DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DESIGN AND IMPLEMENTATION OF AN INTERACTIVE FLAT PANEL DISPLAY

by
Yunus YÜCEL

July, 2015
İZMİR

DESIGN AND IMPLEMENTATION OF AN INTERACTIVE FLAT PANEL DISPLAY

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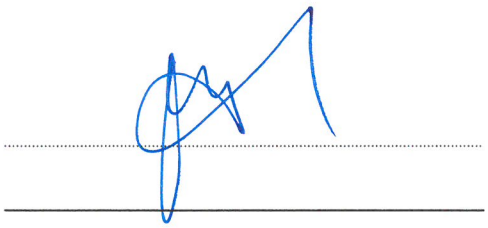
M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"DESIGN AND IMPLEMENTATION OF AN INTERACTIVE FLAT PANEL DISPLAY"** completed by **YUNUS YÜCEL** under supervision of **Asst. Prof. Dr. ÖZGÜR TAMER** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.



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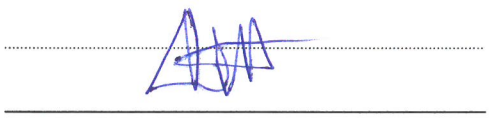

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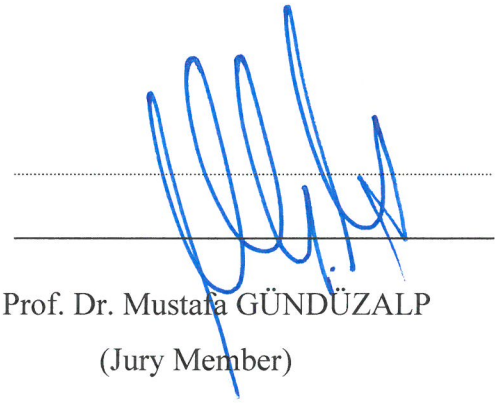

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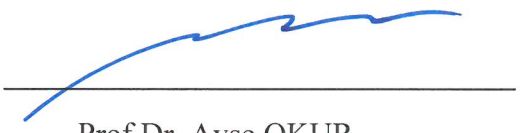

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I dedicate this thesis to my daughter “VERA”.

Yunus YÜCEL

DESIGN AND IMPLEMENTATION OF AN INTERACTIVE FLAT PANEL DISPLAY

ABSTRACT

The thesis will describe full system design of an interactive flat panel display and approval phases in detail. Thesis will explain all the blocks of the interactive flat panel display such as power board, OPS (PC) board and monitor board in detail. Each design steps are explained in the thesis such as schematic design, PCB design (layout), system design and EMC and Safety approvals. EMC (Electromagnetic Compatibility) and Safety concepts and test procedures related with the interactive flat panel display will be mentioned before the mainboard EMC and Safety tests are mentioned. Thesis includes a brief explanation of flat panel display technology and Intel OPS standard as well.

Keywords: Mainboard design, interactive flat panel display, digital signage, OPS, electromagnetic compatibility

ETKİLEŞİMLİ EKRAN TASARIMI VE UYGULAMALARI

ÖZ

Tez, yüksek çözünürlüklü düz panel ekranlı etkileşimli ekranlar, bilgilendirme ekranları veya dijital reklam panoları tasarımını detaylı bir şekilde anlatmaktadır. Öncelikle sistem tasarım aşaması, sonrasında ise anakart tasarımının aşamaları (devre şeması çizimi, baskı devre tasarımı) ve anakart tasarım blokları detaylı bir şekilde anlatılmıştır. Anakart tasarımından sonra bu anakartın sistem entegrasyonu ve bu sistemin tüm test aşamalarından bahsedilmiştir. Tezde ayrıca, bir pazar standardı olan OPS (Open Pluggable Specification) standardından bahsedilmiştir. Avrupa standartlarına göre elektromanyetik uyumluluk testleri ve ürün güvenliği testleri yapılmış ve bu testlerden bahsedilmiştir. Tezde, düz panel teknolojisine de kısaca yer verilmiştir.

Anahtar kelimeler: Anakart tasarımı, etkileşimli ekranlar, dijital bilgilendirme ekranları, OPS, elektromanyetik uyumluluk

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CHAPTER ONE
INTRODUCTION

Nowadays, interactive display technology and digital signage technology is a growing market. People are used to use regular billboards to advertise their goods, movies or meals etc. But now, regular billboards are as not prestigious as interactive displays or digital signage.

There are lots of usage area for these types of information displays and digital signage products. They are used at restaurants, shopping malls, stadiums, airports etc. These types of flat panel displays are very good for system integrators since they can be controlled remotely via RS-232 or via Ethernet. Anyone can control power, volume, brightness and even the advertisement content etc. of these products remotely and can get some feedbacks and alarms.

System designers and also advertisers use digital information displays to advertise their customers' goods. For example; we can design a digital signage including a printer and NFC. We can advertise a movie on this digital signage. Anyone can watch the trailer of the movie and take tickets from printer to go this movie by paying the movie tickets with mobile phone NFC feature. This is just an example of usage scenario.

Formerly, projector displays were used for the purposes that mentioned above. But lamps of the projector displays life cycle are around 2000 hours. But the life cycle of TFT-LCD displays is around 35000 hours. Also, there is one another disadvantage of projector displays that some of them have shadowing problems at especially educational systems. On educational systems, there is a touch screen in front of the screen and it provides writing with an opaque object such as a stylus pen or finger. When someone wants to write something on that screen, he/she cuts the reflection of the projector display. In Figure 1.1, shadowing effect can be seen. One another disadvantage of the projector displays is contrast ratio. If someone uses the projector display, he/she needs a dark room in order to provide a better display to the audience.

Figure 1.1 Shadowing effect on projector displays

TFT-LCD (Thin Film Transistor - Liquid Crystal Display) panel displays are used for interactive displays because of the projector's life cycle and shadowing problems. TFT-LCD technology is a growing technology. There are pixels in the TFT-LCD panels. Each pixel is divided in three sub-pixels which are used to give red, green and blue (RGB) colors. But Sharp divides each pixel in four sub-pixels to give red, green, blue and yellow (RGBY) colors and named this technology as Quattron (Figure 1.2).

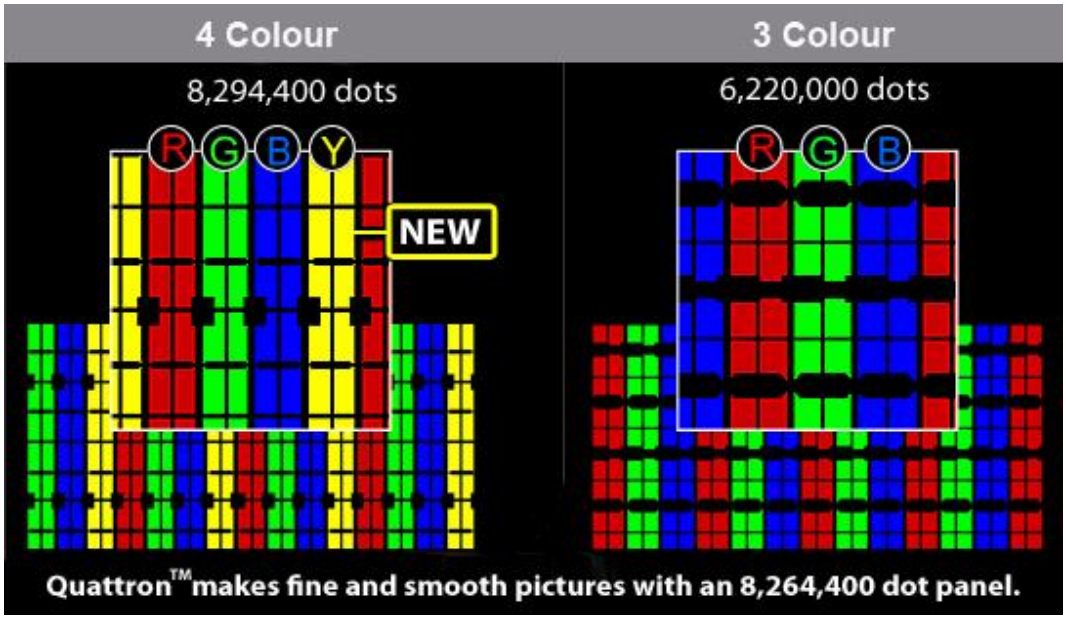


Figure 1.2 Sharp's Quattron technology

A mainboard is needed to drive the TFT-LCD panel. The interface is LVDS (Low Voltage Differential Signaling) between the TFT-LCD panel display and the mainboard. The LVDS has proven speed, low power, noise control, and cost advantages are popular in point-to-point applications for telecommunications, data communications, and displays.

Intel OPS (Open Pluggable Specification) standard is one of the main focuses for this thesis as well. Since digital signage market is growing, the market is looking for a system that can be managed easily and the product maintenance must be very good. Because these type of products have to work 7/24. Intel OPS standard has a good serviceability and maintainability. Because of these reasons, OPS is the top trend in the market.

The other main topic and challenge for these types of mainboards is approvals. EMC (Electromagnetic Compatibility) and Safety approvals must be taken for these mainboards. At these tests, mainboards are tested according to the IEC EN-60950 and IEC EN-55022.

In this thesis, the aim is to explain the system architecture techniques and details of mainboard design for interactive displays. Thesis' focus is designing an interactive system with all approvals and quality criteria.

CHAPTER TWO
TFT-LCD PANEL DISPLAYS

2.1 A Brief Information about TFT-LCDs

Liquid crystal was discovered by Austrian botanist Fredreich Rheinizer in 1888. In mid 1960s, scientists discovered that applying an external electric charge could change the properties of liquid crystals, i.e., the luminance of light passing through them, and demonstrated the first liquid-crystal display.

TFT-LCD stands for Thin Film Transistor Liquid Crystal Display. TFT LCD is a variant of a liquid-crystal display (LCD) that uses thin-film transistor (TFT) technology to improve image qualities such as addressability and contrast. A TFT LCD is an active-matrix LCD, in contrast to passive-matrix LCDs or simple, direct-driven LCDs with a few segments.

Liquid crystal is the material used as a valve for adjusting the light level for each pixel on the display. TFT is the control circuitry of this liquid crystal material. Depending to the voltage level on each transistor, the liquid crystals control the light level at each sub-pixel. TFT-LCD display is the common name used for display devices using the liquid crystal technology. A thin-film transistor liquid-crystal display (TFT-LCD) is a variant of LCD that offers improved image quality.

TFT LCDs are used in appliances including television sets, computer monitors, mobile phones, handheld video game systems, personal digital assistants, navigation systems and projectors.

2.1.1 TFT LCD Structure

TFT-LCDs have a sandwich-like structure with liquid crystal filled between two transparent glass electrode plates coated with indium tin oxide (ITO) as shown in Figure 2.1 (Figueiredo, 2010).

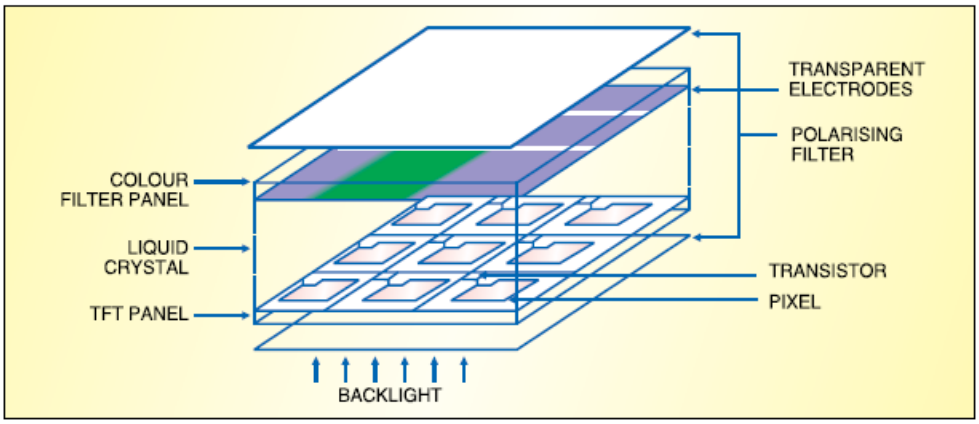


Figure 2.1 TFT LCD structure (Figueiredo, 2010)

Figure 2.2 shows a color TFT-LCD module. It consists of a TFT-LCD panel, a backlight unit and a driving unit (source driver and gate driver). The TFT-LCD panel has TFTs, liquid crystal, pixel electrodes, storage capacitors and color filter. The color filter has a color resin film containing three primary color pigments (red, green and blue) (Figueiredo, 2010).

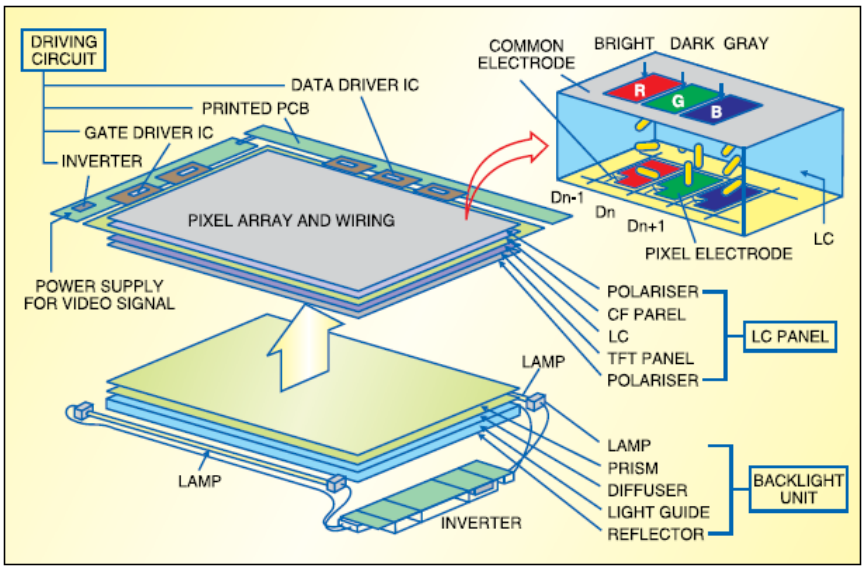


Figure 2.2 Structure of TFT LCD module (Figueiredo, 2010)

As shown in Figure 2.3, the backlight unit consists of a CCFL lamp with inverter, a light guide panel, a diffuser, and bottom and top prisms. The light guide panel guides the light from the lamp. The diffuser uniformly diffuses the light received from the light guide. The prism concentrates the light and increases the luminance of light up to 1.55 times of the light guide (Figueiredo, 2010).

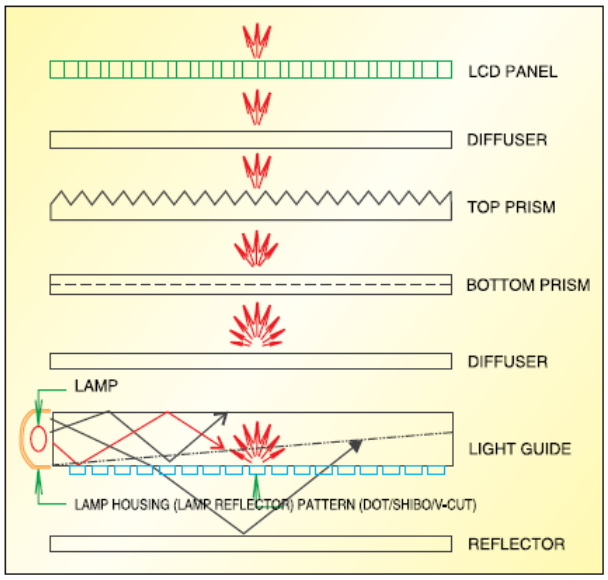


Figure 2.3 Backlight structure (Figueiredo, 2010)

2.1.2 Working Principle of TFT LCDs

Liquid-crystal molecules are arranged randomly when there is no electric field between ITO electrodes and light is allowed to pass through with molecules twisted by 90º, changing the polarization of light from vertical to horizontal. When an electric field is applied between ITO electrodes, liquid crystal molecules get aligned by removing the 90º twist and light is blocked. When a smaller voltage is applied, the twist is less than 90º and lower intensity light is passed. Thus the applied electric field determines the luminance of light passing through the liquid crystal and various grayscales can be obtained. Figure 2.4 and Figure 2.5 shows the operation of LCDs and liquid crystal molecular alignment (Figueiredo, 2010).

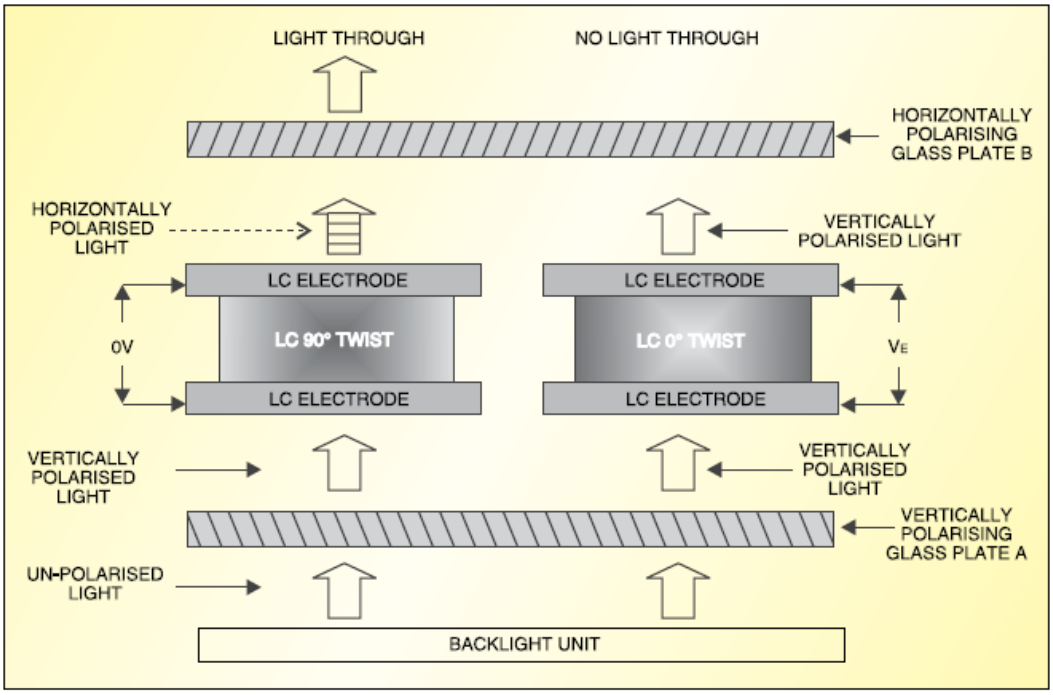


Figure 2.4 Operation of LCD (Figueiredo, 2010)

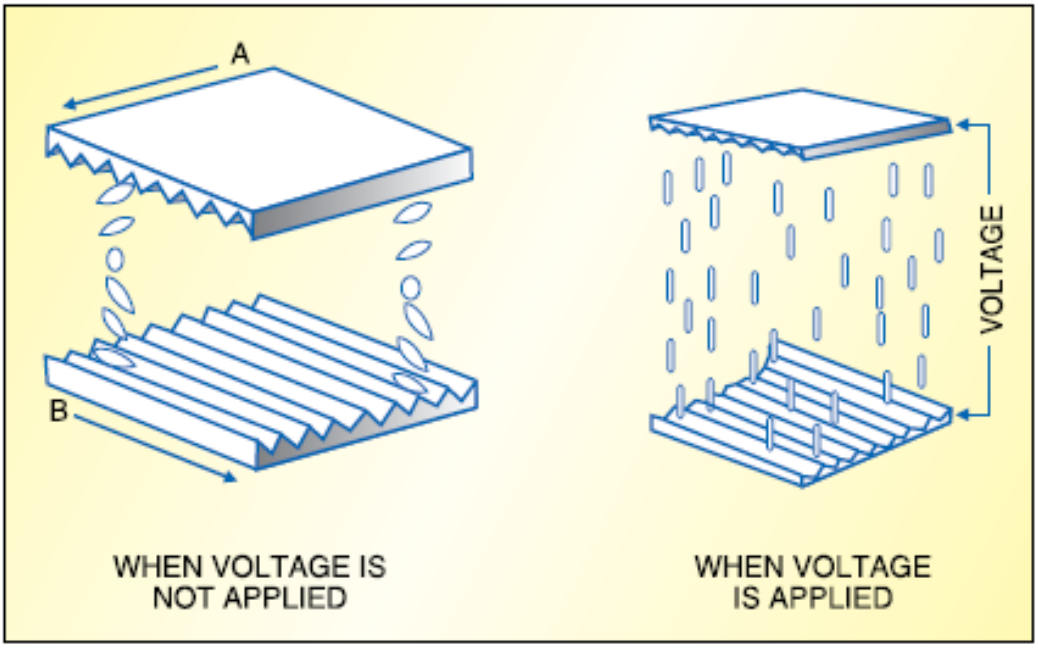


Figure 2.5 Liquid crystals molecular alignment (Figueiredo, 2010)

2.1.3 Types of TFT LCDs

There are two types of TFT-LCDs: passive-matrix and active-matrix.

A passive-matrix LCD uses one transistor for each row and each column. Each transistor is switched on in sequence and the column transistors are turned on/off according to the image to be displayed. When a transistor is turned off, the respective element or pixel loses its charge and blocks the passage of light. Because of this scanning and the slow response (response time greater than 150ms), passive displays are not very bright and have low contrast ratio. The addressing technique causes crosstalk, which results in blurred images as non-selected pixels are driven through secondary voltage.

An active-matrix LCD uses a separate transistor for each unit pixel. This allows the pixels to stay 'on' longer and thus produce a brighter image. Therefore active-matrix LCDs are used in computer monitors, laptops, TVs, mobile screens, etc. (Figueiredo, 2010).

2.1.4 Driving Methods for TFT-LCDs

There are two ways to produce images on a liquid-crystal display: segment driving and matrix driving.

The segment-driving method is mostly used for simple displays, such as segment-type LCDs that are directly connected to the drivers.

The matrix-driving method is used for high-resolution displays. In this method, displays can be either statically driven or dynamically driven. In the static, or direct, driving method, each pixel is individually wired to the driver. But, as the number of pixels increases, wiring becomes complex. In the dynamic driving method, a voltage is applied at the intersections of specific horizontal scanning electrodes and specific vertical signal electrodes in time-division multiplexing mode using pulse drive (Figueiredo, 2010).

2.1.5 TFT-LCD Panel Controlling and Driving Method

The TFT-LCD controller/driver unit consists of a TFT-LCD timing controller with low-voltage differential signaling (LVDS) receiver, reduced-swing differential signaling (RSDS) transmitter, oscillator, gray-scale reference voltage generator, gate driver, and source or column driver as shown in Figure 2.6.

For large panel size, high resolution and high gray-scale, high-speed data transmission is required between the TFT-LCD timing controller and the source driver. To achieve high-speed data transmission, low-voltage techniques such as mini-LVDS and RSDS having differential voltage of 350mV across the 100-ohm termination resistor at clock frequency of 85 MHz to 170 MHz are used.

The LVDS receiver transfers data serially bit-by-bit over a single pair of wires. This allows fast data transfer with less power consumption. The LVDS receiver receives 24-bit video RGB data and control signal through eight pairs of LVDS channels and two pairs of LVDS clocks. The timing controller generates various control signals to drive the gate driver and the source driver in order to produce images on the screen.

As mentioned earlier, in a TFT-LCD panel, scanning is done line-by-line from top to bottom and each pixel is addressed by selecting the gate line and applying the data signal to TFT-LCD cells through the source driver. The controller generates control signals to address each pixel individually in sync with the gate driver and source driver and, at the same time, the RGB video signal is passed through the source driver to TFT-LCD cells. The gray-scale reference generator generates reference voltages to convert the digital RGB signal into analogue RGB signal using either a voltage divider or DC-DC converter. The gate driver selects the TFTs by applying a positive pulse to the gate of TFTs in a specific row and thus allows line-by-line scanning from top to bottom.

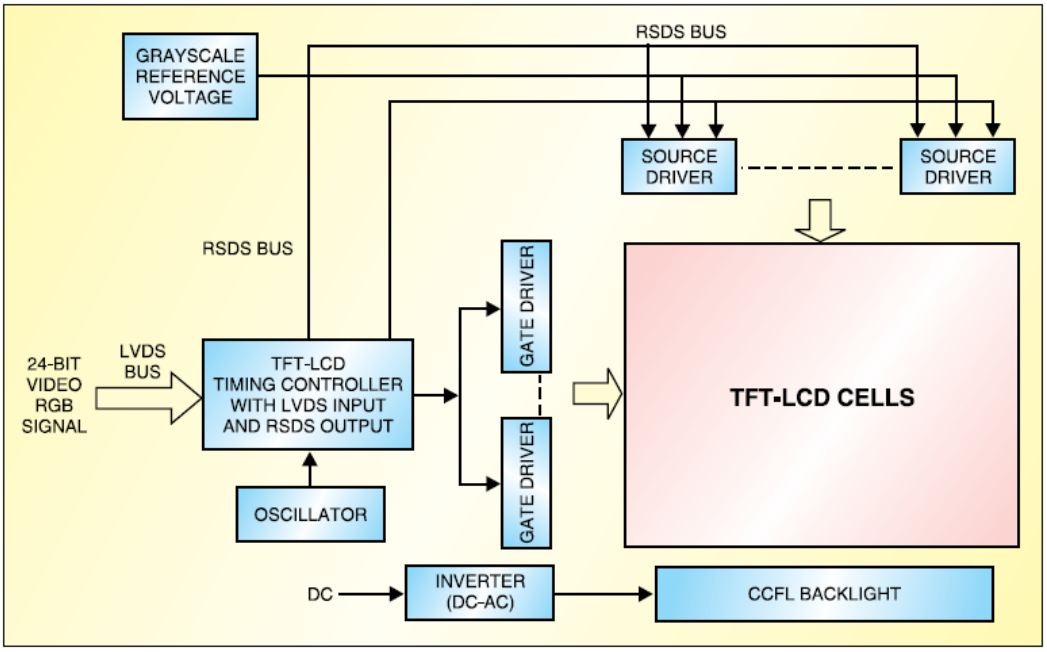


Figure 2.6 Block diagram of TFT-LCD panel T-CON board (Figueiredo, 2010)

The source driver consists of a shift register, data latch, level shifter, digital-to-analogue converter (DAC) and output buffer.

Digital data is loaded and stored in data latches until conversion takes place. Because each output has an independent DAC, data conversion is required only once per line. The DAC converts the digital gray-scale value into an equivalent analogue voltage with very fast conversion rate and this analogue voltage is fed to TFT-LCD cells through the output buffer.

The DAC also allows gamma correction. In a TFT-LCD, TFTs are used to control on/off state of the displayed pixel. But this on/off function is insufficient to display images correctly. Gamma correction is essential because the image is either breached out or too dark. It controls the overall brightness of images displayed on the screen (Figueiredo, 2010).

2.1.6 Gray-scale and Color Generation

The luminance of light depends on the voltage applied between the two transparent electrodes of a liquid crystal. Gray levels are an intermediate level of brightness between the brightest of bright and the darkest of dark that a unit pixel can generate by varying the voltage between the electrodes. This gray-scale voltage can be generated either in analogue or digital form. Gray-scale voltage in analogue form, i.e., continuous range, is generated using a voltage divider. The DC-DC converter can also be used to obtain in-between voltages for gray-scale generation.

In the digital method, grayscale voltage is defined in 8-bit, 10-bit and 12-bit forms. Hence the number of gray levels is determined by the number of bits used to represent the gray-scale voltage. For example, if eight bits are used to represent gray-scale voltage, the number of possible gray levels will be 2^8 (= 256). The color filter of a TFT-LCD consists of three primary colors: red, green and blue. In a color TFT-LCD, each pixel is a combination of three sub-pixels having red (R), green (G) and blue (B) colors. Because the sub-pixels are too small to distinguish them independently, practically any color produced is a mixture of these primary colors. The video signal is composed of R, G and B color signals and 'n' bits are used to represent each color. The number of colors produced is determined by the combinations of R, G and B that are possible with the number of gray-scale levels: If an LCD displays images with 8-bit gray-scale, it will display 2^8 (=256) shades for red, green and blue color each. Thus the total number of different colors, known as True Color, is $2^8 \times 2^8 \times 2^8$ (=16.78 million).

If you compare 8- and 10-bit grayscale displays, you'll find that 10-bit gray-scale images are softer and more natural than 8-bit gray-scale images. This is because 10-bit gray-scale gives 2^{10} (=1024) shades for each primary color and the total number of colors (natural colors) is $2^{10} \times 2^{10} \times 2^{10}$ (=1.07 billion). A 12-bit gray-scale has also been tried. It gives much more realistic picture (Figueiredo, 2010).

2.2 Backlight Technology of TFT-LCD Panels

There are two backlight technologies that are commonly used all over the world.

- CCFL (Cold Cathode Florescent Lamp) Backlight Technology
- LED Backlight Technology

2.2.1 CCFL Backlight Technology

CCFL's are an older technology, and for the moment are the most widely used backlights in laptops LCDs. They consist of a fluorescent tube connected to a voltage inverter board which provides power to the backlight. Sometimes the backlight contains 2 tubes along with 2 pairs of inverters; these are called "Dual Backlights" or 2-CCFL. CCFL backlight unit can be seen in Figure 2.7 below.

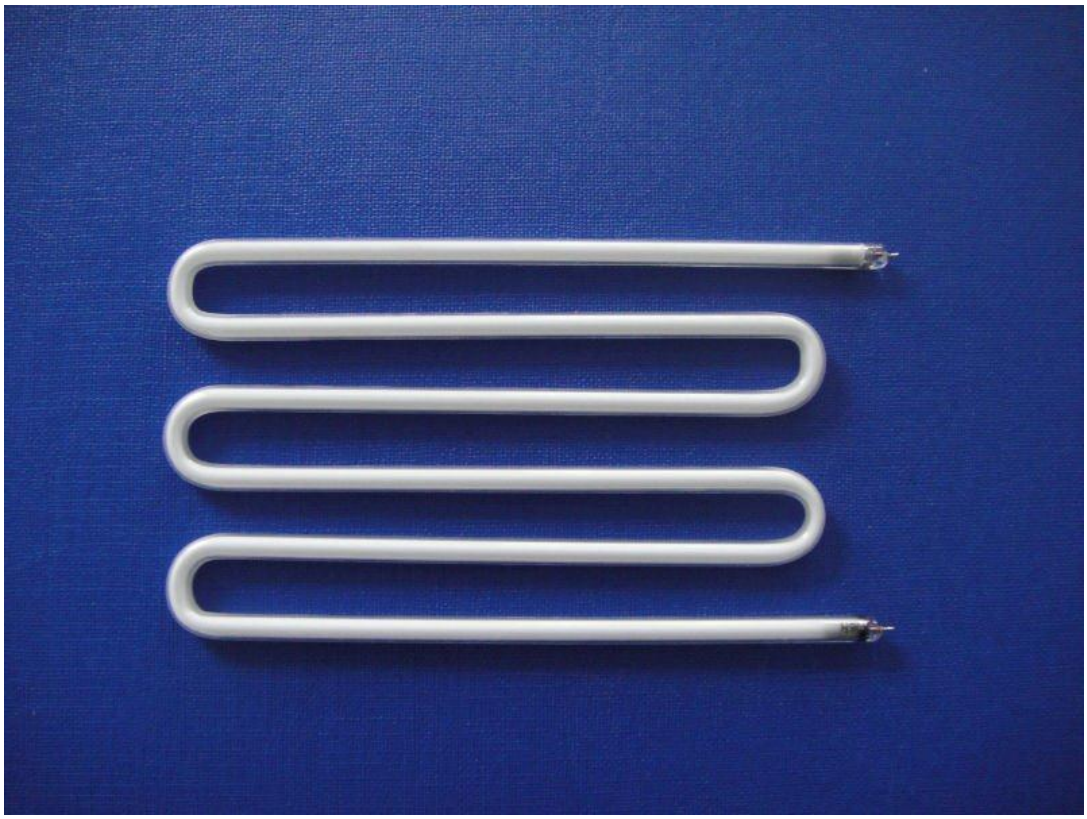


Figure 2.7 Cold cathode florescent lamp

2.2.2 LED Backlight Technology

LED backlight technology is a newer technology than CCFL. There are two designs for LED backlight technology.

- Edge LED Backlight
- Direct LED Backlight

There are some advantages and disadvantages if we compare these two types. For example TFT-LCD panels that are using direct LED backlight are thicker than the panels that are using edge LED backlight (Figure 2.8). But contrast ratios of direct LED backlight panels are better than edge LED backlight panels. This contrast difference can be seen in Figure 2.9.

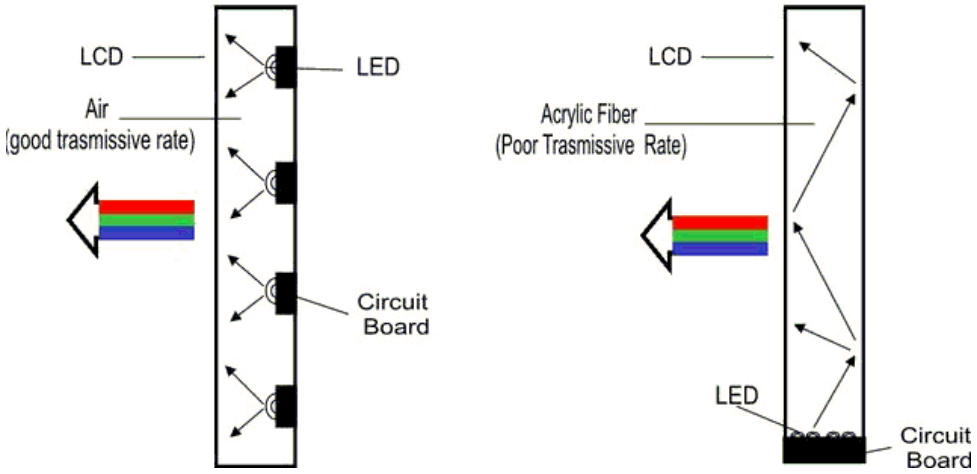


Figure 2.8 Direct LED BLU (backlight unit) and edge LED BLU

Figure 2.9 Comparison of the direct LED BLU and edge LED BLU displays

2.2.3 Comparison of CCFL and LED Backlight Technologies

There is a comparison table between CCFL and LED backlight technologies below in Table 2.1.

Table 2.1 Comparison between CCFL and LED backlight technologies

	CCFL	**LED**
Size	Thicker and heavier	Thinner and lighter
Cost	Cheaper and more cost effective	Affordable cost
Power	Higher power consumption and heat generation	Lower power consumption and heat generation
Brightness	Lower brightness	Generally higher brightness
Finish	Available in Matte or Glossy	Available in Matte or Glossy
Lifespan	Shorter lifespan	Longer lifespan

CHAPTER THREE
SYSTEM DESIGN

The system has several boards including power board, monitor board, touch controlled control board and OPS board. The system has also a TFT LCD panel with LED backlight technology. The main reason behind choosing a LED backlight LCD panel is that they have a long life time (about 35000 hours working time). Also they have a good video quality (1.07 billion color depth).

In this chapter, each board will be explained in detail. The block diagram of the system can be seen below as well.

3.1 Monitor Board Design

3.1.1 Schematics Design

In this chapter, the design techniques and details of monitor board design for interactive displays will be explained.

The monitor board is called 14MON02. This monitor board is designed to drive the TFT-LCD panel and to control all other peripherals such as touch screen, key buttons, LED IR remote controller receiver, speakers and side I/O board. The specification of the monitor board is as listed below;

- FHD panel driving capability
- Control buttons
- VGA input
- HDMI input
- USB B Type (to connect touch screen to external sources)
- Line in
- Line out
- Remote controller support
- 30W audio output support
- OPS 80 Pin Connector Interface (to connect OPS MBs)

- RS232 for remote management (optional)

Firstly, the designer should freeze the specification of the board. Then, a block diagram should be drawn in order to clarify all blocks of the schematics and design.

Figure 3.2 Monitor board top view

Figure 3.3 Monitor board bottom view

3.1.1.1 Scalar Block

Realtek Semiconductor RTD2482D has been selected as main IC in this project. This IC is called display scalar IC as well. RTD2482D has an embedded microcontroller unit inside. So, we do not need any other microcontroller to control other parts of the mainboard. The features of RTD2482D are briefly explained below.

- RGB input
- YPbPr input
- HDMI input
- DVI input
- Embedded MCU
- Embedded Audio DAC
- 1920x1200 and 1920x1080 resolution support

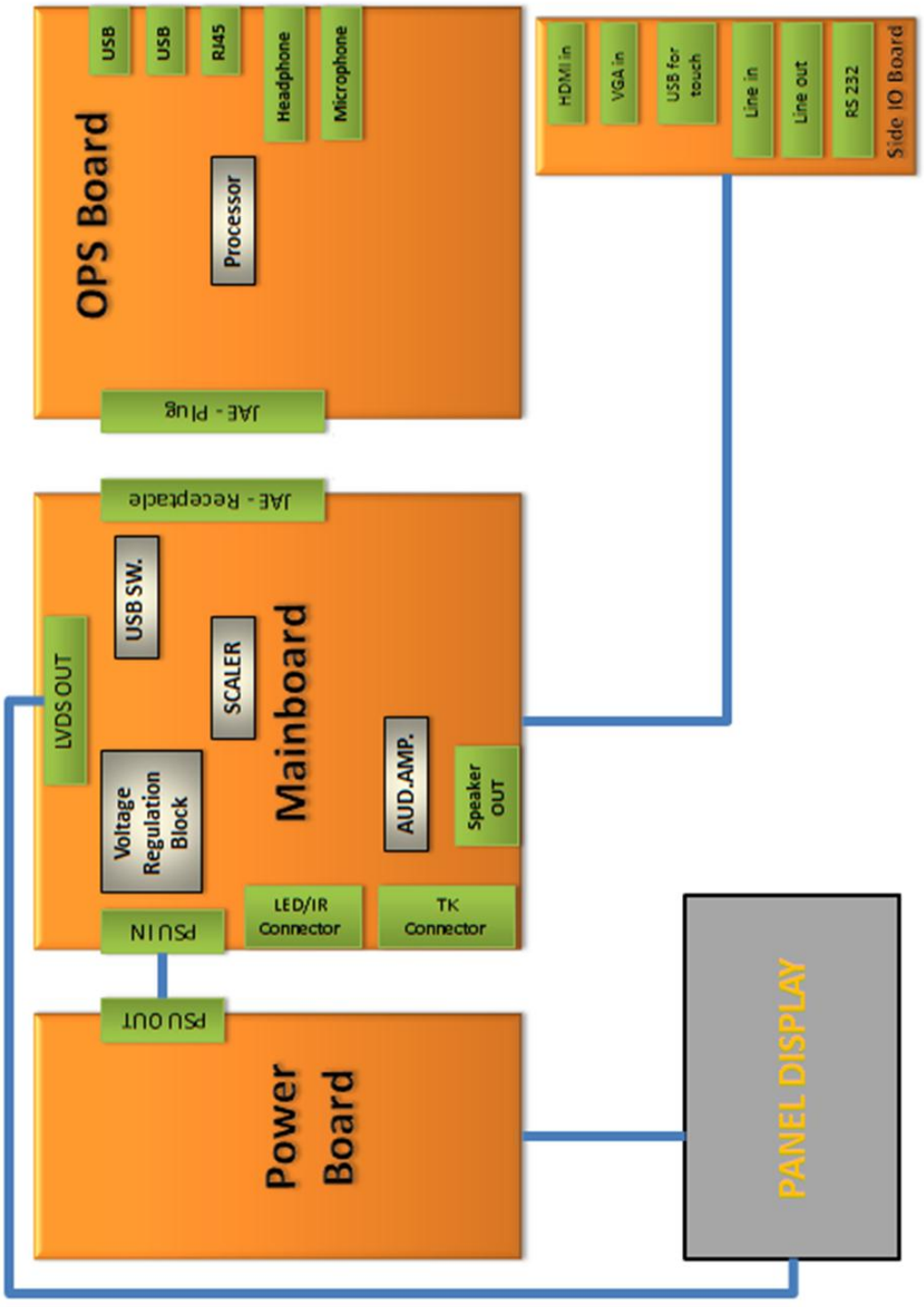


Figure 3.1 Block diagram of IFPD

3.1.1.1.1 Features of RTD2482D. The Realtek RTD2482D is an advanced all-in-one LCD monitor controller with analog (RGB), YPbPr, HDMI, DVI, and DisplayPort 2A+2H inputs. It includes a Microcontroller Unit (MCU), an audio DAC, an advanced 6-axis color engine by VividColor, and an infrared controller, providing a powerful and integrated cost-effective platform supporting up to 1920x1200/1920x1080 (1080p Full HD) resolution. The internal block diagram of RTD2482D can be seen in Figure 3.4 below.

The full-featured RTD2482D is a Frame-Buffer-Less solution offering a low-cost system design by reducing the number of system components, and by deploying on a 2-layer PCB.

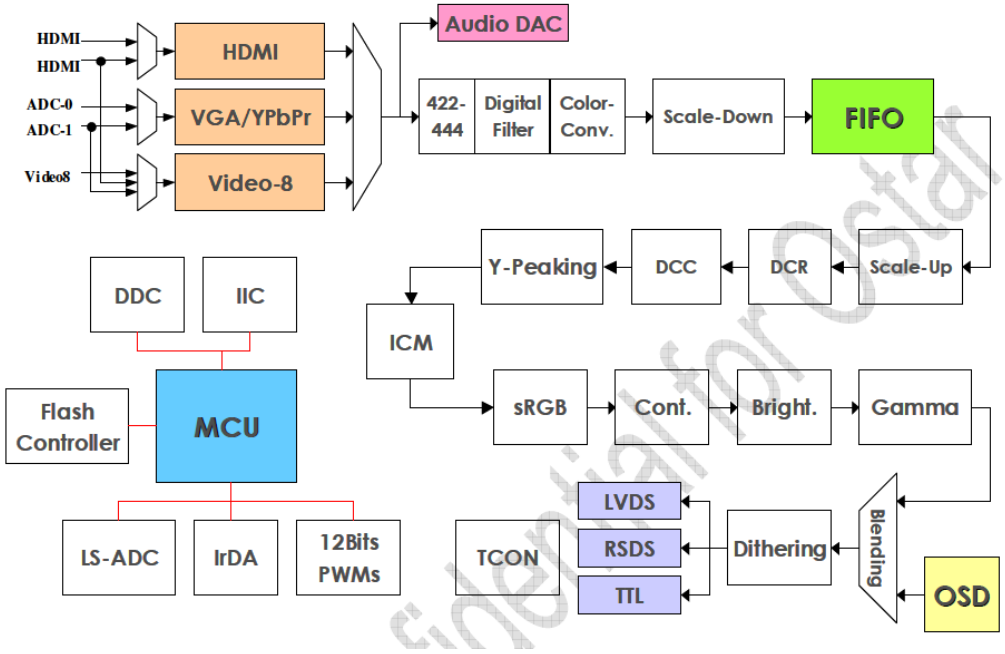


Figure 3.4 Chip data path block diagram of RTD2482D

3.1.1.2 Power Block

2 voltage regulators and 2 low dropout linear regulators has been used for power block. Texas Instruments TPS54229 is used as voltage regulator and LM1117 is used

as LDO. There are three voltages that are supplied by power board. These are 24V for audio and backlight, 12V and 13V for standby.

3.1.1.2.1 TPS54229 Synchronous Buck Converter. The TPS54229 is an adaptive on-time synchronous buck converter. The TPS54229 also has a proprietary circuit that enables the device to adapt to both low ESR output capacitors, such as POSCAP or SP-CAP, and ultra-low ESR ceramic capacitors. The device operates from 4.5V to 18V input. The output voltage can be programmed between 0.76V and 7V. At this project, it is used to convert 12V to 5V and also 3.3V.

3.1.1.2.2 LM1117 Low Dropout Regulator. The LM1117 is a series of low dropout voltage regulators with a dropout of 1.2V at 800mA of load current. The designer can adjust the output, or some versions of LM1117 have fixed output. For this LDO, minimum 10uF tantalum capacitor is required at the output to improve the transient response and stability.

At this project, LM1117 is used for 3.3V to 1.2V conversion and also 5V to 3.3V conversion.

3.1.1.3 Audio Block

Texas Instruments TPA3118D2 is used for this project. TPA3118D2 is a class-D audio amplifier. The high efficiency of the TPA3118D2 allows designer to use 2x15W output without external heat sink on a single layer PCB.

The advanced oscillator/PLL circuit inside TPA3118D2 employs a multiple switching frequency option to avoid AM interferences. This is achieved together with an option of Master/Slave option, making it possible to synchronize multiple devices.

The TPA3118D2 is fully protected against faults with short circuit protection and thermal protection as well as over voltage, under voltage and DC protection. Faults are reported back to the processor to prevent devices from being damaged during overload conditions.

At this project 8 ohm 15W speakers are used as load. Also the gain is set to 26dB. The input of the TPA3118D2 is 24V. Also, as performance quality criteria, maximum %10 total harmonic distortion is allowed.

3.1.1.4 USB Switch

Texas Instruments TS3USB221 is used for this project. The TS3USB221E is a high-bandwidth switch specially designed for the switching of high-speed USB 2.0 signals in handset and consumer applications, such as cell phones, digital cameras, and notebooks with hubs or controllers with limited USB I/Os. The wide bandwidth (1 GHz) of this switch allows signals to pass with minimum edge and phase distortion. The device multiplexes differential outputs from a USB host device to one of two corresponding outputs. The switch is bidirectional and offers little or no attenuation of the high-speed signals at the outputs. It is designed for low bit-to-bit skew and high channel-to-channel noise isolation, and is compatible with various standards, such as high-speed USB 2.0 (480 Mbps).

The TS3USB221E integrates ESD protection cells on all pins, is available in a SON package (3 mm × 3 mm) as well as in a tiny mQFN package (2 mm × 1.5 mm) and is characterized over the free air temperature range from –40°C to 85°C.

The aim of using the USB switch IC is that the 14MON02 allows that user can use the product as All-in-One PC or just a monitor with touch screen feature since the product is interactive. When user use the product as AIO PC, then USB switch is switching the touch screen USB signals to the OPS PC. When user use the product as a touch monitor, then USB switch is switching the touch screen USB signals to the external PC. SON (small-outline no lead) package is used.

3.1.2 Layout Design

For layout design, 2-layer PCB structure has been chosen because of the cost varieties. But for 2-layer PCB, it is hard to pass EMC tests easily. Because of the EMC issues, the designer should check every high speed signals.

Even though the designer should check high speed signals, the designer should also check the voltage nets that related net can carry required current or not. The designer should also check the impedance matching and length matching of the nets. Crosstalk, signal reflections and signal stubs are other issues. The designer has to prevent these issues. There are some examples about layout review below.

1) As shown in Figure 3.5 below, GND plane connected to the GND with only one via. Make the L19 pad connections thinner and make the GND thicker. Then add some more vias.

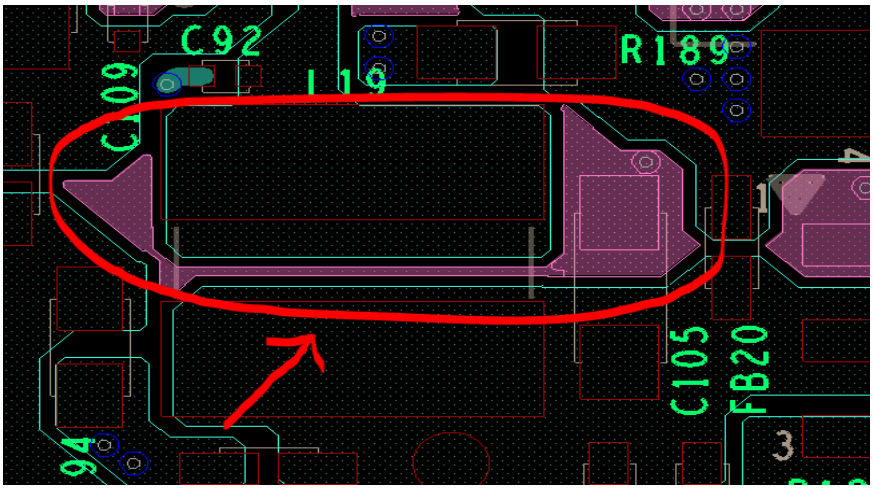


Figure 3.5 GND is very thin and there is only one via

2) As shown in Figure 3.6 below, the GND plane in the circle is connected to the GND in a far place with via. Delete via and connect it to the GND as seen below the circle.

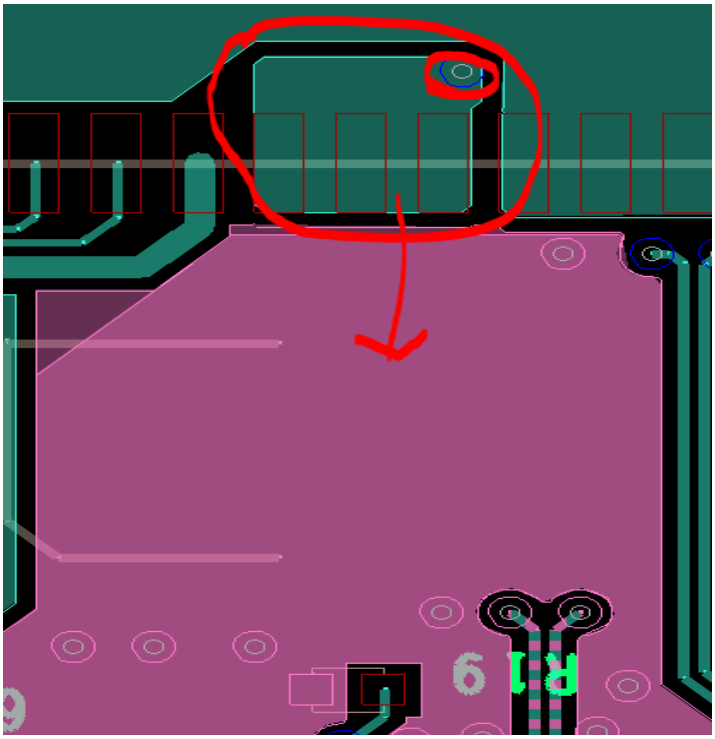


Figure 3.6 Wrong GND connection

3) Add some vias to the plane shown below in Figure 3.7. Because this plane may act as an antenna.

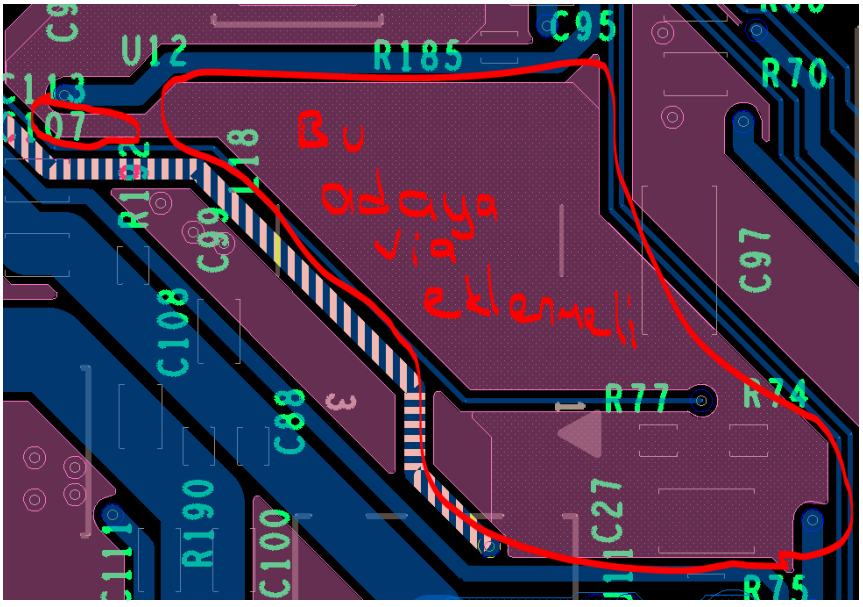


Figure 3.7 Blank plane may act as an antenna

4) Connect these two GND plane shown in Figure 3.8.

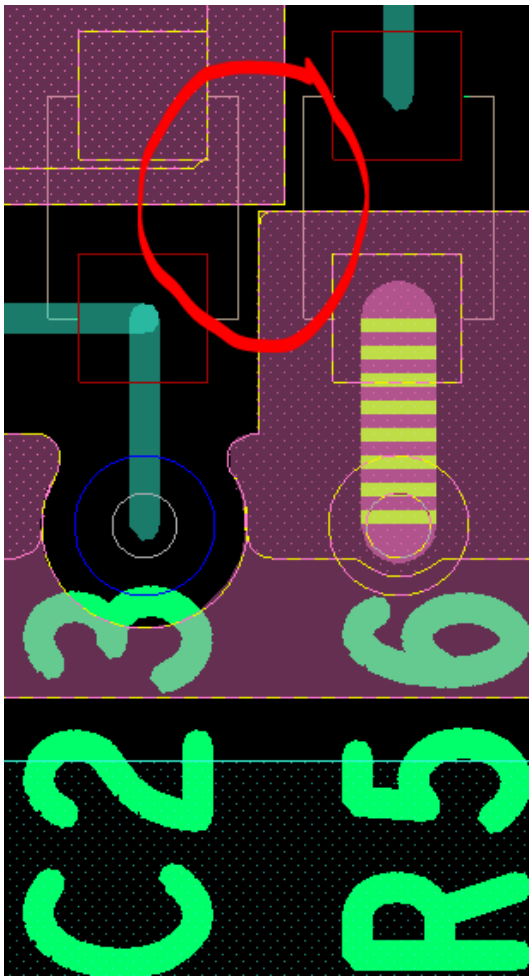


Figure 3.8 Mis-connection of two same planes

The top view and the bottom view of layout design of the monitor board can be seen in Figure 3.9 and Figure 3.10 respectively below.

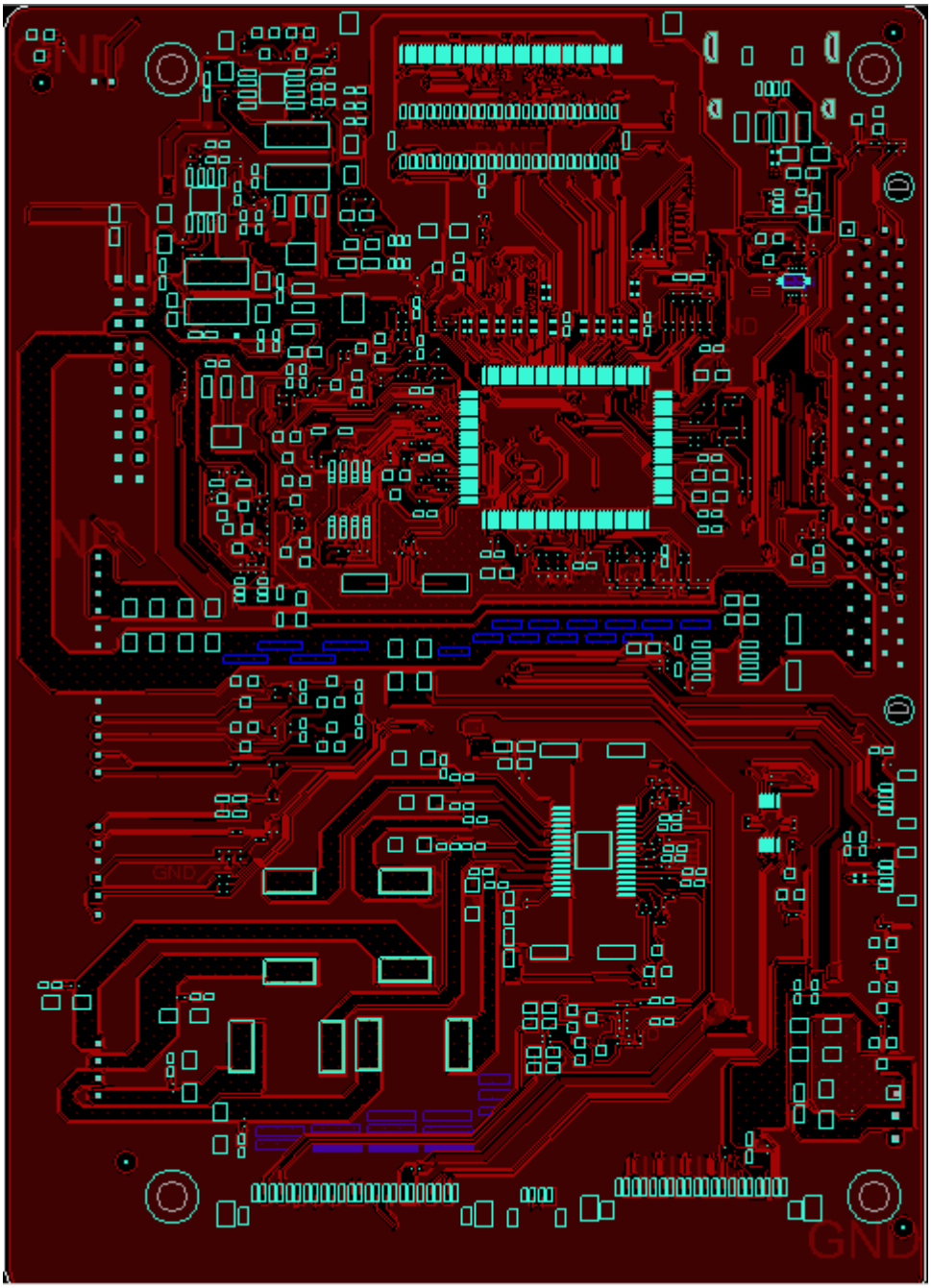


Figure 3.9 PCB top layer

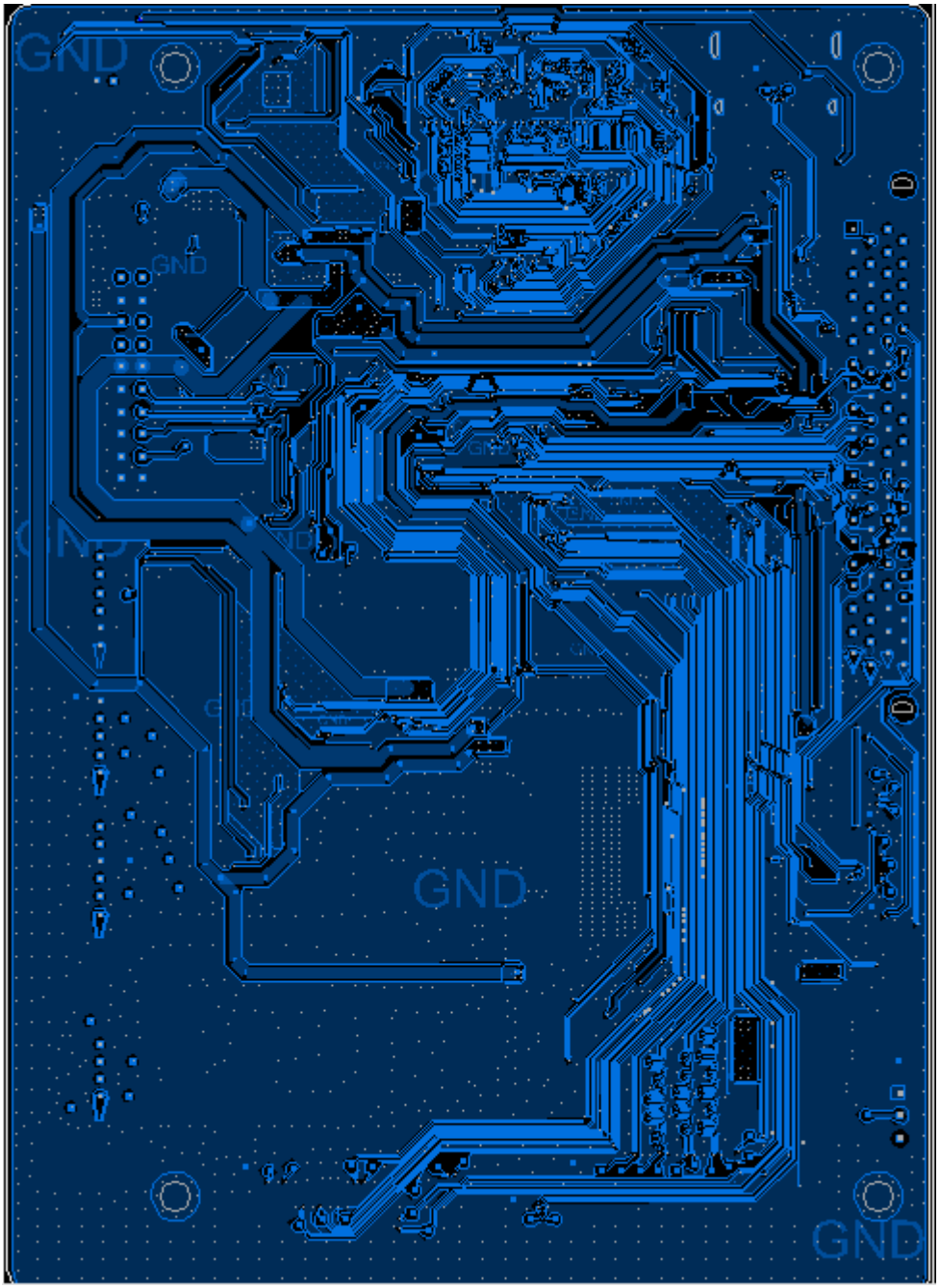


Figure 3.10 PCB bottom layer

I would like to add some rules, which are explained by Dr. Eric Bogatin who is a physicist and has an excellent knowledge about signal integrity, about designing a PCB by caring the EMC.

1) Critical nets must not cross a split in the adjacent reference plane.
2) Critical nets must not change reference planes.
3) Critical nets may not be within a specified distance of the edge of their reference plane.
4) Critical nets may not be routed within a specified distance from an I/O net.
5) All critical nets must be buried between solid planes. The allowable length of the exposed portion of a critical net may be specified.
6) All critical nets must have a "ground-guard" trace on either side of the critical net.
7) All differential critical nets must have a "ground-guard" trace on either side of the differential pair of nets.
8) All differential critical nets must be routed within a specified distance of each other, and the length of the differential pair of nets must match within a specified amount.
9) All power and ground traces longer than a specified distance must be wider than another specified distance. This does not include grounded guard traces.
10) Decoupling capacitors must be placed between all adjacent plane pairs within a specified grid density.
11) A decoupling capacitor must be connected between the power and ground-reference planes and be placed within a specified distance from each IC power pin.
12) The trace connecting between the IC power and/or ground reference pin to the associated via to the power/ground-reference plane must be no longer than the specified distance.
13) The trace connecting between a decoupling capacitor to the associated via to the power/ground-reference plane must be no longer than the specified distance.

14) All power and ground-reference traces longer than a specified length must have a decoupling capacitor within a specified distance from the IC power pin.
15) All I/O filters must be placed within a specified distance from the I/O connector.
16) All oscillators must be placed within a specified distance from the clock driver (or other device) that they drive.

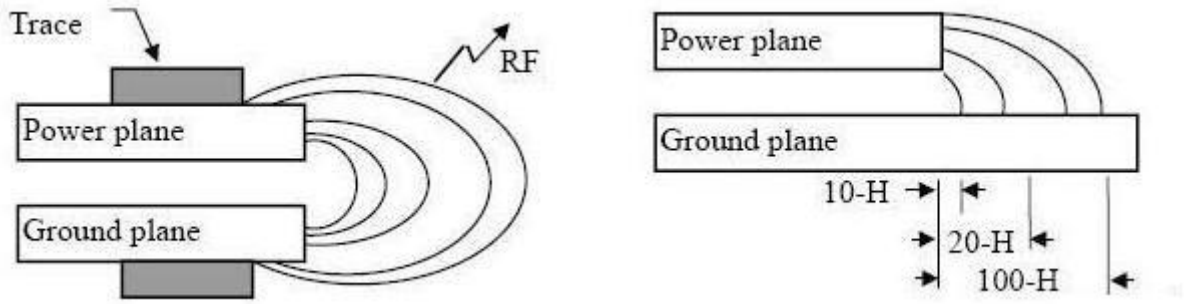
There is also another rule about PCB design called H-20H rule. This will be explained in next section.

3.1.2.1 20H Rule at PCB Design

The 20-H rule, first proposed by W. Michael King and described in the book by Mark I. Montrose, is a design guideline for laying out printed circuit boards with power and ground planes. The rule states that the edges of the power plane should be set back from the edges of the ground plane by a distance equal to 20 times the vertical spacing between the planes. The idea behind this rule is that fringing fields around the edge will be better contained. It has also been suggested that the radiation from this geometry will be lower compared to the radiation from a board where both planes are the same size.

Use of the 20-H rule increases the intrinsic self-resonant frequency of the PCB, because the physical dimensions of the power distribution network are altered. Since less capacitance will be present, there will be a higher self-resonant frequency of operation. Assume that the termination value is about ten times higher than the characteristic impedance of the transmission line. In this situation, however, the "termination" is a value that will not fully terminate the line. The position of the termination is such that a rather long "stub," as compared to the total transmission line length, is created at the end of the line. The fringing of the flux fields depends on the exact relationship and distribution path near the plane edges. The distribution of

the flux depends on the geometry of the component and its distance from the edge of the PCB.



(a) (b)

Figure 3.11 (a) Before applying 20H rule (b) After applying 20H rule

To avoid this fringing effect at the edges of the PCB, there must be some distance between the edges of GROUND and POWER planes of the PCB. If the gap between GROUND and POWER plane is H, then the distance between the edges of these two planes must be minimum 20H.

There is another way to avoid this fringing effect on the PCB edges. To avoid this effect, the designer may also add vias along the PCB edges.

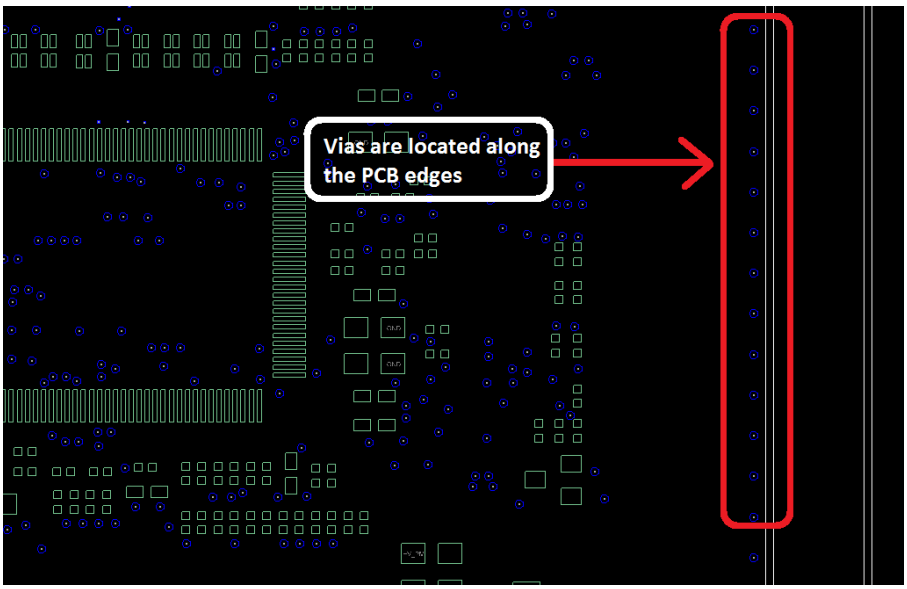


Figure 3.12 Added vias located at the PCB edges to prevent fringing effect

3.2 OPS (Open Pluggable Specification) Board and Interface

The Open Pluggable Specification (OPS) helps standardize the design and development of digital signage devices and pluggable media players. Intel created OPS to address digital signage market fragmentation and simplify device installation, usage, maintenance, and upgrades.

The OPS involves the integration concept of a Pluggable Module into the display panel thru a single and standard interfacing based on the 80 pin JAE plug and receptacle connectors as seen on the figures below. The power supply to the Pluggable Module together with the defined feature interfaces are being routed through this set of connectors to provide a functional system level computing solution for digital signage. Specification of the OPS PC is shown in Table 3.1 below.

Table 3.1 OPS PC specification

Feature	Item	Description
Processor	CPU	Intel Ivy Bridge 3rd Generation Mobile Processor Support (Core i3, Core i5, Core i7) (PGA Type)
Chipset	I/O	Intel 7-series (Panther Point) Chipset
Memory	Type	2 x 204 pin SO-DIMM socket, support up to DDR3 1600MHz with un-buffered and Non-ECC memory module up to 16GB per SO-DIMM
Super IO	SIO	1 x Super IO Chip
Graphics	Graphic Chip	Integrated GPU, Intel HD Graphics 4000 with 512MB memory support
OPS Signals	Interface	1 x TMDS signal to JAE TX25 80 pin connector 1 x DP signal to JAE TX25 80 pin connector 1 x LAN controller support 10/100/1000M DASH
Audio	HD Audio	Input: Mic in Output: Line out

Table 3.1 OPS PC specification (continue)

Feature	Item	Description
Storage	SATA	1 x 22 pin SATA right angle connector for slide in 2.5" SATA HDD/SDD 1 x Mini PCIe connector for mSATA (optional)
USB Signals		-USB 3.0 port 1~2 on the front panel -USB 2.0 port 3~4 on the front panel(inculding USB3.0) -USB 2.0 port 5~7 on the JAE TX25 pin plug connector -USB 2.0 port 8 on board pin-header -USB 2.0 port 9 on the mini-PCIe connector
Control Signals		1 x PWR_STATUS signal to JAE TX25 80 pin plug connector, This pin shall be open collector and pull up to 3.3V on docking board side. 1 x PS_ON# signal to JAE TX25 80 pin plug connector, OPS module shall not exceed 200ms for PS_ON# timing spec. 1 x PB_DET signal to JAE TX25 80 pin plug connector, High: No pluggable, LOW: Pluggable board present None CEC function 1 x SYS_Fan signal to JAE TX25 80 pin plug connector, High: system fan off, low: system fan on 1 x ATX_PWRON[1] signal to Pin41 of JAE TX25-80 connector 1 x WAKE#[1] signal to Pin42 of JAE TX25-80 connector [1] Signal names may change.

Table 3.1 OPS PC specification (continue)

Feature	Item	Description
Other Features		Standby power consumption must be less than 1W. Standby power consumption must be less than 1W. 1 x 3pin CPU fan connector, support smart fan function (CPU fan's noise will not exceed 30dB at max RPM) Wake On LAN and PXE boot support DASH support UART communication with OPS SIO for power modes (S3, S4, S5 etc.) OPS must be compliant with EMC (2004/108/EC) and low voltage (2006/95/EC) regulations according to EN 60950-1:2006, EN 55022:2006 + A1: 2007, EN 55024:1998+A1:2001+A2:2003, EN 61000-3-2:2006 and EN 61000-3-3:1995+A1:2001+A2:2005 or TS EN 60950-1: 2008, TS EN 55022: 2009 + A1: 2009, TS EN 55024: 1998 + IS1: 2008, TS EN 61000-3-2: 2010 and TS EN 61000-3-3: 2005 + A2: 2006
Expansion	mini-PCIe	1 x mini-PCIe full & half size slot, support Wireless LAN, and TV-Tuner
Watchdog Timer		Watchdog timeout can be programmable by Software from 1 second to 255 seconds and from 1 minute to 255 minutes
Power Input		+12V~ +19V ±%15 wide range DC Input from JAE TX25 80 pin plug connector The in-rush current spec for the OPS module shall not exceed 10A to ensure smooth power delivery form the display panel PSU

Table 3.1 OPS PC specification (continue)

Feature	Item	Description
DASH	Required features	• USB Redirection • Boot control • Hardware Information Management (CPU, Fan System Memory etc.) • Physical Asset • Power State Management – Remote Control • Sensors • BIOS Management • Text Console Redirection • Log profile • Software Inventory • Opaque Management Data • Software-Firmware Update • OS Status • Alert Indication • Account Management • Role Management • Network Configuration • Generating a syslog for temperature, storage info and alerts
Input & Output Ports	Front I/Os	1 x RJ45 with LEDs for Gigabit LAN 2 x USB 2.0 (USB connectors must be on a seperate small board and connected to MB with a board-to-board connector) 2 x USB 3.0 (USB connectors must be on a seperate small board and connected to MB with a board-to-board connector) 1 x Mic in phone jack 1 x Line out phone jack

Table 3.1 OPS PC specification (continue)

Feature	Item	Description
Input & Output Ports	JAE 80 pin I/Os	1 x TMDS signal 1 x DP signal 2 x USB 2.0 signal 1 x USB 3.0 signal 1 x Audio out L/R signal 1 x RX/TX 3.3V (UART) DC +12V~+19V input
On Board RTC		1 x External Li-ion Battery
Environment Conditions		Operating Temperature: 0~50°C Storage Temperature: -20~80°C Operating Relative Humidity(Non-condensing): 90% ROHS

3.2.1 80 Pin OPS Connector

The connector used for the Pluggable Module and the docking board interconnect is based on the JAE TX24/TX25 family of plug and receptacle connectors. The JAE connector pins are capable of supporting up to a maximum current of 1A. For details refer to the JAE connector datasheet or contact a JAE representative. The 80-pin right angle blind mate plug connector (p/n: TX25-80P-LT-H1E) and its receptacle (p/n: TX24-80R-LT-H1E) provide interfacing for the following features:

Power: DC IN +12V~+19V @ 8A max

Display Interface: DVI-D/TMDS and Display Port

Audio: Left and Right Channel

USB: 3*USB 2.0 (when USB3.0 is not used) or 2*USB 2.0 and 1*USB 3.0

UART: Serial communication (TX and RX only)

Control Signals: Pluggable Module Power Status, Power ON via display panel, Pluggable Board Detect, Consumer Electronics Control (CEC), and System Fan Control.

3.2.1.1 Pin Assignment of 80 Pin Connector

The JAE connector pin definition and assignment with regards to the features are listed in Table 3.2. Pin mapping indicated was based on the placement on the connector from top view as indicated in Figure 3.13.

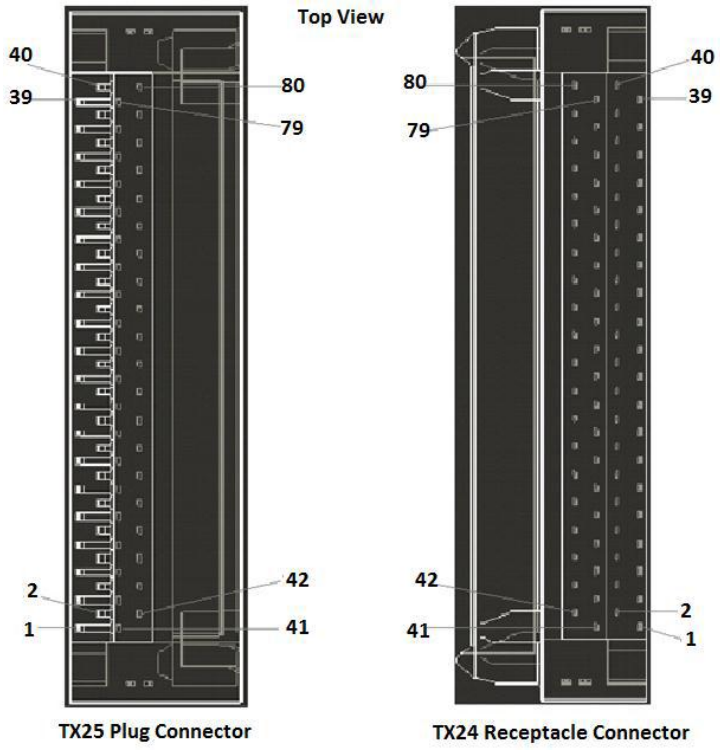


Figure 3.13 TX24/25 connector pin layout

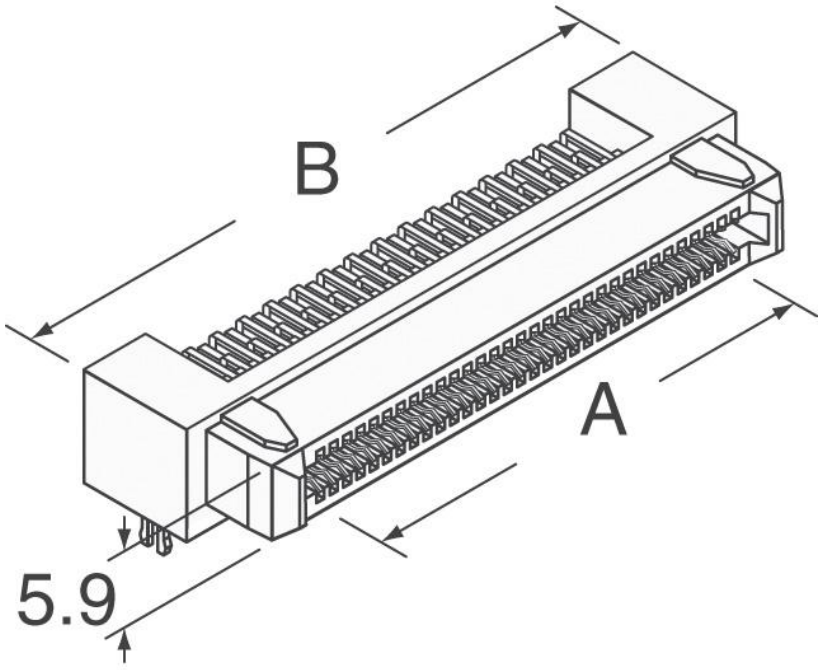


Figure 3.14 80 pin OPS connector (Docking Side)

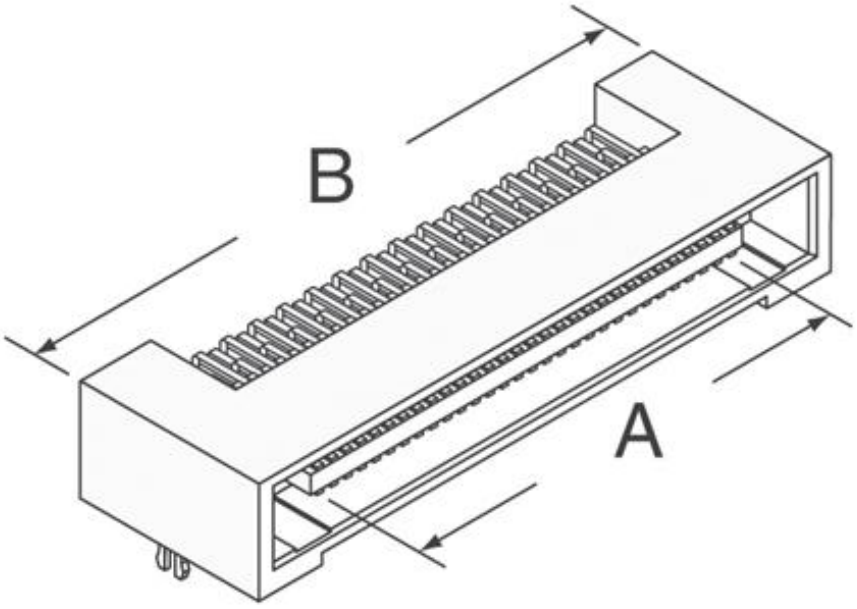


Figure 3.15 80 pin OPS connector (OPS PC Side)

Table 3.2 Pin assignment of 80 pin connector

Pin No	Signal	Description	I/O		Pin No	Signal	Description	I/O
1	DDP_3N	Display Port	O		**21**	TMDS0+	DVI-D	O
2	DDP_3P	Display Port	O		**22**	GND	Ground	-
3	GND	Ground	-		**23**	TMDS1-	DVI-D	O
4	DDP_2N	Display Port	O		**24**	TMDS1+	DVI-D	O
5	DDP_2P	Display Port	O		**25**	GND	Ground	-
6	GND	Ground	-		**26**	TMDS2-	DVI-D	O
7	DDP_1N	Display Port	O		**27**	TMDS2+	DVI-D	O
8	DDP_1P	Display Port	O		**28**	GND	Ground	-
9	GND	Ground	-		**29**	DVI_DDC_DATA	DVI-D	O
10	DDP_0N	Display Port	O		**30**	DVI_DDC_CLK	DVI-D	O
11	DDP_0P	Display Port	O		**31**	DVI_HPD	DVI-D	O
12	GND	Ground	-		**32**	GND	Ground	-
13	DDP_AUXN	Display Port	I/O		**33**	+12V~+19V	Power	-
14	DDP_AUXP	Display Port	I/O		**34**	+12V~+19V	Power	-
15	DDP_HPD	Display Port	I		**35**	+12V~+19V	Power	-
16	GND	Ground	-		**36**	+12V~+19V	Power	-
17	TMDS_CLK-	DVI-D	O		**37**	+12V~+19V	Power	-
18	TMDS_CLK+	DVI-D	O		**38**	+12V~+19V	Power	-
19	GND	Ground	-		**39**	+12V~+19V	Power	-
20	TMDS0-	DVI-D	O		**40**	+12V~+19V	Power	-

Table 3.2 Pin assignment of 80 pin connector (continue)

Pin No	Signal	Description	I/O	Pin No	Signal	Description	I/O
41	RSVD	Reserved	-	**61**	USB_PP2	USB	I/O
42	RSVD	Reserved	-	**62**	GND	Ground	-
43	RSVD	Reserved	-	**63**	USB_PN1	USB	I/O
44	RSVD	Reserved	-	**64**	USB_PP1	USB	I/O
45	RSVD	Reserved	-	**65**	GND	Ground	-
46	RSVD	Reserved	-	**66**	USB_PN0	USB	I/O
47	RSVD	Reserved	-	**67**	USB_PP0	USB	I/O
48	RSVD	Reserved	-	**68**	GND	Ground	-
49	RSVD	Reserved	-	**69**	LINEOUT_L	Audio-Lch	O
50	SYS_FAN	Fan Control	O	**70**	LINEOUT_R	Audio-Rch	O
51	UART_RXD	UART 3.3V	I	**71**	CEC	Consumer Electronic Control	I/O
52	UART_TXD	UART 3.3V	O	**72**	PB_DET	Pluggable Board Detect	O
53	GND	Ground	-	**73**	PS_ON#	Pluggable Signal ON	I
54	StdA_SSRX-	USB3.0	I	**74**	PWR_STATUS	Power Good	O (OC)
55	StdA_SSRX+	USB3.0	I	**75**	GND	Ground	-
56	GND	Ground	-	**76**	GND	Ground	-
57	StdA_SSRX-	USB3.0	I	**77**	GND	Ground	-
58	StdA_SSRX+	USB3.0	I	**78**	GND	Ground	-
59	GND	Ground	-	**79**	GND	Ground	-
60	USB_PN2	USB	I/O	**80**	GND	Ground	-

3.2.2 OPS Signals Description

There are some important signals that should be explained. These signals are UART signals and control signals. Some reference designs are shown below as well.

3.2.2.1 UART Signals

There is a communication between OPS PC and the docking board via UART signals. Designer can communicate with the OPS PC by using these signals. The specification of the UART signals can be seen in Table 3.3 below.

Table 3.3 OPS PC UART signals

Pin No	Name	Type	Description
52	UART_TXD	O	Transmitted UART data from pluggable board, UART 3.3V LVTTL signal. Assign as COM 1 for the UART port in the pluggable module
51	UART_RXD	I	Received UART data for pluggable board, UART 3.3V LVTTL signal. Assign as COM 1 for the UART port in the pluggable module

3.2.2.2 Control Signals

There are some control signals that designer can control the OPS PC by using these signals. By the help of these signals, designer can understand the existence of the OPS PC and can power ON or OFF the OPS PC. The specification of the control signals can be seen in Table 3.4 below.

Table 3.4 Control signals of OPS

Pin No	Name	Type	Description
74	PWR_STATUS	OC	Power status indication signal or Power Good status of the pluggable board. This pin shall be Open Collector and pull up to +3.3V on the docking/control board side. High: Pluggable board power off state Low: Pluggable board power on state
73	PS_ON#	I	Pluggable Signal ON: This is meant for signal initiation to power ON or boot up the Pluggable Module. PS_ON# shall be asserted at least 500ms after power is delivered from PSU to the board via the JAE connector (G3 to S5 state). Pull up to +3.3V on the pluggable board. **A pulse width present on the PS_ON# shall be detected and responded within 200ms to ensure successful operation.**
72	PB_DET	O	Pluggable board detection. Output signal, recommend rounded on the pluggable board side with pull up to +3.3V on the docking/control board side High:No Pluggable Low: Pluggable board Present
71	CEC	I/O	Consumer Electronics Control for Proof of Play/Display initiative. Can also be used for display panel status detection and other control functions. The display panel control CPU shall support this functionality.
50	SYS_FAN	O	System Fan: This signal shall be used to control the display panel system fan. Recommended pull up +3.3V on docking board side and routed to the system fan control. High: System Fan OFF Low: System Fan ON

3.2.2.3 Reference Design Examples for Control Signals

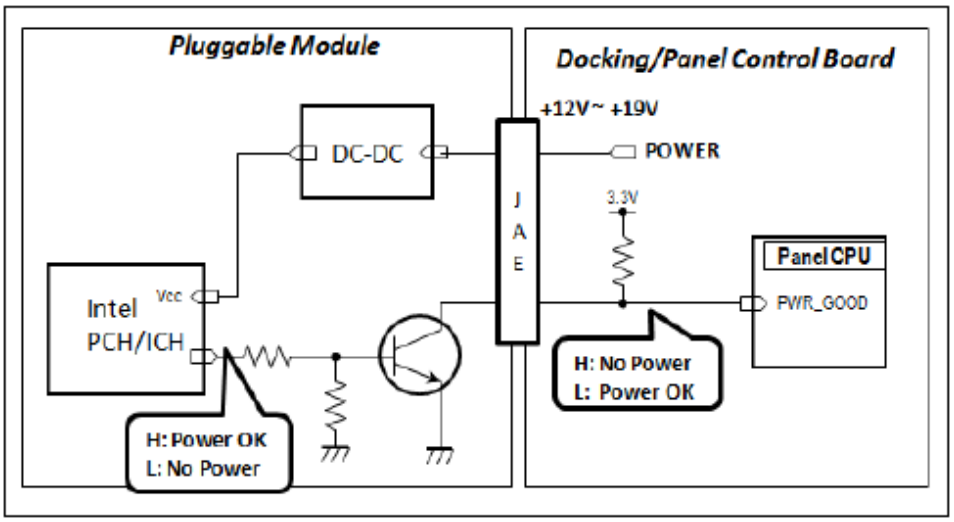


Figure 3.16 Reference design example for PWR_STATUS

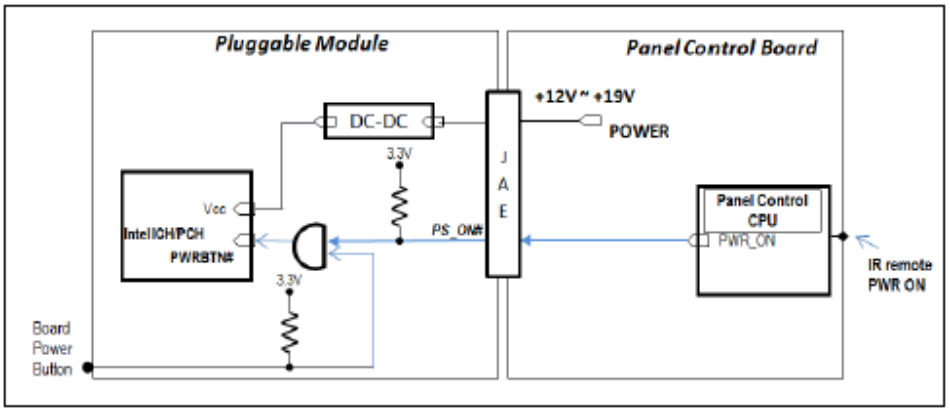


Figure 3.17 Reference design example for PS_ON#

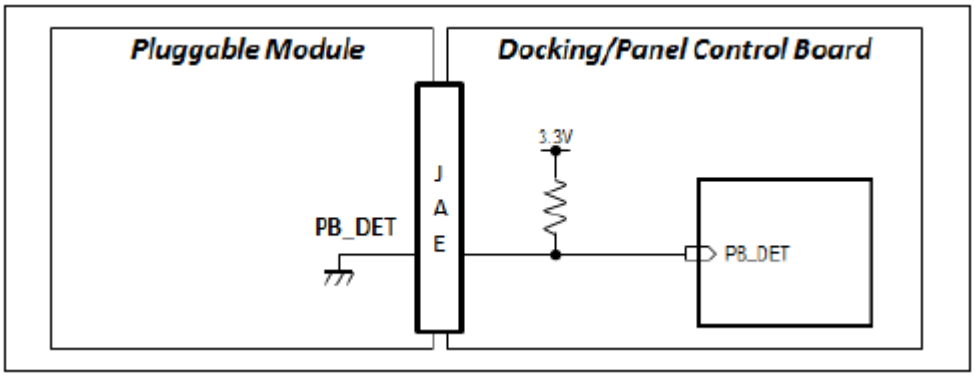


Figure 3.18 Reference design example for PB_DET

For control signals, some special circuits according to the OPS specification need to be designed. These special circuits can be seen in Figure 3.16, 3.17 and 3.18 above respectively.

Figure 3.19 OPS PC mainboard top view

Figure 3.20 OPS PC mainboard bottom view

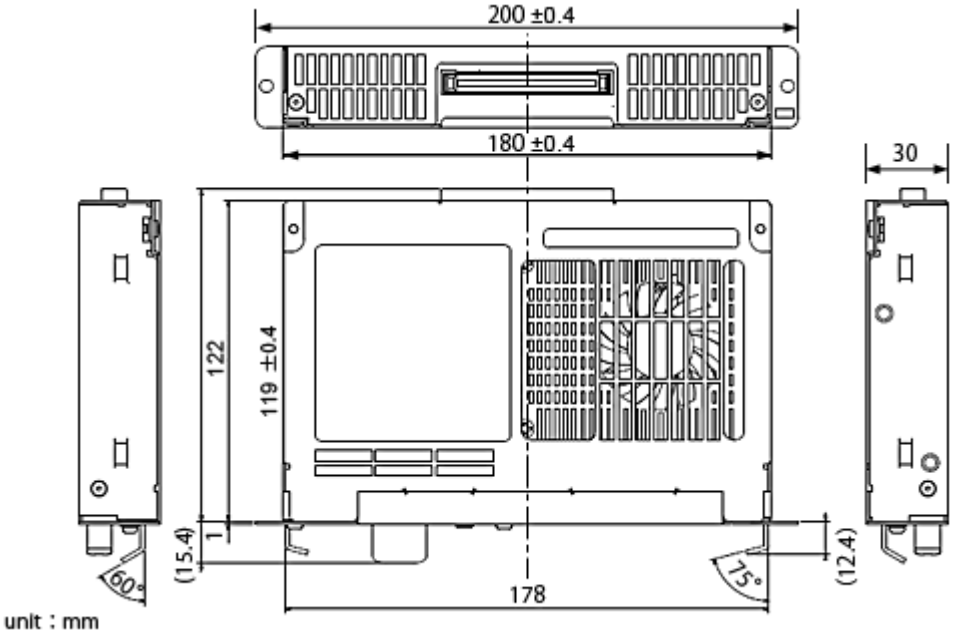


Figure 3.21 OPS PC mechanical dimensions (NEC)

3.3 SMPS Power Supply

In this product, a 300W output capable SMPS power supply is used. SMPS power supply has different types of voltages as outputs such as DC24V for backlight and audio amplification, DC12V for system supply and also has some control signals such as backlight on/off and standby on/off.

The power board includes AC-DC resonant half bridge converter and DC-DC converter. This PSU has active PFC (Power Factor Correction) unit. Total max output power is 300W. Stand by power consumption is under 0.5W when 13Vstby-15mA @AC 220V and other outputs have no load.

The input specifications and currents can be drawn from each outputs are listed below in Table 3.5 and Table 3.6 respectively.

Table 3.5 Input specifications of the power board

Standard Voltage Range	AC 220V-240V
Maximum Voltage Range	AC 100V-264V
Frequency Range	50Hz – 60Hz

Table 3.6 Output specifications of the power board

CH#	Output Name	Output Typical (V)	Variable Voltage Range (V)	Voltage Tolerance (%)	Output Current (mA)	
					Minimum	Maximum
CH1	+13V_STBY	13	12.5 – 13.5	±3	10	400
CH2	3.3V	3.4	3.3 – 3.45	±3	30	2500
CH3	5V	5.1	4.95 – 5.15	±3	30	2500
CH4	12V	11.8	11.5 – 12.3	±3	500	6000
CH5	24V	24	23.7 – 24.4	±3	1000	10000
CH6	24V_PL806	24	23.5 – 24.2	±3	0	1000
CH7	+18V_A	18.5	17 - 19	±3	0	1000

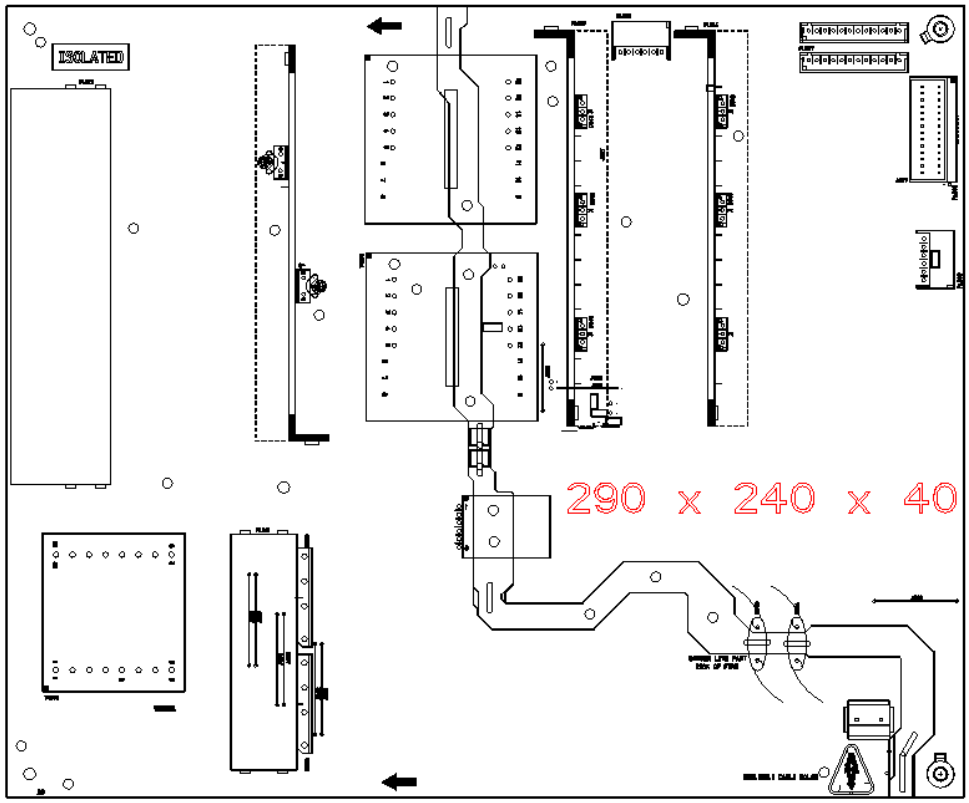


Figure 3.22 Drawing of the SMPS power board

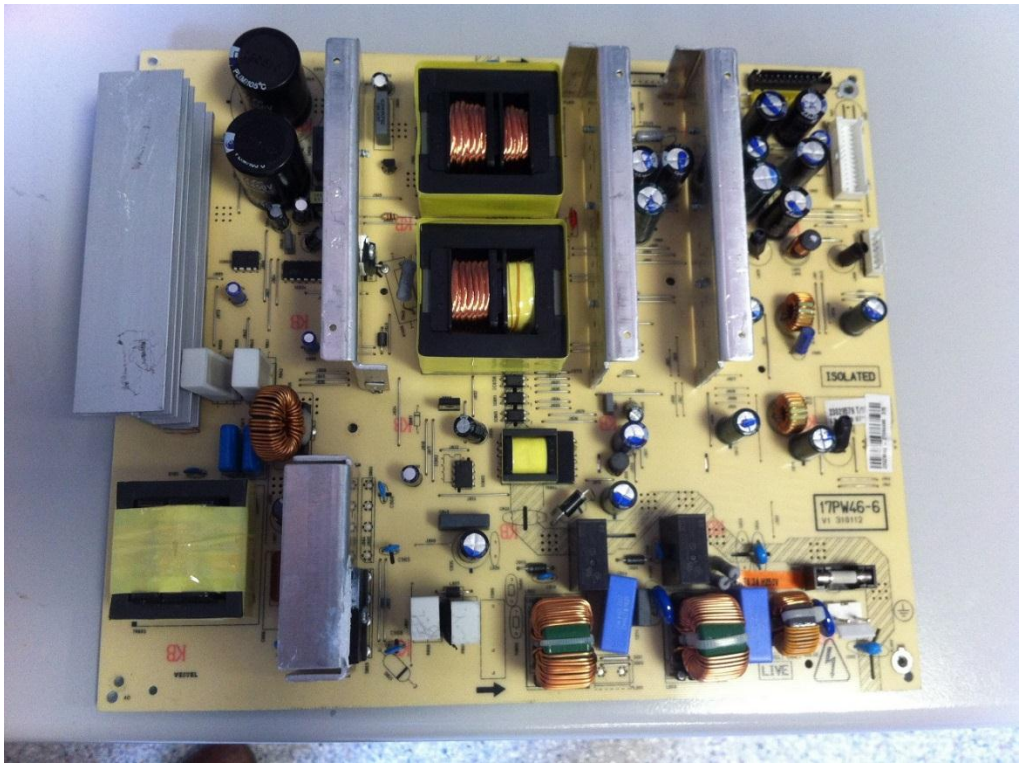


Figure 3.23 Power board top view

3.4 I/R Touch Screen

Infrared technology relies on the interruption of an IR light grid in front of the display screen. The touch frame or opto-matrix frame contains a row of IR-light emitting diodes (LEDs) and photo transistors, each mounted on two opposite sides to create a grid of invisible infrared light. The frame assembly is comprised of PCBs on which the opto-electronics are mounted and are concealed behind an IR-transparent bezel which shields the opto's from the operating environment whilst allowing the IR beams to pass through. When touching the screen one or more of the beams are obstructed resulting in an X and a Y coordinate being sent to the control electronics to indicate the exact touch point.

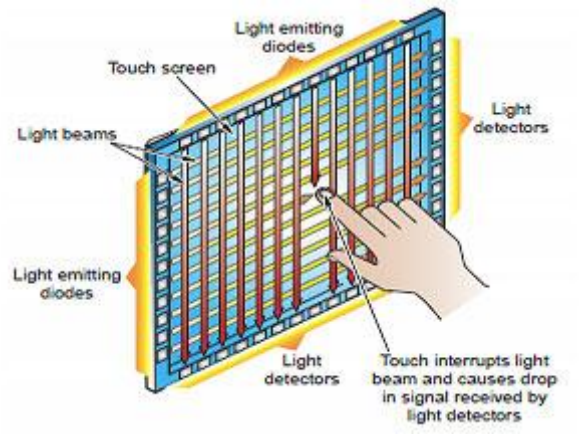


Figure 3.24 Infrared touch screen technology

In this design, infrared touch screen is used. As described above there are some receiving and emitting LEDs on the edges of the PCBs. The illustration below shows these PCBs.

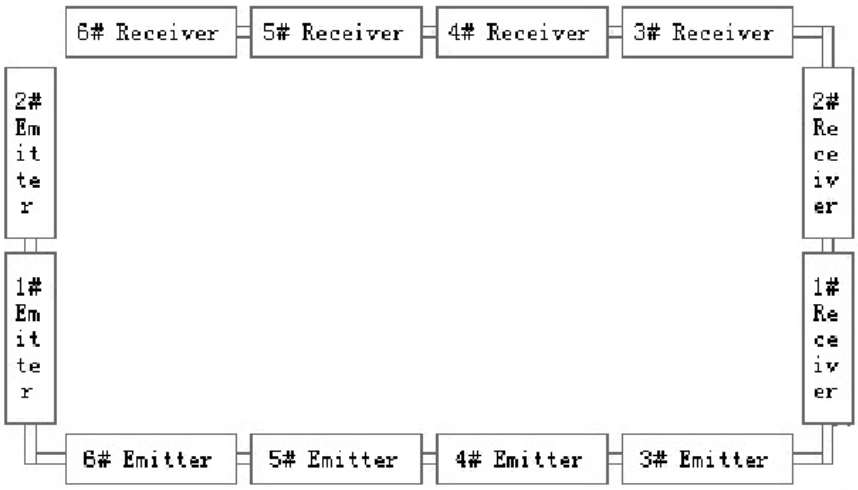


Figure 3.25 Configuration of the touch screen PCBs

At infrared touch screen design, some special LEDs must be used in order to achieve quality criteria. These LEDs must have a special light angle and more luminance according to common LEDs.

Infrared noise and ambient light have a bad influence on infrared touch screens. Because these two items may affect the receiver LEDs and may cause ghost touch events.

The influence of ambient light on the detector signal may be suppressed and reduced in several ways. The most important technique is to block visible light in a way that the detector is only sensitive to a narrow wavelength range in the IR region. Some LED vendors offers to the designer a range of products with so called ‘daylight blocking filter’. OSRAM silicon-detectors with daylight blocking filter are sensitive within the narrow 800 nm - 1100 nm wavelength range. These components are characterized by their black (visible-absorbing, IR transmitting) packages. This measure generally provides sufficient ambient visible light suppression for most applications. Note that usage of devices with daylight blocking filter is recommended in every case to avoid detector saturation. However, there are additional sources of IR light which might interfere with the signal of interest. The following gives a brief overview of possible distortions and sketches a more demanding solution, if the conventional ‘daylight blocking filter’ is not sufficient.

Minimizing and counter-fighting unintended infrared light, which acts as noise in the detector, is the main design challenge. Using visible LED sources (e.g. monitor backlighting) in IR touchscreen solutions is recommended, as these LEDs have no IR content. In contrast most conventional (non-LED based) light sources emit also in the IR spectral range. E.g. sunlight and incandescent bulbs contain components of equal or even higher amplitudes in the visible as well as IR wavelengths range1. For applications where intense incandescent or halogen illumination is expected, some additional electrical-domain effort is advised to enhance the signal-to-noise ratio. There are several steps with increasing complexity to counter-fight the IR noise topic. The implementation depends on the signal compared to the IR noise level. The simplest version is the operation of the emitter and detector in a pulsed and synchronized operation. An AC-coupling of the detector signal might efficiently filter out the present DC-components of the ambient light. If the IR background noise becomes more dominant, a more complex implementation is necessary. This measure compares two subsequent measurements. The first, called the reference (without IR illumination) is compared with the second, the signal (with IR illumination). Based on the difference signal the touch event can be extracted. The most demanding solution is the inclusion of a lock-in amplifier type circuitry, which demands a modulated emitter signal. In this case the IRED is modulated with a carrier frequency

and the signal is detected through a frequency synchronous receiver, either in a homodyne or heterodyne structure. Alternatively, digital signal processing allows a direct detection by employing computational algorithms (e.g. Fourier-type). Such a system can be made immune even to severe IR ambient light (noise). The selection of the right modulation frequency and the implementation of a narrow band-/low-pass filter are key elements for a high signal-to-noise ratio. Similar considerations should be undertaken for camera/line scan systems. In this case, it is recommended as a first measure to insert a narrow optical band-pass filter (matching the IRED wavelength) in front of the camera. This increases significantly the signal-to-noise ratio.

CHAPTER FOUR
RESULTS

4.1 Board Standalone Tests

Each board is tested before integrating the board to the system in order to prevent some short circuit problems or such these problems. At following sections, each board standalone tests will be explained.

4.1.1 Power Board Tests

Power board is one of the most critical components for the system. We can call the power board as the heart of the system.

There are some test points on board. Here are the instructions for the power board test.

1. Put the interface board to the test setup by controlling the reference voltage pins.
2. Control each test point at the related test pin.
3. Be careful about high voltage sections.
4. Check the voltages as shown the table 4.1 below. Vin is 220V AC.

Table 4.1 Output voltage values for the power board

CH#	Output Name	Output Typical (V)	Variable Voltage Range (V)	Voltage Tolerance (%)	Output Current (mA)	
					Minimum	Maximum
CH1	+13V_STBY	13	12.5 – 13.5	±3	10	400
CH2	3.3V	3.4	3.3 – 3.45	±3	30	2500
CH3	5V	5.1	4.95 – 5.15	±3	30	2500
CH4	12V	11.8	11.5 – 12.3	±5	500	6000
CH5	24V	24	23.7 – 24.4	±3	1000	10000
CH6	24V_PL806	24	23.5 – 24.2	±3	0	1000
CH7	+18V_A	18.5	17 - 19	±5	0	1000

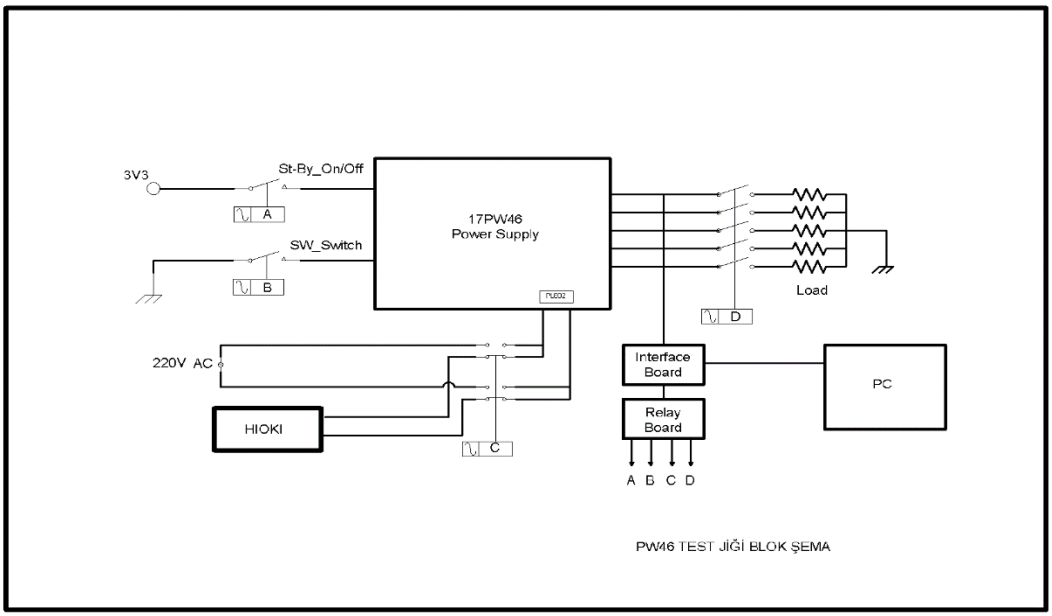


Figure 4.1 Power board test block scheme

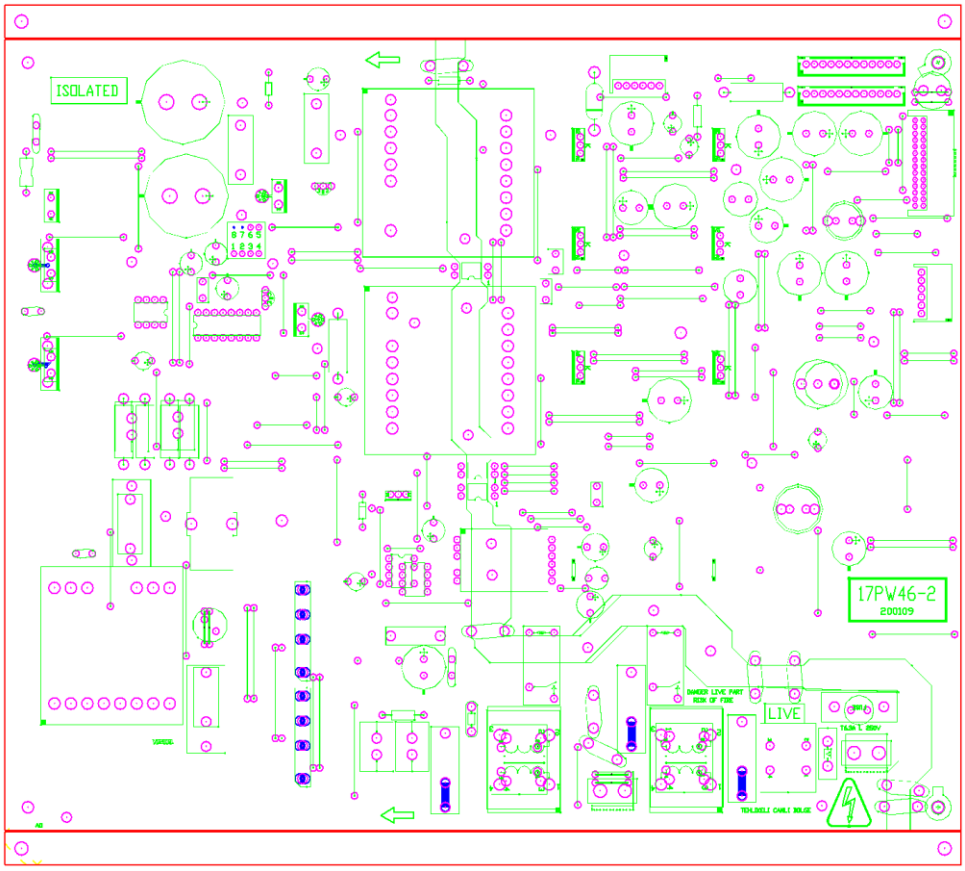


Figure 4.2 Power board test points

Figure 4.3 Power board test tool software

4.1.2 Monitor Board Tests

There is a test setup to test the monitor board as shown in Figure below. After connecting the monitor board, the special test software tool is applied to the monitor board.

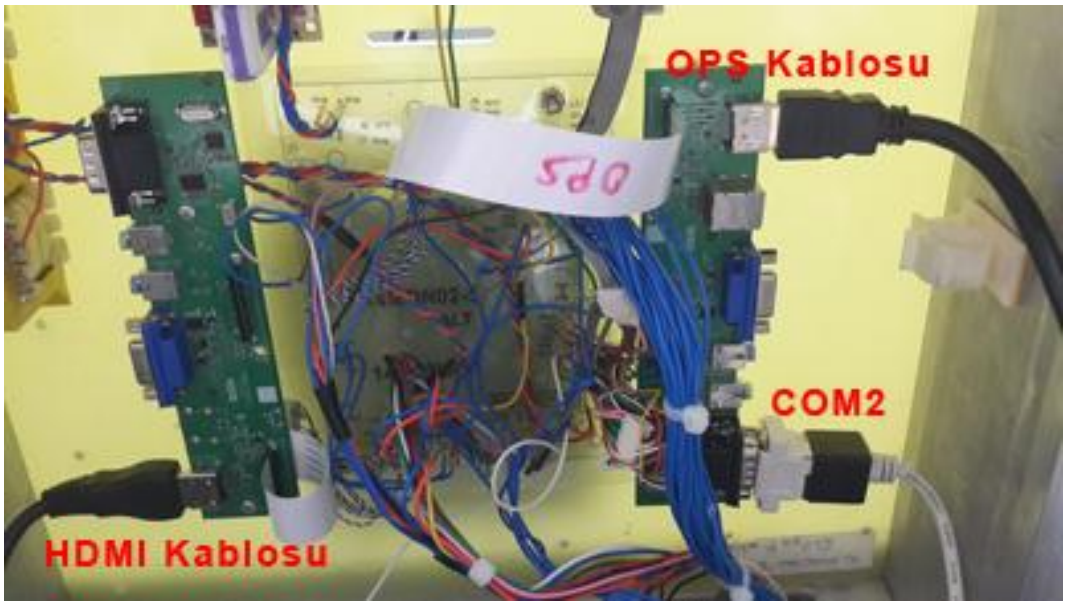


Figure 4.4 Monitor board test jig

Figure 4.5 Monitor board test tool software

4.1.3 Touch Screen Tests

Each touch screen PCBs are tested after PCB assembly because after assembly of the whole touch screen, it is very hard to dis-assemble the touch screen again. The picture below shows us the touch screen PCB test method.

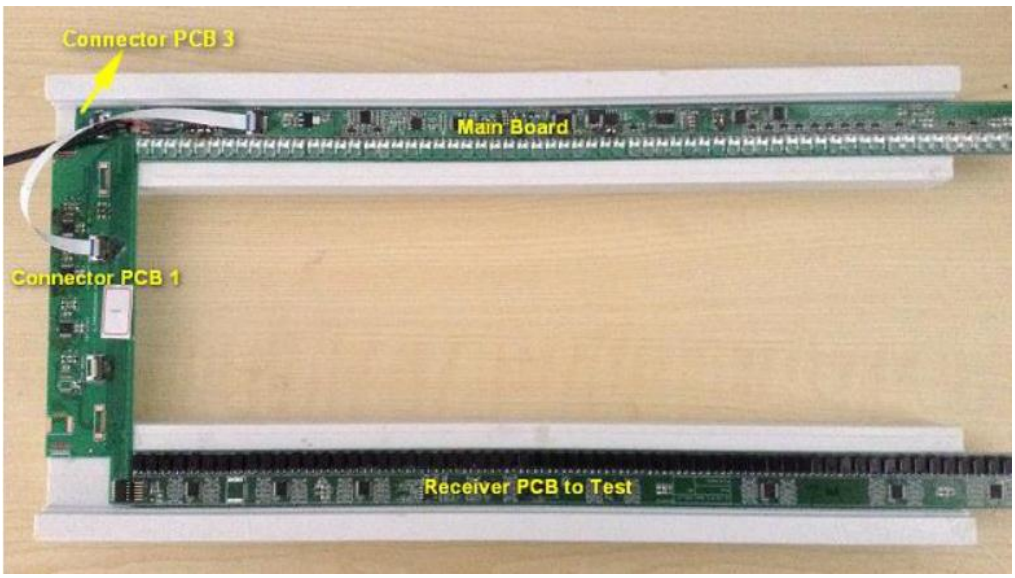


Figure 4.6 Touch screen PCB test jig

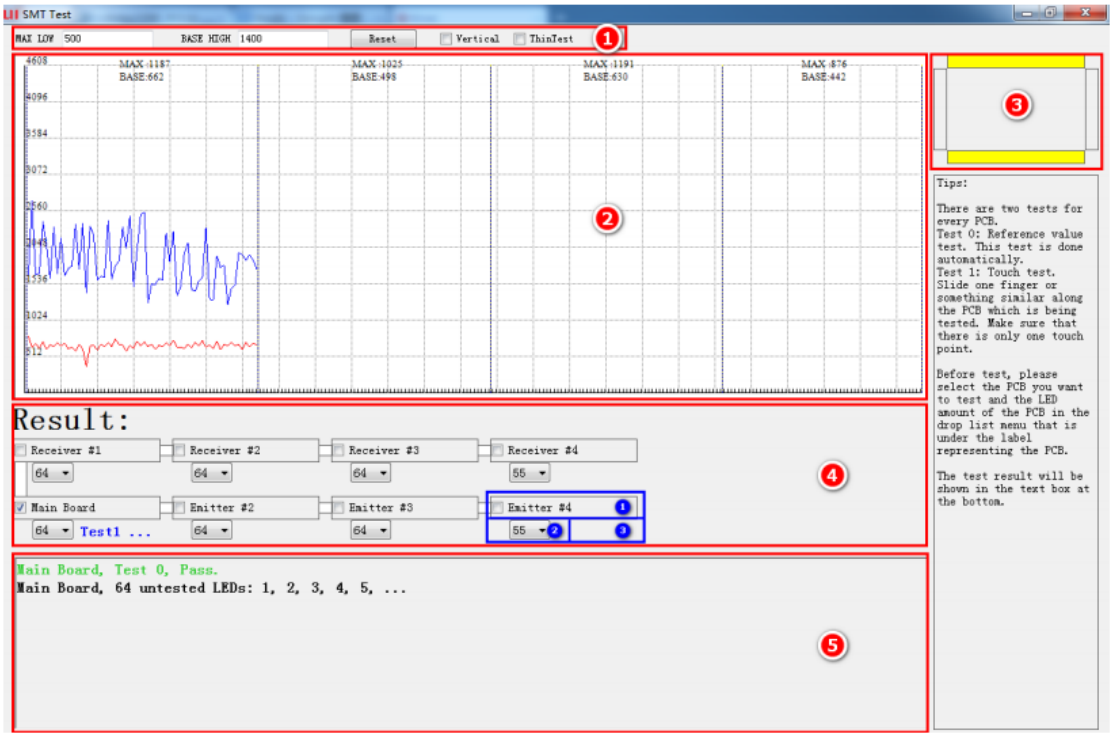


Figure 4.7 Touch screen PCB test tool

CHAPTER FIVE
DESIGN APPROVAL TESTS

5.1 EMC (Electromagnetic Compatibility) Tests

5.1.1 What is EMC?

All electric devices or installations influence each other when interconnected or close to each other. Sometimes you observe interference between your TV set, your GSM handset, and your radio and nearby washing machine or electrical power lines.

The purpose of electromagnetic compatibility (EMC) is to keep all those side effects under reasonable control. EMC designates all the existing and future techniques and technologies for reducing disturbance and enhancing immunity.

EMC means nothing more than “an electronic or electrical product shall work as intended in its environment. The electronic or electrical product shall not to generate electromagnetic disturbance, which may influence other products”.

Any electrical product cannot be designed seriously unless all aspects of EMC are taken into consideration.

5.2 EMC Tests

We can group EMC tests as shown at Table.4.

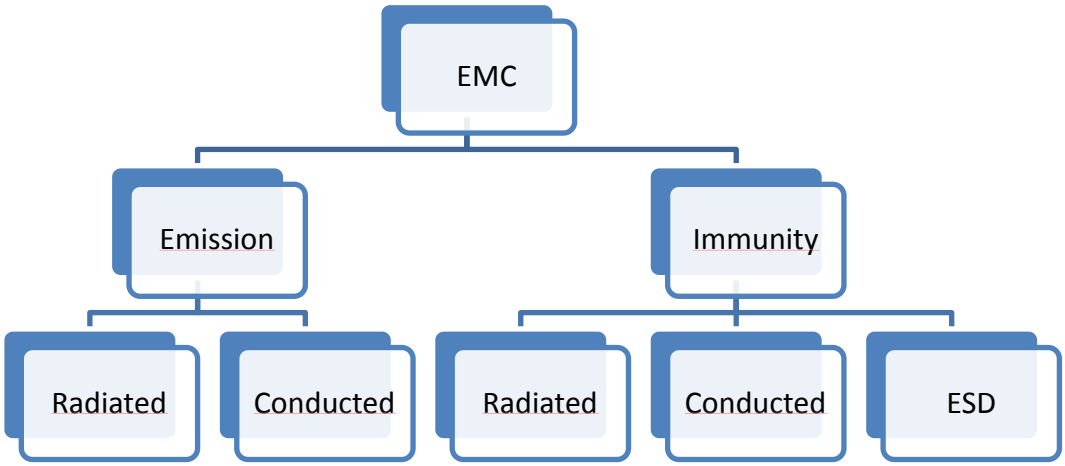


Figure 5.1 EMC test phases

After designing all boards related with the product, all boards combined to generate a complete system. At this thesis, the complete system is an interactive display. Then, the product is tested according to the EMC regulations. Here are some photos and test results from tests.

5.2.1 Radiated Emission

There is a test setup for radiated emission tests shown in Figure 5.1. A semi-anechoic chamber that includes an antenna 3m far from the product is used for this test. Antenna height can be changed between 1m and 3m and also antenna angle can be changed vertical and horizontal. The product is put on a turn table that is able to turn 360 degrees. The product is tested between the frequencies 30MHz and 6GHz and the tester checks the emission level coming from the product.

Figure 5.2 Radiated emission test at semi-anechoic chamber

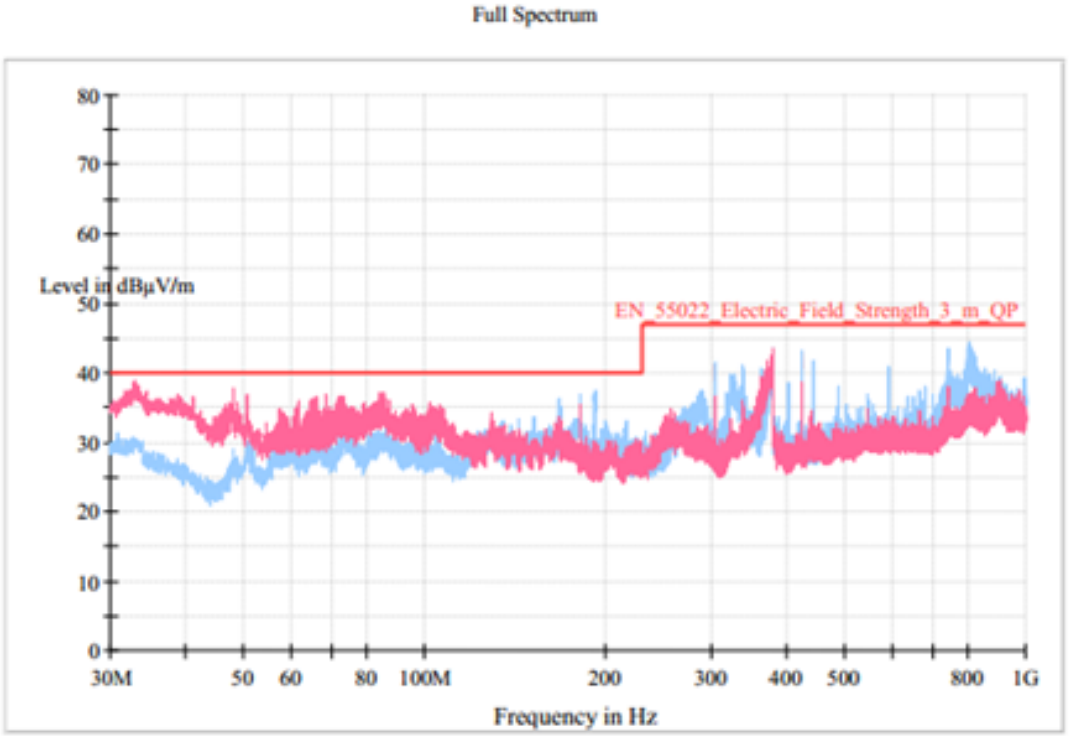


Figure 5.3 Radiated emission test result

Table 5.1 Radiated emission test result table

FINAL RESULTS

Frequency (MHz)	QuasiPeak (dBuV/m)	Antenna Height (cm)	Polarization	Azimuth (deg)	Limit (dBuV/m)	Margin (dBuV/m)
32.94	34.82	116	V	175	40	5.18
48.06	36.96	100	V	125	40	3.04
50.67	31.63	107	V	280	40	8.37
68.7	33	156	V	209	40	7
85.41	33.19	100	V	195	40	6.81
192.21	32.51	197	H	53	40	7.49
303.72	38.91	182	H	252	47	8.09
379.74	39.66	205	H	228	47	7.34
425.22	41.32	146	H	192	47	5.68
741.63	41.25	165	H	131	47	5.75
805.2	37.57	255	H	235	47	9.43

5.2.2 Radiated Immunity

A full-anechoic chamber shown in Figure 5.4 is used for radiated immunity tests. There is an antenna that suppresses radiated noise to the product. The product is supposed to work properly under this noise.

Figure 5.4 Radiated immunity tests at full-anechoic chamber

5.2.3 ESD (Electrostatic Discharge)

ESD test is applied to all connectors and some openings. There are two test methods that have to be applied to the products.

- Air Discharge – 8kV for each discharge
- Conducted Discharge – 4kV for each discharge

Here are some photos that show us the application points.

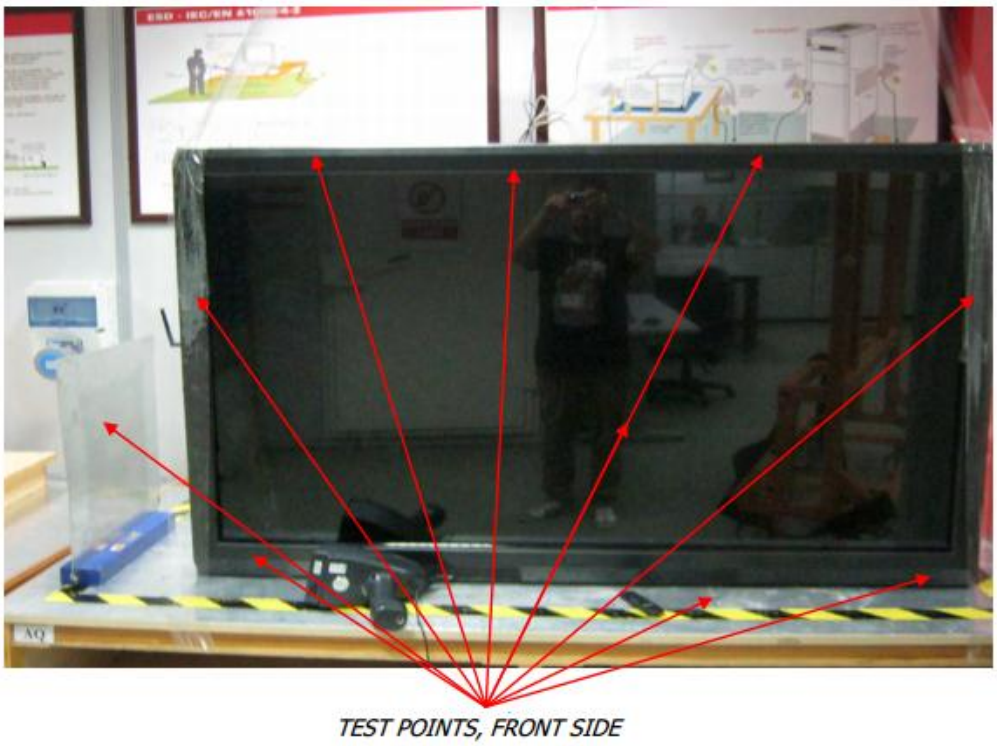


Figure 5.5 ESD test points, front side of the product

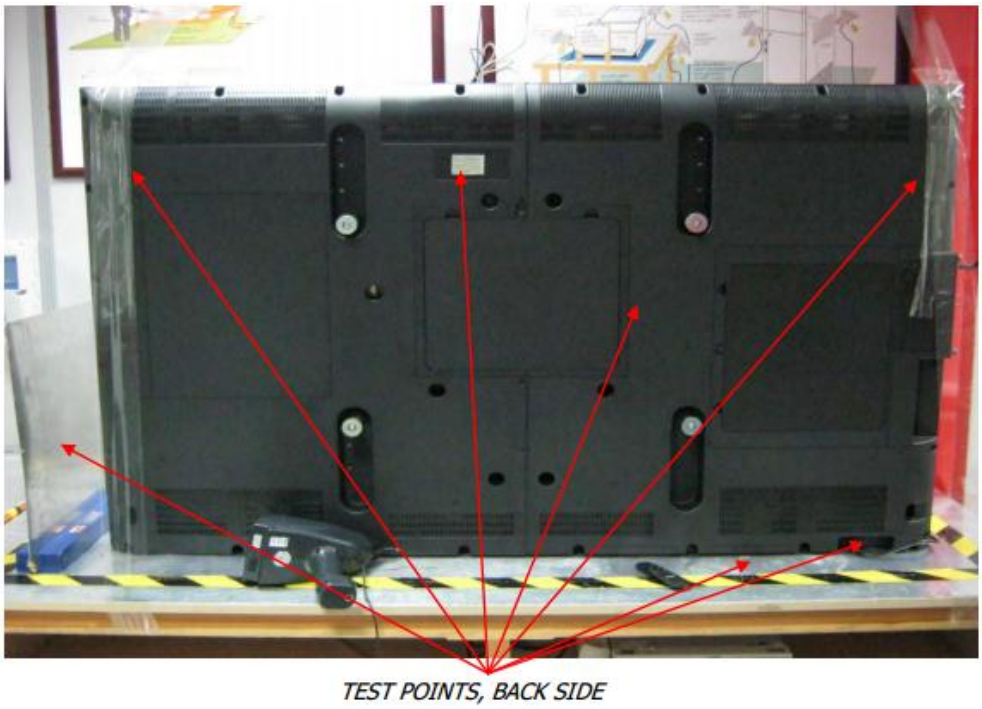


Figure 5.6 ESD test points, back side of the product

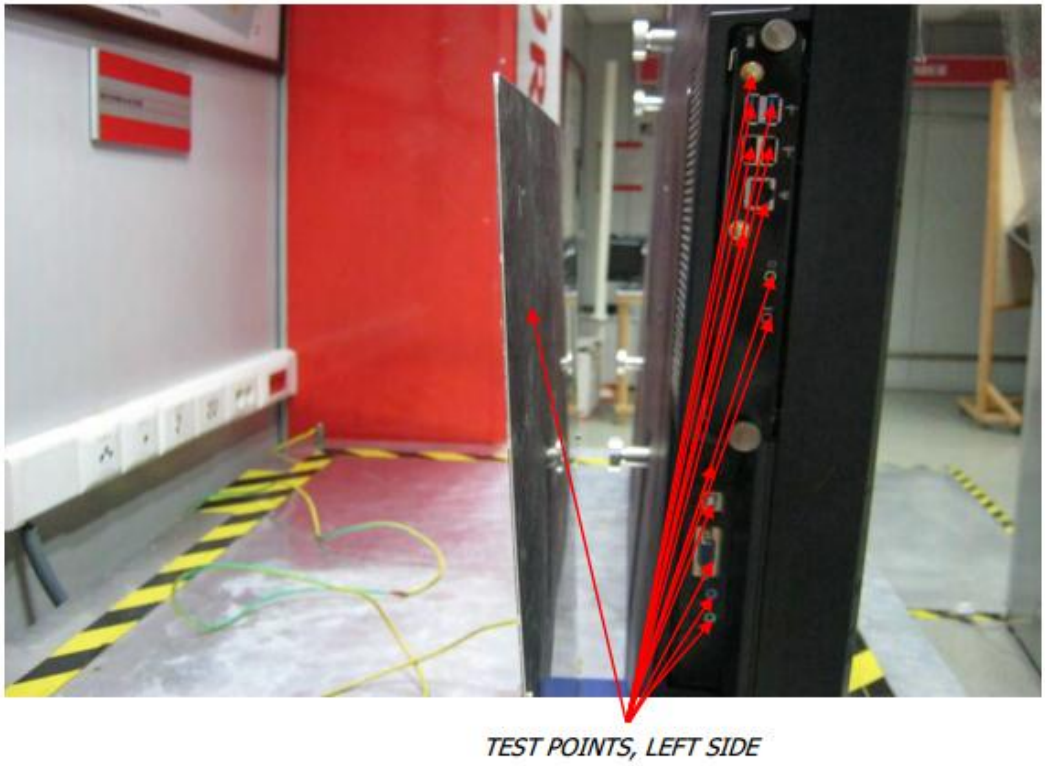


Figure 5.7 ESD test points, left side of the product

5.3 Product Safety and Reliability Tests

IEC EN-60950 is the safety standard for IT equipment. In this standard, there are so many tests including;

- Input current measurement (Item 1.6.2 of IEC60950)
- Durability of markings (Item 1.7 of IEC60950)
- Discharge of capacitors in equipment (Item 2.1.1.7 of IEC60950)
- Limited current circuits (Item 2.4 of IEC60950)
- Limited power sources (Item 2.5 of IEC60950)
- Determination of working voltage (Item 2.10.3 and 2.10.4 of IEC60950)
- Clearance and creepage distances measurement (Item 2.10.3 and 2.10.4 of IEC60950)
- Cord anchorages and strain relief tests (Item 3.2.6 of IEC60950)
- Stability test (Item 4.1 of IEC60950)
- Impact test (Item 4.2.5 of IEC60950)
- Stress relief test (Item 4.2.7 of IEC60950)
- Wall or ceiling mounting test (Item 4.2.10 of IEC60950)
- Direct plug-in equipment (Item 4.3.6 of IEC60950)
- Temperature test (Item 4.5.2 of IEC60950)
- Touch current test (Item 5.1 of IEC60950)
- Electric strength test (Item 5.2 of IEC60950)
- Simulation of faults (Item 5.3 of IEC60950)
- Impulse and voltage current test (Item 6 and Item 7 of IEC60950)
- Transformer overload test (Additional item of IEC60950)

After designing all boards related with the product, all boards combined to generate a complete system. At this thesis, the complete system is an interactive display. Then, the product is tested according to the Safety regulations. Here are some photos and test results from tests.

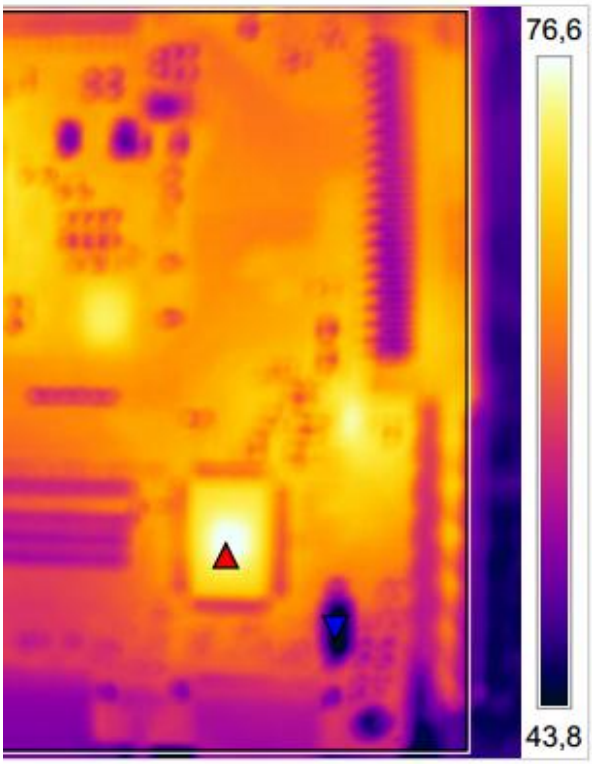


Figure 5.8 Safety temperature stress test measurement (mainboard scalar IC)

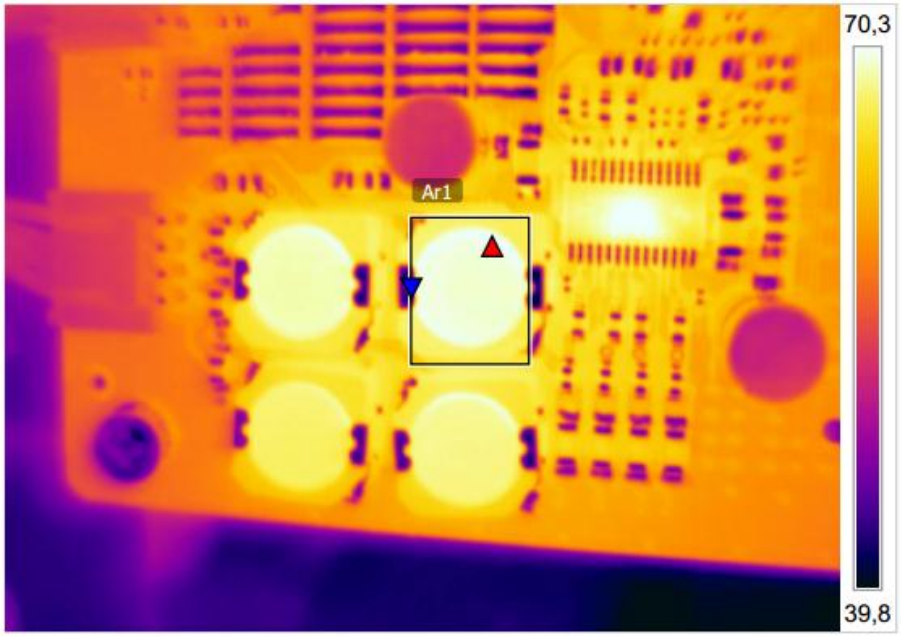


Figure 5.9 Safety temperature stress test measurement (mainboard audio amplifier and filters)

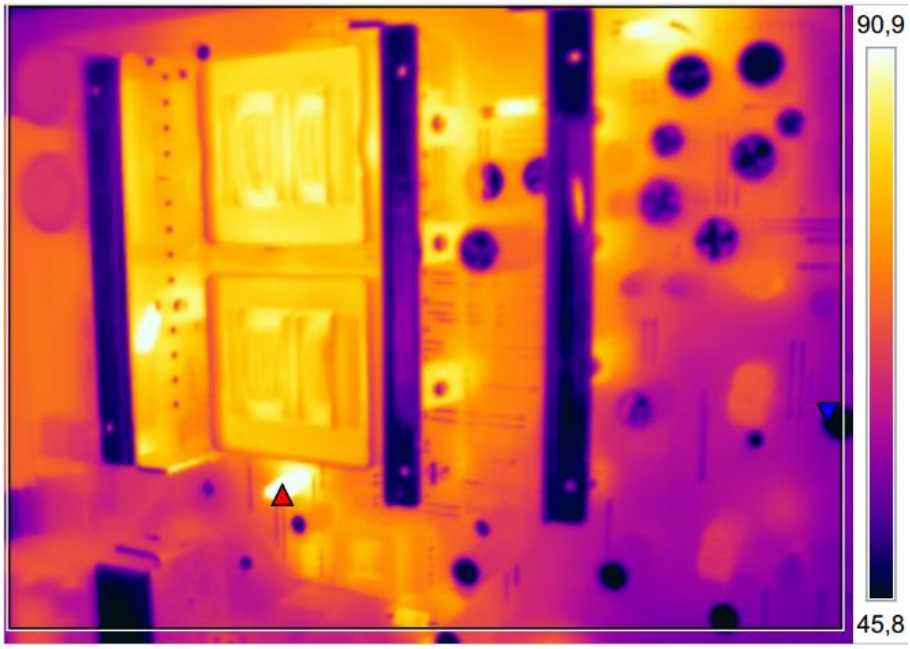


Figure 5.10 Safety temperature stress test measurement (power supply unit)

The product is tested at 50 degrees Celsius and % 90 humidity non-condensing environments.

CHAPTER SIX
FUTURE WORKS

I would like to tell something about possible future works can be done on this Interactive Flat Panel Display project.

Voice recognition would be an excellent feature for this project. Because for the current educational systems, the teachers have to write on board each sentences. But if interactive flat panel display has voice recognition feature, the teacher says something and IFPD can recognize the teacher's voice and translate this voice into writing. By this feature, a lot of time can be saved.

Real time student interactivity would be another excellent feature for IFPDs. For the current systems, students solve the problems on their tablet PCs and send their answers to the IFPD as an image. But if real time student interactivity can be implemented, student can solve the problem from his/her desk and other students can see the solution real time. Also the teacher may interfere on time if needed.

CHAPTER SEVEN
CONCLUSION

Flat panel display technology is taking place in digital signage and information display market with a growing share rather than classical billboards. Flat panel displays includes liquid crystal module and backlight module. Liquid crystal module technology is growing year after year. Backlight module technology has some types such as CCFL (Cold Cathode Fluorescent Lamp) and LED (Light Emitting Diode) technologies. There are also some structures called LGP (Light Guide Plate) inside the flat panel display. There is a board called T-CON (time controller) board on flat panel displays. T-CON board drives the liquid crystal displays. The necessary video information and control signals such as bit selection and LVDS selection are provided by a mainboard.

Mainboard achieves video and audio information from sources such as VGA input or HDMI input. Since the panel interface is LVDS (Low Voltage Differential Signal), the mainboard converts these HDMI or VGA signals to LVDS signals to drive the panel. The audio signals are passing through an audio amplifier to increase the audio output power. Then the audio output of the amplifier is connected to the speakers.

One of the main advantages of this mainboard is that the mainboard is compatible with OPS standard in order to connect an x86 based OPS board or ARM based OPS board via 80-pin connector. This connector pin out has been assigned at the definition of the standard. Anyone can connect any OPS PC to this mainboard and can use it properly. This feature provides flexibility to end user that they can choose any system and use it with a one product since OPS PC is a plug and play device.

Product approval tests have been applied after the mainboard become a part of a complete system. EMC (electromagnetic compatibility) is one of the most important issues for the designers. Any electrical or electronic IT device has to meet the requirements of the IEC EN-55022 standard. We have faced some EMC problem about the mainboard. These problems have been overcome by changing the layout.

For example, all high speed signals have to have a reference because of the crosstalk issue. According to this reason, we have checked all high speed signals again and again and change the reference plane or signals in order to overcome the EMC issues. In this thesis, all EMC test parts are explained in detail.

Product Safety tests have been applied to the boards and product as well. Safety tests are done according to the international safety standard IEC EN-60950. There are many tests including; temperature stress, input current and voltage, product cabinet strength, wall mount test etc. We have faced some safety problems during the tests. For example; some of the components cannot pass from temperature stress test. In order to pass the temperature stress test, we had to change related components with higher temperature featured components. For safety tests, fire enclosure and ventilation holes are another issue. The designer has to know related standards before starting to design. In this thesis, all parts of the test have been explained in detail.

The main advantage for these systems is that they can be managed remotely. User can manage the product via RS-232 or via Ethernet. There are plenty of SW solutions for this purpose. User can manage the signage or information content; can also schedule some events and contents.

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