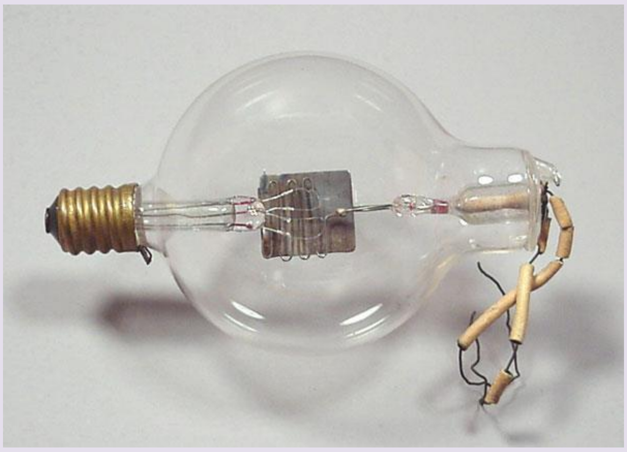
# UNIT 1

## From past to present; AMPLIFIER

- The history of amplifier
- The typical amplifier parameters
- Classification of amplifiers

### 1. Introduction to the amplifier

Time to think a little. For you, what kind of a relation is there between these two pictures given above?



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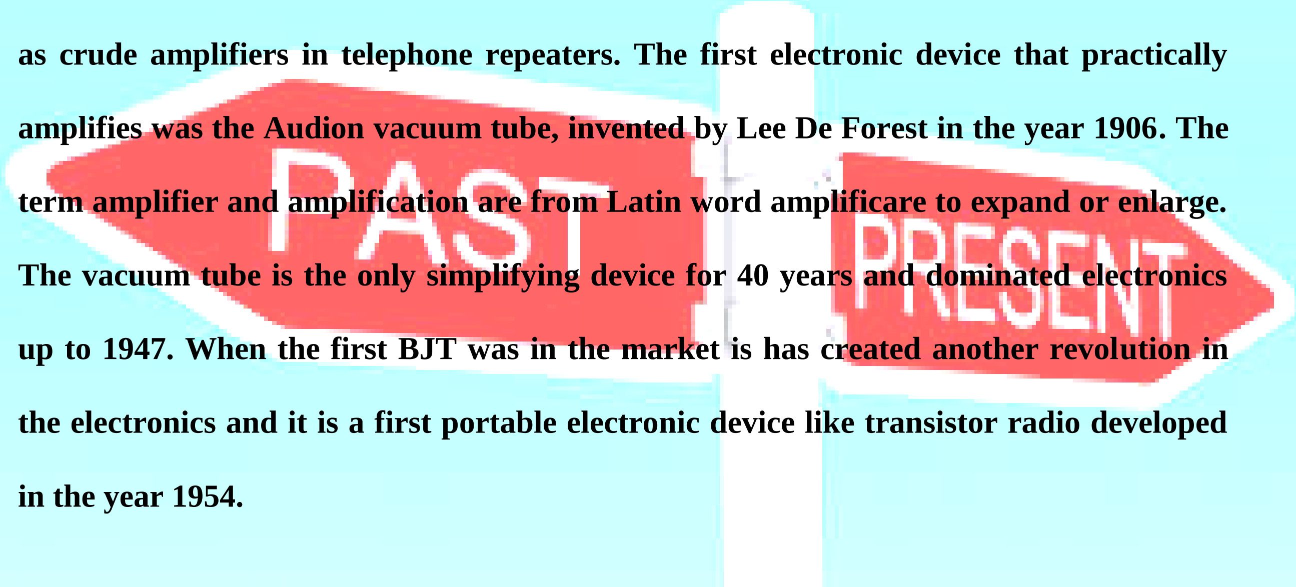
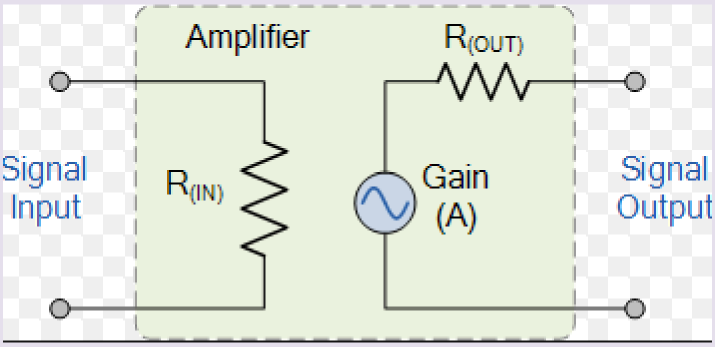
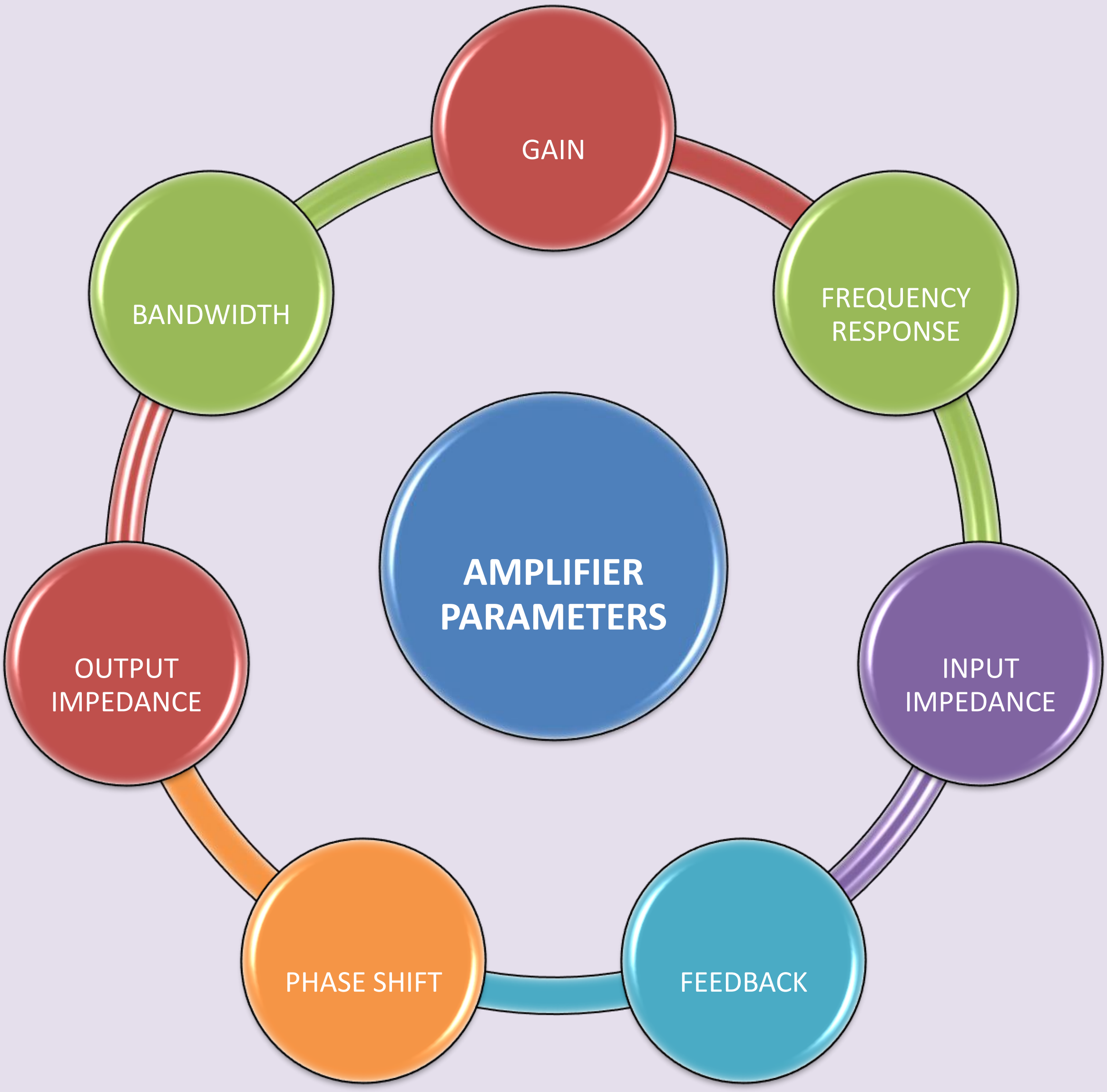


**Before the invention of electronic amplifiers, the coupled carbon microphones are used as crude amplifiers in telephone repeaters. The first electronic device that practically amplifies was the Audion vacuum tube, invented by Lee De Forest in the year 1906. The term amplifier and amplification are from Latin word amplificare to expand or enlarge. The vacuum tube is the only simplifying device for 40 years and dominated electronics up to 1947. When the first BJT was in the market is has created another revolution in the electronics and it is a first portable electronic device like transistor radio developed in the year 1954.**



Amplifier is the generic term used to describe a circuit which increases its input signal, but not all amplifiers are the same as they are classified according to their circuit configurations and methods of operation.



## 1. Gain

The gain of an amplifier is a measure of the "Amplification" of an amplifier, i.e. how much it increases the amplitude of a signal. More precisely it is the ratio of the output signal amplitude to the input signal amplitude, and is given the symbol "A". It can be calculated for voltage ($A_v$), current ($A_i$) or power ($A_p$). The ratio of output current to input current of an amplifier is defined as current gain, the ratio of output voltage to input voltage is defined as voltage gain and similarly the ratio of output power to input power of an amplifier is known as power gain of amplifier.

The gain or amplification for the three different types of amplifiers can be described using the appropriate formula:

**Voltage gain $A_v$ = Amplitude of output voltage ÷ Amplitude of input voltage.**

$$A_V = \frac{V_{out}}{V_{in}}$$

**Current gain $A_i$ = Amplitude of output current ÷ Amplitude of input current.**

$$A_i = \frac{I_{out}}{I_{in}}$$

**Power gain $A_p$ = Signal power out ÷ Signal power in.**

$$A_p = \frac{P_{out}}{P_{in}}$$

For example if the input voltage of an amplifier is 2.5 $V_{RMS}$ and output voltage is 50 $V_{RMS}$, the voltage gain would be,

$$A_V = \frac{V_{output}}{V_{input}} = \frac{50}{2.5} = 20$$

## 2. Frequency Response

Amplifiers do not have the same gain at all frequencies. For example, an amplifier designed for audio frequency amplification will amplify signals with a frequency of less than about 20kHz but will not amplify signals having higher frequencies. An amplifier designed for radio frequencies will amplify a band of frequencies above about 100kHz but will not amplify the lower frequency audio signals. In each case the amplifier has a particular frequency response, being a band of frequencies where it provides adequate amplification, and excluding frequencies above and below this band, where the amplification is less than adequate.

Let's compare these two figures specified below;

Figure1

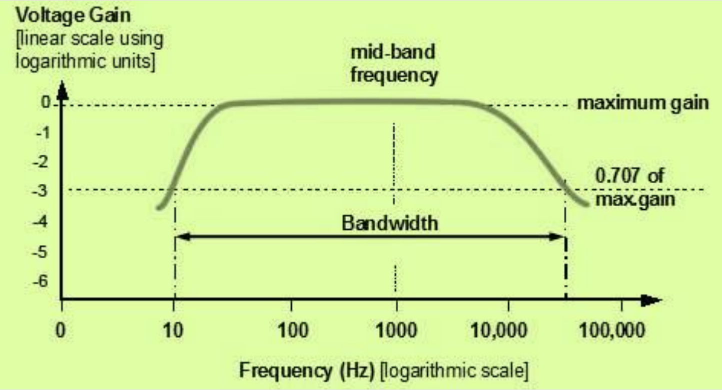
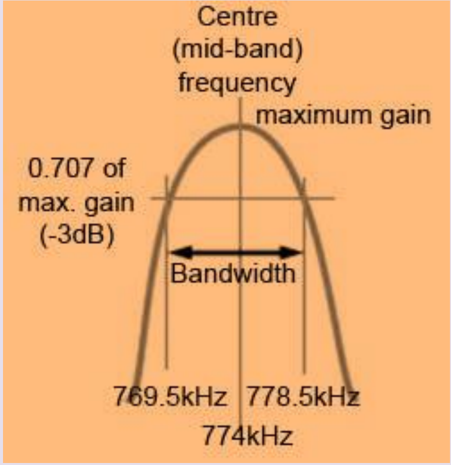


Figure2



These two graphs, the typical frequency response of the amplifier left; the response curve of a RF amplifier, have been used to show how the gain of an amplifier varies with frequency. In such graphs, it is common that very large values may be encountered for both gain and frequency. For this reason it is usual for both the frequency and gain axes of the graph to use logarithmic scales. It can be seen from Fig. 1 that scales on the (horizontal) x-axis do not increase in a linear manner; each equal division represents a tenfold increase in the frequency plotted. This ensures that a very wide range of frequency can be plotted on a single graph. The (vertical) y-axis uses linear divisions but logarithmic units (deciBels dB). The curve of the graph shows how gain, measured in deciBels, varies with frequency.

## 3. Bandwidth

An important piece of information that can be obtained from a frequency response curve is the Bandwidth of the amplifier. The bandwidth represents the amount or "width" of frequencies, or the "band of frequencies" that the amplifier is most effective in amplifying. The bandwidth of an amplifier is the difference between the frequency limits of the amplifier. For example, the band of frequencies for an amplifier may be from 10 kilohertz (10kHz) to 30 kilohertz (30kHz). In this case, the bandwith would be 20 kilohertz (20kHz).

## 4. Input Impedance

The word impedance means opposition to AC current flow. At 0 Hz, (that is, DC) impedance (symbol Z) is the same as resistance (R), but at frequencies other than 0Hz impedance and resistance are not the same. The input impedance of an amplifier is the effective impedance between the input terminals. "Effective" means that the impedance is not necessarily just that of the amplifier components (resistors, capacitors etc.) actually connected across the input terminals, but is the impedance experienced as the amount of current able to flow into the input terminals for a given signal voltage applied at a particular frequency. Input Impedance is influenced by a number of factors including the frequency of the applied signal, the gain of the amplifier, any signal feedback used and even what is connected to the output of the amplifier.

## 5. Output Impedance

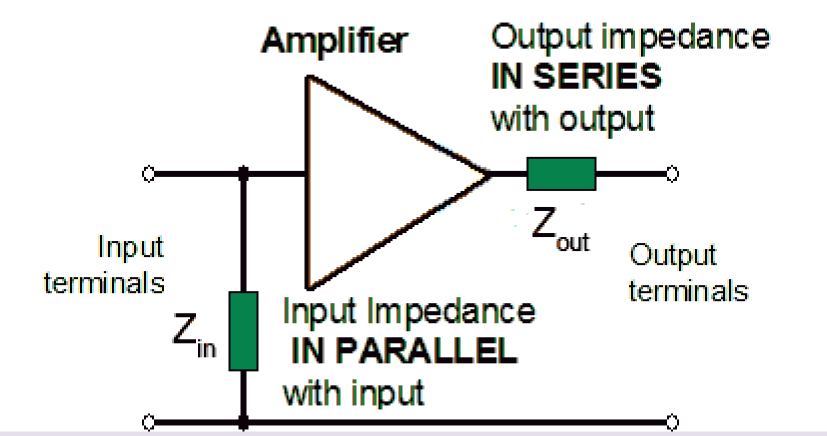
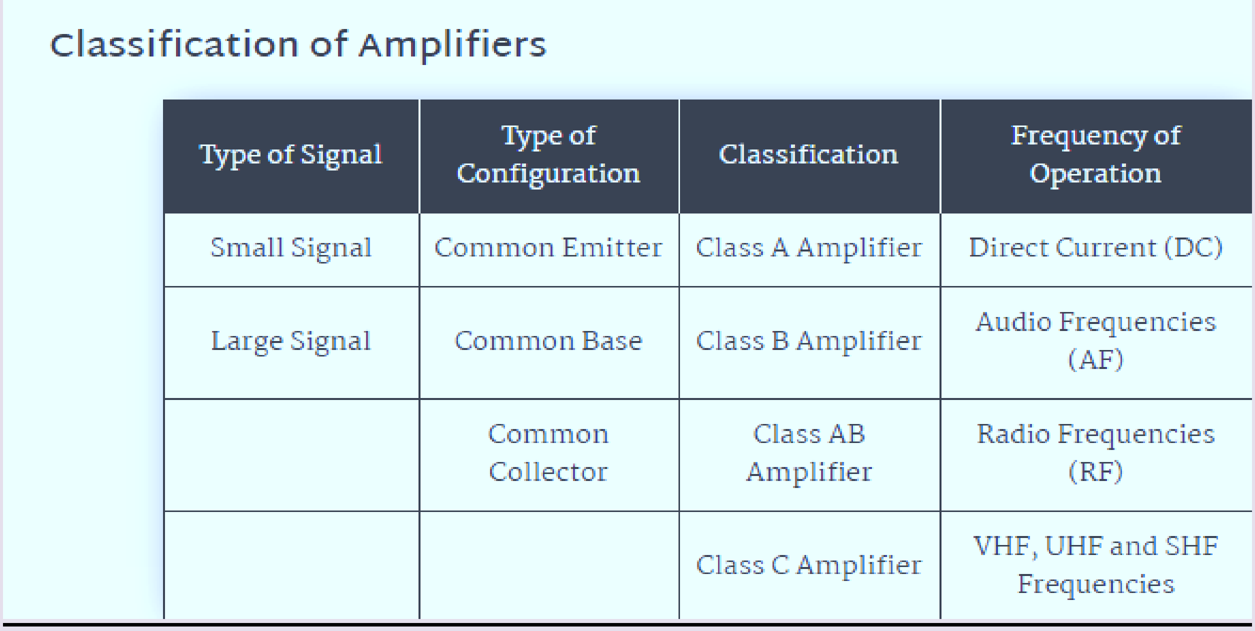


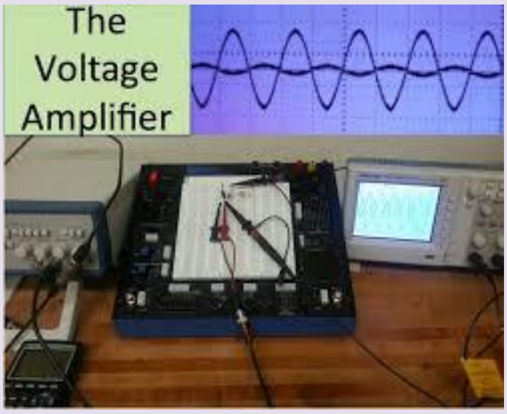
**Fig. 1.1.2 Amplifier Input and Output Impedances**

The output impedance of an amplifier is not solely dependent on the actual components connected within the output of an amplifier. It is an ‘apparent’ impedance and can best be demonstrated as being responsible for a fall in signal voltage at the output terminals of an amplifier, when a current is drawn from the output terminals. The more current drawn from the output terminals, the greater the reduction in output signal voltage. The effect is that of an impedance or resistance in series with the output terminals.



## Classification of Amplifiers

| Type of Signal | Type of Configuration | Classification | Frequency of Operation |
|---|---|---|---|
| Small Signal | Common Emitter | Class A Amplifier | Direct Current (DC) |
| Large Signal | Common Base | Class B Amplifier | Audio Frequencies (AF) |
|  | Common Collector | Class AB Amplifier | Radio Frequencies (RF) |
|  |  | Class C Amplifier | VHF, UHF and SHF Frequencies |



**Small Signal Amplifiers**

- Small Signal Amplifiers are also known as **Voltage Amplifiers**.
- Voltage Amplifiers have 3 main properties, **Input Resistance**, **Output Resistance** and **Gain**.
- The Gain of a small signal amplifier is the amount by which the amplifier “Amplifies” the input signal.
- Gain is a ratio of input divided by output, therefore it has no units but is given the symbol (A) with the most common types of transistor gain being, **Voltage Gain (Av), Current Gain (Ai)** and **Power Gain (Ap)**
- The power Gain of the amplifier can also be expressed in **Decibels** or simply **dB**.
- In order to amplify all of the input signal distortion free in a Class A type amplifier, DC Base Biasing is required.
- DC Bias sets the Q-point of the amplifier half way along the load line.
- This DC Base biasing means that the amplifier consumes power even if there is no input signal present.
- The transistor amplifier is non-linear and an incorrect bias setting will produce large amounts of distortion to the output waveform.
- Too large an input signal will produce large amounts of distortion due to clipping, which is also a form of amplitude distortion.
- Incorrect positioning of the Q-point on the load line will produce either **Saturation Clipping** or **Cut-off Clipping**.
- The **Common Emitter Amplifier** configuration is the most common form of all the general purpose voltage amplifier circuit using a Bipolar Junction Transistor.
- The **Common Source Amplifier** configuration is the most common form of all the general purpose voltage amplifier circuit using a Junction Field Effect Transistor.

## Large Signal Amplifiers

- Large Signal Amplifiers are also known as **Power Amplifiers**.
- Power Amplifiers can be sub-divided into different Classes, for example:
  - Class A Amplifiers – where the output device conducts for all of the input cycle.
  - Class B Amplifiers – where the output device conducts for only 50% of the input cycle.
  - Class AB Amplifiers – where the output device conducts for more than 50% but less than 100% of the input cycle.
- An ideal Power Amplifier would deliver 100% of the available DC power to the load.
- Class A amplifiers are the most common form of power amplifier but only have an efficiency rating of less than 40%.
- Class B amplifiers are more efficient than Class A amplifiers at around 70% but produce high amounts of distortion.
- Class B amplifiers consume very little power when there is no input signal present.
- By using the "Push-pull" output stage configuration, distortion can be greatly reduced.
- However, simple push-pull Class B Power amplifiers can produce high levels of**Crossover Distortion** due to their cut-off point biasing.
- Pre-biasing resistors or diodes will help eliminate this crossover distortion.
- Class B Power Amplifiers can be made using Transformers or Complementary Transistors in its output stage.

## Voltage Amplifier

Voltage amplifiers are devices that amplify the input voltage, if possible with minimal current at the output. Technically, an amplifier with high voltage gain is a voltage amplifier, but it may or may not have a low current gain. The power gain of an amplifier is also low due to these properties. Transistors, and op amps, given proper biasing and other conditions, act as basic voltage amplifiers. The main application of voltage amplifiers is to strengthen the signal to make it less affected by noise and attenuation. When transmitted signals lose its strength and get deformed, an amplification of the voltage at the transmitter will minimize the effect and receiver will be able to capture and interpret the signal with reasonable accuracy.

Ideal voltage amplifiers have infinite input impedance and zero output impedance. In practice, an amplifier with high input impedance relative to the output impedance is considered as a good voltage amplifier.

## Power Amplifiers

Power amplifiers are devices to amplify the input power, if possible with minimal change in the output voltage with respect to the input voltage. That is, power amplifiers have a high power gain, but the output voltage may or may not change. The amplifier efficiency of power amplifiers is always lower than 100%. Therefore, high heat dissipation is observed at power amplification stages. Power amplifiers are used in devices which require a large power across the loads. In multi stage amplifiers, power amplification is made in the final stages of amplification. Audio amplifiers and RF amplifiers use power amplifiers at the final stage to deliver sufficient power the load. Servo motor controllers also use power amplifiers to drive the motors. Power amplifiers are classified into several classes depending on the fraction of the input signal used in amplification. Classes A, B, AB and C are used in analog circuits, while classes D and E are used in switching circuits.

In modern electronics, most power amplifiers are constructed with semiconductor based components while, vacuum tube (valve) based amplifiers are still used in environments, where precision, frequency response, and endurance are a primary requirement. For example, guitar amplifiers use valves for quality and military equipment use valves for its endurance against strong electromagnetic pulses.

## What is the difference between Voltage Amplifiers and Power Amplifiers?

- Voltage amplifiers have a high voltage gain, while power amplifiers have a high power gain.

- In most voltage amplifiers, current gain is very low, while power amplifiers have a significant current gain, which results the power gain.

- Voltage amplifiers dissipate relatively less heat than power amplifiers. Therefore, voltage amplifiers have higher power efficiency than power amplifiers. Also, power amplifiers require additional cooling mechanism due to this fact

## Example No1

Determine the Voltage, Current and Power Gain of an amplifier that has an input signal of 1mA at 10mV and a corresponding output signal of 10mA at 1V. Also, express all three gains in decibels, (dB).

The Various Amplifier Gains:

$$A_v = \frac{\text{Output Voltage}}{\text{Input Voltage}} = \frac{1}{0.01} = 100$$

$$A_i = \frac{\text{Output Current}}{\text{Input Current}} = \frac{10}{1} = 10$$

$$A_p = A_v \times A_i = 100 \times 10 = 1{,}000$$

Also in Decibels (dB):

$$a_v = 20 \log A_v = 20 \log 100 = 40\,\text{dB}$$

$$a_i = 20 \log A_i = 20 \log 10 = 20\,\text{dB}$$

$$a_p = 10 \log A_p = 10 \log 1000 = 30\,\text{dB}$$

Then the amplifier has a Voltage Gain of 100, a Current Gain of 10 and a Power Gain of 1,000.