# Energy-Based Metrics for Mobile Displays




mirasol®

Displays by Qualcomm

## Table of Contents

## Introduction / Motivation

The role of the cellular phone handset within the consumer electronics space is evolving rapidly. Once no more than a "mobile phone" it now serves that function as well as the functions of PDA, digital still camera, photo album, video camera, email appliance, gaming platform, Web browser, television set, GPS navigator, MP3 player, FM radio and more. Attempts to create a definitive list of handset capabilities are near impossible as new applications arise before the list can be published.

Delivering these capabilities has stimulated rapid development of the handset's fundamental capabilities. Screen size has stretched the limits of the platform, and screen resolution equals or surpasses that of early PCs. Processor speeds have passed that of laptop computers sold just 7-8 years ago, and camera resolution has surpassed the level provided in digital still cameras of the same era. Most consumers take for granted the technology environment, ruled by Moore's Law, which has made all this possible at price points that allow a majority of consumers to participate.

However, Moore's Law does not apply to advances in fundamental scientific disciplines such as battery technology. The rate of increase in energy density lags behind the increase in energy that would be consumed by constant, widespread use of the features discussed above. Consumers will increasingly (sometimes consciously and sometimes unconsciously) be required to trade off battery capacity among the multiple features and functionalities available on their handset.

Consumers looking at handsets today rarely confront, or even think about, questions of battery capacity. The topic arises only in the form of two metrics that appear in typical handset specifications. These metrics are Talk Time and Standby Time. In many cases these will be the only performance metrics the consumer considers as part of their handset selection. Performance metrics are much more common in other industries such as the computer industry (processor speed, RAM, hard drive capacity, bus speed, etc.) or automotive industry (horsepower, engine size, wheelbase, turning radius, etc.) In purchasing a phone, parameters such as processor speed, amplifier sensitivity, flash-memory capacity, and many others are seldom discussed or considered.

Talk Time and Standby Time are indirect measures of battery capacity. If one does nothing but talk, talk constantly, and talk in a nearly perfect radio environment, Talk Time represents the duration over which battery energy will be completely exhausted. Likewise, if one's phone is left stationary in a similar nearly-perfect environment, Standby Time represents the duration over which battery energy will be completely exhausted.

The dilemma for the consumer is that neither Talk Time nor Standby Time addresses how long battery energy will remain available while watching streaming video, or while snapping flash photos, or while browsing the Web. Talk Time and Standby Time will not tell the user how long to expect a battery to last if the user practices a mix of these features. The capabilities of the cellular handset have moved beyond the ability of common metrics to define the energy consumption behavior of the handset.

This white paper proposes a new type of metric and examples of this metric to better inform consumers regarding the energy performance that can be expected from a given handset.

Additionally, the metric allows consumers to evaluate the impact on the handset's energy performance made by the display in the handset.

## Energy versus Power

Discussions of the efficiency of electronic products often center on power dissipation. Indeed, energy ratings are based on a product's time-averaged level of power dissipation. When we talk about products that connect to and operate while connected to the electrical power grid, average power dissipation and energy consumption are essentially synonymous. There's an endless supply of energy, and power is the rate at which it is consumed.

In a handheld product, energy is precisely limited. There is the energy in the battery, and there is no more. A user's concern is not so much, "How much power am I consuming?" but rather, "Do I have enough energy left in my battery to do the things I want to do?" Maximum Talk Time is not particularly important, nor is Maximum Standby Time, nor is Maximum Web Browsing Time or Maximum MP3 Listening Time. The real user question when buying a cellular phone is, "If I do my normal mix of these activities throughout the day, will I have any energy left in my battery at the end of the day?"

In general, the prospective buyer does not have the information needed to answer this question. If she knew the power dissipation rate of these activities, the energy capacity of the battery, and the time-mix of her activities, the consumer could calculate the answer. But few consumers will ever know all those numbers, and fewer still will do the calculation. This situation is analogous to (but more complicated than) the prediction of automobile gas mileage. Everyone knows that going fast uses more gas and going slow uses less, but predicting an individual's gas mileage in a particular vehicle from that knowledge is difficult. The U.S. Government stepped in decades ago, determined that there could be no one simple answer to the problem, and promulgated a two parameter metric, City Mileage and Highway Mileage.

These two metrics may or may not be adequate for automobiles, but the two metrics of Standby Time and Talk Time are no longer adequate for handsets. The proposal here is to create a new, limited set of metrics that can simplify and inform the handset buyer's choice without burying her in a confusing, multi-dimensional metric space or a withering array of detailed product specifications.

## The Metrics

In creating a limited and reasonable set of energy performance metrics, the first task was to define a limited and meaningful set of representative handset "user types." A usage model could then be created for each user type, and that model could be extrapolated throughout a 24-hour day to generate an energy consumption profile.

At the end of the day each model would result in a residual amount of energy remaining in the battery. Since most users have little feel for the operational value of a given amount of energy expressed in scientific units (How long can I talk on 1000 joules? Can I send 10 text messages on 750 calories?), the residual energy would be expressed in terms of a standard handset activity.

This method would allow prospective cellular phone buyers to identify with a particular usage profile. Target profiles might be Gamers, Video Fanatics, Web Enthusiasts, All Talk, etc. A buyer, identifying himself with the profile he felt best matched his handset use, could use the published metric to determine which handset provided the greatest amount of residual energy after a day's full use. The product with the largest energy residual associated with his metric of interest would be the product most efficient at serving that user's particular needs.

The models discussed here are ascribed to one form or another of "power users." The assumption is that moderate users will have no trouble making it through a day, indeed perhaps through two days, with battery energy left over. The first metric was built around an Average Power User – someone who uses her cellular phone extensively and exploits many of the phone's features without focusing on any particular feature. The proposed usage model for the 24-hour period is:

- 90 minutes of talk time
- 15 minutes of keyboard time (this includes menu navigation, searching through contact lists, making notes)
- 10 minutes sending and receiving SMS messages
- 30 minutes of Web connectivity
- 30 minutes of MP3 play
- 20 minutes of GPS navigation

This amounts to over two hours of active phone use (such as making calls) and just less than one hour of passive phone use (such as listening to MP3).

In order to estimate the energy that would be expended by such a consumption profile it was necessary to apply the profile to a particular cellular handset. Our approach was to create a mathematical model for a 'generic' handset. Building such a model is an involved task due to the complexity and variations of the components within the handset and the differences between and within the networks they connect to. We proceeded by directly measuring the power dissipation on several common handsets while the handsets were performing specific functions. This data was compared with published values from component data sheets (where such data sheets were available) to augment and validate the measured values. Specific data for Talk Time and Standby Time was further compared with published product reviews to ensure that our model captured data that would be closer to genuine user experiences as opposed to what might be experienced in a near idealized radio environment.

With data established for the handset's IC components, we added models for two separate display modules to complete the handset model. The display modules considered were a typical TFT LCD and a module based on Qualcomm's color mirasol display, both with diagonals of 2.4". Power consumption data for the typical TFT LCD display module was taken from published data sheets from several display manufactures. In this context, the module power consumption is divided between the display and its backlight. Data for the mirasol module was taken from Qualcomm's own mirasol power consumption models. These models have been validated with current bichrome (two colors) displays and extended to the full-color main displays discussed in this white paper. The power consumption of the frontlight associated with the mirasol display was based upon current measured values extrapolated to frontlights properly sized for use with main displays.

This handset model does not reproduce the performance of any particular phone model, but, since the sole difference between the handsets compared in this white paper occur in the display modules used by the handsets, any errors in the model are applied equally to both handsets. For direct comparison, it is assumed that the TFT LCD module backlight is used 100% of the time when the TFT LCD is in use, and the mirasol display's frontlight is in use 10% of the time when the display is used to watch video.

For this first Average Use scenario the model yields the results that the residual energy left in a generic cellular phone equipped with a TFT LCD display module is 16% of the battery's initial charge. This 16% capacity is adequate to watch 70 minutes of video. The residual energy left in the same phone equipped with an mirasol display module is 31% of the battery's initial charge. This capacity is adequate to watch 206 minutes of video.

The next power user considered was a Video Fanatic who spends less time using 'normal' handset functions, but downloads videos throughout the day to be viewed as time becomes available. The proposed usage model for the 24 hour period is:

- 60 minutes of talk time
- 15 minutes of keyboard work
- 15 minutes sending and receiving SMS Text Messages
- 30 minutes of Web connectivity
- 30 minutes of MP3 play
- 20 minutes of GPS navigation
- 20 minutes watching YouTube clips
- 15 minutes watching Broadcast Video

In this case the phone with a TFT LCD display provides residual video watching time of up to 24 minutes, and the phone with a mirasol display provides residual video watching time of up to 160 minutes.

The mirasol display's advantage is driven by three factors.

- The mirasol display panel on average consumes less energy than the TFT LCD display panel.
- The mirasol display frontlight consumes significantly less energy than the TFT LCD backlight.
- The mirasol display frontlight is used much less than the TFT LCD backlight.

These factors act to increase the residual video viewing metric in two ways. First, throughout the day they reduce energy consumption in the usage model activities. Second, at the end of the day (when the residual video viewing metric is measured) the reduced energy consumption provides more minutes of video time for every unit of energy that has been saved throughout the day.

To better appreciate these savings refer to where we see that while watching streaming video the TFT LCD module consumes 29% of the energy expended while the mirasol module consumes only 4%. While text messaging, the TFT LCD module consumes 73%, and the mirasol module consumes 10%. During Web Browsing the TFT LCD module consumes 48% of the required energy while the mirasol module consumes 6%. While navigating from received GPS data the TFT LCD module consumes 41% of the energy used while the mirasol module consumes only 4% of the energy that is needed. Since the energy consumed by the non-display-related components of both the TFT and mirasol display equipped generic phones is identical in each of these activities, all of the difference in consumption is due to the effects of modeling the two different display types.

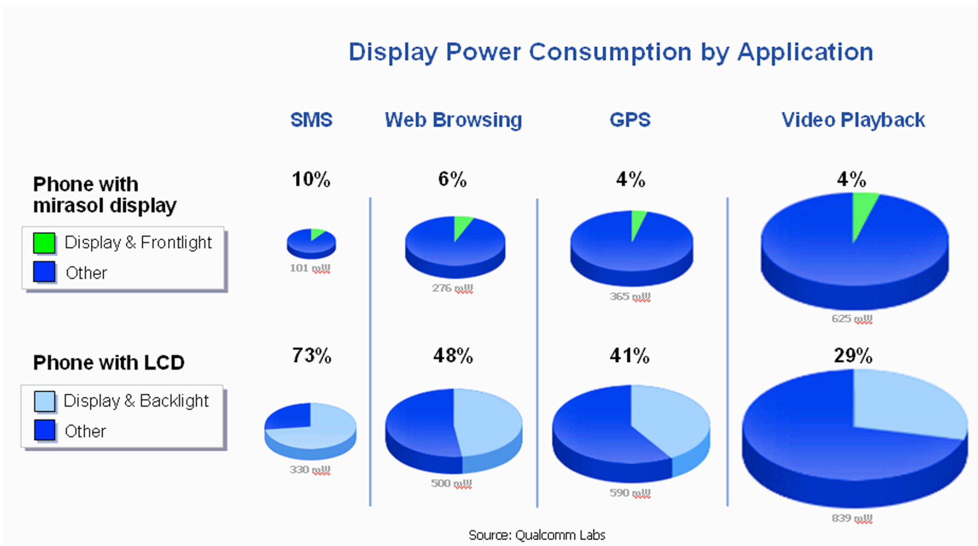


Figure 1. TFT LCDs Can Consume Almost 50% of Power – mirasol Displays Use Much Less
Source: Qualcomm Labs

Figure 2 illustrates one way the metrics might be displayed to a buyer. The figure shows the metric data for the hypothetical generic TFT LCD-equipped phone used in the calculations of this white paper as well as the metric data for the hypothetical generic mirasol display-equipped phone. You will note that an additional metric has been added as a companion to the original Talk Time and Standby Time Metrics. The added metric is Video Watching Time. It represents the time to battery exhaustion if the phone is connected to a mobile TV video signal and left undisturbed until the battery is exhausted. Once again, the expected mirasol display advantage is apparent.

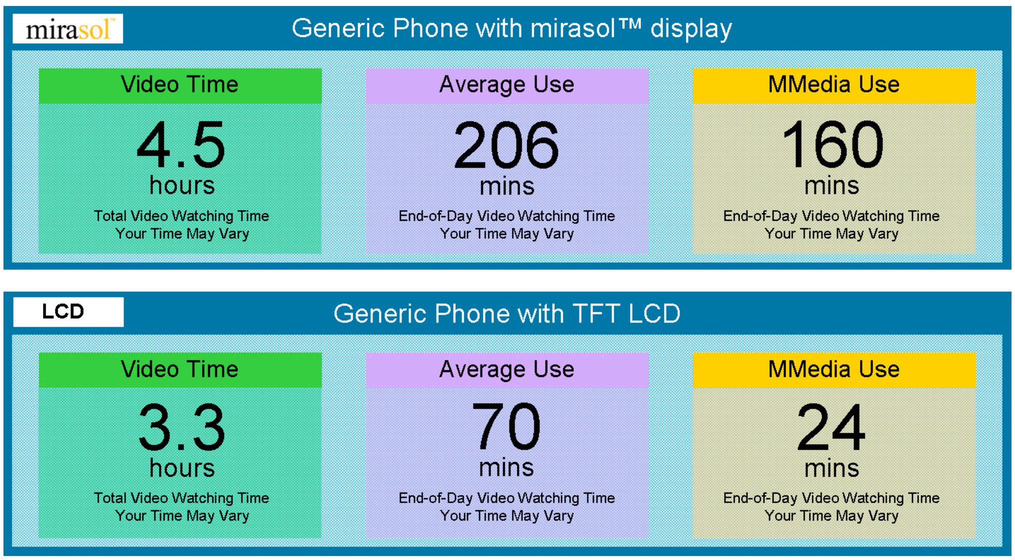


Figure 2. Generic Cellular Phone with TFT LCD and mirasol display.

## Summary

The convergence of many and diverse applications onto cellular phone handsets assures that many such phones will be used actively for significantly more time during the day than they were used in the past. This increase in usage outstrips the approximately 8%* annual increase in battery capacity. This means that increased efficiency of handset components will become increasingly important. The ability of any given handset to provide the battery reserve required by its user will become increasingly important as well.

This white paper has proposed a new set of handset metrics that are usage model-based and focused on revealing the end-of-day residual energy available in a given cellular phone operated under a given usage model.

The metrics provide easy-to-understand and useful information for cellular phone buyers, and they clearly demonstrate the value of high efficiency components such as the Qualcomm mirasol display module.

*Strategy Analytics, Stuart Robinson, Director, Handset Component Technologies

www.mirasoldisplays.com

mirasol®

For more information on
mirasol displays contact us:

**GENERAL**
contactqmt@qualcomm.com

**BUSINESS**
qmtbizdev@qualcomm.com

**WEB**
www.mirasoldisplays.com