



National Semiconductor

June 1999

# CLC405 Low-Cost, Low-Power, 110MHz Op Amp with Disable

## CLC405 Low-Cost, Low-Power, 110MHz Op Amp with Disable

### General Description

The CLC405 is a low-cost, wideband (110MHz) op amp featuring a TTL-compatible disable which quickly switches off in 18ns and back on in 40ns. While disabled, the CLC405 has a very high input/output impedance and its total power consumption drops to a mere 8mW. When enabled, the CLC405 consumes only 35mW and can source or sink an output current of 60mA. These features make the CLC405 a versatile, high-speed solution for demanding applications that are sensitive to both power and cost.

Utilizing National's proven architectures, this current feedback amplifier surpasses the performance of alternative solutions and sets new standards for low power at a low price. This power-conserving op amp achieves low distortion with -72dBc and -70dBc for second and third harmonics respectively. Many high source impedance applications will benefit from the CLC405's 6MΩ input impedance. And finally, designers will have a bipolar part with an exceptionally low 100nA non-inverting bias current.

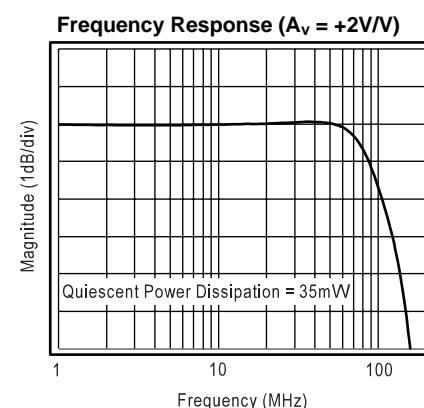
With 0.1dB flatness to 50MHz and low differential gain and phase errors, the CLC405 is an ideal part for professional video processing and distribution. However, the 110MHz -3dB bandwidth ( $A_v = +2$ ) coupled with a 350V/μs slew rate also make the CLC405 a perfect choice in cost-sensitive applications such as video monitors, fax machines, copiers, and CATV systems.

### Features

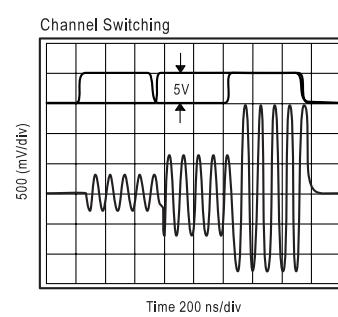
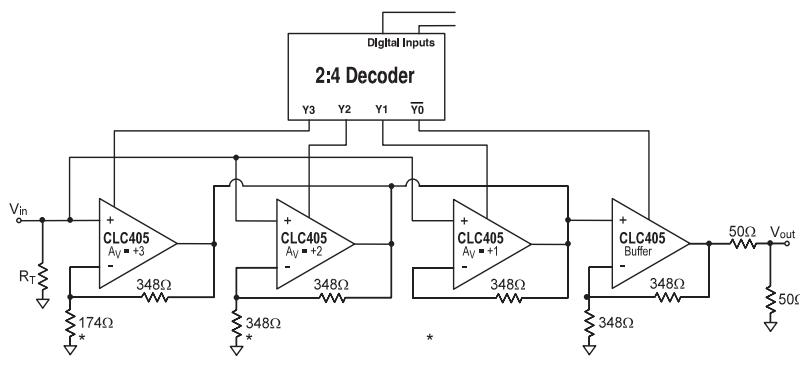
- Low-cost
- Very low input bias current: 100nA
- High input impedance: 6MΩ
- 110MHz -3dB bandwidth ( $A_v = +2$ )
- Low power:  $I_{cc} = 3.5\text{mA}$
- Ultra-fast enable/disable times
- High output current: 60mA

### Applications

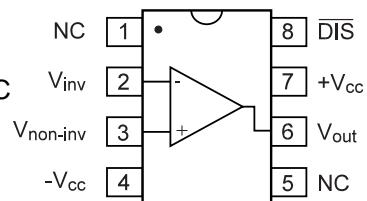
- Desktop video systems
- Multiplexers
- Video distribution
- Flash A/D driver
- High-speed switch/driver
- High-source impedance applications
- Peak detector circuits
- Professional video processing
- High resolution monitors



### Typical Application Wideband Digitally Controlled Programmable Gain Amplifier



### Pinout DIP & SOIC



# CLC405 Electrical Characteristics (A<sub>V</sub> = +2, R<sub>f</sub> = 348Ω: V<sub>cc</sub> = ± 5V, R<sub>L</sub> = 100Ω unless specified)

PARAMETERS	CONDITIONS	TYP	MIN/MAX RATINGS			UNITS	NOTES
Ambient Temperature	CLC405AJ	+25°C	+25°C	0 to 70°C	-40 to 85°C		
<b>FREQUENCY DOMAIN RESPONSE</b>							
-3dB bandwidth	V <sub>out</sub> < 1.0V <sub>pp</sub>	110	75	50	45	MHz	
	V <sub>out</sub> < 5.0V <sub>pp</sub>	42	31	27	26	MHz	
-3dB bandwidth A <sub>V</sub> = +1	V <sub>out</sub> < 0.5V <sub>pp</sub> (R <sub>f</sub> = 2K)	135				MHz	1
±0.1dB bandwidth	V <sub>out</sub> < 1.0V <sub>pp</sub>	50	15			MHz	
gain flatness	V <sub>out</sub> < 1.0V <sub>pp</sub>						
peaking	DC to 200MHz	0	0.6	0.8	1.0	dB	
rolloff	<30MHz	0.05	0.3	0.4	0.5	dB	
linear phase deviation	<20MHz	0.3	0.6	0.7	0.7	deg	
differential gain	NTSC, R <sub>L</sub> =150Ω	0.01	0.03	0.04	0.05	%	
	NTSC, R <sub>L</sub> =150Ω (Note 2)	0.01				%	
differential phase	NTSC, R <sub>L</sub> =150Ω	0.25	0.4	0.5	0.55	deg	2
	NTSC, R <sub>L</sub> =150Ω (Note 2)	0.08				deg	2
<b>TIME DOMAIN RESPONSE</b>							
rise and fall time	2V step	5	7.5	8.2	8.4	ns	
settling time to 0.05%	2V step	18	27	36	39	ns	
overshoot	2V step	3	12	12	12	%	
slew rate	A <sub>V</sub> = +2	2V step	350	260	225	V/μs	
	A <sub>V</sub> = -1	1V step	650			V/μs	
<b>DISTORTION AND NOISE RESPONSE</b>							
2 <sup>nd</sup> harmonic distortion	2V <sub>pp</sub> , 1MHz/10MHz	-72/-52	-46	-45	-44	dBc	B
3 <sup>rd</sup> harmonic distortion	2V <sub>pp</sub> , 1MHz/10MHz	-70/-57	-50	-47	-46	dBc	B
equivalent input noise							
non-inverting voltage	>1MHz	5	6.3	6.6	6.7	nV/√Hz	
inverting current	>1MHz	12	15	16	17	pA/√Hz	
non-inverting current	>1MHz	3	3.8	4	4.2	pA/√Hz	
<b>STATIC DC PERFORMANCE</b>							
input offset voltage		1	5	7	8	mV	A
average drift		30	50		50	μV/°C	
input bias current	non-inverting	100	900	1600	2800	nA	A
average drift		3		8	11	nA/°C	
input bias current	inverting	1	5	7	10	μA	A
average drift		17		40	45	nA/°C	
power supply rejection ratio	DC	52	47	46	45	dB	
common-mode rejection ratio	DC	50	45	44	43	dB	
supply current	R <sub>L</sub> = ∞	3.5	4.0	4.1	4.4	mA	A
disabled	R <sub>L</sub> = ∞	0.8	0.9	0.95	1	mA	A
<b>SWITCHING PERFORMANCE</b>							
turn on time		40	55	58	58	ns	
turn off time	to >50dB attn. @ 10MHz	18	26	30	32	ns	
off isolation	10MHz	59	55	55	55	dB	
high input voltage	V <sub>IH</sub>		2	2	2	V	
low input voltage	V <sub>IL</sub>		0.8	0.8	0.8	V	
<b>MISCELLANEOUS PERFORMANCE</b>							
input resistance	non-inverting	6	3	2.4	1	MΩ	
input resistance	inverting	182				Ω	
input capacitance	non-inverting	1	2	2	2	pF	
common mode input range		±2.2	1.8	1.7	1.5	V	
output voltage range	R <sub>L</sub> = 100Ω	+3.5, -2.8	+3.1, -2.7	+2.9, -2.6	+2.4, -1.6	V	
output voltage range	R <sub>L</sub> = ∞	+4.0, -3.3	+3.9, -3.2	+3.8, -3.1	+3.7, -2.8	V	
output current		40	40	38	20	mA	
output resistance, closed loop		0.06	0.2	0.25	0.4	Ω	

Recommended gain range ±1 to ±40V/V

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

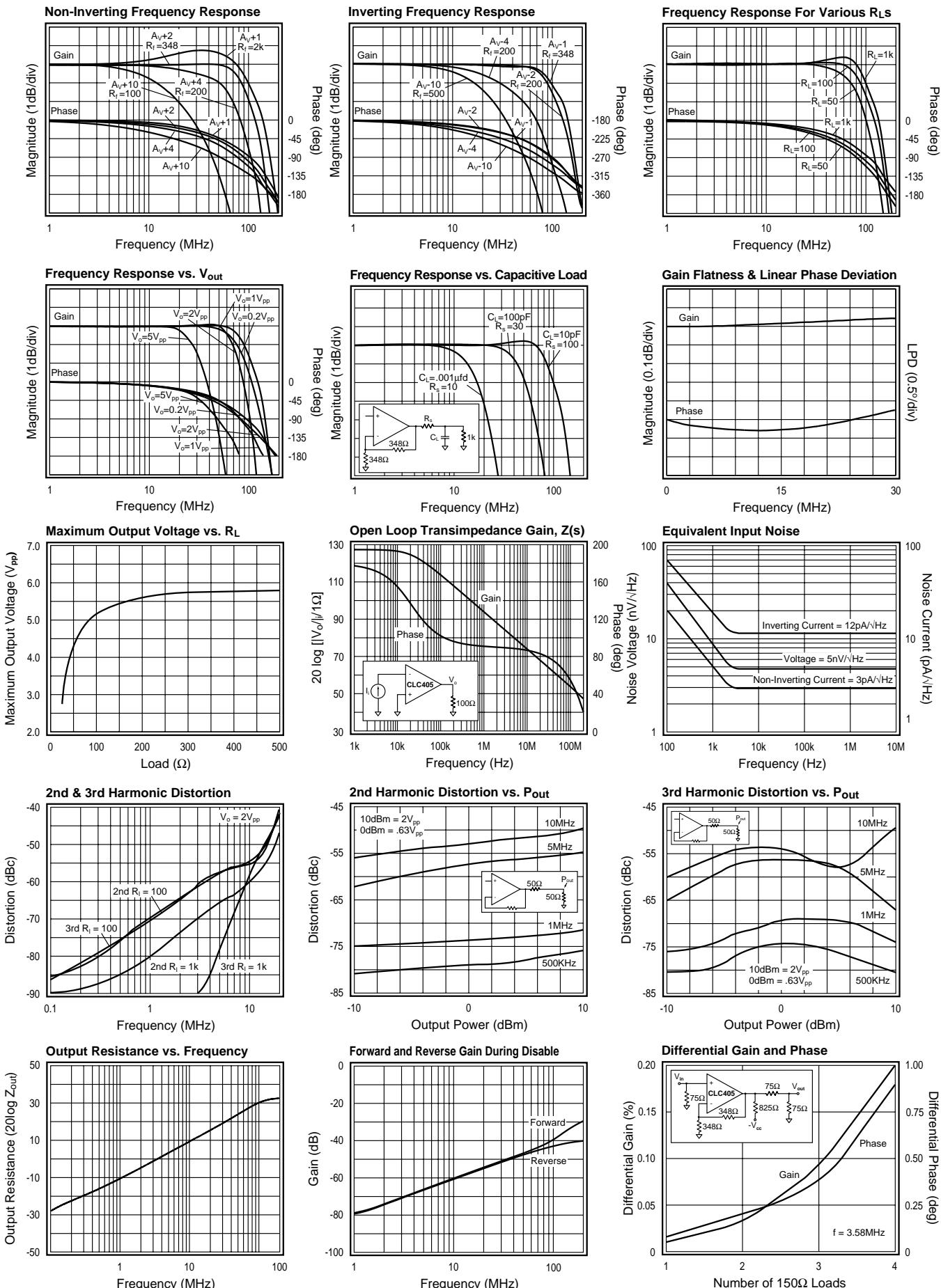
Transistor count

68

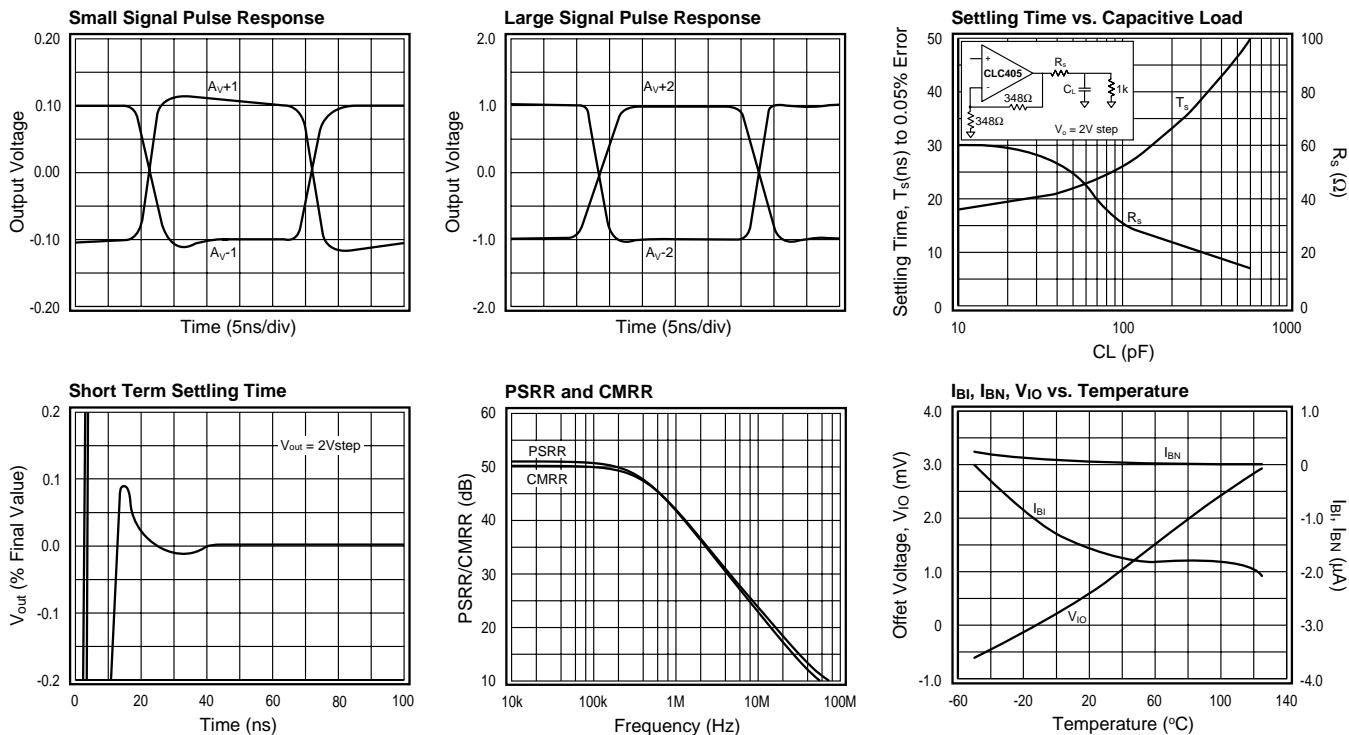
## Notes

- 1) At temps < 0°C, spec is guaranteed for R<sub>L</sub> = 500Ω.
- 2) An 825Ω pull-down resistor is connected between V<sub>o</sub> and -V<sub>cc</sub>.
- A) J-level: spec is 100% tested at +25°C
- B) Guaranteed at 10MHz.

# CLC405 Typical Performance Characteristics ( $A_V = +2$ , $R_f = 348\Omega$ ; $V_{cc} = \pm 5V$ , $R_L = 100\Omega$ unless specified)



## CLC405 Typical Performance Characteristics ( $A_V = +2$ , $R_f = 348\Omega$ ; $V_{cc} = \pm 5V$ , $R_L = 100\Omega$ unless specified)



## CLC405 OPERATION

### Feedback Resistor

The feedback resistor,  $R_f$ , determines the loop gain and frequency response for a current feedback amplifier. Unless otherwise stated, the performance plots and data sheet specify CLC405 operation with  $R_f$  of  $348\Omega$  at a gain of  $+2V/V$ . Optimize frequency response for different gains by changing  $R_f$ . Decrease  $R_f$  to peak frequency response and extend bandwidth. Increase  $R_f$  to roll off of the frequency response and decrease bandwidth. Use a  $2k\Omega$   $R_f$  for unity gain, voltage follower circuits.

Use application note OA-13 to optimize your  $R_f$  selection. The equations in this note are a good starting point for selecting  $R_f$ . The value for the inverting input impedance for OA-13 is approximately  $182\Omega$ .

### Enable/Disable Operation Using $\pm 5V$ Supplies

The CLC405 has a TTL & CMOS logic compatible disable function. Apply a logic low (i.e.  $< 0.8V$ ) to pin 8, and the CLC405 is guaranteed disabled across its temperature range. Apply a logic high to pin 8, (i.e.  $> 2.0V$ ) and the CLC405 is guaranteed enabled. Voltage, not current, at pin 8 determines the enable/disable state of the CLC405.

Disable the CLC405 and its inputs and output become high impedances. While disabled, the CLC405's quiescent power drops to 8mW.

Use the CLC405's disable to create analog switches or multiplexers. Implement a single analog switch with one CLC405 positioned between an input and output. Create an analog multiplexer with several CLC405s. Tie the outputs together and put a different signal on each CLC405 input.

Operate the CLC405 without connecting pin 8. An internal  $20k\Omega$  pull-up resistor guarantees the CLC405 is enabled when pin 8 is floating.

### Enable/Disable Operation for Single or Unbalanced Supply Operation

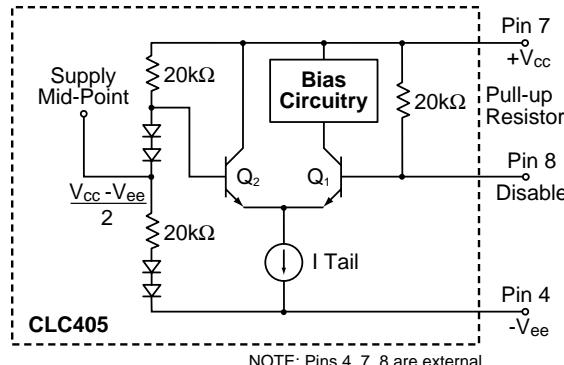


Figure 1

Figure 1 illustrates the internal enable/disable operation of the CLC405. When pin 8 is left floating or is tied to  $+V_{cc}$ ,  $Q_1$  is on and pulls tail current through the CLC405 bias circuitry. When pin 8 is less than  $0.8V$  above the supply midpoint,  $Q_1$  stops tail current from flowing in the CLC405 circuitry. The CLC405 is now disabled.

### Disable Limitations

The feedback resistor,  $R_f$ , limits off isolation in inverting gain configurations. Do not apply voltages greater than  $+V_{cc}$  or less than  $-V_{ee}$  to pin 8 or any other pin.

## Input - Bias Current, Impedances, and Source Termination Considerations

The CLC405 has:

- a  $6M\Omega$  non-inverting input impedance.
- a  $100nA$  non-inverting input bias current.

If a large source impedance application is considered, remove all parasitic capacitance around the non-inverting input and source traces. Parasitic capacitances near the input and source act as a low-pass filter and reduce bandwidth.

Current feedback op amps have uncorrelated input bias currents. These uncorrelated bias currents prevent source impedance matching on each input from canceling offsets. Refer to application note OA-07 of the data book to find specific circuits to correct DC offsets.

## Layout Considerations

Whenever questions about layout arise, USE THE EVALUATION BOARD AS A TEMPLATE.

Use the CLC730013 and CLC730027 evaluation boards for the DIP and SOIC respectively. These board layouts were optimized to produce the typical performance of the CLC405 shown in the data sheet. To reduce parasitic capacitances, the ground plane was removed near pins 2, 3, and 6. To reduce series inductance, trace lengths of components and nodes were minimized.

Parasitics on traces degrade performance. Minimize coupling from traces to both power and ground planes. Use low inductive resistors for leaded components.

Do not use dip sockets for the CLC405 DIP amplifiers. These sockets can peak the frequency domain response or create overshoot in the time domain response. Use flush-mount socket pins when socketing is necessary. The 730013 circuit board device holes are sized for Cambion P/N 450-2598 socket pins or their functional equivalent.

Insert the back matching resistor ( $R_{out}$ ) shown in Figure 2 when driving coaxial cable or a capacitive load. Use the plot in the typical performance section labeled "Settling Time vs. Capacitive Load" to determine the optimum resistor value for  $R_{out}$  for different capacitive loads. This optimal resistance improves settling time for pulse-type applications and increases stability.

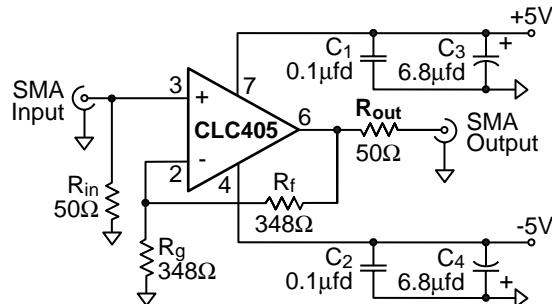
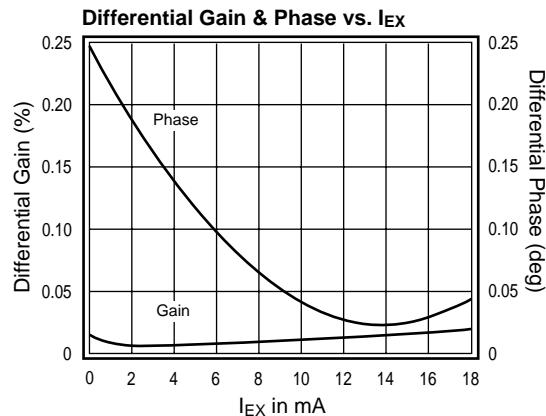


Figure 2

Use power-supply bypassing capacitors when operating this amplifier. Choose quality  $0.1\mu F$  ceramics for  $C_1$  and  $C_2$ . Choose quality  $6.8\mu F$  tantalum capacitors for  $C_3$  and  $C_4$ . Place the  $0.1\mu F$  capacitors within 0.1 inches from the power pins. Place the  $6.8\mu F$  capacitors within 3/4 inches from the power pins.

## Video Performance vs. $I_{EX}$

Improve the video performance of the CLC405 by drawing extra current from the amplifier output stage. Using a single external resistor as shown in Figure 3, you can adjust the differential phase. Video performance vs.  $I_{EX}$  is illustrated below in Graph 1. This graph represents positive video performance with negative synchronization pulses.



Graph1

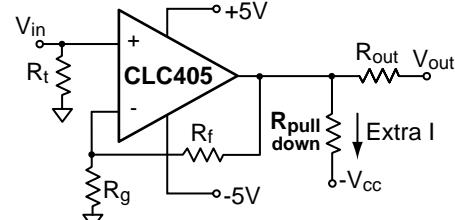


Figure 3

The value for  $R_{pd}$  in Figure 3 is determined by :

$$R_{pd} = \frac{5}{I_{EX}}$$

at  $\pm 5V$  supplies.

## Wideband Digital PGA

As shown on the front page, the CLC405 is easily configured as a digitally controlled programmable gain amplifier. Make a PGA by configuring several amplifiers at required gains. Keep  $R_f$  near  $348\Omega$  and change  $R_g$  for each different gain. Use a TTL decoder that has enough outputs to control the selection of different gains and the buffer stage. Connect the buffer stage like the buffer of the front page. The buffer isolates each gain stage from the load and can produce a gain of zero for a gain selection of zero. Use of an inverter (7404) on the buffer disable pin to keep the buffer operational at all gains except zero. Or float the buffer disable pin for a continuous enable state.

# CLC405 Low-Cost, Low-Power, 110MHz Op Amp with Disable

## Amplitude Equalization

Sending signals over coaxial cable greater than 50 meters in length will attenuate high frequency signal components. Equalizers restore the attenuated components of this signal. The circuit in Figure 4, is an op amp equalizer. The RC networks peak the response of the CLC405 at higher frequencies. Graph 2 shows how the equalizer actually restored a digital word through 150 meters of coaxial cable.

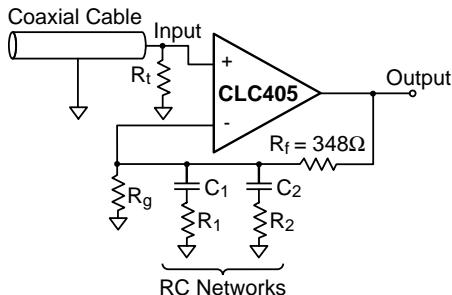
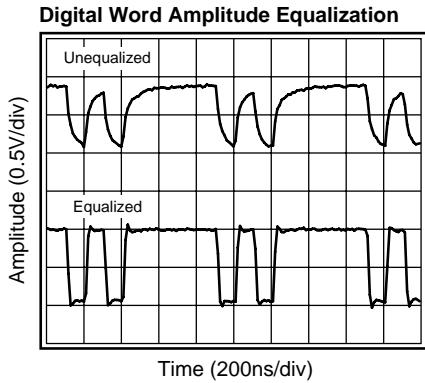


Figure 4



Graph 2

The values used to produce Graph 2 are:

$$\begin{aligned} R_g &= 348\Omega & C_1 &= 470\text{pF} & C_2 &= 70\text{pF} \\ R_1 &= 450\Omega & R_2 &= 90\Omega \end{aligned}$$

## Customer Design Applications Support

National Semiconductor is committed to design excellence. For sales, literature and technical support, call the National Semiconductor Customer Response Group at **1-800-272-9959** or fax **1-800-737-7018**.

### Life Support Policy

National's products are not authorized for use as critical components in life support devices or systems without the express written approval of the president of National Semiconductor Corporation. As used herein:

1. Life support devices or systems are devices or systems which, a) are intended for surgical implant into the body, or b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



### National Semiconductor Corporation

1111 West Bardin Road  
Arlington, TX 76017  
Tel: (1800) 272-9959  
Fax: (1800) 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  
Francais Tel: (+49) 0-180-532 93 58  
Italiano Tel: (+49) 0-180-534 16 80

### National Semiconductor Hong Kong Ltd.

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

### National Semiconductor Japan Ltd.

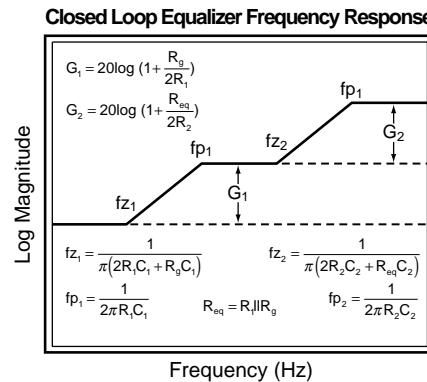
Tel: 81-043-299-2309  
Fax: 81-043-299-2408

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.

## Amplitude Equalizer

Place the first zero ( $fz_1$ ) at some low frequency (540 khz for Graph 2).  $R_1$  &  $C_1$  produce a pole ( $fp_1$  @ 750khz) that cancels  $fz_1$ . Place a second zero at a higher frequency ( $fz_2$  @ 12Mhz).  $R_2$  &  $C_2$  provide a canceling pole (of  $fp_2$  = 25Mhz).

Graph 3 shows the closed loop response of the op amp equalizer with equations for the poles, zeros, and gains.



Graph 3

Note: For very-high frequency equalization, use a higher bandwidth part (i.e. CLC44X)

## Package Thermal Resistance

Package	$\theta_{jc}$	$\theta_{jA}$
Plastic (AJP)	75°/W	125°/W
Surface Mount (AJE)	130°/W	150°/W
CerDip	65°/W	155°/W

## Ordering Information

Model	Temperature Range	Description
CLC405AJP	-40°C to +85°C	8-pin PDIP
CLC405AJE	-40°C to +85°C	8-pin SOIC
CLC405AIB	-40°C to +85°C	8-pin CerDIP
CLC405ALC	-40°C to +85°C	dice
CLC405AMC	-55°C to +125°C	dice, MIL-STD-883
CLC405A8B	-55°C to +125°C	8-pin CerDIP, MIL-STD-883

Contact factory for other packages and DESC SMD number.

Contact factory for other packages and DESC SMD number.