[0011] Examples of possible configurations are shown in Figure 1 for a magnetic inductor ballast 5 and in Figure 2 for an electronic ballast 6, connected to mains power supply 7. The LED lamp 1 comprises LEDs 2 and an LED driver circuit 3, as well as safety devices 4 to secure proper functioning of the LED driver. Such safety devices 4 ensure that prior fluorescent lamps are connected on both sides to a combination of the ballast 5, 6 and mains power 7, before circuits are actually established for lighting the fluorescent lamp.

[0012] This approach entails a two-stage conversion of the power to (at least approximately) again obtain mains power supply for the LEDs 2. The first conversion is performed by the ballast 5 or 6 and the second conversion is performed by the internal LED driver 3 in the LED lamp 1. With respect to regulating power to the LEDs, a conversion step or stage by the LED driver 3 in the LED lamp 1 should be at least approximately inverse to the transfer characteristics of the ballast 5 or 6, requiring two operating modes of the LED driver 3 for an electronic ballast as the precise type of ballast (a magnetic inductor based ballast or electronic ballast) is normally not known when inserting a LED lamp 1 into an existing luminaire.

[0013] It is highly desired to be able to manufacture a single type of LED lamp, and not several types to comply with the type of ballast, which would also avoid the problem of having to determine the type of ballast before purchasing a replacement LED lamp of the required type. The preferably uniform LED driver 3 of Figures 1 and 2 would be required to detect the type of ballast actually arranged in the luminaire and operate differently for different types of ballast, adding to the complexity, cost and inefficiency of the resulting configuration, at least in terms of manufacture, in order to provide this selection in dependence of the type of ballast.

[0014] ~~The~~ Embodiments of the present invention seek to address ~~addresses~~ the above problems.

BRIEF SUMMARY OF THE INVENTION

[0015] In a first aspect of the invention, an ~~LED lamp~~ arrangement adapted to replace a fluorescent lamp in a luminaire having a magnetic or an electronic ballast, the arrangement ~~comprising~~ comprises a plurality of LEDs switchable among a plurality of circuit configurations, a first means ~~or circuit~~ for sensing a frequency of power supplied to the arrangement by ~~the ballast of~~ the luminaire and generating an output, and a second means ~~or circuit~~ for switching the

[0023] The arrangement is preferably adapted to generate a power output of the plurality of LEDs in the first circuit configuration used with one of a magnetic or electronic ballast which is substantially equivalent to a power output of the plurality of LEDs in the second circuit configuration used with the other of a magnetic or electronic ballast. The arrangement is preferably designed to provide approximately the same light output from the LEDs in both the first and second configuration, i.e. regardless of the type of ballast fitted in the luminaire.

[0024] In a luminaire, the light flux level produced by the plurality of LEDs configured in one of the first or second circuit configurations used with a magnetic ballast is preferably substantially equivalent to the light flux level produced by a fluorescent tube used with said magnetic ballast. The arrangement thus is preferably designed to provide approximately the same light output from the LEDs as a conventional fluorescent tube when placed in a luminaire fitted with a magnetic ballast. The arrangement may also be designed to provide approximately the same light output from the LEDs as a conventional fluorescent tube when placed in a luminaire fitted with an electronic ballast.

[0025] In ~~a second aspect~~an embodiment of the invention, the LED lamp arrangement may optionally further include a third means or circuit for sensing a condition indicating that current through at least a portion of the plurality of LEDs is below a threshold, and generating an output, and a fourth means or circuit for switching the circuit configuration of the plurality of LEDs on the basis of the output of the third means.

[0026] The fourth means for switching the circuit configuration may be adapted to switch between the first circuit configuration and another circuit configuration, or between the second circuit configuration and another circuit configuration, at a duty cycle. The fourth means for switching the circuit configuration may be designed to switch between different circuit configurations with a certain duty cycle, e.g. during each cycle of the power supply voltage. For example, the duty cycle may comprise switching to the first circuit configuration for a first portion of a cycle of the power supply voltage and switching to another different circuit configuration for a remaining portion of the cycle of the power supply voltage. In this example, the other circuit configuration could be the second circuit configuration, or it could be a third circuit configuration which is different from both the first and second circuit configurations. The third and fourth means may be designed to make use of the inductance of a magnetic ballast fitted in the luminaire for switching the circuit configuration, since the

inductance of the magnetic ballast acts to shorten the time period of zero or nearly zero current through the LEDs. As a result, a separate inductance may be omitted from the circuits, or a smaller inductance may be used than would otherwise be required.

[0027] The duty cycle may be selected to reduce a difference between a power output of the plurality of LEDs in the first and second circuit configurations. For example, the light output when in the second circuit configuration can be adjusted by switching between the second circuit configuration and another (third) circuit configuration at a certain duty cycle, which is selected to achieve light output closer to that of the first circuit configuration. In this way, the arrangement can output the same of similar amount of light regardless of the type of ballast, e.g. magnetic or electronic, which is fitted in the luminaire.

[0028] The fourth means for switching the circuit configuration may also or additionally be adapted to switch between the circuit configurations at a duty cycle which is determined at least in part on the basis of the output of the first means for sensing frequency. In this way, switching between circuit configurations at a certain duty cycle may be adjusted, additionally or alternatively, in dependence on the type of ballast, e.g. magnetic or electronic, which is fitted in the luminaire. For example, the duty cycle used with one type of ballast, e.g. a magnetic ballast, may be different from the duty cycle when the arrangement is used with another type of ballast, e.g. an electronic ballast. The type of ballast may be determined e.g. by an output of the first means for sensing a frequency of power supplied to the arrangement ~~of the first aspect of the invention~~.

[0029] The fourth means for sensing a condition when current through at least a portion of the plurality of LEDs is below a threshold may be adapted to measure current flowing through at least a portion of the plurality of LEDs, to measure voltage applied to at least a portion of the plurality of LEDs, and/or to measure phase of a voltage applied to at least a portion of the plurality of LEDs. The fourth means may thus use different measurements to detect the condition of low current through the LEDs.

[0030] The fourth means for switching the circuit configuration may be constructed similarly to the second means ~~of the first aspect of the invention~~, and the second means and the fourth means may be embodied at least in part in the same circuit element or elements. In this way, the second and fourth means can use some or all of the same circuit elements to

reduce the number of components required. For example, the same one or more transistors switches which constitute the second means may also constitute the fourth means.

[0031] The third means for sensing a condition when current through at least a portion of the plurality of LEDs is below a threshold may be configured for activating the fourth means for switching the circuit configuration of the plurality of LEDs during at least a portion of the time period when current through at least a portion of the plurality of LEDs is substantially zero. In this way, the circuit configuration may be changed during the part of the power supply cycle when current through the LEDs is zero or nearly zero, i.e. around the zero crossing point of the power supply voltage.

[0032] Note that it is also possible that the LED lamp arrangement ~~of the second aspect of the invention~~ may also be applied in an arrangement which omits the first means and second means ~~of the first aspect of the invention~~.

[0033] In ~~a third aspect~~another embodiment of the invention, the arrangement may optionally further include a fifth means or circuit for sensing a condition indicating that current through at least a portion of the plurality of LEDs is above a first threshold or below a second threshold, and energy storage means or circuit for storing at least part of electrical energy provided to the arrangement, where the energy storage means is adapted to store additional energy when the output of the fifth means indicates that current through at least a portion of the plurality of LEDs is above the first threshold, and to release previously stored energy when the output of the fifth means indicates that current through at least a portion of the plurality of LEDs is below the second threshold. In this way, the energy may be stored in the energy storage means during peaks in the power supply cycle (e.g. when current through the LEDs is above the first threshold) and energy previously stored in the energy storage means may be released so that it flows through the LEDs during valleys in the power cycle (e.g. when current through the LEDs is below the second threshold).

[0034] The arrangement may be configured for supplying only a part of the energy stored in the energy storage means to at least a portion of the plurality of the LEDs. Releasing only a portion of the stored energy leads to more efficient operation of the energy storage means.

[0035] The fifth means for sensing a condition indicating that current through at least a portion of the plurality of LEDs is above a first threshold or below a second threshold may be

constructed similarly to the third means ~~of the first aspect of the invention~~, and the third means and the fifth means may be embodied at least in part in the same circuit element or elements. In this way, the third and fifth means can use some or all of the same circuit elements to reduce the number of components required.

[0036] In ~~a fourth aspect~~another embodiment of the invention, the arrangement may optionally further include a sixth means or circuit for sensing a frequency of power supplied to the arrangement by the luminaire, and generating an output, and a variable impedance connected across two input power connection lines of the arrangement, the variable impedance providing an impedance which varies in accordance with the output of the fifth means for sensing a frequency. As described above, sensing the frequency of power supplied to the arrangement may discriminate between a magnetic or electronic ballast, and so the variable impedance may be varied in dependence on the type of ballast fitted to the luminaire.

[0037] The sixth means for sensing a frequency and the variable impedance may be adapted to increase the impedance of the variable impedance if the sensed frequency is within a certain predetermined frequency range. The predetermined frequency range may correspond to a frequency range output from one of a magnetic ballast or an electronic ballast.

[0038] The sixth means for sensing a frequency may be constructed similarly to the first means ~~of the first aspect of the invention~~, and the first means for sensing a frequency and the sixth means for sensing a frequency may be embodied at least in part in the same circuit element or elements. In this way, the first and sixth means can use some or all of the same circuit elements to reduce the number of components required.

[0039] The variable impedance may comprise an impedance and a switch for connecting or disconnecting the impedance across the two input power connection lines of the arrangement. The variable impedance may alternatively comprise a first impedance, a second impedance, and a switch for connecting one of the first impedance or the second impedance across the two input power connection lines of the arrangement.

[0040] The arrangement may comprise two conducting pins located at one end of a housing and adapted for connection to the luminaire, the pins connected to the two input power connection lines of the arrangement, wherein the variable impedance is connected between the conducting pins.

[0041] The variable impedance may be adapted to increase in impedance when the output of the sixth means for sensing a frequency is indicative of operation with a magnetic ballast. The variable impedance may be adapted to increase in impedance to an impedance sufficient such that a starter element present in the luminaire is not activated when a magnetic ballast is used for supplying power to the arrangement.

[0042] A ~~fifth~~ second aspect of the invention comprises a luminaire adapted for using one or more fluorescent lamps, the luminaire comprising one or more magnetic or electronic ballasts suitable for energizing the fluorescent lamps, wherein the luminaire is fitted with one or more ~~LED lamp~~ arrangements as described herein in place of the one or more fluorescent lamps.

[0043] A ~~sixth~~ third aspect of the invention provides a method of operating LEDs in an arrangement adapted to replace a fluorescent lamp in a luminaire having either a magnetic or an electronic ballast, the arrangement comprising a plurality of LEDs switchable among a plurality of circuit configurations. The method comprises sensing a frequency of power supplied to the arrangement by the luminaire, and switching from a first circuit configuration to a second circuit configuration if the sensed frequency is within a predetermined frequency range. The predetermined frequency range may correspond to a frequency range output from one of a magnetic ballast or an electronic ballast.

[0044] The method may comprise switching the plurality of LEDs to a first circuit configuration if the sensed frequency is within a first predetermined frequency range, and switching the plurality of LEDs to a second circuit configuration if the sensed frequency is within a second predetermined frequency range different from the first predetermined frequency range. The first predetermined frequency range may correspond to a frequency range output from a magnetic ballast and the second predetermined frequency range may correspond to a frequency range output from an electronic ballast. The same features and considerations described herein for the first ~~to fourth~~ aspect~~s~~ of the invention also apply for the methods described herein.

[0045] The plurality of LEDs may be arranged into a plurality of groups of LEDs. The first circuit configuration may correspond to a series connection of the groups of LEDs, and the second circuit configuration may correspond to a parallel connection of at least a portion of the groups of LEDs.