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(54) SAFE DISCONNECT SWITCH

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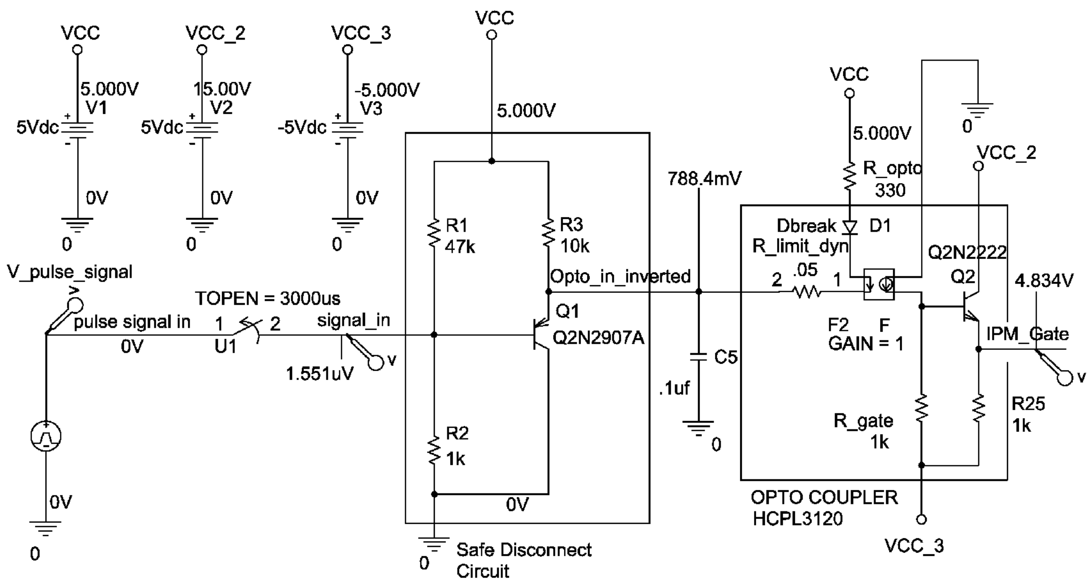
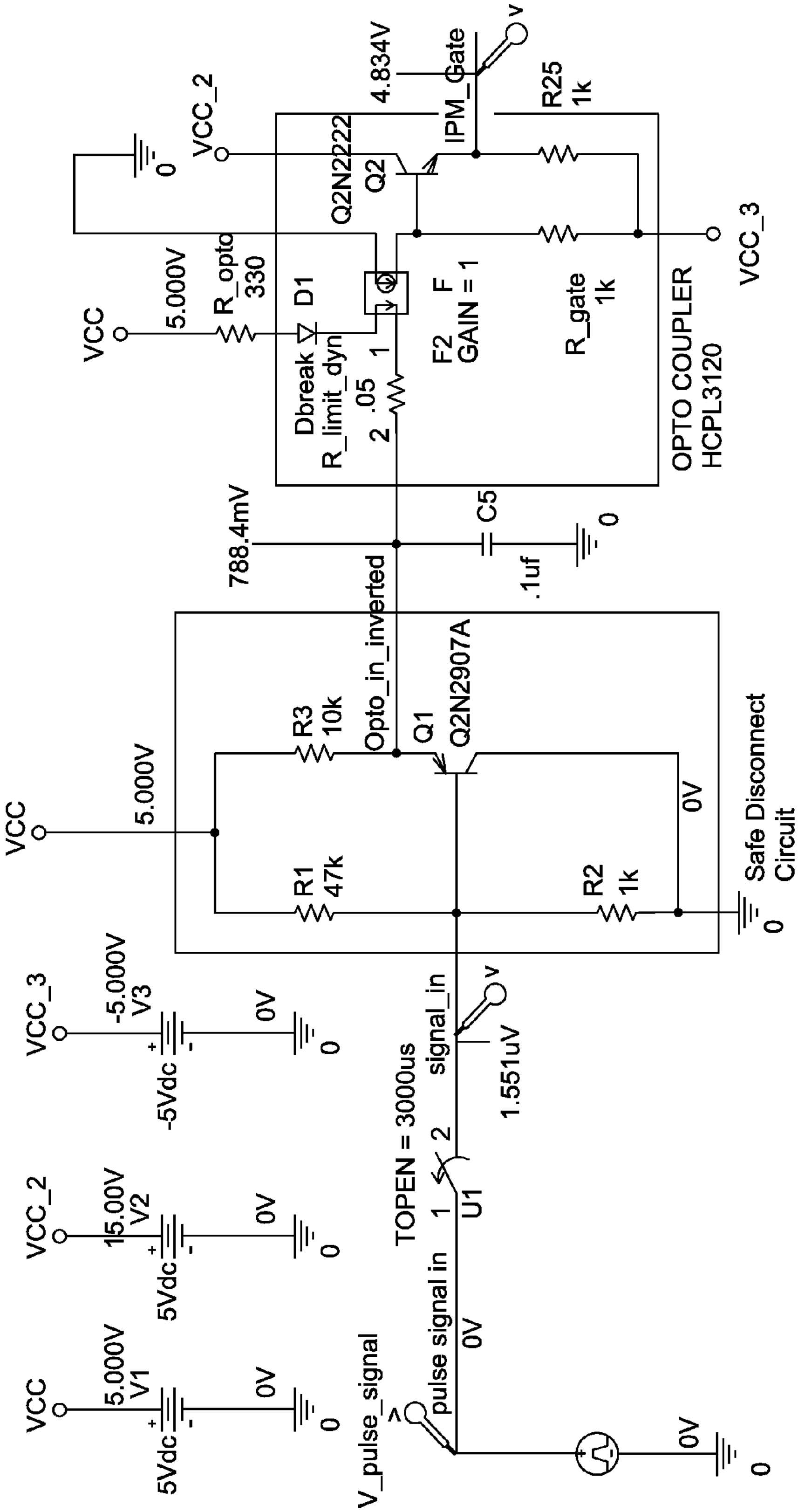
(57) **ABSTRACT**

A safe disconnect circuit is provided for mitigating the effect of harmful circuit conditions upon a load, such as an integrated power module (IPM). The safe disconnect circuit comprises a switching circuit operative to receive a pulsed input signal, and to detect the presence of a load threatening input signal, e.g. a load control signal, having an amplitude below a preset amplitude threshold and a duration beyond a present duration threshold. The switching circuit is operative to terminate load power in response to detect a presence of the load threatening signal.

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V1
5Vdc
0V
0
VCC_2
15.00V
V2
5Vdc
VCC_3
-5.000V
V3
-5Vdc
V_pulse_signal
pulse signal in
TOPEN = 3000us
U1
signal_in
1.551uV
R1
47k
R2
1k
R3
10k
Q1
Q2N2907A
Safe Disconnect
Circuit
Opto_in_inverted
788.4mV
C5
.1uf
Dbreak
D1
R_limit_dyn
.05
R_opto
330
F2 F
GAIN = 1
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1k
Q2
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IPM_Gate
4.834V
R25
1k
OPTO COUPLER
HCPL3120

FIG. 1

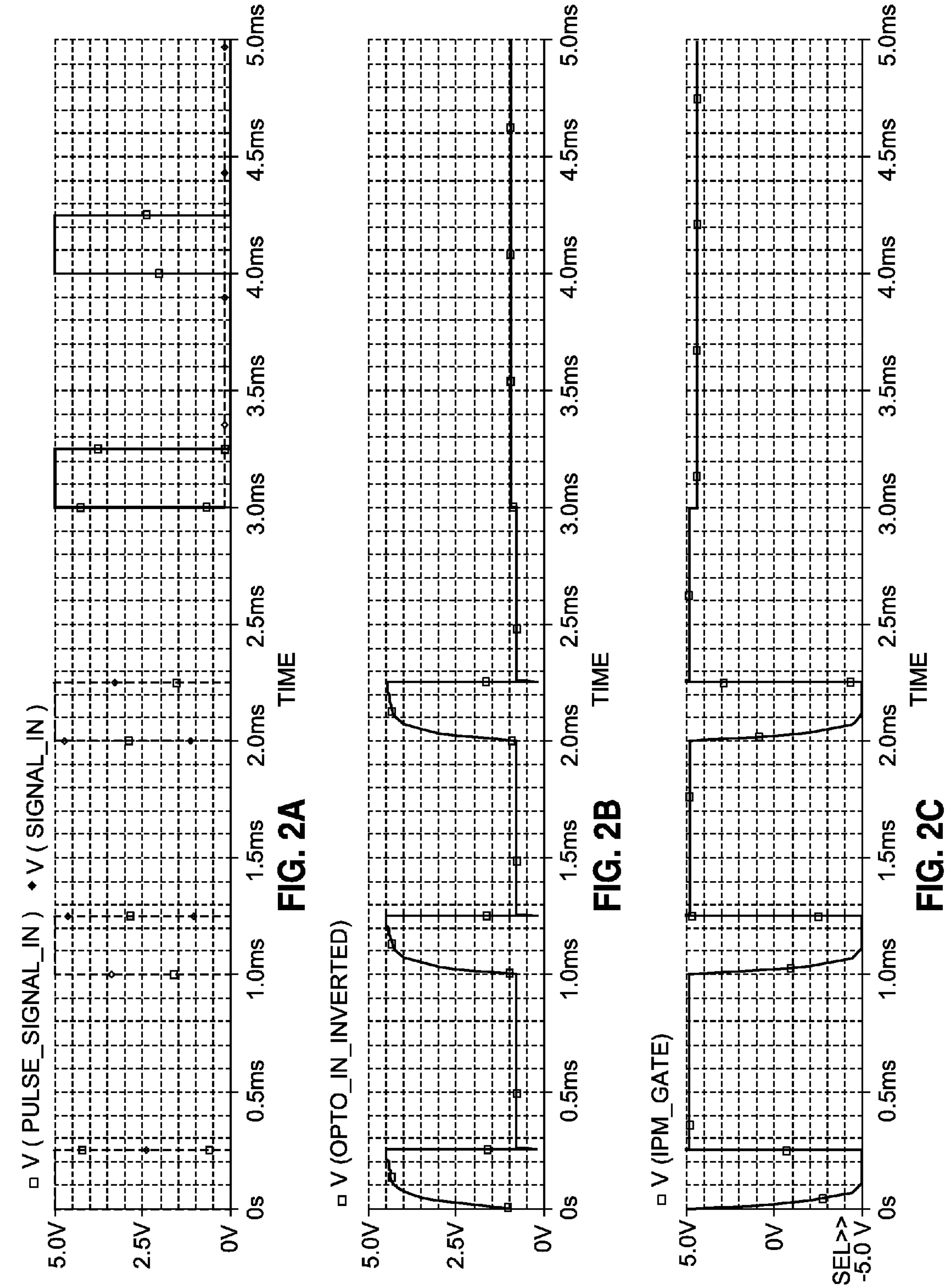

FIG. 2A

FIG. 2B

FIG. 2C

SAFE DISCONNECT SWITCH

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not Applicable

STATEMENT RE: FEDERALLY SPONSORED RESEARCH/DEVELOPMENT

[0002] Not Applicable

BACKGROUND

[0003] The present invention relates to circuits regulating the operation of high-powered, high-voltage circuits, such as integrated power modules. More particularly, the present invention relates to a safe disconnect circuit for turning off integrated power modules in response to the loss of a control signal.

[0004] Integrated power modules (IPMs) and the like function to provide high-current/high-voltage outputs. Given the high-power outputs, switching the modules off/on must be done with considerable care to avoid damaging components or otherwise creating unsafe conditions.

[0005] In many cases such modules are constructed to operate in a normally on condition, such that loss of a control signal would not cause the module to turn itself off. This can be useful to avoid unnecessary switching of the module in response to spurious control signals.

[0006] However, once it is determined that a pulse in the circuit is causing loss of the control signal, leaving the module in an on condition can create hazards, as the circuit may not be able to be properly regulated.

[0007] Accordingly, it is desirable to provide a safe disconnect circuit for interfacing high-voltage/high-current supplies, such as integrated circuit modules.

[0008] It is further desirable that the safe disconnect circuit be able to detect and respond to fault conditions, such as open circuits, causing the loss of control signals.

[0009] It is further desirable that the safe disconnect circuit be operative to differentiate between spurious variations in a control signal and fault conditions, in order to avoid unnecessary shut down of the IPM in response to such spurious conditions.

[0010] It is further desirable that, upon detection of a fault, the safe disconnect circuit generates a signal that turns off the IPM, and holds the IPM in an off condition, notwithstanding the occurrence of spurious input signals.

[0011] It is further desirable that the safe disconnect circuit include features to electrically isolate the circuit output signal to the IPM from the circuit input, to avoid potentially hazardous conditions of the input circuit and at the IPM.

[0012] These and other objects and advantages are achieved in accordance with the invention as described and illustrated herein.

BRIEF SUMMARY

[0013] A safe disconnect circuit is provided for mitigating the effect of harmful circuit conditions upon a load, such as an integrated power module (IPM). The safe disconnect circuit comprises a switching circuit operative to receive a pulsed input signal, and to detect the presence of a load threatening input signal, e.g. a load control signal, having an amplitude below a preset amplitude threshold and a duration beyond a present duration threshold. The switching circuit is operative to terminate load power in response to detect a presence of the load threatening signal.

[0014] The safe disconnect circuit may be useful to determine shorts or openings on the input to a high voltage, high current load that operates in a normally on condition. As the input circuit controls the operation of the load, such shorts and opens may operate to cause the load to transition between off and on conditions, in response to spurious signals, thereby damaging the load.

[0015] In the presently preferred embodiment the safe disconnect circuit may comprise an RC circuit for maintaining a load in an off condition until such time as the switching circuit detects the presence of a proper input signal, e.g. having an amplitude in excess of a preset amplitude threshold, and a duration in excess of a preset duration threshold. The RC circuit may be operative to maintain the load in an off condition where the circuit detects the presence of an input signal having an amplitude less than the preset amplitude threshold and/or a duration less than the preset duration threshold.

[0016] The safe disconnect circuit may further include a pull-down circuit for maintaining the switching circuit in a conductive state, i.e. terminating load power, until the input signal exceeds the preset amplitude threshold.

[0017] In one embodiment the preset amplitude threshold is 0.7 volts, and the preset duration threshold is 0.05 msec.

[0018] The safe disconnect circuit may further include an optical coupler circuit disposed intermediate the switch and the load, the optical coupler circuit being operative to electrically isolate the load from the switch.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] These and other features and advantages of the various embodiments disclosed herein will be better understood with respect to the following description and drawings, in which like numbers refer to like parts throughout, and in which:

[0020] FIG. **1** is a circuit diagram of one embodiment of the invention;

[0021] FIG. **2***a-c* illustrate signals generated in the circuit shown in FIG. **1**, during normal operation and in response to a detected fault.

DETAILED DESCRIPTION

[0022] The above description is given by way of example, and not limitation. Given the above disclosure, one skilled in the art could devise variations that are within the scope and spirit of the invention disclosed herein, including various ways of detecting and responding to fault conditions, e.g. depending upon the input signal parameters. Further, the various features of the embodiments disclosed herein can be used alone, or in varying combinations with each other and are not intended to be limited to the specific combination described herein. Thus, the scope of the claims is not to be limited by the illustrated embodiments.

[0023] FIG. **1** illustrates a circuit diagram illustrating one implementation of the presently preferred embodiment. The load control signal input to the circuit is a pulsed input signal identified as V(Pulse_Signal_In). The pulsed input signal in the illustrated embodiment is approximately a five volt (5 Volt) signal having a pulse width of 200 μs and a period of 1000 μs. Switch U**1** represents a fault in the control circuit resulting in an open connection between the pulse generator and the safe disconnect circuit.

[0024] Under normal operating conditions (no fault) a high pulsed input signal into disconnect circuit **11** (i.e. approximately 3.5 v or more) creates a positive voltage on the base of Q**1**, turning Q**1** off. When Q**1** is off the output of circuit **11** goes high, to approximately 4.5 volts, which precludes current flow through the coupling unit **15** of optocoupler **13**, which turns off Q**2**, causing the output of optocoupler **13** to substantially conform with VCC**3**, i.e. minus 5 volts. Where the IPM is normally on circuit, the high output from optocoupler **13** operates to turn the IPM off. As a result, the overall operation is that high pulsed input signal (control signal) into circuit **11** will normally operate to turn the IPM off, provided that the control signal remains positive for a sufficient period of time.

[0025] Referencing FIGS. **1** and **2***a*, the input to Q**1**, i.e. V(Signal_In) follows the pulse modulator output, V(Pulse_Signal_In), for the first three pulses, each having a pulse width of **250** ns and a period of 1 ms. However, at 3 ms a fault condition is represented to occur (U**1** open), such that while V(Pulse_Signal_In) continues to pulse, V(Signal_In) stays at near 0, i.e. approximately 1.551 micro volts. This causes Q**1** to turn on and the input to the optocoupler, V(Opto_In_Inverted), to remain low (i.e. below 1.5v).

[0026] FIG. **2***b* illustrates how V(Opto_In_Inverted) normally follows the pulsed signal V(Pulse_Signal_In) when no fault occurs. However, when a fault occurs, V(Signal_In) remains low and V(Opto_In_Inverted) also remains low.

[0027] When a fault occurs, the output of disconnect circuit **11**, which varies as Q**1** is turned on and off under normal conditions, no longer follows V(Pulse_Signal_In) as the input to the base of Q**1** remains low and Q**1** remains in an on condition. The R**1**/R**2** voltage divider network of disconnect circuit **11** then locks on, with an output of Q**1**, approximately 1 volt (i.e. low, as shown at FIG. **2***b*), starting at 3.0 ms.

[0028] As shown at FIG. **2***c*, the output of optical coupler circuit **13**, taken from the output of Q**2**, normally is the inverse of the output of disconnect circuit **11**, V(Opto_In_Inverted). Under normal operating conditions, as the output of disconnect circuit **11**, V(Opto_In_Inverted), goes high, the current through optical coupler circuit **13** is turned off, turning off Q**2** and driving the output signal, V(IPM_Gate) low, to approximately −5 volts.

[0029] However, when Q**1** is turned on, in response to positive pulsed signal, or in response to a fault, the output of disconnect circuit **11**, V(Opto_In_Inverted), becomes low, allowing current to flow through optical coupler circuit **13**, which in turn turns on Q**2** and causes the output of optical coupler circuit **13**, V(IPM_Gate), to rise to approximately 5 volts.

[0030] When an open condition occurs (starting at 3.0 ms) Q**1** remains on, causing current to flow through the optocoupler **15**, which turns on Q**2**, holding the output of optical coupler circuit **13**, V(IPM_Gate), at a high level, thereby turning of a normally on ICM.

[0031] As the voltage divider R**1**/R**2** holds the output of Q**1** at approximately 1.551 microvolts, the output of Q**2** is therefore held at approximately 4.34 volts. That signal level causes the normally on IPM to turn off after it is maintained for a preset period of time, e.g. 2 ms, indicating that the pulsed input is no longer present.

[0032] R**3**/C**5** form an RC circuit which dictates the rise time of the output of disconnect circuit **11**, V(Opto_In_Inverted), and correspondingly the output of optical coupler circuit **13**, V(IPM_Gate). The values of R**3** and C**5** are selected to be sufficient to dampen any response to spurious input signals which do not extend for a predetermined period of time, less than 0.05 ms.

[0033] Resistor network R**1**, R**2** functions as a pull down circuit, to maintain Q**1** in the conductive state until V_signal_in returns to a sufficiently high, unambiguous level, e.g. greater than 0.7 volts, and remains at such voltage level for a sufficient time, e.g. as may be dictated by the RC network of R**3**, C**5**. The RC network may additionally operate to maintain Q**1** in a non-conductive state for a period of time, notwithstanding transient low-level pulses on the base of Q**1**, as are represented in FIG. **2***b*. Accordingly, the safe disconnect circuit is adapted to generate an output to turn off the load where a low signal level appears for periods of time representative of conditions such as opens or shorts, but will not respond to substantially instantaneous pulses below a threshold level, which are shorter in time and unlikely to result in conditions that will cause damage to the load or associated equipment.

[0034] By dampening the response of the disconnect circuit to spurious inputs, and by locking the output signal level at a load disabling level when the pulse signal is not present for a sufficient period of time (until a threshold level input signal reappears), the present invention allows for safe regulation of a normally on IPM, within suitable parameters for detecting and responding to related conditions.

[0035] As one of ordinary skill will recognize, the safe disconnect switching circuit may be directly coupled to the load, omitting optical coupler circuit **13**. Further, the functions of optical coupler circuit **13**, i.e. to invert the output of disconnect circuit **11** and to electrically isolate the load from disconnect circuit **11**, can be implemented in a variety of alternate ways, within the scope and spirit of the present invention. For example, where the load is constructed to be normally off, optical coupler **13** may be implemented in an alternate manner to generate an output that follows, rather than inverts, the output of disconnect circuit **11**.

What is claimed is:

1. A safe disconnect circuit for mitigating the effect of harmful circuit conditions upon a load comprising:

- a switching circuit operative to receive a pulsed input signal, and to detect the presence of a load threatening input signal having an amplitude below a preset amplitude threshold and a duration beyond a preset duration threshold;
- a switching circuit further being operative to terminate load power in response to the detected presence of the load threatening signal.

2. The circuit as recited in claim **1** further comprising an RC circuit for maintaining the load in an off condition until such time as the switching circuit detects the presence of an input signal having an amplitude in excess of the preset amplitude threshold, and an input signal duration in excess of the preset duration threshold.

3. The circuit as recited in claim **2** wherein the RC circuit is further operative to maintain the load in an off condition where the circuit detects the presence of an input signal having an amplitude less than the preset amplitude threshold and a duration less than the preset duration threshold.

4. The circuit as recited in claim **2** wherein the RC circuit is further operative to maintain the load in an off condition where the circuit detects the presence of an input signal having an amplitude less than the preset amplitude threshold and a pulse duration more than the preset pulse duration threshold.

5. The circuit as recited in claim **1** further comprising a pull down circuit for maintaining the switching circuit in a conductive state until the input signal exceeds the preset amplitude threshold.

6. The circuit as recited in claim **1** where in the load threatening signal is a signal representative of open or short conditions.

7. The circuit as recited in claim **1** wherein the preset amplitude threshold is 0.7 volts.

8. The circuit as recited in claim **1** wherein the preset duration threshold is 0.0.5 msec.

9. The circuit as recited in claim **1** further including an optical coupler circuit disposed intermediate the switch and the load, the optical coupler circuit being operative to electrically insulate the load from the switch.

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