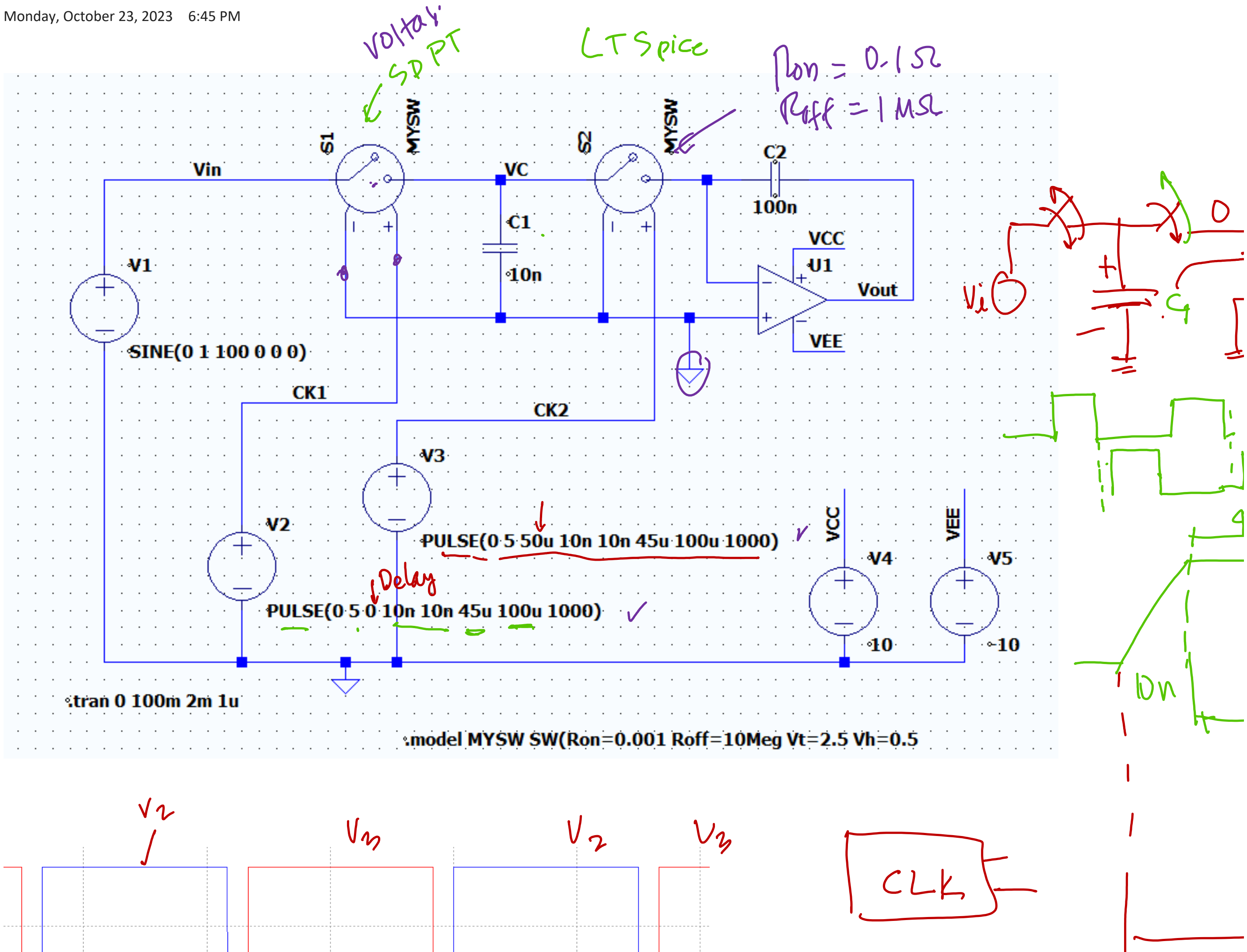
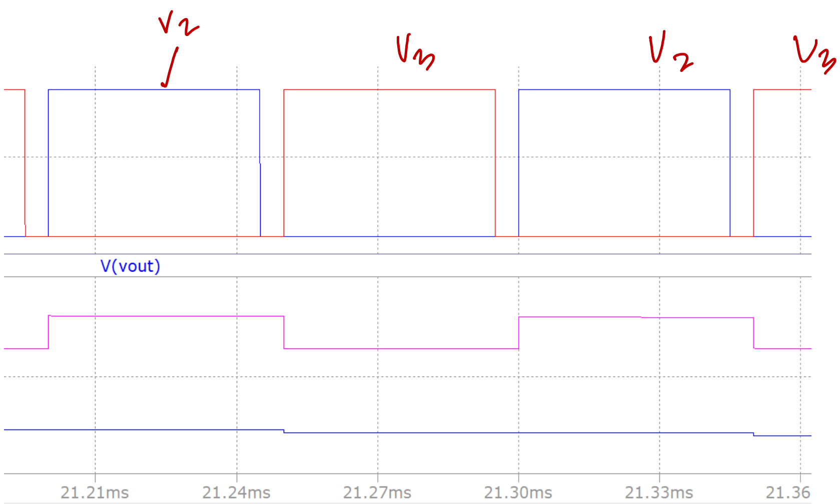
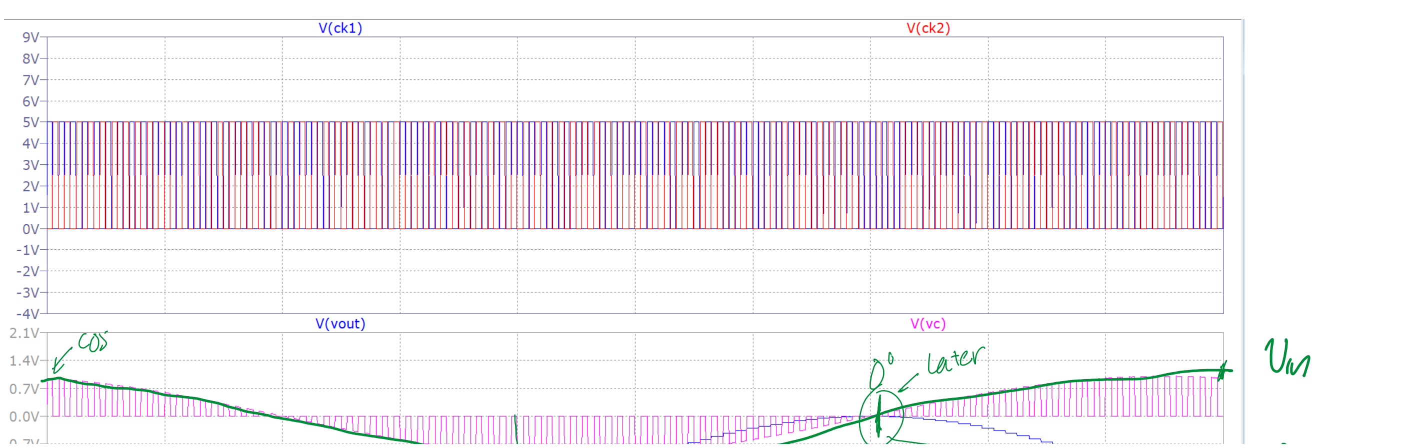
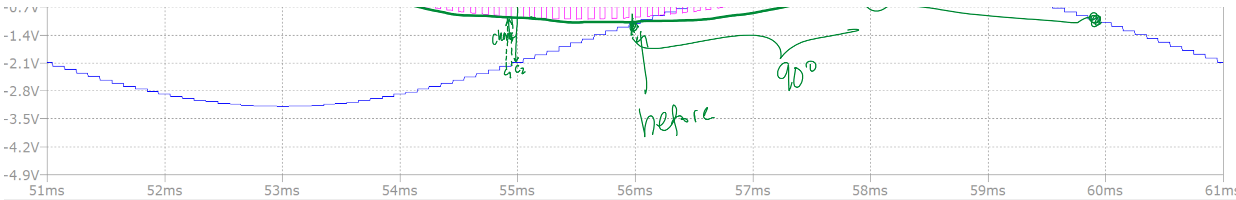
Lecture 17 - Signal Generators

Monday, October 23, 2023 6:45 PM



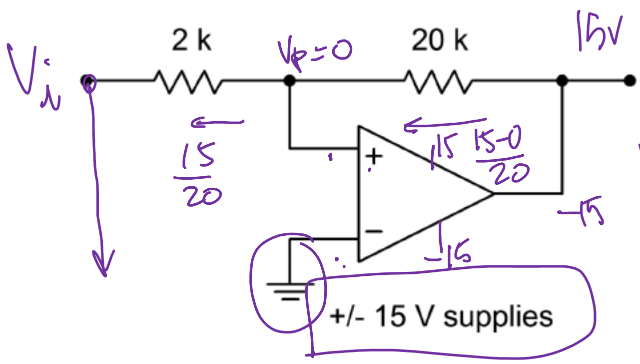






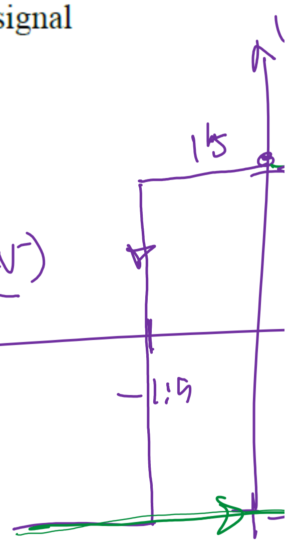
Example 7.7

Sketch the output waveform for the circuit of Figure 7.49 if the input signal is a 5 V peak sine wave.



$V_0 = 15$

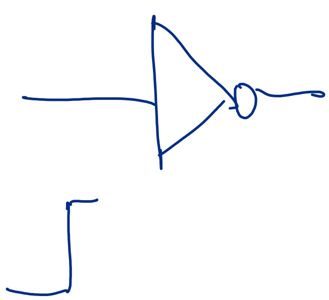
$V_0 = A_V(V^+ - V^-)$

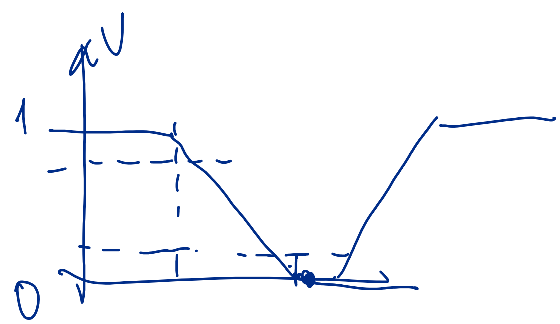


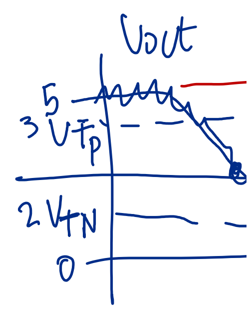
First, determine the upper and lower threshold voltages.

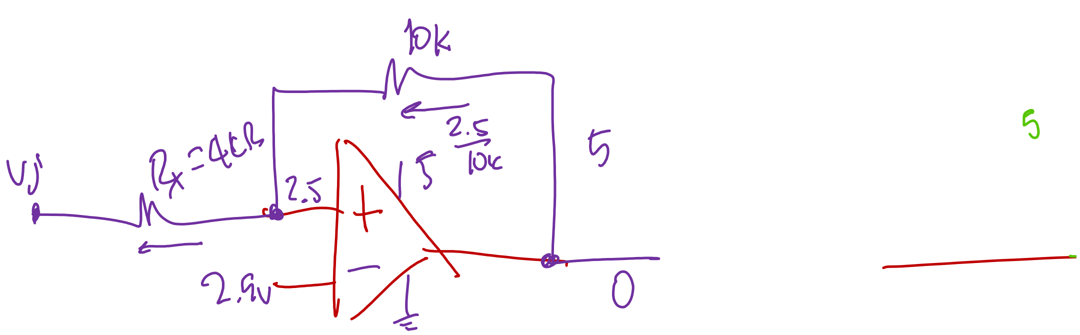
$V_0 =$

$V_i = -\frac{15}{20}\, 2k = -1.5$





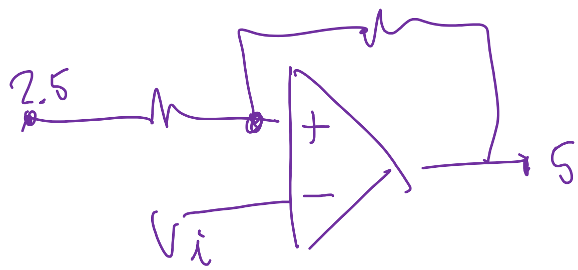


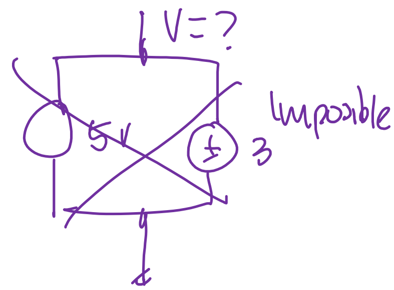


5

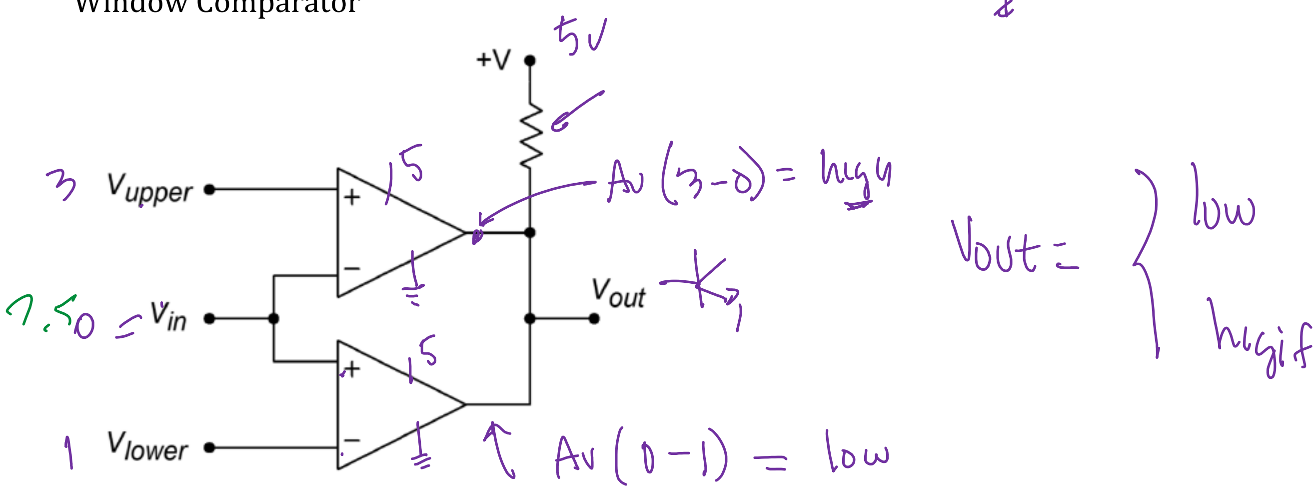
$$1.5 = \frac{2.5 - 1.5}{R_x} = \frac{2.5}{10k}$$

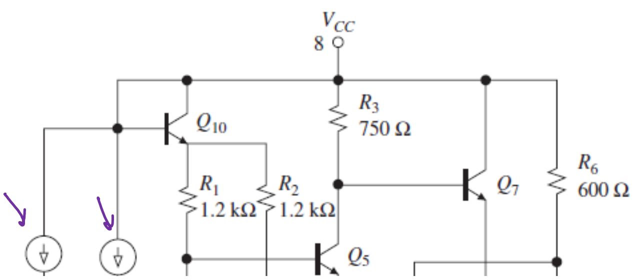
$$R_x = \frac{2.5 - 1.5}{2.5/10k} = \frac{1 \cdot 10}{2.5} = 4k\Omega$$

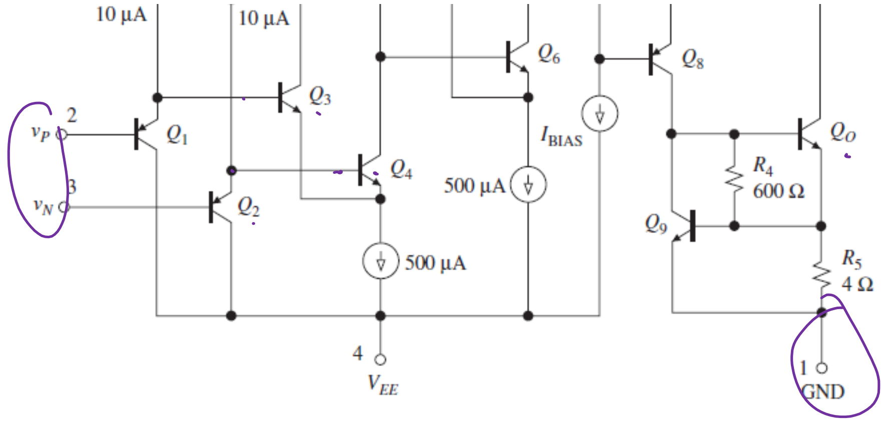




Window Comparator







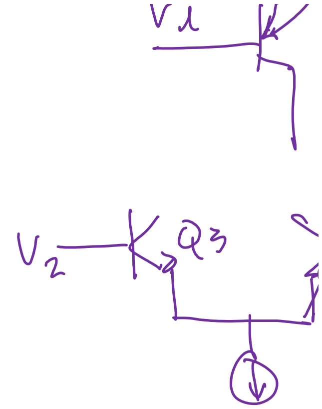
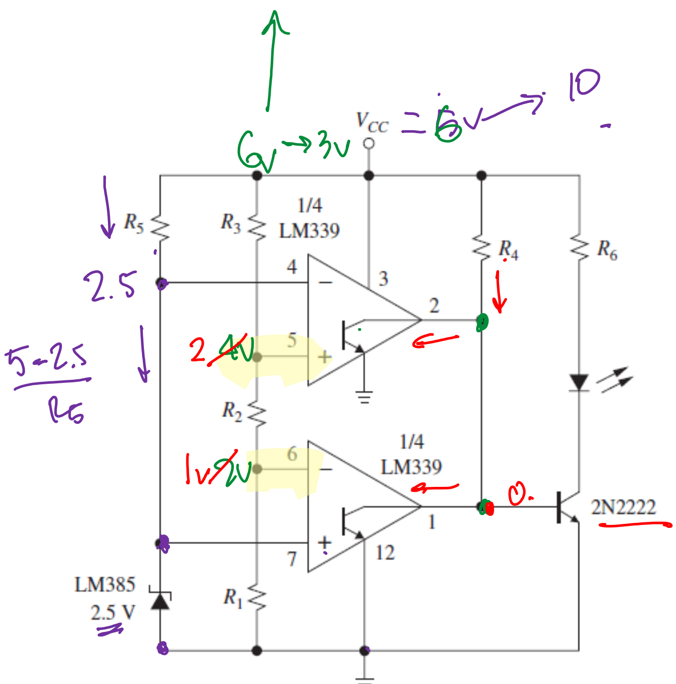


FIGURE 9.4
Simplified circuit diagram of the LM311 voltage comparator. (Courtesy of Texas Instruments.)



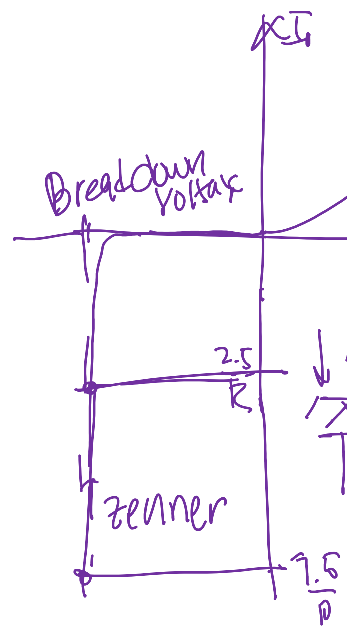
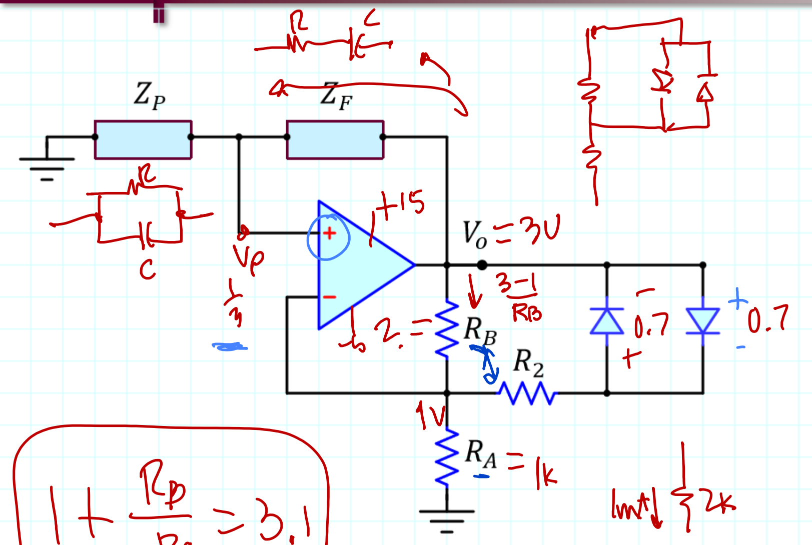


FIGURE 9.15
Power-supply monitor; LED glows as long as V_{CC} is within specification.

$R_3 = R_2 = R_1$

Single Amplifier Implementation



$$\boxed{1 + \frac{R_B}{R_A} = 3.1}$$

$$\frac{R_B}{R_A} = 2$$

$$H(s) = K_N \frac{\frac{\omega_o}{Q} s}{s^2 + \frac{\omega_o}{Q} s + \omega_o^2} = V_p$$

1.At low-signal levels the diodes are O

→ The loop gain is unaffected: $T > 1$

→ Oscillation builds up

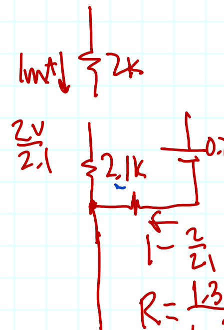
2. When the oscillation grows, the dio
brought into conduction in alternating

→ $R2 = 2R + \varepsilon \,||10R \rightarrow T < 1$

→ Oscillation is damped by negative fe

Oscillation will automatically stabilize

Oscillation amplitude will be depende
diode's threshold voltage!



$$R = \frac{1.3}{1-\frac{2}{2.1}} = \frac{1.3(2.1)}{0.1} = \frac{2.73}{0.1} = 27.3k\Omega$$

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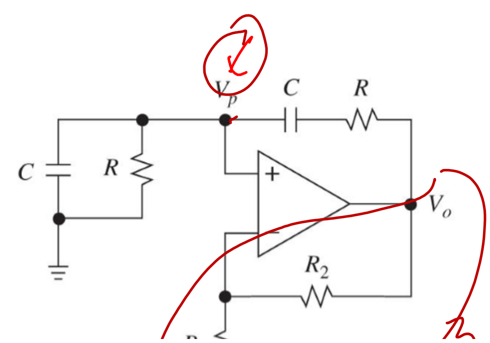
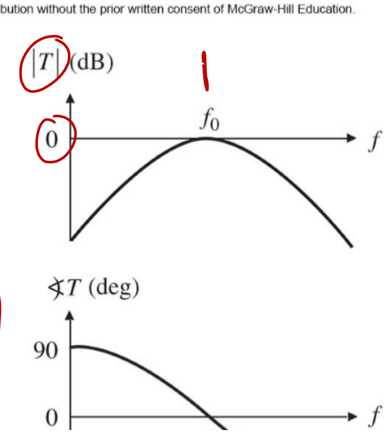
$$\frac{R \,||\, \frac{1}{sC}}{R \,||\, \frac{1}{sC} + R + \frac{1}{sC}} \; V_p = \frac{\frac{R}{1+sRC}}{\frac{R}{1+sRC} + R + \frac{1}{sC}} = \frac{\frac{R}{(1+s}}{\frac{2RC + RsC(1}{SC(\cancel{1+sR}}}$$

Wien-Bridge Oscillator





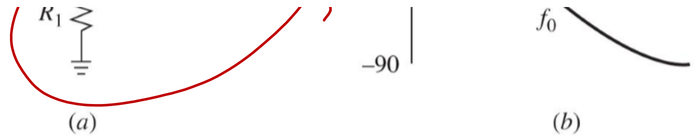
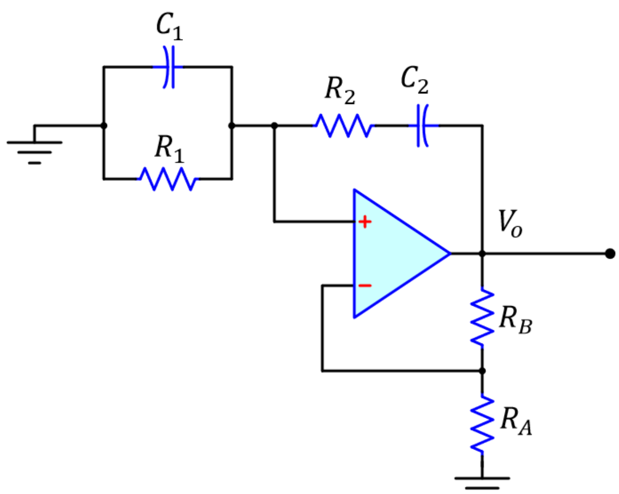


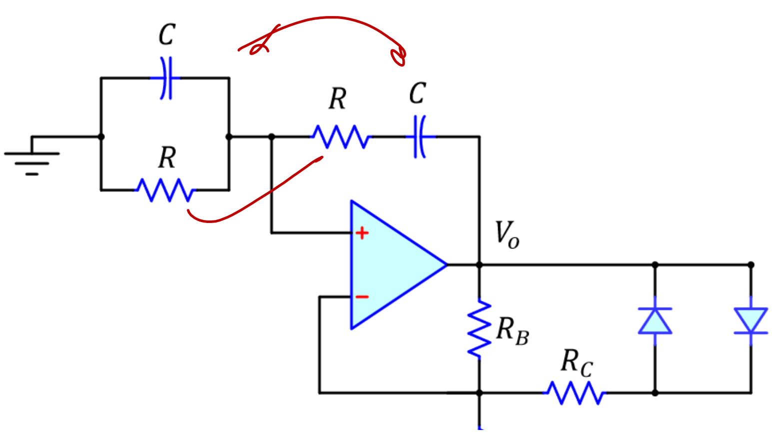
Figure 10.2 Wien-bridge circuit and its loop gain *T(jf)* for the case $R_2/R_1=2$

Wien-Bridge Oscillator



- Wien-bridge circuit 2 uses both negative feedback
  - Circuit behavior is strongly affec
    - If $T(j\omega_0 < 1)$, negative fee and a stable system results
    - If $T(j\omega_0 > 1)$, positive feec a unstable system results, c the saturation limit is reach
    - If $T(j\omega_0 = 1)$, the system i

Wien-Bridge Oscillator



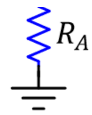
For $T(j\omega_0 > 1)$,

$$A = \frac{V_o}{V_p} = 1 + \frac{R_B}{R_A}$$

$$V_p = \frac{Z_p}{Z_p + Z_s} V_o = \frac{\frac{R}{1+sRC}}{\frac{R}{1+sRC} + \frac{1+sRC}{sC}} =$$

$$B(j\omega) = \frac{V_p}{V_o} = \frac{s/\omega_o}{s^2 + 3\frac{s}{\omega_o} + \omega_o^2}, whe$$

R_B

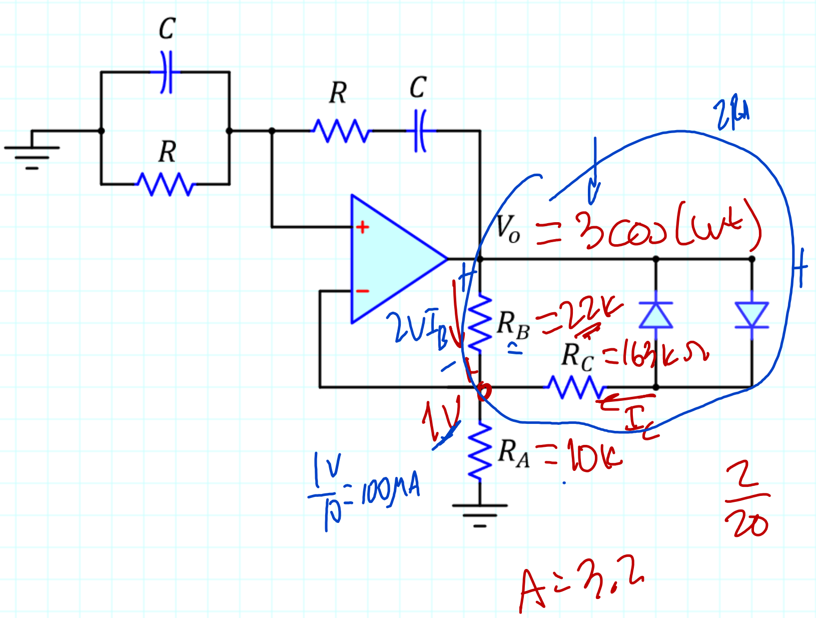


$$T(j\omega) = \frac{1 + \frac{R_B}{R_A}}{s^2 + 3\frac{s}{\omega_o} + \omega_o^2}$$

$At\ resonant\ frequency\ |T(j\omega_o)|$

Therefore, for sustained oscillations, $\frac{R_B}{R_A}$

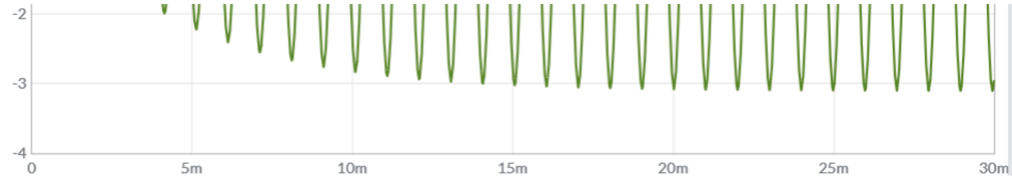
Wien-Bridge Oscillator



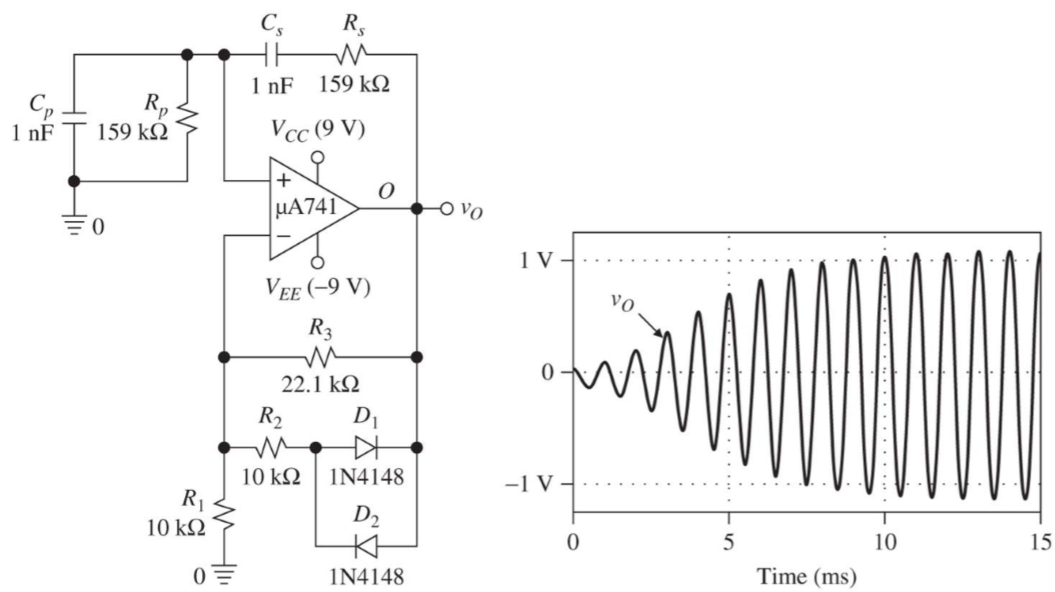
Design an oscillator such that it produ
$V_o = 3\cos(\omega t)\,, and\ \omega = 1KHz$

- For sustained oscillations, $\frac{R_B}{R_A} > 2$
- Example:
- Let $R_B = 22k\Omega\ and\ R_A = 10k\Omega$, (
- At the peak value we want to redu therefore:
- $I_B = \frac{2V}{22k\Omega}$, must fall to $I_B = \frac{2V}{20k\Omega}$ c circuit is added
- $I_C = \frac{2V}{22k\Omega} - \frac{2V}{20k\Omega} = 9.09\mu A$
- Use diode equation with $I_0 = 1 \times$
- $I_D = I_0 e^{\frac{V_D}{V_T}} \Rightarrow V_D = V_T \ln\left(\frac{9.09mA}{I_0}\right)$
- $R_C = \frac{2-0.515}{9.091\mu A} = 163k\Omega$

Make sure V_T is determined according to the simulation temperature



Wien-Bridge Oscillator

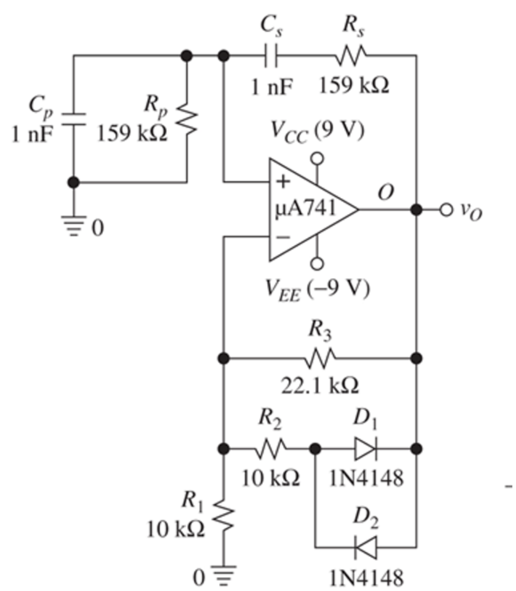


(*a*) (*b*)

Sine Wave Generators

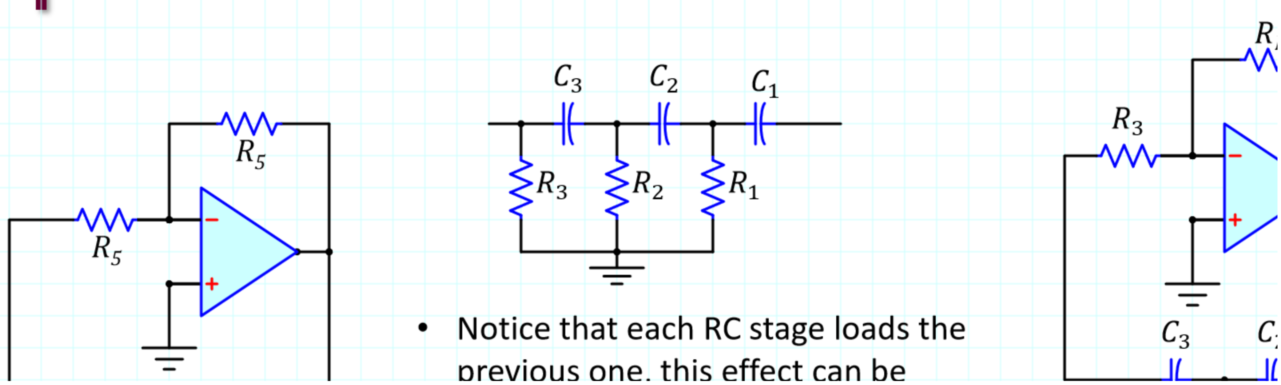
- Oscillation accuracy and stability
  - Affected by quality of passive components and op amp dynamics
- Good choices for elements in the positive feedback network
  - Polycarbonate capacitors and thin-film resistors
- Use trimmers for exact adjustment of f_0

Sine Wave Generators

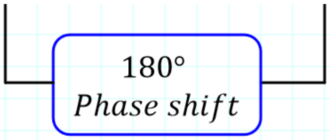


- FET-input op amps used to minimiz bias-current errors
- Quadrature oscillators
  - Can make an oscillator out of any sec filter
  - Dual-integrator-loop type filters are g candidates
    - Provide two oscillations with rel shift of 90 degrees

Phase Shift Oscillator

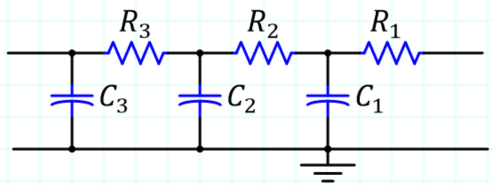


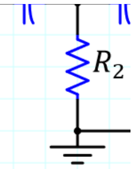
- Notice that each RC stage loads the previous one, this effect can be



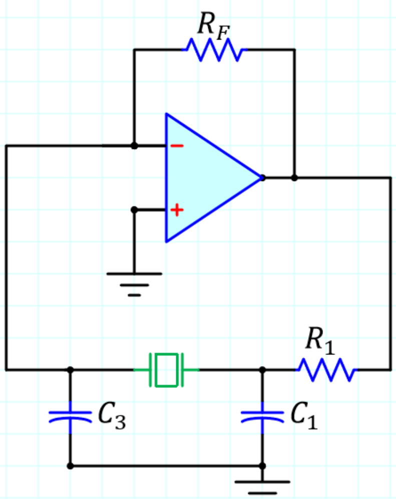
reduced by choosing:

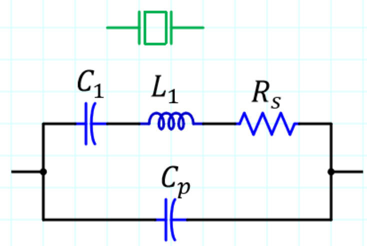
- $R_3 = 10R_2 = 100R_1$, and
- $C_1 = 10C_2 = 100C_3$



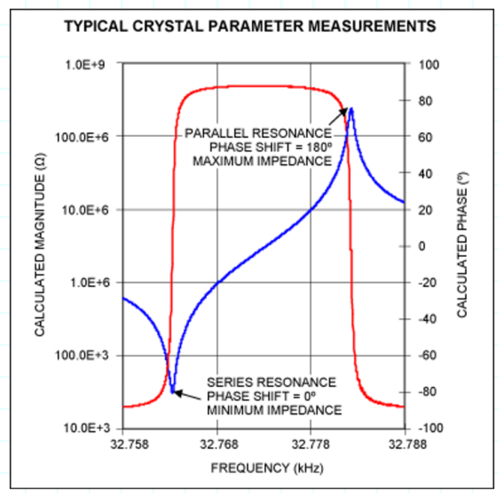


Crystal Oscillator



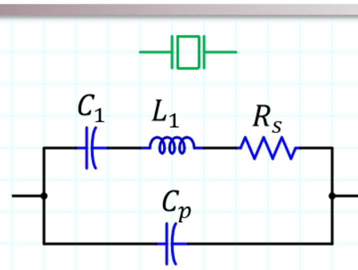


Series R
Parallel

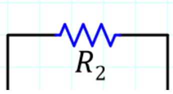


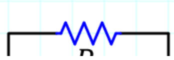
[Max

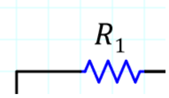
Crystal Oscillator

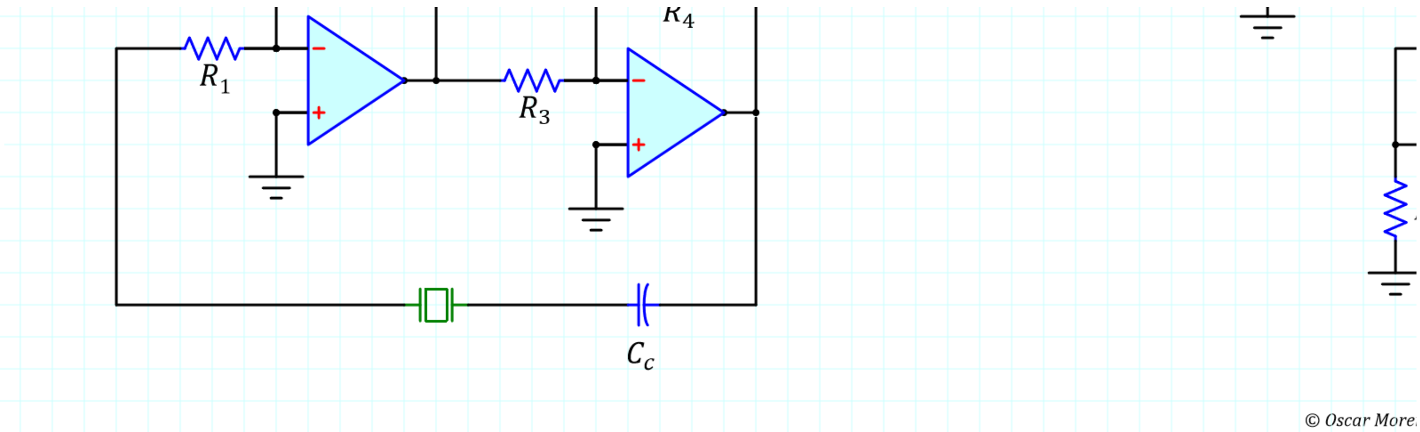


Series Resonan
Parallel Resona









10.2 Multivibrators

- Regenerative circuits for timing applications
  - Can be bistable, astable, or monostable
- Bistable multivibrator
  - Both states are stable
  - External commands needed to force circuit to a given state

Multivibrators

- Astable multivibrator
  - Toggles spontaneously between one state and the other
- Monostable multivibrator
  - Also called one-shot

- Is stable in only one of its two states
- If forced into other state by a trigger, it returns to its stable state

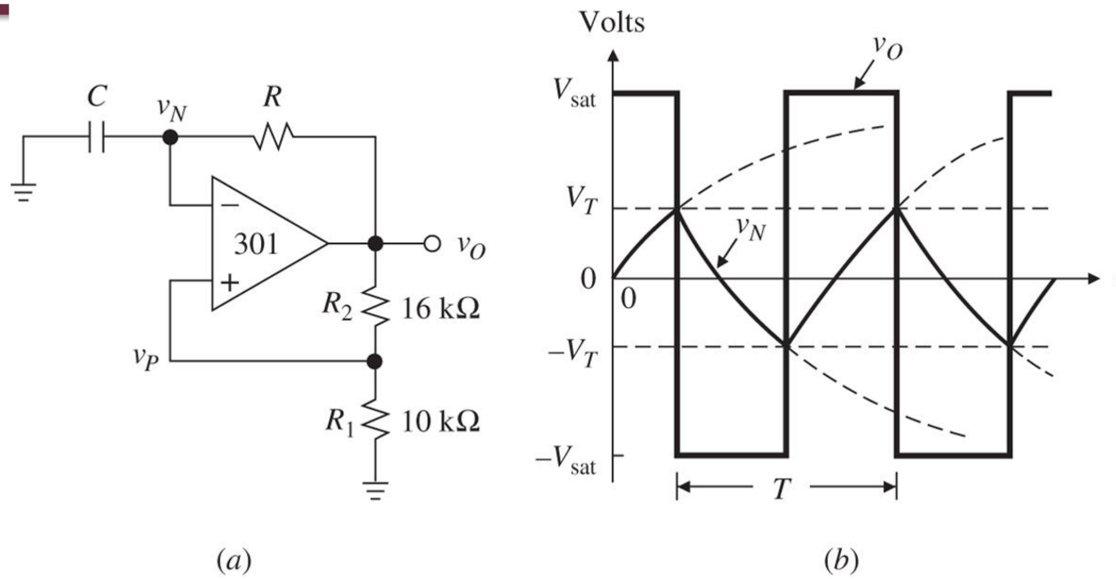


Figure 10.7 Basic free-running multivibrator

Multivibrators

- Free-running multivibrator using CMOS gates
  - CMOS logic gates are attractive when digital and analog functions r on a chip
- CMOS crystal oscillators

- CMOS crystal oscillators
  - Used for precise timekeeping applications
- Monostable multivibrator
  - Produces a pulse of specified duration in response to a trigger

Multivibrators

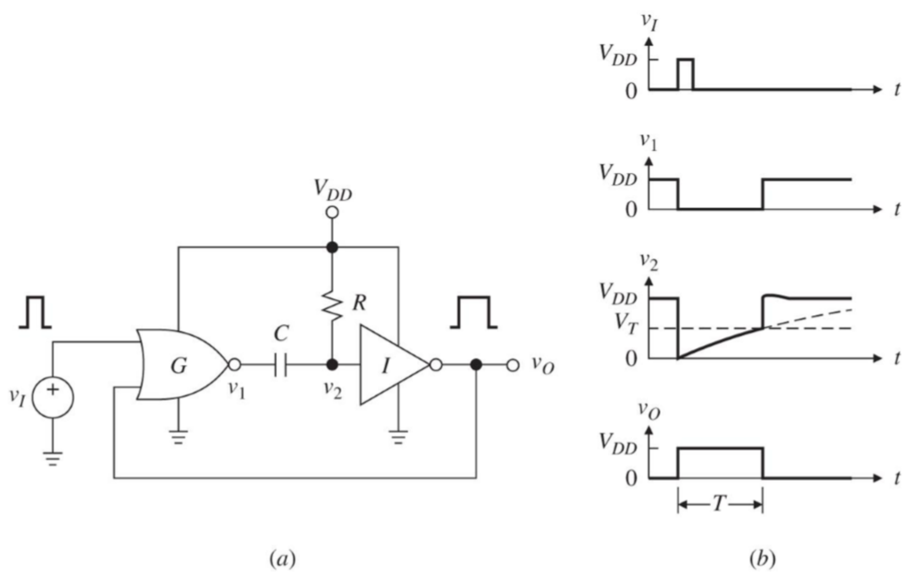


Figure 10.14 CMOS-gate one-shot

10.3 Monolithic Timers

- The 555 timer components
  - Three identical resistors
  - Two voltage comparators

- A flip-flop
- A BJT switch

- The 555 timer is available in bipolar and CMOS versions
  - CMOS version has low power consumption and very high input im

Monolithic Timers

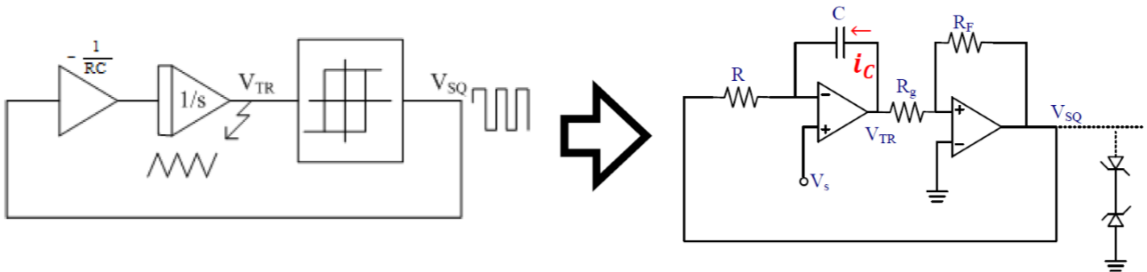
- The 555 timer can be configured for astable or monostable operation
- The 555 timing characteristics
  - Can be modified via the CONTROL input
    - Pulse-position modulation: in astable operation
    - Pulse-width modulation: in monostable operation
- Timer/counter circuits are used for applications with long delays

10.4 Triangular Wave Generators

- Triangular waves generated by alternately charging and disc capacitor with a constant current
- Slope control

➤ Charge and discharge times can be adjusted independently to gene asymmetric waves

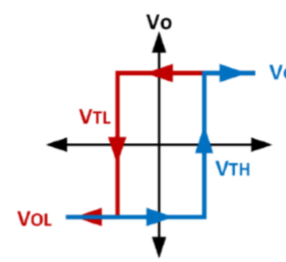
Basic Triangular/Square Wave Generator



Non-inverting Schmitt trigger toggles between V_{OH} and V_{OL}

The transition occurs when:

$$V_{TR}(t) = V_{TL/H} = -\left(\frac{R_G}{R_F}\right)V_{OH/L}$$



Because of negative feedback, the current through the capacitor is given by:

$$i_C(t) = \frac{V_s - V_{SQ}(t)}{R}$$

Between transitions V_{SQ} can be considered a DC voltage, so V_{TR} is linearly increasing or decreasing with a constant current.

$$\pm\Delta V_{TR}(t)_{t_0\to t_1} = \left(\frac{i_C}{C}\right)\Delta t = \left(\frac{V_s - V_{OL/H}}{RC}\right)\Delta t$$

$if\ V_{SQ} = V_{OL} \quad V_{TR}\uparrow$

$if\ V_{SQ} = V_{OH} \quad V_{TR}\downarrow$

Inversion from V_{TR} to V_{SQ}!

Basic Triangular/Square Wave Generator

V_{TR} will toggle between two voltages: $\Delta V_{TR} = V_{TH} - V_{TL} = \left(\frac{R_G}{R_F}\right)(V_{OH} - V_{OL})$

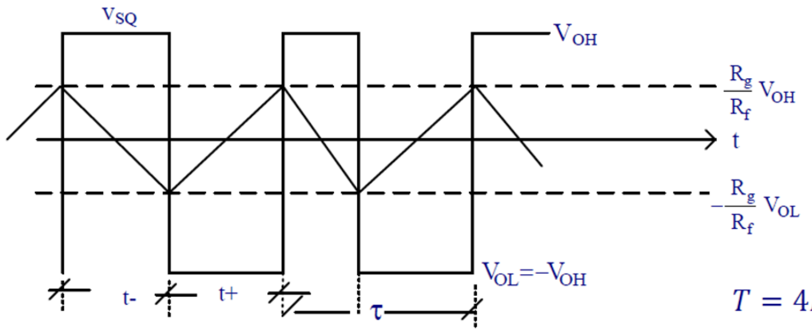
The rise/fall times of the triangular waveform are given by: $\Delta t_{R/F} = \frac{\pm\Delta V_{TR}}{\left(\frac{\delta V_{TR}}{\delta t}\right)} = RC\left(\frac{R_G}{R_F}\right)\frac{\pm(V_{OH} - V_{OL}}{(V_S - V_{OL/H}}$

Assuming symmetrical saturation voltages:

Assuming symmetrical saturation voltages:
$(V_{OH} = -V_{OL} = V_{SAT})$

$$\Delta t_{R/F} = 2RC\left(\frac{R_G}{R_F}\right)\frac{V_{SAT}}{(V_{SAT} \pm V_S)}$$

The oscillation period is: $T = \Delta t_R + \Delta t_F = 4RC\left(\frac{R_G}{R_F}\right)\frac{V_{SAT}^2}{(V_{SAT}^2 - V_S^2)}$



What's the Duty Cycle?

$$D_{TR} = \frac{\Delta t_R}{T} = \frac{1}{2}\left(1 - \frac{V_s}{V_{SAT}}\right)$$

$$D_{SQ} = 1 - D_{TR}$$

What happens If $V_S = 0$?

$$T = 4RC\left(\frac{R_G}{R_F}\right) \qquad D_{TR} = D_{SQ} =$$

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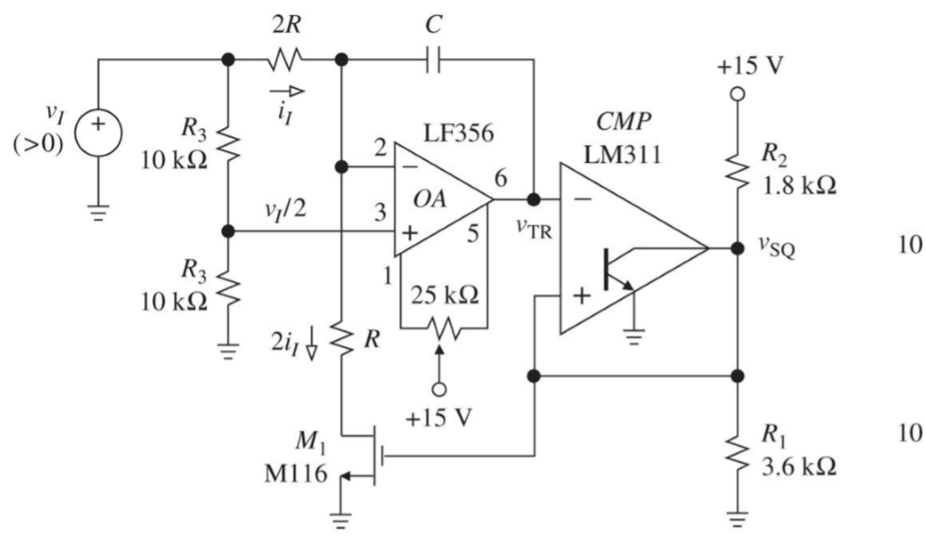

(a)

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10.5 Sawtooth Wave Generators

- Sawtooth cycle generated by charging a capacitor at a consta then rapidly discharging it using a switch

- Circuit can function as current-controlled oscillator (CCO)
  - Common application: electronic music

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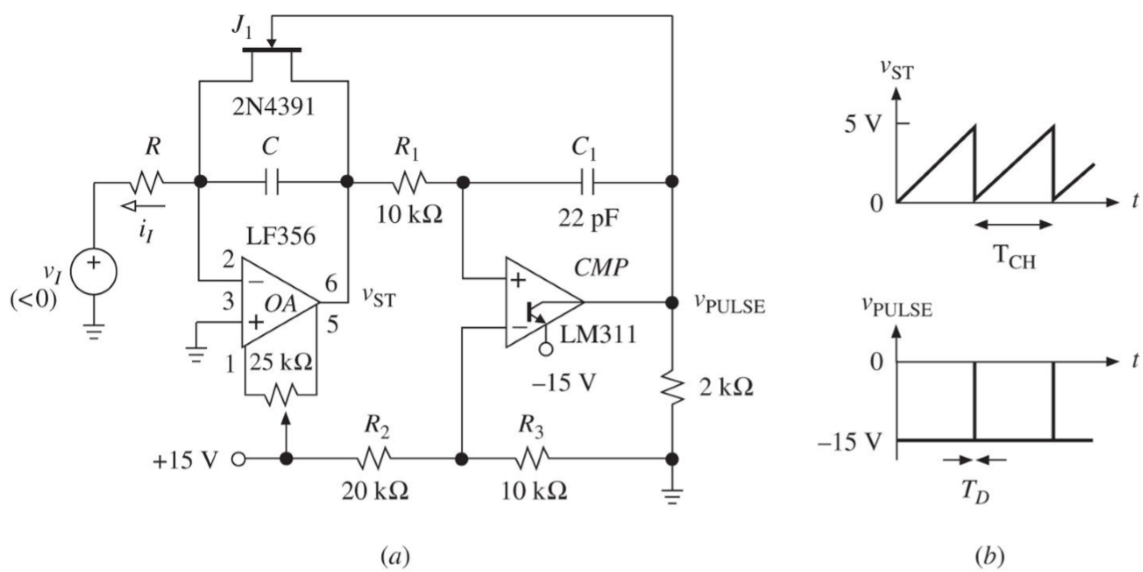
Voltage-controlled triangular/square-wave oscillat



10.6 Monolithic Waveform Generators

- Circuits are designed to provide basic waveforms with the m external components

- Also called function generators
- Waveform generator contains a VCO that generates the trian square waves
  - Sine wave generated from triangular wave by on-chip wave shaper

Monolithic Waveform Generators

- Grounded-capacitor VCOs
  - Charge and discharge a grounded capacitor
    - Rates controlled by programmable current generators
  - Popular products: NE566 function generator and ICL 8038 wavefo
- Emitter-coupled VCOs
  - Popular products: XR2206/07 monolithic function generator and A converter

Monolithic Waveform Generators

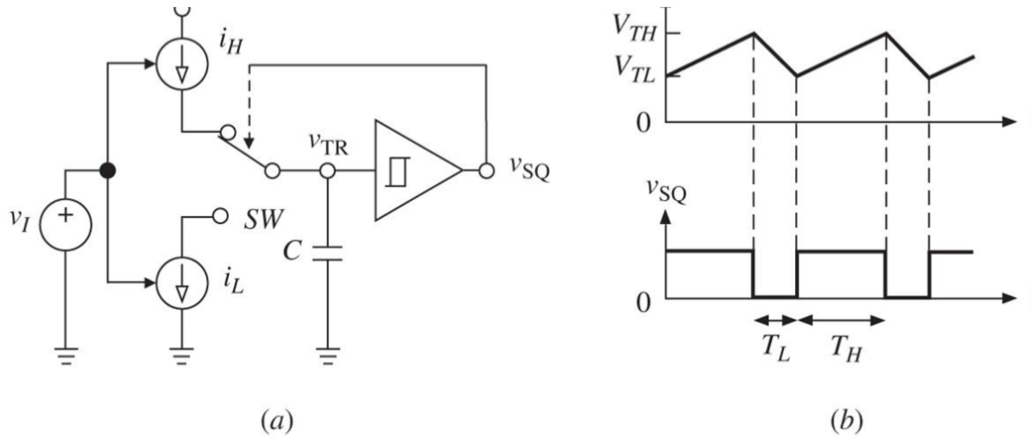


Figure 10.25 Grounded-capacitor VCO

Monolithic Waveform Generators

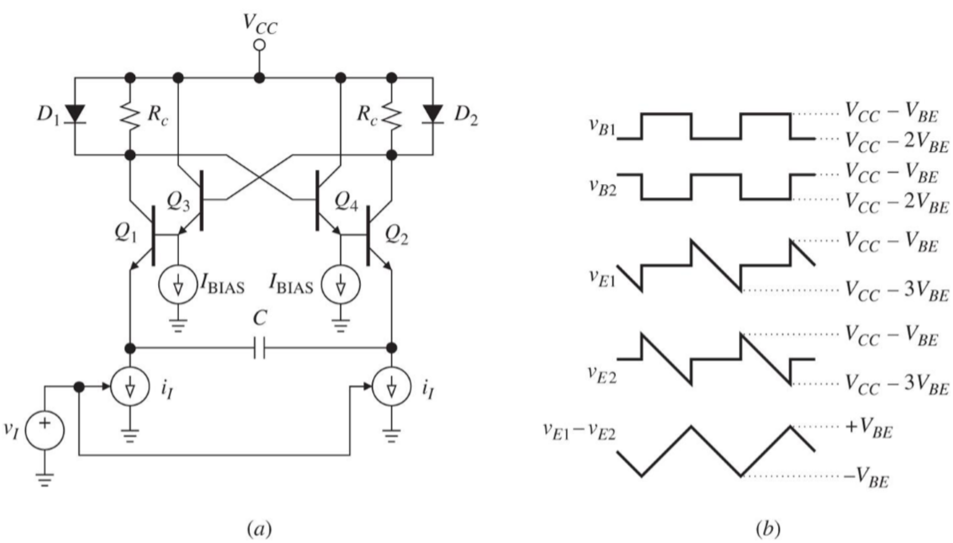


Figure 10.30 Emitter-coupled VCO

10.7 V-F and F-V Converters

- Voltage-to-frequency converter (VFC)

- Accepts analog input
- Generates a pulse train with frequency

$$f_O = kv_I \qquad (10.27)$$

where k is the VFC sensitivity in hertz per volt

- Performance specifications of VFCs
  - Wide dynamic range
  - High frequency operation

V-F and F-V Converters

- Performance specifications of VFCs (cont'd.)
  - Low linearity error
  - High scale-factor accuracy and stability with temperature and suppl
- VFC categories
  - Wide-sweep multivibrators
  - Charge-balancing VFCs

V-F and F-V Converters

- Frequency-to-voltage converter (FVC)

- Accepts a periodic waveform of frequency f_I
- Yields analog output voltage

$$v_O = k f_I$$

where k is the FVC sensitivity in volts per hertz

- Application: tachometers