

Basic Electronics for Amateur Radio

Audio Amplifiers

by

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Introduction

We will discuss the design of a simple one transistor amplifier suitable for low frequency, small signal applications such as an audio amplifier.

There are three often used configurations for a single transistor amplifier:

Common Emitter

Common Collector

Common Base

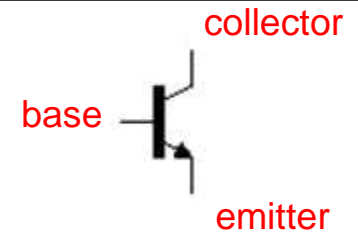
The most frequently use configuration is the common emitter, that is the one we will study today.

Common Collector, more frequently known as Emitter Follower is used in applications where a low output impedance is required.

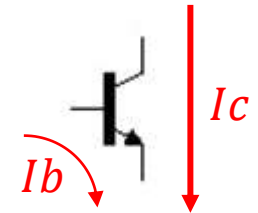
Common Base has a low input impedance which can often be a problem, but is often used in RF applications.

Some basic things about a transistor - 1

A silicon NPN transistor has three external connections:

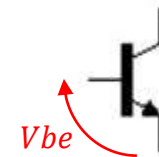


When connected in a suitable circuit, and power is applied, a small current will flow from base to emitter, this causes a much larger current to flow from collector to emitter. The ratio of these two currents is the gain of the transistor.



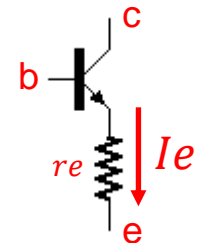
$$\beta = \frac{I_c}{I_b}$$

When a silicon transistor is operating in its normal linear region, the voltage between base and emitter V_{be} will be about 0.6 to 0.7 volts.

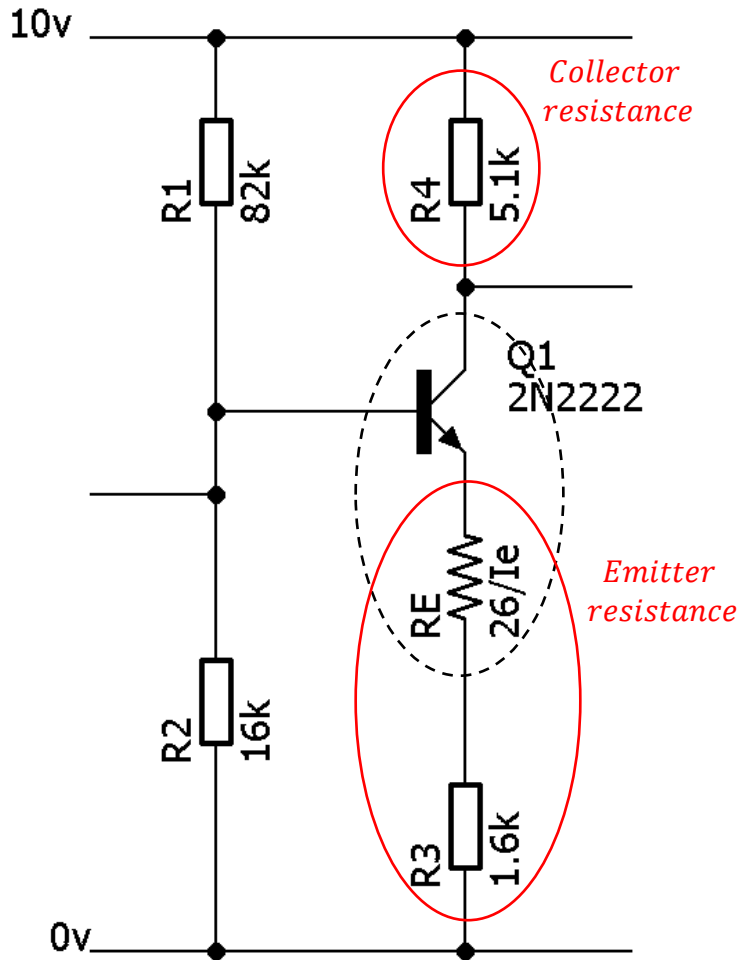


There is an intrinsic resistance in the emitter of the transistor. This can sometimes be important when calculating the gain of an amplifier stage.

The value of this resistance can be calculated using $r_e = \frac{26}{I_e(mA)} \text{ Ohm}$



Some basic things about a transistor - 2



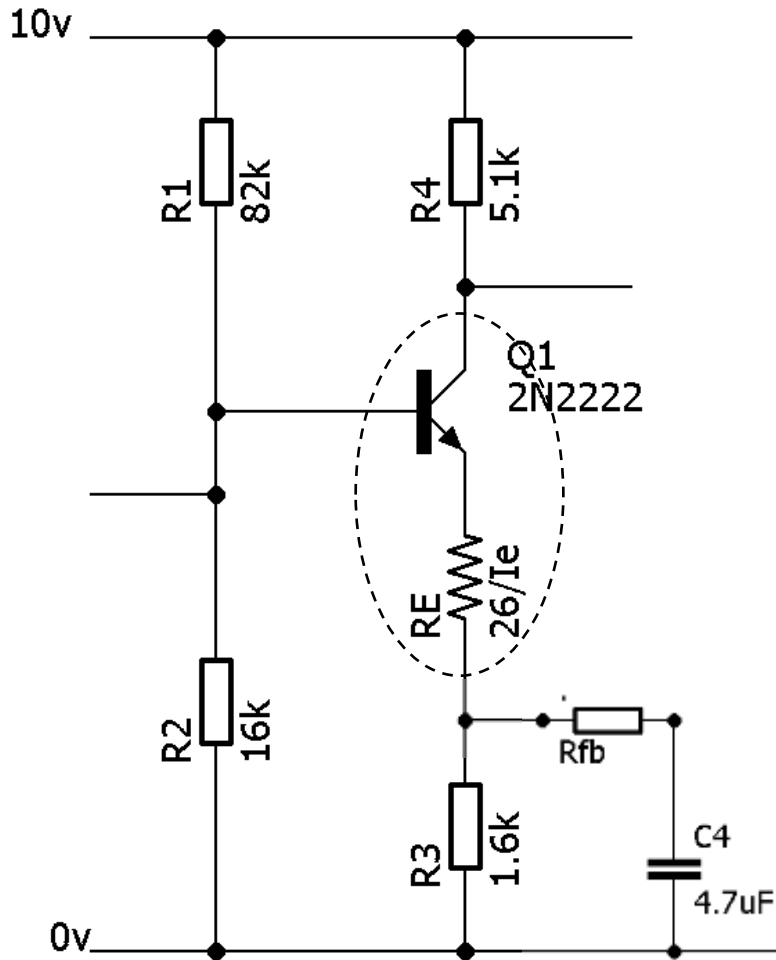
The voltage gain of a common emitter amplifier may be calculated as:

$$G_v = \frac{\text{Collector resistance}}{\text{Emitter resistance}}$$

The Emitter resistance is the sum of the circuit resistance (R3) and the intrinsic emitter resistance (RE) of the transistor.

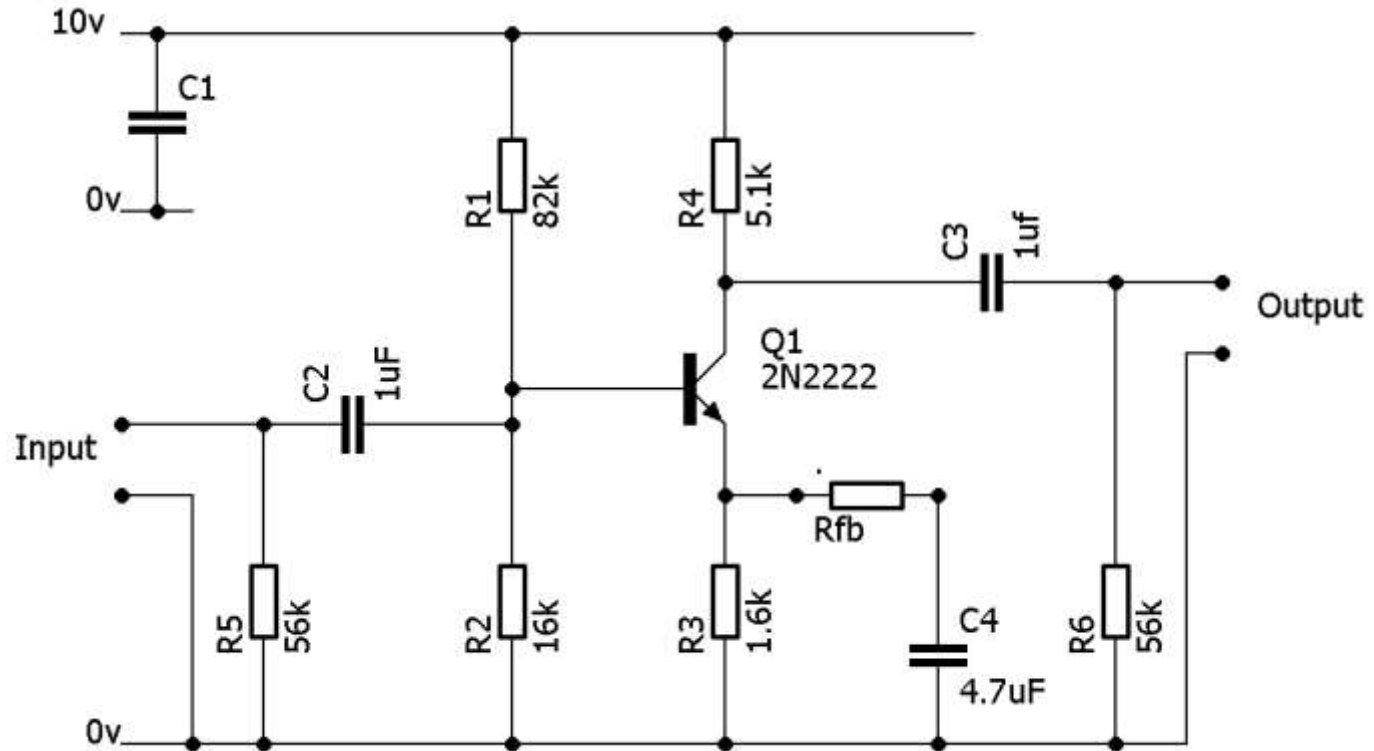
If we can change the emitter resistance, we can set the gain of the amplifier as we require.

Setting the gain of the amplifier

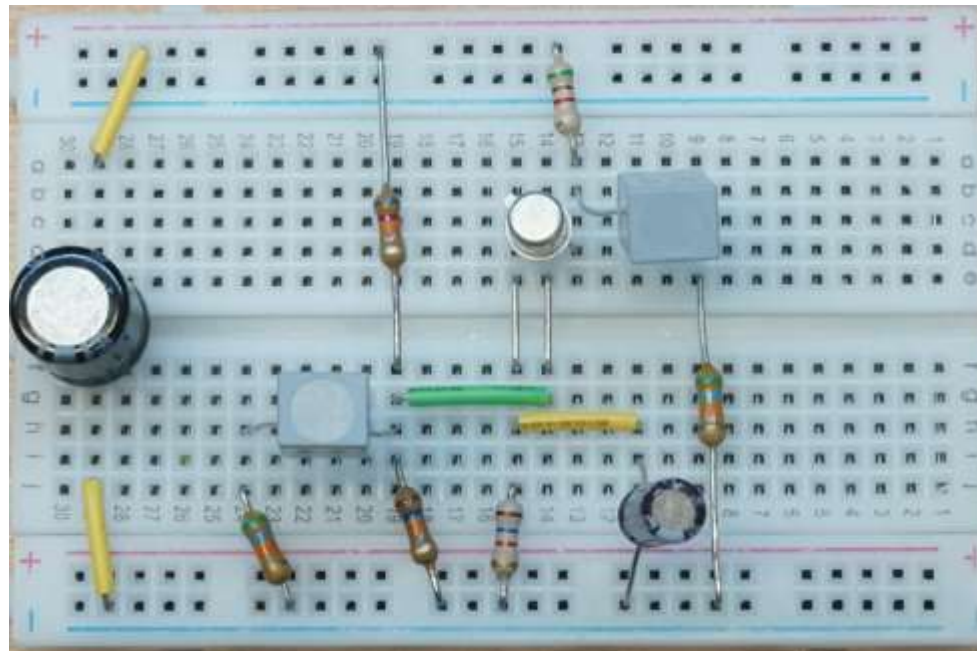
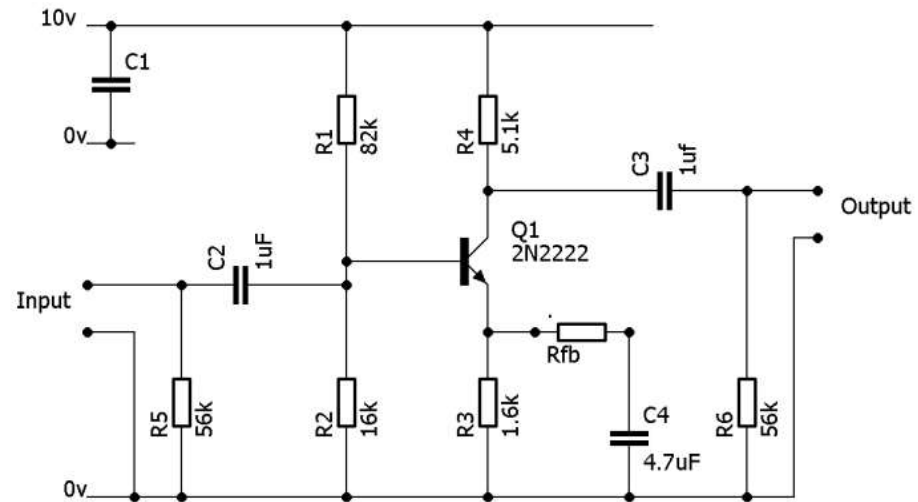


By adding the series pair of Rfb and C4 in parallel with the emitter resistor R3, we can vary the effective emitter resistance for AC signals without altering the DC bias and changing the operating conditions of the transistor.

A Practical Common Emitter Amplifier

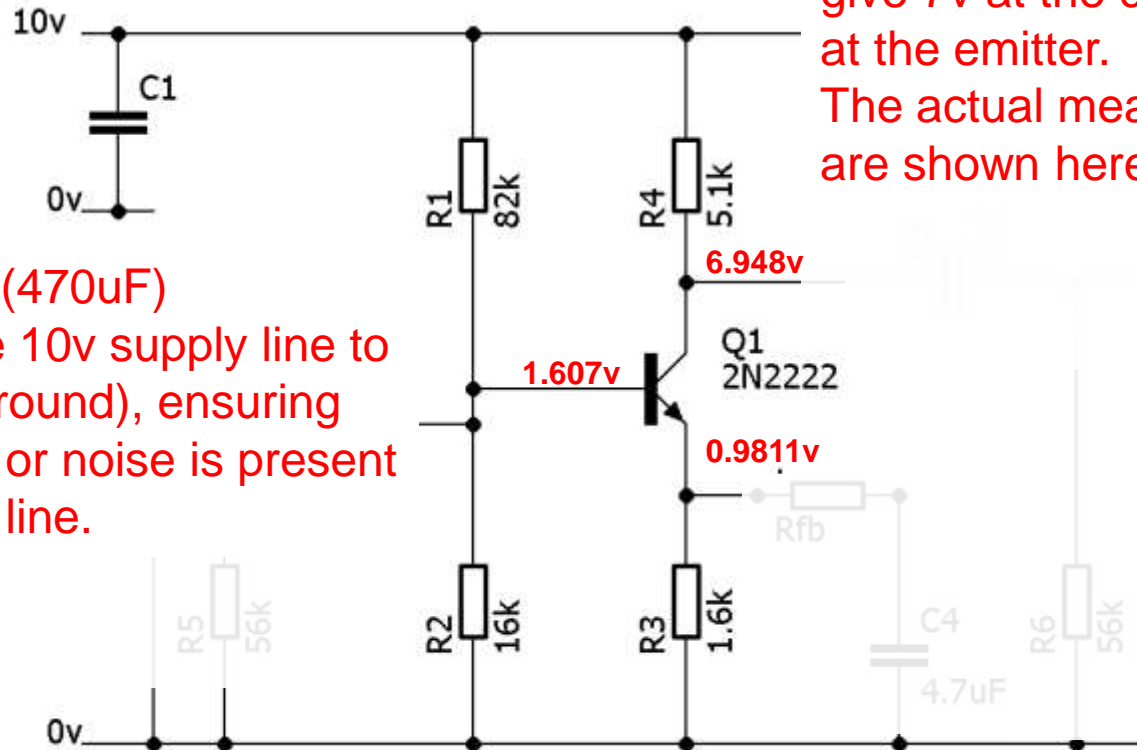


A C-E Amplifier on the breadboard



... the DC bias arrangement

Capacitor C1 (470uF) decouples the 10v supply line to the 0v line (Ground), ensuring that no signal or noise is present on the supply line.

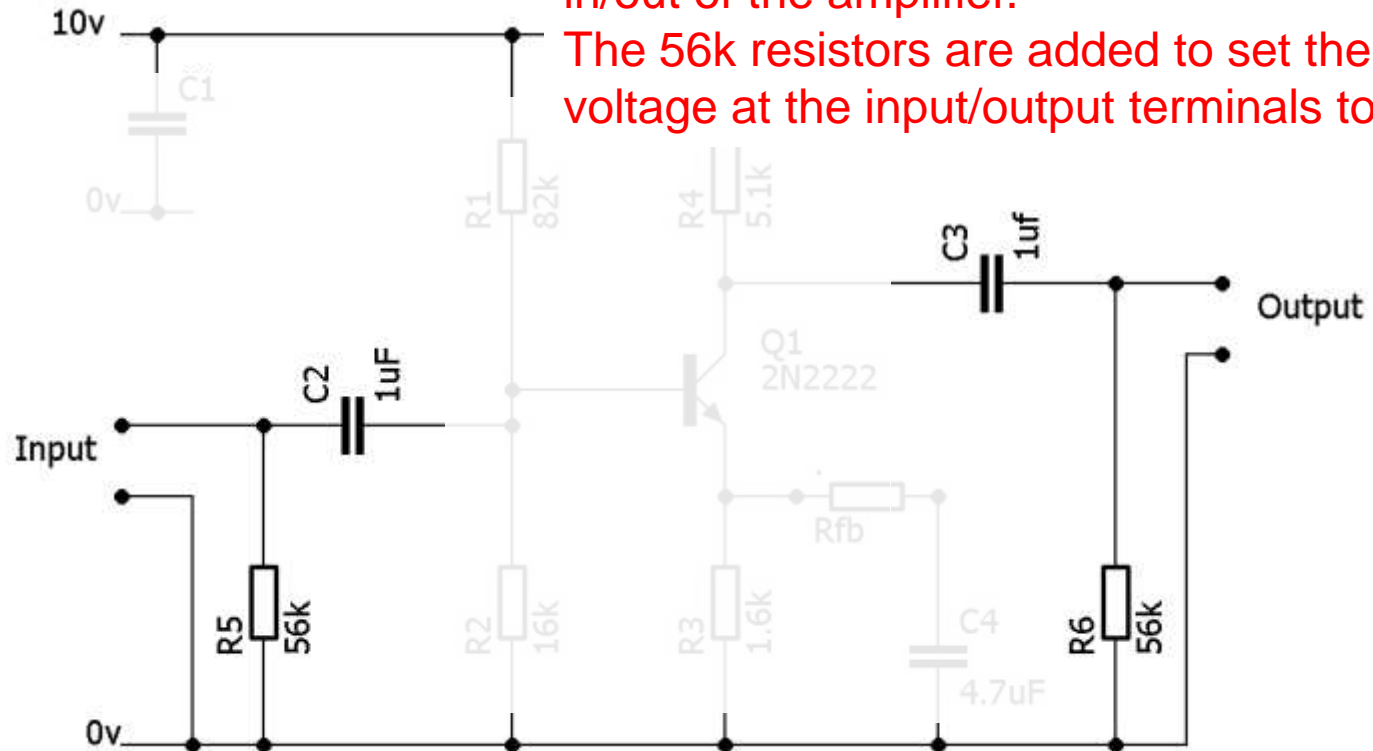


This circuit was designed to give 7v at the collector and 1v at the emitter. The actual measured values are shown here.

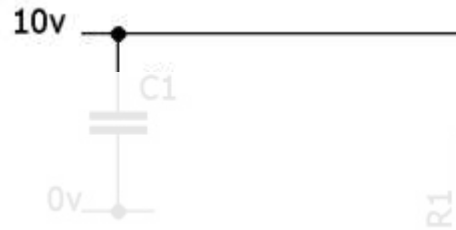
...the signal coupling arrangement

The 1uF capacitors couple the AC signal in/out of the amplifier.

The 56k resistors are added to set the DC voltage at the input/output terminals to 0v.



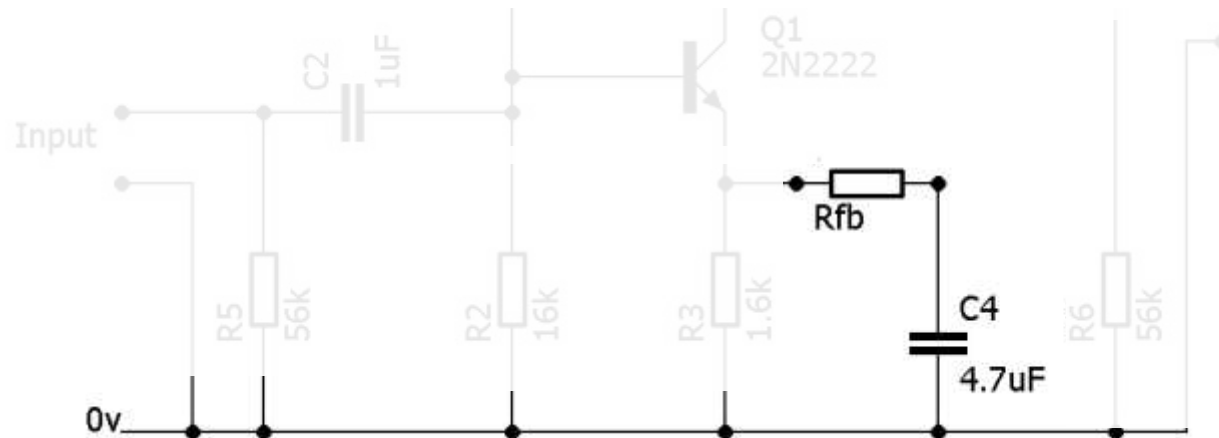
... emitter de-coupling



The 4.7uF capacitor (C4) is used to de-couple AC signals from the emitter.

The resistor (Rfb) is used to determine the effectiveness of the decoupling and hence the gain of the amplifier.

But why the designation Rfb ?



The emitter signal is effectively negative feedback which reduces the gain of the amplifier. The greater the value of Rfb, the greater the negative feedback and the lower the gain.

Testing the Amplifier

There are various tests that we can make to verify the operation of our amplifier, these include:

- Transistor bias. i.e. voltages at the emitter, base and collector.

- Overall gain.

- Frequency response.

Measuring Voltage Gain - 1

- 1 Set Rfb to an open circuit.
- 2 Inject a 10mV 1kHz sinewave into the input of the amplifier.
- 3 Measure the output voltage of the amplifier.
(The measuring device could be a suitable voltmeter instead of an oscilloscope.)
- 4 Calculate the voltage gain of the amplifier.

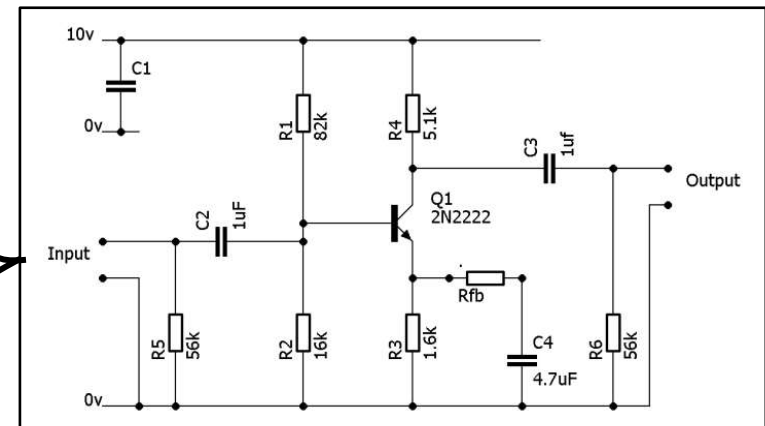
$$Gain = \frac{Output\ Voltage}{Input\ Voltage}$$

- 5 Repeat steps 2 to 4 for a range of values of Rfb.

Measuring Device



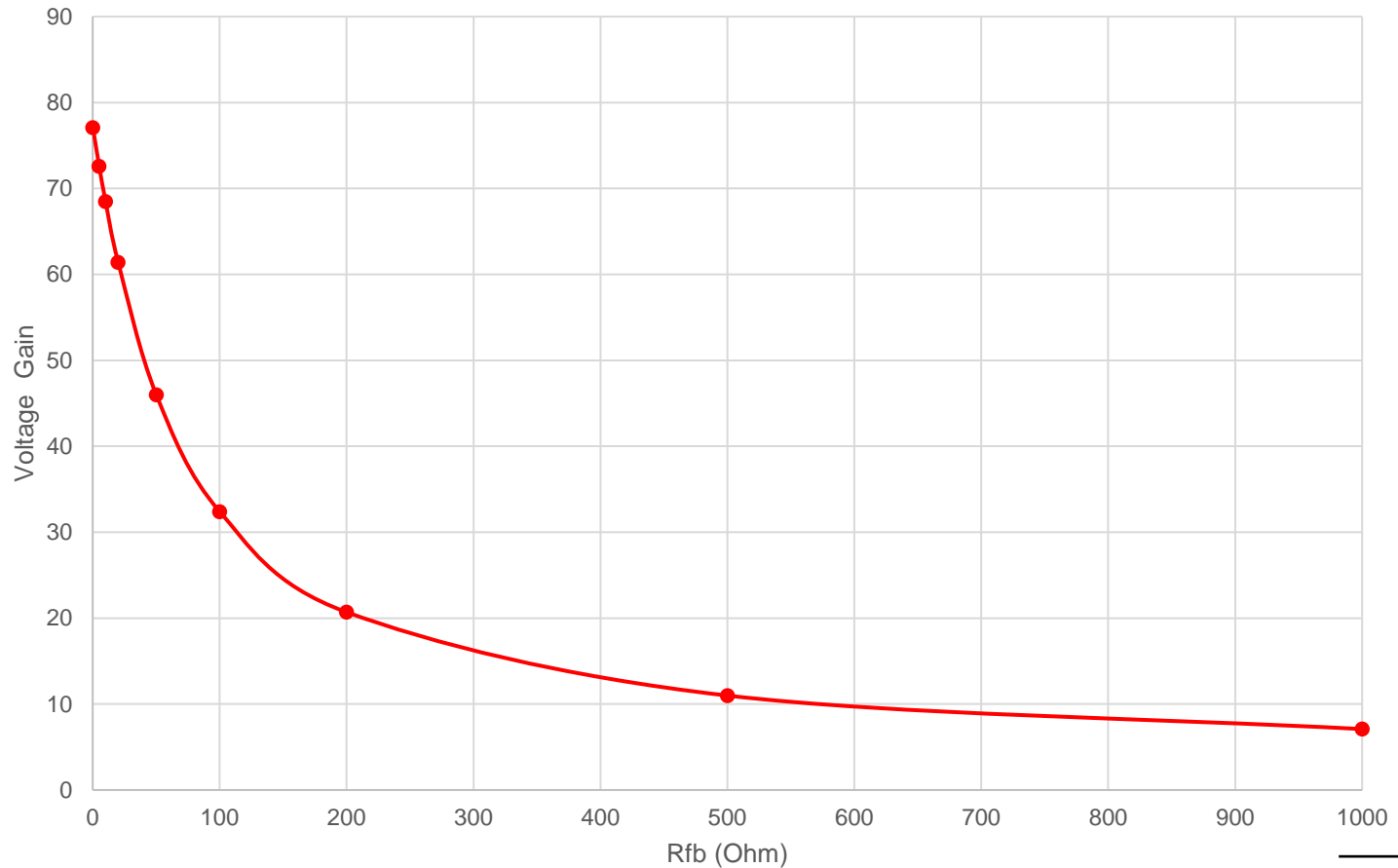
Signal Source



Device Under Test

Measuring Voltage Gain - 2

Voltage Gain vs Rfb (Measured at 1kHz)



With Rfb open circuit,
the gain was measured as 2.9

Signal inversion and Phase Shift

Note:

On the scope screen, the amplifier output signal (blue trace), is inverted when compared with the input signal (yellow trace).

This is quite normal and is due to the configuration of the common emitter amplifier.

This inversion of the sine wave is equivalent to a phase shift of 180 degrees.

This phase shift is not important for simple amplifiers, but when the amplifier is part of an oscillator, the phase shift must be taken into account for correct operation of the oscillator.

In mathematical analysis of amplifier behaviour, the signal inversion is usually expressed by treating the gain as negative.

As shown here:

$$Gain = - \frac{Output\ Voltage}{Input\ Voltage}$$



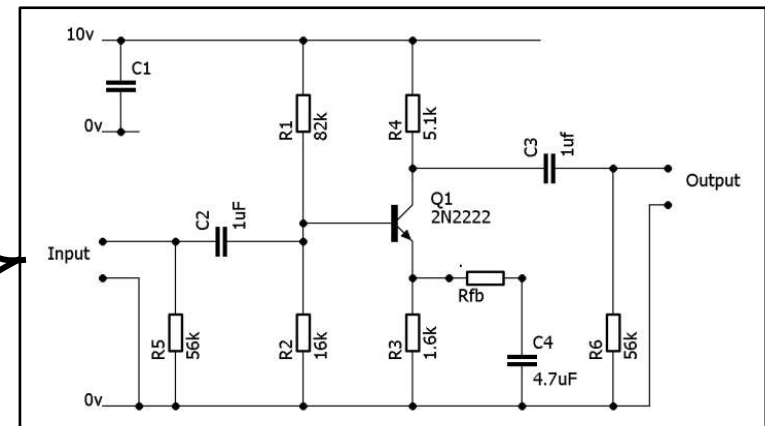
Measuring Frequency Response - 1

- 1 Set R_{fb} to an open circuit.
- 2 Inject a 10mV 1kHz sinewave into the input of the amplifier.
- 3 Measure the output voltage of the amplifier.
- 4 Calculate the voltage gain of the amplifier.
- 5 Repeat steps 2 to 4 for a range of frequencies (10Hz to 100kHz).
- 6 Repeat steps 2 to 5 for a range of values of R_{fb} .

Measuring Device

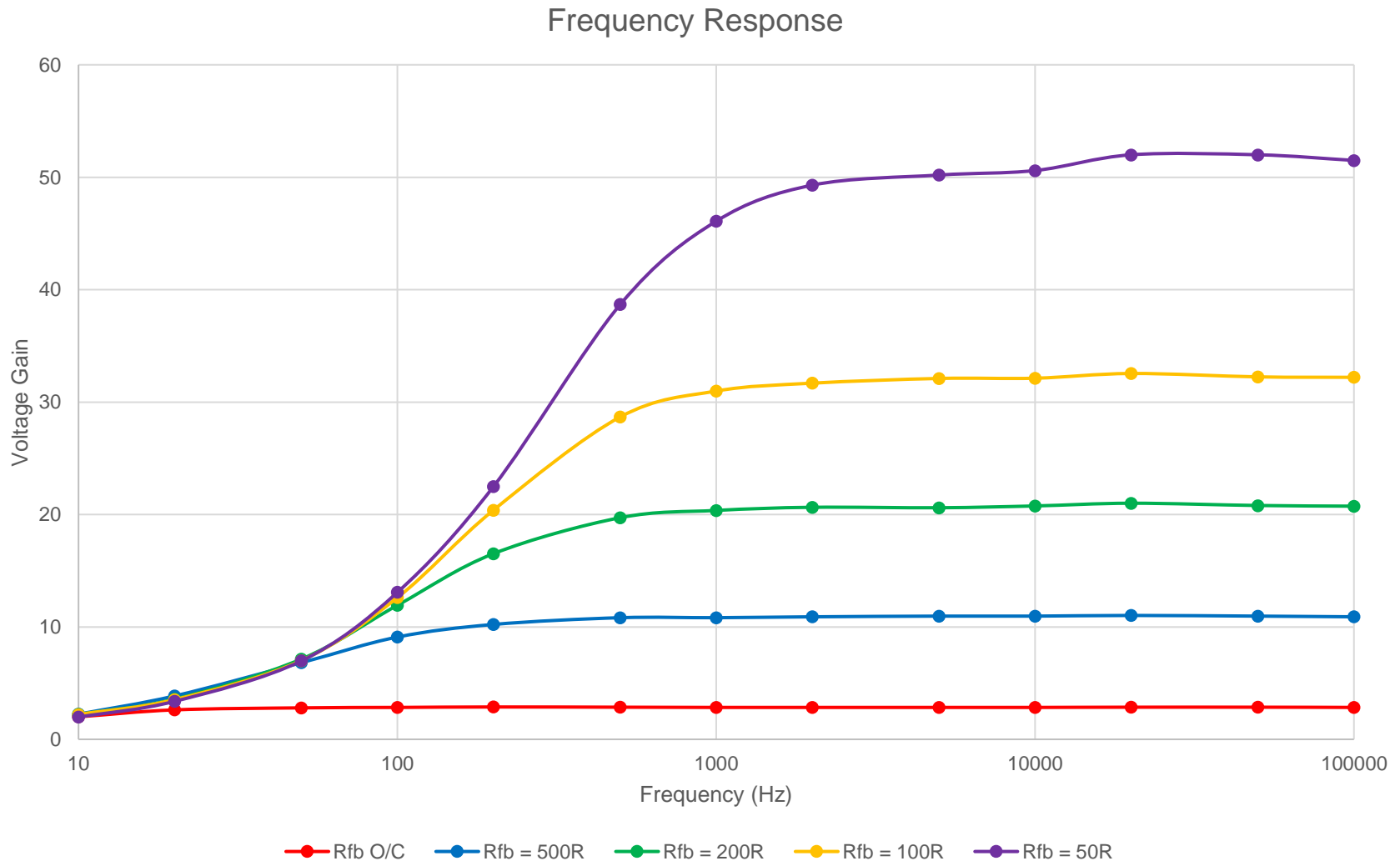


Signal Source



Device Under Test

Measuring Frequency Response - 2



Frequency Response - Comment

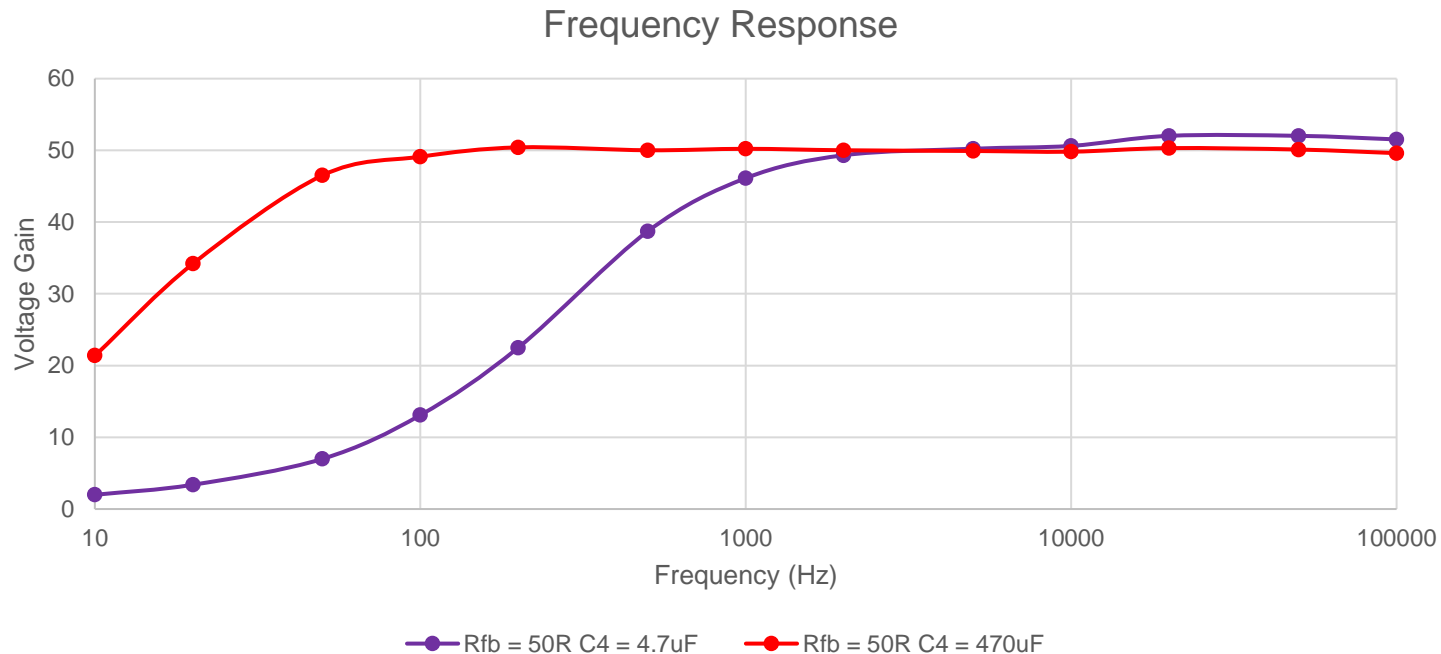
Looking at the graph of frequency response for different gain settings (values of R_{fb}), it is noticeable that at higher gain settings the frequency response is poor at low frequencies.

If we used the amplifier in the audio stages of a transmitter or a receiver, the audio output would be very thin and lacking in bass content.

The problem is due to the value of capacitor C_4 .

At 100Hz, the reactance of a 4.7 μ F capacitor is 330 Ohm, much larger than the 50 Ohm of R_{fb} .

Increasing the value of C_4 to 470 μ F has this effect:

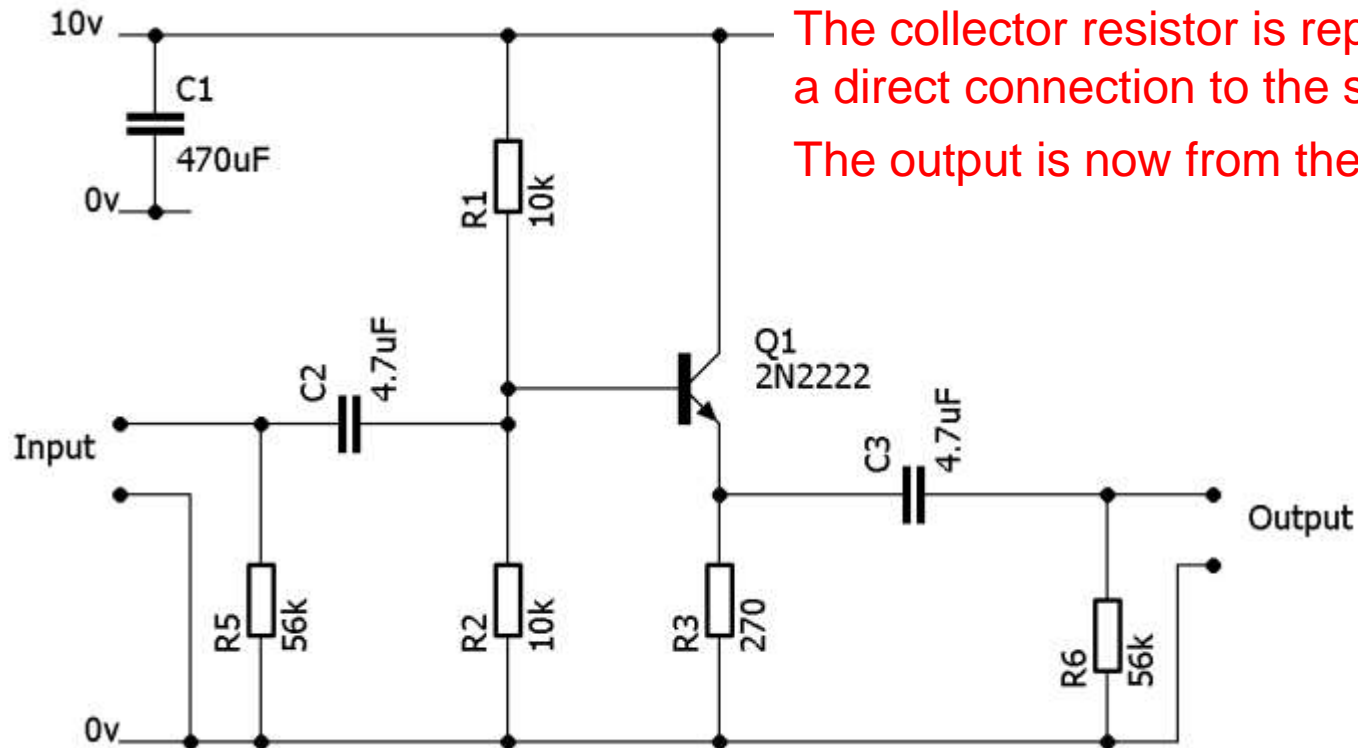


A Practical Emitter Follower Amplifier

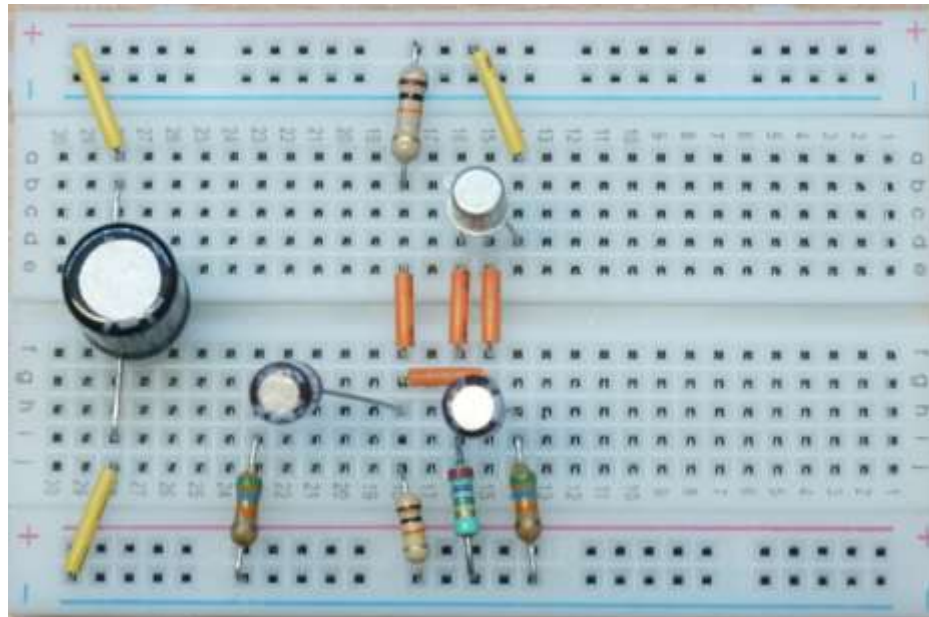
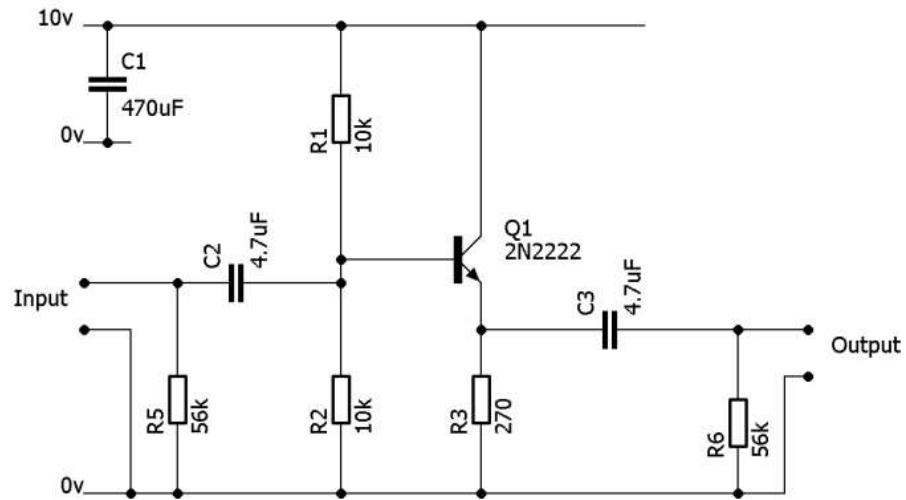
Similar to the common emitter circuit, except:

The collector resistor is replaced by a direct connection to the supply.

The output is now from the emitter.



An E-F Amplifier on the breadboard

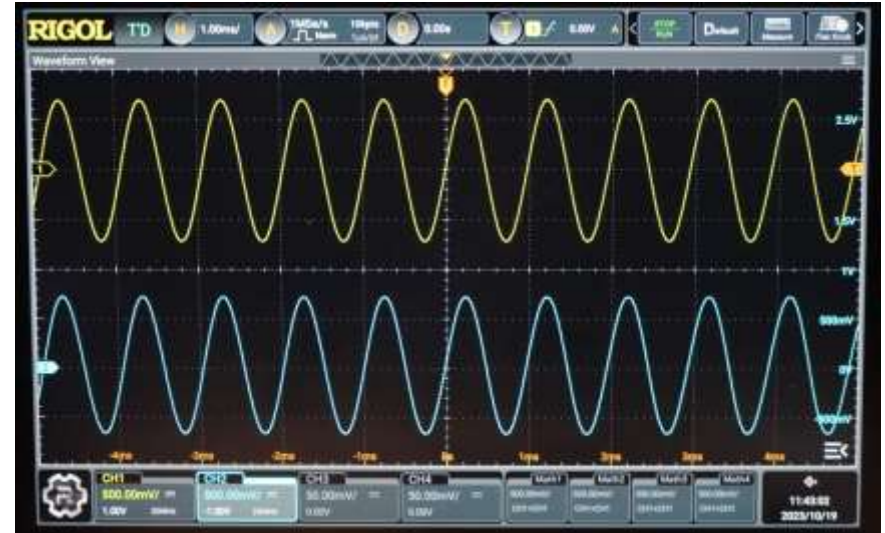


Emitter follower input/output characteristics

Note:

On the scope screen, the amplifier output signal (blue trace), is in phase and not inverted when compared with the input signal (yellow trace). This is opposite from the inverting behaviour of the common emitter amplifier.

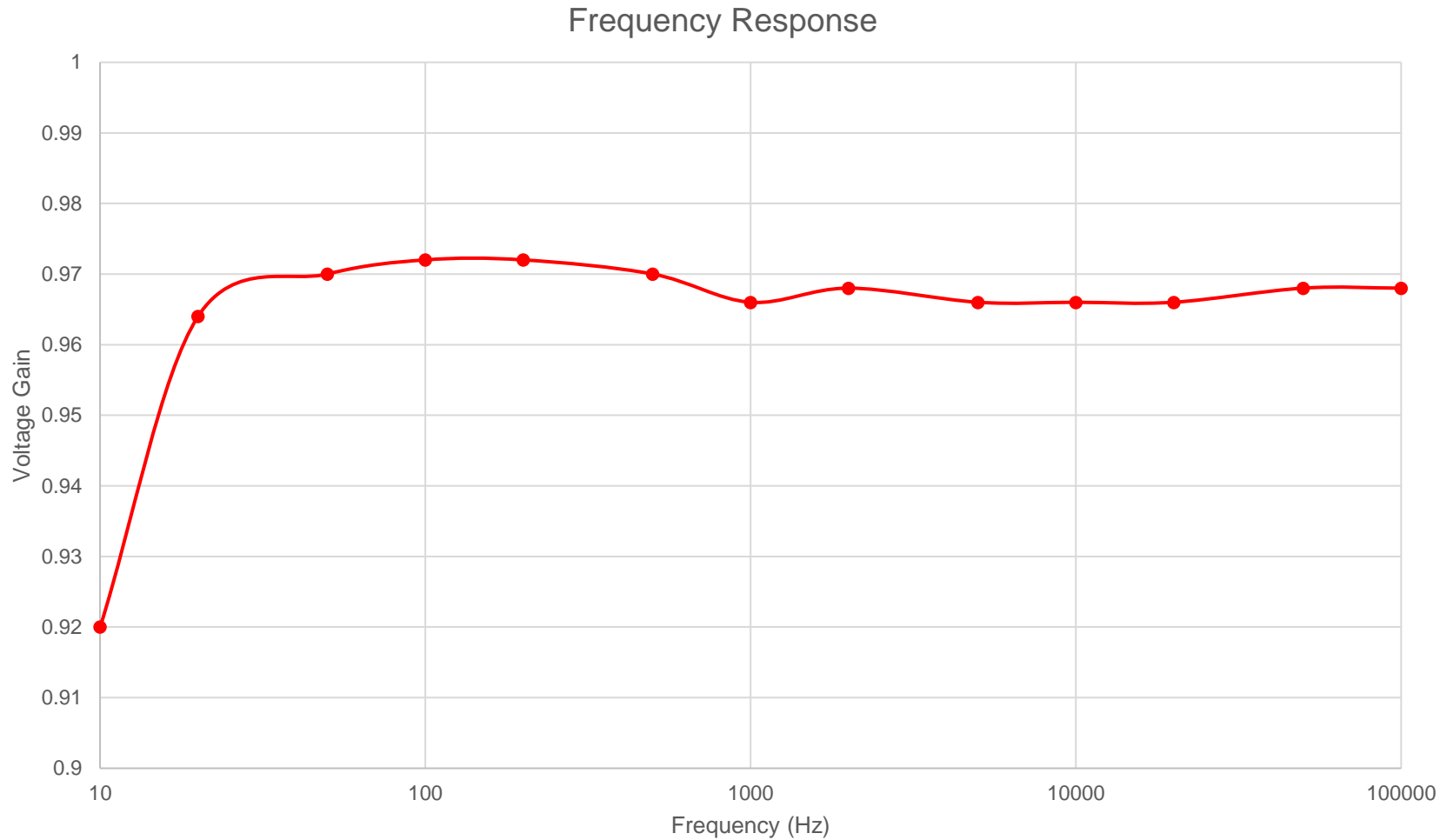
The voltage gain is slightly less than one, and can never be greater than one.



The current gain however is much greater than one, and the input impedance is quite high and the output impedance is low.

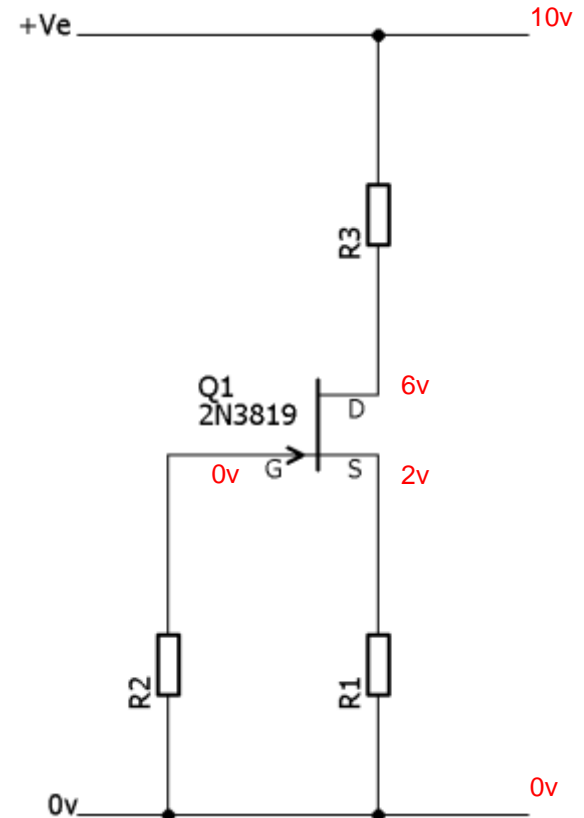
This means that the emitter follower is very useful when a buffer amplifier is required to create isolation between two stages of a circuit.

Emitter Follower Frequency Response



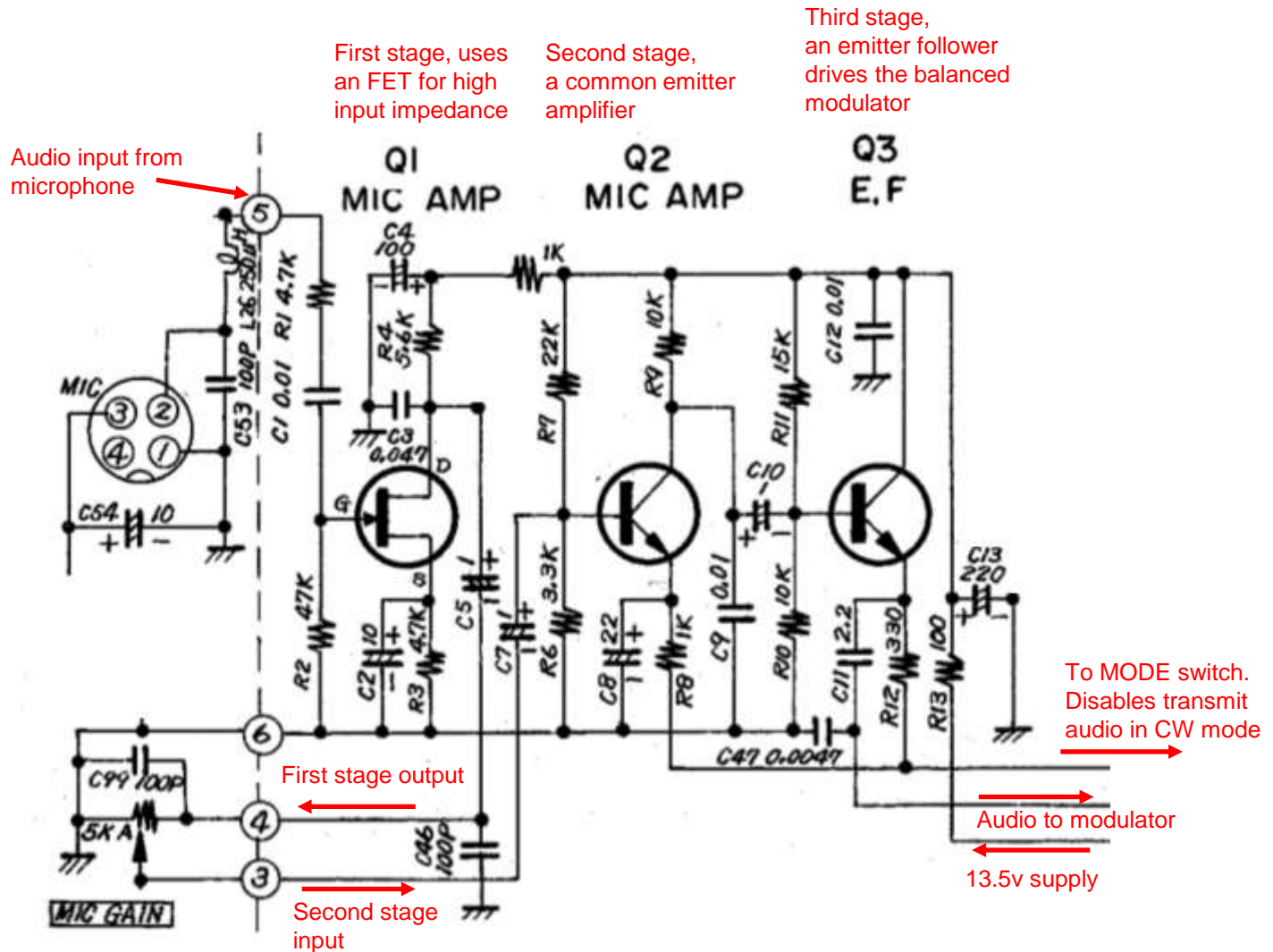
Junction FET Basics

- 1 The J-FET passes (conventional) current from **D**rain to **S**ource.
- 2 The **G**ate does not conduct, it has a very high resistance to drain and source.
- 3 The gate controls the current flowing from drain to source, when the gate has a negative voltage with respect to the source the drain to source current is reduced.
- 4 At some voltage the drain to source current will be “Pinched Off” to zero.
- 5 A common biasing scheme is shown here, the drain current creates voltage drops in resistors R1 and R3.
Let us assume that the resulting voltages on drain and source are as shown in the diagram.
- 6 The gate is connected to the 0v line via R2.
No current can flow in R2 because the gate has a very high resistance, hence the gate voltage is 0v.
- 7 The gate is at 0v, the source is at +2v, hence the gate is biased negative with respect to the source.
This is the usual working state for an N-Channel Junction FET.



A Real World Example (Yaesu FT101 microphone amplifier)

Yaesu FT101 schematic fragment edited for clarity



The End