Application Report
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Simple Backlight Driver Dimming Performance

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ABSTRACT

The TPS61158, TPS61160/61, TPS61162A/63A, TPS61165, and TPS61169 (hereafter "TPS611xx") are simple backlight drivers commonly used in smartphones and tablets. These devices support PWM dimming with an input voltage as low as 2.7 V. This application note discusses the requirements for using the TPS611xx parts at the lowest performance specifications for PWM dimming.

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1 Minimum PWM On-Time Requirement

All devices mentioned except for the TPS61169 are equipped with both PWM dimming and EasyScale™ 1-wire control interface; the TPS61169 only has PWM dimming. All devices with 1-wire control have a minimum PWM input on time of 50 ns. For pulse widths below 50 ns, or equivalently a 0.5% duty cycle at the maximum frequency, 100 kHz, the internal-glitch rejection on the PWM (or CTRL) input can randomly detect or ignore logic pulses. As a result, going below 50 ns can inadvertently trigger the device to enter 1-wire mode. To ensure proper detected logic levels, keep the pulse width above 50 ns. When 1-wire control is randomly activated, the default current output is maximum current, causing the device to output inconsistent output current. Because the TPS61169 does not have 1-wire control, at lower input voltages- the device does not stop outputting current unless the PWM signal is 0 V. *Any pulse width greater than 50 ns at any frequency within the range of each chip, respectively, outputs a stable and steady current.*

2 Minimum Performance Specifications

The 100-kHz PWM frequency and 3.3-V input voltage was used to test each device. The maximum current for all the devices was set to 20 mA.

2.1 Linearity

These devices maintain their linearity as low as 1% duty cycle at all frequencies in range.

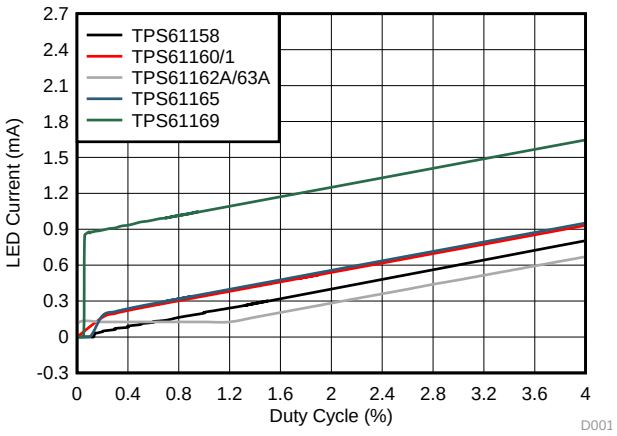

Figure 1. Low Duty-Cycle Behavior

2.2 Internal Low Pass Filter to Error Amplifier

All devices mentioned have an internal low-pass filter on the control pin. The output of the low-pass filter is connected to the error amplifier as a DC-reference voltage for the FB pin regulation. Though a PWM signal is used to control the LED current, the LED current has a varying DC current that is proportional to PWM input duty cycle. Using this low pass filter eliminates any audible noise due to the output voltage ripple at the PWM frequency and also allows the regulation voltage to be independent of the PWM logic voltage, which often has large variations. Figure 2 shows the internal low-pass filter and error amplifier schematic.

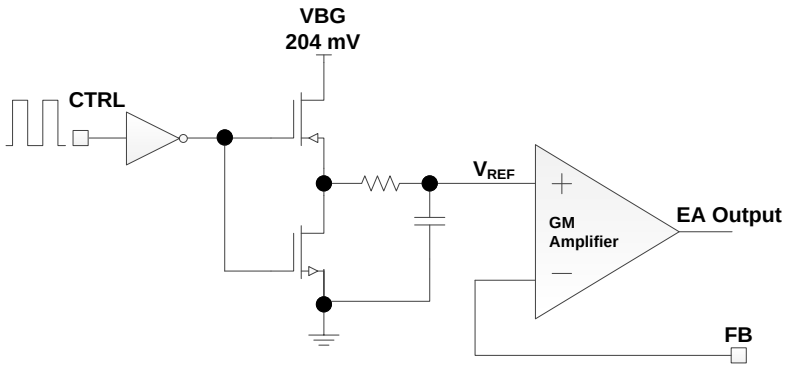

Figure 2. Internal Low-Pass Filter to Error Amplifier

2.3 *Offset Voltage in Error Amplifier*

Offset voltage is a non-zero value of a differential input created when the inputs of the GM amplifier are not exactly matched. It can be modeled as shown in Figure 3.

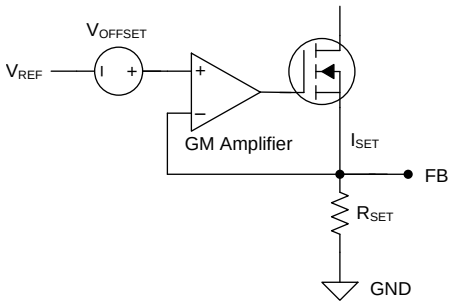

Figure 3. Offset Voltage Model

Table 1. Typical Voltage Offset

Device	TPS61158	TPS61160/61	TPS61162A/63A	TPS61165	TPS61169
Voltage offset (mV)	0.039	0.68	1.27	0.83	8.6

3 TPS61162A/3A Special Cases

The TPS61162A/63A are the only devices listed in Table 1 that use a 9-bit ADC to convert the low-pass filtered PWM signal-to-digital current values. Figure 4 is the block diagram of the front end before the error amplifier. This creates special cases as described below.

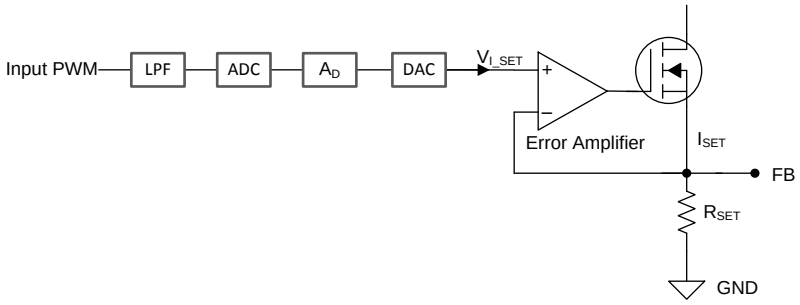

Figure 4. TPS61162A/TPS61163A Error Amplifier Block Diagram

3.1 Hysteresis

Hysteresis is the system dependence on the history of the previous current. It prevents any PWM jitter from feeding through to the LED current by preventing duty-cycle-to-LED current changes until the duty cycle overcomes 2 LSBs after a change in direction.

The minimum current the TPS61162A/TPS61163A can supply is 3 × $I_{FULL\ SCALE}$ / 512 and supplies this current as soon as a measurable PWM signal is detected. Furthermore, when using the device at either maximum or minimum ADC values to output 3 × $I_{FULL\ SCALE}$ / 512 or $I_{FULL\ SCALE}$, the hysteresis holds these values for longer, typically about 3 LSBs, as opposed the 2 LSBs of hysteresis in the intermediate steps (see Figure 5).

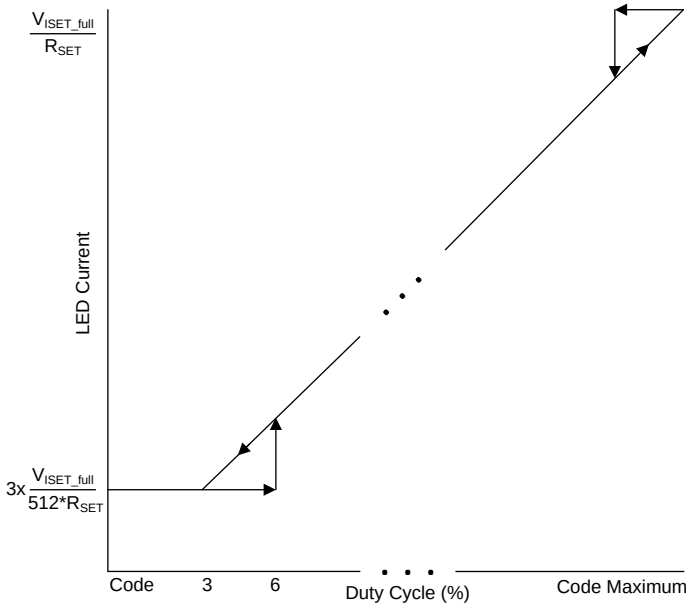

Figure 5. Hysteresis

3.2 Resolution

The TPS61162A/63A has a 9-bit ADC, which provides for a minimum of $I_{FULL\ SCALE}$ / 512 increment in LED current. Any PWM signal with greater than 9-bit resolution steps still results in 9-bit incremented current steps.

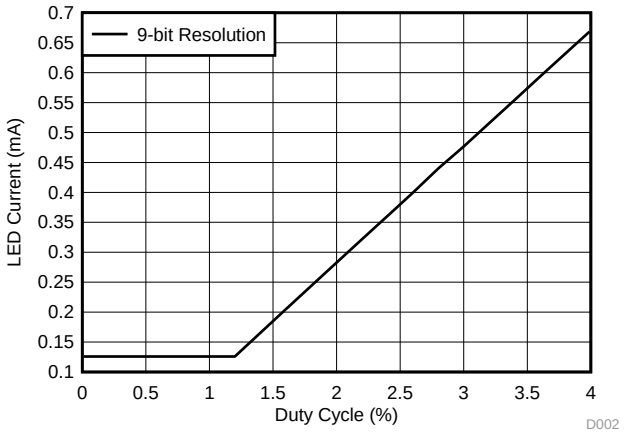

Figure 6. Incrementation Effects on Resolution

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