Voltage-Shunt Feedback

The constant-gain op-amp circuit of Fig.1a provides voltage-shunt feedback. Referringto Fig.1 and the op-amp ideal characteristics *Ii* = 0, *Vi*= 0, and voltage gain of infinity, we have

$$A = \frac{V_o}{I_i} = \infty$$

$$\beta = \frac{I_f}{V_o} = \frac{-1}{R_o}$$

The gain with feedback is then

$$A_f = \frac{V_o}{I_s} = \frac{V_o}{I_i} = \frac{A}{1 + \beta A} = \frac{1}{\beta} = -R_o$$

This is a transfer resistance gain. The more usual gain is the voltage gain with feedback,

$$A_{vf} = \frac{V_o}{I_s}\frac{I_s}{V_1} = (-R_o)\frac{1}{R_1} = \frac{-R_o}{R_1}$$

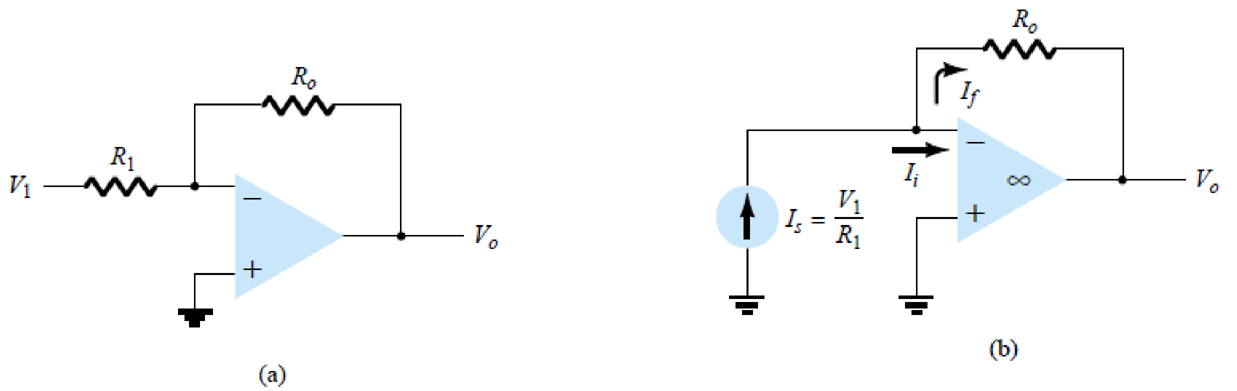


Fig.1: Voltage-shunt negative feedback amplifier: (a) constant-gain circuit; (b) equivalent circuit.

OSCILLATOR OPERATION

An oscillator circuit then provides a varying output signal.If the output signal varies sinusoidally, the circuit is referred to as a *sinusoidal oscillator*.If the output voltage rises quickly to one voltage level and later drops quickly to anothervoltage level, the circuit is generally referred to as a *pulse* or *square-wave oscillator*.

The output waveform will still exist after the switch is closed if the condition

$$\beta A = 1$$

This is known as the *Barkhausen criterion* for oscillation

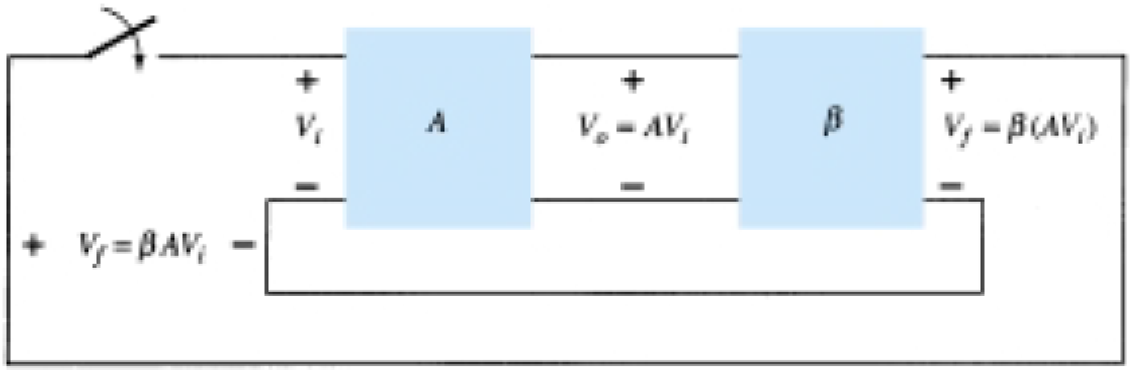


Fig.2: Feedback circuit used as an oscillator.

Fig.3 shows below how the noise signal results in a buildup of a steady-state oscillationcondition.

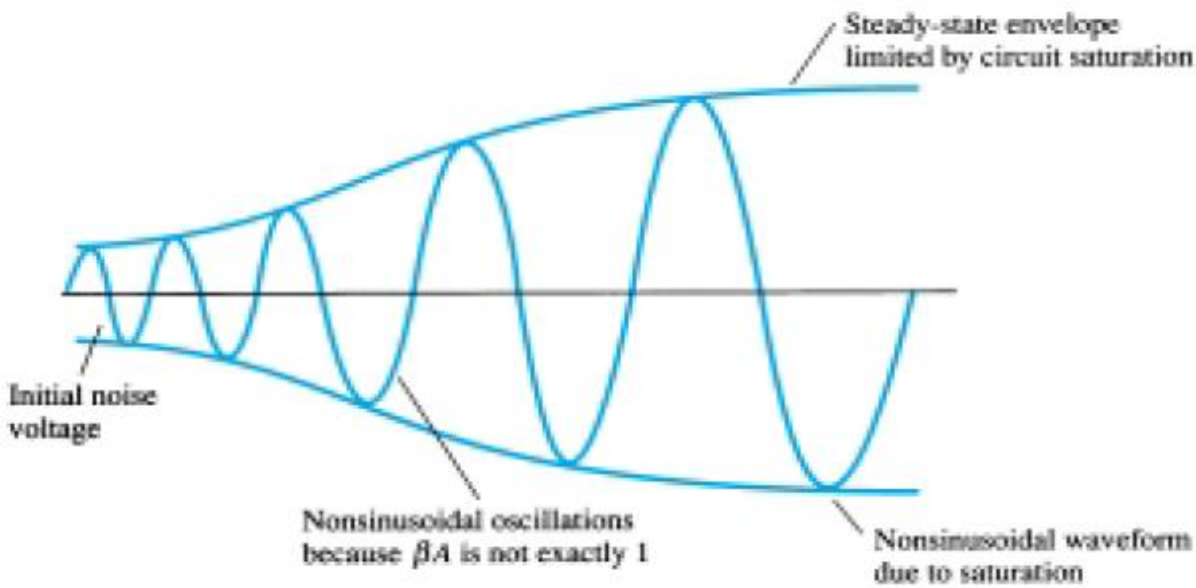


Fig.3: Buildup of steady-state oscillations.

Another way of seeing how the feedback circuit provides operation as an oscillatoris obtained by noting the denominator in the basic feedback equation ,

$A_f = A/(1 + \beta A)$. When $\beta A = \_1$ or magnitude 1 at a phase angle of 180°, the denominatorbecomes 0 and the gain with feedback, A_f, becomes infinite. Thus, an infinitesimalsignal (noise voltage) can provide a measurable output voltage, and the circuitacts as an oscillator even without an input signal.

PHASE-SHIFT OSCILLATOR

An idealized version of this circuit is shown inFig.4. Recall that the requirements for oscillation are that the loop gain, β*A*, is greater than unity *and* that the phase shift around the feedback network is 180° (providing positive feedback)

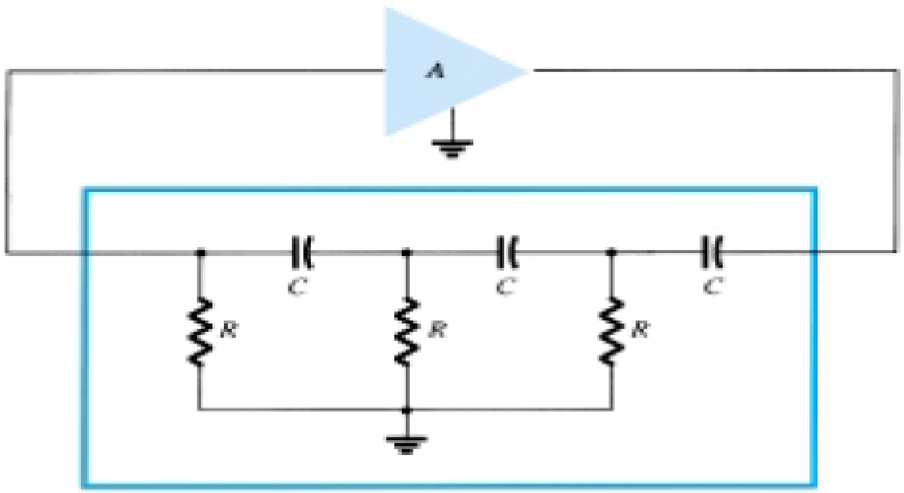


Fig.4: Idealized phase-shift oscillator.

Concentrating our attention on the phase-shift network, we are interested in the attenuation of the network at the frequency at which the phase shift is exactly 180°. Using classical network analysis, we find that

$$\boxed{f = \frac{1}{2\pi RC\sqrt{6}}}$$

$$\beta = \frac{1}{29}$$

and the phase shift is 180°. For the loop gain _*A* to be greater than unity, the gain of the amplifier stage must be greater than 1/β or 29:

$A > 29$

When considering the operation of the feedback network, one might naively selectthe values of *R* and *C* to provide (at a specific frequency) 60°-phase shift per section for three sections, resulting in a 180° phase shift, as desired. This, however, is not the case, since each section of the *RC* in the feedback network loads down the previous one. The net result that the *total* phase shift be 180° is all that is important.The frequency given by Eq. of frequency above is that at which the *total* phase shift is 180°. If one measured the phase shift per *RC* section, each section would not provide the same phase shift (although the overall phase shift is 180°). If it were desired to obtain exactly a 60° phase shift for each of three stages, then emitter-follower stages would be needed for each *RC* section to prevent each from being loaded from the following circuit.

Transistor Phase-Shift Oscillator

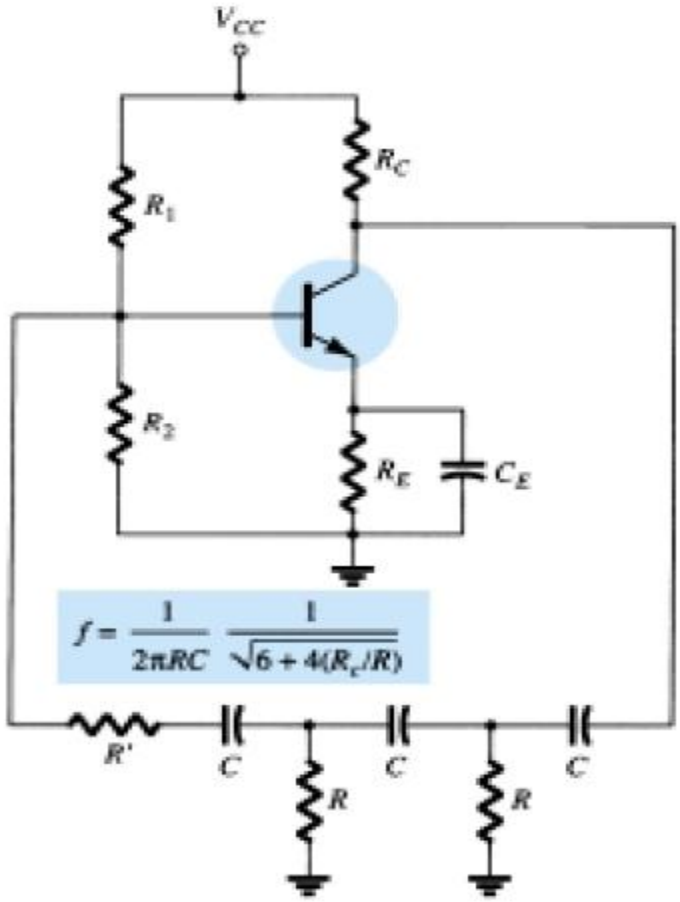


Fig.5: Practical phase-shift oscillator circuits: BJT version.

transistor stage is desired, however, the use of voltage-shunt feedback (as shown in Fig.5) is more suitable. In this connection, the feedback signal is coupled through the feedback resistor *R_* in *series* with the amplifier stage input resistance (*Ri*).

Analysis of the ac circuit provides the following equation for the resulting oscillator frequency:

$$f = \frac{1}{2\pi RC} \frac{1}{\sqrt{6+4(R_C/R)}}$$

For the loop gain to be greater than unity, the requirement on the current gain of the transistor is found to be

$$h_{fe} > 23 + 29\frac{R}{R_C} + 4\frac{R_C}{R}$$

IC Phase-Shift Oscillator

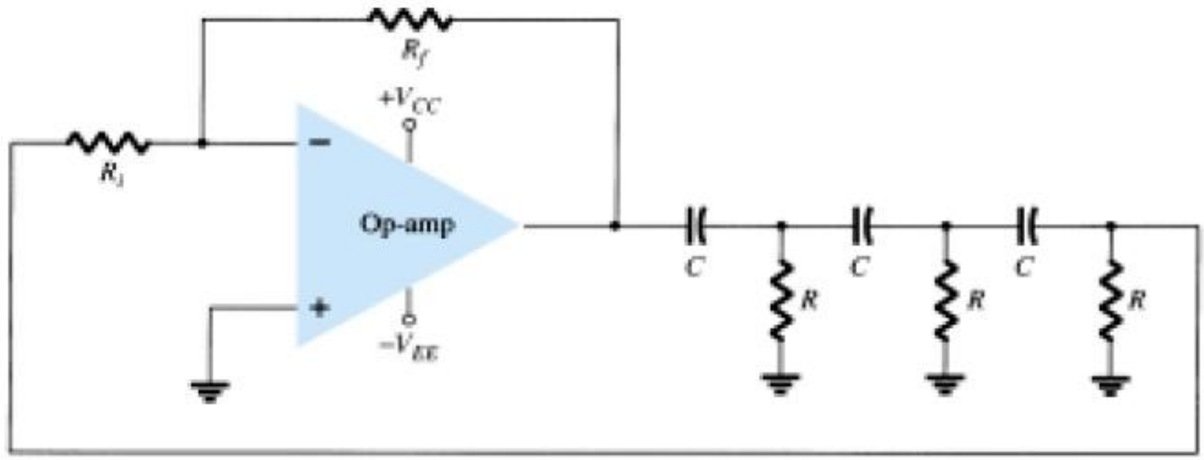


Fig.6:Phase-shift oscillator using op-amp.

The output of the op-amp is fed to a three-stage *RC* network, which provides the needed 180° ofphase shift (at an attenuation factor of 1/29). If the op-amp provides gain (set by resistors*Ri*and *Rf*) of greater than 29, a loop gain greater than unity results and the circuitacts as an oscillator [oscillator frequency is given by

$$\boxed{f = \frac{1}{2\pi RC\sqrt{6}}}$$

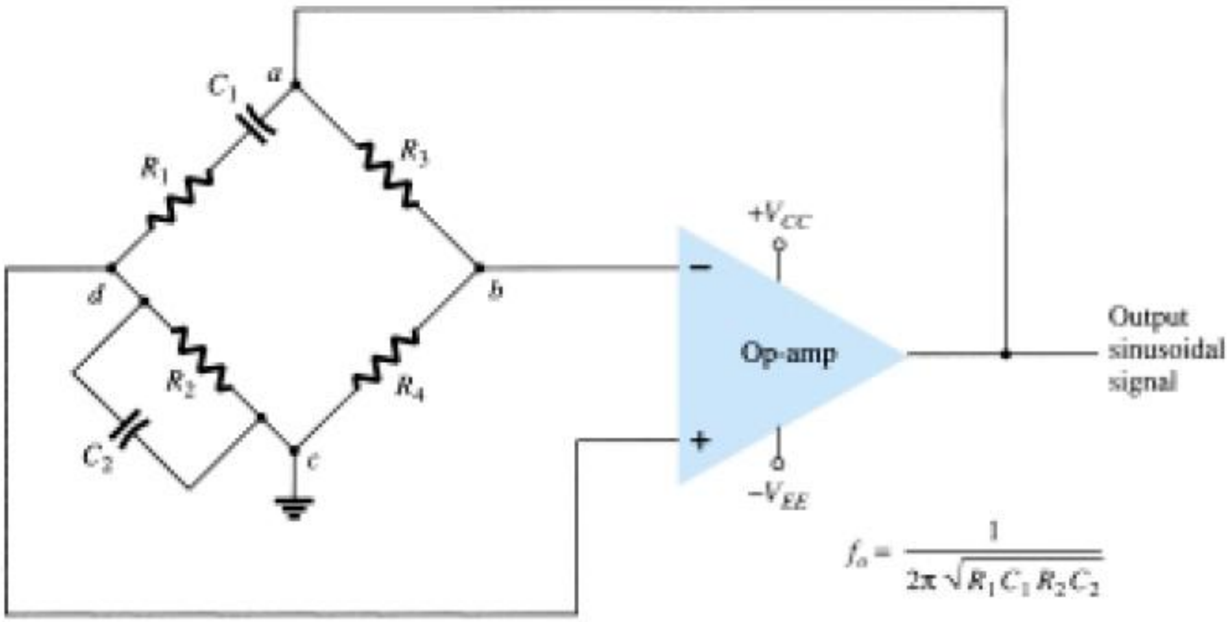
WIEN BRIDGE OSCILLATOR

Fig.7 shows a basic version ofa Wien bridge oscillator circuit. Note the basic bridge connection. Resistors *R*1 and*R*2 and capacitors *C*1 and *C*2 form the frequency-adjustment elements, while resistors*R*3 and *R*4 form part of the feedback path. The op-amp output is connected as thebridge input at points *a* and*c*. The bridge circuit output at points*b* and *d* is the inputto the op-amp.

Neglecting loading effects of the op-amp input and output impedances, the analysisof the bridge circuit results in

$$\frac{R_3}{R_4} = \frac{R_1}{R_2} + \frac{C_2}{C_1}$$

$$\boxed{f_o = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}}}$$



Neglecting loading effects of the op-amp input and output impedances, the analysis of the bridge circuit results in

$$\frac{R_3}{R_4} = \frac{R_1}{R_2} + \frac{C_2}{C_1}$$

$$\boxed{f_o = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}}}$$

If, in particular, the values are $R_1 = R_2 = R$ and $C_1 = C_2 = C$, the resulting oscillator frequency is

$$f_o = \frac{1}{2\pi RC}$$

$$\frac{R_3}{R_4} = 2$$

Thus a ratio of *R*3 to *R*4 greater than 2 will provide sufficient loop gain for the circuit to oscillate at the frequency calculated

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