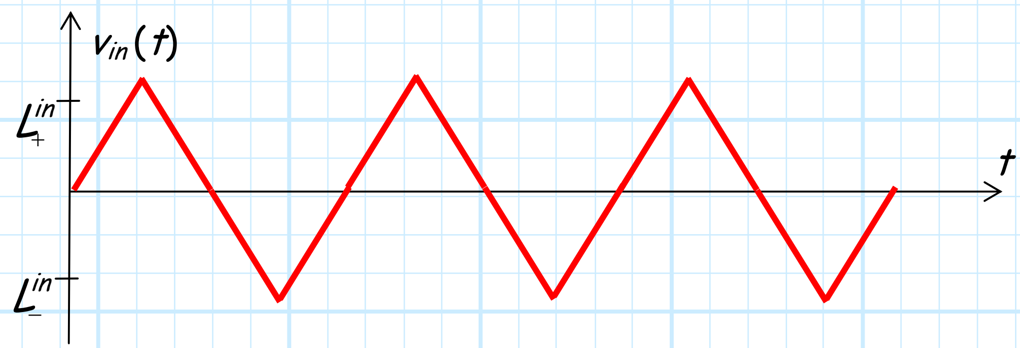
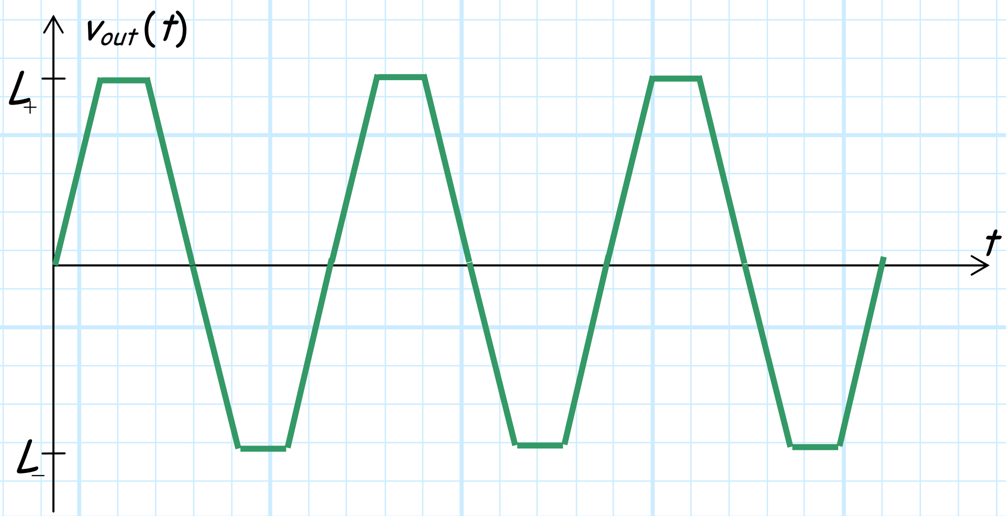
Slew Rate

We know that the output voltage of an amplifier circuit is **limited**, i.e.:

$$L_{-} < v_{out}(t) < L_{+}$$

During any period of time when the output tries to exceed these limits, the output will **saturate**, and the signal will be **distorted**! E.G.:





Limits on the time derivative

But, this is **not** the only way in which the output signal is **limited**, **nor** is saturation the only way it can be **distorted**!

A **very** important op-amp parameter is the **slew rate** (S.R.).

Whereas L_- and L_+ set limits on the values of output signal $v_{out}(t)$, the slew rate sets a limit on its **time derivative** !!!! I.E.:

$$-\text{S.R.} < \frac{d\, v_{out}(t)}{dt} < +\text{S.R.}$$

In other words, the output signal can **only change so fast**! Any attempt to exceed this fundamental op-amp limit will result in **slew-rate limiting**.

The red means distortion

So, in addition to **saturation**:

$$v_{out}(t) = \begin{cases} L_+ & \text{if} \quad A_{vo}\, v_{in}(t) > L_+ \\ A_{vo}\, v_{in}(t) & \text{if} \quad L_- < A_{vo}\, v_{in}(t) < L_+ \\ L_- & \text{if} \quad L_- > A_{vo}\, v_{in}(t) \end{cases}$$

we find the following **output** signal condition:

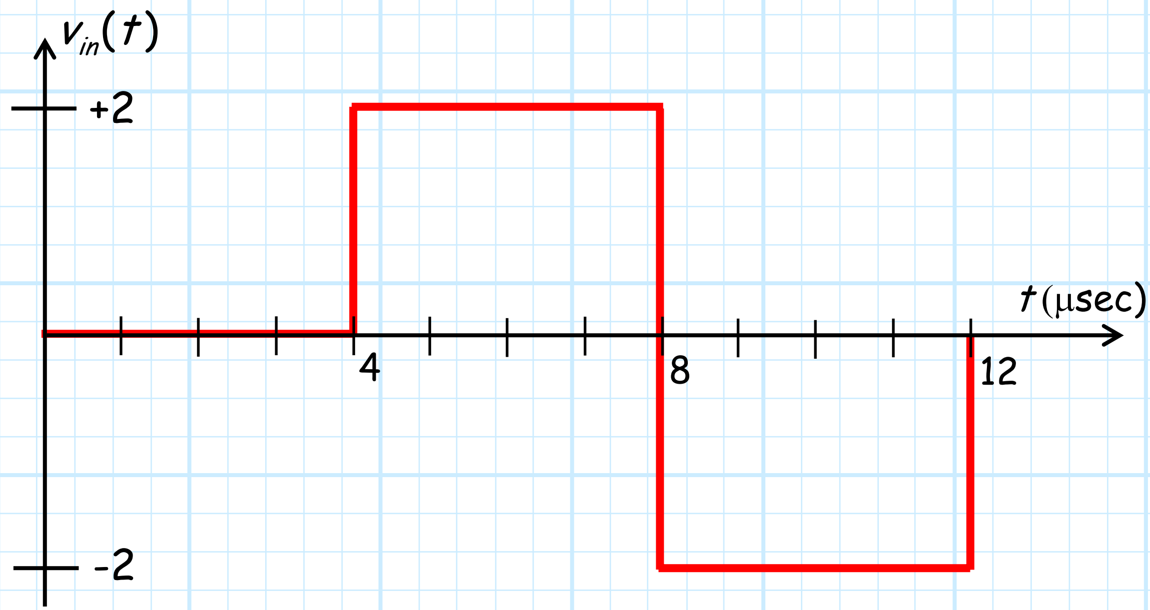
$$v_{out}(t) = \begin{cases} A_{vo}\, v_{in}(t) & \text{if} \quad \left| \dfrac{d\, A_{vo}\, v_{in}(t)}{dt} \right| < S.R. \\ \pm (S.R.)\, t + C & \text{if} \quad \left| \dfrac{d\, A_{vo}\, v_{in}(t)}{dt} \right| > S.R. \end{cases}$$

For example

For example, say we build a **non-inverting** amplifier with mid-band gain $A_{vo} = 2$.

This amplifier was constructed using an op-amp with a **slew rate** equal to 4V/μsec.

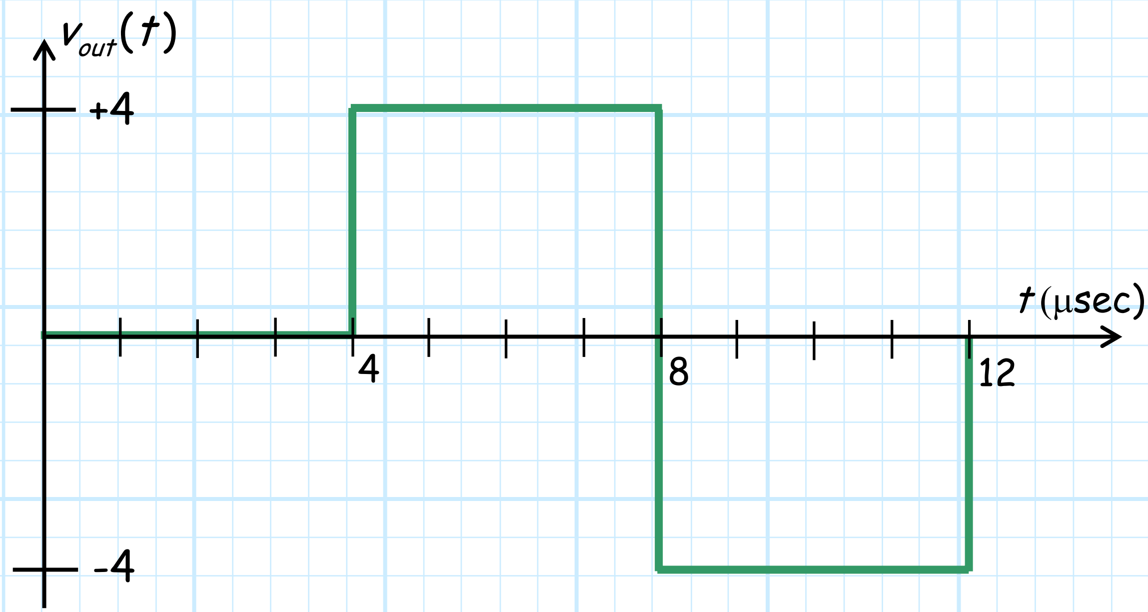
Q: *If we **input** the following signal $v_{in}(t)$, what will we see at the **output** of this amplifier?*



This is what it should look like

A: **Ideally**, the output would look exactly like the input, only multiplied by $A_{vo} = 2$:

$$v_{out}(t) = 2\, v_{in}(t) \quad \text{(ideal)}$$



Note that the time derivative of this output is **zero** at **almost** every time t:

$$\frac{d\, v_{out}(t)}{dt} = 0 \quad \text{for } \textit{almost} \text{ all time } t$$

Now you see the problem!

The **exceptions** are at times t =4, t =8, and t =12 μsec, where we find that the time derivative is **infinite**!

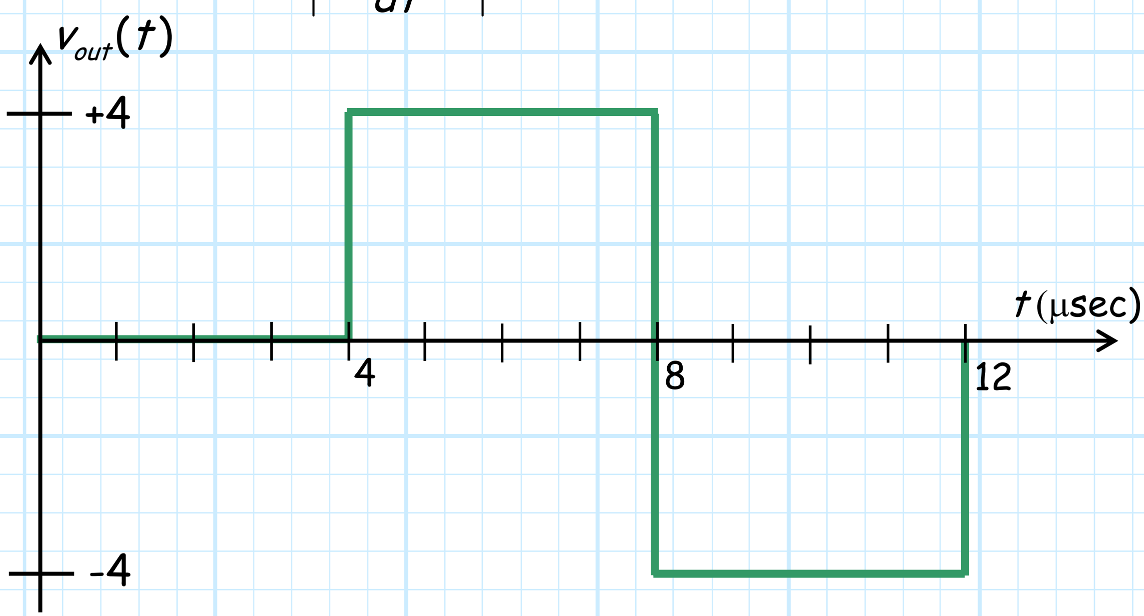
$$\frac{d\,v_{out}(t)}{dt} = \infty \quad \text{at times } t = 4 \text{ and } t = 12$$

and

$$\frac{d\,v_{out}(t)}{dt} = -\infty \quad \text{at time } t = 8$$

This is a **problem**!

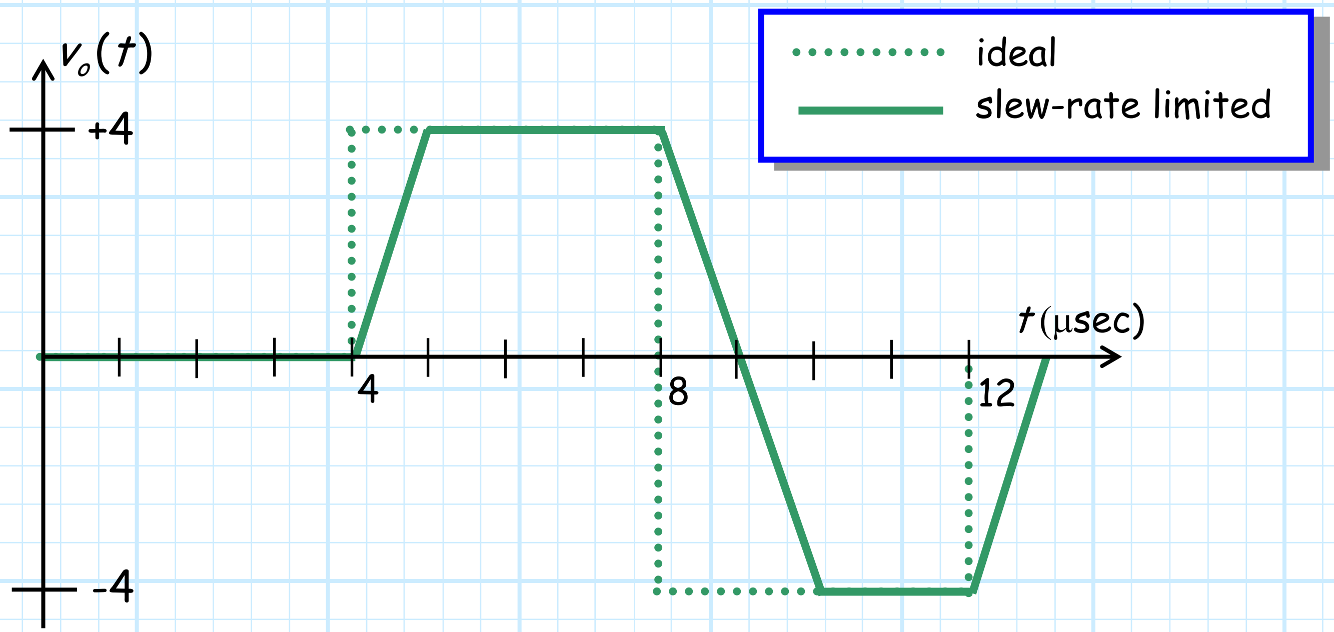
$$\left|\frac{d\,v_{out}(t)}{dt}\right| = \infty \quad > \quad 4V/\mu sec \text{ !!!!}$$



This is what it actually looks like!

Thus, the output signal **exceeds** the slew rate of the op-amp—or at least, it **tries** too!

The reality is that since the op-amp output **cannot** change at a rate greater than $\pm 4V/\mu sec$, the output signal will be **distorted**!



Note the derivative of the **actual** output signal is limited to a maximum value ($\pm 4V/\mu sec$) by the op-amp **slew rate**.