Lab 138 - Transistors and Amplifiers

Jonas Sjöberg (Högskolan i Gävle, Elektronikingenjörsprogrammet)
Esther Hedlund (Högskolan i Gävle, Elektronikingenjörsprogrammet)

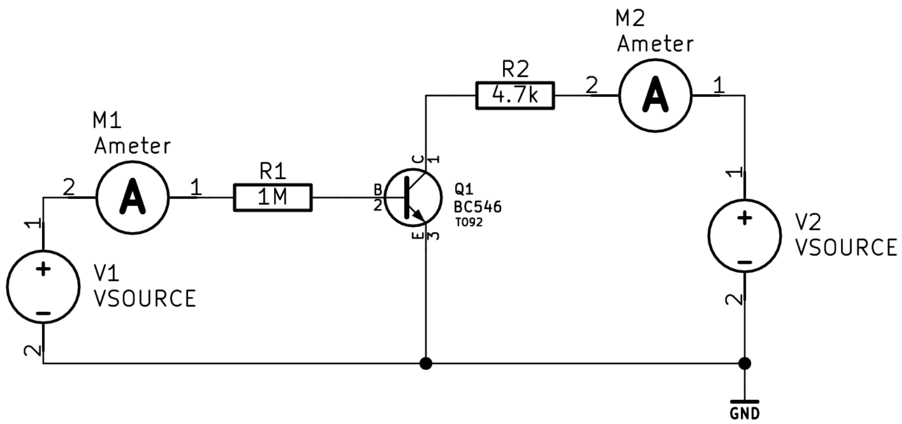
Abstract

"This lab is meant to teach and show the practical use of NPN bjt amplifiers. The lab includes constructing and measuring DC circuits, calculating biasing networks, amplification, bandwidth and plotting characteristic curves of circuit parameters."

Contents

1 Ic-Uce-characteristics

1.1 Circuit



1.1.1 Fixed collector voltage

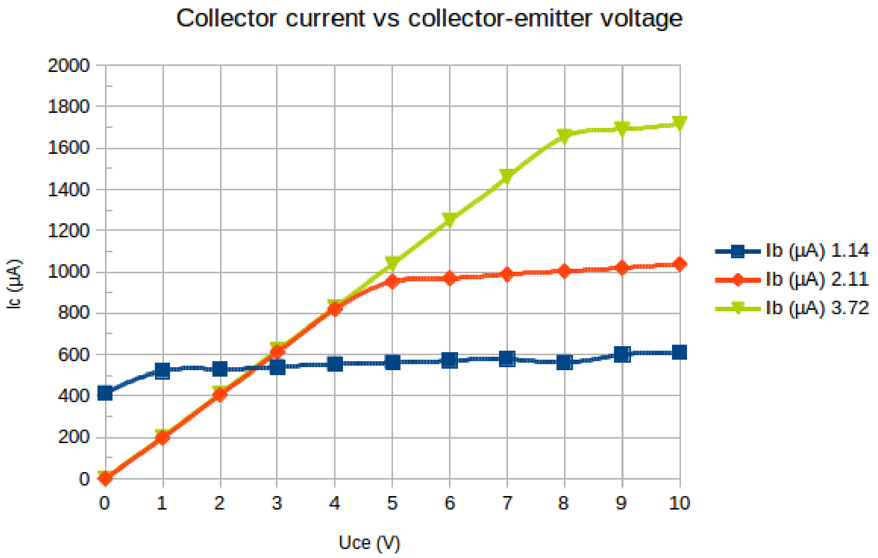
With the collector resistor R2 left out or shorted, an adjustable power supply is connected directly across the collector-emitter junction, fixing the collector voltage. First we get the base currents for known collector currents. Adjusting voltage V1 translates to varying the base current Ib and in turn the collector current Ic. The transistor used is a BC547C.

1.1.2 Measurements

Ic (mA)	Ib (µA)
0.5	1.14
1.0	2.11
1.8	3.72

Table 1: Measurement of base current vs collector current

The base current is then held at a constant value and the collector-emitter voltage is swept over a range of 0-10V in 1V steps. The results is given in the plot.



1.1.3 Simulation

Spice circuit simulation confirms that measurements reflect typical bjt characteristics. The program used is Linear Technology LTspice, transistor model extracted from transistor datasheet parameters.

2 Quiescent conditions

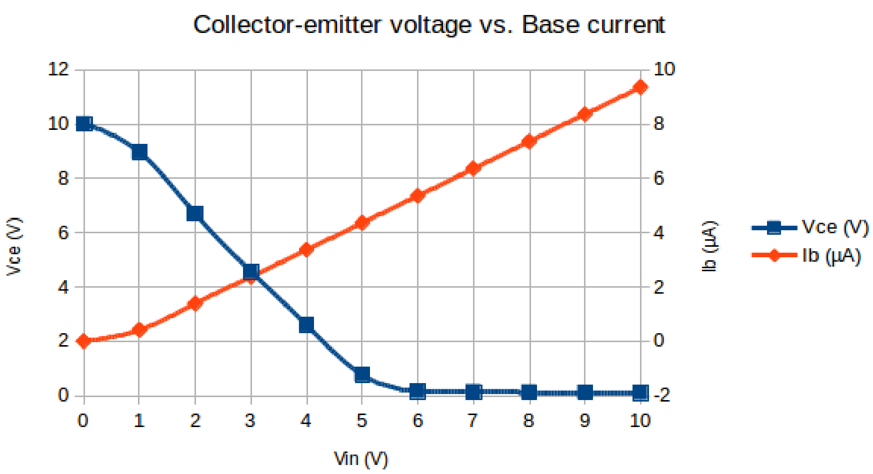
2.1 Circuit

TODO!

Plot — TODO

3 Uce/Ib transfer function

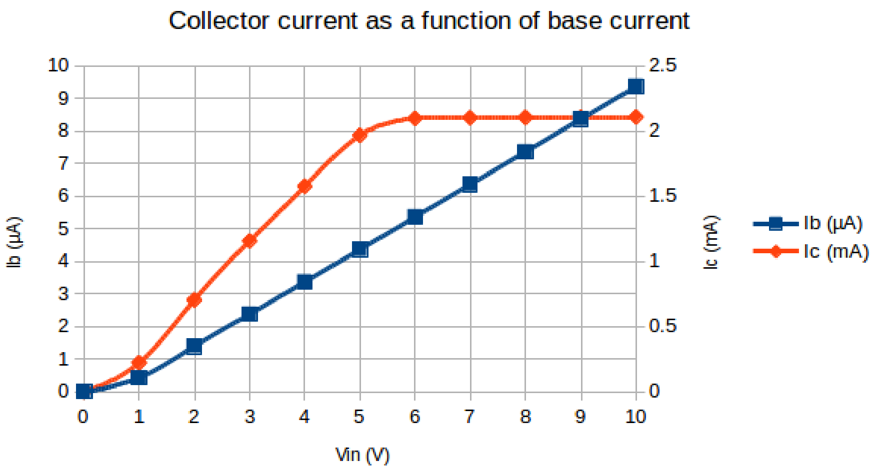
Examine the output signal of the first circuit. Determine the linearity of the output, as in the relation of Uce to Ib. Uses the measurement setup and circuit shown in Figure 1. The input voltage source is low enough impedance to be considered constant. The linear region is very small, the transistor is best used as a switch in this configuration.

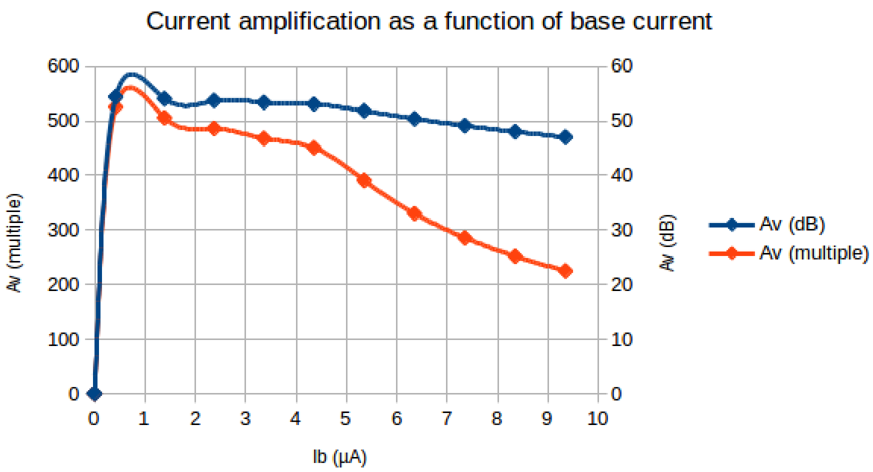


4 Ic/Ib characteristics and current amplification

4.1 Measurements

Circuits are simulated in LTspice.





4.2 Comments

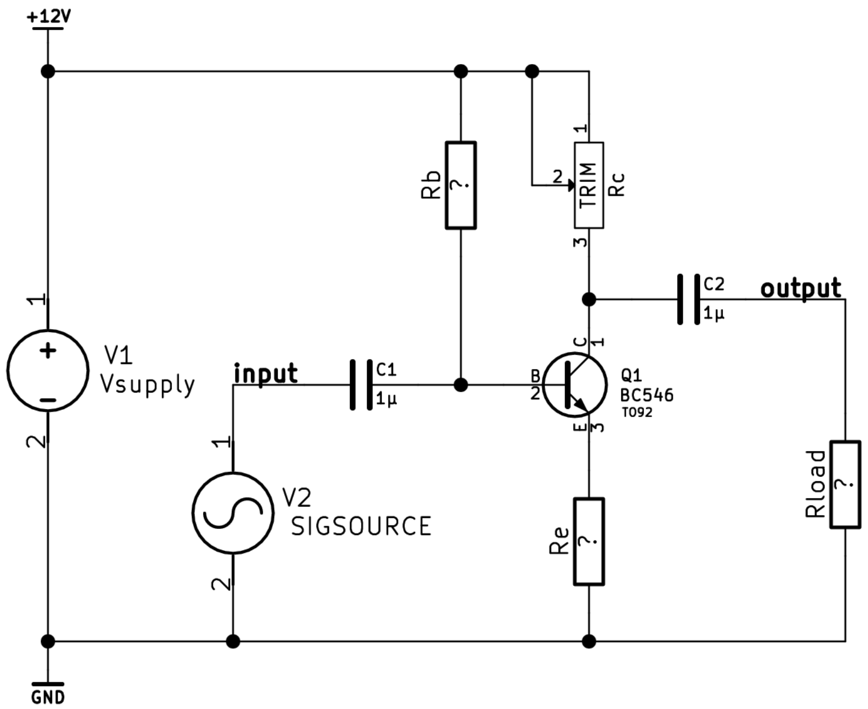
Current gain decreases with base current. This is one of many nonideal characteristics of the transistor. The phenomenon is called a “high injection effect”. Source included in references.

5 BJT biasing

Making Vce 10V maximizes the dynamic range of the amplifier, I.E. improves linearity and reduces clipping of higher amplitude signals, by centering the operating “bias” point. The available voltage is split evenly between the three droppers; collector resistor collector-emitter resistance and emitter resistor.

Rb (Ω)	Ve (V)	Rc (Ω)
390k	10.3	1
470k	9.3	47
560k	8.2	1k
680k	7.7	1k
820k	6.8	1.2k
1M	5.9	3.3

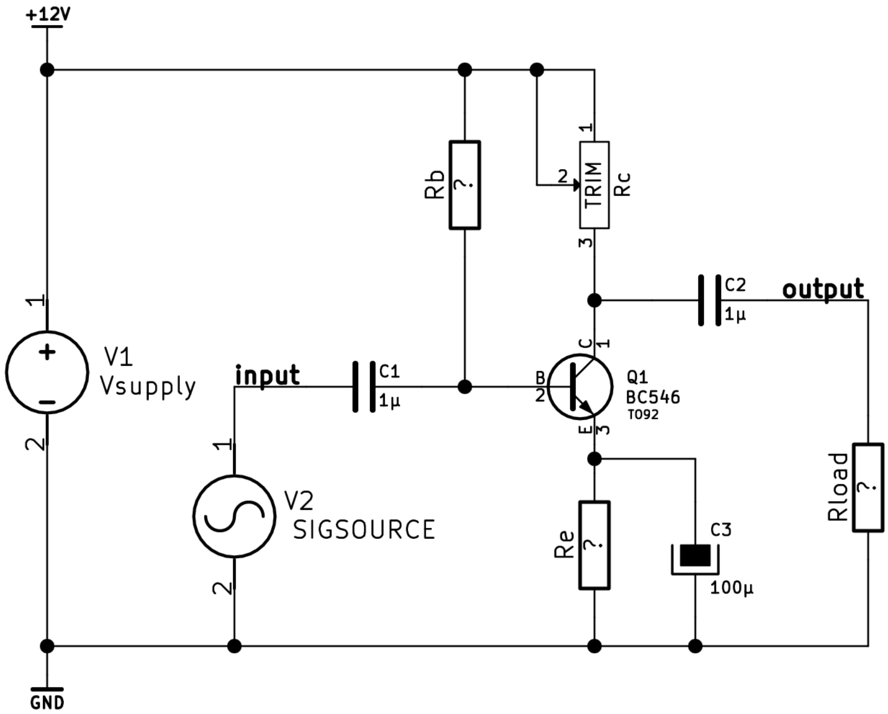
Table 2: Bias resistor with bias voltages



The collector resistor would have to be a short to put Vce at 10V. This method of biasing is thoroughly unpractical.

6 BJT amplifier

6.0.1 Amplification



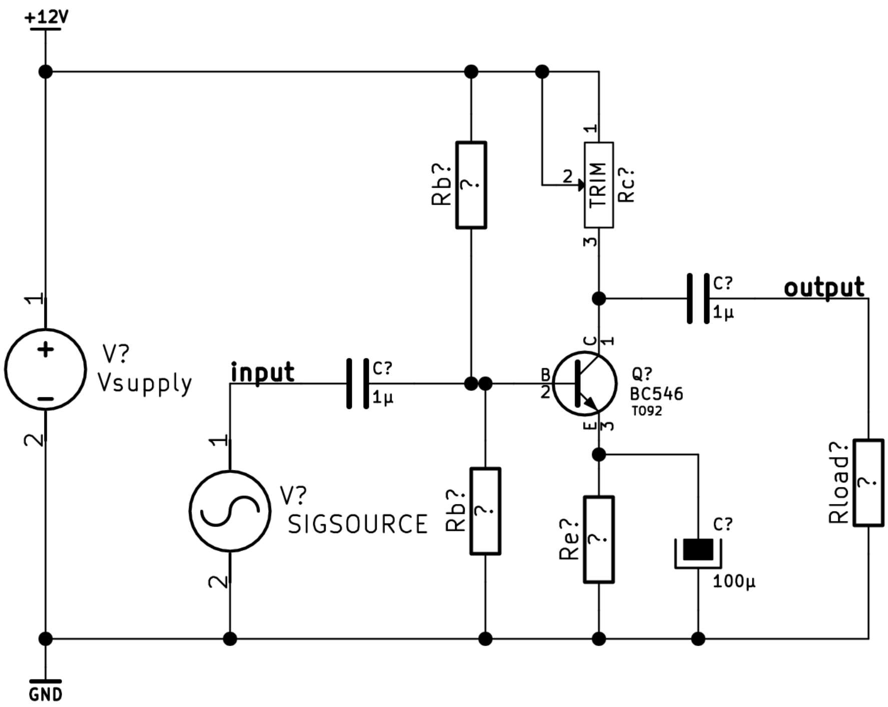
	Without AC bypass	AC bypassed
Input voltage (mVtt)	111	111
Output voltage (Vtt)	111	111
Voltage gain (multiple)	111	111
Voltage gain (dB)	111	111
Phase shift (degrees)	111	111

Table 3: Amplifier gain measurements

6.0.2 Frequency response

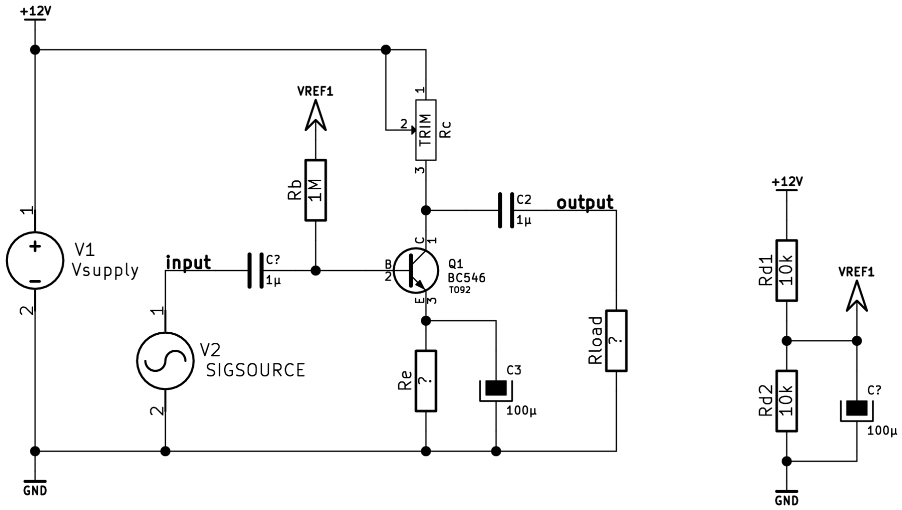
6.0.3 Improved biasing

The one resistor base bias is in practice not very reliable as it is dependant on transistor beta. A more practical design that scales better for production adds a second resistor, forming a voltage divider that fixes the base at a suitable level. For maximum dynamic range half of Vsupply, plus a diode drop to compensate for the base-emitter voltage.



6.0.4 "Noiseless" biasing

For small signals and high input impedance, the biasing can be improved further in terms of bias voltage "stiffness" and power supply noise rejection. The bias voltage is derived from a separate low impedance voltage divider, heavily filtered and almost a short circuit as far as AC signals are concerned. The bias voltage is tapped with a higher value resistor which effectively sets the input impedance of the stage.



7 References

7.1 WWW

High injection effects http://ecee.colorado.edu/~bart/book/book/chapter5/ch5_4.htm

7.2 Literature

Horowitz and Hill - The Art of Electronics, Cambridge University Press 1989.
Horowitz and Hayes - Student Manual for the Art of Electronics, Cambridge 1989.

7.3 Sources

Full source, including spice simulation files, CSV data, schematics, etc is available at https://github.com/jonasjberg/EE413-lab01