

PATENT SPECIFICATION

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(54) THERMAL IMAGING SYSTEM

(71) We, TEXAS INSTRUMENTS INCORPORATED, a Corporation organized according to the laws of the State of Delaware, United States of America, of 13500 North Central Expressway, Dallas, Texas, 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 thermal imagers.

In the past, thermal imaging systems have included an image moving optics for focusing an image on a linear array of quantum detectors, a cryogenic cooler for cooling the detector array to an operating temperature, a linear array of emitters coupled to the array of quantum detectors for producing output signals indicative of an image of the scene, and a derotation member in the path of the emitter output signals for unscrambling the visible image of the scene. Such prior art systems have many disadvantages. For example, for scanning a scene either the scanning mirrors must be scanned or the detector mechanism rotated to produce an image; therefor, these systems have all the problems attending mechanical mechanisms having moving parts. Further the quantum detectors require expensive, complex cryogenic coolers to maintain them at operating temperatures. Many problems attend systems which must be operated at temperatures of 77°K and below. Such problems stem from the use of sophisticated metals, materials and components necessary to produce images. The systems are bulky, weighty, and not readily susceptible to mass production techniques are of marginal performance and have a lifetime limited by the cooling system.

Accordingly, it is an object of this invention to provide an improved thermal imager.

According to the present invention there is provided a thermal imager including: a matrix of spaced thermally sensitive capacitors; a drive circuit for biasing the capacitors so that the potentials on the capacitors vary according to their temperature; a housing allowing selected capacitors of the matrix to be exposed to a pattern of thermal energy; and a signal processor for monitoring the potentials on the capacitors and producing a signal representative of the intensity of thermal energy impinging on the capacitors. A thermal imager embodying the present invention will now be described by way of example only, making reference to the accompanying drawings in which:

Figure 1 is a block diagram of a thermal imaging system;

Figure 2 is an isometric view of a thermal imaging system;

Figure 3 is a schematic diagram illustrative of a ferroelectric optical transducer signal generation technique;

Figure 4 is a cross-sectional view of the detector matrix for the ferroelectric imaging system;

Figures 5a, b and c depict fabrication of the capacitor matrix;

Figure 6 depicts the resolution area of each element of the detector matrix;

Figure 7 is a schematic view of an addressable matrix array; and

Figure 8 is a schematic view showing in greater detail the addressable matrix array of Figure 7.

Referring now to Figure 1, the thermal imager system 10 comprises a lens system 12, a detector matrix 14, drive and readout electronics 16, a video processor 18, a timing and control means 20, and a display means 22. The lens system 12 may be, for example, an infrared lens system having an object lens, correction lens, and a focusing lens for focusing

thermal energy emanating from a scene (not shown) onto the detector matrix 14. It will be understood by those skilled in the art that various types of lens systems exist capable of performing the desired optical functions. The detector matrix 14 includes a plurality of thermal energy sensors and reference elements for producing electrical signals representative of the thermal energy impinging on the sensors for the video processor 18. The detector matrix 14 is more fully described hereinafter in detail. The video processor 18 processes the signals representative of the scene into display signals for display by the means 22. The display means 22 may be, for example, a cathode ray tube. The drive and readout electronics 16 is connected to the detector matrix 14 for biasing the thermal sensors and reference elements, and reading out electrical signals representative of the scene. The timing and control mechanism 18 guides the action of the drive and readout electronics 16, and video processor 18 to selectively produce signals of the scene in a desired format for display by display means 22.

Referring now to Figure 2, the lens system 12 is a cylindrical lens system mounted in housing 24. The housing 24 is rigidly attached to detector matrix housing 26. Thus, the lens system is a staring system; that is, neither the lens system 12 nor the detector matrix 14 move for scanning. The detector matrix housing 26 is mounted in a housing 28. The housing 28 houses the drive and readout electronics 16, video processor 18 and timing and control mechanism 20 (Figure 1). Leads 30 connect the video processor output to the cathode ray tube display 22 (Figure 2).

The detector technique or principle utilized in the ferroelectric imaging system is illustrated in Figure 3. Figure 3 is for illustrative purposes only and is not to be considered limitative of the detector matrix structure. As shown, a pair of signal generators 32 and 34 have terminals coupled to a common ground 36. The signal generators 32 and 34 are coupled, respectively, to a reference element 38 and a thermal sensor 40. The reference element 38 and thermal sensor 40 are coupled together at junction 42. Thus, the reference elements 38 and thermal sensor 40 are coupled in a bridge relationship with the signal generators 32 and 34.

The signal generators 32 and 34 provide substantially equal bias voltages, respectively, to the reference element 38 and thermal sensor 40. Thermal sensor 40 is heat sensitive and its response to impinging thermal energy changes its bias voltage in proportion to the intensity of the thermal energy. The voltage of the thermal sensor 40 is compared in the bridge circuit with the voltage of the reference element 38 and the output voltage at junction 42 is representative of the thermal energy impinging on the thermal sensor 40.

The technique is described mathematically as follows:

$$V_s = e_o/2 (C-C_o/C_o) \quad (1)$$

$$C-C_o = \Delta C = C_o (\Delta T/T-\theta) \quad (2)$$

$$V_s = [e_o/2(T-\theta)] \Delta T \quad (3)$$

where:

e_o = signal generators voltage

C_o = bias signal voltage (reference)

C = thermal sensor voltage

T = temperature

ΔT = temperature difference between the thermal sensor and reference element

θ = Curie temperature

V_s = thermal signal voltage

Referring now to Figure 4 for a description of a detector structure 44 used in the ferroelectric imaging system, the detector 44 comprises the housing 26 which may be, for example, a stainless steel housing having a window 46 formed in one major surface. The window, for thermal energy, may be of, for example, a variety of glasses (silicon, chalcogenide, etc.), which transmit from the near IR through gamma rays, and germanium or indium which transmit, respectively, in the 8-14 μ m and 3-5 μ m infrared wavelengths. The window 46 is positioned in the light or thermal path to the detector matrix 14. The detector matrix 14 is mounted in a well formed in a substrate 48. The substrate 48 is a ceramic substrate of, for example, beryllium oxide and forms the surface of housing 26 opposite the window bearing surface. Space 50 between housing 44 and substrate 48 is preferably evacuated to form a vacuum. The substrate 48 acts as a heat sink for the detector matrix 14 and where the detector matrix requires heating is heated by electrical heater elements 49.

The ferroelectric material 56 (Figure 5c) may be in slab form having the orthogonal lead

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patterns 52 and 54 (Figures 5a & b) formed thereon by evaporation/etching techniques; or if the ferroelectric material is a powder, the lead pattern 52 (Figure 5a) for the back surface of the ferroelectric material is formed, for example, by the evaporation/etching technique in the bottom of the well of substrate 48 (Figure 4). Next, the fine grain ferroelectric material 56 is poured into the well 48 over lead pattern 52. Next, the top surface of the material is sealed by either sputtering or by sintering prior to forming the top lead pattern 54 (Figure 5b). Lead pattern 54 is formed, for example, by the evaporation/etching technique, and is perpendicular to lead pattern 52. The intersections of the orthogonal lead patterns 52 and 54 together with the ferroelectric material 56 form the elements of the detector matrix 14. The resulting detector matrix 14 is a plurality of such detector elements represented by the squares of Figure 5c. Squares in the unshaded area represent thermal sensors 40 and squares within the shaded area 60 represent reference elements 38. The shaded area 60 is a shielded row of detector elements; that is, a row of detectors is shielded, for example, by the housing 26 from thermal exposure to form a row of reference elements 38. The function of the thermal sensors and reference elements will be described hereinafter.

The ferroelectric material, i.e., a material having dielectric properties, preferably is one having a Curie temperature near ambient temperature (0° to 150°C) such as, for example, barium titanate (BaTi_2O_3), triglycenesulfate (TGS), barium strontium titanate, lead titanate, potassium dihydrogen phosphate, and Rochelle salt. Barium titanate having a Curie temperature of about 125°C is the preferred material. The thermal conductivity of the pure dense slab of barium titanate is much too high to achieve acceptable response levels; thus, a fine grain powder is used. The thermal conductivity of pressed powder is a function of the material, the degree of porosity, and the properties of the pores; it is controlled through trial and error.

Whichever ferroelectric material 56 is selected it must be used near its Curie temperature (8), i.e., temperature above which a ferroelectric material ceases to be spontaneously polarized. Above the Curie temperature barium titanate, is a cubic crystal structure strongly susceptible to polarization; thus, its dielectric constant is a strong function of the temperature. The detector elements, constructed as described above, form capacitors which are temperature dependent and are the basis for the ferroelectric transducer. This structure is to be contrasted to one utilizing ferroelectric material at temperatures well below its Curie temperature. Well below the Curie temperature, ferroelectric material exhibits a spontaneous dipole moment. This produces an internal electric field and surface charges then accumulate to quench the field. Since the degree of polarization is temperature dependent, this is the basis for the pyroelectric vidicon. This detection technique, however, operates only when the radiation flux from the scene is constantly changing; the target, therefore, must be moving or the scene must be chopped mechanically.

Referring now to Figure 6, the resolution of each thermal sensor 40 is shown by the dotted lines around the center square. The resolution of each thermal sensor 40 is limited by the extent of thermal spread within the dielectric of ferroelectric material 56. The effective thermal sensor size is determined by the center-to-center spacing of the thermal sensors. For a uniform, isotropic material slice placed in thermal contact with a heat sink, the thermal spread is about twice the thickness of the dielectric. Thus, the preferred dielectric thickness is about one mil and produces a modulation transfer efficiency of approximately 81 percent. Spatial frequency response is independent of the thermal properties of the dielectric for time invariant scenes.

Referring now to Figure 7, there is shown the addressable detector matrix array. The addressable matrix array, as shown, includes a detector array 14 of twenty thermal sensors arranged in five rows 64-72 and four columns 74-80. Row 72 is shielded from the thermal energy to provide a row of reference elements 38 of the thermal sensors 40. It will be understood that the small number of thermal sensors and reference elements shown are to simplify the description of the invention and it will be appreciated by those skilled in the art that any number of sensors can be used to meet a particular display requirement. Also, as each detector element is a thermal sensitive capacitor, they are shown as capacitors.

The detector matrix 14 is coupled to the drive and readout electronics 16 (Figure 1). The drive electronics includes a scan multiplexer 82 (Figure 7) and a pair of sine wave signal generators 32 and 34. Rows 64-70 of thermal sensors 40 are connected to outputs of the scan multiplexer 82; whilst row 72 of reference elements 38 is coupled to signal generator 32. Signal generator 34 is coupled to scan multiplexer 82. The readout electronics comprises preamplifiers 84-90 and a signal multiplexer 92. Columns 74-80 are connected, respectively, to the preamplifiers 84-90; and the signal multiplexer 92 is coupled to the outputs of the preamps 84-90. The signal multiplexer 92 multiplexes the detector matrix signals to the video processor 18.

Referring now to Figure 8 there follows a description of the timing and control means 18

and a description of the drive and readout electronics 16. For the thermal sensors 40, rows 64-70 are coupled, respectively, to switches 94-100 forming the scan multiplexer 82. The switches 94-100 may be, for example, C-MOS transistors having their sources coupled to the junctions between the thermal sensors 40 of rows 64-70 and the grounded resistors 102-108 respectively. Resistors 102-108 discharge the thermal sensors 40 of rows 64-70 when they are inactivated. The drains of the C-MOS transistors 94-100 are connected to signal generator 34 which may be, for example, a square-wave generator. The gates of C-MOS transistors 94-100 are coupled to shift register 110 having outputs 114-118. A source of accurately timed pulses 120, hereinafter referred to as a clock, is connected to shift register 110. Shift register 110 may be, for example, a plurality of C-MOS stages that converts a sequence of input signals from clock 120 into a parallel binary number, by moving stored characters sequentially through outlets 112-118.

For an interlaced TV format every other row of thermal sensors 40 is sequentially charged in 1/60th of a second beginning, for example, with the top row and progressing downwardly every other row, and then sequentially charging the remaining thermal sensors 40 in 1/60th of a second beginning, for example, with the next to the top row. Thus, the matrix of thermal sensors are charged in 1/30th of a second. For the matrix of thermal sensors shown (Figure 8) rows 64-70 are coupled to the outputs 112-118 of shift register 110 as follows: row 64 is coupled to output 112, row 68 to output 114, row 66 to output 116, and row 70 to output 118.

For row 72, the reference elements 62 are coupled to signal generator 32. Signal generator 32 may be, for example, a square wave generator. One terminal of each of the signal generators 32 and 34 is coupled to ground 36. Each of the reference elements 62 of row 72 is connected to all the thermal sensors 40 in a respective column of columns 74-80. A preamplifier 122 is coupled to each junction of a column of thermal sensors 40 and its respective reference element 62. Thus, as previously stated a bridge is formed and the preamplifiers receive signals indicative of the thermal energy impinging on the thermal sensors 40. Decoders 124 are connected to the preamplifiers to convert the modulated information to an analog form. The signal multiplexer 92 comprises, for example, four C-MOS transistors 128-132 acting as switches. The C-MOS transistors 128-132 have their drains coupled to the decoders 124, their sources to the video processor 18, and their gates to shift register 134 outputs 136-142. The shift register is coupled to a source of accurately timed pulses 144. Shift register 134 may be, for example, a plurality of C-MOS transistor stages that converts a sequence of input pulses from clock 144 into a parallel binary number by moving stored characters sequentially through outlets 136-142 to address switches 126-132 in sequence to read a difference signal for each thermal sensor of each row 64-70 as charged by the scan multiplexer 82. For the sixteen element matrix shown (Figure 8) the shift register must sequence once each 480th of a second.

The video processor 18 may be, for example, any commercial type TV signal processor which processes the electrical signals of the signal multiplexer 92 into an interlaced TV format for display on a cathode ray tube.

In operation, the ferroelectric imaging system may be used in an infrared environment and is positioned with the IR lens system 12 in the path of infrared energy emanating from a scene. The lens system 12 focuses the infrared image of the scene onto the detector matrix 14. Then the scan multiplexer 82 upon command of the timing and control means 24 connects the generator 34 to row 64 to charge its thermal sensors 40. The charge of the generator is varied by the intensity of thermal energy impinging on each thermal sensor 40. The reference elements 38 are charged by generator 32. The signal multiplexer 92 upon command of the timing and control mechanism 24 closes the circuit through column 74. The current path of interest is from the positive terminal of upper generator 34, through the upper left thermal sensor 40 of row 64 down through the lead of column 74, through the reference element 38, and back to the negative side of the lower generator 32. A signal equal to the difference of the charges on the thermal sensor and the reference element is produced for amplification by the preamplifier 122, decoded by decoder 124 and passes to the video processor 18. Signal multiplexer 92 similarly connects sequentially the remaining thermal sensors 40 of row 64 to the remaining reference elements 38 of columns 76-80 to complete one cycle. The cycle is then repeated selectively for rows 66-70 to produce video signals representative of the scene for display on the cathode ray tube 22.

Although only a single embodiment of this invention has been described herein, it will be apparent to a person skilled in the art that various modifications to the details of construction shown and described may be made without departing from the scope of this invention.

WHAT WE CLAIM IS:-

1. A thermal imager including:
a matrix of spaced thermally sensitive capacitors;



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and a description of the drive and readout electronics 16. For the thermal sensors 40, rows 64-70 are coupled, respectively, to switches 94-100 forming the scan multiplexer 82. The switches 94-100 may be, for example, C-MOS transistors having their sources coupled to the junctions between the thermal sensors 40 of rows 64-70 and the grounded resistors 102-108 respectively. Resistors 102-108 discharge the thermal sensors 40 of rows 64-70 when they are inactivated. The drains of the C-MOS transistors 94-100 are connected to signal generator 34 which may be, for example, a square-wave generator. The gates of C-MOS transistors 94-100 are coupled to shift register 110 having outputs 114-118. A source of accurately timed pulses 120, hereinafter referred to as a clock, is connected to shift register 110. Shift register 110 may be, for example, a plurality of C-MOS stages that converts a sequence of input signals from clock 120 into a parallel binary number, by moving stored characters sequentially through outlets 112-118.

For an interlaced TV format every other row of thermal sensors 40 is sequentially charged in 1/60th of a second beginning, for example, with the top row and progressing downwardly every other row, and then sequentially charging the remaining thermal sensors 40 in 1/60th of a second beginning, for example, with the next to the top row. Thus, the matrix of thermal sensors are charged in 1/30th of a second. For the matrix of thermal sensors shown (Figure 8) rows 64-70 are coupled to the outputs 112-118 of shift register 110 as follows: row 64 is coupled to output 112, row 68 to output 114, row 66 to output 116, and row 70 to output 118.

For row 72, the reference elements 62 are coupled to signal generator 32. Signal generator 32 may be, for example, a square wave generator. One terminal of each of the signal generators 32 and 34 is coupled to ground 36. Each of the reference elements 62 of row 72 is connected to all the thermal sensors 40 in a respective column of columns 74-80. A preamplifier 122 is coupled to each junction of a column of thermal sensors 40 and its respective reference element 62. Thus, as previously stated a bridge is formed and the preamplifiers receive signals indicative of the thermal energy impinging on the thermal sensors 40. Decoders 124 are connected to the preamplifiers to convert the modulated information to an analog form. The signal multiplexer 92 comprises, for example, four C-MOS transistors 128-132 acting as switches. The C-MOS transistors 128-132 have their drains coupled to the decoders 124, their sources to the video processor 18, and their gates to shift register 134 outputs 136-142. The shift register is coupled to a source of accurately timed pulses 144. Shift register 134 may be, for example, a plurality of C-MOS transistor stages that converts a sequence of input pulses from clock 144 into a parallel binary number by moving stored characters sequentially through outlets 136-142 to address switches 126-132 in sequence to read a difference signal for each thermal sensor of each row 64-70 as charged by the scan multiplexer 82. For the sixteen element matrix shown (Figure 8) the shift register must sequence once each 480th of a second.

The video processor 18 may be, for example, any commercial type TV signal processor which processes the electrical signals of the signal multiplexer 92 into an interlaced TV format for display on a cathode ray tube.

In operation, the ferroelectric imaging system may be used in an infrared environment and is positioned with the IR lens system 12 in the path of infrared energy emanating from a scene. The lens system 12 focuses the infrared image of the scene onto the detector matrix 14. Then the scan multiplexer 82 upon command of the timing and control means 24 connects the generator 34 to row 64 to charge its thermal sensors 40. The charge of the generator is varied by the intensity of thermal energy impinging on each thermal sensor 40. The reference elements 38 are charged by generator 32. The signal multiplexer 92 upon command of the timing and control mechanism 24 closes the circuit through column 74. The current path of interest is from the positive terminal of upper generator 34, through the upper left thermal sensor 40 of row 64 down through the lead of column 74, through the reference element 38, and back to the negative side of the lower generator 32. A signal equal to the difference of the charges on the thermal sensor and the reference element is produced for amplification by the preamplifier 122, decoded by decoder 124 and passes to the video processor 18. Signal multiplexer 92 similarly connects sequentially the remaining thermal sensors 40 of row 64 to the remaining reference elements 38 of columns 76-80 to complete one cycle. The cycle is then repeated selectively for rows 66-70 to produce video signals representative of the scene for display on the cathode ray tube 22.

Although only a single embodiment of this invention has been described herein, it will be apparent to a person skilled in the art that various modifications to the details of construction shown and described may be made without departing from the scope of this invention.

WHAT WE CLAIM IS:-

1. A thermal imager including:
a matrix of spaced thermally sensitive capacitors:



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a drive circuit for biasing the capacitors so that the potentials on the capacitors vary according to their temperature;

a housing allowing selected capacitors of the matrix to be exposed to a pattern of thermal energy; and

a signal processor for monitoring the potentials on the capacitors and producing a signal representative of the intensity of thermal energy impinging on the capacitors.

2. A thermal imager according to claim 1 wherein said matrix of spaced thermal sensitive capacitors form an infra-red radiation detector matrix.

3. A thermal imager according to claim 2 wherein a thermal lens system is included in the path of the thermal energy for focusing the thermal energy to produce the pattern on the detector matrix.

4. A thermal imager according to claim 3 wherein the thermal lens system and the detector matrix are stationary for forming a staring detector system.

5. A thermal imager according to any preceding claim including at least one reference capacitor, shielded from impinging thermal energy by a shield and connected to the drive circuit and wherein the signal processor produces a signal representing the difference between the potentials on the selected thermally sensitive capacitors and the potential on the reference capacitor.

6. A thermal imager according to claim 5 wherein the shield is integral with the housing.

7. A thermal imager according to any preceding claim wherein the signal processor includes a video processor coupled to the matrix of capacitors for producing a video signal representing the pattern of thermal energy impinging on the capacitors, and a video display for displaying the pattern in response to the video signals.

8. A thermal imager according to any preceding claim wherein said matrix is an addressable matrix array of thermally sensitive capacitors.

9. A thermal imager according to any preceding claim wherein the matrix of spaced thermally sensitive capacitors includes a body of ferro-electric material sandwiched between a first and second plurality of spaced leads arranged to form the matrix of spaced thermal sensitive capacitors, the body of ferro-electric material and leads forming, respectively, the dielectric and plates of the capacitors.

10. A thermal imager according to claim 9 wherein the body of ferro-electric material is a slab.

11. A thermal imager according to claim 9 wherein the body of ferro-electric material is a powder and has at least one side sintered for supporting a plurality of leads.

12. A thermal imager according to any of claims 9, 10 and 11 wherein said dielectric of ferro-electric material includes ferro-electric material having a Curie point between about 0° and 150° centigrade.

13. A thermal imager according to any of claims 9 to 12 wherein said dielectric of ferro-electric material is barium titanate.

14. A thermal imager according to any of claims 9 to 13 further including a heater for heating the ferro-electric material.

15. A thermal imager according to any preceding claim wherein said matrix of thermally sensitive capacitors includes a first group of thermally sensitive capacitors and a second group of thermal sensitive capacitors, the second group being shielded from the impinging thermal energy; the drive circuit includes a signal source coupled to the second group of thermally sensitive capacitors, which second group form a plurality of reference elements, and coupled to a multiplexer coupled to the first group of thermal sensitive capacitors for selectively biasing the first group of thermal sensitive capacitors; and the signal processor includes a multiplexer connected to the first and second groups of thermal sensitive capacitors, and a comparator connected to the multiplexer for producing, selectively, signals representative of the thermal energy impinging on the first group of thermally sensitive capacitors.

16. A thermal imager according to claim 15 wherein the drive circuit and signal processor circuit include a common clock.

17. A thermal imager for producing a display representing a view of thermal radiation from a scene, the imager including a drive circuit, connected to supply bias to a two dimensional detector array of thermal detector elements having a first group and a second group of elements, each detector element of the first group being responsive to thermal radiation from the scene impinging thereon to produce a voltage at its output representative of the intensity of the impinging thermal radiation, and the second group being shielded from the thermal radiation to provide reference output voltages; a comparator mechanism for comparing the outputs of the first and second groups of thermal detector elements; and a signal processing mechanism operatively connected to the comparator for producing video signals representing the view of thermal radiation from the scene and to a display; wherein each thermal detector element includes a temperature dependent capacitor with a

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dielectric of ferro-electric material.

18. A thermal imager including:

a thermal lens system for focusing thermal energy emanating from a scene onto a matrix of temperature dependent ferro-electric ceramic capacitors, the matrix including a first group of said ferro-electric ceramic capacitors for detecting the focused thermal energy, and a second group of said ferro-electric ceramic capacitors shielded by a shield from the focused thermal energy;

a drive circuit including first and second signal generators and a scan multiplexer, said first and second generators having terminals connected to a common ground and respectively to said first and second groups of ferro-electric ceramic capacitors to form a bridge whereby the thermal energy impinging on the first group of the ferro-electric ceramic capacitors changes the dielectric constant thereof in proportion to the intensity of the impinging thermal energy which alters the balance of said bridge to provide a difference potential across the bridge indicative of the thermal energy impinging on the first group of ferro-electric ceramic capacitors;

a read-out circuit including a plurality of preamplifiers each one coupled to a junction of a ferro-electric ceramic capacitor of the first group and a ferro-electric ceramic capacitor of the second group, and a signal multiplexer coupled to the plurality of preamplifiers for selectively receiving amplified signals representative of the thermal energy impinging on each in turn of the ferro-electric ceramic capacitors of the first group;

a controller including clocking and gate mechanism for selectively actuating the scan multiplexer and signal multiplexer, respectively, of the drive and read-out circuits;

a video processor coupled to the signal multiplexer and controller for processing the electrical signals indicative of the thermal energy impinging on the first group of ferro-electric ceramic capacitors into video signals; and

a display means connected to the video processor for visually displaying the thermal image of the scene.

19. A thermal imager according to claim 18 wherein said thermal lens system is an infra-red lens system and the thermal imager further includes a housing having major opposing sides, an infra-red transmissive window defined in one of said major opposing sides for admitting infra-red energy from the infra-red lens, a substrate mounted in the other of said major opposing sides, the substrate having a well formed therein, a first lead pattern formed on the well side of the substrate, a layer of ferro-electric material forming a dielectric layer in the well over the first lead pattern, a second lead pattern with leads transversely positioned with respect to the first lead pattern over the layer of ferro-electric material, said first and second lead patterns co-acting with the dielectric layer of ferro-electric material to define the matrix of ferro-electric ceramic capacitors, and wherein said housing has a portion forming the shield for shielding the second group of said ferro-electric ceramic capacitors.

20. An imager according to claim 18 further including a housing having first and second major opposing sides, a window defined in the first of said major opposing sides for admitting infra-red light and a substrate mounted in the second of said major opposing sides, said substrate supporting a dielectric of ferro-electric material having opposing major surfaces, leads formed on the opposing major surfaces of the dielectric, the leads on one major opposing surface being perpendicular to the leads on the other major opposing surface, the leads and dielectric coacting to form the matrix of ferro-electric ceramic capacitors.

21. An imager according to either claim 20 or 21 wherein the housing further includes a heater for heating the ferro-electric material.

22. A thermal imager substantially as herein described with reference to the accompanying drawings.

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