CHAPTER 3

Noise

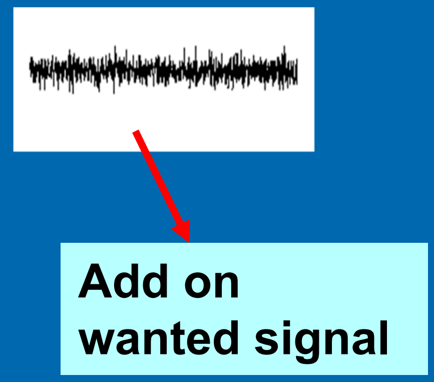
(Part 1 of 2)

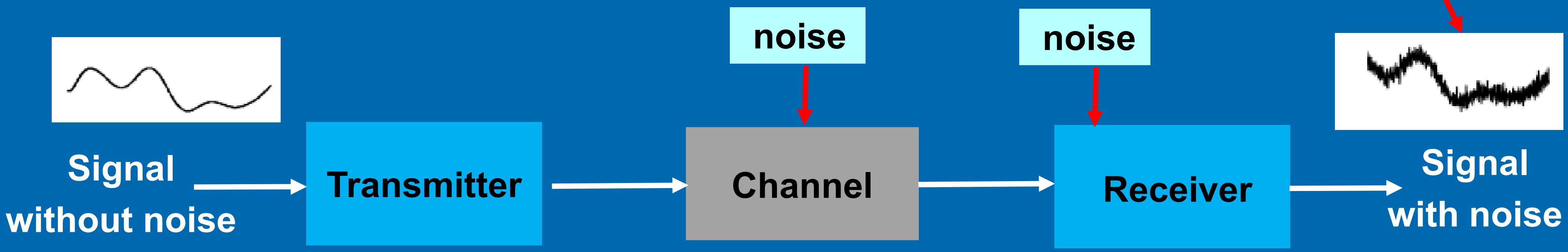
Introduction

Noise

Unwanted signal interfering with/distorting wanted signal

- Produced internally within a communication system
- Picked up by a communication system from external sources.
- Noise present in the channel and at the input of a receiver is of major concern.





3.1 Noise sources and classification

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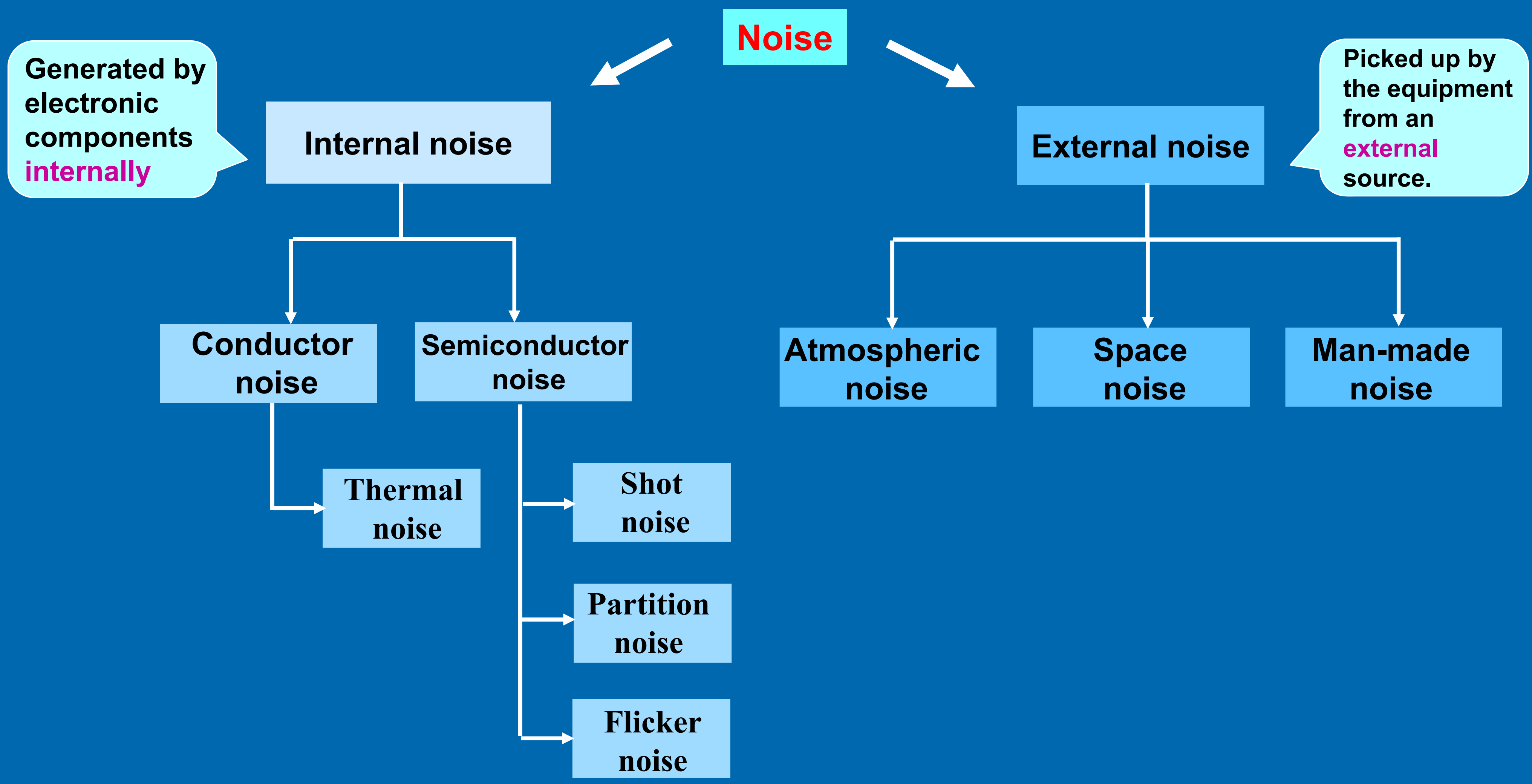
Noise

- **Internal noise** — Generated by electronic components **internally**
  - **Conductor noise** — antenna, wires, cables, resistors, inductors
  - **Semiconductor noise** — diodes, transistors, ICs
- **External noise** — Picked up by the equipment from an **external** source.
  - **Atmospheric noise**
  - **Space noise**
  - **Man-made noise**

3.1 Noise sources and classification



3.1 Noise sources and classification

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Noise

- **Internal noise** — Generated by electronic components **internally**
  - Conductor noise
    - Thermal noise
  - Semiconductor noise
    - Shot noise
    - Partition noise
    - Flicker noise
- **External noise** — Picked up by the equipment from an **external** source.
  - Atmospheric noise
  - Space noise
    - Solar noise
    - Cosmic noise
  - Man-made noise

3.1 Noise sources and classification

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Noise

- **Internal noise**
  - Conductor noise
  - Semiconductor noise
  - → **Conducted interference**: Noise that is conducted into a communication system
- **External noise**
  - Atmospheric noise
  - Space noise
  - → **Radiated interference**: Noise originated from electromagnetic radiations
  - Man-made noise
  - → **Conducted/Radiated interference**

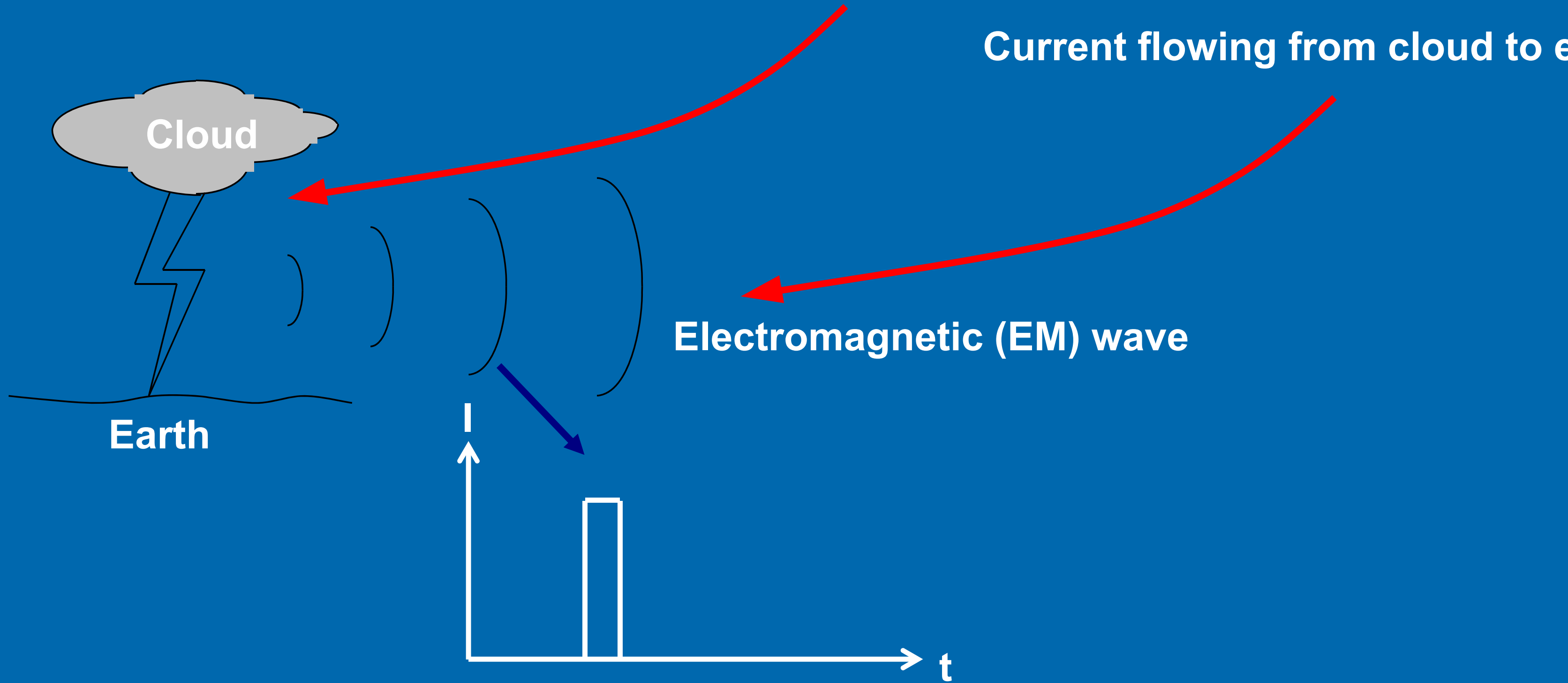
3.1 Noise sources and classification

External Noise

Atmospheric noise | **Radiated interference**

When lightning strikes, a single current pulse flows through the air.

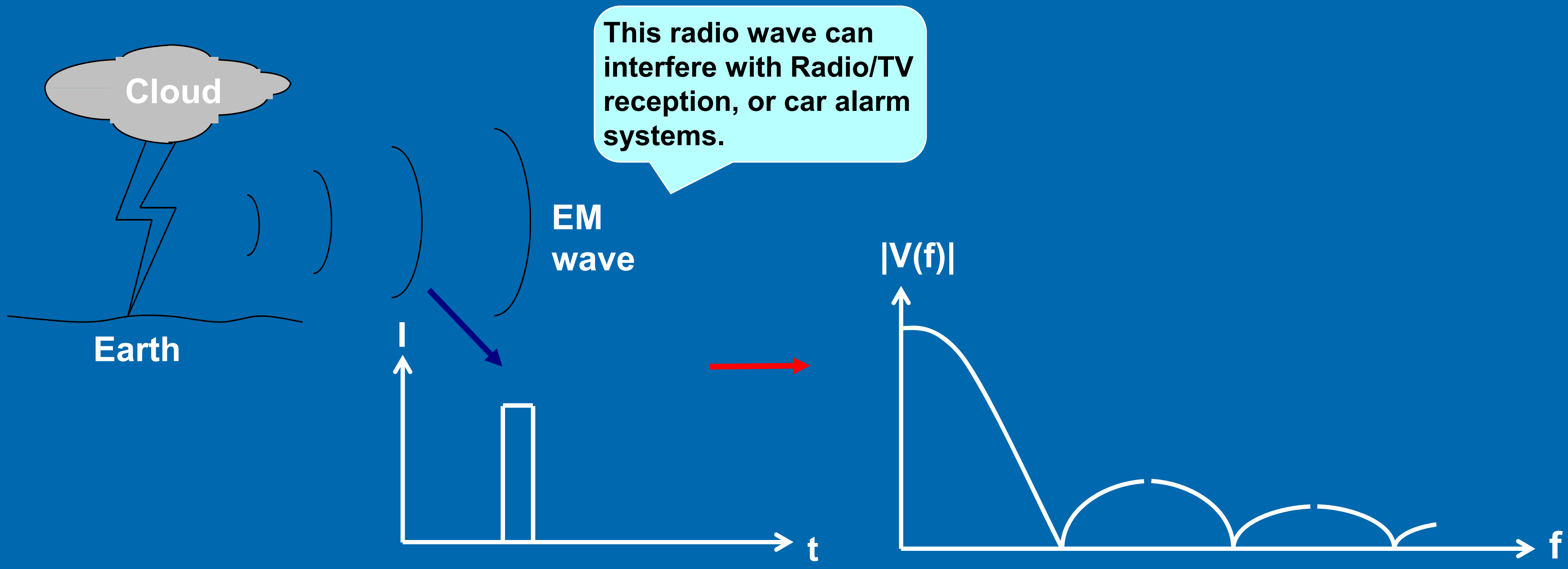
Current flowing from cloud to earth produces



3.1 Noise sources and classification

External Noise

Atmospheric noise | **Radiated interference**



3.1 Noise sources and classification

External Noise - Space noise (Radiated interference)

Produced by the **Sun** (solar noise) and the **stars** (cosmic noise)

(i) Solar noise

- Electromagnetic energy radiated by the Sun.
- Spread over a very wide spectrum of frequencies.

3.1 Noise sources and classification

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External Noise - Space noise (Radiated interference)

(ii) <u>Cosmic noise</u>

- electromagnetic energy radiated by the stars.
- Spread over a very wide spectrum of frequencies.

There are many of them though very far away

Interference caused by cosmic noise is significant

3.1 Noise sources and classification

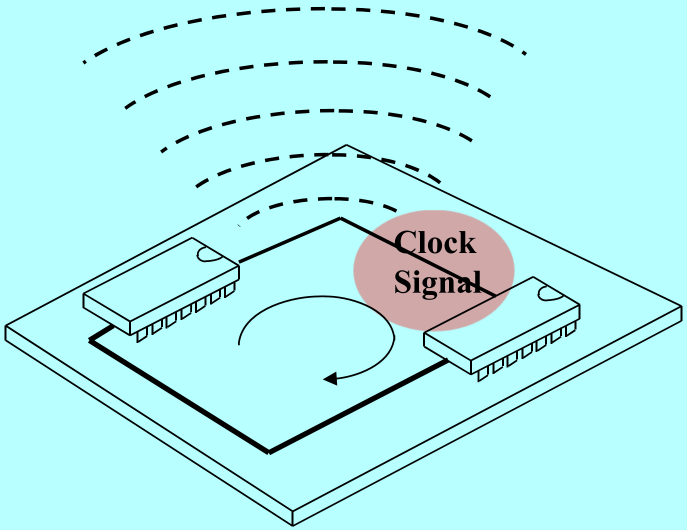
External Noise - Man-made noise (Conducted or radiated interference)

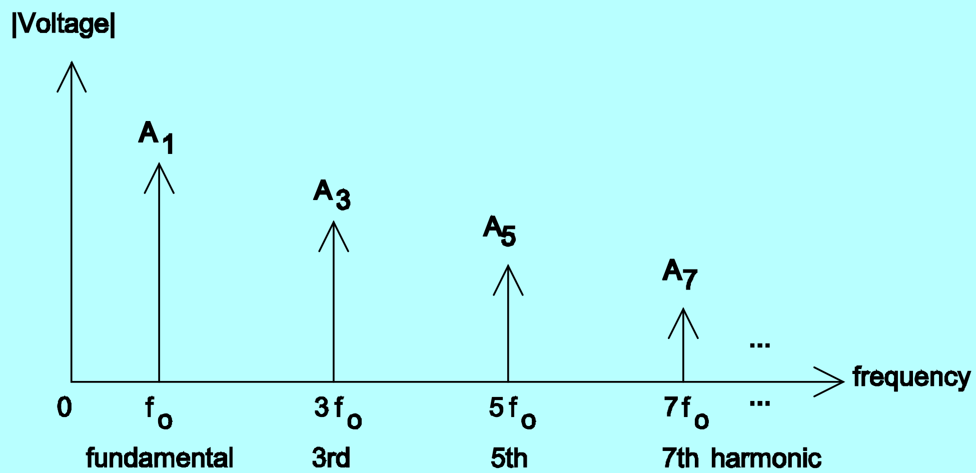
Radiated Man-made Interference

(i) **Clock signals in Digital equipment**

- Contain large harmonics
- Generate radio wave causing interference

One of these large harmonics could affect the operation of a plane navigation system!





3.1 Noise sources and classification

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External Noise - Man-made noise (Conducted or radiated interference)

Radiated Man-made Interference

(ii) Interruption of current in electrical machines

e.g. electric motors, car ignition systems, fluorescent lights, home appliances

- **Pulses caused by interruptions of current in electrical machines**
- **Rapid and large changes in voltages or currents tend to produce a large number of frequency components.**

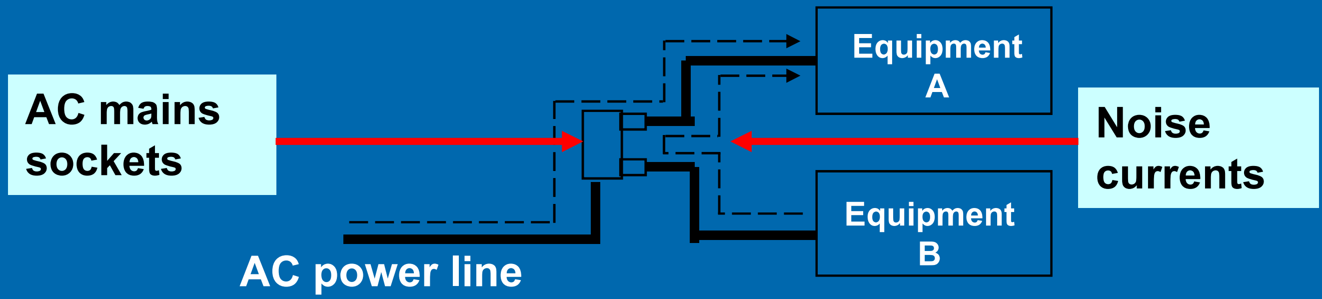
The frequency components will radiate out as an EM wave and affect radio reception.

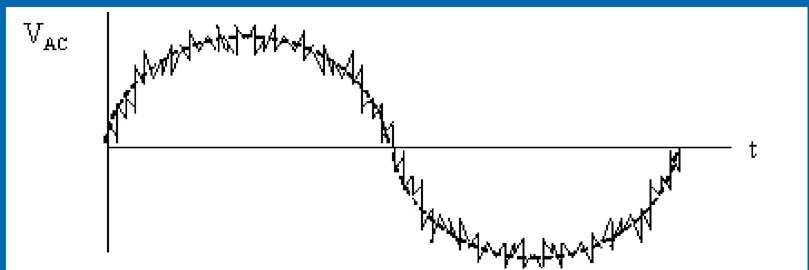
3.1 Noise sources and classification

External Noise - Man-made noise (Conducted or radiated interference)

<u>Conducted Man-made Interference</u>

(i) Noise generated by one equipment may flow through the <u>AC mains wire</u> to the mains socket of another equipment.





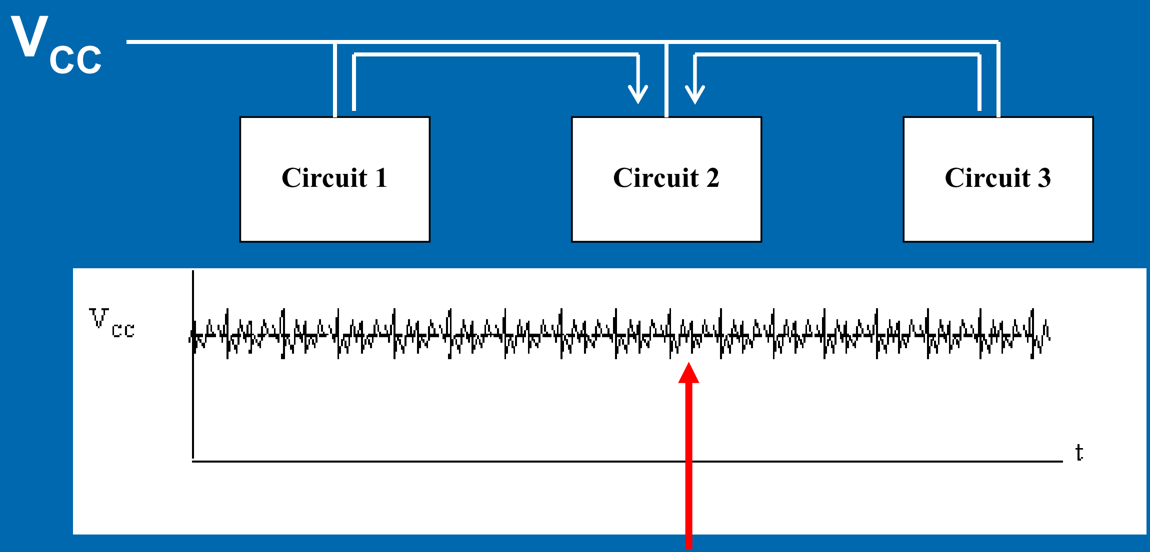
Noise riding on 50Hz AC mains signal

3.1 Noise sources and classification

External Noise - Man-made noise (Conducted or radiated interference)

Conducted Man-made Interference

(ii) noise generated by one circuit may flow through the DC power supply line to another circuit.



Noise riding on DC signal

3.1 Noise sources and classification

Internal Noise

<u>Noise in conductors: Thermal noise (Conducted interference)</u>

- Generated by random motion of free electrons in conductors.

e.g. wires, antennas, resistors, inductors

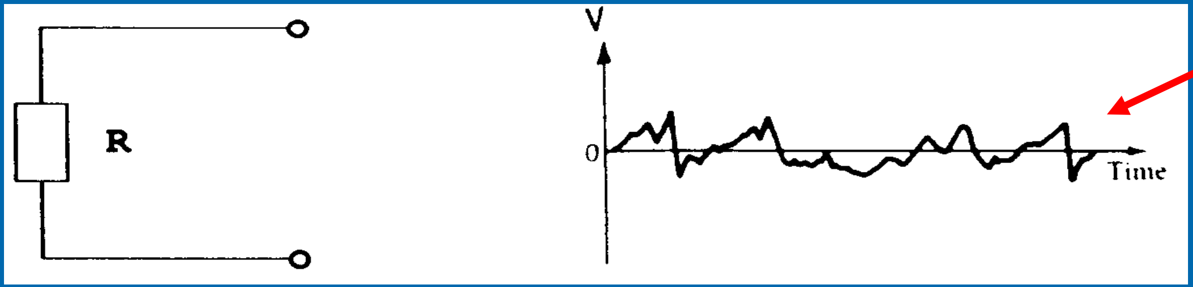
- The random motion of free electrons will produce a noise voltage across a conductor.

If temperature of conductor increases

→ free electrons move more vigorously

→ noise voltage increases

THERMAL noise



Noise voltage generated in a conductor

3.1 Noise sources and classification

Internal Noise

Noise in conductors: Thermal noise (Conducted interference)

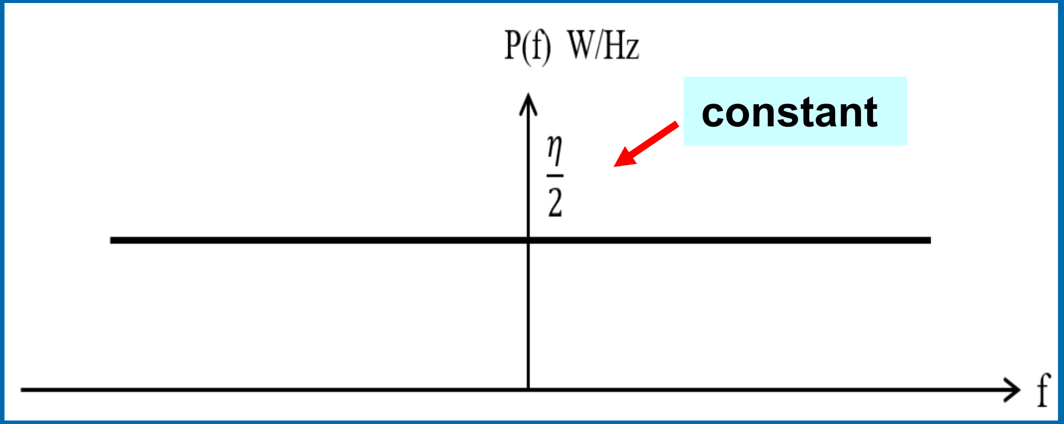
- Thermal noise signal is non-periodic and thus has continuous spectrum.
- Thermal noise power has a uniform spectral density. White noise

$$P(f) = \frac{\eta}{2} = \frac{kT}{2} \text{ Watts/Hz}$$

Noise power per unit bandwidth

$P(f) \propto T$

where
k = 1.38 x 10^{-23} J/K (Boltzmann's constant)
T is the temperature of the conductor in Kelvin.



3.1 Noise sources and classification

Internal Noise

Noise in conductors: Thermal noise (Conducted interference)

- Thermal noise power, P_n over a bandwidth, B is given by

$$P_n = kTB \text{ Watts}$$

Where K = Boltzmann's constant (1.38 x 10^{-23} J/K)

T = temperature (K) $\Rightarrow y°c = (273 + y)K$

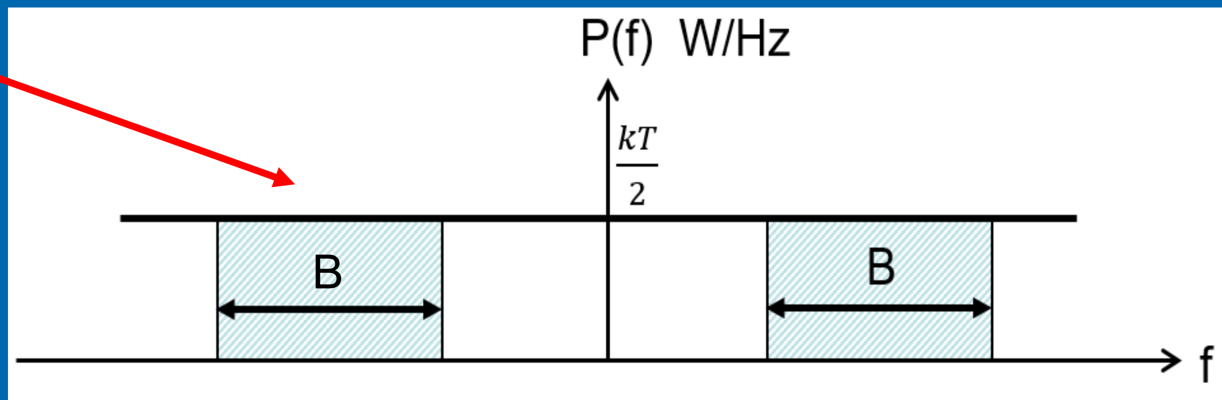
B = bandwidth (Hz)

Shaded area

$$P_n = \frac{kT}{2} \times (2B)$$

$$= \frac{kT}{2} \times (2B) = \text{kTB Watts}$$

Watts/~~Hz~~ ~~Hz~~



3.1 Noise sources and classification

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Internal Noise

Noise in conductors: Thermal noise (Conducted interference)

- **Thermal noise power is NOT dependent on the resistance of the conductor.**
- **All conductors produce the same noise power.**

3.1 Noise sources and classification

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Internal Noise

Noise in conductors: Thermal noise (Conducted interference)

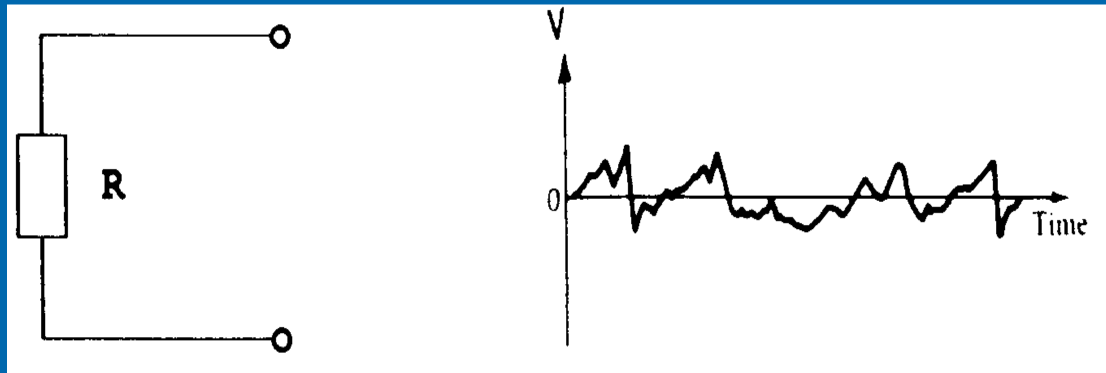
- The rms noise voltage across a resistor of R ohms at a temperature of T K over a bandwidth of B is given by

increases with resistance of the conductor.

rms noise voltage, $E_n = \sqrt{4kTBR}$

P_n

R = Resistance of conductor



3.1 Noise sources and classification

Internal Noise

<u>Noise in conductors: Noise in semiconductors (Conducted interference)</u>

Examples of semiconductor noise are:

(i) **Shot noise** — **Uniform power spectral density**

(ii) **Partition noise**

(iii) **Low frequency or flicker noise.** — **Low frequency components have high amplitude**
High frequency components have low amplitudes

3.1 Noise sources and classification

Example 3.1

The temperature of a 10kΩ resistor is 20°C.

(a) Draw the spectrum of the noise produced by the resistor.

(b) Calculate the noise power and rms noise voltage over a 15kHz bandwidth.

Solution

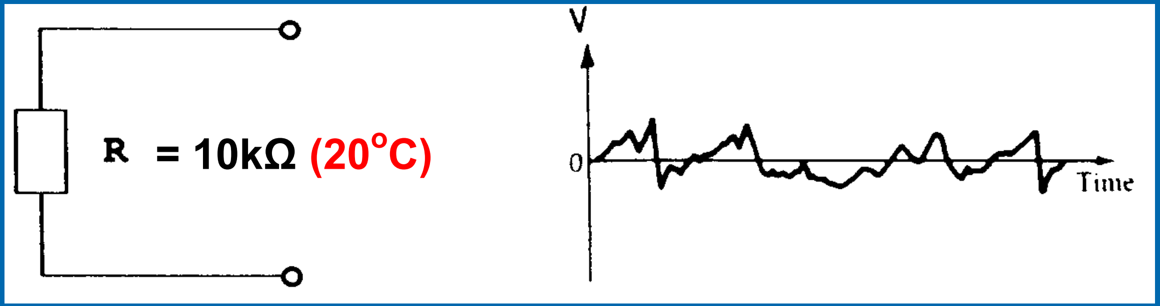
(a) Draw the noise spectral density

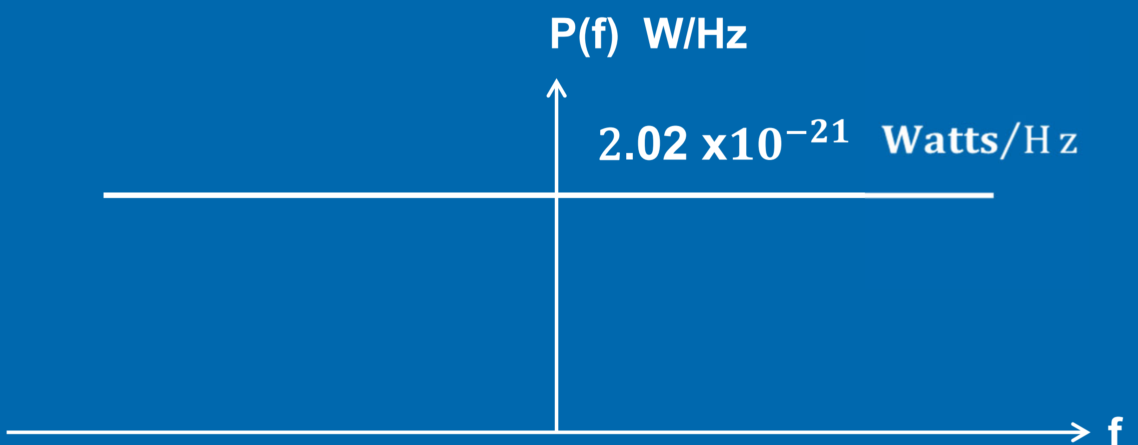
T = 20°C + 273 = 293 K

$$P(f) = \frac{\eta}{2} = \frac{kT}{2} \ \text{Watts/Hz}$$

$$= \frac{(20 \times 10^{-23}) \times (20^{\circ}C + 273)}{2}$$

$$= 2.02 \times 10^{-21} \ \text{Watts/Hz}$$





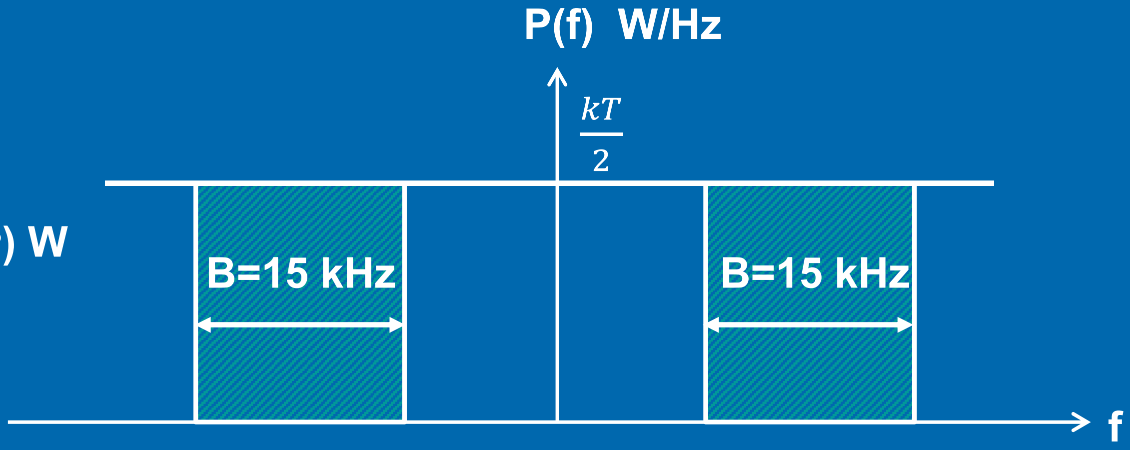
Solution

(b) Calculate noise power, P_n over a 15kHz bandwidth

$$P_n = \frac{kT}{2} \times (2B) \text{ Watts}$$

$$= (1.38 \times 10^{-23}) \times (20^\circ C + 273) \times (15 \times 10^3) \text{ W}$$

$$= 6.06 \times 10^{-17} \text{ W}$$



Solution

(c) Calculate the rms noise voltage, E_n over a 15kHz bandwidth

$$E_n = \sqrt{4kTBR}$$

$$= \sqrt{4P_nR}$$

$$= \sqrt{4 \times (6.06 \times 10^{-17}) \times (10 \times 10^{3})}$$

$$= 1.56\ \mu V$$

Additional notes

Although P_n and E_n are small, they may be of the same order as the signal power or voltage at the input of a radio receiver.

$P_n = 6.06 \times 10^{-17}$ W

$E_n = 1.56$ µV

Induced current in receiving antenna

Thermal noise produced by antenna

noisy antenna output

P_n and E_n cannot be ignored.

End

CHAPTER 3

(Part 1 of 2)