

CURRENT REGULATION AND RELIABILITY OF LED ARRAYS

5 This invention relates to a new means for improving the reliability and efficiency of a Light Emitting Diode (LED) array signal, and a method of same.

10 Signals are widely used for the control of vehicular and pedestrian traffic. In these applications, it is desirable for the signal to have a high level of reliability and a long service life, to ensure the on-going safety of the traffic that is being controlled and to minimise maintenance costs. The efficiency of the signal is also a consideration, as this will impact the on-going operating costs.

15 Signals that incorporate LED arrays are becoming more widespread, as they provide a number of advantages over conventional incandescent or quartz halogen lamp designs:

- 20 • LEDs have a significantly longer operational life time than either incandescent or quartz halogen lamps. This means the LED array based signalling lamp will last longer and require less frequent replacement, reducing maintenance costs.
- 25 • LED array lighting provides redundancy in the event that a single LED fails, improving reliability. The single LED represents only a fraction of the total light output, so overall the signal remains functional. For conventional incandescent or quartz halogen applications, failure of the single light bulb causes the whole signal to fail.
- LED array lighting is much more energy efficient than either incandescent or quartz halogen equivalents, providing beneficial savings in operating costs and reducing energy wastage.

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A typical LED array signal might consist of a quantity of parallel "strings" of LEDs. Each string consists of a number of LEDs connected in series

together with an impedance, such as a resistor, and energised from a power source. The function of the series impedance is to reduce the sensitivity of the LED light output to variations in the supply voltage. The output light intensity of an LED is a function of the drive current and without the series
5 impedance, small variations in supply voltage may result in large variations in drive current, and hence LED light output.

It is desirable to maximise the number of LEDs connected in series in each string, as this allows the overall current to the LED array to be reduced, thus
10 reducing losses and improving efficiency.

One problem with the approach of having multiple LEDs in series is that should a single LED in the series string fail to an open circuit, the rest of the LEDs in that string will extinguish. This limits the number of LEDs that can
15 be connected together in a string, as failure of the entire string due to the failure of a single LED may result in the signal becoming inoperable. So the design of existing LED based signals involves a trade-off between efficiency (using a large number of LEDs per string) and reliability (using a small number of LEDs per string)

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An additional problem exists for the case where one LED in the string fails to a short circuit. Here, the decrease in overall impedance of the string due to the LED failure may cause a significant increase in the current through the remaining LEDs, such that the operating current may be outside the range for
25 reliable long-life.

An LED array that provides a means of ensuring continued operation in the event of a single LED failure, and that enables an increased number of LEDs to be connected in series in a string would offer significant improvements in
30 operational life-time and efficiency over the prior art. This is the objective of the present invention.

According to a first aspect of the present invention there is provided an electrical circuit for powering a plurality of LEDs, the electrical circuit comprising: a series combination of at least two LED's, an alternative current path in parallel with each LED; a current limiting device; a current regulating device; a current sensing device; and a control circuit that takes its input from the current sensing device and provides input to the current regulating device.

The current limiting device may take the form of a resistor, selected so as to provide the most significant contribution to the overall circuit impedance. This feature has the advantage that current in the circuit, and thus the intensity of the light output from the LEDs, is less sensitive to variations in the input voltage of the energising source.

The alternative current path in parallel with each LED may take the form of a voltage clamping device. This feature has the advantage that, in the event of open circuit failure of the LED, current will flow via the alternative parallel path and the overall circuit will remain functional.

The current sensing device provides a means of monitoring the instantaneous current in the circuit. Output from the current sensing device provides input to the control circuit, the output of which provides input to the current regulating device. This feature has the advantage that in the event that there is a short circuit failure of any LED, the current sensing device will detect the instantaneous change in current and then operate the current regulating device to control the current to within operating limits.

More than two LEDs may be connected in series. The number of LEDs connected in series may be significantly more than two. This feature has the advantage that the total current required to energise the signal can be reduced, improving the efficiency.

These features of the present invention enable the design of an LED array that is more tolerant to failure of any individual LED, has a longer operational life and which can be made more efficient than the prior art.

- 5 For a better understanding of the present invention and to show how it may be carried into effect, reference shall now be made, by way of example only, to the accompanying drawing, in which:

FIGURE 1 shows an embodiment of the present invention.

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- Figure 1 shows two LEDs (1, 2) connected in series. In parallel with each LED is a zener diode (3, 4). The clamping voltage of the zener diodes (3, 4) is chosen to be greater than the forward voltage drop of the LEDs (1, 2). In series with the two LEDs (1, 2) is a current limiting device (5), current
15 regulating device (6) and a current sensing device (7). The current regulating device is preferably constructed by means of a transistor switch. A control circuit (8) takes input from the current sensing device (7) and provides a control signal (9) as input to the current regulating device (6).
- 20 Under normal operating conditions, the forward voltage drop across the LED (1) is less than the operating voltage of zener diode (3) and so the majority of current flows from anode to cathode of the LED (1). A similar situation exists with LED (2) and zener diode (4).
- 25 In the event that the LED (1) should fail to an open circuit, the voltage across the zener diode (3) increases rapidly and approaches, within the limit, the level of the energising source. At the point where the voltage reaches the clamping level of the zener diode (3), it current will begin to conduct and current will flow from cathode to anode, bypassing the failed LED (1). In this
30 way, the continuity of the overall circuit is restored and the LED (2) will continue to receive current and thus continue to provide light output.

If LED (2) should fail to an open circuit, zener diode (4) would act in the same way as described for zener diode (3) in the example above, LED (2) would continue to receive current and thus continue too provide light output.

- 5 Current limiting resistor (5) connects to the cathode of LED (2). It acts to limit the total current through the circuit to within the operating limits of LEDs (1,2)

If there is a short circuit failure of either LED (1,2), then the current flowing through the circuit will increase. The current sensing device (7) monitors the
10 instantaneous current in the circuit. It provides as output an input to the control circuit (8). The control circuit (8) compares this signal to an internal reference representing the acceptable average current through the circuit and provides control signal (9) to operate the current regulation device (8). In this way, the control circuit (9) is able to pulse width modulate the current
15 regulation device (8) from the off state to the on-state and then back to the off-state so as to control the average current through the circuit.

The speed of operation of this control loop is sufficient so as to be able to detect the instantaneous short circuit failure of either LED (1, 2) whilst at the
20 same time adapting the current flow if there is an open circuit failure of either LED (1,2).

Whilst in the drawing, there has been described an array of two LEDs, it is to be understood that the circuit will provide satisfactory control for very much
25 larger arrays and, generally is adapted to cope with the failure of more than one LED, either by open circuit or short circuit, to permit the other LEDs in the array to continue to operate under conditions which will maintain the operating conditions to maximise their life.

30 Whilst there has been described herein one particular circuit arrangement which will provide the required control of the current flow on failure of one or more LEDs, it is to be understood that variations may be made in this whilst

providing the essential aspects of the invention, an alternative circuit if one or more LEDs fails open circuit, and current limiting means if one or more LEDs fail through becoming open circuit.

The claims defining the invention are as follows:

- 5 1. An electrical circuit for powering a plurality of LEDs, the electrical circuit comprising: a series combination of at least two LED's, an alternative current path in parallel with each LED; a current limiting device; a current regulating device; a current sensing device; and a control circuit the input to which is from the current sensing device and provides an input to control the current regulating device.
- 10 2. An electrical circuit as claimed in claim 1 wherein the alternative current path comprises a voltage clamping device which, under normal operation when the LED is functional carries little current but if the LED fails to open circuit, the clamping device provides the
15 alternative current path.
3. An electric circuit as claimed in claim 2 wherein the voltage clamping device is a zener diode connected in parallel with each LED.
- 20 4. An electric circuit as claimed in any preceding claim wherein the current regulating device is an impedance.
5. An electric circuit as claimed in claim 4 wherein the current regulating device is a resistance.
- 25 6. An electric circuit as claimed in any preceding device wherein the current limiting device is a pulse width modulating device whereby the average current passing through the circuit can be controlled.
- 30 7. An electric circuit as claimed in claim 6 wherein the current sensing device provides an input to the control circuit which, in turn, provides

an output to effect the control of the pulse width modulating device to maintain a required average current through the circuit.

- 5 8. An electric circuit as claimed in claim 7 wherein the control circuit includes reference means which act as a comparator with the output from the current sensing device to provide the required output to effect operation of the pulse width modulator.
- 10 9. An electric circuit substantially as hereinbefore described in relation to the accompanying drawings.