Upgrading to LQ121S1LG84 from CCFT-Backlit Modules

Sharp Microelectronics of the Americas

INTRODUCTION

Many manufacturers of LCD modules are moving to LED-backlit units, and Sharp is a leader, responding to increasing Customer demand for LED-backlit modules. LED backlights offer several advantages over CCFTs, with the primary reason being power savings, followed by the absence of mercury and superior low-temperature operation.

Moving a product from a CCFT-backlit module to an LED-backlit module raises a number of concerns for the designer:

- Overall compatibility
- Mechanical compatibility
- Optical compatibility
- Color compatibility
- Revision control
- Long-term availability

This Application Note will use a common upgrade as an example, along with breakdown photos of the parts to answer these questions. The parts we will be using as a specific example are the LQ121S1LG42 and LQ121S1LG61 (CCFT-backlit) and their upgrade, the LQ121S1LG84 (LED-backlit).

Why Change At All

The advantages of LED backlighting are many: better cold, shock and vibration tolerance, better color, less power consumption, more environmentally-friendly, and complete lack of RF output created by an inverter.

However, as our world goes "greener," more and more CCFT backlight subassembly suppliers are closing shop or restricting product output due to environmental concerns. This means a fundamental shift for designers and customers who are currently purchasing or considering CCFT-backlit LCD modules.

Longevity of the backlight luminaire is often considered when contemplating the transition to LED, and the extreme ends of the temperature specification had been an area of concern. The rule-of-thumb used to be, "Hot - CCFT, Cold - LED," but no longer.

CCFTs have long been the choice when a module is being operated at its maximum operating temperature, yet their lifetime is severely shortened when operating them near their minimum operating temperature. In some cases of continued operation in extreme cold, CCFTs may not reach even the greater half of their rated lifetime. LEDs tend to perform best in the opposite manner: long-lived when being operated at the module's minimum operating temperature, and shorter-lived when operating near the module's maximum operating temperature.

In the past, the LED's shortened lifetime at higher temperatures was a reason to reject an LED-backlit module for a high-temperature application. However, LED technology continues to evolve, allowing them to become better-suited for higher temperature applications.

Modern LED backlights feature higher-efficacy emitters, meaning in a watts-per-lumen sense they are not being operated nearly as close to the upper end of their performance envelope as in times past. They also feature adequate heatsinking so that all generated heat is dissipated properly. In Figure 1, the LED string and circuit board is bonded to the back chassis of the LCD module. This gives the LED string more than adequate heatsinking.

Figure 1. Closeup of LED Backlight Assembly

Meanwhile, by testing modules to the maximum limit of their Specifications, Sharp guarantees their modules will perform to Specifications at those published extremes. So even though the target application may involve higher ambient temperatures, as long as the design maintains the module within its published *Absolute Maximum Values*, you can have confidence that a Sharp module will perform to its lifetime specifications. Often the LED-backlit upgrade module will have the same *Absolute Maximum Values* specified.

When it comes to driver circuits for the two different backlight types, LED drivers again are at an advantage. CCFT drivers must generate a high ‘start-up’ (or striking) voltage and then maintain a certain high run voltage at a given current level. These high voltages require proper management and precautions in the final design; for instance sealing against high dust and humidity levels.

LED drivers are much less complex in nature, with no high voltages to generate and manage in the design. The LED string(s) do however require a constant-current supply with current limiting to prevent thermal runaway. Some suppliers are now making a’ driver-in-a-chip’ solution so driving an LED backlight is becoming even simpler.

MAKING THE TRANSITION

Fortunately, companies like Sharp are working hard to ease the transition, by introducing upgrade LCD modules that are as close to a “drop-in replacement” for their CCFT-counterparts as possible.

Whenever Sharp is forced to discontinue a CCFT-backlit module and replace it with an LED-backlit one, extensive research is performed to properly map form, fit, and function issues between the discontinued module and its upgrade.

Often, the upgraded module will be slightly thinner and slightly lighter due to the LED strip requiring less space and less mechanical reinforcement. While most customers do not find this a drawback, designers should always be aware of these differences and how they may affect their particular design.

In all cases where there are differences in the upgraded module, these differences will be called out in Sharp's Product Change Notice document.

These items are also reviewed for compatibility:

- Electrical - the connectors will typically be the same and have similar functionality, unless otherwise stated.
- Hardware-based display functions - such as Display Invert and Display Reverse are typically supported, using the same combinations of pin voltages.
- Driver availability - many third-party driver manufacturers have built replacement backlight drivers for LED-based modules to be 'drop-in' replacements for existing CCFT inverter units; these units are made to utilize the same power supplies with minimal modifications to the existing design.
- Built-in LED Drivers - Sharp is building many modules (many as upgrades) with built-in LED backlight drivers, so Designers need not consider the expense of replacing a CCFT inverter with a standalone backlight driver.

Sharp’s upgrade modules come with a built-in advantage in backlight drivers that are designed to be compatible with common CCFT driver supply voltages, Backlight ON/OFF signals, and PWM dimming signals.

COMPARING LED AND CCFT BACKLIGHTS

Light Output

CCFTs (Cold Cathode Fluorescent Tubes) make light by striking and maintaining an arc through a noble gas and exciting a phosphor layer on the inside of the tube. The CRI (Color Rendering Index) of these tubes is high, but the light output tends to be 'peaky' in that it has lots of output in some narrow bands and next to none in other bands of the visible spectrum. Manufacturers can manipulate this characteristic to some extent, but Figure 2 is representative of a typical CCFT. Note how the manufacturer has peaked the output in the green/yellow portion of the spectrum to produce more apparent brightness; since the eye is more sensitive in this portion of the visual spectrum.

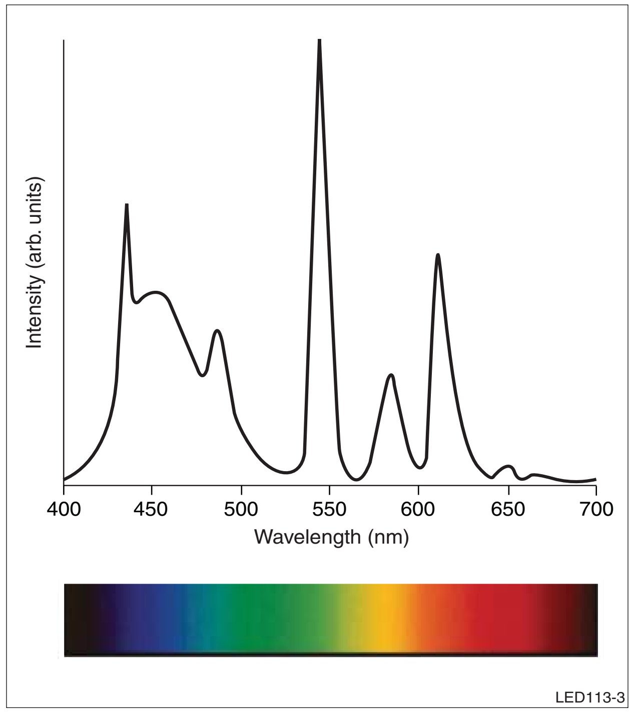

Figure 2. Spectral Output of a Typical CCFT Backlight

LEDs make light by using a blue die to excite a phosphor, and the resulting light has a much smoother spectral curve (See Figure 3). Today's LED phosphors benefit from continued development in light output, efficacy, and consistency of color. The CRI of the LEDs is equal that of the CCFT, but because the light output is higher over a broader range of the spectrum, LCD modules with LED backlights can have a 'richer' look to their color palette since their intermediate colors are somewhat more saturated.

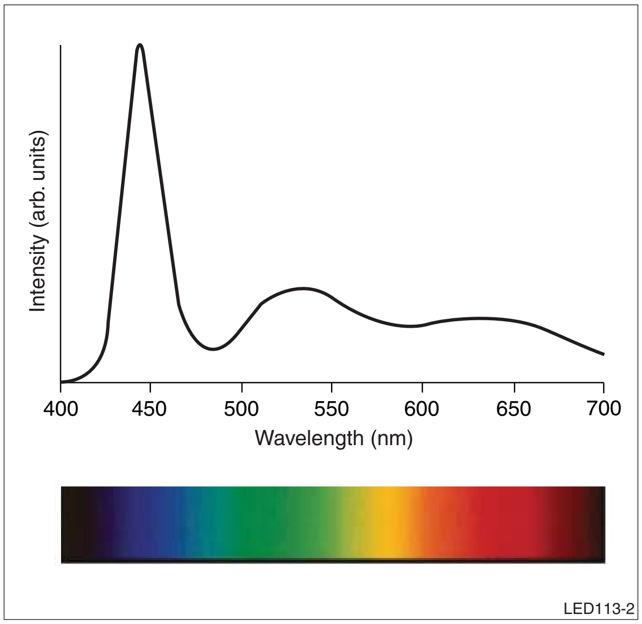

Figure 3. Spectral Output of a Typical LED Backlight

COMPARING SPECTRAL CURVES

When glancing back and forth between these two spectral curves, the differences become apparent. But it's when the two sets of spectral curves are superimposed that the inherent smoothness of the LED backlight's output becomes apparent. See Figure 4.

With this overlay, it also becomes even more apparent how the green/yellow portion of the output has been peaked by the manufacturer of the CCFT backlight to gain more apparent brightness; as the eye is most sensitive to the 550 nm (green/yellow) band of light.

When dimming CCFTs, many inverter boards offer extended capability, allowing CCFTs to be dimmed reliably to about 5%. Some care must be exercised in cold environments, as attempting to dim a CCFT in such environments can greatly shorten its life. LEDs have no such restrictions, as they are dimmable all the way to zero, without restriction of temperature, within the limits of the Specifications.

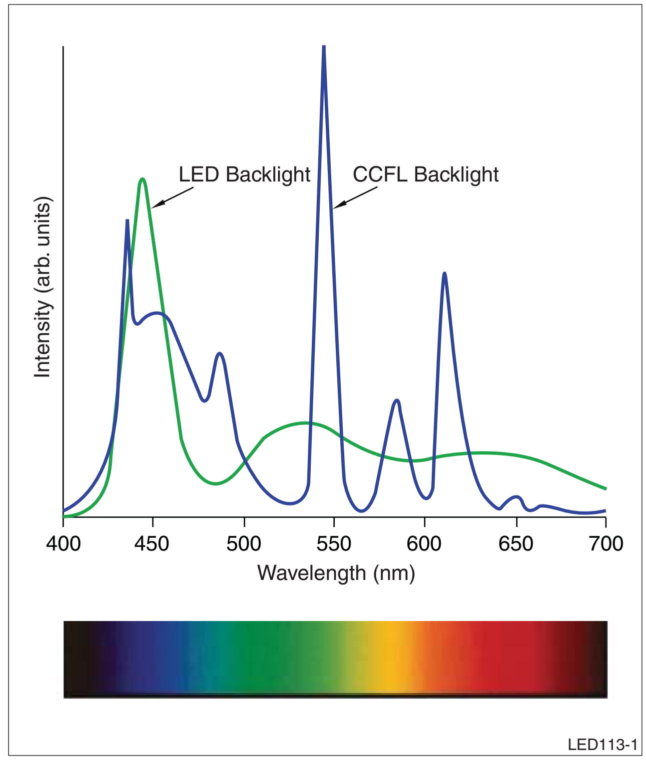

Figure 4. Comparison of CCFT and LED Backlights

Internal Drive Circuitry

Modules smaller than the 12- to 15-inch sizes seldom incorporate onboard CCFT drivers, due to the power-handling needs and isolation problems caused by a CCFT driver sharing a power supply with, and in close proximity to, the panel drive circuits.

Onboard LED drivers are far easier to incorporate as a part of the overall panel circuitry, and are often included in all but 'economy-grade' modules. The onboard LED backlight driver is included in our example, below.

External Drive Circuitry

When comparing a CCFT inverter to an LED driver, there are a number of positives for the LED driver - no need for the precautions required by high voltage, less power used, and similar form-factors are available from most suppliers for inverter boards and LED driver boards.

In cases where all other things are equal (except the backlight), changing the LCD module type is as simple as removing the CCFT-backlit unit, removing the inverter, replacing the inverter board with an LED driver board from the same manufacturer, hooking up the new LED-backlit unit, and replacing it. Sharp has a video online that shows how simple this process can be. Go to http://www.sharpledlcd.com/resources.html to watch Todd Stonewall demonstrate how easily the change can be made.

For a drop-in driver solution, Endicott Research Group (ERG) has the Smart Force™ Drop-in Replacement Series of LED drivers that have the same footprint and input voltages as their CCFT-driver counterparts.

When using a PWM for dimming, many available LED driver boards offer plug-and-play replacements, with PWM inputs as well as analog inputs for dimming. Generally, LED backlights are made to be compatible with existing PWM and DC dimming schemes. A number of manufacturers offer outboard LED drivers that utilize common dimming input methods for their driver boards.

When contemplating an overall redesign from scratch, mSilica (now owned by Atmel) markets a line of controller chips that only require a few external components to form a complete LED backlight driver.

UPGRADING A DESIGN INCORPORATING LQ121S1LG42/LG61 TO LQ121S1LG84

Let's take a real-world example: Sharp is superseding the LQ121S1LG42 and LQ121S1LG61 with the LQ121S1LG84. As of the publication date for this Application Note, the LQ121S1LG42 and LQ121S1LG61 are being phased out because the backlight for the parts is no longer being manufactured. The LQ121S1LG84 is essentially the same part, but with the backlight structure and films modified to incorporate LED backlighting; plus a built-in backlight driver circuit. The accompanying comparison photographs will also show the similarities in the two parts.

Comparing Form and Fit Differences

MECHANICAL

Table 1 compares Form and Fit through the Mechanical Specifications for these modules.

Note how the mechanical dimensions as shown by the Specifications are a match, and the mass for LQ121S1LG84 is somewhat less (as expected).

Table 1. Mechanical Specifications

Parameter	LQ121S1LG42 (CCFT)	LQ121S1LG61 (CCFT)	LQ121S1LG84 (LED)
Display size	12.1-inch (31 cm) Diagonal	12.1-inch (31 cm) Diagonal	12.1-inch (31 cm) Diagonal
Active area	246.0 (H) × 184.5 (V) mm	246.0 (H) × 184.5 (V) mm	246.0 (H) × 184.5 (V) mm
Pixel format	800 (H) × 600 (V)	800 (H) × 600 (V)	800 (H) × 600 (V)
Number of colors	262,144 colors (64-level grayscale)	262,144 colors (64-level grayscale)	262,144 colors (64-level grayscale)
Pixel pitch	0.3075 (H) × 0.3075 (V) mm	0.3075 (H) × 0.3075 (V) mm	0.3075 (H) × 0.3075 (V) mm
Display mode	Normally White	Normally White	Normally White
External Dimensions	276.0 (W) × 209.0 (H) × 11.0 (D)	276.0 (W) × 209.0 (H) × 11.0 (D)	276.0 (W) × 209.0 (H) × 9.1 (D)
Mass (MAX.)	660 g	800 g	600 g
Surface treatment	Anti-glare and 3H hard-coating	Anti-glare and 3H hard-coating	Anti-glare and 3H hard-coating

MOUNTING AND CONNECTOR LOCATIONS

Let's look next at the mounting scheme. See the following mechanical drawings for a direct comparison.

The greatest difference between the panels is that the LQ121S1LG84 does not require a separate backlight driver as the driver is integrated into the panel.

Figure 5 shows the back of the LQ121S1LG84 and the location of the backlight connector, near the main interface connector for the panel.

When we look at the mechanical illustrations we can see that the mounting schemes appear exactly the same. However, when the illustrations can be adjusted to exactly the same scale, it's best to superpose the drawings just to check, as shown in the following figures.

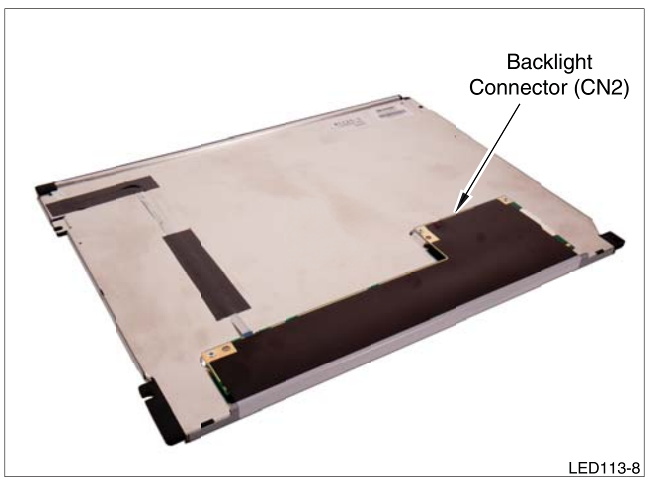

Figure 5. Backlight Connector Location

INTERFACE CONNECTORS

Mating connectors for all three modules' interfaces as listed in the Specifications are:

- FI-SE20ME (JAE)
- FI-S20S (JAE)

So again there is a mechanical match.

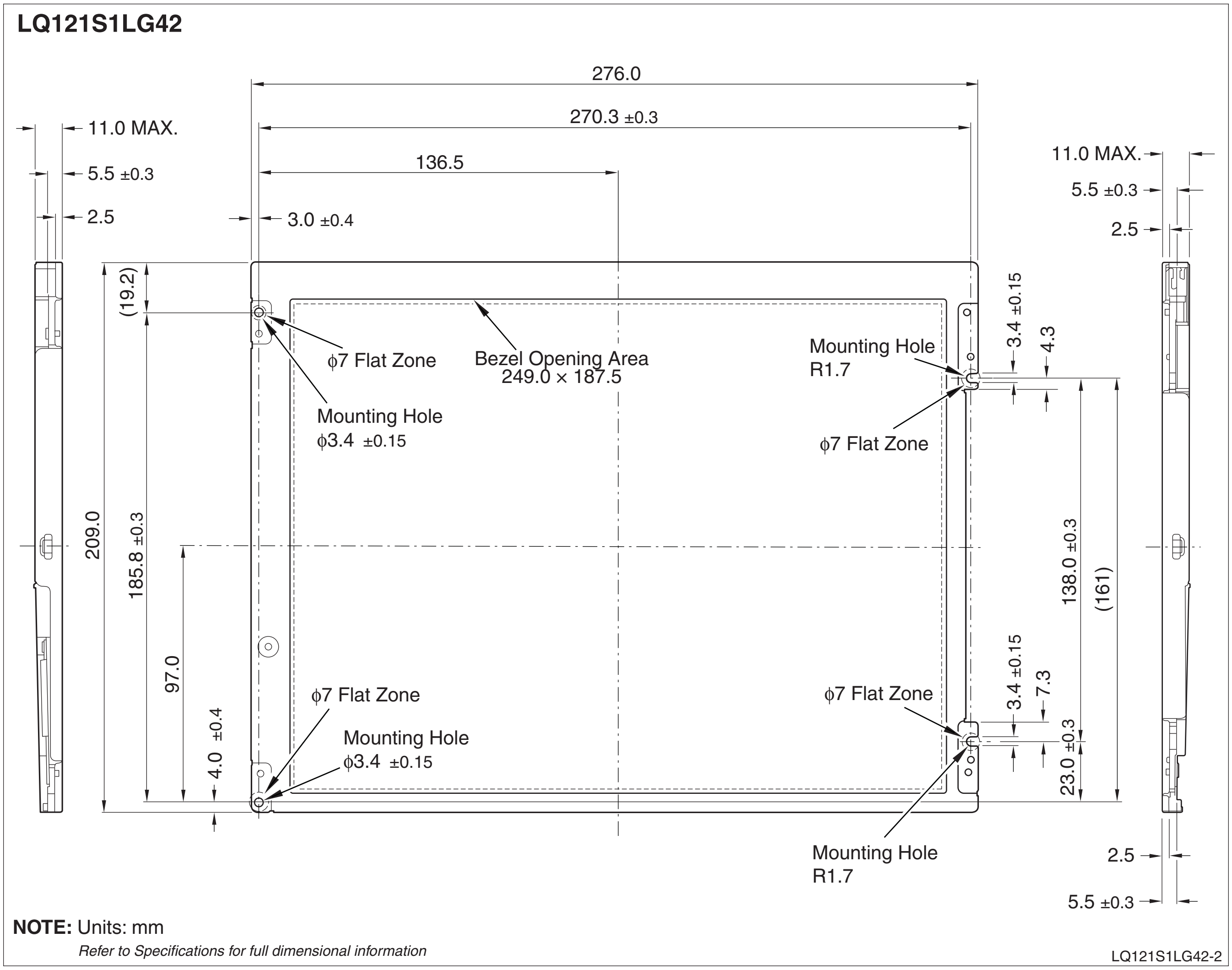

Figure 6. Mechanical Dimensions for LQ121S1LG42

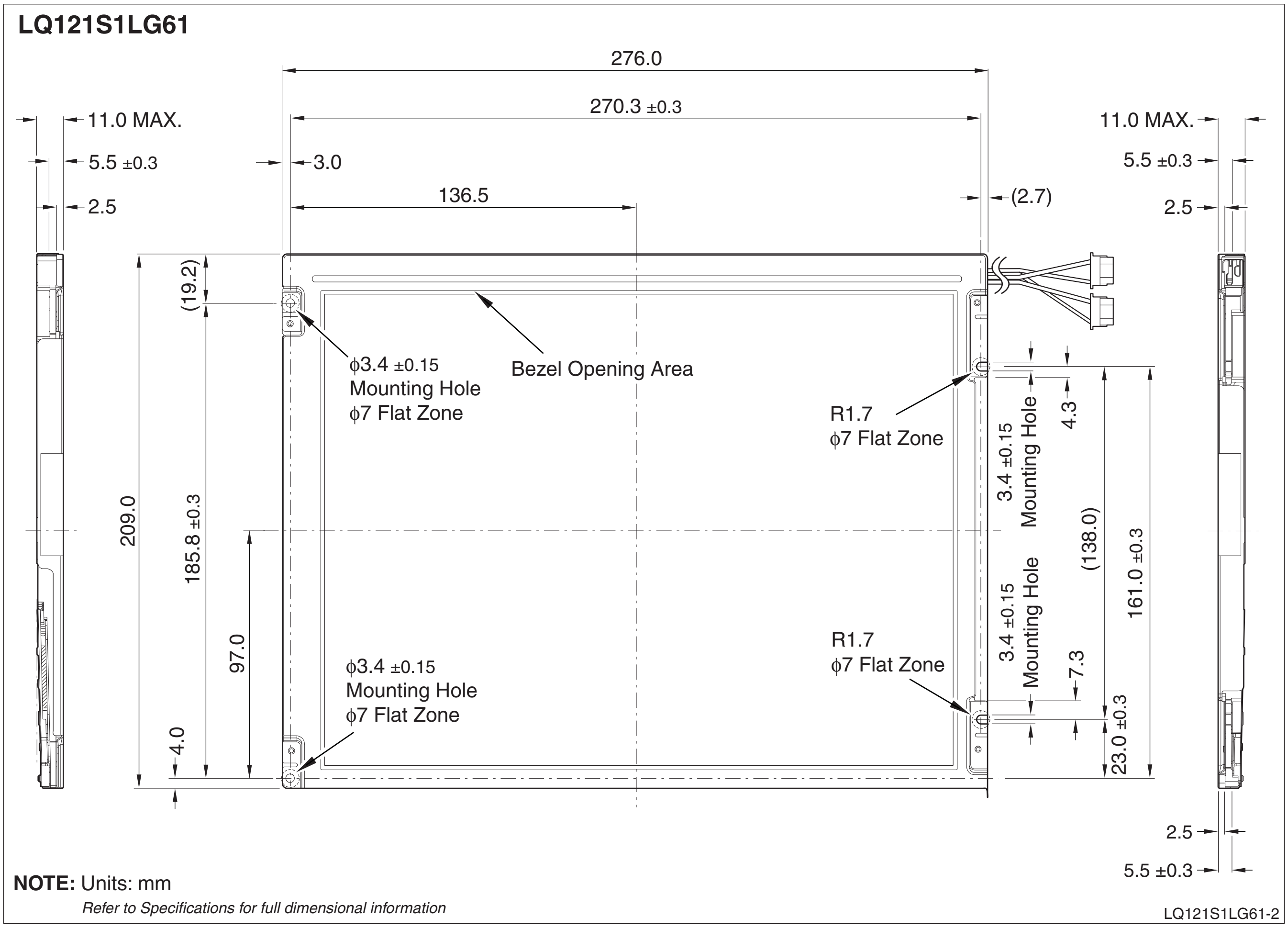

Figure 7. Mechanical Dimensions for LQ121S1LG61

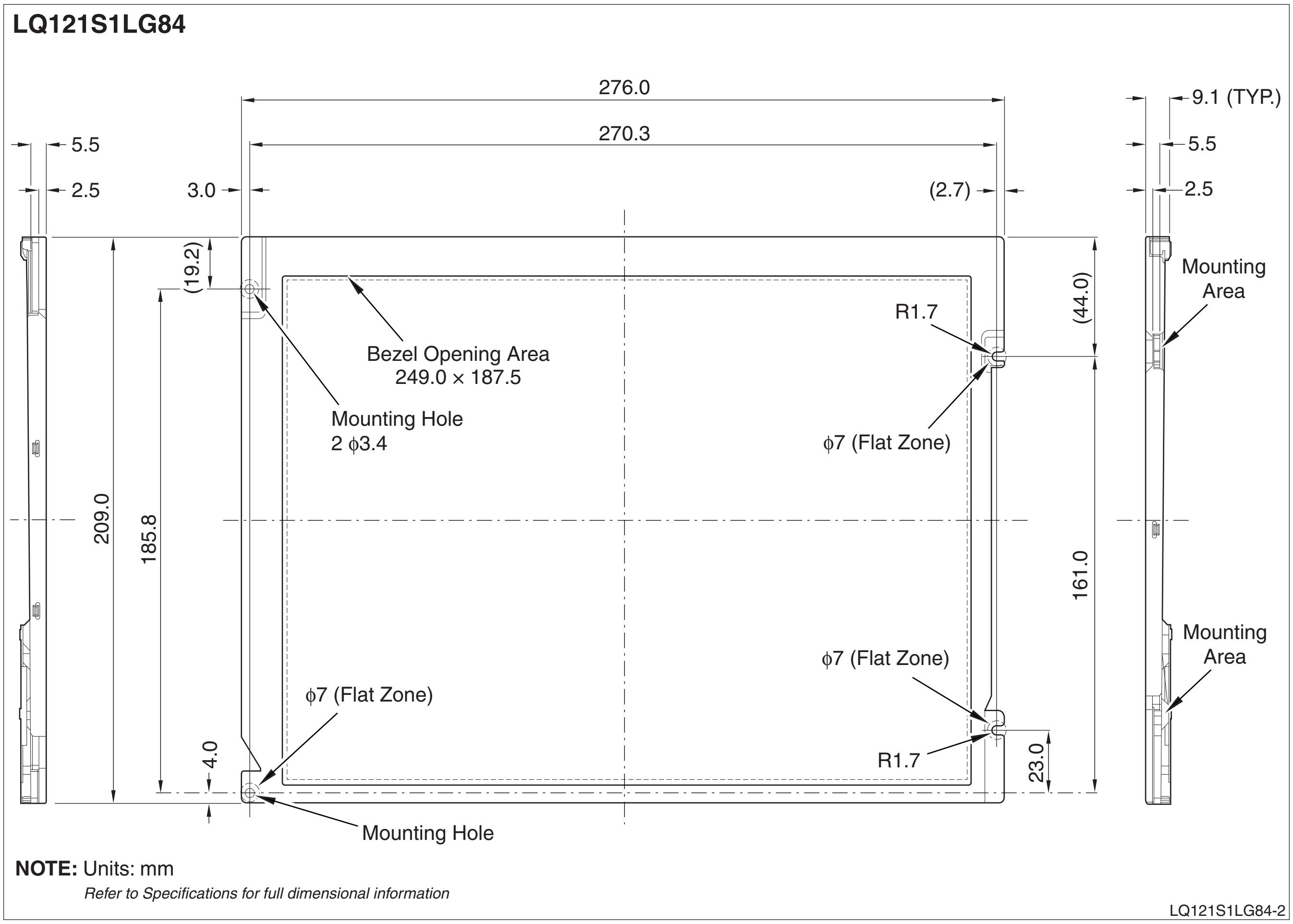

Figure 8. Mechanical Dimensions for LQ121S1LG84

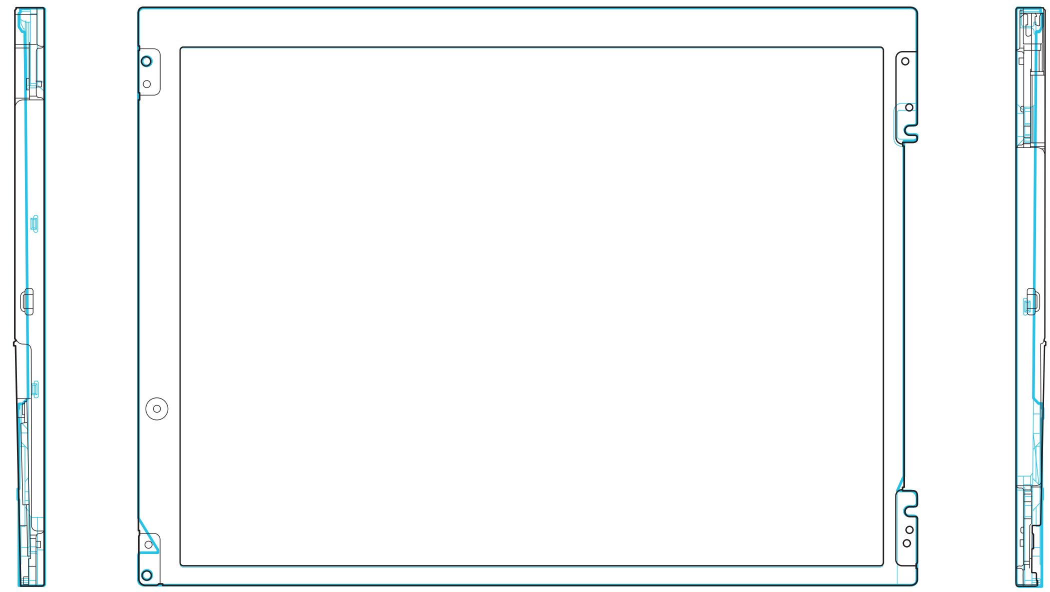

Figure 9. Superposition of LQ121S1LG84 and LQ121S1LG42

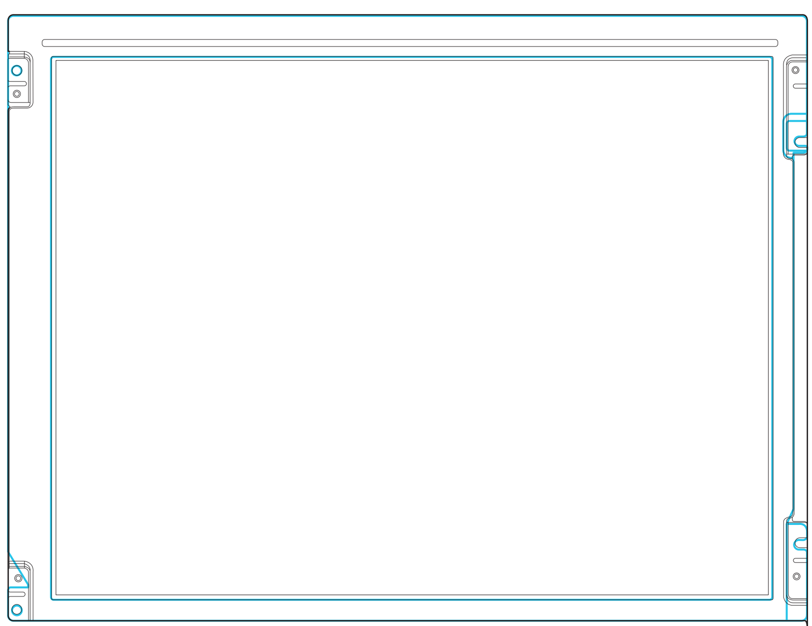

Figure 10. Superposition of LQ121S1LG84 and LQ121S1LG61

Functional Differences

When looking at the functional differences between a module and its upgrade, it is often asked, "Can this upgrade withstand the same environment?" The Absolute Maximum Values table provides a qualified *yes* answer, as the LQ121S1LG84 is designed to use a +3.3 V supply.

ELECTRICAL INTERFACE MATCHING

Now that we know we have a mechanical match of the connectors, we'll begin looking into the electrical match. Connectors for all three modules are the same type, accepting a FI-SE20ME (JAE) or FI-S20S (JAE). The pinouts match, as shown in Table 3; however there are differences in both power supply and display invert/ reverse functions.

Note how the LQ121S1LG84 is a single-voltage module and only accepts 3.3 V, where the LQ121S1LG42 and LQ121S1LG61 it replaces allow for either a 3.3 V or 5.0 V supply.

The display reverse function also differs. See *Display Orientation* for more information.

Table 2. Absolute Maximum Ratings (Conditions Ta = 25°C unless otherwise noted)

Parameter	LQ121S1LG42 (CCFT)	LQ121S1LG61 (CCFT)	LQ121S1LG84 (LED)
Supply Voltage	-0.3 V to + 6.0 V	0 V to + 6.0 V	-0.3 V to + 4.0 V
Input voltage VI1 (RXIN)	-0.3V to Vcc+0.3V	-0.3 V to Vcc + 0.3 V	-0.3 V to Vcc + 0.3 V
Input voltage VI1 (RXCLK IN)	-0.3V to 3.3V[1]	-0.3 V to 3.3 V	-0.3 V to 3.3 V
Input voltage VI2 (R/L, U/D)	-0.3V to Vcc+0.3V	-0.3 V to Vcc + 0.3 V	-0.3 V to Vcc + 0.3 V
Storage temperature (Tstg)	-30°C to +70°C	-30°C to +80°C	-30°C to +80°C
Operating temperature (Topa)	-10°C to +65°C	-30°C to +80°C	-30°C to +80°C

NOTES:
1. When Vcc ≥ 3.0 V; otherwise same as other input voltages.
2. Storage humidity: 95% RH (MAX.) at Ta ≤ 40°C; Maximum wet-bulb temp at 39°C or less at Ta > 40°C; non-condensing.

Table 3. Interface Connectors

LQ121S1LG42 / LQ121S1LG61 (CCFT)			LQ121S1LG84 (LED)		
PIN NO.	SYMBOL	FUNCTION	SYMBOL	FUNCTION	NOTES
1	VCC	+3.3 V / +5.0 V power supply	VCC	+3.3 V power supply	Single Voltage
2	VCC	+3.3 V / +5.0 V power supply	VCC	+3.3 V power supply	Single Voltage
3	GND		GND		
4	GND		GND		
5	RXIN0-	Negative Data Input, CH 0	RXIN0-	Negative Data Input, CH 0	LVDS signal
6	RXIN0+	Positive Data Input, CH 0	RXIN0+	Positive Data Input, CH 0	LVDS signal
7	GND		GND		
8	RXIN1-	Negative Data Input, CH 1	RXIN1-	Negative Data Input, CH 1	LVDS signal
9	RXIN1+	Positive Data Input, CH 1	RXIN1+	Positive Data Input, CH 1	LVDS signal
10	GND		GND		
11	RXIN2-	Negative Data Input, CH 2	RXIN2-	Negative Data Input, CH 2	LVDS signal
12	RXIN2+	Positive Data Input, CH 2	RXIN2+	Positive Data Input, CH 2	LVDS signal
13	GND		GND		
14	RXCLK IN-	Negative Clock Input	CLK IN-	Negative Clock Input	LVDS signal
15	RXCLK IN+	Positive Clock Input	CLK IN+	Positive Clock Input	LVDS signal
16	GND		GND		
17	R/L	Horizontal display mode select	NC	Not Connected	See *Display Orientation*
18	U/D	Vertical display mode select	R/L,U/D	Display Reverse	
19	GND		GND		
20	GND		GND		

NOTE: All clock and Data signal inputs are differential, or balanced, input.

SIGNAL FUNCTIONS AND TIMING

The next things to check are signal functions and timing. Since the panels use LVDS (Low Voltage Differential Signaling), it's important to know their compatibility with possible transmitters in host application.

There's an easy shortcut here: The Specifications for both modules does not list a special byte-ordering table, therefore all modules use standard byte ordering. Another easy route when upgrading is to assure the use of a compatible LVDS transmitter, which will handle all signal timing issues. See Table 4 for a comparison between the parts.

Display Orientation

The Display Orientation pins for these two modules are different. The LQ121S1LG84 reverses *both* side-to-side and top-to-bottom at the same time when it has a HIGH on Pin 18. But the LQ121S1LG42 and LQ121S1LG61 it replaces allowed for individual side-to-side and top-to-bottom reversing with a HIGH on Pin 17 for side-to-side reversing, and a HIGH on Pin 18 for top-to-bottom reversing. See Table 3 and Figure 11.

Table 4. LVDS Transmitter Comparison

LQ121S1LG84 (UPGRADE)		LQ121S1LG42 / LQ121S1LG61 (CCFT)	
RECIEVER	**SUGGESTED TRANSMITTER**	**RECIEVER**	**SUGGESTED TRANSMITTER(S)**
THC63LVDF84B	THC63LVDM83R	THC63LVDF64A	DS90C363, DS90C363A, DS90C383, DS90C383A (National), THC63LVDF63A,THC63LVDM63A (THine) SN75LVDS84 (TI)

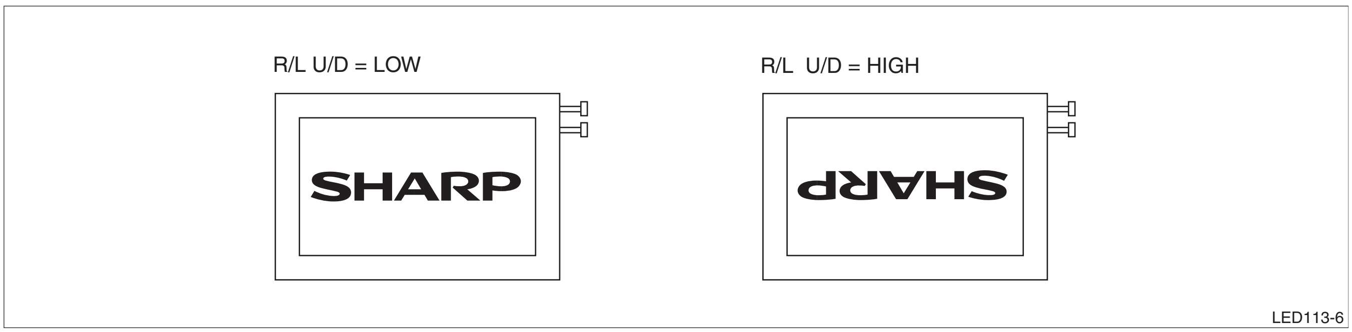

Figure 11. Scan Reverse Pin Functions

LED Backlight Connection

The LQ121S1LG84 has an onboard backlight driver and that driver utilizes typical power supplies and signals.

The connector requires a JST SHLP-06V-S-B for its mating connection. Pinout is as shown in Table 5.

Pins 5 and 6 are logic-level inputs and have a 10k Ω pull-down resistor. Pin 5 is the backlight enable, and Pin 6 is the dimming input.

Setting pin 5 HIGH will enable the backlight; however, note that Pin 5 must be pulled HIGH to enable the backlight. If Pin 5 is allowed to float, the backlight will not be enabled.

For Pin 6, applying a PWM signal with a frequency of between 200 Hz and 1k Hz and a duty cycle of 10% to 100% will control dimming. A duty cycle of 100% is 'ON full' or no dimming.

Table 5. Backlight Connector (CN2)

PIN NO.	SYMBOL	FUNCTION
1	VDD	+12 V power supply
2	VDD	+12 V power supply
3	GND	GND
4	GND	GND
5	XSTABY	Backlight ON/OFF signal*
6	VBR	PWM signal*

NOTE: Pins 5 and 6 are logic-level inputs.

EDGE-LIGHTING VS. DIRECT LIGHTING

The discussion of backlights presents us with an opportunity to discuss one or two of the differences between edge-lit modules and direct-lit modules.

Edge-lit modules offer economy and simplicity, along with an overall thinner module. Direct-lit modules offer a number of different advantages. Because they use individual LED emitters, these modules can allow for dynamic backlight changes to enhance contrast. This means the backlight can be locally dimmed or brightened as needed for greater contrast. The penalty is somewhat higher power usage and a thicker module due to the necessary heatsink.

The modules described in this Application Note are all edge-lit, and with the LED backlight using the rear frame as a heatsink, the profile can be kept to a minimum. Figure 12 shows a high-performance, direct-lit, high-brightness, high-color-gamut industrial module; note how it requires a set of heatsinks to maintain its backlight within lifetime specifications; this module is specified for a 50,000 hour lifetime, even at +70°C.

Optical Comparisons

Comparing Optical Characteristics from the Specifications also shows us a good match, with some upgrades to performance:

Note that the viewing angles are approximately 10° better in all directions (half of the horizontal measurement = 10°), while contrast is higher. Brightness is similar, so the upgrade module will appear similar, but contrast is much improved; the eye tends to perceive this as clarity, so the upgrade module will appear sharper than the ones it replaces. Response time is also better in the upgrade module.

CONCLUSION

In this Application Note, we’ve shown how to compare Specifications and Mechanical Samples when considering updating an existing design to include an LED-backlit LCD module.

This example shows how two Sharp modules which were built to be an exact match will compare, but when comparing similar assemblies (but not exact matches), it becomes a judgement-call for the Designer as to how much difference to tolerate in the final design update.

Figure 12. Direct-lit LED-backlit Industrial Module

Table 6. Optical Comparison

PARAMETER	LQ121S1LG42 (CCFT)			LQ121S1LG61 (CCFT)			LQ121S1LG84 (LED)		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
Horizontal Viewing angle	120	140		120	140		120	160	
Vertical Viewing angle (12 o'clock)	40	50		35	50		35	60	
Vertical Viewing angle (6 o'clock)	50	60		55	60		60	80	
Contrast ratio		450			600		500	800	
Response time (Rise/Fall, ms)		45			35			30	
White Chromaticity (x)	0.263	0.313	0.363	0.263	0.313	0.363	0.255	0.305	0.355
White Chromaticity (y)	0.279	0.329	0.379	0.279	0.329	0.379	0.275	0.325	0.375
White Luminance (nits)	300	370		360	450		350	450	

SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE.

NORTH AMERICA

SHARP Microelectronics of the Americas
5700 NW Pacific Rim Blvd.
Camas, WA 98607, U.S.A.
Phone: (1) 360-834-2500
Fax: (1) 360-834-8903
www.sharpsma.com

EUROPE

SHARP Microelectronics Europe
Division of Sharp Electronics (Europe) GmbH
Sonninstrasse 3
20097 Hamburg, Germany
Phone: (49) 40-2376-2286
Fax: (49) 40-2376-2232
www.sharpsme.com

JAPAN

SHARP Corporation
Electronic Components & Devices
22-22 Nagaike-cho, Abeno-Ku
Osaka 545-8522, Japan
Phone: (81) 6-6621-1221
Fax: (81) 6117-725300/6117-725301
www.sharp-world.com

TAIWAN

SHARP Electronic Components
(Taiwan) Corporation
8F-A, No. 16, Sec. 4, Nanking E. Rd.
Taipei, Taiwan, Republic of China
Phone: (886) 2-2577-7341
Fax: (886) 2-2577-7326/2-2577-7328

SINGAPORE

SHARP Electronics (Singapore) PTE., Ltd.
438A, Alexandra Road, #05-01/02
Alexandra Technopark,
Singapore 119967
Phone: (65) 271-3566
Fax: (65) 271-3855

KOREA

SHARP Electronic Components
(Korea) Corporation
RM 501 Geosung B/D, 541
Dohwa-dong, Mapo-ku
Seoul 121-701, Korea
Phone: (82) 2-711-5813 ~ 8
Fax: (82) 2-711-5819

CHINA

SHARP Microelectronics of China
(Shanghai) Co., Ltd.
28 Xin Jin Qiao Road King Tower 16F
Pudong Shanghai, 201206 P.R. China
Phone: (86) 21-5854-7710/21-5834-6056
Fax: (86) 21-5854-4340/21-5834-6057
Head Office:
No. 360, Bashen Road,
Xin Development Bldg. 22
Waigaoqiao Free Trade Zone Shanghai
200131 P.R. China
Email: smc@china.global.sharp.co.jp

HONG KONG

SHARP-ROXY (Hong Kong) Ltd.
3rd Business Division,
17/F, Admiralty Centre, Tower 1
18 Harcourt Road, Hong Kong
Phone: (852) 28229311
Fax: (852) 28660779
www.sharp.com.hk
Shenzhen Representative Office:
Room 13B1, Tower C,
Electronics Science & Technology Building
Shen Nan Zhong Road
Shenzhen, P.R. China
Phone: (86) 755-3273731
Fax: (86) 755-3273735