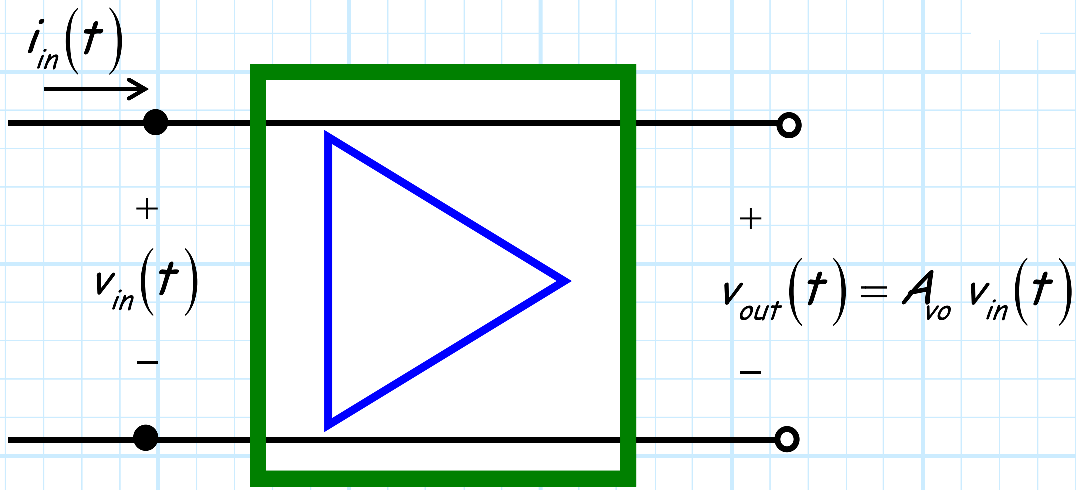
Amplifiers

An **ideal** amplifier is a two-port circuit that takes an input signal $v_{in}(t)$ and reproduces it **exactly** at its output, only with a **larger** magnitude!



The real value A_{vo} is the **open-circuit voltage gain** of this ideal amplifier, and has a magnitude much larger than unity ($A_{vo} \gg 1$).

We actually *can* find $g(t)$!

Now, let's express this result using our knowledge of **linear circuit theory**!

Recall, the output $v_{out}(t)$ of a linear device can be determined by **convolving** its input $v_{in}(t)$ with the device **impulse response** $g(t)$:

$$v_{out}(t) = \int_{-\infty}^{t} g(t-t')\, v_{in}(t')\, dt'$$

Q: *Yikes! What is the impulse response of this ideal amp? How can we determine it?*

A: It's actually quite **simple**!

Remember, the impulse **response** of linear circuit is just the output that results when the **input** is an impulse function $\delta(t)$.

Every function an Eigen function

Since the output of an ideal amplifier is just the input multiplied by A_{vo}, we conclude if $v_{in}(t) = \delta(t)$:

$$g(t) = v_{out}(t) = A_{vo}\,\delta(t)$$

Thus:

$$\begin{aligned} v_{out}(t) &= \int_{-\infty}^{t} g(t-t')\, v_{in}(t')\, dt' \\ &= \int_{-\infty}^{t} A_{vo}\,\delta(t-t')\, v_{in}(t')\, dt' \\ &= A_{vo}\int_{-\infty}^{t} \delta(t-t')\, v_{in}(t')\, dt' \\ &= A_{vo}\, v_{in}(t) \end{aligned}$$

→ **Any** and **every** function $v_{in}(t)$ is an **Eigen function** of an **ideal** amplifier!!

And now the Eigen value

Now, we can determine the **Eigen value** of this linear operator relating input to output:

$$v_{out}(t) = \mathcal{L}\{v_{in}(t)\}$$

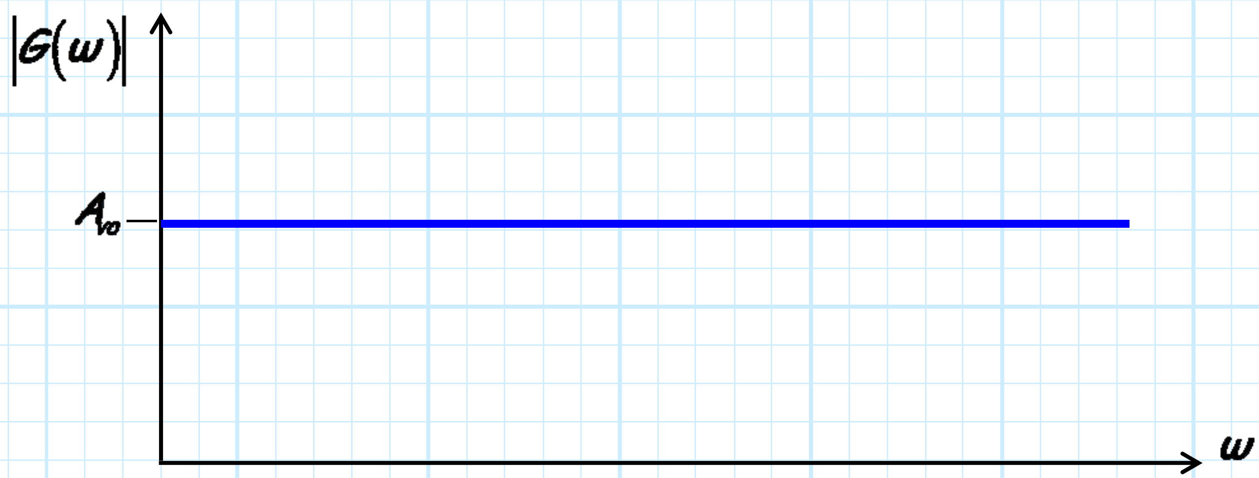
Recall this Eigen value is found from the **Fourier transform** of the impulse response:

$$\begin{aligned} G(\omega) &= \int_{-\infty}^{\infty} h(t)\, e^{-j\omega t}\, dt \\ &= \int_{-\infty}^{\infty} A_{vo}\, \delta(t)\, e^{-j\omega t}\, dt \\ &= A_{vo} + j0 \\ &= A_{vo} e^{j0} \end{aligned}$$

This result, although simple, has an interesting interpretation…

DC to daylight

…it means that the amplifier exhibits gain of A_{vo} for sinusoidal signals of **any** and **all** frequencies!



BUT, there is one **big** problem with an ideal amplifier:

➡ They are **impossible** to build!!

Real amplifier have finite bandwidths

The **ideal** amplifier has a frequency response of $|G(\omega)| = A_{vo}$.

Note this means that the amplifier gain is A_{vo} for **all** frequencies $0 < \omega < \infty$ (D.C. to daylight!).

The **bandwidth** of the **ideal** amplifier is therefore **infinite**!

* Since every electronic device will exhibit **some** amount of inductance, capacitance, and resistance, every device will have a **finite** bandwidth.

* In other words, there will be frequencies ω where the device does **not work**!

* From the standpoint of an amplifier, "not working" means $|G(\omega)| \ll A_{vo}$ (i.e., **low gain**).

→ Amplifiers therefore have **finite** bandwidths.

Amplifier bandwidth

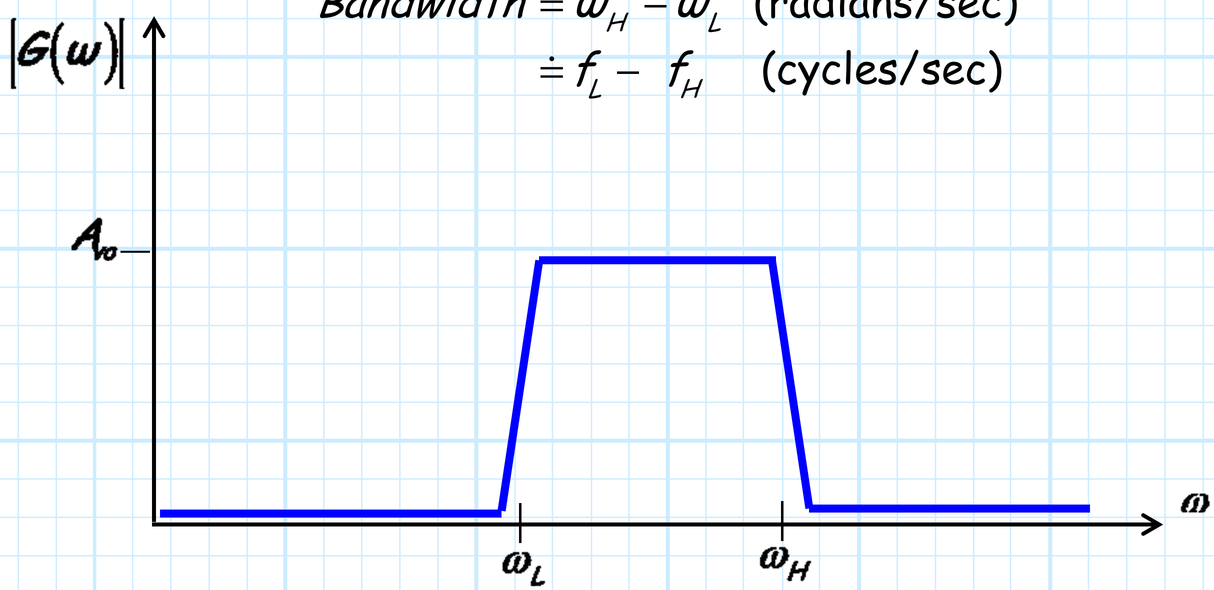
There is a range of frequencies ω between ω_L and ω_H where the gain will (approximately) be A_{vo}.

For frequencies outside this range, the gain will typically be small (i.e. $|G(\omega)| \ll A_{vo}$):

$$|G(\omega)| = \begin{cases} \approx A_{vo} & \omega_L < \omega < \omega_H \\ \ll A_{vo} & \omega < \omega_L, \omega > \omega_H \end{cases}$$

The **width** of this frequency range is called the amplifier **bandwidth**:

$$\begin{aligned} Bandwidth &\doteq \omega_H - \omega_L \quad \text{(radians/sec)} \\ &\doteq f_L - f_H \quad \text{(cycles/sec)} \end{aligned}$$



Wideband is desirable

One result of a **finite bandwidth** is that the amplifier impulse response is **not** an impulse function !

$$h(t) = \int_{-\infty}^{\infty} H(\omega)\, e^{+j\omega t} dt \neq A_{vo}\, \delta(t)$$

therefore **generally** speaking:

$$v_{out}(t) \neq A_{vo}\, v_{in}(t) \text{ !!}$$

However, if an input signal **spectrum** $V_{in}(\omega)$ lies completely **within** the amplifier bandwidth, then we find that will (approximately) behave like an **ideal** amplifier:

$$v_{out}(t) \cong A_{vo}\, v_{in}(t) \quad \text{if } V_{in}(\omega) \text{ is within the amplifier bandwidth}$$

As a result, **maximizing** the bandwidth of an amplifier is a typically and important **design goal**!