United States Patent	12388693
Kind Code	B2
Date of Patent	August 12, 2025
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Data carrier apparatus, communication system, and replaceable unit

Abstract

In a data carrier apparatus, a reception unit receives, from a data carrier driving apparatus, a pulse signal that alternatingly repeats a first-level period and a second-level period, which are set based on individual data values. A measurement unit measures respective time widths of the first-level period and the second-level period in the received pulse signal. A demodulation unit demodulates data conveyed by the received pulse signal, by determining the data value corresponding to the first-level period based on a measured value of the first-level period output from the measurement unit and a first reference value, and determining the data value corresponding to the second-level period based on a measured value of the second-level period output from the measurement unit and a second reference value.

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Appl. No.: **18/391818**

Filed: **December 21, 2023**

Prior Publication Data

Document Identifier	Publication Date
US 20240214251 A1	Jun. 27, 2024

Foreign Application Priority Data

JP	2022-208797	Dec. 26, 2022

Publication Classification

Int. Cl.: **H04L27/233** (20060101)

U.S. Cl.:

CPC **H04L27/2331** (20130101); **H04L27/2337** (20130101);

Field of Classification Search

CPC: H04L (27/2331); H04L (27/2337)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
4497060	12/1984	Yang	N/A	N/A
5459751	12/1994	Okamoto	N/A	N/A
6064697	12/1999	Yoshikawa	N/A	N/A
11101972	12/2020	Ittogi et al.	N/A	N/A
11743078	12/2022	Ittogi et al.	N/A	N/A
2006/0098691	12/2005	Yamazaki	370/518	H03M 5/04
2015/0349993	12/2014	Tyrrell	315/294	H04L 23/00
2023/0090431	12/2022	Banin	375/295	H04B 1/04

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
S59112747	12/1983	JP	N/A
H06216778	12/1993	JP	N/A
H09130254	12/1996	JP	N/A
2019103123	12/2018	JP	N/A

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Background/Summary

BACKGROUND OF THE INVENTION

Field of the Invention

(1) The present invention relates to a data carrier apparatus, a communication system including a data carrier apparatus and a data carrier driving apparatus, and a replaceable unit, and in particular relates to data communication between a data carrier apparatus and a data carrier driving apparatus.

Description of the Related Art

(2) As a type of two-wire communication interface for communicating between two apparatuses, there is known a two-wire communication interface in which data communication, power supply, and synchronization signal supply are performed using two communication lines (signal lines). Japanese Patent Laid-Open No. 2019-103123 describes a technique for, in a communication system in which communication is performed using two communication lines, increasing the communication rate by transmitting and receiving data through modulation of the frequency of

each pulse of a pulse signal in addition to modulation of the duty ratio of each pulse. In such a communication system, data can be transmitted and received in units of 2 bits by modulating the duty ratio and frequency of each pulse of one cycle consisting of a high-level period and a low-level period in a pulse signal.

(3) As described above, by enabling transmission and reception of data in units of 2 bits per cycle of the pulse signal, it is possible to increase the communication rate. However, the minimum unit of data transmission is limited to 2 bits. For this reason, for example, if the number of bits of the data to be transmitted is an odd number, it may be necessary to adjust the data to 2-bit data before transmitting it.

SUMMARY OF THE INVENTION

(4) In view of this, the present disclosure provides a technique that makes it possible to transmit and receive data in units of 1 bit while increasing the communication rate in cases of transmitting and receiving data using a pulse signal.

(5) According to one aspect of the present invention, there is provided a data carrier apparatus capable of communicating with a data carrier driving apparatus, comprising: a reception unit configured to receive, from the data carrier driving apparatus, a pulse signal that alternatingly repeats a first-level period and a second-level period, and in which the first-level period and the second-level period are set based on individual data values; a measurement unit configured to measure respective time widths of the first-level period and the second-level period in the received pulse signal received by the reception unit; and a demodulation unit configured to demodulate data conveyed by the received pulse signal, by determining the data value corresponding to the first-level period based on a measured value of the first-level period output from the measurement unit and a first reference value, and determining the data value corresponding to the second-level period based on a measured value of the second-level period output from the measurement unit and a second reference value.

(6) According to another aspect of the present invention, there is provided a data carrier apparatus capable of communicating with a data carrier driving apparatus, comprising: a reception unit configured to receive, from the data carrier driving apparatus, a pulse signal that alternatingly repeats a first-level period and a second-level period, and in which the first-level period and a cycle of a pulse consisting of the first-level period and the second-level period are set based on individual data values; a measurement unit configured to measure a time width of the first-level period and the cycle of the pulse including the first-level period in the received pulse signal received by the reception unit; and a demodulation unit configured to demodulate data conveyed by the received pulse signal, by determining the data value corresponding to the first-level period based on a measured value of the first-level period output from the measurement unit and a first reference value, and determining the data value corresponding to the cycle based on a measured value of the cycle output from the measurement unit and a second reference value.

(7) According to still another aspect of the present invention, there is provided a replaceable unit that is attachable to an image forming apparatus, comprising: a process member to be used for image formation; and a data carrier apparatus capable of communicating with a data carrier driving apparatus provided in the image forming apparatus, when attached to the image forming apparatus, wherein the data carrier apparatus comprises: a reception unit configured to receive, from the data carrier driving apparatus, a pulse signal that alternatingly repeats a first-level period and a second-level period, and in which the first-level period and the second-level period are set based on individual data values; a measurement unit configured to measure respective time widths of the first-level period and the second-level period in the received pulse signal received by the reception unit; and a demodulation unit configured to demodulate data conveyed by the received pulse signal, by determining the data value corresponding to the first-level period based on a measured value of the first-level period output from the measurement unit and a first reference value, and determining the data value corresponding to the second-level period based on a measured value of the second-

level period output from the measurement unit and a second reference value.
(8) According to yet another aspect of the present invention, there is provided a communication system comprising: a data carrier apparatus; and a data carrier driving apparatus to be connected to the data carrier apparatus by two communication lines, wherein the data carrier driving apparatus comprises: a modulation unit configured to generate a pulse signal that alternatingly repeats a first-level period and a second-level period, and that is modulated based on data to be transmitted, the modulation unit being configured to generate the pulse signal in which the first-level period and the second-level period are set based on individual data values; and a transmission unit configured to transmit the pulse signal generated by the modulation unit to the data carrier apparatus based on a potential difference provided between the two communication lines, and the data carrier apparatus comprises: a reception unit configured to receive the pulse signal from the data carrier driving apparatus; a measurement unit configured to measure respective time widths of the first-level period and the second-level period in the received pulse signal received by the reception unit; and a demodulation unit configured to demodulate data conveyed by the received pulse signal, by determining the data value corresponding to the first-level period based on a measured value of the first-level period output from the measurement unit and a first reference value, and determining the data value corresponding to the second-level period based on a measured value of the second-level period output from the measurement unit and a second reference value.
(9) According to still yet another aspect of the present invention, there is provided a communication system comprising: a data carrier apparatus; and a data carrier driving apparatus to be connected to the data carrier apparatus by two communication lines, wherein the data carrier driving apparatus comprises: a modulation unit configured to generate a pulse signal that alternatingly repeats a first-level period and a second-level period, and that is modulated based on data to be transmitted, the modulation unit being configured to generate the pulse signal in which the first-level period and a cycle of a pulse constituting of the first-level period and the second-level period are set based on individual data values; and a transmission unit configured to transmit the pulse signal generated by the modulation unit to the data carrier apparatus based on a potential difference provided between the two communication lines, and the data carrier apparatus comprises: a reception unit configured to receive the pulse signal from the data carrier driving apparatus; a measurement unit configured to measure a time width of the first-level period and the cycle of the pulse including the first-level period in the received pulse signal received by the reception unit; and a demodulation unit configured to demodulate data conveyed by the received pulse signal, by determining the data value corresponding to the first-level period based on a measured value of the first-level period output from the measurement unit and a first reference value, and determining the data value corresponding to the cycle based on a measured value of the cycle output from the measurement unit and a second reference value.
(10) Further features of the present invention will become apparent from the following description of exemplary embodiments (with reference to the attached drawings).

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** shows a configuration example of a data communication system.
(2) FIG. **2** shows an example of change in a communication state of the data communication system and a pulse voltage Vab corresponding to each communication state.
(3) FIG. **3** shows an example of signal waveforms in a data communication system.
(4) FIG. **4** shows an example of a configuration of a demodulation unit of a data carrier driving apparatus.
(5) FIGS. **5**A to **5**D show examples of a pulse voltage Vab corresponding to command data.

(6) FIG. **6** shows an example of signal waveforms in a data carrier apparatus.
(7) FIG. **7** shows an example of time width measurement using an internal clock in a data carrier apparatus.
(8) FIG. **8**A shows a configuration example of a determination unit of a data carrier apparatus (second embodiment).
(9) FIG. **8**B shows a configuration example of a determination unit of a data carrier apparatus (fourth embodiment).
(10) FIGS. **9**A to **9**D show examples of a pulse voltage Vab corresponding to command data.
(11) FIG. **10** shows a configuration example of a data communication system (third and fourth embodiments).
(12) FIG. **11** is a cross-sectional view showing a schematic configuration example of a printer.
(13) FIG. **12** is a block diagram showing an example of a control configuration of a printer.

DESCRIPTION OF THE EMBODIMENTS

(14) Hereinafter, embodiments will be described in detail with reference to the attached drawings. Note, the following embodiments are not intended to limit the scope of the claimed invention. Multiple features are described in the embodiments, but limitation is not made to an invention that requires all such features, and multiple such features may be combined as appropriate.
(15) Furthermore, in the attached drawings, the same reference numerals are given to the same or similar configurations, and redundant description thereof is omitted.

First Embodiment

(16) FIG. **1** shows a configuration example of a data communication system **100** according to a first embodiment of the present disclosure. The data communication system **100** includes a data carrier apparatus **101** and a data carrier driving apparatus **102**. The data carrier driving apparatus **102** has a terminal A and a terminal B. The data carrier apparatus **101** has a contact A and a contact B. As shown in FIG. **1**, the terminal A and the contact A are connected to each other by a communication line, and the terminal B and the contact B are connected to each other by a communication line, whereby the data carrier apparatus **101** and the data carrier driving apparatus **102** can communicate via these two communication lines. The data carrier apparatus **101** and the data carrier driving apparatus **102** transmit and receive data via two communication lines. The data carrier driving apparatus **102** further supplies power for operation of the data carrier apparatus **101** to the data carrier apparatus **101** via these two communication lines.
(17) The data communication system **100** according to this embodiment is applicable to, for example, an image forming apparatus as exemplified in a later-described embodiment. Specifically, the data carrier driving apparatus **102** may be provided in the main body of the image forming apparatus, and the data carrier apparatus **101** may be provided in a replaceable unit that can be attached to the image forming apparatus. The image forming apparatus is configured such that when a replaceable unit is attached to the image forming apparatus, the data carrier driving apparatus **102** and the data carrier apparatus **101** are connected to each other by two communication lines and can communicate with each other. The data carrier apparatus **101** is provided with a memory (not shown) in which information is stored. The memory may store information related to the replaceable unit, such as information regarding authentication of the replaceable unit or information regarding control parameters in image formation control performed using the replaceable unit. The image forming apparatus can use the data communication system **100** to acquire information stored in the memory provided in the data carrier apparatus **101**.
(18) FIG. **2** shows an example of change in the communication state of the data communication system **100** and a pulse voltage Vab corresponding to each communication state. The data communication system **100** has four communication states (standby state, data transmission state, interval state, and data reply state). As shown in FIG. **2**, the data communication system **100** performs data communication while changing communication states in the order of the standby state, the data transmission state, the interval state, and the data reply state.

(19) In the data transmission state, the data carrier driving apparatus **102** transmits command data to the data carrier apparatus **101**. For example, the data carrier driving apparatus **102** instructs the data carrier apparatus **101** to read out data stored in a memory (not shown) of the data carrier apparatus **101** using the command data. In the interval state, the data carrier apparatus **101** analyzes the command data received in the data transmission state, and it executes processing according to the command data. In the data reply state, the data carrier apparatus **101** transmits reply data to the data carrier driving apparatus **102** as a response to the command data received from the data carrier driving apparatus **102** in the data transmission state. For example, in a case where command data received in the data transmission state instructs readout of data stored in the memory, the data stored in the memory is transmitted as reply data. When the data reply state ends, the data communication system **100** transitions to the standby state. The standby state corresponds to a state before the data carrier driving apparatus **102** transmits the next command data to the data carrier apparatus **101**.
(20) Data Carrier Driving Apparatus **102**
(21) Next, the configuration and operation of the data carrier driving apparatus **102** will be described. FIG. **3** shows an example of a signal waveform in the data communication system **100**. FIG. **4** shows a configuration example of a demodulation unit **106** of the data carrier driving apparatus **102**.
(22) As shown in FIG. **1**, the data carrier driving apparatus **102** includes a first power supply **107** that outputs a voltage V1, and a second power supply **108** that outputs a voltage V2 lower than the voltage V1. The first power supply **107** outputs the voltage V1 to a current detection unit **110** and a threshold setting unit **111** of the demodulation unit **106**. The second power supply **108** outputs the voltage V2 to a voltage conversion unit **112**. A data processing unit **103** generates command data to be transmitted to the data carrier apparatus **101** and executes processing based on reply data received from the data carrier apparatus **101**.
(23) The modulation unit **105** includes a pulse signal generation unit **113**, a high level setting unit **201**, and a low level setting unit **202**, and generates a pulse signal (clock pulse signal) according to the data to be transmitted (command data) generated by the data processing unit **103**. In this embodiment, the high level setting unit **201** stores a high-level period A and a high-level period B, which are two setting values for the high-level (H-level) period of the pulse signal. The low level setting unit **202** stores a low-level period A and a low-level period B, which are two setting values for the low-level (L-level) period of the pulse signal.
(24) The high level setting unit **201** and the low level setting unit **202** operate alternatingly. The high level setting unit **201** selects (sets) the high-level period A or the high-level period B according to the data value of the command data, and notifies the pulse signal generation unit **113** of the selection result. The low-level setting unit **202** selects (sets) the low-level period A or the low-level period B according to the data value of the command data, and notifies the pulse signal generation unit **113** of the selection result.
(25) The pulse signal generation unit **113** generates a clock pulse signal including a pulse having the high-level period set by the high level setting unit **201** and the low-level period set by the low level setting unit **202**, and outputs the generated clock pulse signal to the voltage conversion unit **112**. That is, the pulse signal generation unit **113** of this embodiment outputs a clock pulse signal including any of the following four types of pulses. A pulse with the high-level period A and the low-level period A A pulse with the high-level period B and the low-level period A; A pulse with the high-level period A and the low-level period B A pulse with the high-level period B and the low-level period B
In this way, the modulation unit **105** generates a pulse signal that alternatingly repeats a high-level period (first level period) and a low-level period (second level period), and in which the high-level period and the low-level period are set based on separate data values.
(26) The voltage conversion unit **112** outputs, to the terminal B, a voltage V2 output from the

second power supply **108** during a period when the level of the input clock pulse signal is a low level (L level). On the other hand, the voltage conversion unit **112** outputs 0 V (GND) to the terminal B during a period when the level of the input clock pulse signal is a high level (H level). For example, when the clock pulse signal shown in FIG. **3** is input from the modulation unit **105** (pulse signal generation unit **113**) to the voltage conversion unit **112**, the voltage conversion unit **112** outputs a voltage Vb having the waveform shown in FIG. **3** to the terminal B. In this way, the voltage conversion unit **112** changes the potential difference (pulse voltage Vab) provided between the above-described two communication lines by changing the voltage Vb based on the clock pulse signal generated by the modulation unit **105**. That is, the voltage conversion unit **112** is configured to transmit the clock pulse signal generated by the modulation unit **105** to the data carrier apparatus **101** based on the potential difference provided between the two communication lines.
(27) The demodulation unit **106** includes a current determination unit **109**, a current detection unit **110**, and a threshold setting unit **111**, demodulates the reply data transmitted from the data carrier apparatus **101** to the data carrier driving apparatus **102**, and outputs the demodulation result to the data processing unit **103**. As shown in FIG. **4**, the current detection unit **110** includes a current detection resistor Ri. Due to a current I flowing from the first power supply **107** to the data carrier apparatus **101** via the current detection unit **110**, a voltage drop occurs at the current detection resistor Ri of the current detection unit **110**. A voltage Va at the contact A of the data carrier apparatus **101** (the terminal A of the data carrier driving apparatus **102**) changes according to the voltage drop (=I×Ri) that occurs in the current detection resistor Ri due to the current I. For example, if the voltage Va is Vy in the case where the value of the current I is Iy, the voltage Va at the contact A (terminal A) of the data carrier apparatus **101** is
(28) $Va = Vy = (V1 - Iy \times Ri)$
(29) The threshold setting unit **111** has voltage dividing resistors R1 and R2, and generates a threshold voltage Vth by dividing the voltage V1 output by the first power supply **107** using the voltage dividing resistors R1 and R2. The current determination unit **109** has a comparator to which the threshold voltage Vth and the voltage Va at the terminal A are input. The comparator determines the magnitude of the voltage drop that occurs in the current detection resistor Ri due to the current I by comparing the input voltages, and outputs the determination result to the data processing unit **103**.
(30) Note that, as will be described later, in this embodiment, it is the data carrier apparatus **101** that changes the value of the current I. Specifically, the data carrier apparatus **101** sets the value of current I to Iy in a communication state other than the data reply state. Also, in the data reply state, the data carrier apparatus **101** sets the value of the current I to Ix or Iy according to the data value of the reply data, and Ix is set to a value larger than Iy (i.e., Ix>Iy). In the following, the voltage Va is set as Vy in the case where the value of the current I is Iy, and the voltage Va is set as Vx in the case where the value of the current I is Ix. When Ix>Iy holds true, Vx<Vy holds true. Note that Vx>V2 holds true.
(31) FIG. **3** shows, in addition to the waveform of the clock pulse signal output from the modulation unit **105**, the waveforms of the voltage Vb at the terminal B, the voltage Va at the terminal A, and the pulse voltage Vab in the case where the value of the current I is Iy. The pulse voltage Vab is a potential difference between the terminal A and the terminal B, and is supplied to the data carrier apparatus **101** via the contact A and the contact B. In the example of FIG. **3**, in a case where the value of the current I is Iy, the voltage Va at the terminal A is Vy. The voltage Vb at the terminal B changes between 0 V and V2 in response to the clock pulse signal, as described above. In this case, the waveform of the pulse voltage Vab is a pulse waveform that alternatingly repeats a high level and a low level, the high level being approximately Vy, and the low level being approximately (Vy−V2).
(32) Transmission Processing Performed by Data Carrier Driving Apparatus
(33) Next, command data transmission processing performed by the data carrier driving apparatus

102 will be described. When transmitting command data in the data transmission state, the modulation unit **105** of the data carrier driving apparatus **102** generates a clock pulse signal modulated according to the data value of the command data. As described above, the clock pulse signal output by the pulse signal generation unit **113** includes one of four types of pulses corresponding to the combination of the high-level period (high-level periods A and B) and the low-level period (low-level periods A and B). In the data transmission state, the data carrier driving apparatus **102** transmits command data by supplying the pulse voltage Vab corresponding to the clock pulse signal generated by the modulation unit **105** to the data carrier apparatus **101**.
(34) As described above, in this embodiment, the value of the current I is constant at Iy in a communication state other than the data reply state (i.e., the standby state, the data transmission state, and the interval state). For this reason, as shown in FIG. **3**, in the data transmission state, the waveform of the pulse voltage Vab supplied to the data carrier apparatus **101** is a pulse waveform that alternatingly repeats a high level and a low level, similarly to the clock pulse signal generated by the modulation unit **105**. Also, in a case where the clock pulse signal is at a high level, the pulse voltage Vab is the voltage Vy, and in a case where the clock pulse signal is at a low level, the pulse voltage Vab is a voltage (Vy−V2) lower than the voltage Vy.
(35) FIG. **5**A shows an example of the pulse voltage Vab corresponding to the command data in the case where the data carrier driving apparatus **102** transmits the command data including the data string "00100111" in the data transmission state. As shown in FIG. **5**A, the data carrier driving apparatus **102** outputs to the data carrier apparatus **101** a pulse voltage Vab in which a high-level period and a low-level period are set according to respective individual data values. The pulse voltage Vab is applied between the contact A and the contact B of the data carrier apparatus **101**.
(36) In the example of FIG. **5**A, regarding the high-level period, the bit value "O" is associated with the high-level period A, and the bit value "1" is associated with the high-level period B, which is longer (has a wider time width) than the high-level period A. Also, regarding the low-level period, the bit value "0" is associated with the low-level period A, and the bit value "1" is associated with the low-level period B, which is longer (has a wider time width) than the high-level period A. In this example, as shown in FIG. **5**A, the high-level period A and the low-level period A have the same time width, and the high-level period B and the low-level period B have the same time width. The high-level period A and the high-level period B are examples of a first setting value and a second setting value associated with respective different bit values, and the low-level period A and the low-level period B are examples of a third setting value and a fourth setting value associated with respective different bit values.
(37) Note that the data carrier driving apparatus **102** of this embodiment repeatedly outputs (transmits) a pulse having a predetermined high-level period and a predetermined low-level period in a communication state other than the data transmission state.
(38) Data Carrier Apparatus **101**
(39) Next, the configuration and operation of the data carrier apparatus **101** will be described.
(40) As shown in FIG. **1**, the data carrier apparatus **101** includes an internal clock generation unit **116**, a switching unit **117**, an internal power source generation unit **118**, a demodulation unit **122**, a data processing unit **123**, a conversion unit **124**, and a determination unit **125**. The internal power source generation unit **118** generates a voltage Vp to be used by the data carrier apparatus **101** based on the pulse voltage Vab supplied from the data carrier driving apparatus **102**, and it supplies the voltage Vp to each unit of the data carrier apparatus **101**. The conversion unit **124** converts the pulse voltage Vab into a voltage that can be used in logic units within the data carrier apparatus **101**. The internal clock generation unit **116** generates an internal clock with a frequency higher than the frequency of the pulse voltage Vab and outputs the internal clock to the determination unit **125**.
(41) Reception Processing Performed by Data Carrier Apparatus **101**
(42) FIG. **6** shows the waveforms of the pulse voltage Vab, the voltage generated by the internal power source generation unit **118**, and the received pulse signal output to the determination unit

125 in a case where the value of the current I is Iy. In this embodiment, the conversion unit **124** converts the pulse voltage Vab into the voltage Vp in a case where the pulse voltage Vab is at a high level, and it converts the pulse voltage Vab into a reference voltage that is lower than the voltage Vp in a case where the pulse voltage Vab is at a low level. The conversion unit **124** outputs the converted voltage to the determination unit **125** as a received pulse signal. Note that in this embodiment, the reference voltage of the data carrier apparatus **101** is set to the same potential as the contact B, and is expressed as 0 V.
(43) In the data transmission state, the determination unit **125** measures the time width of the received pulse signal, performs determination based on the measurement result and the reference value, and outputs the determination result to the demodulation unit **122**. In the configuration example of FIG. **1**, the determination unit **125** includes a time width measurement unit **400**, a high level determination unit **401**, and a low level determination unit **402**. A reference value X for determination is set in the high level determination unit **401**, and a reference value Y for determination is set in the low level determination unit **402**.
(44) FIG. **7** shows an example of time width measurement using an internal clock. The time width measurement unit **400** uses the internal clock generated by the internal clock generation unit **116** to measure the time widths of the high-level period t1 and the low-level period t2 in the received pulse signal received by the conversion unit **124**. The high-level period corresponds to the period from the rising edge to the falling edge of the received pulse signal. The low-level period corresponds to the period from the falling edge to the rising edge of the received pulse signal. As shown in FIG. **7**, the time width measurement unit **400** acquires a measurement value as a count value obtained by counting the internal clock for the high-level period t1 and the low-level period t2 of the received pulse signal. The time width measurement unit **400** outputs the measured value of the period t1 to the high level determination unit **401** at the timing when the high-level period ends. Also, the time width measurement unit **400** outputs the measured value of the period t2 to the low level determination unit **402** at the timing when the low-level period ends.
(45) The high level determination unit **401** compares the measured value of the period t1 and the reference value X, and outputs the result of determining whether the measured value is larger than the reference value X to the demodulation unit **122**. The low level determination unit **402** compares the measured value of the period t2 and the reference value Y, and outputs the result of determining whether the measured value is larger than the reference value Y to the demodulation unit **122**.
(46) The demodulation unit **122** demodulates the data (command data) conveyed by the received pulse signal, based on the determination result output from the determination unit **125**. Specifically, the demodulation unit **122** demodulates the command data in units of 1 bit each time a determination result is input from either the high level determination unit **401** or the low level determination unit **402**.
(47) The demodulation unit **122** determines the data value corresponding to the high-level period based on the result of determining whether the measured value of the high-level period in the received pulse signal is larger than the reference value X, which is output from the high level determination unit **401**. When the pulse signal shown in FIG. **5**A is received, the data value is determined to be “1” according to the determination result that the measured value of the high-level period is larger than the reference value X, and the data value is determined to be “0” according to the determination result that the measured value is not larger than the reference value X.
(48) Also, the demodulation unit **122** determines the data value corresponding to the low-level period based on the result of determining whether or not the measured value of the low-level period in the received pulse signal is larger than the reference value Y, which is output from the low level determination unit **402**. When the pulse signal shown in FIG. **5**A is received, the data value is determined to be “1” according to the determination result that the measured value of the low-level period is larger than the reference value Y, and the data value is determined to be “0” according to the determination result that the measured value is not larger than the reference value Y. In this

way, the demodulation unit **122** outputs the determined data value to the data processing unit **123** each time determination of the data value is performed in units of 1 bit for the high-level period and the low-level period of the received pulse signal. The data processing unit **123** generates reply data based on the content of the command data, and outputs the reply data to the switching unit **117**.
(49) In this way, in the present embodiment, the demodulation unit **122** determines the data value corresponding to the first-level period (high-level period) based on the determination result of the high level determination unit **401**, and determines the data value corresponding to the second-level period (low-level period) based on the determination result of the low level determination unit **402**. That is, the demodulation unit **122** is configured to demodulate the data conveyed by the received pulse signal by determining the data value corresponding to the first-level period based on the measured value of the first-level period and the first reference value (reference value X), and determining the data value corresponding to the second-level period based on the measured value of the second-level period and the second reference value.
(50) Note that the demodulation unit **122** may sequentially determine the data value in units of 2 bits for each cycle of the received pulse signal and output the determined 2-bit data value to the data processing unit **123**. FIG. **5**B shows an example of demodulation in units of 2 bits performed by the demodulation unit **122**. In this example, the demodulation unit **122** can demodulate and output the data value in units of 2 bits based on the determination result output from the high level determination unit **401** and the determination result output from the low level determination unit **402** for each cycle of the received pulse signal.
(51) Transmission Processing in Data Carrier Apparatus **101**
(52) Next, reply data transmission processing performed by the data carrier apparatus **101** will be described. As described above, when the interval state ends after the data transmission state, the data communication system **100** transitions to the data reply state. In the data reply state, the data carrier apparatus **101** transmits the reply data by changing the magnitude of the current I flowing from the data carrier driving apparatus **102** to the data carrier apparatus **101** according to the reply data.
(53) Specifically, the switching unit **117** of the data carrier apparatus **101** switches the magnitude of the current I by changing the load according to the reply data input from the data processing unit **123**. For example, in a case where the data value of the reply data is “0”, the switching unit **117** changes the load such that the value of the current I is Ix during the period when the pulse voltage Vab is at a high level. In this way, the switching unit **117** transmits the reply data to the data carrier driving apparatus **102** by changing the current I flowing from the data carrier driving apparatus **102** to the data carrier apparatus **101** according to the data value of the reply data.
(54) Setting Reference Values X and Y
(55) Next, an example of setting (calibration) of the reference value X and the reference value Y, which are used to determine the high-level period and the low-level period, respectively, in the data carrier apparatus **101**, will be described. In the present embodiment, the determination unit **125** sets the reference value X based on the measured value of the high-level period in the pulse signal received from the data carrier driving apparatus **102** at a predetermined timing, and it sets the reference value Y based on the measured value of the low-level period.
(56) Specifically, the data carrier driving apparatus **102** transmits a setting pulse signal for setting the reference values X and Y to the data carrier apparatus **101** during a standby state in which data is not transmitted to the data carrier apparatus **101**. The setting pulse signal is configured as a pulse signal in which the high-level period is set to an intermediate value between the above-mentioned high-level period A and high-level period B, and the low-level period is set to an intermediate value between the above-mentioned low-level period A and low-level period B. In the data carrier apparatus **101**, the time width measurement unit **400** measures the time width of the high-level period and the time width of the low-level period in the setting pulse signal received from the data carrier driving apparatus **102**.

(57) In this case, the determination unit **125** sets the measured value of the high-level period measured by the time width measurement unit **400** for the setting pulse signal as the reference value X, and sets the measured value of the low-level period as the reference value Y. In this way, a reference value X by which the high-level period A and the high-level period B can be distinguished from each other can be appropriately set for the high-level period of the received pulse signal, and a reference value Y by which the low-level period A and the low-level period B can be distinguished from each other can be appropriately set for the low-level period.
(58) The data communication system **100** may be configured such that the reference values X and Y are set as follows. For example, if the data carrier apparatus **101** is configured to set the reference values X and Y in a standby state before starting the first data communication, the data carrier apparatus **101** can also set the reference values X and Y each time the standby state occurs. Also, in the standby state, the data carrier apparatus **101** may measure not only one pulse but multiple pulses in the received pulse signal and set the reference values X and Y based on the average value of the obtained measured values. In this case, the data carrier driving apparatus **102** may continue to transmit the setting pulse signal to the data carrier apparatus **101** during the standby state. Also, the data carrier driving apparatus **102** may transmit the setting pulse signal at a timing when data is not transmitted in a communication state other than the standby state. The data carrier apparatus **101** may also set the reference values X and Y based on the received pulse signal in accordance with such a timing.
(59) The setting pulse signal may also be configured as pulse signals in which the high-level period (first-level period) is set to the above-mentioned high-level period A (first setting value), and the low-level period (second-level period) is set to the above-mentioned low-level period A (third setting value). In this case, in the data carrier apparatus **101**, the determination unit **125** is configured to set the reference value X and the reference value Y through a predetermined calculation based on the reference value of the high-level period and the reference value of the low-level period, which are measured for the setting pulse signal. Also, the determination unit **125** may be configured to correct the reference value X and the reference value Y set previously based on the measured value of the high-level period and the measured value of the low-level period, which are measured for the setting pulse signal for setting the reference value X and the reference value Y.
(60) In this embodiment, an example has been described in which the reference values X and Y are set based on the measurement results of the time width measurement unit **400** in the standby state, but the reference values X and Y that are set in advance and stored in a non-volatile memory (not shown) may also be used.
(61) Modified Example of Communication Start Timing
(62) In this embodiment, as shown in FIG. **5**A, the start timing of communication (transmission of command data) in the data transmission state is set to the rising edge of the clock pulse signal and the received pulse signal. This start timing may be set in advance between the data carrier apparatus **101** and the data carrier driving apparatus **102**, and may be set, for example, to the falling edges of the clock pulse signal and the received pulse signal.
(63) FIG. **5**C shows an example of the pulse voltage Vab corresponding to the command data in the case where the falling edges of the clock pulse signal and the received pulse signal are set as the start timing of communication. In this case, the data carrier driving apparatus **102** starts the operation from the low level setting unit **202** out of the high level setting unit **201** and the low level setting unit **202** when starting the generation of the clock pulse signal. This makes it possible to generate a clock pulse signal having a waveform as shown in FIG. **5**C.
(64) On the other hand, the data carrier apparatus **101** can demodulate the data conveyed by the received pulse signal by starting the determination performed by the low level determination unit **402** before the high level determination unit **401**. In this way, even if the start timing of communication (transmission of command data) in the data transmission state is set to the falling edges of the clock pulse signal and reception pulse signal, it is possible to transmit and receive data

in units of 1 bit.

(65) In the data carrier apparatus **101**, even if the pulse signal shown in FIG. **5**C is received, the demodulation unit **122** may sequentially determine the data values in units of 2 bits for each cycle of the received pulse signal, and output the determined 2-bit data values to the data processing unit **123**. FIG. **5**D shows an example of demodulation in units of 2 bits by the demodulation unit **122**. In this example, the demodulation unit **122** can perform demodulation and output of the data values in units of 2 bits based on the determination result output from the low level determination unit **402** and the determination result output from the high level determination unit **401** for each cycle of the received pulse signal.

(66) As described above, the data carrier apparatus **101** of this embodiment is configured to be able to communicate with the data carrier driving apparatus **102** using a pulse signal that alternatingly repeats a high-level period (first-level period) and a low-level period (second-level period). The data carrier apparatus **101** receives from the data carrier driving apparatus **102** a pulse signal in which a high-level period and a low-level period are set based on individual data values. The time width measurement unit **400** measures the respective time widths of the high-level period and the low-level period in the received pulse signal. The determination unit **125** determines the data value corresponding to the high-level period based on the measured value of the high-level period and the reference value X, and determines the data value corresponding to the low-level period based on the measured value of the low-level period and the reference value Y. As a result, the demodulation unit **122** demodulates the data conveyed by the received pulse signal.

(67) Specifically, the high level determination unit **401** determines whether or not the measured value of the high-level period is larger than the reference value X, and outputs the determination result to the demodulation unit **122**. The low level determination unit **402** determines whether or not the measured value of the low-level period is larger than the reference value Y, and outputs the determination result to the demodulation unit **122**. The demodulation unit **122** determines the data value corresponding to the high-level period based on the determination result of the high level determination unit **401**, and it determines the data value corresponding to the low-level period based on the determination result of the low level determination unit **402**.

(68) In this way, according to the present embodiment, the data carrier apparatus **101** can separately determine the data value (1 bit) corresponding to the high-level period and the data value (1 bit) corresponding to the low-level period in the received pulse signal. For this reason, 2-bit data communication is possible for each cycle of the pulse signal, and data communication can also be performed in units of 1 bit using, for example, one of the high-level period and the low-level period. Thus, according to the present embodiment, in cases of transmitting and receiving data using pulse signals, it is also possible to transmit and receive data in units of 1 bit while increasing the communication rate. For example, even if the number of bits of the data to be transmitted is odd, there is no need to adjust the data to 2-bit data (for example, by adding 1 bit) and the minimum necessary data can be transmitted and received at a higher speed.

Second Embodiment

(69) Next, a second embodiment of the present disclosure will be described. Note that for the sake of simplicity of description, description of parts common to the above-described first embodiment is omitted.

(70) FIG. **8**A shows a configuration example of the determination unit **125** of the data carrier apparatus **101** in the data communication system **100** according to the second embodiment. A data communication system **100** according to this embodiment has a configuration similar to that of the first embodiment (FIG. **1**). However, the determination unit **125** of the data carrier apparatus **101** according to the present embodiment is configured to include a calculation determination unit **422** instead of the low level determination unit **402**, as shown in FIG. **8**A.

(71) In the determination unit **125** of this embodiment, the time width measurement unit **400** outputs the measured value of the high-level period to the high level determination unit **401** at the

timing when the high-level period (first-level period) in the received pulse signal ends, as in the first embodiment. Also, the time width measurement unit **400** outputs the measured value of the high-level period and the measured value of the low-level period to the calculation determination unit **422** at the timing when the low-level period (second-level period) ends.
(72) The high level determination unit **401** compares the measured value of the high-level period of the received pulse signal output from time width measurement unit **400** with the reference value X, as in the first embodiment. The high level determination unit **401** outputs the result of determining whether or not the measured value is larger than the reference value X to the demodulation unit **122**. On the other hand, the calculation determination unit **422** performs a predetermined calculation using the measured value of the high-level period and the measured value of the low-level period output from the time width measurement unit **400**. In this embodiment, the predetermined calculation is a calculation for obtaining the sum of two measured values, and the calculated value that is obtained corresponds to the cycle of the received pulse signal. The calculation determination unit **422** further compares the calculated value obtained through the predetermined calculation with the reference value Y, and outputs the result of determining whether or not the calculated value is larger than the reference value Y to the demodulation unit **122**.
(73) The demodulation unit **122** demodulates the data (command data) conveyed by the received pulse signal, based on the determination result output from the determination unit **125**. Specifically, the demodulation unit **122** demodulates the command data in units of 1 bit each time a determination result is input from either the high level determination unit **401** or the calculation determination unit **422**.
(74) FIG. **9**A shows an example of the pulse voltage Vab corresponding to the command data in the case where the data carrier driving apparatus **102** transmits the command data including the data string “00100111” in the data transmission state. In the example of FIG. **9**A, similarly to the example of FIG. **5**A, regarding the high-level period, the bit value “0” is associated with the high-level period A, and the bit value “1” is associated with the high-level period B, which is longer (has a wider time width) than the high-level period A. Also, regarding the low-level period, the bit value “0” is associated with the low-level period A, and the bit value “1” is associated with the low-level period B, which is longer (has a wider time width) than the high-level period A. However, the high-level period A and the low-level period A are set to differ from each other and the high-level period B and the low-level period B are set to differ from each other such that the calculation determination unit **422** can determine the data value based on the calculation value indicating the cycle of the received pulse signal.
(75) The demodulation unit **122** determines the data value corresponding to the high-level period based on the result of determining whether or not the measured value of the high-level period in the received pulse signal is larger than the reference value X, which is output from the high level determination unit **401**. When the pulse signal shown in FIG. **9**A is received, the data value is determined to be “1” according to the determination result that the measured value of the high-level period is larger than the reference value X, and the data value is determined to be “0” according to the determination result that the measured value is not larger than the reference value X.
(76) Also, the demodulation unit **122** determines the data value corresponding to the low-level period based on the result of determining whether or not the calculation value indicating the cycle of the received pulse signal is larger than the reference value Y, which is output from the calculation determination unit **422**. When the pulse signal shown in FIG. **9**A is received, the data value is determined to be “1” according to the determination result that the calculated value is larger than the reference value Y, and the data value is determined to be “0” according to the determination result that the calculated value is not larger than the reference value Y.
(77) In this way, the demodulation unit **122** outputs the determined data value to the data processing unit **123** each time the data values are determined in units of 1 bit for the high-level period and the cycle of the received pulse signal. When a pulse signal having the waveform shown

in FIG. **9**A is received, the data carrier apparatus **101** can demodulate the data string “00100111” through the above-described demodulation based on the determination result of the determination unit **125**.
(78) Note that, as in the first embodiment, the demodulation unit **122** may sequentially determine the data value in units of 2 bits for each cycle of the received pulse signal and output the determined 2-bit data value to the data processing unit **123**. Also, in this embodiment, a case has been described in which the above-mentioned predetermined calculation is a calculation for obtaining the sum of two measured values, but the predetermined calculation may also be a calculation for obtaining the difference or ratio of two measured values. In the determination based on a calculated value indicating the difference between the two measured values, the data value may be determined based on whether or not the calculated value is 0 or more. Also, in the determination based on a calculated value indicating the ratio of two measured values, the data value may be determined based on whether or not the calculated value is 1 or more.
(79) Setting Reference Values X and Y
(80) In the present embodiment, the reference values X and Y can be set through the same method using the same setting pulse signal as in the first embodiment. However, regarding the reference value Y, the determination unit **125** of the data carrier apparatus **101** sets the calculated value obtained through the predetermined calculation as the reference value Y based on the measured value of the high-level period and the measured value of the low-level period in the standby state. For example, if the predetermined calculation is a calculation for obtaining the sum of two measured values, the sum of the measured value of the high-level period and the measured value of the low-level period is set as the reference value Y.
(81) Also, as in the first embodiment, the setting pulse signal may be configured as a pulse signal in which the high-level period is set to the high-level period A and the low-level period is set to the low-level period A. In this case, similarly to the first embodiment, the determination unit **125** is configured to set the reference value X and the reference value Y through the predetermined calculation based on the measured value of the high-level period and the measured value of the low-level period, which are measured for the setting pulse signal. Also, the determination unit **125** may be configured to correct the reference value X and the reference value Y set previously, based on the measured value of the high-level period and the measured value of the low-level period, which are measured for the setting pulse signal for setting the reference value X and the reference value Y.
(82) Modified Example of Communication Start Timing
(83) In this embodiment, as shown in FIG. **9**A, the start timing of communication (transmission of command data) in the data transmission state is set to the rising edges of the clock pulse signal and the received pulse signal. Similarly to the first embodiment, this start timing may be set in advance between the data carrier apparatus **101** and the data carrier driving apparatus **102**, and for example, it may be set to the falling edges of the clock pulse signal and the received pulse signal.
(84) FIG. **9**B shows an example of the pulse voltage Vab corresponding to the command data in a state where the falling edges of the clock pulse signal and the received pulse signal are set as the communication start timing. In this case, the data carrier driving apparatus **102** starts the operation from the low level setting unit **202** out of the high level setting unit **201** and the low level setting unit **202** when starting the generation of the clock pulse signal. This makes it possible to generate a clock pulse signal having a waveform as shown in FIG. **9**B. On the other hand, in the data carrier apparatus **101**, the determination unit **125** is configured to have a low level determination unit **402** instead of the high level determination unit **401**, and can demodulate the data conveyed by the received pulse signal by starting the determination from the low level determination unit **402**.
(85) As described above, in this embodiment, the high level determination unit **401** determines whether or not the measured value of the high-level period (first-level period) is larger than the reference value X, and outputs the determination result to the demodulation unit **122**. The

calculation determination unit **422** determines whether or not the calculated value obtained through the predetermined calculation using the measured value of the high-level period and the measured value of the low-level period (second-level period) is larger than the reference value Y, and outputs the determination result to the demodulation unit **122**. The demodulation unit **122** determines the data value corresponding to the high-level period based on the determination result of the high level determination unit **401**, and determines the data value corresponding to the low-level period based on the determination result of the calculation determination unit **422**.

(86) According to this embodiment, the data value (1 bit) corresponding to the high-level period in the received pulse signal and the data value (1 bit) corresponding to the low-level period can be determined individually by using the measured value of the high-level period and the calculated value obtained based on the measured values of the high-level period and the low-level period. As a result, in cases of transmitting and receiving data using pulse signals, it is possible to transmit and receive data in units of one bit while increasing the communication rate.

Third Embodiment

(87) Next, a third embodiment of the present disclosure will be described. Note that for the sake of simplicity of description, description of parts common to the above-described first embodiment is omitted.

(88) FIG. **10** shows a configuration example of a data communication system **100** according to the third embodiment. The data communication system **100** according to this embodiment has a configuration similar to that of the first embodiment (FIG. **1**). However, in this embodiment, the modulation unit **105** of the data carrier driving apparatus **102** is configured to include a cycle setting unit **212** instead of the low level setting unit **202**. Also, the determination unit **125** of the data carrier apparatus **101** is configured to include a cycle determination unit **412** instead of the low level determination unit **402**.

(89) In this embodiment, the high level setting unit **201** stores a high-level period A and a high-level period B, which are two setting values for the high-level (H-level) period of the pulse signal. The cycle setting unit **212** stores a cycle A and a cycle B, which are two setting values for the cycle of each pulse included in the pulse signal.

(90) In the data carrier driving apparatus **102**, the high level setting unit **201** selects (sets) the high-level period A or the high-level period B according to the data value of the command data, and notifies the pulse signal generation unit **113** of the selection result. The cycle setting unit **212** selects (sets) the cycle A or the cycle B according to the data value of the command data, and notifies the pulse signal generation unit **113** of the selection result. The pulse signal generation unit **113** generates a clock pulse signal including a pulse having a high-level period set by the high level setting unit **201** and including pulses having a cycle set by the cycle setting unit **212**, and outputs the generated clock pulse signal to the voltage conversion unit **112**.

(91) In the data carrier apparatus **101**, a reference value X for determination is set in the high level determination unit **401**, and a reference value Y for determination is set in the cycle determination unit **412**. The time width measurement unit **400** uses the internal clock generated by the internal clock generation unit **116** to measure the time width of the high-level period in the received pulse signal received by the conversion unit **124**, and the cycle of the pulses including the high-level period.

(92) Similarly to the first embodiment, the high level determination unit **401** compares the high-level measured value and the reference value X, and outputs the result of determining whether or not the measured value is larger than the reference value X to the demodulation unit **122**. On the other hand, the cycle determination unit **412** compares the measured value of the cycle with the reference value Y, and outputs the result of determining whether or not the measured value is larger than the reference value Y to the demodulation unit **122**.

(93) FIG. **9**C shows an example of the pulse voltage Vab corresponding to the command data in the case where the data carrier driving apparatus **102** transmits the command data including the data

string "00100111" in the data transmission state. In the example of FIG. **9**C, as with the examples of FIGS. **5**A and **9**A, regarding the high-level period, the bit value "0" is associated with the high-level period A, and the bit value "1" is associated with the high-level period B, which is longer (has a wider time width) than the high-level period A. Regarding the cycle of the pulse, a bit value "0" is associated with the cycle A, and a bit value "1" is associated with the cycle B that is longer (has a wider time width) than the cycle A.
(94) The demodulation unit **122** demodulates the data (command data) conveyed by the received pulse signal, based on the determination result output from the determination unit **125**. Specifically, the demodulation unit **122** demodulates the command data in units of one bit each time a determination result is input from either the high level determination unit **401** or the cycle determination unit **412**.
(95) The demodulation unit **122** determines the data value corresponding to the high-level period based on the result of determining whether or not the measured value of the high-level period in the received pulse signal is larger than the reference value X, which is output from the high level determination unit **401**. When the pulse signal shown in FIG. **9**C is received, the data value is determined to be "1" according to the determination result that the measured value of the high-level period is larger than the reference value X, and the data value is determined to be "0" according to the determination result that the measured value is not larger than the reference value X.
(96) Also, the demodulation unit **122** determines the data value corresponding to the period based on the result of determining whether or not the measured value of the cycle of the pulse in the received pulse signal is larger than the reference value Y, which is output from the cycle determination unit **412**. When the pulse signal shown in FIG. **9**C is received, the data value is determined to be "1" according to the determination result that the measured value of the cycle is larger than the reference value Y, and the data value is determined to be "0" according to the determination result that the measured value is not larger than the reference value Y.
(97) In this way, the demodulation unit **122** outputs the determined data value to the data processing unit **123** each time the data values are determined in units of 1 bit for the high-level period and the cycle in the received pulse signal. When the pulse signal having the waveform shown in FIG. **9**C is received, the data carrier apparatus **101** can demodulate the data string "00100111" through the above-described demodulation based on the determination result of the determination unit **125**.
(98) Note that, similarly to the first and second embodiments, the demodulation unit **122** may sequentially determine the data values in units of 2 bits for each cycle of the received pulse signal, and output the determined 2-bit data values to the data processing unit **123**.
(99) Setting Reference Values X and Y
(100) In the present embodiment, the reference values X and Y can be set through the same method using the same setting pulse signal as in the first embodiment. In the present embodiment, the determination unit **125** sets the reference value X based on the measured value of the high-level period in the pulse signal received from the data carrier driving apparatus **102** at a predetermined timing, and sets the reference value Y based on the measured value of the cycle of the pulse.
(101) Specifically, the data carrier driving apparatus **102** transmits a setting pulse signal for setting the reference values X and Y to the data carrier apparatus **101** during a standby state in which data is not transmitted to the data carrier apparatus **101**. The setting pulse signal is configured as a pulse signal in which the high-level period is set to an intermediate value between the high-level period A and the high-level period B, and the cycle is set to an intermediate value between the cycle A and the cycle B. In the data carrier apparatus **101**, the time width measurement unit **400** measures the time width of the high-level period and the cycle of the pulse including the high-level period in the setting pulse signal received from the data carrier driving apparatus **102**.
(102) In this case, the determination unit **125** sets the measured value of the high-level period measured by the time width measurement unit **400** for the setting pulse signal as the reference

value X, and sets the measured value of the cycle as the reference value Y. In this way, for the high-level period of the received pulse signal, the reference value X by which the high-level period A and the high-level period B can be distinguished from each other, and for the period, the reference value Y by which the cycle A and the cycle B can be distinguished from each other can be set appropriately.
(103) The setting pulse signal may be configured as a pulse signal in which the high-level period (first-level period) is set to the high-level period A (first setting value) and the cycle of the pulse is set to the cycle A (third setting value). In this case, in the data carrier apparatus **101**, the determination unit **125** is configured to set the reference value X and the reference value Y through the predetermined calculation, based on the measured value of the high-level period and the measured value of the cycle, which are measured for the setting pulse signal. Also, the determination unit **125** may be configured to correct the reference value X and the reference value Y set previously, based on the measured value of the high-level period and the measured value of the cycle, which are measured for the setting pulse signal for setting the reference value X and the reference value Y.
(104) In this embodiment, an example has been described in which the reference values X and Y are set based on the measurement results of the time width measurement unit **400** in the standby state, but the reference values X and Y that are set in advance and stored in a non-volatile memory (not shown) may also be used.
(105) Modified Example of Communication Start Timing
(106) In this embodiment, as shown in FIG. **9**C, the start timing of communication (transmission of command data) in the data transmission state is set to the rising edges of the clock pulse signal and the received pulse signal. Similarly to the first and second embodiments, this start timing may be set in advance between the data carrier apparatus **101** and the data carrier driving apparatus **102**, and for example, may be set to the falling edges of the clock pulse signal and the received pulse signal.
(107) FIG. **9**D shows an example of the pulse voltage Vab corresponding to the command data in the case where the falling edges of the clock pulse signal and the received pulse signal are set as the communication start timing. In this case, the data carrier driving apparatus **102** is configured to have a low level setting unit **202** instead of the high level setting unit **201**. As a result, it is possible to generate a clock pulse signal having a waveform as shown in FIG. **9**D. On the other hand, in the data carrier apparatus **101**, the determination unit **125** is configured to have a low level determination unit **402** instead of the high level determination unit **401**, and can demodulate the data conveyed by the received pulse signal by starting the determination from the low level determination unit **402**.
(108) As described above, the data carrier apparatus **101** of this embodiment is configured to be able to communicate with the data carrier driving apparatus **102** using a pulse signal that alternatingly repeats a high-level period (first-level period) and a low-level period (second-level period). The data carrier apparatus **101** receives from the data carrier driving apparatus **102** a pulse signal in which a high-level period and a cycle of a pulse consisting of a high-level period and a low-level period are set based on individual data values. The time width measurement unit **400** measures the time width of the high-level period and the cycle of a pulse including the high-level period in the received pulse signal. The determination unit **125** determines the data value corresponding to the high-level period based on the measured value of the high-level period and the reference value X, and determines the data value corresponding to the cycle based on the measured value of the cycle and the reference value Y. As a result, the demodulation unit **122** demodulates the data conveyed by the received pulse signal.
(109) Specifically, the high level determination unit **401** determines whether or not the measured value of the high-level period is larger than the reference value X, and outputs the determination result to the demodulation unit **122**. The cycle determination unit **412** determines whether or not

the measured value of the cycle is larger than the reference value Y, and outputs the determination result to the demodulation unit **122**. The demodulation unit **122** determines the data value corresponding to the high-level period based on the determination result of the high level determination unit **401**, and determines the data value corresponding to the cycle based on the determination result of the cycle determination unit **412**.

(110) As described above, according to the present embodiment, the data carrier apparatus **101** can individually determine the data value (1 bit) corresponding to the high-level period and the data value (1 bit) corresponding to the cycle in the received pulse signal. For this reason, 2-bit data communication is possible for each cycle of the pulse signal, and data communication can also be performed in units of 1 bit using, for example, only the high-level period. Thus, according to the present embodiment, in cases of transmitting and receiving data using pulse signals, it is also possible to transmit and receive data in units of 1 bit while increasing the communication rate. For example, even if the number of bits of the data to be transmitted is odd, there is no need to adjust the data to 2-bit data (for example, by adding 1 bit) and transmit the adjusted data, and the minimum necessary data can be transmitted and received at a higher speed.

Fourth Embodiment

(111) Next, a fourth embodiment of the present disclosure will be described. Note that for the sake of simplicity of description, description of parts common to the third embodiment described above is omitted.

(112) FIG. **8**B shows a configuration example of the determination unit **125** of the data carrier apparatus **101** in the data communication system **100** according to the fourth embodiment. The data communication system **100** according to this embodiment has a configuration similar to the configuration in the third embodiment (FIG. **10**). However, the determination unit **125** of the data carrier apparatus **101** according to the present embodiment is configured to include a calculation determination unit **422** instead of the cycle determination unit **412**, as shown in FIG. **8**B.

(113) In the determination unit **125** of the present embodiment, the time width measurement unit **400** outputs the measured value of the high-level period to the high level determination unit **401**, as in the third embodiment. Also, the time width measurement unit **400** outputs the measured value of the high-level period and the measured value of the cycle to the calculation determination unit **422**.

(114) The high level determination unit **401** compares the measured value of the high-level period of the received pulse signal output from time width measurement unit **400** with the reference value X, as in the third embodiment. The high level determination unit **401** outputs the result of determining whether or not the measured value is larger than the reference value X to the demodulation unit **122**. On the other hand, the calculation determination unit **422** performs a predetermined calculation using the measured value of the high-level period and the measured value of the cycle output from the time width measurement unit **400**. In this embodiment, the predetermined calculation is a calculation for obtaining the difference between two measured values, and the calculated value that is obtained corresponds to the time width of the low-level period of the received pulse signal. The calculation determination unit **422** further compares the calculated value obtained through the predetermined calculation with the reference value Y, and outputs the result of determining whether or not the calculated value is larger than the reference value Y to the demodulation unit **122**.

(115) The demodulation unit **122** demodulates the data (command data) conveyed by the received pulse signal, based on the determination result output from the determination unit **125**. Specifically, the demodulation unit **122** demodulates the command data in units of 1 bit each time a determination result is input from either the high level determination unit **401** or the calculation determination unit **422**.

(116) The demodulation unit **122** determines the data value corresponding to the high-level period based on the result of determining whether or not the measured value of the high-level period in the received pulse signal is larger than the reference value X, which is output from the high level

determination unit **401**. When the pulse signal shown in FIG. **9**C is received, the data value is determined to be "1" according to the determination result that the measured value of the high-level period is larger than the reference value X, and the data value is determined to be "0" according to the determination result that the measured value is not larger than the reference value X.

(117) Also, the demodulation unit **122** determines the data value corresponding to the cycle, based on the result of determining whether or not the calculated value indicating the time width of the low-level period of the received pulse signal is larger than the reference value Y, which is output from the calculation determination unit **422**. When the pulse signal shown in FIG. **9**C is received, the data value is determined to be "1" according to the determination result that the calculated value is larger than the reference value Y, and the data value is determined to be "0" according to the determination result that the calculated value is not larger than the reference value Y.

(118) In this way, the demodulation unit **122** outputs the determined data value to the data processing unit **123** each time the data value is sequentially determined in units of 1 bit for the high-level period and the low-level period of the received pulse signal. When the pulse signal having the waveform shown in FIG. **9**C is received, the data carrier apparatus **101** can demodulate the data string "00100111" through the above-described demodulation based on the determination result of the determination unit **125**.

(119) Note that, as in the third embodiment, the demodulation unit **122** may sequentially determine the data value in units of 2 bits for each cycle of the received pulse signal, and output the determined 2-bit data values to the data processor **123**. Also, in this embodiment, a case has been described in which the above-described predetermined calculation is a calculation for obtaining the difference between two measured values, but the predetermined calculation may also be a calculation for obtaining the ratio of two measured values. In the determination based on the calculated value indicating the ratio of two measured values, the data value may be determined based on whether or not the calculated value is 1 or more.

(120) Setting Reference Values X and Y

(121) In this embodiment, the reference values X and Y can be set in the same manner as in the third embodiment using the same setting pulse signal. However, regarding the reference value Y, the determination unit **125** of the data carrier apparatus **101** sets the calculated value obtained through the predetermined calculation as the reference value Y, based on the measured value of the high-level period in the standby state and the measured value of the cycle. For example, if the predetermined calculation is a calculation for obtaining the difference between two measured values, the difference between the measured value of the high-level period and the measured value of the cycle is set as the reference value Y. Also, as in the third embodiment, the setting pulse signal may be configured as a pulse signal in which the high-level period (first-level period) is set to the high-level period A (first setting value) and the cycle of the pulse is set to the cycle A (third setting value). In this case, similarly to the third embodiment, the determination unit **125** is configured to set the reference value X and the reference value Y through the predetermined calculation, based on the measured value of the high-level period and the measured value of the cycle, which are measured for the setting pulse signal. Also, the determination unit **125** may be configured to correct the reference value X and the reference value Y set previously, based on the measured value of the high-level period and the measured value of the cycle, which are measured for the setting pulse signals for the reference value X and the reference value Y.

(122) Modified Example of Communication Start Timing

(123) In this embodiment, as in the first to third embodiments, the start timing of communication (transmission of command data) in the data transmission state is set to the rising edges of the clock pulse signal and the received pulse signal. As in the first to third embodiments, this start timing may be determined in advance between the data carrier apparatus **101** and the data carrier driving apparatus **102**, and for example, may be set to the falling edges of the clock pulse signal and the received pulse signal.

(124) As described above, in this embodiment, the high level determination unit **401** determines whether or not the measured value of the high-level period (first-level period) is larger than the reference value X, and outputs the determination result to the demodulation unit **122**. The calculation determination unit **422** determines whether or not the calculated value obtained through the predetermined calculation using the measured value of the high-level period and the measured value of the cycle is larger than the reference value Y, and outputs the determination result to the demodulation unit **122**. The demodulation unit **122** determines the data value corresponding to the high-level period based on the determination result of the high level determination unit **401**, and determines the data value corresponding to the cycle based on the determination result of the calculation determination unit **422**.
(125) According to this embodiment, the data value (1 bit) corresponding to the high-level period in the received pulse signal and the data value (1 bit) corresponding to the cycle are individually determined using the measured value of the high-level period and the calculated value obtained based on the measured values of the high-level period and the cycle. As a result, when transmitting and receiving data using pulse signals, it is possible to transmit and receive data in units of 1 bit while increasing the communication rate.
OTHER EMBODIMENTS
(126) The data communication systems **100** of the embodiments described above are applicable to, for example, an image forming apparatus. In that case, a configuration may be applied in which the data carrier driving apparatus **102** is mounted on the main body side of the image forming apparatus, and the data carrier apparatus **101** is mounted on a replaceable component such as a consumable item. Hereinafter, a configuration example of an image forming apparatus to which the data communication systems of the first and second embodiments described above are applied will be described.
(127) FIG. **11** is a cross-sectional view showing a schematic configuration example of a printer **300** as an example of the image forming apparatus of this embodiment. The printer **300** is configured as an electrophotographic laser beam printer. The printer **300** includes a photosensitive drum **311**, a charging unit **317**, and a developing unit **312**, as an image forming unit. The photosensitive drum **311** is an example of an image carrier on which an electrostatic latent image is formed. The charging unit **317** uniformly charges the photosensitive drum **311**. The developing unit **312** forms a toner image on the photosensitive drum **311** by developing the electrostatic latent image formed on the photosensitive drum **311** with toner. The photosensitive drum **311**, the charging unit **317**, and the developing unit **312** can be attached to and detached from the main body of the image forming apparatus as an integrated cartridge C. A fixing device **314** fixes the toner image transferred to a sheet onto the sheet. The sheet that has passed through the fixing device **314** is discharged onto a tray **315**.
(128) The printer **300** further includes a controller **320** including a CPU for controlling the image forming operations described above. The controller **320** includes a memory (ROM, RAM, etc.) that stores programs for controlling the operations of the printer **300** and data used to execute the programs.
(129) FIG. **12** is a block diagram showing an example of a control configuration in the case where a data communication system is applied to the printer **300**. The main body of the printer **300** includes a data carrier driving apparatus **102** that can communicate bidirectionally with the controller **320**. The cartridge C includes a data carrier apparatus **101** and a data storage unit **101**A. The data carrier apparatus **101** controls the readout and writing of data in the data storage unit **101**A. As the data storage unit **101**A, a nonvolatile memory such as an EEPROM can be used.
(130) The data carrier driving apparatus **102** executes data communication with the data carrier apparatus **101** mounted on the cartridge C based on commands from the controller **320**. The data carrier apparatus **101** of the cartridge C can, for example, process data transmitted from the data carrier driving apparatus **102** and store the processed data in the data storage unit **101**A. Also, the

data carrier apparatus **101** can read out data stored in the data storage unit **101**A based on a signal from the data carrier driving apparatus **102**, and transmit the data as reply data to the data carrier driving apparatus **102**.
(131) In this way, the above-described embodiments are applicable to a data communication system in which the data carrier apparatus **101** is mounted as a replaceable component (replaceable unit) of an image forming apparatus (printer **300**). By storing data regarding a cartridge serving as a consumable of the image forming apparatus in the data storage unit **101**A, it is possible to provide a system for managing, for example, the usage status of the cartridge, such as the remaining amount of toner and the usage amount of the photosensitive drum.
(132) Note that the above-described embodiment is not limited to the image forming apparatus (printer **300**) illustrated in FIG. **11**, but is also applicable to, for example, a color image forming apparatus including a plurality of image forming units. Also, the replaceable component (replaceable unit) on which the data carrier apparatus **101** is provided is not limited to a cartridge. For example, it is possible to provide a data communication system by providing the data carrier apparatus **101** in various replaceable components, including process members used for image formation, such as an intermediate transfer belt unit including an intermediate transfer belt to which the toner image on the photosensitive drum **311** is transferred, or a toner unit containing toner.
(133) According to the present disclosure, in cases of transmitting and receiving data using a pulse signal, it is possible to transmit and receive data even in units of 1 bit while increasing the communication rate.
(134) Embodiment(s) of the present invention can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions (e.g., one or more programs) recorded on a storage medium (which may also be referred to more fully as a 'non-transitory computer-readable storage medium') to perform the functions of one or more of the above-described embodiment(s) and/or that includes one or more circuits (e.g., application specific integrated circuit (ASIC)) for performing the functions of one or more of the above-described embodiment(s), and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable instructions from the storage medium to perform the functions of one or more of the above-described embodiment(s) and/or controlling the one or more circuits to perform the functions of one or more of the above-described embodiment(s). The computer may comprise one or more processors (e.g., central processing unit (CPU), micro processing unit (MPU)) and may include a network of separate computers or separate processors to read out and execute the computer executable instructions. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)™), a flash memory device, a memory card, and the like.
(135) While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.
(136) This application claims the benefit of Japanese Patent Application No. 2022-208797, filed Dec. 26, 2022, which is hereby incorporated by reference herein in its entirety.

Claims

1. A data carrier apparatus capable of communicating with a data carrier driving apparatus, comprising: a reception unit configured to receive, from the data carrier driving apparatus, a pulse signal that alternatingly repeats a first-level period and a second-level period, and in which the

first-level period and the second-level period are set based on individual data values; a measurement unit configured to measure respective time widths of the first-level period and the second-level period in the received pulse signal received by the reception unit; and a demodulation unit configured to demodulate data conveyed by the received pulse signal, by determining the data value corresponding to the first-level period based on a measured value of the first-level period output from the measurement unit and a first reference value, and determining the data value corresponding to the second-level period based on a measured value of the second-level period output from the measurement unit and a second reference value.

2. The data carrier apparatus according to claim 1, further comprising: a first determination unit configured to determine whether or not the measured value of the first-level period is larger than the first reference value; and a second determination unit configured to determine whether or not the measured value of the second-level period is larger than the second reference value, wherein the demodulation unit determines the data value corresponding to the first-level period based on the determination result of the first determination unit and determines the data value corresponding to the second-level period based on the determination result of the second determination unit.

3. The data carrier apparatus according to claim 1, further comprising: a first determination unit configured to determine whether or not the measured value of the first-level period is larger than the first reference value; and a second determination unit configured to determine whether or not a calculated value obtained through a predetermined calculation using the measured value of the first-level period and the measured value of the second-level period is larger than the second reference value, wherein the demodulation unit determines the data value corresponding to the first-level period based on the determination result of the first determination unit and determines the data value corresponding to the second-level period based on the determination result of the second determination unit.

4. The data carrier apparatus according to claim 3, wherein the calculated value is a sum, a difference, or a ratio of the measured value of the first-level period and the measured value of the second-level period.

5. The data carrier apparatus according to claim 1, further comprising a setting unit configured to set the first reference value and the second reference value based on a setting pulse signal for setting the first reference value and the second reference value, which is transmitted from the data carrier driving apparatus and received by the reception unit while the data carrier driving apparatus is not transmitting data.

6. The data carrier apparatus according to claim 5, wherein the setting pulse signal is a pulse signal in which the first-level period is set to an intermediate value between a first setting value and a second setting value for the first-level period, which are associated with respective different bit values, and the second-level period is set to an intermediate value between a third setting value and a fourth setting value for the second-level period, which are associated with respective different bit values.

7. The data carrier apparatus according to claim 6, wherein the setting unit sets the measured value of the first-level period and the measured value of the second-level period, which are measured by the measurement unit for the setting pulse signal, as the first reference value and the second reference value, respectively.

8. The data carrier apparatus according to claim 5, wherein a pulse signal conveying data is a pulse signal in which the first-level period is set to a first setting value or a second setting value, which are associated with respective different bit values, and the second-level period is set to a third setting value or a fourth setting value, which are associated with respective different bit values, the setting pulse signal is a pulse signal in which the first-level period is set to the first setting value and the second-level period is set to the third setting value, and the setting unit sets the first reference value and the second reference value through a predetermined calculation based on the measured value of the first-level period and the measured value of the second-level period, which

are measured by the measurement unit for the setting pulse signal.
9. The data carrier apparatus according to claim 5, wherein the setting unit corrects the first reference value and the second reference value set previously, based on the setting pulse signal for setting the first reference value and the second reference value.
10. The data carrier apparatus according to claim 1, wherein the data carrier apparatus is connected to the data carrier driving apparatus by two communication lines, and receives the pulse signal from the data carrier driving apparatus based on a potential difference provided by the data carrier driving apparatus between the two communication lines.
11. A data carrier apparatus capable of communicating with a data carrier driving apparatus, comprising: a reception unit configured to receive, from the data carrier driving apparatus, a pulse signal that alternatingly repeats a first-level period and a second-level period, and in which the first-level period and a cycle of a pulse consisting of the first-level period and the second-level period are set based on individual data values; a measurement unit configured to measure a time width of the first-level period and the cycle of the pulse including the first-level period in the received pulse signal received by the reception unit; and a demodulation unit configured to demodulate data conveyed by the received pulse signal, by determining the data value corresponding to the first-level period based on a measured value of the first-level period output from the measurement unit and a first reference value, and determining the data value corresponding to the cycle based on a measured value of the cycle output from the measurement unit and a second reference value.
12. The data carrier apparatus according to claim 11, further comprising: a first determination unit configured to determine whether or not the measured value of the first-level period is larger than the first reference value; and a second determination unit configured to determine whether or not the measured value of the cycle is larger than the second reference value, wherein the demodulation unit determines the data value corresponding to the first-level period based on the determination result of the first determination unit and determines the data value corresponding to the cycle based on the determination result of the second determination unit.
13. The data carrier apparatus according to claim 11, further comprising: a first determination unit configured to determine whether or not the measured value of the first-level period is larger than the first reference value; and a second determination unit configured to determine whether or not a calculated value obtained through a predetermined calculation using the measured value of the first-level period and the measured value of the cycle is larger than the second reference value, wherein the demodulation unit determines the data value corresponding to the first-level period based on the determination result of the first determination unit and determines the data value corresponding to the cycle based on the determination result of the second determination unit.
14. The data carrier apparatus according to claim 13, wherein the calculated value is a sum, a difference, or a ratio of the measured value of the first-level period and the measured value of the cycle.
15. The data carrier apparatus according to claim 11, further comprising a setting unit configured to set the first reference value and the second reference value based on a setting pulse signal for setting the first reference value and the second reference value, which is transmitted from the data carrier driving apparatus and received by the reception unit while the data carrier driving apparatus is not transmitting data.
16. The data carrier apparatus according to claim 15, wherein the setting pulse signal is a pulse signal in which the first-level period is set to an intermediate value between a first setting value and a second setting value for the first-level period, which are associated with respective different bit values, and the cycle is set to an intermediate value between a third setting value and a fourth setting value for the cycle, which are associated with respective different bit values.
17. The data carrier apparatus according to claim 16, wherein the setting unit sets the measured value of the first-level period and the measured value of the cycle, which are measured by the

measurement unit for the setting pulse signal, as the first reference value and the second reference value, respectively.

18. The data carrier apparatus according to claim 15, wherein a pulse signal conveying data is a pulse signal in which the first-level period is set to a first setting value or a second setting value, which are associated with respective different bit values, and the cycle is set to a third setting value or a fourth setting value, which are associated with respective different bit values, the setting pulse signal is a pulse signal in which the first-level period is set to the first setting value and the cycle is set to the third setting value, and the setting unit sets the first reference value and the second reference value through a predetermined calculation based on the measured value of the first-level period and the measured value of the cycle, which are measured by the measurement unit for the setting pulse signal.

19. The data carrier apparatus according to claim 15, wherein the setting unit corrects the first reference value and the second reference value set previously, based on the setting pulse signal for setting the first reference value and the second reference value.

20. The data carrier apparatus according to claim 11, wherein the data carrier apparatus is connected to the data carrier driving apparatus by two communication lines, and receives the pulse signal from the data carrier driving apparatus based on a potential difference provided by the data carrier driving apparatus between the two communication lines.

21. A replaceable unit that is attachable to an image forming apparatus, comprising: a process member to be used for image formation; and a data carrier apparatus capable of communicating with a data carrier driving apparatus provided in the image forming apparatus, when attached to the image forming apparatus, wherein the data carrier apparatus comprises: a reception unit configured to receive, from the data carrier driving apparatus, a pulse signal that alternatingly repeats a first-level period and a second-level period, and in which the first-level period and the second-level period are set based on individual data values; a measurement unit configured to measure respective time widths of the first-level period and the second-level period in the received pulse signal received by the reception unit; and a demodulation unit configured to demodulate data conveyed by the received pulse signal, by determining the data value corresponding to the first-level period based on a measured value of the first-level period output from the measurement unit and a first reference value, and determining the data value corresponding to the second-level period based on a measured value of the second-level period output from the measurement unit and a second reference value.

22. A communication system comprising: a data carrier apparatus; and a data carrier driving apparatus to be connected to the data carrier apparatus by two communication lines, wherein the data carrier driving apparatus comprises: a modulation unit configured to generate a pulse signal that alternatingly repeats a first-level period and a second-level period, and that is modulated based on data to be transmitted, the modulation unit being configured to generate the pulse signal in which the first-level period and the second-level period are set based on individual data values; and a transmission unit configured to transmit the pulse signal generated by the modulation unit to the data carrier apparatus based on a potential difference provided between the two communication lines, and the data carrier apparatus comprises: a reception unit configured to receive the pulse signal from the data carrier driving apparatus; a measurement unit configured to measure respective time widths of the first-level period and the second-level period in the received pulse signal received by the reception unit; and a demodulation unit configured to demodulate data conveyed by the received pulse signal, by determining the data value corresponding to the first-level period based on a measured value of the first-level period output from the measurement unit and a first reference value, and determining the data value corresponding to the second-level period based on a measured value of the second-level period output from the measurement unit and a second reference value.

23. The communication system according to claim 22, wherein the data carrier driving apparatus is

provided in a main body of an image forming apparatus, and the data carrier apparatus is provided in a replaceable unit of the image forming apparatus.

24. A communication system comprising: a data carrier apparatus; and a data carrier driving apparatus to be connected to the data carrier apparatus by two communication lines, wherein the data carrier driving apparatus comprises: a modulation unit configured to generate a pulse signal that alternatingly repeats a first-level period and a second-level period, and that is modulated based on data to be transmitted, the modulation unit being configured to generate the pulse signal in which the first-level period and a cycle of a pulse constituting of the first-level period and the second-level period are set based on individual data values; and a transmission unit configured to transmit the pulse signal generated by the modulation unit to the data carrier apparatus based on a potential difference provided between the two communication lines, and the data carrier apparatus comprises: a reception unit configured to receive the pulse signal from the data carrier driving apparatus; a measurement unit configured to measure a time width of the first-level period and the cycle of the pulse including the first-level period in the received pulse signal received by the reception unit; and a demodulation unit configured to demodulate data conveyed by the received pulse signal, by determining the data value corresponding to the first-level period based on a measured value of the first-level period output from the measurement unit and a first reference value, and determining the data value corresponding to the cycle based on a measured value of the cycle output from the measurement unit and a second reference value.