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THE 555 IC PROJECT BOOK

ROBERT J. TRAISTER

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To long-time friends, Kirk and Betty Stratton, who have been a source of inspiration at times when it was greatly needed.

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Introduction

How many different circuits, devices, and equipment has the 555 chip been an integral part of? The actual quantities are unknown, but certainly number in the hundreds of thousands to date. The numbers are increasing every day, as the 555 and the 556, its dual-circuit counterpart, are still being used in the most modern and sophisticated offerings available from the electronics industry. In this age of rapidly accelerating industry advances in the electronics field, it is unusual to find a component like the 555 that has not been improved upon and replaced by these advancements. The 555 has been used in circuits that compare with the old hourglass egg timers to the most sophisticated frequency counters and computers.

The 555 does its job of outputting timing pulses, time delays, etc., and does this in a manner that is not only acceptable, but sought after by the manufacturers of sophisticated electronic equipment. It is a simple IC, as integrated circuits go. Most packages contain only eight external pins, but hidden in the recesses of that combination of plastic, metal, and silicon are more than 25 transistors, the same number of resistors, and a large sampling of silicon chip connections. If the 555 integrated circuit, which is less than ½ inch long and ¼ inch wide, were to be built using discrete components, the finished circuit would cost many times its present $1 price and would fill a space that might weigh a pound or more. All of these many components, however, are contained on a tiny silicon chip.

Because the 555 IC is a highly complex circuit contained on a single chip, it offers a myriad of possible applications. Amateur radio transceivers often use the 555 as a low-frequency tone source for tripping vhf repeaters. Combinations of these circuits are used in pulse devices to bring about delays that are accurate to less than a microsecond. Computers use the 555 to generate internal timing pulses. You can even use this circuit to time the correct cooking interval for a hard-boiled egg.

This book includes 33 projects which use this IC, or which are designed to power it and deliver its output in a modified form. The circuits cover many applications and may be used for entertainment, experimentation, and even as building blocks in highly sophisticated electronic equipment.

The 555 is an ideal chip to begin building with integrated circuits. Although it will do many different things in a highly efficient manner, it is probably the least expensive chip available today. You can pick one up from most hobby stores for about a dollar. By going through electronics wholesale outlets, you may even purchase a batch of them for less than 50 cents each. This eases the mental strain on the beginning builder, who is often afraid of experimenting with IC circuits due to the high cost and replacement difficulty associated with many other chips. If you burn up a 555, so what? It's only going to cost you a dollar or so to replace it. The 555 is quite forgiving, however, and will tolerate some circuit errors and component value deviations that would quickly fry some of its temperamental and highly delicate counterparts.

I think you will find the basic technical discussions in this book to be quite informative and the projects to be fun, easy to build, and quite useful. Exotic ICs may come and go, but the 555 has proven itself time and again over the past decade. It will certainly be around a decade from now.

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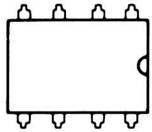
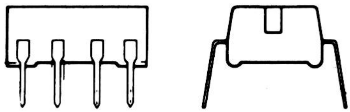


Chapter 1



Microelectronics

Microelectronics is the process by which microscopic-sized components are fabricated on silicon chips. The term is also used to describe the building of extremely tiny circuits using transistors, diodes, integrated circuits, and other components. This book is the result of the great strides taken in microelectronics, although it deals with an integrated circuit that has been with us for many years.

The 555 integrated circuit is called a timer, but it can be used in many electronics applications. It has been used by the electronic industry since its inception. Although the chip is quite old by now, it is still incorporated in some of the most sophisticated electronic devices currently being released.

I often compare the 555 timer with the old 6146 vacuum tube, which was developed several decades ago to fill the need for a multi-purpose oscillator/amplifier which would work within the high frequency spectrum. This tube filled a very large gap between extremely low powered tubes and those of highpower outputs. It was improved upon with the 6146A and later by the 6146B, and by now, there may even be C and D models as well. The point here is that while this tube was developed many years ago, it has not become obsolete, as have so many which were produced in the same era.

The same can be said of the 555 integrated circuit. It is available from almost every manufacturer of solid-state electronic components, and while improvements have been incorporated due to the strides taken by the microelectronics industry, it is still sold in a form that is nearly identical to the original chip. Microelectronics is improving life in general by incorporating whole complex circuits in tiny packages, but it's hard to improve upon perfection, and the 555 certainly approaches this state.

Microelectronics or microminiaturization, as it is sometimes called, is an advancing technology in recent years of constructing electronic circuits and devices in extremely small packages. This is accomplished by many different types of techniques. Microelectronics is the result of many years of research and development in the field of electronics in an effort to meet the need for miniature circuits which perform the same functions as larger circuits. They are becoming increasingly more complex and miniature at the same time. Today, solid-state discrete devices and integrated circuitry have largely replaced the electron tubes which were used for many years in electronic systems. These, in turn are being replaced by medium and large scale integrated circuitry.

The ever-expanding field of microelectronics now encompasses many types of circuits, including thin-film, thick-film, hybrid, and integrated. All of these types of circuits are finding wide application in the fields of digital, analog and other types of electronics. Today, it is possible to produce a number of circuits on a single chip, which continues to increase the packaging density of circuits, while at the same time reducing size, weight, and the number of connections. Reliability, logistics, and system capability are also increasing rapidly.

An integrated circuit is one which combines all the elements of an electronic circuit on a tiny chip of silicon. The significance of this can be readily seen by comparing a J-K flip-flop circuit that used solid-state discrete components with the same circuit utilizing integrated circuitry. The first circuit (Fig. 1-1) requires many discrete elements, connections, seals and processing operations, each of which represents a possible source of circuit problems. If this circuit were instead integrated onto a single silicon chip, however, connections are drastically decreased because all circuit elements are intraconnected inside the package by means of a process known as vapor metalization.

This same circuit is shown in comparison to the previous one in Fig. 1-2. The result of this process is greater efficiency and

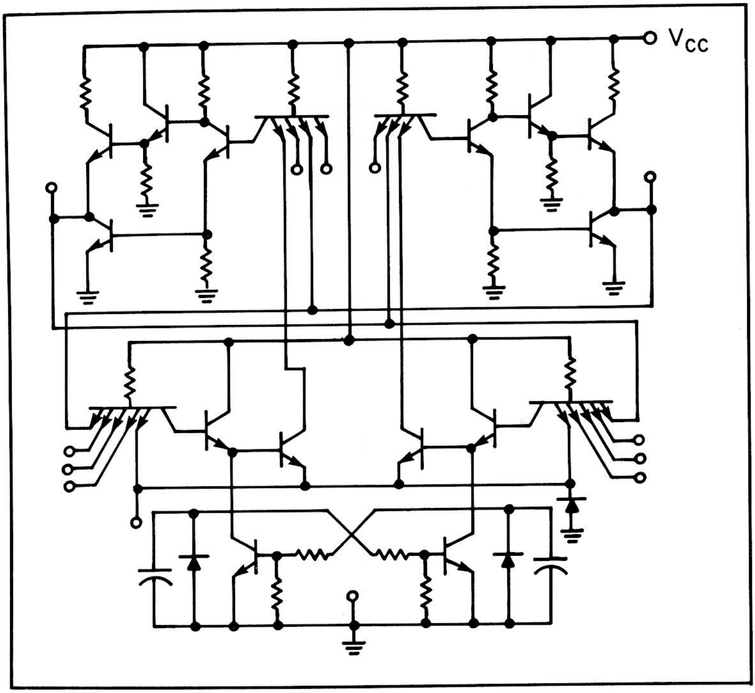


Fig. 1-1. Detailed schematic of the equivalent circuitry of a J-K flip-flop.

reliability and a reduction in the probability of malfunctions and thus, troubleshooting procedures. It can be seen that integrated circuitry has greatly aided the electronics industry as a whole.

The process of creating an integrated circuit is a bit complicated and requires careful manufacturing processes. Before the actual fabrication begins, the silicon crystal must be sliced into paper-thin wafers, as shown in Fig. 1-3. These wafers are then lapped and polished (only on the side that will be used for active elements). Only when special processing is involved is the back side of the wafer polished. Otherwise, it is left in the lapped state.

Lapping is done with an abrasive (usually aluminum oxide) until all visible traces of the saw cuts are removed. Only one side of the wafer is then polished many times with slurries of abrasive grits, with a grit of smaller size being used for each succeeding step. As a final step, the wafer is chemically etched to remove any irregularities in the surface that may have occurred during the polishing process.

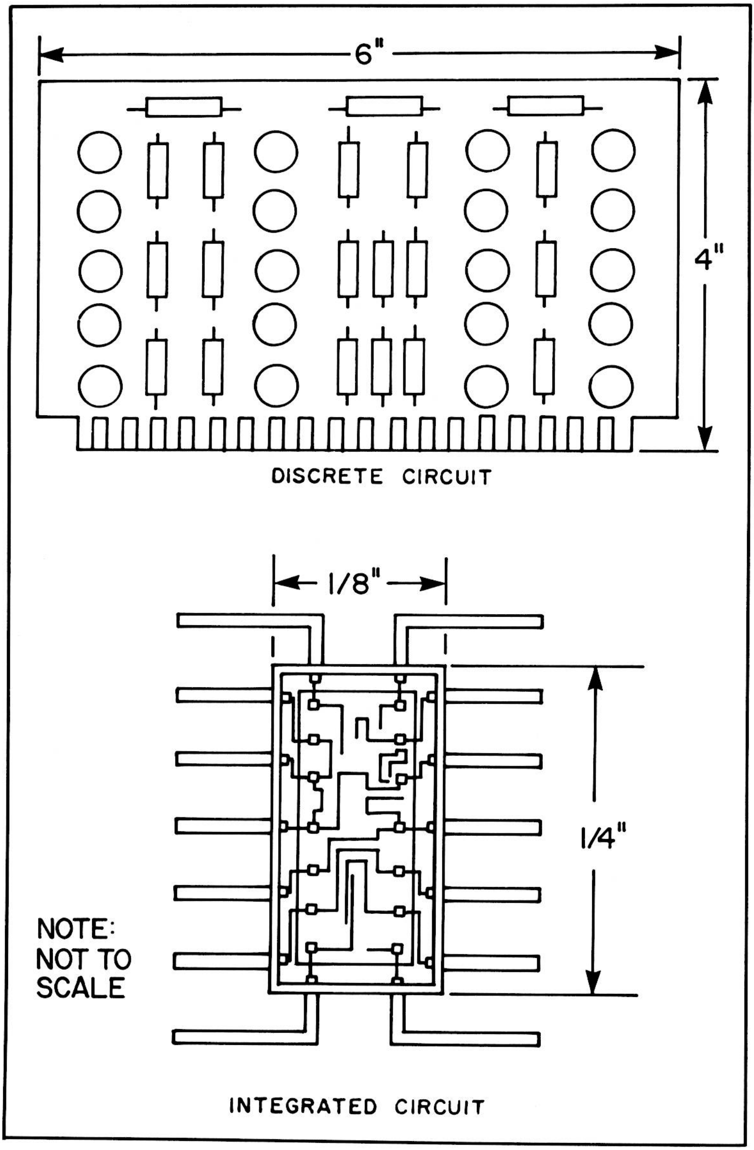


Fig. 1-2. Size comparison between a discrete and an integrated circuit.

The next step is the diffusion process, which begins with placing the highly polished silicon wafer in an oven containing impurity atoms. The oven is pictured in Fig. 1-3. The impurity atoms serve to yield the desired electrical characteristics. The concentration of impurity atoms diffused into the wafer is controlled by controlling both the temperature of the oven and the time the wafer remains in the oven. Once the wafer has been uniformly doped, the fabrication of semiconductor devices begins. In this manner, several hundred circuits can be produced simultaneously (Fig. 1-4).

FILM CIRCUITS

Film circuits differ from the integrated circuits discussed thus far, in that instead of being diffused into the substrate, components are layered on the substrate material (usually ceramic) by deposition, screening, etching, or a combination of

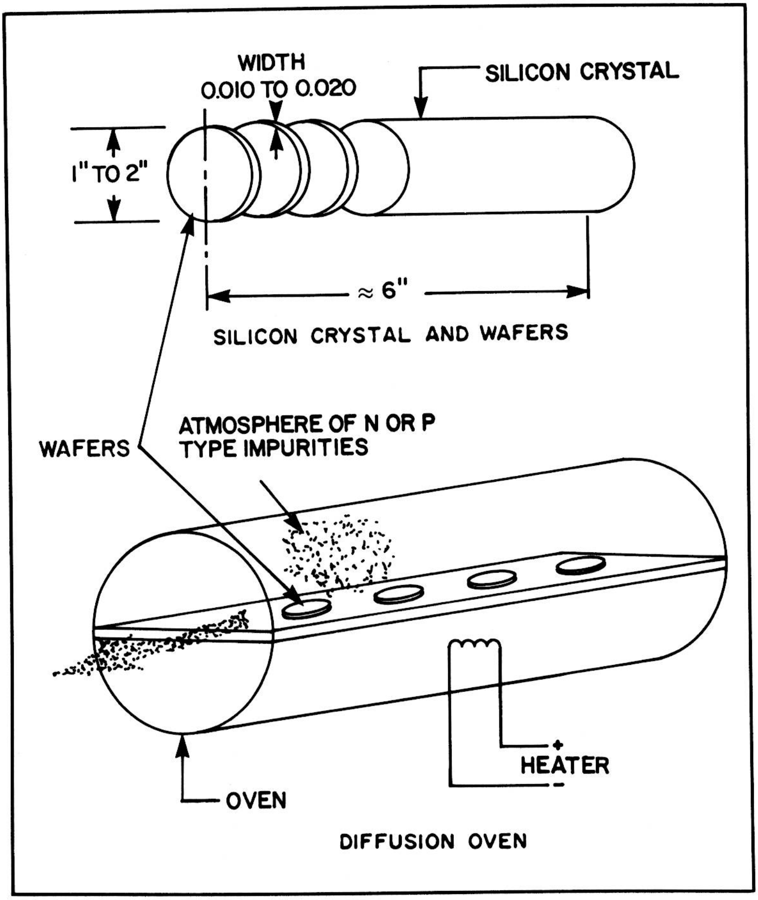


Fig. 1-3. The diffusion method of IC construction.

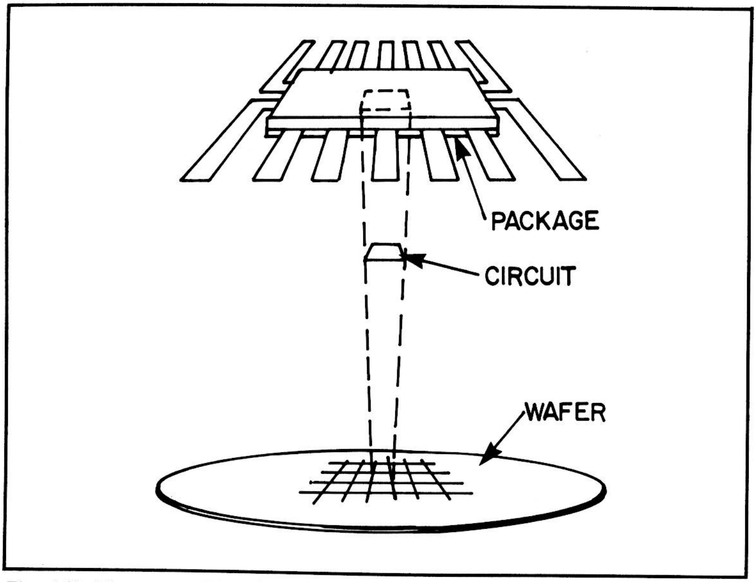


Fig. 1-4. The assembly of an integrated circuit.

these processes. Only passive devices are produced by this technique, since it does not lend itself to the production of active components. Active components are attached and interconnections between components made in much the same way as leads are bonded to integrated circuits or transistors.

HYBRID CIRCUITS

Hybrid circuits can be defined as those that are fabricated by combining two or more circuits types (i.e., film circuits and semiconductor circuits), or a combination of one or more circuit types and discrete elements. This is shown in Fig. 1-5. The main advantage of hybrid microcircuits over other microcircuits is design flexibility. These types of circuits find a great deal of application in low-volume and high-frequency circuits of a specialized nature.

Many elements and circuits are available for hybrid applications, such as discrete components which are electrically and mechanically compatible with integrated circuits. They can be used to perform functions supplementary to ICs and can be handled, tested and assembled with the same technology and tools. Complete circuits are available in the form of uncased chips (unencapsulated IC dice). These chips are usually identical to those sold as part of the manufacturer's regular production line. They must be properly packaged and connected by the user if a high-quality final assembly is to be the result. The circuits are usually sealed in a package to protect them from mechanical and environmental stresses. One-mil (.001″) gold wire leads are connected to the appropriate pins which extend out of the package to allow external connections.

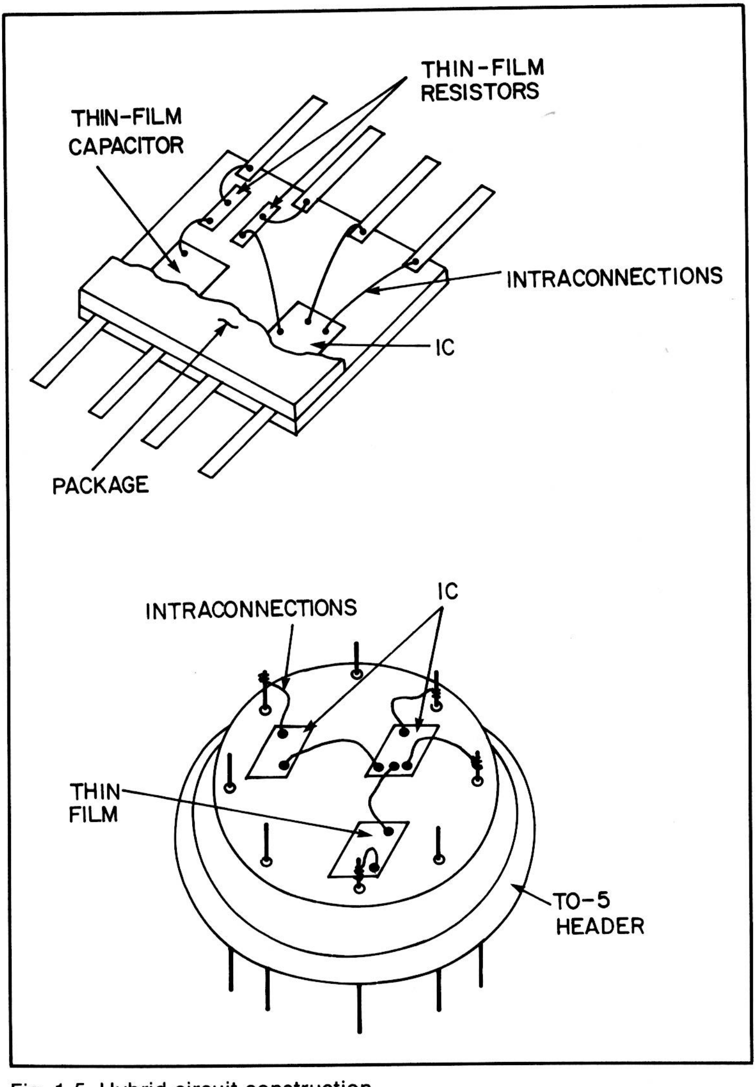


Fig. 1-5. Hybrid circuit construction.

MICROELECTRONIC DEVICE PACKAGING

Integrated circuit packages have evolved from the still-used transistor type (modified to include more leads), to the widely used flat pack, to the dual inline package (DIP). Generally, these packages are limited to 14 leads, but some configurations are available with many more. Packages with up to 160 leads are being developed for large-scale integrated devices.

MODIFIED TO-5 PACKAGE

Modified TO-5 is a term used to describe a packaging having the same general appearance as a standard TO-5 transistor package, but which has been modified by increasing the number of external leads and the dimensions of the package.

Modified TO-5 assembly methods are extensions of the techniques used in the production of standard transistor packages. Since the modified TO-5 package typically has 10 leads compared with the 3 or 4 leads of the standard transistor packages, its pincircle diameter is slightly larger (0.230 inch vs. 0.200 inch). The modified TO-5 package is shown in Fig. 1-6. Kovar, a nickel-iron alloy, is used for the leads and eyelet, and 7052 glass for the preform. The cover may be German silver, kovar, or nickel, but kovar is used most frequently because its coefficient of thermal expansion is similar to that of the glass preform, thus allowing a matched seal.

The glass preform and eyelet are assembled as shown in Fig. 1-6 and then sealed by fusion in a 1000° C oven. After it is

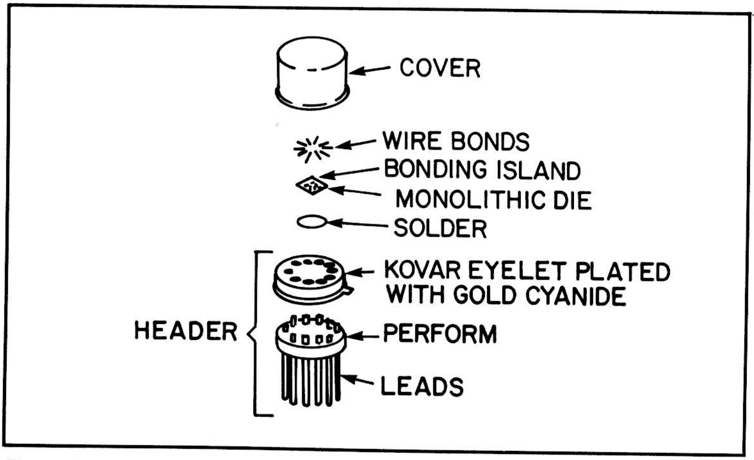


Fig. 1-6. Exploded view of the modified TO-5 package.

sealed, the entire assembly, called the header, is cleaned and the leads are clipped to the desired length. The header is then plated with 0.001 inch of gold cyanide. The IC die is bonded to the header by inserting a solder preform between the die and the header; placing a weight on top of the assembly, and heating the entire header to approximately 395° C so that the die, solder, and header are fused together.

Because the elements of integrated circuits (transistors, diodes, etc.) are so small, it would be impossible to attach wires directly to points in the circuit. For this reason, a series of relatively large bonding islands are placed around the edges of the die during its fabrication, and these are connected by metalization to appropriate points in the circuit. During packaging, the bonding islands are connected to the package leads by fine lead wires (0.001 inch to 0.003 inch). These wires may be either gold or aluminum and are attached by thermocompression or ultrasonic bonding techniques. As the final step in TO-5 packaging, the cover is welded to the header in a controlled atmosphere.

The modified TO-5 package can be either plugged into or embedded in a board (Fig. 1-7). The latter method is preferred, but whether the package is plugged in or embedded, the interconnection area of the package leads must not be impinged by other printed conductors on either side of the board. The plug-in method does not provide sufficient clearance between the pads to route additional circuitry, but when the packages are embedded, there is sufficient space between the pads (because of the increased diameter of the interconnection pattern) for additional conductors.

The 555 integrated circuit is normally housed in a small 8-pin DIP plastic package. It is occasionally seen, however, in a circular metal can arrangement using the TO-5 configuration. The same is true of the 556 integrated circuit, which is simply two 555s on a single chip. Most hobby stores, however, will carry only the DIP plastic package, which is pretty much standard for these timer ICs.

COMPONENT TESTING

For those individuals who have worked only with discrete components, there is bound to be a bit of hesitation about switching to integrated circuits. This is only because of the newness of these devices within their field of experience.