Cell Phone Camera Flash Solution Using the AAT3110-4.5 Charge Pump

General Description
Cell phone cameras are now prevalent in the market place. These cameras are capable of taking still pictures and some are able to record short segments of video in "movie-mode." One limitation to these phone cameras is the lack of proper lighting sources for nighttime photos and video. A standard capacitor-charged flash is fine for still photos, but it cannot provide a constant light source for movie-mode recording. Most constant light sources do not provide the luminous intensity needed for a camera flash.

Application Problem
A small bank of three or four white light emitting diodes (LEDs) can be used to provide a constant background light for nighttime movie-mode recording or a flash for still photos. Recent advancements in white "flash" LEDs have resulted in products that can emit as much as 500mcd\(^1\) with 15mA of forward current and over 2000mcd with a forward current of 75mA. The challenge in using flash LEDs for this application is to generate 60mA of constant current (when using four flash LEDs) and a pulsed current of much larger value.

White LEDs have the unusual property of a variable forward voltage drop dependent on current. The white flash LEDs for this application typically have a 3.3V drop with 15mA of forward current and a 3.8V drop with 75mA of current\(^2\). (Note: It is suggested that only flash LEDs be used for this application.) The power supply to the LED circuit must be able to account for this change in forward voltage drop, while still providing the necessary current output.

The last major issue to address is supply voltage. Typical cell phone handsets are powered by a single cell lithium-ion/polymer battery operated within a voltage range of 4.2V to 3.0V. A power device for this design solution must stabilize the varying input voltage supply to the white flash LEDs.

Application Solution
The AAT3110-4.5 charge pump can generate the current required to fulfill flash and movie-mode light needs. The following notes outline two solutions for this flash application. One solution uses a single AAT3110-4.5 and can generate more than 200mA of pulsed current. The second solution uses two AAT3110-4.5 devices to generate as much as 490mA of pulsed current. The amount of current needed for the flash (and hence the desired brightness) will determine which solution should be implemented.

Background Information
As briefly stated above, a white LED is a nonlinear device. Therefore, it can be misleading to present data using white LEDs without first offering some background to the performance of the AAT3110-4.5 charge pump. For this reason, the discussion will begin by providing a brief description of the output current capabilities of the AAT3110-4.5 under a resistive (constant) load.

The AAT3110-4.5 voltage doubling charge pump IC can generate a large output current under even low input voltages. To demonstrate the capabilities of a single AAT3110-4.5, the maximum pulsed output current was measured while maintaining \(V_{\text{OUT}}\) above 10% of regulation value (\(V_{\text{OUT(min)}} = 4.0V\)). Data was gathered for

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1. Candela (cd): The luminous intensity of a light source producing single-frequency light at a frequency of 540 terahertz (THz) with a power of 1/683 watt per steradian, or 18.3988 milliwatts over a complete sphere centered at the light source.
2. Nichia NBCW011T high-output white LEDs (4 LEDs/package)
varying input voltages at 25°C and 70°C. As shown in Figure 1, at room temperature the AAT3110-4.5 can generate over 250mA of current at even the lowest input voltages. The pulse time was varied for the output current to demonstrate the response for different camera flash durations.

Generally speaking, the AAT3110-4.5 has slightly lower, but similar performance at higher temperatures (see Figure 2). The main difference is the high temperature performance at $V_{IN} = 4.2V$. Due to the large amount of power at high input voltage and high output current, the internal thermal management circuitry can shut down the device. As a result, the maximum output current is reduced.

It is also necessary to understand the nonlinear characteristics of the flash white LED. Figure 3 shows a forward current ($I_F$) to forward voltage ($V_F$) curve for a typical flash LED. The $V_F$ drop varies from about 2.9V at low current to almost 4.0V at 100mA of forward current. These unusual characteristics make it difficult to accurately predict the response a charge pump may produce in a circuit at high forward currents. Overstressing a poorly designed charge pump circuit will create a drop in the output voltage and limit the amount of forward current that can be driven through the flash LEDs. Fortunately, this Application Note can provide the information necessary to implement a properly operating circuit.

Standard white LEDs exhibit an $I_F$ to $V_F$ response significantly different than their flash LED counterparts. Figure 3 shows the increased impedance characteristics of a standard LED. The performance of the flash circuits described below would not be possible with standard white LEDs. Even if we could drive enough current through standard white LEDs, their luminous intensity versus forward current is worse than flash LEDs. Standard white LEDs deliver only about 200mcd to 300mcd at 15mA, while a flash LED delivers 500mcd at 15mA. Standard white LEDs cannot even approach the high intensity output of a flash LED at large forward currents (above 2000mcd with $I_F = 100mA$).

Solution 1
Customer applications with a lower requirement for flash intensity can use one AAT3110-4.5 to generate between 170mA and 200mA of current. The circuit shown in Figure 4 illustrates a simple layout with a gate used to regulate current through the LEDs.

Under normal background or movie-mode light requirements, the Enable Light signal is high, while the Enable Flash signal is low. This state will turn on the AAT3110-4.5 and the flash gate will remain open. The selection
of the bias resistor and flash resistor will depend on the actual LEDs used. For the LEDs in our design, we
selected a bias resistor ($R_b = 20\ \Omega$) to regulate the output current to 60mA total (15mA per LED).

When the Enable Flash signal is pulsed high, the flash bias resistor ($R_F = 6.3\ \Omega$) is grounded and the current
surges through the LEDs. The AAT3110-4.5 will maintain the output voltage within 10% of regulation for $V_{IN}$
varying from 3.0V to 4.2V while delivering a minimum of 170mA. Figures 5 and 6 show the output current of
the single AAT3110-4.5 circuit versus the pulse width of the Enable Flash signal at room temperature and 70°C
(measurements are based on a 20% duty-cycle pulse).

Under most conditions, the single AAT3110-4.5 flash circuit can reliably produce 190mA of pulsed current.
Only at low input voltage and high temperatures will the output current drop below 190mA ($V_{IN} = 3.0V$ and tem-
perature $= 70°C$).

![Figure 3: White LED Response (Forward Current [mA] vs. Forward Voltage [V]).](image1)

![Figure 4: Illustration of Gate-Regulated Current Through LEDs.](image2)
Solution 2

Need more power? The solution is to use two parallel-connected AAT3110-4.5 charge pumps to drive a brighter flash when the LEDs need more current. A second AAT3110-4.5 charge pump can provide a nearly instantaneous doubling of the output current.

Figure 7 shows how two AAT3110s can be configured in parallel to provide two levels of current supply and, as a result, two levels of light intensity. The advantage to this design is that under normal movie-mode light conditions only one AAT3110 is used to provide current. To maximize system efficiency, the second charge pump remains off and draws less than 1µA of current.

Under normal movie-mode light requirements, the Enable Light signal is high while the Enable Flash signal is low. This state will turn on the first AAT3110 (labeled "A") while the second AAT3110 (labeled "B") is off. The flash gate will remain open. For this circuit, the same bias resistor (R_B = 20Ω) was selected to regulate the output current to 60mA total (15mA per LED).

To generate a flash, the Enable Light signal is maintained high, while Enable Flash is pulsed high (pulse width may vary depending on need). When Enable Flash is activated, the second AAT3110 (B) is turned on. In order to account for the start-up time of this device (200µs), a simple RC delay circuit is included to delay the gate closure time (see Figure 7 for values). Closure of the gate grounds the flash bias resistor (R_F =1Ω). The current drive produced by the second AAT3110, combined with the drop in the load resistance by 19Ω, produces a large surge of current that flashes the LEDs. (The diode across R_D is used to eliminate the RC delay when Enable Flash is shut off.)

Figures 8 and 9 show the output current versus the pulse time of the circuit. The actual flash current produced by the circuit varies from 350mA to 490mA at room temperature, as V_IN is varied from 3.0V to 4.2V, respectively. Performance of this circuit will also vary slightly with temperature (see Figure 9 for output current versus pulse time at 70°C).
Figure 7: AAT3110 Parallel Configuration.

V_{IN} = 3.0V to 4.2V

Enable Light

AAT3110 (A)

VIN

OUT

C_{IN}

10\mu F

V_{OUT} = 4.5V

C_{FLY}

1\mu F

VIN

AAT3110 (B)

SHDN

GND

C_{FLY}

1\mu F

VIN

Enable Flash

Flash Gate

R_0 = 20\Omega

R_F = 1\Omega

C_D = 0.1\mu F

Figure 8: Output Current (mA) vs. Pulse Time (ms) (two AAT3110-4.5 devices @ 25°C; V_{OUT(min)} = 4.0V).

\begin{align*}
V_{IN} &= 4.2V \\
V_{IN} &= 3.6V \\
V_{IN} &= 3.2V \\
V_{IN} &= 3.0V \\
\end{align*}

Output Current (mA) vs. Pulse Time (ms)

Figure 9: Output Current (mA) vs. Pulse Time (ms) (two AAT3110-4.5 devices @ 25°C; V_{OUT(min)} = 4.0V).

\begin{align*}
V_{IN} &= 4.2V \\
V_{IN} &= 3.6V \\
V_{IN} &= 3.2V \\
V_{IN} &= 3.0V \\
\end{align*}

Output Current (mA) vs. Pulse Time (ms)
Comments
The AAT3110s shown in this Application Note have been tested over varying input voltages and temperatures (the LEDs and bias circuit were not tested over temperature). The bias resistors were chosen to maximize output current while maintaining $V_{\text{OUT}}$ within 10% of regulation limits ($V_{\text{OUT}}[\text{min}] = 4.0\,\text{V}$) and to limit the AAT3110 from reaching its thermal limits at high temperature and high input voltage.

The output currents shown above are dependent on the selection of the bias resistors and LEDs in the circuit. Any variation to the LED will likely change the output current response of this circuit. For example, less expensive standard white LEDs had higher impedance and reduced the output current of the AAT3110s, while the use of lower impedance flash LEDs allowed a pulsed current of up to 650mA for 50ms. (Note: Pulsed currents of over 600mA can be unstable and lead to thermal shutdown of the circuit at high temperature, input voltages, and long pulse times.)

Conclusion
Using the AAT3110-4.5 charge pump to power camera flashes can provide two distinct advantages over standard capacitor charged flashes. First, the AAT3110 powers up in 200µs. This means the user does not need to endure the usual waiting time for a standard flash capacitor to charge up. Photos can be taken one after another without delay. Second, the AAT3110-4.5 allows the camera to operate at two levels of flash intensity for movie-mode video and still photos, while maximizing system efficiency.

The robust design of the AAT3110-4.5 enables this device to provide large instantaneous pulses of current to power cell phone camera flashes. From a single lithium-ion/polymer battery power source, a single AAT3110-4.5 can provide over 200mA of current for a 500ms flash. Two AAT3110-4.5 devices can produce nearly 500mA of pulsed current for a camera flash.