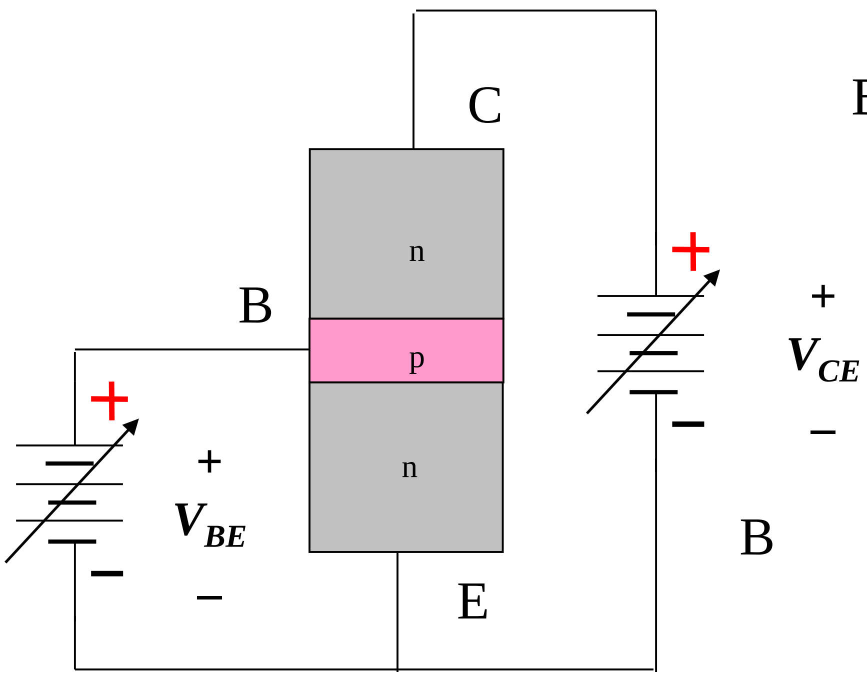
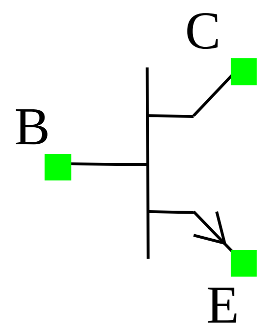
Electronic Circuits Laboratory EE462G Lab #8

BJT Common Emitter Amplifier

npn Bipolar Junction Transistor

BJT in a common-emitter configuration





B – Base

C – Collector

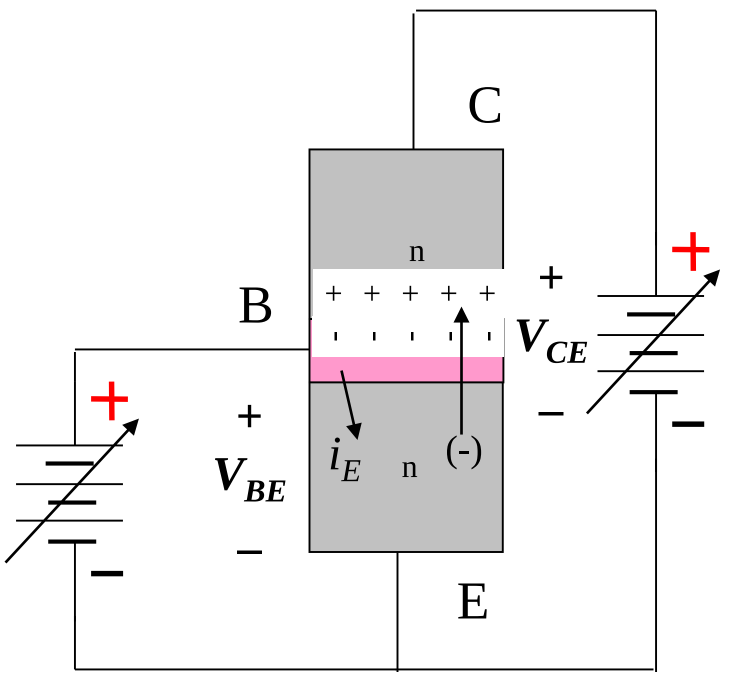
E – Emitter

For most applications the BJT is operated in the active region where:

$$V_{BE} \cong 0.6\text{V} \text{ and } V_{CE} > V_{BE}$$

npn BJT Operation

BJT in a common-emitter configuration in active region ($V_{CE} > V_{BE} \sim .6V$):



The *pn* junction for V_{BE} is forward biased and current i_{BE} flows according to the Shockley equation:

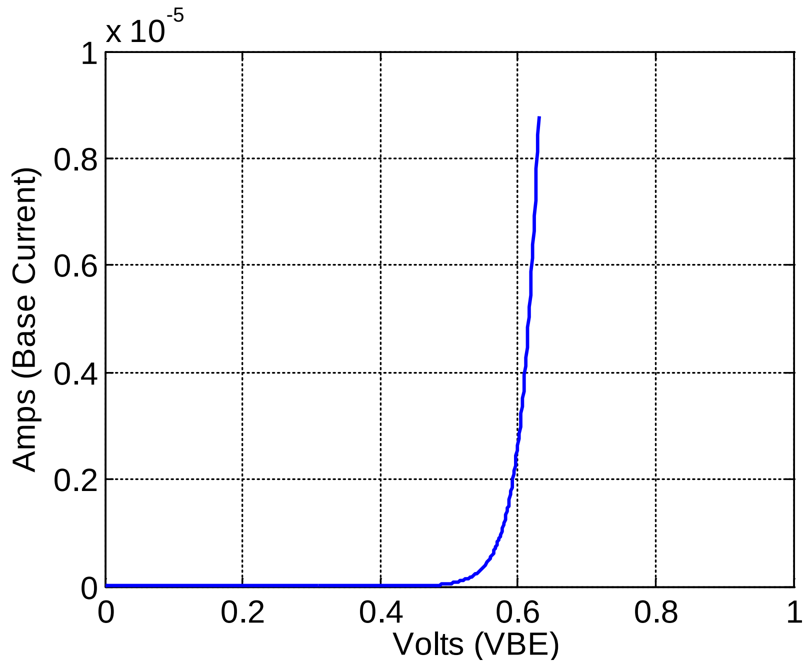
$$i_E = I_{ES}\left[\mathbf{exp}\left(\frac{V_{BE}}{V_T}\right) - 1\right]$$

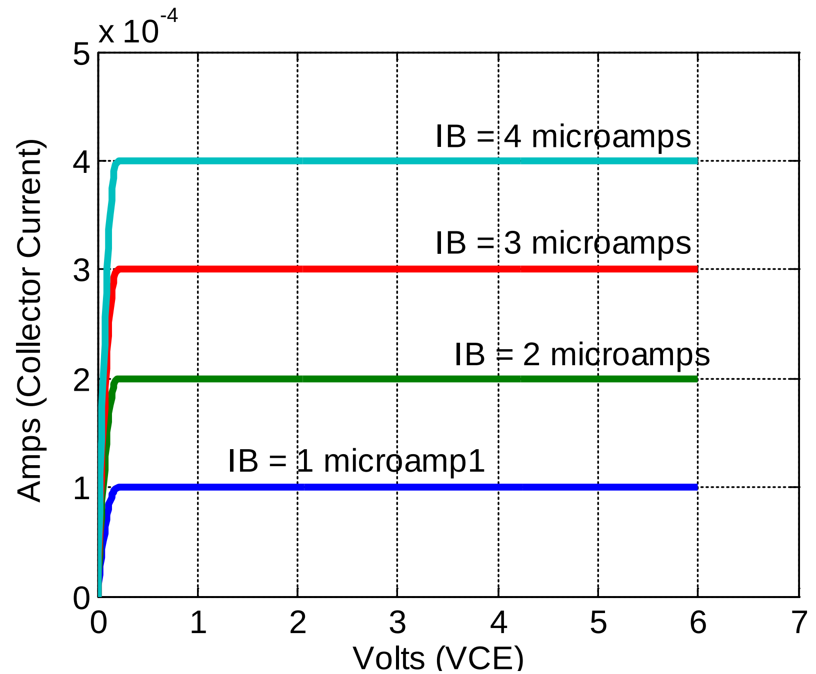
where $V_T \cong .26$ mV and I_{ES} ranges from 10^{-12} to 10^{-17}.

Electrons from the emitter flow into the base and are pulled into the depletion region of the reversed biased collector-base junction.

npn BJT Characteristics

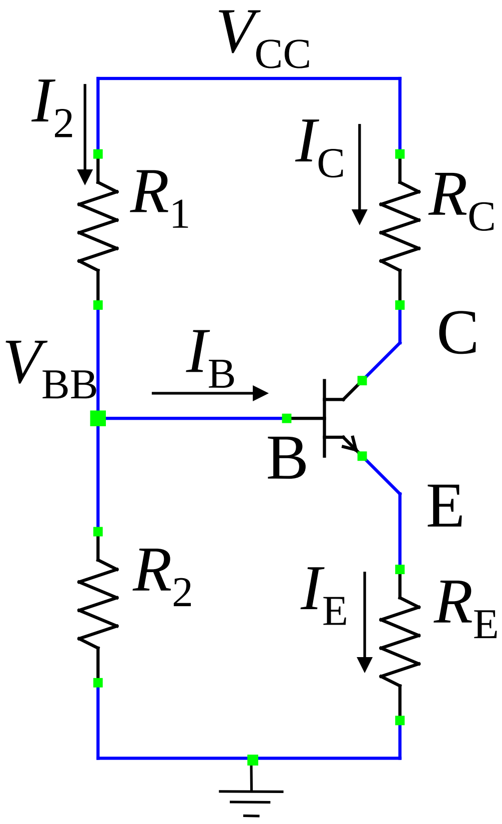
BJT Transfer Characteristics in active region with $\beta = I_C / I_B = 100$:





DC (Biasing) Model

Equations for the DC operating point, assume I_B <<<< I_2:



$$V_{BB} = V_{CC} \frac{R_2}{R_1 + R_2}$$

$$V_{CC} = I_C R_C + V_{CE} + I_E R_E$$

$$I_C = \beta I_B \qquad I_C + I_B = I_E$$

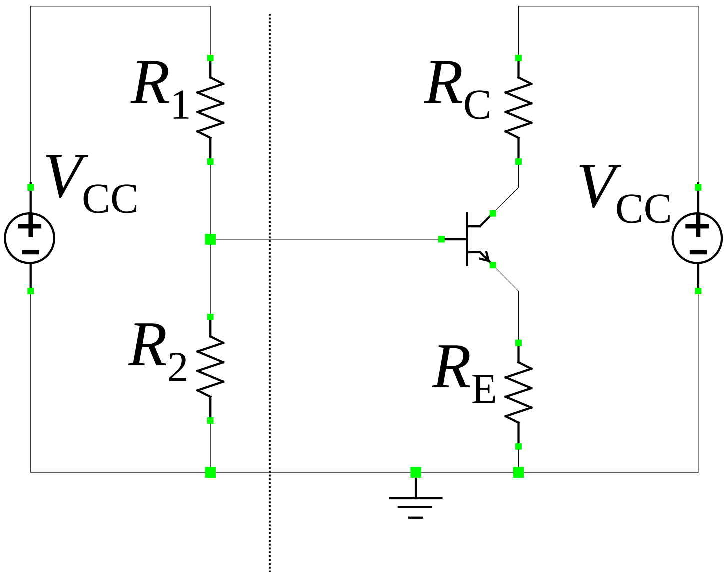
Key Result (Load-line Equation):

$$I_C = \frac{V_{CC}}{R_C + \frac{\beta + 1}{\beta} R_E} - \frac{V_{CE}}{R_C + \frac{\beta + 1}{\beta} R_E}$$

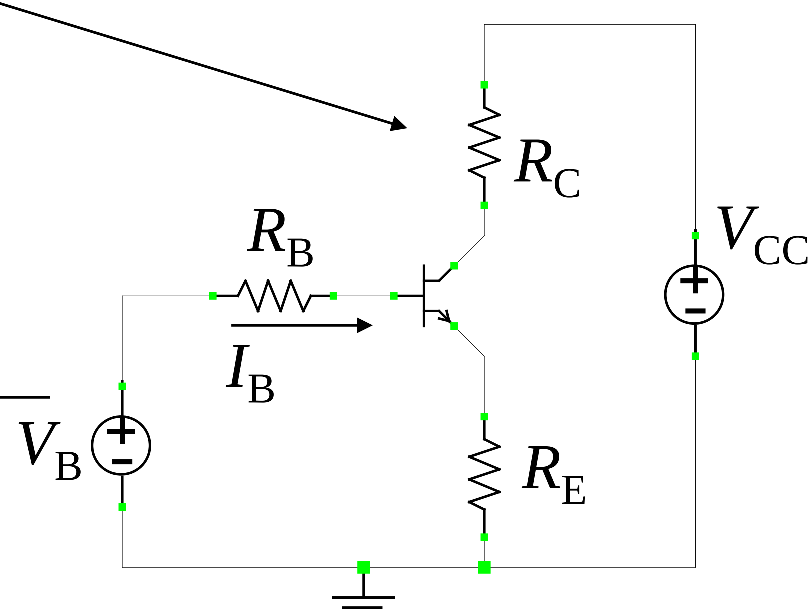
How sensitive is I_c to changes in β?

DC (Biasing) Equivalent Model

Apply Thévenin model to base terminal:



$$V_B = V_{CC}\frac{R_2}{R_1 + R_2} \qquad R_B = \frac{R_2 R_1}{R_1 + R_2}$$



Load-Line Equation

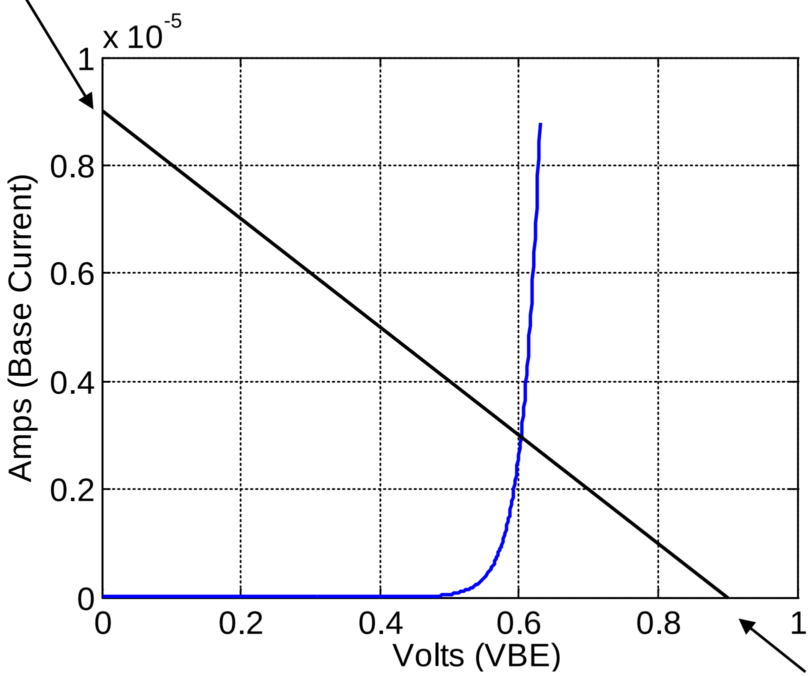
$$I_B = \frac{V_B}{R_B + (1+\beta)R_E} - \frac{V_{BE}}{R_B + (1+\beta)R_E}$$

Load Line Analysis: **How to determine the DC current gain β?**

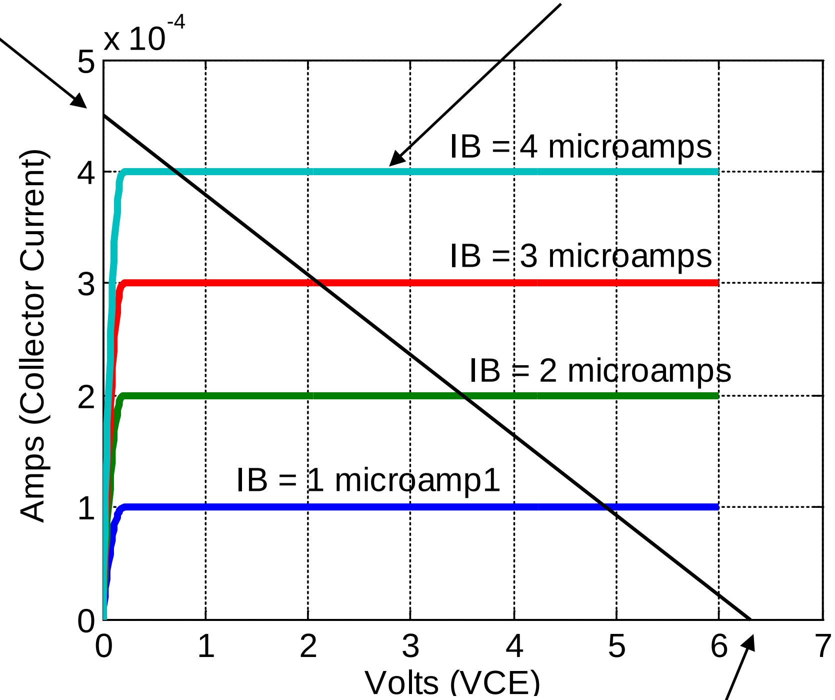
$$\frac{V_B}{R_B+(1+\beta)R_E}$$

$$\frac{V_{CC}}{R_C+\frac{\beta}{\beta+1}R_E}$$

If β changes, I_C does not change



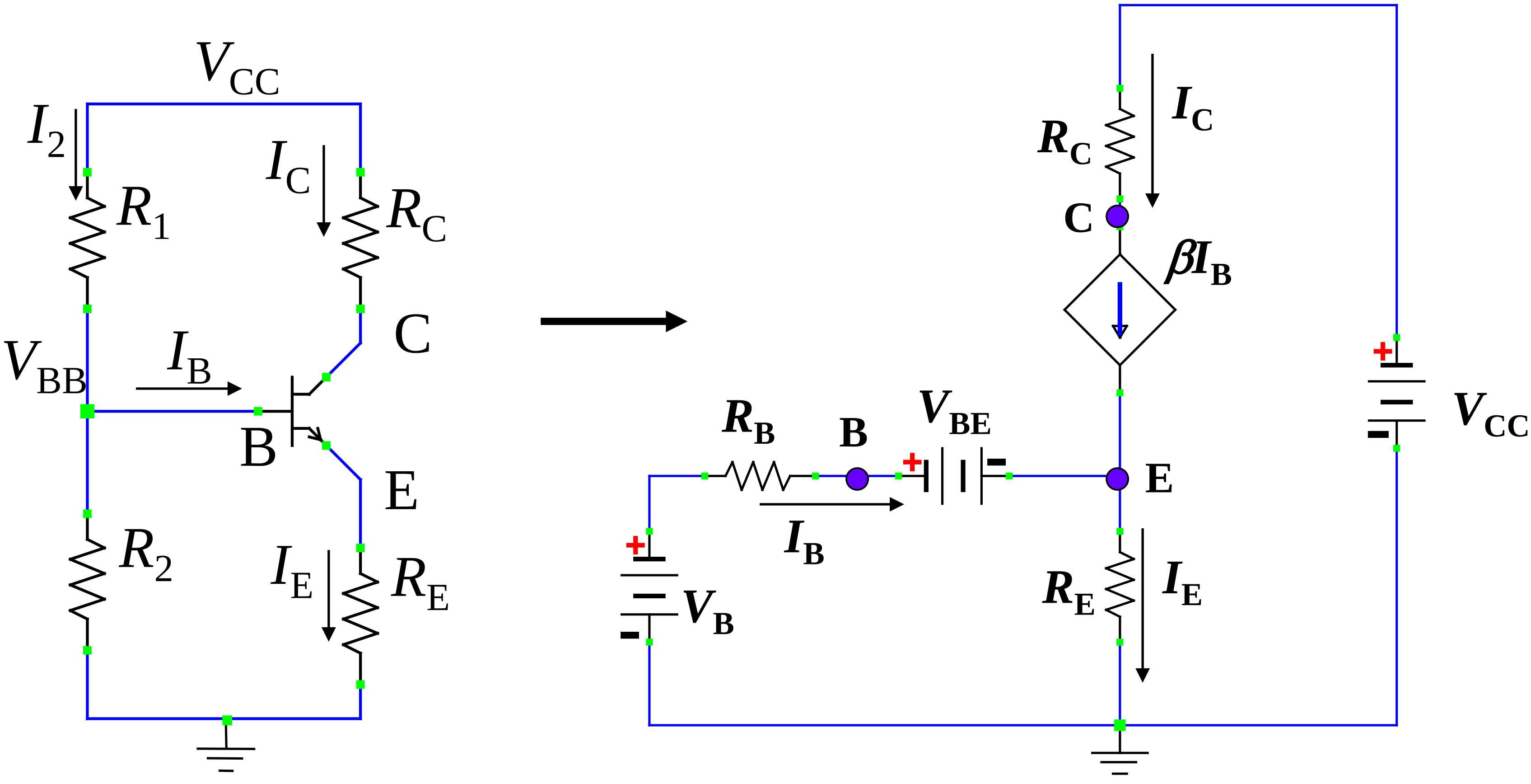
V_B



V_{CC}

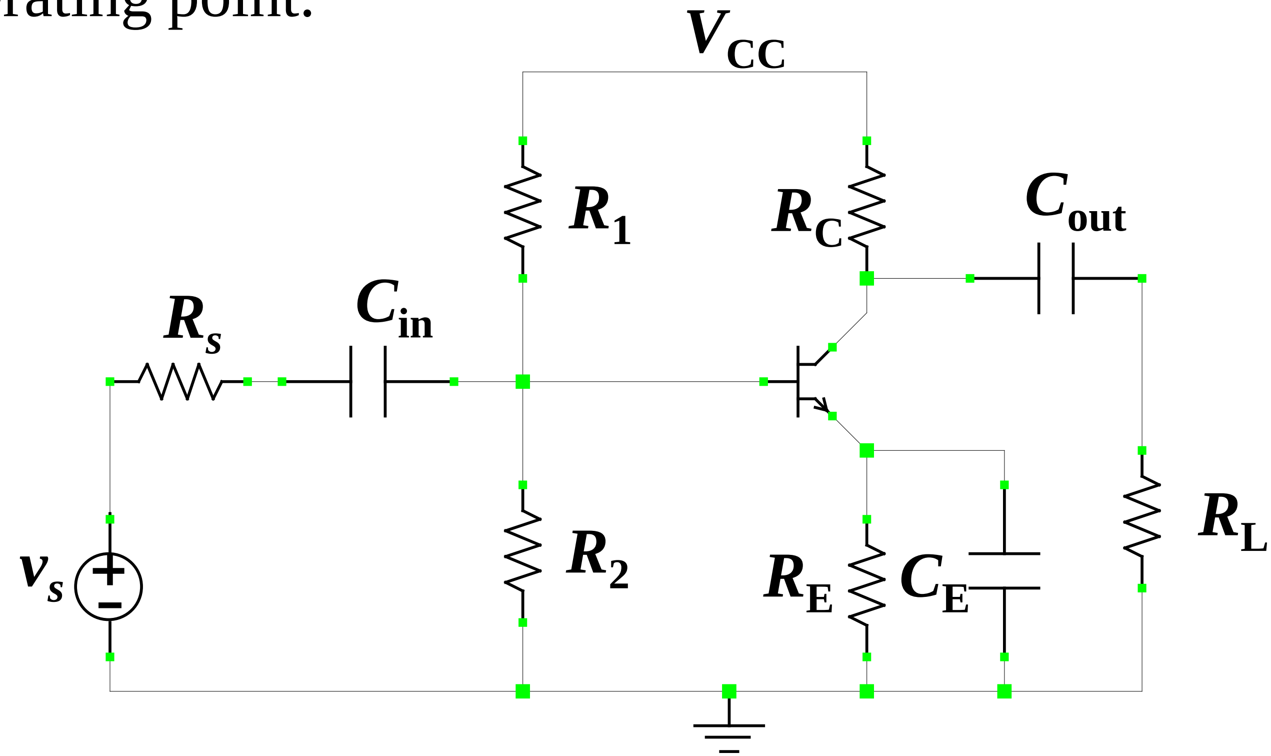
Qualitatively describe what happens in both curves when β increases(or decreases).

Large-Signal (DC) Model



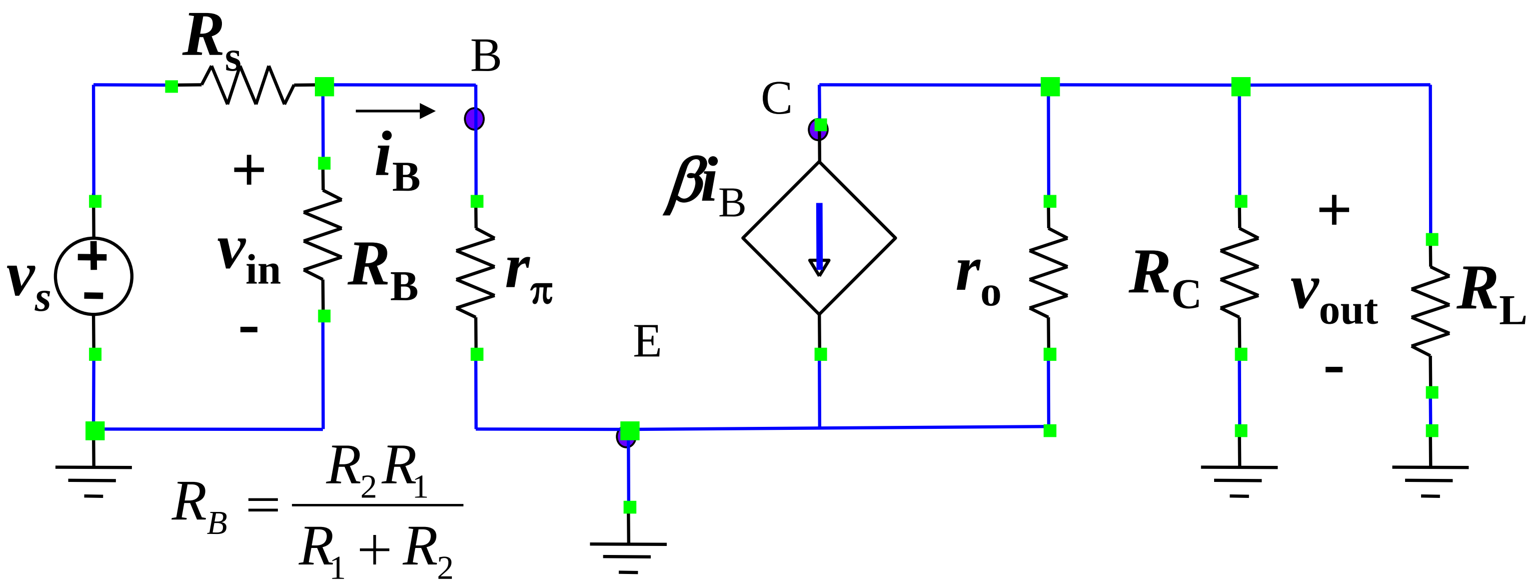
BJT Amplifier

Once the DC operating point is set, the AC input and output are coupled to the amplifier with capacitors so as not to perturb the operating point.



BJT Amp Small-Signal Model

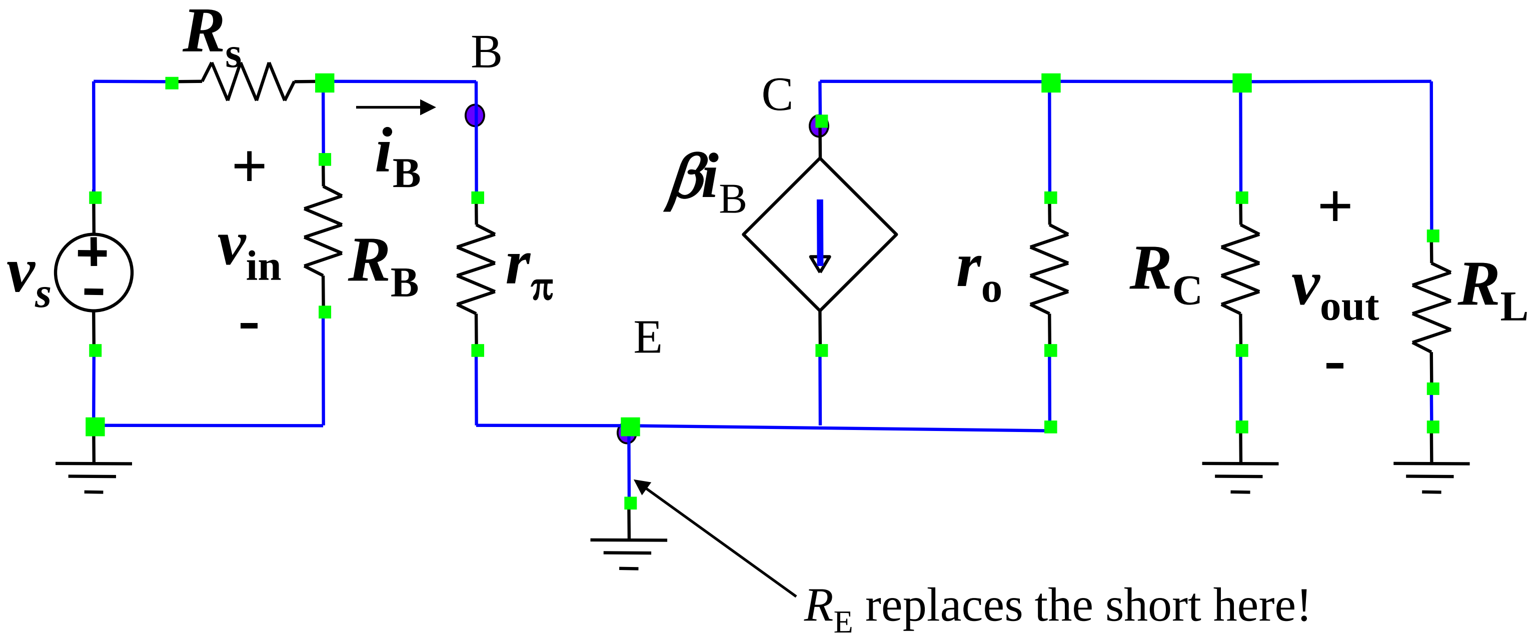
Consider the capacitors as short circuits for the small signal AC and open circuit for DC to obtain the model below. The resistor r_o accounts for the small slope of the I-V characteristics in the forward-active region (often assumed to be infinite). The resistance r_π is found from linearizing the nonlinear base-emitter characteristic, which is an exponential diode curve.



$$R_B = \frac{R_2 R_1}{R_1 + R_2}$$

BJT Amp Small-Signal Model

Determine the voltage gain. How would the emitter resistor affect the gain if it was not bypassed?



Taylor Series

Recall that a function can be expressed as a polynomial through a Taylor Series expansion:

$$f(x) = f(a) + \frac{(x-a)}{1!}\frac{df(x)}{dx}\bigg|_{x=a} + \frac{(x-a)^2}{2!}\frac{d^2 f(x)}{dx^2}\bigg|_{x=a} + \cdots$$

where *a* is a point about which the function is expanded. Note that if *a* represents a quiescent point for a voltage, then the reciprocal of the coefficient first linear represents the small signal impedance.

SPICE Example

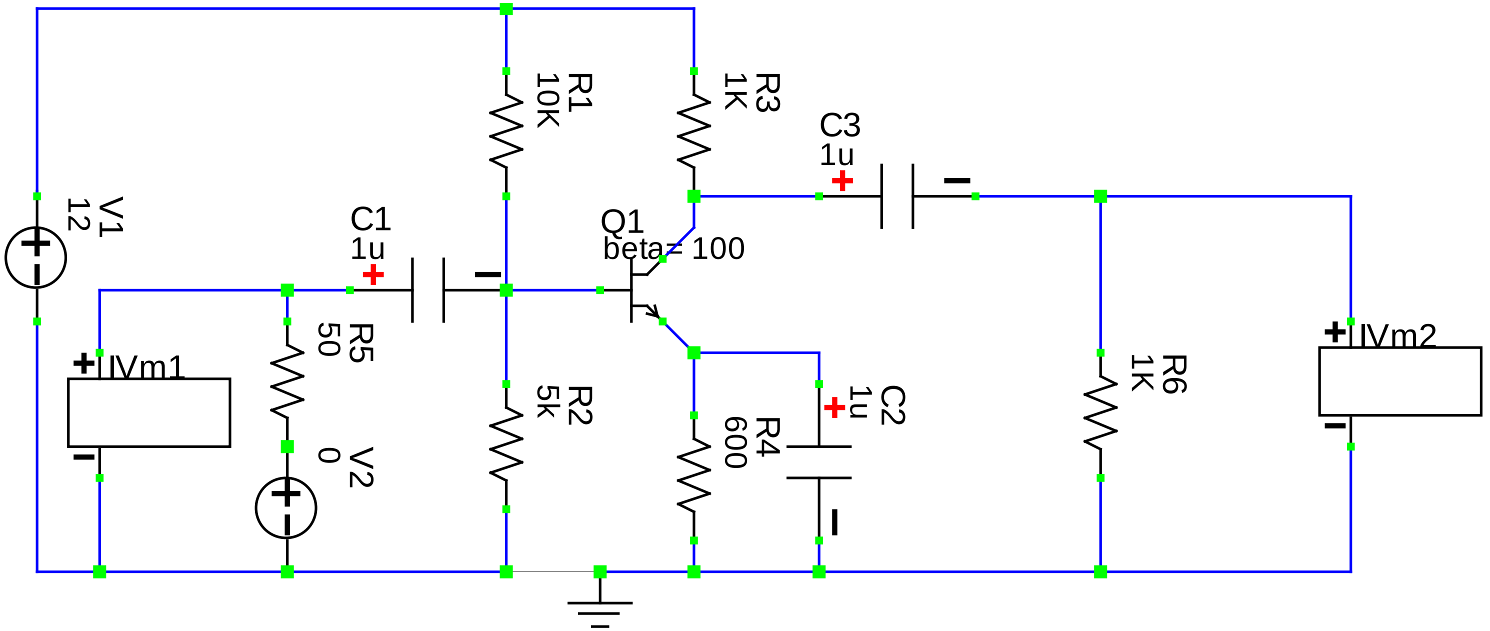
The amplifier circuit can be constructed in B2SPICE using the BJT npn (Q) part from the menu. The “edit simulation model” option can then be used to set the “ideal forward beta”

The input can be set to a sinusoid at desired frequency and amplitude for a transient analysis.

SPICE can also do a Fourier analysis to observed effects of clipping and distortion. There should be no harmonic energy for perfect amplification.

SPICE Example

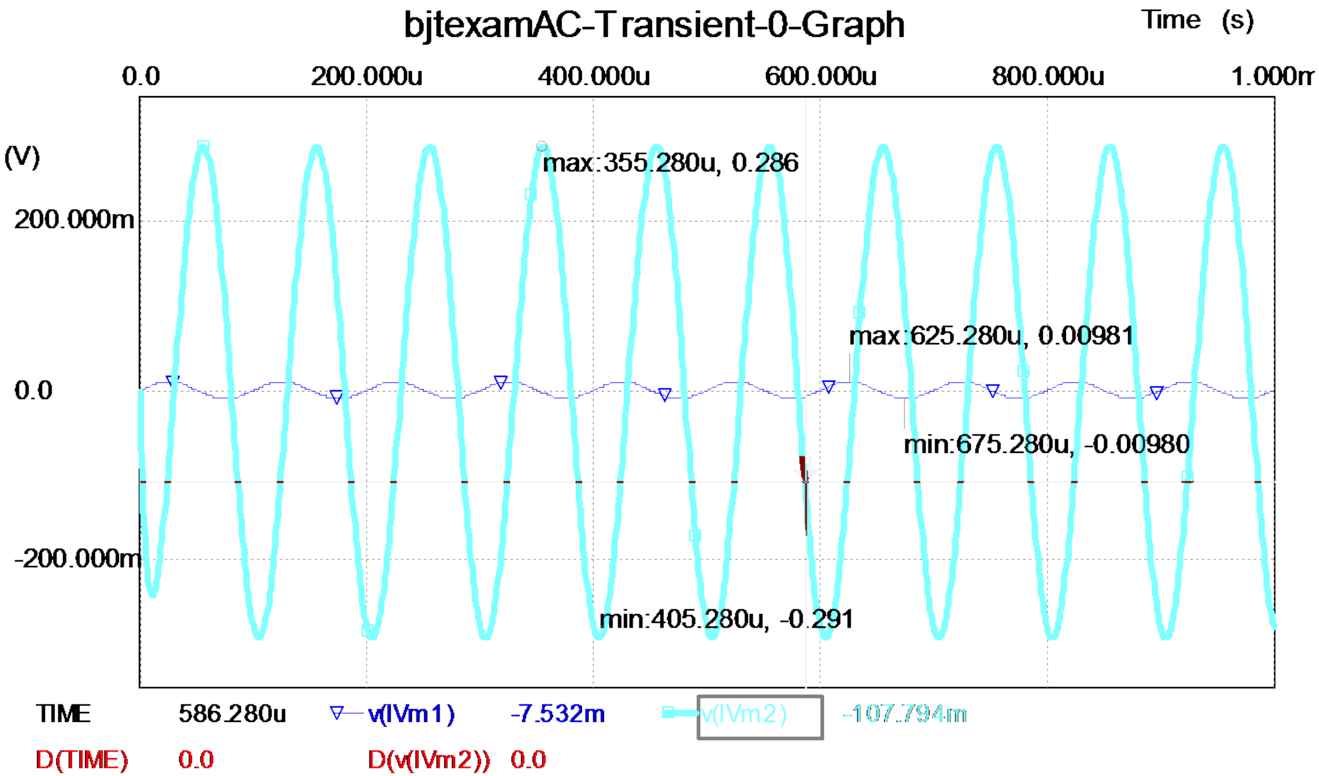
Example circuit with meters to monitor input and output:



SPICE Example

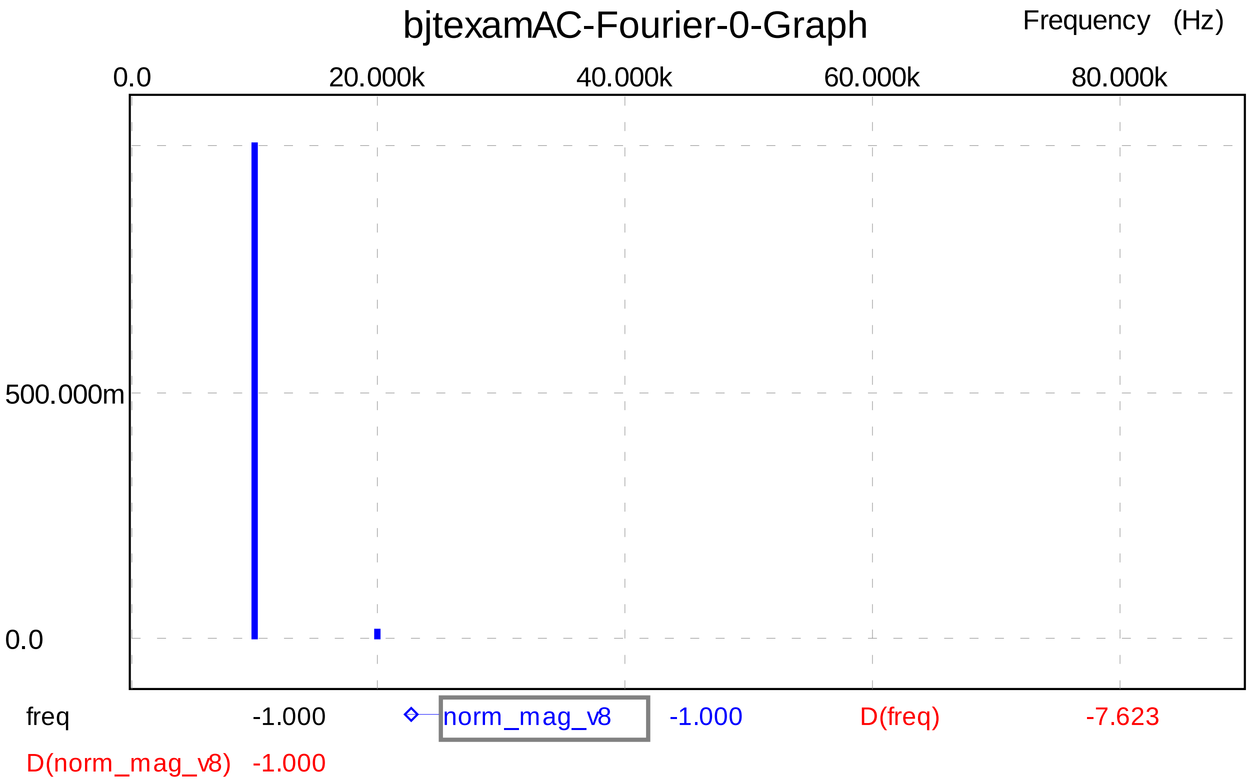
Graphic output for .03 V sine wave input (IVM1) at 10 kHz. Output is shown for meter IVM2.

What would the gain of this amplifier be at 10 kHz?



SPICE Example

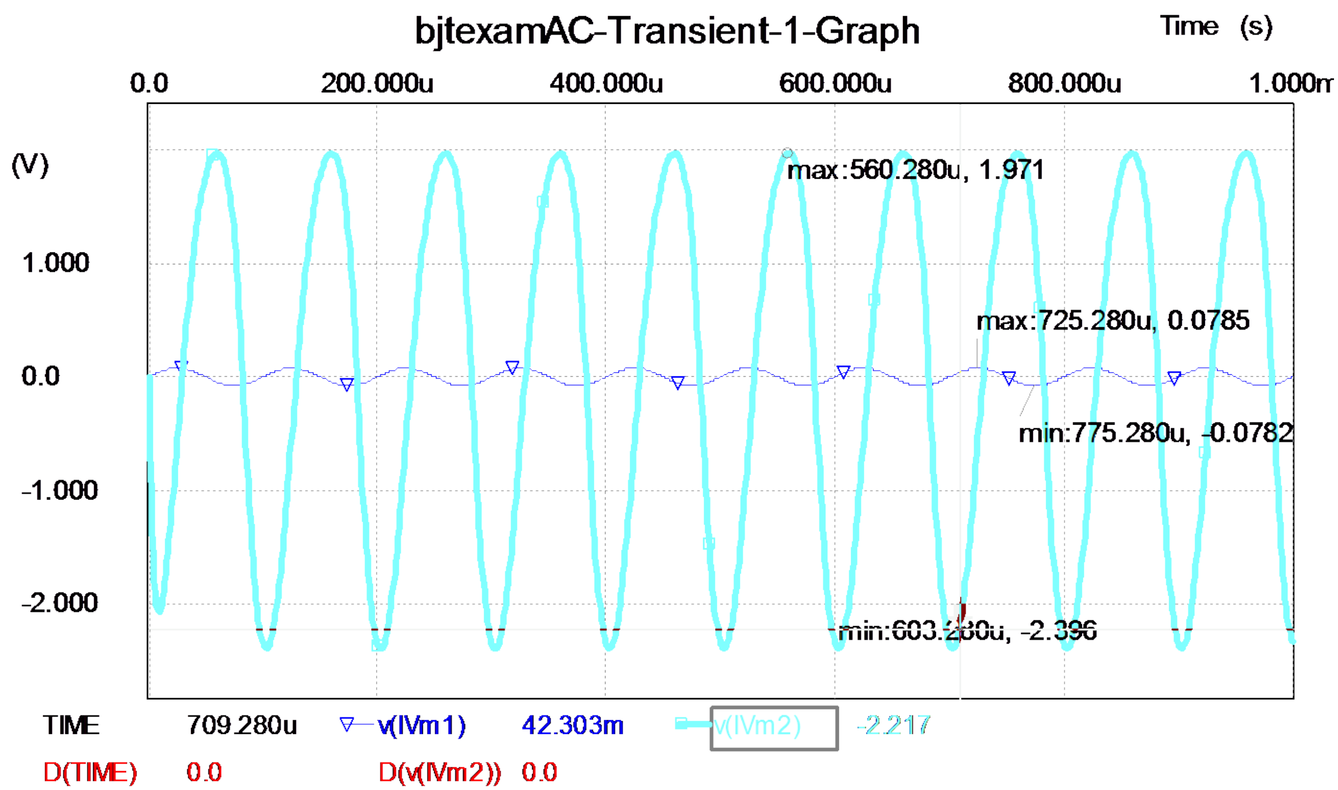
Fourier analysis of output. Frequency magnitude plot for output at meter IVM2.



SPICE Example

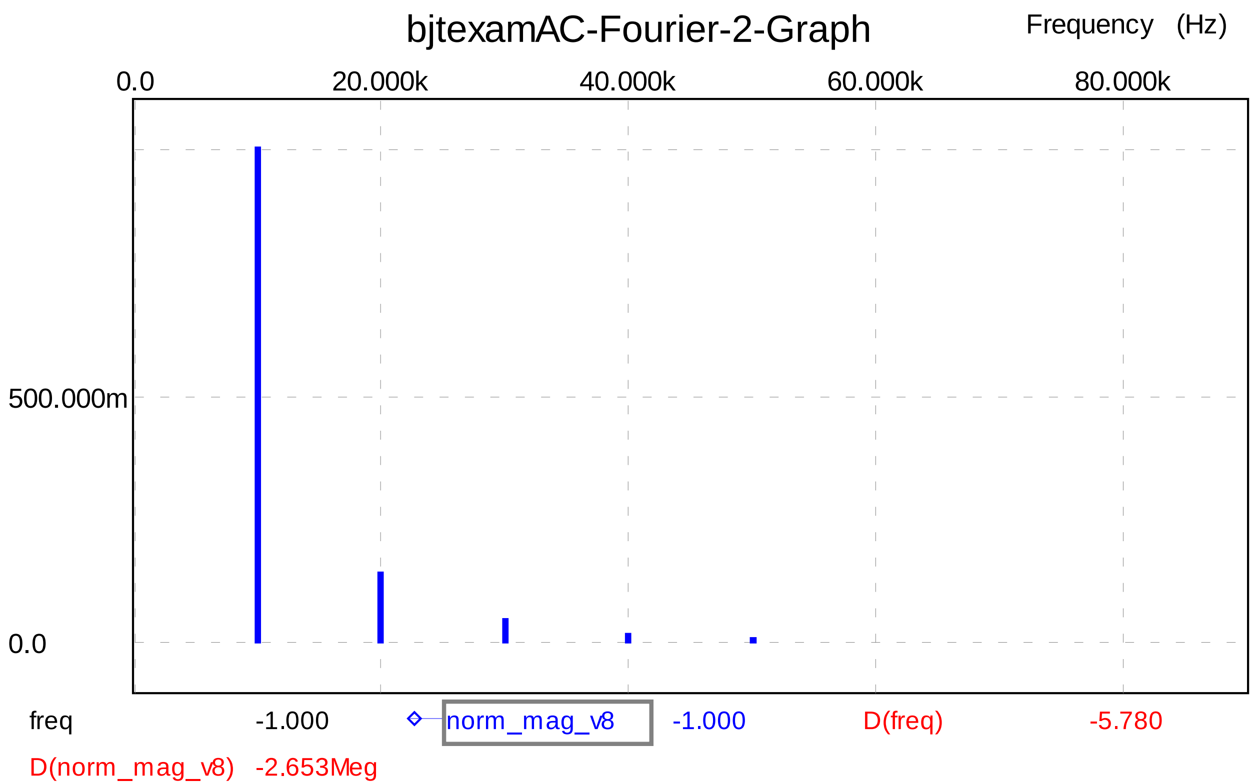
Graphic output for .08 V sine wave input (IVM1) at 10 kHz. Output is show for meter IVM2.

What would the gain of this amplifier be at 10 kHz?



SPICE Example

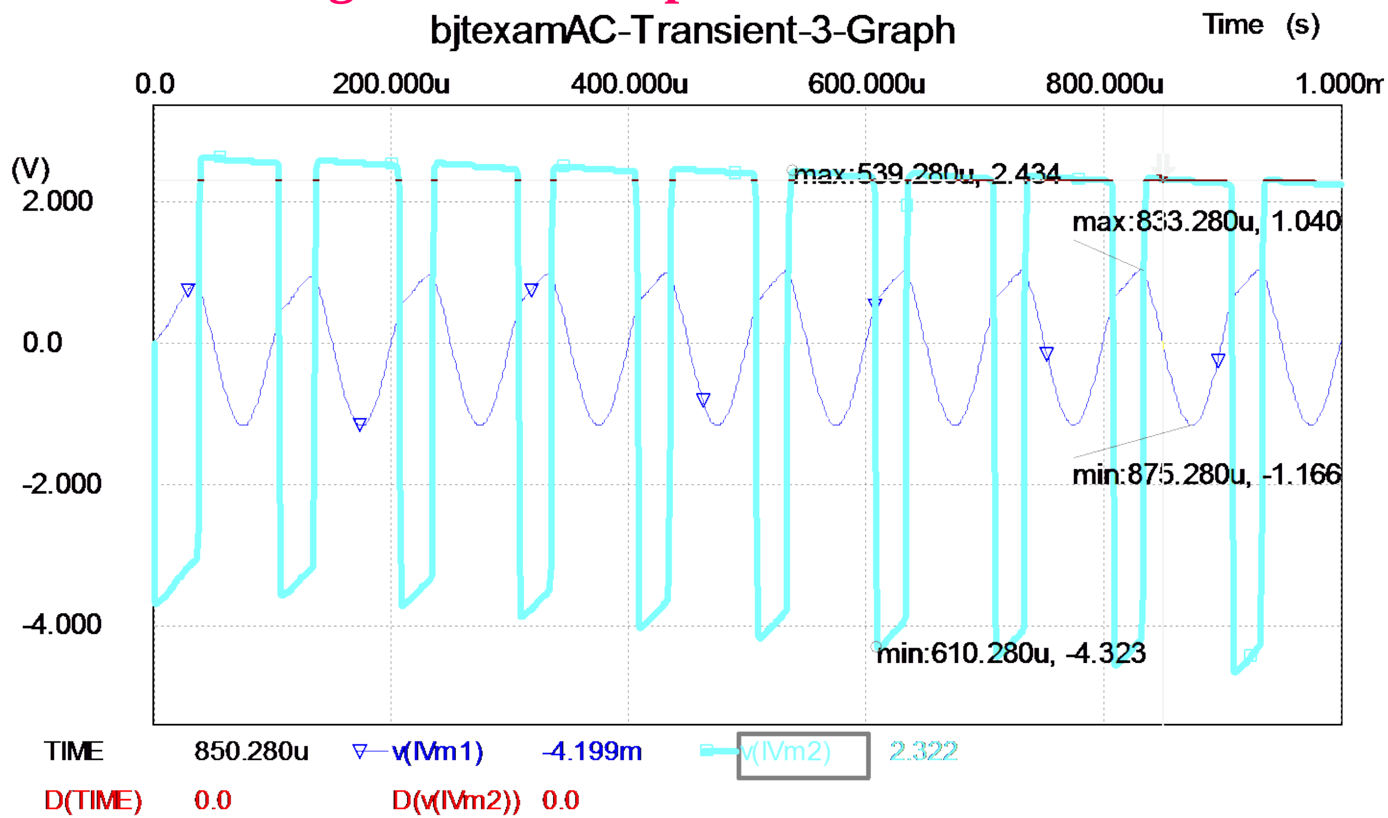
Fourier analysis of output. Frequency magnitude plot for output at meter IVM2.



SPICE Example

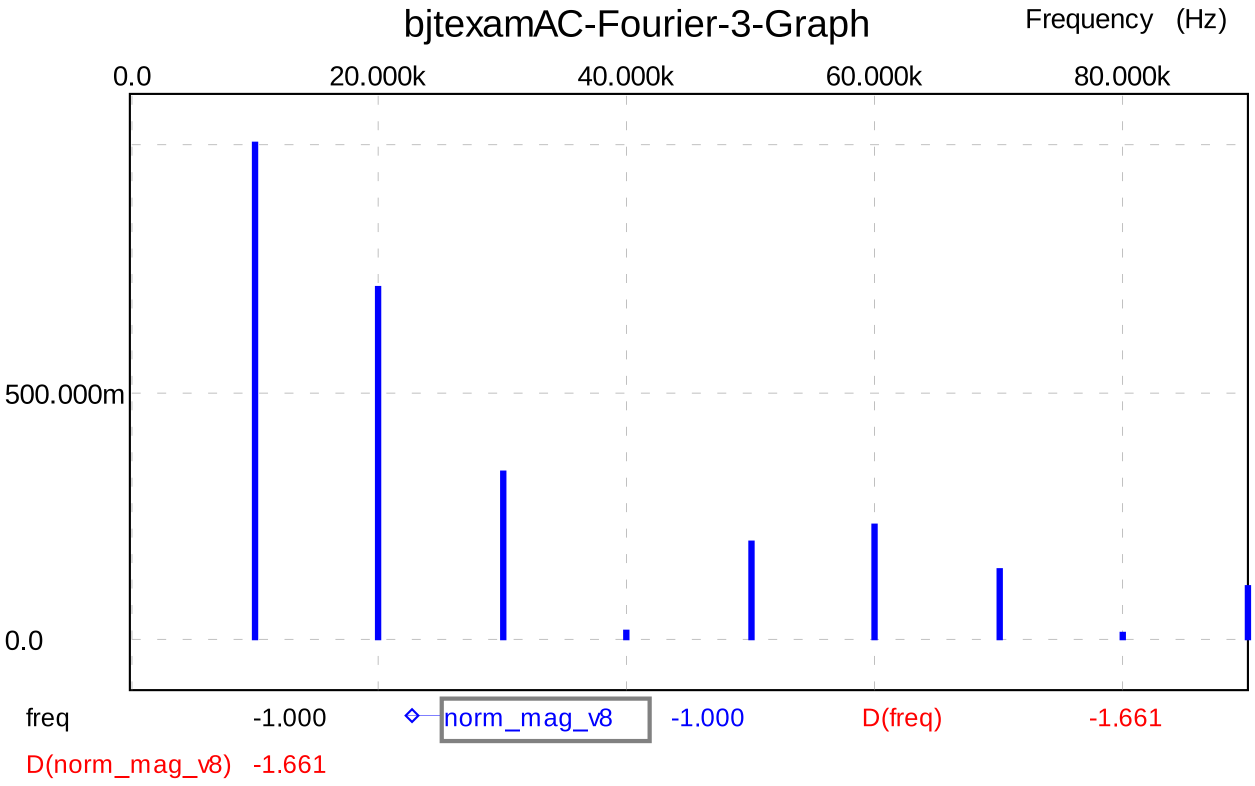
Graphic output for 1.2 V sine wave input (IVM1) at 10 kHz. Output is show for meter IVM2.

What would the gain of this amplifier be at 10 kHz?



SPICE Example

Fourier analysis of output. Frequency magnitude plot for output at meter IVM2.



BJT Circuit Parameters

How can β be found experimentally?

How can voltage gain be determined experimentally?

How can the input and output resistances be determined experimentally?