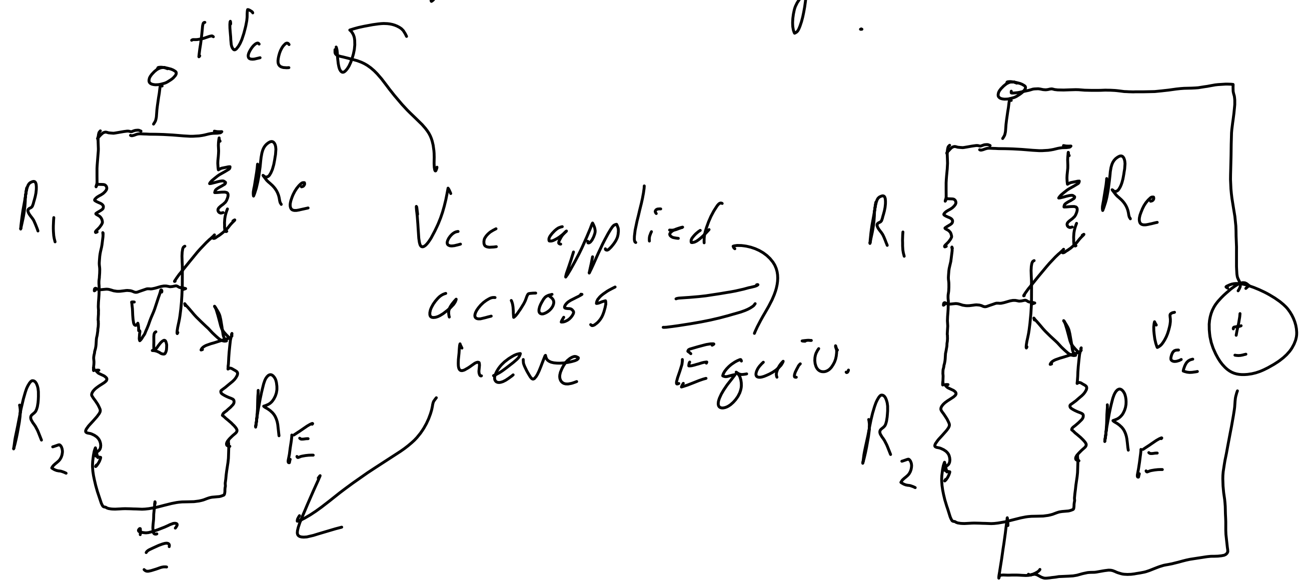
"AC Coupling"

Transistor amplifiers are often "AC coupled" & 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 (2) is to ensure that V_b is somewhere around $\frac{V_{cc}}{2}$ so that <u>if</u> we somehow make V_b wiggle up & down... there <u>is</u> room to wiggle:

- if V_b is too close to 0 then can't "wiggle <u>down</u>" very much

- if V_b is too close to V_{cc} then can't "wiggle <u>up</u>" very much

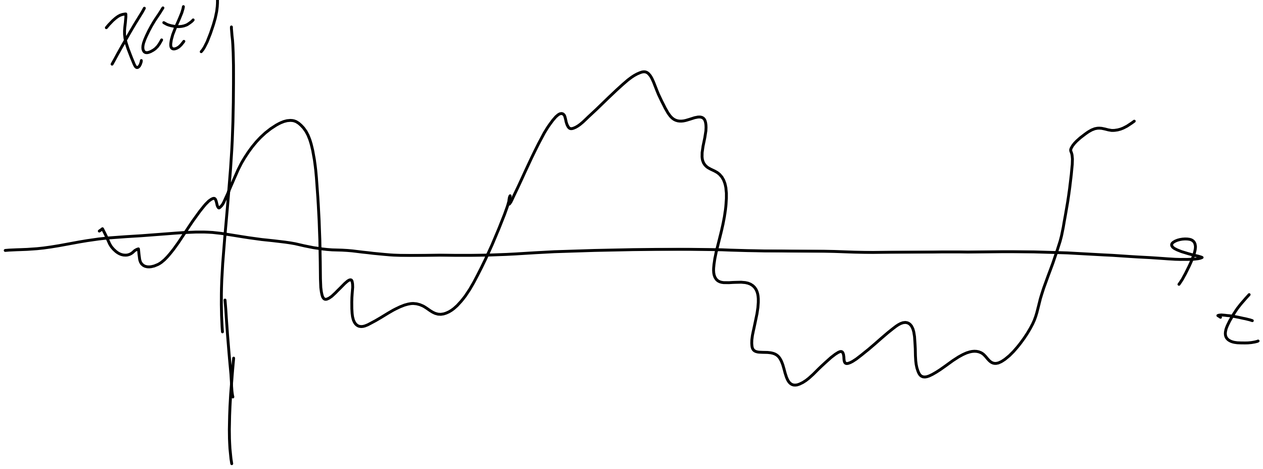
The other goal is to ensure the $V_{be} \approx 0.7\,V$ & $V_{CE} > 0$

By choosing $R_1, R_2, R_c,$ & R_E we <u>can</u> 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 & down.

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

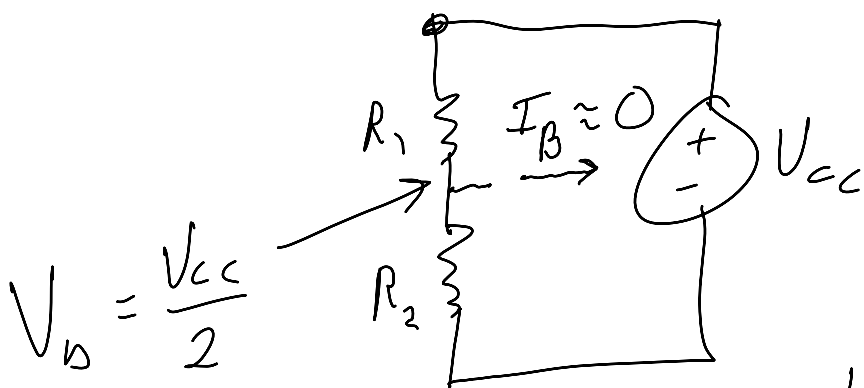


Can we connect this directly to the V_b point? No!

To see why let's just consider the case of
$x(t) = \sin(\omega_0 t)$

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:



We only need to analyze this front part to see the need for AC coupling

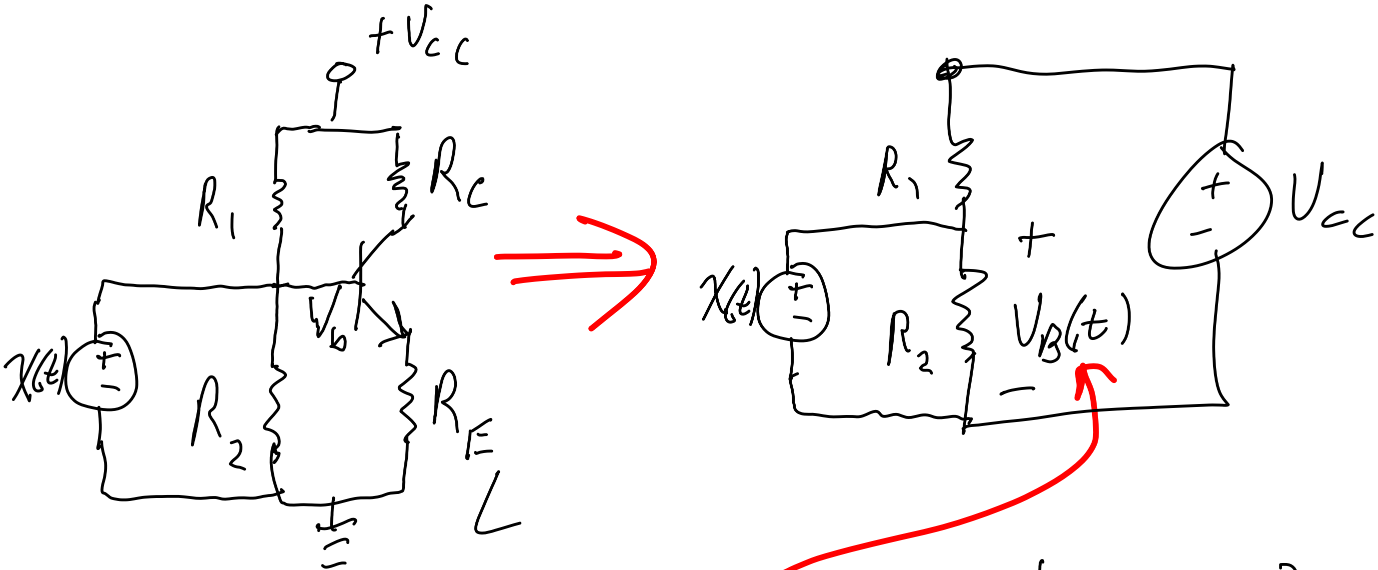
So... without the sinusoidal signal applied we have $V_b = \frac{V_{cc}}{2}$.

When we apply the sinusoid we want

$$V_b(t) = \frac{V_{cc}}{2} + \underbrace{\sin(\omega_0 t)}$$

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

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



Does $V_B(t) = \frac{V_{cc}}{2} + \sin(\omega_0 t)$?

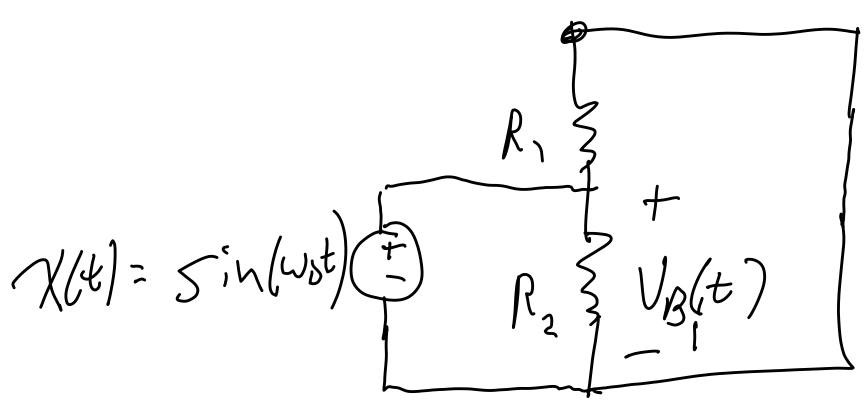
There are many ways to analyze this (Loop, Nodal, etc.)

We'll use superposition:

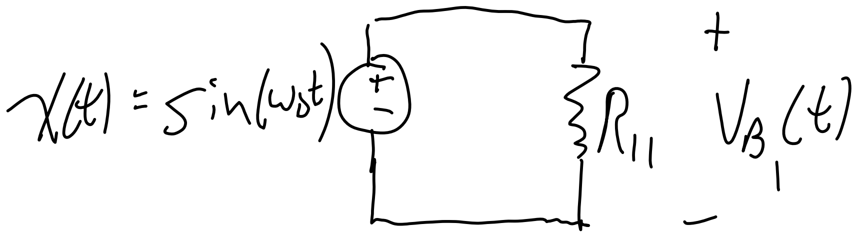
- Set the other sources to zero (i.e. short a voltage source, open a current source) and find the response.
- Repeat for each source
- Add all the responses

So...

1. Set $V_{cc} = 0$ (short V_{cc})



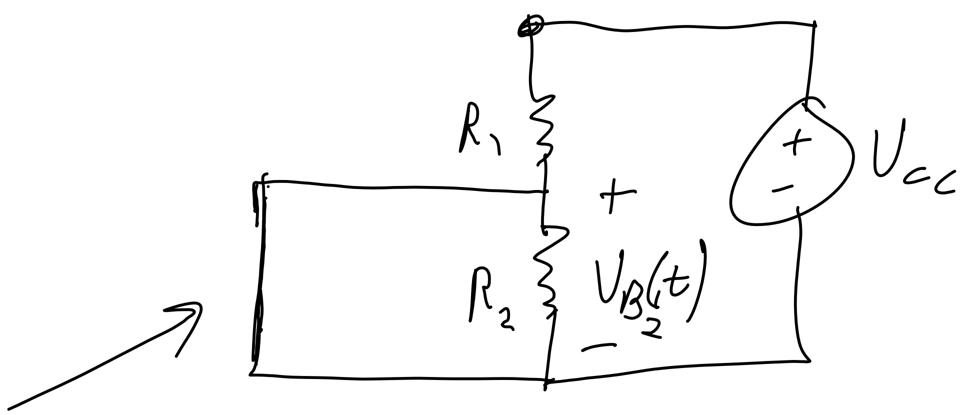
Re-Arranging gives:



$R_{11} = R_1 \| R_2$

$\Longrightarrow V_{B_1}(t) = \sin(\omega_0 t)$

2. Set $x(t) = 0$ (short it)



This short across R_2 Causes $V_{B_2}(t) = 0$!!

$$\Longrightarrow V_B(t) = V_{B_1}(t) + \underbrace{V_{B_2}(t)}_{=0} = \sin(\omega_0 t)$$

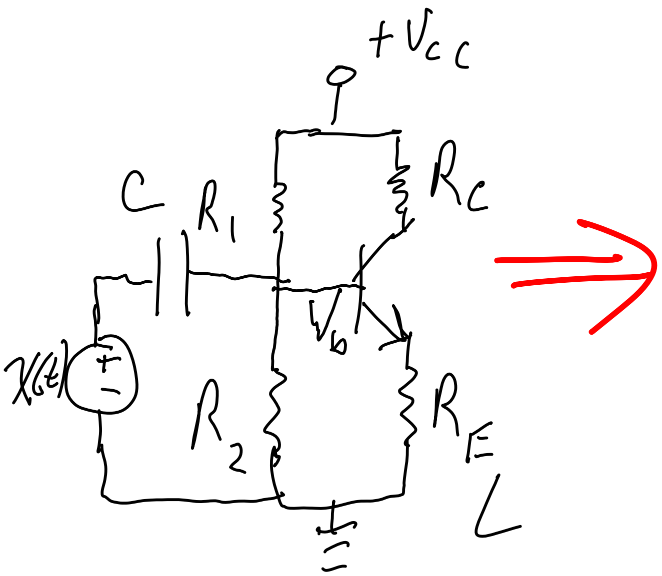
Not $\frac{V_{cc}}{2} + \sin(\omega_0 t)$ as desired!

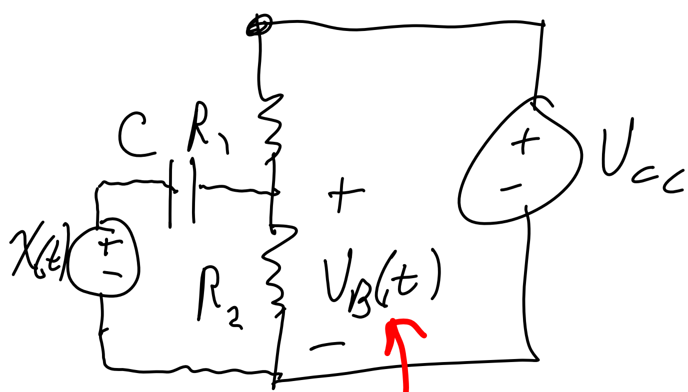
So.... applying $x(t)$ directly causes $V_B(t)$ to go negative which will reverse biase B-E, which makes the transistor amp Not Work!

So how do we Fix This!?

⇒ AC Coupling!!

AC Coupling used in Actual circuit $\Rightarrow$ Equiv. Ckt. to analyze



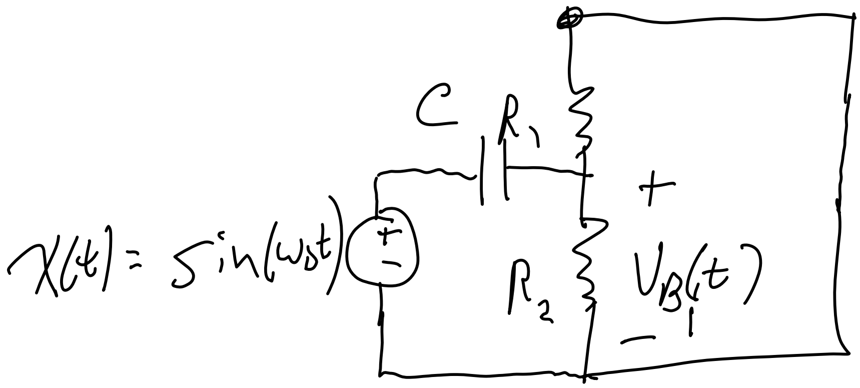


Does $V_B(t) = \frac{V_{cc}}{2} + \sin(\omega_0 t)$?

Now Re-analyze using superposition:

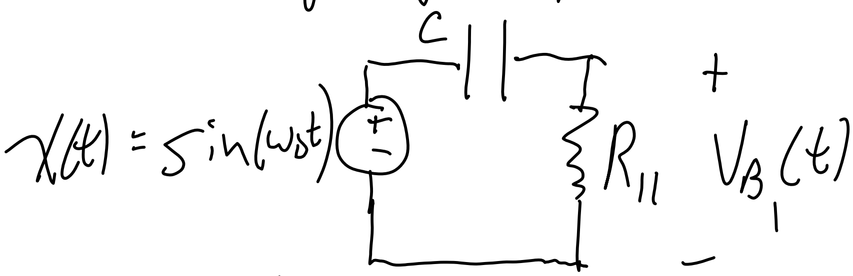
So...

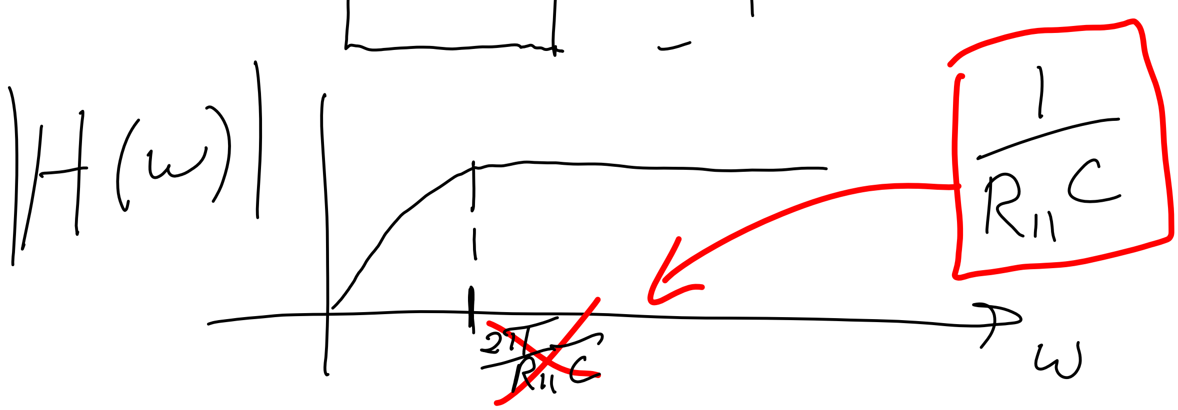
1. Set $V_{cc} = 0$ (short V_{cc})



Re-Arranging gives:

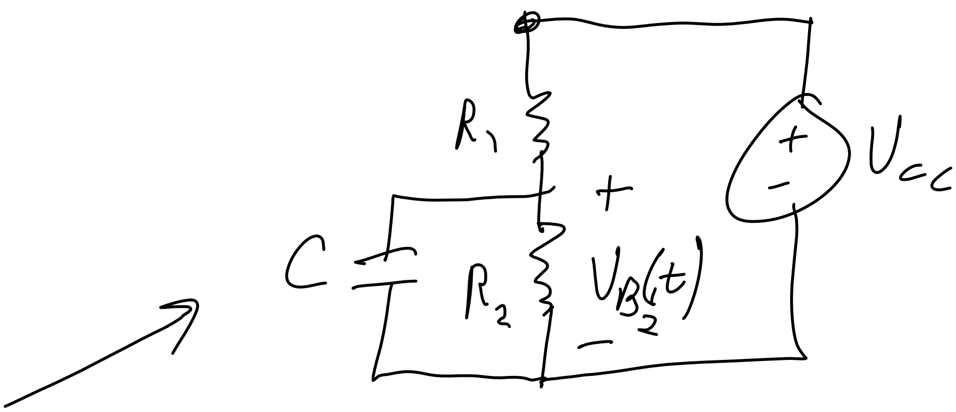
$R_{\parallel} = R_1 \parallel R_2$





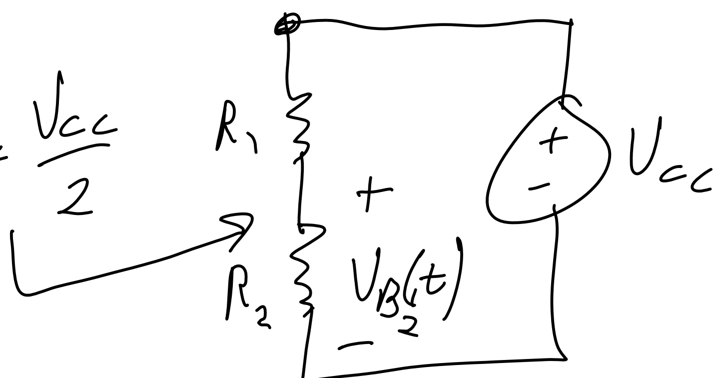
$$\Longrightarrow \quad V_{B_1}(t) = \sin(\omega_0 t) \quad \text{if } \frac{1}{R_{\parallel} C} < \omega_0$$

2. Set $x(t) = 0$ (short it)



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

$V_{B_2}(t) = \frac{V_{cc}}{2}$



$$\Rightarrow V_B(t) = V_{B_1}(t) + V_{B_2}(t)$$
$$= \frac{V_{cc}}{2} + \sin(\omega_0 t)$$

AC Coupling Works!!