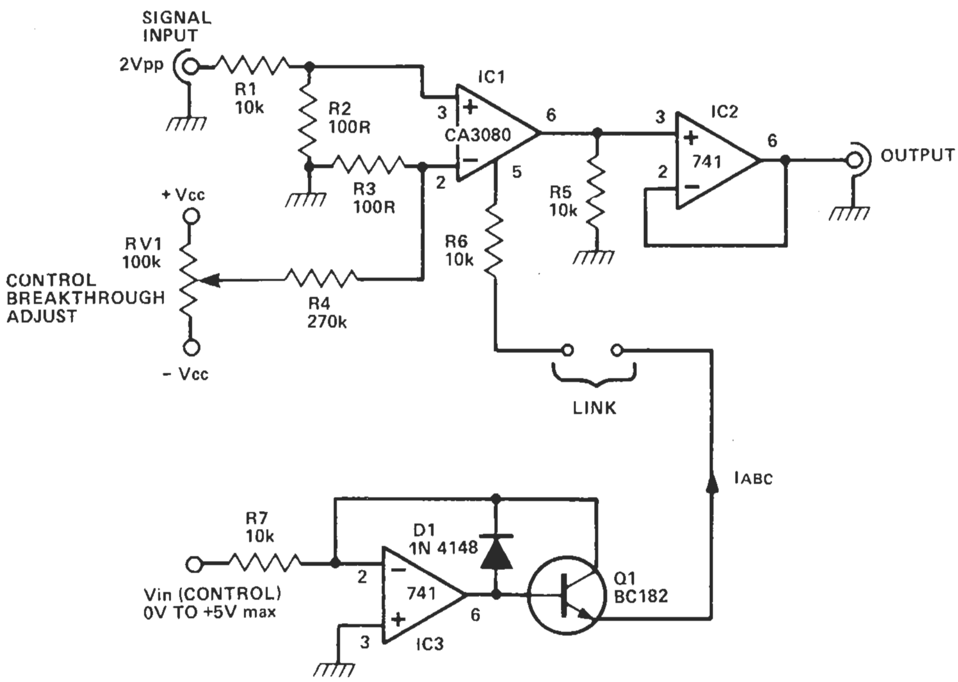
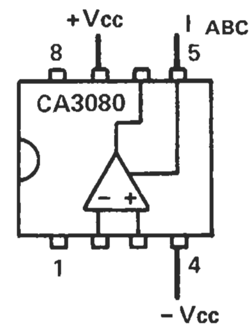
3080 CIRCUITS

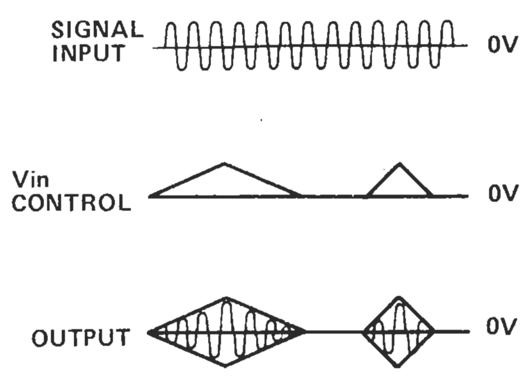
The 3080 is not a run of the mill op amp. These ten circuits from Tim Orr show you why.

The CA3080 is known as an operational transconductance amplifier, (OTA). This is a type of op amp, the gain of which can be varied by use of a control current, (I_{ABC}). The device has a differential input, a control input known as the 'Amplifier bias input' and a current output. It differs in many respects from conventional op amps and it is these differences that can be used to realize many useful circuit blocks.





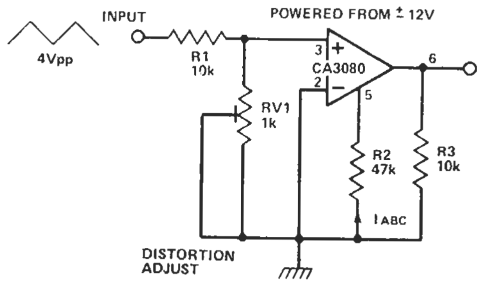
Voltage Controlled Amplifier

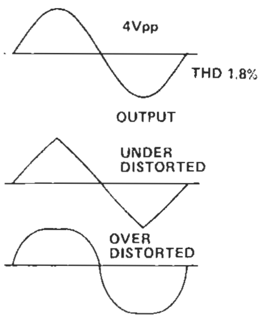


The CA3080 can be used as a gain controlling device. The input signal is attenuated by R1, R2 such that a 20 mVpp signal is applied to the input terminals. If this voltage is much larger, then significant distortion will occur at the output. In fact, this distortion is put to good use in the triangle-to-sinewave converter. The gain of the circuit is controlled by the magnitude of the current I_{ABC}. This current flows into the CA3080 at pin 5, which is held at one diode voltage drop above the −Vcc rail. If you connect pin 5 to 0 V, then this diode will get zapped, (and so will the IC)! The maximum value of I_{ABC} permitted is 1 mA and the device is 'linear' over 4 decades of this current. That is, the gain of the CA3080 is 'linearly' proportional to the magnitude of the I_{ABC} current over a range of 0.1uA to 1 mA. Thus, by controlling I_{ABC}, we can control the signal level at the output. The output is a current output which has to be 'dumped' into a resistive load (R5) to produce a voltage output. The output impedance seen at IC1 pin 6 is 10k (R5), but this is 'unloaded' by the voltage follower (IC2) to produce a low output impedance. The circuit around IC3 is a precision voltage-to-current converter and this can be used to generate I_{ABC}. When Vin (control) is positive, it linearly controls the gain of the circuit. When it is negative, I_{ABC} is zero and so the gain is zero.

This type of circuit is known by several names. It is a voltage controlled amplifier, (VCA), or an amplitude modulator, or a two quadrant multiplier.

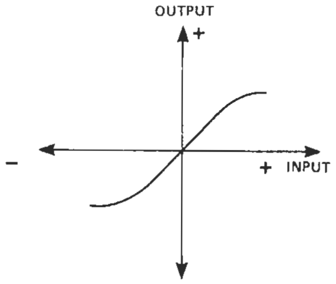
One problem that occurs with the CA3080 is that of the 'input offset voltage'. This is a small voltage offset between its input terminals. When there is no signal input and the control input is varied a voltage similar to the control input will appear at the output. By adjusting RV1 it is possible to null out most of this control breakthrough.



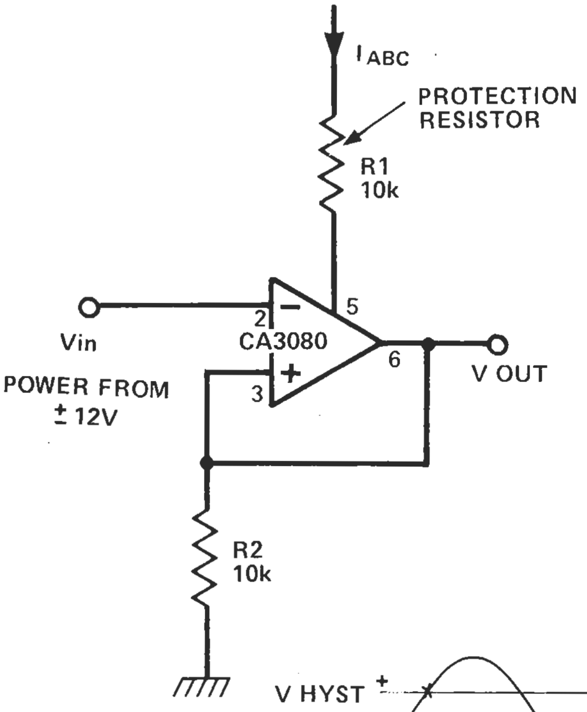


Triangle To Sinewave Converter

By overloading the input of a CA3080 it is possible to produce a 'sinusoidal' transfer function. That is, if a triangle waveform of the correct magnitude is applied to the CA3080 input, the output will be distorted in such a way as to produce a sinewave approximation. In the circuit shown, RV1 is adjusted so that the output waveform resembles a sinewave. I tested this circuit using an automatic distortion analyser and found the sinewave distortion to be only 1.8%, mostly third harmonic distortion, which, for such a simple arrangement, seems very reasonable indeed. This could be used to produce a sinewave output from a triangle/square wave oscillator.



TRANSFER FUNCTION



Schmitt Trigger

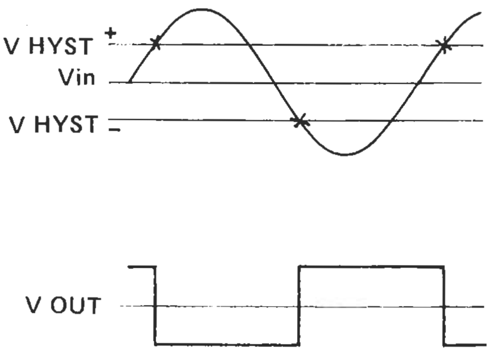
Most Schmitt trigger circuits prove to be very complicated when it comes to calculating the hysterysis levels. However, by using the CA 3080 these calculations are rendered trivial plus there is the added bonus of fast operation. The hysterysis levels are calculated from the simple equation,

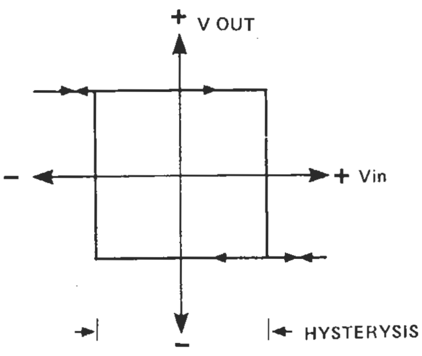
$$V_{HYST} \approx \pm (I_{ABC} \times R2)$$

The output squarewave level is in fact equal in magnitude to the hysterysis levels. The circuit operation is as follows.

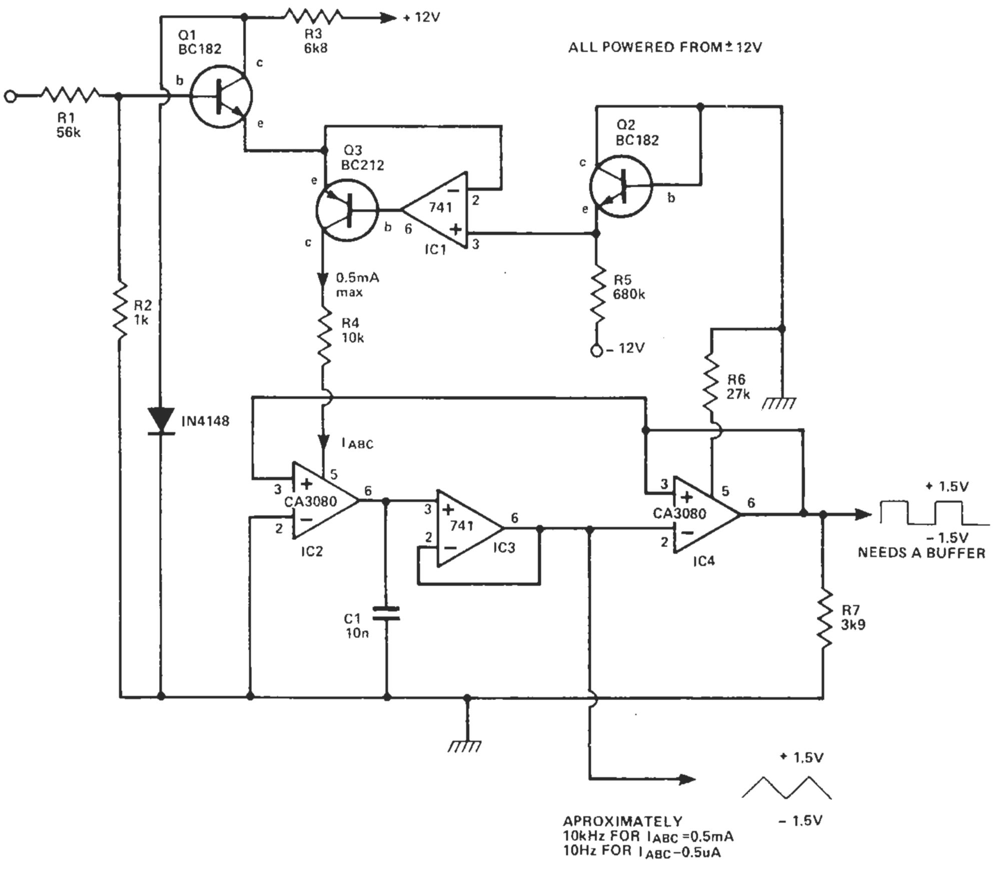
Imagine the output voltage is high. The output voltage will then be equal to (R2 × I_{ABC}) which we will call $+V_{HYST}$. If V_{IN} becomes more positive than $+V_{HYST}$, the output will start to move in a negative direction, which will increase the voltage between the input terminals which will further accelerate the speed of the output movement. This is known as regenerative feedback and is responsible for the schmitt trigger action. The output snaps into a negative state, at a voltage equal to — (R2 × I_{ABC}) which is designated as $-V_{HYST}$. Only when V_{IN} becomes more negative than — V_{HYST} will the output change back to the $+V_{HYST}$ state.

The Schmitt trigger is a very useful building block for detecting two descrete voltage levels and finds many uses in circuit designs. ▶

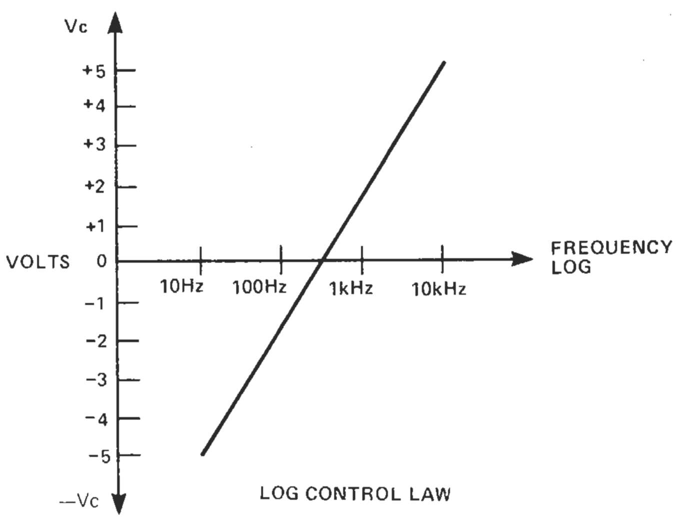




IABC CONTROLS HYSTERYSIS LEVELS AND OUTPUT LEVEL



Voltage Controlled Oscillator



By using two CA3080's and some op amps it is possible to make an oscillator, the frequency of which is voltage controllable. This unit finds many applications in the field of electronic music production and test equipment. The circuit has been given a logarithmic control law, that is, the frequency of operation doubles for every volt increase in the control voltage. This makes it ideal for musical applications where linear control voltages need to be converted into musical intervals (which are logarithmically spaced) and also for audio testing where frequencies are generally measured as logarithmic functions.

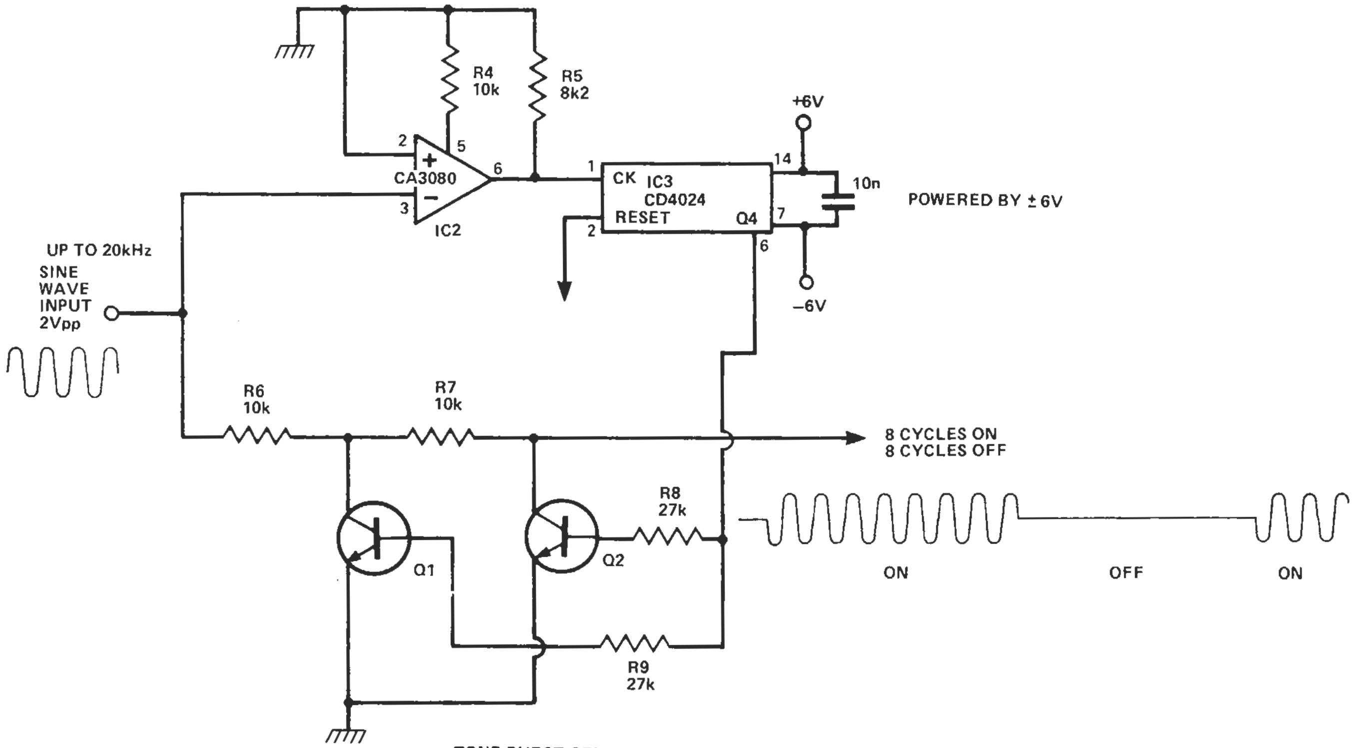
IC2 is an integrator. The I_{ABC} current that drives this IC is used to either charge or discharge C1. This produces triangular waveforms which are buffered by IC3, which then drives the Schmitt trigger IC4. The hysterysis levels for this device are fixed at ± 1.5V, being determined by R6, R7.

The output of the schmitt is fed back in such a way as to control the direction of motion of the integrator's output. If the Schmitt output is high, then the integrator will ramp upwards and vice versa. Imagine that the integrator is ramping upwards. When the integrators output reaches the positive hysterysis level, the Schmitt will flip into its low state, and the integrator will start to ramp downwards. When it reaches the low hysterysis level the Schmitt will flip back into its high state. Thus the integrator ramps up and down in between the two hysterysis levels. The speed at which it does this, and hence the oscillating frequency is determined by the value of I_{ABC} into IC2. The larger the current, the faster the capacitor is charged and discharged. Two outputs are produced, a triangle wave (buffered) from IC3 and a squarewave (unbuffered) from IC4. If the squarewave output is loaded then the oscillation frequency will change.

The log law generator is composed of Q1, 2, 3 and IC1. Transistors Q1 and Q2 should be matched so that their base emitter voltages (Vbe) are the same for the same emitter current, (50uA). Matching these devices to within 5 mV is satisfactory, although unmatched pairs could be used. When matching transistors take care not to touch them with your fingers. This will heat them up and produce erroneous measurements. Transistor Q2 is used to produce a reference voltage of about —OV6 which is connected to IC1 pin 3. This op amp and Q3 is used to keep Q1 emitter at this same voltage of —OV6. The input control voltage is attenuated by R1, R2 such that a +1 V increase at the input produces a change of only +18 mV at the base of Q1. However the emitter of Q1 is fixed at —OV6, so the current through Q1 doubles. (It is a property of transistors that the collector current doubles for every 18 mV increase in Vbe).

The emitter current of Q1 flows through Q3 and into IC2 thus controlling the oscillator frequency. It is possible to get a control range of over 1000 to 1 using this circuit. With the values shown, operation from 10 Hz to 10 kHz is achieved. Reducing C1 to 1 n will increase the maximum frequency to 100 kHz, although the waveform quality may be somewhat degraded.

Changing C1 to 1uf (non-polarized) will give a minimum frequency of 0.1 Hz.

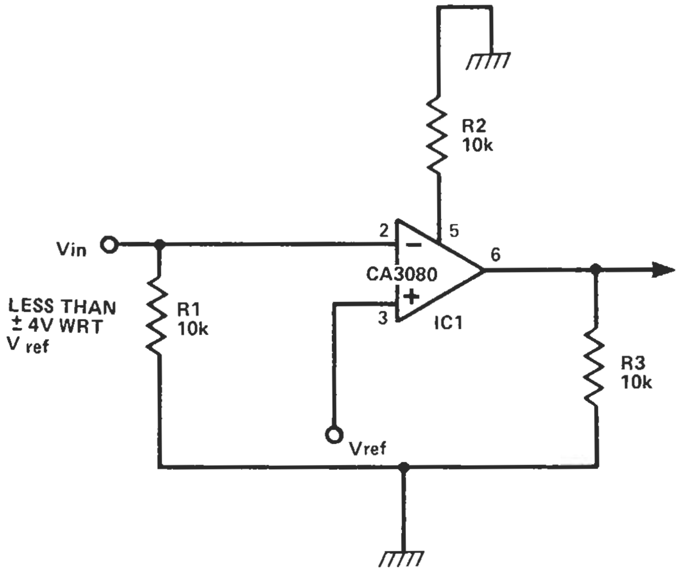


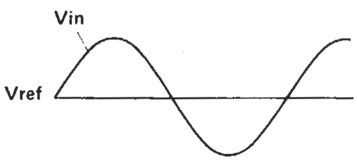
TONE BURST GENERATOR

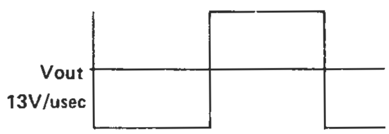
Fast Comparator

The high slew rate of the CA3080 makes it an excellent fast voltage comparator. When pin 2, IC1 is more positive than Vref the output of IC1 goes negative and vice versa. Vref can be moved around so that the point at which the output changes can be varied. As long as the input sinewave level is quite large (1 V say) then the output can be made to move at very fast rates indeed. However, care must be taken to avoid overloading the inputs. If the differential input voltage exceeds 5 V, then the input stage breaks down and may cause an undesired output to occur.

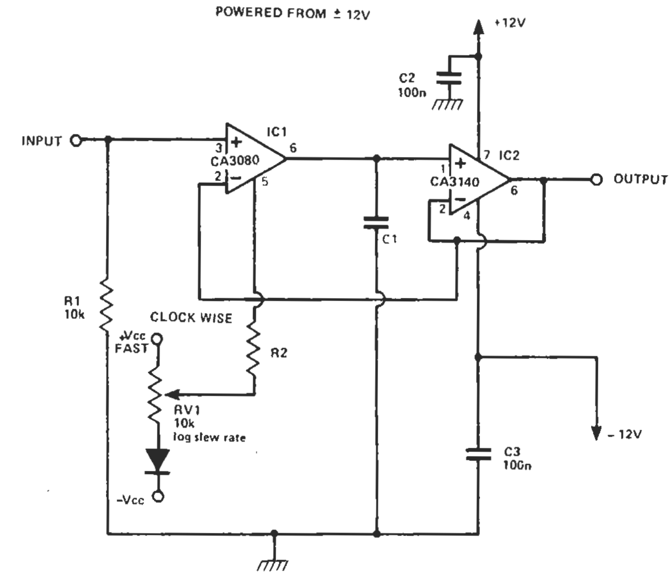
One use of a fast comparator is in a tone burst generator. This device produces bursts of sinewaves, the burst starting and finishing on axis crossings of the sinusoid. The comparator is used to detect these axis crossings and to produce a square wave output which then drives a binary divider (IC3). The divider produces a 'divide by sixteen' output which is high for eight sinewave cycles and then low for the next eight. This signal is then used to gate ON and OFF the sinewave. The gate mechanism is a pair of transistors which short the sinewave to ground when the divider output is high and let it pass when the divider output is low. The resulting output is a toneburst. However, if the comparator is not very fast, then there will be a delay in generating the gate and so the tone burst will not start or finish on axis crossings. Using the circuit shown, operation up to 20 kHz is obtainable.

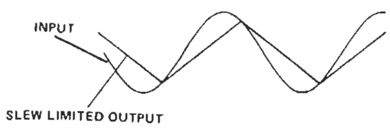






Slew Limiter





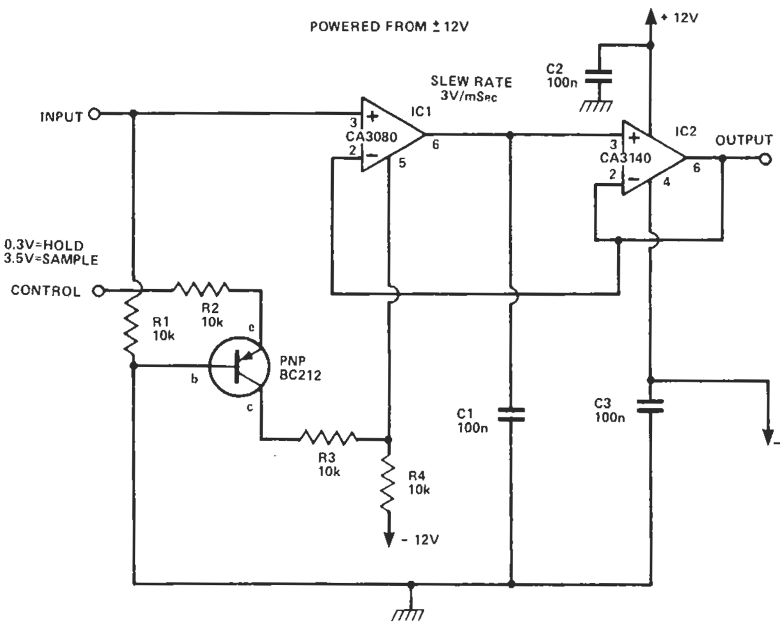
The current output of a CA3080 can be used to produce a controlled slew limiter. By connecting the output current to a capacitor, the output voltage cannot move faster than a rate given by

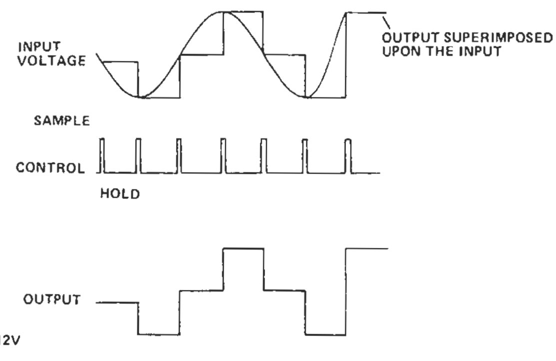
$$\text{slew rate} = \frac{I_{ABC}}{C1} \text{ Volts per sec.}$$

Note that I_{ABC} determines the slew rate and as I_{ABC} is a variable then so is the slew rate. The output voltage is buffered by a voltage follower, IC2. This is a MOSFET op amp which has a very high input impedance, which is necessary to minimise the loading on C1.

When an input signal is applied to IC1 the output tries to move towards this voltage but its speed is limited by the slew rate. Thus the output produces a linear ramp which stops when it reaches the input signal level.

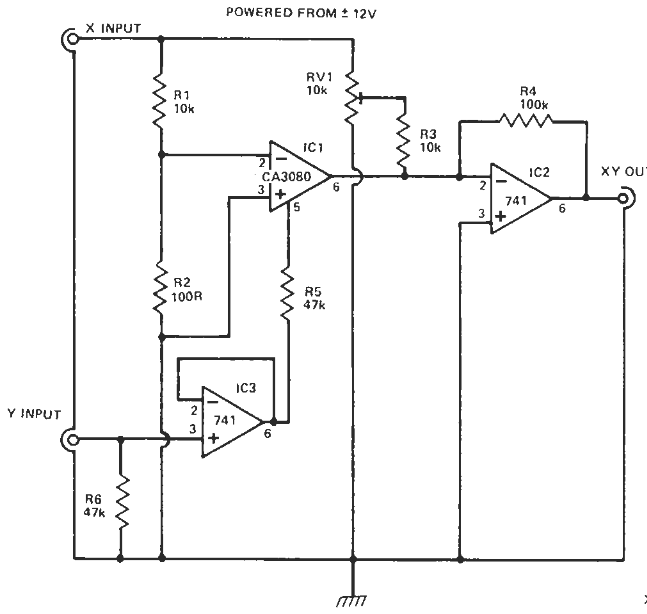
R2	C1	FASTEST SLEW RATE
150k	100n	1.5V/mSec
150k	10n	15V/mSec
150k	1u0	0.15V/mSec
1M5	1u0	15V/Sec

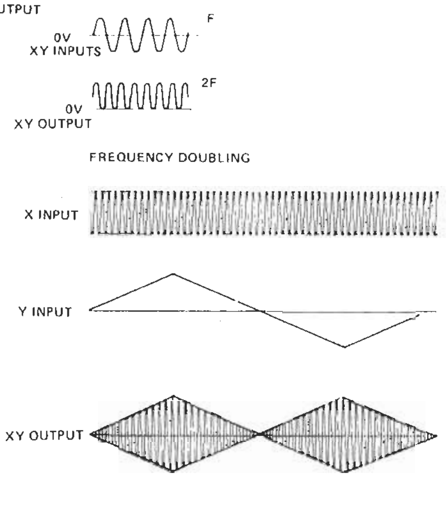




Sample And Hold

The slew limiter can be modified so that it becomes a sample and hold unit. In this circuit I_{ABC} is either hard ON (sample) or completely OFF (hold). In the sample mode, the output voltage quickly adjusts itself so that it equals the input voltage. This enables a short sample period to be used. In the HOLD mode, I_{ABC} is zero and so the voltage on C1 should remain fixed. The circuit is in fact an analogue memory. It is used in music synthesisers (to remember the pitch), in analogue to digital converters and many other circuits.



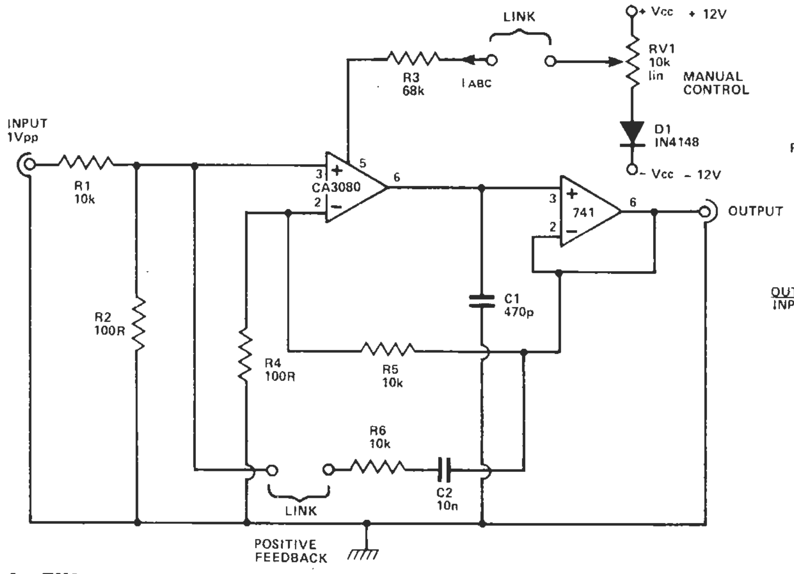


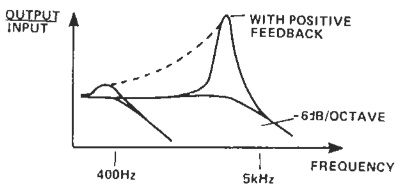
RING MODULATION

4 Quadrant Multiplier

The CA3080 is a two quadrant multiplier but, with the addition of a few extra bits of electronics, it can be made into a four quadrant circuit. A two quadrant multiplier has two inputs, one can accept bipolar signals (the inverting or non inverting input) and one can only accept a unipolar signal, (the IABC current). However, a four quadrant multiplier can accept bipolar signals on both of its inputs which enables it to perform frequency doubling and ring modulation.

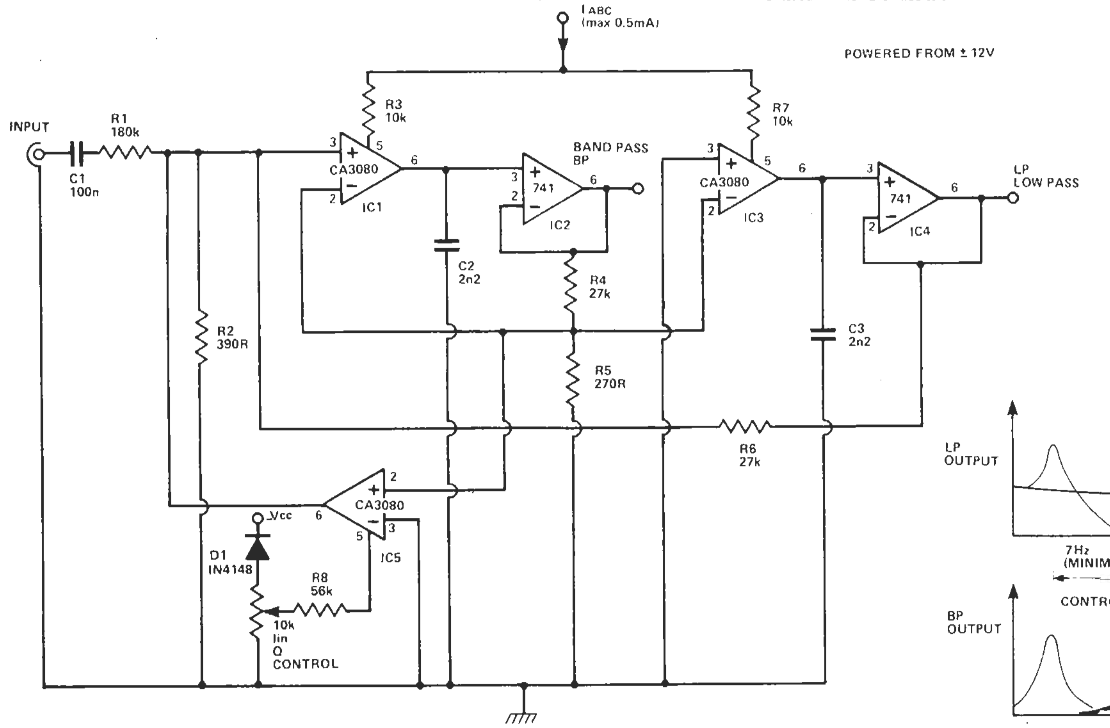
The circuit is fairly similar to that of the two quadrant multiplier described earlier except for two differences. IC3 is used to generate IABC in such a way that the Y input can go both positive and negative, thus the Y input is bipolar, when Y is at 0 V and there is a signal on the X input the desired output (X × Y) should be zero. This is achieved by adjusting RV1 so that the signal via IC1 (this is inverted) is exactly cancelled out by that via R3. Now, when Y is increased positively, a non-inverted value of X is produced at the output and, when Y is increased negatively, an inverted value of X is produced. When Y is zero, so is the output. This is known sometimes as ring modulation. If a speech signal is connected to the X input and a variable frequency oscillator to the Y input the resulting sound is that of a 'dalek'. Also, if a sinewave is connected to both the X and Y inputs, the XY product is a sinewave of twice the frequency. This is known as a frequency doubler, but it will only work with sinewaves.

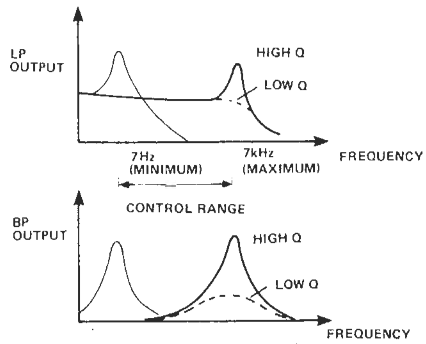




Single Pole Filter

A singlepole lowpass filter can be constructed using a CA3080 as a current controlled resistor. The filter is, in fact, just a simple RC low pass section where the R, which is controllable, is constructed out of IC1, R4, R5. Varying IABC changes the amount of current drive to C1. This would normally make the circuit a slew limiter, but because the signal level that IC1 (pins 2 and 3) handles is so small, the CA3080 works in its linear mode. This enables it to look like a variable resistor. When this resistor is varied, the break frequency of the filter also varies. By applying some positive feedback around the filter (R6, C2) it is possible to produce a peaky filter response. The peak actually increases with frequency making the circuit useful as a guitar Wah Wah unit. ▶





Voltage Controlled Filter

A standard dual integrator filter can be constructed using a few CA3080's. By varying IABC the resonant frequency can be swept over a 1000 to 1 range. IC1, 3 are two current controlled integrators. IC2, 4 are voltage followers which serve to buffer the high impedance outputs of the integrators. A third CA3080 (IC5) is used to control the Q factor of the filter. Q factors as high as 50 can be obtained. The resonant frequency of the filter is linearly proportional to IABC and hence this unit is very useful in electronic music production. There are two outputs produced, a low pass and a band pass response.

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