



Display Subsystem Power Measurement Recommendations

Revision History

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0.3	07/03/2003	Release to EBLWG
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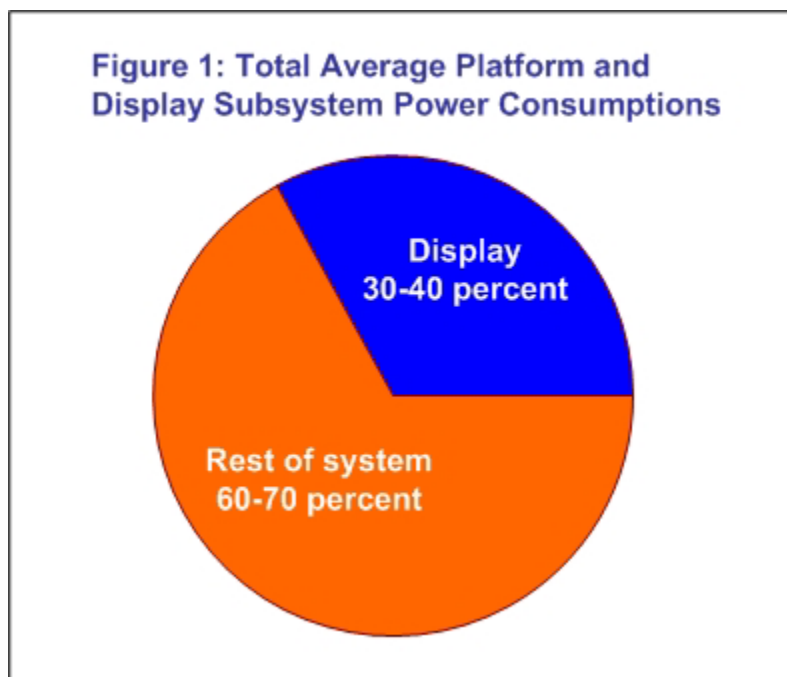
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Display Subsystem Power Measurement Recommendations

Introduction

The display subsystem constitutes a significant portion of the overall, average power consumed by a mobile PC. Among the various components and subsystems within a mobile PC, the display subsystem is by far the largest consumer of power. As new display technologies develop with a particular focus on reducing display power consumption, it becomes absolutely imperative that, at a minimum, the display subsystem continues to consume less and less power and keep pace with the downtrend in overall platform power consumption.

Figure 1 shows the average platform power measured using the MobileMark* 2002 benchmark for average notebooks with XGA 14.1" displays.



The total display subsystem power consumption includes power consumed by the display panel electronics, as well as the display panel backlight system, including the backlight inverter module.

The Mobile PC Extended Battery Life Work Group (EBL WG), <http://www.eblwg.org/> is an industry-wide group of companies working together to extend the battery life of mobile PCs. The EBL WG has developed these display subsystem measurement recommendations to enable uniform and consistent display subsystem power measurement across the mobile PC LCD industry.

These recommendations cover how to measure the panel electronics power, backlight power (including the backlight inverter module), as well as measurement of screen luminance. Appropriate color patterns, ambient room conditions, and a suggested list of equipment are provided.

This paper contains two subsequent sections. The first is an overview and should be understood by a general technical audience. The second is the detailed setup and may require some familiarity with computer and software setup and configuration.

Measuring Display Subsystem Power

LCD panel power comprises of two parts — the panel electronics and the panel backlight. The panel electronics include all the circuitry that drives the image on the notebook computer's screen. The panel electronics power is strongly influenced by the pattern that is displayed on the screen. The panel backlight in a notebook computer with a transmissive display typically includes an inverter and a cold cathode fluorescent lamp (CCFL). The backlight power is strongly influenced by lamp luminance. The total panel power equals the sum of the panel electronics plus the panel backlight power at a particular pattern and luminance setting.

As an example, the Customer Reference Board (CRB) for the Intel® 855GM chipset provides two sense resistors through which LCD panel power can be measured — one for the panel electronics and one for the backlight. Resistor R5N6 is a shunt resistor between +V3.3S and +V3.3S_LVDS for measuring panel electronics power, and R5N7 is a shunt resistor between +VDC (12V) and +VCC_LVDSBKLT for measuring panel backlight power. These two resistors are on the bottom side of the CRB. See Figure 5.

To measure power using the CRB above, use the Fluke NetDaq* logger to measure *current* as voltage drop across a sense resistor, and to measure *voltage* as voltage drop from power rail to ground.

To measure current for panel electronics, Ohm's Law was applied to the sense resistor example as follows:

$$I = V_s/R_s$$

where:

I = current for the panel electronics

V_s = voltage drop from +V3.3S to +V3.3S_LVDS

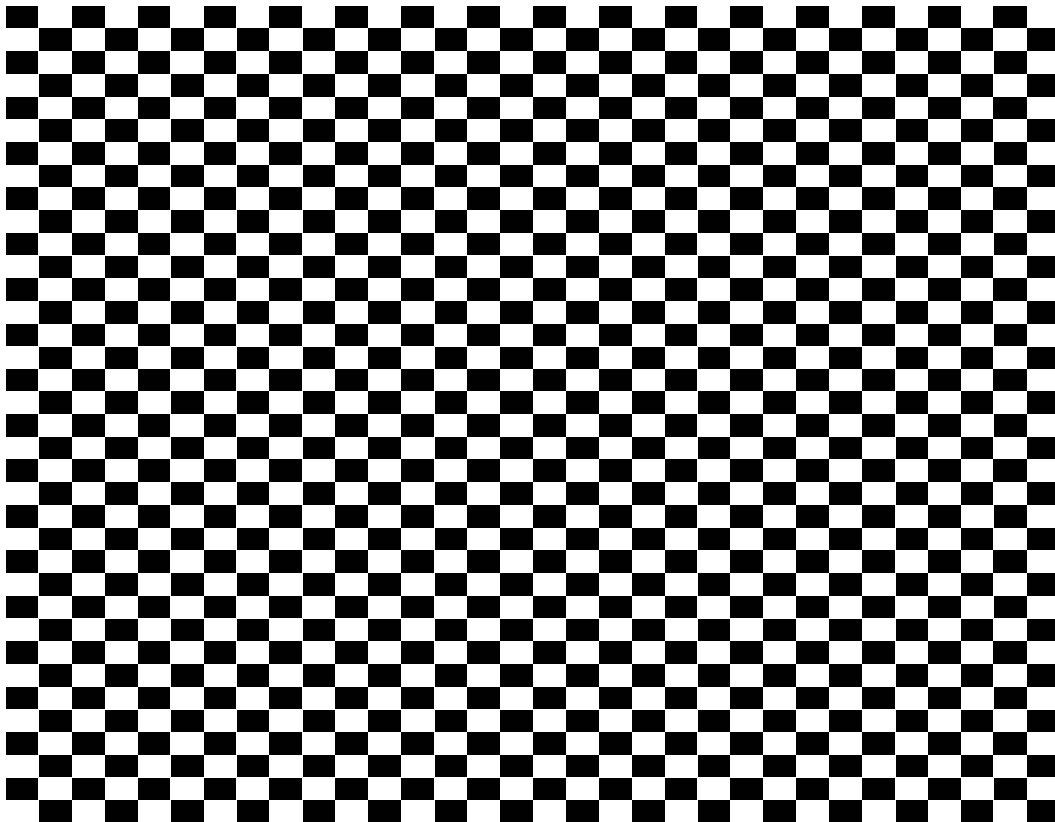
R_s = resistance of R5N6

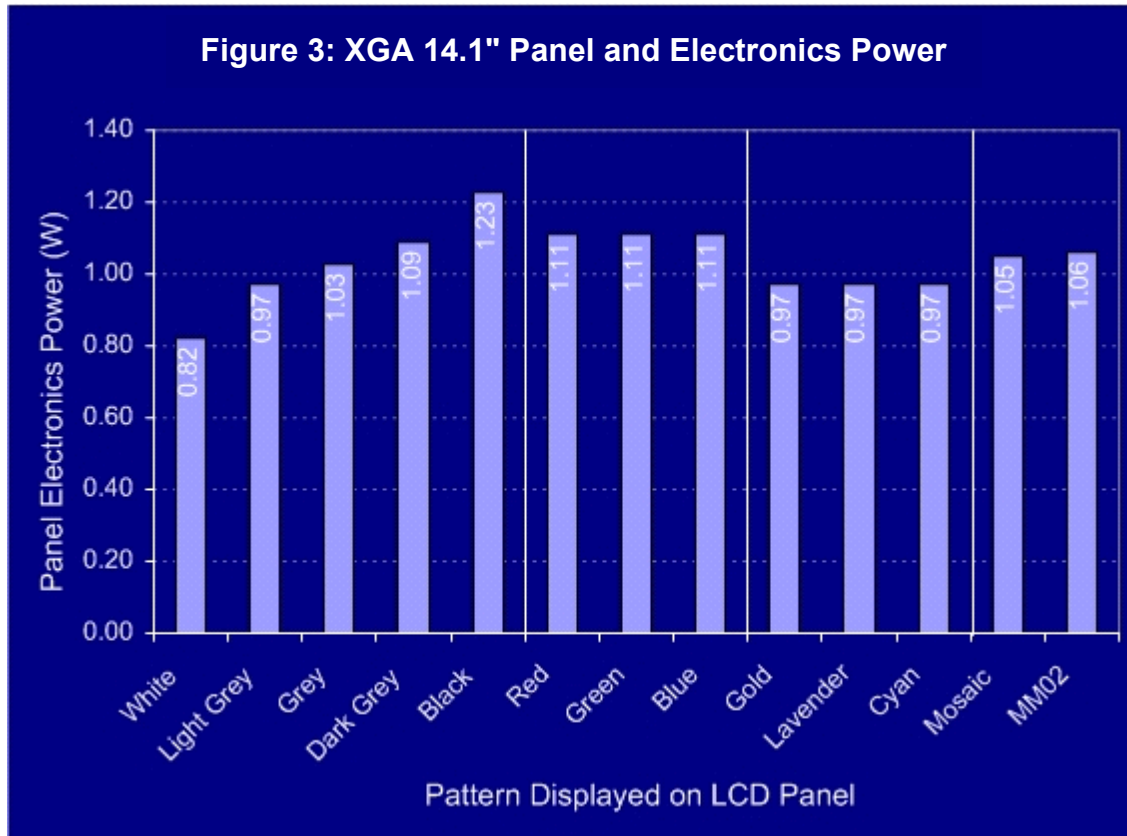
Since measuring +V3.3S_LVDS to GND determines voltage V for panel electronics, power is easily determined by automatically calculating $P = IV$ with the Netdaq Logger software.

Measuring Panel Electronics Power

The panel electronics power is strongly influenced by the pattern displayed on the screen. To standardize the patterns used, the VESA Flat Panel Display Measurement document can be referenced (FPDM2.pdf), and specifically Section 401-1 on Power Consumption. VESA provides an additional document, FPDMSBM.ppt, which contains test patterns described in each section of the FPDM2.pdf document. Under Section 401 of FPDMSBM.ppt, there are three patterns — full screen white, full screen black, and mosaic (see screen shot of Full Screen Mosaic in Figure 2). Figure 3 indicates power consumption data taken on a sample XGA 14.1” panel.

Figure 2: Screen Shot of Mosaic Pattern from Last Slide of VESA’s FPDMSBM.ppt (See [Reference and Links](#) at end of this document on where to obtain FPDMSBM.ppt.)



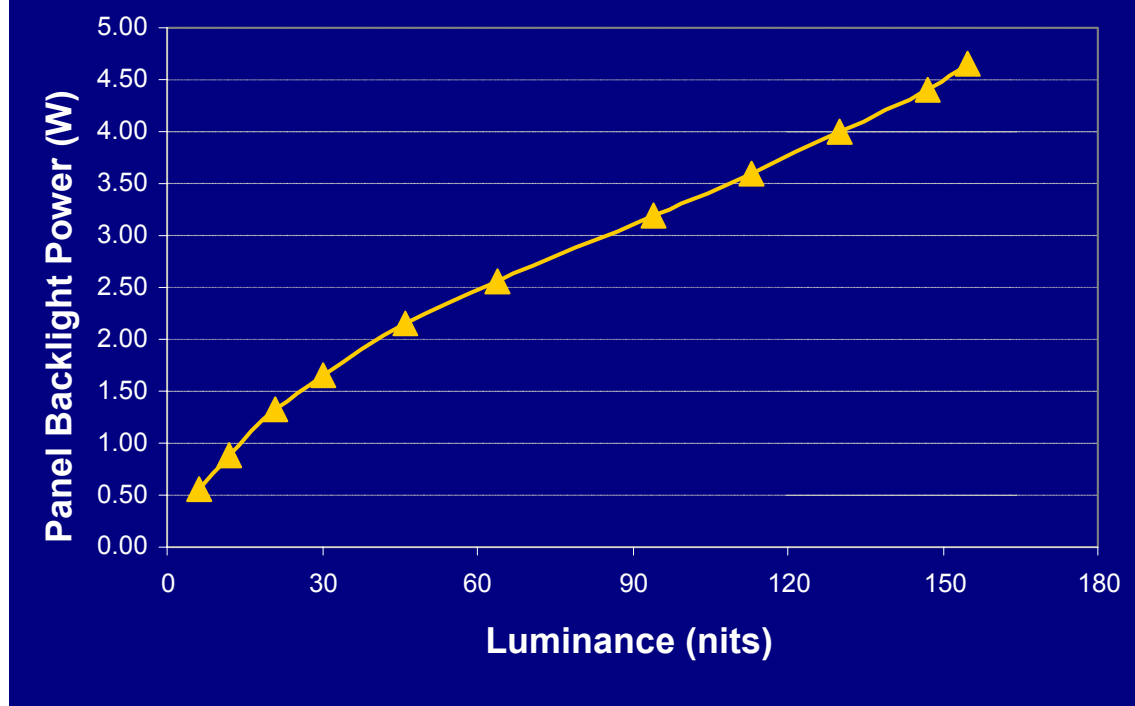


On this panel, panel electronics power was measured for various full-screen patterns, where white is 0.82W, black is 1.23W, and mosaic is 1.00W. To estimate the platform power and battery life, BapCo's MobileMark 2002* can currently be utilized. Since the panel electronics depends on patterns displayed, a benchmark was run and the average of the power consumed over a workload of 90 minutes was taken. On this panel, the average power consumed amounted to 1.01W, which is very similar to that measured for the mosaic, full-screen pattern. In other panels, the average power consumed by the various patterns was also very close to that of the mosaic, full-screen measurement. As a result, the mosaic, full-screen measurement can be used as estimation for MobileMark 2002 panel electronics power if needed. Notice in Figure 3 that other basic colors (RGB, CYM, and various grey levels) were also measured; however, the minimum set that should be measured are white, black, and mosaic.

Measuring Panel Backlight Power

The backlight power of the LCD panel subsystem depends on lamp luminance. Figure 4 illustrates that a sample XGA 14.1" panel with a luminance of 60 nits consumes approximately 2.46W (64nits, 2.55W is the exact measurement point).

Figure 4: Panel Backlight Power vs. Luminance



The panel electronics for varying luminance measurements was 0.82W, since these measurements were all taken at full white background. In accordance with VESA FPDM2.pdf, Section 302-1, Luminance on Full Screen White and Section 401-1 Power Consumption, backlight power was measured with full screen white to enable the measurement of backlight power and luminance at the same time for each of the luminance settings. Thus, to measure this change in the brightness setting, wait for the lamp to settle, and then take an average of the power over time and measure the luminance using a luminance meter at the center of the display. Often, the brightness level settings do not allow for exactly 60 nits. In such cases, a linear approximation is taken using the two points closest to 60 nits (in this case this would be 46 nits (2.16W) and 64 nits (2.55W), which is how 2.46W was determined for backlight at 60 nits.

Once the panel electronics powers are measured under different patterns and the panel backlight is measured under certain luminance settings, the total panel power for a specific level and pattern are easily extracted. The point of comparison here is LCD panel power consumption at 60 nits using the mosaic pattern. Using the above example, panel electronics for mosaic is 1.00W, and panel backlight for 60nits is 2.46W. Therefore, the power consumption for the panel is 3.46W.

Detailed Test Setup

Materials Needed

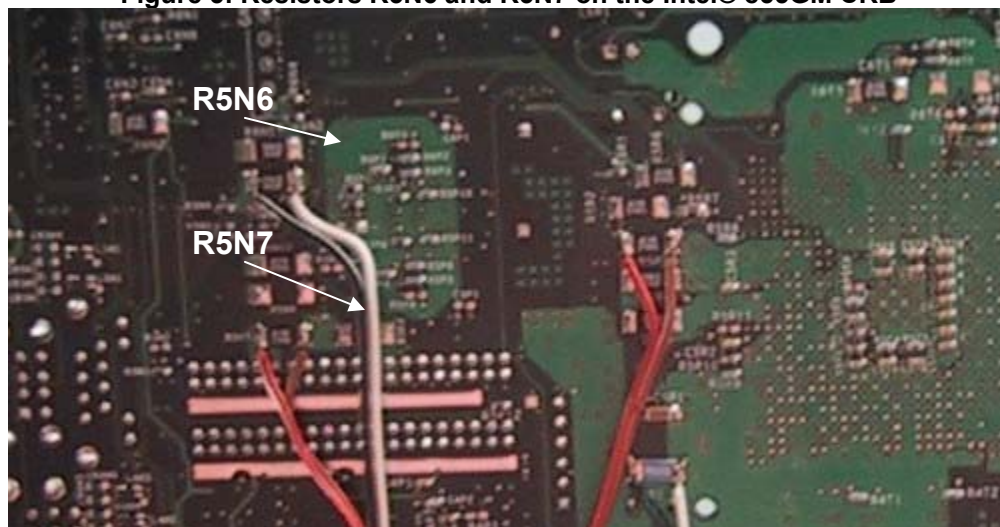
- Intel® 855GM I & Kit (includes panel cables and reference inverter)¹
- ATX Power Supply (300W minimum)
- Mobile HDD
- LCD Panel + Inverter
- Fluke NetDaq* Data Acquisition (Model: 2645A)
- Computer with Fluke NetDaq and Canary Lab's Trend Link software as storage of Power Data
- Gossen Mavomonitor Luminance Meter
- Wire
- Solder
- Soldering Iron

Set Up

1. Solder wires to each side of the resistors R5N6 and R5N7 on the Intel® 855GM CRB for power measurements. These resistors are located on the bottom side of the CRB, as shown in Figure 5.

NOTE: If you already have wires connected, you can skip this step. If you do not have wires attached and your motherboard is in a white box chassis, see [Appendix A](#) for instructions regarding motherboard removal.

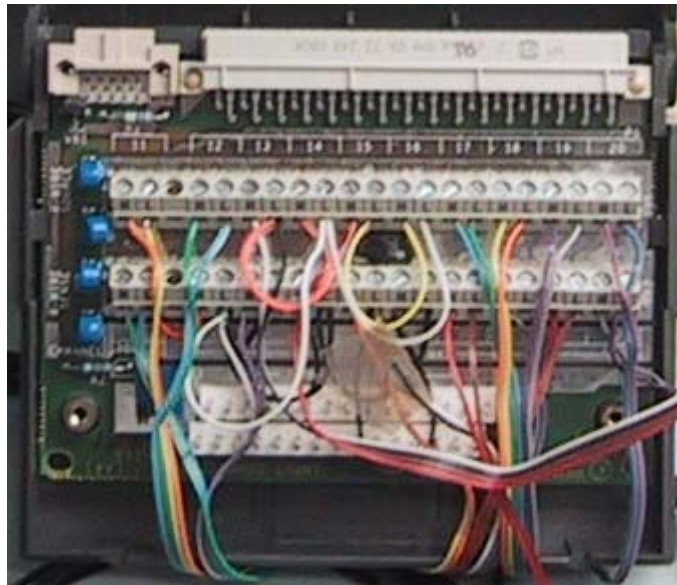
Figure 5: Resistors R5N6 and R5N7 on the Intel® 855GM CRB



¹ Please contact ebllwginfo@ebllwg.org for this reference board.

2. Connect the other end of the wires to the NetDaq Universal Input Module. An example of the inside of that Universal Input Module is seen in photo below where each of the 20 channels has a high and a low. Table 1 below is an example of the channels that can be used for setting up the 2 power measurements of interest. For example Channel 101 will measure the panel electronics current so 101 high should have the wire from +V3.3S from the CRB and 101 low should have the wire from +V3.3S_LVDS connected to them.
3. Channel 102 in the module should have +V3.3S_LVDS connected to high and GND connected to low. Repeat for current and voltage of the backlight also into Channel 103 and 104.
4. After all the wires are connected to the Universal Input Module (in this case there should be four channels used), plug the module into the back of the Fluke NetDaq Logger. Figure 6 shows a sample Universal Input Module with wires connected.

Figure 6: Sample Universal Input Module Wiring



5. The NetDaq Logger is connected via a cross cable to the network port of a host computer where the Fluke NetDaq and Trend Link software are installed. The network port IP needs to be configured to read data from the NetDaq, our settings for the configuration are: 198.178.246.100.
6. In the NetDaq Logger software (see Figure 7) go to Instrument Configurations (see Figure 8) under Setup and make sure the Interval Trigger is selected and interval set to 0.05 seconds. Select Fast for the Read Rate and make sure Drift Correction is checked. Then click on Data File and select a place where the files will be written. In order to use the Trend Link software to visually see the power plot, you need to select File

Format as Trend Link. If you just want the data you can select ASCII (CSV) option also.

7. Back at the Instrument Configurations click on the Channels and setup the channels to correspond to the wires in the Universal Input Module. If you followed the examples in Table 1, the channels would be configured as shown in second screen shot of Channel Configurations (see Figure 9). Channels 101 to 104 function is set to Auto range. Mx+B would be change for the current channels 101 and 103 only to M=100 (M = 1/R, R = 0.01 Ohms, so M = 1/0.01 = 100). (Default M = 1, example for Channel 101 in Figure 10) Equations are set for power where channel 121 is product of channel 101 and 102 to get panel electronics power as the product of it's current and voltage (P=IV).

Table 1: Example of Fluke NetDaq* Channel Set Up

Channel	Measurement/Calculation	
101	Panel Electronics Current	+V3.3S to +V3.3S_LVDS
102	Panel Electronics Voltage	+V3.3S_LVDS to GND
103	Backlight Current	+VDC to +VCC_LVDSBKLT
104	Backlight Voltage	+VCC_LVDSBKLT to GND
121	Panel Electronics Power	= Ch101 x Ch102
122	Backlight Power	= Ch103 x Ch104

Figure 7: Sample Screen Capture of Fluke Netdaq Logger Software

The screenshot shows the 'displaypower.stp - Fluke NetDAQ Logger' window. The menu bar includes Setup, View, Logging, Plot/Trend, Utilities, Options, and Help. The toolbar contains icons for file operations and playback. The main area displays 'INSTRUMENT CONFIGURATION - 01' with the following settings:

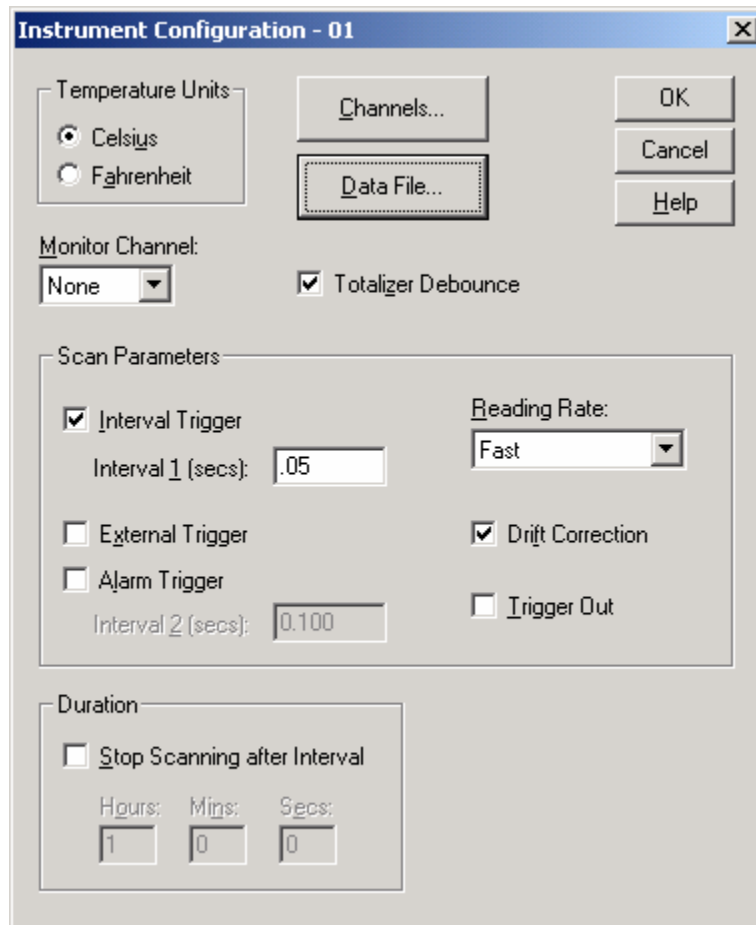
- Description:** (None)
- Model:** 2645A
- Trigger Type:** Interval
- Interval 1:** 0.050 sec
- Interval 2:** NA
- Temp Units:** Celsius
- Monitor Chan:** None
- Total Debounce:** Yes
- Reading Rate:** Fast
- Drift Correction:** Yes
- Duration:** NA
- Data File:** c:\netdaq_powerdata\displaypower.set
- File Mode:** NA
- File Format:** Trend Link

Below the configuration is a table of channels:

Chan	Function	Range	Alarm 1	Alarm 2	Trg	Mx+B	Units	Label
0101	VDC	Auto	OFF	OFF	NA	ON	A	LVDS_A
0102	VDC	Auto	OFF	OFF	NA	OFF	V	LVDS_V
0103	VDC	Auto	OFF	OFF	NA	ON	A	Bklt_A
0104	VDC	Auto	OFF	OFF	NA	OFF	V	Bklt_V
0121	Equation		OFF	OFF	NA	OFF	W	LVDS_W
0122	Equation		OFF	OFF	NA	OFF	W	Bklt_W

At the bottom left, it says 'For Help, press F1'. At the bottom right, there is a 'NUM' button.

Figure 8: Instrument Configuration



The image shows a software dialog box titled "Instrument Configuration - 01". It contains several sections for configuring the instrument's operation. At the top left, there is a "Temperature Units" section with radio buttons for "Celsius" (selected) and "Fahrenheit". To the right of this are three buttons: "Channels...", "Data File..." (highlighted with a dashed border), and "OK". Below the temperature units is a "Monitor Channel:" dropdown menu set to "None" and a checked checkbox for "Totalizer Debounce". The "Scan Parameters" section includes a checked "Interval Trigger" with an "Interval 1 (secs)" field set to ".05" and a "Reading Rate:" dropdown set to "Fast". It also has unchecked checkboxes for "External Trigger" and "Alarm Trigger" with an "Interval 2 (secs)" field set to "0.100". On the right side of this section are checked checkboxes for "Drift Correction" and an unchecked checkbox for "Trigger Out". The "Duration" section at the bottom has an unchecked checkbox for "Stop Scanning after Interval" and three spin boxes for "Hours:" (set to 1), "Mins:" (set to 0), and "Secs:" (set to 0). At the bottom right of the dialog are "Cancel" and "Help" buttons.

Figure 9: Channel Configuration

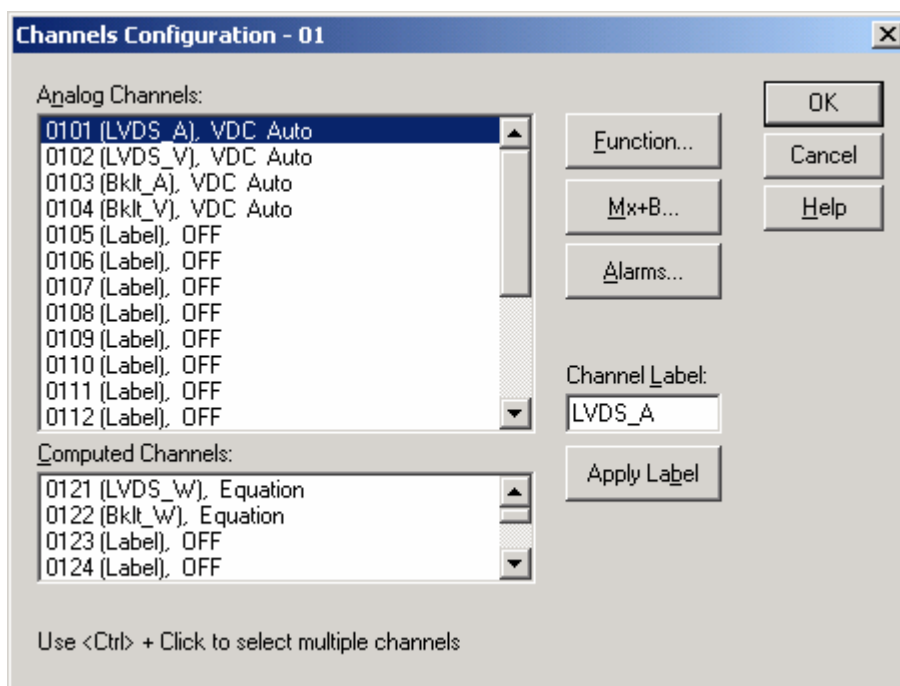
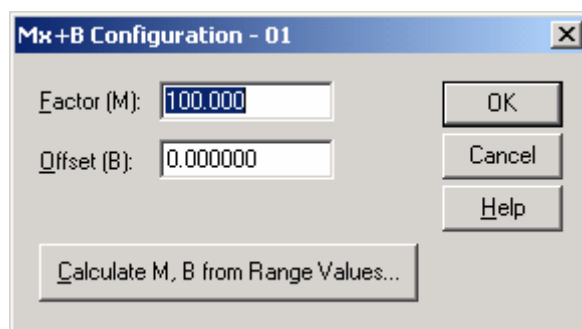
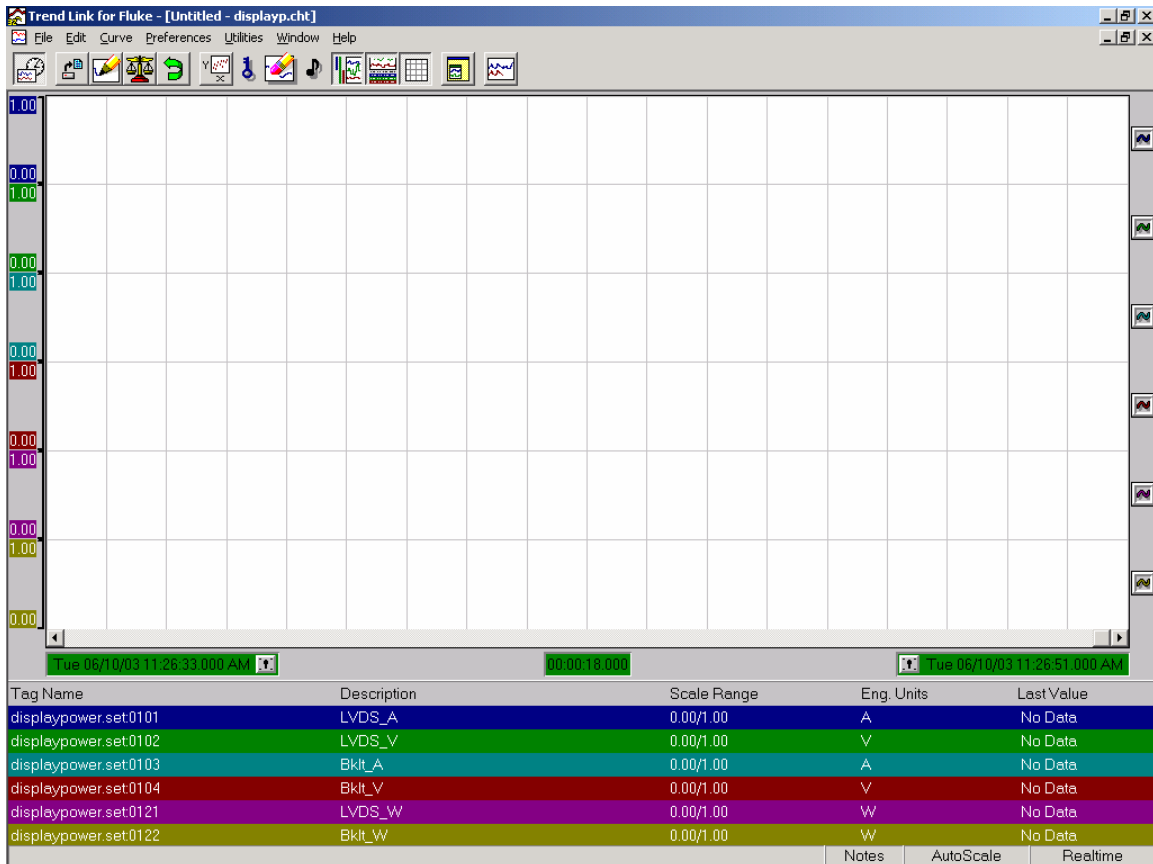


Figure 10: Mx+B Configuration for Channel 101



8. To start the power log, click the **Play** button or go to **Logging → Start Instrument**. Then, start Trend Link by going to **Plot/Trend → Show Trend Link**. Add the proper channels to observe if needed. A grid should appear across the screen to indicate current, voltage, and power levels measured on each channel. (See Figure 11 as an example of what Trend Link looks like.)

Figure 11: Sample Screen Capture of Trend Link for Fluke



9. Install Windows* XP and Microsoft PowerPoint* with all the proper Intel® 855GM drivers, and copy the file with test patterns on the hard drive. For the test patterns, use those indicated in FPWDSBM.ppt Section 401-1, which are the last three slides for full-screen white, black, and mosaic.

Notes:

With the Intel® 855GM CRB system BIOS, you must select the correct LVDS and Panel settings for the panel that you connected, otherwise the display may not boot. For example if you have an XGA 1024x768 panel you'll need to select this in the BIOS under the Graphics/Video section.

As an alternative to using the Fluke NetDaq Logger for measuring current and voltage, you can use a Digital Multimeter (DMM) — preferably one that has an averaging functionality. Otherwise, the powers are measured as instantaneous power rather than averaged over 5 minutes.

Backlight Measurement

1. Turn on Intel® 855GM CRB with LCD Panel and set to the highest luminance. Press **CTRL-ALT-SHIFT-F10** to increase and **CTRL-ALT-SHIFT-F9** to decrease screen brightness. Bring up the full-screen white pattern in FPDMSBM.ppt, Section 401-1. Wait for 30 minutes for the CCFL to warm up.
2. For each screen brightness setting, there is a ten-minute settling period where luminance is measured instantaneously at the end of the ten minutes. Luminance is measured with the Gossen Mavomonitor luminance meter by placing the meter up to the surface of the LCD panel at the center of the LCD panel. The panel backlight power is taken as the average over the last five minutes of the settling period. At the end of the ten minutes, after power and luminance measurements are recorded, change to the next lower luminance setting and repeat. Typically, there are 11 settings (0-10) allowed on the CRB. (Basically at Time $t = 0$ your panel is warmed up, at $t = 10$ min you take the Luminance measurement, and the backlight power is an average of power from $t = 5$ min to $t = 10$ min. After reading the measurements you change the level and repeat.)
3. Table 2 is a sample data table that would be filled out for this measurement.

Table 2: Sample Data Table for Backlight Measurements

Levels	Luminance (nits)	Backlight Current (A)	Backlight Voltage (V)	Backlight Power (W)
L0				
L1				
L2				
L3				
L4				
L5				
L6				
L7				
L8				
L9				
L10				

Panel Electronics Measurement

1. Turn on the Intel® 855GM CRB and set the luminance to a particular level. This will not need to be changed. Load FPDMSBM.ppt and make it full screen on white, no settling time is required in this case.
2. Take a five-minute average for the panel electronics power using the white image at full screen. Change to black and mosaic and repeat the five-minute average.
3. Table 2 is a sample data table that would be filled out for this measurement.

Table 3: Sample Data Table for Panel Electronics Measurements

Pattern	R	G	B	Panel Current (A)	Panel Voltage (V)	Panel Power (W)
White	255	255	255			
Black	0	0	0			
Mosaic	X	X	X			

Note: The minimum requirement for color patterns would be those included in the above table. However, other color patterns could be measured such as RGB (red, green, and blue). These are optional and the patterns are provided in FPDMSMB.ppt.

References and Links

EBLWG (Mobile PC Extended Battery Life Working Group)

<http://www.eblwg.org>
eblwginfo@eblwg.org

BAPCo MobileMark 2002

<http://www.bapco.com>

VESA

<http://www.vesa.org>

FPDMSBM.ppt Patterns

(<http://www.vesa.org/public/Fpdm2/FPDMSBM.ppt>)

Fluke

<http://www.fluke.com>

Gossen

<http://www.gossen-photo.de/>

Gossen Mavomonitor (make sure to click on Mavomonitor)

http://www.gossen-photo.de/english/lichtmess_produkte.html

Spec: http://www.gossen-photo.de/pdf/Datenblatt_e_Mavomonitor.pdf

Appendix A: Removing the Motherboard from the Chassis for Power Instrumentation

To remove the motherboard from the white box chassis, you must first disconnect several things from the motherboard.

1. Remove the side panels of the case by removing the screws in back and pulling on the side cover.

Once the case is open, you will see the motherboard inside.

2. Remove the screw in back that holds the bracket for the power delivery card on the motherboard.

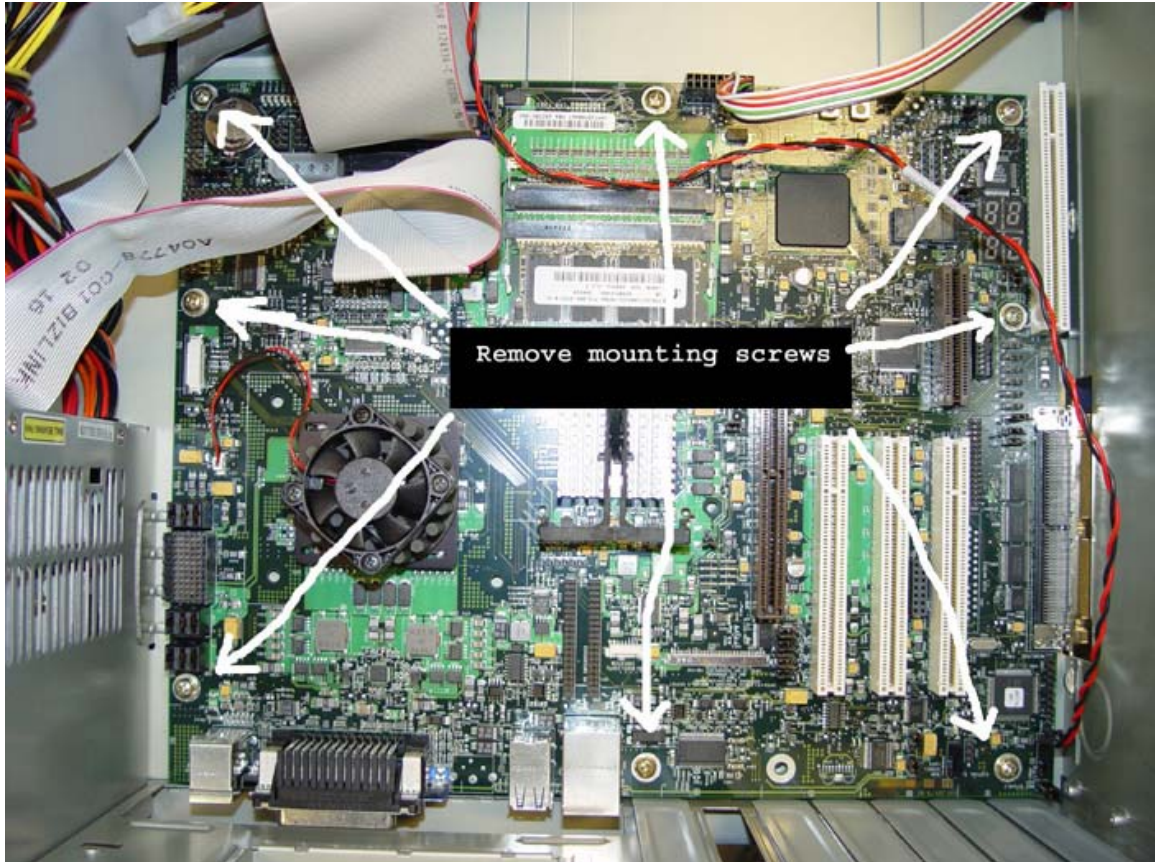
The photo in Figure 11 shows how to locate and remove this bracket.

Figure 11. Removing the Screw and Bracket From the Chassis Back



3. Remove the eight mounting screws that hold the motherboard to the chassis as indicated in Figure 12.

Figure 12: Removing Mounting Screws Holding Motherboard to Chassis



4. Make sure any other wires connected to the motherboard are disconnected.

Be sure to note where and how those wires must be reconnected. At this point, the motherboard should be loosened from the chassis.

5. Remove the motherboard and turn it upside down so that you can locate the resistors of interest and attach wires so as to measure power.
6. Follow the directions in the main document regarding which resistors to instrument.
7. Once all the wires are in place, replace the motherboard into the chassis and replace all the wires and mounting screws.

8. Replace the bracket holding the power delivery card and make sure the ATX power supply is still attached to it.
9. Make sure that the wires that you just soldered are routed out the back of the chassis where there is already a hole left for routing out the cables to connect to the LCD Panel.
10. Double check to make sure everything has been reconnected before booting up the machine again.
11. Continue with the rest of the set up.