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[54] **DRIVING CIRCUITS FOR LIGHT EMITTING DIODES**

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[52] **U.S. Cl.**........ **307/40**, 178/7.3 D, 315/169 TV, 340/166 EL, 340/324 R

[51] **Int. Cl.** **H05b 33/00**

[58] **Field of Search**............... 307/40; 315/169 TV; 340/324 R, 166 EL, 334, 343; 178/5.4 EL, 7.3 D; 317/235

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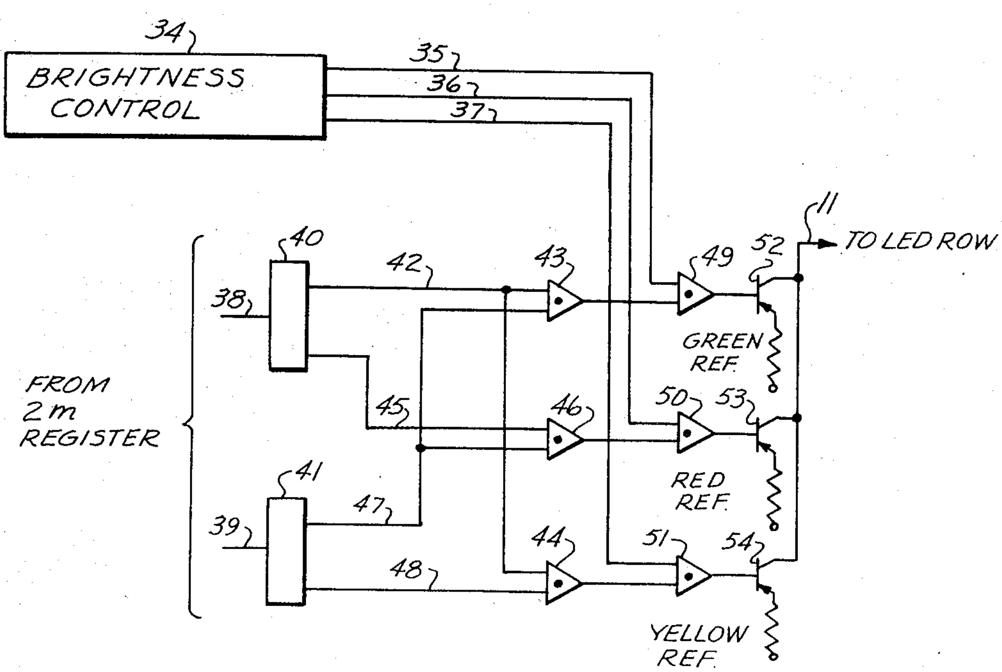
[57] **ABSTRACT**

LEDs are arranged in a matrix and driven by a pair of registers. A column register sequentially enables the columns of LEDs and a row register selectively operates the LEDs of each column in accordance with a predetermined binary code. A color control and a brightness control circuit may be included in connection with the row register to selectively control driving currents to the LEDs to control color hue, and to selectively control the duration of "on" time to control apparent brightness.

17 Claims, 5 Drawing Figures



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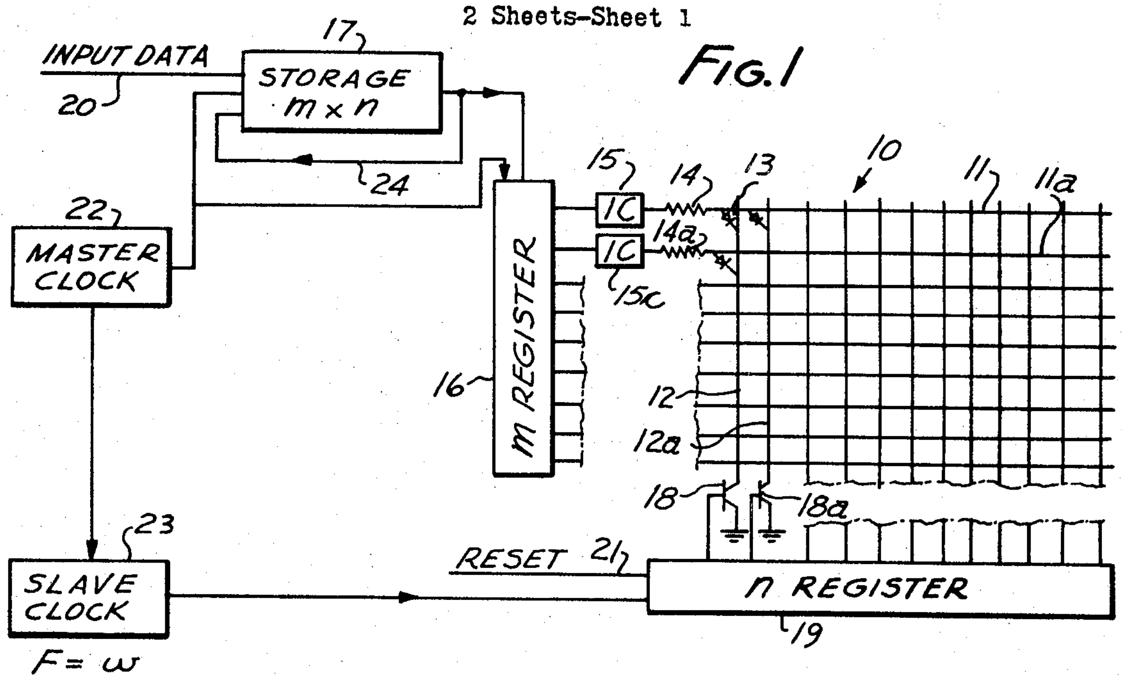

FIG. 1

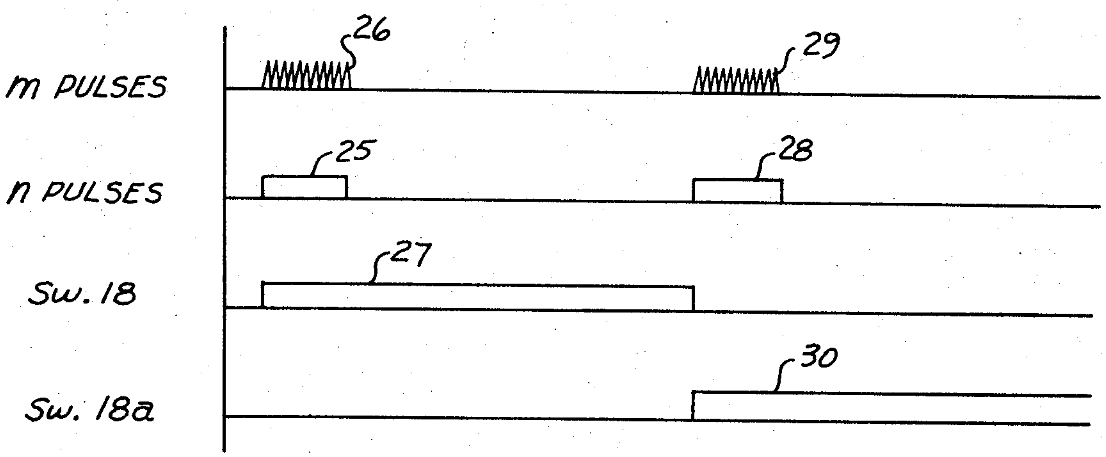

FIG. 2

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FIG. 3

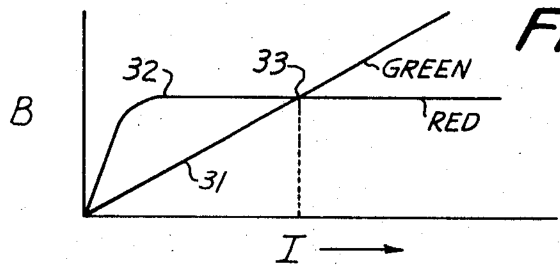


FIG. 4

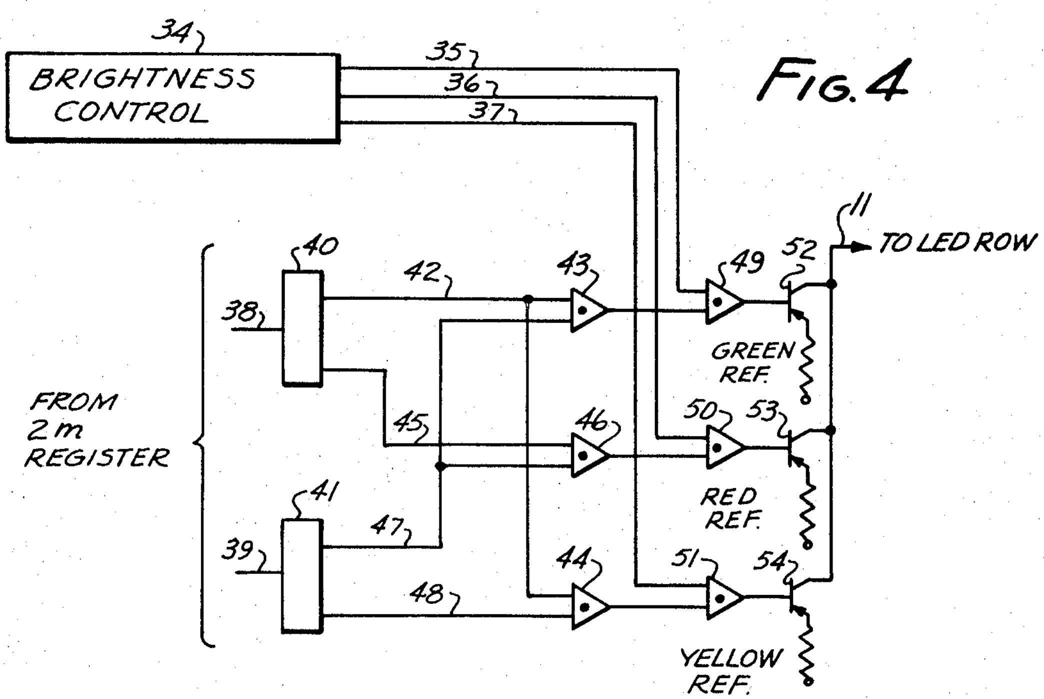
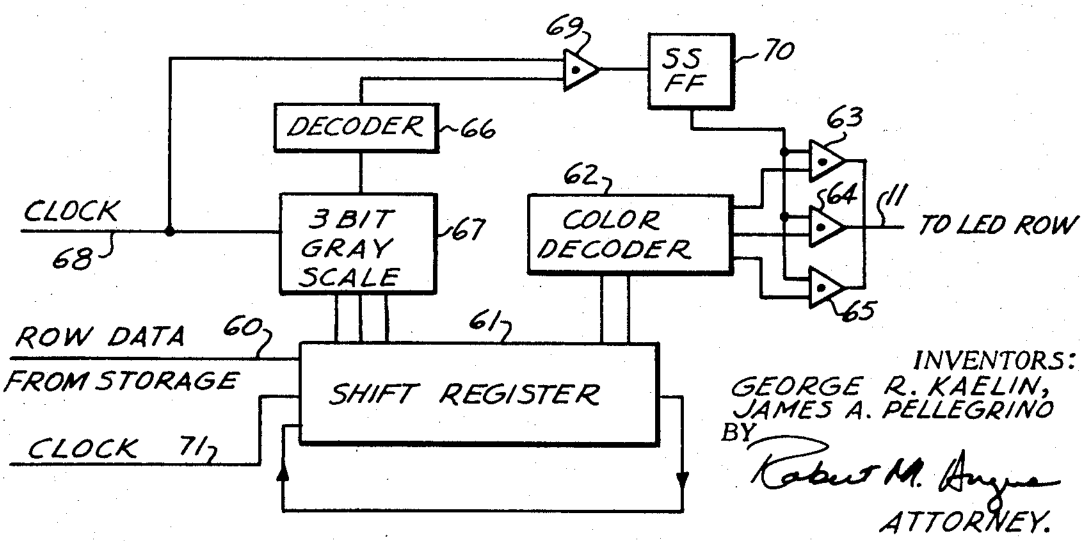


FIG. 5



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DRIVING CIRCUITS FOR LIGHT EMITTING DIODES

This invention relates to driving circuits for light emitting diodes, and particularly to circuits for driving light emitting diodes to achieve color display.

Light emitting diodes (LEDs) are useful for alpha-numeric display purposes. LED matrices, when properly driven, can provide alpha-numeric read out of information from a computer. However, in prior LED matrices, the individual diodes were separately operated, so that driving circuits required for operating prior LED displays required numerous connections to the display. The number of connections to prior LED display matrices rendered such matrices cumbersome in use and often expensive to manufacture.

It is an object of the present invention to provide driving circuits for LED display matrices whereby the LEDs may be selectively operated.

It is another object of the present invention to provide a LED driving and memory circuit which may be integrated with a LED matrix to form LED display apparatus requiring fewer interconnections than heretofore achieved.

Certain LEDs exhibit different colors when subjected to driving currents of various amplitudes. Accordingly, it is yet another object of the present invention to provide a driving circuit for a LED matrix for selectively varying the driving currents to the individual LEDs of the matrix to achieve a selectable color display.

Another object of the present invention is to provide intensity control apparatus in multicolor LED display apparatus.

Another object of the present invention is to provide a LED driving circuit for selectively varying the pulse widths of driving current pulses to achieve selective intensity control of the LEDs.

In accordance with the present invention, a plurality of LEDs are disposed in a two-dimensional matrix. The LEDs are arranged in rows and columns. A first shift register is provided for driving the LEDs along the rows and a second shift register is provided for driving the LEDs along the columns. Information is stored in the shift registers to effectuate selective driving of selected ones of the LEDs.

In accordance with one feature of the present invention, the driving circuit includes means for selectively applying driving currents of various amplitudes to the LEDs so that the LEDs display selected colors.

In accordance with another feature of the present invention, means is provided for varying the pulse widths of the driving current pulses to selectively vary the intensity of the display.

The above and other features of this invention will be more fully understood from the following detailed description and the accompanying drawings, in which:

FIG. 1 is a schematic block diagram of a LED display matrix having a driving circuit in accordance with the presently preferred embodiment of the present invention;

FIG. 2 is a diagrammatic representation of waveforms associated with the driving circuit illustrated in FIG. 1;

FIG. 3 is a diagram illustrating the color display characteristics of a light emitting diode;

FIG. 4 is a schematic block diagram of a logic circuit for color control of light emitting diodes in accordance

FIG. 5 is a block logic diagram of a color driving circuit for controlling the intensity and the color of display of light emitting diodes in accordance with another embodiment of the invention.

Referring to FIG. 1 there is illustrated a matrix **10** having *m* number of leads **11**, **11***a*, etc. arranged in rows and *n* number of leads **12**, **12***a*, etc. arranged in columns. Leads **11** and **12** are electrically isolated, and are interconnected by a matrix of m n number of light emitting diodes **13**. For example, the anode of each diode **13** may be connected to a respective lead **11** while the cathode of the diode may be connected to a respective lead **12**. Leads **11**, **11***a*, etc. are connected through resistors **14**, **14***a*, etc. and integrated circuits **15**, **15***a*, etc. to individual outputs of m register **16**. The input for register **16** is connected to the output of shift register **17**. Leads **12**, **12***a*, etc. are connected through transistors **18**, **18***a*, etc. to ground, the base of each transistor **18** being connected to a separate output of *n* register **19**.

Register **19** is a shift register capable of sequencing enable signals to the various outputs of the register. Shift register **19** has a first input **21** for resetting the register and to condition operation of the first transistor **18**. A second input is connected to slave clock **23** to sequence an enable signal to the outputs of register **19** to sequentially operate transistors **18**, **18***a*, etc. Register **17** has an input **20** for supplying data to register **17**. The input data may be supplied by means (not shown) which develops the input signals in accordance with data to be displayed. The input data to register **17** includes at least one bit for each LED device in matrix **10**. As will be more fully understood hereinafter, the input data may include more than one bit per LED device to achieve color and intensity control.

Master clock **22** is connected to one input of storage register **17** and shift register **16**, and is connected to an input of slave clock **23**. The output of clock **23** is connected to an input of shift register **19**. As illustrated in FIG. **1**, storage register **17** includes a feed-back path **24** connecting the output of the storage register to its input.

With reference to FIG. **2**, the operation of the driving circuit illustrated in FIG. **1** may be explained. Light emitting diodes **13** are connected between each lead **12** and each lead **11** so that connection is made from the *m* e register **16** through the light emitting diodes **13** and transistors **18** to ground, input data is supplied to storage register **17**. The input data to register **17** comprises at least *m n* number of bits of information, where *m* is equal to the capacity of register **16** and *n* is equal to the capacity of register **19**. As will be more fully understood hereinafter, the input data may include some multiple of m n bits for color and intensity control. With an *m* by *n* matrix **10**, the input data to storage register **17** corresponds in length to some multiple of the number of diodes in matrix **10**.

Master clock **22** is operated at a frequency equal to $x\, m\, n\, \omega$ where ω is the display cycle refresh frequency of the display, and where *x* is the number of bits associated with the color and intensity control circuits, if any. Master clock **22** conditions storage register **17** to store *x m n* bits of input data, and clocks register **16** to accept *x m* bits from register **17** during each cycle ω. Master clock **22** also drives slave clock **23** to supply n pulses to register **19** to step the output of register **19**. The biter **16** operates through integrated circuit **15** to control the current on each of leads **11.** The presence of the n pulse to the input of n register **19** conditions the first transistor **18** to conduct. Hence, current flows through integrated circuits **15,** through the light emitting diodes, and transistor **18** in accordance with the binary value of the signals stored in register **16.** For example, if eight rows **11** are connected to register **16,** *m* equals 8, and the *x m* code will consist of *x* 8 bits. If no color or intensity circuits are associated with integrated circuits **15** (so x=1), each "1" bit from register **16** will supply sufficient current to condition the diodes connected to the respective row leads to conduct, whereas those diodes receiving a "0" bit will not be conditioned to conduction. Energization of a selected transistor **18** for each column will complete the conduction path for the LEDs so that those LEDs associated with the 1's from register **16** and associated with the particular column **12** will be energized.

Assuming, for example, that the display is to be in single color and single intensity (x=1) during the first n pulse **25,** *m* pulses **26** are stored into register **16.** Pulse **25** also conditions register **19** to provide an output to transistor switch **18** to complete a path for all diodes in the first column. The period of conduction for transistor **18** is shown at **27** in FIG. **2.** The LEDs remain on during the remainder of pulse **27,** at which time clock **22** conditions a new set of m pulses **29** to be stored in register **16.** At the same time, clock **22** drives clock **23** to condition shift register **29** to its second output to transistor switch **18***a*. Transistor **18***a* conducts for the period illustrated at **30** in FIG. **2.**

If during the first n pulse, the m pulse pattern is 11010110 and the integrated circuits are condition to respond to only the 1's of the code, it is evident that the first, second, fourth, sixth and seventh LEDs of the first column will be energized. If during the second *n* pulse, the *m* pulse pattern is 00111010, it is evident that the third, fourth, fifth and seventh LEDs of the second column will be energized. The pattern continues through the entire cycle of n register **19.** By establishing the cycle frequency ω of n register **19** sufficiently high, the selected LEDs of the matrix will appear, to the human eye, to be conducting at the same time. The m n pulses are recycled through register **17** through loop **24** so that the display will continue for any desirable period of time.

One feature of the present invention resides in the utilization of the color emitting capabilities of certain light emitting diodes. For example, gallium phosphide light emitting diodes available from Bowmar Canada, Ltd., when subjected to a low current emit a predominantly red light. However, when subjected to a relatively high current, such diodes emit a predominantly green light. The brightness of the red and green hues is illustrated in FIG. **3** as a function of current. At low currents, the red hue, illustrated by waveform **32** is predominate over the green hue, illustrated by waveform **31,** whereas at high current the green hue predominates. At cross-over point **33,** the hues are about equal and will blend to appear as yellow.

FIGS. **4** and **5** relate to driving circuits to take advantage of the color phenomenon for selective color display from LED matrices. The circuits illustrated in FIGS. **4** and **5** may be used for integrated circuits **15** in FIG. **1.** In FIG. **4,** brightness control circuit **34** has outhereinafter, brightness control **34** provides pulses of different pulse widths on the output leads **35, 36** and **37.** Input leads **38** and **39** are connected to a shift register having a length equal to 2 *m*, since x=2 to provide for conditions for each LED, three colors and off. For example, the shift register to which leads **38** and **39** are connected is similar to register **16** illustrated in FIG. **1** but so arranged that two bits of information will operate on the circuit illustrated in FIG. **4.** Lead **38** provides an input to bistable multivibrator **40,** and lead **39** provides an input to multivibrator **41.** Multivibrators **40** and **41** each have two outputs, output **42** of multivibrator **40** being connected to an input of AND gates **43** and **44,** output **45** of multivibrator **40** being connected to one input of AND gate **46,** output **47** of multivibrator **41** being connected to inputs of AND gates **43** and **46,** and output **48** of multivibrator **41** being connected to the second input of AND gate **44.** AND gate **49** has inputs connected to the output lead **35** from brightness control circuit **34** and to the output from AND gate **43,** AND gate **50** has inputs connected to the output **36** of brightness control circuit **34** and to the output of AND gate **46,** and AND gate **51** has inputs connected to output lead **37** from brightness control circuit **34** and to the output from AND gate **44.** Each of AND gates **49, 50** and **51** are connected to the base of respective transistors **52, 53** and **54.** The emitters of transistors **52, 53** and **54** are connected to respective sources (not shown) of constant voltage through resistors, and the collectors of transistors **52, 53** and **54** are connected together to lead **11** of the particular LED row. The driving currents established by the voltage sources and series resistors are different for each transistor **52, 53** and **54.** For example, the source connected to the emitter of transistor **52** may produce a relatively high current for green displays, the source connected to emitter of transistor **53** may produce a relatively low current for red displays, and the source connected to the emitter of transistor **54** may produce an intermediate current for yellow displays.

The brightness of a particular LED is determined by the current applied to that diode, which also affects the color hue. However, the "apparent" brightness of such diodes, as perceived by the human eye, is determined by the length of time that the diode is emitting light, as well as actual brightness. Hence, if it is desirable to provide an apparent bright display of red colors, brightness control circuit **34** provides pulses of longer duration on output lead **36** than the pulses on the leads **35** and **37.** On the other hand, if it is desired that all colors have substantially the same apparent brightness, the length of pulses applied to each lead **35–37** is inversely proportioned to the pulse amplitude so that the average current to each lead is substantially the same. However, the pulse lengths may be adjusted somewhat to compensate for the differing efficiency of the human eye for different colors.

In operation of the color driving circuit illustrated in FIG. **4,** the input signals representative of 1's and 0's are applied to input leads **38** and **39.** Multivibrators **40** and **41** provide output signals at one or the other of their outputs depending on the binary value of the input signals. For example, if the input signal to lead **38** is a "1," multivibrator **40** will provide an output at lead **42,** where as if the input lead **38** is a "0," multivibrator **40** will provide an output at lead **45.** Likewise, multivi-

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