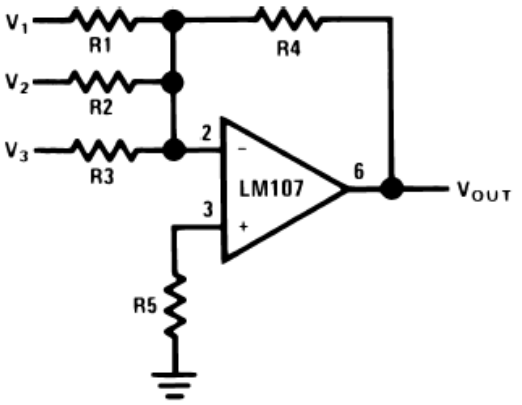
的OP可能会进入阻塞状态。LM107可以避免上述问题，另外也可以选用高速OP，LM102。

jhbcd
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5. Summing Amplifier

加法器：

The summing amplifier, a special case of the inverting amplifier, is shown in Figure 4. The circuit gives an inverted output which is equal to the weighted algebraic sum of all three inputs. The gain of any input of this circuit is equal to the ratio of the appropriate input resistor to the feedback resistor, R4. Amplifier bandwidth may be calculated as in the inverting amplifier shown in Figure 1 by assuming the input resistor to be the parallel combination of R1, R2, and R3. Application cautions are the same as for the inverting amplifier. If an uncompensated amplifier is used, compensation is calculated on the basis of this bandwidth as is discussed in the section describing the simple inverting amplifier. The advantage of this circuit is that there is no interaction between inputs and operations such as summing and weighted averaging are implemented very easily.



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

R5 = R1 ‖ R2 ‖ R3 ‖ R4

For minimum offset error due to input bias current

FIGURE 4. Summing Amplifier

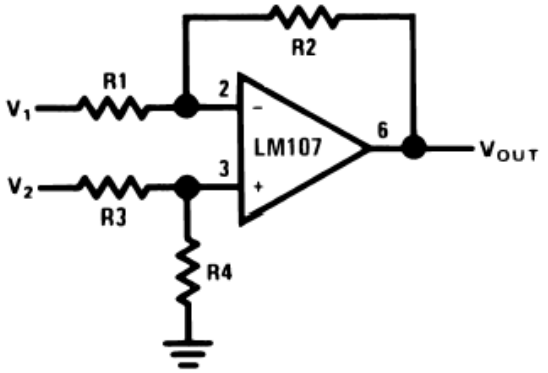
求和电路是反相放大器的一种特殊形式。如*图4*。其输出电压为3个输入电压加权代数和取反（因为其为反相电路，其每路的增益为负值——译者）。每路输入电压的增益等于其反馈电阻和输入电阻之比（取反——译者）。增益带宽的计算方式和反相放大电路相同，参见例1，将其输入电阻替换为R1、R2、R3的并联电阻值。应用上的注意事项和反相放大电路相同。如果使用了没有内部补偿功能的OP，应该在简单反相器的带宽的基础上计算补偿量。这个电路的特点在于：各个输入之间相互不影响，求和或者取平均的功能很容易就可以实现。

6. The Difference Amplifier

差分放大器：

The difference amplifier is the complement of the summing amplifier and allows the subtraction of two voltages or, as a special case, the cancellation of a signal common to the two inputs. This circuit is shown in Figure 5 and is useful as a computational amplifier, in making a differential to single-ended conversion or in rejecting a common mode signal.

Circuit bandwidth may be calculated in the same manner as for the inverting amplifier, but input impedance is somewhat more complicated. Input impedance for the two inputs is not necessarily equal; inverting input impedance is the same as for the inverting amplifier of Figure 1 and the non-inverting input impedance is the sum of R3 and R4. Gain for either input is the ratio of R1 to R2 for the special case of a differential input single-ended output where R1 = R3 and R2 = R4. The general expression for gain is given in the figure. Compensation should be chosen on the basis of amplifier bandwidth. Care must be exercised in applying this circuit since input impedances are not equal for minimum bias current error.



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

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

FIGURE 5. Difference Amplifier

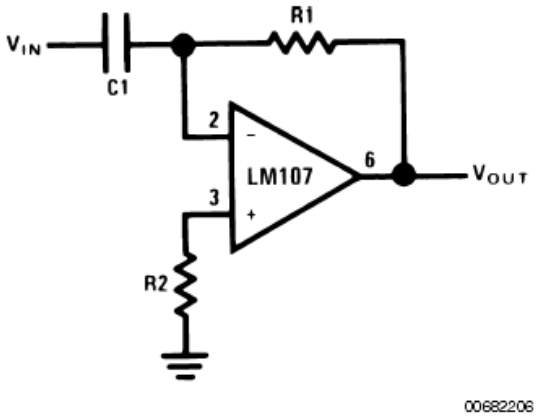
差分放大器是对求和电路的发展，这种电路可以减小甚至去处两个输入信号中的共模成分。电路见***图5***，这种电路在运算电路中相当有用，比如差分对单端的转换，抑制共模信号。

电路带宽的计算方式和反相电路相同。输入阻抗的计算方式相对复杂。两个输入端的输入阻抗没有必要相等；反相放大部分的输入阻抗和反相放大器的计算方法相同。同相放大部分的输入阻抗为R3、R4之和。在R1=R3，R2=R4，差分输入，单端输出的特殊情况下，两个输入的增益都是R2/R1。一般情况下增益的计算方法见图中说明。补偿可以按照放大器的具体带宽进行。在应用中应该注意一点：两端的输入阻抗是不相等的，要注意输入偏置电流的引起的误差。

7. Differentiator

微分器：

The differentiator is shown in Figure 6 and, as the name implies, is used to perform the mathematical operation of differentiation. The form shown is not the practical form, it is a true differentiator and is extremely susceptible to high frequency noise since AC gain increases at the rate of 6 dB per octave. In addition, the feedback network of the differentiator, R1C1, is an RC low pass filter which contributes 90° phase shift to the loop and may cause stability problems even with an amplifier which is compensated for unity gain.



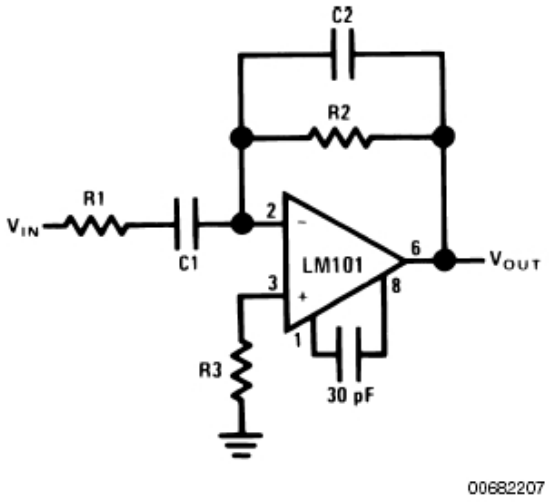
$$V_{OUT} = -R1C1\frac{d}{dt}(V_{IN})$$

R1 = R2

For minimum offset error due to input bias current

FIGURE 6. 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.



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

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

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

FIGURE 7. Practical Differentiator

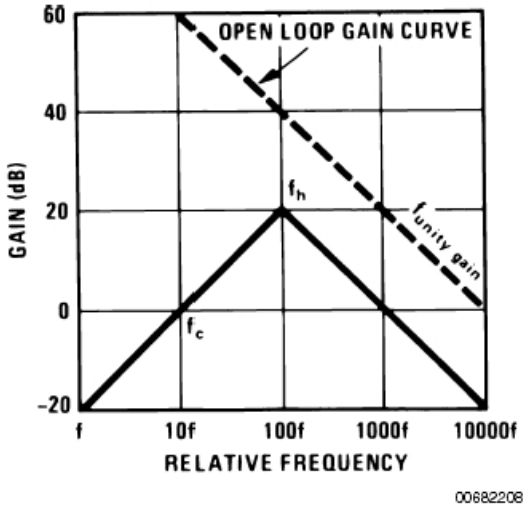


FIGURE 8. Differentiator Frequency Response

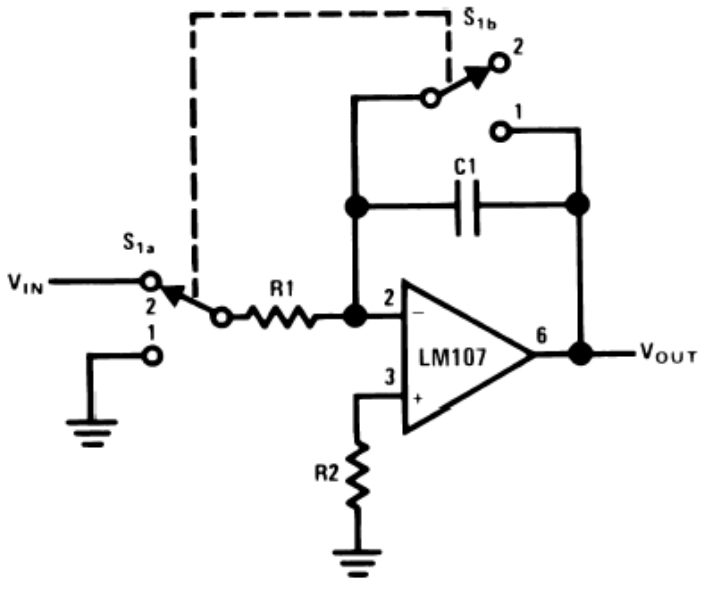
微分器的电路如***图6***，其用于实现数学上的微分运算。这里给出的电路形式不是实际的应用形式。由于其6dB/2倍频程的交流增益特性，其对高频噪声将相当敏感。反馈环路中，R1C1组成了一个等效的低通滤波器，由于其在反馈环中90°的相移，即使对单位增益采取了补偿措施，在这里也可能出现稳定性问题。

图7为微分器的实际应用电路。这个电路考虑了稳定性因素和噪声因素，增加了R1和C2。R2-C2在反馈环路上构成了一个6dB/2倍频程的高频衰减网络，R1-C1在输入上构成了一个6dB/2倍频程衰减网络，这样，整个频率特性呈现为12dB/2倍频程的高频衰减，抑制了由于高频信号输入OP所带来的噪声。R1C1、R2C2一同在反馈环路上构成了一个网络，如果将其频点设置在OP的单位增益带宽之内，其将提供90°前向相移，以补偿由R2-C1带来的90°相位滞后，提高环路的稳定性。波特图如***图8***所示。

8. Integrator

积分器：

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. The circuit must be provided with an external method of establishing initial conditions. This is shown in the figure as S1. 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 S1 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.



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

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

$$R1 = R2$$

For minimum offset error due to input bias current

FIGURE 9. Integrator

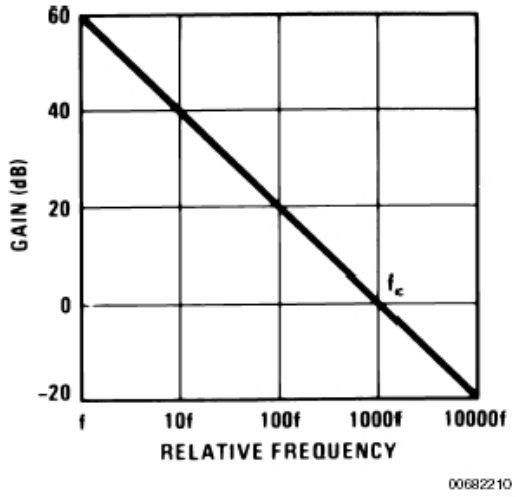


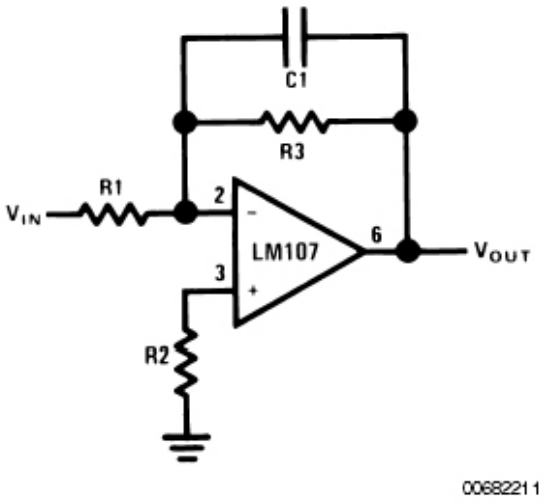
FIGURE 10. Integrator Frequency Response

积分器用于实现数学上的积分运算，如***图9***所示。在本质上，积分器可以看成是一个呈6dB/2倍频程频率特性的LPF，波特图见***图10***。积分器必须加入初始化电路，以给电路创造积分的初始化条件。图中S1的目的就在于此，当S1在1位置时，OP工作在单位增益（跟随器）状态。电容C1上的电荷被释放掉，使得积分初始值为0；当S1在2位置时，OP工作在积分器状态，其输出将为输入信号电压幅度对时间的积分与一个常数之积。在使用本电路时注意两点：OP在单位增益状态下应能稳定，R1和R2的阻值必须相等，以减小输入偏置电流所带来的误差。

9. Simple Low-pass Filter

简单低通滤波器：

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 fc. 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 fc; however, the time domain response is that of a single RC rather than an integral. 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. A gain frequency plot of circuit response is shown in Figure 12 to illustrate the difference between this circuit and the true integrator.



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

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

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

FIGURE 11. Simple Low Pass Filter