

Photo-receiver Arrangement

Field of the Invention

- 5 The invention relates to a photo-receiver arrangement comprising a photo-sensor and a preamplifier for detecting and measuring light, in particular infrared light being incident on the photo sensor.

Background of the Invention

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Wireless technology has become a highly desirable technology due to its convenience and ease of use. Infrared (IR) technology is one such wireless technology that is commonly utilized in electronic devices, like laptop computers, handphones and PDAs (personal digital assistant) due to its low cost of implementation and high data
15 transfer rates in the order of Mb/s.

IR technology allows users to link to each other through various IR devices over a short distance. Generally, known IR devices comprise an IR transceiver for transmitting, receiving and processing an infrared signal, the IR transceiver including
20 an IR sensor for capturing IR light and converting the same into an electrical signal, and a preamplifier for amplifying the electrical signal generated by the IR sensor. The power of the incident infrared light varies in orders of magnitude, depending on the distance between the source of the infrared signal, which can be e.g. a transceiver of another IR device or a remote control unit, and the sensor of the IR transceiver. As
25 the distance increases, the infrared signal received by the sensor of the IR receiver

decreases in an exponential manner. Therefore, to allow communication between IR devices within a reasonable range of distances, a wide dynamic range of the IR device and, in particular, of its transceiver is essential.

5 Furthermore, IR devices usually operate in conditions where there is ambient light. Such ambient light will reduce the Signal-to-Noise Ratio (SNR), and the sensor of the IR transceiver must still be able to detect the desired infrared signal despite the overwhelming photocurrent generated by the sensor corresponding to ambient light.

10 When an infrared signal is captured by the IR sensor, a photocurrent which is proportional to the signal strength is generated by the same. The photocurrent generated by the IR sensor needs to be amplified, and a transimpedance amplifier is commonly used as the preamplifier. The transimpedance amplifier used in said known preamplifier is desired to be a low noise amplifier and should provide for a high gain.

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However, when using IR devices in the abovementioned reasonable range of distances, the intensity of the incident infrared light captured by the IR sensor varies typically in a dynamic range of about 100dB ($3.6 \mu\text{W/SR}$ to 500 mW/SR). Therefore, the intensity of the photocurrent generated by the IR sensor in response to the incident

20 IR light and input to the preamplifier has also a dynamic range in the order of 100 dB. In contradistinction, the dynamic range of a typical transimpedance amplifier is only between 40 dB to 60 dB, beyond which the amplifier loses its linear properties and enters into saturation. As such, the transimpedance amplifier is not able to accommodate the wide dynamic range of the photocurrent generated by the IR sensor
25 without losing its linearity.

A typical implementation of the receiver part of a known IR transceiver is shown in Fig. 1. The IR receiver comprising an IR sensor 100 including a photodiode 130, and a preamplifier is shown in Fig 1. The preamplifier is implemented by a transimpedance amplifier 200 comprising an operational amplifier 210, a feedback resistor R_f 220 and a feedback capacitor C_f 230.

There are many constraints in designing the transimpedance amplifier 200 of this IR receiver. The lower bound of the dynamic range of the transimpedance amplifier 200 is determined by the level of the input referred noise of the transimpedance amplifier 200. Any signal with a signal level below the lower bound of the dynamic range will be very difficult to detect, as the SNR is very low in this range. The upper bound of the dynamic range of the transimpedance amplifier 200 is determined at the input signal level when the transimpedance amplifier 200 becomes saturated and the gain is no longer linear. Hence the dynamic range in which the transimpedance amplifier 200 should be operated must be between the upper and the lower bound so that on the one hand a low level input signal can be detected, and on the other hand a high level input signal is still amplified with a linear gain.

Further, the bandwidth requirement places a large constraint on the design of the transimpedance amplifier 200. The bandwidth of the transimpedance amplifier is approximated by

$$BW \cong 1/(2\pi C_f R_f),$$

where R_f is the feedback resistor 220 connected between the inverting input and the output of the operational amplifier 210 and C_f is the feedback capacitor 230 connected in parallel with the feedback resistor 220.

- 5 The desired operational bandwidth should not be too narrow so as to avoid distortions such as intersymbol interferences, jitters, etc. On the other hand, the bandwidth should not be too wide, either, as a wide bandwidth would reduce the SNR. Therefore, the values of C_f 230 and R_f 220 should be carefully chosen to obtain an optimal operational bandwidth. However, this is not so easy as the values of C_f 230
10 and R_f 220 themselves are also subject to various constraints.

The photodiode 130 of the IR sensor 100 is desired to have a large surface area and thereby a large sensing area in order to achieve a high signal strength resulting in a good SNR. However, a large photodiode will inevitably introduce a high parasitic
15 capacitance C_{pd} 110 (also known as the pin capacitance) as the parasitic capacitance 110 is directly proportional to the size of the photodiode 130. Depending on the bias condition of the transimpedance amplifier 200, the C_{pd} 110 can be as high as 10 pF to 15 pF. With such a high C_{pd} 110, the circuit might have stability problems.

- 20 As a rule of thumb, in order to ensure stability of the transimpedance amplifier 200, its phase margin has to be larger than 45° , this requires the zero of the open loop gain to be less than 10 times the dominant pole, i.e.

$$\omega_z \leq 10\omega_p,$$

- 25 where the position of the zero is given by $\omega_z = 1/(C_f R_f)$,

and the position of the dominant pole is given by $\omega_p = 1/R_f(C_{pd} + C_f)$,

which implies that

$$C_f \geq 9C_{pd}$$

- 5 It can be seen from the above equation that it is desirable to design the feedback capacitor C_f 230 as large as possible.

However, increasing the value of the feedback capacitor C_f 230 also decreases the bandwidth, resulting in increased distortion of the input signal. Hence this poses a
10 constraint on how large the value of the feedback capacitor C_f 230 can be chosen without significantly distorting the input signal.

Furthermore, the gain of the transimpedance amplifier 200 is directly proportional to the value of the feedback resistor R_f 220. The value of R_f 220 should be high on the
15 one hand to achieve a high gain, but should not be too high on the other hand to avoid saturating the transimpedance amplifier 200 and narrowing its bandwidth. Reducing the value of the feedback resistor R_f 220 will reduce gain and inevitably increase the bandwidth of the transimpedance amplifier 200, resulting in reduction of the SNR. This poses another constraint on the value of the feedback resistor R_f 220.

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As can be seen from above explanations, requirements regarding the sensitivity, dynamic range, Signal-to-Noise Ratio (SNR), bandwidth and stability of the IR receiver, and especially of its transimpedance amplifier, all pose constraints in designing the amplifier 200, and, therefore, many compromises have to be made.

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Various implementations of this type of preamplifier had been developed in order to overcome the above described constraints and problems resulting therefrom. However, none of the known implementations is able to overcome all described problems.

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One commonly known implementation of a transimpedance amplifier is shown in Fig. 2 and uses an AGC (automatic gain control) unit 300 to vary the value of the feedback resistor R_f 220' so as to avoid saturation of the transimpedance amplifier 200 by scaling the input photocurrent 120 generated by the IR sensor 100 to a range within
10 40 dB to 60 dB.

One problem of this implementation is that since the dynamic range of the input photocurrent is very large as explained above, a feedback resistor R_f 220' with a plurality of different values is needed to achieve a sufficient number of gain steps.

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Furthermore, though output linearity can be achieved through switching between the different values of the feedback resistor R_f 220' of the transimpedance amplifier 200 by means of the AGC unit 300, the transimpedance amplifier 200 has to be able to sink the input photocurrent 120 which can range from a few tens of nA to a few tens
20 of mA. Therefore, this known implementation operates with high current values and has, therefore, high power dissipation. However, high power consumption is a problem especially in battery operated and small-sized portable electronic devices like handphones, personal digital assistants (PDA) and laptops.

Another known implementation of a preamplifier of an IR receiver is a diode clamping transimpedance circuitry 400 as shown in Fig 3. The transimpedance circuitry 400 comprises a clamping diode 410 and a resistor 420 connected parallel to the clamping diode 410. The bandwidth of this diode clamping transimpedance

5 circuitry 400 is approximated as $BW \cong 1/(2\pi C_{pd}R)$

wherein C_{pd} is the parasitic capacitor 110 of the photo-sensor 100 and R 420 is the transimpedance when the input current is low.

The clamping diode 410 limits the transimpedance gain at the inverting input of the operational amplifier 210 of the preamplifier 200 at high input current. Therefore, the input voltage to the preamplifier 200 is limited, resulting in that the latter will not enter into saturation. Furthermore, the high parasitic or pin capacitance C_{pd} 110 interacts with the clamping resistor R 420 to limit the bandwidth of the preamplifier 200 automatically.

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One drawback of this known diode clamping transimpedance circuitry 400 is that it is only suitable for low speed implementations. Furthermore, there is no control over the gain of the preamplifier 200.

20 **Summary of Invention**

It is an object of the invention to provide a photo-receiver arrangement, and in particular an infrared receiver arrangement, which is capable to capture, detect and amplify and thereby process incident light having a large dynamic range in an accurate manner, which is less susceptible to the problems based on the constraints in

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sensitivity, SNR, bandwidth and stability of the known devices, and which has a low power dissipation being necessary for battery operated portable electronic devices like ~~handphones~~, personal digital assistants (PDA), laptops, etc.

5 This object is solved according to the invention with a photo-receiver arrangement which comprises a photo-sensor for capturing light being incident thereon and having a predetermined range of light intensity values, and for converting the captured incident light into a first electrical signal; a pre-scaler connected to an output of the photo-sensor for producing a second scaled electrical signal based on and
10 corresponding to said first electrical signal which is input into the pre-scaler; and a preamplifier connected to an output of the pre-scaler for amplifying said second scaled electrical signal which is input into the preamplifier, the preamplifier having a dynamic range of at least substantially linear gain, wherein the pre-scaler and the preamplifier are designed in a mutually matching configuration such that the second
15 scaled electrical signal falls within the dynamic range of the preamplifier for any light intensity value falling into said predetermined range of light intensity values.

According to this proposal of the invention a separate pre-scaler is inserted between the photo-sensor and the preamplifier of the photo-receiver arrangement. The
20 electrical signal generated by the photo-sensor in response to the incident light is scaled, for all operational light intensity values, by the separate pre-scaler such as to produce a scaled electrical signal with a value which falls within the preamplifier's dynamic range with linear gain characteristics and which unambiguously and distinctively corresponds to the respective value of the electrical signal generated by
25 the photo-sensor. In other words, the input light of a large dynamic range is converted

in total by the photo-sensor and the pre-scaler to a scaled electrical signal with a dynamic range corresponding to the linear gain dynamic range of the preamplifier. Accordingly, the pre-scaler of the photo-receiver arrangement according to the invention performs the signal scaling in such a manner that for every light intensity
5 value of the incident light a scaled electrical signal being specific for and assigned to that light intensity value of the incident light is produced so that no signal information is lost during the scaling. In this context, specific scaled electrical signal means a scaled electrical signal with a specific signal value or, if a pre-scaler with a variable scaling factor is used, a scaled electrical signal with a specific combination of a signal
10 value and a scaling factor used to produce the scaled electrical signal with that signal value.

Since the electrical signal input to the preamplifier is scaled according to the invention by a separate pre-scaler and not by a circuit element of the preamplifier
15 itself, the characteristics of the scaling, such as the extent of the scaling and the characteristics of the preamplifier such as its gain can be set independently from each other.

In particular and in contradistinction to the above discussed prior art arrangement,
20 with the pre-scaler according to the invention, it is not necessary to vary a feedback resistor of the preamplifier in order to scale the electrical signal input to the preamplifier. Rather, the feedback resistor can be fully used to adjust the gain of the preamplifier without having to consider the large dynamic range of the input electrical signal, and the feedback capacitor 230 can be fully used to adjust the bandwidth of the

preamplifier without having to consider the large parasitic capacitance C_{pd} of the photo sensor with regard to the question of stability of the circuit.

Furthermore, since the photo-sensor and the preamplifier are separated and isolated
5 from each other by the pre-scaler according to the invention, the photo-sensor does not have any direct influence on the bandwidth, the Signal-to-Noise Ratio and the stability of the preamplifier. Also, by introducing the pre-scaler according to the invention, the pre-scaler can be designed so that the effect of the photo-sensor on the preamplifier with regard to its bandwidth, SNR and stability is compensated by that of
10 the pre-scaler so that the photo-sensor and the pre-scaler jointly as a unit seen by the input of the preamplifier do not have any negative effect on the mentioned characteristics of the preamplifier.

The photo-receiver according to the invention can be used for detecting and
15 processing any kind of light signal which has a wide dynamic range regarding its intensity. However, the photo-receiver according to the invention can be utilized very advantageously for detecting and processing infrared light, since infrared light has a very wide signal intensity range. Therefore, according to a preferred embodiment of the invention, the photo-sensor is an infrared sensor and the photocurrent generated
20 by the infrared sensor as output electrical signal corresponds to the signal power of the infrared light which is detected by the infrared sensor.

The pre-scaler of the photo-receiver according to the invention can be any circuitry which varies the value of its input current supplied by the photo-sensor so as to match

it with the operational linear gain dynamic range of the preamplifier. It can e.g. be implemented by current modifying circuits.

According to the invention the pre-scaler can be implemented such that it performs a scaling operation with a variable scaling value. However, according to a preferred embodiment of the invention, the pre-scaler is designed to perform a variable scaling of the electrical signal generated by the photo-sensor with a set of discrete scaling factors. In this embodiment of the invention the scaling factor to be used for a specific signal value of the electrical signal generated by the photo-sensor is preferably determined by that signal value of the electrical signal itself.

According to a further preferred embodiment of the invention, the pre-scaler is a programmable current mirror coupled with a current sensing circuit. The photocurrent produced by the photo-sensor is input into the current mirror and a current being proportional to the photocurrent is drawn from the current sensing circuit. Based on the current drawn, the current sensing circuit determines the level of the photocurrent and thereby a scaling factor to be applied to the photocurrent, and produces a corresponding control signal input into the current mirror to scale the photocurrent according to the determined scaling factor. The scaled current, which is kept within the dynamic range of the preamplifier, is then supplied to the preamplifier as an input signal.

In this embodiment of the invention the current sensing circuit is preferably implemented by an A/D converter.

According to a preferred embodiment of the invention, the preamplifier is a transimpedance amplifier which amplifies the scaled input current to an output voltage. In this embodiment of the invention, a feedback resistor and a feedback capacitor are connected between the input and the output of the transimpedance amplifier. The feedback resistor is used to control the gain of the transimpedance amplifier, and the capacitor, together with the resistor, is used to control the bandwidth of the said amplifier. Choice of the resistor and capacitor values is not restricted by the large parasitic capacitance C_{pd} of the photo sensor, since in the photo-receiver arrangement according to the invention the parasitic capacitance does not threaten the stability of the circuit.

As the input current of the preamplifier is prevented from being too high by the pre-scaler according to the invention, the power consumption and dissipation of the preamplifier is small so that the photo-receiver according to the invention can be advantageously utilized as infrared receiver for portable electrical devices having infrared communication units for infrared data transfer.

Brief description of the Drawings

Figure 1 shows a schematic circuit diagram of a prior art photo-receiver with a transimpedance amplifier;

Figure 2 shows a schematic circuit diagram of a prior art photo-receiver with transimpedance amplifier comprising an automatic gain control unit;

Figure 3 shows a schematic circuit diagram of a prior art photo-receiver using a diode clamping transimpedance circuitry;

Figure 4 shows a block diagram of the photo-receiver arrangement according to the invention;

Figure 5 shows a schematic circuit diagram of the photo-sensor of the photo-receiver arrangement according to a preferred embodiment of the invention;

5 Figure 6 shows a schematic circuit diagram of the pre-scaler of the photo-receiver arrangement according to the preferred embodiment of the invention;

Figure 7 shows a schematic circuit diagram of the preamplifier of the photo-receiver arrangement according to the preferred embodiment of the invention; and

10 Figure 8 shows a schematic circuit diagram of the photo-receiver arrangement according to the preferred embodiment of the invention.

Detailed Description of the Invention

15 In the following, a preferred embodiment of the invention is described with reference to Figures 4 to 8.

As can be seen from Fig. 4, a photo-receiver arrangement according to the invention comprises a photo-sensor 500, a pre-scaler 600 and a preamplifier 700. When light falls on and is captured by the sensor 500, a photocurrent I_{pd} 510 is generated by the sensor, wherein the value of the generated photocurrent is proportional to the intensity
20 of the light received by the sensor 500. The pre-scaler 600 receives the generated photocurrent I_{pd} 510 as input signal and scales the value of the photocurrent I_{pd} 510, thereby generating an input current I_{in} 610 to be fed into the preamplifier 700. After scaling by the pre-scaler, the value of the input current I_{in} is such that it falls within

the operational, linear gain dynamic range of the preamplifier 700. The preamplifier 700 amplifies the input current I_{in} 610 to produce a suitable output signal.

According to the preferred embodiment of the invention, the photo-sensor 500 is an
 5 infrared (IR) sensor which detects any IR signal being incident thereon and produces a corresponding photocurrent I_{pd} 510. The IR sensor 500 comprises a photodiode 520 with a parasitic capacitance C_{pd} 530 connected in parallel with the photodiode 520 as shown in Fig. 5. The photocurrent I_{pd} 510 is fed into the pre-scaler 600.

10 The main purpose of the pre-scaler 600 is to have an independent scaling function to scale the photocurrent I_{pd} 510 to an input current I_{in} 610 which is within the linear gain dynamic range of the preamplifier 700. According to the preferred embodiment of the invention, the pre-scaler 600 comprises a programmable current mirror 630 and a current sensing circuit 620 as shown in Fig. 6. The photocurrent I_{pd} 510 output by
 15 the IR sensor 500 is fed directly into the programmable current mirror 630 and a corresponding sensing current I_s 640 being proportional to the photocurrent I_{pd} 510 is drawn from the current sensing circuit 620. Based on the sensing current I_s 640 drawn, the sensing circuit 620 judges whether the value of the photocurrent I_{pd} 510 is too high so that the preamplifier 700 would be saturated if the photocurrent I_{pd} 510
 20 were directly supplied to it, or the photocurrent I_{pd} 510 is too small to produce a good Signal-to-Noise ratio (SNR). Based on this judgement a scaling factor m is determined by the current sensing circuit 620. The current sensing circuit 620 generates then a control signal 650 corresponding to the said scaling factor m and outputs the same to the programmable current mirror 630 which, in turn, scales the

photocurrent I_{pd} 510 according to the scaling factor m and thereby produces at its output the input current I_{in} 610 to be input into the preamplifier 700.

Therefore, the input current I_{in} 610 fed to the preamplifier 700 is either a multiple or a
 5 fraction of the photocurrent I_{pd} 510 given by the following equation

$$I_{in} = m \cdot I_{pd}$$

wherein I_{in} 610 is a multiple of I_{pd} 510 with $m < 1$ when I_{pd} 510 is at or above the
 10 higher bound of the operational linear gain dynamic range of the preamplifier 700,
 and $m > 1$ when I_{pd} 510 is at or below the lower bound of the said dynamic range to
 achieve good SNR.

Accordingly, the function of the current sensing circuit 620 is to determine the scaling
 15 factor m in order to scale the photocurrent I_{pd} 510. In contradistinction, the current
 sensing circuit 620 does not have tight bandwidth, SNR and stability requirements.
 Moreover, the current sensing circuit 620 is also isolated from the preamplifier 700
 and therefore the components used in the current sensing circuit 620 do not affect the
 performance of the preamplifier 700. As a result, the current sensing circuit 620 is
 20 easy to design and implement.

In the preferred embodiment of the invention the programmable current mirror 630 is
 a multi-stage current mirror which allows the photocurrent I_{pd} 510 to be scaled up or
 down in steps according to the number of stages utilized. The current mirror can be
 25 implemented by using MOS or BJT transistors as basic electronic components.

The preamplifier 700 amplifies the input current I_{in} 610 to produce a suitable output signal. Depending on the implementation of the preamplifier 700, the output signal can be a current or a voltage signal. According to the preferred embodiment, the preamplifier 700 is implemented as a transimpedance amplifier comprising an operational amplifier 710 with a feedback resistor R_f 720 and a feedback capacitor C_f 730 as shown in Fig. 7. The resistor R_f 720 can be made as a variable resistor to control the gain of the amplifier 710, and to set, together with the capacitor C_f 730, the bandwidth of the preamplifier 700.

Since the pre-scaler 600 scales the photocurrent I_{pd} 510, the dynamic range of the input current I_{in} 610 produced by the pre-scaler 600 is reduced as well. Therefore, it is not necessary for the preamplifier 700 to utilize a variable feedback resistor to achieve a number of variable gain steps. Consequently, according to the preferred embodiment of the invention, the resistance of the resistor R_f 720 can even be set to a fix value.

Figure 8 shows a schematic circuit diagram of the entire photo-receiver arrangement according to the preferred embodiment of the invention. Although the shown and described embodiment refers to a single-ended implementation of the photo-receiver arrangement according to the invention, it should be noted that the invention is not restricted thereto. Rather, it is within the scope of the invention to implement the photo-receiver arrangement in a differential or pseudo-differential configuration. The advantage of a single-ended configuration over a differential configuration is that it has a much lower power consumption, which is an important aspect when the photo-

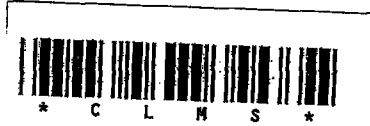
receiver arrangement is utilized in a portable electronic device. However, a differential configuration has the advantage of a far better noise compensation. According to the invention a pseudo-differential configuration of the photo-receiver arrangement is preferred which is a compromise between the single-ended and
5 differential configurations.

Referring further to Fig. 8, as the dynamic range of the input current I_{in} 610 of the preamplifier 700 is reduced by the current mirror 630, the preamplifier 700 does not enter into saturation even in case of high infrared light intensity values and hence
10 always gives a gain which is linear for all input signal values. Also, even if the photocurrent I_{pd} 510 based on a low intensity infrared light is so small that it would lie below the lower bound of the linear gain dynamic range of the preamplifier 700, the input current I_{in} 610 fed to the preamplifier 700 is within the said dynamic range since it is scaled up by the pre-scaler 600. Therefore the input current I_{in} 610 will always be
15 within the lower and upper bound of the linear gain dynamic range of the preamplifier 700 so as to give good SNR. As a result, the value of the feedback resistor R_f 720 need not be restricted to prevent the preamplifier 700 from saturation or to give a good SNR. The problem of large power consumption and dissipation by the preamplifier 700 is also circumvented as the input current I_{in} 610 is controlled from
20 being too high.

In the photo-receiver arrangement according to the invention the parasitic capacitance C_{pd} 530 is isolated from the preamplifier 700 by the pre-scaler 600, and hence does not affect the stability of the amplifier 700. Therefore, the photodiode 520 can be
25 large-sized, thereby improving the sensitivity of the photo-sensor 500. Further, there

is no constraint to set the value of the feedback capacitor C_f 730 high in order to provide for a high stability of the preamplifier 700. Since the feedback resistor R_f 720 and the feedback capacitor C_f 730 are not restricted to certain values by bandwidth, stability and Signal-to-Noise Ratio aspects, they can be set to values so
5 as to obtain the desired gain and bandwidth for the preamplifier 700.

The photo-receiver arrangement according to the invention can be utilized in any kind of electrical devices, in particular in PDAs, handphones and laptops.



What is claimed is:

1. Photo-receiver arrangement comprising
 - a photo-sensor for capturing light being incident thereon within a predetermined range of light intensity values, and for converting the captured incident light into a first electrical signal;
 - a pre-scaler connected to an output of the photo-sensor for producing a second scaled electrical signal based on and corresponding to said first electrical signal input into the pre-scaler; and
 - a preamplifier connected to an output of the pre-scaler for amplifying said second scaled electrical signal input into the preamplifier, the preamplifier having a dynamic range of at least substantially linear gain;wherein the pre-scaler and the preamplifier are designed in a mutually matching configuration such that the second scaled electrical signal falls within the said dynamic range of the preamplifier for any light intensity value falling into said predetermined range of light intensity values.
2. Photo-receiver arrangement according to claim 1, wherein the photo-sensor is an infrared sensor, and the pre-scaler and the preamplifier are designed in matching relationship with the infrared sensor.
3. Photo-receiver arrangement according to claim 1, wherein the pre-scaler is designed such as to perform a scaling of said first electrical signal with a set of discrete scaling factors.



4. Photo-receiver arrangement according to claim 3, wherein the pre-scaler is designed such that its scaling factor is determined by said first electrical signal.
- 5 5. Photo-receiver arrangement according to any one of claims 1 to 4, wherein the pre-scaler comprises a programmable current mirror.
6. Photo-receiver arrangement according to claim 5, wherein the pre-scaler comprises a current sensing circuit, the current sensing circuit being connected
10 to said programmable current mirror for controlling the same.
7. Photo-receiver arrangement according to claim 6, wherein the current sensing circuit is an A/D converter.
- 15 8. Photo-receiver arrangement according to any one of claims 5 to 7, wherein the programmable current mirror is implemented by MOS or BJT transistors.
9. Photo-receiver arrangement according to any one of claims 1 to 8, wherein the preamplifier is a transimpedance amplifier comprising an operational
20 amplifier, a feedback resistor and a feedback capacitor connected between the output and the negative input of the operational amplifier.
10. Photo-receiver arrangement according to any one of claims 1 to 9, wherein the photo-sensor, the pre-scaler and the preamplifier are designed in a single-
25 ended configuration.



11. Photo-receiver arrangement according to any one of claims 1 to 9, wherein the photo-sensor, the pre-scaler and the preamplifier are designed in a differential or pseudo-differential configuration.
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12. Electrical device comprising a photo-receiver arrangement according to any one of claims 1 to 11.
13. Electrical device according to claim 12, wherein the electrical device is a
- 10 personal digital assistant, a handphone or a portable computer.