Peaking current source.

1.0 Introduction:

A peaking current source is a circuit that generates a current output from a reference current. It is useful to very low voltages. The behavior of the current is such that, the output current peaks at a value determined by the input current and falls off on either side of this peak as shown in Figure 1.0 below.

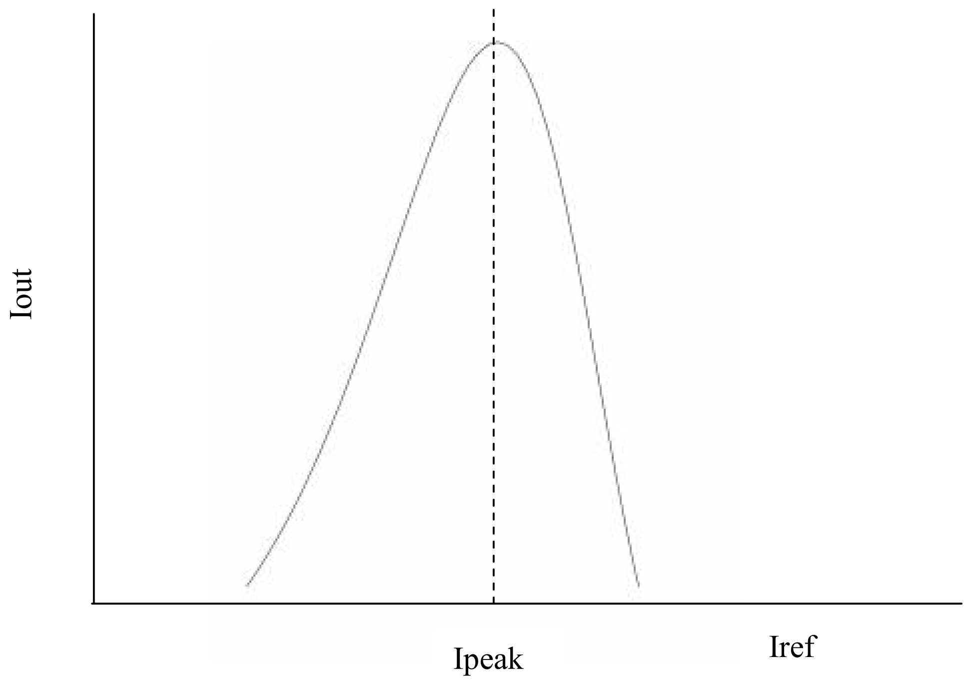


Figure 1.0

The schematic of the peaking current source is shown below.

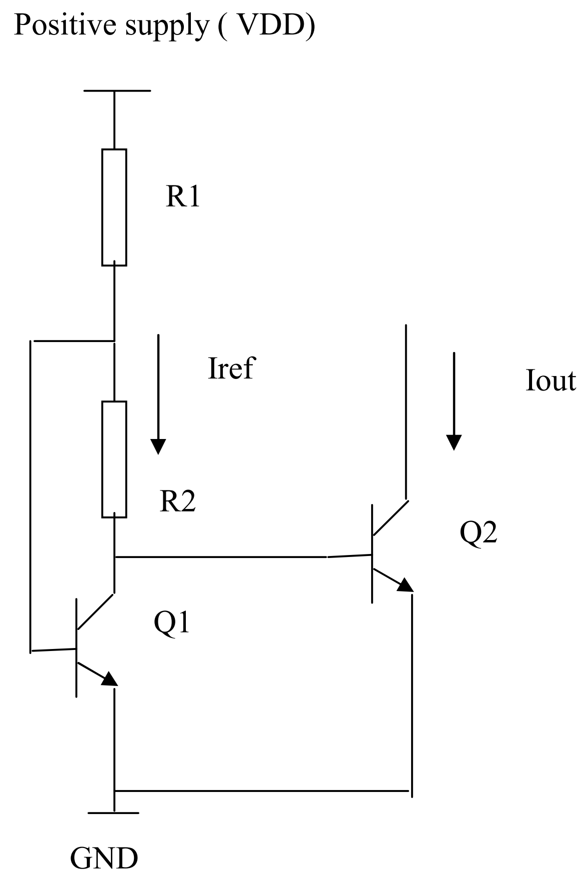


Figure 2.0

The design equations for this source are as follows:

The relationship between Iref and Iout is:

$$\ln(Iout/Is2) = \ln(Iref/Is1) - Iref*R1/(kT/q) \quad (1)$$

or

$$Iout = Iref(Is2/Is1)\exp(-Iref*R1/(kt/q)) \quad (2)$$

If the two transistors are identical, then Is2 = Is1 and thus,

$$Iout = Iref*\exp(-Iref*R1/(kt/q)) \quad (3)$$

At the peak of the output current the voltage across R2 is the thermal voltage kT/q = 0.026V at room temperature.

Also, at the peak, the ratio between currents is given by:

$$Iout/Iref = 1/e*(Is1/Is2) \quad (4).$$

Note that Is1 and Is2 are the leakage currents of the transistors proportional to the emitter area.

e is the exponential constant = 2.71828 to 5 decimal places. Lets round it off to 2.72.

To design such a source then, with the same size transistors, choose the current needed for Iout. Lets say this is 100uA. Then the current Iref becomes:

$$100uA/Iref = 1/2.72 \quad (5)$$

or

$$Iref = 272\ uA \quad (6)$$

Then the resistor R2 mut be chosen such that:

$$Iref * R2 = 0.026V \quad (7)$$

at room temperature.

Or,

$$R2 = 0.026/272E\text{-}6 \quad (8)$$

$$R2 = 95.5\ Ohms \quad (9)$$

To set the current in Q1, we must calculate the value of R1.

Therefore :

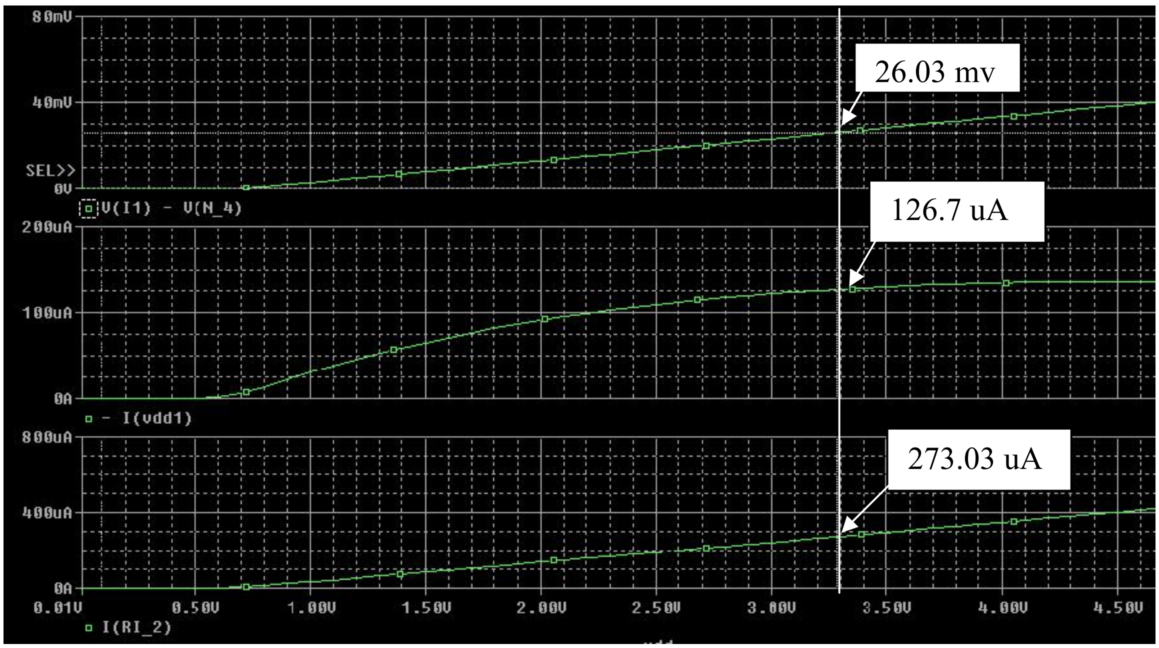
$$(VDD - Vbe)/R1 = 272E\text{-}6 \quad (10)$$

For a VDD = 3.3V and Vbe = 0.8V (approximately)

$$R1 = 9.2\ Kohm \quad (11)$$

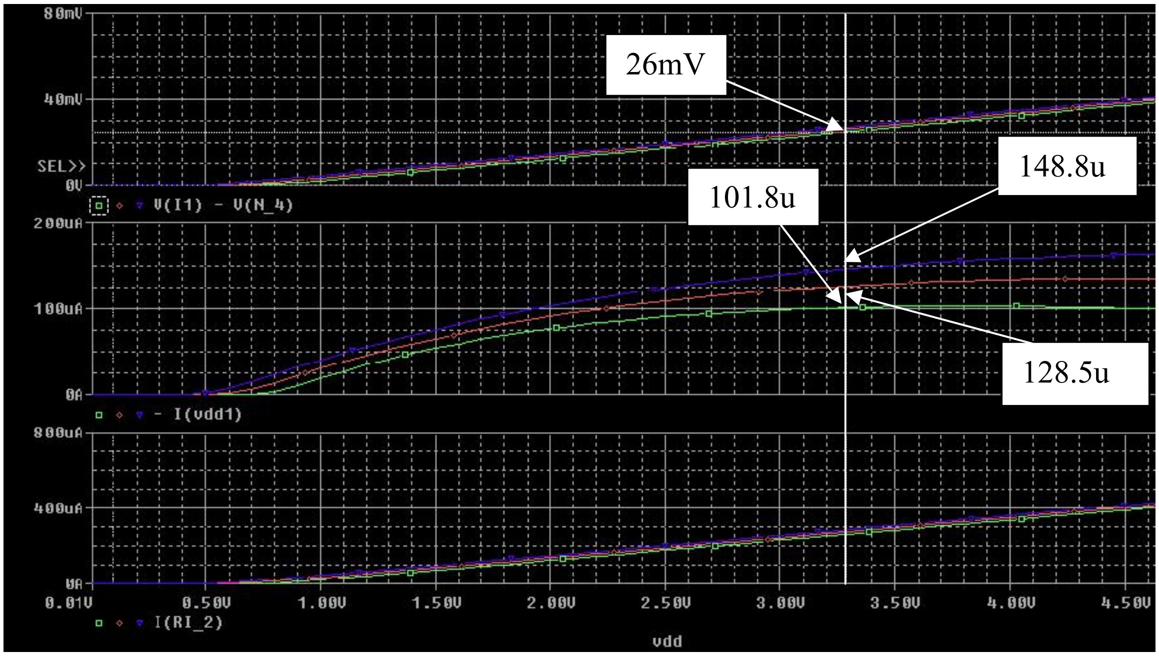
To really fine tune the design, simulation is required. The simulation results for the above design are shown in the following graphics. The bipolar model parameters used were from a a popular BiCMOS process. Note the discrepancies in the results owing to the non-ideal effects of the model.

Temperature = 27 Deg C



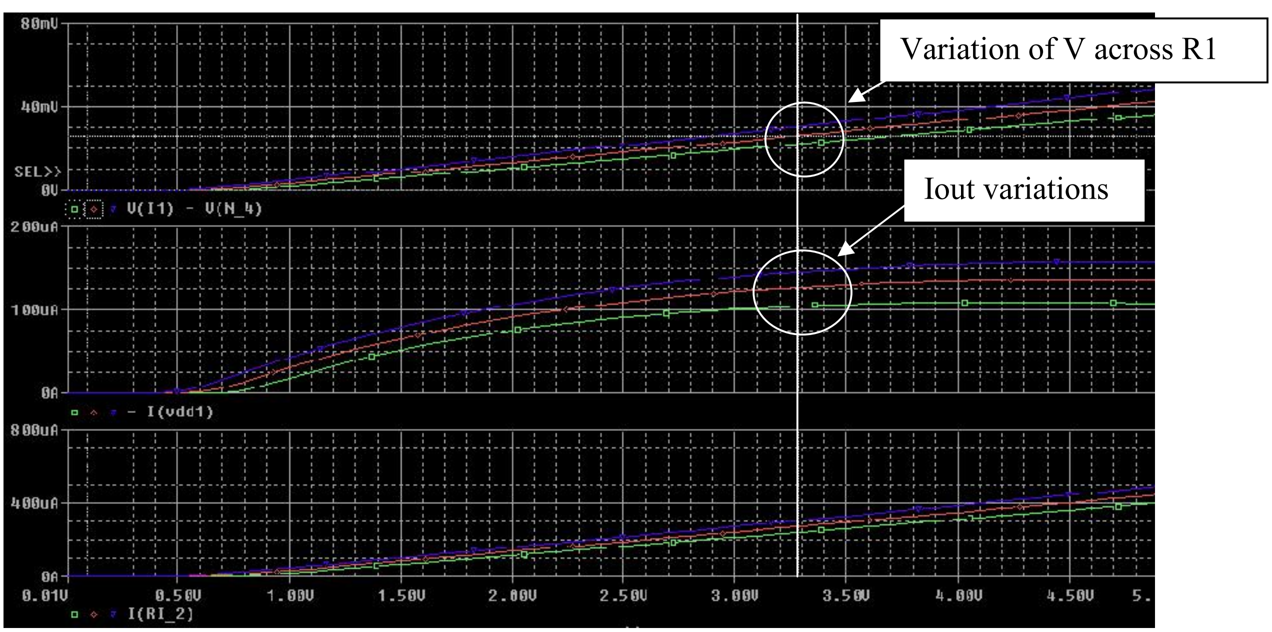
Here

I(vdd1) = Iout = 126.7uA
I(RI_2) = Iref = 273.03 uA
V(I1)-V(n_4) = 0.026V



Variations with temperature -40, 27, 85 Deg C. Top curve (for the output current) in blue is for 85 Deg, middle curve is for 27 Deg and bottom curve is for -40 Deg. This plot represents change because of bipolars only. The resistors do not change with temp. Next curve shows this also.

The total change is ±15% due to the bipolars alone.



Variations with temperature -40, 27, 85 Deg C. Top curve (for the output current) in blue is for 85 Deg, middle curve is for 27 Deg and bottom curve is for -40 Deg. This plot represents change because of bipolars and resistors. Resistor R1 tempco = -1.2e-3 and R2 tempco = 0.7E-3.

Note in this case the voltage across R1 varies significantly also:

At 85 Deg it is:	30.33 mV
At 27 Deg it is:	26.075 mV
At -40 Deg it is:	21.952 mV

At that point the current Iout varies as:

At 85 Deg it is:	145 uA
At 27 Deg it is:	126 uA
At -40 Deg it is:	104.uA

The blue curve is for 85 Deg, the red curve is for 27 Deg and the green curve id for -40 Deg.

There does not seem to be a major difference in results as that due to the variations contributed by the bipolars alone.

<u>Layout tip:</u>

The output current is sensitive to the variation of resistor R2. So layout this resistor with a wide piece of poly or diffusion so that the absolute value variation can be reduced.