Advanced Electronics Circuit (3-0-0)

Module 1 (10 Hours)

Review of Selected Topics in Electronic Circuits, Active Filters: First & Second order low pass/high pass, band pass, band reject, and all pass filters. Universal active filter design, Comparators, Sawtooth wave generator using OP Amps, Waveform Conversion, Instrumentation Amplifier. Wideband amplifiers: Frequency response, Transient response of transistor stage, shunt compensation of a transistor stage in cascade, Rise time of cascaded compensated stages, low frequency compensation. Tuned Amplifiers: Single tuned, Double tuned, Staggered tuned.

Module 2 (9 Hours)

Bistable Multivibrator: Stable States of a binary, Fixed Biased and Self-biased Transistor binary, Commutating Capacitors, Symmetrical and Unsymmetrical triggering, Direct connected binary, Schmitt trigger Circuit, Emitter coupled Binary. The Monostable Multivibrator: Collector coupled Monostable Multi, Waveforms, Emitter-coupled Monostable Multi, triggering of Monostable Multi. Astable-Multivibrator: Emitter Coupled, Collector Coupled, Waveforms.

Module 3 (9 Hours)

Negative resistance devices and Negative Resistance Switching Circuits: Tunnel diode, UJT operation and characteristics, Application of UJT to generate Sawtooth waveform, Tunnel diode monostable, astable, bistable and comparator circuits.

Module 4 (7 Hours)

Analysis of Voltage time base generator, Current time base generator, IC 555 Timer Circuit and Applications, Voltage Controlled Oscillator, Phase Locked Loop.

Text Book:

1. Pulse, Digital and switching Waveforms – Jacob Millman, Herbert Taub, M. Prakash Rao, 2nd Ed, The McGraw-Hill Companies (Selected portions from Chapters 4, 5, 10, 11, 12, 13, 14 and 15)

2. Electronic Principles- A.Malvino, D.Bates, 7th ed, The McGraw-Hill Companies. (Selected Portions from Chapters 21, 22, 23 for Module 1 and 4 only)

3. OP-Amps and Linear Integrated Circuits-Ramakant A.Gayakwad (PHI Learning Pvt.Ltd.)

Reference:

Pulse and Digital Circuits by A.Anand Kumar, PHI Learning Pvt. Ltd.

Lesson Plan

Module: 1

Topics to be covered	***No of classes***
Review of selected topics in electronic circuits:	01
Active Filters:	
Passive and active filter, Low pass filter, High pass filter, Band pass filter, Band stop filter, All pass filter, Attenuator, Approximate responses	01
First order low pass and high pass stages, VCVS unity gain and equal component second order low pass filter, VCVS second order high pass filter	01
Narrow band and wide band band pass filter, band stop filter, first order and second order all pass filter, universal filter	01
Inverting and non-inverting comparators	01
Saw tooth wave generator using OPAMP, wave conversion	01
Instrumentation amplifier	01
Wide band amplifiers:	
Frequency response and transient response of transistor stage	01
Shunt compensation of a transistor stage in cascade	01
Rise time of cascaded compensated stages, low frequency compensation	01
Single stage tuned amplifier	01
Double tuned and staggered tuned amplifier	01

Module: 2

Topics to be covered	***No of classes***

Bistable multivibrator:

Stable states of a binary	01
Fixed biased and self biased transistor binary, commutating capacitors	01
Unsymmetrical and symmetrical triggering	01
Direct connected binary, Schmitt trigger circuit	01
Emitter coupled binary	01
Monastable multivibrator:	01
Collector coupled monostable multivibrator with waveforms	
Emitter coupled monostable multivibrator	01
Triggering of monostable multivibrator	01
Astable multivibrator:	
Emitter coupled astable multivibrator	01
Collector coupled astable multivibrator	01

Module: 3

Topics to be covered	***No of classes***

Negative resistance devices and negative resistance switching circuits:

Tunnel diode	01
Tunnel diode monostable circuit	01
Tunnel diode bistable multivibrator	01
Comparator circuit	01
UJT operation and characteristics	01
Saw tooth waveform generator using UJT	

Module: 4

Topics to be covered	***No of classes***
Analysis of voltage time base generator	02
Current time base generator	02
IC 555 timer circuit and applications	02
Voltage controlled oscillator	02
Phase locked loop	02

Module - I

Active filters:

The circuit which separates desired signal from the undesired signal by passing one band of frequencies and rejecting another is called a filter. Filters block interfering signals, enhance speech and video, and alter signals in other ways. Considering the components used the filters are of two types:

1. Passive filter.
2. Active filter.

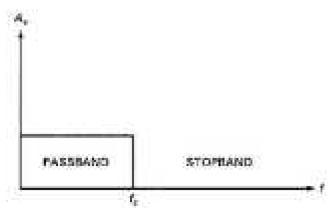
Passive filters are built with resistors, capacitors, and inductors. They are generally used above 1 MHz, have no power gain, and are relatively difficult to tune.

Active filters are built with resistors, capacitors, and op amps. They are useful below 1 MHz, have power gain, and are relatively easy to tune.

The frequency response of a filter is the graph of its voltage gain versus frequency. There are five types of filters:

1. Low-pass filter
2. High-pass filter
3. Bandpass filter
4. Bandstop filter
5. All-pass filter

Low-pass filter:

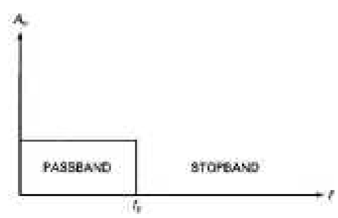


It is also called as a brick wall response because the right edge of the rectangle looks like a brick wall. A low-pass filter passes all frequencies from zero to the cutoff frequency called the passband and blocks all frequencies above the cutoff frequency called the stopband.

The roll-off region between the passband and the stopband is called the transition.

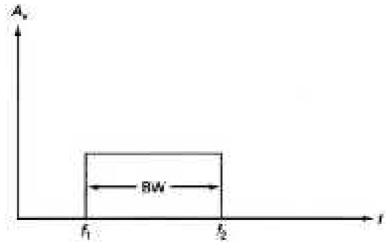
An ideal low-pass filter has zero attenuation (signal loss) in the passband, infinite attenuation in the stopband, and a vertical transition.

High-pass filter:



A high-pass filter blocks all frequencies from zero to the cutoff frequency called the stopband and passes all frequencies above the cutoff frequency called the passband. An ideal high-pass filter has infinite attenuation in the stopband, zero attenuation in the passband, and a vertical transition.

Bandpass filter:



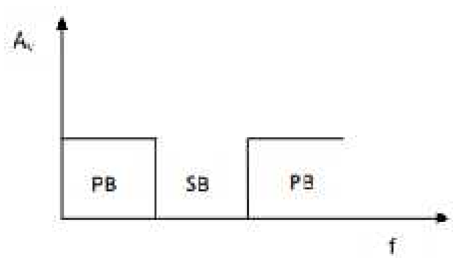
A bandpass filter is useful in tuning a radio or television signal. It is also useful in telephone communications equipment for separating the different phone conversations that are being simultane- ously transmitted over the same communication path.

For a bandpass filter, the passband is all the frequencies between the lower and upper cutoff frequencies. The frequencies below the lower cutoff frequency and above the upper cutoff frequency are the stopband.

An ideal bandpass filter has zero attenuation in the passband, infinite attenuation in the stopband, and two vertical transitions.

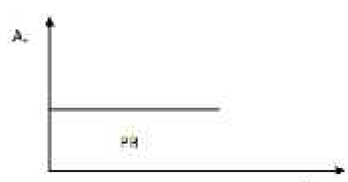
The bandwidth (BW) of a bandpass filter is the difference between its upper and lower 3-dB cutoff frequencies BW = f2 – f1.
Center frequency f0 = $\sqrt{f_1 f_2}$.
Figure of merit Q = f0 /BW.
If Q > 10 f0 can be averaged as (f1+f2) / 2.
For Q < 1, the bandpass filter is called a wideband bandpass filter.
Q > 1, the filter is a narrow band bandpass filter.

Bandstop filter:



It is same as the bandPass filter and sometimes called as a notch filter.

All-pass filter:



The reason it is called a filter is because of the effect of phase change. Each distinct frequency can be shifted by a certain amount. Allpass filter is widely used in industry to shift the phase of the output signal without changing the magnitude. Another descriptive title would be the time-delay filter, since time delay is related to a phase shift.

Response approximations:

An approximation is a trade off between the characteristics of the pass band, stop band and transition region. The approximations may optimize the flatness of the passband or the roll off rate or the phase shift.

Attenuation:

Attenuation refers to a loss of signal and is defined as the output voltage at any frequency divided by the output voltage in the midband:

Attenuation = Vout / Vout(mid)

Attenuation is normally expressed in decibels using this equation:

Decibel attenuation = 20 log attenuation.

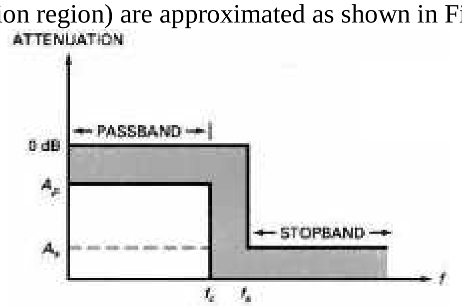
For an attenuation of 0.5, the decibel attenuation is:

Decibel attenuation = -20 log 0.5 = 6 dB

Because of the minus sign decibel attenuation always is a positive number. Decibel attenuation uses the midband output voltage as a reference. Basically, we are comparing the output voltage at any frequency to the output voltage in the midband of the filter. Because attenuation is almost always expressed in decibels, we will use the term attenuation to mean decibel attenuation. For instance, an attenuation of 3 dB means that the output voltage is 0.707 of its midband value. An attenuation of 6 dB means that the output voltage is 0.5 of its midband value. An attenuation of 12 dB means that the output voltage is 0.25 of its midband value. An attenuation of 20 dB means that the output .voltage is 0.1 of its midband value.

Passband and Stopband Attenuation:

In filter analysis and design, the low-pass filter is a prototype, a basic circuit that can be modified to get other circuits. Any filter problem is converted into an equivalent low-pass filter problem and solved as a low-pass filter problem; the solution is convened back to the original filter type. To build a practical low-pass filter, the three regions (passaband, stopband, transition region) are approximated as shown in Figure given below.



The passband is the set of frequencies between 0 and fc. The stopband is all the frequencies above fs. The transition region is between fc and fs.

The passband no longer has zero attenuation. Instead, we are allowing for an attenuation between 0 and Ap.

Similarly, the stopband no longer has infinite attenuation. Instead, we are allowing the stopband attenuation to be anywhere from As to infinity.

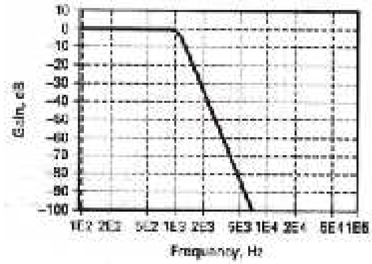
The transition region is no longer vertical. Instead, we are accepting a nonvertical rolloff. The roll-off rate will be detemtined by the values of fc, fs, Ap, and As.

Order of Filter:

The order of a passive filter equals the number of inductors and capacitors in the filter. The order of an active fiIter depends on the number of RC circuits (called poles) it contains. Counting the individual RC circuits in an active filter is usually difficult. Therefore, it is determined by the numberof capacitors.

Butterworth Approximation:

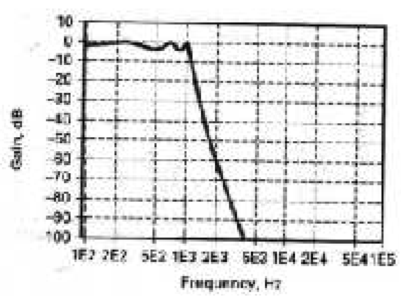
The Butterworth approximation is sometimes called the maximally flat approximation. Here the pass- band attenuation is zero through most of the passband and decreases gradually to Ap at the edge of the passband.



For this approximation
Roll off = 20n dB/decade
= 6n dB/octave
Where n is the order of the filter.

Chebyshev Approximation:

If a flat passband response is not important, then a Chebyshev approximation may be preferred.



Its rolls off is faster in the transition region than a Butterworth fllter. Because of this, for the same order, the attenuation with a Chebyshev filter is always greater than the attenuation of a Butterworth filter.

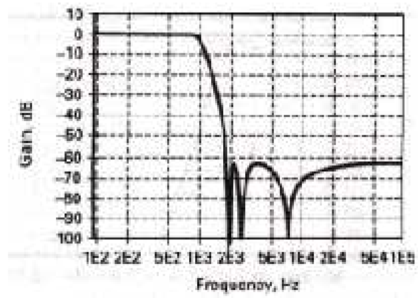
The number of ripples in the passband of a Chebyshev low-pass filter equals half of the filter order:

Number of Ripples = n / 2.

In a Chebyshev approximation the ripples have the same peak-to-peak value. This is why it is sometimes called the equal-ripple approximation.

Inverse Chebyshev Approximation:

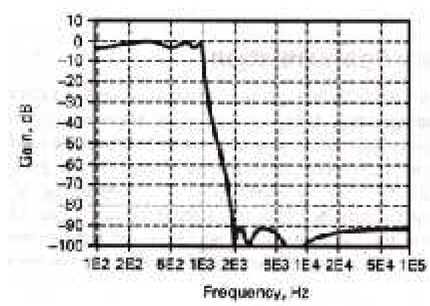
If a flat passband response is required, as well as a fast roll-off, the inverse Chebyshev approximation is used. It has a flat passband response and a rippled stopband response. The roll-off rate in the transition region is comparable to the roll-off rate of a Chebyshev filter.



We can see that the inverse Chebyshev filter has a flat passband, a fast roll-off, and a rippled stopband. Monotonic means that the stopband has no ripples. With the approximations discussed so far, the Butterworth and Chebyshev fllters have monotonic stopbands. The inverse Chebyshev has a rippled stop band. The inverse Chebyshev filter has components that notch the response at certain frequencies in the stopband. In other words, there are frequencies in the stopband at which the attenuation approaches infinity.

Elliptic Approximation:

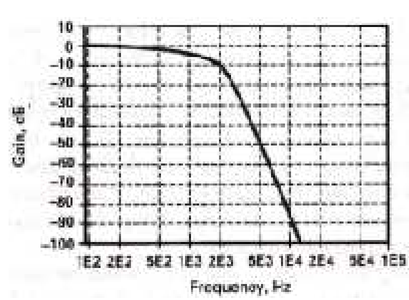
Some applications need the fastest possible roll-off in the transition region. If a rippled passband and a rip- pled stopband are acceptable, a designer may choose the elliptic approximation.



This is also known as the Cauer filter and it optimizes the transition region at the expense of the passband and stopband. The elliptic filter has a rippled passband, a very fast roll-off, and a rippled stopband. After the response breaks at the edge frequency, the initial roll-offis very rapid, slows down slightly in the middle of the transition, and then becomes very rapid toward the end of the transition. Given a set of specifications for any complicated filter, the elliptic approximation will always produce the most efficient design; that is, it will have the lowest order.

Bessel Approximation:

The Bessel approximation has a flat passband and a monotonic stopband similar to those of the Butterworth approximation. For the same filter order, however, the roll-off in the transition region is much less with a Bessel filter than with a Bufterworth filter.



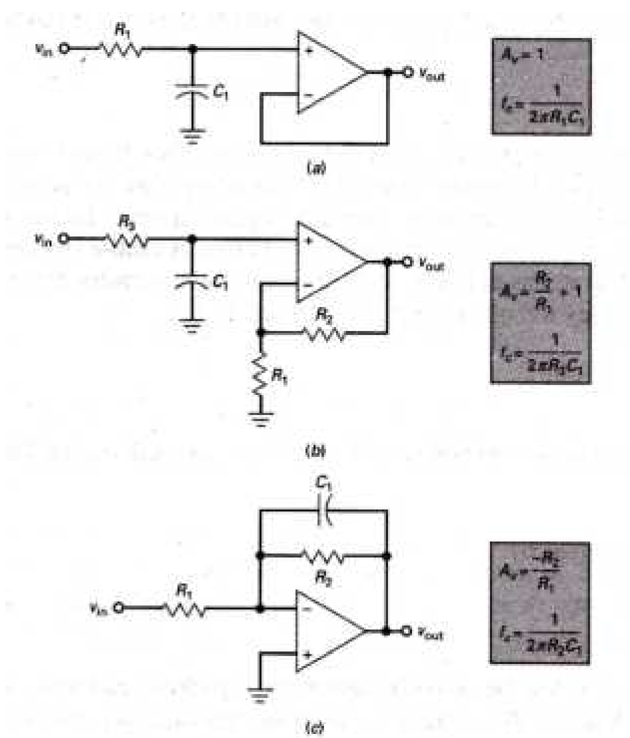
Given a set of specifications for a complicated filtet the Bessel approximation will always produce the least roll-off of all the approximations. It has the highest order or greatest circuit complexity of all approximations. Bessel approximation is optimized to produce a linear phase shift with frequency. In other words, the Bessel filter trades off some of the roll-off rate to get a linear phase shift.

With a Bessel filter we cannot get a phase shift of 0^0, but we can get a linear phase response. The major advantage of the Bessel filter is that it produces the least distortion of nonsinusoidal signals.

First-Order Stages:

First-order or 1-pole active-filter stages have only one capacitor. Because of this, they can produce only a low-pass or a high-pass response. Bandpass and bandstop filters can be implemented only when n is greater than 1.

Low-Pass Stage:



Fiure (a) shows the simplest circuit of a first-order low-pass active filter.It is nothing more than an RC lag circuit and a voltage follower.

The voltage gain is Av = 1.

The 3-dB cutoff frequency is given by:

fc = 1/ 2πR1C1

When the frequency increases above the cutoff frequency, the capacitive reactance decreases and reduces the noninverting input voltage. Since the R1C1 lag circuit is outside the feedback loop, the output voltage rolls off. As the frequency approaches infinity, the capacitor becomes a short and there is zero input voltage.

Figure (b) shows another noninverting first-order low-pass filter. Although it has two additional resistors, it has the advantage of voltage gain of:

Av = (R2/R1)+1

The 3-dB cutoff frequency is given by:

fc = 1/ 2πR3C1

Above the cutoff frequency, the lag circuit reduces the noninverting input voltage. Since the R3C1 lag circuit is outside the feedback loop, the output voltage rolls off at a rate of 2O dB per decade.

Figure (c) shows an inverting first-order low-pass filter and its equations. At low frequencies, the capacitor appears to be open and the circuit acts like an inverting amplifier with a voltage gain of:

Av = - R2/R1

The 3-dB cutoff frequency is given by:

fc = 1/ 2πR2C1

As the frequency increases, the capacitive reactance decreases and reduces the impedance of the feedback branch. This implies less voltage gain. As the frequency approaches infinity, the capacitor becomes a short and there is no voltage gain.

High-Pass Stage:

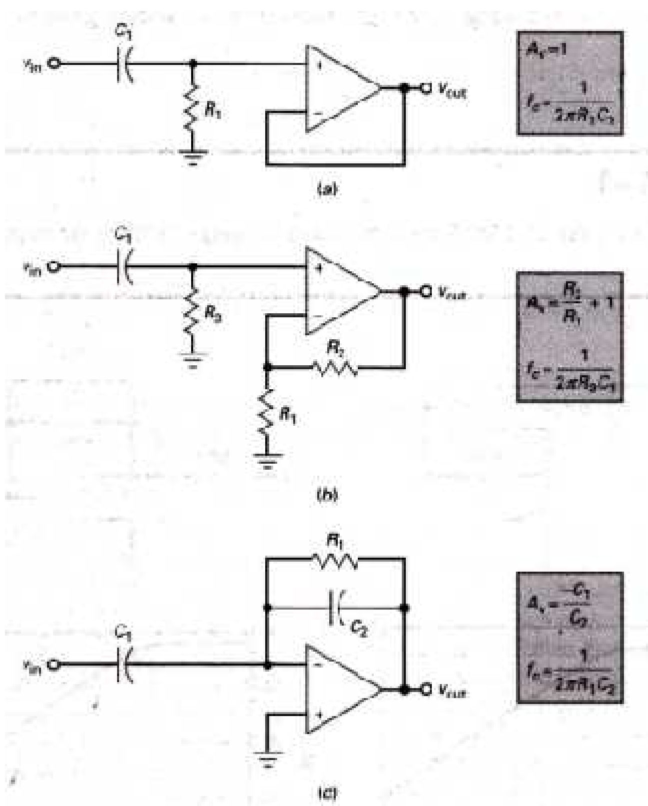


Figure (a) shows the simplest form of a first-order high-pass active filter.

The voltage gain is:
Av = 1.

The 3-dB cutoff frequency is given by:

$fc = 1/ 2\pi R1C1$

When the frequency decreases below the cutoff frequency, the capacitive reactance increases and reduces the noninverting input voltage. Since the R1C1 circuit is outside the feedback loop, the output voltage rolls off. As the frequency approaches zero, the capacitor becomes an open and there is zero input voltage

Figure (b) shows another noninverting first-order high-pass filter. The voltage gain well above the cutoff frequency is given by:

$Av = (R2/R1)+1$

The 3-dB cutoff frequency is given by:

$fc = 1/ 2\pi R3C1$

Well below the cutoff frequency, the RC circuit reduces the noninverting input voltage. Since the R3C1 lag circuit is outside the feedback loop, the output voltage rolls off at a rate of 20 dB per decade.

Figure (c) shows another first-order high-pass filter and its equations. At high frequencies the circuit acts like an inverting amplifier with a voltage gain of:

$Av = - Xc2 / Xc1 = - C1 / C2$

As the frequency decreases, the capacitive reactances increase and eventually reduce the input signal and the feedback. This implies less voltage gain. As the frequency approaches zero, the capacitors become open and there is no input signal.

The 3-dB cutoff frequency is given by:

$fc = 1/ 2\pi R1C2$

MODULE -III

THE TUNNEL DIODE:

In the tunnel diode the concentration of impurity atoms is greatly increased, say to 1 part in 103 in both sides. The width of the junction barrier varies inversely as the square root of impurity concentration and therefore is reduced. This thickness is only about one-fiftieth the wavelength of visible light. Quantum mechanics dictates that there is a large probability that an electron will penetrate through the barrier. The quantum mechanical behavior is referred to as "tunneling," and hence these high impurity-density p-n junction devices are called "tunnel diodes".

The tunneling effect and the band structure of heavily doped semiconductors the volt-ampere characteristic of Fig. 1 is obtained.

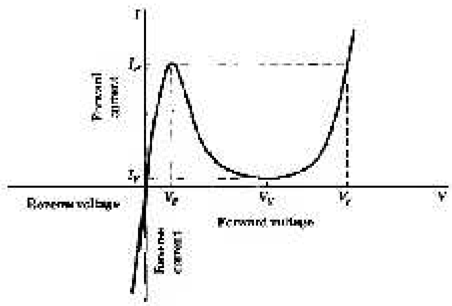


Fig-1: Volt-ampere characteristic of a tunnel diode.

The device is an excellent conductor in the reverse direction (p side of junction negative with respect to the n side). Also, for small forward voltages (up to 50 mV for Ge) the resistance remains small (of the order, of 5 Ω). At the peak current I_P corresponding to the voltage V_p the slope dl/dV of the characteristic is zero. If V is increased beyond V_p, then the current decreases. As a consequence the dynamic conductance g = dl/dV is negative. The tunnel diode exhibits a negative-resistance characteristic between the peak current I_P and the minimum value I_v, called the valley current. At the valley voltage V_v at which $I = I_v$ the conductance is again zero, and beyond this point the resistance becomes and remains positive. At the so-called peak forward voltage V_p the current again reaches the value I_P. For larger voltages the current increases beyond this value. The portion of the characteristic beyond V_v is caused by the injection current in an ordinary p-n junction diode. The remainder of the characteristic is a result of the tunneling phenomenon in the highly doped diode. For currents whose values are between I_v and I_p the curve is triple-valued, because each current can be obtained at three different applied voltages.

Note that whereas the characteristic in Fig. 1 is a multivalued function of current, it is a single-valued function of voltage. Each value of V corresponds to one and only one current. Hence, the tunnel diode is said to be voltage-controllable.

The standard circuit symbol for a tunnel diode is given in Fig. 2a.The small-signal model for operation in the negative-resistance region is indicated in Fig. 2b. The negative resistance $-R_n$„ has a minimum at the point of inflection between I_p and I_v.The series resistance R_s, is ohmic resistance. The series inductance L_s, depends upon the lead length and the geometry of the diode package. The junction capacitance C depends upon the bias and is usually measured at the valley point. Typical values for these parameters for a tunnel diode of peak current value I_p = 10 mA are $-R_n$ = -30 Ω, R_s, = 1Ω, L_s = 5 nH, and C = 20 pF.

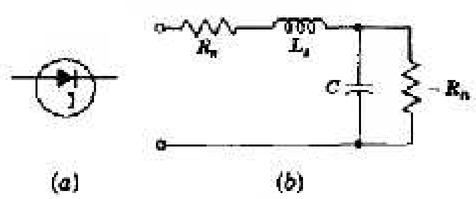


Fig 2:(a) Symbol for a tunnel diode (b) small-signal model in the negative-resistance region.

The **advantages** of the tunnel diode are low cost, low noise, simplicity, high speed, environmental immunity, and low power. The **disadvantages** of the diode are its low output-voltage swing and the fact that it is a two terminal device. Because of the latter feature, there is no isolation between input and output, and this leads to serious circuit-design difficulties. Hence, a transistor (an essentially unilateral device) is usually preferred for frequencies below about 1 GHz (a kilomegacycle per second) or for switching times longer than several nanoseconds.

THE UNIJUNCTION TRANSISTOR:

The construction of this device is indicated in Fig. 3 a. A bar of high resistivity n-type silicon of typical dimensions 8 X 10 X 35 mils, called the base B, has attached to it at opposite ends two ohmic contacts B1 and B2. A 3-mil aluminum wire, called the emitter E, is alloyed to the base to form a p-n rectifying junction. This device was originally described in the literature as the double-base diode but is now commercially available under the designation unijunction transistor (UJT).

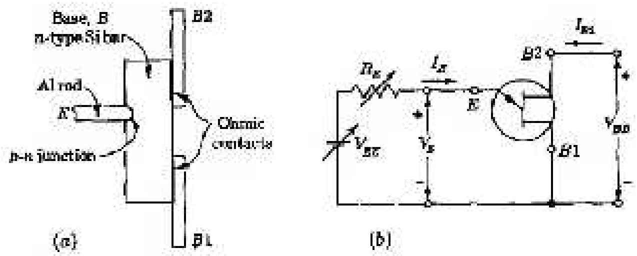


Fig -3 Unijunction transistor (a) Constructional details; (b) circuit symbol

Note that the emitter arrow is inclined and points toward B1, whereas the ohmic contacts B1 and B2 are brought out at right angles to the line which represents the base.
As usually employed, a fixed interbase potential V_{BB} is applied between Bl and B2. The most important characteristic of the UJT is that of the input diode between E and Bl . If B2 is open-circuited so that $I_{B2}= 0$, then the input volt-ampere relationship is that of the usual p-n junction diode. In Fig. 4 the input current-voltage characteristics are plotted for I_{B2} = and also for a fixed value of interbase voltage V_{bb}. The latter curve is seen to have the current-controlled negative-resistance characteristic which is single-valued in current but may be multivalued in voltage. A qualitative explanation of the physical origin of the negative resistance will now be given.

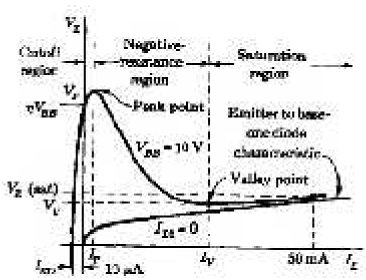


Fig 4: Idealized input characteristic of a unijunction transistor.

If I_b = then the silicon bar may be considered as an ohmic resistance R_{bb} between base leads. Usually R_{bb} lies in the range between 5 and 10 K. Between Bl (or B2) and the n side of the emitter junction the resistance is R_{Bi} (or R_{B2}, respectively), so that $R_{BB}= R_{B1} + R_{B2}$. Under this condition of zero or very small emitter current the voltage on the n side of the emitter junction is ηV_{BB}, where $\eta = R_{B1}/R_{BB}$ is called the intrinsic stand-off ratio.

If V_E is less than ηV_{BB}, then the p-n junction is reverse-biased and the input current I_E is negative. As indicated in Fig.4, the maximum value of this negative current is the reverse saturation current I_{EO}, which is of the order of only 10 µA even at 150°C. If V_{EE} is increased beyond ηV_{BB} the input diode becomes forward-biased and I_E goes positive. However, as already noted in connection with Fig. 4, the current remains quite small until the forward bias equals the cutin voltage V_γ (« 0.6 V), and then increases very rapidly with small increases in voltage.

The emitter current increases the charge concentration between E and B1 because holes are injected into the n-type silicon. Since conductivity is proportional to charge density, the resistance R_{B1} decreases with increasing emitter current. Hence, for voltages above the threshold value V_γ, as I_B is increased (by either increasing V_{EE} or decreasing R_E in Fig.3b) the voltage V_E between E and B1 decreases because of the decrease in the value of the resistance R_{B1}. Since the current is increasing while the voltage is decreasing, then this device possesses a negative resistance.

After the emitter current has become very large compared with I_{B2} , then we may neglect I_{B2}. Hence, for very large IB the input characteristic asymptotically approaches the curve for $I_{B2} = 0$. As indicated in Fig. 4, this behavior results in a minimum or valley point where the resistance changes from negative to positive. For currents in excess of the valley current I_V the resistance remains positive. This portion of the curve is called the saturation region. The voltage at $I_E = 50$ mA is arbitrarily called the saturation voltage V_E(sat).
At the maximum voltage or peak point V_P the current is very small (I_p □ 25 mA), and hence the region to the left of the peak point is called the cutoff region. For many applications the most important parameter is the peak voltage V_P, which, as explained above, is given by

$$V_P = \eta V_{BB} + V\gamma$$

THE NEGATIVE-RESISTANCE V-I CHARACTERISTIC

The voltage to current characteristics is as follows.

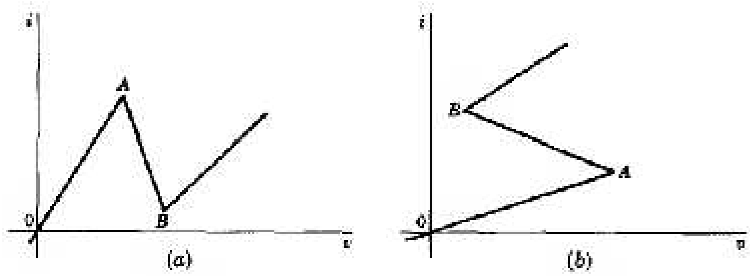


Fig-5 (a) A voltage-controllable negative-resistance characteristic (b) a current-controllable negative-resistance characteristic

We observe in Fig. 5.a that associated with each voltage there is a unique current, but the plot does not everywhere associate a unique voltage with each current. In the plot of Fig. 5.b the inverse applies. To distinguish the one from the other we call the characteristic in Fig. 5.a voltage controllable and in Fig. 5.b is current-controllable. The tunnel diode falls into the voltage-controllable class, whereas UJT have a current-controllable characteristic.

BASIC CIRCUIT PRINCIPLES:

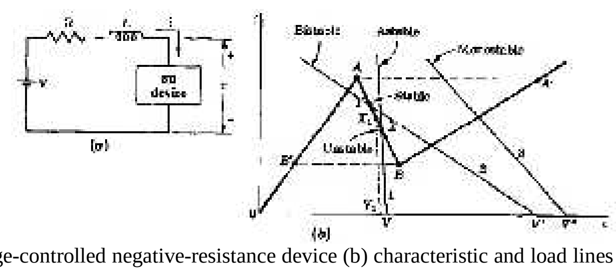


Fig 6.(a) A circuit involving a voltage-controlled negative-resistance device (b) characteristic and load lines for bistable, astable, and monostable operation.

The stability of an operating point may be investigated as follows

$$L\frac{di}{dt} = V - iR - v$$

If the operating point is momentarily at X_E (i_E, v_E), where $i_E R + v_E = V_E$, and if the supply voltage is Vs, then this equation may be written as

$$L\frac{di}{dt} at X_E = V_S - V_E$$

If the device is operating at X_E, which would be an equilibrium point if the supply voltage were V_E, but if in reality $V = V_S$, then di/dt is positive if $V_S > V_E$. Alternatively, if $V_S < V_E$ then di/dt is negative.

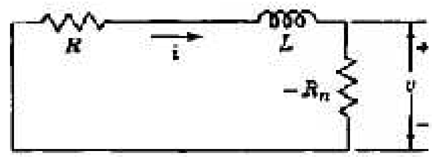


Fig. 7 Equivalent circuit for calculating response of circuit of Fig. 6 a for small excursions in the negative-resistance region.

TUNNEL-DIODE MONOSTABLE CIRCUIT:

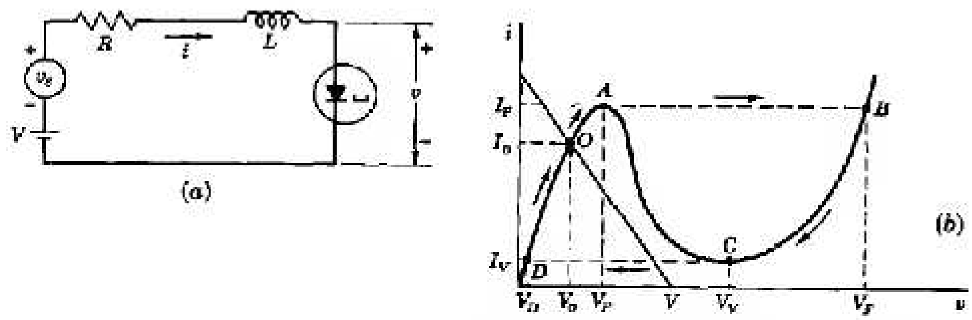


Fig 8: Monostable operation of a tunnel-diode (a) circuit, (b) operating path

A monostable tunnel-diode circuit is shown in Fig.8.a. Bias is provided by the source V in Fig. 8.a, which is adjusted so that the load line intersects the characteristic at one point on the positive-resistance portion. Then operating point is initially at point O, where $v = V_0$, and the diode current is $i=I_0$. A positive voltage pulse v_s, is applied to raise the load line so that it clears the peak at A. This trigger must have a time duration t_p adequate to allow the current in the inductor to change from $I_0$to I_P. The operating point having been raised to A, the circuit, of its own accord, follows the path indicated by the arrows, returning eventually to the starting point at O.

The application of the voltage pulse carries the diode from to A, increasing the voltage from V_0 to V_p and the current from I_0 to I_P. If the pulse amplitude were large enough so that the asymptotic limit to which the current were headed was much larger than I_P and if the diode resistance in the range from O to A were constant, then the rise of voltage from O to A would be linear.

At A the voltage jumps abruptly to B, where the voltage is V_F, while the current remains constant at I_p. As the operating point now moves from B to C, the voltage drops from V_F to V_v and the current from I_p to I_v. If the pulse persisted indefinitely, the load line would establish a stable equilibrium point on the high-voltage positive-resistance portion of the characteristic somewhat below B. We have assumed, however, that long before this equilibrium point is approached the pulse has terminated. Hence the operating point continues from B to C. There is then an abrupt transition in voltage from V_V to V_D at point D, and finally the circuit settles down to initial point O in an asymptotic manner.

The Waveforms of monostable tunnel-diode circuit, are shown below.

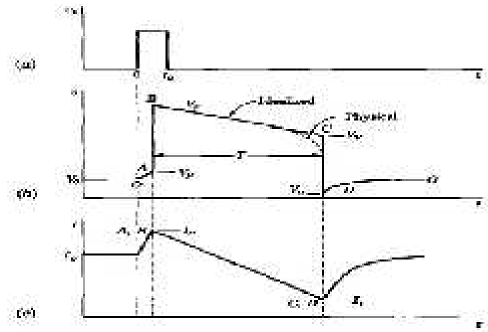


Fig.9 Waveforms of monostable tunnel-diode circuit,(a) Triggering pulse; (b) output voltage; (c) tunnel diode Current.

Calculation of the duration T:

A reasonable fit with the tunnel-diode curve is obtained if we choose

$V'_P = 0.75V_P$ and $V'_V = \dfrac{V_F + V_V}{2}$

If the diode resistance of the portion passing through the origin is called R_1 and if the second positive-resistance region is designated by R2, then

$$R_1 = \frac{V'_P}{I_P} \text{ and } R_2 = \frac{V_F - V'_V}{I_P - I_V}$$

To calculate T, the time duration from I_P to I_v, we replace the device by a resistor R2 in series with a battery $V' = V'_V - I_v R_2$. The equivalent circuit is now indicated in Fig. 10 (a) and (b), which are equivalent since

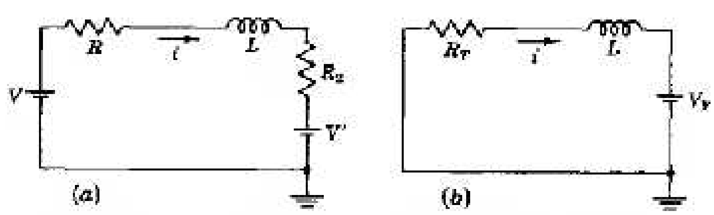


Fig. 10 (a) In the region from B to C where the current decreases from I_p to I_v the tunnel diode is replaced by a battery V' in series with a resistor R_2; (b) simplified circuit.

$$R_T = R + R_2$$
$$V_Y = V' - V - I_V R_2$$

Let us shift the time origin so that t = 0 when $i = I_P$. If the circuit of Fig. 10 were valid indefinitely, then at $t = \infty$, $i = V_Y/R_T$. Since this is a single-time-constant circuit,

$$i = -\frac{V_Y}{R_T} + \left(I_P + \frac{V_Y}{R_T} \right) e^{-\frac{R_T t}{L}}$$

Since i decreases to I_v at t = T we can solve this equation to obtain

$$T = \frac{L}{R_T} \ln \frac{V_Y + I_P R_T}{V_Y + I_V R_T}$$

TUNNEL-DIODE ASTABLE CIRCUIT:

In Fig.11.a the supply voltage and load line have been selected to yield an equilibrium point at O. This point is unstable, and the operating point having moved, say, to point A, it will thereafter follow the circuital path indicated by arrows. Waveforms of diode voltage and diode current are shown in Fig. 11b and c. Again these waveforms have been idealized somewhat. If the diode characteristic were piecewise linear the rises and falls of voltage and current in the waveforms would be exponential.

The tunnel-diode astable-circuit waveform is not necessarily exactly symmetrical (T_1 and T2 may not equal) because the portions DA and BC of the device characteristic are not identical,

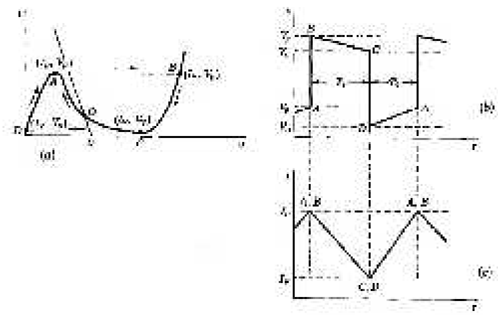


Fig. 11 Tunnel-diode astable multivibrator, (a) Adjustment of load line; (b) voltage waveform; (c) current waveform.

Using the piecewise linear approximation like for monostable multivibrators the time period T_1 and T_2 are as follows

$$T_1 = \frac{L}{R_T} \ln \frac{V_Y + I_P R_T}{V_Y + I_V R_T}$$

And

$$T_2 = \frac{L}{R'_T} \ln \frac{V - I_V R'_T}{V + I_P R'_T}$$

The total period is $T_1 + T_2$ and the free-running frequency is the reciprocal of this time.

TUNNEL-DIODE BISTABLE CIRCUIT:

With the load line selected as in Fig.12 the circuit has two stable states at the points of intersection of the load line with the positive-resistance portions of the device characteristic at X and X". If the circuit is at X and the signal source furnishes a positive pulse adequate to raise the load line to position 2, a transition will occur, and when the pulse has passed, the circuit will find itself at X". Similarly, a negative pulse adequate to drop the load line to the point where it clears the bottom of the characteristic will reset the circuit to its original stable point at X. Thus the circuit has two permanent stable states and may be used to store binary information or for any of the other purposes for which binary devices are employed.

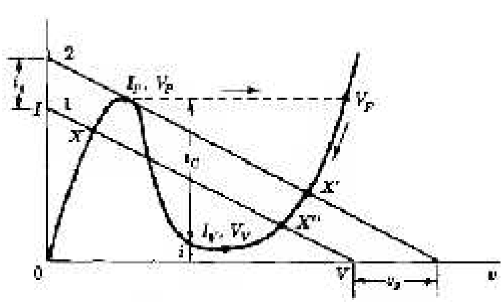


Fig.12: The tunnel diode used as a bistable multivibrator.

Sawtooth Generator using the Unijunction Transistor (UJT):

A relaxation-oscillator circui using UJT is shown in Fig.13. The circuit must be biased for astable operation; that is, the load line determined by V_{yy} and R must intersect the input characteristic in the negative-resistance region. The resistors R_{b1} and R_{b2} are not essential to the circuit but are included because the voltages developed across these resistors may prove useful.The capacitor C charges to the peak voltage V_p, the device turns on, and the capacitor discharges to the valley voltage V_v,

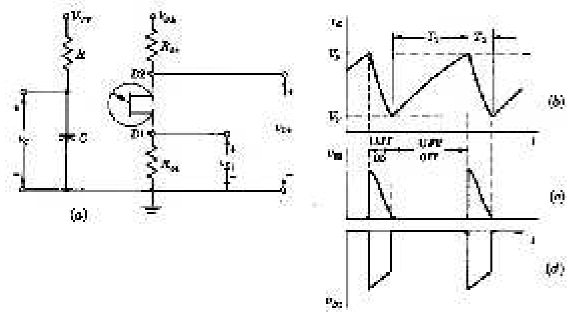


Fig. 13 (a) Unijunction transistor sawtooth-waveform generator; (b) capacitor voltage waveform; (c) voltage waveform at Bl (d) voltage waveform at B2.