

LINEAR INTEGRATED CIRCUITS AND APPLICATIONS

UNIT-I

IC FABRICATION

INTEGRATED CIRCUITS

An integrated circuit (IC) is a miniature ,low cost electronic circuit consisting of active and passive components fabricated together on a single crystal of silicon. The active components are transistors and diodes and passive components are resistors and capacitors.

Advantages of integrated circuits

1. Miniaturization and hence increased equipment density.
2. Cost reduction due to batch processing.
3. Increased system reliability due to the elimination of soldered joints.
4. Improved functional performance.
5. Matched devices.
6. Increased operating speeds.
7. Reduction in power consumption

Basic processes involved in fabricating Monolithic ICs

1. Silicon wafer (substrate) preparation
2. Epitaxial growth
3. Oxidation
4. Photolithography
5. Diffusion
6. Ion implantation
7. Isolation technique
8. Metallization
9. Assembly processing & packaging

Silicon wafer (substrate) preparation

1. Crystal growth & doping
2. Ingot trimming & grinding
3. Ingot slicing
4. Wafer polishing & etching
5. Wafer cleaning



Typical wafer

Epitaxial growth

1. Epitaxy means growing a single crystal silicon structure upon a original silicon substrate, so that the resulting layer is an extension of the substrate crystal structure.
2. The basic chemical reaction in the epitaxial growth process of pure silicon is the hydrogen reduction of silicon tetrachloride.



Oxidation

1. SiO_2 is an extremely hard protective coating & is unaffected by almost all reagents except by hydrochloric acid. Thus it stands against any contamination.
2. By selective etching of SiO_2 , diffusion of impurities through carefully defined through windows in the SiO_2 can be accomplished to fabricate various components.

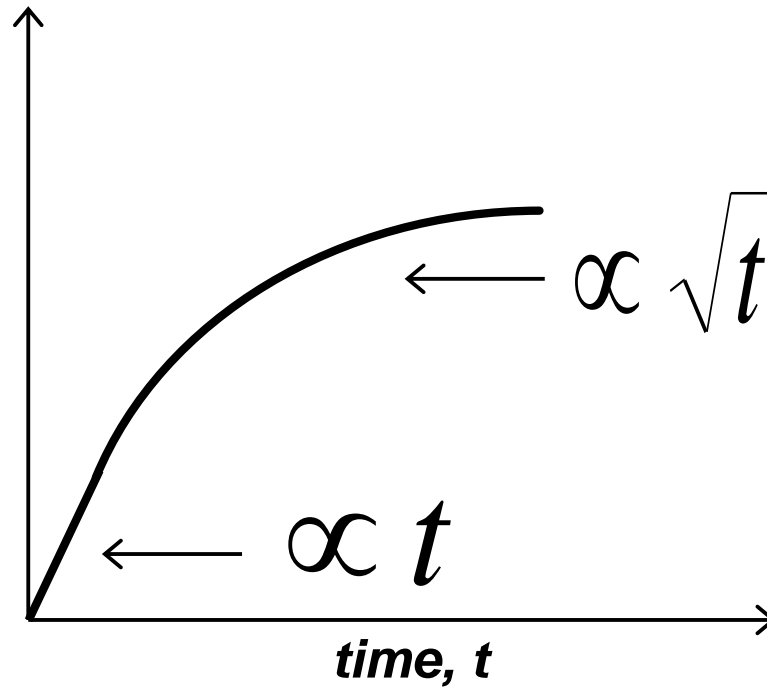
Oxidation

The silicon wafers are stacked up in a quartz boat & then inserted into quartz furnace tube. The Si wafers are raised to a high temperature in the range of 950 to 1150 °C & at the same time, exposed to a gas containing O₂ or H₂O or both. The chemical action is



Oxidation

*oxide
thickness*



Photolithography

The process of photolithography makes it possible to produce microscopically small circuit and device pattern on si wafer

Two processes involved in photolithography

- a) Making a photographic mask
- b) Photo etching

Photographic mask

The development of photographic mask involves the preparation of initial artwork and its diffusion. reduction, decomposition of initial artwork or layout into several mask layers.

Photo etching

Photo etching is used for the removal of SiO_2 from desired regions so that the desired impurities can be diffused

Diffusion

The process of introducing impurities into selected regions of a silicon wafer is called diffusion. The rate at which various impurities diffuse into the silicon will be of the order of $1\mu\text{m/hr}$ at the temperature range of 900°C to 1100°C . The impurity atoms have the tendency to move from regions of higher concentrations to lower concentrations.

Ion implantation technique

1. It is performed at low temperature. Therefore, previously diffused regions have a lesser tendency for lateral spreading.
2. In diffusion process, temperature has to be controlled over a large area inside the oven, where as in ion implantation process, accelerating potential & beam content are dielectrically controlled from outside.

Dielectric isolation

In dielectric isolation, a layer of solid dielectric such as SiO_2 or ruby completely surrounds each component thereby producing isolation, both electrical & physical. This isolating dielectric layer is thick enough so that its associated capacitance is negligible. Also, it is possible to fabricate both pnp & npn transistors within the same silicon substrate.

Metallization

The process of producing a thin metal film layer that will serve to make interconnection of the various components on the chip is called metallization.

Aluminium is preferred for metallization

1. It is a good conductor
2. it is easy to deposit aluminium films using vacuum deposition.
3. It makes good mechanical bonds with silicon
4. It forms a low resistance contact

IC packages available

1. Metal can package.
2. Dual-in-line package.
3. Ceramic flat package.

UNIT-II

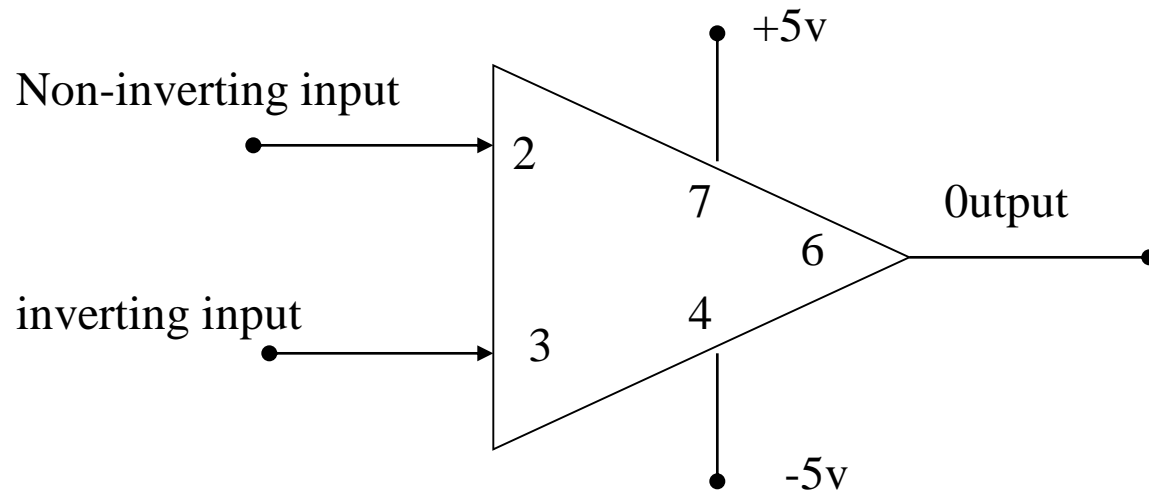
Characteristics of Op-Amp

OPERATION AMPLIFIER

An operational amplifier is a direct coupled high gain amplifier consisting of one or more differential amplifiers, followed by a level translator and an output stage.

It is a versatile device that can be used to amplify ac as well as dc input signals & designed for computing mathematical functions such as addition, subtraction, multiplication, integration & differentiation

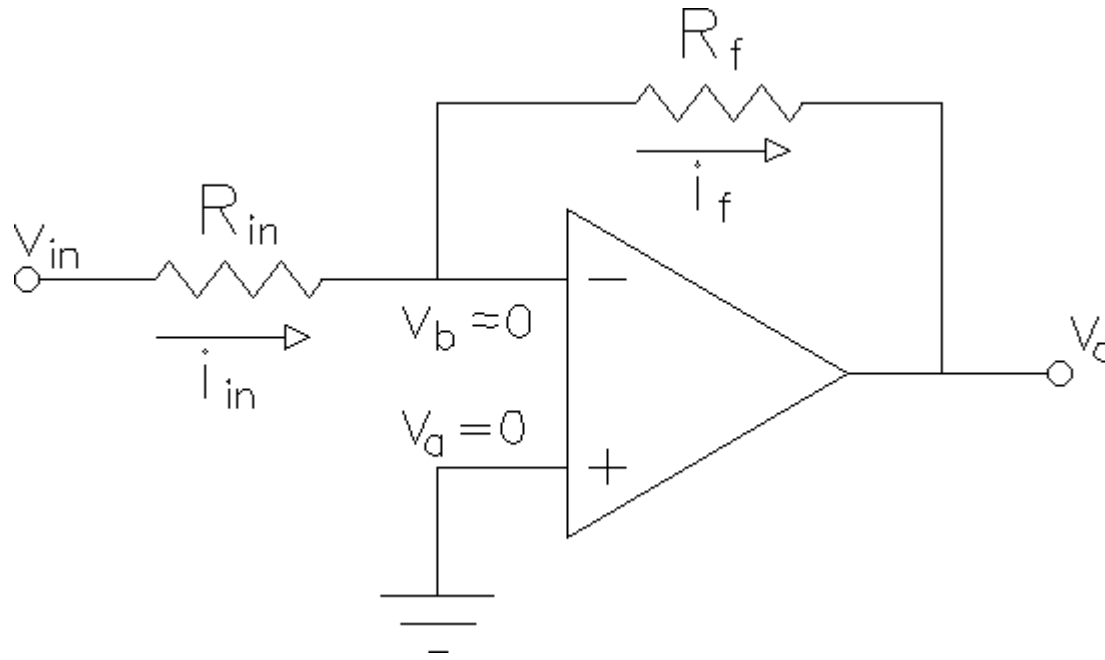
Op-amp symbol



Ideal characteristics of OPAMP

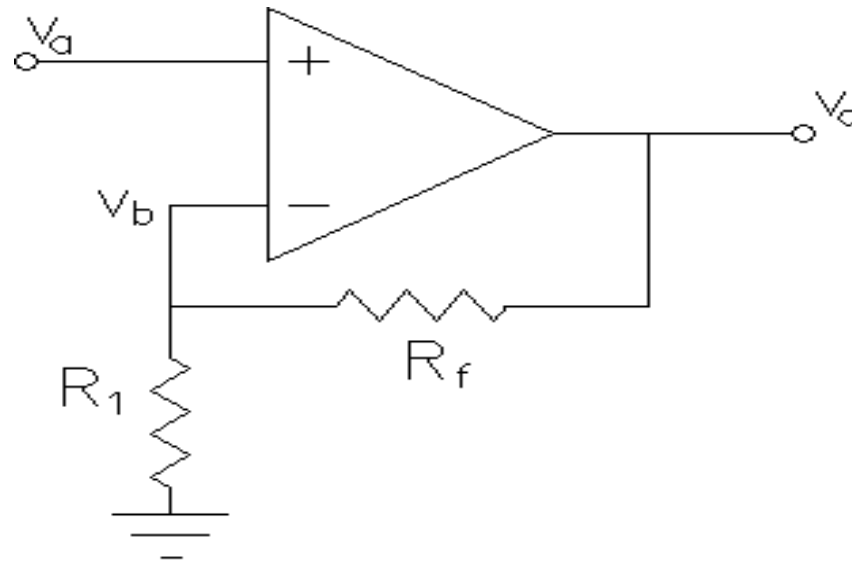
1. Open loop gain infinite
2. Input impedance infinite
3. Output impedance low
4. Bandwidth infinite
5. Zero offset, ie, $V_o=0$ when $V_1=V_2=0$

Inverting Op-Amp



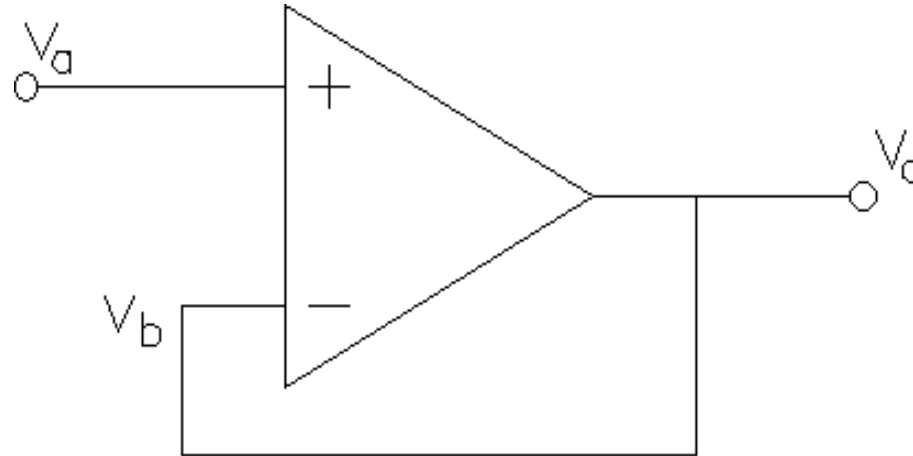
$$V_{OUT} = -V_{IN} \frac{R_f}{R_1}$$

Non-Inverting Amplifier



$$V_{OUT} = V_{IN} \left(1 + \frac{R_1}{R_2} \right)$$

Voltage follower



$$V_{OUT} = V_{IN}$$

DC characteristics

Input offset current

The difference between the bias currents at the input terminals of the op- amp is called as input offset current. The input terminals conduct a small value of dc current to bias the input transistors. Since the input transistors cannot be made identical, there exists a difference in bias currents

DC characteristics

Input offset voltage

A small voltage applied to the input terminals to make the output voltage as zero when the two input terminals are grounded is called input offset voltage

DC characteristics

Input offset voltage

A small voltage applied to the input terminals to make the output voltage as zero when the two input terminals are grounded is called input offset voltage

DC characteristics

Input bias current

Input bias current I_B as the average value of the base currents entering into terminal of an op-amp

$$I_B = \frac{I_{B^+} + I_{B^-}}{2}$$

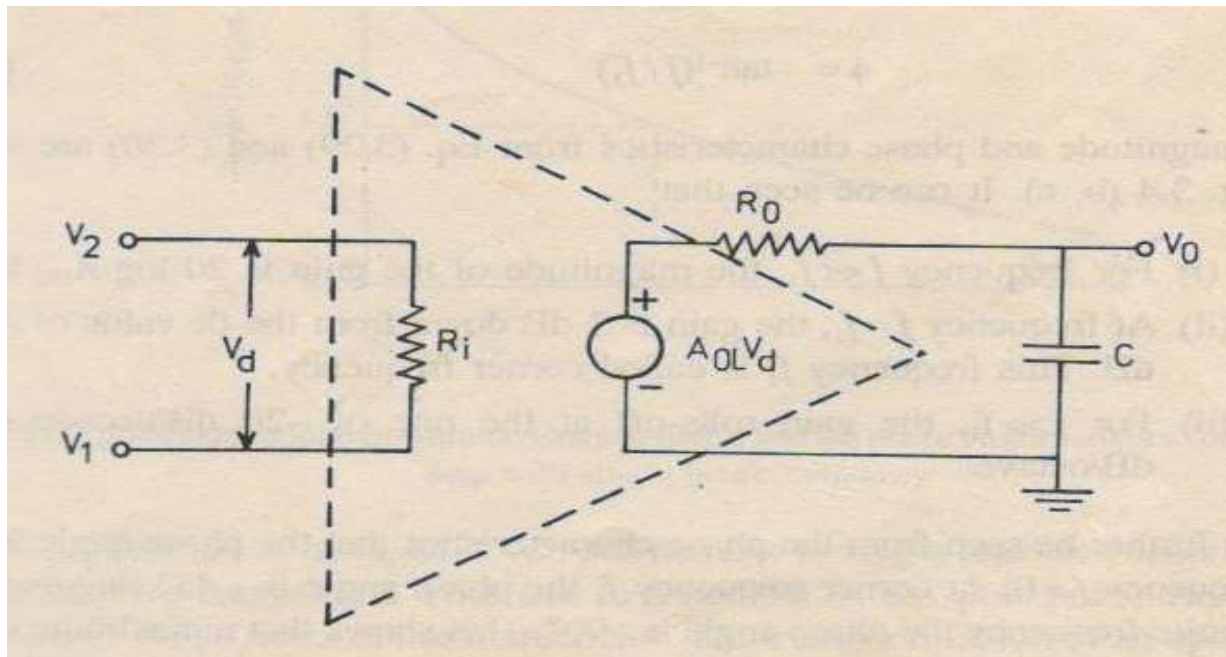
DC characteristics

THERMAL DRIFT

Bias current, offset current and offset voltage change with temperature. A circuit carefully nulled at 25°C may not remain so when the temperature rises to 35°C. This is called drift.

AC characteristics

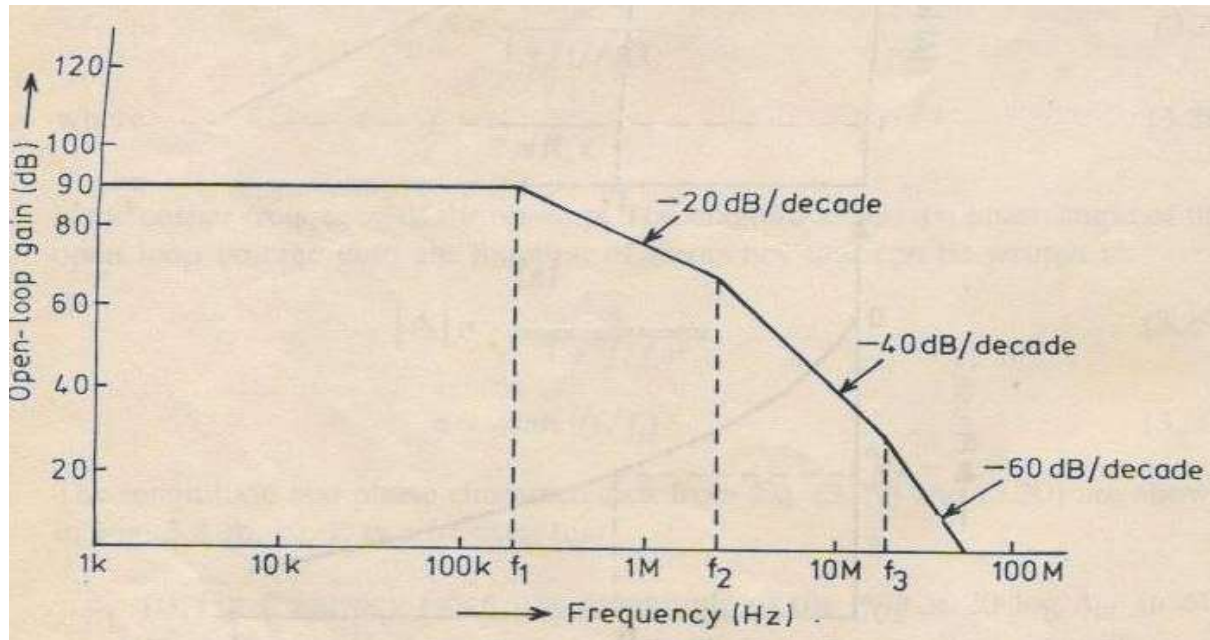
Frequency Response



HIGH FREQUENCY MODEL OF OPAMP

AC characteristics

Frequency Response



OPEN LOOP GAIN VS FREQUENCY

Need for frequency compensation in practical op-amps

- Frequency compensation is needed when large bandwidth and lower closed loop gain is desired.
- Compensating networks are used to control the phase shift and hence to improve the stability

Frequency compensation methods

- Dominant- pole compensation
- Pole- zero compensation

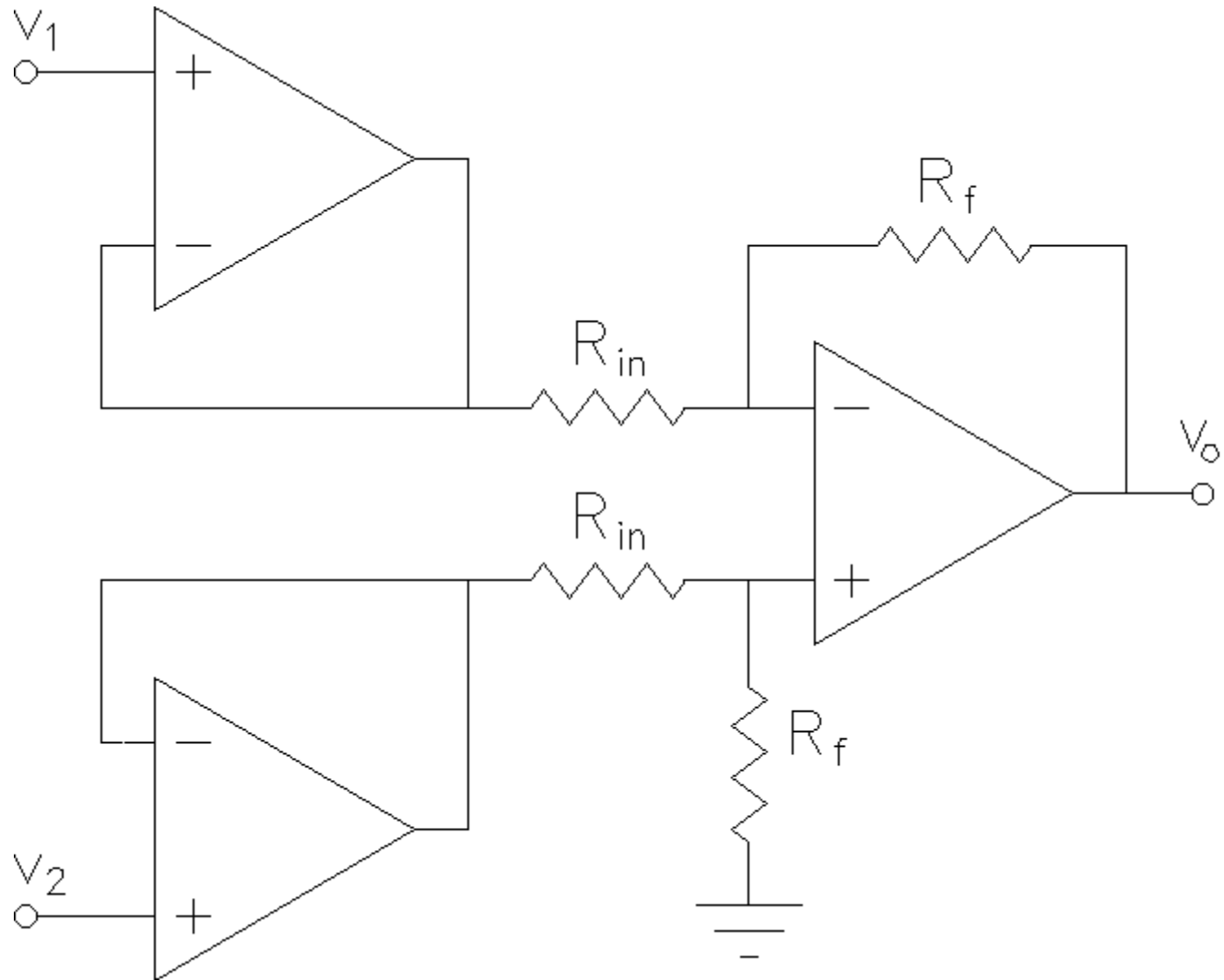
Slew Rate

- The slew rate is defined as the maximum rate of change of output voltage caused by a step input voltage.
- An ideal slew rate is infinite which means that op-amp's output voltage should change instantaneously in response to input step voltage

UNIT-III

Applications of Op Amp

Instrumentation Amplifier



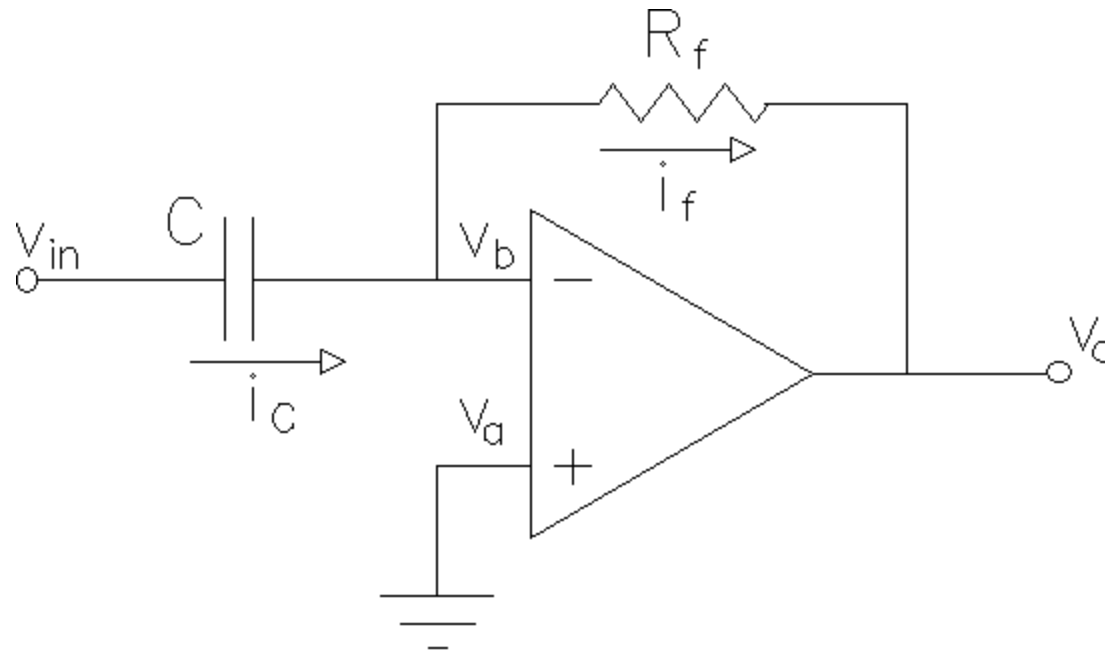
Instrumentation Amplifier

In a number of industrial and consumer applications, the measurement of physical quantities is usually done with the help of transducers. The output of transducer has to be amplified So that it can drive the indicator or display system. This function is performed by an instrumentation amplifier

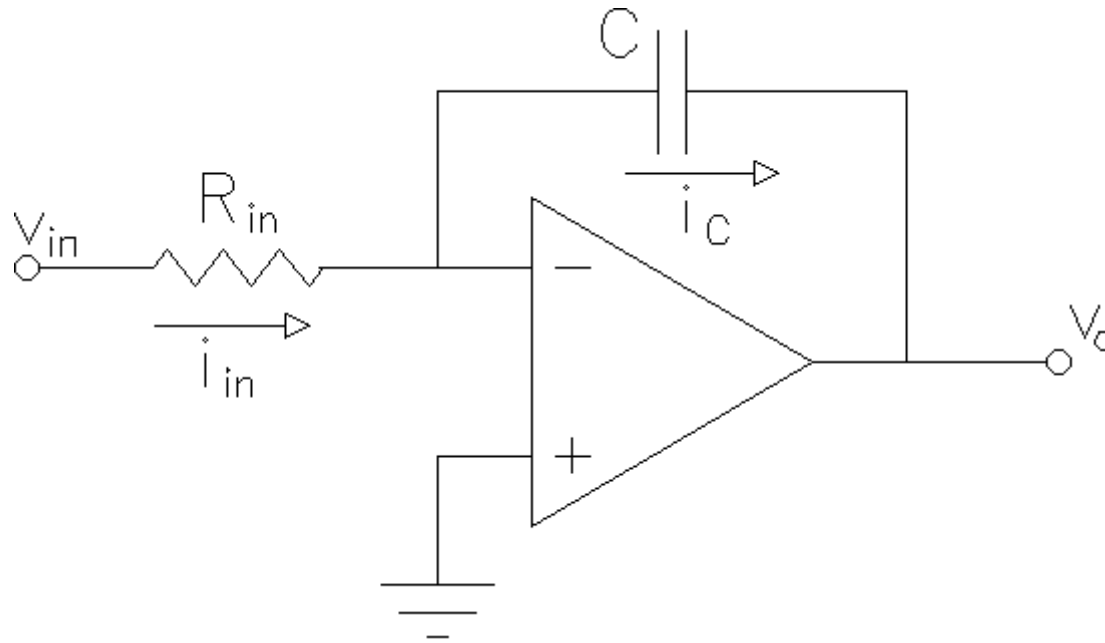
Features of instrumentation amplifier

1. high gain accuracy
2. high CMRR
3. high gain stability with low temperature coefficient
4. low dc offset
5. low output impedance

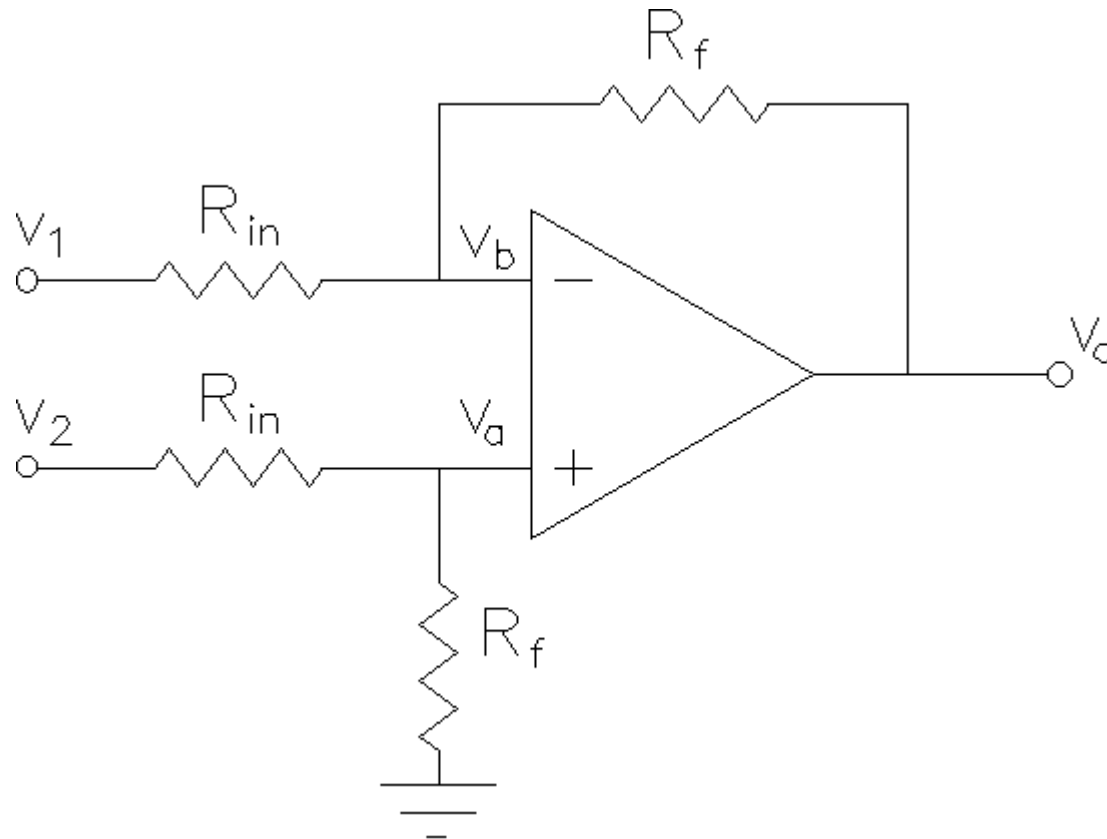
Differentiator



Integrator



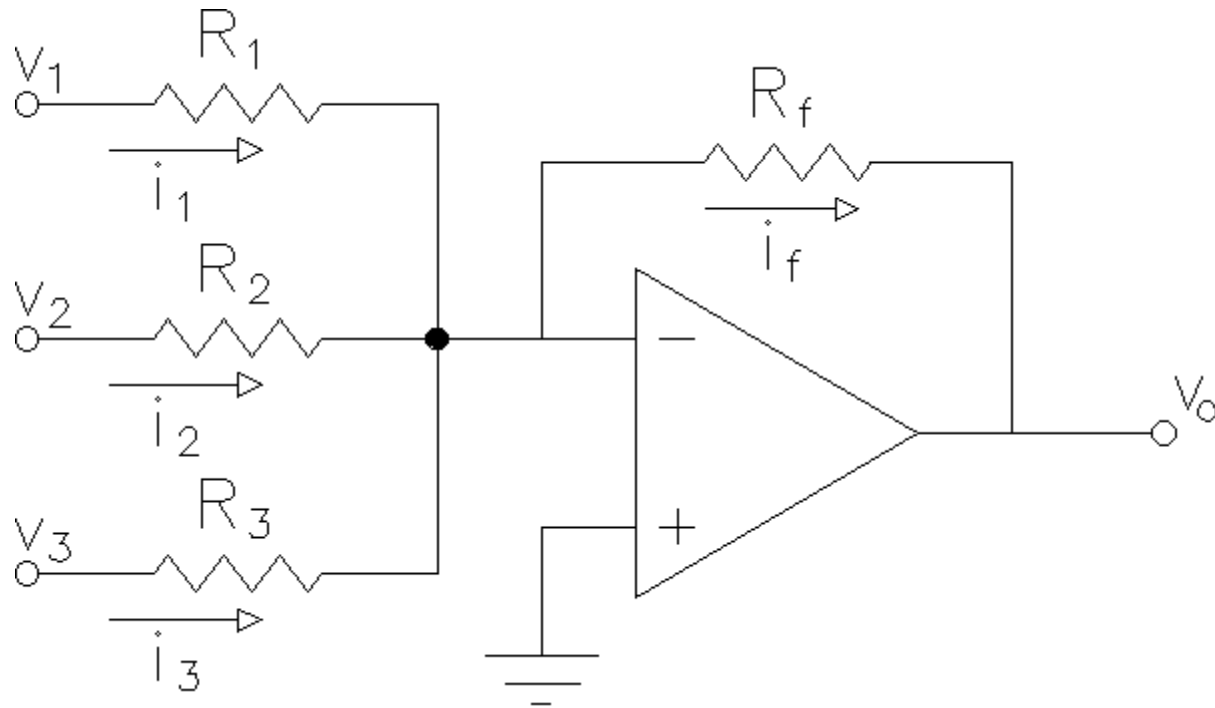
Differential amplifier



Differential amplifier

This circuit amplifies only the difference between the two inputs. In this circuit there are two resistors labeled R_{IN} Which means that their values are equal. The differential amplifier amplifies the difference of two inputs while the differentiator amplifies the slope of an input

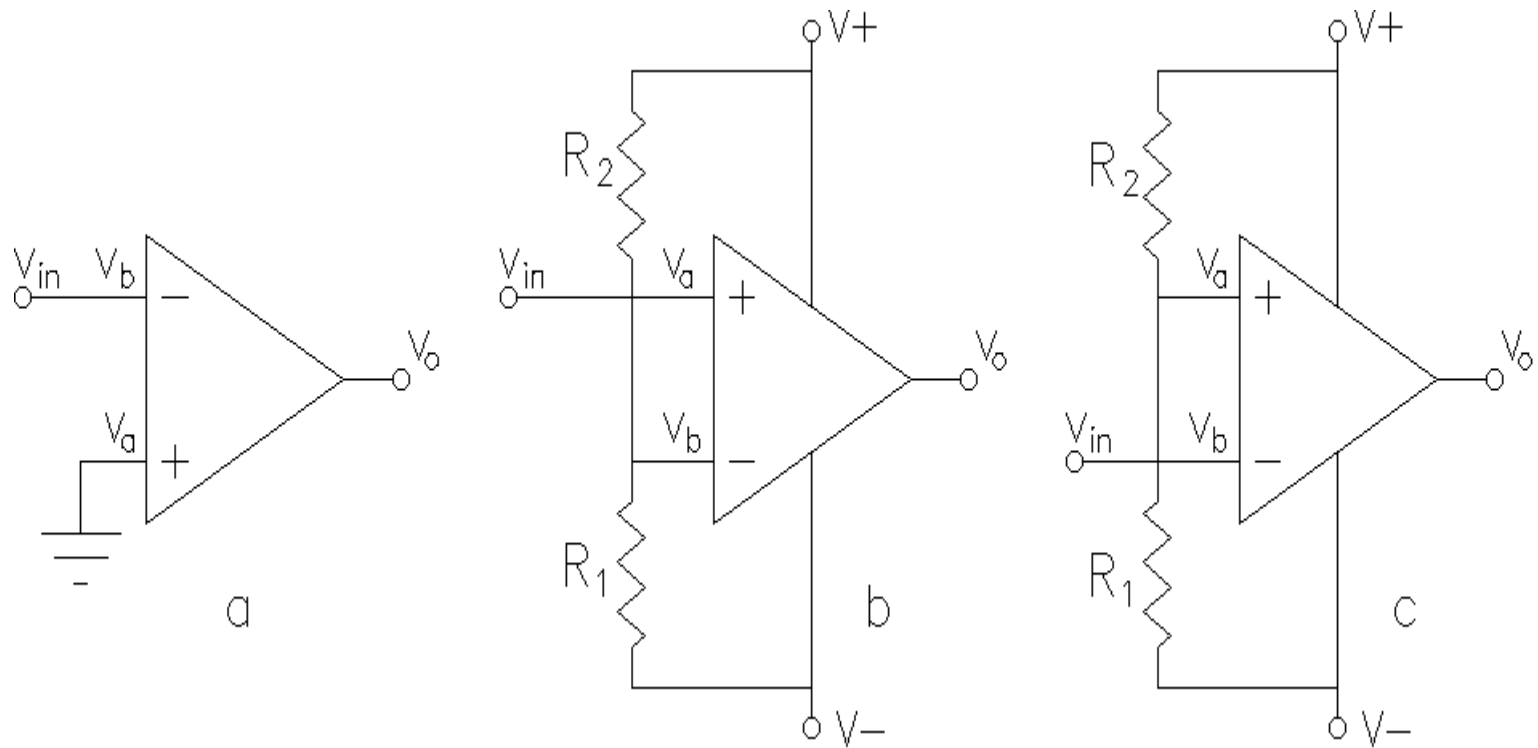
Summer



Comparator

A comparator is a circuit which compares a signal voltage applied at one input of an op- amp with a known reference voltage at the other input. It is an open loop op - amp with output + V_{sat}

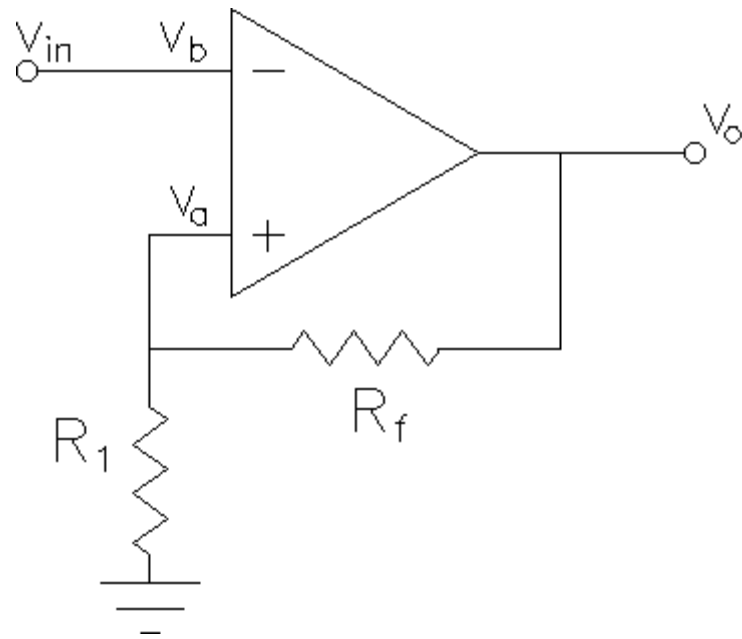
Comparator



Applications of comparator

1. Zero crossing detector
2. Window detector
3. Time marker generator
4. Phase detector

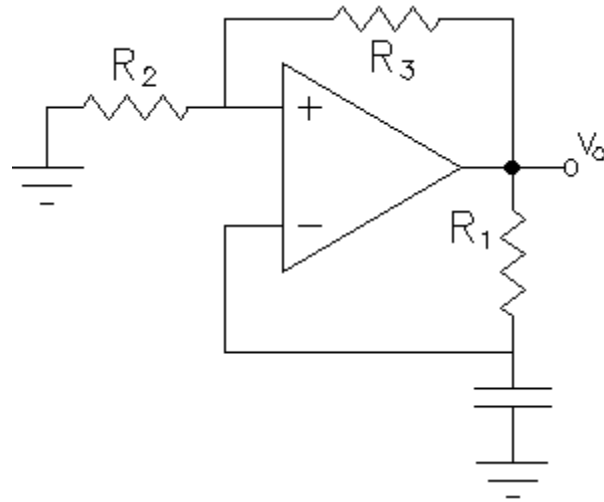
Schmitt trigger



Schmitt trigger

Schmitt trigger is a regenerative comparator. It converts sinusoidal input into a square wave output. The output of Schmitt trigger swings between upper and lower threshold voltages, which are the reference voltages of the input waveform

square wave generator



Multivibrator

Multivibrators are a group of regenerative circuits that are used extensively in timing applications. It is a wave shaping circuit which gives symmetric or asymmetric square output. It has two states either stable or quasi- stable depending on the type of multivibrator

Monostable multivibrator

Monostable multivibrator is one which generates a single pulse of specified duration in response to each external trigger signal. It has only one stable state. Application of a trigger causes a change to the quasi-stable state. An external trigger signal generated due to charging and discharging of the capacitor produces the transition to the original stable state

Astable multivibrator

Astable multivibrator is a free running oscillator having two quasi-stable states. Thus, there is oscillations between these two states and no external signal are required to produce the change in state

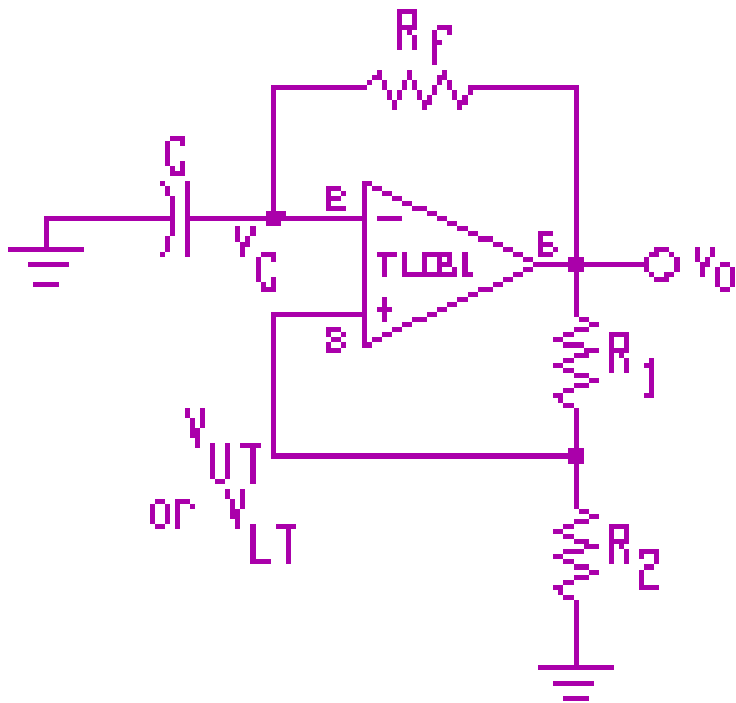
Astable multivibrator

Bistable multivibrator is one that maintains a given output voltage level unless an external trigger is applied . Application of an external trigger signal causes a change of state, and this output level is maintained indefinitely until an second trigger is applied . Thus, it requires two external triggers before it returns to its initial state

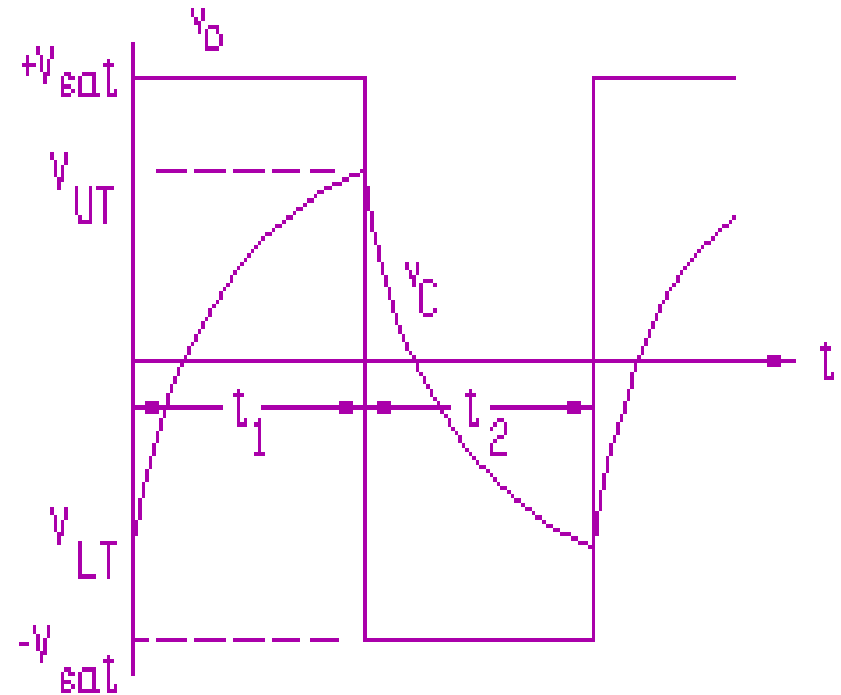
Bistable multivibrator

Bistable multivibrator is one that maintains a given output voltage level unless an external trigger is applied . Application of an external trigger signal causes a change of state, and this output level is maintained indefinitely until an second trigger is applied . Thus, it requires two external triggers before it returns to its initial state

Astable Multivibrator or Relaxation Oscillator



Circuit



Output waveform

Equations for Astable Multivibrator

$$V_{UT} = \frac{+V_{sat}R_2}{R_1 + R_2}; \quad V_{LT} = \frac{-V_{sat}R_2}{R_1 + R_2}$$

Assuming $|+V_{sat}| = |-V_{sat}|$

$$T = t_1 + t_2 = 2\tau \ln \left(\frac{R_1 + 2R_2}{R_1} \right) \quad \text{where } \tau = R_f C$$

If R_2 is chosen to be $0.86R_1$, then $T = 2R_f C$ and

$$f = \frac{1}{2R_f C}$$

Notes on Monostable Multivibrator

- **Stable state:** $v_o = +V_{sat}$, $V_C = 0.6 \text{ V}$
- **Transition to timing state:** apply a -ve input pulse such that $|V_{ip}| > |V_{UT}|$; $v_o = -V_{sat}$. Best to select $R_i C_i \ll 0.1 R_f C$.
- **Timing state:** C charges r through R_f . Width of timir $t_p = R_f C \ln \left(\frac{|V_{sat}| + 0.6}{|V_{sat}| + V_{LT}} \right)$
 - ▶ If we pick $R_2 = R_1/5$, then $t_p = R_f C/5$.
 - ▶ **Recovery state:** $v_o = +V_{sat}$; circuit is not ready for retriggering until $V_C = 0.6 \text{ V}$. The *recovery time* t_p . To speed up the recovery time, $R_D (= 0.1 R_f)$ & C_D can be added.

Filter

Filter is a frequency selective circuit that passes signal of specified Band of frequencies and attenuates the signals of frequencies outside the band

Type of Filter

1. Passive filters
2. Active filters

Passive filters

Passive filters works well for high frequencies. But at audio frequencies, the inductors become problematic, as they become large, heavy and expensive. For low frequency applications, more number of turns of wire must be used which in turn adds to the series resistance degrading inductor's performance ie, low Q, resulting in high power dissipation

Active filters

Active filters used op-amp as the active element and resistors and capacitors as passive elements. By enclosing a capacitor in the feed back loop, inductor less active filters can be obtained

some commonly used active filters

1. Low pass filter
2. High pass filter
3. Band pass filter
4. Band reject filter

Active Filters

- Active filters use op-amp(s) and RC components.
- Advantages over passive filters:
 - op-amp(s) provide gain and overcome circuit losses
 - increase input impedance to minimize circuit loading
 - higher output power
 - sharp cutoff characteristics can be produced simply and efficiently without bulky inductors
- Single-chip universal filters (e.g. switched-capacitor ones) are available that can be configured for any type of filter or response.

Review of Filter Types & Responses

- 4 major types of filters: low-pass, high-pass, band pass, and band-reject or band-stop
- 0 dB attenuation in the pass band (usually)
- 3 dB attenuation at the *critical* or *cutoff frequency*, f_c (for Butterworth filter)
- Roll-off at 20 dB/dec (or 6 dB/oct) per *pole* outside the passband (# of poles = # of reactive elements).

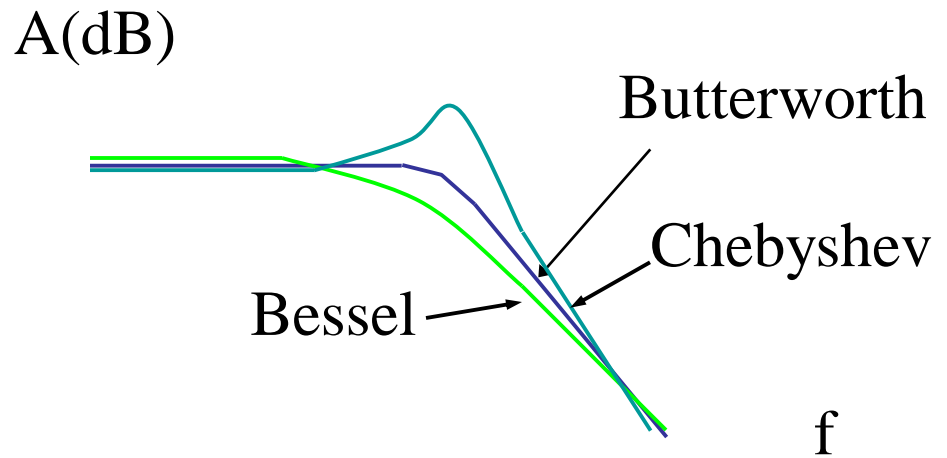
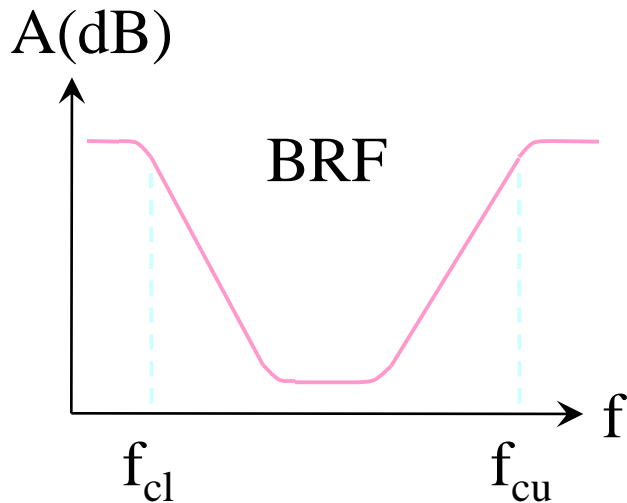
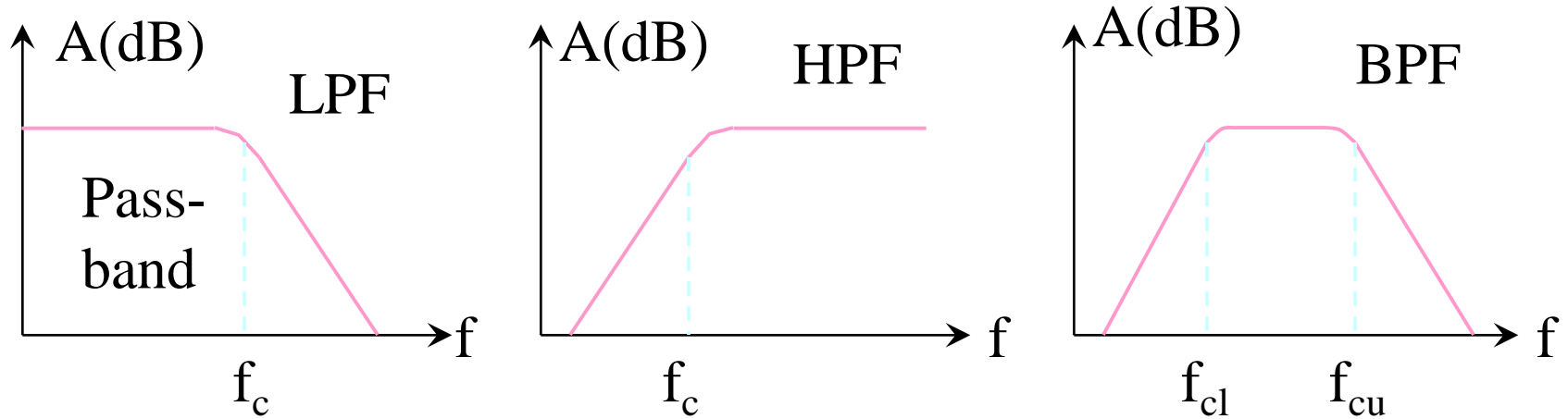
Attenuation at any frequency, f , is:

$$atten.(dB) at f = \log\left(\frac{f}{f_c}\right) \times atten.(dB) at f_{dec}$$

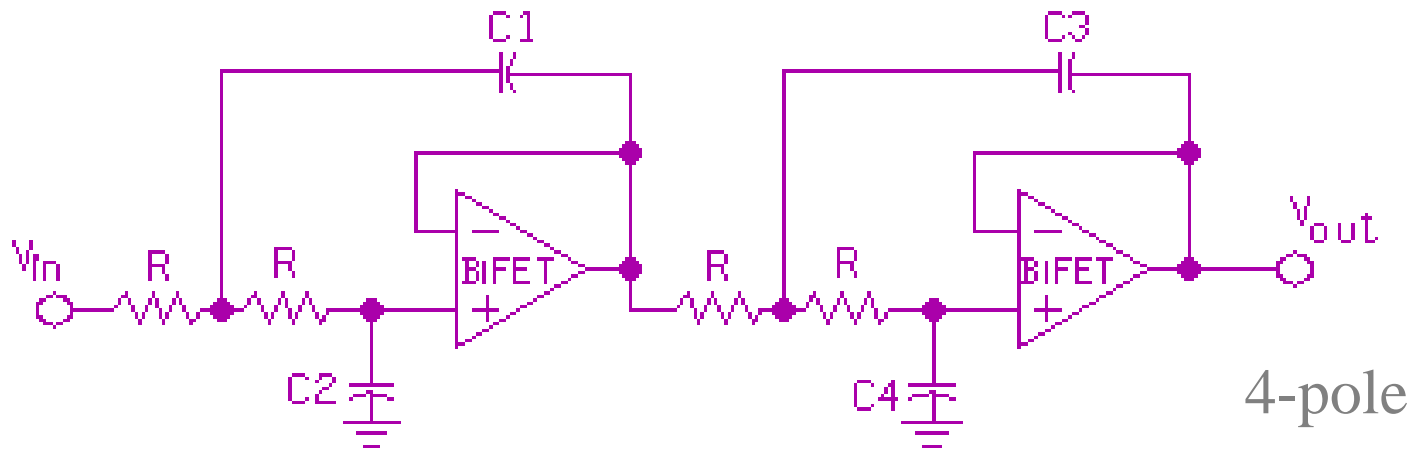
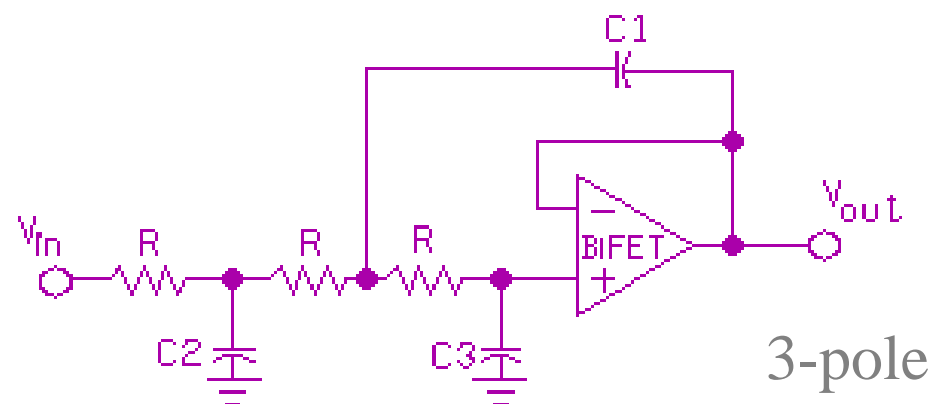
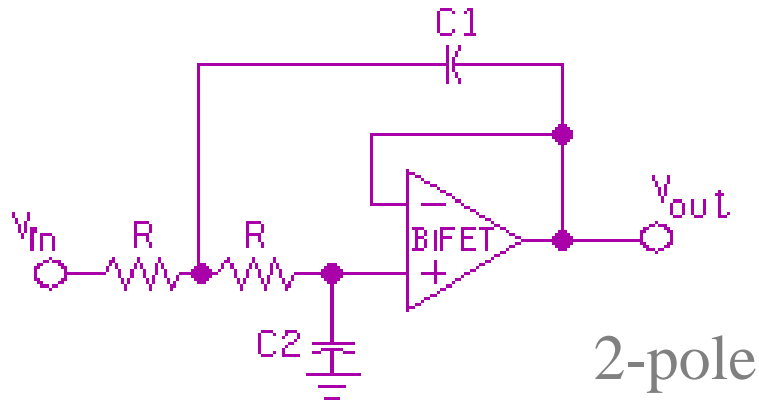
Review of Filters (cont'd)

- Bandwidth of a filter: $BW = f_{cu} - f_{cl}$
- Phase shift: $45^\circ/\text{pole}$ at f_c ; $90^\circ/\text{pole}$ at $\gg f_c$
- 4 types of filter responses are commonly used:
 - Butterworth - maximally flat in passband; highly non-linear phase response with frequency
 - Bessel - gentle roll-off; linear phase shift with freq.
 - Chebyshev - steep initial roll-off with ripples in passband
 - Cauer (or elliptic) - steepest roll-off of the four types but has ripples in the passband and in the stop band

Frequency Response of Filters



Unity-Gain Low-Pass Filter Circuits



Design Procedure for Unity-Gain LPF

- ★ Determine/select number of poles required.
- ★ Calculate the frequency scaling constant, $K_f = 2\pi f$
- ★ Divide normalized C values (from table) by K_f to obtain frequency-scaled C values.
- ★ Select a desired value for one of the frequency-scaled C values and calculate the impedance scaling factor:

$$K_x = \frac{\text{frequency - scaled C value}}{\text{desired C value}}$$

- ⊞ Divide all frequency-scaled C values by K_x
- ⊞ Set $R = K_x \Omega$

An Example

Design a unity-gain LP Butterworth filter with a critical frequency of 5 kHz and an attenuation of at least 38 dB at 15 kHz.

The attenuation at 15 kHz is 38 dB

⑧ the attenuation at 1 decade (50 kHz) = 79.64 dB.

We require a filter with a roll-off of at least 4 poles.

$K_f = 31,416$ rad/s. Let's pick $C_1 = 0.01 \mu\text{F}$ (or 10 nF). Then

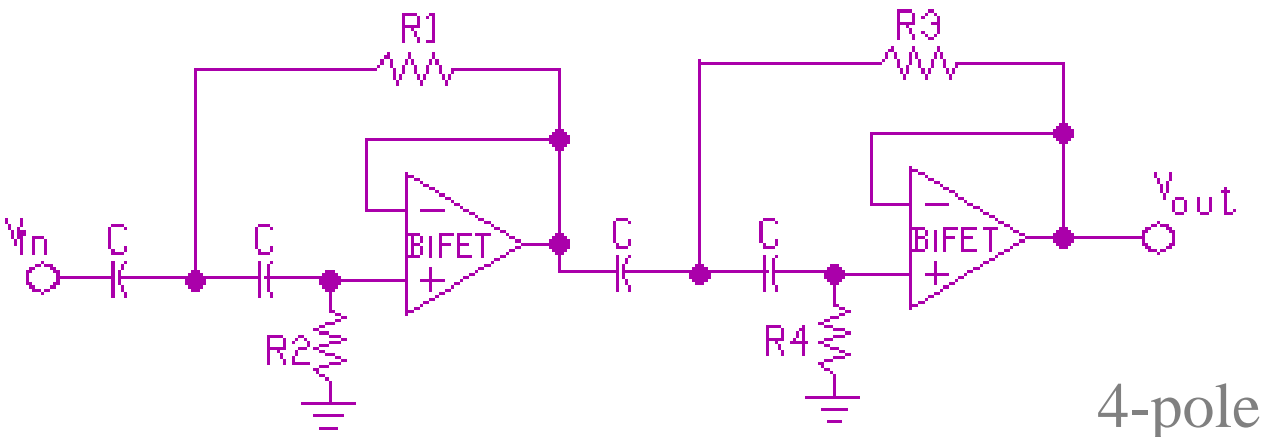
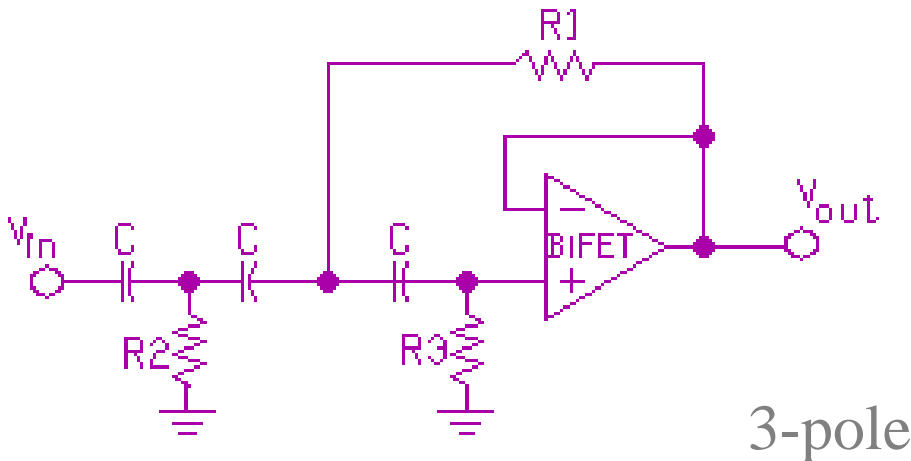
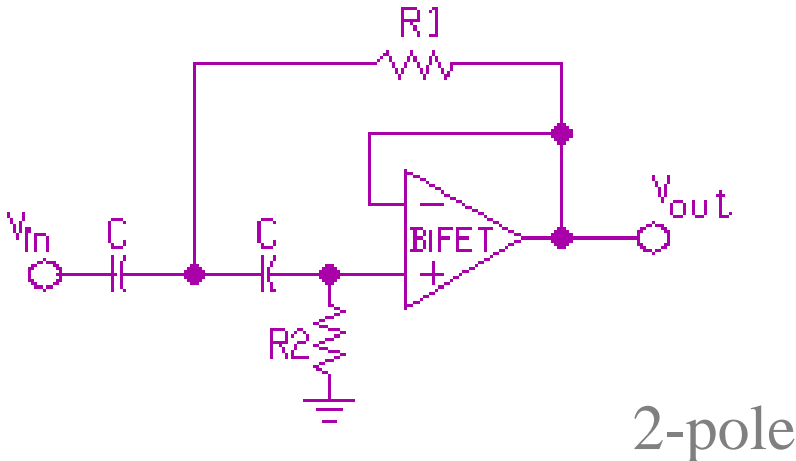
$C_2 = 8.54$ nF, $C_3 = 24.15$ nF, and $C_4 = 3.53$ nF.

Pick standard values of 8.2 nF, 22 nF, and 3.3 nF.

$K_x = 3,444$

Make all $R = 3.6$ k Ω (standard value)

Unity-Gain High-Pass Filter Circuits

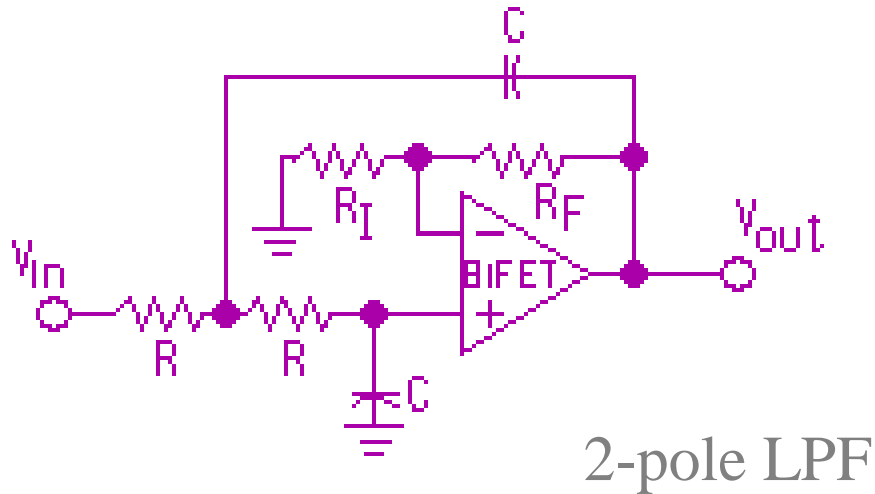


Design Procedure for Unity-Gain HPF

- The same procedure as for LP filters is used except for step #3, the normalized C value of 1 F is divided by K_f . Then pick a desired value for C, such as 0.001 μF to 0.1 μF , to calculate K_x . (Note that all capacitors have the same value).
- For step #6, multiply all normalized R values (from table) by K_x .

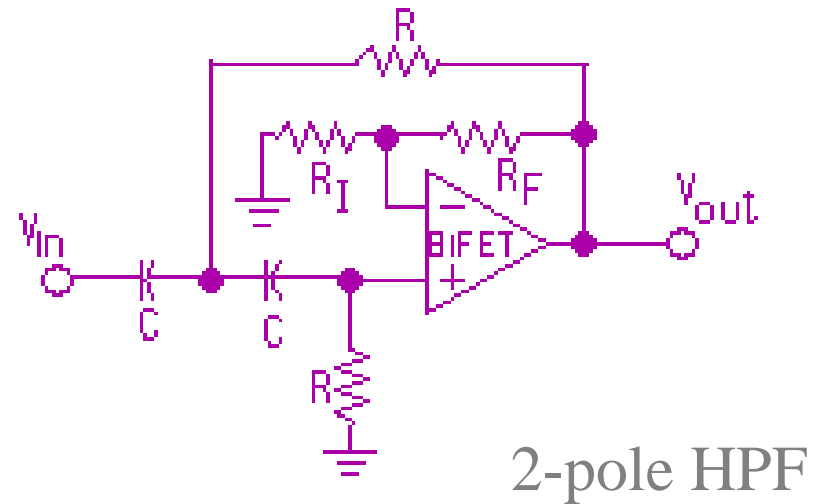
E.g. Design a unity-gain Butterworth HPF with a critical frequency of 1 kHz, and a roll-off of 55 dB/dec. (Ans.: $C = 0.01 \mu\text{F}$, $R_1 = 4.49 \text{ k}\Omega$, $R_2 = 11.43 \text{ k}\Omega$, $R_3 = 78.64 \text{ k}\Omega$.; pick standard values of 4.3 $\text{k}\Omega$, 11 $\text{k}\Omega$, and 75 $\text{k}\Omega$).

Equal-Component Filter Design



Same value R & same value C are used in filter.

Select C (e.g. 0.01 μF), then:



A_v for # of poles is given in a table and is the same for LP and HP filter design.

$$A_v = \frac{R_F}{R_I} + 1$$

Example

Design an equal-component LPF with a critical frequency of 3 kHz and a roll-off of 20 dB/oct.

Minimum # of poles = 4

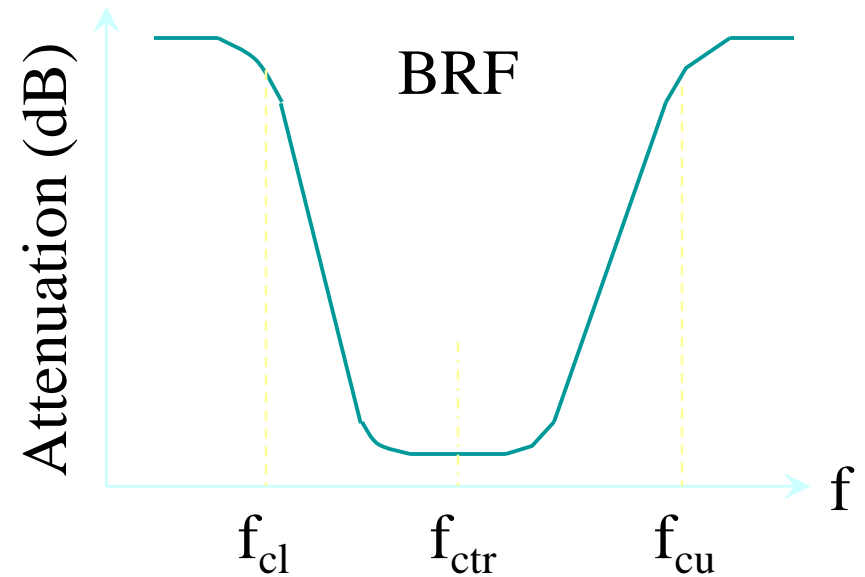
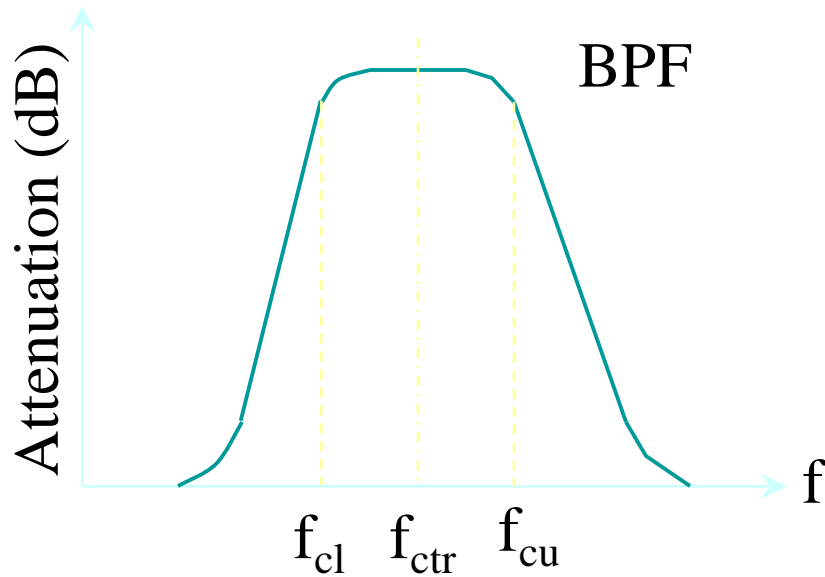
Choose $C = 0.01 \mu\text{F}$; $\textcircled{8} R = 5.3 \text{ k}\Omega$

From table, $A_{v1} = 1.1523$, and $A_{v2} = 2.2346$.

Choose $R_{I1} = R_{I2} = 10 \text{ k}\Omega$; then $R_{F1} = 1.5 \text{ k}\Omega$, and $R_{F2} = 12.3 \text{ k}\Omega$.

Select standard values: 5.1 k Ω , 1.5 k Ω , and 12 k Ω .

Bandpass and Band-Rejection Filter



The **quality factor**, Q , of a filter is given by:

where $BW = f_{cu} - f_{cl}$ and

$$Q = \frac{f_{ctr}}{BW}$$

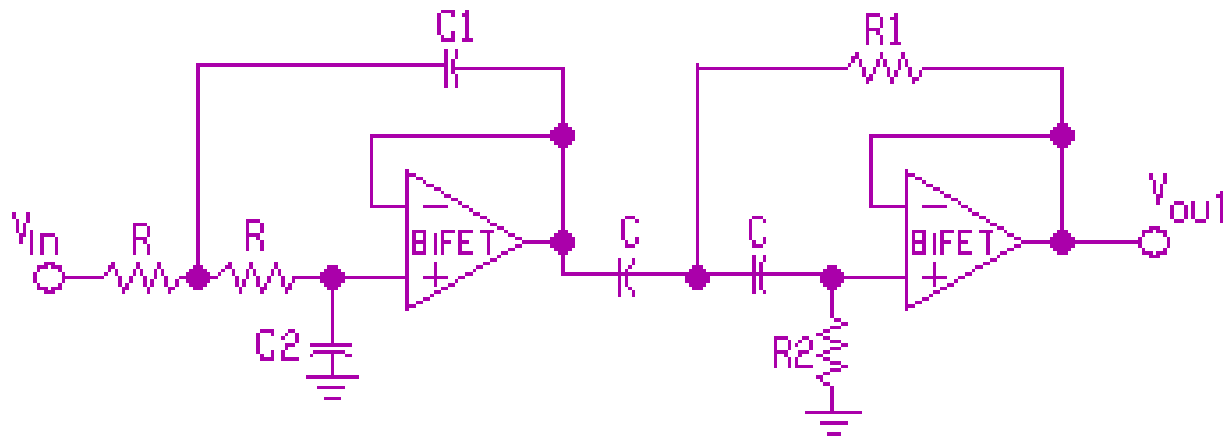
$$f_{ctr} = \sqrt{f_{cu} f_{cl}}$$

More On Bandpass Filter

If BW and f_{centre} are given, then:

$$f_{cl} = \sqrt{\frac{BW^2}{4} + f_{ctr}^2} - \frac{BW}{2} ; f_{cu} = \sqrt{\frac{BW^2}{4} + f_{ctr}^2} + \frac{BW}{2}$$

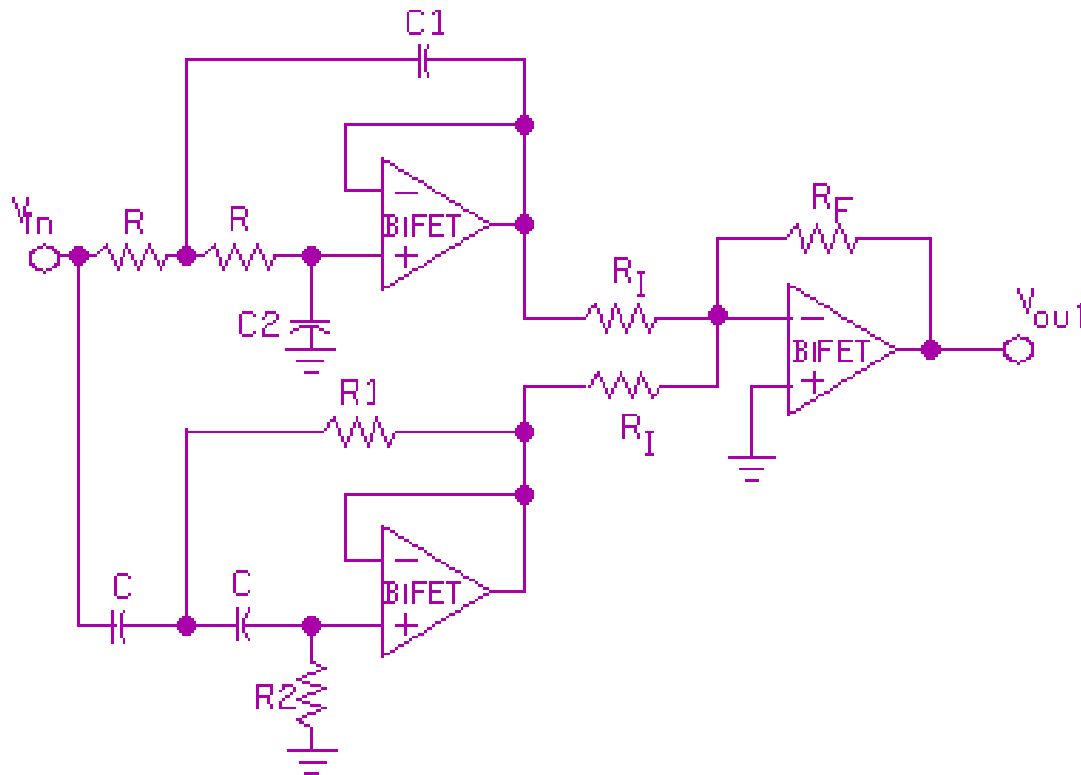
A *broadband* BPF can be obtained by combining a LPF and a HPF:



The Q of this filter is usually > 1 .

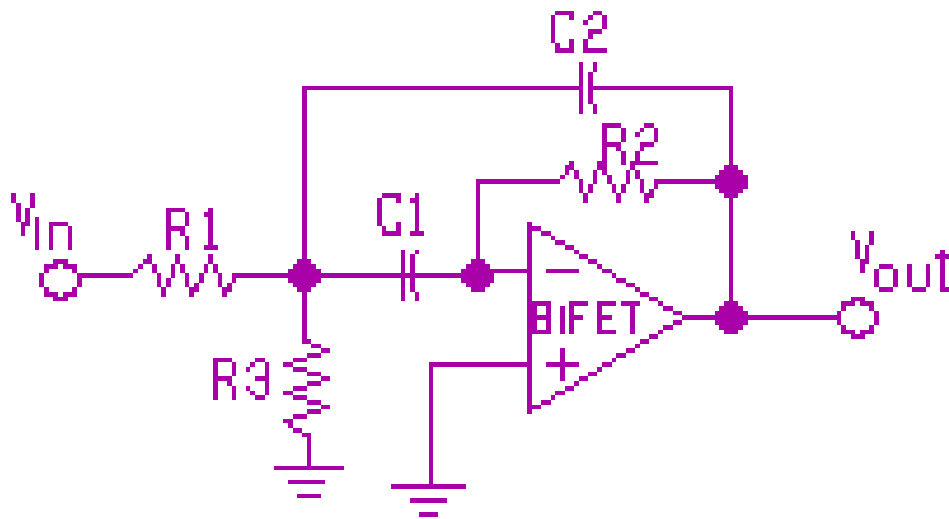
Broadband Band-Reject Filter

A LPF and a HPF can also be combined to give a broadband BRF:



2-pole band-reject filter

Narrow-band Bandpass Filter



$$BW = \frac{f_{ctr}}{Q} = \frac{1}{2\pi R_1 C}$$

$$C1 = C2 = C$$

$$R_2 = 2 R_1$$

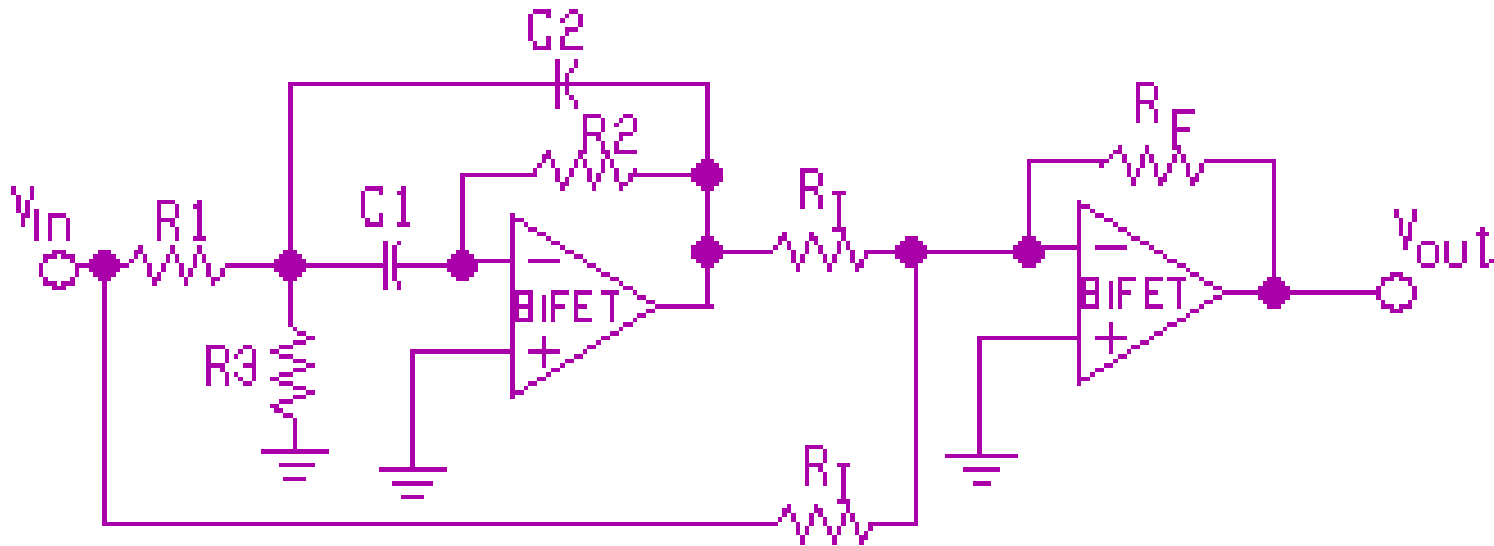
$$R_3 = \frac{R_1}{2Q^2 - 1}$$

$$f_{ctr} = \frac{1}{2\sqrt{2}\pi R_1 C} \sqrt{1 + \frac{R_1}{R_3}}$$

R_3 can be adjusted or trimmed to change f_{ctr} without affecting the BW. Note that $Q < 1$.

Narrow-band Band-Reject Filter

Easily obtained by combining the inverting output of a narrow-band BRF and the original signal:



The equations for R_1 , R_2 , R_3 , C_1 , and C_2 are the same as before. $R_I = R_F$ for unity gain and is often chosen to be $\gg R_1$.

Classification of ADCs

1. Direct type ADC.
2. Integrating type ADC

Direct type ADCs

1. Flash (comparator) type converter
2. Counter type converter
3. Tracking or servo converter.
4. Successive approximation type converter

Integrating type converters

An ADC converter that perform conversion in an indirect manner by first changing the analog I/P signal to a linear function of time or frequency and then to a digital code is known as integrating type A/D converter

Sample and hold circuit

A sample and hold circuit is one which samples an input signal and holds on to its last sampled value until the input is sampled again. This circuit is mainly used in digital interfacing, analog to digital systems, and pulse code modulation systems.

Sample and hold circuit

The time during which the voltage across the capacitor in sample and hold circuit is equal to the input voltage is called sample period. The time period during which the voltage across the capacitor is held constant is called hold period

UNIT-IV

Special ICs

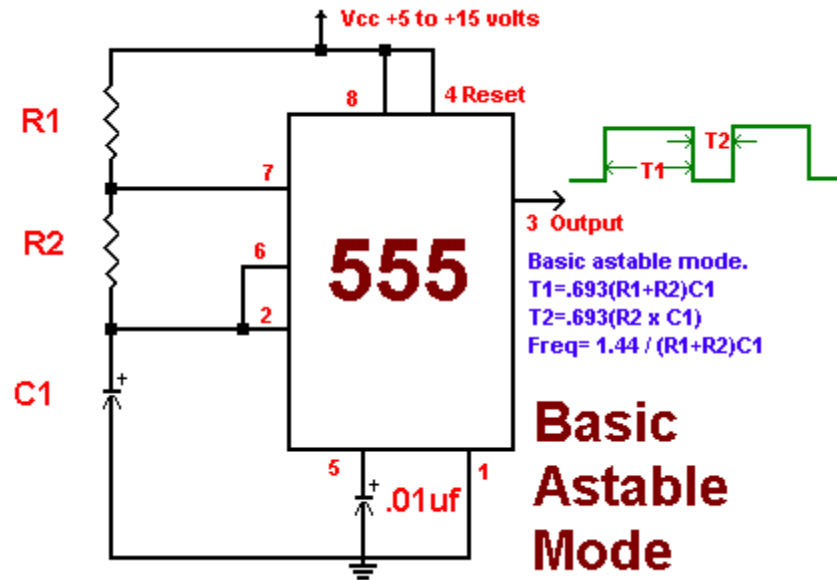
Features of 555 Timer Basic blocks

1. It has two basic operating modes: monostable and astable
2. It is available in three packages. 8 pin metal can , 8 pin dip, 14 pin dip.
3. It has very high temperature stability

Applications of 555 Timer

1. astable multivibrator
2. monostable multivibrator
3. Missing pulse detector
4. Linear ramp generator
5. Frequency divider
6. Pulse width modulation
7. FSK generator
8. Pulse position modulator
9. Schmitt trigger

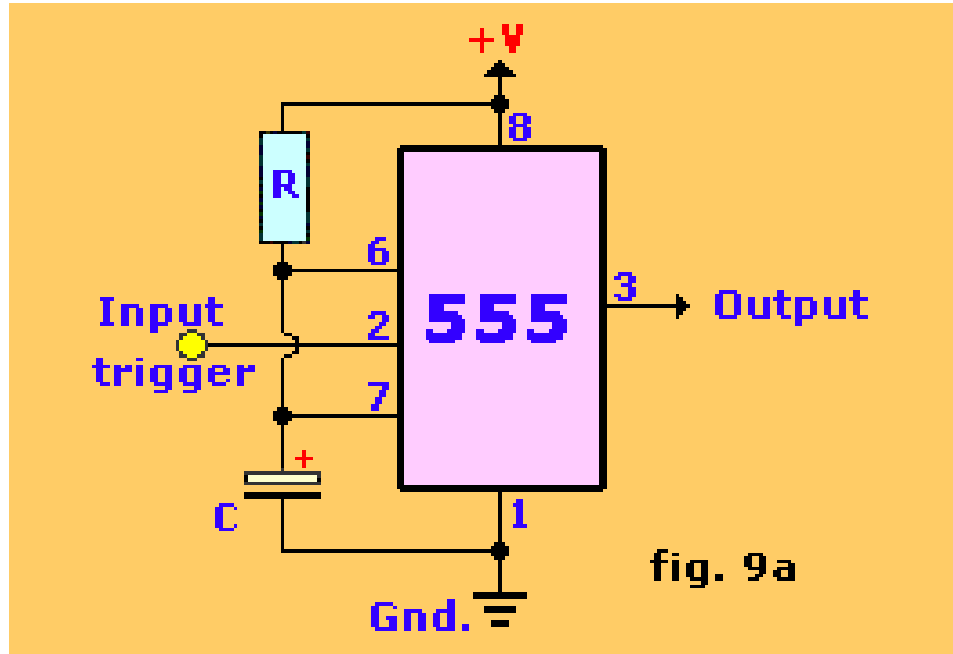
Astable multivibrator



Astable multivibrator

- When the voltage on the capacitor reaches $(2/3)V_{cc}$, a switch is closed at pin 7 and the capacitor is discharged to $(1/3)V_{cc}$, at which time the switch is opened and the cycle starts over

Monostable multivibrator



Voltage controlled oscillator

A voltage controlled oscillator is an oscillator circuit in which the frequency of oscillations can be controlled by an externally applied voltage

The features of 566 VCO

1. Wide supply voltage range(10- 24V)
2. Very linear modulation characteristics
3. High temperature stability

Phase Lock Looped

A PLL is a basically a closed loop system designed to lock output frequency and phase to the frequency and phase of an input signal

Applications of 565 PLL

1. Frequency multiplier
2. Frequency synthesizer
3. FM detector

UNIT-V

APPLICATION ICs

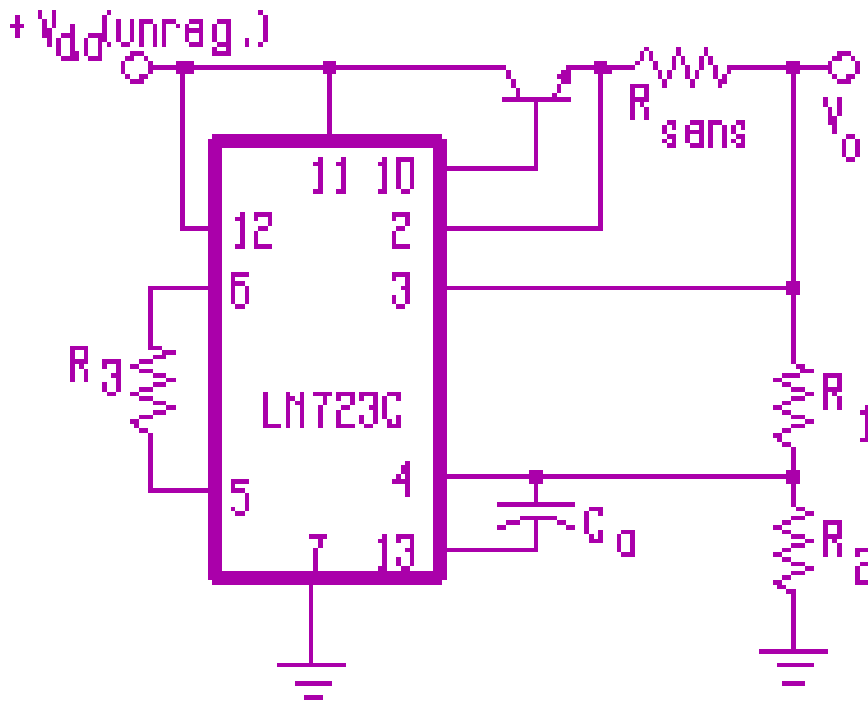
IC Voltage Regulators

- There are basically two kinds of IC voltage regulators:
 - Multipin type, e.g. LM723C
 - 3-pin type, e.g. 78/79XX
- Multipin regulators are less popular but they provide the greatest flexibility and produce the highest quality voltage regulation
- 3-pin types make regulator circuit design simple

LM723 Voltage Regulator

- Can be either 14-pin DIP or 10-pin TO-100 can
- May be used for either +ve or -ve, variable or fixed regulated voltage output
- Using the internal reference (7.15 V), it can operate as a high-voltage regulator with output from 7.15 V to about 37 V, or as a low-voltage regulator from 2 V to 7.15 V
- Max. output current with heat sink is 150 mA
- Dropout voltage is 3 V (i.e. $V_{CC} > V_{o(max)} + 3$)

LM723 in High-Voltage Configuration



External pass transistor and current sensing added.

Design equations:

$$V_o = \frac{V_{ref} (R_1 + R_2)}{R_2}$$

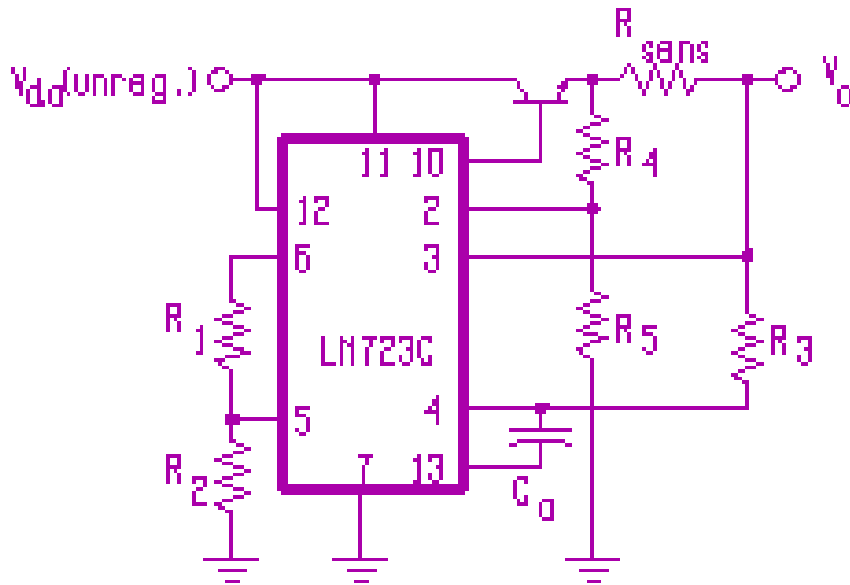
$$R_3 = \frac{R_1 R_2}{R_1 + R_2}$$

$$R_{sens} = \frac{0.7}{I_{max}}$$

Choose $R_1 + R_2 = 10 \text{ k}\Omega$,
and $C_c = 100 \text{ pF}$.

To make V_o variable,
replace R_1 with a pot.

LM723 in Low-Voltage Configuration



With external pass transistor
and foldback current limiting

$$V_o = \frac{R_2 V_{ref}}{R_1 + R_2}$$

$$I_{L(max)} = \frac{R_4 V_o + 0.7(R_4 + R_5)}{R_5 R_{sens}}$$

$$I_{short} = \frac{0.7(R_4 + R_5)}{R_5 R_{sens}}$$

$$R_{sens} = \frac{0.7V_o}{I_{short}(V_o + 0.7) - 0.7I_{L(max)}}$$

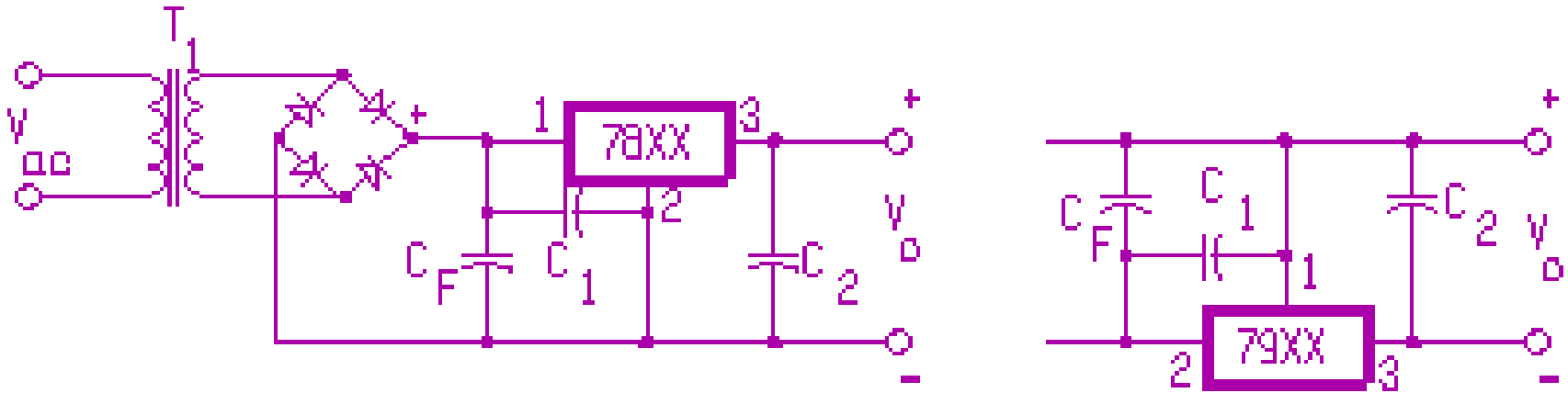
Under foldback condition:

$$V_o' = \frac{0.7R_L(R_4 + R_5)}{R_5 R_{sens} - R_4 R_L}$$

Three-Terminal Fixed Voltage Regulators

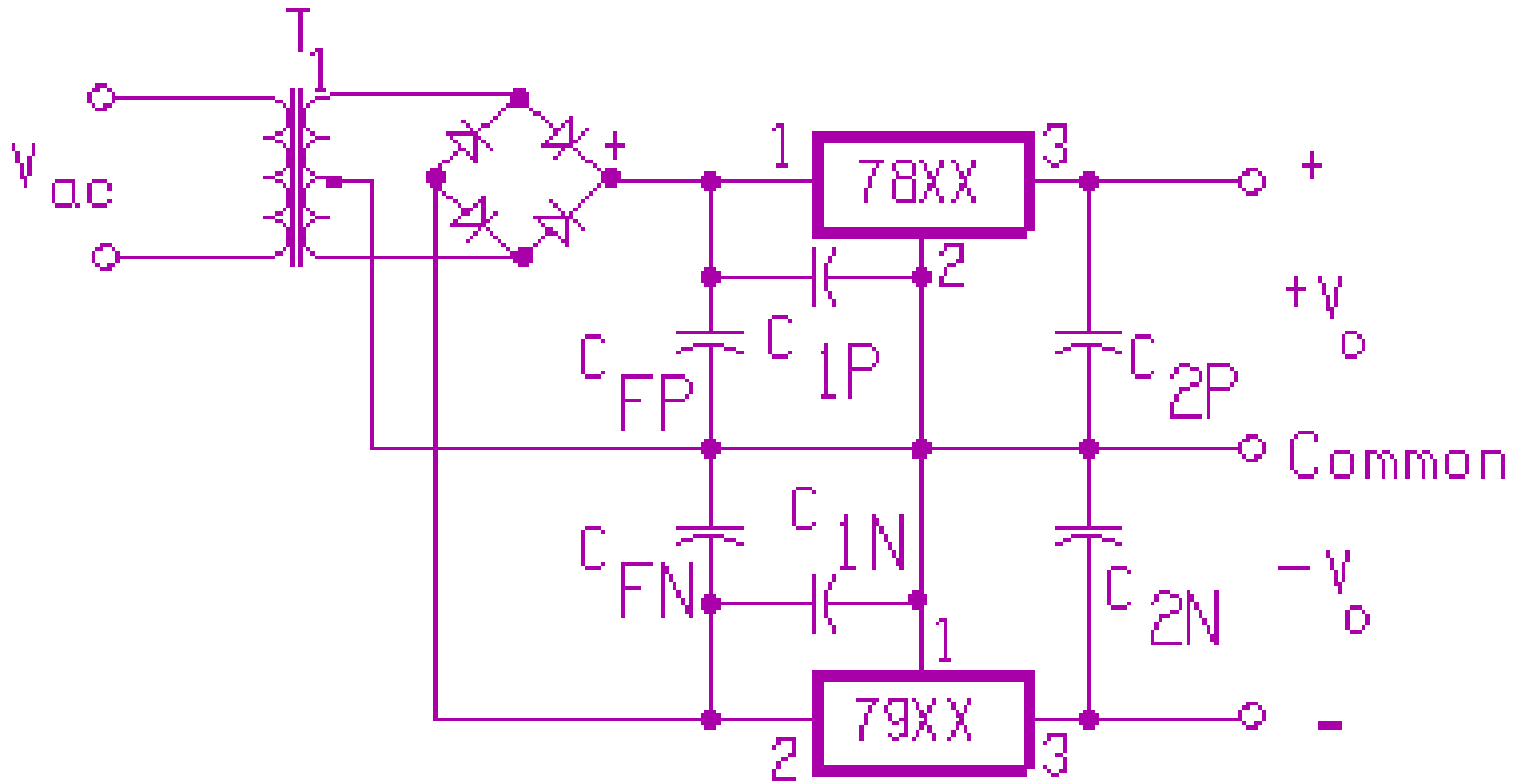
- Less flexible, but simple to use
- Come in standard TO-3 (20 W) or TO-220 (15 W) transistor packages
- 78/79XX series regulators are commonly available with 5, 6, 8, 12, 15, 18, or 24 V output
- Max. output current with heat sink is 1 A
- Built-in thermal shutdown protection
- 3-V dropout voltage; max. input of 37 V
- Regulators with lower dropout, higher in/output, and better regulation are available.

Basic Circuits With 78/79XX Regulators

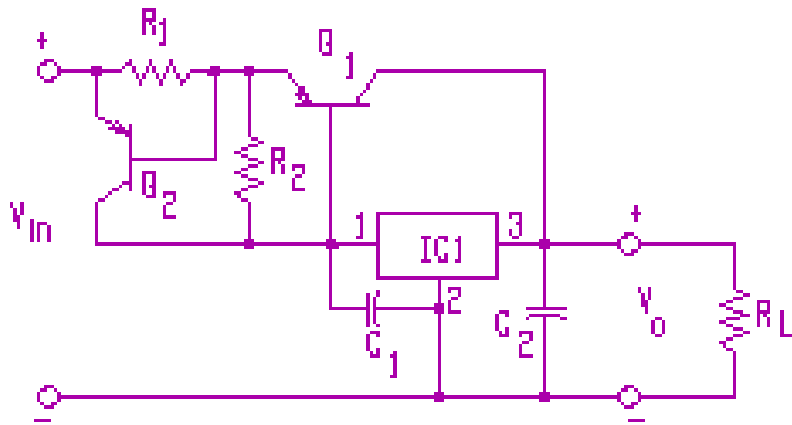


- Both the 78XX and 79XX regulators can be used to provide +ve or -ve output voltages
- C_1 and C_2 are generally optional. C_1 is used to cancel any inductance present, and C_2 improves the transient response. If used, they should preferably be either $1 \mu\text{F}$ tantalum type or $0.1 \mu\text{F}$ mica type capacitors.

Dual-Polarity Output with 78/79XX Regulators



78XX Regulator with Pass Transistor

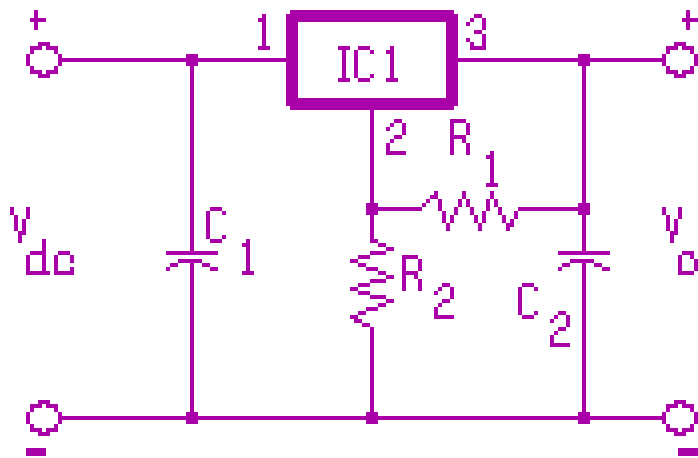


$$R_1 = \frac{0.7}{I_{\max}}$$

$$R_2 = \frac{0.7}{I_{R2}}$$

- Q_1 starts to conduct when $V_{R2} = 0.7 \text{ V}$.
- R_2 is typically chosen so that max. I_{R2} is 0.1 A.
- Power dissipation of Q_1 is $P = (V_i - V_o)I_L$.
- Q_2 is for current limiting protection. It conducts when $V_{R1} = 0.7 \text{ V}$.
- Q_2 must be able to pass max. 1 A; but note that max. V_{CE2} is only 1.4 V.

78XX Floating Regulator



- It is used to obtain an output $>$ the V_{reg} value up to a max. of 37 V.
- R_1 is chosen so that $R_1 \ll 0.1 V_{reg}/I_Q$, where I_Q is the

$$V_o = V_{reg} + \left(\frac{V_{reg}}{R_1} + I_Q \right) R_2$$

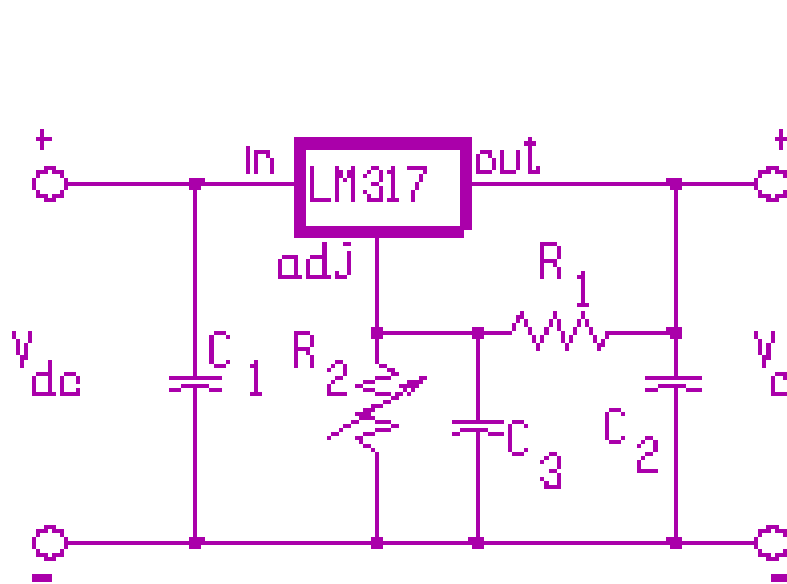
or

$$R_2 = \frac{R_1 (V_o - V_{reg})}{V_{reg} + I_Q R_1}$$

3-Terminal Variable Regulator

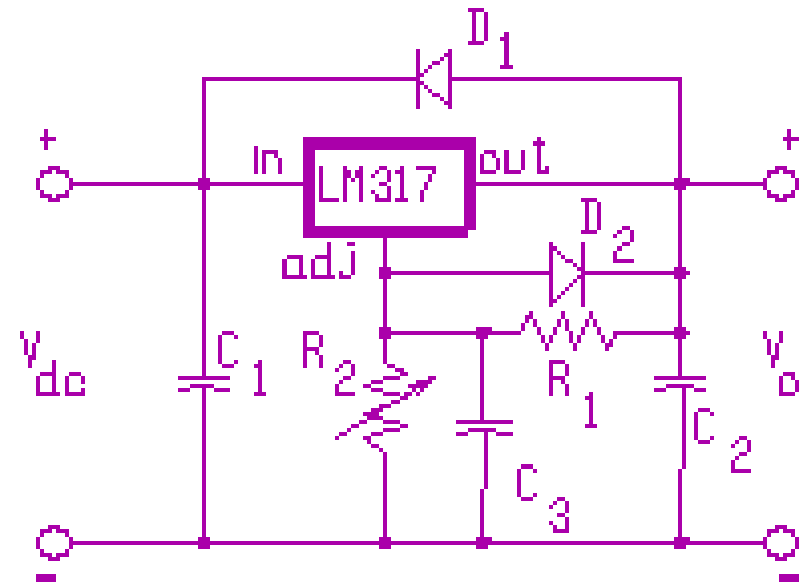
- The floating regulator could be made into a variable regulator by replacing R_2 with a pot. However, there are several disadvantages:
 - Minimum output voltage is V_{reg} instead of 0 V.
 - I_Q is relatively large and varies from chip to chip.
 - Power dissipation in R_2 can in some cases be quite large resulting in bulky and expensive equipment.
- A variety of 3-terminal variable regulators are available, e.g. LM317 (for +ve output) or LM 337 (for -ve output).

Basic LM317 Variable Regulator Circuits



(a)

Circuit with capacitors to improve performance



(b)

Circuit with protective diodes

Notes on Basic LM317 Circuits

- The function of C_1 and C_2 is similar to those used in the 78/79XX fixed regulators.
- C_3 is used to improve ripple rejection.
- Protective diodes in circuit (b) are required for high-current/high-voltage applications.

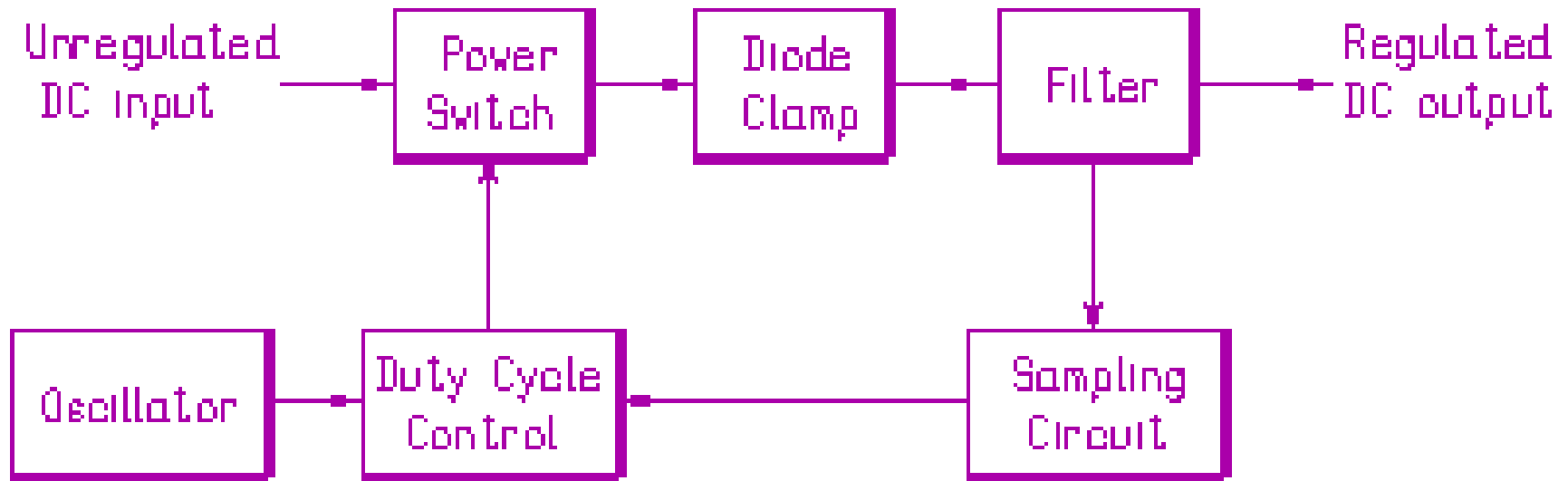
$$V_o = V_{ref} + \left(\frac{V_{ref}}{R_1} + I_{adj} \right) R_2$$

$$R_2 = \frac{R_1(V_o - V_{ref})}{V_{ref} + I_{adj}R_1}$$

where $V_{ref} = 1.25$ V, and I_{adj} is the current flowing into the adj. terminal (typically $50 \mu\text{A}$).

$R_1 = V_{ref} / I_{L(\min)}$, where $I_{L(\min)}$ is typically 10 mA.

Block Diagram of Switch-Mode Regulator



It converts an unregulated dc input to a regulated dc output. Switching regulators are often referred to as dc to dc converters.

Comparing Switch-Mode to Linear Regulators

Advantages:

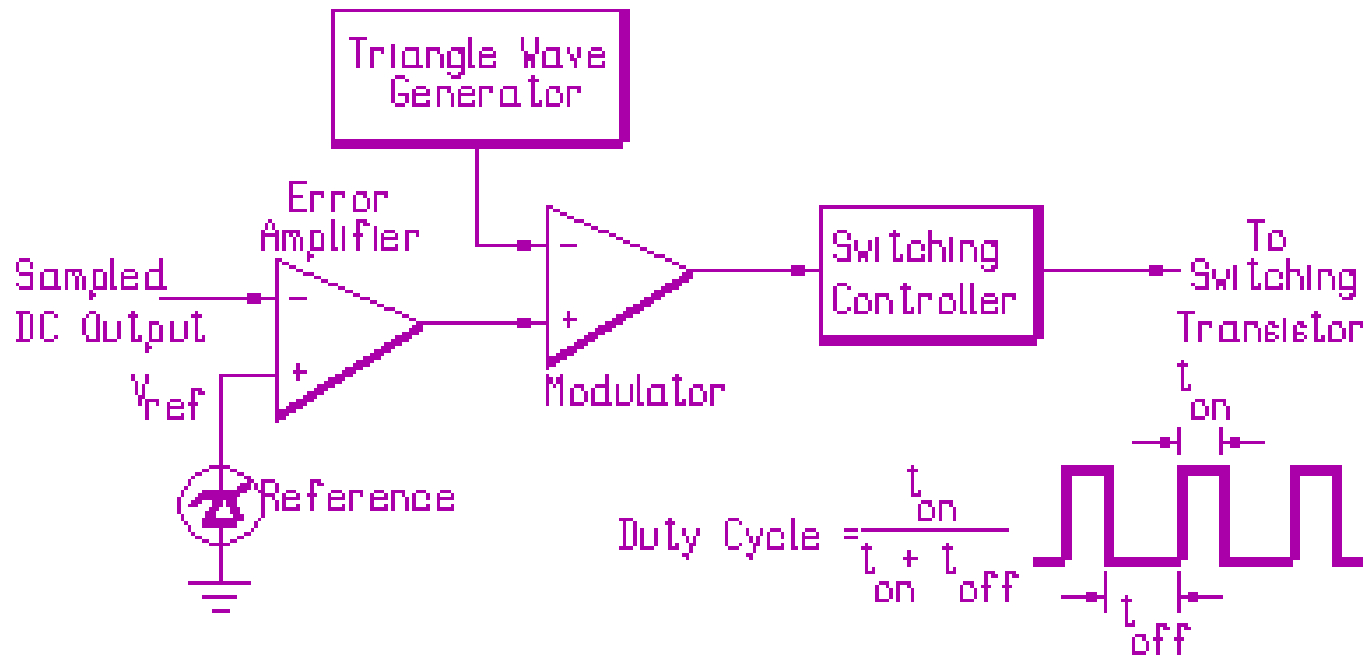
- 70-90% efficiency (about double that of linear ones)
- can make output voltage $>$ input voltage, if desired
- can invert the input voltage
- considerable weight and size reductions, especially at high output power

Disadvantages:

- More complex circuitry
- Potential EMI problems unless good shielding, low-loss ferrite cores and chokes are used

General Notes on Switch-Mode Regulator

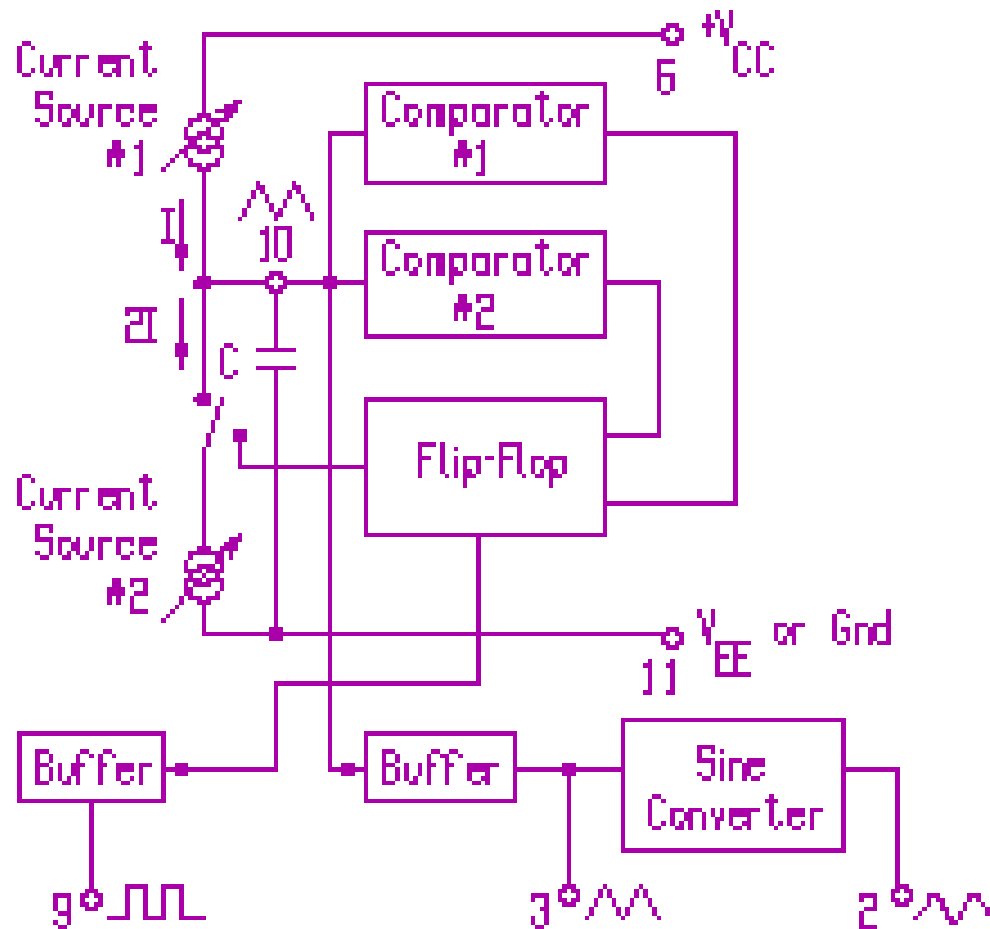
The duty cycle of the series transistor (power switch) determines the average dc output of the regulator. A circuit to control the duty cycle is the *pulse-width modulator* shown below:



General Notes cont'd . . .

- The *error amplifier* compares a sample of the regulator V_o to an internal V_{ref} . The difference or error voltage is amplified and applied to a *modulator* where it is compared to a triangle waveform. The result is an output pulse whose width is proportional to the error voltage.
- Darlington transistors and TMOS FETs with f_T of at least 4 MHz are often used. TMOS FETs are more efficient.
- A fast-recovery rectifier, or a Schottky barrier diode (sometimes referred to as a *catch diode*) is used to direct current into the inductor.
- For proper switch-mode operation, current must always be present in the inductor.

ICL8038 Function Generator IC

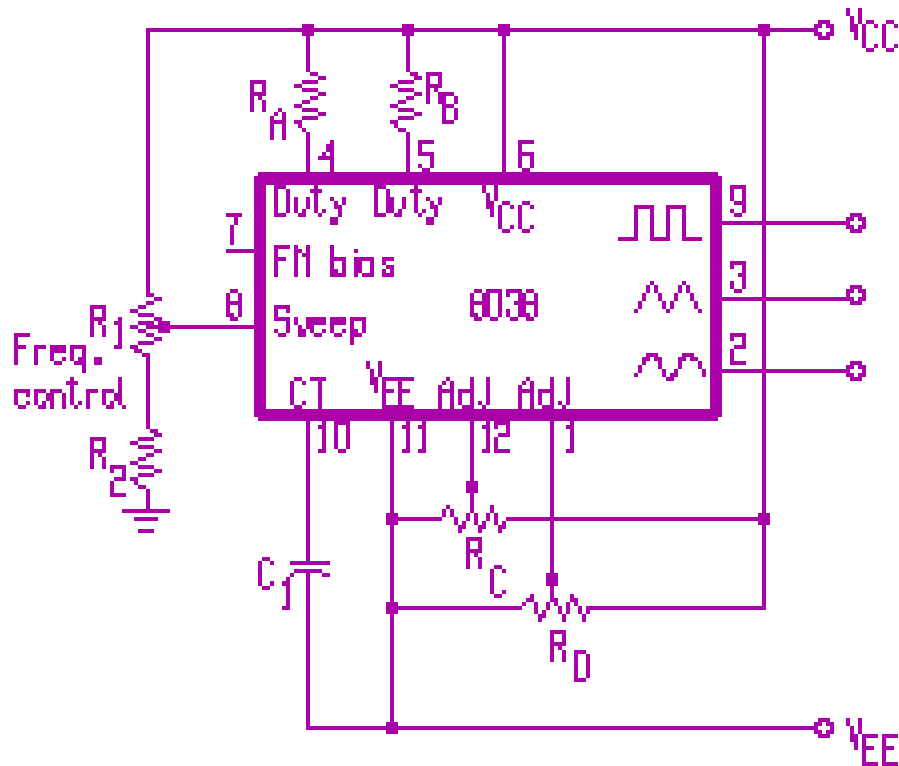


- Triangle wave at pin10 is obtained by linear charge and discharge of C by two current sources.
- Two comparators trigger the flip-flop which provides the square wave and switches the current sources.
- Triangle wave becomes sine wave via the sine converter .

ICL8038 Function Generator IC

- To obtain a square wave output, a pull-up resistor (typically 10 to 15 k Ω) must be connected between pin 9 and V_{CC} .
- Triangle wave has a linearity of 0.1 % or better and an amplitude of approx. $0.3(V_{CC}-V_{EE})$.
- Sine wave can be adjusted to a distortion of $< 1\%$ with amplitude of $0.2(V_{CC}-V_{EE})$. The distortion may vary with f (from 0.001 Hz to 200 kHz).
- IC can operate from either single supply of 10 to 30 V or dual supply of ≈ 5 to ≈ 15 V.

ICL8038 Function Generator Circuit



$$f_o = \frac{3(V_{CC} - V_{sweep})}{2RC_1V_{total}}$$

where $R = R_A = R_B$

If pin 7 is tied to pin 8,

$$f_o = \frac{3}{5R_A C_1 \left(1 + \frac{R_A}{2R_A - R_B} \right)}$$

For 50 % duty cycle,

$$f_o \approx \frac{0.3}{RC_1}$$

$$+V_{CC} > V_{sweep} > \Delta V_{total} + V_{EE} + 2$$

where $V_{total} = V_{CC} + |V_{EE}|$

Isolation Amplifier

- Provides a way to link a fixed ground to a floating ground.
- Isolates the DSP from the high voltage associated with the power amplifier.

ISOLATION AMPLIFIER

Purposes

- To break ground to permit incompatible circuits
- to be interfaced together while reducing noise
- To amplify signals while passing only low leakage current to prevent shock to people or damage to equipment
- To withstand high voltage to protect people, circuits, and equipment

Methods

- Power Supply Isolation : battery, isolated power
- Signal Isolation : opto-isolation, capacitive

OPTOCOUPLER

- The optocouplers provide protection and high-speed switching
- An optocoupler, also known as an opto-isolator, is an integral part of the opto electronics arena. It has fast proven its utility as an electrical isolator or a high-speed switch, and can be used in a variety of applications.
- The basic design for optocouplers involves use of an LED that produces a light signal to be received by a photodiode to detect the signal. In this way, the output current or current allowed to pass can be varied by the intensity of light.

OPTOCOUPLER

- A very common application for the opto coupler is a FAX machine or MODEM, isolating the device from the telephone line to prevent the potentially destructive spike in voltage that would accompany a lightning strike. This protective tool has other uses in the opto electronic area. It can be used as a guard against EMI, removing ground loops and reducing noise.
- This makes the optocoupler ideal for use in switching power supply and motor control applications. Today as semiconductors are being designed to handle more and more power, isolation protection has become more important than ever before.

Optoelectronic Integrated Circuits

Applications

- Inter- and intra-chip optical interconnect and clock distribution
- Fiber transceivers
- Intelligent sensors
- Smart pixel array parallel processors

Optoelectronic Integrated Circuits

Approaches

- Conventional hybrid assembly: multi-chip modules
- Total monolithic process development
- Modular integration on ICs:
 - epitaxy-on-electronics
 - flip-chip bump bonding w. substrate removal
 - self-assembly

LM380 Power Amplifier

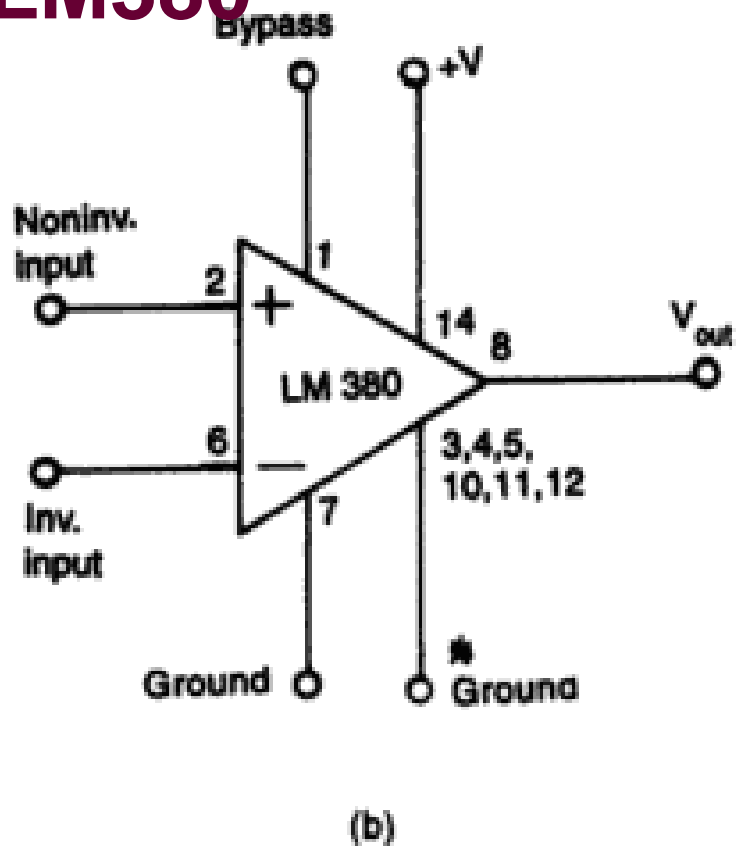
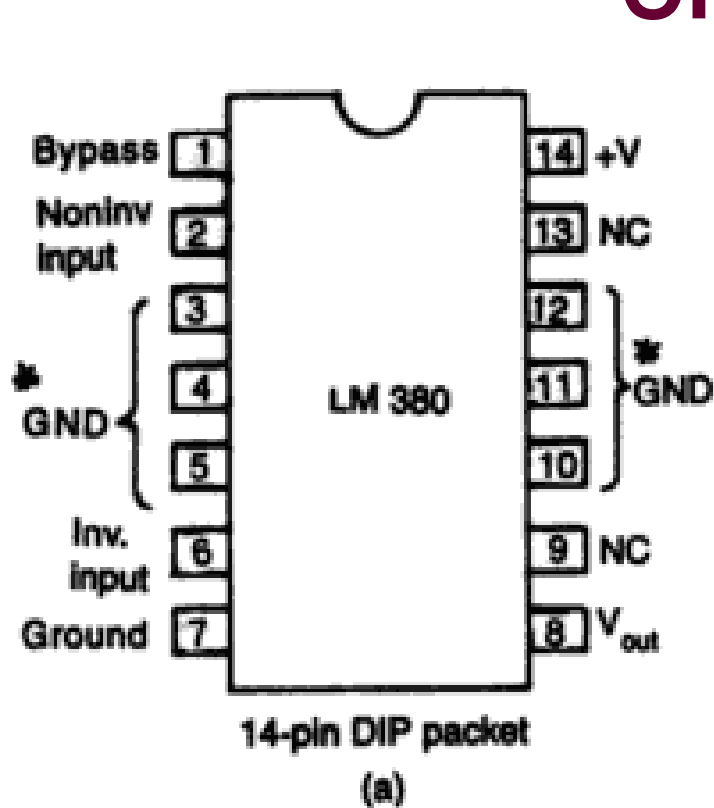
General Description

- The LM380 is a power audio amplifier for consumer application. In order to hold system cost to a minimum, gain is internally fixed at 34 dB. A unique input stage allows inputs to be ground referenced. The output is automatically self centering to one half the supply voltage. The output is short circuit proof with internal thermal limiting.
- The package outline is standard dual-in-line. A copper lead frame is used with the center three pins on either side comprising a heat sink. This makes the device easy to use in standard p-c layout.

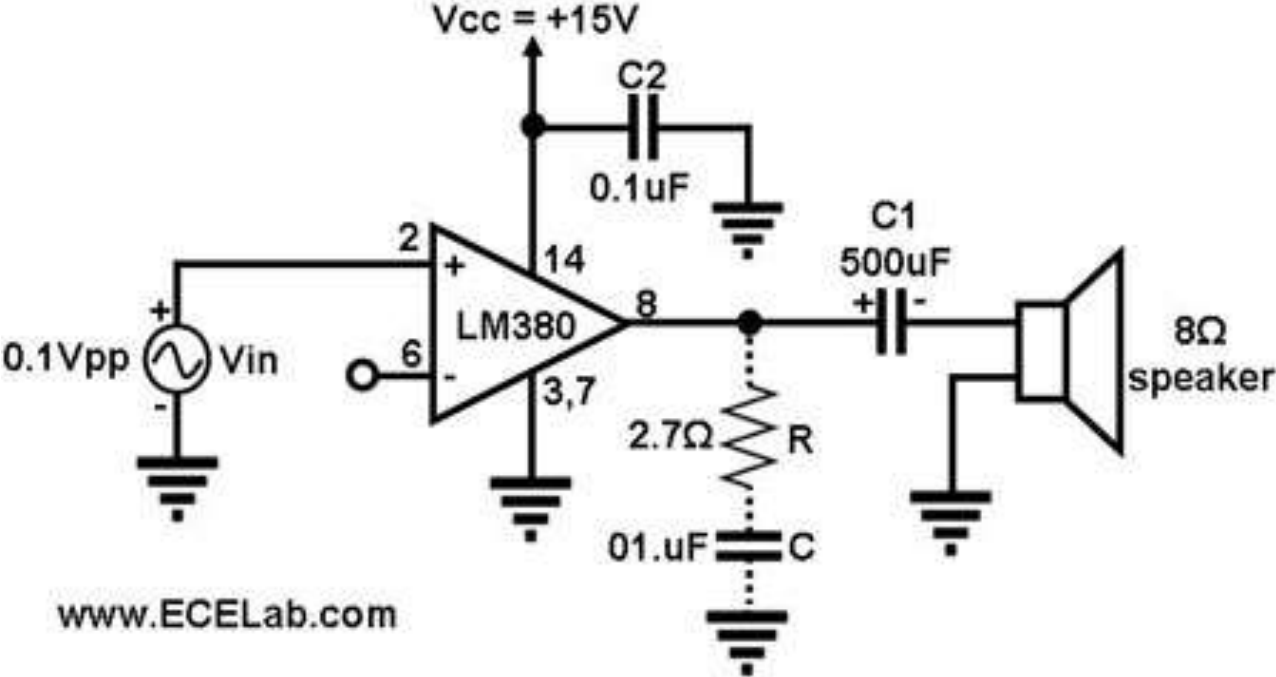
Features

- Wide supply voltage range
- Low quiescent power drain
- Voltage gain fixed at 50
- High peak current capability
- Input referenced to GND
- High input impedance
- Low distortion
- Quiescent output voltage is at one-half of the supply voltage
- Standard dual-in-line package

PIN DIAGRAM AND BLOCK DIAGRAM OF LM380



Circuit Diagram for a Simple LM380-Based Power Amplifier



www.ECELab.com