Low Power Quad 741 Operational Amplifiers

DESCRIPTION

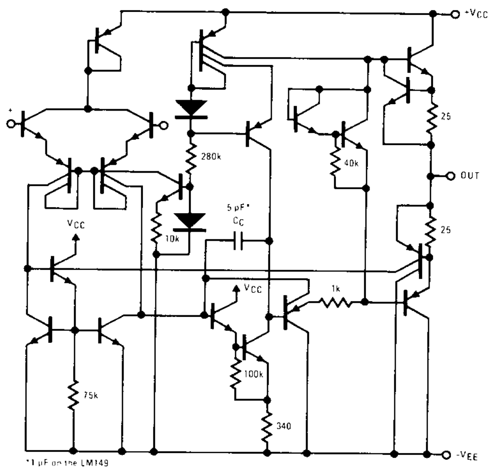
The LM148 series is a true quad 741. It consists of four independent, high gain, internally compensated, low power operational amplifiers which have been designed to provide functional characteristics identical to those of the familiar 741 operational amplifier. In addition, the total supply current for all four amplifiers is comparable to the supply current of a single 741 type op amp. Other features include input offset currents and input bias current which are much less than those of a standard 741. Also, excellent isolation between amplifiers has been achieved by independently biasing each amplifier and using layout techniques which minimize thermal coupling. The LM149 series has the same features as the LM148 plus a gain bandwidth product of 4 MHz at a gain of 5 or greater.

The LM148 can be used anywhere multiple 741 or 1558 type amplifiers are being used and in applications where amplifier matching or high packing density is required.

FEATURES

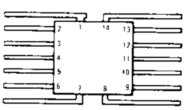
- 741 op amp operating characteristics
- Low supply current drain (0.6 mA/Amplifier)
- Class AB output stage - no crossover distortion
- Pin compatible with the LM124
- Low input offset voltage (1 mV)
- Low input offset current (4 nA)
- Low input bias current (30 nA)
- Gain bandwidth product: LM148 (unity gain) (1.0 MHz)
  LM149 ($A_V \geq 5$) (4 MHz)
- High degree of isolation between amplifiers (120 dB)
- Overload protection for inputs and outputs

SCHEMATIC DIAGRAM (1/4 Shown)



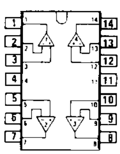
CONNECTION INFORMATION

CJ Flatpak
(Top View)



Order Part Nos.:
LM148F, LM149F,
LM148J, LM248J, LM348J,
LM248N, LM348N,
LM149J, LM249J, LM349J,
LM149N, LM349N

DC and DB Dual In-Line Packages
(Top View)



PIN	FUNCTION
1	OUTPUT A
2	$-V_{IN}$ A
3	$+V_{IN}$ A
4	V+
5	$+V_{IN}$ B
6	$-V_{IN}$ B
7	OUTPUT B
8	OUTPUT C
9	$-V_{IN}$ C
10	$+V_{IN}$ C
11	V-
12	$+V_{IN}$ D
13	$-V_{IN}$ D
14	OUTPUT D

HIGH RELIABILITY OPTIONS

Part Number	Screening
LM148J03	MIL-STD-883 Class B
LM248J03* LM348J03	Raytheon A+3 screening including Burn-in and tightened AQL
LM248N02* LM348N02	Raytheon A+2 screening including temp cycles, Burn-in, "Hot Rail" testing and tightened AQL
LM248N01* LM348N01	Raytheon A+1 screening including temp cycles, "Hot Rail" testing and tightened AQL

*Complete details are shown in the quality section of this catalog.

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Low Power Quad 741 Operational Amplifiers

ABSOLUTE MAXIMUM RATINGS

		LM148/LM149	LM248/LM249	LM348/LM349
Supply Voltage		±22V	±18V	±18V
Differential Input Voltage		±44V	±36V	±36V
Input Voltage		±22V	±18V	±18V
Output Short Circuit Duration (Note 1)		Continuous	Continuous	Continuous
Power Dissipation (P_d at 25°C) and Thermal Resistance (θ_{jA}) (Note 2)				
Molded DIP (N)	P_d	–	–	500 mW
	θ_{jA}	–	–	150°C/W
Cavity DIP (D) (J)	P_d	900 mW	900 mW	900 mW
	θ_{jA}	100°C/W	100°C/W	100°C/W
Flat Pack (CJ)	P_d	675 mW	–	–
	θ_{jA}	185°C/W	–	–
Maximum Junction Temperature (T_{jMAX})		150°C	110°C	100°C
Operating Temperature Range		-55°C ≤ T_A ≤ +125°C	-25°C ≤ T_A ≤ +85°C	0°C ≤ T_A ≤ +70°C
Storage Temperature Range		-65°C to +150°C	-65°C to +150°C	-65°C to +150°C
Lead Temperature (Soldering 60 seconds)		300°C	300°C	300°

ELECTRICAL CHARACTERISTICS (See Note 3)

PARAMETER	CONDITIONS	LM148/149 MIN	LM148/149 TYP	LM148/149 MAX	LM248/249 MIN	LM248/249 TYP	LM248/249 MAX	LM348/349 MIN	LM348/349 TYP	LM348/349 MAX	UNITS
Input Offset Voltage	T_A = 25°C, R_S ≤ 10 kΩ		1.0	5.0		1.0	6.0		1.0	6.0	mV
Input Offset Current	T_A = 25°C		4	25		4	50		4	50	nA
Input Bias Current	T_A = 25°C		30	100		30	200		30	200	nA
Input Resistance	T_A = 25°C	0.8	2.5		0.8	2.5		0.8	2.5		MΩ
Supply Current All Amplifiers	T_A = 25°C, V_S = ±15V		2.4	3.6		2.4	4.5		2.4	4.5	mA
Large Signal Voltage Gain	T_A = 25°C, V_S = ±15V, V_{OUT} = ±10V, R_L ≥ 2 kΩ	50	160		25	160		25	160		V/mV
Amplifier to Amplifier Coupling	T_A = 25°C, f = 1 Hz to 20 kHz		-120			-120			-120		dB
Small Signal Bandwidth	T_A = 25°C, LM148		1.0			1.0			1.0		MHz
	T_A = 25°C, LM149		4.0			4.0			4.0		MHz
Phase Margin	T_A = 25°C, LM148(A_V=1)		60			60			60		degrees
	T_A = 25°C, LM149(A_V=5)		60			60			60		degrees
Slew Rate	T_A = 25°C, LM148(A_V=1)		0.5			0.5			0.5		V/µs
	T_A = 25°C, LM149(A_V=5)		2.0			2.0			2.0		V/µs
Output Short Circuit Current	T_A = 25°C		25			25			25		mA
Input Offset Voltage	R_S ≤ 10 kΩ			6.0			7.5			7.5	mV
Input Offset Current				75			125			100	nA
Input Bias Current				325			500			400	nA
Large Signal Voltage Gain	V_S = ±15V, V_{OUT} = ±10V, R_L > 2 kΩ	25			15			15			V/mV
Output Voltage Swing	V_S = ±15V, R_L = 10 kΩ	±12	±13		±12	±13		±12	±13		V
	R_L = 2 kΩ	±10	±12		±10	±12		±10	±12		V
Input Voltage Range	V_S = ±15V	±12			±12			±12			V
Common Mode Rejection Ratio	R_S ≤ 10 kΩ	70	90		70	90		70	90		dB
Supply Voltage Rejection	R_S ≤ 10 kΩ	77	96		77	96		77	96		dB

Note 1: Any of the amplifier outputs can be shorted to ground indefinitely; however, more than one should not be simultaneously shorted as the maximum junction temperature will be exceeded.

Note 2: The maximum power dissipation for these devices must be derated at elevated temperatures and is dictated by T_{jMAX}, θ_{jA}, and the ambient temperature, T_A. The maximum available power dissipation at any temperature is $P_d = (T_{jMAX} - T_A)/\theta_{jA}$ or the 25°C P_{dMAX}, whichever is less.

Note 3: These specifications apply for V_S = ±15V and over the absolute maximum operating temperature range ($T_L \leq T_A \leq T_H$) unless otherwise noted.

APPLICATION GUIDES

The 148 series are low power quad operational amplifiers that exhibit performance comparable to the popular 741. Substitution can therefore be made with no change in circuit behavior.

The 149 series is similar to the 148 except it is decompensated to yield a wider gain-bandwidth product. Consequently, it must be operated at a minimum closed loop gain of 5.

The input characteristics of these devices allow differential voltages which exceed the supplies. Output phase will be correct as long as one of the inputs are within the operating common mode range. If both exceed the negative limit, the output will latch positive. Current limiting resistors should be used on the inputs in case voltages become excessive.

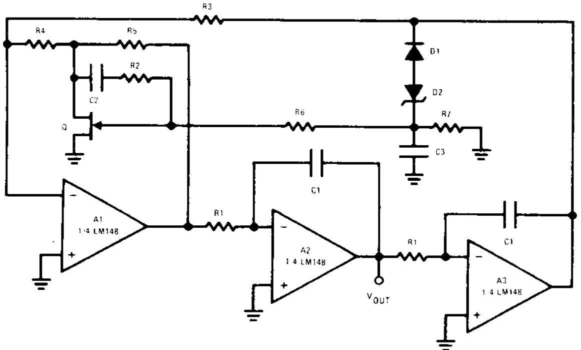
When capacitive loading becomes much greater than 100 pf, a resistor should be placed between the output and feedback connection in order to reduce phase shift.

The 148/149 series is short circuit protected to either ground or the supplies continuously when only one of the four amplifiers are shorted. If multiple shorts occur simultaneously, the unit can be destroyed due to excessive power dissipation.

To assure stability, feedback resistors should be placed close to the input to maximize the feedback pole frequency (function of input to ground capacitance) and to minimize pickup. A good rule of thumb is that the feedback pole frequency should be 6 times the operating 3 dB frequency. If less, a lead capacitor should be placed between the output and input.

TYPICAL APPLICATIONS

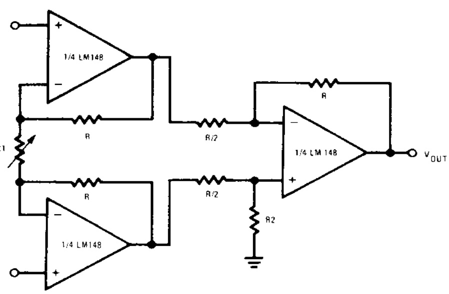
One Decade Low Distortion Sinewave Generator



$$f = \frac{1}{2\pi R1C1} \times \sqrt{K},\ K = \frac{R4R5}{R3}\left(\frac{1}{r_{DS}} + \frac{1}{R4} + \frac{1}{R5}\right),\ r_{DS} \cong \frac{R_{ON}}{\left(1 - \frac{V_{GS}}{V_P}\right)^{1/2}}$$

f_{MAX} = 5 kHz, THD ≤ 0.03%
R1 = 100k pot., C1 = 0.0047μF, C2 = 0.01μF, C3 = 0.1μF, R2 = R6 = R7 = 1M,
R3 = 5.1k, R4 = 12Ω, R5 = 240Ω, Q = NS5102, D1 = 1N914, D2 = 3.6V avalanche diode (ex. LM103), V_S = ±15V
A simpler version with some distortion degradation at high frequencies can be made by using A1 as a simple inverting amplifier, and by putting back to back zeners in the feedback loop of A3.

Low Cost Instrumentation Amplifier



$$V_{OUT} = 2\left(\frac{2R}{R1} + 1\right),\ V_S^- - 3V \leq V_{IN\,CM} \leq V_S^+ - 3V,$$

V_S = ±15V
R = R2, trim R2 to boost CMRR

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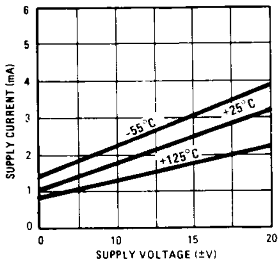
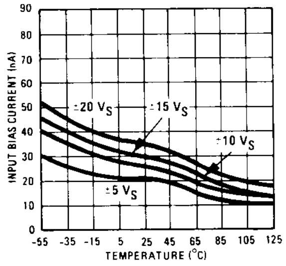
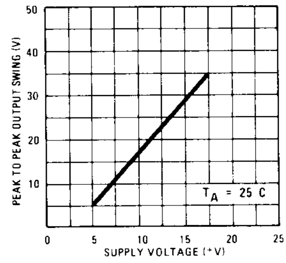
TYPICAL PERFORMANCE DATA



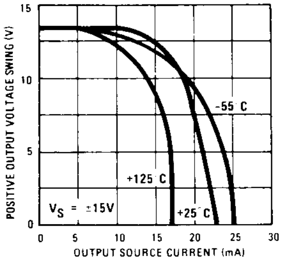
Supply Current vs Supply Voltage



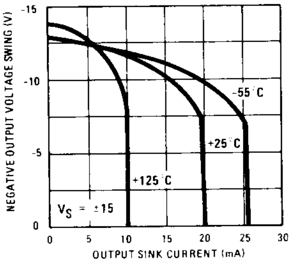
Input Bias Current vs Temperature



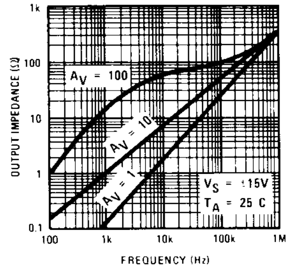
Voltage Swing vs Supply Voltage



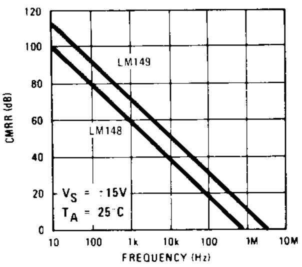
Positive Current Limit vs Supply Voltage



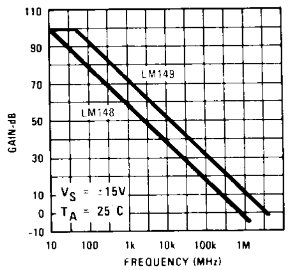
Negative Current Limit vs Supply Voltage



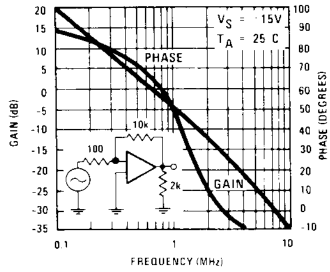
Output Impedance vs Frequency



Common-Mode Rejection Ratio vs Frequency

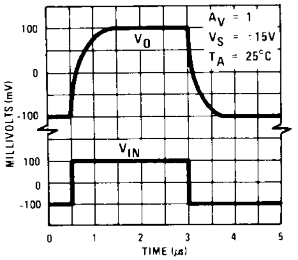


Open Loop Frequency Response

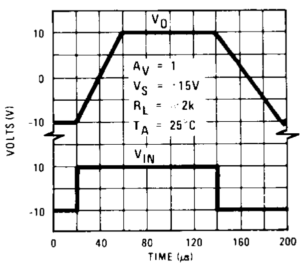


LM148

Phase Margin vs Frequency

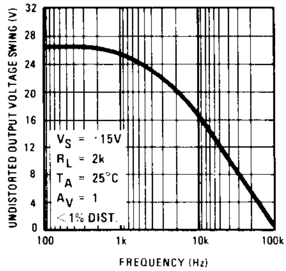


Small Signal Pulse Response



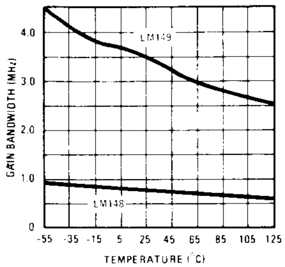
LM148

Large Signal Pulse Response

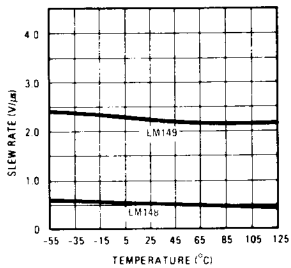


Undistorted Output Voltage Swing vs Frequency

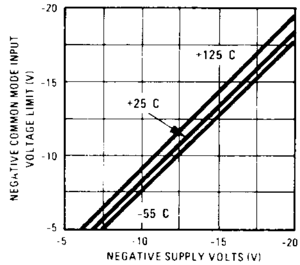
TYPICAL PERFORMANCE DATA (CONT)



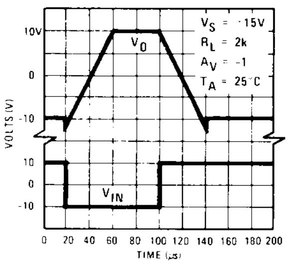
Gain Bandwidth vs Temperature



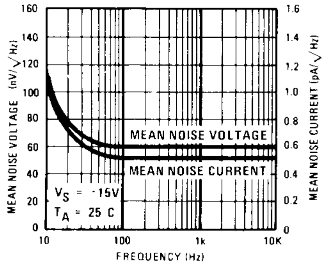
Slew Rate vs Temperature



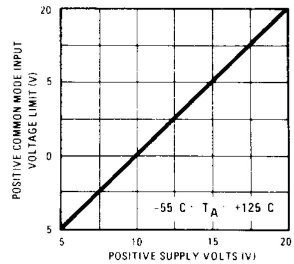
Negative Common-Mode Input Voltage Limit



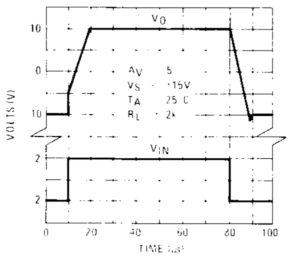
Inverting Large Signal Pulse Response (LM148)



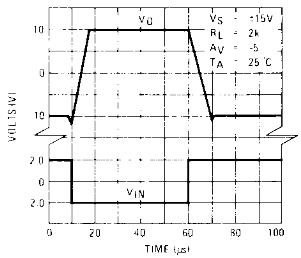
Input Noise Voltage and Noise Current



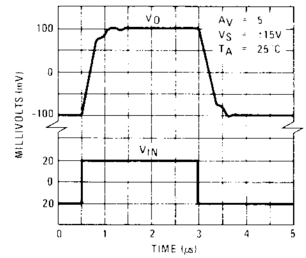
Positive Common-Mode Input Voltage Limit



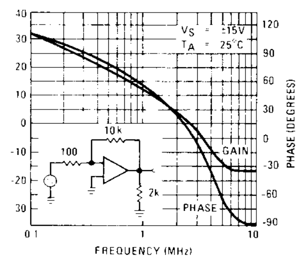
Large Signal Pulse Response (LM149)



Inverting Large Signal Pulse Response (LM149)



Small Signal Pulse Response (LM149)



Bode Plot LM149

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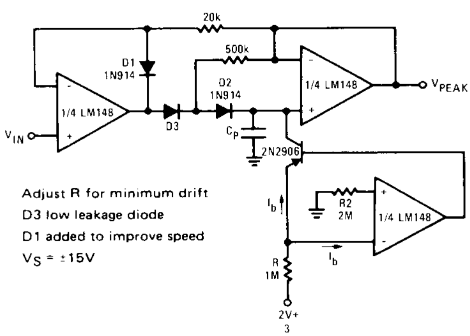
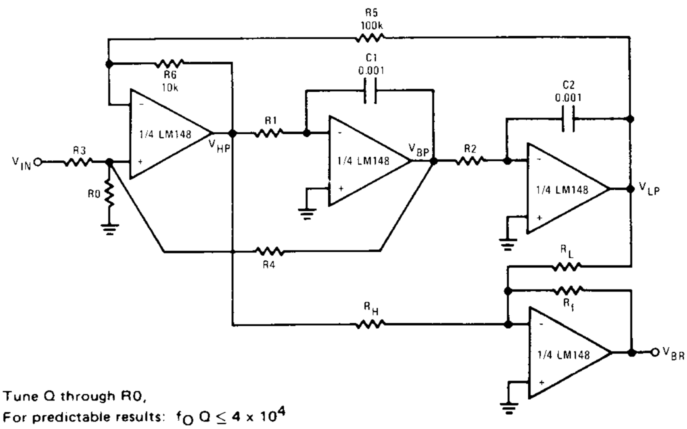
TYPICAL APPLICATIONS—LM148

Low Drift Peak Detector with Bias Current Compensation



Adjust R for minimum drift
D3 low leakage diode
D1 added to improve speed
$V_S = \pm 15V$

Universal State-Space Filter



Tune Q through R0,
For predictable results: $f_O\,Q \le 4 \times 10^4$
Use Band Pass output to tune for Q

$$\frac{V(s)}{V_{IN}(s)} = \frac{N(s)}{D(s)},\quad D(s) = S^2 + \frac{S\omega_o}{Q} + \omega_o^2$$

$$N_{HP}(s) = S^2 H_{OHP},\quad N_{BP}(s) = \frac{-S\omega_O H_{OBP}}{Q}\qquad N_{LP} = \omega_o^2 H_{OLP}$$

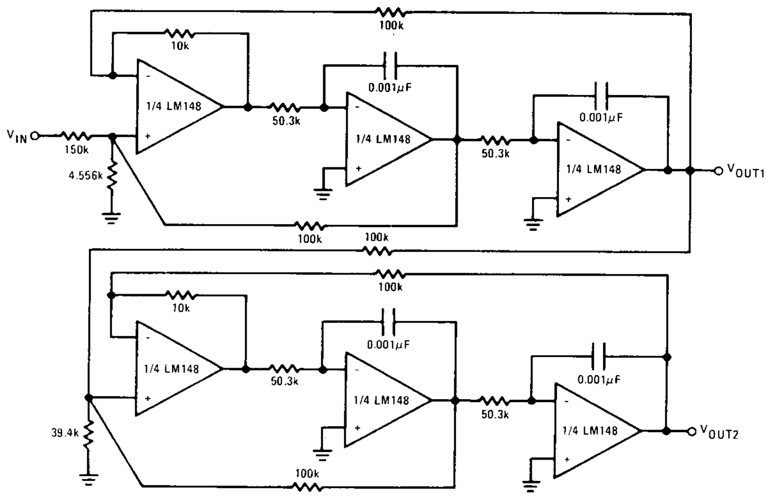
$$f_o = \frac{1}{2\pi}\sqrt{\frac{R6}{R5}}\sqrt{\frac{1}{t1t2}},\quad t_i = R_iC_i,\quad Q = \left(\frac{1 + R4/R3 + R4/R0}{1 + R6/R5}\right)\left(\frac{R6}{R5}\,\frac{t_1}{t_2}\right)^{1/2}$$

$$f_{NOTCH} = \frac{1}{2\pi}\left(\frac{R_H}{R_L t_1 t_2}\right)^{1/2},\quad H_{OHP} = \frac{1 + R6/R5}{1 + R3/R0 + R3/R4},\quad H_{OBP} = \frac{1 + R4/R3 + R4/R0}{1 + R3/R0 + R3/R4}$$

$$H_{OLP} = \frac{1 + R5/R6}{1 + R3/R0 + R3/R4}$$

TYPICAL APPLICATIONS LM148 (CONT)

A 1 kHz 4 Pole Butterworth

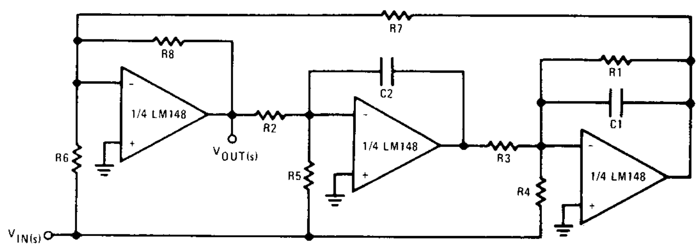


Use general equations, and tune each section separately

$Q_{1st SECTION} = 0.541$, $Q_{2nd SECTION} = 1.306$

The response should have 0 dB peaking

A 3 Amplifier Bi-Quad Notch Filter



$$Q = \sqrt{\frac{R8}{R7}} \times \frac{R1C1}{\sqrt{R3C2R2C1}}, \quad f_o = \frac{1}{2\pi}\sqrt{\frac{R8}{R7}} \times \frac{1}{\sqrt{R2R3C1C2}}, \quad f_{NOTCH} = \frac{1}{2\pi}\sqrt{\frac{R6}{R3R5R7C1C2}}$$

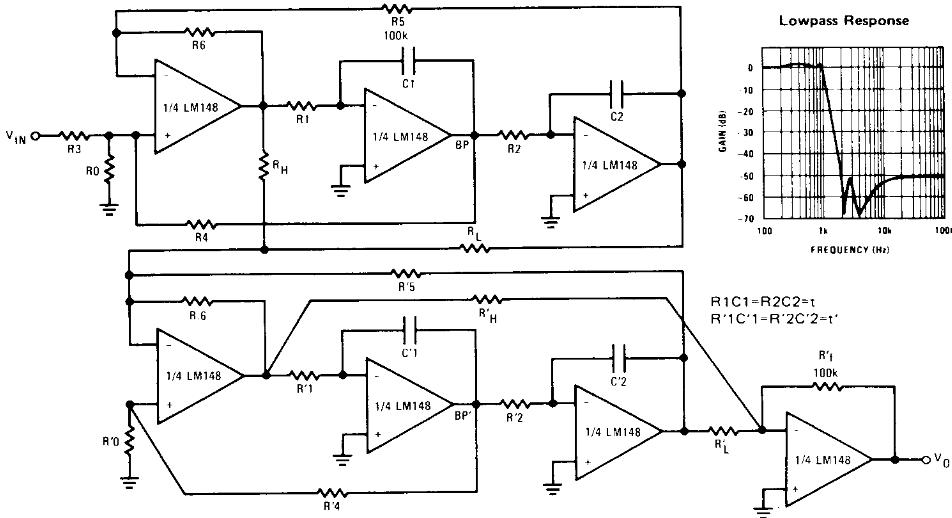
Necessary condition for notch: $\frac{1}{R6} = \frac{R1}{R4R7}$

Ex: f_{NOTCH} = 3 kHz, Q = 5, R1 = 270k, R2 = R3 = 20k, R4 = 27k, R5 = 20k, R6 = R8 = 10k, R7 = 100k, C1 = C2 = 0.001μF

Better noise performance than the state-space approach

TYPICAL APPLICATIONS LM148 (CONT)

A 4th Order 1 kHz Elliptic Filter (4 Poles, 4 Zeros)



f_C = 1 kHz, f_S = 2 kHz, f_p = 0.543, f_Z = 2.14, Q = 0.841, f'_p = 0.987, f'_Z = 4.92, Q' = 4.403, normalized to ripple BW

$$f_p = \frac{1}{2\pi}\sqrt{\frac{R6}{R5}} \times \frac{1}{t},\quad f_Z = \frac{1}{2\pi}\sqrt{\frac{R_H}{R_L}} \times \frac{1}{t},\quad Q = \left(\frac{1 + R4/R3 + R4/R0}{1 + R6/R5}\right) \times \sqrt{\frac{R6}{R5}},\quad Q' = \sqrt{\frac{R'6}{R'5}}\ \frac{1 + R'4/R'0}{1 + R'6/R'5 + R'6/R_P}$$

$$R_P = \frac{R_H R_L}{R_H + R_L}$$

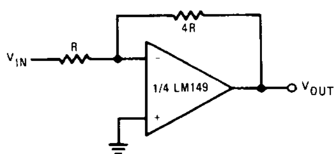
Use the BP outputs to tune Q, Q', tune the 2 sections separately

R1 = R2 = 92.6k, R3 = R4 = R5 = 100k, R6 = 10k, R0 = 107.8k, R_L = 100k, R_H = 155.1k,

R'1 = R'2 = 50.9k, R'4 = R'5 = 100k, R'6 = 10k, R'0 = 5.78k, R'_L = 100k, R'_H = 248.12k, R'f = 100k. All capacitors are 0.001μF.

TYPICAL APPLICATIONS—LM149

Minimum Gain to Insure LM149 Stability



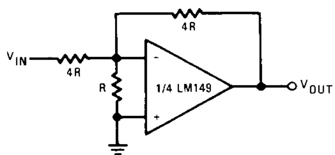
$$A_{CL(S)} = \frac{V_{OUT}}{V_{IN}} = \frac{-4}{\left(1 + \frac{5}{A_{OL(s)}}\right)} \cong -4$$

$$V_O \Big|_{V_{IN}=0} \cong \pm 5\ V_{OS}$$

Power BW = 40 kHz

Small Signal BW = G BW/5

The LM149 as a Unity Gain Inverter



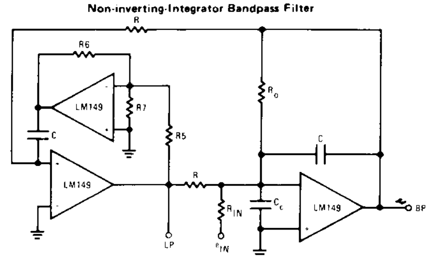
$$A_{CL(s)} = \frac{V_{OUT}}{V_{IN}} = \left(\frac{1}{1 + \frac{6}{A_{OL(s)}}}\right) \cong -1$$

$$V_O \Big|_{V_{IN}=0} \cong \cdot 5\ V_{OS}$$

Small signal BW = G BW/5

TYPICAL APPLICATIONS—LM149 (CONT)

Non-inverting-Integrator Bandpass Filter



For stability purposes R7 = R6/4, 10R6 = R5, C_C = 10C

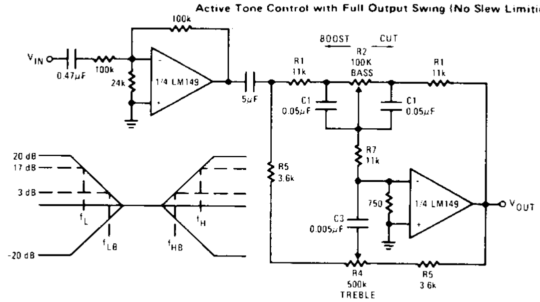
$$f_O = \frac{1}{2\pi}\sqrt{\frac{R5}{R6}} \times \frac{1}{RC},\ Q = \frac{R_Q}{R}\sqrt{\frac{R5}{R6}},\ Ho_{BP} = \frac{R_Q}{R_{IN}}$$

$(f_{O(MAX)}, Q_{MAX})$ 20 kHz, 10

Better Q sensitivity with respect to open loop gain variations than the state variable filter.

R7, C_C added for compensation

Active Tone Control with Full Output Swing (No Slew Limiting at 20 kHz)



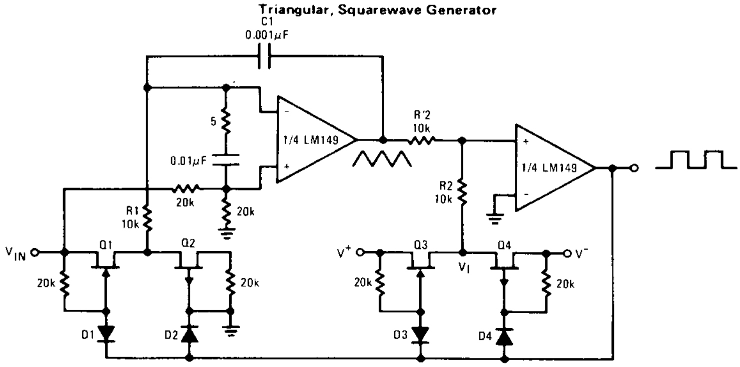
V_S = ±15V, $V_{OUT(MAX)}$ = 9.1 V_{RMS},
f_{MAX} = 20 kHz, THD ≤ 1%
Duplicate the above circuit for stereo

$$f_L = \frac{1}{2\pi R2C1},\ f_{LB} = \frac{1}{2\pi R1C1}$$

$$f_H = \frac{1}{2\pi R5C3},\ f_{HB} = \frac{1}{2\pi(R1 + 2R7)\,C3}$$

Max Bass Gain ≃ (R1 + R2)/R1
Max Treble Gain ≃ (R1 + 2R7)/R5
as shown: f_L ≃ 32 Hz, f_{LB} ≃ 320 Hz
f_H ≃ 11 kHz, f_{HB} ≃ 1.1 Hz

Triangular, Squarewave Generator



$$f = \frac{K \times V_{IN}}{8V^{+}C1R1},\ K = R2/R'2,\ \frac{2V_I}{K} \le 25V,\ V^{+} = V^{-},\ V_S = \pm 15V$$

Use LM125 for ±15V supply

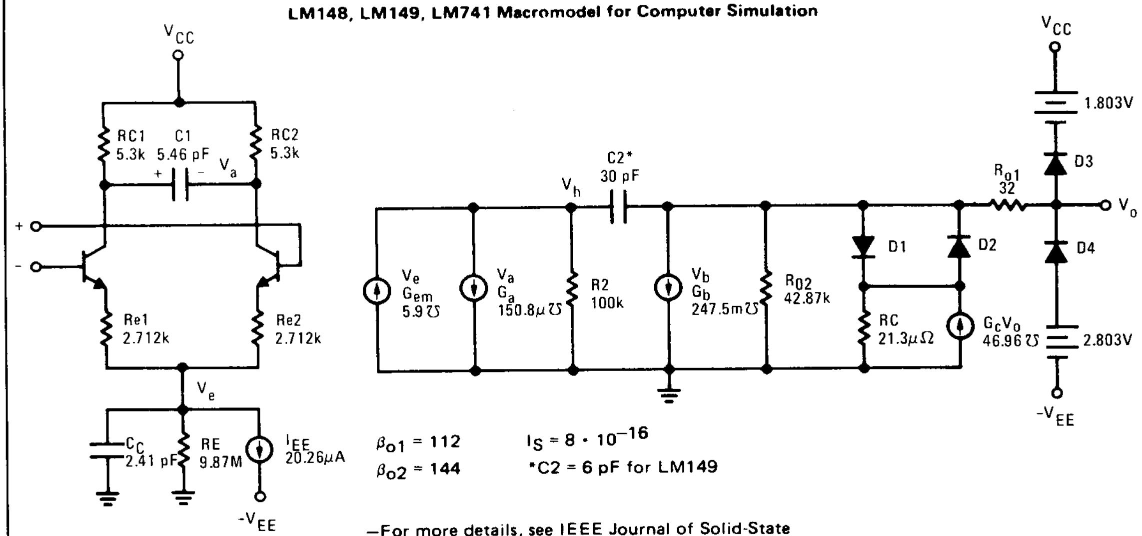
The circuit can be used as a low frequency V/F for process control.

Q1, Q3: KE4393, Q2, Q4: P1087E, D1–D4 = 1N914

RAYTHEON

TYPICAL SIMULATION

LM148, LM149, LM741 Macromodel for Computer Simulation



$\beta_{o1} = 112$ $I_S = 8 \cdot 10^{-16}$

$\beta_{o2} = 144$ *C2 = 6 pF for LM149

—For more details, see IEEE Journal of Solid-State Circuits, Vol. SC-9, No. 6, December 1974