UNIT - 3

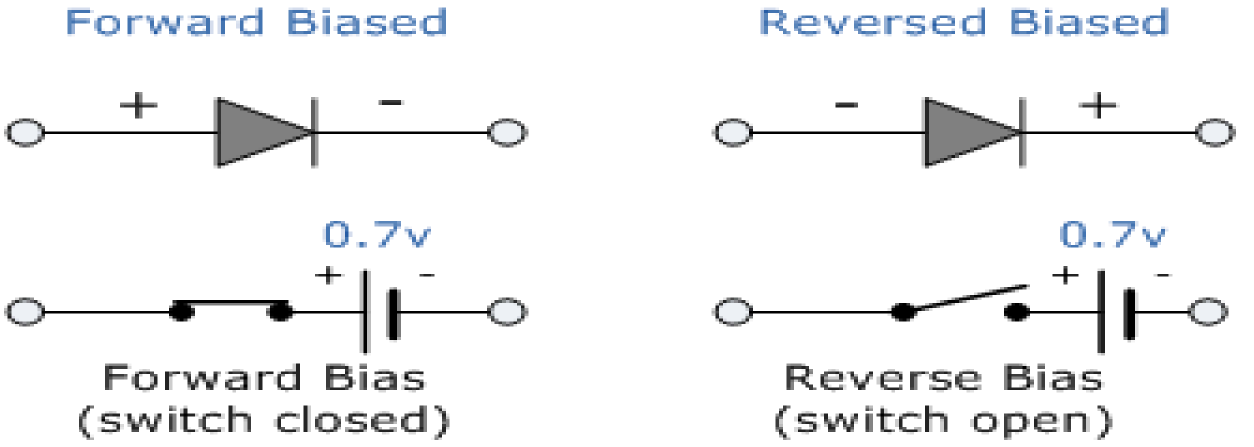
Steady State Switching Characteristics of Devices

Transistors as switches

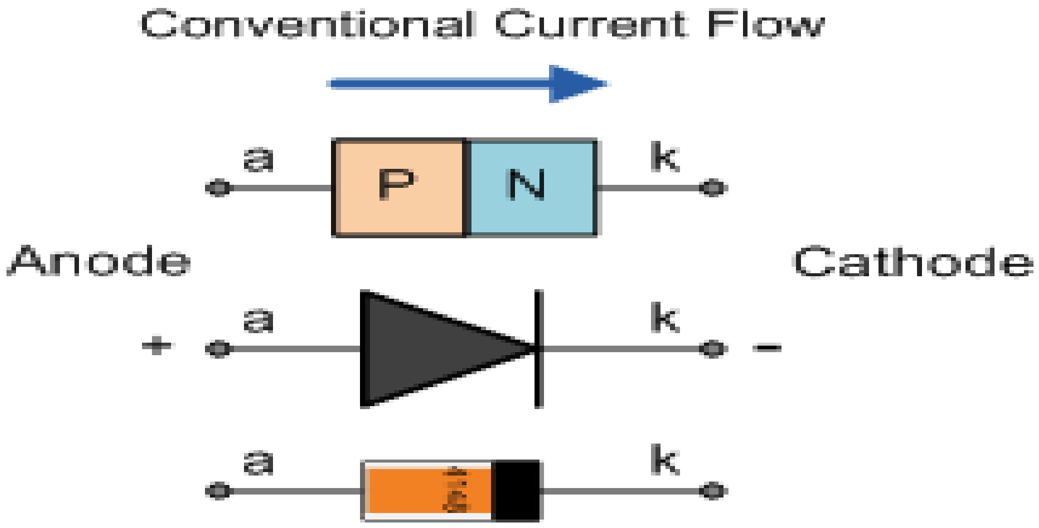
- both FETs and bipolar transistors make good switches
- neither form produce *ideal* switches and their characteristics are slightly different
- both forms of device take a finite time to switch and this produces a slight delay in the operation of the gate
- this is termed the **propagation delay** of the circuit

Diode As a Switch

- The semiconductor Signal Diode is a small non-linear semiconductor devices generally used in electronic circuits, where small currents or high frequencies are involved such as in radio, television and digital logic circuits



Diode As a Switch



Silicon Diode and its
V-I Characteristics

Piece-wise linear model

- Unlike the resistor, whose two terminal leads are equivalent, the behavior of the diode depend on the relative polarity of its terminals.
- Ideal Diode

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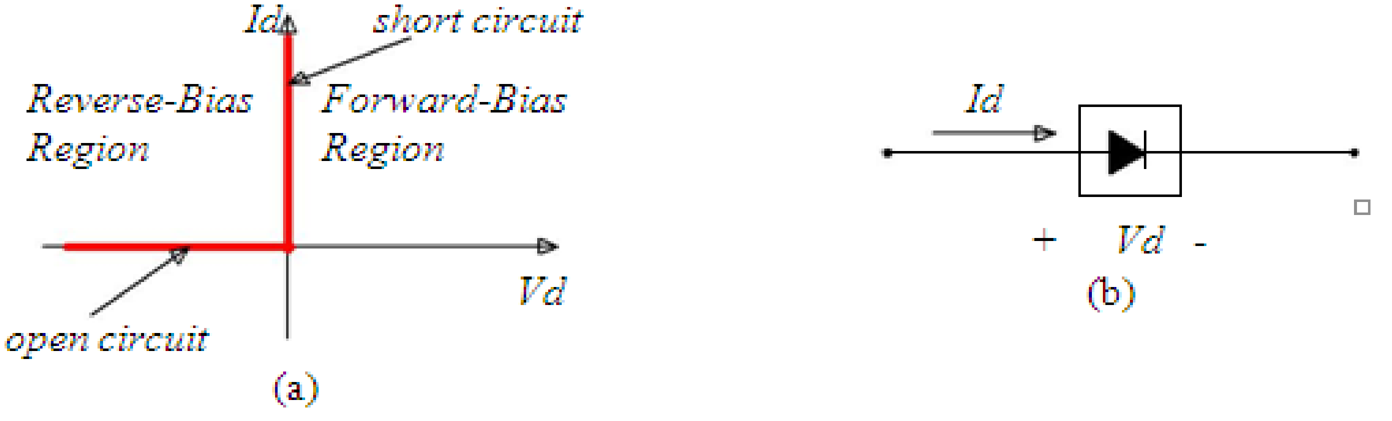

Figure 2. I-V characteristic (a) and symbol (b) of the ideal diode.

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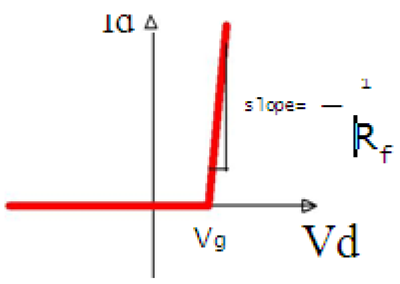
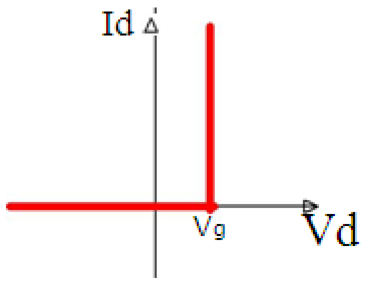


. Piecewise linear approximation model of the diode.



. Offset diode model (0.7 Volt model)

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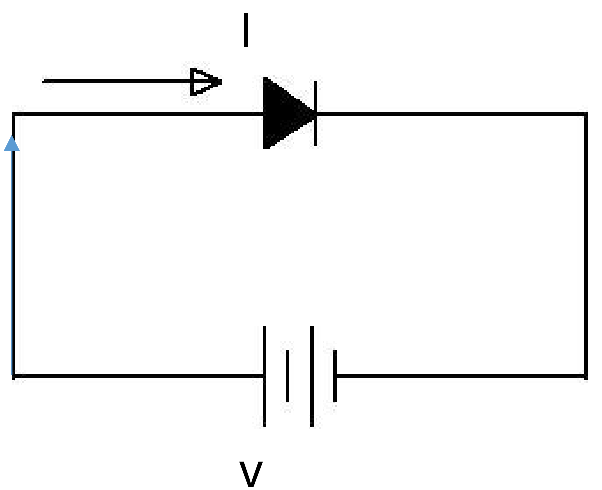
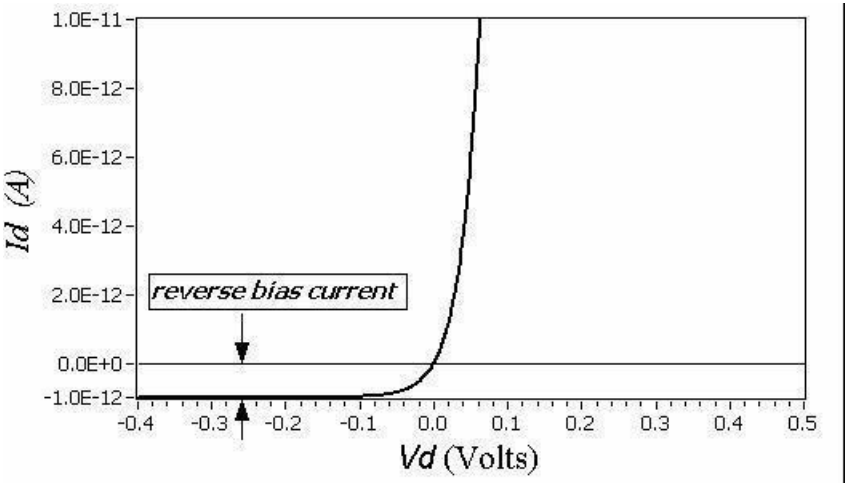
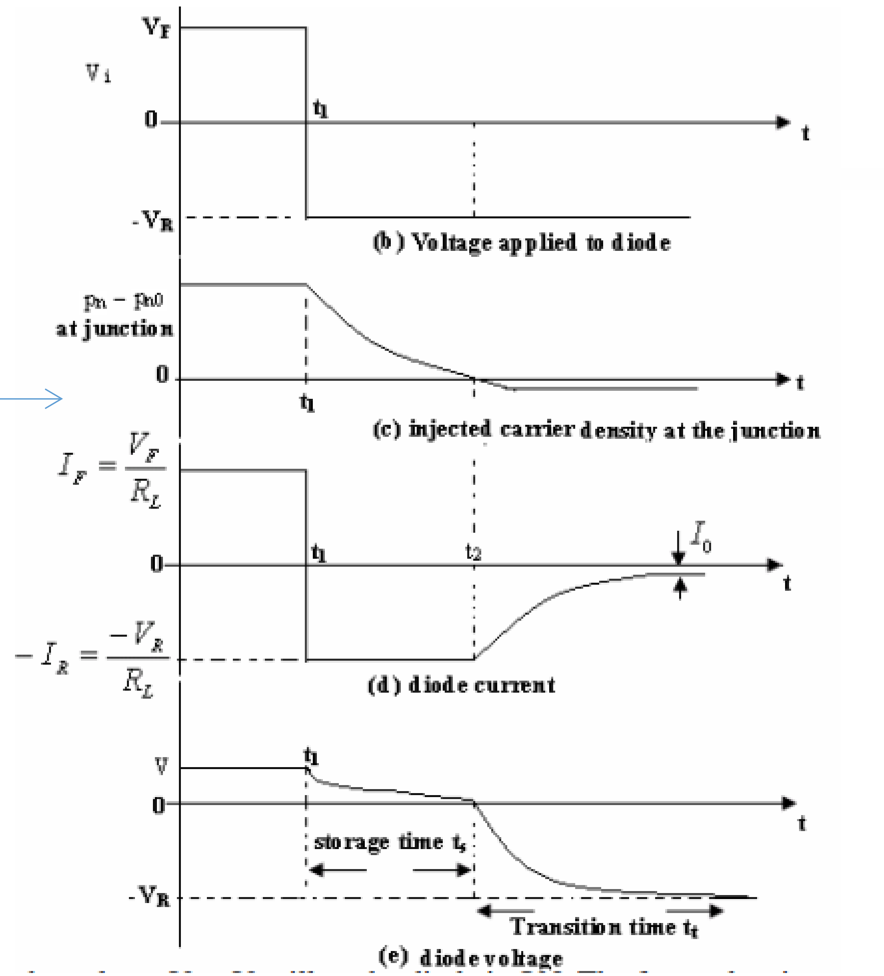

I
V


1.0E-11
8.0E-12
6.0E-12
4.0E-12
2.0E-12
0.0E+0
-1.0E-12
Id (A)
reverse bias current
-0.4
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
Vd (Volts)

Diode Switching times

- Reverse recovery time of the diode
- Forward recovery time of the diode



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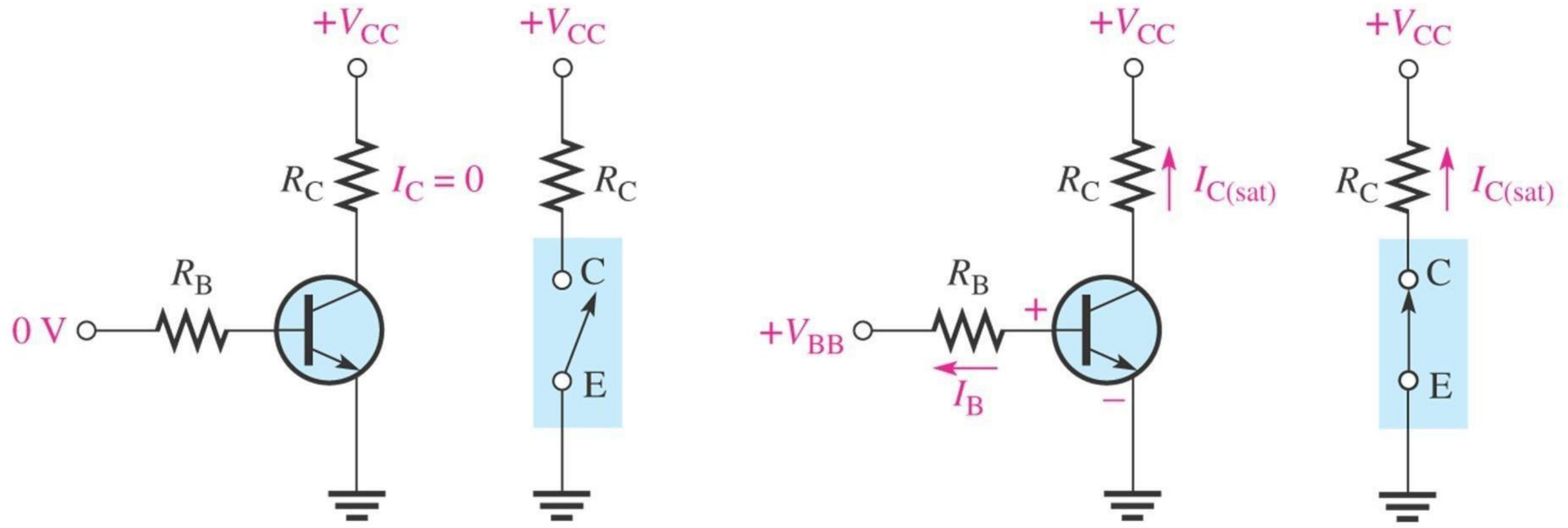
- As long as the voltage $V_i = V_F$ till t_1, the diode is ON. The forward resistance of the diode being negligible when compared to R_L, therefore $I_f = V_f/R$. At $t = t_1$, the polarity of V_i is abruptly reversed, i.e. $V_i = -V_R$ and $I_r = -V_r/R$ until $t = t_2$ at which time minority carrier density p_n at $x = 0$ has reached the equilibrium value p_{n0}.
- At $t = t_2$ the charge carriers have been swept, the polarity of the diode voltage reverses, the diode current starts to decrease. The time duration, t_1 to t_2, during which period the stored minority charge becomes zero is called the storage time t_s. The time interval from t_2 to the instant that the diode has recovered ($V = -V_R$) is called the transition time, t_t. The sum total of the storage time, t_s and the transition time, t_t is called the reverse recovery time of the diode, t_{rr}.
- $t_{rr} = t_s + t_t$

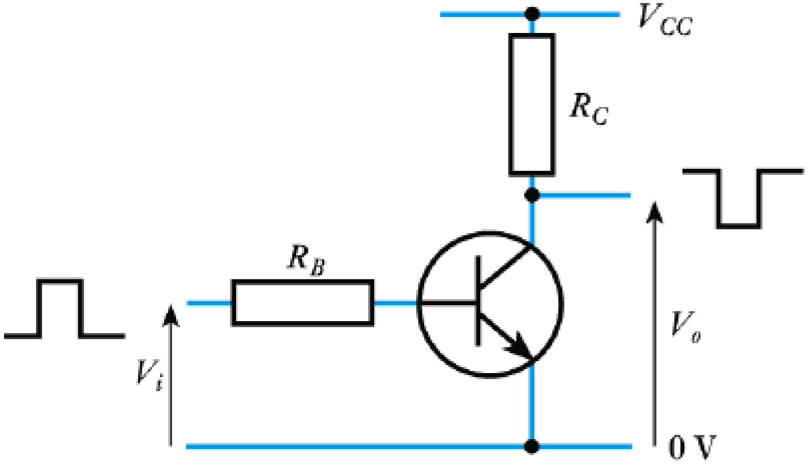
The BJT as a Switch

- Transistor as a Switch works in two regions
- Cut off
- Saturation

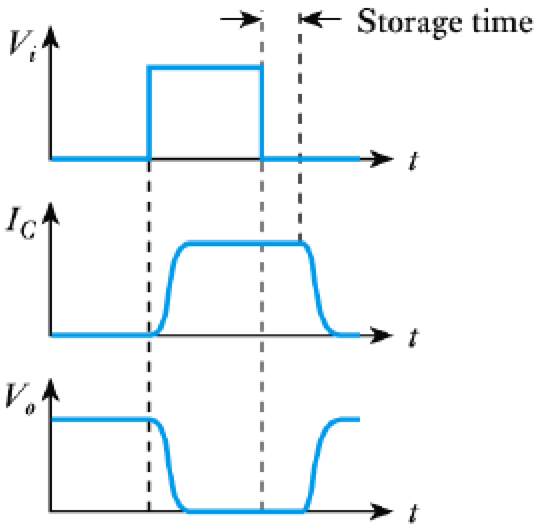


(a) Cutoff — open switch (b) Saturation — closed switch

- The bipolar transistor as a logical switch



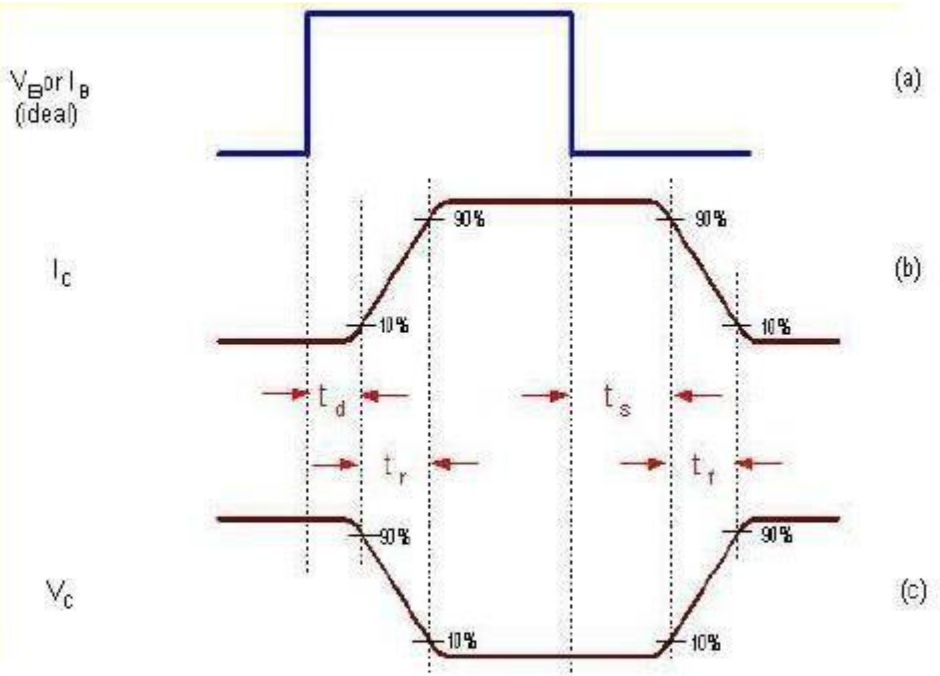
(a) Circuit



(b) Waveforms

Transistor Switching Times

- Delay time(td)
- Rise time(tr)
- Storage time(ts)
- Fall time(tf)



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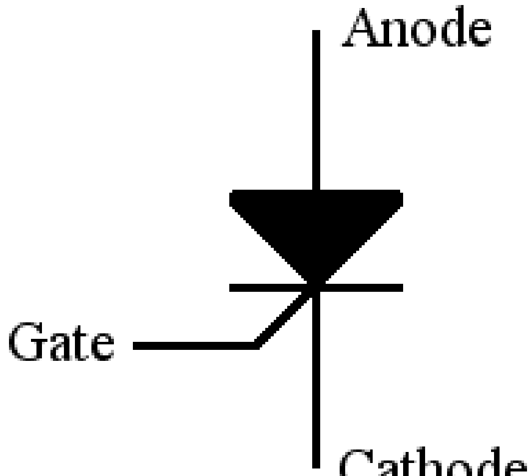
- **Delay Time, td** : It is the time taken for the collector current to reach from its initial value to 10% of its final value If the rise of the collector current is linear, the time required to rise to 10%IC(sat) is 1/8 the time required for the current to rise from 10% to 90% IC(sat). where tr is the rise time
- **Rise Time,tr** : It is the time taken for the collector current to reach from 10% of its final value to 90% of its final value. However, because of the stored charges, the current remains unaltered for sometime interval ts1 and then begins to fall. The time taken for this current to fall from its initial value at ts1 to 90% of its initial value is ts2. The sum of these ts1 and ts2 is approximately ts1 and is called the storage time.
- **Storage time, ts** : It is the time taken for the collector current to fall from its initial value to 90% of its initial value.
- **. Fall time, tf** : It is the time taken for the collector current to fall from 90% of its initial value to 10% of its Initial value.
- Ton= td+tr
- Toff= ts+tf

Breakdown mechanisms in BJTs

- The breakdown voltage of a BJT also depends on the chosen circuit configuration:
- In a common base mode (i.e. operation where the base is grounded and forms the common electrode between the emitter-base input and collector-base output of the device) the breakdown resembles that of a p-n diode.
- In a common emitter mode (i.e. operation where the emitter is grounded and forms the common electrode between the base-emitter input and the collector-emitter output of the device) the transistor action further influences the *I-V characteristics and breakdown voltage.*
- Avalanche breakdown of the base-collector junction is further influenced by transistor action in common-emitter mode of operation, since the holes generated by impact ionization are pulled back into the base region which results in an additional base current. This additional base current causes an even larger additional flow of electrons through the base and into the collector due to the current gain of the BJT. This larger flow of electrons in the base collector junction causes an even larger generation of electron-hole pairs.

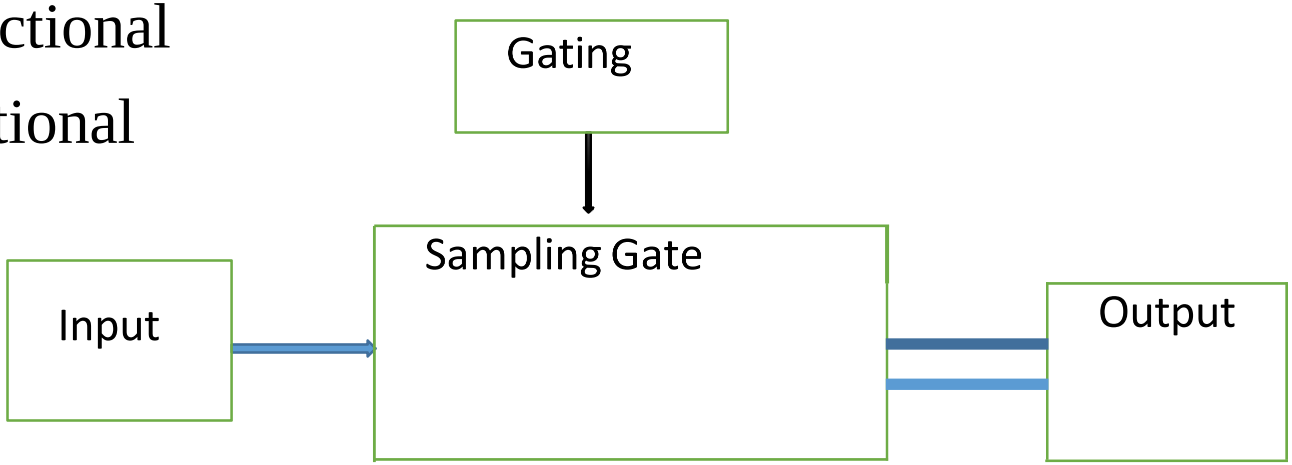
SCR

- A **S**ilicon **C**ontrolled **R**ectifier (or **S**emiconductor **C**ontrolled **R**ectifier) is a four layer solid state device that controls current flow
- The name "silicon controlled rectifier" is a trade name for the type of **thyristor** commercialized at General Electric in 1957



Sampling Gates

- Sampling Gates are also called as Transmission gates ,linear gates and selection circuits,in which the output is exact reproduction of the input during a selected time interval and zero otherwise.
- It has two inputs – gating signal, rectangular wave
- Two types
- Unidirectional
- Bidirectional



Principle of operation of a linear gate:

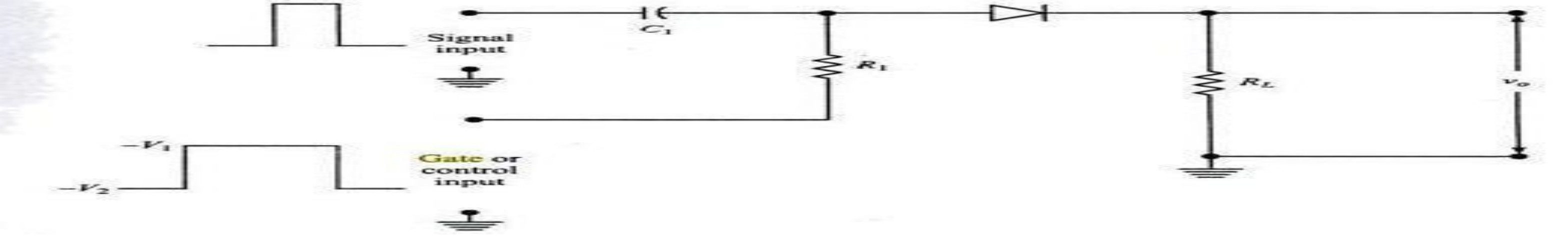
- Principle of operation of a linear gate: Linear gates can use (a) a series switch or (b) a shunt switch fig

Fig. Linear gates

In (a) the switch closes for transmitting the signal whereas in (b) the switch is open for transmission to take place.

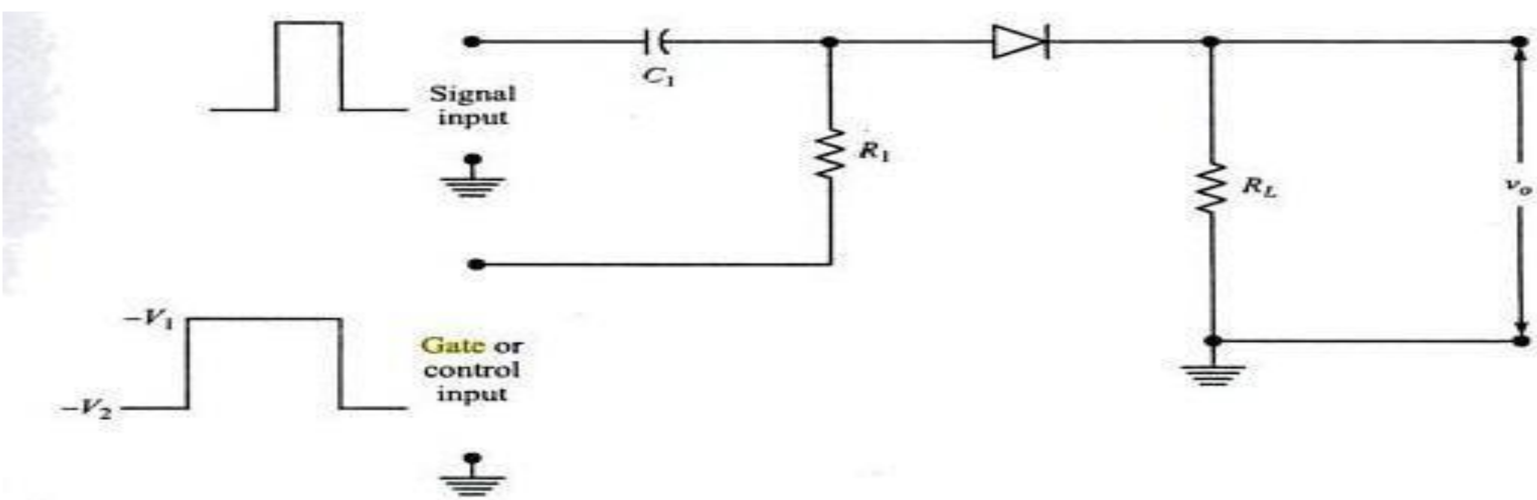
Unidirectional Gate

- unidirectional sampling gates are those which transmit signals of only one polarity(i.e,. either positive or negative)
- The gating signal is also known as control pulse, selector pulse or an enabling pulse. It is a negative signal, the magnitude of which changes abruptly between –V2 and –V1.



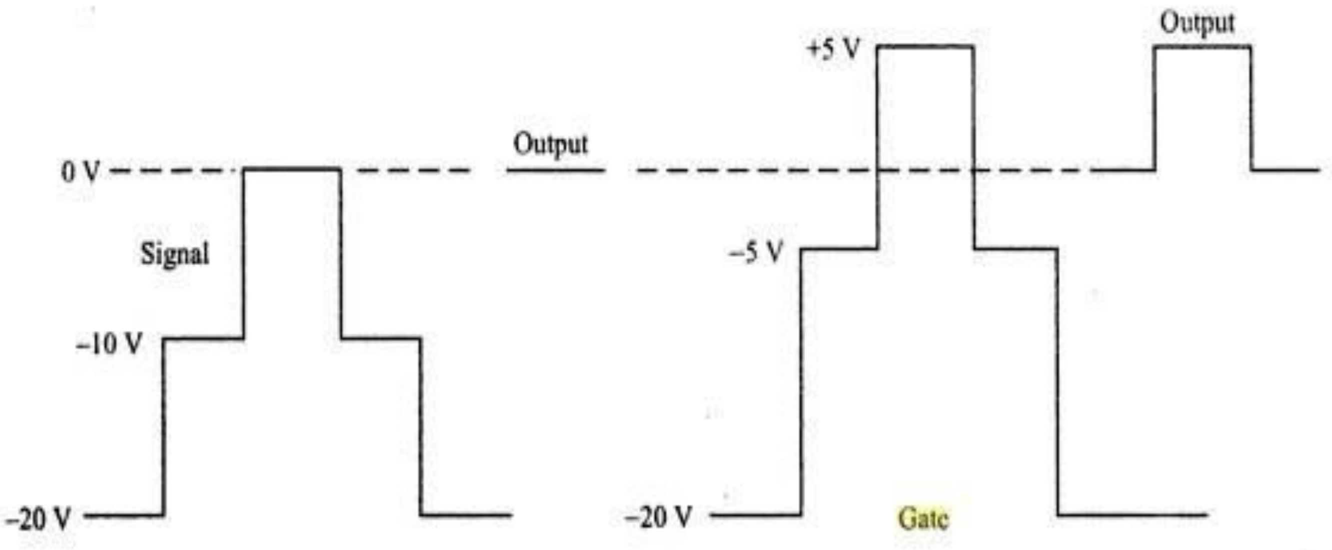
Unidirectional gate

- Consider the instant at which the gate signal is –V1 which is a reasonably large negative voltage. Even if an input pulse is present at this time instant, the diode remains OFF as the input pulse amplitude may not be sufficiently large so as to forward bias it. Hence there is no output. Now consider the duration when the gate signal has a value –V2 and when the input is also present (coincidence occurs).



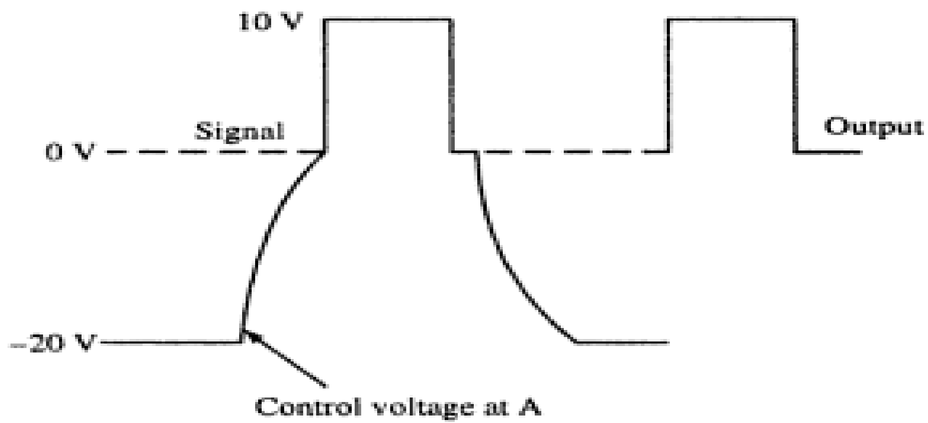
Output waveform

- When the control signal shifted to upward



pedestal

- When the control signal is shifted to positive value ,so it will be superimposed on input and control signals .so the pedestal occurs



Unidirectional diode coincidence gate

- When any of the control voltages is at –V1, point X is at a large negative voltage, even if the input pulse Vs is present., D0 is reverse biased. Hence there is no signal at the output.
- When all the control voltages, on the other hand, are at –V2 , if an input signal Vs is present, D0 is forward biased and the output is a pulse of 5V. Hence this circuit is a coincidence circuit or AND circuit.

A unidirectional diode coincidence gate is shown below.

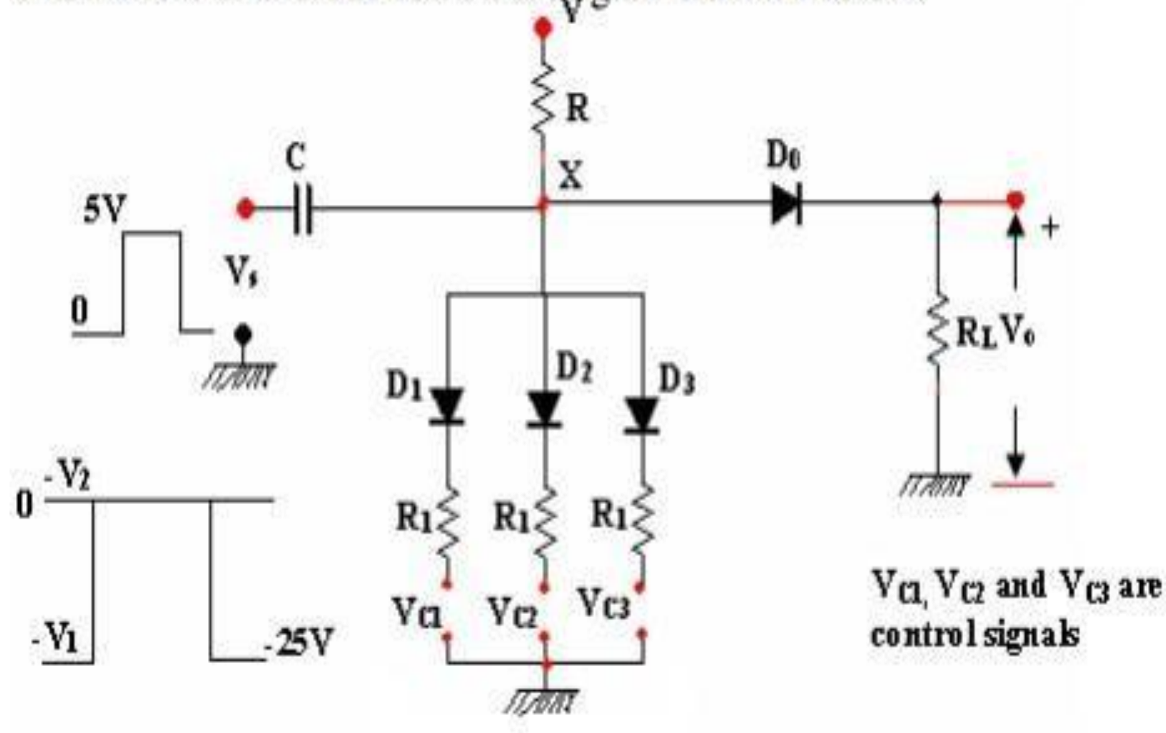
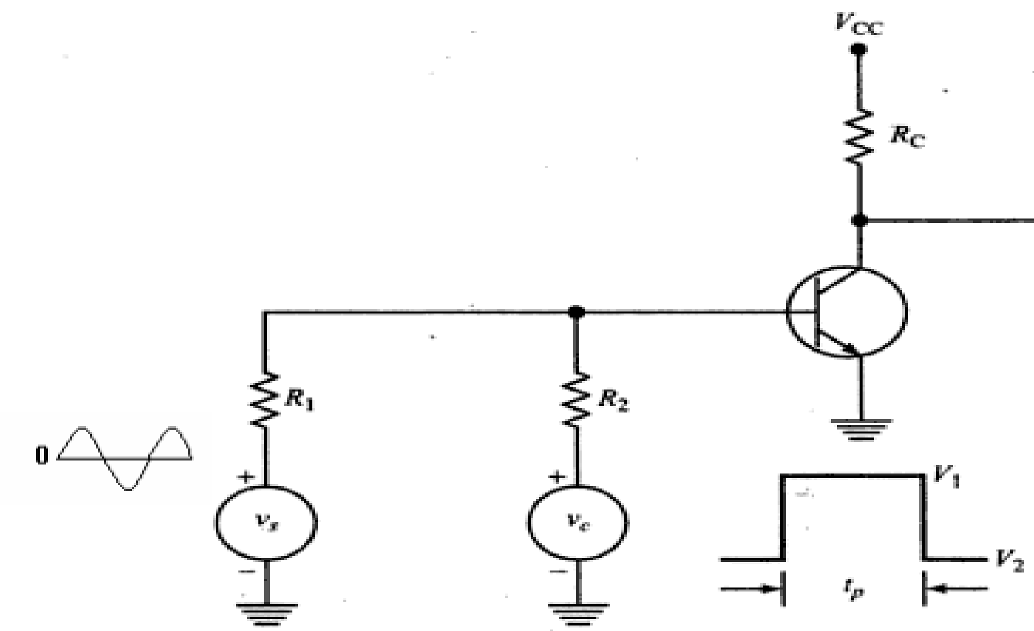
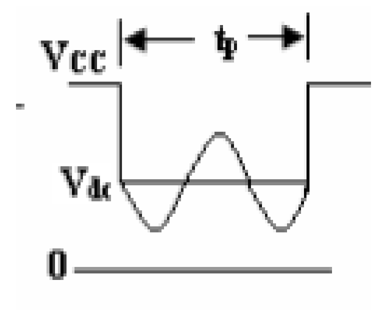


Fig. A unidirectional diode AND gate

Bidirectional Sampling gate

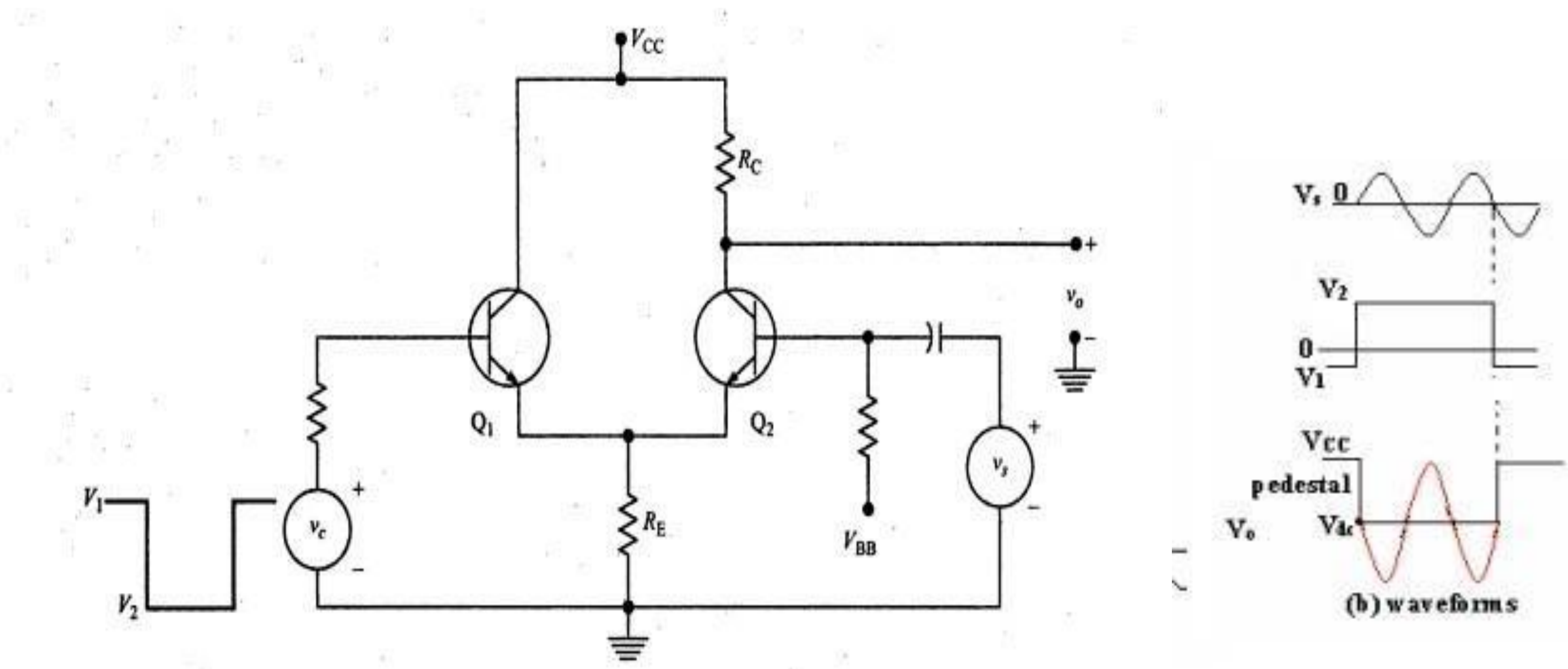
- Bidirectional sampling gates are those which transmit signals of both the polarities.





Bidirectional Sampling gate using Transistor

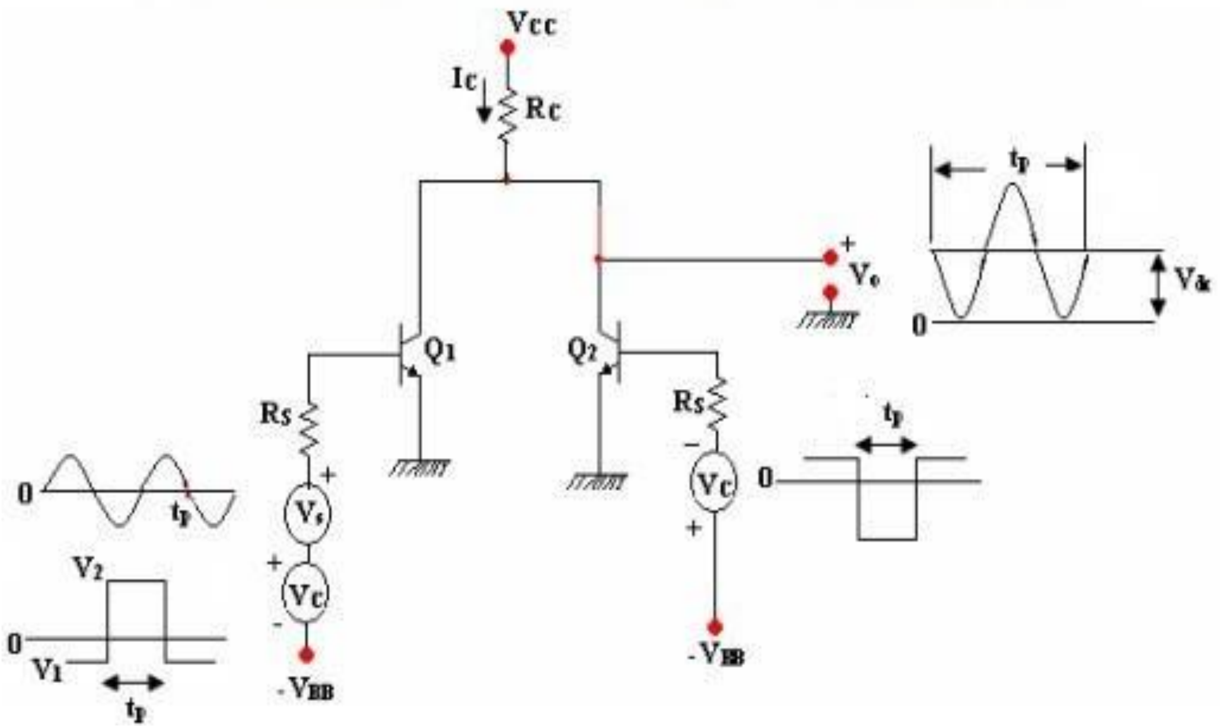
- Bidirectional sampling gates are those which transmit signals of both the polarities.



Circuit that minimizes the pedestal

- Circuit that minimizes the pedestal

A circuit arrangement that reduces this pedestal is shown in fig.



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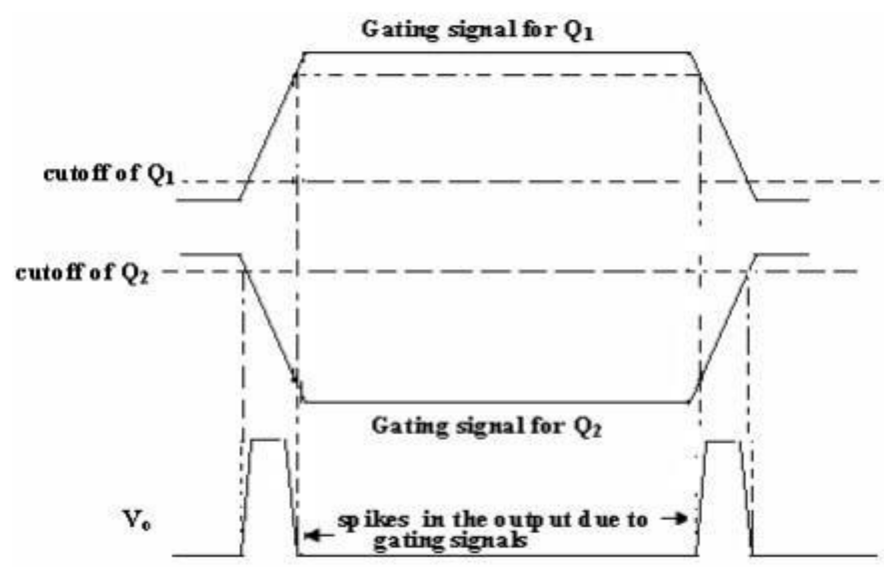
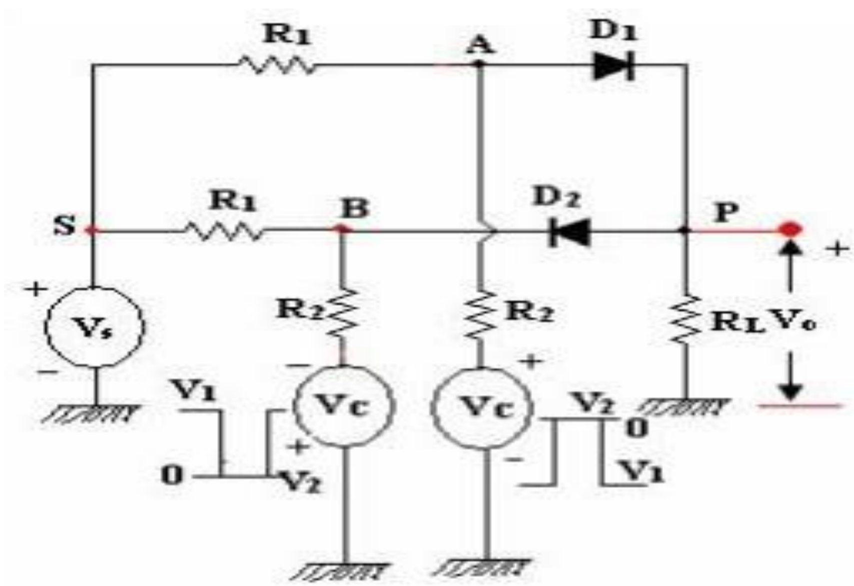
- The control signal applied to the base of Q2 is of opposite polarity to that applied to the base of Q1. When the gating signal connected to Q1 is negative, Q1 is OFF and at the same time the gating signal connected to Q2 drives Q2 ON and draws current IC. As a result there is a dc voltage Vdc at the collector. But when the gate voltage at the base of Q1 drives Q1 ON, Q2 goes OFF. But during this gate period if the input signal is present, it is amplified and is available at the output, with phase inversion. But the dc reference level practically is Vdc. As such the pedestal is either eliminated or minimized.



(a) when the rise time of the gating signal is large

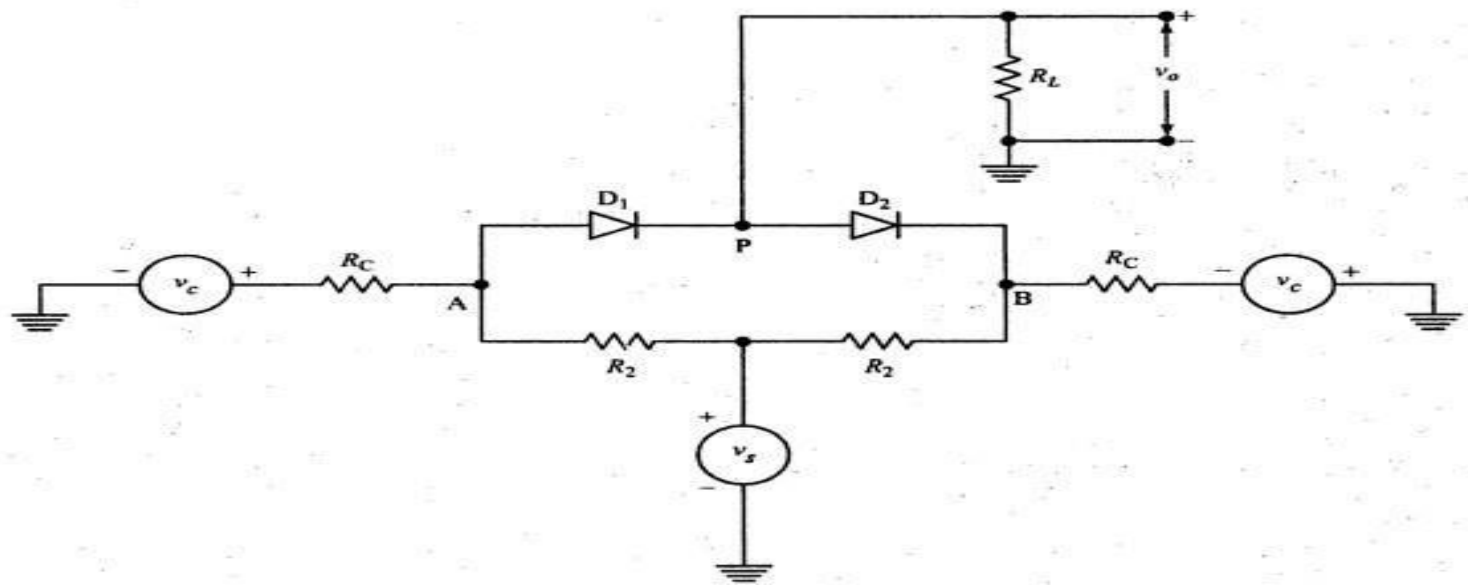
Two Diode Sampling gate

- When the control signals are at V1, D1 and D2 are OFF, no input signal is transmitted to the output. But when control signals are at V2, diode D1 conducts if the input is positive pulses and diode D2 conducts if the input is negative pulses. Hence these bidirectional inputs are transmitted to the output. This arrangement eliminates pedestal, because of the circuit symmetry.



Four Diode Sampling gate

- When the control signals are at V1, D1 and D2 are OFF, no input signal is transmitted to the output. But when control signals are at V2, diode D1 conducts if the input is positive pulses and diode D2 conducts if the input is negative pulses. Hence these bidirectional inputs are transmitted to the output. This arrangement eliminates pedestal, because of the circuit symmetry.

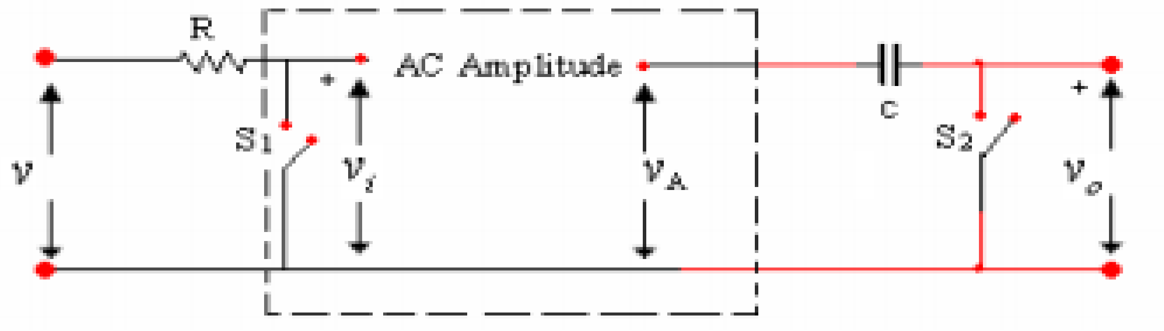


Applications

- ChopperAmplifier
- Multiplexers
- ADC
- Sampling Scope
- Sample and hold circuits

Chopper Amplifier

- Sometimes it becomes necessary to amplify a signal v that has very small dv/dt and that the amplitude of the signal itself is very small, typically of the order of millivolts. Neither, ac amplifiers using large coupling condensers nor dc amplifiers with the associated drift would be useful for such an application. A chopper stabilized amplifier employing sampling gates canbe a useful choice in such a applications



Chopper stabilized amplifier