



## Experiment 8: Frequency Response

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### Purpose:

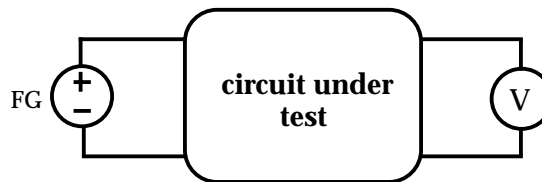
To develop a procedure for obtaining the Bode magnitude plot, or gain vs frequency, for a filter or an amplifier, and to determine the cutoff frequency(s), or the frequency(s) at which the gain becomes less than the midband value by a factor of  $1/\sqrt{2}$ .

### Method :

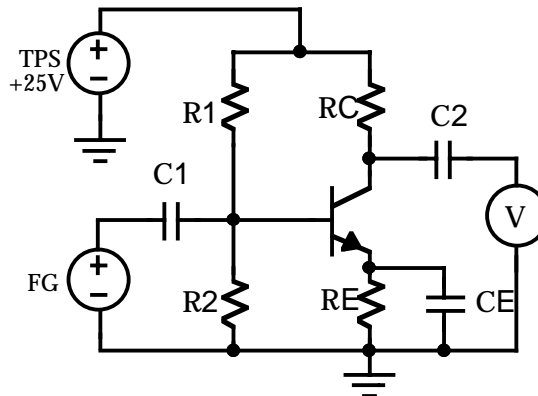
The voltage gain of a BJT voltage amplifier will be measured at different frequencies, and the voltage transfer function  $20\log_{10}|V_{out}/V_{in}|$  will be plotted as a function of frequency on a logarithmic scale (Bode magnitude plot). Provision will be made to stop the frequency scan whenever the transfer function reaches the -3 dB point, and to display the frequencies where this occurs.

### Hardware Setup:

The general circuit will be simply this:



where the circuit under test may be anything from a series RC pair to an active filter, or a multistage amplifier that contains many active elements and many capacitors and/or inductors. In this experiment, you will measure the frequency response of a basic-cell BJT common-emitter amplifier with the following configuration:



You will have designed and built this circuit earlier, having chosen the resistor values to provide a stable operating point and relatively large voltage gain. Capacitors  $C_1$  and  $C_2$  will be about  $10 \mu\text{F}$ , and  $C_E$  will be around  $100 \mu\text{F}$  to maximize the midband gain.



### Software Setup:

Place on the screen the usual instrument panels and component drivers for the function generator and multimeter, and a Direct I/O driver for the triple power supply.

The function generator driver needs FREQUENCY input and output pins and an AMPLITUDE output pin, and the multimeter driver needs a READINGS output pin. You can set a default amplitude for the input signal, or you may provide a means for selecting it. Since the measurement will cover several decades of frequency, drive the function generator with a For Log Range object. At least 15 points per decade are recommended to obtain a smooth plot. The logarithmic sequence can be a decreasing one if you wish. In this case, the points/decade value must be negative.

The frequency output of the function generator goes to a **Formula** object that contains the expression **log10(a)**. This output is connected to the X-axis input of an **X vs Y Plot** object, where the Bode plot will be displayed. Include the **Markers** and Delta options when you create your plot object.

To calculate the voltage gain for each point, combine the multimeter output with the amplitude output of the function generator in another **Formula** object, to which you will add a second input pin (automatically labeled **b**). With the multimeter output connected to the **a** input, and the function generator output connected to the **b** input, the formula is **20\*log10(a/b)**. This expresses the gain in dB. The output goes to the Y-axis input of the XY plot. You are urged to give meaningful names to all objects and to their input and output terminals.

Now you will add provisions for stopping the experiment when the cutoff frequency, or the characteristic frequency, where the voltage gain is reduced from the midband value by -3 dB, is reached. To do this, add an **If/Then** object (**Flow --> If/Then**). Open it and enter the expression **a<-3**. Connect its input pin to the output of the gain-calculation object. Connect a **Break** object to the **Then** output, and nothing to the **Else** output. When the program runs, the If/Then object will see each gain value, producing no output at the Then terminal until the statement **a<-3** is true. It will then send a pulse to the **Then** terminal, which activates the Break command, stopping the program. Note that this **If/Then** object acts exactly as an If-Then loop in a conventional program.

To read the cutoff frequency, connect an Alphanumeric display to the frequency output of the function generator. Each value will be displayed in turn until the program stops. Connect another alphanumeric display to the output of the gain calculation object to read the gain at this frequency.

The procedure just described will work properly for a low-pass filter when the frequency is increasing, or for a high-pass filter when the frequency is decreasing. However, your amplifier will have both high and low-frequency cutoff points. There are several ways to identify and display both critical frequencies (not necessarily simultaneously); some require no change in the software. You might want to devise a more elegant software approach to solving this problem.

### Procedure:

Run the program with the Break object disconnected and the XY plot visible. You should see the entire Bode plot being drawn. If not, click **Auto Scale**. You might have to do this more than once if the plot goes off scale. Also observe the two alphanumeric displays at the bottom of the screen. They will display the gain and the cutoff frequency at each point.

Now connect the Break object, and use whatever method you have devised to find both  $f_L$  and  $f_H$  for your amplifier. When execution ceases, if the gain is considerably different from -3 dB, you should rerun the program with more points per decade of frequency to increase the resolution of the measurement.

Compare the observed cutoff frequency with the value calculated for your circuit. Comment on any discrepancies. Do you expect close agreement between the two values?

Use the markers on the plot to calculate the rolloff rates beyond the cutoff frequency. Compare the result with the expected value.