

# CLC411 High-Speed Video Op Amp with Disable

## General Description

The CLC411 combines a state-of-the-art complementary bipolar process with National's patented current-feedback architecture to provide a very high-speed op amp operating from  $\pm 15V$  supplies. Drawing only 11mA quiescent current, the CLC411 provides a 200MHz small signal bandwidth and a 2300V/ $\mu s$  slew rate while delivering a continuous 70mA current output with  $\pm 4.5V$  output swing. The CLC411's high-speed performance includes a 15ns settling time to 0.1% (2V step) and a 2.3ns rise and fall time (6V step).

The CLC411 is designed to meet the requirements of professional broadcast video systems including composite video and high definition television. The CLC411 exceeds the HDTV standard for gain flatness to 30MHz with its  $\pm 0.05dB$  flat frequency response and exceeds composite video standards with its very low differential gain and phase errors of 0.02%, 0.03°. The CLC411 is the op amp of choice for all video systems requiring upward compatibility from NTSC and PAL to HDTV.

The CLC411 features a very fast disable/enable (10ns/55ns) allowing the multiplexing of high-speed signals onto an analog bus through the common output connections of multiple CLC411's. Using the same signal source to drive disable/enable pins is easy since "break-before-make" is guaranteed.

The CLC411 is available in several versions:

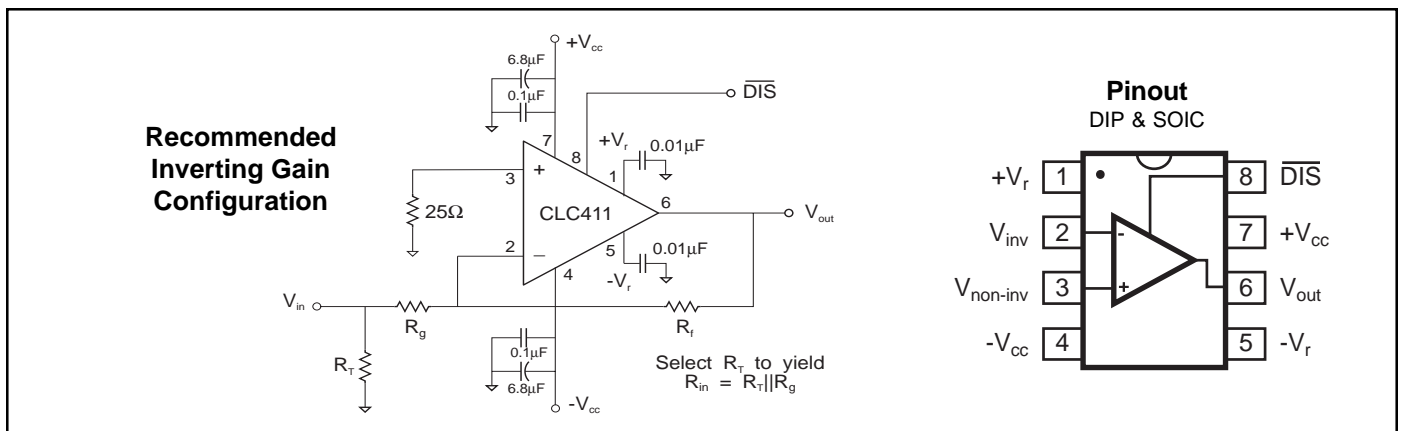
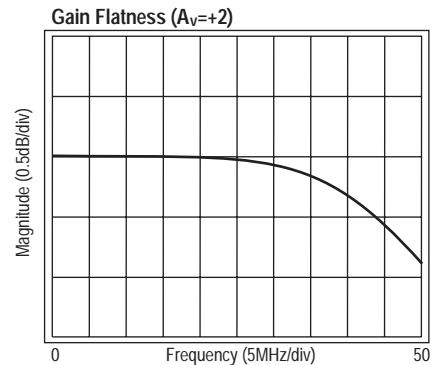
CLC411AJP	-40°C to +85°C	8-pin plastic DIP
CLC411AJE	-40°C to +85°C	8-pin plastic SOIC
CLC411A8B	-55°C to +125°C	8-pin hermetic CERDIP, MIL-STD-883
CLC411AMC	-55°C to +125°C	dice, MIL-STD-883, Level B
DESC SMD number: 5962-94566		

## Features

- 200MHz small signal bandwidth ( $1V_{pp}$ )
- $\pm 0.05dB$  gain flatness to 30MHz
- 0.02%, 0.03° differential gain, phase
- 2300V/ $\mu s$  slew rate
- 10ns disable to high-impedance output
- 70mA continuous output current
- $\pm 4.5V$  output swing into 100 $\Omega$  load
- $\pm 4.0V$  input voltage range

## Applications

- HDTV amplifier
- Video line driver
- High-speed analog bus driver
- Video signal multiplexer
- DAC output buffer



# CLC411 Electrical Characteristics ( $A_V = +2$ ; $V_{CC} = \pm 15V$ ; $R_L = 100\Omega$ ; $R_i = 301\Omega$ , unless noted)

PARAMETERS	CONDITIONS	TYP	MIN/MAX RATINGS				UNITS	SYMBOL
			-40°C	+25°C	+85°C			
Ambient Temperature	CLC411 AJ	+25°C	-40°C	+25°C	+85°C			
<b>FREQUENCY DOMAIN RESPONSE</b>								
-3dB bandwidth	$V_{out} < 1V_{pp}$	200	150	150	110	MHz	SSBW	
	$V_{out} < 6V_{pp}$	75	50	50	40	MHz	LSBW	
gain flatness	$V_{out} < 1V_{pp}$							
peaking	DC to 30MHz	0.05	0.2	0.2	0.3	dB	GFPL	
rolloff	DC to 30MHz	0.05	0.2	0.2	0.4	dB	GFRL	
peaking	DC to 200MHz	0.1	0.6	0.5	0.6	dB	GFPH	
rolloff	DC to 60MHz	0.2	0.7	0.4	0.7	dB	GFRH	
linear phase deviation	DC to 60MHz	0.3	1.0	1.0	1.0	°	LPD	
differential gain	4.43MHz, $R_L = 150W$	0.02				%	DG	
differential phase	4.43MHz, $R_L = 150W$	0.03				°	DP	
<b>TIME DOMAIN RESPONSE</b>								
rise and fall time	6V step	2.3				ns	TR	
settling time to 0.1%	2V step	15	23	18	23	ns	TS	
overshoot	2V step	5	15	10	15	%	OS	
slew rate	6V step	2300				V/ $\mu$ s	SR	
<b>DISTORTION AND NOISE RESPONSE (note 1)</b>								
2 <sup>ND</sup> harmonic distortion	$2V_{pp}$ , 20MHz	-48	-35	-35	-35	dBc	HD2	
3 <sup>RD</sup> harmonic distortion	$2V_{pp}$ , 20MHz	-52	-42	-42	-35	dBc	HD3	
equivalent noise input voltage	>1MHz	2.5				nV/ $\sqrt{Hz}$	VN	
inverting current	>1MHz	12.9				pA/ $\sqrt{Hz}$	ICI	
non-inverting current	>1MHz	6.3				pA/ $\sqrt{Hz}$	ICN	
noise floor	>1MHz	-157				dBm <sub>1Hz</sub>	SNF	
integrated noise	1MHz to 200MHz	45				$\mu$ V	INV	
<b>STATIC DC PERFORMANCE</b>								
*input offset voltage		$\pm 2$	$\pm 13$	$\pm 9.0$	$\pm 14$	mV	VIO	
average temperature coefficient		+30	$\pm 50$	—	$\pm 50$	$\mu$ V/°C	DVIO	
*input bias current	non-inverting	12	65	30	$\pm 20$	$\mu$ A	IBN	
average temperature coefficient		$\pm 200$	$\pm 400$	—	$\pm 250$	nA/°C	DIBN	
*input bias current	inverting	$\pm 12$	$\pm 40$	$\pm 30$	$\pm 30$	$\mu$ A	IBI	
average temperature coefficient		$\pm 50$	$\pm 200$	—	$\pm 150$	nA/°C	DIBI	
power supply rejection ratio		56	48	50	48	dB	PSRR	
common mode rejection ratio		52	44	46	44	dB	CMRR	
*supply current	no load	11	14	12	12	mA	ICC	
supply current	disabled	2.5	4.5	3.5	4.5	mA	ICCD	
<b>DISABLE/ENABLE PERFORMANCE (note 2)</b>								
disable time	to >50dB attenuation @10MHz	10	30	30	60	ns	TOFF	
enable time		55				ns	TON	
DIS voltage	pin 8							
to disable		4.5	<3.0	<3.0	<3.0	V	VDIS	
to enable		5.5	>7.0	>6.5	>6.5	V	VEN	
off isolation	at 10MHz	59	55	55	55	dB	OSD	
<b>MISCELLANEOUS PERFORMANCE</b>								
non-inverting input resistance		1000	250	750	1000	k $\Omega$	RIN	
non-inverting input capacitance		2.0	3.0	3.0	3.0	pF	CIN	
output voltage range	no load	$\pm 6.0$		$\pm 4.5$		V	VO	
output voltage range	$R_L = 100\Omega$	$\pm 4.5$		$\pm 4.0$		V	VOL	
common mode input range		$\pm 4.0$		$\pm 3.5$		V	CMIR	
output current		70	30	50	40	mA	IO	

Min/max ratings are based on product characterization and simulation. Individual parameters are tested as noted. Outgoing quality levels are determined from tested parameters.

## Absolute Maximum Ratings

$V_{CC}$	$\pm 18V$
$I_{out}$	125mA
common-mode input voltage	$\pm V_{CC}$
differential input voltage	$\pm 15V$
maximum junction temperature	+150°C
operating temperature range: AJ	-40°C to +85°C
storage temperature range	-65°C to +150°C
lead temperature (soldering 10 sec)	+300°C
ESD (human body model)	1000V

## Miscellaneous Ratings

Recommended gain range  $\pm 1$  to  $\pm 10V/V$

Notes: \* AJ : 100% tested at +25°C.

note 1 : Specifications guaranteed using 0.01mF bypass capacitors on pins 1 & 5.

note 2 : Break before make is guaranteed.

## Package Thermal Resistance

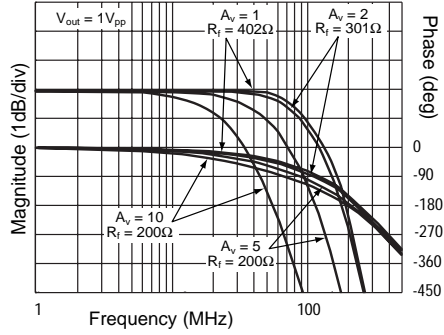
Package	$\theta_{JC}$	$\theta_{JA}$
AJP	65°C/W	120°C/W
AJE	55°C/W	135°C/W
A8B	25°C/W	115°C/W

## Reliability Information

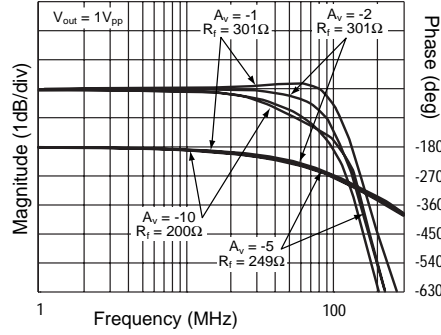
Transistor count	70
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# CLC411 Typical Performance ( $T_A=+25^\circ\text{C}$ , $A_V=+2$ , $V_{CC}=\pm 15\text{V}$ , $R_L=100\Omega$ , $R_I=301\Omega$ , unless noted)

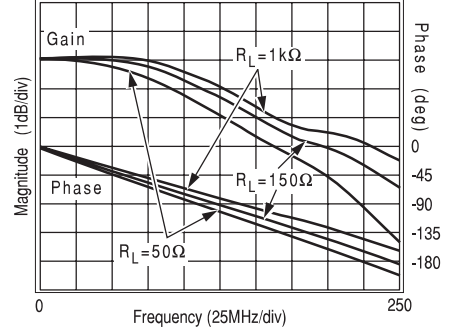
**Non-Inverting Frequency Response**



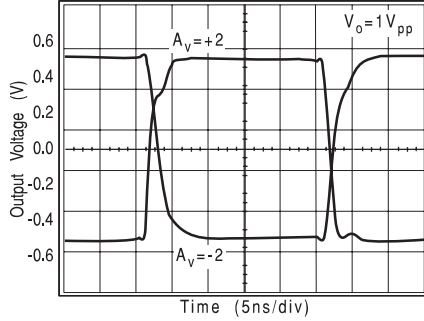
**Inverting Frequency Response**



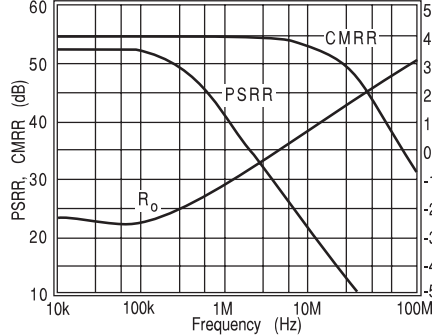
**Non-Inverting Frequency Response vs. Load**



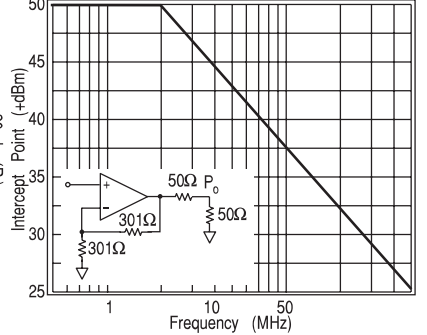
**Pulse Response**



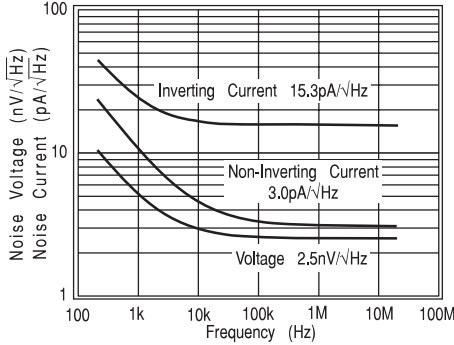
**PSRR, CMRR, and Closed Loop  $R_o$**



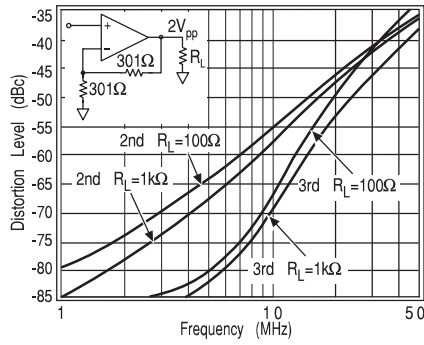
**2-Tone, 3rd Order Intermodulation Intercept**



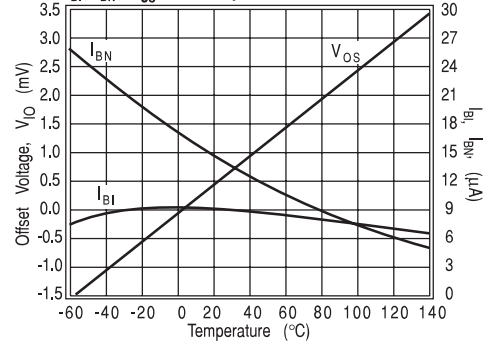
**Equivalent Input Noise**



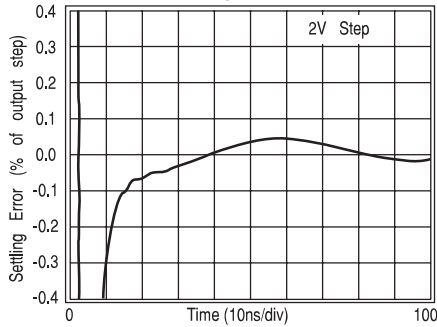
**2nd and 3rd Harmonic Distortion**



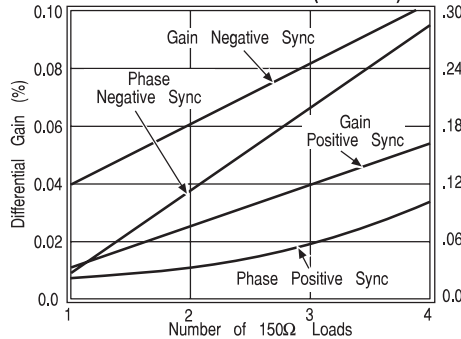
**$I_{BI}$ ,  $I_{BN}$ ,  $V_{OS}$  vs. Temperature**



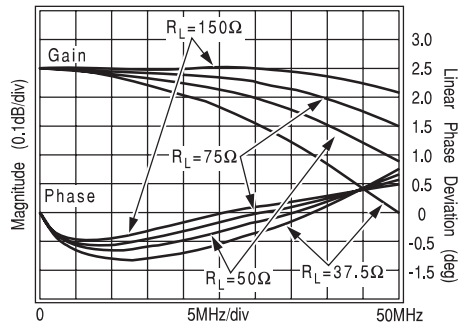
**Short Term Settling Time**



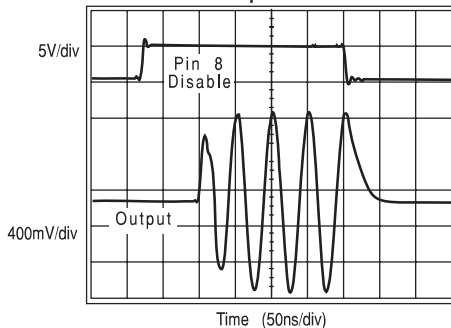
**Differential Gain and Phase (4.43 MHz)**



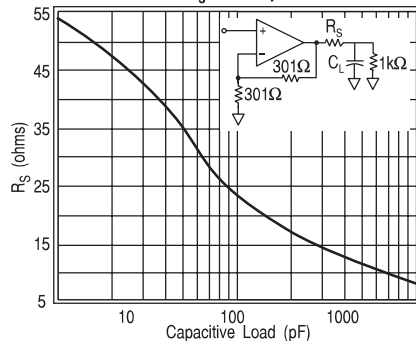
**Gain Flatness and Linear Phase Deviation**



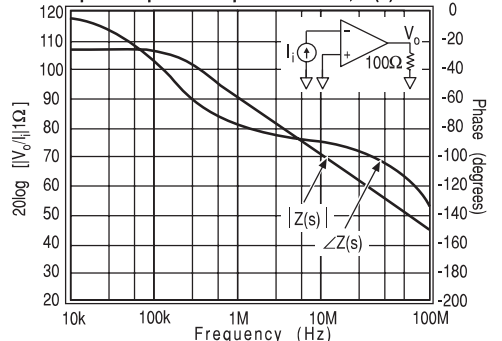
**Enable/Disable Response**

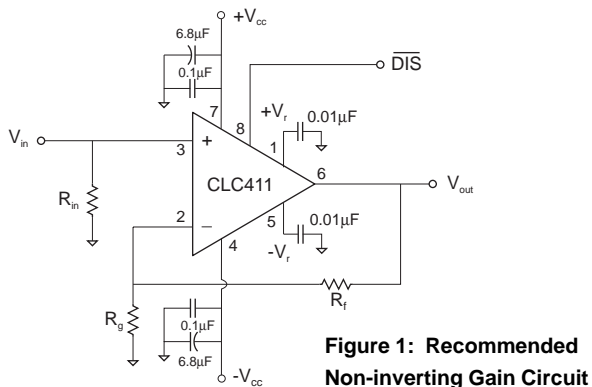


**Recommended  $R_s$  vs. Capacitive Loads**



**Open-Loop Transimpedance Gain,  $Z(s)$**



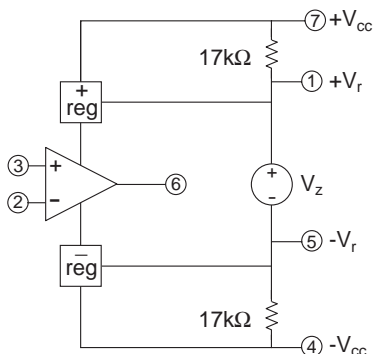


**Figure 1: Recommended Non-inverting Gain Circuit**

**Description**

The CLC411 is a high-speed current-feedback operational amplifier which operates from  $\pm 15V$  power supplies. The external supplies ( $\pm V_{CC}$ ) are regulated to lower voltages internally. The amplifier itself sees approximately  $\pm 6.5V$  rails. Thus the device yields performance comparable to Comlinear's  $\pm 5V$  devices, but with higher supply voltages. There is no degradation in rated specifications when the CLC411 is operated from  $\pm 12V$ . A slight reduction in bandwidth will be observed with  $\pm 10V$  supplies. Operation at less than  $\pm 10V$  is not recommended.

A block diagram of the amplifier and regulator topology is shown in Figure 2, "CLC411 Equivalent Circuit." The regulators derive their reference voltage from an internal floating zener voltage source. External control of the zener reference pins can be used to level-shift amplifier operation which is discussed in detail in the section entitled "Extending Input/Output Range with  $V_r$ ."

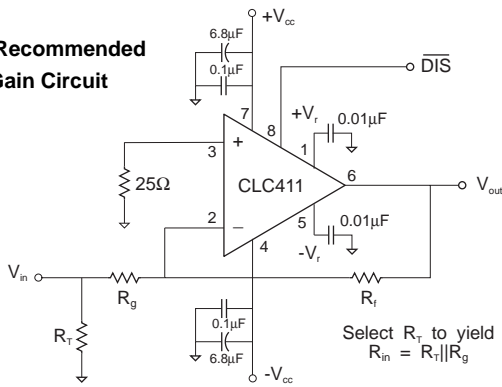


**Figure 2: CLC411 Equivalent Circuit**

**Power Supply Decoupling**

There are four pins associated with the power supplies. The  $V_{CC}$  pins (4,7) are the external supply voltages. The  $V_r$  pins (5,1) are connected to internal reference nodes. Figures 1 and 3, "Recommended Non-inverting Gain Circuit" and "Recommended Inverting Gain Circuit" show the recommended supply decoupling scheme with four ceramic and two electrolytic capacitors. The ceramic capacitors must be placed immediately adjacent to the device pins and connected directly to a good

**Figure 3: Recommended Inverting Gain Circuit**



Select  $R_f$  to yield  $R_{in} = R_f || R_g$

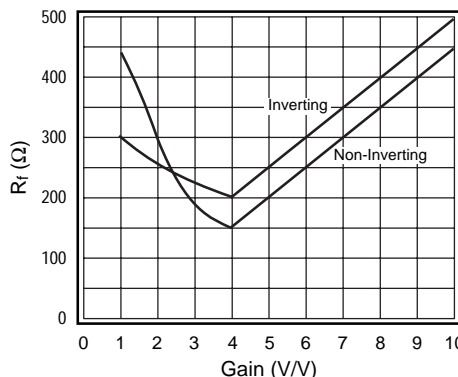
low-inductance ground plane. Bypassing the  $V_r$  pins will reduce high frequency noise ( $>10MHz$ ) in the amplifier. If this noise is not a concern these capacitors may be eliminated.

**Differential Gain and Phase**

The differential gain and phase errors of the CLC411 driving one doubly-terminated video load ( $R_L=150\Omega$ ) are specified and guaranteed in the "Electrical Characteristics" table. The "Typical Performance" plot, "Differential Gain and Phase (4.43MHz)" shows the differential gain and phase performance of the CLC411 when driving from one to four video loads. Application note OA-08, "Differential Gain and Phase for Composite Video Systems," describes in detail the techniques used to measure differential gain and phase.

**Feedback Resistor**

The loop gain and frequency response for a current-feedback operational amplifier is determined largely by the feedback resistor,  $R_f$ . The electrical characteristics and typical performance plots contained within the datasheet, unless otherwise stated, specify an  $R_f$  of  $301\Omega$ , a gain of  $+2V/V$  and operation with  $\pm 15V$  power supplies. The frequency response at different gain settings and supply voltages can be optimized by selecting a different value of  $R_f$ . Generally, lowering  $R_f$  will peak the frequency response and extend the bandwidth while increasing its value will roll off the response. For unity-gain voltage follower circuits, a



**Figure 4: Recommended  $R_f$  vs. Gain**

non-zero  $R_f$  must be used with current-feedback operational amplifiers such as the CLC411. Application note OA-13, "Current-Feedback Loop-Gain Analysis and Performance Enhancements," explains the ramifications of  $R_f$  and how to use it to tailor the desired frequency response with respect to gain. The equations found in the application note should be considered as a starting point for the selection of  $R_f$ . The equations do not factor in the effects of parasitic capacitance found on the inverting input, the output nor across the feedback resistor. Equations in OA-13 require values for  $R_f$  ( $301\Omega$ ),  $A_v$  ( $+2$ ) and  $R_i$  (inverting input resistance,  $50\Omega$ ). Combining these values yields a  $Z_f^*$  (optimum feedback transimpedance) of  $400\Omega$ . Figure 4 entitled "Recommended  $R_f$  vs. Gain" will enable the selection of the feedback resistor that provides a maximally flat frequency response for the CLC411 over its gain range.

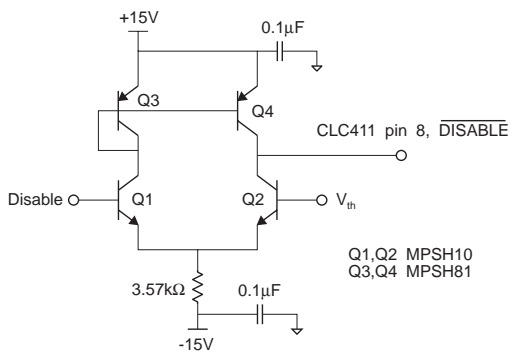


Figure 5A: Disable Interface

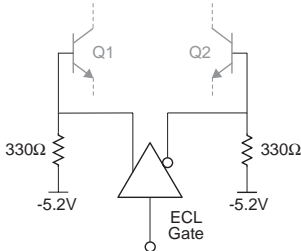


Figure 5B: Differential ECL Interface

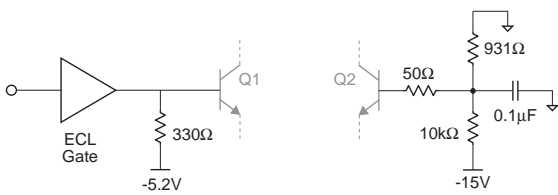


Figure 5C: ECL Interface

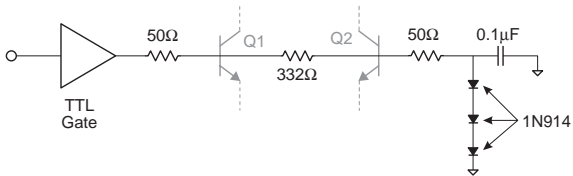


Figure 5D: TTL Interface

The linear portion of the two curves (i.e.  $A_v > 4$ ) results from the limitation on  $R_g$  (i.e.  $R_g \geq 50\Omega$ ).

### Enable/Disable Operation

The disable feature allows the outputs of several CLC411 devices to be connected onto a common analog bus forming a high-speed analog multiplexer. When disabled, the output and inverting inputs of the CLC411 become high impedances. The disable pin has an internal pull-up resistor which is pulled-up to an internal voltage, not to the external supply. The CLC411 is enabled when pin 8 is left open or pulled-up to  $\geq +7V$  and disabled when grounded or pulled below  $+3V$ . CMOS logic devices are necessary to drive the disable pin. For example, CMOS logic with  $V_{DD} \geq +7V$  will guarantee proper operation over temperature. TTL voltage levels are inadequate for controlling the disable feature.

For faster enable/disable operation than 15V CMOS logic devices will allow, the circuit of Figure 5 is recommended. A fast four-transistor comparator, Figure 5A, interfaces between the CLC411 DISABLE pin and several standard logic families. This circuit has a differential input between the bases of Q1 and Q2. As such it may be driven directly from differential ECL logic, as in shown in Figure 5B. Single-ended logic families may also be used by establishing an appropriate threshold voltage on the  $V_{th}$  input, the base of Q2.

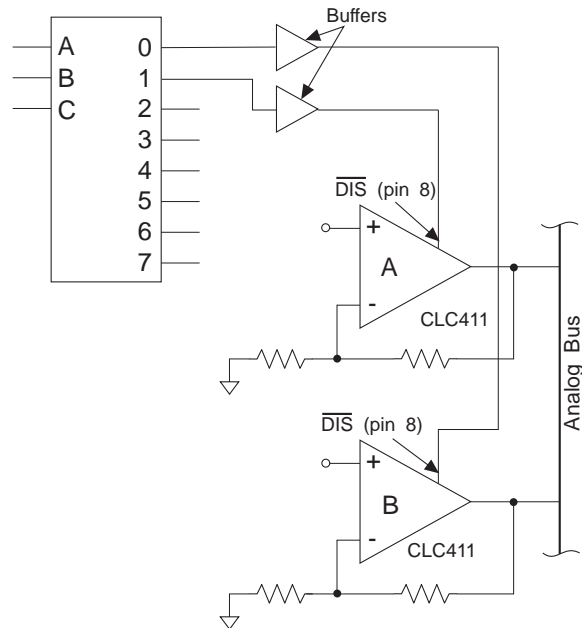


Figure 6: General Multiplexing Circuit

Figures 5C and 5D illustrate a single-ended ECL and TTL interface respectively. The Disable input, the base of Q1, is driven above and below the threshold,  $V_{th}$ .

Fastest switching speeds result when the differential voltage between the bases of Q1 and Q2 is kept to less

than one volt. Single-ended ECL, Figure 5C, maintains this desired maximum differential input voltage. TTL and CMOS have higher  $V_{high}$  to  $V_{low}$  excursions. The circuit of figure 5D will ensure the voltage applied between the bases of Q1 and Q2 does not cause excessive switching delays in the CLC411. Under the above proscribed four-transistor interface, all variations were evaluated with approximately 1ns rise and fall times which produced switching speeds equivalent to the rated disable/enable switching times found in the "CLC411 Electrical Characteristics" table.

A general multiplexer configuration using several CLC411s is illustrated in figure 6, where a typical 8-to-1 digital mux is used to control the switching operation of the paralleled CLC411s. Since "break-before-make" is a guaranteed specification of the CLC411 this configuration works nicely. Notice the buffers used in driving the disable pins of the CLC411s. These buffers may be 15V CMOS logic devices mentioned previously or any variation of the four-transistor comparator illustrated above.

### Extending Input/Output Range with $V_r$

As can be seen in Figure 3, the magnitude of the internal regulated supply voltages is fixed by  $V_z$ . In normal operation, with  $\pm 15V$  external supplies,  $+V_r$  is nominally +9V when left floating. CMIR (common mode input range) and VO (output voltage range, no load) are specified under these conditions. These parameters

implicitly have 0V as their midpoint, i.e. the VO range is  $\pm 6V$ , centered at 0V.

An external voltage source can be applied to  $+V_r$  to shift the range of the input/output voltages. For example, if it were desired to move the positive VO range from +6V to a +9V maximum in unipolar operation, Figure 7, "DC Parameters as a Function of  $+V_r$ ", is used to determine the required supply and  $+V_r$  voltages. Referring to Figure 7, locate the point on the  $+VO_{MAX}$  line where the ordinate is +9V. Draw a vertical line from this point intersecting the other lines in the graph. The circuit voltages are the ordinates of these intersections. For this example these points are shown in the graph as solid dots. The required voltage sources are  $+V_r = +12V$ ,  $+V_{CC} = +12V$ ,  $-V_{CC} = -12V$ . When these supply and reference voltages are applied, the range for VO is -3V to +9V, and CMIR ranges from -1V to +7V. The difference between the minimum and maximum voltages is constant, i.e. 12V for VO, only the midpoint has been shifted, i.e. from 0V to +3V for VO.

Note that in this example the  $-V_r$  pin has been left open (or bypassed to reduce high-frequency noise). The difference between  $+V_r$  and  $-V_r$  is fixed by  $V_z$ . A level-shifting voltage can be applied to only one of the reference pins, not both. If extended operation were needed in the negative direction, Figure 4 may be used by changing the signs, and applying the resultant negative voltage to the  $-V_r$  pin. It is recommended that  $+V_r$  be used for positive shifts, and  $-V_r$  for negative shifts of input/output voltage range.

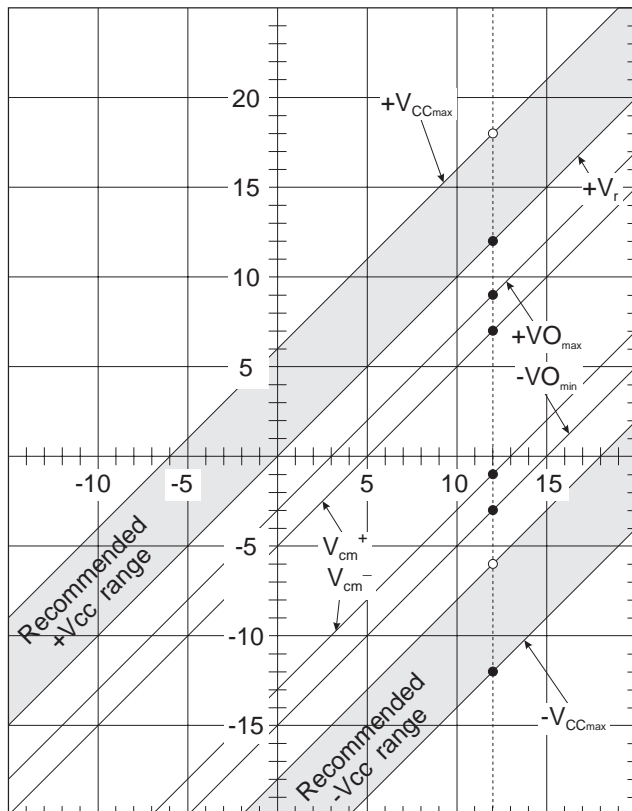


Figure 7: DC Parameters as a Function of  $+V_r$

### Printed Circuit Layout & Evaluation Board

Refer to application note OA-15, "Frequent Faux Pas in Applying Wideband Current Feedback Amplifiers," for board layout guidelines and construction techniques. Two very important points to consider before creating a layout which are found in the above application note are worth reiteration. First the input and output pins are sensitive to parasitic capacitances. These parasitic capacitances can cause frequency-response peaking or sustained oscillation. To minimize the adverse effect of parasitic capacitances, the ground plane should be removed from those pins to a distance of at least 0.25" Second, leads should be kept as short as possible in the finished layout. In particular, the feedback resistor should have its shortest lead on the inverting input side of the CLC411. The output is less sensitive to parasitic capacitance and therefore can drive the longer of the two feedback resistor connections. The evaluation board available for the CLC411 (part #730013 for through-hole packages, 730027 for SO-8) may be used as a reference for proper board layout. Application schematics for this evaluation board are in the product accessories section of the Comlinear databook.

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#### National Semiconductor Corporation

1111 West Bardin Road  
Arlington, TX 76017  
Tel: 1(800) 272-9959  
Fax: 1(800) 737-7018

#### National Semiconductor Europe

Fax: (+49) 0-180-530 85 86  
E-mail: europe.support.nsc.com  
Deutsch Tel: (+49) 0-180-530 85 85  
English Tel: (+49) 0-180-532 78 32  
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#### National Semiconductor Hong Kong Ltd.

2501 Miramar Tower  
1-23 Kimberley Road  
Tsimshatsui, Kowloon  
Hong Kong  
Tel: (852) 2737-1600  
Fax: (852) 2736-9960

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