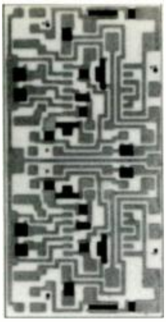
The Lenkurt

NOVEMBER 1968

DEMODULATOR

Hybrid Microcircuitry

Part 2



New techniques in microelectronics may lead to breakthroughs in microwave design and packaging.

Impressive as many of the current applications of thick film technology are, its potential uses and extensions are even more so.

Significant space savings and increased reliability have been achieved in several Lenkurt systems employing thick film circuits. Among them are the 82A and 83A Station Carrier Systems and Lenkurt's 91A PCM Cable Carrier.

At this point most are filter circuits such as the one in Figure 2. Beyond simple filter circuits, the heightening interest is in developing hybrid microcircuits for use at microwave frequencies. To do this, other, more complex areas of microelectronics must be explored.

One of the outstanding aspects of thick film technology is its commonality with other microelectronic techniques. Whether the medium is printed circuitry, thick film, thin film or integrated circuitry, the goal is essentially the same – increased reliability through miniaturization. And regardless of the means employed – from PC's to IC's – the initial steps are the same. The circuit design is first laid out as original artwork, then reduced photographically (Fig. 3).

Through this similarity, other microelectronic techniques such as thin film may be viewed as extensions of thick film technology. The thick film process is most effectively employed in the miniaturization of general purpose electronic circuits which may allow relatively loose tolerances. But thin films have accuracy requirements roughly ten times as stringent as those for thick films.

Stripline and Microstrip

Tight tolerances on this order are required of components intended for use in systems designed to operate at microwave frequencies. Typical of such components are stripline, microstrip and other microwave integrated circuits (MIC's).

Strictly speaking, integrated circuits have a different function at microwave frequencies than at the lower frequencies. At low frequencies, hybrid IC's simply provide the interconnections between the various active components in a circuit. But in the microwave range, they essentially become transmission lines and provide all the same functions as sections of transmission line – such as waveguide – can be made to provide.

Stripline and microstrip are techniques for miniaturizing circuits. As a replacement for conventional circuits, stripline and microstrip are especially effective at the higher frequencies where tight control of a line's characteristic impedance is essential.

Since a line's ability to carry a signal is a function of its electrical properties as well as its size and shape, it is a rather straightforward process to go from cable to stripline.

Basically, a coaxial transmission line consists of a round center conductor located concentrically inside a cylindrical outer conductor. The stripline

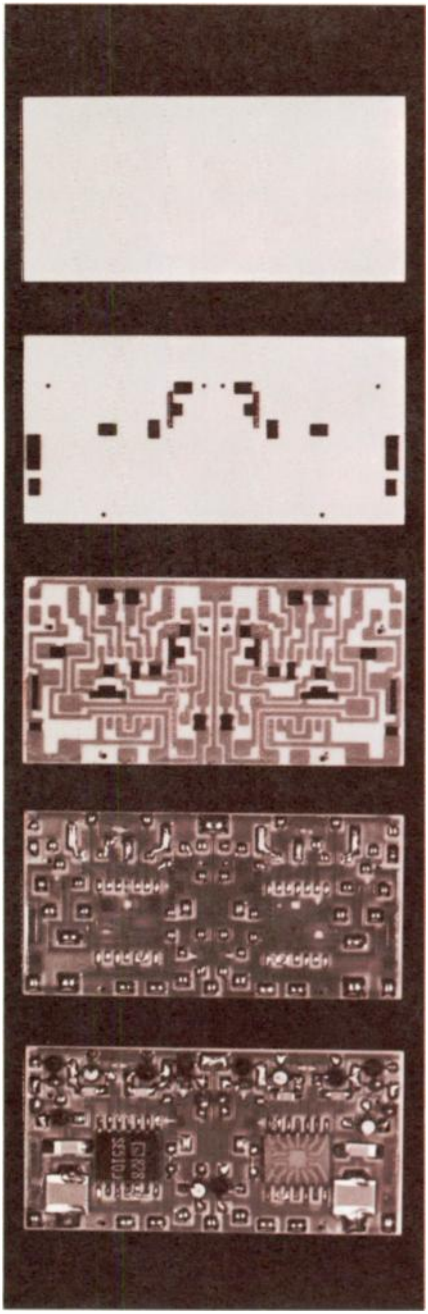


Figure 1. From the top down, these substrates show the various steps in fabricating a circuit using the thick film technique.

is much the same thing, only the shape and size are different. It consists of a conductor in a dielectric material (may be air) supported by two parallel ground planes in a kind of sandwich configuration.

The next step in this evolution is to simply lift the top off the sandwich and the stripline becomes a microstrip (Fig. 4).

Photoetching

Circuit patterns required for stripline and microstrip configurations generally require dimensional accuracies that cannot be achieved using direct screening techniques. Consequently, they are often produced by etching a metallic conductor layer on the surface of a suitable dielectric substrate. The substrate may be teflon-glass laminate, ceramic or glass. And the metallic surface layer is usually a copper sheet, silver applied by thick film process or evaporated thin films such as gold on chrome.

Photoetching begins with a large scale drawing of the required pattern which is later reduced photographically to a one-to-one facsimile. Large-scale original artwork permits greater accuracy and provides a more convenient working dimension.

After thorough cleaning and drying, the metallic surface to be etched is uniformly coated with a thin film of photoresist. The film is applied by dipping, spraying, roller coating or spinning the substrate. It is then fired to remove residual solvents before exposure.

A photographic image of the circuit pattern is produced on the surface by placing the 1:1 scale transparency in contact with the coated substrate and exposing it to ultraviolet radiation for a pre-determined time. For a negative acting resist, the action of the ultraviolet radiation is to change the molecular structure (polymerize) in the areas

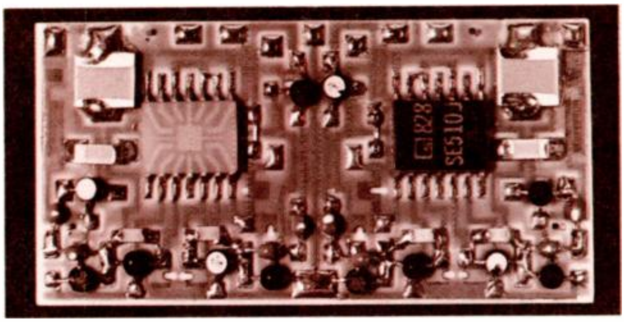


Figure 2. This filter circuit is an example of Lenkurt thick film technology. (Shown here actual size.)

of the photoresist corresponding to the transparent regions of the photographic image.

After processing in a developing solution, the polymerized areas remain as a tough chemical-resistant surface. The areas corresponding to the opaque regions of the image dissolve in the developer and expose the metallic surface underneath.

There is also a method using positive acting resist in which this action is essentially reversed. In this method, the circuit pattern on the photographic image is transferred to the metal surface of the substrate. The polymerized resist acts as protective covering and prevents etching of the covered areas. The unprotected regions are etched away, leaving the desired circuit pattern.

In cases where one metal is deposited atop another, it is possible to etch each one separately. This technique is called selective etching and is possible due to different etching properties of different solutions in relation to certain metals. Other methods are the photomask technique and selective electro-chemical plating.

Stripline and microstrip are two of several circuit configurations which can be produced by these methods. Furthermore, they can have active components such as semiconductors attached and become working hybrid microcircuits.

When perfected, stripline and microstrip may be used in microwave radio systems to help replace bulky waveguide plumbing.

Some Extensions

Another related area of microelectronics is concerned with developing solid-state devices for microwave output power. The primary emphasis is on components such as diodes and semiconductors rather than circuitry, although, the components obviously must work in or with microcircuits.

Already, some lower frequency systems such as Lenkurt's 71F2 Radio (2 GHz) are solid-state. But ultimately, engineers hope to replace the klystron with a small solid-state device in the higher microwave bands as well.

High frequency application is the major obstacle to the development of operational, all solid-state microwave devices. This is not universally true – devices such as switches, couplers, multipliers, filters and some amplifiers and oscillators have been successfully designed for use throughout the microwave spectrum. But operational, high frequency replacements for transmitter tubes are still in the future, albeit the near future.

Then why all the emphasis on microcircuitry and solid-state? Although the advantages of microcircuitry do not necessarily *outnumber* the disadvantages they do *outweigh* them. Improved overall performance is of course the greatest advantage offered by solid-state devices and microcircuitry. This is primarily a result of the near-perfect stability that can be achieved by using thick film and other hybrid integrated circuits in communications systems. Also, increased ruggedness of the components themselves adds to the overall reliability of the system.

A considerable cost advantage is realized since microcircuitry fabrication techniques are readily adaptable to mass production methods.

At the present state of the microelectronic art, there are still many problems. Higher line losses, parasitic capacitances, and other spurious modes resembling cross-talk in a telephone circuit are among the knottier ones currently facing the design engineer. Also, limited handling characteristics in terms of voltage and power present unique problems. Moreover, the high potential packaging density of

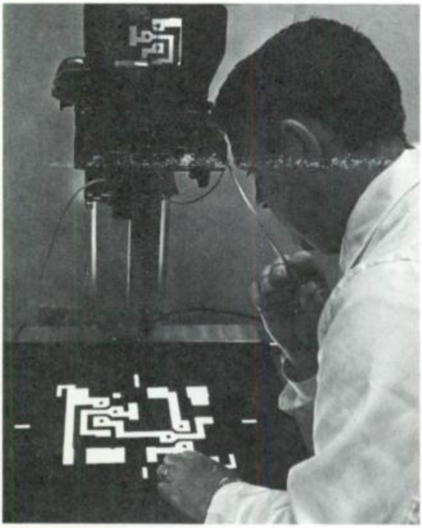


Figure 3. Photographic reduction of the circuit design is an indispensable part of any microelectronic technique.

miniature circuits on substrates can create problems of heat conductivity.

The problems, however, are not considered insurmountable. The art is still quite young – and even some of the problems are just now being recognized.

The problems are extremely complex, and vary with each new device. In all of them, however, the primary problem is the same and very elementary. It is simply to develop a small, solid-state apparatus capable of generating and manipulating sufficient signal power for continuous wave (cw) propagation at microwave frequencies.

Three Candidates

Progress is being made. Currently, some of the more likely devices are gallium-arsenide (GaAs) crystals such as Gunn diodes, limited space charge (LSA) devices, impact avalanche transit time (IMPATT) and other avalanche diodes.

A GaAs crystal can be made to oscillate at microwave frequencies simply by applying a high voltage (dc bias) across it. First though, to achieve the desired electron activity, the crystal must be "doped" with a foreign element such as sulphur or selenium.

What goes on inside the crystal is not so simple. But it is basically a series of electron movements which, taken cumulatively, cause an oscillation. This, in turn, can be used to create output power. The oscillation, called the Gunn effect, is named for its discoverer, J.B. Gunn. The device itself consists of a doped GaAs crystal and wafer mounted in a heat sink cavity and surrounded by dielectric material.

Gunn oscillators provide cw power with peak outputs ranging from a few milliwatts to about one kilowatt, depending on frequency. As the frequency goes higher, power output falls off. Low average power is one of the limitations of Gunn devices. Up to now, it hasn't been possible to generate sufficient average power output at high enough frequencies for microwave applications.

Gunn devices are further limited in their present usefulness by inherent problems of heat dissipation. They are reliable to only about 100°C. Beyond that, the entire device usually breaks down.

LSA devices, on the other hand, are not hampered so. Related to the Gunn effect, limited space-charge accumulation is another related phenomenon which may make possible power outputs of a watt or more in the microwave spectrum.

In the case of LSA devices, oscillation is the result of a negative resistance characteristic (see the *Demodulator*, Sept. 1968) in a high dc bias field.

Unlike the Gunn devices, the power output of an LSA oscillator is not dependent on frequency. This is because the accumulated space charge is not a function of the electron's transit time – an important fact in Gunn diodes. As the thickness of a Gunn diode's active region increases, the device's efficiency decreases correspondingly. This is not true of LSA devices.

An LSA oscillator can be many times as thick as a Gunn diode of the same frequency. Consequently, it can withstand much higher voltages and temperatures. It is therefore able to produce consistently higher average power outputs.

An IMPATT diode is a simple silicon PN junction capable of generating more than one watt of cw power at about 12 GHz. Here too, oscillation is a result of negative resistance caused by a combination of the crystal's internal emission (the avalanche effect) and electrons moving at saturation velocities.

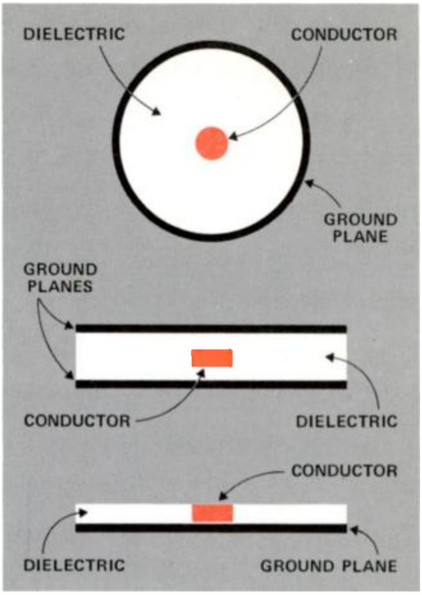


Figure 4. Transmission lines have undergone changes from coaxial cable (top) to stripline (center) and microstrip (bottom).

Right now, the biggest problem with IMPATT devices is the inherent noise which accompanies any avalanche device. Stabilizing cavities have been able to reduce avalanche noise to a useable level for some devices with limited applications at lower frequencies.

But, problems such as noise, heat and low voltage capacities are not insurmountable. One or another of these devices is destined to replace tube-type transmitters in the foreseeable future.

At the present state of the art, no one of the devices discussed here is capable of doing the job done by conventional tube-type power sources. However, some kind of hybrid circuit incorporating the features of many of these components is another area of interesting possibilities.

MIC's

Within certain frequency and power limitations, the most effective devices in use today are hybrid MIC's employing thin and thick film technology.

Microwave integrated circuits employing microstrip transmission lines have met with considerable success at the lower frequencies. But because of its small circuit size, transmission losses are high compared to waveguides or coax. This becomes a limiting factor in high power applications. One of the ironies of microelectronics is the fact that as engineers come closer to their performance goals through miniaturization of devices, the devices are more vulnerable to power and heat. Consequently, the ability to produce useable power output is limited by the technique itself. But again, these problems are considered as only temporary.

Smaller, stabler and more reliable microwave radio systems are but one promise offered by the art of microelectronics. Compact, portable radar systems is another. The idea of small, highly portable radar systems is, of course, very appealing to the world's defense agencies. This is especially true of airborne radar and other systems intended for use in battle zones where there is a high probability of damage to components. Miniaturization of components will allow duplication and redundancy sufficient to provide back-up operation in almost any situation.

Whether any one or a combination of several of the devices discussed here is finally adopted as the industry standard, the effects will be dramatic and far-reaching.

Each of the individual devices has much to offer, yet each is beset with problems. Therefore, the best bet for the future will probably be a device resulting from joint efforts involving several technologies.

Millimeter Communications?

What then? A simpler, less expensive microwave radio comes to mind first. Another – if somewhat more remote – possibility might be the capability to really open the millimeter portion of the spectrum for communications. A small amount of successful exploration has been done. Experimental, prototype, millimeter systems do exist.

If sufficient channels to meet the demands of the future are to be found, other areas of the spectrum must be opened. The increased bandwidth offered by the millimeter range can do much to further the work in these areas. Experimental efforts at using the millimeter band for communications have been generally successful. An LSA device is currently being used in guided wave PCM system operating above 50 GHz.

But none of the possibilities mentioned here will be realized until the problems are worked out. And in microelectronics, just as in other technologies, problems exist to be solved.

Success in one area often hinges on previous successes in related areas. So, what has been learned from thick film and IC fabrication will provide the foundation for success in the efforts toward microwave miniaturization.

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