"AC Coupling"

Transistor amplifiers are often "AC coupled" and here I'll explain why. A transistor must be biased before it will work as an amp.

**Biasing:** Using Resistors & Voltage supplies to establish the needed DC voltages (& currents) to get the transistor "ready" to work as an amp.

Here is a typical biasing circuit:
The goal of this biasing is to ensure that \( V_b \) is somewhere around \( \frac{V_{cc}}{2} \) so that if we somehow make \( V_b \) wiggle up & down... there is room to wiggle:
- if \( V_b \) is too close to 0 then can't "wiggle down" very much
- if \( V_b \) is too close to \( V_{cc} \) then can't "wiggle up" very much

The other goal is to ensure the \( V_{ce} \approx 0.7 \) \& \( V_{ce} > 0 \)
By choosing \( R_1, R_2, R_3, \) \& \( R_4 \) we can do this!
Now we are all set to inject the signal we want to amplify.

We must use this signal to make \( V_b \) wiggle up and down.

Most signals we want to amplify wiggle around 0V (e.g., audio signals):

\[
X(t)
\]

Can we connect this directly to the \( V_b \) point? No!
To see why let's just consider the case of $X(t) = \sin(\omega t)$

And... instead of analyzing the transistor exactly we'll make some approximations... namely that the current $I_b$ into the base is small compared to the current through $R_1$ & $R_2$.

Then the "front part" of the biasing circuit looks like:

$$V_b = \frac{V_{cc}}{2}$$


We only need to analyze this front part to see the need for AC coupling.
So... without the sinusoidal signal applied we have $V_b = \frac{V_{cc}}{2}$.

When we apply the sinusoid we want:

$$V_b(t) = \frac{V_{cc}}{2} + \sin(\omega t)$$

which makes $V_b$ wiggle above & below $\frac{V_{cc}}{2}$.

Let's see if this works if we directly connect $X(t)$:

Does $V_b(t) = \frac{V_{cc}}{2} + \sin(\omega t)$?
There are many ways to analyze this (Loop, Node, etc.)

We'll use superposition:

- Set the other sources to zero (i.e. short a voltage source, open a current source) and find the response.
- Repeat for each source.
- Add all the responses.

So...

1. Set \( V_{CC} = 0 \) (short \( V_{CC} \))

\[ V(t) = 5 \sin(wt) \]
Re-arranging gives:

\[ V_b(t) = 5 \sin(\omega t) \]

\[ R_{11} \]

\[ R_{11} = \frac{R_1}{R_2} \]

\[ \Rightarrow V_{b_1}(t) = 5 \sin(\omega t) \]

2. Set \[ x(t) = 0 \] (short it)

This short across \( R_2 \) causes \( V_{b_2}(t) = 0 \)!!

\[ \Rightarrow V_b(t) = V_{b_1}(t) + V_{b_2}(t) = 5 \sin(\omega t) \]

Not \[ \frac{V_{cc}}{2} + 5 \sin(\omega t) \] as desired!
So... applying \( V_{ct} \) directly causes \( V_{bt} \) to go negative which will reverse bias B-E, which makes the transistor not work!

So how do we fix this!? = AC coupling!!
AC Coupling used in actual circuit $\Rightarrow$ Equiv. Ckt. to analyze

Does $V_B(t) = \frac{V_{cc}}{2} + \sin(\omega t)$?

Now re-analyze using superposition.
So...

1. Set $Vcc = 0$ (short $Vcc$)

\[ v(t) = 5\sin(\omega_0 t) \]

\[ R_{11} \quad + \quad R_2 \quad - \]

\[ V_{B_1}(t) \]

Re-Arranging gives:

\[ R_{11} = R_1 \parallel R_2 \]

\[ v(t) = 5\sin(\omega_0 t) \]

\[ R_{11} \quad + \quad V_{B_1}(t) \]

\[ |H(\omega)| \]

\[ \frac{1}{R_{11}C} \]

\[ \omega \]

\[ \Rightarrow V_{B_1}(t) = 5\sin(\omega_0 t) \quad \text{if} \quad \frac{\omega}{R_{11}C} < \omega_0 \]
2. Set $X(t) = 0$ (short it)

This cap. across $R_2$ causes acts like open circuit to DC source $V_{CC}$.

$$V_{B_1}(t) = \frac{V_{CC}}{2}$$

$$\Rightarrow V_B(t) = V_{B_1}(t) + V_{B_2}(t) = \frac{V_{CC}}{2} + \sin(\omega t)$$

AC Coupling Works!!