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(54) **Traffic light luminaire with colour stabilization**

(57) A traffic light luminaire (11; 31; 51, 52), in particular a railway traffic light luminaire, with
- a plurality of solid state light sources (12a-12e; 32a-32e), comprising a plurality of types (13-15; 33-35) of solid state light sources having different colours of emitted light,
- at least one light detector (16, 17; 36-41), and
- a control device (18; 42),
is characterized in that for a mixed operation mode, the control device (18; 42) is adapted to simultaneously operate at least two of said solid state light sources (12a-12e; 32a-32e), comprising at least two of said types (13-15; 33-35), such that a mixed colour light (19; 43) is generated, wherein the control device (18; 42) is adapted to maintain a luminous intensity of the solid state light sources (12a-12e; 32a-32e) of each of said at least two types (13-15; 33-35), as determined by means of the at least one light detector (16, 17; 36-41), at a predetermined intensity level for said type. The invention presents a traffic light luminaire, based on solid state light sources, which makes a broader range of colours available and allows keeping a selected color, corresponding to a particular signal state to be indicated, and its luminous intensity in a reliable way.

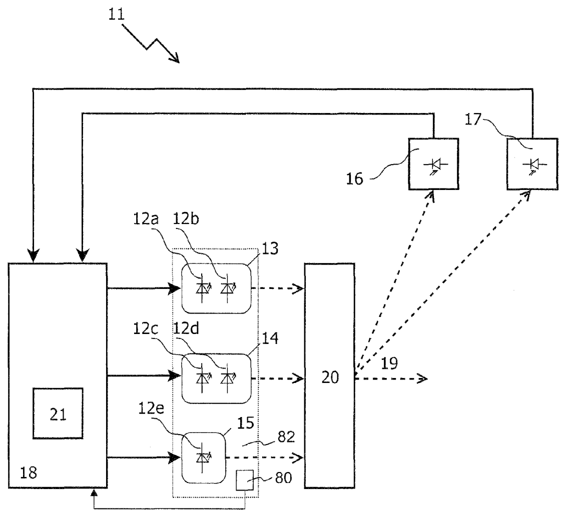

FIG. 1

EP 2 677 387 A1

Description

[0001] The invention relates to a traffic light luminaire, in particular a railway traffic light luminaire, with

- a plurality of solid state light sources, comprising a plurality of types of solid state light sources having different colours of emitted light,
- at least one light detector, and
- a control device.

[0002] Such a traffic light luminaire is known from WO 2011/086027 A1.

[0003] Traffic light luminaires which can emit different colours of light are integrated into various types of traffic lights, for example railway traffic lights.

[0004] To emit light for a specific signal state, a common traffic light luminaire comprises an electric light bulb combined with a colour filter. Light bulbs have the drawback of a rather limited lifetime, low light output efficiency and high energy consumption. The use of colour filters reduces the overall light output efficiency of a bulb-based luminaire even more.

[0005] Because of their long lifetime and low energy consumption, it is desired to use solid state light sources, especially light emitting diodes, in traffic light luminaires. Light emitting diodes are available in different types emitting different light colours.

[0006] A drawback of light emitting diodes is a considerable variation in the emitted luminous intensity level and chromaticity value of light emitting diodes of the same type with the same current supply. This variation depends on several parameters, for example tolerances during production, operating temperature and aging. In order to guarantee a minimum luminous intensity, which is often required by safety regulations, traffic light luminaires comprising light emitting diodes are often operated at a higher luminous intensity output than needed.

[0007] WO 2011/086027 A1 proposes a traffic light luminaire comprising different types of light emitting diodes for emitting different light colours. The luminous intensity of the luminaire is measured by two light detectors and maintained at a specified level by a control device. Different signal states are indicated by emitting different light colours wherein each light colour is solely emitted by one particular type of light emitting diodes.

[0008] On the one hand, light emitting diodes are only available in a limited number of emitted light colours or wavelengths, respectively. On the other hand, safety regulations often require a very specific light colour for a particular signal state of the traffic light luminaire. If no light emitting diodes of an appropriate colour are available, a corresponding signal state cannot be indicated by the traffic light luminaire of WO 2011/086027 A1. Even if light emitting diodes with a required light colour were available, the above mentioned variations in chromaticity can be so large that required safety regulations cannot be met reliably in practice.

[0009] In WO 00/37904 a luminaire is presented which emits a colour stabilized white light by simultaneously using light emitting diodes of different light colours. For maintaining the chromaticity of the white light, a photodiode measures the light output for each colour separately in a sequence of time pulses. In US 7,950,832 B2 a ceiling mount luminaire, in particular for domestic use, is presented which emits a mixed colour light of a desired chromaticity by simultaneously using light emitting diodes with different light colours. None of these two luminaires is designed to meet reliability requirements of traffic light signaling technology.

<u>Object of the Invention</u>

[0010] It is the object of the invention to present a traffic light luminaire, based on solid state light sources, which makes a broader range of colours available and allows keeping a selected colour, corresponding to a particular signal state to be indicated, and its luminous intensity in a reliable way.

<u>Short Description of the Invention</u>

[0011] This object is achieved by a traffic light luminaire as introduced above, characterized in that for a mixed operation mode, the control device is adapted to simultaneously operate at least two of said solid state light sources, comprising at least two of said types, such that a mixed colour light is generated, wherein the control device is adapted to maintain a luminous intensity of the solid state light sources of each of said at least two types, as determined by means of the at least one light detector, at a predetermined intensity level for said type.

[0012] The control device and the at least one light detector establish a feedback control loop on the luminous intensity of each type of said solid state light sources. Thereby the luminous intensity of each type of said solid state light sources can be independently maintained at a predetermined intensity level (applying "retroaction"). In particular, production tolerances, temperature changes, and aging of the solid state light sources which affect the emission efficiency and also (to some extent) emission wavelength can be compensated for. Note that the luminous intensities of the different types are typically not continuously determined, but intermittently (preferably periodically) determined, in general with intervals of unmonitored operation interrupted by reference cycles. In order to change the luminous intensity of a solid state light source, the control device typically alters the ratio of illuminated time and dark time at a constant peak current value (pulse width modulation).

[0013] By means of a mixing device, the output light of the solid state light sources of all types can be mixed together, to generate the mixed colour output light of the traffic light luminaire, preferably with a basically uniform intensity distribution and a desired directional characteristic.

[0014] Depending on the types of solid state light sources of the luminaire, a (continuous) range of colours or, to be more exact, chromaticity coordinates (colour locations) is available by mixing the light of the different types of solid state light sources. With three different types, mixed colours within a corresponding colour triangle are available, the corners of which correspond to the single colours of said types, compare the CIE 1931 colorimetry diagram. Two types allow mixed colours along a connecting line of the single colours in said diagram.

[0015] When the emission characteristics (including a central emission wavelength) of the types of the solid state light sources used are known (from the manufacturer, or checked by measurement, if variations are significant), the required intensity levels of each type (or level ratios) in order to obtain a desired mixed colour light of a specific chromaticity coordinate can be calculated (or obtained by experiment, if need may be). For example, for obtaining a green colour chromaticity coordinate of a central wavelength of 505 nm, a blue of 460 nm and a green of 530 nm central wavelength can be mixed at an intensity ratio of 1:13. The absolute intensity values for each type then result from the overall intensity level desired. By this means, in the example given, a green chromaticity coordinate signal in a defined target zone with a 505 nm central wavelength, which is required by a railway regulation (and for which no suitable single LED realizing exactly this chromaticity coordinate target zone is commercially available), can be generated with a green LED of 530 nm and a blue LED of 460nm, both of which are commercially available.

[0016] Due to the feedback control loop on the luminous intensity of each type of said solid state light sources, the chromaticity coordinate or output light colour, respectively, and the luminous intensity of the traffic light luminaire, is stabilized. If desired, the overall luminous intensity of the luminaire (including all colours) may additionally be monitored directly for checking plausibility.

[0017] In case that not all types of solid state light sources are needed to emit a particular mixed colour light, the at least one type of solid state light sources not needed is switched off, which means that it is operated at a zero luminous intensity level.

[0018] If necessary, the luminaire may be adapted to meet the requirements of a particular safety integrity level by including redundancies, in particular with respect to the light detector and/or the control device. More specifically, in order to prevent systematic faults and the control of random and systematic faults according CENELEC EN50129, the optical supervision can be based on dual electronic structure. Dual electronic structure is based on composite fail-safety with fail-safe comparison. For availability reason each supervision path is doubled.

[0019] Typically light emitting diodes or laser diodes are used as solid state light sources, and photo diodes or photo transistors are used as light detectors in accordance with the invention.

[0020] If required, the traffic light luminaire may be calibrated before a first time use or during maintenance, so that the luminous intensity values measured by the at least one light detector can reliably be correlated with the luminous intensities emitted by the different types of solid state light sources. The calibration may include a compensation for different detector sensitivities at different wavelengths. Further, a calibration may be done to identify the chromaticity coordinate of the different types of solid state light sources actually built in the traffic light luminaire, so that the predetermined intensity levels may be chosen appropriately; this is particularly useful if production tolerances of the solid state light sources considerably affect their emission wavelength. If needed, the chromaticity coordinates of the different types of solid state light sources can be determined as a function of temperature, so temperature induced variations can be compensated for during normal operation; for this purpose, the temperature of the solid state light sources has to be monitored and the predetermined intensity levels have to be adjusted according to said temperature. More generally, temperature dependent equipment of the retroaction loop (such as the light detectors or amplifiers) or the retroaction loop as a whole may be calibrated at different temperatures, if need may be.

Preferred Embodiments of the Invention

[0021] In a preferred embodiment, the inventive traffic light luminaire further comprises a light mixing device, mixing the light emitted from the plurality of solid state light sources, and the at least one light detector is coupled to the light mixing device. The light mixing device creates a mixed colour output light of the traffic light luminaire, with a basically uniform luminous intensity distribution and a desired directional characteristic. By coupling the at least one light detector to the light mixing device, scattered light of the light mixing device can be used which otherwise would be lost. In this embodiment, the at least one light detector may register light of any colour; it is not necessary to provide a light detector (or light detectors) for each type of solid state light sources separately.

[0022] Another preferred embodiment is characterized in that for determining the luminous intensity of the solid state light sources of each of said at least two types, the control device is adapted to regularly initiate reference cycles. By using reference cycles, it is possible to determine the luminous intensity of each type of solid state light sources with one light detector. Typically, the reference cycles are short enough so they cannot be detected by the naked eye; when a reference cycle has a duration of 20 ms or less, it cannot be detected by the naked eye. Further, reference cycles are typically spaced by at least 500 ms of normal operation. During a reference cycle, the solid state light sources or their types, respectively, are switched, in order to learn about the luminous intensity of each of the at least two types. In other words, the luminous intensities of the different types of solid state light sources are determined by means of a temporal discrimination. Note that if at least one detector with a matching colour filter is provided for each type at the mixing device, the intensity levels of the types can be measured directly, i.e. without reference cycles or temporal discrimination, respectively. Instead of a colour filters, a dispersive element can be used to obtain the spectral components of the mixed colour light.

[0023] In a further preferred development of the above mentioned embodiment, the control device is adapted such that a reference cycle includes determining and/or compensating for an ambient light intensity. This makes the determination of the luminous intensities of the solid state light sources more accurate. Determining and compensating for the ambient light intensity is unnecessary (and therefore can be done without) when no significant amount of ambient light reaches the detector(s). If desired, a determined ambient light intensity can be evaluated to adapt the overall luminous intensity of the luminaire, such as for switching between day and night operation.

[0024] In another preferred further development of the above mentioned embodiment, the control device is adapted such that a reference cycle includes

- a measurement of an overall light intensity, with the solid state light sources of all of said at least two types switched on,
- measurements of all partial light intensities, each with the solid state light sources of all but one of said at least two types switched on. By subtracting a measured partial light intensity from the measured overall light intensity, the luminous intensity of the solid state light sources of the type not switched on during the measurement of this partial light intensity can be calculated. This calculated luminous intensity is automatically compensated for ambient light intensity. Alternatively, the control device may be adapted such that a reference cycle includes a measurement of an ambient light intensity, with the solid state light sources of none of said at least two types switched on, and measurements of all single light intensities, each with the solid state light sources of only one of the at least two types switched on. The intensity of the solid state light sources of a particular type is calculated here by subtracting the measured ambient light intensity from the single light intensity of this type. Note that in the first approach the measured intensities tend to be higher than in the second approach, what makes the first approach less sensitive to measurement errors.

[0025] In a preferred embodiment of the inventive traffic light luminaire, the plurality of solid state light sources comprises at least three types of solid state light sources having different colours of emitted light. By using three or more different types of solid state light sources having different colours of emitted light, the possible light output colours of the traffic light luminaire can be selected within a broad range of colours. Typically a red light emitting type, a blue light emitting type and a green type emitting type is used, making available a practically complete colour palette. In addition or alternatively, a yellow light emitting type is used.

[0026] Also preferred is an embodiment of the inventive traffic light luminaire characterized in that the luminaire comprises at least one optical guide coupled to the plurality of solid state light sources, and that the at least one light detector is positioned for detecting the side illumination of the at least one optical guide. Optical guides are used to transport the light emitted by the plurality of solid state light sources, e.g. to the light mixing device of the traffic light luminaire. The side illumination i.e. stray light of the optical guides can be used by the at least one light detector to measure the luminous intensity of each of the at least two types of solid state light sources. Alternatively, a light detector can be placed close to a solid state light source to catch lost light from it.

[0027] In an also preferred embodiment, the controller device of the inventive traffic light luminaire comprises a storage with different sets of predetermined intensity levels for each type of the solid state light sources, corresponding to the different operation modes between which the controller device is switchable. The different operation modes allow the generation of different colours of emitted light with the same traffic light luminaire or its solid state light sources, respectively. The different sets of predetermined intensity levels for each type stored in the controller device are typically used for providing different signal colours (such as stop/pass signal colours), and/or for different ambient light conditions (such as day/night operation switching). The different operation modes include one or a plurality of mixed operation modes (generating a mixed colour each) and possibly one or a plurality of single operation modes (generating a single colour each), see below.

[0028] An also preferred embodiment of the inventive traffic light luminaire is characterized in that for a single operation mode, the control device is further adapted to operate the solid state light sources of one type only, such that a single colour light is generated, wherein the control device is adapted to maintain a luminous intensity of the solid state light sources of said one type, as determined by means of the at least one light detector, at a predetermined intensity level for said one type. In a single operation mode, only one type (i.e. colour) of solid state light sources is used for generating a light of a specific colour; all solid state light sources of other types (i.e. colours) are turned off (i.e. have a predetermined "zero" intensity level).

[0029] A particularly preferred embodiment provides that the traffic light luminaire further comprises at least one temperature sensor for measuring a temperature of the solid state light sources or a temperature correlated to the temperature of the solid state light sources, and that the control device is adapted to derive at least some of the predetermined intensity levels from a temperature measured with said at least one temperature sensor and a predetermined function of the measured temperature for the corresponding predetermined intensity level. In this way, chromaticity coordinate changes of a signal due to temperature induced changes in the emission wavelength of the different types of solid state light sources can be avoided. The chromaticity coordinate is kept reliably.

[0030] Further within the scope of the invention is a traffic light signal comprising at least one inventive traffic light luminaire. Typical traffic light signals include traffic lights known from road traffic, but may also include railway signals, airport signals, lock signals for ship traffic and the like. A traffic light signal often includes a plurality of the inventive traffic light luminaires, in particular for different signal colours.

[0031] A preferred embodiment of the above mentioned traffic light signal is characterized in that the traffic light signal is a railway signal.

[0032] For railway signals, there are particularly strict requirements for colour stability, which may be easily met by means of the inventive traffic light signal.

[0033] Also within the scope of the invention is a method for operating a traffic light luminaire with a plurality of solid state light sources comprising a plurality of types of solid state light sources having different colours of emitted light, characterized in that in a mixed operation mode, at least two of said solid state light sources, comprising at least two of said types, are operated simultaneously such that a mixed colour light is generated, wherein the luminous intensity of the solid state light sources of each of said at least two types, as determined by at least one light detector, is maintained at a predetermined intensity level for said type. The inventive method is typically used with an inventive traffic light luminaire as described above. The luminous intensities of the different types are feedback controlled, in accordance with the invention. Accordingly, the generated resulting mixed colour is highly stable in colour location and luminous intensity.

[0034] In a preferred variant of the above mentioned inventive method, the traffic light luminaire is switched between different operation modes, in which different sets of predetermined intensity levels for the plurality of types of solid state light sources are applied. This allows a switching of colour of the traffic light luminaire. The different operation modes include one or a plurality of mixed operation modes (generating a mixed colour each) and possibly one or a plurality of single operation modes (generating a single colour each), see below. In a mixed operation mode the output colour is generated by using at least two different types of solid state light sources. In a single operation mode only one type of solid state light sources is used.

[0035] Another preferred variant of the above mentioned method of operating the inventive traffic light luminaire is characterized in that at least one of the operation modes is a single operation mode in which the solid state light sources of one type only are operated, such that a single colour light is generated, wherein the luminous intensity of the solid state light sources of said one type, as determined by means of the at least one light detector, is maintained at a predetermined intensity level for said one type.

[0036] In a particularly preferred variant, at least some of the predetermined intensity levels are derived from a measured temperature of the solid state light sources or a measured temperature correlated to the temperature of the solid state light sources and a predetermined function of the measured temperature for the corresponding predetermined intensity level. In this way, changes in the emission wavelength of the different types of solid state light sources (e.g. LEDs) due to temperature variations can be compensated for, making the chromaticity coordinate of the signal more reliable.

[0037] In a preferred further development of this variant, for several specific temperature values, specific function values of the predetermined function are tabulated, and for temperature values between the specific temperature values, function values of the predetermined function are derived by interpolation, in particular linear, parabolic or exponential interpolation. This is simple to realise. By using enough interpolation points (i.e. specific temperature values and corresponding specific function values), even a complex temperature behaviour of the solid state light sources (e.g. LEDs) may be compensated for. The type of interpolation may be chosen depending on the underlying physical effects and the precision necessary.

[0038] An also preferred variant of the above mentioned method is characterized in that for determining the luminous intensity of the solid state light sources of each of said at least two types, the control device is adapted to regularly initiate reference cycles. Within a reference cycle the luminous intensity of each type of the solid state light sources can be determined with one light detector, preferably in a temporal discrimination approach.

[0039] An especially preferred variant of the above mentioned operation method is characterized in that a reference cycle includes determining and/or compensating for an ambient light intensity Thus the intensity levels of the solid state light sources of the different types can be measured (and controlled) more accurately.

[0040] Preferred is further a method to operate the inventive traffic light luminaire, characterized in that a reference cycle includes

- a measurement of an overall light intensity, with the solid state light sources of all of said at least two types switched on,
- measurements of all partial light intensities, each with the solid state light sources of all but one of said at least two types switched on. From these measurements, the luminous intensities of the different types can be calculated with a good accuracy, with an automatic compensation for ambient light.

[0041] Especially preferred is a method to operate the inventive traffic light luminaire, characterized in that for setting the luminous intensity of the solid state light sources of each of said at least two types, the duty cycles of the solid state light sources of each of said types are adjusted. In other words, the ratio of illuminated time and dark time is adjusted. This adjustment is highly linear and therefore easy to handle.

[0042] Further advantages can be extracted from the description and the enclosed drawing. The features mentioned above and below can be used in accordance with the invention either individually or collectively in any combination. The embodiments mentioned are not to be understood as exhaustive enumeration but rather have exemplary character for the description of the invention.

Detailed Description of the Invention and Drawings

[0043] The invention is shown in the drawings and will be explained in detail using exemplary embodiments. In the drawings:

FIG. 1: shows a schematic drawing of a first embodiment of the inventive traffic light luminaire, wherein the luminous intensity of each type of solid state light sources is determined after passing a light mixing device;

FIG. 2: shows a schematic drawing of a second embodiment of the inventive traffic light luminaire, wherein the luminous intensity of each type of solid state light sources is determined before reaching a light mixing device;

FIG. 3: shows an inventive traffic light signal comprising two inventive traffic light luminaires.

FIG. 4: shows a first driving scheme (current vs. time t) of a traffic light luminaire in accordance with the invention, comprising a reference cycle wherein the luminous intensity of each type of light emitting diodes is determined by sequentially switching off all but one of said types of light emitting diodes, and switching off all light emitting diodes;

FIG. 5: shows a second driving scheme (current vs. time t) of the traffic light luminaire in accordance with the invention, comprising a reference cycle wherein the luminous intensity of each type of light emitting diodes is determined by sequentially switching off one of said types of light emitting diodes, and switching on all light emitting diodes.

[0044] In FIG. 1 a schematic drawing of a preferred embodiment of the invention is presented. The inventive traffic light luminaire 11 comprises a plurality of light emitting diodes 12a-12e of here three different types 13, 14, 15. Instead of light emitting diodes, also laser diodes or other semiconductor light sources can be used as solid state light sources.

[0045] The different types 13-15 of light emitting diodes are characterized by emitting different light colours. In FIG. 1 the traffic light luminaire 11 comprises two light emitting diodes 12a, 12b of a first type 13 of light emitting diodes which emit a red colour light, two light emitting diodes 12c, 12d of a second type 14 of light emitting diodes which emit a blue colour light and one light emitting diode 12e of a third type which emits a green colour light.

[0046] The different types 13-15 of light emitting diodes are driven by a control device 18. To control the luminous intensity of the different types 13-15 of light emitting diodes 12a-12e, pulse width modulation or a current strength adjustment can be used in particular.

[0047] In FIG. 1 optical paths are marked by dashed lines and electrical paths are marked by continuous lines. The optical paths from the light emitting diodes 12a-12e to a light mixing device 20 can be realized by using optical light guides. The light emitted by the red colour type 13, the blue colour type 14 and the green colour type 15 is combined in the light mixing device 20 which generates mixed colour output light 19. The design of the light mixing device 20 (or light mixing and shaping block, optical building block) also cares for a uniform luminous intensity and a desired directional characteristic of the light emitted by the luminaire 11. Concepts known from flat panel display backlighting (light pipe) and/or LCD projectors (light integrator and light combiner) may be applied to provide the mixed colour light. If desired, a collecting block may be used before the mixing device 20 to facilitate the connection of the different optical paths to the mixing device 20, and/or a magnification block may be used after the mixing device 20 to further shape a light signal requested, and/or a distributor may be used after the magnification block (or after the mixing device 20) to adapt to the actual location of the light signal (curve, slope, etc.).

[0048] To maintain the light output colour at a constant chromaticity value and the luminous intensity at a constant intensity level, a feedback control loop is established by using the control device 18. The mixed colour output light 19 is measured by two light detectors 16, 17 in order to determine the luminous intensity emitted by each of said types 13-15 of light emitting diodes. The light detectors for example can be placed in a way that they detect the scattered light of the light mixing device 20. As light detecting devices 16, 17 for example photodiodes or phototransistors can be used. The detected luminous intensity values of each of said types 13-15 of light emitting diodes 12a-12e are compared to preset (predetermined) intensity levels. If, for example, the luminous intensity emitted by the red colour type 13 and detected by the two light detectors 16, 17 is lower than a preset intensity level, the ratio of illuminated time and dark time can be increased, or a driving current for the light emitting diodes 12a, 12b can be increased by the control device 18 until the preset (average) luminous intensity level for the red colour type is reached. On the contrary, if the luminous intensity is higher than the preset intensity level, said ratio can be decreased, or said driving current can be reduced.

[0049] In order to compensate for a temperature dependence of the detector characteristic, a temperature sensor (not shown) can be installed nearby the detectors 16, 17. The correlation of the detector signals to a luminous intensity can then be done taking into account the present detector temperature, e.g. by consulting a stored table of detector characteristics for different temperature intervals.

[0050] By controlling the luminous intensity of each of said types 13-15 of light emitting diodes 12a-12e, a desired chromaticity value and overall luminous intensity of the mixed output light 19, arbitrarily chosen within a possible range, determined by the light emitting diodes 12a-12e used, can be emitted by the luminaire 11. By using the feedback control loop, the mixed output colour light 19 is stabilized. The mixed output colour light 19 is independent of variations in the emission efficiency of the plurality of light emitting diodes (12a-12e). Such variations can occur due to production process tolerances, temperature changes or aging for example. If desired, variations of the light colour (emission wavelength) due to production tolerances of the LEDs 12a-12e can be compensated for by choosing (relative) luminous intensities of the different types compensating for these variations; the (average) light colour of the different types of LEDs may be identified and compensated intensity levels may be determined before a first operation ("initial calibration"). Therefore traffic light safety regulations regarding a stabilized chromaticity value and light intensity level can easily be met by the inventive traffic light luminaire 11.

[0051] To display different signal states with one traffic light luminaire 11, the control device 18 comprises a storage (memory) 21, in which the luminous intensity levels for each of said types 13-15 of light emitting diodes 12a-12e corresponding to each signal state are stored. For example a signal state indicating "stop" with a red mixed light with a touch of orange output colour (intensity levels single red : single green : single blue = 15 : 1: 0 in arbitrary units) and a signal state indicating "go" with a green mixed light with a touch of blue output colour (intensity levels single red : single green : single blue = 0 : 14: 2 in arbitrary units) can be displayed by using only one traffic light luminaire 11. Each signal state or corresponding (mixed or single) colour light, respectively, corresponds to a different operation mode, and the storage 21 has stored a set of predetermined intensity levels for the types 13-15 for each operation mode.

[0052] In order to compensate for a temperature dependence of the emission wavelength of the LEDs 12a-12e, the traffic light luminaire 11 can be modified as follows: a temperature sensor 80 is installed near the light emitting diodes 12a-12e. In the embodiment shown, all LEDs 12a-12e are placed on a common metal carrier 82, such that all LEDs 12a-12e have the same temperature in good approximation, and the temperature sensor 80 on the carrier 82 measures a temperature closely correlated to the common LED temperature (if the different types 13-15 of LEDS 12a-12e have significantly different temperatures during normal operation, a temperature sensor for each type 13-15 may be employed). The predetermined intensity levels are stored in the storage 21 as predetermined functions of the temperature of the LEDs. For the above mentioned red "stop" signal with the touch of orange, for example, it is known that at higher temperatures, a higher green content is necessary to stick to the required chromaticity coordinate of the signal, since the emission of the green LED 12e moves towards longer wavelengths. The memory 21 has stored as red "stop" signal intensity level information or predetermined function for the single red colour: 15 at 20°C and 14 at 80°C, further for the single green colour: 1 at 20°C and 2 at 80°C, and further for the single blue colour: 0 at all temperatures (in arbitrary units again); all temperatures in between 20°C and 80°C are to be interpolated linearly. If the LEDs 12a-12e are operated at 50°C, the interpolation gives predetermined intensity levels of single red : single green : single blue of 14.5 : 1.5 : 0. For other temperatures, other predetermined intensity levels will result, so that the desired chromaticity coordinate of the (total) signal is adhered to at every LED temperature. Note that for a complex temperature behaviour of the LEDs 12a-12e, a higher number of calibration points (such as five or more) may be necessary.

[0053] To meet specified safety requirements, parts of the traffic light luminaire 11 can be implemented redundant. In FIG. 1 two light detectors 16, 17 are used to increase reliability. Also the control device 18 in parts or as a whole can be implemented redundant (not shown in detail). Further, additional light emitting diodes 12a-12e of each of said types 13-15 can be used to compensate for defective light emitting diodes during operation. By means of the chromaticity value and luminous intensity stabilized mixed output light 19, together with the redundancies mentioned above, even strict requirements for traffic light luminaires imposed by law (including various safety integrity levels for traffic lights) can be met easily.

[0054] Before the traffic light luminaire 11 is used for the first time or during maintenance activities, it can also be calibrated to compensate for deviations in the sensitivity of the light detectors 16,17 or variations of the optical properties of the optical paths and the light mixing device 20.

[0055] **FIG.** 2 depicts a second traffic light luminaire 31 according to the invention, similar to the one shown in Fig. 1; accordingly, emphasis is put on describing the differences here. The traffic light luminaire 31 comprises a plurality of light emitting diodes 32a-32e of three different types 33-35 again. The traffic light luminaire 31 also comprises a control device 42 with a storage (memory) 45 and a light mixing device 44 for mixing the output light 43.

[0056] In contrast to the embodiment in FIG. 1, the light detectors 36-41 are measuring the luminous intensities of the light emitted by the different types 33-35 of light emitting diodes 32a-32e separately, i.e. before entering the light mixing device 44, for example as scattered light of an optical guide leading form the LEDs 32a-32e to the mixing device 44 ("edge injection"). The luminous intensity emitted by the light emitting diodes 32a, 32b of a first, red light colour type 33 is only measured by the light detectors 36, 37. The light detectors 38, 39 only measure the light emitted by the light emitting diodes 32c, 32d of a second, blue colour type. Finally the light detectors 40, 41 only measure the light emitted by a third, green light colour type. Note that the light of the LEDs of the same type (such as the light of LEDs 32a, 32b of type 33) is mixed here (at least on the detector) before detection (here with light detectors 36, 37).

[0057] To improve reliability the embodiment of the invention diagrammed in FIG. 2 comprises two light detectors 36-41 for each type 33-35 of light emitting diodes.

[0058] Note that the concept of Fig. 1, with common intensity detection for the solid state light sources of all types is particularly suited when plenty of solid state light sources per type are used, such as twelve solid state light sources or more per type. The concept of Fig. 2, with separate detectors for each type of solid state light sources is particularly suited when only few solid state light sources per type are used, such as only one solid state light source per type.

[0059] In **FIG.** 3 an inventive traffic light signal 50 comprising two inventive traffic light luminaires 51, 52 is shown. Such a traffic light signal can be applied to any kind of traffic control, for example road traffic, rail traffic and airport taxiway traffic.

[0060] In the example shown, luminaire 51 comprises LEDs of a (single) red and (single) green type, so a mixed colour red "stop" signal (with a touch of orange) can be generated. Luminaire 52 comprises LEDs of (single) green and (single) blue type, so a mixed colour green "pass" signal (with a touch of blue) can be generated.

[0061] It should be noted that in general an inventive traffic light luminaire and an inventive traffic light can be used to generate mixed colour red ("stop") signal and/or a mixed colour green ("pass") signal and/or a mixed colour yellow ("alert") signal.

[0062] Due to the use of semiconductor light sources, for example light emitting diodes or laser diodes, a better directivity of light emission of each luminaire 51, 52 of the traffic light 50 in FIG. 3 can be achieved, which increases the visibility of the traffic light 50 at long distances.

[0063] **FIG.** 4 shows a possible driving scheme of the inventive traffic light luminaire depicted in FIG. 1 described above, based on single intensity measurements. In this driving scheme all light emitting diodes 12a-12e are operated by using pulse width modulation.

[0064] The first row 60 in FIG. 4 illustrates the output signal of the control device 18 for the first, red type 13 of light emitting diodes 12a, 12b over time t; the second row 61 shows the output signal for the second, blue type 14 of light emitting diodes 12c, 12d and the third row 62 shows the output signal for the light emitting diode 12e of the third, green type 15. The first time interval 63 corresponds to a normal operation phase, in which a fresh green mixed colour (with moderate red and low blue content) is emitted. Within the time interval of a reference cycle 68, four luminous intensity measurements 64-67 are carried out; note that these measurements are of integral type, indicating the average luminous flux (and not the peak power).

[0065] During the time interval of the first measurement 64 of the reference cycle 68 only the light emitting diodes 12a, 12b of the red light colour type 13 are switched on. During the time interval of the second measurement 65 only the light emitting diodes 12c, 12d of the blue light colour type 14 are switched on, and during the third time interval 66 only the green light colour type 15 light emitting diode 12e is switched on. Note that the duty cycle corresponds to the normal operation of the time interval 63 (to be checked) in each case for the illuminated LEDs. Finally during the time interval 67 of the last measurement in the reference cycle all types 13-15 of light emitting diodes are switched off; this directly reveals an ambient light intensity level reaching the detectors 16, 17.

[0066] After conducting the reference cycle 68 the control device 18 determines the luminous intensities of all of said types 13-15 of light emitting diodes 12a-12e. By subtracting the luminous intensity value measured by the light detectors 16, 17 during the time interval 67 from luminous intensity value measured during the time interval 64, the luminous intensity value of the red light colour type 13, independent of any ambient light influence, can be determined. In the same way, by subtracting the luminous intensity value measured during the time interval 67 from that value measured during the time interval 65, the luminous intensity value of the blue light colour type 14, can be determined. Finally by subtracting the luminous intensity value measured during the time interval 67 from the value measured during time interval 66, the luminous intensity value of the green light colour type 15 can be determined.

[0067] In addition a measurement of an overall light intensity can be conducted by the control device 18. During the time interval 63 of this measurement, all types 13-15 of light emitting diodes are switched on.

[0068] In **FIG.** 5 another driving scheme of the inventive traffic light luminaire depicted in FIG. 1, based on partial light intensity measurements, is diagrammed. In this driving scheme, again all light emitting diodes 12a-12e are operated by using pulse width modulation.

[0069] The first row 70 in FIG. 5 illustrates the output signal of the control device 18 for the first, red type 13 of light emitting diodes 12a, 12b over time t; the second row

71 shows the output signal for the second, blue type 14 of light emitting diodes 12c, 12d and the third row 72 shows the output signal for the light emitting diode 12e of the third, green type 15. Time interval 73 again indicates the duty cycles during normal operation, but is here also part of a reference cycle 78; a fresh green mixed colour (with moderate red and low blue content) is emitted again during normal operation. Within the time interval of the reference cycle 78, four luminous intensity measurements 73-76 are carried out.

[0070] During the time interval of the first measurement 73 of the reference cycle 78 all types 13-15 of light emitting diodes 12a-12e are switched on. During the time interval of the second measurement 74 only the light emitting diodes 12a, 12b of the red light colour type 13 are switched off, during the third time interval 75 only the blue light colour type 14 light emitting diodes 12c, 12d are switched off. Finally during the time interval 76 of the last measurement in the reference cycle only the light emitting diode 12e of the green light colour type 15 is switched off. Note that in these partial light intensity measurements, for the illuminated LEDs, the same duty cycles as in the normal operation mode (to be checked) are applied.

[0071] After conducting the reference cycle 78 the control device 18 determines the luminous intensities of all of said types 13-15 of light emitting diodes 12a-12e. By subtracting the luminous intensity value measured by the light detectors 16, 17 during the time interval 74 from luminous intensity value measured during the time interval 73, the luminous intensity value of the red light colour type 13, independent of any ambient light influence, can be determined (ambient light is present in both intensity values, and therefore is intrinsically compensated for). In the same way, by subtracting the luminous intensity value measured during the time interval 75 from that value measured during the time interval 73, the luminous intensity value of the blue light colour type 14, can be determined. Finally by subtracting the luminous intensity value measured during the time interval 76 from the value measured during time interval 73, the luminous intensity value of the green light colour type 15 can be determined.

[0072] In addition a direct measurement of an ambient light intensity level can be conducted by the control device 18. During the time interval 77 of this measurement, all types 13-15 of light emitting diodes are switched off.

[0073] Besides the driving schemes presented in FIG. 4 and FIG. 5, a plurality of other driving schemes for conducting a reference cycle is possible. As long as there are at least as many measurement intervals as there are types of light emitting diodes used in the inventive traffic light luminaire and in each measurement interval an independent combination of said types of light emitting diodes is switched off, the luminous intensity of each of said types of light emitting diodes can be determined by the control device. However, the driving scheme of FIG. 5 is particularly preferred, since it can provide the luminous intensities of the types quickly with inherent compensation of ambient light (without the need to switch off the luminaire completely during a measurement interval) and at a high accuracy (with all intensities well above noise level).

Claims

1. A traffic light luminaire (11; 31; 51, 52), in particular a railway traffic light luminaire, with

   - a plurality of solid state light sources (12a-12e; 32a-32e), comprising a plurality of types (13-15; 33-35) of solid state light sources having different colours of emitted light,
   - at least one light detector (16, 17; 36-41), and
   - a control device (18; 42),

   characterized in
   that for a mixed operation mode, the control device (18; 42) is adapted to simultaneously operate at least two of said solid state light sources (12a-12e; 32a-32e), comprising at least two of said types (13-15; 33-35), such that a mixed colour light (19; 43) is generated, wherein the control device (18; 42) is adapted to maintain a luminous intensity of the solid state light sources (12a-12e; 32a-32e) of each of said at least two types (13-15; 33-35), as determined by means of the at least one light detector (16, 17; 36-41), at a predetermined intensity level for said type.

2. A traffic light luminaire (11; 31; 51, 52) according to claim 1, **characterized in that** the traffic light luminaire (11; 31; 51, 52) further comprises a light mixing device (20; 44), mixing the light emitted from the plurality of solid state light sources (12a-12e; 32a-32e), and that the at least one light detector (16, 17; 36-41) is coupled to the light mixing device (20; 44).

3. A traffic light luminaire (11; 31; 51, 52) according to claim 1, **characterized in that** for determining the luminous intensity of the solid state light sources (12a-12e; 32a-32e) of each of said at least two types (13-15; 33-35), the control device (18; 42) is adapted to regularly initiate reference cycles (68; 78).

4. A traffic light luminaire (11; 31; 51, 52) according to claim 3, **characterized in that** the control device (18; 42) is adapted such that a reference cycle (68; 78) includes determining and/or compensating for an ambient light intensity.

5. A traffic light luminaire (11; 31; 51, 52) according to claim 3, **characterized in that** the control device (18; 42) is adapted such that a reference cycle (78) includes

- a measurement of an overall light intensity (73), with the solid state light sources (12a-12e; 32a-32e) of all of said at least two types (13-15; 33-35) switched on,
- measurements of all partial light intensities (74-76), each with the solid state light sources (12a-12e; 32a-32e) of all but one of said at least two types (13-15; 33-35) switched on.

6. A traffic light luminaire (11; 31; 51, 52) according to claim 1, **characterized in that** the controller device (18; 42) comprises a storage (21; 45) with different sets of predetermined intensity levels for each type (13-15; 33-35) of the solid state light sources (12a-12e; 32a-32e), corresponding to the different operation modes between which the controller device (18; 42) is switchable.

7. A traffic light luminaire according to claim 1, **characterized in that** the traffic light luminaire (11) further comprises at least one temperature sensor (80) for measuring a temperature of the solid state light sources (12a-12e; 32a-32e) or a temperature correlated to the temperature of the solid state light sources (12a-12e; 32a-32e), and that the control device (18; 42) is adapted to derive at least some of the predetermined intensity levels from a temperature measured with said at least one temperature sensor (80) and a predetermined function of the measured temperature for the corresponding predetermined intensity level.

8. A traffic light signal (50) comprising at least one traffic light luminaire (11; 31; 51, 52) according to claim 1.

9. A traffic light signal (50) according to claim 8, **characterized in that** the traffic light signal is a railway signal.

10. A method for operating a traffic light luminaire (11; 31;51, 52) with a plurality of solid state light sources (12a-12e; 32a-32e) comprising a plurality of types (13-15; 33-35) of solid state light sources having different colours of emitted light,
characterized in
that in a mixed operation mode, at least two of said solid state light sources (12a-12e; 32a-32e), comprising at least two of said types (13-15; 33-35), are operated simultaneously such that a mixed colour light (19; 43) is generated,
wherein the luminous intensity of the solid state light sources (12a-12e; 32a-32e) of each of said at least two types (13-15; 33-35), as determined by at least one light detector (16, 17; 36-41), is maintained at a predetermined intensity level for said type.

11. Method according to claim 10, **characterized in that** the traffic light luminaire (11; 31; 51, 52) is switched between different operation modes, in which different sets of predetermined intensity levels for the plurality of types (13-15; 33-35) of solid state light sources (12a-12e; 32a-32e) are applied.

12. Method according to claim 10, **characterized in that** at least some of the predetermined intensity levels are derived from a measured temperature of the solid state light sources (12a-12e; 32a-32e) or a measured temperature correlated to the temperature of the solid state light sources (12a-12e; 32a-32e) and a predetermined function of the measured temperature for the corresponding predetermined intensity level.

13. Method according to claim 12, **characterized in that** for several specific temperature values, specific function values of the predetermined function are tabulated, and for temperature values between the specific temperature values, function values of the predetermined function are derived by interpolation, in particular linear, parabolic or exponential interpolation.

14. A method according to claim 10, **characterized in that** for determining the
luminous intensity of the solid state light sources (12a-12e; 32a-32e) of each of said at least two types (13-15; 33-35), the control device (18; 42) is adapted to regularly initiate reference cycles (68; 78).

15. A method according to claim 10, **characterized in that** a reference
cycle (68; 78) includes determining and/or compensating for an ambient light intensity.

16. A method according to claim 10, **characterized in that** a reference
cycle (78) includes

- a measurement of an overall light intensity (73), with the solid state light sources (12a-12e; 32a-32e) of all of said at least two types (13-15; 33-35) switched on,
- measurements of all partial light intensities (74-76), each with the solid state light sources (12a-12e; 32a-32e) of all but one of said at least two types (13-15; 33-35) switched on.

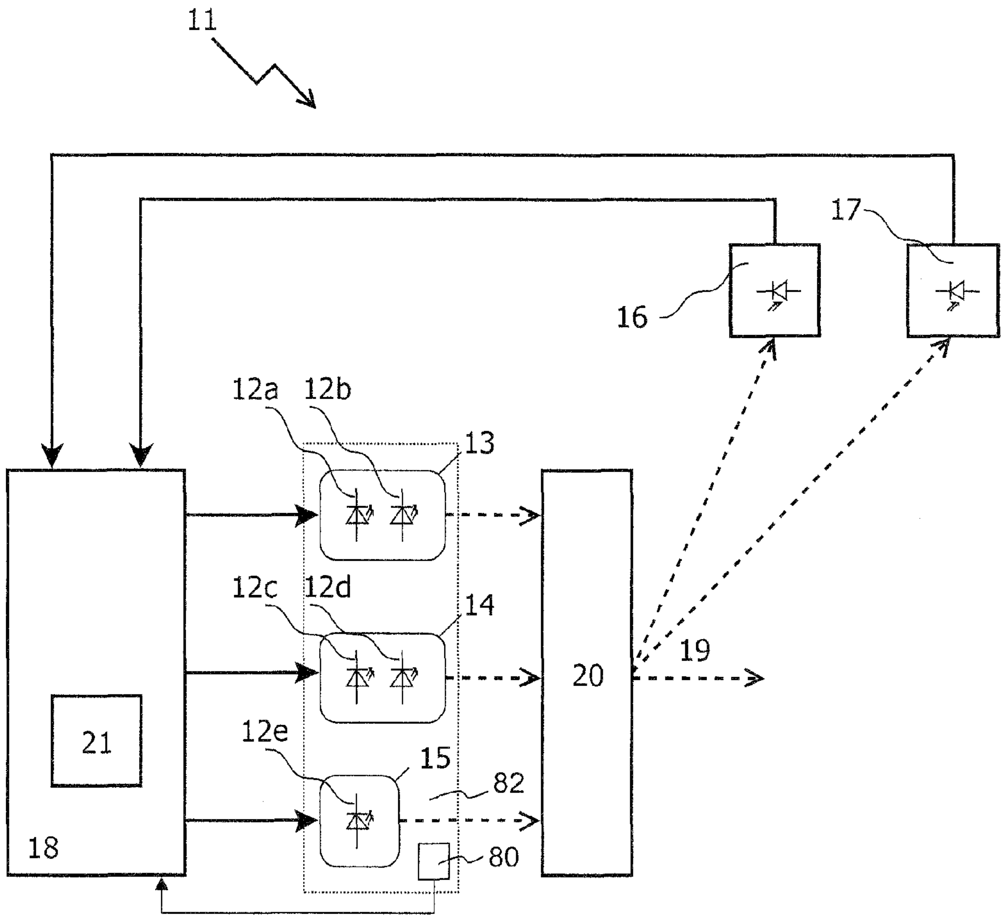

FIG. 1

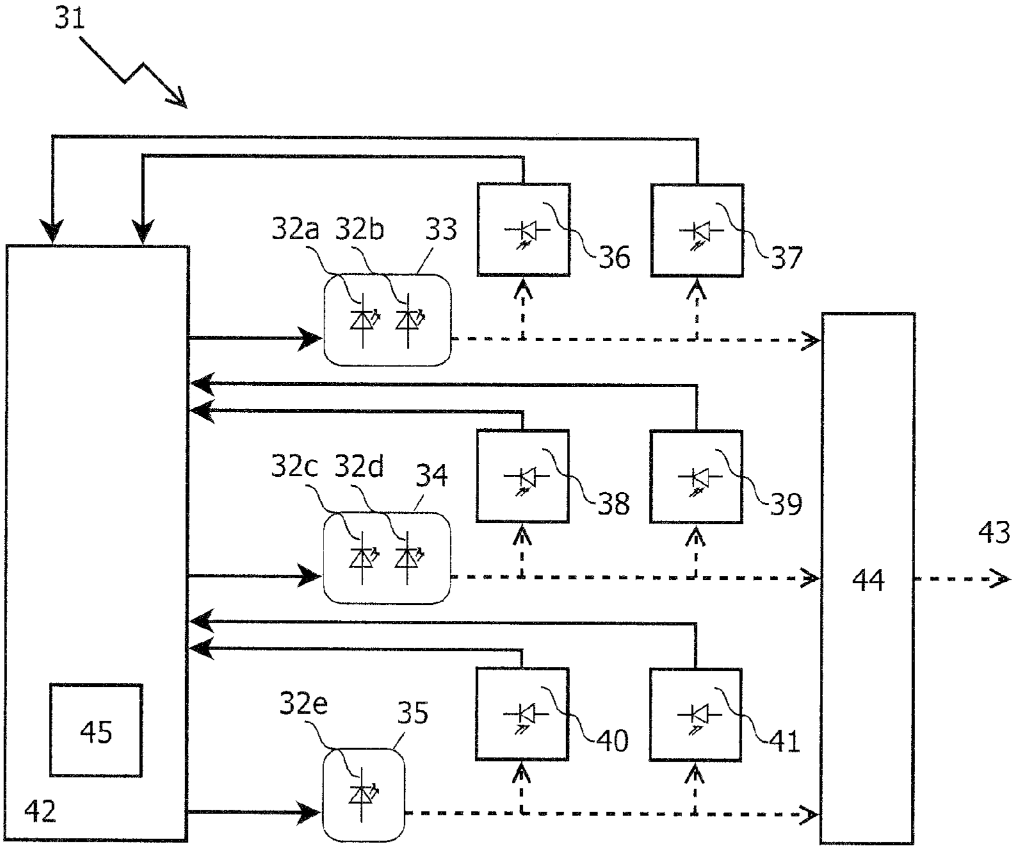

FIG. 2

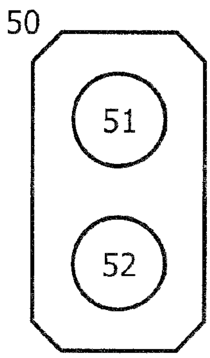

FIG. 3

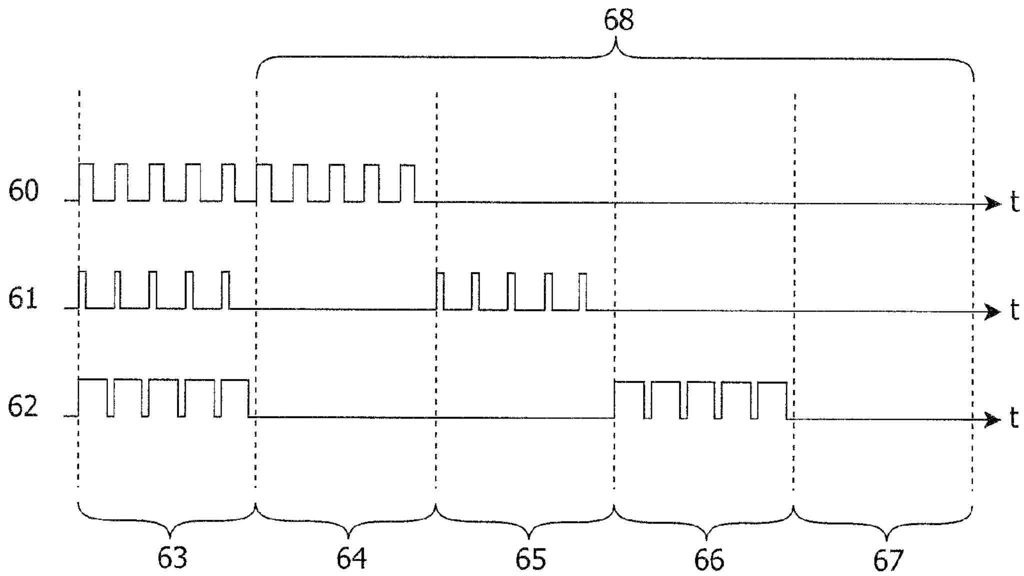

FIG. 4

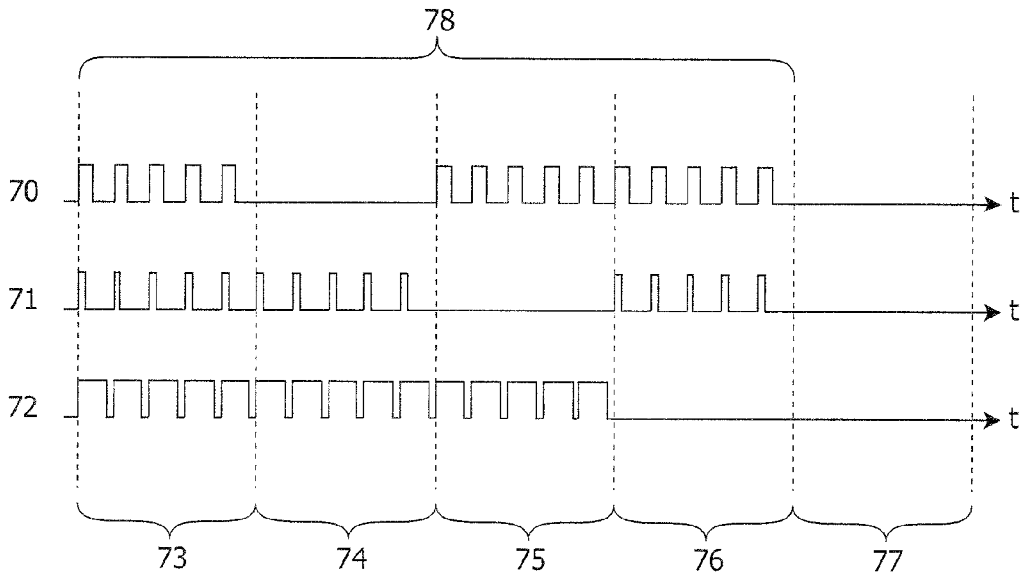

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 12 17 2424

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2008/251690 A1 (KEIPER OLIVER [DE] ET AL) 16 October 2008 (2008-10-16) * paragraphs [0035], [0041], [0071], [0078] * * figure 3 *	1-3,5,7, 10,12, 14,16	INV. G05D25/02 H05B33/08
X	WO 2011/098334 A1 (OSRAM GMBH [DE]; FROST TOBIAS [DE]; LANCHAVA BAKURI [DE]) 18 August 2011 (2011-08-18) * page 7, lines 4-6 * * claim 1 * * figure 1 *	1,3-5,7, 10,12, 14-16	
X,D	WO 00/37904 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]) 29 June 2000 (2000-06-29) * the whole document *	1-3,5, 10,14,16	
X	DE 10 2007 036978 A1 (TRIDONICATCO GMBH & CO KG [AT]) 12 February 2009 (2009-02-12) * paragraphs [0008], [0020] * * figures 3-5 *	1,3,5, 10,14,16	TECHNICAL FIELDS SEARCHED (IPC) G05D H05B
X,D	US 7 950 832 B2 (TANAKA KENICHIRO [JP] ET AL) 31 May 2011 (2011-05-31) * abstract * * column 5, lines 28-38 *	1,2,10	
X,D	WO 2011/086027 A1 (SIEMENS AG [DE]; TEMMING RUDOLF [DE]) 21 July 2011 (2011-07-21) * page 6, lines 1-17 *	1,2,10	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	28 November 2012	Westholm, Mats

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 17 2424

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28-11-2012

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008251690 A1	16-10-2008	DE 102007018224 A1	23-10-2008
		US 2008251690 A1	16-10-2008
WO 2011098334 A1	18-08-2011	CN 102754526 A	24-10-2012
		DE 102010028406 A1	18-08-2011
		EP 2499883 A1	19-09-2012
		WO 2011098334 A1	18-08-2011
WO 0037904 A1	29-06-2000	CN 1291282 A	11-04-2001
		DE 69906260 D1	30-04-2003
		DE 69906260 T2	04-12-2003
		EP 1056993 A1	06-12-2000
		JP 4147004 B2	10-09-2008
		JP 4642870 B2	02-03-2011
		JP 2002533870 A	08-10-2002
		JP 2008198618 A	28-08-2008
		US 6127783 A	03-10-2000
		WO 0037904 A1	29-06-2000
DE 102007036978 A1	12-02-2009	CN 101772988 A	07-07-2010
		DE 102007036978 A1	12-02-2009
		EP 2177078 A1	21-04-2010
		US 2010301757 A1	02-12-2010
		WO 2009018958 A1	12-02-2009
US 7950832 B2	31-05-2011	CN 101390451 A	18-03-2009
		EP 1988752 A1	05-11-2008
		JP 4720904 B2	13-07-2011
		KR 20080091248 A	09-10-2008
		US 2010219760 A1	02-09-2010
		WO 2007099860 A1	07-09-2007
WO 2011086027 A1	21-07-2011	DE 102010005088 A1	21-07-2011
		WO 2011086027 A1	21-07-2011

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- WO 2011086027 A1 **[0002] [0007] [0008]**
- WO 0037904 A **[0009]**
- US 7950832 B2 **[0009]**