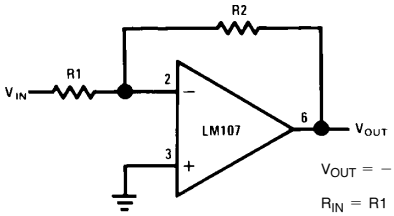
# Op Amp Circuit Collection

National Semiconductor
Application Note 31
February 1978



## SECTION 1—BASIC CIRCUITS

### Inverting Amplifier

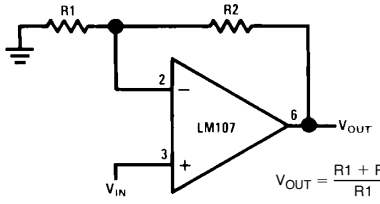



$$V_{OUT} = -\frac{R2}{R1} V_{IN}$$

$R_{IN} = R1$

TL/H/7057–1

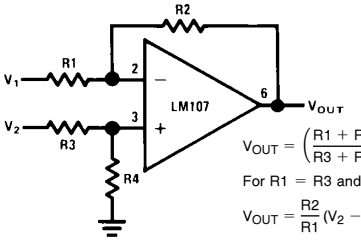
### Non-Inverting Amplifier




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

TL/H/7057–2

### Difference Amplifier




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

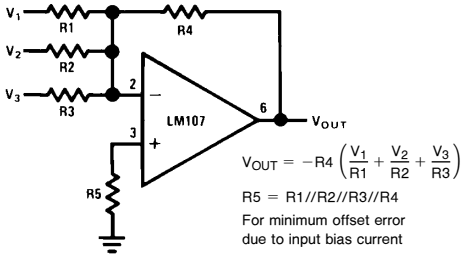
For R1 = R3 and R2 = R4

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

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

TL/H/7057–3

### Inverting Summing Amplifier

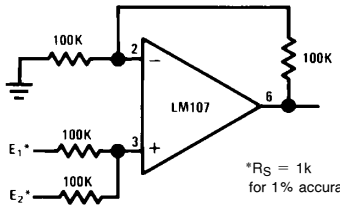



$$V_{OUT} = -R4\left(\frac{V_1}{R1} + \frac{V_2}{R2} + \frac{V_3}{R3}\right)$$

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

TL/H/7057–4

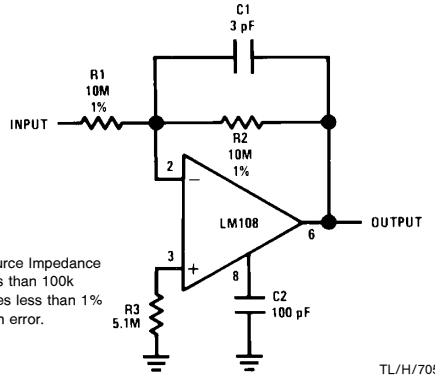
### Non-Inverting Summing Amplifier




*$R_S$ = 1k for 1% accuracy

TL/H/7057–5

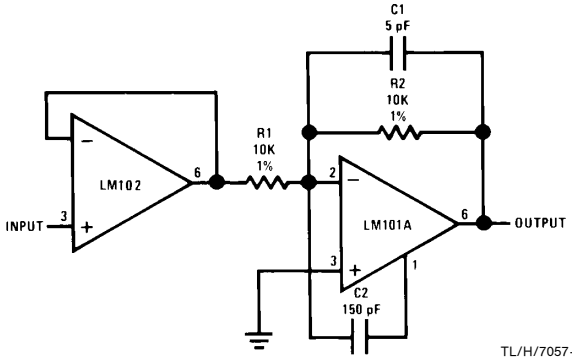
### Inverting Amplifier with High Input Impedance




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

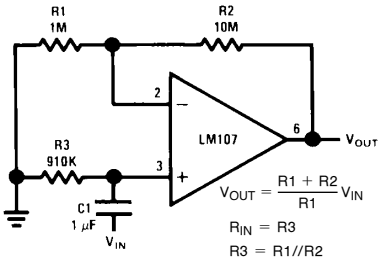
TL/H/7057–6

### 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

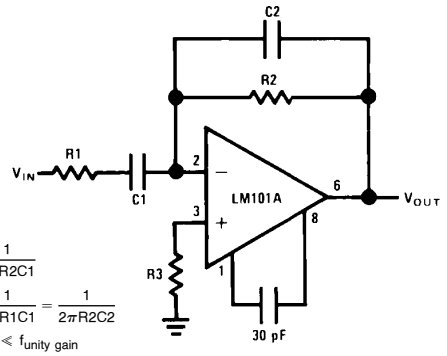
TL/H/7057–8



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

**Practical Differentiator**



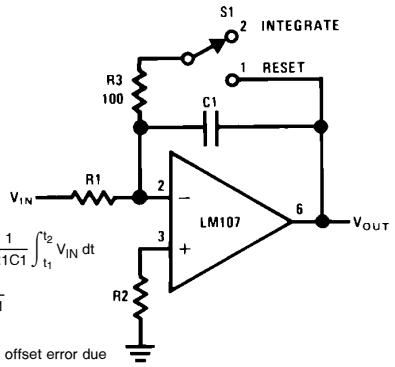

$$f_c = \frac{1}{2\pi R2C1}$$

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

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

TL/H/7057–9

**Integrator**




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

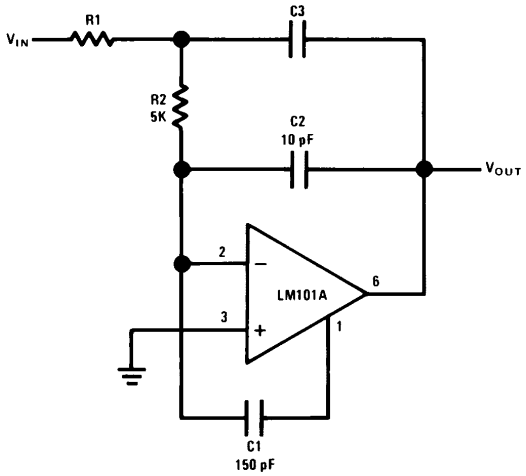
$$f_c = \frac{1}{2\pi R1C1}$$

$R1 = R2$

For minimum offset error due to input bias current

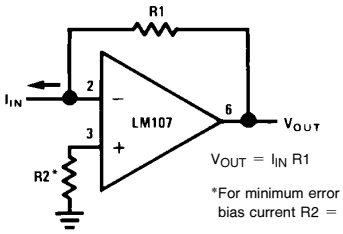
TL/H/7057–10

**Fast Integrator**




TL/H/7057–11

**Current to Voltage Converter**

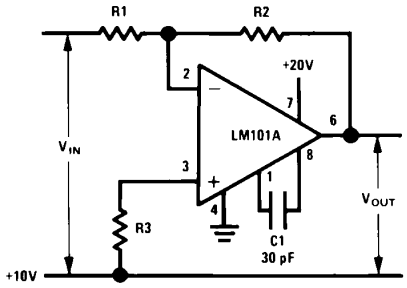



$V_{OUT} = I_{IN}\,R1$

*For minimum error due to bias current R2 = R1

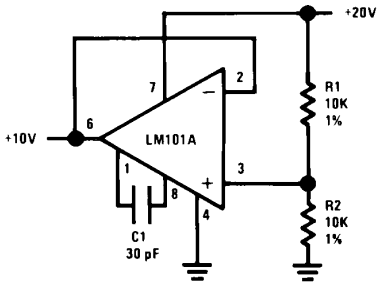
TL/H/7057–12

**Circuit for Operating the LM101 without a Negative Supply**



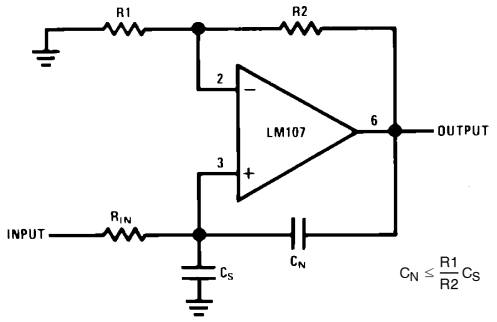

TL/H/7057–13

**Circuit for Generating the Second Positive Voltage**



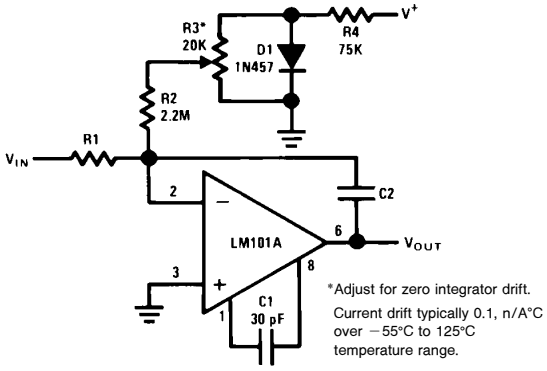

TL/H/7057–14

**Neutralizing Input Capacitance to Optimize Response Time**




TL/H/7057–15

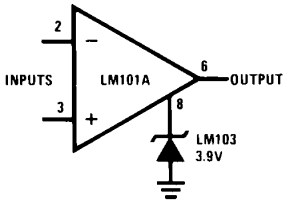
**Integrator with Bias Current Compensation**




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

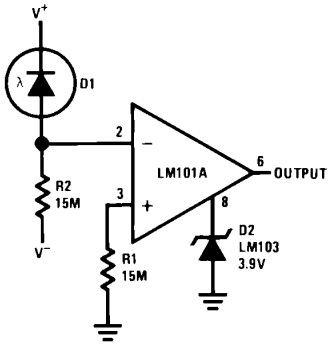
TL/H/7057–16

**Voltage Comparator for Driving DTL or TTL Integrated Circuits**



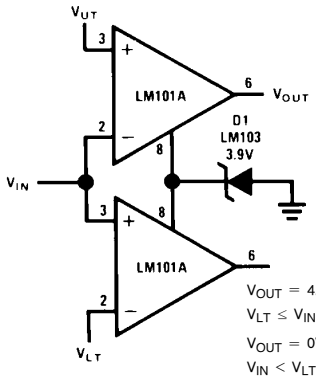

TL/H/7057–17

**Threshold Detector for Photodiodes**




TL/H/7057–18

**Double-Ended Limit Detector**

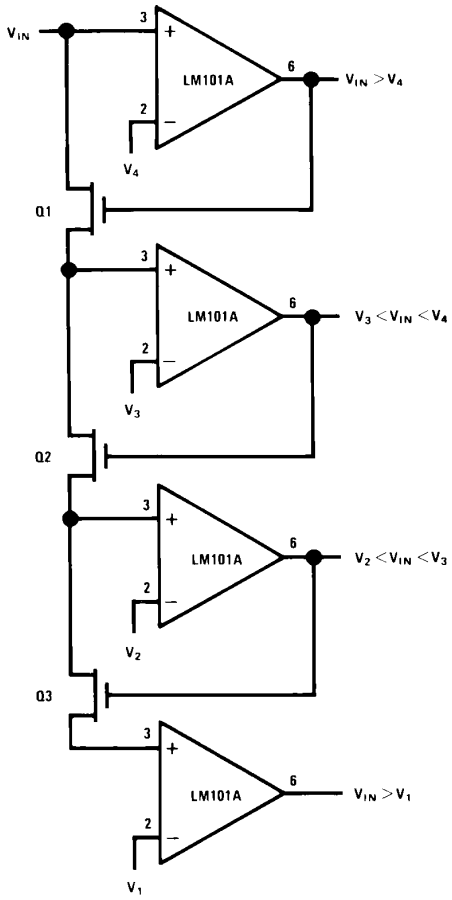



$V_{OUT}$ = 4.6V for $V_{LT} \leq V_{IN} \leq V_{UT}$

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

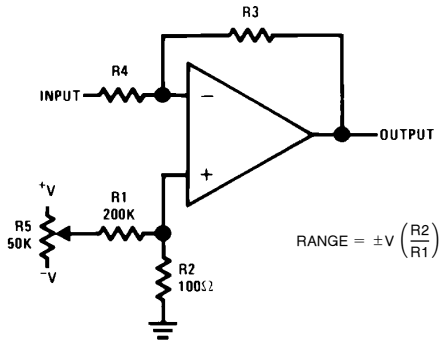
TL/H/7057–19

**Multiple Aperture Window Discriminator**




TL/H/7057–20

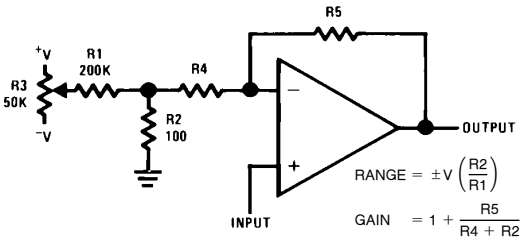
**Offset Voltage Adjustment for Inverting Amplifiers Using Any Type of Feedback Element**




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

TL/H/7057–21

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

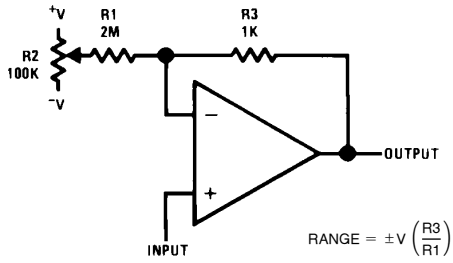



$$\text{RANGE} = \pm V\left(\frac{R2}{R1}\right)$$

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

TL/H/7057–22

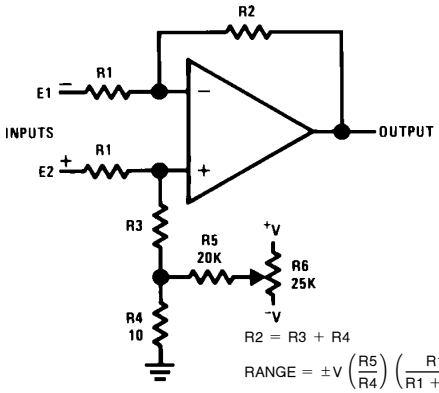
**Offset Voltage Adjustment for Voltage Followers**




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

TL/H/7057–23

**Offset Voltage Adjustment for Differential Amplifiers**



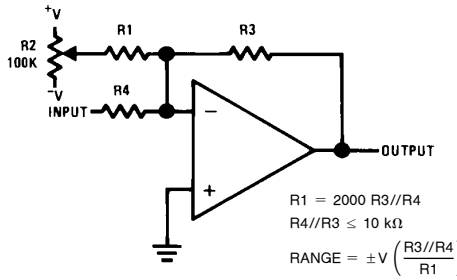

$$R2 = R3 + R4$$

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

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

TL/H/7057–24

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




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

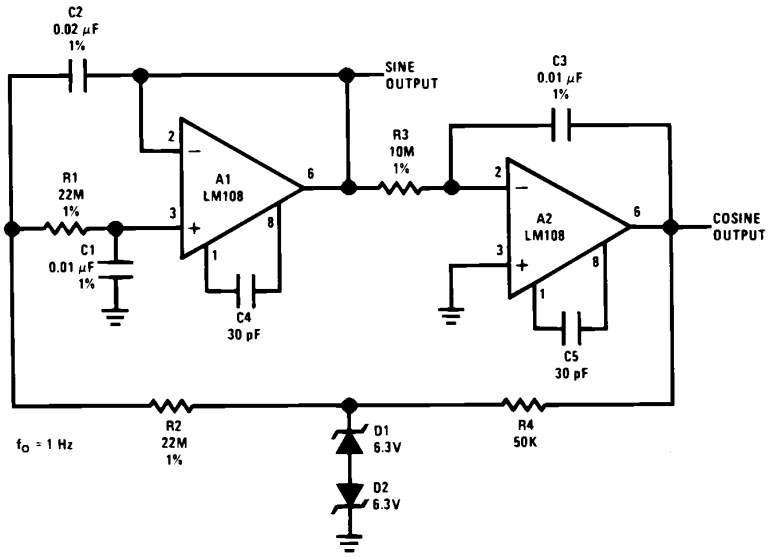
$$R4//R3 \leq 10\ k\Omega$$

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

TL/H/7057–25

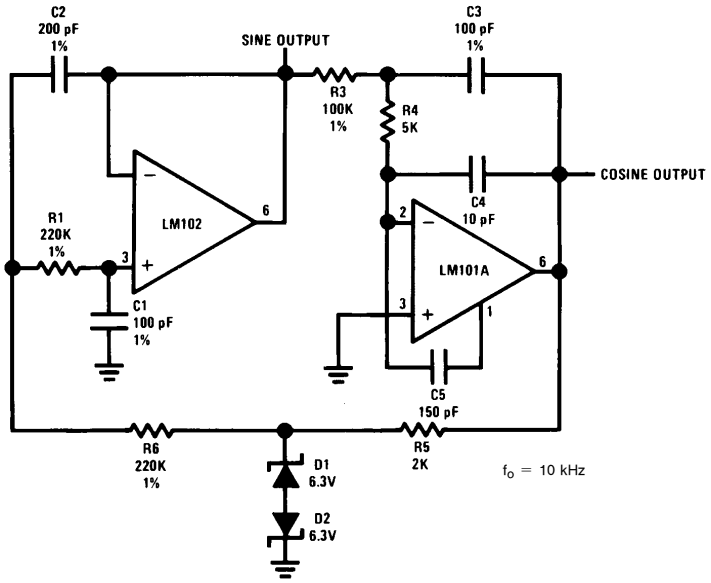
## SECTION 2 — SIGNAL GENERATION

### Low Frequency Sine Wave Generator with Quadrature Output



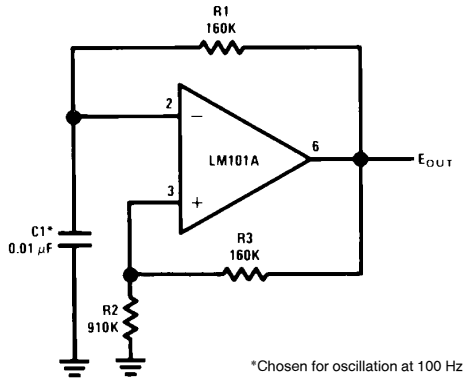

TL/H/7057–26

### High Frequency Sine Wave Generator with Quadrature Output




TL/H/7057–27

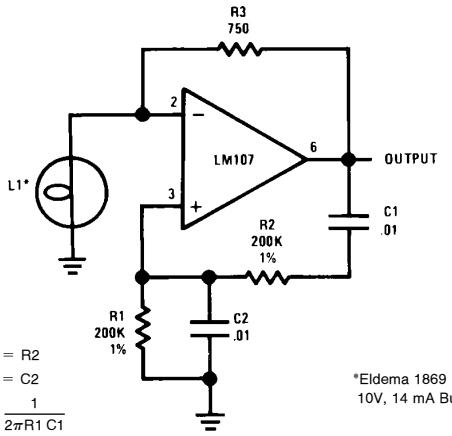
**Free-Running Multivibrator**




*Chosen for oscillation at 100 Hz

TL/H/7057–28

**Wein Bridge Sine Wave Oscillator**




R1 = R2

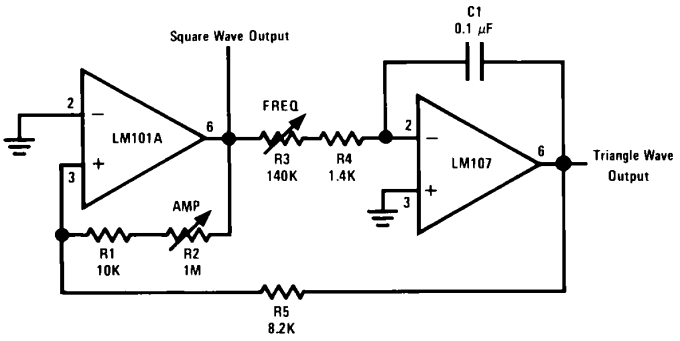
C1 = C2

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

*Eldema 1869
10V, 14 mA Bulb

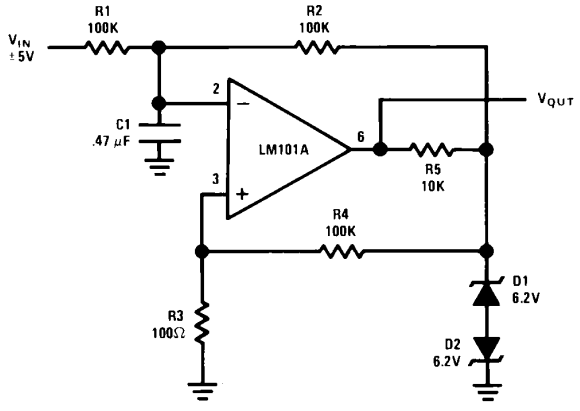
TL/H/7057–29

**Function Generator**



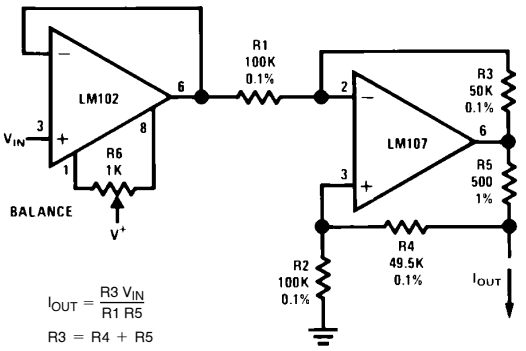

TL/H/7057–30

**Pulse Width Modulator**




TL/H/7057–31

**Bilateral Current Source**



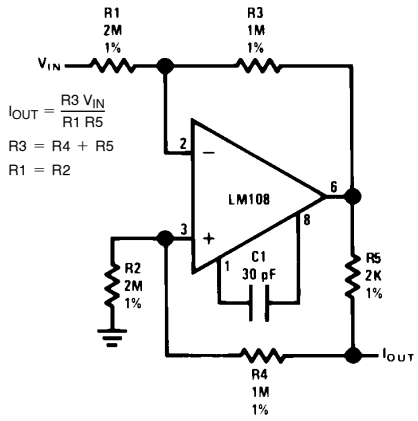

$$I_{OUT} = \frac{R3\ V_{IN}}{R1\ R5}$$

R3 = R4 + R5

R1 = R2

TL/H/7057–32

**Bilateral Current Source**



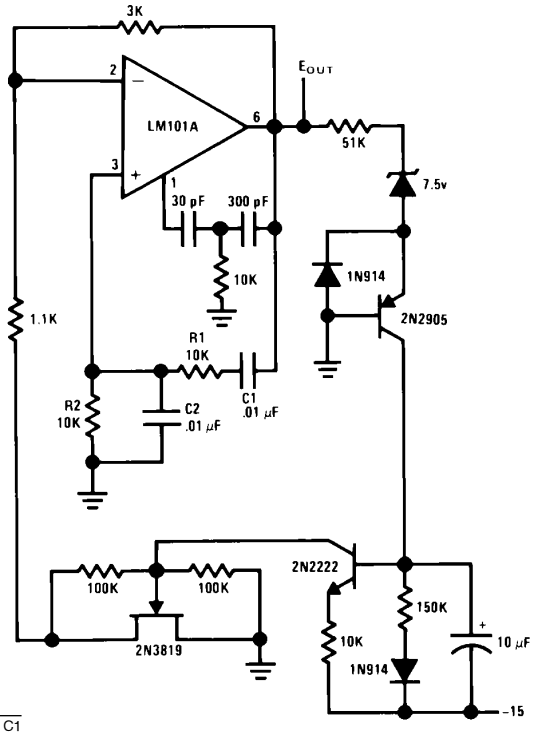

$$I_{OUT} = \frac{R3\ V_{IN}}{R1\ R5}$$

R3 = R4 + R5

R1 = R2

TL/H/7057–33

**Wein Bridge Oscillator with FET Amplitude Stabilization**



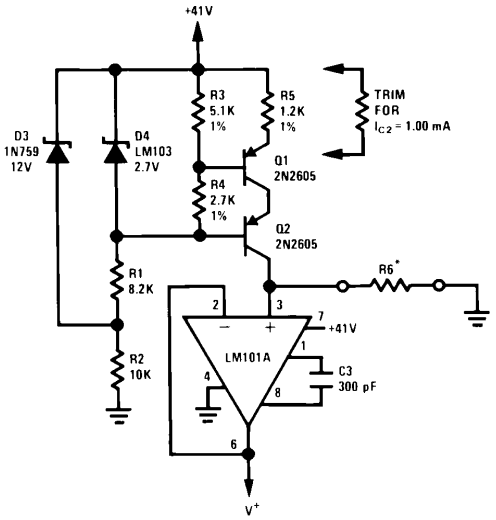

R1 = R2

C1 = C2

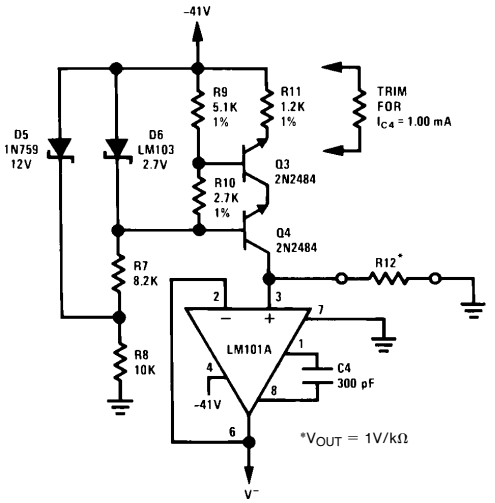
$$f = \frac{1}{2\pi R1\ C1}$$

TL/H/7057–34

**Low Power Supply for Integrated Circuit Testing**

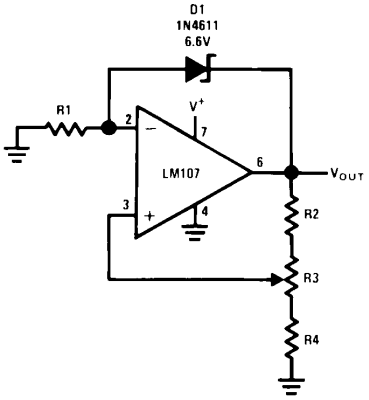



TL/H/7057–35



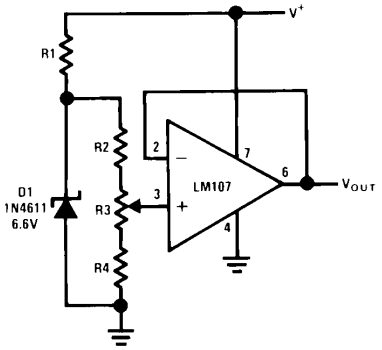

TL/H/7057–91

**Positive Voltage Reference**



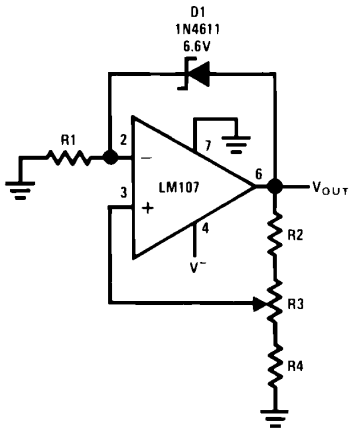

TL/H/7057–36

**Positive Voltage Reference**



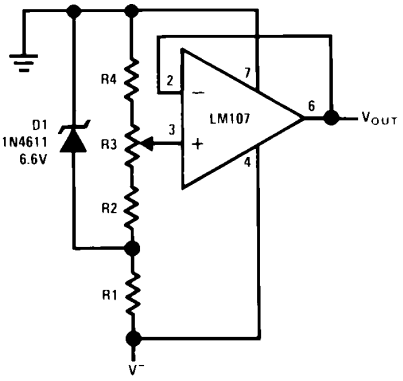

TL/H/7057–37

**Negative Voltage Reference**



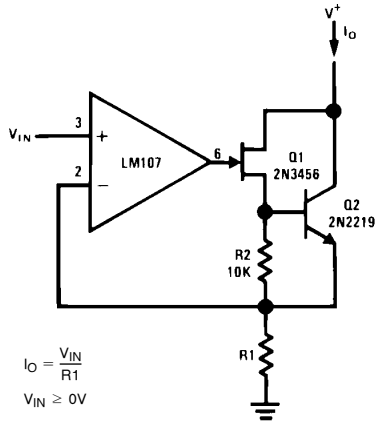

TL/H/7057–38

**Negative Voltage Reference**



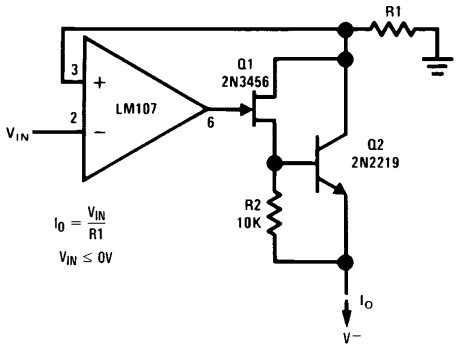

TL/H/7057–39

**Precision Current Sink**




TL/H/7057–40

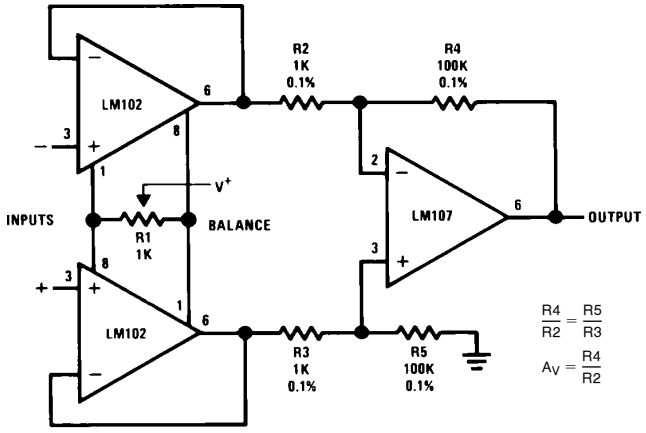
**Precision Current Source**




TL/H/7057–41

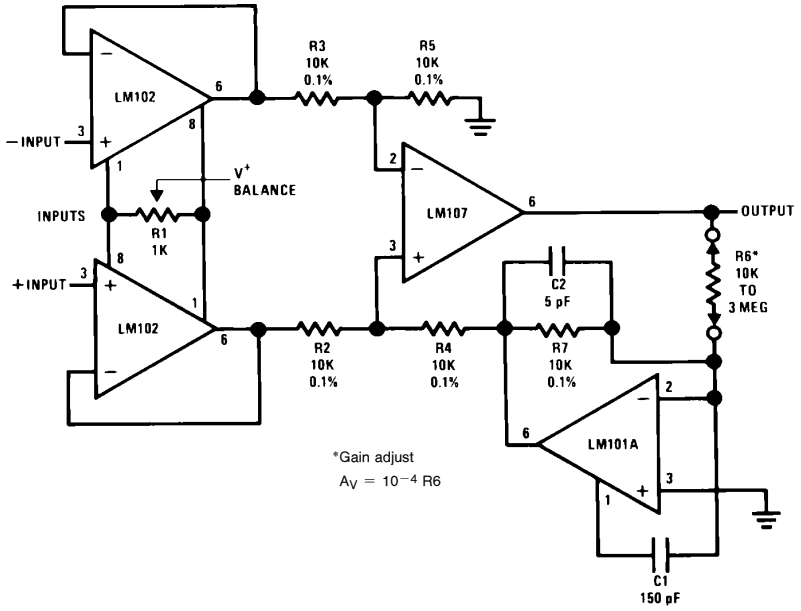
## SECTION 3 — SIGNAL PROCESSING

**Differential-Input Instrumentation Amplifier**




TL/H/7057–42

**Variable Gain, Differential-Input Instrumentation Amplifier**

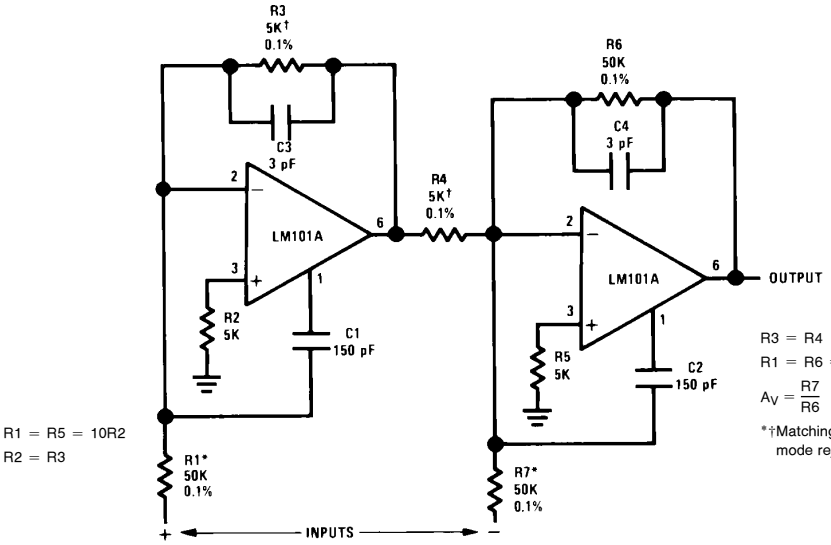



*Gain adjust

$A_V = 10^{-4}$ R6

TL/H/7057–43

**Instrumentation Amplifier with ±100 Volt Common Mode Range**




R1 = R5 = 10R2

R2 = R3

R3 = R4

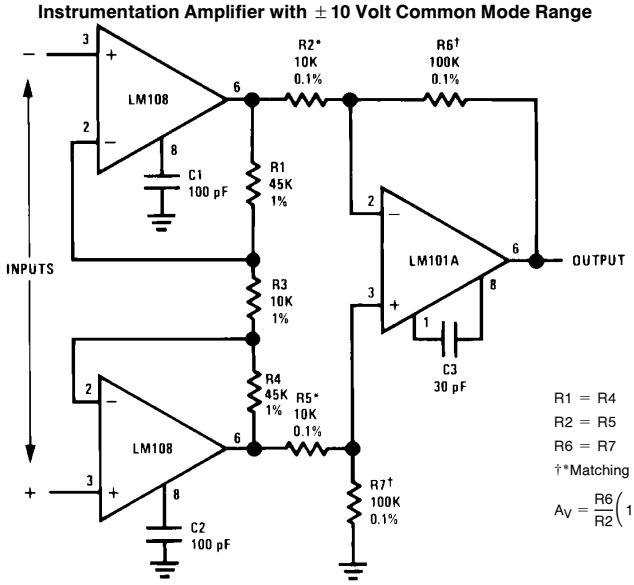
R1 = R6 = 10R3

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

*†Matching determines common mode rejection.

TL/H/7057–44

### Instrumentation Amplifier with ±10 Volt Common Mode Range

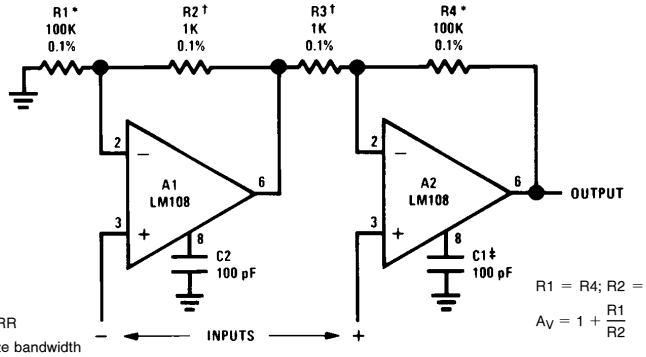



R1 = R4
R2 = R5
R6 = R7
†*Matching Determines CMRR

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

TL/H/7057–45

### High Input Impedance Instrumentation Amplifier



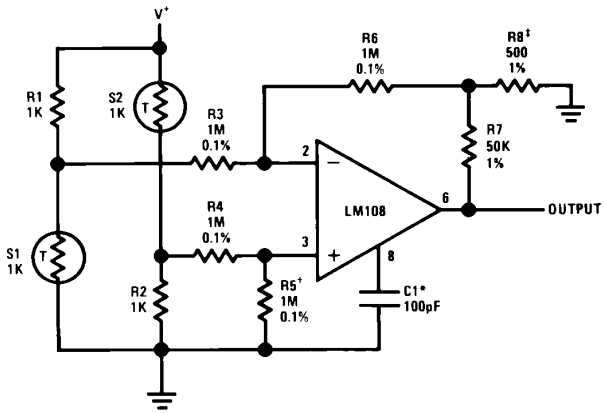

*†Matching determines CMRR
‡May be deleted to maximize bandwidth

R1 = R4; R2 = R3

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

TL/H/7057–46

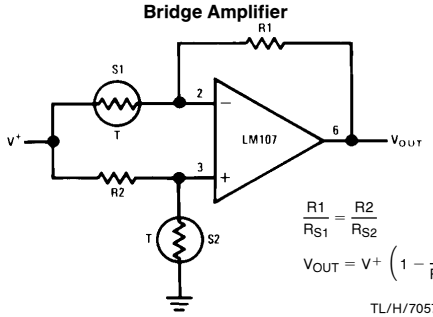
### Bridge Amplifier with Low Noise Compensation




*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

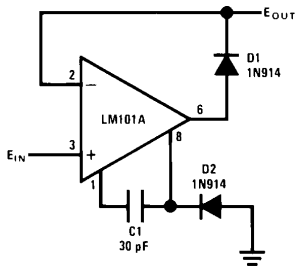



$$\frac{R1}{R_{S1}} = \frac{R2}{R_{S2}}$$

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

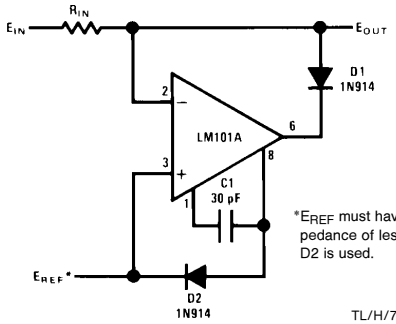
TL/H/7057–48

### Precision Diode




TL/H/7057–49

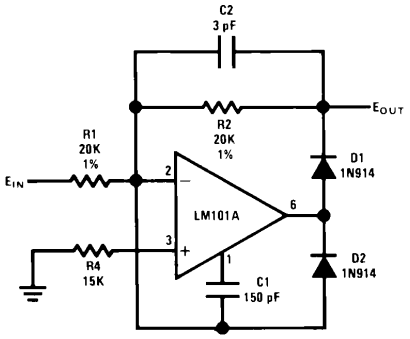
### Precision Clamp




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

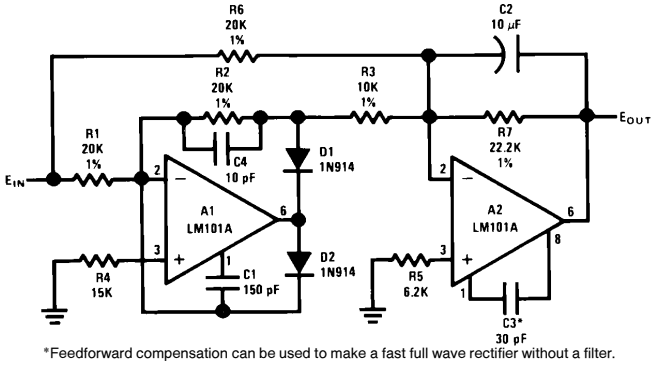
TL/H/7057–50

### Fast Half Wave Rectifier




TL/H/7057–51

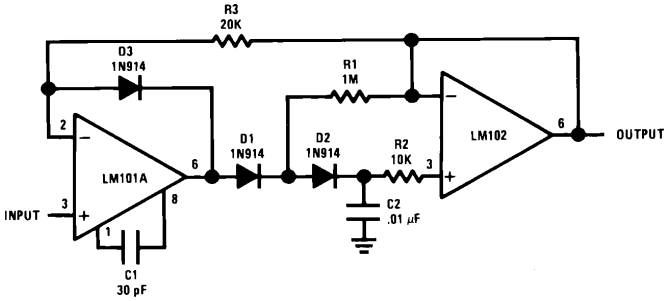
### Precision AC to DC Converter




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

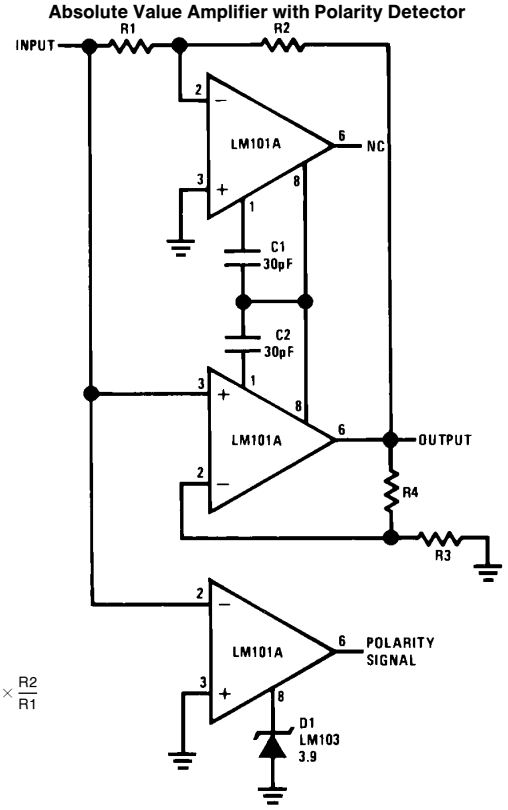
TL/H/7057–52

### Low Drift Peak Detector




TL/H/7057–53

**Absolute Value Amplifier with Polarity Detector**

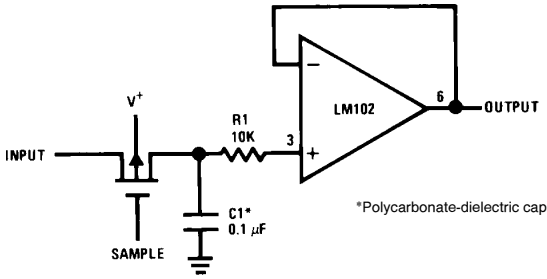



$$V_{OUT} = -|V_{IN}| \times \frac{R2}{R1}$$

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

TL/H/7057–54

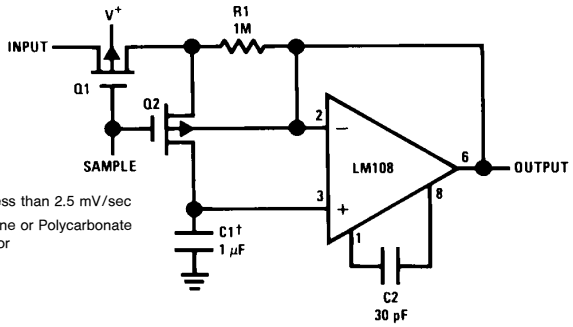
**Sample and Hold**




*Polycarbonate-dielectric capacitor

TL/H/7057–55

**Sample and Hold**

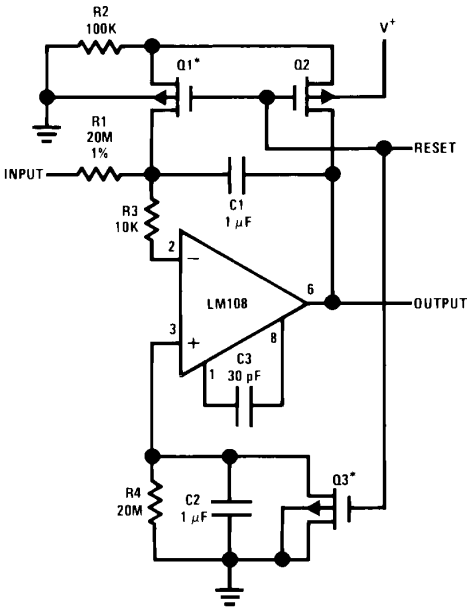



*Worst case drift less than 2.5 mV/sec

†Teflon, Polyethylene or Polycarbonate Dielectric Capacitor

TL/H/7057–56

## Low Drift Integrator

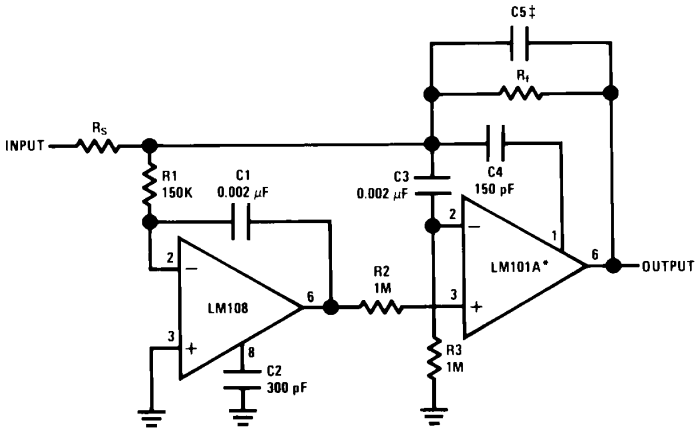



TL/H/7057–57

*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



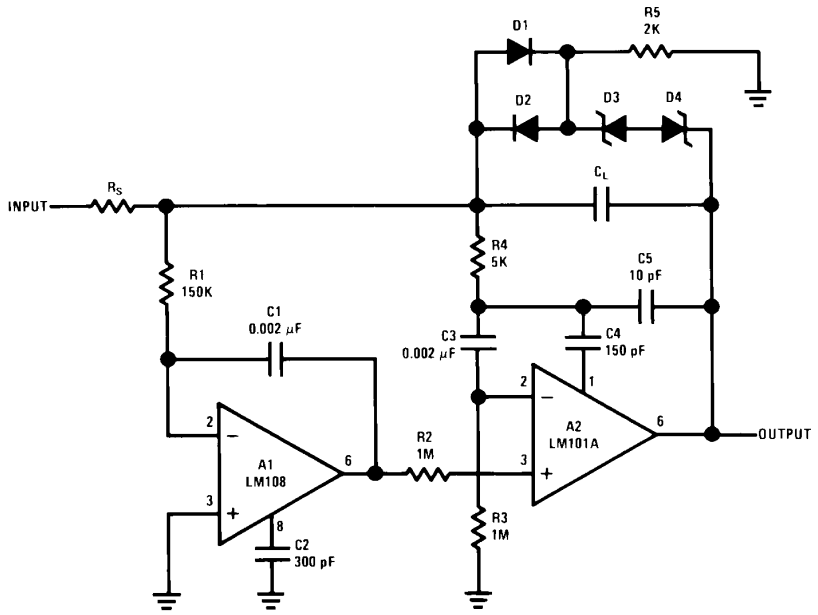

TL/H/7057–58

* 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

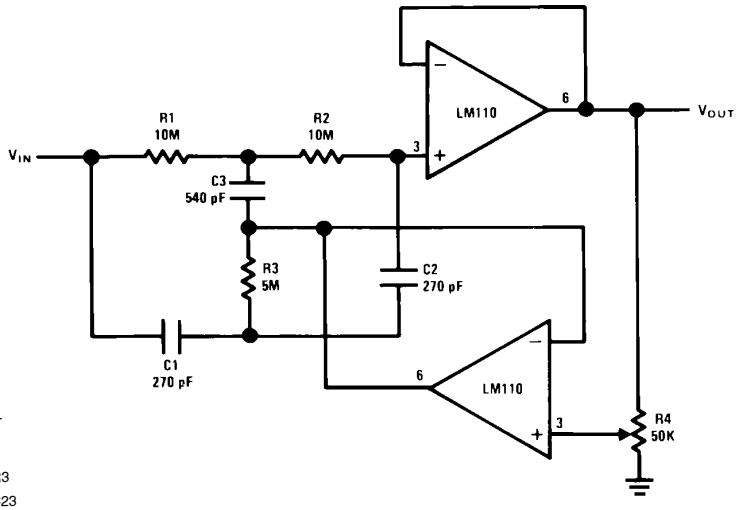
‡ $C5 = \frac{6 \times 10^{-8}}{R_f}$

**Fast Integrator with Low Input Current**




TL/H/7057–59

**Adjustable Q Notch Filter**




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

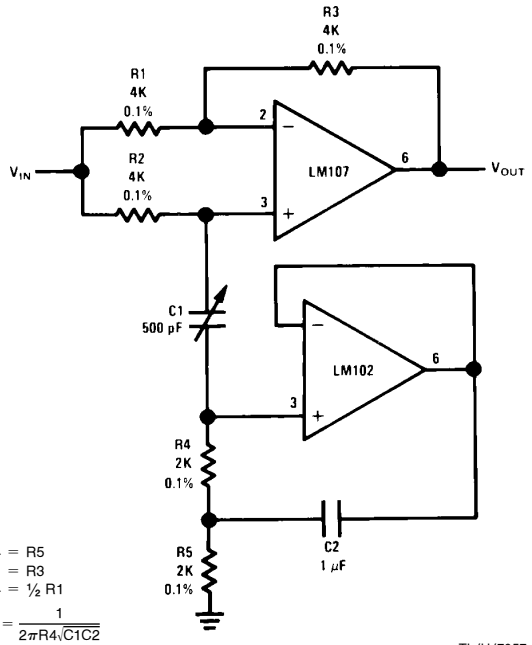
$= 60$ Hz

R1 = R2 = R3

C1 = C2 = C23

TL/H/7057–60

**Easily Tuned Notch Filter**

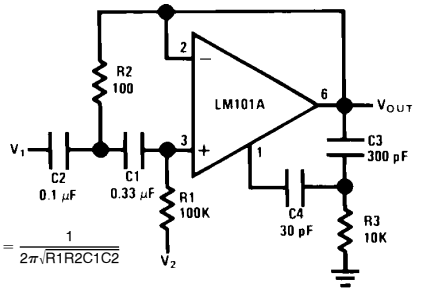



R4 = R5
R1 = R3
R4 = ½ R1

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

TL/H/7057–61

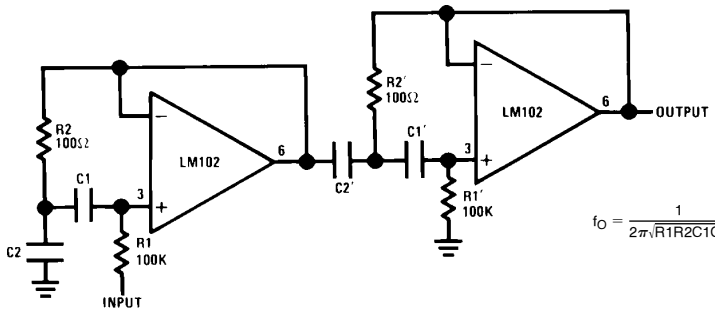
**Tuned Circuit**




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

TL/H/7057–62

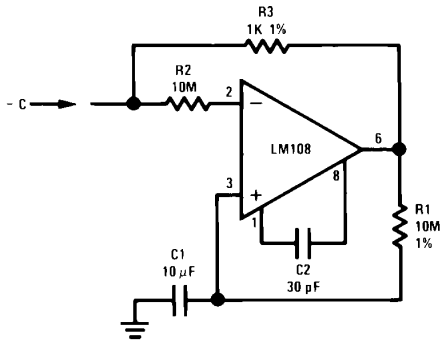
**Two-Stage Tuned Circuit**




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

TL/H/7057–63

### Negative Capacitance Multiplier




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

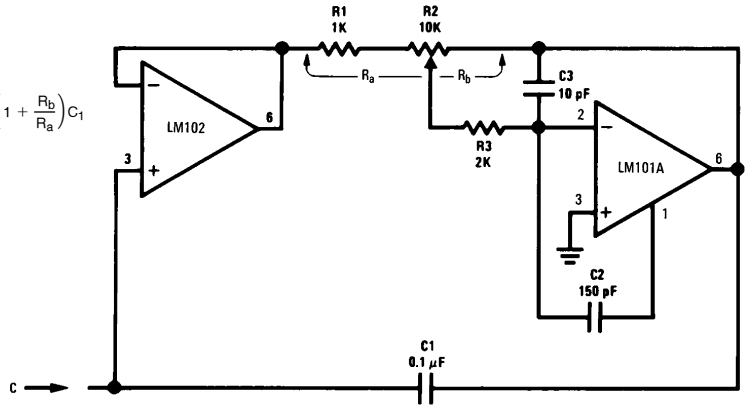
$$I_L = \frac{V_{OS} + R2\, I_{OS}}{R3}$$

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

TL/H/7057–65

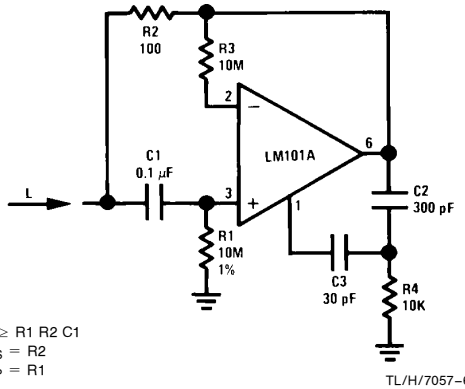
### Variable Capacitance Multiplier

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




TL/H/7057–66

### Simulated Inductor



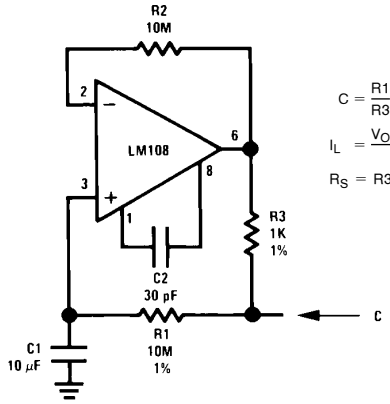

$L \geq R1\, R2\, C1$

$R_S = R2$

$R_P = R1$

TL/H/7057–67

### Capacitance Multiplier



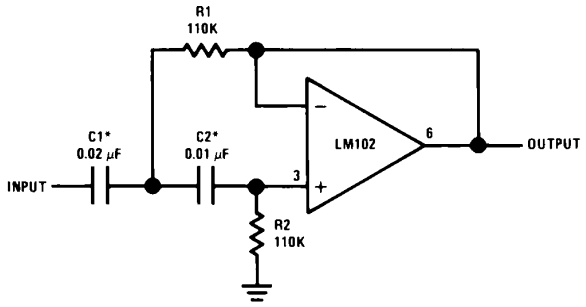

$$C = \frac{R1}{R3} C1$$

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

$$R_S = R3$$

TL/H/7057–68

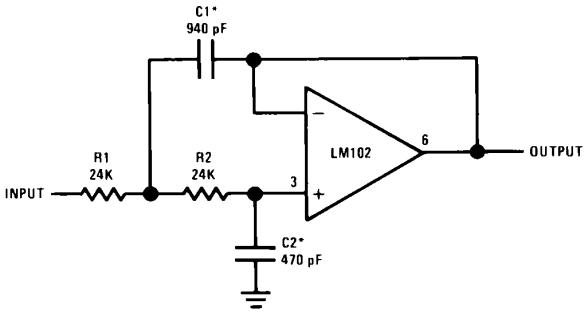
**High Pass Active Filter**




TL/H/7057–71

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

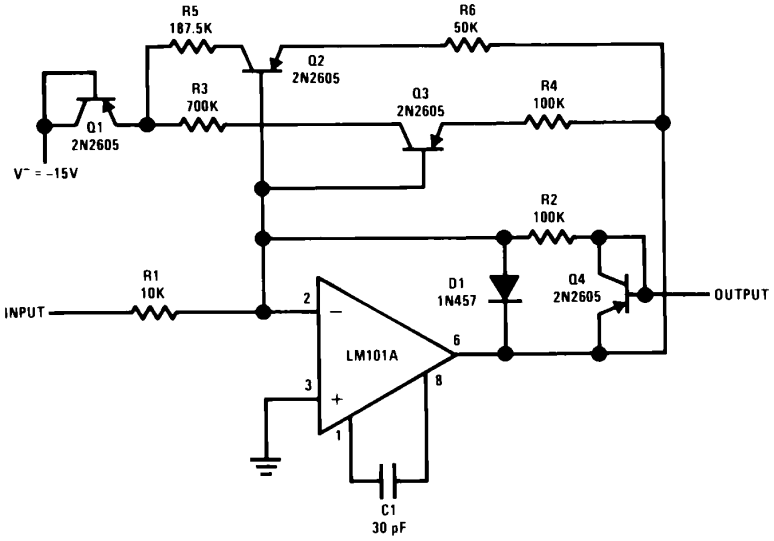
**Low Pass Active Filter**




TL/H/7057–72

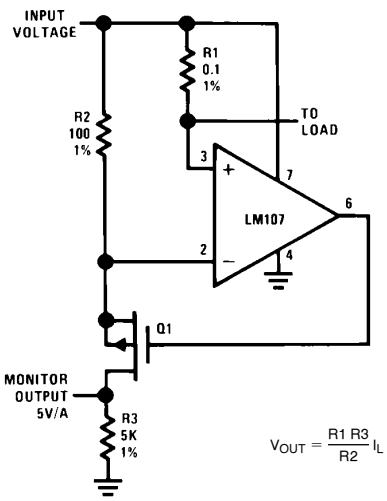
*Values are for 10 kHz cutoff. Use silvered mica capacitors for good temperature stability.

**Nonlinear Operational Amplifier with Temperature Compensated Breakpoints**




TL/H/7057–73

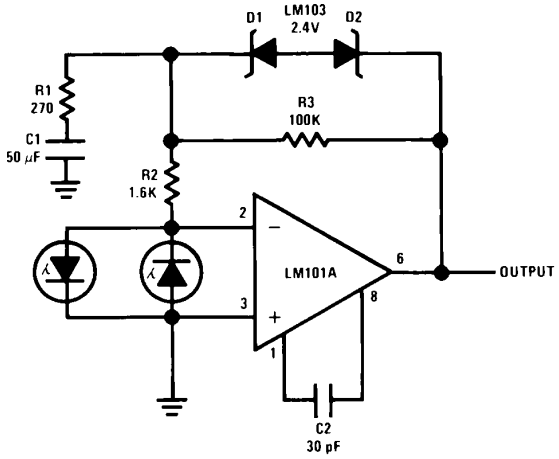
**Current Monitor**




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

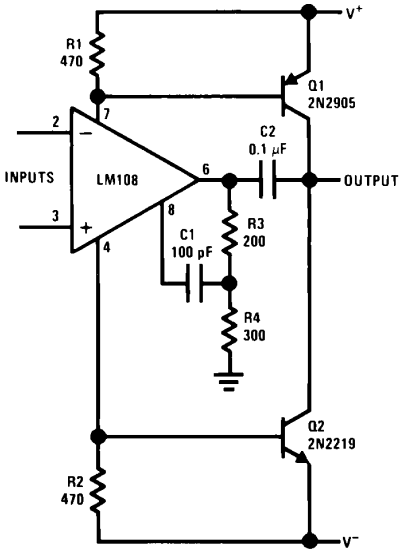
TL/H/7057–74

**Saturating Servo Preamplifier with Rate Feedback**



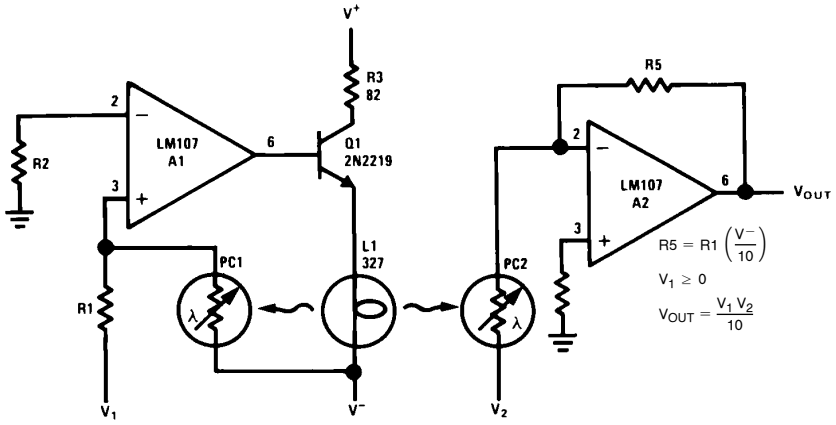

TL/H/7057–75

**Power Booster**



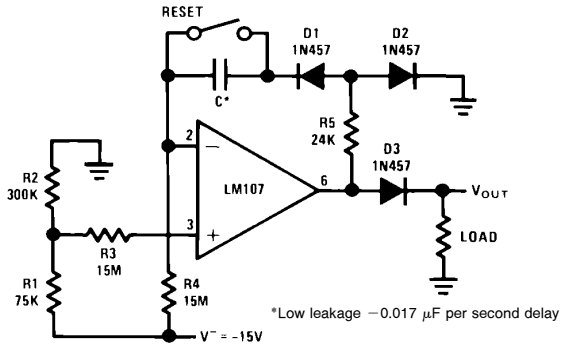

TL/H/7057–76

### Analog Multiplier




TL/H/7057–77

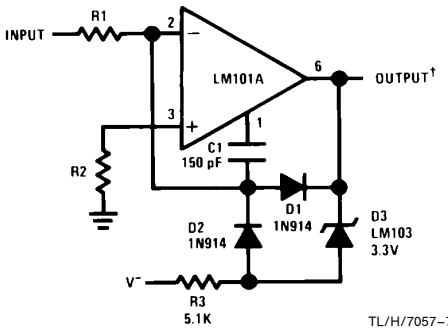
### Long Interval Timer




*Low leakage −0.017 μF per second delay

TL/H/7057–78

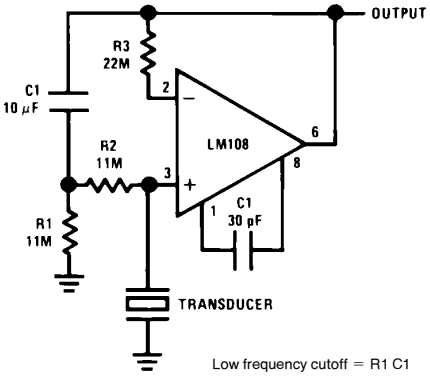
### Fast Zero Crossing Detector




TL/H/7057–79

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

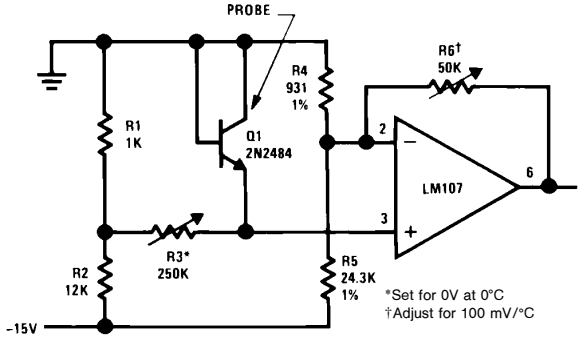
### Amplifier for Piezoelectric Transducer




Low frequency cutoff = R1 C1

TL/H/7057–80

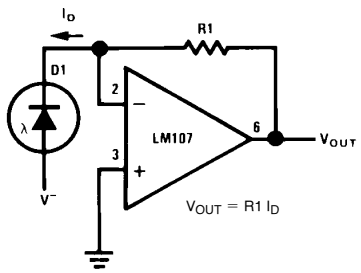
### Temperature Probe




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

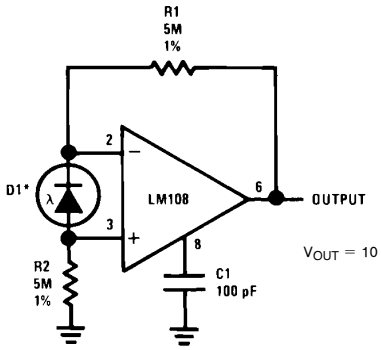
TL/H/7057–81

**Photodiode Amplifier**




TL/H/7057–82

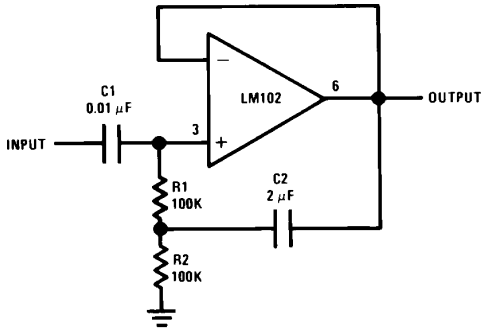
**Photodiode Amplifier**




TL/H/7057–83

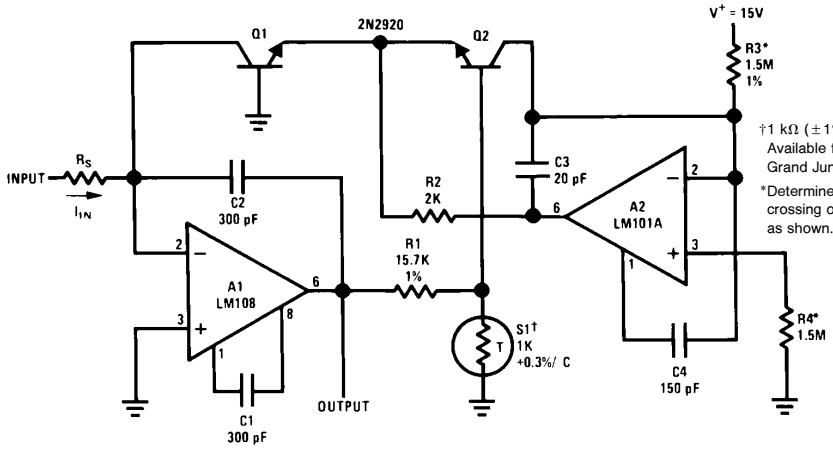
*Operating photodiode with less than 3 mV across it eliminates leakage currents.

**High Input Impedance AC Follower**




TL/H/7057–84

**Temperature Compensated Logarithmic Converter**

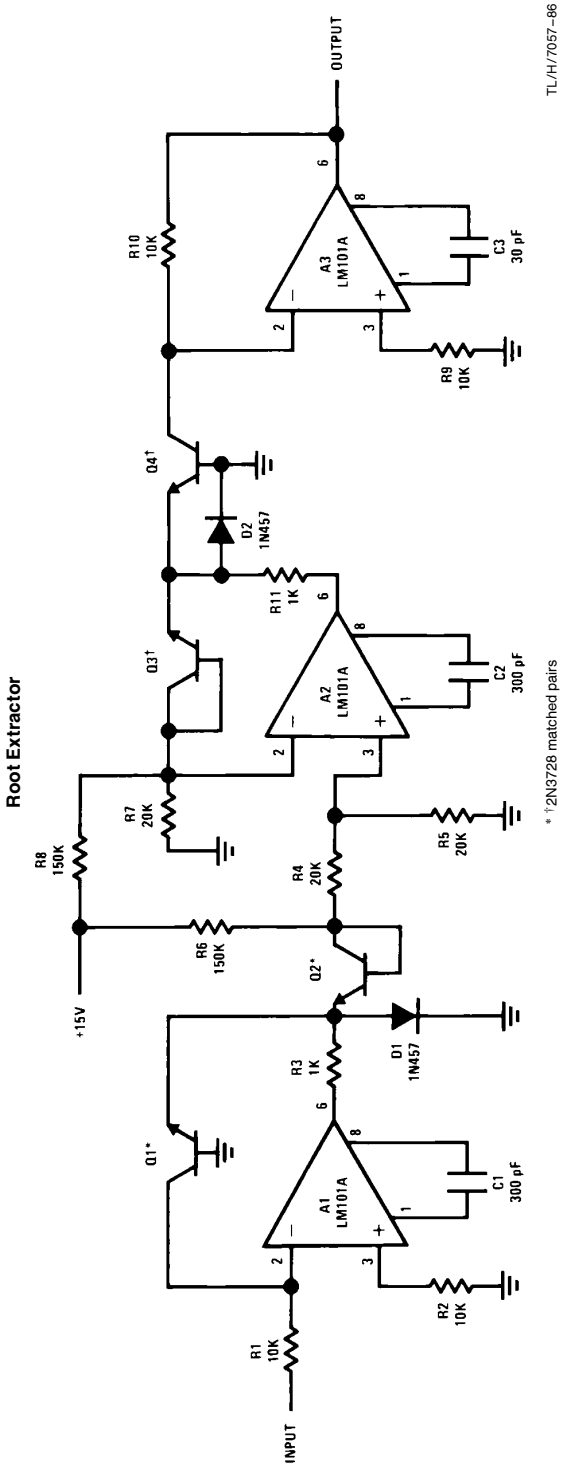



†1 kΩ (±1%) at 25°C, +3500 ppm/°C. Available from Vishay Ultronix, Grand Junction, CO, Q81 Series.

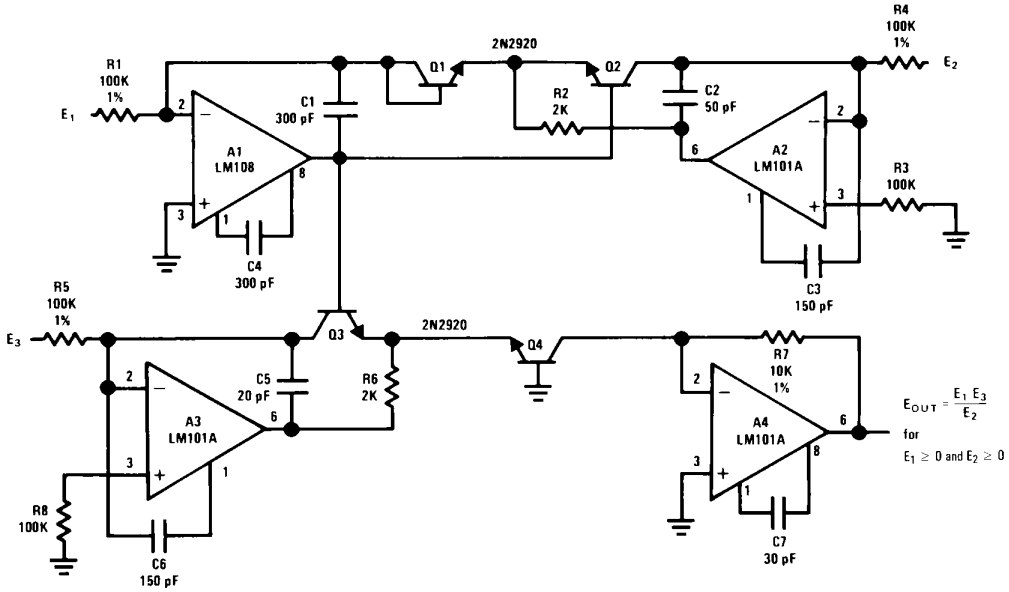
*Determines current for zero crossing on output: 10 μA as shown.

TL/H/7057–85

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

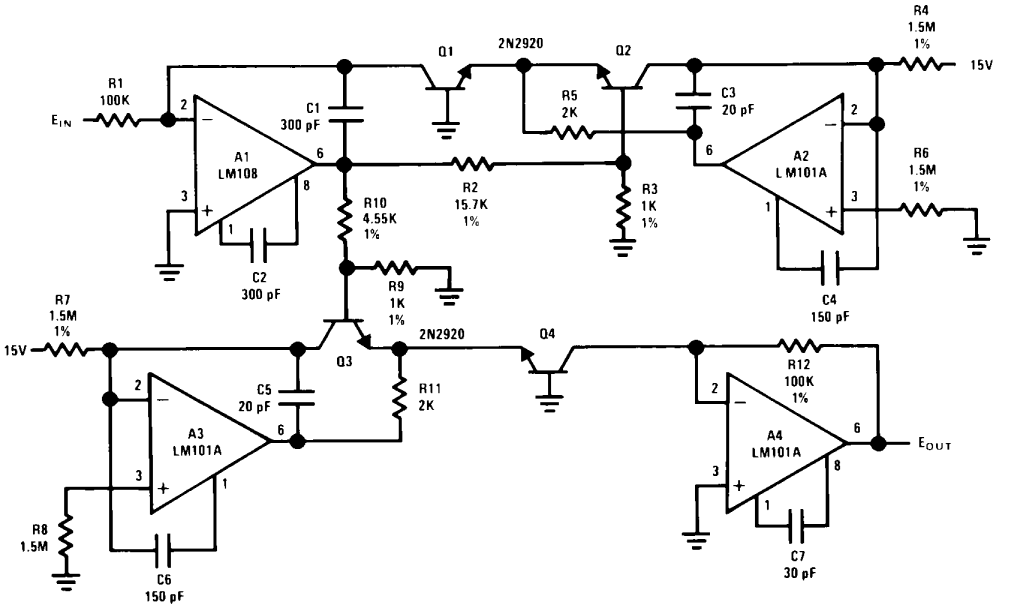

Root Extractor
OUTPUT
INPUT
+15V
R1 10K
R2 10K
R3 1K
R4 20K
R5 20K
R6 150K
R7 20K
R8 150K
R9 10K
R10 10K
R11 1K
C1 300 pF
C2 300 pF
C3 30 pF
D1 1N457
D2 1N457
A1 LM101A
A2 LM101A
A3 LM101A
Q1*
Q2*
Q3†
Q4†
* †2N3728 matched pairs
TL/H/7057–86

**Multiplier/Divider**



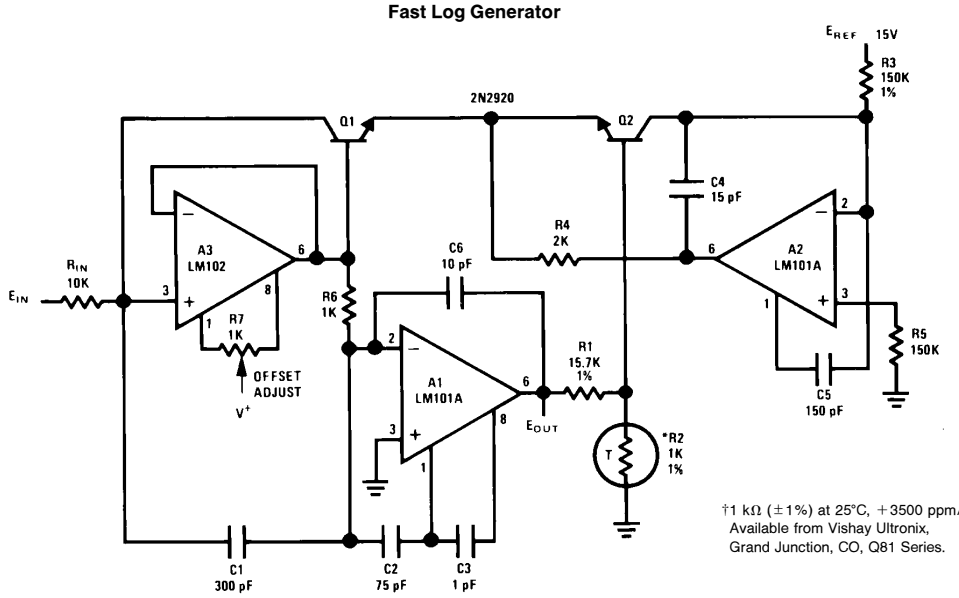

TL/H/7057–87

**Cube Generator**




TL/H/7057–88

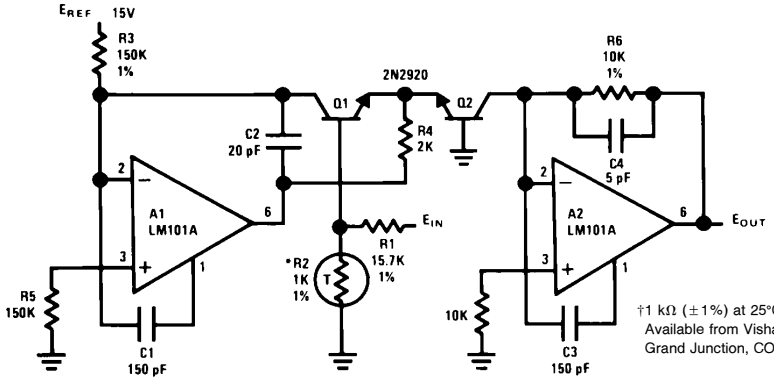
**Fast Log Generator**




†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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Fax: 81-043-299-2408

# 射 频 和 天 线 设 计 培 训 课 程 推 荐

易迪拓培训(www.edatop.com)由数名来自于研发第一线的资深工程师发起成立，致力并专注于微波、射频、天线设计研发人才的培养；我们于 2006 年整合合并微波 EDA 网(www.mweda.com)，现已发展成为国内最大的微波射频和天线设计人才培养基地，成功推出多套微波射频以及天线设计经典培训课程和 ADS、HFSS 等专业软件使用培训课程，广受客户好评；并先后与人民邮电出版社、电子工业出版社合作出版了多本专业图书，帮助数万名工程师提升了专业技术能力。客户遍布中兴通讯、研通高频、埃威航电、国人通信等多家国内知名公司，以及台湾工业技术研究院、永业科技、全一电子等多家台湾地区企业。

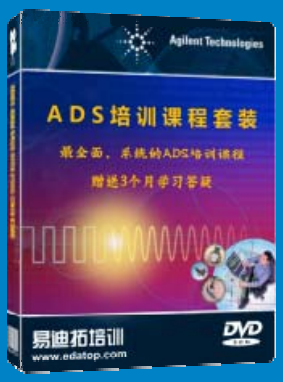
易迪拓培训课程列表：http://www.edatop.com/peixun/rfe/129.html


## 射频工程师养成培训课程套装

该套装精选了射频专业基础培训课程、射频仿真设计培训课程和射频电路测量培训课程三个类别共 30 门视频培训课程和 3 本图书教材；旨在引领学员全面学习一个射频工程师需要熟悉、理解和掌握的专业知识和研发设计能力。通过套装的学习，能够让学员完全达到和胜任一个合格的射频工程师的要求…

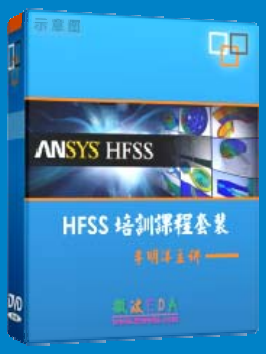
课程网址：http://www.edatop.com/peixun/rfe/110.html

## ADS 学习培训课程套装




该套装是迄今国内最全面、最权威的 ADS 培训教程，共包含 10 门 ADS 学习培训课程。课程是由具有多年 ADS 使用经验的微波射频与通信系统设计领域资深专家讲解，并多结合设计实例，由浅入深、详细而又全面地讲解了 ADS 在微波射频电路设计、通信系统设计和电磁仿真设计方面的内容。能让您在最短的时间内学会使用 ADS，迅速提升个人技术能力，把 ADS 真正应用到实际研发工作中去，成为 ADS 设计专家...

课程网址： http://www.edatop.com/peixun/ads/13.html




## HFSS 学习培训课程套装

该套课程套装包含了本站全部 HFSS 培训课程，是迄今国内最全面、最专业的 HFSS 培训教程套装，可以帮助您从零开始，全面深入学习 HFSS 的各项功能和在多个方面的工程应用。购买套装，更可超值赠送 3 个月免费学习答疑，随时解答您学习过程中遇到的棘手问题，让您的 HFSS 学习更加轻松顺畅…

课程网址：http://www.edatop.com/peixun/hfss/11.html

## CST 学习培训课程套装


该培训套装由易迪拓培训联合微波 EDA 网共同推出，是最全面、系统、专业的 CST 微波工作室培训课程套装，所有课程都由经验丰富的专家授课，视频教学，可以帮助您从零开始，全面系统地学习 CST 微波工作的各项功能及其在微波射频、天线设计等领域的设计应用。且购买该套装，还可超值赠送 3 个月免费学习答疑…

**课程网址**：http://www.edatop.com/peixun/cst/24.html


## HFSS 天线设计培训课程套装

套装包含 6 门视频课程和 1 本图书，课程从基础讲起，内容由浅入深，理论介绍和实际操作讲解相结合，全面系统的讲解了 HFSS 天线设计的全过程。是国内最全面、最专业的 HFSS 天线设计课程，可以帮助您快速学习掌握如何使用 HFSS 设计天线，让天线设计不再难…

**课程网址**：http://www.edatop.com/peixun/hfss/122.html

## 13.56MHz NFC/RFID 线圈天线设计培训课程套装


套装包含 4 门视频培训课程，培训将 13.56MHz 线圈天线设计原理和仿真设计实践相结合，全面系统地讲解了 13.56MHz 线圈天线的工作原理、设计方法、设计考量以及使用 HFSS 和 CST 仿真分析线圈天线的具体操作，同时还介绍了 13.56MHz 线圈天线匹配电路的设计和调试。通过该套课程的学习，可以帮助您快速学习掌握 13.56MHz 线圈天线及其匹配电路的原理、设计和调试…

**详情浏览**：http://www.edatop.com/peixun/antenna/116.html

## 我们的课程优势：

※ 成立于 2004 年，10 多年丰富的行业经验，

※ 一直致力并专注于微波射频和天线设计工程师的培养，更了解该行业对人才的要求

※ 经验丰富的一线资深工程师讲授，结合实际工程案例，直观、实用、易学

## 联系我们：

※ 易迪拓培训官网：http://www.edatop.com

※ 微波 EDA 网：http://www.mweda.com

※ 官方淘宝店：http://shop36920890.taobao.com