Cell Phones as Fashion Create New Design Challenges

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Technology Edge

Cell Phones as Fashion Create New Design Challenges

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"Phones are fashion" as we enter the third millennium, and the cell phone makers that learned this lesson first are reaping the market share gains. Snap-on covers are only the beginning of non-functional "features" that reach out to the majority of the world's population that still, believe it or not, do not own a mobile phone. While mobile handsets will continue to be sold on size, weight and battery life (talk time and standby time), the "coolness factor" is playing an ever increasing role in consumers' buying decisions. A phone's "coolness" is important to several segments of the phone buying public, and most importantly, it is critical to the fastest growing segments: young people and non-business users. High-end business users will still get first crack at functional changes like Wireless Application Protocol (WAP) phones that enable e-commerce, organizer functions and data connectivity, but new low- to mid-range phones focus on serving the basics in a much more attractive package. The size, shape and color of these phones will be the first things you notice, but the next level of impression is likely to be the display and display / keypad lighting. Lighting a phone's display, keypad and network status indicator is becoming a significant differentiator in the "coolness factor" wars.

PHONE LIGHTING - SO 90'S

You may remember phones in our recent past offering orange vacuum florescent character displays. These made the transition to graphic mode (square pixel) displays in the early 90's, but as the need increased for higher information content, it became impractical to keep up with the small pixel size and higher pixel count the newer Liquid Crystal Displays (LCD) could offer. LCD technology is now used in essentially 100% of cell phone displays. Since the displays are no longer emissive, some sort of light is needed for viewing in dark conditions. Super Twist Nematic (STN) or Film-STN (F-STN) LCD displays were almost exclusively lit from the front or behind with green Light Emitting Diodes (LEDs). Why green? It was better than the alternative red, the only other low-cost color available at the time. Green LEDs also had the fortunate property of low 1.8V to 2.7V forward voltages, making them easy to drive directly from the phone's battery.

The fully discharged cell voltage provided by Lithium Ion cells is approximately 2.7V, although less than 10% of the energy of the battery remains when the single cell voltage drops below 3.0V. Multi-cell NiMH power supplies present similar voltages: 3 cells at 0.9V fully discharged is 2.7V. These voltages are important because they are all generally higher than the forward voltage needed to light a green LED to full brightness. Thus, simple Low Dropout Linear Regulators (LDOs) with a series current-limiting resistor are used to drive most of the lighting in today's cell phones. One might question the low efficiency of this method but, since the usage profile of the phone caused the LEDs to be powered for such a short time, as a percentage of total power drawn from the battery, the LEDs were almost negligible.

Changing usage profiles as users move to more data-centric applications, and a relentless drive toward higher "coolness factor" phones is changing this fortuitous battery - LED voltage relationship.

THIRD MILLENNIUM PHONE LIGHTING

As with many things electronic, it is instructive to look to Japan where cell phone adoption is second only to Western Europe, for indicators of coming trends. The success of NTT's DoCoMo iMode services and the KDD J-Phone web serivces, has accelerated the adoption of phones with color displays. Even in phones with standard Black and White (B/W) STN displays there is often a choice of backlight color. Creating all these colors, and doing so cost effectively, with small size and high efficiency, has created a new set of challenges for cell phone, handheld PC and organizer devices.

MOBILE PHONE IN LIGHTS

There are three basic areas where lighting is needed in modern mobile handsets: the display, the keypad and the network status indicator. There are two other areas where lighting is found, but it has little or no functional purpose. Antenna lights use some of the RF energy emitted by the transmitter to light an LED and indicate a ring. Secondly, flashing case lights can be added as an aftermarket product where they are typically found on the battery packs from third-party manufacturers. Presently these are most popular in Asian Pacific markets.

Functional	Fun
Display Keypad Network Status	Antenna Tip Flasher Flashing Case Lighting What's Next?

Some mobile phone lighting accomplishes serious tasks, but all of it counts for fashion.

Display lighting has received the most attention from phone manufacturers because users can perceive small brightness differences or unevenness that may lead to quality judgments about the phone. Keypad lighting has used a large number of LEDs (up to 12) in the past, but color purity and matching is less important here. The network status LED is not found on all phones, but those that have it typically use green only or red/green combination LEDs to represent various network conditions (connected to cell site, out of range, on foreign network, ring, etc.). Some vendors are moving to Blue LEDs more recently.

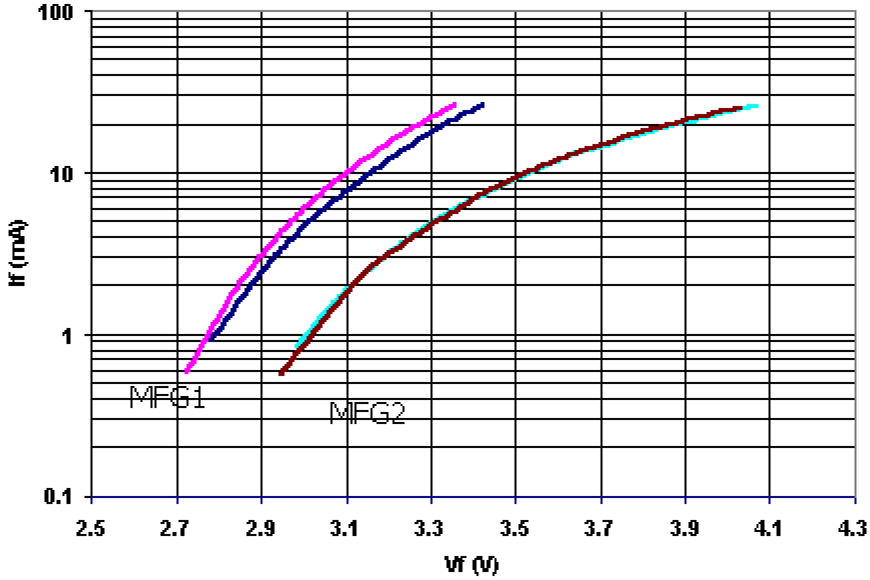
Small LCD Backlight Technology

	Light Emitting Diode	Electroluminescent	Cold Cathode Fluorescent Tube
Acronym	LED	EL	CCFT
Voltage Required	<5V, current limited	40V - 180V	300V - 1000V
Current Required	10mA - 40mA	1mA - 3mA	2mA - 6mA
Typical Converter	Constant Current	Inductive Switcher	Inductive Switcher
Half Life	50Khrs. min.	3Khrs. - 5Khrs.	10Khrs. - 15Khrs.
Primary Application	Cell Phone	PDA, H/PC, Organizer	Notebook PC
Relative Cost	$	$$	$$$
Worst Problem	Uneven light (diffuser)	Audible Noise, Life	EMI, High Power
Biggest Benefit	Low Cost (Green)	Even light, thin	Bright

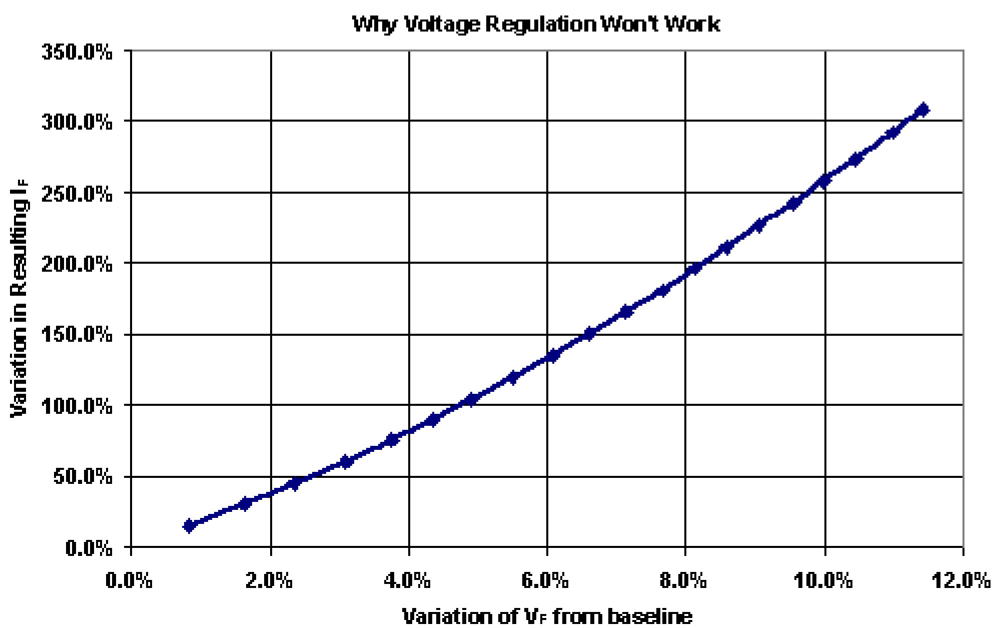
With B/W LCD displays, the lighting color can be completely dictated by style, as found in the red, orange, green, blue, white and other choices offered in Japan. This is achieved by a combination of LED and electro-luminescent (EL) technology, each with its strengths and weaknesses. Adding a color LCD display means addressing the question of how to provide a white light. In a transmissive LCD, subtracting all the other colors from each of a red, green and blue sub-pixel produces color. Therefore a white "color" source is necessary to begin with. After red, green and blue is generated in a controlled amount for each pixel, the light is added beyond the display (by your eye) to create essentially any color. White LEDs and fluorescent tubes are the most common ways to generate this white light. Cold Cathode Fluorescent Tubes (CCFT) are only common in displays greater than about four inches in diagonal because of the difficulty in making very thin, short tubes. They deliver high brightness and are relatively efficient, but CCFTs have not been adapted to typical cell phone display sizes of 1.5" to 2.0" diagonal. Today, these small displays are the exclusive domain of the white LED.

SPECIAL CHALLENGE OF THE WHITE LED

A white LED starts life as a blue LED based on an Indium Gallium Nitride (InGaN) junction. A yellow phosphor is applied over the top of the junction where the blue light energy causes emission from the phosphor and mixes with the original blue light. This is how a broad spectrum of wavelengths can be generated from the relatively narrow spectral content of the blue LED. Nichia Corporation invented this method, based on a high efficiency blue LED, quite recently. The light emitted is not a collection of narrow bandgap related frequencies, but is fairly broad and even, except for an overabundance of blue. As might be expected, driving a white LED is identical to driving a blue LED based on the same elements. (InGaN)

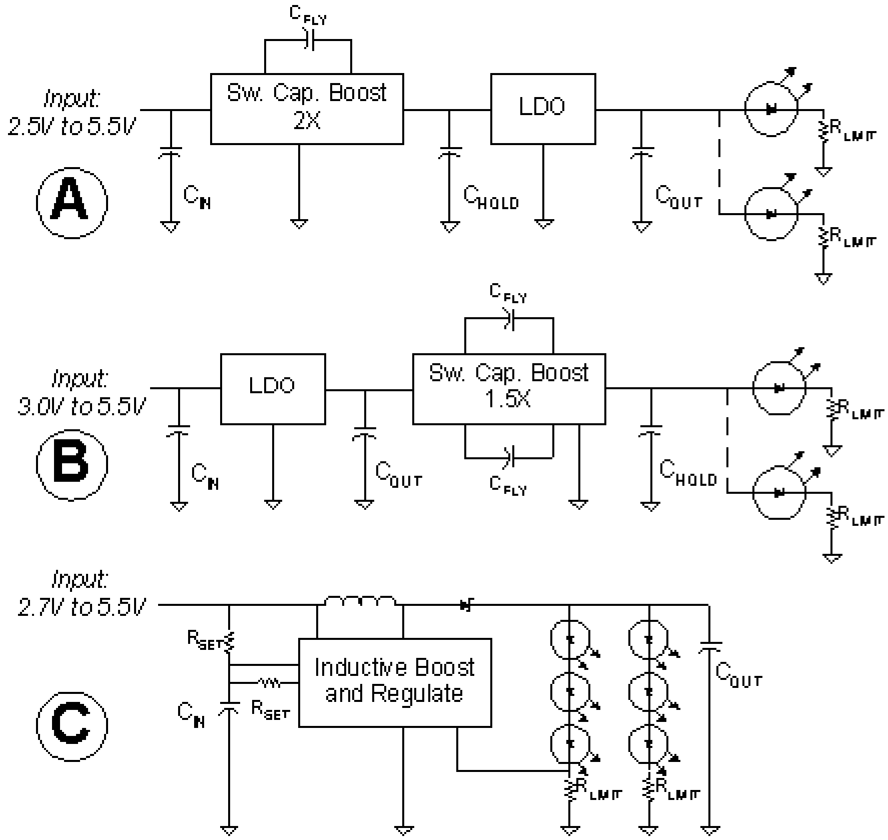


Unlike red and green LEDs, the forward voltage required for highest efficiency from the new LEDs is higher, falling between 3.1V and 4.0V, but depending upon manufacturer somewhat. This is just high enough that boost power converters are necessary to drive the white LEDs from common battery based supplies. Driving any color LED adds another complication: that of wanting to be driven from a constant current supply rather than a constant voltage. Diodes, like transistors are current mode devices. A slight variation in applied voltage results in immense difference in current flow. In addition, manufacturing variations in the forward voltage can produce additional brightness variation when constant voltage is applied. To minimize brightness variation, as well as color shift in W-LED, a constant current supply is better. This has the added benefit of being more efficient in most cases, since the power dissipation of the current limiting resistor is eliminated in constant current designs.



FIRST GENERATION SOLUTIONS

As white LEDs became available in volume, the lowest cost solutions to driving them typically used off-the-shelf boost and voltage regulation feedback, thus reusing common architectures found when developing power supplies for other 5 volt needs within cell phones. Producing voltages around 5V allowed enough headroom for the worst case LED forward voltage, plus a small drop across a current limiting resistor. Switched capacitor techniques were used for designs with one to about four LEDs, while inductive boost chips were used when four or more LEDs were required.

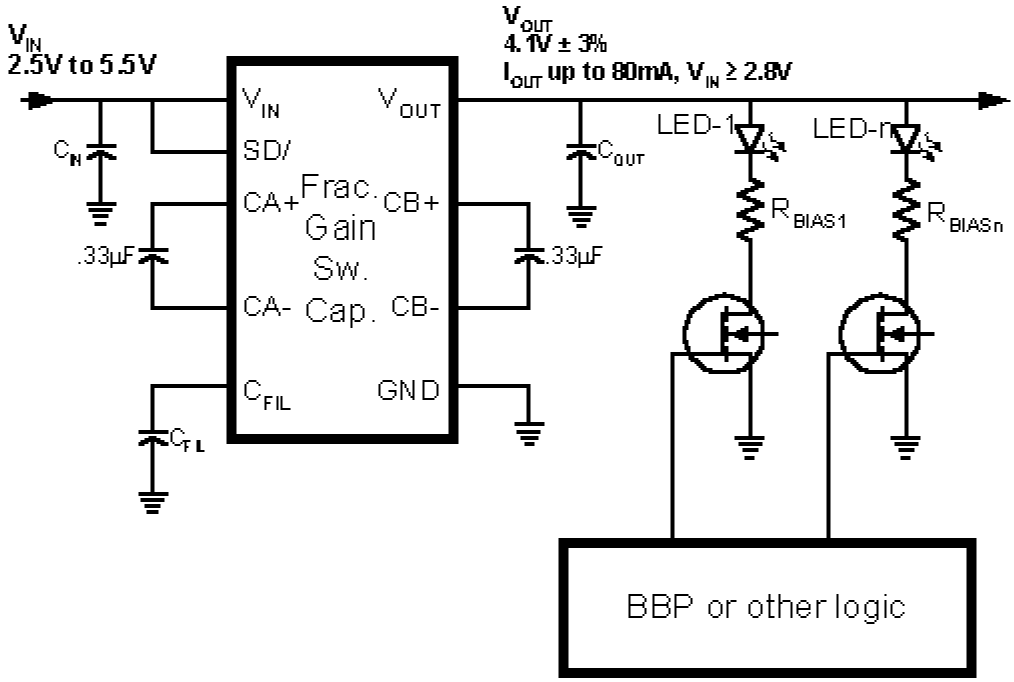


First Generation White LED Solutions

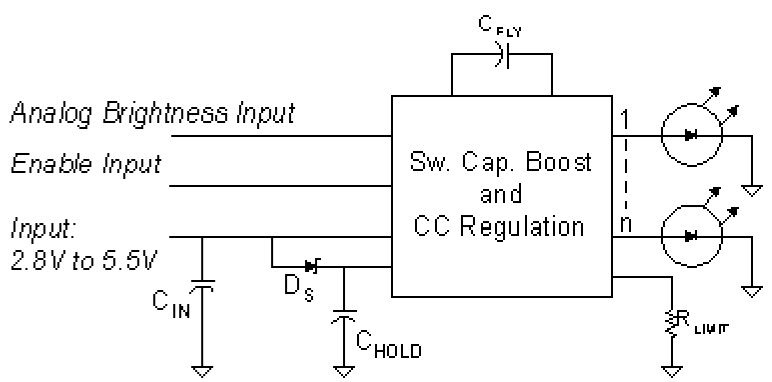
Option A can accommodate the full LiIon input range and produces a voltage regulated output. Setting the output at 4.1V to 4.3V minimizes the dissipation in RLIMIT. Option B sacrifices a little input voltage range, but is more efficient than "A", and the LDO helps to filter conducted noise from the switched capacitor charge pump. However, the voltage regulation is not as good. Option C is used when more than about four LEDs are driven, as the total power needed is more cost effectively supplied when inductive architectures are used. This technique provides constant current by taking the feedback voltage from above the current limiting resistor.

Due to the high cost of W-LEDs, high volume applications continue to use four or fewer LEDs, which emphasize the use of non-optimal voltage regulation solutions.

SECOND GENERATION SOLUTIONS

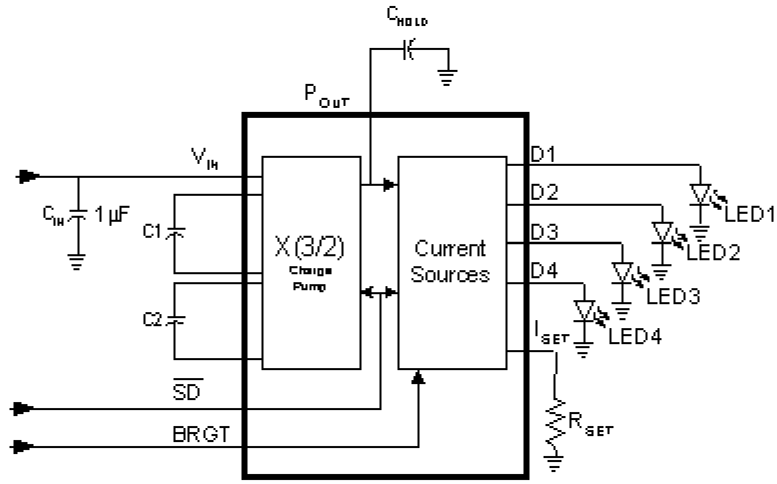


Non-functional phone features incorporating LEDs, keypad backlights and network status LEDs, are likely to continue to use mainly constant voltage power solutions because the absolute accuracy and brightness variation is not as noticeable in these applications. Fractional gain switched capacitor regulators are idea for these applications as they maximize efficiency without the use of inductors. By including series FETS as switches, an external digital brightness control can be included at low cost, and provide independent brightness control for several LEDs. Color LCD displays, on the other hand, will migrate quickly to switched capacitor boost products with constant current regulation. Adoption of color displays is driven by low-speed data applications like iMode, WAP, Symbian and Palm OS's that add organizer and browser functionality. The cell phone makers are not waiting for 3G infrastructure buildout before adding color. In fact, the largest barrier to adding color displays today is cost, followed by increased power consumption.



Second Generation White LED Solutions

Second generation W-LED power solutions for small color LCD backlights and frontlights (used with reflective and transflective LCDs) will be adopted for several reasons. Foremost among these is brightness matching between each LED. This is most important when using only two LEDs where users should perceive equal brightness from each side of the display. Due to the process variation in LED forward voltage, supplying a constant current means various voltages may be presented to each LED. Although power will still vary (I * V), the best brightness matching is achieved.



Other benefits to this type of constant current supply include higher efficiency than the double plus regulate architecture, as well as several options to actively control the brightness of the LED. Since a current mirror architecture is used, LED current for all LEDs is set by one resistor using a large amplification ratio. By using a 20:1 or greater ratio, power consumption of the system is minimized.

Brightness can be controlled with a low-noise analog input, or with a simple digital output driven by a pulse width modulation (PWM) algorithm. These inputs, along with active control of the RLIMIT resistor may also be used for temperature compensation of the system.

Using these second generation LED power solutions will allow cell phone makers to adopt color displays with lower cost and higher brightness while improving their phone's "coolness factor" through the innovative use of brightness controls.