Department of Electronics & Communication Engg.

Course : Analog Electronics -15EC32. **Sem.: 3rd(2016-17)**

Module -4

Feedback and Oscillator Circuits

Course Coordinator:

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4.1 Feedback Concepts

Negative feedback results in

1. **Higher input impedance.**
2. **Better stabilized voltage gain.**
3. **Improved frequency response.**
4. **Lower output impedance.**
5. **Reduced noise.**
6. **More linear operation.**
7. **reduced overall voltage gain,**

4.1 Feedback Concepts

There are four basic ways of connecting the feedback signal. Both voltage and current can be fed back to the input either in series or parallel. Specifically, there can be:

1. **Voltage-series feedback**
2. **Voltage-shunt feedback**
3. **Current-series feedback**
4. **Current-shunt feedback**

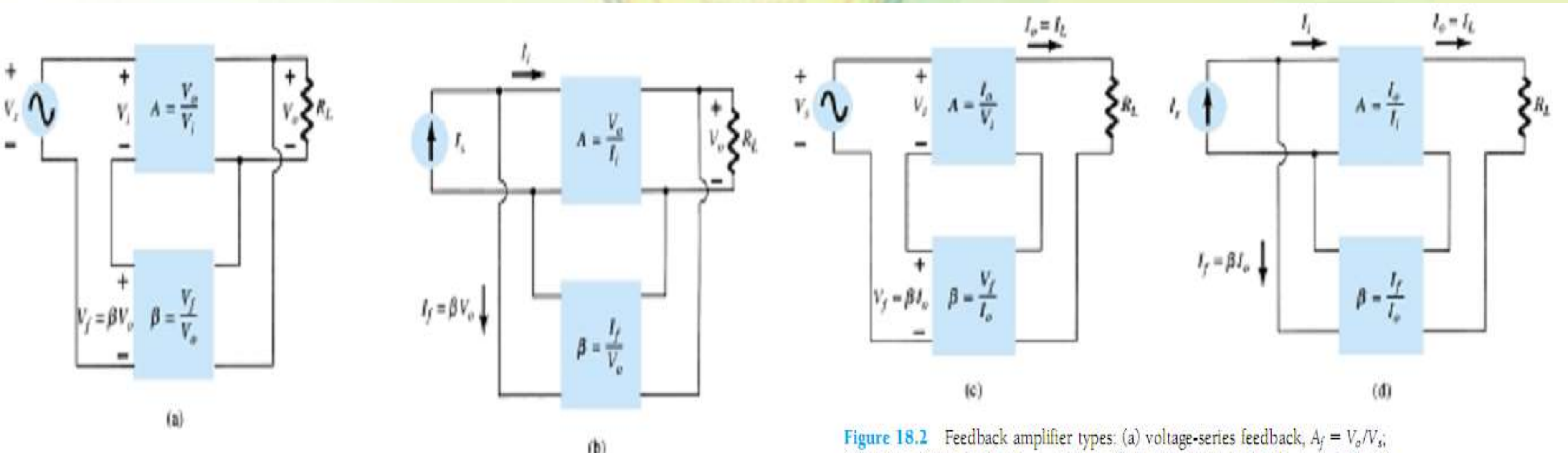
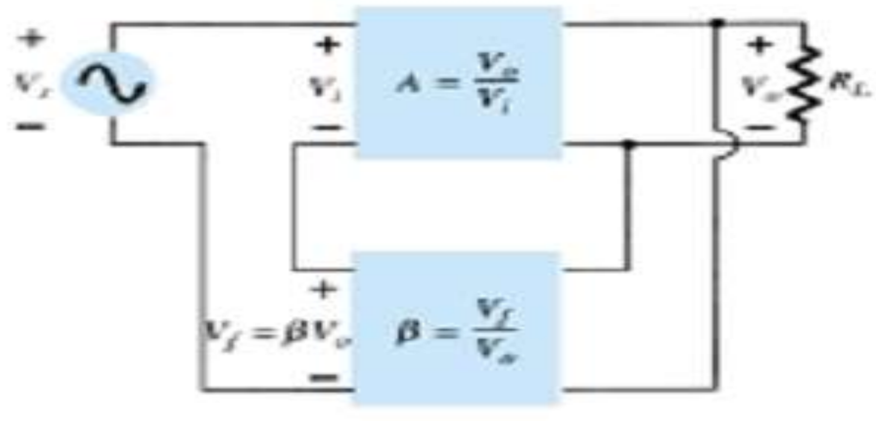


Figure 18.2 Feedback amplifier types: (a) voltage-series feedback, $A_f = V_o/V_s$; (b) voltage-shunt feedback, $A_f = V_o/I_s$; (c) current-series feedback, $A_f = I_o/V_s$; (d) current-shunt feedback, $A_f = I_o/I_s$.



(a)

VOLTAGE-SERIES FEEDBACK

Figure 18.2a shows the voltage-series feedback connection with a part of the output voltage fed back in series with the input signal, resulting in an overall gain reduction. If there is no feedback ($V_f = 0$), the voltage gain of the amplifier stage is

$$A = \frac{V_o}{V_s} = \frac{V_o}{V_i} \tag{18.1}$$

If a feedback signal, V_f, is connected in series with the input, then

$$V_i = V_s - V_f$$

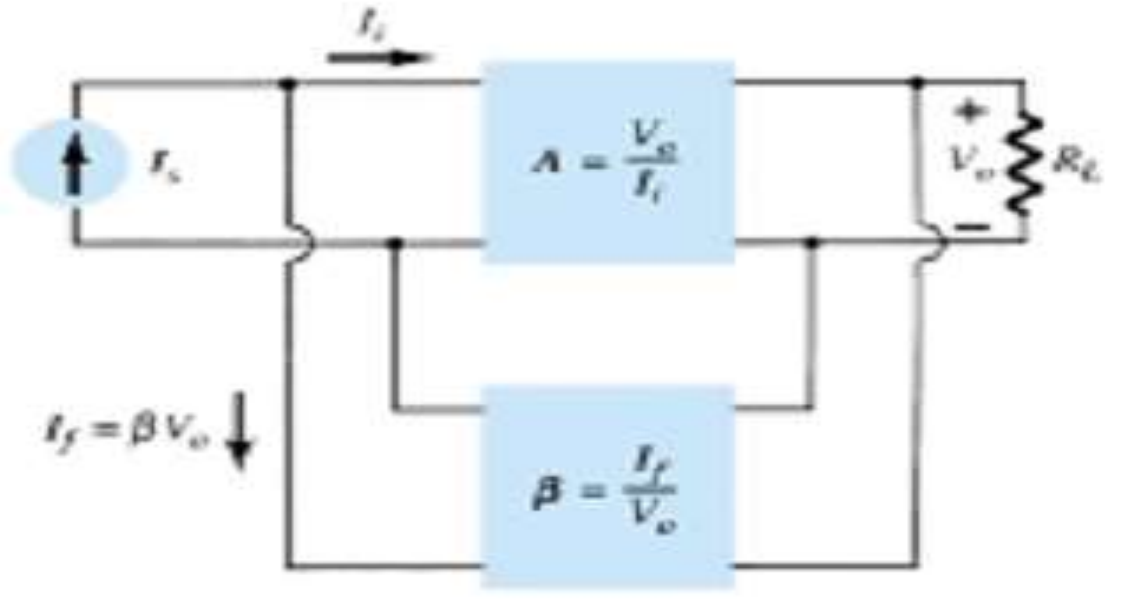
Since $$V_o = AV_i = A(V_s - V_f) = AV_s - AV_f = AV_s - A(\beta V_o)$$

then $$(1 + \beta A)V_o = AV_s$$

so that the overall voltage gain *with* feedback is

$$\boxed{A_f = \frac{V_o}{V_s} = \frac{A}{1 + \beta A}} \tag{18.2}$$

Equation (18.2) shows that the gain *with* feedback is the amplifier gain reduced by the factor $(1 + \beta A)$. This factor will be seen also to affect input and output impedance among other circuit features.



(b)

VOLTAGE-SHUNT FEEDBACK

The gain with feedback for the network of Fig. 18.2b is

$$A_f = \frac{V_o}{I_s} = \frac{A\,I_i}{I_i + I_f} = \frac{A\,I_i}{I_i + \beta V_o} = \frac{A\,I_i}{I_i + \beta A\,I_i}$$

$$\boxed{A_f = \frac{A}{1 + \beta A}} \qquad (18.3)$$

Input Impedance with Feedback

VOLTAGE-SERIES FEEDBACK

A more detailed voltage-series feedback connection is shown in Fig. 18.3. The input impedance can be determined as follows:

$$I_i = \frac{V_i}{Z_i} = \frac{V_s - V_f}{Z_i} = \frac{V_s - \beta V_o}{Z_i} = \frac{V_s - \beta A V_i}{Z_i}$$

$$I_i Z_i = V_s - \beta A V_i$$

$$V_s = I_i Z_i + \beta A V_i = I_i Z_i + \beta A I_i Z_i$$

$$\boxed{Z_{if} = \frac{V_s}{I_i} = Z_i + (\beta A) Z_i = Z_i (1 + \beta A)} \qquad (18.4)$$

The input impedance with series feedback is seen to be the value of the input impedance without feedback multiplied by the factor $(1 + \beta A)$ and applies to both voltage-series (Fig. 18.2a) and current-series (Fig. 18.2c) configurations.

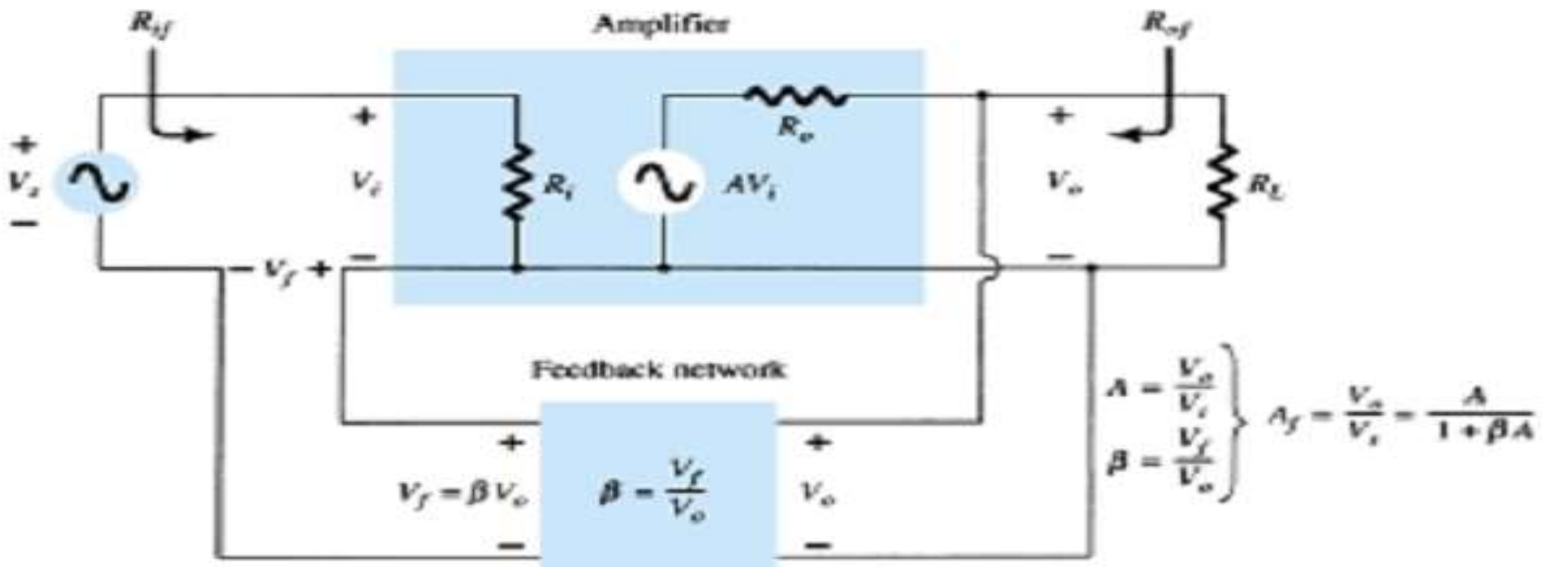


Figure 18.3 Voltage-series feedback connection.

VOLTAGE-SHUNT FEEDBACK

A more detailed voltage-shunt feedback connection is shown in Fig. 18.4. The input impedance can be determined to be

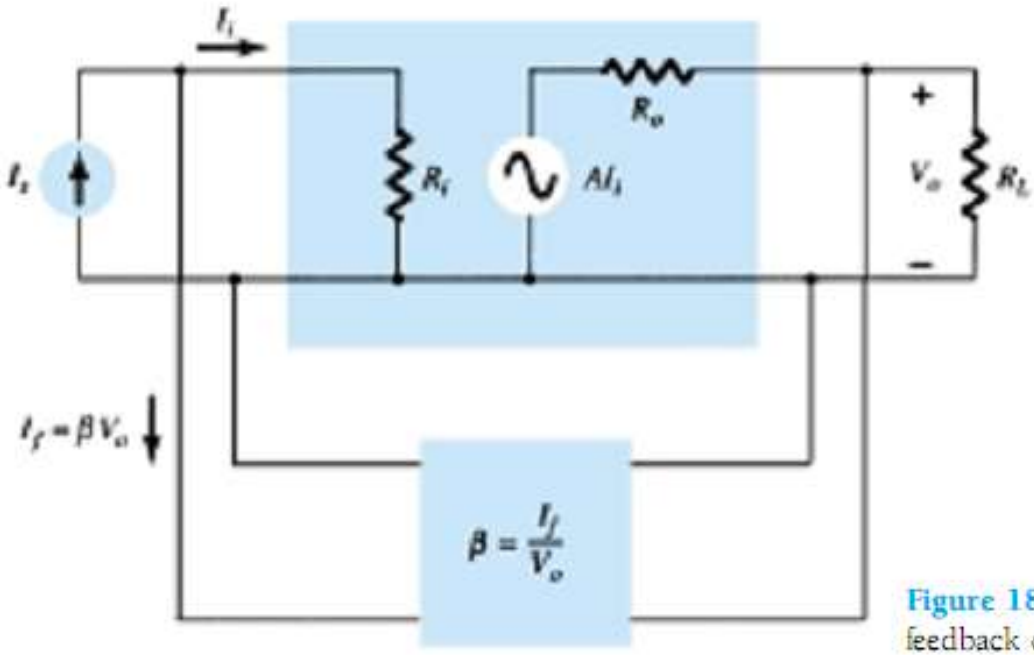


Figure 18.4 Voltage-shunt feedback connection.

$$Z_{if} = \frac{V_i}{I_s} = \frac{V_i}{I_i + I_f} = \frac{V_i}{I_i + \beta V_o}$$

$$= \frac{V_i/I_i}{I_i/I_i + \beta V_o/I_i}$$

$$\boxed{Z_{if} = \frac{Z_i}{1 + \beta A}}$$

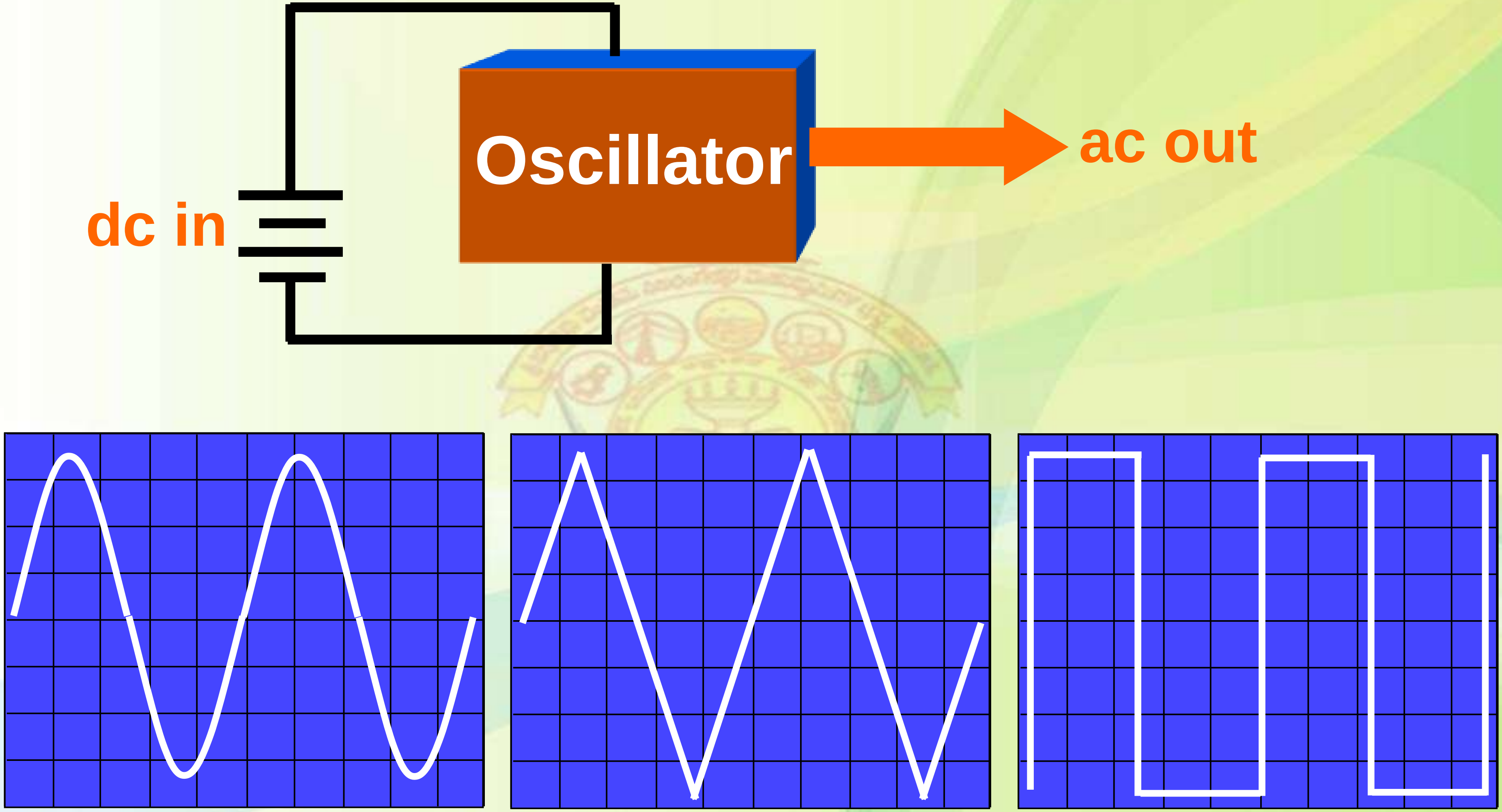
TABLE 18.2 Effect of Feedback Connection on Input and Output Impedance

	Voltage-Series	*Current-Series*	*Voltage-Shunt*	*Current-Shunt*
Z_{if}	$Z_i(1+\beta A)$ (increased)	$Z_i(1+\beta A)$ (increased)	$\frac{Z_i}{1+\beta A}$ (decreased)	$\frac{Z_i}{1+\beta A}$ (decreased)
Z_{of}	$\frac{Z_o}{1+\beta A}$ (decreased)	$Z_o(1+\beta A)$ (increased)	$\frac{Z_o}{1+\beta A}$ (decreased)	$Z_o(1+\beta A)$ (increased)

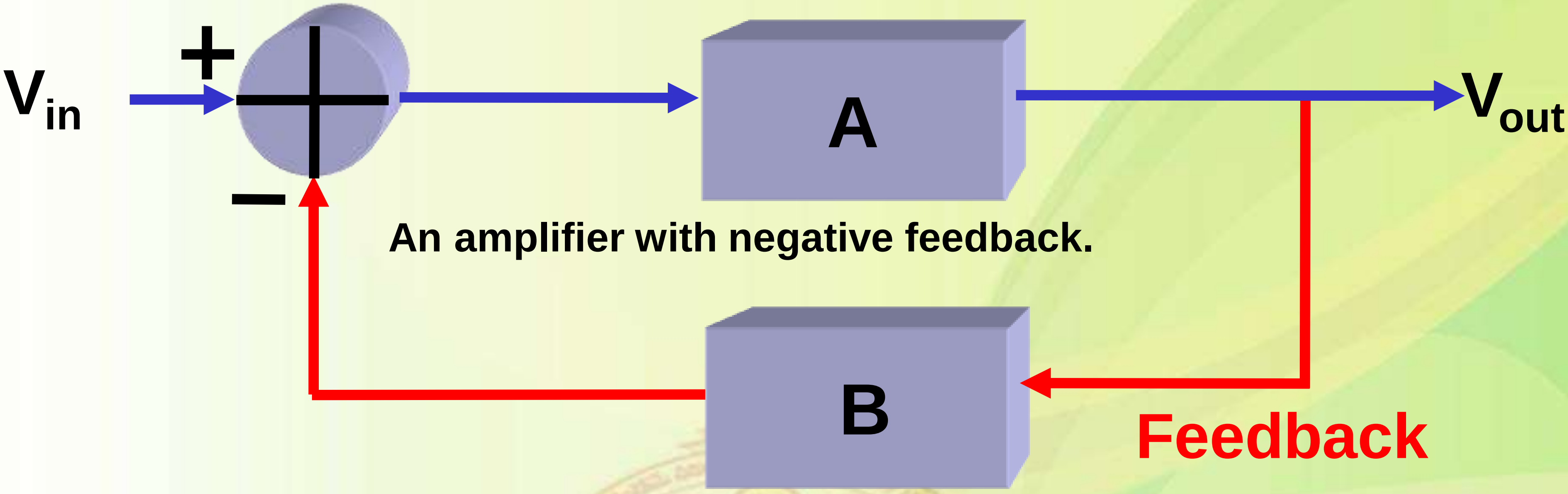
4.2 Oscillators

- **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

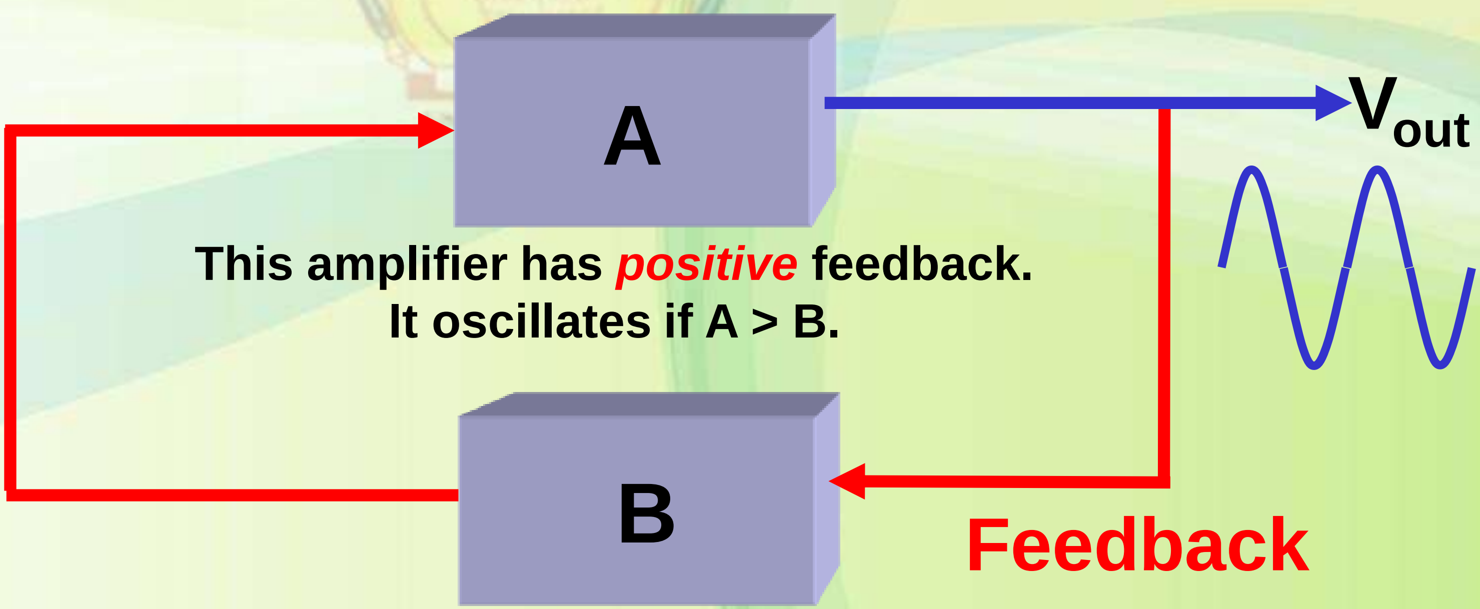


Some possible output waveforms



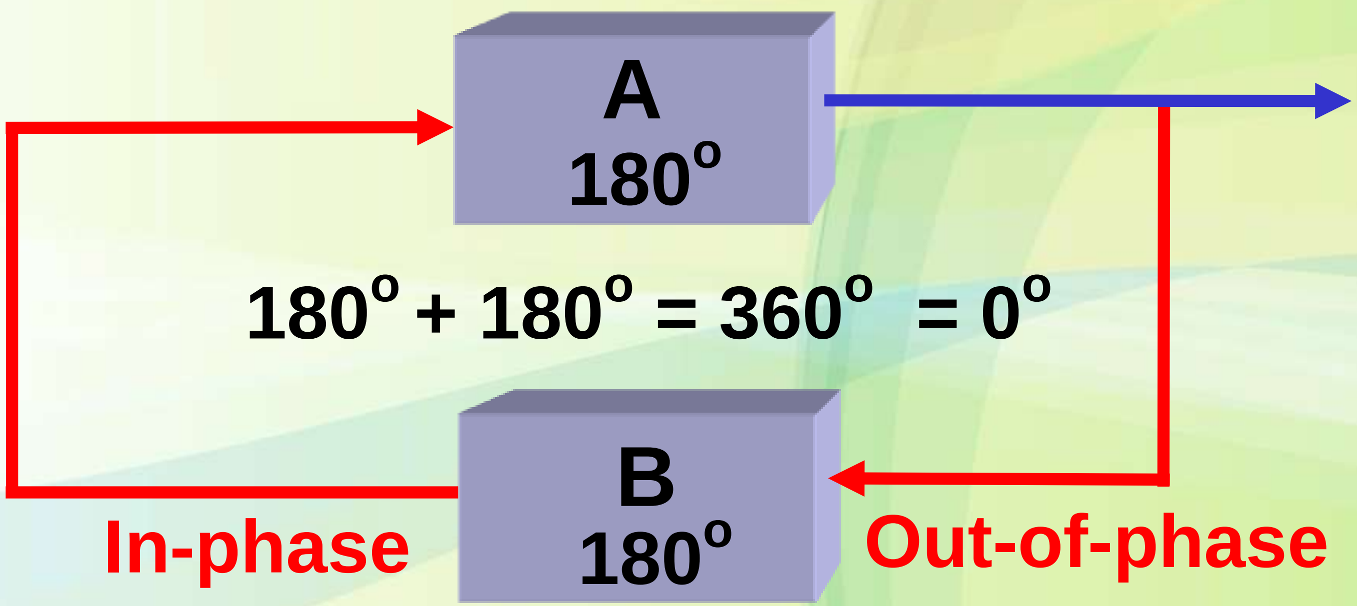
An amplifier with negative feedback.

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

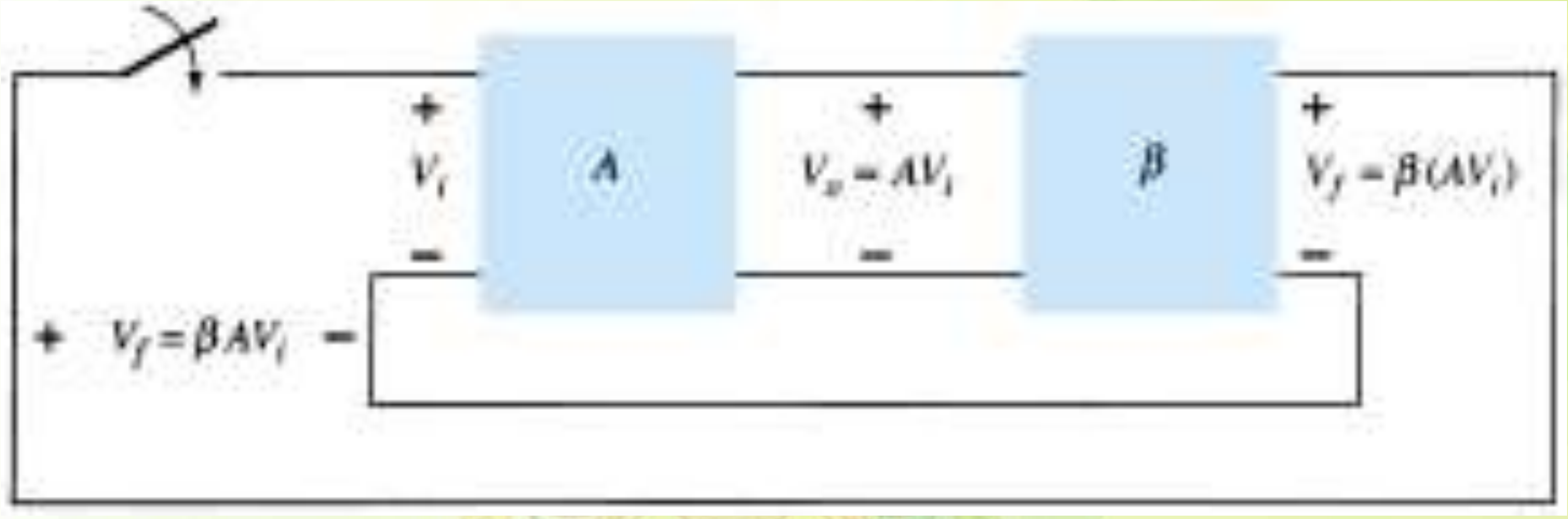


This amplifier has *positive* feedback.
It oscillates if A > B.

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



Feedback Circuit Used As An Oscillator.



The use of positive feedback that results in a feedback amplifier having closed-loop gain |*Af* | *greater than 1 and satisfies the phase conditions will result in operation as* an oscillator circuit. An oscillator circuit then provides a varying output signal. If the output signal varies sinusoidally, the circuit is referred to as a *sinusoidal oscillator.*

When the switch at the amplifier input is open, no oscillation occurs. Consider that we have a *fictitious voltage at the amplifier input (Vi).*

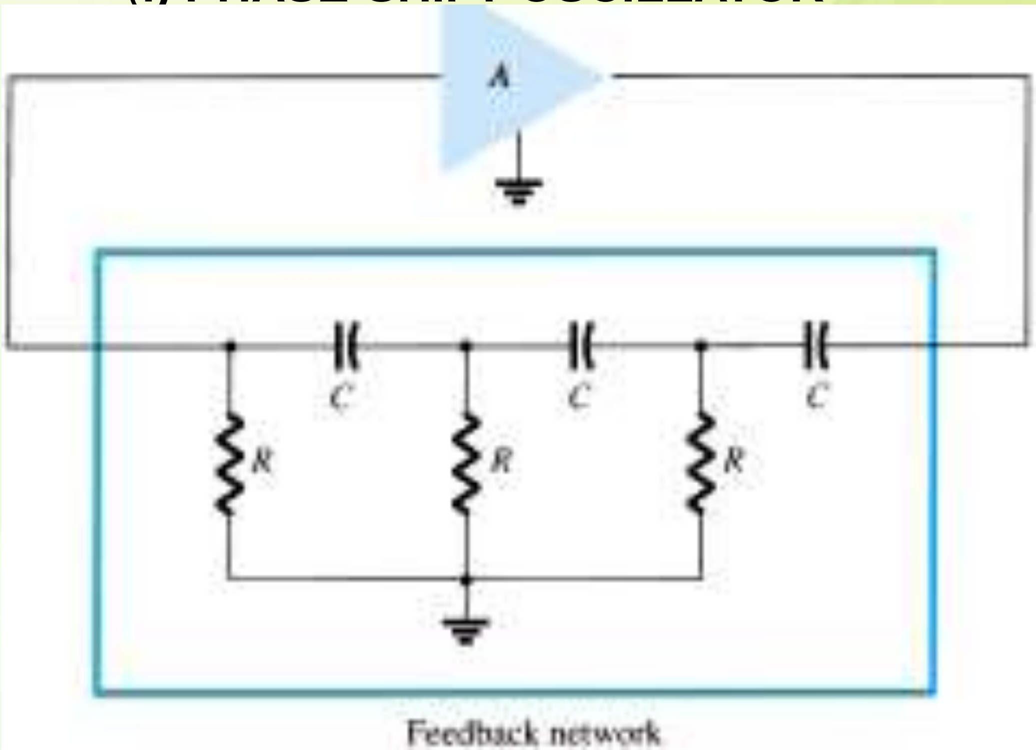
**This results in an output voltage *Vo AVi after the amplifier stage and in a voltage Vf (AVi) after the feedback stage. Thus, we have a feedback voltage Vf Avi,*
where *A is referred to as the loop gain. If the circuits of the base amplifier and feedback* network provide *A of a correct magnitude and phase, Vf can be made equal toVi.***

***Then, when the switch is closed and fictitious voltage Vi is removed, the circuit*
will continue operating since the feedback voltage is sufficient to drive the amplifier and feed back circuits resulting in a proper input voltage to sustain the loop operation.**

**The output waveform will still exist after the switch is closed if the condition
A = 1 is met. This is known as the *Barkhausen criterion for oscillation.***

4.3 Types of Oscillators

(i) PHASE-SHIFT OSCILLATOR



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

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

and the phase shift is 180°.

For the loop gain βA to be greater than unity, the gain of the amplifier s be greater than $1/\beta$ or 29:

$$A > 29$$

FET Phase-Shift Oscillator

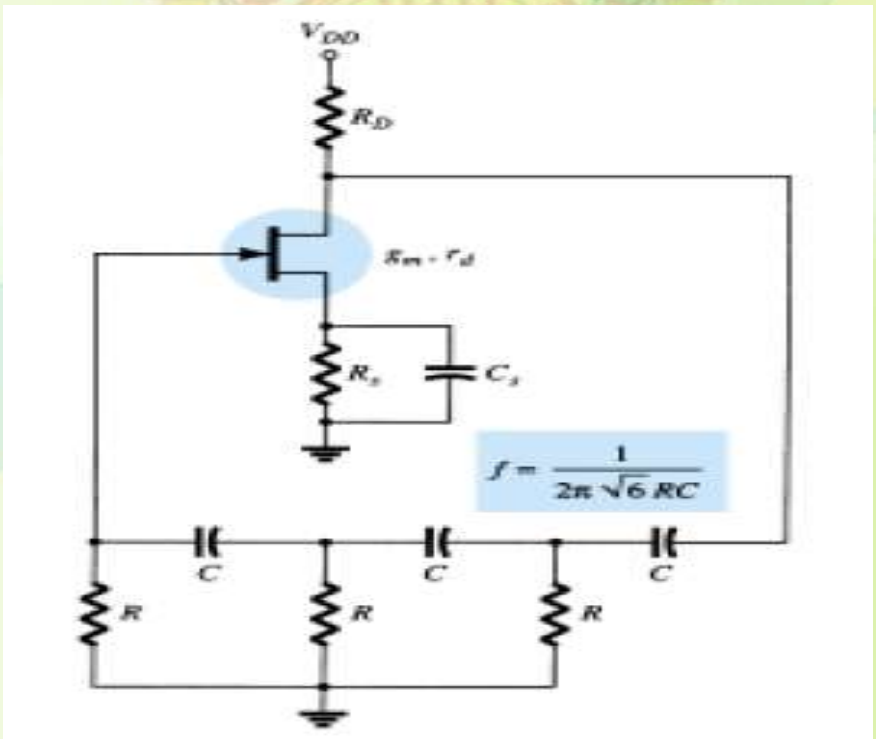
A practical version of a phase-shift oscillator circuit is shown in Fig. 4.3(i). The circuit is drawn to show clearly the amplifier and feedback network. The amplifier stage is self-biased with a capacitor bypassed source resistor *RS and a drain bias resistor RD. The FET device parameters of interest are gm and rd.* The amplifier gain magnitude is calculated from

A = gmRL

$$|A| = g_m R_L$$

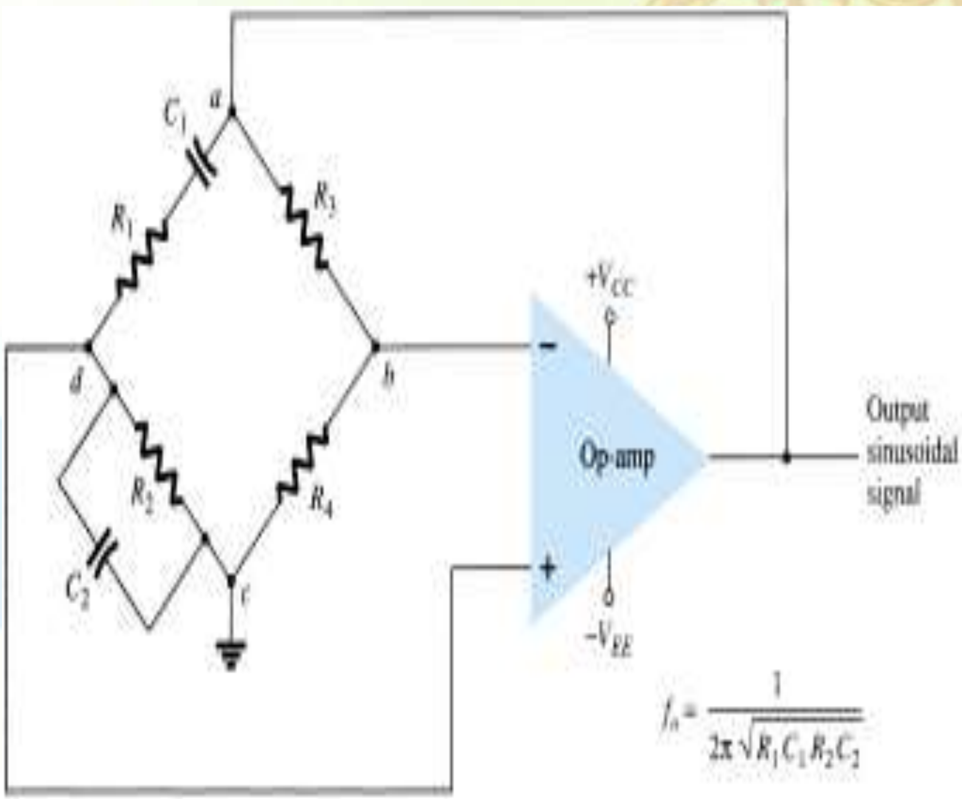
where R_L in this case is the parallel resistance of R_D and r_d

$$R_L = \frac{R_D r_d}{R_D + r_d}$$



(ii) WIEN BRIDGE OSCILLATOR

A practical oscillator circuit uses an op-amp and *RC bridge circuit, with the oscillator* frequency set by the *R and C components. Figure 18.23 shows a basic version of* a Wien bridge oscillator circuit. Note the basic bridge connection. Resistors *R1 and R2 and capacitors C1 and C2 form the frequency-adjustment elements, while resistors R3 and R4 form part of the feedback path. The op-amp output is connected as the* bridge input at points *a and c. The bridge circuit output at points b and d is the input* to the op-amp.



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

and

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

If, in particular, the values are $R_1 = R_2 = R$ and $C_1 = C_2 =$ [illegible]
tor frequency is

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

and

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

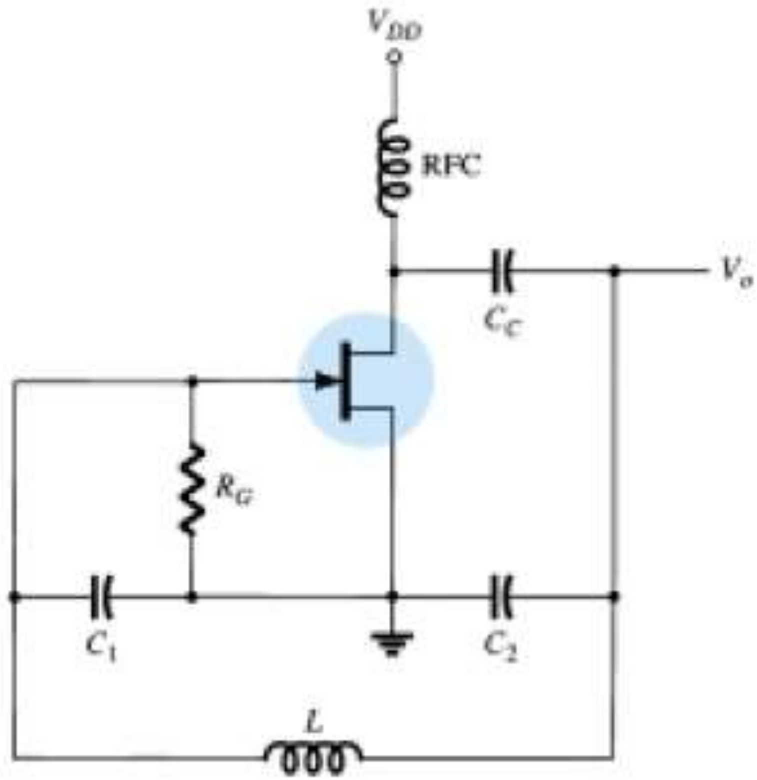
[illegible]

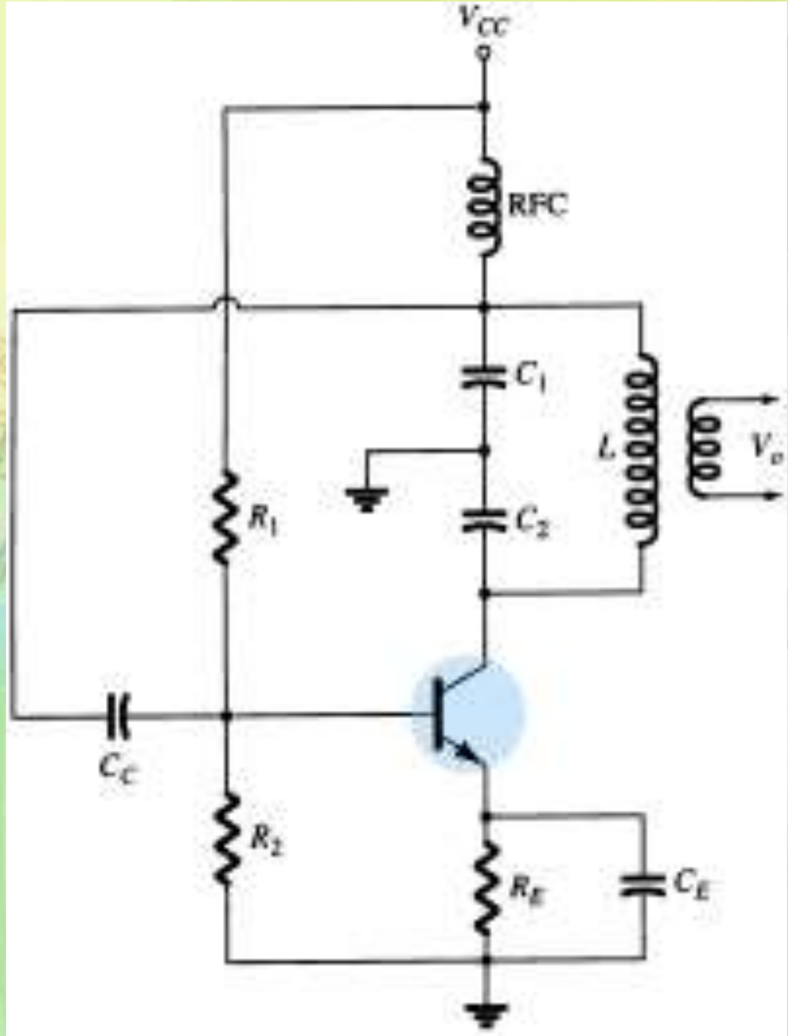
(iv) Colpitts Oscillator

(iii)A practical version of an FET Colpitts and Transistor oscillator are shown below

$$f_o = \frac{1}{2\pi\sqrt{LC_{eq}}}$$

where $$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$





(v) FET HARTLEY OSCILLATOR

An FET Hartley oscillator circuit is shown in Fig. 18.29. The circuit is drawn so that the feedback network conforms to the form shown in the basic resonant circuit Note, however, that inductors *L1 and L2 have a mutual coupling, M,* which must be taken into account in determining the equivalent inductance for the resonant tank circuit. The circuit frequency of oscillation is then given approximately by *fo =1/(2Pisqrt(Leq C))*

with *Leq = L1 L2 2M*

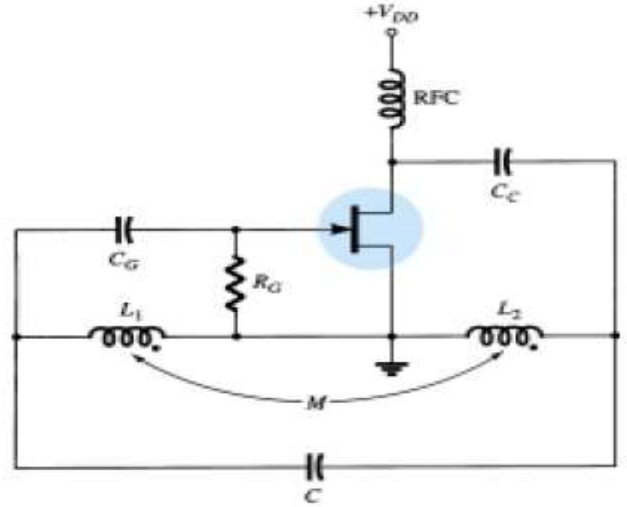


Figure 18.29 FET Hartley oscillator.

TRANSISTOR HARTLEY OSCILLATOR

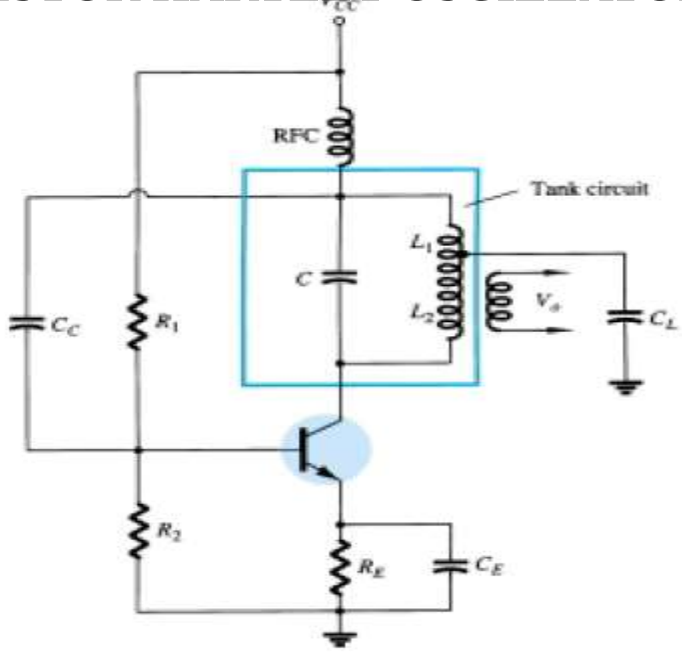
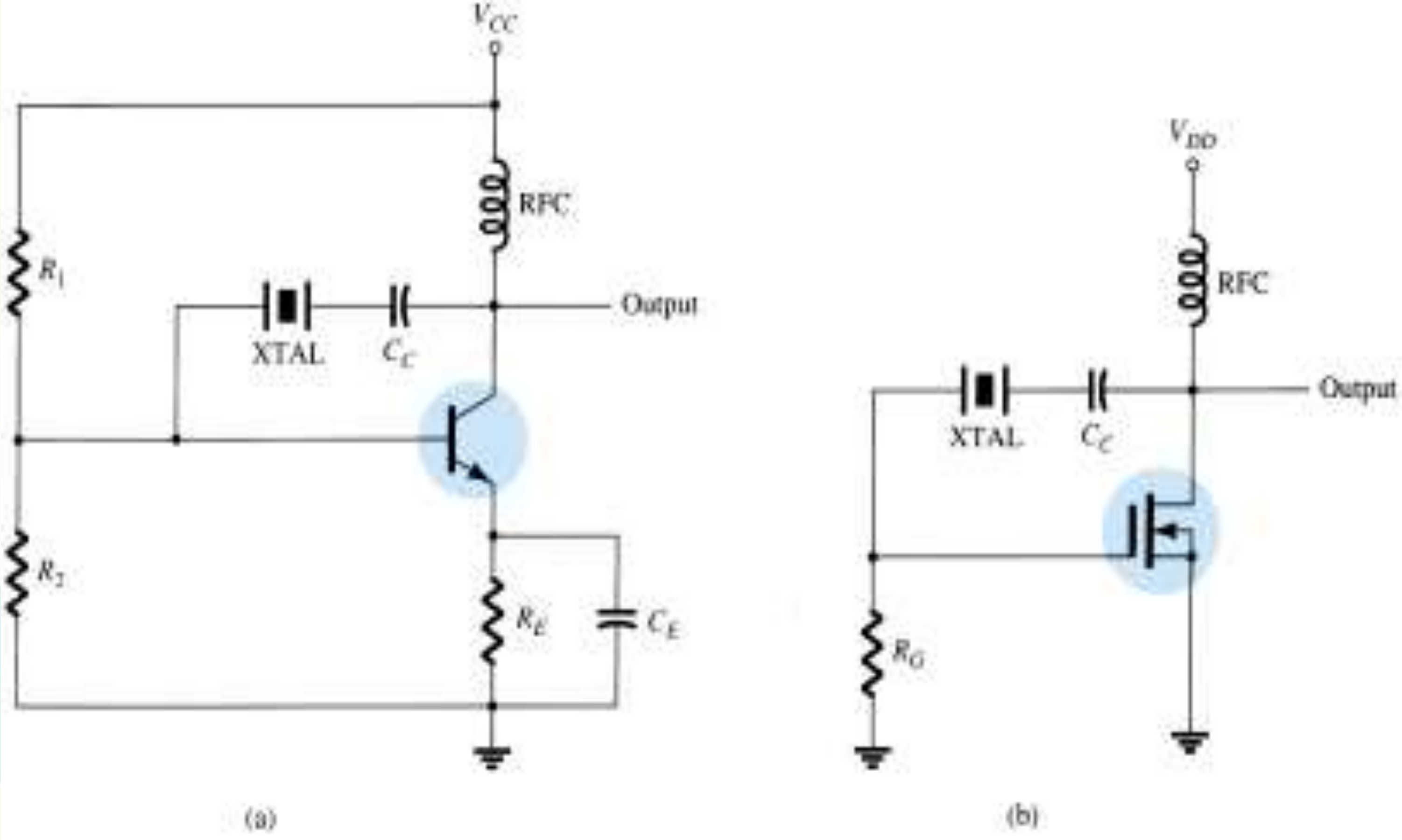


Figure 18.30 Transistor Hartley oscillator circuit.

(VI)CRYSTAL OSCILLATOR

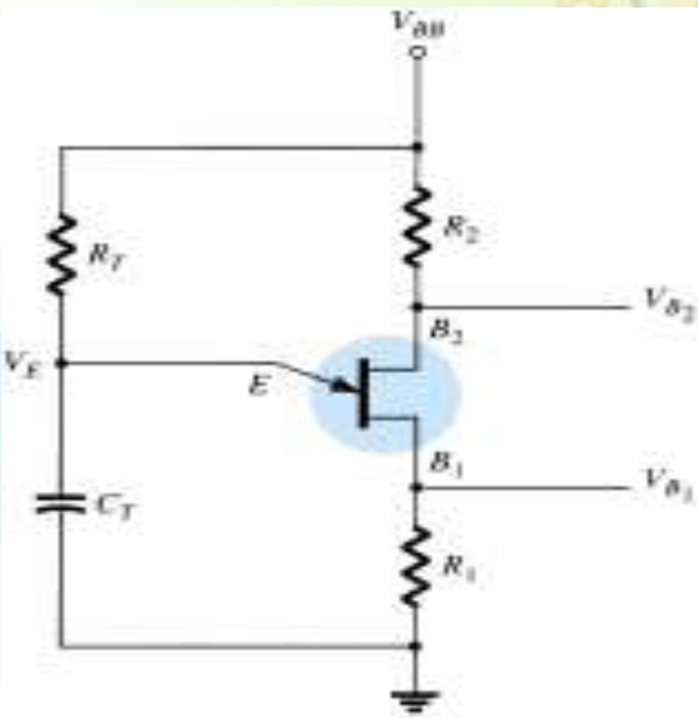
A crystal oscillator is basically a tuned-circuit oscillator using a piezoelectric crystal as a resonant tank circuit. The crystal (usually quartz) has a greater stability in holding constant at whatever frequency the crystal is originally cut to operate. Crystal oscillators are used whenever great stability is required. such as in communication transmitters and receivers.



Crystal-controlled oscillator using crystal in series-feedback path: (a) BJT circuit; (b) FET circuit

(VI)UNIJUNCTION OSCILLATOR

A particular device, the unijunction transistor can be used in a single-stage oscillator circuit to provide a pulse signal suitable for digital-circuit applications. The unijunction transistor can be used in what is called a *relaxation oscillator as shown by the* basic circuit . Resistor *RT and capacitor CT are the timing components* that set the circuit oscillating rate. The oscillating frequency may be calculated using thr following equation, which includes the unijunction transistor *intrinsic stand-off ratio as a* factor (in addition to *RT and CT) in the oscillator operating frequency.*



$$\boxed{f_o \cong \frac{1}{R_T C_T \ln[1/(1-\eta)]}} \qquad (18.48)$$

Typically, a unijunction transistor has a stand-off ratio from 0.4 to 0.6. Using a value of $\eta = 0.5$, we get

$$f_o \cong \frac{1}{R_T C_T \ln[1/(1-0.5)]} = \frac{1.44}{R_T C_T \ln 2} = \frac{1.44}{R_T C_T}$$

$$\cong \frac{1.5}{R_T C_T} \qquad (18.49)$$

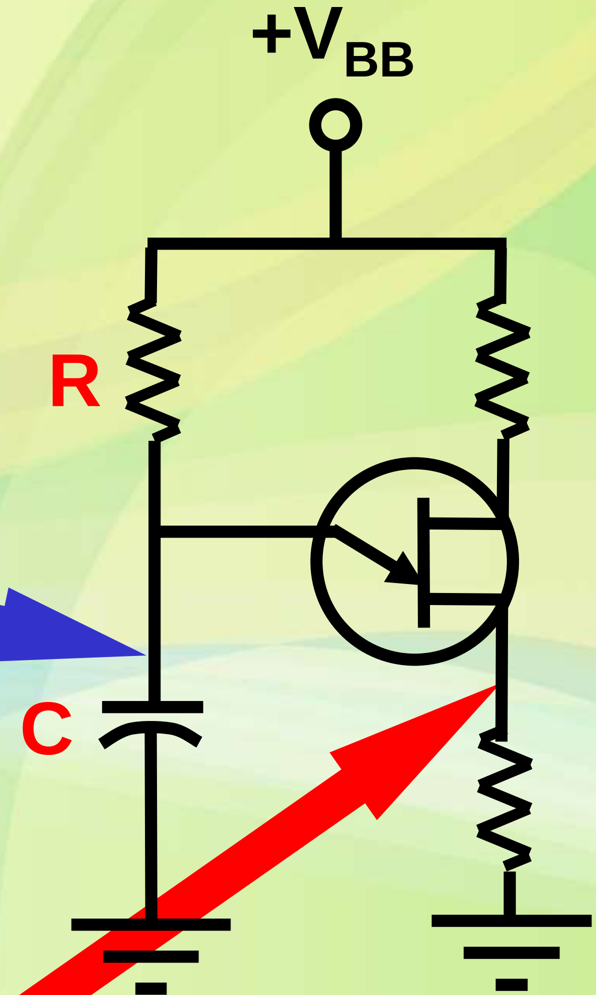
Capacitor C_T is charged through resistor R_T toward supply voltage V_{BB}. As long as the capacitor voltage V_E is below a stand-off voltage (V_P) set by the voltage across $B_1 - B_2$ and the transistor stand-off ratio η

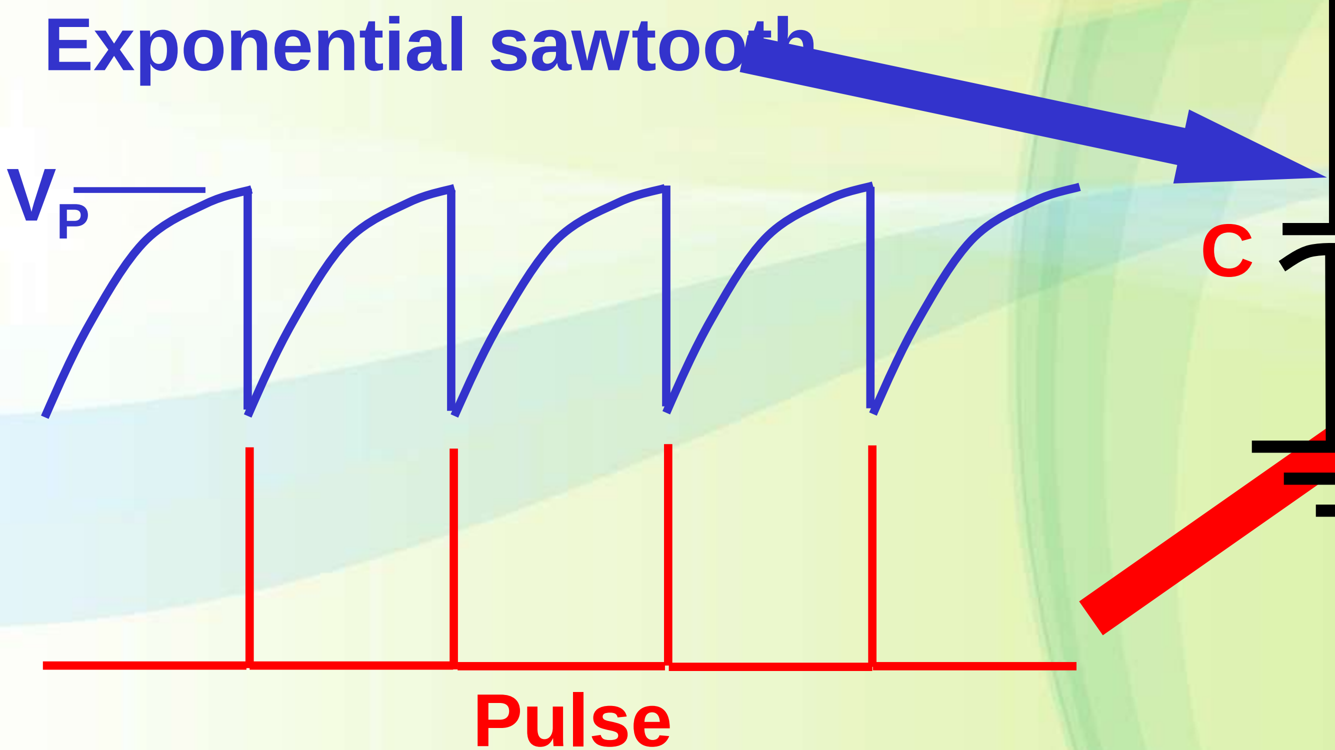
$$V_P = \eta V_{B_1} V_{B_2} - V_D \qquad (18.50)$$

the unijunction emitter lead appears as an open circuit. When the emitter voltage

A UJT relaxation oscillator provides two waveforms.

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





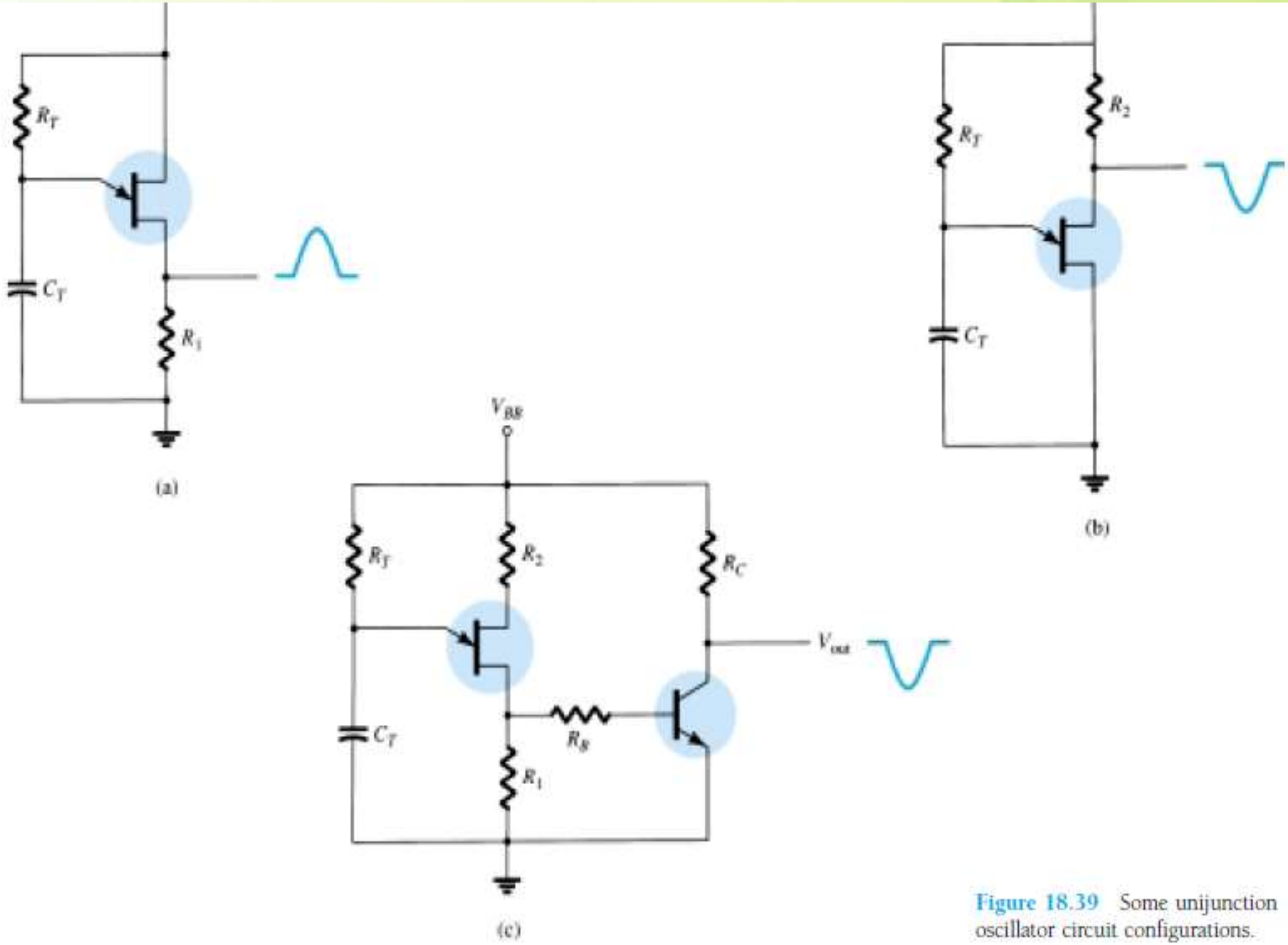


Figure 18.39 Some unijunction oscillator circuit configurations.

Queries …?