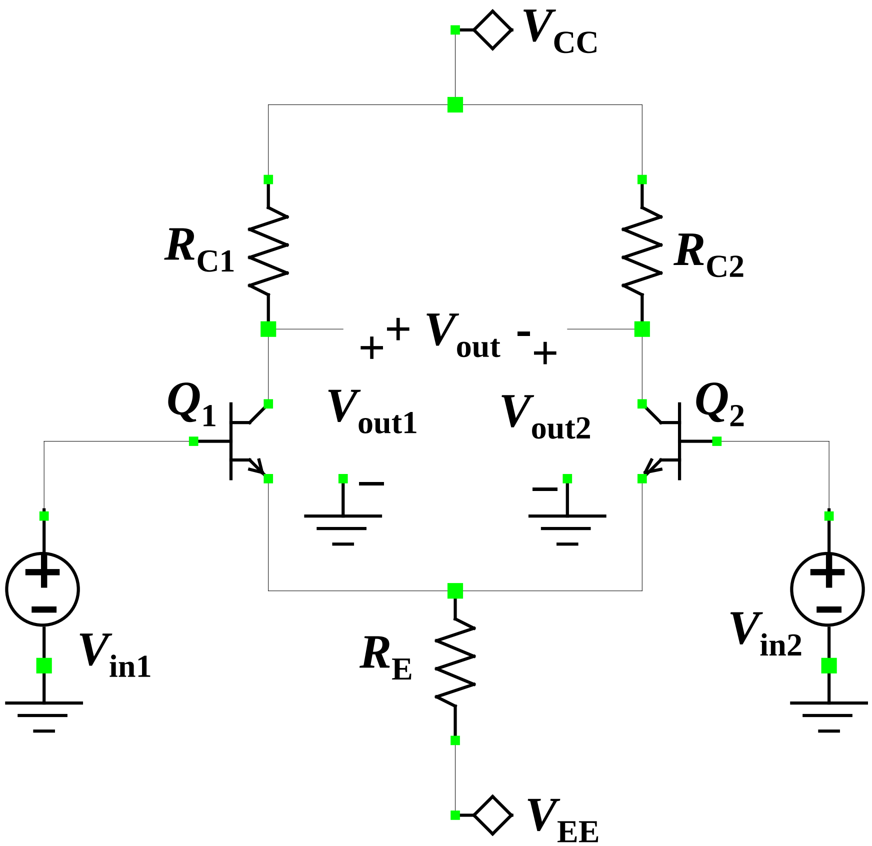
Electronic Circuits Laboratory
EE462G
Simulation Lab #9

The BJT Differential Amplifier

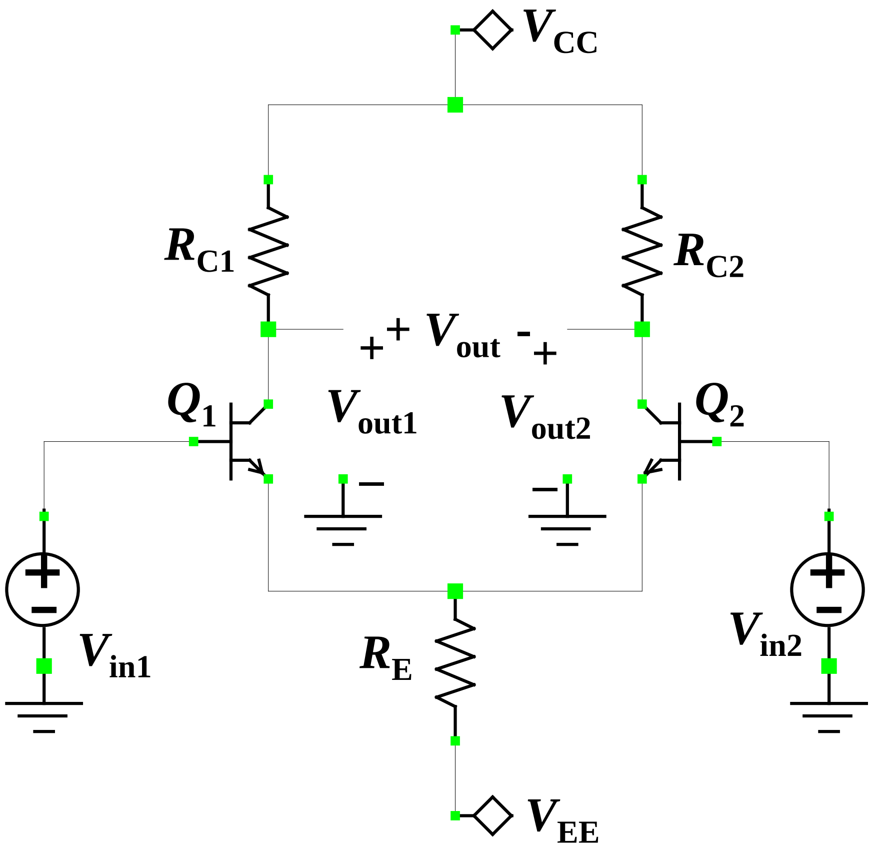
Differential Amplifier



The object of the differential amplifier is to amplify the difference between V_{in1} and V_{in2} for output V_{out}.

In many applications $V_{EE} = -V_{CC}$. This can be obtained in the lab by setting the one negative and positive terminals of the dual power supply to earth ground and then set the power supply for the positive connection to the circuit to V_{CC} and the negative connection to V_{EE}.

Differential Amplifier Inputs



The ideal differential amplifier suppresses the common mode input given by:

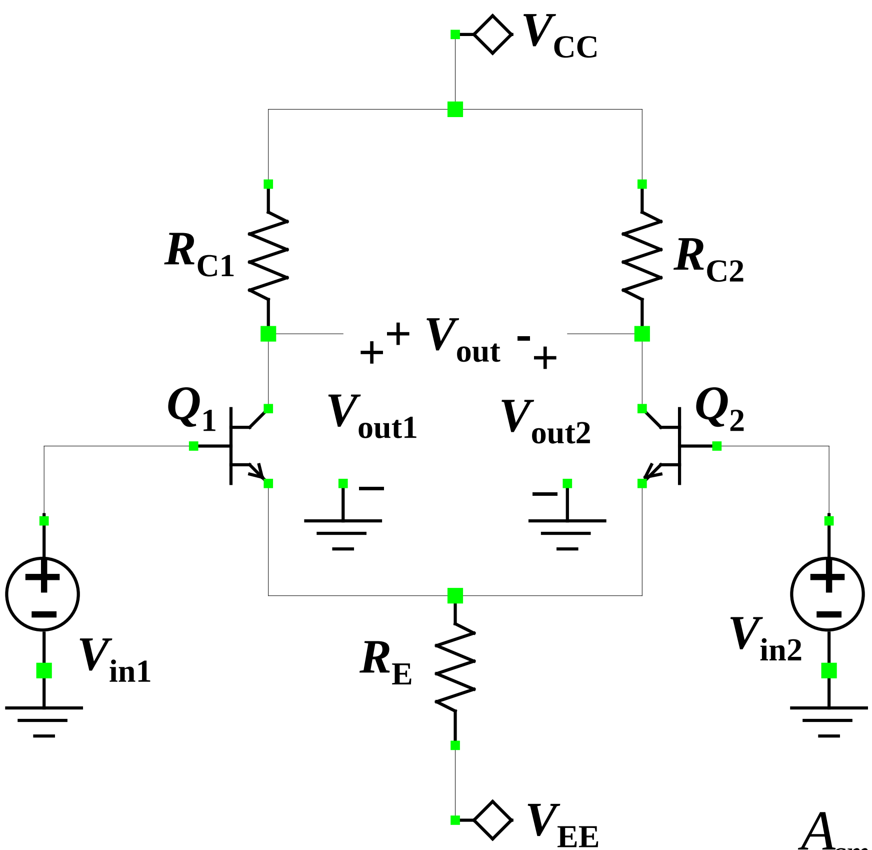
$$V_{icm} = \left(\frac{V_{in1} + V_{in2}}{2} \right)$$

and amplifies differential mode input given by:

$$V_{idm} = V_{in1} - V_{in2}$$

Note that the input to this system is uniquely determined by the (V_{in1}, V_{in2}) pair or the (V_{icm}, V_{idm}) pair. There are several types of gain that can now be described for this amplifier.

Differential Amplifier Gain



The gain between V_{idm} and V_{out1} is described as the single-ended ideal differential gain given by:

$$A_{dmse1} = \left(\frac{V_{out1}}{V_{idm}}\right)\bigg|_{V_{icm}=0}$$

A similar gain is described for V_{out2}:

$$A_{dmse2} = \left(\frac{V_{out2}}{V_{idm}}\right)\bigg|_{V_{icm}=0}$$

Similar gains can be described for the common mode input:

$$A_{cmse1} = \left(\frac{V_{out1}}{V_{icm}}\right)\bigg|_{V_{idm}=0} \qquad A_{cmse2} = \left(\frac{V_{out2}}{V_{icm}}\right)\bigg|_{V_{idm}=0}$$

Differential Amplifier Gain

The single ended output can be computed from the previously defined gains using superposition given by:

$$V_{out1} = A_{dmse1}V_{idm} + A_{cmse1}V_{icm} = A_{dmse1}(V_{in1} - V_{in2}) + A_{cmse1}\left(\frac{V_{in1} + V_{in2}}{2}\right)$$

$$V_{out2} = A_{dmse2}V_{idm} + A_{cmse2}V_{icm} = A_{dmse2}(V_{in1} - V_{in2}) + A_{cmse2}\left(\frac{V_{in1} + V_{in2}}{2}\right)$$

The differential output $V_{out} = V_{out1} - V_{out2}$ can be computed from the above two equations in the following slide:

Differential Amplifier Gain

$$V_{out} = V_{out1} - V_{out2}$$

$$= (A_{dmse1} - A_{dmse2})(V_{in1} - V_{in2}) + (A_{cmse1} - A_{cmse2})\left(\frac{V_{in1} + V_{in2}}{2}\right)$$

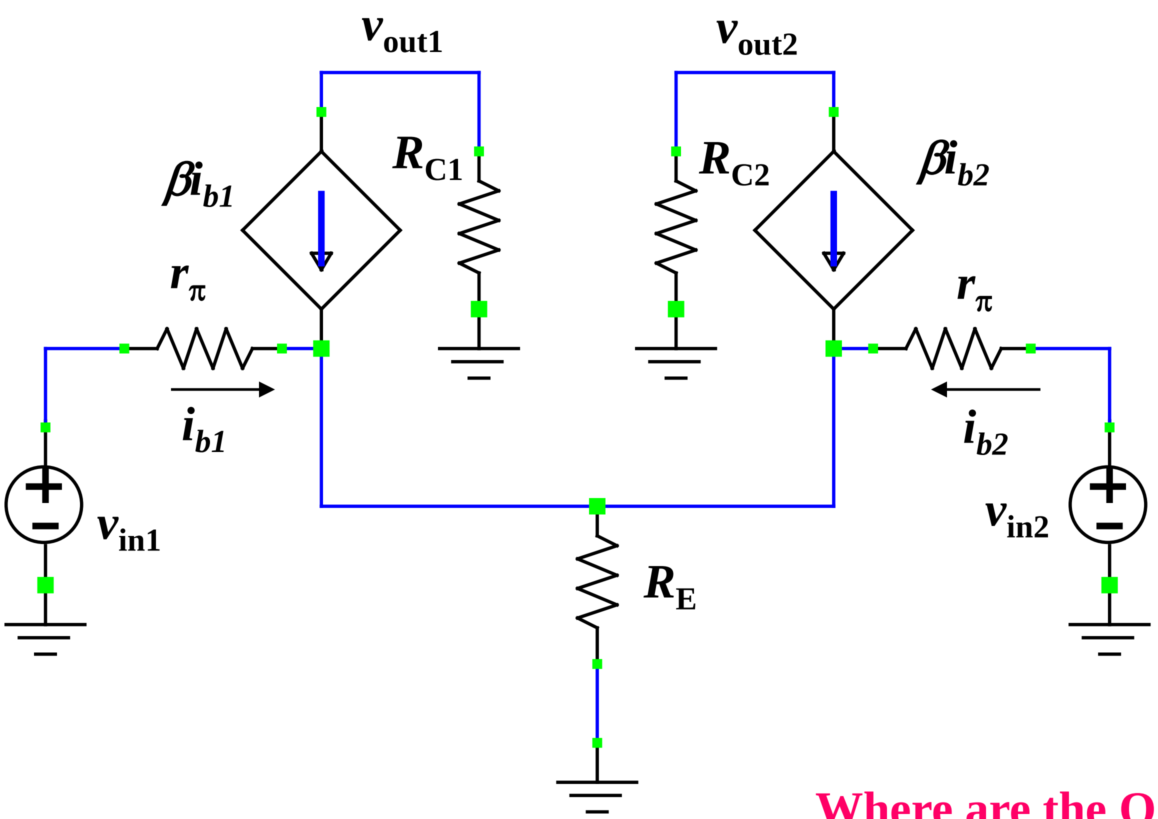
$$V_{out} = (A_{dmse1} - A_{dmse2})V_{idm} + (A_{cmse1} - A_{cmse2})V_{icm}$$

V_{out} consists of two parts: one is from differential input and the other one is from the common mode input. The common mode input V_{icm} is always there. The only thing can be done is to suppress $(A_{cmse1} - A_{cmse2})$.

An important performance measure for differential amplifiers is the common-mode rejection ratio (CMRR) given by:

$$\mathbf{CMRR} = 20\,\mathbf{log}\left|\frac{A_{dmse1} - A_{dmse2}}{A_{cmse1} - A_{cmse2}}\right|$$

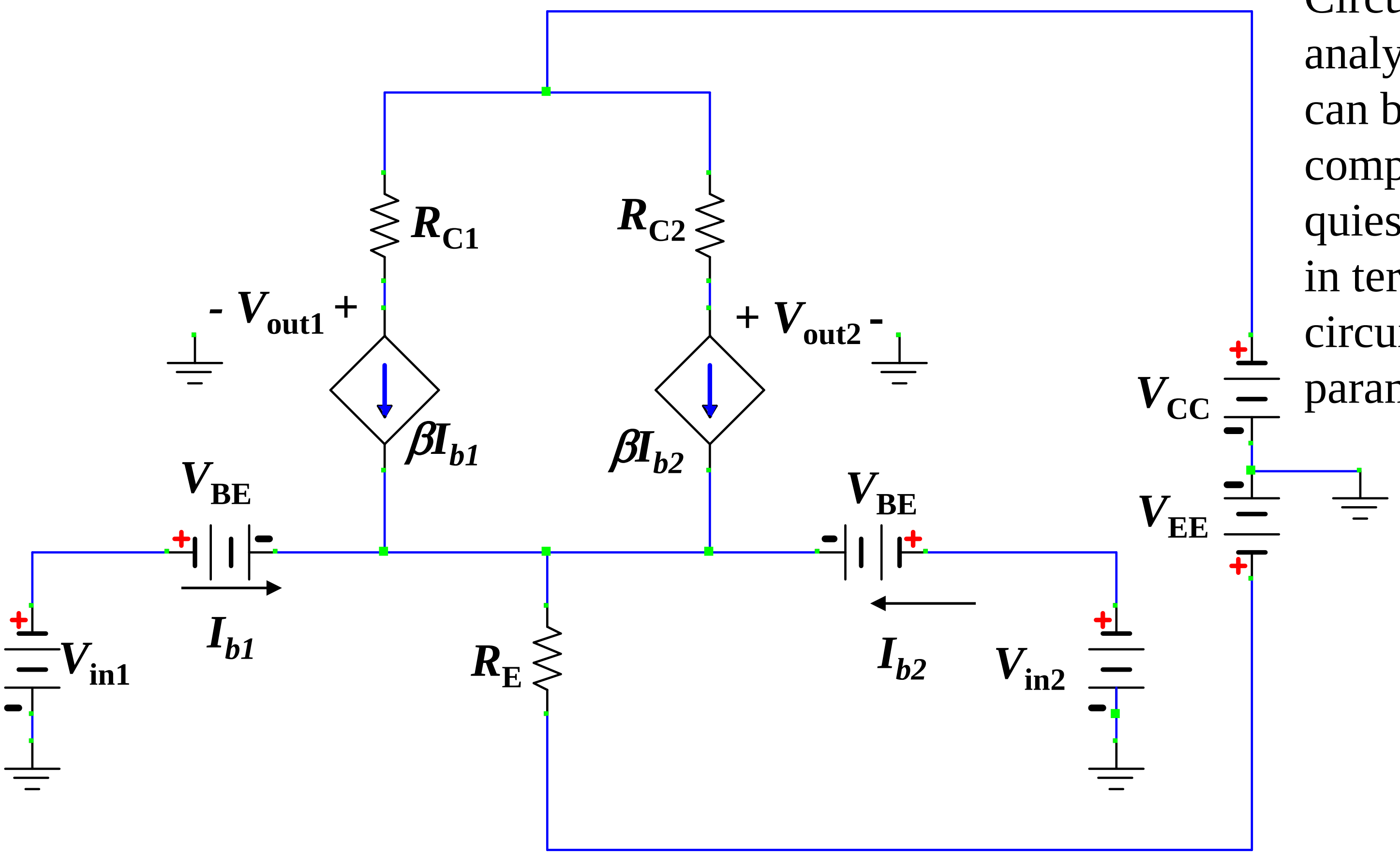
Small Signal Model



Circuits I analysis methods can be applied to compute the previously described gains and CMRR in terms of circuit parameters.

Where are the Q1 and Q2 transistor nodes on this model?

Large Signal Model



Circuits I analysis methods can be applied to compute the quiescent points in terms of circuit parameters.

Where are the Q1 and Q2 transistor nodes on this model?

Crude Op Amp

A simple Op Amp can be create from the differential amp. Most Op Amps have additional stages to buffer the output (See http://www.williamson-labs.com/480_opam.htm).