Lars Lunn

FAIRCHILD SILICON TRANSISTORS

FAIRCHILD SEMICONDUCTOR CORPORATION • *Affiliated with the Fairchild Camera and Instrument Corporation*

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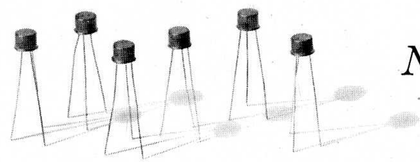
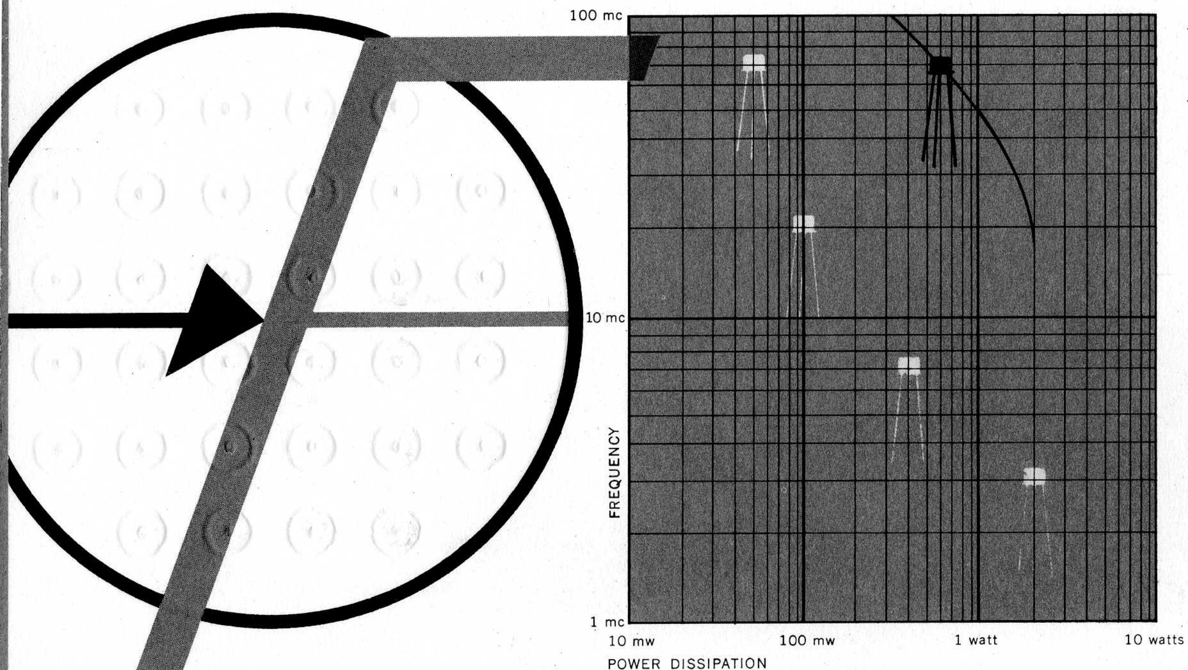


New performance, uniformity and reliability achieved by the



A higher order of magnitude in silicon-transistor performance is now available. It is a direct and logical result of Fairchild's quantity production by the solid-state diffusion process.

To the circuit designer and systems engineer, the resulting performance parameters can upgrade overall electronic-system capabilities, further reduce equipment size and improve its ability to cope with severe environments.

Switching speeds in millimicroseconds from silicon transistors make possible the design of compact computing machines with higher switching rates than heretofore.

Cut-off frequencies in the 100-megacycle range become readily attainable in silicon transistors allowing the further transistorization of communications equipment intended for severe environments.

Power dissipation as high as 2 watts in the Jetec 30 case. Also saturation resistance is lower resulting in higher current capability at any power level. These characteristics afford opportunities to simplify high-performance circuitry.

N-P-N or P-N-P silicon transistors can be made with similar characteristics such as current gain, rise times, leakage current and general performance. After nominal development time, this choice can be offered wherever it is warranted by sufficient demand.

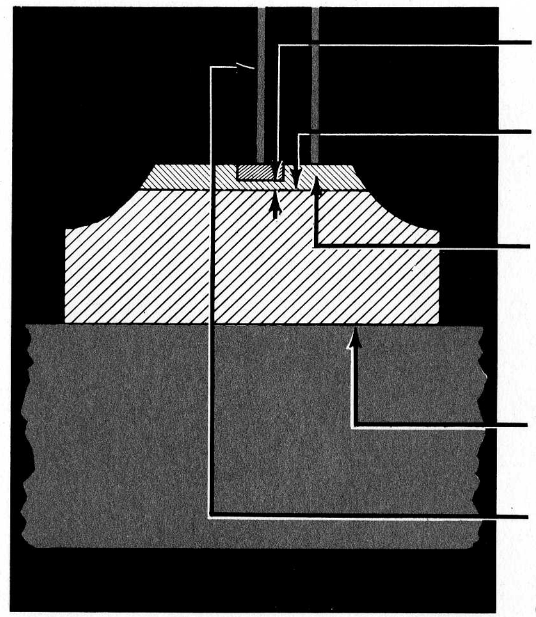
Uniformity is inherently superior because of the simplified crystal-growing requirements and controllable means by which the junctions are created and connections made.

solid-state diffusion process

INSIDE REASONS FOR A TREND

The solid-state diffused silicon transistor has superior performance because it is a distinct departure in construction. The diffusion process has little in common with other processes used in the manufacture of silicon transistors. Yet the resulting characteristics are so rewarding that every major manufacturer of silicon transistors is engaged either in laboratory exploration or preliminary production of diffused transistors — regardless of which techniques have been used for the prior units in their product lines. By offering diffused transistors in production quantities, Fairchild is a leader in a growing trend.

As the accompanying cross section shows, each performance parameter of Fairchild's silicon transistors relates to the controllability of dimensions and impurity distribution in the diffused silicon die:



ELECTRICAL ADVANTAGES

High-frequency capability • *Frequencies of the order of 100 megacycles require a graded base and a base width of less than 1/10,000th inch. The only way this has been done successfully in silicon is by the solid-state diffusion process.*

Lower capacitance • *At the base-collector junction, a low impurity gradient occurs as a result of diffusion. The effect is the same as spreading the plates of a condenser. The reduced capacitance achieved this way further improves high-frequency characteristics.*

Lower base spreading resistance • *A high impurity density near the surface reduces base resistivity exactly where such a reduction has the most effect on total base spreading resistance. The impurity gradient results in high base resistivity at the collector junction where it has a favorable effect on capacitance and adds little to total resistance.*

MECHANICAL ADVANTAGES

Lower thermal resistance • *The diffused transistor's structural configuration permits the collector to be soldered directly to the case. Thus the heat generated by power dissipation is readily conducted to the heat sink.*

Ruggedness • *Another advantage in soldering the transistor die directly to the header, under shock and vibration nothing but the tiny masses of base and emitter leads can exert any forces on the connections. The favorable configuration of the diffusion transistor keeps these well within safe limits.*

THE DIFFUSION PRINCIPLE

When statistical probability takes place at a molecular level, the results are a certainty

A glass of water and a drop of ink tell half the story

Molecular movement diffuses the ink with statistical uniformity throughout the water. But this takes place far too quickly to permit a controlled arresting of any intermediate stage.

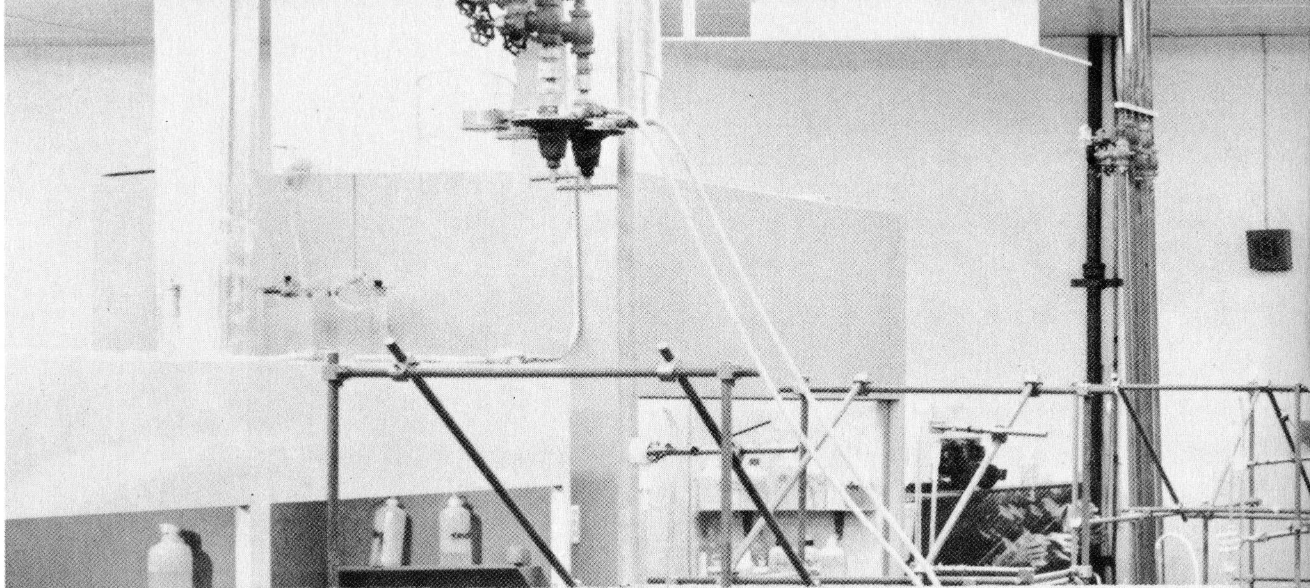
In a block of ice diffusion takes place slowly...

So slowly in fact that it might take a million years for the drop of ink to diffuse throughout. At any stage in time, the distribution of the diffused ink would for practical purposes be completely fixed and stable.

In a silicon transistor diffusion can be rapid, controlled, and then stable

Silicon is heated to as much as 1000° Centigrade higher than its ultimate operating temperature as a transistor. Though it is still a solid, diffusion takes place rapidly. The desired impurities for a semiconductor have appreciable vapor pressure at this temperature. They impinge on the silicon surface as gas molecules and diffuse into the crystalline lattice with statistical uniformity and a known rate of inward travel.

Reducing the temperature by only 100° C. virtually stops further impurity movement. The maximum operating temperature is 1000° C. below diffusion temperature. Impurity movement is completely stopped. The silicon is like the block of ice.



APPLICATION TO A MANUFACTURING PROCESS

Though simple in principle, the solid-state diffusion process has numerous variables when applied to transistor manufacture. A large body of accumulated knowledge is required. An ultimate in cleanliness is needed. However, once the process variables have been fixed for a particular device, they are readily repeatable to manufacture quantity lots with excellent uniformity.

CRYSTAL GROWING

The solid-state diffusion process somewhat simplifies the problem of crystal growing. It allows the crystal pulling to be done at constant rate and without making additions to the melt. Desired impurities are present at the beginning. By growing its own crystals, Fairchild is able to exercise a degree of care that is producing an unequalled level of crystalline perfection. And with this first vital step done in our own plant, it is kept under close observation both for production and for continuing research.

CUTTING AND LAPPING

This step too is more subject to good control in the diffusion process. Wafers are rough cut from the crystal with diamond saws and are lapped to finished thickness and smoothness. Though impurity density and orientation of the crystalline lattice are critical, the problems of laying out the transistor dice on the wafers are much reduced by comparison with older processes.

DIFFUSION

This key operation takes place in several stages, each controlled by the three variables, time, temperature and furnace atmosphere.

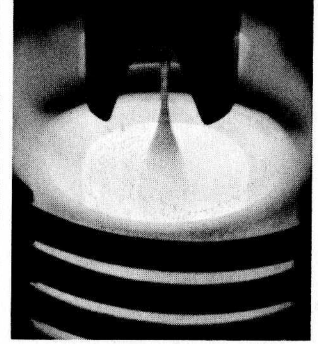
At the beginning the crystal wafer has a uniform distribution of the collector impurity. The portion not reached by the diffused impurities ultimately becomes the collector body of each die.

The base is diffused first. In an N-P-N device, the "P" impurity is introduced into the diffusion-furnace atmosphere as a gas in a continuous flow. Temperature and time determine very precisely the distance of penetration, hence the depth of the base-collector junction. Desired variations in the impurity density through this layer can be achieved by variations in the time-temperature programming of the diffusion run and impurity concentration in the furnace. Since the times involved are relatively long, they permit a high degree of control.

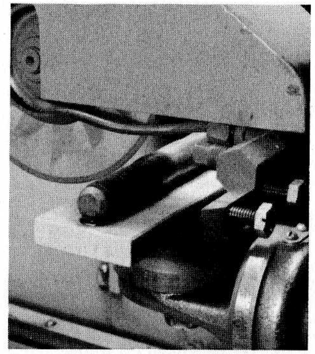
The emitter is a second diffusion performed after a necessary masking operation that shields all but the correct emitter location. Control of this second diffusion is similarly precise, making it practical to control base thicknesses of two microns with a variation of less than 10%.

FURTHER STEPS

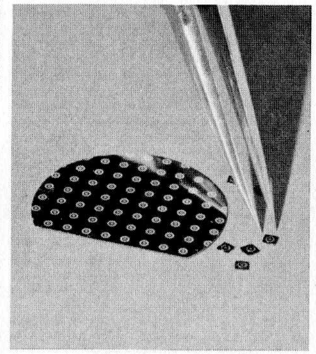
Beyond diffusion there are many further operations necessary to produce a finished, packaged transistor. Contacts are plated on the wafer. The wafer is separated into individual dice. These are soldered to the header. Fluxless solder used in this step is a vital precaution against contamination. Leads are then affixed. A washing step and a vacuum bakeout remove any loose or volatile impurities. Finally the can is welded to the header permanently sealing the transistor.



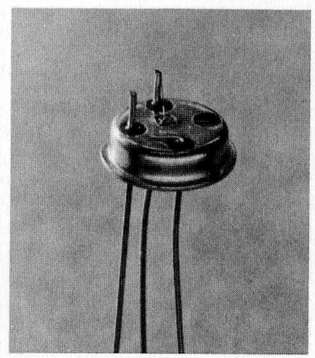
CRYSTAL GROWING



CUTTING CRYSTAL INTO WAFERS



FINISHED WAFER AND DICE



TRANSISTOR BEFORE CAPPING

DIFFUSION FURNACES AT FAIRCHILD

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GORDON D. MOORE, PhD.
Head of Engineering

JEAN A. HOERNI, PhD.
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JAY T. LAST, PhD.
Senior Physicist

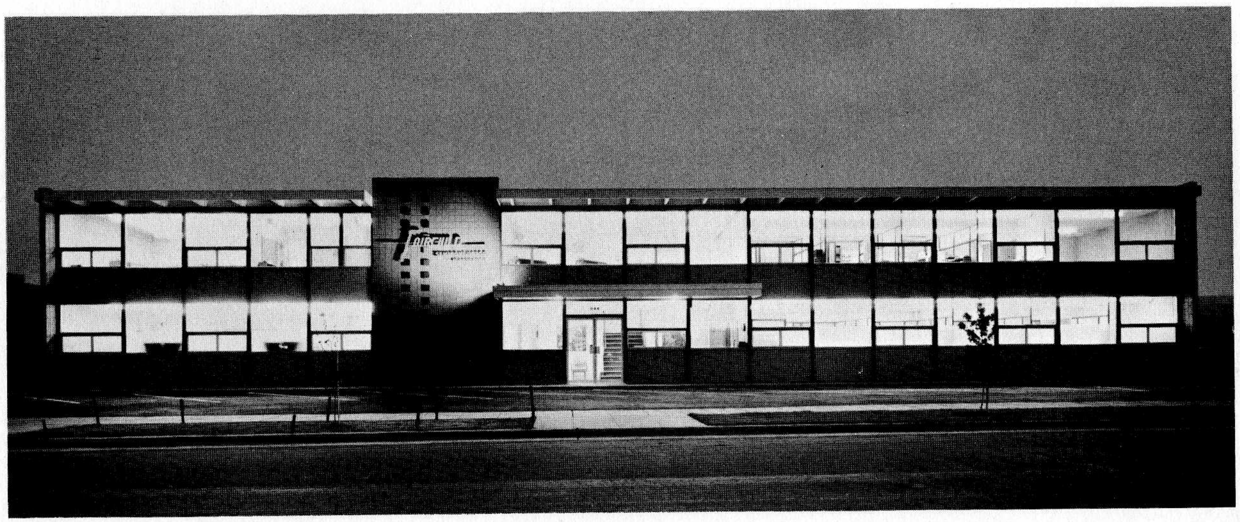
THOMAS H. BAY, BS.
Marketing Manager

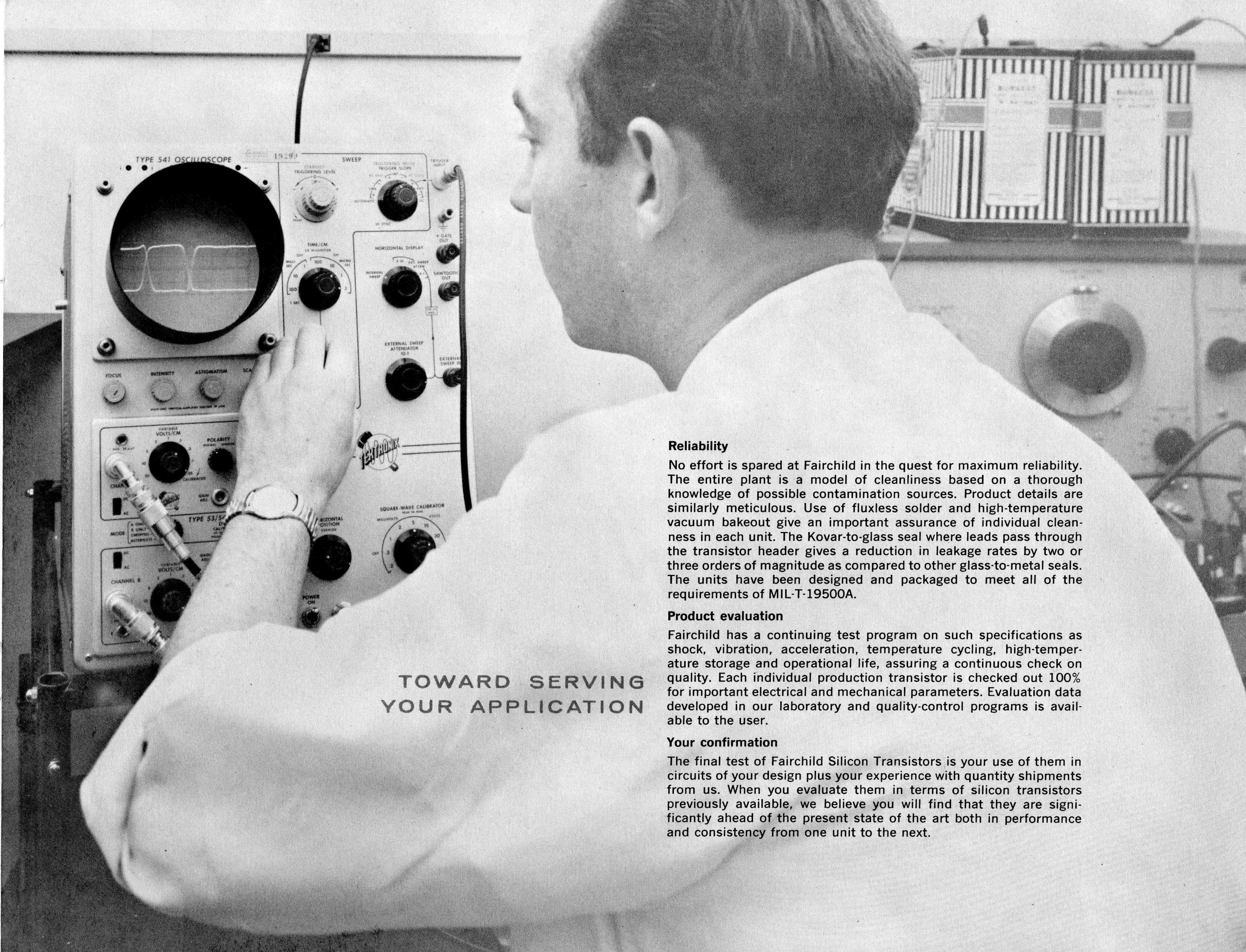
EUGENE KLEINER, BME, MIE.
Production Manager

JULIUS BLANK, BME.
Chief Engrg. Services

HISTORY

The Fairchild Semiconductor Corporation was organized by a team of scientists, engineers and production specialists uniquely qualified in every phase of semiconductor work. They had previously worked together for 1½ years. The company was formed with a well defined goal and a large fund of specialized knowledge. The diffusion process for silicon-transistor manufacture had been slow to get started elsewhere — perhaps because Germanium transistors had preceded silicon and had not been amenable to practical diffusion techniques. Here was an opportunity. To make an all out assault on the problem, the group obtained backing and affiliation with the Fairchild Camera and Instrument Corporation. This permitted an ample period of further research, equipment design and pilot production. The result was a finished product and a capacity to meet delivery schedules at the time of the first product announcement.





TOWARD SERVING YOUR APPLICATION

Reliability

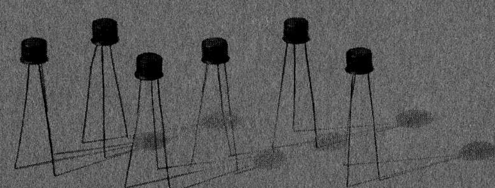
No effort is spared at Fairchild in the quest for maximum reliability. The entire plant is a model of cleanliness based on a thorough knowledge of possible contamination sources. Product details are similarly meticulous. Use of fluxless solder and high-temperature vacuum bakeout give an important assurance of individual cleanness in each unit. The Kovar-to-glass seal where leads pass through the transistor header gives a reduction in leakage rates by two or three orders of magnitude as compared to other glass-to-metal seals. The units have been designed and packaged to meet all of the requirements of MIL-T-19500A.

Product evaluation

Fairchild has a continuing test program on such specifications as shock, vibration, acceleration, temperature cycling, high-temperature storage and operational life, assuring a continuous check on quality. Each individual production transistor is checked out 100% for important electrical and mechanical parameters. Evaluation data developed in our laboratory and quality-control programs is available to the user.

Your confirmation

The final test of Fairchild Silicon Transistors is your use of them in circuits of your design plus your experience with quantity shipments from us. When you evaluate them in terms of silicon transistors previously available, we believe you will find that they are significantly ahead of the present state of the art both in performance and consistency from one unit to the next.



Products of the Fairchild Semiconductor Corporation are sold through representatives covering all of the United States. Technical inquiries will also be served by correspondence from the Palo Alto main office.

FAIRCHILD
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