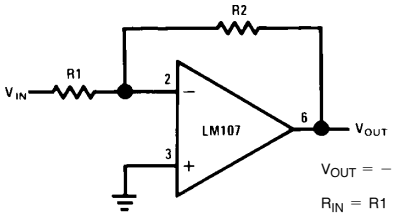
Op Amp Circuit Collection

National Semiconductor
Application Note 31
February 1978

SECTION 1—BASIC CIRCUITS

Inverting Amplifier

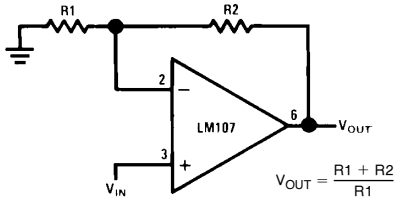


$$V_{OUT} = -\frac{R2}{R1} V_{IN}$$

$$R_{IN} = R1$$

TL/H/7057–1

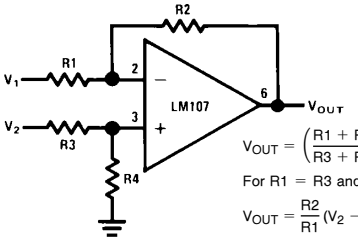
Non-Inverting Amplifier



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

TL/H/7057–2

Difference Amplifier



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

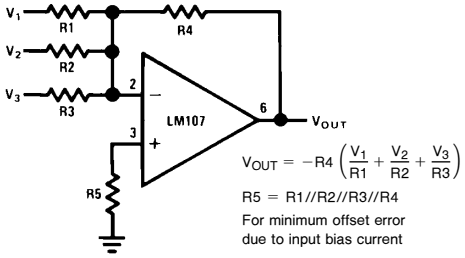
For R1 = R3 and R2 = R4

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

R1//R2 = R3//R4
For minimum offset error due to input bias current

TL/H/7057–3

Inverting Summing Amplifier

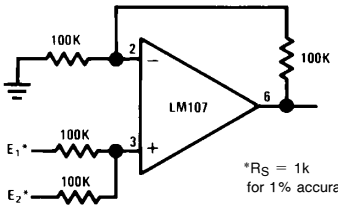


$$V_{OUT} = -R4\left(\frac{V_1}{R1} + \frac{V_2}{R2} + \frac{V_3}{R3}\right)$$

R5 = R1//R2//R3//R4
For minimum offset error due to input bias current

TL/H/7057–4

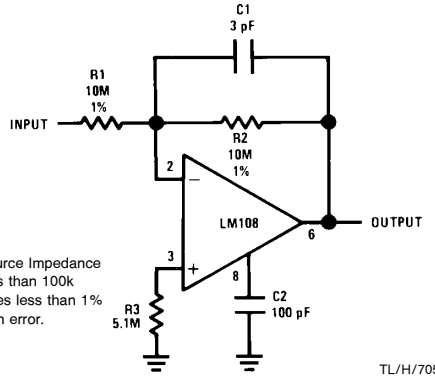
Non-Inverting Summing Amplifier



*R_S = 1k for 1% accuracy

TL/H/7057–5

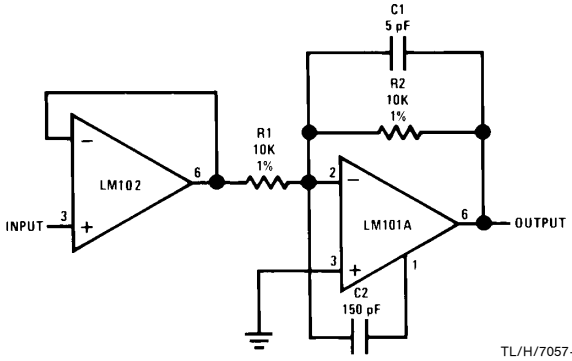
Inverting Amplifier with High Input Impedance



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

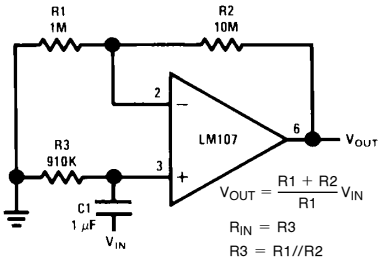
TL/H/7057–6

Fast Inverting Amplifier with High Input Impedance



TL/H/7057–7

Non-Inverting AC Amplifier



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

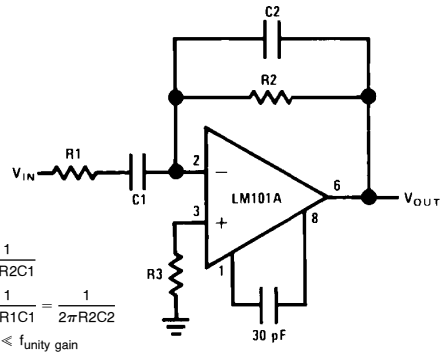
$$R_{IN} = R3$$

R3 = R1//R2

TL/H/7057–8

RRD-B30M115/Printed in U. S. A.

Practical Differentiator



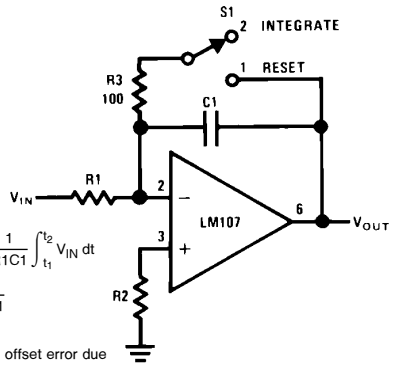
$$f_c = \frac{1}{2\pi R2C1}$$

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

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

TL/H/7057–9

Integrator



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

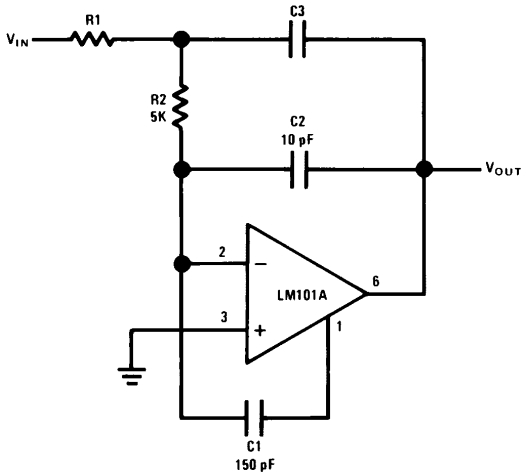
$$f_c = \frac{1}{2\pi R1C1}$$

$R1 = R2$

For minimum offset error due to input bias current

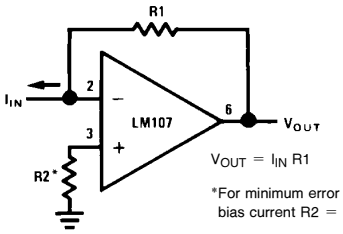
TL/H/7057–10

Fast Integrator



TL/H/7057–11

Current to Voltage Converter

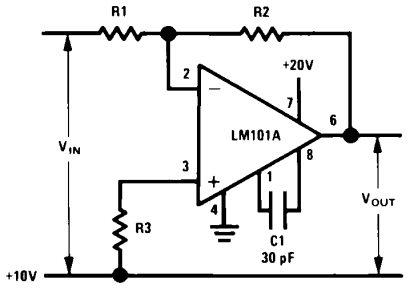


$V_{OUT} = I_{IN}\,R1$

*For minimum error due to bias current R2 = R1

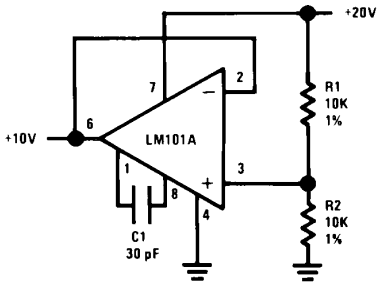
TL/H/7057–12

Circuit for Operating the LM101 without a Negative Supply



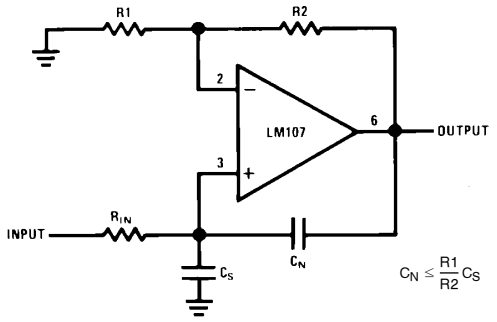
TL/H/7057–13

Circuit for Generating the Second Positive Voltage



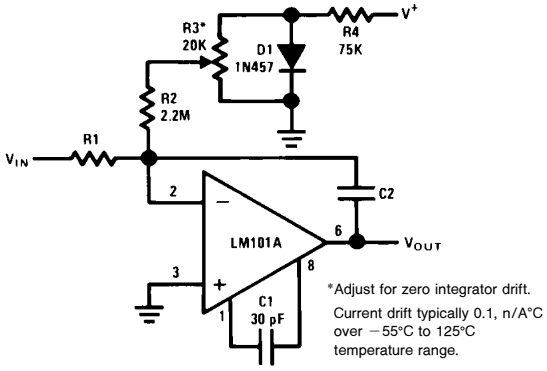
TL/H/7057–14

Neutralizing Input Capacitance to Optimize Response Time



TL/H/7057–15

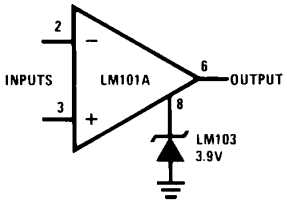
Integrator with Bias Current Compensation



*Adjust for zero integrator drift. Current drift typically 0.1, n/A°C over −55°C to 125°C temperature range.

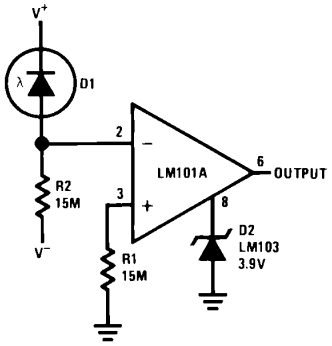
TL/H/7057–16

Voltage Comparator for Driving DTL or TTL Integrated Circuits



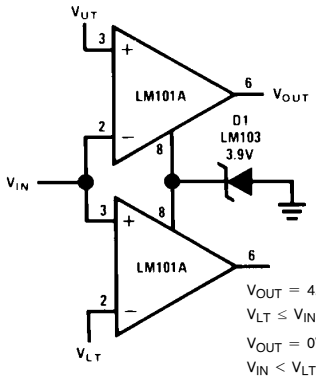
TL/H/7057–17

Threshold Detector for Photodiodes



TL/H/7057–18

Double-Ended Limit Detector

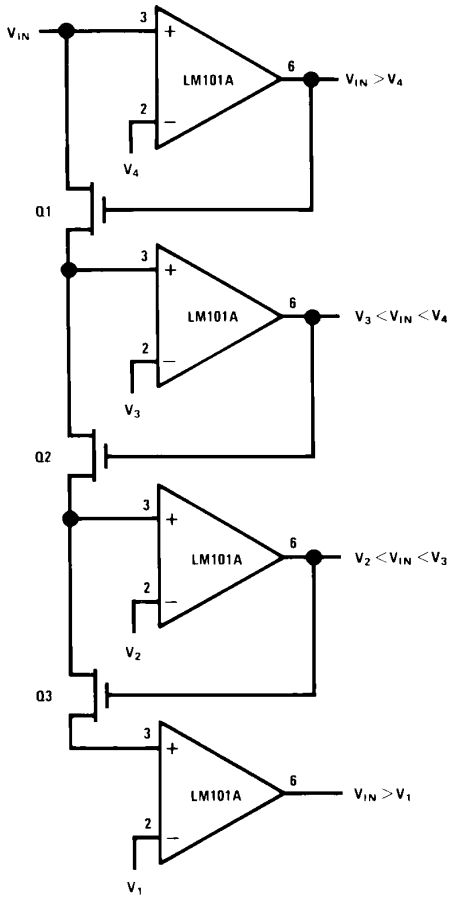


V_{OUT} = 4.6V for $V_{LT} \leq V_{IN} \leq V_{UT}$

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

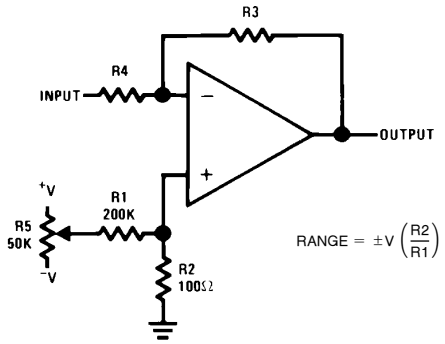
TL/H/7057–19

Multiple Aperture Window Discriminator



TL/H/7057–20

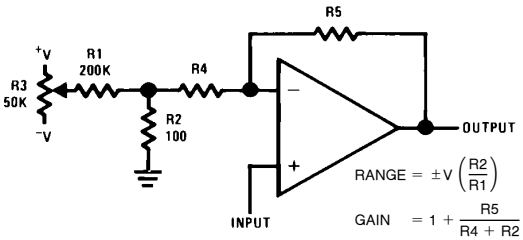
Offset Voltage Adjustment for Inverting Amplifiers Using Any Type of Feedback Element



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

TL/H/7057–21

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

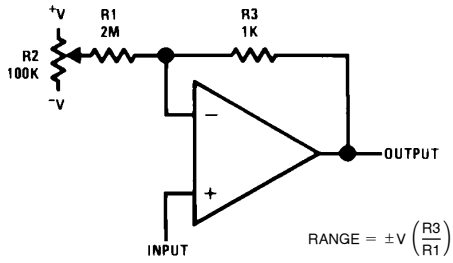


$$\text{RANGE} = \pm V\left(\frac{R2}{R1}\right)$$

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

TL/H/7057–22

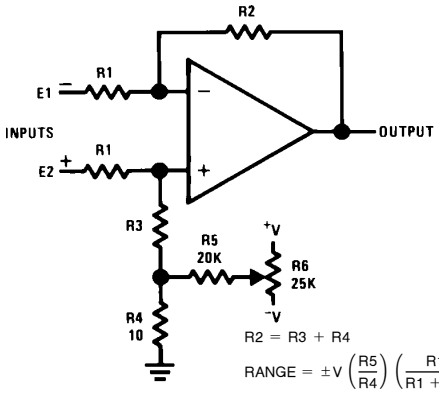
Offset Voltage Adjustment for Voltage Followers



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

TL/H/7057–23

Offset Voltage Adjustment for Differential Amplifiers



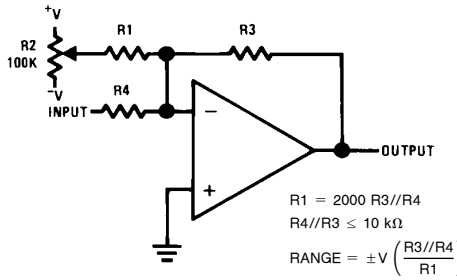
$$R2 = R3 + R4$$

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

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

TL/H/7057–24

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



$$R1 = 2000\ R3//R4$$

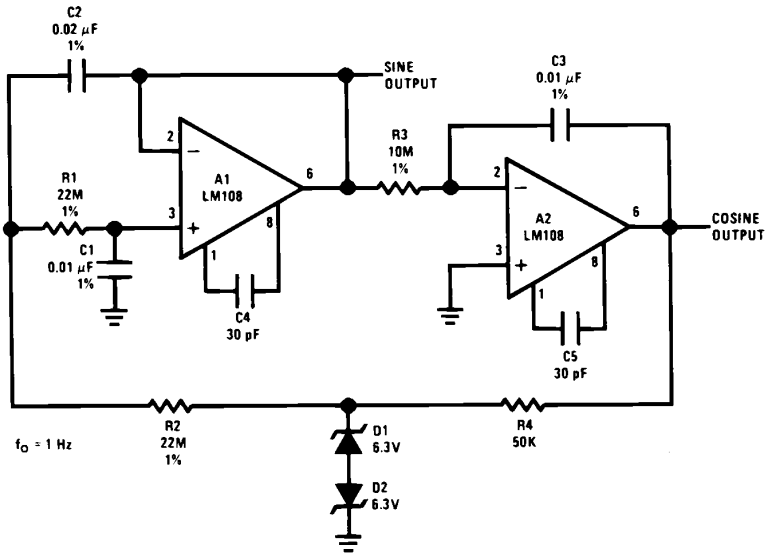
$$R4//R3 \leq 10\ k\Omega$$

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

TL/H/7057–25

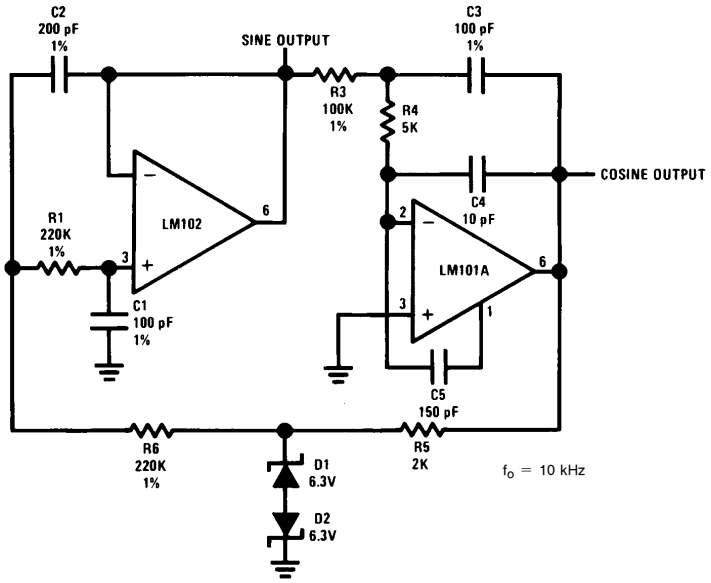
SECTION 2 — SIGNAL GENERATION

Low Frequency Sine Wave Generator with Quadrature Output



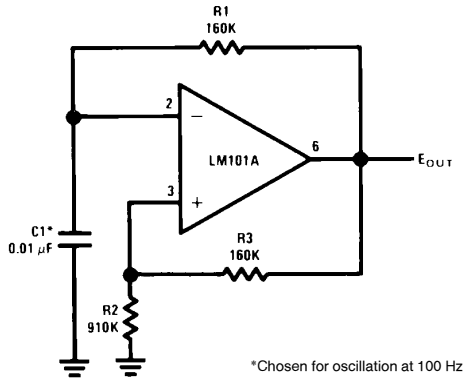
TL/H/7057–26

High Frequency Sine Wave Generator with Quadrature Output



TL/H/7057–27

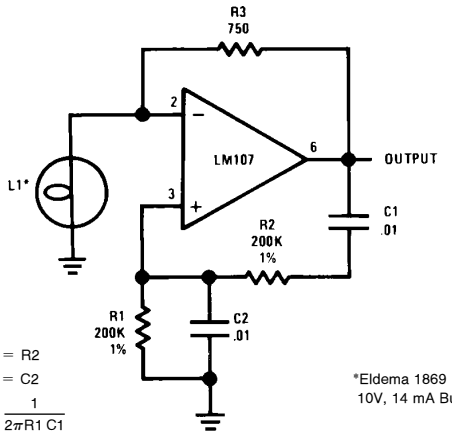
Free-Running Multivibrator



*Chosen for oscillation at 100 Hz

TL/H/7057–28

Wein Bridge Sine Wave Oscillator



R1 = R2

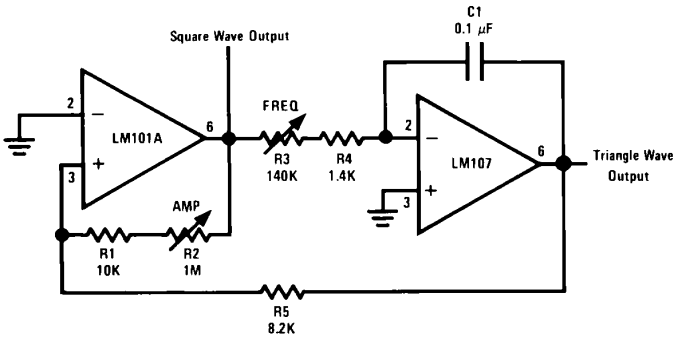
C1 = C2

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

*Eldema 1869
10V, 14 mA Bulb

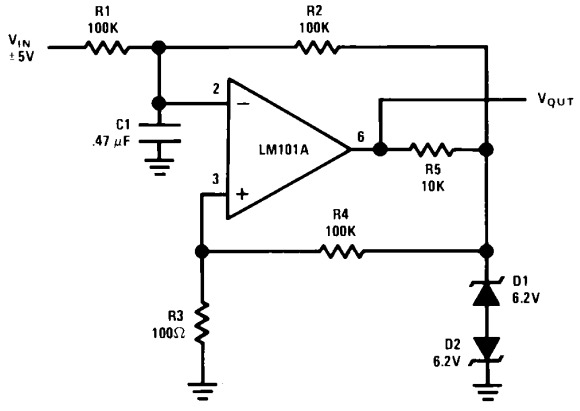
TL/H/7057–29

Function Generator



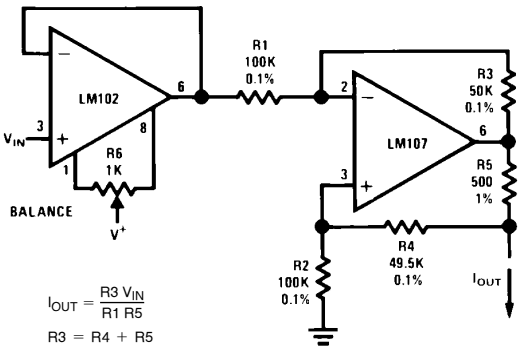
TL/H/7057–30

Pulse Width Modulator



TL/H/7057–31

Bilateral Current Source



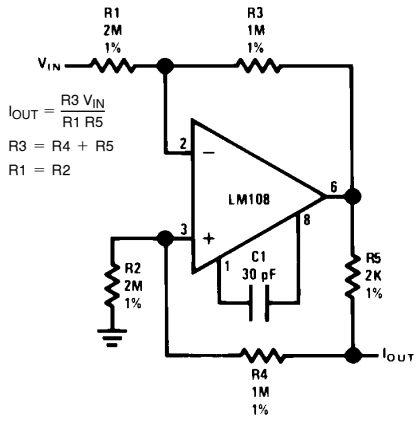
$$I_{OUT} = \frac{R3\ V_{IN}}{R1\ R5}$$

R3 = R4 + R5

R1 = R2

TL/H/7057–32

Bilateral Current Source



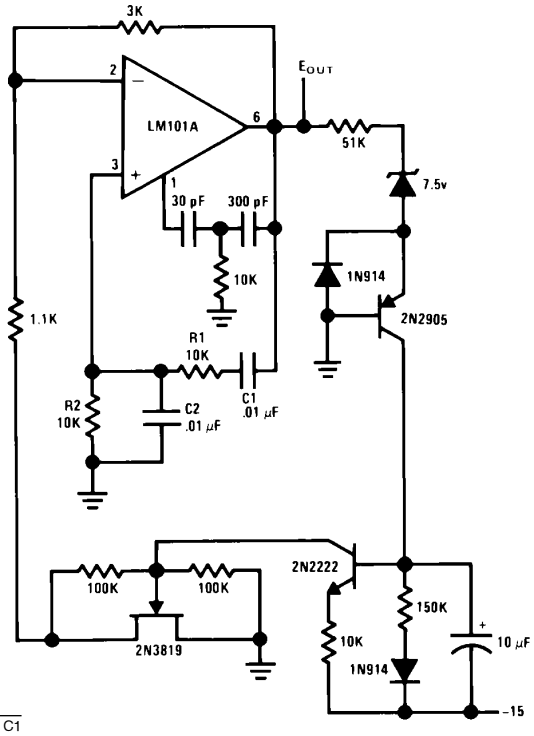
$$I_{OUT} = \frac{R3\ V_{IN}}{R1\ R5}$$

R3 = R4 + R5

R1 = R2

TL/H/7057–33

Wein Bridge Oscillator with FET Amplitude Stabilization



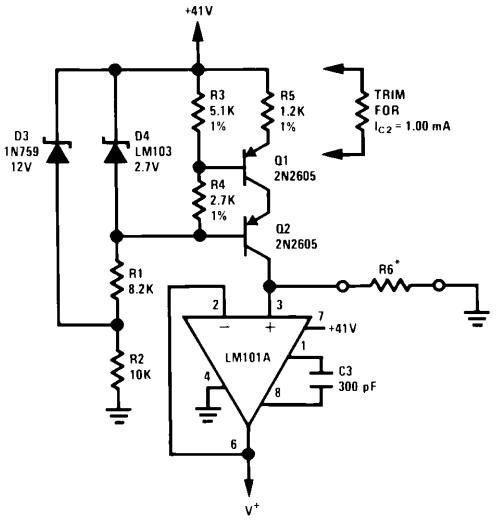
R1 = R2

C1 = C2

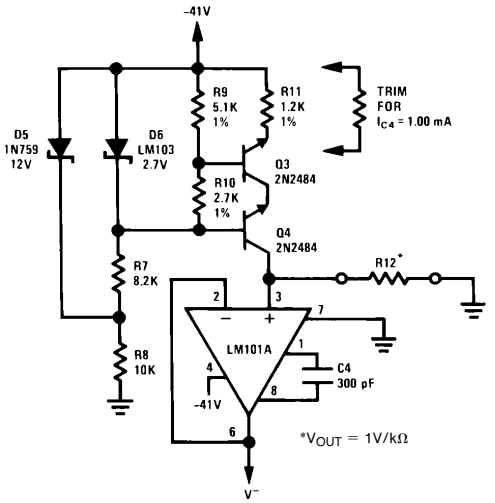
$$f = \frac{1}{2\pi R1\ C1}$$

TL/H/7057–34

Low Power Supply for Integrated Circuit Testing

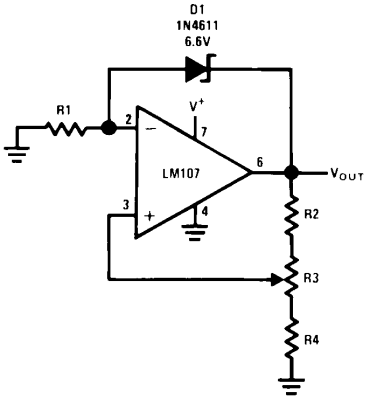


TL/H/7057–35



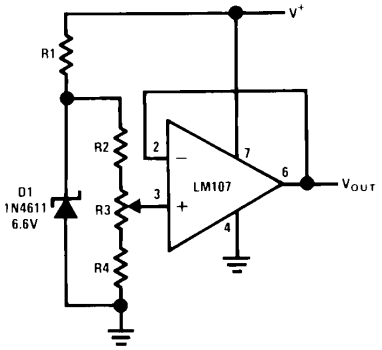
TL/H/7057–91

Positive Voltage Reference



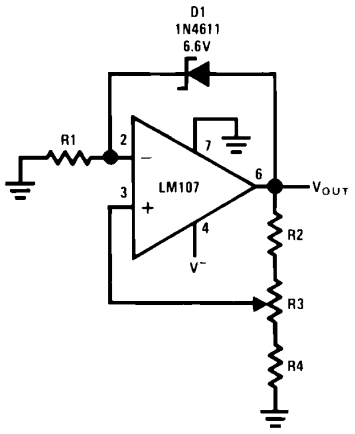
TL/H/7057–36

Positive Voltage Reference



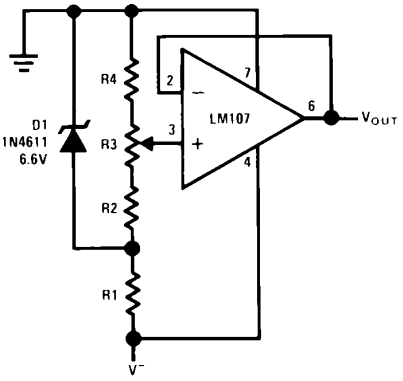
TL/H/7057–37

Negative Voltage Reference



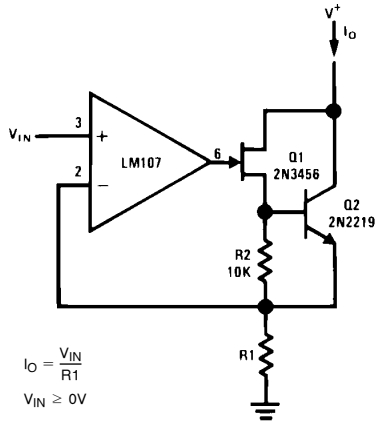
TL/H/7057–38

Negative Voltage Reference



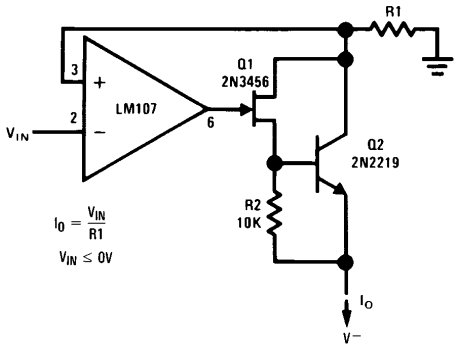
TL/H/7057–39

Precision Current Sink



TL/H/7057–40

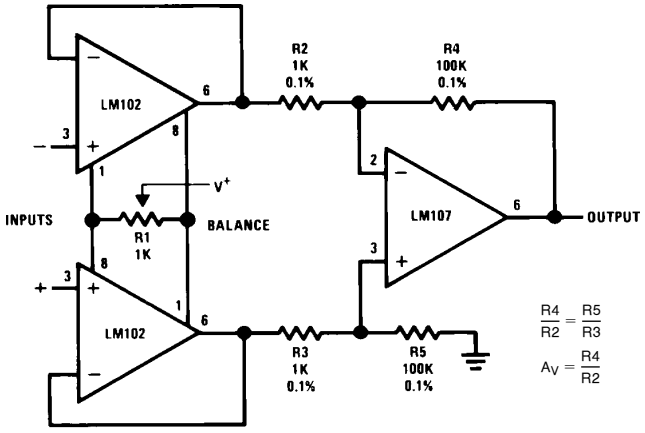
Precision Current Source



TL/H/7057–41

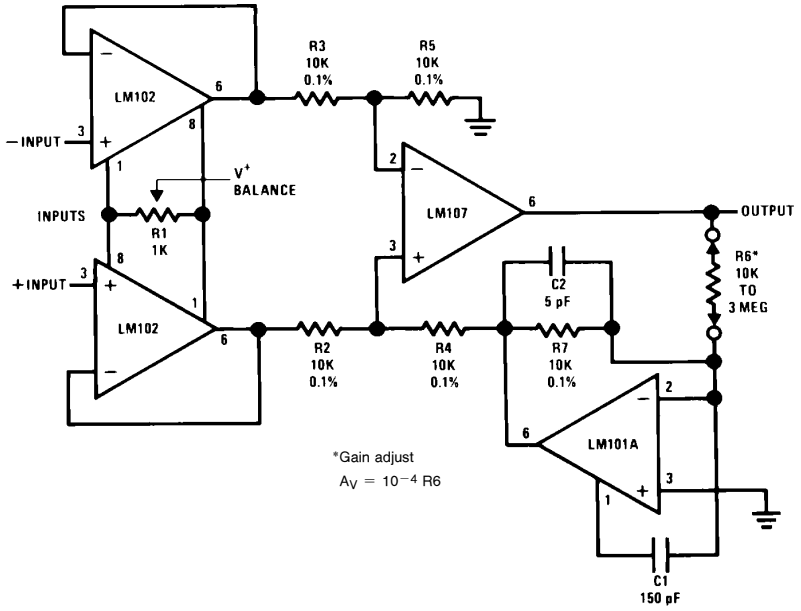
SECTION 3 — SIGNAL PROCESSING

Differential-Input Instrumentation Amplifier



TL/H/7057–42

Variable Gain, Differential-Input Instrumentation Amplifier

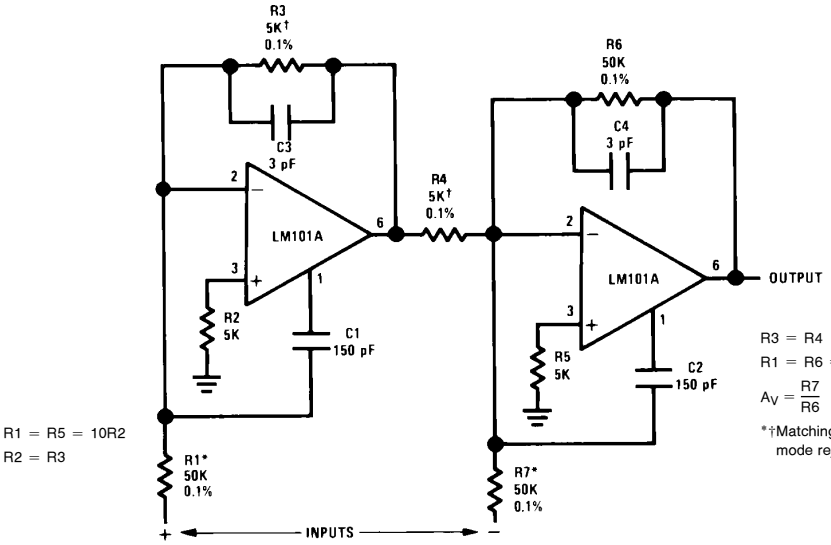


*Gain adjust

$A_V = 10^{-4}$ R6

TL/H/7057–43

Instrumentation Amplifier with ±100 Volt Common Mode Range



R1 = R5 = 10R2

R2 = R3

R3 = R4

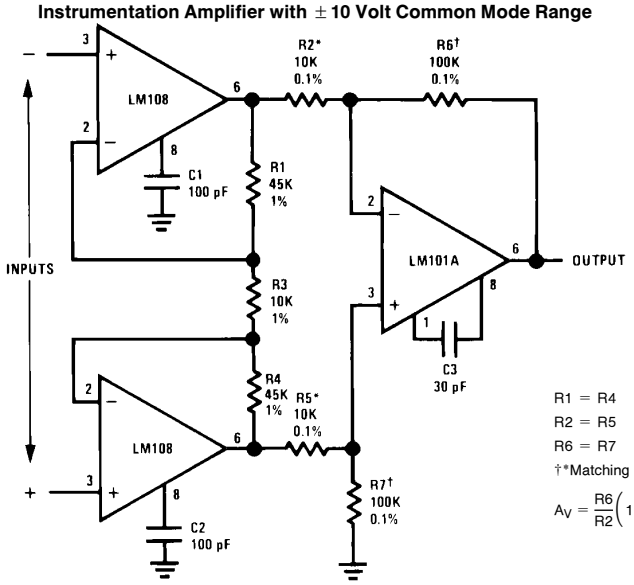
R1 = R6 = 10R3

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

*†Matching determines common mode rejection.

TL/H/7057–44

Instrumentation Amplifier with ±10 Volt Common Mode Range

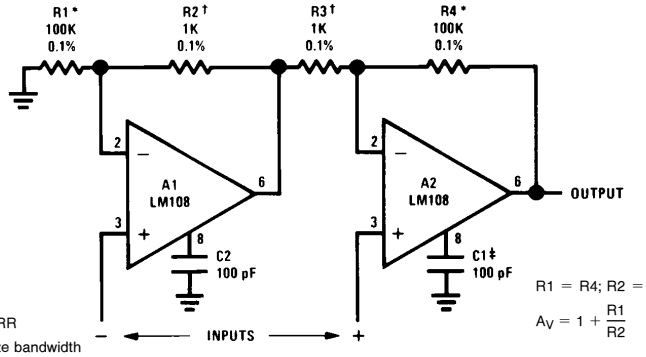


R1 = R4
R2 = R5
R6 = R7
†*Matching Determines CMRR

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

TL/H/7057–45

High Input Impedance Instrumentation Amplifier



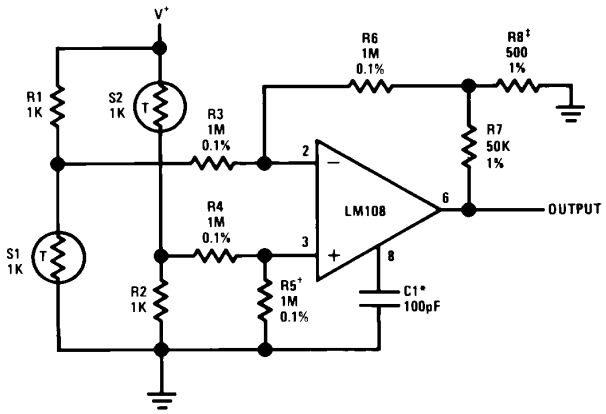
*†Matching determines CMRR
‡May be deleted to maximize bandwidth

R1 = R4; R2 = R3

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

TL/H/7057–46

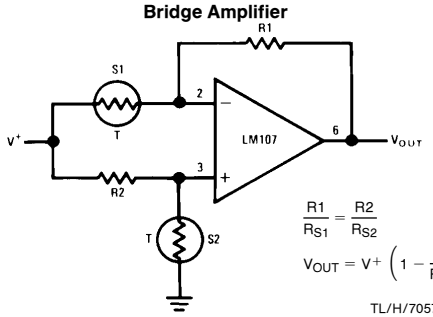
Bridge Amplifier with Low Noise Compensation



*Reduces feed through of power supply noise by 20 dB and makes supply bypassing unnecessary.
†Trim for best common mode rejection
‡Gain adjust

TL/H/7057–47

Bridge Amplifier

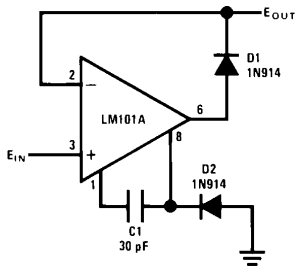


$$\frac{R1}{R_{S1}} = \frac{R2}{R_{S2}}$$

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

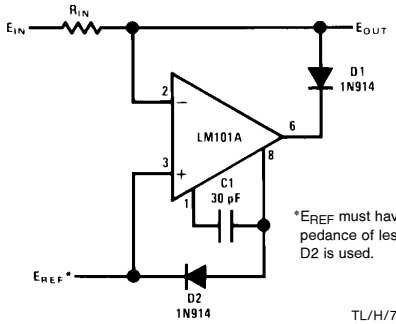
TL/H/7057–48

Precision Diode



TL/H/7057–49

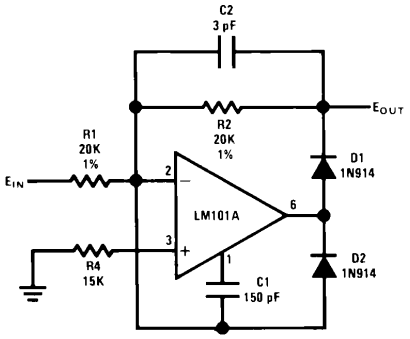
Precision Clamp



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

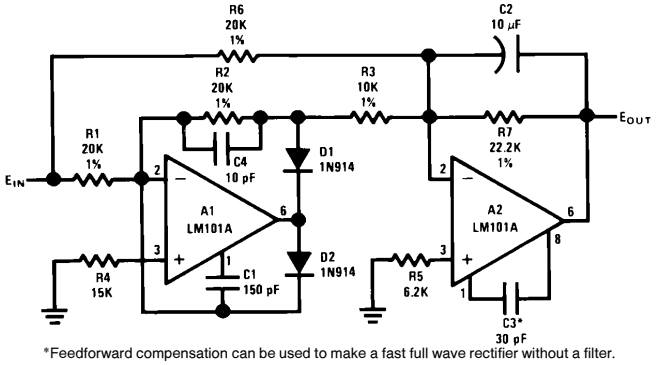
TL/H/7057–50

Fast Half Wave Rectifier



TL/H/7057–51

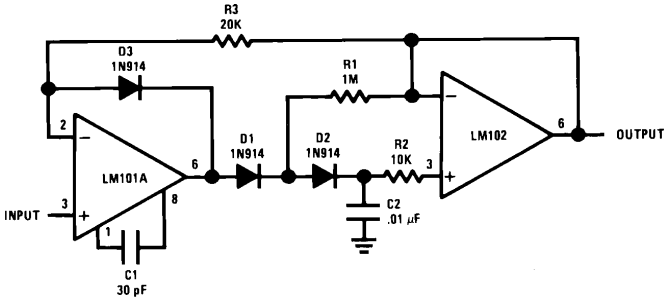
Precision AC to DC Converter



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

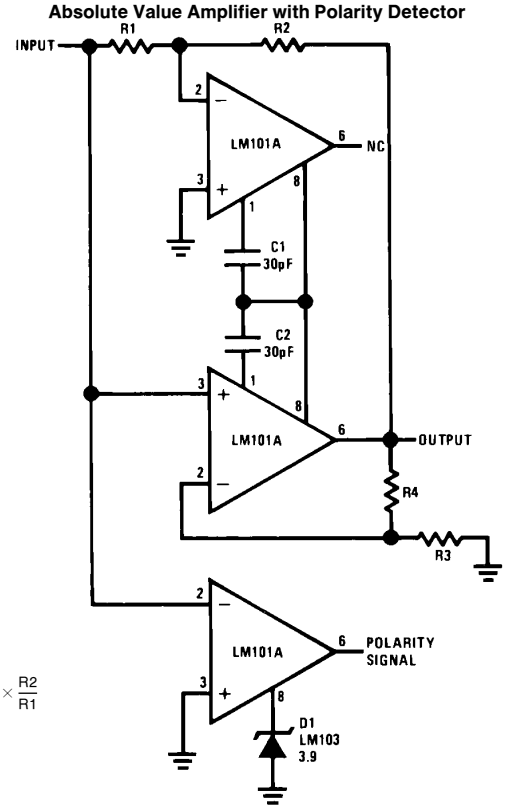
TL/H/7057–52

Low Drift Peak Detector



TL/H/7057–53

Absolute Value Amplifier with Polarity Detector

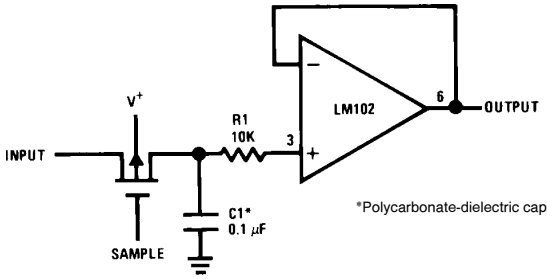


$$V_{OUT} = -|V_{IN}| \times \frac{R2}{R1}$$

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

TL/H/7057–54

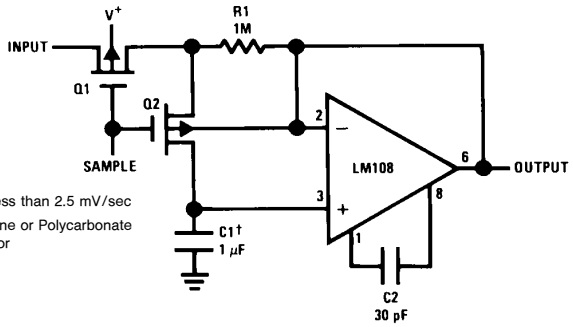
Sample and Hold



*Polycarbonate-dielectric capacitor

TL/H/7057–55

Sample and Hold

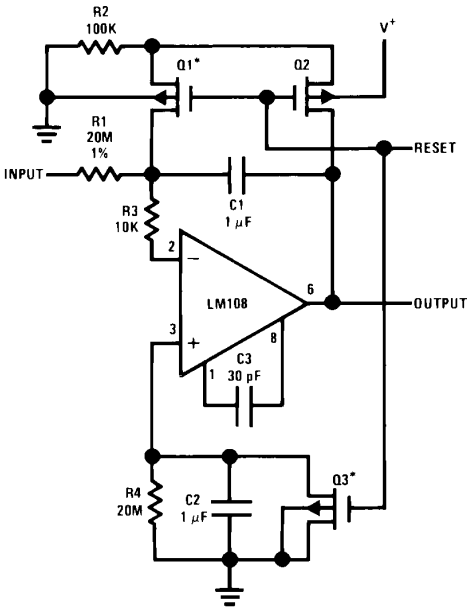


*Worst case drift less than 2.5 mV/sec

†Teflon, Polyethylene or Polycarbonate Dielectric Capacitor

TL/H/7057–56

Low Drift Integrator

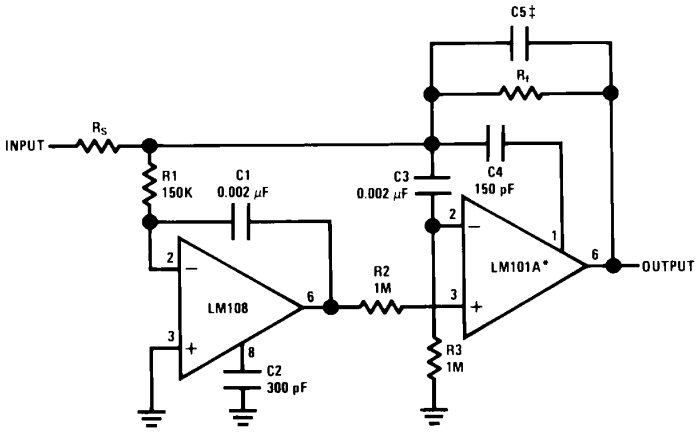


TL/H/7057–57

*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



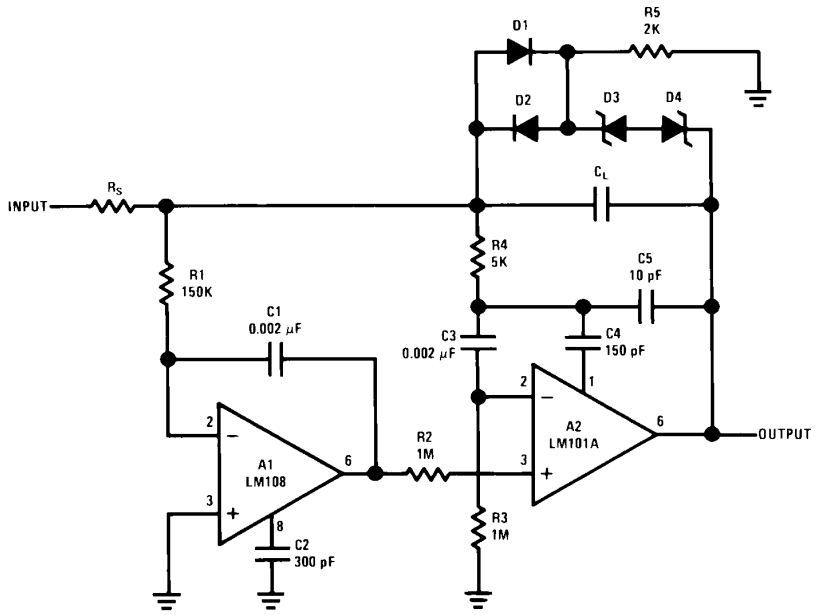
TL/H/7057–58

* 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

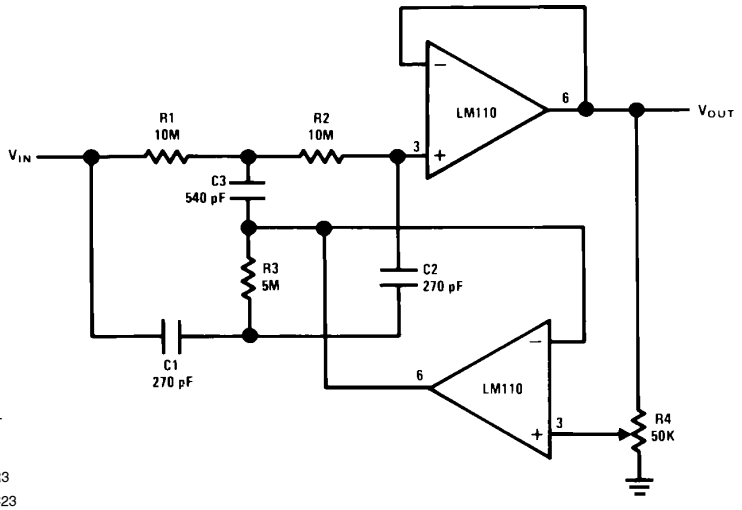
‡ $C5 = \frac{6 \times 10^{-8}}{R_f}$

Fast Integrator with Low Input Current



TL/H/7057–59

Adjustable Q Notch Filter



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

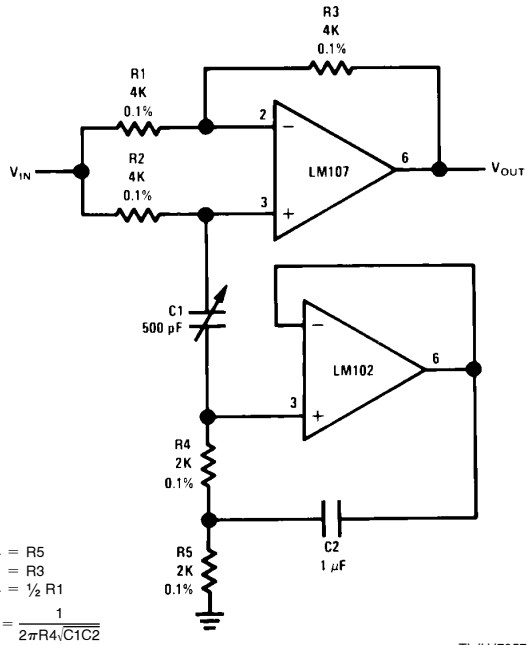
$= 60$ Hz

R1 = R2 = R3

C1 = C2 = C23

TL/H/7057–60

Easily Tuned Notch Filter

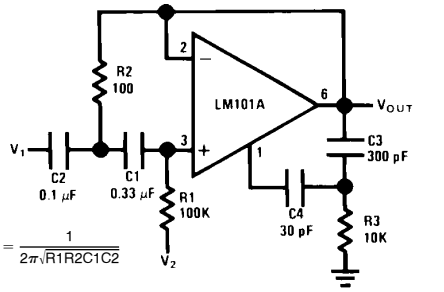


R4 = R5
R1 = R3
R4 = ½ R1

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

TL/H/7057–61

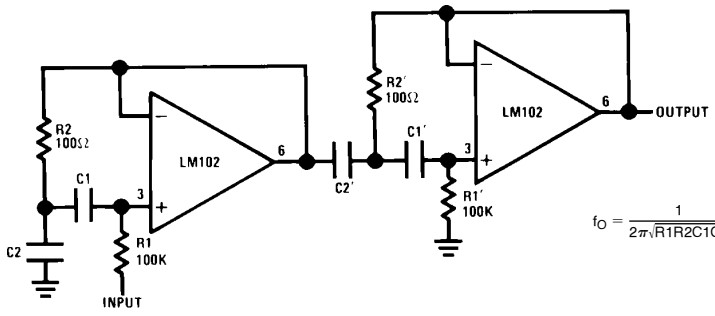
Tuned Circuit



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

TL/H/7057–62

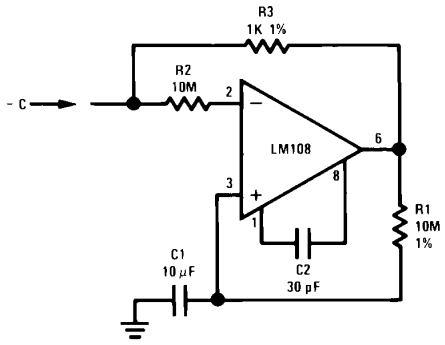
Two-Stage Tuned Circuit



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

TL/H/7057–63

Negative Capacitance Multiplier



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

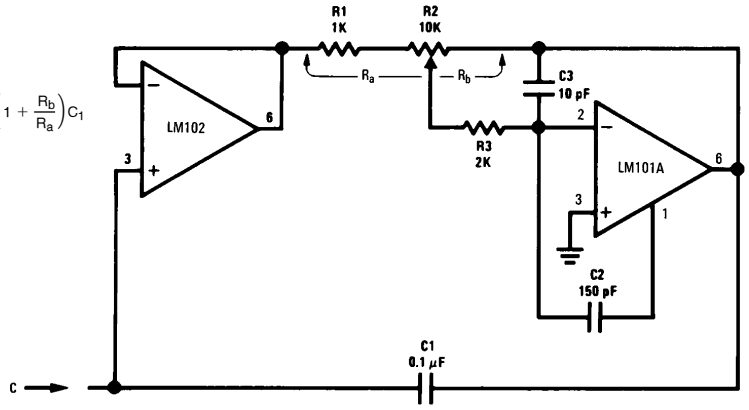
$$I_L = \frac{V_{OS} + R2\, I_{OS}}{R3}$$

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

TL/H/7057–65

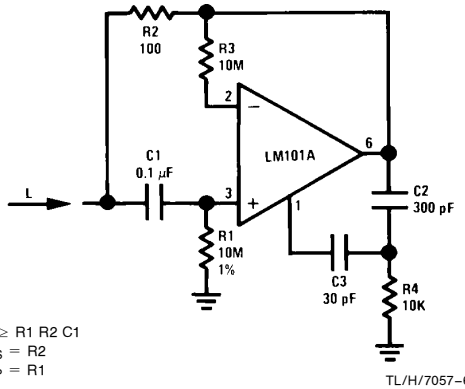
Variable Capacitance Multiplier

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



TL/H/7057–66

Simulated Inductor



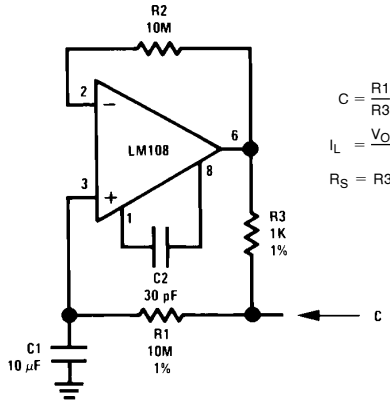
$L \geq R1\, R2\, C1$

$R_S = R2$

$R_P = R1$

TL/H/7057–67

Capacitance Multiplier



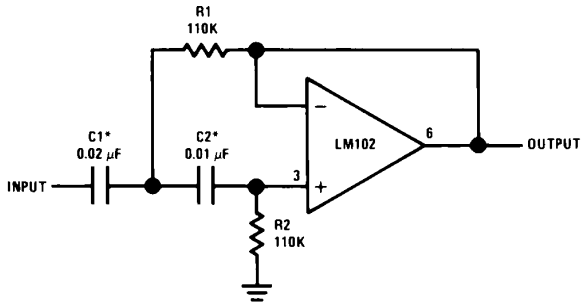
$$C = \frac{R1}{R3} C1$$

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

$$R_S = R3$$

TL/H/7057–68

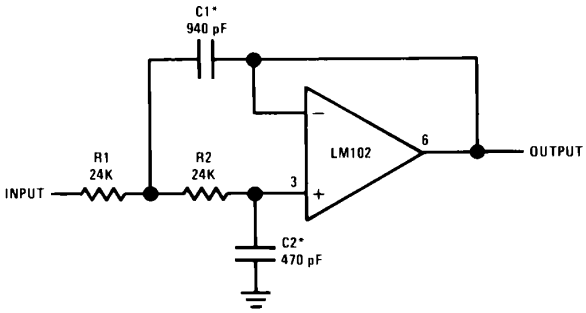
High Pass Active Filter



TL/H/7057–71

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

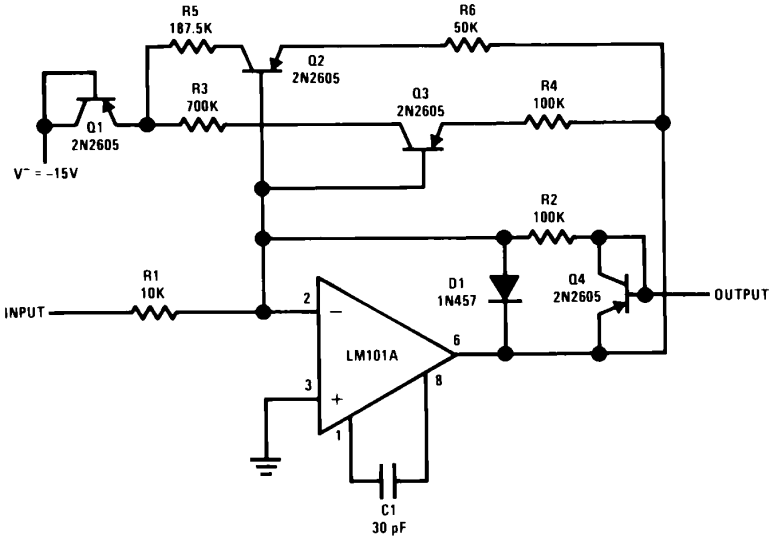
Low Pass Active Filter



TL/H/7057–72

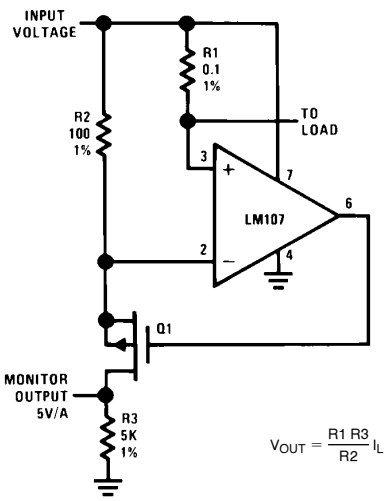
*Values are for 10 kHz cutoff. Use silvered mica capacitors for good temperature stability.

Nonlinear Operational Amplifier with Temperature Compensated Breakpoints



TL/H/7057–73

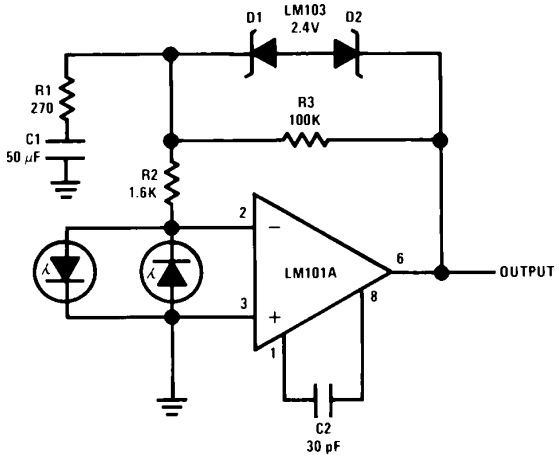
Current Monitor



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

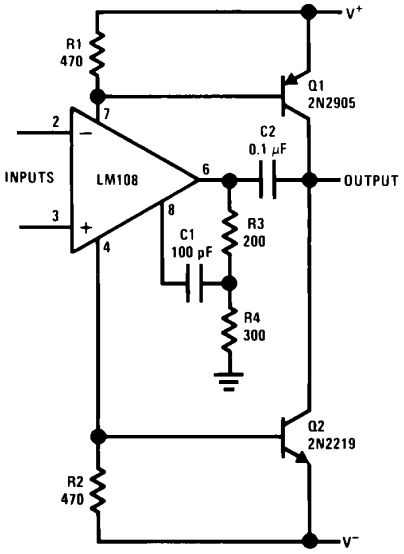
TL/H/7057–74

Saturating Servo Preamplifier with Rate Feedback



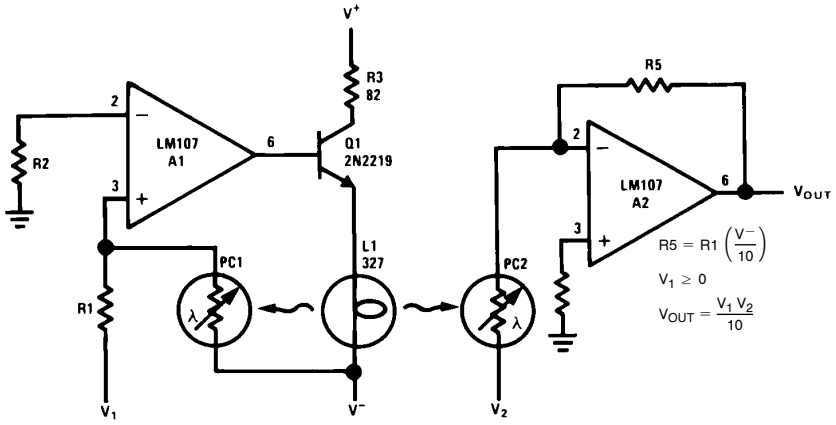
TL/H/7057–75

Power Booster



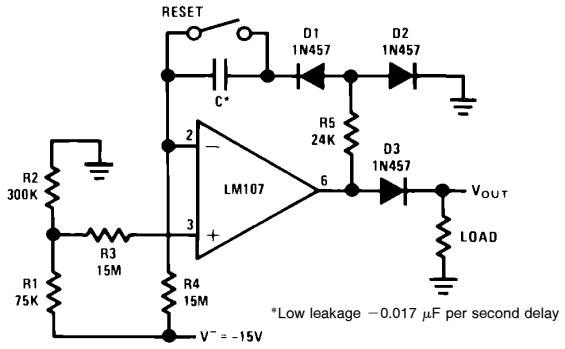
TL/H/7057–76

Analog Multiplier



TL/H/7057–77

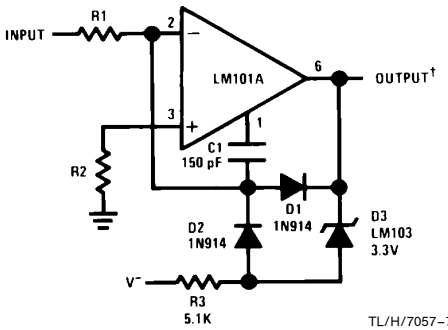
Long Interval Timer



*Low leakage −0.017 μF per second delay

TL/H/7057–78

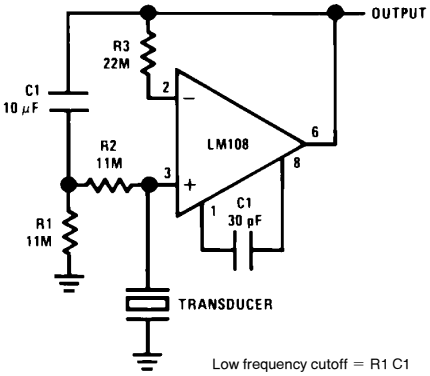
Fast Zero Crossing Detector



TL/H/7057–79

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

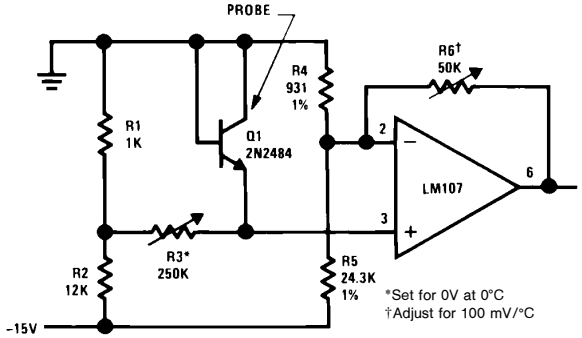
Amplifier for Piezoelectric Transducer



Low frequency cutoff = R1 C1

TL/H/7057–80

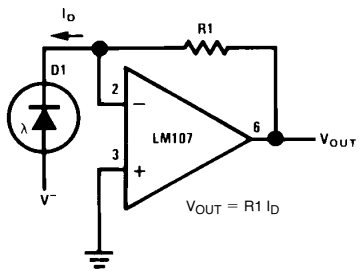
Temperature Probe



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

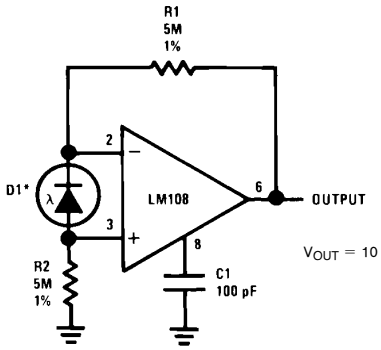
TL/H/7057–81

Photodiode Amplifier



TL/H/7057–82

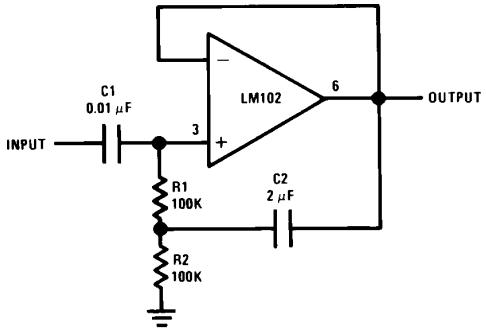
Photodiode Amplifier



TL/H/7057–83

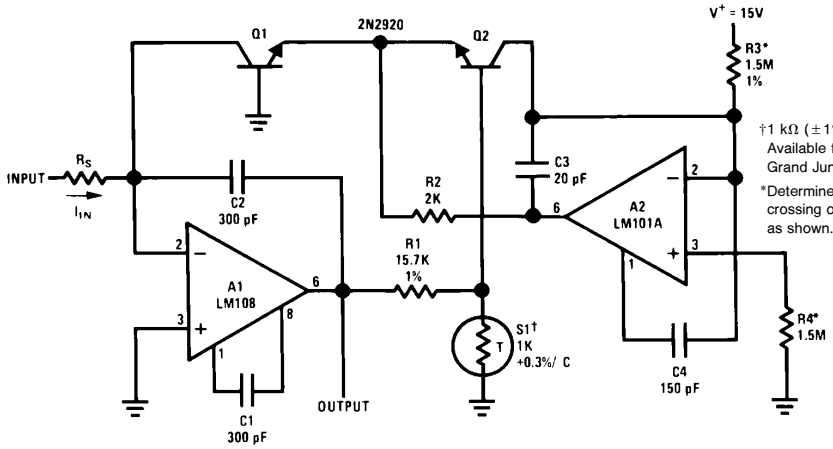
*Operating photodiode with less than 3 mV across it eliminates leakage currents.

High Input Impedance AC Follower



TL/H/7057–84

Temperature Compensated Logarithmic Converter

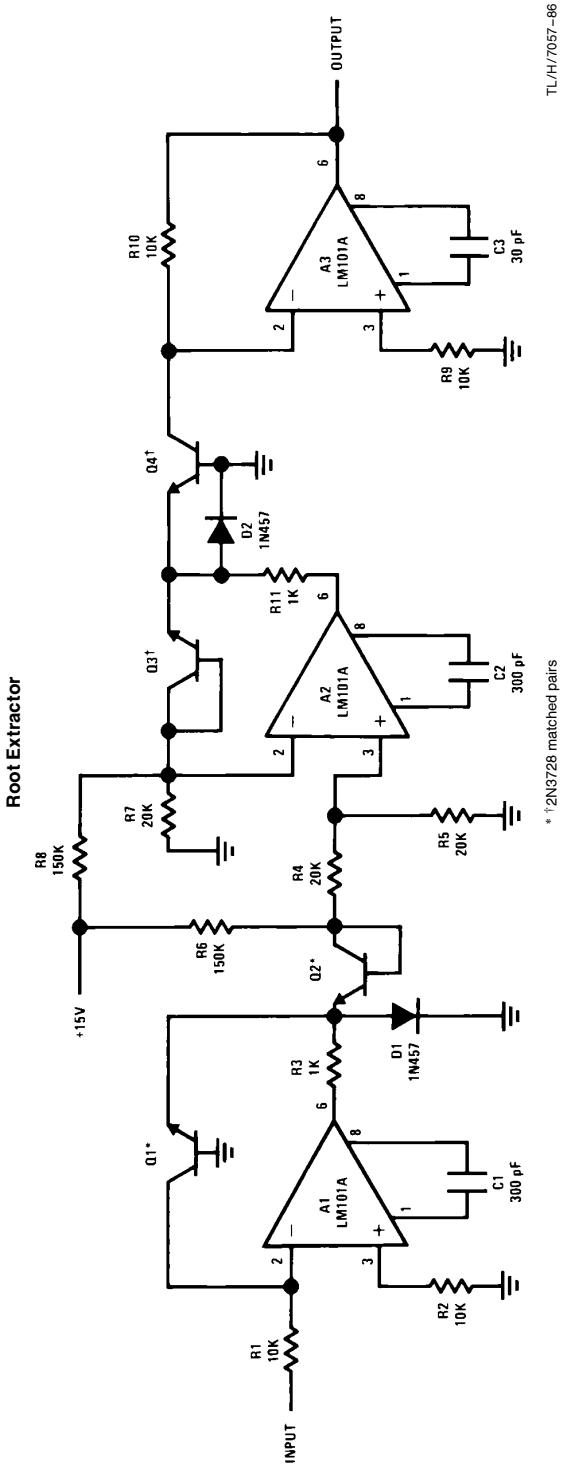


†1 kΩ (±1%) at 25°C, +3500 ppm/°C. Available from Vishay Ultronix, Grand Junction, CO, Q81 Series.

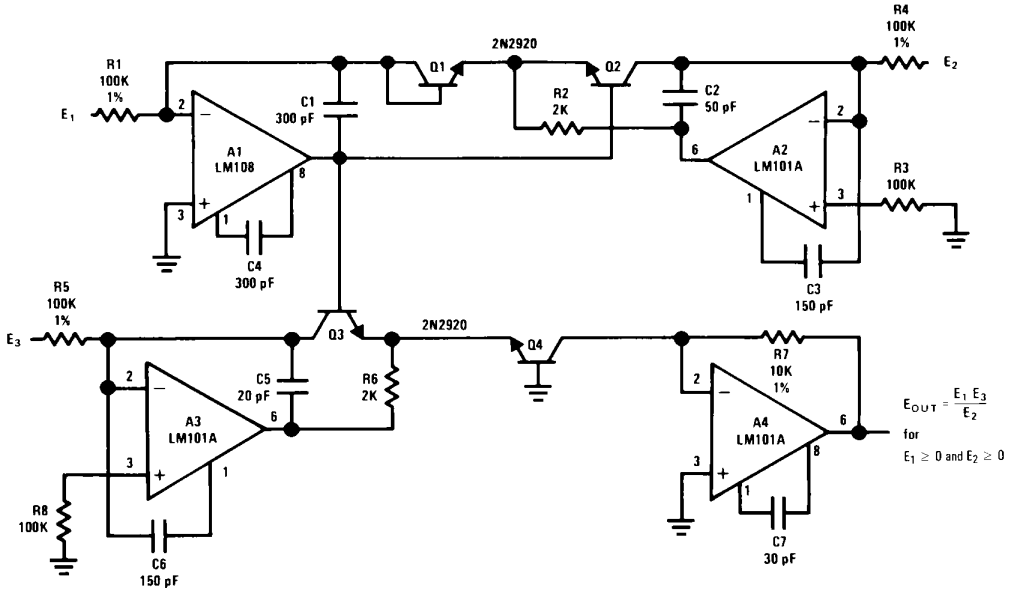
*Determines current for zero crossing on output: 10 μA as shown.

TL/H/7057–85

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

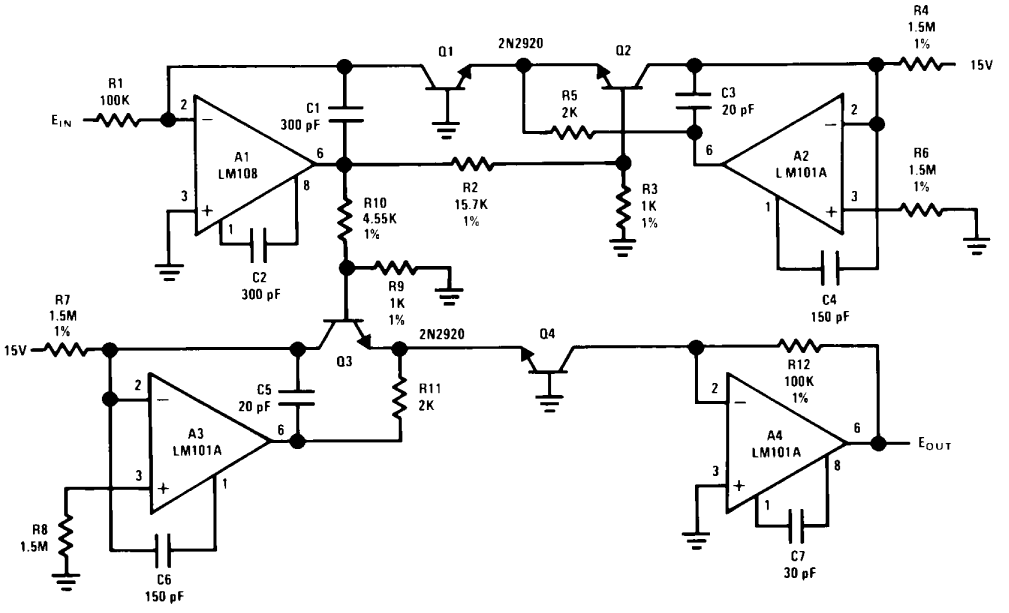

Root Extractor
OUTPUT
INPUT
+15V
R1 10K
R2 10K
R3 1K
R4 20K
R5 20K
R6 150K
R7 20K
R8 150K
R9 10K
R10 10K
R11 1K
C1 300 pF
C2 300 pF
C3 30 pF
D1 1N457
D2 1N457
A1 LM101A
A2 LM101A
A3 LM101A
Q1*
Q2*
Q3†
Q4†
* †2N3728 matched pairs
TL/H/7057–86

Multiplier/Divider



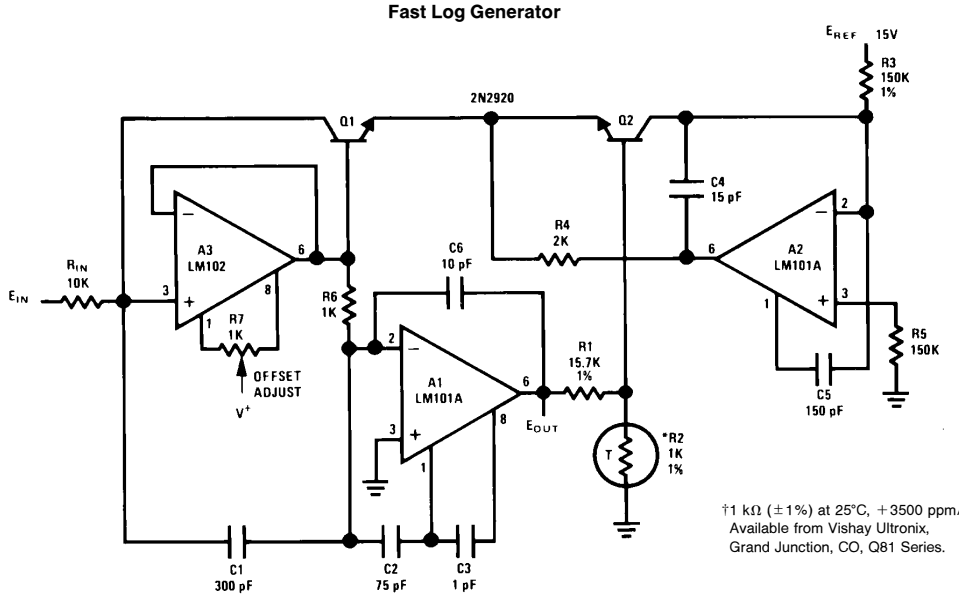
TL/H/7057–87

Cube Generator



TL/H/7057–88

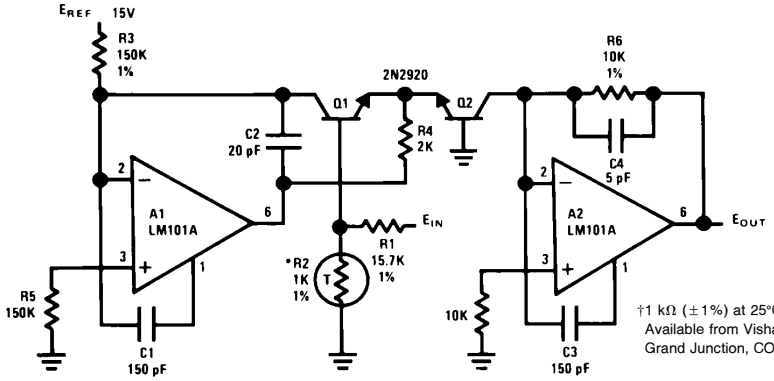
Fast Log Generator



†1 kΩ (±1%) at 25°C, +3500 ppm/°C.
Available from Vishay Ultronix,
Grand Junction, CO, Q81 Series.

TL/H/7057–89

Anti-Log Generator



†1 kΩ (±1%) at 25°C, +3500 ppm/°C.
Available from Vishay Ultronix,
Grand Junction, CO, Q81 Series.

TL/H/7057–90

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