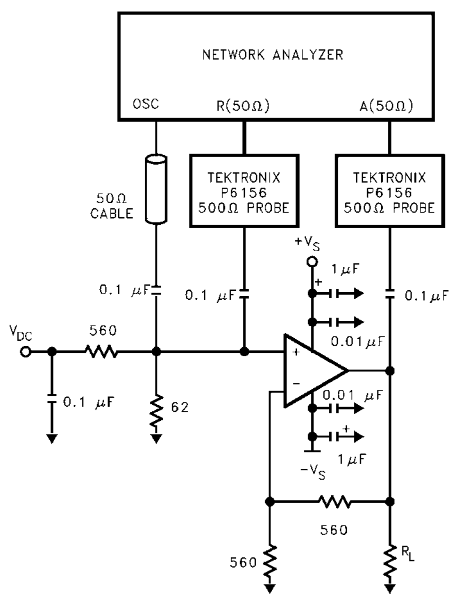
16-Pin Plastic SO Maximum Power Dissipation vs Ambient Temperature



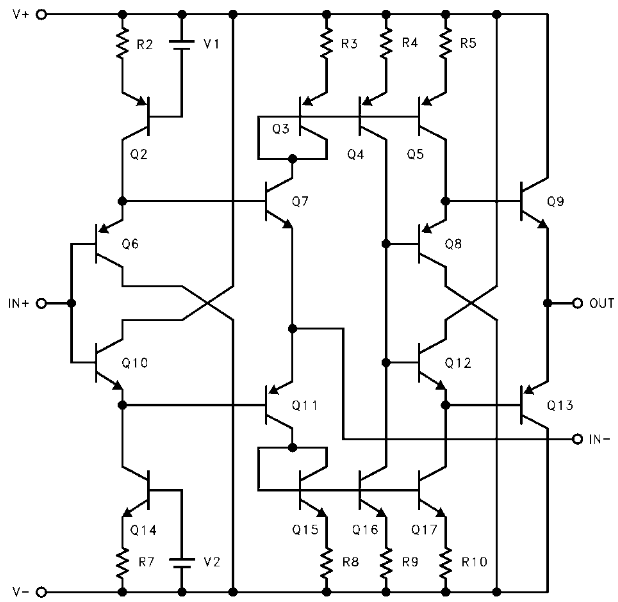
16-Pin Plastic DIP Maximum Power Dissipation vs Ambient Temperature



Differential Gain And Phase Test Circuit



Simplified Schematic (One Amplifier)



Applications Information

Product Description

The EL2360 is a triple current feedback amplifier that offers wide bandwidth and good video specifications at moderately low supply currents. It is built using Elantec's proprietary complimentary bipolar process and is offered in both a 16-pin PDIP and SOIC packages. Due to the current feedback architecture, the EL2360 closed-loop -3dB bandwidth is dependent on the value of the feedback resistor. First the desired bandwidth is selected by choosing the feedback resistor, R_F, and then the gain is set by picking a gain resistor, R_G. The curves at the beginning of the Typical Performance Curves section show the effect of varying both R_F and R_G. The -3dB bandwidth is somewhat dependent on the power supply voltage. As the supply voltage is decreased, internal junction capacitances increase, causing a reduction in the closed loop bandwidth. To compensate for this, smaller values of feedback resistor can be used at lower supply voltages.

Power Supply Bypassing and Printed Circuit Board Layout

As with any high-frequency device, good printed circuit board layout is necessary for optimum performance. Ground plane construction is highly recommended. Lead lengths should be as short as possible, preferably below 1/4". The power supply pins must be well bypassed to reduce the risk of oscillation. The combination of a 1.0µF tantalum capacitor in parallel with a 0.01µF ceramic capacitor has been shown to work well when placed at each supply pin.

For good AC performance, parasitic capacitance should be kept to a minimum especially at the inverting input (see the Capacitance at the Inverting Input section). This implies keeping the ground plane away from this pin. Carbon or Metal-Film resistors are acceptable with the Metal-Film resistors giving slightly less peaking and bandwidth because of their additional series inductance. Use of sockets, particularly for the SO package should be avoided if possible. Sockets add parasitic inductance and capacitance which will result in some additional peaking and overshoot.

Capacitance at the Inverting Input

Any manufacturer's high-speed voltage- or current-feedback amplifier can be affected by stray capacitance at the inverting input. The characteristic curve of gain vs. frequency with variations in C_{IN}- emphasizes this effect. The curve illustrates how the bandwidth can be extended to beyond 200MHz with some additional peaking with an additional 2pF of capacitance at the V_{IN}- pin. For inverting gains, this parasitic capacitance has little effect because the inverting input is a virtual ground, but for non-inverting gains, this capacitance (in conjunction with the feedback and gain resistors) creates a pole in the feedback path of the amplifier. This pole, if low enough in frequency, has the same destabilizing effect as a zero in the forward open-loop response. The use of large value feedback and gain resistors further exacerbates the problem by further lowering the pole frequency.

Feedback Resistor Values

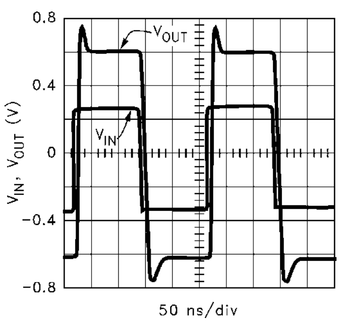
The EL2360 has been designed and specified at a gain of +2 with $R_F = 560\Omega$. This value of feedback resistor yields relatively flat frequency response with little to no peaking out to 130MHz. Since the EL2360 is a current-feedback amplifier, it is also possible to change the value of R_F to get more bandwidth. As seen in the curve of Frequency Response For Various R_F and R_G, bandwidth and peaking can be easily modified by varying the value of the feedback resistor. For example, by reducing R_F to 430Ω, bandwidth can be extended to 170MHz with under 1dB of peaking. Further reduction of R_F to 360Ω increases the bandwidth to 195MHz with about 2.5dB of peaking.

Bandwidth vs Temperature

Whereas many amplifier's supply current and consequently -3dB bandwidth drop off at high temperature, the EL2360 was designed to have little supply current variation with temperature. An immediate benefit from this is that the -3dB bandwidth does not drop off drastically with temperature. With V_S = ±15V and A_V = +2, the bandwidth varies only from 150MHz to 110MHz over the entire die junction temperature range of -50°C < T < 150°C.

Supply Voltage Range and Single Supply Operation

The EL2360 has been designed to operate with supply voltages from ±2V to ±15V. Optimum bandwidth, slew rate, and video characteristics are obtained at higher supply voltages. However, at ±2V supplies, the -3dB bandwidth at A_V = +2 is a respectable 70MHz. The following figure is an oscilloscope plot of the EL2360 at ±2V supplies, A_V = +2, R_F = R_G = 560Ω, driving a load of 150Ω, showing a clean ±600mV signal at the output.



If a single supply is desired, values from +4V to +30V can be used as long as the input common mode range is not exceeded. When using a single supply, be sure to either 1) DC bias the inputs at an appropriate common mode voltage and AC couple the signal, or 2) ensure the driving signal is within the common mode range of the EL2360, which is typically 1.5V from each supply rail.

Settling Characteristics

The EL2360 offers superb settling characteristics to 0.1%, typically in the 35ns to 40ns range. There are no aberrations created from the input stage which often cause longer settling times in other current feedback amplifiers. The EL2360 is not slew rate limited, therefore any size step up to ±10V gives approximately the same settling time.

As can be seen from the Long Term Settling Error curve, for A_V = +1, there is approximately a 0.035% residual which tails away to 0.01% in about 40µs. This is a thermal settling error caused by a power dissipation differential (before and after the voltage step). For A_V = -1, due to the inverting mode configuration, this tail does not appear since the input stage does not experience the large voltage change as in the non-inverting mode. With A_V = -1, 0.01% settling time is slightly greater than 100ns.

Power Dissipation

The EL2360 amplifier combines both high speed and large output current capability at a moderate supply current in very small packages. It is possible to exceed the maximum junction temperature allowed under certain supply voltage, temperature, and loading conditions. To ensure that the EL2360 remains within it's absolute maximum ratings, the following discussion will help to avoid exceeding the maximum junction temperature.

The maximum power dissipation allowed in a package is determined according to [1]:

$$PD_{MAX} = \frac{T_{JMAX} - T_{AMAX}}{\theta_{JA}}$$

where:

- T_{JMAX} = Maximum Junction Temperature
- T_{AMAX} = Maximum Ambient Temperature
- θ_{JA} = Thermal Resistance of the Package
- PD_{MAX} = Maximum Power Dissipation in the Package

The maximum power dissipation actually produced by an IC is the total quiescent supply current times the total power supply voltage, plus the power in the IC due to the load, or [2] :

$$PD_{MAX} = N \times \left(V_S \times I_{SMAX} + (V_S - V_{OUT}) \times \frac{V_{OUT}}{R_L} \right)$$

where:

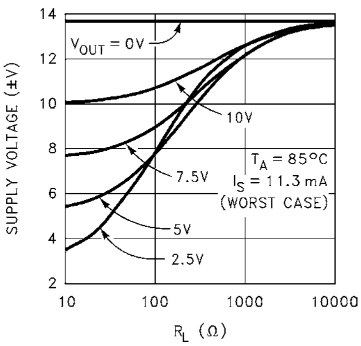
- N =Number of amplifiers
- V_S = Total Supply Voltage
- I_{SMAX} = Maximum Supply Current per amplifier
- V_{OUT} = Maximum Output Voltage of the Application
- R_L = Load Resistance tied to Ground

If we set the two PD_{MAX} equations, [1] and [2], equal to each other, and solve for V_S, we can get a family of curves for various loads and output voltages according to [3]:

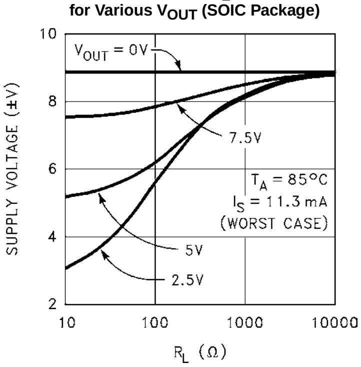
$$V_S = \frac{\dfrac{R_L \times (T_{JMAX} - T_{AMAX})}{N \times \theta_{JA}} + (V_{OUT})^2}{(I_S \times R_L) + V_{OUT}}$$

The figures below show total supply voltage V_S vs R_L for various output voltage swings for the PDIP and SOIC packages. The curves assume WORST CASE conditions of T_A = +85°C and I_S = 11.3mA per amplifier. The curves do not include heat removal or forcing air, or the simple fact that the package will be attached to a circuit board, which can also provide some form of heat removal. Larger temperature and voltage ranges are possible with heat removal and forcing air past the part.

Supply Voltage vs R_L for Various V_{OUT} (PDIP Package)



Supply Voltage vs R_L for Various V_{OUT} (SOIC Package)



Current Limit

The EL2360 has internal current limits that protect the circuit in the event of an output being shorted to ground. This limit is set at 100mA nominally and reduces with the junction temperature. At T_J = 150°C, the current limits at about 65mA. If any one output is shorted to ground, the power dissipation could be well over 1W, and much greater if all outputs are shorted. Heat removal is required in order for the EL2360 to survive an indefinite short.

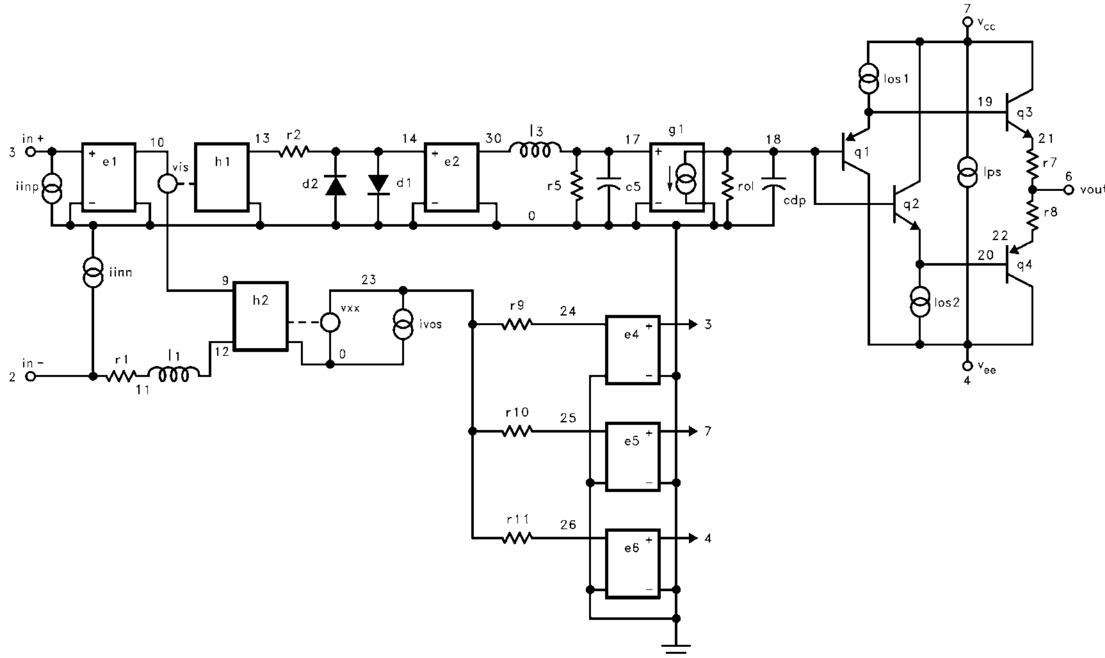
Driving Cables and Capacitive Loads

When used as a cable driver, double termination is always recommended for reflection-free performance. For those applications, the back-termination series resistor will de-couple the EL2360 from the cable and allow extensive capacitive drive. However, other applications may have high capacitive loads without a back-termination resistor. In these applications, a small series resistor (usually between 5Ω and 50Ω) can be placed in series with the output to eliminate most peaking. The gain resistor (R_G) can then be chosen to make up for any gain loss which may be created by this additional resistor at the output. In many cases it is also possible to simply increase the value of the feedback resistor (R_F) to reduce the peaking.

EL2360 Macromodel

```
*EL2360 Macromodel
*Revision A, June 1996
*AC characteristics used: Rf = Rg = 560 ohms
*Pin numbers reflect a standard single opamp
*Connections:        +input
*                    |    -input
*                    |    |    +Vsupply
*                    |    |    |    -Vsupply
*                    |    |    |    |    output
*                    |    |    |    |    |
.subckt EL2360/EL    3    2    7    4    6
*
*Input Stage
*
e1 10 0 3 0 1.0
vis 10 9 0V
h2   9 12 vxx 1.0
r1   2 11 130
l1  11  12 25nH
iinp 3  0 0.5µA
iinm 2  0 5µA
r12  3  0 2 Meg
*
*Slew Rate Limiting
*
h1 13  0 vis 600
r2 13 14 1K
d1 14  0  dclamp
d2  0 14  dclamp
*
*High Frequency Pole
*
e2 30 0 14 0 0.00166666666
l3 30 17 0.43µH
c5 17 0 0.27pF
r5 17 0 500
*
*Transimpedance Stage
*
g1 0 18 17 0 1.0
rol 18 0 2Meg
cdp 18 0 2.285pF
*
*Output Stage
*
q1 4 18 19 qp
q2 7 18 20 qn
q3 7 19 21 qn
q4 4 20 22 qp
r7 21 6  4
r8 22 6  4
ios1 7 19 2mA
ios2 20 4 2mA
*
*Supply Current
*
ips 7 4 2.5mA
*
*Error Terms
```

```
*
ivos 0 23 2mA
vxx 23  0 0V
e4  24 0 3 0 1.0
e5  25 0 7 0 1.0
e6  26 0 4 0 -1.0
r9  24 23 562
r10 25 23 1K
r11 26 23 1K
*
*Models
*
.model qn npn(is=5e-15 bf=100 tf=0.1ns)
.model qp pnp(is=5e-15 bf=100 tf=0.1ns)
.model dclamp d(is=1e-30 ibv=0.266
+ bv=2.24v n=4)
.ends
```



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