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**Tannas, Jr. et al.**

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[54] **LIQUID CRYSTAL BAR GRAPH DISPLAY**


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[73] Assignee: **Rockwell International Corporation**, El Segundo, Calif.



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[52] **U.S. Cl.** ..... **340/324 R**, 315/169 R, 340/378 R, 350/160 LC

[51] **Int. Cl.** ..... **G08b 5/36**

[58] **Field of Search** ..... 340/324 R, 378 R, 336; 315/169 R; 350/160 LC



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 3,289,025 | 11/1966 | Bullinger | 340/324 R X |
| 3,327,163 | 6/1967 | Blank | 315/169 R |
| 3,410,999 | 11/1968 | Fergason et al. | 340/324 M X |
| 3,496,410 | 2/1970 | MacIntyre | 315/169 R |
| 3,524,726 | 8/1970 | Koster | 350/160 LC |
| 3,750,139 | 7/1973 | Blishak | 340/336 |



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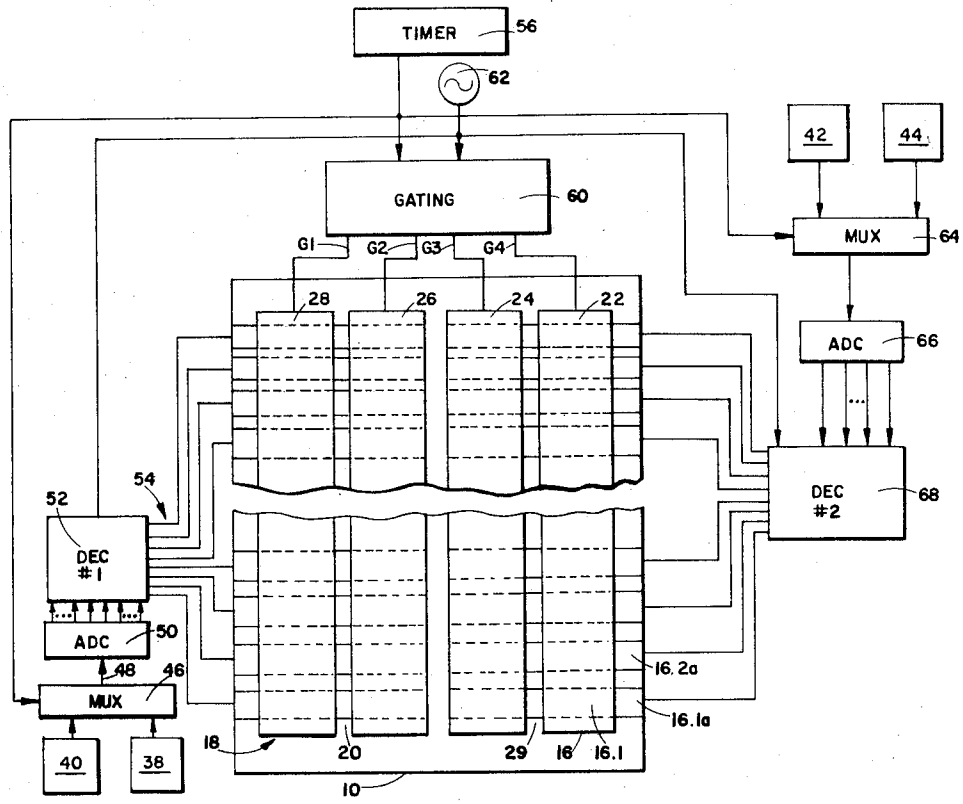
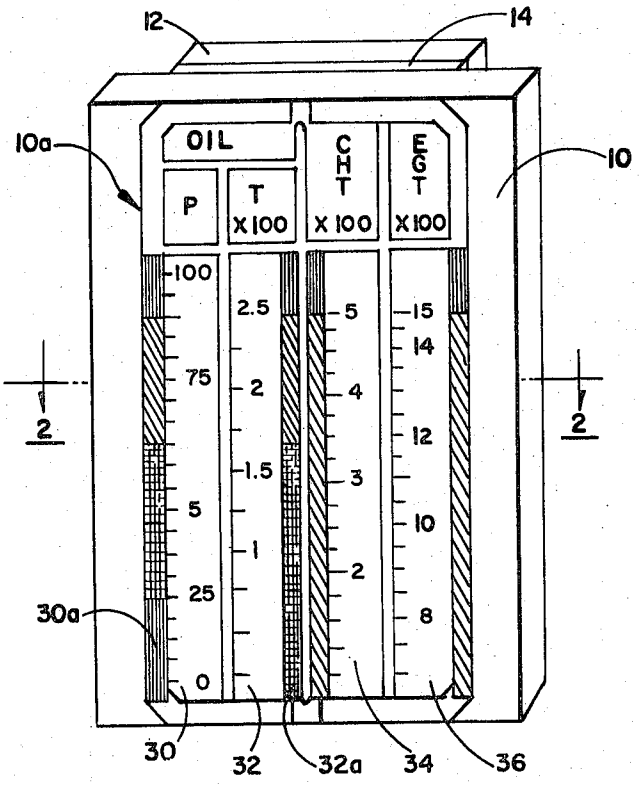
[57] **ABSTRACT**

An analog display in the form of a plurality of bar graphs is provided by an arrangement of horizontally extending graphic electrode strips cooperating with vertically disposed and mutually discrete common electrode strips and a film of liquid crystal material confined between the electrodes. Selected groups of the horizontal graphic electrode strips are energized in accordance with the magnitude of a bidirectionally varying signal, and a selected one or more of the common electrodes are concurrently energized to selectively display the several bar graphs in a time shared arrangement.


**7 Claims, 3 Drawing Figures**

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14
10a
10
OIL
P
T
X100
CHT
X100
EGT
X100
100
75
5
25
0
2.5
2
1.5
1
5
4
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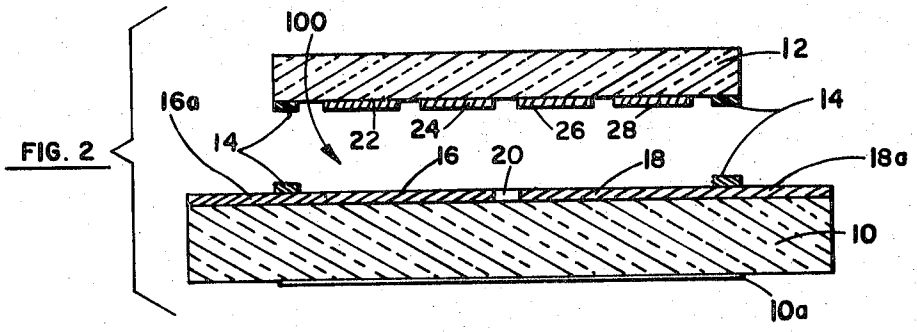
2
15
14
12
10
8
2
2
30a
30
32
32a
34
36

FIG. 1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16a
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22
24
26
28
14
16
20
18
18a
10
10a

FIG. 2

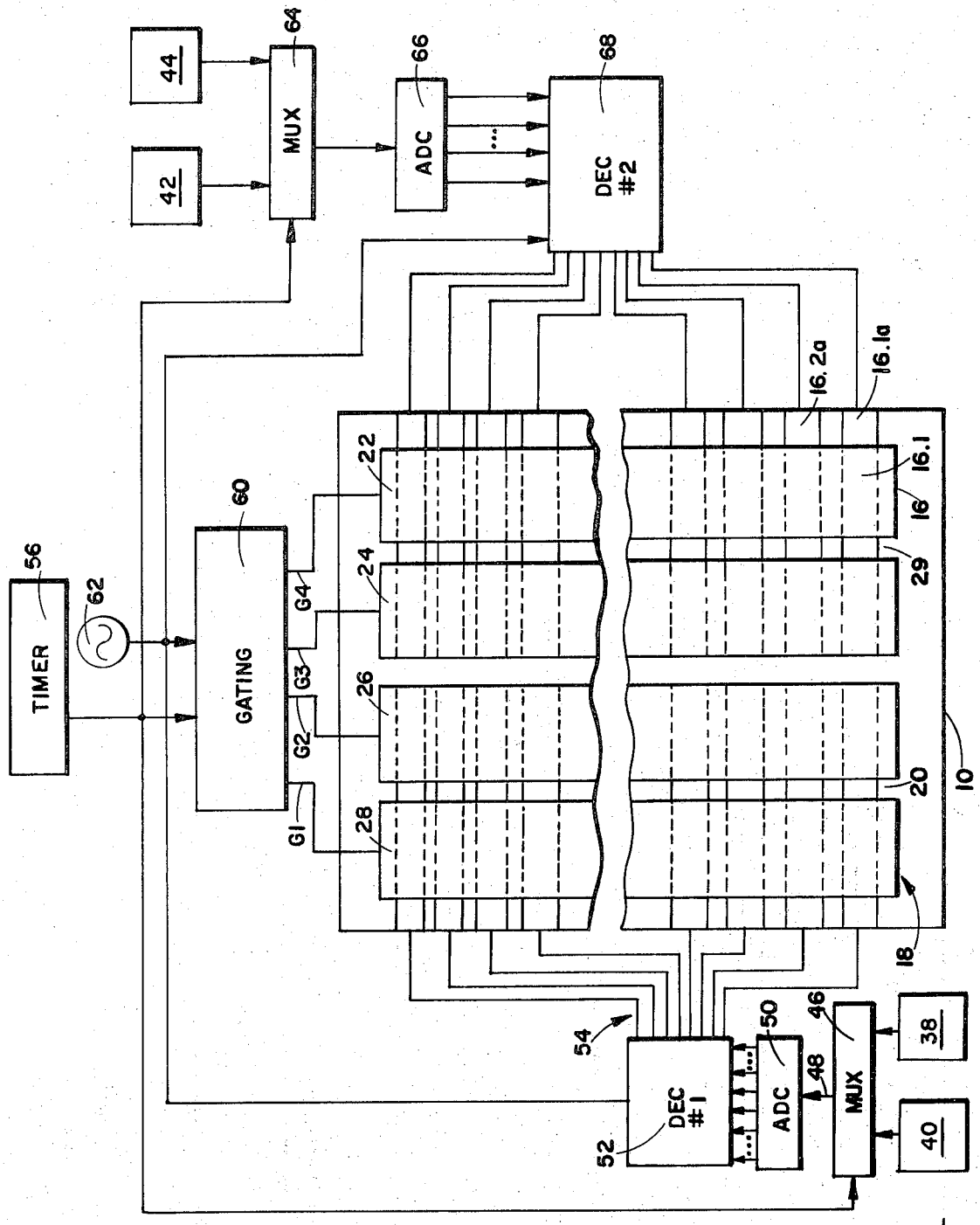
44
42
64
MUX
66
ADC
68
DEC #2
16.2a
16.1a
22
24
26
28
16.1
16
29
20
10
18
60
GATING
G4
G3
G2
G1
56
TIMER
62
54
DEC #1
52
50
ADC
48
46
MUX
38
40

FIG. 3

# LIQUID CRYSTAL BAR GRAPH DISPLAY

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to display devices of the liquid crystal type and, more particularly, concerns a liquid crystal display of information in an analog form.

2. Description of Prior Art

Liquid crystal displays are widely employed for presenting patterns of numbers or letters. The common alphanumeric or numeric liquid crystal display employs a group of electrodes deposited in a pattern that allows selected ones of the electrodes to be energized together with a back electrode that is common to all of the elements of the electrode pattern. The pattern of front electrodes selected for energization activates an interposed thin film of confined liquid crystal material to provide a readily visible display. Although the numeric and alphanumeric liquid crystal display devices are quite satisfactory, in many instances analog displays are necessary or desirable. In particular, analog displays in the form of bar graphs are highly desirable. This type of analog display deivce is readily adaptable to operations which require quick, easy reference by an operator such as display of aircraft engine parameters and the like. The extent of the movable end of the bar graph may be readily correlated with indicia permanently located on the face of the display to thereby directly identify ranges of operating conditions from normal to marginal to failure or emergency. For these and other reasons, an analog display is often preferred.

Accordingly, it is an object of the present invention to employ liquid crystal display techniques to provide an analog display. Herein, the term liquid crystal is to be interpreted to include suspended liquid and other similar materials and technologies.

Reference is hereby made to the co-pending application of L. E. Tannas, Jr., et al, entitled Liquid Crystal Display, filed Feb. 28, 1973, bearing U.S. Ser. No. 337,258, as well as to the co-pending continuation application of R. Chang et al, entitled Nematic Liquid Crystal Compositions, filed Oct. 12, 1972, bearing U.S. Ser. No. 297,172, each of which applications has been assigned to the common assignee. The cross-reference is made to these applications in order to incorporate the teachings thereof in this application.

## SUMMARY OF THE INVENTION

An improved display device utilizing techniques currently used in providing liquid crystal type displays. First and second plates, sealed together by a suitable sealer form a container or chamber between the plates. Electrodes are placed on each of the plates. In particular, a plurality of relatively large common electrodes are placed on the inner surface of one of the plates. A plurality of relatively smaller electrodes are placed on the other plate. The electrodes are generally oriented transverse to each other. Control circuitry is provided to selectively energize various ones of each of said plurality of electrodes in order to provide a variable display indicator. Thus, an analog type display is provided.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of one embodiment of the multiple bar graph display of the present invention.

FIG. **2** is an exploded and enlarged cross-sectional view taken generally along the line **2—2** of the display shown in FIG. **1.**

FIG. **3** is a diagram illustrating electrical connections and positioning of the electrodes of the display of FIGS. **1** and **2.**

## DETAILED DESCRIPTION

Referring concurrently to FIGS. **1** through **3,** a front plate **10** is sealed, in spaced relation, to a back plate **12** by means of sealing strips **14.** Typically, plates **10** and **12** are transparent glass and strip **14** is glass frit or other suitable spacing and sealing means. A chamber **100** is provided between the opposed inner faces of the plates and within strip **14.** In a preferred embodiment, plate **10** is wider than plate **12** whereby plate **10** extends beyond two sides of plate **12.** A liquid crystal material (not shown) is retained in chamber **100.** Deposited upon the inner surface of front plate **10,** within the space defined by chamber **100,** are first and second rows of horizontally extending graphic electrode strips generally designated at **16** and **18** (FIGS. **2** and **3**).

The external surface of the front glass plate **10** has imprinted thereon suitable legends, scaling indicia and color patterns indicated generally as **10***a* (FIG. **2**) to complete the visual display afforded by the described electrode pattern.

Imprinted upon the outer surface of the front glass plate are identifications of the several bar graphs, such as, for example, the term "OIL" and the letters "P" and "T" for graphs **30** and **32,** to indicate oil pressure and temperature, respectively. Also imprinted on the face of the front plate **10** and directly over the graph itself are the various numbers indicating the values of the pattern displayed. If desired, color coded strips **30***a* and **32***a* may also be formed on the face of the display. Typically, the color coded strips may be used for indicating red at extremely low and extremely high oil pressures; green at an intermediate pressure in the vicinity of 75; and yellow for a pressure of roughly 25–60. Obviously, the colors chosen and the extent of each color are matters of choice and design, according to the particular display employed.

Also shown in the exemplary display of FIG. **1** are graphs **34** and **36** bearing legends identifying these parameters as cylinder head temperature (CHT) and exhaust gas temperature (EGT), thus providing a display typical of those used with aircraft engines. Each of bar graphs **34** and **36** will have appropriate color strips indicating safe or normal (green), emergency (red) or marginal (yellow) operating conditions. These imprinted legends are designated generally by reference numeral **10**a as in FIG. **2.**

In one embodiment, electrode strips in row **16** are separated from the electrode strips in row **18** by a distance represented by isolating space **20.** A strip of insulating material similar to sealer **14** may be inserted in space **20.** Each electrode strip of row **16** is connected to a separate conductor portion **16***a.* Similarly, each electrode strip of row **18** is connected to a separate conductor portion **18***a.* The conductor portions **16***a* and **18***a* extend beneath the spacer sealer strips **14** and along the inner surface of that portion of the front plate **10** that extends laterally beyond the edges of back plate **12.** Conductor portions **16***a* and **18***a* are arranged at

opposite sides of chamber **100.** The arrangement of laterally extending side portions of front plate **10** and conductors **16***a* and **18***a* facilitates connection to external circuitry to be described hereinafter.

Each row of graphic electrode strips comprises a plurality of mutually discrete, but closely spaced, strips which are generally parallel to each other and extend transverse to the extent of the pattern collectively formed by the strips. Thus, each row of strips can delineate a substantially vertically extending bar pattern formed by a number of mutually discrete horizontally extending strips. The display is, effectively, an analog appearing display, although actually achieved by a number of energized electrode strips. The strips may be so closely spaced that there is little or no visually detectable demarcation between liquid crystal areas energized by adjacent strips rendering the appearance of a continuous display when all horizontal strips below the indicated value are energized. Of course, the electronic control circuitry could be so configured that only a single horizontal electrode strip is energized at the reading to be indicated thereby simulating a needle type display.

FIG. **3** illustrates the pattern of strips of the rows **16** and **18.** For example, row **16** comprises a plurality of individual strips **16.1, 16.2** and so forth which may include any desired number, for example **40.** Each of the strips **16.1, 16.2,** has an associated conductor portion **16.1***a*, **16.2***a*. Similarly, the row of strips **18** includes a suitable number of horizontally extending strips collectively forming the bar graph pattern illustrated in FIG. **3.** The horizontal strips in FIG. **3** are designed for 2:1 multiplexing. That is, two common electrodes have to be controlled relative to one electrode strip. The horizontal strips could extend across the four independent common electrodes if so desired, but 4:1 multiplexing would be necessary.

Deposited upon the inner surface of the back plate **12** in continuous vertically extending bar patterns are common electrodes **22, 24, 26** and **28.** These common electrodes are illustrated in FIG. **3** as overlying the rows **16, 18** of graphic electrode strips. The first pair of common electrodes **22, 24** together are substantially coextensive with the full vertical extent of the row of graphic electrode strips **16.** However, the two common electrodes are laterally spaced apart along line **29.** Accordingly, each common electrode **22** and **24** overlies a portion, e.g., one-half, of each of the electrode strips of row **16.** In particular, outer common electrode **22** overlies the outer portion of the electrode strips of row **16** and inner common electrode **24** overlies the inner portion of each of the electrode strips of row **16.** However, it should be noted that outer common electrode **22** terminates laterally near the outer edges of the graphic electrode strips, but does not overlie the conductor portions **16.1***a*, **16.2***a* and so forth.

Similarly, common electrodes **26, 28** collectively are substantially coextensive with row **18** of graphic electrode strips. Each of common electrodes **26** and **28** is mutually spaced from the other. Outer electrode **28** has the laterally outward edge near the outer edges of all the electrode strips of row **18.** In effect, each graphic electrode strip terminates at an edge of a corresponding common electrode, although each strip includes a conductor portion integral therewith. However, because the conductor portions **16***a*, **18***a* and the like extend beyond the edges of the common electrode, there is no liquid crystal material interposed between a pair of electrodes. Therefore, application of a signal to conductor portions **16***a* or **18***a* will not activate the liquid crystal material and cause a display thereby.

Manufacture and assembly of glass plates, electrodes and insertion of liquid crystal material confined between the plates may be performed with conventional techniques. Briefly, the electrode patterns and the patterns of conductors are formed on the glass plates of a transparent tin oxide by suitable masking and/or silk-screen techniques. The spacer, sealer may be a glass frit fused to the peripheral edges of the back plate and to mating portions of the front plate, providing suitable channels to allow cleaning of the chamber formed between the spaced and sealed plates. Vacuum filling of the chamber with a thin film of a suitable liquid crystal material is then accomplished through the aforesaid channels. Various types of liquid crystal materials are described in the prior art and in the above-mentioned copending applications.

A thin film of confined nematic liquid crystal material, as is well known, is substantially transparent to light when at least one of the electrodes is unenergized. When electrodes on the front and back plates are concurrently energized to provide an electrical potential across an interposed portion of liquid crystal material, the latter is activated over the area thereof that is directly between the electrically energized electrode portions. The activated material scatters light to provide an opalescent effect. Accordingly, if a common electrode, e.g., common electrode **22,** is energized and, concurrently, the lowermost strip **16.1** of row **16** is energized, a thin opalescent horizontal line is produced. This opalescent line has a width or vertical extent (as viewed in FIG. **3**) equal to the width of the strip **16.1,** and a horizontal extent equal to the width of common electrode **22.** Moreover, the opalescent line will exhibit a strong visual contrast with the remainder of the display. Similarly, if the lower two strips **16.1** and **16.2** are energized concurrently with energization of the common electrode **22,** the liquid crystal material between the energized electrodes is activated. According to one embodiment of the invention, as will be described hereinafter, strips **16** are energized in groups of consecutive strips, always including the lowermost strip **16.1** and including a number of strips proportional to a magnitude that is to be displayed. Accordingly, a vertically extending portion of the common electrode **22** (when this is energized together with the strips of graphic electrode **16**) will activate a vertical length of the adjacent nematic liquid having a height equal to the number of graphic electrode strips energized.

If common electrode **24** is energized and electrode **22** is not, then an opalescent display having a vertical extent, as viewed in FIG. **3,** will appear in the second bar graph pattern that is delineated by the common electrode **24.** Similarly, common electrodes **26** and/or **28** may be caused to cooperate with energized electrode strips of the row **18,** whereby third and fourth bar graphs may be individually displayed. Each of these bar graphs will have an opalescent vertical extent according to the number of electrode strips that are energized at any given instant.

The arrangement of electrode bar graph patterns is such as to provide for mutually discrete vertically extending bar graph areas, respectively identified by numerals **30, 32, 34** and **36** in FIG. **1.** Each of these graph

areas is essentially coextensive with a respective one of common electrodes **22, 24, 26** and **28.** As previously stated, FIG. **1** is a perspective view from the front of front plate **10.** FIG. **3** is a view from the back of the front plate and shows the back (or common) electrode pattern overlying the graphic electrode rows. FIG. **3** illustrates the overlapping arrangement of certain common electrodes and certain portions of the rows of graphic electrode strips.

The bar graph display shown in FIG. **1** provides a visual indication of various conditions or parameters sensed by parameter detecting transducers **38, 40, 42,** and **44,** shown in FIG. **3.** Transducers **38** and **40** provide analog signals having magnitudes proportional to the conditions sensed thereby, e.g., exhaust gas temperature and cylinder head temperature, respectively. These analog signals are fed to multiplexer **46** which provides output signals on common line **48** in accordance with timing signals from timer **56.** The signals on line **48** represent the analog values sensed by transducers **38** and **40.** The signals on line **48** are in sequence or time shared relation as controlled by multiplexer **46.** These signals are fed to analog-to-digital converter **50** which provides digital signals to decoder **52.** The digital signals are representative of the analog signals from the transducers. Decoder **52** has a plurality of output leads collectively indicated at **54.** Leads **54** are selectively enabled in accordance with the output signals from converter **50.** The number of output leads **54** is equal to the number of electrode strips of row **18.** These leads are individually connected to separate conductor portions of the electrode strips. A timer **56** feeds timing signals to multiplexer **46** to cause the latter to sequentially transmit the analog signals from transducers **38** and **40,** respectively. Timer **56** also supplies timing signals via lead **58** to gating circuit **60.** Gating circuit **60** selectively transfers a signal from A.C. source **62,** via leads G1, G2 G3 and G4, to common electrodes **28, 26, 24** and **22,** respectively. Source **62** produces the energizing signal that, in one embodiment, is fed via selectively enabled leads of decoder **52** to the electrode strips of row **18.** The arrangement of timing signals from timer **52** to gating circuit **60** and multiplexer **46** is such that multiplexer **46** transmits signals from transducer **40** to analog to digital converter **50** while gating circuit **60** energizes common electrode **28** via line G1. Converter **50** operates upon the signals from multiplexer **46** and supplies a digitized value of the analog signal detected by transducer **40** to the decoder **52.** Decoder **52** supplies energizing signals to the electrode strips of row **18.** Thus, the concurrent energization of common electrode **28** and strips of row **18** determines that only exhaust gas temperature is displayed at graph **36.**

At a different interval of the timer, multiplexer **46** is permitted to feed the output signal from transducer **38** to analog to digital converter **50** which causes decoder **52** to energize a group of graphic electrode strips in row **18** representative of the value of sensed cylinder head temperature. Concurrently, gating circuit **60** is permitted to provide energization to common electrode **26** via line G2. Line G1 and common electrode **28** are not energized at this time or energized in phase. Thus, only cylinder head temperature bar graph **34** is made opalescent.

Similarly, analog signals from transducers **42** and **44,** respesenting magnitude of detected oil pressure and temperature, alternately appear at the output of second multiplexer **64** and are fed, in sequence, to second analog to digital converter **66** to operate a second decoder **68.** Decoder **68** selectively feeds energy from source **62** to conductors of graphic electrode strips in row **16.** Again, timer **56** synchronizes operation of multiplexer **64** with gating circuitry **60.** Thus, when analog to digital converter **66** presents a digitized version of the analog signal detected by transducer **42,** gating circuit **60** will permit energization of common electrode **22** via lead G4. Likewise, when the analog to digital converter **66** energizes decoder **68** with a digitized signal representing the analog signal detected by transducer **44,** timer **56** will permit gating circuit **60** to energize common electrode **24** via lead G3.

The overall sequence of gating energization may provide sequential energization of the four bar graphs, one at a time. For example, graph **30,** graph **32,** graph **34** and graph **36** may each be energized for a discrete interval of time and then de-energized, whereupon the next graph is energized. However, with the arrangement shown, viz. graphic electrode strip rows **16** and **18** are common to a pair of common electrodes with separate multiplexers, converters and decoders, the timing of one pair of graphs, such as graphs **30** and **32,** need not be synchronized with the timing of the second pair of graphs **34, 36.** Accordingly, graphs **30** and **34** may be energized simultaneously and graphs **32** and **36** may be energized simultaneously in some desirable chronological relation. For example, common electrodes **28** and **24** may be energized at a given instant, and suitable groups of the first and second rows of graphic electrode strips **18** and **16** may be likewise energized by the appropriate one of the pair of transducers assigned thereto.

Where all four graphs are multiplexed (a 4:1 multiplexing), that is, sequentially at a separate instant of time, the multiplexer, analog to digital converter and decoder need not be duplicated. This last mentioned arrangement would employ a single four-channel multiplexer, a single analog to digital converter and single decoder. The decoder output leads in such case are connected to electrode strips of both rows **16** and **18.**

The arrangement illustrated in FIG. **3,** wherein two rows of graphic electrode strips are provided with each row being employed for two bar graphs, enables simultaneous display of one of the pair of graphs of row **16** and one of the pair of graphs of row **18.** If deemed necessary or desirable, the electrode strips of rows **16** and **18** may be made continuous, i.e., not separated as at isolating space **20** of FIG. **2.** With each of the strips of rows **16** and **18** extending entirely across all four common electrodes, the common electrodes must be sequentially energized. Thus, each bar graph can be activated about 25 percent of the time. Relaxation rates of the liquid crystal material (i.e., time required for the material to return to its inactive state upon termination of its electrical energization) may be such as to require discrete rows **16** and **18** of graphic electrode strips illustrated herein. In addition, duplication of multiplexer, analog to digital converter and decoder may be necessary so as to provide a longer active time for each of the graphs. The arrangement of FIG. **3** is preferred for such situations.

As is well known, liquid crystal displays may be of either the transmissive or reflective type. In the transmis-

sive type, both the electrodes on the front plate and the electrodes on the back plate are made of a transparent material, such as tin oxide, and light is transmitted from behind the display through the thin film of liquid crystal material to the viewer who is positioned in front of the front plate. In the reflective type, the common electrode which is formed on the inner surface of the back plate is made of a reflective material, for example gold, and light is transmitted from the front of the display through the front plate, through the liquid crystal material, and reflected from the back electrode to the viewer positioned in front of the front plate.

Principles of the present invention may be applied to either a reflective or transmissive display.

In an exemplary arrangement employing forty graphic electrode strips, each having a width (vertical extent as viewed in FIG. **3**) of **90** mils and each spaced from an adjacent strip by 10 mils, the total height of the bar graphs may be about 4 inches, the display having a total width of 2 inches or less for all four bar graphs.

The described arrangement provides a display that vividly presents analog information in a readily readable bar graph form, requiring little power and minimized space. These attributes of the display are extremely useful in aircraft, automotive or other applications wherein small size and easy readability to the operator are desired.

The foregoing detailed description is to be clearly understood as given by way of illustration and example only, the spirit and scope of this invention being limited solely by the appended claims.

What is claimed is:

**1.** A display comprising

a panel including first and second plates,

a layer of liquid crystal material confined between said plates,

common electrode means on said first plate,

a plurality of discrete electrode strips arranged on said second plate in a pattern to collectively delineate a continuous bar extending normal to the extent of individual ones of said strips,

means for electrically energizing said common electrode means,

means for electrically energizing one or more of said electrode strips whereby the energized electrode strips will visually express the value of an analog signal by activating a portion of said confined liquid crystal layer along a length of said bar pattern,

a first transducer for developing a first variable analog signal,

a second transducer for developing a second variable analog signal,

said means for electrically energizing said electrode strips including a multiplexer responsive to signals fed from said first and second transducers for energizing groups containing a number of strips substantially proportional to the signals fed from said transducers to said multiplexer,

said common electrode means comprising first and second discrete common electrodes each extending the full length of said bar pattern and each having a width less than the full extent of said individual electrode strips, and

means for alternately energizing said common electrodes in synchronism with said multiplexer.

**2.** The display of claim **1** wherein

said common electrode means includes first and second discrete common electrodes each extending in a direction normal to the extent of individual ones of said electrode strips,

each of said discrete common electrodes having the length of said bar pattern and a width of a fraction of the length of said electrode strips,

said means for electrically energizing said electrode strips comprising means for energizing different electrode strips in accordance with different analog signals,

said means for energizing said common electrode means comprising means for energizing said first and second common electrodes in synchronism with the energization of said electrode strips in accordance with said analog signals.

**3.** The display of claim **1** wherein, said display includes a scale positioned in proximity to said bar pattern and having indicia extending along said bar, said scale includes a plurality of strips of different colors respectively indicating different conditions of the values displayed.

**4.** The display of claim **1** wherein each of a group of said strips extends continuously from an intermediate portion of said second plate to an edge of said second plate for connection with said strip energizing means, and including

a second plurality of discrete electrode strips arranged in a pattern to collectively delineate a second continuous bar extending normal to the extent of individual ones of said second plurality of electrodes strips,

said second continuous bar being positioned adjacent to said first continuous bar, each of the strips of said second plurality of electrode means extending from said intermediate portion of said second plate to a second edge of said second plate,

means connected to said second plurality of electrode means at said second edge for energizing one or more of said second plurality of electrode strips,

second common electrode means on said first plate oppositely disposed with respect to said second bar pattern, and

means for electrically energizing said second common electrode means.

**5.** The display of claim **4** wherein each strip of said first graphic electrode means extends continuously for the width of both said first and second common electrodes.

**6.** The display of claim **4,** wherein said second graphic electrode means is electrically isolated from said first-mentioned graphic electrode means.

**7.** A parameter display comprising

first and second glass plates and a liquid crystal material confined between said plates,

first and second mutually discrete common electrodes extending substantially continuously in a bar pattern on said first plate,

graphic electrode means on said second plate,

said graphic electrode means comprising a plurality of mutually discrete, adjacent and parallel electrode strips each extending continuously across the width of both of said common electrodes to an edge of said second plate,

said graphic electrode means collectively delineating first and second continuous bars, each congruent with a respective one of said common electrodes,

means for receiving first and second bidirectionally variable analog signals,

means responsive to said analog signals for electrically energizing said electrode strips in alternate groups of adjacent strips,

said groups including a number of strips that varies in either sense in accordance with alternate ones of said analog signals,

means for alternately energizing said first and second common electrodes,

means for synchronizing the alternate energization of said common electrodes with the alternate energization of said groups of graphic electrode strips in accordance with said first and second bidirectionally variable analog signals,

third and fourth common electrodes on said first plate each extending for the length of said first and second common electrodes and being insulated relative to each other and to said first and second common electrodes, second graphic electrode means electrically isolated from said first-mentioned graphic electrode means and comprising a plurality of mutually discrete, adjacent and mutually parallel electrode strips arranged in a pattern congruent with both of said third and fourth common electrodes to collectively delineate third and fourth continuous bars congruent to said third and fourth common electrodes, respectively,

means for receiving third and fourth analog signals,

means for electrically energizing the electrode strips of said second graphic electrode means in alternate groups of adjacent strips,

said groups including a number of strips that varies in either sense in accordance with said third and fourth analog signals alternately,

means for electrically energizing said third and fourth common electrodes alternately in synchronism with the energization of said alternate groups of strips of said second graphic electrode means in accordance with said third and fourth analog signals, respectively,

electrode strips of said first graphic electrode means extending to a first edge of said second plate for external electrical connection, and

electrode strips of said second graphic electrode means extending to a second edge of said second plate for external electrical connection.

* * * * *