

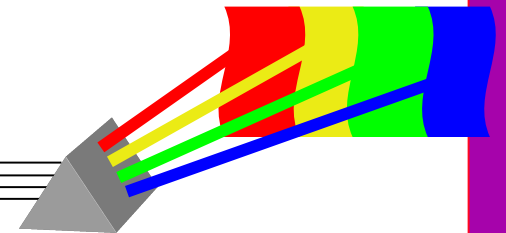
Electronics

Principles & Applications

Seventh Edition

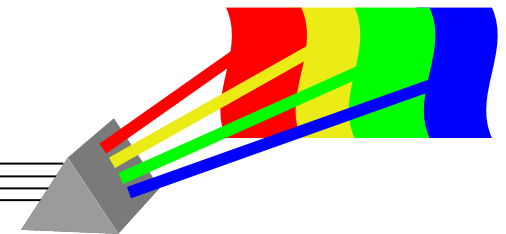
Charles A. Schuler

Chapter 11
Oscillators
(student version)



INTRODUCTION

- **Oscillator Characteristics**
- **RC Circuits**
- **LC Circuits**
- **Crystal Circuits**
- **Relaxation Oscillators**
- **Undesired Oscillations**
- **Troubleshooting**
- **Direct Digital Synthesis**



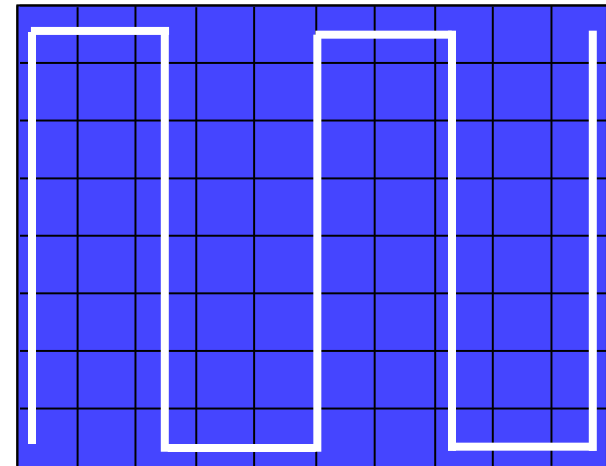
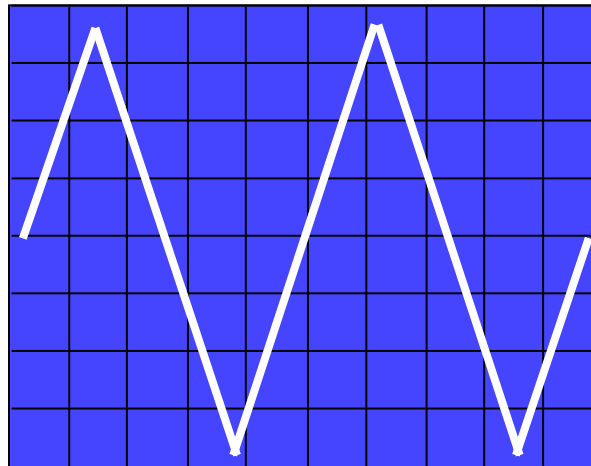
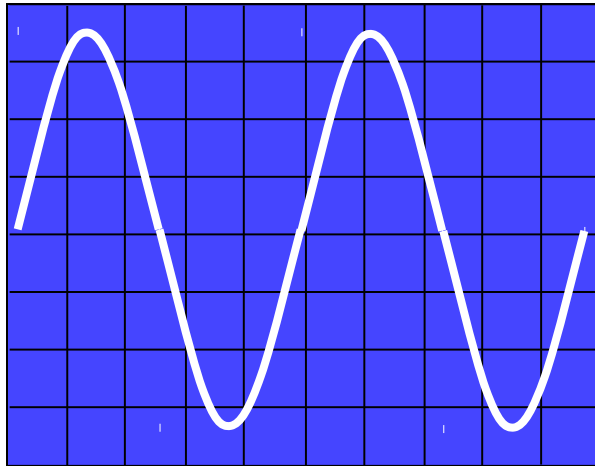
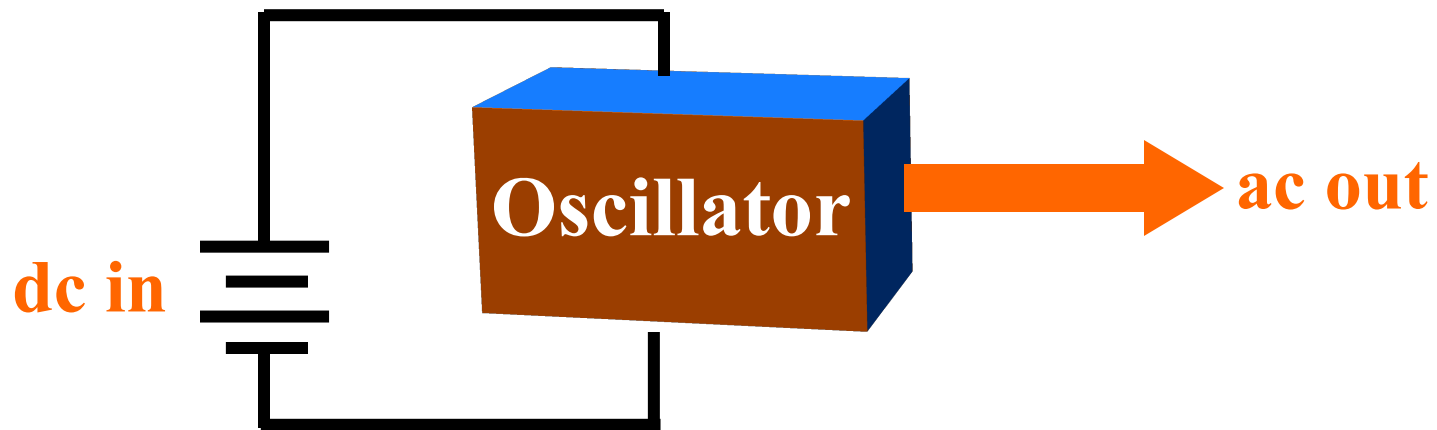
Dear Student:

This presentation is arranged in segments. Each segment is preceded by a *Concept Preview* slide and is followed by a *Concept Review* slide. When you reach a *Concept Review* slide, you can return to the beginning of that segment by clicking on the Repeat Segment button. This will allow you to view that segment again, if you want to.

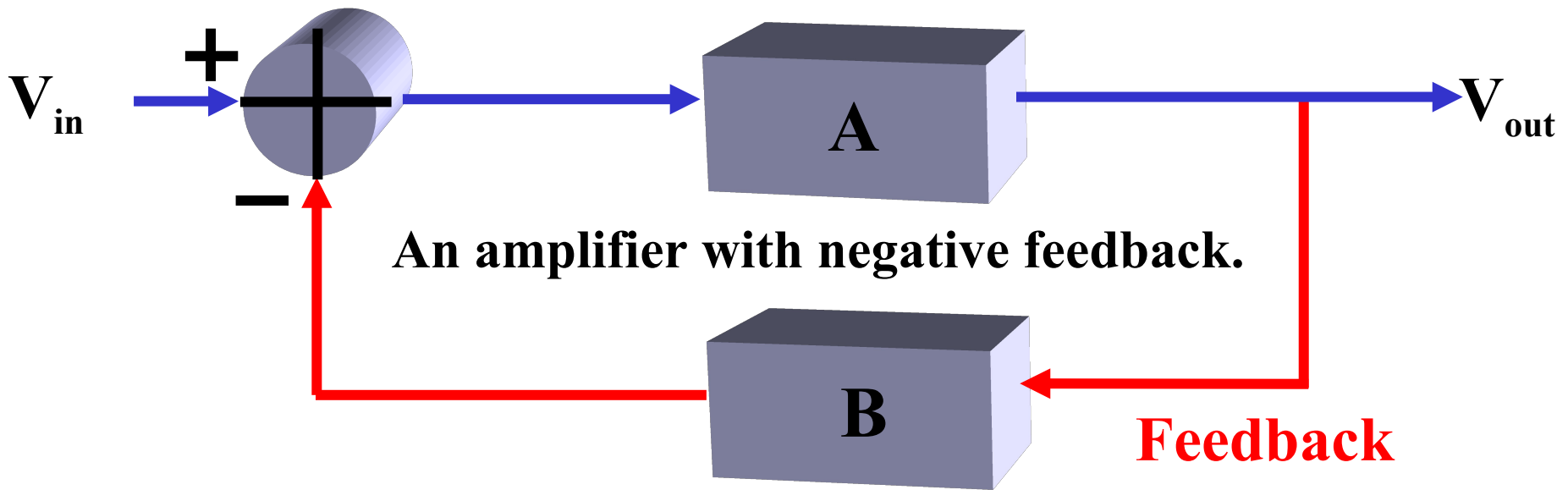
Concept Preview

- Oscillators convert dc to ac.
- Oscillators use positive feedback.
- An amplifier will oscillate if it has positive feedback and has more gain than loss in the feedback path.
- Sinusoidal oscillators have positive feedback at only one frequency.
- A lead-lag network produces a phase shift of 0 degrees at only one frequency.

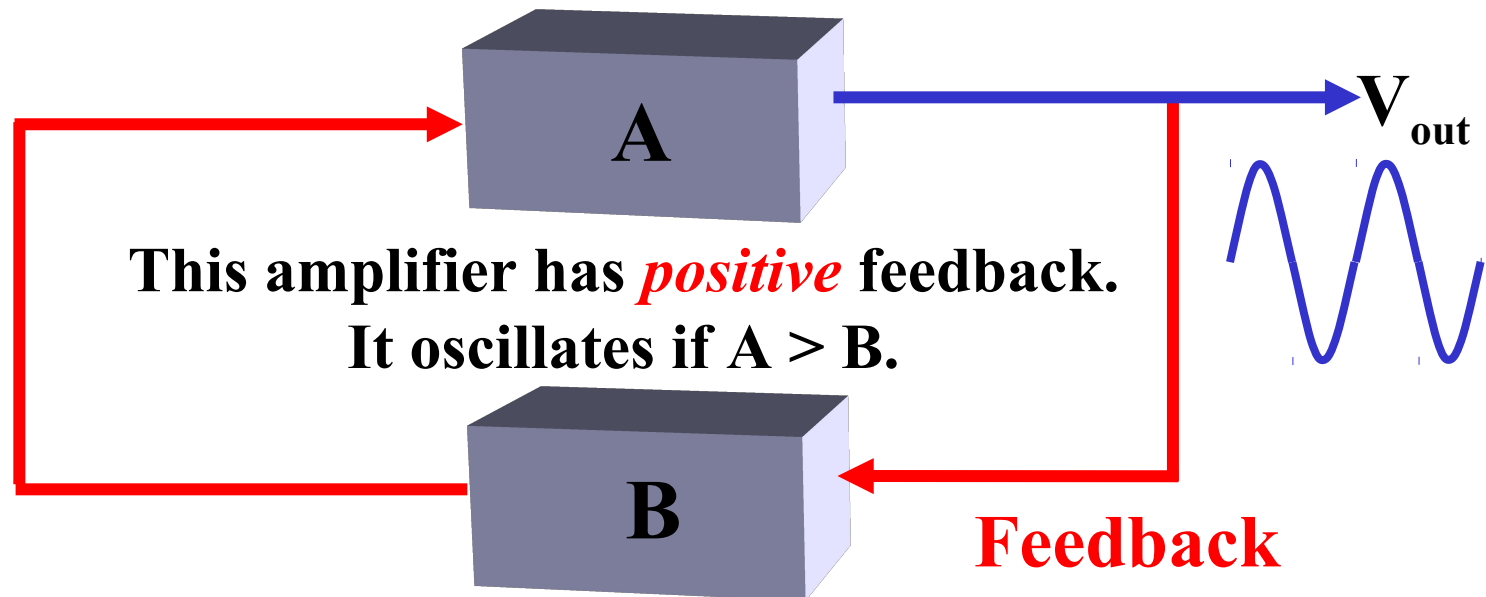
Oscillators convert dc to ac.

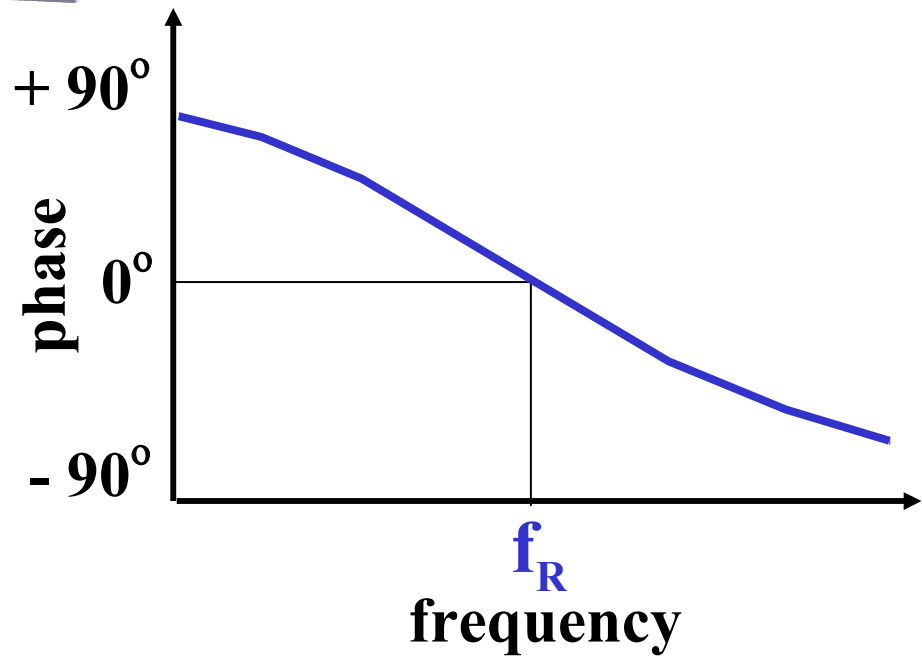
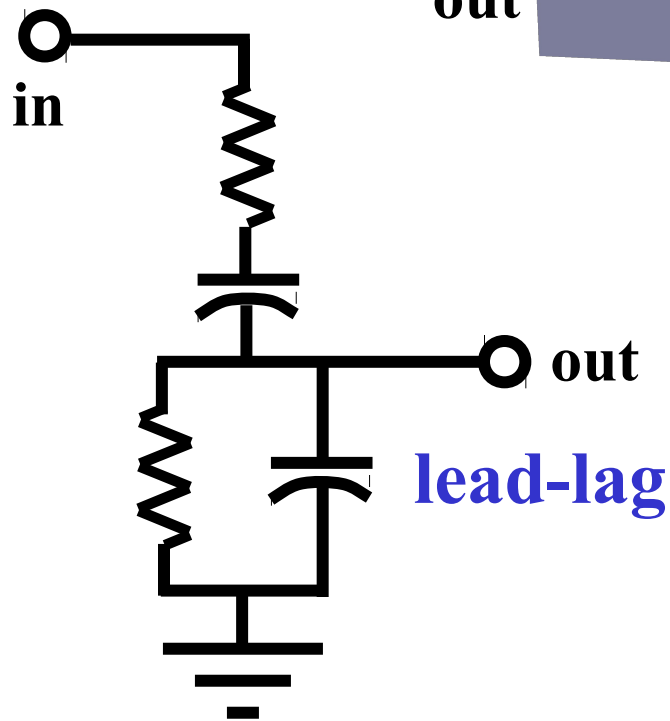
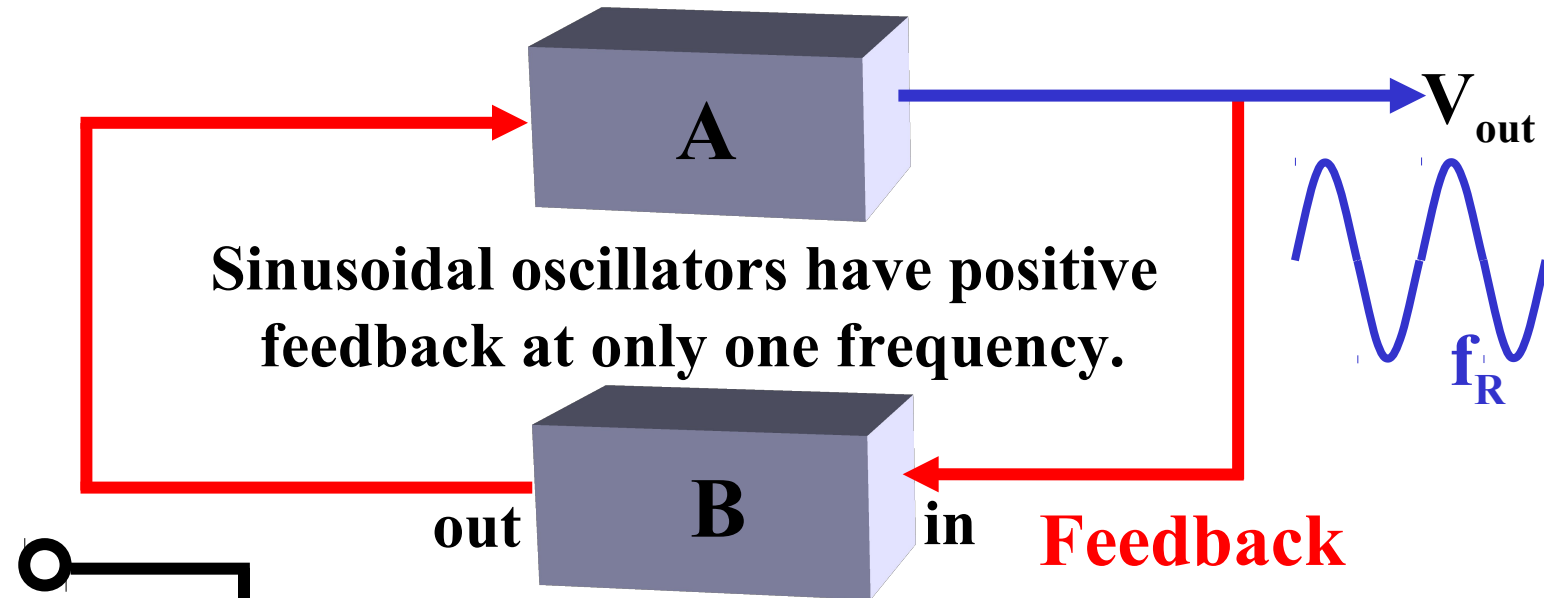


Some possible output waveforms



Recall: A = open-loop gain and B = feedback fraction





This can be accomplished with RC or LC networks.

Oscillator basics quiz

Oscillators convert dc to _____.
ac

In order for an oscillator to work, the feedback must be _____.
positive

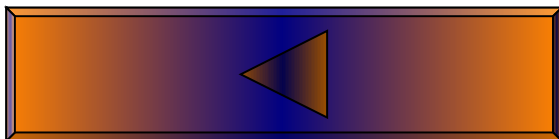
An oscillator can't start unless gain (A) is _____ than feedback fraction (B). **greater**

Sine wave oscillators have the correct feedback phase at one _____.
frequency

The phase shift of an RC lead-lag network at f_R is _____.
 0°

Concept Review

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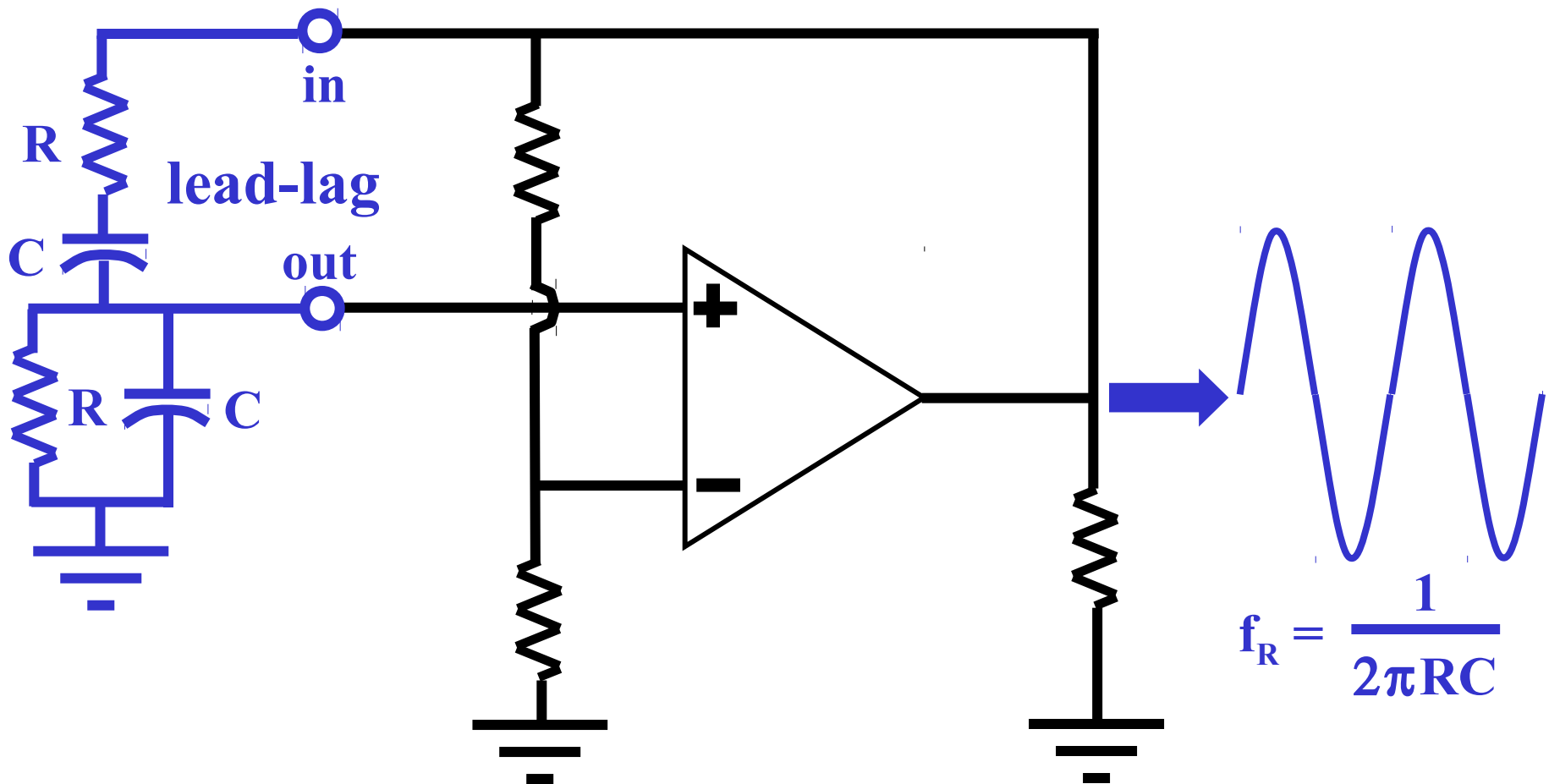
Repeat Segment

Concept Preview

- The Wien bridge oscillator can produce a low-distortion sine wave output.
- A Wien bridge oscillator operates at the resonant frequency of its lead-lag network.
- The gain of some oscillator circuits must be reduced after oscillations begin to avoid clipping.
- Since common emitter amplifiers produce a phase inversion, a second phase inversion is required for positive feedback.
- RC networks can provide a 180 degree phase shift at the desired frequency of oscillation.

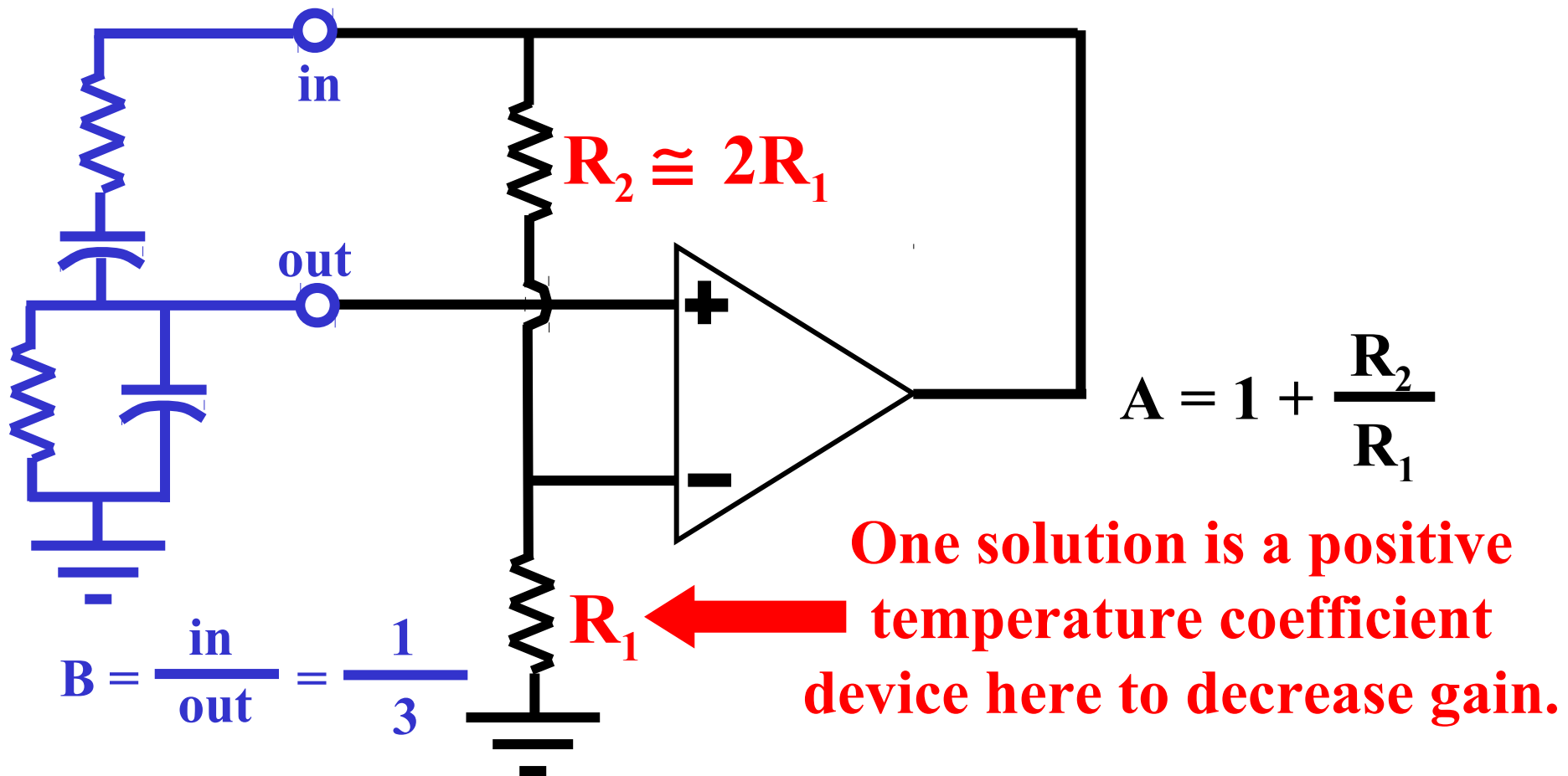
Wien bridge oscillator

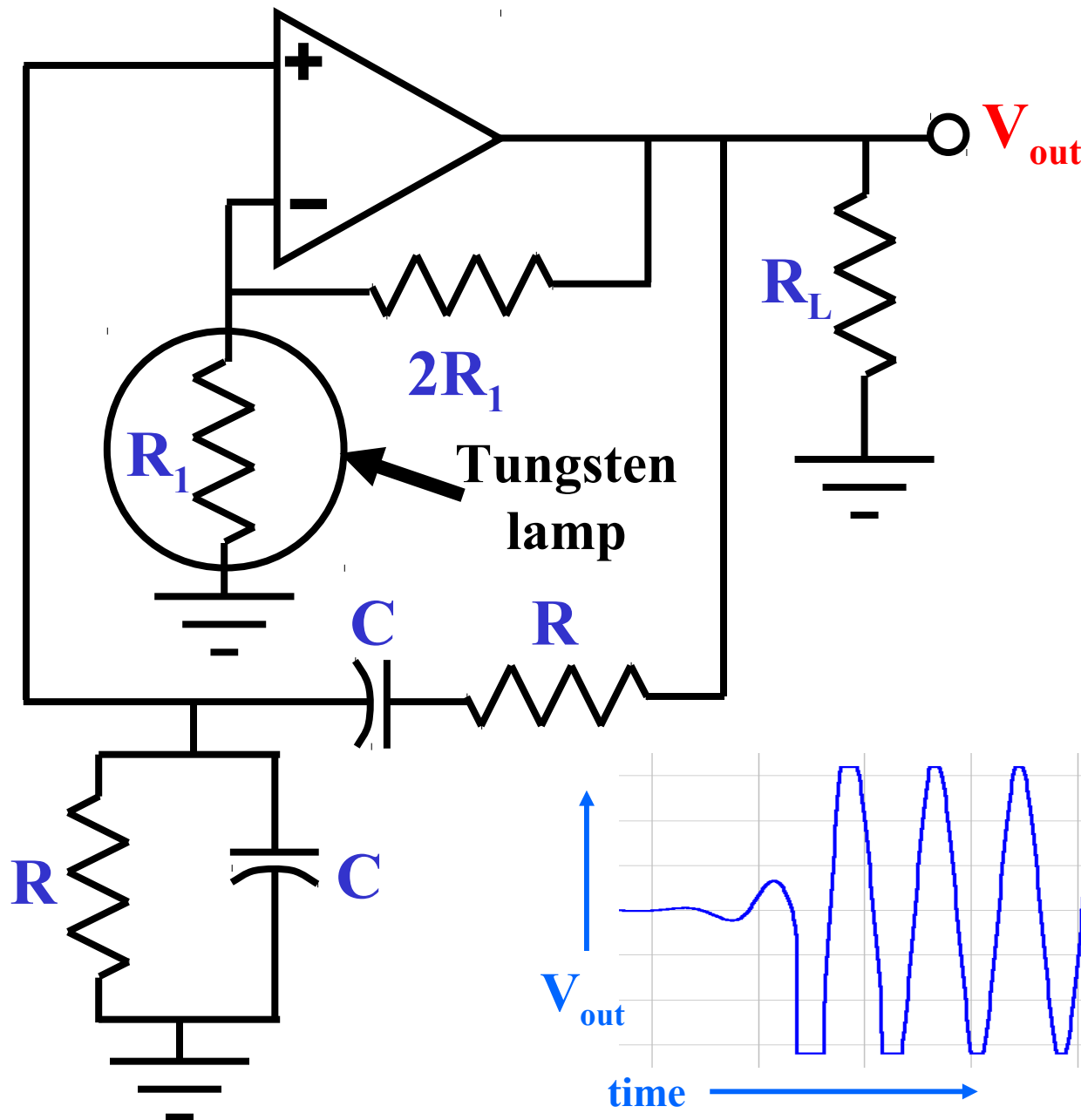
Only f_R arrives at the + input in phase.



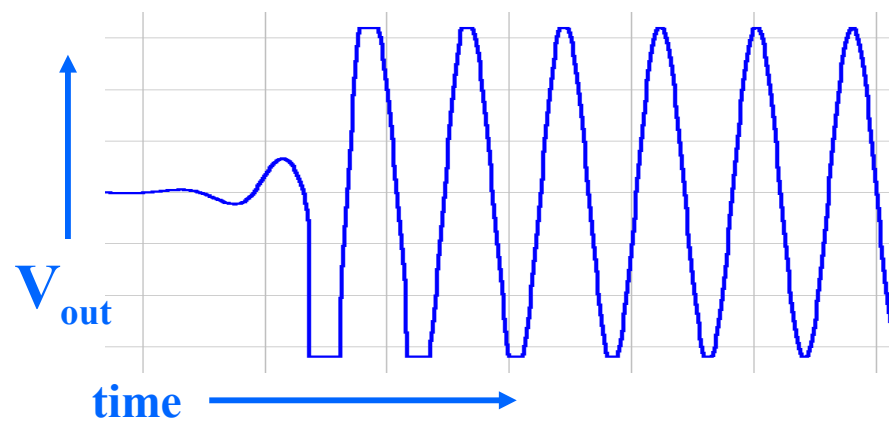
The feedback fraction at f_R in this circuit is one-third:

A must be > 3 for oscillations to start. After that, A must be reduced to avoid driving the op amp to V_{SAT} .

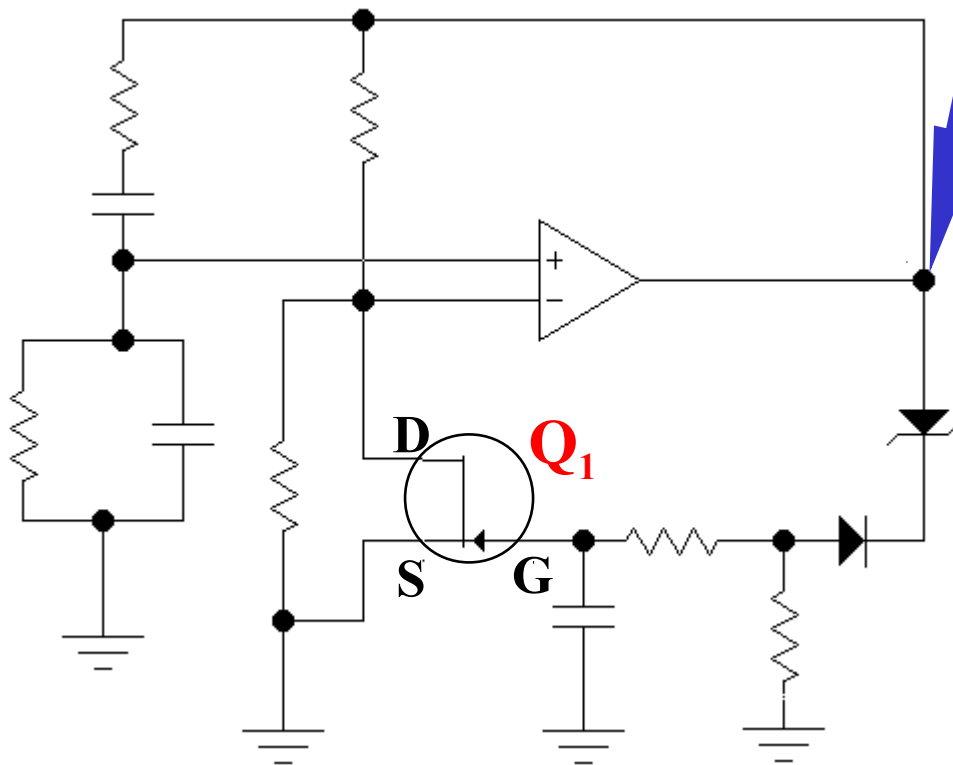
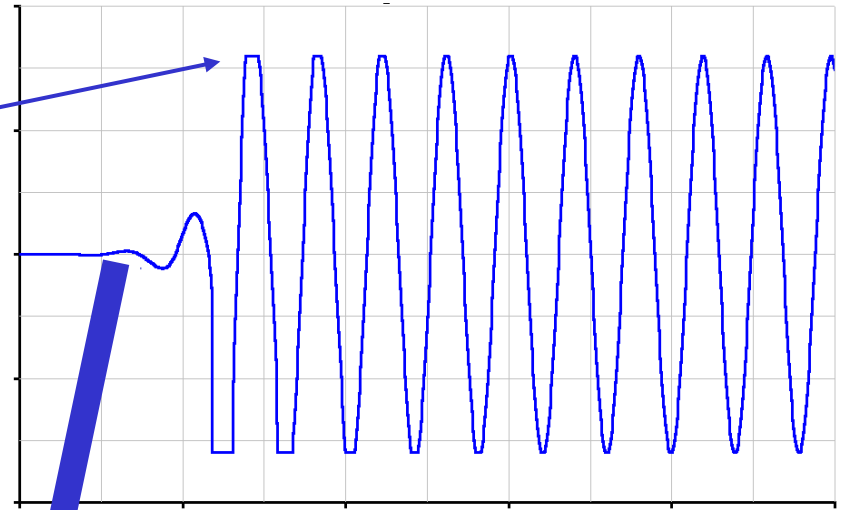




After the oscillations start, the lamp heats to reduce gain and clipping.

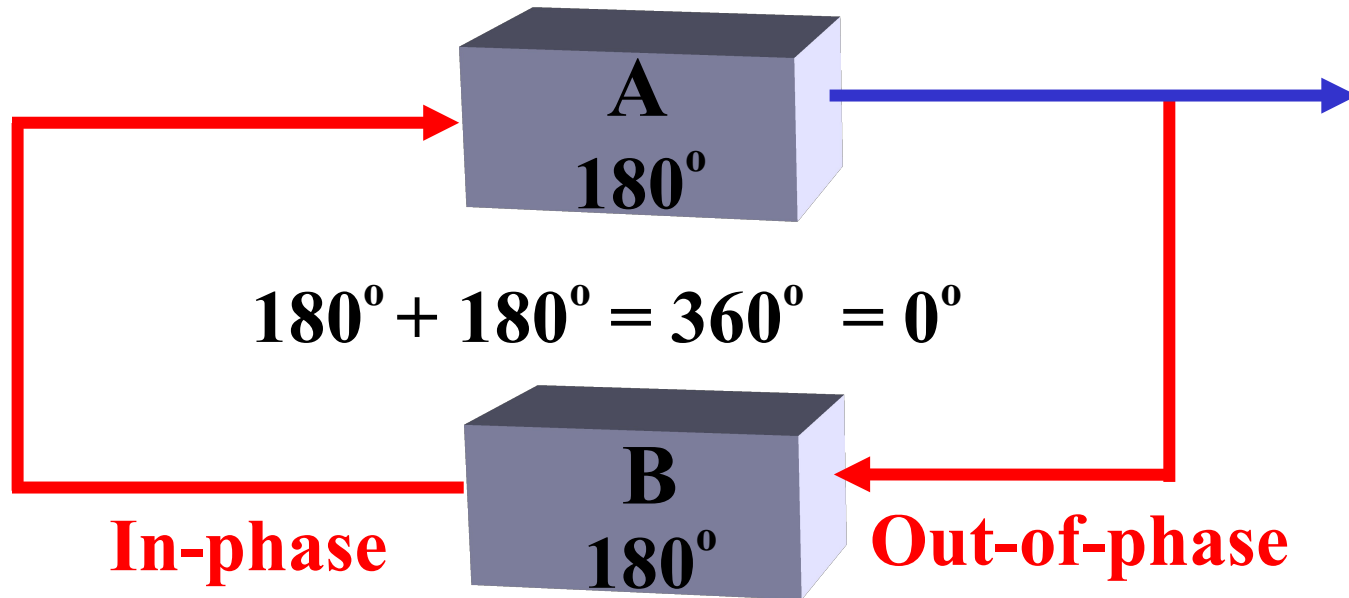


Notice that the clipping subsides as Q_1 reduces the loop gain.

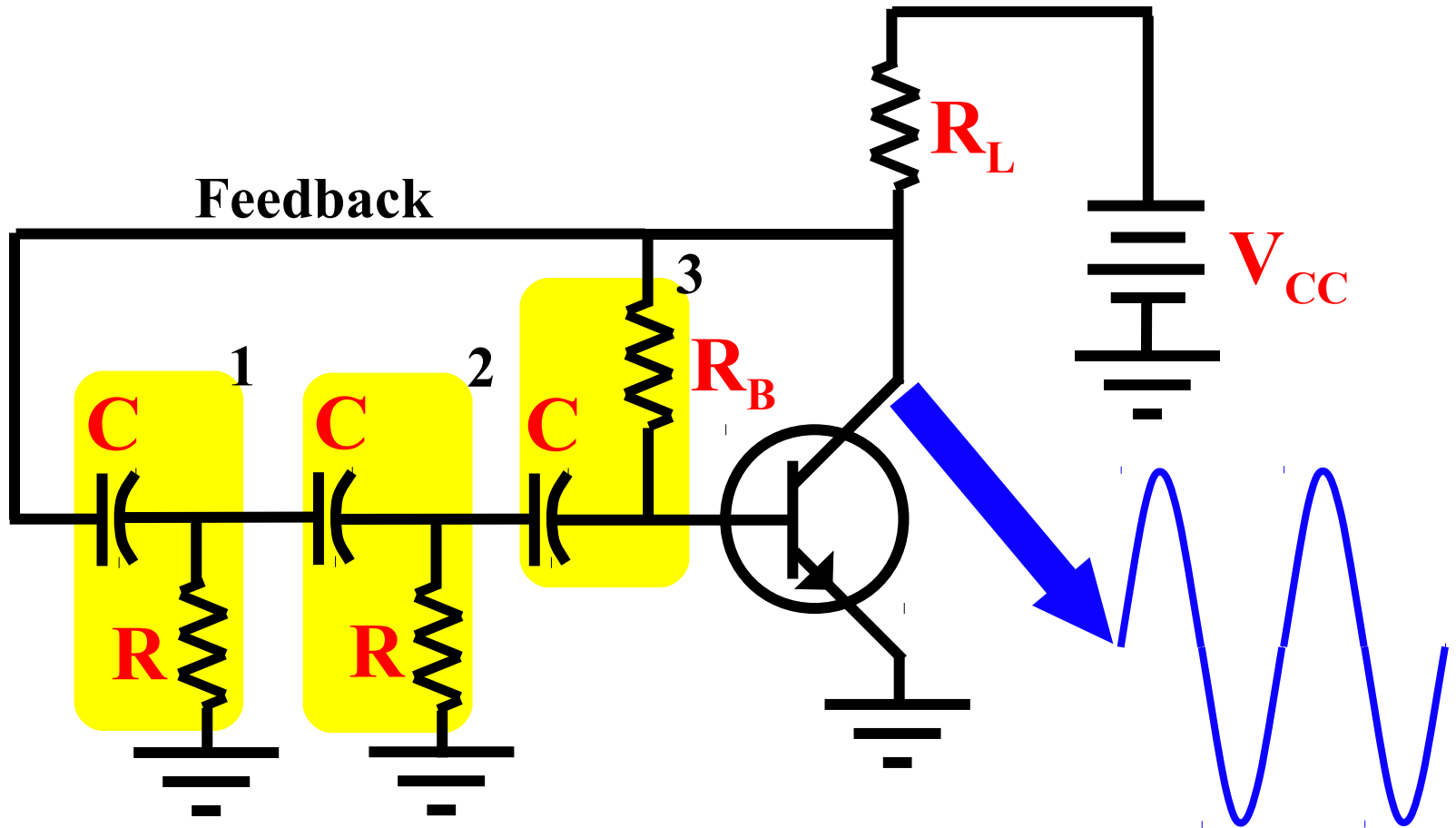


Q_1 is an N-channel JFET. After oscillations start, the output signal is rectified and the negative voltage is applied to the JFET's gate. This increases its D-S resistance which decreases the gain of the op amp.

When common-emitter amplifiers are used as oscillators, the feedback circuit must provide a 180° phase shift to make the circuit oscillate.



A phase-shift oscillator based on a common-emitter amplifier



3 RC networks provide a total phase shift of 180° .

RC oscillator quiz

A properly designed Wien bridge oscillator provides a _____ waveform. **sine**

The feedback fraction in a Wien bridge oscillator is _____ . **0.333**

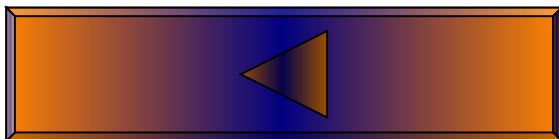
A tungsten lamp has a _____ temperature coefficient. **positive**

The feedback circuit in a common-emitter oscillator provides _____ of phase shift. **180°**

A phase shift oscillator uses three RC sections to provide a total shift of _____. **180°**

Concept Review

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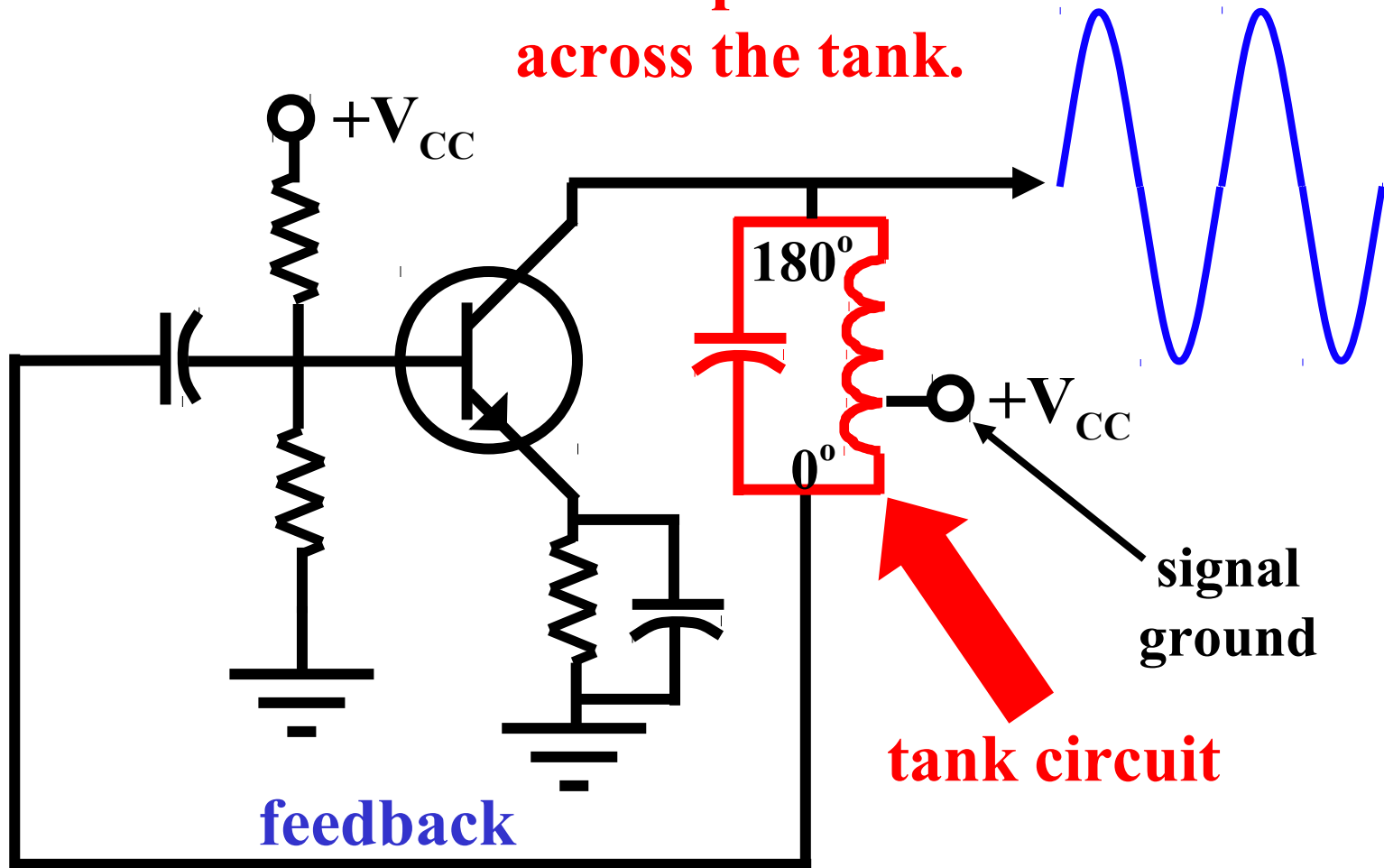


Repeat Segment

Concept Preview

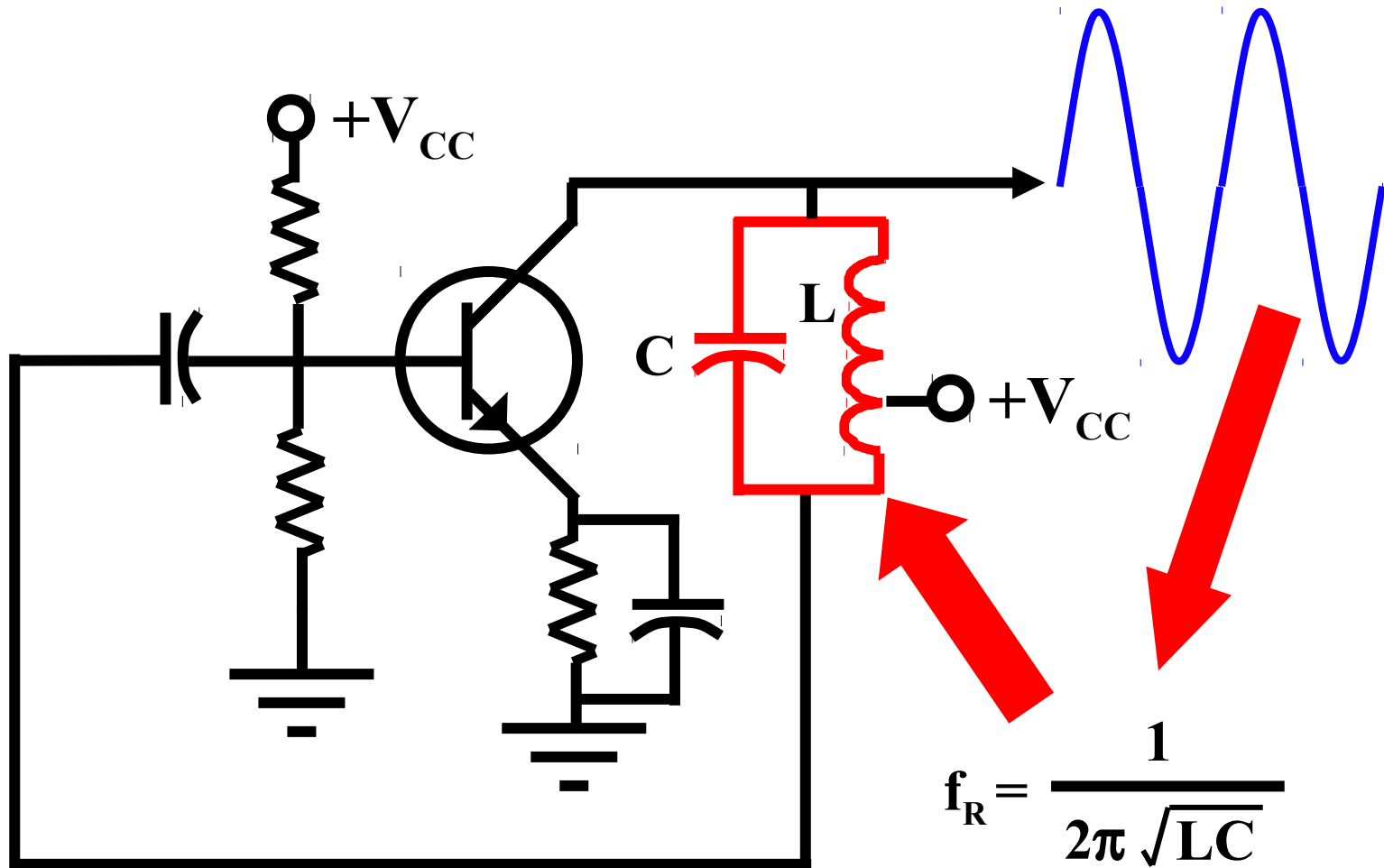
- RF oscillators often use LC tank circuits to control the frequency of oscillation. The tank circuits are tapped to control the amount of feedback.
- Hartley oscillators use tapped coils while Colpitts oscillators use capacitive taps.
- Common emitter oscillators require a 180 degree phase shift across their tank circuits.
- Quartz is a piezoelectric material. When it vibrates, it produces an electrical signal.
- Quartz crystals can replace tank circuits and provide exceptional frequency stability.

The supply tap is a signal ground. There is a 180° phase shift across the tank.



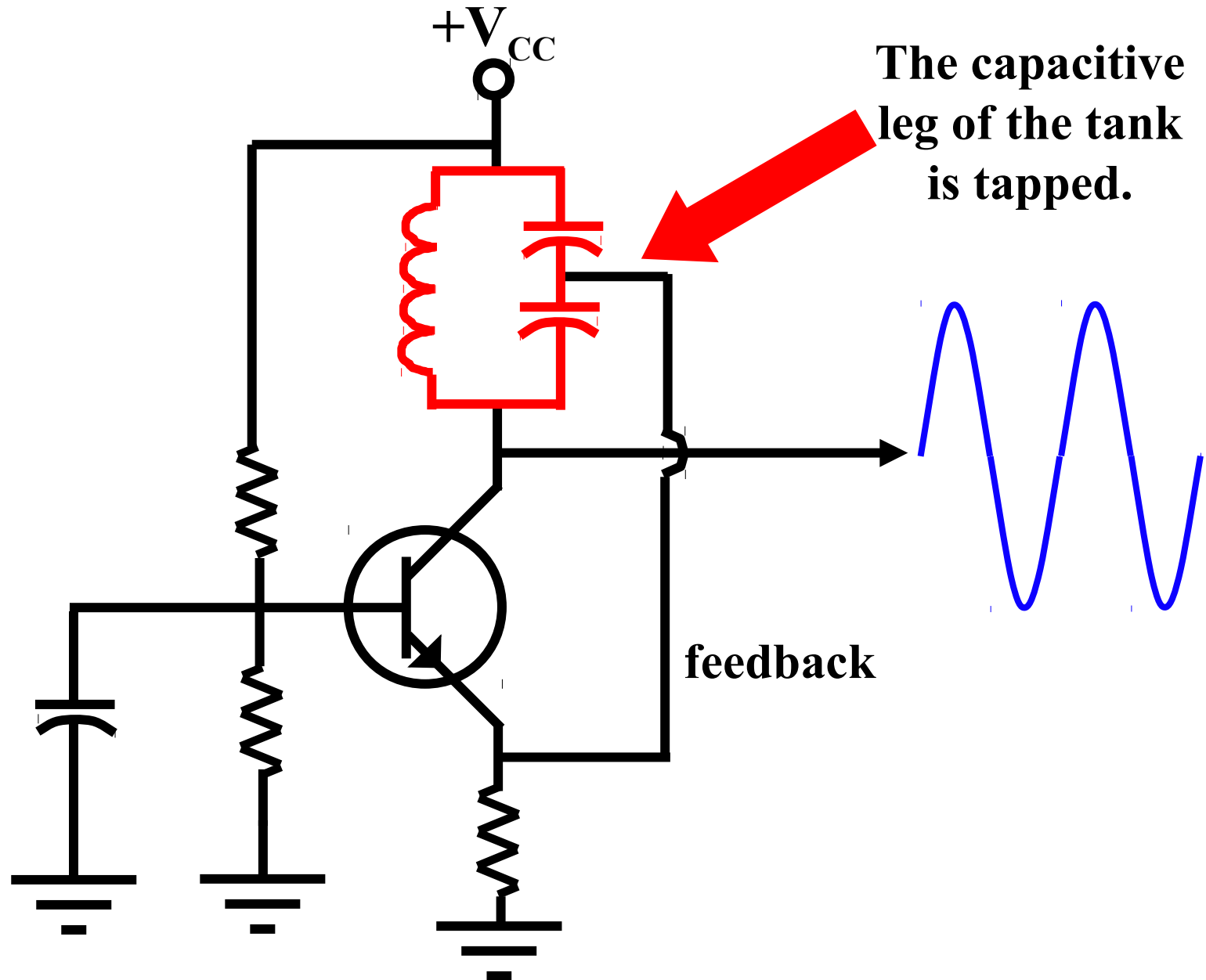
The Hartley oscillator is LC controlled.

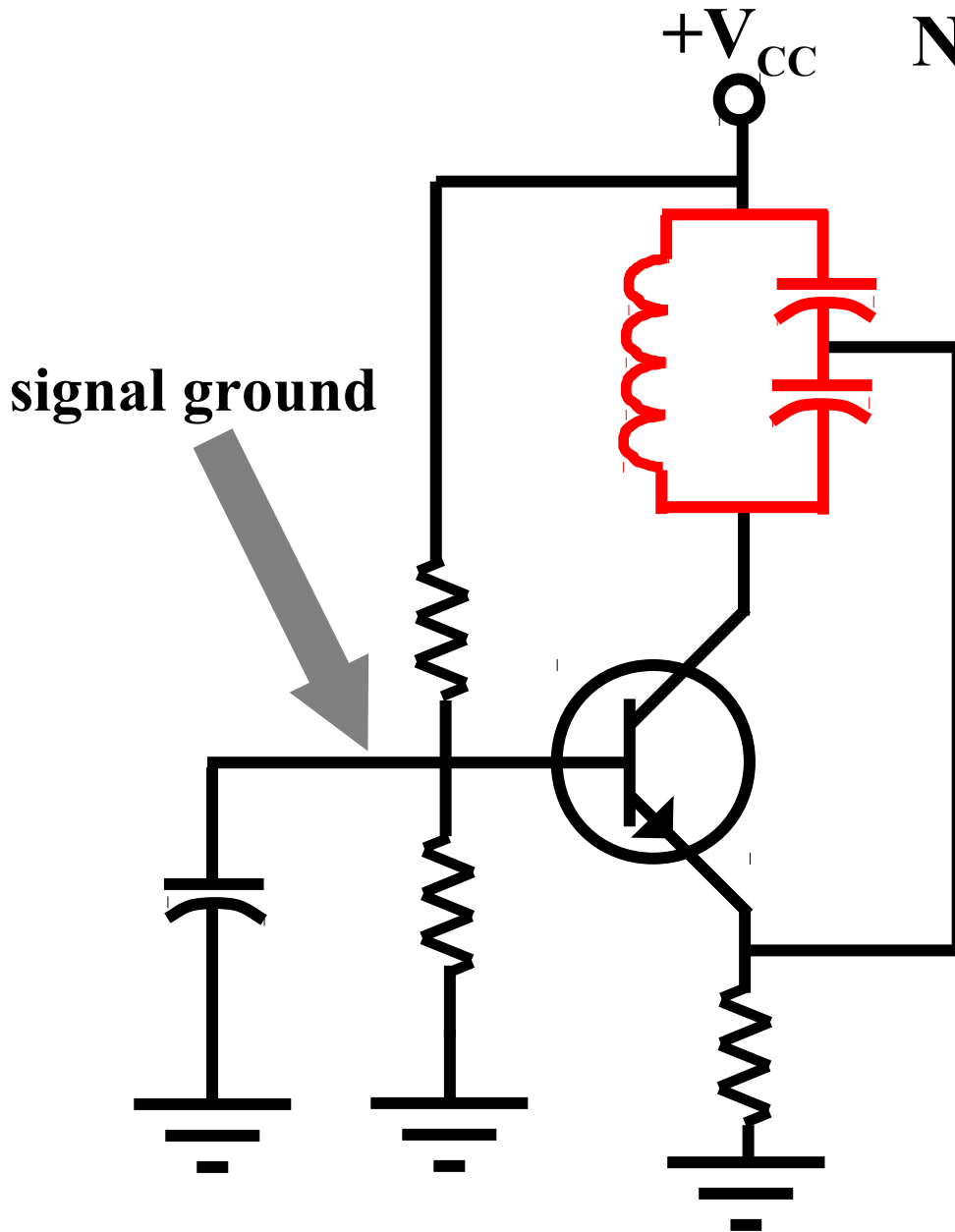
The output frequency is equal to the resonant frequency.



L is the value for the entire coil.

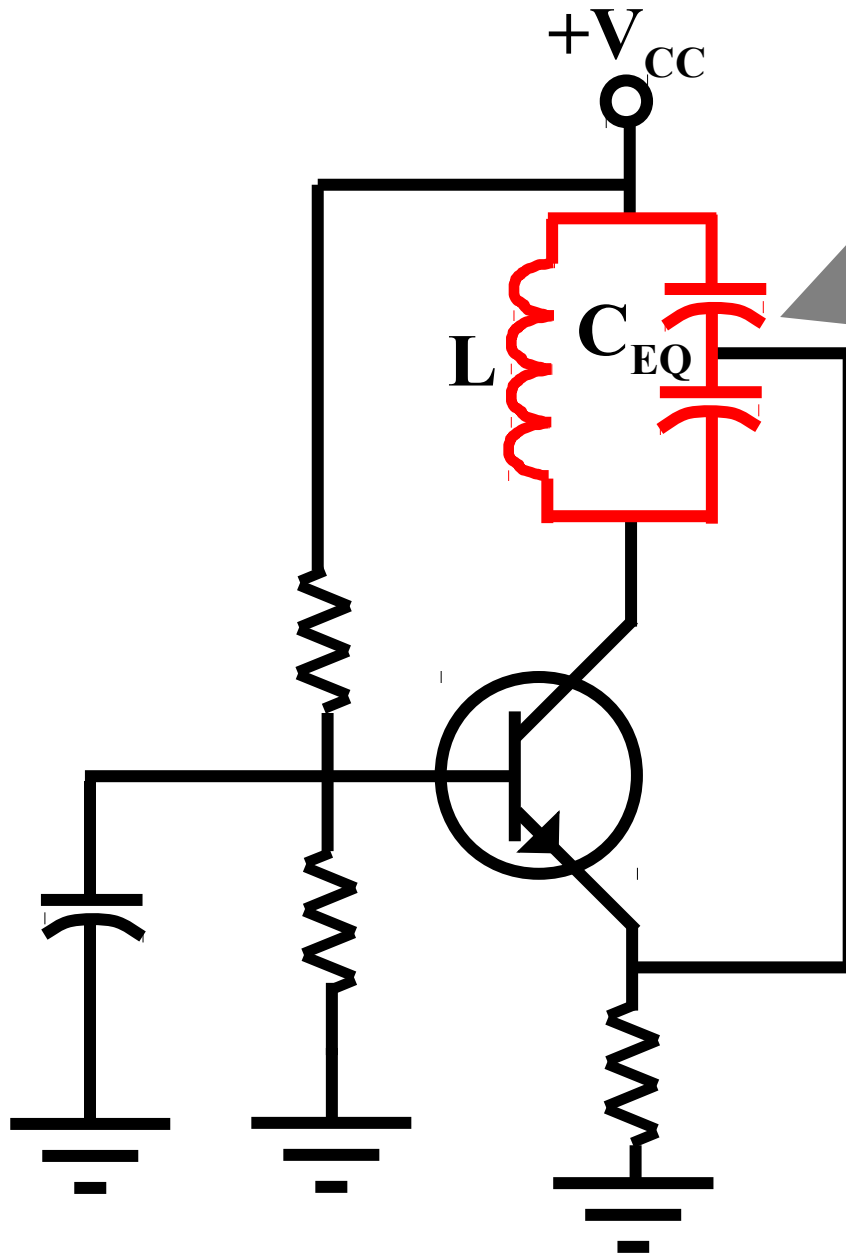
This is called a Colpitts oscillator.





Note that the amplifier configuration is common-base.

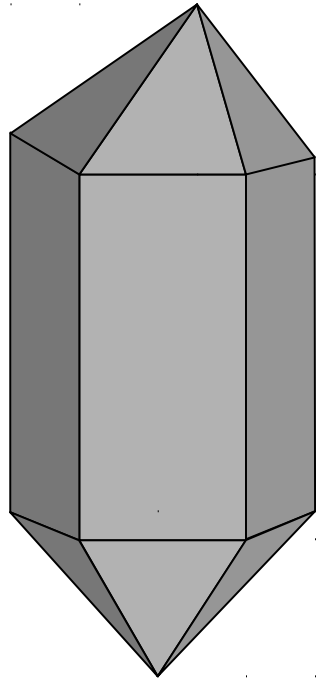
The emitter is the input and the collector is the output. The feedback circuit returns some of the collector signal to the input with no phase shift.



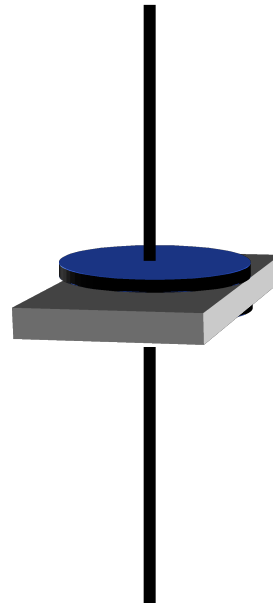
$$f_R = \frac{1}{2\pi \sqrt{LC_{EQ}}}$$

Quartz is a piezoelectric material.

Quartz crystal

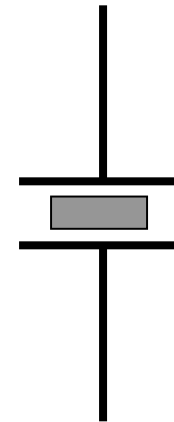


**Slab cut from
crystal**

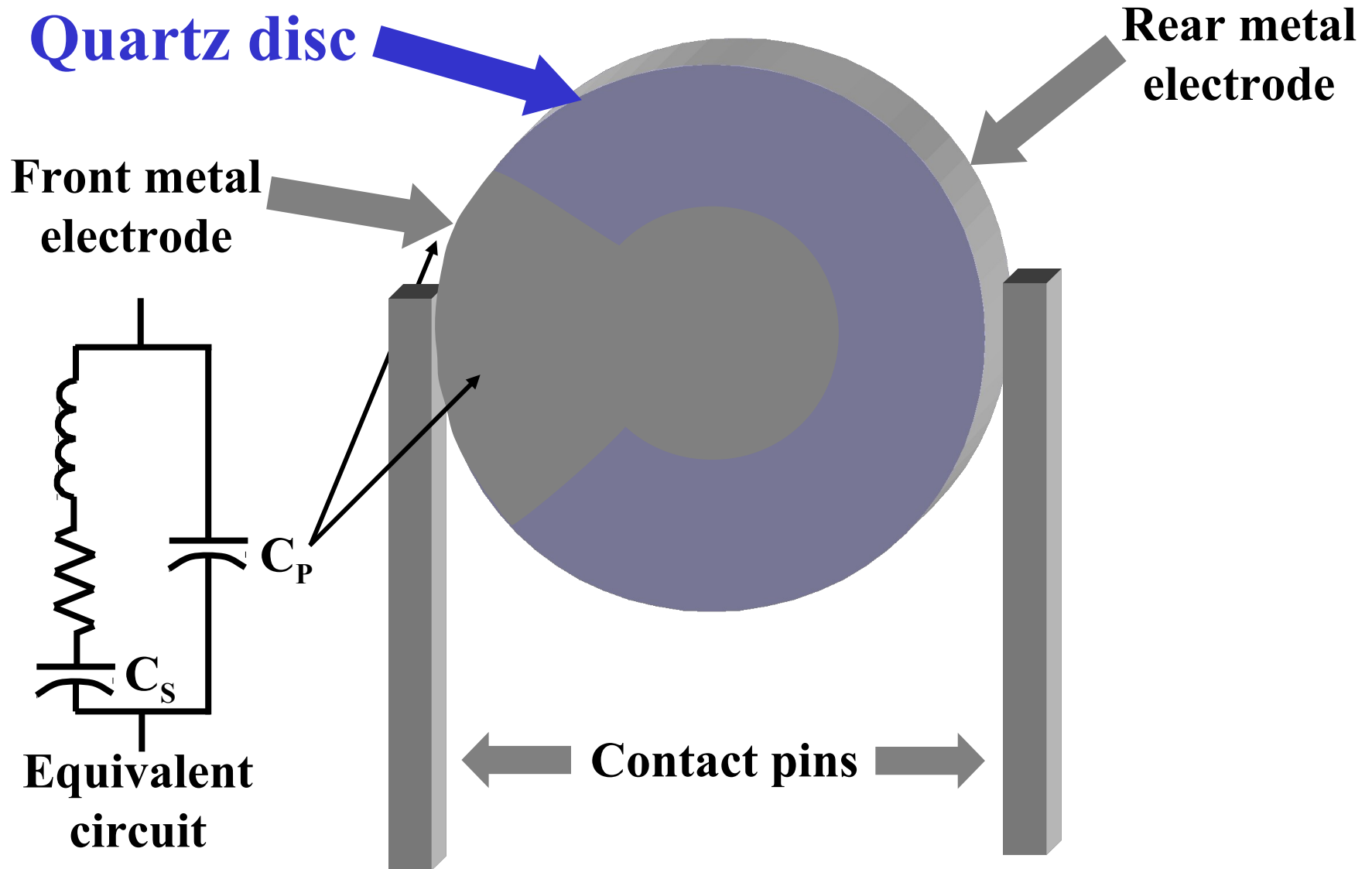


**Electrodes
and leads**

**Schematic
symbol**



Quartz crystals replace LC tanks when frequency accuracy is important.

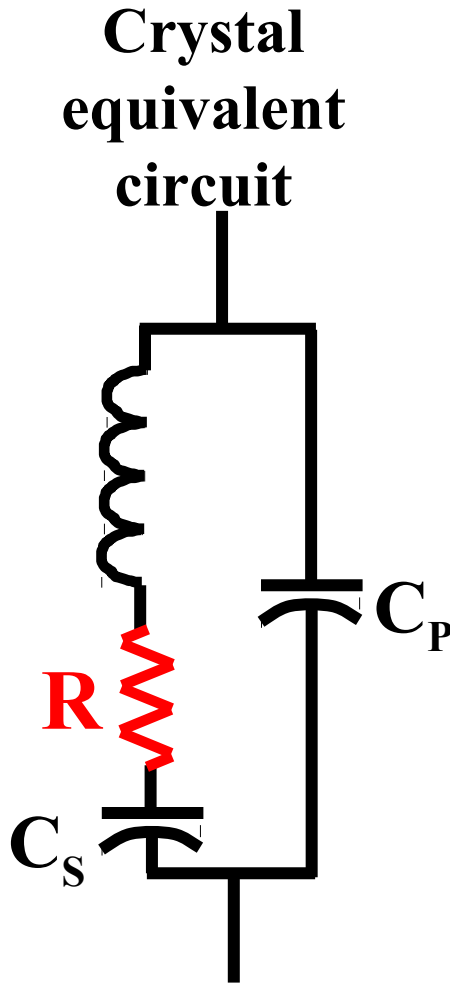


The equivalent R is very small and the Q is often several thousand.

High-Q tuned circuits are noted for narrow bandwidth and this translates to frequency stability.

The equivalent circuit also predicts *two* resonant frequencies: **series and **parallel**.**

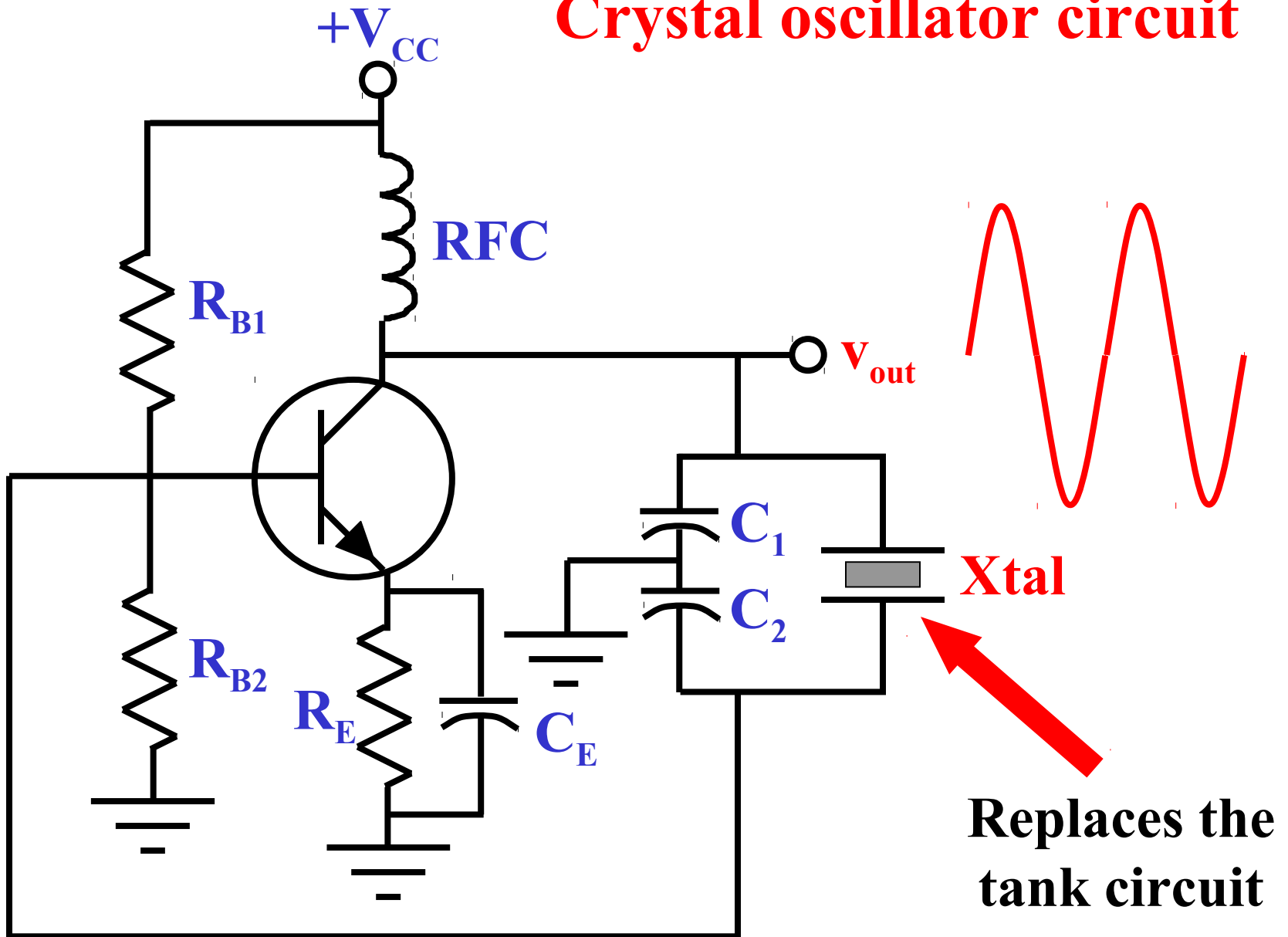
A given oscillator circuit is designed to use one or the other.



Crystals

- **The fundamental frequency (series resonance) is controlled by the quartz slab or quartz disk thickness.**
- **Higher multiples of the fundamental are called overtones.**
- **The electrode capacitance creates a parallel resonant frequency which is slightly higher.**
- **Typical frequency accuracy is measured in parts per million (ppm).**

Crystal oscillator circuit



Packaged oscillators contain a quartz crystal and the oscillator circuitry in a sealed metal can.



High-frequency oscillator quiz

A Hartley oscillator has a tapped _____
in its tank circuit. **coil**

When the capacitive leg is tapped, the circuit
might be called _____. **Colpitts**

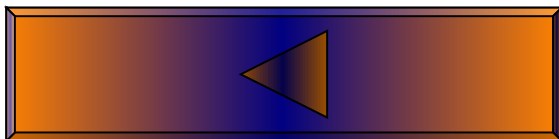
A quartz crystal is a solid-state replacement
for the _____ circuit. **tank**

Crystals are more stable than LC tanks due
to their very high _____. **Q**

Higher multiples of a crystal's resonant
frequency are called _____. **overtones**

Concept Review

- RF oscillators often use LC tank circuits to control the frequency of oscillation. The tank circuits are tapped to control the amount of feedback.
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Repeat Segment

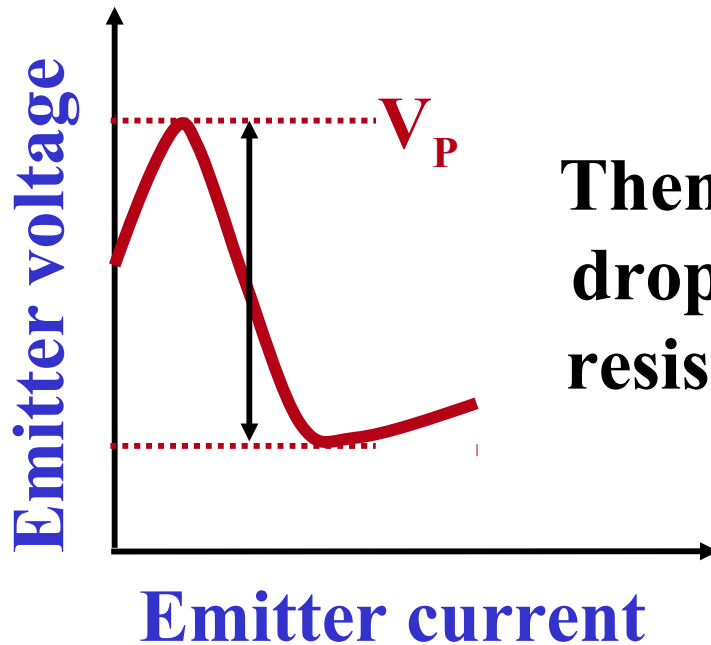
Concept Preview

- Relaxation oscillators are controlled by RC time constants.
- Unijunction transistors have a relatively high resistance from emitter to base 1 before they fire.
- A UJT relaxation oscillator produces two waveforms: exponential sawtooth and pulse.
- The operating frequency of a UJT oscillator is approximately equal to the reciprocal of its RC time constant.
- Astable multivibrators are also RC controlled and provide a rectangular output.

So far, we have learned that:

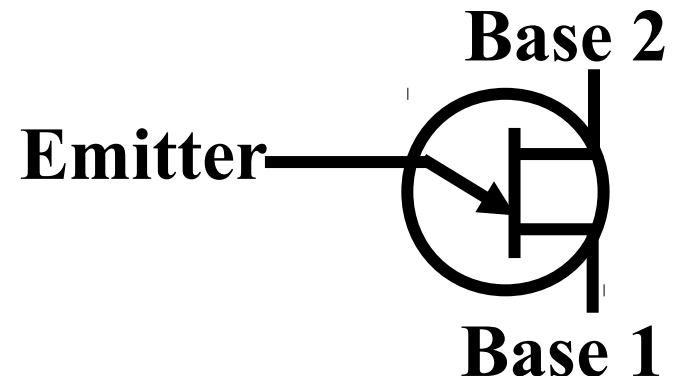
- Oscillators can be RC controlled by using phase-shifts.
- Oscillators can be LC controlled by using resonance.
- Oscillators can be crystal controlled by using resonance or overtones.
- There is another RC type called **relaxation oscillators**. These are *time-constant controlled*.

RECALL that a unijunction transistor fires when its emitter voltage reaches V_P .



Then, the emitter voltage drops due to its negative resistance characteristic.

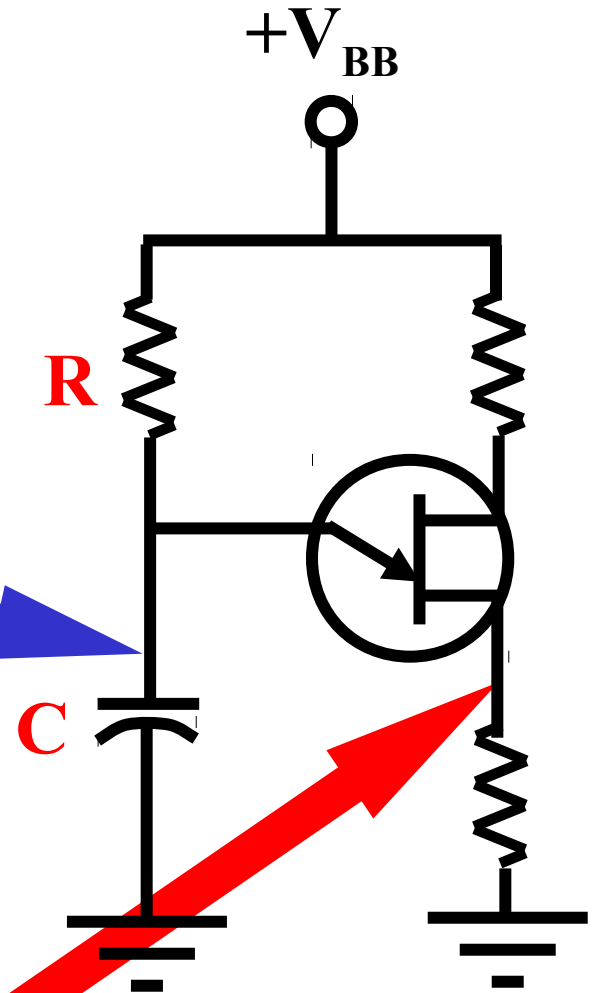
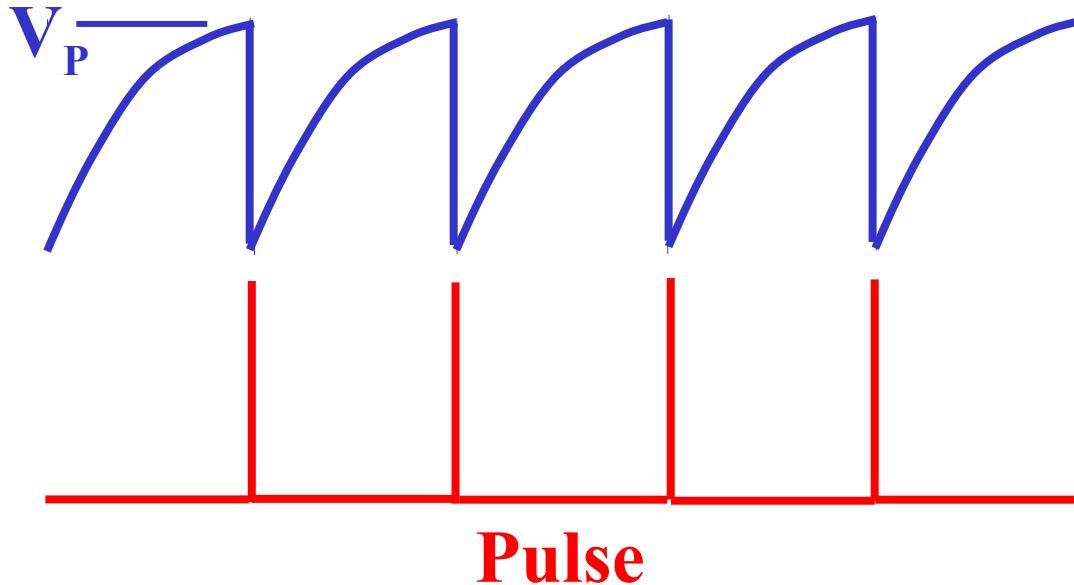
UJTs can be used in relaxation oscillators.



A UJT relaxation oscillator provides two waveforms.

$$\tau = RC \quad f \cong \frac{1}{RC}$$

Exponential sawtooth



This multivibrator is also RC controlled.

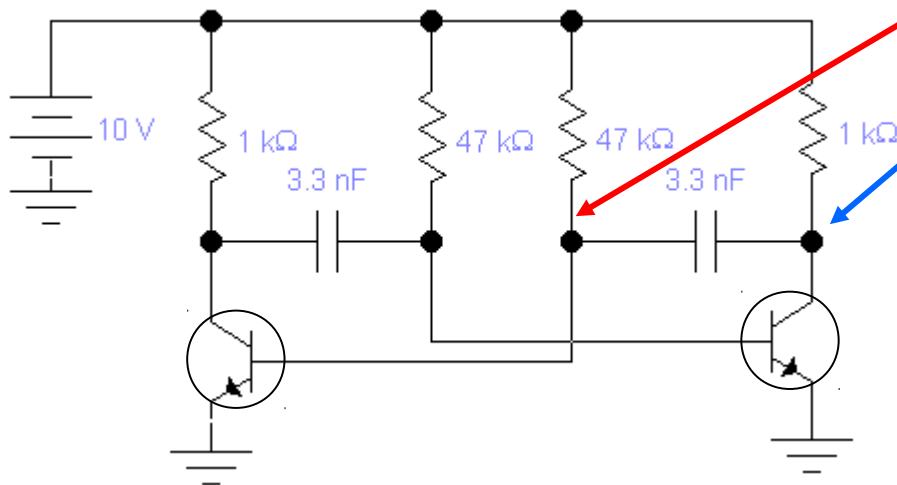
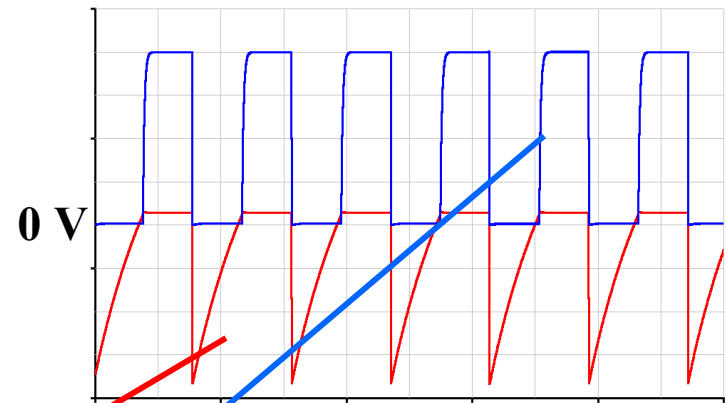
$$\tau = 0.69RC$$

$$= 0.69 \times 47 \text{ k}\Omega \times 3.3 \text{ nF}$$

$$= 0.107 \text{ ms}$$

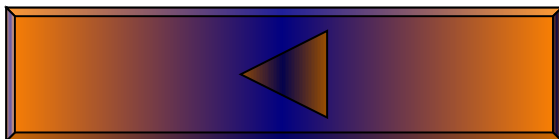
$$t = 2\tau = 0.214 \text{ ms}$$

$$f = 1/t = 4.67 \text{ kHz}$$



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Repeat Segment

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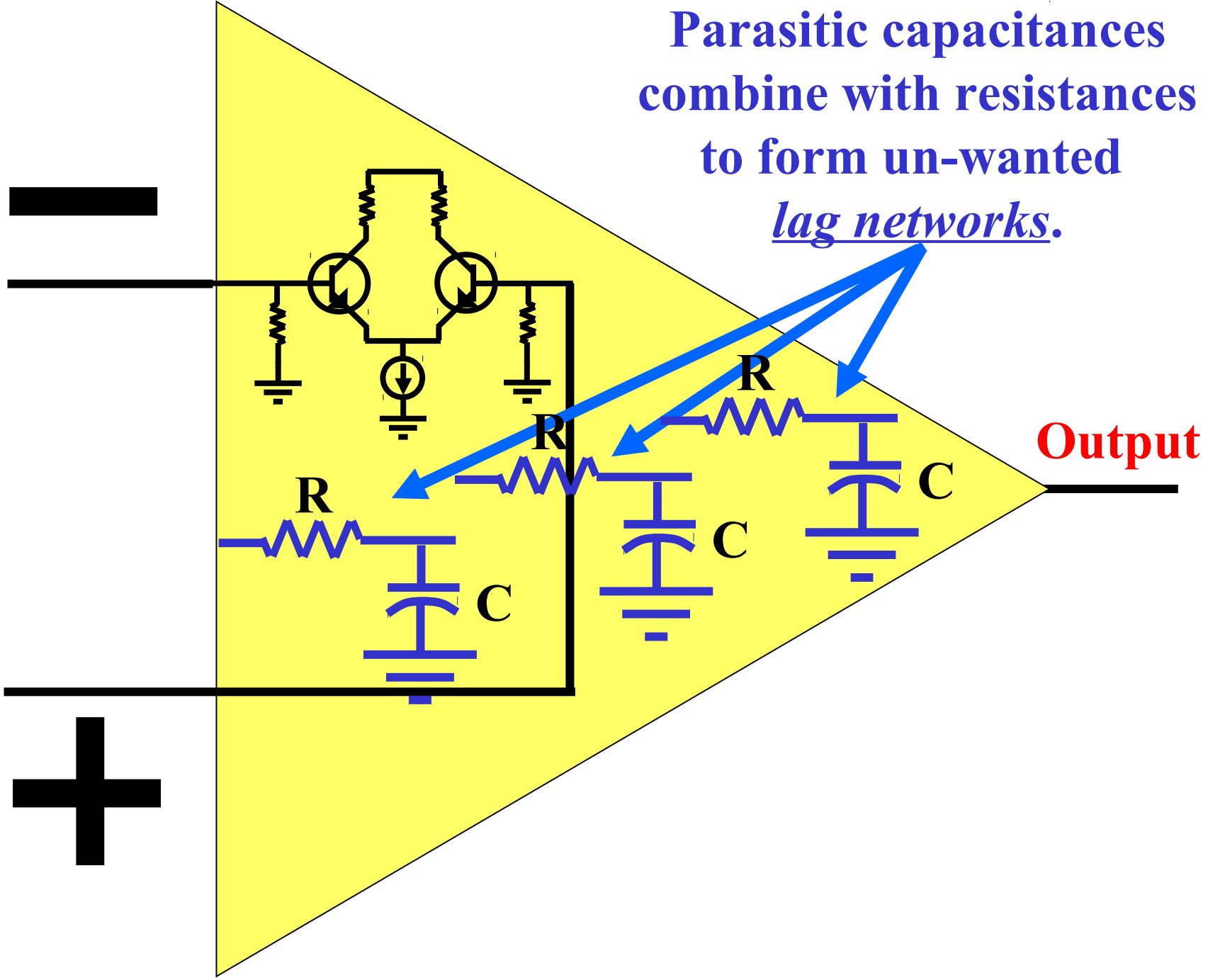
- Amplifiers provide gain but should not oscillate.
- Parasitic RC lag networks make negative feedback positive at some frequency. If there is gain at that frequency, an amplifier will be unstable.
- Frequency compensation stabilizes feedback amplifiers by decreasing the gain at those frequencies where the feedback becomes positive.
- Bypassing, shielding, neutralization, and phase compensation are other ways to ensure stability.
- Direct digital synthesis is a method to generate many, highly accurate, frequencies.

Undesired oscillations:

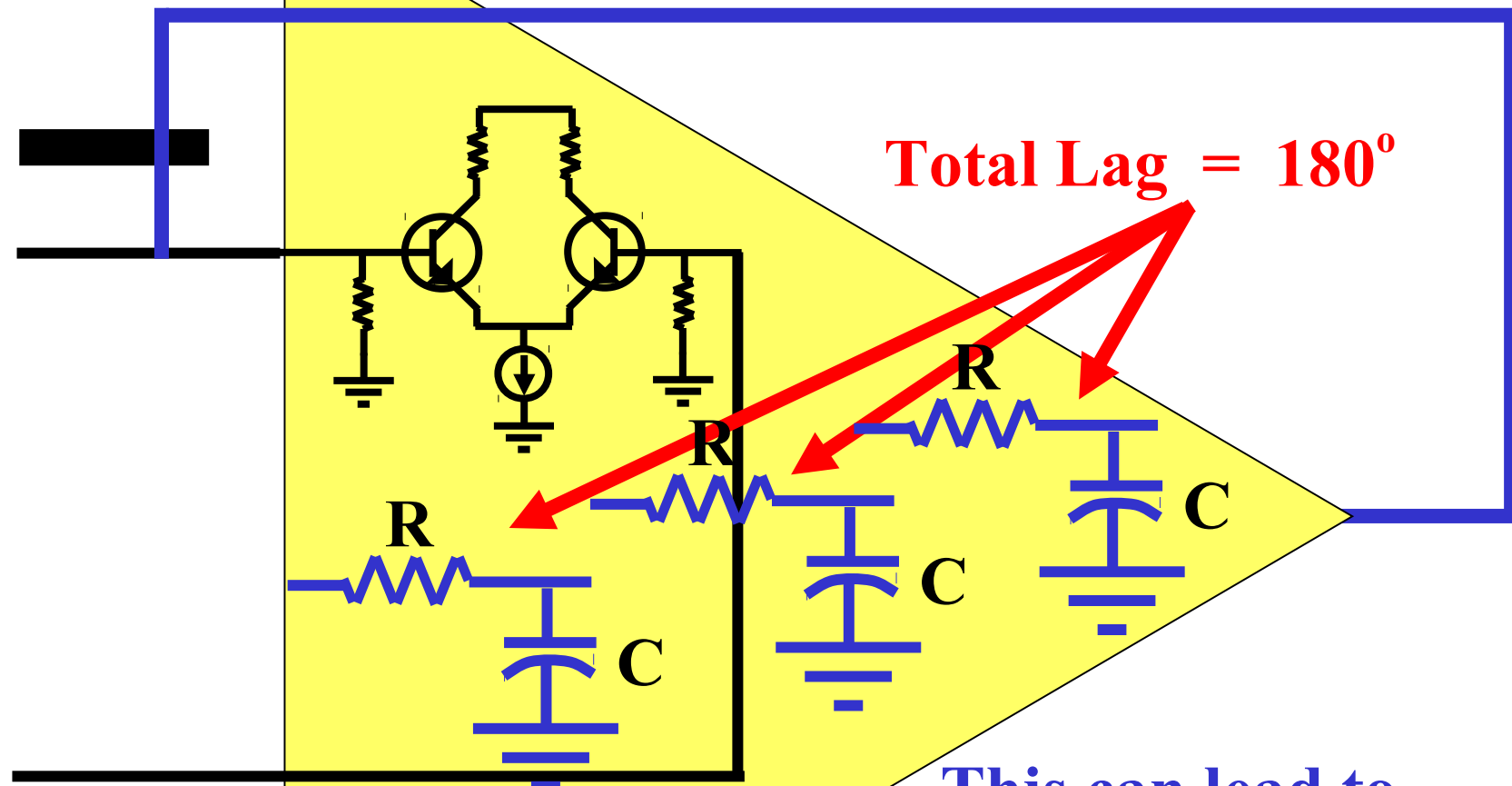
make amplifiers *useless*.

Why is this a problem?

Parasitic capacitances
combine with resistances
to form un-wanted
lag networks.



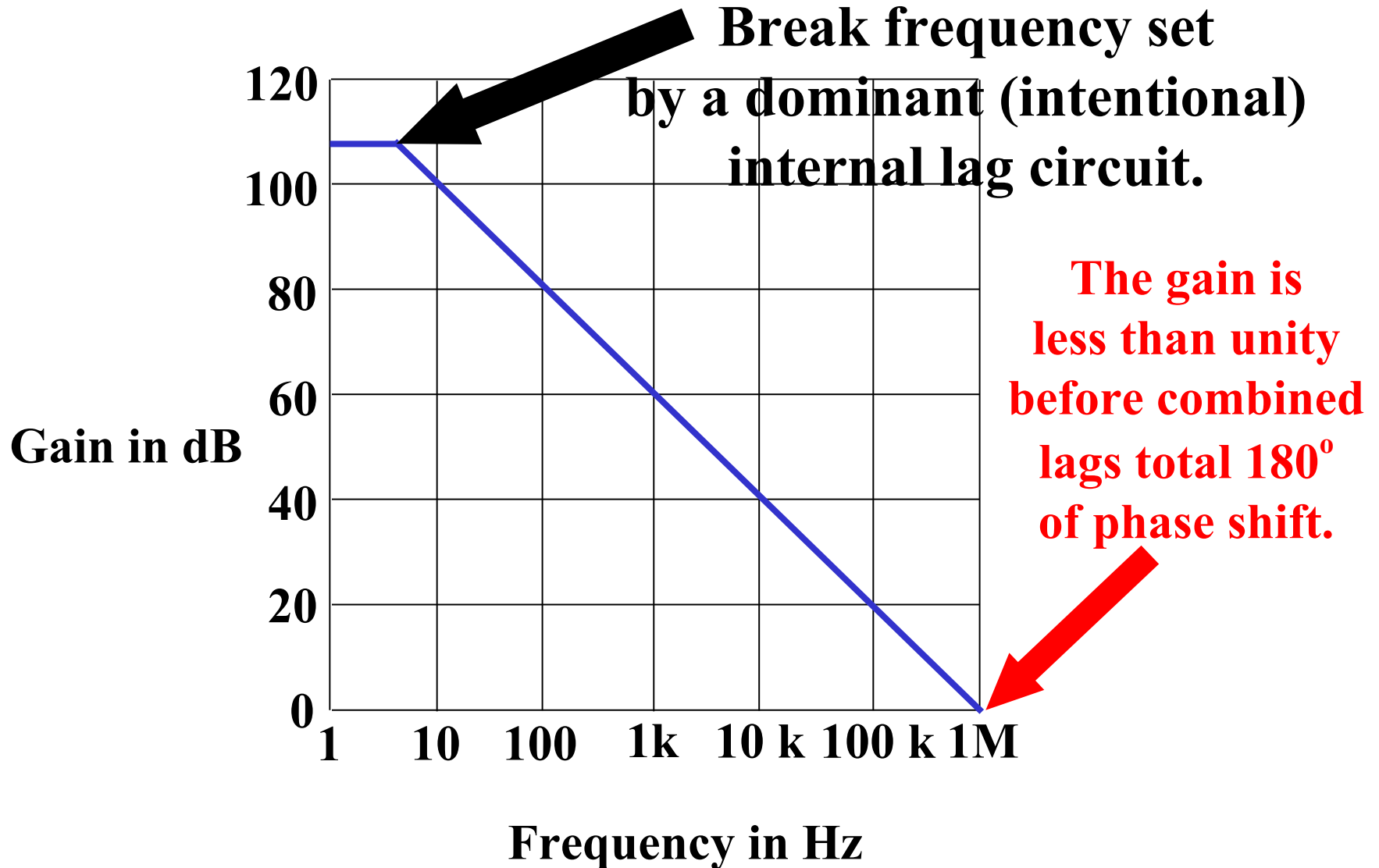
It's the equivalent of a phase-shift oscillator.



Total Lag = 180°

This can lead to unwanted oscillations since the feedback becomes positive at some higher frequency.

The typical op amp has this characteristic:



Methods of preventing oscillation:

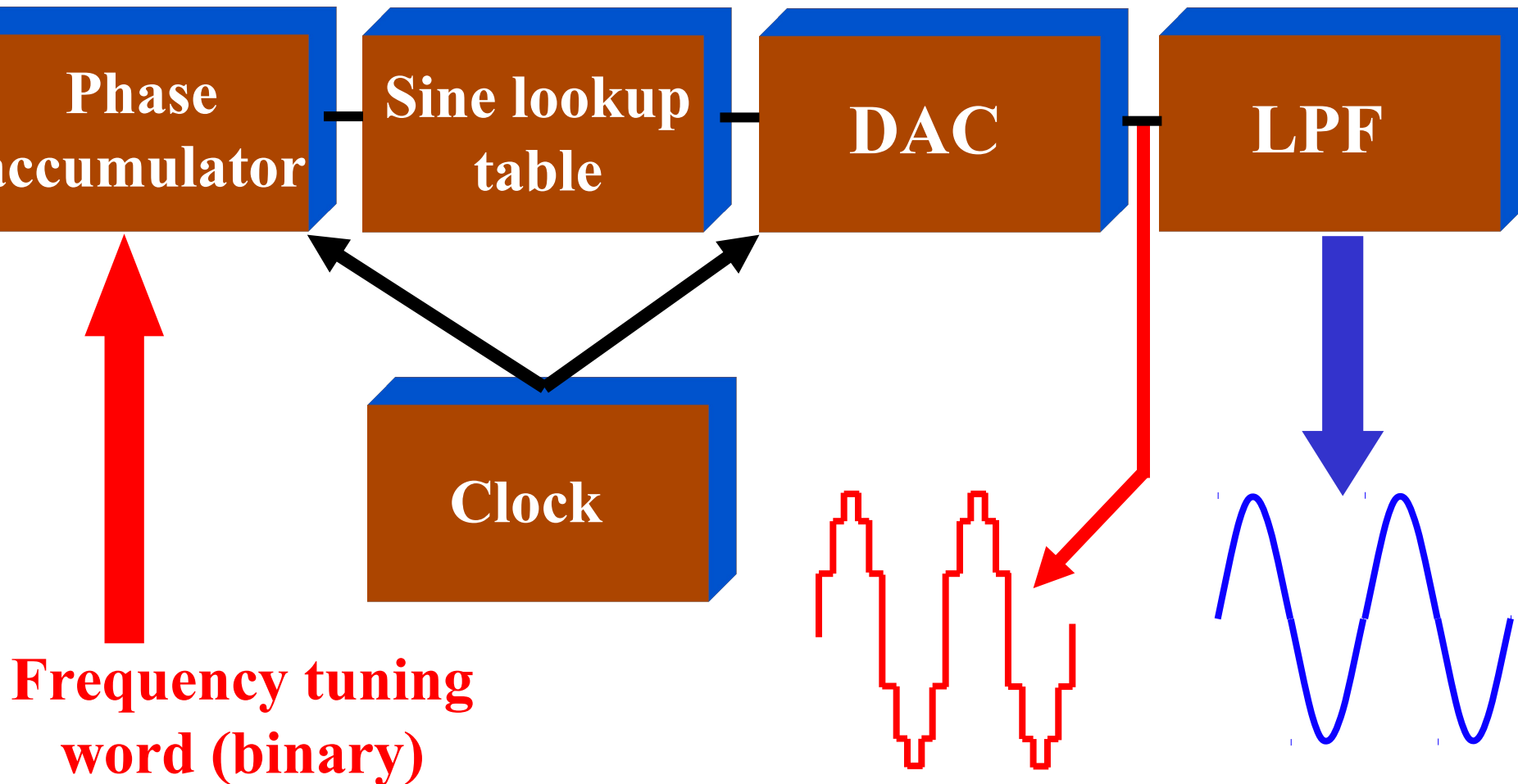
- Reduce the feedback with bypass circuits, shields, and careful circuit layout.
- Cancel feedback with a second path ... this is called neutralization.
- Reduce the gain for frequencies where the feedback becomes positive ... this is called frequency compensation.
- Reduce the total phase shift ... this is called phase compensation.

Oscillator troubleshooting:

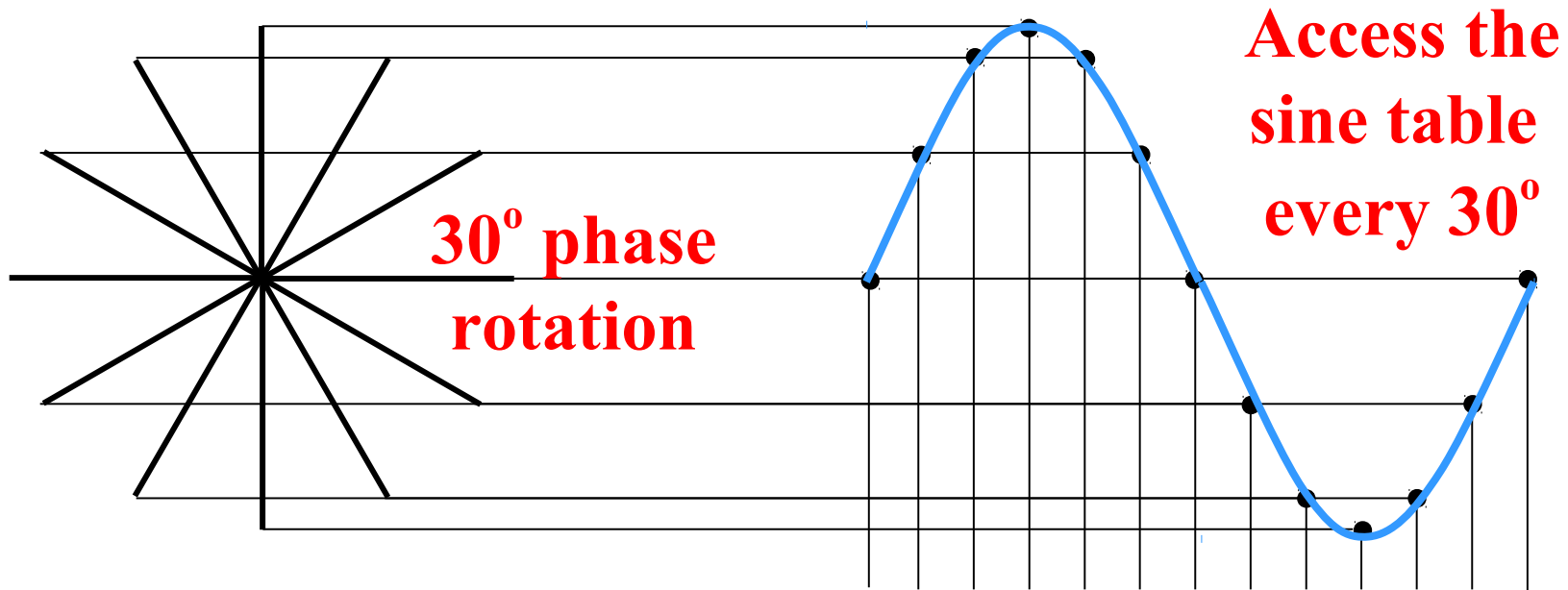
- **No output:** supply voltage; component failure; oscillator is overloaded.
- **Reduced output:** low supply voltage; bias; component defect; loading.
- **Frequency instability:** supply voltage; poor connection or contact; temperature; RC, LC, or crystal.
- **Frequency error:** supply voltage; loading; RC, LC, or crystal.

Direct digital synthesizer

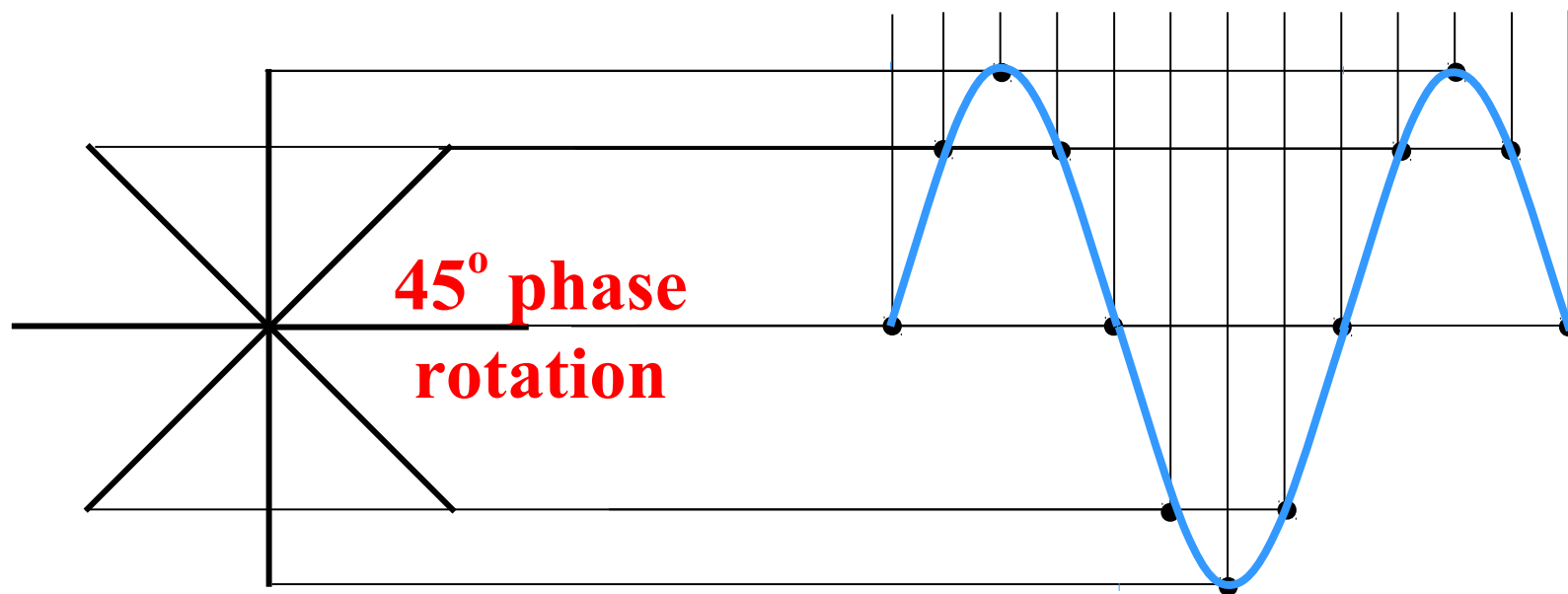
(also called a numerically controlled oscillator)



The tuning word changes the phase increment value.



NOTE: Increasing the phase increment increases the frequency.



Oscillator wrap-up quiz

Relaxation oscillators are controlled by RC _____ **time constants**

Negative feedback becomes positive at some frequency due to _____. **RC lags**

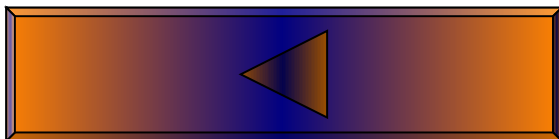
Gain rolloff to prevent oscillation is called _____ compensation. **frequency**

Direct digital synthesizers are also called _____ oscillators. **numerically controlled**

Direct digital synthesizers use a sine _____ table. **lookup**

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