



Low Cost Dual and Triple 300MHz Current Feedback Amplifiers with Shutdown

December 1998

FEATURES

- 300MHz Bandwidth on $\pm 5V$ ($A_V = 1, 2$ and -1)
- 0.1dB Gain Flatness: 150MHz ($A_V = 1, 2$ and -1)
- Completely Off in Shutdown, 0 μ A Supply Current
- High Slew Rate: 800V/ μ s
- Wide Supply Range: $\pm 2V(4V)$ to $\pm 6V(12V)$
- 80mA Output Current
- Low Supply Current: 4.5mA/Amplifier
- Fast Turn-On Time: 30ns
- Fast Turn-Off Time: 40ns
- 16-Pin Narrow SO Package

APPLICATIONS

- RGB Cable Drivers
- Spread Spectrum Amplifiers
- MUX Amplifiers
- Composite Video Cable Drivers
- Portable Equipment

DESCRIPTION

The LT[®]1399 contains three independent 300MHz current feedback amplifiers, each with a shutdown pin. These amplifiers are designed for excellent linearity while driving cables and other low impedance loads. They are especially suited to RGB video applications. These amplifiers operate on all supplies from a single 4V to $\pm 6V$ and draw only 4.5mA per amplifier when active. The LT1398 is a two amplifier version of the LT1399.

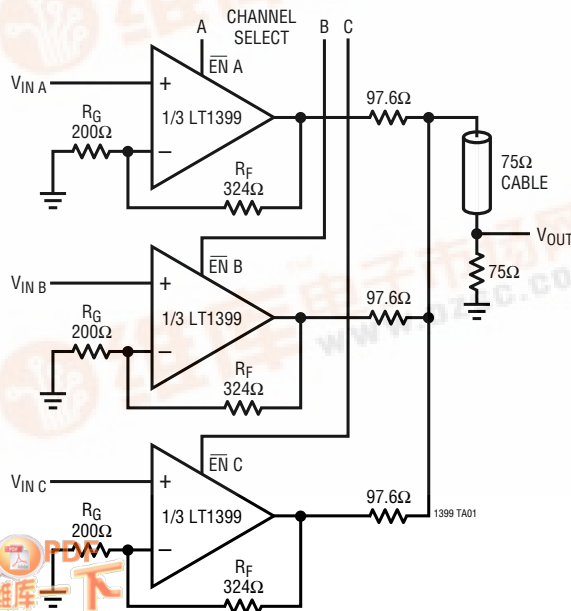
When disabled, the LT1398/LT1399 amplifiers draw zero supply current and their outputs become high impedance. These amplifiers turn on in only 30ns and turn off in 40ns, making them ideal in spread spectrum and portable equipment applications.

The LT1398/LT1399 amplifiers are manufactured on Linear Technology's proprietary complementary bipolar process. The LT1399 is a pin-for-pin upgrade to the LT1260 optimized for use on $\pm 5V$ supplies.

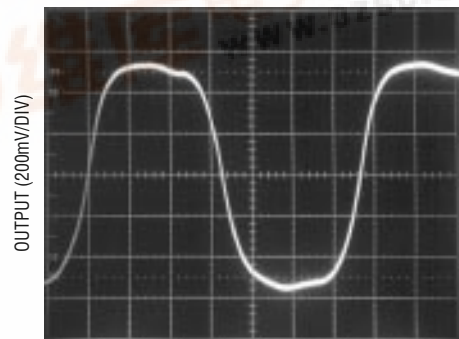
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TYPICAL APPLICATION

3-Input Video MUX Cable Driver



Square Wave Response



$R_L = 100\Omega$
 $R_F = R_G = 340\Omega$
 $f = 30\text{MHz}$

1398/99 TA02



LT1398/LT1399

ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage (V^+ to V^-)	12.6V	Operating Temperature Range	-40°C to 85°C
Input Current (Note 2)	$\pm 10\text{mA}$	Specified Temperature Range (Note 4) ..	-40°C to 85°C
Output Current	$\pm 100\text{mA}$	Storage Temperature Range	-65°C to 150°C
Differential Input Voltage (Note 2)	$\pm 5\text{V}$	Junction Temperature (Note 5)	150°C
Output Short-Circuit Duration (Note 3)	Continuous	Lead Temperature (Soldering, 10 sec)	300°C

PACKAGE/ORDER INFORMATION

	ORDER PART NUMBER LT1398CS		ORDER PART NUMBER LT1399CS
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*Ground pins are not internally connected. For best channel isolation, connect to ground. Consult factory for Industrial and Military grade parts.

ELECTRICAL CHARACTERISTICS

$T_A = 25^\circ\text{C}$, for each amplifier: $V_{CM} = 0\text{V}$, $V_S = \pm 5\text{V}$, $\overline{\text{EN}} = 0\text{V}$, pulse tested, unless otherwise noted. (Note 4)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage		●	1.5	10	mV
					12	mV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift		●	15		$\mu\text{V}/^\circ\text{C}$
I_{IN}^+	Noninverting Input Current		●	10	25	μA
					30	μA
I_{IN}^-	Inverting Input Current		●	10	50	μA
					60	μA
e_n	Input Noise Voltage Density	$f = 1\text{kHz}$, $R_F = 1\text{k}$, $R_G = 10\Omega$, $R_S = 0\Omega$		4.5		$\text{nV}/\sqrt{\text{Hz}}$
$+i_n$	Noninverting Input Noise Current Density	$f = 1\text{kHz}$		6		$\text{pA}/\sqrt{\text{Hz}}$
$-i_n$	Inverting Input Noise Current Density	$f = 1\text{kHz}$		25		$\text{pA}/\sqrt{\text{Hz}}$
R_{IN}	Input Resistance	$V_{IN} = \pm 3.5\text{V}$	●	0.3	1	$\text{M}\Omega$
C_{IN}	Input Capacitance	Amplifier Enabled		2.0		pF
		Amplifier Disabled		2.5		pF
C_{OUT}	Output Capacitance	Amplifier Disabled		8.5		pF
V_{INH}	Input Voltage Range, High	$V_S = \pm 5\text{V}$	●	3.5	4.0	V
		$V_S = 5\text{V}, 0\text{V}$			4.0	V

ELECTRICAL CHARACTERISTICS

$T_A = 25^\circ\text{C}$, for each amplifier: $V_{CM} = 0\text{V}$, $V_S = \pm 5\text{V}$, $\overline{\text{EN}} = 0\text{V}$, pulse tested, unless otherwise noted. (Note 4)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{INL}	Input Voltage Range, Low	$V_S = \pm 5\text{V}$ $V_S = 5\text{V}, 0\text{V}$	●	-3.5	-4.0	V
					1.0	V
V_{OUTH}	Maximum Output Voltage Swing, High	$V_S = \pm 5\text{V}, R_L = 100\text{k}$ $V_S = \pm 5\text{V}, R_L = 100\text{k}$ $V_S = 5\text{V}, 0\text{V}; R_L = 100\text{k}$	●	3.9	4.2	V
				3.7	4.2	V
						V
V_{OUTL}	Maximum Output Voltage Swing, Low	$V_S = \pm 5\text{V}, R_L = 100\text{k}$ $V_S = \pm 5\text{V}, R_L = 100\text{k}$ $V_S = 5\text{V}, 0\text{V}; R_L = 100\text{k}$	●	-3.9	-4.2	V
				-3.7	0.8	V
						V
V_{OUTH}	Maximum Output Voltage Swing, High	$V_S = \pm 5\text{V}, R_L = 150\Omega$ $V_S = \pm 5\text{V}, R_L = 150\Omega$ $V_S = 5\text{V}, 0\text{V}; R_L = 150\Omega$	●	3.4	3.6	V
				3.2	36	V
						V
V_{OUTL}	Maximum Output Voltage Swing, Low	$V_S = \pm 5\text{V}, R_L = 150\Omega$ $V_S = \pm 5\text{V}, R_L = 150\Omega$ $V_S = 5\text{V}, 0\text{V}; R_L = 150\Omega$	●	-3.4	-3.6	V
				-3.2	-0.6	V
						V
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm 3.5\text{V}$	●	42	52	dB
$-I_{CMRR}$	Inverting Input Current Common Mode Rejection	$V_{CM} = \pm 3.5\text{V}$ $V_{CM} = \pm 3.5\text{V}$	●		10	16
						22
PSRR	Power Supply Rejection Ratio	$V_S = \pm 2\text{V}$ to $\pm 5\text{V}$	●	56	70	dB
$+I_{PSRR}$	Noninverting Input Current Power Supply Rejection	$V_S = \pm 2\text{V}$ to $\pm 5\text{V}$	●		1	2
						3
$-I_{PSRR}$	Inverting Input Current Power Supply Rejection	$V_S = \pm 2\text{V}$ to $\pm 5\text{V}$	●		2	7
A_V	Large-Signal Voltage Gain	$V_{OUT} = \pm 2\text{V}, R_L = 150\Omega$		50	65	dB
R_{OL}	Transimpedance, $\Delta V_{OUT}/\Delta I_{IN}^-$	$V_{OUT} = \pm 2\text{V}, R_L = 150\Omega$	●	40	100	k Ω
I_{OUT}	Maximum Output Current	$R_L = 0\Omega$	●	80		mA
I_S	Supply Current per Amplifier	$V_{OUT} = 0\text{V}$	●		4.5	6.5
	Disable Supply Current per Amplifier	$\overline{\text{EN}}$ Pin Voltage = 4.5V, $R_L = 150\Omega$	●		0	100
I_{EN}	Enable Pin Current		●		30	110
					200	μA μA
SR	Slew Rate (Note 6)	$A_V = 10, R_L = 150\Omega$		500	800	V/ μs
t_{ON}	Turn-On Delay Time (Note 7)	$R_F = R_G = 324\Omega, R_L = 100\Omega$		30	75	ns
t_{OFF}	Turn-Off Delay Time (Note 7)	$R_F = R_G = 324\Omega, R_L = 100\Omega$		40	100	ns
t_r, t_f	Small-Signal Rise and Fall Time	$R_F = R_G = 324\Omega, R_L = 100\Omega, V_{OUT} = 1V_{P-P}$		1.3		ns
t_{PD}	Propagation Delay	$R_F = R_G = 324\Omega, R_L = 100\Omega, V_{OUT} = 1V_{P-P}$		2.5		ns
os	Small-Signal Overshoot	$R_F = R_G = 324\Omega, R_L = 100\Omega, V_{OUT} = 1V_{P-P}$		10		%
t_S	Settling Time	0.1%, $A_V = -1\text{V}, R_F = R_G = 309\Omega, R_L = 150\Omega$		25		ns
dG	Differential Gain (Note 8)	$R_F = R_G = 324\Omega, R_L = 150\Omega$		0.13		%
dP	Differential Phase (Note 8)	$R_F = R_G = 324\Omega, R_L = 150\Omega$		0.10		DEG

The ● denotes specifications which apply over the specified operating temperature range.

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: This parameter is guaranteed to meet specified performance through design and characterization. It has not been tested.

Note 3: A heat sink may be required depending on the power supply voltage and how many amplifiers have their outputs short circuited.

Note 4: The LT1398/LT1399 are guaranteed to meet specified performance from 0°C to 70°C and are designed, characterized and expected to meet these extended temperature limits, but are not tested at -40°C and 85°C . Guaranteed I grade parts are available, consult factory.

Note 5: T_J is calculated from the ambient temperature T_A and the power dissipation P_D according to the following formula:

$$T_J = T_A + (P_D \cdot 100^\circ\text{C}/\text{W})$$

LT1398/LT1399

ELECTRICAL CHARACTERISTICS

Note 6: Slew rate is measured at $\pm 2V$ on a $\pm 3V$ output signal.

Note 7: Turn-on delay time (t_{ON}) is measured from control input to appearance of 1V at the output, for $V_{IN} = 1V$. Likewise, turn-off delay time (t_{OFF}) is measured from control input to appearance of 0.5V on the output for $V_{IN} = 0.5V$. This specification is guaranteed by design and characterization.

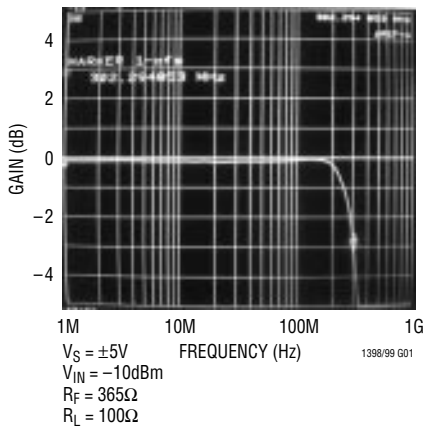
Note 8: Differential gain and phase are measured using a Tektronix TSG120YC/NTSC signal generator and a Tektronix 1780R Video Measurement Set. The resolution of this equipment is 0.1% and 0.1°. Ten identical amplifier stages were cascaded giving an effective resolution of 0.01% and 0.01°.

TYPICAL AC PERFORMANCE

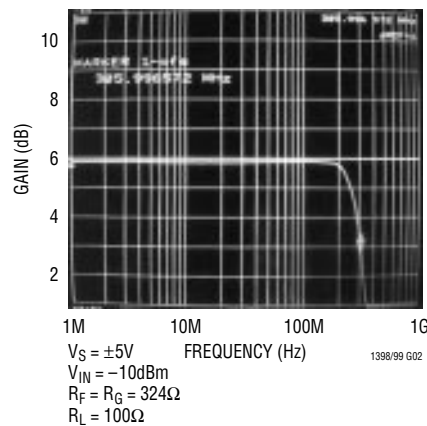
V_S (V)	A_V	R_L (Ω)	R_F (Ω)	R_G (Ω)	SMALL SIGNAL -3dB BW (MHz)	SMALL SIGNAL 0.1dB BW (MHz)	SMALL SIGNAL PEAKING (dB)
± 5	1	100	365	—	300	150	0.05
± 5	2	100	324	324	300	150	0
± 5	-1	100	309	309	300	150	0

TYPICAL PERFORMANCE CHARACTERISTICS

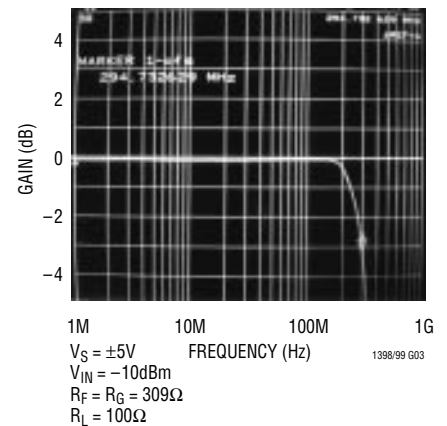
Closed-Loop Gain vs Frequency
($A_V = 1$)



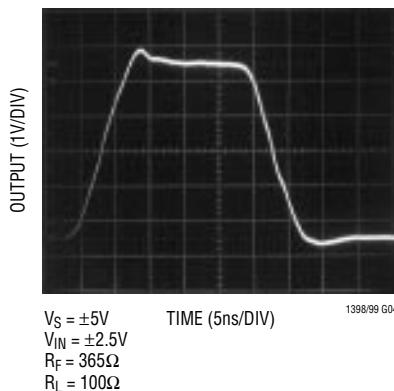
Closed-Loop Gain vs Frequency
($A_V = 2$)



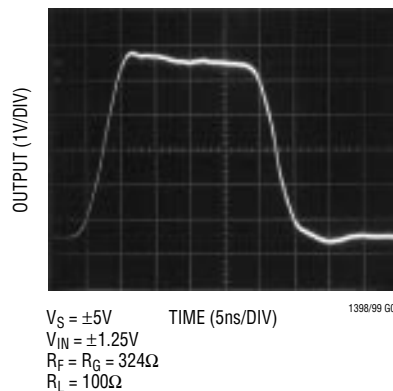
Closed-Loop Gain vs Frequency
($A_V = -1$)



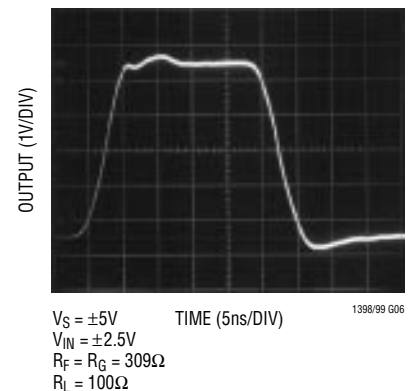
Large-Signal Transient Response
($A_V = 1$)



Large-Signal Transient Response
($A_V = 2$)



Large-Signal Transient Response
($A_V = -1$)



PIN FUNCTIONS

LT1398

- IN A (Pin 1):** Inverting Input of A Channel Amplifier.
- +IN A (Pin 2):** Noninverting Input of A Channel Amplifier.
- GND (Pins 3, 4, 5, 6):** Ground. Not connected internally.
- +IN B (Pin 7):** Noninverting Input of B Channel Amplifier.
- IN B (Pin 8):** Inverting Input of B Channel Amplifier.
- $\overline{\text{EN B}}$ (Pin 9):** B Channel Enable Pin. Logic low to enable.
- OUT B (Pin 10):** B Channel Output.
- V[–] (Pin 11):** Negative Supply Voltage, Usually –5V.
- GND (Pins 12, 13):** Ground. Not connected internally.
- V⁺ (Pin 14):** Positive Supply Voltage, Usually 5V.
- OUT A (Pin 15):** A Channel Output.
- $\overline{\text{EN A}}$ (Pin 16):** A Channel Enable Pin. Logic low to enable.

LT1399

- IN R (Pin 1):** Inverting Input of R Channel Amplifier.
- +IN R (Pin 2):** Noninverting Input of R Channel Amplifier.
- GND (Pin 3):** Ground. Not connected internally.
- IN G (Pin 4):** Inverting Input of G Channel Amplifier.
- +IN G (Pin 5):** Noninverting Input of G Channel Amplifier.
- GND (Pin 6):** Ground. Not connected internally.
- +IN B (Pin 7):** Noninverting Input of B Channel Amplifier.
- IN B (Pin 8):** Inverting Input of B Channel Amplifier.
- $\overline{\text{EN B}}$ (Pin 9):** B Channel Enable Pin. Logic low to enable.
- OUT B (Pin 10):** B Channel Output.
- V[–] (Pin 11):** Negative Supply Voltage, Usually –5V.
- OUT G (Pin 12):** G Channel Output.
- $\overline{\text{EN G}}$ (Pin 13):** G Channel Enable Pin. Logic low to enable.
- V⁺ (Pin 14):** Positive Supply Voltage, Usually 5V.
- OUT R (Pin 15):** R Channel Output.
- $\overline{\text{EN R}}$ (Pin 16):** R Channel Enable Pin. Logic low to enable.

APPLICATIONS INFORMATION

Feedback Resistor Selection

The small-signal bandwidth of the LT1398/LT1399 is set by the external feedback resistors and the internal junction capacitors. As a result, the bandwidth is a function of the supply voltage, the value of the feedback resistor, the closed-loop gain and the load resistor. The LT1398/LT1399 have been optimized for $\pm 5\text{V}$ supply operation and have a –3dB bandwidth of 300MHz at a gain of 2. Please refer to the resistor selection guide in the Typical AC Performance table.

Capacitance on the Inverting Input

Current feedback amplifiers require resistive feedback from the output to the inverting input for stable operation. Take care to minimize the stray capacitance between the

output and the inverting input. Capacitance on the inverting input to ground will cause peaking in the frequency response (and overshoot in the transient response).

Capacitive Loads

The LT1398/LT1399 can drive capacitive loads directly when the proper value of feedback resistor is used. The required value for the feedback resistor will increase as load capacitance increases and as closed-loop gain decreases. Alternatively, a small resistor (10 Ω to 20 Ω) can be put in series with the output to isolate the capacitive load from the amplifier output. This has the advantage that the amplifier bandwidth is only reduced when the capacitive load is present. The disadvantage is that the gain is a function of the load resistance.

APPLICATIONS INFORMATION

Power Supplies

The LT1398/LT1399 will operate from single or split supplies from $\pm 2\text{V}$ (4V total) to $\pm 6\text{V}$ (12V total). It is not necessary to use equal value split supplies, however the offset voltage and inverting input bias current will change. The offset voltage changes about $600\mu\text{V}$ per volt of supply mismatch. The inverting bias current will typically change about $2\mu\text{A}$ per volt of supply mismatch.

Slew Rate

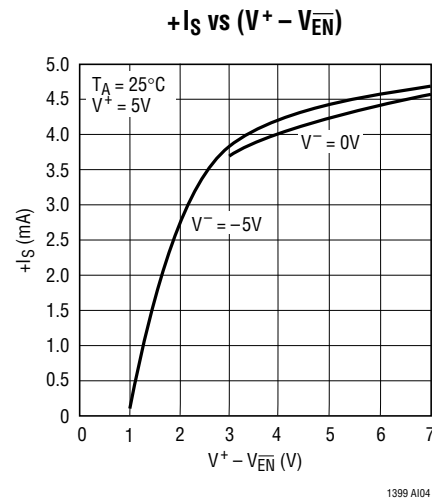
Unlike a traditional voltage feedback op amp, the slew rate of a current feedback amplifier is not independent of the amplifier gain configuration. In a current feedback amplifier, both the input stage and the output stage have slew rate limitations. In the inverting mode, and for gains of 2 or more in the noninverting mode, the signal amplitude between the input pins is small and the overall slew rate is that of the output stage. For gains less than 2 in the noninverting mode, the overall slew rate is limited by the input stage.

The input slew rate of the LT1398/LT1399 is approximately $600\text{V}/\mu\text{s}$ and is set by internal currents and capacitances. The output slew rate is set by the value of the feedback resistor and internal capacitance. At a gain of 2 with 324Ω feedback and gain resistors and $\pm 5\text{V}$ supplies, the output slew rate is typically $800\text{V}/\mu\text{s}$. Larger feedback resistors will reduce the slew rate as will lower supply voltages.

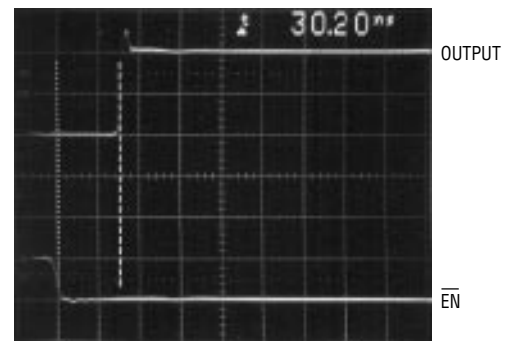
Enable/Disable

Each amplifier of the LT1398/LT1399 has a unique high impedance, zero supply current mode which is controlled by its own $\overline{\text{EN}}$ pin. These amplifiers are designed to operate with CMOS logic; the amplifiers draw zero current when these pins are high. To activate each amplifier of the LT1399, its $\overline{\text{EN}}$ pin is normally pulled to a logic low. However, supply current will vary as the voltage between the V^+ supply and $\overline{\text{EN}}$ is varied. As seen in the graph below, $+I_S$ does vary with $(V^+ - V_{\overline{\text{EN}}})$, particularly when the voltage difference is less than 3V. For normal operation, it is important to keep the $\overline{\text{EN}}$ pin at least 3V below the V^+ supply. If a V^+ of less than 3V is desired, and the amplifier will remain enabled at all times, then the $\overline{\text{EN}}$ pin

should be tied to the V^- supply. The enable pin current is approximately $30\mu\text{A}$ when activated. If using CMOS open-drain logic, an external 1k pull-up resistor is recommended to ensure that the LT1399 remains disabled in spite of any CMOS drain-leakage currents.

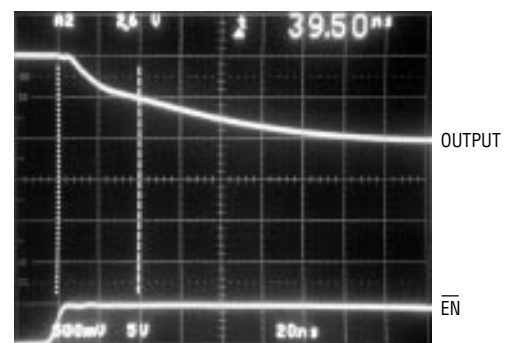


Amplifier Enable Time, $A_V = 2$



$V_S = \pm 5\text{V}$ $R_F = 324\Omega$ $R_L = 100\Omega$
 $V_{IN} = 1\text{V}$ $R_G = 324\Omega$

Amplifier Disable Time, $A_V = 2$



$V_S = \pm 5\text{V}$ $R_F = 324\Omega$ $R_L = 100\Omega$
 $V_{IN} = 1\text{V}$ $R_G = 324\Omega$

APPLICATIONS INFORMATION

The enable/disable times are very fast when driven from standard 5V CMOS logic. The amplifier enables in about 30ns (50% point to 50% point) while operating on $\pm 5V$ supplies. Likewise, the disable time is approximately 40ns (50% point to 50% point).

Differential Input Signal Swing

To avoid any breakdown condition on the input transistors, the differential input swing must be limited to $\pm 5V$. In normal operation, the differential voltage between the input pins is small, so the $\pm 5V$ limit is not an issue. In the disabled mode however, the differential swing can be the same as the input swing, and there is a risk of device breakdown if input voltage range has not been properly considered.

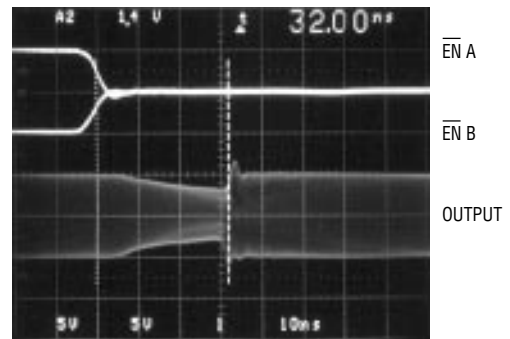
3-Input Video MUX Cable Driver

The application on the first page of this data sheet shows a low cost, 3-input video MUX cable driver. The scope photo displays the cable output of a 30MHz square wave driving 150Ω . In this circuit the active amplifier is loaded by the sum of R_F and R_G of each disabled amplifier.

Resistor values have been chosen to keep the total back termination at 75Ω while maintaining a gain of 1 at the 75Ω load. The switching time between any two channels is approximately 32ns when both enable pins are driven.

When building the board, care was taken to minimize trace lengths at the inverting input. The ground plane was also pulled away from R_F and R_G on both sides of the board to minimize stray capacitance.

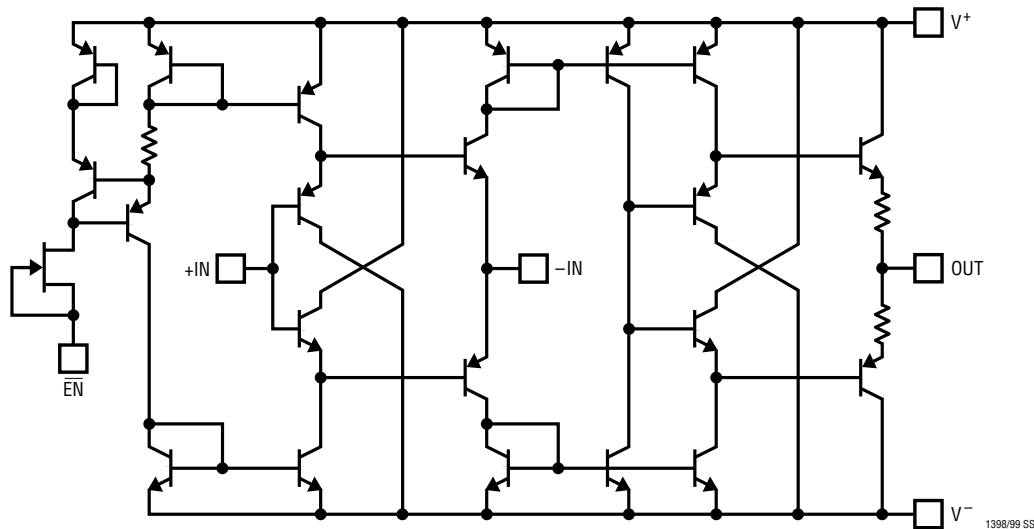
3-Input Video MUX Switching Response ($A_V = 2$)



$V_S = \pm 5V$
 $V_{INA} = V_{INB} = 2V_{p-p}$ at 3.58MHz

1398/99 AI03

SIMPLIFIED SCHEMATIC, each amplifier

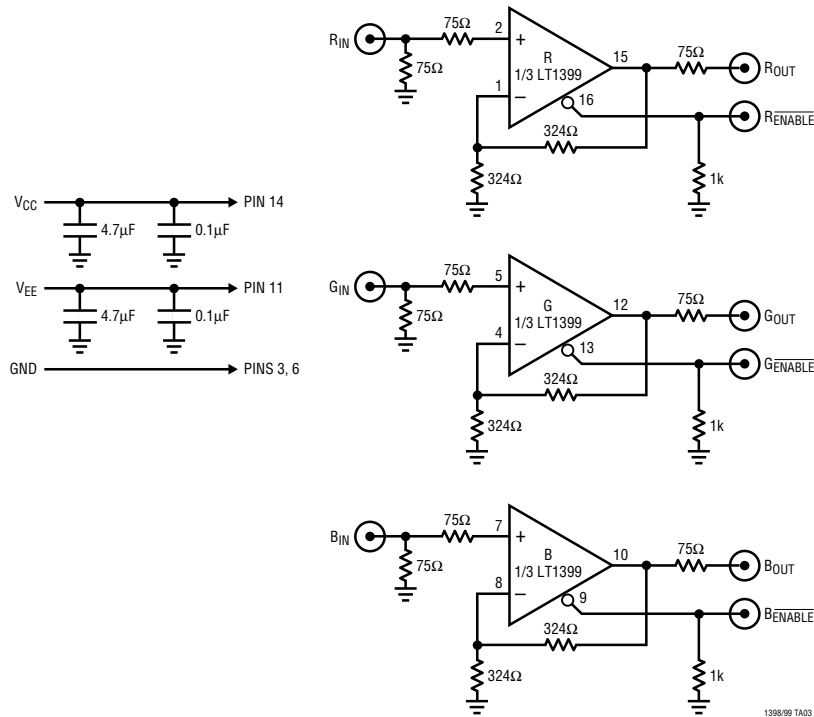


1398/99 SS

LT1398/LT1399

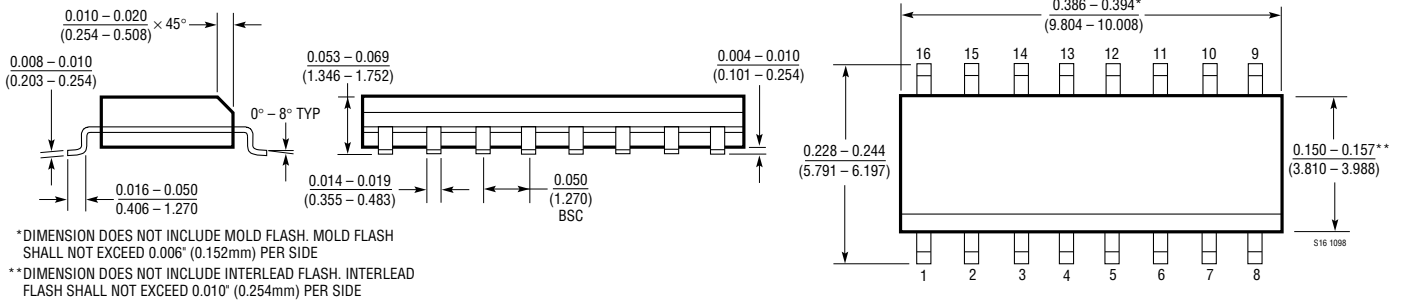
TYPICAL APPLICATION

PC Board Schematic



PACKAGE DESCRIPTION Dimensions in inches (millimeters) unless otherwise noted.

S Package 16-Lead Plastic Small Outline (Narrow 0.150) (LTC DWG # 05-08-1610)



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1203/LT1205	150MHz Video Multiplexers	2:1 and Dual 2:1 MUXes with 25ns Switch Time
LT1204	4-Input Video MUX with Current Feedback Amplifier	Cascadable Enable 64:1 Multiplexing
LT1227	140MHz Current Feedback Amplifier	1100V/μs Slew Rate, Shutdown Mode
LT1252/LT1253/LT1254	Low Cost Video Amplifiers	Single, Dual and Quad Current Feedback Amplifiers
LT1259/LT1260	Dual/Triple Current Feedback Amplifier	130MHz Bandwidth, 0.1dB Flatness > 30MHz
LT1675	Triple 2:1 Buffered Video Multiplexer	2.5ns Switching Time, 250MHz Bandwidth