Title: ELECTRONIC CIRCUIT FOR DRIVING A DIODE LOAD

Abstract: An electronic circuit includes circuit portions for identifying a largest voltage drop through one of a plurality of series connected diode strings and for controlling a boost switching regulator according to the largest voltage drop. The electronic circuit can sense an open circuit series connected diode string, which would otherwise have the largest voltage drop, and can disconnect that open circuit series connected diode string from control of the boost switching regulator. Another electronic circuit includes a current limiting circuit coupled to or within a boost switching regulator and configured to operate with a diode load. Another electronic circuit includes a pulse width modulation circuit configured to dim a series connected string of light emitting diodes.
1. An electronic circuit, comprising:
   
a current regulator having a current sense node, wherein the current regulator is
configured to pass a predetermined current through the current regulator;

   an open-circuit detection circuit having an input node and an output node, wherein the
input node of the open-circuit detection circuit is coupled to the current sense node of the
current regulator, and wherein the open-circuit detection circuit is configured to provide an
output signal at the output node of the open-circuit detection circuit indicative of a current
flowing through the current regulator being below a predetermined current threshold; and

   a switch having an input node, an output node, and a control node, wherein the input
node of the switch is coupled to the current sense node of the current regulator, wherein a
selected one of the input node or the output node of the switch is coupled to the input node of
open-circuit detection circuit, wherein the control node of the switch is coupled to the open-
circuit detection circuit, and wherein the open-circuit detection circuit is configured to open the
switch in response to the current flowing through the current regulator being below the
predetermined current threshold.

2. The electronic circuit of Claim 1, further comprising:
   
a minimum select circuit having an input node and an output node, wherein the input
node of the minimum select circuit is coupled to the output node of the switch, wherein the
minimum select circuit is configured to provide a signal at the output node of the minimum
select circuit indicative of a signal at the output node of the switch; and
a switching circuit having a switching node and a control node, wherein the control
node of the switching circuit is coupled to the output node of the minimum select circuit,
wherein a duty cycle of the switching circuit is responsive to the signal at the output node of the
minimum select circuit.

3. The electronic circuit of Claim 2, further comprising an over-voltage detection circuit
having an input node and an output node, wherein the input node of the over-voltage detection
circuit is coupled to the switching node of the switching circuit, wherein the output node of the
over-voltage protection circuit is coupled to a second input node of the open-circuit detection
circuit, wherein the over-voltage detection circuit is configured to provide an output signal at
the output node of the over-voltage protection circuit indicative of a voltage at the input node of
the over-voltage detection circuit being above a predetermined voltage threshold, wherein the
output signal at the output node of the open-circuit detection circuit is indicative of the current
flowing through the current regulator being below the predetermined current threshold and
also indicative of the voltage at the input node of the over-voltage detection circuit being above
the predetermined voltage threshold.

4. The electronic circuit of Claim 1, further comprising an over-voltage detection circuit
having an input node and an output node, wherein the output node of the over-voltage
protection circuit is coupled to a second input node of the open-circuit detection circuit,
wherein the over-voltage detection circuit is configured to provide an output signal at the
output node of the over-voltage protection circuit indicative of a voltage at the input node of the
over-voltage detection circuit being above a predetermined voltage threshold, wherein the
output signal at the output node of the open-circuit detection circuit is indicative of the current
flowing through the current regulator being below the predetermined current threshold and also
indicative of the voltage at the input node of the over-voltage detection circuit being above the
predetermined voltage threshold.

5. The electronic circuit of Claim 1, further comprising a temperature detection circuit
having an output node coupled to a second input node of the open-circuit detection circuit,
wherein the temperature detection circuit is configured to provide an output signal at the output
node of the temperature detection circuit indicative of a temperature of the electronic circuit
being above a predetermined temperature threshold, and wherein the output signal at the output
node of the open-circuit detection circuit is indicative of the current flowing through the current
regulator being below the predetermined current threshold and also indicative of the
temperature of the electronic circuit being above the predetermined temperature threshold.

6. The electronic circuit of Claim 1, wherein the open-circuit detection circuit comprises:
an open detect comparator having an input node and an output node, wherein the input
node of the open detect comparator is coupled to the input node of the open-circuit detection
circuit;

   a first logic gate having an input node and an output node, wherein the input node of the
   first logic gate is coupled to the output node of the open detect comparator; and

   a latching circuit having an input node and an output node, wherein the input node of
   the latching circuit is coupled to the output node of the first logic gate, and wherein the output
   node of the latching circuit is coupled to the output node of the open-circuit detection circuit.
7. The electronic circuit of Claim 6, wherein the open-circuit detection circuit further comprises:

   a second logic gate having an input node and an output node, wherein the input node of the second logic gate is coupled to the output node of the open detect comparator; and

   a delay module having an input node and an output node, wherein the input node of the delay module is coupled to the output node of the second logic gate, and wherein the output node of the delay module is coupled to a second input node of the first logic gate.

8. An electronic circuit, comprising:

   a switch having an input node, an output node, and a control node;

   a current-passing circuit having first and second nodes, wherein the first node of the current-passing circuit is coupled to the input node of the switch and the second node of the current-passing circuit is coupled to the output node of the switch;

   a boost switching regulator having an input node and an output node, wherein the input node of the boost switching regulator is coupled to the output node of the switch, and wherein the output node of the boost switching regulator is configured to couple to a diode load; and

   a resistor having first and second nodes, wherein the first node of the resistor is coupled to the control node of the switch and wherein the second node of the resistor is coupled to the output node of the boost switching regulator.

9. The electronic circuit of Claim 8, wherein the current-passing circuit comprises a resistor.
10. The electronic circuit of Claim 8, wherein the current-passing circuit comprises a current source.

11. The electronic circuit of Claim 8, wherein the switch comprises a field effect transistor.

12. The electronic circuit of Claim 11, wherein the current-passing circuit corresponds to a leakage of the field effect transistor.

13. The electronic circuit of Claim 12, wherein the boost switching regulator comprises:
   - an inductor having first and second nodes, wherein the first node of the inductor is coupled to the input node of the boost switching regulator and is coupled to the output node of the switch;
   - a diode having an anode and a cathode, wherein the anode is coupled to the second node of the inductor;
   - a capacitor coupled to the cathode; and
   - a switching circuit having an input node coupled to the second node of the inductor.

14. The electronic circuit of Claim 8, wherein the boost switching regulator comprises:
   - an inductor having first and second nodes, wherein the first node of the inductor is coupled to the input node of the boost switching regulator and is coupled to the output node of the switch;
a diode having an anode and a cathode, wherein the anode is coupled to the second node of the inductor;
a capacitor coupled to the cathode; and
a switching circuit having an input node coupled to the second node of the inductor.

15. An electronic circuit for dimming a light emitting diode having an anode and a cathode, the electronic circuit comprising:
a current regulator having a current node and a control node, wherein the current node of the current regulator is configured to couple to the light emitting diode;
a boost switching regulator having an input node, an output node, and a control node, wherein the output node of the boost switching regulator is configured to couple to a selected one of the anode of the light emitting diode or to the current regulator, and wherein the boost switching regulator is enabled to switch or is disabled from switching in response to an input signal at the control node of the boost switching regulator; and
a pulse width modulation circuit having an output node and a control node, wherein the output node of the pulse width modulation circuit is coupled to the control node of the current regulator, wherein the pulse width modulation circuit is configured to generate an AC output signal at the output node of the pulse width modulation circuit, which enables and disables the current regulator at a predetermined frequency and at a selected duty cycle in response to a respective selected input signal at the input node of the pulse width modulation circuit, wherein the duty cycle is selected in accordance with a selected brightness of the light emitting diode, and wherein, substantially simultaneously with the current regulator being disabled, the input
signal at the control node of the switching regulator is indicative of the boost switching regulator being disabled.

16. The electronic circuit of Claim 15, wherein an output voltage at the output node of the boost switching regulator is substantially the same when the boost switching regulator is disabled from switching as when the boost switching regulator is enabled to switch.

17. The electronic circuit of Claim 15, wherein the output node of the pulse width modulation circuit is coupled to the control node of the current regulator via a single-wire or multi-wire serial interface.

18. The electronic circuit of Claim 15, further comprising:

   a switch having an input node, an output node, and a control node, wherein the output node of the switch is coupled to the control node of the boost switching regulator, and wherein the control node of the switch is coupled to the pulse width modulation circuit, wherein the switch is closed when the current regulator is enabled and open when the current regulator is disabled; and

   a capacitor coupled to the input node of the switch, wherein the capacitor approximately holds a voltage when the switch is open corresponding to a voltage of the control node of the switching regulator when the switch is closed.

19. The electronic circuit of Claim 15, wherein the boost switching regulator is disabled in response to the current regulator being disabled.
20. The electronic circuit of Claim 19, wherein the predetermined frequency is within a range of about twenty to one thousand cycles per second.

21. An open circuit protection method for an LED driver circuit comprising a boost switching regulator, the method comprising:
   - drawing a respective predetermined current through each of a plurality of LEDs and through a respective plurality of current regulators;
   - detecting a smallest current passing through one of the plurality of current regulators;
   - and detecting a respective current passing through each one of the plurality of current regulators to determine whether the respective current is less than a predetermined current threshold; wherein the detecting the smallest current does not take into account a current passing through at least one of the plurality of current regulators that is less than the predetermined current threshold.

22. The method of Claim 21, further comprising detecting whether an output voltage of the boost switching regulator is greater than a predetermined voltage threshold, wherein the disconnecting comprises disconnecting the LED from the LED driver circuit in response to a determination that the current passing through the current regulator is less than the predetermined current threshold and a determination that the output voltage of the boost switching regulator is greater than the predetermined voltage threshold.
23. The method of Claim 21, further comprising detecting whether a temperature of the LED driver circuit is greater than a predetermined temperature threshold, wherein the disconnecting comprises disconnecting the LED from the LED driver circuit in response to a determination that the current passing through the current regulator is less than the predetermined current threshold and a determination that the temperature of the LED driver circuit is greater than the predetermined temperature threshold.

24. The method of Claim 21, further comprising providing a delayed detection signal that is a delayed version of a signal indicative of whether the current passing through the current regulator is less than the predetermined current threshold, wherein the disconnecting comprises disconnecting the LED from the LED driver circuit in response to the delayed detection signal.

25. The method of Claim 21, further comprising:
   regulating an output voltage of the boost switching regulator in accordance with the detected smallest current.