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Gildea et al.

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[54] **DIFFERENTIAL GPS RECEIVER SYSTEM LINKED BY INFRARED SIGNALS**

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[73] Assignee: **Trimble Navigation Limited**, Sunnyvale, Calif.

[21] Appl. No.: **359,604**

[22] Filed: **Dec. 20, 1994**

[51] **Int. Cl.**[6] **G01S 5/02**

[52] **U.S. Cl.** **342/357**

[58] **Field of Search** 342/357

[56] **References Cited**

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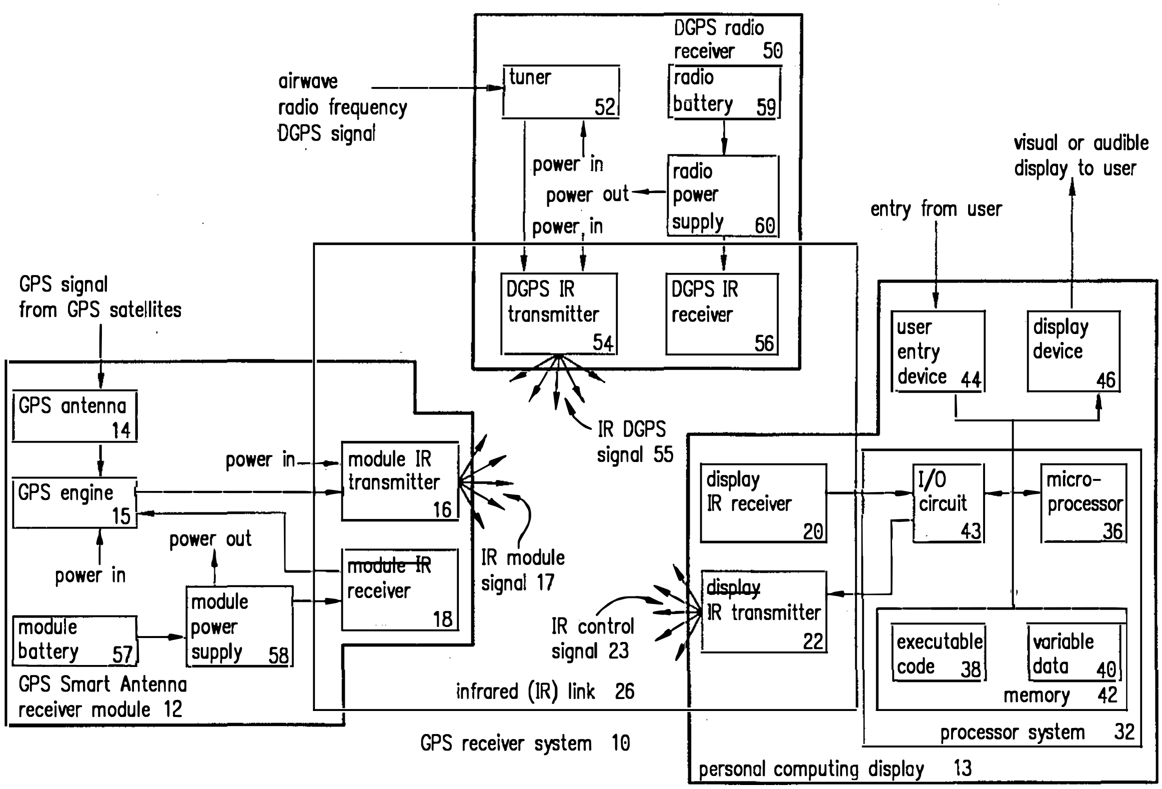
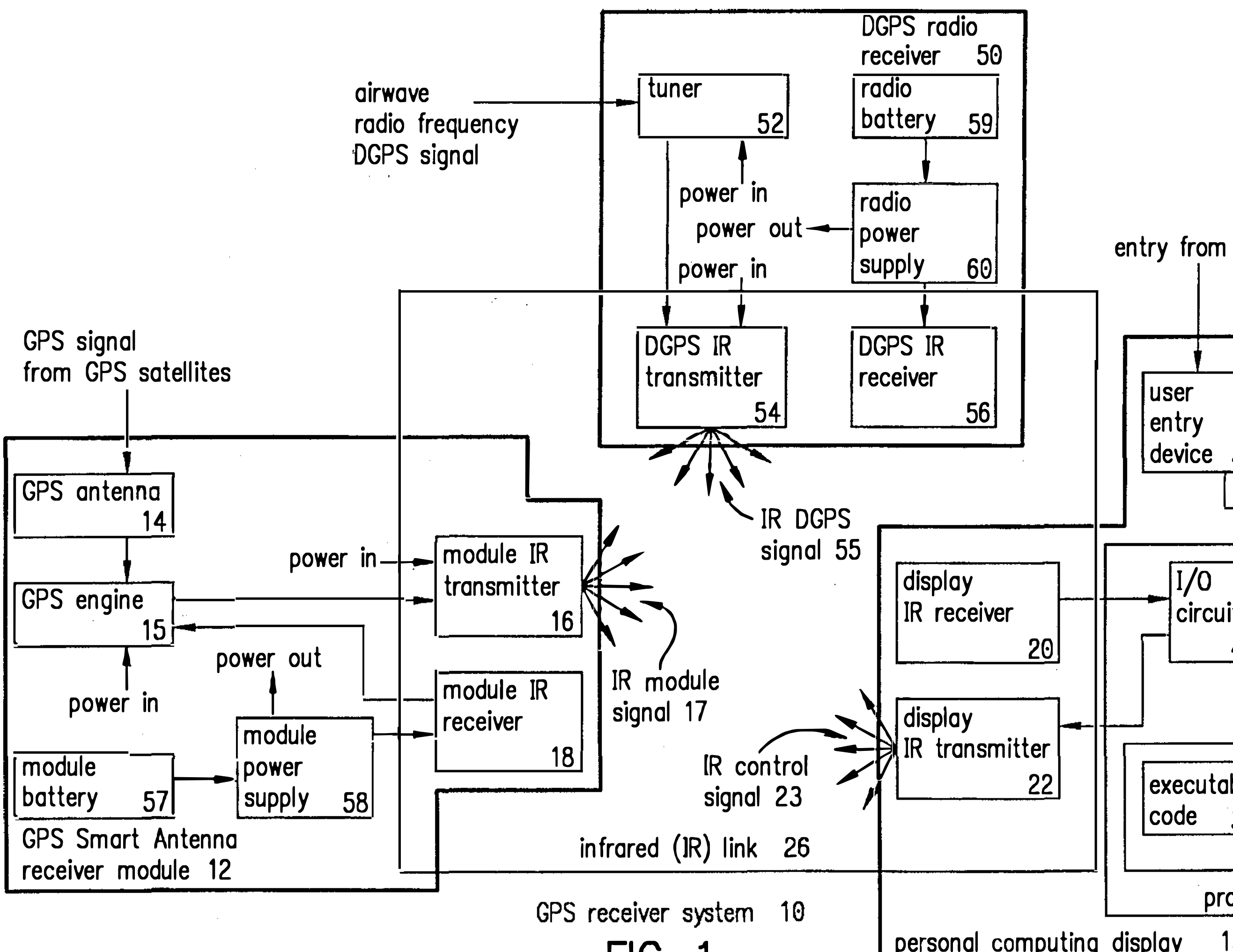
Primary Examiner—Gregory C. Issing
Attorney, Agent, or Firm—David R. Gildea

[57] **ABSTRACT**

A GPS receiver system to determine and display a geographical differential Global Positioning System (DGPS) location where the components of the system are interconnected with an airwave infrared (IR) link. The system includes a GPS Smart Antenna receiver module to determine the geographical location of the module, a DGPS radio receiver to receive an airwave radio frequency DGPS signal having DGPS correction information, and a personal computing display to run an application program and to display the geographical DGPS location and application information that is useful to a user. The GPS Smart Antenna receiver module and the DGPS radio receiver are switched on and off from the personal computing display through the airwave IR link.

15 Claims, 2 Drawing Sheets




DGPS radio
receiver 50
radio
battery 59
tuner
52
airwave
radio frequency
DGPS signal
power in
power out
radio
power
supply 60
power in
DGPS IR
transmitter
54
DGPS IR
receiver
56
entry from
user
entry
device 4
GPS signal
from GPS satellites
GPS antenna
14
GPS engine
15
power in
module IR
transmitter
16
IR DGPS
signal 55
power out
power in
module
power
supply 58
module IR
receiver
18
IR module
signal 17
module
battery 57
GPS Smart Antenna
receiver module 12
display
IR receiver
20
I/O
circuit
4
display
IR transmitter
22
IR control
signal 23
executab
code 3
infrared (IR) link 26
proc
GPS receiver system 10
personal computing display 13
FIG. 1

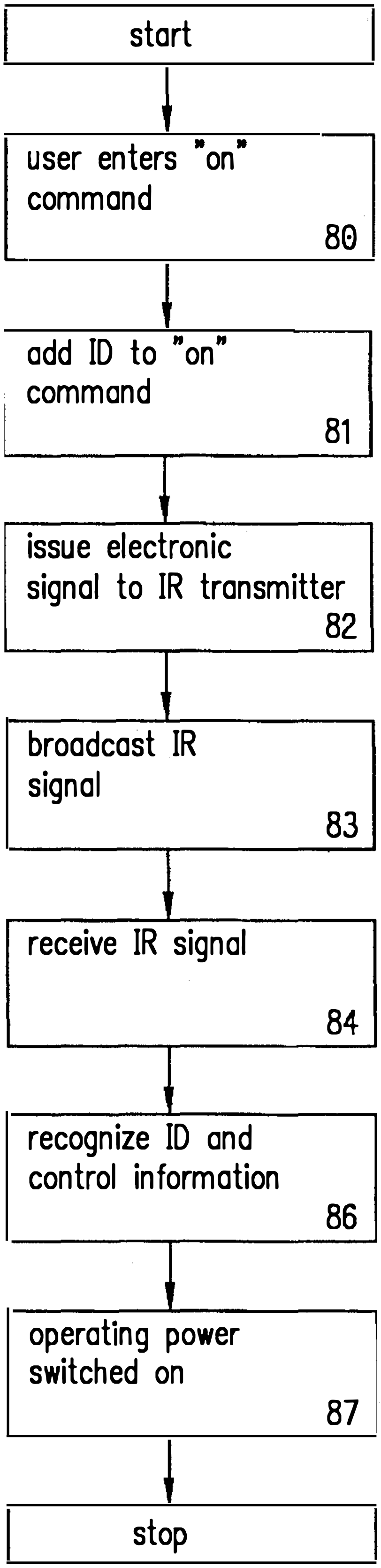

start
user enters "on" command
80
add ID to "on" command
81
issue electronic signal to IR transmitter
82
broadcast IR signal
83
receive IR signal
84
recognize ID and control information
86
operating power switched on
87
stop

FIG. 2a

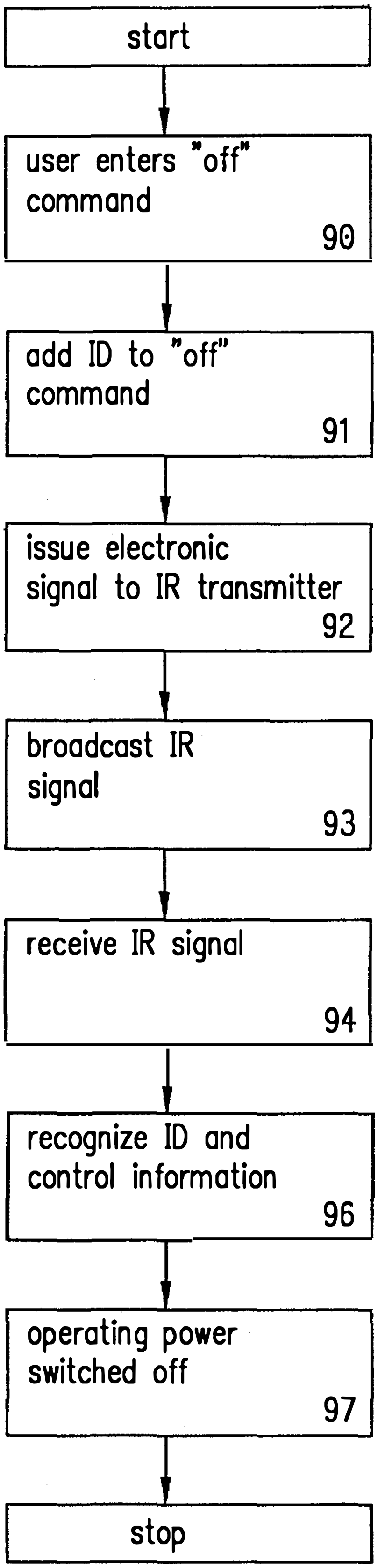

start
user enters "off" command
90
add ID to "off" command
91
issue electronic signal to IR transmitter
92
broadcast IR signal
93
receive IR signal
94
recognize ID and control information
96
operating power switched off
97
stop

FIG. 2b

DIFFERENTIAL GPS RECEIVER SYSTEM LINKED BY INFRARED SIGNALS

CROSS REFERENCE OF RELATED APPLICATIONS

This application is related to a continuation in part application of David R. Gildea et al., Ser. No. 08/225125, filed Apr. 6, 1994, to its parent application Ser. No. 07/978274, filed Nov. 18, 1992, to an application of David R. Gildea, Ser. No. 08/157609, filed Nov. 23, 1993, and to an application of Glenn C. Steiner et al., Ser. No. 08/293048 filed Aug. 19, 1994. All of these applications are assigned to the assignee of the present application.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates generally to Global Positioning System (GPS) receivers and more particularly to a GPS receiver system wherein a GPS Smart Antenna, a differential GPS radio receiver, and a personal computing device are coupled by an infrared link.

2. Description of the Prior An

GPS receivers are now used for many applications to provide a geographical location. The GPS receiver includes a GPS antenna to receive a GPS signal transmitted from one or more GPS satellites, a GPS engine to compute the geographical location of the antenna and the time of observation of that location, a display processor to convert the location and observation time into information that is useful for an application, and a display device to show the information to the user. The antenna must be positioned with a direct line of sight to the satellite or satellites from which the signals are received.

An important figure of merit in a GPS receiver is accuracy of the geographical location. The inherent accuracy of the GPS location measured by a commercial GPS receiver is approximately 20 meters. However, the United States Government currently employs selective availability (SA) to degrade the accuracy of the GPS location that is determined by a commercial GPS receiver. With SA the GPS location accuracy is approximately 100 meters. Several applications require a geographical location accuracy that is better than 100 meters or even 20 meters. For example, a 100 to 20 meter location error could lead to unintentional trespassing, make the return to an underground marker or mineral difficult, place a motor vehicle on the wrong block, or cause a navigator to choose an incorrect course for a boat or an airplane.

Fortunately, both the inherent and the SA-degraded GPS location accuracy can be improved by the application of differential GPS (DGPS) corrections. In general, the DGPS corrections are derived by taking the difference between a GPS location determined by a GPS receiver located at a reference site and a surveyed location of the reference site. Various airwave radio frequency signals are now available from a variety of sources to provide the DGPS corrections in real time to a mobile GPS receiver system. A DGPS radio receiver included as a part of a GPS receiver system receives the airwave signal carrying the DGPS corrections. The mobile GPS receiver system uses the DGPS corrections to correct the GPS location. The corrected GPS location, termed a "DGPS location" has an accuracy in a range of 10 constructions for the DGPS radio receiver are required

depending upon which of the various airwave signals the DGPS radio receiver is to receive.

Another important figure of merit for a GPS receiver is portable computing power. In many applications, the GPS location or the DGPS location is processed to provide further information that is useful to a user. For example, a geographic information system (GIS) application may store the geographical locations and attributes of map features in the form of an electronic map. A navigation application may need to compute a distance and a direction to a selected map feature or to a map feature having a selected set of the attributes. Such applications require a large memory and are most expediently programmed in a processing system that has the power to run a standard operating system, such as DOS, DOS with Windows, Macintosh, GeoWorks, and others. Fortunately, personal computing devices have recently become available that have the portability, memory, and processing power to run these applications.

Several formats of GPS receiver systems exist or have been proposed that include system components of the GPS receiver, the DGPS radio receiver, and the personal computing device in order to provide DGPS location capability, portability, and processing power. In a first format, the system components are integrated into a single unit. Such units may be "hardwired" into a single unit, or the GPS receiver and the DGPS radio receiver may be housed on Personal Computer Memory Card Interface Association (PCMCIA) cards that plug into the personal computing device to give the effect of a single unit. An advantage of using PCMCIA cards, is that the various constructions of DGPS radio receivers do not prevent the manufacture of a standard construction of the GPS receiver on a separate card. A problem with this format is that the user must remain in the open to preserve a direct line of sight from the GPS antenna to one or more GPS satellites while operating and observing the personal computing device. One solution to this problem is to place the GPS antenna in a separate unit, connected with the GPS receiver system by a cable. In a second format, the system components are each housed in separate units and interconnected with cables. This format retains the advantages of separating the GPS antenna from the system and of having a standardized construction of the GPS receiver. However, cables and their connections are expensive, prone to breakage or malfunction, and inconvenient for some applications.

In a third format, the GPS receiver and the DGPS radio receiver components are integrated into a GPS/DGPS Smart Antenna unit. The GPS/DGPS Smart Antenna unit may use a wireless radio frequency or infrared (IR) frequency link to connect to the personal computing device. The IR frequency link has the advantage that it does not interfere with reception of airwave radio frequency signals used for navigation and does not require testing or certification by the FAA or FCC. This format eliminates the expense, reliability problems, and inconvenience of the cable but, does not allow a standard construction of the GPS receiver component.

There is a need for a GPS receiver system to provide a geographical DGPS location, where the system includes a GPS receiver having a standard construction and where the system components are interconnected by an infrared (IR) link.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a GPS receiver system to determine and display a geographical DGPS location where the system includes a GPS Smart

Antenna receiver module, a DGPS radio receiver, and a personal computing display in separate packages each communicating with the others without cables by using an airwave infrared (IR) link.

Another object is to provide internal batteries to supply operating power within the GPS Smart Antenna receiver module and within the DGPS radio receiver and to control the supply of operating power within the module and within the radio from the personal computing display through the IR link.

Briefly, the preferred embodiment includes the GPS Smart Antenna receiver module to determine the geographical location of the module, the DGPS radio receiver to receive an airwave radio frequency DGPS signal having DGPS correction information, and the personal computing display to run an application program and to display the geographical DGPS location and application information that is useful to a user. The GPS Smart Antenna module, the DGPS radio receiver, and the personal computing display communicate information through the airwave IR link.

An advantage of the present invention is that the GPS Smart Antenna receiver module, the DGPS radio receivers, and the personal computing display are packaged separately, thereby allowing various constructions of DGPS radio receivers while retaining standardization of the construction of the GPS receiver.

Another advantage is that the GPS receiver, the DGPS radio receiver, and the personal computing display communicate via a cableless IR link, thereby eliminating the cost, failure potential, and inconvenience of cable connections.

Another advantage is that the lifetimes of the internal batteries in the GPS Smart Antenna receiver module and in the DGPS radio receiver may be prolonged by controlling the supply of operating power within the module and within the radio receiver from the personal computing display through the IR link.

These and other objects and advantages of the present invention will no doubt become obvious to those of ordinary skill in the art after having read the following detailed description of the preferred embodiments which are illustrated in the various figures.

IN THE DRAWINGS

FIG. **1** is a block diagram of a GPS receiver system providing a geographical differential GPS location;

FIG. **2*a*** is a flow chart of the steps to turn on the operating power in a GPS Smart Antenna receiver module and in a DGPS radio receiver that are a part of the system of FIG. **1**; and

FIG. **2*b*** is a flow chart of the steps to turn off the operating power in the GPS Smart Antenna receiver module and in the DGPS radio receiver of FIG. **2*a***.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** illustrates a GPS receiver system of the present invention and referred to by the general reference number **10**. The system **10** includes a GPS Smart Antenna receiver module **12** to determine a geographical location of the module **12** and a personal computing display **13** to display the location to a human user. The module **12** is housed in a single waterproof package, no more than 15 centimeters high and no more than 15 centimeters wide in any dimension perpendicular to the height. The module **12** includes a GPS antenna **14** to receive an airwave GPS signal, having information for the determination of a GPS location, from a plurality of GPS satellites and to issue a responsive electronic antenna output signal to a GPS engine **15**. The GPS engine **15** computes the geographic location from the information in the GPS signal and issues data indicative of the location in an electronic signal to a module infrared (IR) transmitter **16**. Several GPS antennas **14** and the GPS engines **15** that are suitable for the construction of the present invention are commercially available, such as a model "**SV6**" manufactured by Trimble Navigation that includes both the GPS antenna **14** and the GPS engine **15**, a model "NavCore Microtracker" manufactured by Rockwell that includes the GPS engine **15**, and a variety of models manufactured by MicroPulse located in Camarillo, Calif. that include the GPS antenna **14**.

The module IR transmitter **16** transmits an IR module signal **17**, including the location data, by illuminating a cone of local airspace emerging from the module IR transmitter **16** with energy in the IR wavelength range. The module **12** includes a module IR receiver **18** to receive IR signals having information to control the operation of the module **12**. The personal computing display **13** includes a display IR receiver **20** to receive IR signals in the local airspace including the IR module signal **17** and a display IR transmitter **22** to transmit an IR control signal **23** by illuminating a cone of local airspace with IR energy. The module IR transmitter **16** and the display IR transmitter **22** may be constructed from a light emitting diode (LED), such as a "TSUS5402" or a "TSHA5503" manufactured by Telefunken Semiconductors driven by a transistor, using application information available from Telefunken. The use of multiple LEDs in the module IR transmitter **16** and/or the display IR transmitter **22** can be used to widen the cone of the IR module signal **17** and/or the IR control signal **23**, respectively IR receiver **18** and the display IR receiver **20** may be constructed from a photodiode, such as a "BPV23F" or a BPV23NF" manufactured by Telefunken Semiconductors, and an "SIRComm2" integrated circuit IR receiver manufactured by Irvine Sensors using application information available from Telefunken or Irvine. Alternatively, a model "CS8130 Multi- Standard Infrared Transceiver" manufactured by Crystal Semiconductors can be used with the above-identified LED and photodiode for both the module IR transmitter **16** and the module IR receiver **18** and/or for both the display IR transmitter **22** and the display IR receiver **20**. Another source of parts is Hewlett-Packard which provides licenses to use its serial infrared communications interface (SIR) transceivers disclosed in U.S. Pat. No. 5,075,792, the teachings of which are incorporated herein by reference. The module IR transmitter **16**, the module IR receiver **18**, the display IR receiver **20**, the display IR transmitter **22**, the IR module signal **17**, and the IR control signal **23** are included in an IR link **26** to communicate information between components of the system **10** including the GPS Smart Antenna receiver module **12** and the personal computing display **13**.

The personal computing display **13** includes a processor system **32** for receiving, processing, and issuing electronic signals. The processor system **32** includes a microprocessor **36** that operates in a conventional manner to receive electronic signals and to process the signals according to preprogrammed instructions in an executable code **38** and variable data **40** stored in a memory **42**. An I/O circuit **43**, such as a Universal Asynchronous/synchronous Receiver Transmitter (UART), available as an electronic part from many vendors, converts parallel data electronic signals from

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