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(71) Applicant: **COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION** [AU/AU]; Clunies Ross St, Acton, Australian Capital Territory 2601 (AU).

(72) Inventors: **MOHANARANGAM, Krishna**; c/- Clunies Ross St, Acton, Australian Capital Territory 2601 (AU). **MONCH, Andreas**; c/- Clunies Ross St, Acton, Australian Capital Territory 2601 (AU).

(74) Agent: **FB RICE**; 90 Collins Street, Melbourne, Victoria 3000 (AU).

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(54) Title: AUTOMATIC SEDIMENTATION AND SEPARATION CURVE GENERATOR

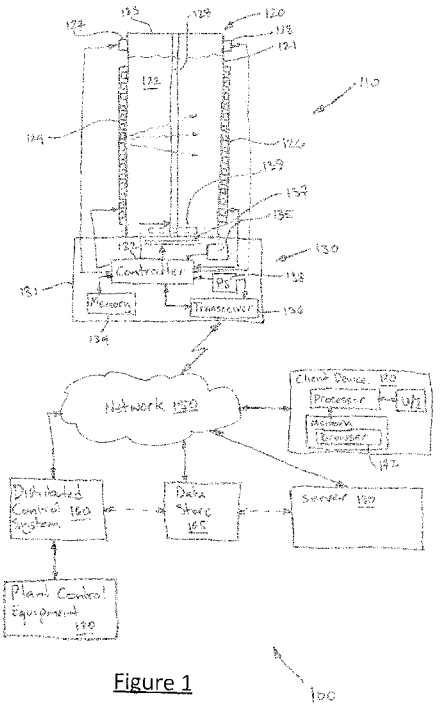


Figure 1

(57) Abstract: Described embodiments relate to a hand-held portable sedimentation measurement device, comprising: a closeable fluid container having a container wall and defining a chamber to receive fluid for sedimentation measurement and defining a central longitudinal axis; multiple light sources disposed along the container and generally parallel to the longitudinal axis to direct light through the wall into the chamber; multiple light sensors disposed along the container arranged to detect light passing through the chamber from at least one of the light sources; a controller configured to control emission of light from the sources and to receive detection signals from the light sensors, wherein sedimentation measurements are derived from the light emitted from the light sources and the detection signals; a communication interface coupled to the controller and arranged to transmit sedimentation data to an external computing device; and a housing connected to the container and housing the controller and interface.

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Automatic sedimentation and separation curve generator

Technical Field

[0001] Embodiments generally relate to devices, systems and methods for determining sedimentation or separation rate within in a multiphase liquid sample.

Background

[0002] For certain mineral extraction processes, particularly those involving very low concentrations of a desirable mineral in the extracted ore body, it can be desirable to ascertain a rate of sedimentation in process liquids over time.

[0003] In prior techniques, this has been done by taking a liquid sample during a stage of the mineral separation process and having a human operator take measurements over time by observing the sample in the settling cylinder as sediment in the sample settles to the bottom of the tube. However, the reliance on human judgement can be problematic, since the human operator may find it difficult to precisely determine the transition between different parts of the fluid sample due to cloudiness or otherwise blurred boundaries.

[0004] Accurate tracking of the rate of sedimentation of a sample can be important to determining how much flocculent to use in the separation process. The amount of flocculent used in the separation process over time can have a significant cost impact in operation of the core processing facility. Further, applying the right amount of flocculent can have an effect on the waste output from the separation process. In particular, when consistent tailings output through the separation process can be maximised, which can result in millions of dollars in savings by avoiding prematurely upgrading tailings capture infrastructure, such as tailing dams which are expensive to build and/or upgrade.

[0005] Any discussion of documents, acts, materials, devices, articles or the like which has been included in the present specification is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present disclosure as it existed before the priority date of each claim of this application.

[0006] Throughout this specification the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

Summary

[0007] Some embodiments relate to a hand-held portable sedimentation measurement device, comprising:

a closeable fluid container having a container wall and defining a chamber to receive fluid for sedimentation measurement and defining a central longitudinal axis;

a plurality of light sources disposed along the fluid container and generally in a direction parallel to the longitudinal axis to direct light through the container wall into the chamber;

a plurality of light sensors disposed along the fluid container and arranged to detect light passing through the chamber from at least one of the light sources;

a controller configured to control emission of light from the plurality of light sources and to receive light detection signals from the plurality of light sensors, wherein sedimentation measurements can be obtained based on the light emitted from the plurality of light sources and the light detection signals;

a communication interface communicably coupled to the controller and arranged to transmit sedimentation measurement data to an external computing device; and

a housing connected to the container to house the controller and the communication interface.

[0008] The plurality of light sources may be light-emitting diodes (LEDs). The LEDs may be infra-red (IR) light transmitting LEDs. An emission spectrum of each of the LEDs may have a peak at a wavelength in the range of about 880 nm to about 950 nm.

[0009] The device may further comprise a battery power supply housed in the housing and arranged to supply power to all power-consuming components of the device.

[0010] The device may further comprise an accelerometer arranged to detect movement of the fluid container and to provide an accelerometer output signal to the controller to allow the controller to measure agitation of the fluid container. The accelerometer may be disposed in the housing and configured to measure acceleration of the fluid container in three dimensions. The controller may be configured to determine, based on received accelerometer output signals, whether a minimum agitation amount has occurred. When the controller determines that agitation of the fluid chamber has ceased before the minimum agitation amount has been reached, the controller may be configured to generate a first alarm signal. The controller may be configured to determine, based on received accelerometer output signals, whether a maximum agitation amount has occurred. When the controller determines that a maximum agitation amount has occurred, the controller may be configured to generate a second alarm signal.

[0011] The plurality of light sources may be disposed along between 50% and 90% of the longitudinal length of the fluid chamber. The number of light sensors may be less than the number of light sources.

[0012] The plurality of light sources and the plurality of light sensors may be arranged so that a path of maximum light transmission efficiency from the light sources to the light sensors is offset from the central longitudinal axis.

[0013] The fluid container may comprise a light shield disposed at or around a first side of the container to completely or substantially attenuate light from the light sources through the first side of the fluid container.

[0014] A second side of the container wall that is opposite the first side may be substantially light-transmissive for human-visible wavelengths of light. The device may further comprise at least one second light source configured to emit human-visible wavelengths of light and disposed on the first side to emit light toward the second side.

[0015] The controller may be configured to separately control emission of light from each of the light sources. The controller may be configured to operate each of the light sources at a high intensity for a short time.

[0016] The controller may be configured to separately control each of the light sensors to detect light at a time when at least one of the light sources is emitting light. The controller may be configured to enable light detection at only one light sensor while controlling light emission from multiple ones of the light sources.

[0017] The light sources and light sensors may be disposed at least partially in the container wall. In some embodiments, the container and the light sources and/or light detectors may be integrally formed.

[0018] The container may be free of fixed internal agitation means.

[0019] The device may further comprise an excitation coil in the housing to induce rotational motion of a magnet when the magnet is freely disposed in a base of the container.

[0020] A volumetric capacity of the container may be between about 0.5 litres and about 2 litres. The container may be cylindrical. An inside diameter of the container may be between about 30 mm and about 100 mm.

[0021] The light sources may be of a power sufficiently high to reliably penetrate a high density mineral slurry sample during settling of the sample.

[0022] Some embodiments relate to a sedimentation measurement method, comprising:

receiving a sample liquid of a metallurgical process in a chamber of a liquid container having a volumetric capacity of between about 0.5 litres to about 2 litres;

transmitting control signals to one or more of multiple high radiant intensity infra-red (IR) light sources to cause light from the one or more IR light sources to be directed into the chamber through a wall of the liquid container;

detecting light passing through the chamber from the one or more light sources by at least one of a plurality of light sensors; and

determining sedimentation measurements for the sample based on the control signals and based on light detection signals received from the at least one light sensor.

[0023] The container may be cylindrical and an inside diameter of the container may be between about 30 mm and about 100 mm.

[0024] The light sources may be of a power sufficiently high to reliably penetrate a high density mineral slurry sample during settling of the sample.

[0025] The method may further comprise emit human-visible wavelengths of light from at least one second light source disposed on a first side of the liquid container toward a second side of the liquid container.

[0026] In some embodiments, the transmitting may be performed by a controller and the controller may be configured to separately control emission of light from each of the light sources. For example, the controller may be configured to operate each of the light sources at a high intensity for a short time. In some embodiments, the controller may be configured to separately control each of the light sensors to detect light at a time when at least one of the light sources is emitting light. In some embodiments, the controller may be configured to enable light detection at only one light sensor while controlling light emission from multiple ones of the light sources.

[0027] The method may further comprise measuring agitation of the liquid sample in the fluid container. The measuring agitation may be performed using an accelerometer arranged to detect movement of the fluid container and to provide an accelerometer output signal. The method may further comprise determining, based on received accelerometer output signals, whether a minimum agitation amount has occurred.

[0028] In some embodiments, the method may comprise generating a first alarm signal when it is determined that agitation of the fluid chamber has ceased before the minimum agitation amount has been reached. In some embodiments, the method may further comprise determining, based on received accelerometer output signals, whether a maximum agitation amount has occurred. In some embodiments, the method may further comprise generating a second alarm signal when the controller determines that a maximum agitation amount has occurred.

[0029] In some embodiments, the one or more light sources and/or the plurality of light sensors are disposed at least partially in the wall of the liquid container. For

example, the liquid container and the one or more light sources and/or the plurality of light detectors are integrally formed.

[0030] Some embodiments relate to a hand-held portable sedimentation measurement device, comprising:

a closeable fluid container having a container wall and defining a chamber to receive fluid for sedimentation measurement and defining a central longitudinal axis;

a plurality of light sources disposed along the fluid container and generally in a direction parallel to the longitudinal axis to direct light through the container wall into the chamber;

a plurality of light sensors disposed along the fluid container and arranged to detect light passing through the chamber from at least one of the light sources;

a controller configured to control emission of light from the plurality of light sources and to receive light detection signals from the plurality of light sensors, wherein sedimentation measurements can be obtained based on the light emitted from the plurality of light sources and the light detection signals;

a communication interface communicably coupled to the controller and arranged to transmit sedimentation measurement data to an external computing device; and

a housing connected to the container to house the controller and the communication interface;

wherein the light sources and light sensors are disposed at least partially in the container wall.

[0031] Some embodiments relate to a sedimentation measurement method, comprising:

receiving a sample liquid of a metallurgical process in a chamber of a liquid container having a volumetric capacity of between about 0.5 litres to about 2 litres;

transmitting control signals to one or more of multiple high radiant intensity infra-red (IR) light sources to cause light from the one or more IR light sources to be directed into the chamber through a wall of the liquid container;

detecting light passing through the chamber from the one or more light sources by at least one of a plurality of light sensors;

determining sedimentation measurements for the sample based on the control signals and based on light detection signals received from the at least one light sensor;

wherein the one or more light sources and/or the plurality of light sensors are disposed at least partially in the wall of the liquid container.

Brief Description of Drawings

[0032] Embodiments are described in further detail below by way of example and with reference to the accompanying drawings, in which:

[0033] Figure 1 is a schematic block diagram of a system comprising a sedimentation measurement device;

[0034] Figure 2 is a schematic plan view in cross-section of a container of the sedimentation measurement device;

[0035] Figure 3 is a schematic plan view in cross-section of a part of the container of the sedimentation measurement device, showing light sources and associated circuitry positioned in the container wall, according to some embodiments;

[0036] Figure 4 is a schematic illustration in plan view of the sedimentation measurement device, illustrating positioning of light sources and light detectors according to some embodiments;

[0037] Figure 5 is a schematic illustration in elevation view of a liquid container of the sedimentation measurement device according to some embodiments;

[0038] Figure 6 is an example graph of excitation voltage applied to the light sources and light detectors over time;

[0039] Figure 7 is a plot of relative current (%) versus wavelength of infrared LEDs used as light sources in some embodiments;

[0040] Figure 8 is a plot of radiant intensity for the infrared LEDs used in some embodiments;

[0041] Figure 9 is a circuit diagram of an example header chip to interface between a controller and a light source circuit;

[0042] Figure 10 is a circuit diagram of a current signal low pass filter and buffer for driving current supply to the light source circuit;

[0043] Figure 11 is a circuit diagram of a power supply circuit for supplying power to the lighting circuit;

[0044] Figure 12 is a circuit diagram of a lighting circuit;

[0045] Figure 13 is a circuit diagram of a further lighting circuit;

[0046] Figure 14 is a circuit diagram of a further lighting circuit;

[0047] Figure 15 is a circuit diagram of a header chip to interface with the controller and the light detectors of the sedimentation measurement device;

[0048] Figure 16 is a circuit diagram of multiplexer chips to selectively enable outputs from ones of the light detectors;

[0049] Figure 17 is a circuit diagram of a low pass filter circuit and power supply circuit for the light detectors;

[0050] Figure 18 is a circuit diagram of a reference voltage generating circuit for the light detectors;

[0051] Figure 19 is a set of circuit diagrams for multiple light detectors of a first group;

[0052] Figure 20 is a circuit diagram of further multiplexer chips to selectively enable selection of ones of the light detectors;

[0053] Figure 21 is a set of circuit diagrams for light detectors of a second group;

[0054] Figure 22 is a circuit diagram of a further set of multiplexer chips to selectively enable selection of ones of a light detector;

[0055] Figure 23 is a set of circuit diagrams of light detectors of a third group; and

[0056] Figure 24 is an example plot of settling rate of a sample slurry within a sedimentation measurement device according to some embodiments.

Detailed Description

[0057] Embodiments generally relate to devices, systems and methods for measuring sedimentation or separation rate within a multiphase liquid sample.

[0058] Embodiments have specific application to measuring the sedimentation rate (also called settling rate) of liquid samples taken from mineral processing operations where the density of the sample taken can be relatively high. With high density samples such as those that may be obtained for mineral processing of low grade ores, a light source of relatively high radiant intensity may be required for accurate determination of the level of "mud-line" (the level below which the solids in the sample have settled and above which is relatively clear water over time).

[0059] Accurate detection of the mud line is important for determining an optimal amount of sedimentation enhancing chemicals, such as flocculent, to be added during the mineral processing. If too much flocculent is added during the mineral processing (i.e. overdosing), then there is a monetary cost for unnecessary wastage of flocculent. Additionally, there is also a risk that the sediment from the process can get too thick, in which case there is a higher risk that blades of a thickener rake in a sedimentation tank can break, which can lead to costly downtime and operational losses. On the other hand, if the flocculent is inadequately supplied to the process (i.e. underdosed), then there may be less separation of fine particles and potentially less mineral capture from the process. This reduced capture can be particularly costly when the minerals sought to be captured from the process is already present in only small concentrations, such as 1 to 5 grams per metric tonne or even lower.

[0060] Described embodiments therefore aim to provide an accurate measurement of rate of sedimentation for mineral processes directed to extracting high value of low concentration of minerals from ore bodies. Since the rate of sedimentation or settlement of such samples is relatively high compared to sewerage sedimentation, for example, and the density of particulate in the samples is relatively higher, high intensity light sources are required.

[0061] Referring now to Figure 1, a system 100 is shown, comprising a sedimentation measurement device 110. The sedimentation measurement device 110 is in communication with a client computing device 170 over a network 150 in order to provide data to enable display of a sedimentation curve (indicating a rate of settlement

of solids in liquid samples) over time. The client computing device 170 may be in communication with a server 190 via the network 150. The sedimentation measurement device 110 may also interact with the server 190 in order to process data received from a transceiver 136 of the sedimentation measurement device 110 so that a suitable graphical display can be generated at a browser application 172 executing (as stored executable programme code executed by a processor) at the client device 170. For this purpose, server 190 has at least one processor and memory to store executable programme code for interacting with the sedimentation measurement device 110 and client device 170. The server 190 is configured to access a data store 165, either directly or via the interwork 150, in order to serve suitable web page code to the client device 170 for rendering display by the bowser application 172. Data store 165 may store, for example, historical sedimentation curves and other sedimentation measurement related information.

[0062] The network 150 may include local network components that are part of a local area network (LAN) including wireless and/or wired communication connections. Further, the network 150 may include mobile data communication connections, public communication infrastructure or a combination of various local, public, private or mobile data network components and connections.

[0063] In some embodiments, the system 100 may form part of or be associated with a mineral (separation) processing facility or another processing facility requiring sedimentation measurement. Such processing facilities may rely on a distributed control system 160 (DCS) to monitor and control the mineral separation or other process. In specific embodiments, the sedimentation measurement device 110 may provide its data output from transceiver 136 to DCS 160 via the network 150 (which may include a local area network of the processing facility). The DCS 160 may access data store 165, via the network 150 or directly, for storage of data received from sedimentation measurement device 110 or to look up historical sedimentation measurement data, for example.

[0064] In some instances, the DCS 160 may automatically adjust one or more monitoring or control parameters associated with the processing facility based on sedimentation measurement data received from the sedimentation measurement device 110. The DCS 160 may therefore issue control commands to operate (or adjust operation of) plant control equipment 180 forming part of the processing facility, in order to achieve a better process result. For example, the DCS 160 may issue control commands to plant control equipment 180 in order to increase or decrease the amount of flocculent provided to a mineral separation process performed by the processing facility.

[0065] The sedimentation measurement device 110 comprises a container 120 that is coupled (mechanically and/or by adhesion) to a housing 130 at a base end of the container 120. The container 120 has a container wall 121 that defines an inner chamber to receive a liquid sample 122, and a lid, top or cap 123 to close and seal the chamber. The container wall 121 may be cylindrical, somewhat cylindrical or oval, for example.

[0066] A volumetric capacity of the container 120 may be about 0.5 litres to about 2.0 litres, for example. In one embodiment, the volumetric capacity of the container 120 is about 1 litre. The inside diameter of the container 120 may be about 50 mm, although in some embodiments, this may be varied between about 30 mm and about 80 mm, and possibly up to about 100 mm in diameter. A height of the container 120 may be around 420 mm, from its base to its top, for example. However, the height may vary, depending on the volume of liquid sample to be contained within the container 120 and/or the inside diameter of the container wall 121. Depending on the volumetric capacity of the container 120 and whether it is full of a liquid sample or not and depending on the material of the container 120, the mass of the sedimentation measurement device 110 may be in the range of about 0.2 kg to about 1kg when empty of liquid and about 0.7 kg to about 3 kg when full. The sedimentation measurement device 110 is therefore suitably sized and arranged to be handheld and portable for manual carrying and agitation as required.

[0067] The housing 130 is configured to house most of the electronics of the sedimentation measurement device 110. For example, the housing 130 comprises a controller 132 in signal communication with the transceiver 136 in order to exchange data by network 150. The housing 130 may comprise a sealed or sealable solid plastic housing body defining an inner housing chamber to contain at least some of the electronics, for example. Although not shown in the drawings, the housing 130 may accommodate buttons, switches, lights or a display, for example to allow an operator to ascertain an operational status and/or manipulate certain functions of the sedimentation measurement device 110.

[0068] Further, the housing 130 houses a power supply 138 to supply power to all of the electrical and electronic components of the sedimentation measurement device 110. The power supply 138 may comprise a battery, such as a long life battery, for example. The housing 130 may allow manual and/or electrical jack (or inductive charging coil) access to the battery to charge and/or replace it, for example. The controller 132 accesses a memory 134 that stores programme instructions executable by the controller 132 in order to perform the functions described herein, such as controlling operation of light sources 124, light detectors 126 and communication of measurement data to external devices via transceiver 136.

[0069] In some embodiments, the base unit of the sedimentation measurement device 110 also comprises an accelerometer 135 disposed in the housing 130 that provides output to controller 132. The accelerometer 135 may be a three dimensional accelerometer to measure movement of the sedimentation measurement device 110 in any of three dimensions (x, y, z) or it may measure movement in six degrees of freedom (three spatial axes and three rotational axes).

[0070] Based on the output of the accelerometer 135, the controller 132 is configured to determine whether a minimum agitation amount has occurred for the sedimentation measurement device 110. This agitation may occur as manual agitation by an operator that has taken the sample liquid and decanted it in or otherwise placed it into the liquid chamber in the container 120. A certain degree of agitation of the liquid

sample is desirable in order for the sedimentation measurement of the liquid sample to be considered to be reliable. With some prior art systems, operators may sometimes fail to agitate the liquid sample at all, which can lead to uneven distribution of solids particles within the sample, and in some instances may agitate the sample too much, which can induce more froth than is desirable in the liquid sample. Further, aggregates (flocculants attached to particles) within the sample may be relatively porous and fragile, and may be destroyed by excessive mixing.

[0071] Where it is an operational requirement for the liquid sample to be agitated prior to measurement of the settlement rate, the input of the accelerometer 135 to the controller 132 allows the controller 132 firstly to determine whether any agitation has occurred, secondly to determine whether some agitation has occurred but it is inadequate to properly agitate the sample for purposes of reliability, and thirdly to determine whether the liquid sample has been agitated too much. The controller may also be configured to monitor the output of the accelerometer during the measurement process (i.e. after agitation has occurred and while the sedimentation measurement device 110 needs to remain still so that the heavier liquids or particles settle toward the bottom of the container 120). Thus, in a fourth scenario, the controller 132 may be configured to determine whether movement of the container has occurred during settlement measuring to such a degree that the accuracy on the measurement process is questionable. In each of these first, second, third and fourth situations, the controller 132 may be configured to generate an alarm signal, either to trigger a local alarm on the sedimentation measurement device 110 (such as an audible or visual alarm), and/or to transmit an alarm signal to the server 190 and/or client device 170 via transceiver 136. The client device 170 and/or server 190 may then generate a further alarm, for example by either an audible or visual alarm at the client device 170 or by the server 190 generating and sending an alarm message to another computing device. Depending on which situation has occurred, the alarm may be transmitted or emitted differently, so that each alarm situation may be uniquely identified.

[0072] In addition to, or instead of, the accelerometer 135, an excitation coil 137 may be included within sedimentation measurement device 110 in the housing 130.

This excitation coil 137 may be responsive to control signals from the controller 132 in order to generate a selectively varying electric field in the vicinity of a bottom end of the container 120. This electric field can be controlled by the controller 132 to induce rotation of a free floating untethered bar magnet 139 that has been placed in the bottom of the container 120 for agitation purposes, for example. The chamber 122 of the container is otherwise free of fixed agitation means. Controlled application of the excitation coil 137 allows achievement of a controlled level of agitation of the liquid sample within the container 120, rather than relying on manual agitation. For example, excitation of the excitation coil 137 may be controlled by the controller 132 to occur for a set period of time prior to commencing each sample measurement task.

[0073] Figure 1 illustrates schematically the presence of a series of light sources 124 positioned generally vertically in a linear or roughly linear array along one side of the container wall 121. These light sources 124 may be LEDs, for example, such as infrared (IR) LEDs. The light sources 124 are preferably relatively high powered (i.e. high in radiant intensity) and may be operated at a relatively high current, such as 1 amp to 5 amps, in order to generate sufficient light to penetrate the liquid sample near the mud line. An emission spectrum of each of the LEDs may have a peak at a wavelength in the range of about 880 nm to about 950 nm. A suitable high powered IR LED light source may the SFH 4544 Infrared Emitter (940 nm) available from Osram™ Opto Semiconductors, for example.

[0074] The selective activation of the light sources 124 is controlled by the controller 132 so that only selected ones of the light sources 124 are switched on according to a specific light control sequence during a measurement operation. Such light sources 124, when switched on, emit light through the container wall 121 (or at least a part thereof) in order to cause the emitted light to travel through the liquid sample.

[0075] A series of light sensors (also described as light detectors) 126, such as photodiodes, is positioned generally vertically in a corresponding linear or roughly linear array along another side of the container wall 121. The light detectors 126 are

positioned generally oppositely from the light sources 124 on a chord through the cylindrical (or generally cylindrical) profile of the container wall 121. In other words, the light sources 124 and light detectors 126 are arranged on the container wall so that a path of maximum light transmission efficiency from the light sources 124 to the light detectors 126 is laterally offset from, and does not coincide with, a central longitudinal axis 224 (i.e. the centre) of the cylindrical container wall 121. The light detectors 126 are configured to detect light at wavelengths corresponding to the peak emission spectrum of the light sources 124. A suitable form of light detector 126 is the BPV10NF Silicon PIN Photodiode from Vishay Intertechnology, Inc., for example.

[0076] If the light sources 124 and light detectors 126 were disposed substantially diametrically opposite to each other, the horizontal distance of travel of light through chamber to the light detectors 126 would be at a maximum and any associated attenuation due to distance of travel would also be maximised. Some embodiments reduce the distance that the light must travel from the sources 124 to the sensors 126 by positioning the light sources 124 and light sensors 126 at opposite ends of a laterally offset chord. This allows a smaller distance of travel and therefore less light attenuation through the liquid sample. However, if the cord is too small, then the light may encounter transmission attenuation due to other effects, such as reflection or refraction from the container wall 121 due to the shallow angle of incidence from the light sources 124 into the container wall 121. It is therefore desirable that the position of the light sources 124 and light detectors 126 be radially separated (relative to the vertical centre line 224, which is shown as a point in plan view in Figure 2 and 4) by between about 60 degrees and about 120 degrees, optionally between about 80 degrees and 100 degrees.

[0077] In some embodiments, the light detectors 126 may be slightly offset from a notional cord line extending in the direction of initial transmission of light from the light sources 124 in the direction of the light detectors 126. This offset may be in the order of 1 to 4 degrees, for example, to account for a change in transmission angle due to refraction through the container wall 121 and/or liquid sample 122.

[0078] The light detectors 126 are individually controllable by controller 132 (as described later in this disclosure) in order to be selectively enabled to detect light. In some embodiments, the light detector 126 that is opposite a transmitting light source 124 is the one that is turned on. However, in some embodiments, a light detector 126 may be switched on to detect light from a light source 124 that is not directly horizontally opposite to the light detector 126.

[0079] The light sources 124 and the light detectors 126 may be disposed along most, but not all of the longitudinal length (height) of the container 120. For example, they may be disposed along around 50% to about 90% of the length of the container wall 121. The light sources 124 and the light detectors 126 may be substantially uniformly spaced from each adjacent light source 124 or light detector 126, or in some embodiments may be non-uniformly spaced.

[0080] In some embodiments, multiple light sources, such as two adjacent or three adjacent light sources 124, may be switched on while only one opposite light detector 126 is enabled to detect light from the two or three sources. This example is diagrammatically illustrated in Figure 5. In this example, there are nine transmitting (T_x) light sources 124 and seven receiving (R_x) light detectors 126 that are positioned generally opposite to the sources. In this example, when the first three light sources 124 (counting down from the top of the vertical array of light sources) are turned on, the first light detector 126 may also be turned on. Then, when the second, third and fourth light sources 124 are turned on, the second light detector 126 is turned on. Then, when the third, fourth and fifth light sources 124 are turned on, the third light detector 126 is turned on, and so on.

[0081] The controller 132 is configured to time the on and off switching of the light sources 124 and light detectors 126 so that each light detector 126 is turned on (i.e its signal output is enabled) within a time period that the one or more opposite light sources 124 is turned on, as shown in Figure 6. The switching on of the light source 124 may be for a time in the range of about 50 milliseconds to about a 1000 milliseconds, depending on the time required to allow the light source 124 to ramp up

to reach its maximum intensity. The light detector 126 positioned to detect light from that light source 124 need only be switched on for a lesser time, being a time period within which the maximum intensity of the light source 124 is achieved. However, the maximum intensity of the light source 124 may only be reached for a much shorter time, such as 1 to 500 nanoseconds, depending on the selection of 124 light sources, for example. The delay between each successive switching off and then on of one of the light sources 124 is configured as a multiple of the on time, such as an integer multiple like one to ten times.

[0082] The sedimentation measurement device 110 may further comprise one or more indicator LEDs 127, 128 responsive to control signals issued from controller 132. The indicator LEDs 127, 128 may be visible light LEDs that are turned on or caused to blink by the controller 132 to indicate a status of operation of the sedimentation measurement device 110, for example. Where the sedimentation measurement device 110 is operating to take measurements of sedimentation of a liquid sample 122, the indicator LEDs 127, 128 may be caused to blink alternatively or together. Alternatively, where inadequate agitation has occurred or excessive agitation has occurred, the LED 127, 128 may be used to indicate an alarm condition, optionally in addition to an audible alarm signal, for example. Although two indicator LEDs 127, 128 are shown in Figure 1, some embodiments may use one such indicator LED or may use more than two. In some embodiments, the indicator LEDs 127, 128 may be positioned close to a top 123 of the container wall 121 on opposite sides thereof. Alternatively, the indicator LEDs 127, 128 may be positioned on or in the housing 130 so that light from the indicator LEDs 127, 128 is visible from the housing 130.

[0083] The liquid container 120 further comprises a visible light strip or array or a series of lights 129 positioned circumferentially in between the light sources 124 and the light detectors 126. The light strip or series of lights 129 emit human visible light and are selected to avoid emitting light in a range that corresponds to the detection range of light detectors 126, in order to avoid polluting the light detection signal from the light sources 124. The visible light array 129 is arranged generally vertically along the outside of the container wall 121, for example as shown in Figure 1 and 4 and

arranged to generally transmit light from an approximate mid-point between the light sources 124 and the light detectors 126 toward an opposite side of the container wall 121 that is substantially light transmissive for human visible wave lengths. The light series 129 is intended to aid in human perception of the sedimentation process and does not factor into the automatic sedimentation rate determinations made (e.g. at client device 170 or server 190) by operation of the controller 132.

[0084] Reference is now made to the circuit diagrams shown in Figures 9 to 14. The controller 132 is configured to selectively control emission of light from one or a number of the light sources 124 by application of an enable signal to the header chip 910, together with a current demand signal to indicate the magnitude of DC current to be supplied to each selected light source 124, as given by signals to anyone of eight switching outputs (ON1, ON2, ON3, ON4, ON5, ON6, ON7 and ON8). These switching outputs ON1 to ON8 are provided to the transistor switches 954 that are each arranged in series with a respective light source 124, as shown in lighting circuit 952 in Figure 12, for example. Each of the eight light sources 124 in lighting circuit 952 and its corresponding series switching output ON1 to ON8 are arranged in parallel with each other.

[0085] The light sources 124 are arranged in three groups of eight LEDs, each group of which is selected by a signal from the controller 132 to one of the enable lines 953 (enable 1), 963 (enable 2) and 973 (enable 3). Depending on which group selection is enabled and which of the switching lines ON 1 to ON8 are switched on, any or all of the LEDs (LED 1 to LED 25, noting that 24 LEDs are shown but that there is no LED 9 shown) can be turned on. For each LED light source 124 that is turned on by the controller 132, the level of current demand specified by the controller 132 is provided via the circuit 930 shown in Figure 10 and driven by the reference currents VP and VCC shown in power supply circuit 940 in Figure 11.

[0086] Figures 12, 13 and 14 are circuit diagrams of lighting circuits 952, 962 and 972, respectively. Each of these lighting circuits 952, 962, 972 includes eight LED light sources 124 and a series of eight selectable switch groups 954, 964 and 974 that

can be selectively operated by control signals from the controller 132 when the enable signal 953, 963 or 973 is also applied by the controller 132.

[0087] Referring also now to Figures 15 to 23, the control circuitry associated with the light detectors 126 is described in further detail. In Figure 15, a header chip 1510 is shown that receives detector selection signals (select 1, select 2, select 3, select 4, select 5 or select 6) and one or more of four output signal lines (out 1, out 2, out 3 and out 4). Each of these selection lines corresponds to one of the multiplexer chips 1520, 1521 (Figure 16), 1522, 1523 (Figure 20), 1524 and 1525 (Figure 22). Each of the light detectors 126 can be selectively turned on (by having its output enabled) by a signal from the controller 132 to one of the selection outputs of multiplexer chips 1520 to 1525, which correspond to the 24 light detectors 126 shown by way of example in Figures 19, 21 and 23.

[0088] Each multiplexer chip 1520 to 1525 allows selection of one or more of four light detector outputs via any of the output lines (out 1, out 2, out 3 and out 4). For example, where the output of photodetector PD1 (Figure 21) is to be enabled, channel CH9 is required to be selected on multiplexer chip 1522, which corresponds to one of the output lines out 1 to out 4 (the mapping of which to the channel lines is set at configuration), thereby returning to the controller 132 an output signal corresponding to (but filtered and amplified based on) the output of the photodetector PD1. Similarly, for the output signal of any one of the light detectors 126 to be provided to the controller 132, the controller 132 provides a selection output to the header chip 1510 to indicate any of select 1 to select 6 (or more if a larger number of light detectors 126 is required), which designates the multiplexer chip corresponding to the group of light detectors 126 the desired light detector 126 is part of. In addition to the select signal, the controller 132 provides one or more output line signals out 1 to out 4 that maps to the output channel (e.g. CH5 to CH8 for multiplexer chip 1521) that provides the output from the respective photodetector (e.g. PD13 to PD16 for CH5 to CH8).

[0089] In order to provide power to the light detector control circuitry, a power supply circuit 1512 is provided, together with a low pass filter circuit 1514, to generate

appropriate reference voltage outputs, as shown in Figure 17. Additionally, a half rail reference generation circuit 1515 (Figure 18) is used to generate a reference voltage VREF for the amplifiers on each of the light detection circuits (shown in Figures 19, 21 and 23) to which the respective photodiodes PD1 to PD 24 are coupled.

[0090] Figures 2, 3 and 4 show optional arrangements of the liquid container 120. Depending on a particular configuration selected for the container wall 121, and whether the light sources 124 or light detectors 126 are to be potted into a part of the container wall 121 or positioned to be slightly spaced therefrom by an air gap (i.e. as in Figure 4), some variation in the physical constitution of the container wall 121 of the container 120 is permitted. For example, as shown in Figure 2, the container may have a container wall that comprises an approximately half-cylindrical first part 210 that is formed of a thickened material to house or encase the light sources 124 and light detectors 126, optionally together with the drive circuitry shown in Figures 9 to 23 or parts thereof.

[0091] In some embodiments, as shown in Figures 2 and 3, the sedimentation measurement device 110 is an integrated device wherein the container 120 and the light sources 124 and/or light detectors 126 are integrally formed. For example, the light sources 124 and/or light detectors 126 may be disposed at least partially in the container wall 121. In other words, the light sources 124 and/or light detectors 126 may be partially or fully potted into a part of the container wall 121. In some embodiments, the light sources 124 and/or light detectors 126 may be fused into or embedded within the container 120, or the container wall 121. In some embodiments, the light sources 124 and/or light detectors 126 may be disposed or encapsulated into the outside of the container wall 121.

[0092] In some embodiments, the light sources 124 and/or light detectors 126 may be disposed into the container wall 121 using a suitable potting material. The refractive index of the potting material may be altered using a suitable additive in order to optimise the transmissive power of the light sources 124 and mitigate losses due to

attenuation. Nonetheless, any losses may be measurable and the integrated sedimentation measurement device 110 may be calibrated accordingly.

[0093] As the light sources 124 and/or light detectors 126 are fixed relative to the container 120, the integrated sedimentation measurement device 110 may be calibrated to account for light bending effects caused by the container 120, and for example, a thickness of the container wall 121. For example, the light sources 124 and/or light detectors 126 may be suitably aligned and/or angled to account for such light bending effects. Furthermore, a likelihood of misalignment or positioning inaccuracies between the container 120, the light sources 124 and/or light detectors 126 is mitigated or eliminated.

[0094] Further, an integrated sedimentation measurement device 110 is more robust and more portable than an non-integrated sedimentation measurement device 110 and it allows for controlled manual agitation or mixing of the contents of the container 120 by moving, shaking and/or inverting the whole integrated sedimentation measurement device 110.

[0095] Yet further, by providing an integrated sedimentation measurement device 110, settling tests or sedimentation measurement methods carried out using the sedimentation measurement device 110 may be reproducible irrespective of an operator, there providing for standardisation of the settling tests or sedimentation measurement methods.

[0096] Opposite the thickened potion 210, which is configured to be substantially non transmissive to infrared and visible light, is the approximately half-cylindrical container wall section 220 that is substantially light transmissive for human visible wavelengths, so that a person observing the sedimentation process can watch its progress through the clear wall section 220. In the embodiment shown in Figure 2, the thickened wall portion 210, which may be positioned notionally at a “back” of the sedimentation measurement device 110 (from the user’s perspective) may be generally integrally formed or otherwise sealingly coupled to the opposite “front” clear wall

portion 220. The two opposite wall portions 210, 220 are shaped to generally define a substantially cylindrical chamber therebetween.

[0097] Figure 3 illustrates an example embodiment in which the back container wall section 210 is coupled to the front of container wall section 220 in a sealing, but optionally removable, manner by a mechanical connection, such as tongue in groove or other interference- or snap-fit sealing connection. Additionally, Figure 3 shows that, together with the LED light sources 124, a printed circuit board (PCB) 234 may be positioned closely thereby and embedded within the material of the back wall section 210. The PCB 234 may comprise some or all of the circuity shown in Figures 9 to 14, for example, and is electrically coupled to the light sources 124 by suitable conductors 235.

[0098] A similar arrangement for encased and/or embedded positioning of the light detectors 126 is illustrated by embodiments shown in Figure 4, where a PCB 236 is positioned to be embedded within a housing portion 245 (separate, connected to, or integrally formed with, housing 130) to house the detector circuitry PCB 236 and the transmitter circuitry PCB 234. The arrangement shown in Figure 4 is similar to that shown in Figures 2 and 3, except that the IR LEDs 124 and IR PDs 126 are separated from the wall 121 by an air gap. In Figure 4, there is also shown the series of lights 129 (or light strip), seen in plan view, transmitting human-visible light toward the front wall of the container 120 in a direction generally through the centre 224 of the chamber. The receiver circuitry 236 may include some or all of the circuits shown and described in relation to Figures 15 to 23, for example, and may be electrically coupled to the light detectors 126 via conductors 237.

[0099] In the embodiments shown in Figure 4, the back wall 248 of a substantially cylindrical container wall 121 is substantially light-transmissive in order to allow light to travel away from the housing portion 245 towards the open light-transmissive wall on the other side of the container 120. However, the housing portion 245 in such embodiments may be substantially non-transmissive to visible light.

[0100] Embodiments described herein are, for the reasons given above, generally suitable for automatic detection of a liquid/solid blanket (or mud-line) in order to measure the efficiency of solid-liquid and liquid-liquid separation systems as a function of time using photometric non-contact infrared light attenuation measurement techniques. The IR transmitter LEDs are arranged approximately linearly (although separated from each other by a spacing of a few millimetres) adjacent to a static liquid container (cell) containing the liquid medium for which sedimentation is to be measured. A corresponding set of IR-tuned receivers are located at a certain angle opposite to the transmitters and positioned in order to obtain the maximum light intensity from the transmitter LEDs. The light detectors 126 can be fewer in number than the light sources 124 or may be the same in number. The transmitter and receiver devices (light sources 124 and light detectors 126) are positioned and aligned relative to the static liquid container, adjacent to or at least partly received within a wall thereof, in order to maximise transmitted and received signals, respectively.

[0101] The IR LED light sources 124 are selected to be relatively high-powered devices that are capable of being driven at constant currents of up to 5 times the maximum current rating of the device for a short time. For example, for an IR LED light source 124, such as the SFH 4554 OSRAM device mentioned above, that has a radiant intensity of about 550 milliwatts per steradian (mW/sr) at a drive current of 100 milliamps, the same device may be driven at up to 5 Amps in order to generate a desired level of radiant intensity for penetration through the liquid sample 122. It has been determined that such IR LEDs can operate at such high current without failure as long as they are pulsed on for relatively short periods of time, such as between 50 and 400 microseconds, and possibly up to a 1000 microseconds, as long as there is sufficient delay to allow for cooling before the next ON pulse.

[0102] Prior to conducting sedimentation measurement of a given liquid sample 122, the sedimentation measurement device 110 conducts a calibration of the IR LED power in order to obtain a reference for each LED. A signal to noise ratio (SNR) is then obtained based on the references and a light detection signal measured at the opposite light detector 126. What is stored in the memory 134 as an acceptable SNR

can be user selectable (and programmed remotely through client device 170). What is considered to be an acceptable SNR may vary depending on the properties of the slurry being tested.

[0103] As part of the calibration process for each light source 124, following initial pulsing on of the light sources 124, the power of each of the light sources 124 is automatically increased by the controller 132 to a point where an acceptable SNR (i.e. of a predetermined stored threshold SNR) is achieved, and the controller 132 then stores in the memory 134 the reference power level at which the threshold SNR was mapped for each light source 124. The reference signal for each light source 124 is then subtracted from the measured signal at the corresponding light detector 126 for the duration of the measurement process for one liquid sample 122.

[0104] Since the settling rate of liquid samples from mineral slurries with high density is relatively quick, for example in the order of a few minutes (as compared to sewerage settling rates of hours), the light sources 124 are controlled by controller 132 in order to sample at a relatively high rate, for example up to about 300 hertz. For a settling rate of around 1 centimetre per second, a sample may be taken approximately every 4 milliseconds, for example.

[0105] A suitable mathematical function can be applied to determine the position of the mud-line (or blanket) as it decreases (while the container 120 is held upright and vertical) down the level of the container over time. A third order polynomial function may be used, as one example of a mathematical function. In order to determine the settlement rate, each of the measurements taken by the controller 132 from the light detectors 126 is time stamped and so, for each sampling time, the control signals driving the current level to generate a certain radiant intensity output at the IR LED light sources 124 are known, and the attenuation through the liquid sample 122 can therefore be calculated based on the control signals to the light sources 124 and the output signals of the light detectors 126. As each time stamped set of measurements is gathered by the controller 132, these are stored in memory 134 and/or transmitted

immediately, after a short delay or periodically to the client device 170 via the transceiver 136.

[0106] Following is an example procedure for fitting a 3rd order polynomial (for example by a separate computing device such as the client device 170 or the server 190) to the raw data that was generated by operation of the sedimentation measurement device 110 to determine the distance (drop) over time of the mud-line/blanket/interface:

- The approximate time corresponding to a transition (i.e., maximum or minimum) in the time averaged signal within a measurement time period is determined.

- 100 samples above the maximum value and 100 below the maximum value are used for further processing, discarding the rest of the measured values.

- A 3rd order polynomial (signal as a function of time) is fitted via the least squares minimisation technique to the selected data.

- The 3rd order polynomial (signal as a function of time) is differentiated to create a 2nd order polynomial (signal as a function of time).

- The quadratic formula is used to solve the 2nd order polynomial. This gives rise to two roots, only one of which is within the data set. This value is the best estimate of the time that the signal maximum occurs, and therefore the elapsed time of settling mudline/blanket/interface since the measurement was started.

- The elapsed time and the known location of the photodetectors gives the settling rate of the material being tested.

[0107] Figure 24 shows an example plot of elapsed time as a function of movement of the detected mud-line across 6 IR LED (124) and photodiode (126) pairs. The top of the Y-axis (0 mm) represents the container lip at the top 123 of the container 120. Each value in the plot of Figure 24 was obtained by applying the procedure

described above. The slope of the interpolation line shown in the graph represents the settling rate (mm/s) of the liquid sample 122.

[0108] It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the above-described embodiments, without departing from the broad general scope of the present disclosure. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

CLAIMS:

1. A hand-held portable sedimentation measurement device, comprising:

a closeable fluid container having a container wall and defining a chamber to receive fluid for sedimentation measurement and defining a central longitudinal axis;

a plurality of light sources disposed along the fluid container and generally in a direction parallel to the longitudinal axis to direct light through the container wall into the chamber;

a plurality of light sensors disposed along the fluid container and arranged to detect light passing through the chamber from at least one of the light sources;

a controller configured to control emission of light from the plurality of light sources and to receive light detection signals from the plurality of light sensors, wherein sedimentation measurements can be obtained based on the light emitted from the plurality of light sources and the light detection signals;

a communication interface communicably coupled to the controller and arranged to transmit sedimentation measurement data to an external computing device; and

a housing connected to the container to house the controller and the communication interface.

2. The device of claim 1, wherein the plurality of light sources are light-emitting diodes (LEDs), wherein the LEDs are infra-red (IR) light transmitting LEDs.

3. The device of claim 2, wherein an emission spectrum of each of the LEDs has a peak at a wavelength in the range of about 880 nm to about 950 nm.

4. The device of claim 1 or claim 2, further comprising a battery power supply housed in the housing and arranged to supply power to all power-consuming components of the device.

5. The device of any one of claims 1 to 4, further comprising:

an accelerometer arranged to detect movement of the fluid container and to provide an accelerometer output signal to the controller to allow the controller to measure agitation of the fluid container.

6. The device of claim 5, wherein the accelerometer is disposed in the housing and configured to measure acceleration of the fluid container in three dimensions.

7. The device of claim 5 or claim 6, wherein the controller is configured to determine, based on received accelerometer output signals, whether a minimum agitation amount has occurred.

8. The device of claim 7, wherein when the controller determines that agitation of the fluid chamber has ceased before the minimum agitation amount has been reached, the controller is configured to generate a first alarm signal.

9. The device of any one of claims 5 to 8, wherein the controller is configured to determine, based on received accelerometer output signals, whether a maximum agitation amount has occurred.

10. The device of claim 9, wherein when the controller determines that a maximum agitation amount has occurred, the controller is configured to generate a second alarm signal.

11. The device of any one of claims 1 to 10, wherein the plurality of light sources is disposed along between 50% and 90% of the longitudinal length of the fluid chamber.

12. The device of any one of claims 1 to 11, wherein the number of light sensors is less than the number of light sources.

13. The device of any one of claims 1 to 12, wherein the plurality of light sources and the plurality of light sensors are arranged so that a path of maximum light transmission efficiency from the light sources to the light sensors is offset from the central longitudinal axis.

14. The device of any one of claims 1 to 13, wherein the fluid container comprises a light shield disposed at or around a first side of the container to completely or substantially attenuate light from the light sources through the first side of the fluid container.

15. The device of claim 14, wherein a second side of the container wall that is opposite the first side is substantially light-transmissive for human-visible wavelengths of light.

16. The device of claim 15, further comprising at least one second light source configured to emit human-visible wavelengths of light and disposed on the first side to emit light toward the second side.

17. The device of any one of claims 1 to 15, wherein the controller is configured to separately control emission of light from each of the light sources.

18. The device of any one of claims 1 to 15 and 17, wherein the controller is configured to operate each of the light sources at a high intensity for a short time.

19. The device of claim 17 or claim 18, wherein the controller is configured to separately control each of the light sensors to detect light at a time when at least one of the light sources is emitting light.

20. The device of any one of claims 17 to 19, wherein the controller is configured to enable light detection at only one light sensor while controlling light emission from multiple ones of the light sources.

21. The device of any one of claims 1 to 20, wherein the light sources and light sensors are disposed at least partially in the container wall.

22. The device of any one of claims 1 to 21, wherein the container is free of fixed internal agitation means.

23. The device of any one of claims 1 to 22, further comprising an excitation coil in the housing to induce rotational motion of a magnet when the magnet is freely disposed in a base of the container.

24. The device of any one of claims 1 to 23, wherein a volumetric capacity of the container is between about 0.5 litres and about 2 litres.

25. The device of any one of claims 1 to 24, wherein the container is cylindrical and an inside diameter of the container is between about 30 mm and about 100 mm.

26. The device of any one of claims 1 to 25, wherein the light sources are of a power sufficiently high to reliably penetrate a high density mineral slurry sample during settling of the sample.

27. The device of any one of claims 1 to 26, wherein the container and the light sources and/or light detectors are integrally formed.

28. A sedimentation measurement method, comprising:

receiving a sample liquid of a metallurgical process in a chamber of a liquid container having a volumetric capacity of between about 0.5 litres to about 2 litres;

transmitting control signals to one or more of multiple high radiant intensity infra-red (IR) light sources to cause light from the one or more IR light sources to be directed into the chamber through a wall of the liquid container;

detecting light passing through the chamber from the one or more light sources by at least one of a plurality of light sensors;

determining sedimentation measurements for the sample based on the control signals and based on light detection signals received from the at least one light sensor.

29. The method of claim 28, wherein the container is cylindrical and an inside diameter of the container is between about 30 mm and about 100 mm.

30. The method of claim 28 or claim 29, wherein the light sources are of a power sufficiently high to reliably penetrate a high density mineral slurry sample during settling of the sample.

31. The method of claim 30, further comprising emit human-visible wavelengths of light from at least one second light source disposed on a first side of the liquid container toward a second side of the liquid container.

32. The method of any one of claims 28 to 31, wherein the transmitting is performed by a controller and the controller is configured to separately control emission of light from each of the light sources.

33. The method of claim 32, wherein the controller is configured to operate each of the light sources at a high intensity for a short time.

34. The method of claim 32 or claim 33, wherein the controller is configured to separately control each of the light sensors to detect light at a time when at least one of the light sources is emitting light.

35. The method of any one of claims 32 to 34, wherein the controller is configured to enable light detection at only one light sensor while controlling light emission from multiple ones of the light sources.

36. The method of any one of claims 28 to 35, further comprising measuring agitation of the liquid sample in the fluid container.

37. The method of claim 36, wherein the measuring agitation is performed using an accelerometer arranged to detect movement of the fluid container and to provide an accelerometer output signal.

38. The method of claim 37, further comprising determining, based on received accelerometer output signals, whether a minimum agitation amount has occurred.

39. The method of claim 38, further comprising generating a first alarm signal when it is determined that agitation of the fluid chamber has ceased before the minimum agitation amount has been reached.

40. The method of any one of claims 37 to 39, further comprising determining, based on received accelerometer output signals, whether a maximum agitation amount has occurred.

41. The method of claim 40, further comprising generating a second alarm signal when the controller determines that a maximum agitation amount has occurred.

42. The method of any one of claims 28 to 41, wherein the one or more light sources and/or the plurality of light sensors are disposed at least partially in the wall of the liquid container.

43. The method of any one of claims 28 to 41, wherein the liquid container and the one or more light sources and/or the plurality of light detectors are integrally formed.

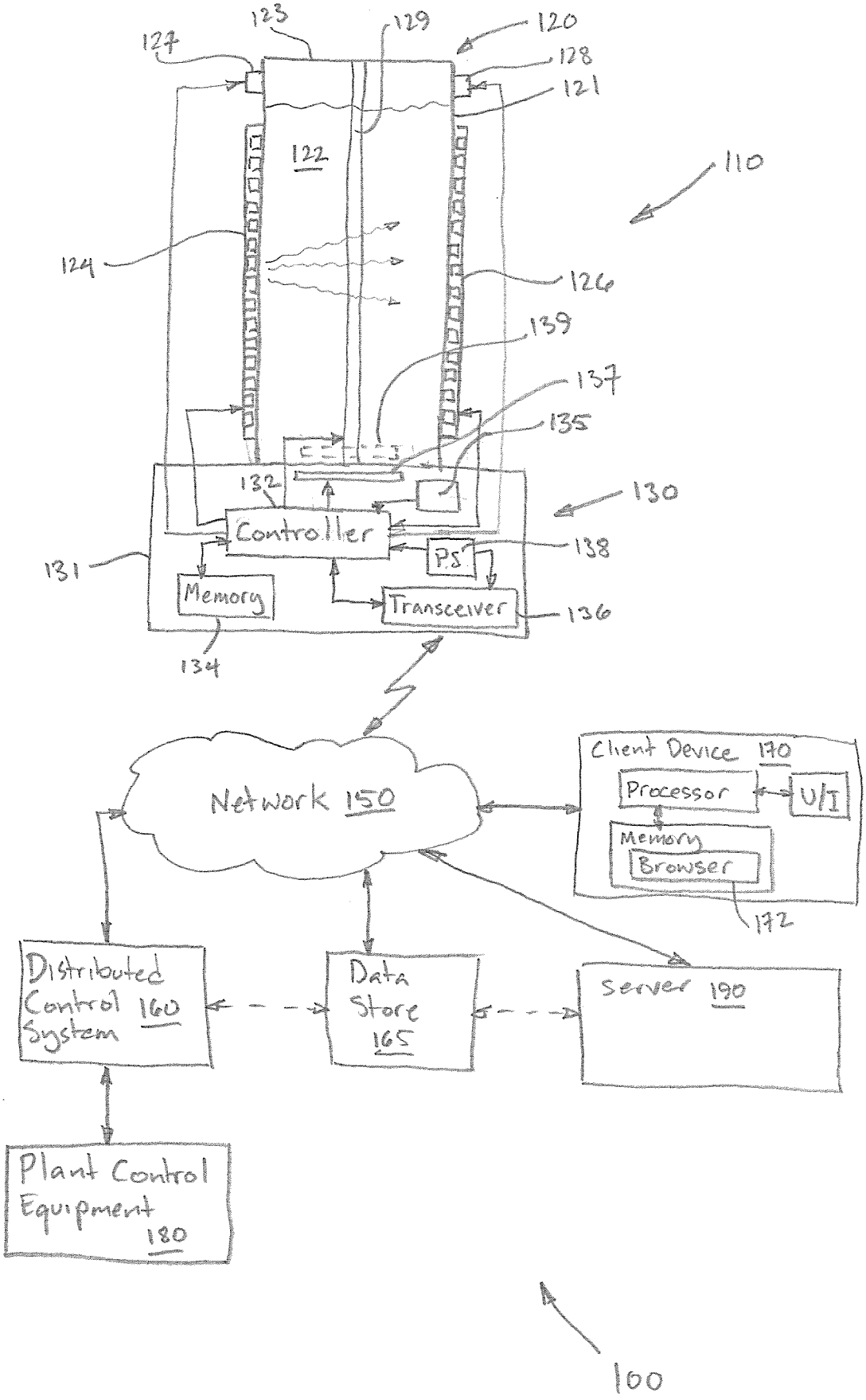

123
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139
137
135
132
130
Controller
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138
131
Memory
Transceiver
136
134
Network 150
Client Device 170
Processor
U/I
Memory
Browser
172
Distributed Control System 160
Data Store 165
Server 190
Plant Control Equipment 180
100

Figure 1

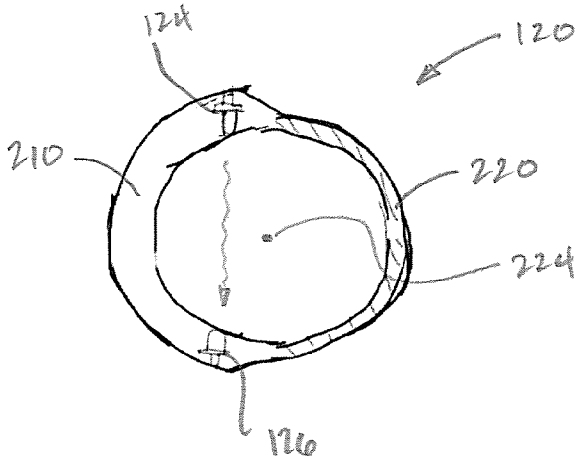


Figure 2

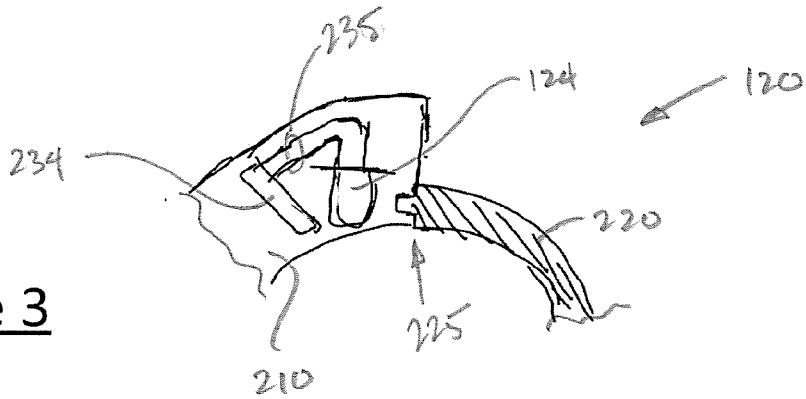


Figure 3

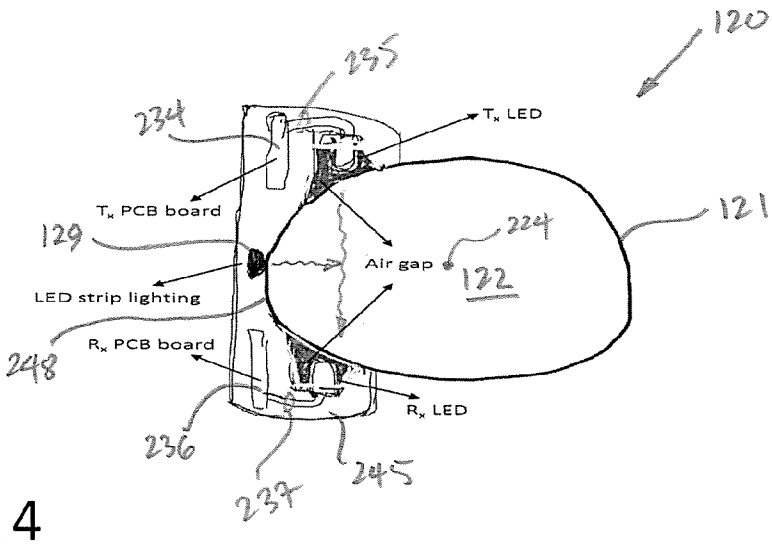
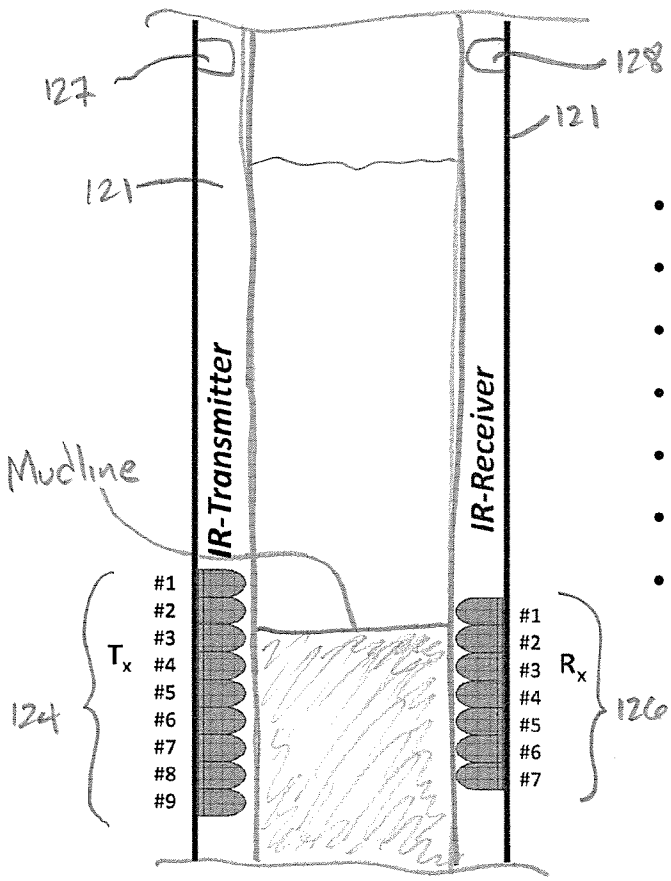


Figure 4



- T_x #1, #2 and #3 => R_x #1
- T_x #2, #3 and #4 => R_x #2
- T_x #3, #4 and #5 => R_x #3
- T_x #4, #5 and #6 => R_x #4
- T_x #5, #6 and #7 => R_x #5
- T_x #6, #7 and #8 => R_x #6
- T_x #7, #8 and #9 => R_x #7

Figure 5

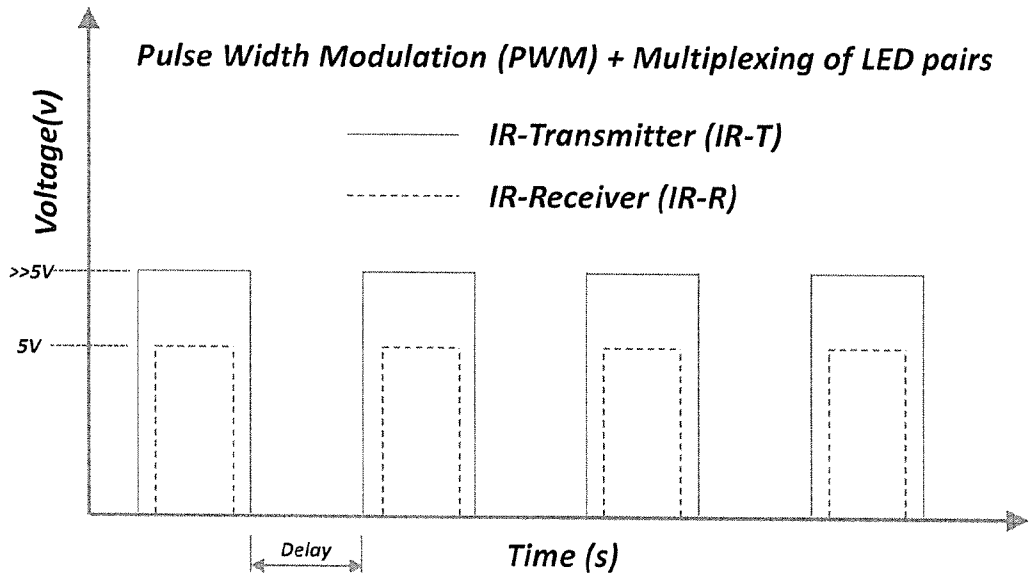


Figure 6

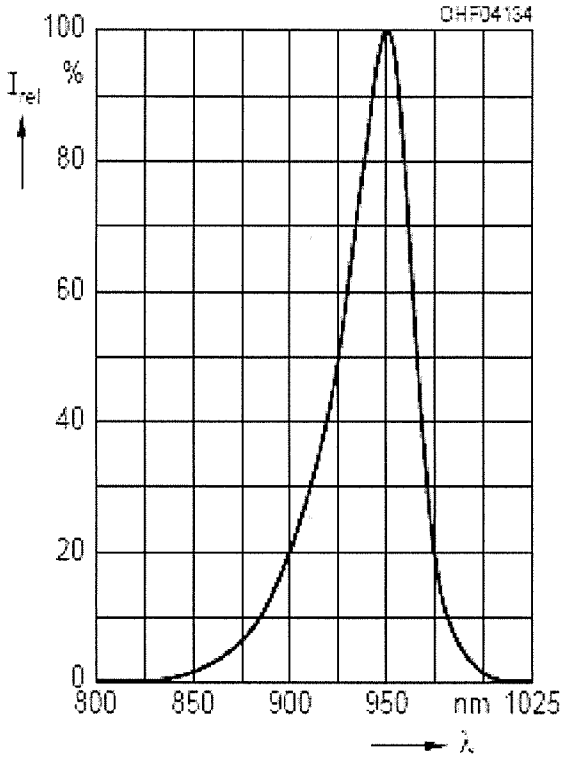


Figure 7

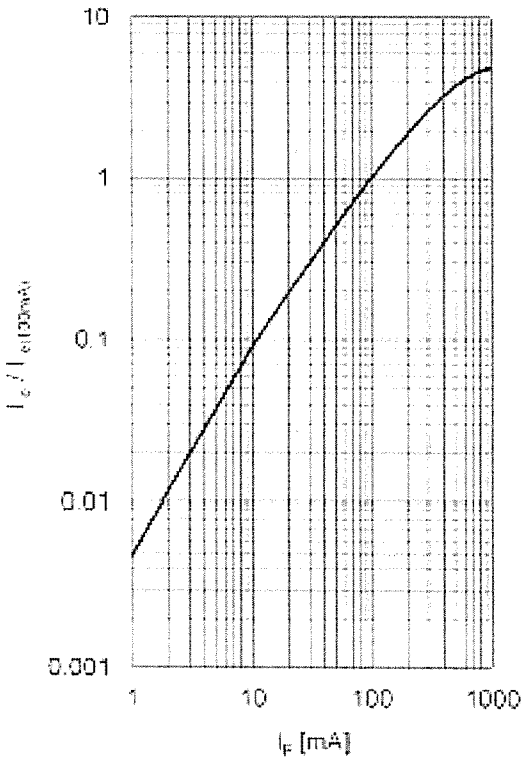


Figure 8

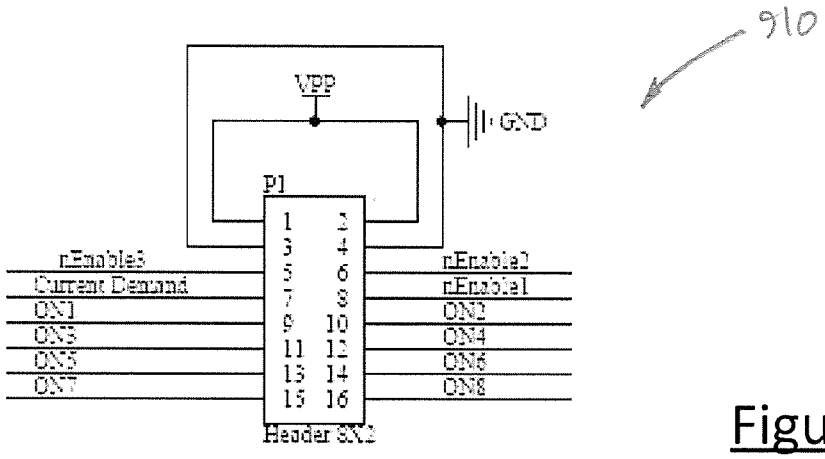


Figure 9

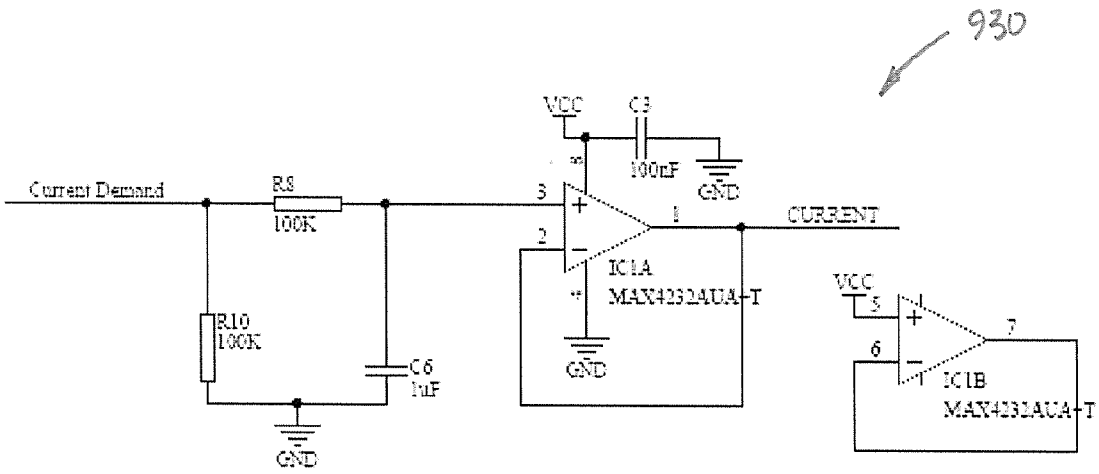


Figure 10

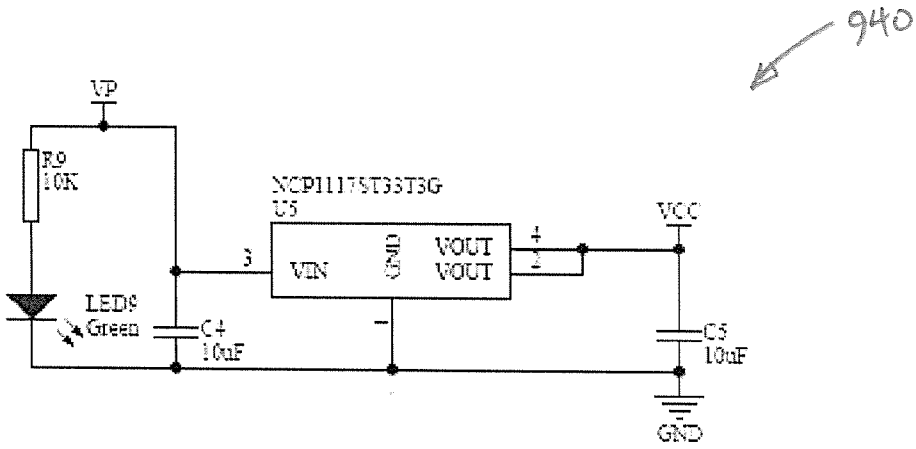


Figure 11

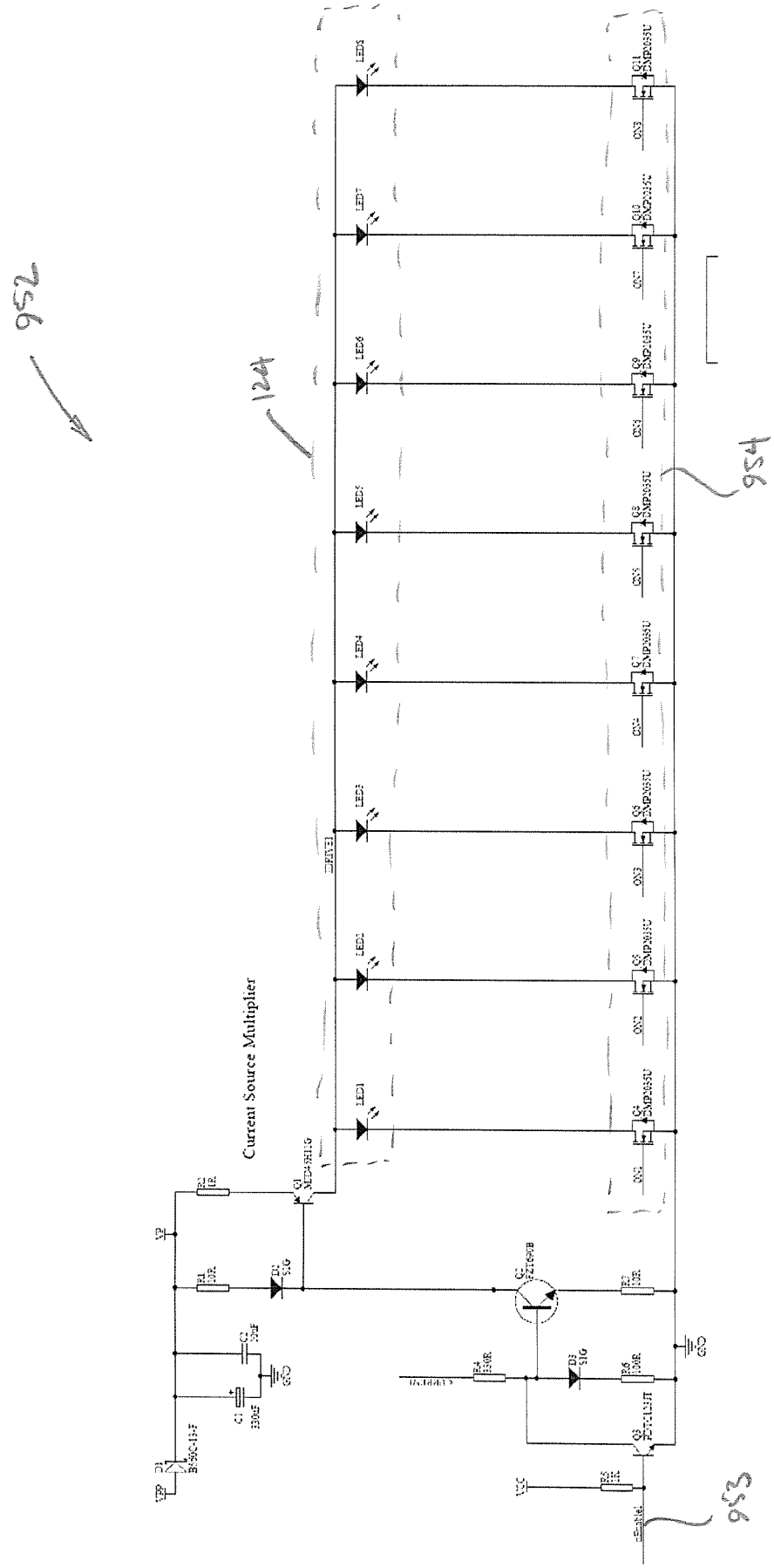


Figure 12

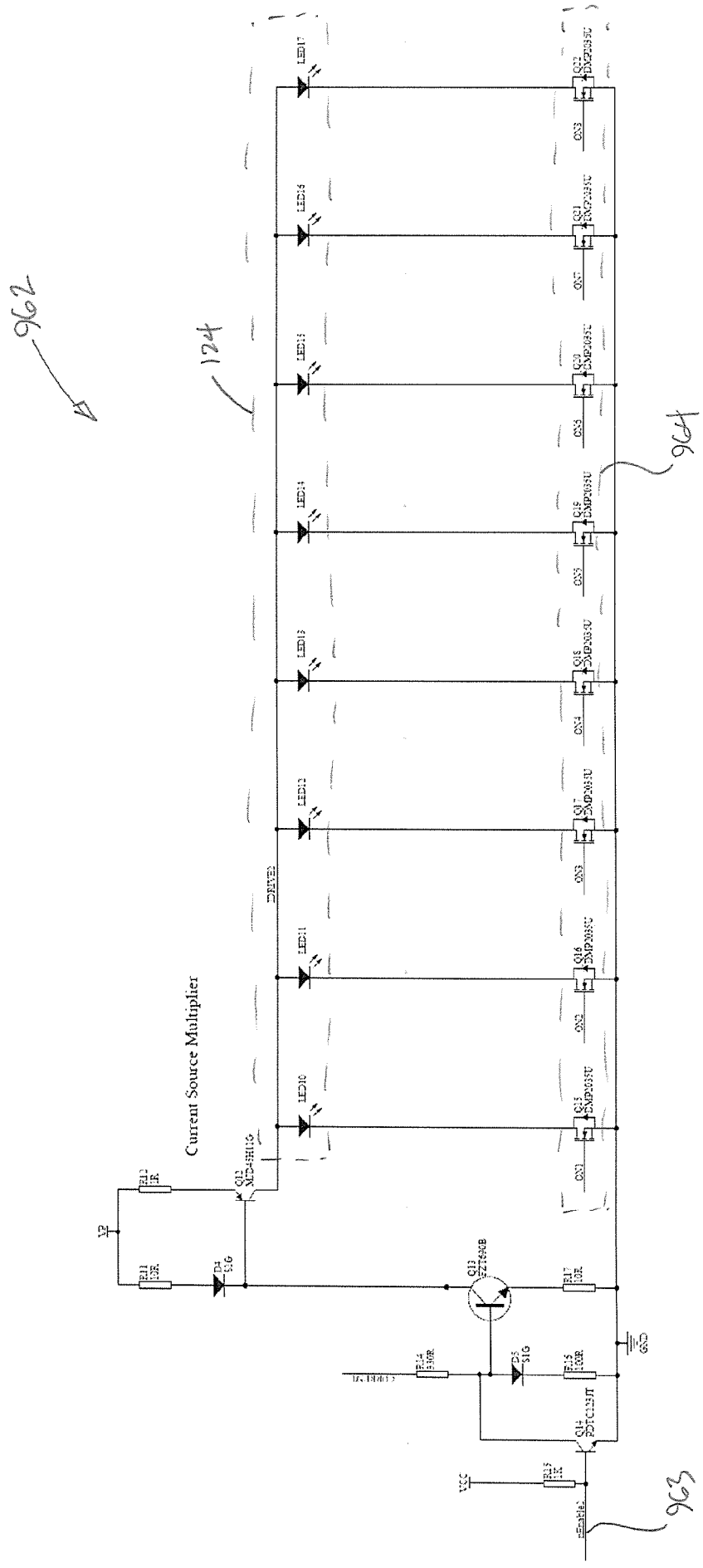

962
124
964
963
Current Source Multiplier
DRIVER
LED17
LED16
LED15
LED14
LED13
LED12
LED11
LED10
Q22
Q21
Q20
Q19
Q18
Q17
Q16
Q15
Q13
Q14
R11
R12
R13
R14
R15
R16
R17
R18
D4
D5
VCC
GND

Figure 13

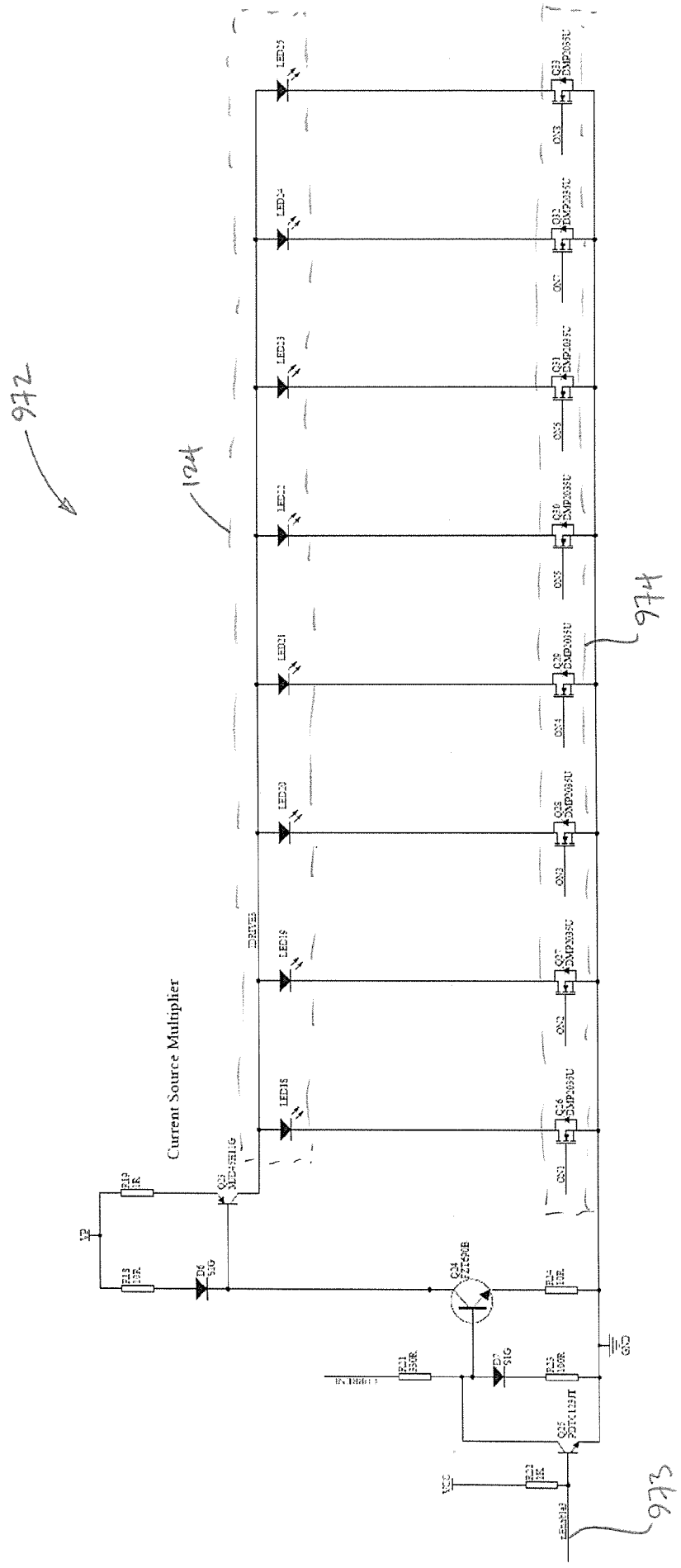


Figure 14

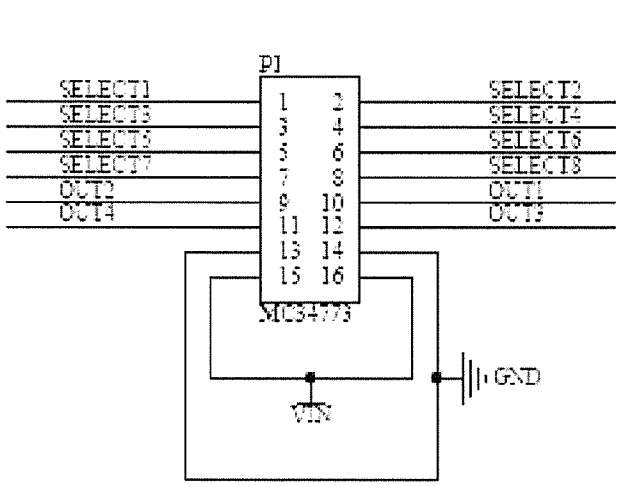


Figure 15

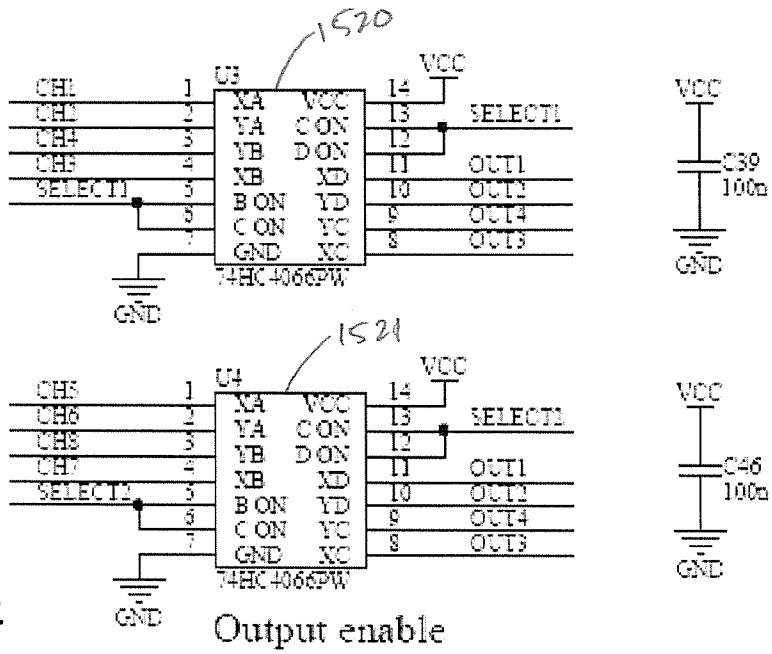


Figure 16

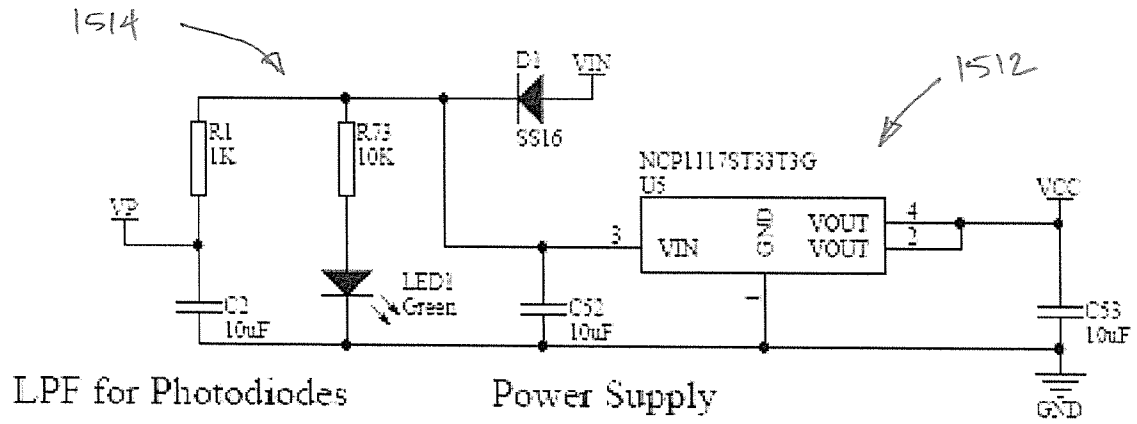


Figure 17

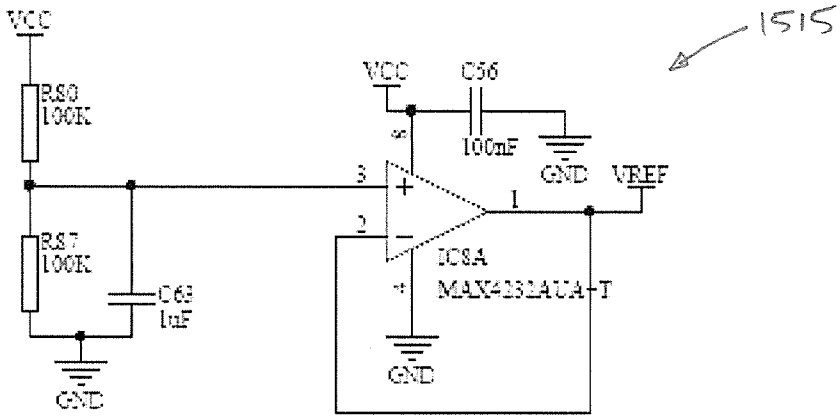
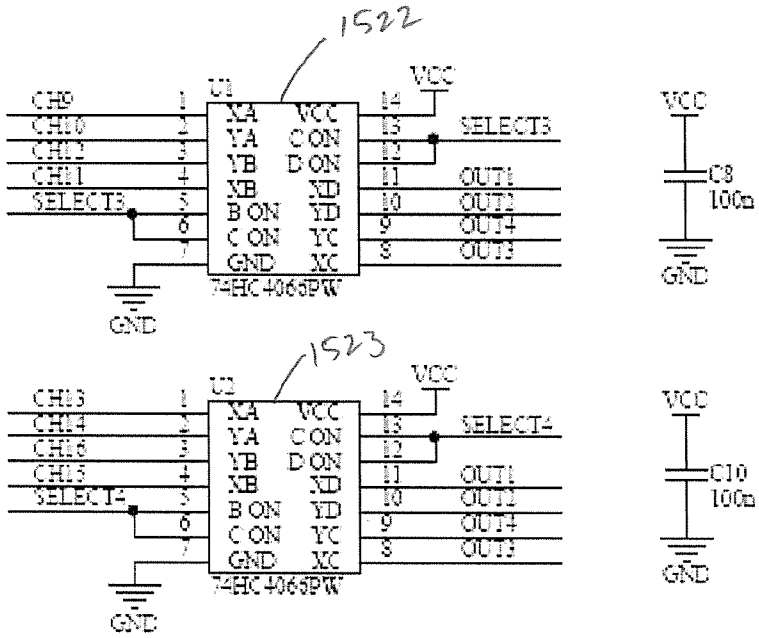


Figure 18

half rail reference



Output enable

Figure 20

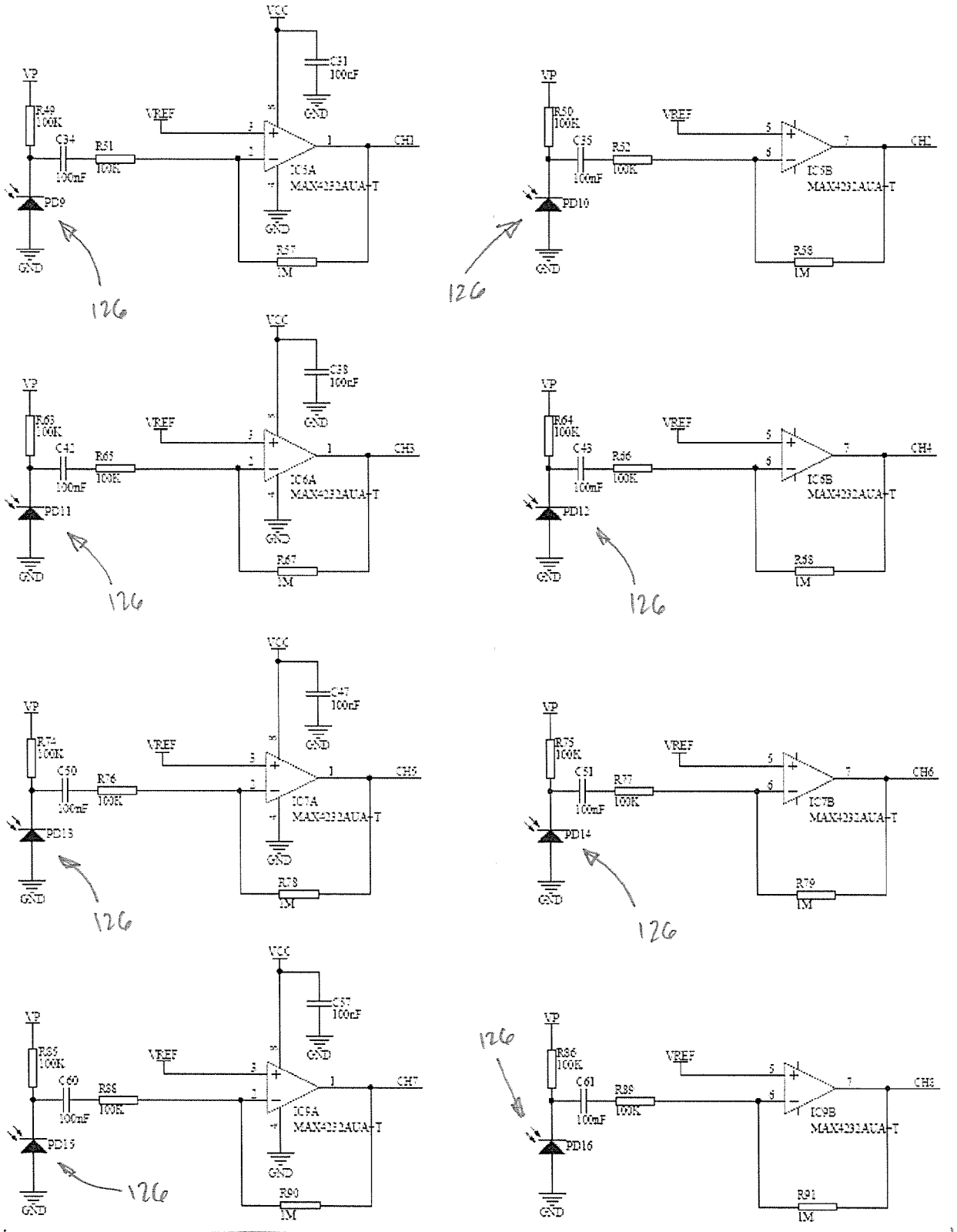

VCC
VP
VREF
GND
R49 100K
C34 100nF
R51 100K
PD9
126
IC5A MAX4232AUA+T
CH1
R57 1M
C51 100nF
R50 100K
C35 100nF
R52 100K
PD10
IC5B MAX4232AUA+T
CH2
R58 1M
C38 100nF
R63 100K
C42 100nF
R65 100K
PD11
IC6A MAX4232AUA+T
CH3
R67 1M
R64 100K
C45 100nF
R66 100K
PD12
IC6B MAX4232AUA+T
CH4
R68 1M
C47 100nF
R74 100K
C50 100nF
R76 100K
PD13
IC7A MAX4232AUA+T
CH5
R78 1M
R75 100K
C51 100nF
R77 100K
PD14
IC7B MAX4232AUA+T
CH6
R79 1M
C57 100nF
R85 100K
C60 100nF
R88 100K
PD15
IC9A MAX4232AUA+T
CH7
R90 1M
R86 100K
C61 100nF
R89 100K
PD16
IC9B MAX4232AUA+T
CH8
R91 1M
1530

Figure 19

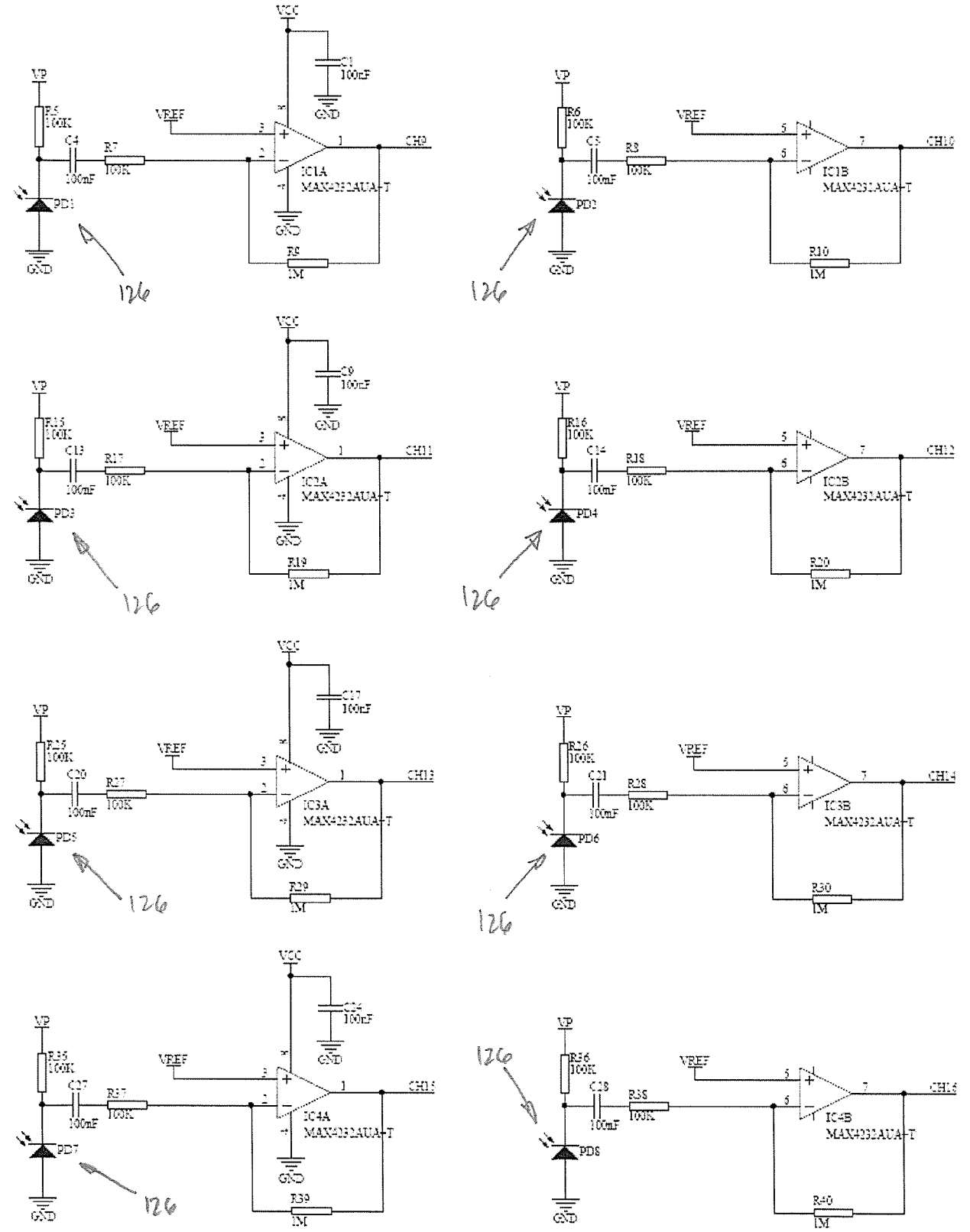
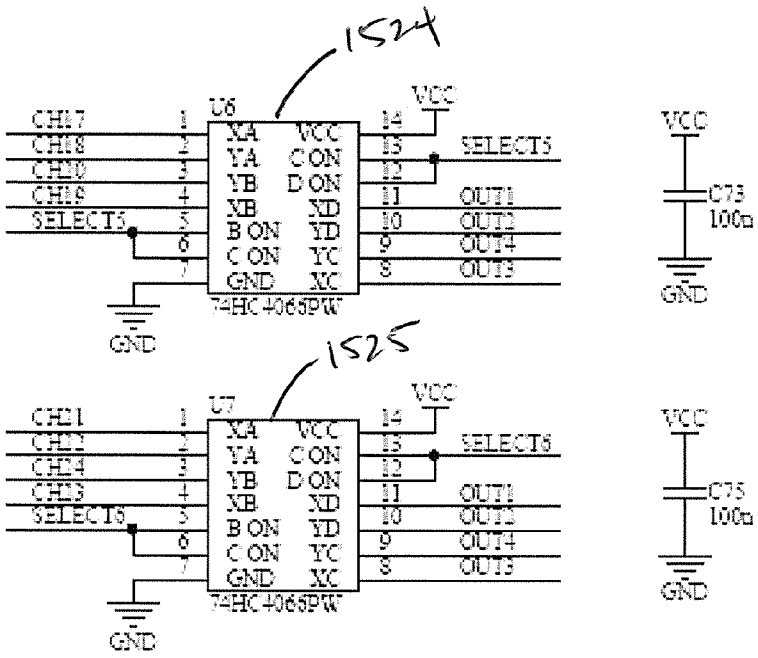

VCC
VP
VREF
GND
126
1532
IC1A
IC1B
IC2A
IC2B
IC3A
IC3B
IC4A
IC4B
MAX4232AUA+T
CH9
CH10
CH11
CH12
CH13
CH14
CH15
CH16
PD1
PD2
PD3
PD4
PD5
PD6
PD7
PD8
100nF
100K
1M

Figure 21



Output enable

Figure 22

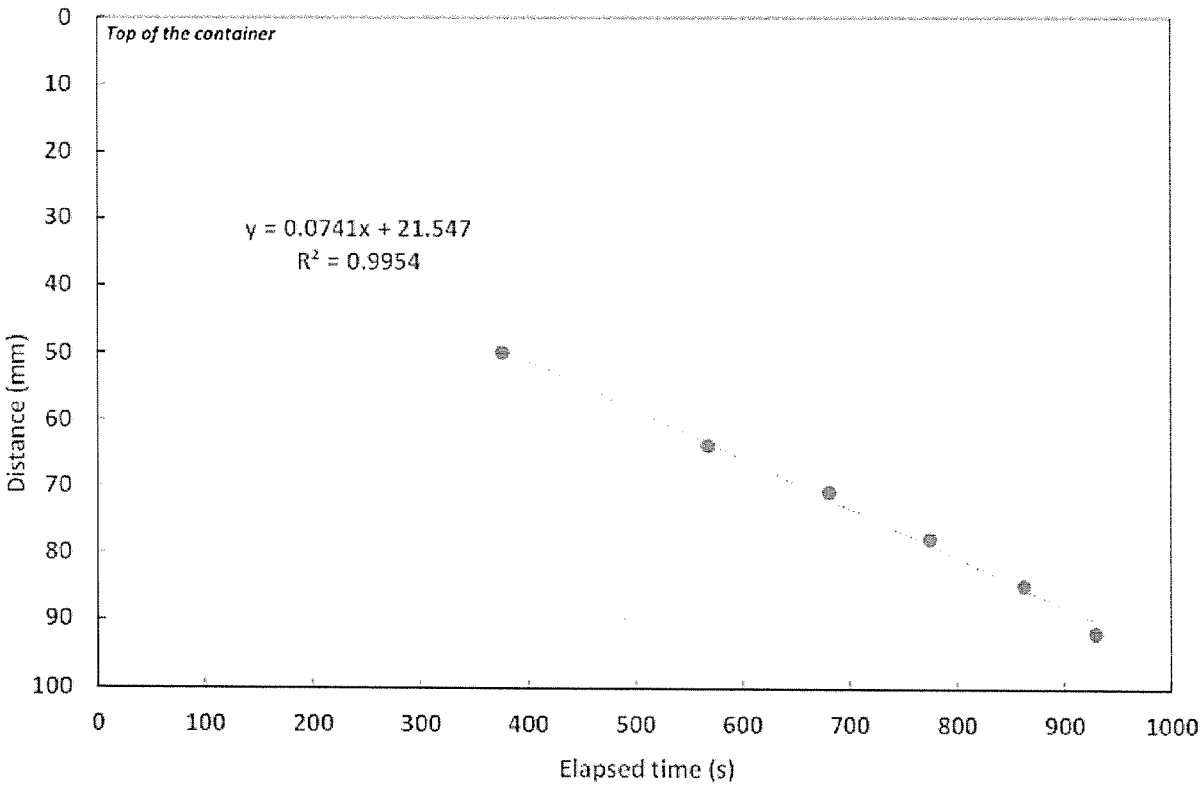


Figure 24

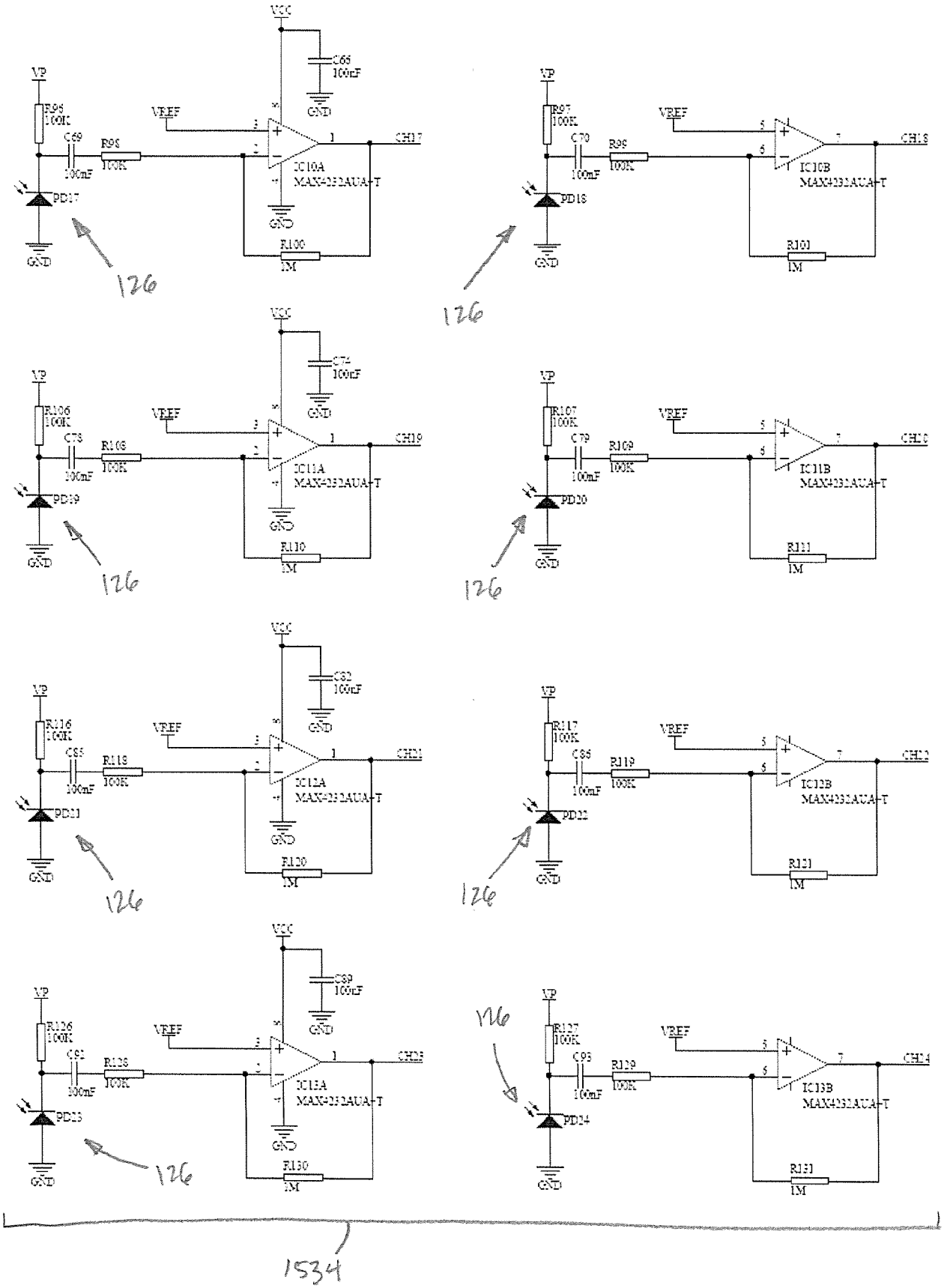

VCC
VP
VREF
GND
C66
100nF
R95
100K
C69
100nF
R98
100K
PD17
126
IC10A
MAX4232AUA+T
R100
1M
CH17
R97
100K
C70
100nF
R96
100K
PD18
IC10B
MAX4232AUA+T
R101
1M
CH18
C72
100nF
R106
100K
C78
100nF
R108
100K
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R110
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CH19
R107
100K
C79
100nF
R109
100K
PD20
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R111
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100nF
R116
100K
C85
100nF
R118
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PD21
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CH21
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C86
100nF
R119
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IC12B
MAX4232AUA+T
R121
1M
CH22
C89
100nF
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100K
C92
100nF
R128
100K
PD23
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R130
1M
CH23
R127
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C93
100nF
R129
100K
PD24
IC13B
MAX4232AUA+T
R131
1M
CH24
1534

Figure 23

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2017/050872

A. CLASSIFICATION OF SUBJECT MATTER

G01N 15/04 (2006.01) G01N 21/47 (2006.01) G01N 21/59 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Databases: WPIAP, EPODOC and TXTE with the following keywords: G01N15/04, G01N15/0205, G01N21/17, sediment, silt, deposit, rate, speed, array, series, row, sensor, detector, photodetector, mineral, mining, ore, slurry, portable, handheld, stir, agitate, mix, infrared, accelerate, centrifuge, and like terms.

PAMS Non-OPI Enquiry, Espacenet, Google and Google Patents: Applicant and inventor names along with keywords such as sedimentation rate, detector, analyse, measure, sensor, agitate, stir, mix, mineral, metallurgical, light, diode, IR, infrared, ore, slurry, handheld, mobile, array.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 September 2017	07 September 2017

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
Email address: pct@ipaustralia.gov.au

Authorised officer

Bao-Loc Nguyen
AUSTRALIAN PATENT OFFICE
(ISO 9001 Quality Certified Service)
Telephone No. +61262223618

INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/AU2017/050872**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 1998/002726 A1 (CDR S.R.L.) 22 January 1998 Title; Abstract; Figures 1, 6A-7, 12-13; Lines 13-17, Page 7; Lines 9-11, 22-25, Page 8; Line 14, Page 9 - Line 8, Page 11	1-43
X	CN 105865991 A (SHANDONG XINHAI MINING TECHNOLOGY EQUIP) 17 August 2016 Title; Abstract; Figure 1; [0001]-[0002], [0007], [0024]-[0026]	1-43

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2017/050872

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
the subject matter listed in Rule 39 on which, under Article 17(2)(a)(i), an international search is not required to be carried out, including

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Supplemental Box for Details

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT	International application No. PCT/AU2017/050872

Supplemental Box

Continuation of: **Box III**

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

• **Claims 1-27** are directed to a hand-held portable sedimentation measurement device. The features of a closeable fluid container having a container wall and defining a chamber to receive fluid for sedimentation measurement and defining a central longitudinal axis, the plurality of light sources being disposed in a direction parallel to the longitudinal axis, the sensors being disposed along the fluid container, a controller configured to control emission of light from the plurality of light sources and to receive light detection signals from the plurality of light sensors, a communication interface communicably coupled to the controller and arranged to transmit sedimentation measurement data to an external computing device, and a housing connected to the container to house the controller and the communication interface, are specific to these claims.

• **Claims 28-43** are directed to a sedimentation measurement method. The features of receiving a sample liquid of a metallurgical process in a chamber of a liquid container having a volumetric capacity of between about 0.5 litres to about 2 litres and transmitting control signals to one or more high radiant intensity infra-red light sources to direct light from the IR sources into the chamber, are specific to these claims.

Unity of invention is only fulfilled when there is at least one "special technical feature" present in the claims that both:

• provides a technical relationship among all the claims; and,

• makes a contribution over the prior art.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. The only features common to all of the claimed inventions and which provide a technical relationship among them are a liquid container, controlling the emission of light from some sources to enter the chamber through a wall of the liquid container, detecting light passing through the chamber from the one or more light sources by at least one of a plurality of light sensors, and determining sedimentation based on the light detection.

However, it is considered that these features are generic in the art of spectrophotometry (See also discussion of novelty and inventive step of **D1-D2** below).

Therefore in the light of this document this common feature cannot be a special technical feature. Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a priori*.

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2017/050872**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
WO 1998/002726 A1	22 January 1998	WO 9802726 A1	22 Jan 1998
		AU 4201597 A	09 Feb 1998
		EP 0912884 A1	06 May 1999
		IT FI960169 A1	16 Jan 1998
		IT 1286674 B1	15 Jul 1998
CN 105865991 A	17 August 2016	CN 105865991 A	17 Aug 2016

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.