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DRAWINGS ATTACHED.

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COMPLETE SPECIFICATION.

Interconnecting Miniature Circuit Modules.

We, TEXAS INSTRUMENTS INCORPORATED, of 6000 Lemmon Avenue, Dallas, Texas, United States of America, a Corporation organized and existing under the laws of the State of Delaware, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method and apparatus for providing electrical connections to miniature circuit modules. The expression "circuit module" used herein and in the claims appended hereto is to be construed as defining a box containing the electrical circuit elements required to form an electrical network therein, the box including a plurality of lead elements positioned on the external surface thereof which are connected to predetermined points of the electrical network and are adapted for connection to one or more external devices or elements.

By use of semiconductor fabrication techniques, electronic circuits can be made so small that the interconnection of the leads to these circuits become a serious problem. For example, by using semiconductor fabrication techniques, it is possible to produce as a circuit module a multivibrator which is only about a quarter of an inch wide and $^1/_{32}$ of an inch thick. This particular circuit module has ten leads which must be connected to other external circuits. When several of these modules are to be connected together in a system, it is impossible to space the modules closely and interconnect them with conventional circuitry techniques. If the modules are not closely spaced, much of the space saving advantage of using the modules is wasted.

An object of the present invention is to provide interconnecting circuitry permitting the modules to be closely spaced.

A further object of this invention is to provide a method of making electrical connections to extremely small circuit elements.

The present invention is an assembly comprising a stack of circuit modules, a stack of electrically conducting sheets mounted against one side of said stack of circuit module elements, and means insulating each of said conducting sheets from each other, said stack of conducting sheets having a plurality of aligned holes defined therein passing through each of said sheets, each of said circuit modules having a plurality of leads extending into different ones of said holes and each connected to selected ones of said conducting sheets.

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, wherein:—

Figures 1*a* and 1*b* illustrate, respectively, the top and side views of a stack of circuit modules which are to be interconnected to form an assembly according to the present invention.

Figures 2*a* and 2*b* illustrate, respectively, a plan view and a cross sectional view of one of a plurality of conducting sheets used to provide reference or supply potentials to the modules.

Figure 3 illustrates an example of one of a plurality of insulating sheets for interconnecting the signal leads of the modules.

[*Price* 4*s.* 6*d.*]

Figures 4*a* and 4*b* schematically illustrate the assembly of the modules, the conducting sheets, and the insulating sheets.

Figure 5 illustrates an alternative arrangement of means for carrying away heat from the circuit modules.

Usually there are two types of electrical connections required in an electrical device or system. First, means must be provided for applying supply potentials to the device which requires a source of power other than the signal being acted upon. Normally several components will utilize the same supply potential, although more than one supply potential may be required. Second, means must be provided for transferring the electrical signal being acted upon from one device or component to the next.

The circuit modules are preferably stacked one on top of the other with the leads of each protruding stiffly from the edges thereof. Interconnections are then provided by a plurality of thin conducting sheets. A different sheet is used to connect each supply potential to the modules. Means are provided to insulate each conducting sheet from the others. One or more insulating sheets with printed circuits provide the signal interconnections to the modules. The insulating and conducting sheets are each perforated with holes which correspond to the leads from the modules. The sheets are dropped one at a time over the leads and the correct leads from the modules are connected to each conducting sheet and the printed circuits of each insulating sheet after such sheet is dropped.

Because of the small size and close packing of the module, large amounts of heat may be generated in a very small volume. This heat generation necessitates in some instances the provision of a means for the removal of the heat.

With reference now to the drawings, there is shown in Figure 1*a* an example of a circuit module 11 of the type disclosed in the above-mentioned co-pending Application. Each circuit module 11 may have a number of electrical leads 12, ten being shown here for purposes of illustration. The electrical leads 12 are in the form of thin flat conducting tabs of a pliable material, such as gold plated copper or "Kovar" (Registered Trade Mark) the trade name for a nickel, iron, and cobalt alloy. Five electrical leads 12 are shown located on each side of each circuit module. The leads 12 on each circuit module 11 are evenly spaced, and are positioned in a common plane. The circuit modules 11 are stacked one on top of the other, as shown in Figure 1*b*, and are positioned so that the leads 12 on each circuit module 11 are aligned with leads 12 on the other circuit modules 11.

As shown in Figures 2*a* and 2*b*, each thin conductor sheet used to provide the supply potentials to the circuit modules is designated generally by the reference numeral 13. The conductor sheet 13 comprises a conductive film 25, for example, copper, laminated to a sheet of insulating material 15, such as, for example, "Teflon" (Registered Trade Mark), which is the trade name for polytetrafluoroethylene. The sheet 13 is perforated with a plurality of holes 14 arranged in parallel rows. These holes 14 are so arranged that the sheets may be dropped over the leads 12 from the stacked circuit modules with each lead 12 passing through a different hole. The holes 14 are oblong shaped, and are of such a size that leads 12 will pass through the holes 14. As may be observed in Figures 2*a*, the holes 14*a* passing through the insulating sheet 15 are smaller than the corresponding hole 14*b* passing through the conductive film 25, thus preventing unintentional contact of the leads 12 and conductive film 25. The conductor sheets 13 are dropped over the leads 12 on each side of the stack of circuit modules 11, one at a time. After each conductor sheet is dropped over the leads 12, some of the leads 12 will be bent over and connected to the conducting film 25, for example, by soldering. Thus, the strips are stacked one on top of the other over the leads 12 with different leads from the circuit modules bent over and connected to each conducting film 25. The leads 12 from each circuit module 11, which are to receive the same supply potential are connected to the same conductive film 25. Thus, by connecting one supply potential to one conducting film, this supply potential is applied to each of the leads 12 connected to this conducting film. In this manner, each of the necessary supply potentials may be connected to the correct lead of each of the circuit modules. The sheets 15 of insulating material separate and insulate the conductive surfaces 25 of the conducting sheets 13 from each other. In this specific example, tab 26, which is part of sheet 13, provides a means for connecting a supply potential to the sheet 13.

The thin sheet shown in Figure 3, which is used for interconnecting signals paths between the circuit modules, comprises insulating material and is generally designated by the reference number 16. This sheet is perforated with holes 17 arranged in parallel rows corresponding to the positions of leads 12 extending from the stack of circuit modules 11. The holes 17 are of an oblong shape and are positioned so that the sheet 16 may be mounted with the leads 12 passing through the holes 17. The holes 17 are of such size that the leads 12 will pass through. On the sheet 16 of insulating material, conductive elements 18 are provided which run between selected ones of the holes 17. The conductve elements 18 may be

formed on the sheets 16 by any of the well known techniques generally known as "printed circuit" techniques, or by other suitable means. The sheet 16 is placed over the leads 12 with the leads 12 passing through the holes 17. The appropriate ones of the leads 12 which comprise the signal leads of the circuit module are then bent over and connected to the conductive elements 18. The conductive elements 18 are preselected to run between the correct holes so that the connection of the signal leads to the conductive elements results in the correct connection for the desired operation. Where a large number of signal leads are used which require the conductive elements 18 to cross over one another, one or more additional insulating sheets 16 with conductive elements are used. These additional insulating sheets may be stacked along with the other sheets, both those for circuit potential connecting (13) and those for signal interconnection (16), the leads 12 extending from the stack of circuit modules 11 through the aligned holes in the sheets of the stack. There results then a stack of sheets on each side of the stack of circuit modules 11 providing a completed circuit interconnecting the circuit modules and providing the necessary supply potentials to each circuit module. The electrical signal which is to be acted upon may be introduced into the circuit by means of one or more of the tabs 27, which may take any desired form. Similarly, the signal may be removed from the circuit by means of additional tab or tabs 27. Although separate stacks of the modules may be interconnected using lead wire to connect the taps 26 and 27, an alternative method is, of course, to use larger sheets of the types described above. The larger sheets may be of either or both of the types described above, depending on whether it is necessary to provide a common supply potential or a signal path or both. These larger sheets would extend from the leads of one stack of modules to the leads of another stack or stacks of modules. For example, several stacks of the modules can be placed adjacent one another with the leads 12 oriented in the same direction. One or more of the larger sheets can then be used for interconnecting the stacks in the manner described above. Several of these subassemblies can then be interconnected using still larger sheets lying in a plane perpendicular to the first-mentioned sheets and interconnecting the tabs 26 or 27. In this manner, complex systems can be assembled in a minimal amount of space and without the use of conventional interconnecting lead wires. It may be desirable to provide insulation over both surfaces of the conductors except in regions where connections are being made. Also, it would be unnecessary to provide slots except where connections are required.

Figure 4*a* shows the assembled package with the conductor sheets 13 and the insulating sheets 16, having conductive elements 18 thereon, mounted on each side of a stack of circuit modules. Figure 4*b*, which shows a partial cross section of the assembly through the stacked sheets 13 and 16, illustrates that the leads 12 extend into the apertures formed by the aligned holes in the stacks of sheets 13 and 16 and that each conducting sheet 13 is connected to selected ones of the leads 12 and the conductive elements on the insulating sheets 16 are each connected to selected ones of the leads 12.

Because of the close packing of the circuit modules, a relatively large amount of heat may be generated by the module stack. Therefore, it is sometimes necessary to provide a means for dissipating the heat from the stack. This means may comprise sheets 19 of a material such as copper, having high thermal conductivity which are stacked between the circuit modules 11. Alternatively, the circuit modules may be placed in slots 21 machined into a heat conducting block 20, as shown in Figure 5. The heat conducting sheets 19 or block 20 carry away the excess heat and maintain the circuit modules at the proper operating temperature.

The present invention is applicable to provide interconnections and reference potentials to any miniature circuit modules or any system where a large number of leads must be interconnected in a small space. For example, rather than having circuit modules the system may be comprised of a large number of individual components mounted on separate wafers of an appropriate substrate material. Also, it is possible to use rigid tabs of metal or ceramic and the apertures in the various circuit connecting sheets may be selectively sized to obtain electrical contact between the rigid tabs and the circuit connecting sheets when the circuit connecting sheets are placed on the rigid tabs.

WHAT WE CLAIM IS:—

1. An assembly comprising a stack of circuit modules, a stack of electrically conducting sheets mounted against one side of said stack of circuit module elements, and means insulating each of said conducting sheets from each other, said stack of conducting sheets having a plurality of aligned holes defined therein passing through each of said sheets, each of said circuit modules having a plurality of leads extending into different ones of said holes and each connected to selected ones of said conducting sheets.

2. An assembly according to Claim 1,

formed on the sheets 16 by any of the well known techniques generally known as "printed circuit" techniques, or by other suitable means. The sheet 16 is placed over the leads 12 with the leads 12 passing through the holes 17. The appropriate ones of the leads 12 which comprise the signal leads of the circuit module are then bent over and connected to the conductive elements 18. The conductive elements 18 are preselected to run between the correct holes so that the connection of the signal leads to the conductive elements results in the correct connection for the desired operation. Where a large number of signal leads are used which require the conductive elements 18 to cross over one another, one or more additional insulating sheets 16 with conductive elements are used. These additional insulating sheets may be stacked along with the other sheets, both those for circuit potential connecting (13) and those for signal interconnection (16), the leads 12 extending from the stack of circuit modules 11 through the aligned holes in the sheets of the stack. There results then a stack of sheets on each side of the stack of circuit modules 11 providing a completed circuit interconnecting the circuit modules and providing the necessary supply potentials to each circuit module. The electrical signal which is to be acted upon may be introduced into the circuit by means of one or more of the tabs 27, which may take any desired form. Similarly, the signal may be removed from the circuit by means of additional tab or tabs 27. Although separate stacks of the modules may be interconnected using lead wire to connect the taps 26 and 27, an alternative method is, of course, to use larger sheets of the types described above. The larger sheets may be of either or both of the types described above, depending on whether it is necessary to provide a common supply potential or a signal path or both. These larger sheets would extend from the leads of one stack of modules to the leads of another stack or stacks of modules. For example, several stacks of the modules can be placed adjacent one another with the leads 12 oriented in the same direction. One or more of the larger sheets can then be used for interconnecting the stacks in the manner described above. Several of these subassemblies can then be interconnected using still larger sheets lying in a plane perpendicular to the first-mentioned sheets and interconnecting the tabs 26 or 27. In this manner, complex systems can be assembled in a minimal amount of space and without the use of conventional interconnecting lead wires. It may be desirable to provide insulation over both surfaces of the conductors except in regions where connections are being made. Also, it would be unnecessary to provide slots except where connections are required.

Figure 4*a* shows the assembled package with the conductor sheets 13 and the insulating sheets 16, having conductive elements 18 thereon, mounted on each side of a stack of circuit modules. Figure 4*b*, which shows a partial cross section of the assembly through the stacked sheets 13 and 16, illustrates that the leads 12 extend into the apertures formed by the aligned holes in the stacks of sheets 13 and 16 and that each conducting sheet 13 is connected to selected ones of the leads 12 and the conductive elements on the insulating sheets 16 are each connected to selected ones of the leads 12.

Because of the close packing of the circuit modules, a relatively large amount of heat may be generated by the module stack. Therefore, it is sometimes necessary to provide a means for dissipating the heat from the stack. This means may comprise sheets 19 of a material such as copper, having high thermal conductivity which are stacked between the circuit modules 11. Alternatively, the circuit modules may be placed in slots 21 machined into a heat conducting block 20, as shown in Figure 5. The heat conducting sheets 19 or block 20 carry away the excess heat and maintain the circuit modules at the proper operating temperature.

The present invention is applicable to provide interconnections and reference potentials to any miniature circuit modules or any system where a large number of leads must be interconnected in a small space. For example, rather than having circuit modules the system may be comprised of a large number of individual components mounted on separate wafers of an appropriate substrate material. Also, it is possible to use rigid tabs of metal or ceramic and the apertures in the various circuit connecting sheets may be selectively sized to obtain electrical contact between the rigid tabs and the circuit connecting sheets when the circuit connecting sheets are placed on the rigid tabs.

WHAT WE CLAIM IS:—

1. An assembly comprising a stack of circuit modules, a stack of electrically conducting sheets mounted against one side of said stack of circuit module elements, and means insulating each of said conducting sheets from each other, said stack of conducting sheets having a plurality of aligned holes defined therein passing through each of said sheets, each of said circuit modules having a plurality of leads extending into different ones of said holes and each connected to selected ones of said conducting sheets.

2. An assembly according to Claim 1,

wherein each of said leads comprises a thin conducting tab.

3. An assembly according to Claim 1 or 2, wherein each of said holes is in the shape of an oblong slot.

4. An assembly according to any of Claims 1 to 3, wherein said leads extend into said holes with clearance.

5. An assembly according to any of Claims 1 to 4, wherein sheets of heat conducting material are mounted between the circuit modules.

6. An assembly according to any of the preceding claims further including a second stack of electricially conducting sheets mounted against a second side of said stack of circuit modules, means insulating each of said sheets of said second stack from each other, each of said stacks of conducting sheets having a plurality of aligned holes passing through all of the sheets of such stack, each of said circuit modules having a plurality of leads each extending into a different one of said holes and each connected to selected ones of said conducting sheets.

7. A method of fabricating an assembly according to any of the preceding claims, comprising the steps of placing said circuit modules in such a manner that all of said leads extend in the same direction, perforating a plurality of rows of holes in each of a plurality of sheets of conducting material corresponding to the positions of said leads extending from said circuit modules, positioning said conducting sheets one at a time over said leads so that said leads extend through said holes, insulating each conducting sheet from the or each adjacent conducting sheet, and connecting some of said leads to each conducting sheet after such sheet is positioned and before the next sheet is positioned.

8. A method of fabricating an assembly of circuit modules substantially as hereinbefore described with reference to Figs. 1 to 4*b* or Figs. 1 to 3 and 5 of the accompanying drawings.

9. An assembly of circuit modules when fabricated by the method of Claim 7.

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