

LM394

Application Note 31 Op Amp Circuit Collection



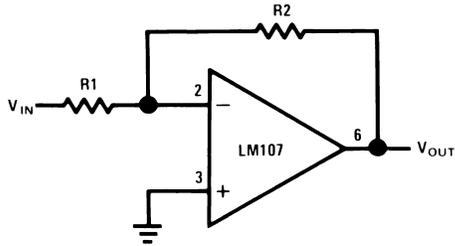
Literature Number: SNLA140A



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

Section 1—Basic Circuits

Inverting Amplifier

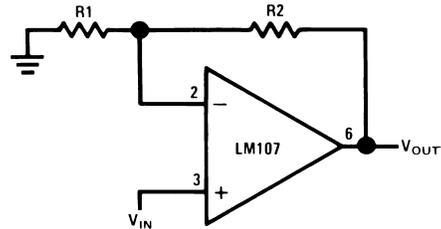


00705701

$$V_{OUT} = -\frac{R_2}{R_1} V_{IN}$$

$$R_{IN} = R_1$$

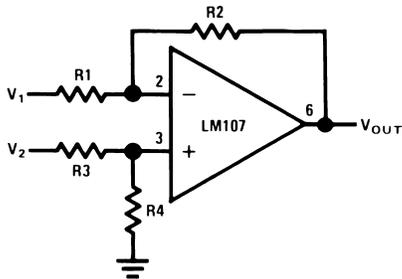
Non-Inverting Amplifier



00705702

$$V_{OUT} = \frac{R_1 + R_2}{R_1} V_{IN}$$

Difference Amplifier



00705703

$$V_{OUT} = \left(\frac{R_1 + R_2}{R_3 + R_4} \right) \frac{R_4}{R_1} V_2 - \frac{R_2}{R_1} V_1$$

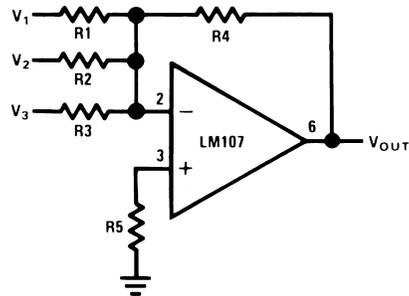
For $R_1 = R_3$ and $R_2 = R_4$

$$V_{OUT} = \frac{R_2}{R_1} (V_2 - V_1)$$

$$R_1 // R_2 = R_3 // R_4$$

For minimum offset error due to input bias current

Inverting Summing Amplifier



00705704

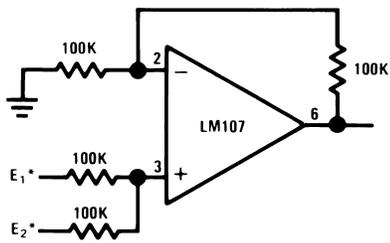
$$V_{OUT} = -R_4 \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right)$$

$$R_5 = R_1 // R_2 // R_3 // R_4$$

For minimum offset error due to input bias current

Section 1—Basic Circuits (Continued)

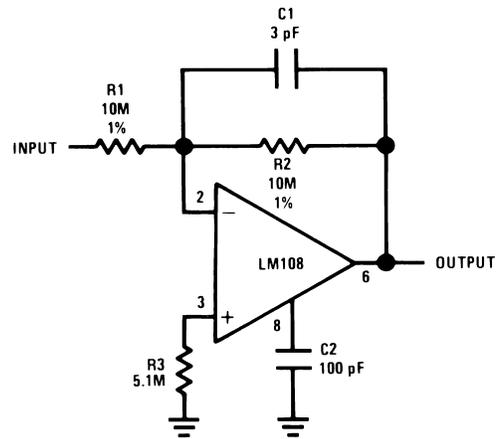
Non-Inverting Summing Amplifier



00705705

* $R_S = 1k$ for 1% accuracy

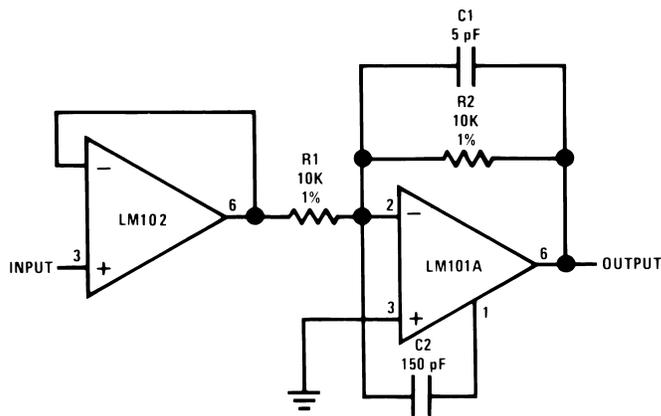
Inverting Amplifier with High Input Impedance



00705706

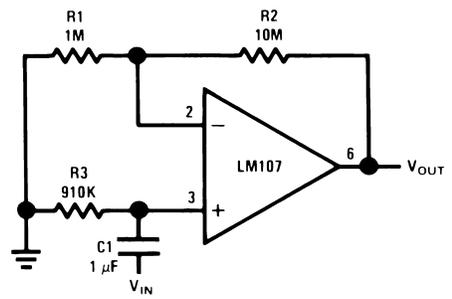
*Source Impedance less than 100k gives less than 1% gain error.

Fast Inverting Amplifier with High Input Impedance



00705707

Non-Inverting AC Amplifier



00705708

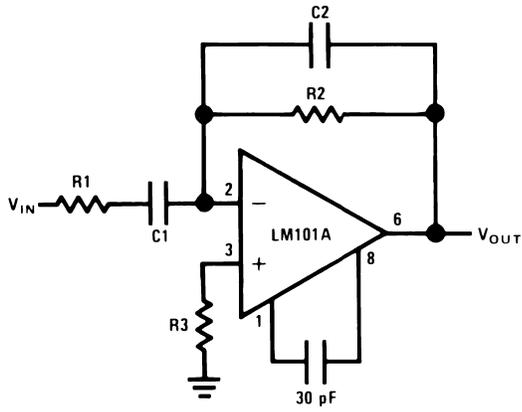
$$V_{OUT} = \frac{R1 + R2}{R1} V_{IN}$$

$$R_{IN} = R3$$

$$R3 = R1 // R2$$

Section 1—Basic Circuits (Continued)

Practical Differentiator



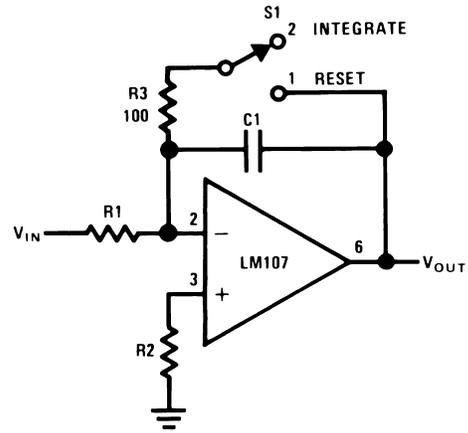
00705709

$$f_c = \frac{1}{2\pi R_2 C_1}$$

$$f_h = \frac{1}{2\pi R_1 C_1} = \frac{1}{2\pi R_2 C_2}$$

$$f_c < f_h < f_{\text{unity gain}}$$

Integrator



00705710

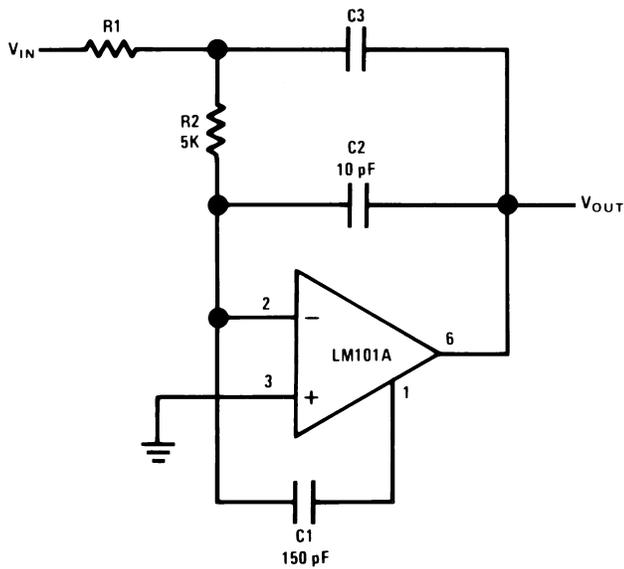
$$V_{OUT} = -\frac{1}{R_1 C_1} \int_{t_1}^{t_2} V_{IN} dt$$

$$f_c = \frac{1}{2\pi R_1 C_1}$$

$$R_1 = R_2$$

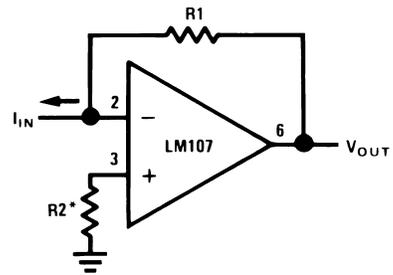
For minimum offset error due to input bias current

Fast Integrator



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Current to Voltage Converter



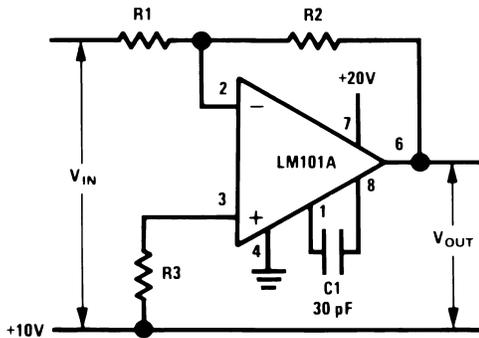
00705712

$$V_{OUT} = I_{IN} R_1$$

*For minimum error due to bias current $R_2 = R_1$

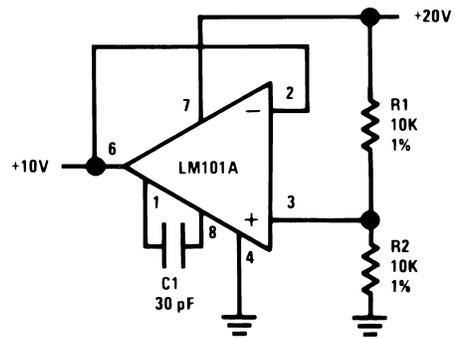
Section 1—Basic Circuits (Continued)

Circuit for Operating the LM101 without a Negative Supply



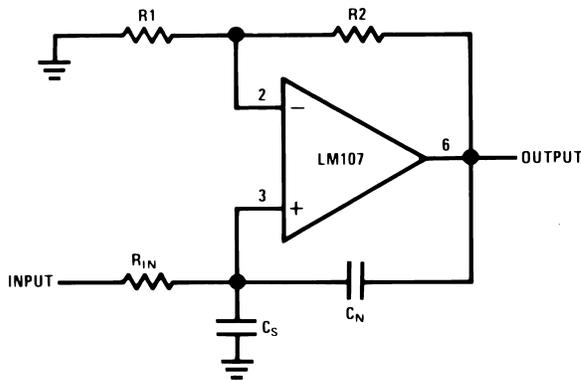
00705713

Circuit for Generating the Second Positive Voltage



00705714

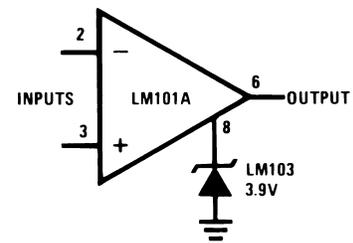
Neutralizing Input Capacitance to Optimize Response Time



00705715

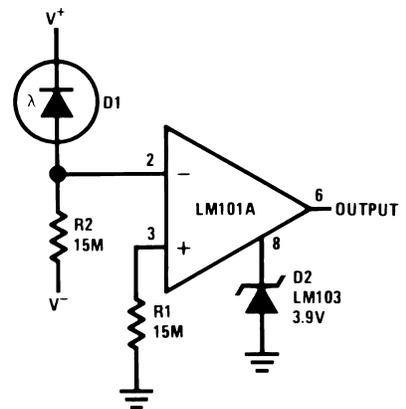
$$C_N \leq \frac{R_1}{R_2} C_S$$

Voltage Comparator for Driving DTL or TTL Integrated Circuits



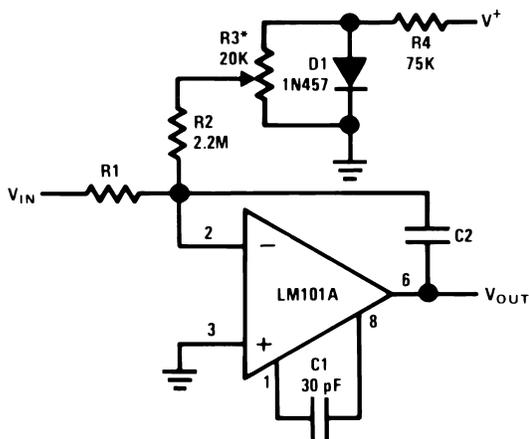
00705717

Threshold Detector for Photodiodes



00705718

Integrator with Bias Current Compensation



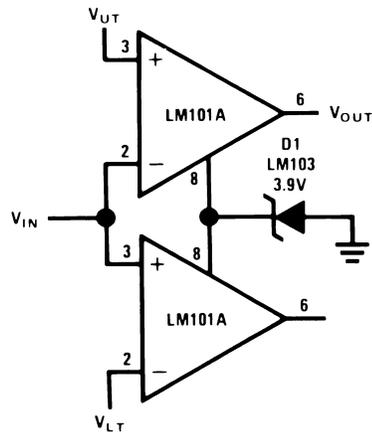
00705716

*Adjust for zero integrator drift.

Current drift typically 0.1 nA/°C over -55°C to 125°C temperature range.

Section 1—Basic Circuits (Continued)

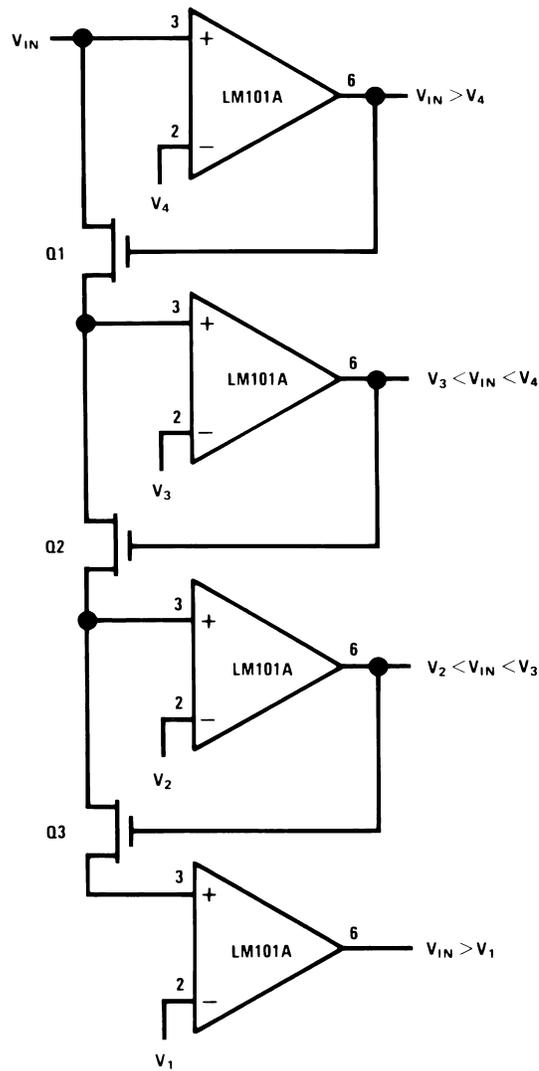
Double-Ended Limit Detector



00705719

$V_{OUT} = 4.6V$ for $V_{LT} \leq V_{IN} \leq V_{UT}$
 $V_{OUT} = 0V$ for $V_{IN} < V_{LT}$ or $V_{IN} > V_{UT}$

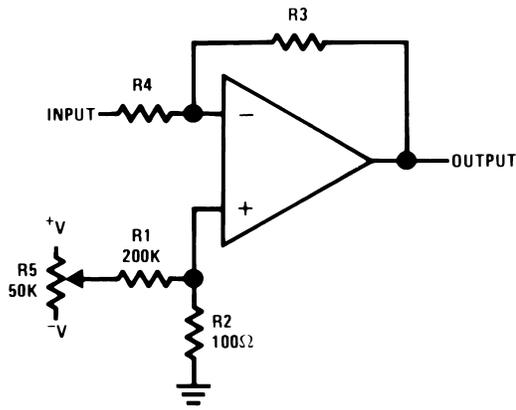
Multiple Aperture Window Discriminator



00705720

Section 1—Basic Circuits (Continued)

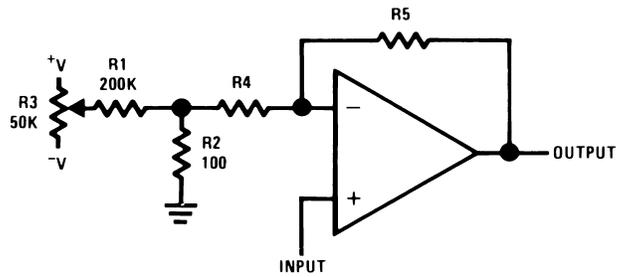
Offset Voltage Adjustment for Inverting Amplifiers Using Any Type of Feedback Element



00705721

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

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

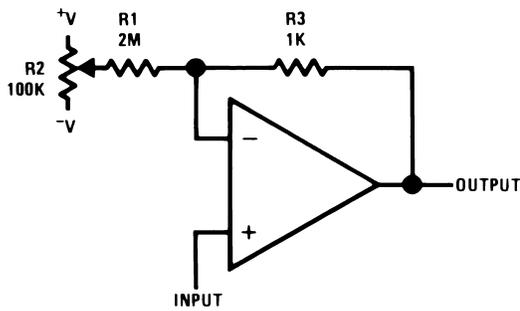


00705722

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

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

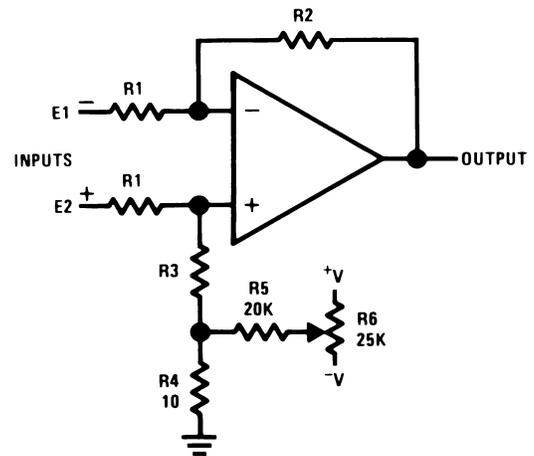
Offset Voltage Adjustment for Voltage Followers



00705723

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

Offset Voltage Adjustment for Differential Amplifiers



00705724

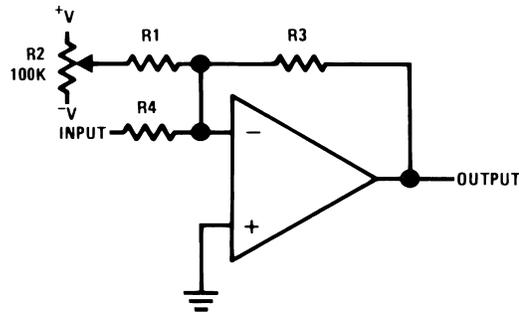
$$R2 = R3 + R4$$

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

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

Section 1—Basic Circuits (Continued)

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



00705725

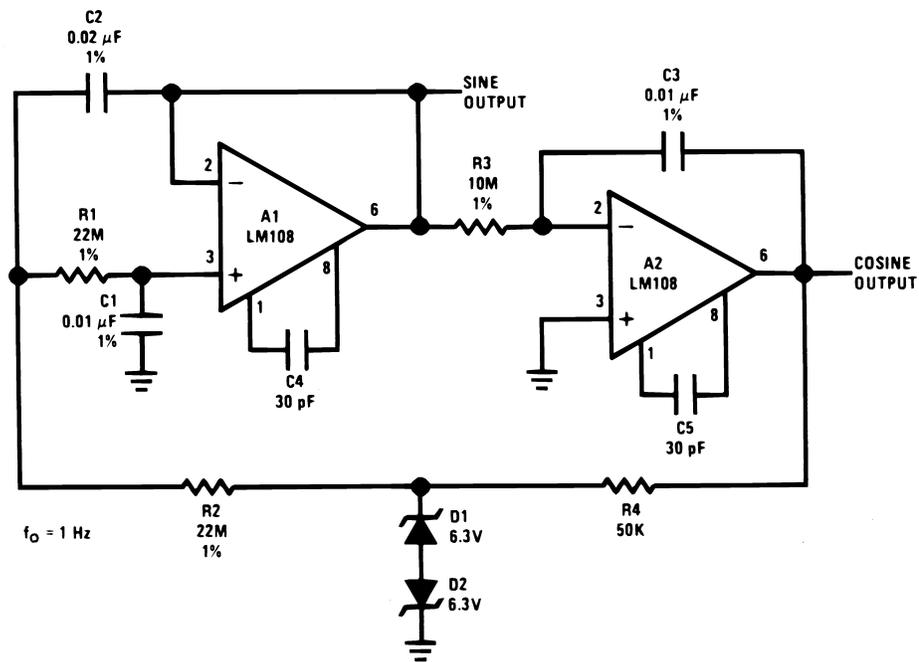
$$R1 = 2000 R3 // R4$$

$$R4 // R3 \leq 10 \text{ k}\Omega$$

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

Section 2 — Signal Generation

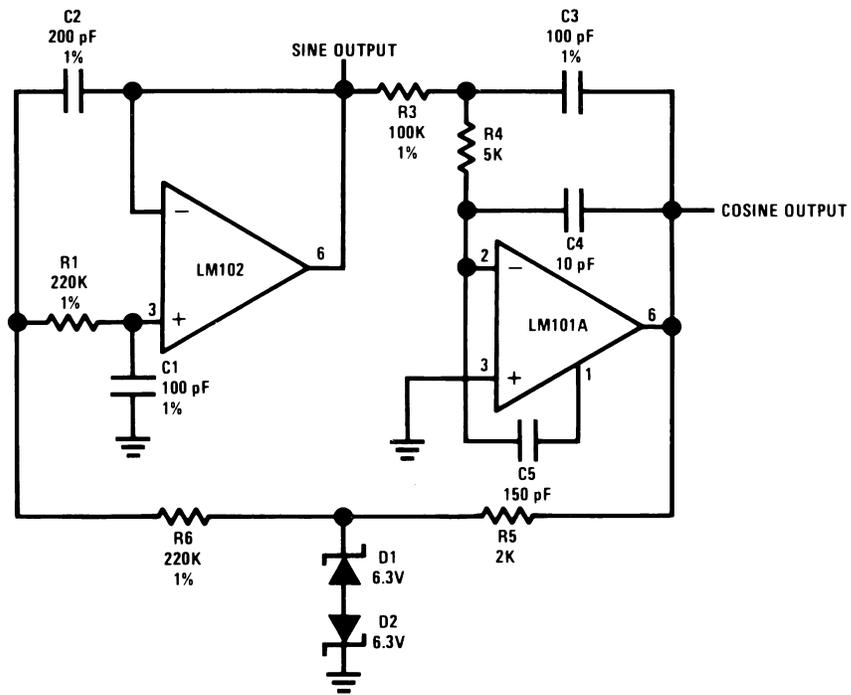
Low Frequency Sine Wave Generator with Quadrature Output



00705726

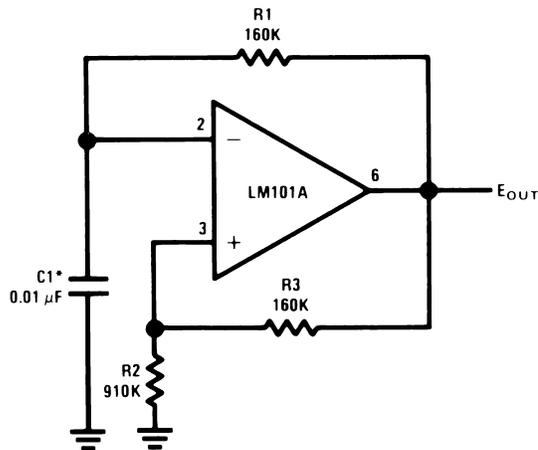
Section 2 — Signal Generation (Continued)

High Frequency Sine Wave Generator with Quadrature Output



00705727

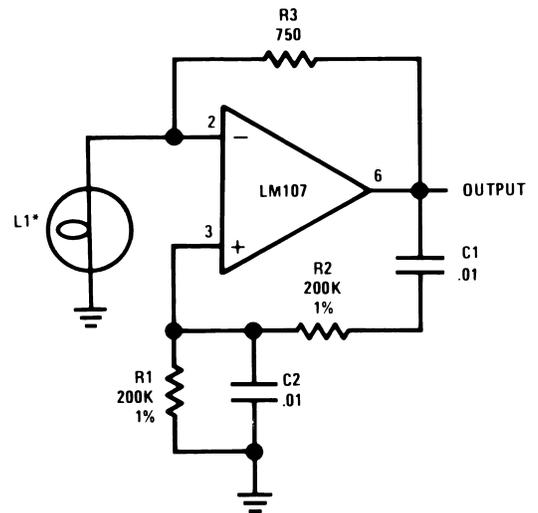
Free-Running Multivibrator



*Chosen for oscillation at 100 Hz

00705728

Wein Bridge Sine Wave Oscillator



00705729

$$R1 = R2$$

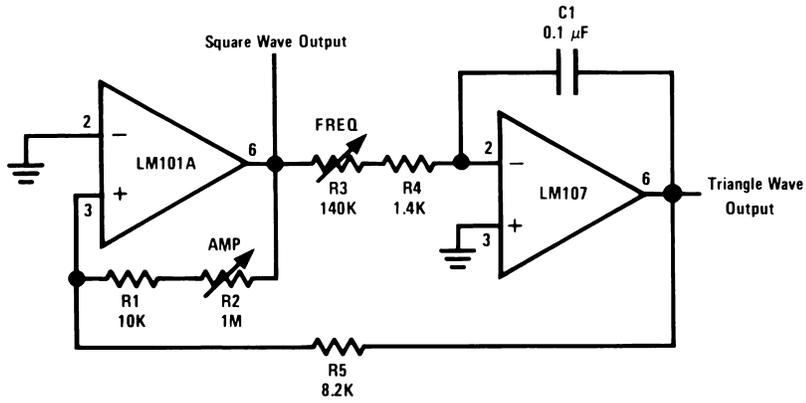
$$C1 = C2$$

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

*Eldema 1869 10V, 14 mA Bulb

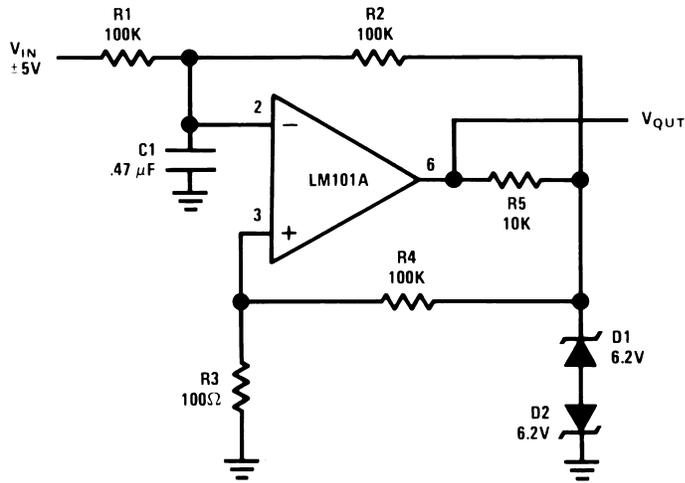
Section 2 — Signal Generation (Continued)

Function Generator



00705730

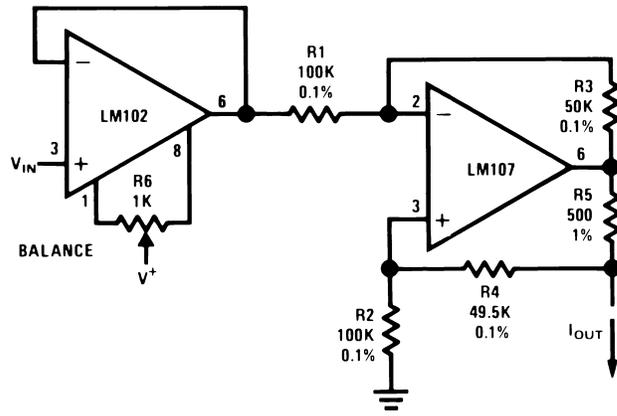
Pulse Width Modulator



00705731

Section 2 — Signal Generation (Continued)

Bilateral Current Source



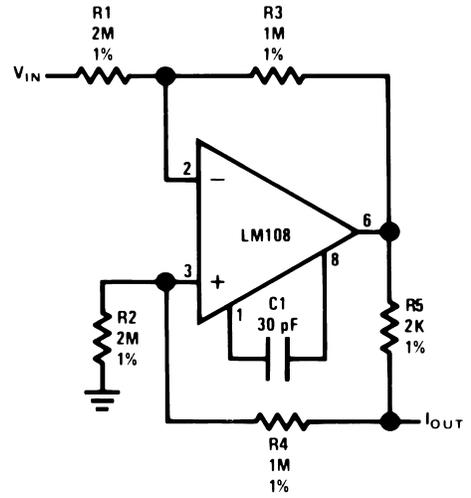
00705732

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

$$R3 = R4 + R5$$

$$R1 = R2$$

Bilateral Current Source



00705733

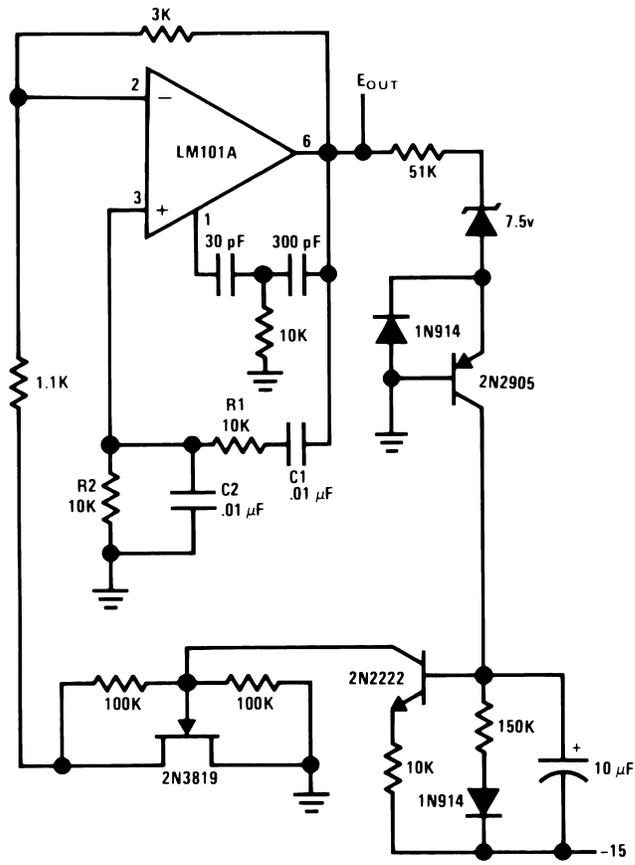
$$I_{OUT} = \frac{R3 V_{IN}}{R1 R5}$$

$$R3 = R4 + R5$$

$$R1 = R2$$

Section 2 — Signal Generation (Continued)

Wein Bridge Oscillator with FET Amplitude Stabilization



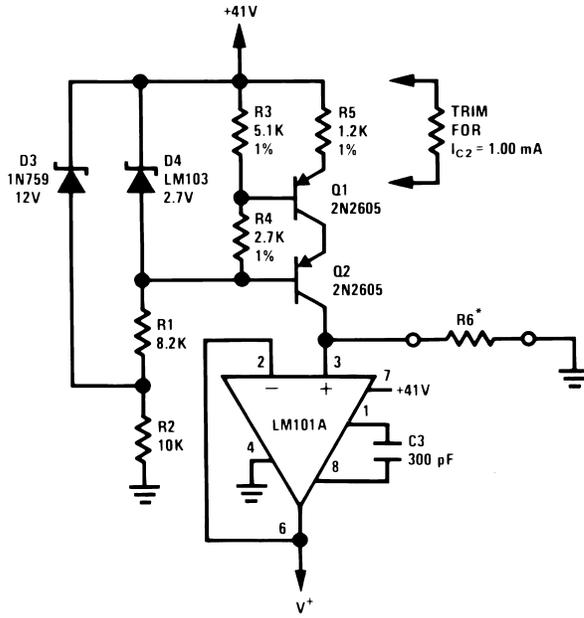
00705734

R1 = R2
 C1 = C2

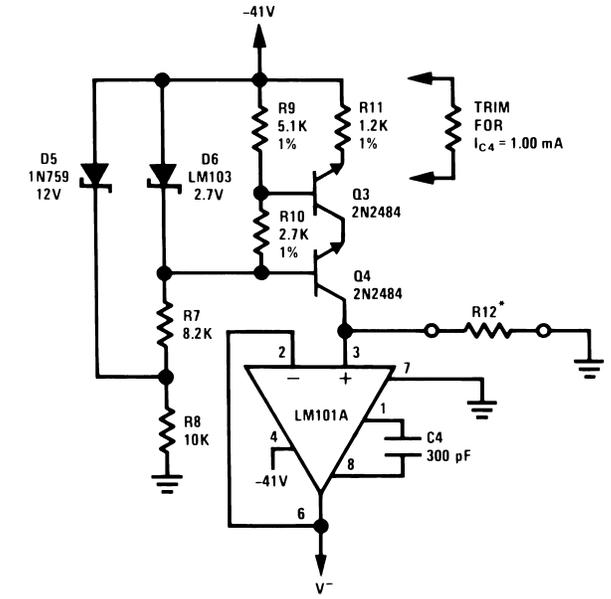
$$f = \frac{1}{2\pi R1 C1}$$

Section 2 — Signal Generation (Continued)

Low Power Supply for Integrated Circuit Testing



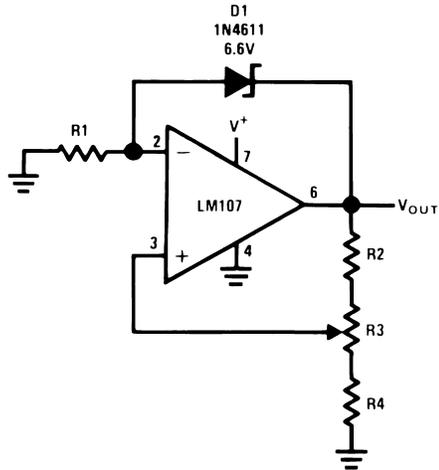
00705735



00705791

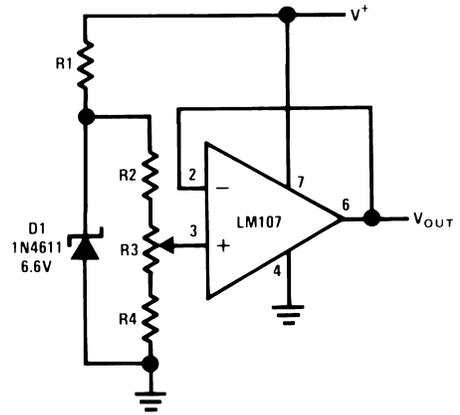
* $V_{OUT} = 1V/k\Omega$

Positive Voltage Reference



00705736

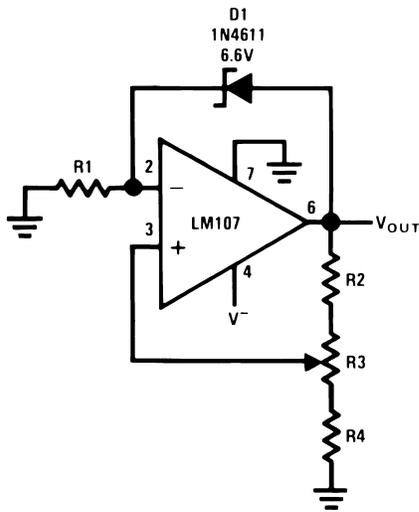
Positive Voltage Reference



00705737

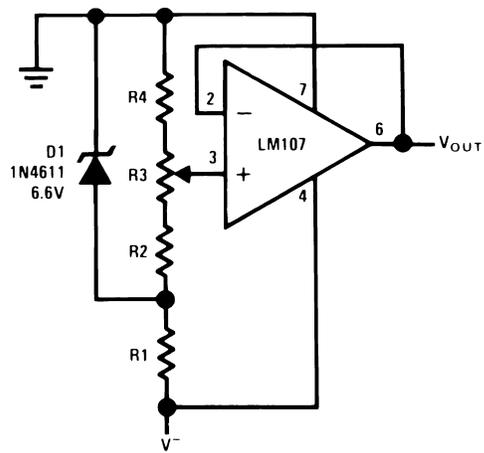
Section 2 — Signal Generation (Continued)

Negative Voltage Reference



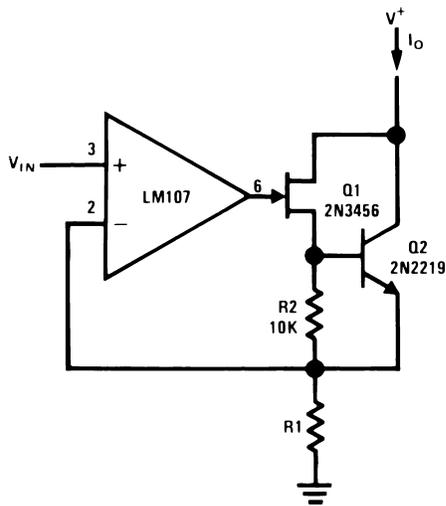
00705738

Negative Voltage Reference



00705739

Precision Current Sink

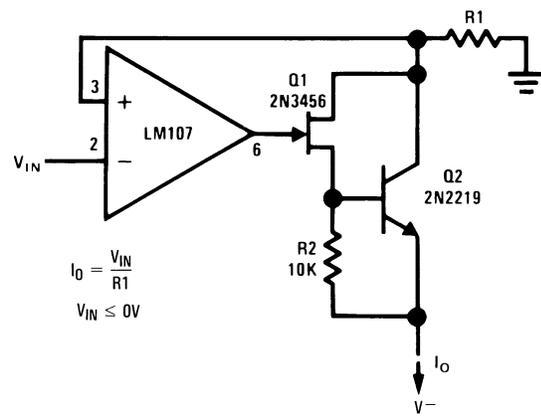


00705740

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

$$V_{IN} \geq 0V$$

Precision Current Source



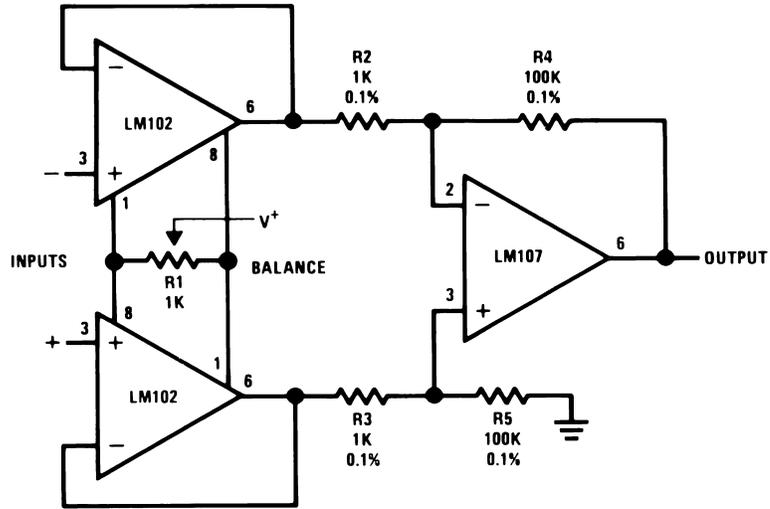
$$I_o = \frac{V_{IN}}{R1}$$

$$V_{IN} \leq 0V$$

00705741

Section 3 — Signal Processing

Differential-Input Instrumentation Amplifier

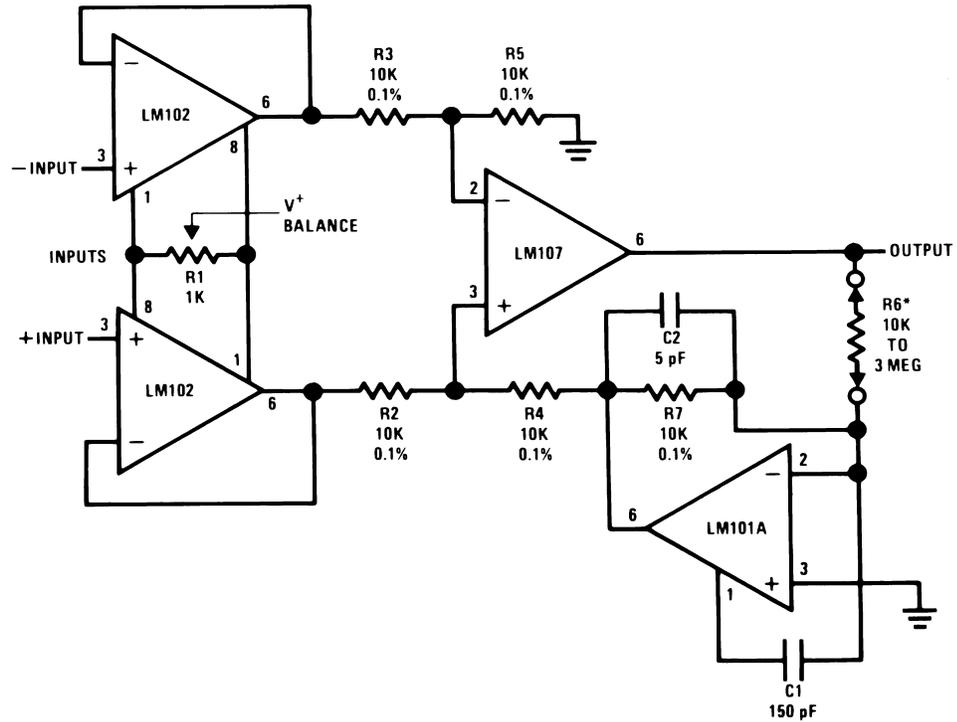


00705742

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

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

Variable Gain, Differential-Input Instrumentation Amplifier

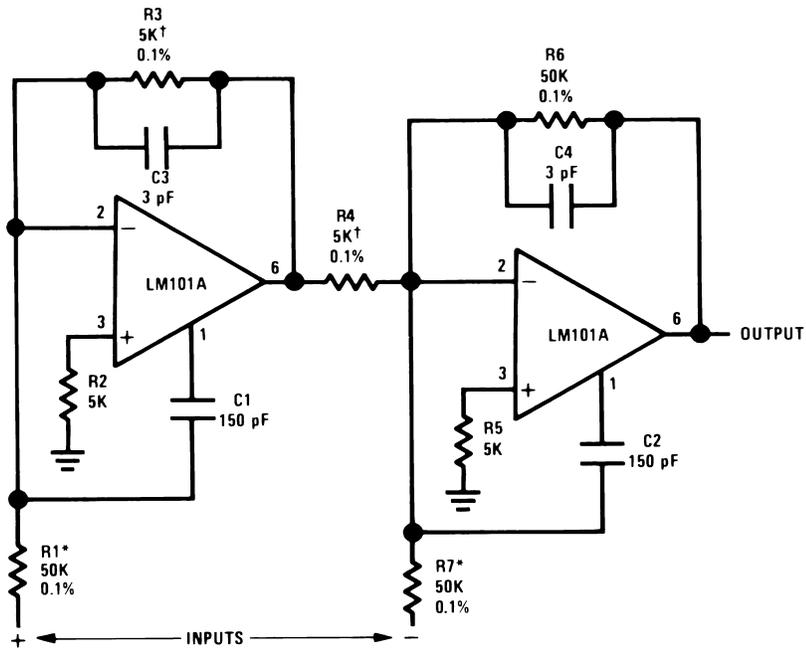


00705743

*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.

$$R1 = R5 = 10R2$$

$$R2 = R3$$

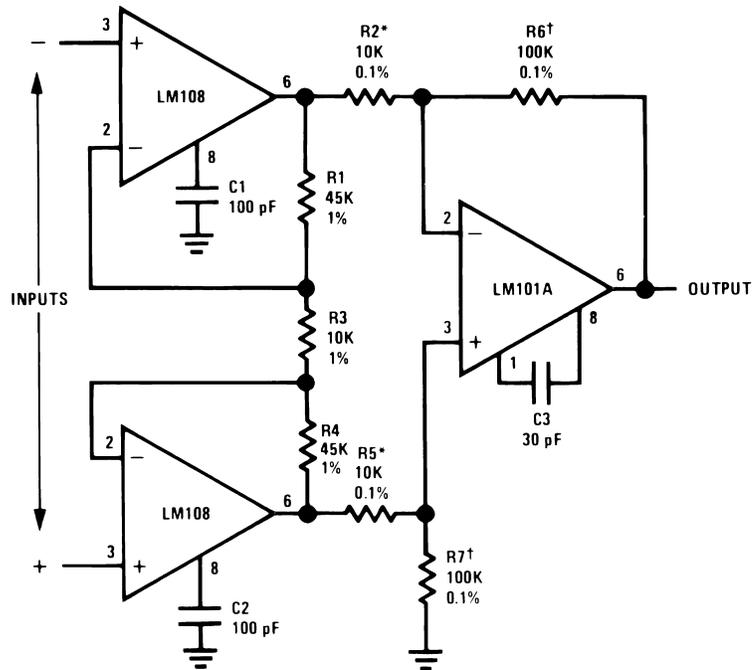
$$R3 = R4$$

$$R1 = R6 = 10R3$$

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

Section 3 — Signal Processing (Continued)

Instrumentation Amplifier with ±10 Volt Common Mode Range

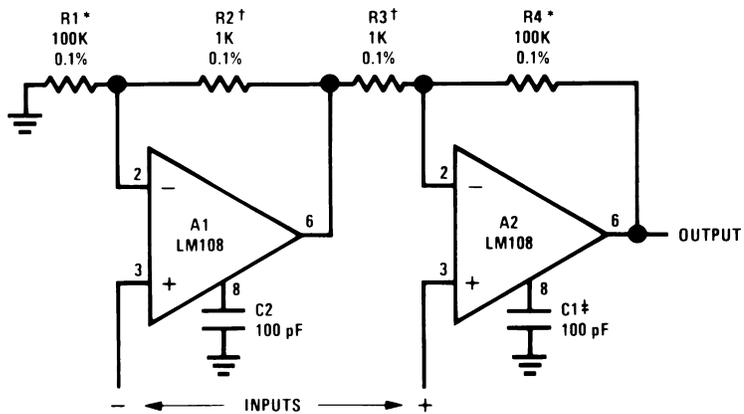


00705745

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

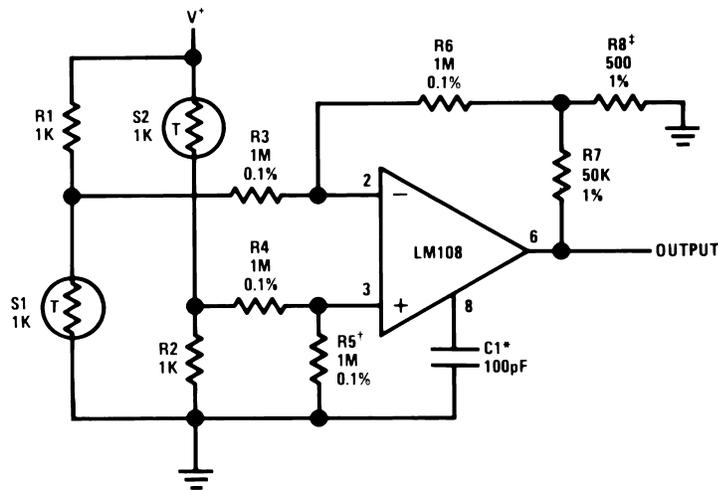
$$A_v = 1 + \frac{R1}{R2}$$

*†Matching Determines CMRR

‡May be deleted to maximize bandwidth

Section 3 — Signal Processing (Continued)

Bridge Amplifier with Low Noise Compensation



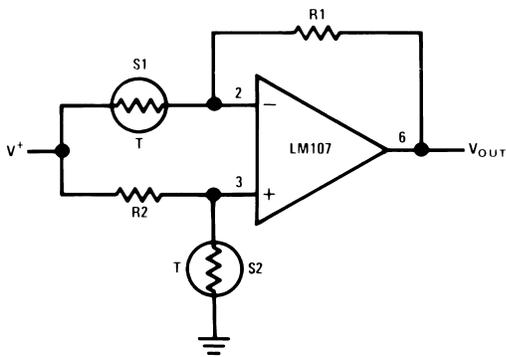
00705747

*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

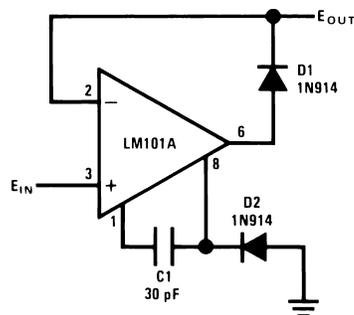


00705748

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

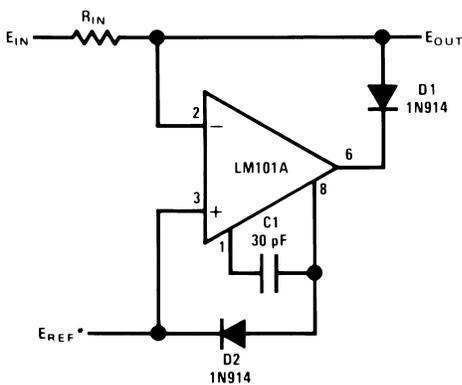
$$V_{OUT} = V^+ \left(1 - \frac{R1}{R_{S1}} \right)$$

Precision Diode



00705749

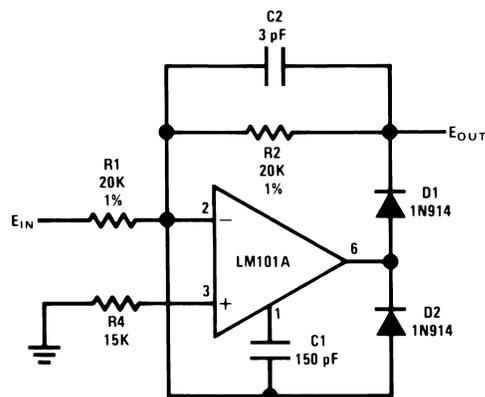
Precision Clamp



00705750

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

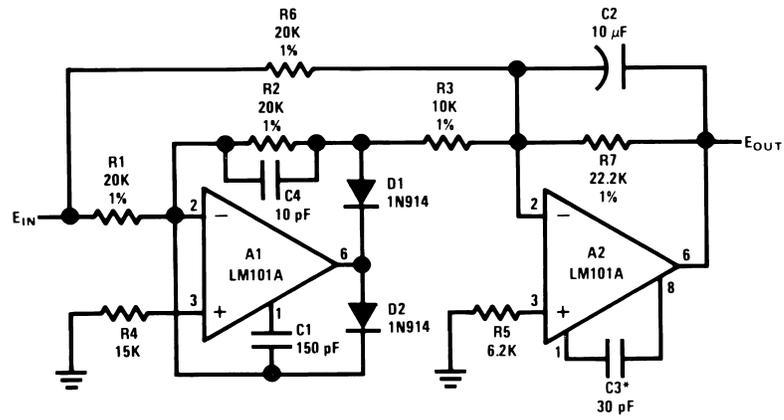
Fast Half Wave Rectifier



00705751

Section 3 — Signal Processing (Continued)

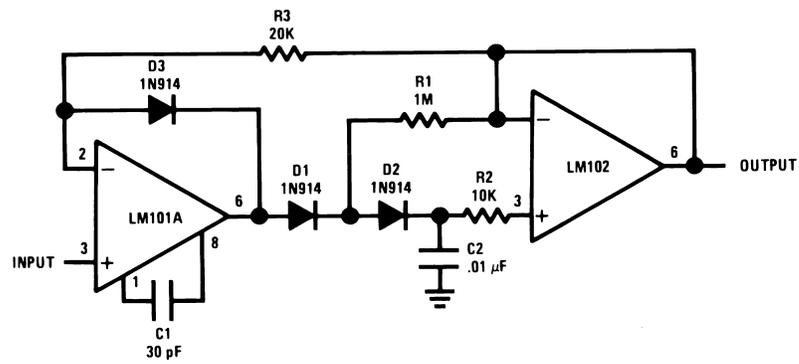
Precision AC to DC Converter



00705752

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

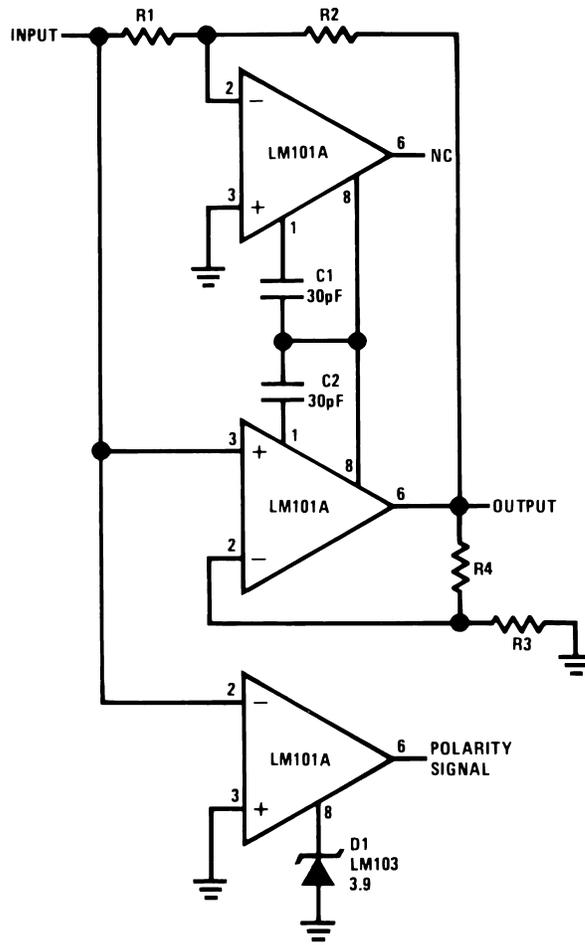
Low Drift Peak Detector



00705753

Section 3 — Signal Processing (Continued)

Absolute Value Amplifier with Polarity Detector

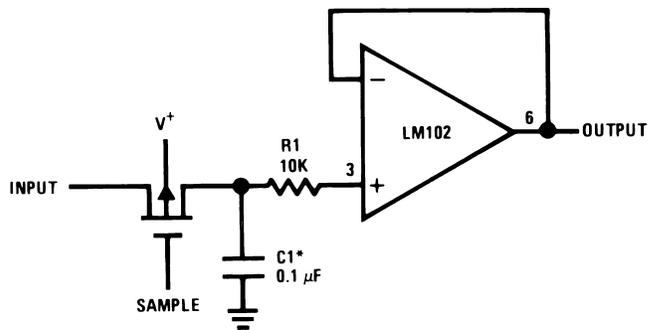


00705754

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

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

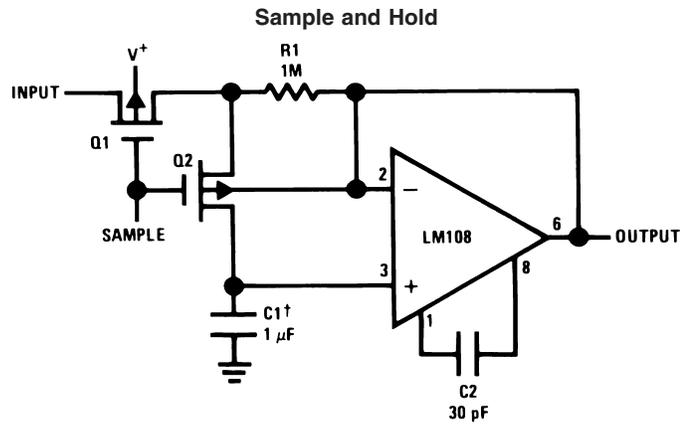
Sample and Hold



00705755

*Polycarbonate-dielectric capacitor

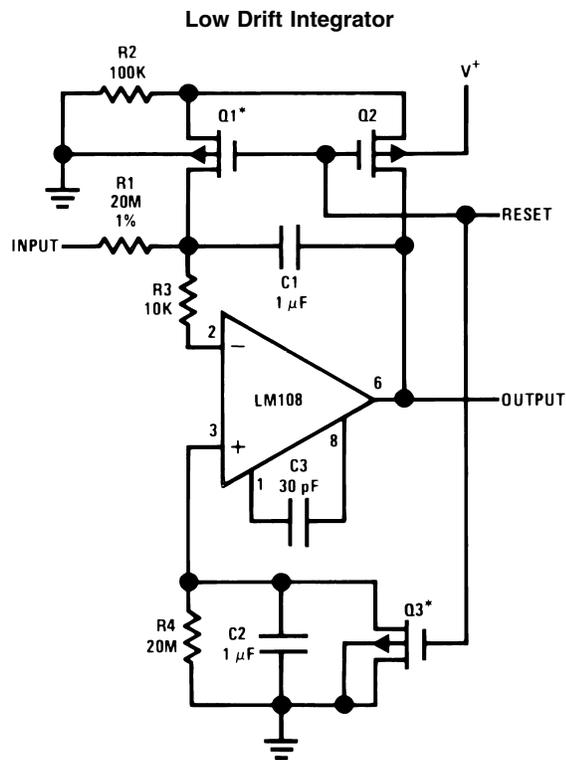
Section 3 — Signal Processing (Continued)



00705756

*Worst case drift less than 2.5 mV/sec

†Teflon, Polyethylene or Polycarbonate Dielectric Capacitor

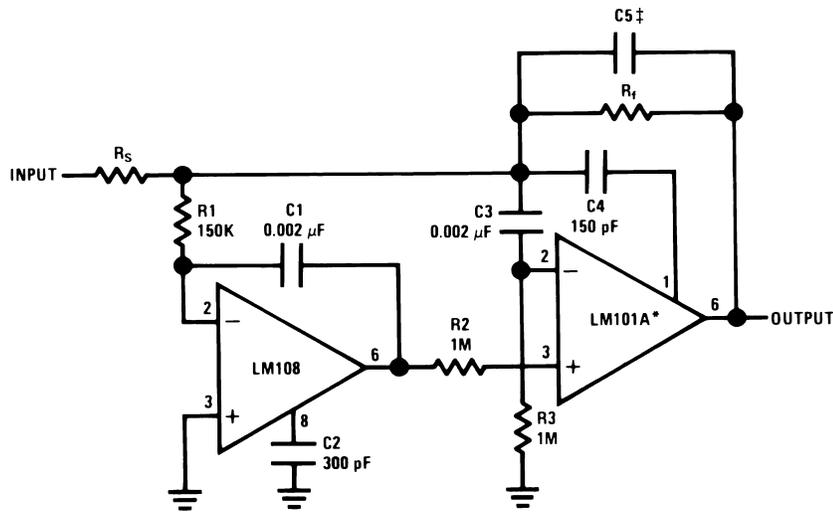


00705757

*Q1 and Q3 should not have internal gate-protection diodes.
Worst case drift less than 500 μ V/sec over -55°C to $+125^{\circ}\text{C}$.

Section 3 — Signal Processing (Continued)

Fast† Summing Amplifier with Low Input Current



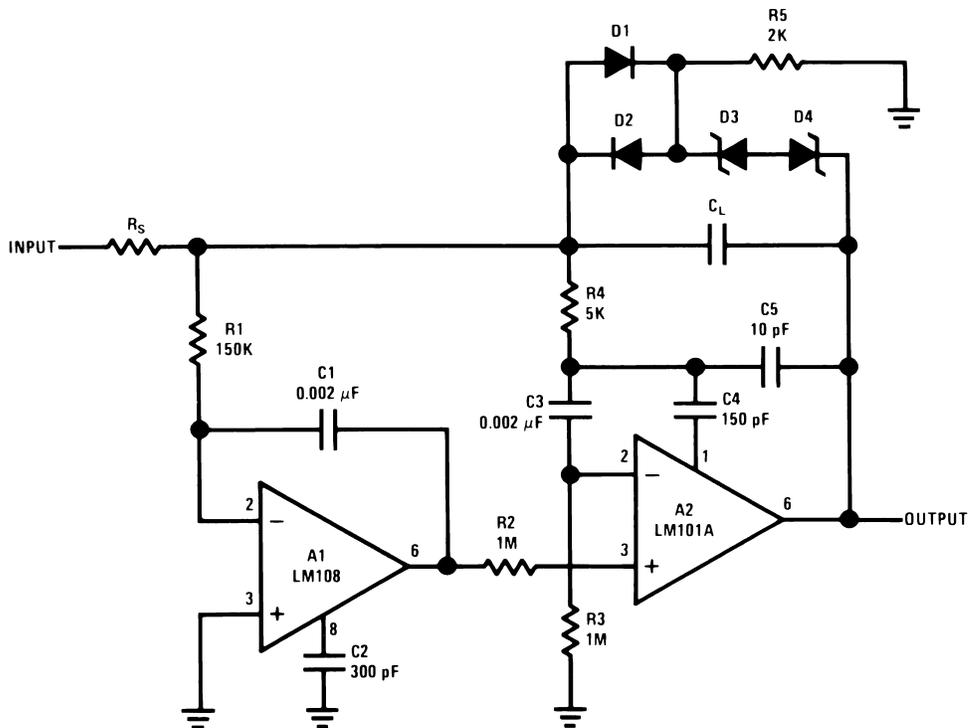
00705758

*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

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

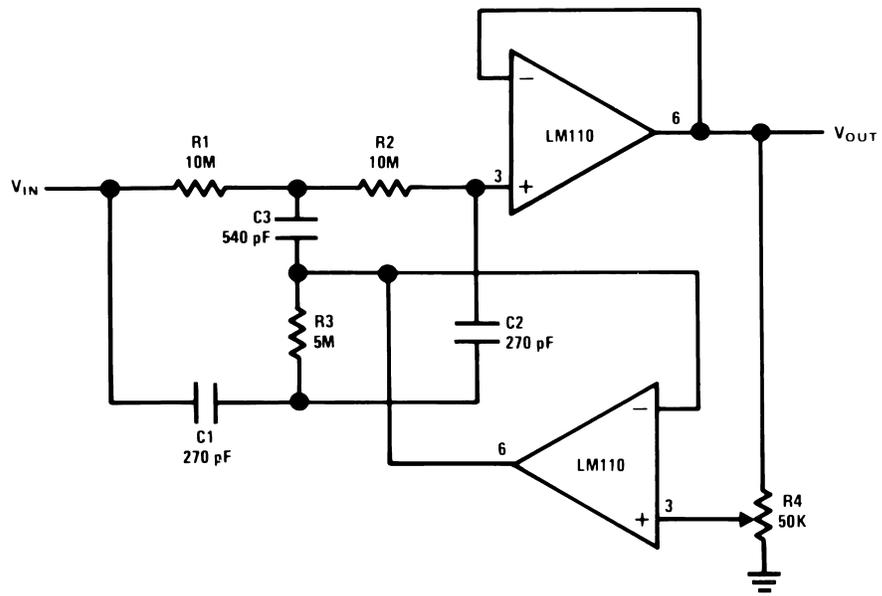
Fast Integrator with Low Input Current



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Section 3 — Signal Processing (Continued)

Adjustable Q Notch Filter



00705760

$$f_0 = \frac{1}{2\pi R1 C1}$$

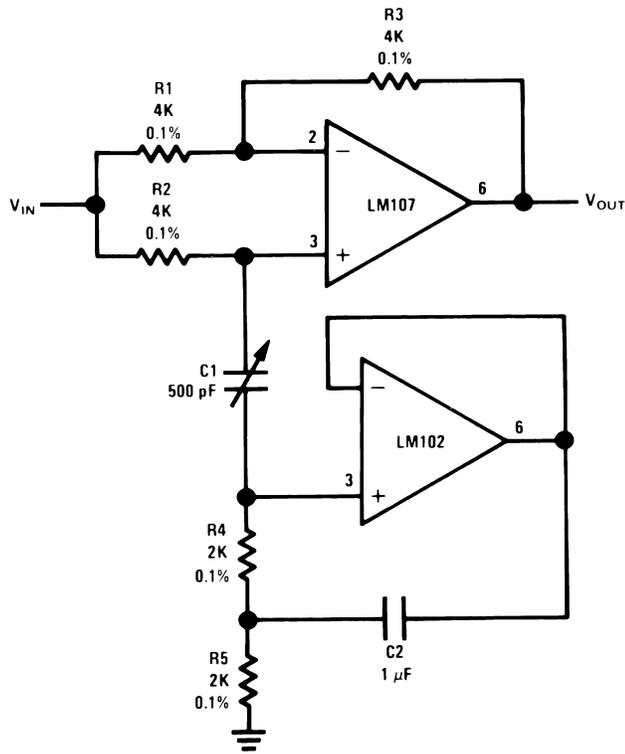
$$= 60 \text{ Hz}$$

$$R1 = R2 = R3$$

$$C1 = C2 = C23$$

Section 3 — Signal Processing (Continued)

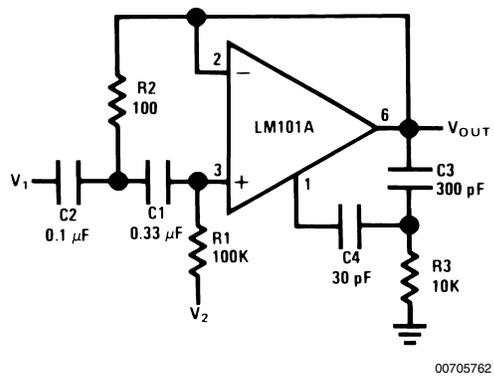
Easily Tuned Notch Filter



00705761

$R4 = R5$
 $R1 = R3$
 $R4 = \frac{1}{2} R1$
 $f_o = \frac{1}{2\pi R4 \sqrt{C1 C2}}$

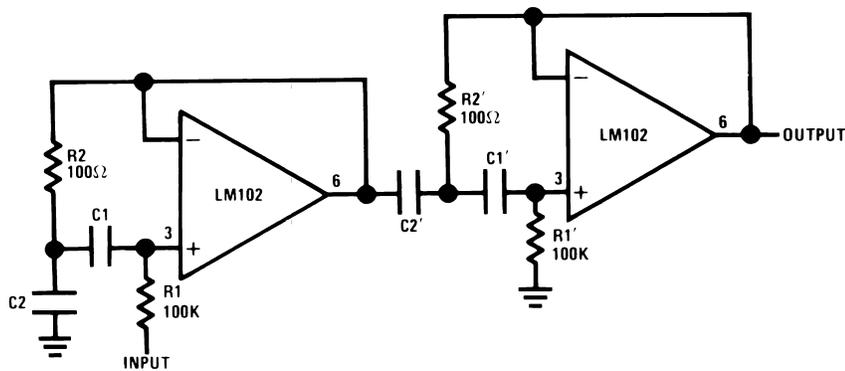
Tuned Circuit



00705762

$$f_o = \frac{1}{2\pi \sqrt{R1 R2 C1 C2}}$$

Two-Stage Tuned Circuit

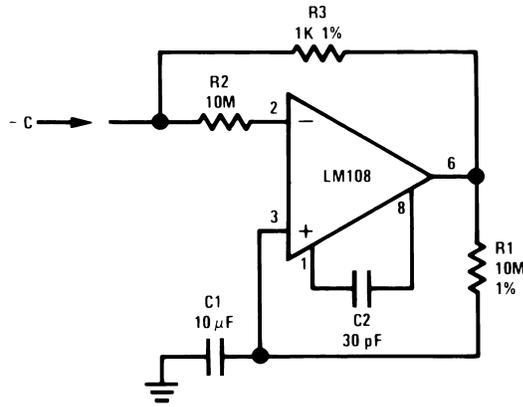


00705763

$$f_o = \frac{1}{2\pi \sqrt{R1 R2 C1 C2}}$$

Section 3 — Signal Processing (Continued)

Negative Capacitance Multiplier



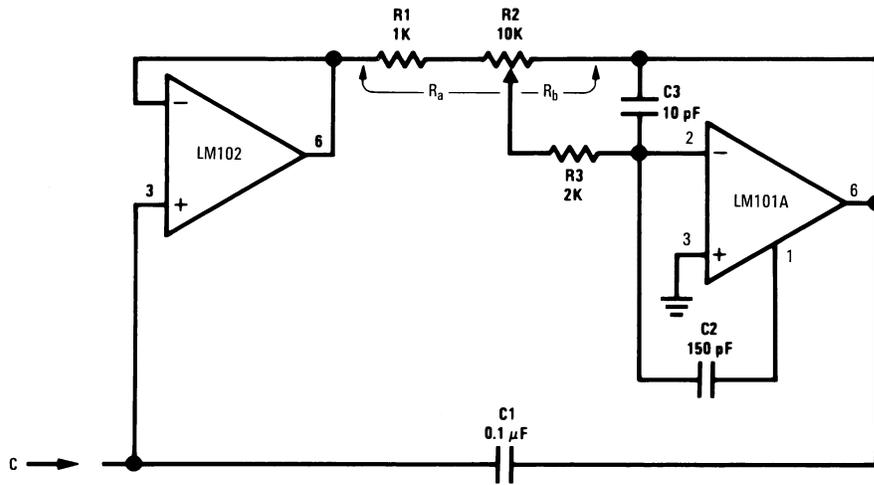
00705765

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

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

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

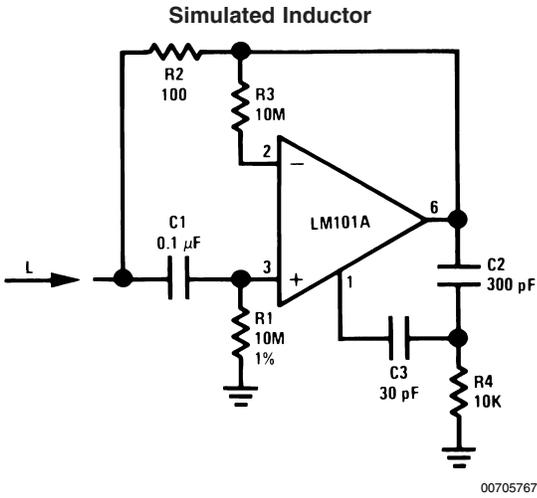
Variable Capacitance Multiplier



00705766

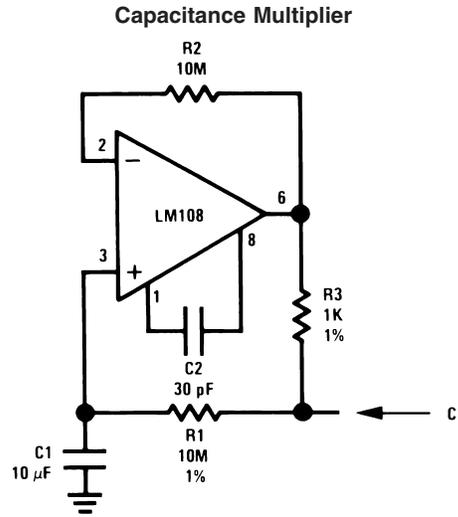
$$C = \left(1 + \frac{R_b}{R_a} \right) C_1$$

Section 3 — Signal Processing (Continued)



$L \geq R1 R2 C1$
 $R_S = R2$
 $R_P = R1$

00705767

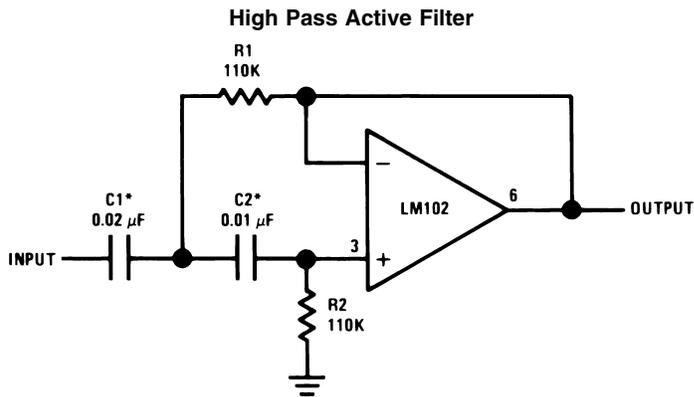


00705768

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

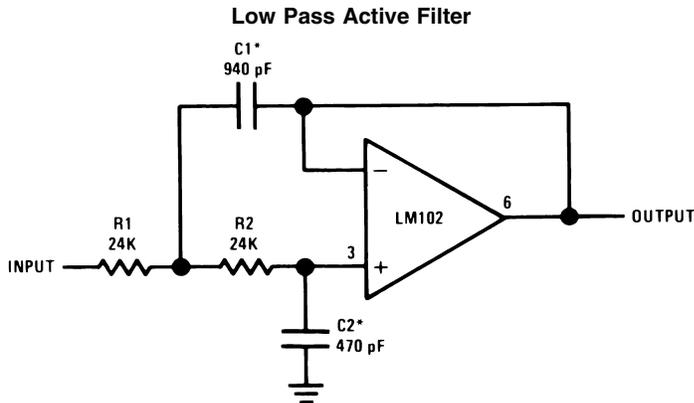
$$I_L = \frac{V_{os} + I_{os} R1}{R3}$$

$$R_S = R3$$



00705771

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

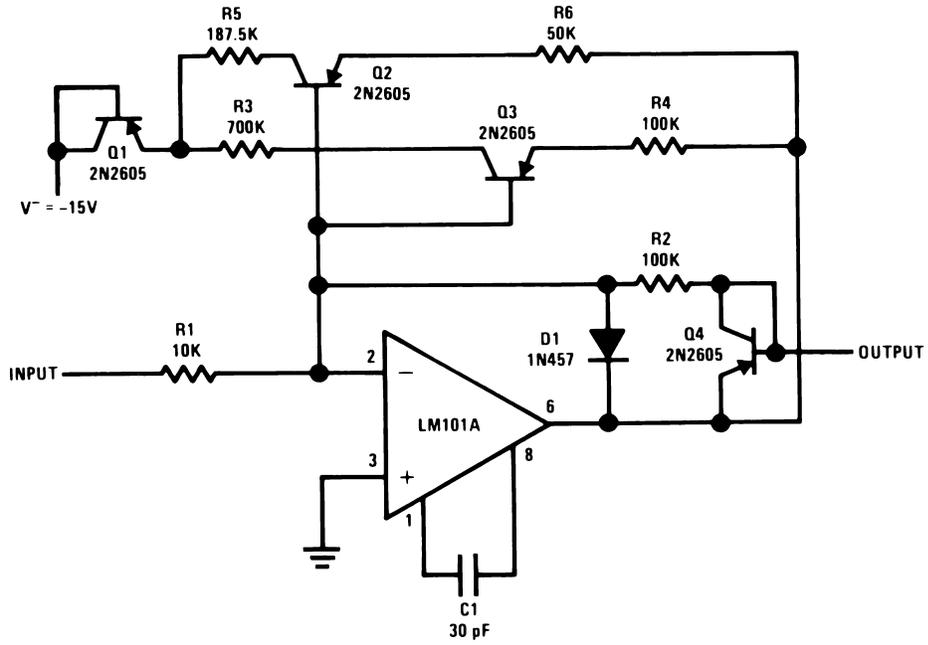


00705772

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

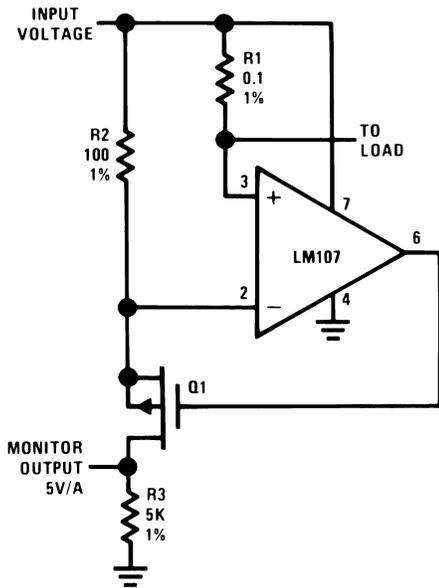
Section 3 — Signal Processing (Continued)

Nonlinear Operational Amplifier with Temperature Compensated Breakpoints



00705773

Current Monitor

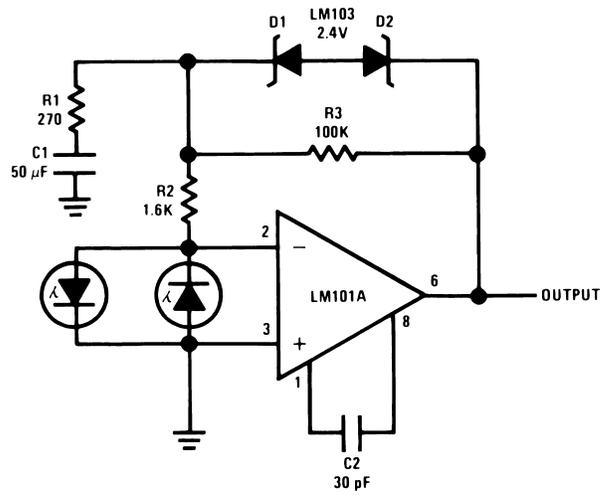


00705774

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

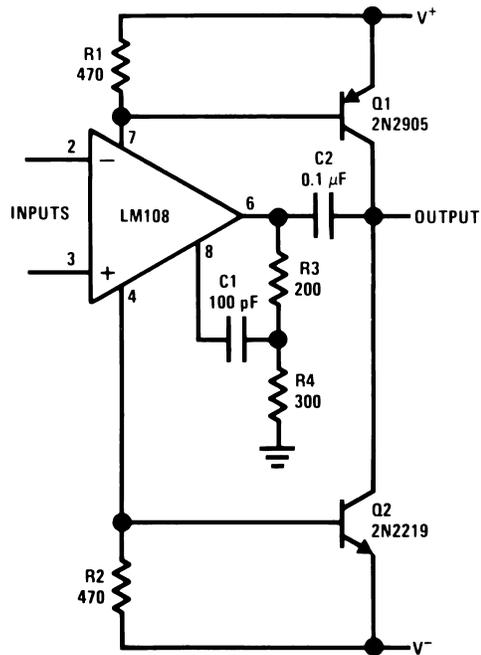
Section 3 — Signal Processing (Continued)

Saturating Servo Preamplifier with Rate Feedback



00705775

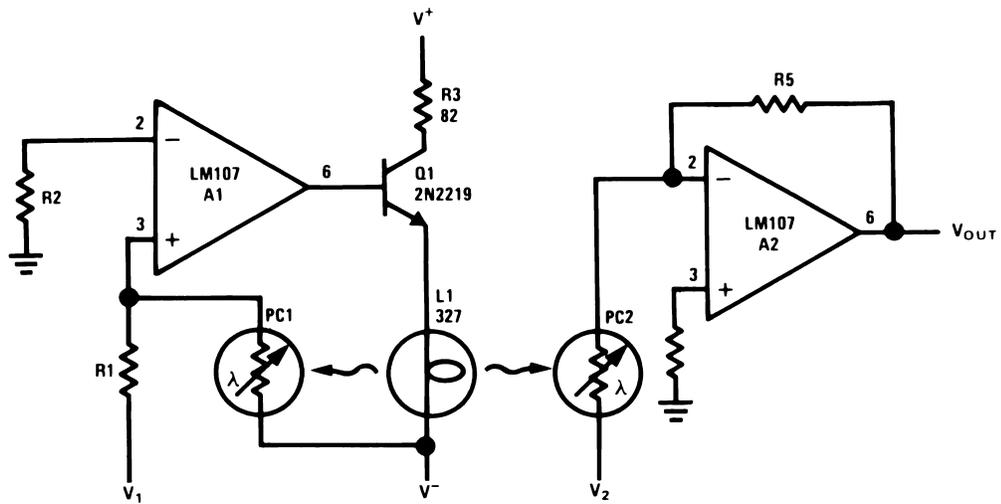
Power Booster



00705776

Section 3 — Signal Processing (Continued)

Analog Multiplier



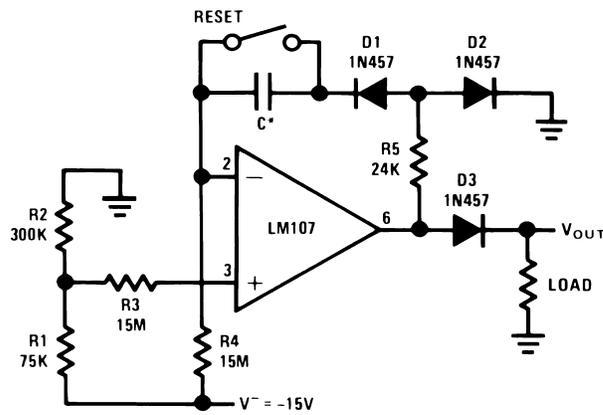
00705777

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

$$V1 \geq 0$$

$$V_{OUT} = \frac{V1 V2}{10}$$

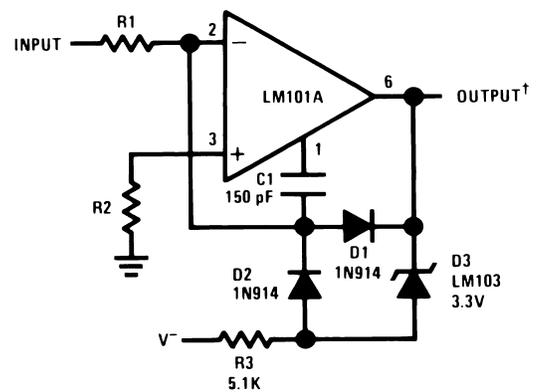
Long Interval Timer



*Low leakage -0.017 μF per second delay

00705778

Fast Zero Crossing Detector

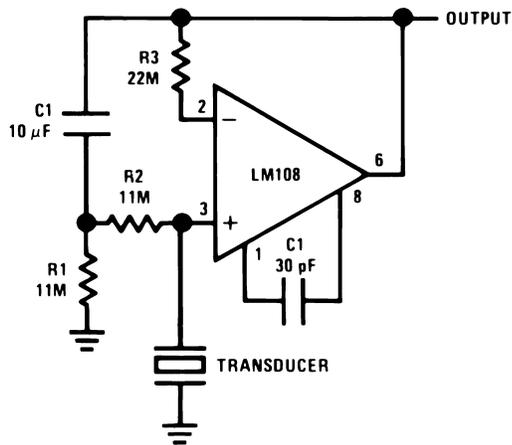


00705779

Propagation delay approximately 200 ns
 †DTL or TTL fanout of three.
 Minimize stray capacitance
 Pin 8

Section 3 — Signal Processing (Continued)

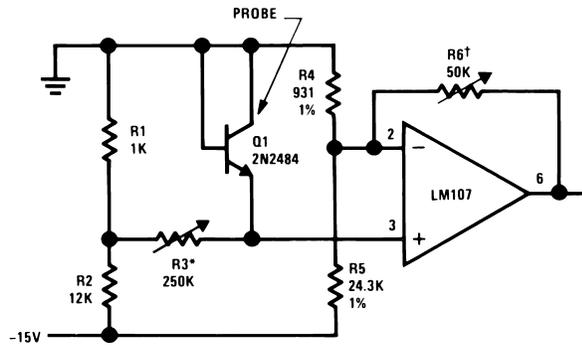
Amplifier for Piezoelectric Transducer



00705780

Low frequency cutoff = $R1 C1$

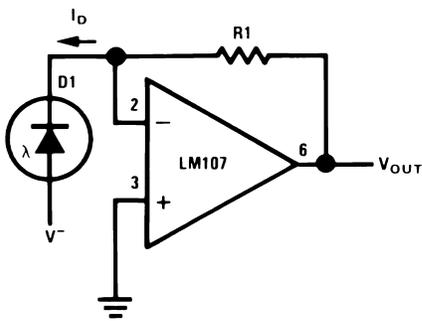
Temperature Probe



00705781

*Set for 0V at 0°C
 †Adjust for 100 mV/°C

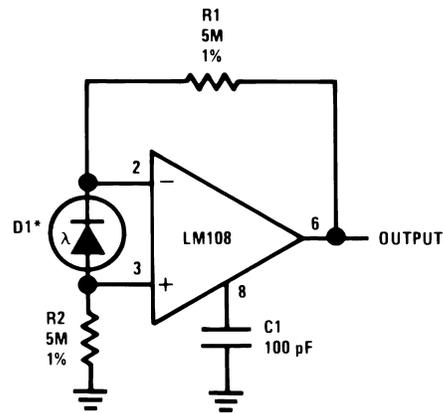
Photodiode Amplifier



00705782

$V_{OUT} = R1 I_D$

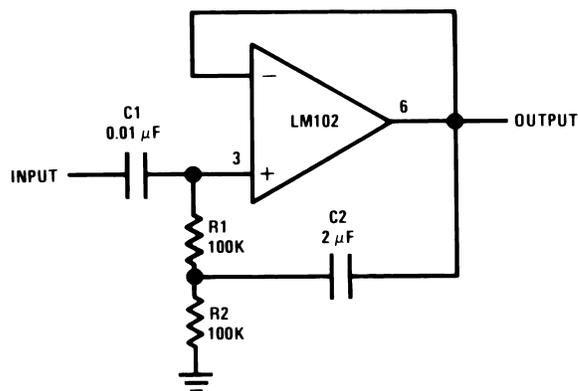
Photodiode Amplifier



00705783

$V_{OUT} = 10 V/\mu A$
 *Operating photodiode with less than 3 mV across it eliminates leakage currents.

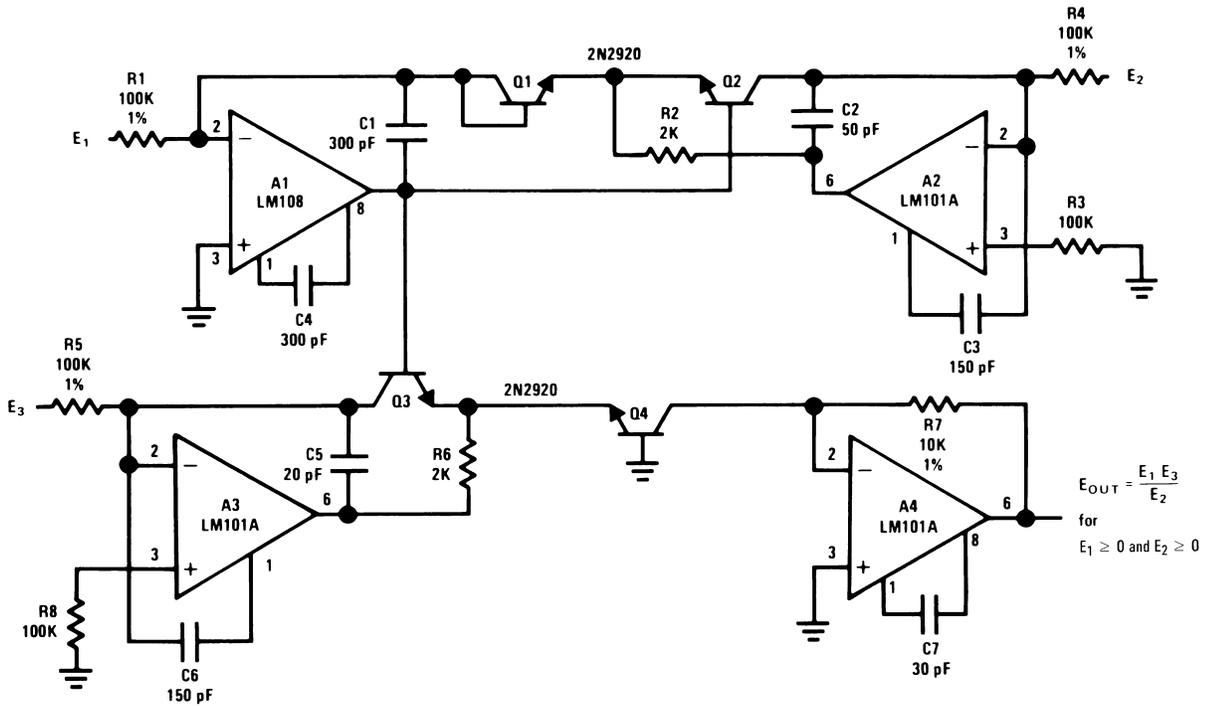
High Input Impedance AC Follower



00705784

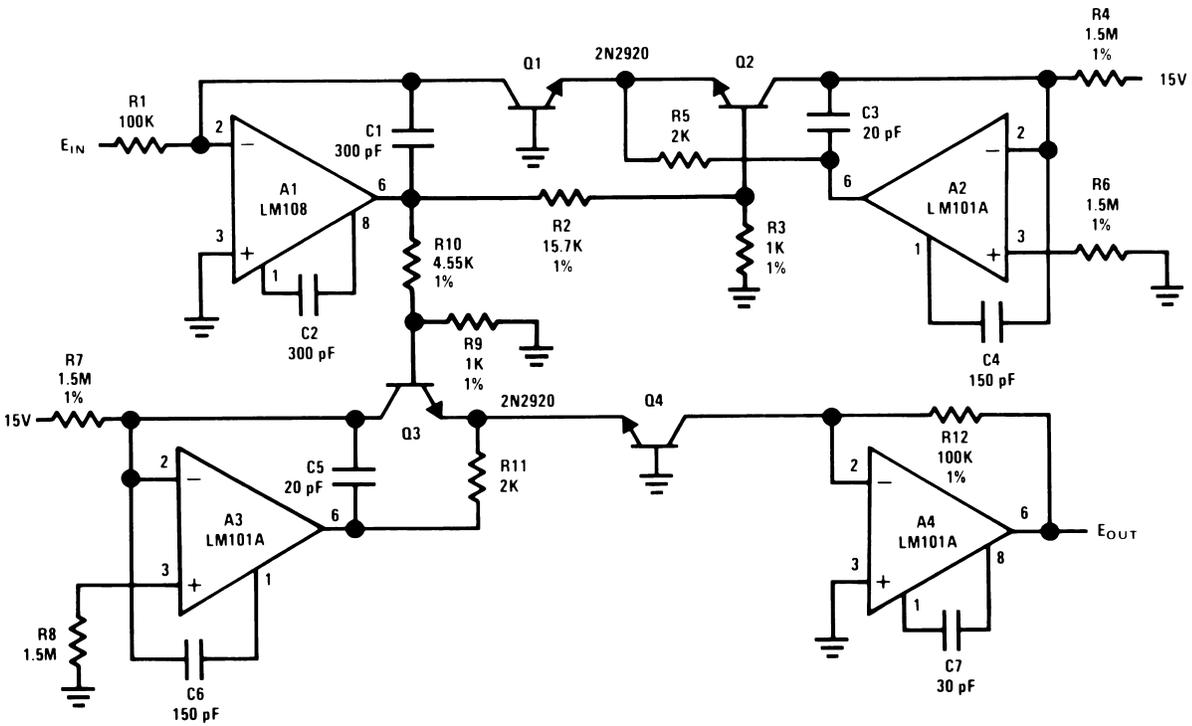
Section 3 — Signal Processing (Continued)

Multiplier/Divider



00705787

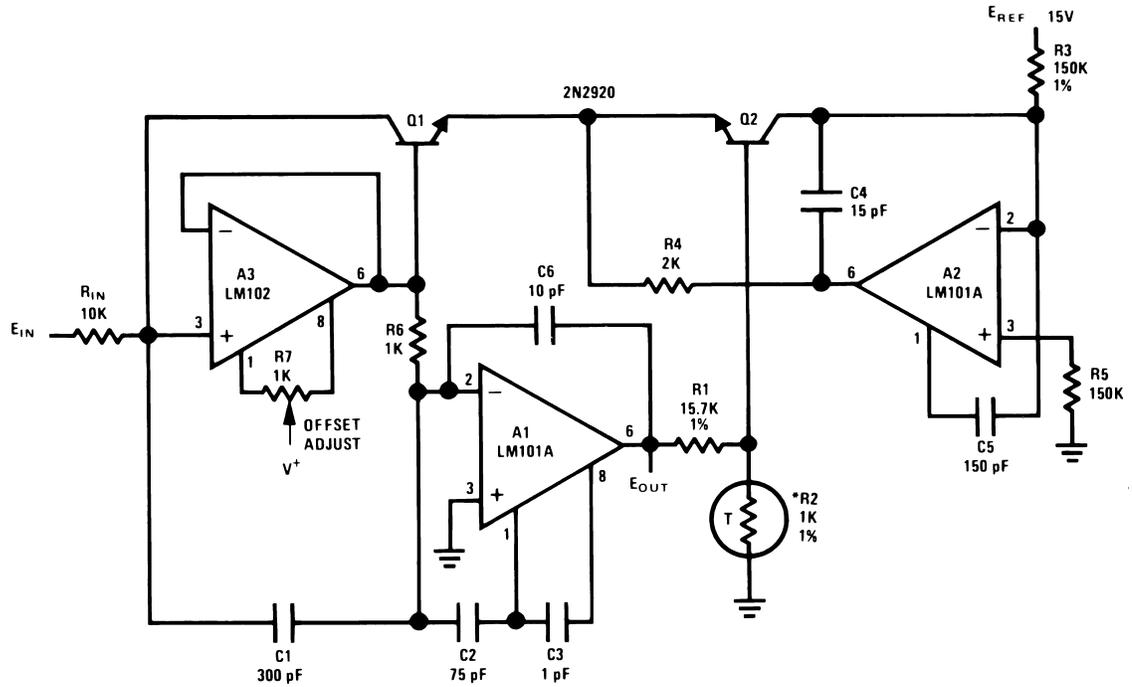
Cube Generator



00705788

Section 3 — Signal Processing (Continued)

Fast Log Generator

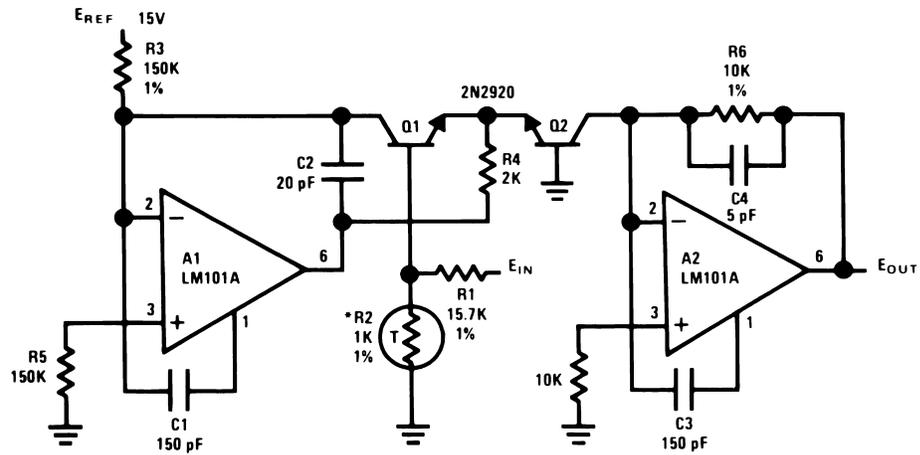


†1 kΩ (±1%) at 25°C, +3500 ppm/°C.

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

00705789

Anti-Log Generator



†1 kΩ (±1%) at 25°C, +3500 ppm/°C.

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

00705790

Notes

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