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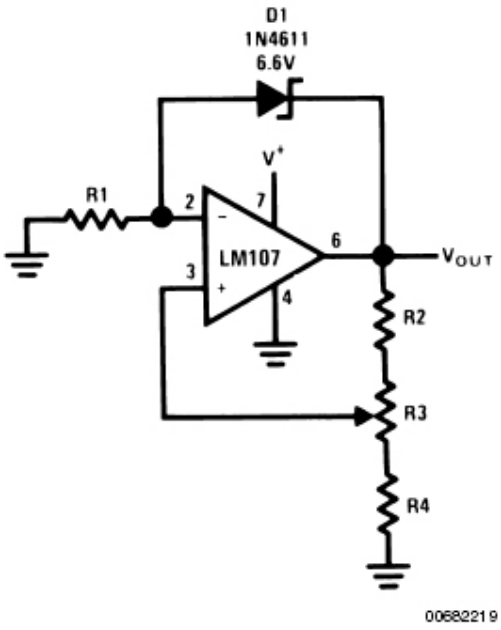


FIGURE 19. Positive Voltage Reference

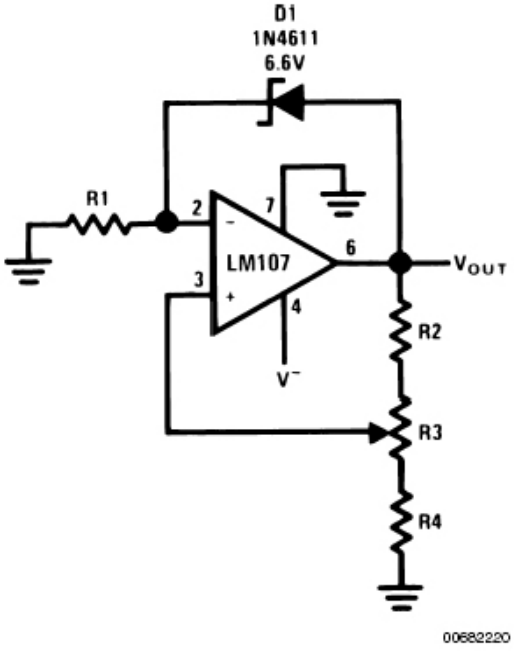


FIGURE 20. Negative Voltage Reference

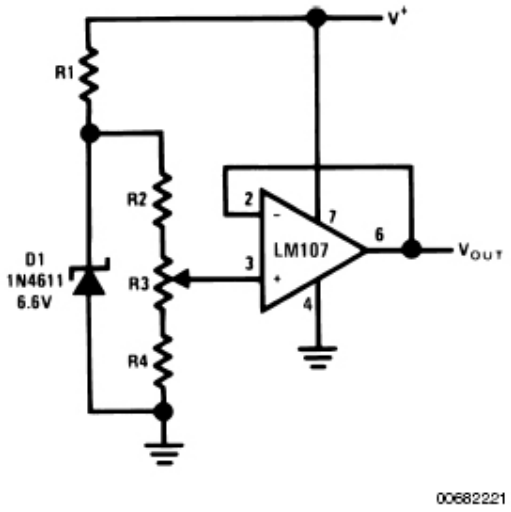


FIGURE 21. Positive Voltage Reference

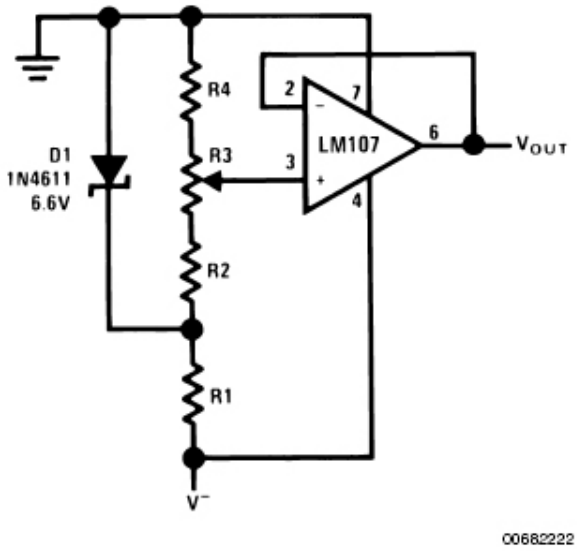


FIGURE 22. Negative Voltage Reference

可调电压参考源的电路示于***图 19***、***20***、***21***、***22*** 中。图中的两种电路形式有着不同的应用范围，最基本的区别在于，***图 19*** 和 ***20*** 所示的电路可以提供大于电路中所使用的稳压二极管稳定电压的输出电压，而***图 21*** 和 ***22*** 中的电路的输出电压小于稳压管的稳定电压。在每种形式的电路中，又分别给出了正电压和负电压输出的应用电路。

由于温度因素会影响精度，***图 19***、***20*** 中电路的输出电压范围不能太宽。另外，由于 Iz（流过稳压管的电流）与 V+无关（仅取决于 R1）， R1 的取值应该尽量使得稳压管的击穿电流大小合适，借此来减小其温度特性的影响。

图21、22 中的电路适合于要求在宽温度范围内取得较好精度的情况下使用，由于 Iz 和 V+有关，这种电路要求 V+相对稳定。R1、2、3、4 应该适当选择，以给稳压管提供适当的击穿电流和减小其温度特性的影响。

以上电路中的 OP 必须对单位增益做频率补偿，如果负载呈较大的容性，则可能需要做过补偿。如果想减小输出噪声，可以在上述电路的输入端采取旁路措施。

图中的电源采用单电源供电，这就对 OP 的共模输入范围的选择提出了要求，如果所要求的输入电压范围超过共模输入范围，则应该使用双电源供电。LH101 的共模电压范围达 V+到 V-之上 2V，可以在单电源的情况下使用。

14. The Reset Stabilized Amplifier

复位稳定放大器：

The reset stabilized amplifier is a form of chopper-stabilized amplifier and is shown in Figure 23. As shown, the amplifier is operated closed-loop with a gain of one.

The connection is useful in eliminating errors due to offset voltage and bias current. The output of this circuit is a pulse whose amplitude is equal to V_{IN}. Operation may be understood by considering the two conditions corresponding to the position of S1. When S 1 is in position 2, the amplifier is connected in the unity gain connection and the voltage at the output will be equal to the sum of the input offset voltage and the drop across R2 due to input bias current. The voltage at the inverting input will be equal to input offset voltage. Capacitor C1 will charge to the sum of input offset voltage and V_{IN} through R1. When C1 is charged, no current flows through the source resistance and R1 so there is no error due to input resistance. S1 is then changed to position 1. The voltage stored on C1 is inserted between the output and inverting input of the amplifier and the output of the amplifier changes by V_{IN} to maintain the amplifier input at the input offset voltage. The output then changes from (V_{OS} + I_{bias}R2) to (V_{IN} + I_{bias}R2) as S1 is changed from position 2 to position 1. Amplifier bias current is supplied through R2 from the output of the amplifier or from C2 when S1 is in position 2 and position 1 respectively. R3 serves to reduce the offset at the amplifier output if the amplifier must have maximum linear range or if it is desired to DC couple the amplifier.

An additional advantage of this connection is that input resistance approaches infinity as the capacitor C1 approaches full charge, eliminating errors due to loading of the source resistance. The time spent in position 2 should be long with respect to the charging time of C1 for maximum accuracy.

The amplifier used must be compensated for unity gain operation and it may be necessary to overcompensate because of the phase shift across R2 due to C1 and the amplifier input capacity. Since this connection is usually used at very low switching speeds, slew rate is not normally a practical consideration and overcompensation does not reduce accuracy.

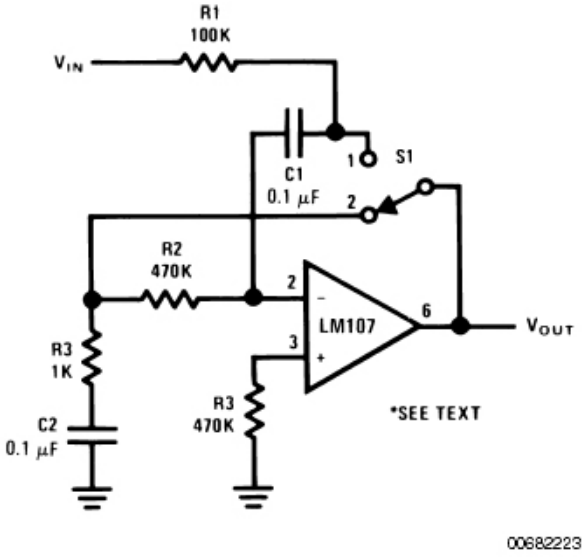


FIGURE 23. Reset Stabilized Amplifier

复位稳定放大器是斩波稳定放大器的一种，其电路如***图 23*** 所示。在图中的状态为，放大器工作于闭环增益为 1 的情况。

这种电路可有效消除因失调电压和偏置电流引起的误差。该电路的输出是一个幅值等于 VIN 的脉冲。为了理解其工作原理，需要分析一下将开关 S1 拨向不同的位置时，电路结构如何改变。先将 S1 拨到位置 2，此时放大器为单位增益接法——输出端电压等于输入失调电压加上 R2 与输入偏置电流产生的电压，反相端的电压等于输入失调电压，电容 C1 持续充电直到其端电压等于输入失调电压与 VIN 的代数和。C1 充电完毕时，流经信号源内阻及 R1 的电流为零，因此信号源内阻不会造成误差。接着 S1 拨到位置 1，使 C1 的电压加在放大器的输出端和反相输入端之间，（由于电容端电压不能突变，所以）输出端的电压将产生大小等于 VIN 的变化，使放大器输入端维持输入失调电压，即当开关 S1 从位置 2 拨到位置 1 时，输出端电压将从(VOS + IbiasR2)变为(VIN + IbiasR2)。S1 处于位置 2 时，放大器的偏置电流是由输出端经电阻 R2 提供的，当 S1 转向位置 1 时则由 C2 提供。R3 的作用是降低输出失调电压，如果要求放大器具有最大的线性范围，或者采用直流耦合，就应该使用该电容。

上面这个电路的另一个优点在于，当电容 C1 充电完毕后，输入电阻将趋于无穷大，因此可以消除因信号源内阻产生的误差。开关接通位置 2 的持续时间要足够长，以保证电容 C1 完成充电，这样才能获得最佳的精度。

此电路必须使用单位增益稳定的 OP，因为 R2—C1 产生的相移，所以还可能需要一定的过补偿。鉴于本电路常用于切换频率很低的场合，转换速率（SR）一般不是关键指标，因此过补偿不会降低精度。

15. The Analog Multiplier

模拟乘法器：

A simple embodiment of the analog multiplier is shown in Figure 24. This circuit circumvents many of the problems associated with the log-antilog circuit and provides three quadrant analog multiplication which is relatively temperature insensitive and which is not subject to the bias current errors which plague most multipliers.

Circuit operation may be understood by considering A2 as a controlled gain amplifier, amplifying V2, whose gain is dependent on the ratio of the resistance of PC2 to R5 and by considering A1 as a control amplifier which establishes the resistance of PC2 as a function of V 1. In this way it is seen that VOUT is a function of both V1 and V2.

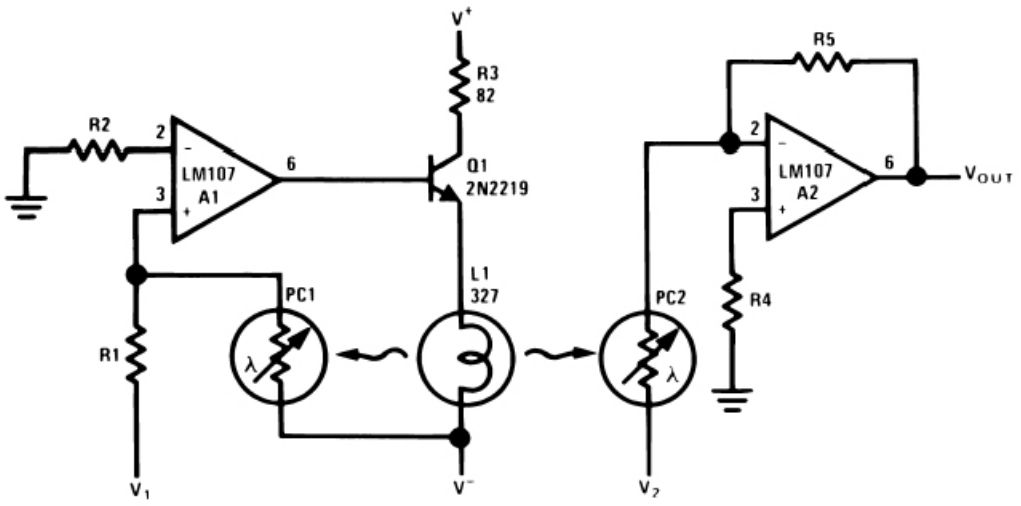
A1, the control amplifier, provides drive for the lamp, L1. When an input voltage, V1, is present, L1 is driven by A1 until the current to the summing junction from the negative supply through PC1 is equal to the current to the summing junction from V1 through R1. Since the negative supply voltage is fixed, this forces the resistance of PC1 to a value proportional to R1 and to the ratio of V1 to V -. L1 also illuminates PC2 and, if the photoconductors are matched, causes PC2 to have a resistance equal to PC1.

A2, the controlled gain amplifier, acts as an inverting amplifier whose gain is equal to the ratio of the resistance of PC2 to R5. If R5 is chosen equal to the product of R1 and V-, then VOUT becomes simply the product of V1 and V2. R5 may be scaled in powers of ten to provide any required output scale factor.

PC1 and PC2 should be matched for best tracking over temperature since the T.C. of resistance is related to resistance match for cells of the same geometry. Small mismatches may be compensated by varying the value of R5 as a scale factor adjustment. The photoconductive cells should receive equal illumination from L1, a convenient method is to mount the cells in holes in an aluminum block and to mount the lamp midway between them. This mounting method provides controlled spacing and also provides a thermal bridge between the two cells to reduce differences in cell temperature. This technique may be extended to the use of FET's or other devices to meet special resistance or environment requirements.

The circuit as shown gives an inverting output whose magnitude is equal to one-tenth the product of the two analog inputs. Input V 1 is restricted to positive values, but V2 may assume both positive and negative values. This circuit is restricted to low frequency operation by the lamp time constant.

R2 and R4 are chosen to minimize errors due to input offset current as outlined in the section describing the photocell amplifier. R3 is included to reduce in-rush current when first turning on the lamp, L1.



$$R5 = R1\left(\frac{V^-}{10}\right)$$

$$V_1 > 0$$

$$V_{OUT} = \frac{V_1 V_2}{10}$$

FIGURE 24. Analog Multiplier

图 24 给出了一个简单的模拟乘法器电路。这个电路不但克服了对数-反对数方式实现乘法的缺陷，而且可以实现不受温度变化影响的 3 象限乘法运算。绝大多数的乘法器都存在偏置电流误差的困扰，本电路解决了这个问题。

为便于理解本电路的原理，可以将 A2 视为一个增益受 A1 控制的放大器，A1 在 PC2 的阻值与 V1 之间建立起函数关系，A2 对 V2 进行放大，其增益由 PC2 和 R5 的阻值之比决定。因此，VOUT 是 V1 和 V2 的函数。

控制方放大器 A1，驱动灯泡 L1。输入电压 V1 时，A1 输出升高，使 L1 逐渐变亮。当求和节点上，经 PC1 流回负电源的电流与 V1 经 R1 流入求和节点的电流相等时，L1 亮度不再变化。因为负电源电压恒定，所以 PC1 的电阻等于-R1V-/V1。L1 发出的光同时照射 PC2，如果两个光敏电阻参数匹配，那么 PC2 的阻值就会等于 PC1。

受控方放大器 A2 相当于一个增益受控制的反相放大器，其增益为-R5/PC2。如果让 R5 的阻值等于 R1V-，那么 VOUT 就等于 V1V2。R5 的阻值是乘法运算的比例系数，可以任意设定以实现任意大小的输出，比如设置为 10 的幂。

PC1 和 PC2 的温度特性应该匹配，这就要求其具有相同的几何尺寸，以保证其 T.C.特性。在失配程度比较小时，可以通过改变 R5 的大小进行补偿。L1 照射到两个光敏电阻上的光强度应该相等，有一个简便的方法可以实现这个要求，将两个光敏电阻固定在同一个铝块上的两个小孔内，灯泡则固定在两个光敏电阻的中间。采用这个方法，光敏电阻与灯泡的间距是可调的，另外，铝块在两个光敏电阻之间起了平衡温度的作用，使得其温度差减小。这个方法也可以推广到 FET 对管或者其他需要性能匹配的场合，满足电阻或者环境方面的特殊要求。

图示电路的输出等于两个输入电压的乘积除以 10，相位相反。输入电压 V1 必须大于零，V2 既可以为正也可以为负。受灯泡的时间常数限制，本电路只能低频工作。

R2 和 R4 用来降低因输入失调电流产生的误差，其原理与前文光电二极管放大器所述一致。R3 用于抑制灯泡 L1 初次通电时的浪涌电流。

16. The Full-Wave Rectifier and Averaging Filter

全波整流器和平均值滤波器：

The circuit shown in Figure 25 is the heart of an average reading, rms calibrated AC voltmeter. As shown, it is a rectifier and averaging filter. Deletion of C2 removes the averaging function and provides a precision full-wave rectifier, and deletion of C1 provides an absolute value generator.

Circuit operation may be understood by following the signal path for negative and then for positive inputs. For negative signals, the output of amplifier A1 is clamped to +0.7V by D1 and disconnected from the summing point of A2 by D2. A2 then functions as a simple unity-gain inverter with input resistor, R1, and feedback resistor, R2, giving a positive going output.

For positive inputs, A1 operates as a normal amplifier connected to the A2 summing point through resistor, R5. Amplifier A1 then acts as a simple unity-gain inverter with input resistor, R3, and feedback resistor, R5. A1 gain accuracy is not affected by D2 since it is inside the feedback loop. Positive current enters the A2 summing point through resistor, R1, and negative current is drawn from the A2 summing point through resistor, R5. Since the voltages across R1 and R5 are equal and opposite, and R5 is one-half the value of R1, the net input current at the A2 summing point is equal to and opposite from the current through R1 and amplifier A2 operates as a summing inverter with unity gain, again giving a positive output.

The circuit becomes an averaging filter when C2 is connected across R2. Operation of A2 then is similar to the Simple Low Pass Filter previously described. The time constant R2C2 should be chosen to be much larger than the maximum period of the input voltage which is to be averaged.

Capacitor C1 may be deleted if the circuit is to be used as an absolute value generator. When this is done, the circuit output will be the positive absolute value of the input voltage.

The amplifiers chosen must be compensated for unity-gain operation and R6 and R7 must be chosen to minimize output errors due to input offset current.

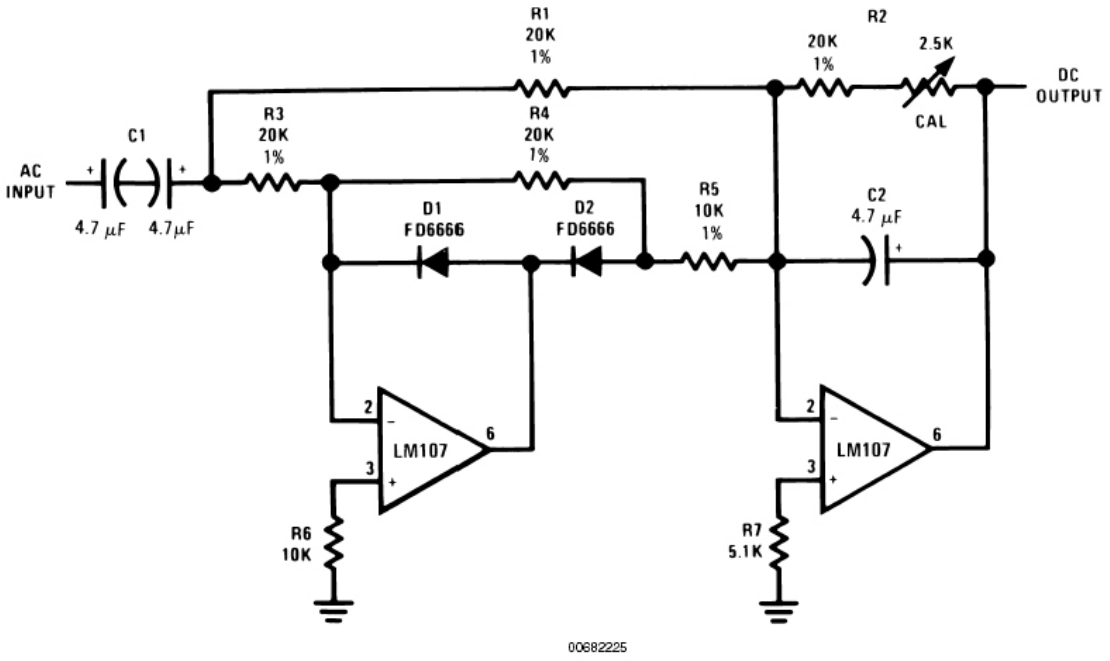


FIGURE 25. Full-Wave Rectifier and Averaging Filter

图 25 是一个平均值输出，有效值刻度的交流电压表头放大电路。它由一个整流器和一个平均值滤波器构成。如果去掉 C2，电路就不再具有平均值滤波功能，只是一个精密全波整流器，如果去掉 C1，电路就变成求绝对值的电路。

为了理解电路原理，下面将从信号路径入手，先分析输入电压小于零的情况，再分析输入电压大于零的情况。对于小于零的输入电压信号，放大器 A1 的输出被二极管 D1 箝位至 +0.7V，二极管 D2 将其与放大器 A2 的求和节点（反相端）隔离开。此时 A2 相当于一个简单的单位增益反相器，输入电阻是 R1，反馈电阻是 R2，输出电压大于零。

输入大于零时，A1 起放大作用，输出经电阻 R5 连到 A2 的求和节点。放大器 A1 接成一个简单的单位增益反相器，输入电阻是 R3，反馈电阻是 R5（此处反馈电阻应该为 R4，疑原文笔误——译者）。由于 D2 位于反馈环路之内，所以它不会影响 A1 的增益精度（译者认为有误，见*注释 1*）。正向电流经 R1 流入 A2 的求和节点，反向电流经电阻 R5 流出 A2 的求和节点。由于 R1 和 R5 上的电压大小相等方向相反，而且 R5 的阻值是 R1 的 1/2，所以 A2 的求和节点处的电流与 R1 上的电流大小相等流向相反，（译者认为有误，见*注释 2*）此时 A2 构成一个单位增益反相加法器，输出仍然为正值。

在 R2 上跨接电容 C2，构成了一个平均值滤波器。此时 A2 的作用与前文所述的“简单低通滤波器”相似。R2C2 的时间常数必须仔细选取，使其远远大于输入电压的最长平均周期。

如果去掉电容 C1，本电路就会变成一个计算绝对值的电路，即电路输出将等于输入电压的绝对值。