the horizontal axis **36** are functionally separated into two groups of twenty-eight LEDs **24** each, in order to center their light beams respectively on upper **38** and lower **40** LCD displays of the GUI display.

[**0040**] With continued reference to **FIG. 4**, the surface mount IrDA receivers **42** are positioned around the perimeter of the touchframe **14** in adequate numbers to resolve the output of all infrared LEDs **24**. To this end, each of the six rows of contiguous LEDs **24** has two associated IrDA receivers **42**, one at each end. The IrDA receivers **42** face the row of LEDs **24** on the opposite side of the touchframe **14** and receive light beams from each of the facing LEDs to detect touches. In one embodiment, the IrDA receivers **42** are special-purpose integrated light detectors produced by Sharp Corporation (part number GP2W001). The IrDA receivers **42** provide a light-detecting element and a signal-processing circuit integrated onto a single chip. The IrDA receivers **42** handle all ambient light rejection and all analog signal processing, producing a low-going digital output pulse whenever they detect a sudden increase in infrared light. They are, in essence, an infrared edge detector.

[**0041**] Each LED **24** is resolved by at least two IrDA receivers **42** to provide redundant operation. The IrDA receivers **42** automatically adapt to variations in ambient light level and operate across a full range of light levels from total darkness to direct sunlight. The IrDA receivers **42** provide a TTL-compatible output signal when illuminated by an LED **24** that has been switched on.

[**0042**] With reference to **FIG. 5**, the PCBA **16** includes a controller **44** and a LED multiplexing system **46**. The controller **44** is an 8 MHz or faster RISC architecture controller with at least thirty-two programmable I/O lines. One such controller is the Atmel AVR AT90S8515. The PCBA **16** also includes 8 KB of FLASH memory, 512 bytes of local high speed SRAM memory, 512 bytes of EEPROM, a 16-bit counter/timer, a watchdog timer, a full duplex on chip UART that may utilize two of the I/O lines as a serial I/O port and a programming port that enables in-system programming of the controller **44** program memory.

[**0043**] The LED multiplexing system **46** includes a network of multiplexers and column drivers that form a multiplexing matrix comprised of rows and columns. Such a matrix is necessary in view of there being more LEDs **24** to operate than there are controller **44** output pins. The LED multiplexing system **46** expands the input/output capability of the controller **44** in order to allow for individual activation of the LEDs **24**. Each LED **24** is independently addressable by the controller **44** such that only one LED is illuminated at a time. The LEDs **24** are addressed by writing an 8-bit LED identifier to an output port of the controller **44**. An LED address is comprised of a 4-bit row identifier and a 4-bit column identifier. Combined, these identifiers serve to address one of up to 256 possible logical LEDs **24** in the touchframe. Row and column identifiers may be assigned to upper or lower 4-bit fields of the output port. Merely writing the LED row and column address to the controller **44** output port does not activate an LED **24**. Two output pins, a row strobe and a column strobe are asserted to activate an LED **24**.

[**0044**] The PCBA **16** also includes an eight pin, asynchronous TTL-compatible serial communication port **48** for passing data back and forth between the GUI CPU **22** and the PCBA **16**, driving hardware **50** for providing a single 5V power supply, VCC, to operate the PCBA circuitry and an in-system programming port **52** that provides for external uploading and downloading of touchframe operating firmware into the controller **44**.

[**0045**] Touchframe Geometry

[**0046**] While the IrDA receivers **42** used in the touchframe system avoid many of the analog problems associated with the receivers of prior art systems, and handle ambient light variations extremely well, they are relatively expensive. Therefore, it is cost prohibitive to have a one-to-one ratio between LEDs and infrared receivers as is used in prior art touchframe systems. Accordingly, the touchframe system of the invention uses a greater number of LEDs and fewer receivers than the prior art systems.

[**0047**] With reference to **FIG. 6**, the LEDs **24** and IrDA receivers **42** are arranged such that the light beam paths **43** defined by each LED **24** and its associated IrDA receivers **42** form an intersecting pattern of triangular zones that provide coverage of the entire screen area. In **FIG. 6**, and **FIGS. 7 and 10**, not all LEDs and IrDA receivers are shown in order to preserve clarity of illustration. Because the intersecting light beam paths or lines that result cross at many different angles, the controller **44** is programmed to execute a mathematical coordinate conversion step that translates to the conventional X/Y coordinate system expected by the GUI CPU **22**. Coordinate conversion involves some rounding and approximation.

[**0048**] With reference to **FIG. 7**, two factors determine the ratio of the number of LEDs **24** to the number of IrDA receivers **42**: the useful angle of light dispersion from the LEDs and the acceptance angle of the IrDA receiver. These dispersion and acceptance angles of the LEDs **24** and IrDA receivers **42** are limited. Both types of components have lenses in front of the active electro-optical elements designed to concentrate the light beam energy into a confined range. If all LEDs **24** on one side of the touchframe communicated only with a single IrDA receiver **42**, they could simply be aimed at that receiver. However, in accordance with a redundancy feature of the invention, each LED **24** on one side of the frame triggers two IrDA receivers **42** on the opposite side of the touchframe. Therefore, the LEDs **24** are aimed at the midpoint **45** between the two IrDA receivers **42** on the opposite side. Likewise, since each IrDA receiver **42** communicates with all of the LEDs **24** on the opposite side of the touchframe, each IrDA receiver is aimed at the midpoint of the LED row on the opposite side.

[**0049**] Logic and Scanning

[**0050**] With reference to **FIG. 8**, operation of the touchframe system is controlled by the 8 Mhz RISC controller U**7**. Twelve IrDA receivers (IR**1**-IR**12**) are directly connected to controller input port bits DA**0**-DA**7**, DB**0**-DB**3**. Although the horizontal LEDs D**2**-D**125** and vertical LEDs D**130**-D**231** are arranged in rows around the periphery of the touchframe, a logical 16×16 output matrix controls all of the LEDs in the system. Standard three-to-eight line decoders U**2**,U**3**,U**51**,U**52** implement the matrix, but not all rows and columns of the matrix are needed.

[**0051**] In accordance with the invention, only one LED **24** is switched on at a time. The controller U**7** turns an LED on by selecting one row and one column and then enabling the