

Engineers improve on the computer's topological diagram, using a light-pen

Computer in the microcircuit design room

Engineer's mechanical aide indicates ability to speed the layout and manufacture of integrated circuits

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In designing an integrated circuit, many an engineer has spent days positioning areas of different kinds of semiconductor materials. Now there are signs that computers can speed the process, thereby cutting costs of producing complex microcircuits.

If scientists of the Norden division of the United Aircraft Corp. are correct, the circuit designer may one day have a fast, accurate mechanical aide — one that can obey specific rules for locating all the p-n junctions and interconnections, display the resulting design on a cathode-ray tube, and follow designer's subsequent suggestions for improving the circuit.

The engineer's role may evolve toward that of a computer supervisor.

In the Air Force-sponsored program in Norwalk, Conn., which began only seven months ago, the Norden researchers successfully applied computer techniques to the two most time-consuming phases of linear microcircuit production: design analysis and mask layout.

The major part of the cost of a nonstandard microcircuit, such as a 100-component, six-watt servo amplifier, is in preparing a design capable of good integration and transferring this design to the best possible topological layout in a silicon chip. "Topological" refers here to the arrangement of p-n junctions, which define the active and passive zones of the crystal, and to the interconnections on the oxide surface, which complete the electrical network.

The missing breadboard — The flow diagram (bottom, page 102) shows how the computer is used in the Norden program.

When an engineering problem arrives, a designer prepares a preliminary basic circuit. The design is then fed into the computer, which makes a complete electrical analysis of the design and equivalent circuit, thereby eliminating the need for breadboarding. Norden has developed programs permitting a-c, d-c and transient analyses in 28 minutes that would normally take several man-months.

The next step is mask layout—deciding where the components should be placed on the crystal, how they should be connected, and what fabrication processes should be used. The goal is maximum yield and performance using a minimum area of crystal and as few interconnections and cross-overs as possible.

In the past the mask designer was guided by an informal set of topological rules accumulated from previous experience. Now these rules have been expanded and organized so that design criteria, constraints and degrees of freedom can be specified in a language that can be handled by a digital computer.

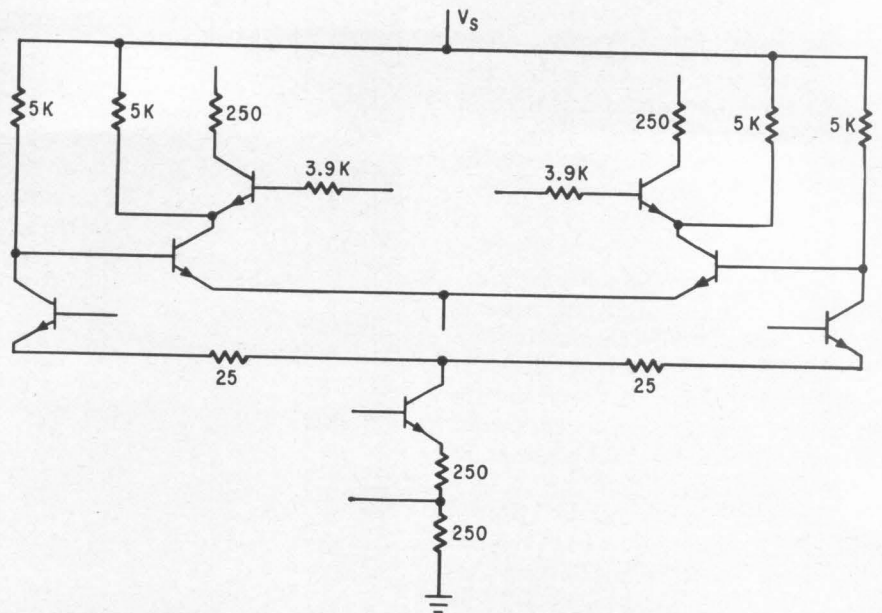
For design by computer, the leads from every element are tabulated, as are the external points and the nodes connecting three or more points of the circuit. The computer searches this list for the reference cycle—the closed loop containing the largest number of circuit elements. The computer then constructs an initial topological layout by arranging the components of the reference cycle into a rectangle and distributing the various component appendages along the rectangle according to previously programmed rules governing the spacing of circuit elements and interconnections.

Commands for the computer —

Several hundred instructions have already been developed for the computer. Eventually there will be thousands to cover all possible manufacturing processes. Typical instructions are:

“Break the circuit at the most negative potential and tie into the

“Find a line or point of sym-
isolation moat.”



Two-strobe sense amplifier, designed with computer techniques into a single silicon chip

metry and place symmetrical circuit elements around it.”

“Keep sensitive elements away from regions of power dissipation.”

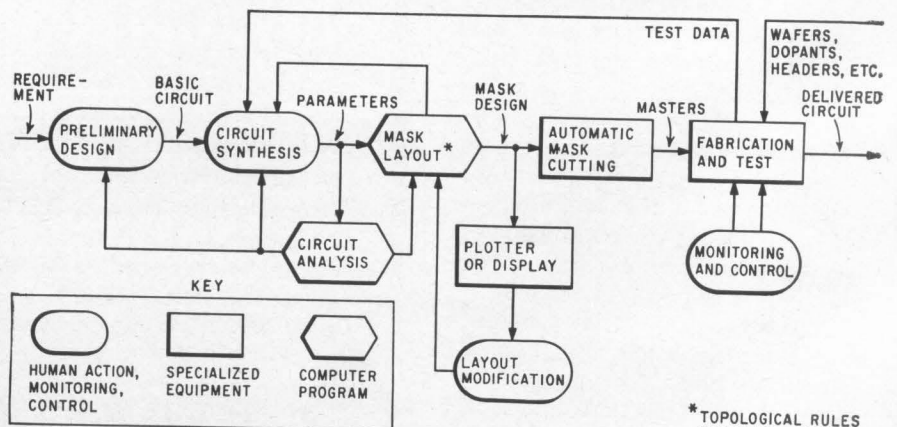
When the computer finishes its calculations, the resulting topological diagram is displayed on a cathode-ray tube. From the display, it may be evident to the mask designer that some space has been wasted or that other elements should have been added. He can reshape and reposition the elements in any way with a light pen—a small photocell. The technique is similar to that used in the Sketch-pad program at the Lincoln Laboratory of the Massachusetts Institute of Technology (Electronics, May 17, 1963, p. 16). The computer will display the consequences of the changes, as determined by the design rules

built into the computer’s program.

Broader role for automation —

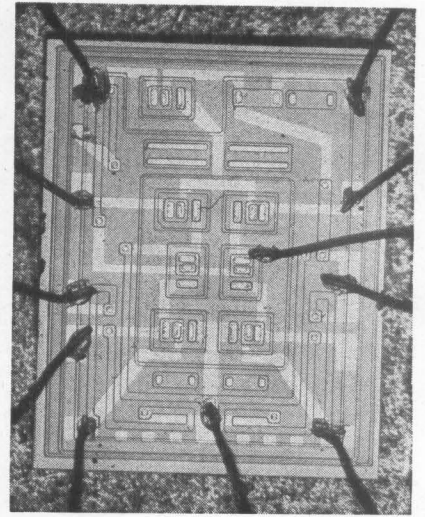
Ultimately, Norden expects automation to play a role not only in mask-cutting and manufacture, but also in complete circuit synthesis and analysis from a transfer function. Because it would depend on geometric considerations rather than on particular manufacturing processes, such a system also would have great flexibility, and ability to quickly reproduce existing circuits that might have been lost or destroyed. Such a system might only be 3 to 5 years off.

Norden scientists have used their design instructions to build a basic integrated circuit that could be either a two-strobe sense amplifier or a two-stage differential amplifier, depending on the final interconnection pattern. The differen-



* TOPOLOGICAL RULES BUILT INTO PROGRAM

Hexagons show where computer techniques fit into Norden's design and manufacture of microcircuits



Two-stage differential amplifier was designed with computer techniques. Note the arrangement of circuit elements about a vertical line of symmetry

tial amplifier (see photo) has an internal common-mode feedback rejection of about 100 db and a power-supply rejection of about 40 db. Depending on external resistor ratios, signal gain can be adjusted from one to 1,000. The stabilized feedback amplifier is flat to about 20 Mc and rolls off 12 db per octave.

The sense amplifier (see circuit diagram) has an over-all gain of 200. Both amplifiers use aluminum interconnections and leads, and consequently have shelf storage in excess of 350°C.

These amplifiers were built according to the flow chart accompanying this article. Circuit analysis was done by the computer, but the topological rules were applied manually. However, other amplifier mask designs have been carried out on the computer. One design cut the size of a 61-by-70-mil sense amplifier to 35 by 51 mils.

Norden believes it has shown that automated design for the manufacture of microcircuits is practical. Future work will be aimed at applying these concepts more fully. The project is conducted in Eugene Tatom's solid-state engineering section. Dr. Melvin W. Aarons, chief of the research and development branch of solid-state engineering, is project engineer. The study is sponsored by the Manufacturing Technology Division of the Materials Laboratory at Wright-Patterson Air Force Base, Ohio.