1. History of Communication

Communication is the process of establishing connection or link between two points for information exchange.
It is simply the basic process of exchanging information.

What is communication system?

⇒ All the equipments which are used for communication purpose when assembled together form a communication system.

Examples are:

→ line ~~telephony~~, telegraphy, line telephony,
→ radio telephony, radio telegraphy, radio broadcasting.
→ point-to-point communication, mobile communication.
→ computer communication, radar communication
→ television broadcasting, radio telemetry, radio aids to navigation.

History:

1. The earliest communication system namely line-telegraphy originated in eighteen fort fourties (1840s).
2. Line-telephony came a few decades later.
3. Radio communication could become possible in the beginning of twentieth century on invention of triode valve. After the invention of transistor, ICs & other semiconductor devices it has been widely used in the recent years.
4. Also in recent years communication has become more widespread with the use of satelites & fiber optics.
5. Nowadays, there has been an increasing emphasis on the use of computers in communication.

a) Communication Process: Elements of Communication System

The purpose of a communication system is to transmit an information-bearing signal, from a source, located at one point, to a user or destination, located at another point some distance away.
The figure 1.1 shows the block diagram of a general communication system in which different elements are represented by blocks.

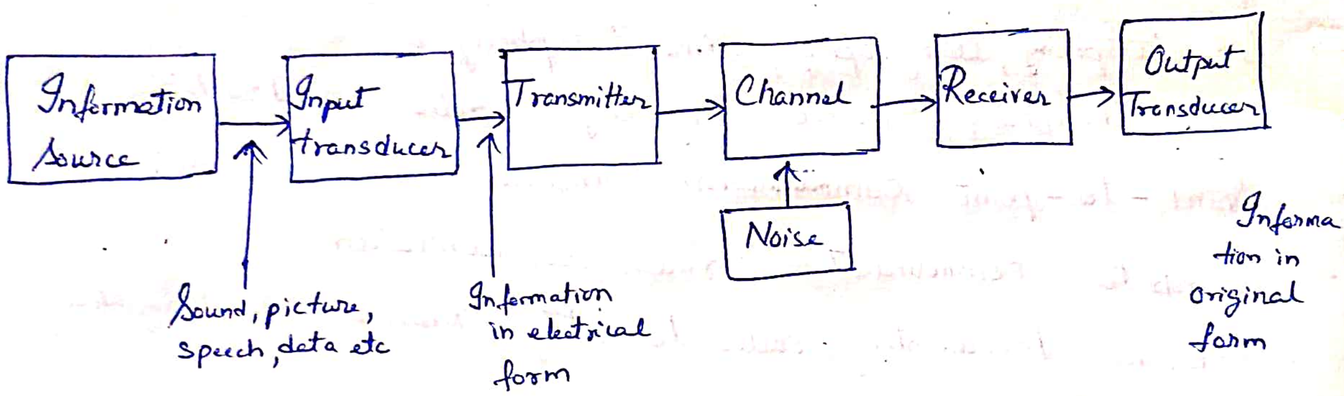


Fig. 1.1 Block diagram of communication system.

The essential components of a communication system are information source, input transducer, transmitter, communication channel, receiver, and destination.
The functioning of the blocks are discussed below:

1. Information Source:

The function of the information source is to produce required message in the form of words, code, symbols, sound signal, speech, data, picture etc which has to be transmitted. However, out of these message only the desired message is selected & conveyed or communicated.

2. Input tranducer :

A transducer is a device which converts one form of energy into another form. When the message signal produced by the information source is not electrical in nature, an input transducer is used to convert it into a time-varying electrical signal.

Ex: In case of radio - broadcasting, a microphone converts the information or message which is in the form of sound waves into electrical signal.

3. Transmitter :

The function of The Transmitter is to process the electrical signal from different aspects. Inside the transmitter all the signal proceedings processings such as restriction of range of audio frequencies, amplification & modulation are achieved.

Ex: In radio-broadcasting the electrical signal obtained from sound signal, is processed to restrict its range of audio frequencies (upto 5kHz) & is often amplified.

4. The Channel & the Noise :

The function of the channel is to provide a physical connection between transmitted & the receiver. There are two types of communication channels -

→ point-to-point channels (wire lines, microwave links & optical fibres)

→ broadcast channels (satellite in geostationary orbit)

✓ Wirelines operate by guided electromagnetic waves & they are used for local telephone transmission.

✓ Microwave links are also guided by electromagnetic wave in free spase for long distance tephone transmission.

✓ Optical fibers are used in optical communications. It is a low-loss, well-controlled, guided optical medium.

All the above channels are used for transmission of signals from ~~fo~~ one point to another point. Therefore, the term point-to-point is used.

On the other hand, the broadcast channels provide a capability where several receiving stations can be reached simultaneously from a ~~sig~~ single transmitter.

Noise :

During the process of transmission & reception the signal gets distorted due to noise introduced in the system.

Noise is an unwanted signal which tend to interfere with the required signal. Noise signal is always random in character. It may interfere with signal at any point in a communication system. However, the noise has its greatest effect on the signal in the channel.

5. Receiver :

The function of the receiver is to reproduce the message signal in the electrical form from the distorted signal. (This process is carried out by a demodulation process ~~in the Transmitted~~.)

6. Destination :

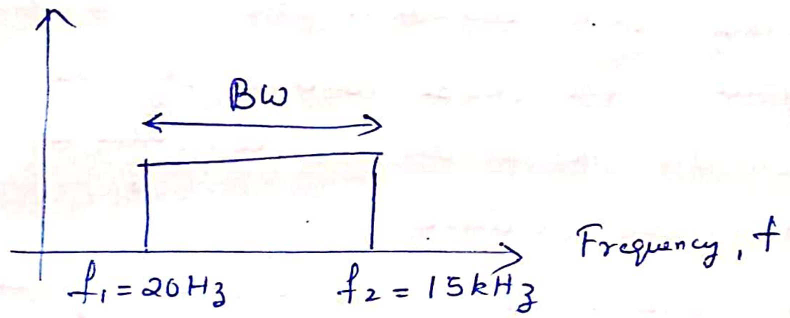
It is the final stage which is used to convert an electrical message signal into its original form.

Ex: In radio broadcasting, the destination is a loudspeaker which converts electrical signal in the form of original signal.

b) Concept of Bandwidth

- Bandwidth may be defined as the portion of the electromagnetic spectrum occupied by a signal.
- It is also defined as the frequency range over which an information signal is transmitted.
- Bandwidth is the difference between upper and lower frequency limits of the signal.

Ex: The range of music signal is 20 Hz to 50 Hz. Determine Bandwidth.



$$BW = f_2 - f_1$$

Ex: $BW = 15000 - 20 = 14980\ Hz$.

There are different types of passband signals such as voice signal, music signal, TV signal, etc. Each of these signals will have its own frequency range known as bandwidth.

	Range of frequency (Hz)	BW
1. Voice signal	300 - 3400	3,100
2. Music signal	20 - 15000	14,980
3. TV signals	0 - 5MHz	5 MHz
4. Digital data	300 - 3400	3,100

2) Issues of noise in communication :

Noise is an unwanted electrical disturbance which gives rise to audible or visual disturbances in the communication system.

a) Sources of Noise :

The noise can arise from different types of sources as discussed below :

1. Natural sources :

The natural phenomena's like electronic storm, solar flares and radiation in space. The noise received by the receiving antenna from the natural sources can ~~also~~ only be reduced by repositioning the antenna.

The noise originating from the sun and the outer space is known as Extraterrestial Noise. It can be divided into two groups -

i) Solar Noise - at very high temperature radiates a lot of noise.

ii) Cosmic Noise - comes from stars (large hot bodies) like sun.

2) Manmade sources (Industrial noise)

The manmade noise is generated due to make and break process in current carrying circuit.

Ex: electrical motors, welding machines, fluorescent lights, switching gears etc.

3) Fundamental or Internal sources of noise

This type of noise are present within the electronic equipment. They can be eliminated by properly designing the electronic circuits & equipments.

3) Fundamental or Internal sources of noise can be divided further into sub-groups -

Classification of Noise:

The fundamental noise sources produce different types of noise. They may be listed as under:

1) Thermal Noise
2) Shot Noise
3) Low frequency or flicker noise
4) High frequency or transit time, noise
5) Partition Noise.

Let us discuss them one by one:

1) Thermal Noise

The free electrons within a conductor are always random in nature. This random motion is due to the thermal energy received by them. The distribution of these free electrons within a conductor at a given instant of time is not uniform.

The average voltage resulting from this non-uniform distribution is zero but the average power is not zero.

The average thermal noise power is given by,

$P_n \propto TB$, $P_n = kTB$ watts

where k = Boltzmann's constant = 1.38×10^{-28} Joules/Kelvin

B = Bandwidth of noise spectrum (Hz)

T = Temperature of conductor (°K).

Ex: A receiver has a noise power bandwidth of 12 kHz. A resistor which matches with the receiver input impedance is connected across the antenna terminals. What is the noise power contributed by this resistor in the receiver bandwidth. Assume temperature to be 30 °C.

Sol: Given, $B = 12 kHz = 12 \times 10^3 Hz$

$T = 30°C = 30 + 273 = 303 °K$

Noise power contributed by the resistance is given by,

$$P_n = kTB$$

$$P_n = 1.38 \times 10^{-23} \times 303 \times 12 \times 10^3$$

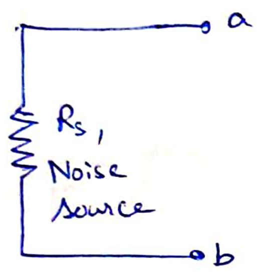
$$P_n = 5.01768 \times 10^{-17} W.$$

Equivalent Circuits for thermal Noise :

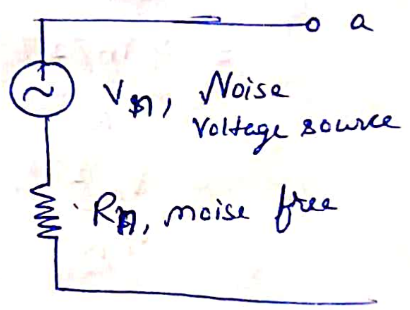
Noise power can be modeled using ~~voltage equi~~

1) Voltage equivalent circuit (Thevenin equivalent circuit)
2) Current equivalent circuit (Norton equivalent circuit)

It can be modeled by a voltage source representing the noise of the non-ideal resistor in series with an ideal noise free resistor.

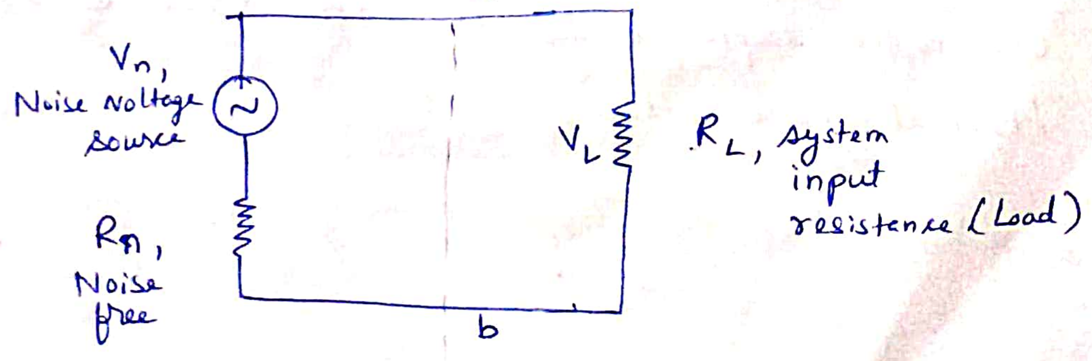


(a) Noise source circuit



(b) Thevenin equivalent circuit

- ✓ Noise source will be connected to a ~~con~~ system with the input resistance R_L.
- ✓ Total noise power is P_n.
- ✓ With the concept of maximum power transfer i.e when $R_n = R_L$ all the power will be transferred to the load, also called as impedance matching.



(c) Thevenin equivalent circuit with the load .

Given, $R_n = R_L = R$

Using voltage divider rule,

$$V_L = \frac{R_L}{R_n + R_L} V_n$$

$$= \frac{R}{2R} V_n$$

$$= \frac{V_n}{2}$$

Power, $P_L = \frac{V_L^2}{R}$

$$= \frac{(V_n/2)^2}{R}$$

$$= \frac{V_n^2}{4R} \quad \text{——— (1)}$$

and $P_n = P_L = kTB$ ——— (2) (thermal noise power by resistance)

On equating eqn (1) & (2)

$$\frac{V_n^2}{4R} = kTB$$

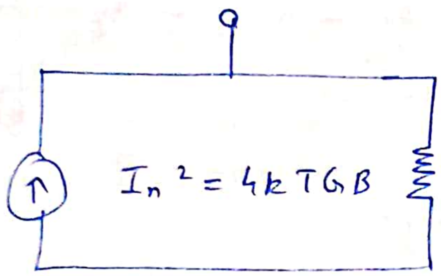
$$V_n^2 = 4kTBR$$

Noise voltage, $\boxed{V_n = \sqrt{4kTBR}}$

This is the expression for the rms value of the thermal noise voltage.

2) Current equivalent circuit :

G = conductance = $\frac{1}{R}$



(d) Norton equivalent circuit

The rms noise current,

$$I_n = \sqrt{4GkTB}.$$

Ex: Calculate the noise voltage at the input of a receivers RF amplifier, using a device that has 100 Ω equivalent noise resistance and a 200 Ω input resistor. The bandwidth of the amplifier is 1M, the temperature is 25°C & Boltzmann's constant = 1.38×10^{-23} J/K.

Sol: Given, $R_i = 200\,\Omega$, $R_n = 100\,\Omega$, $B = 1\,MHz$

$T = 25°C = 25 + 273 = 298\,°K$

Noise voltage at the i/p of RF amplifier is given by,

$$V_n = \sqrt{4kBTR_{eq}}$$

$$R_{eq} = R_i + R_n = 100 + 200 = 300\,\Omega.$$

$$\therefore V_n = \sqrt{4 \times 1.38 \times 10^{-23} \times 298 \times 10^6 \times 300}$$

$$= 2.2\,\mu V.$$

Ex: An amplifier operating over a frequency range from a 17 to 19 MHz has a input resistance of 5 kΩ. What is the rms thermal voltage at the input of this amplifier? Assuming temperature to be 27°C.

Sol:

$k = 1.38 \times 10^{-23}$ J/K.

$T = 27°C = 27 + 273 = 300°K$

$B = 19 - 17 = 2 MHz$, $R = 5 k\Omega$

∴ Rms thermal noise voltage,

$$V_n = \sqrt{4kBTR}$$

$$V_n = \sqrt{4 \times 1.38 \times 10^{-23} \times 300 \times 2 \times 10^6 \times 5 \times 10^3}$$

$$V_n = 12.86 \mu V.$$

White Gaussian Noise

Example of white noise is thermal or Johnson noise

Defn - White noise is the noise whose power spectral density is uniform over the entire frequency range of interest.

a) Why is it called as white noise?

The white noise contains all the frequency components in equal proportion. This is analogous with white light which is the superposition of all visible spectral components.

→ White noise has constant Power spectral density across of frequencies.

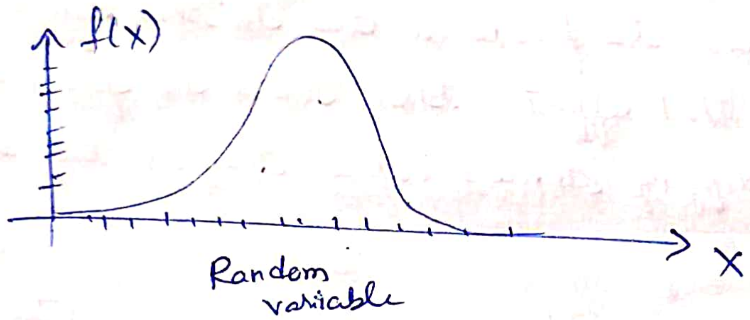
b) Why is it called Gaussian noise ?

The white noise has a gaussian distribution. This means that probability density function of white noise has the shape of gaussian Probability density function. Hence it is called as gaussian noise.

⇒ Gaussian distribution is normalized so that sum over all values of x gives a probability of 1.

⇒ Commonly named as normal distribution.

⇒ described as "bell-shapped curve.

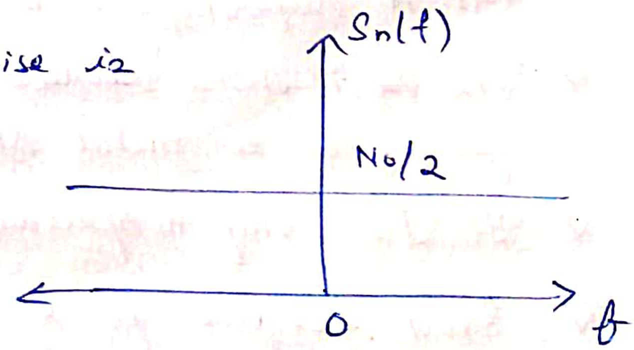


$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

c) Power spectral density of white Noise

Power spectral density of white noise is given by (fig),

$$S_n(f) = \frac{N_0}{2} \quad \text{——} (1)$$



→ Where, $N_0 = kT_e$ —— (2)

k = Boltsmann constant

T_e = Equivalent noise temperature or system.

Equation (1), shows that power spectral density of white noise is independent of frequency.

As N_0 is constant, psd is uniform over the entire frequency range including the positive as well as negative frequencies.

2) Partition Noise

✓ Partition Noise is generated when the current gets divided between two or more paths. It is generated due to random fluctuations in the division.

✓ Therefore, the partition noise in a transistor will be higher than that of diode.

3) Shot Noise

✓ The shot noise is produced due to shot effect.

✓ Due to the shot effect, shot noise is produced in all the amplifying devices rather than in all active devices.

✓ The shot noise is produced because of the random variations in the arrival of electrons (or holes) at the output electrode of an amplifying device.

✓ Hence, it appears as a randomly varying noise current superimposed on the output.

✓ The shot noise 'sounds' like a shower of lead shots falling on a metal ~~shot~~ sheet.

✓ It has uniform spectral density like thermal noise.

✓ Exact formula for shot noise can be obtained only for diodes.

∴ Mean square shot noise current for a diode is given by

$$I_n^2 = 2(I + 2I_0)qB \text{ amperes}^2$$

where, I = direct current across the junction (in amp)

I_0 = reverse saturation current (in amp.)

q = electronic charge = 1.6×10^{-19} C
B = effective noise bandwidth in Hz.

For the amplifying devices, The shot noise is:
i) Inversely proportional to the transconductance of the device.
ii) Directly proportional to the output current.

4) Low frequency or flicker Noise

→ Flicker noise will appear at frequencies below a few kilohertz. It is sometimes called as 1/f noise.
→ In semiconductor devices, the flicker noise is generated due to the fluctuation in the carrier density.
→ This ~~fd~~ fluctuations will cause fluctuations in conductivity & produce a fluctuation voltage drop when a direct current flows through a device.
→ This fluctuating voltage is called a flicker noise voltage.
→ The mean square value of flicker noise voltage is proportional to the square of direct current flowing through the device.

5) High Frequency or Transit Time Noise.

If the time taken by an electron to travel from the emitter to the collector of a transistor becomes comparable to the period of the signal which is being amplified then the transit time effect takes place. This effect is observed at very high frequencies.

Noise Bandwidth, B_N

- ✓ Noise bandwidth, B_N may be defined as the bandwidth of an ideal (rectangular) filter which passes the same noise power as does the real filter.
- ✓ Assume that a white noise is present at the input of a receiver (filter).

  Let the filter have a transfer function $H(f)$.

  This filter is used to reduce the noise power actually passed on to the receiver.
- ✓ Let the bandwidth B_N of ideal filter be adjusted in such a way that noise o/p power of ideal filter is exactly equal to the noise o/p power of a real R-C filter.

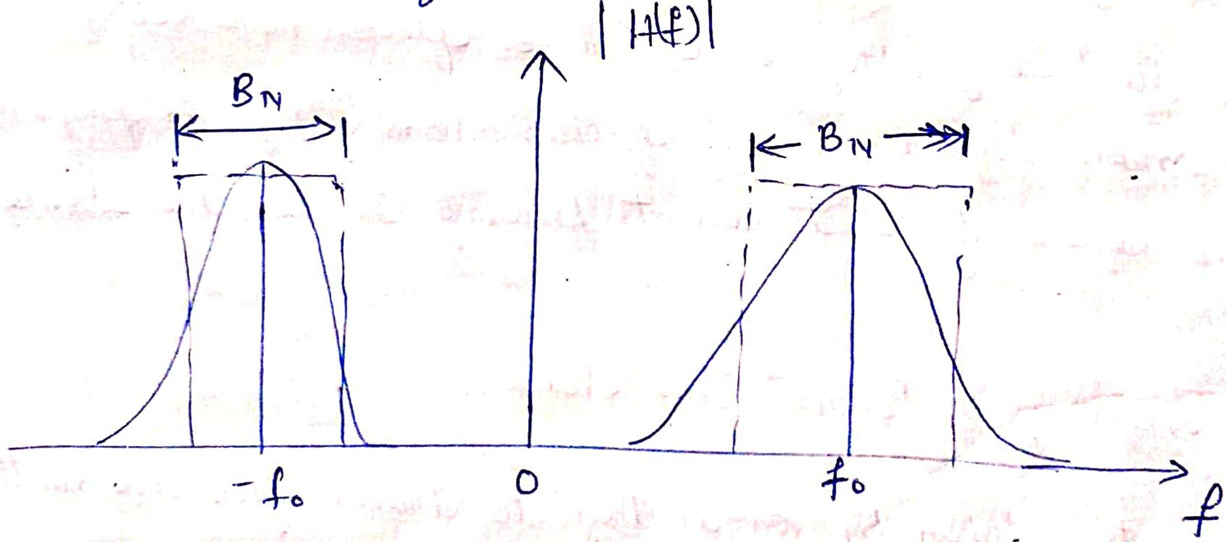


fig: Noise bandwidth of a filter.

Noise Figure :

✓ When noise factor is expressed in decibels, it is known as noise figure.

✓ Noise factor (F) of an amplifier or any network is defined in terms of signal to noise ratio at the input and the output of the system.

✓ Noise factor, $F = \dfrac{S/N \text{ ratio at i/p}}{S/N \text{ ratio at o/p}}$

$$F = \frac{P_{si}}{P_{ni}} \times \frac{P_{no}}{P_{so}}$$

where, P_{si} & P_{ni} = Signal and noise power at the input
P_{so} & P_{no} = Signal & noise power at o/p.

✓ Noise figure (in decibels), $F_{dB} = 10 \log_{10} F$

$$= 10 \log_{10} \left[\frac{S/N \text{ at i/p}}{S/N \text{ at o/p}} \right]$$

$$= 10 \log_{10} (S/N)_i - 10 \log (S/N)_o$$

Noise figure (in short), ~~$F_{dB} = (S/N)_i dB - S/$~~

$$F_{dB} = (S/N)_i \, dB - (S/N)_o \, dB.$$

How to improve noise figure?

-> Prefer diodes & FETS which produce low noise.
-> Receiver can be operated at low temperatures.
-> This is done in Satelite low noise receivers.
-> Use high gain amplifiers.

Ex: The signal to noise ratio at the input of an amplifier is 40dB. If the noise figure of an amplifier is 20dB, calculate the signal to noise ratio (in dB) at the amplifier output.

Sol:) Noise figure (dB) = $(S/N)_i$ dB − $(S/N)_o$ dB

$(S/N)_o$ (dB) = (S/N_i) dB − Noise figure (dB)

= 40 − 20

= 20 dB.

Noise temperature

✓ The equivalent noise temperature of a system is defined as the temperature at which the noisy resistor has to be maintained so that by connecting this resistor to the i/p of noiseless version of the system, it will produce the same amount of noise power at the output as that produced by the actual system.

✓ Equivalent Noise temperature T_{eq} at amplifier o/p

The noise at input of amplifier i/p is given as

$$P_{na} = (F-1) k T_0 B$$

This is the noise contributed by the amplifier. This noise power can be alternatively represented by some fictitious temperature T_{eq}, such that,

$$k T_{eq} B = (F-1) k T_0 B \quad \text{—— (1)}$$

Thus, the equivalent ~~tem~~ noise temperature of amplifier is given by $\boxed{T_{eq} = (F-1) T_0}$ //

Ex: An amplifier has a noise figure of 3dB. Determine its noise temperature.

Sol:- i) Noise figure is given by

$$F_{dB} = 10 \log_{10} (F_{ratio})$$

$$\text{Noise factor, } F = \text{Antilog} (F_{dB}/10)$$

$$= \text{Antilog} (0.3)$$

$$= 2.$$

ii)

$$T_{eq} = (F-1) \, T_0$$

$$= (2-1) \times 300 \quad \left(\text{Assumming } T_0 = 300°K \right)$$

$$\boxed{T_{eq} = 300°K}$$

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