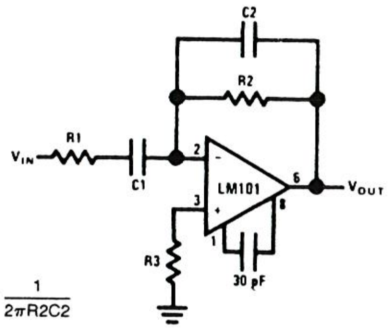


$$f_c = \frac{1}{2\pi R2C1}$$

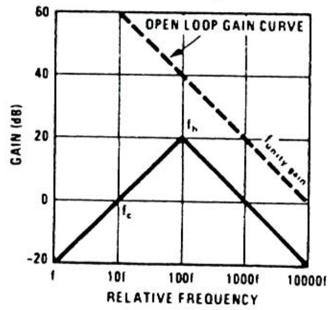
$$f_h = \frac{1}{2\pi R1C1} = \frac{1}{2\pi R2C2}$$

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

TL/H/6822–7

FIGURE 7. Practical Differentiator

A practical differentiator is shown in *Figure 7*. Here both the stability and noise problems are corrected by addition of two additional components, R1 and C2. R2 and C2 form a 6 dB per octave high frequency roll-off in the feedback network and R1C1 form a 6 dB per octave roll-off network in the input network for a total high frequency roll-off of 12 dB per octave to reduce the effect of high frequency input and amplifier noise. In addition R1C1 and R2C2 form lead networks in the feedback loop which, if placed below the amplifier unity gain frequency, provide 90° phase lead to compensate the 90° phase lag of R2C1 and prevent loop instability. A gain frequency plot is shown in *Figure 8* for clarity.

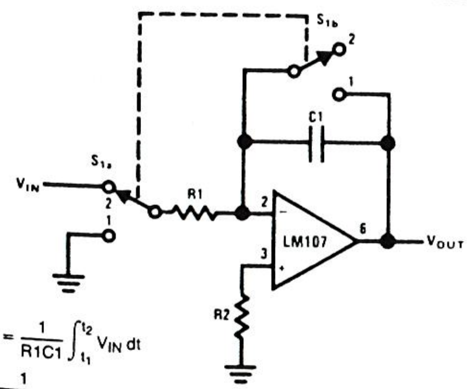


TL/H/6822–8

FIGURE 8. Differentiator Frequency Response

INTEGRATOR

The integrator is shown in *Figure 9* and performs the mathematical operation of integration. This circuit is essentially a low-pass filter with a frequency response decreasing at 6 dB per octave. An amplitude-frequency plot is shown in *Figure 10*.



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

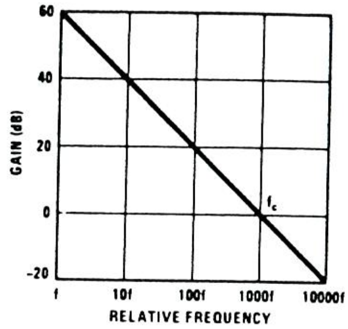
$$f_c = \frac{1}{2\pi R1C1}$$

R1 = R2

For minimum offset error due to input bias current

TL/H/6822–9

FIGURE 9. Integrator



TL/H/6822–10

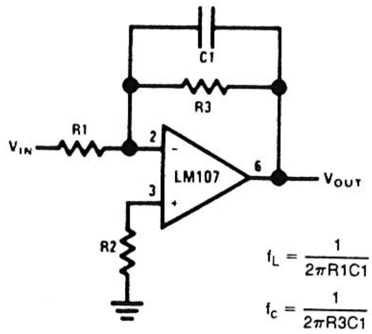
FIGURE 10. Integrator Frequency Response

The circuit must be provided with an external method of establishing initial conditions. This is shown in the figure as S_1. When S_1 is in position 1, the amplifier is connected in unity-gain and capacitor C1 is discharged, setting an initial condition of zero volts. When S_1 is in position 2, the amplifier is connected as an integrator and its output will change in accordance with a constant times the time integral of the input voltage.

The cautions to be observed with this circuit are two: the amplifier used should generally be stabilized for unity-gain operation and R2 must equal R1 for minimum error due to bias current.

SIMPLE LOW-PASS FILTER

The simple low-pass filter is shown in *Figure 11*. This circuit has a 6 dB per octave roll-off after a closed-loop 3 dB point defined by f_C. Gain below this corner frequency is defined by the ratio of R3 to R1. The circuit may be considered as an AC integrator at frequencies well above f_C; however, the time domain response is that of a single RC rather than an integral.



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

$$f_c = \frac{1}{2\pi R3C1}$$

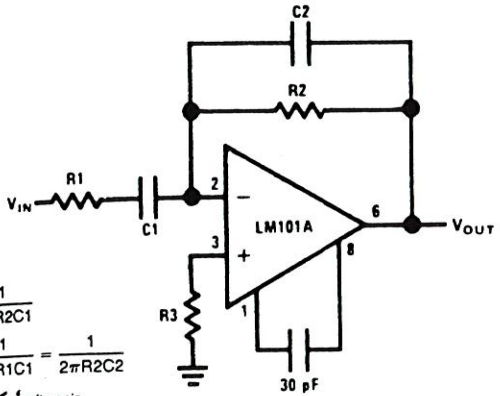
$$A_L = \frac{R3}{R1}$$

TL/H/6822–11

FIGURE 11. Simple Low Pass Filter

R2 should be chosen equal to the parallel combination of R1 and R3 to minimize errors due to bias current. The amplifier should be compensated for unity-gain or an internally compensated amplifier can be used.

Practical Differentiator



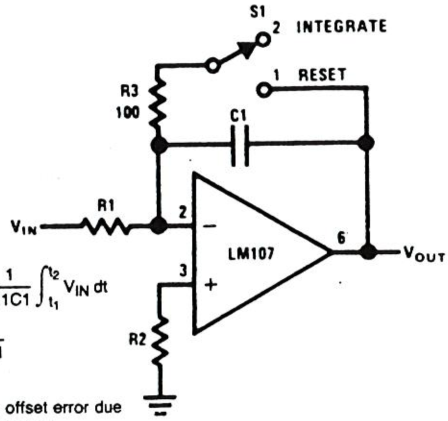
$f_c = \dfrac{1}{2\pi R2C1}$

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

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

TL/H/7057-9

Integrator



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

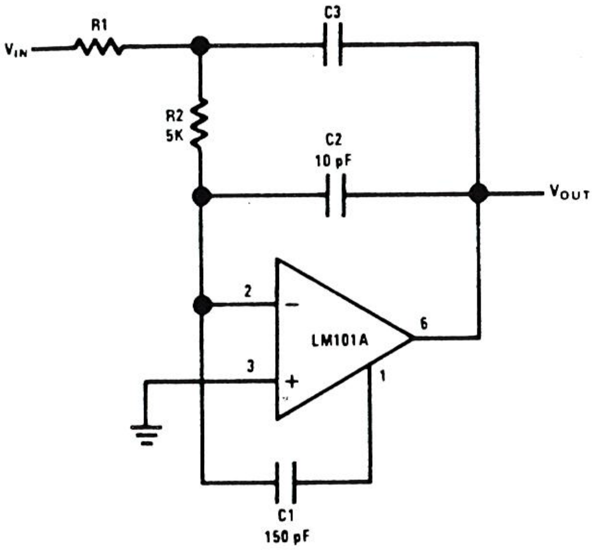
$f_c = \dfrac{1}{2\pi R1C1}$

R1 = R2

For minimum offset error due to input bias current

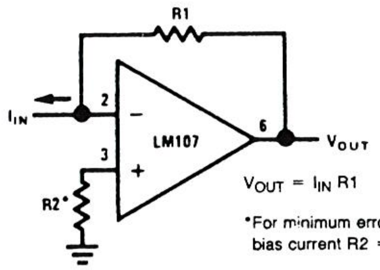
TL/H/7057-10

Fast Integrator



TL/H/7057-11

Current to Voltage Converter

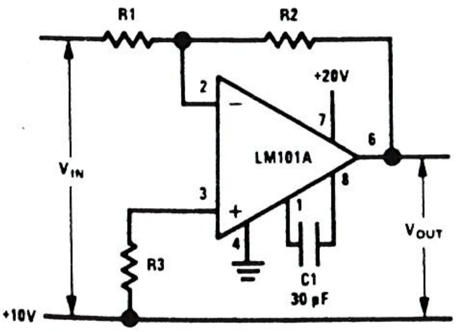


$V_{OUT} = I_{IN}\,R1$

*For minimum error due to bias current R2 = R1

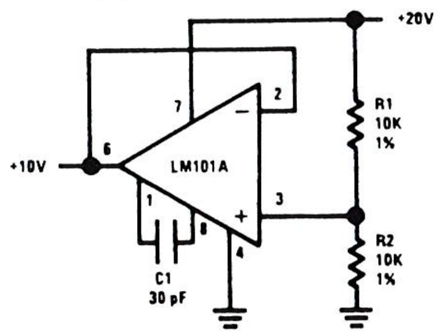
TL/H/7057-12

Circuit for Operating the LM101 without a Negative Supply



TL/H/7057-13

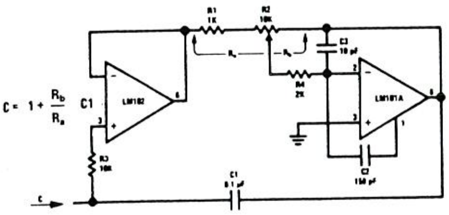
Circuit for Generating the Second Positive Voltage



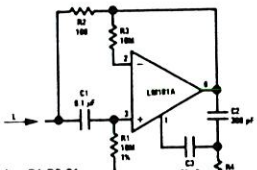
TL/H/7057-14

Typical Applications **

Variable Capacitance Multiplier

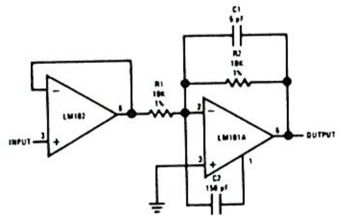


Simulated Inductor

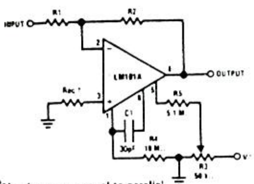


$L \geq R1\ R2\ C1$
$R_S = R2$
$R_P = R1$

Fast Inverting Amplifier With High Input Impedance

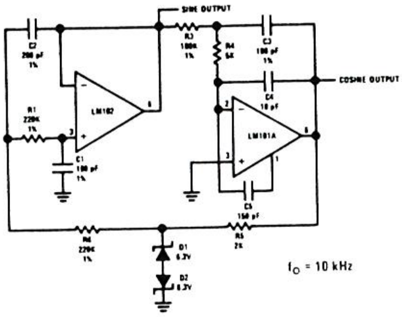


Inverting Amplifier with Balancing Circuit



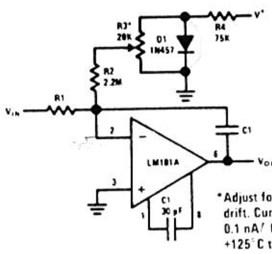
†May be zero or equal to parallel combination of R1 and R2 for minimum offset.

Sine Wave Oscillator



f_O = 10 kHz

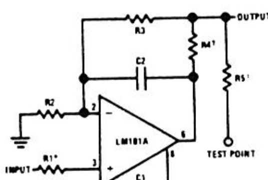
Integrator with Bias Current Compensation



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

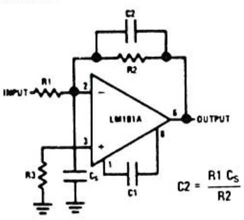
Application Hints **

Protecting Against Gross Fault Conditions



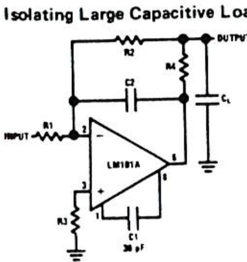
*Protects input
†Protects output
‡Protects output—not needed when R4 is used.

Compensating For Stray Input Capacitances Or Large Feedback Resistor



$C2 = \frac{R1\ C_S}{R2}$

Isolating Large Capacitive Loads



Although the LM101A is designed for trouble free operation, experience has indicated that it is wise to observe certain precautions given below to protect the devices from abnormal operating conditions. It might be pointed out that the advice given here is applicable to practically any IC op amp, although the exact reason why may differ with different devices.

When driving either input from a low-impedance source, a limiting resistor should be placed in series with the input lead to limit the peak instantaneous output current of the source to something less than 100 mA. This is especially important when the inputs go outside a piece of equipment where they could accidentally be connected to high voltage sources. Large capacitors on the input (greater than 0.1 μF) should be treated as a low source impedance and isolated with a resistor. Low impedance sources do not cause a problem unless their output voltage exceeds the supply voltage. However, the supplies go to zero when they are turned off, so the isolation is usually needed.

The output circuitry is protected against damage from shorts to ground. However, when the amplifier output is connected to a test point, it should be isolated by a limiting resistor, as test points frequently get shorted to bad places. Further, when the amplifier drives a load external to the equipment, it is also advisable to use some sort of limiting resistance to preclude mishaps.

Precautions should be taken to insure that the power supplies for the integrated circuit never become reversed—even under transient conditions. With reverse voltages greater than 1V, the IC will conduct excessive current, fuzing internal aluminum interconnects. If there is a possibility of this happening, clamp diodes with a high peak current rating should be installed on the supply lines. Reversal of the voltage between V^+ and V^- will always cause a problem, although reversals with respect to ground may also give difficulties in many circuits.

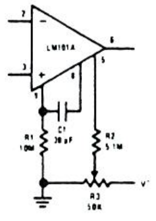
The minimum values given for the frequency compensation capacitor are stable only for source resistances less than 10 kΩ, stray capacitances on the summing junction less than 5 pF and capacitive loads smaller than 100 pF. If any of these conditions are not met, it becomes necessary to overcompensate the amplifier with a larger compensation capacitor. Alternately, lead capacitors can be used in the feedback network to negate the effect of stray capacitance and large feedback resistors or an RC network can be added to isolate capacitive loads.

Although the LM101A is relatively unaffected by supply bypassing, this cannot be ignored altogether. Generally it is necessary to bypass the supplies to ground at least once on every circuit card, and more bypass points may be required if more than five amplifiers are used. When feed-forward compensation is employed, however, it is advisable to bypass the supply leads of each amplifier with low inductance capacitors because of the higher frequencies involved.

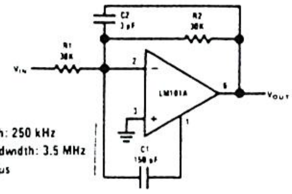
**Pin connections shown are for metal can.

Typical Applications** (Continued)

Standard Compensation and Offset Balancing Circuit

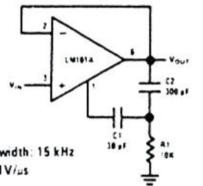


Fast Summing Amplifier



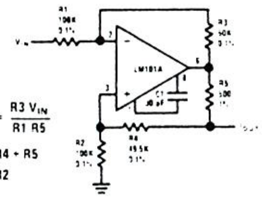
Power Bandwidth: 250 kHz
Small Signal Bandwidth: 3.5 MHz
Slew Rate: 10V/μs

Fast Voltage Follower



Power Bandwidth: 15 kHz
Slew Rate: 1V/μs

Bilateral Current Source

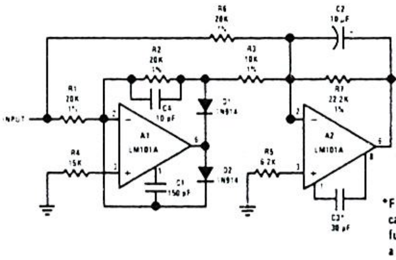


$$I_{OUT} = \frac{R3\ V_{IN}}{R1\ R5}$$

R3 = R4 + R5

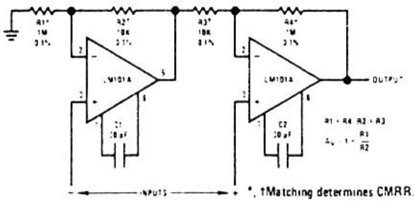
R1 = R2

Fast AC/DC Converter*



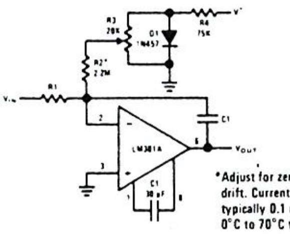
*Feedforward compensation can be used to make a fast full wave rectifier without a filter.

Instrumentation Amplifier



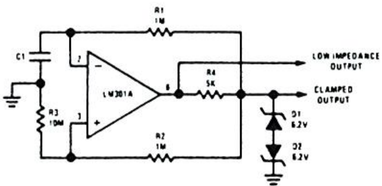
*, †Matching determines CMRR.

Integrator with Bias Current Compensation

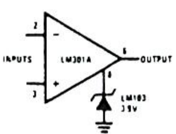


*Adjust for zero integrator drift. Current drift typically 0.1 nA/°C over 0°C to 70°C temperature range.

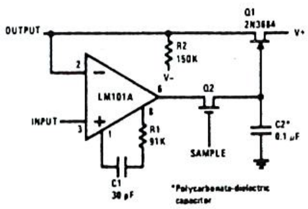
Low Frequency Square Wave Generator



Voltage Comparator for Driving RTL Logic or High Current Driver

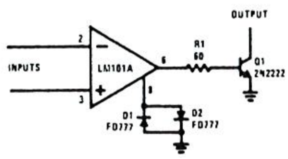


Low Drift Sample and Hold



*Polycarbonate-dielectric capacitor

Voltage Comparator for Driving DTL or TTL Integrated Circuits



**Pin connections shown are for metal can.