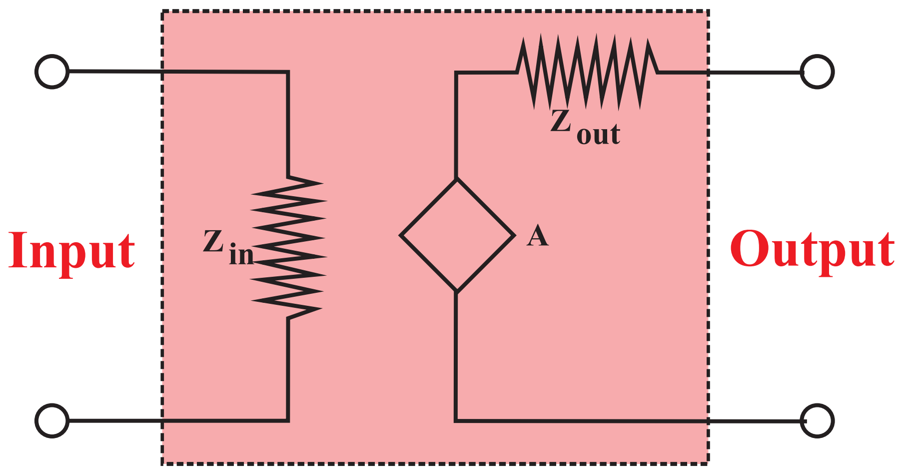
Amplification is the process of increasing the power of an ac signal. The circuits that perform this are called ***amplifiers.***
All Amplifiers have ***3 fundamental properties.***

- Input Impedance
- Output Impedance
- Gain

The general model shows these properties



The General Amplifier Model

Amplifier Gain is a multiplier that exists between the circuit's input and output.(i.e. If we have a gain of 100 and we have 1 unit input, then the output will be 100 units under normal operating conditions.)

Input Impedance is the load that the amplifier presents to it's signal source.

Output Impedance is the source resistance that the amplifier presents to its load.

Amplifier Gain

There are three types of gain:

- Voltage Gain A_V
- Current Gain A_I
- Power Gain A_P

All amplifiers provide some power gain however not all amplifiers are designed for this purpose.

Voltage amplifiers are designed to provide a certain value of A_V. The fact that they provide some power gain is usually a secondary consideration.

Current amplifiers are designed to provide a certain value of A_i.

Power amplifiers are designed to provide a certain value of A_p.

The type of amplifier used in a given application depends on the type of gain required.

Gain As a Ratio *(Often Called Ordinary Gain)*

Gain is traditionally defined as the ratio of a circuit's output to its corresponding input. (i.e. Voltage gain is the ratio of ac output voltage input voltage)

$$\boxed{A_v = \frac{V_{out}}{V_{in}}} \qquad \boxed{V_{out} = A_v V_{in}}$$

Current and Power Gain

These are also defined as ratios

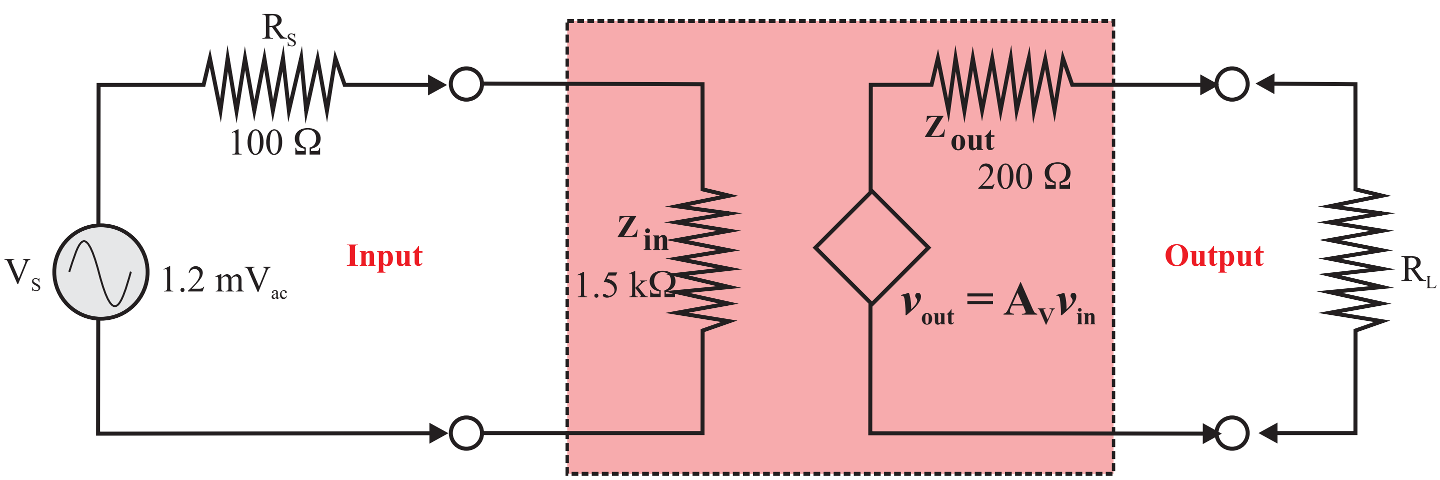
$$A_i = \frac{i_{out}}{i_{in}}$$

$$A_P = \frac{p_{out}}{p_{in}}$$

Example 8-1 & 8-2

The General Amplifier Model

In the model shown below, the diamond shape represents v_{out} and it has a value of $A_V v_{in}$.



The General Amplifier Model

To the general model above, we have added a signal source that consists of V_S and R_S. These will work in conjunction with Z_{in}.

On the output side, we have added R_L, which will work in conjunction with Z_{out}.

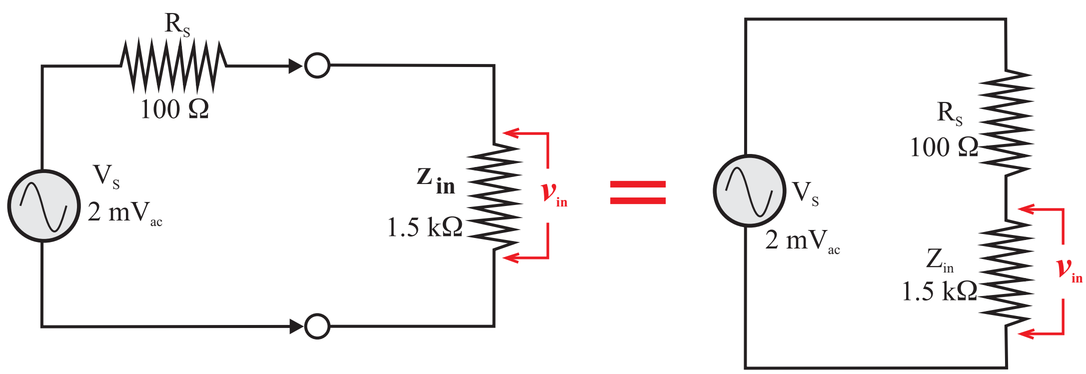
Input Impedance (Z_{in})

When the amplifier is connected to a signal source the source sees the input impedance as its load. In our example, this value is 1.5kΩ This means that the signal source is in series with R_S and Z_{in}.

The voltage we define as v_{in} is the voltage that the amplifier actually sees. This voltage appears across Z_{in}.

The input circuit is actually a simple voltage divider. The value of v_{in} is a portion of the input voltage and is given by:

$$v_{in} = v_s \frac{Z_{in}}{R_S + Z_{in}}$$



Input Circuit Only

Examples 8.3 and 8.4 show the effects of R_S and $Z_{in.}$

Output Impedance (Z_{out})

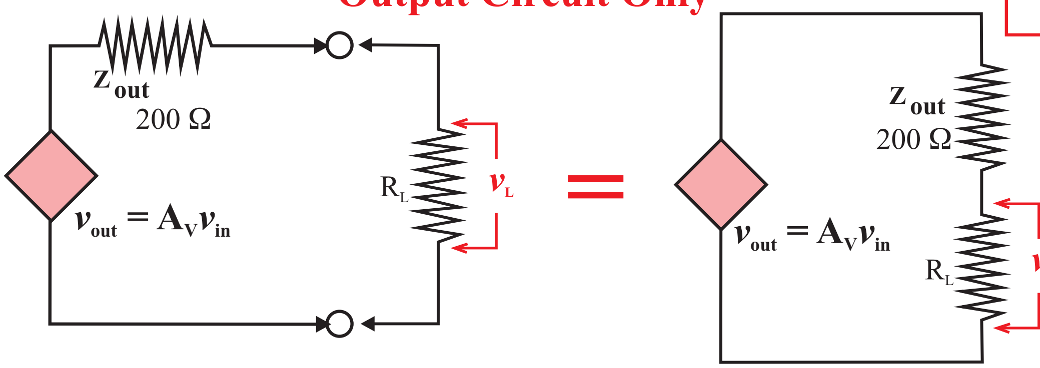
When a load is connected to an amplifier, the amplifier acts as a source for that load. As with any source, there is a measurable value of source resistance. This is the output impedance of the amplifier.

If Z_{out} is 200 Ω, then the load sees the amplifier as a voltage source with an internal resistance of 200 Ω..

The output circuit is a simple voltage divider. The value of v_L is a portion of the output voltage and is given by:

$$v_L = v_{out}\frac{R_L}{Z_{out} + R_L}$$

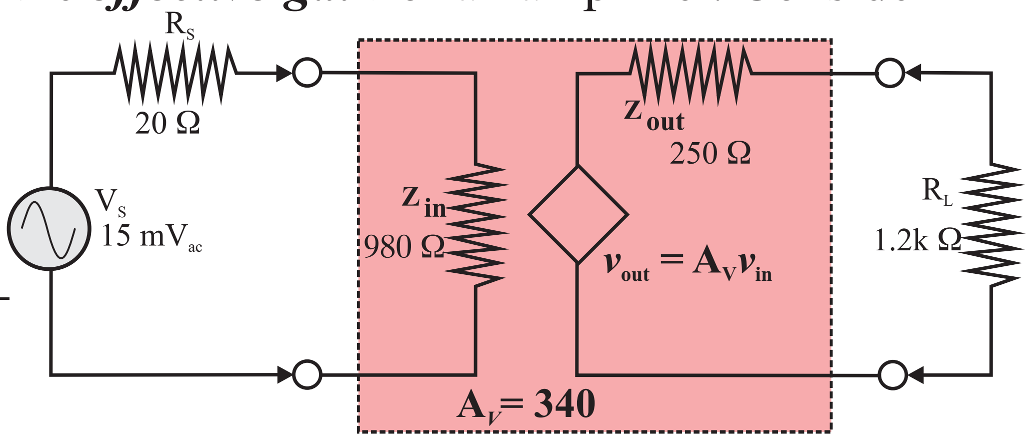
Output Circuit Only



Example 8.5 shows the effect of output impedance.

The Combined Effects of the Input & Output Circuits

The combined effect of both the input and output circuitry can significantly reduce the ***effective gain*** of an amplifier. Consider this circuit:



1 Find v_{in}

$$v_{in} = v_s\frac{Z_{in}}{R_S + Z_{in}}$$

$$= (15\ \text{mV}_{ac})\frac{980\ \Omega}{1\ \text{k}\Omega}$$

$$= 14.7\ \text{mV}_{ac}$$

2 Find v_{out}

$$v_{out} = A_V v_{in}$$

$$= (340)\ 14.7\ \text{mV}_{ac}$$

$$= 5\ \text{V}_{ac}$$

3 Find v_L

$$v_L = v_{out}\frac{R_L}{Z_{out} + R_L}$$

$$= (5\ \text{V}_{ac})\frac{1.2\ \text{k}\Omega}{1.45\ \text{k}\Omega}$$

$$= 4.14\ \text{V}_{ac}$$

4 Find effective A_V

$$A_V = \frac{v_L}{v_S}$$

$$= \frac{4.14\ \text{V}_{ac}}{15\ \text{mV}_{ac}}$$

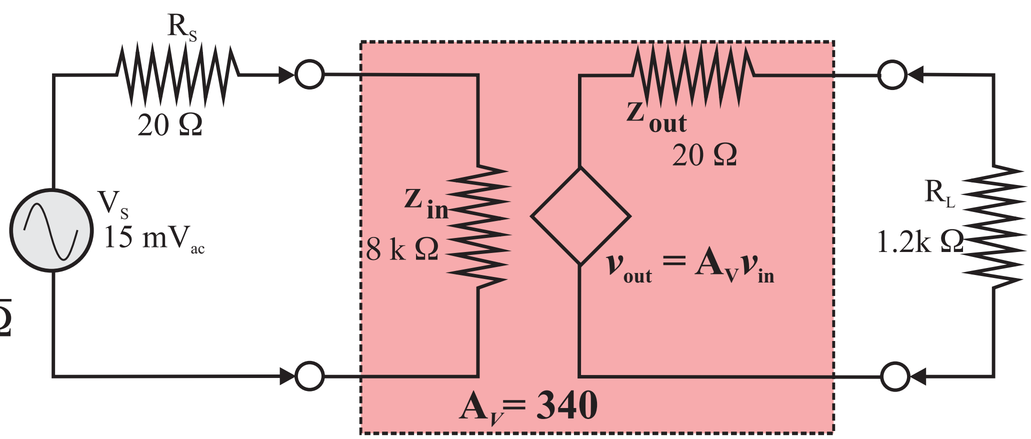
$$= \boxed{276}$$

The input and output circuits have reduced the gain from 340 to an effective value of 276.
Generally, we want the effective value to be as high as possible (or be as close to 340 as possible in our example)
We can accomplish this by:

- increasing the value of Z_{in}
- decreasing the value of Z_{out}

In this example , we are essentially using the same circuit as before. Only Z_{in} and Z_{out} have changed.

- Z_{in} is much higher
- Z_{out} is much lower



❶ Find v_{in}

$$v_{in} = v_s \frac{Z_{in}}{R_S + Z_{in}}$$

$$= (15\ \text{mV}_{ac}) \frac{8\ \text{k}\Omega}{8.02\ \text{k}\Omega}$$

$$= 14.96\ \text{mV}_{ac}$$

❷ Find v_{out}

$$v_{out} = A_V v_{in}$$

$$= (340)\ 14.96\ \text{mV}_{ac}$$

$$= 5.1\ \text{V}_{ac}$$

❸ Find v_L

$$v_L = v_{out} \frac{R_L}{Z_{out} + R_L}$$

$$= (5.1\ \text{V}_{ac}) \frac{1.2\ \text{k}\Omega}{1.22\ \text{k}\Omega}$$

$$= 5\ \text{V}_{ac}$$

❹ Find effective A_V

$$A_V = \frac{v_L}{v_S}$$

$$= \frac{5\ \text{V}_{ac}}{15\ \text{mV}_{ac}}$$

$$= \boxed{333.3}$$

As you can see, the effective gain has increased significantly by ***increasing the value of Z_{in}*** and ***reducing the value of Z_{out}***

In practical circuits, little can be done to change the resistance of a given signal source or load. We can, however, effect the value of Z_{in} and Z_{out} This is done by:

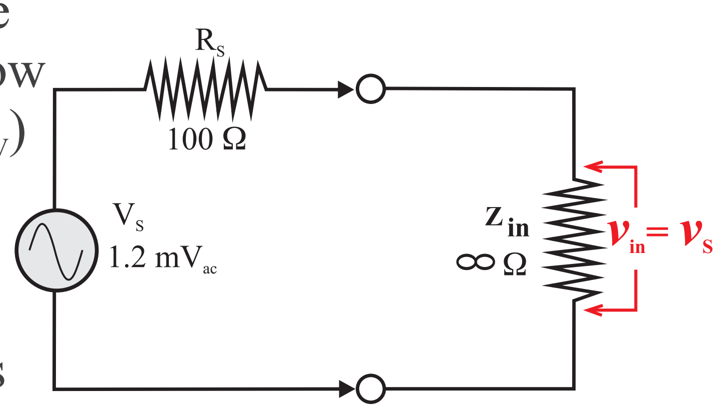
- Our choice of active components
- The value of components we use
- The type of biasing circuit we use.

The Ideal Voltage Amplifier

In a perfect world, the ideal voltage amplifier would have:

- Infinite Gain (if needed)
- Infinite input impedance
- Zero output impedance

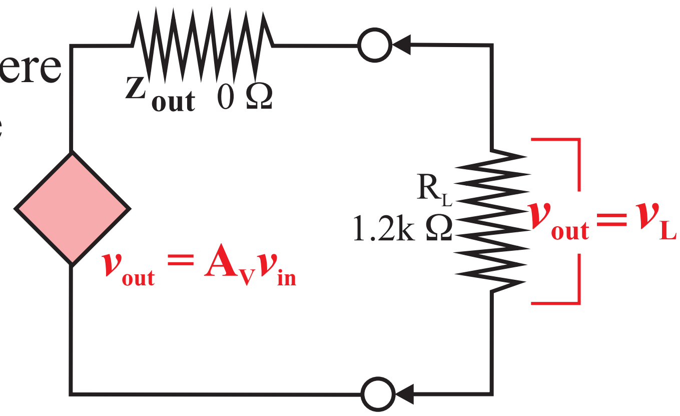
Infinite Gain - This means that the amplifier could produce any value of gain that we need, no matter how high the value. In reality gain (A_V) is limited in part, by the active components (the transistor)



Ideal Input Circuit

Infinite Input Impedance - If this could happen, then there would be no current in the input circuit and no voltage would be dropped across R_S. This means that all the input voltage appears across Z_{in}. This means that the amplifier sees all the input voltage with no losses.

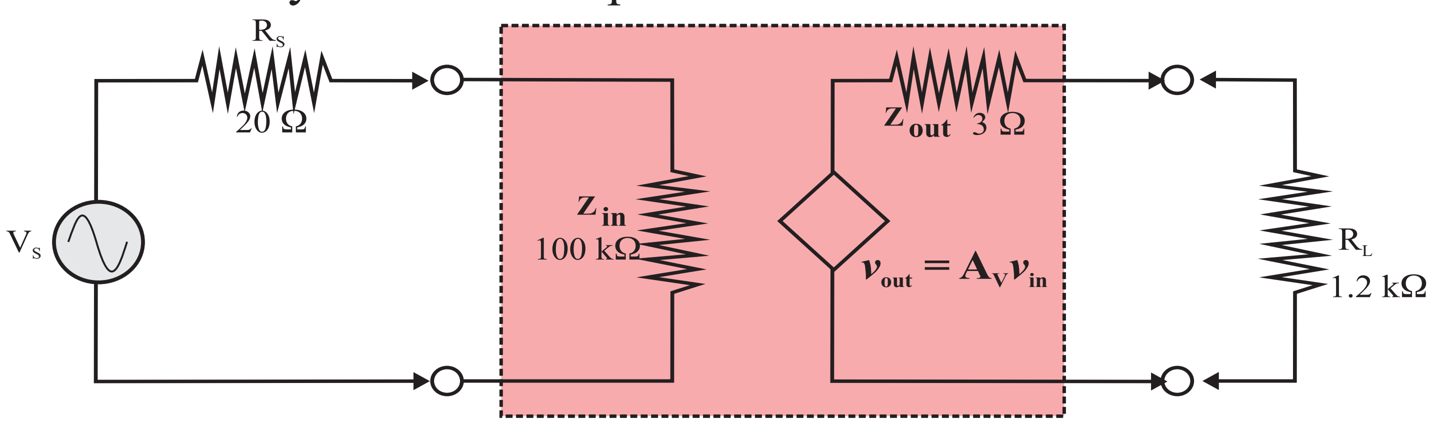
Zero Output Impedance - If this were possible, there would be no voltage divider in the output circuit. This means that all of v_{out} would appear across R_L with no losses across Z_{out}.



As you can see, our ideal amplifier has no losses at the input. The input sees all of the applied input voltage. At the output, there are also no losses. All of v_{out} appears across the load. In an ideal amp, the gain of the amplifier (A) and the effective gain are the same, since there are no losses.

The Real World

The value of $Z_{in} = \infty\ \Omega$ and $Z_{out} = 0\ \Omega$ have not been achieved in practical circuits, but we can get reasonably close by proper circuit design. In the circuit shown, Z_{in} is 100 kΩ . When compared to R_S of 20 Ω , most of V_S will appear across Z_{in}. This means that the losses are very low on the input side of the circuit.



Amplifier Model Optimized for Maximum Effective Gain

On the output side, Z_{out} is only 3 Ω. This again means the the output losses are very low since most of V_{out} is dropped across R_L and very little is lost across Z_{out}.

Gain

Earlier in this notepak, we discussed gain. We said that gain is traditionally defined as the ratio of a circuit's output to its corresponding input. Further, we said that there are three types of gain:

- Voltage Gain A_V
- Current Gain A_I
- Power Gain A_P
-

Where gain is defined as a simple ratio - we called it ***ordinarily gain.***

If you were a look at the specifications for an amplifier, you would often find its voltage gain and/or its power gain values expressed in decibel form.

A decibel (dB) is a logarithmic unit used to express the ratio of one value to another. Using the decibel method allows us to easily represent very large gain values as relatively small numbers. As an example, a power gain of 1,000,000 is expressed as 60 dB.

dB Power Gain

The ***dB power gain*** of an amplifier is the ***ratio of output power to input power, equal to 10 times the common log of that ratio.***

This simply means that the ***dB power gain is 10 times the log of the ordinary power gain.***

$$A_{p(dB)} = 10\log A_p \quad \text{or} \quad A_{p(dB)} = 10\log \frac{P_{out}}{P_{in}}$$

Example 8.7 finds the decibel power gain of an amplifier

Converting dB Power Gain to Ordinary Gain

The formula below will convert a decibel power gain back to an ordinary gain.

$$A_p = \log^{-1} \frac{A_{p(dB)}}{10}$$

This formula says that the ordinary gain is the inverse log of the decibel power gain divided by 10.

Example 8.8 does this conversion.

Example 8.9 demonstrates how to find the output power when the input power and the dB power gain are known.

Example 8-10 demonstrates how to find the input power when the output power and the dB power gain are known.

Positive Versus Negative dB Values

If you compare the results of examples 8.9 and 8.10, we can come to some very important conclusions regarding the use of dB values.

1) ***Positive dB values*** represent a ***power gain.***
   Negative dB values represent a ***power loss.***

2) Positive and negative decibels of equal magnitude represent reciprocal gains and losses.
   A +3dB gain causes power to double, while a -3 dB gain, causes power to be cut in half.

Examples Of Equal Positive And Negative dB Values

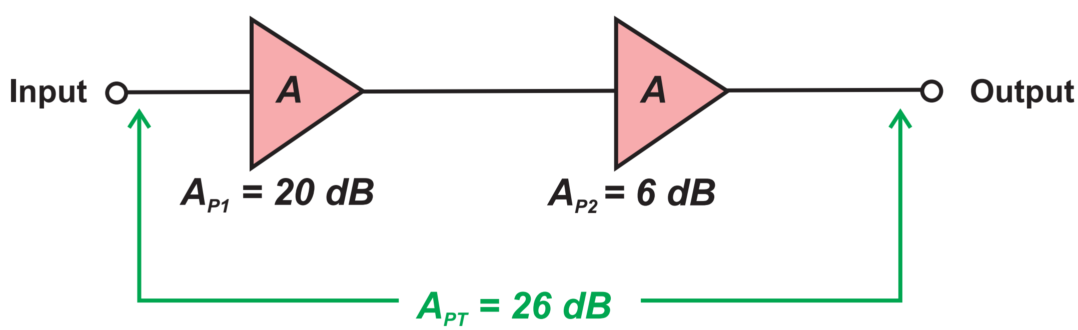
dB Value	Gain	dB Value	Loss
3	2	-3	$\frac{1}{2}$
6	4	-6	$\frac{1}{4}$
12	16	-12	$\frac{1}{16}$
20	100	-20	$\frac{1}{100}$

The Advantages Of Using Decibels

1) One of the reasons that dB values so are commonly used is the fact that the equivalent (+) and (-) dB values represent reciprocal gains and losses.

A gain of ***+3 dB*** indicates that the ***power has doubled***
A gain of ***-3 dB*** indicates that the ***power has decreased to half***

2) dB gains are additive. In multistage amplifiers, the total gain of the complete amplifier is equal to the some of the individual amplifier dB gains.



The dBm Reference

Often, power ratings are listed on specification sheets as dBm values. For example, an amplifier may be listed as having a maximum output power of 50 dBm. The reading tells you that the maximum output power from the amplifier is ***50 dB above 1 mW.***

Power, measured in dBm., is found as:

$$\boxed{P_{dBm} = 10 \log \frac{P}{1\ \text{mW}}}$$

What does this mean?

Up to this point, we have discussed dB power gains and losses. If an amplifier has a 3 dB gain, we know that the power doubles. ***But what is the actual power?*** We have no way of knowing, simply because we have no idea what the input level is.

dBm values represent actual power ***levels.***

dB values represent actual power ***ratios***

Examples 8.11 and 8.12 illustrate this point.

dB Voltage Gain

The dB voltage gain of an amplifier is found as:

$$\boxed{A_{V(dB)} = 20 \log A_V \quad \underline{\textit{or}} \quad A_{V(dB)} = 20 \log \frac{v_{out}}{v_{in}}}$$

The dB voltage gain uses a multiplier of 20 (in place of the 10) when calculating the dB voltage gain.

Example 8.13 calculates dB voltage gain

Converting dB Voltage Gain to Ordinary Gain

The formula below will convert a decibel voltage gain back to an ordinary gain.

$$A_V = \log^{-1} \frac{A_{V(dB)}}{20}$$

Example 8.14 demonstrates this.

Negative dB voltage values indicate a voltage loss

Example 8.15 demonstrates this

Summary *Decibel (dB) Characteristics*

1) Decibels are a ***logarithmic*** representations of gain values.
2) Decibel power gain is found as **10 log A_P**
3) Decibel voltage gain is found as **20 log A_V**
4) Decibel gains are additive.
5) When A_V changes by a given number of decibels, A_P changes by the same number of decibels.