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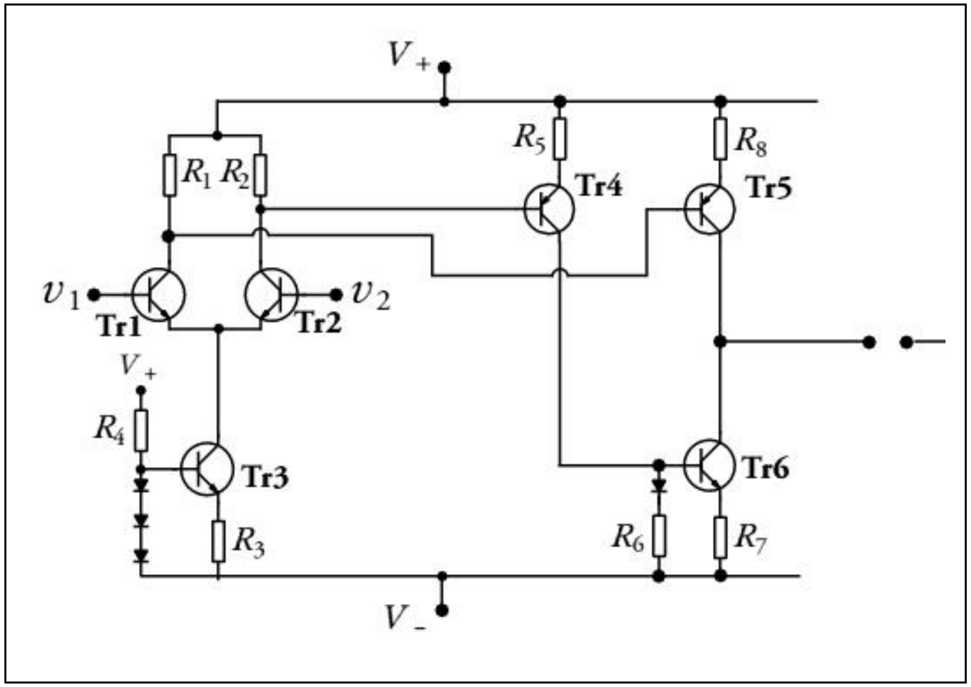
Lesson 10

Linear Integrated Circuits

Definition: LINEAR integrated circuits are electronic devices that have a change of output for any small change of input. Linear integrated circuits literally have an infinite number of input and output levels. (Contrast with DIGITAL integrated circuits that only have two levels of output and switch between the two.)



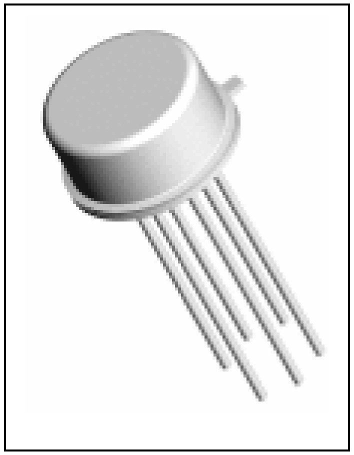
As we found out some time ago, a bipolar transistor makes a pretty good amplifier and a bipolar transistor internally is nothing more than two back-to-back diodes. The problem is that diodes inherently have a forward voltage drop that is directly variable with temperature. Temperature goes up, voltage goes down (for a given current) and vice versa. Thus, while your forward biased diode may have a voltage of 500 millivolts at room temperature, in the summertime in Phoenix it may be only 440 millivolts or so.

That is only a 40 millivolt change, but if you are making an amplifier with a gain of 100,000 or so, that's a 4000 volt difference at the output. That isn't going to work.

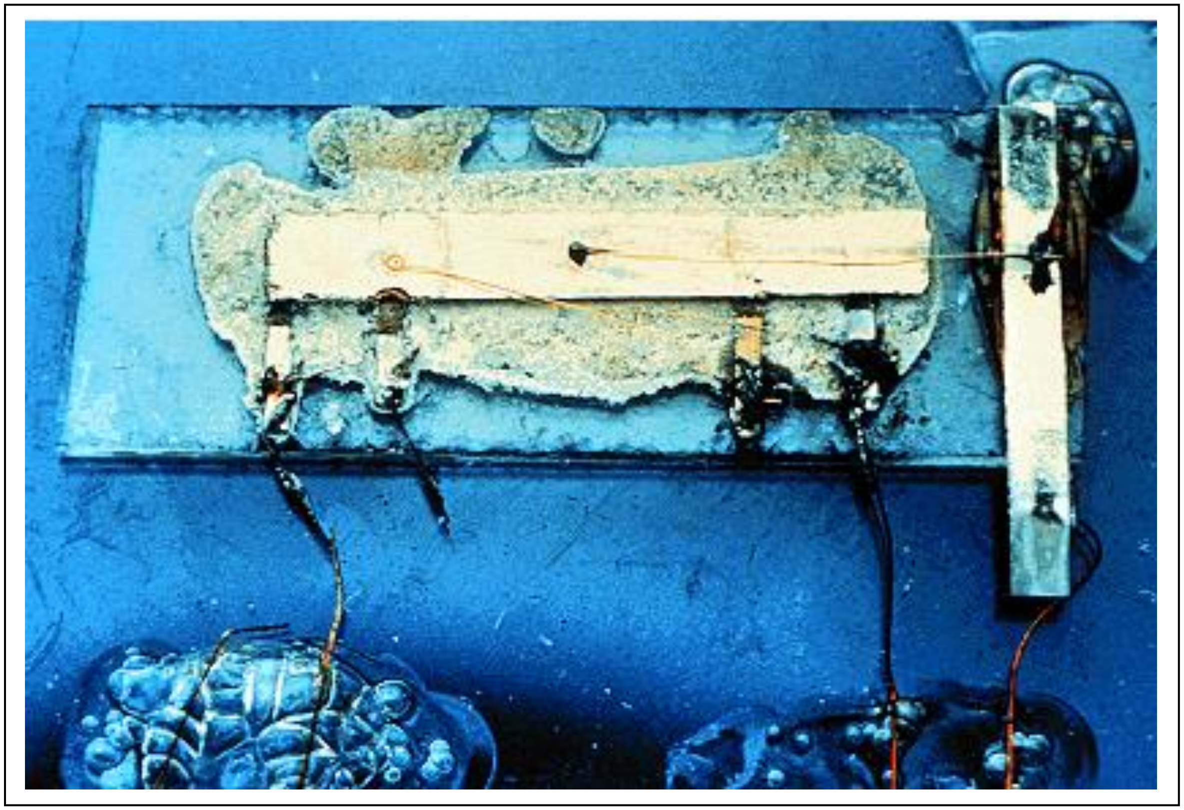
What IS going to work is an invention that was derived from vacuum tube days back in the 1930s. The circuit to the right is called an "operational amplifier". We'll talk about it a little bit later. However, the input voltages are v1 and v2 and we want to amplify the DIFFERENCE between these two voltages. Tr1 and Tr2 (more properly Q1 and Q2) form what is called a DIFFERENTIAL amplifier. The output at the collector of Tr1 (the little dot just below R1) is the difference between the voltages at v1 and v2.

Almost. If there is a difference between the base-emitter diode voltages of Tr1 and Tr2, then it will appear to the output as though there is the same difference between v1 and v2, and this diode difference voltage will be amplified right along with the signal difference. How do we get a difference of diode voltages? Heat up TR1 and cool down Tr2 and just watch the output go nuts. (Go nuts, that's a technical term, you'll get used to it.)

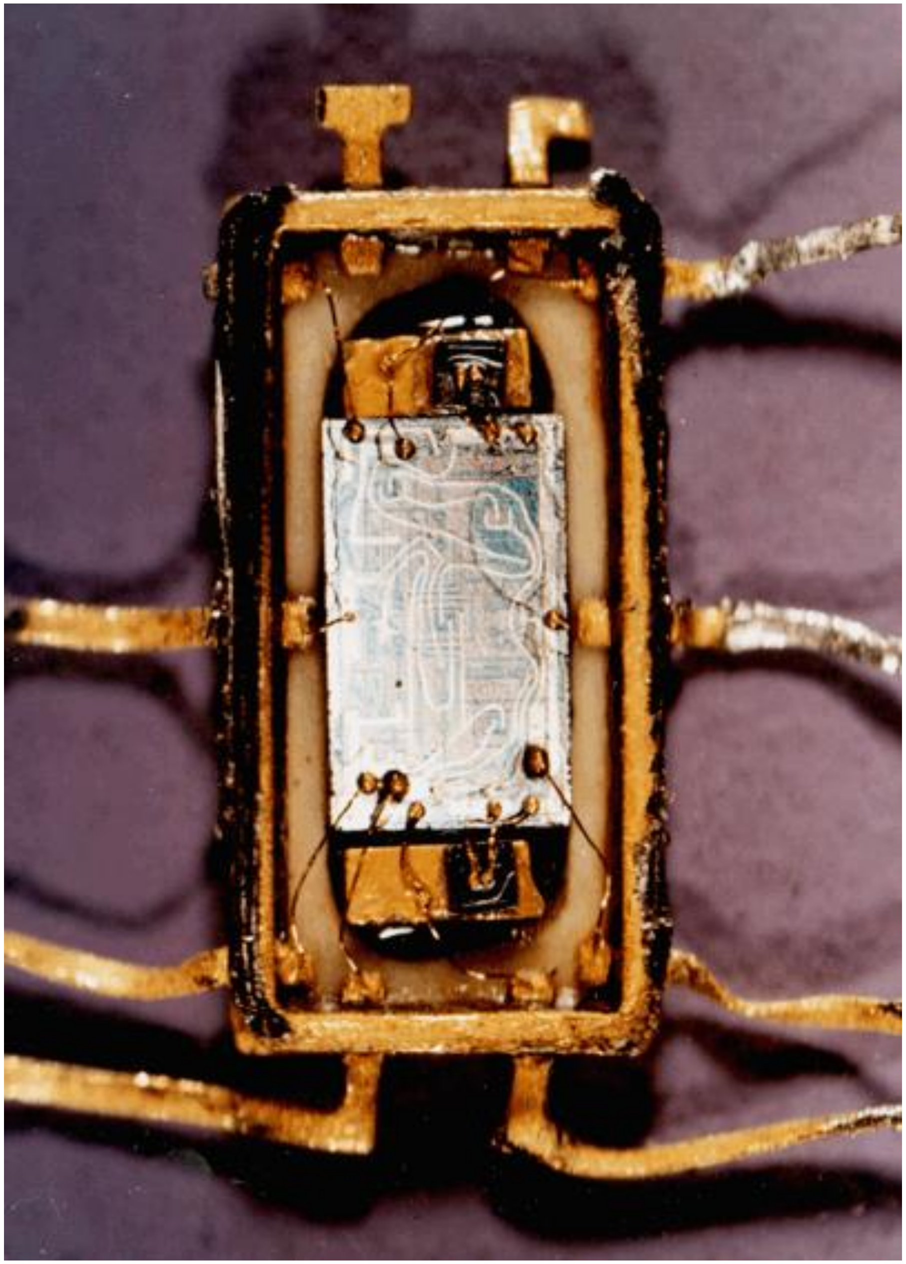
So how do we keep Tr1 and Tr2 at the same temperature? In the early days, we tried gluing the transistors together. We tried metal clips around their cases. We tried hundreds of methods. Most of them worked … sort of. Then somebody got the bright idea of putting both transistors into a single package, welding them to a common metal base, and putting a "thermal chamber" (metal can) over them to keep them at the same exact temperature. What a breakthrough until …



Along come Kilby and Noyce with the harebrained idea of putting BOTH transistors on a SINGLE chunk of semiconductor (germanium in this case), and the rest is Nobel Prize history. The world's first INTEGRATED circuit (shown here) were two PNP transistors side by side. You can see three leads going to one transistor on the left (don't forget the little gold wire going to the top) and three more going to the transistor on the right.



A little more work later with this newfangled silicon stuff and now we have entered the world of integrated circuits that really do the work. This photo of one of the first silicon integrated circuits shows a relatively clumsy design layout but in the late 1950s, it was state of the art.

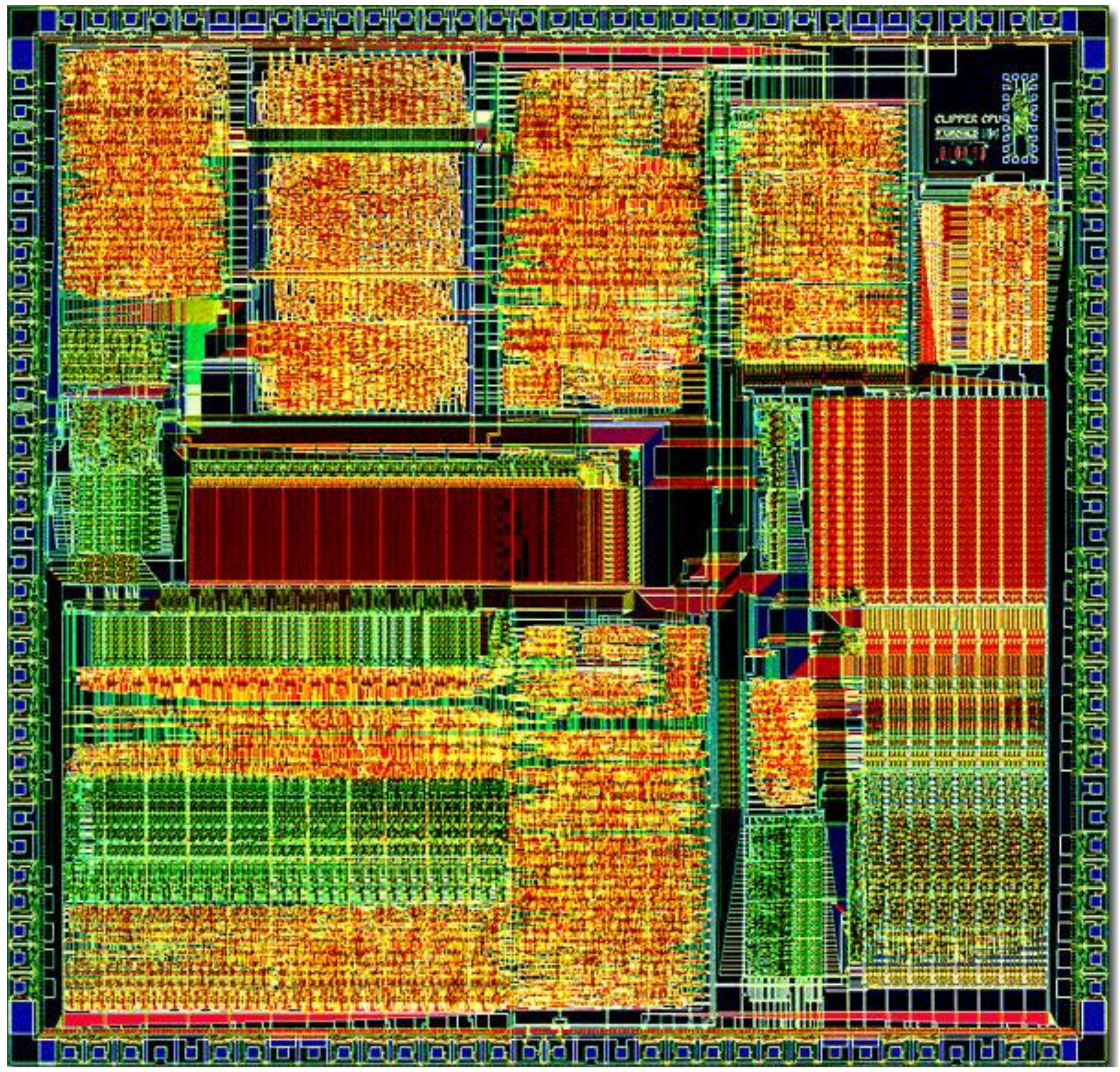


Today's integrated circuits are laid out a good deal "cleaner".

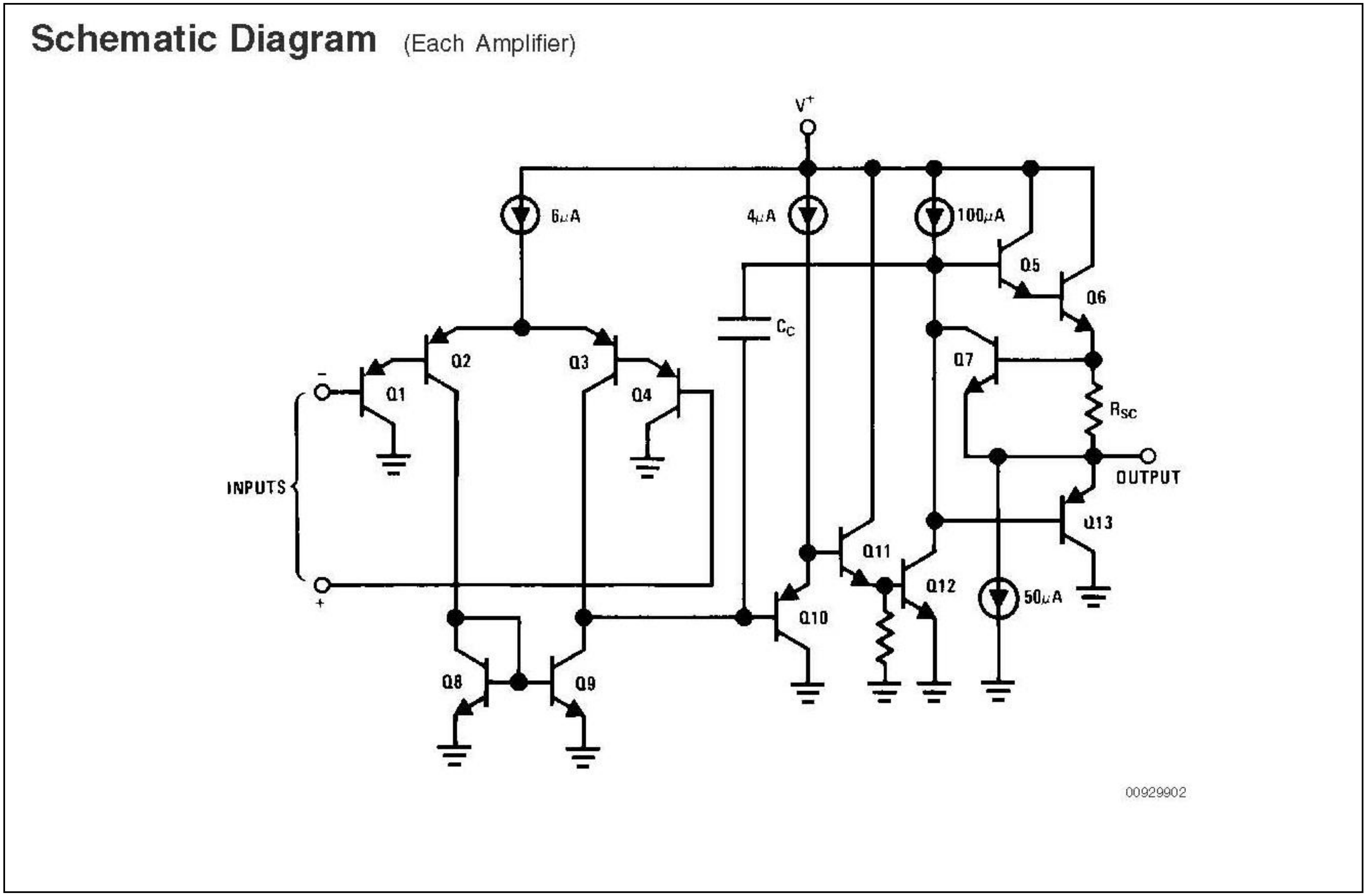
For a good look at what chip layout artists do with too much time on their hands, visit

http://micro.magnet.fsu.edu/creatures/index.html

and scroll down half a page to the silicon zoo inmates.



Here is the schematic diagram of a "typical" op-amp. Note that Q1/Q2 and Q3/Q4 vaguely resemble the setup of Tr1 and Tr2 in our original "diff-amp" circuit above. The maximum gain (called the "open loop" gain is something on the order of 300,000.



Let's take a look at what an "op-amp" can do for us. Open the link below

http://www.ti.com/general/docs/lit/getliterature.tsp?genericPartNumber=lm324-n&fileType=pdf

Note on page 1 of the "features" there are words about "compensation" or "temperature compensation. They have the temperature problem down to a fare-thee-well.

Note also that there are FOUR of these amplifiers in a single package. Less than two bits for the whole package in small quantities -- less than 7¢ an amplifier.

Go to page 13 of the data sheet. Pages 13 to 22 show the many things that you can make with your op-amp and this collection just barely scratches the surface. Note particularly on page 15 in the upper right corner the "power amplifier" shown. Let's make a 50¢ power amplifier in lab today!!!!