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](image)

The schematic of the peaking current source is shown below.
The design equations for this source are as follows:

The relationship between $I_{ref}$ and $I_{out}$ is:

$$\ln\left(\frac{I_{out}}{I_{s2}}\right) = \ln\left(\frac{I_{ref}}{I_{s1}}\right) - \frac{I_{ref}R_1}{kT/q}$$

(1)

or

$$I_{out} = I_{ref}(I_{s2}/I_{s1}) \exp\left(-\frac{I_{ref}R_1}{kt/q}\right)$$

(2)

If the two transistors are identical, then $I_{s2} = I_{s1}$ and thus,

$$I_{out} = I_{ref}\exp\left(-\frac{I_{ref}R_1}{kt/q}\right)$$

(3)

At the peak of the output current the voltage across $R_2$ is the thermal voltage $kT/q = 0.026V$ at room temperature.
Also, at the peak, the ratio between currents is given by:

\[ \frac{I_{\text{out}}}{I_{\text{ref}}} = \frac{1}{e} \left( \frac{I_{s1}}{I_{s2}} \right) \]  

(4).

Note that \( I_{s1} \) and \( I_{s2} \) 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 \( I_{\text{out}} \). Lets say this is 100uA. Then the current \( I_{\text{ref}} \) becomes:

\[ \frac{100\mu A}{I_{\text{ref}}} = \frac{1}{2.72} \]  

(5)

or

\[ I_{\text{ref}} = 272 \mu A \]  

(6)

Then the resistor \( R_2 \) must be chosen such that:

\[ I_{\text{ref}} \times R_2 = 0.026V \]  

(7)

at room temperature.

Or,

\[ R_2 = \frac{0.026}{272 \times 10^{-6}} \]  

(8)

\[ R_2 = 95.5 \text{ Ohms} \]  

(9)

To set the current in \( Q_1 \), we must calculate the value of \( R_1 \).

Therefore:

\[ \frac{(V_{\text{DD}} - V_{\text{be}})}{R_1} = 272 \times 10^{-6} \]  

(10)

For a \( V_{\text{DD}} = 3.3V \) and \( V_{\text{be}} = 0.8V \) (approximately)

\[ R_1 = 9.2 \text{ Kohm} \]  

(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

\[ I(vdd1) = I_{out} = 126.7 \mu A \]
\[ I(RI_2) = I_{ref} = 273.03 \mu A \]
\[ V(I1)-V(n_4) = 0.026V \]
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 is 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.

**Layout tip:**

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.