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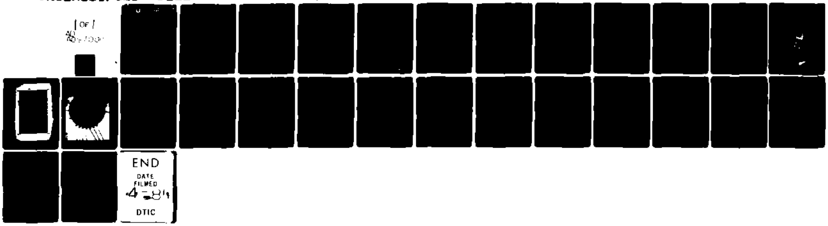

RESEARCH AND DEVELOPMENT TECHNICAL REPORT

DELET-TR-81-1

HYBRID MICROCIRCUITS, FABRICATION AND ASSEMBLY - STATUS, 1980

ISAAC H. PRATT
ELECTRONICS TECHNOLOGY & DEVICES LABORATORY

JANUARY 1981

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: DELET-TR-81-14	2. GOVT ACCESSION NO.: AD-A097000
3. RECIPIENT'S CATALOG NUMBER	Research and development
4. TITLE (and Subtitle): Hybrid Microcircuits, Fabrication and Assembly - Status, 1980.	5. TYPE OF REPORT & PERIOD COVERED: Technical Report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Isaac H. Pratt	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army Electronics Research and Development Command, ATTN: DELET-IA-T, Fort Monmouth, New Jersey 07703	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 1L1 62705 AH 94 0522
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Electronics Research and Development Command, ATTN: DELET-IA-T, Fort Monmouth, New Jersey 07703	12. REPORT DATE: Jan[redacted]81
	13. NUMBER OF PAGES: 22
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hybrid Microcircuits	Substrates
Thin Films	Resistors
Thick Films	Assembly Techniques

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report discusses materials and techniques now being used for the fabrication and assembly of hybrid microcircuits. Hybrid technology provides the means for assembling all major categories of electronics in relatively small enclosures to fulfill size requirements which cannot be met by more conventional packaging techniques. Analog and digital circuits as well as microwave modules are made in hybrid form. The design, fabrication and testing of hybrid microcircuits are included along with the present status of thin and thick film components and assembly techniques.

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HYBRID MICROCIRCUITS
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INTRODUCTION:

Hybrid technology provides the means for assembling all major categories of electronics in relatively small enclosures to fulfill system size requirements which cannot be met by more conventional packaging techniques. Analog and digital circuits as well as microwave modules are made in hybrid form. The enclosure contains an insulating substrate with deposited networks, generally conductors and resistors, to which semiconductor devices, integrated circuits, and passive elements are attached in chip form.

The development of the transistor and associated minicomponents accelerated miniaturization and the growth of electronic applications. New complex products requiring large numbers of components resulted in interconnection problems which were resolved mainly by the development of monolithic integrated circuit technology and of the thick and thin film technologies defined below.

Interconnections formed as part of the silicon in monolithic integrated circuits are supplemented by thin and thick film patterns on the insulating substrate. Since all system electrical requirements cannot be met solely by only one or the other of these technologies, integration of the several technologies into one package has been achieved by the hybrid microcircuit technology.

DEFINITIONS:

a. Monolithic Technology:

Circuit elements formed (by diffusion, ion implantation, evaporation) in situ or within a single semiconductor chip (silicon) to perform an electronic circuit function. Chips are normally of 9 to 14 mils (225-350μm) in thickness and up to 0.40 cm^2 (0.06 in^2) in size.

b. Thin Film Technology:

Electronic elements or networks formed (by vacuum evaporation, sputtering, anodization) on a supporting material (substrate). Film thicknesses are less than 5 μm (50000 Å) and usually in the order of 0.03 to 1.0 μm.

c. Thick Film Technology:

Electronic elements or networks screened (liquid or paste printed through a screen or mask) onto a supporting material and fired. Film thicknesses are usually 10μm or greater.

DESIGN, FABRICATION AND TESTING:

The design begins with the analysis of the schematic diagram of the circuit designer. From the analysis, thick and/or thin film materials are chosen along with the chip components which include uncased active and passive component parts. The basic geometry which defines the dominant parameter of each film type circuit element and the position of each component is designed next. After establishment of the deposition sequence for the individual layers of film materials, master patterns for each layer are prepared. From these, photoreduced transparencies are made for photo-lithographic fabrication of the masks used to deposit or define the film geometry on the substrate after which the chip parts are mounted, attached and interconnected to the film circuit.

Maximum circuit yield with related cost effectiveness necessitates design with:

(1) An optimum number of add-on components per substrate,

(2) A limitation on the range of resistance and capacitance values and tolerances,

(3) Minimum usage of inductors and transformers, and

(4) Division of the circuit into testable subfunctions.

Film depositions and assembly procedures with process and quality controls ensure adequate performance and reliability. A flow diagram (Figure 1) indicates a typical sequence of manufacturing operations from the circuit schematic through delivery.

Hybrid microcircuits, normally packaged in hermetically sealed enclosures to satisfy environmental and life requirements, can be subjected to a variety of screening procedures as defined under the International Society of Hybrid Microelectronics (ISHM) Hybrid Microelectronics Standard Specification Guidelines. These screening procedures, extracted from military specifications (MIL-M-38510) and (MIL-STD-883) for microelectronics, may be carried out to insure that the circuits achieve levels of quality and reliability commensurate with the intended application. Specification and quality control at the material and process level and final product assurance are defined in control documents by each manufacturer.

HYBRID MICROCIRCUIT APPLICATIONS:

One typical hybrid application is a pulse restorer circuit used as an unattended repeater in a two-way pulse code modulation system. The circuit schematic is shown in Figure 2. The physical layout of this linear type circuit (Figure 3) includes an alumina substrate with two-layer thick film gold conductors, integral thick film resistors, and chip transistors, diodes, capacitors and inductors. The fabricated circuit is shown in Figure 4 before and after packaging in a 32 pin 2.3" X 1.4" (5.8 cm X 3.6 cm) platform style package.

Another example is a digital processor circuit used in electronic countermeasures radar jamming sytems (Figure 5). The 2.0" X 3.0" (5.1 cm X 7.6 cm) substrate includes six thick film conductive interconnection multilayers with over 100 chips, inluding large scale integrated (LSI) microprocessors, RAMS, ROMS and other small scale (SSI) and medium scale (MSI) integrated circuit types. Most of the layers include over 1000 vias, and all metal layers are densely populated with interconnections consisting of 10 mil lines (0.25 mm) and 20 mil (0.51 mm) centers.

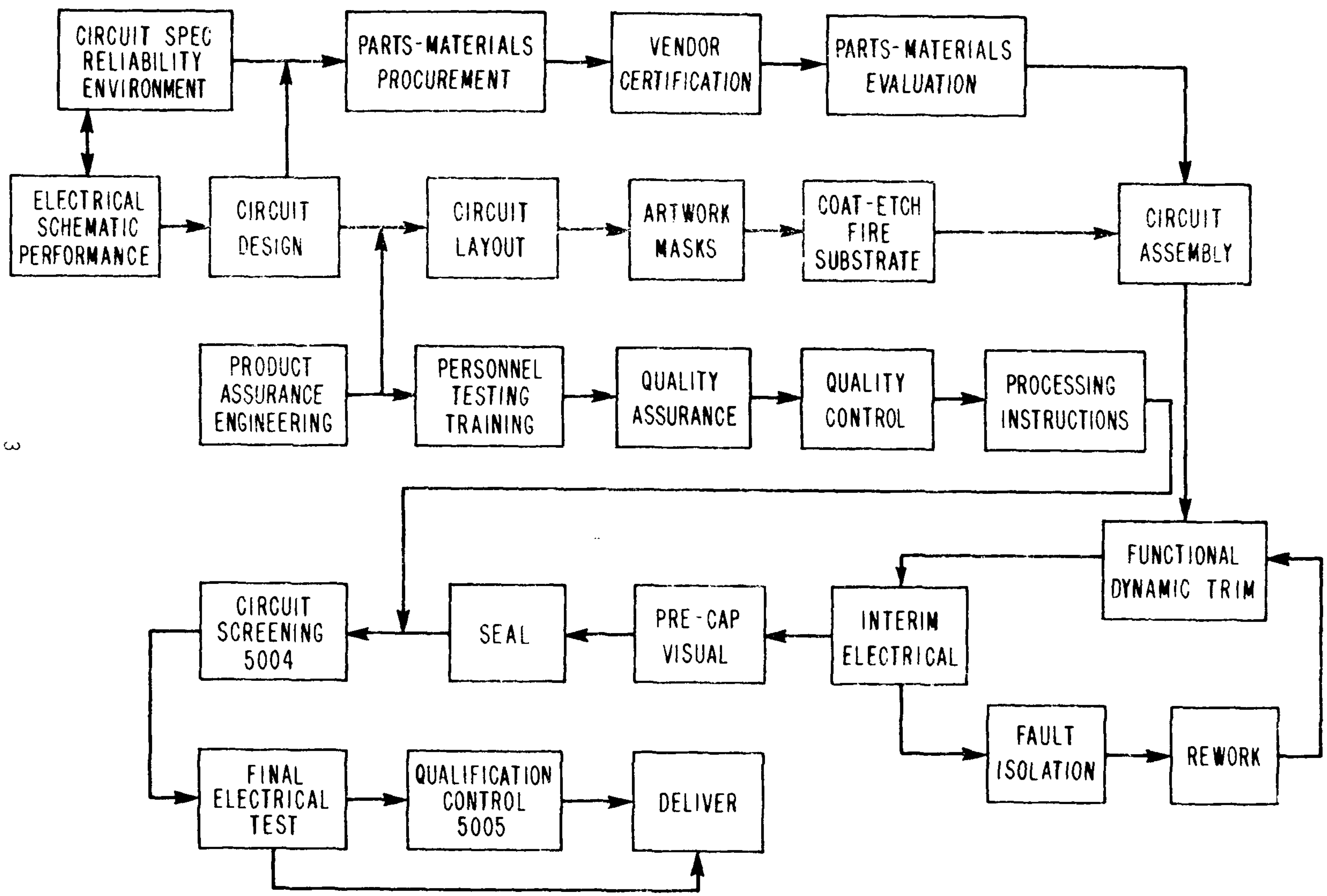


Figure 1. A HYBRID MICROCIRCUIT FLOW DIAGRAM (MANUFACTURE AND SCREENING)

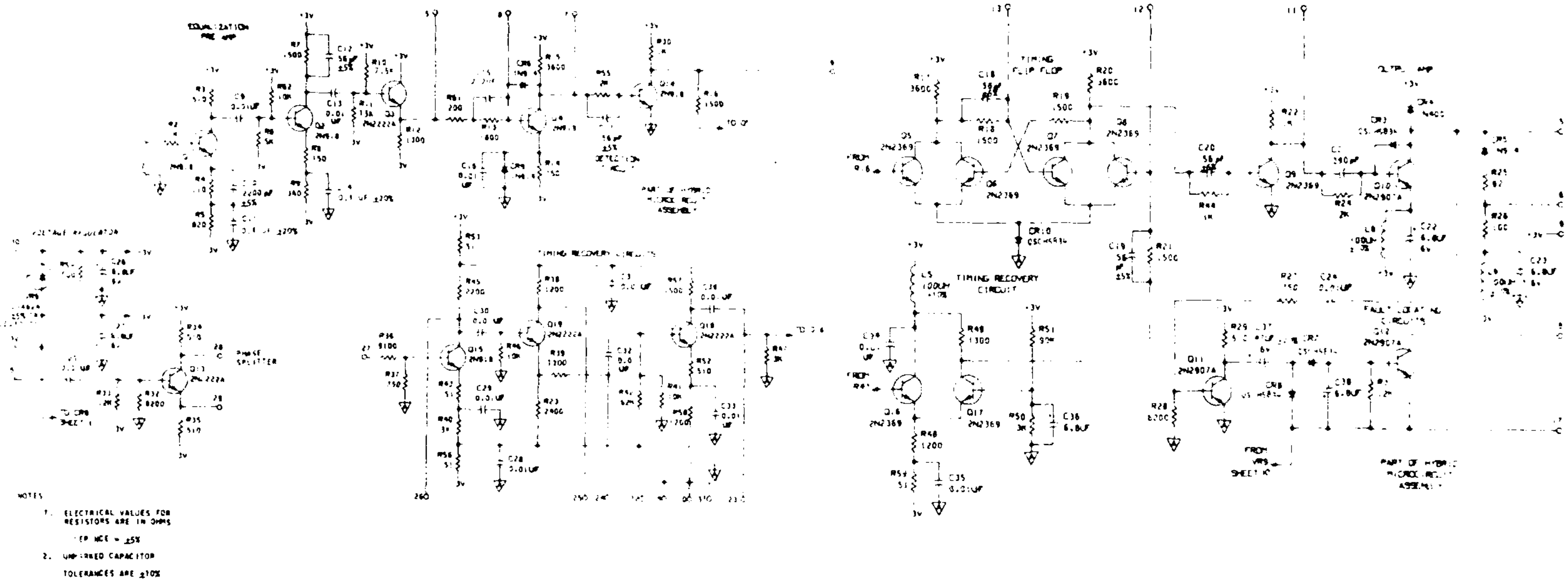


Figure 2. Circuit Schematic - Pulse Restorer Circuit

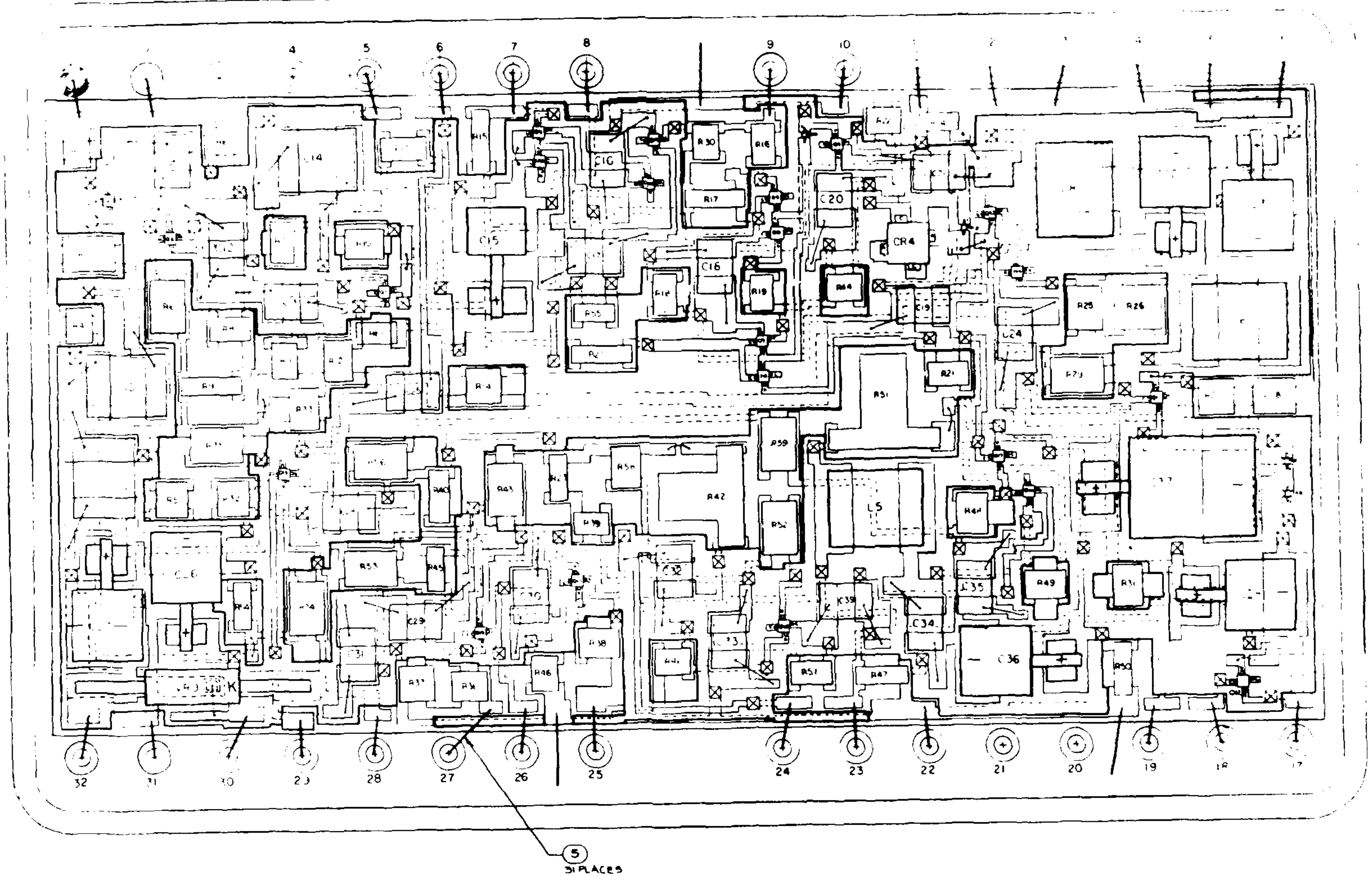


Figure 3. Physical Layout of Pulse Restorer Circuit

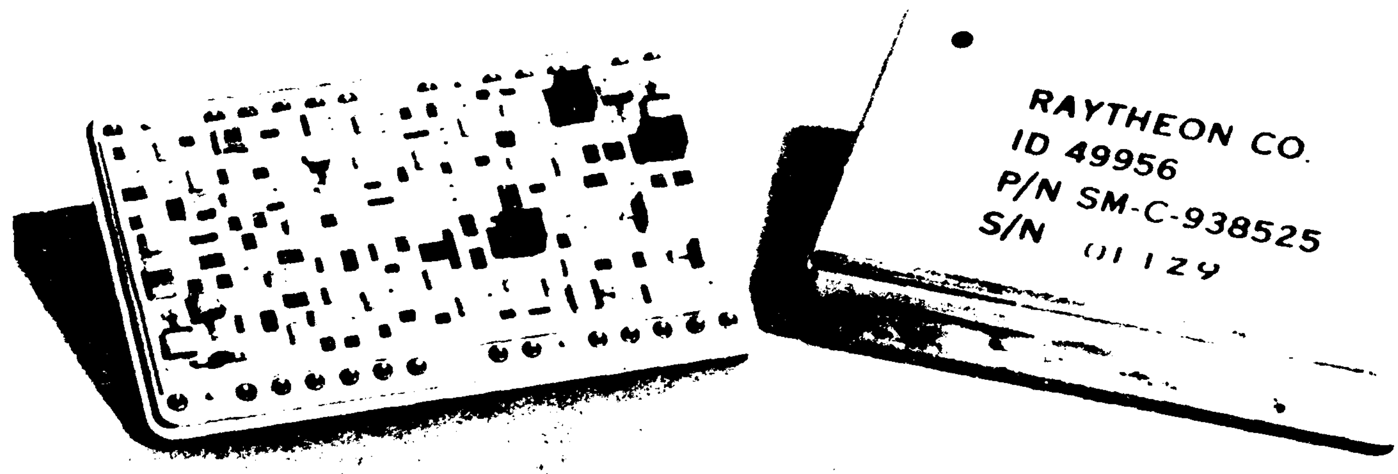


Figure 4. Pulse Restorer Circuit Before and After Packaging

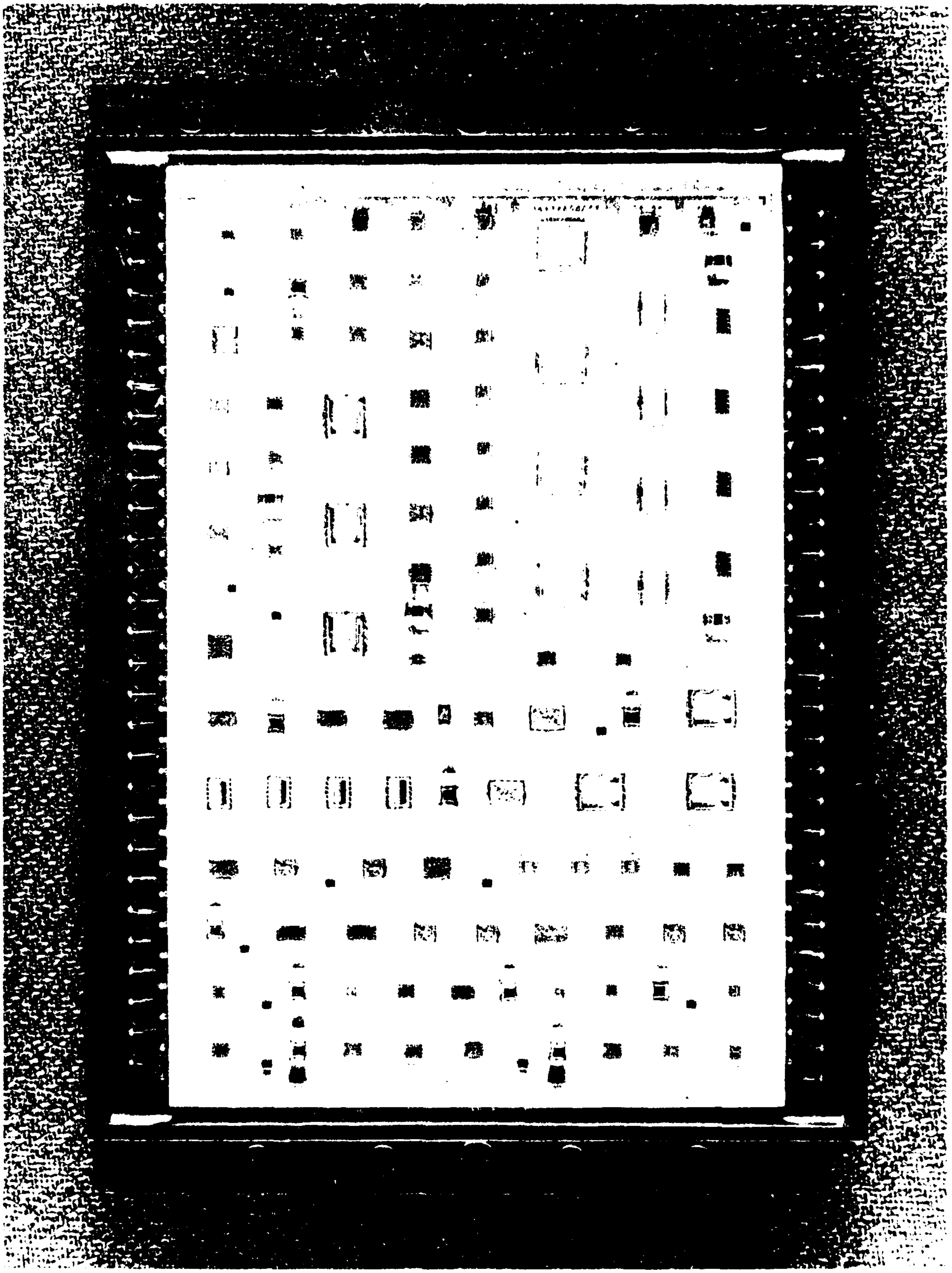


Figure 5. A Digital Processor Circuit

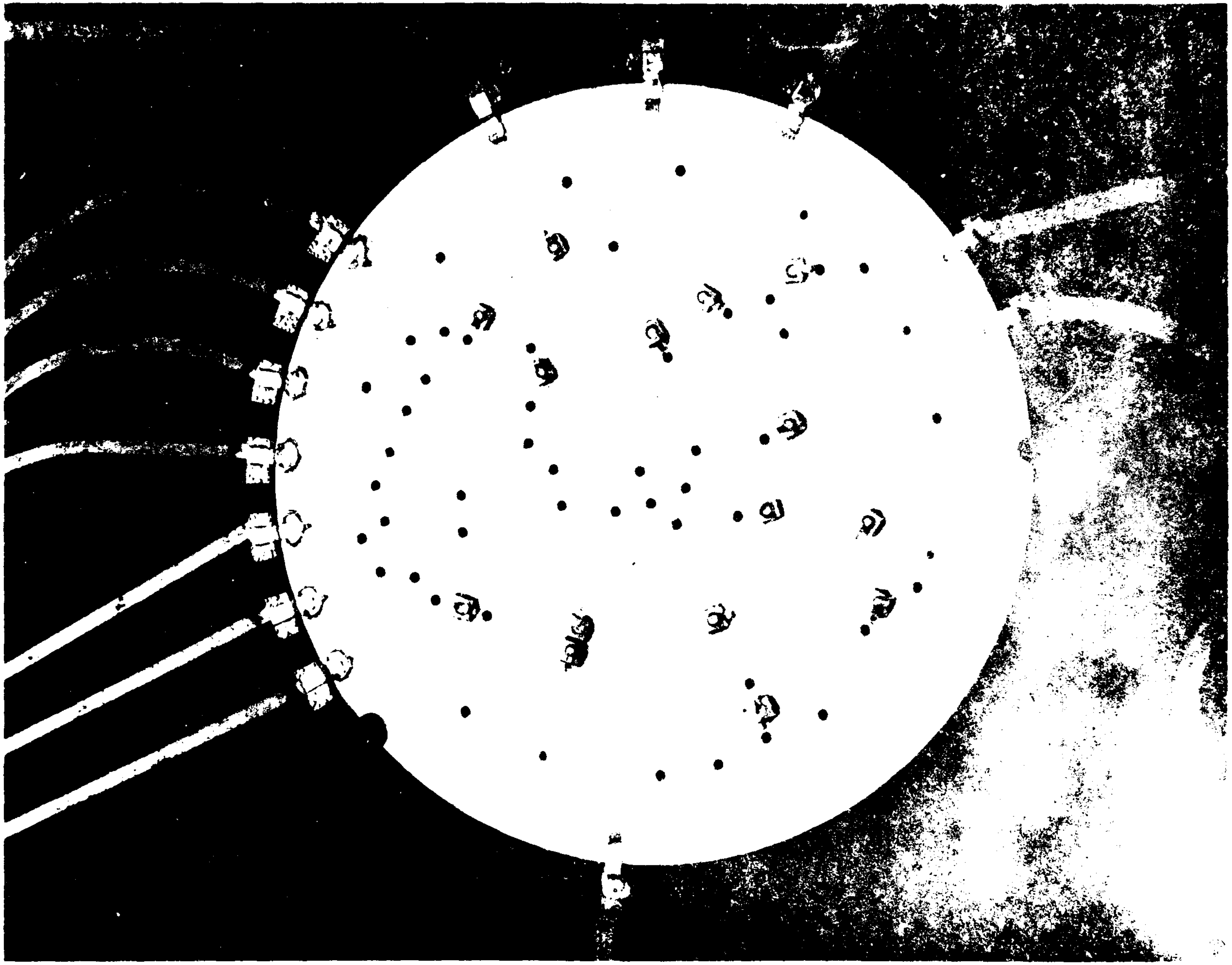


Figure 6. A Microwave Phase Shifter Circuit

A third example is a microwave phase shifter circuit, utilized repetitively on a phased array radar antenna (Figure 6). The 2½" diameter (6.4 cm) substrate consists of a gold, thick film microstrip distributed network and includes 30 thick film capacitors and 15 PIN diodes connected through substrate vias to the thick film ground plane on the backside of the substrate.

FILM COMPONENTS:

Thick and thin film networks include the deposition of passive circuit elements in a predetermined geometric pattern on the surface of the insulating substrate (Figure 7). Deposited thin films can be made with precision and stability for the diverse requirements of linear circuits and can be fabricated with finer lines than those achievable with thick films. On the other hand, the popularity and extensive growth of the thick film technology has led to the development of improved pastes and better printing equipment resulting in high quality films with improved screening properties for ease of fabrication.

Resistive Elements: Resistors are described in terms of sheet resistance (ohms per square), which is actually the resistance of a square of the film material. The resistance varies inversely with the film thickness. The final value of the resistor is determined by its length to width ratio (Figure 8).

Capacitive Elements: Capacitors are fabricated from two layers of conductive material (electrodes) separated by a dielectric layer, the capacitance (C) being a function of area, dielectric constant and dielectric thickness:

$$C = \frac{E_o K A}{t}$$

E_o = Permittivity of Free Space A = Area of Electrode

K = Dielectric Constant t = Dielectric Thickness

Anodic tantalum oxide capacitors, an integral part of the well established tantalum thin film hybrid microcircuit technology, are the most thoroughly studied and developed. The use of thick film capacitors is relatively limited when compared to the extensive use of thick film resistors and conductors. These capacitors are difficult to fabricate to close tolerances, require large substrate areas to achieve high capacitance values, and are plagued with certain dielectric limitations.

Inductive Elements: Flat spiral inductors are made by printing or defining conductor patterns of an appropriate spiral design directly onto the substrate. Such configurations exhibit relatively low Q factors and also require premium substrate area to achieve higher values since the inductance is directly proportional to the overall size and the number of turns.

Microstrip: Microstrip is the transmission line and basic building block for hybrid microwave microcircuits. Microstrip is a planar structure consisting of the dielectric substrate, a conducting strip for the conductor pattern on one side of the substrate and a conducting ground plane on the other. The transmission line is required to provide matched interconnections, various passive components including resonators and filters, and integral parts of phase shifters, isolators and circulators. The geometry is nonsymmetrical and a portion of the electromagnetic energy is contained in the medium above the conductor. The mode of propagation is a pseudo TEM mode which results from the unsymmetrical nature of the transmission line; however, conformal mapping techniques and design curves have been developed for the design of microstrip lines with reasonable accuracy.

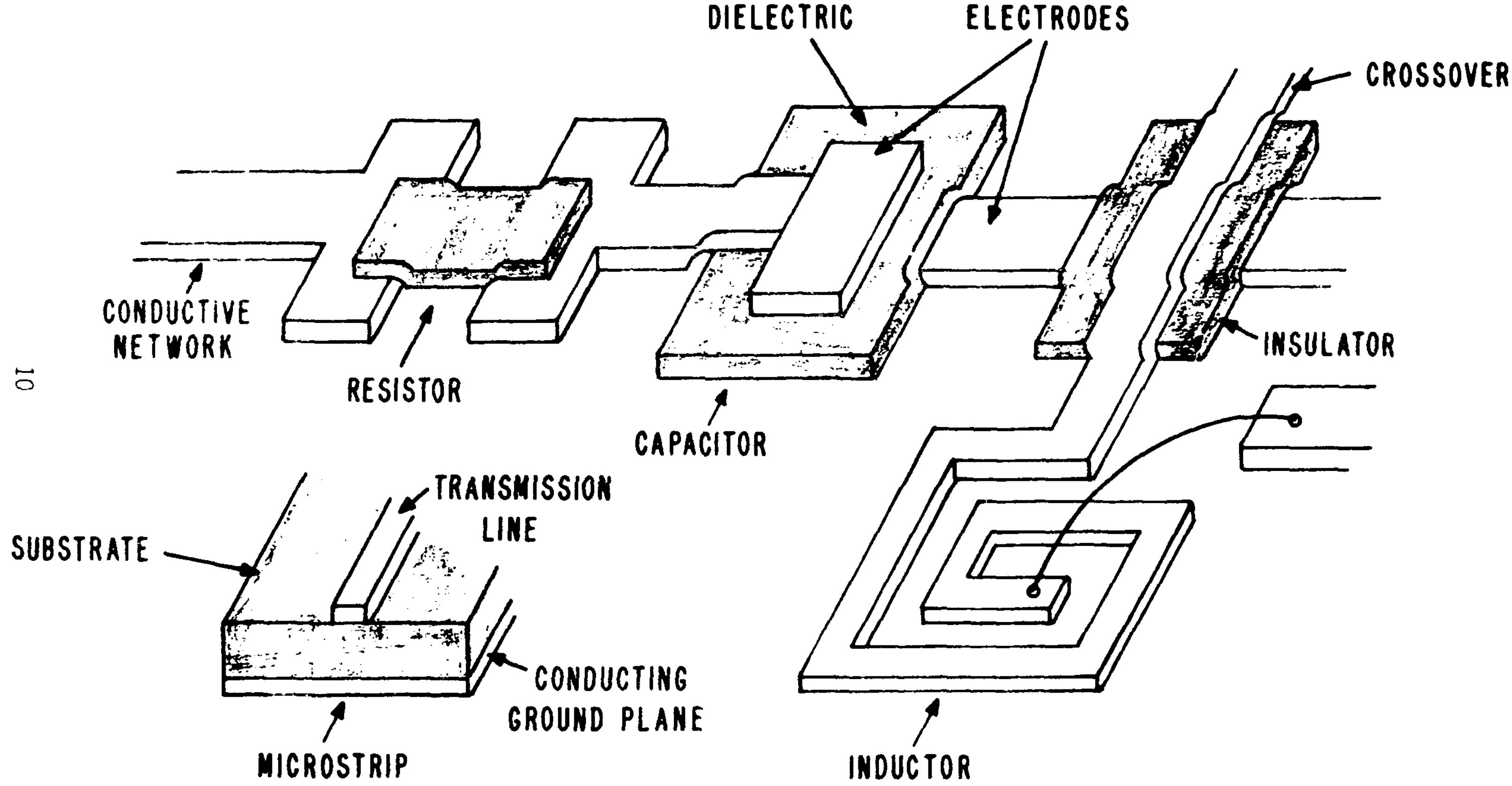
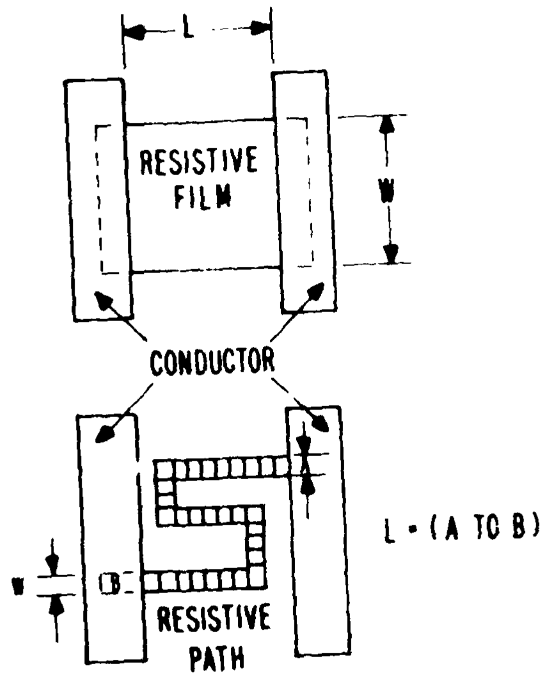


Figure 7. HYBRID MICROCIRCUIT FILM COMPONENTS



$$R = \frac{\rho_B L}{t W}$$

LET $\frac{L}{W} = n$

THEN $R = \frac{\rho_B n}{t}$

DEFINE $\rho_S = \frac{\rho_B}{t} = \frac{R}{n}$

R = RESISTANCE $[\Omega]$

ρ_B = BULK RESISTIVITY $[\Omega\text{-cm}]$

ρ_S = SHEET RESISTANCE $\left[\frac{\Omega}{sq}\right]$

L = LENGTH [cm]

W = WIDTH [cm]

n = NUMBER OF SQUARES [DIMENSIONLESS]

t = THICKNESS [cm]

Figure 8. SHEET RESISTANCE $\left[\frac{ohms}{sq}\right]$

SUBSTRATES:

The substrate of the hybrid microcircuit supports the deposited film and the mounted chip components. Substrate choice is important since film properties can be dependent upon the characteristics of the substrate surface, particularly for thin film components. Thermal conductivity, surface finish, dielectric constant, thermal coefficient of expansion, and ability to withstand processing temperature are significant for different circuit types and applications. The most popular substrate is alumina (aluminum oxide - Al_2O_3), a ceramic substrate, which can withstand the high temperature required for thick film processing. It is available with surface quality for thin film processing, and can be obtained in a wide range of sizes and forms (Table 1). The ceramic substrates are available as 96% Al_2O_3 for thick film applications, 99.5% Al_2O_3 for thin film applications, and as single crystal Al_2O_3 (sapphire) for special applications. Other substrates include beryllia (BeO) which is used for high power applications based on its combination of high thermal conductivity and high electrical resistivity properties, and glasses for use where maximum surface smoothness is required. A relatively new substrate type is a ceramic filled teflon compound (Epsilam - 10) which combines the physical properties of plastic with the dielectric of alumina. [illegible] clad with copper, the substrate is particularly suitable for microwave [illegible] applications. Another new substrate for hybrid microcircuit application is porcelain enameled steel and is of particular interest where larger and more rugged packaging areas are preferred.

THICK FILMS

Specially formulated inks or pastes are applied to ceramic substrates by screen printing techniques [illegible]. Resistor and conductor pastes consist of a finely divided [illegible] phase, a finely divided glass phase, resins, solvents and small amounts of surfactants and wetting agents. Dielectric compositions are [illegible] the finely divided phase being a dielectric material of low or high permittivity. The films are dried after printing and then fired in air to an exact time-temperature profile within the range of 15 minutes to an hour at [illegible] to [illegible]00°C. The main classes of standard conductor compositions are noble metals including Au, PtAu, PdAu, Ag, and PdAg. More recently, some Cu and Ni based pastes are being used which require firing in inert or reducing atmospheres. The resistive components of resistor pastes may comprise any one of the following: ruthenium oxide (most popular), palladium - palladium oxide - silver compositions, mixtures of precious metals, thallium oxide, indium oxide, tungsten - tungsten carbide and tantalum - tantalum oxide. Dielectrics constitute materials with low or high permittivity, the latter largely based on ferroelectric ceramic barium titanate with various additives, and the former based on glasses and glass/ceramic mixtures.

THIN FILMS

Thin films [illegible] deposited in a vacuum by electron-beam evaporation or sputtering and serve as conductors, resistors, and dielectrics similar to the thick film [illegible]. In contrast to the thick films which are applied as bulk materials, thin film growth on a substrate involves the formation of independently nucleated [illegible] which grow together to form a continuous film [illegible]. The physical and electrical properties of deposited films are affected by a number of factors including nature of the substrate, rate of film deposition, the film thickness, structure and composition. Thin film conductors are normally gold films, resistors are either nickel - chromium, tantalum nitride or [illegible] films, and dielectrics

TABLE 1. PROPERTIES OF SUBSTRATE MATERIALS

	Al_2O_3 96	Al_2O_3 99.5	Sapphire	BeO	Glass 7900 96 Silica	Epsilan 10	Porcelainized Steel
Specific Gravity	3.76	3.89	3.98	2.88	2.18	2.98	7.86 (Fe)*
Surface Finish							
As Fired ([illegible])	<25	<10	- -	<20	0.25	- -	9-10
Polished	10	3	1	5	- -	- -	- -
Dielectric Constant	9.5	10.1	9.53	6.4	3.9	10.4	6.8
Thermal Conductivity Cal-cm/^oC cm^2 s	0.063	0.07	0.10	0.8	.003	[illegible]$.9\times10^{-4}$	0.13 (steel) 0.002 (insulator)
Dissipation Factor	.001	.0002	.0001	.0001	.0006	.002	.0016
Tensile Strength (psi)	20000	30000	58000	20000	- -	1400	35000

*Porcelainized steel of 0.050" thickness ≃ 3x as heavy as 0.025" alumina

TABLE 2. FILM ELECTRICAL PROPERTIES

RESISTORS	THIN FILM	THICK FILM
Sheet Resistance (ohms/sq)	10-250	10-1000M
Resistance Range (ohms)	5-300k	10-1000M
Initial-Resistance (Tolerance %)	± 10	± 15
With Trimming (Tolerance %)	.005-1.0	0.1 to 2.0
TCR (ppm/^{o}C)	5-50	50-200
Matching TCR (ppm/^{o}C)	1	± 10
Power Dissipation (W/in^2)	25-100	50-200
(W/cm^2)	3.9-15.5	7.8-31.0
Stability (% / yr)	0.1	0.5
CONDUCTORS		
Sheet Resistance (ohms/sq)	0.015-0.30	0.0017-0.060
Line Resolution (in)	0.001-0.010	0.007-0.010
CAPACITORS		
Dielectric Constant	6 and 25	10-2000
Capacitance per area (μF/cm^2)	0.008-0.05	0.003-0.037
Range of Values	1pF-0.02μF	2pF-0.2μF
TCC (ppm/^{o}C)	+100	+50 to -18%
Allowable Stress (V/cm)	$2x10^6$	$2x10^5$ (500 V/mil)
Operating Voltage (V)	20	100

or insulators include silicon monoxide, silicon dioxide or tantalum oxide.

RESISTOR TRIMMING:

Most film resistors, although [illegible] with [illegible] precision and processed with close controls, must be trimmed to a [illegible] tolerance during production since the inaccuracies [illegible] inherent in the fabricating process cannot be tolerated by most circuit designs. The most popular methods are laser and abrasive trimming for thick film resistors and laser and anodic trimming for thin film [illegible]. Laser trimming systems, specifically designed for trimming resistor elements, utilize yttrium aluminum garnet (YAG) or carbon dioxide (CO_2) lasers and the associated computer controlled electronics. Laser trimming permits [illegible] because of the fine spot diameter of the laser beam [illegible] systems have been developed to achieve maximum trimming speeds for [illegible] throughput and to provide for sophisticated functional trimming. Abrasive trimming (trimming by blasts of fine alumina particles) is an older method [illegible] popular in the hybrid microcircuit [illegible] to achieve adequate accuracies [illegible] formation [illegible] in the substrate as can occur with laser [illegible] is an electrochemical oxidation process used to grow an oxide [illegible] thin film metals. After a tantalum type resistor is anodized, the [illegible] becomes thinner [illegible] converted into an oxide, thereby [illegible] its resistance. The technique, in principle, has infinite resolution, however, standard [illegible] with precision adjustments [illegible] The technique allows resistor adjustment [illegible] and in addition grows a passivating layer over the surface.

DISCRETE [illegible]

A variety of [illegible] active and passive components, generally in chip form, are available [illegible] hybrid microcircuit application and are used to provide functions which are difficult to achieve in [illegible] form or functions with improved [illegible].

Active [illegible]

Most active [illegible] semiconductor manufacturers are available in wafer or [illegible] to the hybrid manufacturer. The growth of the hybrid microcircuit technology has, therefore, followed the continuing growth and advances of the semiconductor [illegible] functions and subsystems have [illegible] the number of components per [illegible] to LSI (Figure 5). Device types include [illegible] circuits, microprocessors, [illegible] silicon diodes and light emitting diodes. As higher density [illegible] integrated circuits emerge from VLSI (very large scale integration) [illegible] speed integrated circuits) development [illegible] demand for improvement in interconnection [illegible] technology to continue to keep pace with the [illegible] growth. Of continuing concern [illegible] damage during handling of the uncased [illegible] as the number, types and [illegible] that as the chip complexities increase, [illegible] available to the hybrid manufacturer [illegible] microelectronic package. The [illegible] carrier is a [illegible] which permits relatively high density packaging. The military is now supporting efforts to make integrated circuits in hermetic chip carriers available for hybrid and other circuit assemblies.

Resistors:

Thick and thin film resistor network chips are well developed technologies with a wide range of values, excellent characteristics and stabilities. Discrete chip resistor use is limited to special conditions where very low or high values may be needed, to eliminate an extra printing sequence, or to conserve circuit space. The number of circuits to be produced will affect whether or not to use the chips. A wide variety of ceramic and silicon chips of the thick and thin types and of the diffused type are available. The latter type, which uses the bulk resistivity of silicon, is available in extra small sizes but finds limited application because of the relatively poor resistor characteristics.

Capacitors:

The limited availability of capacitance per unit area by the thick and thin film techniques and the difficulty in printing thick film capacitors to close tolerances make chip capacitors attractive for hybrid microcircuit application. The variety of capacitor chip types include silicon MOS, porcelain, ceramic, tantalum and glass.

The most commonly used is the ceramic type (class I-II), which has a wide capacitance range, a variety of performance characteristics and high volumetric efficiency. Class I has lower K dielectrics (70-500) and linear temperature coefficients and is used in circuits which require stability and low loss (high Q) of dielectric characteristics over the operating temperature range. Class II dielectrics (K > 500) exhibit non-linear characteristics, with the capacitance and dissipation being voltage, frequency, temperature and time dependent. Silicon MOS chips offer small size but are limited in value. Porcelain, tantalum and glass capacitors are used for special applications.

Inductors:

Where possible, film inductors have been designed out of hybrid microcircuits because of their relatively limited characteristics and inefficient space utilization. Likewise, discrete inductors have been considered too large for microelectronic application; however, improvements in core materials and wire-winding have resulted in inductive components which are more size compatible for hybrid microcircuit application. Miniature fixed inductors are formed by winding fine wire on a small cylindrical magnetic ferrite of powdered iron core and are available over a relatively wide range of values. These fixed inductors are available also in a tunable form with comparable inductance values over the range 0.023 to 5800 uH with a tuning range of 2:1. 5:1 or 10:1 dependent upon size.

ASSEMBLY TECHNIQUES (DEVICE AND WIRE BONDING):

The bonding of dice or chips and other discrete devices is another basic process in the assembly of the hybrid microcircuit following fabrication of the thick and thin film components. Bonding can include eutectic alloy, solder, epoxy, wire, tape, flip-chip and beam-lead technologies. In principle, an optimum die bonding method is one that results in the device's mechanical attachment to the substrate and its electrical contact to the circuit by a single bonding process. Flip-chip and beam-lead represent such single bonding processes. Neither one however, has been able to become the prime technique in the hybrid microcircuit field. Epoxy bonding is the most common, and eutectic bonding is a widely used, mechanical attachment process. Wire bonding is the most extensively used interconnect process.

Eutectic Bonding:

Essentially any type of semiconductor chip may be back-bonded to the thick or thin film substrate by eutectic bonding. The technique uses the silicon from the chip and the gold on the substrate to form a silicon-gold eutectic alloy at about 370°C. The substrate is kept at approximately 400°C while the chip is "scrubbed" or vibrated over the gold land area resulting in the alloy which solidifies on cooling to form an ohmic contact. The ohmic contact is important for connecting the collector on the back of a transistor die to the substrate. Bonding is also done with preforms of gold-silicon. Gold-tin eutectic preforms are used when a lower (280°C) bonding temperature is desired for heat sensitive devices.

Solder Bonding:

Solder bonding is similar to eutectic bonding and is used for mounting active and passive devices to the hybrid substrate. Various soft solder preforms, consisting of tin and lead based systems, are used with melting temperatures in the order of 180°C to 300°C. Solders are also available as pastes, are specifically designed for thick and thin film circuits and can be applied by screen printing, brushing, dipping or with a syringe to provide bonding alloys for device attachment.

Epoxy Bonding:

Hybrid designs can require increasing numbers of integrated circuits on the substrate. As the complexity of the hybrid microcircuit increases, there is a desire to keep the substrate at a lower temperature during device mounting to avoid any degradation of the active devices' characteristics during prolonged assembly. The use of polymer adhesives (epoxy compounds) for chip bonding is desirable from such a manufacturing standpoint because of the relatively low temperature (<150°C) required for curing the epoxy, the relative ease of application and the strength and reliability of the bonds. Epoxies exist in conductive and nonconductive forms, with gold or silver fillers for the conductive type. The use of organic or polymeric material inside a hybrid microcircuit package has been of concern from a reliability point of view, but the development of improved materials specifically for electronic applications has led to the general consensus that, if properly selected, controlled and applied, microelectronic epoxy adhesives are satisfactory for most hybrid microcircuit bonding applications.

Wire Bonding:

After bonding the chip to the substrate, fine aluminum or gold wires are used to make electrical contact between the metallized chip pads and the conductive network on the substrate (Figure 9a). The most commonly used wire diameter is 1.0 mil with available diameters ranging from 0.7 to 20 mils. Wires are bonded one at a time, each wire requiring the making of two bonds. Wire bonding techniques include thermocompression bonding (pressure and heat),

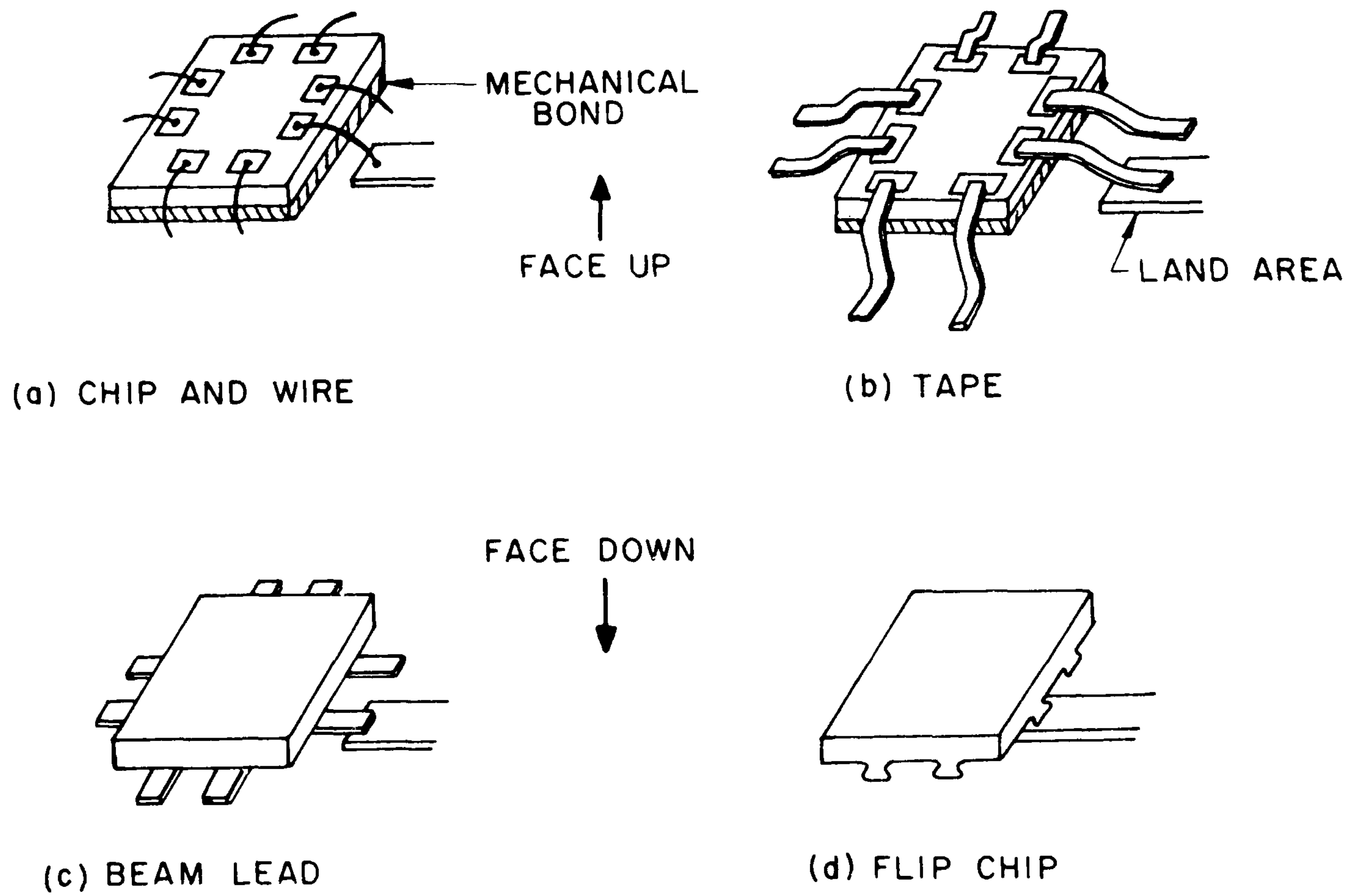


Figure 9. CHIP BONDING TO SUBSTRATE

ultrasonic bonding (friction of wire-pad interface and cold welding of wire) and thermosonic bonding (a combination of the former two processes). Poor physical connections and chemical reactions between the wire and the thin film pads on the die, and between the wire and the thin or thick film land areas on the substrate, can occur with improper bonding controls, thereby making wire bonding one of the weakest parts of the hybrid microcircuit assembly process.

Flip Chip Technology:

Flip chip (Figure 9d), performs both electrical and mechanical connection after the chip is inverted and bonded face down to the substrate interconnection pattern. A raised metallic bump of solder is made on each of the chip bonding pads with the bump corresponding to the conductive land areas on the substrate. Bonding is normally carried out by reflow solder techniques with the bonds being made simultaneously, eliminating one wire and its two bonds per connection. Disadvantages include inability to make visual inspection of the bonds and limitations in removing heat since the chip is not in intimate contact with the substrate surface. More importantly, flip chips have limited availability to most hybrid manufacturers because of reluctance of semiconductor manufacturers to convert to this technology, the bump processing steps adding to the total processing cost of a wafer. The technology has found application almost exclusively by IBM and several other large hybrid microcircuit manufacturers.

Beam Lead Technology:

(Figure 9c): Gold beams (3 mils wide, 5 mils long, spaced on 10 mil centers) are formed as an inherent part of the integrated circuit chip during the processing of the silicon wafer. The metallurgy and sealed junction used for the wafer processing, make the beam leaded device one of the most reliable type chip configurations. The beams are exposed and extend over the edge of the chip after the chip's separation from the wafer. The chip is inverted (face down) and the beam leads are attached simultaneously to the substrate. The chip remains slightly elevated above the substrate and therefore, like the flip chip, is limited in power dissipation capability.

The technology developed by Bell Laboratories is limited to usage almost exclusively by the Western Electric System. Like the flip chip technology, it has not found a wide base in the hybrid microcircuit field because of the general reluctance of semiconductor manufacturers to replace conventional mainstream aluminum chip metallization technology. Future application may be further limited since the beam leads were developed for bipolar silicon SSI and MSI devices and are not available for MOS and bipolar LSI type devices.

Tape Bonding:

(Figure 9b): A tape with copper foil laminated to it acts as a carrier vehicle for semiconductor chips. The foil, etched in the form of gold plated copper leads, is bonded to metallurgical bumps on the chip pads, after which the chip and the attached leads are excised from the tape and bonded to the substrate. The technology lends itself to mass production, is an established method for individually packaging integrated circuits, and has been under active development for hybrid microcircuit application during the past five years. In addition to elimination of the wire bonding, the technology permits pretesting and burn-in of chips on the tape prior to the substrate mounting, a capability which is relatively difficult and normally avoided with any of the previously defined electrical bonding technologies. Pretesting of chips is extremely important to hybrid microcircuits reducing rework during circuit fabrication and increasing circuit yields. For hybrid microcircuit applications, tape is uneconomical if the number of chip types is large and if the number to be produced is small. These disadvantages must be overcome if the tape technology is to find wide usage in hybrid microcircuits.

PACKAGING:

Packages provide mechanical and environmental protection and include bonding areas for electrical connection between the microcircuit and package leads. Package configurations include a variety of types including round header with pin outs for small size circuits, flatpack (or butterfly), platform (or plug in), and other special types. Hybrid packages have tended to grow in size and packages as large as 2.0 X 4.35 inches with 180 leads and packages with 240 leads have been supplied for special applications. Packages are normally defined under 3 classifications: metal, ceramic, and plastic. The majority of hybrid packages used today are made of a Kovar type alloy (Iron-Nickel-Cobalt) of thermal expansion to match the expansion of borosilicate glass for the terminal (lead) seals. Ceramic packages (alumina) include brazed or fused leads. Metal covers are normally gold plated to ensure a positive weld or seal. Ceramic lids are available with metal seal rings or glass preforms where alumina covers are preferred. Most hybrid microcircuits, particularly for the military, are hermetically sealed to prevent moisture from penetrating the package and adding uncertainty to the electrical behavior and life of the enclosed circuit. Hermetic lid sealing can be achieved with both metal and ceramic packages using either the glass or metal seals. Metal seals are most popular. The resistance seam weld technique is most popular for all metal packages and solder sealing is preferred for ceramic packages using metal lids. Organic polymer materials (epoxies) can be used for sealing, but such materials are not truly hermetic as polymers permit moisture to penetrate the seal at a rate which is a function of the temperature, relative humidity, and type of material. Such organic seals, and polymers used as encapsulants over an entire hybrid microcircuit (plastic package), are not commonly used in military systems but are successfully employed in many commercial applications, particularly where cost factors are significant.

CONCLUSIONS:

The hybrid technology provides the means for assembling analog, digital and microwave circuits in relatively small enclosures. Electronic needs that are beyond the range of monolithic integrated circuit technology have been satisfied by combining semiconductors with thin or thick film interconnections on ceramic substrates. The hybrid technology continues to fill the gap that exists between an all discrete part system and a complete monolithic technology.

The technology has played a significant part in the design of many types of military (DOD) and aerospace (NASA) electronic equipments and for commercial radios, computers, telecommunication and automotive applications. A general growth of the technology is predicted during the 1980's, particularly for commercial applications. For the military, circuit complexity and related assembly and testing can make hybrid applications costly. This relatively high cost may become a limiting factor in future military applications other than where weight and volume are overriding factors.

The maturity of the technology is noted by the variety of circuit types for new military and commercial applications and the resolution of basic fabrication problems as hybrid circuit complexity has kept pace with the evolution of monolithic circuits from SSI to VLSI. For the military, problems which still need resolution include lack of efficiency in microwave hybrid module manufacturing, particularly for repetitive modules in antennas, and the continuing need for overall new (automated) cost efficient processing, manufacturing, packaging and testing techniques.

Future interests tend toward high speed, high throughput signal and data processing, particularly in support of requirements for military systems in the mid-eighties and beyond. New circuit packaging approaches will be required to keep pace with the new higher density, very high speed integrated circuit (VHSIC) technology.

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