6.301 Solid-State Circuits

Recitation 19: More on Translinear Circuits
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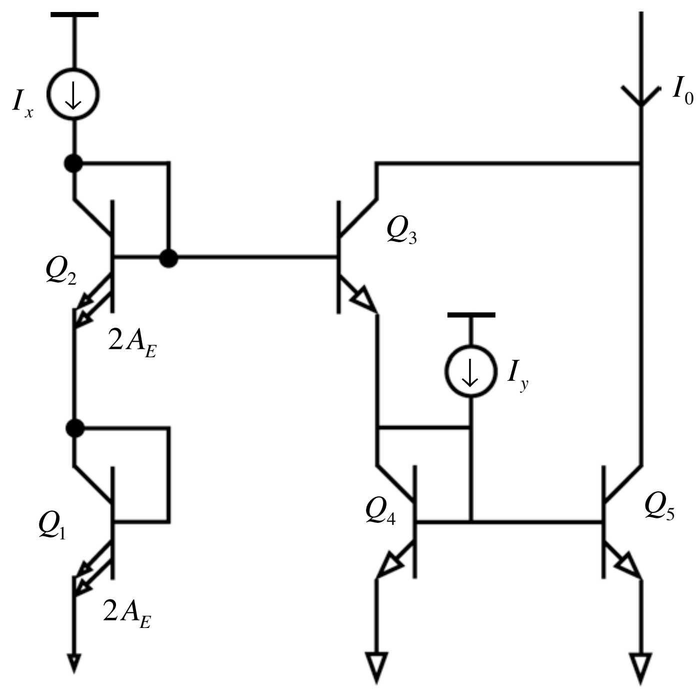
We're going to continue today with more on "Pythagorators," and then talk about an industry design: The LH0091 True RMS to DC converter. It's a <u>very</u> interesting application of some of these translinear ideas. In the middle of the class, though, we'll try our hand at a small translinear design problem.

<u>Five-Transistor Pythagorator</u>



What is I_0 in terms of I_x and I_y? Well, we see a Gilbert loop right away in $Q_1 - Q_4$. Must use the more general form:

$$\frac{I_x}{2A_E} \cdot \frac{I_x}{2A_E} = \frac{I_3}{A_E} \frac{\left(I_3 + I_y\right)}{A_E}$$

$$\tfrac{1}{4} I_x^{\,2} = I_3\left(I_3 + I_y\right)$$

Need the relationship between I_3 and other variables of interest. We can write

$$I_0 = I_3 + I_5$$

Q_4 and Q_5 form a current mirror (which, incidentally, is the simplest possible Gilbert loop):

$$I_5 = I_4 = I_3 + I_y$$

$$I_0 = 2I_3 + I_y \Rightarrow I_3 = \frac{I_0 - I_y}{2}$$

Substituting back into our first expression:

$$\tfrac{1}{4} I_x^2 = \left(\frac{I_0 - I_y}{2}\right)\left(\frac{I_0 - I_y}{2} + I_y\right)$$

$$= \tfrac{1}{4}\left(I_0^2 - \cancel{2I_y I_0} + I_y^2\right) + \cancel{\tfrac{1}{2} I_0 I_y} - \tfrac{1}{2} I_y^2$$

$$\frac{I_x^2}{\cancel{4}} = \frac{I_0^2}{4} - \frac{I_y^2}{4} = \tfrac{1}{\cancel{4}}\left(I_0^2 - I_y^2\right)$$

$$I_0^2 = I_x^2 + I_y^2 \Rightarrow I_0 = \sqrt{I_x^2 + I_y^2}$$

Question of the day: How did someone come up with that? Now let’s try some on our own.

CLASS EXERCISE 1 (to be worked on individually):

Design a translinear circuit that performs the function

$$i_0 = 4 \cdot i_i$$

(Workspace)

CLASS EXERCISE 2 (to be worked on in pairs):

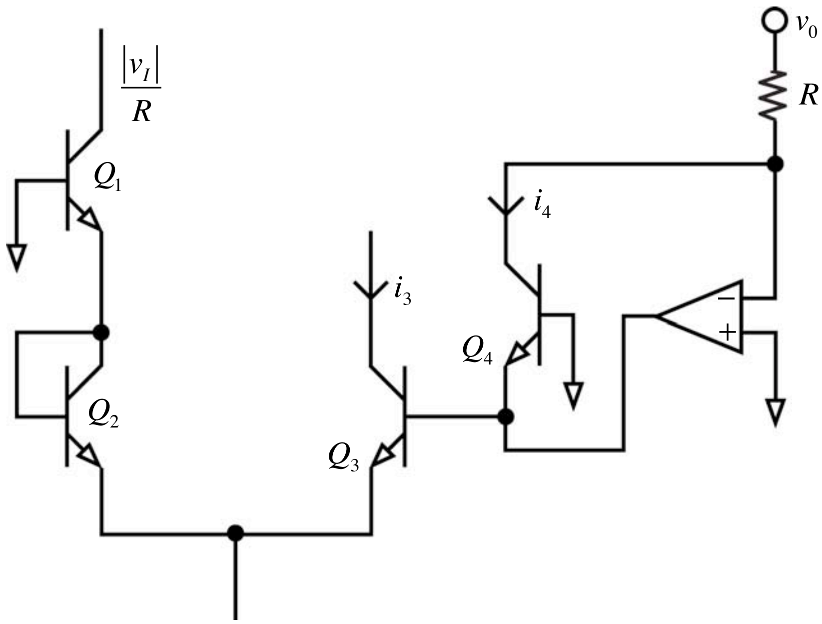
Design a translinear circuit that gives the following input-output relation:

$$i_0 = ki^3$$

Now let's turn our attention to National's LH0091 True RMS to DC converter. It is called this because its output is

$$v_0 = \sqrt{\tfrac{1}{RC}\int |v_I|^2 \, dt}$$

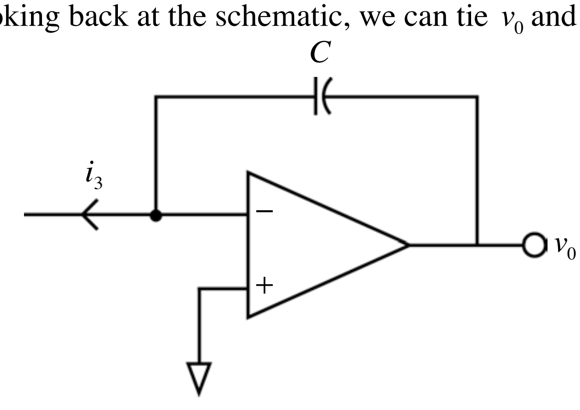
To see how this happens, turn your attention to $Q_1 - Q_4$ indicated on the schematic:



See the Gilbert loop? $I_1 I_2 = I_3 I_4$

But $I_1 = I_2 = \frac{|v_I|}{R}$, and $I_4 = \frac{v_0}{R}$. This gives $\frac{|v_I|^2}{R^2} = i_3\left(\frac{v_0}{R}\right)$.

Looking back at the schematic, we can tie v_0 and i_3 together:



$$C\frac{dv_0}{dt} = i_3$$

$$v_0 = \frac{1}{C}\int i_3 dt$$

So now we can fully analyze the circuit:

$$\frac{|v_I|^2}{R} = i_3 \frac{v_0}{R}$$

Integrate both sides

$$\frac{1}{R^2}\int |v_I|^2\, dt = \frac{1}{R}\int i_3 v_0 dt$$

Now <u>assume</u> v_0 changes slowly compared to v_I, so that we can write

$$\frac{1}{R^2}\int |v_I|^2\, dt = \frac{v_0}{R}\int i_3 dt$$

$$\frac{1}{R^2}\int |v_I|^2\, dt = \frac{v_0}{R} C v_0$$

$$v_0 = \sqrt{\frac{1}{RC}\int |v_I|^2\, dt}$$

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