



US009671903B1

(12) **United States Patent**
Piovanelli et al.

(10) **Patent No.:** **US 9,671,903 B1**
(45) **Date of Patent:** **Jun. 6, 2017**

(54) **MODULAR OPTICAL TOUCH PANEL STRUCTURES**

(71) Applicant: **Sensing Electromagnetic Plus Corp.**,
Palo Alto, CA (US)

(72) Inventors: **Matteo Piovanelli**, Palo Alto, CA (US);
Alessandro Levi, Palo Alto, CA (US);
Silvano Furlan, Palo Alto, CA (US)

(73) Assignee: **Sensing Electromagnetic Plus Corp.**,
Palo Alto, CA (US)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 34 days.

(21) Appl. No.: **14/580,164**

(22) Filed: **Dec. 22, 2014**

Related U.S. Application Data

(60) Provisional application No. 61/920,431, filed on Dec.
23, 2013.

(51) **Int. Cl.**
G06F 3/042 (2006.01)

(52) **U.S. Cl.**
CPC **G06F 3/042** (2013.01)

(58) **Field of Classification Search**
CPC G06F 3/042
USPC 250/349
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,016,961 A * 5/1991 Aldrich H04B 10/22
250/551
8,344,325 B2 * 1/2013 Merrell G06F 3/017
250/349

2009/0105605 A1* 4/2009 Abreu A61B 5/0008
600/549
2010/0171029 A1* 7/2010 Lee G01D 5/34738
250/231.1
2011/0063213 A1* 3/2011 Kang G06F 3/03547
345/158
2011/0096033 A1* 4/2011 Ko G06F 3/017
345/175
2011/0279414 A1* 11/2011 Noma G02F 1/1336
345/175
2011/0310126 A1* 12/2011 Georgiev G06F 3/016
345/660
2012/0162126 A1* 6/2012 Yuan G06F 3/0412
345/174
2013/0307795 A1* 11/2013 Suarez Rovere G06F 3/0488
345/173
2014/0001349 A1* 1/2014 Reime G01D 5/28
250/231.1
2014/0252209 A1* 9/2014 Land G01V 8/20
250/208.2
2014/0267124 A1* 9/2014 Christiansson G06F 3/042
345/173
2014/0326882 A1* 11/2014 Tar G01L 5/166
250/338.1

* cited by examiner

Primary Examiner — David Porta

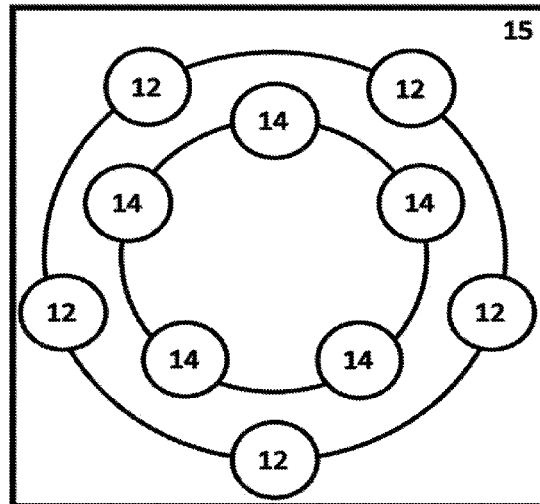
Assistant Examiner — Gisselle Gutierrez

(74) *Attorney, Agent, or Firm* — Cooley LLP

(57) **ABSTRACT**

An apparatus has a first ring of infrared emitters and a second ring of infrared detectors positioned adjacent to the first ring. A controller applies signals to the first ring and collects signals from the second ring.

7 Claims, 13 Drawing Sheets



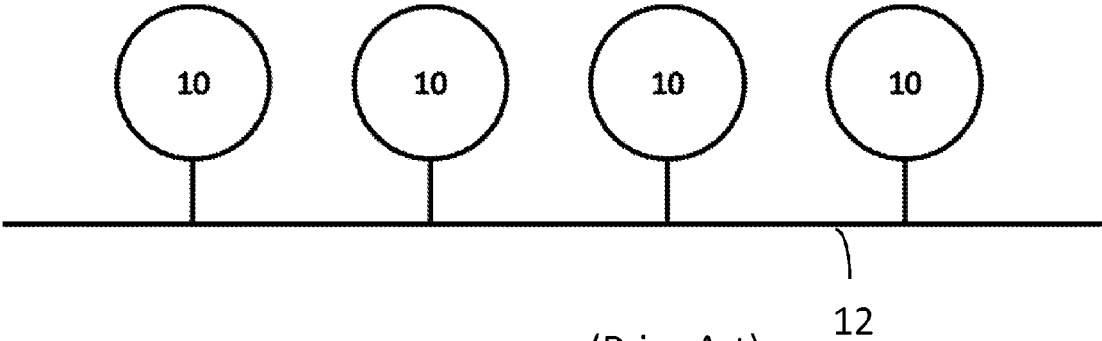


Figure 1 (Prior Art)

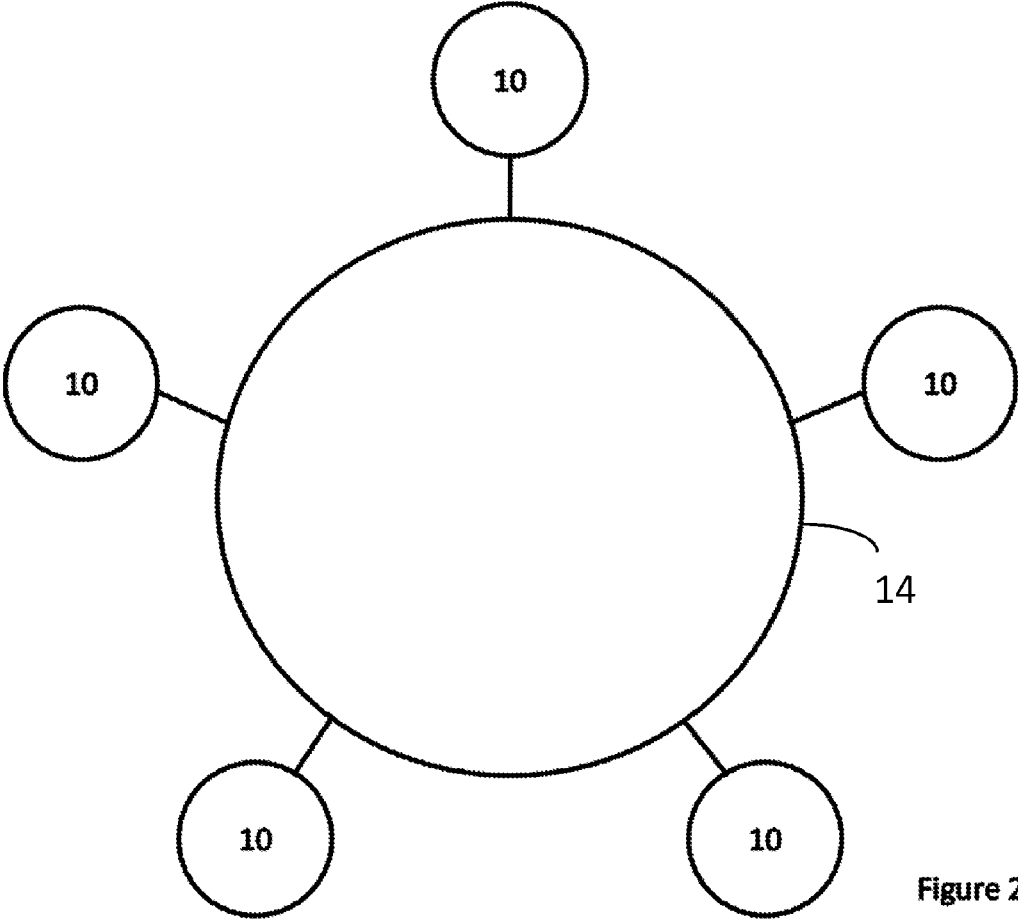


Figure 2 (Prior Art)

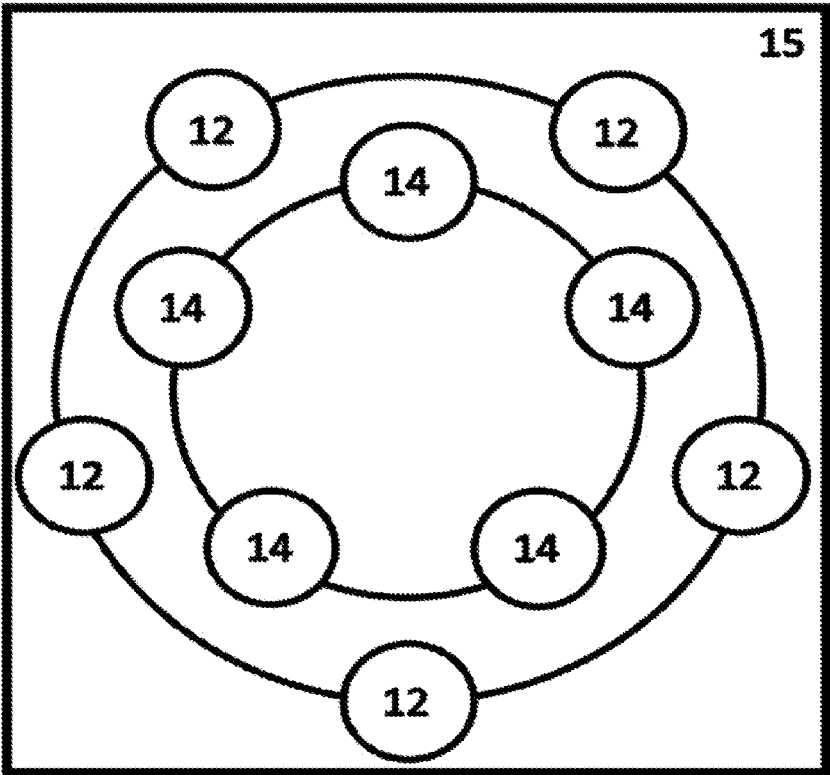


Figure 3

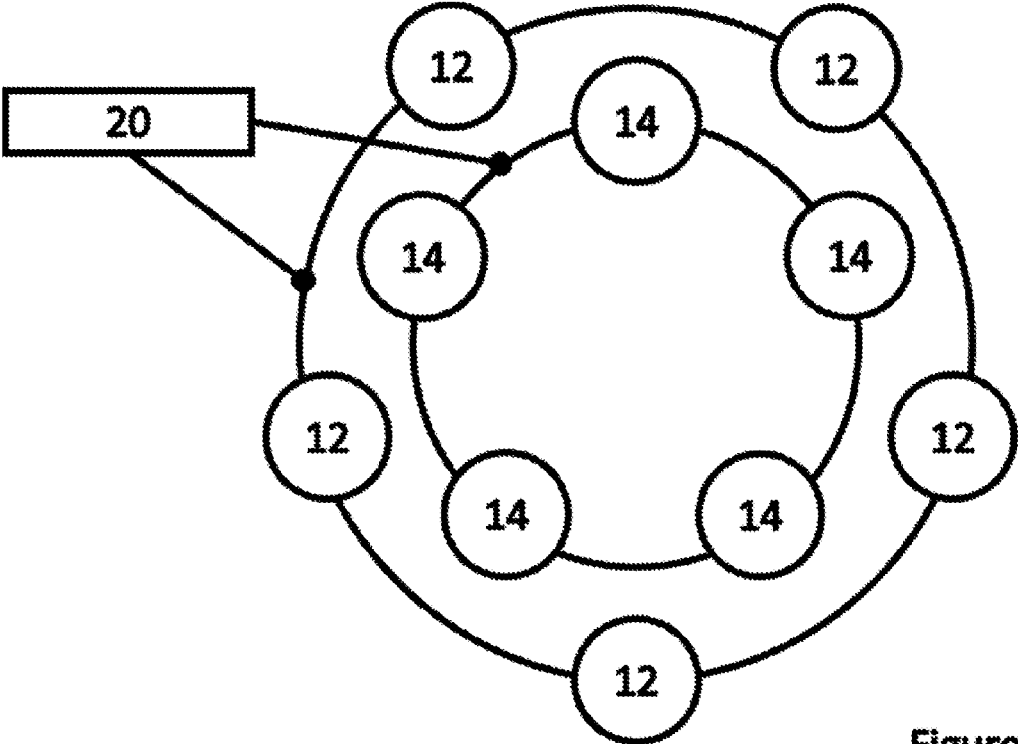


Figure 4

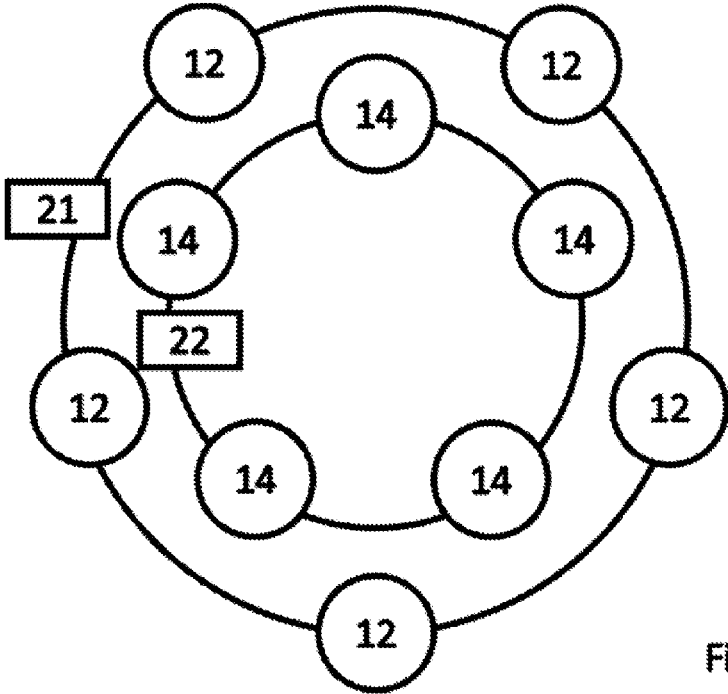


Figure 5

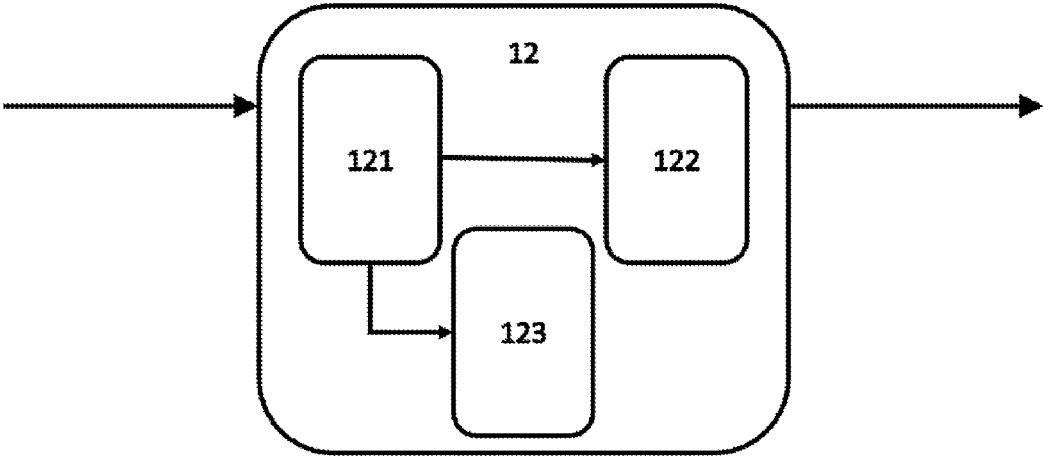


Figure 6

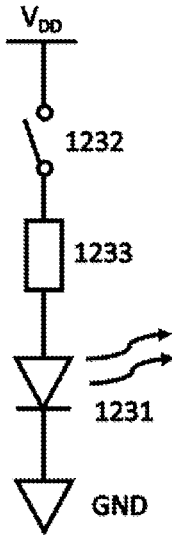


Figure 7(A)

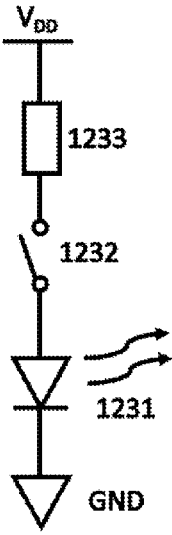


Figure 7(B)

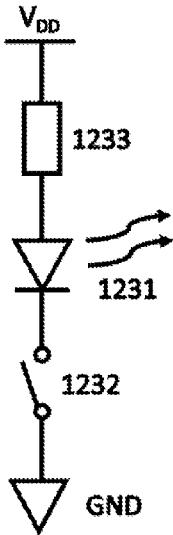


Figure 7(C)

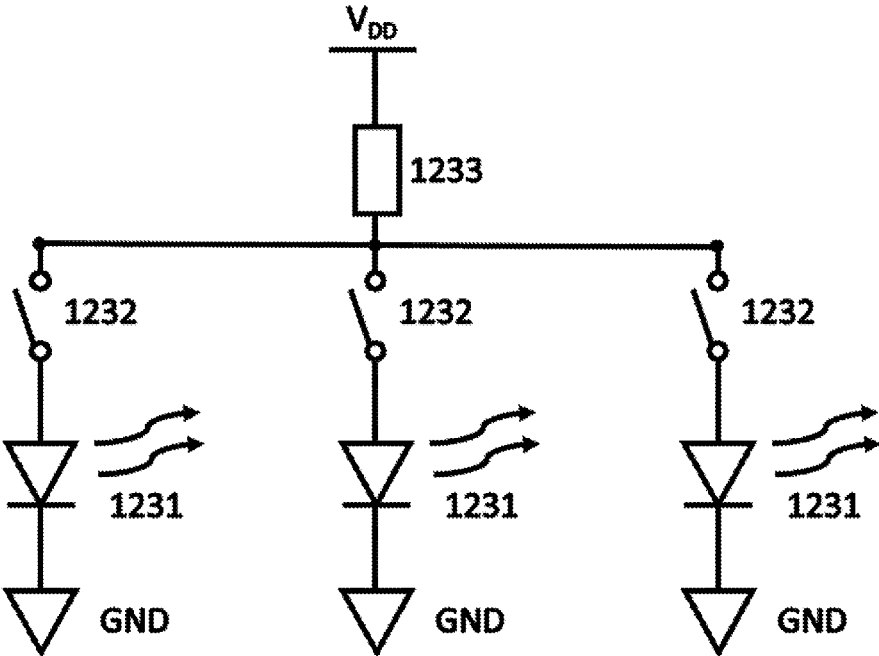


Figure 8

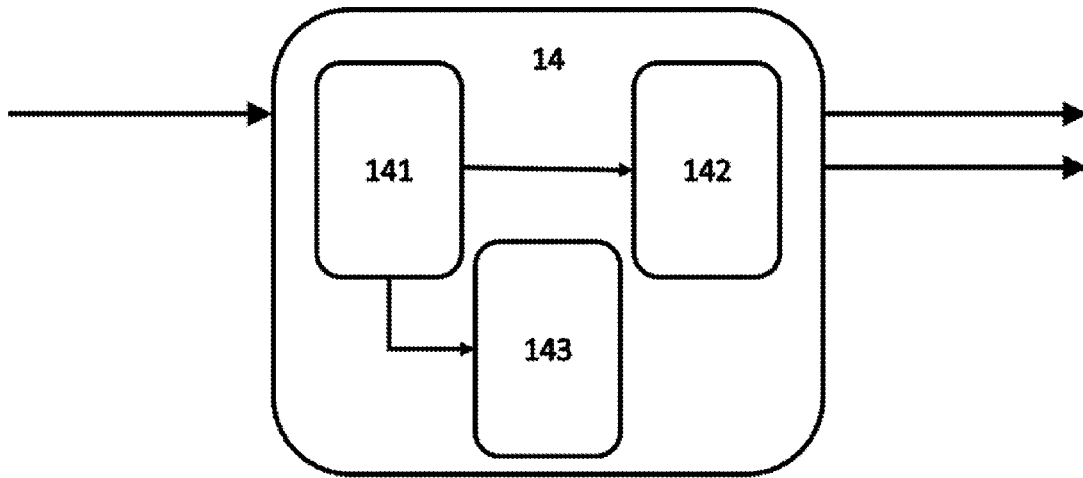


Figure 9

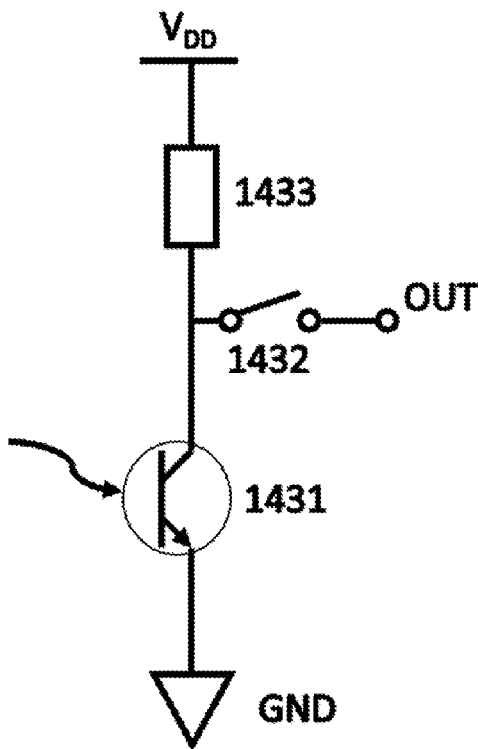


Figure 10(A)

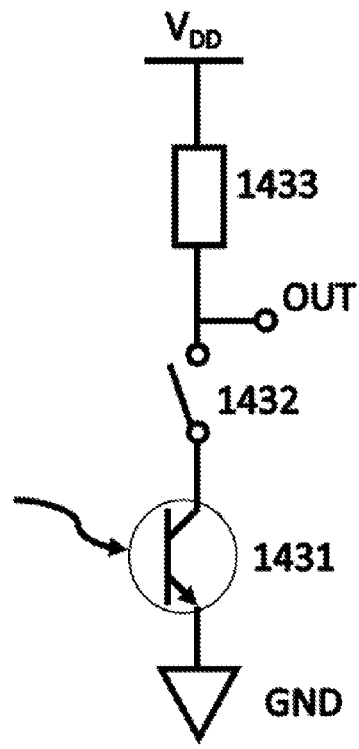


Figure 10(B)

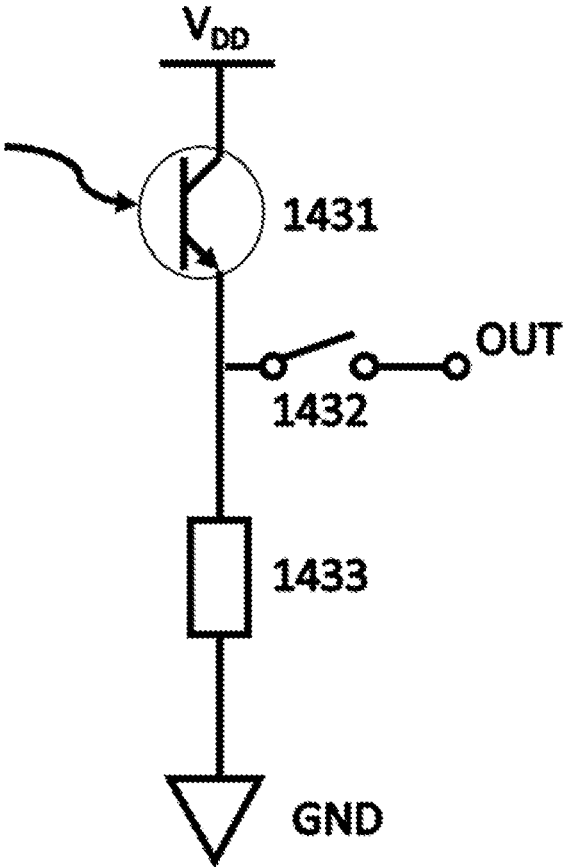


Figure 10(C)

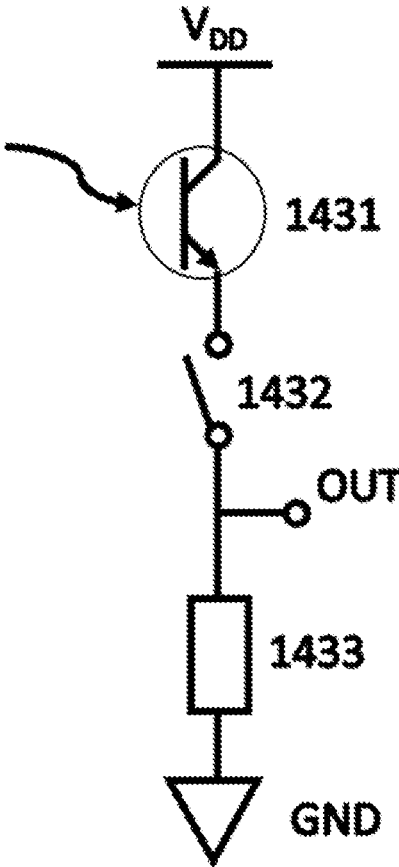


Figure 10(D)

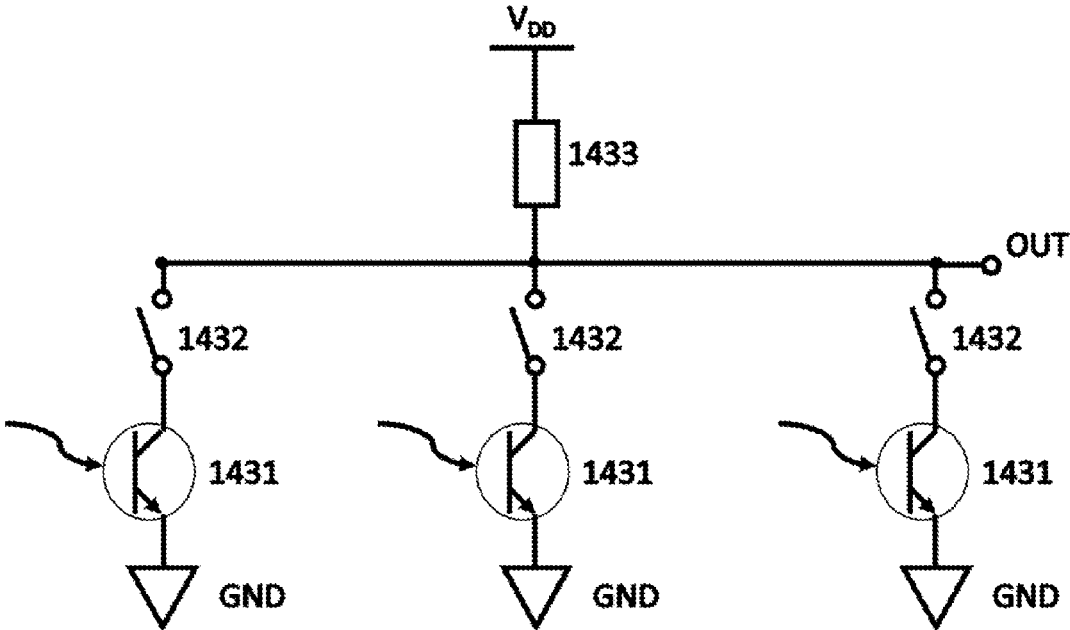


Figure 11

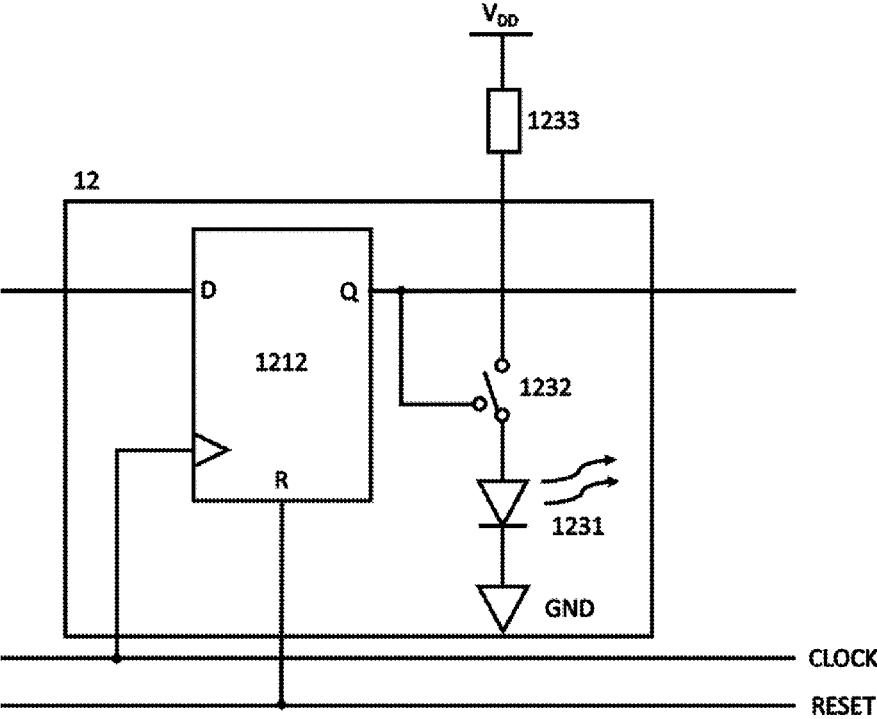


Figure 12

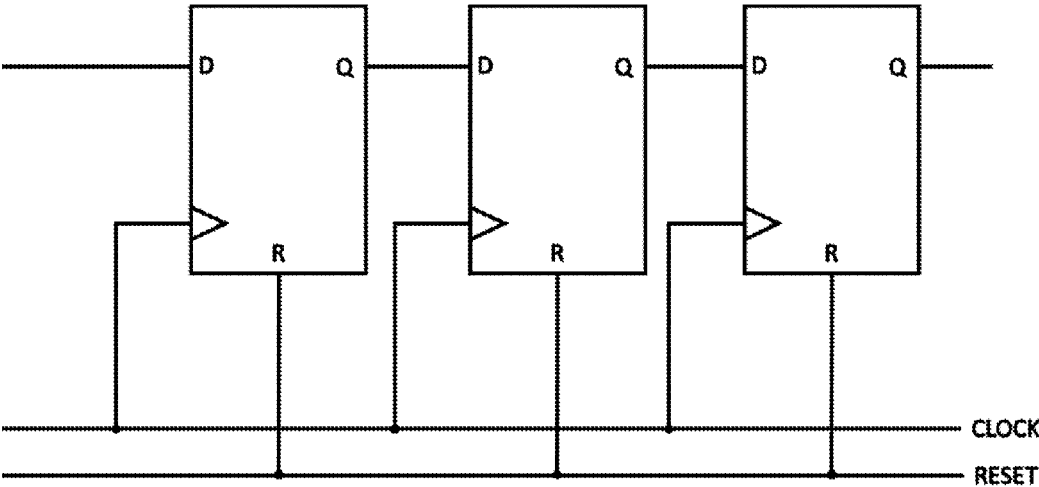


Figure 13

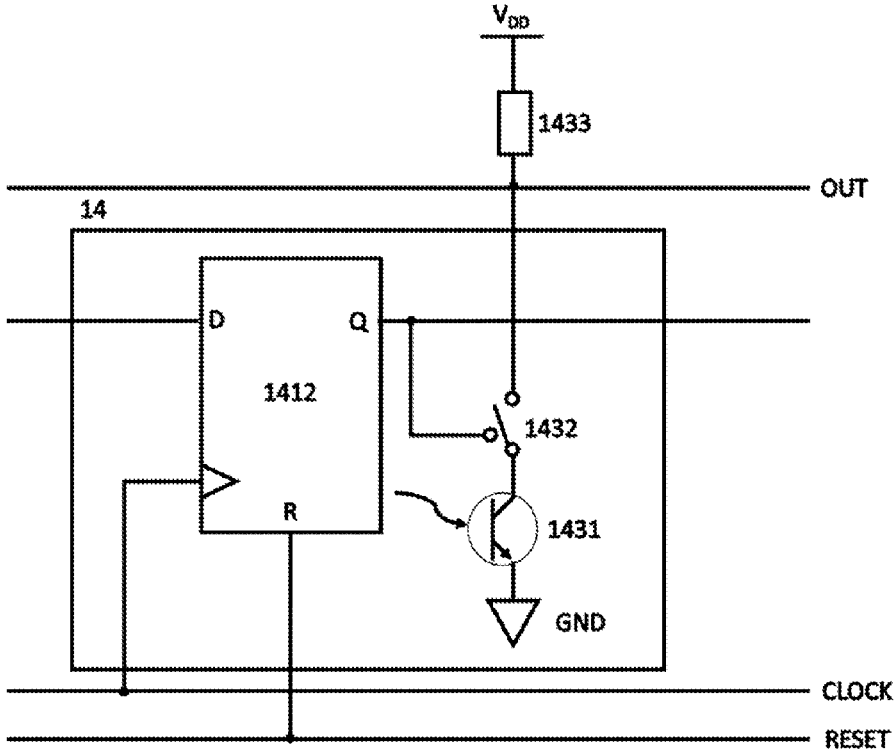


Figure 14

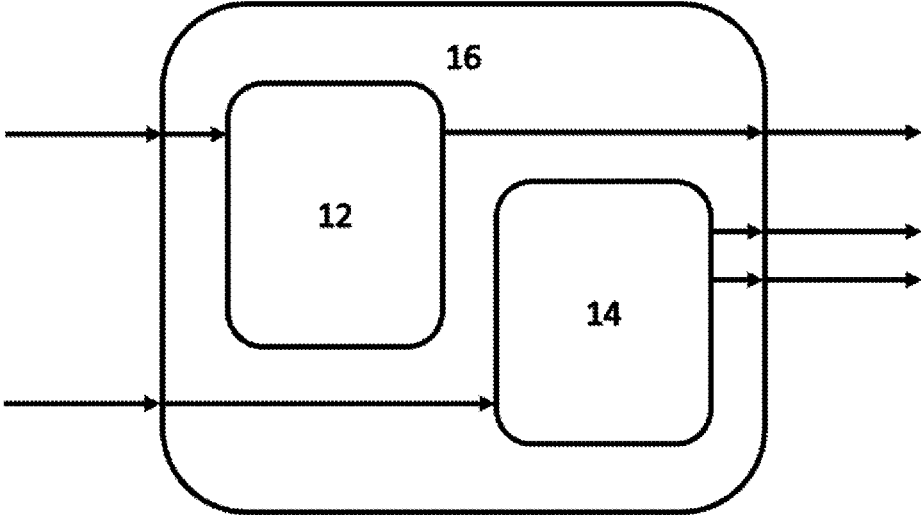


Figure 15

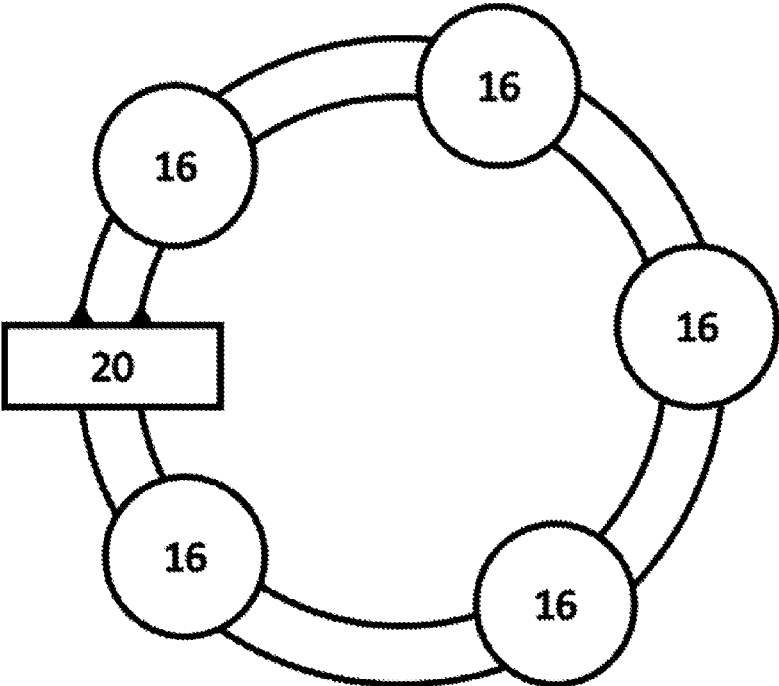


Figure 16

1

MODULAR OPTICAL TOUCH PANEL STRUCTURES

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. Provisional Patent Application Ser. No. 61/920,431, filed Dec. 23, 2013, the contents of which are incorporated herein by reference.

FIELD OF INVENTION

This invention relates generally to electronic devices. More particularly, this invention relates to modular optical touch panel structures.

BACKGROUND OF INVENTION

A number of systems in different fields can be represented as a sequence of repeated modules or units. For example, in the case of network topologies the units are referred to as nodes. Two typical examples of network topologies are the bus and the ring.

In the prior art bus topology of FIG. 1, the nodes 10 of the network are connected via a shared communication line 12 called a bus. This is the simplest and generally the easiest way to connect multiple nodes, although it requires management of collisions that happen when more than one node 10 attempts to use the bus 12 at the same time.

In the prior art ring topology of FIG. 2, each node 10 is connected to exactly two other nodes, forming a single loop 14. It is possible to imagine a ring topology as formed starting from a bus topology by connecting the last node to the first.

Either topology, or any different one, can be implemented on hardware, by physically connecting the nodes accordingly, or on a virtual layer. The latter means that for example it is possible to implement a virtual ring topology even though the nodes are actually connected on a bus topology.

It would be desirable to utilize new topologies for electronic components. More particularly, it would be desirable to provide new modular optical touch panel structures.

SUMMARY OF THE INVENTION

An apparatus has a first ring of infrared emitters and a second ring of infrared detectors positioned adjacent to the first ring. A controller applies signals to the first ring and collects signals from the second ring.

A method includes forming a serial string of infrared emitters in a first ring and constructing a serial string of infrared detectors in a second ring. The first ring is positioned adjacent to the second ring. At least one controller is attached to the first ring or the second ring.

BRIEF DESCRIPTION OF THE FIGURES

The invention is more fully appreciated in connection with the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 illustrates a prior art bus topology.

FIG. 2 illustrates a prior art ring topology.

FIG. 3 illustrates a double ring topology in accordance with an embodiment of the invention.

FIG. 4 illustrates a double ring topology with a control node utilized in accordance with an embodiment of the invention.

2

FIG. 5 illustrates a double ring topology with multiple controller nodes utilized in accordance with an embodiment of the invention.

FIG. 6 illustrates an emitter node configured in accordance with an embodiment of the invention.

FIGS. 7(A)-7(C) illustrate emitters utilized in accordance with embodiments of the invention.

FIG. 8 illustrates emitter nodes connected in parallel.

FIG. 9 illustrates a detector node configured in accordance with an embodiment of the invention.

FIGS. 10(A)-10(D) illustrate detectors utilized in accordance with embodiments of the invention.

FIG. 11 illustrates detectors connected in parallel in accordance with an embodiment of the invention.

FIG. 12 illustrates an emitter node with a command-decoding element.

FIG. 13 illustrates a shift register architecture utilized in accordance with an embodiment of the invention.

FIG. 14 illustrates a detector node with a command-decoding element and the command-forwarding element.

FIG. 15 illustrates a double ring configuration utilized in accordance with an embodiment of the invention.

FIG. 16 illustrates a double ring configuration with a single controller.

Like reference numerals refer to corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 3 illustrates a double ring topology of infrared (IR) emitting nodes 12 and IR detecting nodes 14 encased in a deformable material 15 that allows for the evaluation of haptic pressure. This topology allows one to sequentially activate the IR emitters, and to read in sequence from the IR detectors.

FIG. 4 illustrates a control node 20 connected to the double ring. The control node 20 is responsible for sending the signals to activate and deactivate the IR emitter nodes 12 and to read from the IR detector nodes 14. Advantages of this configuration include:

it is possible to count the IR emitter nodes 12 and the IR detector nodes 14;

nodes can be seamlessly added to the system on either of the rings; and

the controller node can be connected between any two nodes of either ring;

As shown in FIG. 5, the controller node 21 for the ring of IR emitter nodes 12 can be considered distinct from the controller node 22 for the ring of IR detector nodes 14. In some practical applications, however, the two controller nodes will need to communicate and/or be synchronized and thus it may be practical to implement them in a single device.

An IR emitter node 12 needs to be able to communicate with the ring, receiving and forwarding commands. Furthermore, such node needs to be able to opportunistically emit IR light. Hence, a basic IR emitter node 12 will comprise a command-decoding element 121, a command-forwarding element 122, and an IR emitting element 123, as shown in FIG. 6.

The IR emitting element 123 will in general contain an IR emitter 1231, as shown in FIG. 7(a). A light emitting diode (LED) 1231 may be connected to a switching circuit 1232, such as a power transistor. The IR emitter 1231 may require a polarization circuit 1233, for example a resistive load. FIGS. 7(A)-(C) show three example configurations for an IR

emitting element **1231**. In many cases, it will be advantageous to use the configurations in FIG. 7(B) or FIG. 7(C), because the polarization circuit **1233** may be shared among many IR emitting elements, as shown in FIG. 8.

An IR detector node **14** needs to be able to communicate with the ring, receiving and forwarding commands. Furthermore, such node needs to be able to detect IR light and convert it to an opportune signal, which the node needs to be able to send along the ring to the rest of the system. Hence, a basic IR detector node **14** will include a command-decoding element **141**, a command-forwarding element **142**, and an IR converting element **143**, as shown in FIG. 9.

The IR converting element **143** will in general contain a circuit or structure **1431** that is able to convert the IR signal received to a signal that can be transmitted to the rest of the system. Often, this will be an electrical signal, and the structure **1431** may be a photodiode or a phototransistor, as shown in FIGS. 10(A) and 10(B). The IR converting element **143** will in general also contain a switching circuit **1432**, for example a power transistor, to selectively connect the output of the structure **1431** to the rest of the system. Moreover, the IR converting element **143** will often contain a polarization circuit **1433**, for example a resistive load. FIGS. 10(A) through 10(D) show four example configurations for an IR converting element **143**. In many cases, it will be advantageous to use the configurations in FIG. 10(B) or FIG. 10(D), because the polarization circuit **1433** may be shared among many IR emitting elements, as shown in FIG. 11.

In the simplest case, each IR emitter node **12** contains only one IR emitting element **123**, and each IR detector node **14** contains only one IR converting element **143**. In those cases:

the command-decoding element **121** and the command-forwarding element **122** of the IR emitter node **12** may be implemented together as a single flip-flop;

the command-decoding element **141** and the command-forwarding element **142** of the IR detector node **14** may be implemented together as a single flip-flop.

Both these configurations would also use a timing, or clock, signal, shared among all nodes of each ring, and, optionally, a reset signal.

Different configurations are of course possible, in which, for example, each IR emitter node **12** contains more IR emitting elements **123**, and/or each IR detector node **14** contains more IR converting elements **143**. In these cases, the command-decoding element **121** and the command-forwarding element **122** of the IR emitter node **12** may be implemented as separate circuits. Likewise, the command-decoding element **141** and the command-forwarding element **142** of the IR detector node **14** may be implemented as separate circuits.

FIG. 12 shows an example configuration for an IR emitter node **12** in which the command-decoding element **121** and the command-forwarding element **122** have been implemented together as a single flip-flop **1212**. The configuration of the IR emitting element **123** is supposed to be similar to what was shown in FIG. 8, in which the polarization circuit **1233** is shared among many IR emitting elements along the ring: as such, it is represented outside the IR emitter node **12**. Upon receiving an opportune transition on the clock signal, the flip-flop **1212** outputs on its Q terminal the signal it has as input on its D terminal. When the Q output of the flip-flop **1212** is at an opportune level (for example a logic high level), the switching circuit **1232** connects the IR emitter **1231** to the polarization circuit **1233**, causing its activation; on the other hand, when the Q output is at the other level (for example a logic low level), the switching circuit **1232** is

open, and the IR emitter **1231** is deactivated. Assuming the ring to be a sequence of IR emitter nodes as those represented in FIG. 12, at each opportune transition of the clock signal, the signal at the Q output of the flip-flop **1212** of an IR emitter node **12** will appear at the Q output of the flip-flop **1212** of the next IR emitter node **12**. This is similar to a common implementation of a Single-Input-Single-Output (SISO) shift register, as shown in FIG. 13.

FIG. 14 shows an example configuration for an IR detector node **14** in which the command-decoding element **141** and the command-forwarding element **142** have been implemented together as a single flip-flop **1412**. The configuration of the IR converting element **143** is similar to what was shown in FIG. 11, in which the polarization circuit **1433** is shared among many IR converting elements along the ring: as such, it is represented outside the IR detector node **14**. Upon receiving the opportune transition on the clock signal, the flip-flop **1412** outputs on its Q terminal the signal it has as input on its D terminal. When the Q output of the flip-flop **1412** is at an opportune level (for example a logic high level), the switching circuit **1432** connects the IR converting circuit **1431** to the output line: the information from the IR detector node is then available to be read on the ring. On the other hand, when the Q output of the flip-flop **1412** is at the other level (for example a logic low level), the switching circuit **1432** is open, and the IR converting circuit **1431** is not connected to the output line of the ring. Assuming the ring to be a sequence of IR detector nodes, at each opportune transition of the clock signal, the signal at the Q output of the flip-flop **1412** of an IR detector node **14** will appear at the Q output of the flip-flop **1412** of the next IR detector node **14**. This is similar to a common implementation of a SISO shift register, as shown in FIG. 13.

In general, the controller node **21** for the ring of IR emitter nodes **12** is able to determine the number of IR emitter nodes **12** connected on its ring, by sending an opportune instruction sequence and analyzing the information returned by the ring. For example, in the case in which the IR emitter nodes **12** are implemented as represented in FIG. 12, the controller node **21** may be able to determine the number of nodes by:

a. Sending a single high value to the command input (corresponding to the D port of flip-flop **1212**) of the first node;

b. Counting the periods of the clock signal until it receives a single high value from the command output.

Similarly, the controller node **22** for the ring of IR detector nodes **14** is able to determine the number of IR detector nodes **14** connected on its ring by sending an opportune instruction sequence and analyzing the information returned by the ring. For example, in the case in which the IR detector nodes **14** are implemented as represented in FIG. 14, the controller node **22** may be able to determine the number of nodes in a process similar to the one described above.

In many practical implementations of the double ring topology described here, IR emitter nodes **12** and IR detector nodes **14** may be implemented in a single double ring node **16**, as shown in FIG. 15. In this case, it would also be practical for the two controller nodes **21** and **22** to be implemented as a single controller circuit **20**, as shown in FIG. 16.

In the case described above, in which double ring nodes **16** are used, it is possible to see that, starting from a controller node **20**, it is possible to add double ring nodes **16** one after the other seamlessly, and then close the ring by connecting the last double ring node **16** back to the controller node **20**. Likewise, it is possible to remove double ring

nodes **16** without destroying the ability of the system to operate as long as the ring is closed again afterwards. This is useful in a number of practical cases in which it might be useful to produce the double ring nodes **16** as single modules, and then add as many as are needed in the specific application. This has clear benefits where the cost or complexity of designing and producing a whole system tailored for the specific application would be impractical. If the double ring is implemented as a virtual layer, a ring may be automatically closed upon addition or removal of nodes.

The double ring topology may include processing nodes, either as part of the emitter or detector nodes, or as stand-alone nodes. These processing nodes may take information from the control nodes, from the emitter nodes and from the detector nodes and perform operations using that information, or part of it. These operations might be useful to reduce the computational load on the control nodes, or on processing units in a larger system that the double ring is a part of. For example, the nodes can normalize the data read with respect to a known bias. Further examples may include, tuning an amplification or signal conditioning stage based on the signals read at previous times, tuning the characteristics of the polarization circuit of a node, or a set of nodes, or all nodes, and deriving some information from a combination of signals read, to ease the computational load from other components of a larger system. In another embodiment, the processing node removes or adds nodes from a double ring implemented as a virtual layer. This may be done in response to the detection of a fault or to change an operational mode.

In the field of optical touch sensors, this architecture allows one to seamlessly scale the size of the system without changing fabrication steps. For different sizes, it is possible to use more or fewer double ring nodes **16**, which can be produced simply and easily assembled one to the other. This can allow the production of touch layers of different shapes and form factors, without having the requirement to develop a specific fabrication process. Consequences of this are:

a clear advantage in terms of cost, because there is no need to develop a different process or plant for different layer sizes;

an advantage in terms of design options, because shapes, form factors and sizes for the touch layer are not limited to a restricted selection dictated by the usual requirements of the market and, ultimately, the need for a different process for each shape or size.

The disclosed configuration may be used to form a touchscreen that a user controls through gestured applied to the touchscreen. For example, the double ring structure and associated controller may be encased in a deformable material (e.g., a polymer). A user can deploy the touchscreen by reacting to what is displayed. Gestures applied to the touchscreen can provide input to a system. Thus, the touchscreen enables a user to interact directly with what is displayed. Accordingly, the touchscreen may be used in game consoles, personal computers, tablet computers, smartphones, personal digital assistants, satellite navigation devices and electronic books. The deformable material allows for the evaluation of haptic pressure. A non-deformable material may also be used to for position sensing, but not pressure sensing.

A specific example of an application of a touch sensor that would benefit from this architecture is in the automotive space. Supposing one wishes to use an optical touch sensor on a car's dashboard, for each car model one would have a different dashboard, hence one would have to build different touch sensors. Often, this requires modifications of equipment and fabrication tools, at the very least in terms of their

configuration, thus an increased cost. By using the architecture proposed here, it would be possible to build double ring nodes **16** and just connect as many as are needed, in the position they are needed, and the controller node **20** would then take care of counting and operating them. The manufacturing of the double ring nodes **16** would be identical for each car model, thus decreasing the costs associated with setting up different production processes or lines.

In sum, the disclosed system has:

a double ring topology of emitter and detector circuits, where each node includes the emitter (or detector) proper and further circuits to control it and transmit information along the ring;

a controller with the ability to sit in the double ring topology, count the nodes of either kind, drive each emitter in a known fashion and read from each detector; the ability to seamlessly build double rings of any number of nodes, by adding or removing them, without destroying the functionality of the system.

It is also noteworthy that:

the concepts may be applied to any number of rings having nodes of 1, 2, 3, 4, . . . kinds;

The nodes could be different from IR emitter or detectors (for example they could be microwave emitters and detectors);

Implementing in the nodes more advanced functionalities (for example, IR detector nodes might include a circuit to normalize the data read with respect to a given bias).

The foregoing description, for purposes of explanation, used specific nomenclature to provide a thorough understanding of the invention. However, it will be apparent to one skilled in the art that specific details are not required in order to practice the invention. Thus, the foregoing descriptions of specific embodiments of the invention are presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed; obviously, many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, they thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated. It is intended that the following claims and their equivalents define the scope of the invention.

The invention claimed is:

1. An apparatus, comprising:

a first ring of infrared emitters;

a second ring of infrared detectors positioned within or around the first ring in a stationary relationship with the first ring; and

a controller to apply signals to the first ring and to collect signals from the second ring, wherein the first ring of infrared emitters and the second ring of infrared detectors are encased in a deformable material that allows for the evaluation of haptic pressure.

2. The apparatus of claim 1 wherein the controller is configured to count the number of infrared emitters and the number of infrared detectors added to the first ring of infrared emitters and the second ring of infrared detectors.

3. The apparatus of claim 1 wherein each infrared emitter has a command-decoding element, a command-forwarding element and an infrared emitting element.

4. The apparatus of claim 1 wherein each infrared detector has a command-decoding element, a command-forwarding element and an infrared detecting element.

5. A method, comprising:
forming a serial string of infrared emitters in a first ring;
constructing a serial string of infrared detectors in a
second ring;
positioning the first ring within or around the second ring; 5
attaching at least one controller to the first ring or the
second ring; and
encasing the serial string of infrared emitters and the
serial string of infrared detectors in a deformable
material that allows for the evaluation of haptic pres- 10
sure and establishes a stationary relationship between
the first ring and the second ring.

6. The method of claim 5 further comprising adding an
infrared emitter to the first ring and counting with the
controller the infrared emitter added to the first ring. 15

7. The method of claim 5 further comprising adding an
infrared detector to the second ring and counting with the
controller the infrared detector added to the second ring.

* * * * *