élantec
HIGH PERFORMANCE ANALOG INTEGRATED CIRCUITS

EL2022/EL2022C
165 MHz Current Feedback Amplifier

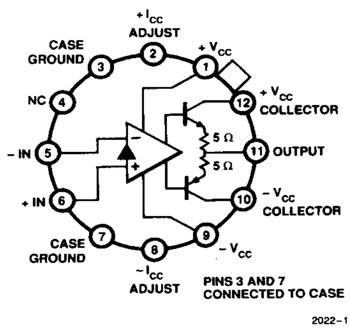
Features
- 165 MHz closed loop −3 dB bandwidth
- Slew rate of ±1900 V/μs
- Internal compensation for all gains
- ±100 mA output current
- 0.1% settling time is 22 ns for 2.5V volt step
- Small TO-8 package
- Vsupply ±5V to ±15V
- 18 mA supply current
- Pin Compatible with CLC231

Applications
- Video gain block
- Driving A/D converters
- Residue amplifier
- Radar systems
- DAC current to voltage converter
- Coax cable driver with gain of 2

Ordering Information

Part No.	Temp. Range	Package	Outline #
EL2022CG	−25°C to +85°C	12-Lead TO-8	MDP0002
EL2022G	−55°C to +125°C	12-Lead TO-8	MDP0002
EL2022G/883B	−55°C to +125°C	12-Lead TO-8	MDP0002

Connection Diagram



Top View

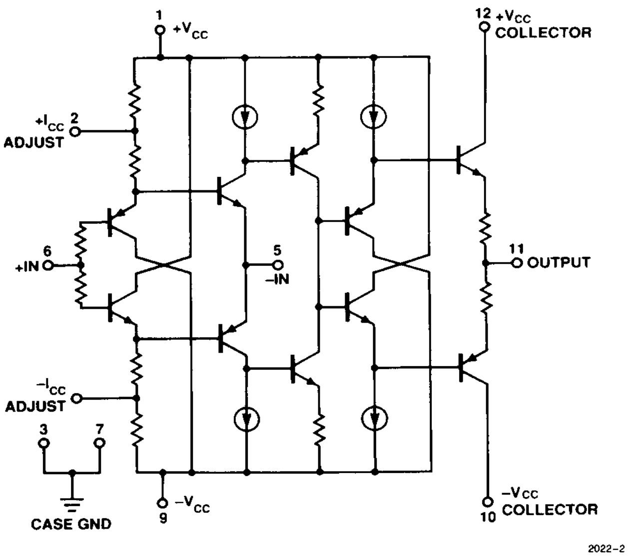
General Description

The EL2022 Amplifier is designed to drive low impedance loads at frequencies up to 165 MHz. The EL2022 is a fast settling, wide bandwidth amplifier optimized for gains between −5 and +5. This amplifier uses current mode feedback to achieve more bandwidth at a given gain than conventional voltage feedback operational amplifiers.

The EL2022 will drive five double terminated 75Ω coax cables to video levels with low distortion. It is a closed loop amplifier and provides better gain accuracy than is possible with open loop buffers. The EL2022 may be used in most applications where a conventional op amp is used, with a significant improvement in speed power product.

Elantec facilities comply with MIL-STD-1772A, MIL-I-45208 and other applicable quality specifications. For information on Elantec's military processing, see QRA-3, Elantec's 883B Program for Hybrid Integrated Circuits.

Simplified Schematic



July 1991 Rev C

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Absolute Maximum Ratings (25°C)

V_S	Supply Voltage	±20V
V_{IN}	Input Voltage	V_S − 3.5V
I_{OP}	Peak Output Current	±100 mA
P_D	Maximum Power Dissipation (See Curves)	1.5 Watts
T_A	Operating Temperature Range	
	EL2022	−55°C to +125°C
	EL2022C	−25°C to +85°C
T_J	Operating Junction Temperature	175°C
T_{ST}	Storage Temperature	−65°C to +150°C
	Lead Temperature (Soldering, 10 seconds)	300°C

Important Note:
All parameters having Min/Max specifications are guaranteed. The Test Level column indicates the specific device testing actually performed during production and Quality inspection. Elantec performs most electrical tests using modern high-speed automatic test equipment, specifically the LTX77 Series system. Unless otherwise noted, all tests are pulsed tests, therefore $T_J = T_C = T_A$.

Test Level	Test Procedure
I	100% production tested and QA sample tested per QA test plan QCX0002.
II	100% production tested at T_A = 25°C and QA sample tested at T_A = 25°C, T_{MAX} and T_{MIN} per QA test plan QCX0002.
III	QA sample tested per QA test plan QCX0002.
IV	Parameter is guaranteed (but not tested) by Design and Characterization Data.
V	Parameter is typical value at T_A = 25°C for information purposes only.

DC Electrical Characteristics

V_S = ±15V, A_V = +2, R_F = 250Ω, R_L = 100Ω, T_A = T_{MIN} to T_{MAX}, unless otherwise specified

Parameter	Description	Temp	Limits			Test Level		Units
			Min	Typ	Max	EL2022	EL2022C	
V_{IO}	Input Offset Voltage	25°C		1.0	2.5	I	I	mV
		T_{Max}			4.5	I	III	mV
		T_{Min}			4.0	I	III	mV
$\Delta V_{IO}/\Delta T$	Input Offset Voltage Temperature Coefficient	T_{Min} to T_{Max}		10		V	V	μV/°C
$+I_{IB}$	Non-Inverting Input Bias Current	25°C		5	21	I	I	μA
		T_{Max}			31	I	III	μA
		T_{Min}			29	I	III	μA
$\Delta(+I_{IB})/\Delta T$	Non-Inverting Input Bias Current Temperature Coefficient	T_{Min} to T_{Max}		50		V	V	nA/°C
$-I_{IB}$	Inverting Input Bias Current	25°C		10	15	I	I	μA
		T_{Max}			35	I	III	μA
		T_{Min}			31	I	III	μA
$\Delta(-I_{IB})/\Delta T$	Inverting Input Bias Current Temperature Coefficient	T_{Min} to T_{Max}		125		V	V	nA/°C
PSRR	Power Supply Rejection Ratio, ±5V CHANGED TO ±15V		50	80		I	II	dB

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DC Electrical Characteristics
$V_S = \pm 15V$, $A_V = +2$, $R_F = 250\Omega$, $R_L = 100\Omega$, $T_A = T_{MIN}$ to T_{MAX}, unless otherwise specified—Contd.

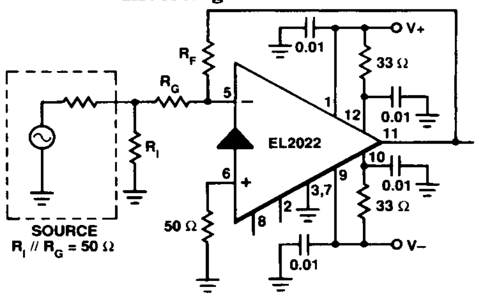
Parameter	Description	Temp	Limits			Test Level		Units
			Min	Typ	Max	EL2022	EL2022C	
CMRR	Common Mode Rejection Ratio, $V_{CM} = \pm 5V$			46		V	V	dB
V_O	Output Voltage Swing No Load		±11	±12		I	II	V
I_{CC}	Supply Current			18	22	I	II	mA

AC Electrical Characteristics
$V_S = \pm 15V$, $A_V = +2$, $R_F = 250\Omega$, $R_L = 100\Omega$

Parameter	Description	Output Voltage	Limits			Test Level		Units
			Min	Typ	Max	EL2022	EL2022C	
Time Domain Parameters								
t_r	Rise Time (Note 1)	−1V to +1V		2.1	2.75	I	III	ns
		−5V to +5V		4.3	5.5	I	III	ns
t_f	Fall Time (Note 1)	+1V to −1V		2.1	2.75	I	III	ns
		+5V to −5V		4.3	5.5	I	III	ns
OS	Overshoot	−2.5V to +2.5V		10	15	I	III	%
		+2.5V to −2.5V		10	15	I	III	%
SR	Slew Rate (Note 2)	−5V to +5V	1500	1900		I	III	V/μs
		+5V to −5V	1500	1900		I	III	V/μs
Frequency Domain Parameters								
BW	−3 dB Bandwidth	0.63 V_{pp}		165		V	V	MHz
G_p	Gain Peaking	0.63 V_{pp}		0.1		V	V	dB
G_r	Gain Rolloff, 100 MHz	0.63 V_{pp}		0.4		V	V	dB
R_{IN}	Non-Inverting Input Resistance			400		V	V	kΩ
C_{IN}	Non-Inverting Input Capacitance			1.3		V	V	pF
R_o	Output Resistance at 100 MHz			5		V	V	Ω
L_o	Output Inductance at 100 MHz			37		V	V	nH

Note 1: Rise and fall times are measured between 10% and 90%.
Note 2: Slew rate measured between +2.5V and −2.5V.

Inverting Test Circuit



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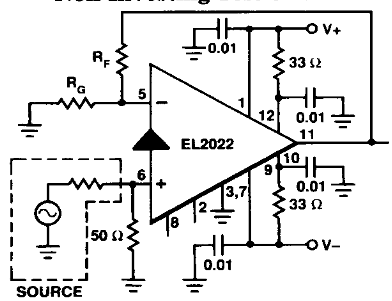
Non-Inverting Test Circuit



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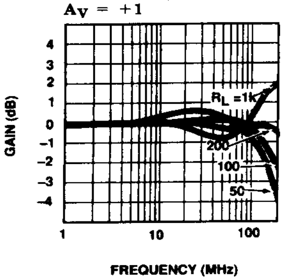
Component Selection Chart

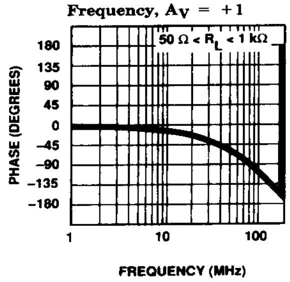
A_V	Circuit	R_F	R_G
−1	Inverting	250Ω	250Ω
−5	Inverting	250Ω	50Ω
+1	Non-Inverting	250Ω	Open
+2	Non-Inverting	250Ω	250Ω
+5	Non-Inverting	250Ω	62.5Ω

Typical Performance Curves

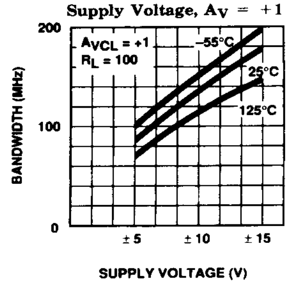
Gain vs Frequency, A_V = +1



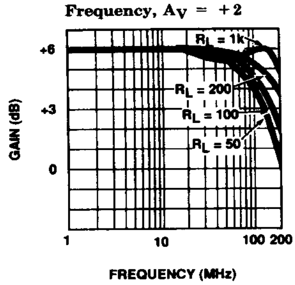
Phase Shift vs Frequency, A_V = +1



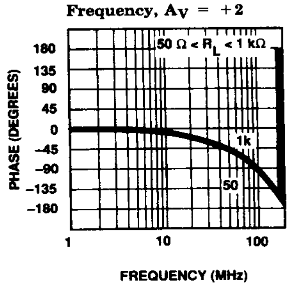
−3 dB Bandwidth vs Supply Voltage, A_V = +1



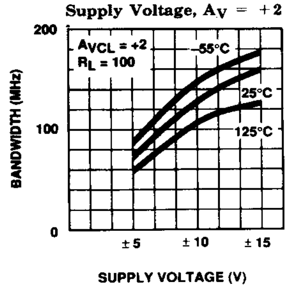
Gain vs Frequency, A_V = +2



Phase Shift vs Frequency, A_V = +2



−3 dB Bandwidth vs Supply Voltage, A_V = +2



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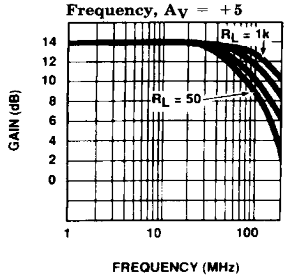
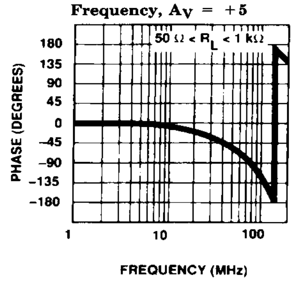
Typical Performance Curves — Contd.

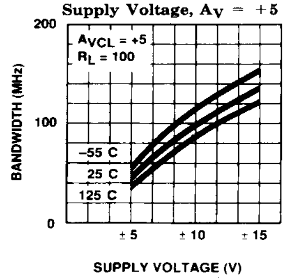
Gain vs Frequency, $A_V = +5$



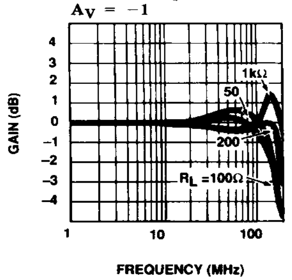
Phase Shift vs Frequency, $A_V = +5$



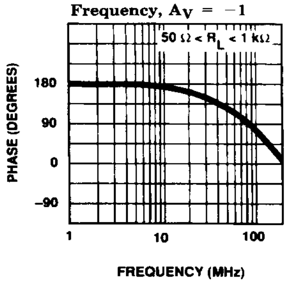
−3 dB Bandwidth vs Supply Voltage, $A_V = +5$



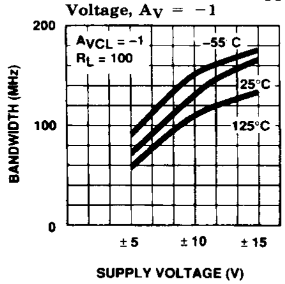
Gain vs Frequency, $A_V = -1$



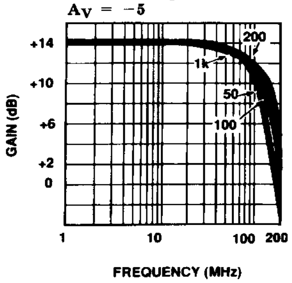
Phase Shift vs Frequency, $A_V = -1$



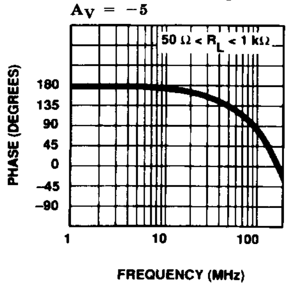
−3 dB Bandwidth vs Supply Voltage, $A_V = -1$



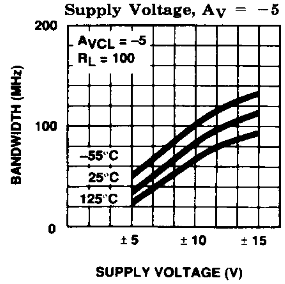
Gain vs Frequency, $A_V = -5$



Phase Shift vs Frequency, $A_V = -5$



−3 dB Bandwidth vs Supply Voltage, $A_V = -5$



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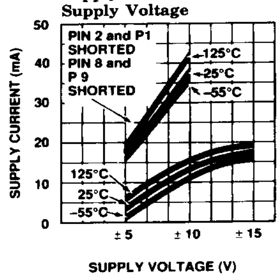
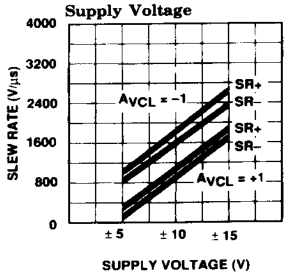
Typical Performance Curves — Contd.

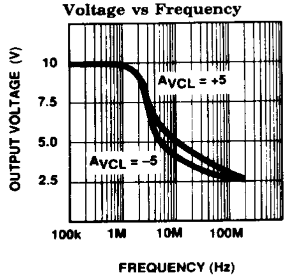
Supply Current vs Supply Voltage



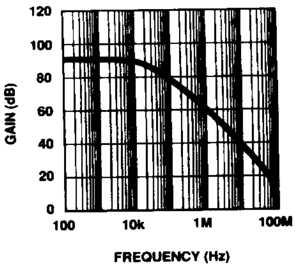
Slew Rate vs Supply Voltage



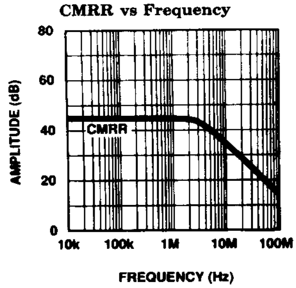
Undistorted Output Voltage vs Frequency



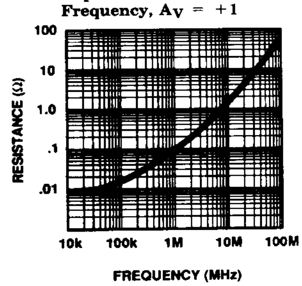
Open-Loop Voltage Gain vs Frequency



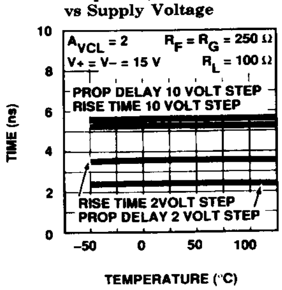
CMRR vs Frequency



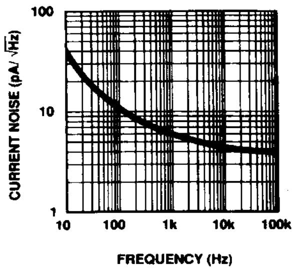
Closed Loop Output Impedance vs Frequency, $A_V = +1$



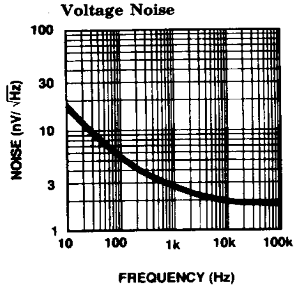
Prop Delay and Rise Time vs Supply Voltage



Current Noise



Voltage Noise



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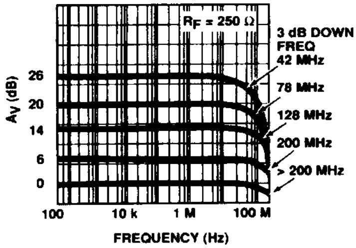
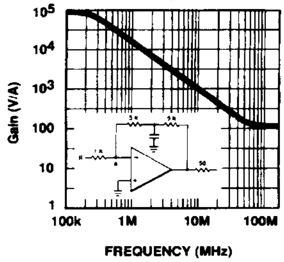
Typical Performance Curves — Contd.

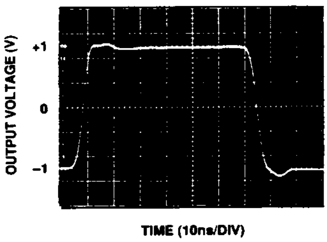
Frequency Response for Various Gains



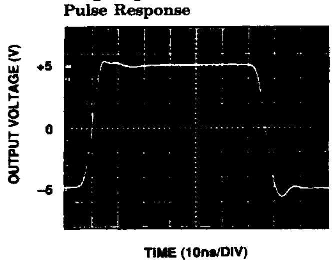
TRANS—Impedance



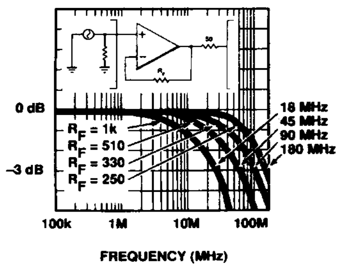
Small Signal Pulse Response



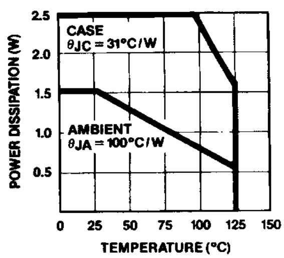
Large Signal Pulse Response



Frequency Response for Various Feedback Resistors Gain +1



Maximum Power Dissipation



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EL2022 Applications

EL2022 Basics

The EL2022 is a New Breed of Amplifier

It has a host of new features with which the user should be familiar. Among these are . . .

1. It has a high impedance non-Inverting (+) input.
2. The impedance looking into the inverting input (−) open loop is low (≈ 10Ω).
3. In steady state, the voltage at the (+) input follows the voltage at the (−) input.
4. The amplifier will try to put a voltage at the output that will force the current into the (−) input to be ≈ 0.
5. Therefore, the impedance looking into the inverting input is *increased* due to closing the loop around the amplifier.
6. The bandwidth of an amplifier subsystem built with the EL2022 is only mildly affected by the gain taken in the stage, provided the feedback resistor is held constant.
7. The bandwidth of an amplifier subsystem built with the EL2022 is strongly affected by the value of the feedback resistor used. The smaller the feedback resistor the more bandwidth, and vice versa. The optimum feedback resistor is 250Ω, with the device exhibiting peaking in the frequency domain if a smaller value is used.

The use of the EL2022 is similar to that of conventional op amps. We can still use the op amp assumptions as a first order approximation for circuit analysis, namely that . . .

1. The voltage across the inputs ≈ 0 and
2. The current into the inputs is ≈ 0

Since the device is designed specifically for low gain applications, the best performance is obtained when the circuit is used at gains between ±5 and ±1. Performance is optimized for when a 250Ω feedback resistor is used.

Layout Considerations

To assure optimum performance the user should follow good layout practices which minimize unwanted coupling of signals between nodes. During initial breadboarding of the circuit, use direct point to point wiring, keeping the lead lengths to less than 0.25″. The use of solid, unbroken ground plane is helpful. Avoid wire-wrap type pc boards and methods. Sockets with small, short pin receptacles may be used with minimal performance degradation although their use is not optimum.

During pc board layout, keep all traces short and direct. The body of R_g should be as close as possible to pin 5 to minimize capacitance at that point. For the same reason, remove ground plane from the vicinity of pins 5 and 6. In other areas, use as much ground plane as possible on one side of the board. It is especially important to provide a ground return path for current from the load resistor to the power supply bypass capacitors. Ceramic capacitors of 0.01 to 0.1 μF (with short leads) should be less than 0.15 inches from pins 1 and 9. Larger tantalum capacitors should be placed within one inch of these pins. V_{CC} connections to pins 10 and 12 can be made directly from pins 9 and 1, but better supply rejection and settling time are obtained if they are separately bypassed as in *Figures 1* and *2*. To prevent signal distortion caused by reflections from impedance mismatches, use terminated microstrip or coaxial cable when the signal must traverse more than a few inches.

Since the pc board forms such an important part of the circuit, much time can be saved if prototype boards of any high frequency sections are built and tested early in the design phase.

With proper layout, the EL2022 has excellent group delay characteristics. In a gain of +1, deviations from linear phase of less than ±1° have been observed over DC to 100 MHz.

Thermal Considerations

At high ambient temperatures or large internal power dissipations, heat sinking is required to maintain acceptable junctions temperatures. Many styles of heat sinks are available for TO-8 packages; the Wakefield 215 and the Thermalloy 2240 are good examples. Some heat sinks are the radial fin type which cover the pc board and may

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EL2022 Applications — Contd.

interfere with external components. An excellent solution to this problem is to use surface mounted resistors and capacitors. They have a very low profile and actually improve high frequency performance.

For use of these heat sinks with conventional components, a 0.1″ high spacer can be inserted under the TO-8 package to allow sufficient clearance.

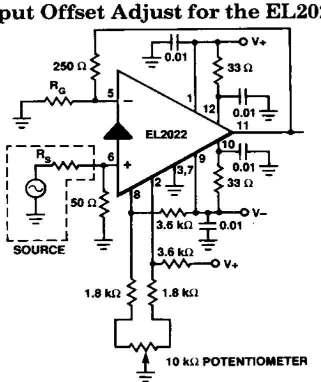
Low V_{CC} Operation: Supply Current Adjustment

The EL2022 is designed to operate on supplies as low as ±5V. In order to improve full bandwidth at reduced supply voltages, the supply current (I_{CC}) must be increased. The plot of supply current vs. V_{CC} shows the effect of shorting pins 1 and 2 and pins 8 and 9; this will increase both bandwidth and supply current. Care should be taken to not exceed the maximum junction temperatures; for this reason this technique should not be used with supplies exceeding ±10V. For intermediate values of V_{CC}, external resistors between pins 1 and 2 and pins 8 and 9 can be used.

Offset Voltage Adjustment

If trimming of the input offset voltage is desired, the circuit below can be used to adjust the V_{OS} approximately ±12 mV. If a narrower or broader adjustment range is desired, the 1.8 kΩ resistors can be scaled upward or downward respectively. Be aware that AC signals are present on pins 2 and 8 with this circuit.

Input Offset Adjust for the EL2022



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Power Supplies

The EL2022 may be operated with single or split power supplies as low as ±3V (6V total) to as high as ±20V (40V total). The slew rate degrades significantly for supply voltages less than ±5V (10V total).

When using power supplies of less than ±10V (20V total), pins 1 and 2 may be connected and pins 8 and 9 may be connected. This increases the supply current, bandwidth and slew rate. For power dissipation reasons this must not be done with supplies greater than 20V total. it is not necessary to use equal value split supplies, i.e., −5V and +12V would be fine for 0 to 2V output signals. Bypass capacitors from each supply pin to a ground plane are recommended. The EL2022 will not oscillate even with minimal bypassing, however, the supply will ring excessively with inadequate capacitance. To eliminate supply ringing and the errors it might cause, a 4.7 μF tantalum capacitor with short leads is recommended for both supplies. Inadequate supply bypassing can also result in lower slew rate and longer settling times.

Input Range

The non-inverting input to the EL2022 looks like a high resistance in parallel with a few picofarads in addition to a DC bias current. The input characteristics change very little with output loading, even when the amplifier is in current limit.

The input characteristics also change when the input voltage exceeds either supply by 0.5V. This happens because the input transistor's base-collector junctions forward bias. If the input exceeds the supply by LESS than 0.5V and then returns to the normal input range, the output will recover in less than 10 ns. However, if the input exceeds the supply by MORE than 0.5V, the recovery time can be 100's of nanoseconds. For this reason it is recommended that Schottky diode clamps from input to supply be used if a fast recovery from large input overloads is required.

Source Impedance

The EL2022 has good input-output isolation and is fairly tolerant of variations in source impedances. Capacitive sources cause no problems at

EL2022 Applications — Contd.

all, resistive sources up to 100 kΩ present no problems as long as care is used in board layout to minimize output to input coupling. Inductive sources can cause oscillations; a 100Ω resistor in series with the non-inverting input lead will usually eliminate problems without sacrificing too much speed. An unterminated cable or other resonant source can also cause oscillations. Again, an isolating resistor will eliminate the problem.

Feedback Resistor Selection

Nominally 250Ω, the value of the resistor has a strong effect on the dynamics of the amplifier.

Typical Non-Inverting Amplifier Characteristics

A_V	R_F	R_G	R_I	Bandwidth	Z_{IN}
+1	250Ω	None	100Ω	180 MHz	400 kΩ
+2	250Ω	250Ω	100Ω	165 MHz	400 kΩ
+5	250Ω	62.5Ω	100Ω	130 MHz	400 kΩ

Typical Inverting Amplifier Characteristics

A_V	R_F	R_G	R_I	Bandwidth
−1	250Ω	250Ω	100Ω	165 MHz
−2	250Ω	125Ω	100Ω	150 MHz
−5	250Ω	50Ω	100Ω	110 MHz

Mount the body of the feedback resistor near pin 5, to minimize capacitance on this node. Non-inductive resistors must be used. Do not use any feedback capacitance, instability may result.

For minimum settling time, minimize any stray capacitance from pin 5 to the output or to ground.

Current Limit

The EL2022 has the ability to have external current limits to protect the output transistors. This current limit is implemented with resistors in series with pins 12 and 10, the collectors of the output emitter followers. Bypassing of pins 12 and 10 is required. The short circuit current is given by $I_{SC} = V_{CC} - 0.6\ V/R_{SC}$. In order to limit the output current to 100 mA with ±15 supplies in the case of the output being shorted to ground, 150Ω 1 Watt resistors should be used here. This will also limit output swing into a heavy load.

Compensation

The EL2022 is compensated primarily with its feedback resistor and an internal capacitor from the gain node. The part is designed for a nominal 250Ω of feedback resistance, although it is possible to get more bandwidth by decreasing the feedback resistance.

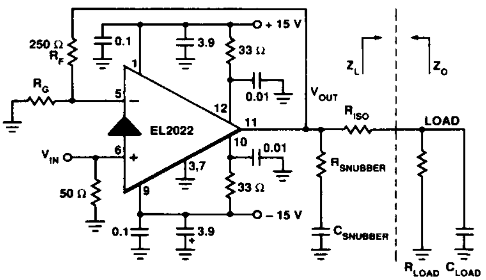
The EL2022 becomes less stable by adding capacitance in parallel with the feedback resistor, so feedback capacitance is not recommended.

The EL2022 is also sensitive to stray capacitance from the inverting input to ground, so the board should be laid out to keep the physical size of this node small.

Capacitive Loads

The EL2022 is stable driving most capacitive loads. However, when driving a pure capacitive load of less than a thousand picofarads the frequency response may have several dB of peaking and the squarewave response may ring for several hundred nanoseconds. To reduce these effects, and their associated peaking in the frequency domain, the circuit below should be used.

Driving Reactive Loads



2022-10

The output stage of the EL2022 looks inductive at high frequencies, and the snubber components have two benefits. First, they de-Q the output stage by adding a real load at high frequency, and second, they provide an upper limit to the impedance from which the load is being driven from.

EL2022/EL2022C
165 MHz Current Feedback Amplifier

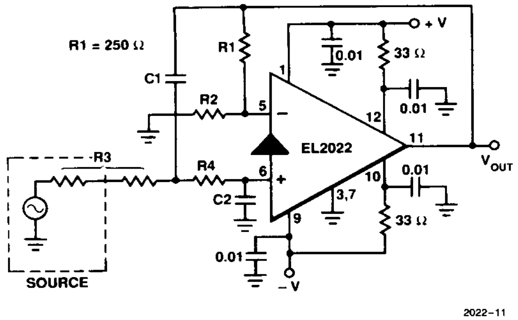
EL2022 Applications — Contd.

The isolation resistor has similar benefits. A value of R_{ISO} of 5Ω will not affect bandwidth or drive capability much, yet it will improve small and large signal response significantly with reactive loads. For a thorough discussion on reducing the effects of load capacitance and selecting optimal component values, see the section on driving capacitive loads in the EL2003 datasheet.

EL2022 Active Filters

The EL2022's low phase lag at high frequencies makes it an excellent choice for high performance active filters, and the filter response more closely approaches the theoretical response than with conventional op amps, due to the EL2022's shorter propagation delay. As long as you use it just as a gain block (called a +KRC realization) and don't put reactive components in the feedback path to the inverting input, it should work well.

2nd Order Low Pass Filter

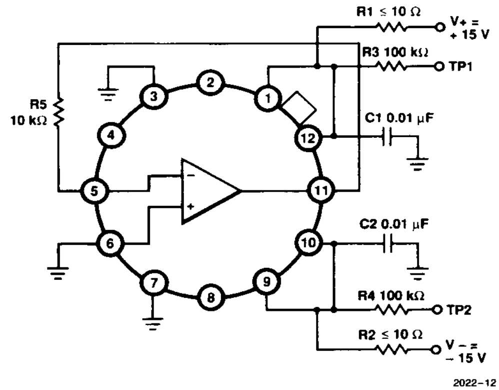


Note that if R3 = R4 = R and C1 = C2 = C then $F_{cutoff} = 2\pi\ (1/RC)$ AND $Q = 1/(3 - (1 + (R1/R2)))$.

The EL2022 as a Coaxial Cable Driver

The EL2022 makes an excellent gain block for wide bandwidth systems. It is capable of driving more than 3 double terminated 75Ω cables with low distortion and very wide bandwidth. The most common application here may be the gain of 2 driving 50Ω or 75Ω double terminated coax. The EL2022 was designed with driving coaxial cables in mind. The 100 mA of output drive and its low output impedance allows it to drive two or three 75Ω double terminated coax cables with one EL2022, and still keep the speed and distortion specifications that professional video requires. The double matched method is the best way to drive coax cables, because the impedance match on both ends of the cable will suppress reflections. For a discussion on some of the other ways to drive cables, see the section on driving cables in the EL2003 datasheet.

Burn-In Circuit



EL2022 Macromodel

```
* Connections:  +input
*               |     -input
*               |     |     +Vcc
*               |     |     |     +Vcc coll
*               |     |     |     |     -Vcc
*               |     |     |     |     |     -Vcc coll
*               |     |     |     |     |     |    output
                |     |     |     |     |     |    |
.subckt M2022   6     5     1     12    9     10   11
* Input Stage
el 30 0 6 0 1.0
r1 5 43 25
11 43 42 29nH
vis 30 41 0V
h4 41 42 v1 1.0
h1 31 0 vis 1.0
r2 31 0 1K
v1 40 0 0V
r4 40 0 1K
ivos 0 40 5mA
* High Frequency Pole
e2 32 0 31 0 1.0
r5 32 0 1K
r6 32 33 1K
12 33 34 0.1uH
c1 34 0 0.2pF
* Transimpedance Stage
gm 0 35 34 0 1.0
rol 35 0 130K
c2 35 0 4pF
* Output Stage
q1 9 35 36 qp
q2 1 35 39 qn
q3 12 36 37 qn
q4 10 39 38 qp
r7 37 11 2
r8 38 11 2
ios1 1 36 2.5mA
ios2 39 9 2.5mA
* Supply and Bias Current
ips 1 9 12mA
iin+ 6 0 5uA
iin- 0 5 10uA
* Models
.model qn npn(is=5e-15 bf=100 tf=0.1nS)
.model qp pnp(is=5e-15 bf=100 tf=0.1nS)
.ends
```

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165 MHz Current Feedback Amplifier

EL2022 Macromodel — Contd.