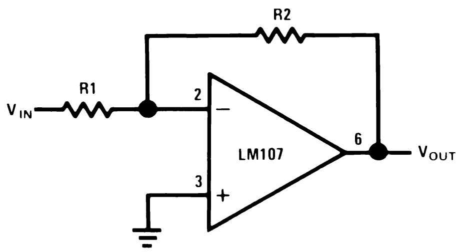
Op Amp Circuit Collection

National Semiconductor
Application Note 31
September 2002

Note: National Semiconductor recommends replacing 2N2920 and 2N3728 matched pairs with LM394 in all application circuits.

Section 1—Basic Circuits

Inverting Amplifier

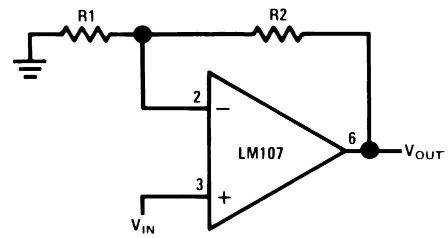


00705701

$$V_{OUT} = -\frac{R2}{R1} V_{IN}$$

$$R_{IN} = R1$$

Non-Inverting Amplifier



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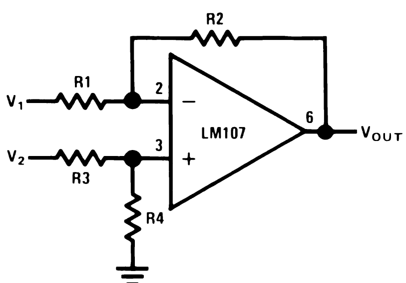
$$V_{OUT} = \frac{R1 + R2}{R1} V_{IN}$$

Difference Amplifier



00705703

$$V_{OUT} = \left(\frac{R1 + R2}{R3 + R4}\right) \frac{R4}{R1} V_2 - \frac{R2}{R1} V_1$$

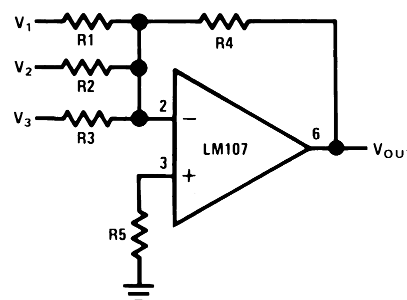
For R1 = R3 and R2 = R4

$$V_{OUT} = \frac{R2}{R1} (V_2 - V_1)$$

R1//R2 = R3//R4

For minimum offset error due to input bias current

Inverting Summing Amplifier



00705704

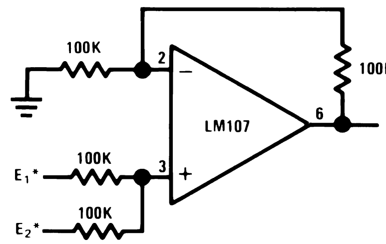
$$V_{OUT} = -R4 \left(\frac{V_1}{R1} + \frac{V_2}{R2} + \frac{V_3}{R3}\right)$$

R5 = R1//R2//R3//R4

For minimum offset error due to input bias current

Section 1—Basic Circuits (Continued)

Non-Inverting Summing Amplifier



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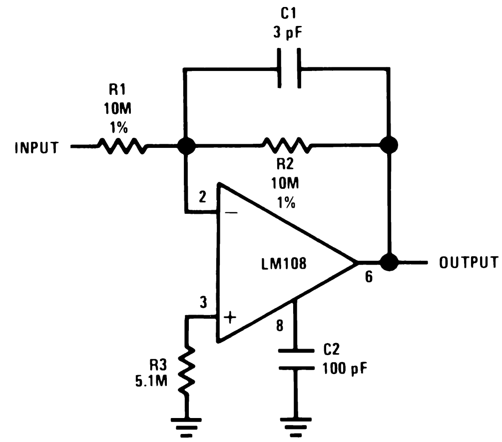
*R_S = 1k for 1% accuracy

Inverting Amplifier with High Input Impedance



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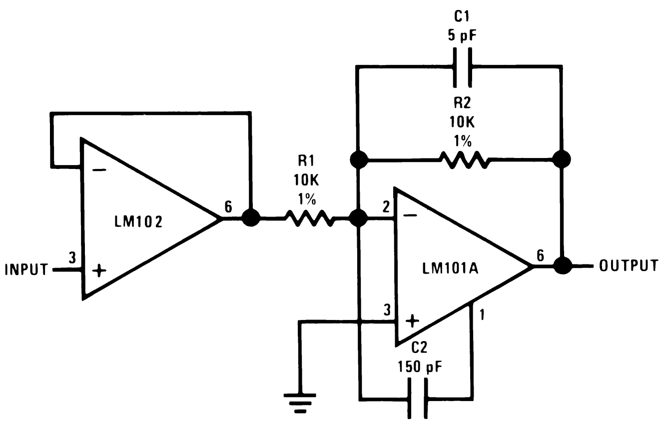
*Source Impedance less than 100k gives less than 1% gain error.

Fast Inverting Amplifier with High Input Impedance



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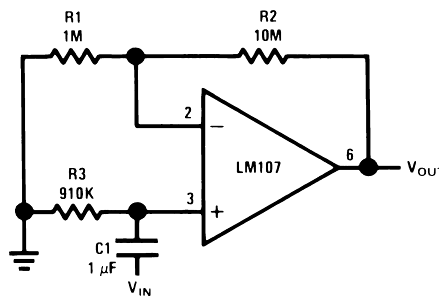
Non-Inverting AC Amplifier



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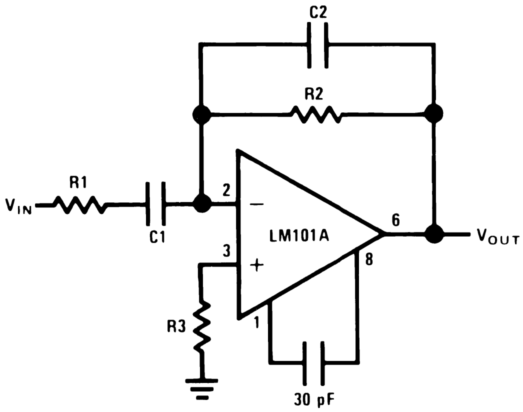
$$V_{OUT} = \frac{R1 + R2}{R1} V_{IN}$$

$R_{IN} = R3$

$R3 = R1 // R2$

Section 1—Basic Circuits (Continued)

Practical Differentiator



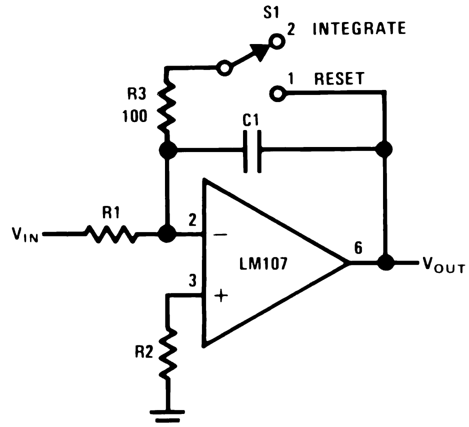
00705709

$$f_c = \frac{1}{2\pi R2C1}$$

$$f_h = \frac{1}{2\pi R1C1} = \frac{1}{2\pi R2C2}$$

$$f_c \ll f_h \ll f_{unity\ gain}$$

Integrator



00705710

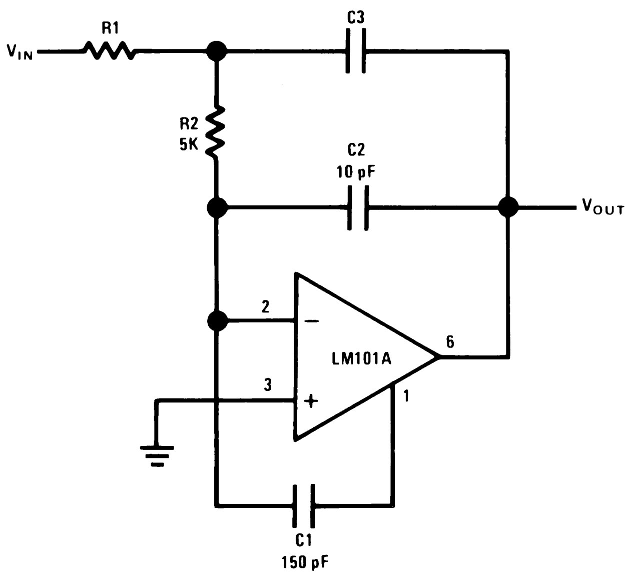
$$V_{OUT} = -\frac{1}{R1C1}\int_{t_1}^{t_2} V_{IN}\,dt$$

$$f_c = \frac{1}{2\pi R1C1}$$

R1 = R2

For minimum offset error due to input bias current

Fast Integrator



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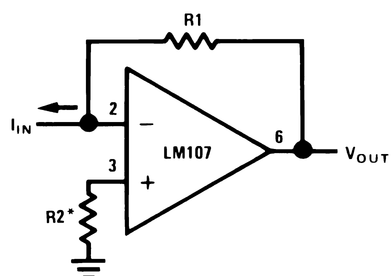
Current to Voltage Converter



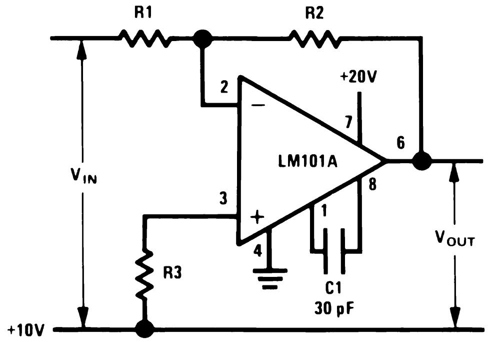
00705712

$V_{OUT} = I_{IN}$ R1

*For minimum error due to bias current R2 = R1

Section 1—Basic Circuits (Continued)

Circuit for Operating the LM101 without a Negative Supply



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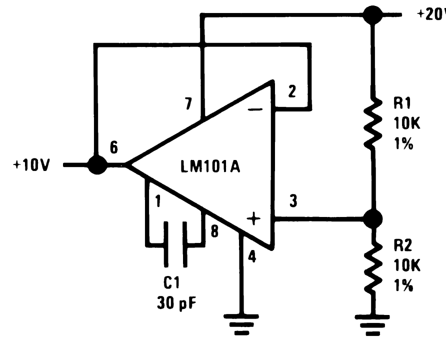
Circuit for Generating the Second Positive Voltage



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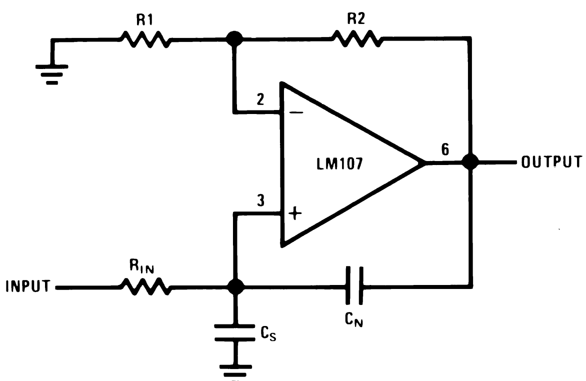
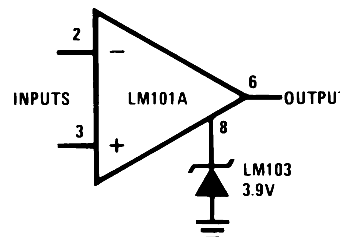
Neutralizing Input Capacitance to Optimize Response Time



00705715

$$C_N \leq \frac{R1}{R2} C_S$$

Voltage Comparator for Driving DTL or TTL Integrated Circuits



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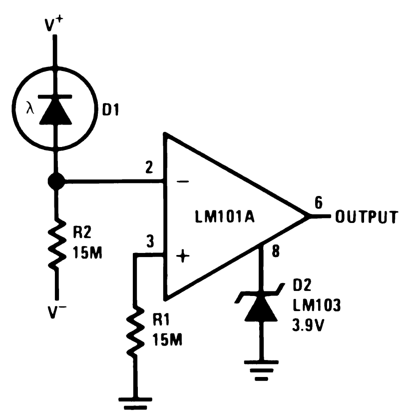
Threshold Detector for Photodiodes



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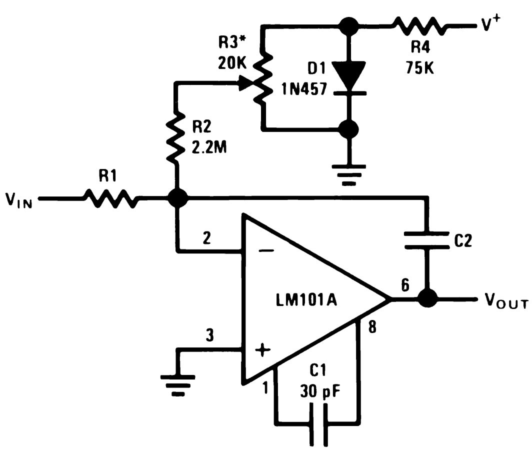
Integrator with Bias Current Compensation



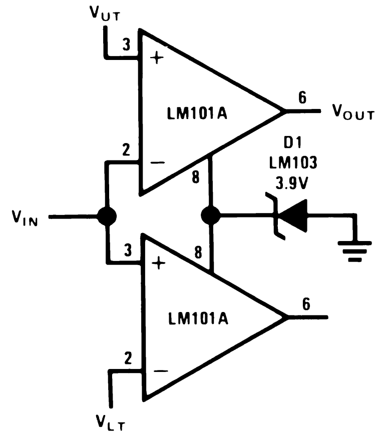
00705716

*Adjust for zero integrator drift.

Current drift typically 0.1 n/A˚C over −55˚C to 125˚C temperature range.

Section 1—Basic Circuits (Continued)

Double-Ended Limit Detector

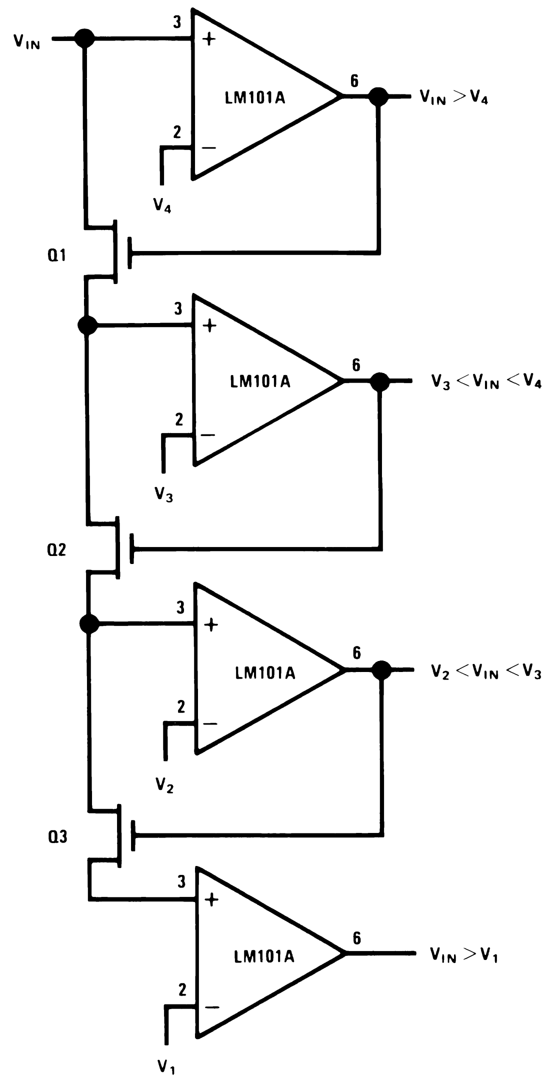


00705719

V_{OUT} = 4.6V for $V_{LT} \leq V_{IN} \leq V_{UT}$

V_{OUT} = 0V for $V_{IN} < V_{LT}$ or $V_{IN} > V_{UT}$

Multiple Aperture Window Discriminator



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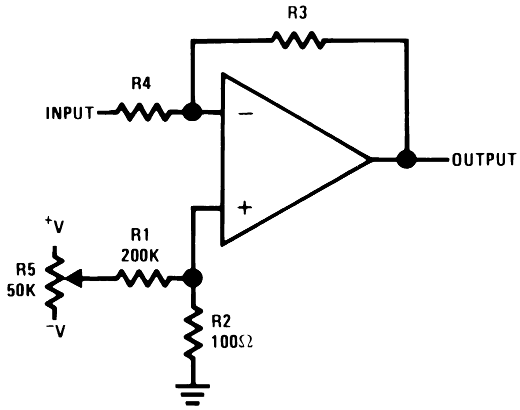
Section 1—Basic Circuits (Continued)

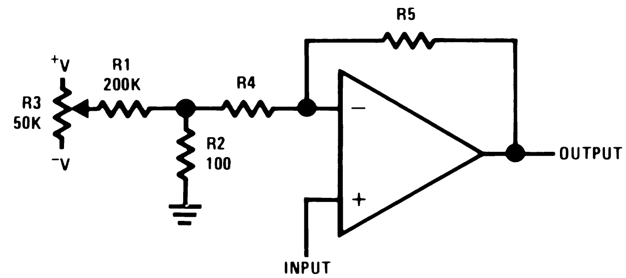
Offset Voltage Adjustment for Inverting Amplifiers Using Any Type of Feedback Element



00705721

$$\text{RANGE} = \pm V\left(\frac{R2}{R1}\right)$$

Offset Voltage Adjustment for Non-Inverting Amplifiers Using Any Type of Feedback Element

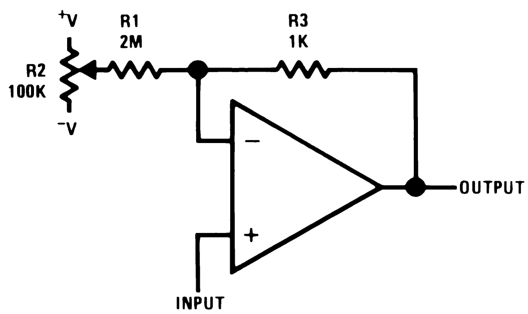


00705722

$$\text{RANGE} = \pm V\left(\frac{R2}{R1}\right)$$

$$\text{GAIN} = 1 + \frac{R5}{R4 + R2}$$

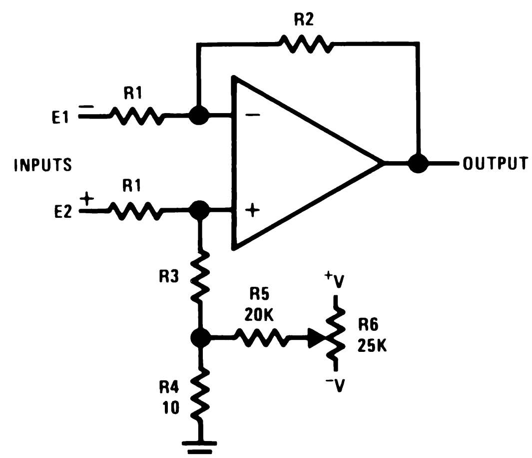
Offset Voltage Adjustment for Voltage Followers



00705723

$$\text{RANGE} = \pm V\left(\frac{R3}{R1}\right)$$

Offset Voltage Adjustment for Differential Amplifiers



00705724

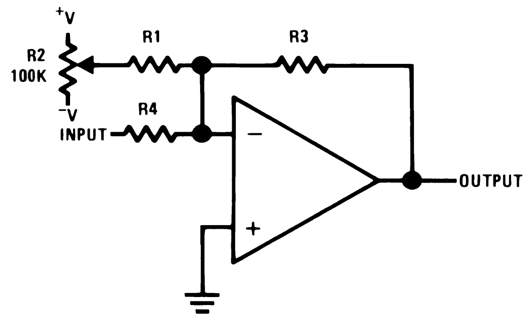
$$R2 = R3 + R4$$

$$\text{RANGE} = \pm V\left(\frac{R5}{R4}\right)\left(\frac{R1}{R1 + R3}\right)$$

$$\text{GAIN} = \frac{R2}{R1}$$

Section 1—Basic Circuits (Continued)

Offset Voltage Adjustment for Inverting Amplifiers Using 10 kΩ Source Resistance or Less



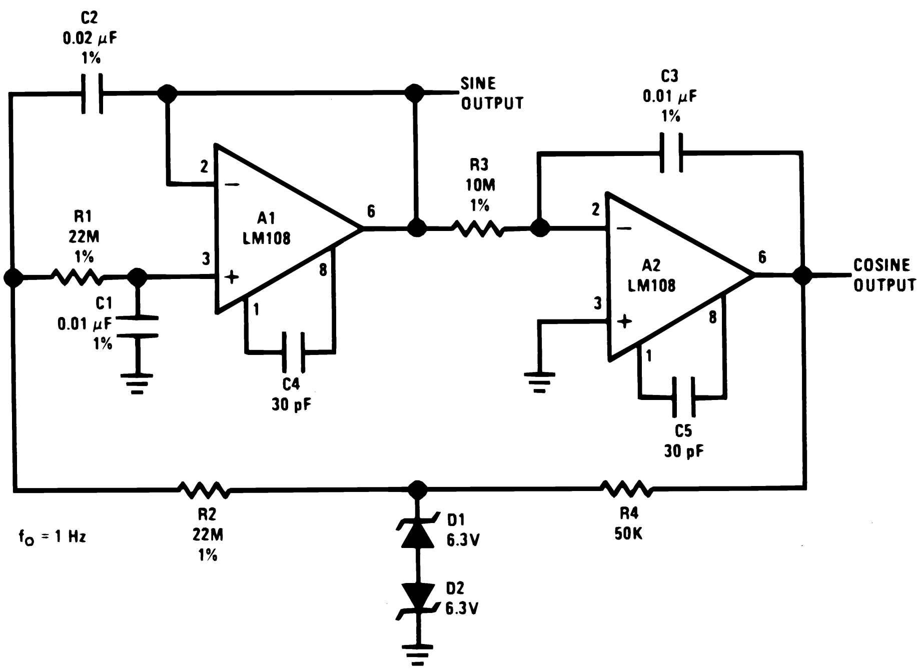
$R1 = 2000\ R3//R4$

$R4//R3 \leq 10\ k\Omega$

$RANGE = \pm V \left(\frac{R3//R4}{R1}\right)$

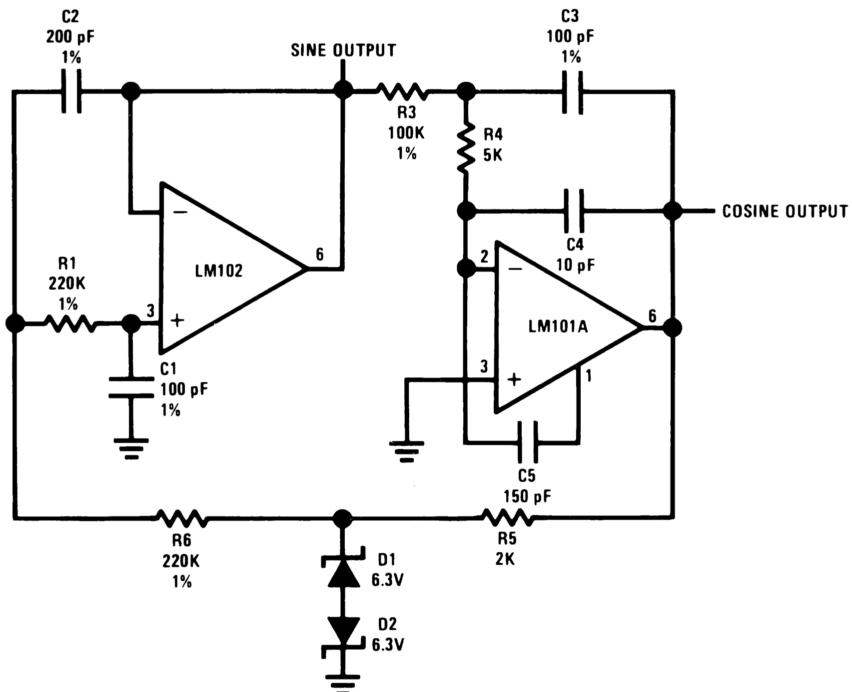
Section 2 — Signal Generation

Low Frequency Sine Wave Generator with Quadrature Output



Section 2 — Signal Generation (Continued)

High Frequency Sine Wave Generator with Quadrature Output



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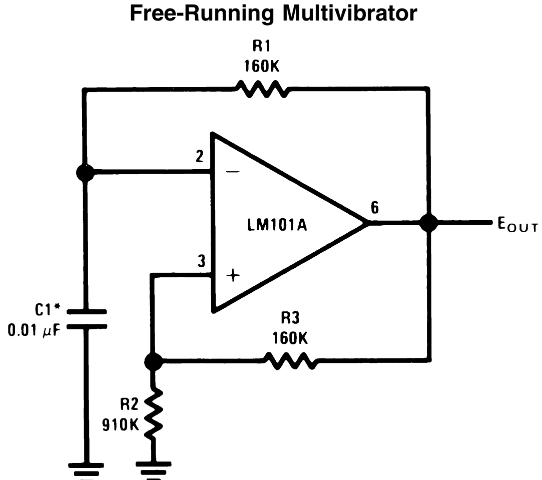
Free-Running Multivibrator



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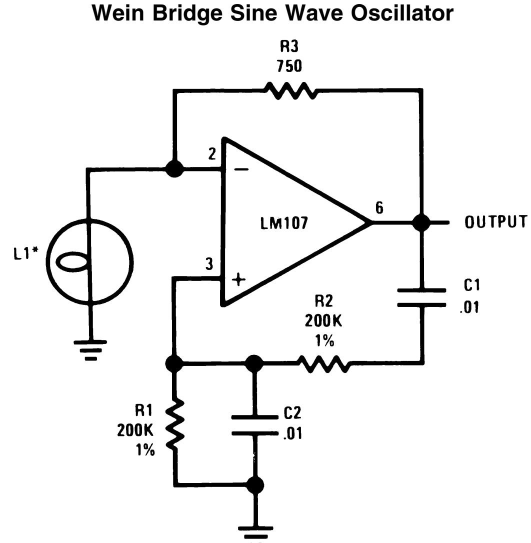
*Chosen for oscillation at 100 Hz

Wein Bridge Sine Wave Oscillator



00705729

R1 = R2

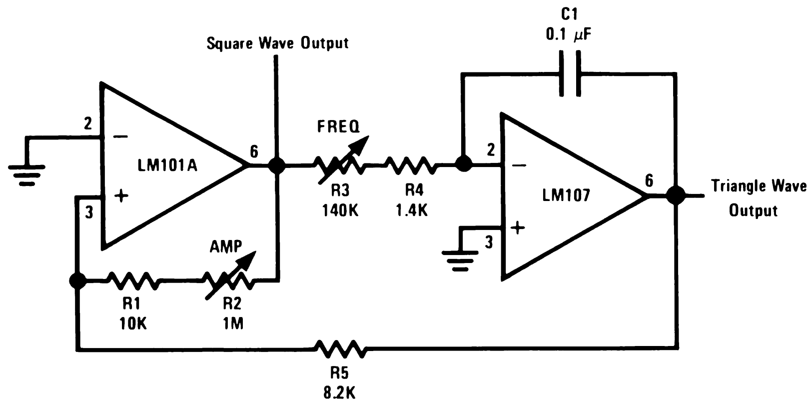
C1 = C2

$$f = \frac{1}{2\pi R1\ C1}$$

*Eldema 1869 10V, 14 mA Bulb

Section 2 — Signal Generation (Continued)

Function Generator



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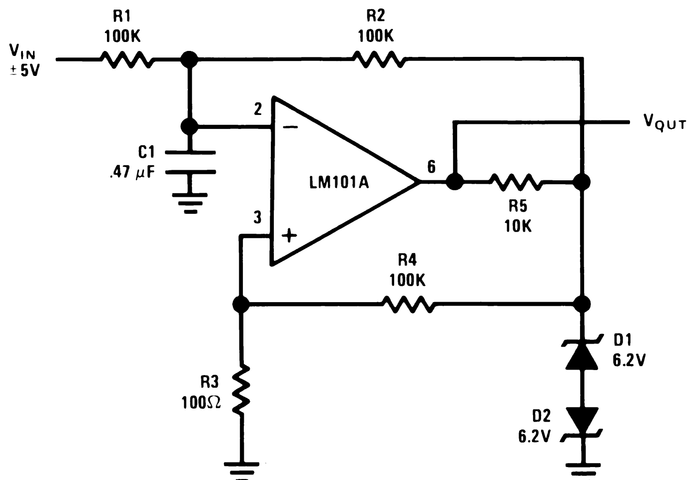
Pulse Width Modulator



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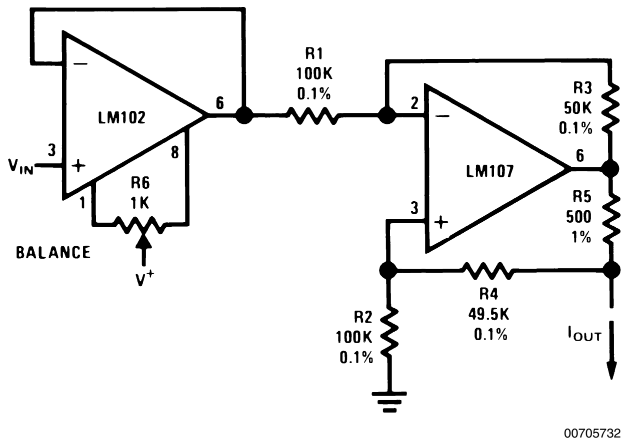
Section 2 — Signal Generation (Continued)

Bilateral Current Source

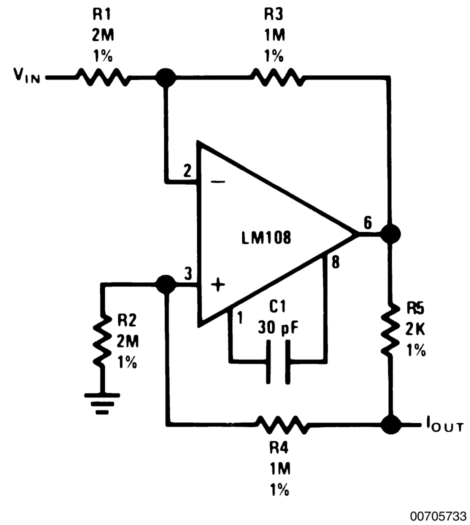


$$I_{OUT} = \frac{R3\ V_{IN}}{R1\ R5}$$

R3 = R4 + R5

R1 = R2

Bilateral Current Source



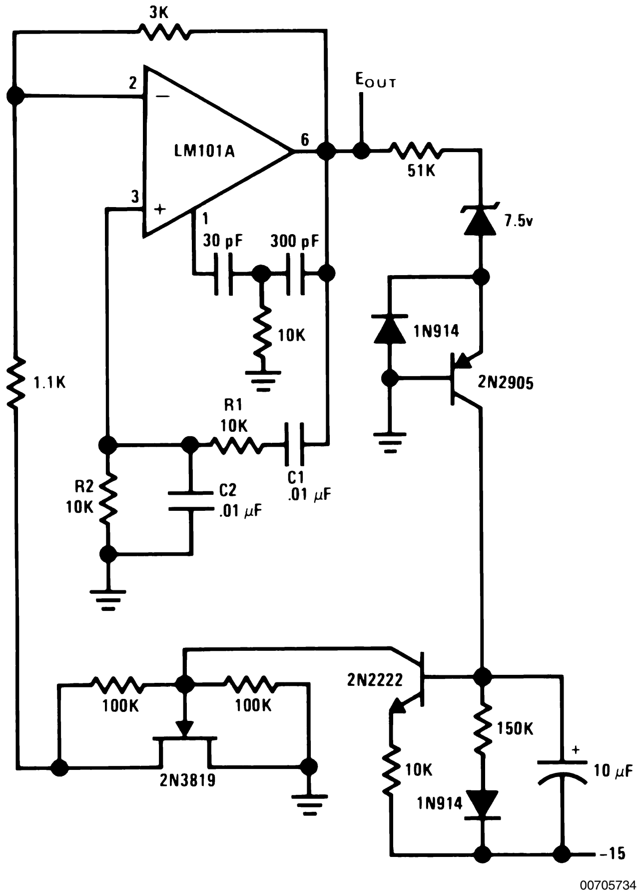
$$I_{OUT} = \frac{R3\ V_{IN}}{R1\ R5}$$

R3 = R4 + R5

R1 = R2

Section 2 — Signal Generation (Continued)

Wein Bridge Oscillator with FET Amplitude Stabilization



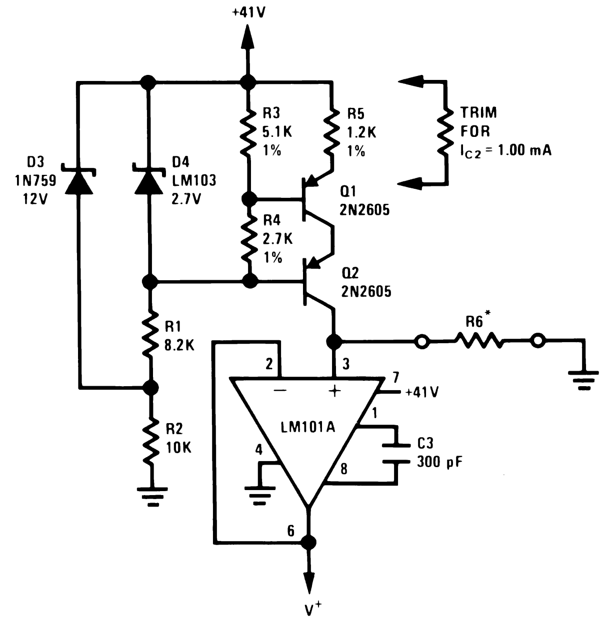
R1 = R2

C1 = C2

$$f = \frac{1}{2\pi R1\, C1}$$

Section 2 — Signal Generation (Continued)

Low Power Supply for Integrated Circuit Testing



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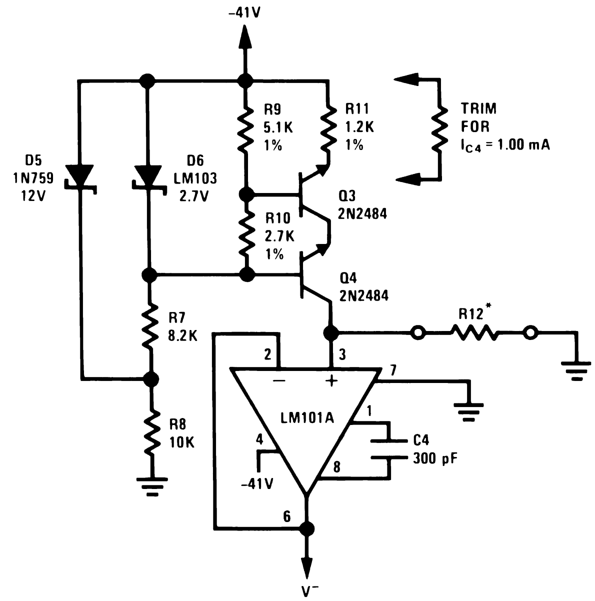

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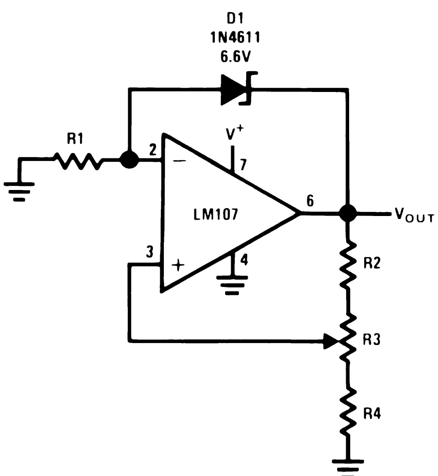
*V_{OUT} = 1V/kΩ

Positive Voltage Reference



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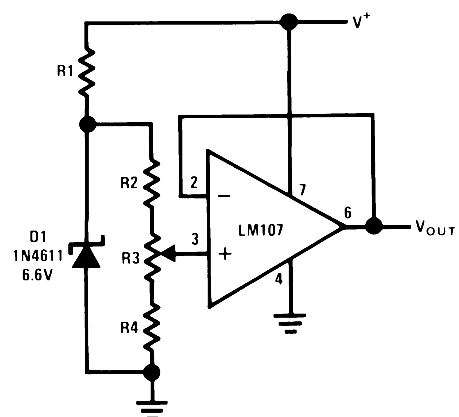
Positive Voltage Reference



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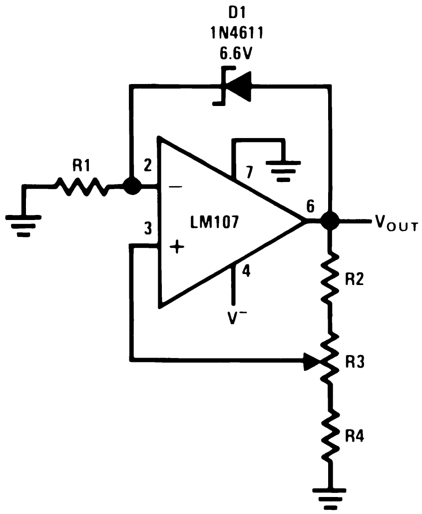
Section 2 — Signal Generation (Continued)

Negative Voltage Reference



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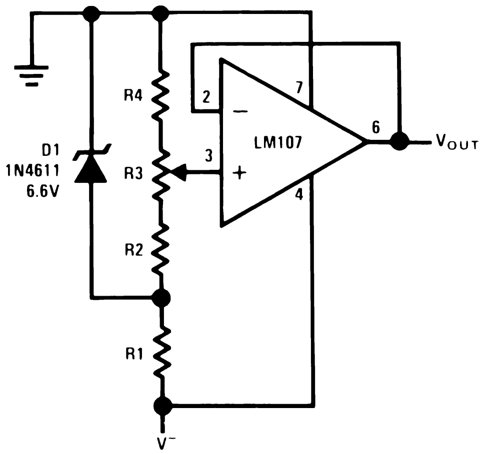
Negative Voltage Reference



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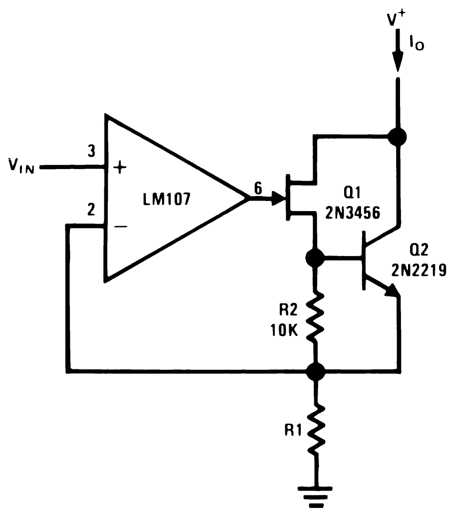
Precision Current Sink

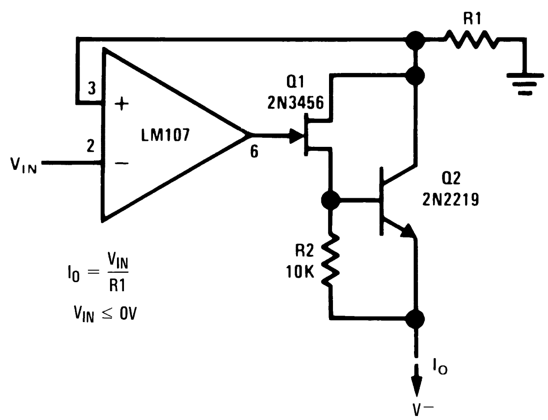


00705740

$I_O = \frac{V_{IN}}{R1}$

$V_{IN} \geq 0V$

Precision Current Source



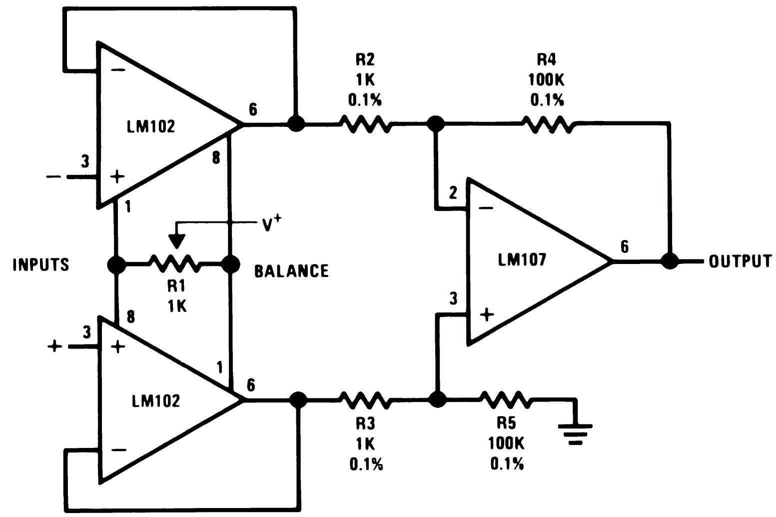
$I_O = \frac{V_{IN}}{R1}$

$V_{IN} \leq 0V$

00705741

Section 3 — Signal Processing

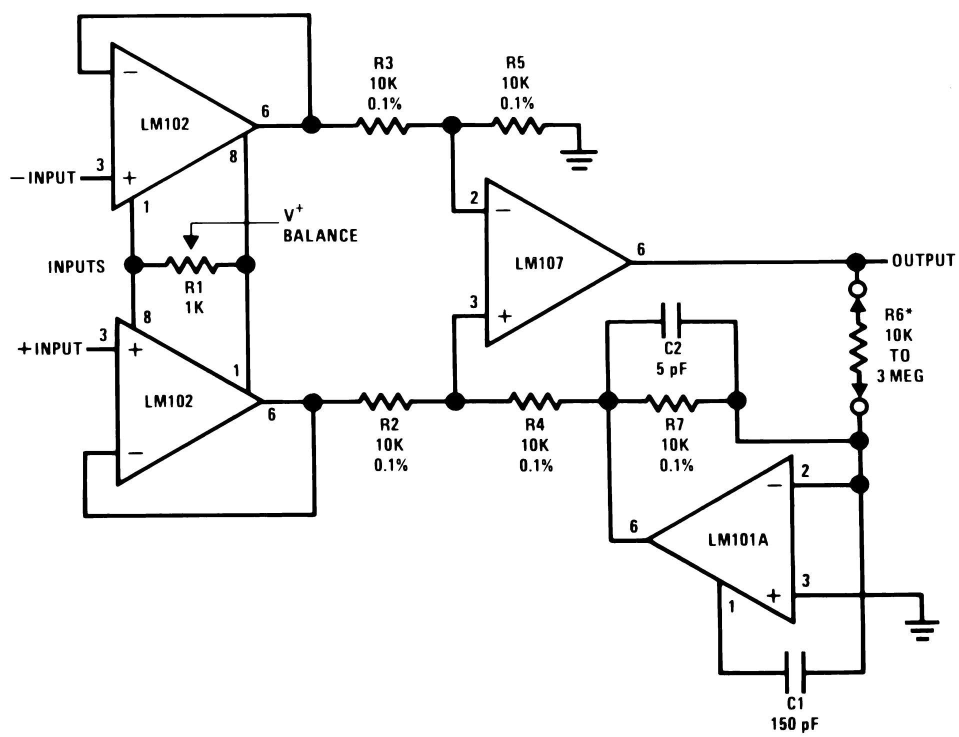
Differential-Input Instrumentation Amplifier



$$\frac{R4}{R2} = \frac{R5}{R3}$$

$$A_V = \frac{R4}{R2}$$

Variable Gain, Differential-Input Instrumentation Amplifier

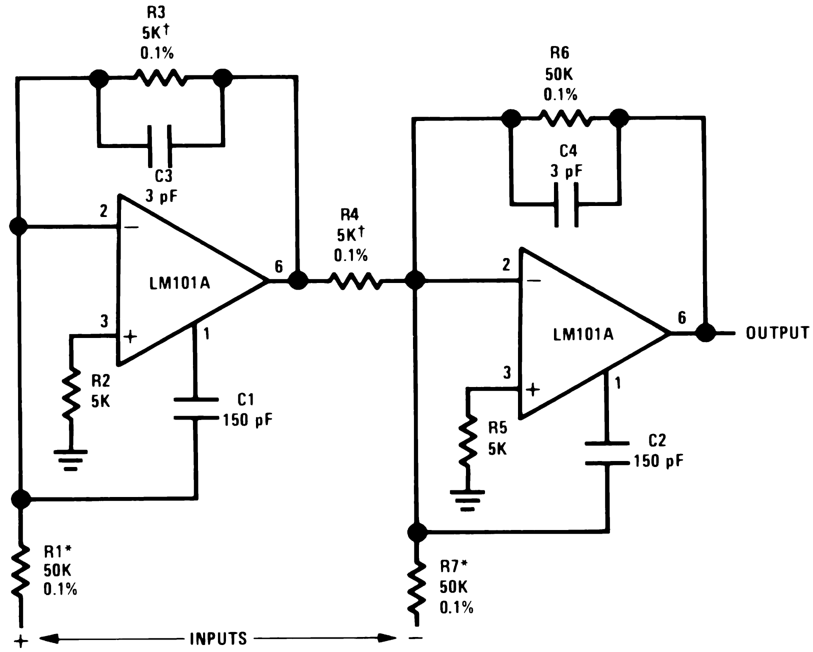


*Gain adjust

$A_V = 10^{-4}$ R6

Section 3 — Signal Processing (Continued)

Instrumentation Amplifier with ±100 Volt Common Mode Range



00705744

†Matching determines common mode rejection.

R1 = R5 = 10R2

R2 = R3

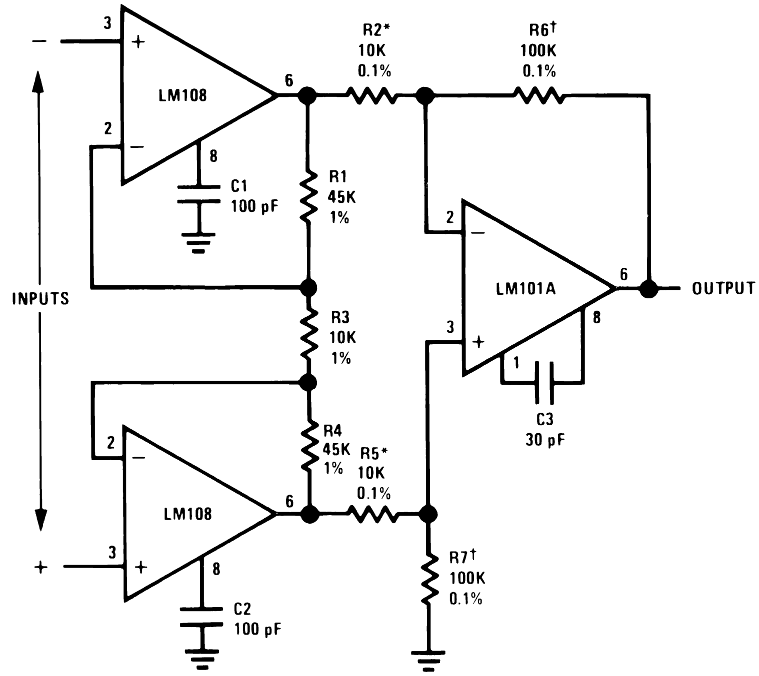
R3 = R4

R1 = R6 = 10R3

$$A_V = \frac{R7}{R6}$$

Section 3 — Signal Processing (Continued)

Instrumentation Amplifier with ±10 Volt Common Mode Range



00705745

R1 = R4

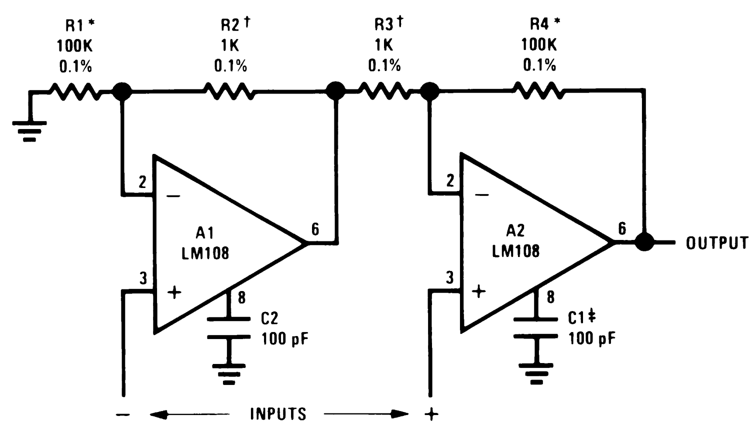
R2 = R5

R6 = R7

†*Matching Determines CMRR

$$A_V = \frac{R6}{R2}\left(1 + \frac{2R1}{R3}\right)$$

High Input Impedance Instrumentation Amplifier



00705746

R1 = R4; R2 = R3

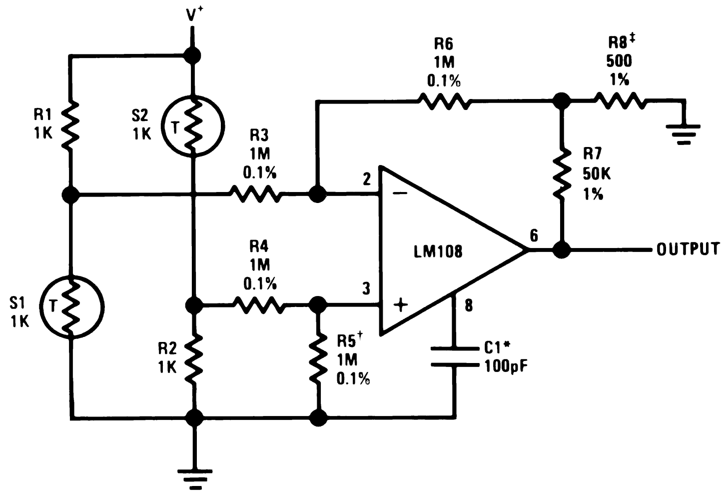
$$A_V = 1 + \frac{R1}{R2}$$

*†Matching Determines CMRR

‡May be deleted to maximize bandwidth

Section 3 — Signal Processing (Continued)

Bridge Amplifier with Low Noise Compensation



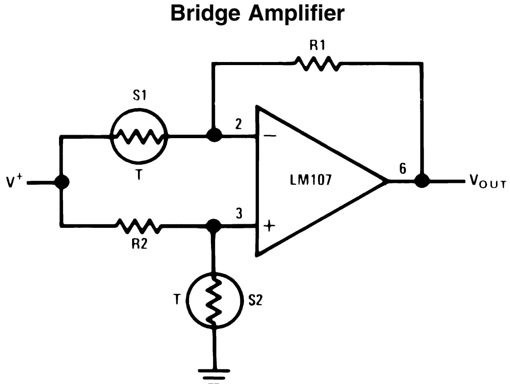
00705747

*Reduces feed through of power supply noise by 20 dB and makes supply bypassing unnecessary.

†Trim for best common mode rejection

‡Gain adjust

Bridge Amplifier

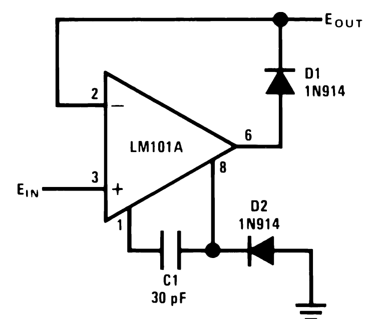


00705748

$$\frac{R1}{R_{S1}} = \frac{R2}{R_{S2}}$$

$$V_{OUT} = V^{+}\left(1 - \frac{R1}{R_{S1}}\right)$$

Precision Diode



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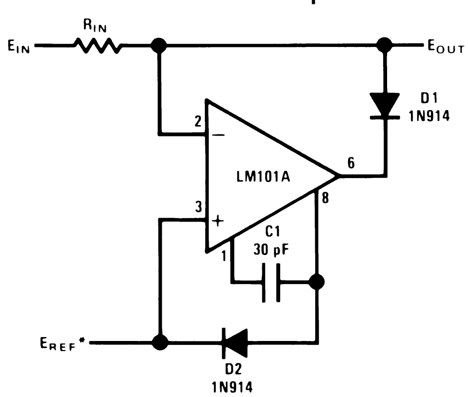
Precision Clamp



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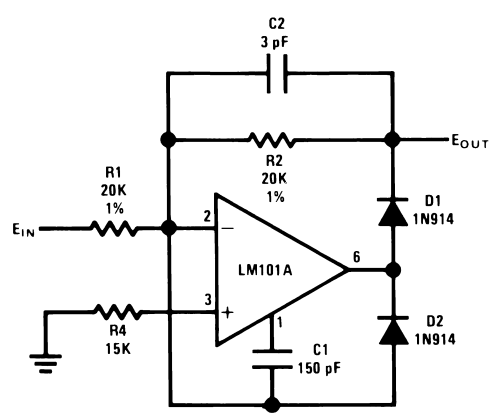
*E_{REF} must have a source impedance of less than 200Ω if D2 is used.

Fast Half Wave Rectifier



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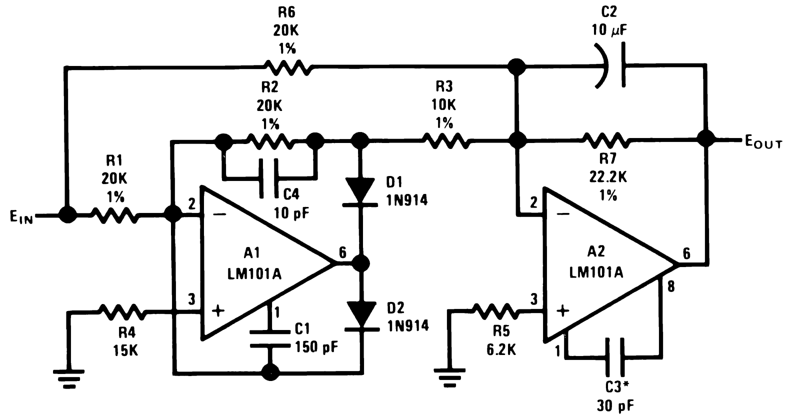
Section 3 — Signal Processing (Continued)

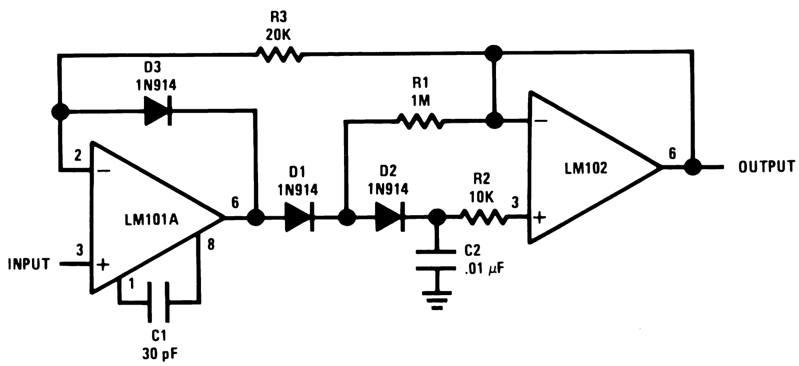
Precision AC to DC Converter



00705752

*Feedforward compensation can be used to make a fast full wave rectifier without a filter.

Low Drift Peak Detector



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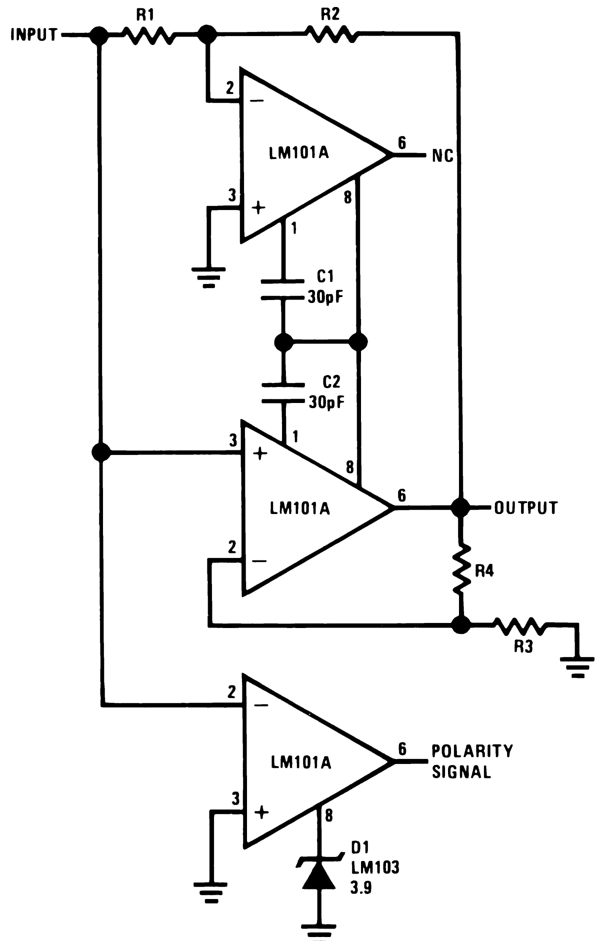
Section 3 — Signal Processing (Continued)

Absolute Value Amplifier with Polarity Detector

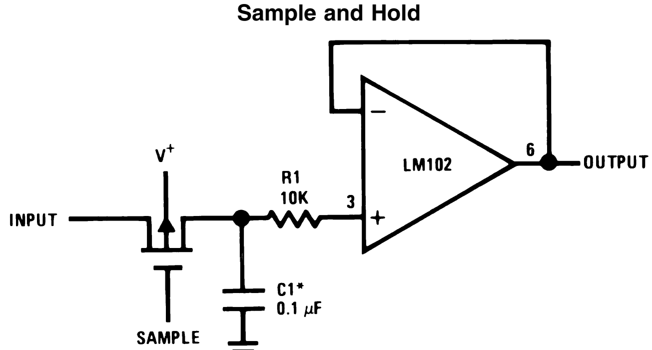


00705754

$$V_{OUT} = -|V_{IN}| \times \frac{R2}{R1}$$

$$\frac{R2}{R1} = \frac{R4 + R3}{R3}$$

Sample and Hold

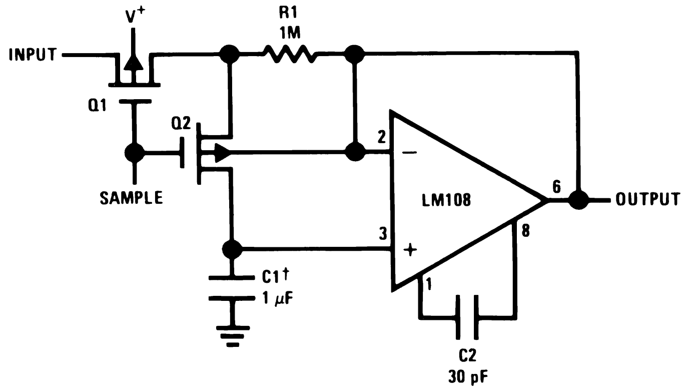


00705755

*Polycarbonate-dielectric capacitor

Section 3 — Signal Processing (Continued)

Sample and Hold

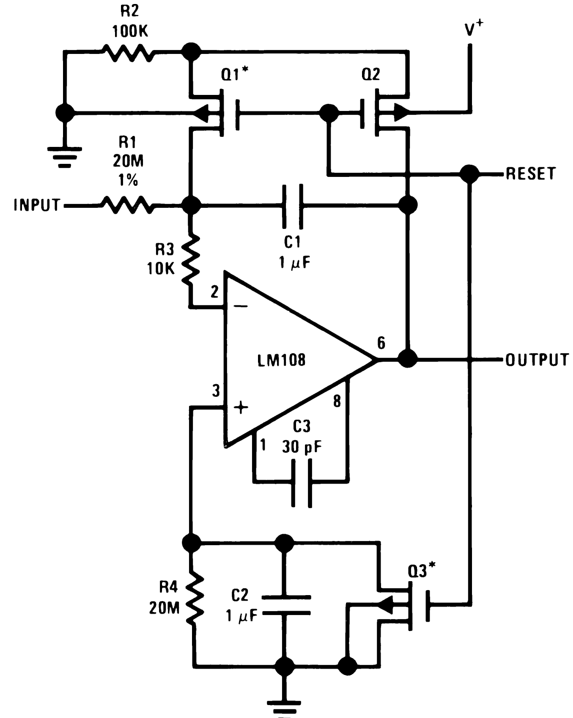


00705756

*Worst case drift less than 2.5 mV/sec

†Teflon, Polyethylene or Polycarbonate Dielectric Capacitor

Low Drift Integrator



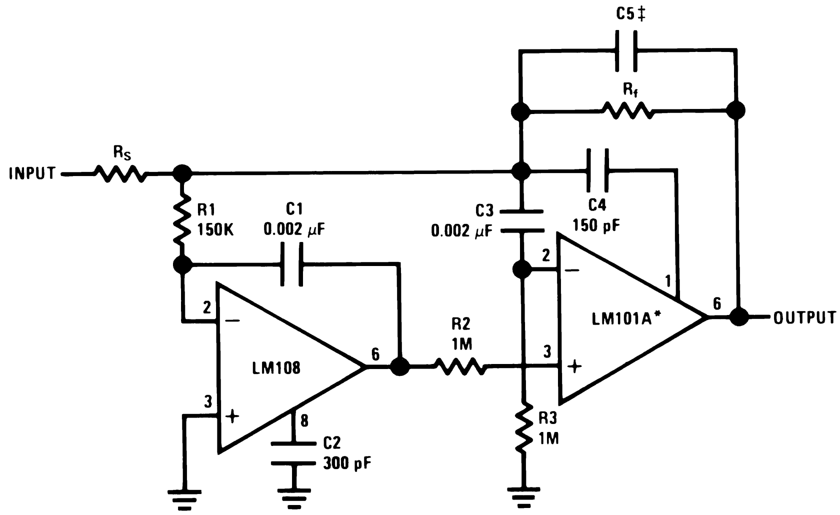
00705757

*Q1 and Q3 should not have internal gate-protection diodes.

Worst case drift less than 500 μV/sec over −55˚C to +125˚C.

Section 3 — Signal Processing (Continued)

Fast† Summing Amplifier with Low Input Current



00705758

*In addition to increasing speed, the LM101A raises high and low frequency gain, increases output drive capability and eliminates thermal feedback.

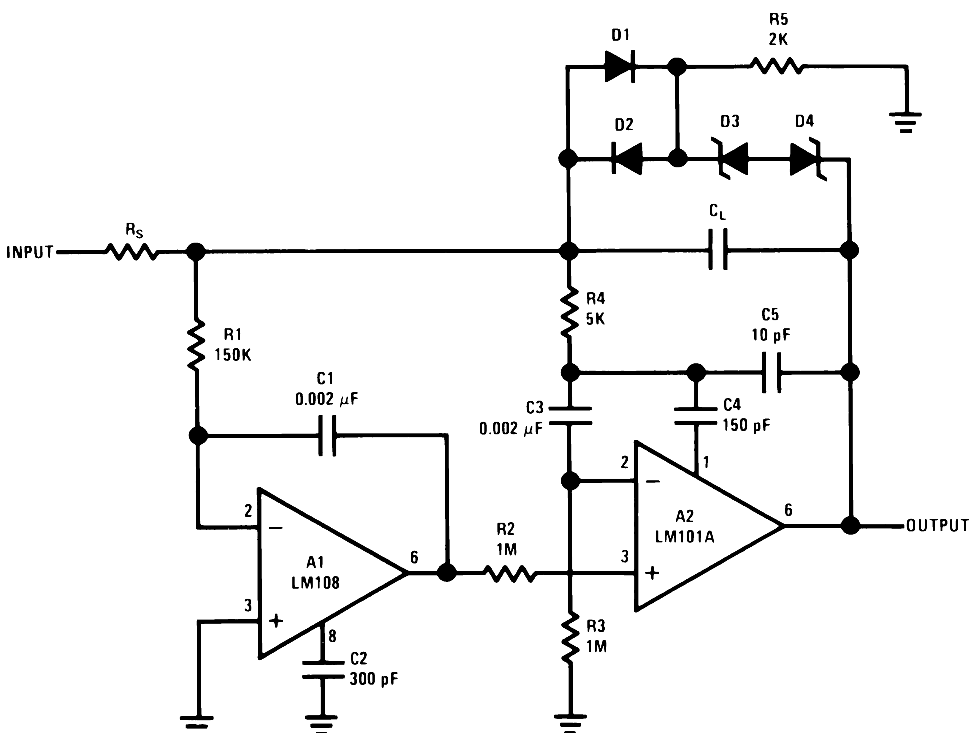
†Power Bandwidth: 250 kHz

Small Signal Bandwidth: 3.5 MHz

Slew Rate: 10V/µs

$$‡\ C5 = \frac{6 \times 10^{-8}}{R_f}$$

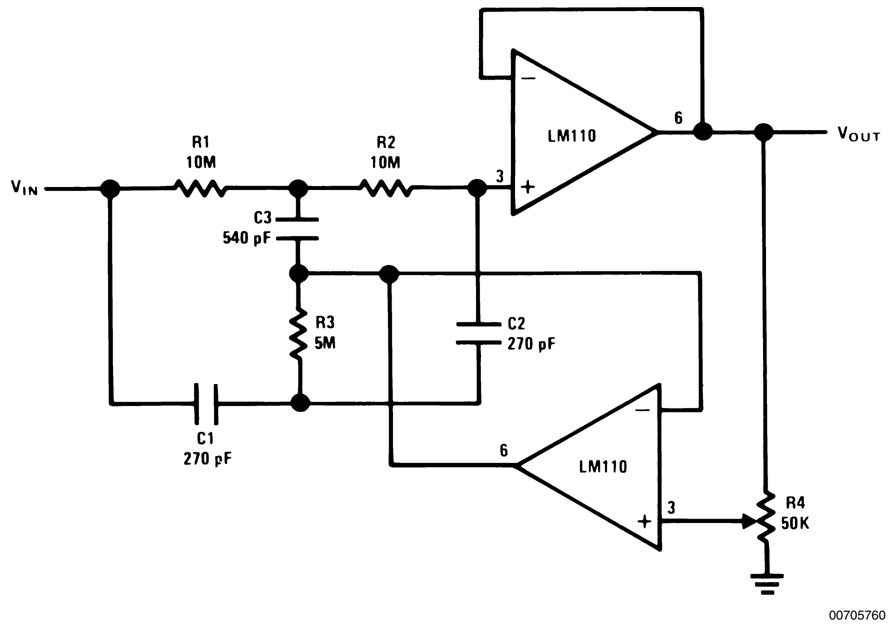
Fast Integrator with Low Input Current



00705759

Section 3 — Signal Processing (Continued)

Adjustable Q Notch Filter



$$f_O = \frac{1}{2\pi R1C1}$$

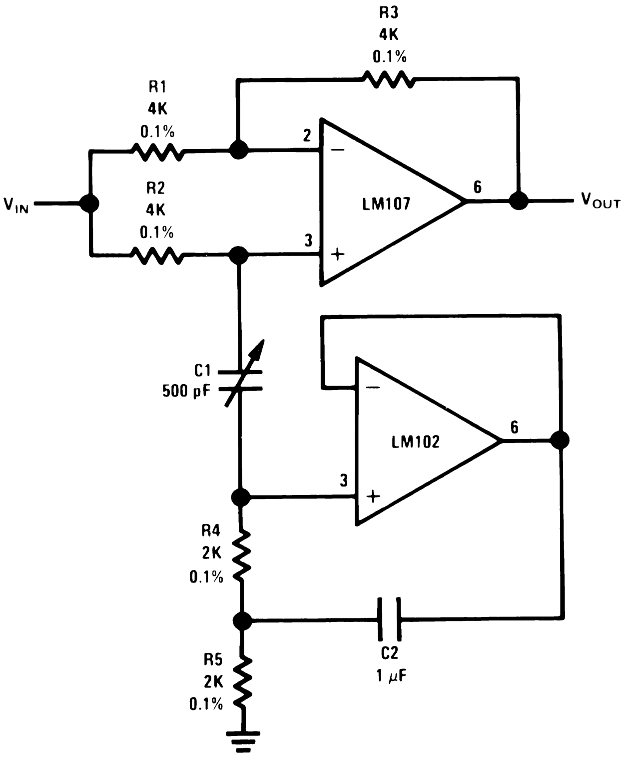
$$= 60\ Hz$$

R1 = R2 = R3

C1 = C2 = C23

Section 3 — Signal Processing (Continued)

Easily Tuned Notch Filter

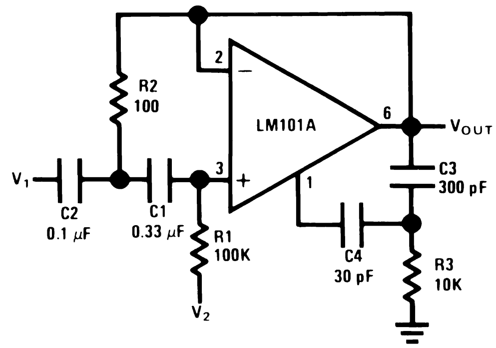


00705761

R4 = R5
R1 = R3
R4 = ½ R1

$$f_O = \frac{1}{2\pi R4\sqrt{C1C2}}$$

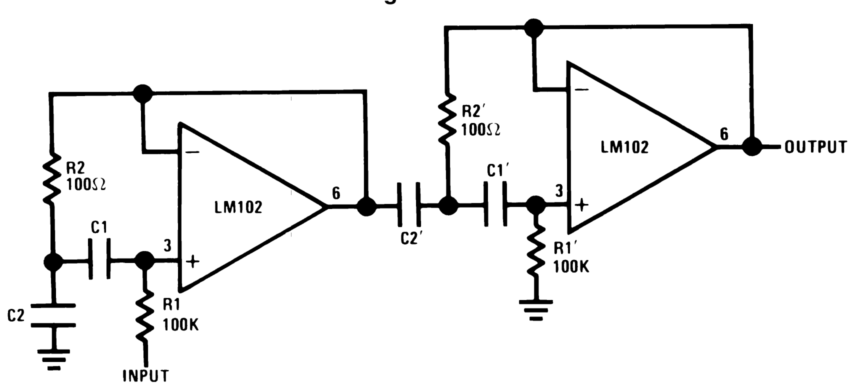
Tuned Circuit



00705762

$$f_O = \frac{1}{2\pi\sqrt{R1R2C1C2}}$$

Two-Stage Tuned Circuit

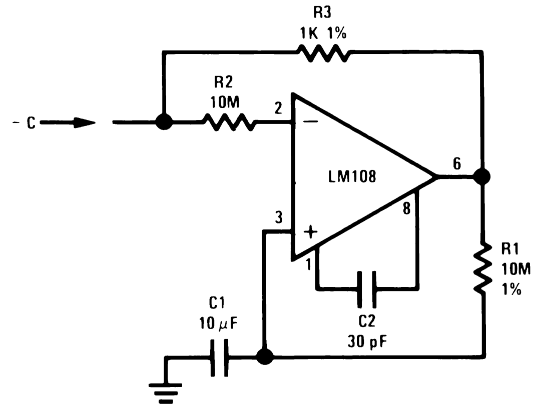


00705763

$$f_O = \frac{1}{2\pi\sqrt{R1R2C1C2}}$$

Section 3 — Signal Processing (Continued)

Negative Capacitance Multiplier



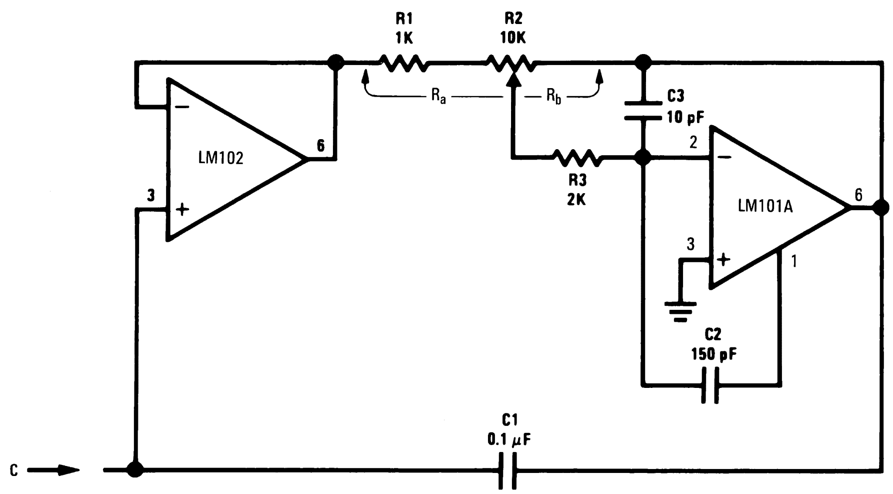
00705765

$$C = \frac{R2}{R3} C1$$

$$I_L = \frac{V_{OS} + R2\, I_{OS}}{R3}$$

$$R_S = \frac{R3(R1 + R_{IN})}{R_{IN}\, A_{VO}}$$

Variable Capacitance Multiplier

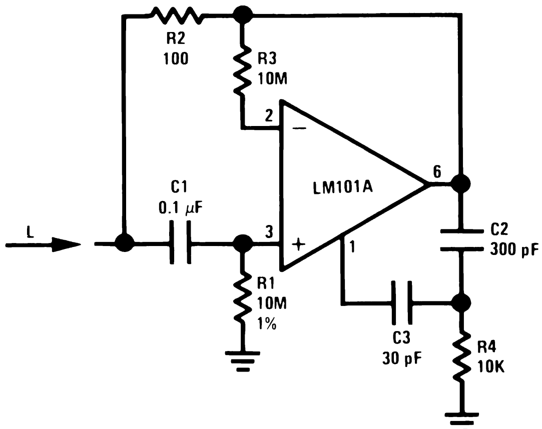


00705766

$$C = \left(1 + \frac{R_b}{R_a}\right) C_1$$

Section 3 — Signal Processing (Continued)

Simulated Inductor



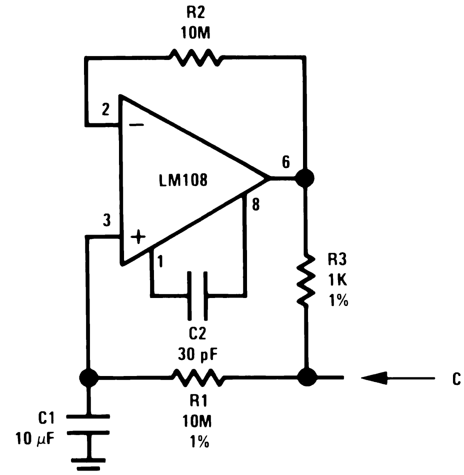
00705767

L ≥ R1 R2 C1

R_S = R2

R_P = R1

Capacitance Multiplier



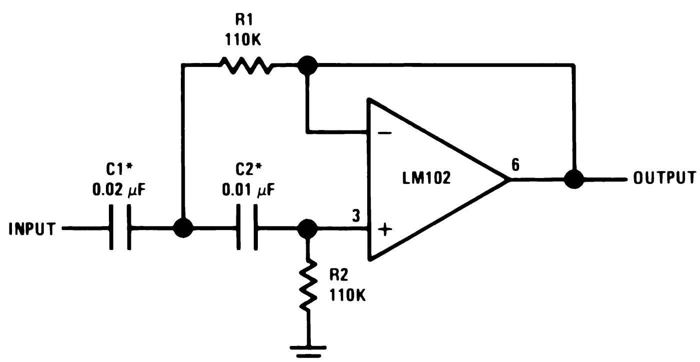
00705768

$$C = \frac{R1}{R3} C1$$

$$I_L = \frac{V_{OS} + I_{OS} R1}{R3}$$

$$R_S = R3$$

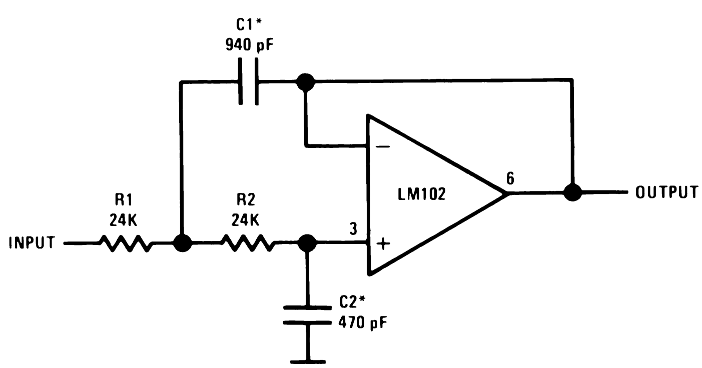
High Pass Active Filter



00705771

*Values are for 100 Hz cutoff. Use metalized polycarbonate capacitors for good temperature stability.

Low Pass Active Filter

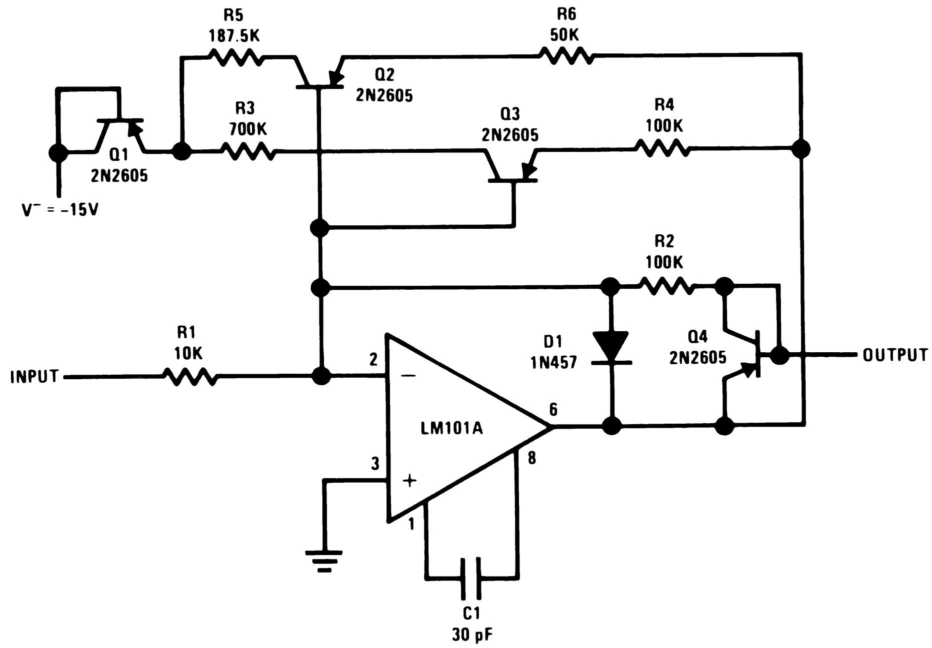


00705772

*Values are for 10 kHz cutoff. Use silvered mica capacitors for good temperature stability.

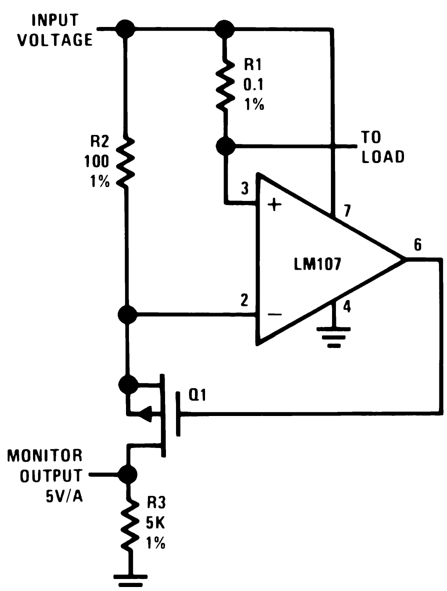
Section 3 — Signal Processing (Continued)

Nonlinear Operational Amplifier with Temperature Compensated Breakpoints



00705773

Current Monitor

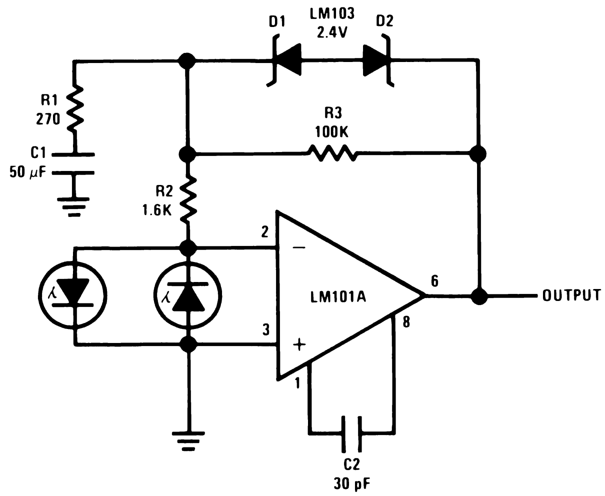


00705774

$$V_{OUT} = \frac{R1\ R3}{R2} I_L$$

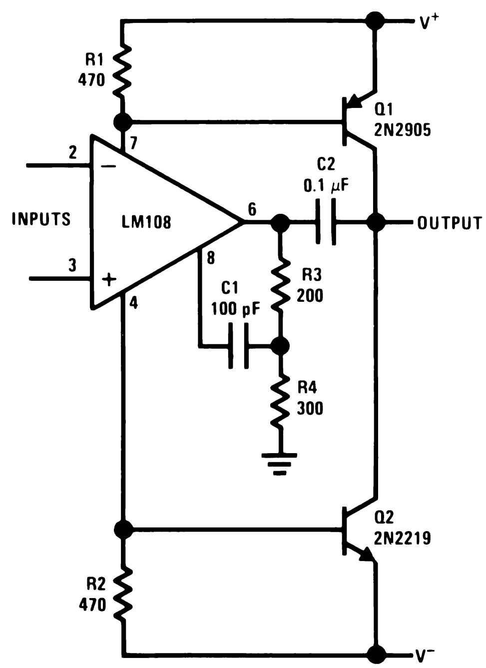
Section 3 — Signal Processing (Continued)

Saturating Servo Preamplifier with Rate Feedback



00705775

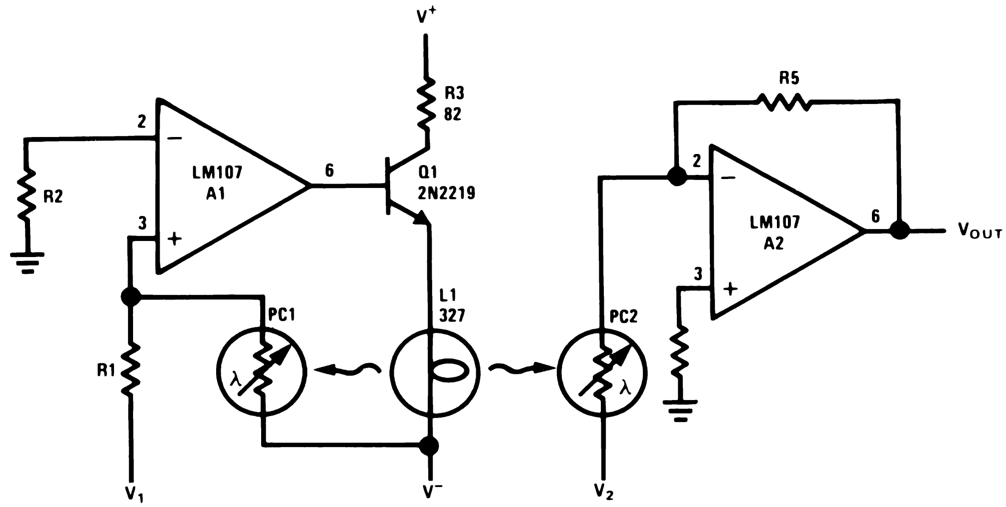
Power Booster



00705776

Section 3 — Signal Processing (Continued)

Analog Multiplier



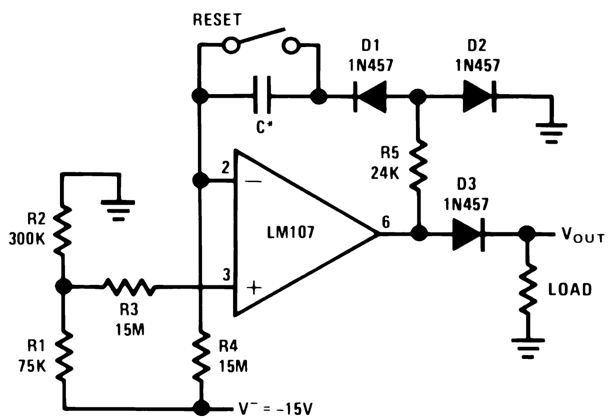
00705777

$$R5 = R1\left(\frac{V^-}{10}\right)$$

$$V_1 \geq 0$$

$$V_{OUT} = \frac{V_1 V_2}{10}$$

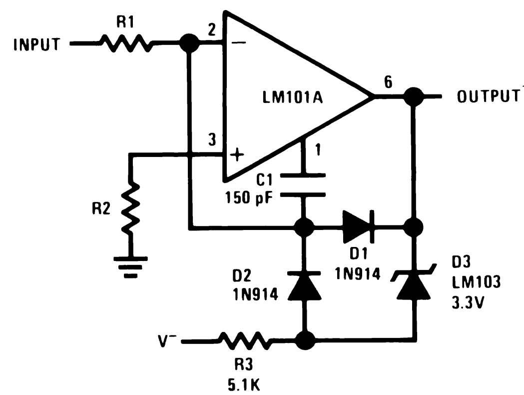
Long Interval Timer



00705778

*Low leakage −0.017 μF per second delay

Fast Zero Crossing Detector



00705779

Propagation delay approximately 200 ns

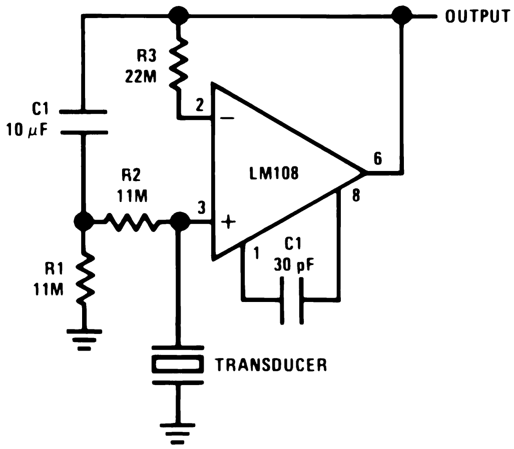
†DTL or TTL fanout of three.

Minimize stray capacitance

Pin 8

Section 3 — Signal Processing (Continued)

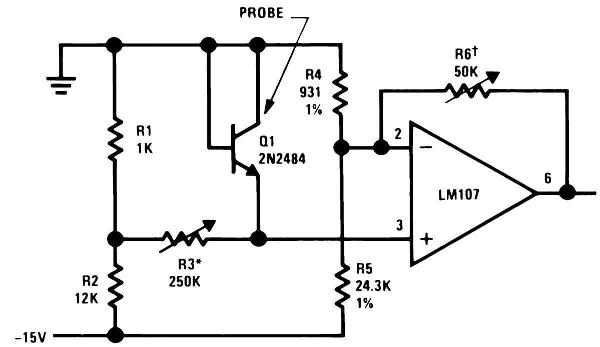
Amplifier for Piezoelectric Transducer



00705780

Low frequency cutoff = R1 C1

Temperature Probe

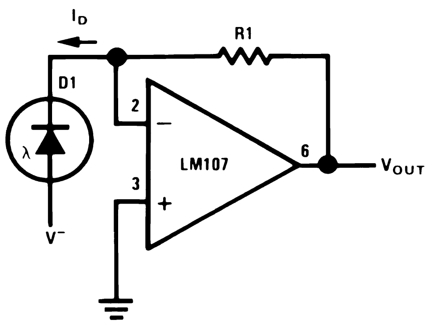


00705781

*Set for 0V at 0˚C

†Adjust for 100 mV/˚C

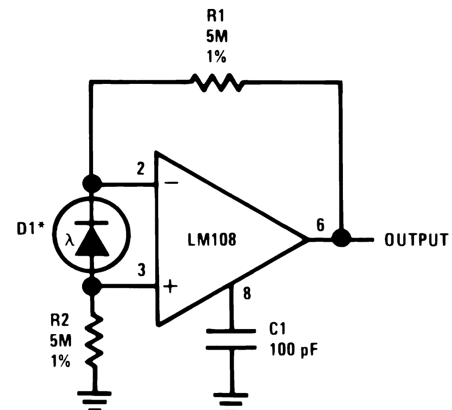
Photodiode Amplifier



00705782

V_{OUT} = R1 I_D

Photodiode Amplifier

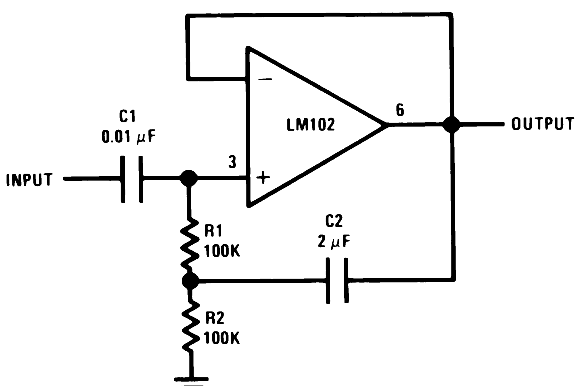


00705783

V_{OUT} = 10 V/μA

*Operating photodiode with less than 3 mV across it eliminates leakage currents.

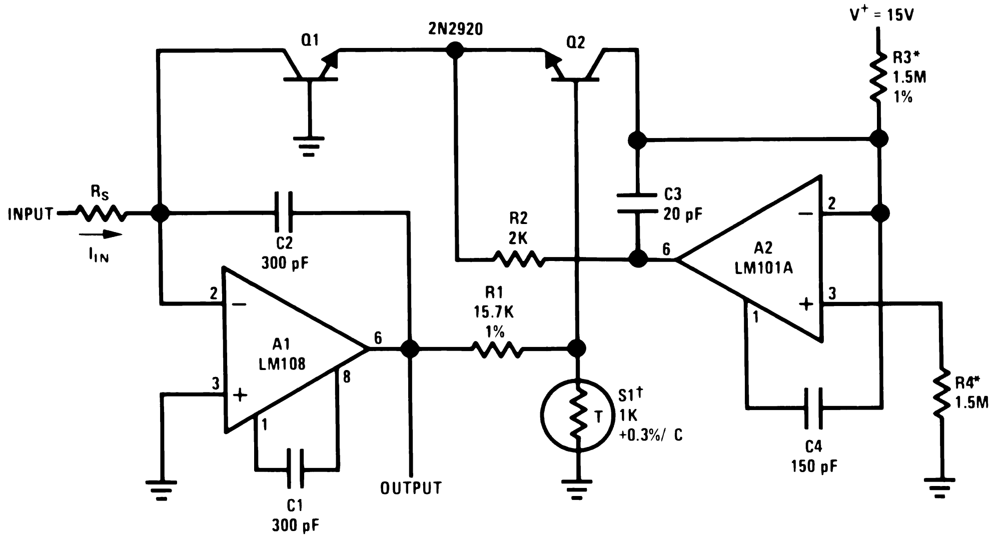
High Input Impedance AC Follower



00705784

Section 3 — Signal Processing (Continued)

Temperature Compensated Logarithmic Converter



00705785

10 nA < I_{IN} < 1 mA

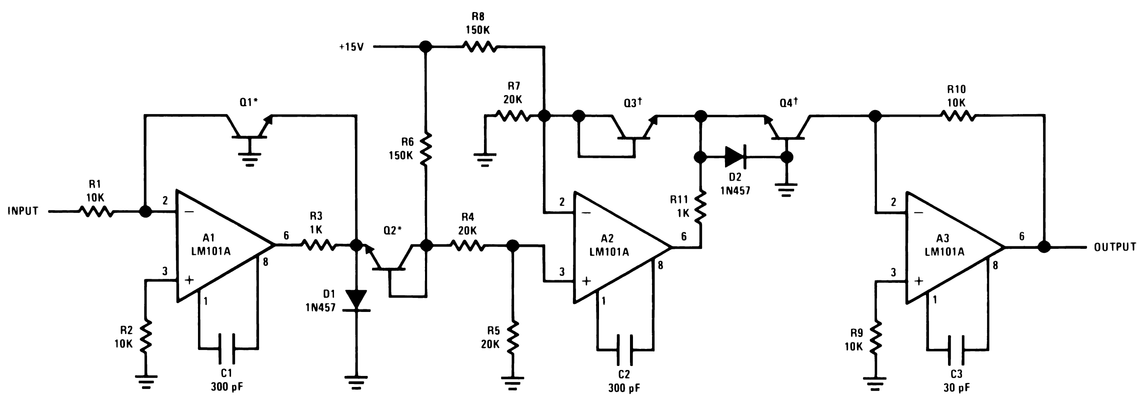
Sensitivity is 1V per decade

†1 kΩ (±1%) at 25˚C, +3500 ppm/˚C.

Available from Vishay Ultronix, Grand Junction, CO, Q81 Series.

*Determines current for zero crossing on output: 10 µA as shown.

Root Extractor

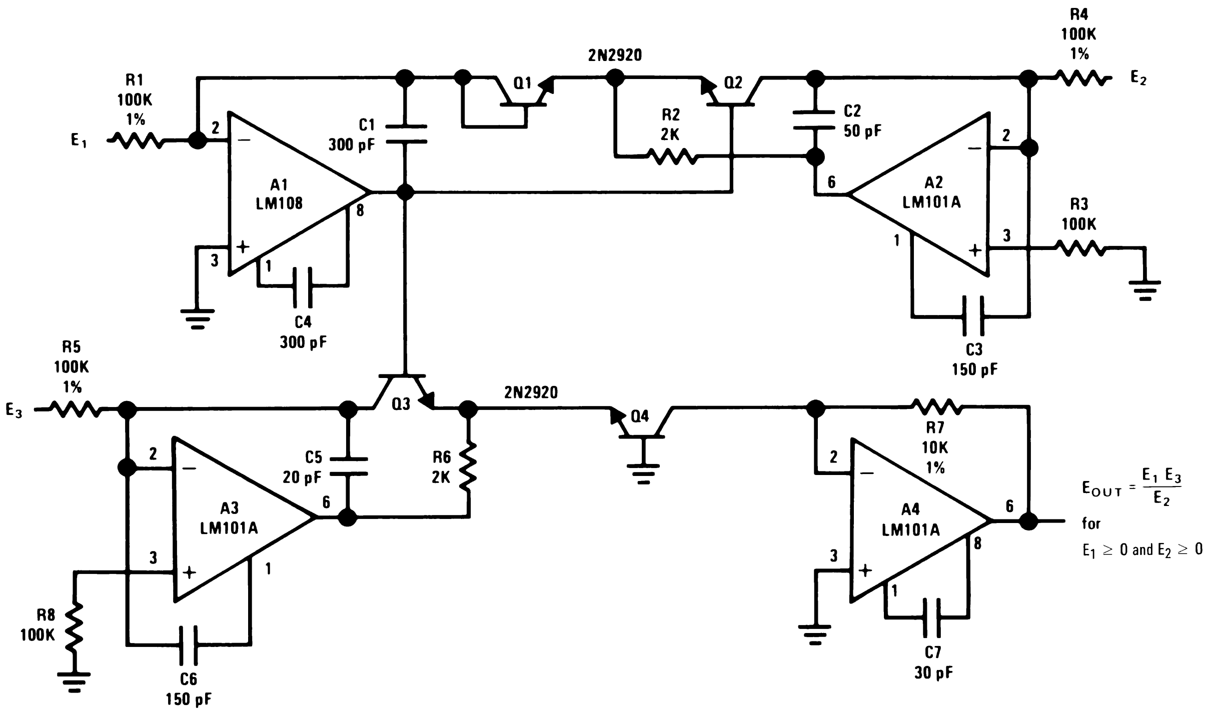


00705786

*†2N3728 matched pairs

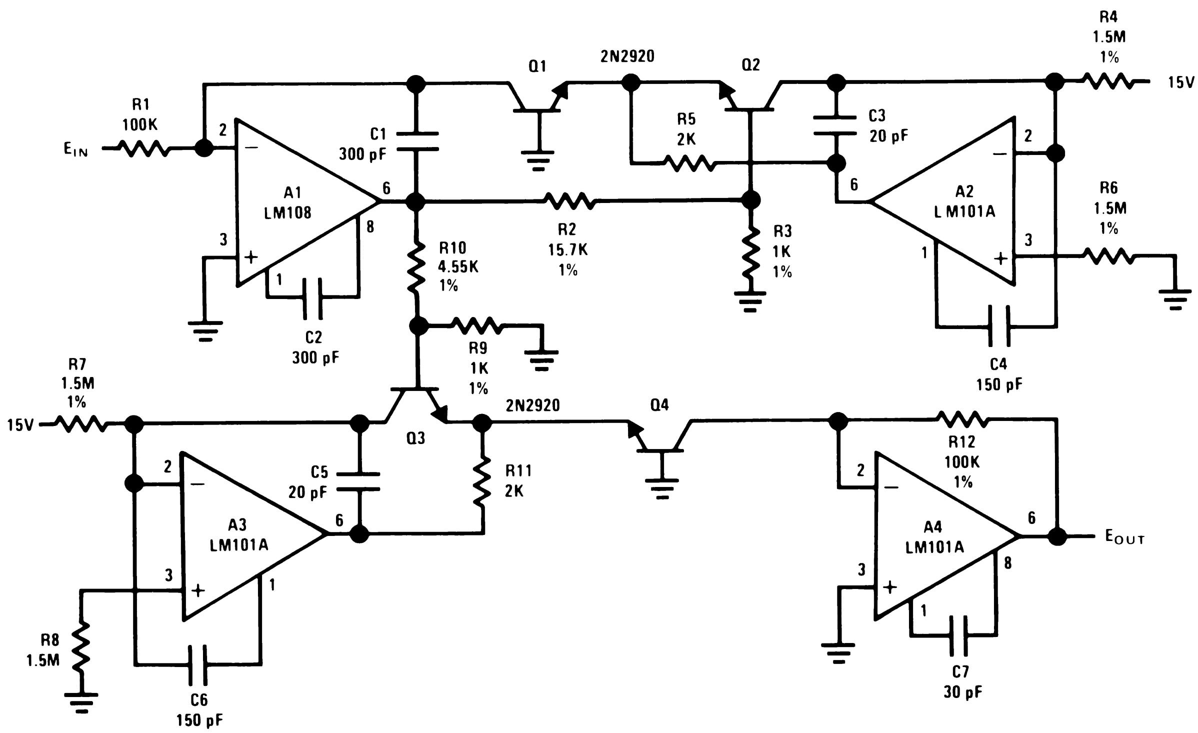
Section 3 — Signal Processing (Continued)

Multiplier/Divider



00705787

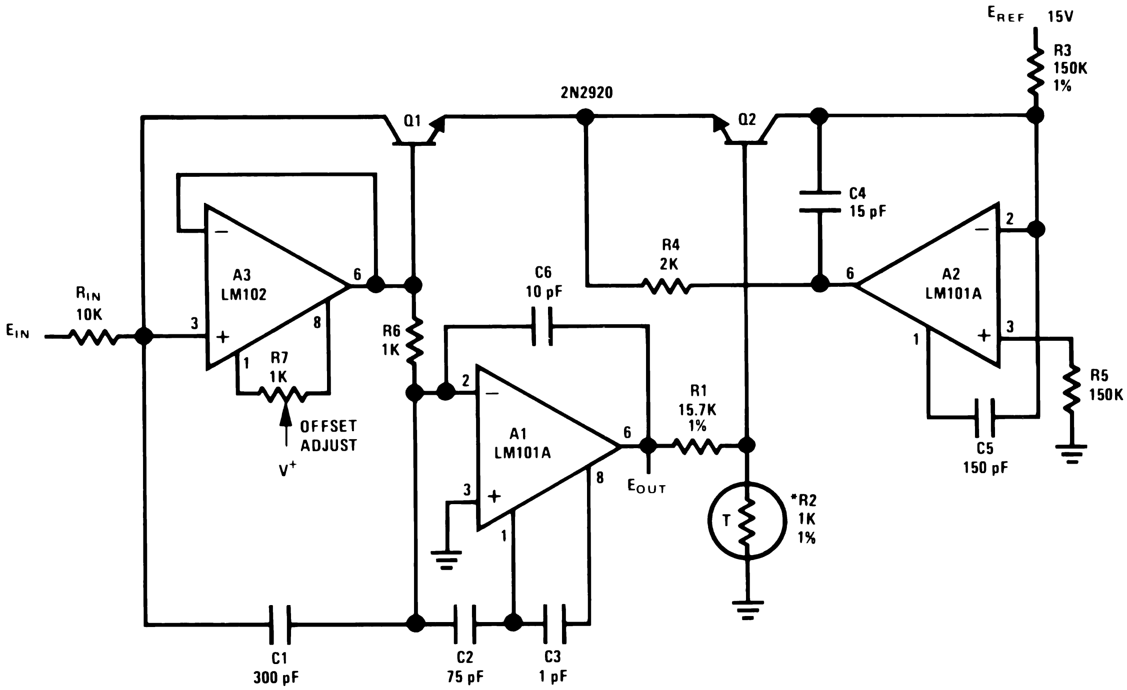
Cube Generator



00705788

Section 3 — Signal Processing (Continued)

Fast Log Generator

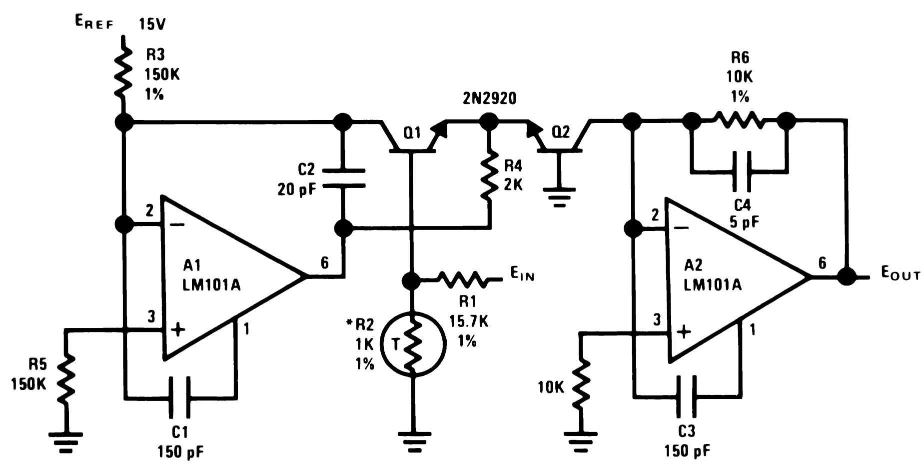


00705789

†1 kΩ (±1%) at 25˚C, +3500 ppm/˚C.

Available from Vishay Ultronix, Grand Junction, CO, Q81 Series.

Anti-Log Generator



00705790

†1 kΩ (±1%) at 25˚C, +3500 ppm/˚C.

Available from Vishay Ultronix, Grand Junction, CO, Q81 Series.

Notes

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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.

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