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NCV7691 Application Note Open Load Detection versus Startup Time

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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.

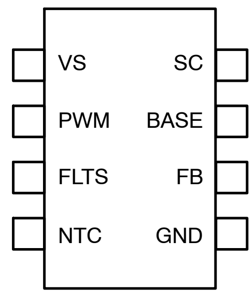

Figure 1. NCV7691 Pin Connection

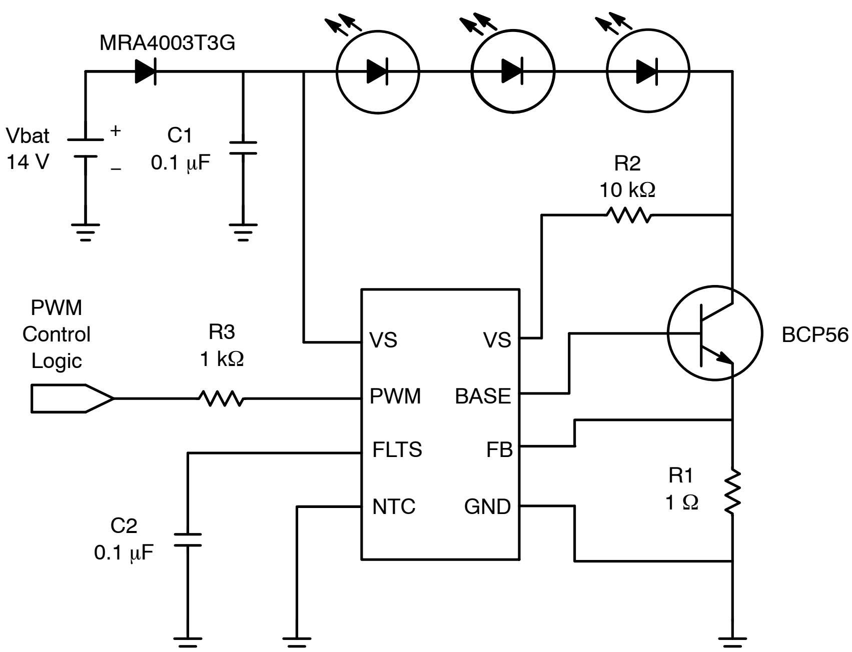

Figure 2. Application Diagram

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 $V_f = V_{Threshold} - V_{CE} - V_{FB}$.

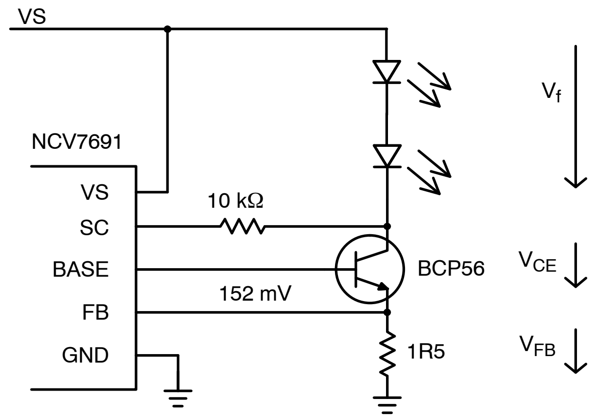

Figure 3. Calculation of Maximum Forward Voltage

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 μs 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 μs 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 kΩ 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 μs 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.

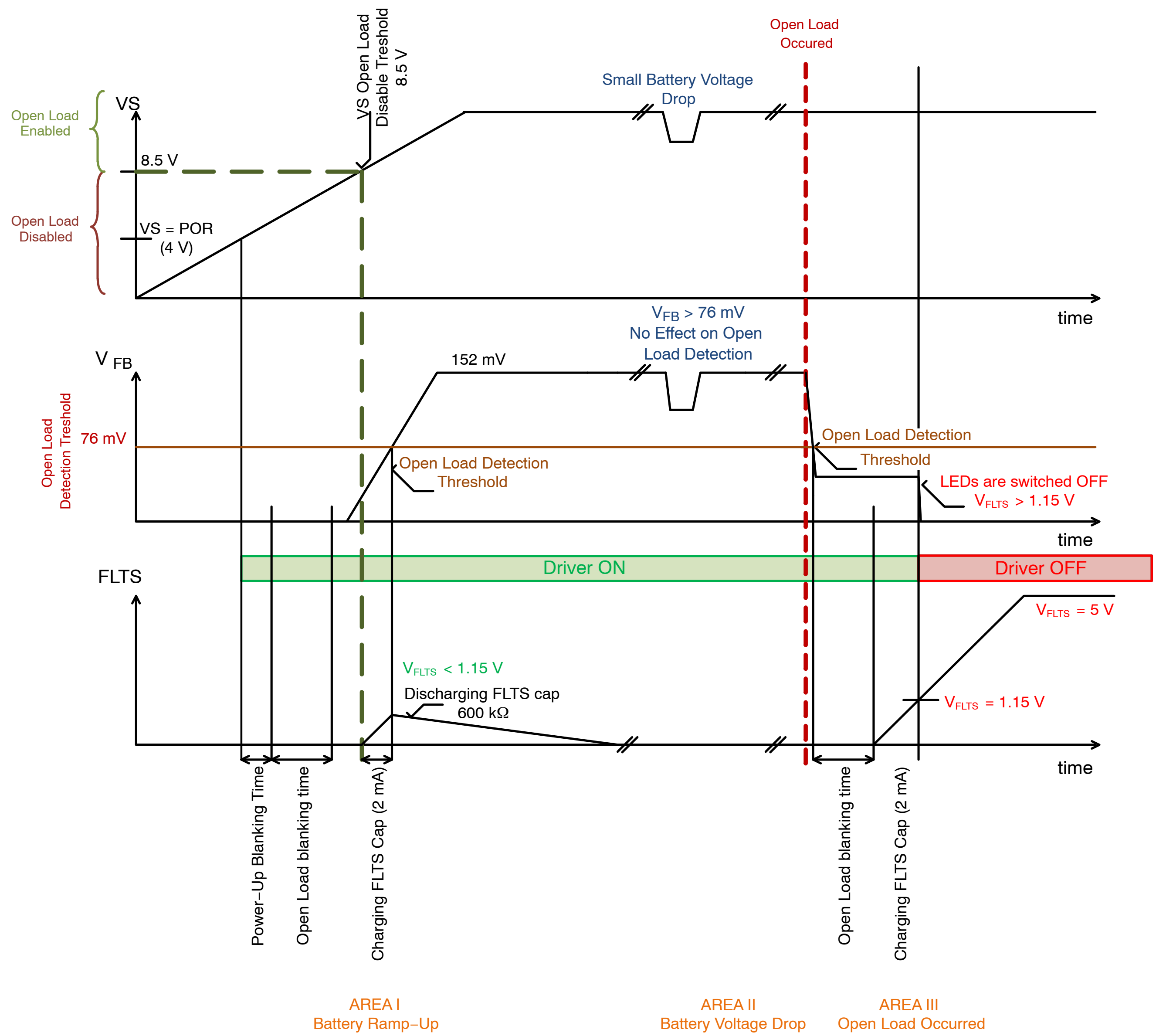

Figure 4. Example of Behavior During the Open Load detection

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.

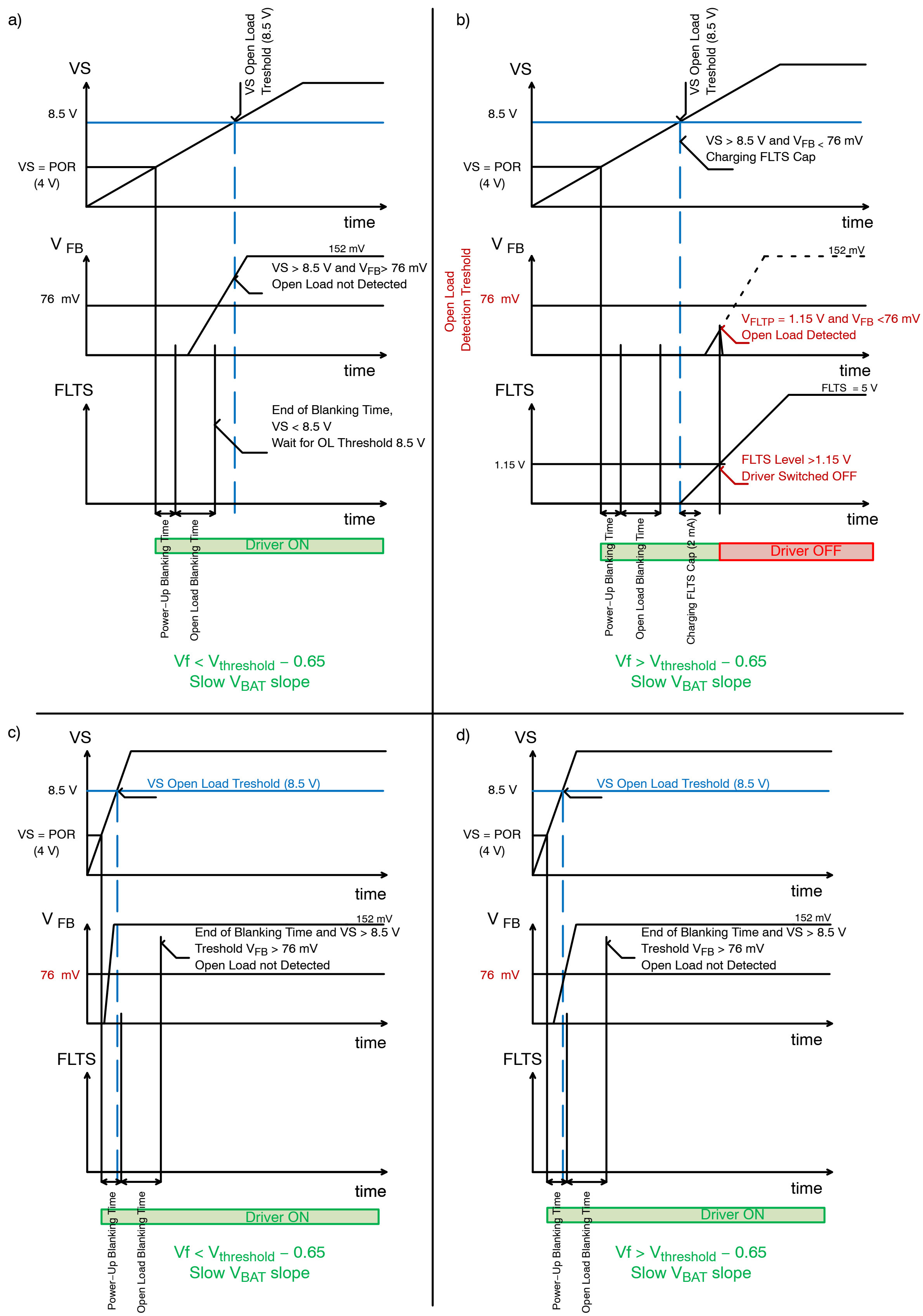

Figure 5. Behavior of the NCV7691 During the Slow and Fast Voltage Ramp up

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 μs. A 220 nF capacitor will increase the FLTS charging time up to 126.5 μs (see comparison between two different capacitors in Figure 6).

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

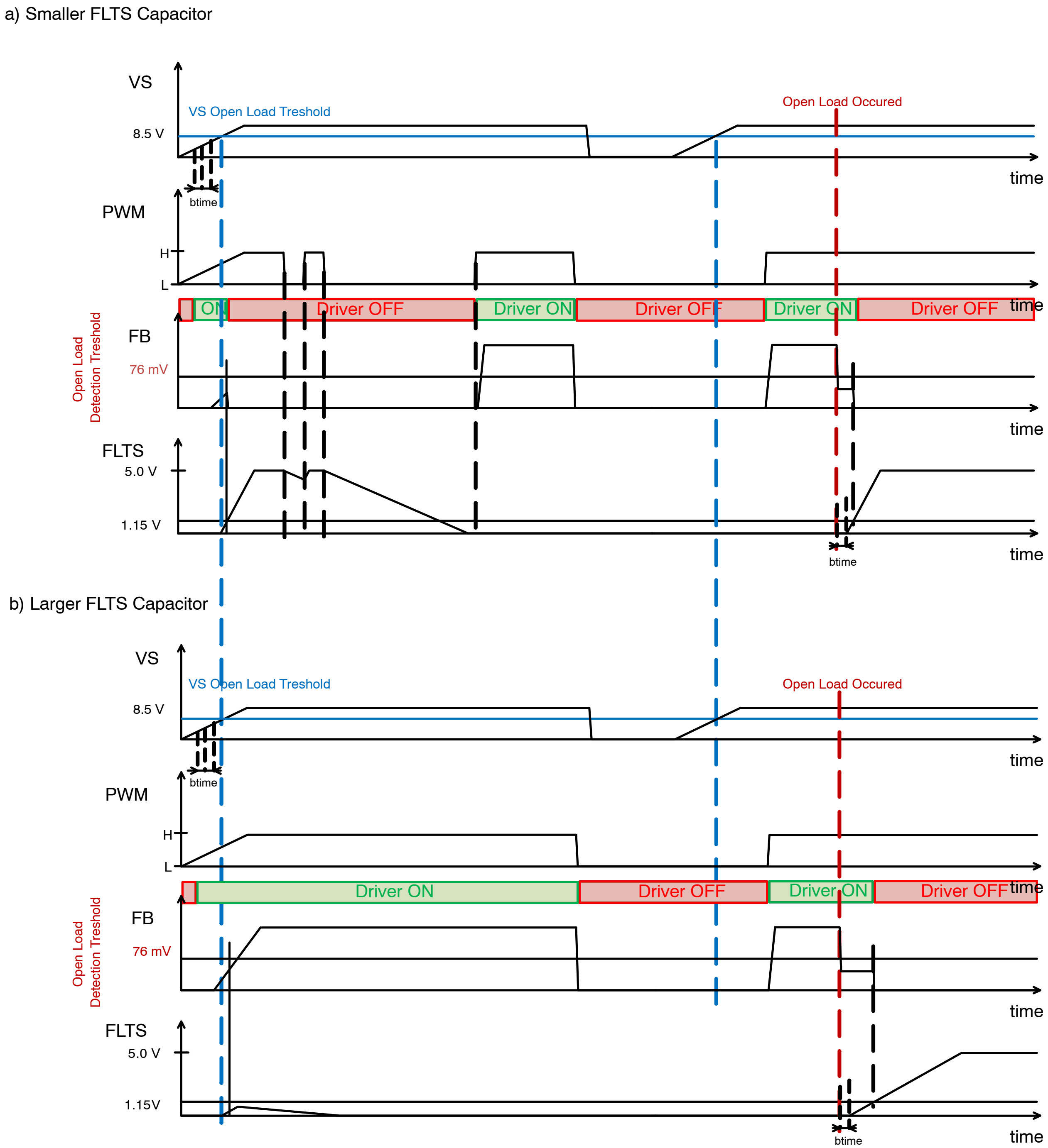

Figure 6. Behavior of NCV7691 with Smaller and Larger FLTS Capacitor during the Startup

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.

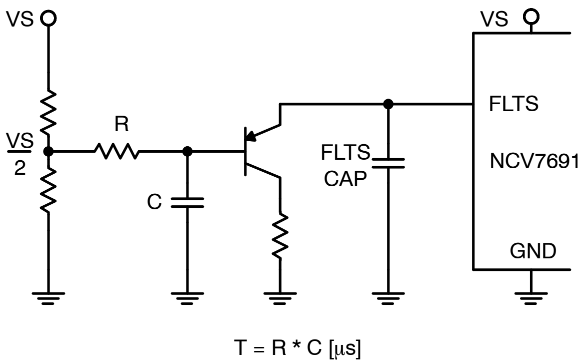

Figure 7. Application without MCU for Avoiding False Open Load Detection

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 untill the FLTS cap is discharged below 1.15 V threshold.

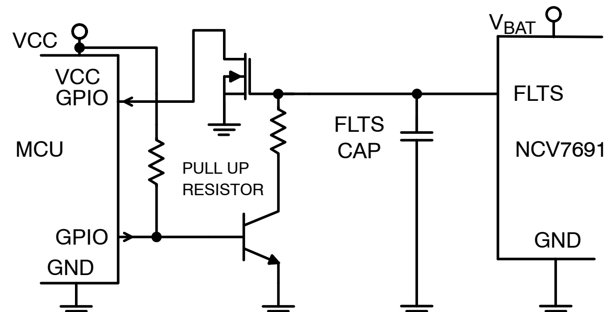

Figure 8. Application without MCU for Avoiding False Open Load Detection

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).

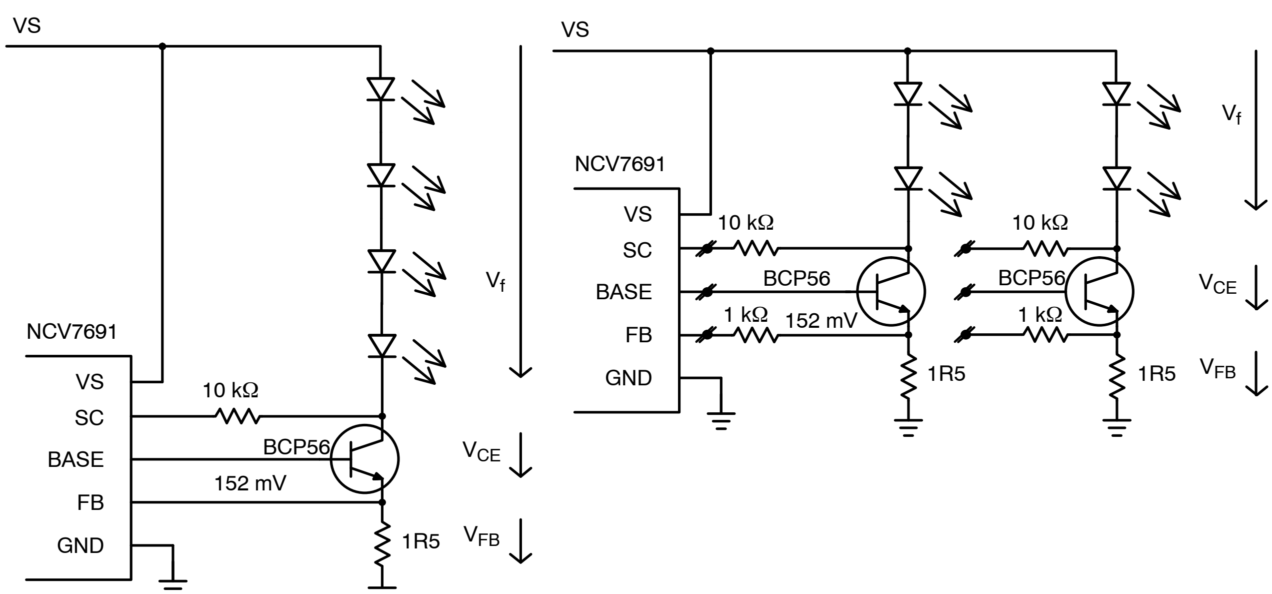

Figure 9. Spread LEDs into Two Strings

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

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