Electronic Circuits

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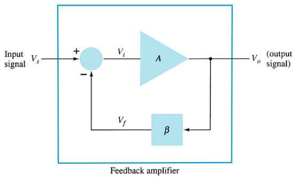
Feedback and Oscillator Circuits
Power Supplies

Feedback Concepts

The effects of negative feedback on an amplifier:

Disadvantage
- Lower gain

Advantages
- Higher input impedance
- More stable gain
- Improved frequency response
- Lower output impedance
- Reduced noise
- More linear operation



Feedback amplifier

Feedback Connection Types

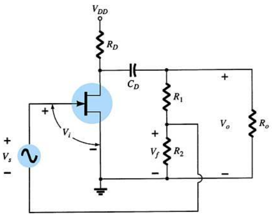
- Voltage-series feedback
- Voltage-shunt feedback
- Current-series feedback
- Current-shunt feedback

Voltage-Series Feedback

For voltage-series feedback, the output voltage is fed back in series to the input.

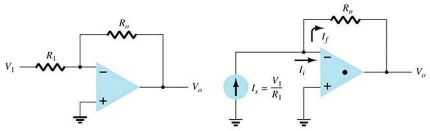
The feedback gain is given by:

$$A_f \cong \frac{1}{\beta} = \frac{R_1 + R_2}{R_2}$$



Voltage-Shunt Feedback

For a voltage-shunt feedback amplifier, the output voltage is fed back in parallel with the input.

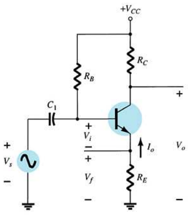


The feedback gain is given by

$$A_f = -\frac{R_o}{R_i}$$

Current-Series Feedback

For a current-series feedback amplifier, a portion of the output current is fed back in series with the input.



To determine the feedback gain:

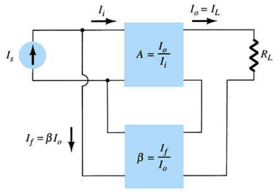
$$A_f = \frac{I_o}{V_s} = \frac{A}{1+\beta A} = \frac{-h_{fe}/h_{ie}}{1+(-R_E)\left(\dfrac{-h_{fe}}{h_{ie}+R_E}\right)} \cong \frac{-h_{fe}}{h_{ie}+h_{fe}R_E}$$

Current-Shunt Feedback

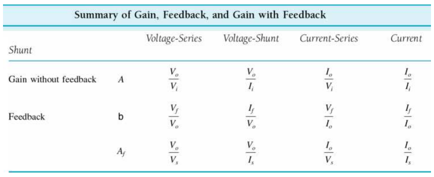
For a current-shunt feedback amplifier, a portion of the output current is directed back in parallel with the input.

The feedback gain is given by:

$$A_f = \frac{I_o}{I_s}$$

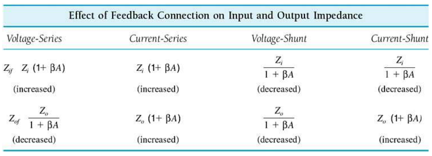


Summary of Feedback Effects



Summary of Gain, Feedback, and Gain with Feedback

Shunt		Voltage-Series	Voltage-Shunt	Current-Series	Current
Gain without feedback	A	$\frac{V_o}{V_i}$	$\frac{V_o}{I_i}$	$\frac{I_o}{V_i}$	$\frac{I_o}{I_i}$
Feedback	b	$\frac{V_f}{V_o}$	$\frac{I_f}{V_o}$	$\frac{V_f}{I_o}$	$\frac{I_f}{I_o}$
	A_f	$\frac{V_o}{V_s}$	$\frac{V_o}{I_s}$	$\frac{I_o}{V_s}$	$\frac{I_o}{I_s}$



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)

Frequency Distortion with Feedback

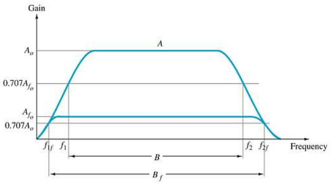
- If the feedback network is purely resistive, then the gain with feedback will be less dependent on frequency variations. In some cases the resistive feedback removes all dependence on frequency variations.
- If the feedback includes frequency dependent components (capacitors and inductors), then the frequency response of the amplifier will be affected.

Noise and Nonlinear Distortion

- The feedback network reduces noise by cancellation. The phase of the feedback signal is often opposite the phase of the input signal.
- Nonlinear distortion is also reduced simply because the gain is reduced. The amplifier is operating in midrange and not at the extremes.

Bandwidth with Feedback

Feedback increases the bandwidth of an amplifier.



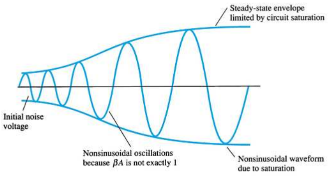
Gain Stability with Feedback

Gain calculations with feedback are often based on external resistive elements in the circuit. By removing gain calculations from internal variations of β and g_m, the gain becomes more stable.

Phase and Frequency Considerations

At higher frequencies the feedback signal may no longer be out of phase with the input. The feedback is thus positive and the amplifier, itself, becomes unstable and begins to

Oscillator Operation



The feedback signal must be positive.

If the feedback signal is not positive or the gain is less than one, the oscillations dampens out.

The overall gain must equal one (unity gain).

If the overall gain is greater than one, the oscillator eventually saturates.

Types of Oscillator Circuits

Phase-shift oscillator
Wien bridge oscillator
Tuned oscillator circuits
Crystal oscillators
Unijunction oscillator

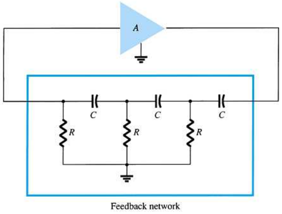
Phase-Shift Oscillator

The amplifier must supply enough gain to compensate for losses. The overall gain must be unity.

The RC networks provide the necessary phase shift for a positive feedback.

The values of the RC components also determine the frequency of oscillation:

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



Feedback network

more…

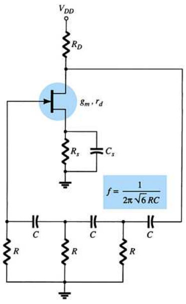
Phase-Shift Oscillator

The amplifier must supply enough gain to compensate for losses. The overall gain must be unity.

The RC networks provide the necessary phase shift for a positive feedback.

The values of the RC components also determine the frequency of oscillation:

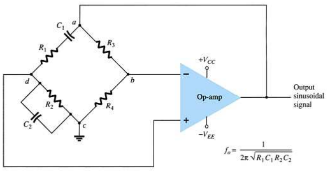
$$f = \frac{1}{2\pi\sqrt{6}RC}$$



Wien Bridge Oscillator

The amplifier must supply enough gain to compensate for losses. The overall gain must be unity.

- The feedback resistors are R_3 and R_4.
- The phase-shift components are R_1, C_1 and R_2, C_2.



Tuned Oscillator Circuits

Tuned oscillators use a parallel LC resonant circuit (LC tank) to provide the oscillations.

There are two common types:

Colpitts—The resonant circuit is an inductor and two capacitors.

Hartley—The resonant circuit is a tapped inductor or two inductors and one capacitor.

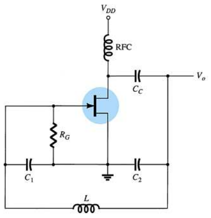
Colpitts Oscillator Circuit

The frequency of oscillation is determined by:

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

where:

$$C_{eq} = \frac{C_1C_2}{C_1 + C_2}$$



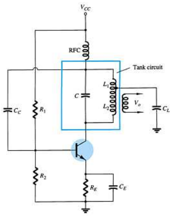
Hartley Oscillator Circuit

The frequency of oscillation is determined by:

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

where:

$$L_{eq} = L_1 + L_2 + 2M$$



Crystal Oscillators

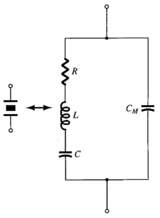
The crystal appears as a resonant circuit.

The crystal has two resonant frequencies:

Series resonant condition
- RLC determine the resonant frequency
- The crystal has a low impedance

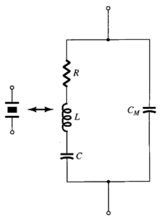
Parallel resonant condition
- RL and C_M determine the resonant frequency
- The crystal has a high impedance

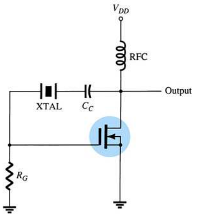
The series and parallel resonant frequencies are very close, within 1% of each other.



Series Resonant Crystal Oscillator

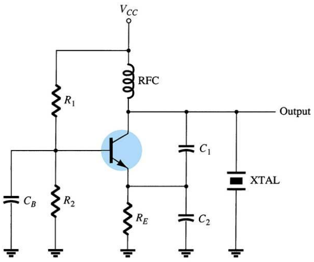
- RLC determine the resonant frequency
- The crystal has a low impedance

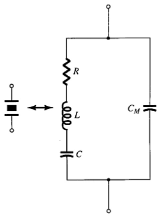




Parallel Resonant Crystal Oscillator

- R_L and C_M determine the resonant frequency
- The crystal has a high impedance



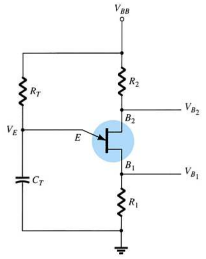


Unijunction Oscillator

The output frequency is determined by:

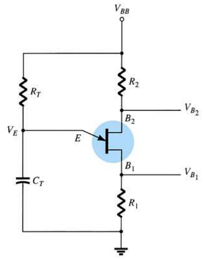
$$f_o = \frac{1}{R_T C_T \ln[1/(1-\eta)]}$$

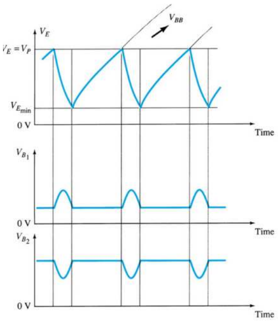
Where η is a rating of the unijunction transistor with values between 0.4 and 0.6.



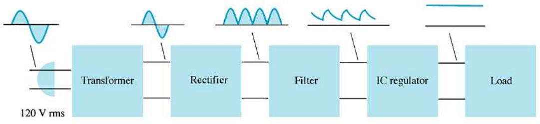
Unijunction Oscillator Waveforms

The unijunction oscillator (or relaxation oscillator) produces a sawtooth waveform.





Power Supply Diagram

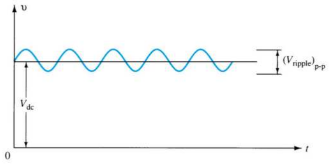


Filter Circuits

- The output from the rectifier section is a pulsating DC.
- The filter circuit reduces the peak-to-peak pulses to a small ripple voltage.

Ripple Factor

After the filter circuit a small amount of AC is still remaining. The amount of ripple voltage can be rated in terms of ripple factor (r).



$$\%r = \frac{\text{ripple voltage (rms)}}{\text{dc voltage}} = \frac{V_{r(rms)}}{V_{dc}} \times 100$$

Rectifier Ripple Factor

Half-Wave

DC output:

$$V_{dc} = 0.318V_m$$

AC ripple output:

$$V_{r(rms)} = 0.385V_m$$

Ripple factor:

$$\%r = \frac{V_{r(rms)}}{V_{dc}} \times 100$$

$$= \frac{0.385V_m}{0.318V_m} \times 100 = 121\%$$

Full-Wave

DC output:

$$V_{dc} = 0.636V_m$$

AC ripple output:

$$V_{r(rms)} = 0.308V_m$$

Ripple factor:

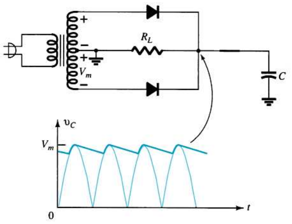
$$\%r = \frac{V_{r(rms)}}{V_{dc}} \times 100$$

$$= \frac{0.308V_m}{0.636V_m} \times 100 = 48\%$$

Types of Filter Circuits

Capacitor Filter
RC Filter

Capacitor Filter



Ripple voltage

$$V_{r(rms)} = \frac{I_{dc}}{4\sqrt{3}fC} = \frac{2.4I_{dc}}{C} = \frac{2.4V_{dc}}{R_LC}$$

The larger the capacitor the smaller the ripple voltage.

DC output

$$V_{dc} = V_m - \frac{I_{dc}}{4fC} = V_m - \frac{4.17I_{dc}}{C}$$

Ripple factor

$$\%r = \frac{V_{r(rms)}}{V_{dc}} \times 100 = \frac{2.4I_{dc}}{CV_{dc}} \times 100 = \frac{2.4}{RLC} \times 100$$

Diode Ratings with Capacitor Filter

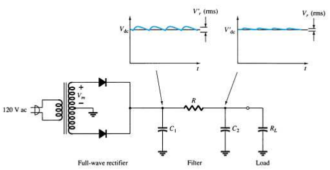
The size of the capacitor increases the current drawn through the diodes—the larger the capacitance, the greater the amount of current.

Peak Current vs. Capacitance:

$$I = \frac{CV}{t}$$

where
C = capacitance
V = change in capacitor voltage during charge/discharge
t = the charge/discharge time

RC Filter Circuit



Adding an RC section further reduces the ripple voltage and decrease the surge current through the diodes.

$$V'_{r(rms)} \approx \frac{X_C}{R} V_{r(rms)}$$

$V'_{r(rms)}$ = ripple voltage after the RC filter
$V_{r(rms)}$ = ripple voltage before the RC filter
R = resistor in the added RC filter
X_C = reactance of the capacitor in the added RC filter

$$\%V_R = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$$

V_{NL} = no-load voltage
V_{FL} = full-load voltage

Voltage Regulation Circuits

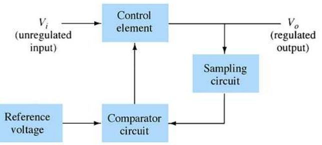
There are two common types of circuitry for voltage regulation:

- **Discrete Transistors**
- **IC's**

Discrete-Transistor Regulators

Series voltage regulator
Current-limiting circuit
Shunt voltage regulator

Series Voltage Regulator Circuit

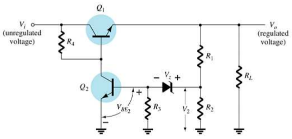


The series element controls the amount of the input voltage that gets to the output.

If the output voltage increases (or decreases), the comparator circuit provides a control signal to cause the series control element to decrease (or increase) the amount of the output voltage.

Series Voltage Regulator Circuit

- R_1 and R_2 act as the sampling circuit
- Zener provides the reference voltage
- Q_2 controls the base current to Q_1
- Q_1 maintains the constant output voltage



When the output increases:

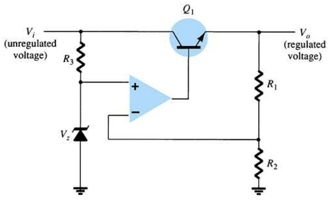
1. The voltage at V_2 and V_{BE} of Q_2 increases
2. The conduction of Q_2 increases
3. The conduction of Q_1 decreases
4. The output voltage decreases

When the output decreases:

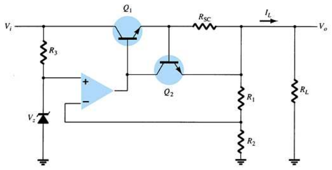
1. The voltage at V_2 and V_{BE} of Q_2 decreases
2. The conduction of Q_2 decreases
3. The conduction of Q_1 increases
4. The output voltage increases

Series Voltage Regulator Circuit

The op-amp compares the Zener diode voltage with the output voltage (at R_1 and R_2) and controls the conduction of Q_1.



Current-Limiting Circuit

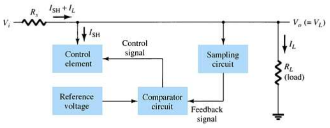


When I_L increases:

- The voltage across R_{SC} increases
- The increasing voltage across R_{SC} drives Q_2 on
- Conduction of Q_2 reduces current for Q_1 and the load

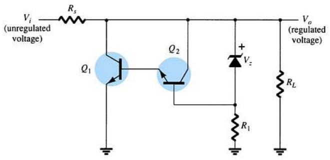
Shunt Voltage Regulator Circuit

The shunt voltage regulator shunts current away from the load.



The load voltage is sampled and fed back to a comparator circuit. If the load voltage is too high, control circuitry shunts more current away from the load.

Shunt Voltage Regulator Circuit



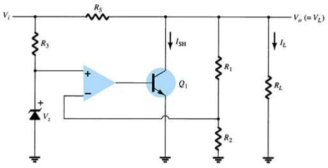
When the output voltage increases:

- **The Zener current increases**
- **The conduction of Q_2 increases**
- **The voltage drop at R_s increases**
- **The output voltage decreases**

When the output voltage decreases:

- **The Zener current decreases**
- **The conduction of Q_2 decreases**
- **The voltage drop at R_s decreases**
- **The output voltage increases**

Shunt Voltage Regulator Circuit



IC Voltage Regulators

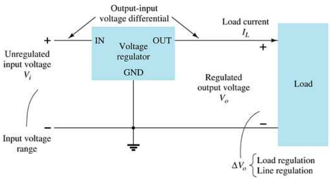
Regulator ICs contain:

- **Comparator circuit**
- **Reference voltage**
- **Control circuitry**
- **Overload protection**

Types of three-terminal IC voltage regulators

- **Fixed positive voltage regulator**
- **Fixed negative voltage regulator**
- **Adjustable voltage regulator**

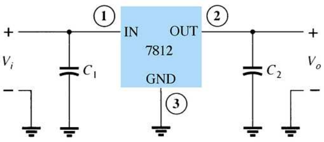
Three-Terminal Voltage Regulators



The specifications for this IC indicate:

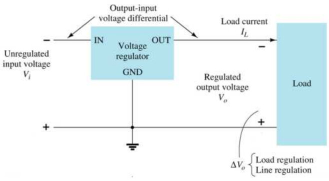
- **The range of input voltages that can be regulated for a specific range of output voltage and load current**
- **Load regulation—variation in output voltage with variations in load current**
- **Line regulation—variation in output voltage with variations in input voltage**

Fixed Positive Voltage Regulator



These ICs provide a fixed positive output voltage.

Fixed Negative Voltage Regulator

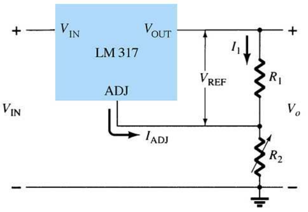


These ICs output a fixed negative output voltage.

Adjustable Voltage Regulator

These regulators have adjustable output voltages.

The output voltage is commonly selected using a potentiometer.



Practical Power Supplies

DC supply (linear power supplies)
Chopper supply (switching power supplies)
TV horizontal high voltage supply
Battery chargers