Secrets of the Phase-shift Oscillator – revealed!

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It's pretty easy to make an oscillator – sometimes it's hard *not* to make one (like when you're trying to build an amplifier).

Here's how it's done: Take an amplifier and feed some of its output back into the input, forming a loop. If the total gain around the loop is one or more, and if the phase-shift around the loop at some frequency is zero or 360 degrees (or some multiple of 360) … then, congratulations! You've made an oscillator.

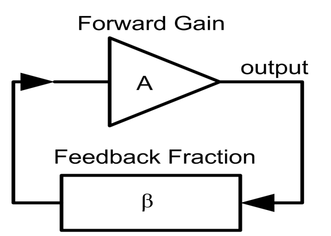
What you have actually done is fulfilled the "Barkhausen criterion" , which states that the conditions for oscillation in a linear electronic circuit containing a feedback loop are:

$$|A\beta| = 1$$

where, A = forward gain of the amplifying element, and
β = fraction of the output fed back to the input.

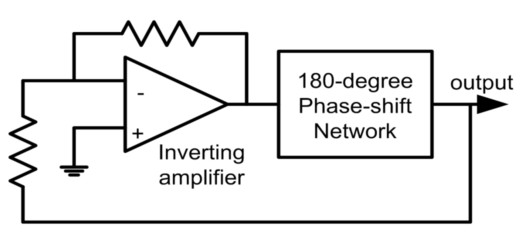
Note that both A and β can (and usually do) vary with frequency.

This is the Barkhausen criterion in block diagram form:



Basic Oscillator Block Diagram

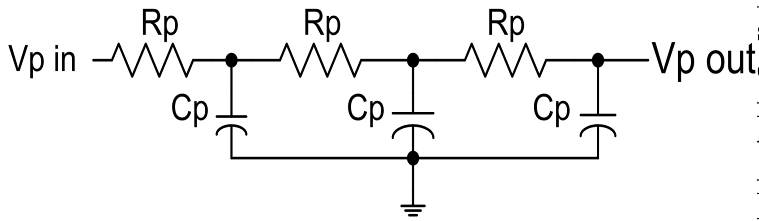
In a conventional phase-shift oscillator, a separate phase shifting network is included to put the phase shift under the control of the designer, and the gain around the loop is controlled by the amplifier.



Basic phase shift oscillator

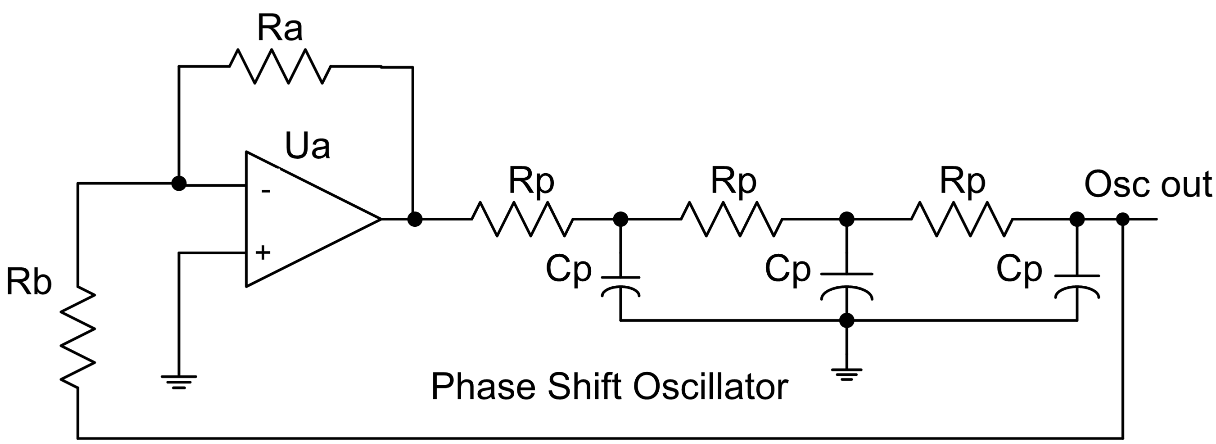
The phase-shift network accounts for 180 degrees of phase at the design frequency and the inverting amplifier adds the remaining 180 degrees for a 360-degree total. The job of the amplifier is to add enough gain to compensate for any amplitude loss in the phase-shift network and bring the total gain around the loop to unity.

The phase-shift network is (usually) a three-stage resistor-capacitor (RC) low-pass network, in which each stage contributes about 60 degrees of phase shift. Since it is impossible to achieve more than 90 degrees of phase shift in a single RC section, this represents a reasonable trade-off between phase shift and signal loss.



Phase Shift Network

In its final form, the phase-shift oscillator looks like this:



Phase Shift Oscillator

The nominal frequency of oscillation of this circuit is given by:

$$\text{frequency} = \frac{\sqrt{6}}{2\pi\, Rp\, Cp}$$

and, *yes*, it *will* oscillate if the gain of inverting amplifier Ua (set by the ratio of Ra to Rb) is made high enough to overcome the signal loss through the phase-shift network – about 30 db.

The above equation is most nearly exact for frequencies well below the closed-loop bandwidth of the amplifier. As we get close to that limit, the amplifier itself contributes some phase shift. Remember, the total phase shift around the loop must be 360 degrees for the Barkhausen criterion to apply, so if there is additional phase-shift around the loop, the oscillator will find a frequency somewhat different than that given by the equation.