AND8450/D

NCV7680 LED Driver Linear Regulator Performance

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APPLICATION NOTE

Introduction

The NCV7680 is an automotive LED driver targeted primarily for rear combination lamp systems. A high input voltage to this type of system can create a situation which will cause the temperature of the IC to exceed its recommended operating condition if not accounted for. The NCV7680 helps prevent exceeding the recommended operating conditions of the IC by partitioning the system power between the analog IC and an external PFET device. This is accomplished by the provided on−chip linear regulator of the NCV7680 which provides the distribution of power network. This application note highlights the performance of the linear regulator in the system.

This example in power distribution has the NCV7680 set up to be 35 mA per string. The 8 strings of LEDs result in 280 mA of current draw.

Figure 1 highlights the issue presented by an unregulated power supply line powering a current source driving LEDs such as with the NCV7680. During normal operation with a battery voltage of 14 V, the subsequent voltage at the cathode at the bottom of the LED string is designed to be 1 V. Under that condition the contribution to the power to the IC is 280 mW.

Typical automotive design requires the system to withstand a double battery condition. In that state, you can see the power to the IC increases dramatically from the rise in voltage level at the cathode of the LEDs. With a normal battery voltage (14 V) the cathode voltage is 1 V. At double battery (28 V), the cathode voltage increases to 15 V.

Since this is a current source, the current remains the same, but the power increases from 280 mW to 4.2 W due to the increase in voltage. This is not an acceptable power level for this package in an automotive environment.

Quiescent current into the IC (6.5 mA) contributes to the power dissipated in the IC (91 mW to 182 mW), but is not the primary source of increased power dissipation.

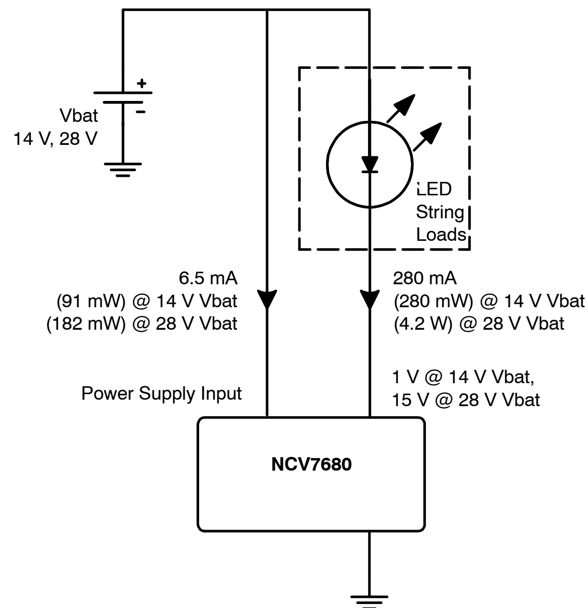

Figure 1. Typical Application without External FET

Figure 2 shows the result of the system setup using the NCV7680 with a regulated voltage of 10.5 V on the anode of the LEDs. Now the situation with respect to power to the IC does not change with changes to the input battery voltage. A regulated voltage of 10.5 V is always supplied regardless of changes in the battery. Total power in the NCV7680 is 360 mW using the same loading conditions as in Figure 1.

Under double battery conditions the PFET will absorb the added power. Normal 14 V battery conditions yield 3.5 V across the PFET. With 288 mA out of the FET, power dissipated is 1 W. An increase to 28 V battery voltage will yield 17.5 V across the FET. The FET will now dissipate

5 W. This is a much more acceptable condition for a discrete FET than an analog IC.

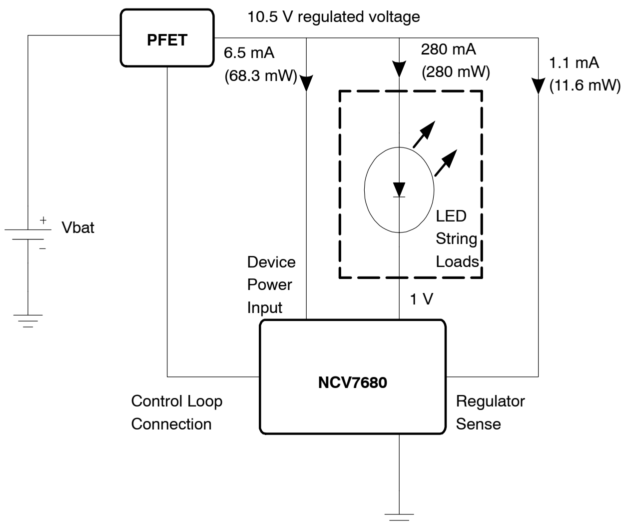

Figure 2. Typical Application with External FET

The 10.5 V regulated voltage in Figure 2 is created from the combination of the NCV7680 linear controller (comprised of the feedback pin [FB] and Ballast Drive [Ballast Drive] pin) and the external PFET as shown in Figure 3.

This voltage regulation, as with all linear regulators, forms a loop around which gain must be controlled. The frequency roll−off characteristics of the gain are mainly controlled by 3 components: 2 poles and a zero.

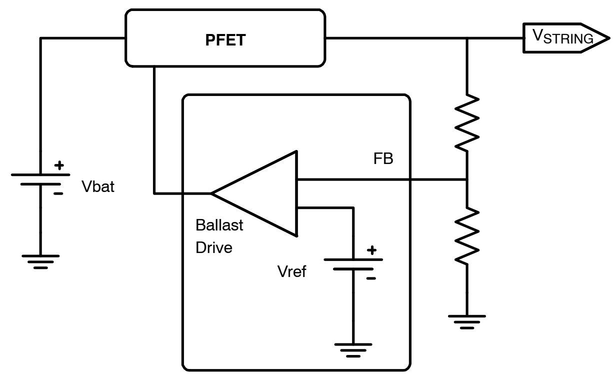

Figure 3. Linear Regulator Controller

Table 1. LINEAR REGULATOR FREQUENCY RESPONSE CONTRIBUTORS

Poles	
1. The Error amplifier (Ballast Drive) output impedance (comprised of the external 1k resistor in parallel with the Ballast Drive output impedance shown in Figure 4) and the capacitance on that node (primarily influenced by the Miller effect of C2 and NTD2955).	This pole is the majority contributor to the system frequency compensation design in this application and can be used as the control knob for stability. This application utilizes a capacitor across the gate−drain of the FET to make use of capacitance multiplication.
2. The equivalent output capacitance (C3 et al) and the equivalent resistive loading comprised of the LEDs and the external feedback resistors. Additionally, The output impedance of the external pass device and the capacitance on that node (C3 plus all capacitance due to the external LEDs) should be considered as minor weighting.	
Zero	
3. The external load capacitance (C3) and its Equivalent Series Resistance (ESR).	

Stability in the loop is designed to be controlled by the external components around the external PFET device. More specifically C2 will be the major contributor to stability. C1 is for line noise considerations. C3 is for EMS (Electromagnetic Susceptibility) considerations. The source−gate resistor provides a voltage to the gate when driven by the Ballast Drive pull−down transistor and is also a contributor to the frequency response.

C2 is commonly known as the "Miller Capacitance". The total input capacitance of the PFET is multiplied by a factor of 1 + A_V and has the effect of lowering the bandwidth slowing the loop and providing stability.

Accordingly, the stability control in the system is by the pole provided from the equivalent output impedance of the drive to the gate of the transistor and the equivalent PFET input capacitance.

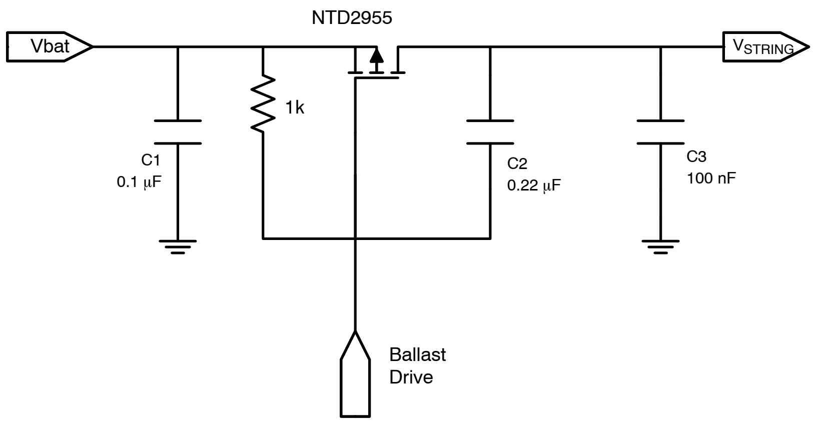

Figure 4. External PFET with external support components including C2

A single pole contribution to the frequency response of the loop causes the gain to change at a rate of −20 dB/decade. The phase shift attributed to a single pole causes a phase shift of 90°.

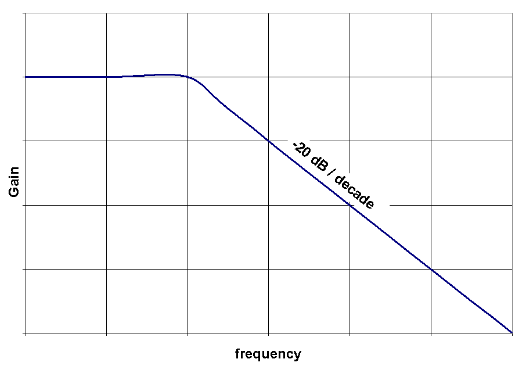

Figure 5. Ideal Single Pole Gain Response

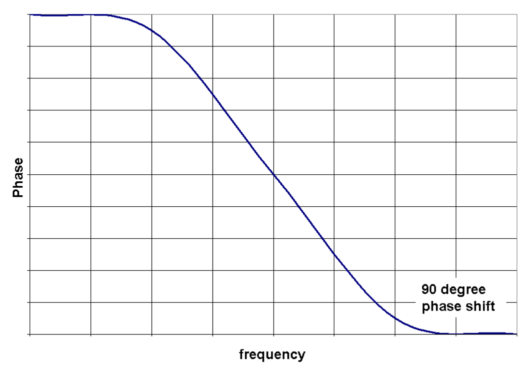

Figure 6. Ideal Single Pole Phase Response

Part Performance

A device setup as in Figure 7 is shown to yield the response shown in Figure 8. Notice the similarities to Figures 5 and 6.

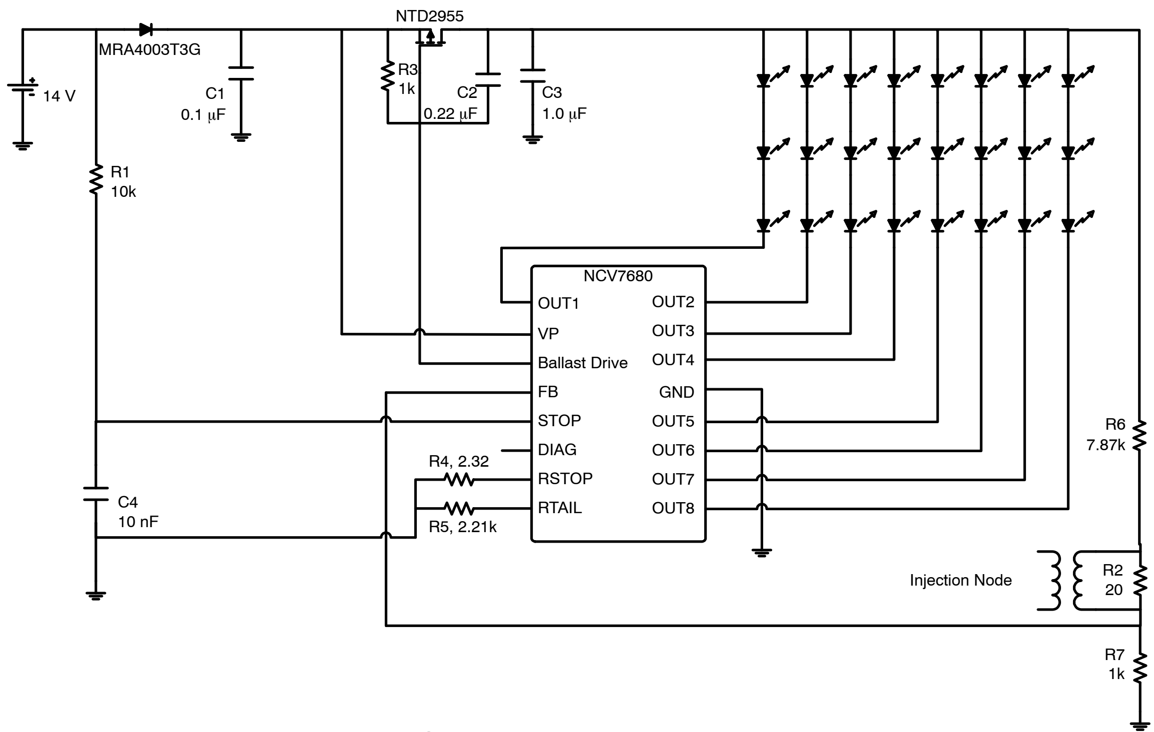

Figure 7. Schematic Used in Bode Plot Testing

The capability of gate−drain capacitor as the controlling entity is displayed by the variation in the capacitor value of C2. A review of Figures 8 and 9 illustrate the effect. Figure 8 utilizes a value of 0.22 μF for C2. Figure 9 raises the value from 0.22 μF to 1 μF. This moves the pole as is displayed in the phase response moving to the left in Figure 9 as compared to Figure 8.

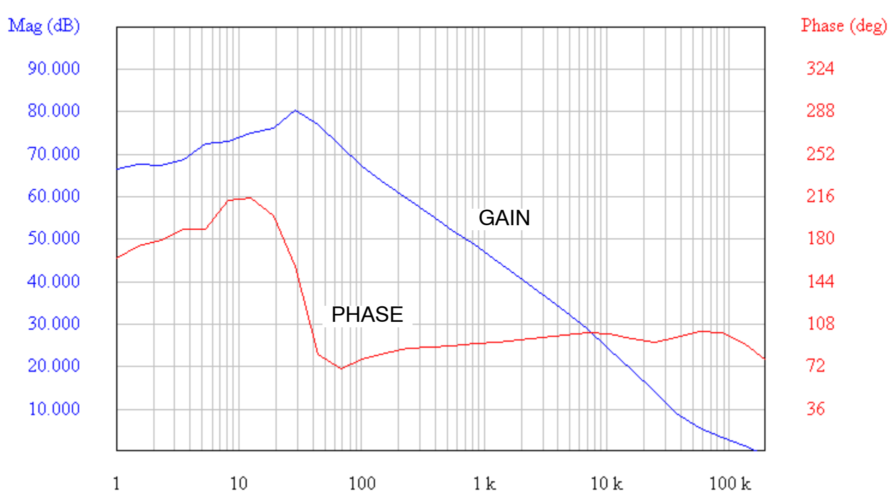

Figure 8. Frequency Response with 0.22 μF Load @ 50 mA / Channel (14 V)

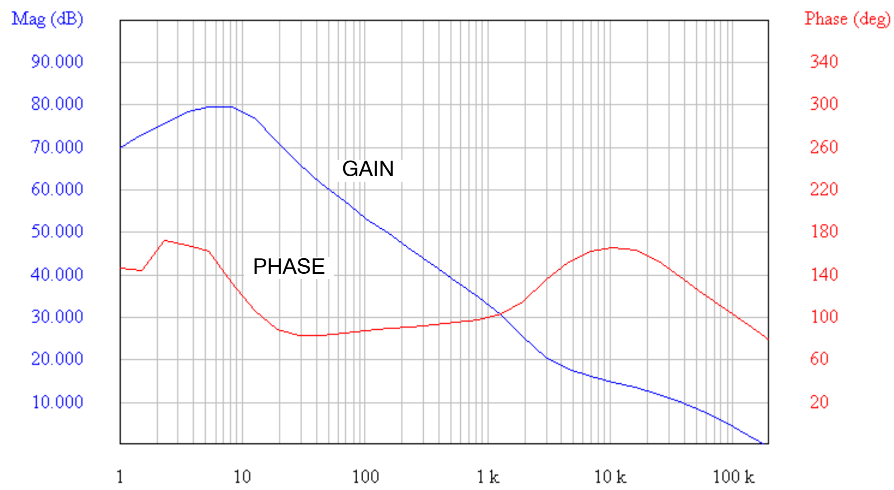

Figure 9. Frequency Response with 1 μF Load @ 50 mA / Channel (14 V)

Summary

System requirements can dictate the need to distribute power to maintain proper integrated circuit operating temperatures. One way to accomplish this is to design a linear voltage regulator in series with main IC.

The control loop of linear regulators needs to be slowed in order to obtain stability in the system. There are multiple poles in the system which effect its' operation, but the use of the Miller capacitance multiplication in the gate−drain of the external FET helps keep the value low. The result is the stability of the NCV7680 linear regulator can be controlled by a single capacitor in the loop.

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