

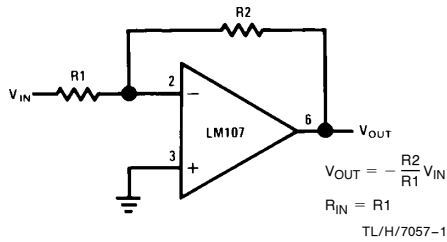
Op Amp Circuit Collection

National Semiconductor
Application Note 31
February 1978

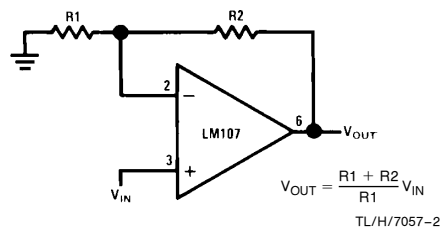


SECTION 1—BASIC CIRCUITS

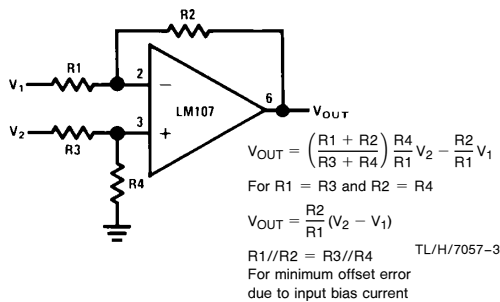
Inverting Amplifier



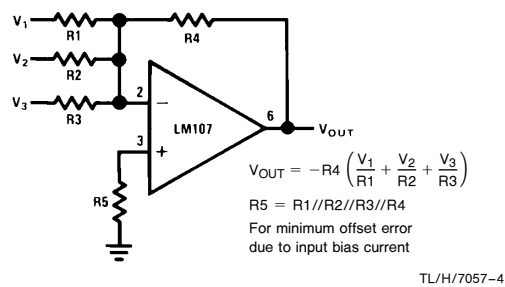
Non-Inverting Amplifier



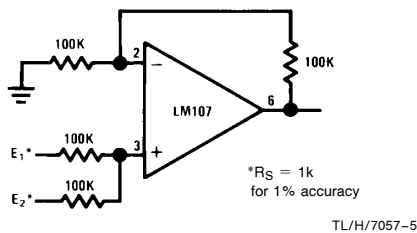
Difference Amplifier



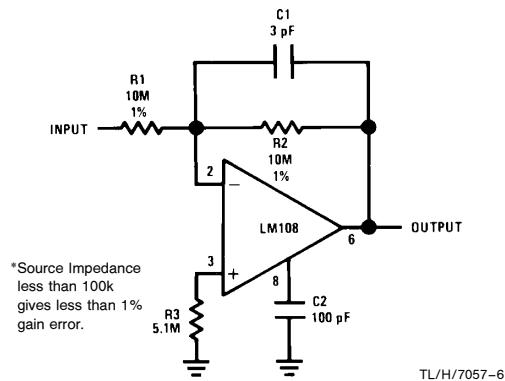
Inverting Summing Amplifier



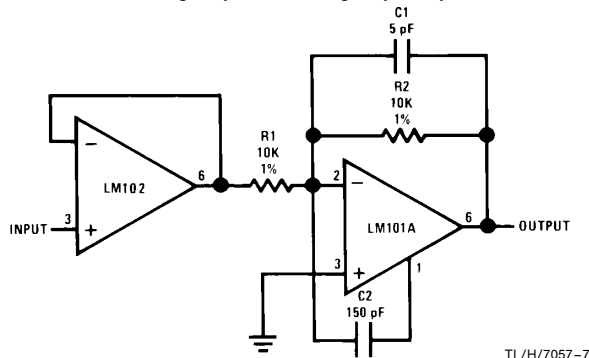
Non-Inverting Summing Amplifier



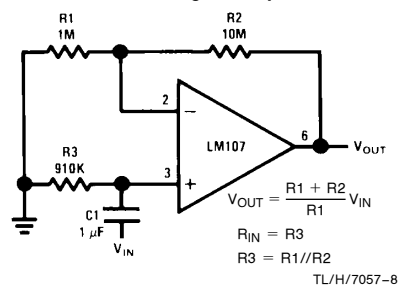
Inverting Amplifier with High Input Impedance



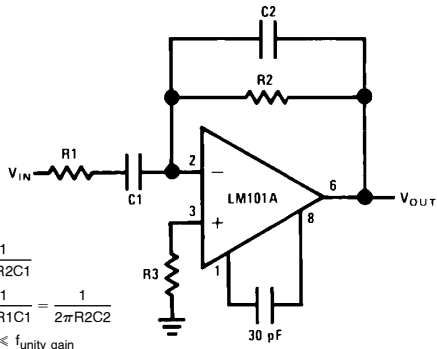
Fast Inverting Amplifier with High Input Impedance



Non-Inverting AC Amplifier



Practical Differentiator



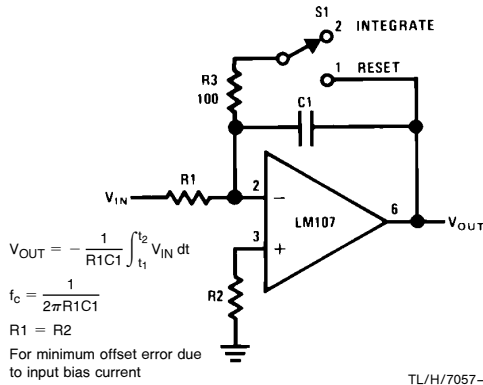
$$f_c = \frac{1}{2\pi R_2 C_1}$$

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

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

TL/H/7057-9

Integrator



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

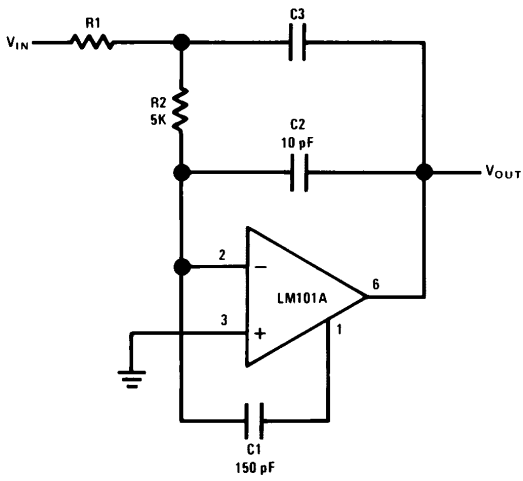
$$f_c = \frac{1}{2\pi R_1 C_1}$$

$$R_1 = R_2$$

For minimum offset error due to input bias current

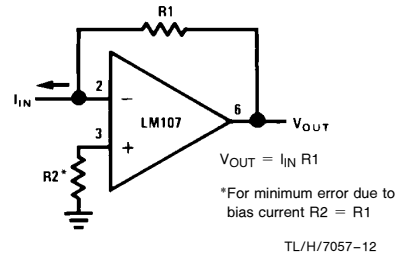
TL/H/7057-10

Fast Integrator



TL/H/7057-11

Current to Voltage Converter

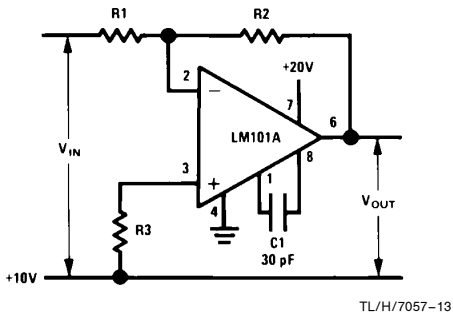


$$V_{OUT} = I_{IN} R_1$$

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

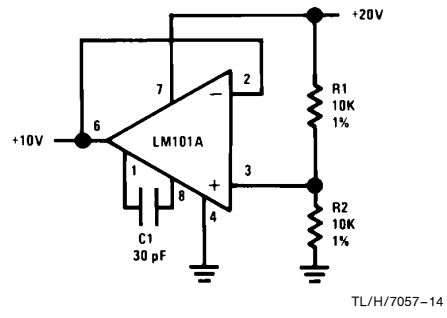
TL/H/7057-12

Circuit for Operating the LM101 without a Negative Supply



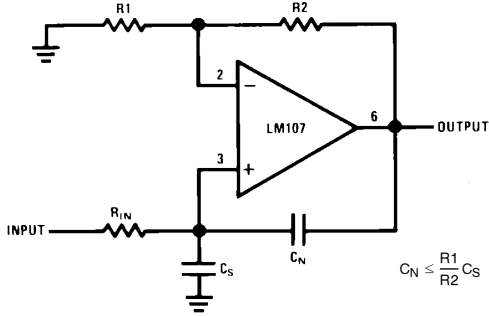
TL/H/7057-13

Circuit for Generating the Second Positive Voltage



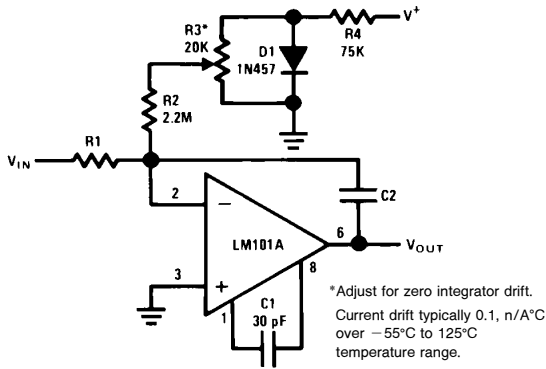
TL/H/7057-14

Neutralizing Input Capacitance to Optimize Response Time



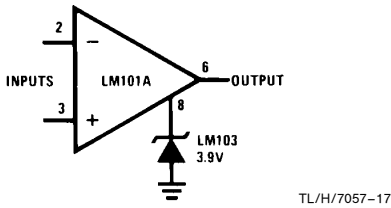
TL/H/7057-15

Integrator with Bias Current Compensation



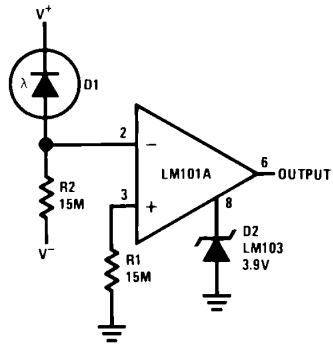
TL/H/7057-16

Voltage Comparator for Driving DTL or TTL Integrated Circuits



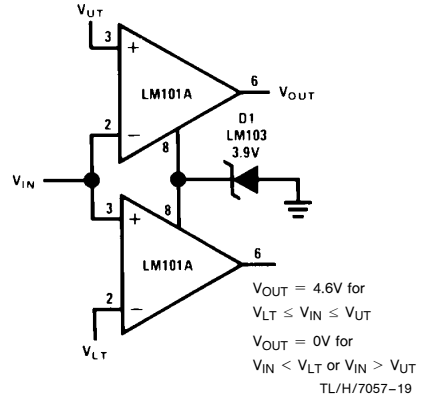
TL/H/7057-17

Threshold Detector for Photodiodes



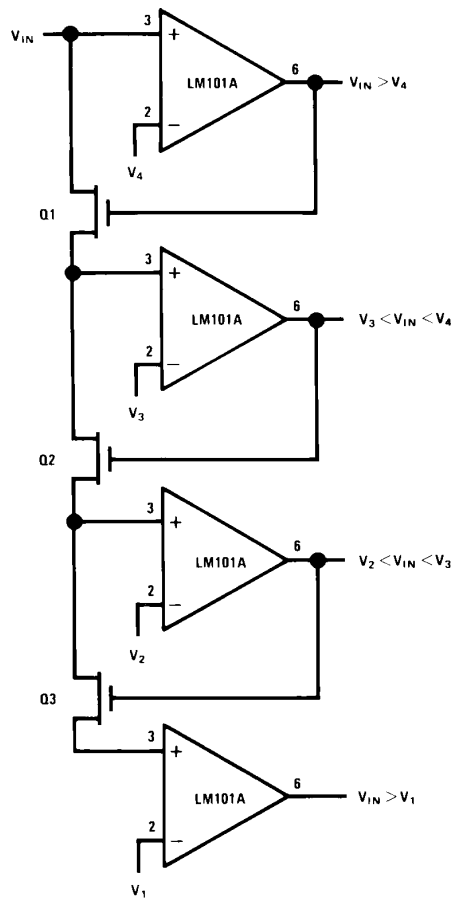
TL/H/7057-18

Double-Ended Limit Detector



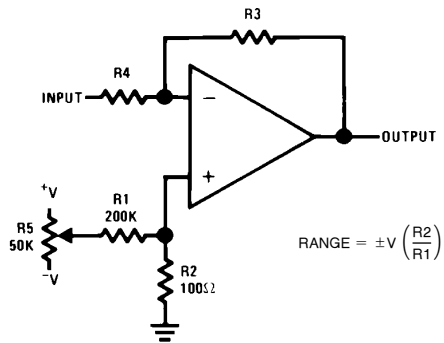
TL/H/7057-19

Multiple Aperture Window Discriminator



TL/H/7057-20

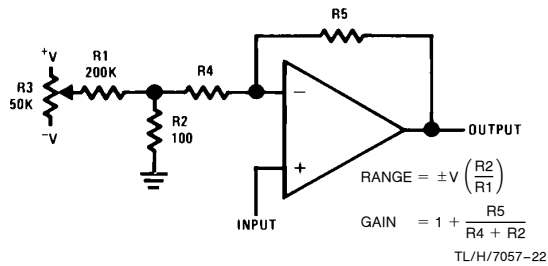
Offset Voltage Adjustment for Inverting Amplifiers Using Any Type of Feedback Element



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

TL/H/7057-21

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

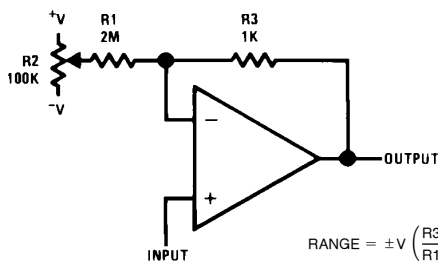


$$\text{RANGE} = \pm V \left(\frac{R2}{R1} \right)$$

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

TL/H/7057-22

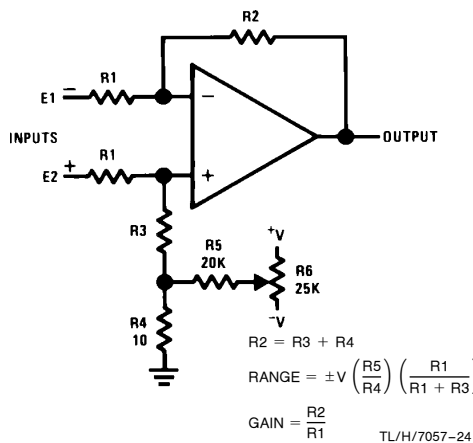
Offset Voltage Adjustment for Voltage Followers



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

TL/H/7057-23

Offset Voltage Adjustment for Differential Amplifiers



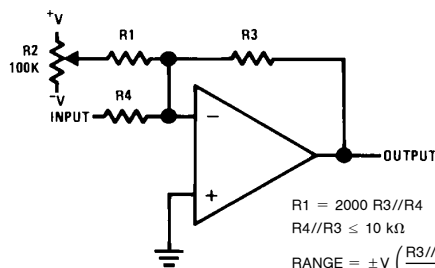
$$R2 = R3 + R4$$

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

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

TL/H/7057-24

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



$$R1 = 2000 R3 // R4$$

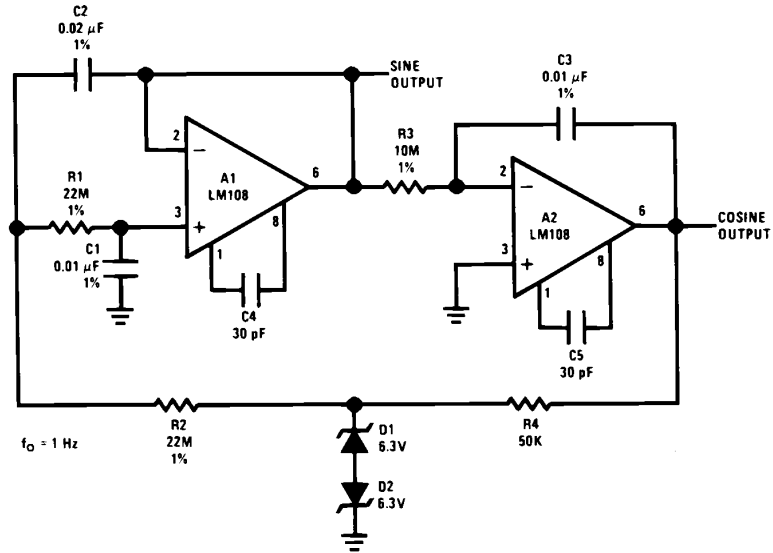
$$R4 // R3 \leq 10 \text{ k}\Omega$$

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

TL/H/7057-25

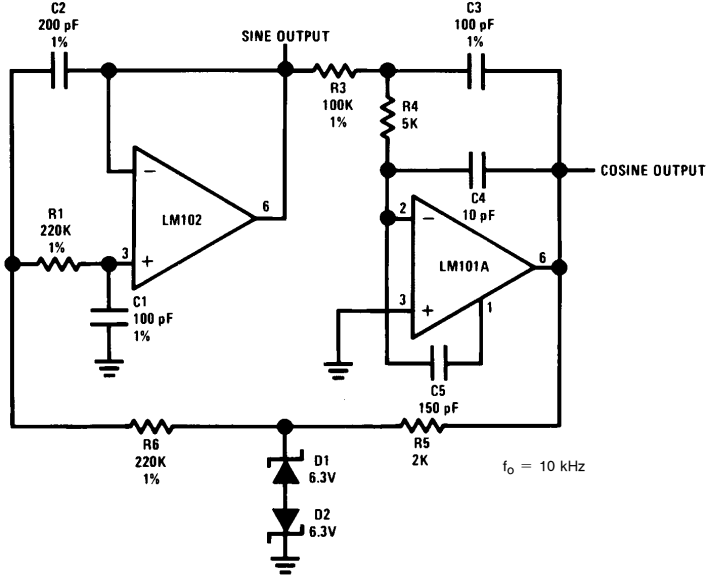
SECTION 2 — SIGNAL GENERATION

Low Frequency Sine Wave Generator with Quadrature Output

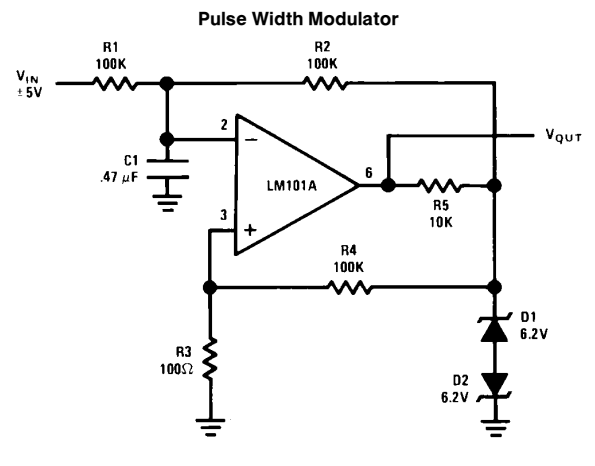
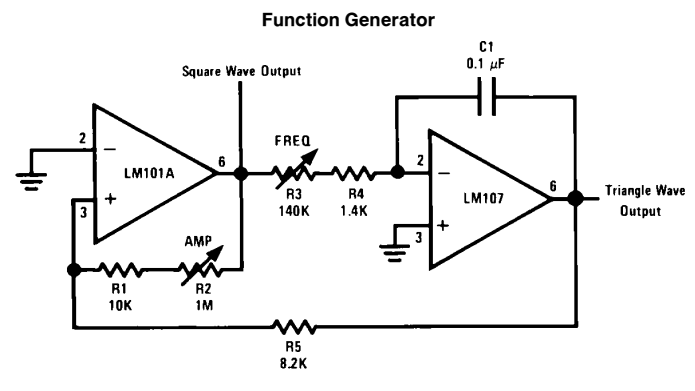
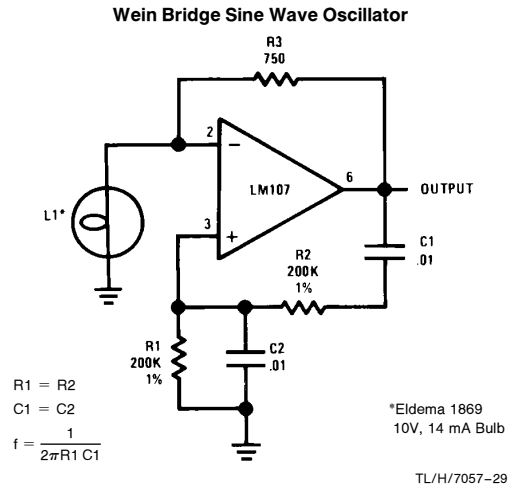
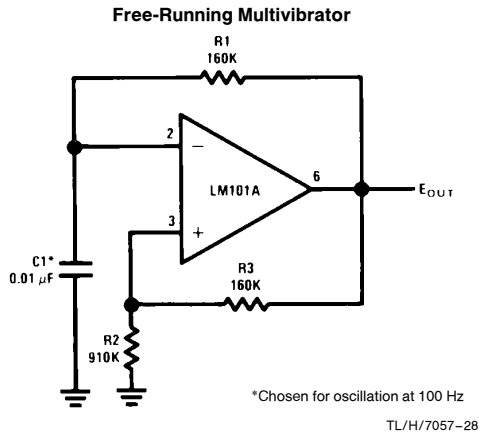


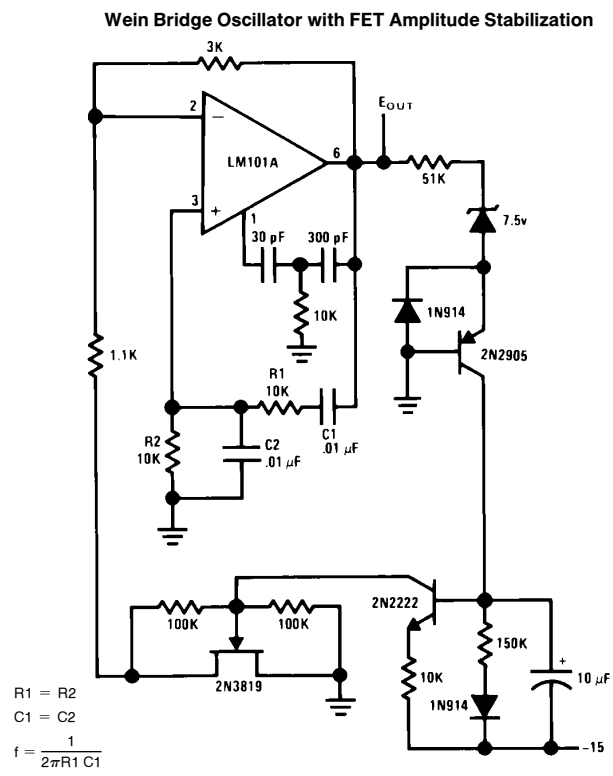
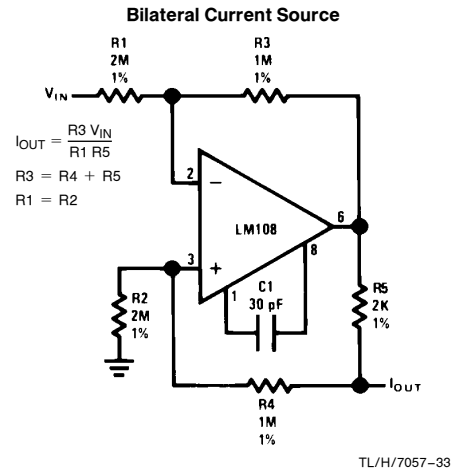
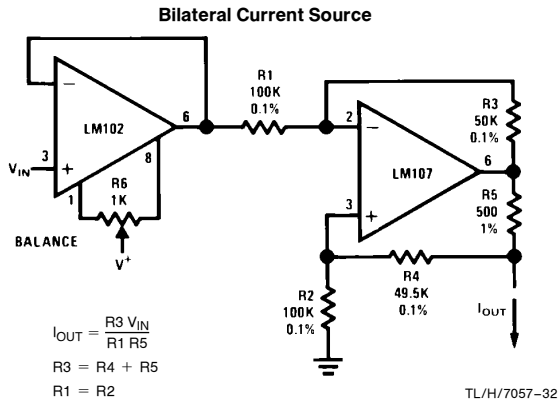
TL/H/7057-26

High Frequency Sine Wave Generator with Quadrature Output

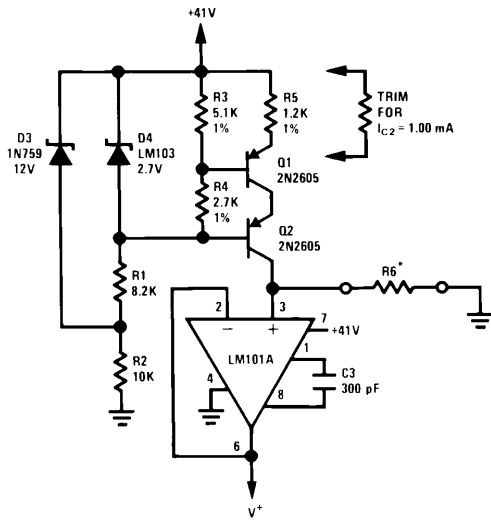


TL/H/7057-27

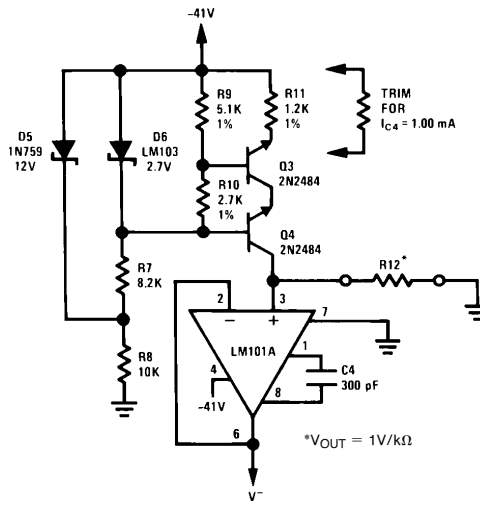




Low Power Supply for Integrated Circuit Testing



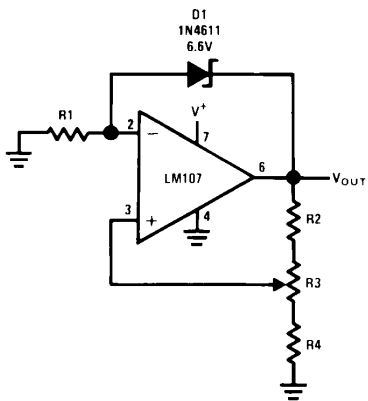
TL/H/7057-35



TL/H/7057-91

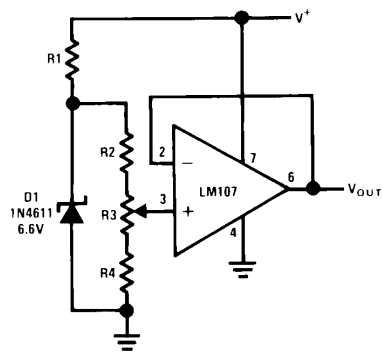
$V_{OUT} = 1V/k\Omega$

Positive Voltage Reference



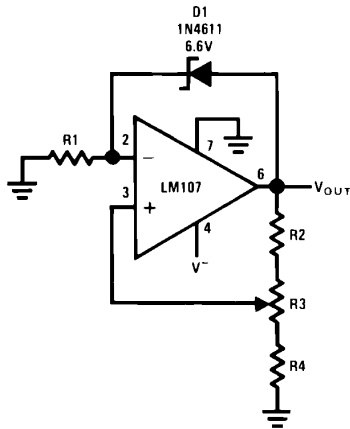
TL/H/7057-36

Positive Voltage Reference



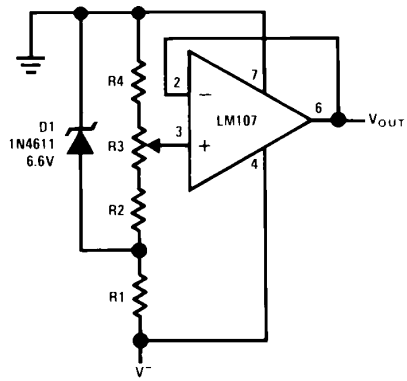
TL/H/7057-37

Negative Voltage Reference



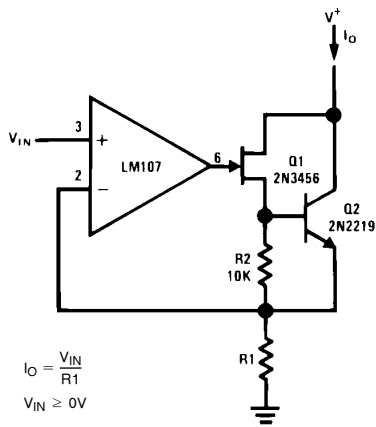
TL/H/7057-38

Negative Voltage Reference



TL/H/7057-39

Precision Current Sink

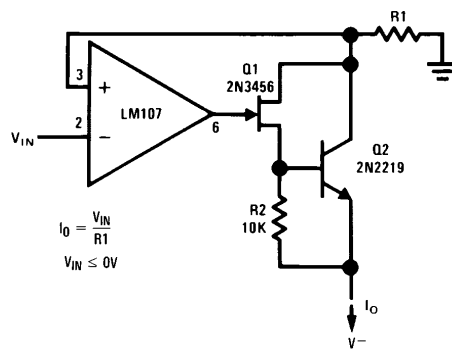


$$I_o = \frac{V_{IN}}{R1}$$

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

TL/H/7057-40

Precision Current Source



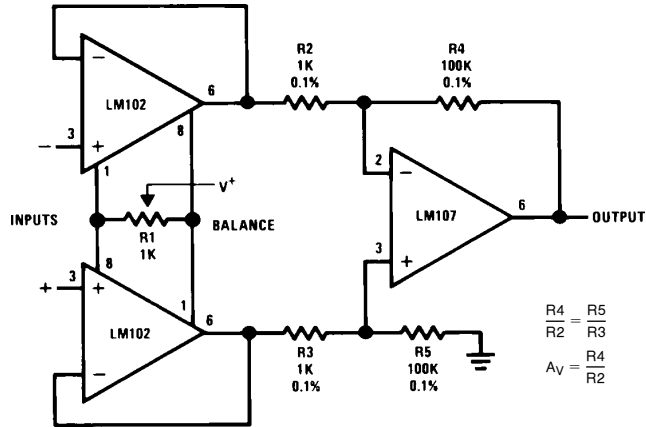
$$I_o = \frac{V_{IN}}{R1}$$

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

TL/H/7057-41

SECTION 3 — SIGNAL PROCESSING

Differential-Input Instrumentation Amplifier

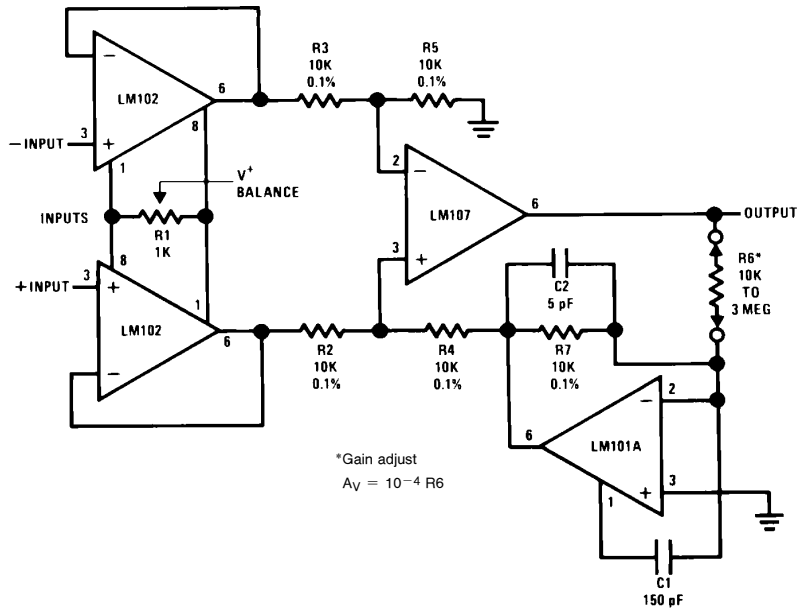


$$\frac{R4}{R2} = \frac{R5}{R3}$$

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

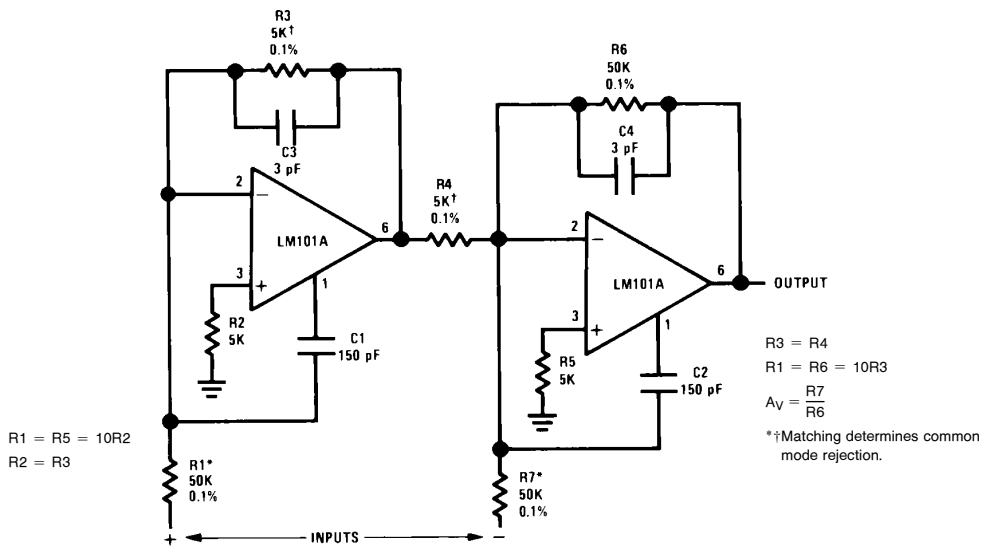
TL/H/7057-42

Variable Gain, Differential-Input Instrumentation Amplifier



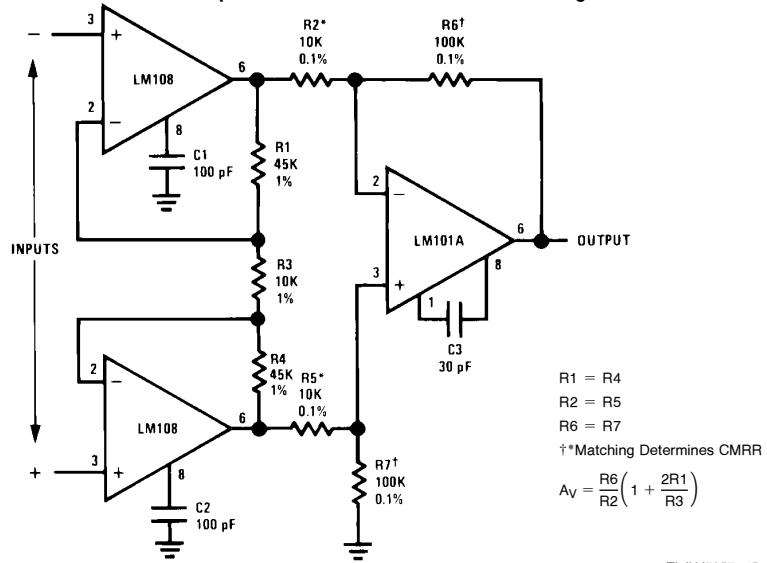
TL/H/7057-43

Instrumentation Amplifier with ± 100 Volt Common Mode Range



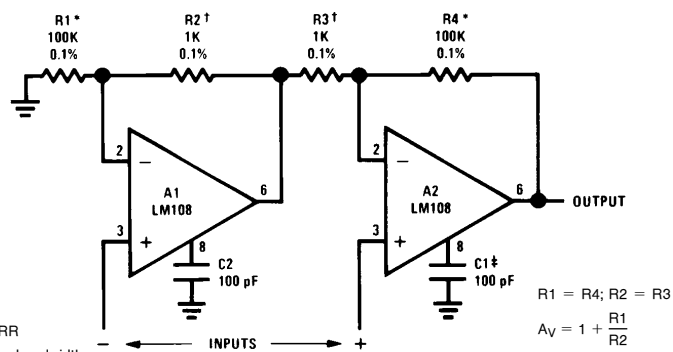
TL/H/7057-44

Instrumentation Amplifier with ± 10 Volt Common Mode Range



TL/H/7057-45

High Input Impedance Instrumentation Amplifier

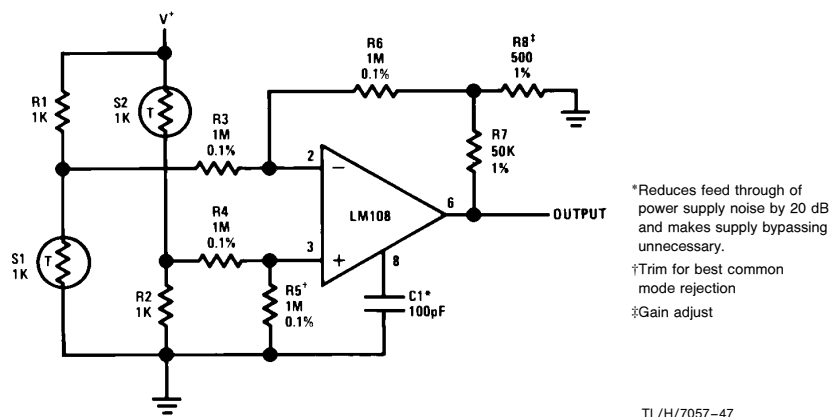


*†Matching determines CMRR

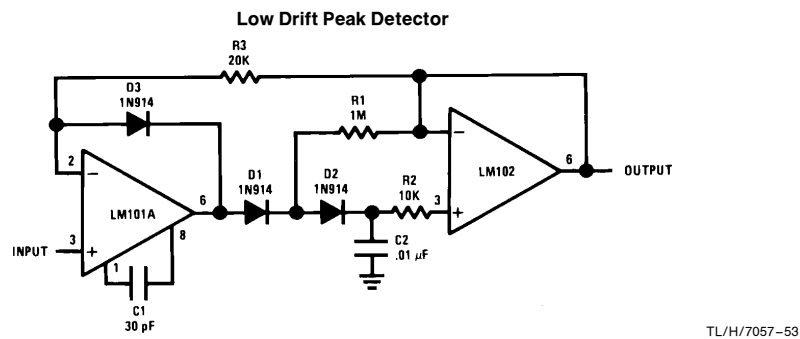
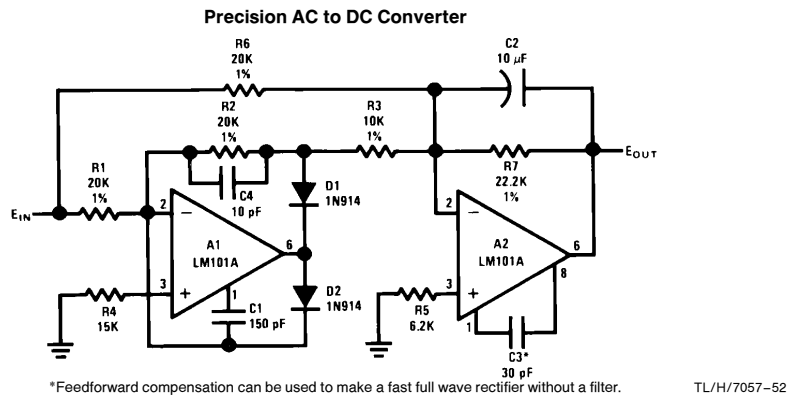
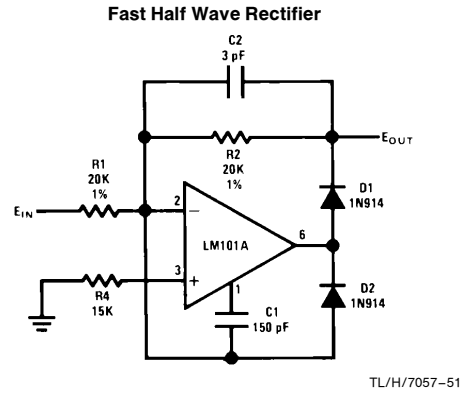
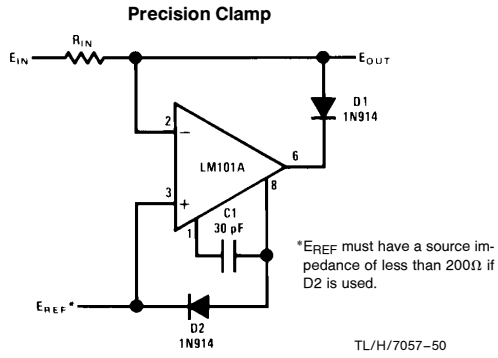
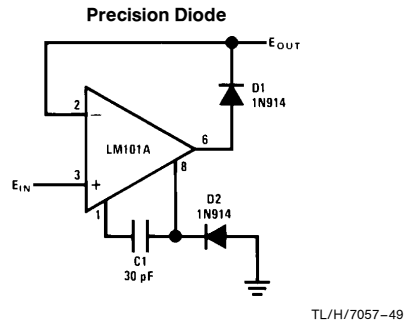
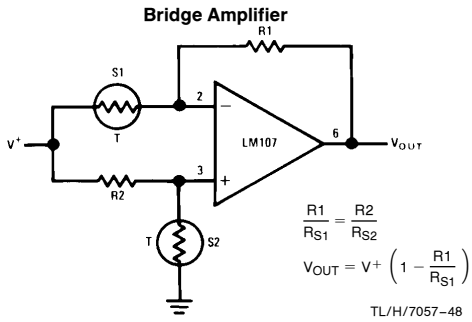
‡May be deleted to maximize bandwidth

TL/H/7057-46

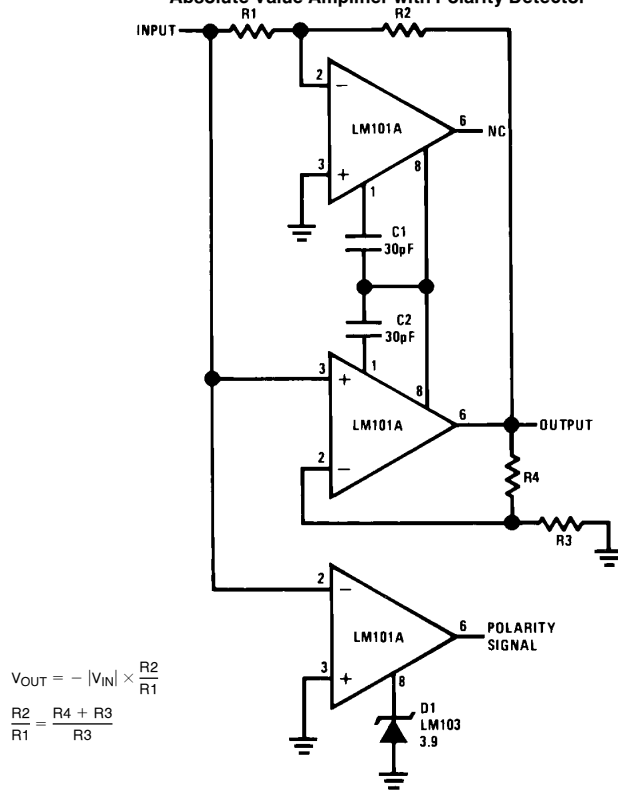
Bridge Amplifier with Low Noise Compensation



TL/H/7057-47

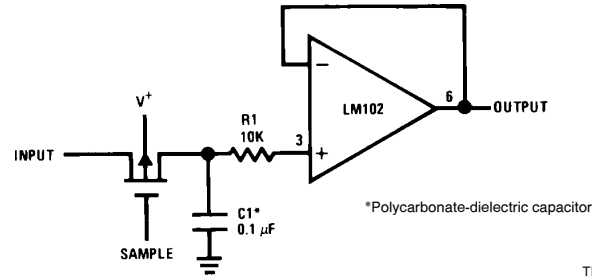


Absolute Value Amplifier with Polarity Detector



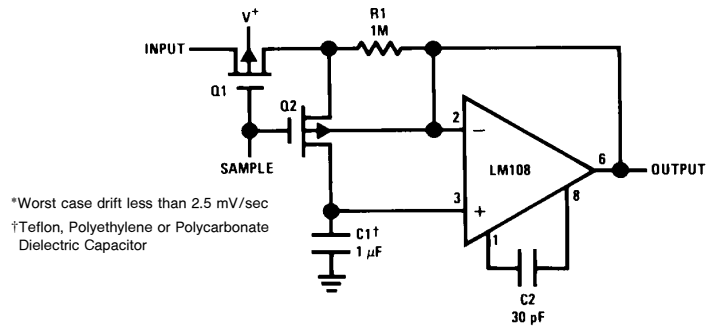
TL/H/7057-54

Sample and Hold



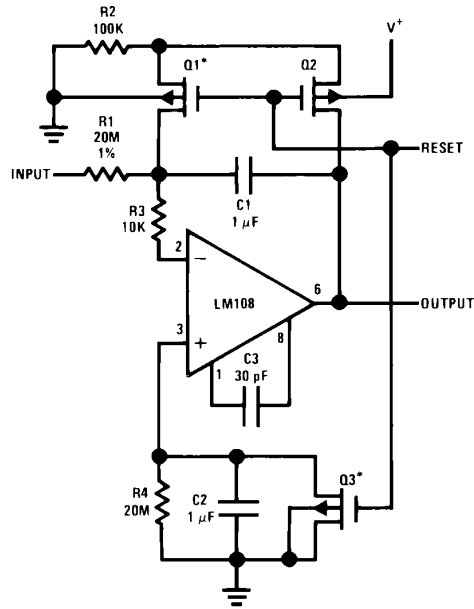
TL/H/7057-55

Sample and Hold



TL/H/7057-56

Low Drift Integrator

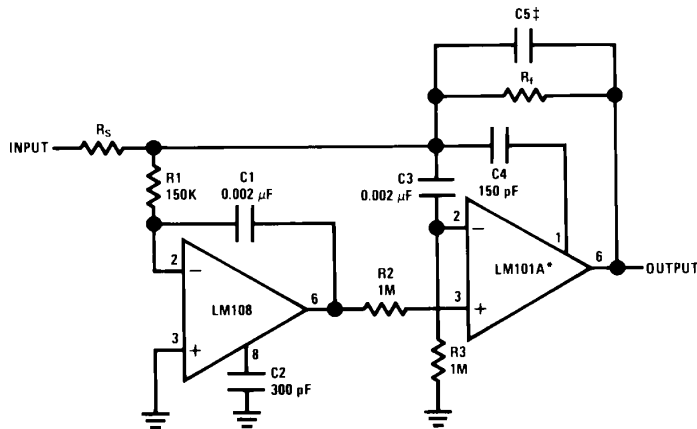


TL/H/7057-57

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

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

Fast[†] Summing Amplifier with Low Input Current



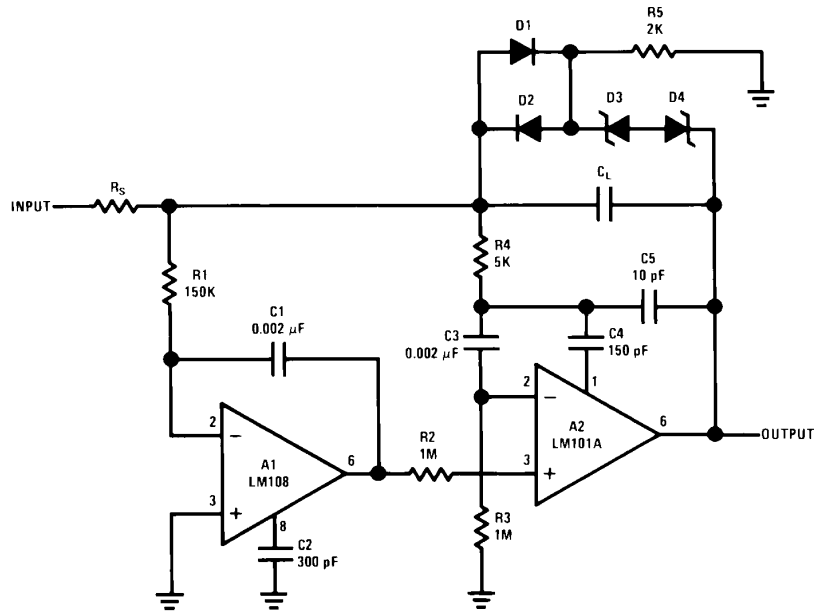
TL/H/7057-58

* 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

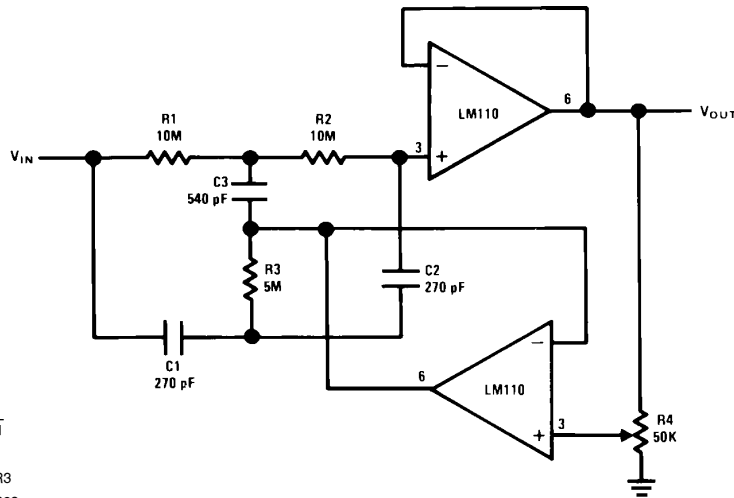
$$\ddagger C5 = \frac{6 \times 10^{-8}}{R_f}$$

Fast Integrator with Low Input Current



TL/H/7057-59

Adjustable Q Notch Filter



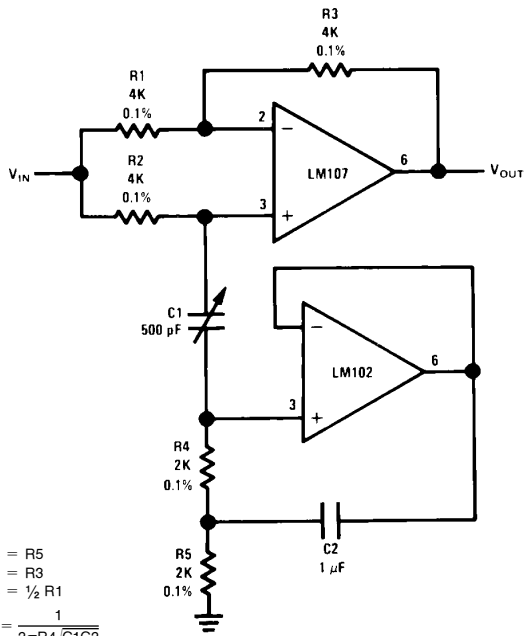
$$f_0 = \frac{1}{2\pi R_1 C_1}$$

$$= 60 \text{ Hz}$$

$R_1 = R_2 = R_3$
 $C_1 = C_2 = C_3$

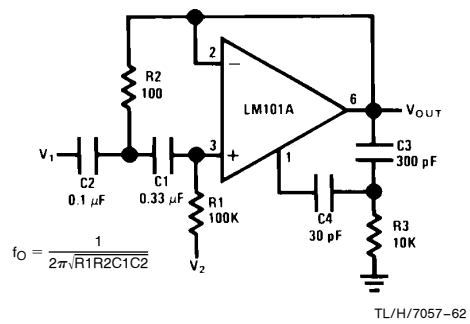
TL/H/7057-60

Easily Tuned Notch Filter

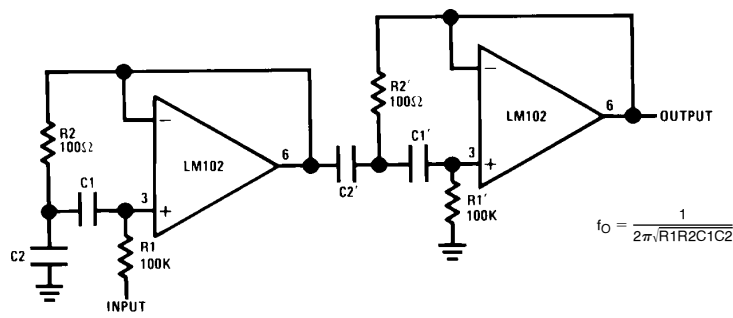


TL/H/7057-61

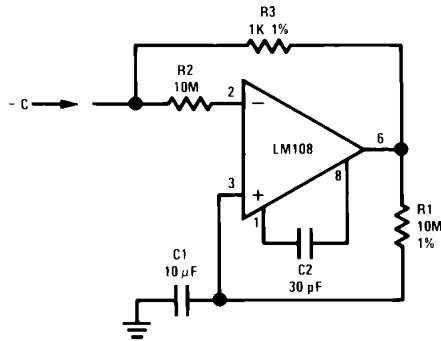
Tuned Circuit



Two-Stage Tuned Circuit



Negative Capacitance Multiplier



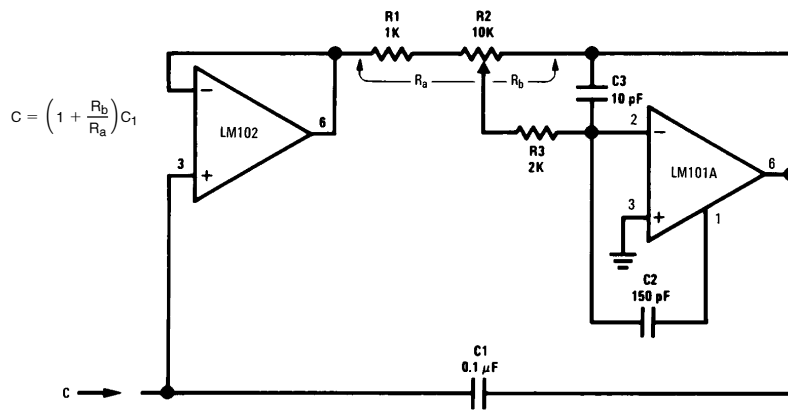
$$C = \frac{R_2}{R_3} C_1$$

$$I_L = \frac{V_{os} + R_2 I_{os}}{R_3}$$

$$R_S = \frac{R_3(R_1 + R_{IN})}{R_{IN} A_{VO}}$$

TL/H/7057-65

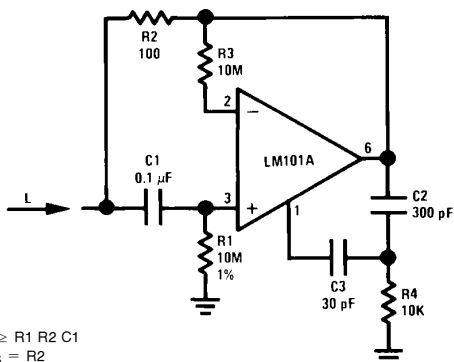
Variable Capacitance Multiplier



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

TL/H/7057-66

Simulated Inductor



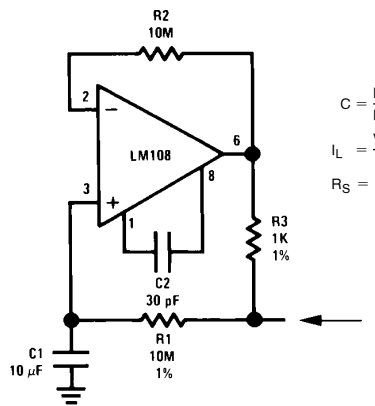
$$L \geq R_1 R_2 C_1$$

$$R_S = R_2$$

$$R_P = R_1$$

TL/H/7057-67

Capacitance Multiplier



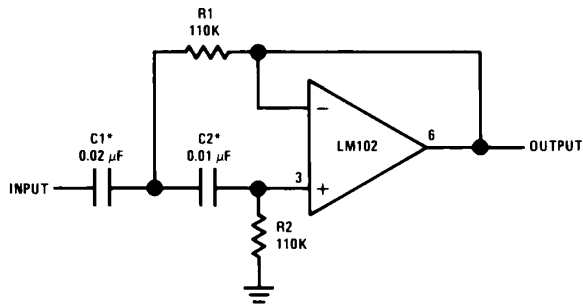
$$C = \frac{R_1}{R_3} C_1$$

$$I_L = \frac{V_{os} + I_{os} R_1}{R_3}$$

$$R_S = R_3$$

TL/H/7057-68

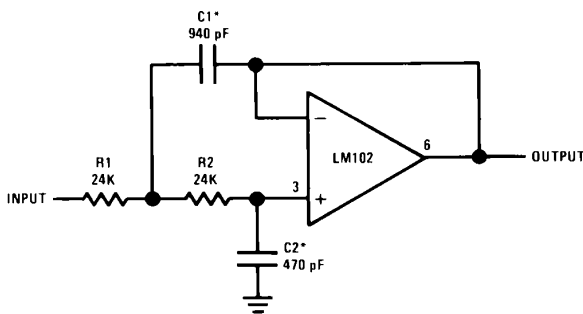
High Pass Active Filter



TL/H/7057-71

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

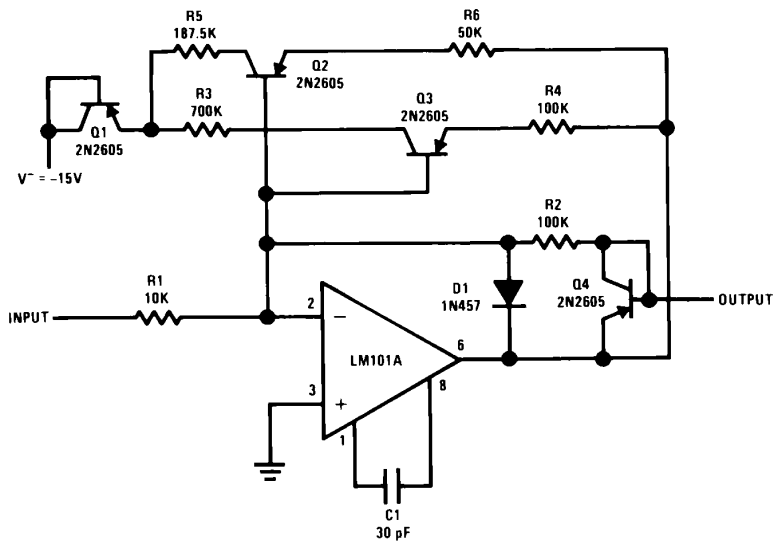
Low Pass Active Filter



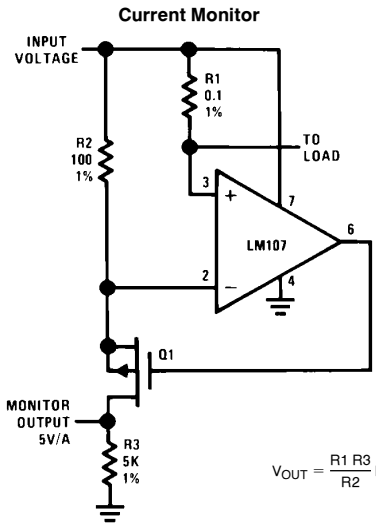
TL/H/7057-72

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

Nonlinear Operational Amplifier with Temperature Compensated Breakpoints

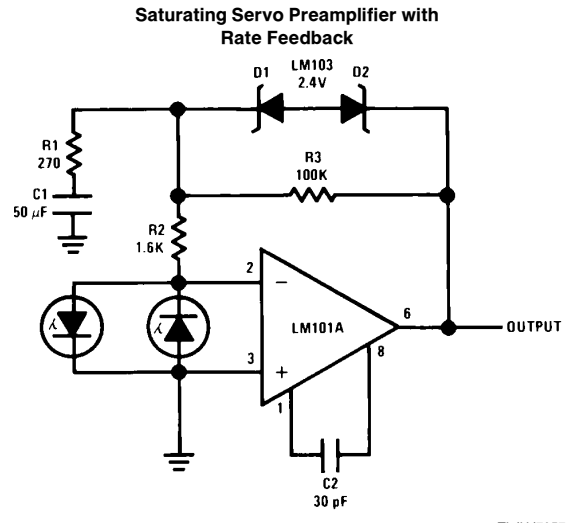


TL/H/7057-73

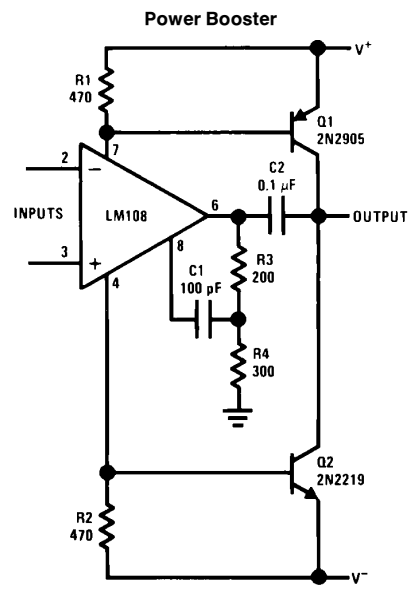


$$V_{OUT} = \frac{R_1 R_3}{R_2} I_L$$

TL/H/7057-74

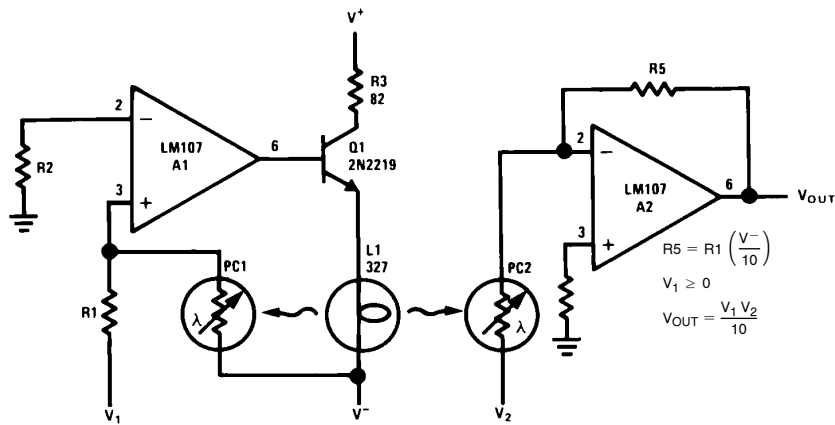


TL/H/7057-75



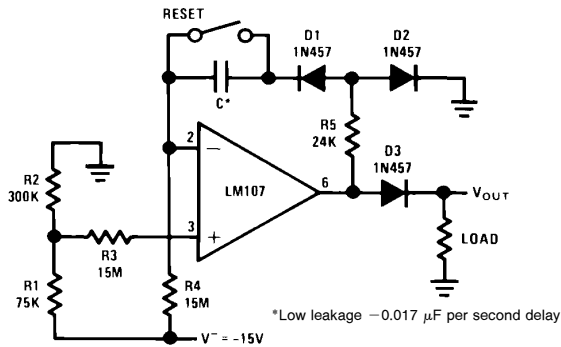
TL/H/7057-76

Analog Multiplier



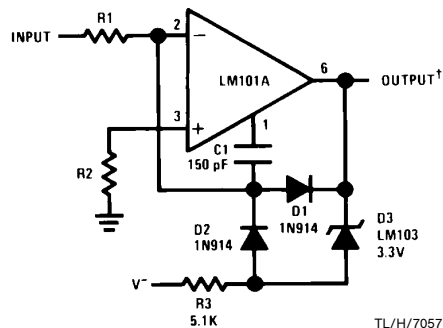
TL/H/7057-77

Long Interval Timer



TL/H/7057-78

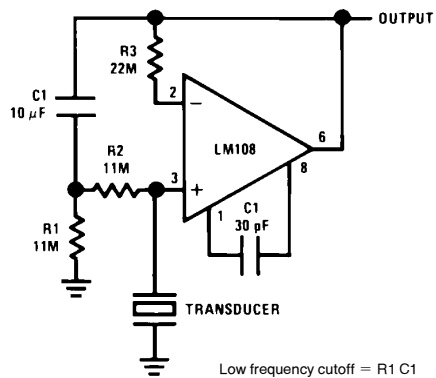
Fast Zero Crossing Detector



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

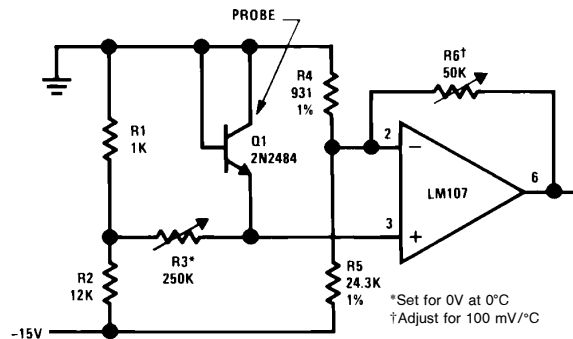
TL/H/7057-79

Amplifier for Piezoelectric Transducer

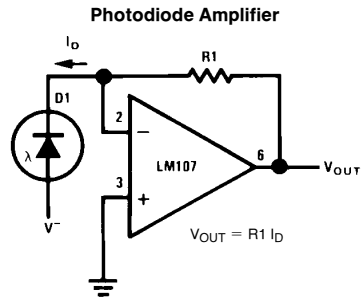


TL/H/7057-80

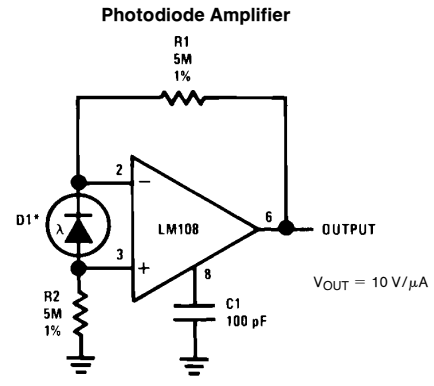
Temperature Probe



TL/H/7057-81

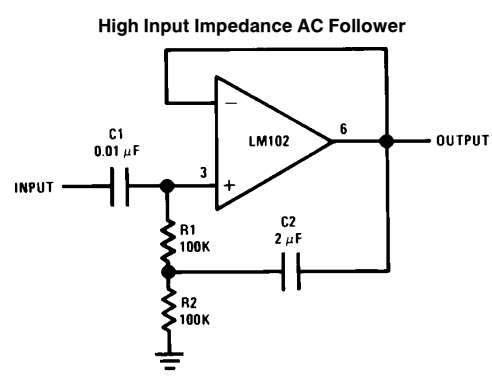


TL/H/7057-82

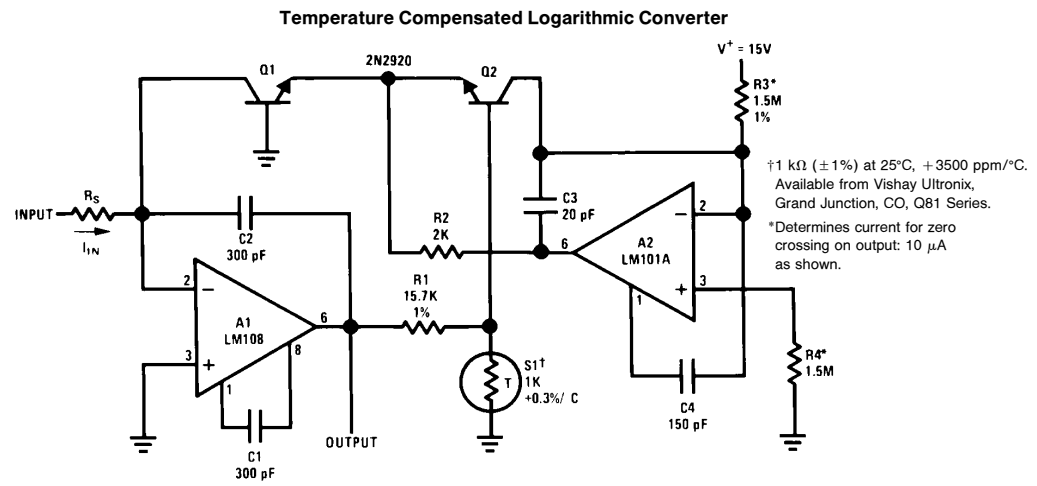


TL/H/7057-83

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



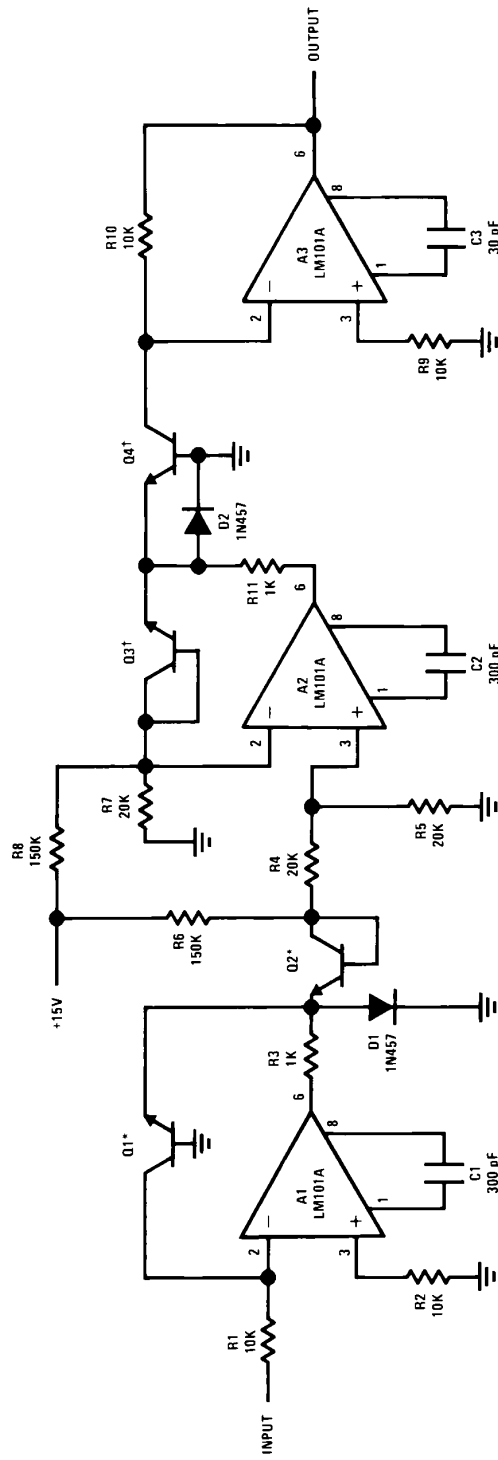
TL/H/7057-84



TL/H/7057-85

$10 \text{ nA} < I_{IN} < 1 \text{ mA}$
Sensitivity is 1V per decade

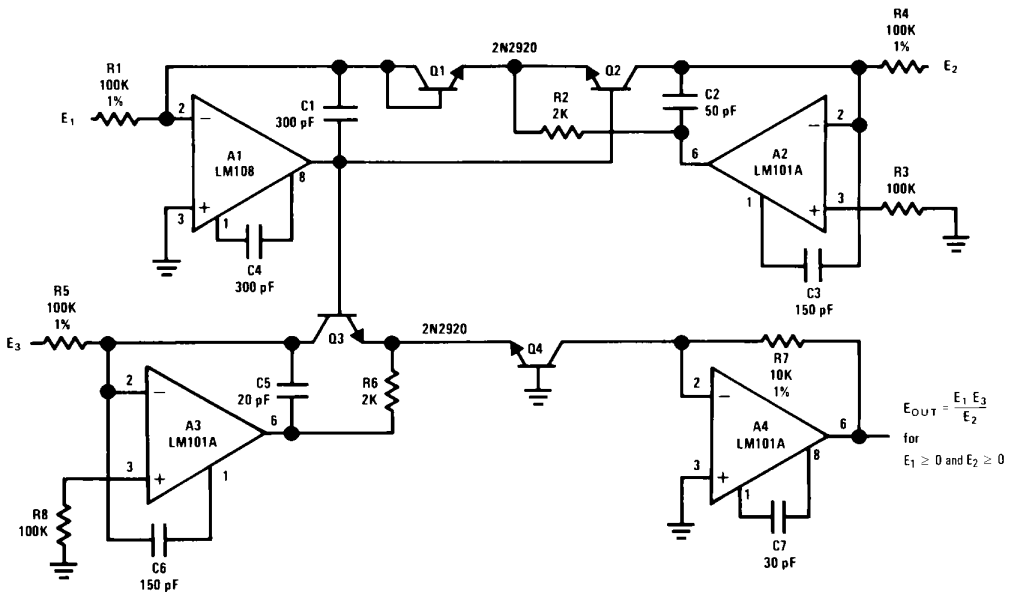
Root Extractor



*: 1/2N3728 matched pairs

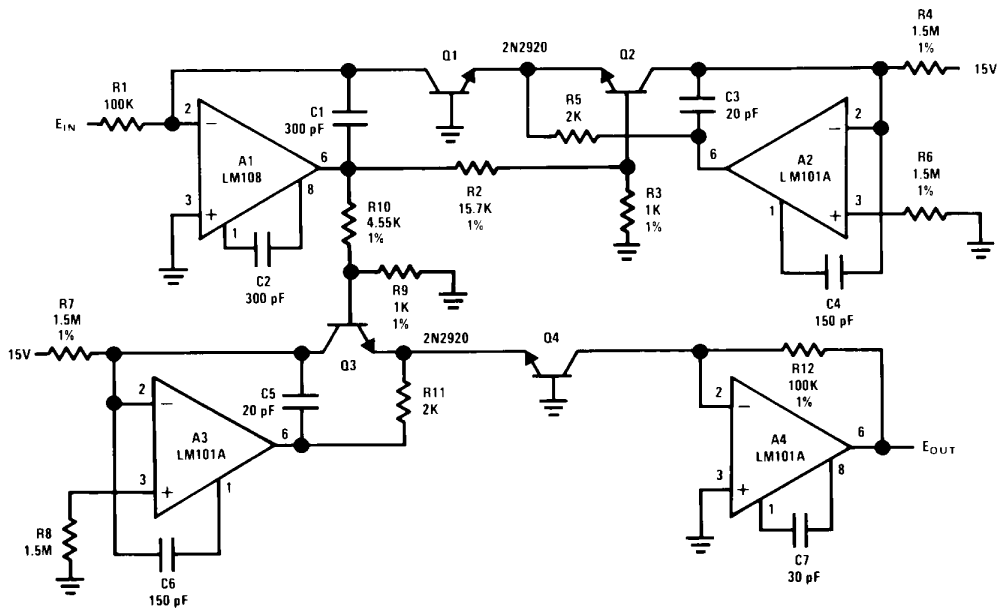
TL/H/7057-86

Multiplier/Divider

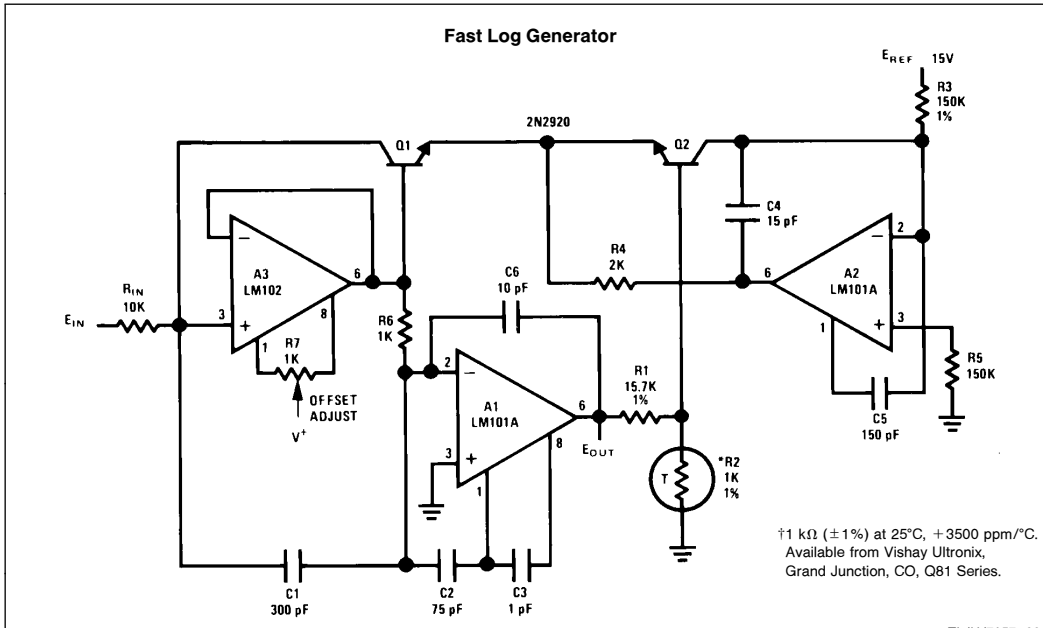


TL/H/7057-87

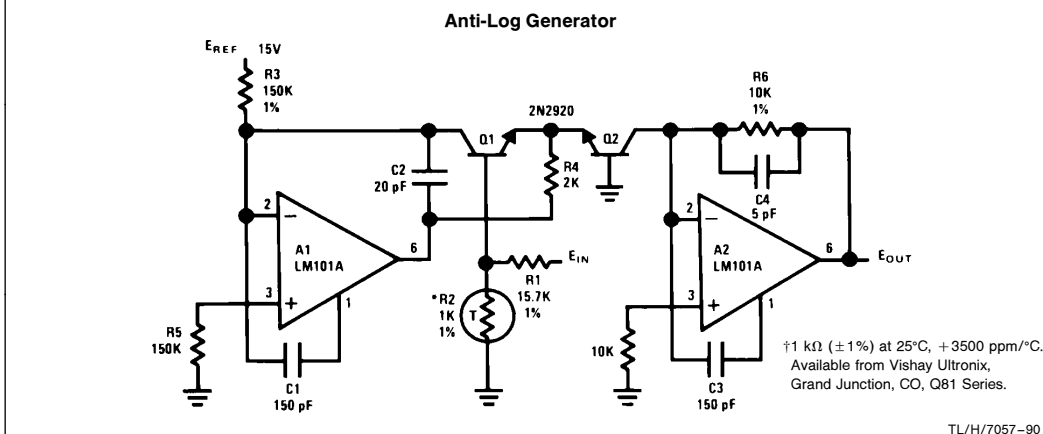
Cube Generator



TL/H/7057-88



TL/H/7057-89



TL/H/7057-90

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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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