

NCV7691 Application Note Open Load Detection versus Startup Time



ON Semiconductor®

www.onsemi.com

APPLICATION NOTE

Introduction

The NCV7691 is a device, which uses an external NPN bipolar device combined with feedback resistor(s) (see Figure 2) to regulate a current for use in driving LEDs. The target application for this device is automotive rear combination lamps. A single driver gives the user flexibility to add single channels to multichannel systems. A dedicated dimming feature is included via the PWM input pin. The individual driver is turned off when an Open Load or short circuit is detected.

LED brightness levels are easily programmed using an external resistor in series with the bipolar transistor. The use of the resistor gives the user the flexibility to use the device over a wide range of currents. Multiple strings of LEDs can be operated with a single NCV7691 device.

In some cases to minimize the power losses outside of the LED lighting the system can be instead of direct battery connection supplied via DC/DC converter.

This application note deals with the Open Load detection during the startup time.

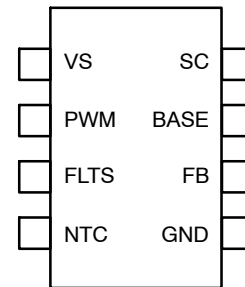


Figure 1. NCV7691 Pin Connection

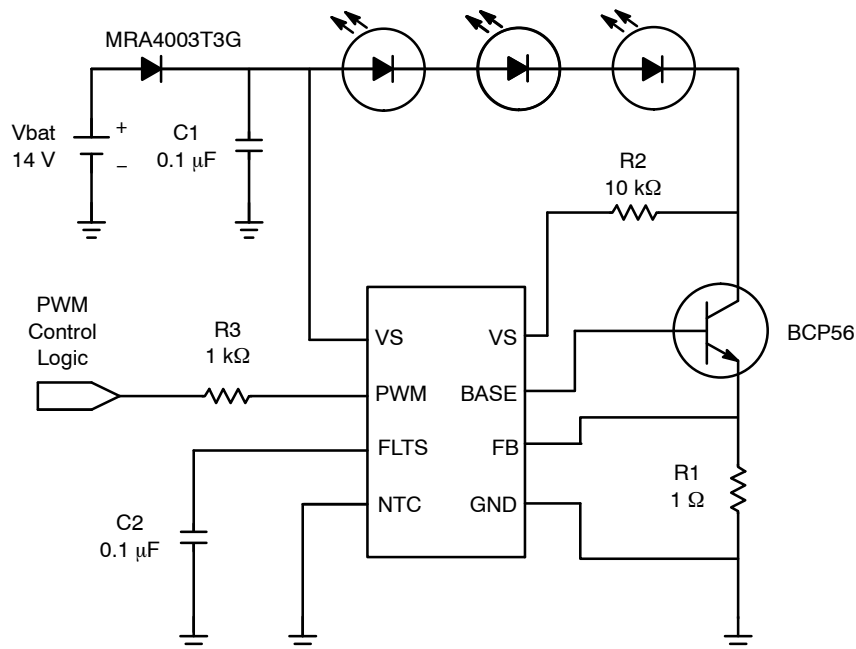


Figure 2. Application Diagram

Open Load Detection Mechanism

To detect an Open Load, the NCV7691 uses two methods. One of them is detecting the FB voltage. If the FB pin voltage is lower than Open Load detection threshold, the error is detected. The Open Load detection threshold is defined by the NTC input. If the NTC input pin is held at low level, the 76 mV Open Load detection threshold is used otherwise $V_{NTC}/20$ voltage reference is used. The second method uses current sensing on the base pin. When the base current rises exceed the 25 mA the error is detected. In application cases described in this document the situations leads to both detections being activated in parallel. In order to simplify the drawings in this document, only FB voltage detection at 76 mV is shown and typical voltage levels and delay times are depicted.

To avoid transient states caused by overshoots or disturbances at the beginning of power up, there is a 42 ms blanking time. The Open Load disable threshold of the NCV7691 is 8.5 V. To simplify the application note, the only VS Open Load Disable Threshold for VS falling is taken into account. The voltage threshold for VS rising is 8.9V. Below this level the Open Load detection is disabled. Open load detection can be detected when the voltage on VS pin rises above the OL disable threshold voltage (see [NCV7691 datasheet](#) [1] for details about the Open Load detections).

The calculation of the maximum forward voltage drop of the LEDs for proper function the Open Load detection during the start-up is $V_f = V_{Threshold} - V_{CE} - V_{FB}$.

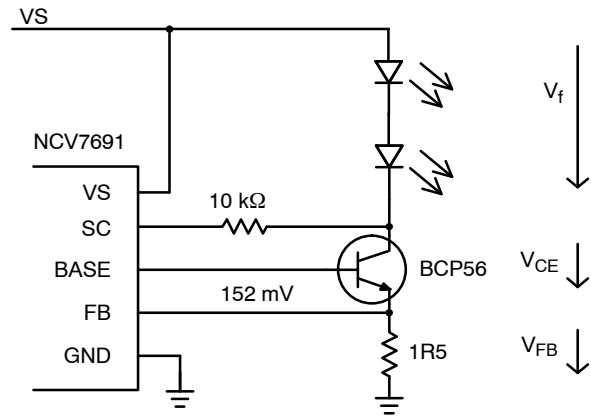


Figure 3. Calculation of Maximum Forward Voltage

In case of Open Load disable threshold is 8.5 V, it is recommended to use the LEDs with forward voltage up to 7.85 V.

$$V_f = 8.5 - 0.5 - 0.15 \text{ V}$$

$$V_f = 7.85 \text{ V}$$

It is recommended to use maximum three red LEDs with voltage drop of 6 V (2 V typ. per LED) or maximum 2 white LEDs with voltage drop of 6 V (3 V typ. per LED).

If more LEDs are used, the problems during the power-up can occurs in case of slow rising supply voltage.

Behavior of the NCV7691 for Three Application Cases

Figure 4 shows the behavior of the NCV7691 for three application cases. The PWM input signal is connected to the VS pin via a Pull-up resistor. A FLTS capacitor is connected to the FLTS pin. The device is inactive until the VS voltage is lower than the Power on Reset threshold. When the voltage on the VS pin reaches POR level, the 23 μ s Power-up blanking timer starts. At the end of the Power-up blanking period, the device checks the conditions for Open Load. If the conditions indicate the Open Load, the device starts counting for 42 μ s of the Open Load blanking time. Open Load is inactive below VS < 8.5 V. When the VS supply voltage is above the “VS Open Load Disable Threshold” and the conditions are met (OL is present and blanking time has expired) the FLTS capacitor is charged

with 2 mA current. If V_{FB} rises above 76 mV and V_{FLTS} is lower than 1.15 V, the FLTS capacitor starts to discharge via a 600 k Ω resistor.

Area II. in Figure 4 shows small battery voltage drop. If the V_{FB} will not drop below 76 mV threshold, no Open Load will be detected.

Area III. shows the case when Open Load in the multiple string application occurred. The device starts counting 42 μ s blanking time as soon as voltage on the FB pin falls below 76 mV. As soon as the Open Load blanking time expires, the FLTS capacitor is being charged. When the voltage on the FLTS exceeds the output deactivation threshold (1.15 V (typ)), the BASE pin is pulled low and the device remains in latched condition.

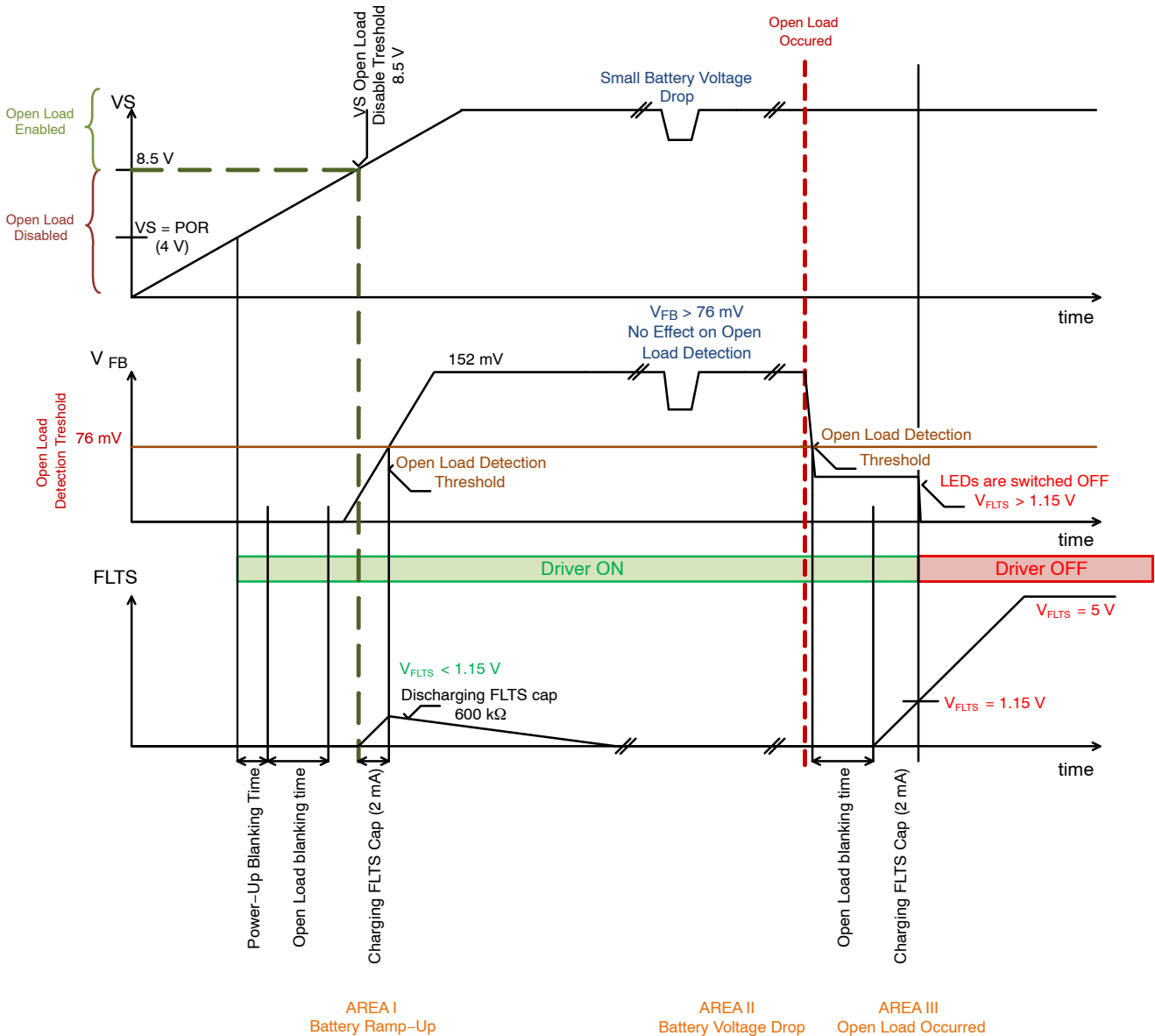


Figure 4. Example of Behavior During the Open Load detection

Open Load Detection Cases

In case a DC/DC converter is used as mentioned on page 1, the ramp up slope of the VS supply needs to be checked. The Figure 5 shows four combinations of slow and fast slope and forward voltage drops of the LEDs.

Figure 5 a) Slow VS slope, V_f is lower than recommended (less LEDs used), correct detection.

Figure 5 b) Slow VS slope, V_f is higher than recommended (more LEDs used), driver is switched OFF.

Figure 5 c) Fast VS slope, V_f is lower than recommended (less LEDs used), correct detection.

Figure 5 d) Fast VS slope, V_f is higher than recommended (more LEDs used), correct detection.

In Figure 5 b) we see that if the VS slope is too slow and V_f is higher than recommended, a false Open Load occurs during the startup.

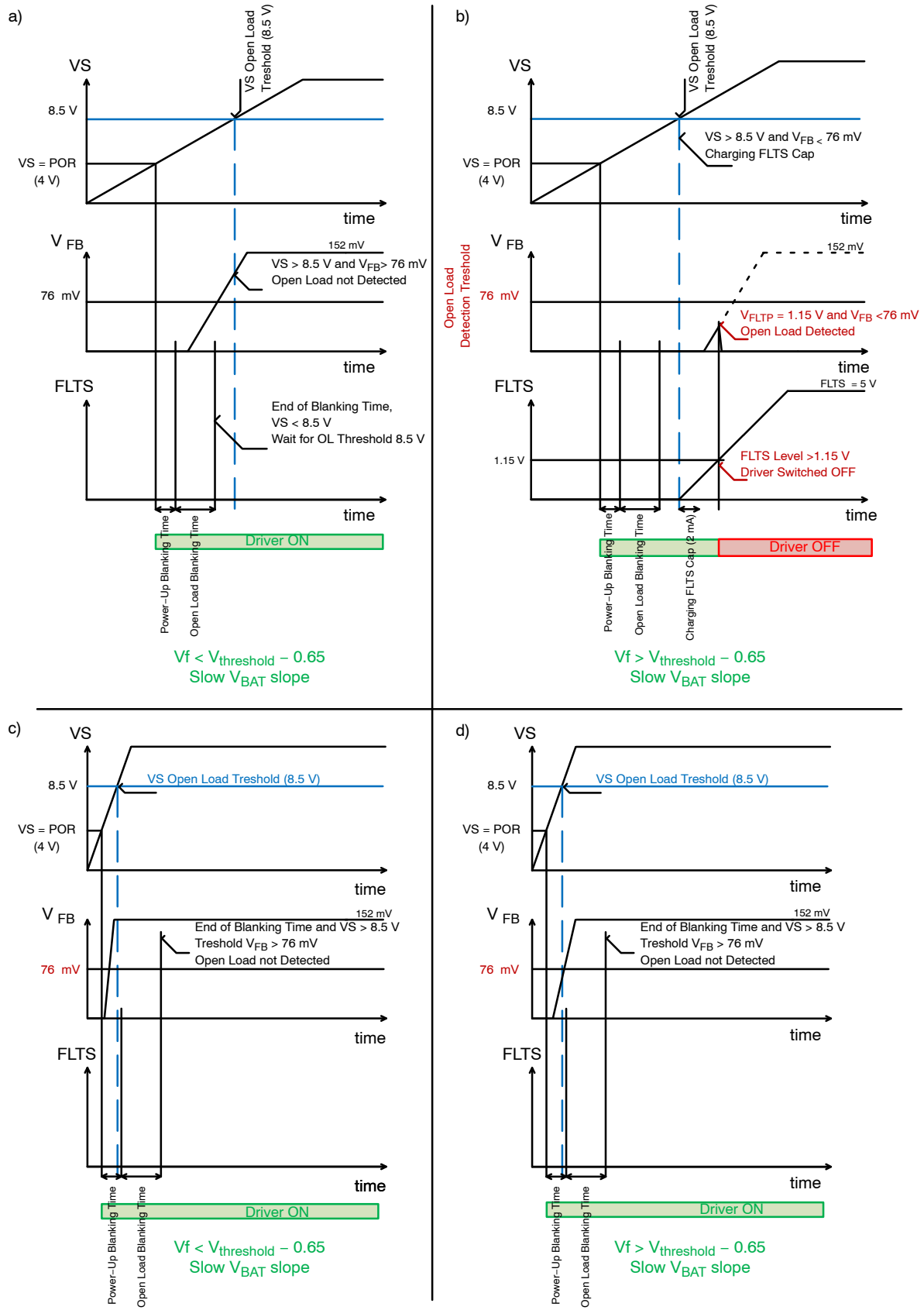


Figure 5. Behavior of the NCV7691 During the Slow and Fast Voltage Ramp up

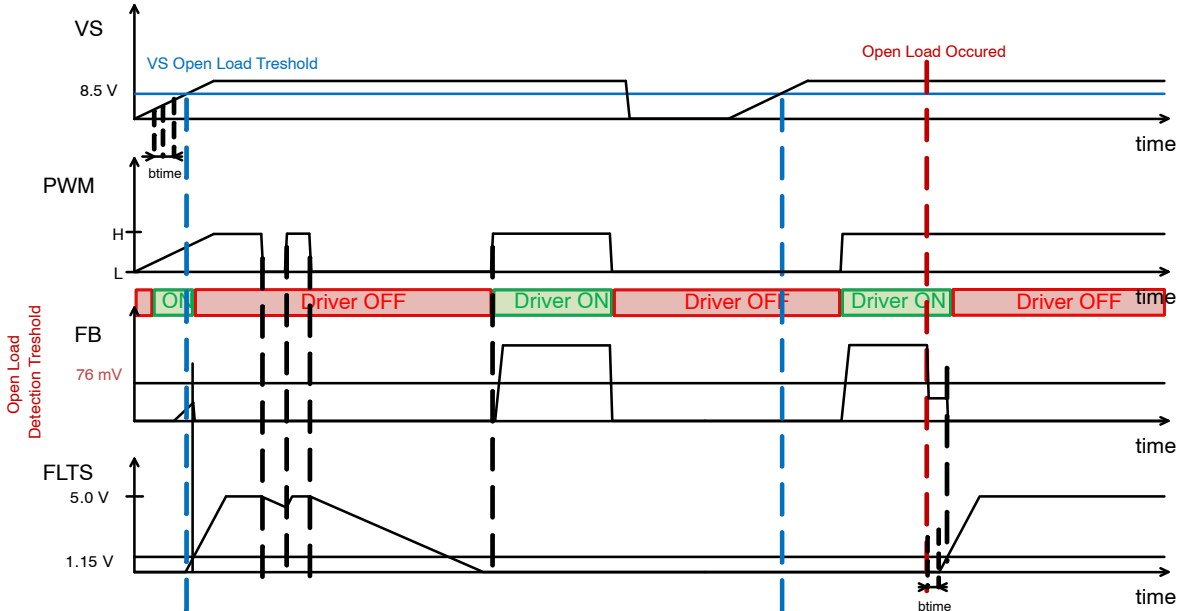
False Open Load Detection Prevention

The simplest solution might be just to *enlarge the FLTS capacitor* to extend the FLTS charging time before the driver is switched OFF. Charging the 10 nF capacitor to 1.15 V will take 5.75 μ s. A 220 nF capacitor will increase

the FLTS charging time up to 126.5 μ s (see comparison between two different capacitors in Figure 6).

The next section deals with various external solutions how to avoid false open load detection.

a) Smaller FLTS Capacitor



b) Larger FLTS Capacitor

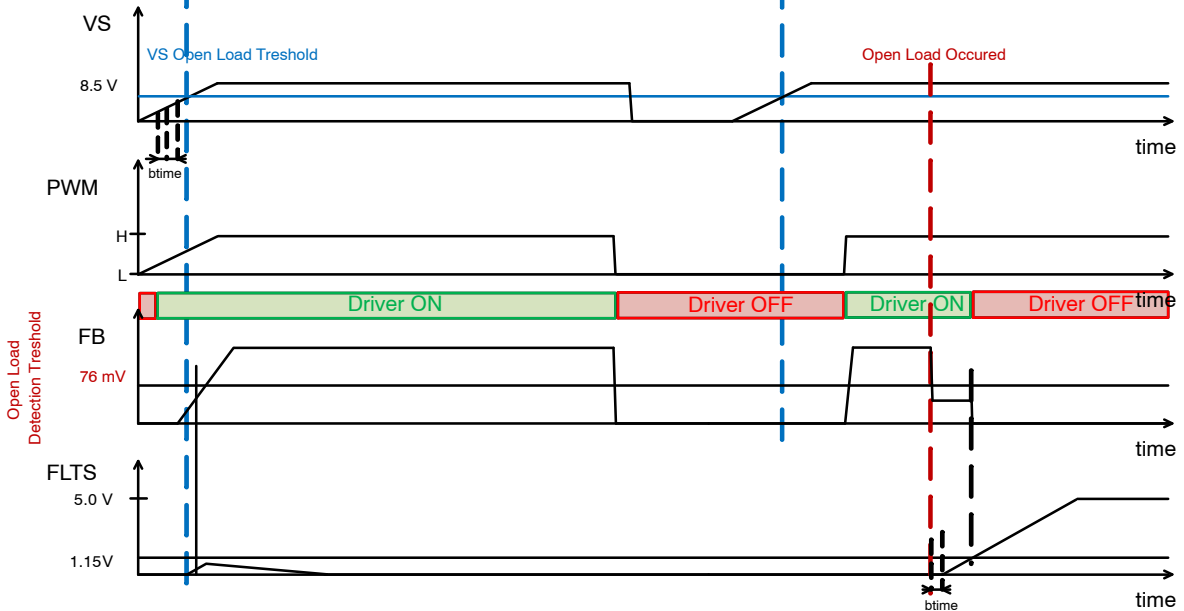


Figure 6. Behavior of NCV7691 with Smaller and Larger FLTS Capacitor during the Startup

First two methods works with holding the FLTS pin below 1.15 V threshold to ensure turning ON the LEDs as soon as possible.

First one is an example of an *application not using a microcontroller*. The FLTS pin is hold below 1.15 V by an extra circuit as depicted in Figure 7. A resistor divider

reduces the voltage from the battery. An **RC circuit** will create a **delay** for base pin of the **PNP transistor**. For a limited amount of time the PNP transistor will be switched ON while FLTS will be in High level (Error state). When the capacitor from the RC circuitry is charged, the PNP transistor is switched OFF and normal operation can begin. It is necessary to calculate the values of the resistor and the capacitor according to the supply voltage and time delay. It must be guaranteed that the PNP transistor has a V_{BE} -breakdown voltage which is sufficiently high to avoid leakage that would pull up the FLTS pin.

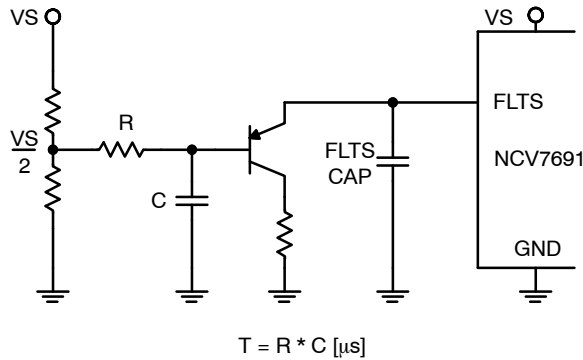


Figure 7. Application without MCU for Avoiding False Open Load Detection

In case of **application with MCU** we can use an MCU to avoid false Open Load detection. The schematic is shown in the Figure 8. The base of an **NPN transistor** is driven by a weak pull-up resistor. The Pull up resistor ensures that the NPN transistor is switched ON as soon as possible because the power-up of the MCU can be very slow. After power up, the controller can take control over the NPN transistor and switch OFF the transistor to continue in normal function of the NCV7691 with active open load detection. Another pin of MCU can be used for sensing

the FLTS output in normal operation. It is important to check the reset state of the MCU pins before developing this application. This solution is suitable for applications where the fast response is needed.

A simple method especially if the activation time of the LEDs is not critical and if the **PWM signal is present**, could be to **toggle with the PWM** input to clear the error after the startup. The LEDs will be switched ON with the rising edge of the PWM signal. The PWM signal must stay at a low level until the FLTS cap is discharged below 1.15 V threshold.

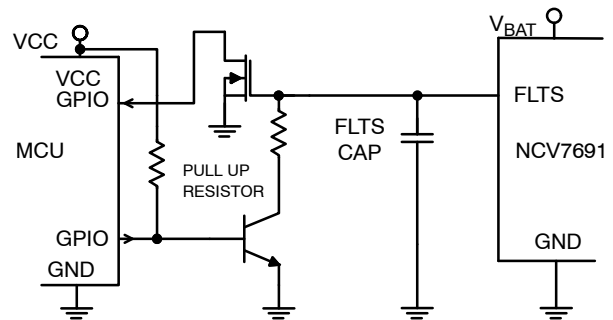


Figure 8. Application without MCU for Avoiding False Open Load Detection

The methods to avoid false open load detection mentioned so far assume that the maximum ramp up time is known. Another solution which would be **independent of ramp-up time** could be to **spread the forward voltage** of the LEDs into two parallel strings by adding an NPN transistor and sense resistor. The problems with false OL detection will disappear by lowering the V_f voltage. The **voltage** between the VS pin and the SC pin must be **greater than 2 V** to avoid false short circuit detection. This means, it is required to use e.g. at least two red LEDs in one string or one white LED (see simplified Figure 9).

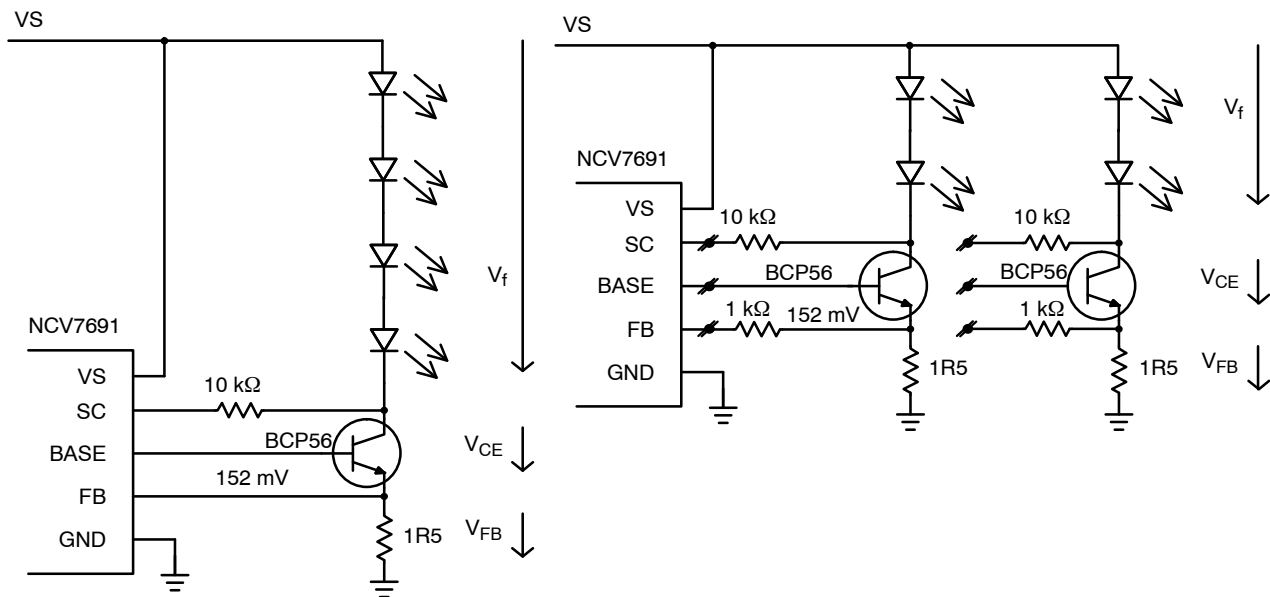


Figure 9. Spread LEDs into Two Strings

Summary

A slow battery slope combined with a high forward voltage of the LED string can cause false Open Load detection during start-up. In this document several solutions were discussed to overcome this effect. It depends on the concrete application which solution can be the most appropriate to avoid false open load detection.


The simplest method to increase the delay is to enlarge FLTS capacitor. Another solution is to add an extra transistor plus RC circuitry, which holds the FLTS pin to ground for a certain amount of time during power-on. An MCU plus an NPN transistor can be used as solution as well. In these cases the LEDs will be switched ON immediately after the

startup. If the switching time in the application is not critical, activation of the driver by rising PWM input can be used.

Another possibility might be splitting one longer LED string into smaller parallel LED strings with total LED forward voltage being lower in the range not causing false detection. This technique is especially useful when it is not possible to determine the ramp up time.

References

- [1] ON Semiconductor, NCV7691, Current Controller for Automotive LED Lamps, August 2017
- [2] ON Semiconductor, BCP56, NPN Silicon Epitaxial Transistors, March 2018

ON Semiconductor and  are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:

Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303-675-2175 or 800-344-3860 Toll Free USA/Canada
Fax: 303-675-2176 or 800-344-3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800-282-9855 Toll Free
USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910

ON Semiconductor Website: www.onsemi.com

Order Literature: <http://www.onsemi.com/orderlit>

For additional information, please contact your local Sales Representative