

Why are Low Impedance Microphones Better Than High-Imp.

Microphones come in a variety of types based on a variety of factors. For example, there are "dynamic" microphones that use a magnet and coil to convert sound waves into electrical signals by exploiting the physics of magnetic fields; there are "condensor" microphones that use a DC voltage source and a capacitor to convert sound waves into electrical signals by exploiting the physics of electric fields. However, there is another factor that leads to a split into two groups: high-impedance microphones and low-impedance microphones. (In principle, any mic can be high- or low- impedance regardless if it is a dynamic mic or a condensor... however, high-impedance condensor mics are not very common at all). We'll see below what defines a low-imp or high-imp mic.

If you search on the web for information about microphones you'll see most sites advising to get low-impedance microphones because they are better (they cost more though). These sites will usually state that low-imp mics are better because they have better frequency response and have better noise immunity. Here we'll use Signals & Systems ideas to understand the first advantage: why do low-imp mics have a better frequency response?

So... physically we have: the mic... connected by a cable... to an audio amplifier of some sort



To do this we first need a circuit model (and then math model) of how a microphone works together with the amplifier it plugs into. So, first there is the microphone... whose job it is to generate a wiggling voltage... so it is a time-varying voltage source... and because it is not an **ideal** source it must be modeled to account for its non-ideal characteristics.

* We have seen in circuits that any physical voltage source can be represented by its Thevenin equivalent circuit.

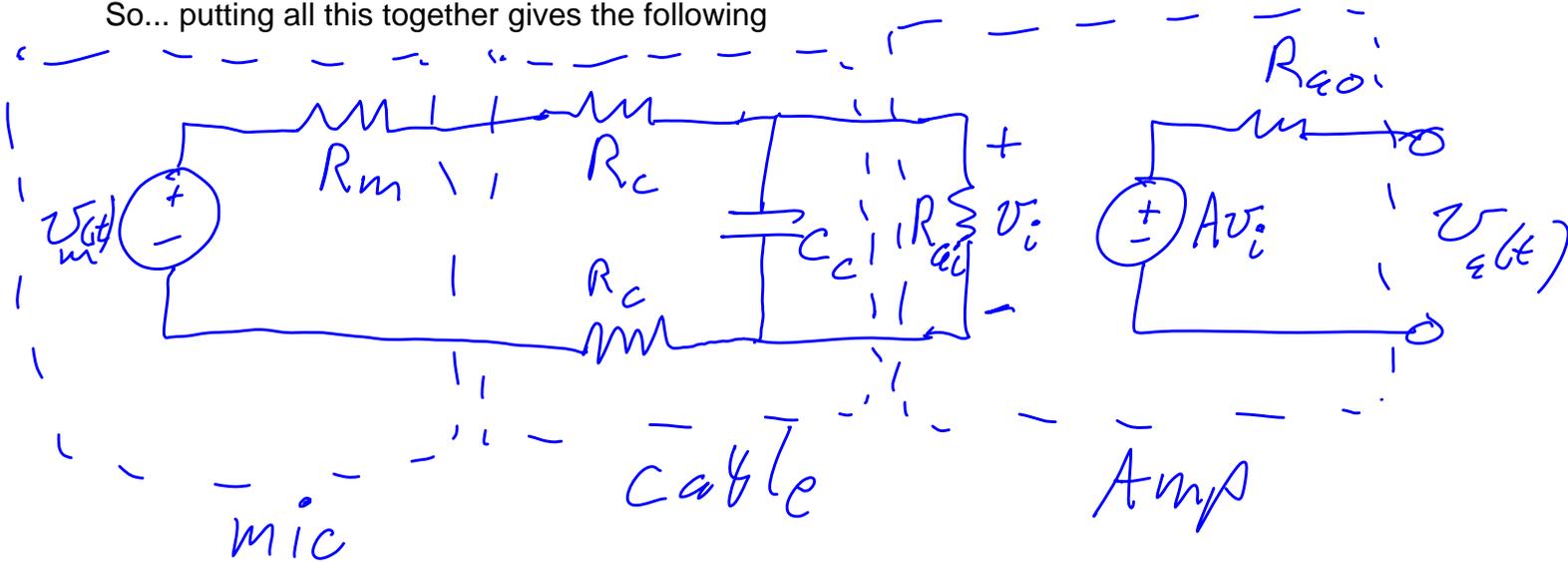
Then there is the cable... whose job it is to convey the voltage generated by the mic over to the amplifier. To do this requires (at least) two wires... a voltage is defined between two points, so we connect a wire to each point (there are some mic cables that have *more* than 2 wires in the cable but we will ignore that case here).

* We have seen in circuits that a two-wire cable can be modeled as a simple RC circuit. The resistance comes from the fact that wires have some small resistance per unit length and the capacitance comes from the fact that the two wires are each covered with insulation so we have two conductors separated by a dielectric... which is a capacitor.

Finally we have an amplifier.. whose job is to take the voltage at its input terminals and amplify it into a bigger voltage to drive the power amp or some other electronics and then that signal gets its power amplified by the power amp to drive speakers (the pre-amp and power amp might be designed as one single unit)

* We can model the amplifier as an input resistance with a dependent voltage source at its output.

So... putting all this together gives the following



Now let's characterize these equivalent circuit parameters:

R_m is the impedance of the mic (simplified here as a pure resistance)...

A high imp mic will have an R_m value in the range of 10kohm or more

A low impedance mic will have an R_m value of 600 ohms or less but not much less than 200 ohms or so

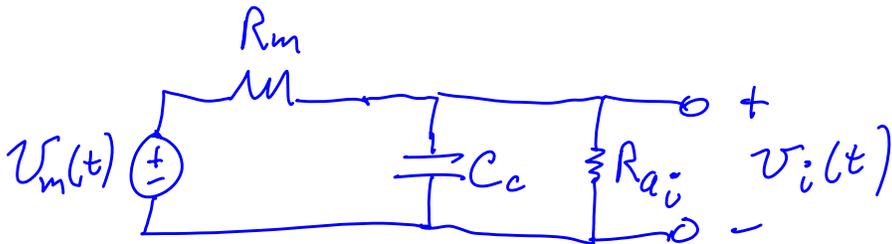
Our goal here is to see the effect of those two cases!

A typical mic cable will have a resistance per unit length of about 0.08 ohms/meter.. so even if we have a long cable of 100m we will only have a cable resistance of 8 ohms... so we can ignore the effect of R_c since it will be small compared to R_m even for the low imp mic.

A typical mic cable will have a capacitance per unit length of about 100 picoF per meter so for a 20 meter cable that would be 2 nanoF... we should not ignore that

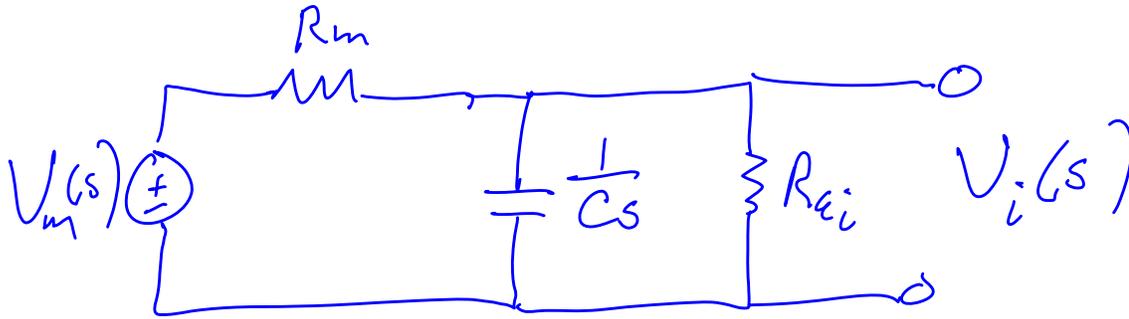
The amplifier design will be done such that input resistance will be large compared to the mic's impedance... usually $R_{a(i)}$ is 10 times or more the value of R_m . Because of the dependent source model for the amplifier the only part of the amplifier model that impacts the behaviour of voltage $v_i(t)$ at the amplifier's input is the amplifier's input resistance (that is the beauty of using such a model for the amplifier!)

So... given all this the equivalent circuit to be analyzed is...



Note: $v_o(t)$ can be found by analyzing the amp's "output side" loop for a given load

Now, we can analyze this circuit to find its frequency response. We convert all voltages to phasor form and convert all Rs and Cs to impedances.. it is easiest to do this in the s-form and then convert to the jw-form



$$Z_{ii} = \left(\frac{1}{Cs}\right) \parallel R_{ai} = \frac{R_{ai}/Cs}{R_{ai} + \frac{1}{Cs}} = \frac{R_{ai}}{R_{ai}Cs + 1}$$

Then by voltage divider:

$$V_i(s) = \frac{Z_{ii}(s)}{R_o + Z_{ii}(s)} V_m(s)$$

H(s)

$$H(s) = \frac{\frac{R_{ai}}{R_{ai}Cs + 1}}{R_m + \frac{R_{ai}}{R_{ai}Cs + 1}}$$

$$= \frac{R_{ai}}{(R_{ai} + R_m) + s R_{ai} R_m C_c}$$

⇓

$$H(s) = \frac{\frac{1}{R_m C_c}}{s + \frac{1}{R_{11} C_c}}$$

where $R_{11} = \frac{R_{ai} R_m}{R_{ai} + R_m}$

Recall... an amp designed for use with a mic having a given R_m would have $R_{ai} \geq 10 R_m$ (*)

$$\Rightarrow R_{11} \approx R_m$$

⇓

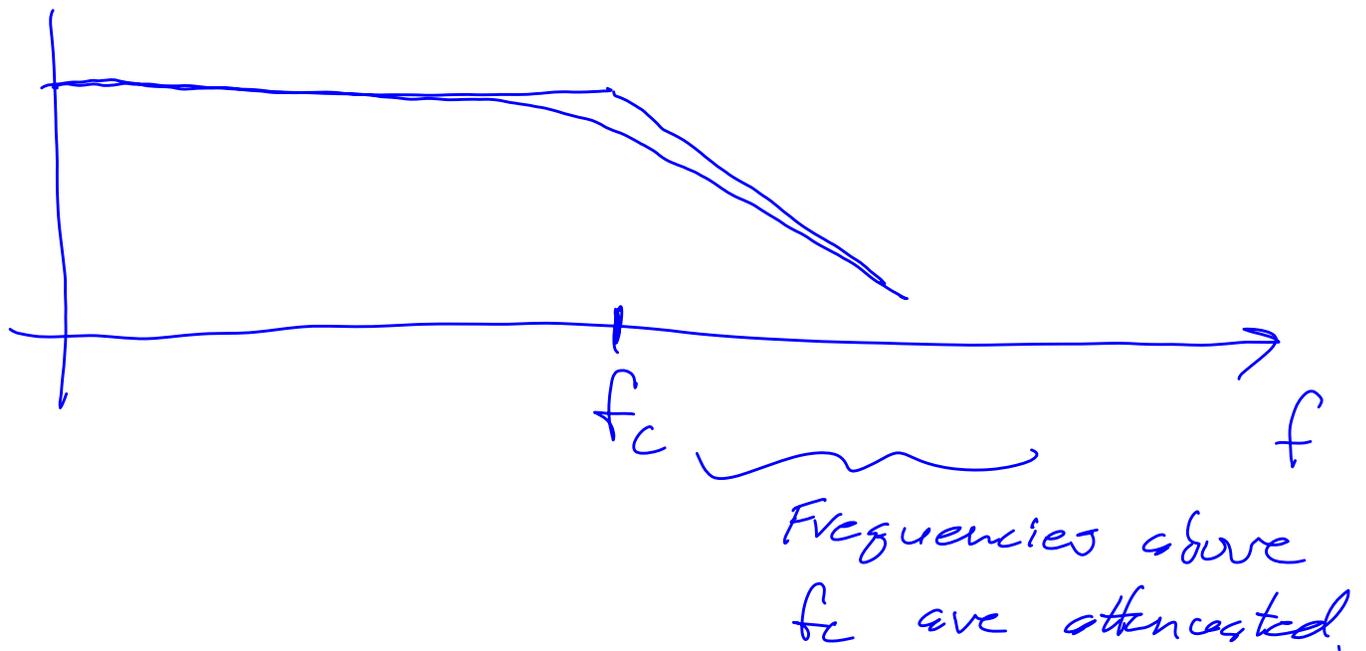
$$H(s) \approx \frac{\frac{1}{R_m C_c}}{s + \frac{1}{R_m C_c}}$$

So R_{ai} has negligible effect when (*) is satisfied.

Note that this is a 1st order low pass filter with cut off frequency of $\omega_c = \frac{1}{R_m C_c}$

$$\text{Or } f_c = \frac{1}{2\pi R_m C_c}$$

So the Bode plot tells us:



Note that C_c is set by the cable length.

★ So ... as mic impedance R_m goes up ... f_c goes down and that reduces more high frequency content.

⇒ Big Picture Result

For a given cable length...
a high imp. mic will have
more high freq. attenuation
than a low imp mic !!

For 20 m cable

$$C_c \approx 2 \text{ nF}$$

Mic Imp	f_c
Low $R_m \approx 600 \Omega$	132 kHz (Far <u>above</u> highest Audio Freq)
High $R_m \approx 10 \text{ k}\Omega$	8 kHz (Far <u>below</u> highest Audio Freq)

Can't even use a 20 m cable
w/ a HiZ Mic!