Integrated Circuits Celebrate Thirty!

By Gina de Miranda of Texas Instruments in Dallas

T'was 30 years ago that Texas Instruments' engineer Jack Kilby demonstrated the first working IC. Since his early invention, ICs have become smaller in size, greater in capability, and lower in cost, allowing you systems once confined to science fiction.

Due in part to the IC, the electronics industry has grown from $25 billion in 1960 to nearly $500 billion. This growth is projected to reach $900 billion by the mid 1990s. To accomodate the market's needs, the latest ICs have reached densities in the megabit range and require geometries of 1-micron and below.

After transistors replaced vacuum tubes, the world searched for a method to connect configurations of components inexpensively. Kilby's IC offered a solution to this problem.

Kilby wrote in an article for *IEEE Transactions* "On Electron Devices" in 1976, "The first electronic equipments were composed of a few dozen components and could be readily assembled by hand-soldering techniques. Each component was manufactured separately by a process optimized for the purpose. As electronic equipment became more complex, shortcomings in this procedure began to appear. The cost of the equipment increased more rapidly than component count, and equipment reliability suffered a corresponding decrease."

In 1958, Kilby moved to Dallas to work for Texas Instruments Semiconductor-Components Division. At that time, TI was exploring microminiaturization and had a contract from RCA to develop the Micro-Module concept. That approach entailed creating discrete components of uniform size and shape with built-in wiring.

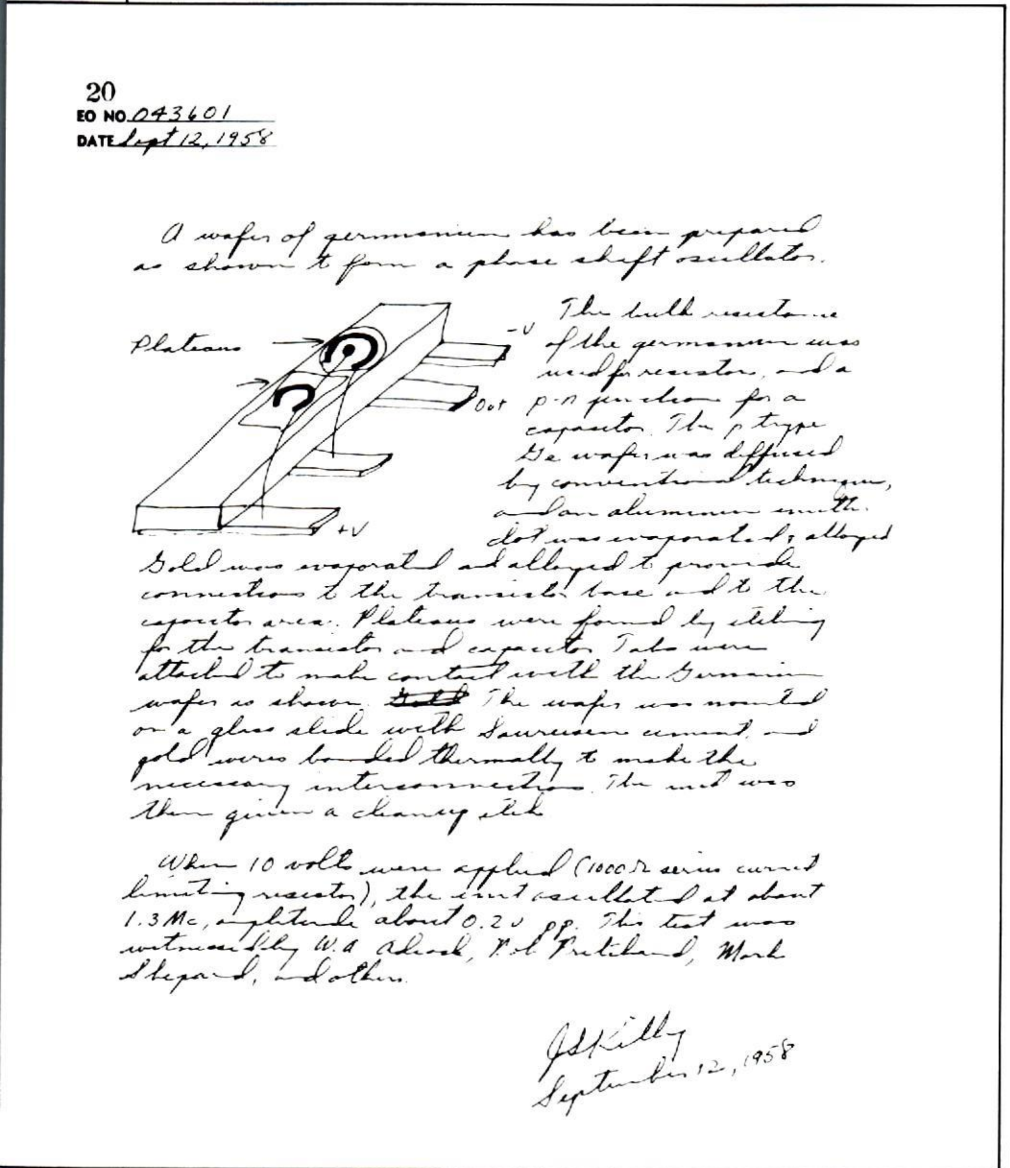
The modules could then be snapped together to form circuits, eliminating the need for wiring the connections.

Kilby disliked the module approach because it didn't address the problem of large quantities of individual components in elaborating circuits. So he looked for alternatives.

Rather than reworking conventional design, Kilby reexamined the problem. He later said, "I began to feel that the only thing that a semiconductor house could make in a cost-effective way was a semiconductor.

"Further thought led me to the conclusion that semiconductors were all that was really required—that resistors and capacitors [passive devices], in

Dinosaur or prehistoric IC?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A wafer of germanium has been prepared as shown to form a phase shift oscillator.

Plateaus
-V
Out
+V

The bulk resistance of the germanium was used for resistor, and a p-n junction for a capacitor. The p type Ge wafer was diffused by conventional techniques, and an aluminum emitter dot was evaporated, alloyed. Gold was evaporated and alloyed to provide connections to the transistor base and to the capacitor area. Plateaus were formed by etching for the transistor and capacitor. Tabs were attached to make contact with the Germanium wafer as shown. The wafer was mounted on a glass slide with Sauereisen cement, and gold wires bonded thermally to make the necessary interconnections. The unit was then given a cleanup etch.

When 10 volts were applied (1000 Ω series current limiting resistor), the unit oscillated at about 1.3 Mc, amplitude about 0.2 v pp. This test was witnessed by W.A. Adcock, P.L. Pritchard, Mark Shepard, and others.

JS Kilby
September 12, 1958

A page taken from Kilby's actual working notebook.

particular, could be made from the same material as the active devices [transistors].

"I also realized that, since all of the components could be made of a single material, they could also be made *in situ*, interconnected to form a complete circuit. I then quickly sketched a proposed design for a flip-flop using these components. Resistors were provided by bulk effect in the silicon, and capacitors by p-n junctions."

BREAKING THROUGH

Encouraged by the results of a preliminary test, Kilby set out to build an integrated circuit. Using a sliver of germanium mounted on a glass slide, he built a phase-shift oscillator. On September 12, 1958, he connected a power source to his device and applied 10 volts.

A sine wave flickered across the screen of a nearby oscilloscope. The age of the IC had begun.

Kilby's breakthrough was followed by IC computers in 1961. The team headed by Kilby created this computer for the US Air Force.

The computer, which was 6.3 cubic inches in volume, weighed 10 ounces and had fewer than 600 parts. It proved that ICs were practical and that they had the potential for making a broader impact. Built conventionally, the same device weighed 480 ounces, had a volume of 1,000 cubic inches, and consisted of 8,500 individual components!

Despite the promise that this new device held for making lighter and less expensive electronic products, it met with lukewarm interest. Designers did not feel comfortable with the idea that their "components" were too small to see or work with.

Long accustomed to hands-on design work in which components could be plugged in and pulled out freely, engineers were unsure how to work with this new invention too small to take apart.

Persuading the industry would require the appropriate demonstration vehicle. With this thought in mind, TI's President Pat Haggerty challenged Kilby to create a calculator that would be powerful and yet small enough to fit in a shirt pocket.

In 1967, they demonstrated a hand-held calculator capable of the basic four functions. The ability to perform multiple calculations quickly was popular. More importantly, the possibilities of the IC were becoming more apparent.

The next 30 years bear witness to the acceptance of the IC. Not only have ICs been accepted, they have become specialized. More functions are captured in silicon. Unique functions such as artificial intelligence, digital signal processing, Video Random Access Memory and voice synthesis are some application of the newer ICs. They are precursors of things yet to come.

All thanks to Jack Kilby who just wouldn't rest until he solved the puzzle! CEE

Quick quiz tests IC smarts!

1. Who's responsible for the planar transistor?

2. What do we mean by *RCTL*?

3. Who developed dielectric isolation?

4. What missile flew with early TI ICs?

5. Who made the 1st commercial microprocessor?

(1. Fairchild's Jean Hoerni; 2. Resistor-capacitor-transistor logic (the basic circuit scheme of antique ICs); 3. Uri Davidsohn of tunnel diode fame; 4. Minuteman; 5. Intel's Ted Hoff with his 4004 CPU chip.) CEE